中国科学技术大学
University of Science and Technology of China

Study of the $e^+e^- \to \gamma\Lambda^0\Sigma^0$ process using ISR method

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2024.10.23

Outline

- Data Samples
- Event Selection
- Background Analysis
- Data Analysis
- Cross Section Measurement

Data Sample

Sample	Year	Run range	Luminosity (pb^{-1})
round03	2010	$11414 - 13988$ $14395 - 14604$	$2931.8 \pm 0.2 \pm 13.8^{a}$
round04	2011	$20448 - 23454$	
round15	2022	$70522 - 73929$	4995 ± 19^{b}
round16	2023	$74031 - 78536$	8157 ± 31^{b}
round17	2024	$78615 - 81094$	4191 ± 16^{b}

Directory	Process	Cross section σ (nb)	Luminosity Scale	N_{evt} ($\times 10^6$) round03-04	round15	round16	round17
D0D0[1]	$e^+e^- \to \psi(3770) \to D^0\bar{D}^0$	3.615^{a}	80×	105.92×8	180.57×8	294.88×8	151.51×8
D+D-[2]	$e^+e^- \to \psi(3770) \to D^+D^-$	2.830^{a}	40×	82.92×4	141.36×4	230.84×4	118.61×4
ditau[2]	$e^+e^- \to \tau^+\tau^-$	3.0	40×	87.95×4	149.85×4	244.71×4	125.73×4
nonDD[2]	$e^+e^- \to \psi(3770) \to \mathrm{non}{-}D\bar{D}$	0.5	40×	14.66×4	24.98×4	40.79×4	20.96×4
qq[2]	$e^+e^- \to q\bar{q}$	16.86^{b}	40×	495.47×4	842.15×4	1375.27×4	706.61×4
RR2S[2]	$e^+e^- \to \gamma_{\mathrm{ISR}}\psi(2S)$	3.4	40×	99.68×4	169.83×4	277.34×4	142.49×4
RR1S[2]	$e^+e^- \to \gamma_{\mathrm{ISR}}J/\psi$	1.1	40×	32.25×4	54.95×4	89.73×4	46.10×4
Bhabha[3]	$e^+e^- \to e^+e^-$	520.5	0.25×	381.5	650.0	1061.4	545.4
digamma[3]	$e^+e^- \to \gamma\gamma$	24.7	3×	217.2	370.1	604.4	310.6
dimu[3]	$e^+e^- \to \mu^+\mu^-$	6.4	15×	281.5	479.5	783.1	402.3

Event Selection

Good charge tracks：

1. $|\cos\theta| < 0.93$
2. $|V_z| < 30$ cm, $V_r < 10$ cm
3. $N_{\mathrm{Good}} \geq 4$

Good photons：

1. $|\cos\theta_\gamma| < 0.8$ for the barrel and $E_\gamma > 25$ MeV;

   $0.86 < |\cos\theta_\gamma| < 0.93$ for the endcap and $E_\gamma > 50$ MeV
2. $d\theta_{min} > 10°$,while for $\bar{p}$ $d\theta_{min} > 20°$
3. $N_{photon} \geq 2$

PID

1. $N_{\pi+} \geq 1$ && $N_{\pi-} \geq 1$ && $N_p \geq 1$ && $N_{p-} \geq 1$

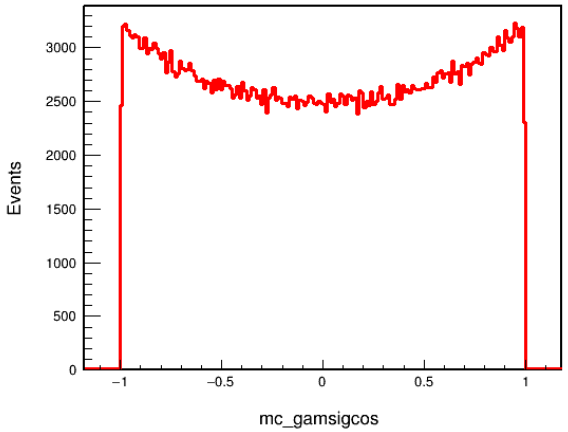
Vertex Fit:

1. Successful vertex fit for $p\bar{\pi}, \bar{p}\pi^+$, and $\chi^2_{Tol} = \chi^2_{Pri} + \chi^2_{Sec}$ is minimal.

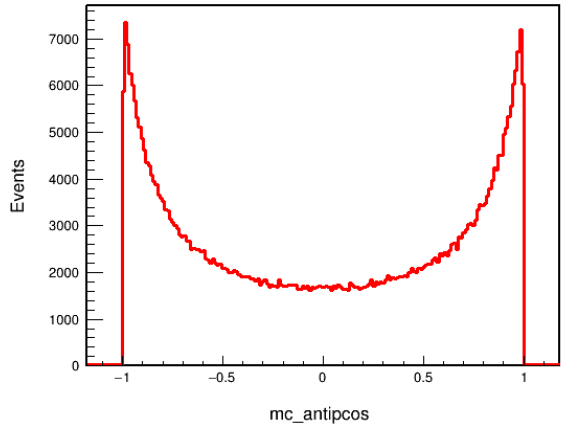
Kinematic Fit:

1. $E_{\gamma isr} > 400$ MeV
2. $\chi^2_{4C} < 200$
3. $\chi^2_{\gamma\gamma\Lambda\Lambda} < \chi^2_{\gamma\gamma\gamma\Lambda\Lambda}$ && $\chi^2_{\gamma\gamma\Lambda\Lambda} < \chi^2_{\gamma\Lambda\Lambda}$

