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

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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.

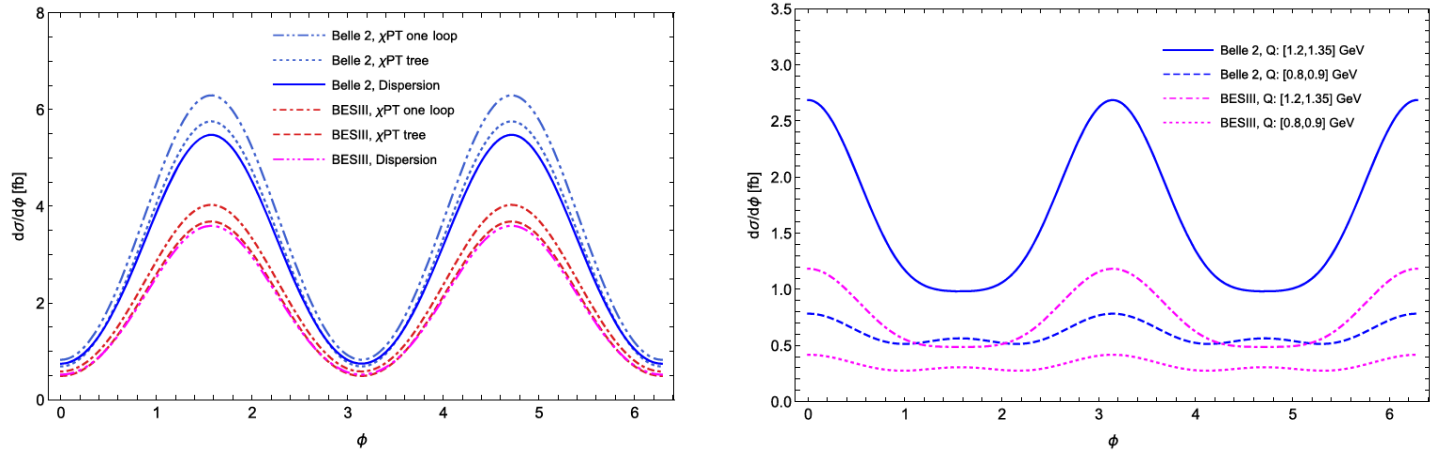


Fig. The differential cross section of $ee \to \gamma\gamma ee \to \pi\pi ee$ with respect to the azimuthal angle ϕ.

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

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

MC Generation

➢ MC Generation

1. cppGamGam Generator helps to obtain the momentum of final particles $e^+e^-p\bar{p}$.
2. Simulation: TrackGen
3. Reweight $M_{p\bar{p}}$ according to the estimated yield.

Decay card

```
noPhotos
Particle vpho 3.773 0.0

Decay vpho
1.000  e-  e+  p+  anti-p-  TrackGen  0;
Enddecay

End
```

Simulation

```
//**************job options for EvtGen***************
#include "$BESEVTGENROOT/share/BesEvtGen.txt"
EvtDecay.userDecayTableName = "gamgamtoppbar.dec";
EvtDecay.FileForTrackGen = {"../../p4sample/ppbar3773-1.dat"};
EvtDecay.ParentParticle = "vpho";
EvtDecay.statDecays = true;
```

MC Generation

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

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

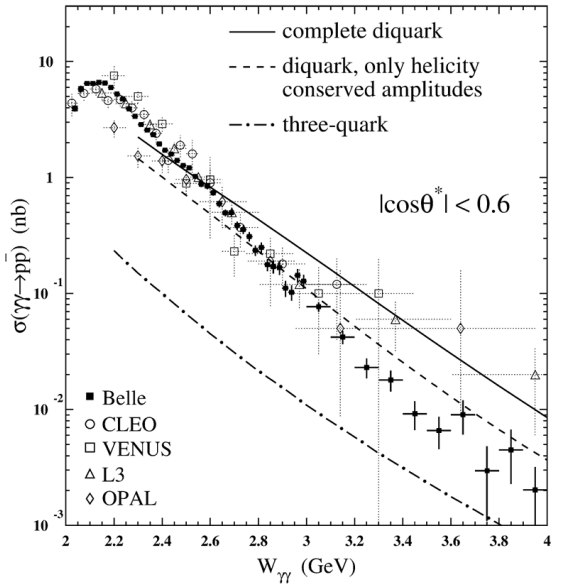


Fig. $\sigma_{\gamma\gamma\to p\bar{p}}(W_{\gamma\gamma})$ Belle Collaboration Physics Letters B 621 (2005) 41–55

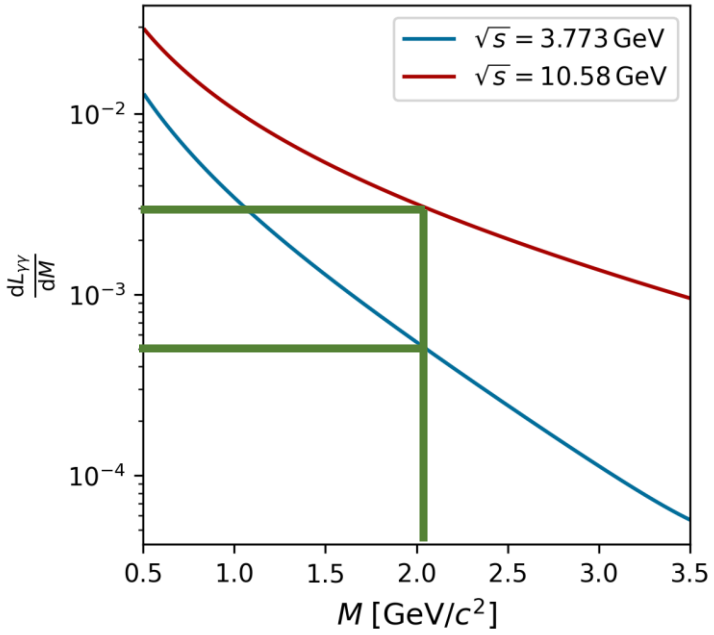
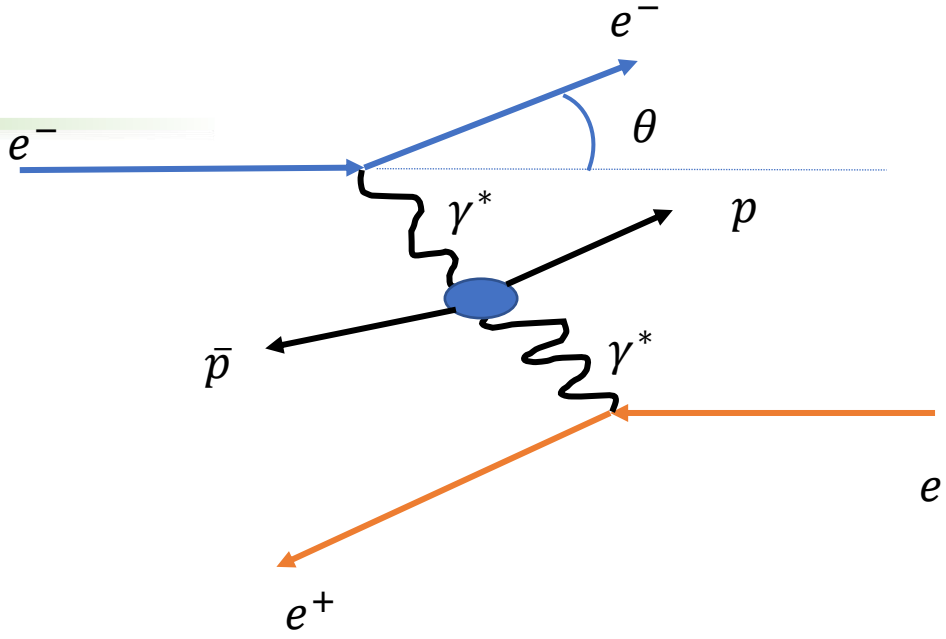


Fig. $\frac{aL_{\gamma\gamma}(W_{\gamma\gamma})}{dW_{\gamma\gamma}}$ calculation.



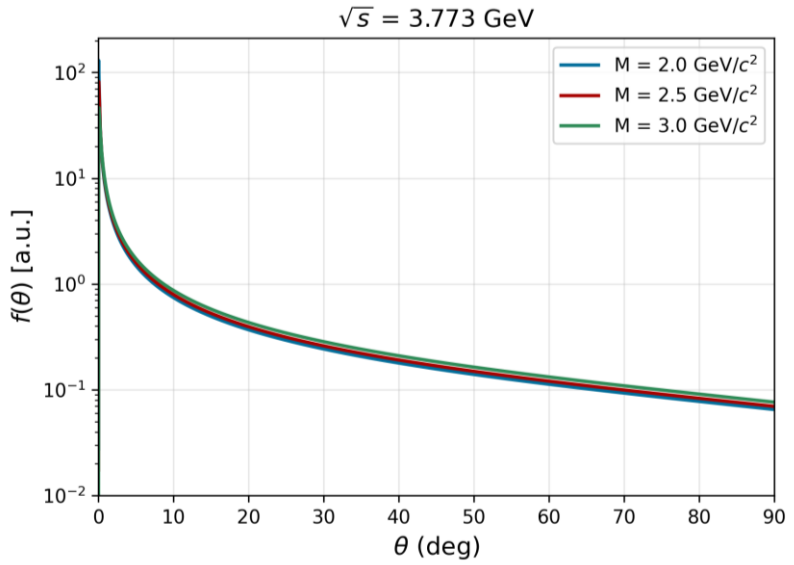
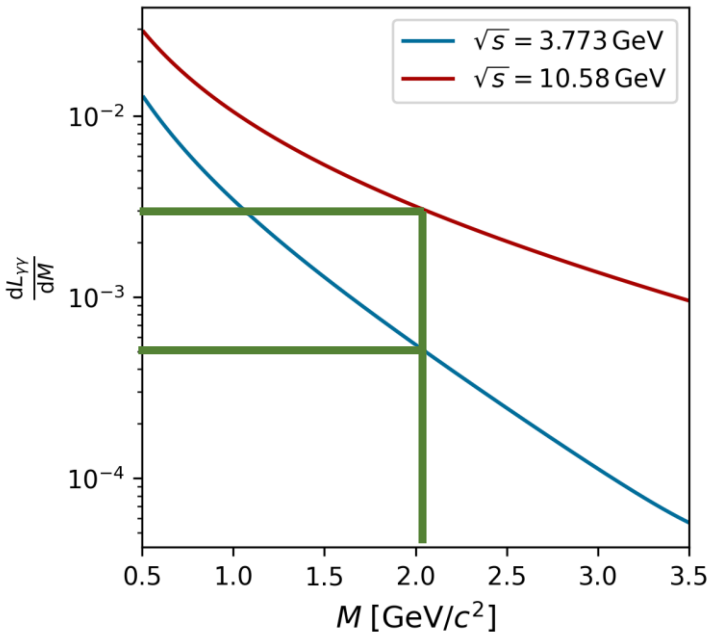
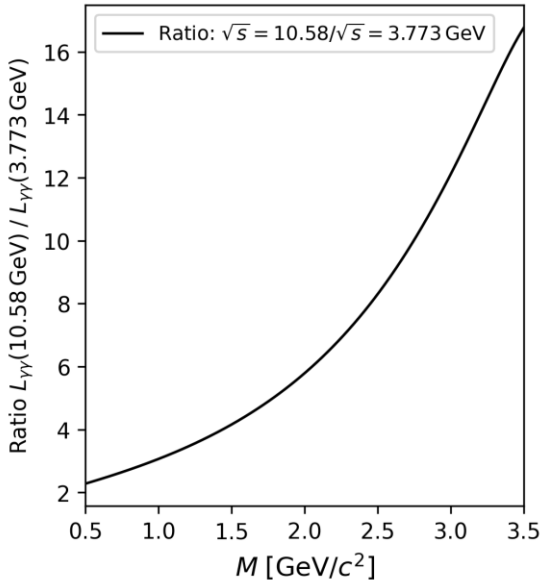


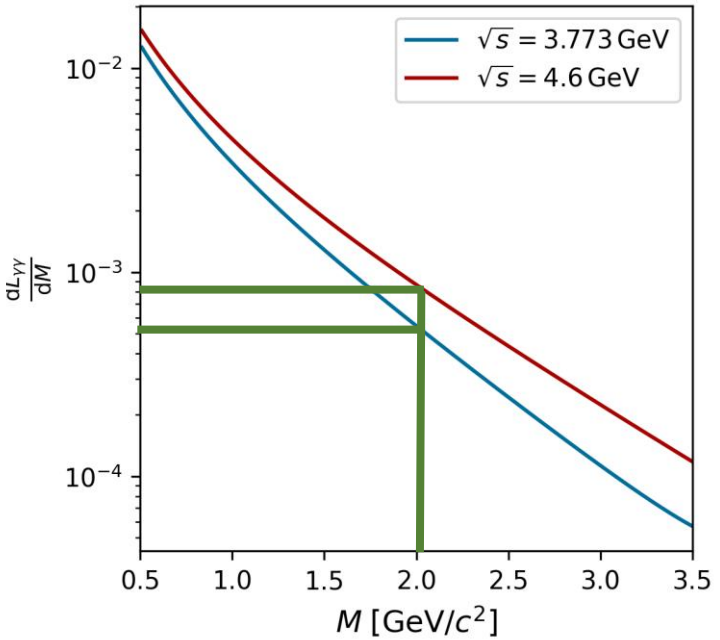
Fig. angular distribution of electron

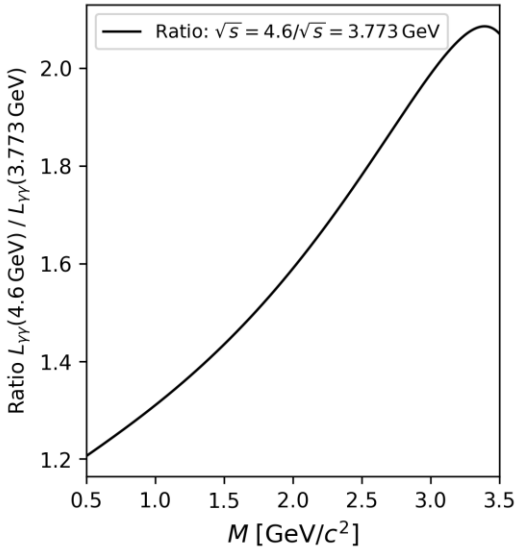
$P(cos\theta > 0.92)$:
0.84 for 2.0GeV
0.82 for 2.5GeV
0.81 for 3.0GeV

Untag:0.69
Single:0.28
Double:0.03

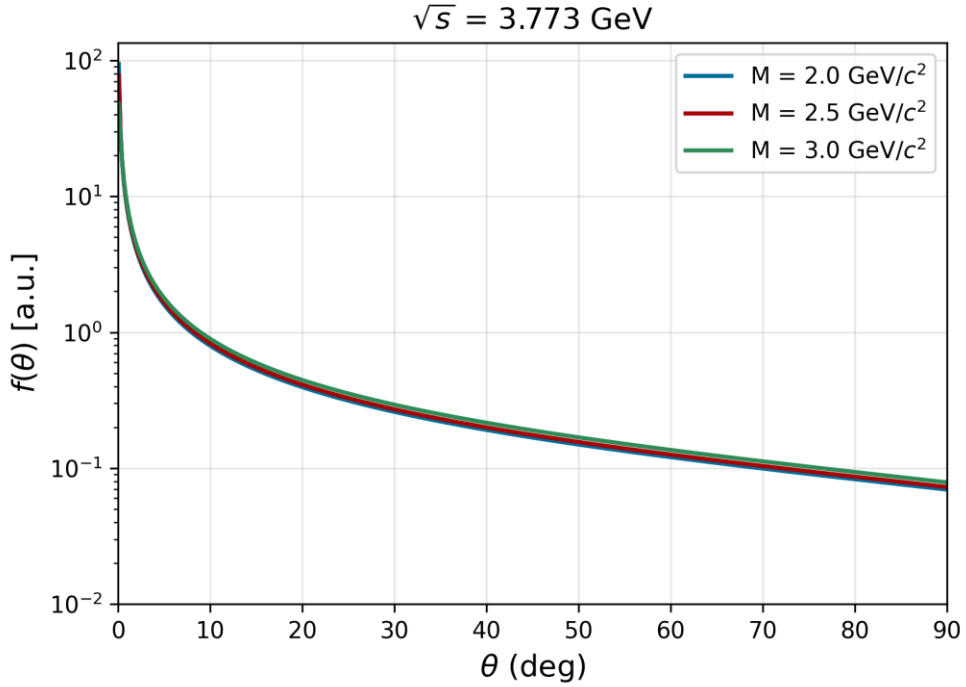

$\sqrt{s} = 3.773\,\mathrm{GeV}$
$\sqrt{s} = 10.58\,\mathrm{GeV}$
$\frac{\mathrm{d}L_{\gamma\gamma}}{\mathrm{d}M}$
$M\,[\mathrm{GeV}/c^2]$

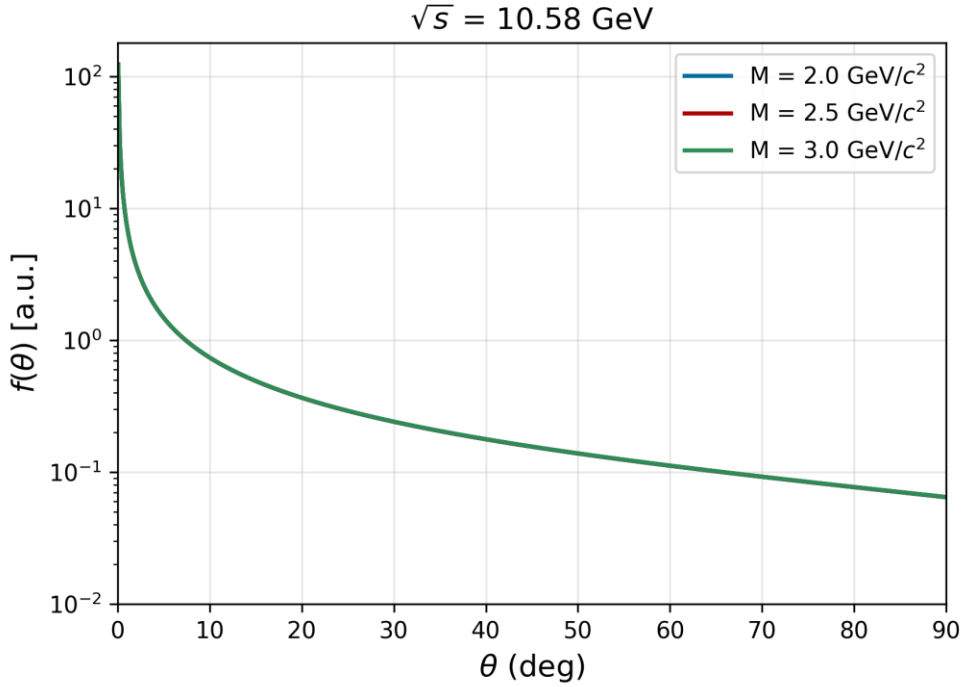

Ratio: $\sqrt{s} = 10.58/\sqrt{s} = 3.773\,\mathrm{GeV}$
Ratio $L_{\gamma\gamma}(10.58\,\mathrm{GeV}) / L_{\gamma\gamma}(3.773\,\mathrm{GeV})$
$M\,[\mathrm{GeV}/c^2]$


$\sqrt{s} = 3.773\,\mathrm{GeV}$
$\sqrt{s} = 4.6\,\mathrm{GeV}$
$\frac{\mathrm{d}L_{\gamma\gamma}}{\mathrm{d}M}$
$M\,[\mathrm{GeV}/c^2]$


Ratio: $\sqrt{s} = 4.6/\sqrt{s} = 3.773\,\mathrm{GeV}$
Ratio $L_{\gamma\gamma}(4.6\,\mathrm{GeV}) / L_{\gamma\gamma}(3.773\,\mathrm{GeV})$
$M\,[\mathrm{GeV}/c^2]$

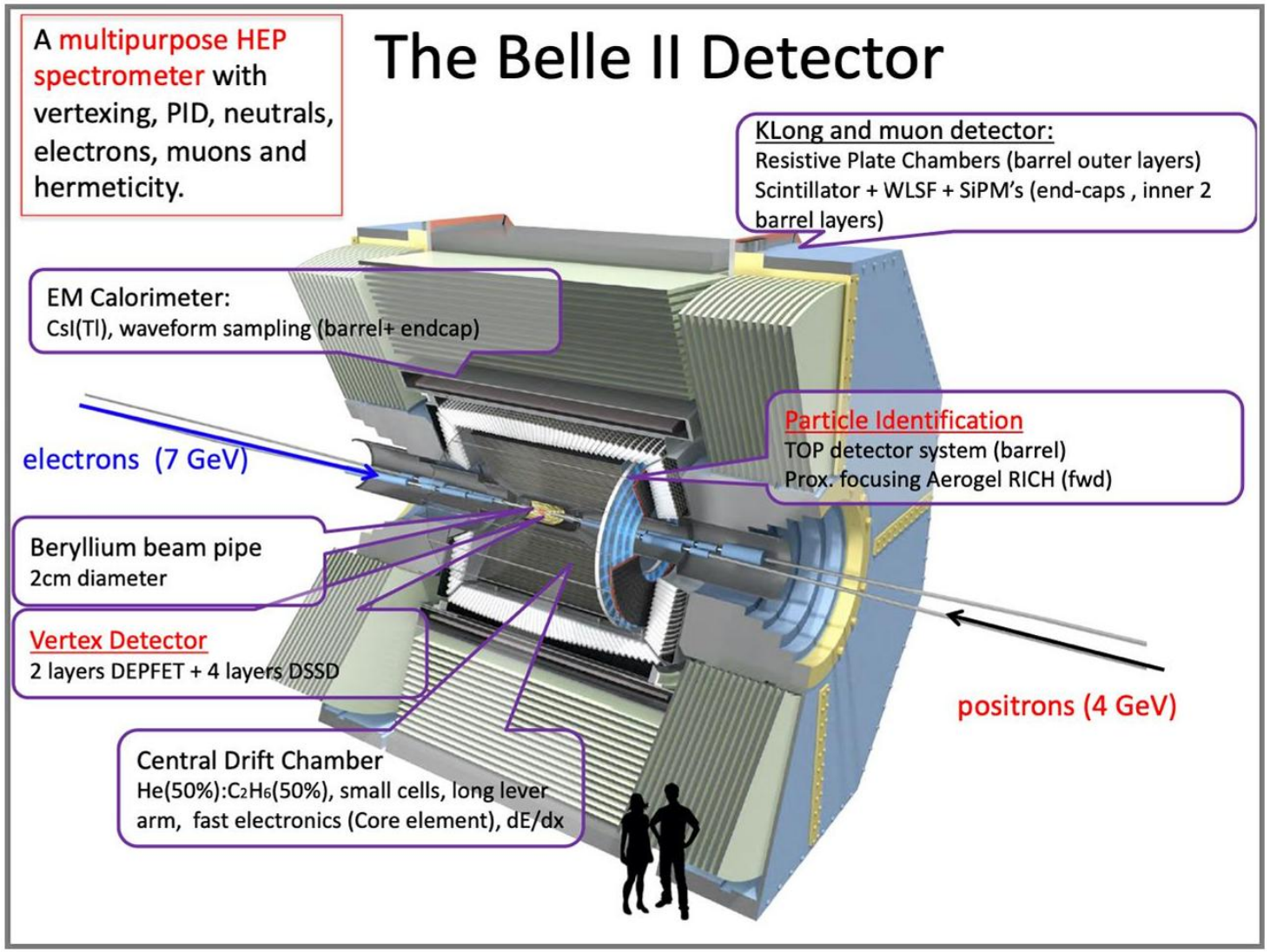
Scattered Electron Angular Distribution in Two-Photon Processes
(Equivalent Photon Approximation, Budnev 1975)





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

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



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)

MC Generation

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

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

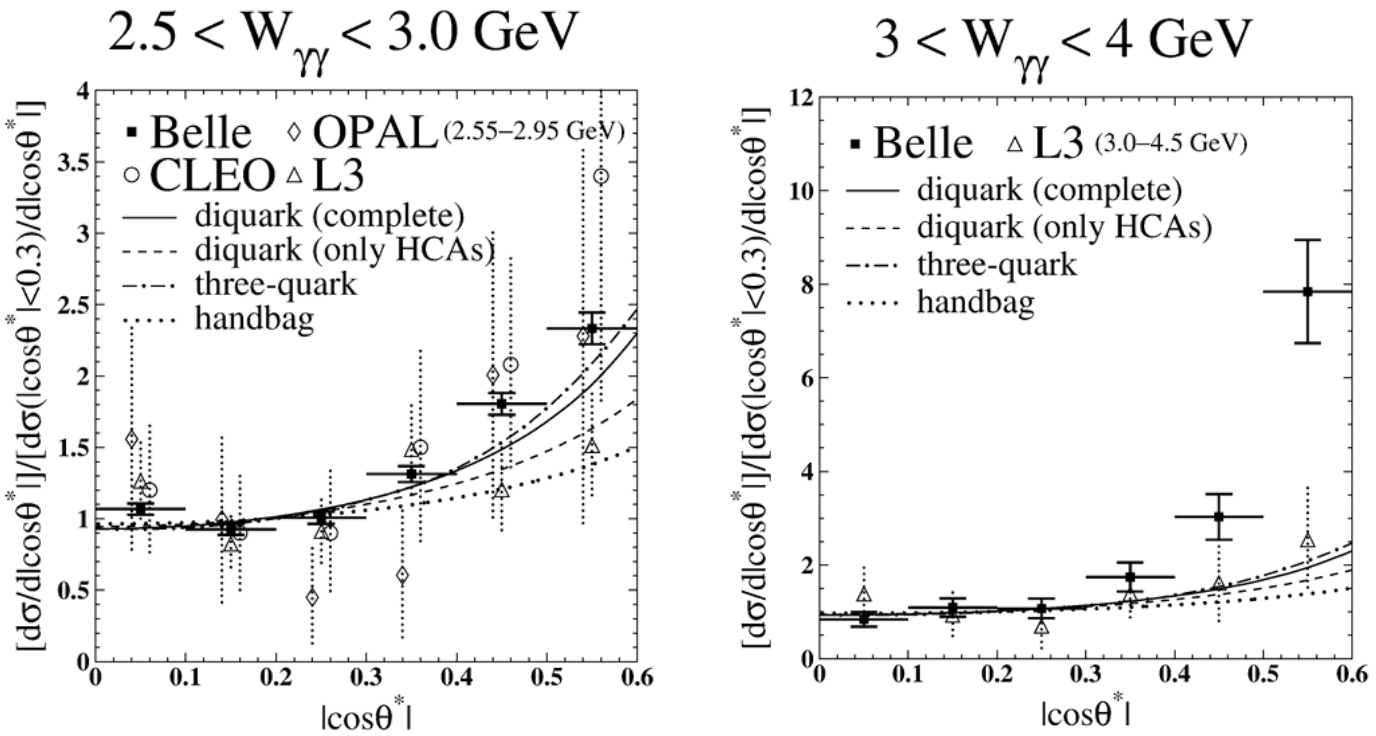


Fig. Differential cross section as a function of $|cos\theta^*|$.

