Update on $\Psi(2S) \to \pi^+\pi^- J/\Psi$, $J/\Psi \to$ invisible

Suyu Xiao, Qian Chen, Ryuta Kiuchi, Kai Liu, Xinchou Lou, Xin Shi,
Dayong Wang, Chi Zhang, Shenjian Chen and Jingzhi Zhang

20180910

Outline

- Result for 2012 data set
- Updated items
- Checking items
- Combined Method
- Question & Discussion

Result for 2012 data set

Number of Ψ(2S) →π⁺π⁻J/Ψ, J/Ψ → invisible

$$N(J/\Psi \rightarrow invisible)$$
$$= N_{invisible} - N_{peaking} - N_{others} \times \varepsilon_{trig}$$
$$= (396471 \pm 683) - (443620 \pm 9357) - 13779 \times (99.8 \pm 0.04)\%$$
$$= -60900 \pm 683\,(stat.) \pm 9541\,(syst.)$$

$$N(J/\Psi \rightarrow invisible)$$
$$= (137770 \pm 406) - (134586 \pm 2919) - 3877 \times (99.4 \pm 0.1)\%$$
$$= -670 \pm 406\,(stat.) \pm 2979\,(syst.)$$

2009 result for comparison

Updated items

Trigger efficiency

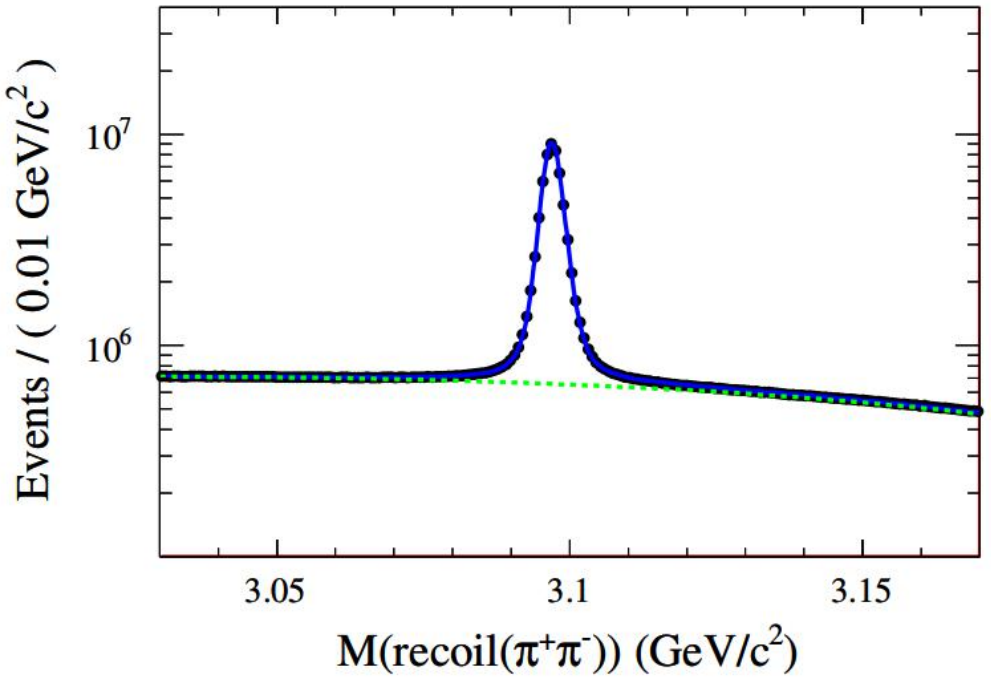
Table 13: Trigger setting for the 2012 $\psi(3686)$ running. Compared with the condition in 2009, Channel 2 is deactivated and a new neutral trigger, Channel 8, is added.

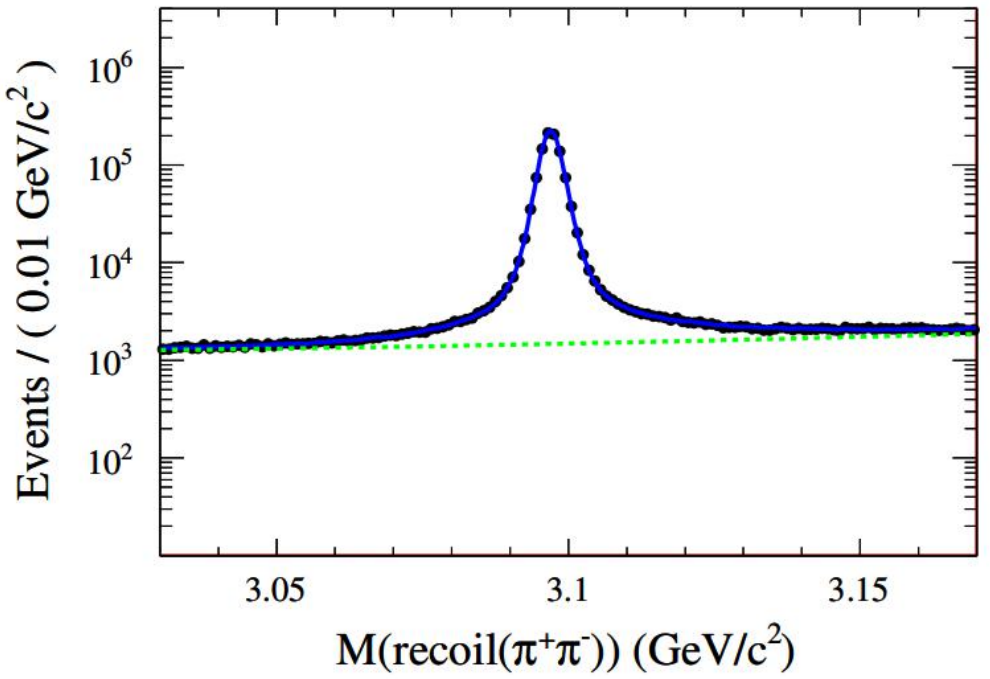
Channel	Conditions
0	STrk_BB && NETOF.GE.1 && NEClus.GE.1
1	NLTrk.GE.2 && NBTOF.GE.2 && NBClus.GE.1
3	LTrk_BB && BTOF_BB
4	NLTrk.GE.1 && NBTOF.GE.1 && Etot_L
5	NLtrk.GE.2 && NBTOF.GE.1 && NBClus.GE.1
8	NClus.GE.1 && BEtot_H
9	random trigger at 60 Hz
11	NClus.GE.2 && Etot_M

$$\varepsilon = \frac{N(Channel\ 0-5\ \&\&\ Channel\ 11)}{N(Channel\ 11)} = \frac{11911}{11934} = (99.8 \pm 0.04)\%$$

Signal yield after fitting on anything & invisible

Take J/Ψ->e^+e^- as signal shape, 2nd-order polynomial as background:





$$N(\Psi(2S)\to\pi^+\pi^- J/\Psi) = (579014 \pm 8.9)\times 10^3$$

$$N_{invisible} = 396471 \pm 683$$

Signal yield for Ψ(2S) →π⁺π⁻J/Ψ, J/Ψ → invisible

$$N_{peaking} = N(\Psi(2S) \to \pi^+\pi^- J/\Psi) \times B_{2B} \times \varepsilon_{2B} \times \varepsilon_{trig}$$

