Measurement of the center-of- mass energy for the new XYZ data

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Introduction

A precise measurement of center-of-mass energy (Ecm) is essential for most physics analyses. We use the process $e^+e^- \rightarrow \mu^+\mu^-$ to measure the Ecm.

There will be about ten data sets. We will give the Ecm distribution run by run to check the stability of beam energy.

We will use 4190MeV data as analytic example.

ECM(MeV)	Run Number	Total Run
4190	47543-48170	489
4200	48172-48713	464
4210	48714-49239	452
4220	49270-49787	456
4237	49788-50254	437

Dataset and BOSS version

- **Data samples**

XYZ data samples (3 energy points)

- **MC samples**

ISR J/psi sample use the BesEvtgen (1million each energy point)
Dimu sample use the BaBayaga 3.5 (1million each energy point)

- **Boss version**

BOSS 7.0.2.p01

Analysis Method

(From gaoq)

For the process $e^+e^- \to \mu^+\mu^-$, we get

$$E_{cms} = M_0(\mu^+\mu^-).$$

But there will be ISR and FSR process, see $e^+e^- \to \mu^+\mu^-\gamma_{ISR}/\gamma_{FSR}$, so

$$E_{fit} = M\ (\mu^+\mu^-).$$

Then we use this mothed to get the E_{cms}, that's

$$E_{cms} = M(\mu^+\mu^-) + \Delta M,\ \ \Delta M = M_0(\mu^+\mu^-) - \mathrm{M}(\mu^+\mu^-).$$

For $\mathrm{M}(\mu^+\mu^-)$

We use the M(J/psi) to do the momentum calibration of $\mu^+\mu^-$ and the control sample is $\gamma_{ISR}\mathrm{J/psi}$.

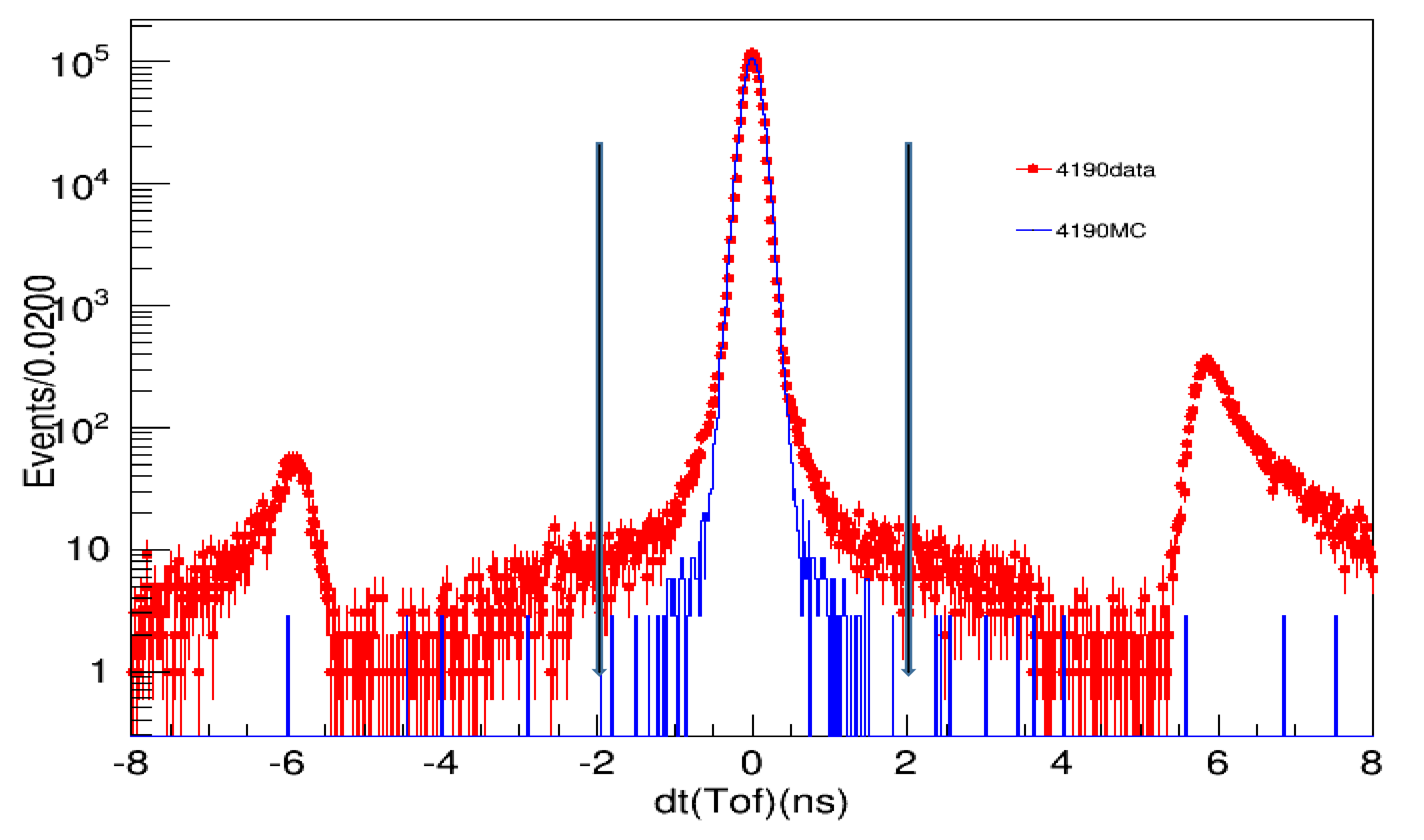
For ΔM

We use the MC simulation of Dimu events with or without ISR and FSR to estimate the ΔM.

Event selection

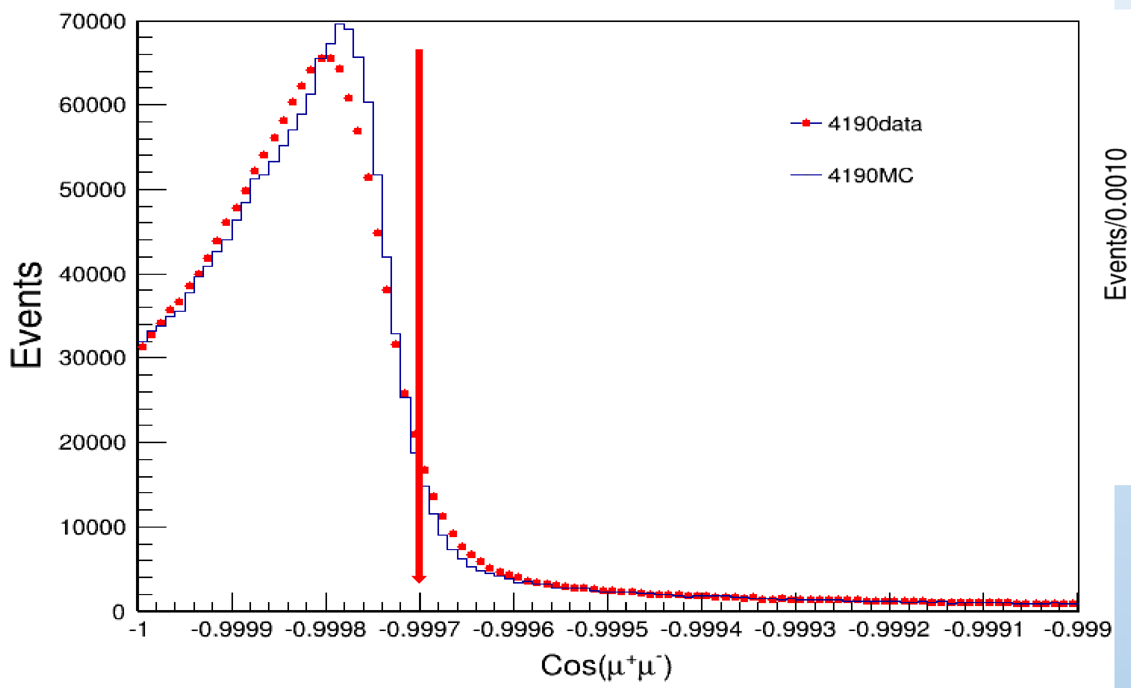
- $|\cos\theta|<0.8$ (only barrel)
- $|V_z|<10.0$cm
- $V_r<1.0$cm
- Two charged tracks
- Total charges = 0
- $|\Delta t|<2$ns
- $\cos(\mu^+\mu^-) < -0.9997$
- EMC<0.4GeV