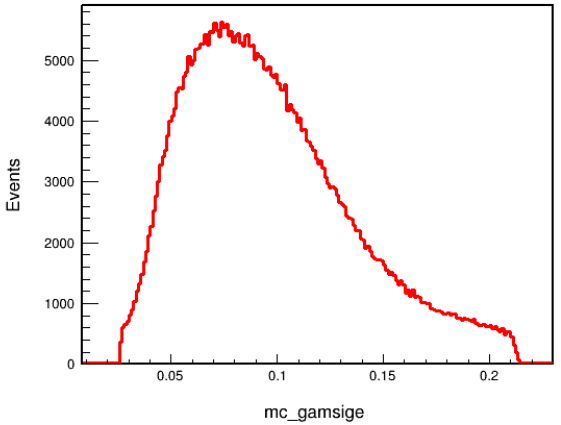
Truth Information



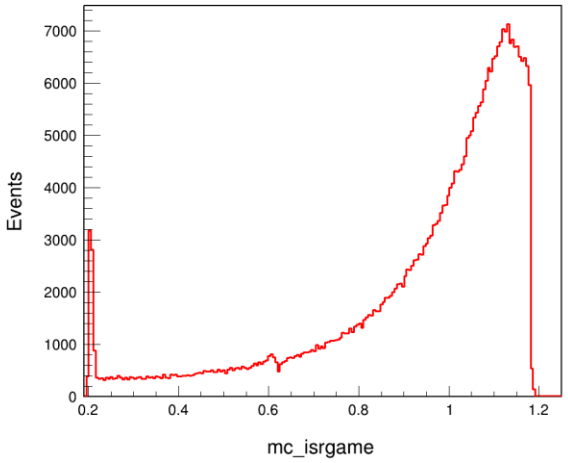
Polar angular of γ_{noISR}



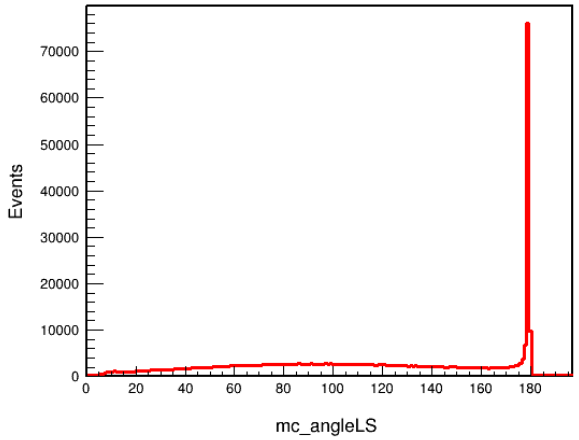
Polar angular of $\bar{p}$



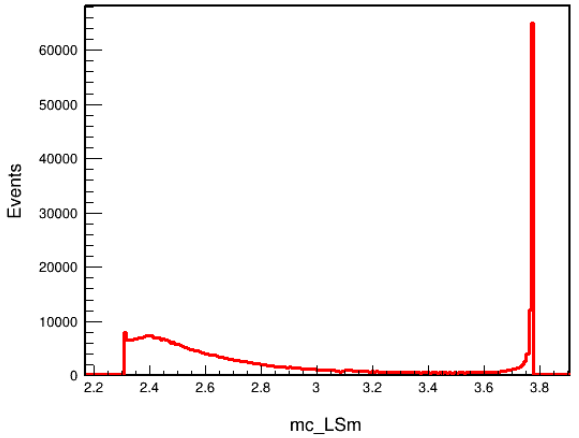
Energy of γ_{noISR}



Energy of γ_{ISR}

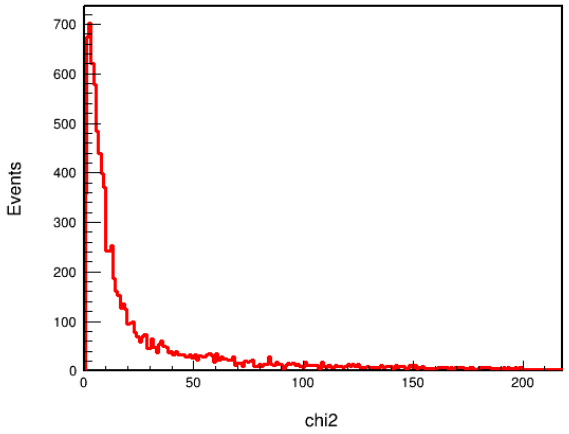


Angle difference between p_{Λ} and p_{Σ}

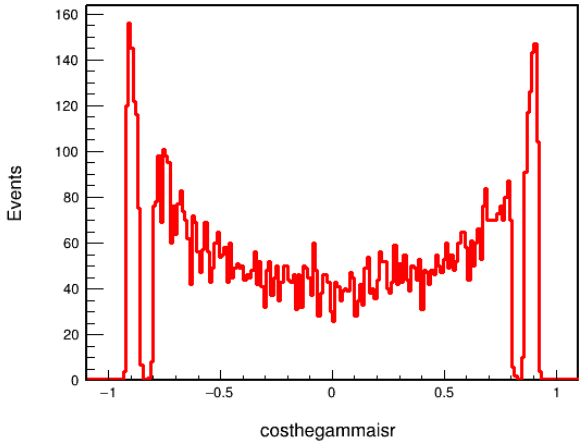


Mass of $\Lambda\Sigma$

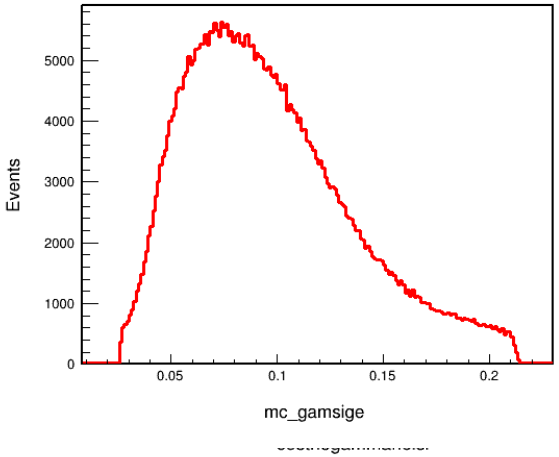
Output Information



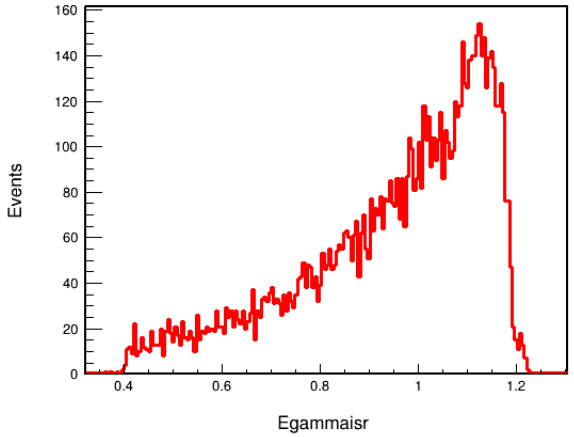
χ^2_{4C}



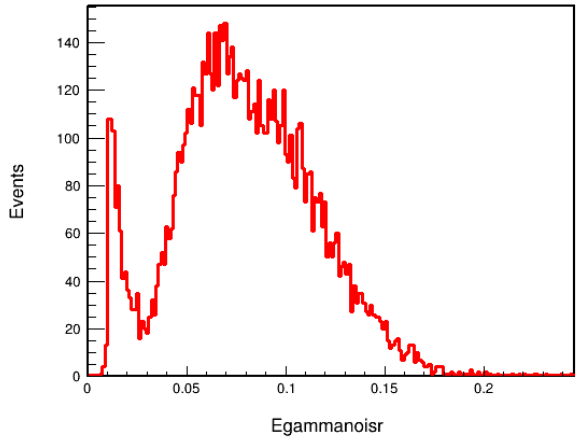
Polar angular of γ_{ISR}



Polar angular of γ_{noISR}

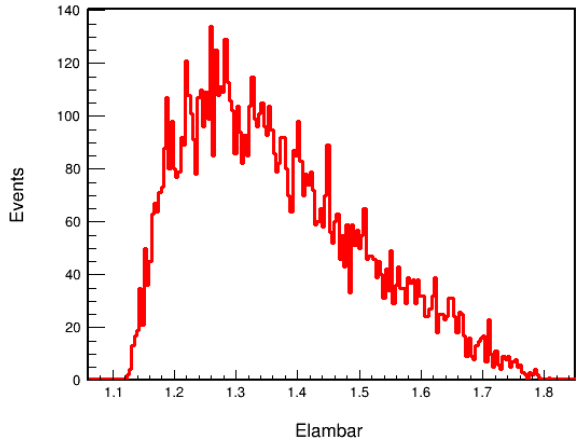


