

Determination of the beam energy and luminosity for the X(3872) data

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30.08.2017

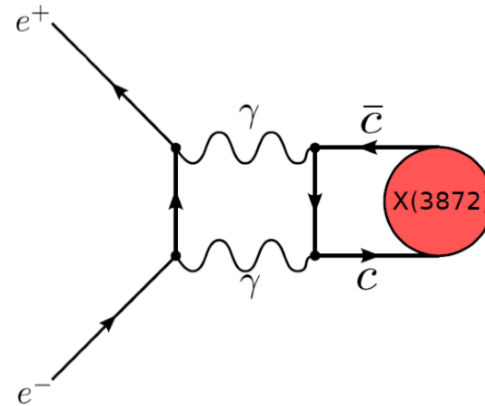
Introduction

Proposal on the 1^{++} state $X(3872)$

Precise beam energy!!!

200/pb on-resonance

200/pb off-resonance



$X(3872)$ data taking at June of 2017

3.8674 GeV	Run: 52108 ~ 52206	Jun 2 nd - 7 th	$L \sim 100/\text{pb}$
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3.8713 GeV	Run: 52207 ~ 52297	Jun 7 th - 11 th	$L \sim 105/\text{pb}$
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Set to 3868 MeV at this time

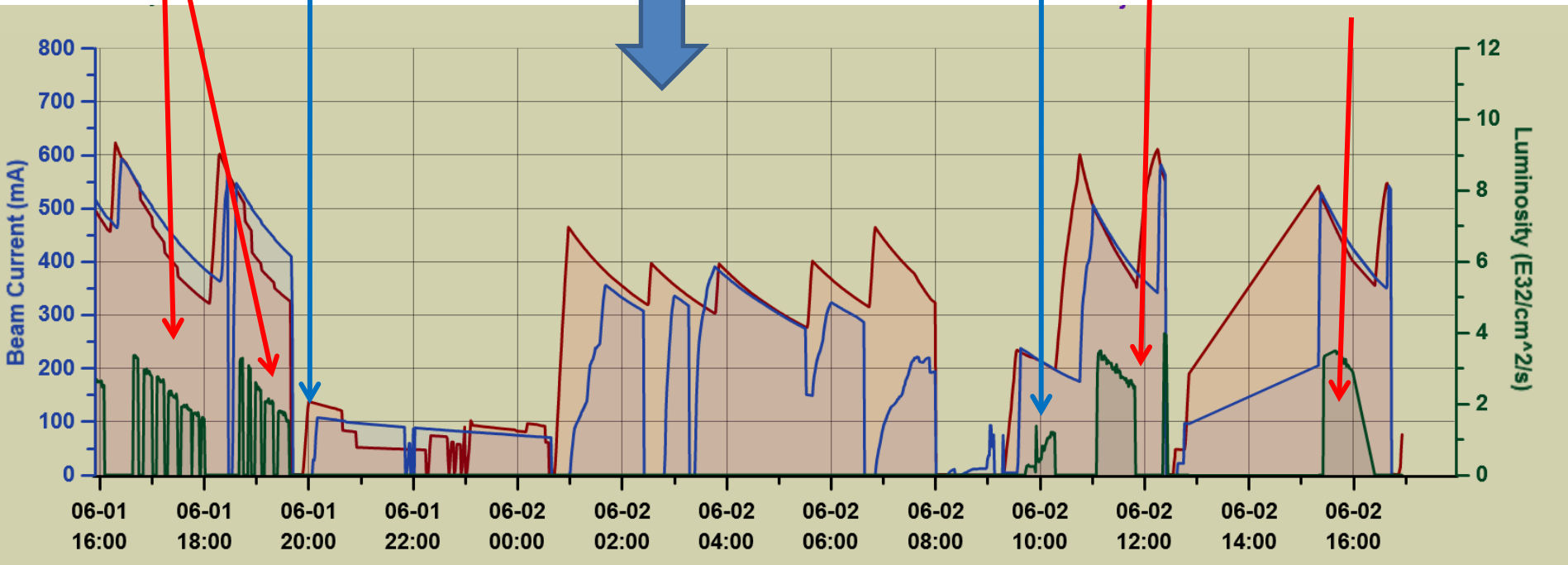
1st and 2nd X(3872) run.
The real E should be
3866.4 MeV

Psi(2S) scan

In these 12 hours, failure
to produce collisions

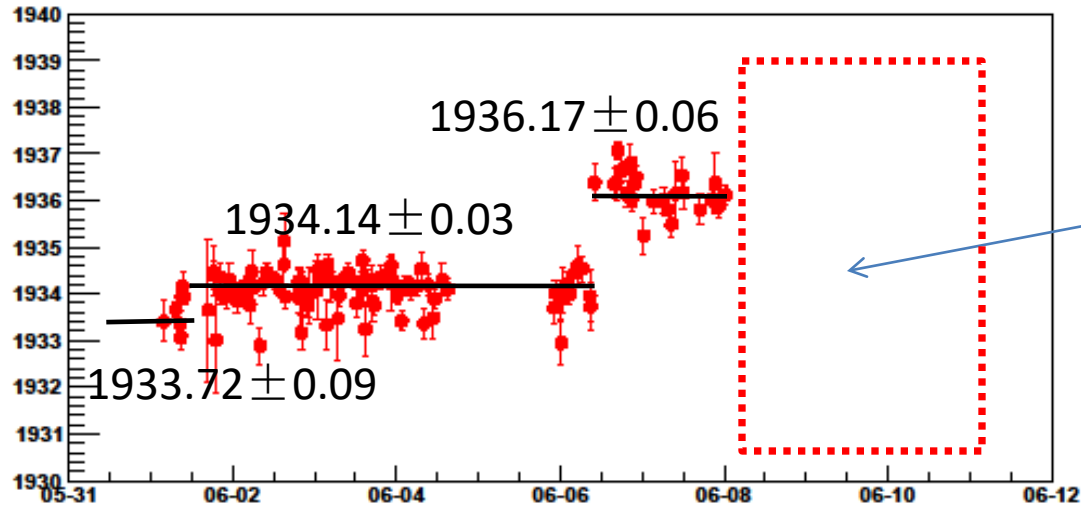
Here, we increase the
beam energy by
0.8 MeV.

1st run at 3868 MeV



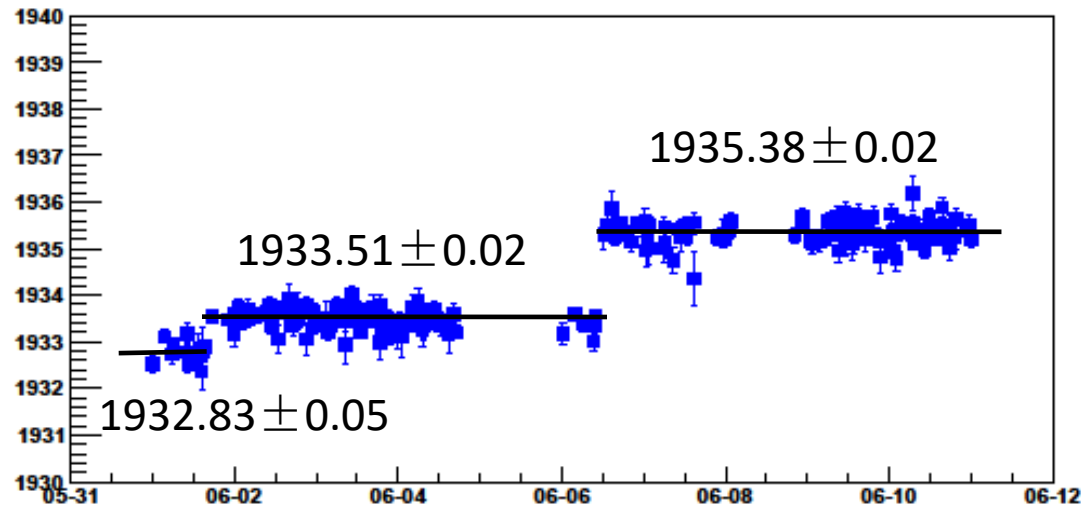
Beam energy measured by BEMS

Beam energy from BEMS for positron beam



BEMS failed to measure positron beam since 9th of June!