MC Generation

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

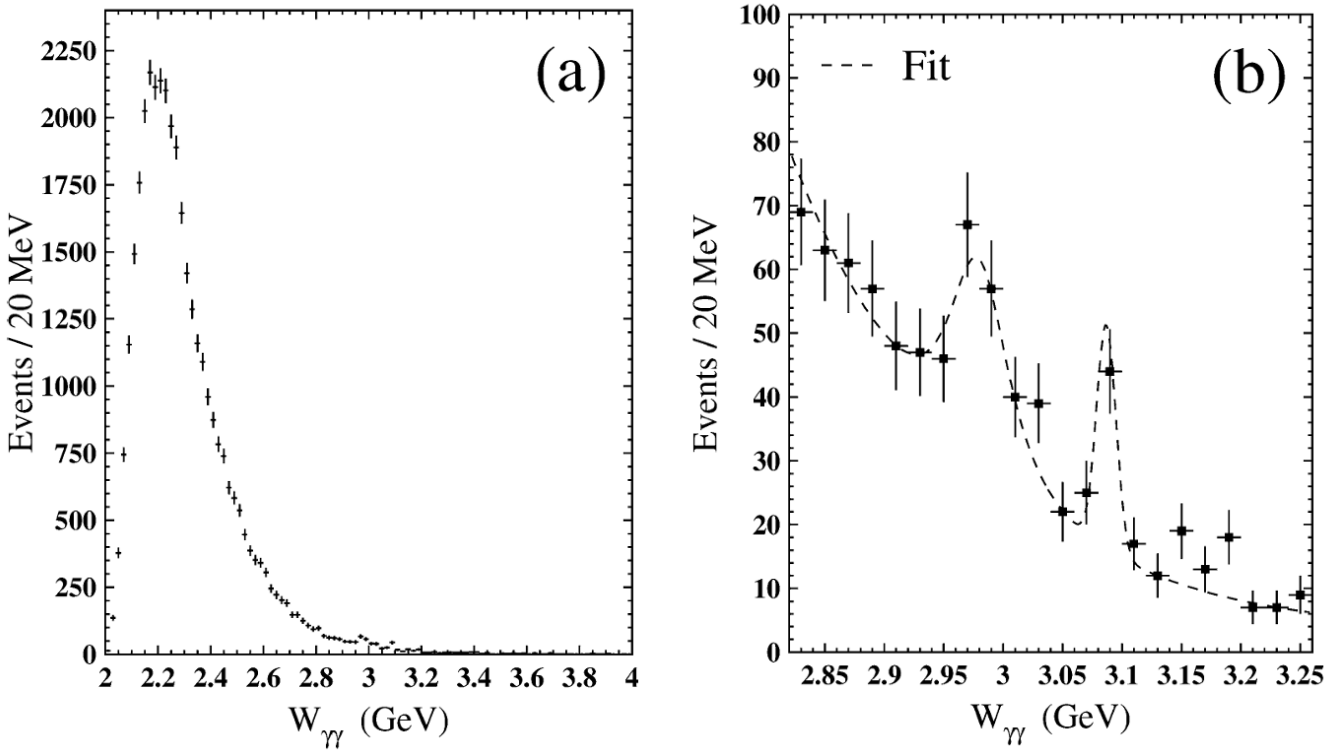


Fig. $W_{\gamma\gamma}$ distribution of events passing all the selection criteria.

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

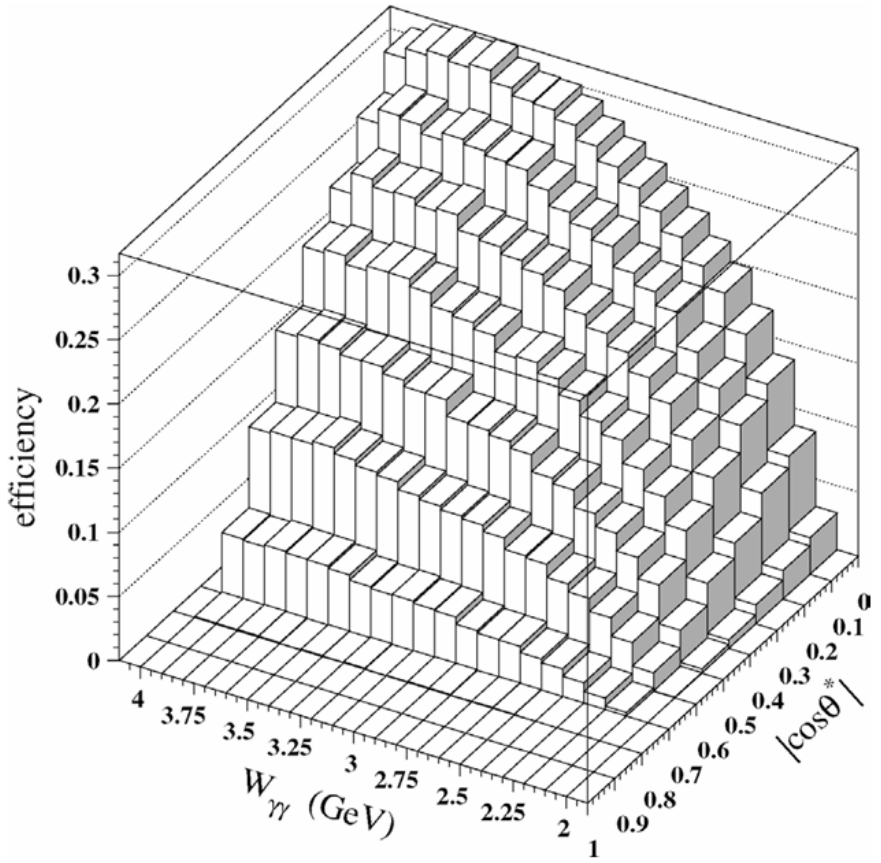


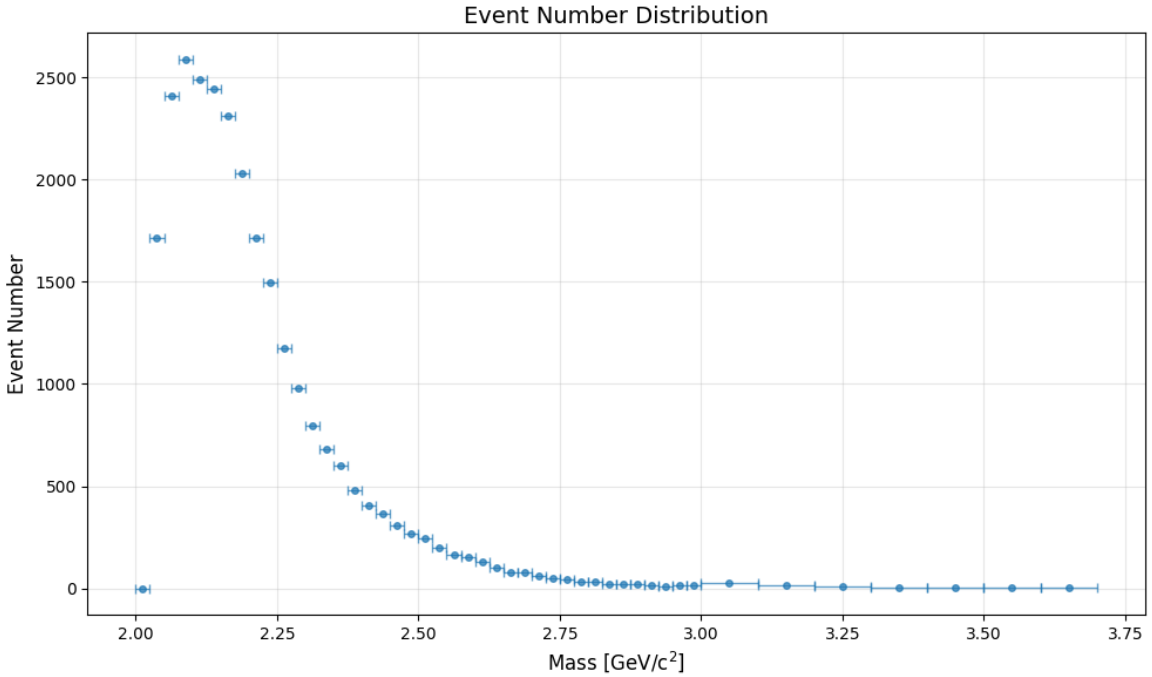
Fig. Overall detection efficiency of $\gamma\gamma \to p\bar{p}$ as a function of $W_{\gamma\gamma}$ and $|cos\theta^*|$

MC Generation

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

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

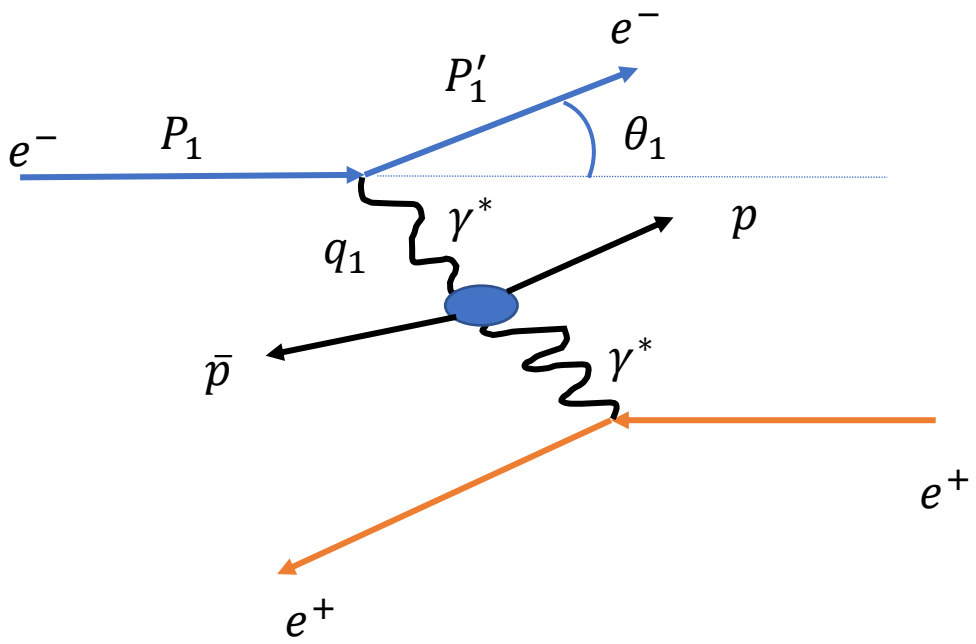
Based on the assumption that $\gamma\gamma \to p\bar{p}$ follows a phase space distribution.



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



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

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

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: 1.5M $\gamma\gamma \to p\bar{p}$

➢ 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;

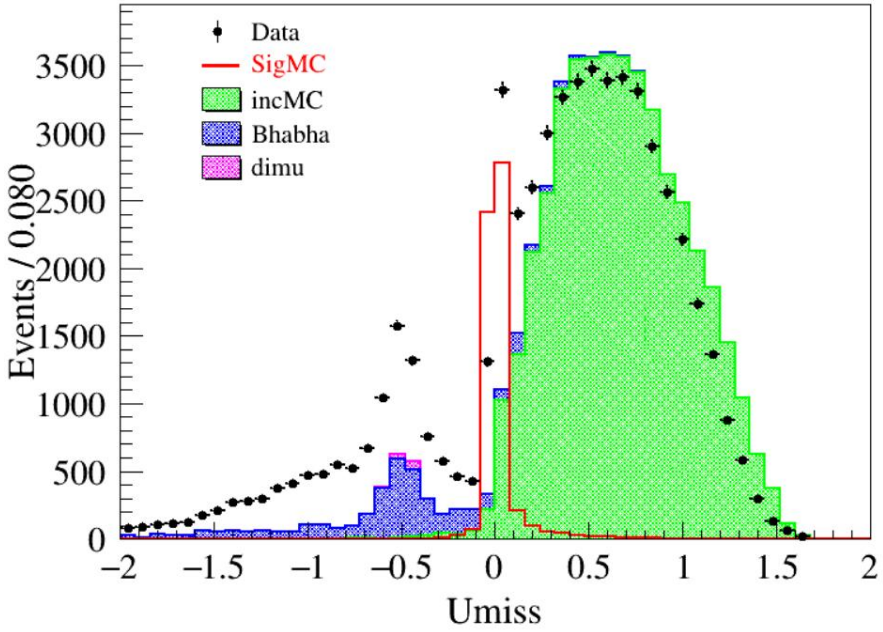
- Other:

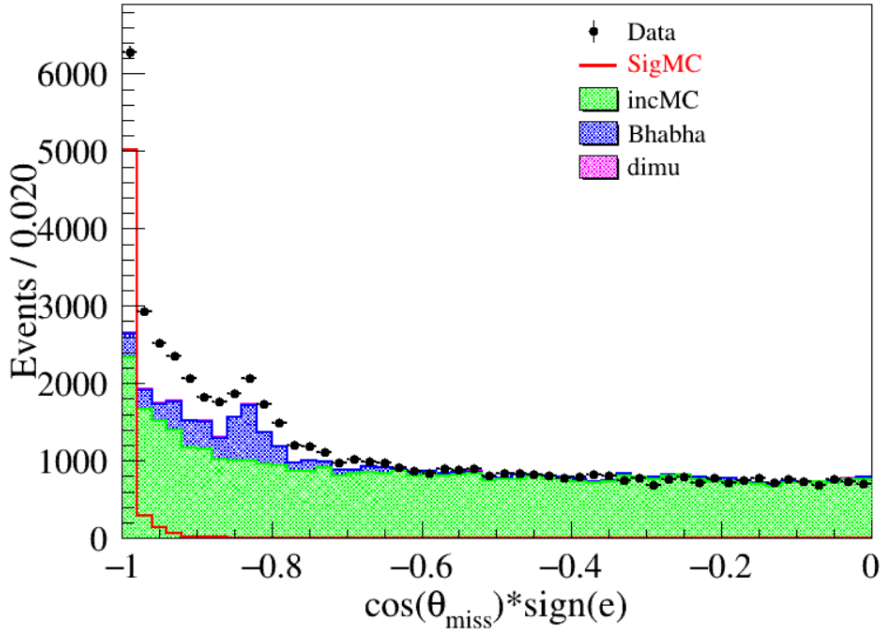
Cosθ_{miss} ×sign(e)<0;

Further Event selection

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

Miss 系统的质量和角度:

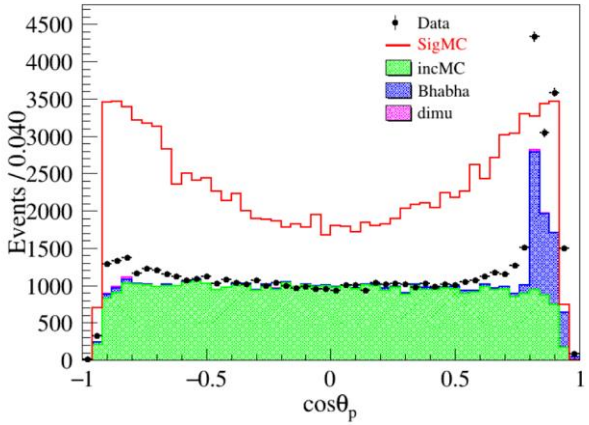


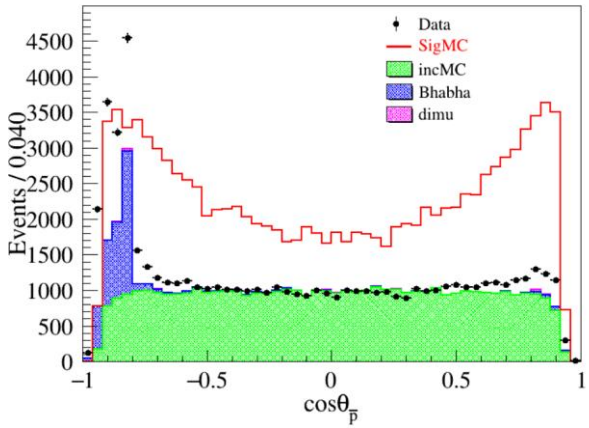


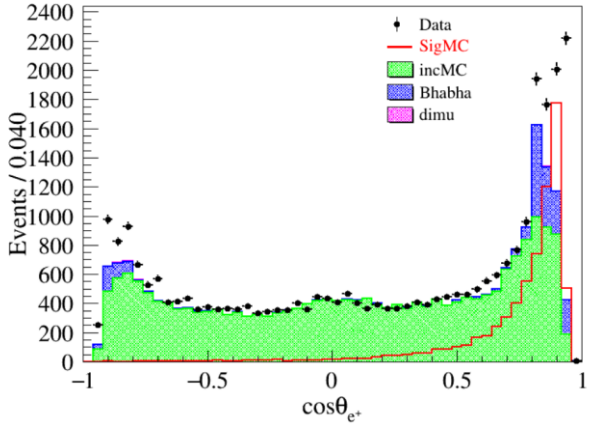
IncMC 主要成分: $p\bar{p} + n * \pi$

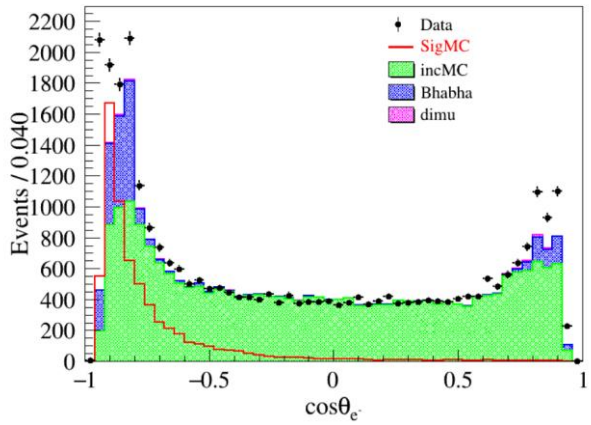
Further Event selection

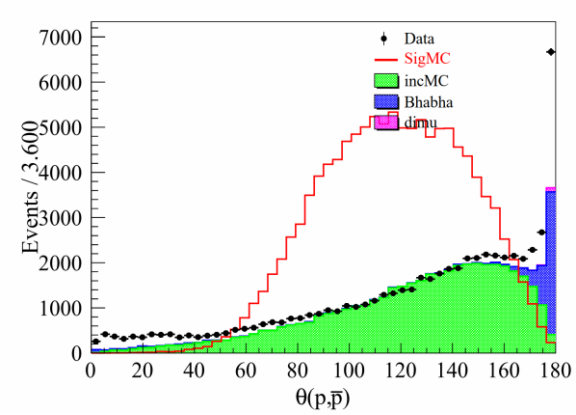
$cos\theta_{miss} * sign(e) < 0;$

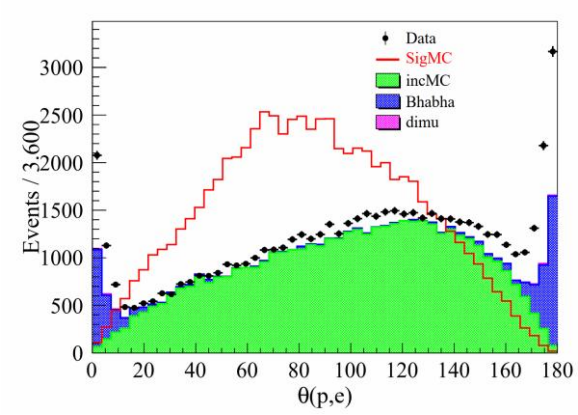


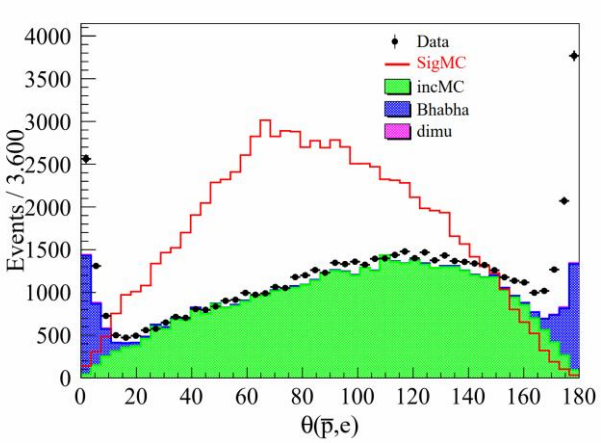










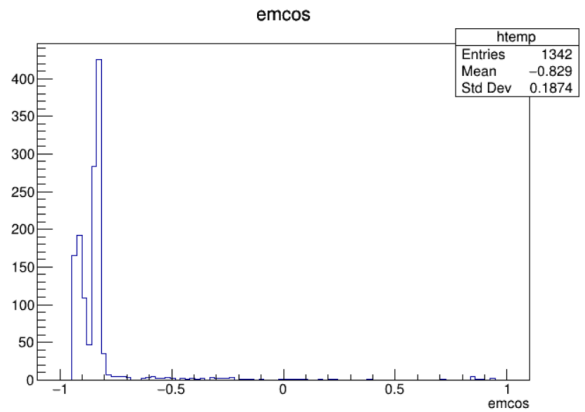


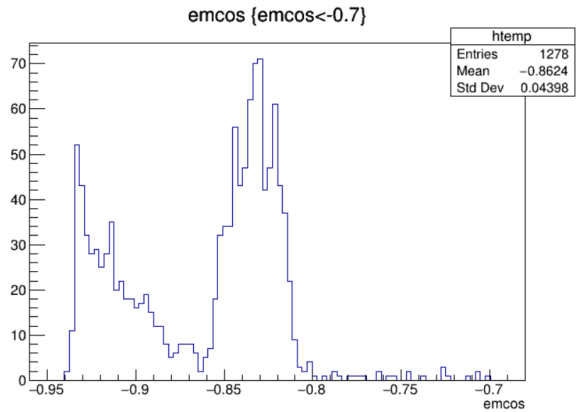
Further Event selection

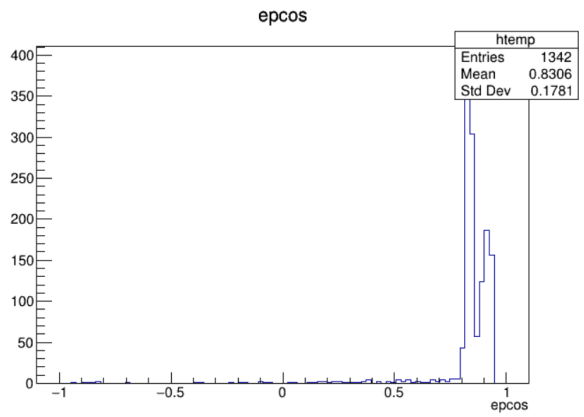
$cos\theta_{miss} * sign(e) < 0;$

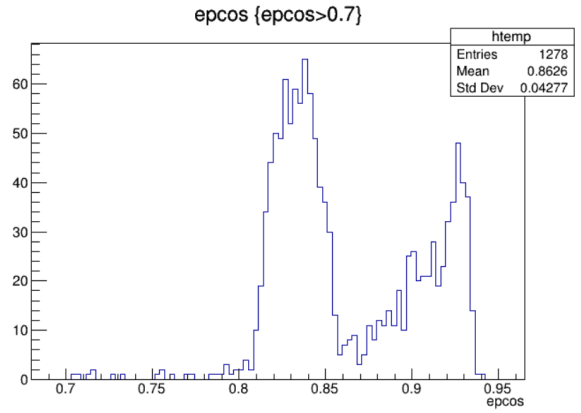
为什么Bhabha MC描述不了数据：只产生了接收度范围的事例

事例挑选后Bhabha事例的Mctruth：

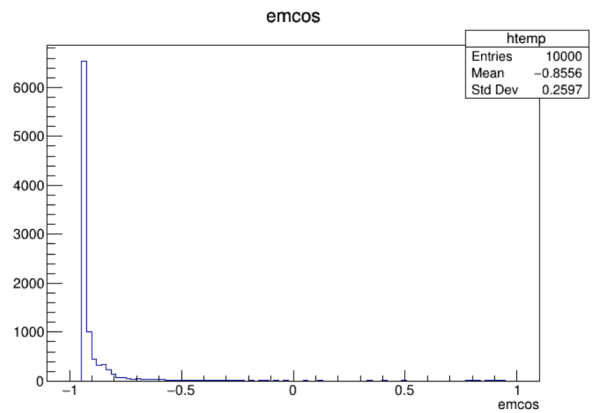


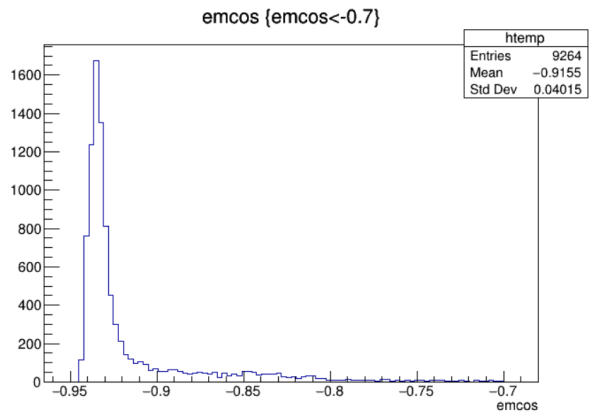


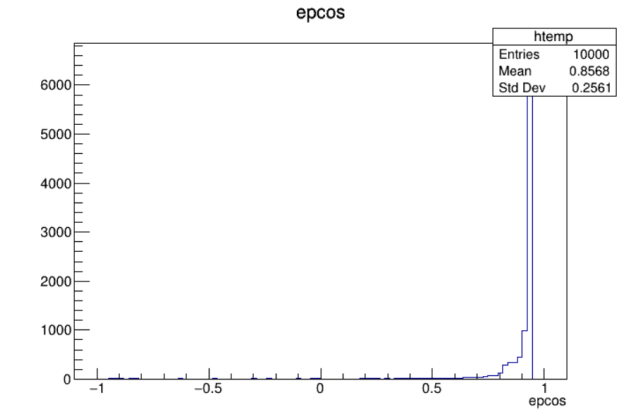


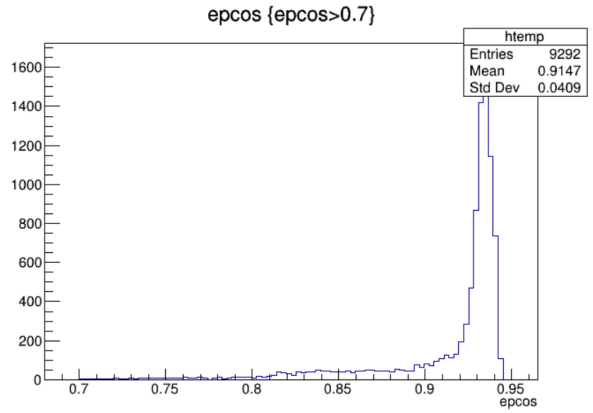


全部Bhabha事例的Mctruth：





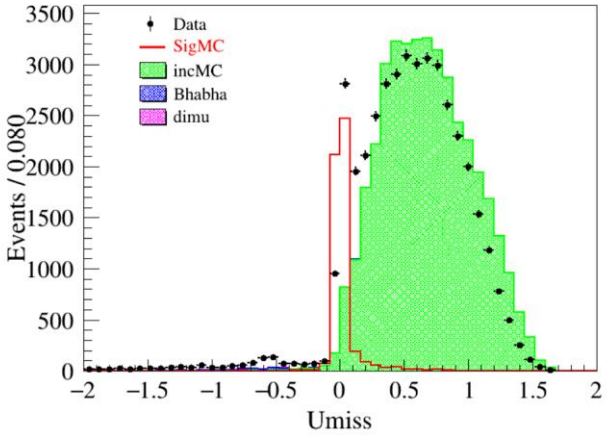


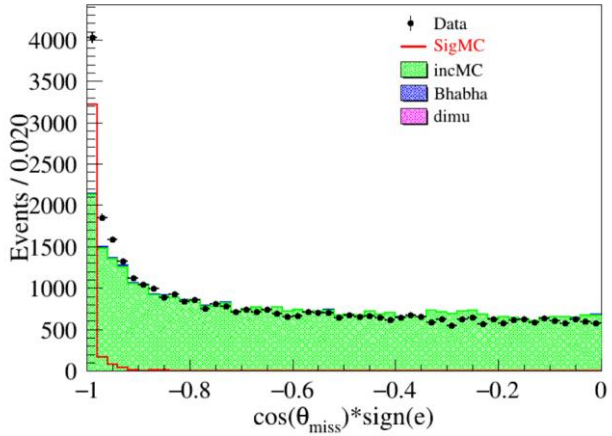


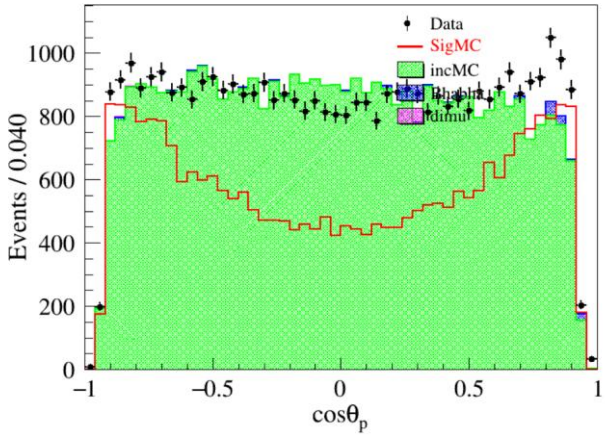
Further Event selection

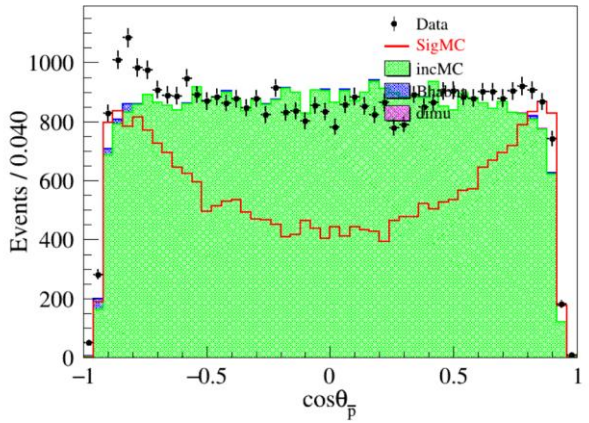
$cos\theta_{miss} * sign(e) < 0;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$

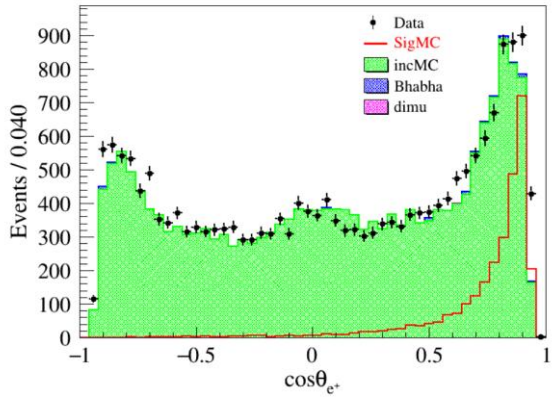
要求 $20 < \theta(p, \bar{p}) < 170$, $10 < \theta(p/\bar{p}, e) < 170$

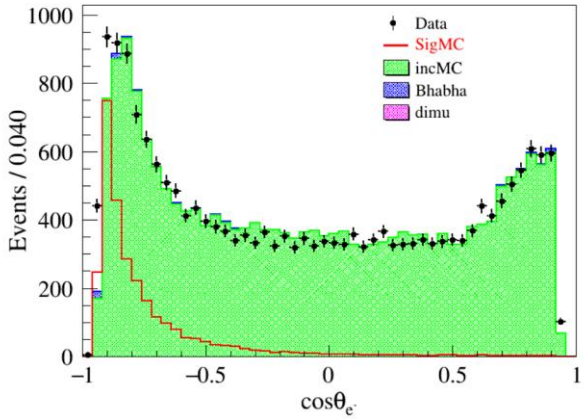








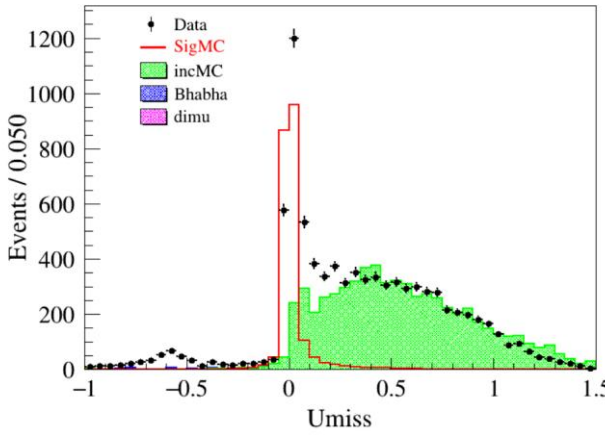


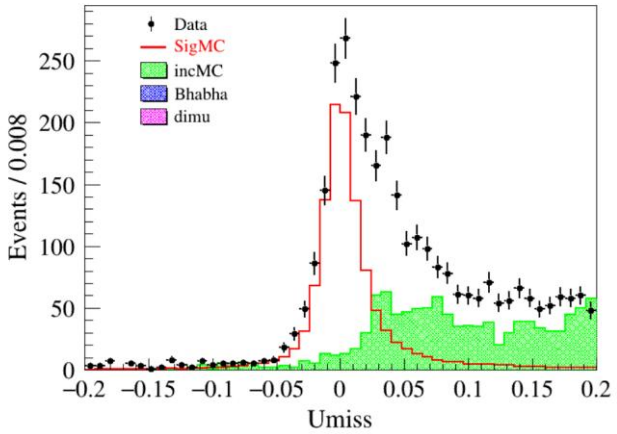


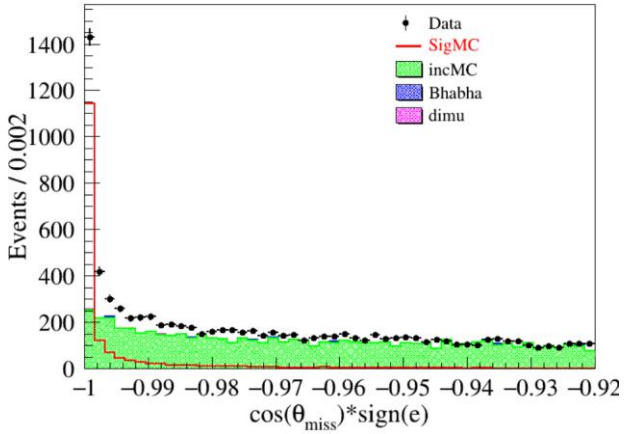
Further Event selection

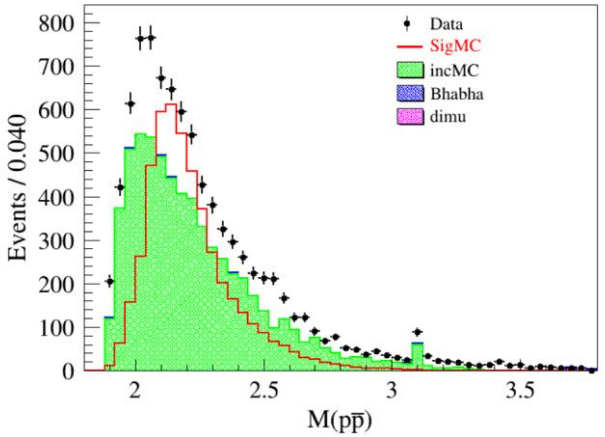
$cos\theta_{miss} * sign(e) < -0.92;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$

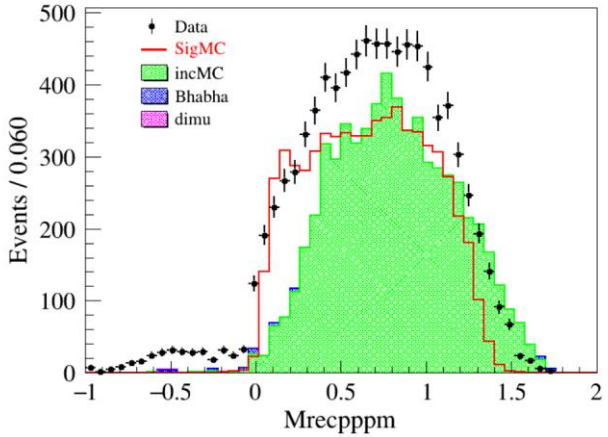
要求 $cos\theta_{miss} * sign(e) < -0.92$





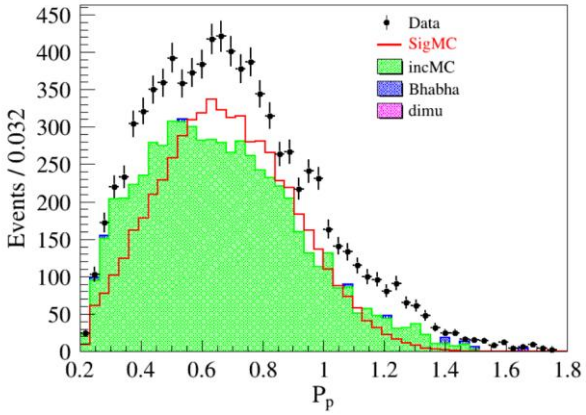


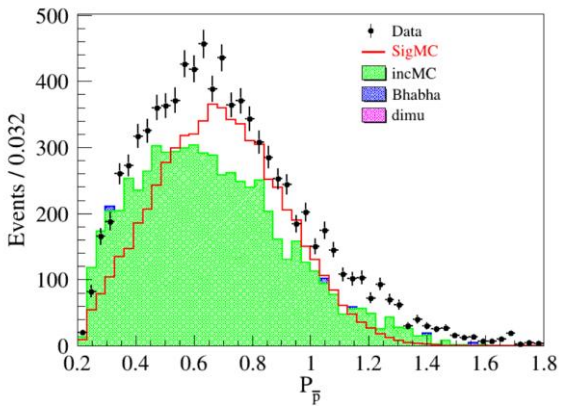


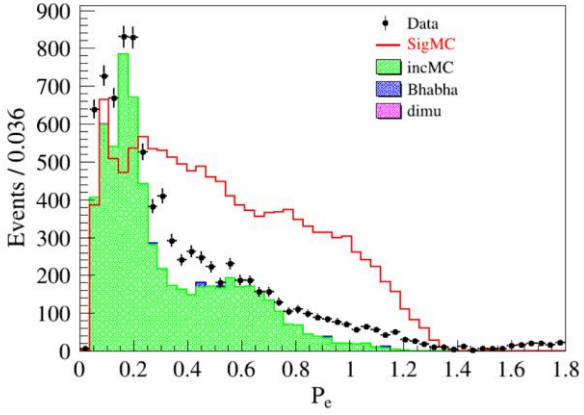


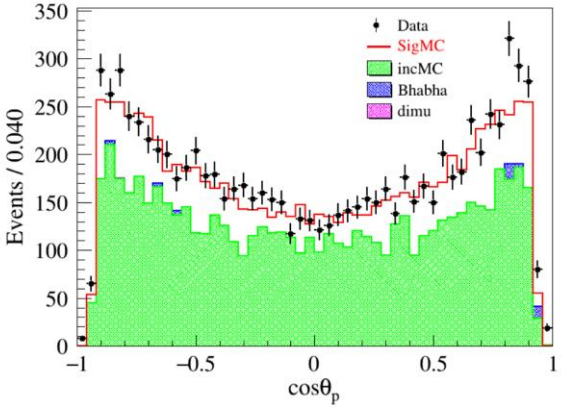
Further Event selection

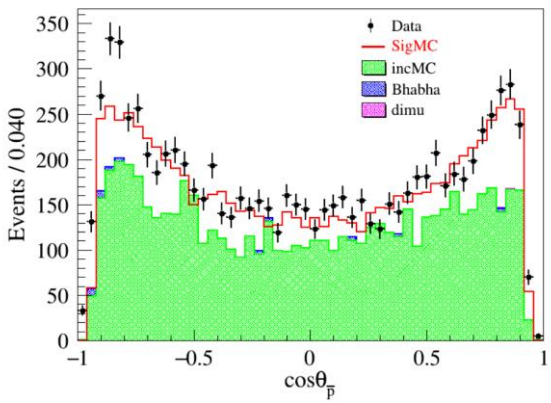
$cos\theta_{miss} * sign(e) < -0.92;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$

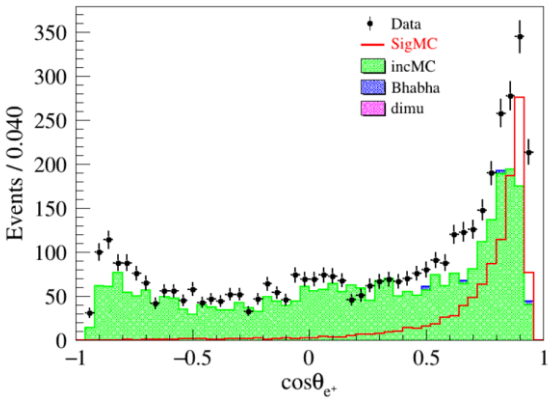


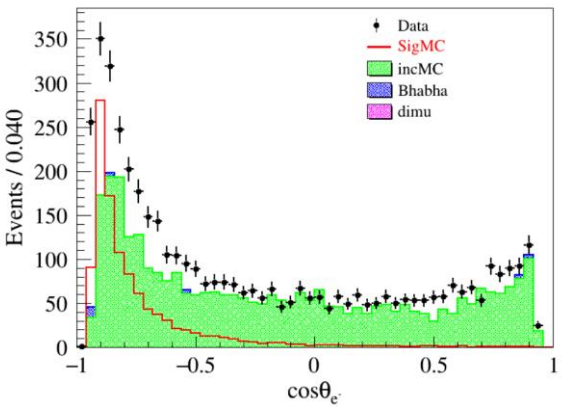












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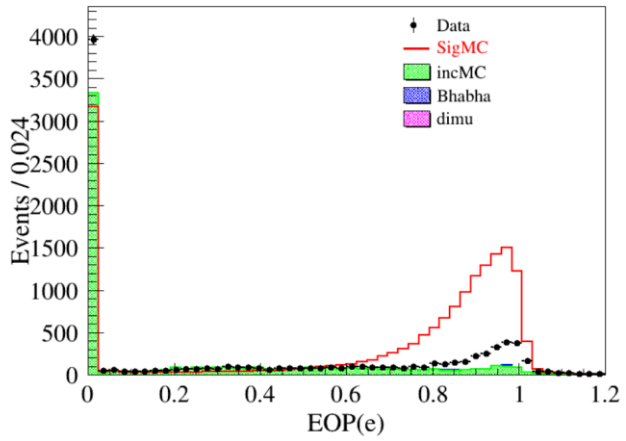

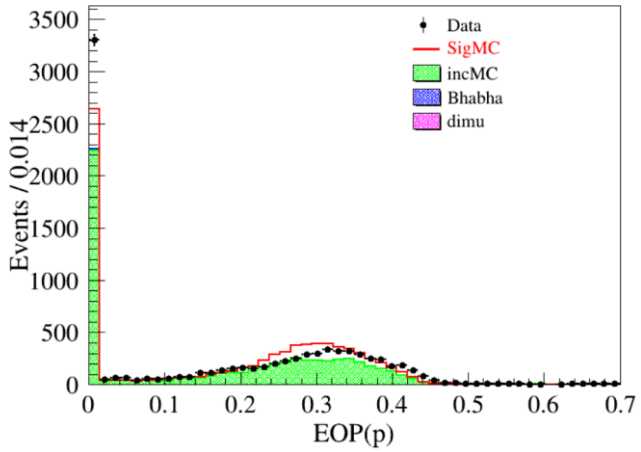

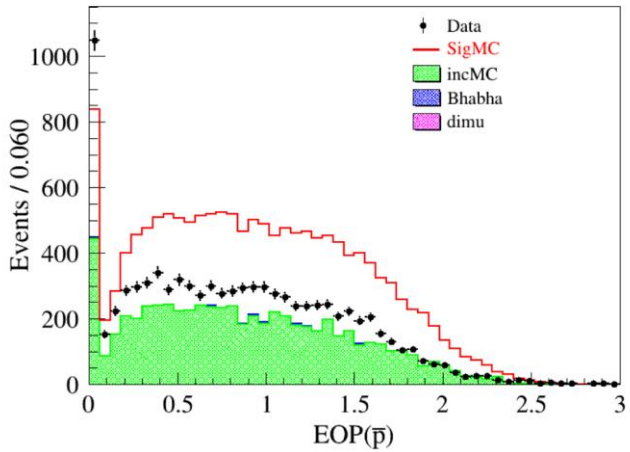

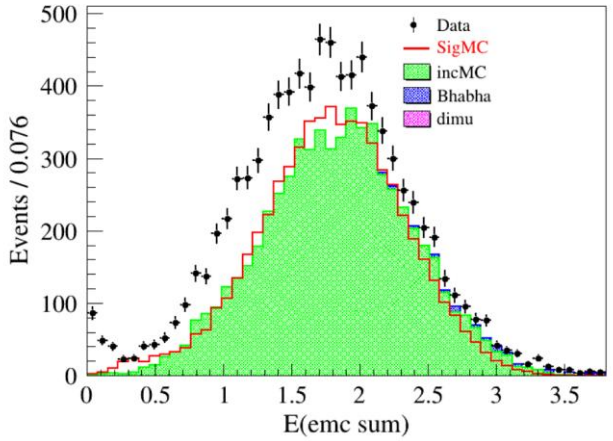

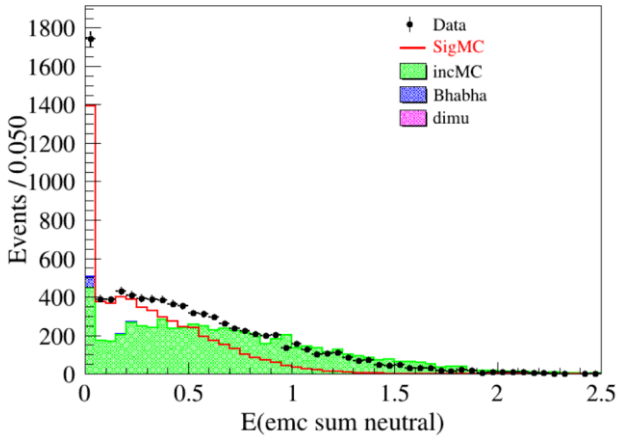

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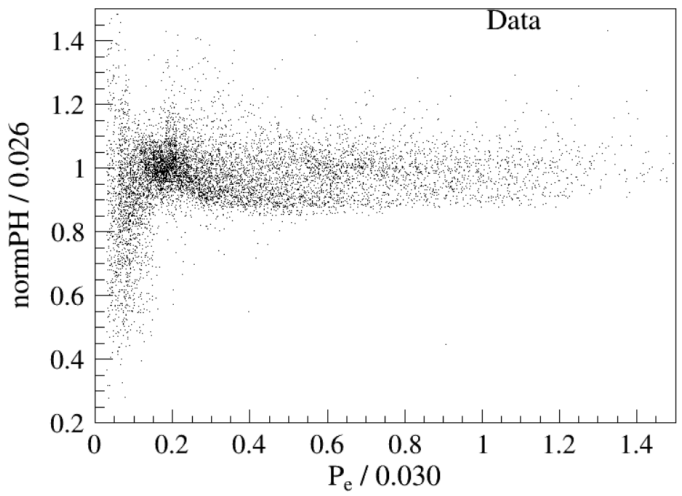
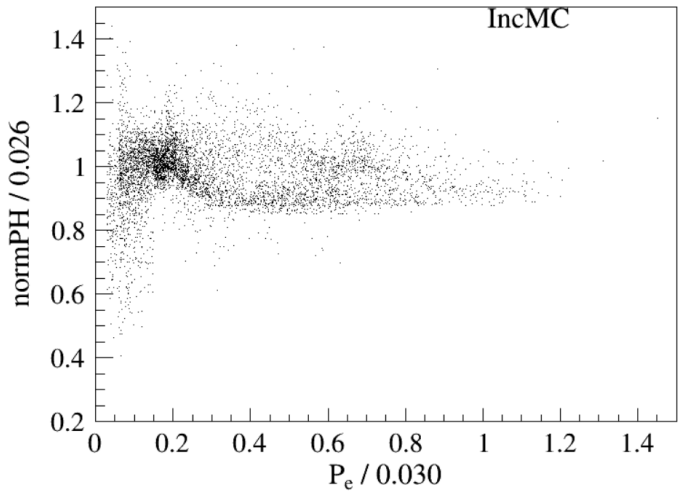
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$

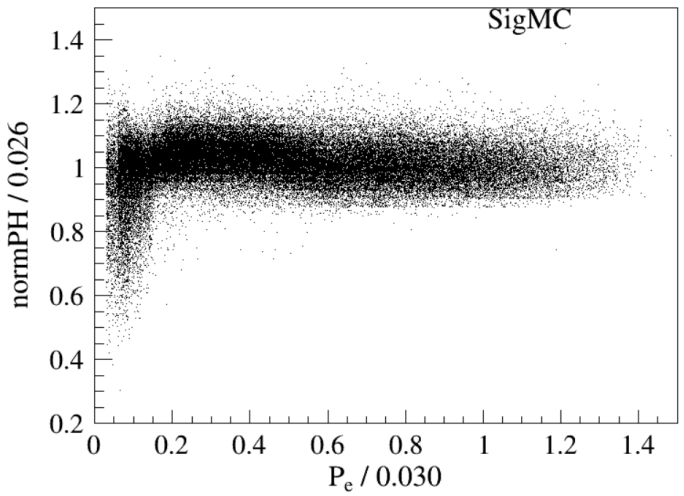
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$x \to K^- p\bar{\Lambda}\gamma^f, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+K^-p\bar{p}\gamma^f$	5	259	259
2	$x \to K^+\bar{p}\Lambda\gamma^f, \Lambda \to \pi^- p$	$\pi^-K^+p\bar{p}\gamma^f$	1	213	472
3	$x \to K^+K^-p\bar{p}\gamma^f$	$K^+K^-p\bar{p}\gamma^f$	3	194	666
4	$x \to \pi^+\pi^-p\bar{p}\gamma^F$	$\pi^+\pi^-p\bar{p}\gamma^F$	81	119	785
5	$x \to J/\psi\gamma, J/\psi \to \pi^+\pi^-p\bar{p}$	$\pi^+\pi^-p\bar{p}\gamma$	61	112	897
6	$x \to K^+K^-p\bar{p}$	$K^+K^-p\bar{p}$	67	87	984
7	$x \to J/\psi\gamma, J/\psi \to \pi^+p\bar{\Delta}^{--}, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^-p\bar{p}\gamma$	73	78	1062
8	$x \to p\bar{p}a_0^0\gamma^f, a_0^0 \to \pi^0\eta, \eta \to \pi^0\pi^0\pi^0$	$\pi^0\pi^0\pi^0\pi^0p\bar{p}\gamma^f$	22	76	1138
9	$x \to K^- p\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+K^-p\bar{p}$	99	68	1206
10	$x \to p\bar{p}a_0^0\gamma^f, a_0^0 \to \pi^0\eta, \eta \to \gamma\gamma$	$\pi^0p\bar{p}\gamma\gamma\gamma^f$	13	57	1263
11	$x \to K^+\bar{p}\Lambda, \Lambda \to \pi^- p$	$\pi^-K^+p\bar{p}$	23	53	1316
12	$x \to \Delta^{++}\bar{\Delta}^{--}\gamma^f, \Delta^{++} \to \pi^+p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^-p\bar{p}\gamma^f$	59	51	1367
13	$x \to \pi^+p\bar{\Delta}^{--}\gamma^f, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^-p\bar{p}\gamma^f$	41	50	1417
14	$x \to J/\psi\gamma, J/\psi \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^0\pi^+\pi^-p\bar{p}\gamma$	71	47	1464
15	$x \to f_2(1270)p\bar{p}\gamma^f, f_2(1270) \to \pi^+\pi^-$	$\pi^+\pi^-p\bar{p}\gamma^f$	42	45	1509
16	$x \to \pi^+\pi^-p\bar{p}\gamma^f$	$\pi^+\pi^-p\bar{p}\gamma^f$	35	44	1553
17	$x \to p\bar{p}a_0^0, a_0^0 \to \pi^0\eta, \eta \to \pi^0\pi^0\pi^0$	$\pi^0\pi^0\pi^0\pi^0p\bar{p}$	40	43	1596
18	$x \to p\bar{p}a_1^0\gamma^f, a_1^0 \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+$	$\pi^0\pi^+\pi^-p\bar{p}\gamma^f$	90	41	1637
19	$x \to \Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^+\pi^-p\bar{p}$	198	41	1678
20	$x \to J/\psi\gamma, J/\psi \to \pi^0\Delta^+\bar{\Delta}^-, \Delta^+ \to \pi^0p, \bar{\Delta}^- \to \pi^0\bar{p}$	$\pi^0\pi^0\pi^0p\bar{p}\gamma$	14	40	1718
.....					
1727	$x \to \psi'\gamma, \psi' \to \pi^0\pi^0J/\psi, J/\psi \to \Xi^-\bar{\Xi}^{*+}, \Xi^- \to \pi^-\Lambda, \bar{\Xi}^{*+} \to \pi^+\bar{\Xi}^0,$ $\Lambda \to \pi^- p, \bar{\Xi}^0 \to \pi^0\bar{\Lambda}, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^0\pi^0\pi^+\pi^+\pi^-\pi^-p\bar{p}\gamma$	1726	1	6225

