Study of $\gamma^*\gamma^* \to p\bar{p}$

Kedi Hao (USTC)

MC Generation

$$\mathbf{q_1 = p_1 - p_1'}$$

$$\mathbf{q_1^2 \approx -2P_1P_1'(1 - cos\theta_1)}$$

$|1 - cos\theta| \sim 0$
$q^2 \sim 0$ 准时光子
沿束流管飞走

$|1 - cos\theta| \gg 0$
$q^2 \gg 0$ 虚光子
被探测到

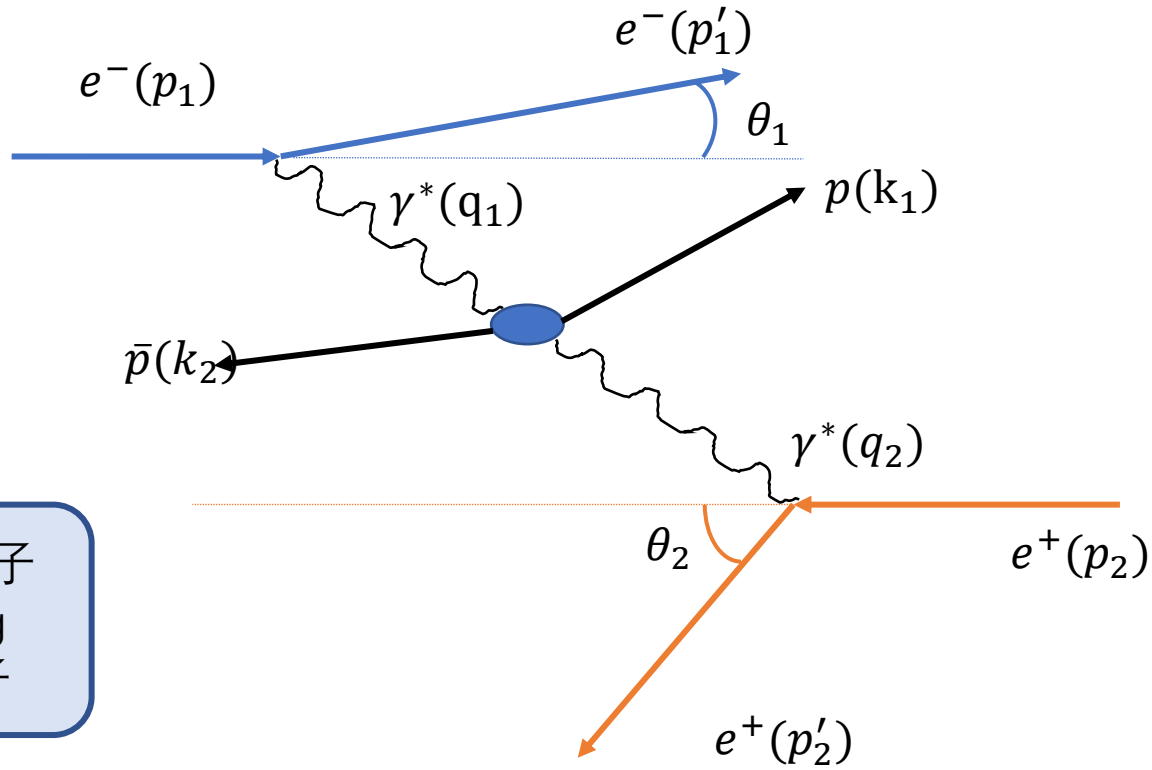
两电子都不探测
Untag
两个准实光子

探测一个电子
Single tag
准实光子+虚光子

探测两个电子
Double tag
两个虚光子

准实光子只有横向极化，$\lambda = \pm 1$

虚光子有横/纵向极化，$\lambda = \pm 1,0$



MC Generation

➢ HadroTOPS Generator $N_{ee\to p\bar{p}} = \int \mathcal{L}_{int} \times \frac{dL_{\gamma\gamma}(W_{\gamma\gamma}, E_{cms}, Q^2)}{dW_{\gamma\gamma}} dW_{\gamma\gamma} \times \sigma_{\gamma\gamma\to p\bar{p}}(W_{\gamma\gamma}, Q^2, cos\theta^*)$

根据双光子的极化分别设定亮度（理论计算）和截面（手动输入）：

$$\frac{d^3\sigma}{dW\,dQ_1^2\,dQ_2^2} = \frac{d^3L_{\mathrm{TT}}}{dW\,dQ_1^2\,dQ_2^2}\sigma_{\mathrm{TT}} + \frac{d^3L_{\mathrm{LL}}}{dW\,dQ_1^2\,dQ_2^2}\sigma_{\mathrm{LL}} + \frac{d^3L_{\mathrm{TL}}}{dW\,dQ_1^2\,dQ_2^2}\sigma_{\mathrm{TL}}$$
$$+ \frac{d^3L_{\mathrm{LT}}}{dW\,dQ_1^2\,dQ_2^2}\sigma_{\mathrm{LT}} + \frac{d^3\tilde{L}_{\mathrm{TT}}}{dW\,dQ_1^2\,dQ_2^2}\tau_{\mathrm{TT}} + \frac{d^3\tilde{L}_{\mathrm{TL}}}{dW\,dQ_1^2\,dQ_2^2}\frac{1}{2}(\tau_0 + \tau_1)$$

初版的signal MC只考虑了TT极化，且不考虑干涉。强子截面只考虑对$W_{\gamma\gamma}$的依赖（Belle测量结果）。

$$\frac{\partial\sigma_{\mathrm{TT}}}{\partial Q^2} = 0, \qquad \frac{\partial\sigma_{LL}}{\partial cos\theta^*} = 0$$

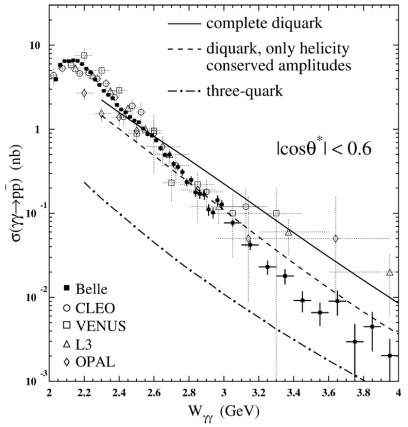
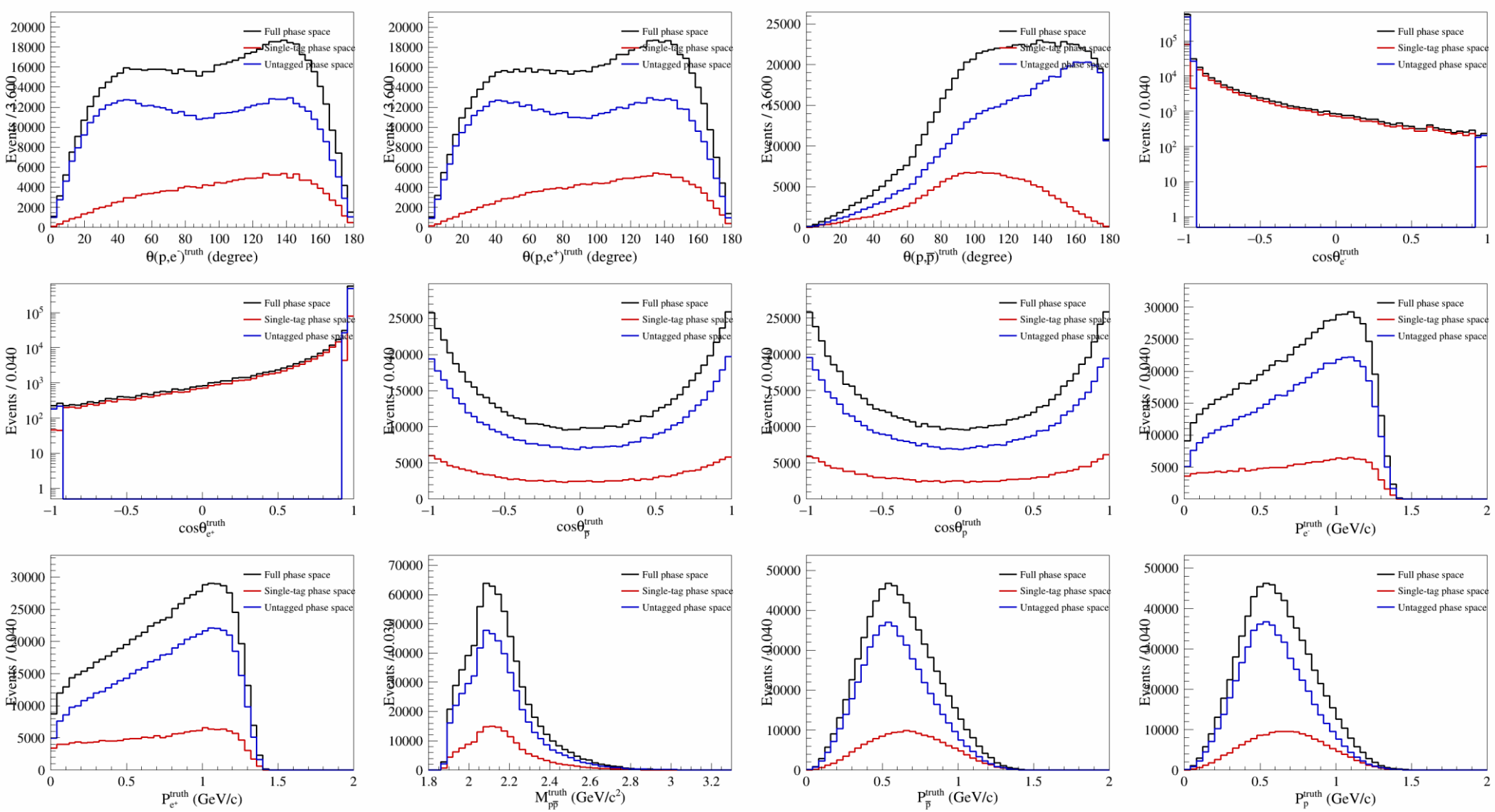


Fig. $\sigma_{\gamma\gamma\to p\bar{p}}(W_{\gamma\gamma})$
Belle Collaboration
Physics Letters B 621 (2005) 41–55

MC Truth Info



Single tag

➢ Data and MC samples:

BOSS: 712

Data set: full data sat at 3.773GeV, 20.3fb $^{-1}$

IncMC sample: Hadron Hybrid; 0.25x Bhabha; 15x dimu; 1x $\gamma\gamma \to ee, \mu\mu, \pi\pi, KK, \eta, \eta'$

ExcMC sample: 1M $\gamma\gamma \to p\bar{p}$ TT-only, 10M $\gamma\gamma \to p\bar{p}$

➢ Event selection:

- Good charged track:

$$|V_{xy}| < 1cm, |V_z| < 10cm, |\cos\theta| < 0.93$$

$$N_{good} = 3, N_{charge} = \pm 1$$

- PID:

p: prob(p)>prob(e, μ, π, K),0.001

e: prob(e)>prob(μ, π, K, p),0.001

$$N_p = N_{\bar{p}} = N_e = 1$$

- Vertex Fit:

Vertex fit for $p\bar{p}e$, success;

- Other:

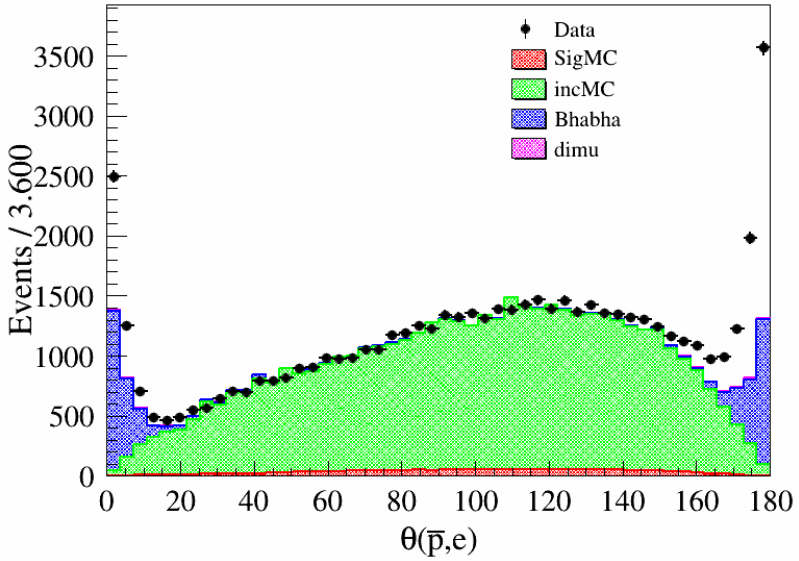
Cosθ_{miss} ×sign(e)<0;

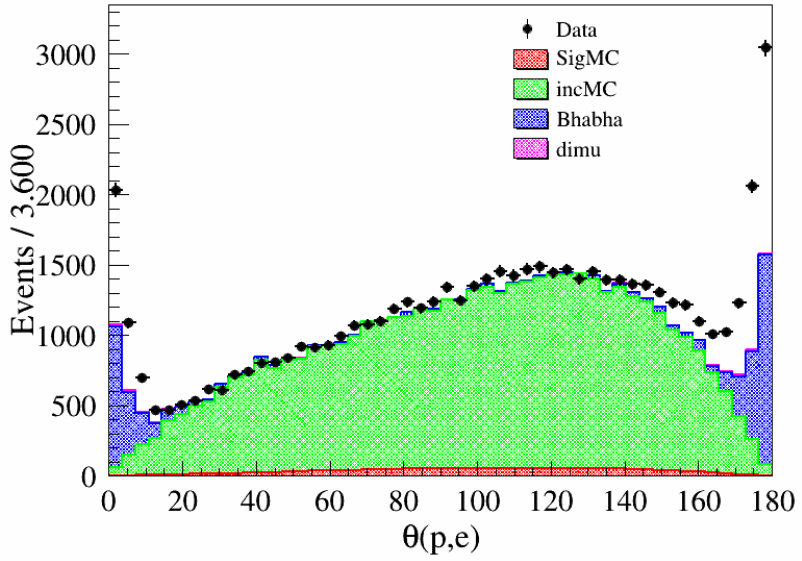
- Good Photon

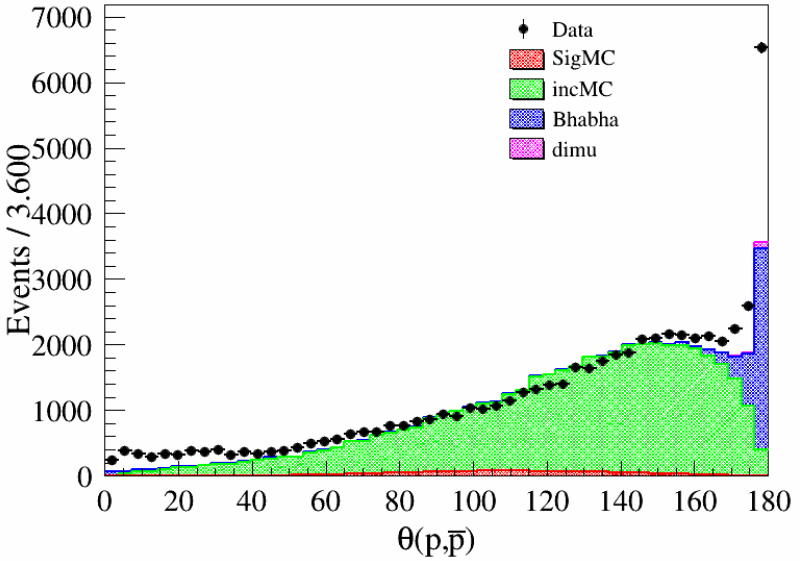
10 degree away from charged tracks and 20 for $\bar{p}$

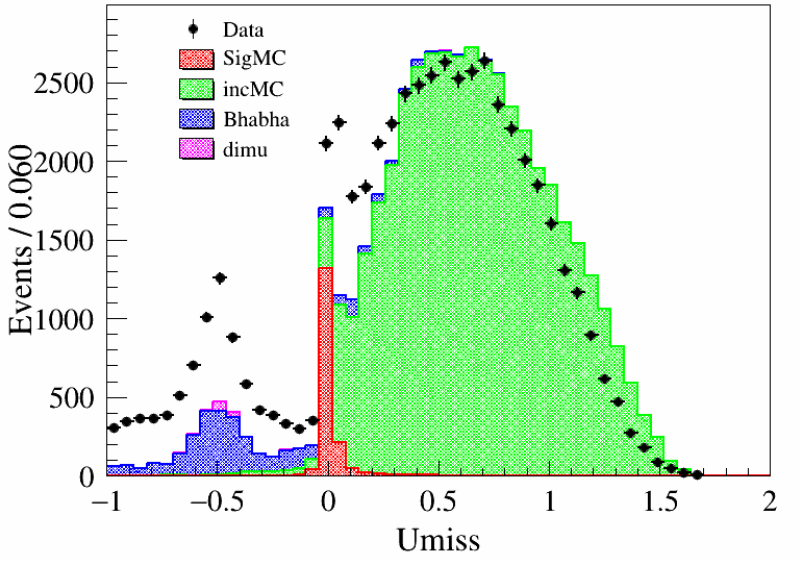
Further Event selection

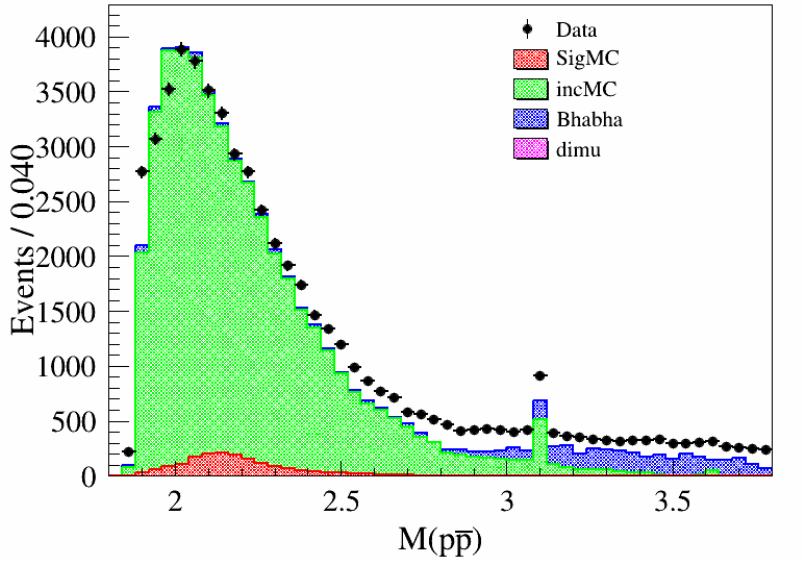
$cos\theta_{miss} * sign(e) < 0;$

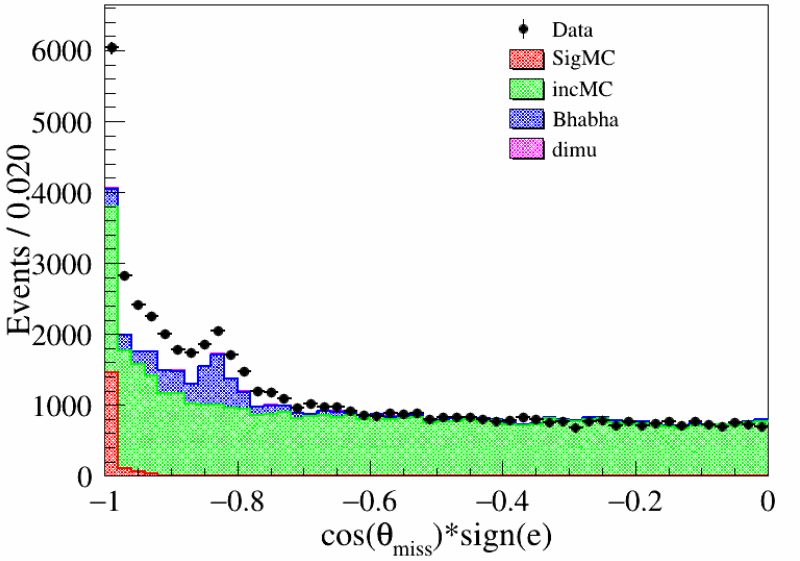












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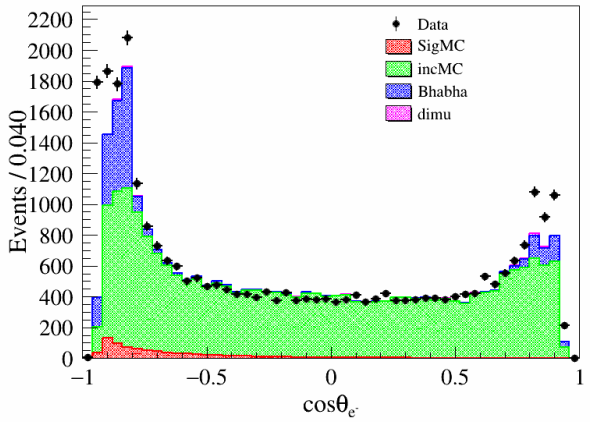
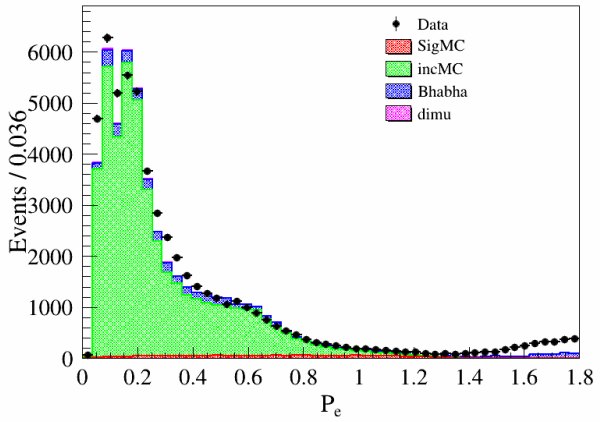
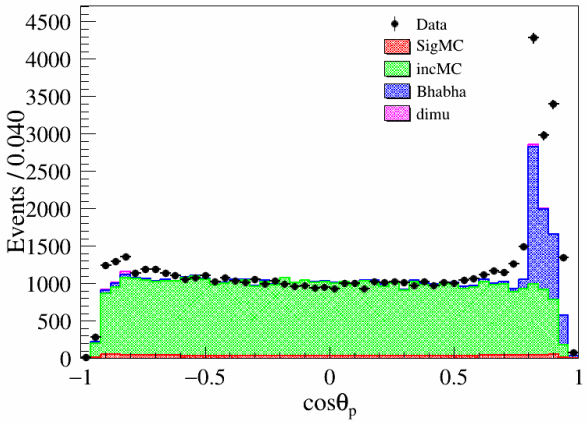
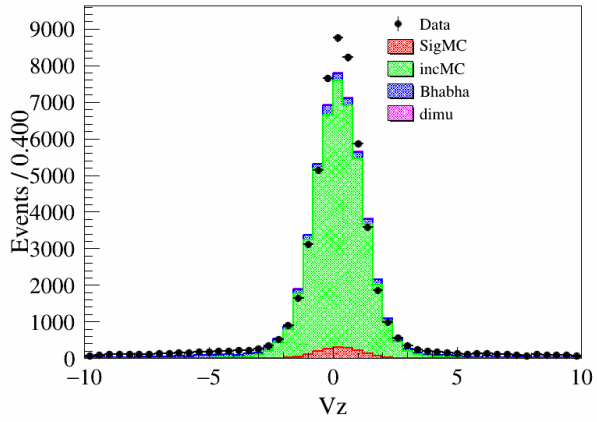
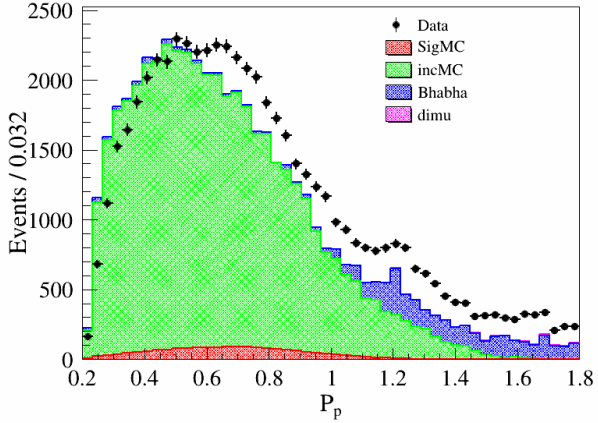
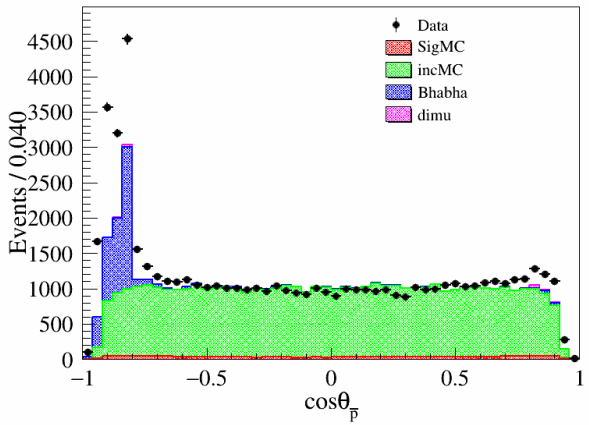


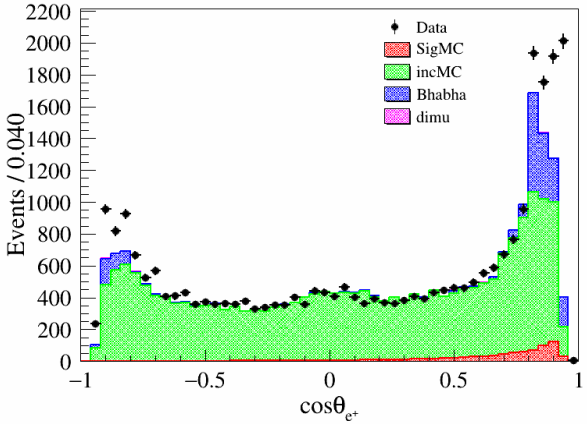


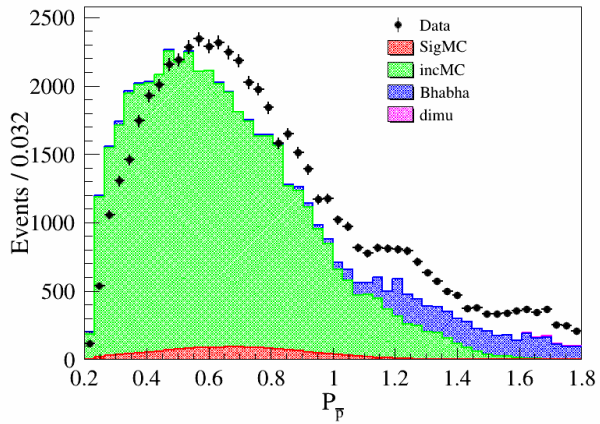








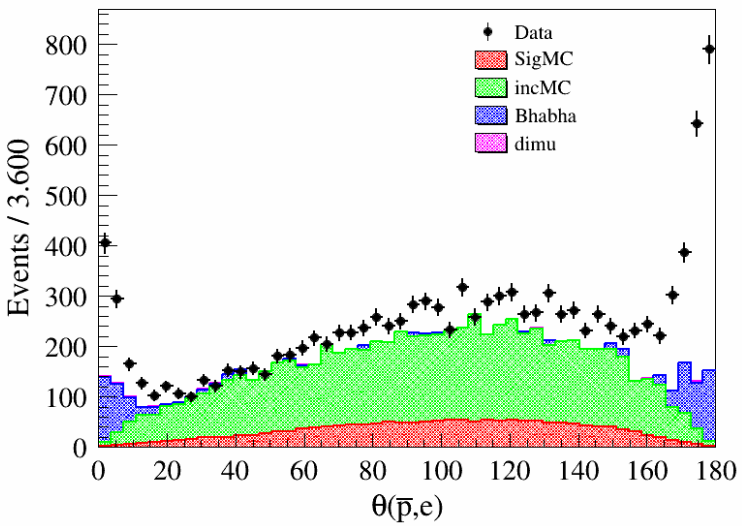


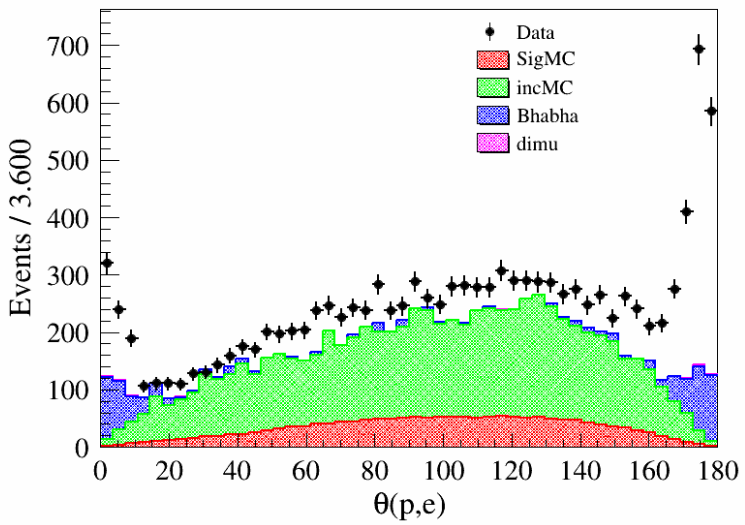


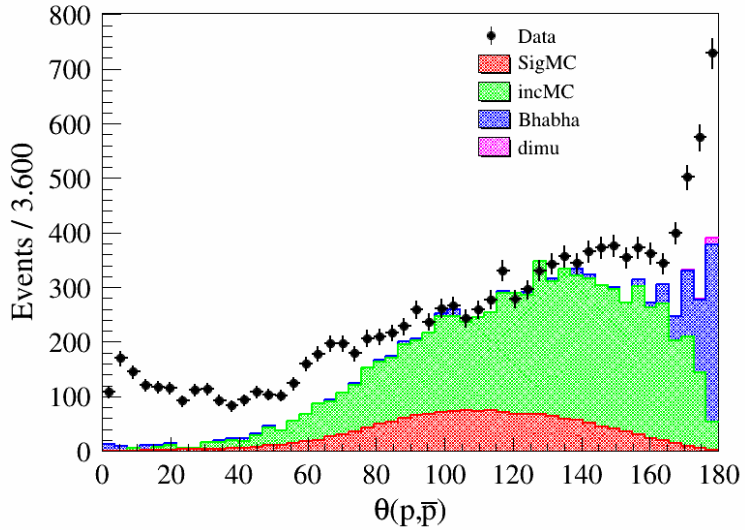
Further Event selection

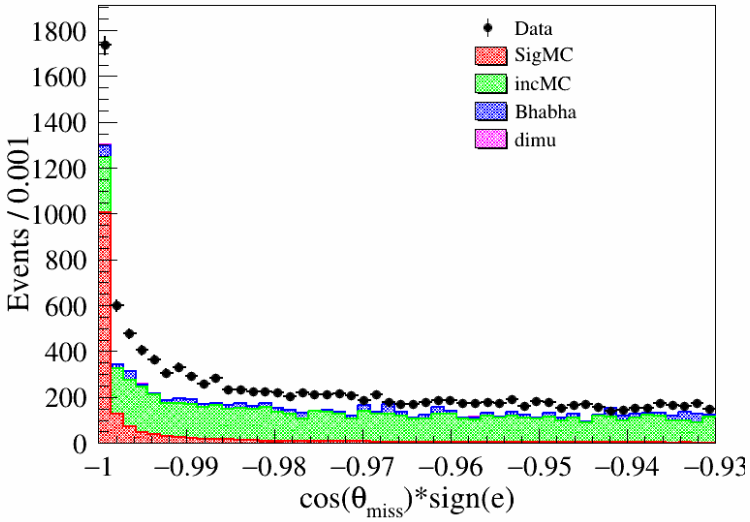
$cos\theta_{miss} * sign(e) < -0.93;$

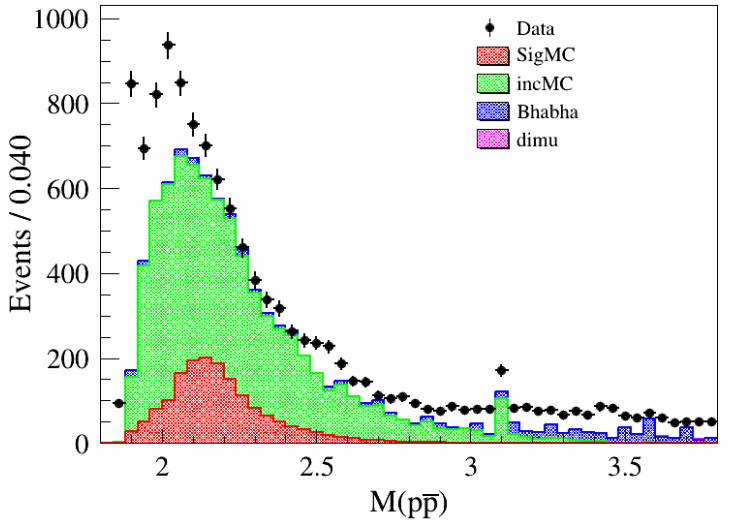
要求 $cos\theta_{miss} * sign(e) < -0.93;$

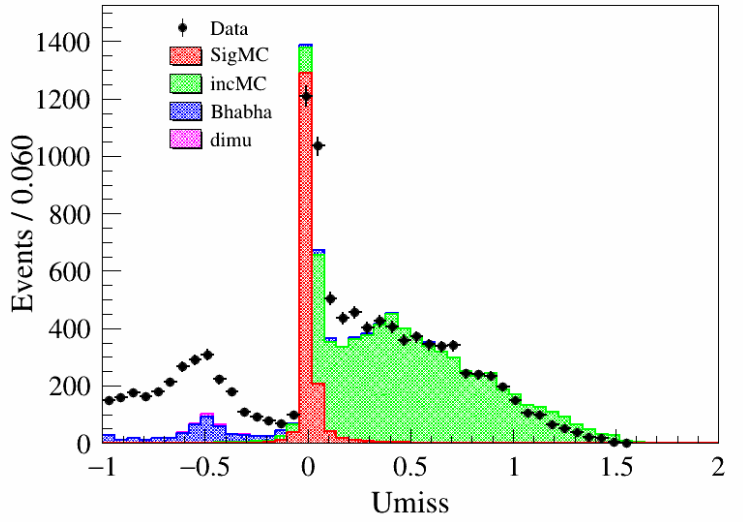












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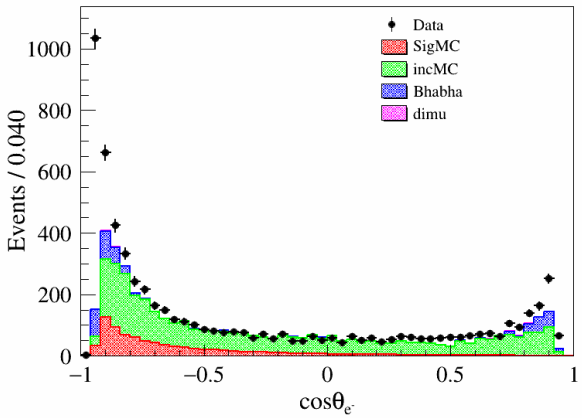
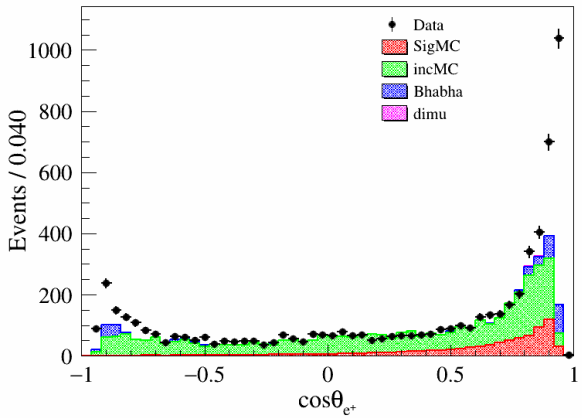
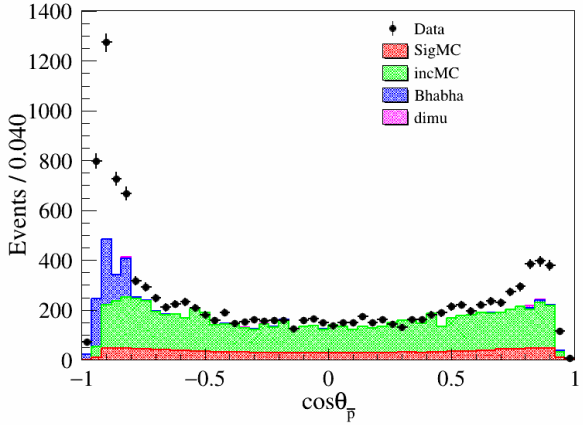
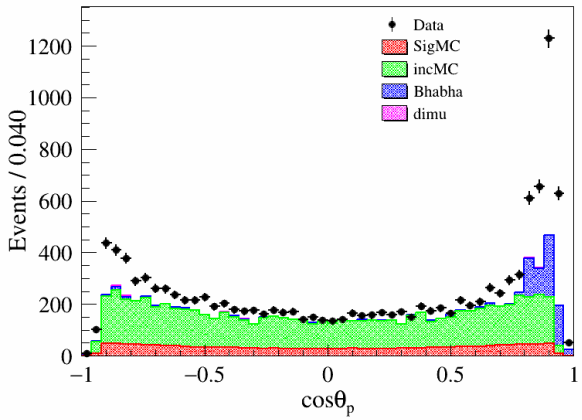
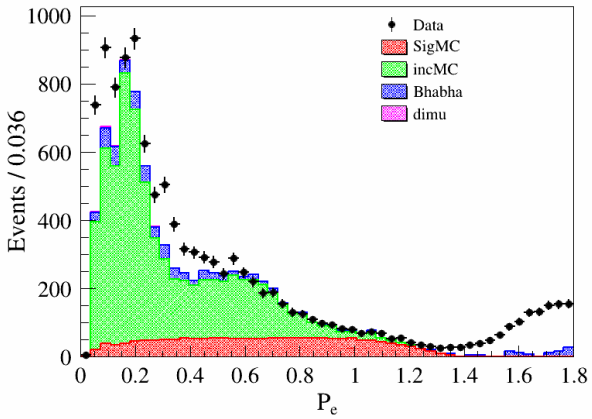
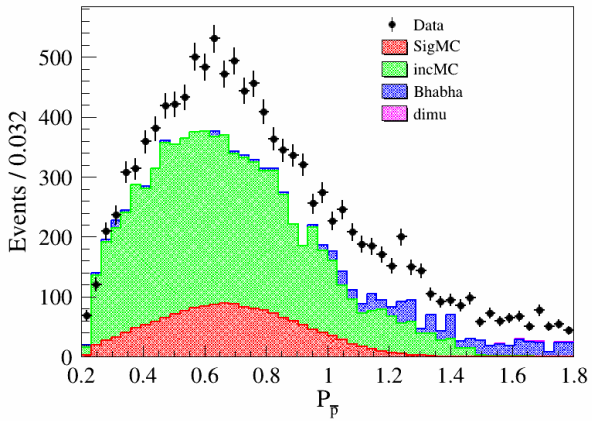