Beam energy from BEMS for electron beam



Run numbers of the 3 segments:
Run [52108, 52109]
Run [52110, 52206]
Run [52207, 52297]

Part I: Beam energy by offline

Offline Ecms determination with $e^+ e^- \rightarrow \mu^+ \mu^-$

Same method in the measurement of Ecms for the new XYZ data
Liao Longzhou, (Jun. 14th 2017, BES Collaboration Meeting)

Boss Version: 7.0.2.p01

MC Samples:

1: $e^+e^- \rightarrow \mu^+ \mu^-$ @ X(3872)

- 1) With ISR, FSR 200K events
- 2) No ISR, no FSR 200K events

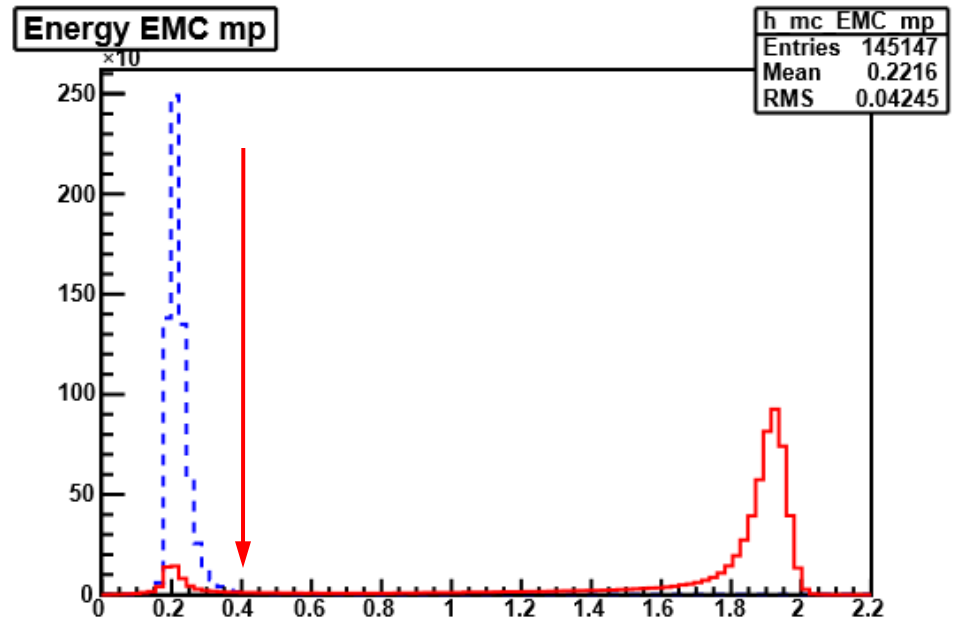
2: $e^+e^- \rightarrow \gamma_{ISR} J/\psi$ @3.872GeV

- 1) With FSR 200K events
- 2) No FSR 200K events

Babayaga 3.5
Ebeam : 1.9357/ 1.93375 GeV
MinThetaAngle: 20
MaxThetaAngle: 160
MinimumEnergy: 0.01 GeV
RunningAlpha: 1
FSR_switch: 1

Event Selection

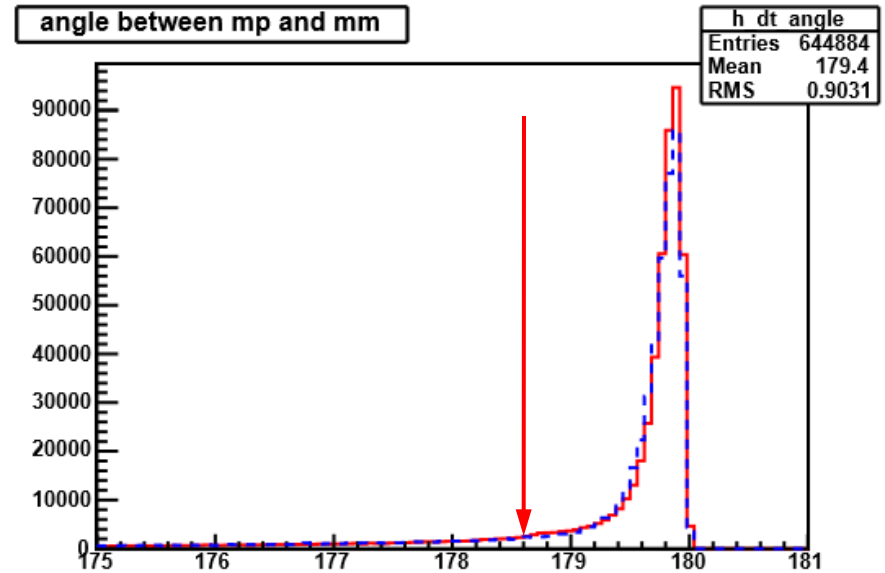
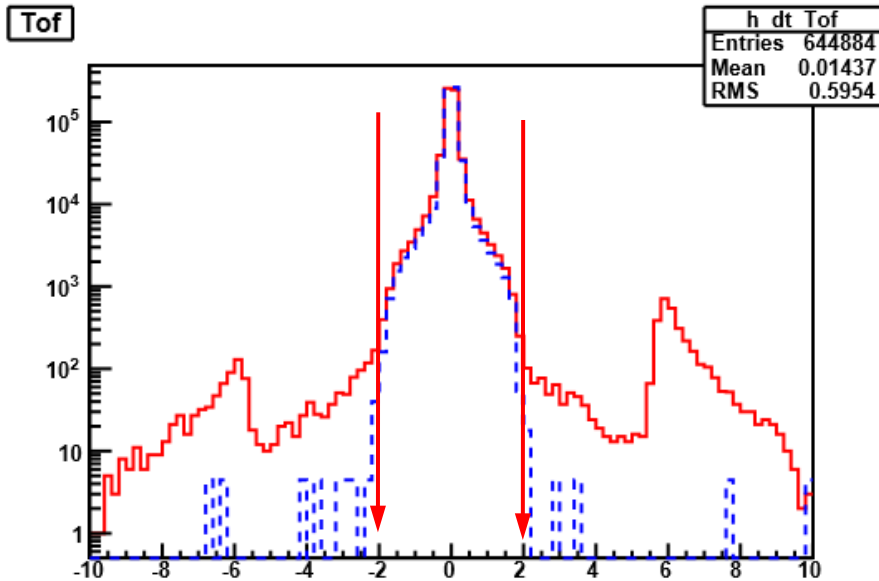
- $|\cos(\theta)| < 0.8$
- $|V_z| < 10.0$ cm
- $|V_r| < 1.0$ cm
- Two charged tracks
- Net charge 0
- Energy deposition at EMS < 0.4 GeV