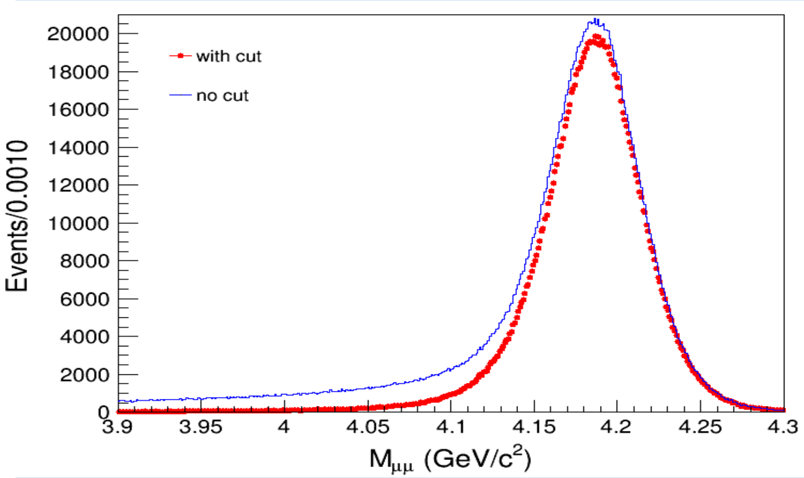
The TOF difference (Δt) of $\mu^+\mu^-$



Choosing two tracks that are both in barrel and absolute value of the time difference (|Δt|=|$t_1 - t_2$)(ns)) is less than 2ns to exclude the cosmic ray.

Suppress the events with large radiation

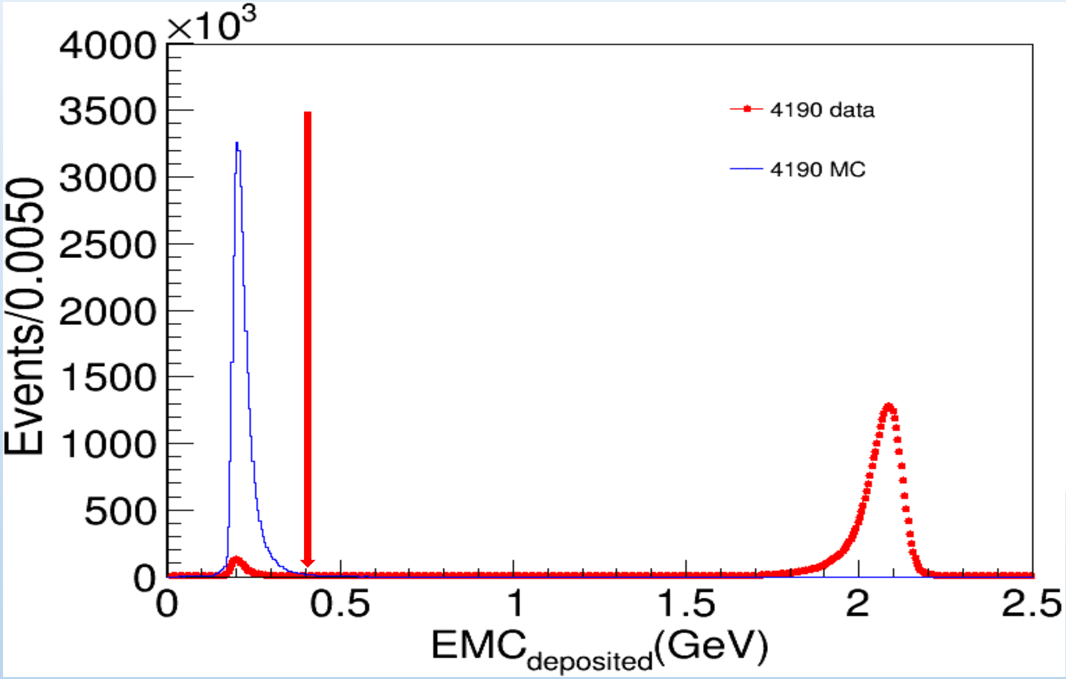


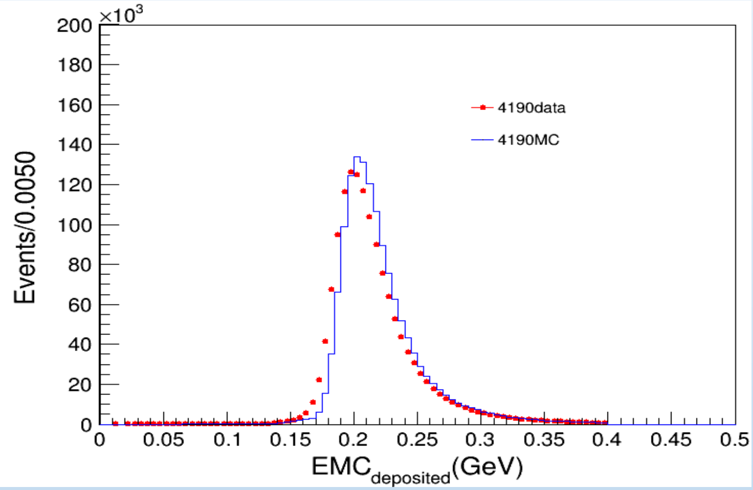


With or without $\cos(\mu^+\mu^-)$ <-0.9997, the distribution of $M(\mu^+\mu^-)$ in 4.19GeV

To eliminate the events with large radiation, a constraint $\cos(\mu^+\mu^-)$ <-0.9997 is needed.