Channel	$\mathcal{B}_{2B}(\%)$	$\epsilon_{2B}(\%)$	$\epsilon_{\text{trig}}(\%)$	Event number
$J/\psi \to \mu^+\mu^-$	5.961 ± 0.033	6.24 ± 0.02	99.8 ± 0.04	214949 ± 4338
$J/\psi \to e^+e^-$	5.971 ± 0.032	6.32 ± 0.02	99.8 ± 0.04	218030 ± 4460
$J/\psi \to n\bar{n}$	0.209 ± 0.016	6.13 ± 0.02	99.8 ± 0.04	7403 ± 3076
$J/\psi \to p\bar{p}$	0.2120 ± 0.0029	2.64 ± 0.02	99.8 ± 0.04	3238 ± 72
Total				443620 ± 9357

little higher

Systematic error study

Summary of the relative systematic uncertainties (%) in the yield extraction for 2012

Sources	$J/\psi \to$ invisible	$J/\psi \to$ anything	$J/\psi \to \mu^+\mu^-$
Fitting range	0.47	0.40	
Signal shape	0.03	0.03	
BG shape		0.01	
Bin size		0.22	
μ track-finding			0.2
E/p ratio cut			0.03
Mass window on $M_{\mu^+\mu^-}$			0.31
Mass window on $M^{rec}_{\pi^+\pi^-}$			0.32
Background components in counting			0.02
Total	0.47	0.46	0.49

consistent with 2009 data set

Systematic error study

Summary of the relative systematic uncertainties (%) in the peaking background estimation

Sources	$J/\psi \to \mu^+\mu^-$	$J/\psi \to e^+e^-$	$J/\psi \to n\bar{n}$	$J/\psi \to p\bar{p}$
$N(\pi^+\pi^- J/\psi)$ statistics		0.02		
Fit in $N(\pi^+\pi^- J/\psi)$		0.46		
$N_\gamma = 0$		1.90		
Trigger		0.04		
$\mathcal{B}(J/\psi \to 2B)$	0.55	0.54	7.66	1.37
MC statistics	0.32	0.32	0.33	0.76
$N_{\text{extra trk(shower)}} = 0$	0.5	0.6	54.8	1.3

commen relative systematic error

individual relative systematic error

$$\Delta = \sqrt{(\sum_i N_i)^2 \sum_i \sigma^2_{com,i} + \sum_i (N_i^2 \sum_j \sigma^2_{unc,i,j})} = 9541$$

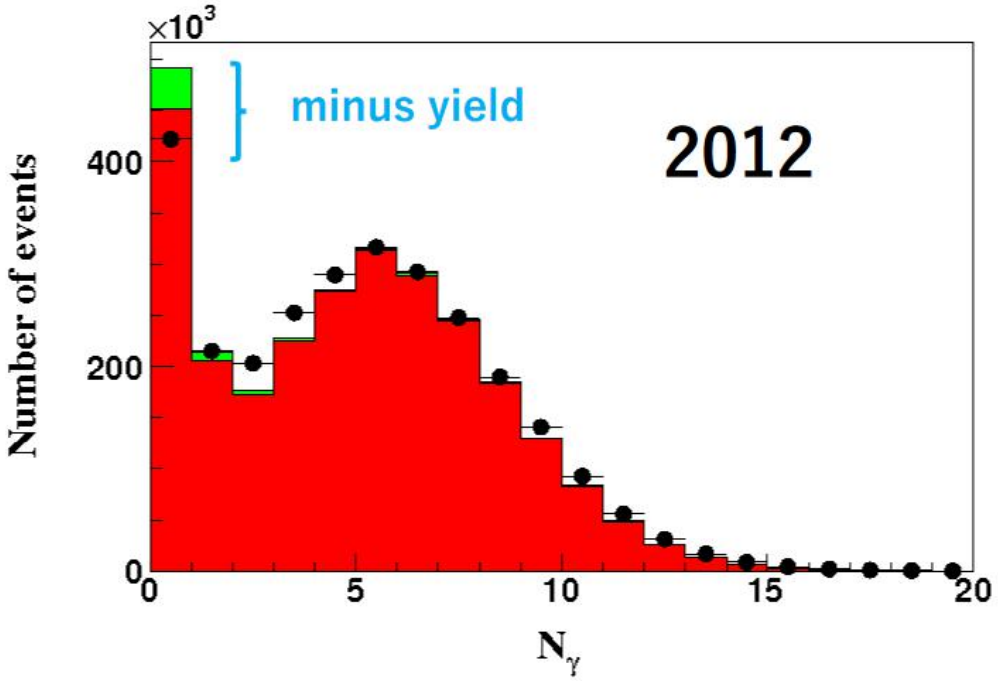
Checking items

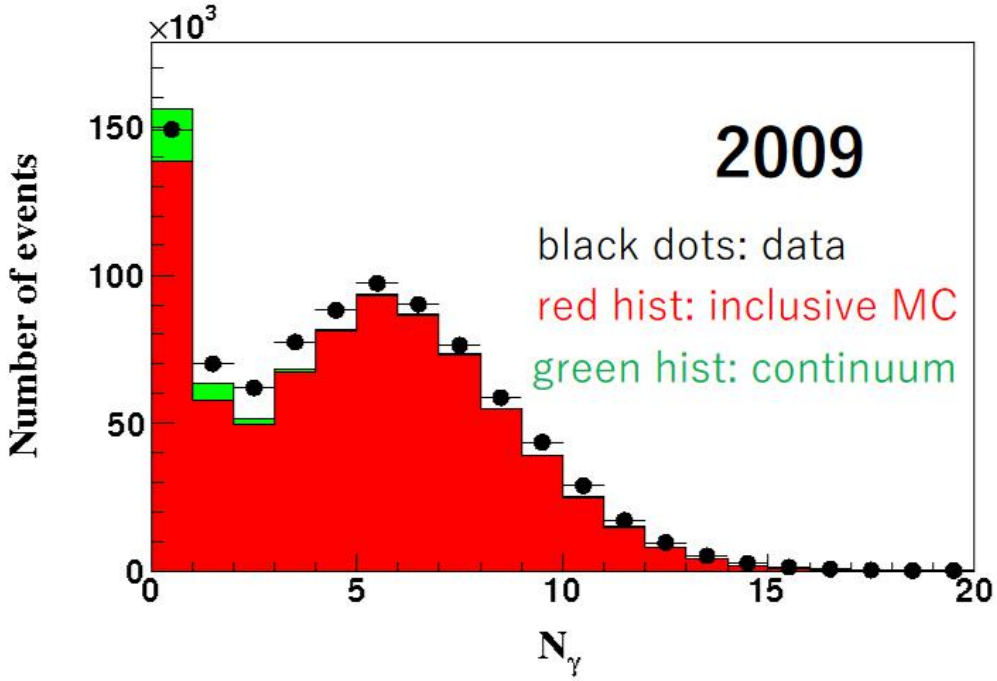
➢ Check items in every process:

Ratio for Ψ(2S) real data 12/09: 341/106 = 3.22

Channel	B_{2B}(%)	ε_{2B}(%)	ε_{trig}(%)	Number of Events(12)	Number of Events(09)	Ratio 12/09
J/Ψ->$\mu^+\mu^-$	5.961±0.033	6.24±0.02	99.8±0.04	214949±4338	65558±1388	3.26 ↑
J/Ψ->e^+e^-	5.971±0.032	6.32±0.02	99.8±0.04	218030±4460	65668±1405	3.30 ↑
J/Ψ->nnbar	0.209±0.016	6.13±0.02	99.8±0.04	7403±3076	2361±997	3.34 ↑
J/Ψ->ppbar	0.2020±0.0029	2.64±0.02	99.8±0.04	3238±72	999±28	3.12 ↓
Total (total/anything)				443620±9357 (0.763%)	134586±2919 (0.721%)	3.30 ↑ (1.058)
N_{others} (others/peaking)				13779 (3.106%)	3877 (2.881%)	3.55 ↑ (1.076)
$N_{anything}$				(57901.4±8.9)*10^3	(18658.1±5.0)*10^3	3.10 ↓
$N_{invisible}$		39.25±0.07		396471±683	137770±406	2.88 ↓

- Check number of good photons:





The histogram for 2012 data set suggests the total number, especially N = 0 differs.