Event Selection

- TOF $|\Delta t| < 2$ ns

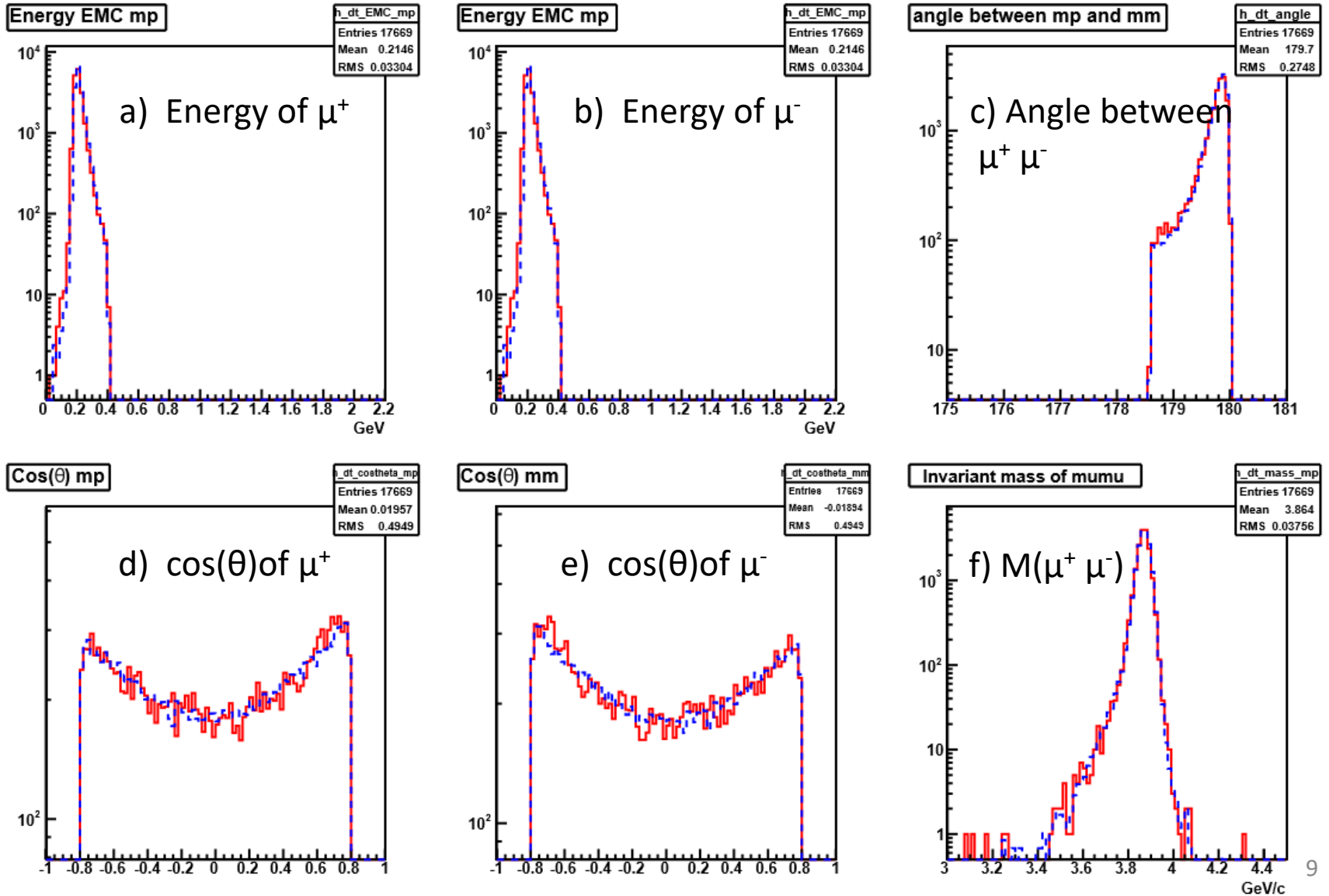
- $\cos(\mu^+ \mu^-) < -0.9997$



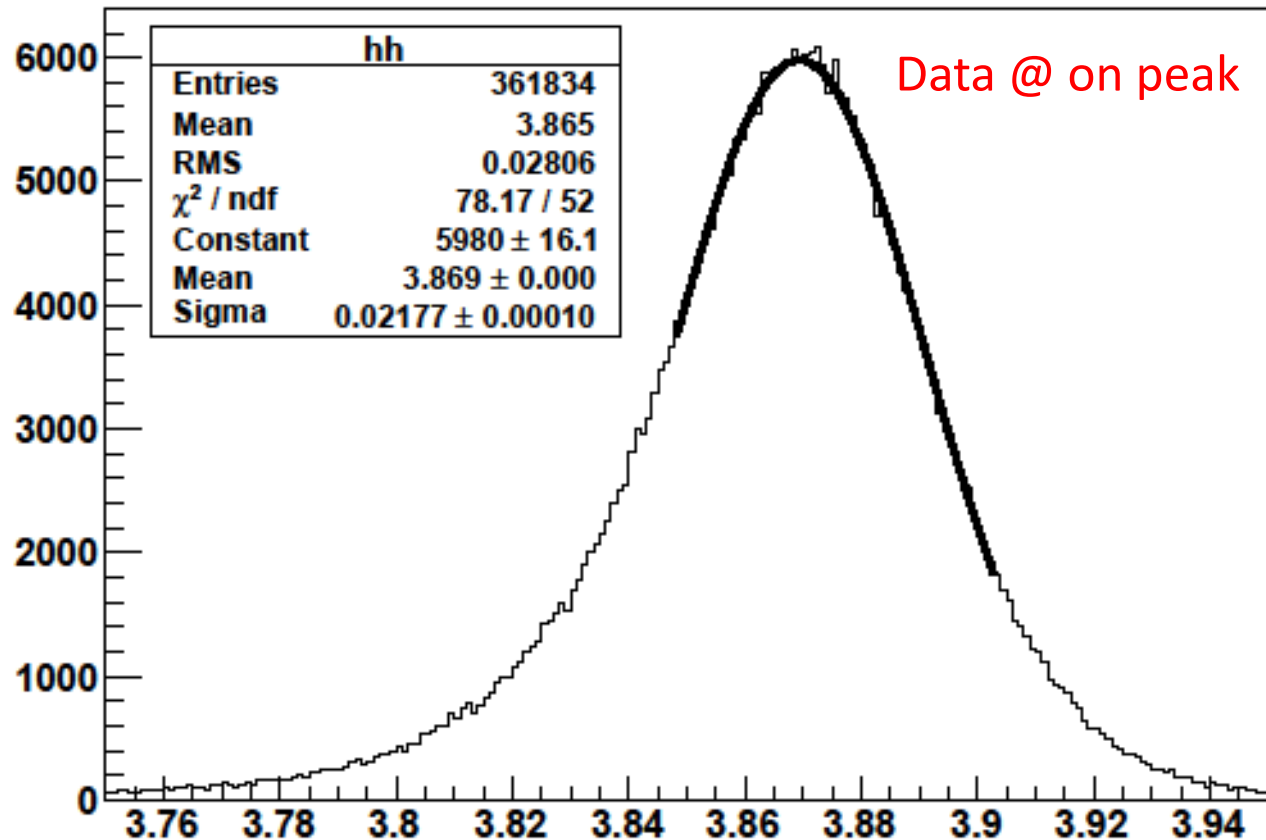
Blue: data

Red: MC

MC compares to data

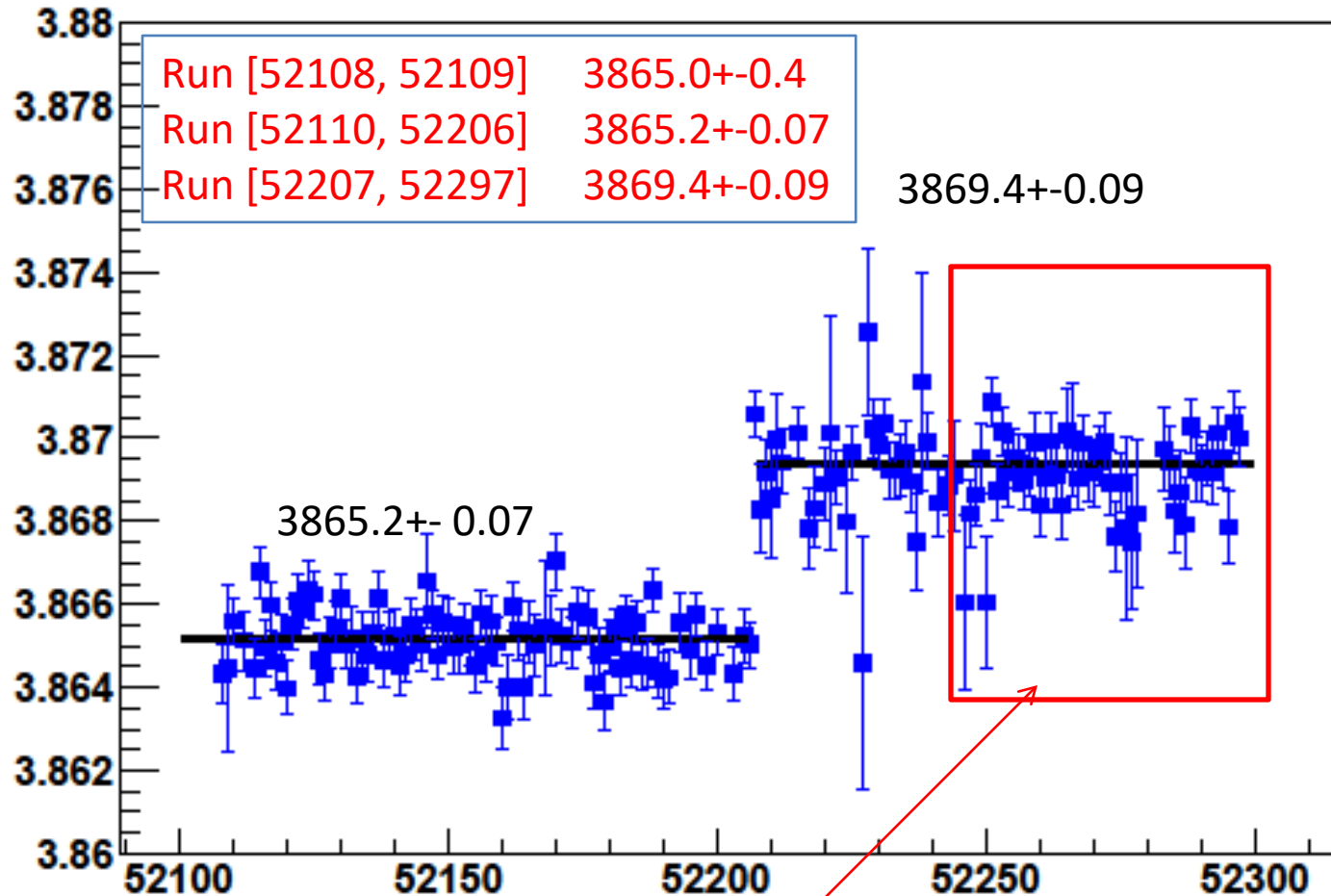


Determine E_{cms} from invariant mass of $\mu^+ \mu^-$



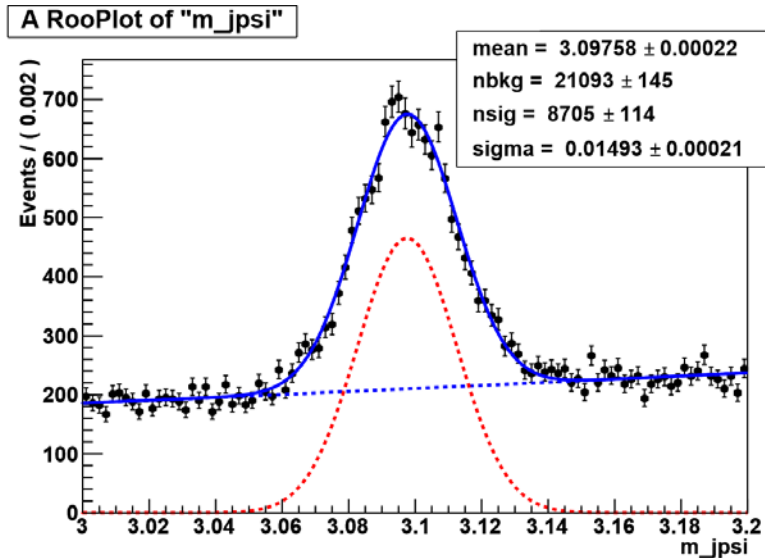