The energy deposited in the EMC

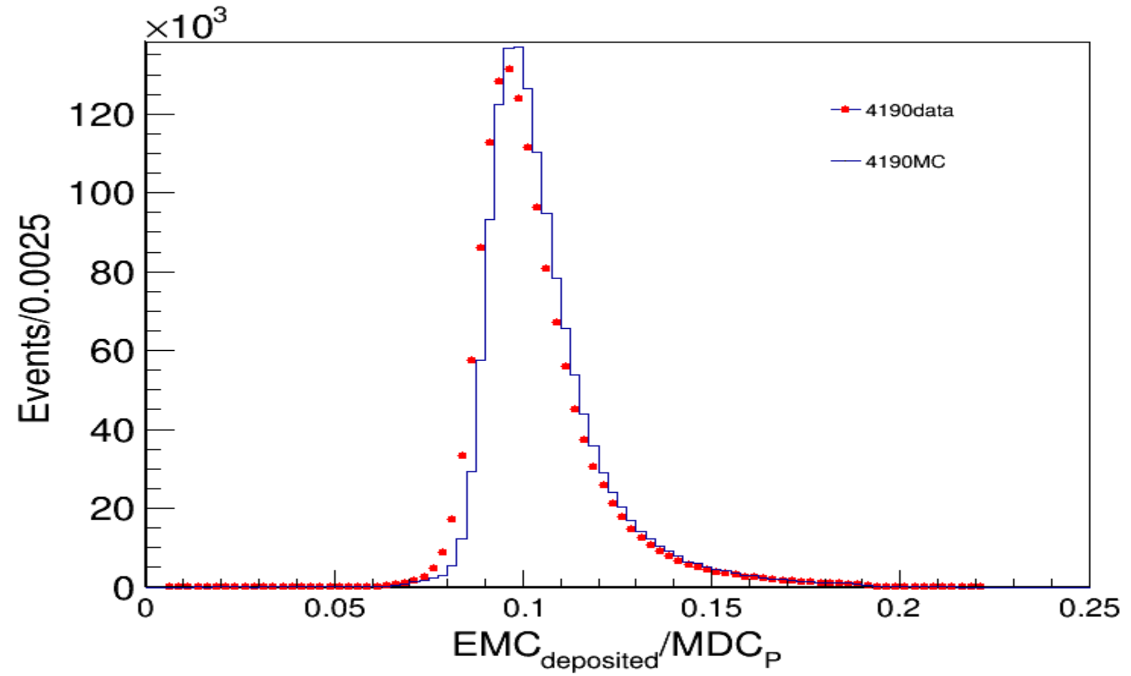




With EMC<0.4GeV, and MC scale to data

From MC simulation, we can see that the deposited energy of muon is less than 0.4GeV.

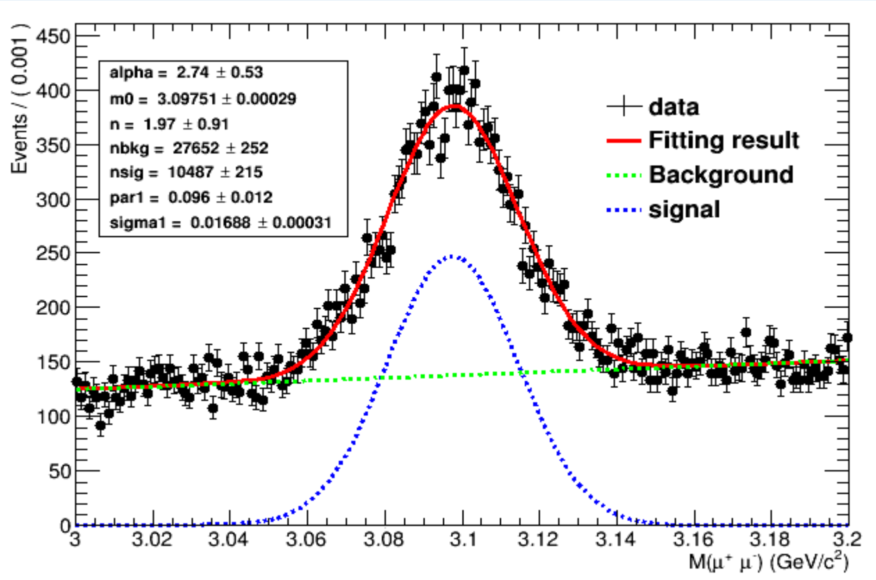
The energy deposited in EMC over the momentum(E/P)

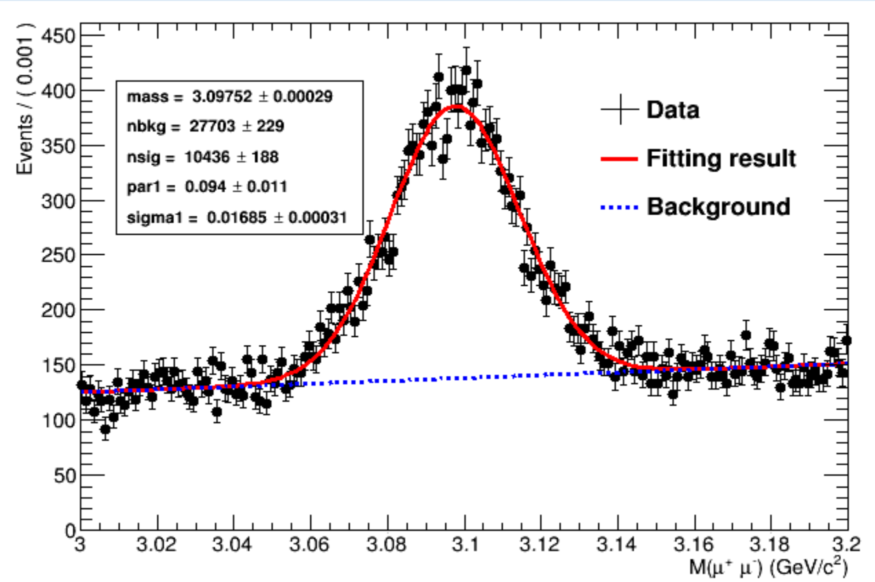


The data E/P distribution is consistent with the MC simulation approximately . (4.19GeV)

Momentum calibration

We use two different methods to fit the ISR J/psi to do the momentum calibration to show that our fitting methods OK.





