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

Liao Longzhou, Yuan Changzheng
IHEP
2017/05/31

OUTLINE

- Introduction
- Dataset and BOSS Version
- Analysis method
  - Event selection
  - Momentum calibration (ISR J/psi sample)
  - ISR and FSR effect (MC)
  - Fit method
- The stability of beam energy over time
- Summary

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 $E cm$.

There are eight 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	458
4237	49788-50254	437
4246	50255-50793	475
4270	50796-51302	471
4280	51305-51498	172

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 $\gamma_{ISR}\mathrm{J/psi}$.

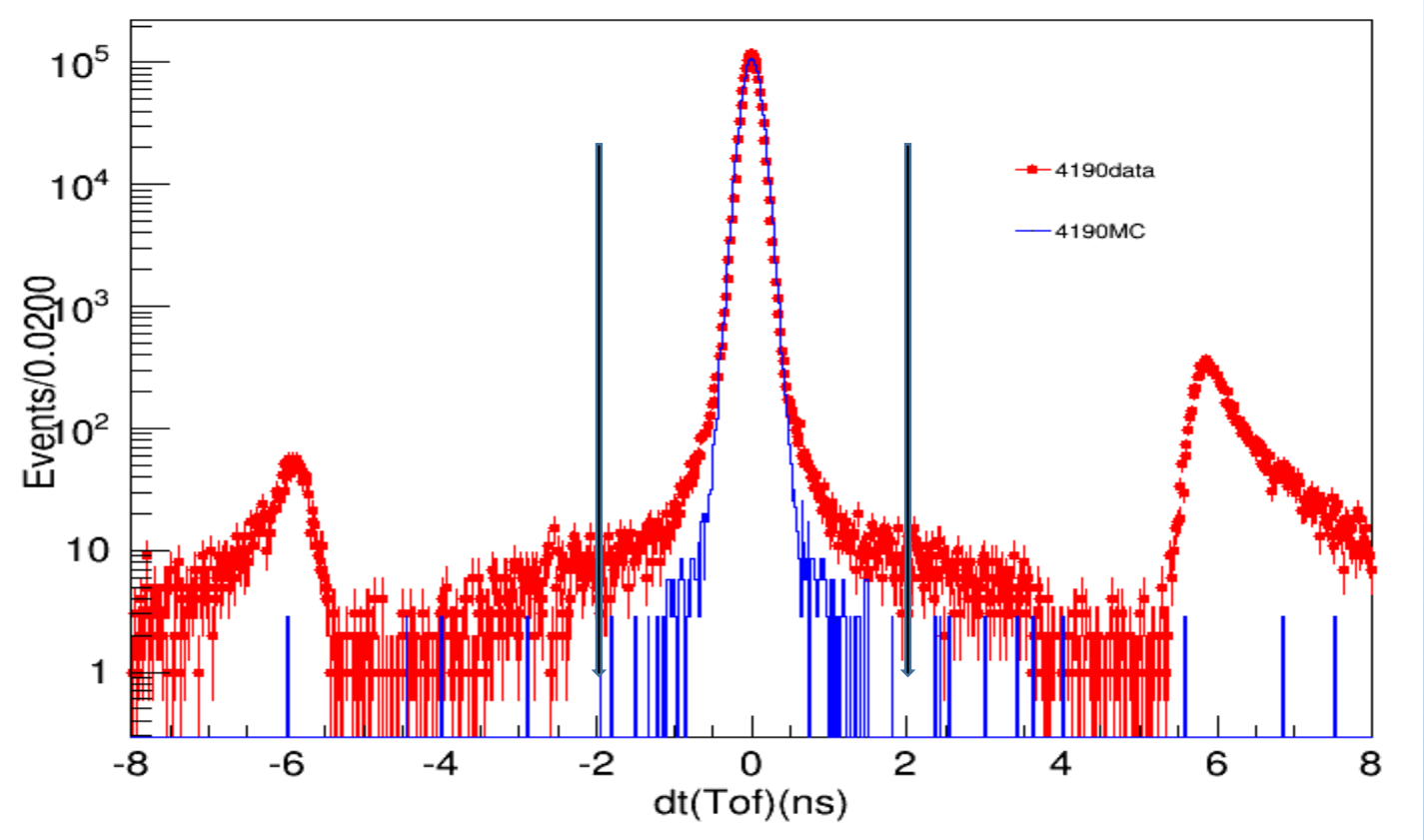
For ΔM

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

Event selection

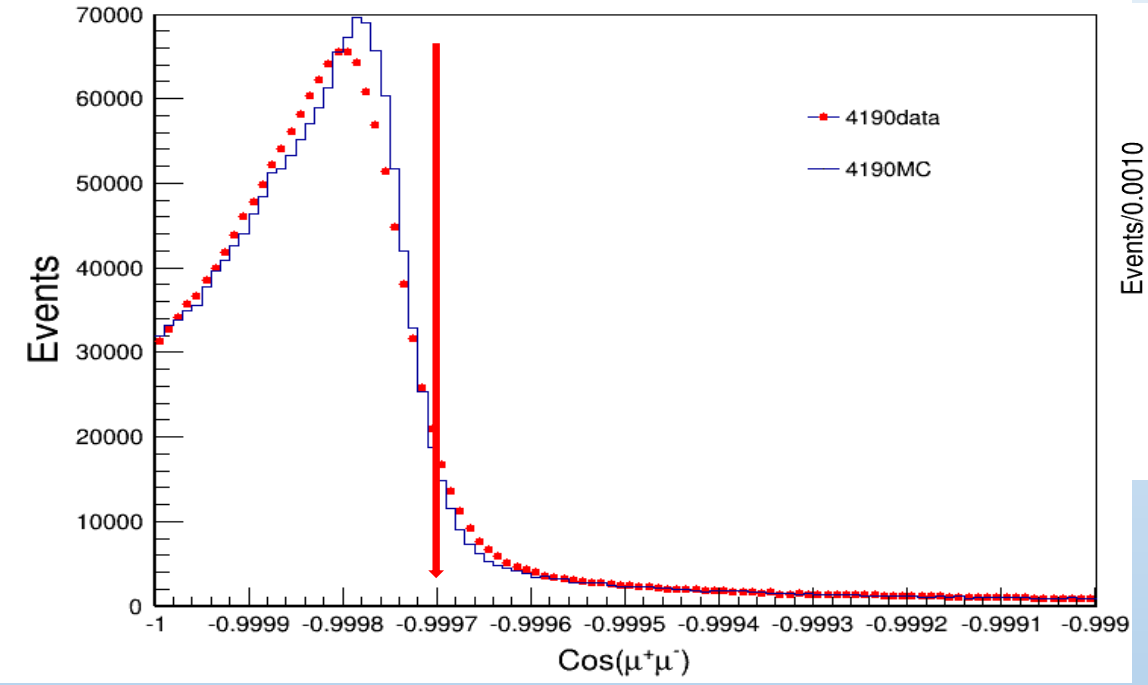
- $|\cos\theta|<0.8$ (only barrel)
- $|V_z|<10.0$cm
- $V_r<1.0$cm
- Two charged tracks
- Total charges = 0
- $|\Delta t|<2$ns
- $\cos(\mu^+\mu^-) <-0.9997$
- EMC<0.4GeV

