

Study of $e^+e^- \rightarrow \phi\Lambda\bar{\Lambda}$ with XYZ data

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Outline

- Motivation
- Data sample
- Event selection
- Study of background
- Efficiency & problems
- Fitting result
- Summary & Next to do

Motivation

1. The study of XYZ states is a hot topic in recent years. Many vector charmonium-(like) states have been discovered in the open charm energy region, i.e. Y(4220), Y(4230), Y(4260), Y(4360). The nature of the states remains mystery to us. The analysis on more decay channels are necessary to be performed.
2. The discovery of penta-quark states, $P_c(4380)$, $P_c(4450)$, inspired greatly the search for other penta-quark states. $\phi\Lambda(\bar{\Lambda})$ would be a good opportunity to search for P_s .

Data Set

- Boss version: 703
- Signal MC: 50,000 for each decay channel at each energy point
- Inclusive MC: 5 Streams (hadron only)
- Decay Channel:

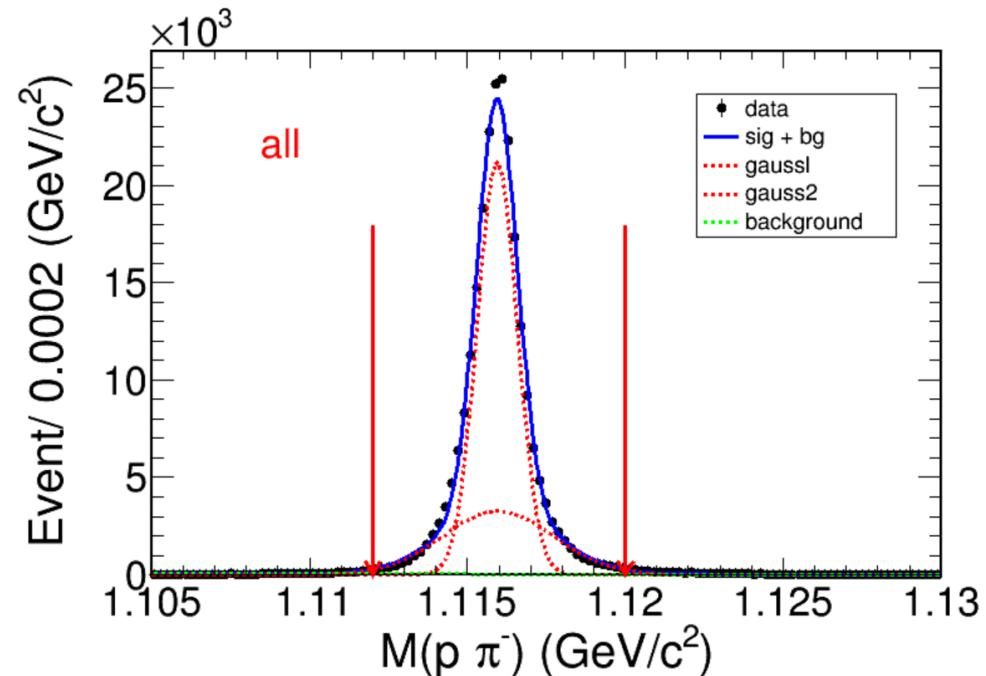
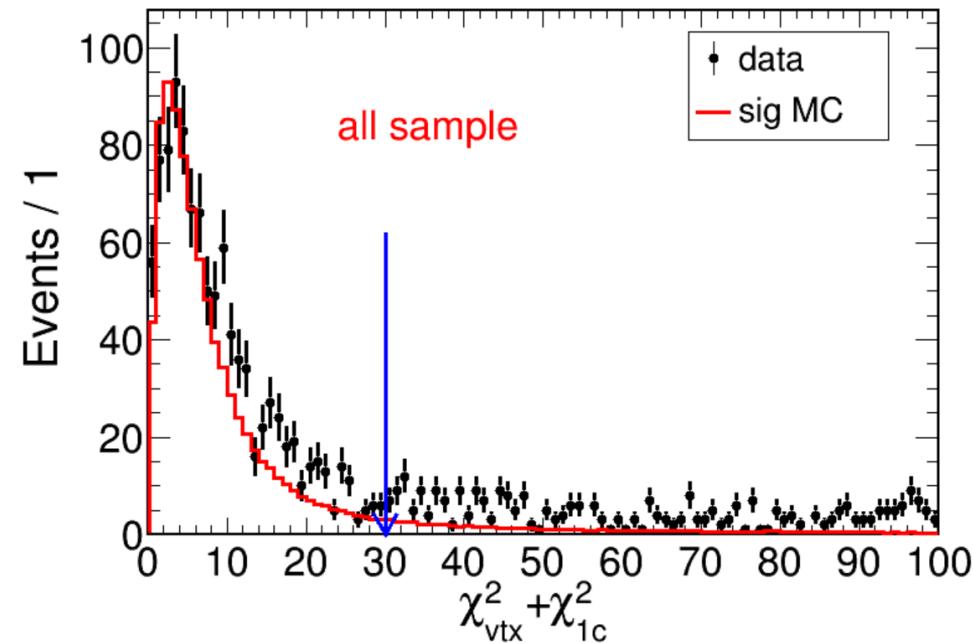
$e^+ e^- \rightarrow \phi \Lambda \bar{\Lambda}$	PHSP
$\phi \rightarrow K^+ K^-$	PHSP
$\Lambda \rightarrow p \pi^-$	PHSP
$\bar{\Lambda} \rightarrow \bar{p} \pi^+$	VLL

Sample	$\sqrt{s}(\text{GeV})$	Luminosity(pb^{-1})
4009	4007.62	482
4180	4178.37	3160
4190	4188.8	565.83
4200	4198.9	524.6
4210	4209.2	573.05
4220	4218.7	568.9
4230	4226.26	1100.94
4237	4235.7	530.6
4246	4243.8	537.4
4260	4257.97	828.4
4270	4266.8	529.7
4280	4277.7	175.5
4360	4358.26	543.9
4420	4415.58	1090.7
4600	4599.53	586.9

Event selection(1)

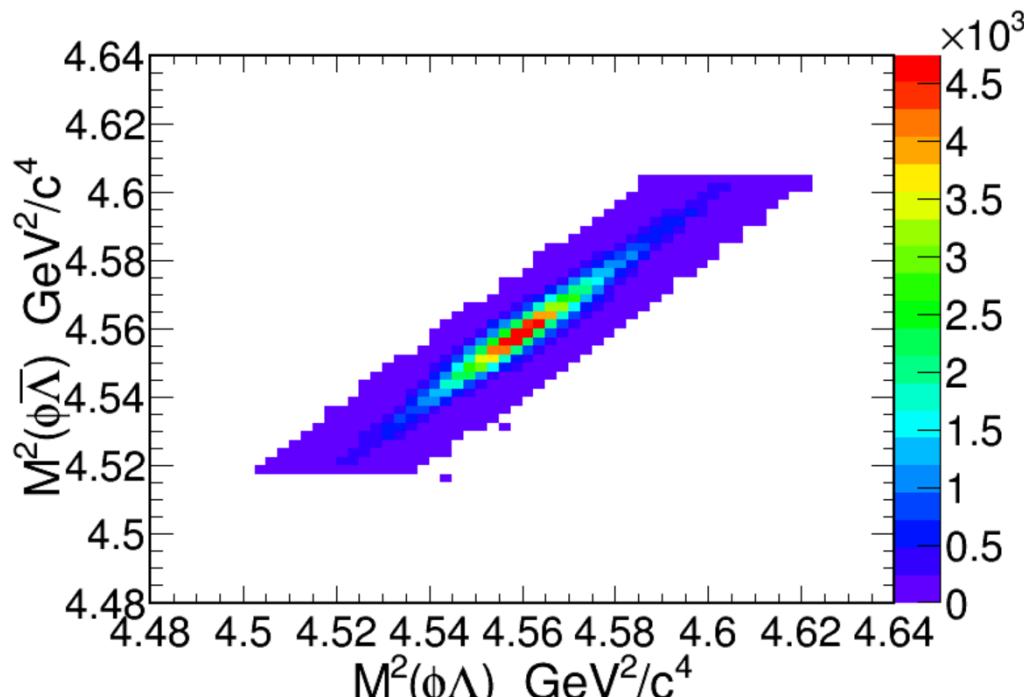
- **Charged Tracks**
 - $|Vz| \leq 20.0 \text{ cm}$, $|Vxy| \leq 10 \text{ cm}$
 - $|\cos\theta| \leq 0.93$
 - $N_{\text{charg}} \geq 4$
- **PID**
 - at least two kaons with opposite charge, one proton and one pion with opposite charge.
- **vertex fit**
 - The proton and the pion selected from PID are come from the same point.
 - The Lambda or Lambda-bar candidates are come from the collision vertex, And the $dL/dLe > 2$.
- **1C kinematic fit**
 - Constraint the missing mass to Lambda's nominal mass.
 - Combination with least $\chi^2_{1C} + \chi^2_{vtx}$ is saved.