Crystal_ball + 1st-order polynomial

Mmp = 3097.51 ±0.29MeV

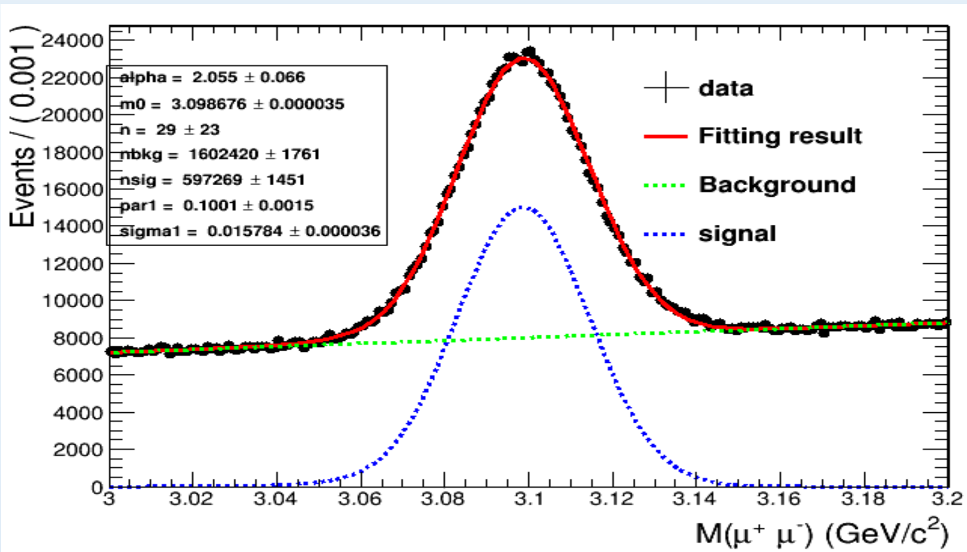
Gauss + 1st-order polynomial

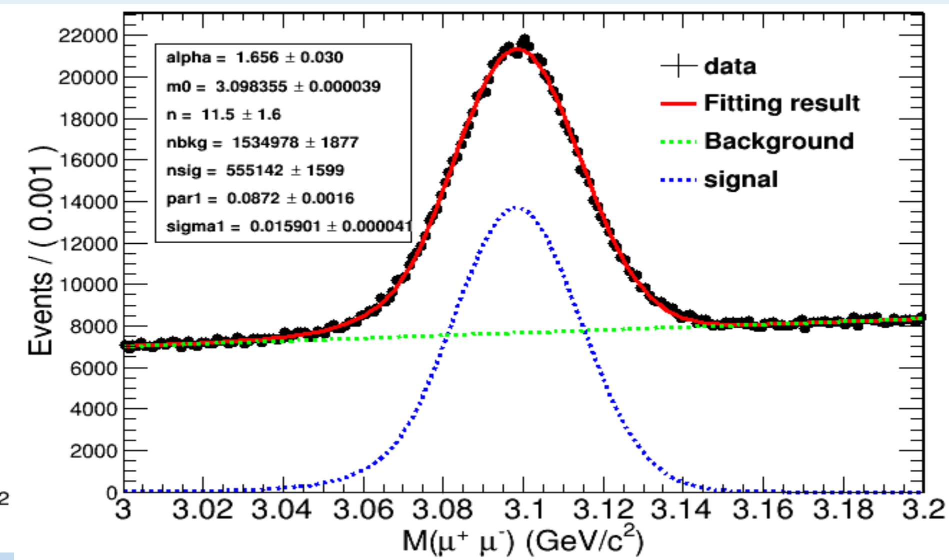
Mmp=3097.52 ± 0.29MeV

The fitting results showing the **consistency** of the two methods.

FSR correction of ISR J/psi process

Using the background of data as the MC background to get the FSR correction.





Fit chi2: 1.94055
Parameters Number: 7
sigma=15.78 ± 0.04
Mmp= 3098.68± 0.04

Fit chi2: 1.83021
Parameters Number: 7
sigma= 15.90 ± 0.04
Mmp= 3098.36 ± 0.04

FSR = 0.32 ± 0.05MeV

Momentum Calibration

(PDG value : 3096.916 +/- 0.011MeV)

Scale factor : 1.28+/-0.02

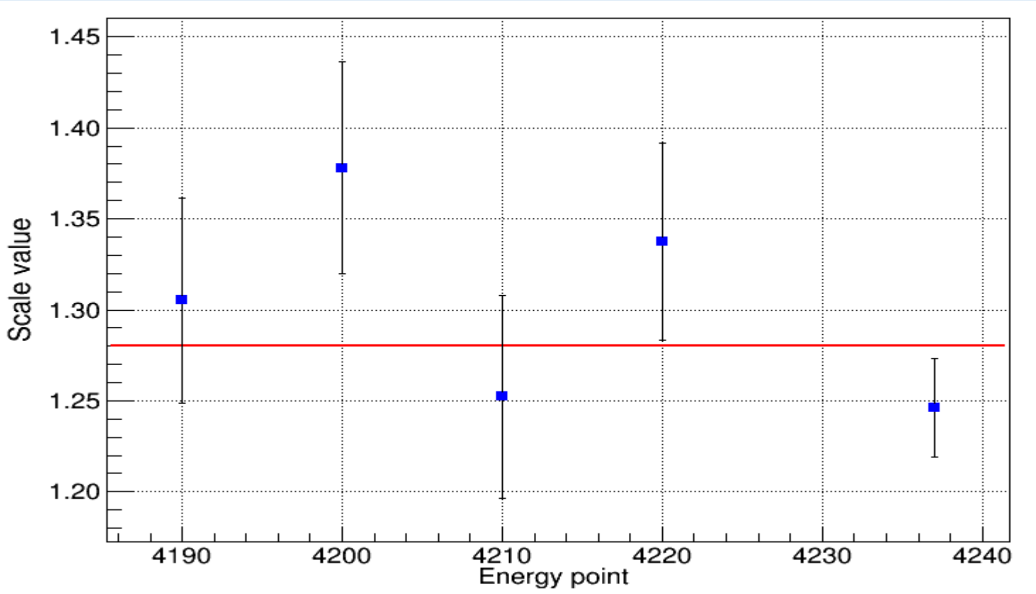
Energy(MeV)	4190	4200	4210	4220	4237	
ISR J/psi	3098.67$\pm$ 0.04	3098.61$\pm$ 0.04	3098.665 $\pm$ 0.04	3098.61$\pm$ 0.04	3098.63$\pm$ 0.04	
IFSR J/psi	3098.35 $\pm$0.04	3098.39 $\pm$ 0.05	3098.384 $\pm$0.04	3098.39$\pm$ 0.04	3098.38$\pm$ 0.04	
FSR correction	0.32$\pm$0.05	0.22$\pm$0.06	0.28$\pm$0.05	0.22$\pm$ 0.05	0.25$\pm$ 0.05	
Data fitting result	3097.51 $\pm$ 0.29	3097.89 $\pm$0.29	3096.92 $\pm$ 0.30	3097.20$\pm$ 0.27	3097.08$\pm$ 0.26	
Difference after correction	0.88$\pm$0.29	1.19$\pm$0.29	0.28$\pm$0.30	0.50$\pm$ 0.27	0.41$\pm$ 0.26	
Momentum Calibration	1.13$\pm$0.37	1.52$\pm$0.37	0.36$\pm$0.39	0.64$\pm$ 0.35	0.52$\pm$0.33	

We use the ISR J/psi (no FSR) and Dimu (no radiation) MC samples to do the input and output check. And we find that we should multiply a scale factor to the difference of the correction ISR J/psi and PDG value.

Scale factor

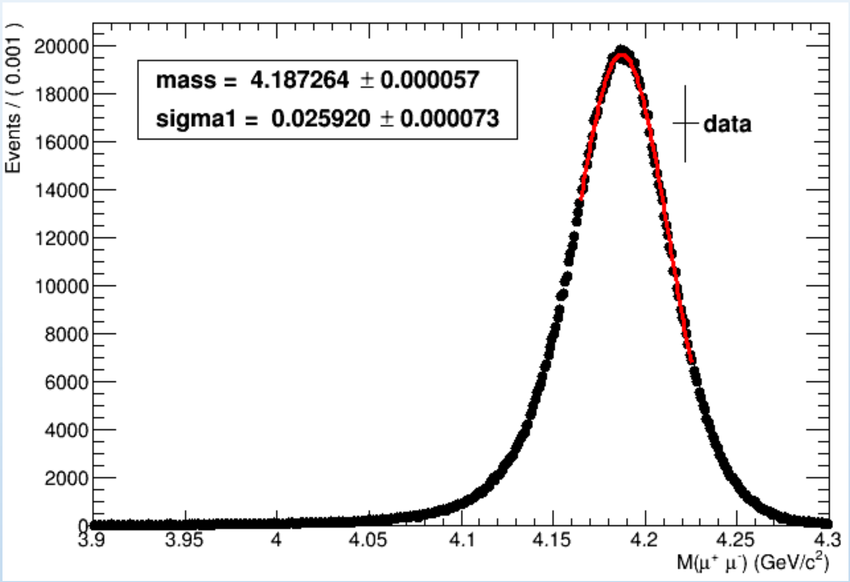
(PDG value : 3096.916 ± 0.011MeV)