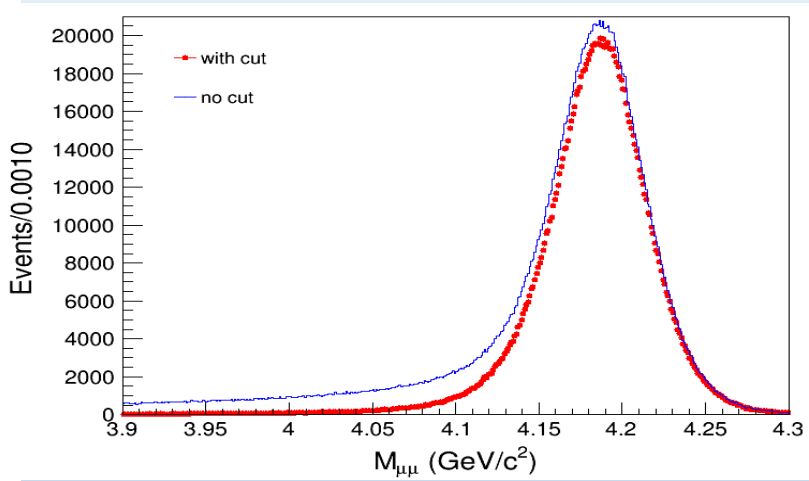
The TOF difference (Δt) of $\mu^+\mu^-$



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

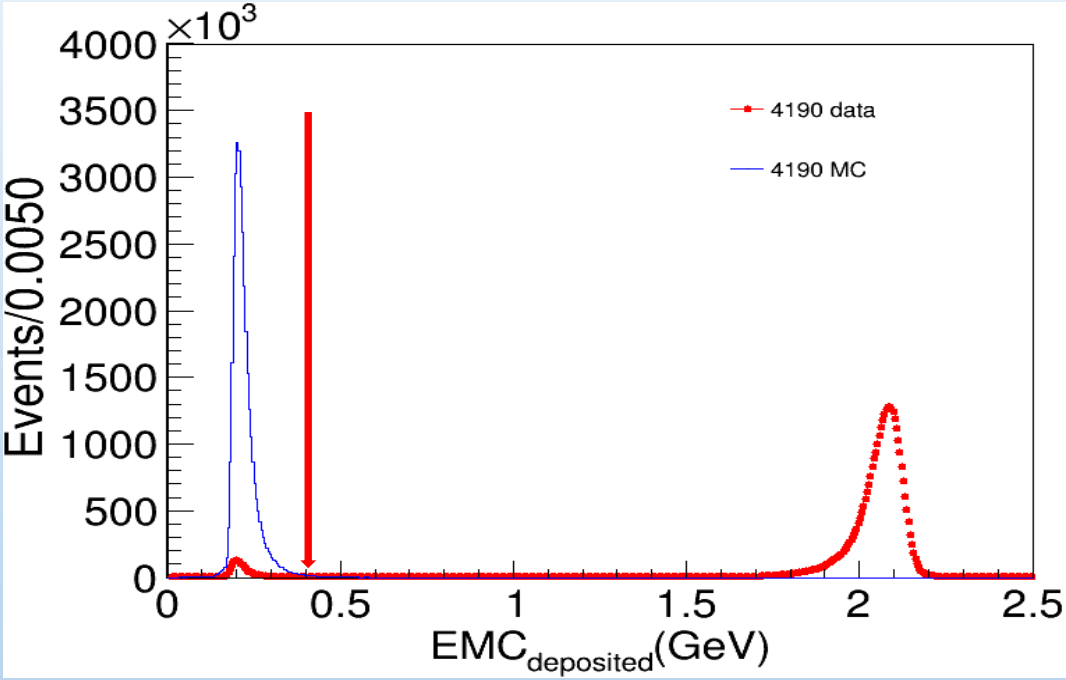


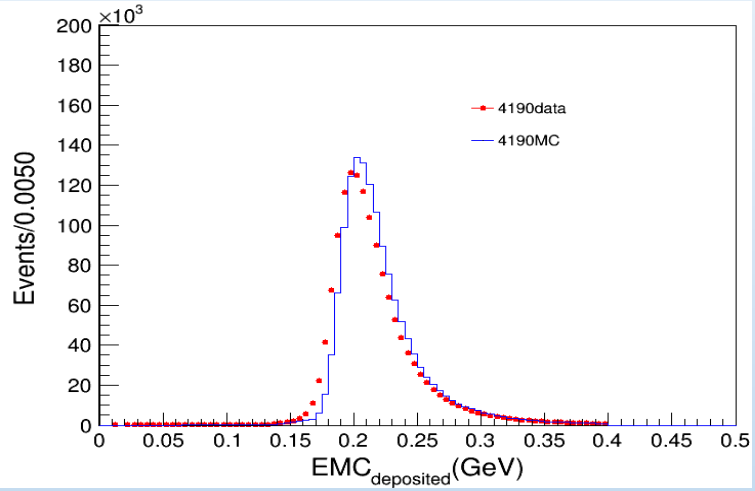


With or without $\cos(\mu^+\mu^-)$ <-0.9997, the distribution of $M(\mu^+\mu^-)$ in 4.19GeV