Event selection(2)

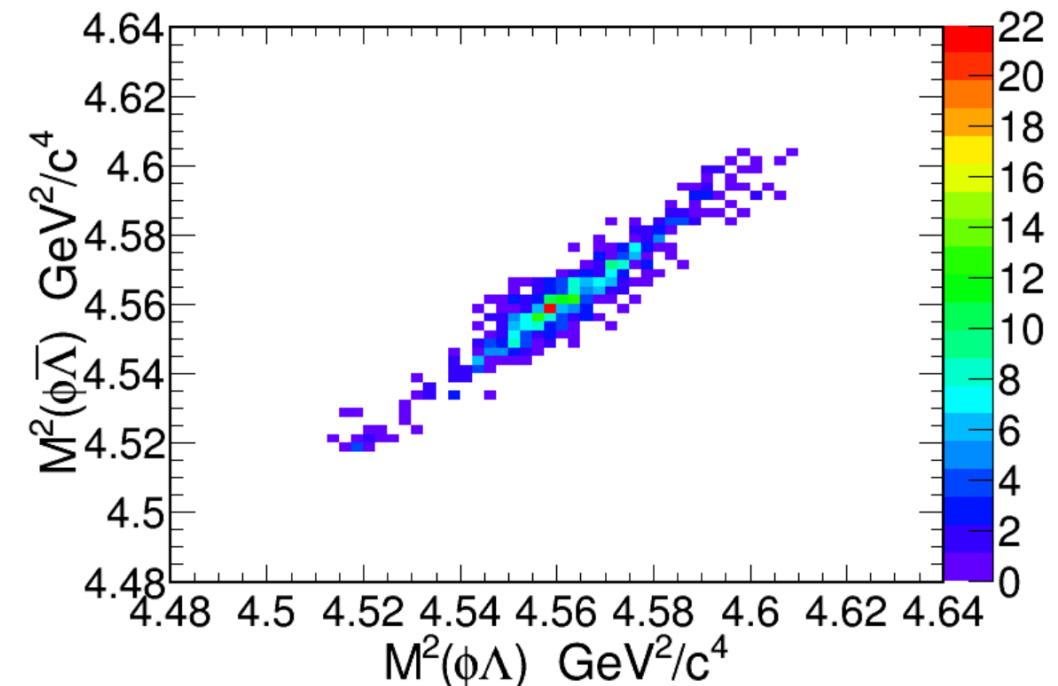


$\chi^2_{\text{vtx}} + \chi^2_{1c} < 30$, and the mass window of $p\pi$ is [1.112, 1.12]

Study of Background (1)

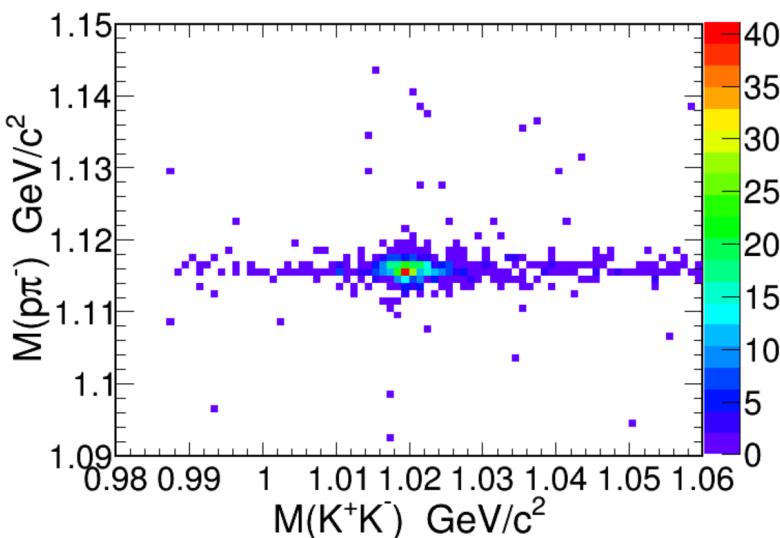


Sig MC

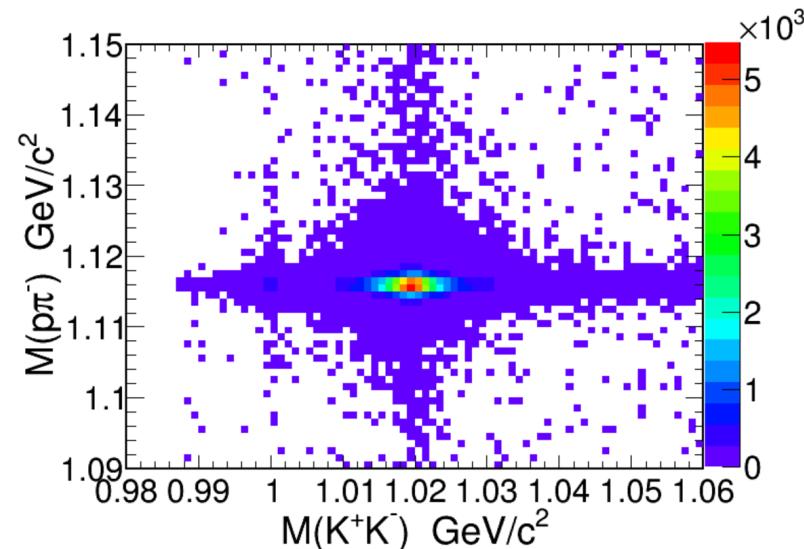


Data

Study of Background (2)



data



inclusive MC

There are very clear clusters of $\phi\Lambda(\bar{\Lambda})$ in both experimental data and inclusive MC sample.