	4190	4200	4210	4220	4237	
ISRJ/psi(nofsr)	3098.686 ± 0.035	3098.614±0.035	3098.665 ± 0.035	3098.608±0.035	3098.626±0.035	
ISRJ/psi-PDG	1.760 ±0.037	1.698±0.037	1.749±0.037	1.692±0.037	1.710 ±0.037	
Dimu(no radiation)	4192.297±0.084	4202.340 ± 0.085	4212.190 ± 0.086	4222.263±0.077	4239.131±0.084	
Dimu-input Value	2.297±0.087	2.340±0.085	2.190±0.086	2.263±0.077	2.131±0.084	



Scale factor: 1.28 ± 0.02

Dimu fitting method



Fit chi2/ndf: 1.90207

Mmp = 4187.26 ± 0.06(MeV)

Range(4.165,4.225)

(pv-1.0sigma, pv+1.5sigma)

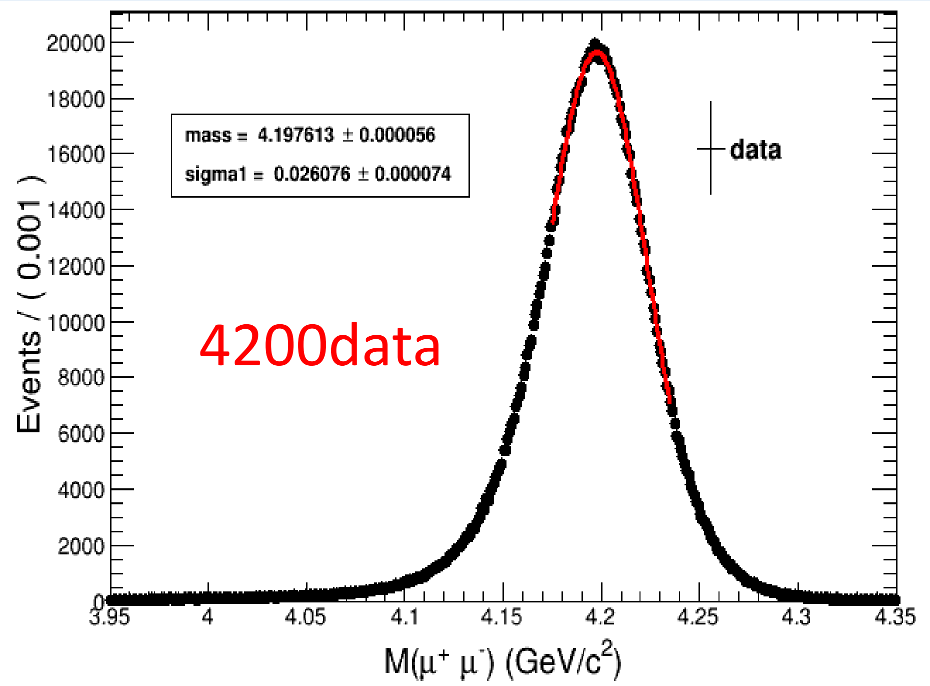
When fitting the Dimu peak with a Gaussian, we give a criterion to confirm the fitting range.

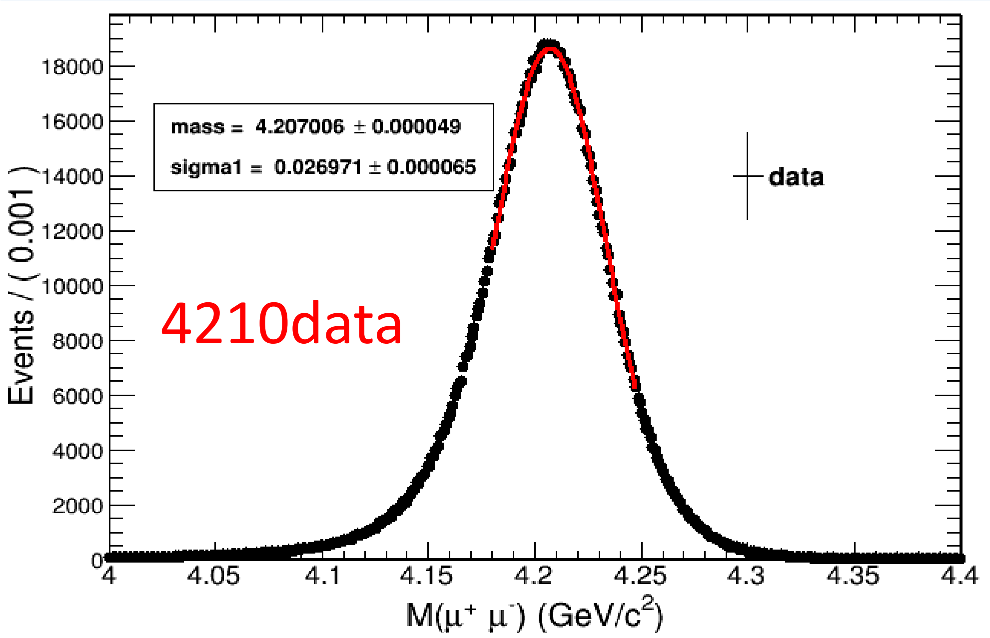
First ,we fit all data with a reasonable range to get the fitting sigma and chisquare over number of freedom degree (chis/ndf), also peak value(pv).

Then we change the fitting range to compare the difference of the fitting result. We find when the chis/ndf <2, the difference is less than 0.1MeV and we decided to use (pv-1.0sigma, pv+1.5sigma) as the fitting range and as the criterion finally.

And the difference of fitting (0.1MeV) because of fitting range change will consider as a system error.