$E_{\text{cms}} = \text{fit_value} + \text{momentum calibration} + \text{radiation correction}$

Data quality check – $M(\mu^+ \mu^-)$ Run by Run



From 9th of June, when the BEMS can not provide positron energy the data looks stable!

Energy shift due to momentum calibration



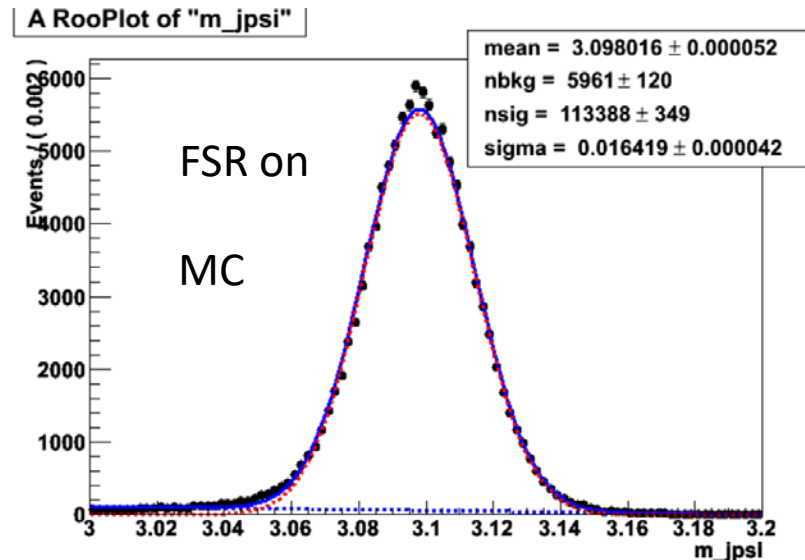
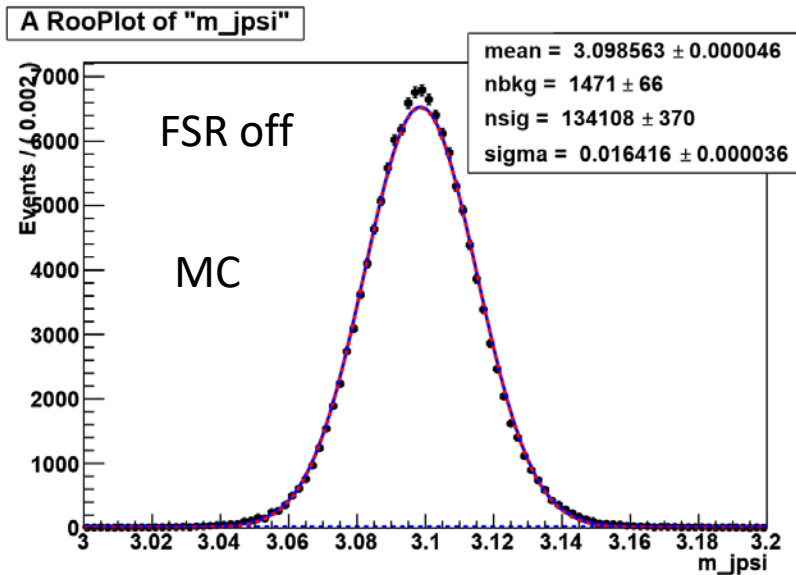
$J/\psi \rightarrow \mu^+ \mu^-$ as reference point.