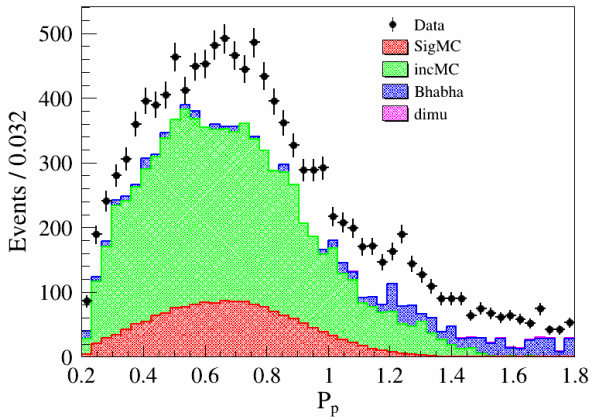


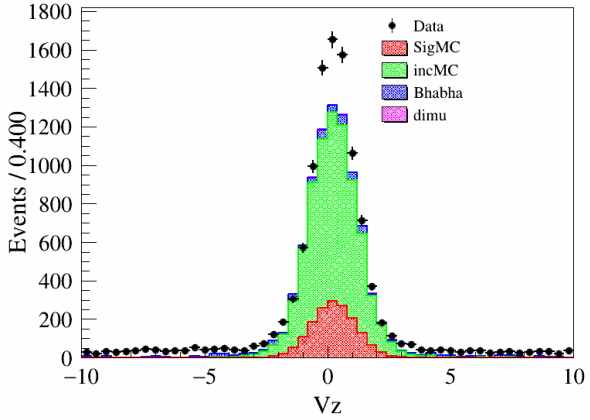








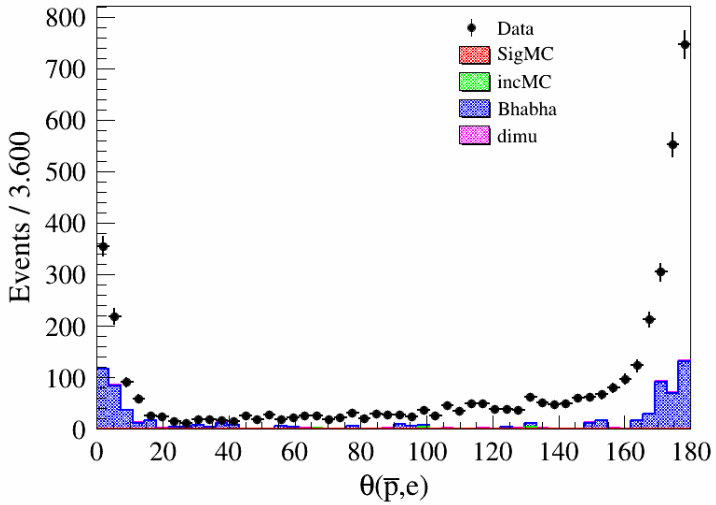


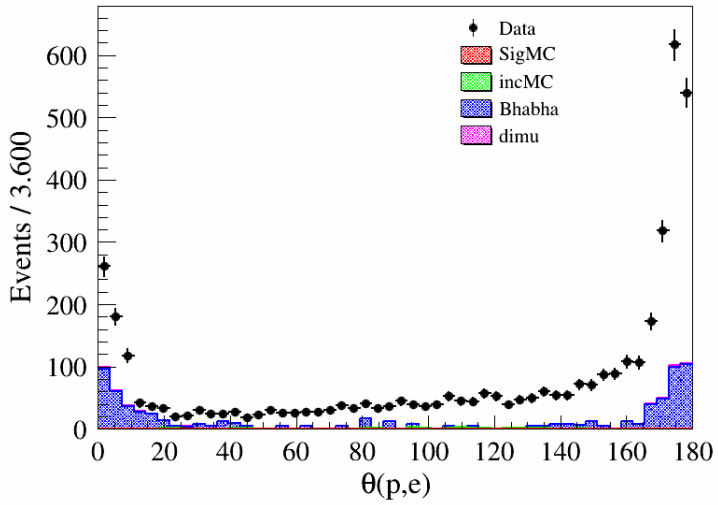


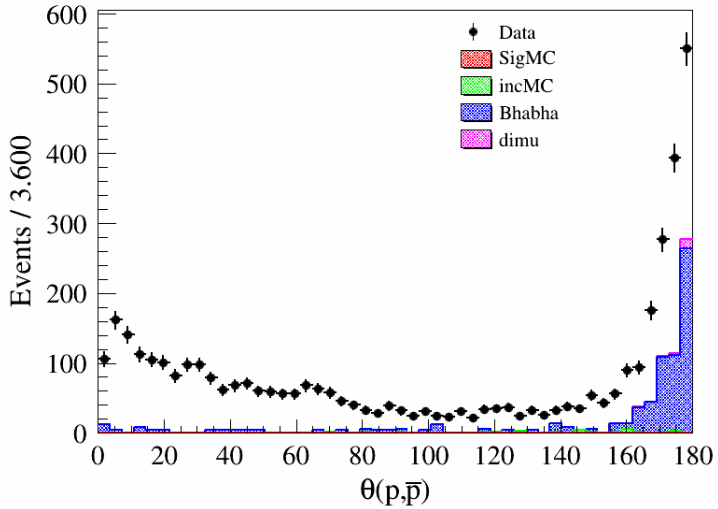
Further Event selection

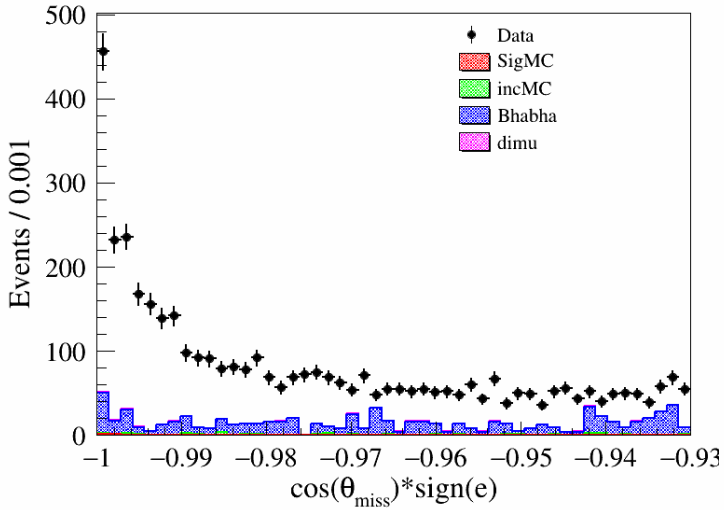
$cos\theta_{miss} * sign(e) < -0.93$;
$Umiss < -0.2$

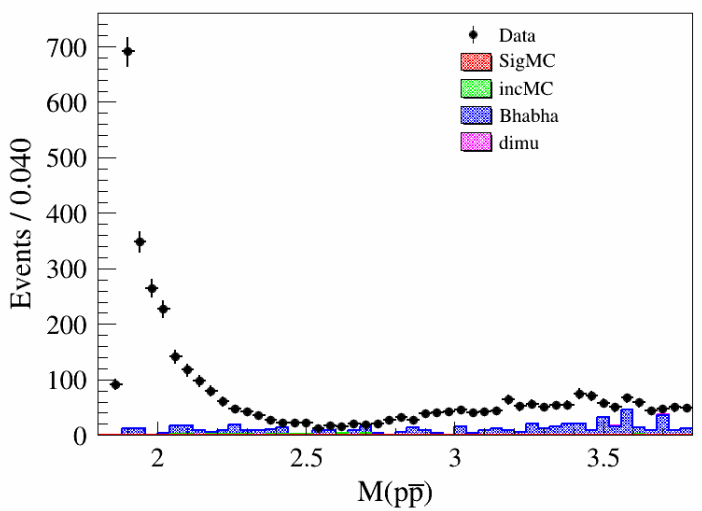
要求 $cos\theta_{miss} * sign(e) < -0.93$; 取出Umiss<-0.2的事例

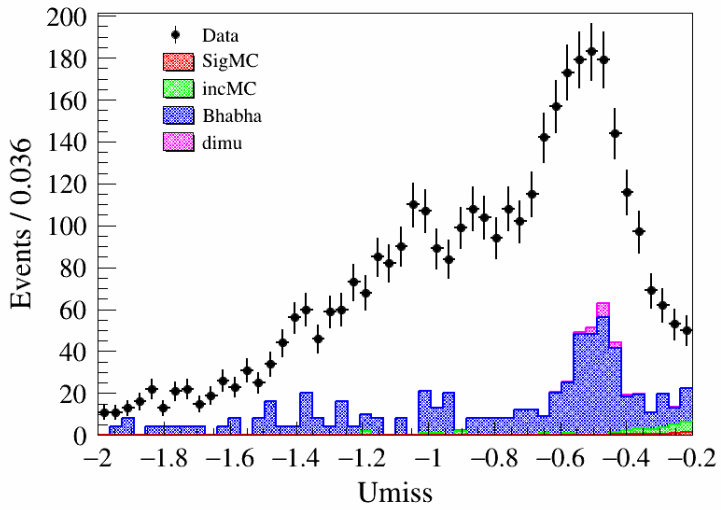












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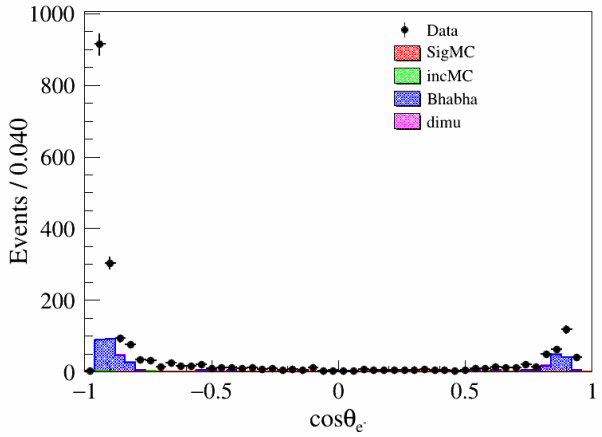

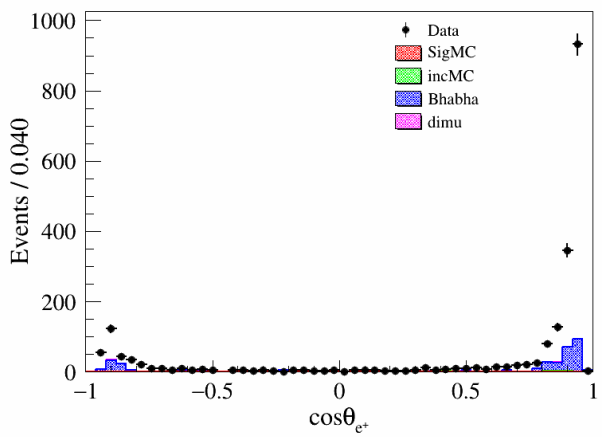

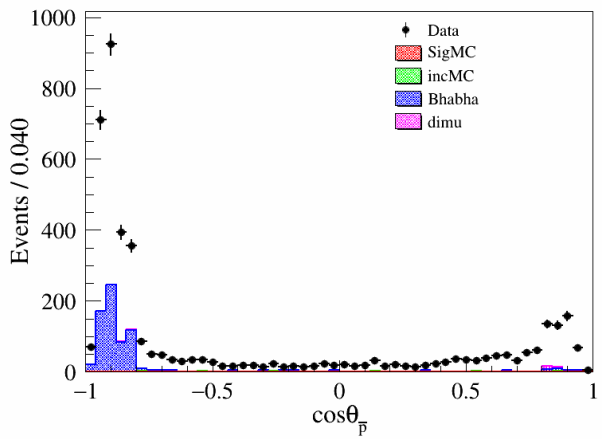

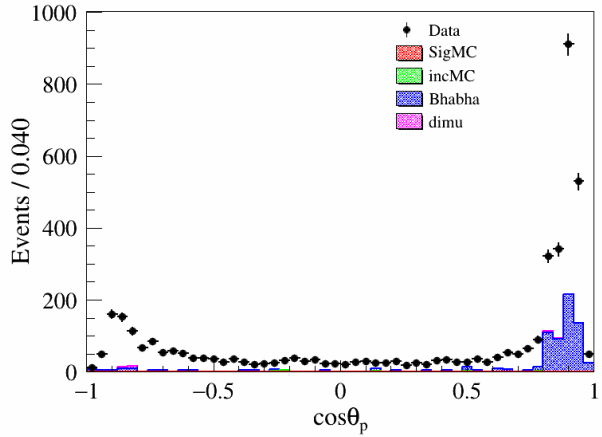

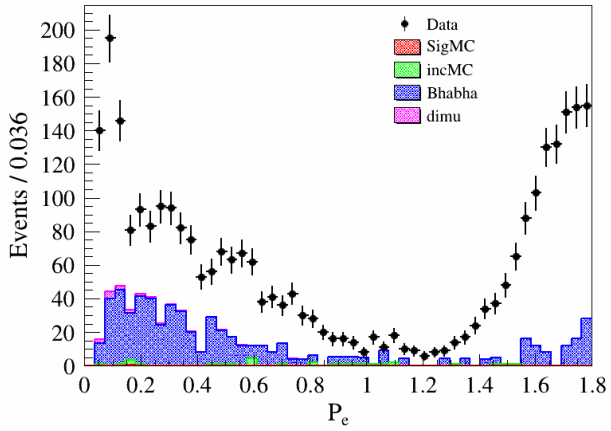

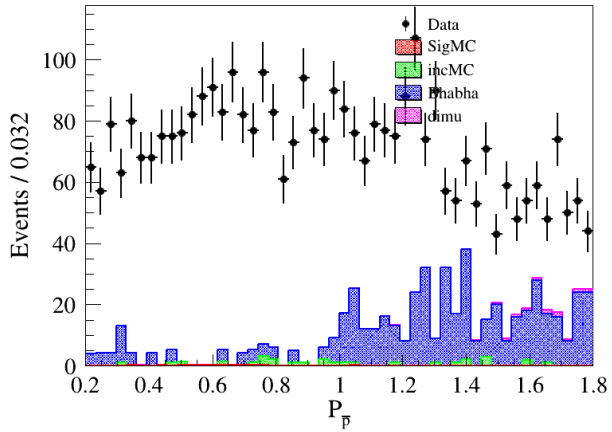

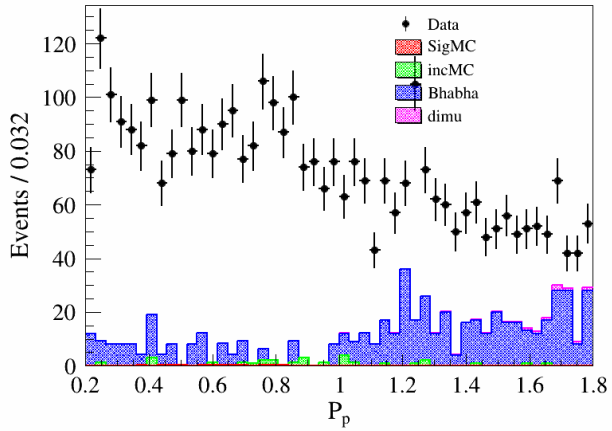

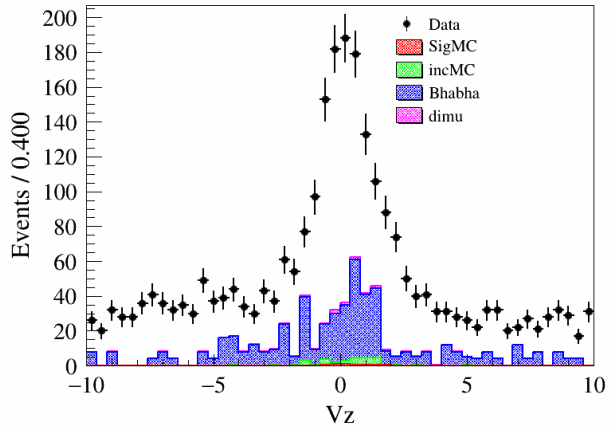

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$cos\theta_{miss} * sign(e) < -0.93;$
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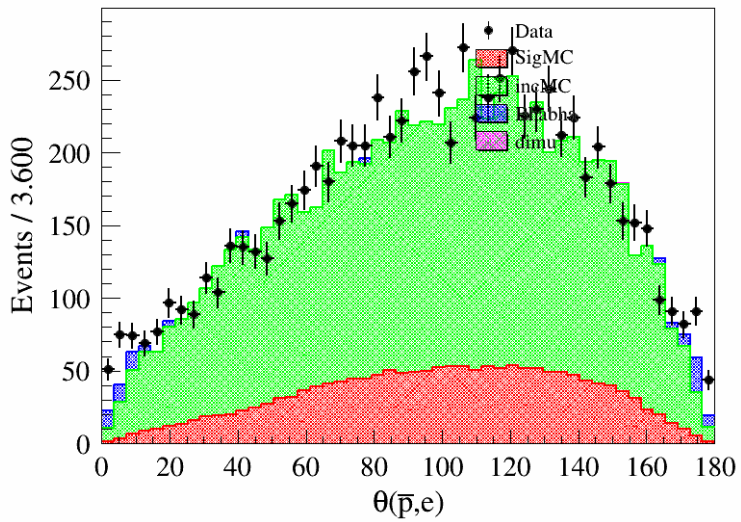
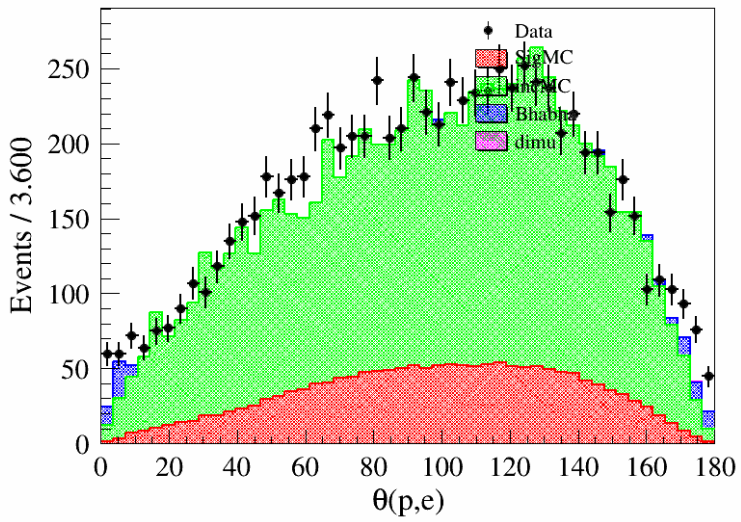
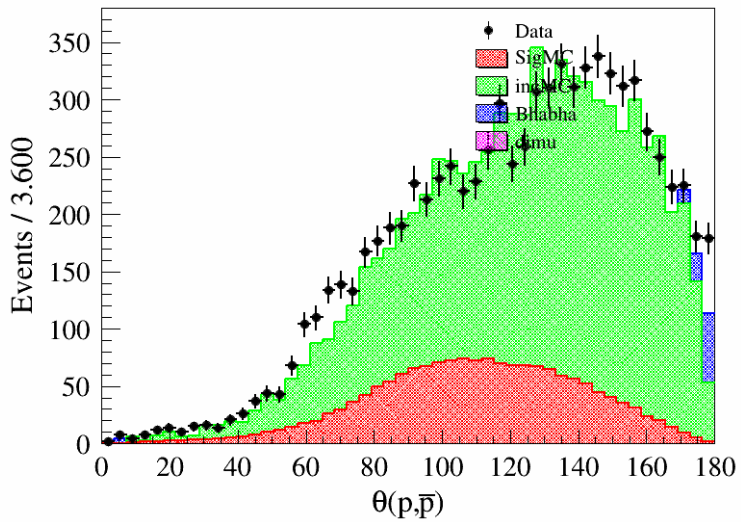
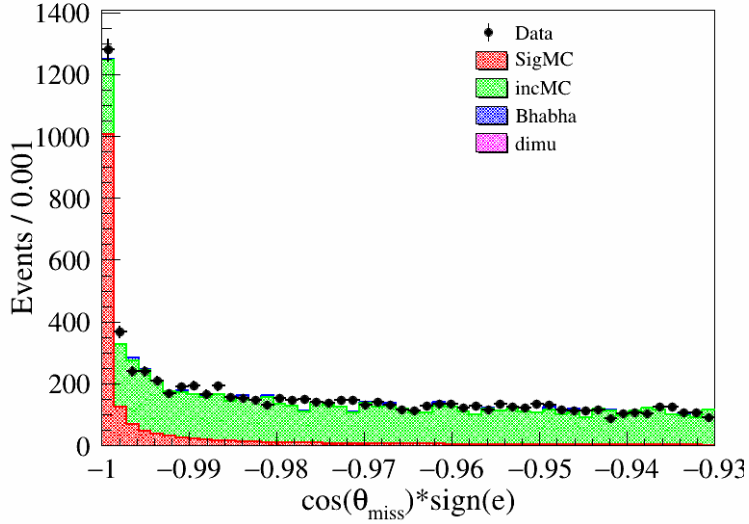
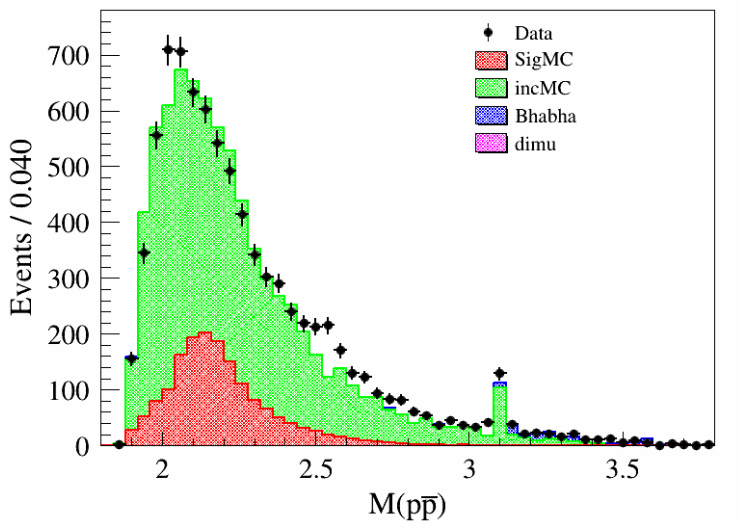
要求$Umiss > -0.2$

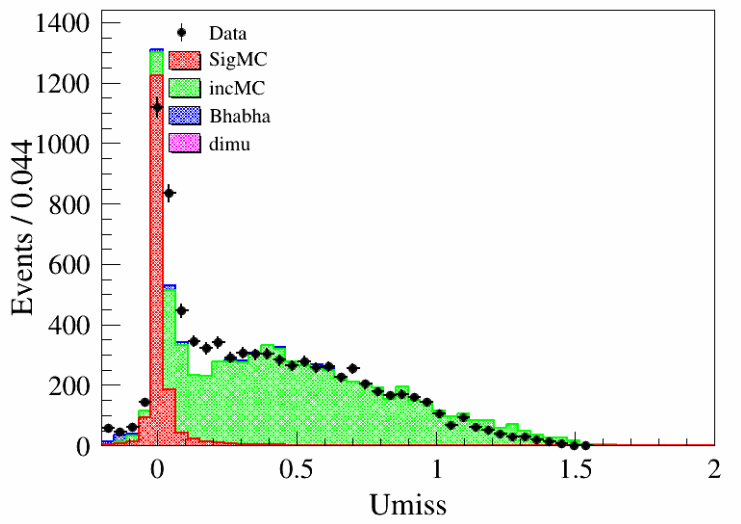












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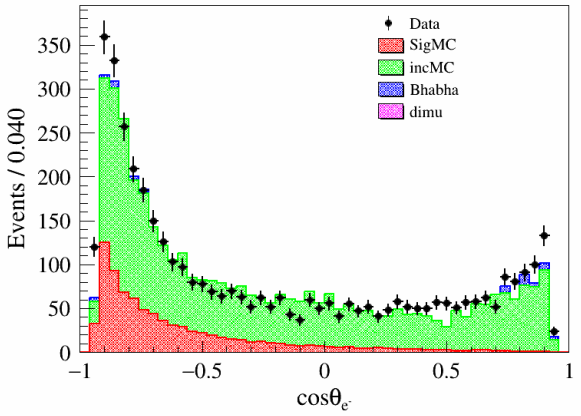
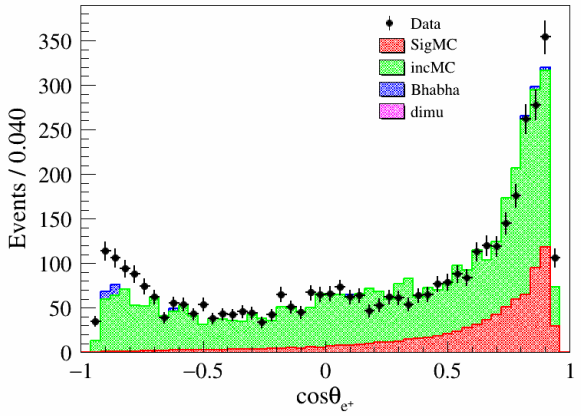
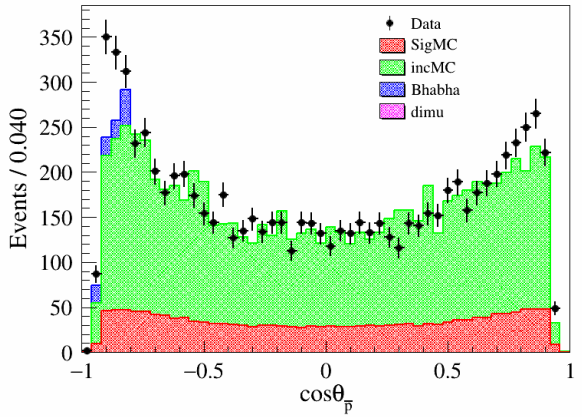
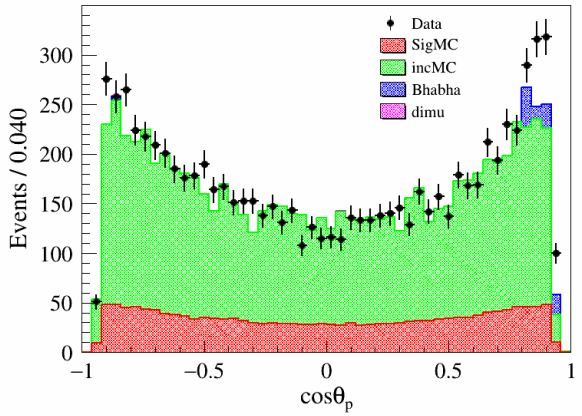
$Umiss > -0.2$

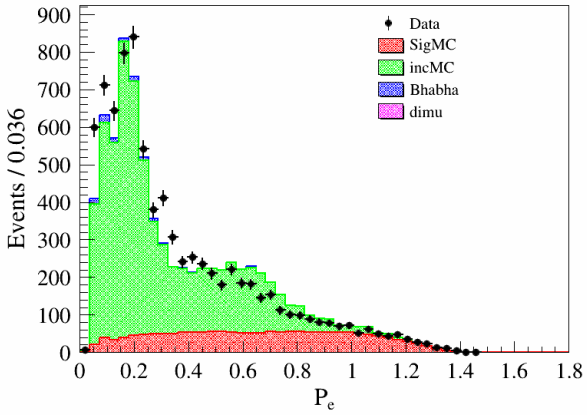
要求$Umiss > -0.2$

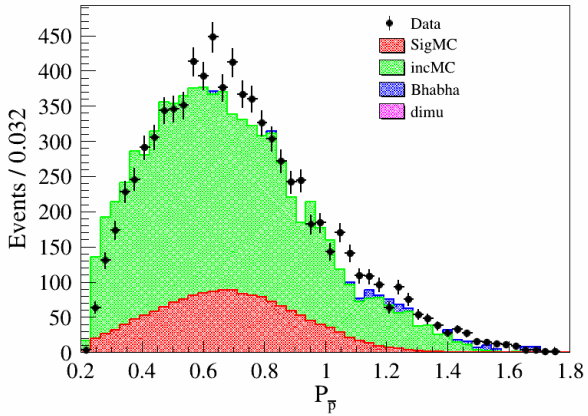


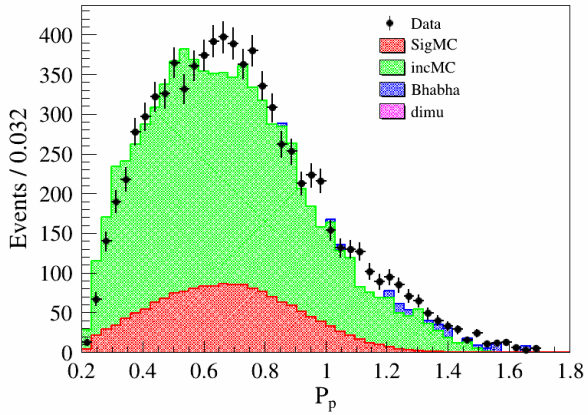


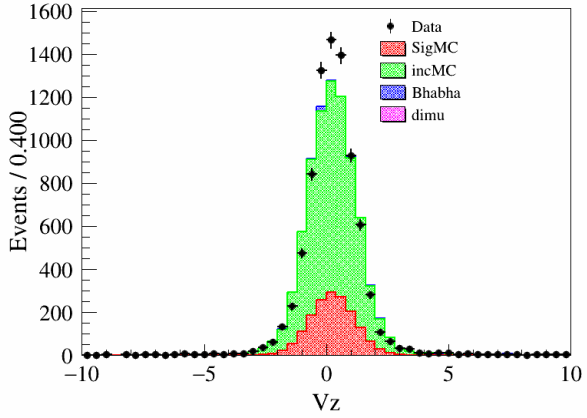








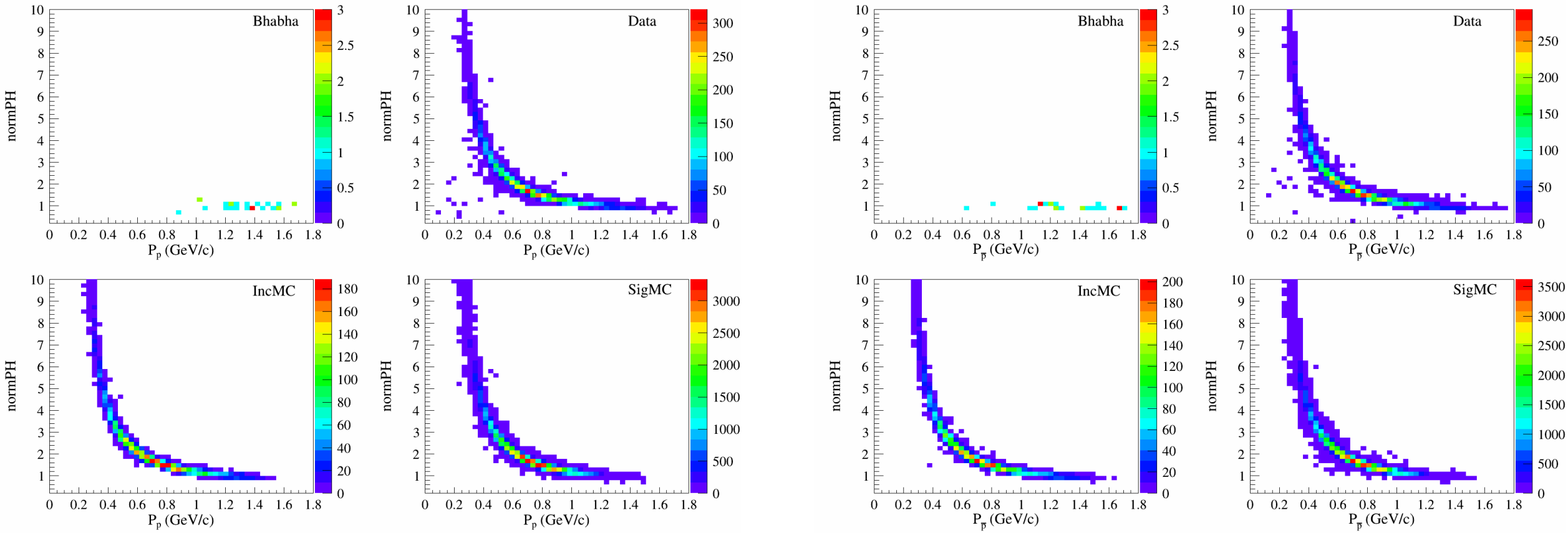




Further Event selection

$cos\theta_{miss} * sign(e) < -0.93;$
$Umiss > -0.2$

要求$Umiss > -0.2$



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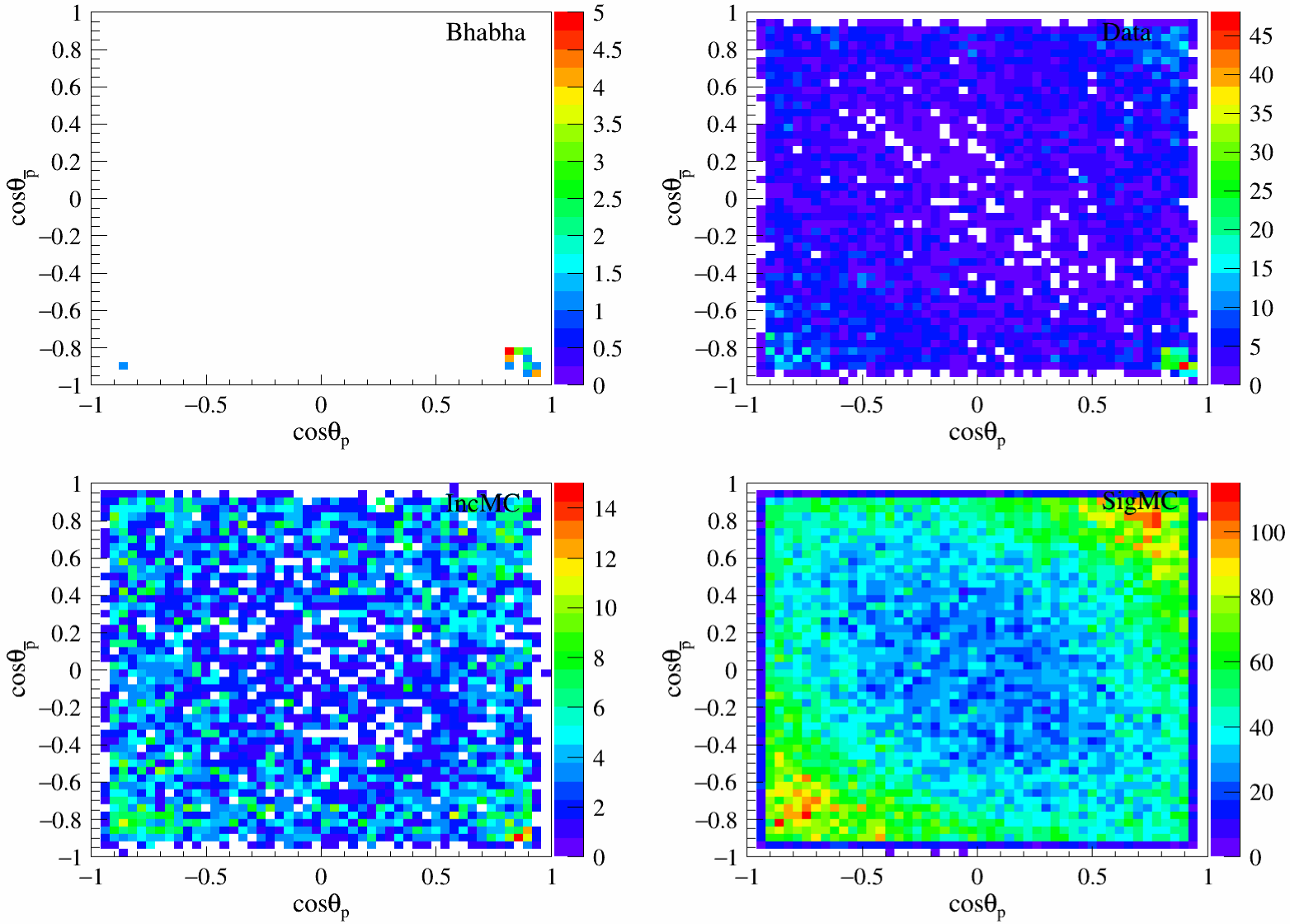
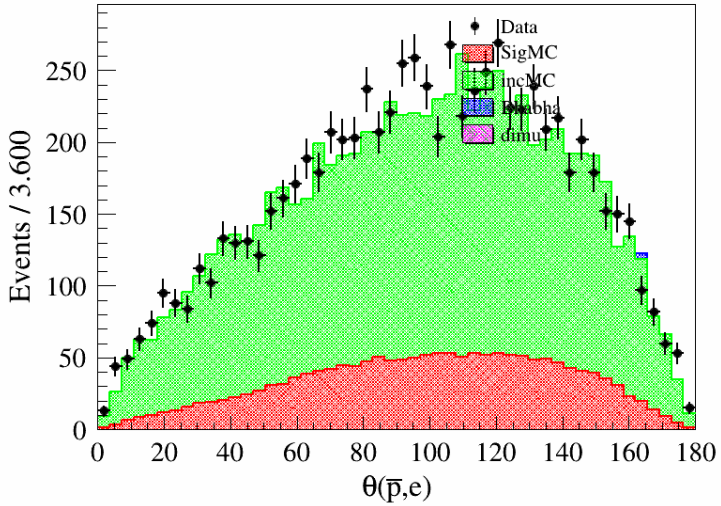
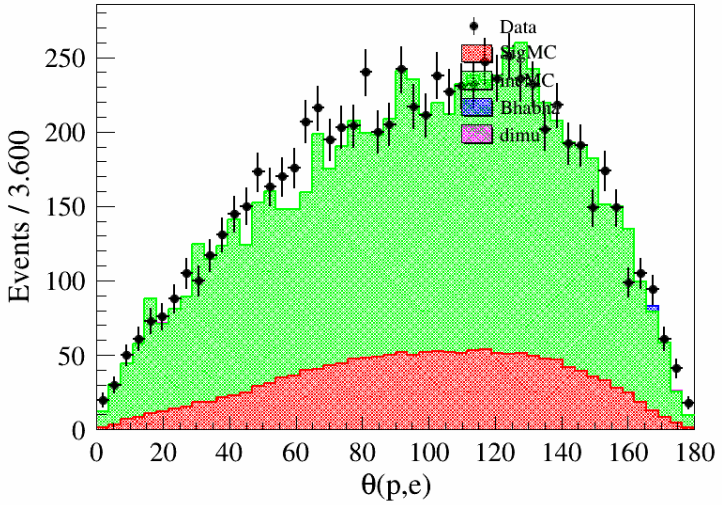