<= Number of 'peaking bkg' or **EMC response between data & MC is different**.

- Comparison of tracks between Data & MC:

As mentioned in the paper, there is discrepancy at large polar angle.

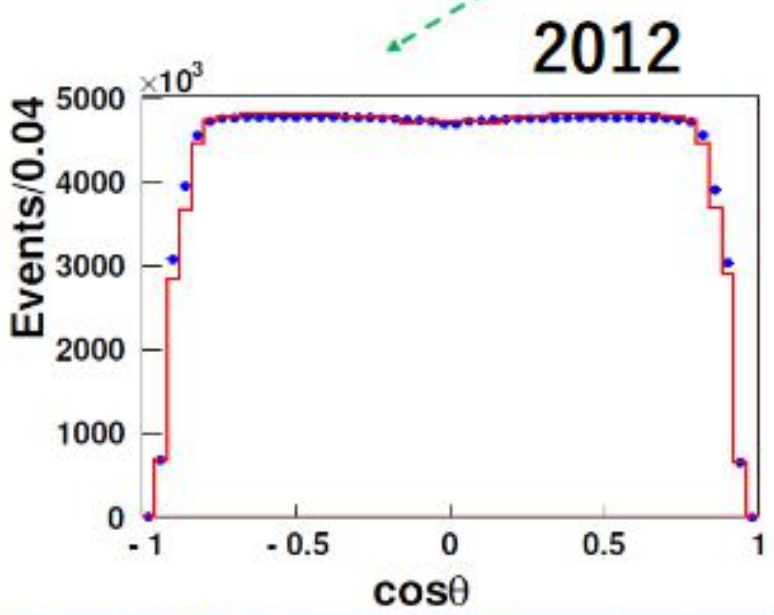


Fig.7 (top-left) from the reference bellow:

"Determination of the number of Psip events at BESIII", Chinese Phys. C Vol.42, No.2 (2018) 023001

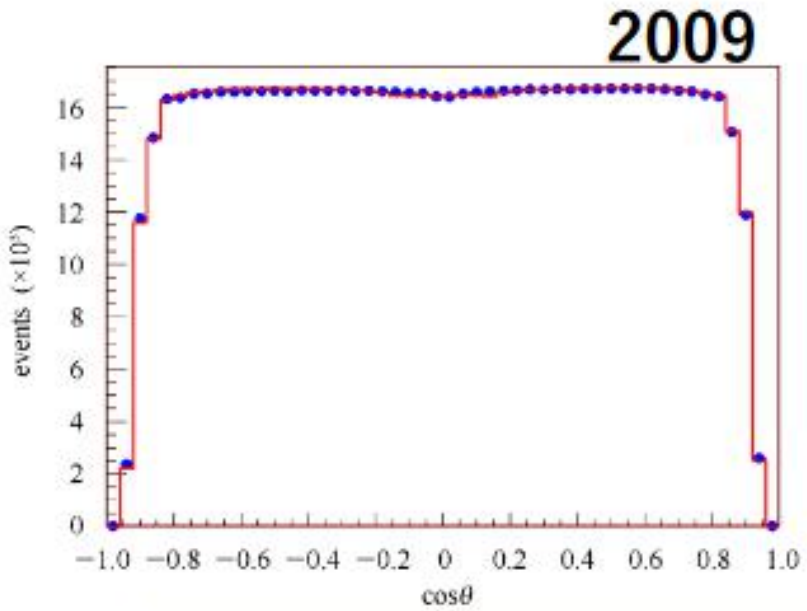
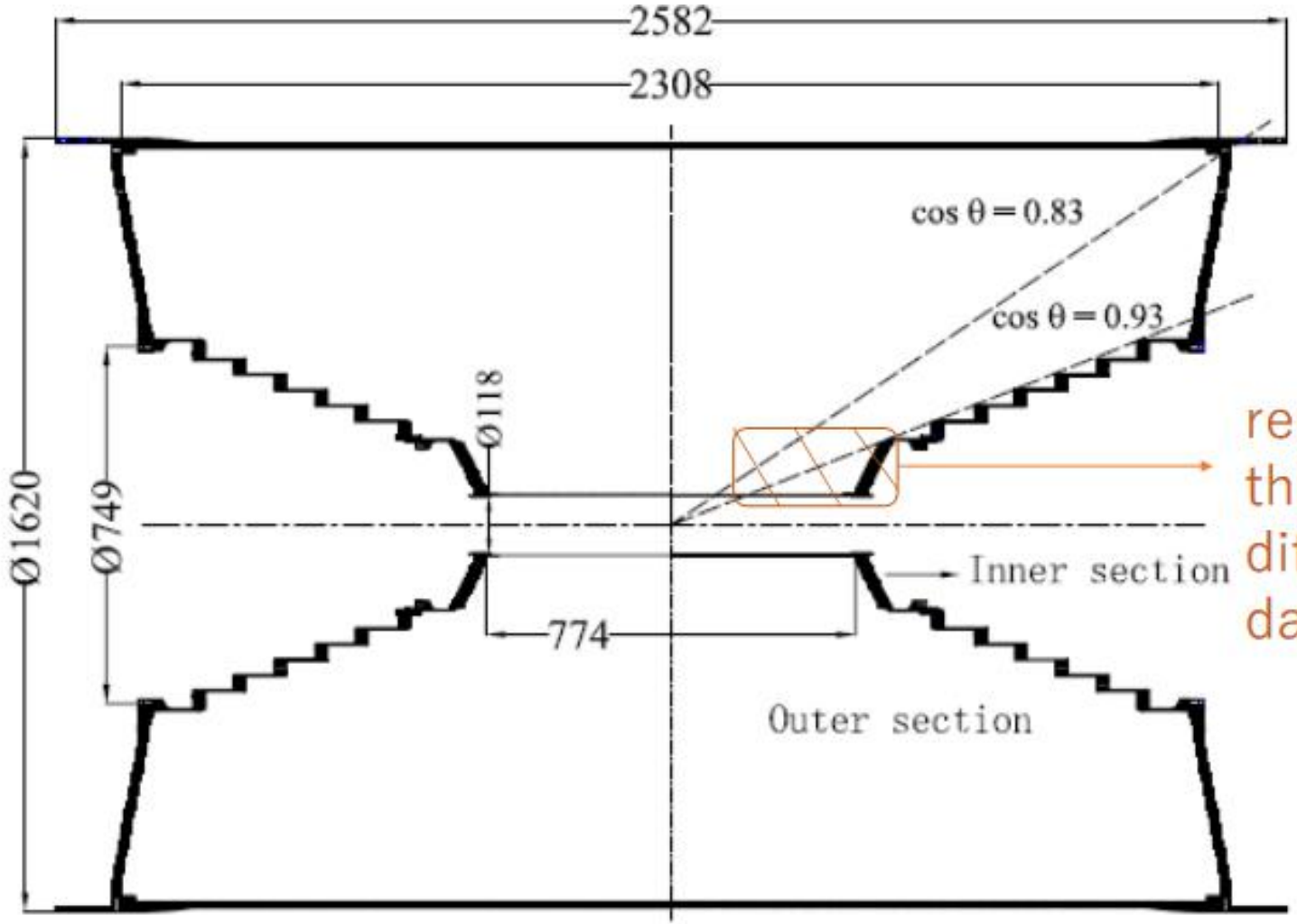