Data: 3097.58 ± 0.22 MeV

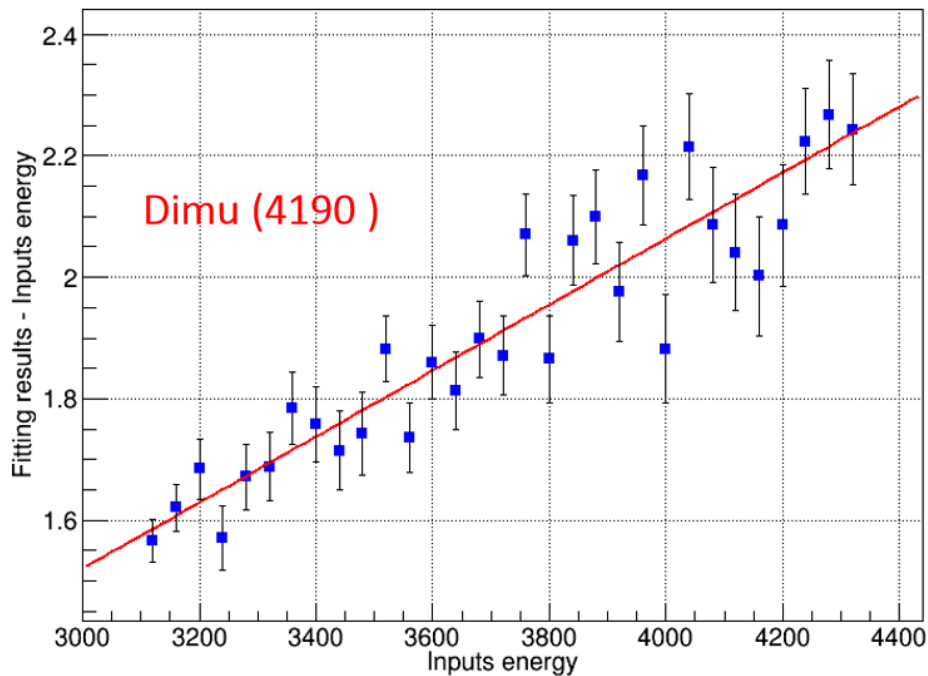
FSR: 0.54 ± 0.05 MeV

Data_FSR: 3098.12 ± 0.23 MeV

Difference to PDG: 1.20 ± 0.23 MeV



Extrapolation of momentum impact

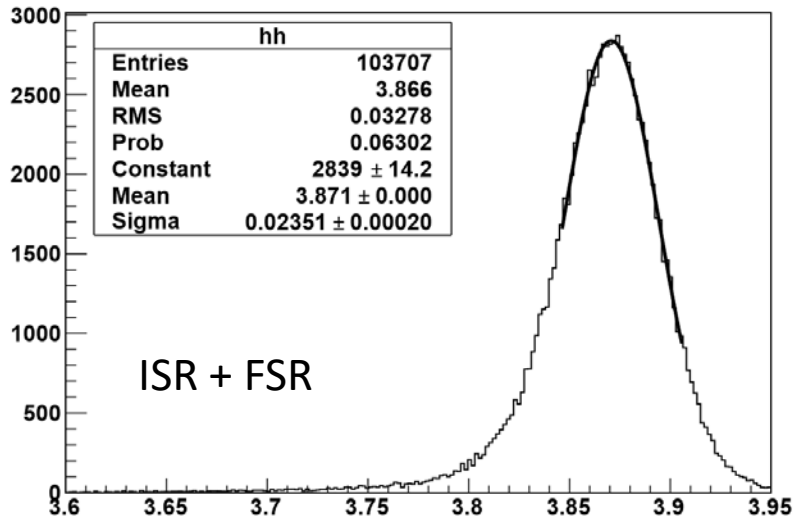


By Longzhou

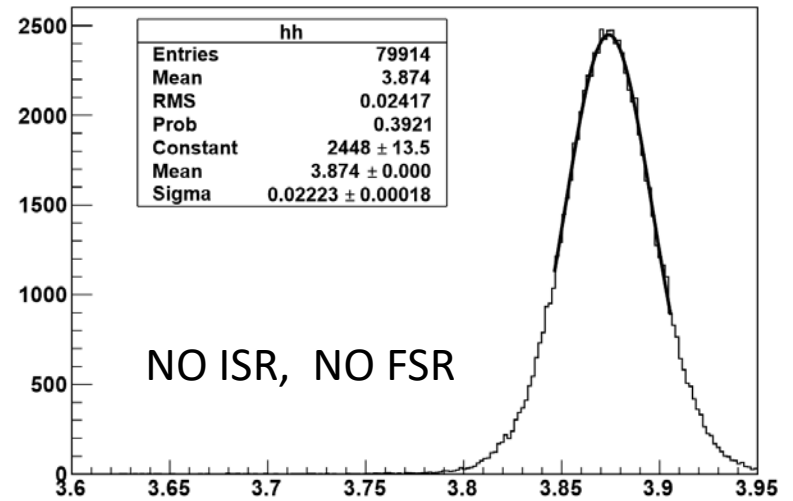
Fitting result : $Y = (5.44 \times 10^{-4} \pm 3.31 \times 10^{-5})X - (0.11 \pm 0.12)$

Effect of momentum calibration: $\Delta E = -1.62 \pm 0.22 \text{ MeV}$

Radiative Correction



$$M = 3870.68 \pm 0.15 \text{ MeV}$$



$$M = 3874.00 \pm 0.13 \text{ MeV}$$

$$\Delta M = 3.32 \pm 0.20 \text{ MeV}$$

Ecms from offline and compares to BEMS

Momentum calibration: -1.19 ± 0.22 MeV

Radiative correction: 3.32 ± 0.20 MeV

	our measurement	BEMS
On peak:	3871.1 ± 0.3 MeV	3871.31 ± 0.06 MeV
Off peak:	3866.9 ± 0.3 MeV	3867.41 ± 0.03 MeV

We measured the Ecms by offline. The results are consistent with the BEMS results.