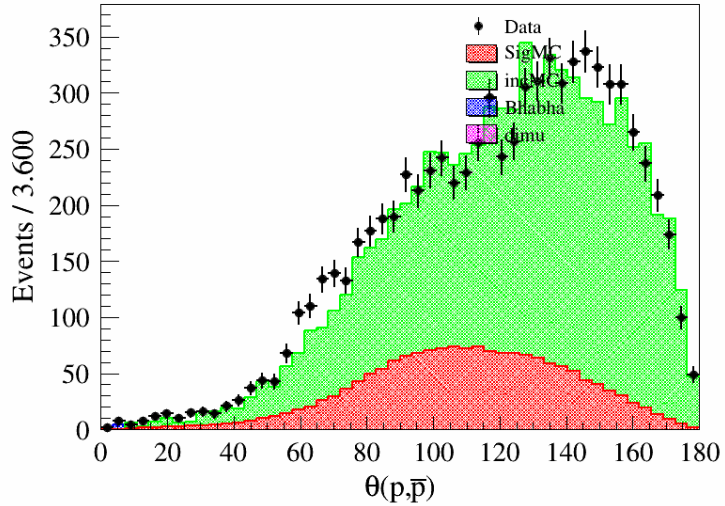
Further Event selection

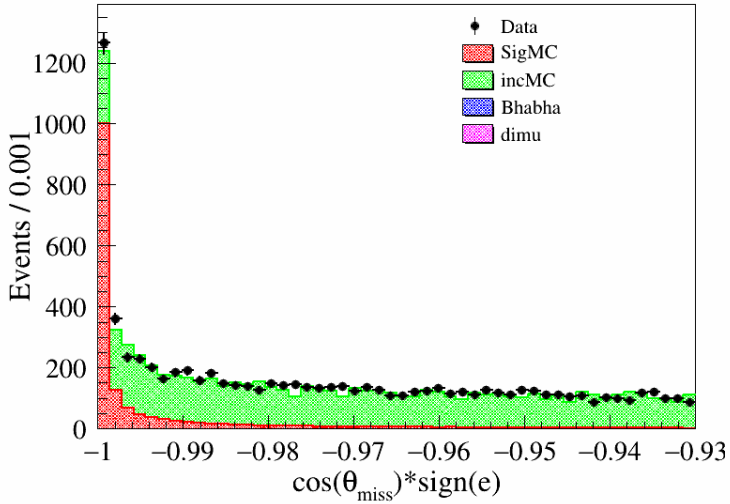
$cos\theta_{miss} * sign(e) < -0.93;$
$Umiss > -0.2$
Reject $cos\theta_p > 0.8$ & $cos\theta_{\bar{p}} < -0.8$

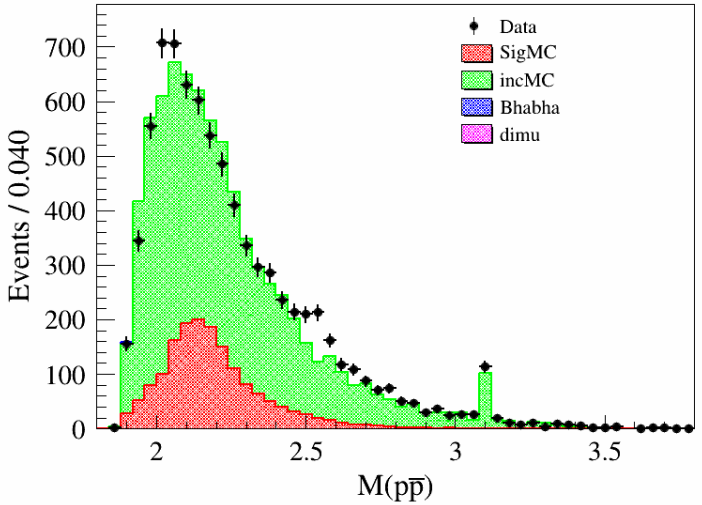
Veto Bhabha by reject events satisfy $cos\theta_p > 0.8$ & $cos\theta_{\bar{p}} < -0.8$

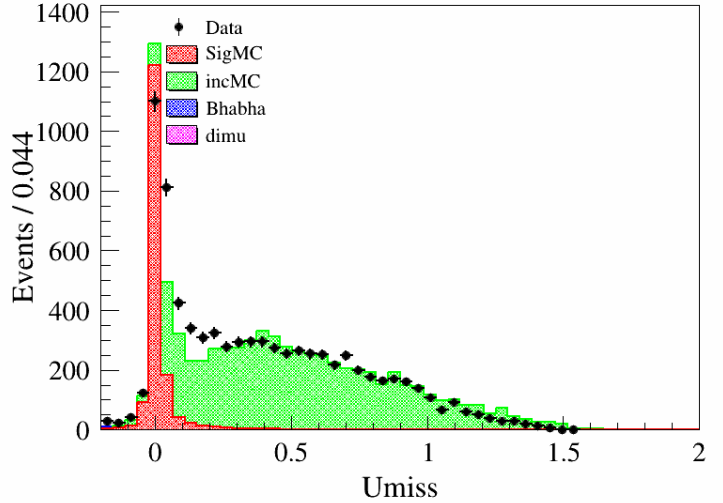












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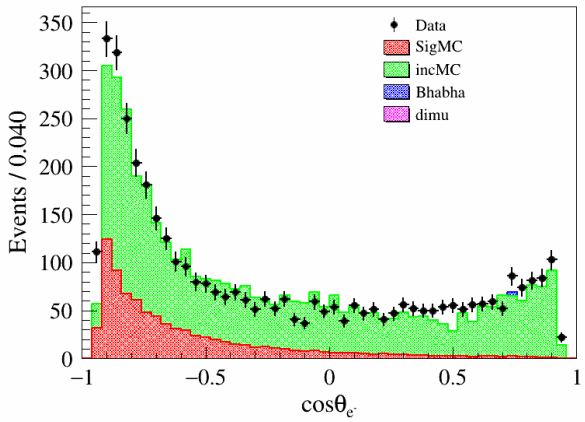
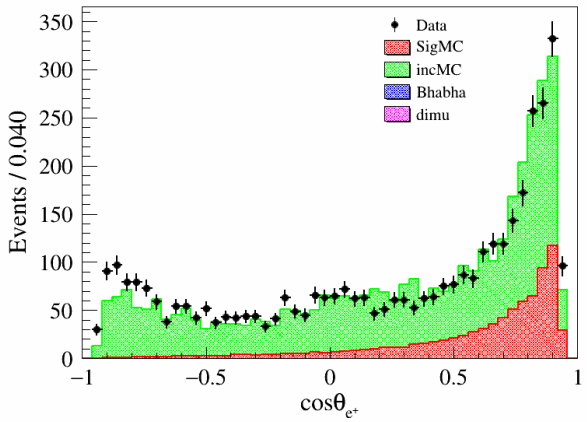
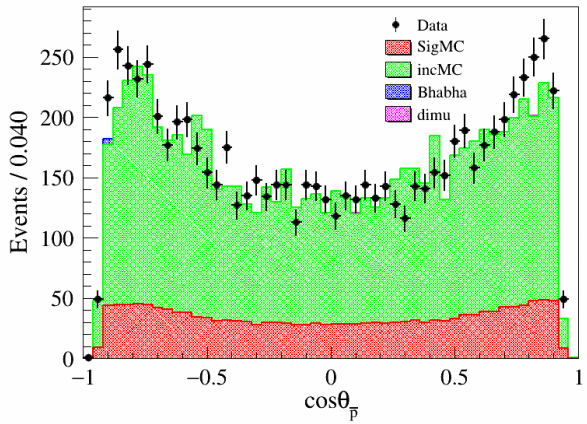
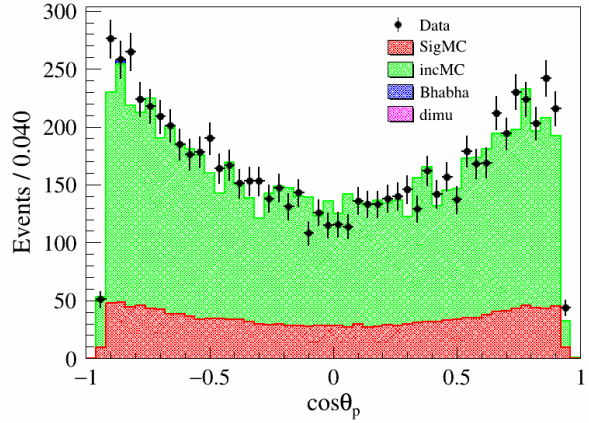
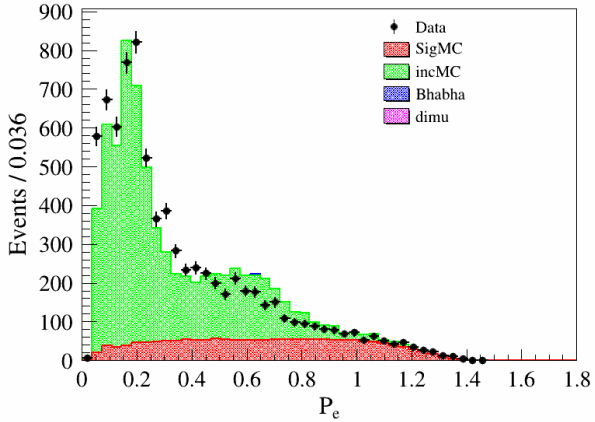
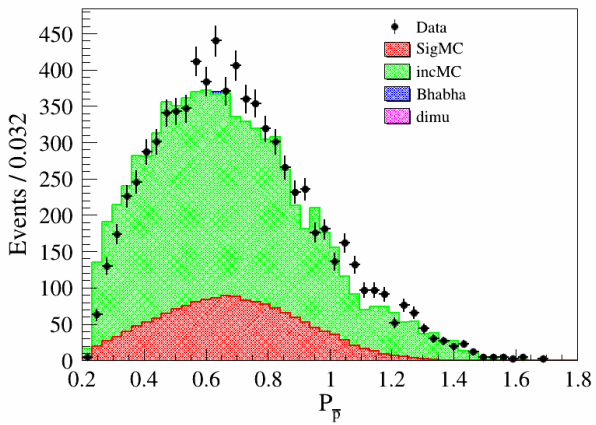


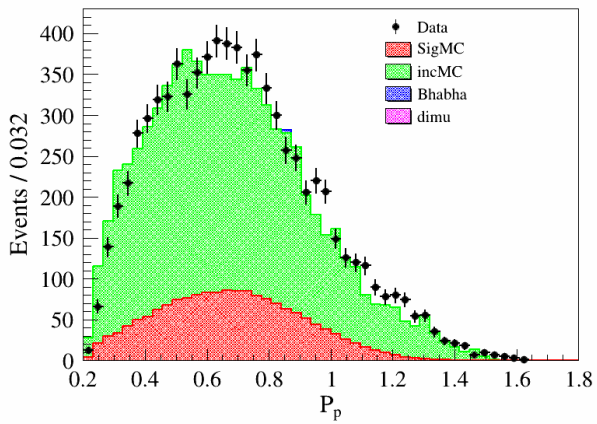


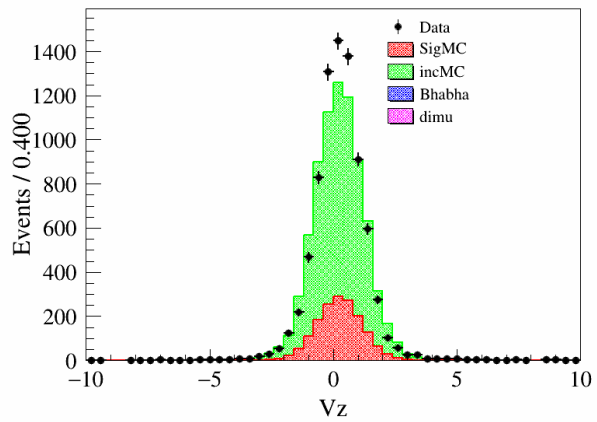








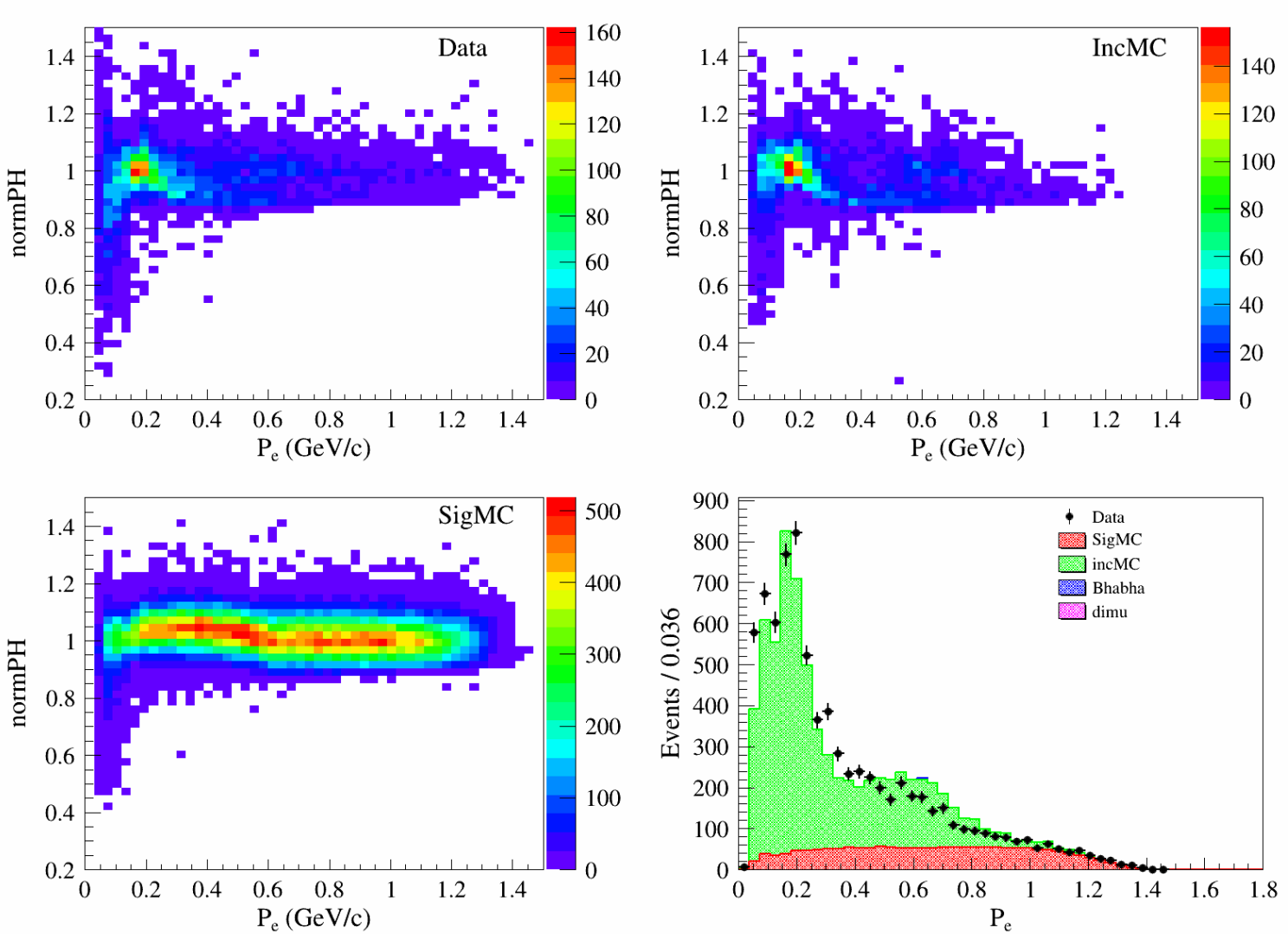




Further Event selection

$cos\theta_{miss} * sign(e) < -0.93;$
$Umiss > -0.2$
Reject $cos\theta_p > 0.8$ & $cos\theta_{\bar{p}} < -0.8$

IncMC中本底主要来自低动量e pi误鉴别:



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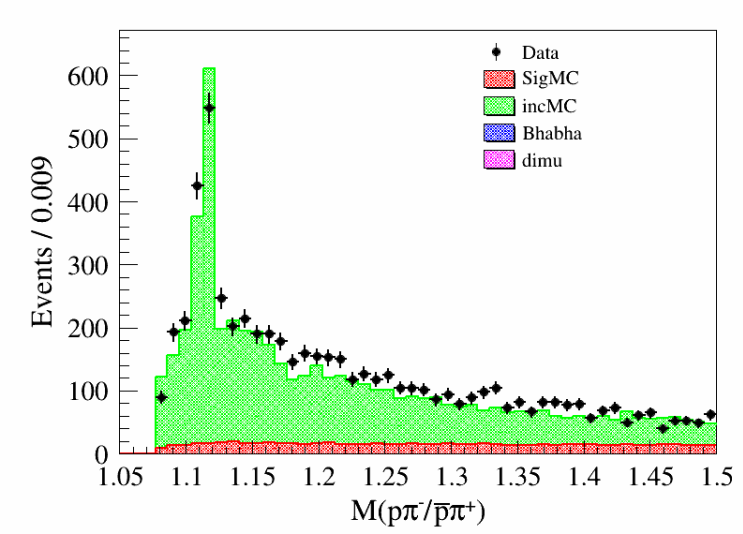
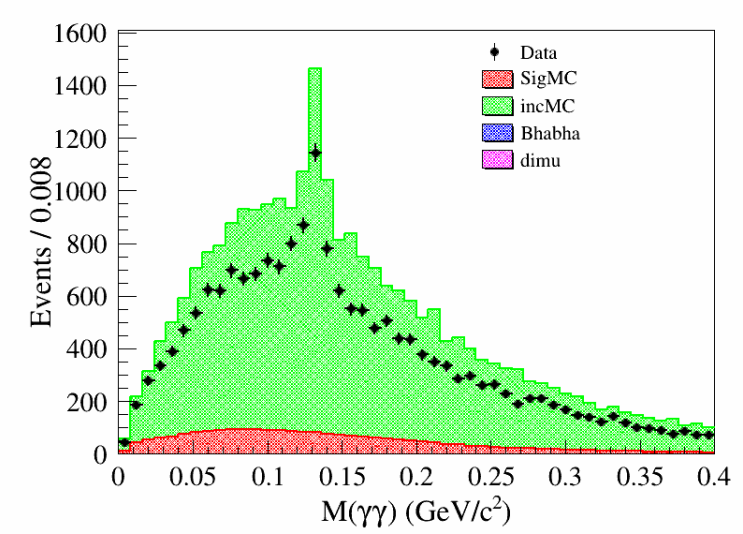
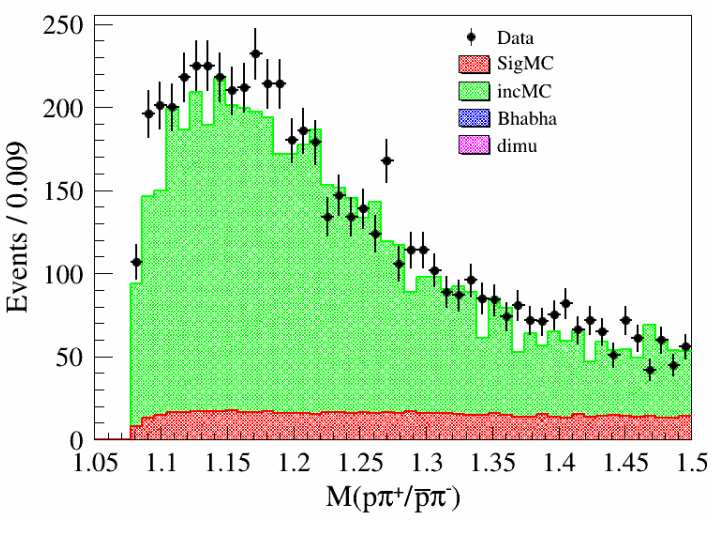
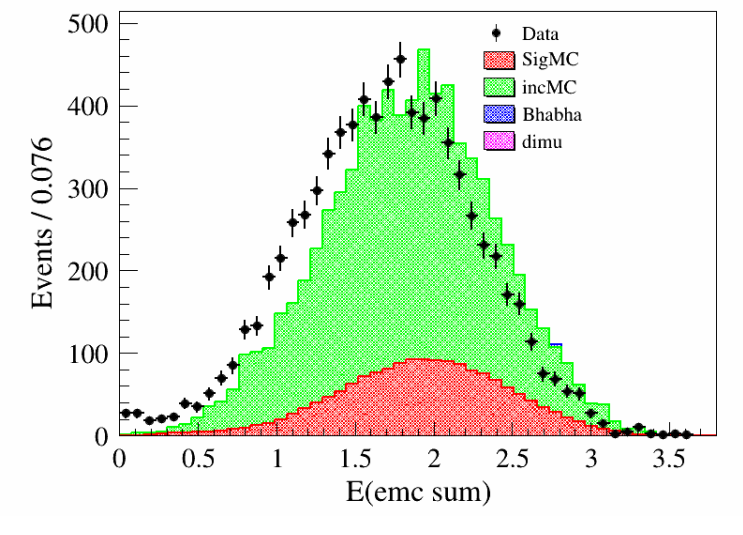
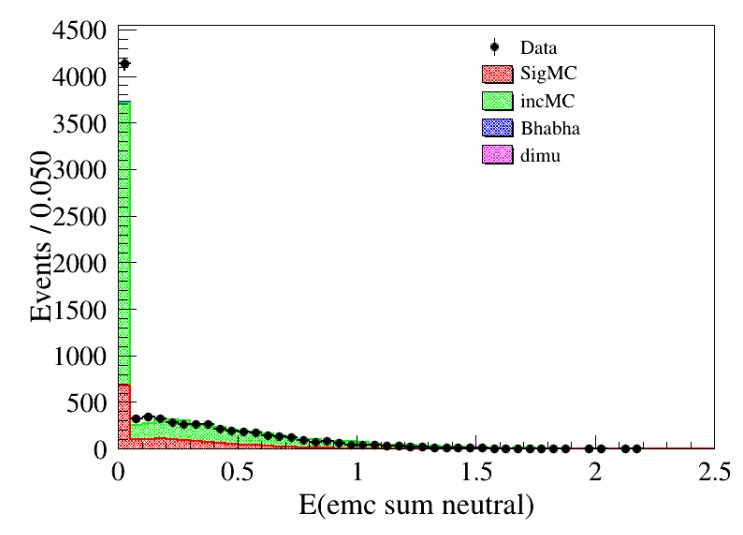
IncMC中有许多含π^0, Λ, Δ的事例







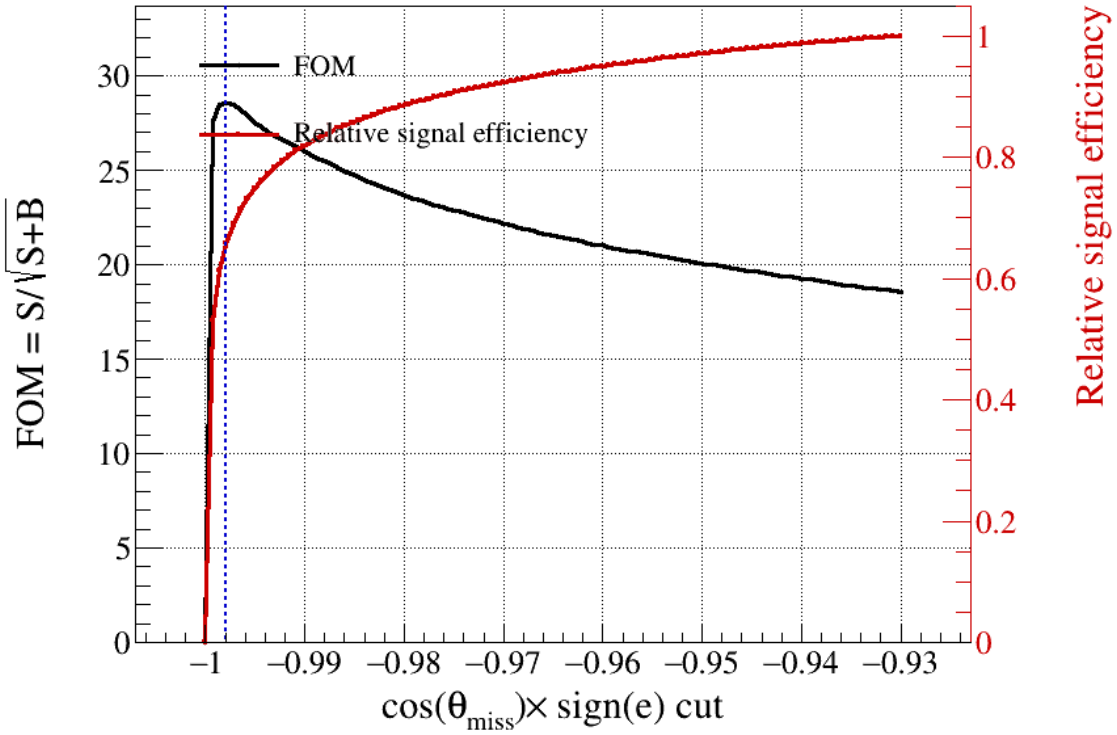


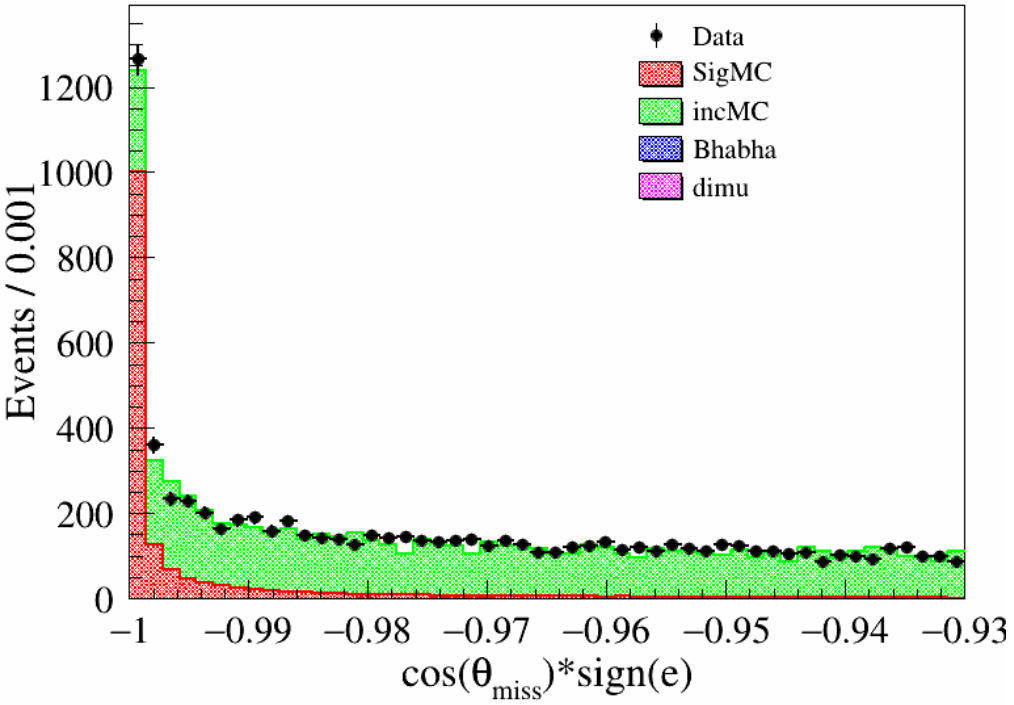


Further Event selection

$cos\theta_{miss} * sign(e) < -0.93;$
$Umiss > -0.2$
Reject $cos\theta_p > 0.8$ & $cos\theta_{\bar{p}} < -0.8$

先进一步收紧$cos\theta_{miss} * sign(e) < -0.99$





Further Event selection

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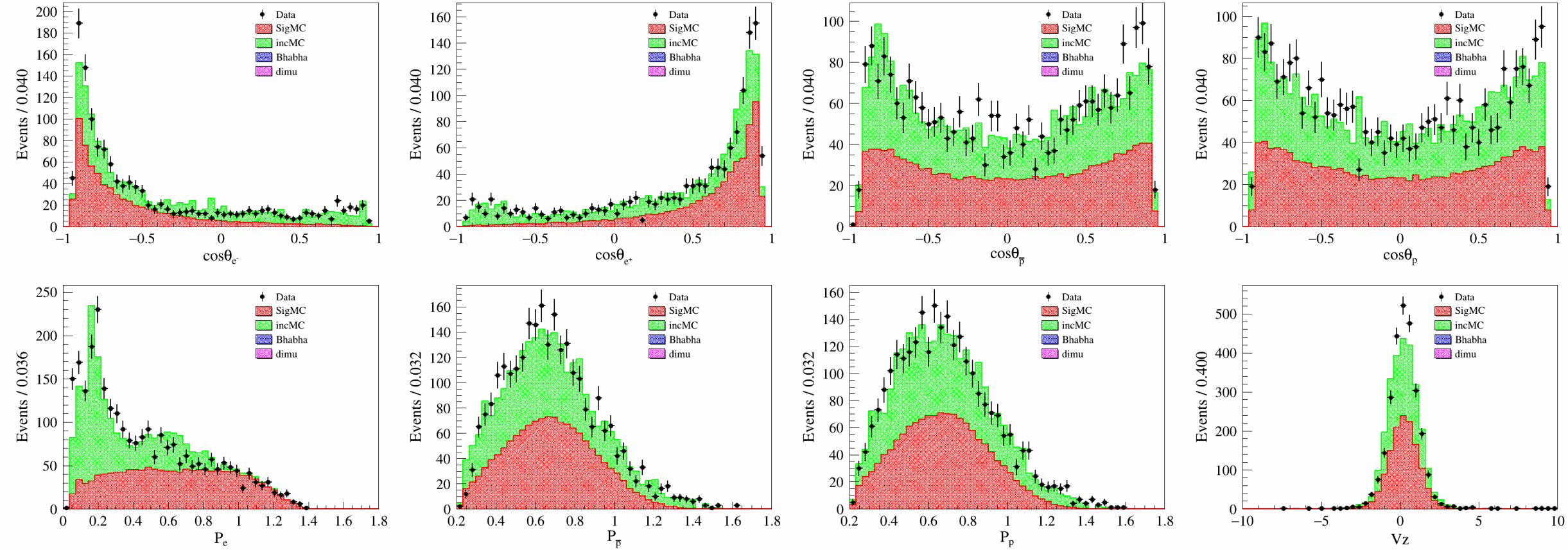

Further Event selection

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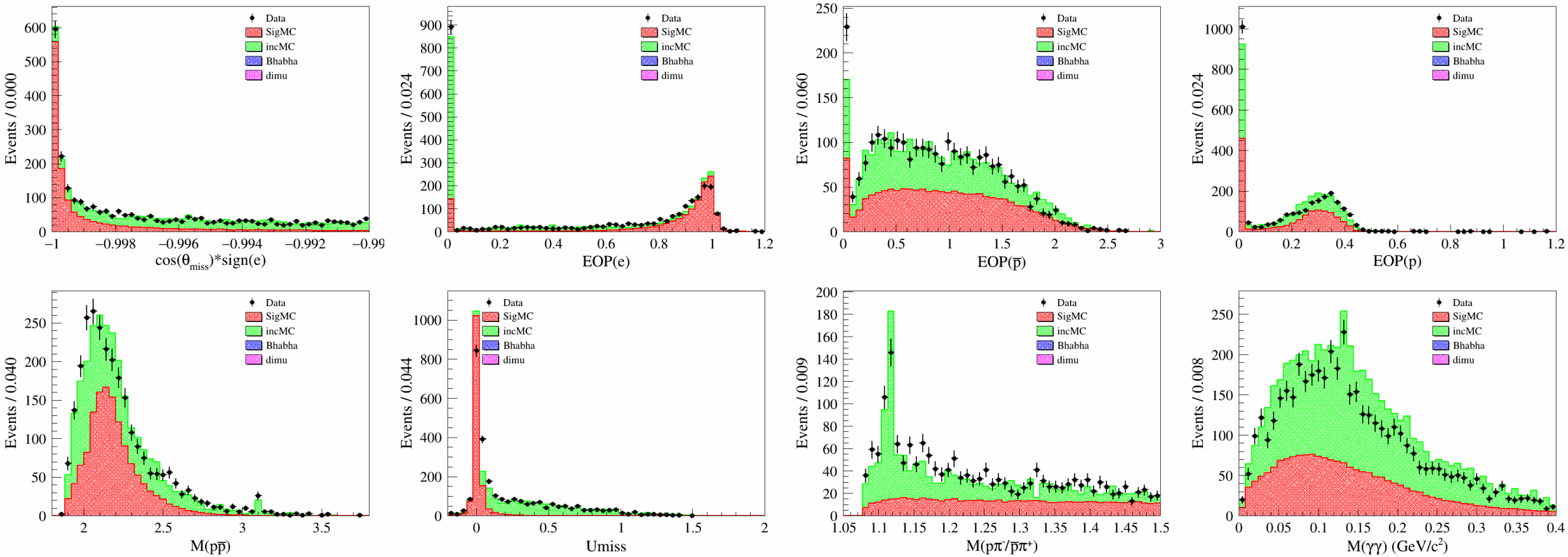

Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
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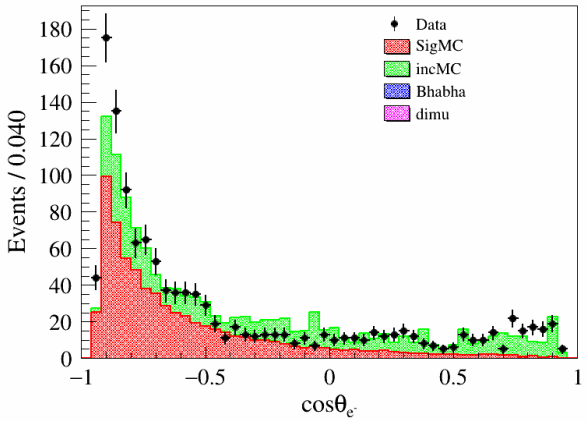
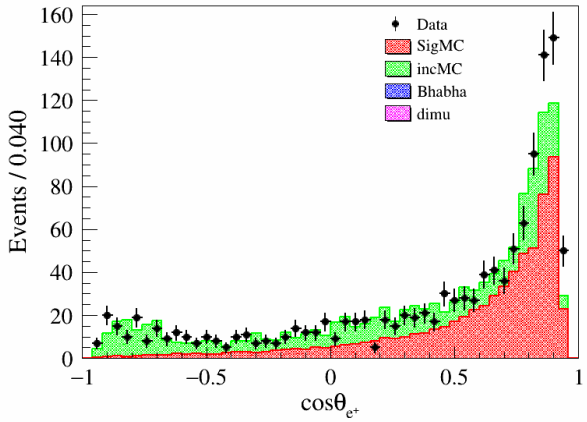
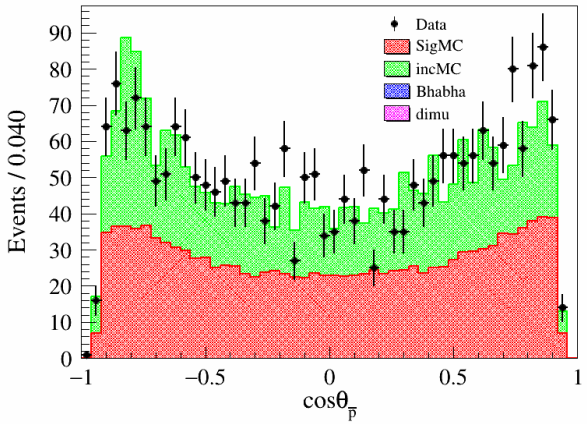
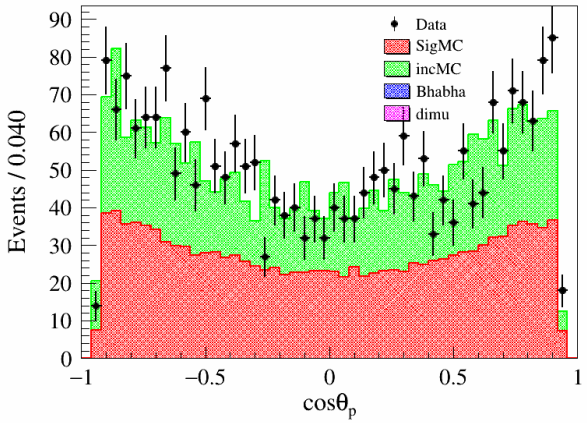
Reject $|M(p\pi) - M(\Lambda)| < 10MeV$

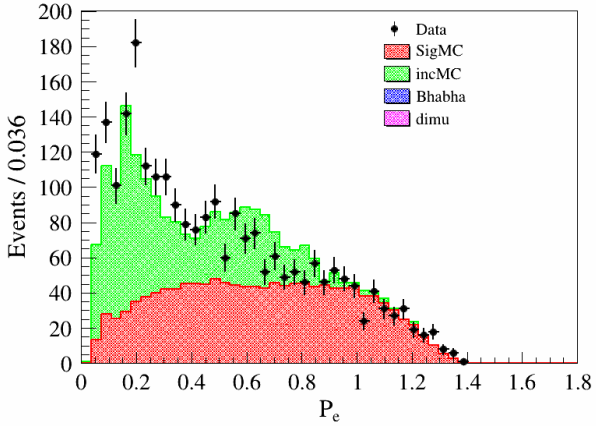
Veto Lambda: Reject $|M(p\pi) - M(\Lambda)| < 10MeV$