Fig.7 from the reference bellow :

"Determination of the number of Psip events at BESIII", Chinese Phys. C Vol.37, No.6 (2013) 063001

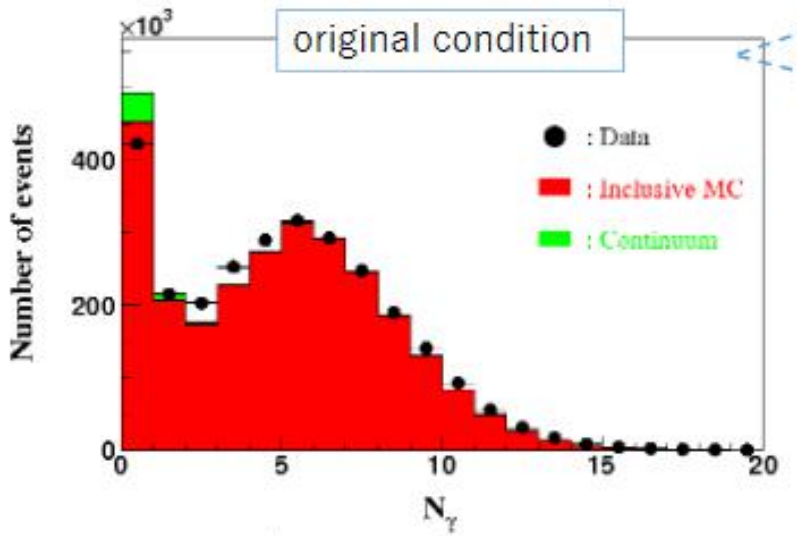
➢ Comparison of tracks between Data & MC:

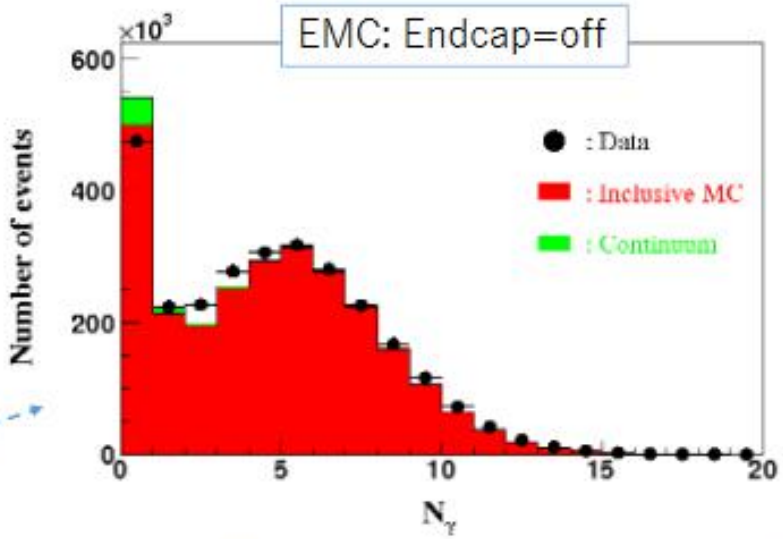


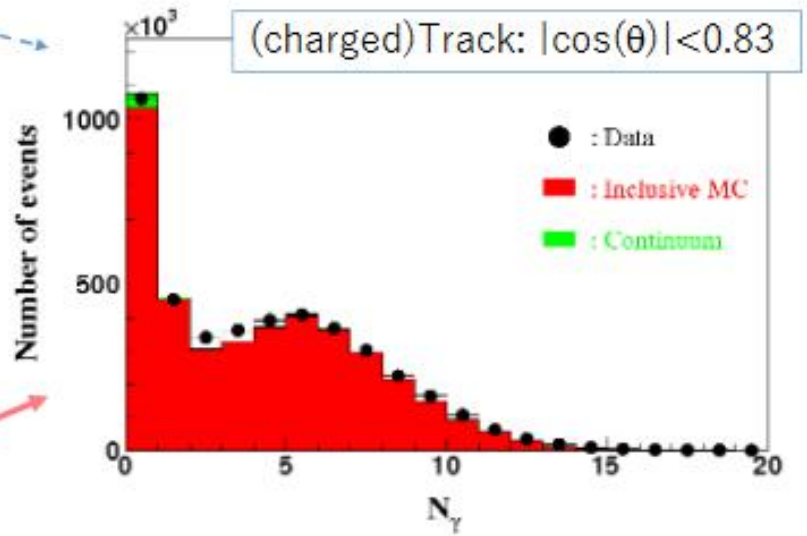
response around this region is different between data & MC ?

2012 Ψ(2S) Data

Number of good photon distribution after the invisible cut criteria, except N_γ=0, are applied.