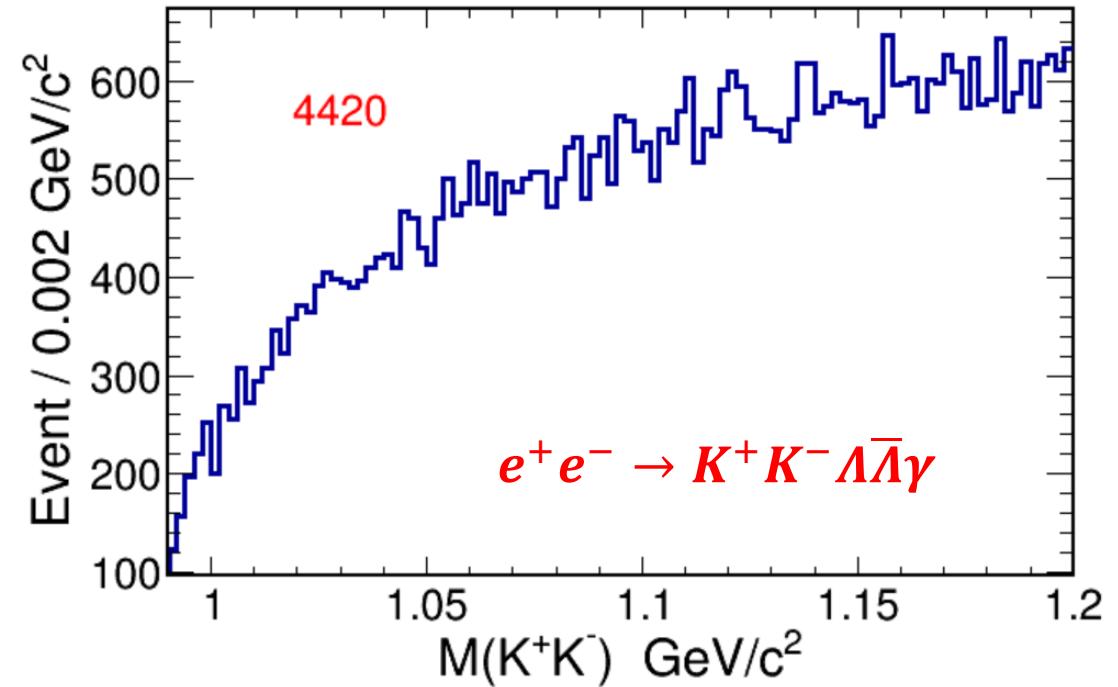
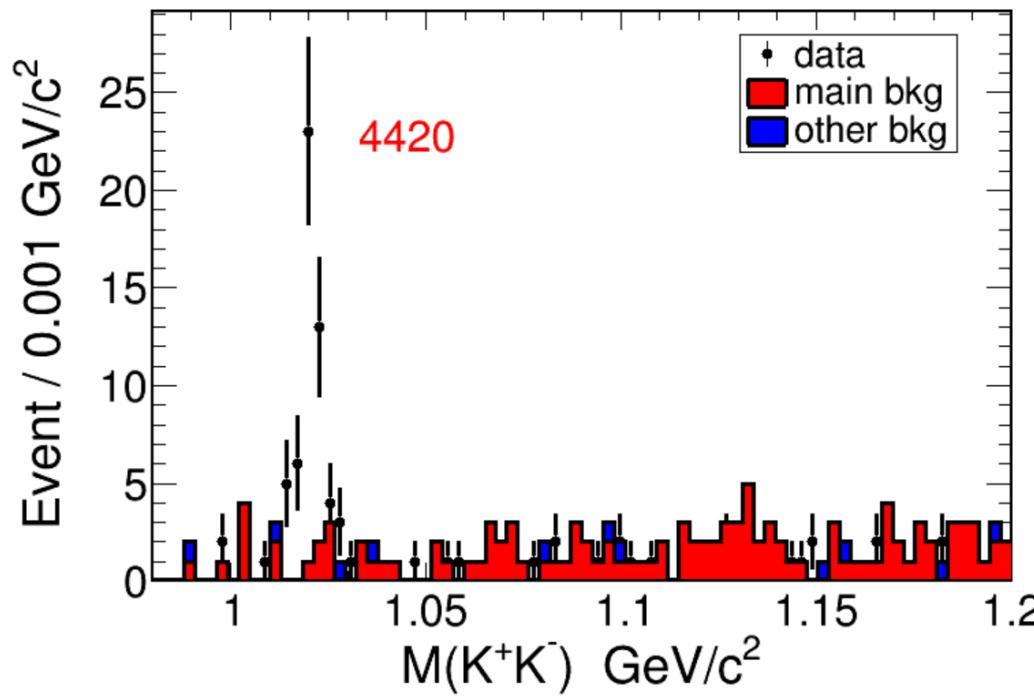
Study of Background (3)

Inclusive MC for ecm4420

Background	Different Final States	nEvts	nCmltEvts
Main Background $e^+e^- \rightarrow K^+K^-\Lambda\bar{\Lambda}\gamma$	$\Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \bar{p}\pi^+$ $\Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \pi^0\bar{n}$ $\Lambda \rightarrow \pi^0n, \bar{\Lambda} \rightarrow \bar{p}\pi^+$	62 27 23	112
$e^+e^- \rightarrow K^+K^-\bar{\Lambda}\Sigma^0\gamma$	$\bar{\Lambda} \rightarrow \pi^0\bar{n}, \Sigma^0 \rightarrow \Lambda\gamma, \Lambda \rightarrow p\pi^-$ $\bar{\Lambda} \rightarrow \bar{p}\pi^+, \Sigma^0 \rightarrow \Lambda\gamma, \Lambda \rightarrow \pi^0n$	1 1	114
$e^+e^- \rightarrow K^+K^-\Lambda\bar{\Sigma}^0\gamma$	$\Lambda \rightarrow p\pi^-, \bar{\Sigma}^0 \rightarrow \bar{\Lambda}\gamma, \bar{\Lambda} \rightarrow \bar{p}\pi^+$ $\Lambda \rightarrow \pi^0n, \bar{\Sigma}^0 \rightarrow \bar{\Lambda}\gamma, \bar{\Lambda} \rightarrow \bar{p}\pi^+$	1 1	116
$e^+e^- \rightarrow \pi^0K^+K^-\Lambda\bar{\Lambda}\gamma$	$\Lambda \rightarrow p\pi^-, \bar{\Lambda} \rightarrow \pi^0\bar{n}$	1	117
$e^+e^- \rightarrow f_2(1270)K^-\Lambda\gamma$	$f_2(1270) \rightarrow \pi^+\pi^-, \Lambda \rightarrow \bar{p}\pi^+$	1	118
$e^+e^- \rightarrow \pi^0\pi^0\psi'$	$\psi' \rightarrow \chi_{c0}\gamma, \chi_{c0} \rightarrow K^*\bar{K}^*\phi,$	1	119
$e^+e^- \rightarrow \pi^+\pi^-\pi^-a_2^+K^+K^-\gamma$	$a_2^+ \rightarrow \rho^0\pi^+, \rho^0 \rightarrow \pi^+\pi^-$	1	120
$e^+e^- \rightarrow \pi^+D^-D^0\gamma$	$D^- \rightarrow \pi^0\pi^-K^+K^-, D^0 \rightarrow \pi^0\pi^+K^-$	1	121
$e^+e^- \rightarrow K^+K^-J/\psi$	$K^+ \rightarrow \mu^+\nu_\mu, J/\psi \rightarrow \Lambda\bar{\Lambda}$	1	122

Study of Background (4)

There is no peaking background.

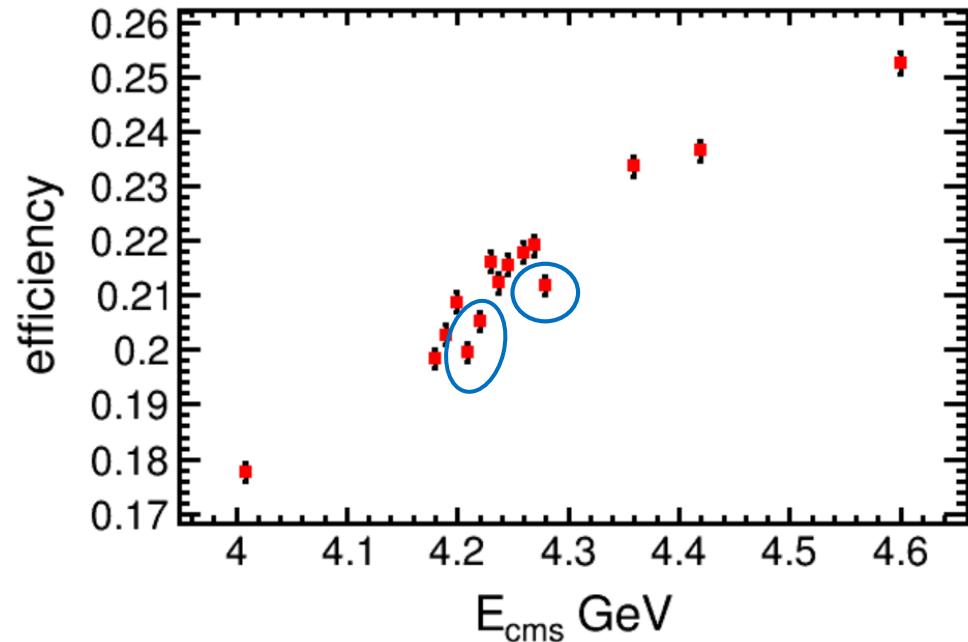


Left plot shows the distribution of main background and other background.

Right plot is the distribution of the 1 million main background MC sample in the fitting range.