Energy of γ_{ISR}

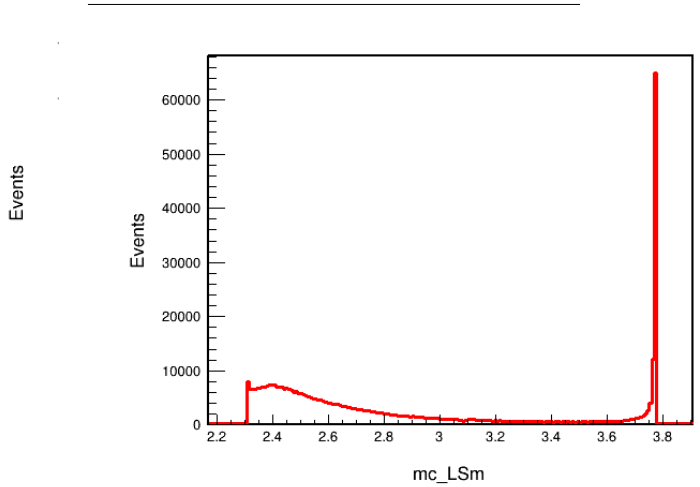


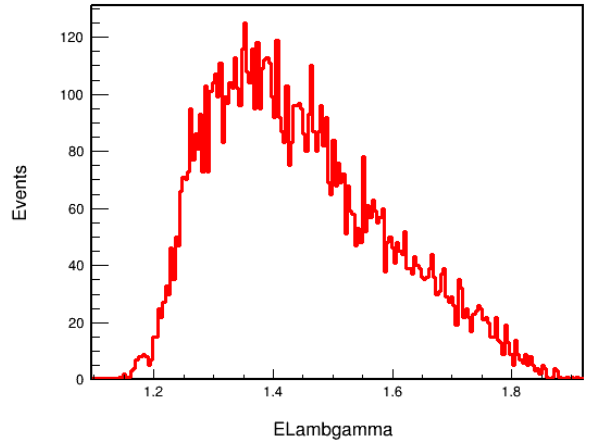
Energy of γ_{noISR}

Output Information

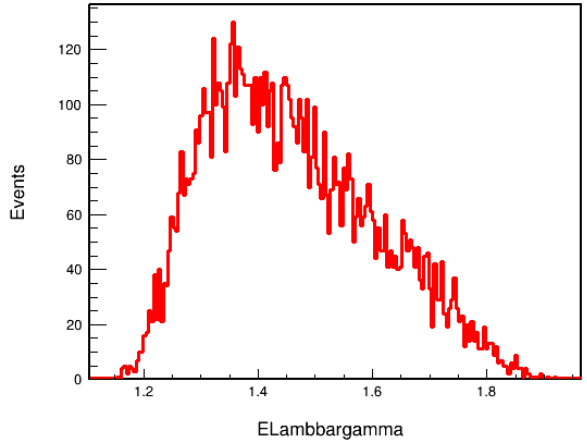


Energy of Λ

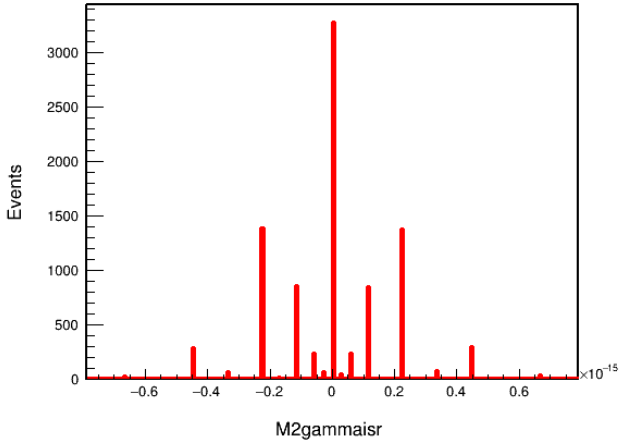




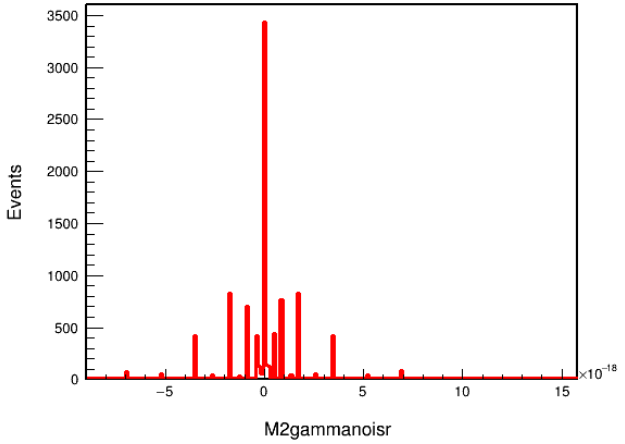
Energy of $\Lambda\gamma_{noISR}$



Energy of $\bar{\Lambda}\gamma_{noISR}$

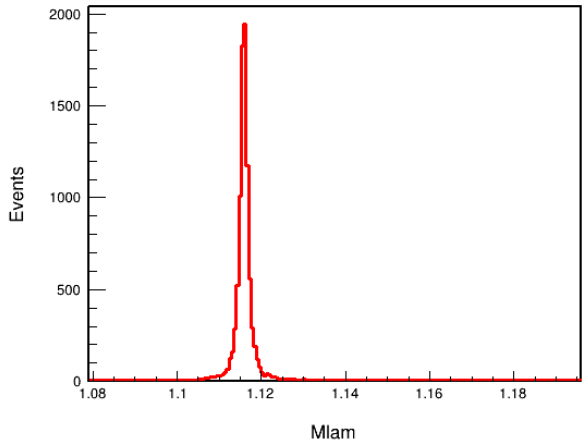


M^2 of γ_{ISR}

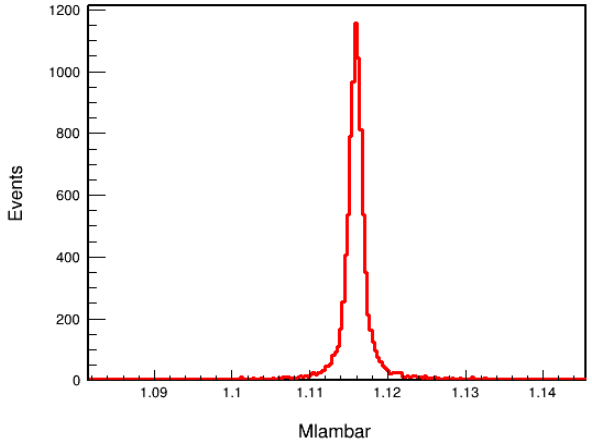


M^2 of γ_{noISR}

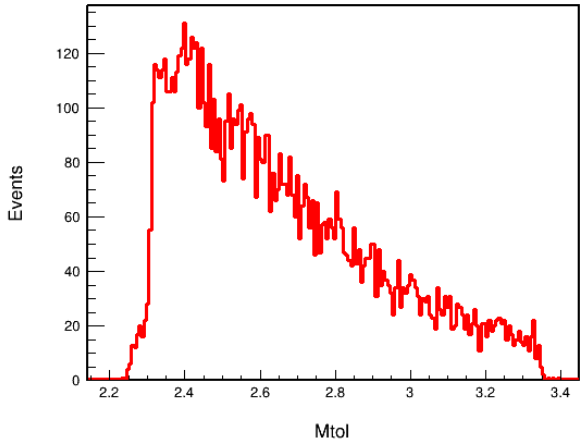
Output Information



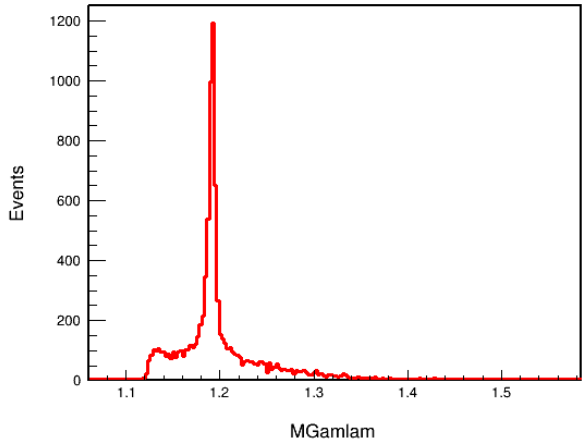
Mass of Λ



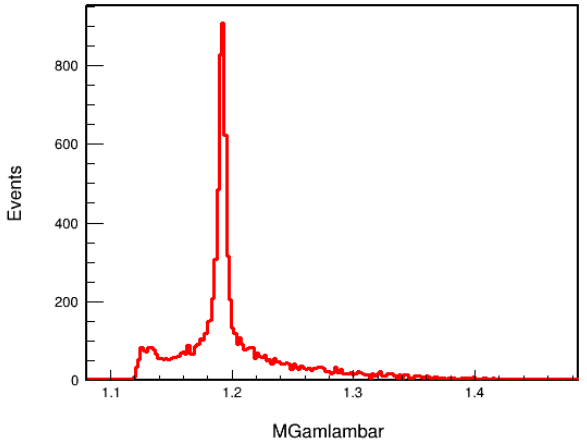
Mass of $\bar{\Lambda}$