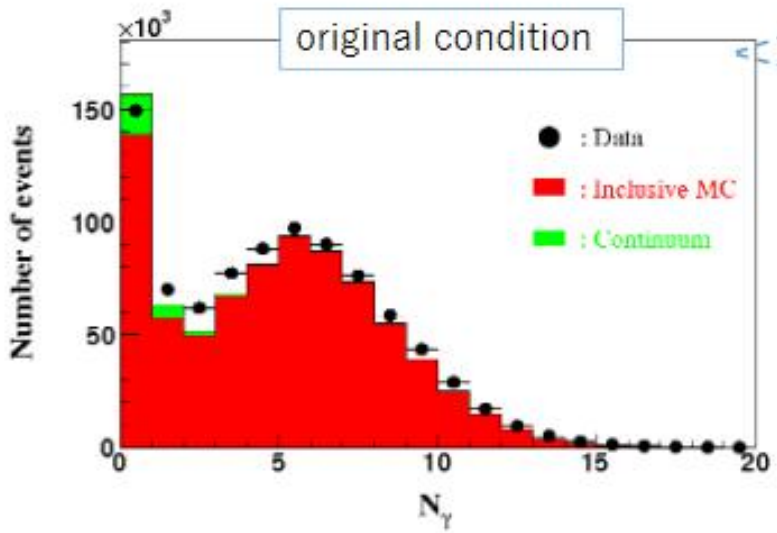


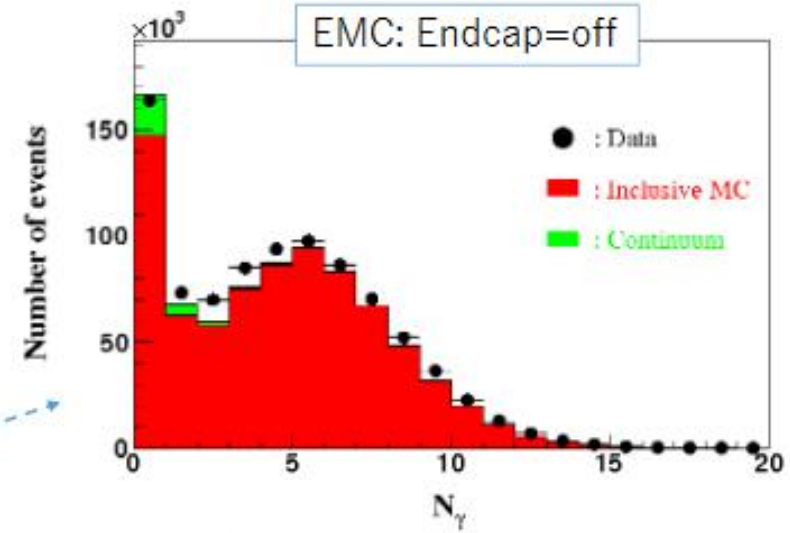


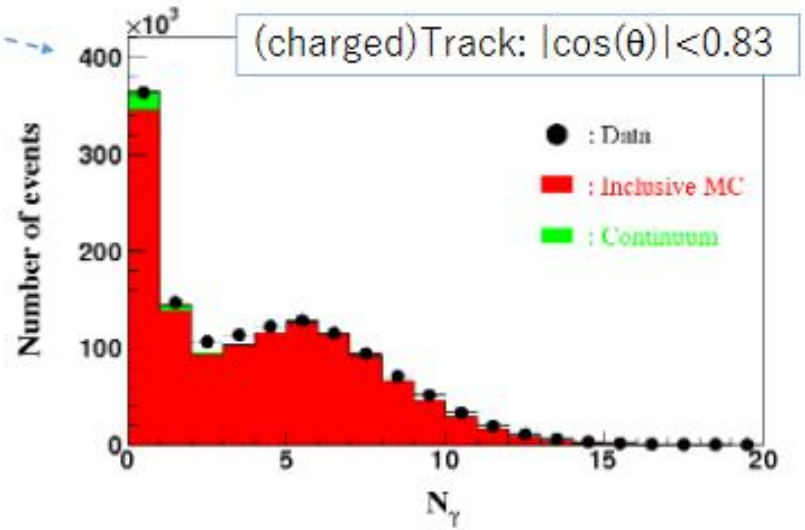
Masking the (charged)track region 0.83<|cos(θ)|<0.93 changes the data&MC ratio.

2009 Ψ(2S) Data

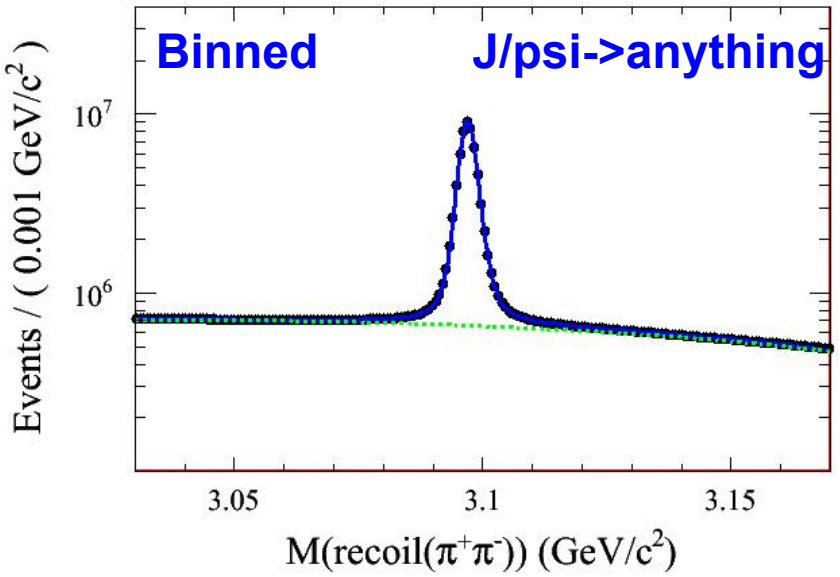
For 2009, the effect of masking the EMC endcap or 0.83<|cos(θ)|<0.93 for tracks has been observed but small. (to compared with that of 2012)



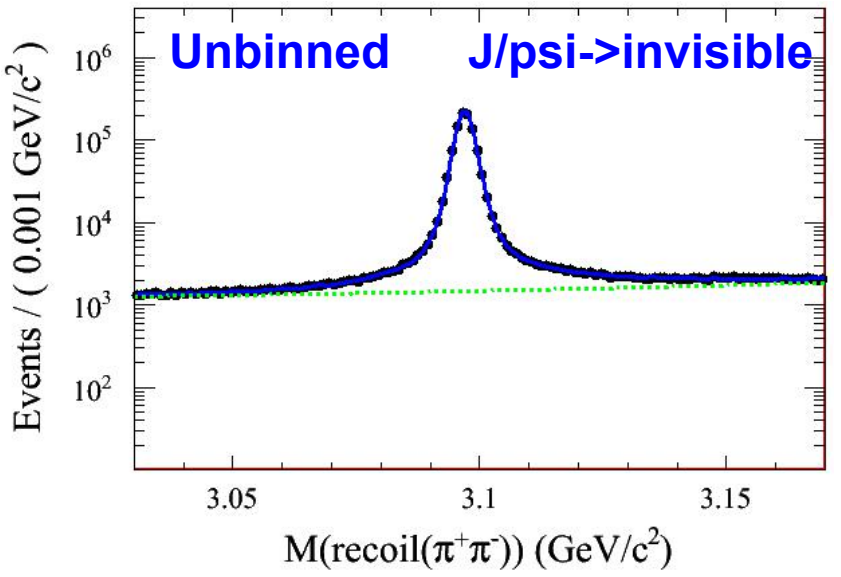




- Masking charged tracks region:



$$nsig = 57957900 \pm 8873$$
$$nbkg = 126360000 \pm 12129$$



$$nsig = 1064400 \pm 1098$$
$$nbkg = 211849 \pm 594$$

➢ Masking charged tracks region:

Condition		mumu	ee	nn	pp	nunu	
|cosθ|<**0.83**	invisible	**139638**	**136498**	**39338**	**33943**	invi	**119250**
	anything	**1511873**	**1279041**	1009248	**1005591**	total	500000
	$eff_{acceptance}$(%)	**9.24**	**10.67**	**3.90**	**3.38**	eff	**23.85**
|cosθ|<0.93	invisible	93770	94983	61413	26370	invi	196600
	anything	1502682	1503130	1001934	997676	total	500000
	$eff_{acceptance}$(%)	6.24	6.32	6.13	2.64	eff	39.32
eff_new/eff_old		**1.48**	**1.69**	**0.64**	**1.28**	**0.6166**	

➢ Masking charged tracks region:

Channel	B_{2B}(%)	ε_{2B}(%)	ε_{trig}(%)	Event number
mumu	5.961±0.033	**9.24**±0.02	99.8±0.04	**318457±6427**
ee	5.971±0.032	**10.67**±0.02	99.8±0.04	**368580±7539**
nn	0.209±0.016	**3.90**±0.02	99.8±0.04	**4711±1958**
pp	0.2020±0.0029	**3.38**±0.02	99.8±0.04	**3944±93**
Total				**695693±14011**

Channel	$\mathcal{B}_{2B}(\%)$	$\epsilon_{2B}(\%)$	$\epsilon_{trig}(\%)$	Event number
$J/\psi \to \mu^+\mu^-$	5.961 ± 0.033	6.24 ± 0.02	99.8 ± 0.04	214949 ± 4338
$J/\psi \to e^+e^-$	5.971 ± 0.032	6.32 ± 0.02	99.8 ± 0.04	218030 ± 4460
$J/\psi \to n\bar{n}$	0.209 ± 0.016	6.13 ± 0.02	99.8 ± 0.04	7403 ± 3076
$J/\psi \to p\bar{p}$	0.2120 ± 0.0029	2.64 ± 0.02	99.8 ± 0.04	3238 ± 72
Total				443620 ± 9357