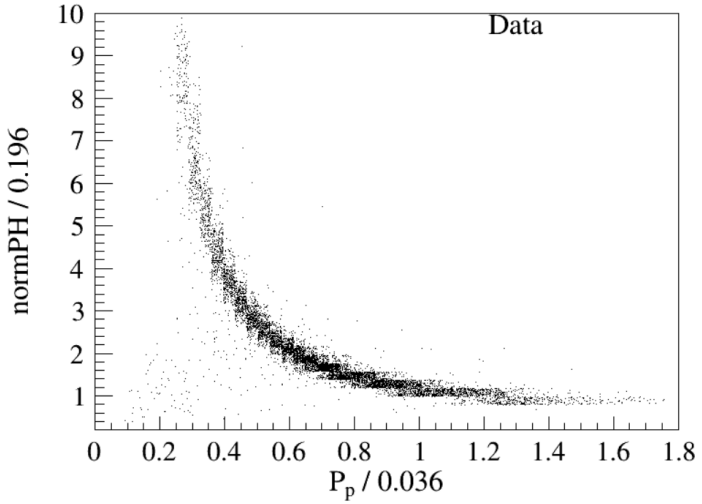
Further Event selection

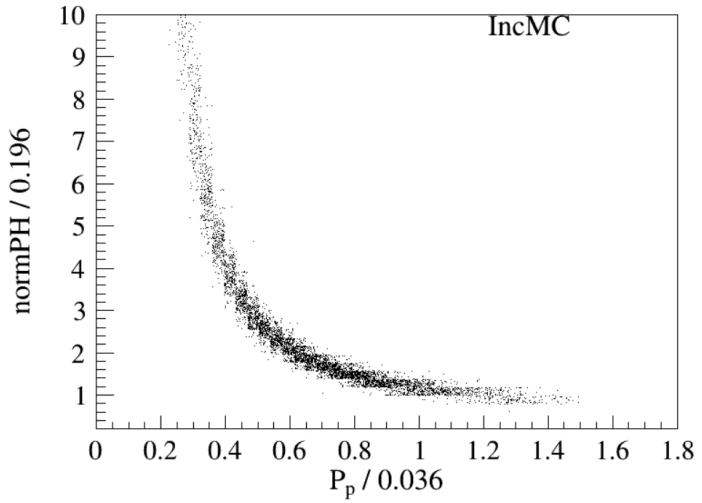
$$cos\theta_{miss} * sign(e) < -0.92;$$
$$20 < \theta(p, \bar{p}) < 170;$$
$$10 < \theta(p/\bar{p}, e) < 170;$$

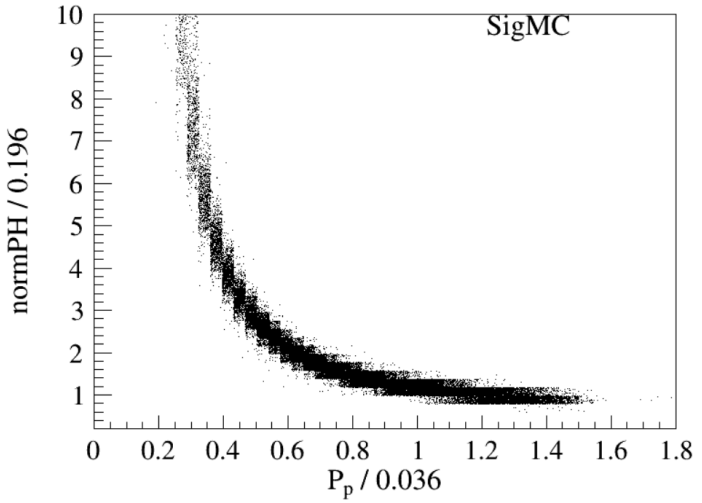












Further Event selection

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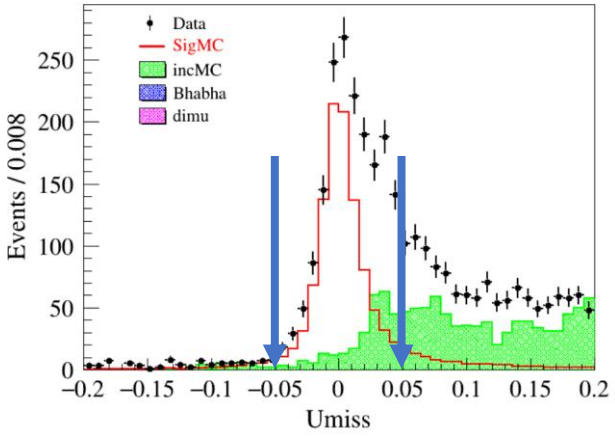
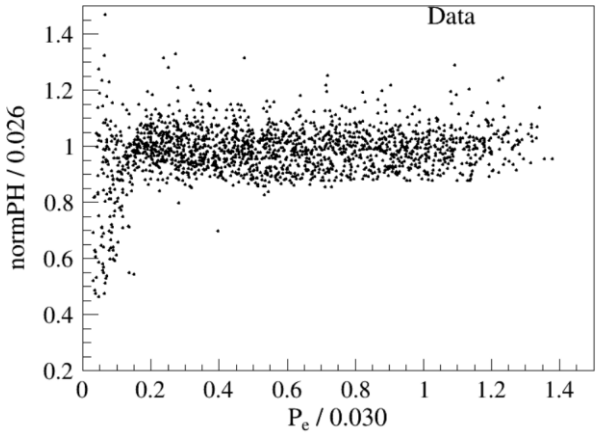
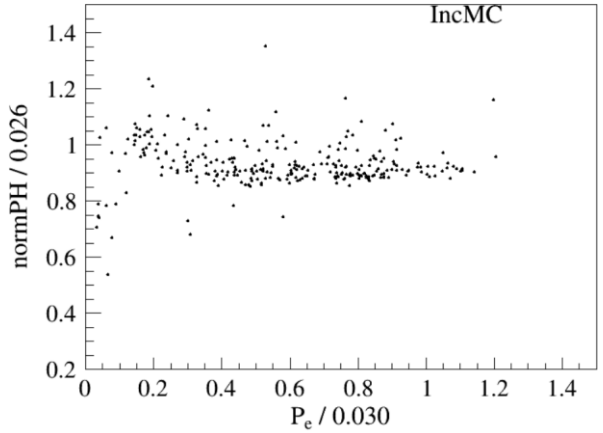
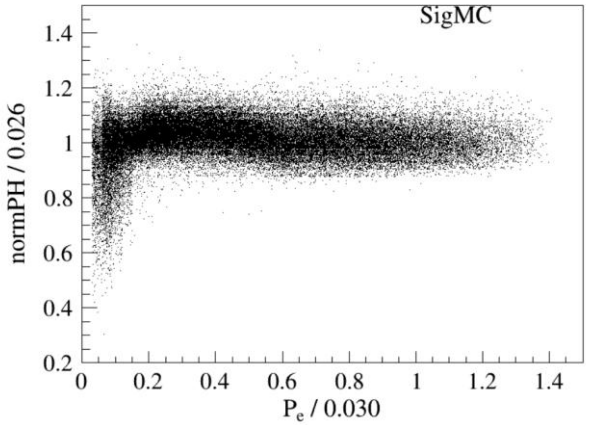


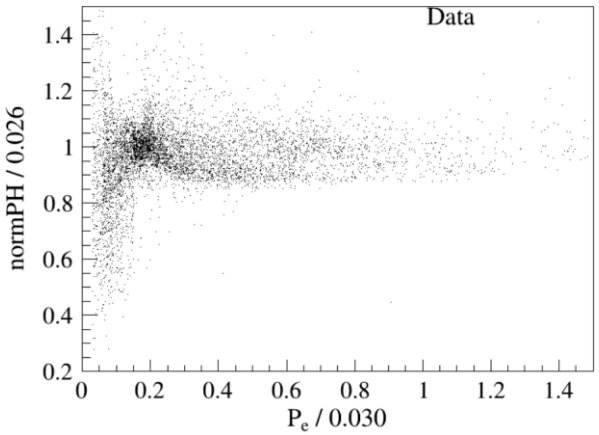
$-0.05 < Umiss < 0.05$

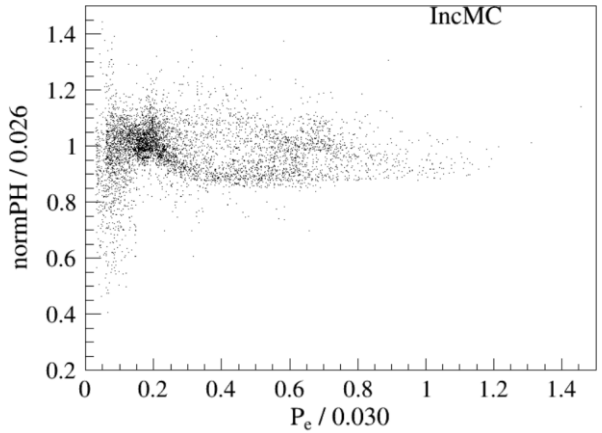


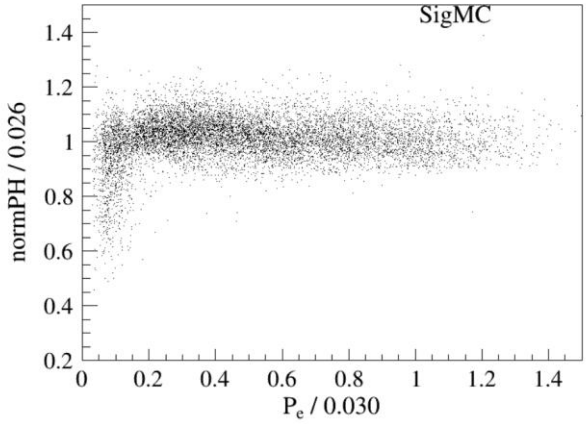




other



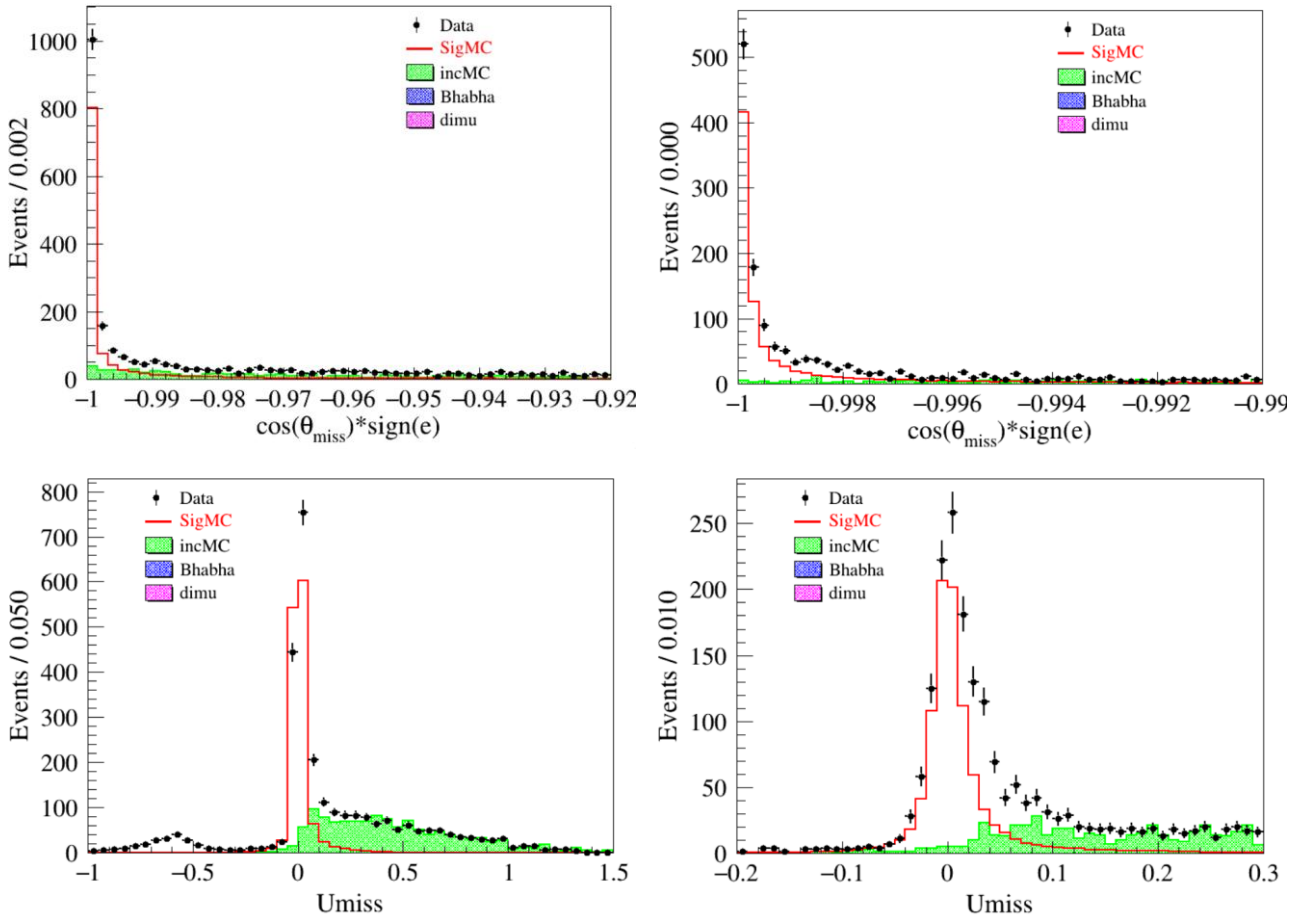




Further Event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$-0.1 < Umiss < 0.1$

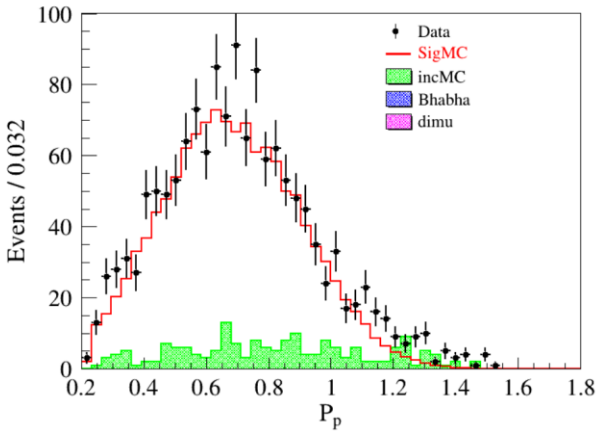
要求 $cos\theta_{miss} * sign(e) < -0.99$, $-0.1 < Umiss < 0.1$

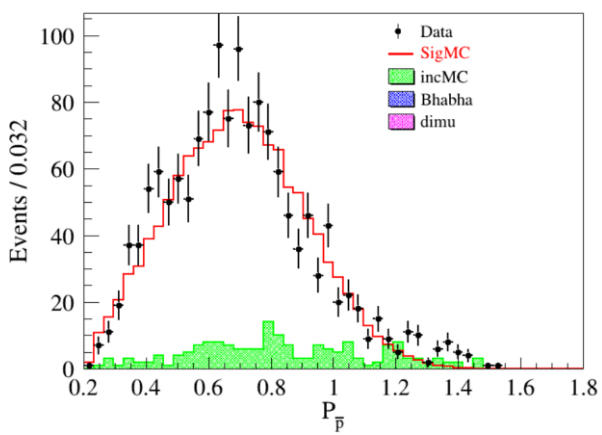


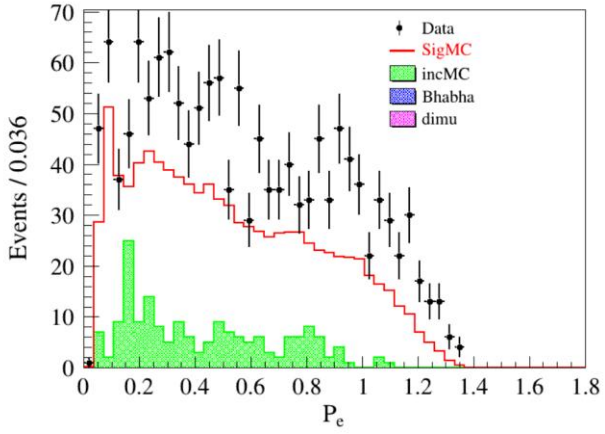
剩余的事例数：1434
MC估计本底率：13%

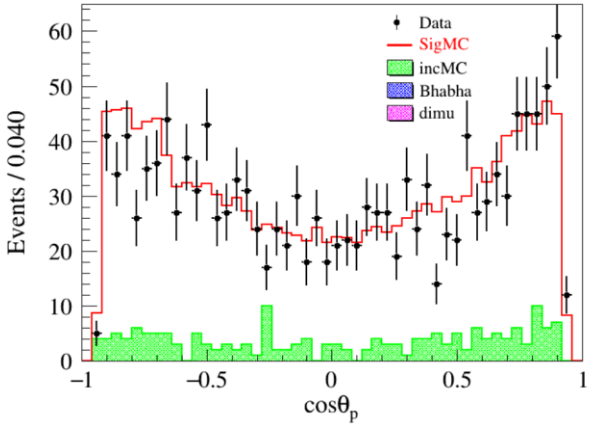
Further Event selection

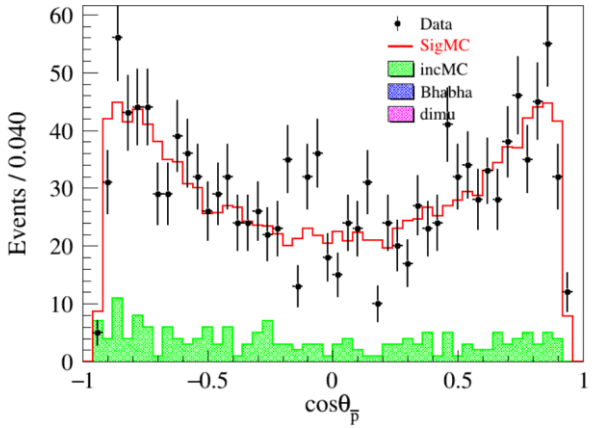
$$cos\theta_{miss} * sign(e) < -0.99;$$
$$20 < \theta(p, \bar{p}) < 170;$$
$$10 < \theta(p/\bar{p}, e) < 170;$$
$$-0.1 < Umiss < 0.1$$

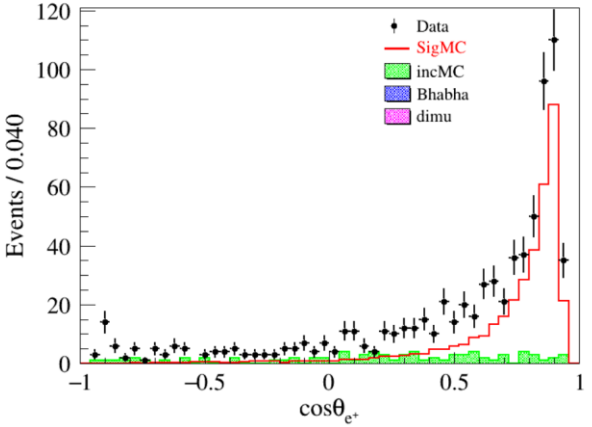


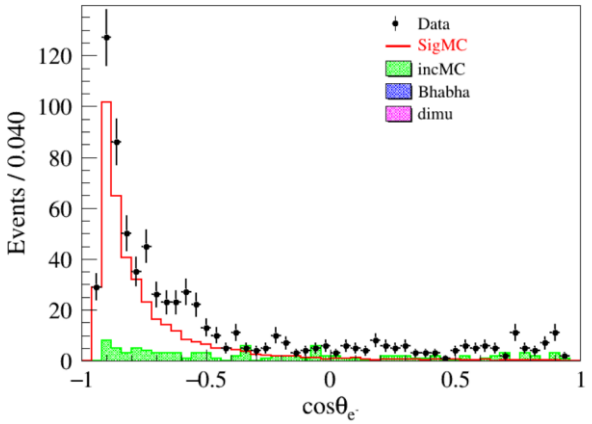












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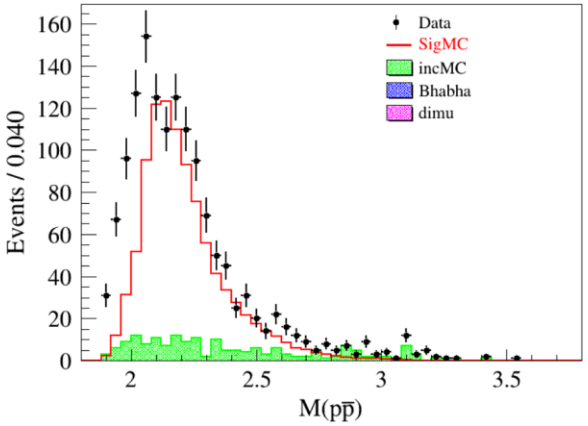