Mass of $\Lambda\Sigma$

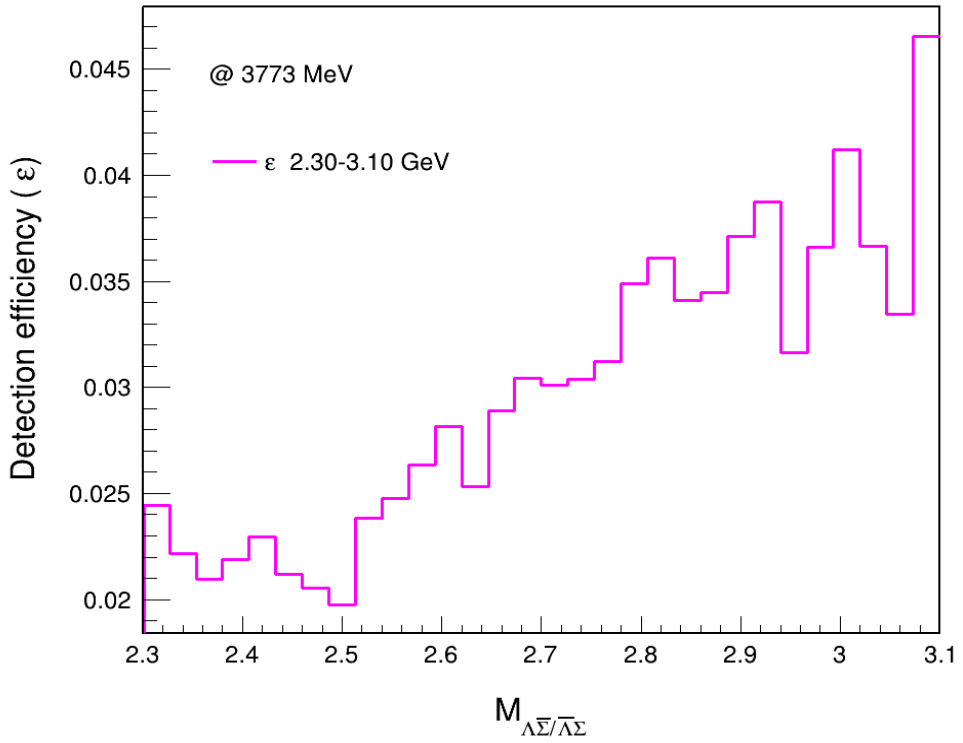


Mass of $\Lambda\gamma_{noISR}$



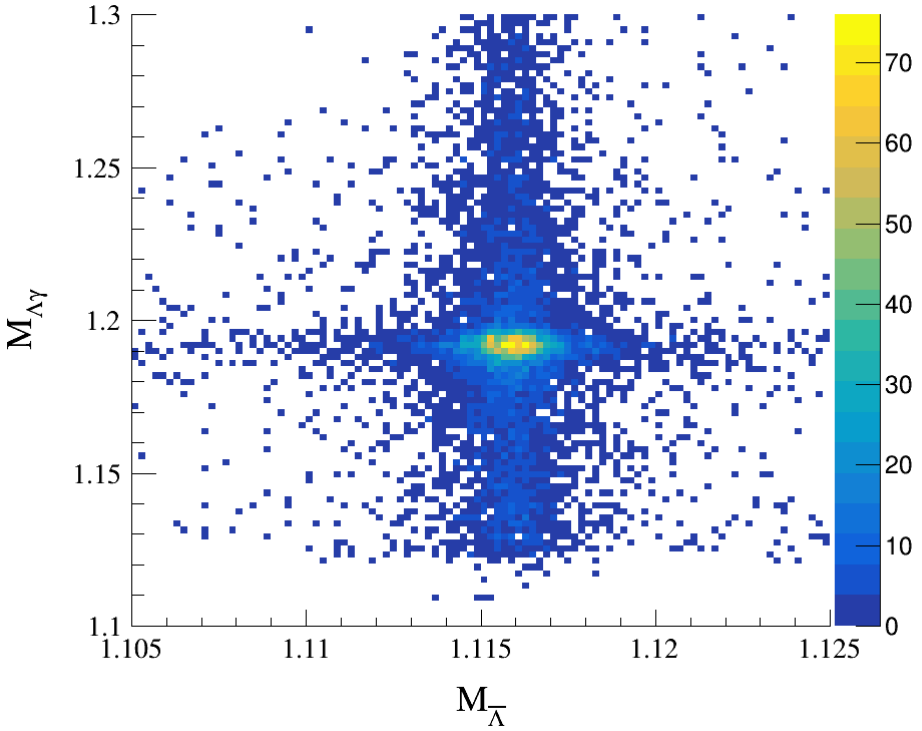
Mass of $\bar{\Lambda}\gamma_{noISR}$

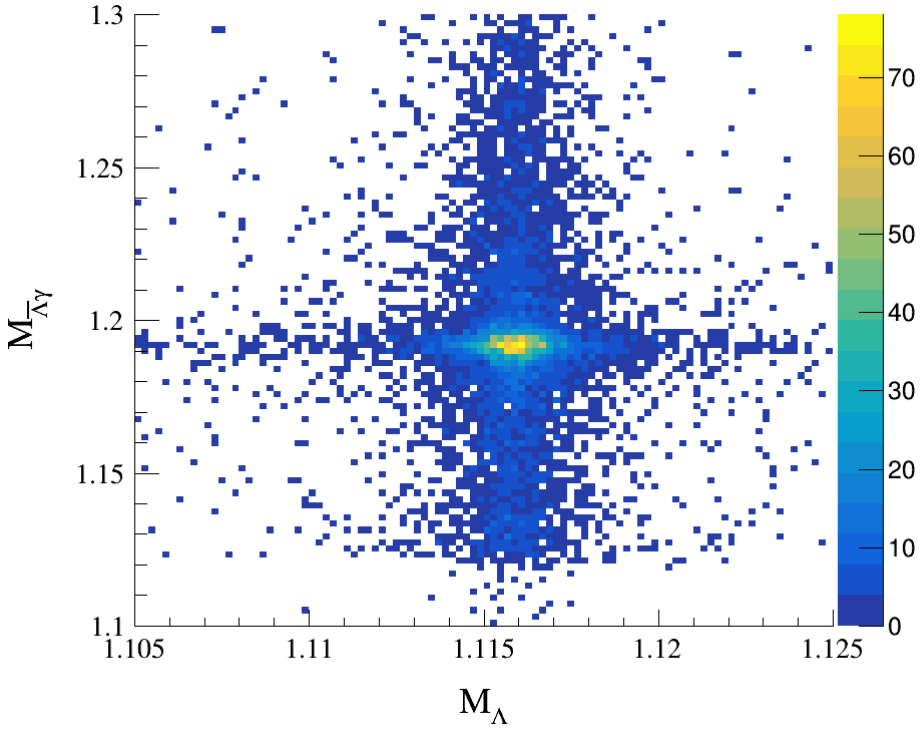
Signal MC


@ 3773 MeV
ε 2.30-3.10 GeV
Detection efficiency (ε)
0.045
0.04
0.035
0.03
0.025
0.02
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
3.1
$M_{\Lambda\bar{\Sigma}/\bar{\Lambda}\Sigma}$

Signal MC

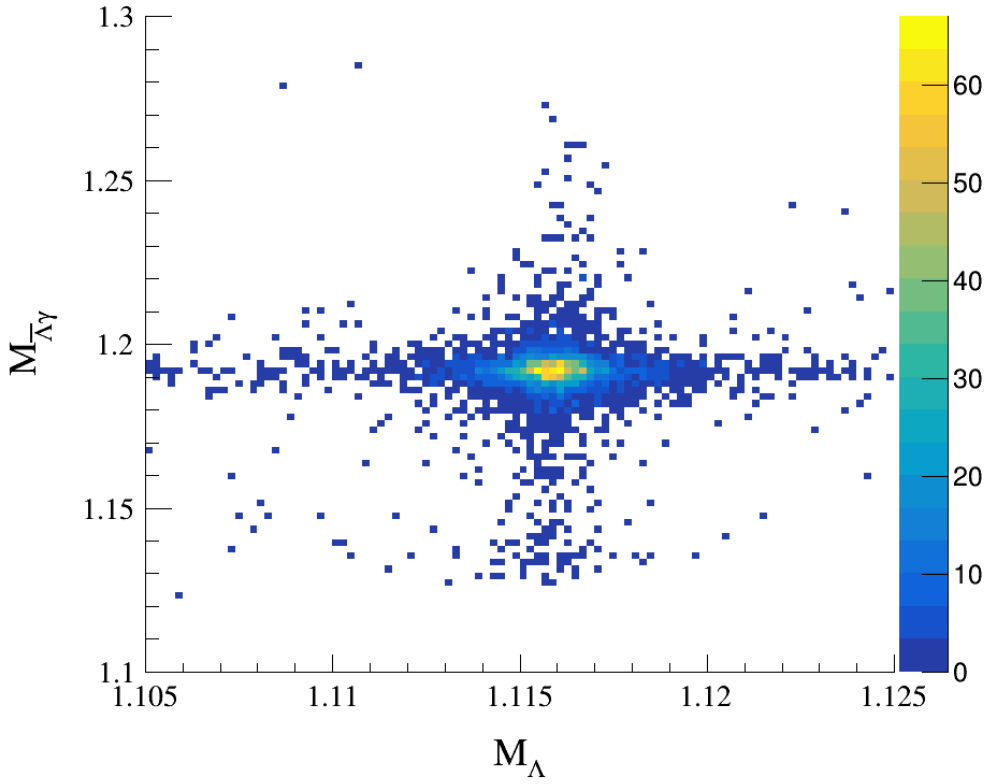
Before distinguishing two channels:

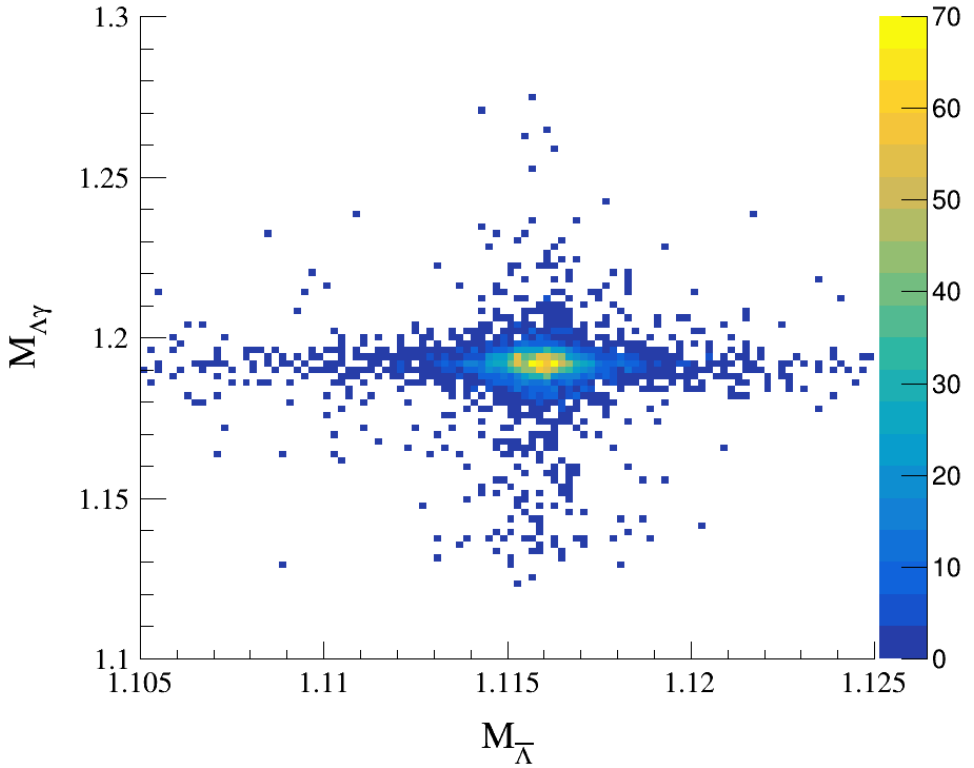




Signal MC

Distinguish two channels by comparing $M_{\Lambda\gamma}$, $M_{\bar{\Lambda}\gamma}$ with $M_{\Sigma/\bar{\Sigma}(PDG)}$