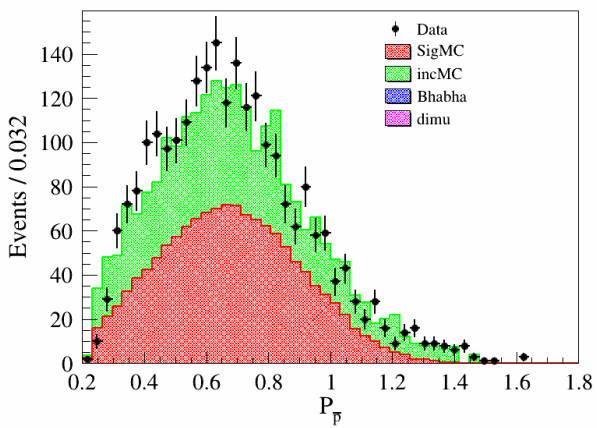


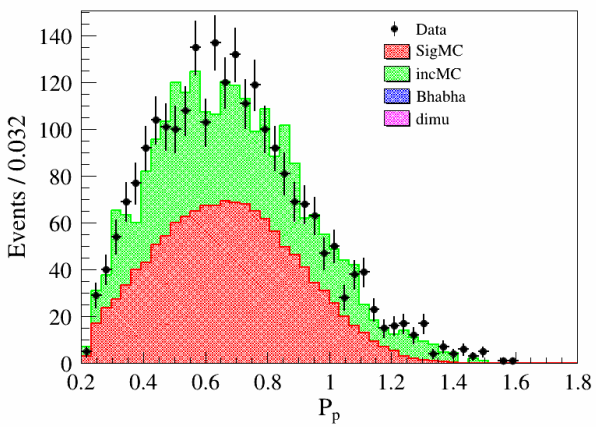


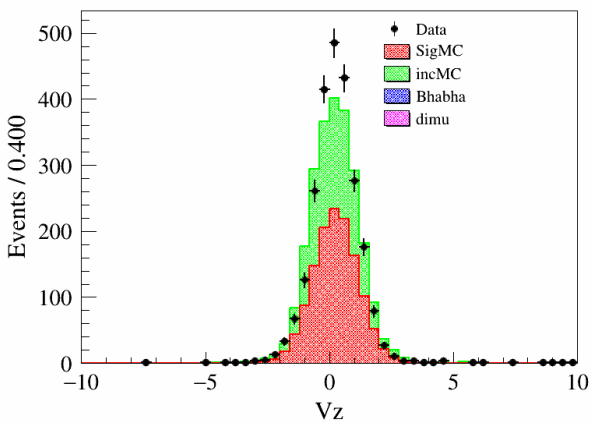








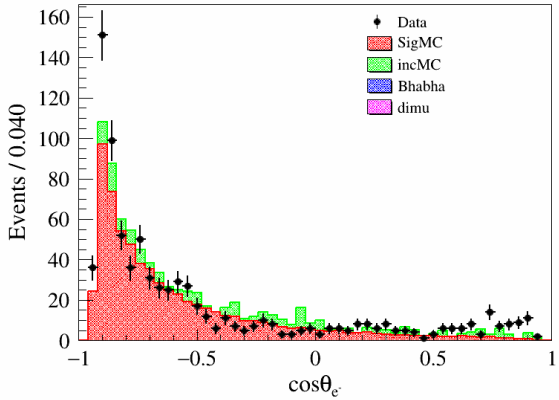


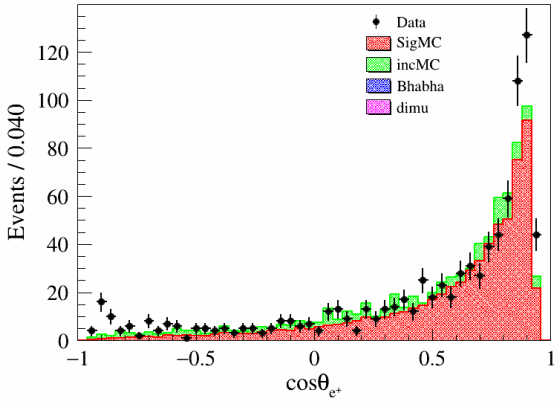


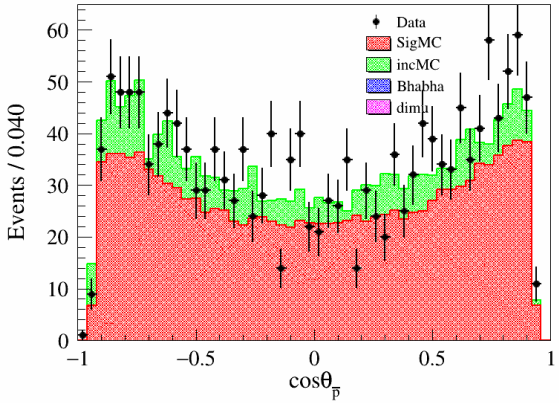
Further Event selection

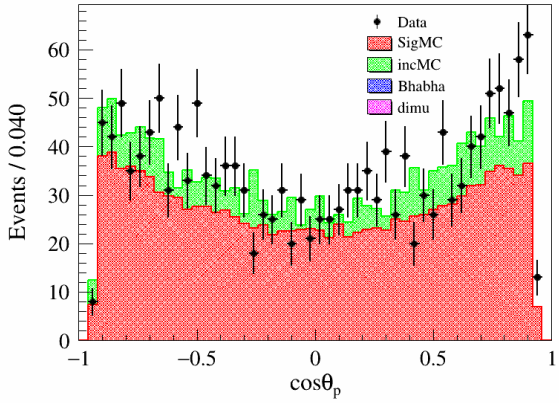
$cos\theta_{miss} * sign(e) < -0.99;$
$|Umiss| < 0.2$
Reject $cos\theta_p > 0.8$ & $cos\theta_{\bar{p}} < -0.8$
Reject $|M(p\pi) - M(\Lambda)| < 10MeV$

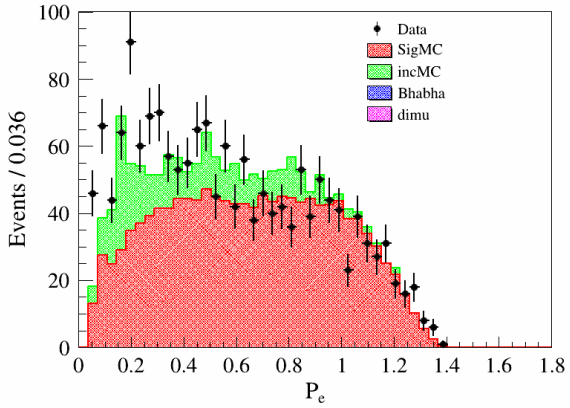
Focus on $|Umiss| < 0.2$

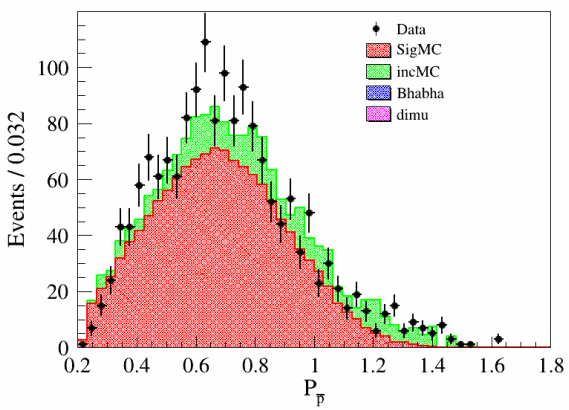


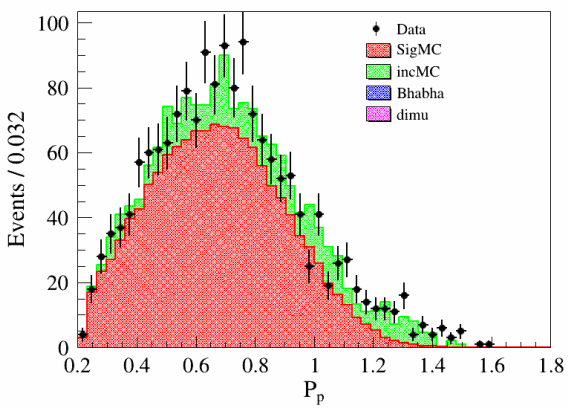


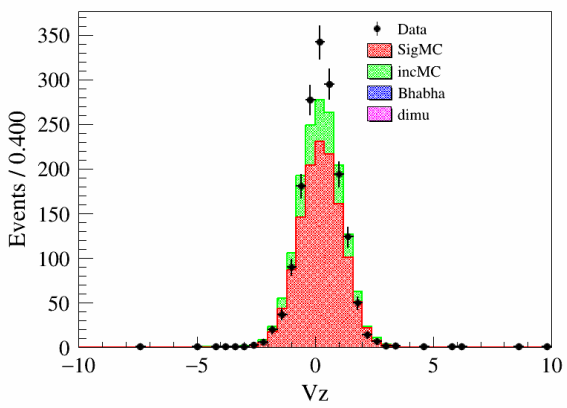












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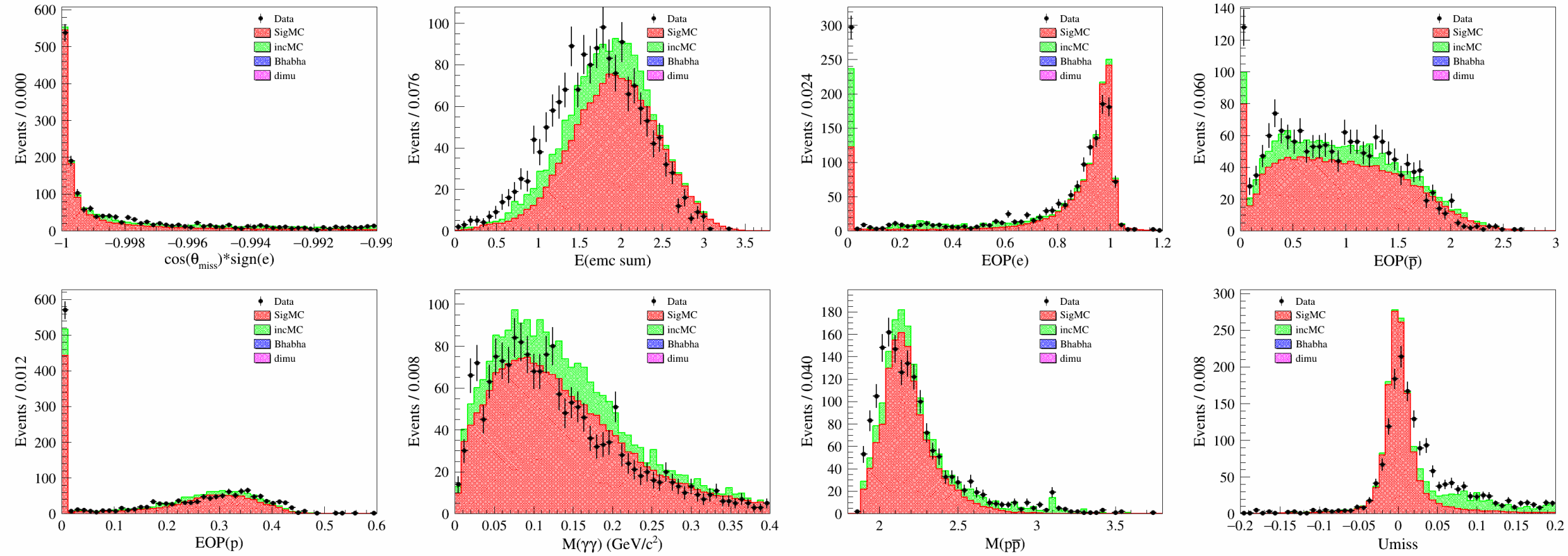
Focus on $|Umiss| < 0.2$



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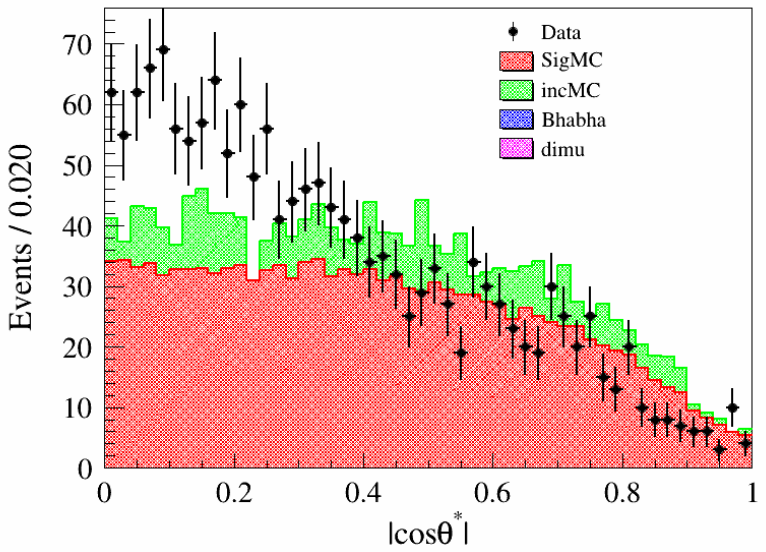
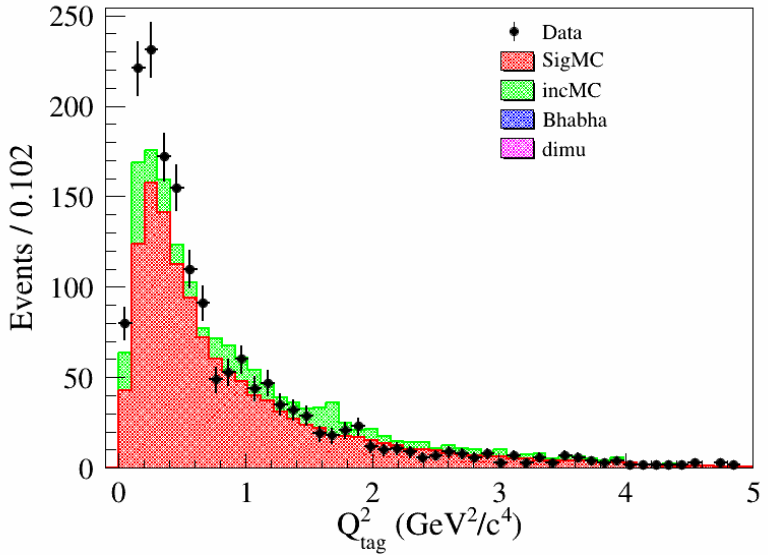
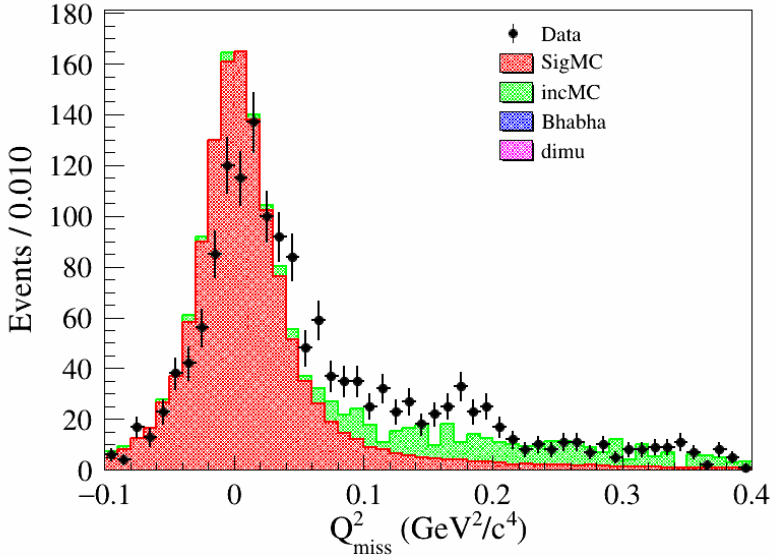


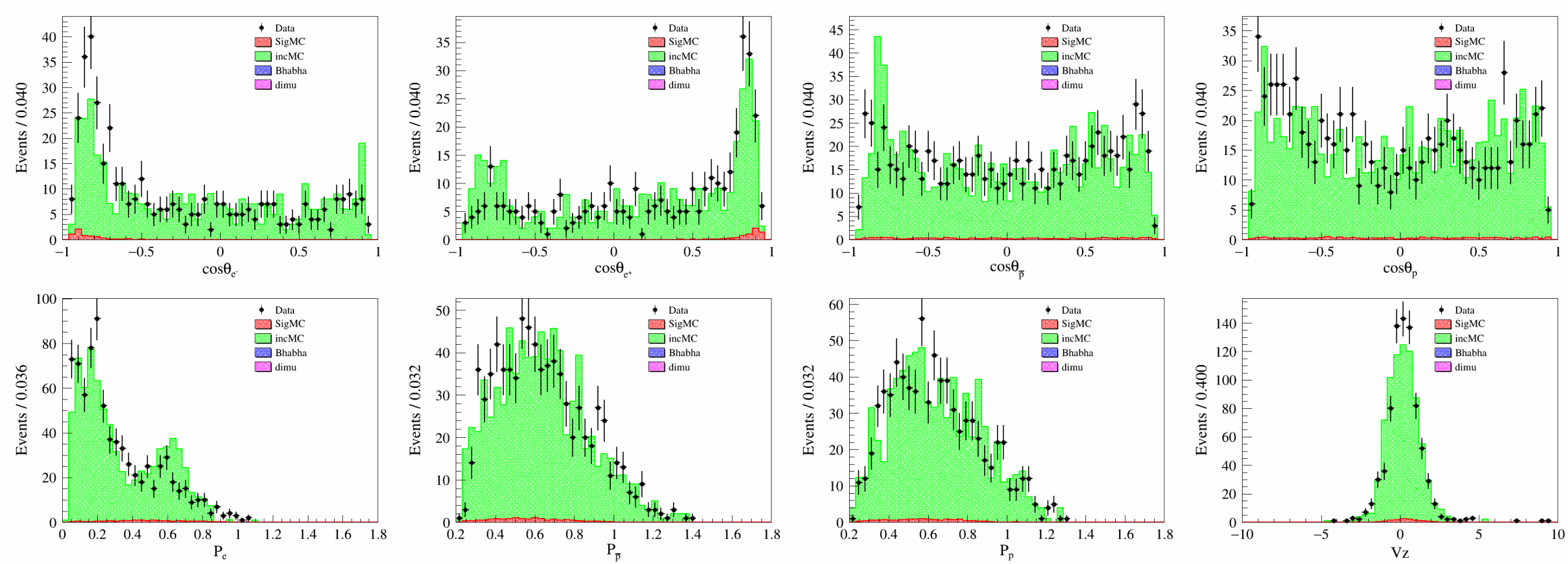




Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$Umiss > 0.2$
Reject $cos\theta_p > 0.8$ & $cos\theta_{\bar{p}} < -0.8$
Reject $|M(p\pi) - M(\Lambda)| < 10MeV$

Focus on $\mathbf{Umiss > 0.2}$



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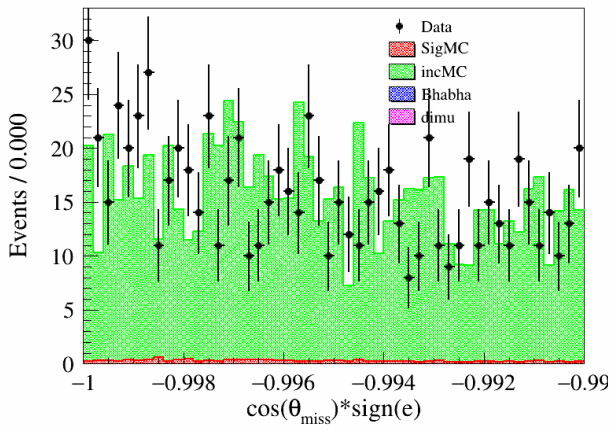
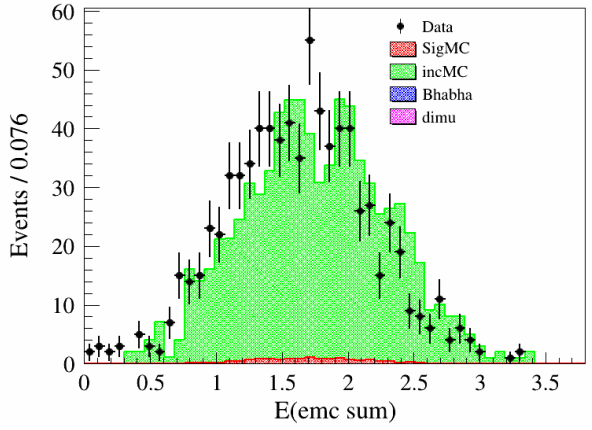
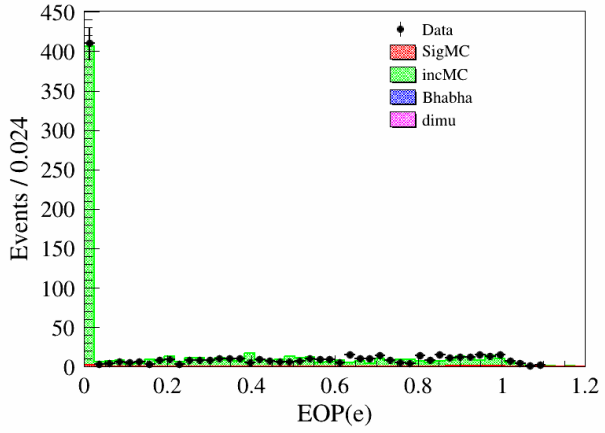
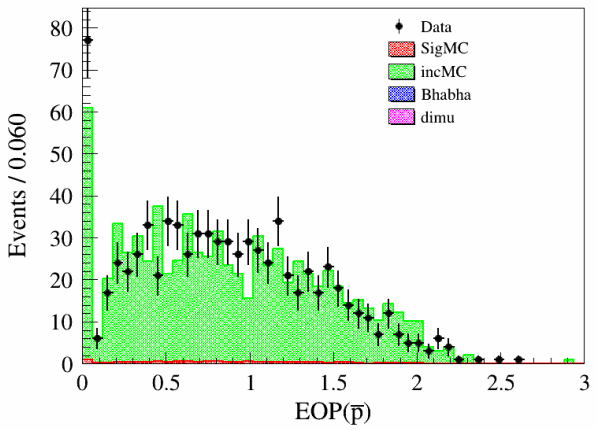
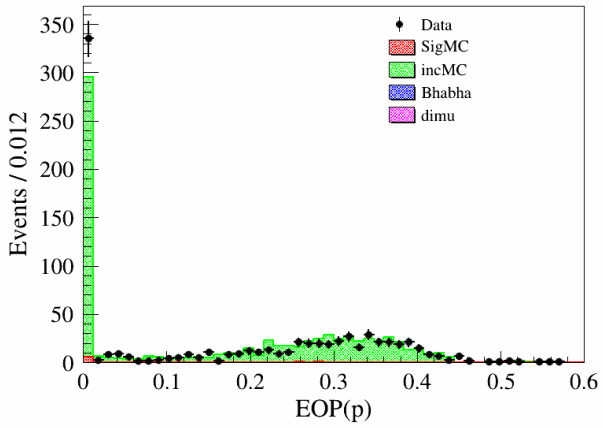
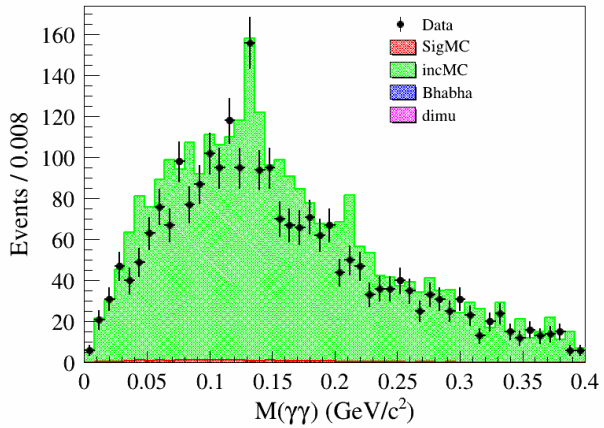


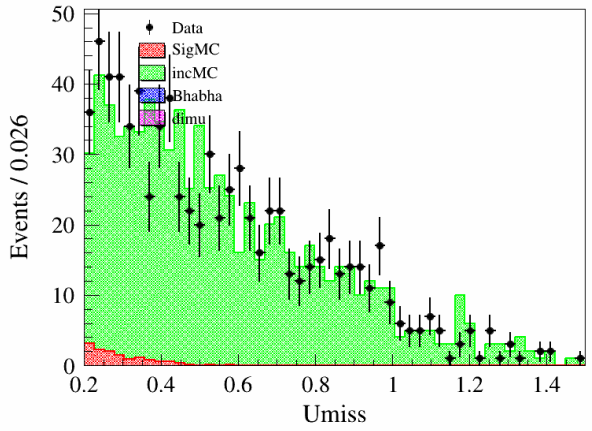








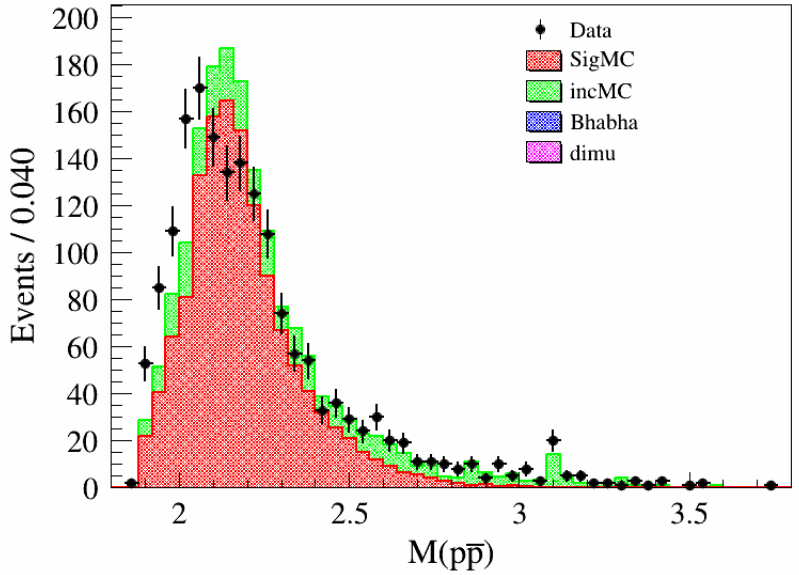


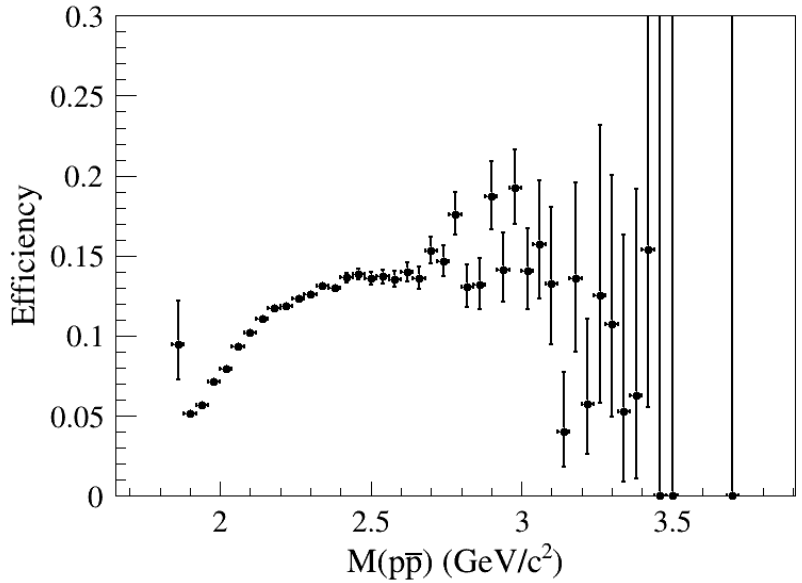


Efficiency

总cutflow：

	Event	Rel eff (%)
total	700000	\
$N_{good} = 3$	119398	17.1
Pass PID	97233	81.4
Pass Vtxfit	95475	98.2
$cos\theta_{miss} * sign(e) < -0.99$	75148	78.7
Reject $cos\theta_p > 0.8$ & $cos\theta_{\bar{p}} < -0.8$	74762	99.5
Reject $1.104 < M(p\pi) < 1.120$	73362	98.1
$-0.2 < Umiss < 0.2$	72379	98.7
eff	10.3%	

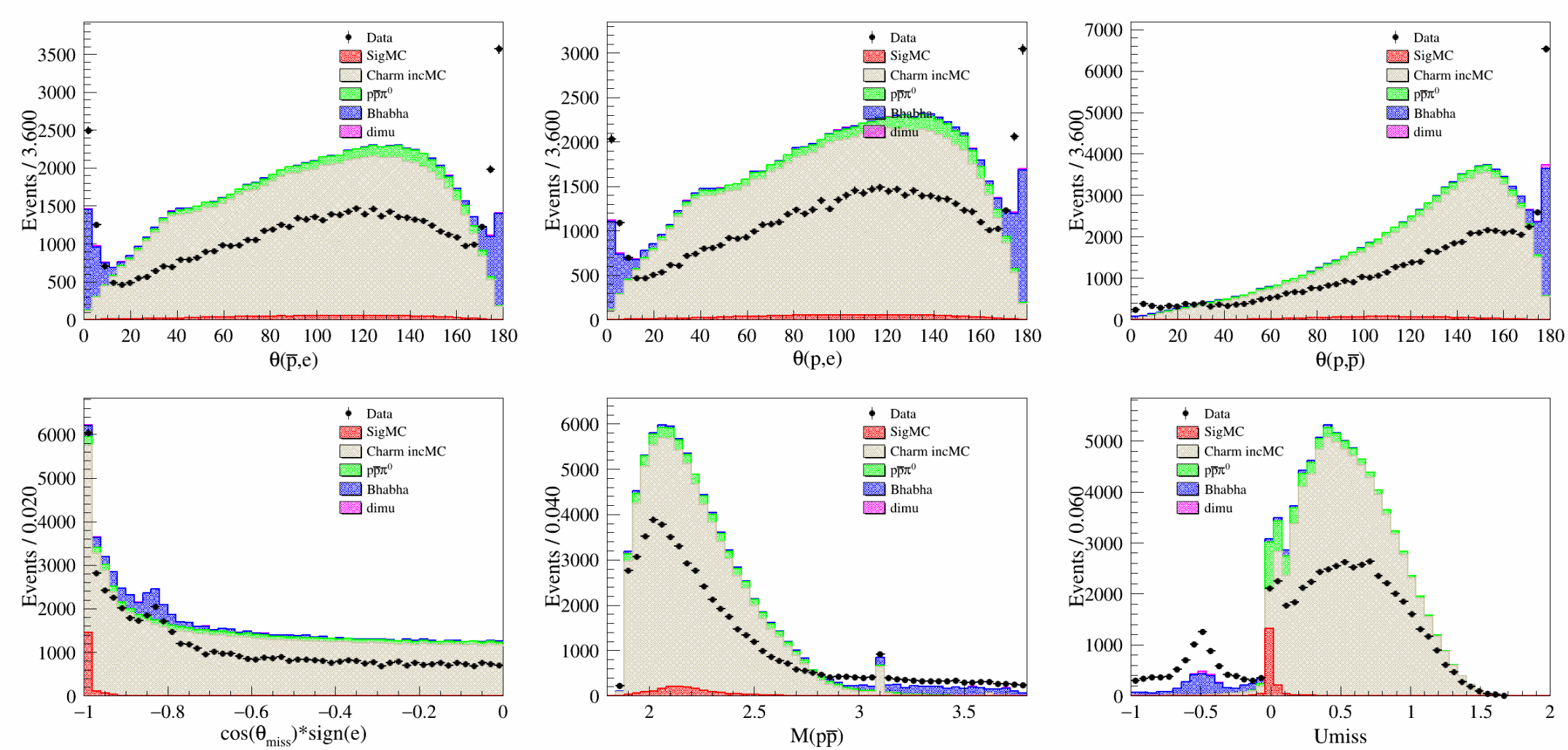




Further Event selection

$cos\theta_{miss} * sign(e) < 0;$

用Charm IncMC进行对比:



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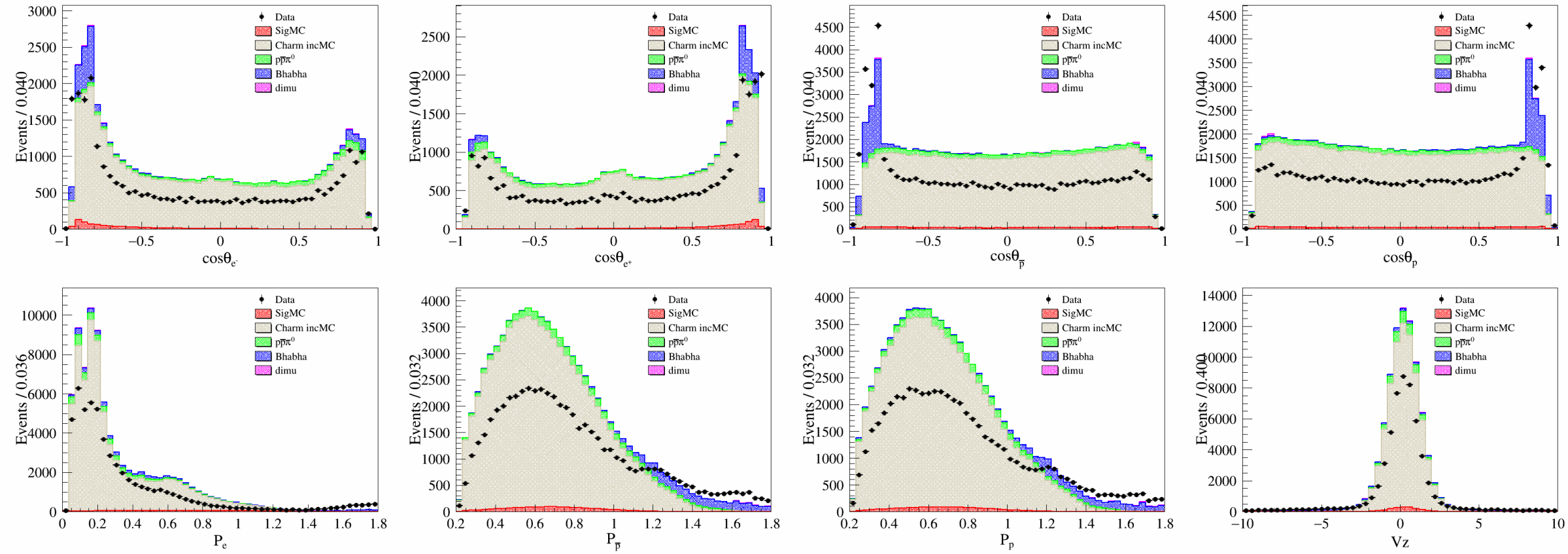

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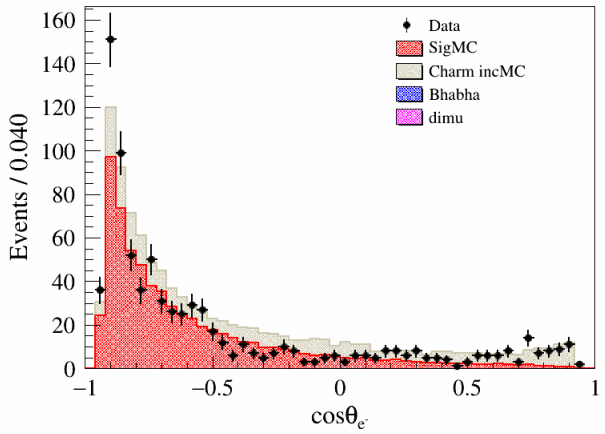

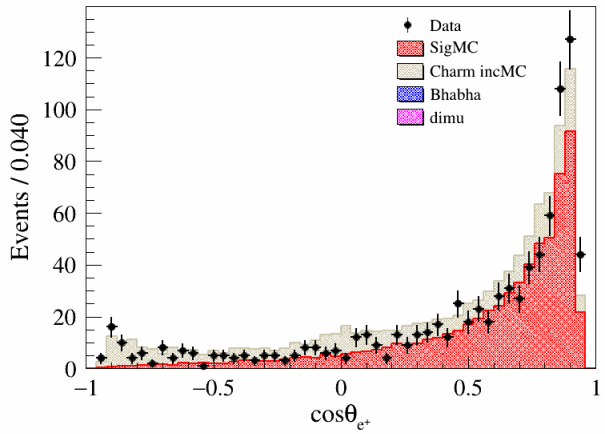

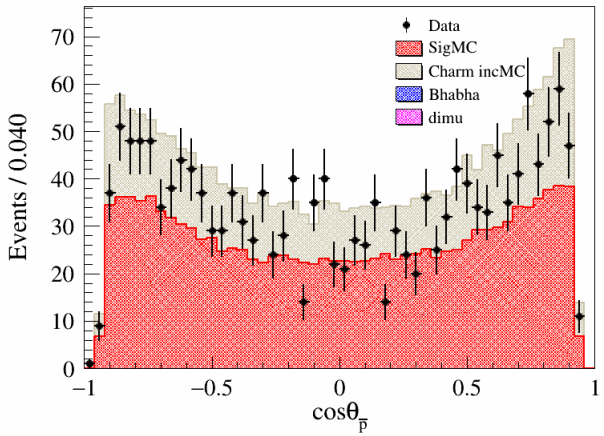

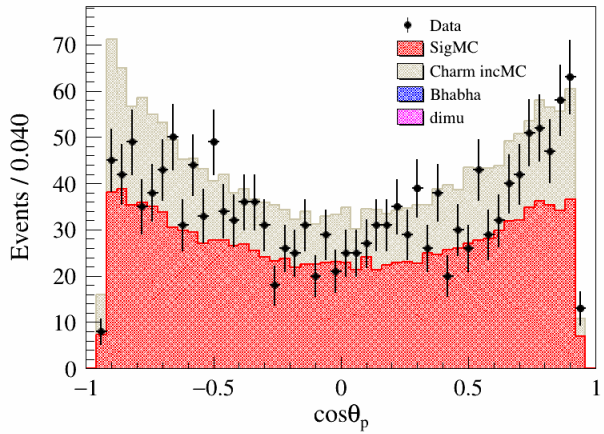

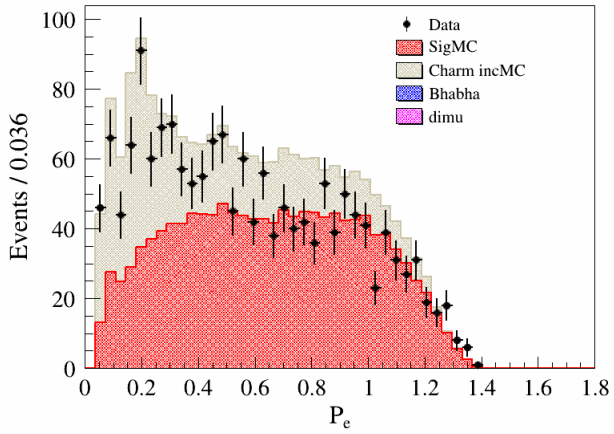

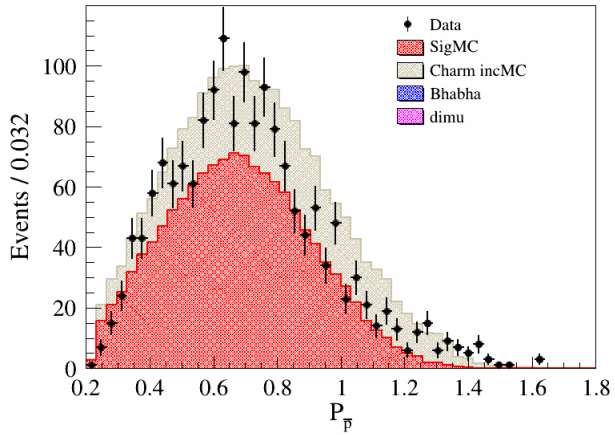

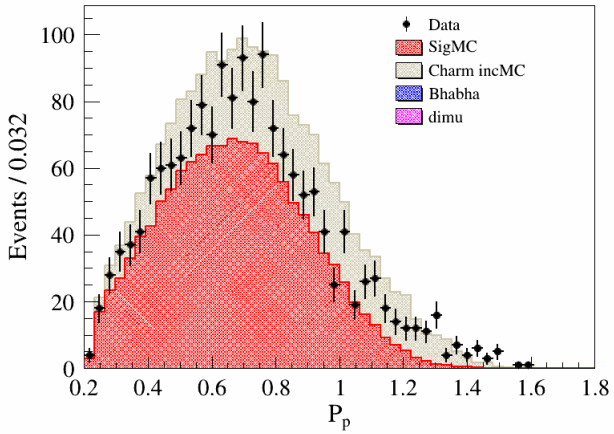

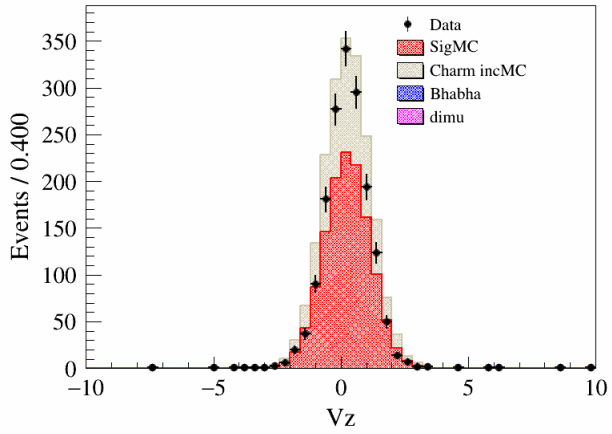

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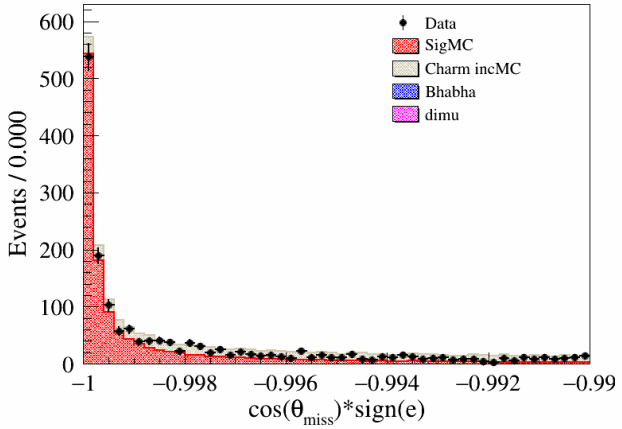

