Inclusive π^0 Production at 2.800GeV

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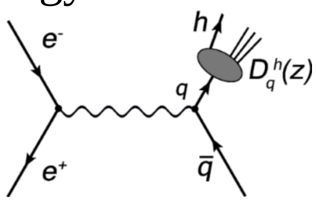
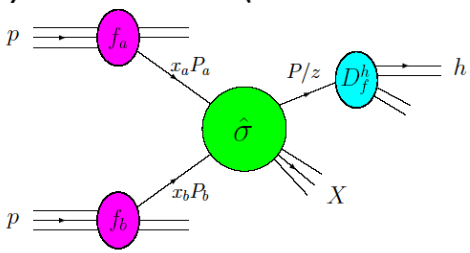
Fragmentation function

● Fragmentation function (FF) $D_q^h(z)$: probability that hadron h is found in the debris of a parton carrying a fraction z of parton's energy



LO

$$\frac{d\sigma}{dz}(\mathrm{e}^-\mathrm{e}^+ \to \mathrm{hX}) = \sum_q \sigma(\mathrm{e}^-\mathrm{e}^+ \to \mathrm{q\bar{q}})\left[D_q^h(z) + D_{\bar{q}}^h(z)\right]$$

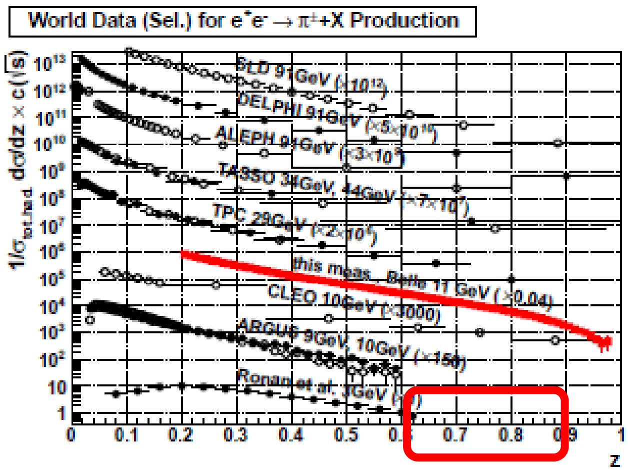


$$\sigma = \sum_{a,b,c} f_a(x_a, Q^2) \otimes f_b(x_b, Q^2)$$

$$\otimes \hat{\sigma}(ab \to cX) \otimes D_c^{\pi}(z, Q^2)$$

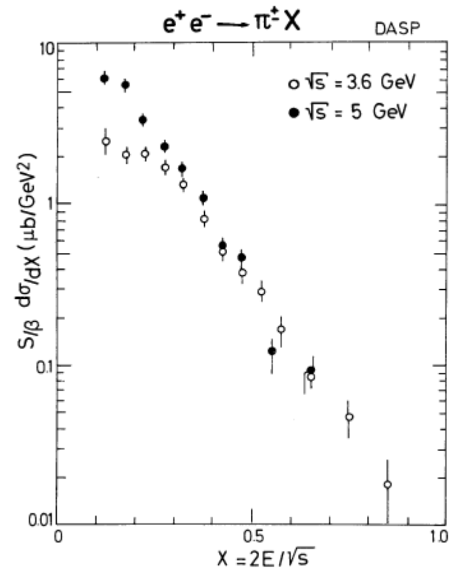
- FF: QCD first principle (NOT YET);
  - FF evolution function: DGLAP (similar to that of PDF)
  - Fitting: parametrization & experimental data (e^+e^-, SIDIS, pp and p $\bar{p}$)

$e^+e^- \to \pi + X$



PRL 111 062002 (2013)

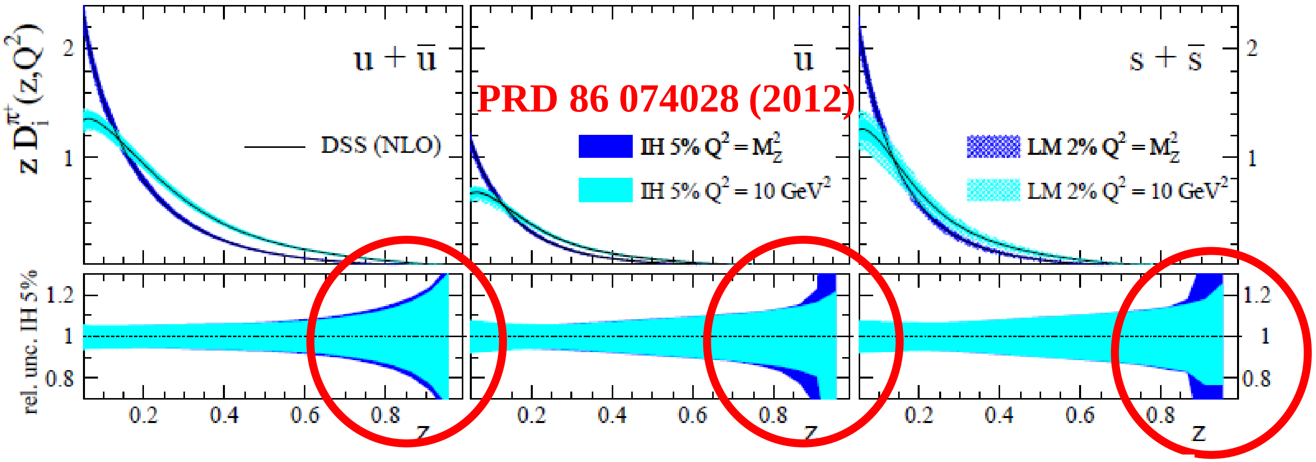
- Lack of data at **low energy scale**
  - BESIII energy: [2, 4.6]GeV
  - Poor precision
- Lack data **at high $z=2E_{hadron}/\sqrt{s}$**

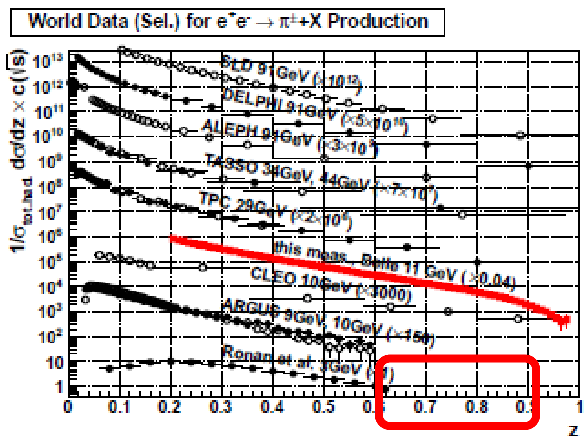


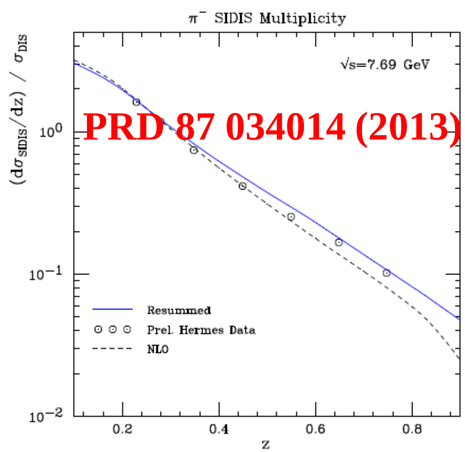
NPB 148 189 (1979)

- DASP: about 35 years ago
- Stat. uncertainty: 18%

- **Theory predictions at high z: with lage unceraInty**







Data Samples

- BOSS 664p01
- Data sets
  - ✓ Collision data at **2.800GeV (**3.753 pb^{-1}**)**
  - ✓ Hadronic event: 4.8**M** via generator ConExc
- Physics QED background: Monte Carlo data sets
  - ✓ Bhabha: **6M** via generator **Babayaga**
  - ✓ $(\gamma)\mu^+\mu^-$: **6M** via generator **Babayaga**
  - ✓ $(\gamma)\gamma\gamma$: 6**M** via generator **Babayaga**
  - ✓ $e^+e^-\rightarrow e^+e^-+X$: 6**M** via generator **BESTWOGAM**
- Non-physics background
  - ✓ Beam-gas, beam-wall, cosmic, and so on
  - ✓ Use sideband method

Hadronic event selection

π^0 production and hadronic event

① **Select hadronic event** ② **π^0 reconstruction**

- Remove Bhabha and (γ) $\gamma\gamma$ events with EMC information
  - ✓ Two showers with $1^{st}/2^{nd}$ energy deposition $|\theta_1+\theta_2-180^\circ| < 10^\circ$ and $E > 0.65*E_{beam}$
- Good track selection
  - ✓ $|Vr| < 1cm$, $|\cos\theta| < 0.93$ **(|Vz| cut ?)**
  - ✓ Momentum $< 0.94*E_{beam}$
  - ✓ $(dE/dx_{mea} - dE/dx_{proton})/\sigma_{proton} < 10$
  - ✓ Veto election with Momentum $> 0.65*E_{beam}$ && $e/p > 0.8$
  - ✓ Veto gamma conversion with $M(e,e) < 100MeV$ && Open angle$<15^\circ$
- good photon selection
  - ✓ $E_{barrel} > 25MeV$; $E_{endcap} > 50MeV$
  - ✓ $0 <= TDC <= 14(\times 50ns)$;
- Isolated photon selection
  - ✓ $E_{barrel} > 25MeV$; $E_{endcap} > 50MeV$
  - ✓ $0 <= TDC <= 14(\times 50ns)$;
  - ✓ Angle $> 20^\circ$ && $E_{deposited} > 100MeV$

Hadronic event selection

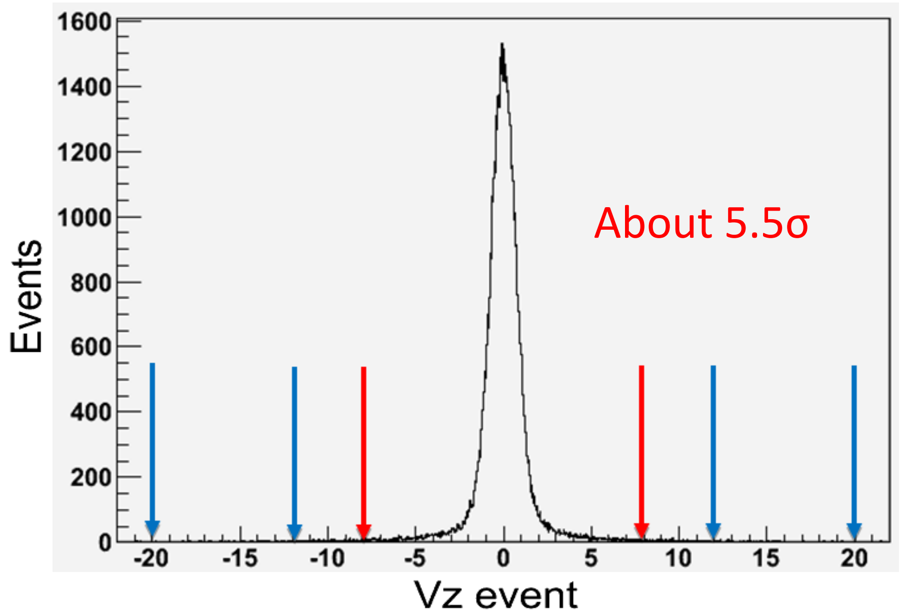
- Event level selection
  - ✓ Number of good track N_{good}>=2
  - ✓ Deposited energy @ EMC >= 0.40*E_{beam}

  1. Event with N_{good}=2
  - ✓ veto $|\theta_1+\theta_2-180^\circ| < 15^\circ$ && $||\varphi_1-\varphi_2|-180^\circ| < 10^\circ$
    number of Isolated photon N >= 2

  2. Event with N_{good}=3
  - ✓ Veto, angle between 1st/2nd energy track
    $|\theta_1+\theta_2-180^\circ| < 15^\circ$ and $||\varphi_1-\varphi_2|-180^\circ| < 10^\circ$

Because the total visible energy of MC have a shift comparing with experiment data. We weight the MC to the experiment data using good charged tracks and good photon tracks distribution.