Part II: Luminosity determination by Offline

Integrated Luminosity by Bhabha scattering process

$$L = N_{\text{obs}} / \epsilon / \sigma$$

1: MC simulation of $e^+ e^- \rightarrow (\gamma) e^+ e^-$ using Babayaga 3.5

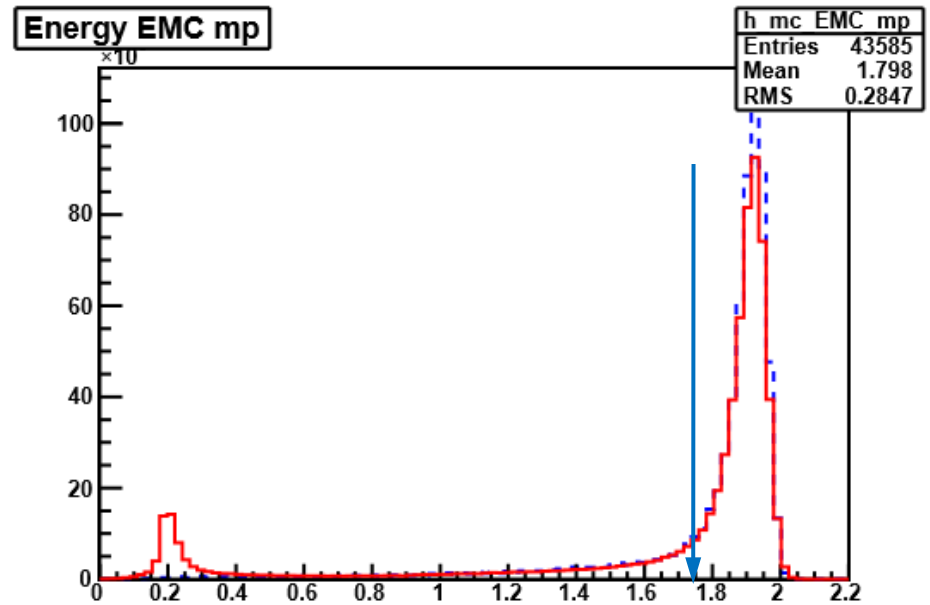
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Ebeam : 1.9357 GeV Or 1.93375 GeV
MinThetaAngle: 20
MaxThetaAngle: 160
MinimumEnergy: 0.01 GeV
RunningAlpha: 1
FSR_switch: 1
```

200000 events @ 3871.3 MeV $\epsilon = (13.8 \pm 0.1) \%$

200000 events @ 3867.5 MeV $\epsilon = (13.8 \pm 0.1) \%$

Event Selection

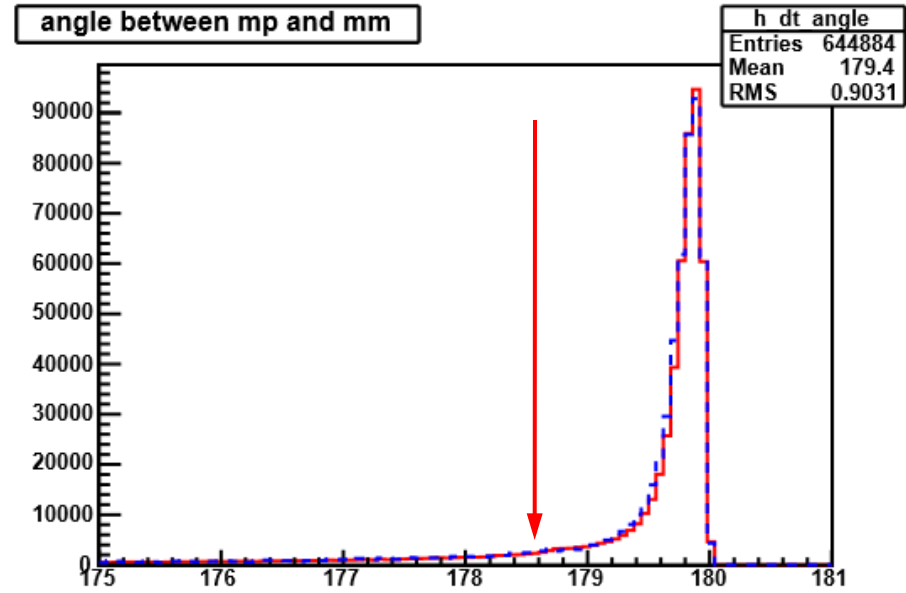
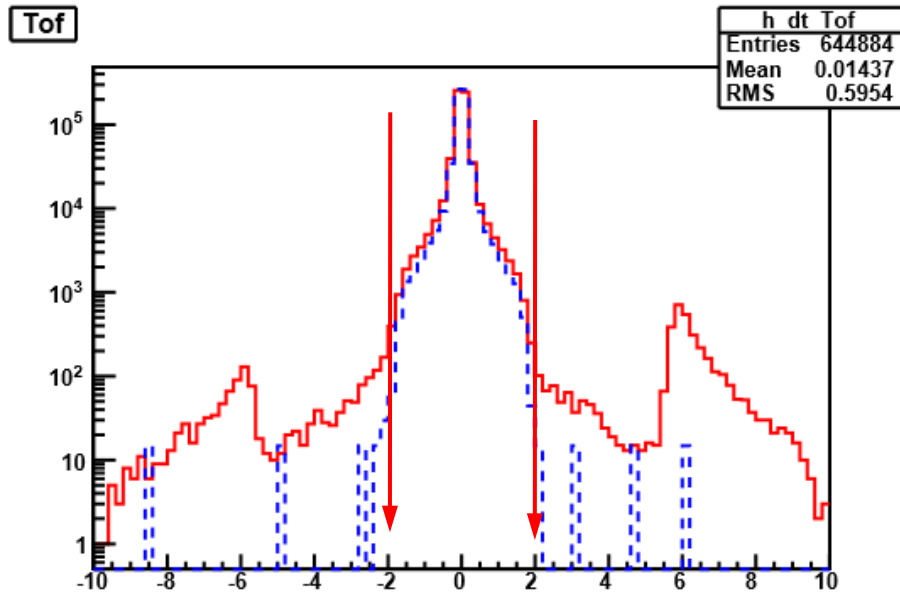
- $|\cos(\theta)| < 0.8$
- $|V_z| < 10.0$ cm
- $|V_r| < 1.0$ cm
- Two charged tracks
- Net charge 0
- Energy deposition at EMS $> 0.9 * E_{\text{beam}}$



Event Selection

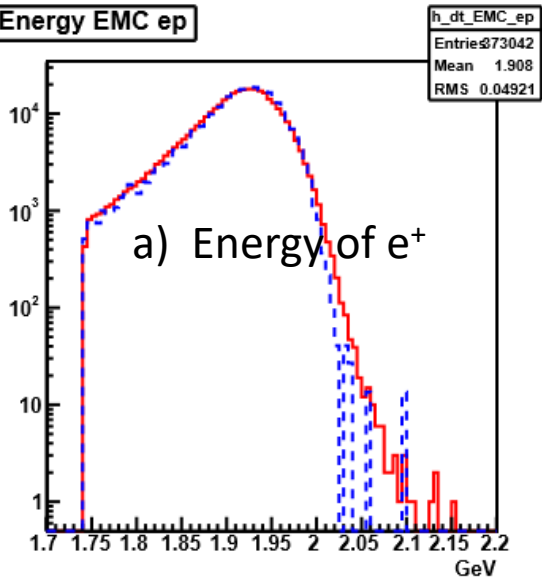
- TOF $|\Delta t| < 2$ ns

- $\cos(\theta_{e^+ e^-}) < -0.9997$

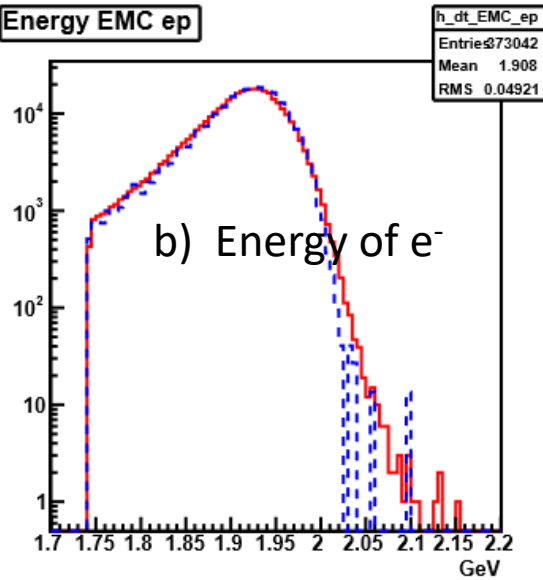