Efficiency & problems(1)

sample	$\varepsilon(\%)$
4009	17.79 ± 0.17
4180	19.86 ± 0.18
4190	20.28 ± 0.18
4200	20.89 ± 0.18
4210	19.96 ± 0.18
4220	20.54 ± 0.18
4230	21.63 ± 0.18
4237	21.25 ± 0.18
4246	21.58 ± 0.18
4260	21.81 ± 0.18
4270	21.92 ± 0.18
4280	21.20 ± 0.18
4360	23.38 ± 0.19
4420	23.68 ± 0.19
4600	25.27 ± 0.19



The reconstruction efficiency behave abnormally at $\sqrt{s} = 4.210, 4.220$, and 4.280 GeV

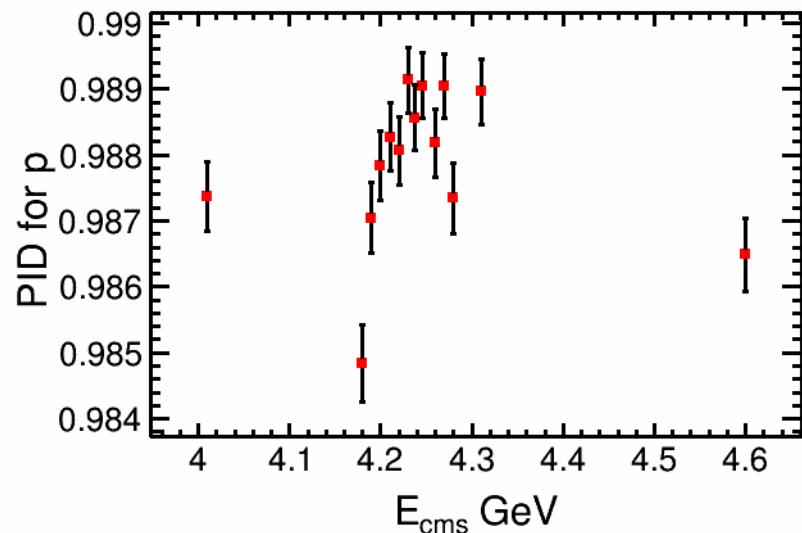
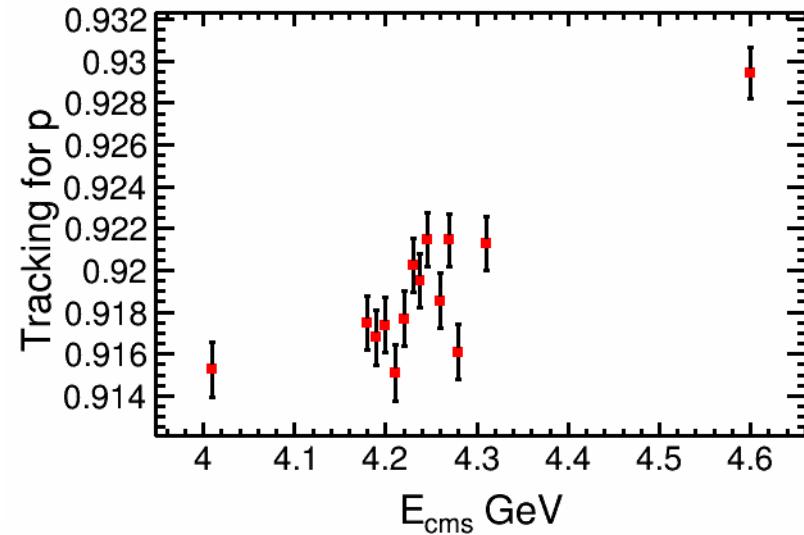
Efficiency & problems(2)

Cut flow

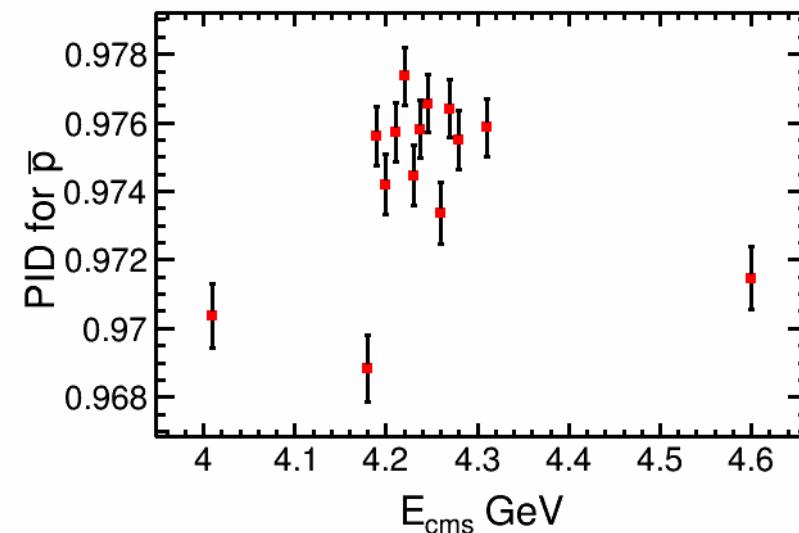
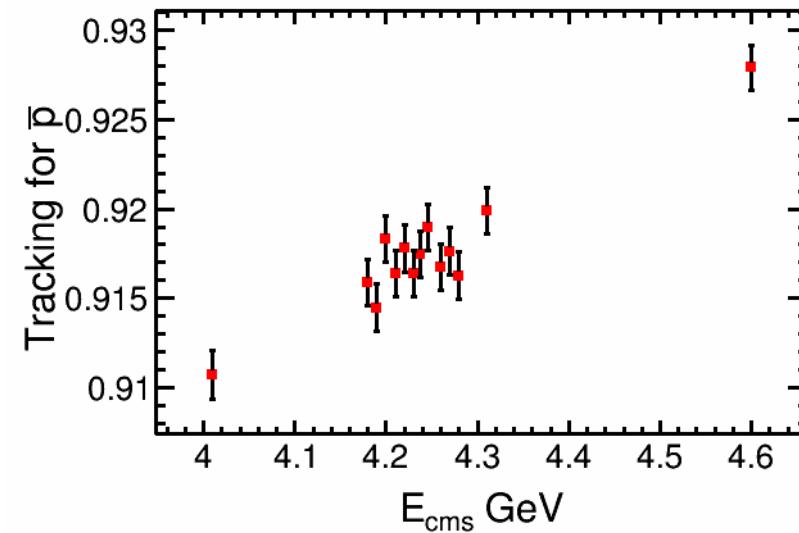
sample	4 tracks	Vertex & PID	$\chi^2_{vtx} + \chi^2_{1c}$	$\chi^2_{vtx} + \chi^2_{1c} < 30$	$\chi^2_{vtx} + \chi^2_{1c} < 30 \text{ &} M(p\pi) \in [1.112, 1.12] GeV$
4009	63.02%	50.84%	77.12%	74.71%	96.34%
4180	63.10%	53.26%	80.02%	75.90%	97.30%
4190	63.03%	55.93%	78.81%	75.23%	97.04%
4200	63.36%	56.58%	80.44%	74.68%	96.98%
4210	62.30%	56.10%	79.34%	74.38%	96.75%
4220	62.68%	56.16%	79.57%	75.51%	97.12%
4230	64.13%	56.33%	80.68%	76.49%	97.02%
4237	63.52%	56.82%	80.12%	75.80%	96.94%
4246	63.51%	57.54%	80.78%	75.56%	96.75%
4260	64.39%	57.07%	80.25%	76.20%	97.03%
4270	64.05%	58.27%	80.10%	75.54%	97.06%
4280	63.06%	57.48%	79.95%	75.46%	96.94%
4360	64.94%	59.16%	81.32%	77.17%	96.98%
4420	65.14%	59.03%	81.63%	77.56%	97.26%
4600	65.48%	60.65%	83.37%	78.68%	97.03%

Efficiency & problems(3)