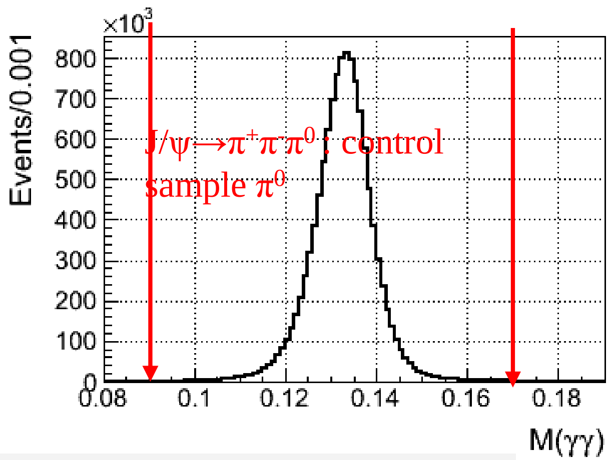
Signal and Non-physics background

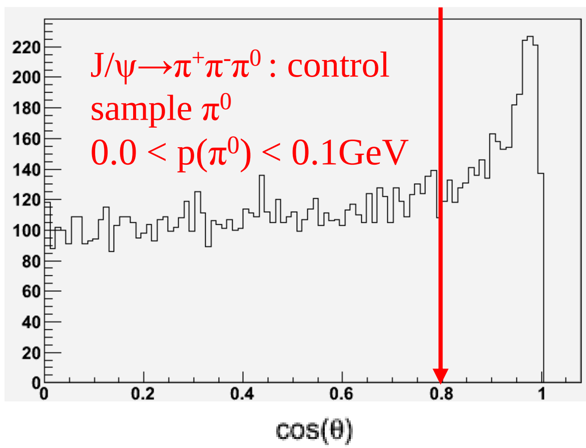


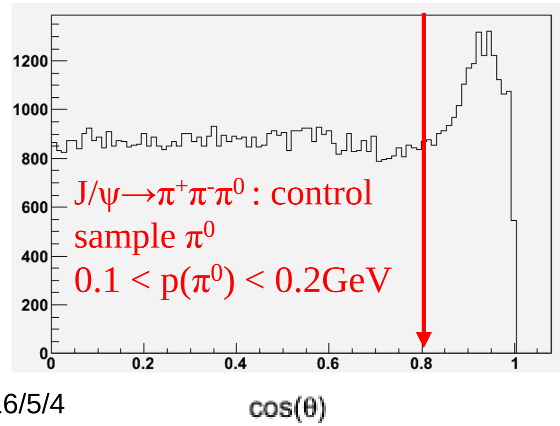
- Average Z-direction vertex for a event $V_z = \sum_{i=1}^{N_{good}} V_z^i \Big/ N_{good}$
- Signal $|V_z| < 8.0$cm; non-physics background: $12.0 < |V_z| < 20.0$cm

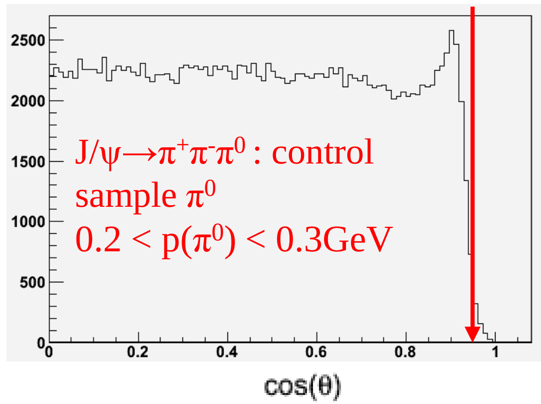
π^0 reconstruction

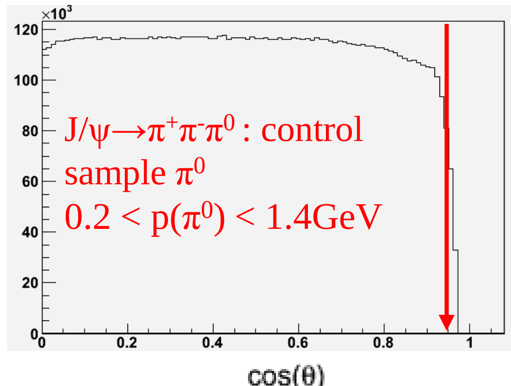
- π^0 selection: neutral track from hadronic selection
  - ✓ $0.09\text{GeV} < M(\gamma\gamma) < 0.17\text{GeV}$
  - ✓ $|\cos\theta_{\gamma\pi}| < 0.95$ (for $0.2 < p(\pi^0) < 1.4\text{GeV}$)
  - ✓ $|\cos\theta_{\gamma\pi}| < 0.8$ (for $0.0 < p(\pi^0) < 0.2\text{GeV}$)



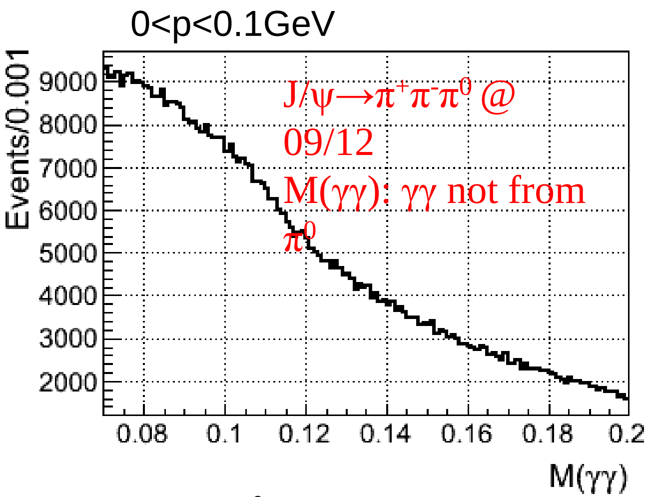




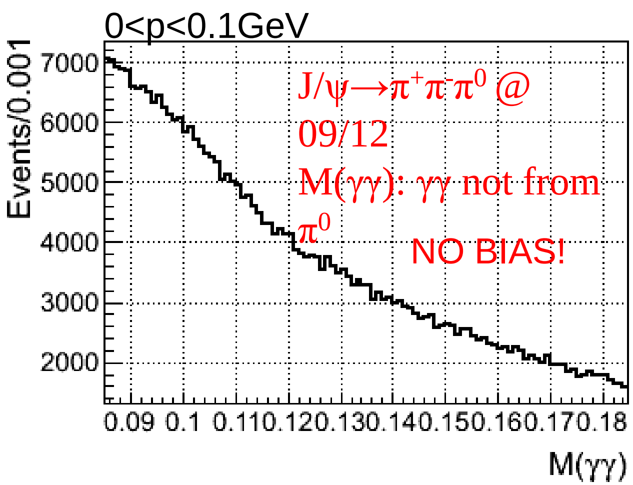




Miscombine of π^0



Before the π^0 selection criteria



After the π^0 selection criteria

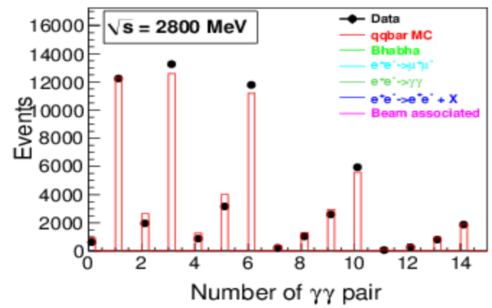
π^0 selection condition :

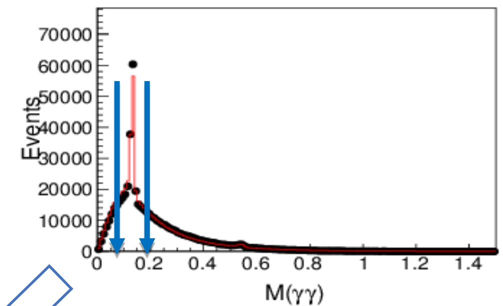
- ✓ 0.09GeV < M(γγ) < 0.17GeV
- ✓ $|\cos\theta_{\gamma\pi}|$< 0.95 (for 0.2 < p(π^0) < 1.4GeV)
- ✓ $|\cos\theta_{\gamma\pi}|$< 0.8 (for 0.0 < p(π^0) < 0.2GeV)

Distribution about π^0 candidates

selection criteria :

✓ $|\cos\theta_{\gamma\pi}| < 0.95$

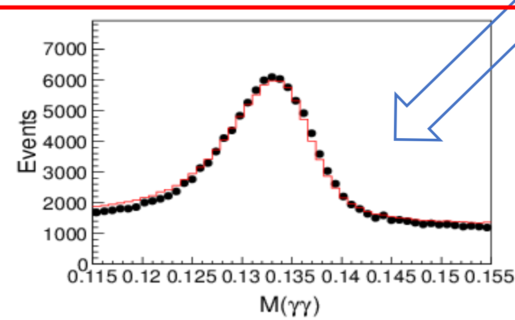


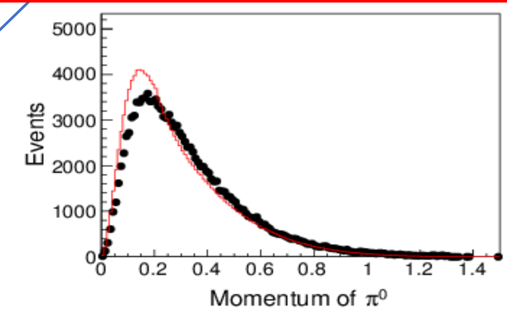


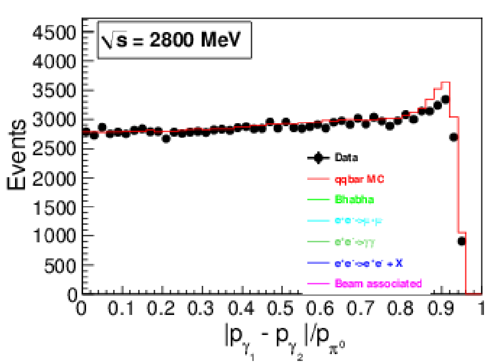
selection criteria :