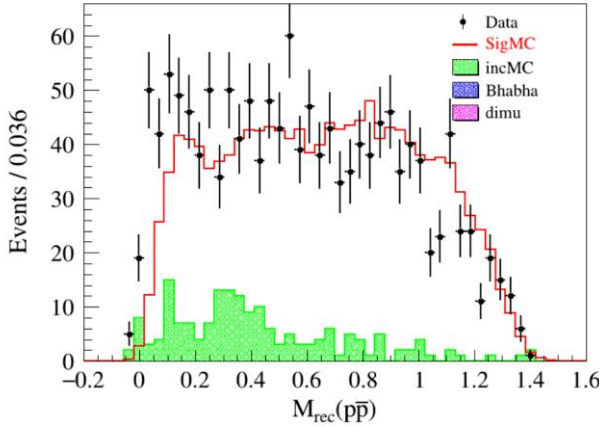

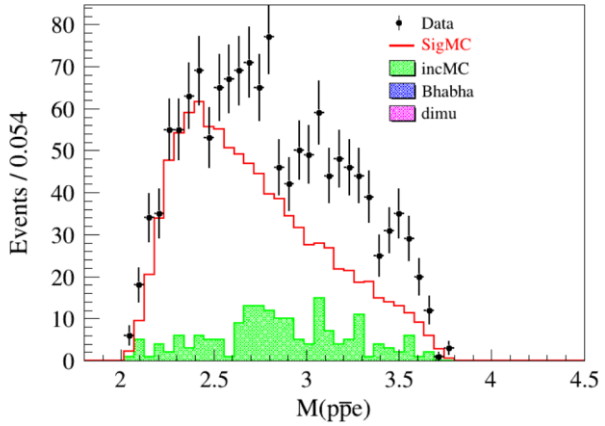

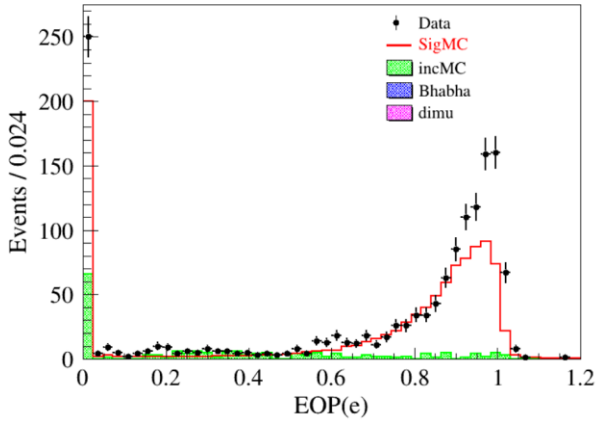

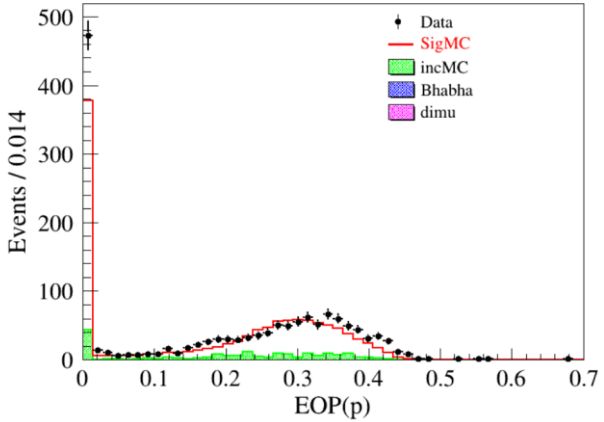

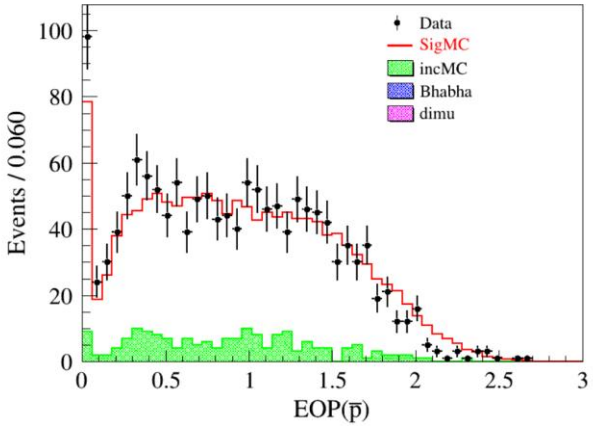

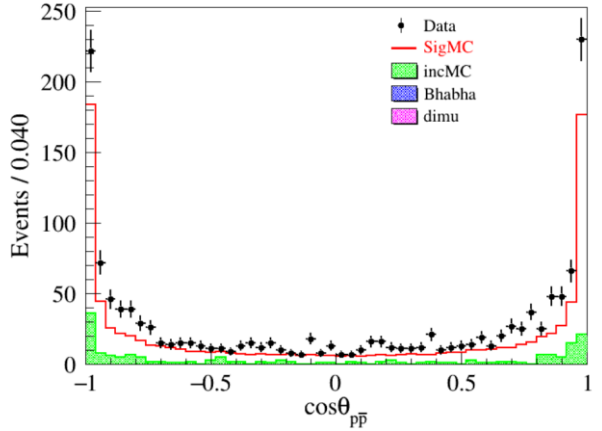

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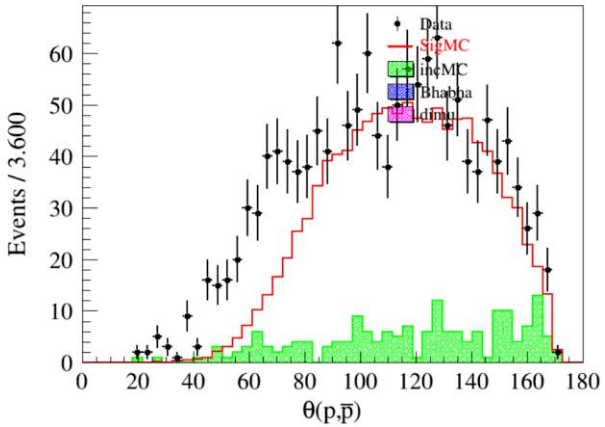
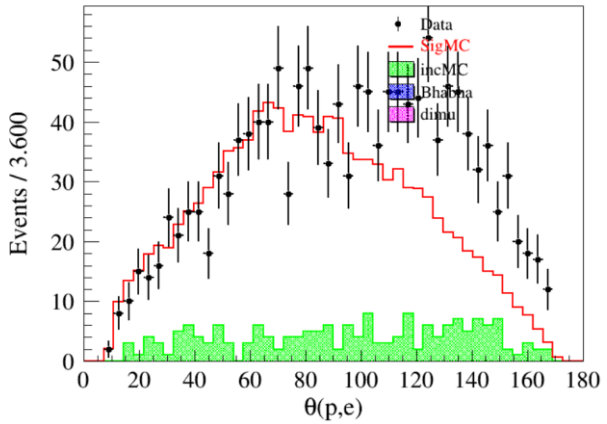
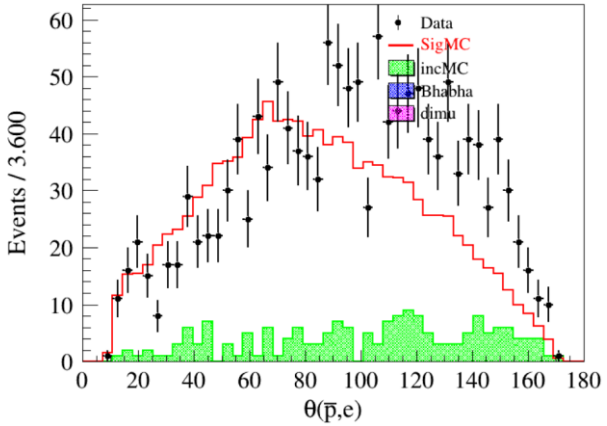
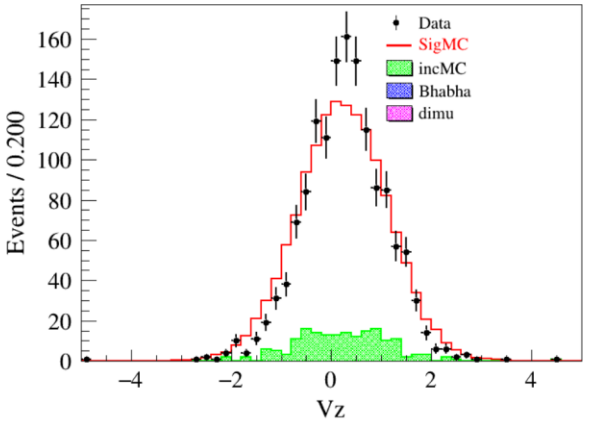
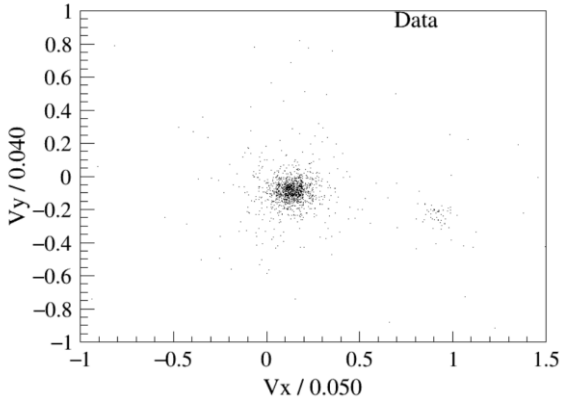
$-0.1 < Umiss < 0.1$





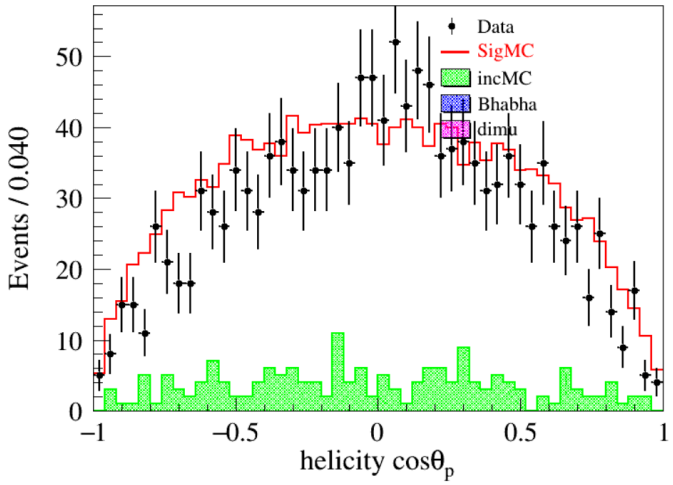


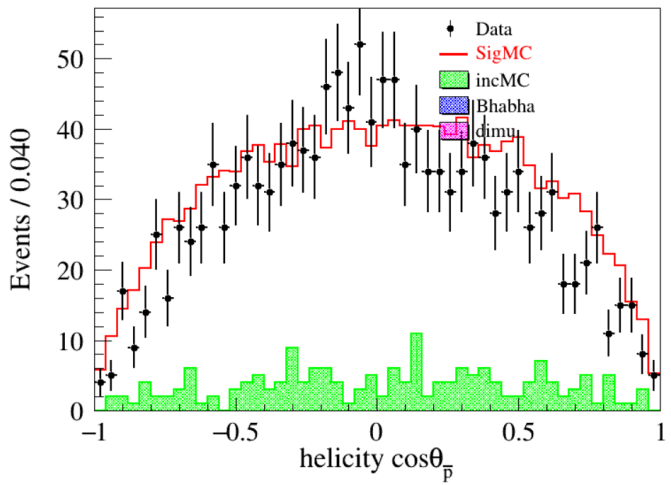


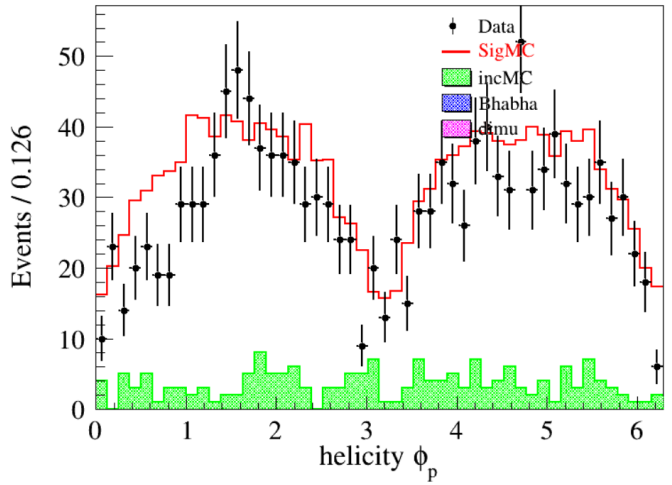


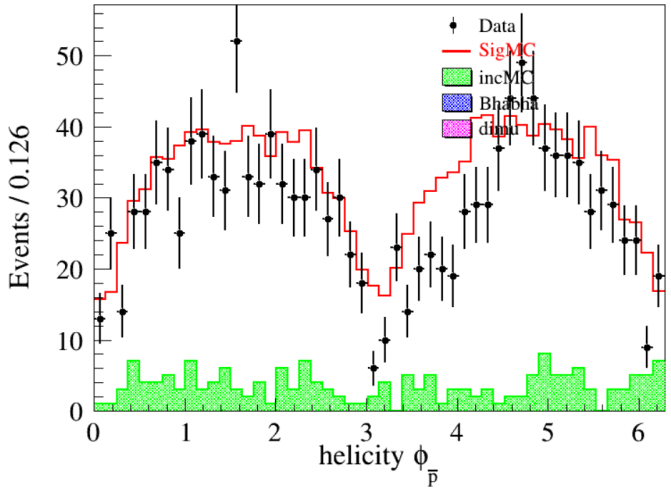
Further Event selection

$$cos\theta_{miss} * sign(e) < -0.99;$$
$$20 < \theta(p, \bar{p}) < 170;$$
$$10 < \theta(p/\bar{p}, e) < 170;$$
$$-0.1 < Umiss < 0.1$$





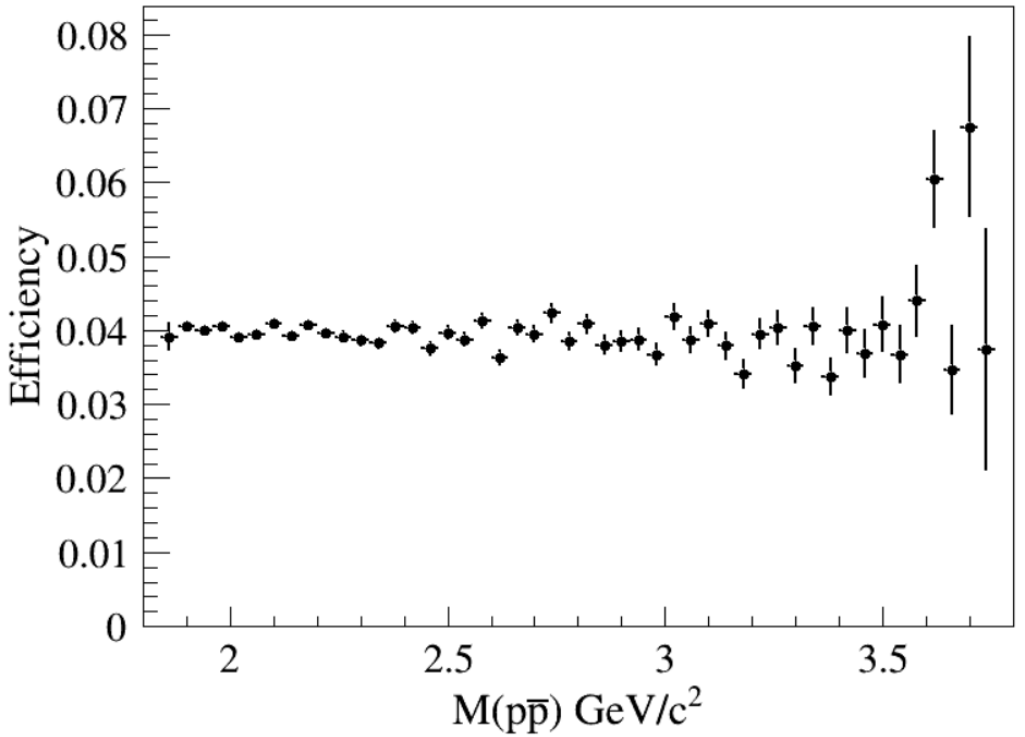




Efficiency

Cut flow 根据没有对$M_{p\bar{p}}$质量reweight的MC给出

	Event	Rel eff (%)
total	1490000	\
$\boldsymbol{N_{good} = 3}$	113512	7.6
Pass PID	88803	78.2
Pass Vtxfit	88391	99.5
$\boldsymbol{cos\theta_{miss} * sign(e) < -0.99}$	69708	78.8
$\boldsymbol{20 < \theta(p,\bar{p}) < 170}$ $\boldsymbol{10 < \theta(p/\bar{p},e) < 170}$	62036	89.0
$\boldsymbol{-0.1 < Umiss < 0.1}$	59008	95.1
eff	3.96%	



Untag

➢ 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: 1.5M $\gamma\gamma \to p\bar{p}$

➢ Event selection:

- Good charged track:

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

$$N_{good} = 2, N_{charge} = 0$$

- PID:

p: prob(p)>prob(e, μ, π, K),0.001

e: prob(e)>prob(μ, π, K, p),0.001

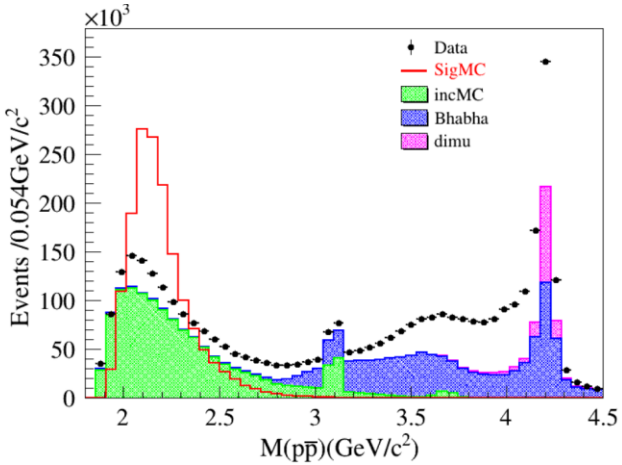
$$N_p = N_{\bar{p}} = 1$$

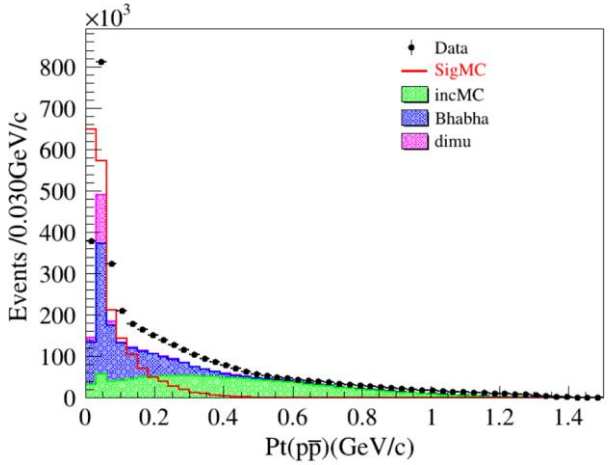
- Vertex Fit:

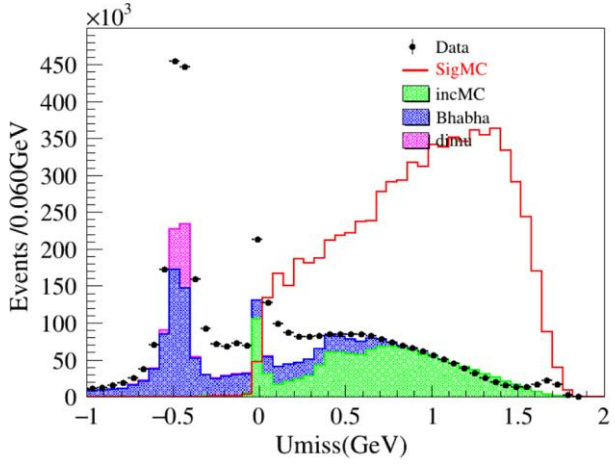
Vertex fit for $p\bar{p}$, success;

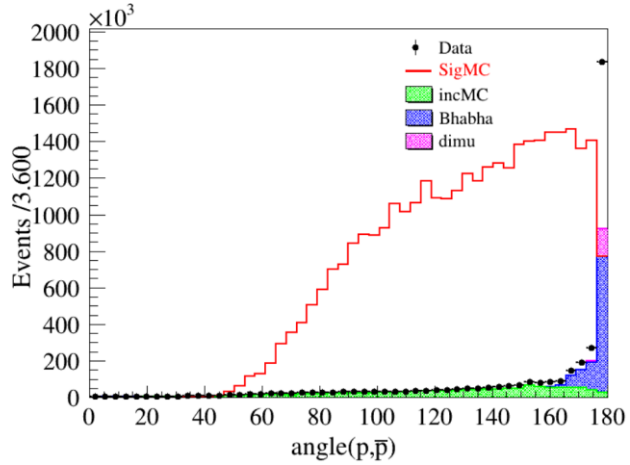
Further Event selection

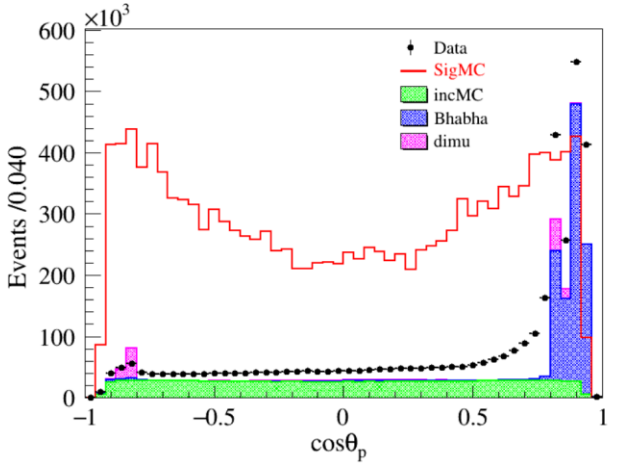
初筛后的质量谱和特征谱:

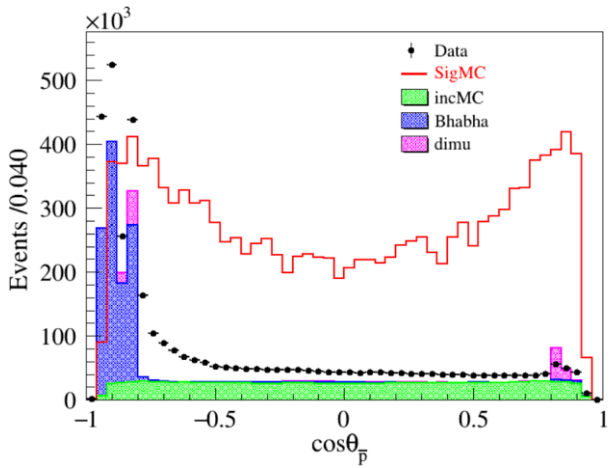


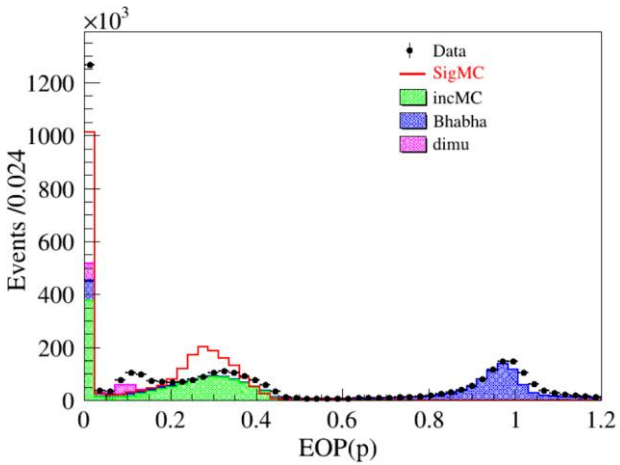


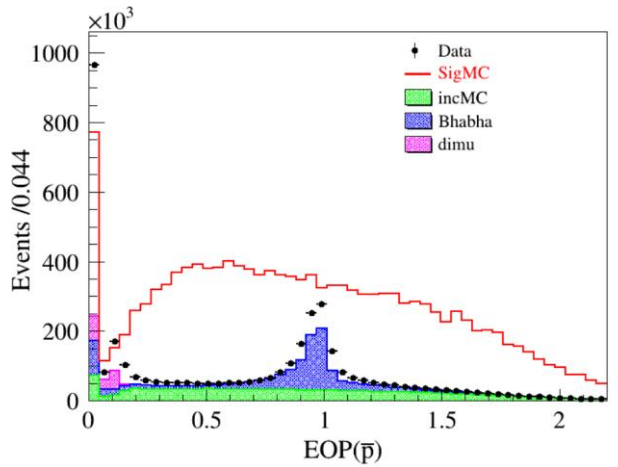






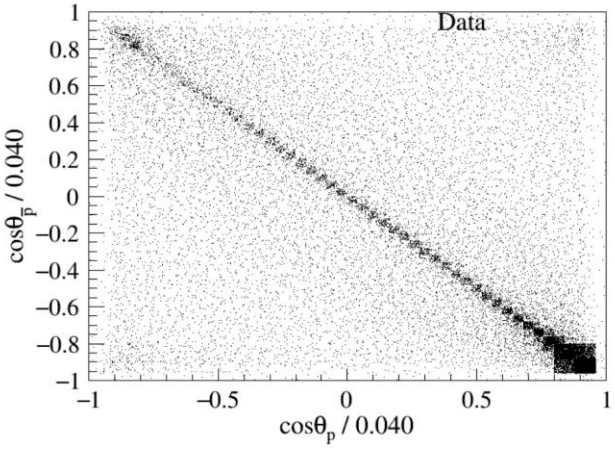


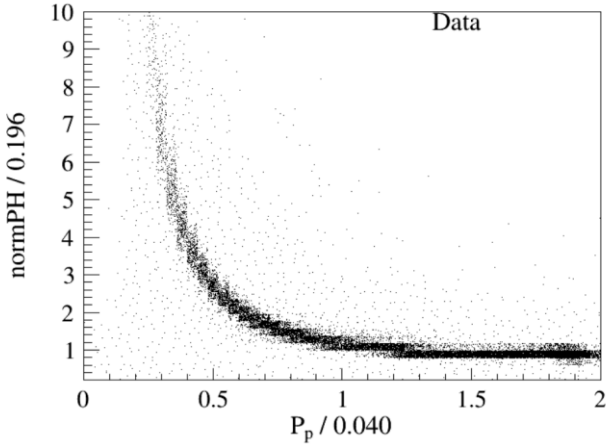


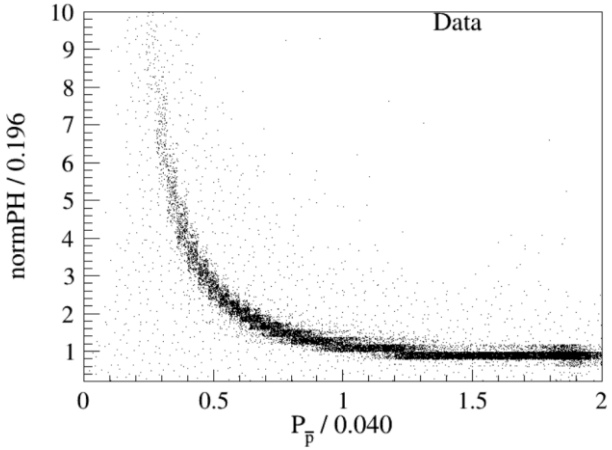


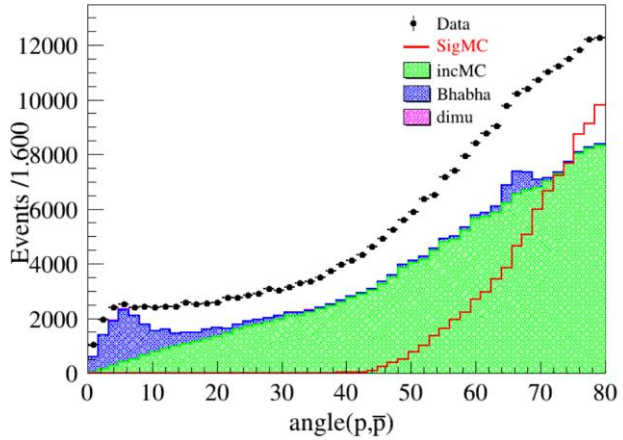
Further Event selection

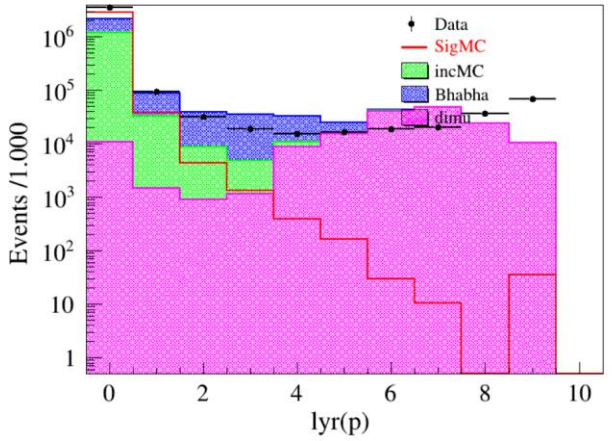
初筛后的质量谱和特征谱:

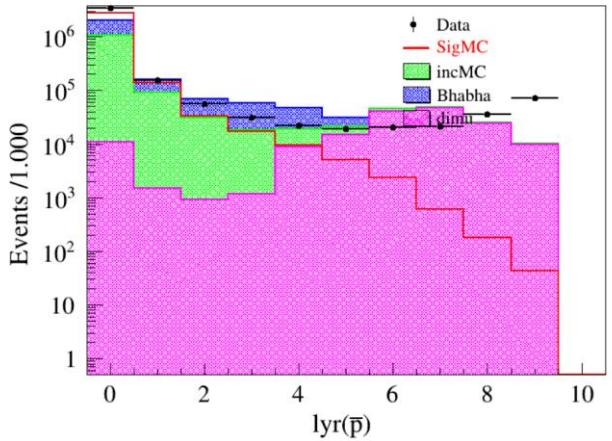


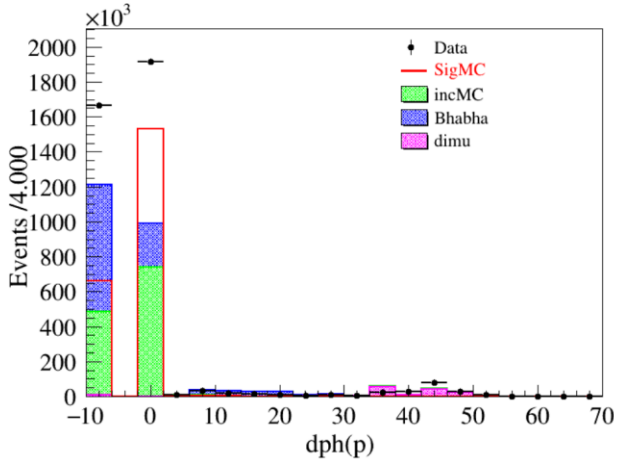


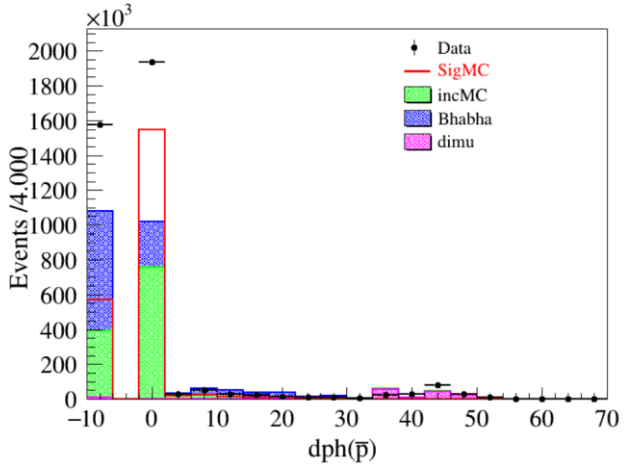








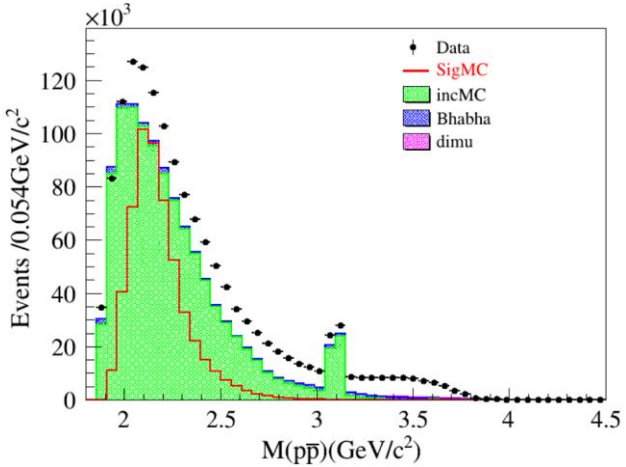


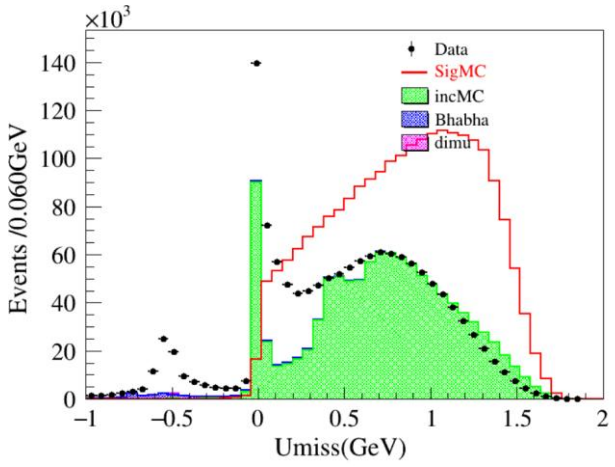


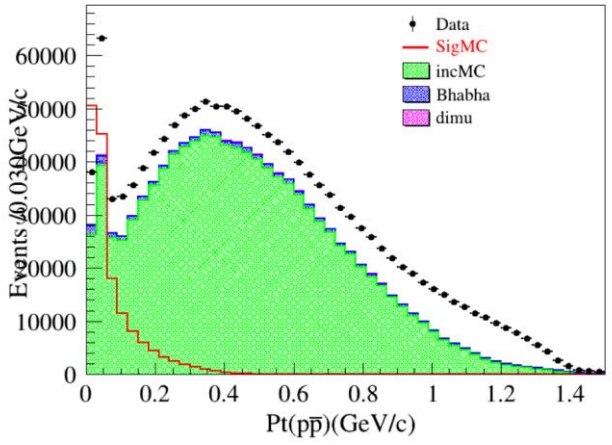
Further Event selection

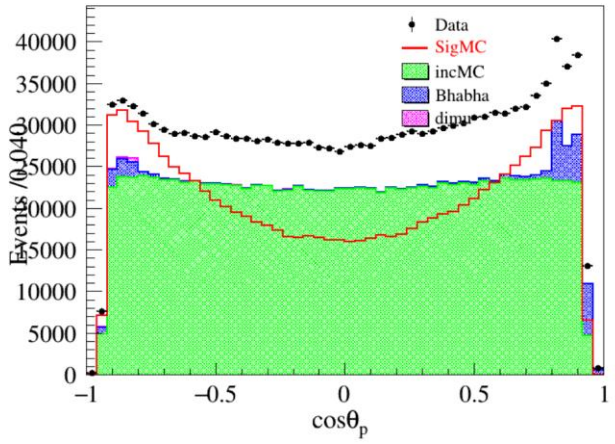
$angle(p, \bar{p}) < 165$

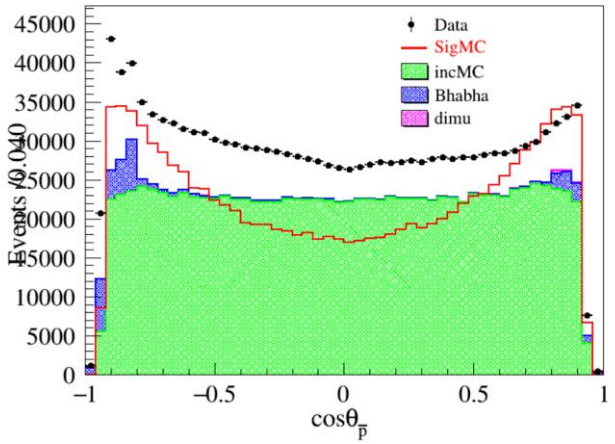
通过ppbar夹角排除Bhabha和dimu本底

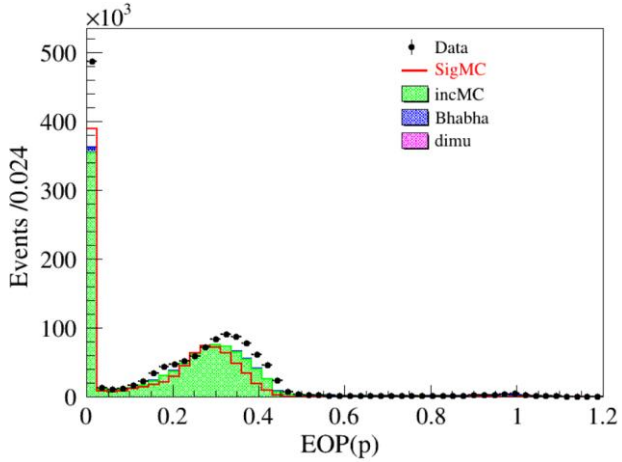


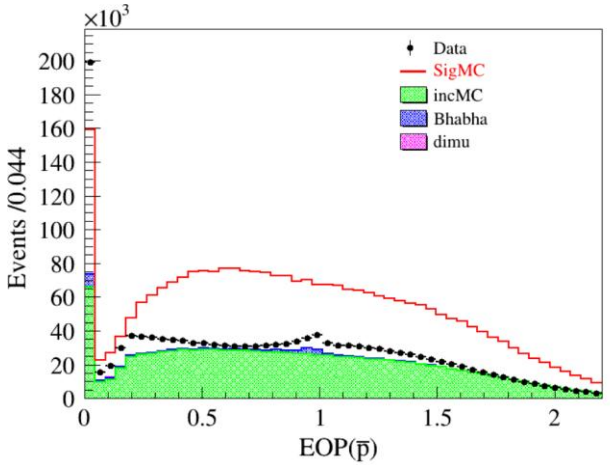








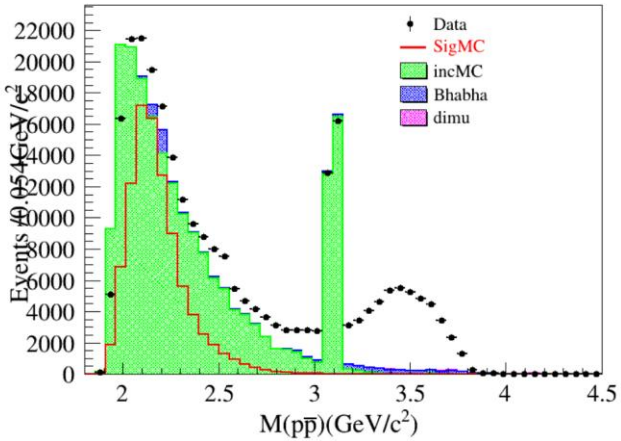


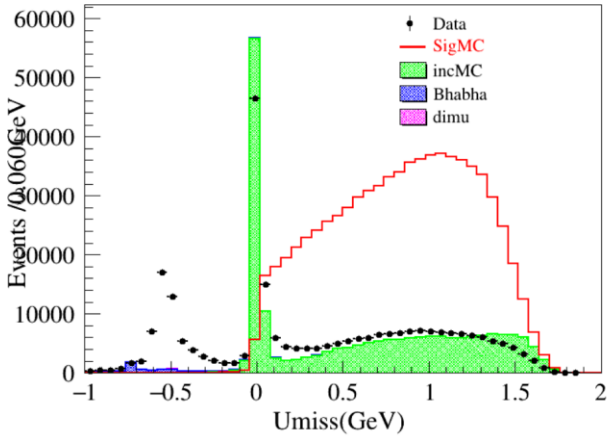


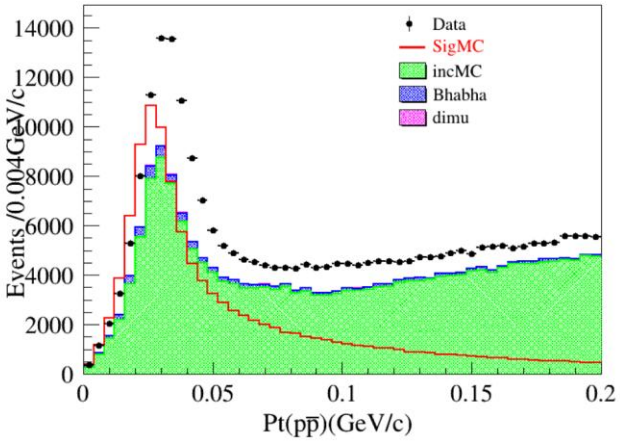
Further Event selection

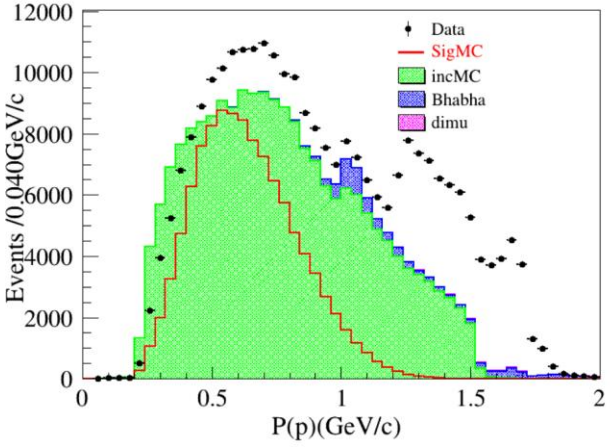
$angle(p,\bar{p}) < 165$
$Pt(p\bar{p}) < 0.2GeV/c$

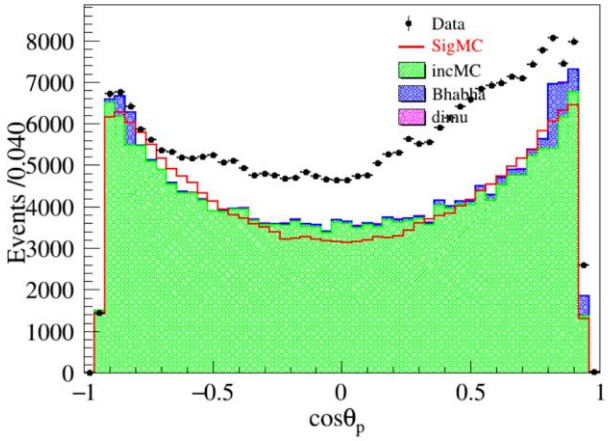
通过ppbar横动量压低本底

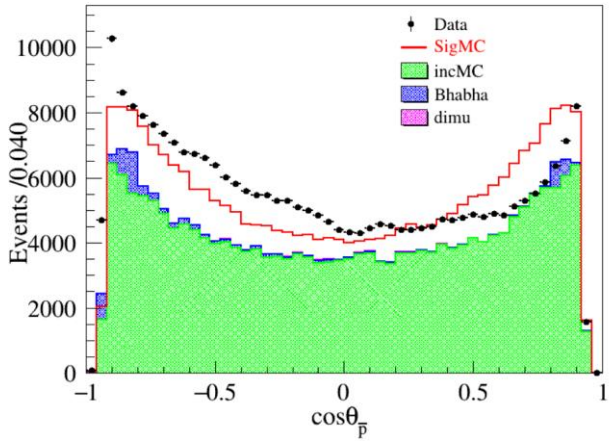


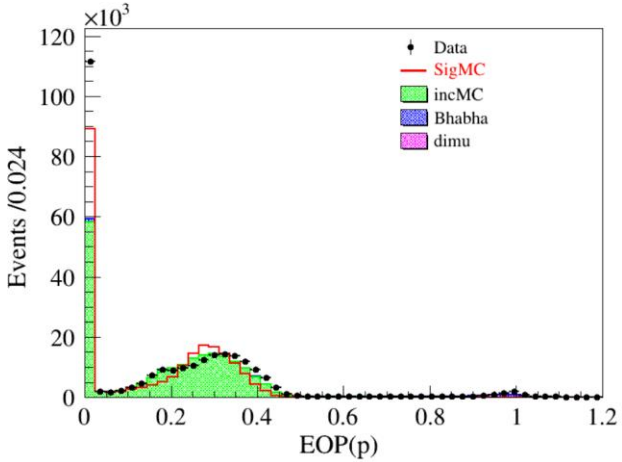


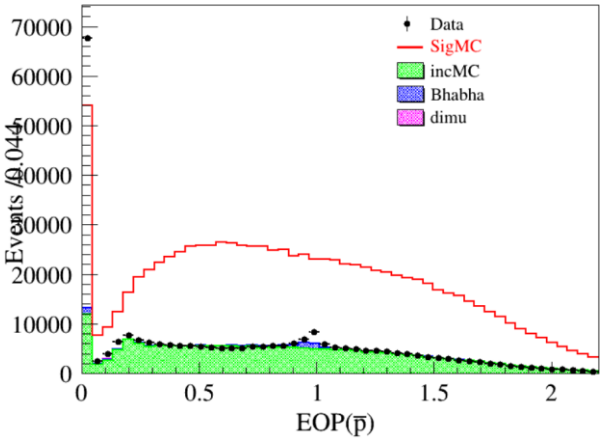








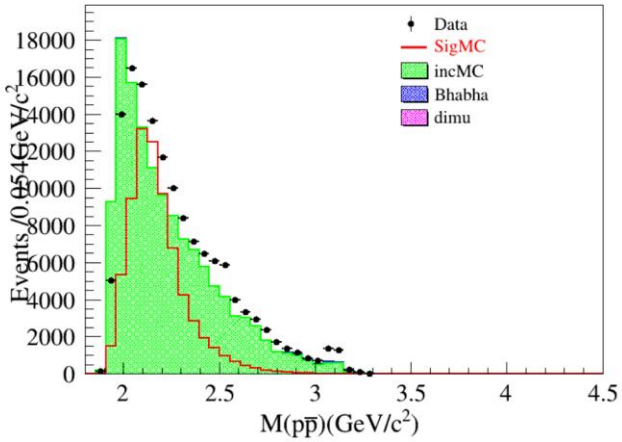


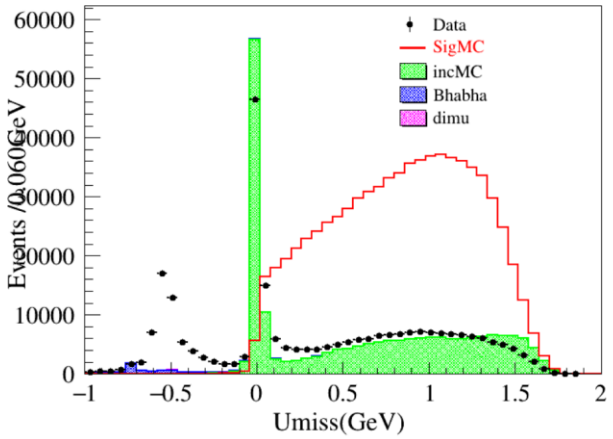


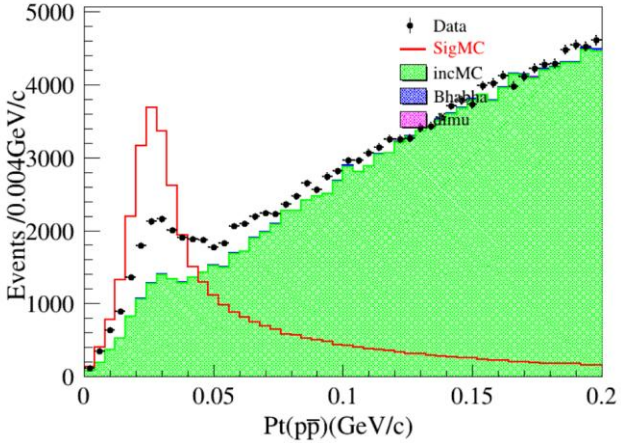
Further Event selection

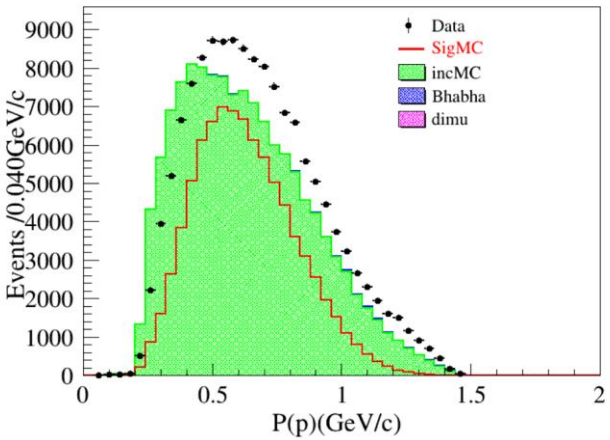
$$angle(p,\bar{p}) < 165$$
$$Pt(p\bar{p}) < 0.2GeV/c$$
$$Umiss > 0.1GeV$$

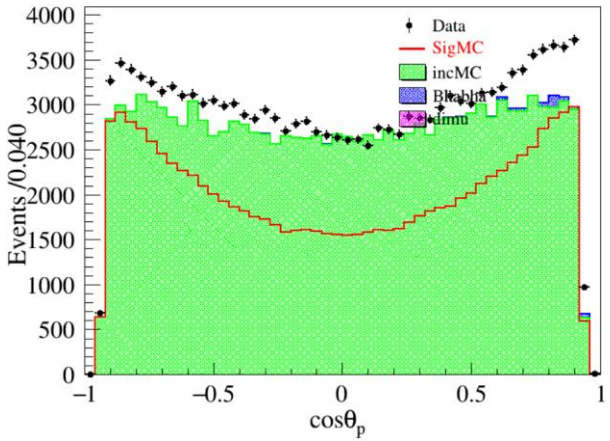
通过Umiss压低误鉴别和辐射ppbar本底

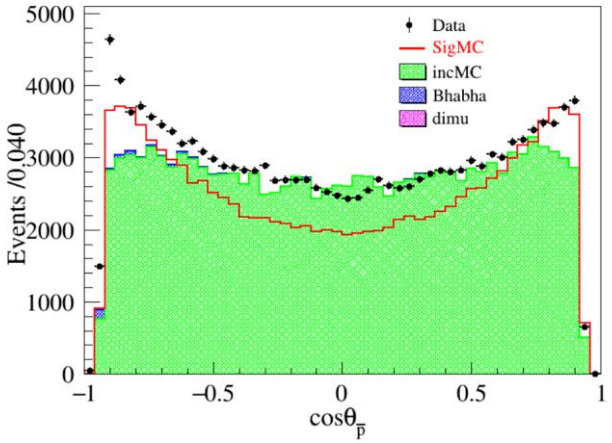


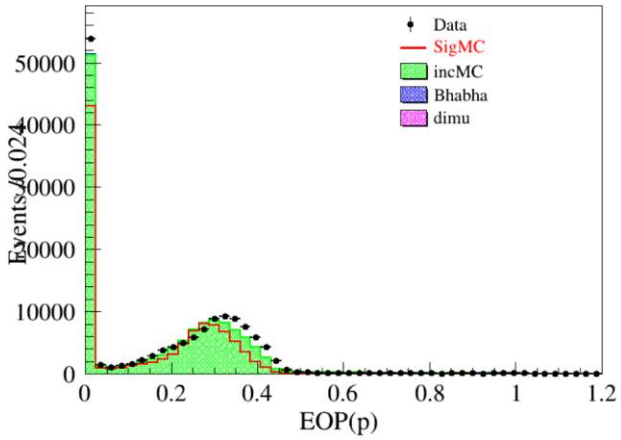


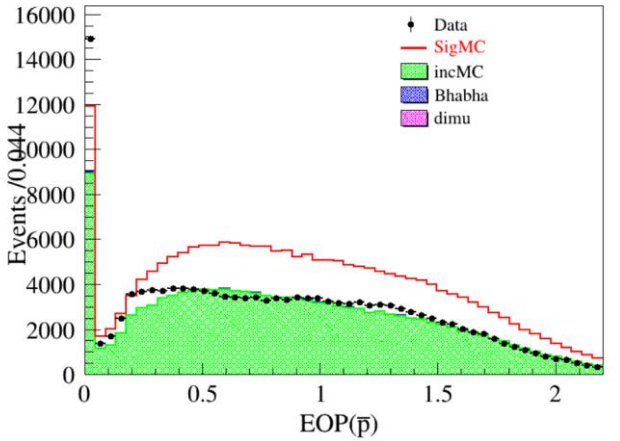








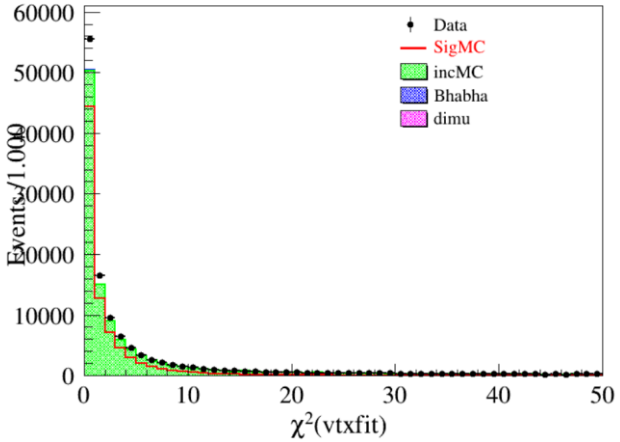


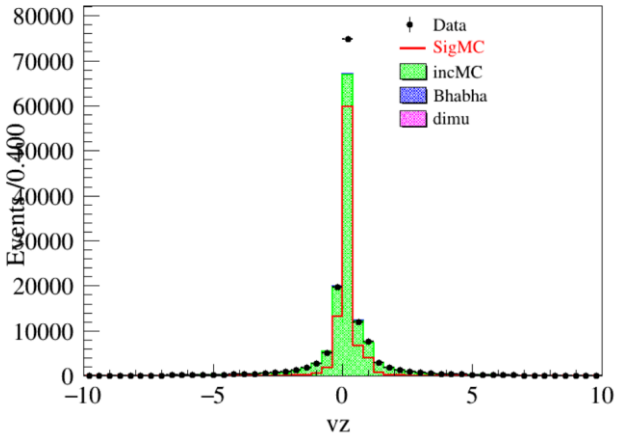


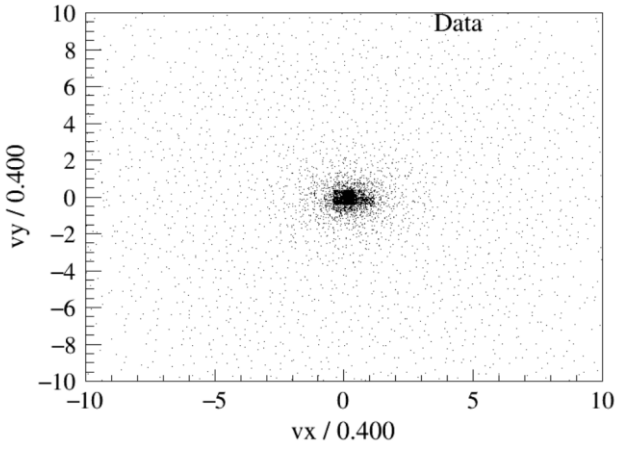
Further Event selection

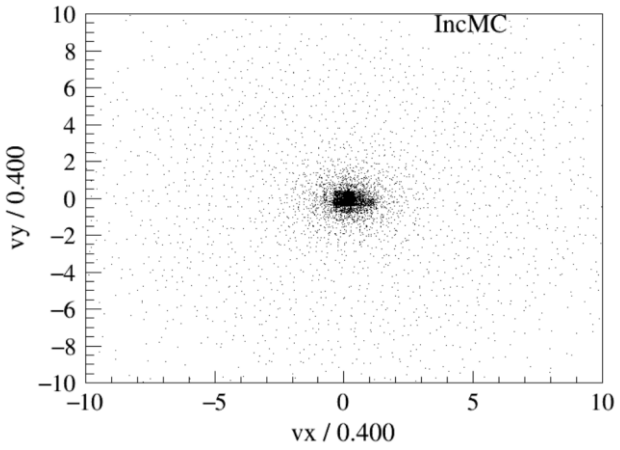
$$angle(p,\bar{p}) < 165$$
$$Pt(p\bar{p}) < 0.2GeV/c$$
$$Umiss > 0.1GeV$$