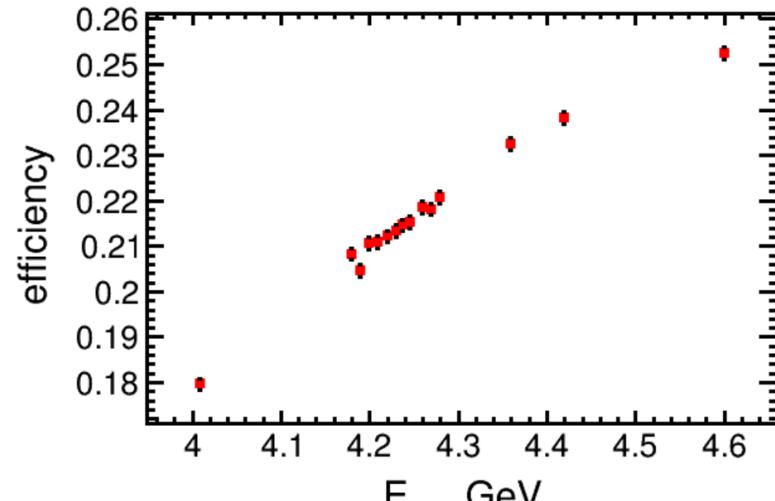
sigMC



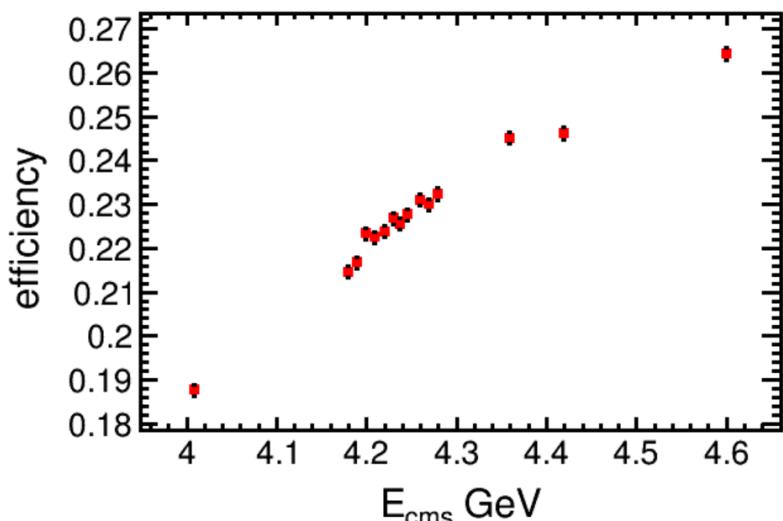
Control sample: $e^+e^- \rightarrow pp\pi\pi$



Efficiency & problems(4)



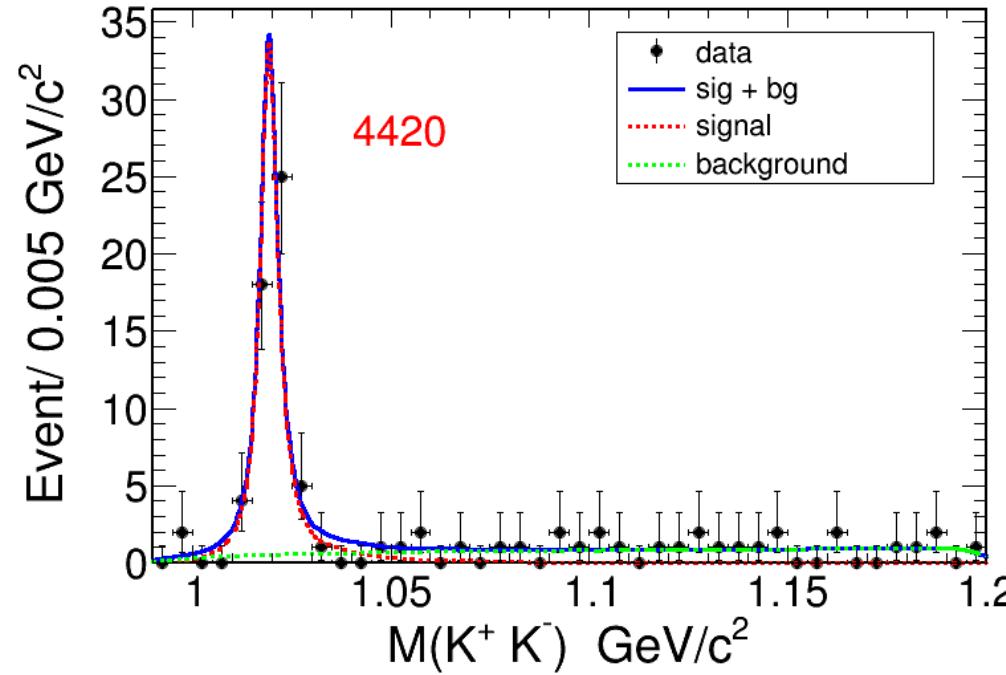
One point run number



no beam background

sample	One Run No. $\varepsilon(\%)$	No Beam Bkg $\varepsilon(\%)$
4009	17.97 ± 0.12	18.76 ± 0.13
4180	20.83 ± 0.13	21.45 ± 0.13
4190	20.46 ± 0.13	21.68 ± 0.13
4200	21.07 ± 0.13	22.33 ± 0.13
4210	21.09 ± 0.13	22.25 ± 0.13
4220	21.22 ± 0.13	22.38 ± 0.13
4230	21.34 ± 0.13	22.68 ± 0.13
4237	21.47 ± 0.13	22.55 ± 0.13
4246	21.53 ± 0.13	22.76 ± 0.13
4260	21.86 ± 0.13	23.10 ± 0.13
4270	21.82 ± 0.13	22.99 ± 0.13
4280	22.08 ± 0.13	23.23 ± 0.13
4360	23.26 ± 0.13	24.51 ± 0.13
4420	23.83 ± 0.13	24.61 ± 0.13
4600	25.24 ± 0.14	26.43 ± 0.13

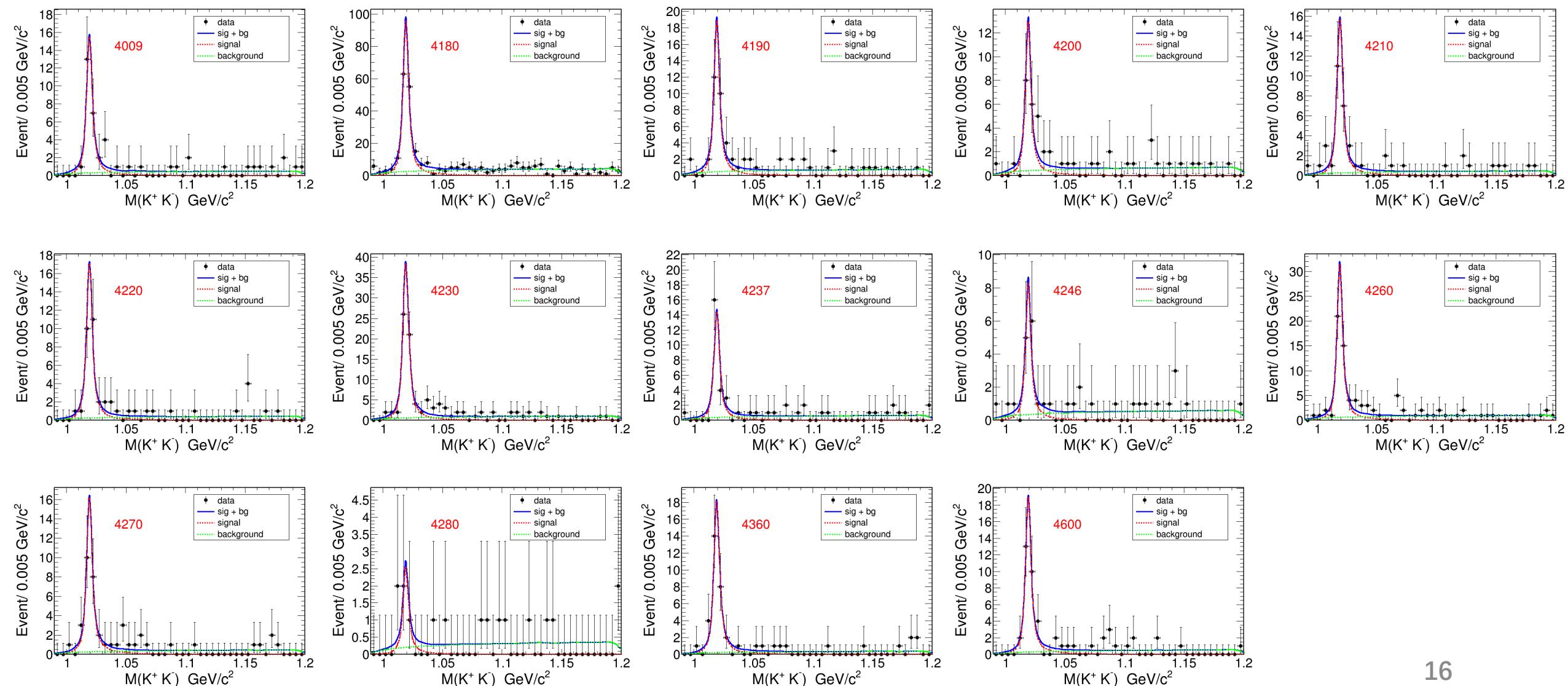
Fitting results (1)



Signal: is described by signal MC shape.

Background: is described by main background MC shape.