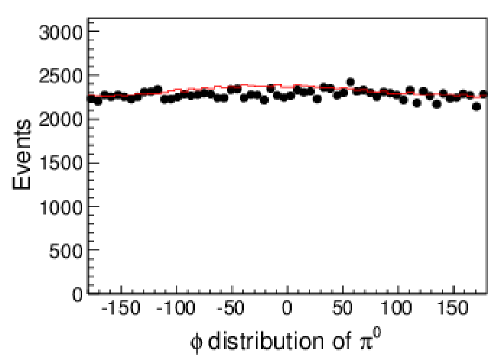
✓ $0.115\text{GeV} < M(\gamma\gamma) < 0.155\text{GeV}$

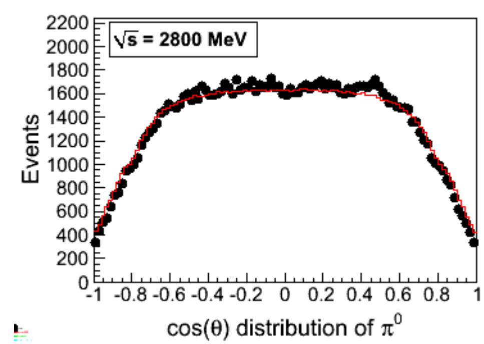
✓ $|\cos\theta_{\gamma\pi}| < 0.95$







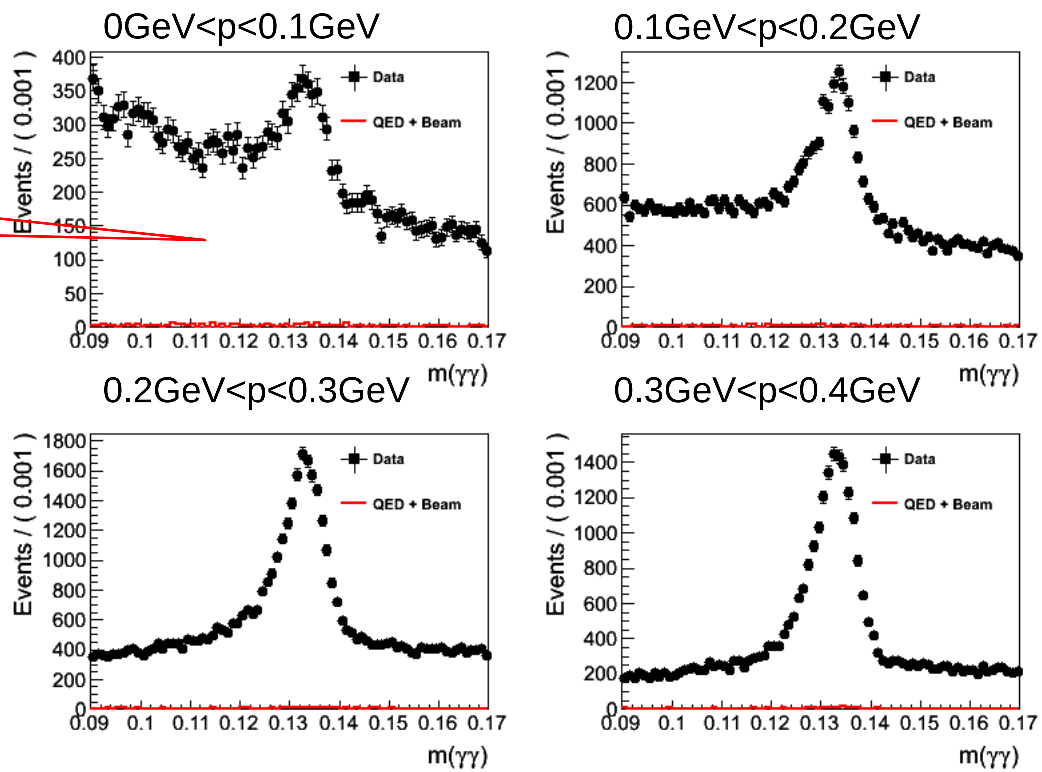




MC and Exp.Data can consist each other

Backgrounds and π^0 candidates

Miss combination



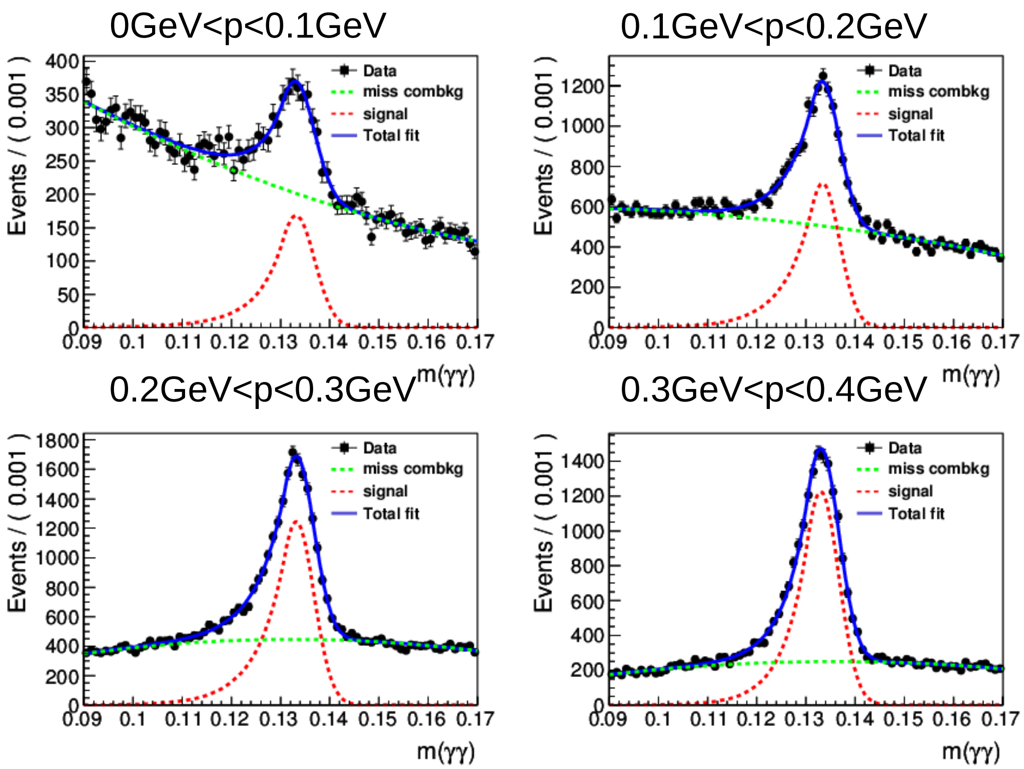
QED and beam associated background are flat

Backgrounds and π^0 candidates

	π^0 candidates (including miss combination) @[0.090-0.170] GeV mass region
$(\gamma)e^+e^-$	88.50 /0.045%
$(\gamma)\mu^+\mu^-$	8.68 /0.004%
$(\gamma)\ \gamma\ \gamma$	4.48 /0.002%
e^+e^-+X	23.46 /0.012%
Non-physics	1566 /0.798%
Exp. data	196206

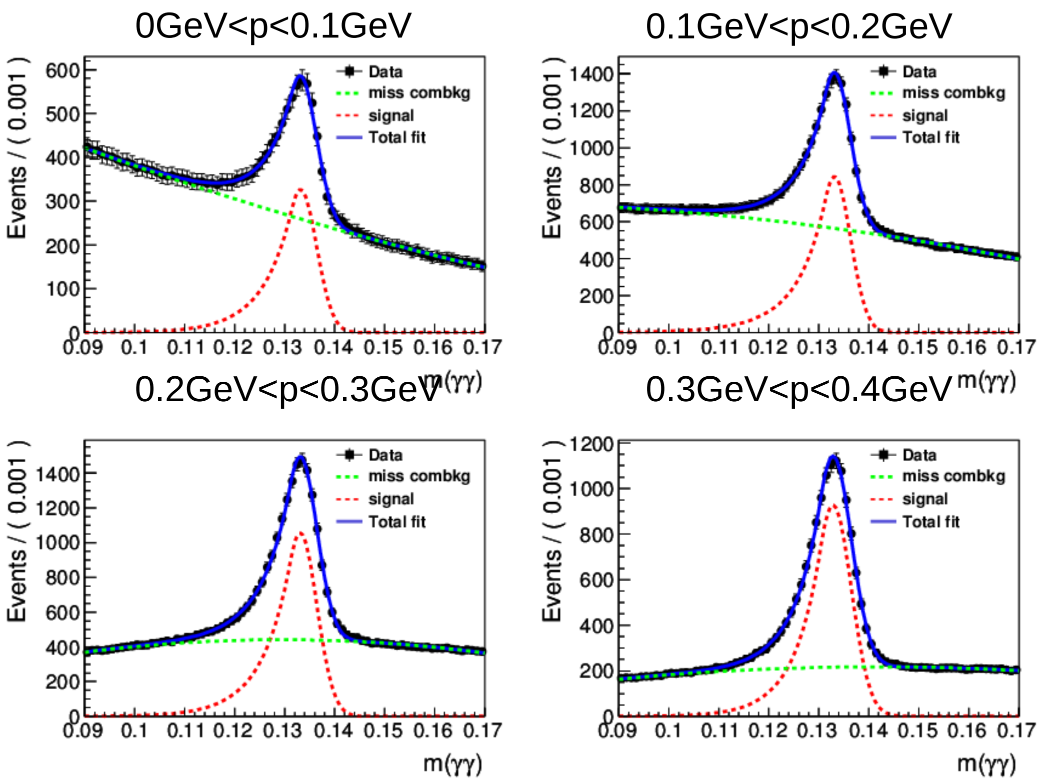
Most contribution come from beam associated background and the events are smaller than 1%