➢ Checking Inclusive MC generator:

Ψ(2S)->π⁺ π⁻ J/Ψ	0.3504	JPIPI	2012
	0.3230	JPIPI	2009

	09				12			Type
	BF		Number	Scale to 12	BF		Number	
J/psi->e+e-	0.0594	0	65296	274896	0.0594	0	252586	PHOTOS VLL
J/psi->mu+mu-	0.0593	1	65229	274614	0.0593	1	247075	PHOTOS VLL
J/psi->n nbar	0.0022	2	2565	10799	0.0022	2	9116	J2BB1
J/psi->p pbar	0.00217	3	1068	4496	0.00217	3	3760	J2BB1
J/psi->n pi0 nbar	-	4	201	846	-	4	671	-
J/psi->rho+ pi-	0.00565	8	129	543	0.00563333	5	626	HELAMP
J/psi->rho0 pi0	0.00560	-	-	-	0.00563333	6	593	HELAMP
J/psi->rho- pi+	0.00565	6	141	594	0.00563333	7	579	HELAMP
J/psi->lambda anti-lambda	0.00161	5	144	606	0.00161	8	561	J2BB1
lambda->p pi-, anti-lambda->pbar pi+	0.6390 for each				0.6390 for each			PHSP
J/psi->pbar n pi+	0.00106	-	-	-	0.00247	9	550	PHSP
J/psi->K*+ K-	0.000545	10	117	493	0.00256	10	534	HELAMP
K*+->K0 pi+	-	-	-	-	-	-	-	-
J/psi->K*- K+	0.000545	9	126	530	0.00256	-	-	HELAMP
K*-->anti-K0 pi-	-				-			-
J/psi->anti-sigma+ sigma-	-	7	132	556	-	-		
anti-sigma+->nbar pi+, sigma-->n pi-	-				-			

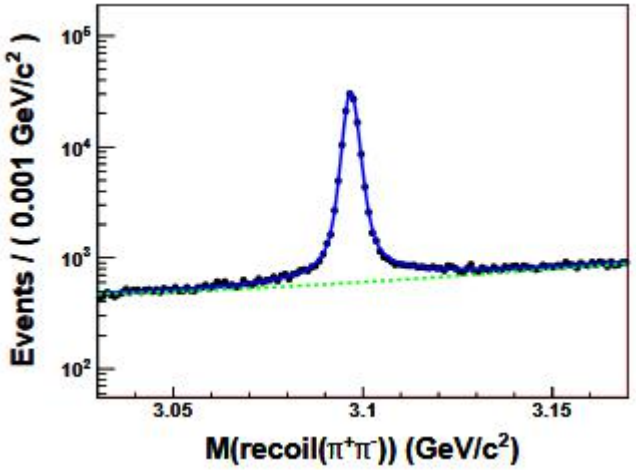
$$Scale_{2009} = \frac{400}{106} \times \frac{0.3504}{0.3230} = 4.21$$

BF & number of events
different BF between 09 & 12

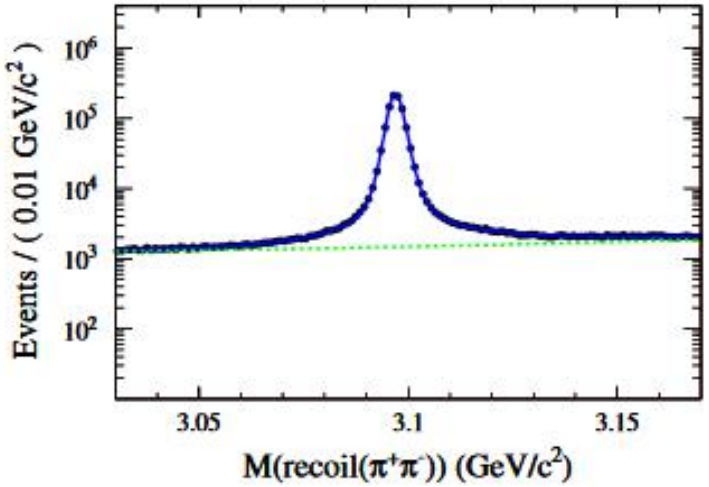
different number of events between 09 & 12
comparison of scaled 2009 events and 2012

HELAMP 1.0 0.0 0.0 0.0 -1.0 0.0

- Checking mass resolution:



From Figure 32 in memo, distribution of J/psi -> invisible for 2009 data set



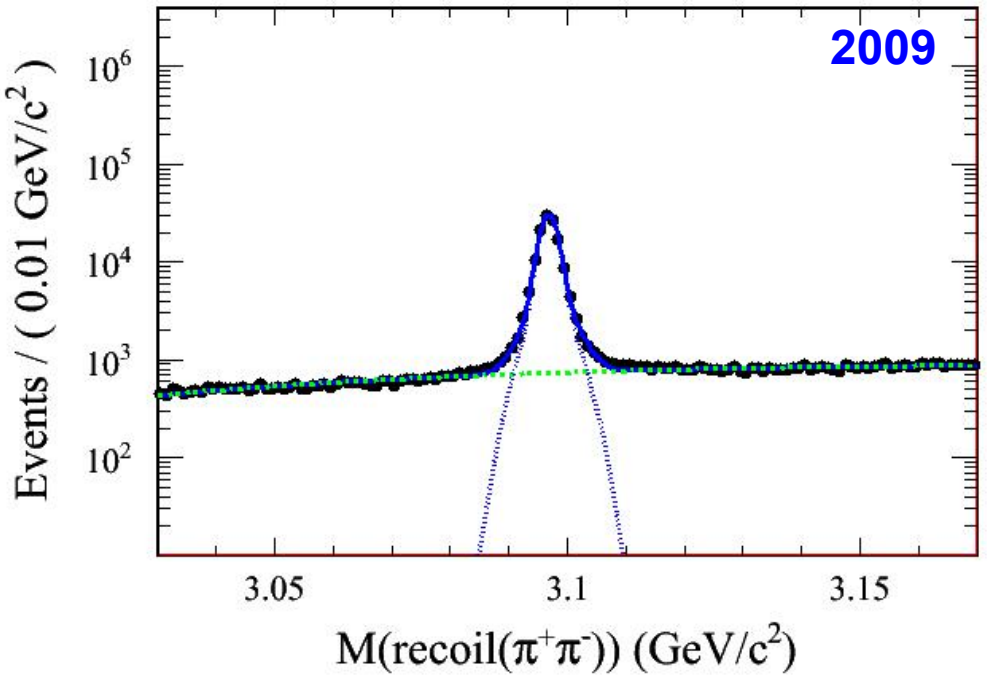
From Figure 65 in memo, distribution of J/psi -> invisible for 2012 data set