MC compares to the data

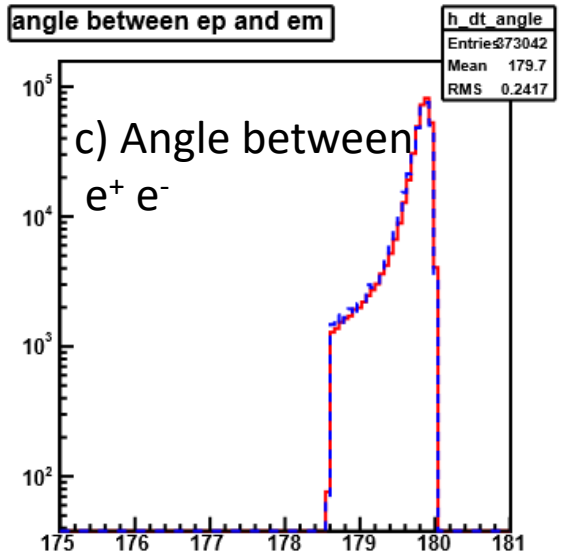
Energy EMC ep



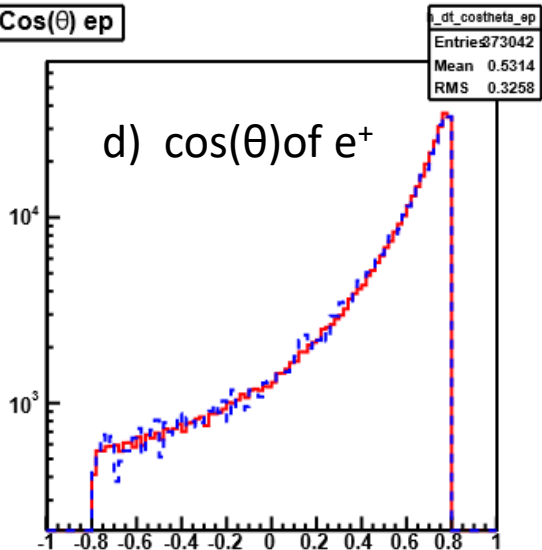
Energy EMC ep



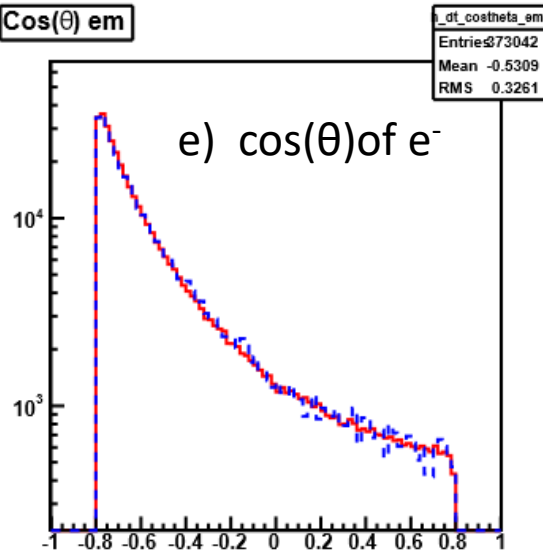
angle between ep and em



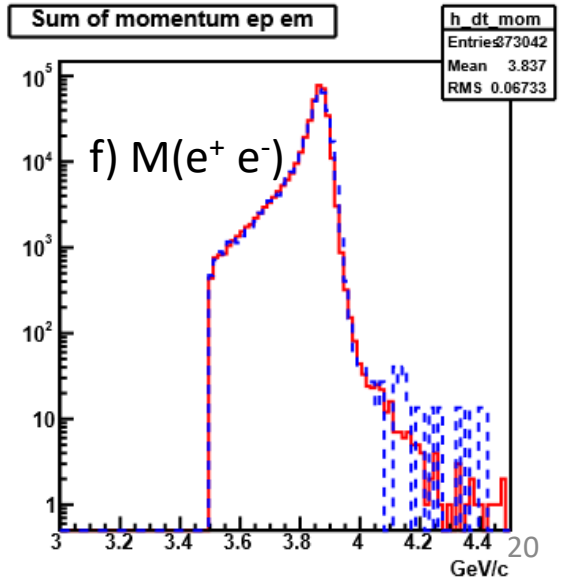
Cos(θ) ep



Cos(θ) em



Sum of momentum ep em



Integrated luminosity determination

Cross section of the bhabha scattering

$$\sigma = 486.61 \pm 0.35 \text{ nb @ } 3871.3 \text{ MeV}$$

$$\sigma = 490.22 \pm 0.35 \text{ nb @ } 3867.5 \text{ MeV}$$

Number of the signal events from data

$$N = 7620825 \text{ @ } 3871.3 \text{ MeV}$$

$$N = 7540613 \text{ @ } 3867.5 \text{ MeV}$$

$$\begin{aligned} L = N / \epsilon / \sigma &= 113.49 \pm 0.16 \text{ @ } 3871.3 \text{ MeV} \\ &= 111.47 \pm 0.16 \text{ @ } 3867.5 \text{ MeV} \end{aligned}$$

Systematic error not yet!

Cross check with $e^+ e^- \rightarrow \mu^+ \mu^-$

$$L = N_{\text{obs}} / \epsilon / \sigma$$

MC simulation of $e^+ e^- \rightarrow (\gamma)\mu^+ \mu^-$ using Babayaga 3.5