Data: π^0 fitting at 2.800GeV



Fitting function: Crystal ball + 2 order of Chebychev

MC: π^0 fitting at 2.800GeV



Fitting function: Crystal ball + 2 order of Chebychev

π^0 systematic study

event selection

Source	Cut	Default	Alternative
veto Bhabha and $\gamma\gamma$	E_{ratio}	$0.65 \cdot E_{beam}$	$0.6 \sim 0.7 \cdot E_{beam}$
	$\Delta\theta$	10°	$5^\circ \sim 15^\circ$
good hadronic tracks determination	Vr	1.0 cm	0.5 cm
	$p(track)$	$0.94 \cdot p_{beam}$	$0.92 \sim 0.96 \cdot p_{beam}$
	dE/dx cut	10	15
	E/p ratio	0.8	$0.75 \sim 0.85$
	Bhabha momentum limit	$0.65 \cdot p_{beam}$	$0.6 \sim 0.7 \cdot p_{beam}$
	isolated photon angle	20°	$15^\circ \sim 25^\circ$
	isolated photon energy	100 MeV	$75 \sim 125$ MeV
	gamma conversion angle	15°	$10^\circ \sim 20^\circ$
	gamma conversion mass	100 MeV	$80 \sim 120$ MeV
visible energy	total energy deposition	$0.4 \cdot E_{beam}$	$0.35 \sim 0.45 \cdot E_{beam}$
2 prong events	$\Delta\theta$	15°	$10^\circ \sim 20^\circ$
	$\Delta\phi$	10°	$5^\circ \sim 15^\circ$
>2 prong events	$\Delta\theta$	15°	$10^\circ \sim 20^\circ$
	$\Delta\phi$	10°	$5^\circ \sim 15^\circ$

π^0 systematic study
fitting uncertainty

1, Fitting range

Default fitting range [0.09, 0.17] GeV

Tight fitting range: [0.095, 0.165] GeV

Loose fitting range: [0.085, 0.175] GeV

Pick up the one which have large differences with default result as the fitting range uncertainty

2, Fitting function

Default fitting function: Crystal ball + 2 order of Chebychev

Change to: Crystal ball + 3 order of Chebychev

Tack the difference as fitting function uncertainty

π^0 systematic study

π^0 reconstruction uncertainty

Use control sample of $J/\psi \rightarrow \rho\,\pi$ to do π^0 reconstruction uncertainty

π^0 cut criteria:

✓ $|\cos\theta_{\gamma\pi}| < 0.95$ (for $0.2 < p(\pi^0) < 1.4$GeV)

✓ $|\cos\theta_{\gamma\pi}| < 0.8$ (for $0.0 < p(\pi^0) < 0.2$GeV)

Take the differences of MC and experiment data as the π^0 reconstruction uncertainty

π^0 systematic study

One dimensional weighting and Model dependent

1, One dimensional weighting (neutral tracks weighting)

Considering the basic difference comes from the neutral tracks, we only do one dimensional weighting of neutral tracks and tack the difference as the weighting uncertainty.

2, Model dependent

Use the qqbar MC generated by Luarlw tuned by Hu Haiming and take the difference with ConExc as model uncertainty.

π^0 errors

Momentum (GeV)	Event level uncertainty	Track level uncertainty	Fitting Uncertainty	Model dependent	Pi0 reconstruction Uncertainty	1D weighting	Total systematic error	Statistics error	Total error
0.0-0.1	2.99%	2.80%	4.51%	6.78%			7.74%	11.20%	13.62%
0.1-0.2	0.87%	1.62%	1.34%	3.33%			3.61%	5.17%	6.31%
0.2-0.3	1.23%	1.58%	1.10%	6.42%			3.45%	3.13%	4.66%
0.3-0.4	1.04%	0.51%	1.03%	5.40%			2.40%	2.51%	3.47%
0.4-0.5	0.62%	0.41%	0.62%	2.86%			1.70%	1.88%	2.54%
0.5-0.6	0.63%	0.54%	0.25%	4.38%			4.92%	2.08%	5.34%
0.6-0.7	0.46%	0.69%	0.31%	2.95%			4.38%	2.47%	5.03%

π^0 errors

Momentum (GeV)	Event level uncertainty	Track level uncertainty	Fitting Uncertainty	Model dependent	Pi0 reconstruction uncertainty	1D weighting	Total systematic error	Statistics error	Total error
0.7-0.8	0.49%	0.58%	0.59%	0.14%			2.57%	3.40%	4.27%
0.8-0.9	0.54%	0.56%	0.63%	1.70%			5.09%	3.93%	6.43%
0.9-1.0	0.84%	0.49%	1.20%	5.45%			4.77%	5.08%	6.97%
1.0-1.1	1.09%	1.62%	2.27%	5.79%			4.38%	7.31%	8.52%
1.1-1.2	7.15%	3.14%	1.12%	22.84%			10.48%	11.12%	15.28%
1.2-1.3	10.91%	5.35%	1.74%	5.20%			13.04%	16.19%	20.80%

π^0 : bin-to-bin correction

$$\frac{1}{\sigma_{had}}\frac{d\sigma_{\pi^0}}{dp} = C\,\frac{1}{Br\left(\pi^0 \to \gamma\gamma\right)}\,\frac{1}{N_{had}^{\exp}}\,\frac{N_{\pi^0}^{\exp}\left(p\right)}{\Delta p}$$

N_{had}^{exp} Observed hadronic event number

$N_{\pi^0}^{\exp}(p)$ Fitted π^0 number in a momentum bin

Δp Bin width in a momentum bin

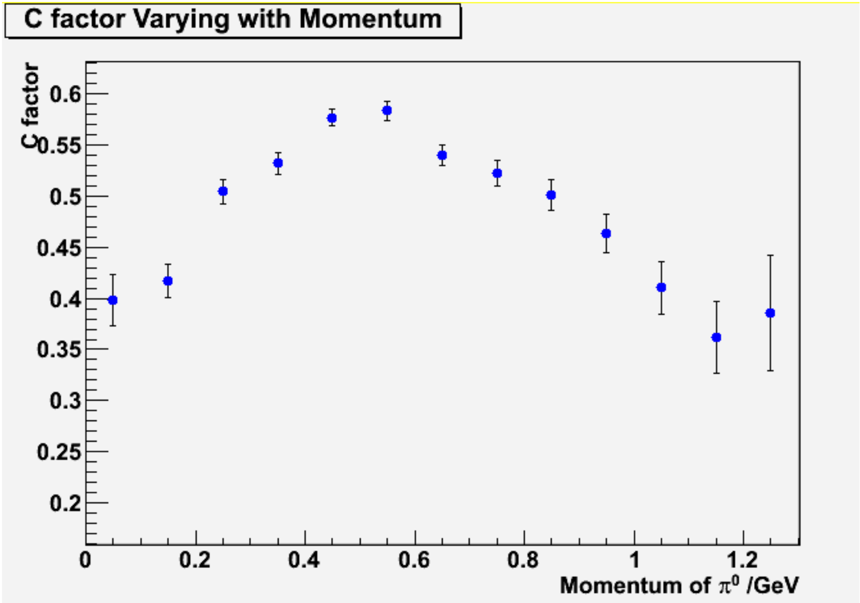
C Correction factor in a momentum bin

π^0 : bin-to-bin correction

$$C = \frac{N_{\pi^0}^{truth} \Big/ N_{had}^{truth} \text{ @ } MC \text{ without } ISR}{N_{\pi^0}^{\det} \Big/ N_{had}^{\det} \text{ @ } MC \text{ with } ISR}$$

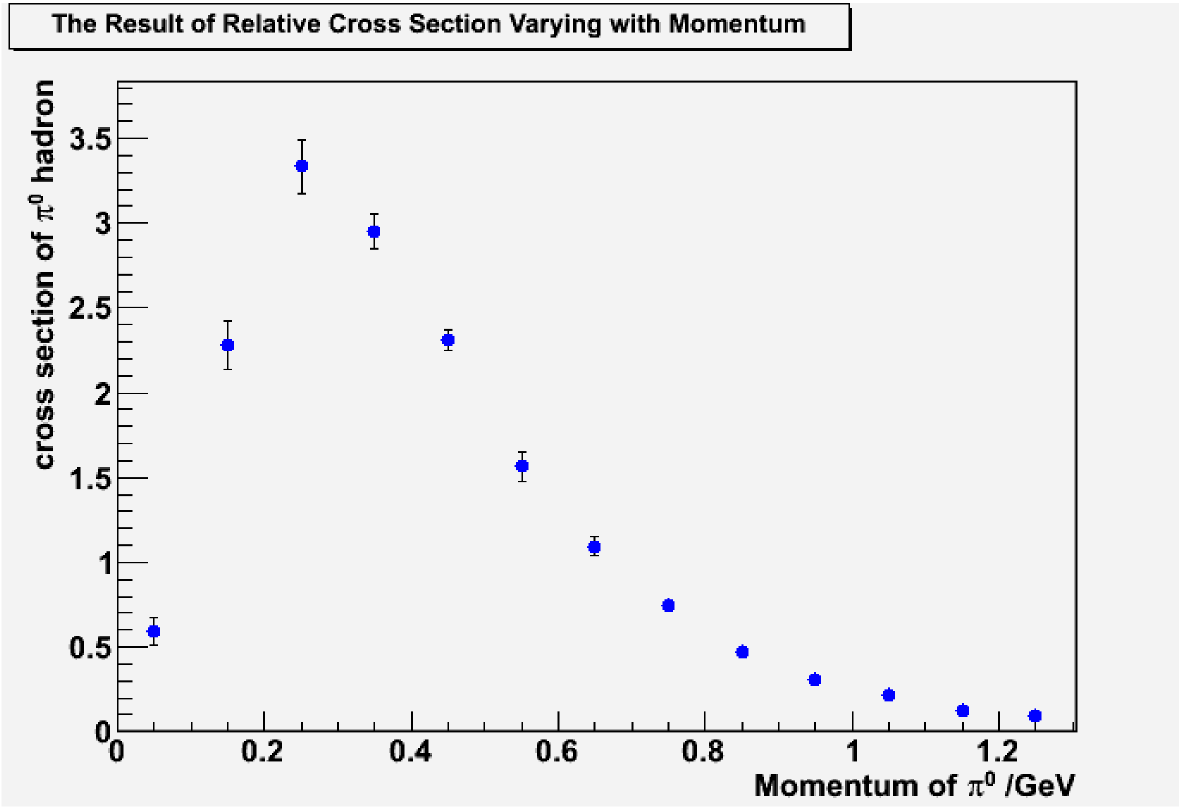
$N_{\pi^0}^{truth}$ π^0 from MC Truth

C corrects for event selection, π^0 reconstruction, ISR and so on.