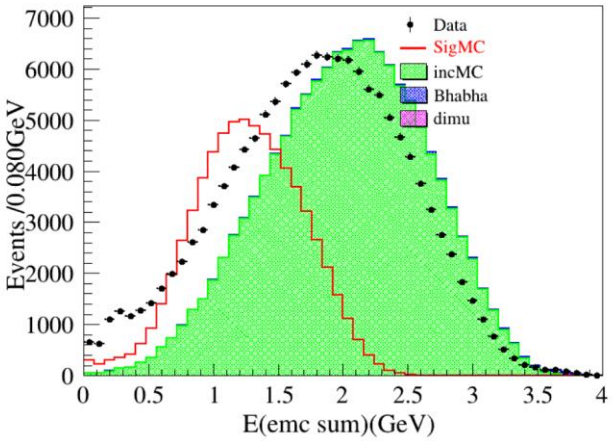
通过Umiss压低误鉴别和辐射ppbar本底

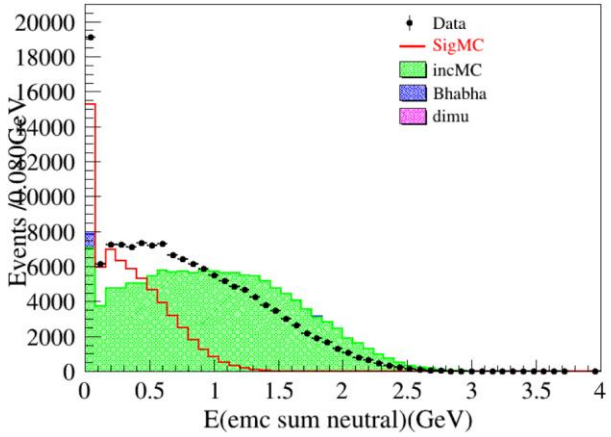












Further Event selection

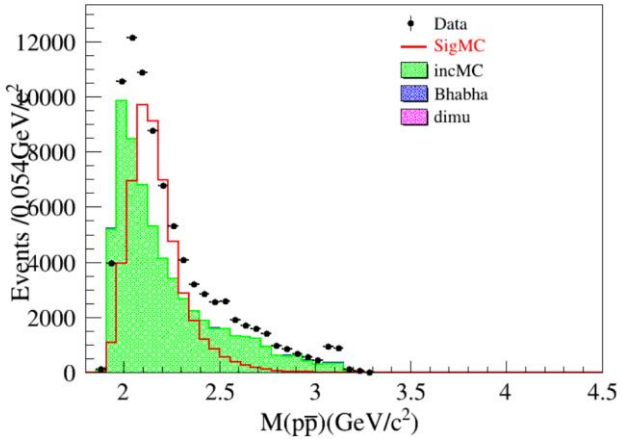
$$angle(p,\bar{p}) < 165$$
$$Pt(p\bar{p}) < 0.2GeV/c$$
$$Umiss > 0.1GeV$$

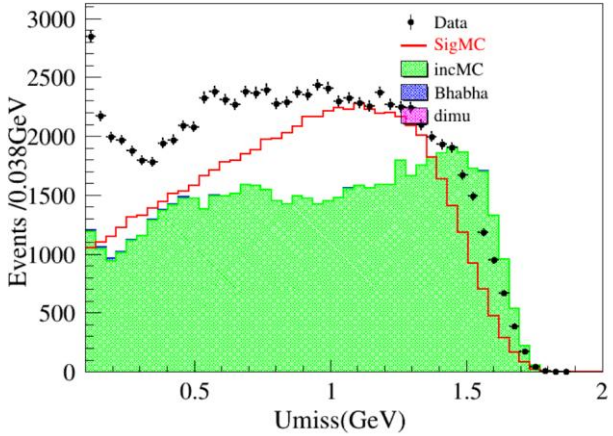
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$x \to p\bar{p}\gamma^F\gamma^F$	$p\bar{p}\gamma^F\gamma^F$	11	6794	6794
2	$x \to p\bar{p}a_0^0\gamma^f, a_0^0 \to \pi^0\eta, \eta \to \gamma\gamma$	$\pi^0 p\bar{p}\gamma\gamma\gamma^f$	156	3265	10059
3	$x \to f_2(1270)p\bar{p}\gamma^f, f_2(1270) \to \pi^0\pi^0$	$\pi^0\pi^0 p\bar{p}\gamma^f$	68	2932	12991
4	$x \to p\bar{p}a_0^0\gamma^f, a_0^0 \to \pi^0\eta, \eta \to \pi^0\pi^0\pi^0$	$\pi^0\pi^0\pi^0\pi^0 p\bar{p}\gamma^f$	12	2708	15699
5	$x \to K^- p\bar{\Lambda}\gamma^f, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+ K^- p\bar{p}\gamma^f$	88	2674	18373
6	$x \to K^+\bar{p}\Lambda\gamma^f, \Lambda \to \pi^- p$	$\pi^- K^+ p\bar{p}\gamma^f$	2	2467	20840
7	$x \to J/\psi\gamma, J/\psi \to \pi^0\Delta^+\bar{\Delta}^-, \Delta^+ \to \pi^0 p, \bar{\Delta}^- \to \pi^0\bar{p}$	$\pi^0\pi^0\pi^0 p\bar{p}\gamma$	26	2079	22919
8	$x \to K^+K^- p\bar{p}\gamma^f$	$K^+K^- p\bar{p}\gamma^f$	61	1753	24672
9	$x \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	9	1751	26423
10	$x \to J/\psi\gamma, J/\psi \to \Xi^0\bar{\Xi}^0, \Xi^0 \to \pi^0\Lambda, \bar{\Xi}^0 \to \pi^0\bar{\Lambda}, \Lambda \to \pi^- p,$ $\bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^0\pi^+\pi^- p\bar{p}\gamma$	17	1508	27931
11	$x \to J/\psi\gamma, J/\psi \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p,$ $\bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma\gamma$	52	1371	29302
12	$x \to \pi^0 p\bar{p}a_0^0\gamma^f, a_0^0 \to \pi^0\eta, \eta \to \gamma\gamma$	$\pi^0\pi^0 p\bar{p}\gamma\gamma\gamma^f$	35	1305	30607
13	$x \to p\bar{p}f_1(1285)\gamma^f, f_1(1285) \to \pi^0 a_0^0, a_0^0 \to \pi^0\eta, \eta \to \gamma\gamma$	$\pi^0\pi^0 p\bar{p}\gamma\gamma\gamma^f$	207	1168	31775
14	$x \to J/\psi\gamma, J/\psi \to \eta p\bar{p}, \eta \to \gamma\gamma$	$p\bar{p}\gamma\gamma\gamma$	83	1155	32930
15	$x \to \pi^0\pi^0 p\bar{p}\gamma^f$	$\pi^0\pi^0 p\bar{p}\gamma^f$	100	1130	34060
16	$x \to f_2(1270)p\bar{p}, f_2(1270) \to \pi^0\pi^0$	$\pi^0\pi^0 p\bar{p}$	54	1097	35157
17	$x \to \pi^0 f_2(1270)p\bar{p}\gamma^f, f_2(1270) \to \pi^0\pi^0$	$\pi^0\pi^0\pi^0 p\bar{p}\gamma^f$	112	1045	36202
18	$x \to J/\psi\gamma, J/\psi \to \pi^0 p\bar{p}$	$\pi^0 p\bar{p}\gamma$	270	1015	37217
19	$x \to p\bar{p}a_0^0, a_0^0 \to \pi^0\eta, \eta \to \gamma\gamma$	$\pi^0 p\bar{p}\gamma\gamma$	157	998	38215
20	$x \to \pi^0 p\bar{p}a_0^0\gamma^f, a_0^0 \to \pi^0\eta, \eta \to \pi^0\pi^0\pi^0$	$\pi^0\pi^0\pi^0\pi^0\pi^0 p\bar{p}\gamma^f$	13	928	39143
.....					
7359	$x \to \pi^0\Sigma^-\bar{\Sigma}^0 a_1^+, \Sigma^- \to \pi^- n, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, a_1^+ \to \pi^0\rho^+, \bar{\Lambda} \to \pi^+\bar{p},$ $\rho^+ \to \pi^0\pi^+$	$\pi^0\pi^0\pi^0\pi^+\pi^+\pi^- n\bar{p}\gamma$	7358	1	130541

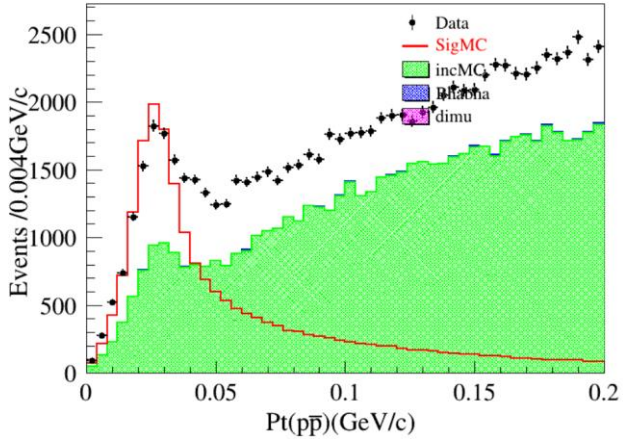
Further Event selection

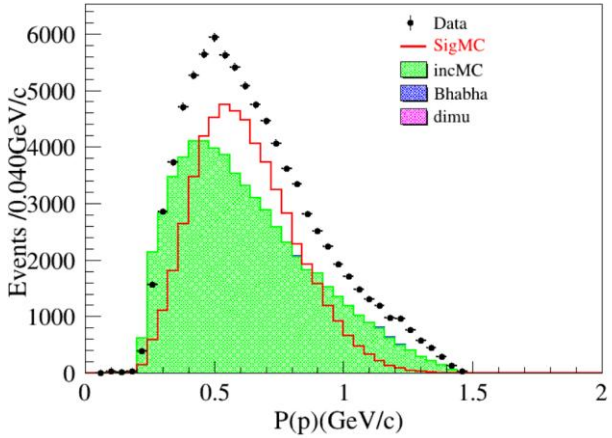
$$angle(p,\bar{p}) < 165$$
$$Pt(p\bar{p}) < 0.2GeV/c$$
$$Umiss > 0.1GeV$$
$$EmcEsum < 2GeV$$

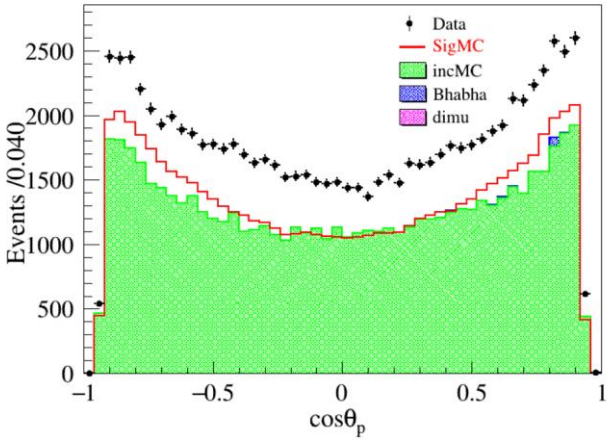
尝试通过EMC能量信息压低本底

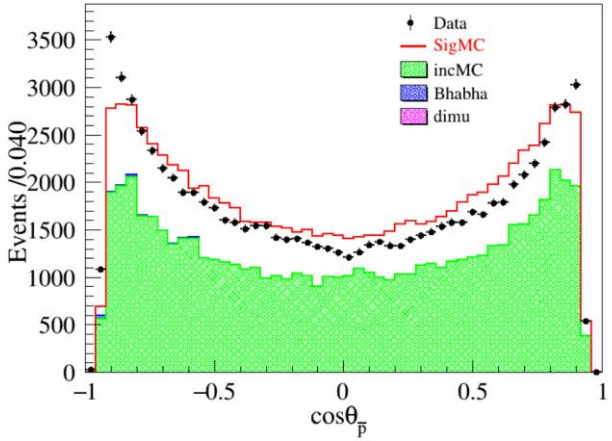


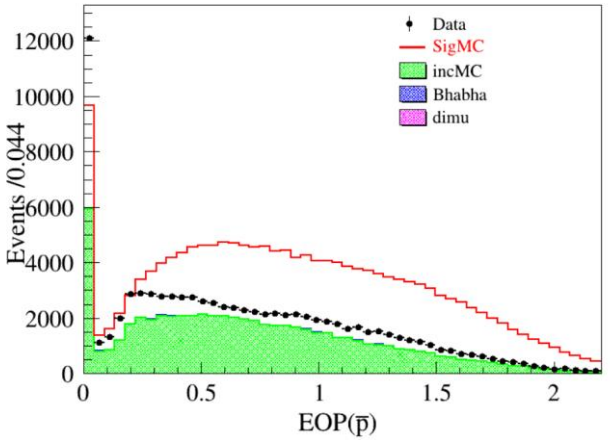








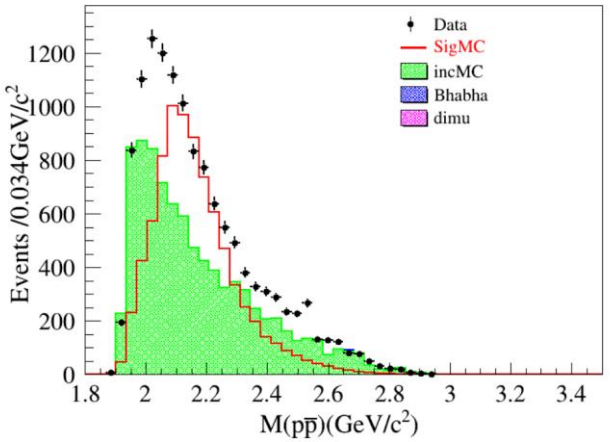


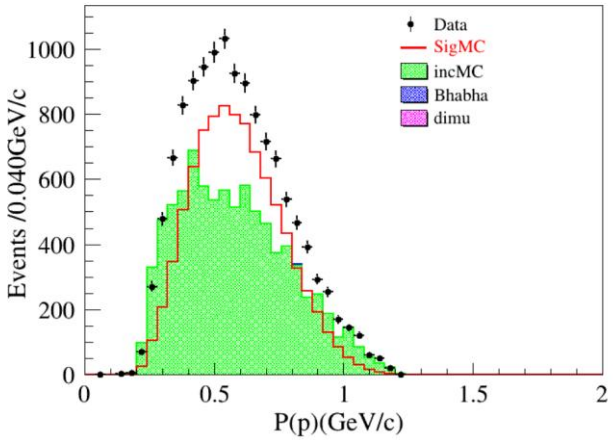


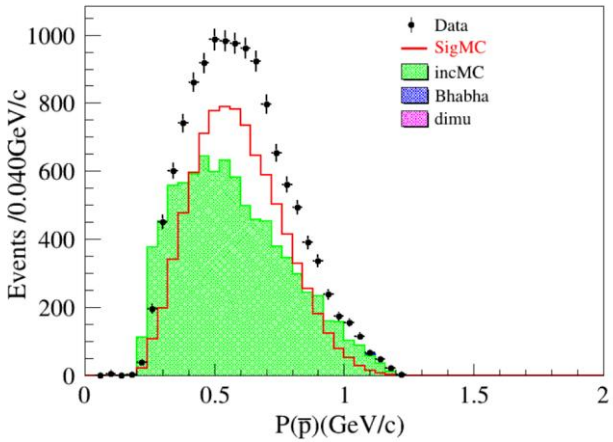
Further Event selection

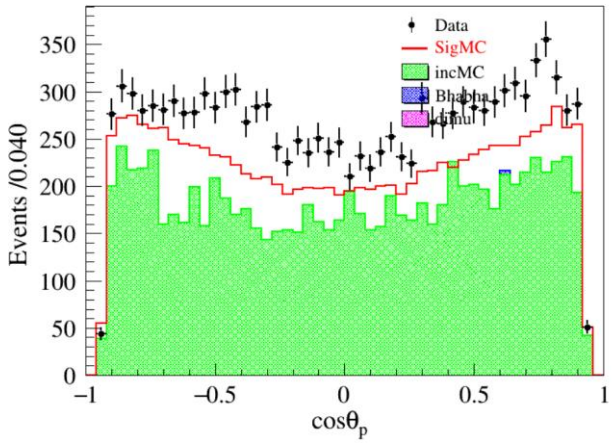
$$angle(p,\bar{p}) < 165$$
$$Pt(p\bar{p}) < 0.05GeV/c$$
$$Umiss > 0.5GeV$$

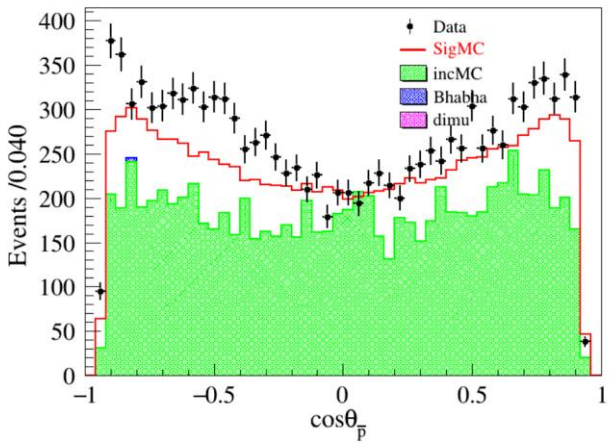
收紧Pt和Umiss要求查看数据和MC的符合情况：







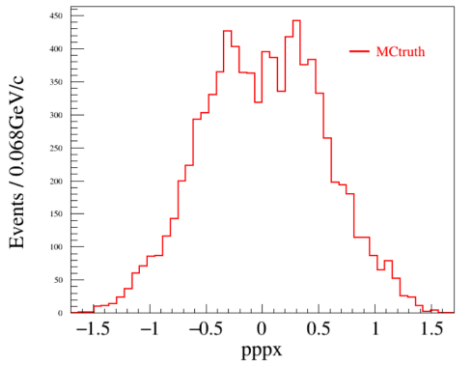


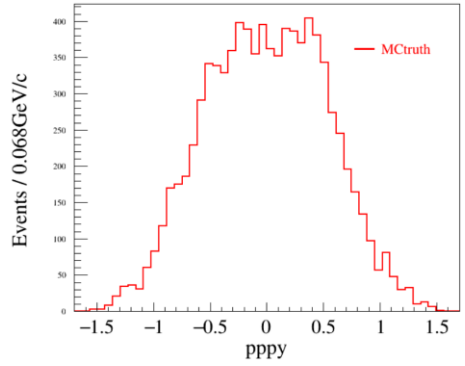


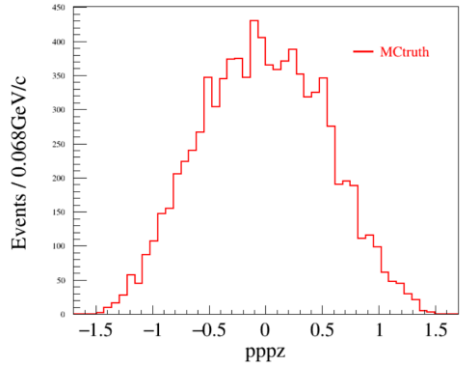
Back Up

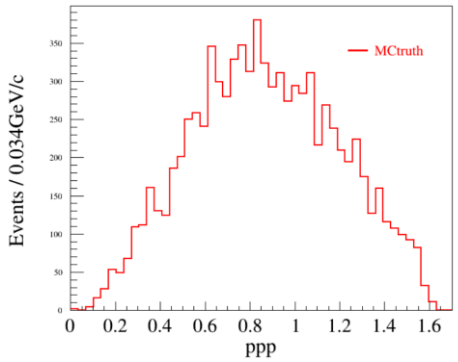
MCtruth information for single-tag acceptance

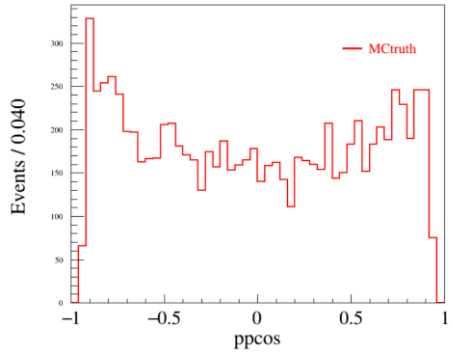
Mctruth information (before selection), Ecms = 3.773GeV, Generator: cpp_gamgam + TrackGen





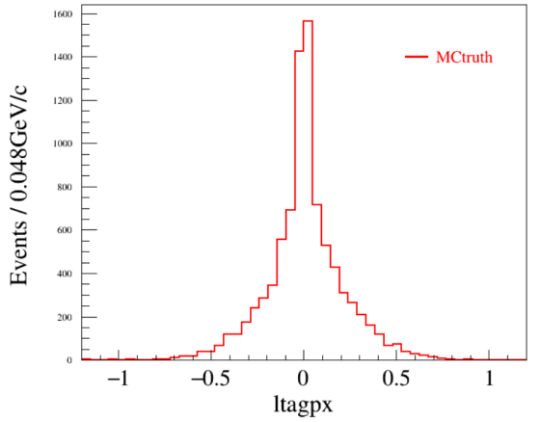


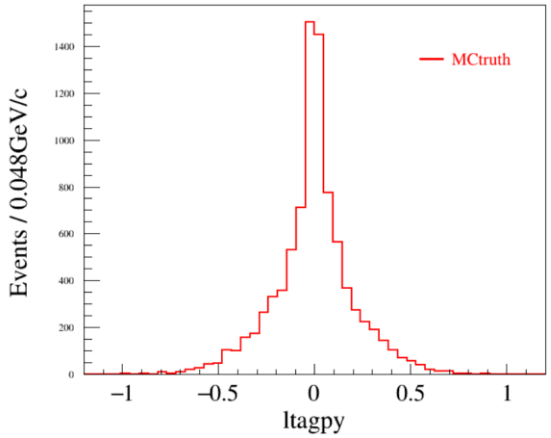


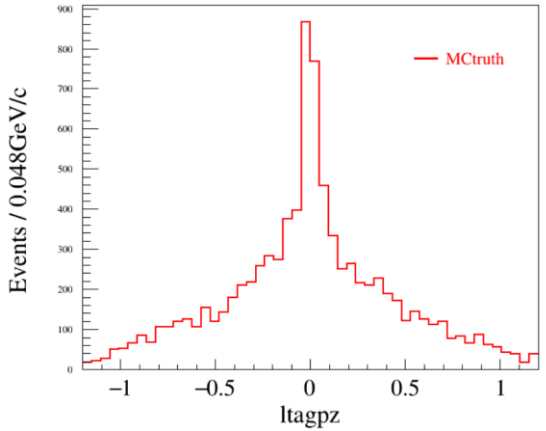


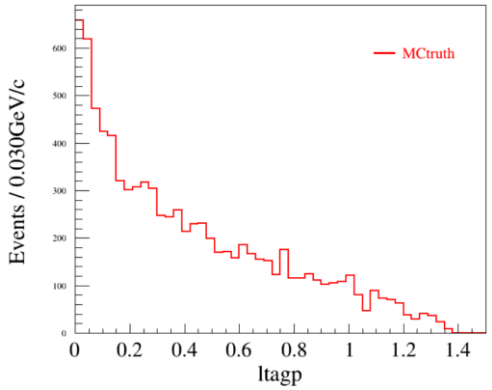
Mctruth information for single-tag

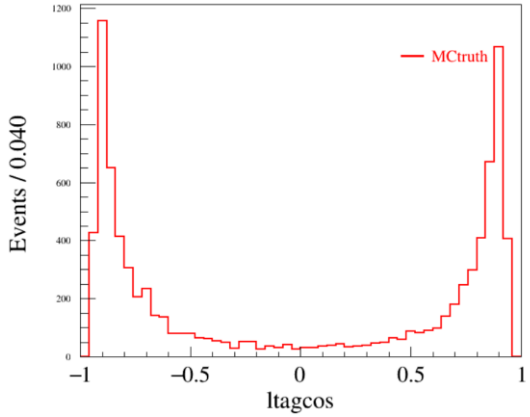
Mctruth information (no selection), Ecms = 3.773GeV, Generator: cpp_gamgam + TrackGen





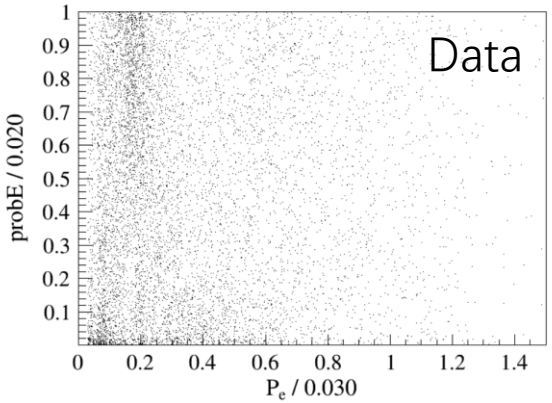


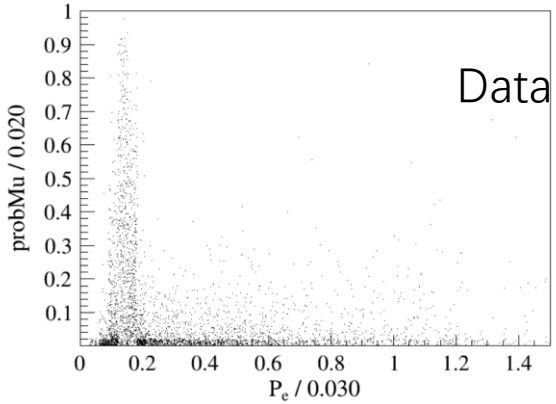


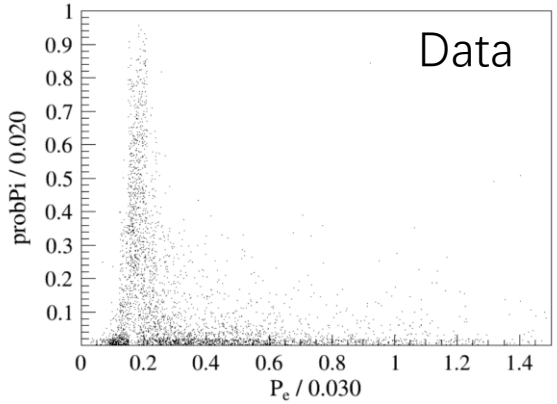


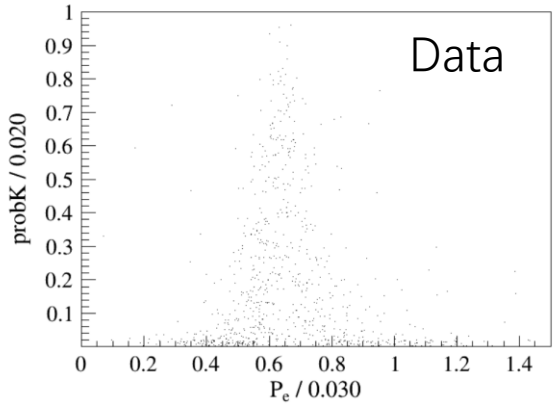
Cos(p4miss.theta())*ltagsign<-0.92;
$20 < \theta(p, \bar{p}) < 170$,
$10 < \theta(p/\bar{p}, e) < 170$