```
Ebeam : 1.9357 GeV Or 1.93375 GeV
MinThetaAngle: 20
MaxThetaAngle: 160
MinimumEnergy: 0.01 GeV
RunningAlpha: 1
FSR_switch: 1
```

200000 events @ 3871.3 MeV $\epsilon = (52.1 \pm 0.2) \%$

200000 events @ 3867.5 MeV $\epsilon = (52.1 \pm 0.2) \%$

Cross check with $e^+ e^- \rightarrow \mu^+ \mu^-$

Cross section of $e^+ e^- \rightarrow \mu^+ \mu^-$

$$\sigma = 6.025 \pm 0.005 \text{ nb @ } 3871.3 \text{ MeV}$$

$$\sigma = 6.096 \pm 0.005 \text{ nb @ } 3867.5 \text{ MeV}$$

Number of the signal events from data

$$N = 367498 \text{ @ } 3871.3 \text{ MeV}$$

$$N = 362334 \text{ @ } 3867.5 \text{ MeV}$$

$$L = N / \epsilon / \sigma = 117.1 \pm 0.2 \text{ @ } 3871.3 \text{ MeV}$$

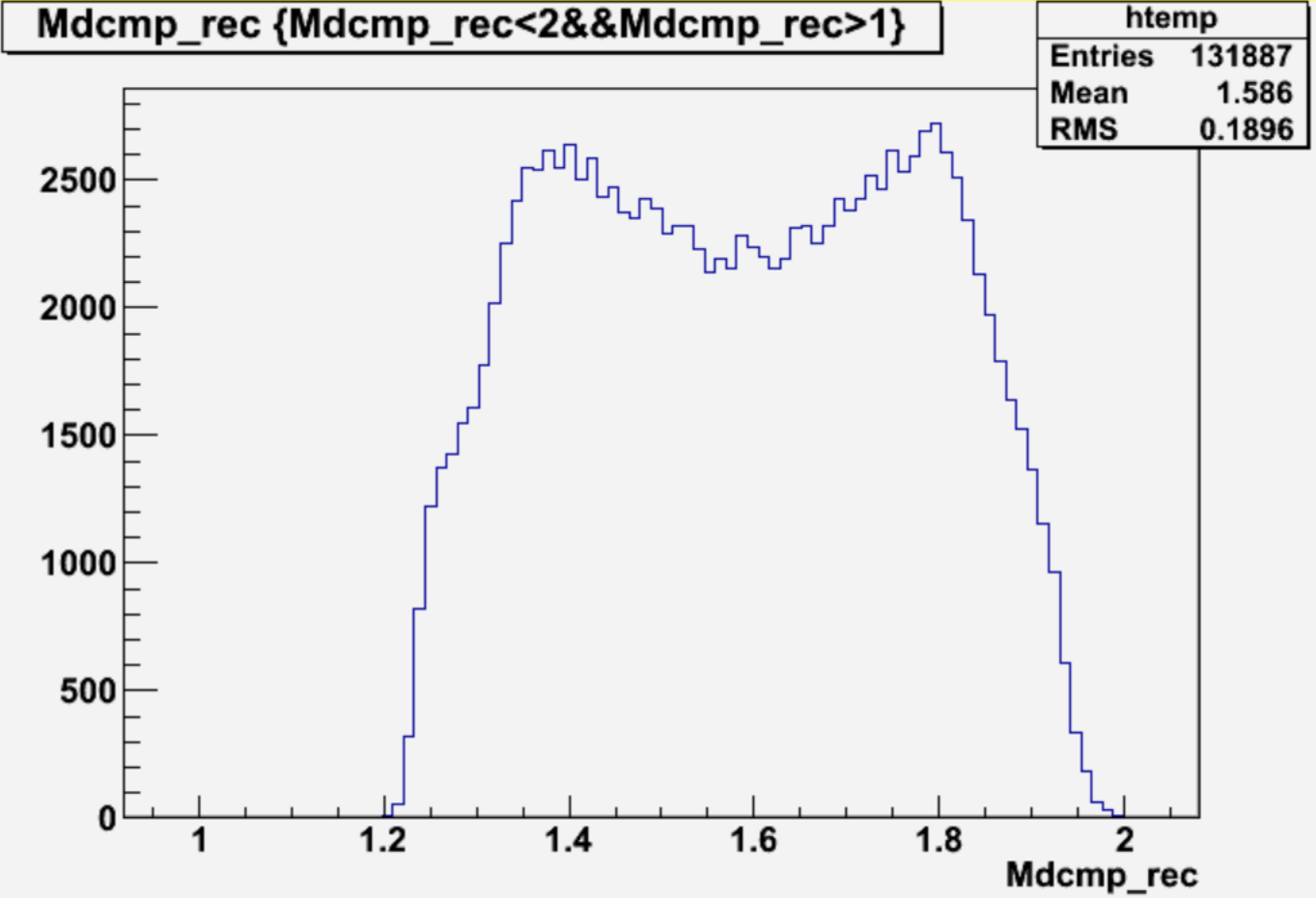
$$= 114.1 \pm 0.2 \text{ @ } 3867.5 \text{ MeV}$$

Systematic error not yet!

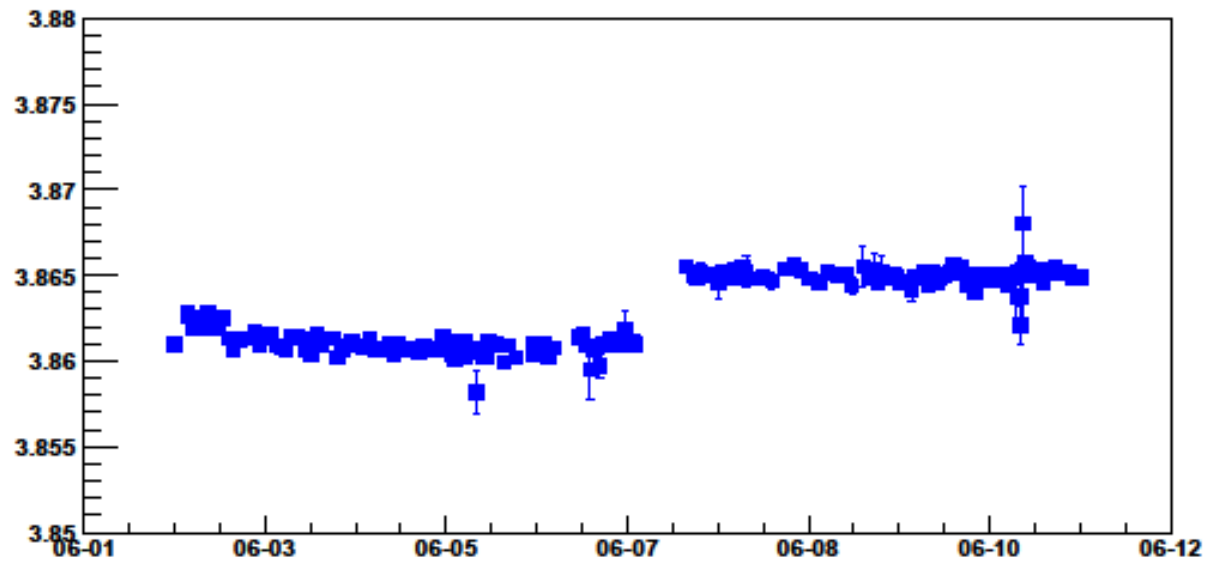
Summary

- ✓ Beam energy for X(3872):
 - determined with $e^+ e^- \rightarrow \mu^+ \mu^-$ process.
 - consistent with the BEMS measurements.
- ✓ Integrated luminosity:
 - determined with $e^+ e^- \rightarrow e^+ e^-$ process.
 - cross check with $e^+ e^- \rightarrow \mu^+ \mu^-$ process.
- ✓ Current BOSS version: 7.0.2.p01 (not very good)
- Next release: 7.0.3 (Systematic studies then)

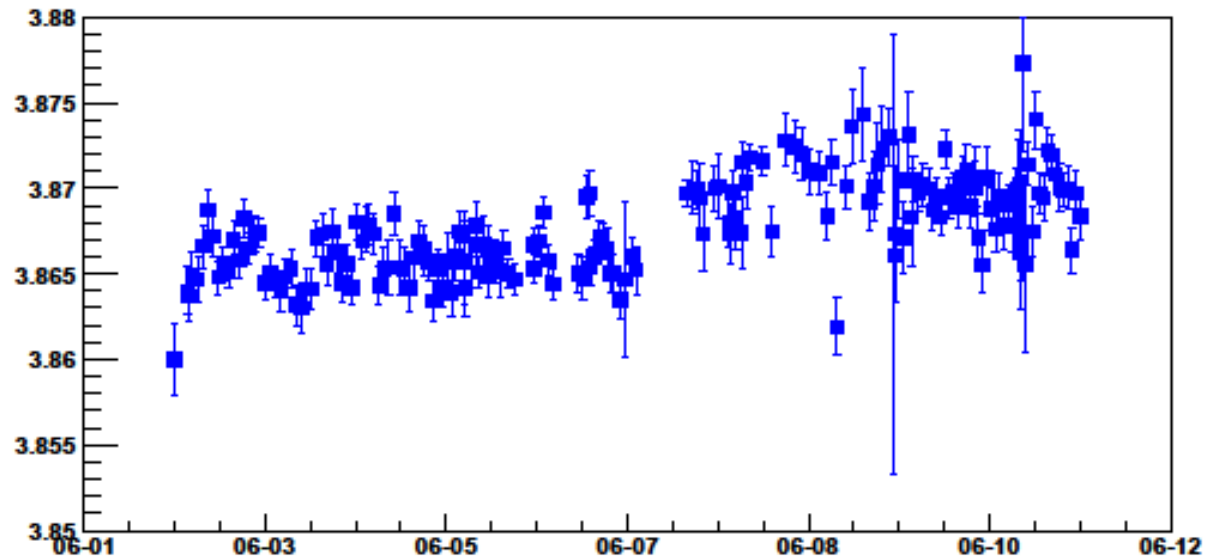
Thank You



Center of mass energy from DQM



Center of mass energy with mumu channel from DQM



Beam energy provided by accelerator