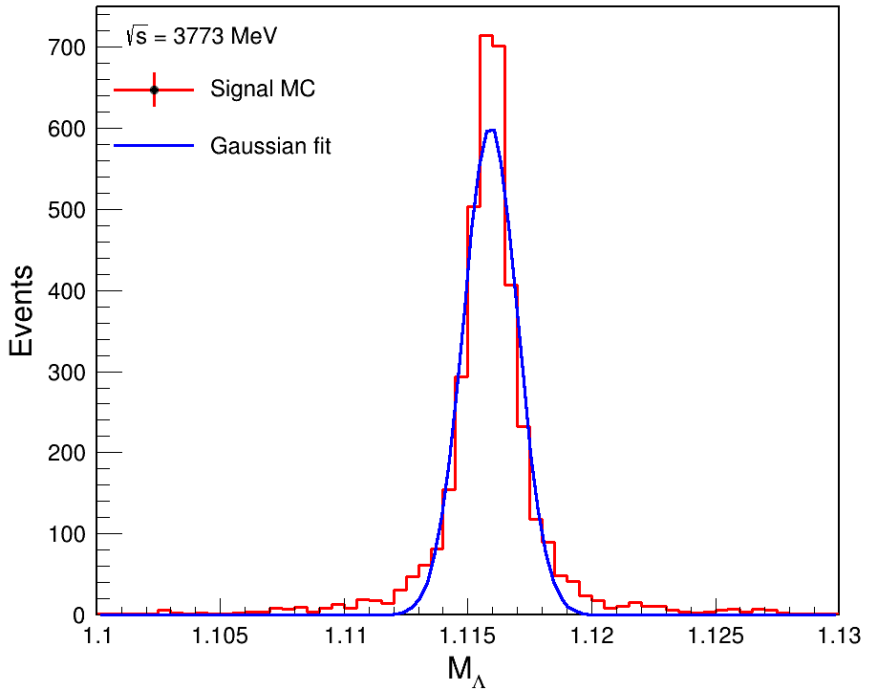
Further Selection

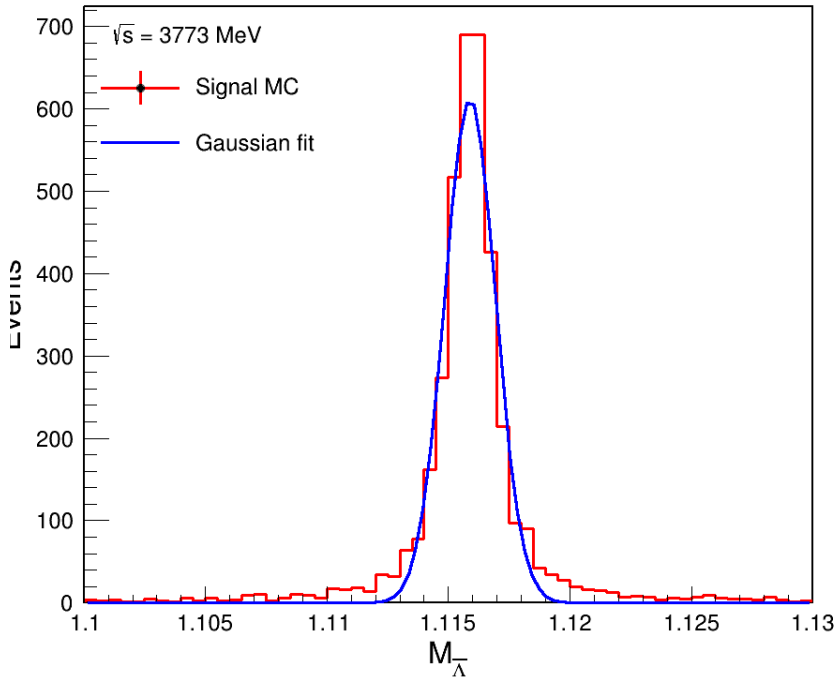
```
FCN=506.428 FROM MIGRAD    STATUS=CONVERGED      108 CALLS         109 TOTAL
                    EDM=6.02471e-10    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1  Constant     6.02338e+02   1.65047e+01   1.15016e-01  -3.02635e-06
  2  Mean         1.11591e+00   1.90852e-05   5.32109e-07  -1.29029e-01
  3  Sigma        1.09865e-03   2.32789e-05   3.20179e-05  -5.33384e-03
```

```
FCN=549.288 FROM MIGRAD    STATUS=CONVERGED
                    EDM=4.99713e-10    STRAT
 EXT PARAMETER
 NO.   NAME      VALUE            ERROR
  1  Constant     6.12139e+02   1.66758e+01
  2  Mean         1.11589e+00   1.86207e-05
  3  Sigma        1.05634e-03   2.20010e-05
```

$$\left|M_{\Lambda/\bar{\Lambda}} - M_{PDG}\right| < 5\sigma$$

$$\left|M_{\Lambda/\bar{\Lambda}} - M_{PDG}\right| < 5.493 \text{ MeV}$$





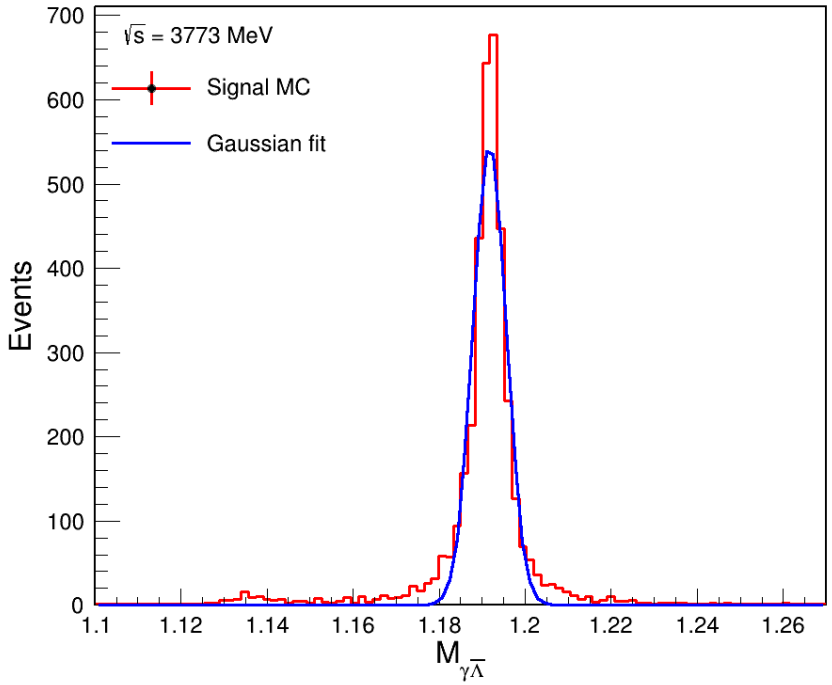
Further Selection

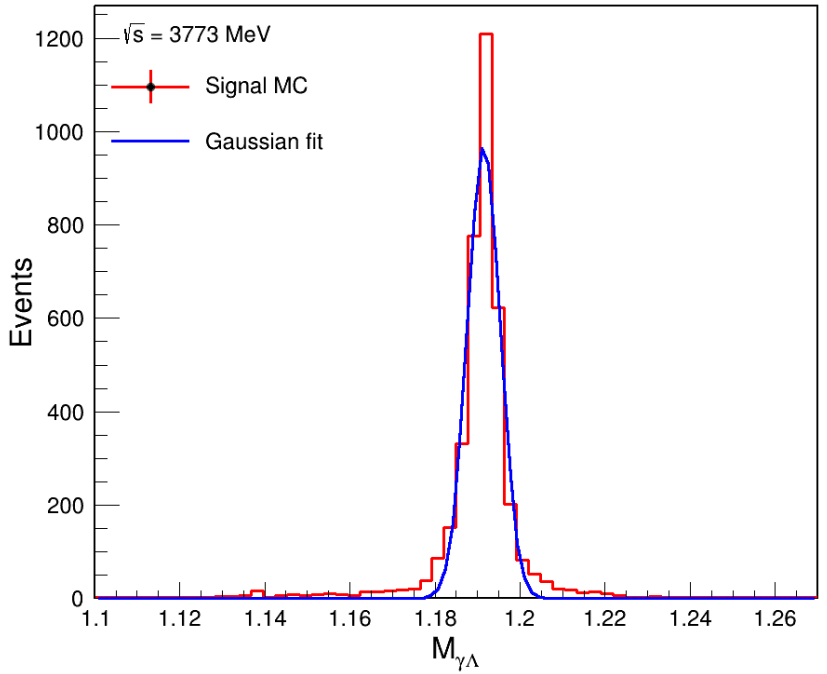
```
FCN=657.239 FROM MIGRAD    STATUS=CONVERGED     127 CALLS         128 TOTAL
                     EDM=2.81408e-09    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1  Constant     5.50223e+02   1.60700e+01   1.23290e-01  -7.28356e-06
  2  Mean         1.19174e+00   7.00315e-05   8.63303e-07   3.03241e-01
  3  Sigma        3.85156e-03   8.88722e-05   3.14733e-05  -2.32313e-02
```

```
                     EDM=3.12644e-09    STRATE
EXT PARAMETER
NO.   NAME      VALUE            ERROR
 1  Constant     9.72512e+02   2.63707e+01
 2  Mean         1.19148e+00   6.87190e-05
 3  Sigma        3.86950e-03   8.07774e-05
```

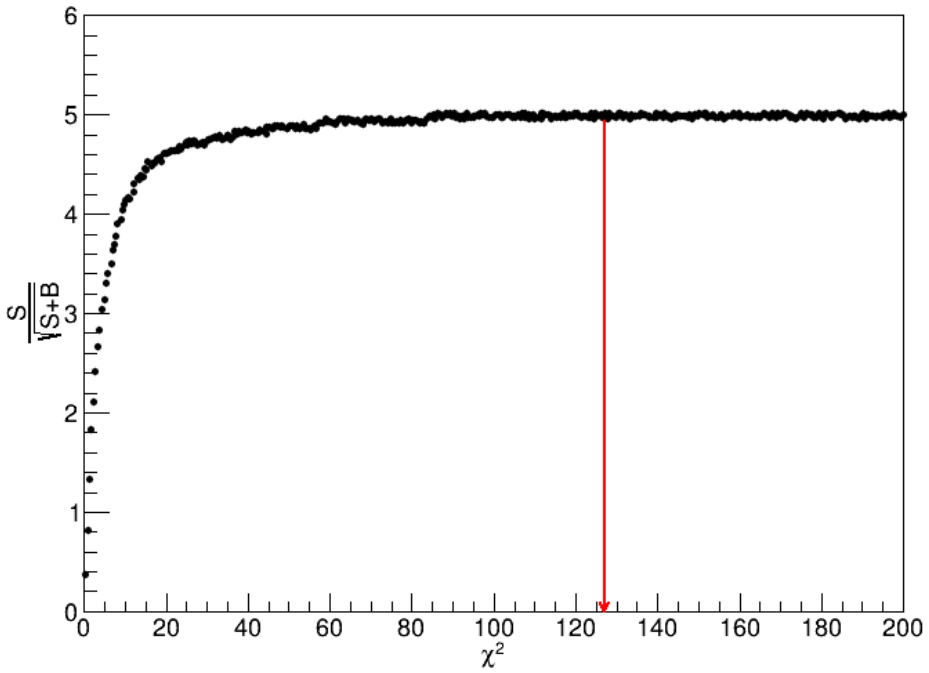
$$\left|M_{\Sigma/\bar{\Sigma}} - M_{PDG}\right| < 5\sigma$$