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

The energy deposited in the EMC

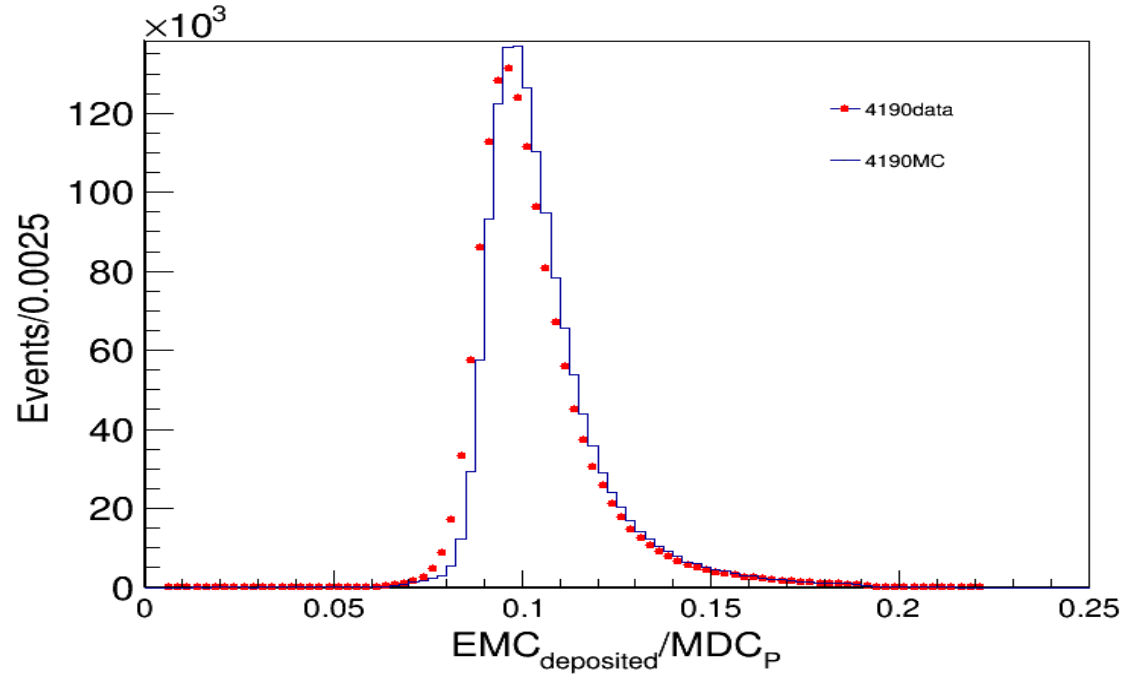




With EMC<0.4GeV, and MC scale to data

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

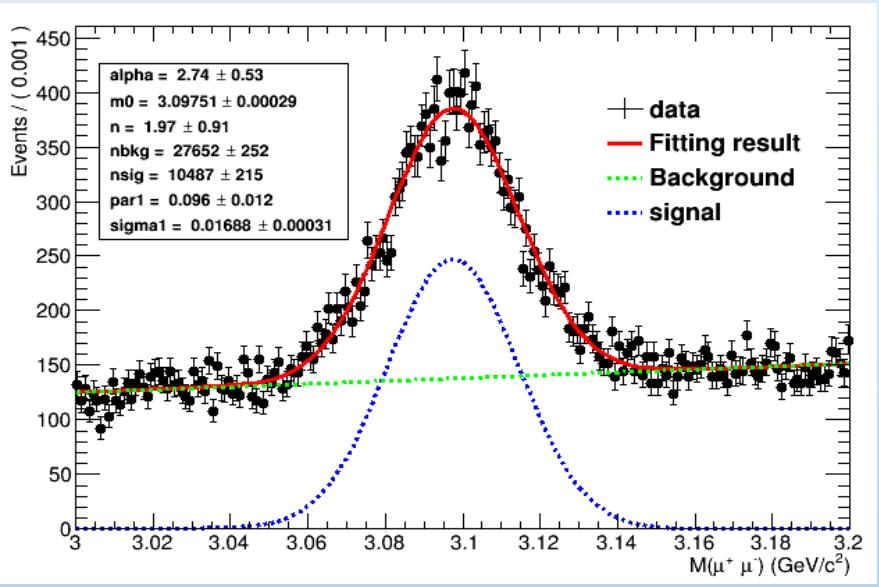
The energy deposited in EMC over the momentum(E/P)