M(μμ) Value of 4200 and 4210 energy point





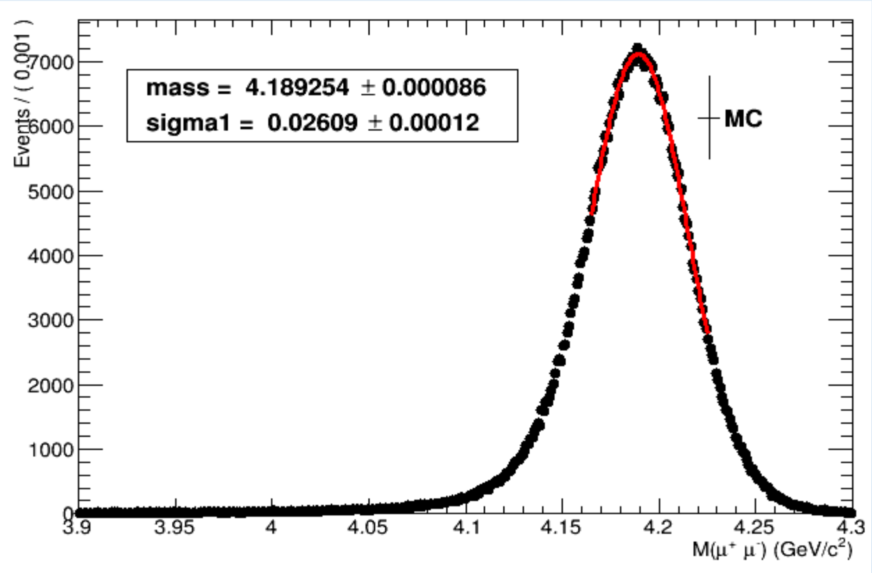
Fit chi2/ndf: 1.317

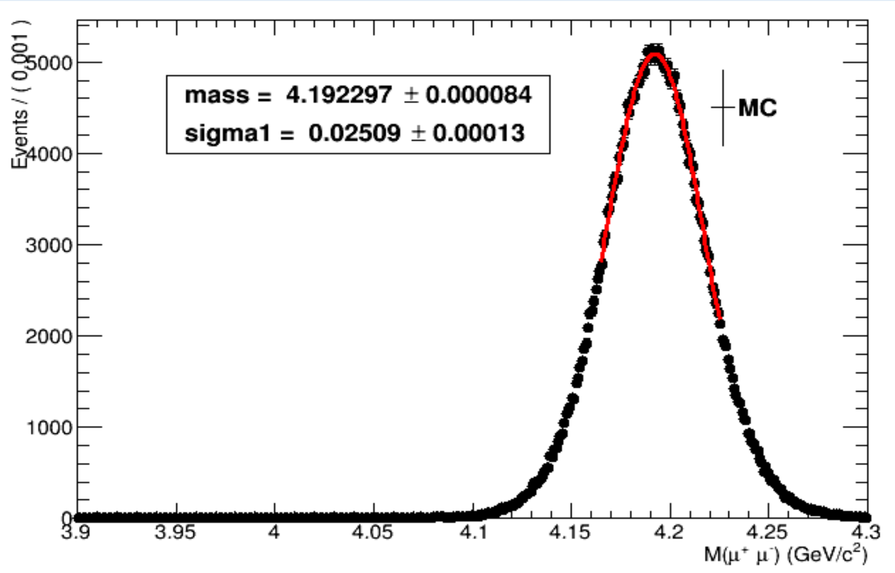
Mmp = 4197.613 ± 0.056MeV

Fit chi2/ndf: 1.554

Mmp= 4207.006 ± 0.049MeV

Radiation correction (ΔM) with MC sample(4190MC)





Mmp =4189.254 ± 0.086MeV

Mmp =4192.297 ± 0.084MeV

ΔM=3.043 ± 0.120MeV

Radiation correction (ΔM)

ECM(MeV)	4190	4200	4210	4220	4237
Radiation	4189.254±0.086	4199.310 ± 0.086	4209.210 ±0.088	4218.551±0.075	4235.355±0.083
No radiation	4192.297±0.084	4202.340 ±0.085	4212.190 ±0.086	4222.263±0.077	4239.131±0.084
ΔM	3.043±0.120	3.030±0.120	2.980±0.120	3.712±0.107	3.776±0.118

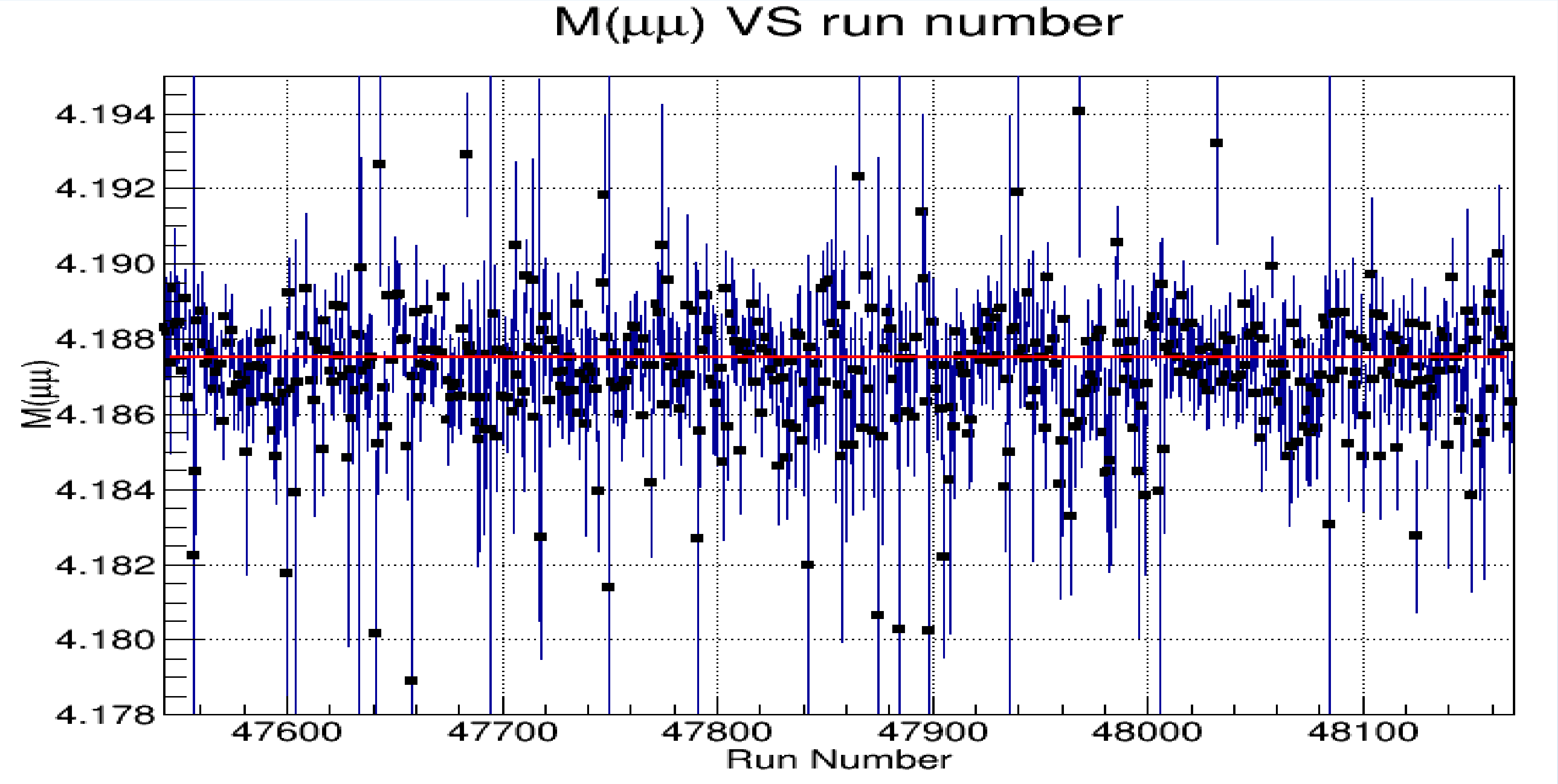
The stability of beam energy over time

To get better known the quality of our data over time, we have do some check run by run.

When we get the M(μμ) run by run, we use the same method as above. Also using Gaussian as the fitting function, we can easily to fit successfully with a large data sets and more precision.