π^0 : bin-to-bin correction

$$\frac{1}{\sigma_{had}}\frac{d\sigma_{\pi^0}}{dp} = C\,\frac{1}{Br\left(\pi^0 \rightarrow \gamma\gamma\right)}\frac{1}{N_{had}^{\exp}}\frac{N_{\pi^0}^{\exp}(p)}{\Delta p}$$



Summary and outlook

- For the inclusive π^0 production @BESIII, we could provide
  - ✓relative cross section of pion @ 2.800 GeV.
  - ✓Preliminary systematic error.
- To do list

  Similar study for other energy points from 2012 and 2015 R value

Backup

The inclusive production of π^0 production is

$$\frac{1}{\sigma_{had}} \cdot \frac{d\sigma_{\pi^0}}{dp}$$

Considering the momentum resolution of π^0 and the luminosity of experiment data, we set the bin width Δp of π^0 momentum to be 0.1 GeV . Then, we have

$$\frac{1}{\sigma_{had}} \cdot \frac{d\sigma_{\pi^0}}{dp} = \frac{1}{\sigma_{had}} \cdot \frac{\sigma_{\pi^0}(p)}{\Delta p}$$

$$= \frac{1}{N_{had}^{\exp}/(L \cdot \varepsilon_{had})} \cdot \frac{N_{\pi^0}^{\exp}(p)/\left(L \cdot \varepsilon_{\pi^0} \cdot Br(\pi^0 \to \gamma\gamma)\right)}{\Delta p}$$

$$= \frac{\varepsilon_{had}}{\varepsilon_{\pi^0}} \cdot \frac{1}{Br(\pi^0 \to \gamma\gamma)} \cdot \frac{N_{\pi^0}^{\exp}(p)}{N_{had}^{\exp} \cdot \Delta p}$$

L is the luminosity of experiment data and $N_{\pi^0}^{\exp}(p)$ is the number of π^0 in one momentum bin from experiment data. $N_{had}^{\exp}$ is the number of hadronic events from experiment data.

Backup

Then we define C_1 correction to be

$$C_1 = \frac{\varepsilon_{had}}{\varepsilon_{\pi^0}} = \frac{N_{had}^{det}/N_{had}^{truth}}{N_{\pi^0}^{det}/N_{\pi^0}^{truth}} = \frac{N_{\pi^0}^{truth}/N_{had}^{truth}}{N_{\pi^0}^{det}/N_{had}^{det}} (with\, ISR)$$

The $N_{\pi^0}^{truth}$ is the number of π^0 at truth level from MC and $N_{\pi^0}^{det}$ means number of π^0 at detect level from MC, as well N_{had}^{truth} and N_{had}^{det}.

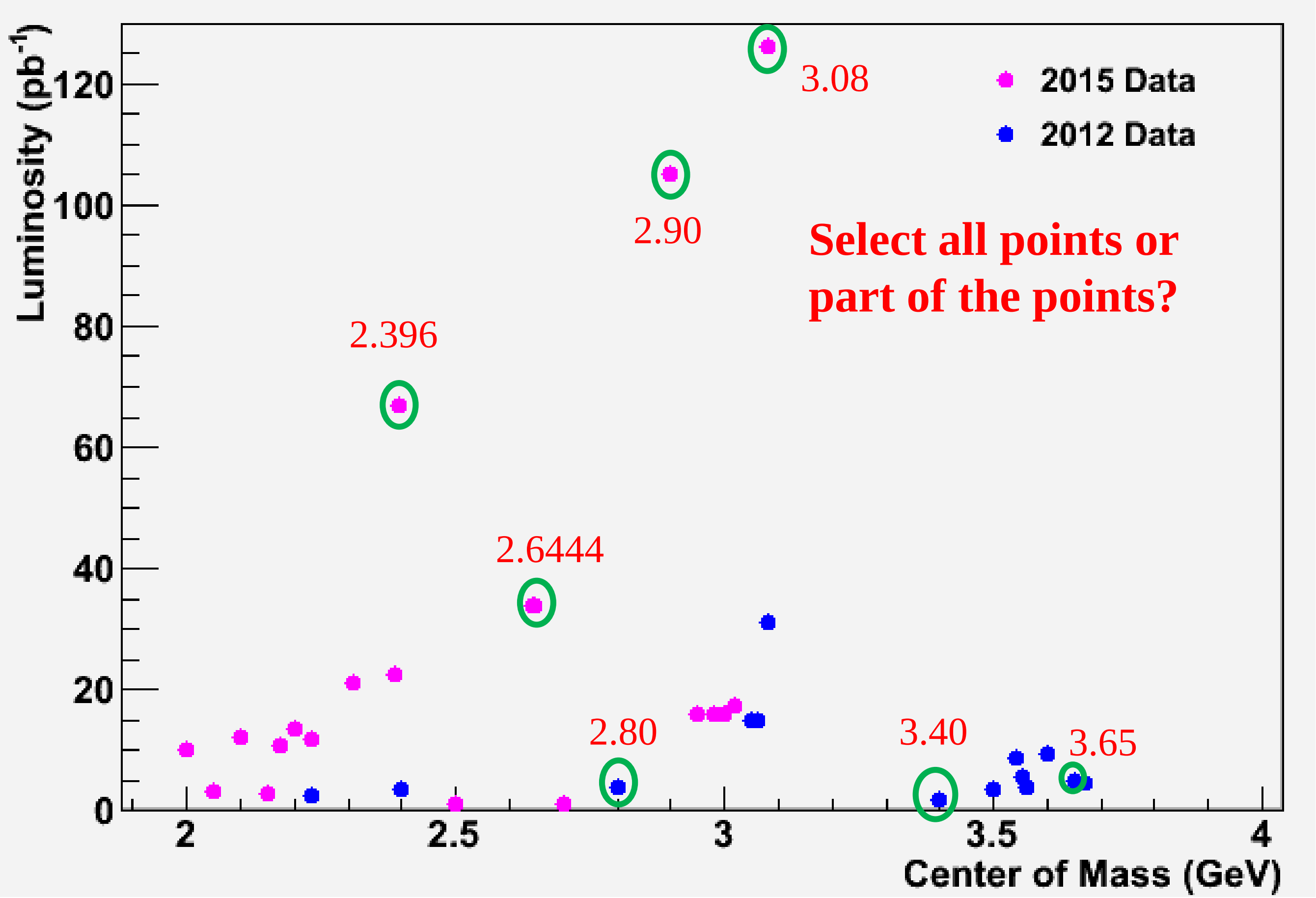
So far, we have obtained the $\frac{\varepsilon_{had}}{\varepsilon_{\pi^0}}$ from MC with ISR process. We want to get the born relative cross section then the C_1 correction become

$$C = \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{with\, ISR}}{\left(N_{\pi^0}^{det}/N_{had}^{det}\right)_{with\, ISR}} \cdot \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{without\, ISR}}{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{with\, ISR}}$$

$$= \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{without\, ISR}}{\left(N_{\pi^0}^{det}/N_{had}^{det}\right)_{with\, ISR}}$$

C corrects for event selection, π^0 reconstruction, ISR and so on.

Luminosity of Data in 2012 and 2015



Luminosity of Data in 2012 and 2015

Table 1: Data samples used for R measurement at BESIII

	E_{cm}(GeV)	Run number	Integrated luminosity (pb^{-1})	Purpose
1	2.2324	28624 – 28648	2.645	R scan
2	2.4000	28577 – 28621	3.415	R scan
3	2.8000	28553 – 28575	3.753	R scan
4	3.0500	28312 – 28346	14.893	J/ψ scan
5	3.0600	28347 – 28381	15.040	J/ψ scan
6	3.0800	27147 – 27233,28241 – 28266	31.019	J/ψ scan
7	3.4000	28543 – 28548	1.733	R scan
8	3.5000	33725 – 33733	3.633	off $\psi(3770)$
9	3.5424	24983 – 25015,33734 – 33743	8.693	τ mass scan
10	3.5538	25016 – 25094	5.562	τ mass scan
11	3.5611	25100 – 25141	3.847	τ mass scan
12	3.6002	25143 – 25243	9.502	τ mass scan
13	3.6500	33747 – 33758	4.760	off $\psi(3686)$
14	3.6710	33759 – 33764	4.628	off $\psi(3770)$

Ecm (GeV)	Run No.	N_hadron (Online)	Luminosity/nb^-1 (Online)	T_pure (h:m)	N_run	N_total	Luminosity/nb^-1 (Offline)
3.080[1]	39355-39618	4959135	123024.75	194:48:13	226	522838948	126.185
3.020[2]	39711-39738	714891	16605.0368	22:22:02	25	58678979	17.290
3.000[3]	39680-39710	660419	15269.1487	20:53:33	24	57711853	15.881
2.981[4]	39651-39679	708798	15391.7057	22:25:15	27	56260525	16.071
2.950[5]	39619-39650	690592	15696.2076	25:35:22	32	78242909	15.942
2.900[6]	39775-40069	4705744	102096.35	214:01:57	280	473251776	105.253
2.6444[7]	40128-40296	1951322	32530.15379	115:24:39	146	262821831	34.003
2.6444+2MeV[8]	40300-40435	2185792	33730.6343	112:05:06	123	320673713	33.722
2.700[9]	40436-40439	52668	987.445	3:44:55	4	8004137	1.034
2.800[10]	40440-40443	50415	964.9689	3:57:22	4	8207632	1.008
2.396[11]	40459-40769	4295641	64841.02	222:28:34	269	601167461	66.869
2.5[12]	40771-40776	77954	1044.06	5:04:12	6	10132267	1.098
Separated-beam2.6444 [13]	40777-40804	208009	0	39:40:04	27	71361521	0
2.3864[14]	40806-40951	1532415	22059.22	89:43:45	94	224667182	22.549
2.2[15]	40989-41121	1048548	13005.09	113:49:35	121	179089129	13.699
2.2324[16]	41122-41239	825991	11247.57	111:27:27	113	174097483	11.856
2.3094[17]	41240-41411	1469271	20481.96	137:27:51	161	306121093	21.089
2.175[18]	41416-41532	1873431	10056.33	102:12:30	112	146758176	10.625
2.15[19]	41533-41570	545929	2775.088	28:23:23	35	63163310	2.841
2.1[20]	41588-41727	1006488	11347.94	104:54:20	127	185372903	12.167
2.0[21]	41729-41909	1052289	9306.01	123:01:09	162	189905829	10.074
2.05[22]	41911-41958	363485	3017.84	42:25:51	46	70554265	3.343
Separated-beam2.2324[23]	41959-41999	105532	0	38:43:45	41	62847942	0

Model dependent uncertainty

The inclusive production of π^0 production is

$$\frac{1}{\sigma_{had}} \cdot \frac{d\sigma_{\pi^0}}{dp}$$

Considering the momentum resolution of π^0 and the luminosity of experiment data, we set the bin width Δp of π^0 momentum to be 0.1 GeV . Then, we have

$$\frac{1}{\sigma_{had}} \cdot \frac{d\sigma_{\pi^0}}{dp} = \frac{1}{\sigma_{had}} \cdot \frac{\sigma_{\pi^0}(p)}{\Delta p}$$

$$= \frac{1}{N_{had}^{\exp}/(L \cdot \varepsilon_{had})} \cdot \frac{N_{\pi^0}^{\exp}(p)/\left(L \cdot \varepsilon_{\pi^0} \cdot Br(\pi^0 \to \gamma\gamma)\right)}{\Delta p}$$

$$= C \cdot \frac{1}{Br(\pi^0 \to \gamma\gamma)} \cdot \frac{N_{\pi^0}^{\exp}(p)}{N_{had}^{\exp} \cdot \Delta p} \quad (include\ ISR\ correction)$$

L is the luminosity of experiment data and $N_{\pi^0}^{\exp}(p)$ is the number of π^0 in one momentum bin from experiment data. $N_{had}^{\exp}$ is the number of hadronic events from experiment data.