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

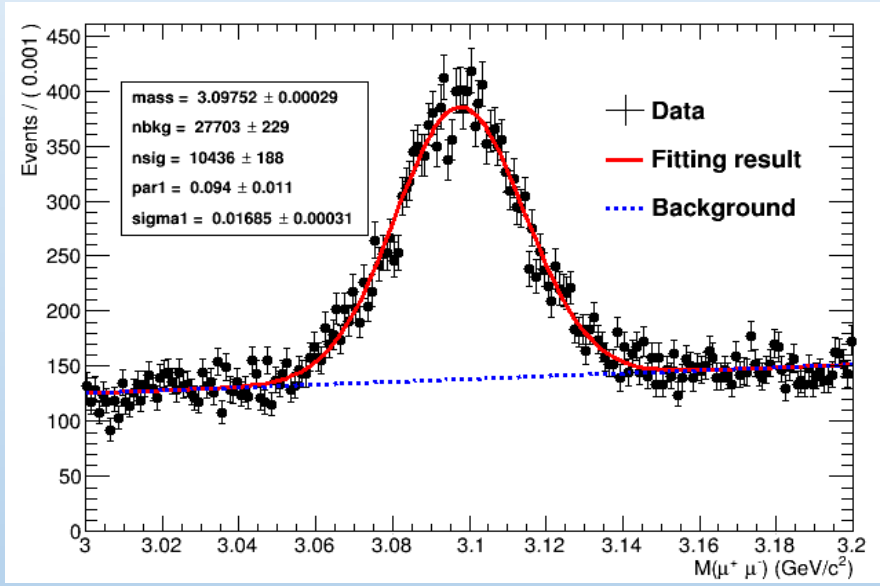
Momentum calibration

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



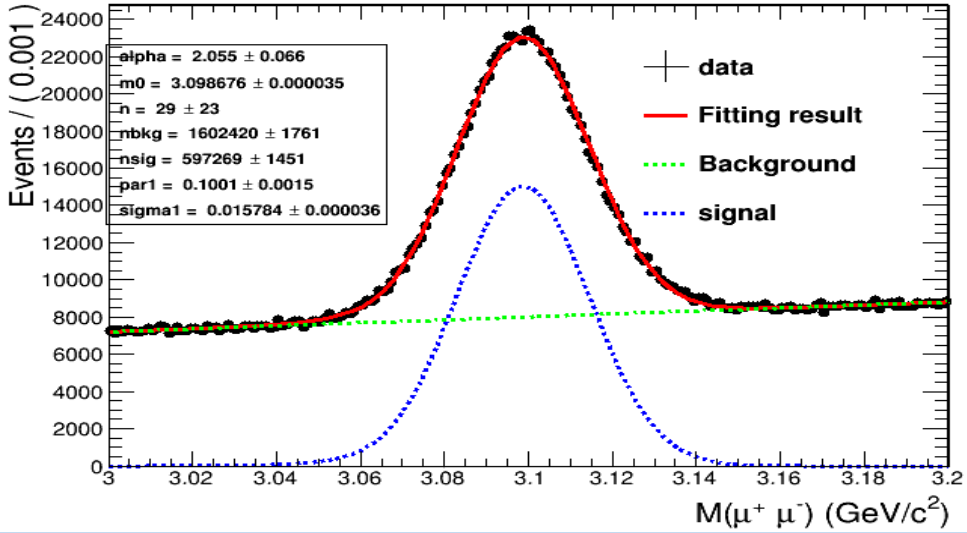
Gauss + 1st-order polynomial