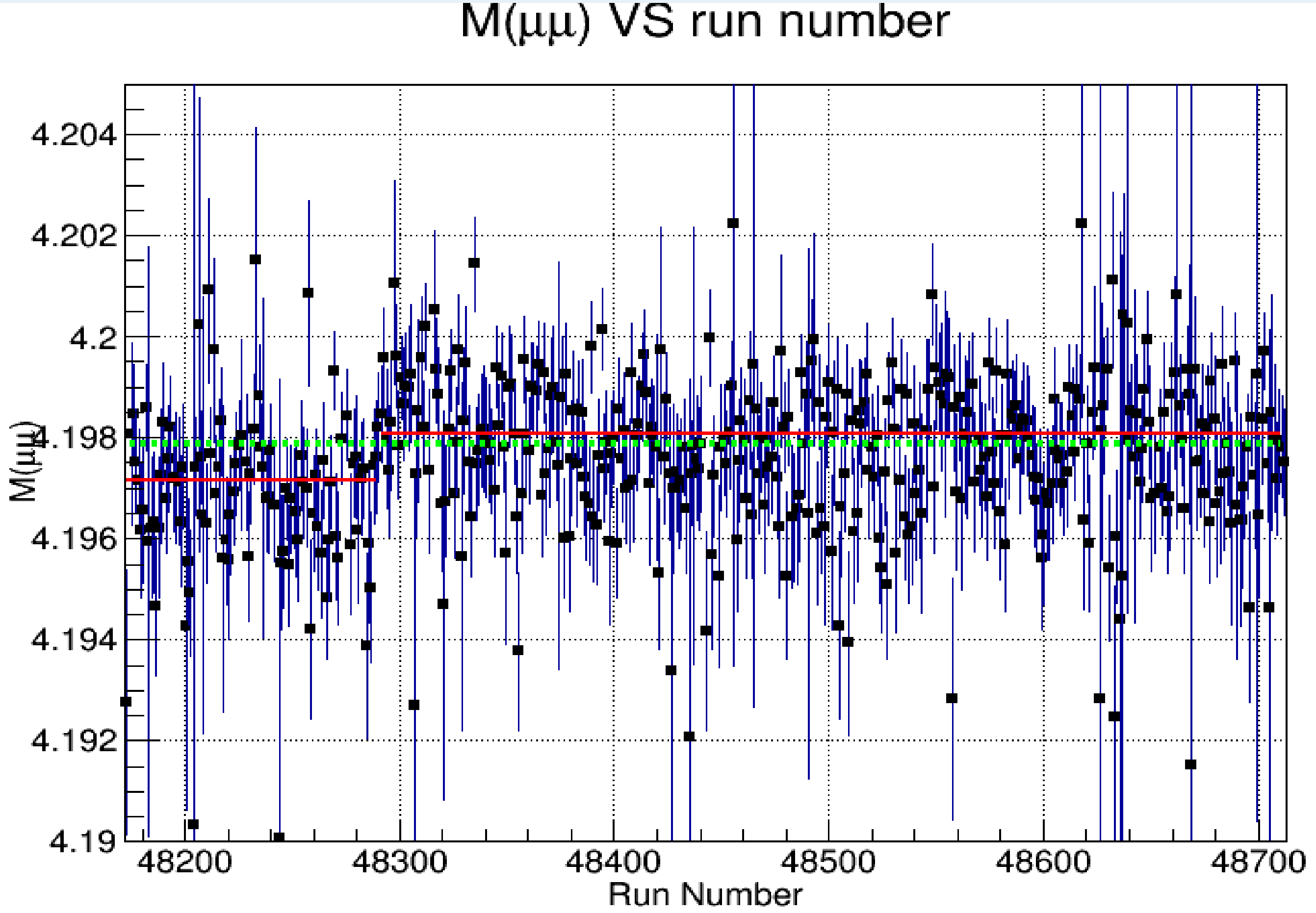
And also we will fit with subsections if it has difference obviously.