$$\left|M_{\Sigma/\bar{\Sigma}} - M_{PDG}\right| < 19.348\ \text{MeV}$$





Further Selection



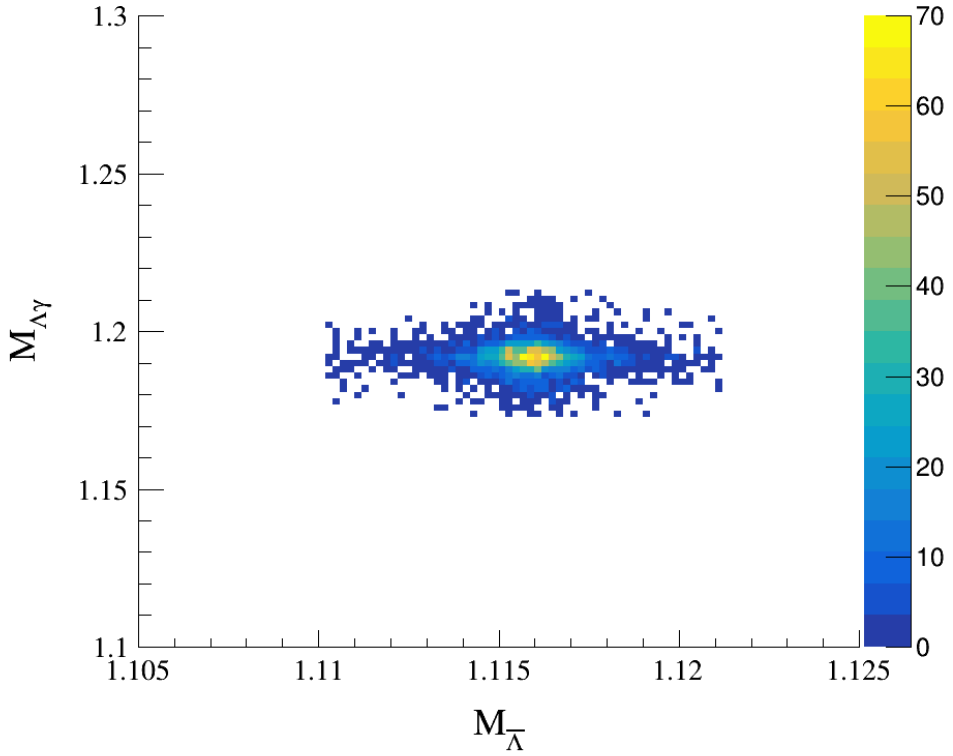
$\chi^2_{4C} < 127$

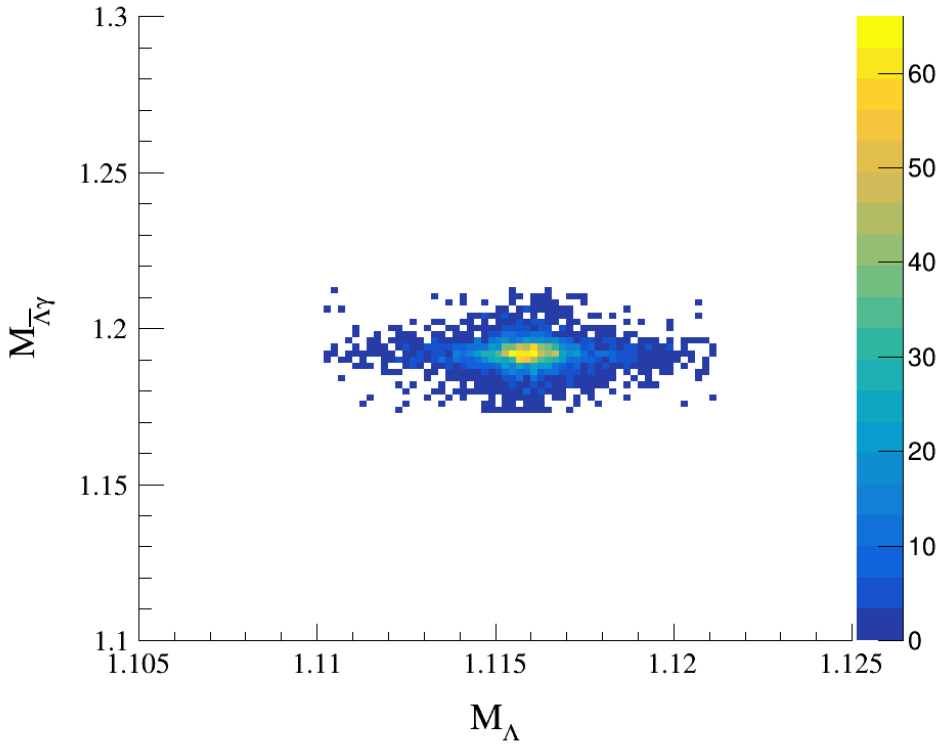
$|M_{\Lambda/\bar{\Lambda}} - M_{PDG}| < 5.493$ MeV

$|M_{\Sigma/\bar{\Sigma}} - M_{PDG}| < 19.348$ MeV

$\chi^2_{4C} < 127$

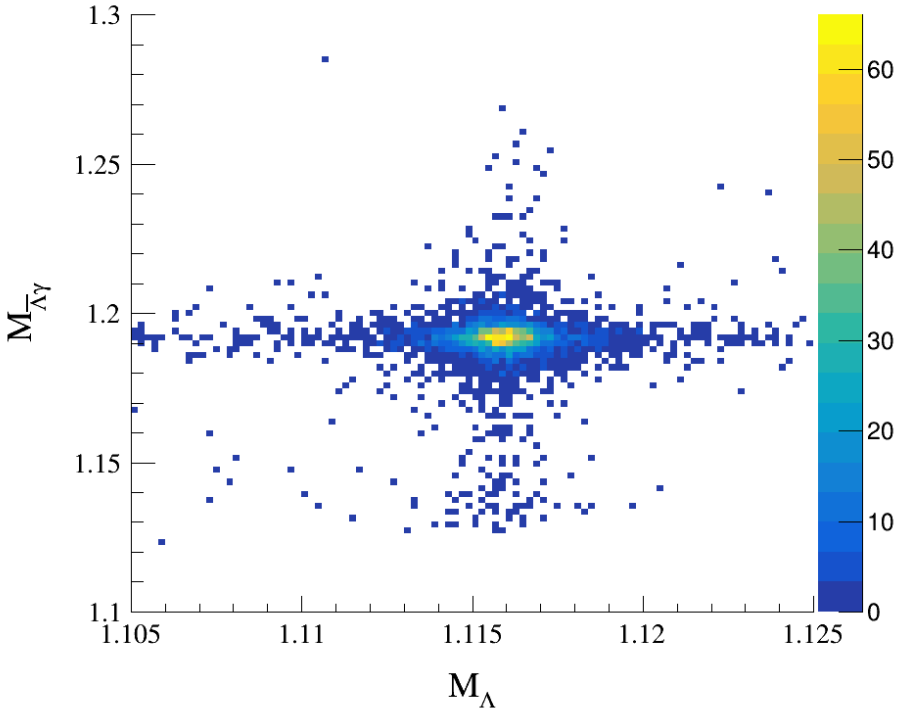
Further Selection





Further Selection

A more relaxed selection strategy:



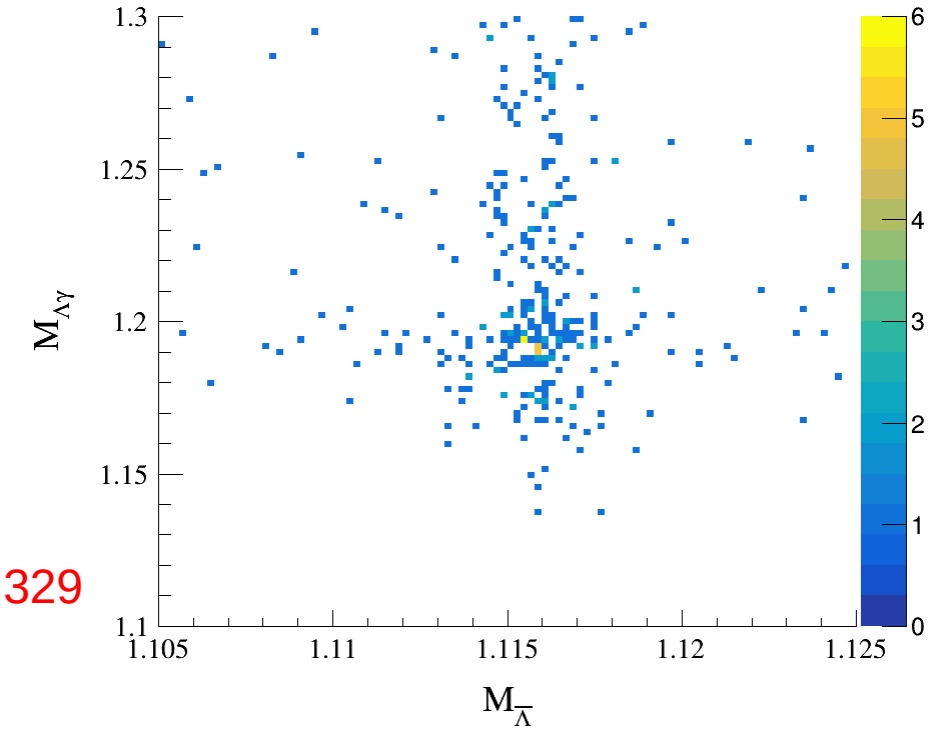
$1.105\ \text{GeV} < M_{\Lambda/\bar{\Lambda}} < 1.125\ \text{GeV}$