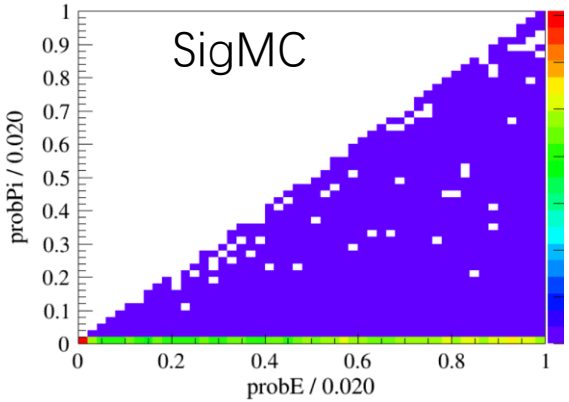
还可以尝试：
1.继续收紧miss系统的角度约束
2.提升pi，e，K鉴别

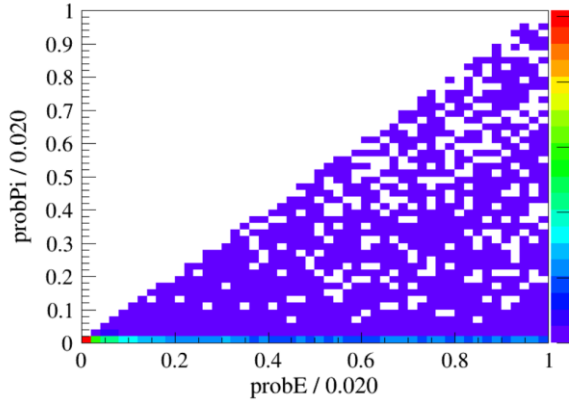


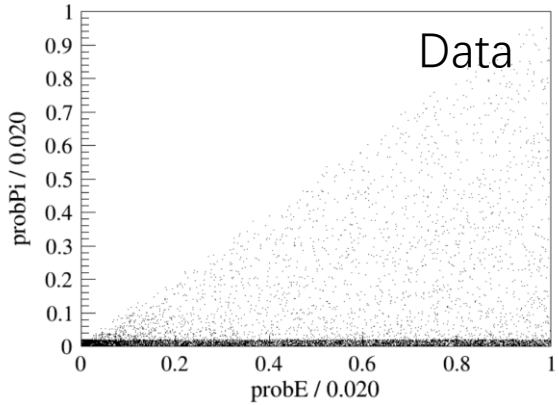


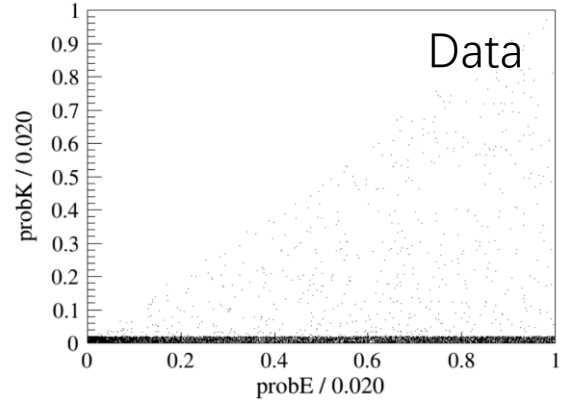








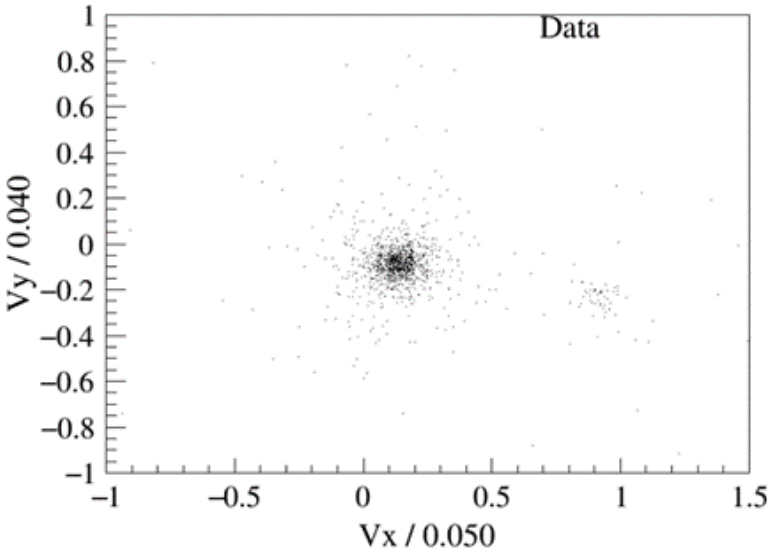


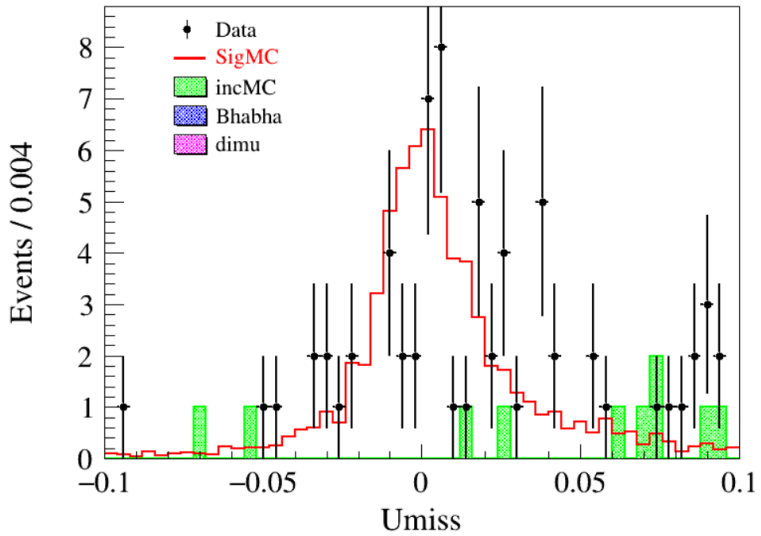


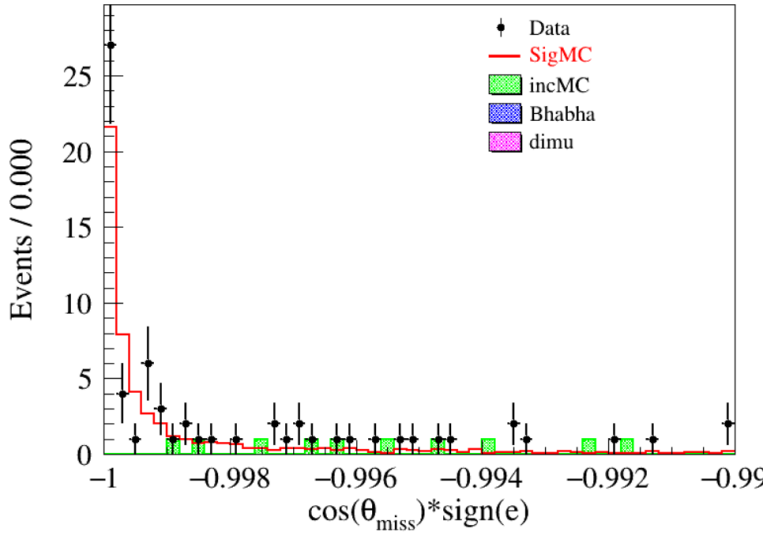
Futher event selection

$$cos\theta_{miss} * sign(e) < -0.99;$$
$$20 < \theta(p, \bar{p}) < 170;$$
$$10 < \theta(p/\bar{p}, e) < 170;$$
$$-0.1 < Umiss < 0.1$$

要求Vx>0.7:



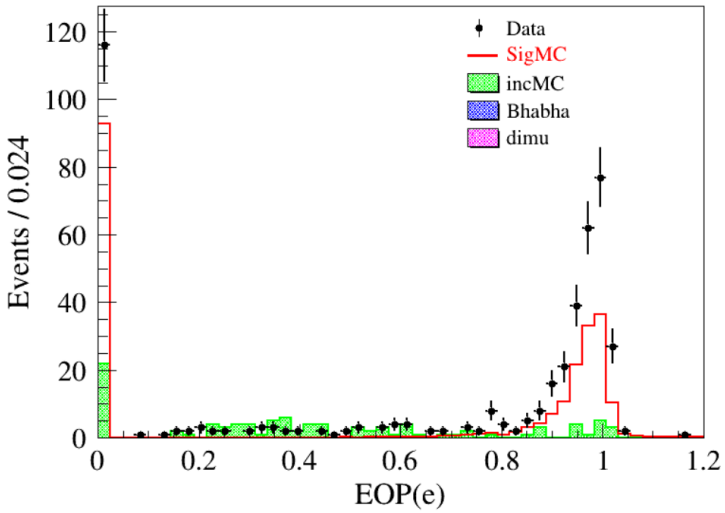




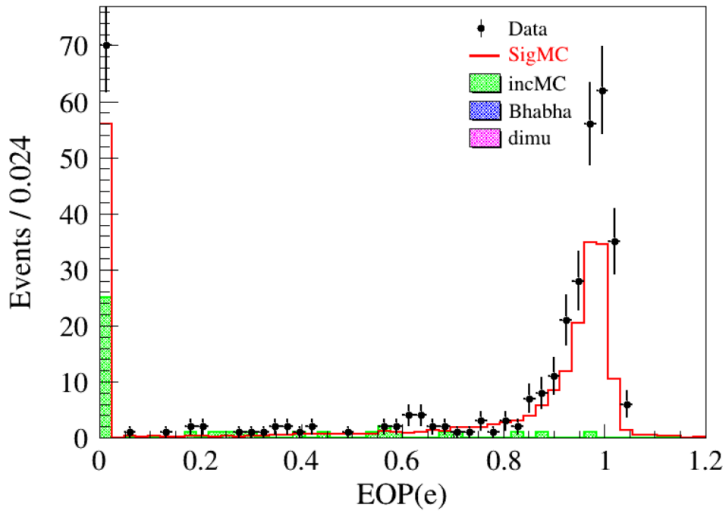
Futher event selection

$cos\theta_{miss} * sign(e) < -0.99;$
$20 < \theta(p, \bar{p}) < 170;$
$10 < \theta(p/\bar{p}, e) < 170;$
$-0.1 < Umiss < 0.1$

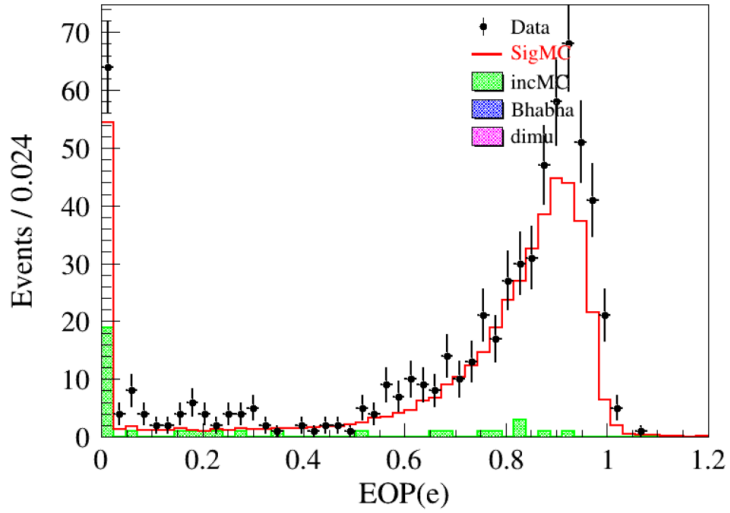
$|cos\theta| < 0.6$



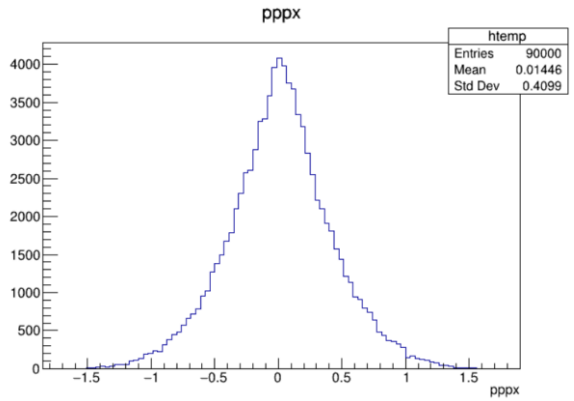
$0.6 < |cos\theta| < 0.8$

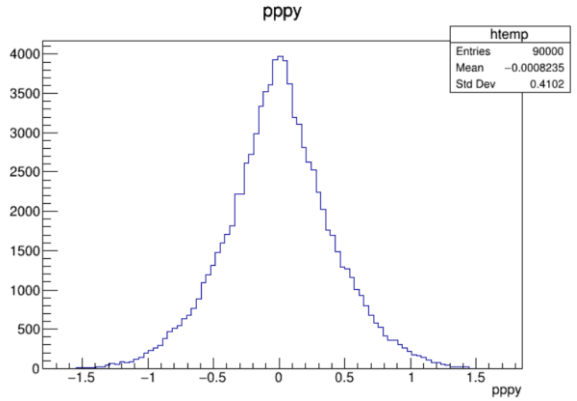


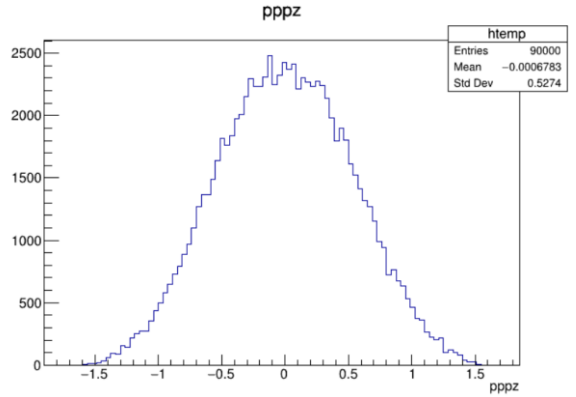
$0.8 < |cos\theta|$

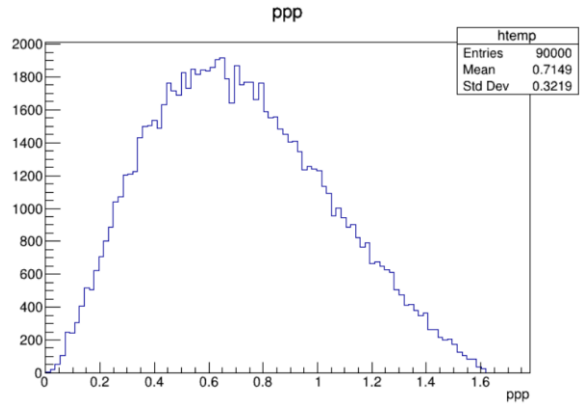


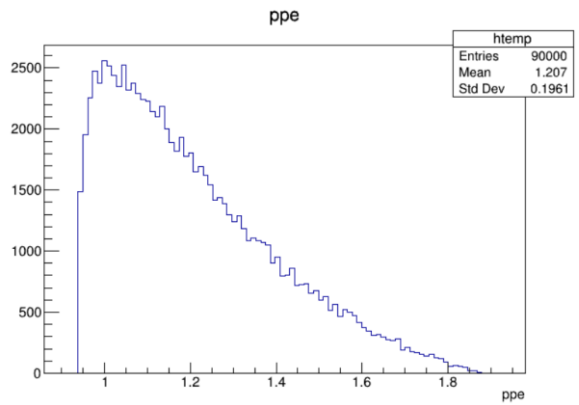
Mctruth information (no selection), Ecms = 3.773GeV, Generator: cpp_gamgam + TrackGen

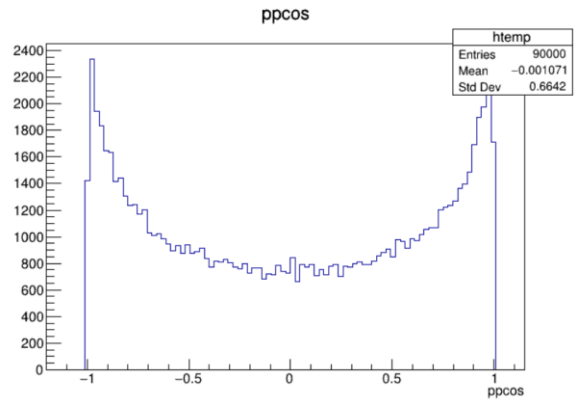




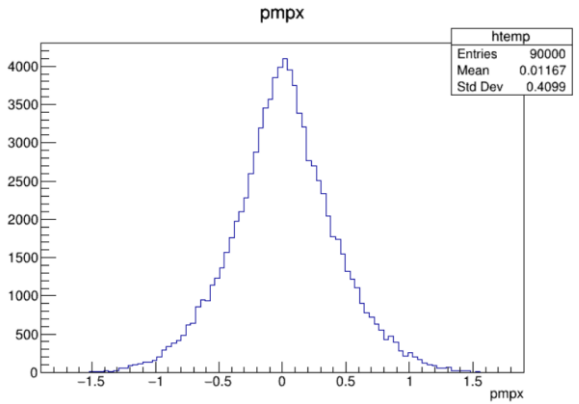


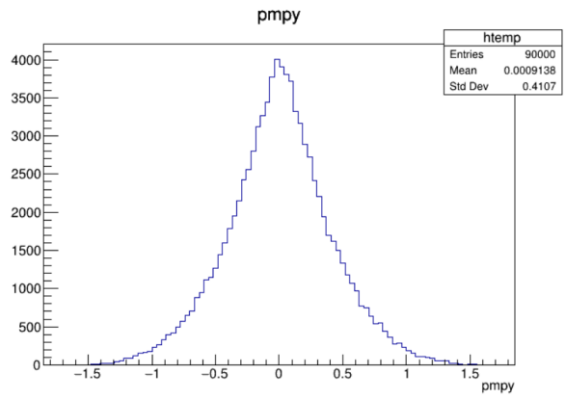


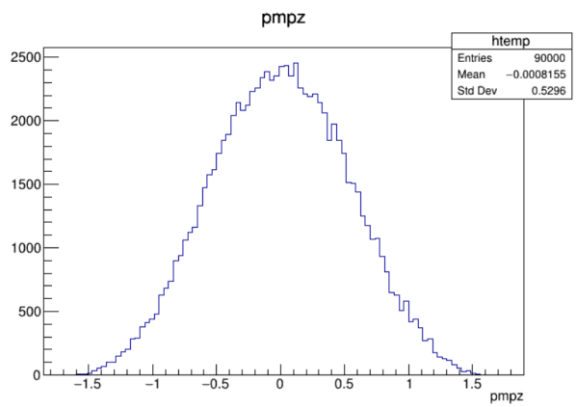


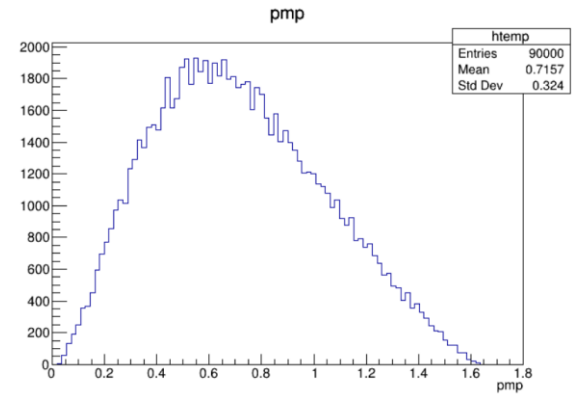


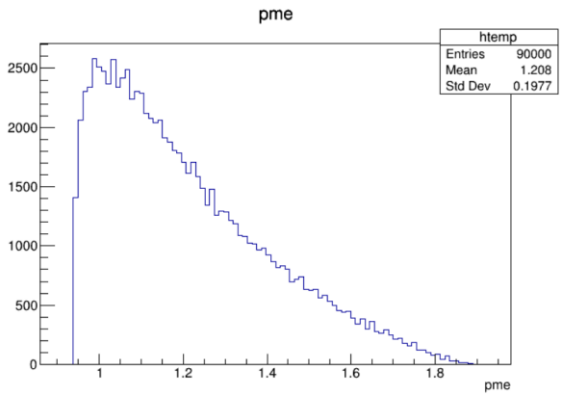
Mctruth information (no selection), Ecms = 3.773GeV, Generator: cpp_gamgam + TrackGen

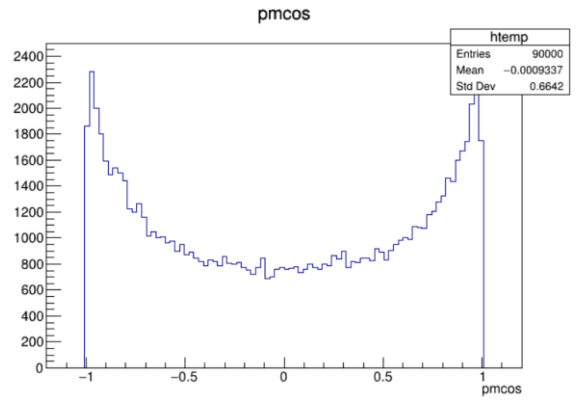




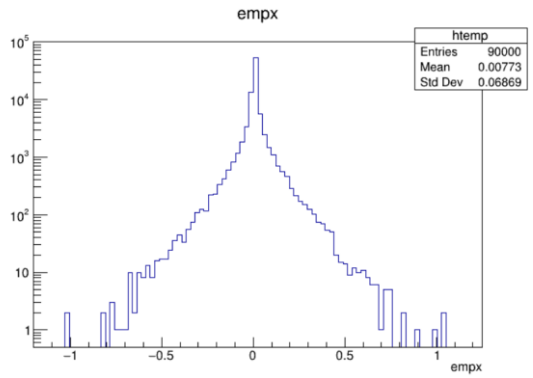


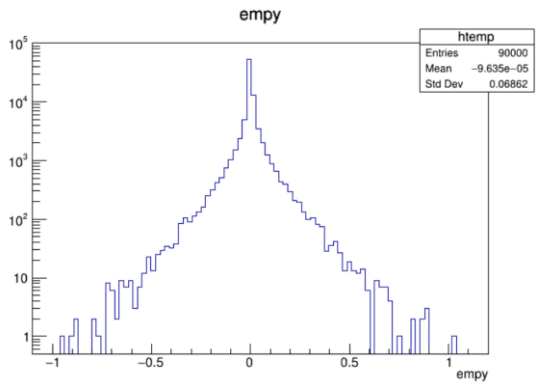


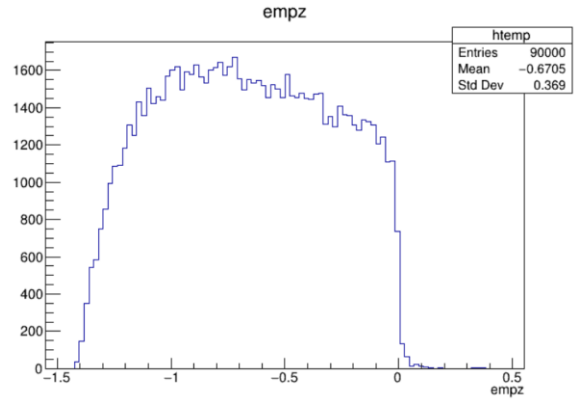


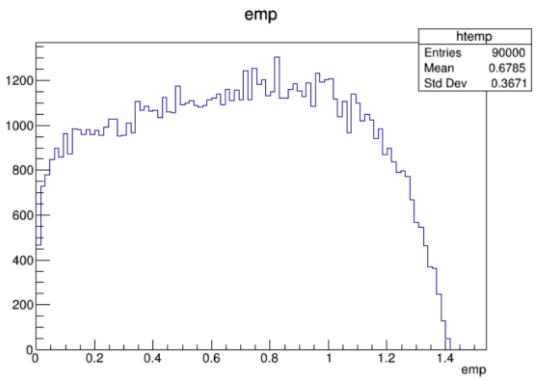


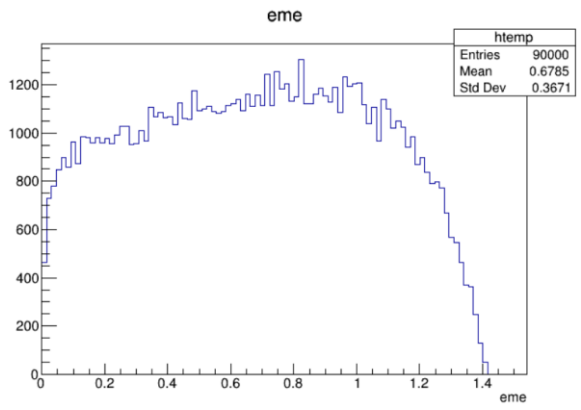
Mctruth information (no selection), Ecms = 3.773GeV, Generator: cpp_gamgam + TrackGen

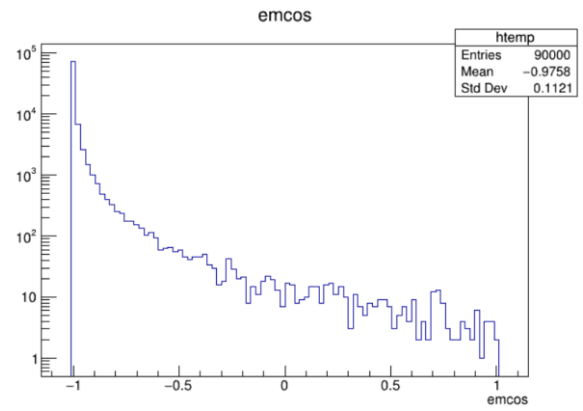












Mctruth information (no selection), Ecms = 3.773GeV, Generator: cpp_gamgam + TrackGen