➢ M(μμ) of 4190data Run by Run



Value:4187.520 ± 0.056MeV

➢ M(μμ) of 4200 data Run by Run

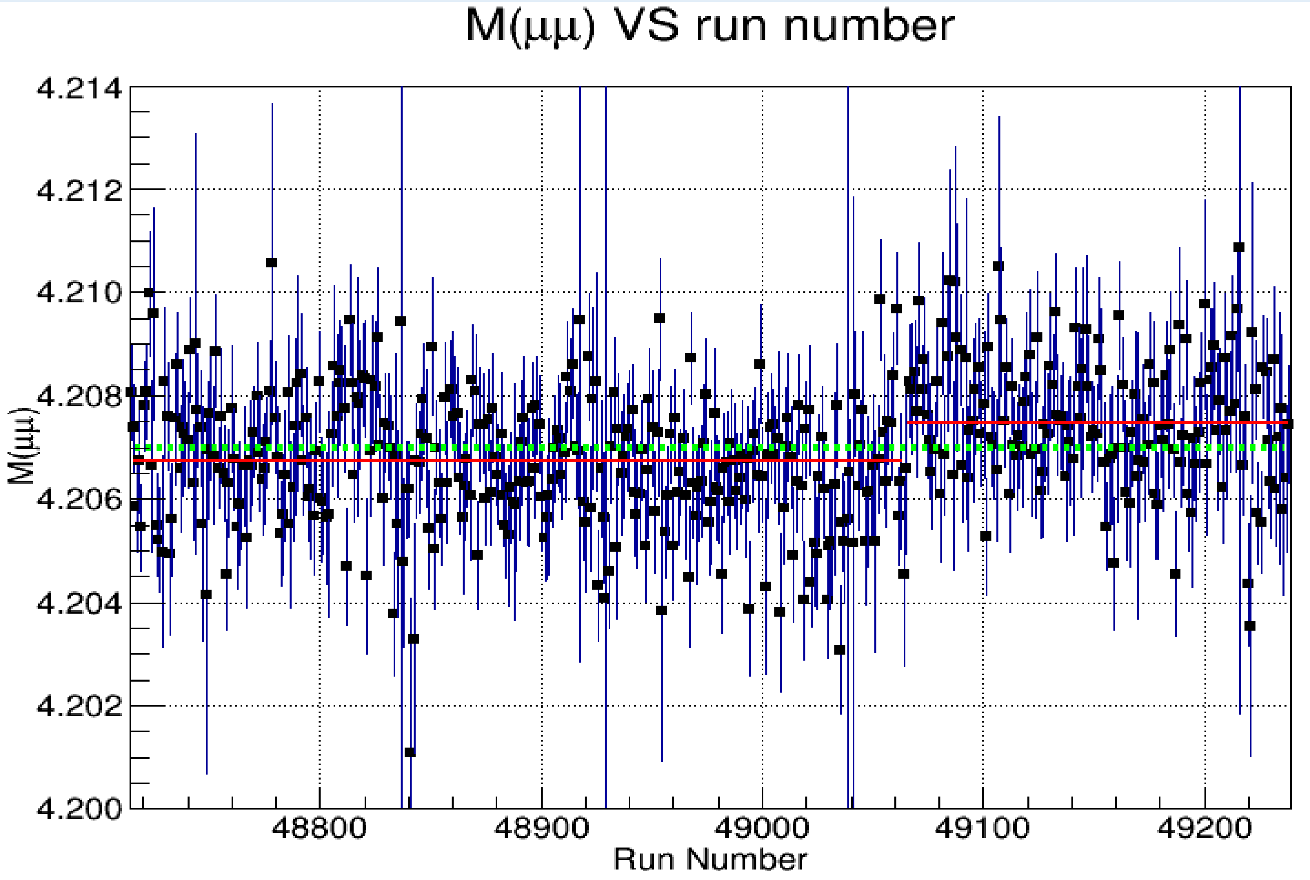


Range (48172, 48290)
Value : 4197.14 $\pm$ 0.12

Range (48291, 48713)
Value: 4198.07 $\pm$ 0.06

Range(48172,48713)
Value: 4197.88 $\pm$ 0.06

➢ M(μμ) of 4210 data Run by Run

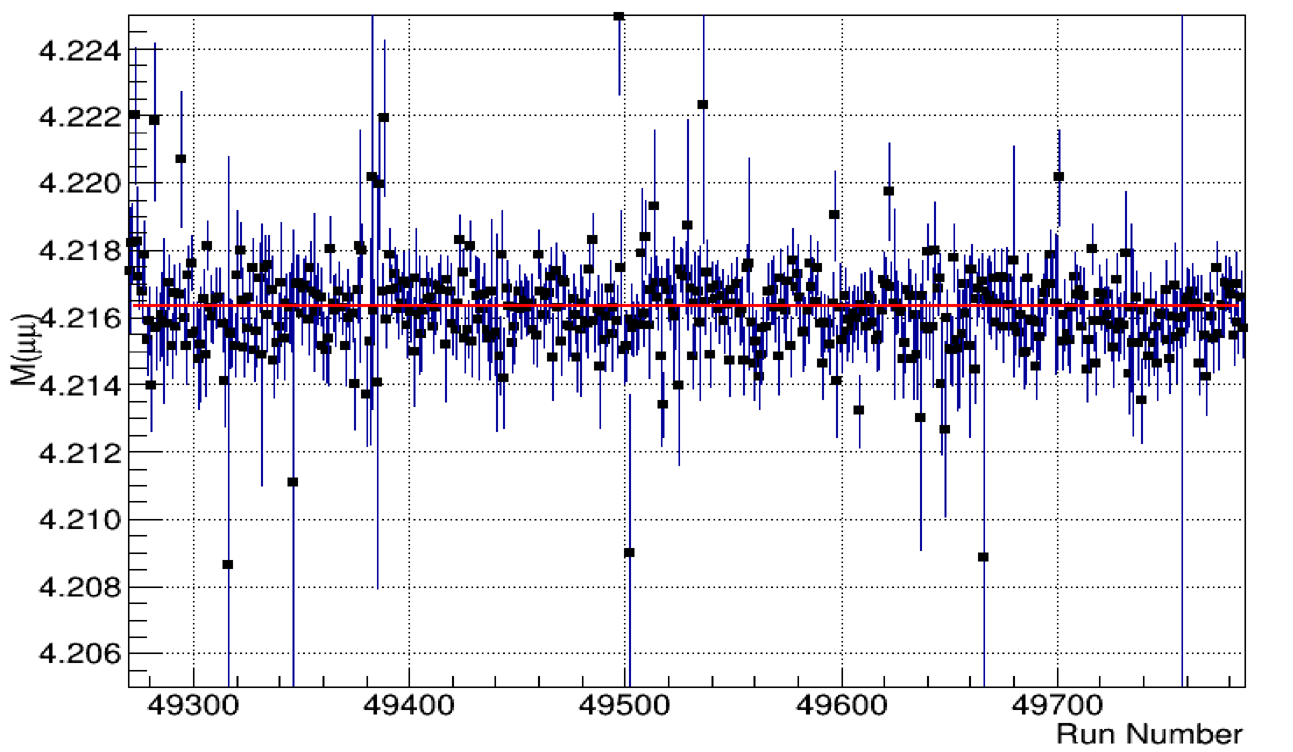


Range (48174, 49065)
Value: 4206.75 ± 0.06

Range (49066, 49239)
Value: 4207.49 ±0.0 9

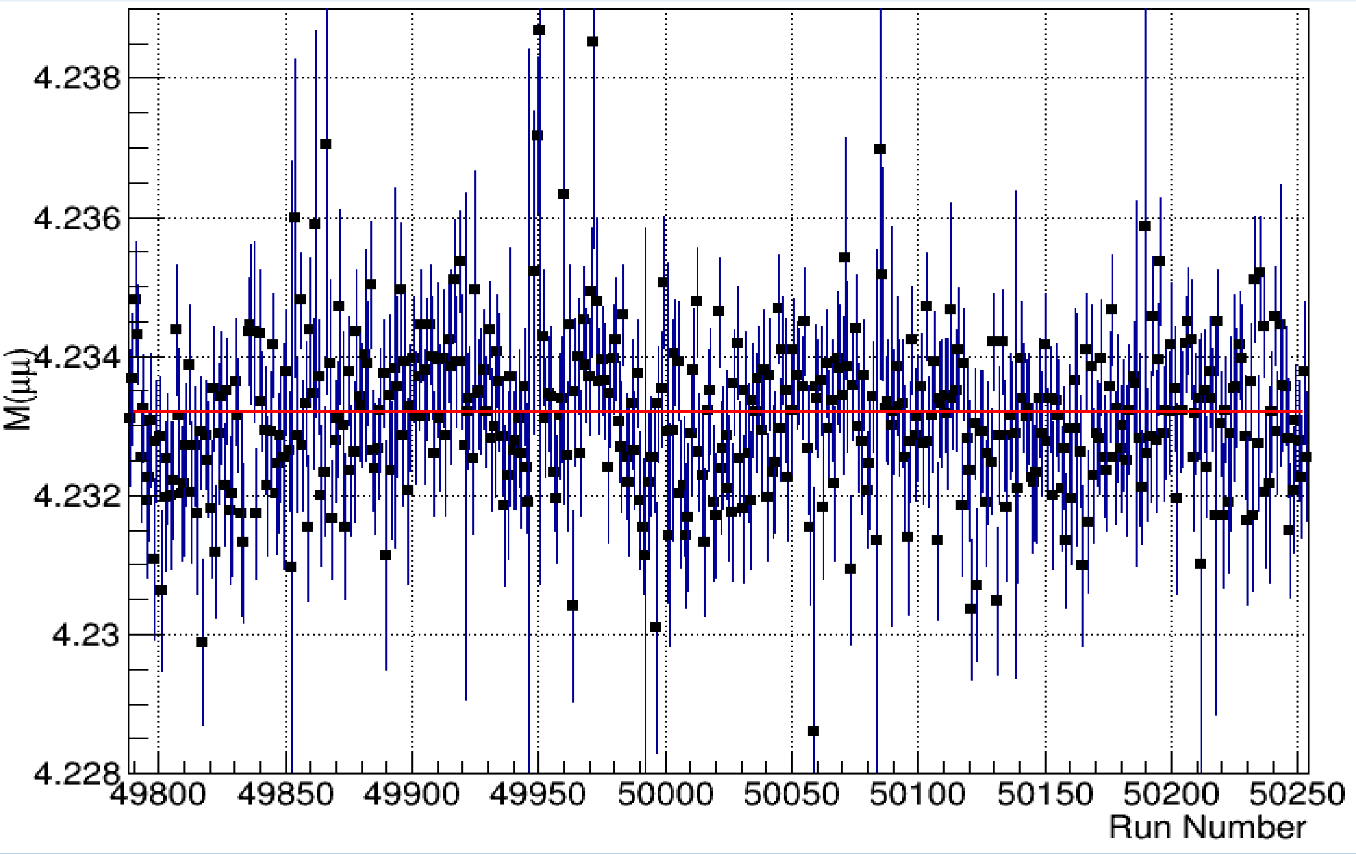
Range (48174, 49239)
Value: 4206.98 ± 0.05

➢ M(μμ) of 4220 data Run by Run



Value: 4216.33 $\pm$ 0.05(MeV)

➢ M(μμ) of 4237 data Run by Run



Value: 4233.21± 0.04(MeV)

Summary

After Momentum calibration and radiation correction the ECM of each energy point is in the table. (ECM = fitting value – Momentum calibration + radiation correction)

Energy (MeV)	Momentum calibration	Radiation correction	M(μμ)	Ecm
4190	1.13±0.37	3.04±0.12	4187.26 ±0.06	4189.17±0.39
4200	1.52±0.37	3.03±0.12	4197.61 ± 0.06	4199.12±0.39
4210	0.36±0.39	2.98±0.12	4207.01 ±0.05	4209.63±0.41
4220	0.64± 0.35	3.71±0.11	4216.21±0.05	4219.28±0.37
4237	0.52±0.33	3.78±0.12	4233.08±0.04	4236.34±0.35

Thank you !!!