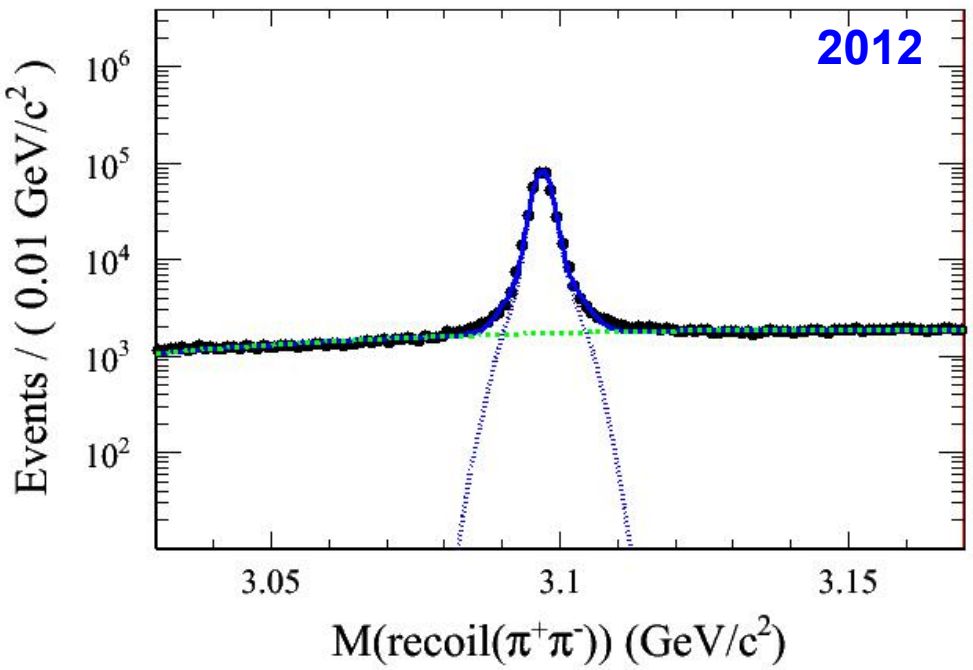
Suggestion from Fang Liu:

Background level seems not the same, is the background function reasonable?

For signal, check mass resolution between two data samples.

➢ Checking mass resolution: Jpsi -> invisible

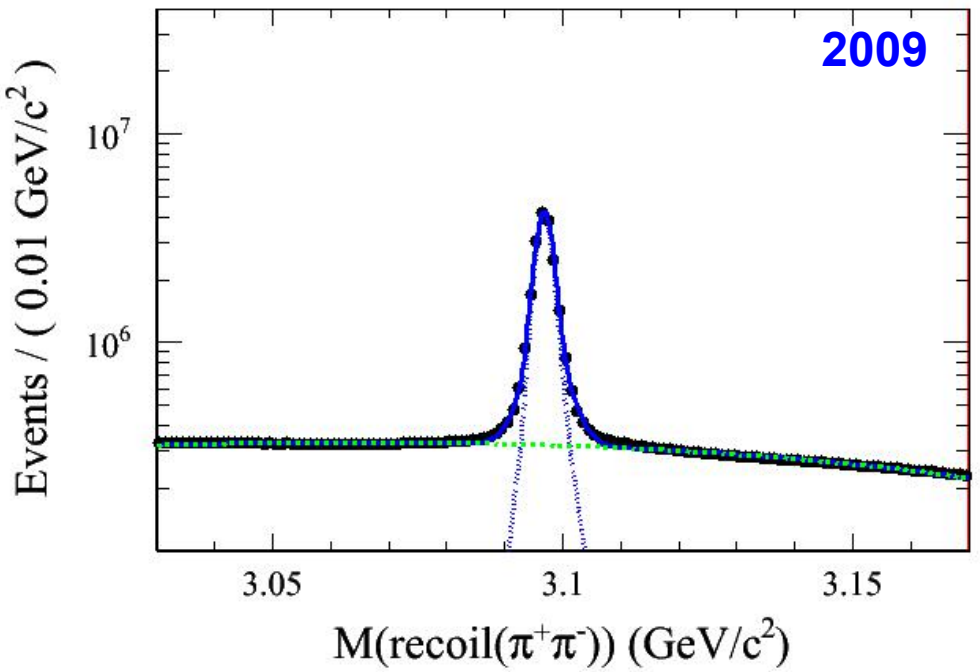


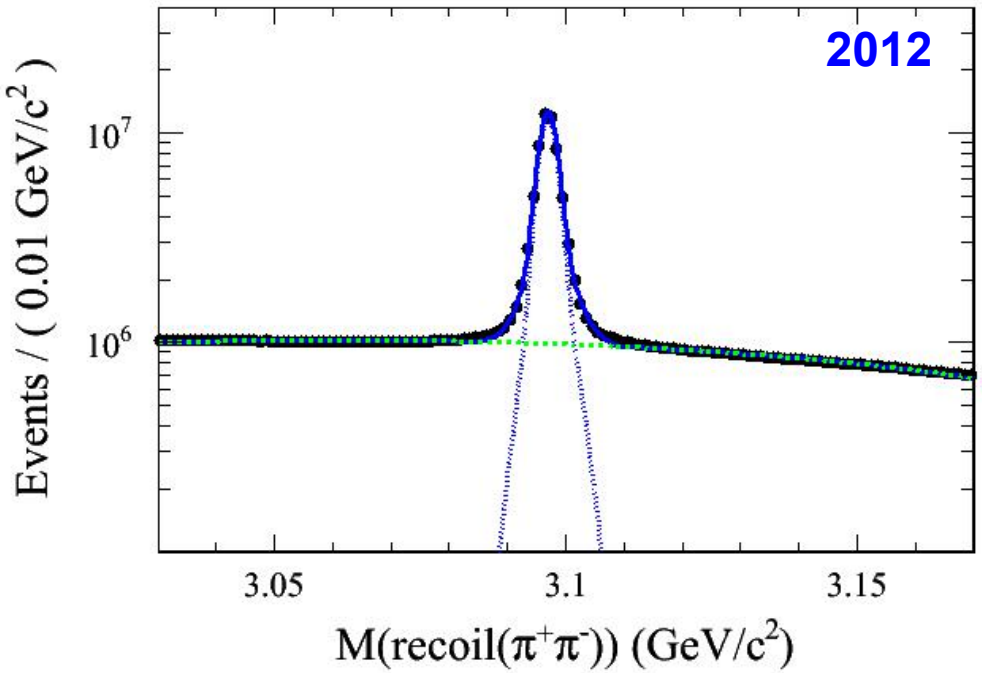


Items	Bkg		Double-Gaussian				%	N		EDM
	c0	c1	mean	mean1	sigma	sigma1	sigfrac	nbkg	nsig	
2009	3.200e+01	-6.550e-02	3.097	3.097	1.454e-03	3.596e-03	7.521e-01	9.977e+04	1.265e+05	5.518e-05
2012	2.504e+01	-8.776e-02	3.097	3.097	1.546e-03	4.099e-03	7.690e-01	2.306e+05	3.687e+05	1.555e-05

12/09: 2.31 2.91

➢ Checking mass resolution: Jpsi -> anything





Items	Bkg		Double-Gaussian				%	N		EDM
	c0	c1	mean	mean1	sigma	sigma1	sigfrac	nbkg	nsig	
2009	-1.643e+01	-8.162e-02	3.097	3.097	1.475e-03	3.570e-03	7.178e-01	4.255e+07	1.723e+07	2.799e-05
2012	-1.779e+01	-7.925e-02	3.097	3.097	1.540e-03	3.681e-03	7.135e-01	1.306e+08	5.377e+07	3.685e-04