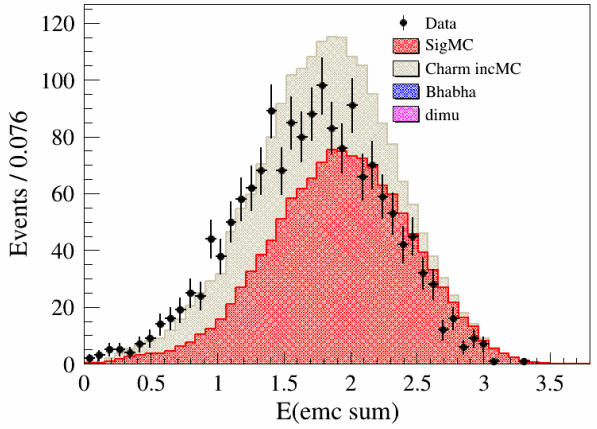

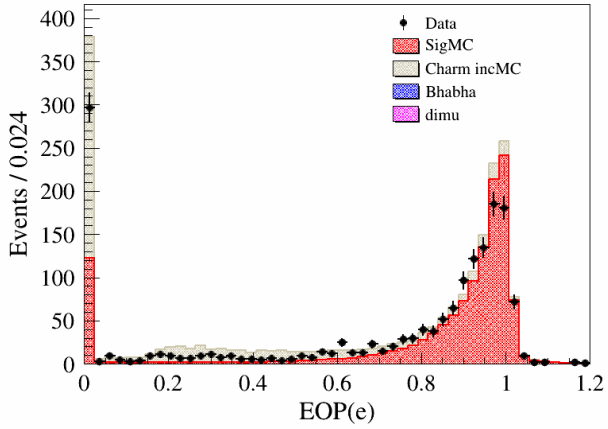

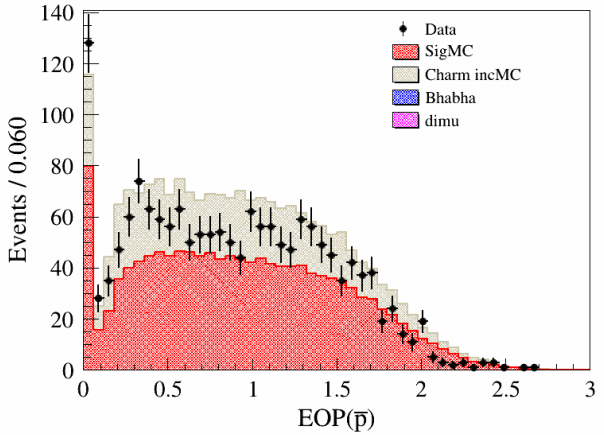

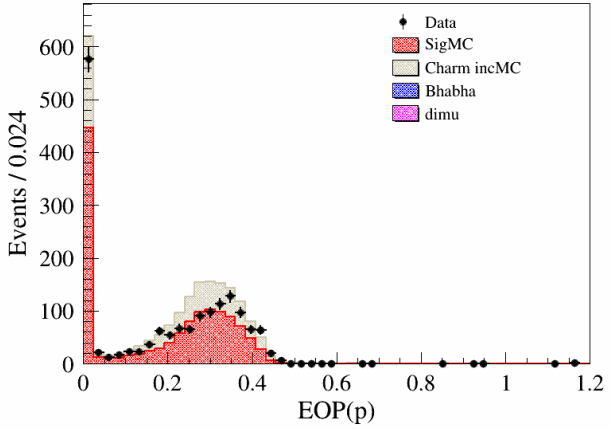

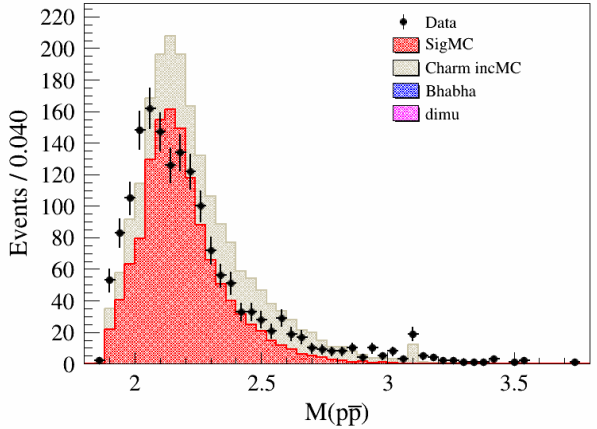

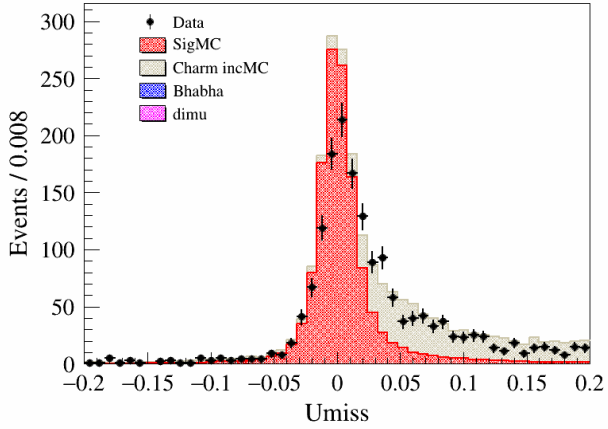

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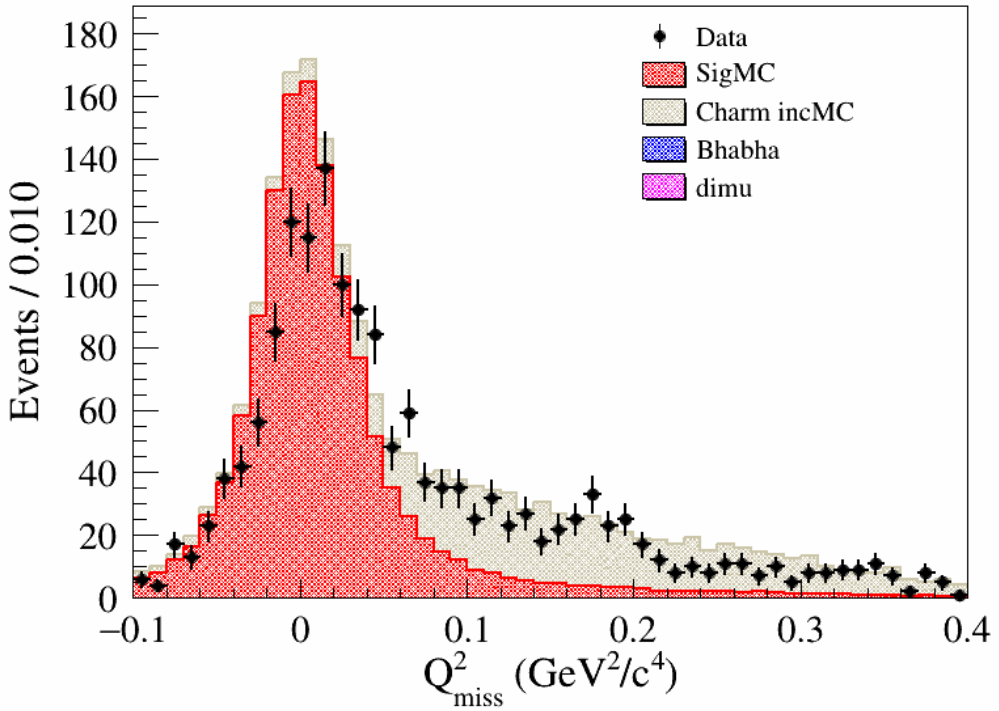

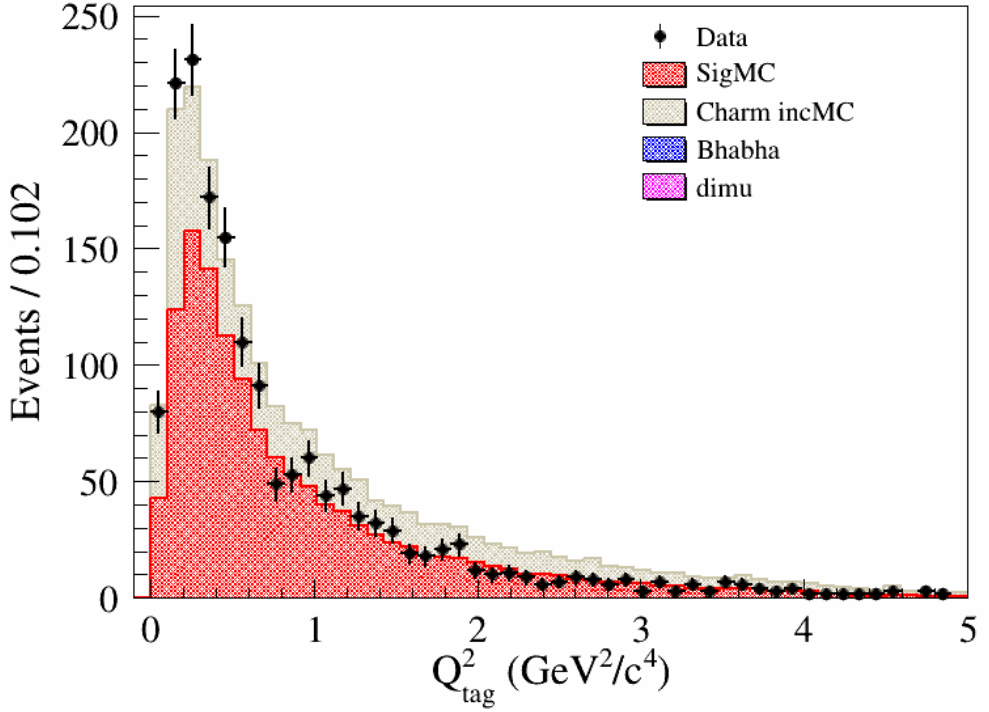

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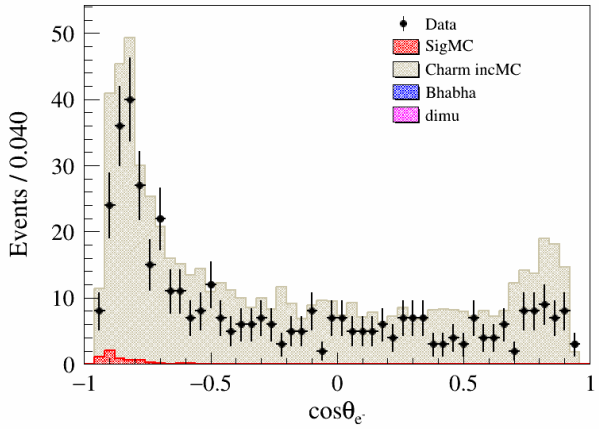

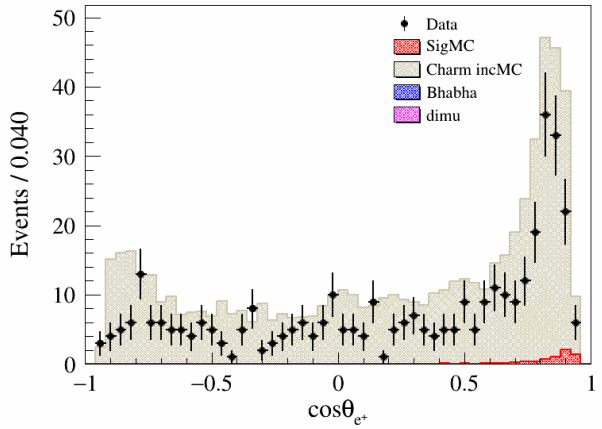

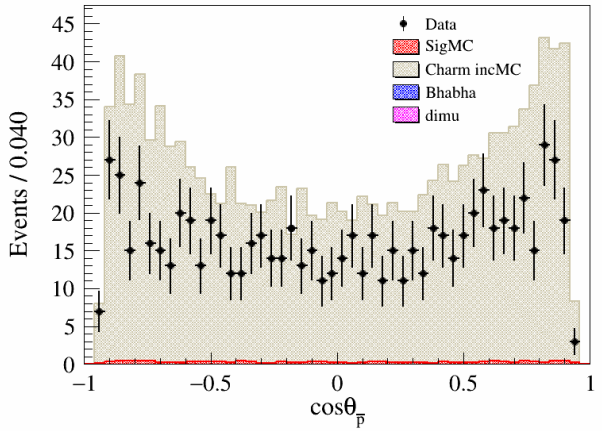

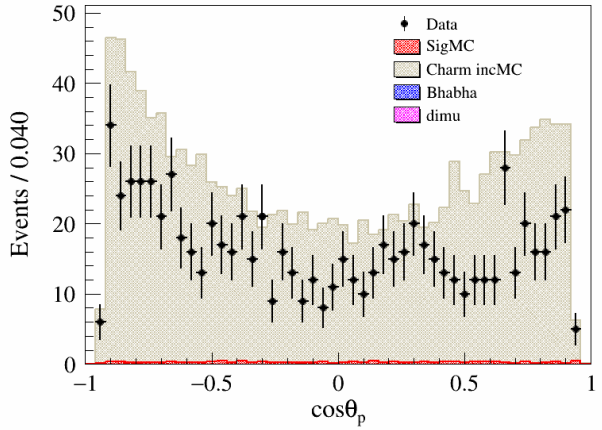

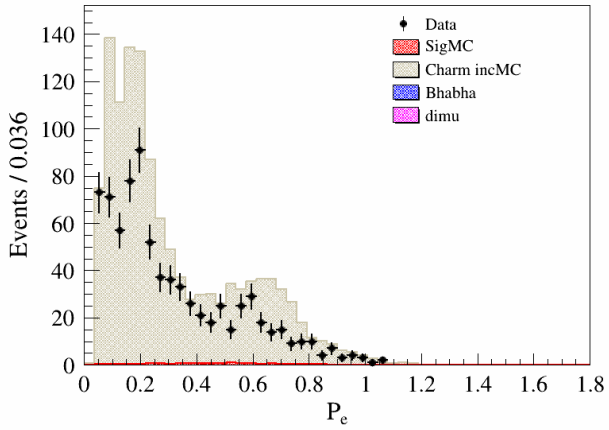

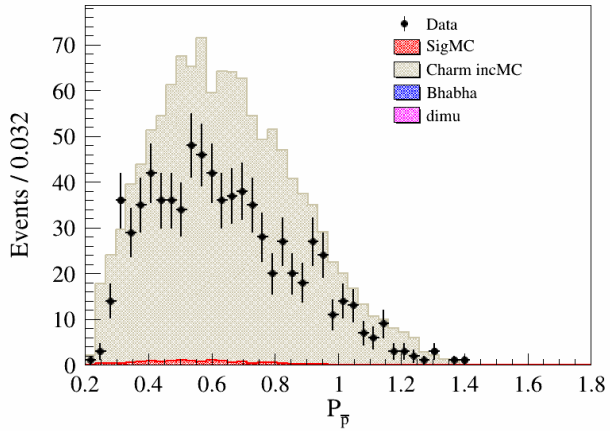

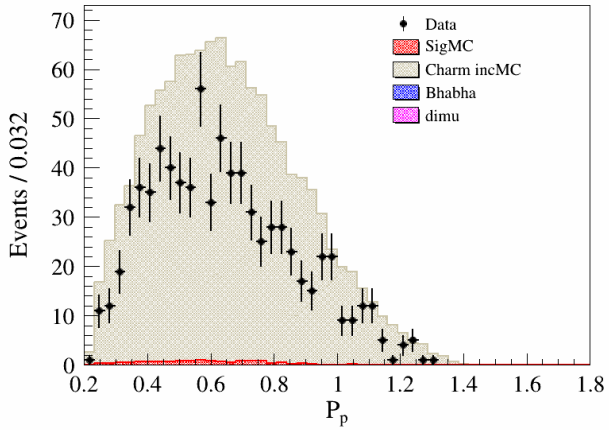

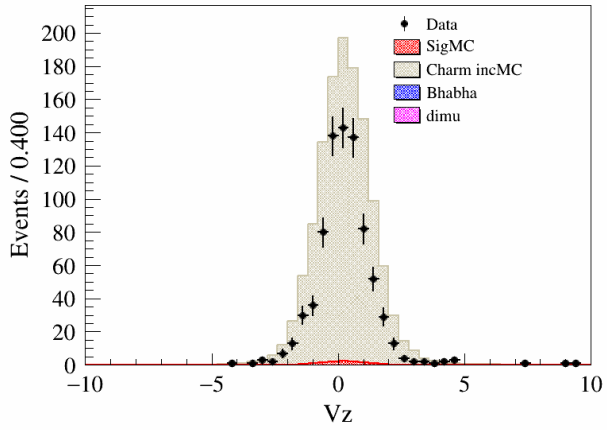

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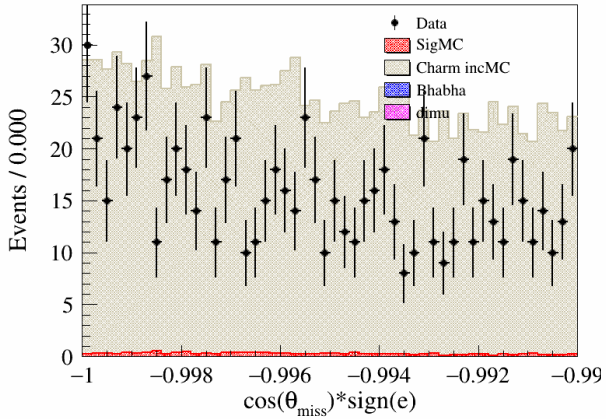

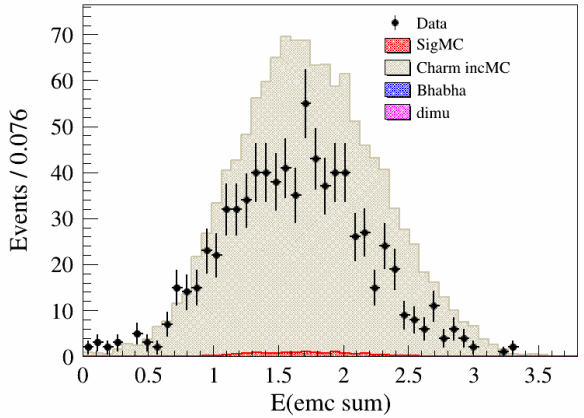

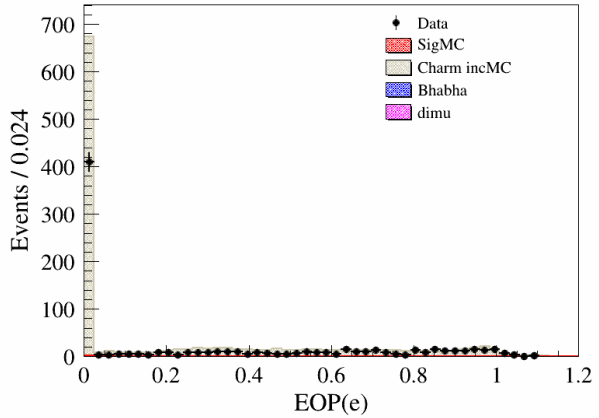

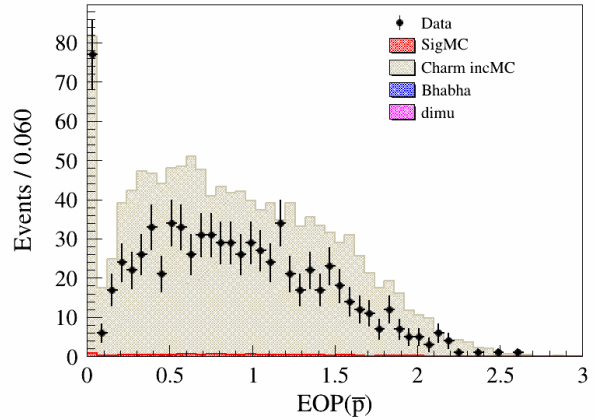

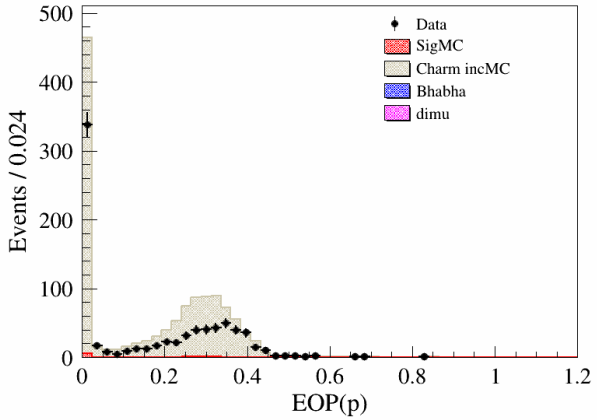

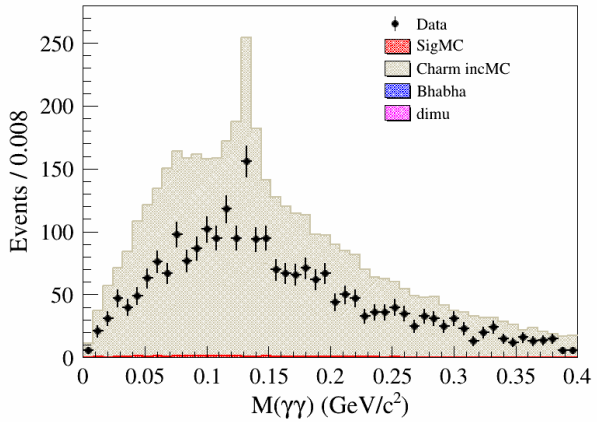

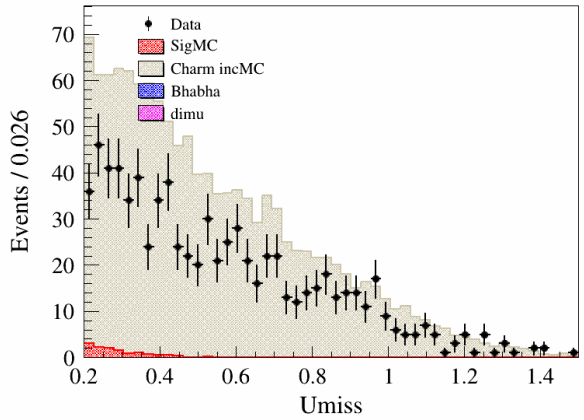

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Reject $|M(p\pi) - M(\Lambda)| < 10MeV$

两种IncMC之间的比较：

Hadron_Hybrid

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$x \to J/\psi\gamma, J/\psi \to \pi^+\pi^- p\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	4	39	39
2	$x \to J/\psi\gamma, J/\psi \to \pi^+ p\bar{\Delta}^{--}, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	5	28	67
3	$x \to \Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}$	17	15	82
4	$x \to p\bar{p}\gamma^F\gamma^F$	$p\bar{p}\gamma^F\gamma^F$	12	14	96
5	$x \to J/\psi\gamma, J/\psi \to \pi^-\bar{p}\Delta^{++}, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}\gamma$	10	14	110
6	$x \to \pi^+ p\bar{\Delta}^{--}\gamma^f, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma^f$	8	12	122
7	$x \to \pi^+\pi^- p\bar{p}\gamma^f$	$\pi^+\pi^- p\bar{p}\gamma^f$	1	11	133
8	$x \to \Delta^{++}\bar{\Delta}^{--}\gamma^f, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma^f$	3	10	143
9	$x \to J/\psi\gamma, J/\psi \to \Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	11	10	153
10	$x \to J/\psi\gamma, J/\psi \to \pi^-\bar{\Delta}^0 p, \bar{\Delta}^0 \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	14	7	160
.....					

CharmIncMC

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$string \to \pi^+ p\bar{\Delta}^{--}, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}$	9	834	834
2	$string \to \pi^+\pi^- p\bar{p}$	$\pi^+\pi^- p\bar{p}$	7	788	1622
3	$string \to \pi^-\bar{p}\Delta^{++}, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}$	4	746	2368
4	$string \to p\bar{p}$	$p\bar{p}$	19	620	2988
5	$string \to \pi^0 p\bar{p}$	$\pi^0 p\bar{p}$	5	498	3486
6	$string \to \bar{p}\Delta^+, \Delta^+ \to \pi^0 p$	$\pi^0 p\bar{p}$	2	264	3750
7	$string \to p\bar{\Delta}^-, \bar{\Delta}^- \to \pi^0\bar{p}$	$\pi^0 p\bar{p}$	12	224	3974
8	$string \to \pi^0 p\bar{p}, \pi^0 \to e^+e^-\gamma^F$	$e^+e^- p\bar{p}\gamma^F$	15	177	4151
9	$string \to K^+\bar{p}\Lambda, \Lambda \to \pi^- p$	$\pi^- K^+ p\bar{p}$	1	174	4325
10	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \pi^+\pi^- p\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	6	170	4495
.....					

Summary

Summary:

1.完成初步的事例挑选。

Next to do:

1.继续完善本底分析

2.对测量过的过程产生exclusive MC进行研究

Back Up

MC Generation

- Yield Estimation of $\gamma\gamma \to p\bar{p}$ at 3.773GeV

$$N_{ee\to p\bar{p}} = \int \sigma_{\gamma\gamma\to p\bar{p}}(W_{\gamma\gamma}) * L_{int} * \frac{dL_{\gamma\gamma}(W_{\gamma\gamma}, E_{cms})}{dW_{\gamma\gamma}} dW_{\gamma\gamma}$$

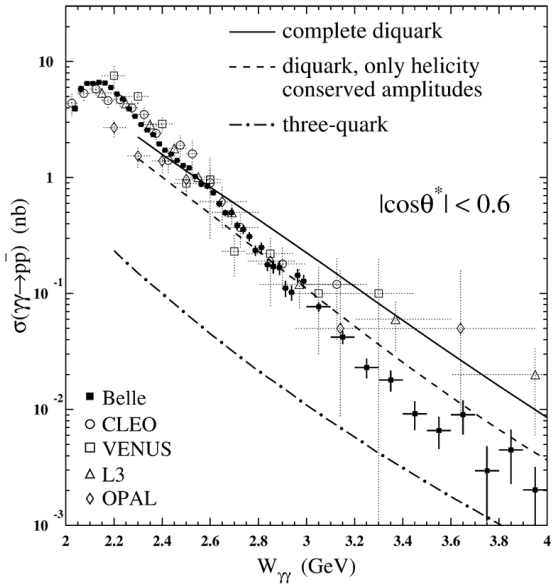


Fig. $\sigma_{\gamma\gamma\to p\bar{p}}(W_{\gamma\gamma})$ Belle Collaboration Physics Letters B 621 (2005) 41–55

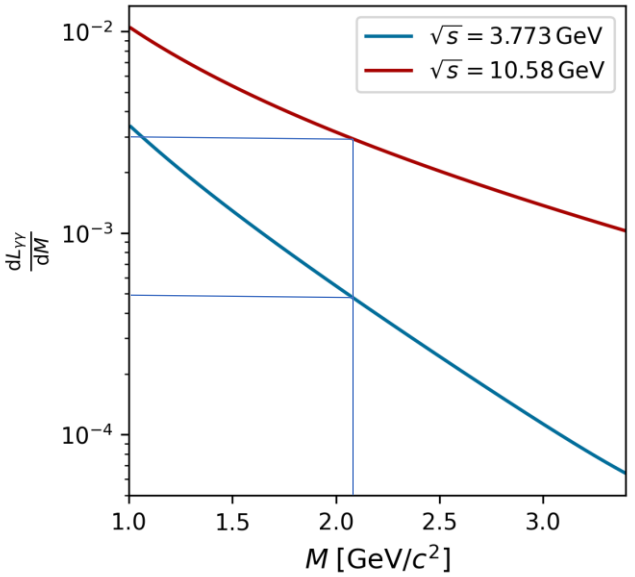
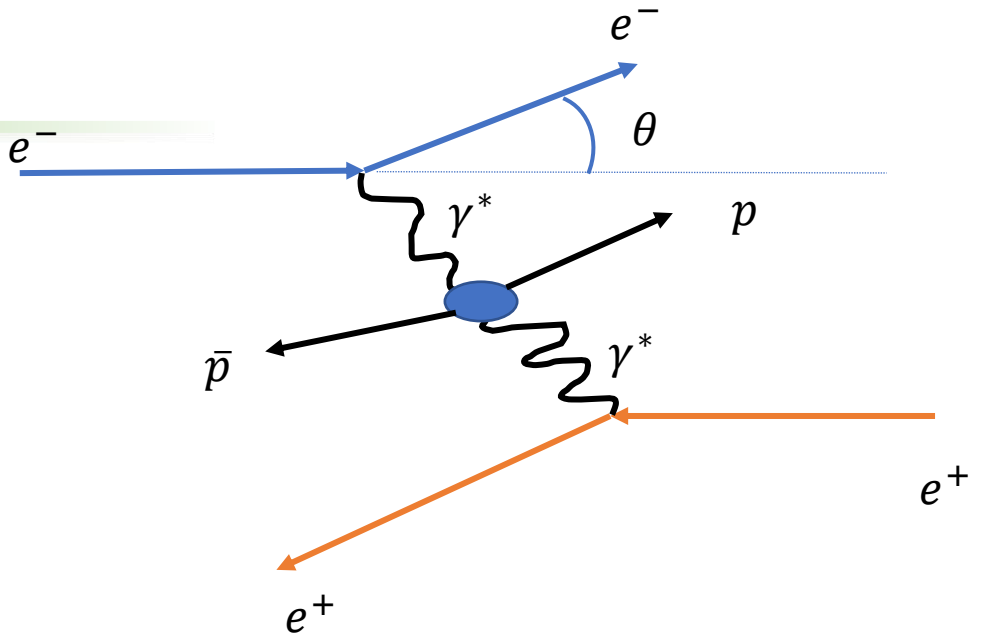


Fig. $\frac{dL_{\gamma\gamma}(W_{\gamma\gamma})}{dW_{\gamma\gamma}}$ calculation.



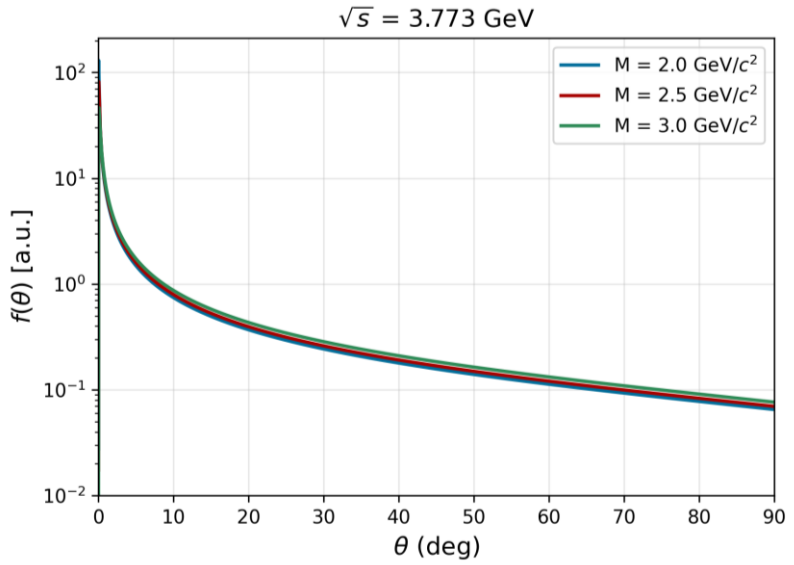


Fig. angular distribution of electron

$P(cos\theta > 0.92)$:
0.84 for 2.0GeV
0.82 for 2.5GeV
0.81 for 3.0GeV

Untag:0.69
Single:0.28
Double:0.03

MC Generation

- Yield Estimation of $\gamma\gamma \to p\bar{p}$ at 3.773GeV

  Angle distribution of $p/\bar{p}$ in $\gamma\gamma \to p\bar{p}$

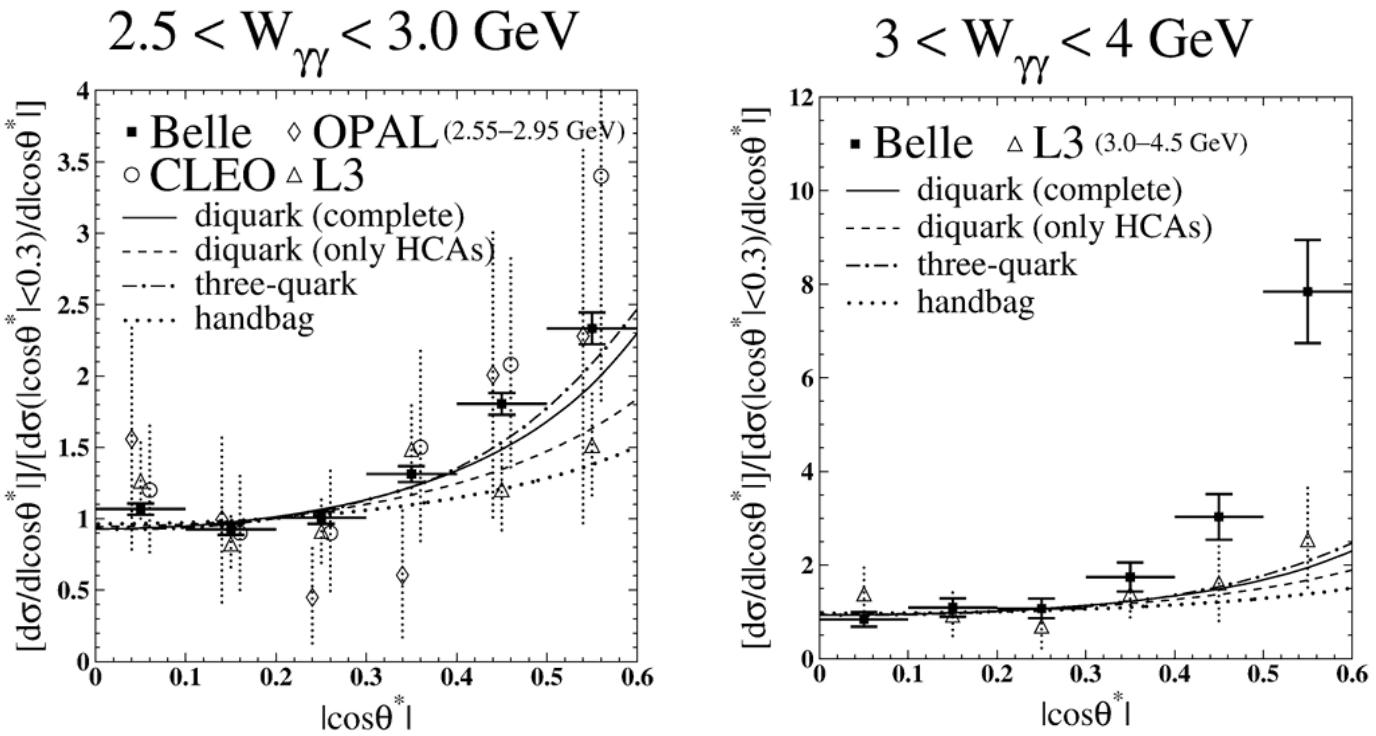


Fig. Differential cross section as a function of $|cos\theta^*|$.

MC Generation

- Yield Estimation of $\gamma\gamma \to p\bar{p}$ at 3.773GeV

Angle distribution of $p/\bar{p}$ in $\gamma\gamma \to p\bar{p}$

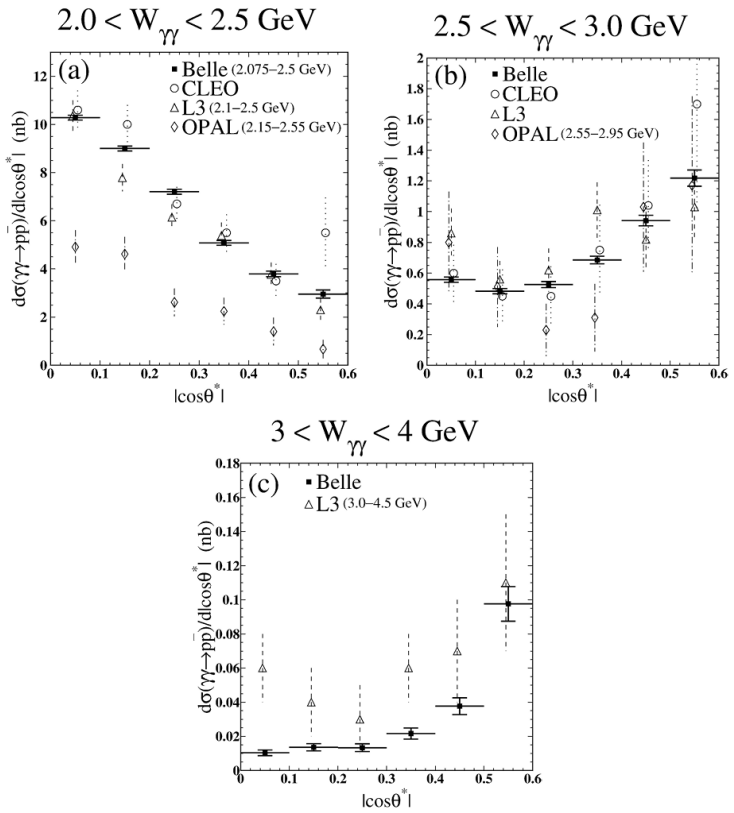


Fig. 6. Measured differential cross sections as a function of $|\cos\theta^*|$ for three ranges of $W_{\gamma\gamma}$. The error bars are statistical only.