Fitting results (2)



Fitting results (3)

sample	$\varepsilon(\%)$	Nobs	σ_{obs}
4009	17.79 ± 0.17	25.59 ± 5.36	0.61 ± 0.13
4180	19.86 ± 0.18	152.99 ± 13.46	0.50 ± 0.04
4190	20.28 ± 0.18	30.09 ± 5.99	0.54 ± 0.11
4200	20.89 ± 0.18	20.58 ± 5.06	0.38 ± 0.09
4210	19.96 ± 0.18	25.90 ± 5.51	0.46 ± 0.10
4220	20.54 ± 0.18	28.06 ± 5.67	0.49 ± 0.10
4230	21.63 ± 0.18	63.16 ± 8.63	0.54 ± 0.07
4237	21.25 ± 0.18	23.00 ± 5.14	0.42 ± 0.09
4246	21.58 ± 0.18	12.91 ± 4.11	0.23 ± 0.07
4260	21.81 ± 0.18	49.16 ± 7.67	0.56 ± 0.09
4270	21.92 ± 0.18	26.70 ± 5.66	0.47 ± 0.10
4280	21.20 ± 0.18	4.07 ± 2.34	0.22 ± 0.13
4360	23.38 ± 0.19	29.47 ± 5.69	0.47 ± 0.09
4420	23.68 ± 0.19	52.66 ± 7.56	0.42 ± 0.06
4600	25.27 ± 0.19	29.87 ± 5.80	0.41 ± 0.08

Summary

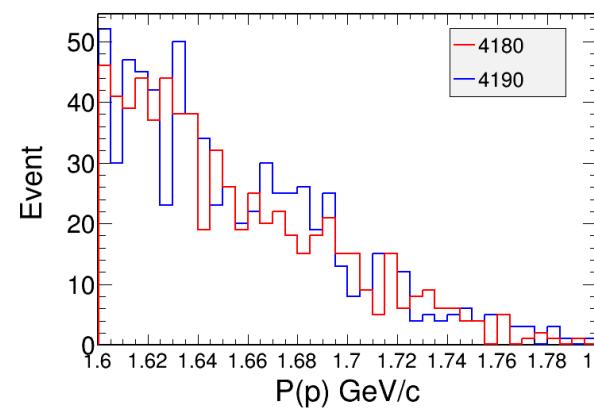
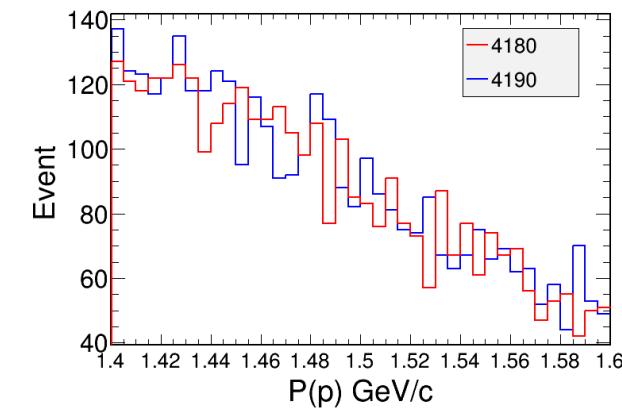
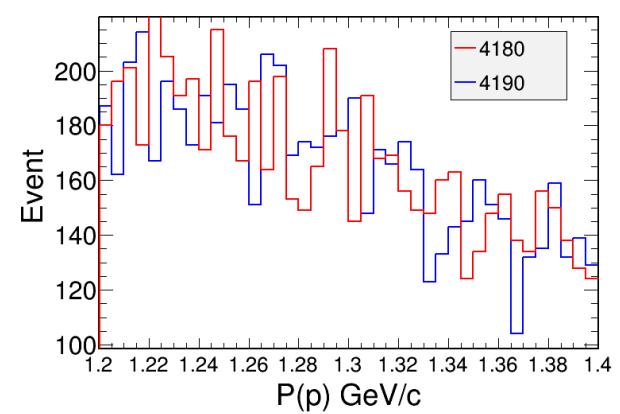
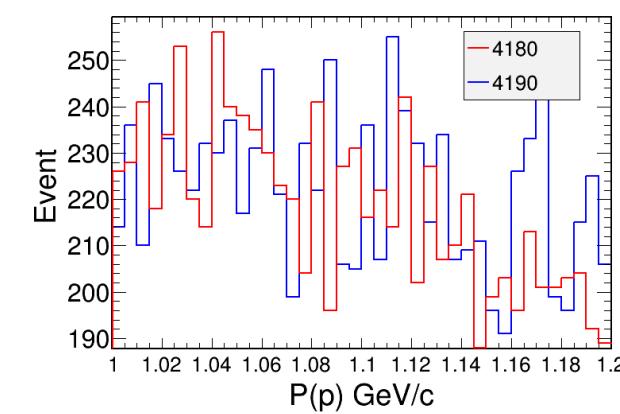
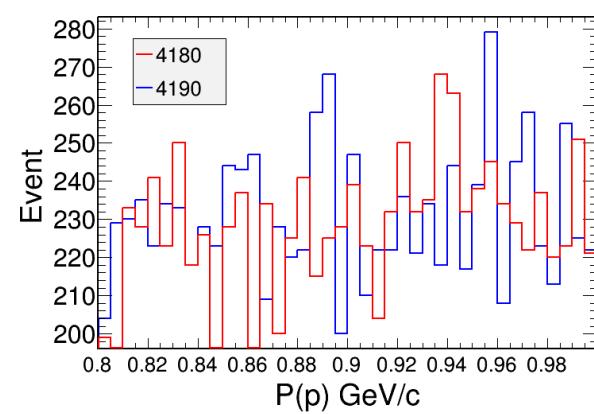
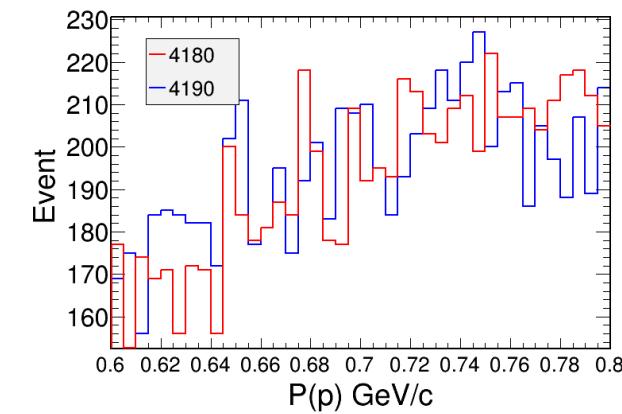
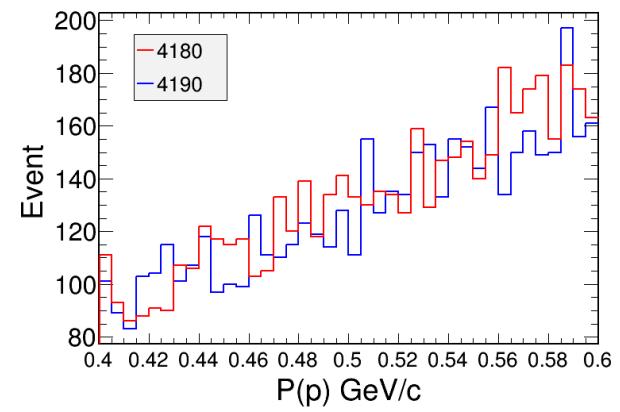
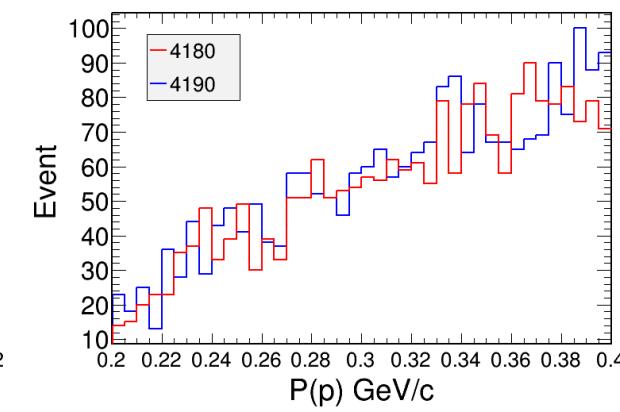
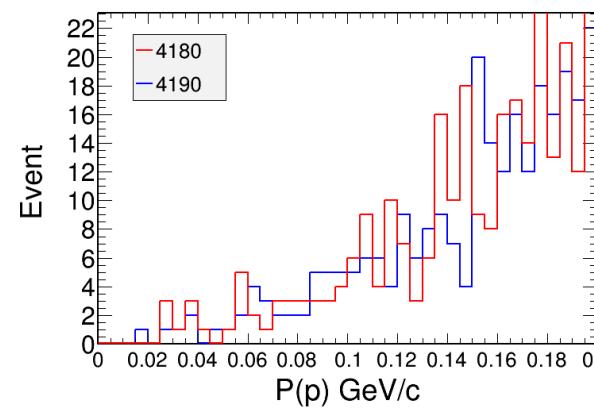
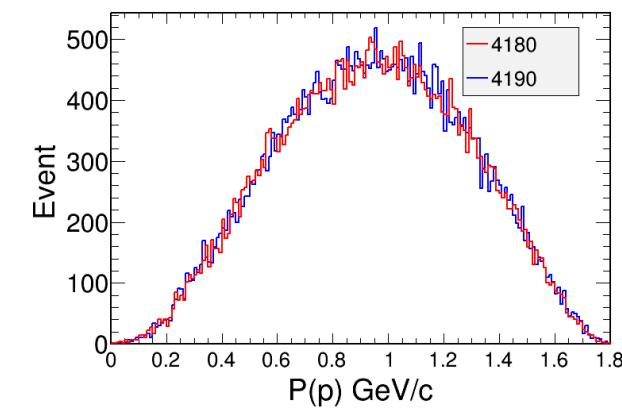
1. The signal of $e^+e^- \rightarrow \phi\Lambda\bar{\Lambda}$ is very clear in XYZ data using semi-reconstruction.
The background level is low, in addition, has been understood clearly.
2. The reconstruction efficiency behave abnormally at $\sqrt{s} = 4.210, 4.220$, and 4.280 GeV, which is caused by the beam background simulation based on the MC study.