Model dependent uncertainty

include 3 parts

Then we define C_1 correction to be

$$C_1 = \frac{\varepsilon_{had}}{\varepsilon_{\pi^0}} = \frac{N_{had}^{det}/N_{had}^{truth}}{N_{\pi^0}^{det}/N_{\pi^0}^{truth}} = \frac{N_{\pi^0}^{truth}/N_{had}^{truth}}{N_{\pi^0}^{det}/N_{had}^{det}} (\textit{without ISR correction})$$

The $N_{\pi^0}^{truth}$ is the number of π^0 at truth level from MC and $N_{\pi^0}^{det}$ means number of π^0 at detect level from MC, as well N_{had}^{truth} and N_{had}^{det}.

So far, we have obtained the $\frac{\varepsilon_{had}}{\varepsilon_{\pi 0}}$ from MC with ISR process. We want to get the born relative cross section then the C_1 correction become

$$C = \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{without\ ISR}}{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{with\ ISR}} \cdot C_1$$

$$= \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{with\ ISR}}{\left(N_{\pi^0}^{det}/N_{had}^{det}\right)_{with\ ISR}} \cdot \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{without\ ISR}}{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{with\ ISR}}$$

$$= \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{without\ ISR}}{\left(N_{\pi^0}^{det}/N_{had}^{det}\right)_{with\ ISR}}$$

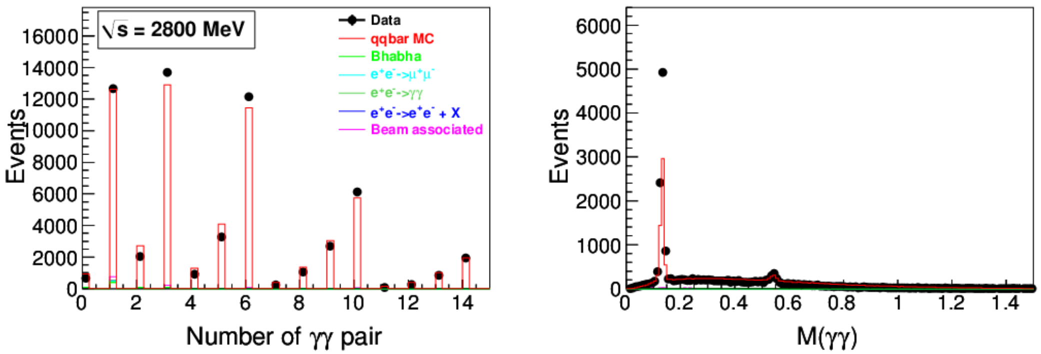
π^0 efficiency

$$\varepsilon_{\pi^0} = N_{\pi^0}^{det} / N_{\pi^0}^{truth} \ (without\ ISR\ correction)$$

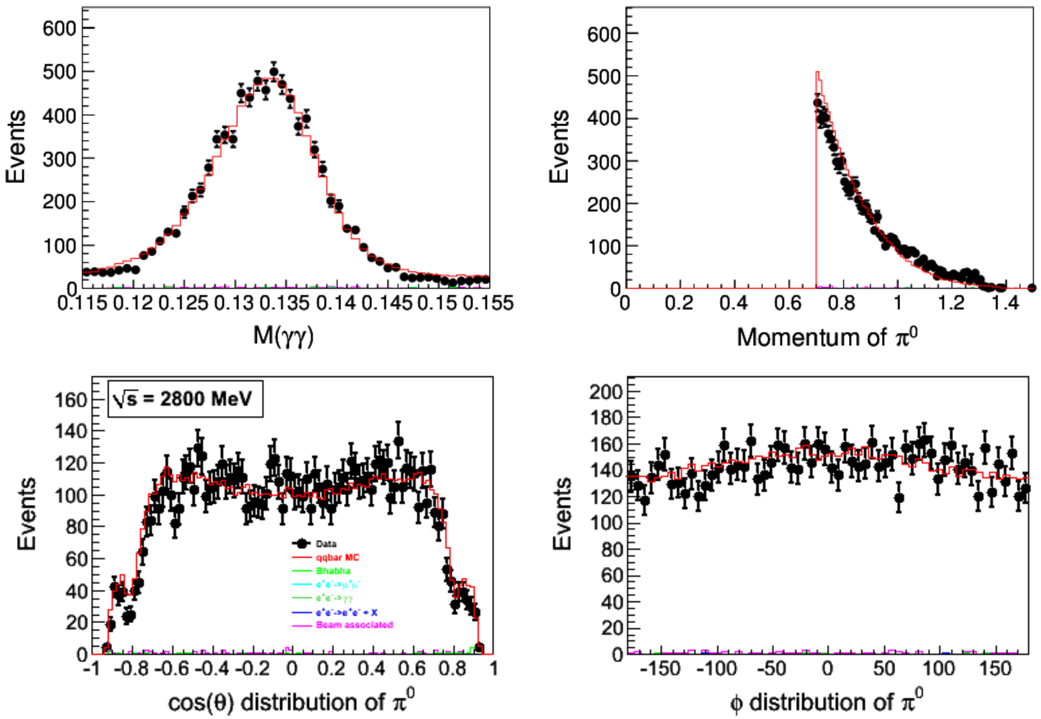
Pingrg WOW	Pingrg WW	Huhm WOW	Huhm WW	WW difference	Momentum (GeV)	Model dependent error
0.354	0.305	0.336	0.306	0.3%	0.0-0.1	6.78%
0.342	0.319	0.349	0.322	0.9%	0.1-0.2	3.33%
0.409	0.387	0.413	0.380	1.8%	0.2-0.3	6.42%
0.424	0.405	0.435	0.401	1.0%	0.3-0.4	5.40%
0.458	0.438	0.474	0.445	1.6%	0.4-0.5	2.86%
0.461	0.441	0.472	0.439	0.4%	0.5-0.6	4.38%
0.454	0.433	0.483	0.440	1.6%	0.6-0.7	2.95%
0.449	0.428	0.467	0.448	4.6%	0.7-0.8	0.14%
0.433	0.411	0.469	0.437	6.3%	0.8-0.9	1.70%
0.404	0.382	0.443	0.422	10.5%	0.9-1.0	5.45%
0.361	0.341	0.399	0.379	11.1%	1.0-1.1	5.79%
0.319	0.303	0.377	0.409	35.0%	1.1-1.2	22.84%
0.339	0.322	0.349	0.357	10.9%	1.2-1.3	5.20%
0.185	0.177	0.235	0.201	13.6%	1.3-1.4	14.90%

Distribution about π^0 candidates (P > 0.7GeV)
(Ping Ronggang)

selection criteria :
- ✓ $|\cos\theta_{\gamma\pi}| < 0.95$



selection criteria :
- ✓ $0.115\text{GeV} < M(\gamma\gamma) < 0.155\text{GeV}$
- ✓ $|\cos\theta_{\gamma\pi}| < 0.95$

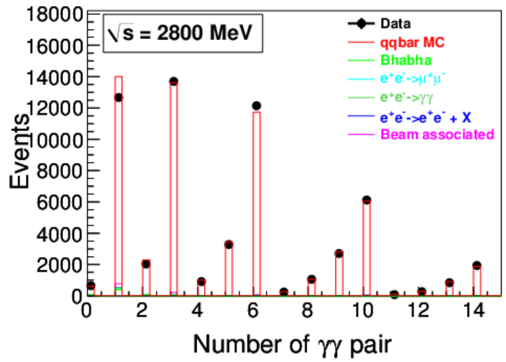


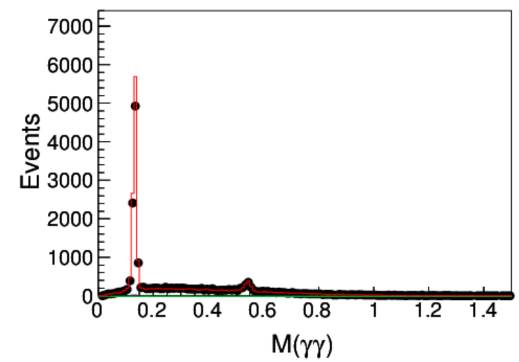
Distribution about π^0 candidates (P > 0.7GeV)

(Hu Haiming)

selection criteria :

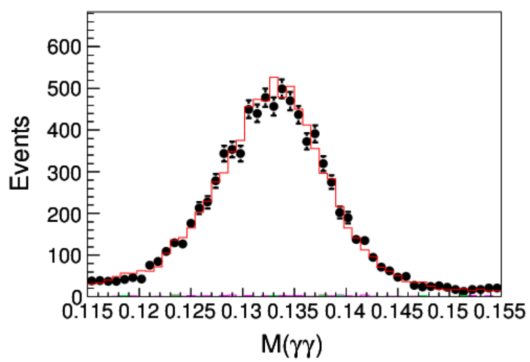
- ✓ $|\cos\theta_{\gamma\pi}| < 0.95$

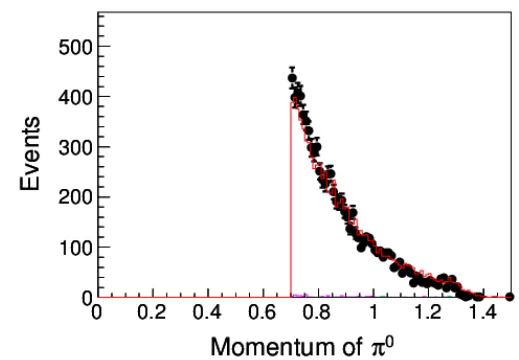


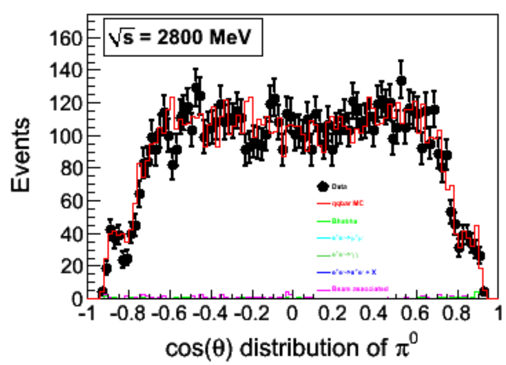


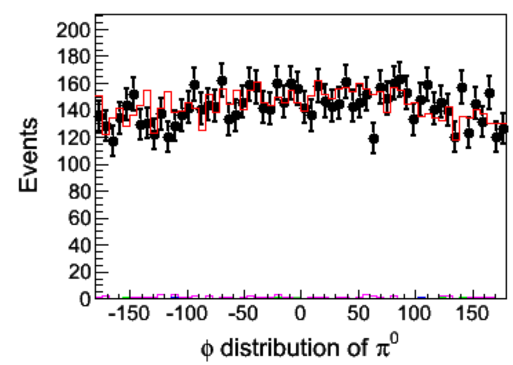
selection criteria :