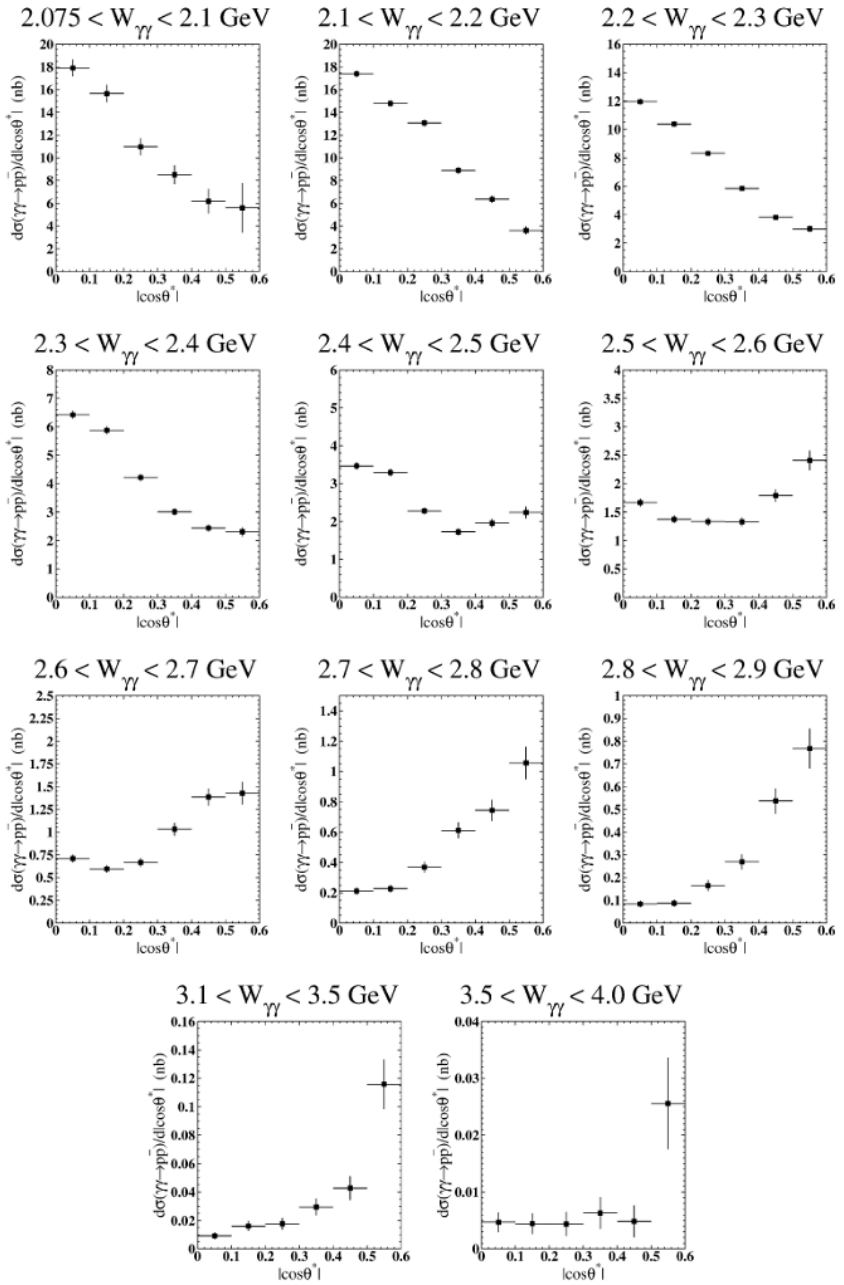


Fig. 5. Measured differential cross sections in 11 ranges of $W_{\gamma\gamma}$ as a function of $|\cos\theta^*|$. The error bars are statistical only.

MC Generation

- Yield Estimation of $\gamma\gamma \to p\bar{p}$ at 3.773GeV

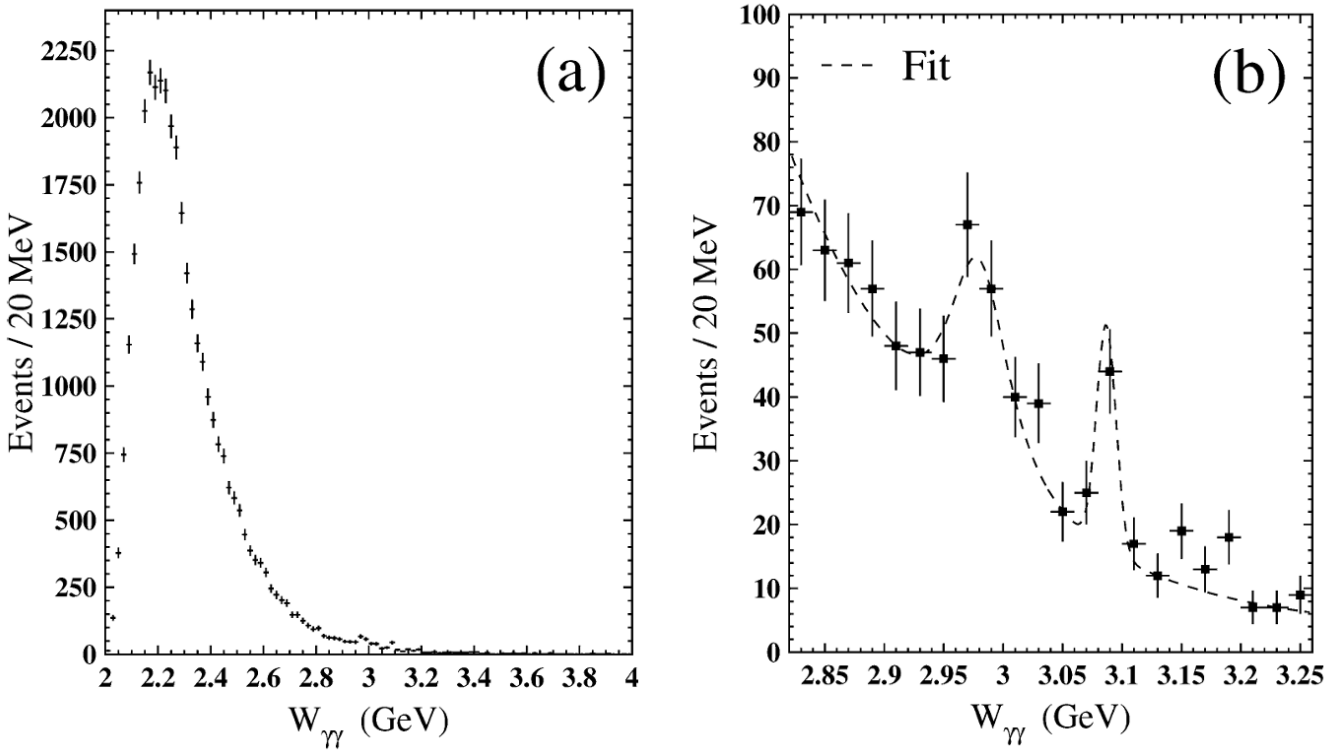


Fig. $W_{\gamma\gamma}$ distribution of events passing all the selection criteria.

Belle 89fb $^{-1}$ at 10.58GeV; $W_{\gamma\gamma} = 2 - 4GeV$, 36094 events

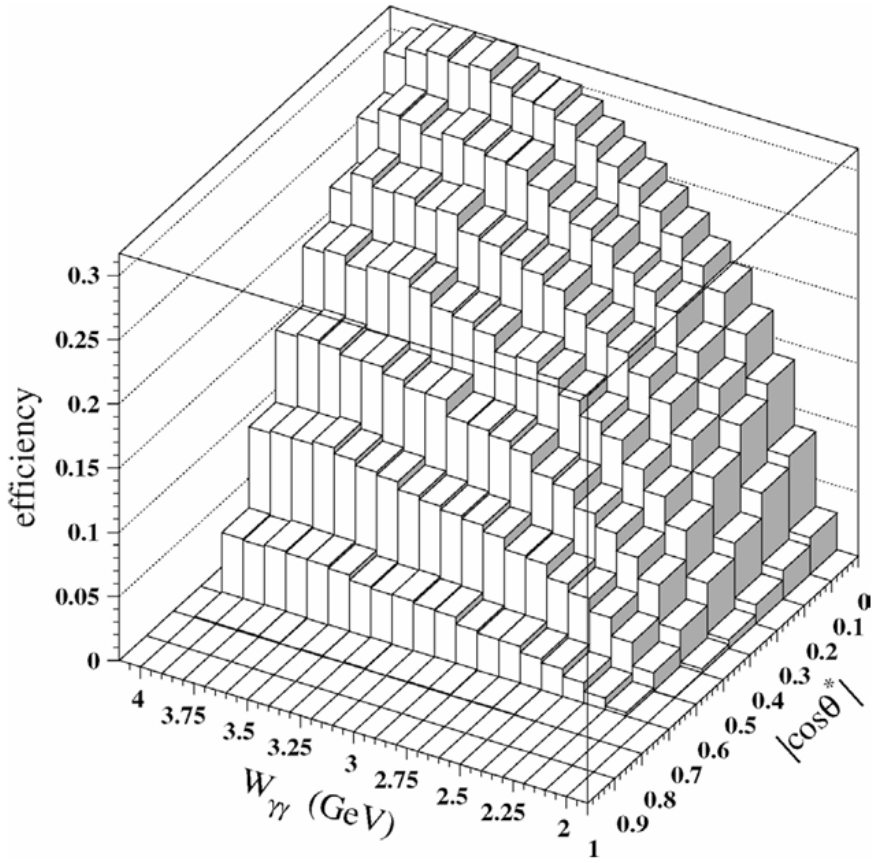


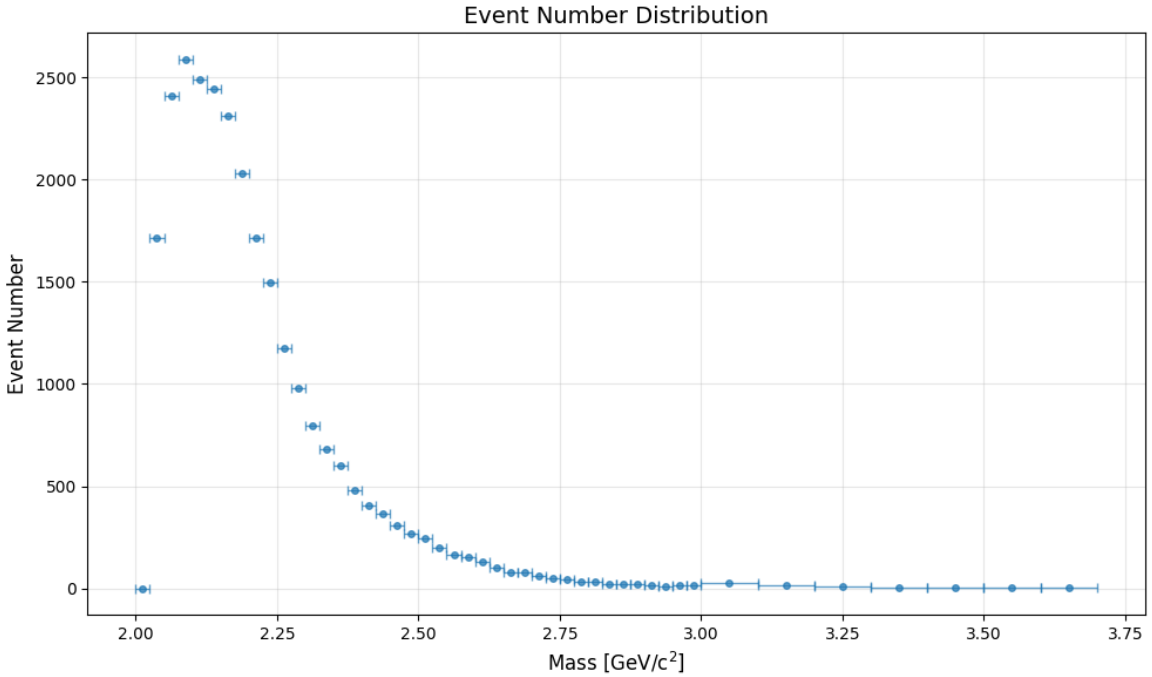
Fig. Overall detection efficiency of $\gamma\gamma \to p\bar{p}$ as a function of $W_{\gamma\gamma}$ and $|cos\theta^*|$

MC Generation

- Yield Estimation of $\gamma\gamma \to p\bar{p}$ at 3.773GeV

$$N_{ee\to p\bar{p}} = \int \sigma_{\gamma\gamma\to p\bar{p}}(W_{\gamma\gamma}) * L_{int} * \frac{dL_{\gamma\gamma}(W_{\gamma\gamma})}{dW_{\gamma\gamma}} dW_{\gamma\gamma}$$

Based on the assumption that $\gamma\gamma \to p\bar{p}$ follows a phase space distribution.



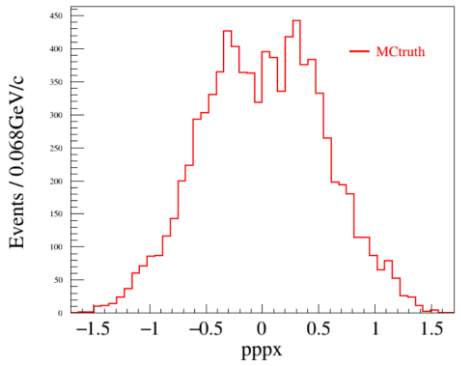
25MeV/Bin 100MeV/Bin

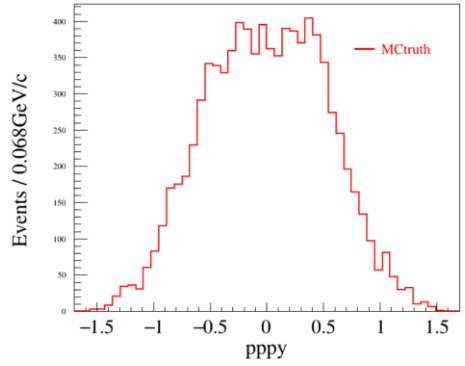
$$\frac{L_{Belle} * \frac{dL}{dW}(Belle) * \epsilon_{Belle}}{L_{BES} * \frac{dL}{dW}(BES) * \epsilon_{BES}} = 4.5*5*0.2=4.5$$

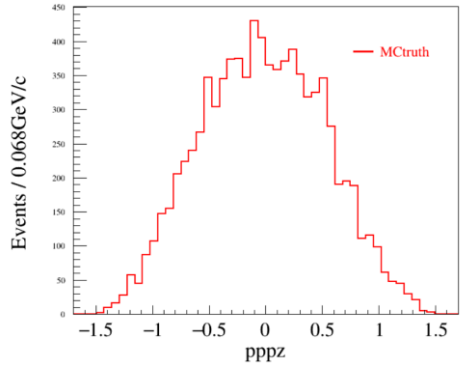
预期:
Untag 10000 events
Stag 1000 events

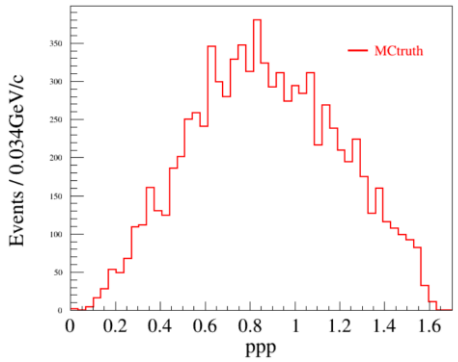
MCtruth information for single-tag acceptance

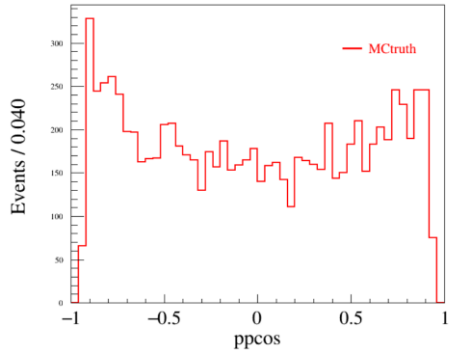
Mctruth information (before selection), Ecms = 3.773GeV, Generator: cpp_gamgam + TrackGen





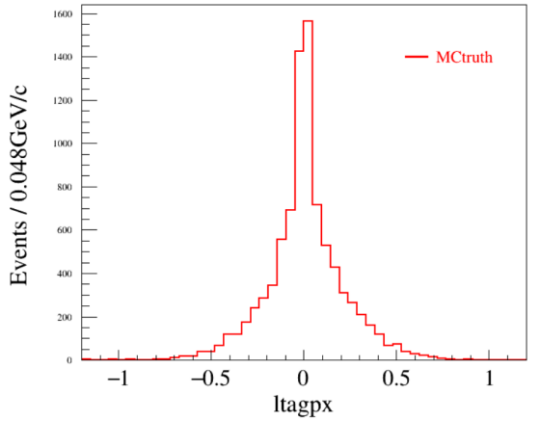


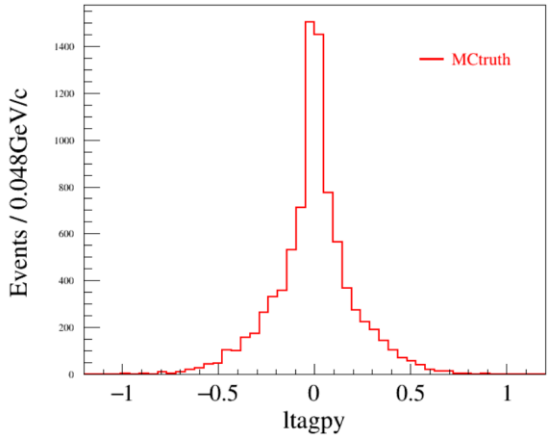


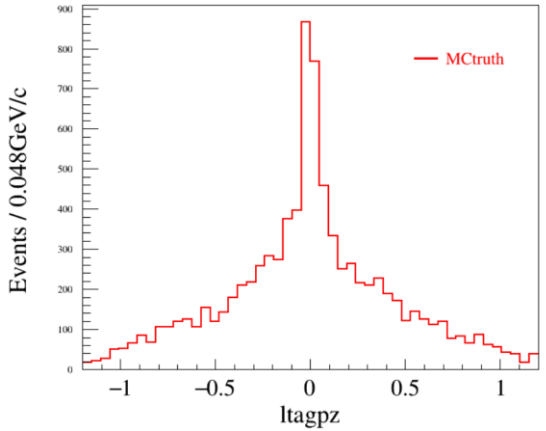


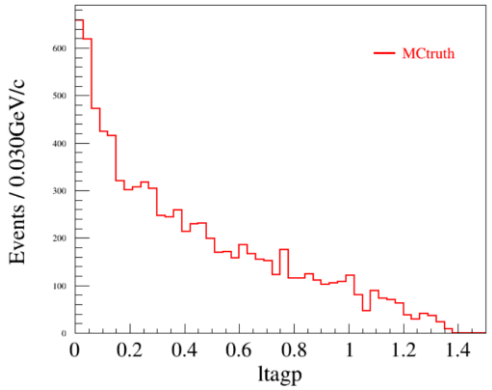
Mctruth information for single-tag

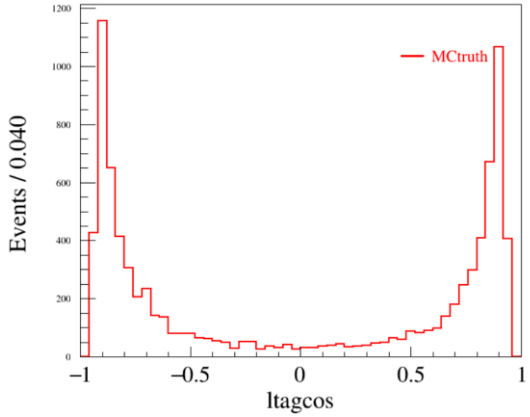
Mctruth information (no selection), Ecms = 3.773GeV, Generator: cpp_gamgam + TrackGen











Outline

- Motivation
- MC Generation
- Single-tag method
- Un-tag method
- Summary and Next to do

Motivation

- A novel theoretical prediction [1] states that a $\cos(2\phi)$ azimuthal asymmetry exists in the $\gamma\gamma \to \pi\pi$ production process, and a similar phenomenon may also occur in $\gamma\gamma \to p\bar{p}$ production.

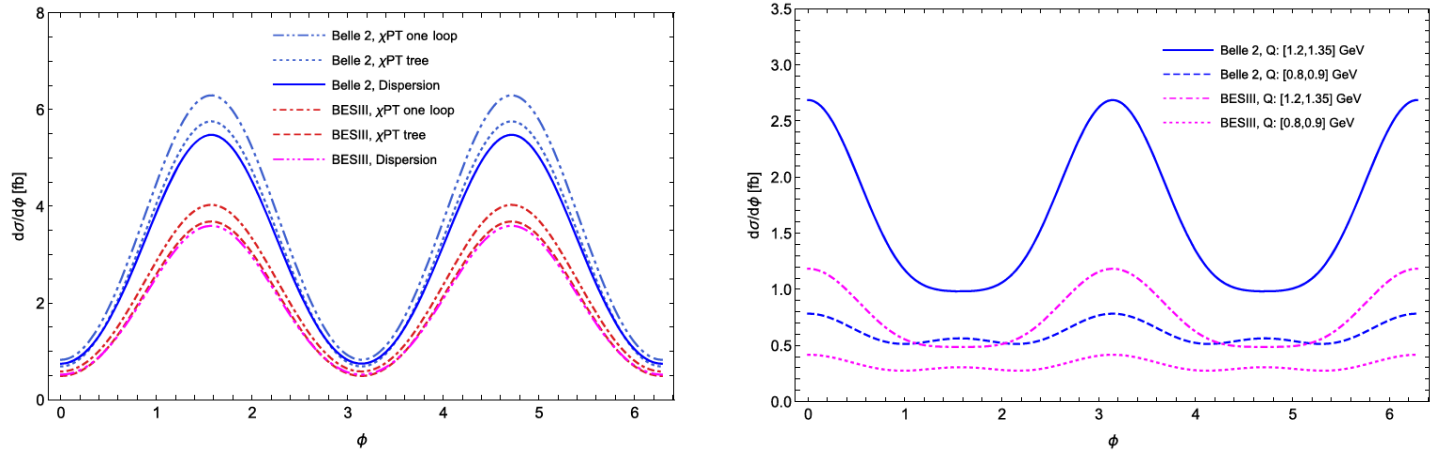
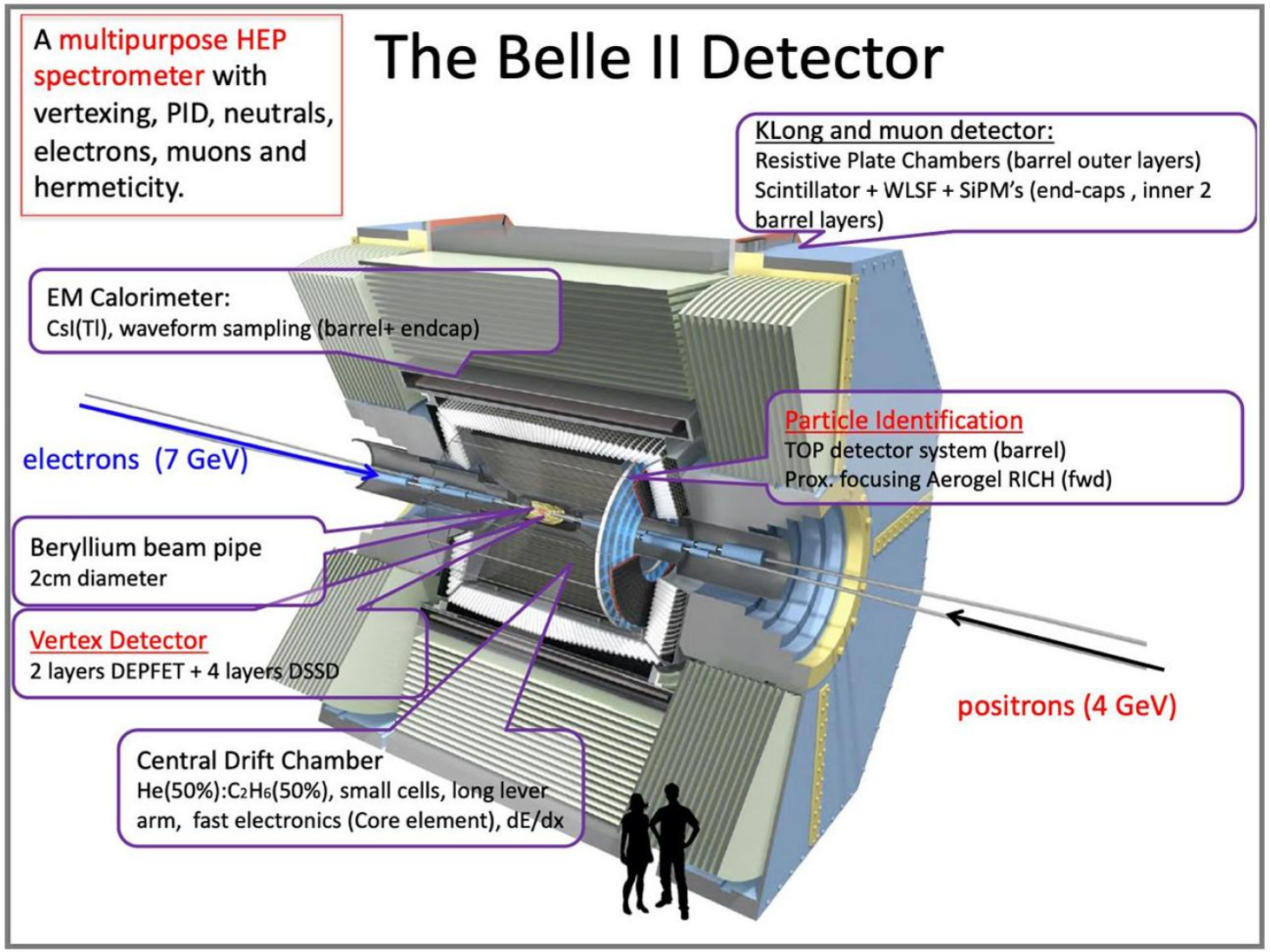


Fig. The differential cross section of $ee \to \gamma\gamma ee \to \pi\pi ee$ with respect to the azimuthal angle ϕ.

- BESIII has collected 41fb $^{-1}$ data samples in the $\sqrt{s}$ = 3.510 – 4.946 GeV.

[1] PHYSICAL REVIEW LETTERS 134, 141901 (2025)



接收度(角度)：　　BESIII: 23~157

KLM: 18~155
KLM: 24~161

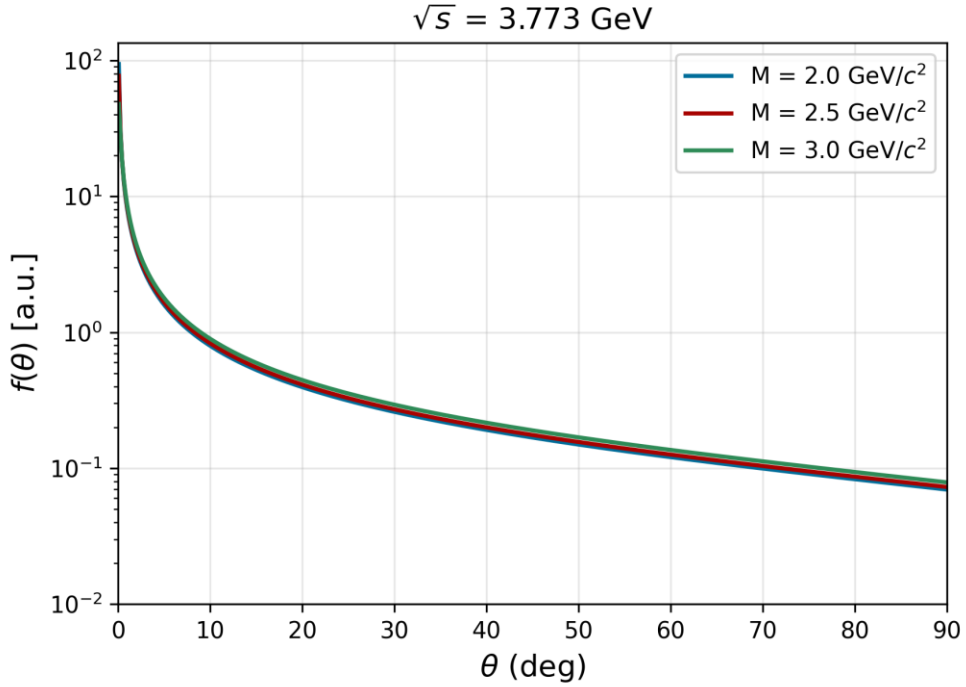
ECL: 12.4~31.4, 32.2~128.7, 130.7~155.1
ECL: 16.4~40.8, 41.8~140.0, 141.7~161.0

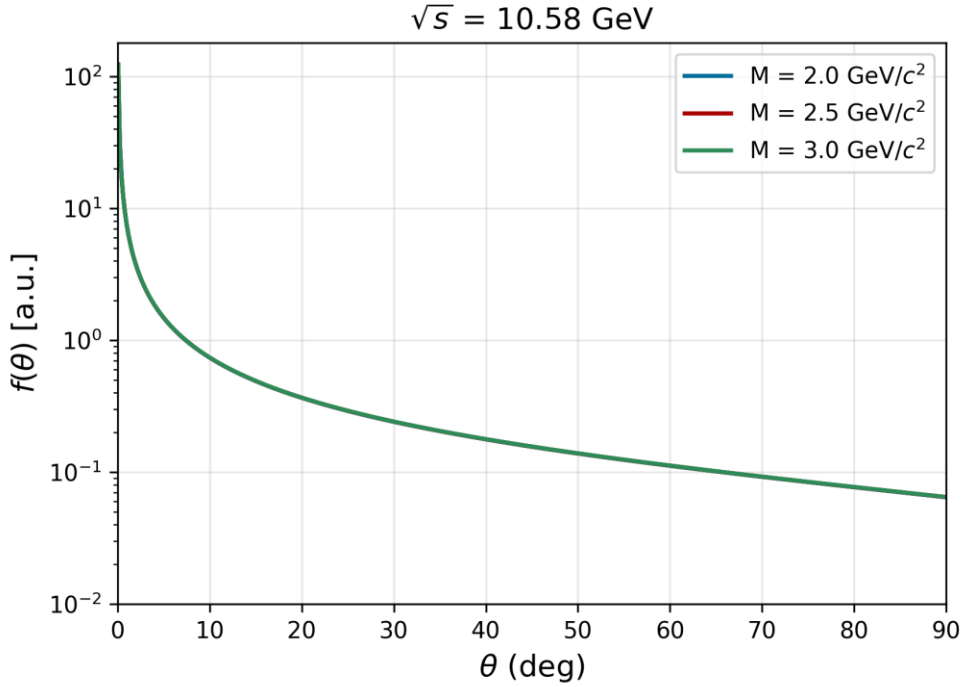
ARICH: 14~30
ARICH: 18.5~39.0
TOP: 31~128
TOP: 40~140

CDC: 17~150
CDC: 22~157

BELLE: 22~140 (157)

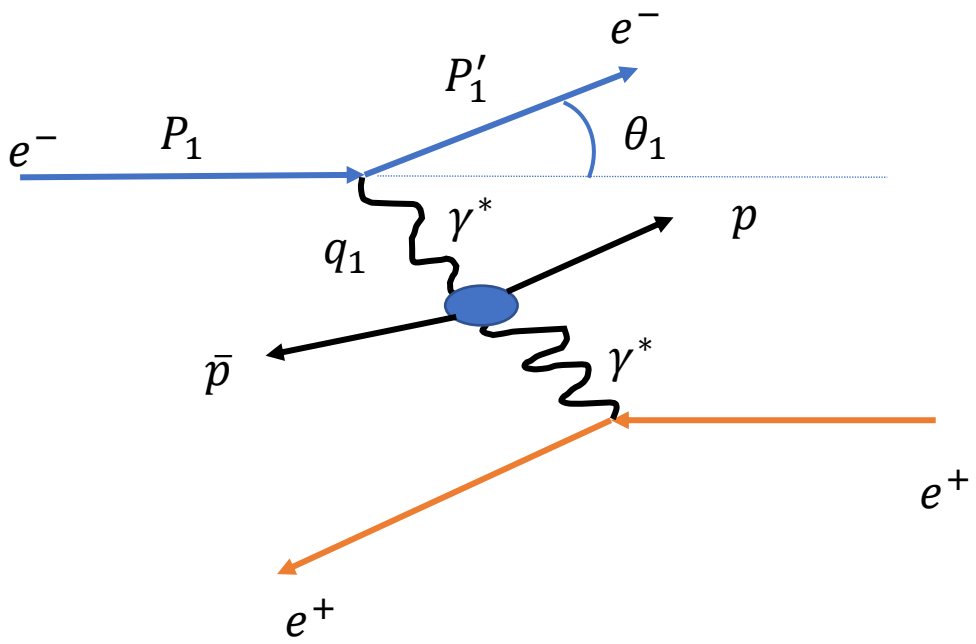
Scattered Electron Angular Distribution in Two-Photon Processes
(Equivalent Photon Approximation, Budnev 1975)





$\boldsymbol{P(cos\theta > 0.92)}$:
0.84 for 2.0GeV
0.82 for 2.5GeV
0.81 for 3.0GeV

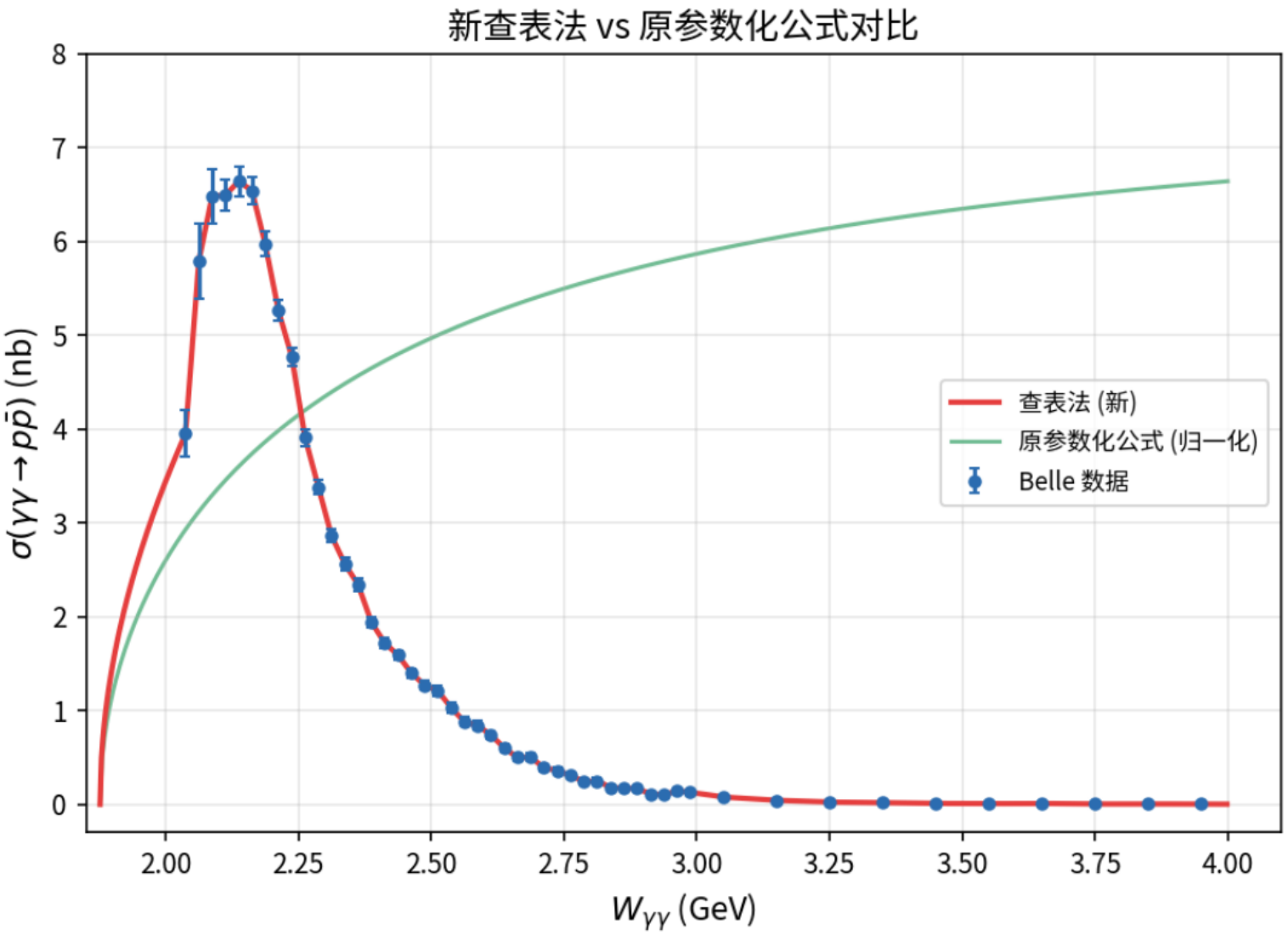
$\boldsymbol{P(cos\theta > 0.92)}$:
0.88 for 2.0GeV
0.87 for 2.5GeV
0.87 for 3.0GeV



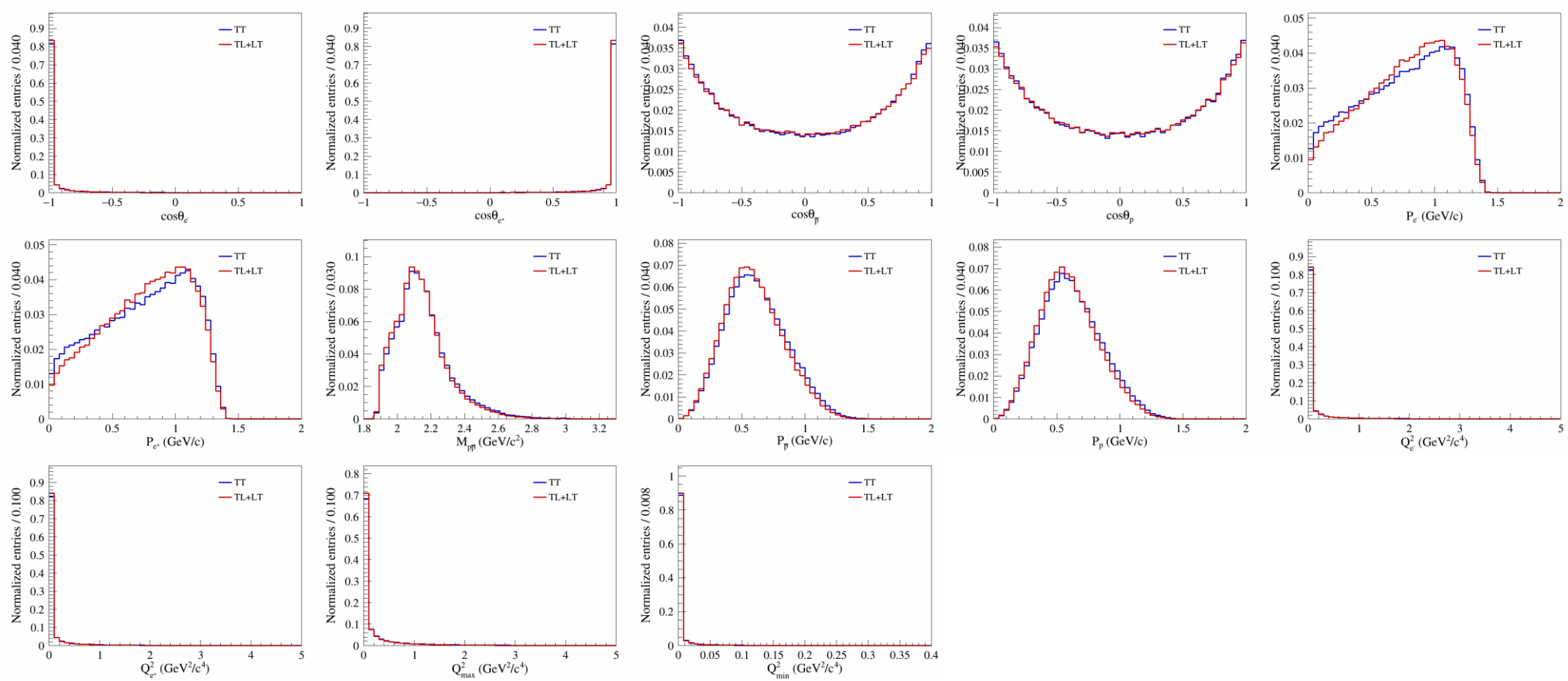
$$\mathbf{q_1} = (\mathbf{E_1} - \mathbf{E_1'}, \mathbf{P_1} - \mathbf{p_1'}),$$

$$\mathbf{q_1^2} \approx -\mathbf{2P_1P_1'(1-\cos\theta_1)} + \mathbf{m^2}(\mathbf{2} - \frac{\mathbf{P_1'}}{\mathbf{P_1}} - \frac{\mathbf{P_1}}{\mathbf{P_1'}});$$