Next to do

1. Keep working on the efficiency study. Study the tracking and PID efficiency with $e^+e^- \rightarrow pp\pi\pi$ channel, and check the discrepancy between data and MC.
2. Helix parameter corrections are also needed to be done.

Thank you!

Back Up



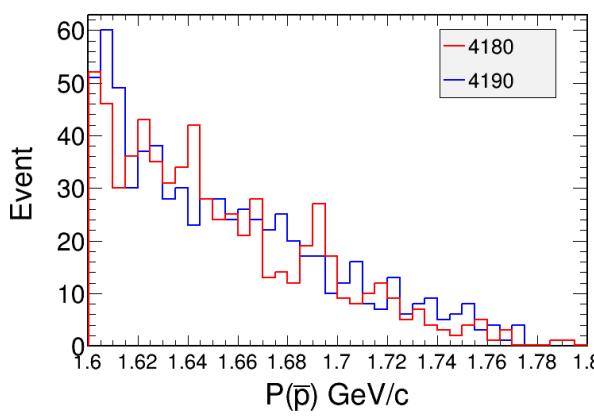
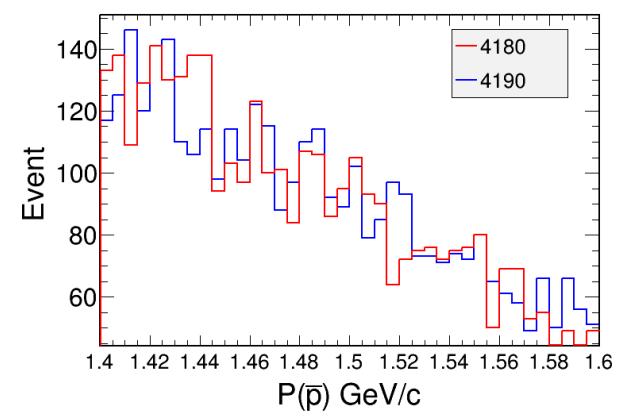
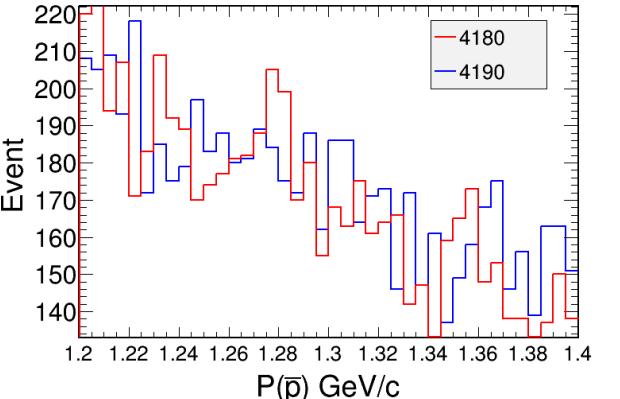
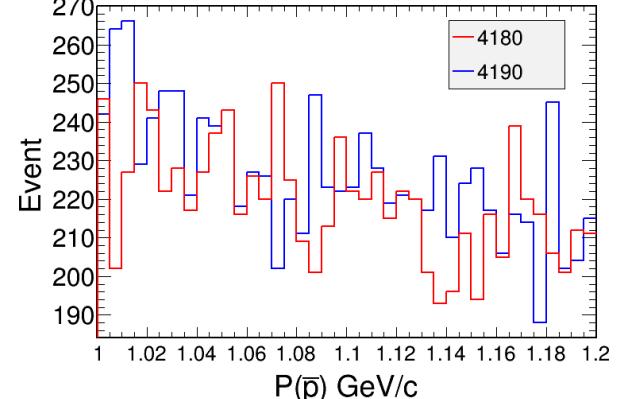
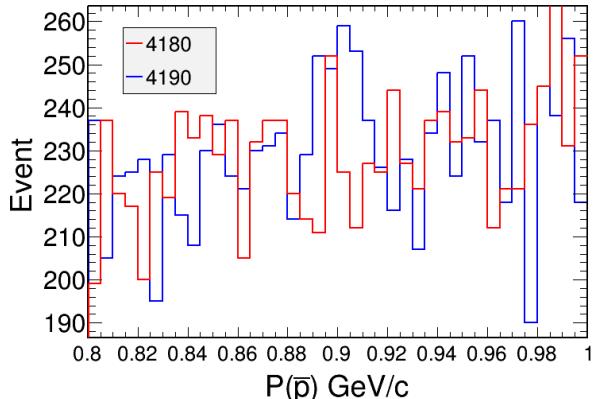
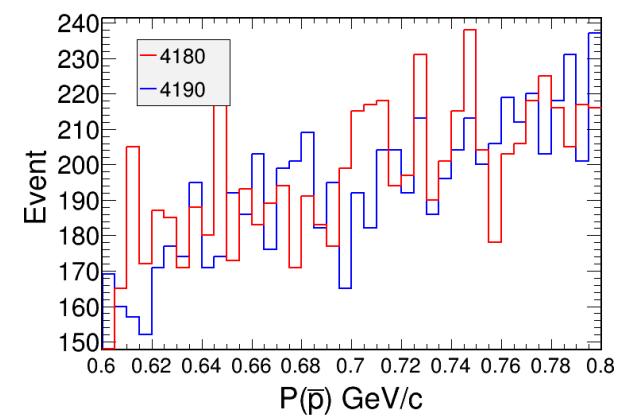
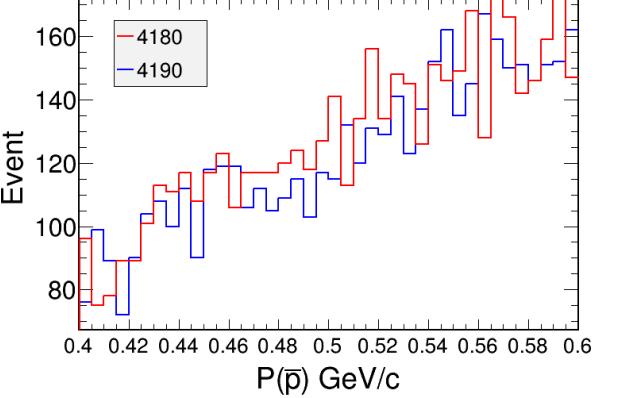
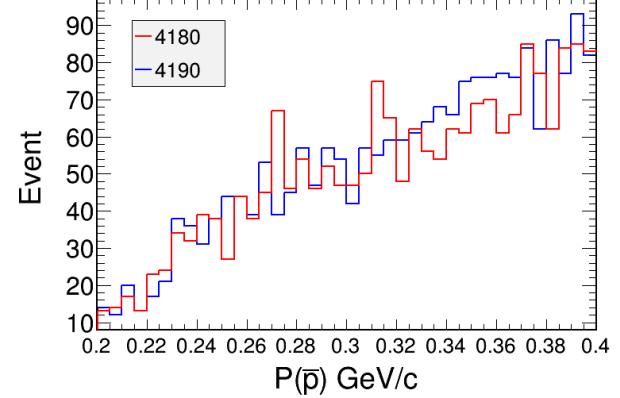
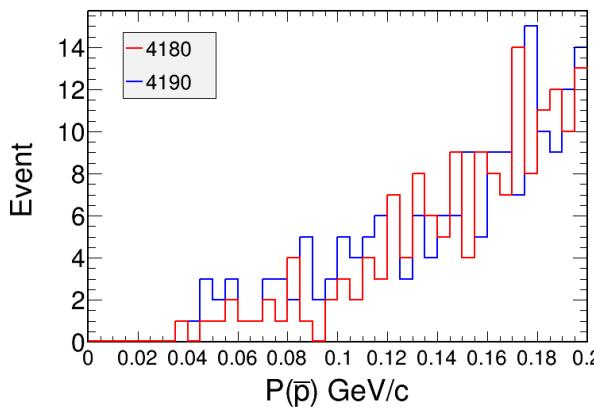
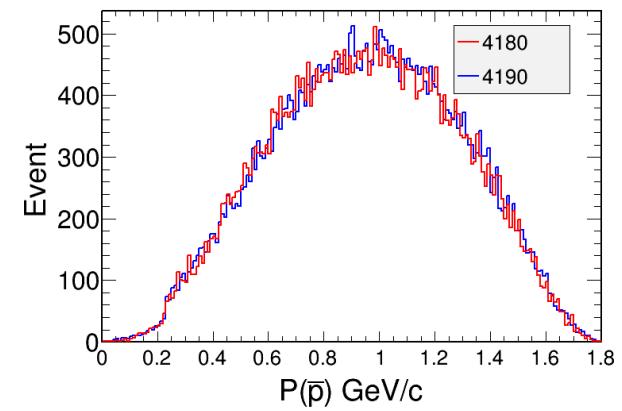