- ✓ 0.115GeV < M($\gamma\gamma$) < 0.155GeV
- ✓ $|\cos\theta_{\gamma\pi}| < 0.95$









Topology (Huhaiming)

No.	decay chain	final states	iTopo	nEvt	nTot
0	$e^+e^- \to \pi^-\gamma\pi^0\rho^+,\ \rho^+ \to \pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^-$	1	1553	1553
1	$e^+e^- \to \rho^-\gamma\pi^0\pi^+,\ \rho^- \to \pi^-\pi^0$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^-$	8	1520	3073
2	$e^+e^- \to \rho^-\gamma\pi^0\rho^+,\ \rho^- \to \pi^-\pi^0,\ \rho^+ \to \pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^0\pi^-$	9	1166	4239
3	$e^+e^- \to \pi^-\gamma\pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^0\pi^-$	12	1157	5396
4	$e^+e^- \to \gamma\pi^0\pi^0\rho^0,\ \rho^0 \to \pi^-\pi^+$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^-$	18	533	5929
5	$e^+e^- \to \gamma\pi^0\pi^0\omega,\ \omega \to \pi^-\pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^0\pi^-$	7	495	6424
6	$e^+e^- \to \rho^-\gamma\rho^0\pi^+,\ \rho^- \to \pi^-\pi^0,\ \rho^0 \to \pi^-\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^-\pi^-$	39	451	6875
7	$e^+e^- \to \pi^-\gamma\rho^0\rho^+,\ \rho^0 \to \pi^-\pi^+,\ \rho^+ \to \pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^-\pi^-$	82	402	7277
8	$e^+e^- \to \pi^-\gamma\rho^+\omega,\ \rho^+ \to \pi^0\pi^+,\ \omega \to \pi^-\pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^0\pi^-\pi^-$	3	395	7672
9	$e^+e^- \to \rho^-\gamma\pi^+\omega,\ \rho^- \to \pi^-\pi^0,\ \omega \to \pi^-\pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^0\pi^-\pi^-$	5	358	8030
10	$e^+e^- \to \gamma\pi^0\rho^0\omega,\ \rho^0 \to \pi^-\pi^+,\ \omega \to \pi^-\pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^0\pi^-\pi^-$	29	342	8372
11	$e^+e^- \to \pi^-\gamma\pi^0\pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^-$	92	284	8656
12	$e^+e^- \to \rho^-\gamma\rho^+,\ \rho^- \to \pi^-\pi^0,\ \rho^+ \to \pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^-$	145	236	8892
13	$e^+e^- \to \rho^-\gamma\rho^0\rho^+,\ \rho^- \to \pi^-\pi^0,\ \rho^0 \to \pi^-\pi^+,\ \rho^+ \to \pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^0\pi^-\pi^-$	4	210	9102
14	$e^+e^- \to K^-\gamma\pi^0K^+$	$e^+e^- \to \gamma K^+\pi^0K^-$	65	200	9302
15	$e^+e^- \to \rho^-\gamma\rho^+\omega,\ \rho^- \to \pi^-\pi^0,\ \rho^+ \to \pi^0\pi^+,\ \omega \to \pi^-\pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^0\pi^0\pi^-\pi^-$	84	192	9494
16	$e^+e^- \to \gamma\pi^0\omega\omega,\ \omega \to \pi^-\pi^0\pi^+,\ \omega \to \pi^-\pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^0\pi^0\pi^-\pi^-$	14	175	9669
17	$e^+e^- \to \gamma\pi^0\rho^0\rho^0,\ \rho^0 \to \pi^-\pi^+,\ \rho^0 \to \pi^-\pi^+$	$e^+e^- \to \gamma\pi^+\pi^+\pi^0\pi^-\pi^-$	47	160	9829
18	$e^+e^- \to \rho^-\gamma\pi^0\pi^0\pi^+,\ \rho^- \to \pi^-\pi^0$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^0\pi^-$	21	159	9988
19	$e^+e^- \to \pi^-\gamma\pi^0\pi^0\rho^+,\ \rho^+ \to \pi^0\pi^+$	$e^+e^- \to \gamma\pi^+\pi^0\pi^0\pi^0\pi^-$	71	142	10130

Table 1: The possible background channels extracted from Inclusive MC sample

selection criteria :

- ✓ 0.115GeV < M(γγ) < 0.155GeV
- ✓ $|\cos\theta_{\gamma\pi}| < 0.95$
- ✓ P > 0.7GeV

Topology (Pingronggang)

No.	decay chain	final states	iTopo	nEvt	nTot
0	$e^+e^- \to \pi^-\pi^0\pi^0\pi^+$	$e^+e^- \to \pi^+\pi^0\pi^0\pi^-$	6	60651	60651
1	$e^+e^- \to \pi^-\pi^-\pi^0\pi^0\pi^+\pi^+$	$e^+e^- \to \pi^+\pi^+\pi^0\pi^0\pi^-\pi^-$	2	49602	110253
2	$e^+e^- \to \pi^-\pi^-\pi^0\pi^0\pi^+\pi^+$	$e^+e^- \to \pi^+\pi^+\pi^0\pi^0\pi^-\pi^-$	3	11420	121673
3	$e^+e^- \to \pi^-\pi^0\pi^+$	$e^+e^- \to \pi^+\pi^0\pi^-$	27	7446	129119
4	$e^+e^- \to \pi^-\pi^-\pi^0\pi^+\pi^+$	$e^+e^- \to \pi^+\pi^+\pi^0\pi^-\pi^-$	12	5394	134513
5	$e^+e^- \to \pi^-\pi^0\pi^+$	$e^+e^- \to \pi^+\pi^0\pi^-$	38	4523	139036
6	$e^+e^- \to K^-\pi^-\pi^0\pi^+K^+$	$e^+e^- \to K^+\pi^+\pi^0\pi^-K^-$	16	4264	143300
7	$e^+e^- \to K^-\pi^0\pi^0K^+$	$e^+e^- \to K^+\pi^0\pi^0K^-$	46	3809	147109
8	$e^+e^- \to \pi^-\pi^0\pi^+$	$e^+e^- \to \pi^+\pi^0\pi^-$	29	3251	150360
9	$e^+e^- \to K^-\pi^0K^+$	$e^+e^- \to K^+\pi^0K^-$	63	3185	153545
10	$e^+e^- \to \pi^-\pi^-\pi^0\pi^+\pi^+$	$e^+e^- \to \pi^+\pi^+\pi^0\pi^-\pi^-$	14	3060	156605
11	$e^+e^- \to K^{*-}\pi^0K^+,\ K^{*-} \to K^-\pi^0$	$e^+e^- \to K^+\pi^0\pi^0K^-$	49	2783	159388
12	$e^+e^- \to K^-\pi^0K^{*+},\ K^{*+} \to \pi^0K^+$	$e^+e^- \to K^+\pi^0\pi^0K^-$	39	2701	162089
13	$e^+e^- \to K^-\pi^0K^{*+},\ K^{*+} \to K_L\pi^+$	$e^+e^- \to \pi^+K_L\pi^0K^-$	17	2592	164681
14	$e^+e^- \to K^{*-}\pi^0K^+,\ K^{*-} \to \pi^-K_L$	$e^+e^- \to K^+K_L\pi^0\pi^-$	55	2491	167172
15	$e^+e^- \to K^-\pi^0K^{*+},\ K^{*+} \to \pi^+K_S,\ K_S \to \pi^-\pi^+$	$e^+e^- \to \pi^+\pi^+\pi^0\pi^-K^-$	22	2330	169502
16	$e^+e^- \to K^{*-}\pi^0K^+,\ K^{*-} \to \pi^-K_S,\ K_S \to \pi^-\pi^+$	$e^+e^- \to K^+\pi^+\pi^0\pi^-\pi^-$	74	2241	171743
17	$e^+e^- \to \pi^-\pi^0\pi^0\pi^+$	$e^+e^- \to \pi^+\pi^0\pi^0\pi^-$	0	1822	173565
18	$e^+e^- \to \pi^-\pi^+f_2(1270),\ f_2(1270) \to \pi^0\pi^0$	$e^+e^- \to \pi^+\pi^0\pi^0\pi^-$	47	1738	175303
19	$e^+e^- \to \pi^-\pi^0a_1^+,\ a_1^+ \to \pi^0\rho^+,\ \rho^+ \to \pi^0\pi^+$	$e^+e^- \to \pi^+\pi^0\pi^0\pi^0\pi^-$	64	1597	176900

Table 1: The possible background channels extracted from Inclusive MC sample

selection criteria :

- ✓ 0.115GeV < $M(\gamma\gamma)$ < 0.155GeV
- ✓ $|\cos\theta_{\gamma\pi}|$< 0.95
- ✓ P > 0.7GeV

Hadron efficiency

$$\varepsilon_{had} = N_{hadron}^{det} / N_{hadron}^{truth}\ (with\, ISR)$$

qqbar Generator from Ping Ronggang	Ping Ronggang (With weighting)	Ping Ronggang (Without weighting)	Ping Ronggang (With weighting) From Gaozhen
Hadron Efficiency	75.92%	77.21%	76.86%
qqbar Generator from Hu haiming	Hu Haiming (With weighting)	Hu Haiming (Without weighting)	Hu Haiming (With weighting) From Gaozhen
Hadron Efficiency	78.90%	80.99%	78.66%
Difference	3.78%	4.67%	2.29%

Model dependent error	Assume same hadron efficiency(75.92%)
6.78%	2.75%
3.33%	0.57%
6.42%	2.39%
5.40%	1.42%
2.86%	1.01%
4.38%	0.44%
2.95%	0.93%
0.14%	3.91%
1.70%	5.42%
5.45%	9.02%
5.79%	9.35%
22.84%	25.75%
5.20%	8.78%
14.90%	18.12%

The value of 1+δ

$$C = \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{with\ ISR}}{\left(N_{\pi^0}^{det}/N_{had}^{det}\right)_{with\ ISR}} \cdot \frac{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{without\ ISR}}{\left(N_{\pi^0}^{truth}/N_{had}^{truth}\right)_{with\ ISR}}$$, **(1+ δ) presented by the red formula**