修改cppgamgam产生子的截面输入



强子作用截面不考虑关于q^2和costheta*的依赖

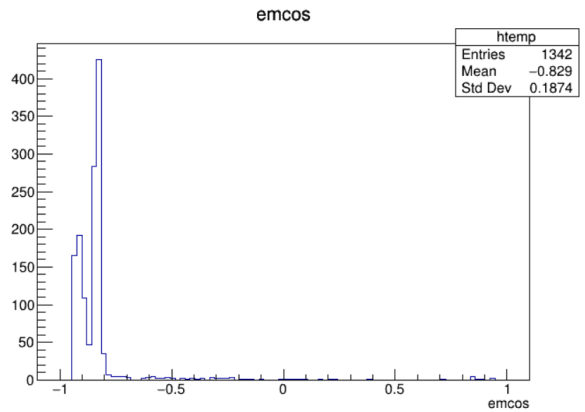


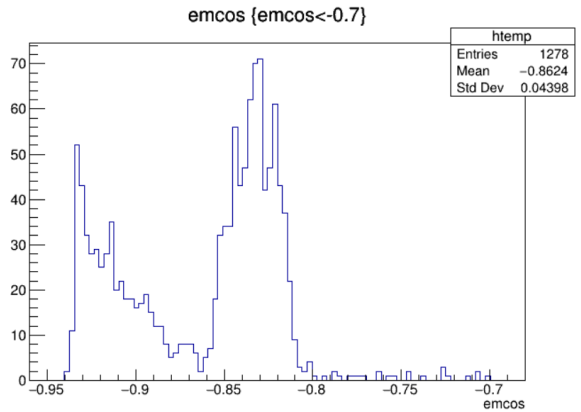
Further Event selection

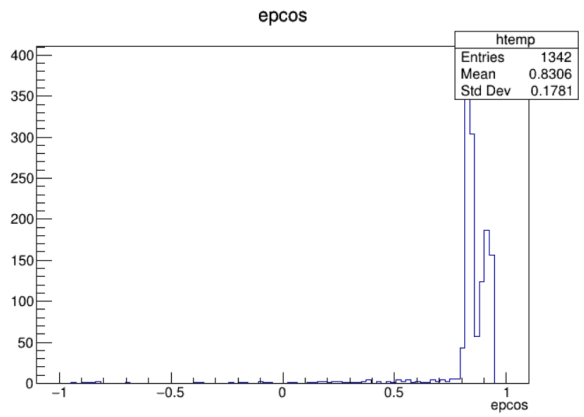
$cos\theta_{miss} * sign(e) < 0;$

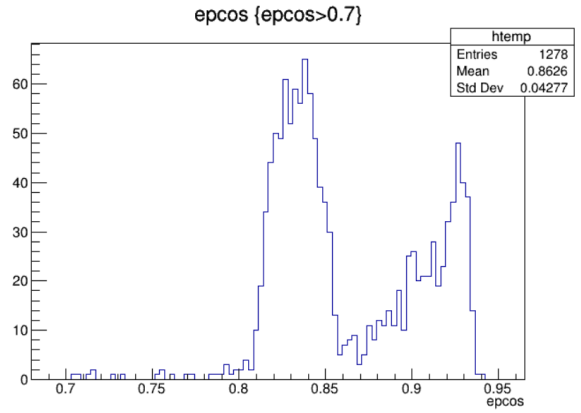
为什么Bhabha MC描述不了数据：只产生了接收度范围的事例

事例挑选后Bhabha事例的Mctruth：

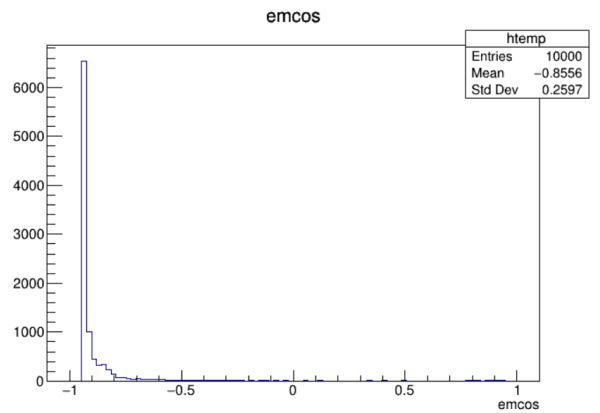


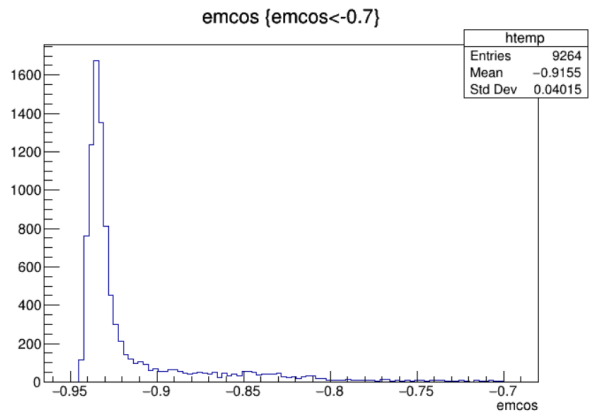


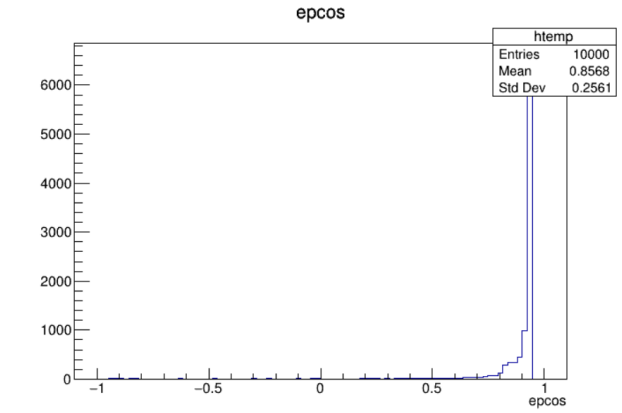


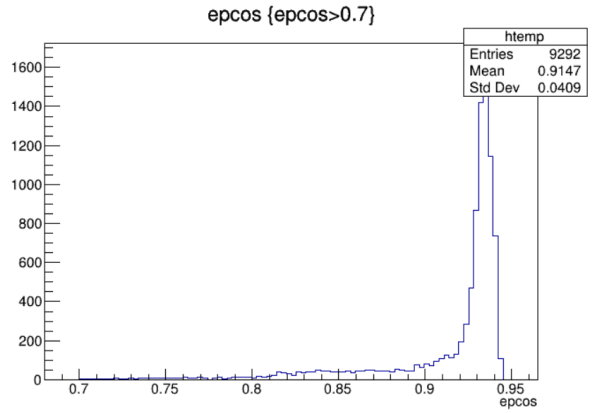


全部Bhabha事例的Mctruth：

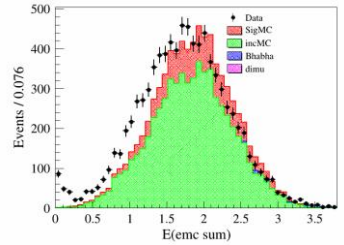






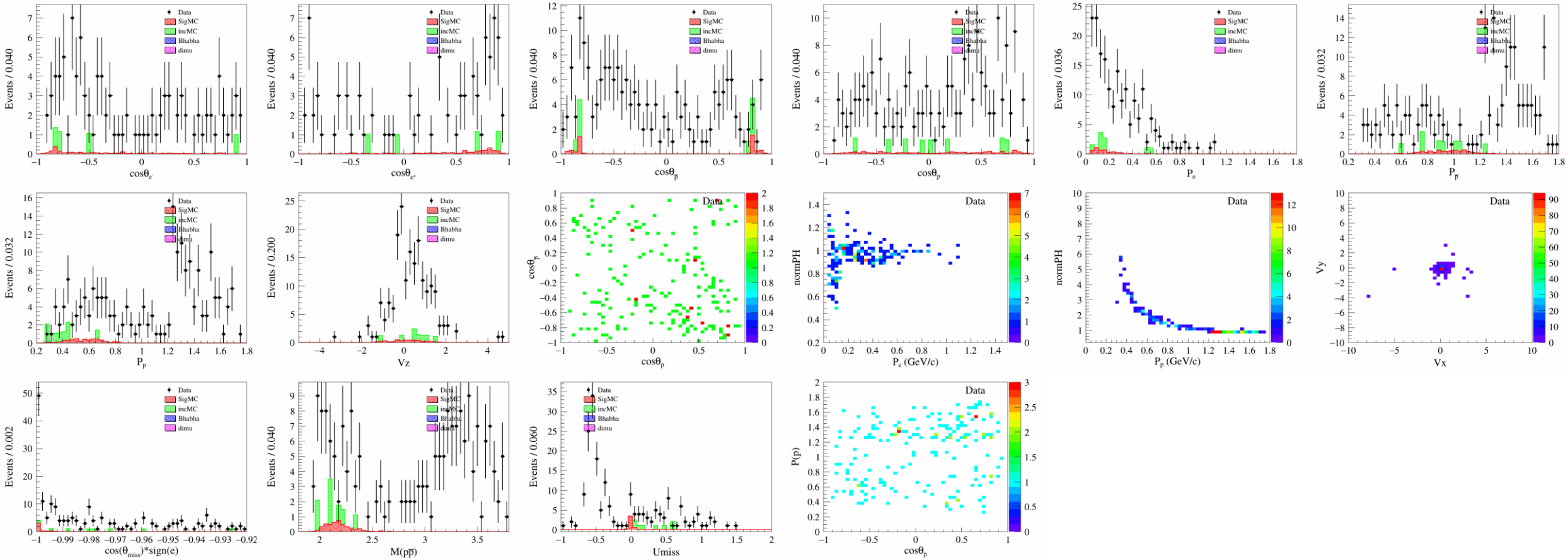


Further Event selection



$$cos\theta_{miss} * sign(e) < -0.92;$$
$$20 < \theta(p, \bar{p}) < 170;$$
$$10 < \theta(p/\bar{p}, e) < 170;$$
$$E(emc\ sum) < 0.3GeV$$

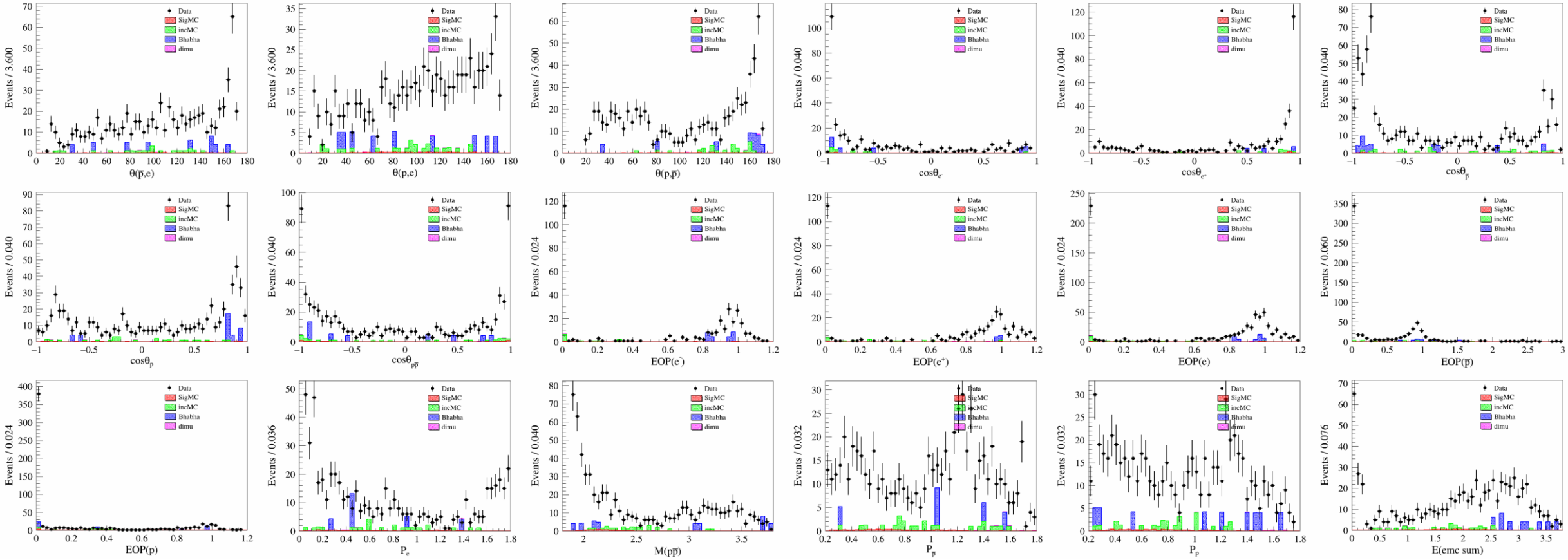
检查E_emc_sum~0数据来源



Further Event selection

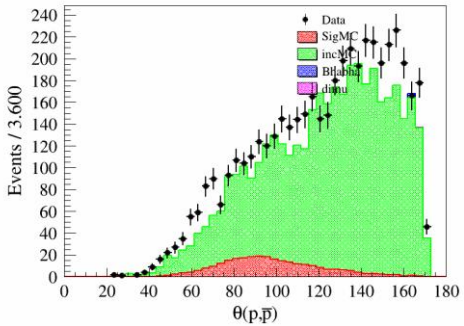
$cos\theta_{miss} * sign(e) < -0.92;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$Umiss < -0.2GeV$

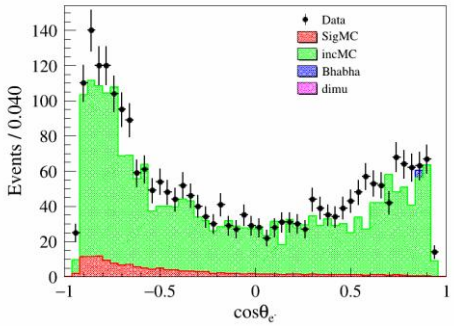
检查p/pbar角分布

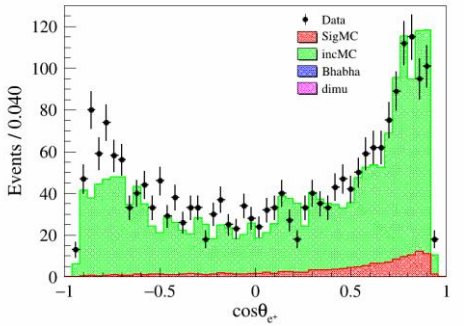


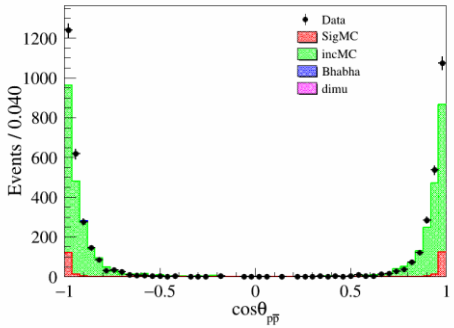
Further Event selection

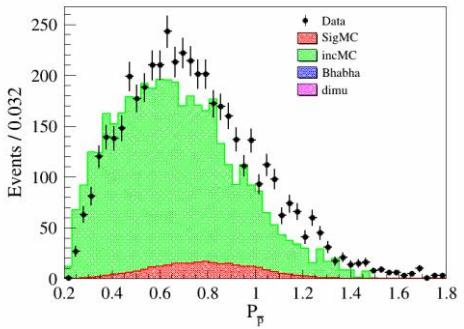
检查p/pbar角分布

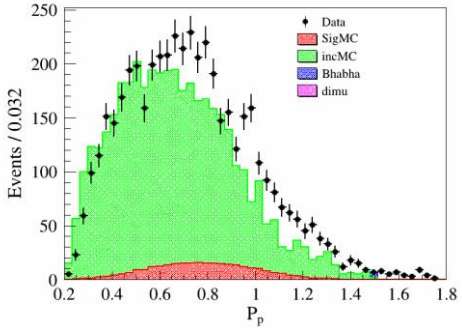


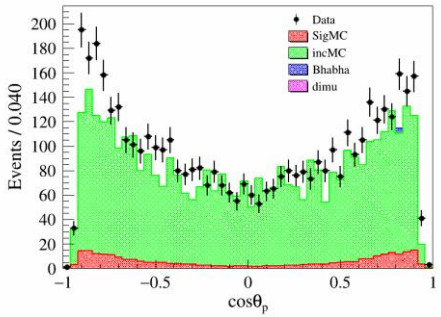


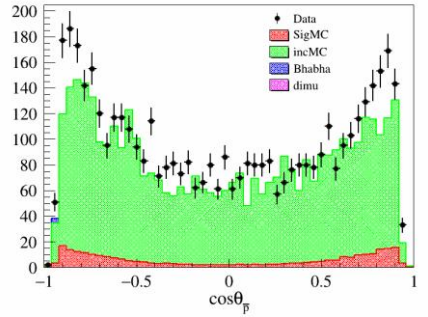


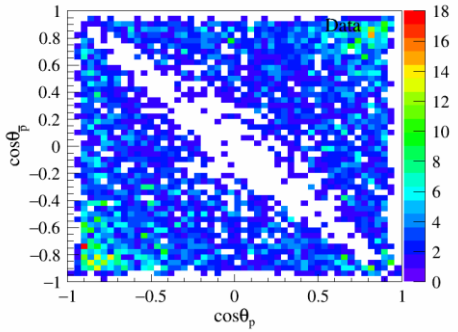


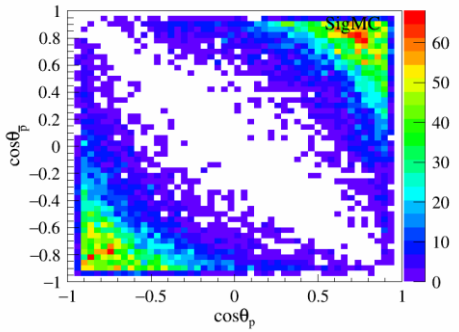


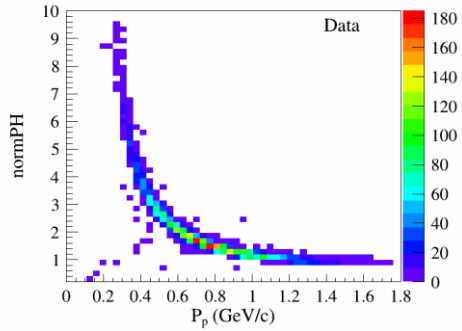


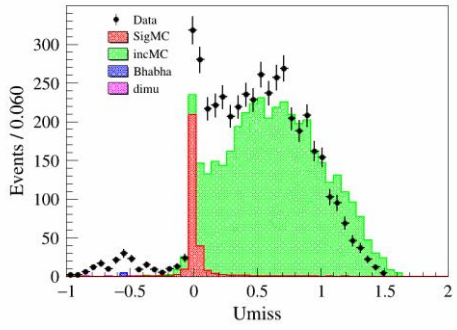












$cos\theta_{miss} * sign(e) < -0.92;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$P_e < 0.3GeV$

Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$Umiss > -0.2$

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$x \to \pi^+\pi^- p\bar{p}\gamma^F$	$\pi^+\pi^- p\bar{p}\gamma^F$	20	95	95
2	$x \to K^+\bar{p}\Lambda\gamma^f, \Lambda \to \pi^- p$	$\pi^- K^+ p\bar{p}\gamma^f$	30	70	165
3	$x \to K^- p\bar{\Lambda}\gamma^f, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+ K^- p\bar{p}\gamma^f$	22	69	234
4	$x \to J/\psi\gamma, J/\psi \to \pi^+\pi^- p\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	12	50	284
5	$x \to J/\psi\gamma, J/\psi \to \pi^+ p\bar{\Delta}^{--}, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	16	34	318
6	$x \to K^+K^- p\bar{p}\gamma^f$	$K^+K^- p\bar{p}\gamma^f$	59	31	349
7	$x \to J/\psi\gamma, J/\psi \to \pi^-\bar{p}\Delta^{++}, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}\gamma$	55	19	368
8	$x \to \pi^+\pi^- p\bar{p}\gamma^f$	$\pi^+\pi^- p\bar{p}\gamma^f$	6	19	387
9	$x \to J/\psi\gamma, J/\psi \to \Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	29	17	404
10	$x \to p\bar{p}a_0^0\gamma^f, a_0^0 \to \pi^0\eta, \eta \to \pi^0\pi^0\pi^0$	$\pi^0\pi^0\pi^0\pi^0 p\bar{p}\gamma^f$	19	17	421
11	$x \to \pi^+ p\bar{\Delta}^{--}\gamma^f, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma^f$	45	15	436
12	$x \to p\bar{p}\gamma^F\gamma^F$	$p\bar{p}\gamma^F\gamma^F$	51	14	450
13	$x \to J/\psi\gamma, J/\psi \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+ K^- p\bar{p}\gamma$	66	14	464
14	$x \to \pi^-\bar{p}\Delta^{++}\gamma^f, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}\gamma^f$	82	13	477
15	$x \to K^+K^- p\bar{p}$	$K^+K^- p\bar{p}$	86	11	488
16	$x \to J/\psi\gamma, J/\psi \to \pi^0 p\bar{p}$	$\pi^0 p\bar{p}\gamma$	258	10	498
17	$x \to J/\psi\gamma, J/\psi \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma\gamma$	4	9	507
18	$x \to J/\psi\gamma, J/\psi \to \pi^-\bar{\Delta}^0 p, \bar{\Delta}^0 \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	73	9	516
19	$x \to p\bar{p}a_0^0\gamma^f, a_0^0 \to \pi^0\eta, \eta \to \gamma\gamma$	$\pi^0 p\bar{p}\gamma\gamma\gamma^f$	75	9	525
449	$x \to p\bar{p}f_1(1285)\gamma^f, f_1(1285) \to \pi^0 K^0\bar{K}^0, K^0 \to K_L^0, \bar{K}^0 \to K_S^0, K_S^0 \to \pi^+\pi^-$	$\pi^0 K_L^0\pi^+\pi^- p\bar{p}\gamma^f$	448	1	1227

Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2$

加一个Umiss较宽的窗

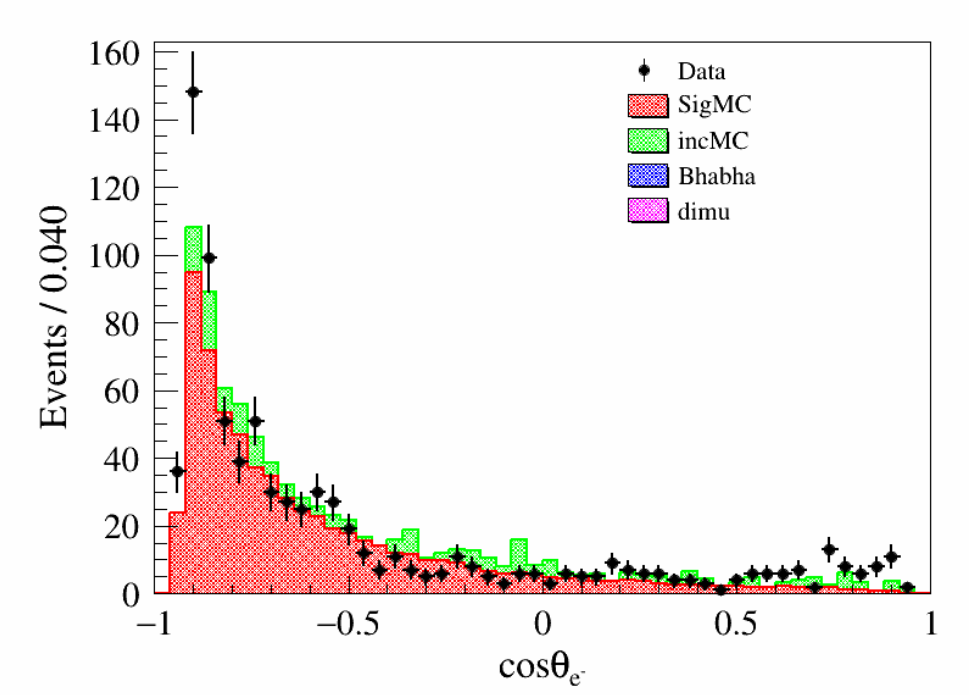
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$x \to J/\psi\gamma, J/\psi \to \pi^+\pi^- p\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	2	37	37
2	$x \to J/\psi\gamma, J/\psi \to \pi^+ p\bar{\Delta}^{--}, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	3	27	64
3	$x \to \pi^+\pi^- p\bar{p}\gamma^F$	$\pi^+\pi^- p\bar{p}\gamma^F$	5	22	86
4	$x \to p\bar{p}\gamma^F\gamma^F$	$p\bar{p}\gamma^F\gamma^F$	10	14	100
5	$x \to J/\psi\gamma, J/\psi \to \pi^-\bar{p}\Delta^{++}, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}\gamma$	12	13	113
6	$x \to \pi^+ p\bar{\Delta}^{--}\gamma^f, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma^f$	9	12	125
7	$x \to \pi^+\pi^- p\bar{p}\gamma^f$	$\pi^+\pi^- p\bar{p}\gamma^f$	1	11	136
8	$x \to J/\psi\gamma, J/\psi \to \Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	13	10	146
9	$x \to \Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}$	35	8	154
10	$x \to K^- p\bar{\Lambda}\gamma^f, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+ K^- p\bar{p}\gamma^f$	36	8	162
11	$x \to J/\psi\gamma, J/\psi \to \pi^0 p\bar{p}$	$\pi^0 p\bar{p}\gamma$	57	8	170
12	$x \to J/\psi\gamma, J/\psi \to p\bar{p}\gamma^F$	$p\bar{p}\gamma^F\gamma$	29	7	177
13	$x \to \psi'\gamma, \psi' \to \pi^+\pi^- J/\psi, J/\psi \to p\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	37	7	184
14	$x \to J/\psi\gamma, J/\psi \to \pi^-\bar{\Delta}^0 p, \bar{\Delta}^0 \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	15	7	191
15	$x \to K^+\bar{p}\Lambda\gamma^f, \Lambda \to \pi^- p$	$\pi^- K^+ p\bar{p}\gamma^f$	53	6	197
16	$x \to \Delta^{++}\bar{\Delta}^{--}\gamma^f, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma^f$	24	6	203
17	$x \to J/\psi\gamma, J/\psi \to \pi^+\Delta^0\bar{p}, \Delta^0 \to \pi^- p$	$\pi^+\pi^- p\bar{p}\gamma$	31	5	208
18	$x \to f_2(1270)p\bar{p}, f_2(1270) \to \pi^+\pi^-$	$\pi^+\pi^- p\bar{p}$	41	5	213
19	$x \to \pi^-\bar{p}\Delta^{++}\gamma^f, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}\gamma^f$	42	5	218
87	$x \to f_2(1270)p\bar{p}\gamma^f, f_2(1270) \to \pi^0\pi^0$	$\pi^0\pi^0 p\bar{p}\gamma^f$	86	1	321

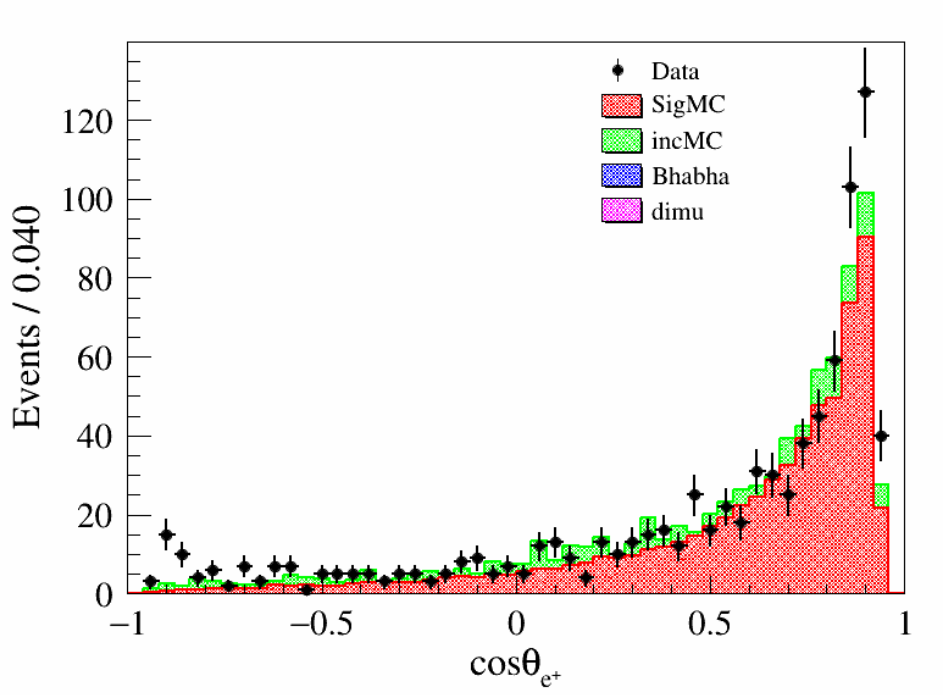
Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2$

分别取出$cos\theta_{e^+} < -0.8, cos\theta_{e^-} > 0.8$的事例

分别取出$cos\theta_{e^+} > 0.8, cos\theta_{e^-} < -0.8$的事例

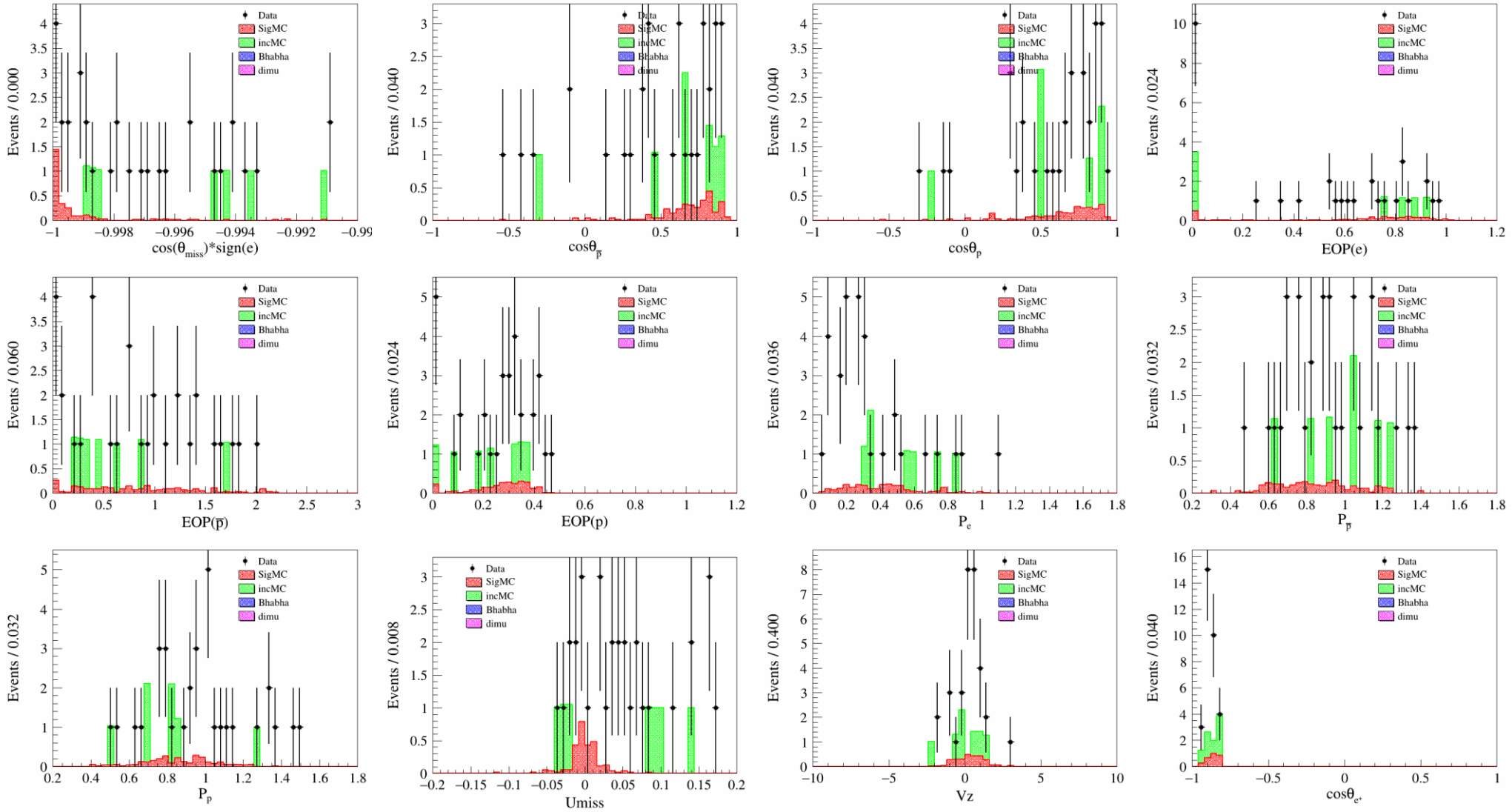




Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$
$cos\theta_{e^+} < -0.8$

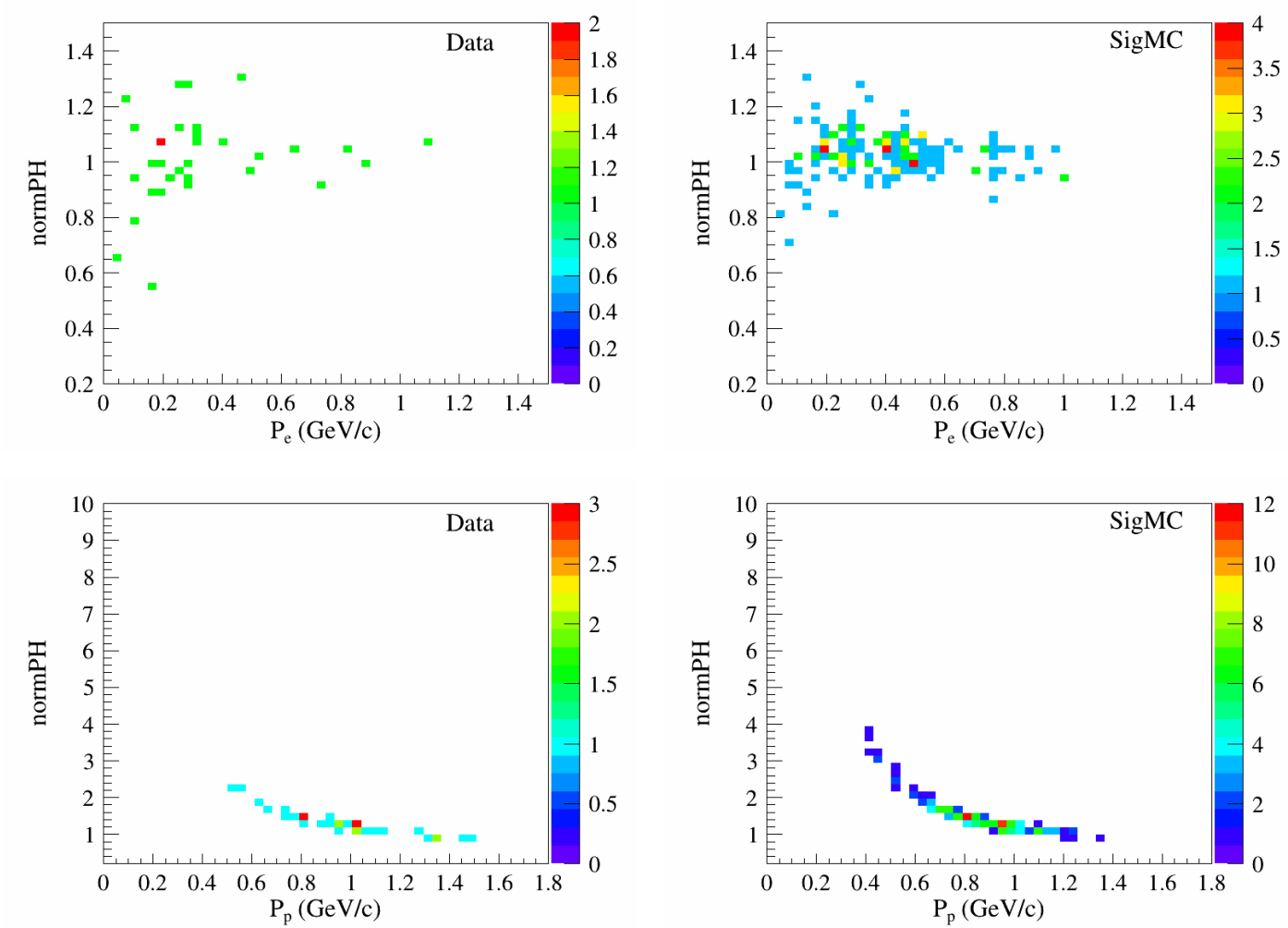
$cos\theta_{e^+} < -0.8$



Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$
$cos\theta_{e^+} < -0.8$

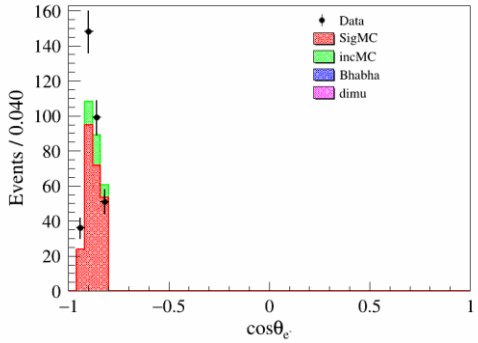
$cos\theta_{e^+} < -0.8$

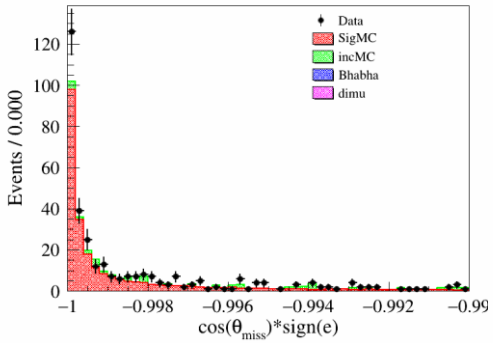


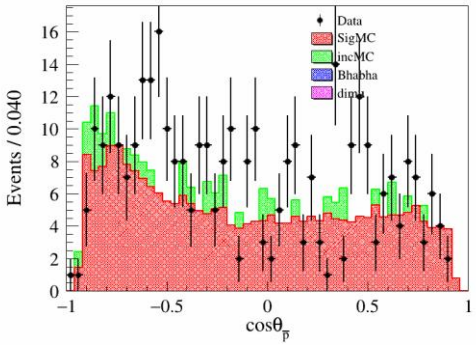
Further Event selection

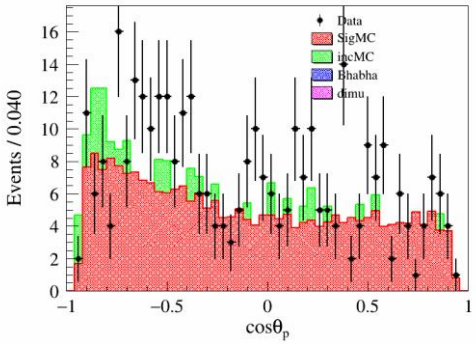
$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$
$cos\theta_{e^-} < -0.8$