12/09: 3.07 3.12

Items	Bkg		Double-Gaussian				%	N		EDM
	c0	c1	mean	mean1	sigma	sigma1	sigfrac	nbkg	nsig	
2009 invi	3.200e+01	-6.550e-02	3.097	3.097	1.454e-03	3.596e-03	7.521e-01	9.977e+04	1.265e+05	5.518e-05
	3.201e+01	5.628e-02						8.827e+04	1.380e+05	5.148e-05
								13.03%	8.33%	
2012 invi	2.504e+01	-8.776e-02	3.097	3.097	1.546e-03	4.099e-03	7.690e-01	2.306e+05	3.687e+05	1.555e-05
	2.409e+01	3.666e-02						2.017e+05	3.976e+05	3.829e-05
								14.33%	7.27%	
2009 incl	-1.643e+01	-8.162e-02	3.097	3.097	1.475e-03	3.570e-03	7.178e-01	4.255e+07	1.723e+07	2.799e-05
	-1.769e+01	-5.020e-02						4.113e+07	1.866e+07	3.751e-07
								3.45%	7.66%	
2012 incl	-1.779e+01	-7.925e-02	3.097	3.097	1.540e-03	3.681e-03	7.135e-01	1.306e+08	5.377e+07	3.685e-04
	-1.902e+01	-4.982e-02						1.264e+08	5.790e+07	2.972e-06
								3.32%	7.13%	

double gaussian fit **## Jpsi->ee shape fit** **## uncertainty for fit method**

Combined method

- Take 2009 & 2012 as one data set:

$$\frac{B(J/\Psi \rightarrow invisible)}{B(J/\Psi \rightarrow \mu^+\mu^-)} = \frac{\frac{N_{invi}}{\varepsilon_{invi} \cdot \varepsilon_{trig}}}{\frac{N_{\mu\mu}}{\varepsilon_{\mu\mu}}}$$

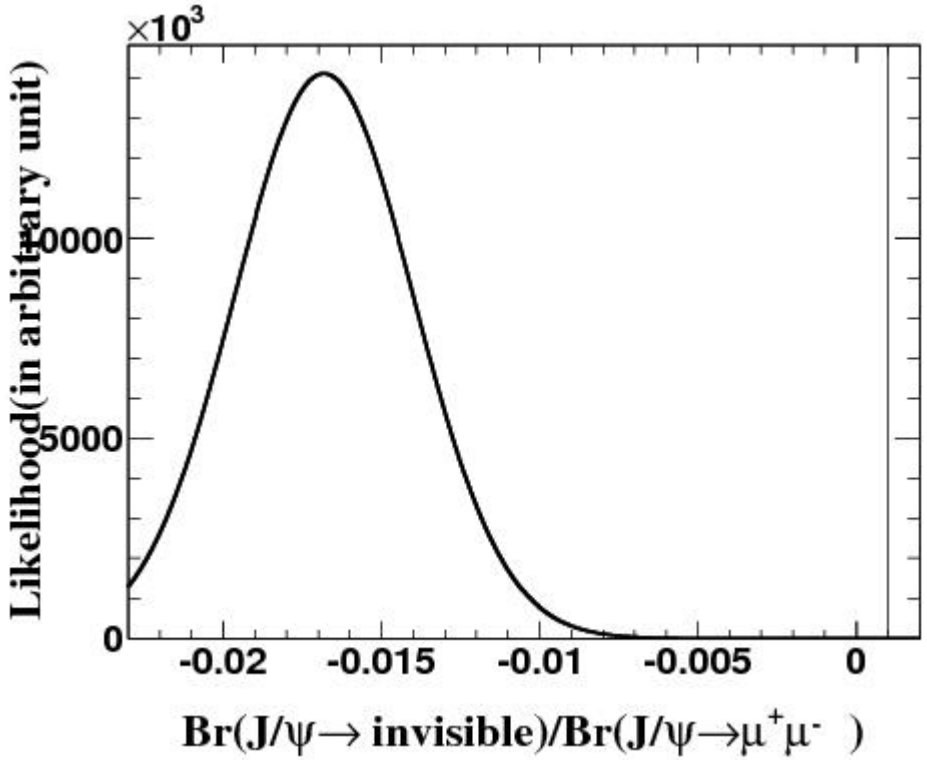
Items	N_{invi}	ε_{invi}(%)	ε_{trig}(%)	$N_{\mu\mu}$	$\varepsilon_{\mu\mu}$(%)	$B_{invi}/B_{\mu\mu}$(*10^{-4})	UL @ 90%(*10^{-3})
2009	-670±406±2987	40.48±0.07	99.4±0.1	713652±693±3497	32.36±0.03	-26.6±4.4±30.0	5.08
2012	-60900±683±9901	39.25±0.07	99.8±0.04	2224671±1275±10901	31.44±0.03	-219.72±2.47±35.74	1.11
Combine	**-61570±784±10342**	**39.86±0.07**	**99.7±0.04**	**2938323±1451±11448**	**31.90±0.03**	**-168.17±2.17±28.26**	**0.987**

mean value
(500,000 *2 MC sample)

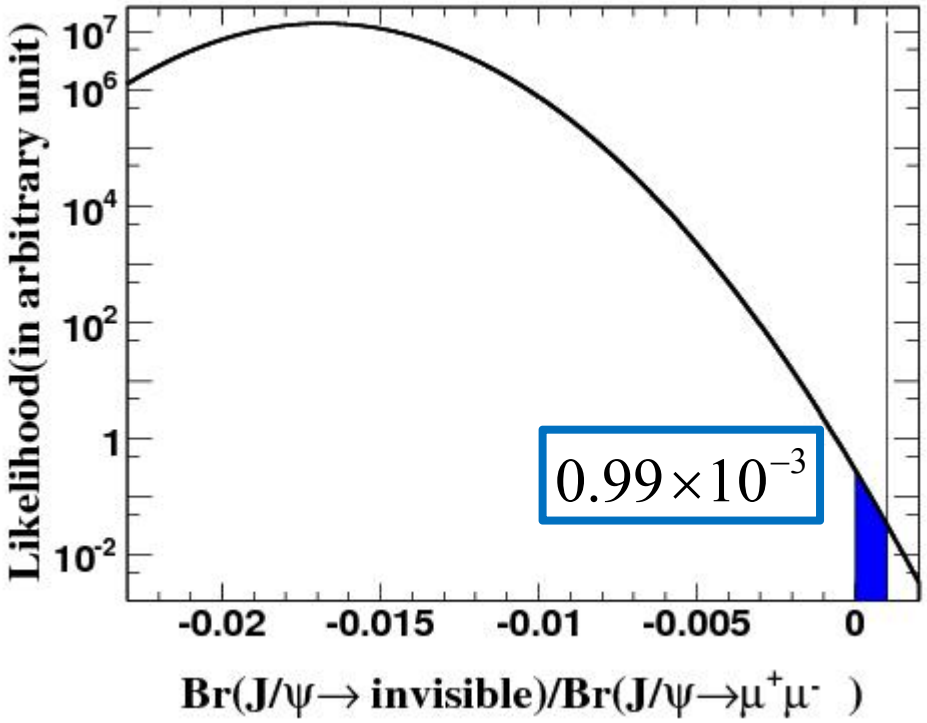
$$\frac{4212+11911}{4237+11934}$$

mean value
(3,000,000 *2 MC sample)

- Take 2009 & 2012 as one data set:



in log scale



Upper limit for 2009: 5.08×10^{-3}

Upper limit for 2012: 1.11×10^{-3}

Question & Discussion

- We've checked some possible items that may cause the value of N(J/psi->invisible) much smaller than 0, but we failed to find out the main reason.

  Is there any other item we need to check?

- What will we do if we check all the items collected today but nothing helps?

- Is there any good suggestion for the combined method?