$1.12\ \text{GeV} < M_{\Sigma/\bar{\Sigma}} < 1.3\ \text{GeV}$

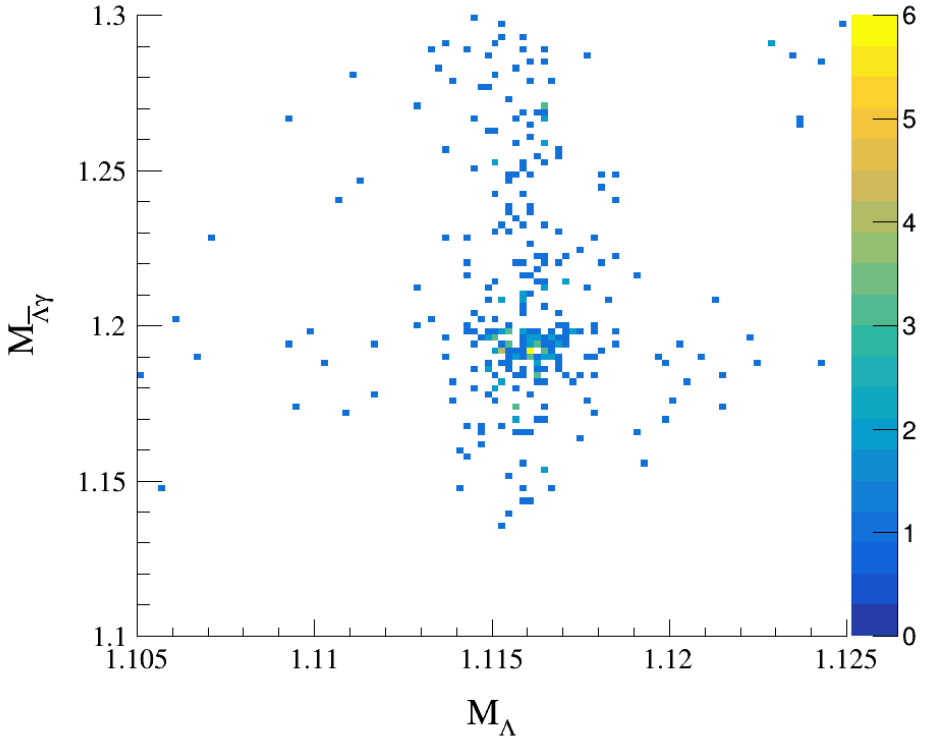
$\chi^2_{4C} < 127$

Data Analysis

Sample	Year	Run range	Luminosity (pb^{-1})
round03	2010	11414 – 13988 14395 – 14604	$2931.8 \pm 0.2 \pm 13.8^a$
round04	2011	20448 – 23454	
round15	2022	70522 – 73929	4995 ± 19^b
round16	2023	74031 – 78536	8157 ± 31^b
round17	2024	78615 – 81094	4191 ± 16^b



N_{event} = 329



N_{event} = 322

Background Analysis

Data Sample	ditau	nonDD	qq	RR2S	RR1S	Bhabha	digamma	dimu
Round0304	0	290	21361	2245	602	0	0	0
Round15	0	422	33867	3519	869	0	0	0
Round16	0	757	56595	5716	1518	0	0	0
Round17	0	376	29168	3028	761	0	0	0
Total	0	1843	140991	14508	3750	0	0	0

Background Analysis

qqbar:

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^-p\bar{p}$	0	20784	20784
2	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^-p\bar{p}$	2	6150	26934
3	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0p\bar{p}$	3	3334	30268
4	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^-p\bar{p}\gamma\gamma$	7	3177	33445
5	$string \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^-p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^-p\bar{p}\gamma$	6	2535	35980
6	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^-p,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^-p\bar{p}\gamma$	8	2469	38449
7	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^-p,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^-p\bar{p}\gamma$	4	2008	40457
8	$string \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^-p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^-p\bar{p}\gamma$	14	1914	42371
9	$string \to \Lambda\bar{\Lambda}, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^-p\bar{p}$	13	1537	43908
10	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu$	$\mu^-\bar{\nu}_\mu\pi^0\pi^+p\bar{p}$	27	1123	45031
11	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^-p\bar{p}\gamma\gamma$	25	805	45836
12	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^-p$	$\pi^0\pi^+\pi^-p\bar{p}\gamma$	24	746	46582
13	$string \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^-p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^-p\bar{p}\gamma$	5	650	47232
14	$string \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+p, \bar{\Delta}^{--} \to \pi^-\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^-p\bar{p}$	10	623	47855
15	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^-p$	$\pi^+\pi^-p\bar{p}\gamma$	49	608	48463
16	$string \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^-p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^-p\bar{p}\gamma$	1	537	49000
17	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu,$ $\pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma\gamma$	18	525	49525
18	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^-p,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^- \to \mu^-\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0p\bar{p}\gamma$	20	480	50005
19	$string \to \Lambda\bar{\Lambda}, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^-p\bar{p}$	42	413	50418
20	$string \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^-p, \bar{\Lambda} \to \pi^+\bar{p},$ $\pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^-p\bar{p}\gamma\gamma$	40	413	50831

Background Analysis

nonDD:

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	0	257	257
2	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	4	85	342
3	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	5	48	390
4	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	25	48	438
5	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}$	16	39	477
6	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma\gamma$	30	23	500
7	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu$	$\mu^-\bar{\nu}_\mu\pi^0\pi^+ p\bar{p}$	38	20	520
8	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	6	19	539
9	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	19	17	556
10	$cluster \to \psi(3770), \psi(3770) \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	2	15	571
11	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	27	15	586
12	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^- \to \mu^-\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}\gamma$	54	10	596
13	$cluster \to \psi(3770), \psi(3770) \to \eta J/\psi, \eta \to \gamma\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	43	9	605
14	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \pi^- \to \mu^-\bar{\nu}_\mu, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}\gamma$	1	7	612
15	$cluster \to \psi(3770), \psi(3770) \to p\bar{p}h_1(1170), h_1(1170) \to \pi^+\rho^-, \pi^+ \to \mu^+\nu_\mu, \rho^- \to \pi^0\pi^-, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	8	7	619
16	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}, \pi^+ \to \mu^+\nu_\mu, \pi^- \to \mu^-\bar{\nu}_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}$	7	6	625
17	$cluster \to \psi(3770), \psi(3770) \to \chi_{c1}\gamma, \chi_{c1} \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	44	6	631

Background Analysis

rr1s:

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma\gamma$	0	372	372
2	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	3	223	595
3	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma$	7	168	763
4	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma\gamma$	2	155	918
5	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	13	74	992
6	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma$	6	73	1065
7	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma\gamma\gamma$	5	68	1133
8	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \eta_c\gamma, \eta_c \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	10	40	1173
9	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	1	35	1208
10	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma$	14	35	1243
11	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma\gamma$	11	31	1274
12	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	31	25	1299
13	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu$	$\mu^-\bar{\nu}_\mu\pi^+ p\bar{p}\gamma\gamma\gamma$	9	23	1322
14	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \eta_c\gamma, \eta_c \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma$	20	15	1337
15	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu$	$\mu^-\bar{\nu}_\mu\pi^+ p\bar{p}\gamma$	8	15	1352
16	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu$	$\mu^-\bar{\nu}_\mu\pi^+ p\bar{p}\gamma\gamma$	21	13	1365

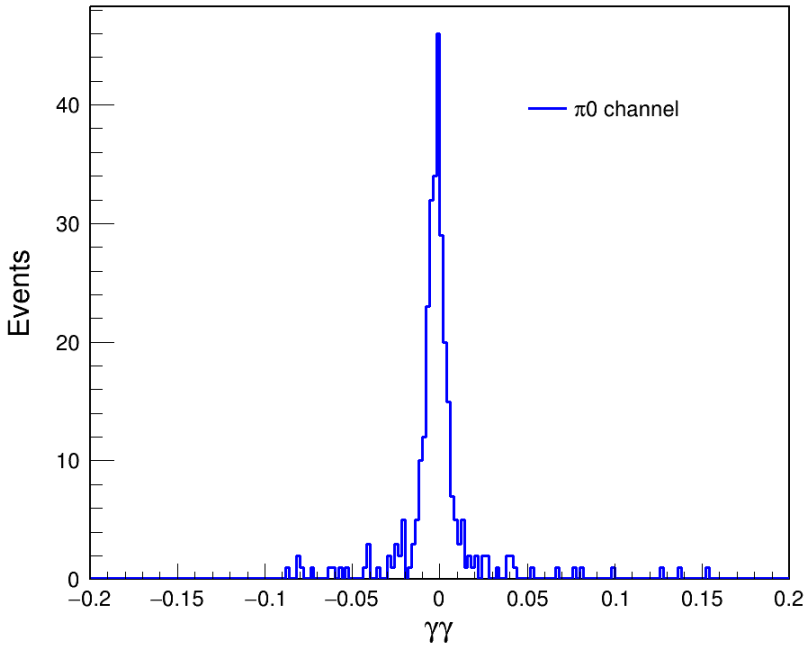
Background Analysis

rr2s:

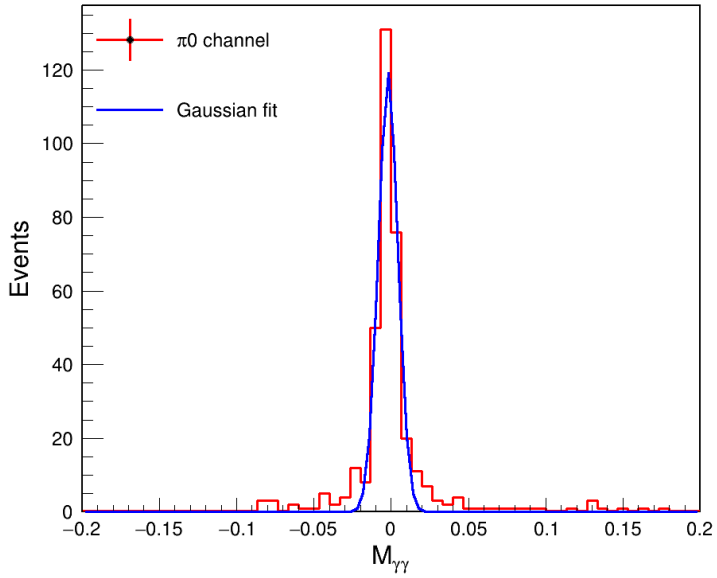
Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	0	3344	3344
2	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma$	2	778	4122
3	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma\gamma$	1	550	4672
4	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu$	$\mu^-\bar{\nu}_\mu\pi^+ p\bar{p}\gamma\gamma$	9	152	4824
5	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \bar{\Lambda}\Sigma^0\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma\gamma$	22	115	4939
6	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \Lambda\bar{\Sigma}^0\gamma, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma\gamma$	10	114	5053
7	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	14	60	5113
8	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \Lambda\bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu$	$\mu^+\nu_\mu\pi^- p\bar{p}\gamma\gamma$	17	49	5162
9	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \Sigma^0\bar{\Sigma}^0\gamma, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma\gamma\gamma$	5	46	5208
10	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \chi_{c2}\gamma, \chi_{c2} \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma\gamma$	6	42	5250
11	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \bar{\Lambda}\Sigma^0\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^+\pi^- p\bar{p}\gamma\gamma\gamma$	36	37	5287
12	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \eta_c\gamma, \eta_c \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	11	29	5316
13	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \Lambda\bar{\Sigma}^0\gamma, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma\gamma$	23	26	5342
14	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \pi^+\pi^- J/\psi, \pi^+ \to \mu^+\nu_\mu, J/\psi \to p\bar{p}\gamma^F, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma^F\gamma$	4	26	5368
15	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \bar{\Lambda}\Sigma^0\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^- \to \mu^-\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma\gamma\gamma$	45	23	5391

Background Analysis




```
 EXT PARAMETER                                   STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1  Constant     1.19179e+02   9.92747e+00   2.99406e-02  -8.70604e-05
  2  Mean        -2.01824e-03   3.86268e-04   1.60513e-06  -1.64238e+00
  3  Sigma        6.38674e-03   3.74553e-04   2.60280e-05   4.17405e-02
Warning in <TCanvas::Constructor>: Deleting canvas with same name: c1
Info in <TCanvas::Print>: png file mlam_fit.png has been created
```



Background Analysis

Data Sample	ditau	nonDD	qq	RR2S	RR1S	Bhabha	digamma	dimu
Round0304	0	290	21361	2245	602	0	0	0
Round15	0	422	33867	3519	869	0	0	0
Round16	0	757	56595	5716	1518	0	0	0
Round17	0	376	29168	3028	761	0	0	0
Total	0	1843	140991	14508	3750	0	0	0

376 -> 80 29168 -> 7619

Background Analysis

nonDD_aftercut:

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	0	12	12
2	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	3	11	23
3	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	18	9	32
4	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	12	6	38
5	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}$	14	3	41
6	$cluster \to \psi(3770), \psi(3770) \to \eta J/\psi, \eta \to \gamma\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	6	3	44
7	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^- \to \mu^-\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}\gamma$	29	3	47
8	$cluster \to \psi(3770), \psi(3770) \to \chi_{c1}\gamma, \chi_{c1} \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	7	2	49
9	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	15	2	51
10	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma\gamma$	10	2	53
11	$cluster \to \psi(3770), \psi(3770) \to \bar{\Lambda}\Sigma^0\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	26	2	55
12	$cluster \to \psi(3770), \psi(3770) \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	2	2	57
13	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \pi^- \to \mu^-\bar{\nu}_\mu, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}\gamma$	1	1	58
14	$cluster \to \psi(3770), \psi(3770) \to K^{*-} p\bar{\Lambda}, K^{*-} \to \pi^-\bar{K}^0, \bar{\Lambda} \to \pi^+\bar{p}, \bar{K}^0 \to K_L^0$	$K_L^0\pi^+\pi^- p\bar{p}$	13	1	59
15	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	4	1	60
16	$cluster \to \psi(3770), \psi(3770) \to \chi_{c1}\gamma, \chi_{c1} \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma\gamma$	8	1	61

Background Analysis

nonDD_before:

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	0	257	257
2	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	4	85	342
3	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	5	48	390
4	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	25	48	438
5	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}$	16	39	477
6	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma\gamma$	30	23	500
7	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu$	$\mu^-\bar{\nu}_\mu\pi^0\pi^+ p\bar{p}$	38	20	520
8	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	6	19	539
9	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	19	17	556
10	$cluster \to \psi(3770), \psi(3770) \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	2	15	571
11	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	27	15	586
12	$cluster \to \psi(3770), \psi(3770) \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^- \to \mu^-\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}\gamma$	54	10	596
13	$cluster \to \psi(3770), \psi(3770) \to \eta J/\psi, \eta \to \gamma\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	43	9	605
14	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \pi^- \to \mu^-\bar{\nu}_\mu, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}\gamma$	1	7	612
15	$cluster \to \psi(3770), \psi(3770) \to p\bar{p}h_1(1170), h_1(1170) \to \pi^+\rho^-, \pi^+ \to \mu^+\nu_\mu, \rho^- \to \pi^0\pi^-, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	8	7	619
16	$cluster \to \psi(3770), \psi(3770) \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}, \pi^+ \to \mu^+\nu_\mu, \pi^- \to \mu^-\bar{\nu}_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}$	7	6	625
17	$cluster \to \psi(3770), \psi(3770) \to \chi_{c1}\gamma, \chi_{c1} \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	44	6	631

Background Analysis

qqbar_aftercut:

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	3	995	995
2	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	10	701	1696
3	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma$	18	636	2332
4	$string \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma$	5	577	2909
5	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	31	569	3478
6	$string \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	0	504	3982
7	$string \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}$	17	467	4449
8	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma$	23	269	4718
9	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^+\pi^- p\bar{p}\gamma$	42	212	4930
10	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	54	195	5125
11	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	16	185	5310
12	$string \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	2	172	5482
13	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma\gamma$	41	170	5652
14	$string \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	4	143	5795
15	$string \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}$	39	126	5921
16	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}$	15	124	6045
17	$string \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	8	120	6165
18	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^- \to \mu^-\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma$	27	101	6266

Background Analysis

qqbar_before:

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	0	20784	20784
2	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	2	6150	26934
3	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}$	3	3334	30268
4	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma\gamma$	7	3177	33445
5	$string \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	6	2535	35980
6	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}\gamma$	8	2469	38449
7	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma$	4	2008	40457
8	$string \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}\gamma$	14	1914	42371
9	$string \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^- p\bar{p}$	13	1537	43908
10	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu$	$\mu^-\bar{\nu}_\mu\pi^0\pi^+ p\bar{p}$	27	1123	45031
11	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma$	25	805	45836
12	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	24	746	46582
13	$string \to \pi^0\Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	5	650	47232
14	$string \to \pi^0\Delta^{++}\bar{\Delta}^{--}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{--} \to \pi^-\bar{p}, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^- p\bar{p}$	10	623	47855
15	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^+\pi^- p\bar{p}\gamma$	49	608	48463
16	$string \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	1	537	49000
17	$string \to \eta\Lambda\bar{\Lambda}, \eta \to \gamma\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}, \pi^- \to \mu^-\bar{\nu}_\mu,$ $\pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu p\bar{p}\gamma\gamma$	18	525	49525
18	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \pi^+ \to \mu^+\nu_\mu, \Lambda \to \pi^- p,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^- \to \mu^-\bar{\nu}_\mu$	$e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^0 p\bar{p}\gamma$	20	480	50005
19	$string \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}$	42	413	50418