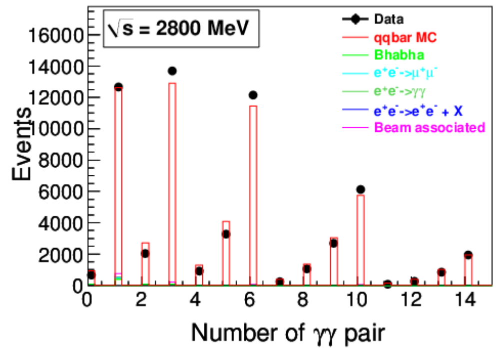
Momentum	Ping rong gang	Hu hai ming	Difference	Model dependent error
0.0-0.1	1.000	1.001	0.1%	6.78%
0.1-0.2	0.999	0.991	0.8%	3.33%
0.2-0.3	1.000	0.998	0.2%	6.42%
0.3-0.4	1.000	0.989	1.1%	5.40%
0.4-0.5	0.999	1.006	0.7%	2.86%
0.5-0.6	0.999	0.998	0.1%	4.38%
0.6-0.7	0.999	0.972	2.7%	2.95%
0.7-0.8	0.999	1.019	2.0%	0.14%
0.8-0.9	0.999	0.991	0.9%	1.70%
0.9-1.0	0.999	1.001	0.2%	5.45%
1.0-1.1	0.999	0.975	2.4%	5.79%
1.1-1.2	0.999	1.081	8.2%	22.84%
1.2-1.3	1.000	0.988	1.2%	5.20%

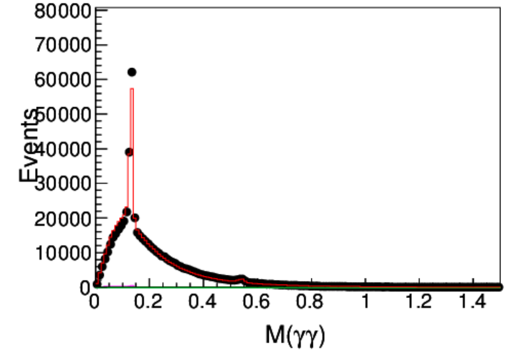
Distribution about π^0 candidates

(Ping Ronggang)

selection criteria :

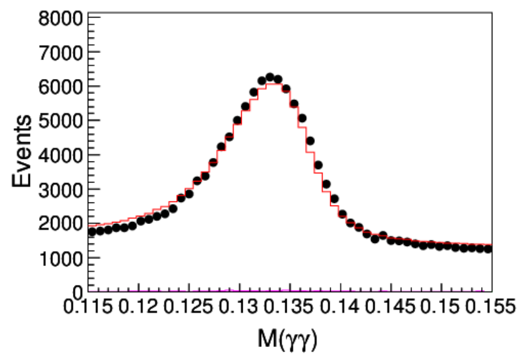
- ✓ $|\cos\theta_{\gamma\pi}| < 0.95$

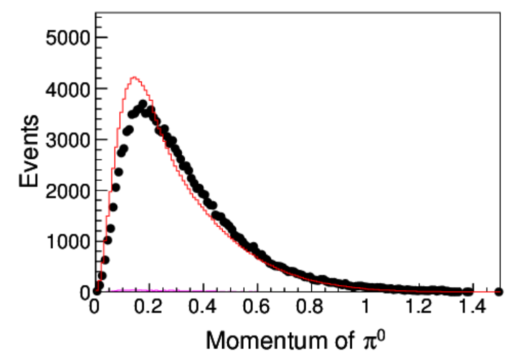


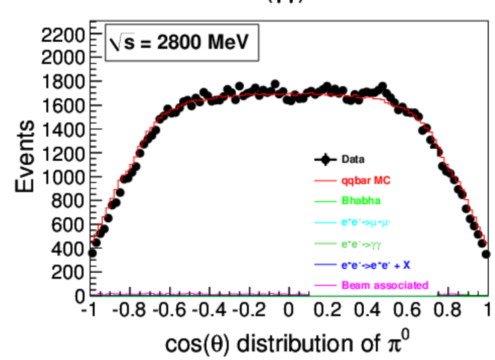


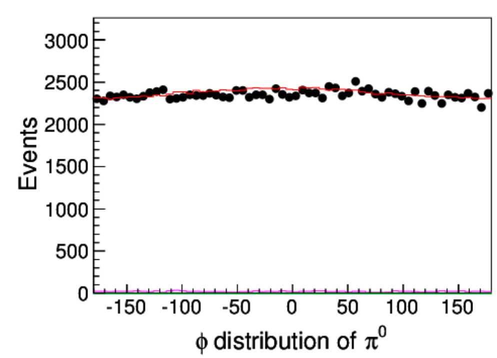
selection criteria :

- ✓ 0.115GeV < M(γγ) < 0.155GeV
- ✓ $|\cos\theta_{\gamma\pi}| < 0.95$





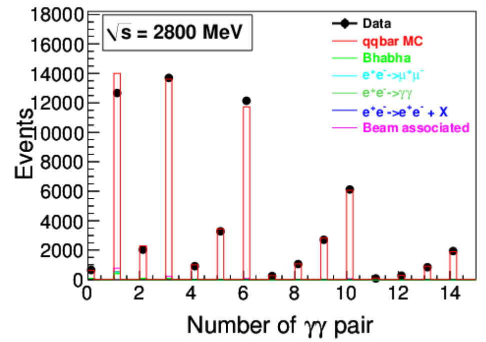


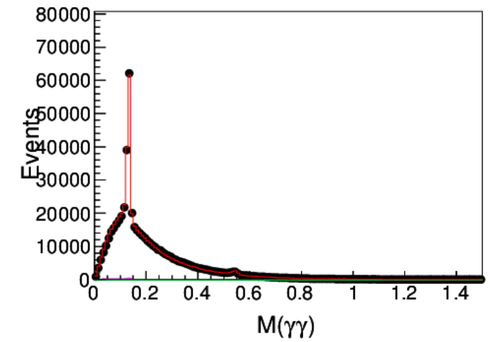


Distribution about π^0 candidates
(Hu Haiming)

selection criteria :

✓ $|\cos\theta_{\gamma\pi}| < 0.95$

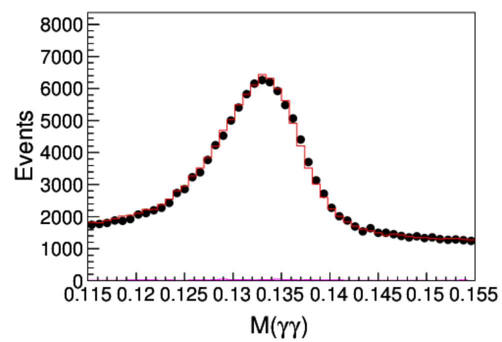


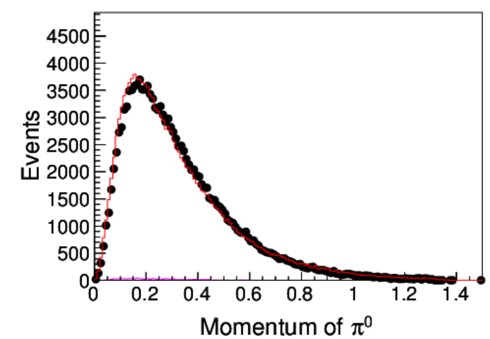


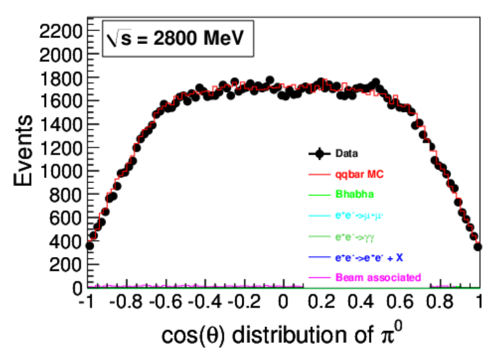
selection criteria :

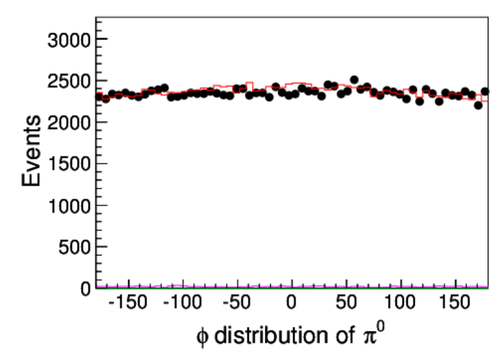
✓ $0.115\mathrm{GeV} < M(\gamma\gamma) < 0.155\mathrm{GeV}$

✓ $|\cos\theta_{\gamma\pi}| < 0.95$

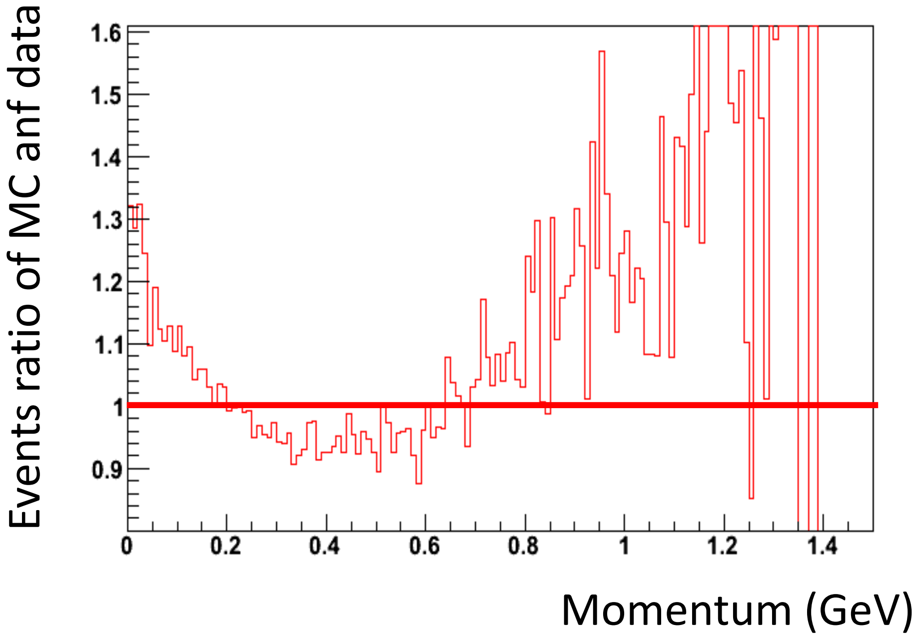








Hu Haiming
(Momentum distribution of MC/Data)



Ping Ranggang
(Momentum distribution of MC/Data)