Table 1: Event trees and their respective initial-final states.

index	event tree (event initial-final states)	iEvtTr	iEvtIFSts	nEvts	nCmltEvts
1	$e^+ e^- \rightarrow K^+ K^- \Lambda \bar{\Lambda} \gamma, \Lambda \rightarrow \pi^- p, \Lambda \rightarrow \pi^+ \bar{p}$ ($e^+ e^- \rightarrow \pi^+ \pi^- K^+ K^- p \bar{p} \gamma$)	0	0	62	62
2	$e^+ e^- \rightarrow K^+ K^- \Lambda \bar{\Lambda} \gamma, \Lambda \rightarrow \pi^- p, \Lambda \rightarrow \pi^0 \bar{n}$ ($e^+ e^- \rightarrow \pi^- K^+ K^- \bar{n} p \gamma \gamma \gamma$)	3	3	26	88
3	$e^+ e^- \rightarrow K^+ K^- \Lambda \bar{\Lambda} \gamma, \Lambda \rightarrow \pi^0 n, \Lambda \rightarrow \pi^+ \bar{p}$ ($e^+ e^- \rightarrow \pi^+ K^+ K^- n \bar{p} \gamma \gamma \gamma$)	1	1	23	111
4	$e^+ e^- \rightarrow f_2(1270) K^- p \Lambda \gamma, f_2(1270) \rightarrow \pi^+ \pi^-, \Lambda \rightarrow \pi^+ \bar{p}$ ($e^+ e^- \rightarrow \pi^+ \pi^+ \pi^- K^- p \bar{p} \gamma$)	2	2	1	112
5	$e^+ e^- \rightarrow \pi^0 \pi^0 \psi', \psi' \rightarrow \chi_{c0} \gamma, \chi_{c0} \rightarrow K^* K^* \phi, K^* \rightarrow \pi^- K^+, K^* \rightarrow \pi^+ K^-, \phi \rightarrow K^+ K^-$, $\pi^+ \rightarrow \mu^+ \nu_\mu, K^- \rightarrow \mu^- \bar{\nu}_\mu, \mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$ ($e^+ e^- \rightarrow e^+ \nu_e \mu^- \nu_\mu \bar{\nu}_\mu \bar{\nu}_\mu \pi^- K^+ K^+ K^- \gamma \gamma \gamma \gamma \gamma$)	4	4	1	113
6	$e^+ e^- \rightarrow K^+ K^- \Lambda \Sigma^0 \gamma, \Lambda \rightarrow \pi^0 \bar{n}, \Sigma^0 \rightarrow \Lambda \gamma, \Lambda \rightarrow \pi^- p$ ($e^+ e^- \rightarrow \pi^- K^+ K^- \bar{n} p \gamma \gamma \gamma \gamma$)	5	5	1	114
7	$e^+ e^- \rightarrow \pi^+ \pi^- \pi^- a_2^+ K^+ K^- \gamma, a_2^+ \rightarrow \rho^0 \pi^+, \rho^0 \rightarrow \pi^+ \pi^-$ ($e^+ e^- \rightarrow \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^- K^+ K^- \gamma$)	6	6	1	115
8	$e^+ e^- \rightarrow K^+ K^- \bar{\Lambda} \Sigma^0 \gamma, \bar{\Lambda} \rightarrow \pi^+ \bar{p}, \Sigma^0 \rightarrow \Lambda \gamma, \Lambda \rightarrow \pi^0 n$ ($e^+ e^- \rightarrow \pi^+ K^+ K^- n \bar{p} \gamma \gamma \gamma \gamma$)	7	7	1	116
9	$e^+ e^- \rightarrow K^+ K^- \Lambda \Sigma^0 \gamma, \Lambda \rightarrow \pi^- p, \Sigma^0 \rightarrow \Lambda \gamma, \bar{\Lambda} \rightarrow \pi^+ \bar{p}$ ($e^+ e^- \rightarrow \pi^+ \pi^- K^+ K^- p \bar{p} \gamma \gamma$)	8	8	1	117
10	$e^+ e^- \rightarrow \pi^+ D^- D^0 \gamma, D^- \rightarrow \pi^0 \pi^- K^+ K^-, D^0 \rightarrow \pi^0 \pi^+ K^-$ ($e^+ e^- \rightarrow \pi^+ \pi^+ \pi^- K^+ K^- K^- \gamma \gamma \gamma \gamma$)	9	9	1	118
11	$e^+ e^- \rightarrow K^+ K^- \Lambda \Sigma^0 \gamma, \Lambda \rightarrow \pi^0 n, \Sigma^0 \rightarrow \Lambda \gamma, \Lambda \rightarrow \pi^+ \bar{p}$ ($e^+ e^- \rightarrow \pi^+ K^+ K^- n \bar{p} \gamma \gamma \gamma \gamma$)	10	7	1	119
12	$e^+ e^- \rightarrow \pi^0 K^+ K^- \Lambda \bar{\Lambda} \gamma, \Lambda \rightarrow \pi^- p, \Lambda \rightarrow \pi^0 \bar{n}$ ($e^+ e^- \rightarrow \pi^- K^+ K^- \bar{n} p \gamma \gamma \gamma \gamma$)	11	10	1	120
13	$e^+ e^- \rightarrow K^+ K^- \Lambda \bar{\Lambda} \gamma, \Lambda \rightarrow \pi^- p, \Lambda \rightarrow \pi^0 \bar{n}, \pi^0 \rightarrow e^+ e^- \gamma$ ($e^+ e^- \rightarrow e^+ e^- \pi^- K^+ K^- \bar{n} p \gamma \gamma$)	12	11	1	121
14	$e^+ e^- \rightarrow K^+ K^- J/\psi, K^+ \rightarrow \mu^+ \nu_\mu, J/\psi \rightarrow \Lambda \bar{\Lambda}, \mu^+ \rightarrow e^+ \nu_e \nu_\mu, \Lambda \rightarrow \pi^+ n, \Lambda \rightarrow \pi^+ p$, $\pi^+ \rightarrow \mu^+ \nu_\mu, \mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$ ($e^+ e^- \rightarrow e^+ e^+ \nu_e \nu_e \nu_\mu \bar{\nu}_\mu \bar{\nu}_\mu K^- n \bar{p} \gamma \gamma$)	13	12	1	122