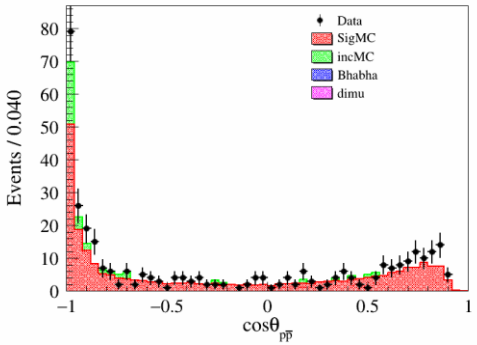
$cos\theta_{e^-} < -0.8$

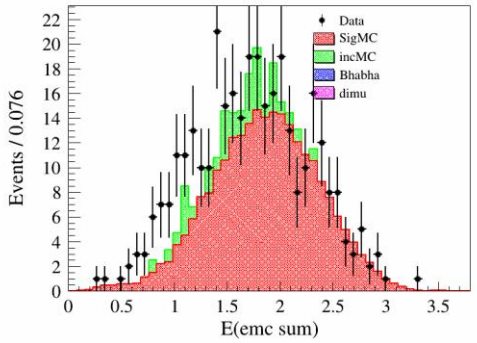


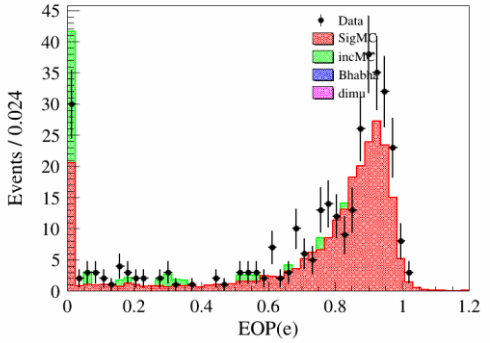


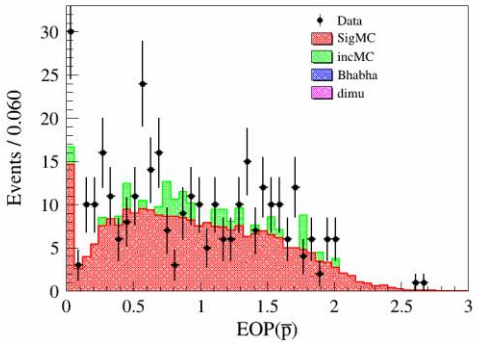


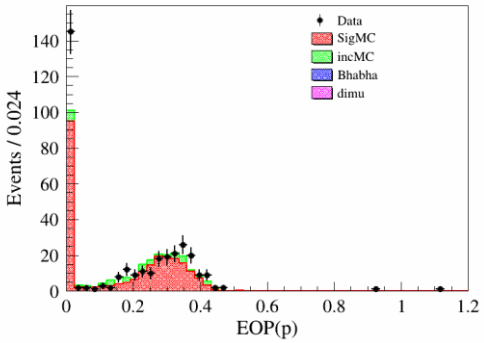


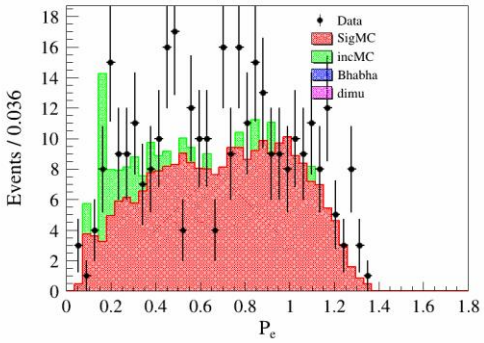


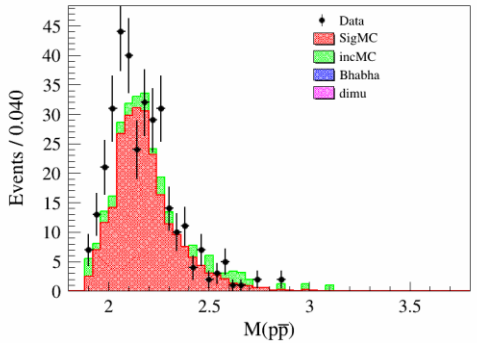


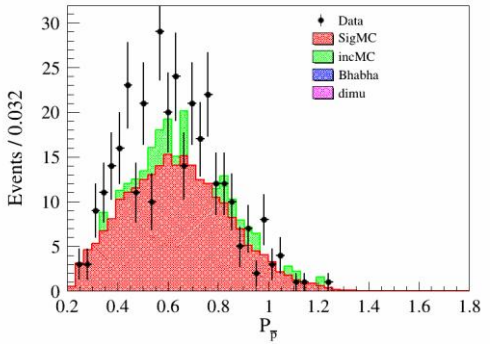


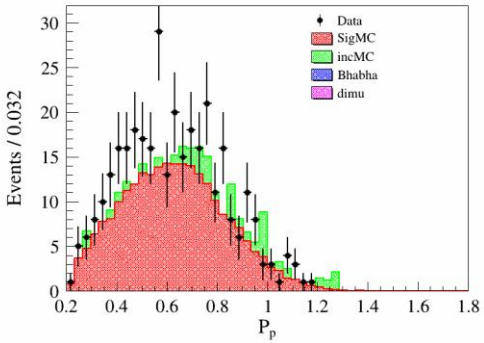


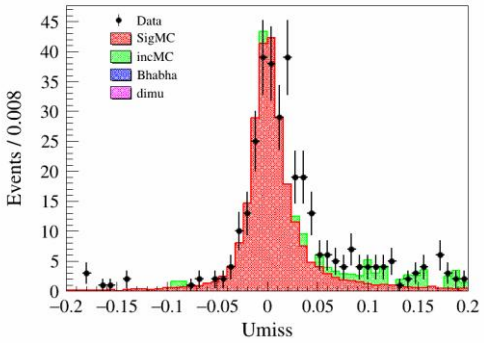








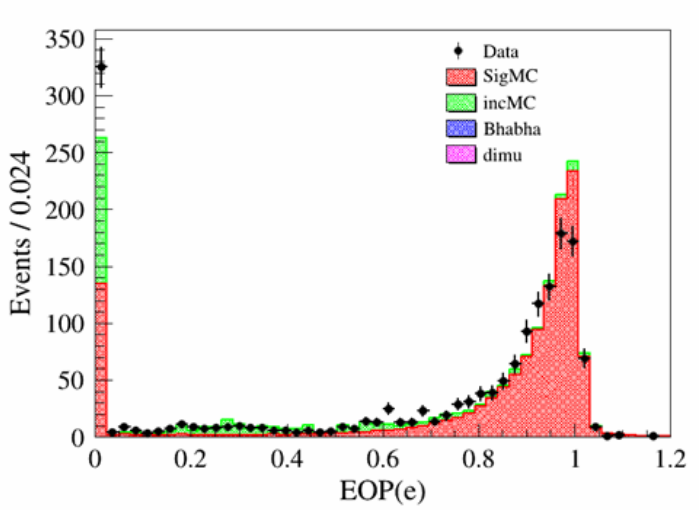




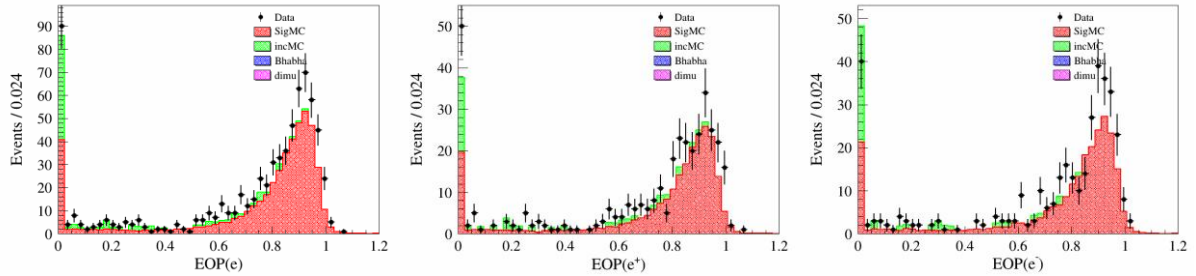
Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$

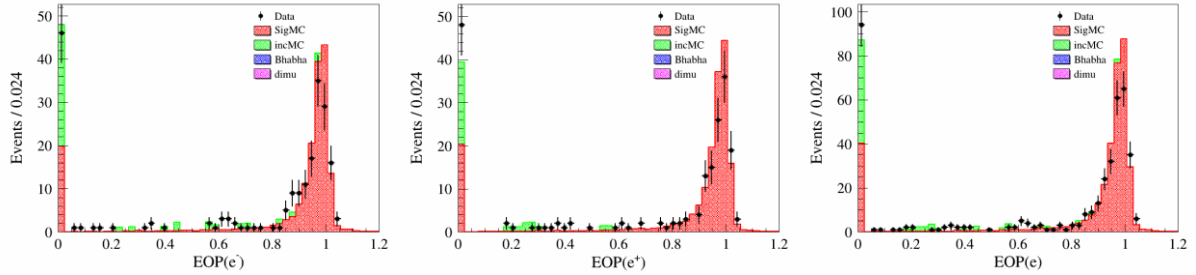
按$cos\theta_e$分bin观察EOPe

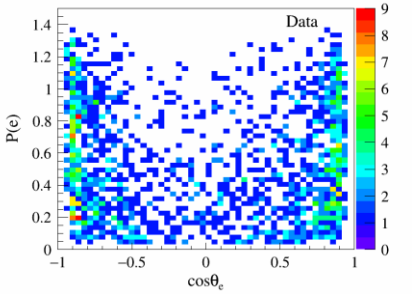


$|cos\theta_e| > 0.8$

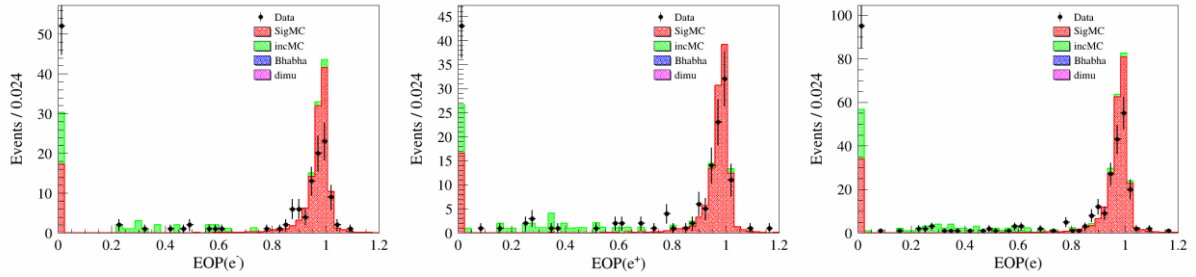


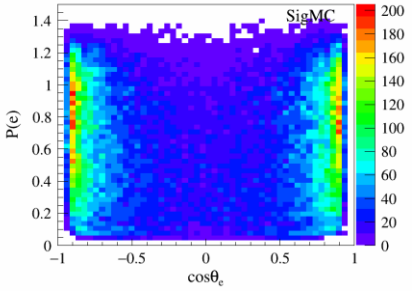
$0.6 < |cos\theta_e| < 0.8$



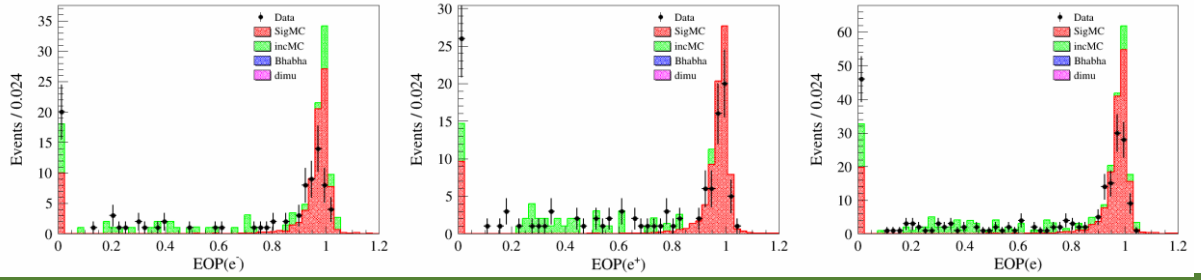


$0.3 < |cos\theta_e| < 0.6$





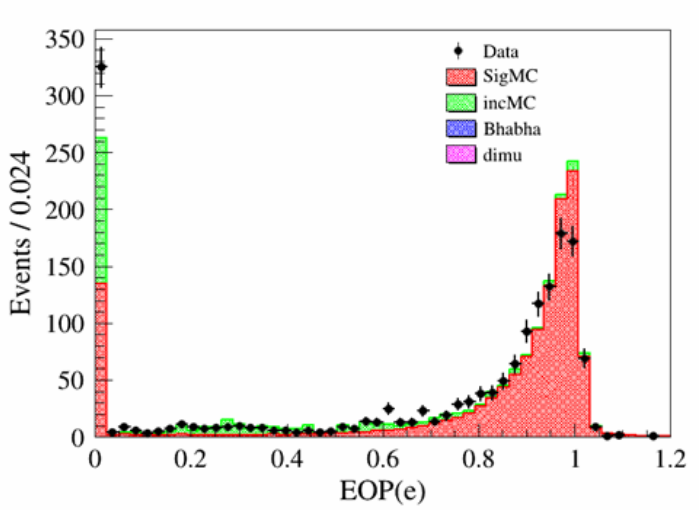
$|cos\theta_e| < 0.3$



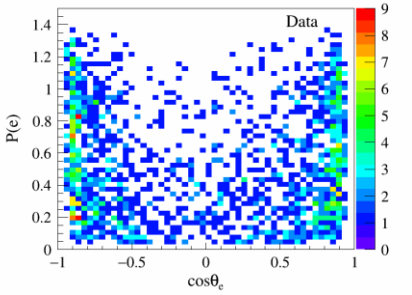
Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$

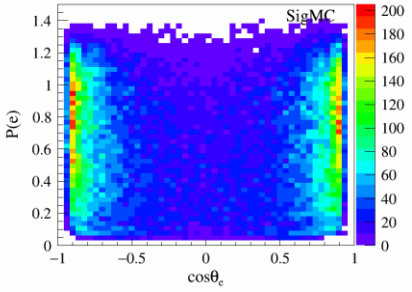
按P_e分bin观察EOPe



$P_e > 1.0$

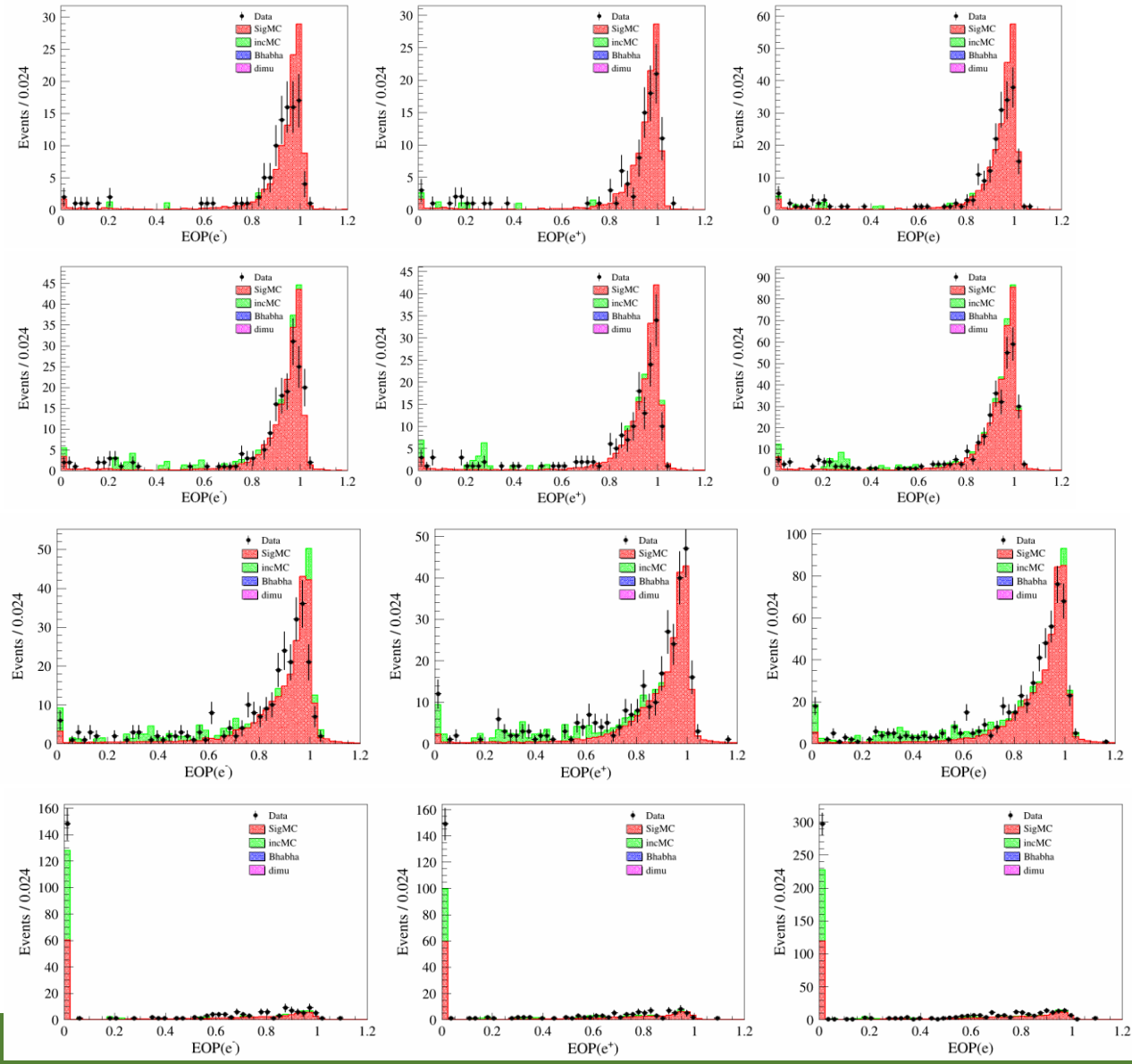


$0.7 < P_e < 1.0$



$0.3 < P_e < 0.7$

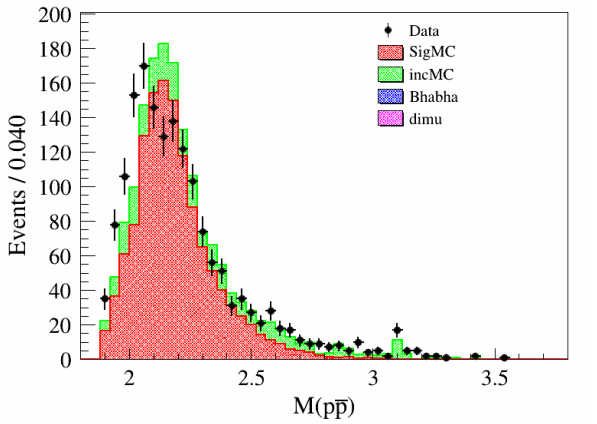
$P_e < 0.3$



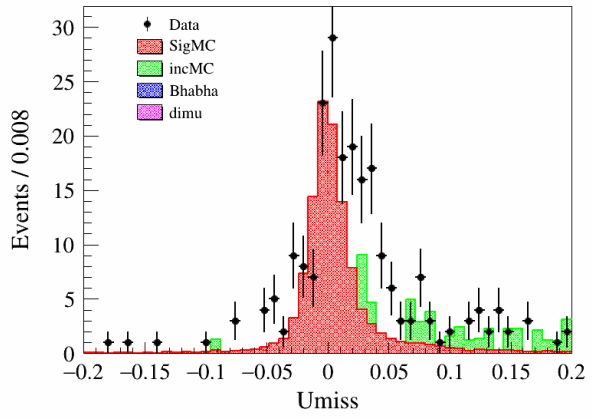
Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$

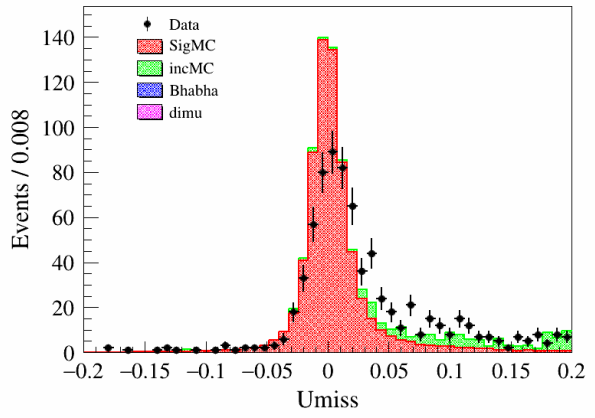
按Mppbar分bin的Umiss谱

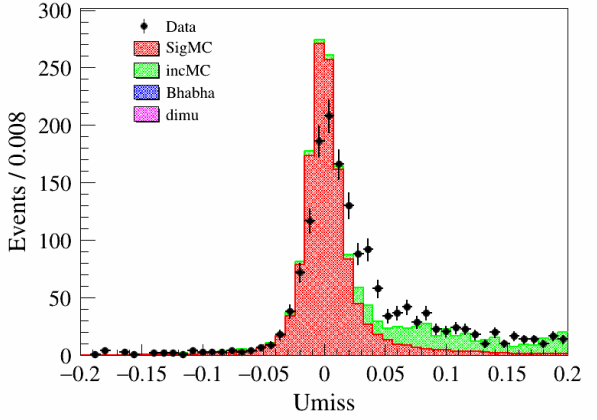


$M(p\bar{p}) < 2.0GeV$

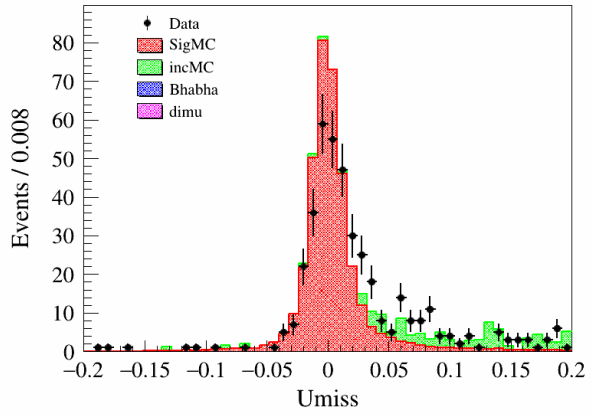


$2.0 < M(p\bar{p}) < 2.2$

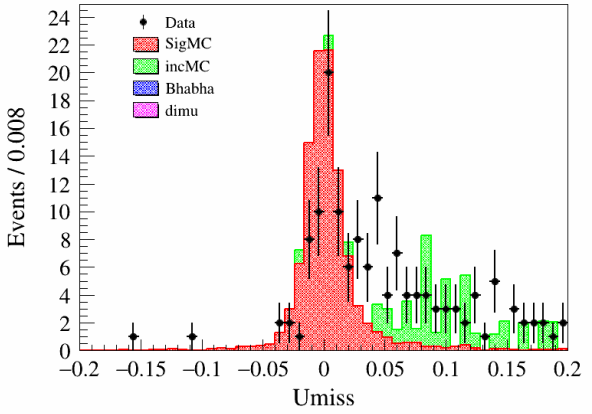




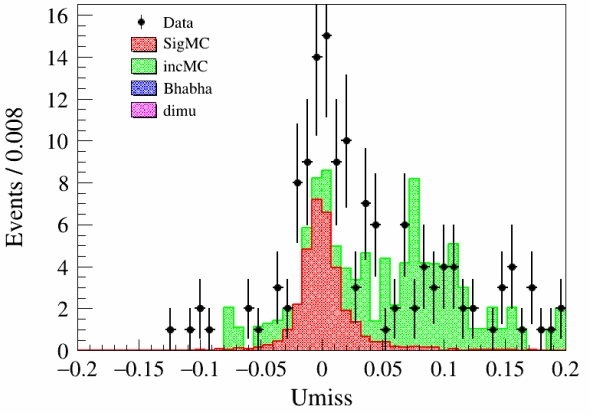
$2.2 < M(p\bar{p}) < 2.4$



$2.4 < M(p\bar{p}) < 2.6$



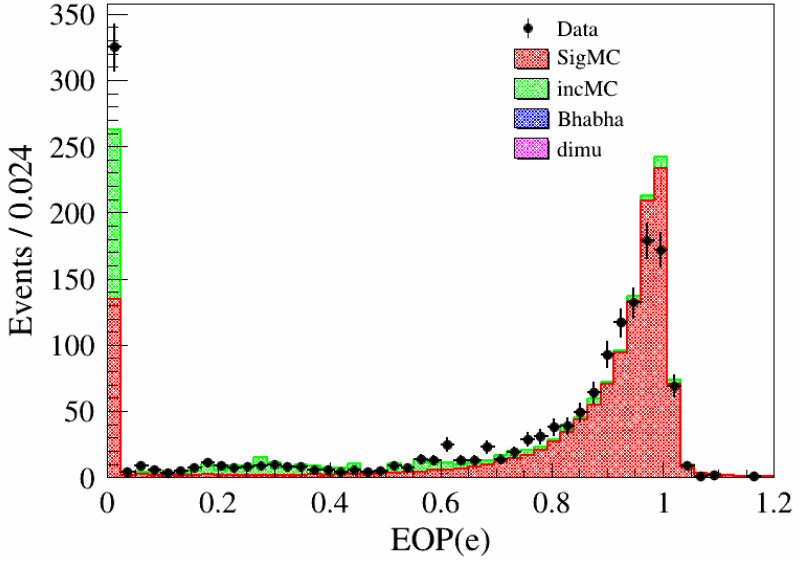
$2.6 < M(p\bar{p})$

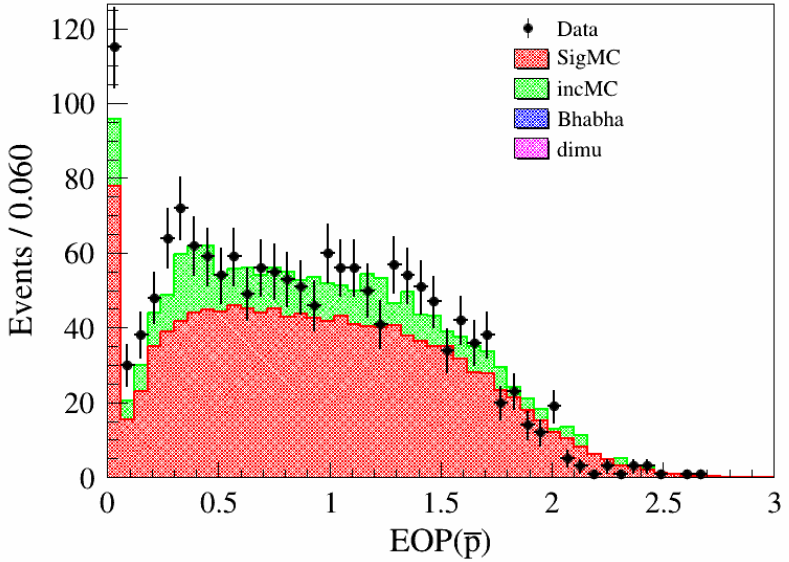


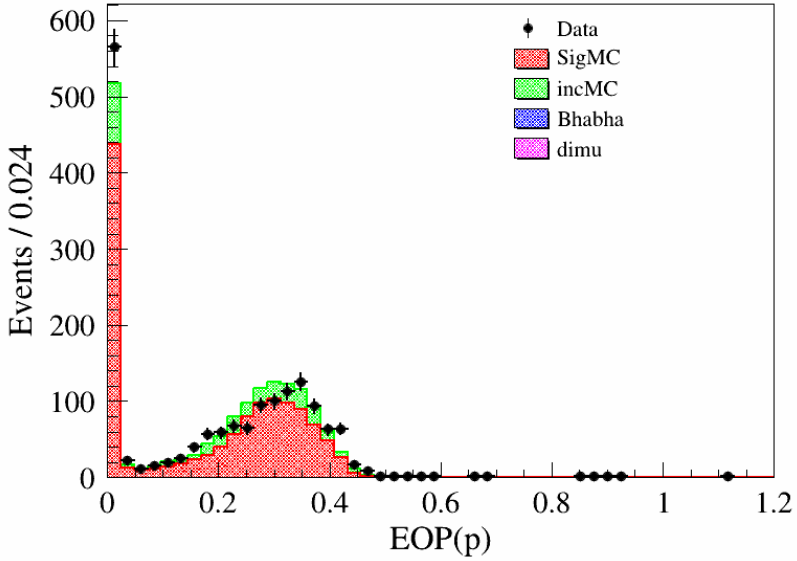
Further Event selection

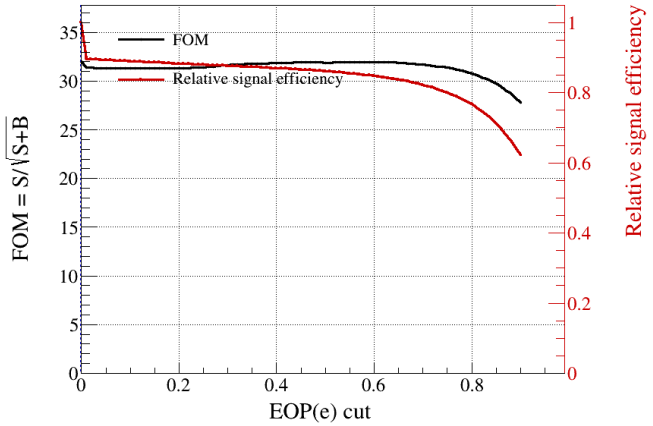
$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$

对EOP做要求：





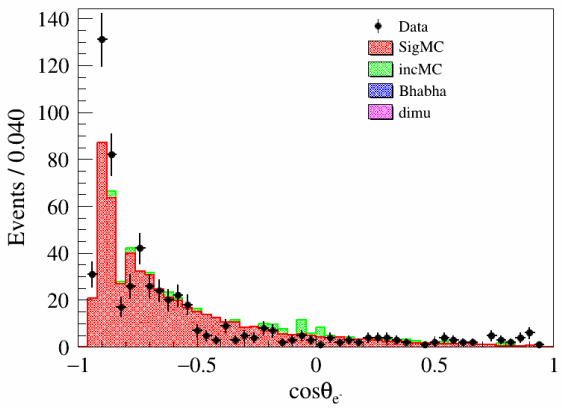


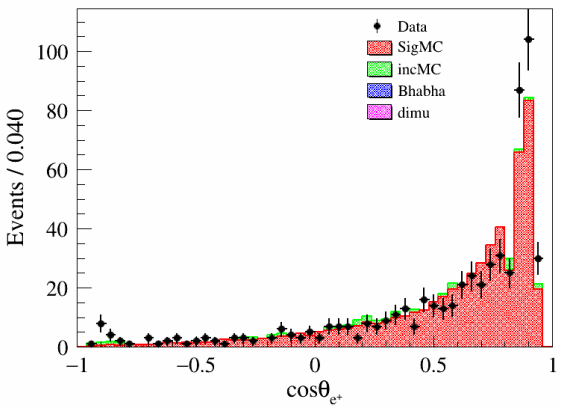


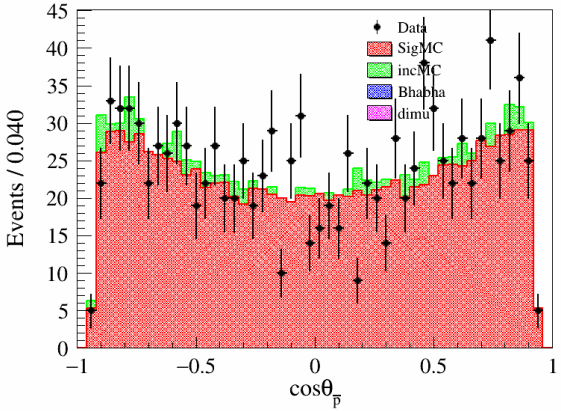
Further Event selection

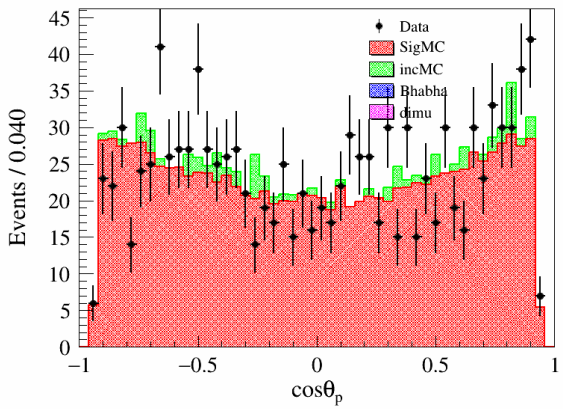
$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$
$EOP(e) > 0.6$

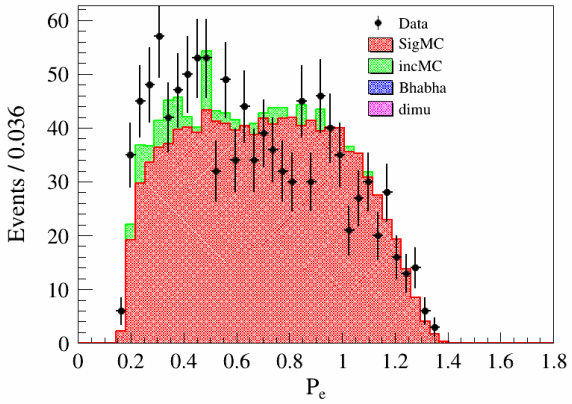
对EOP做要求：EOPItag>0.6

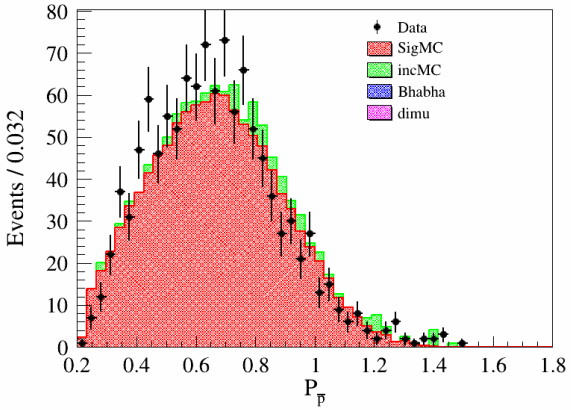


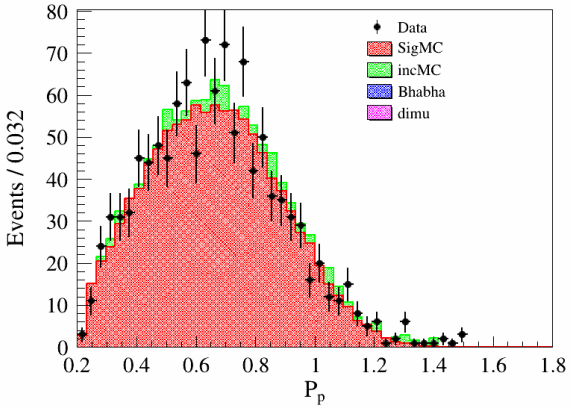








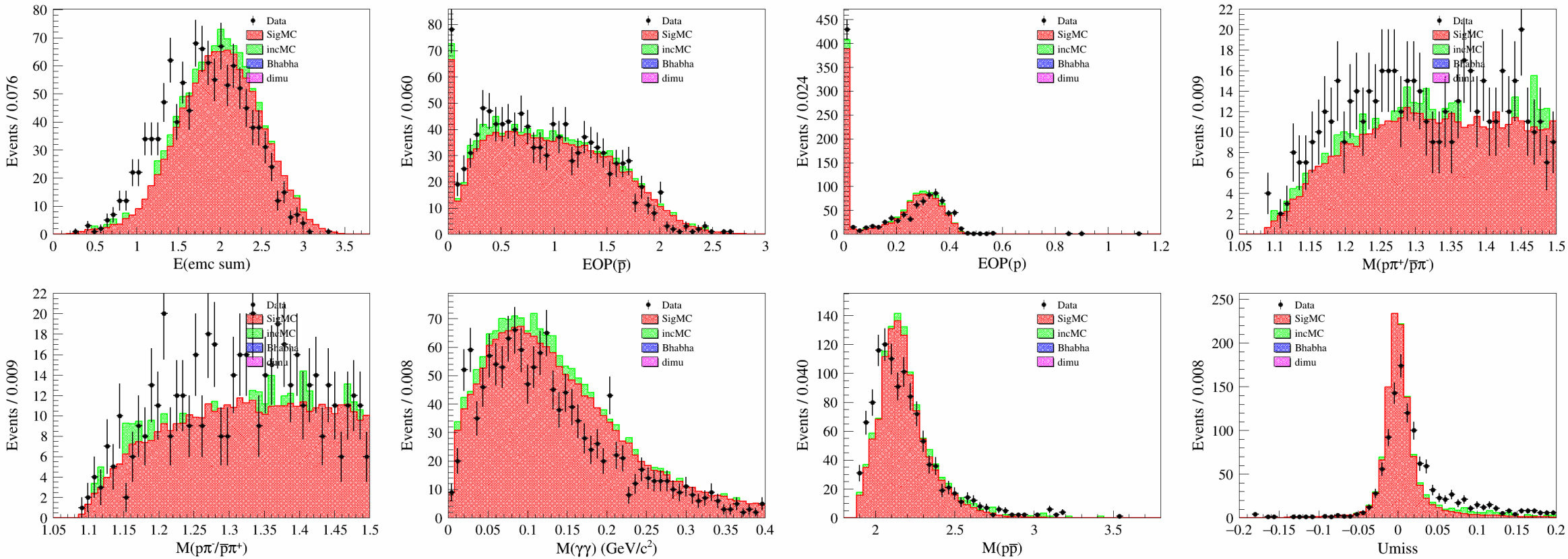




Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$
$EOP(e) > 0.6$

对EOP做要求：EOPItag>0.6



Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$|Umiss| < 0.2;$
$EOP(e) > 0.6$

对EOP做要求：EOPItag>0.6