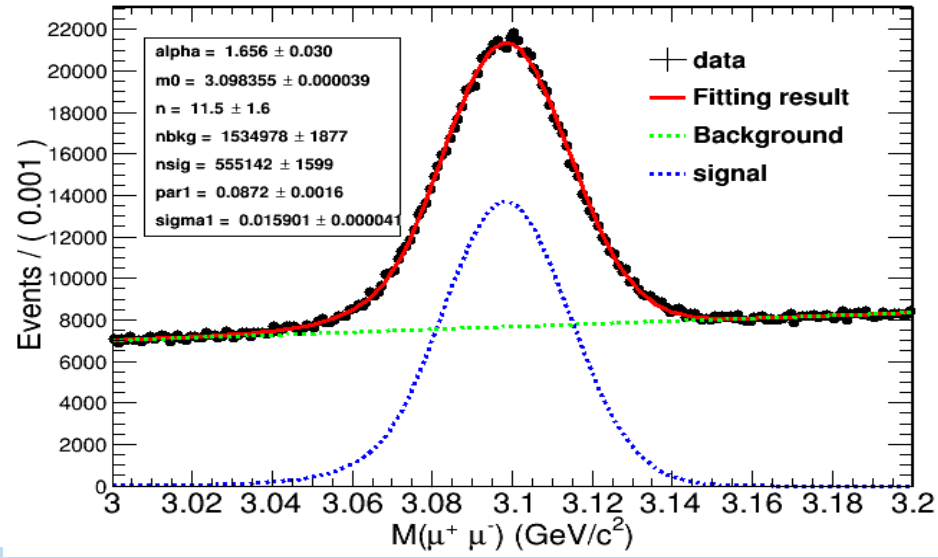
Mmp=3097.52 ± 0.29MeV

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.



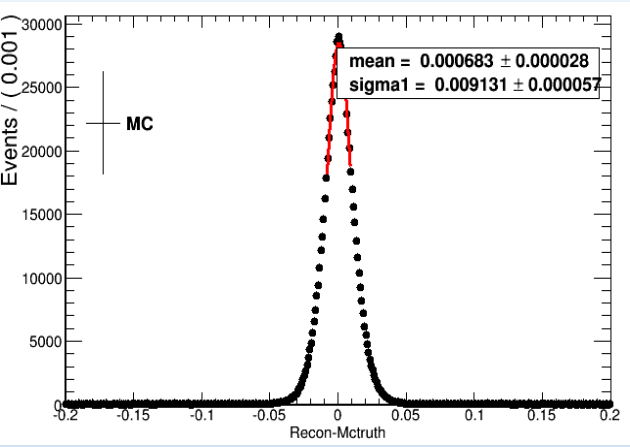


Fit chi2: 1.94055
Parameters Number: 7
sigma=15.78 ± 0.04
Mmp= 3098.68± 0.04

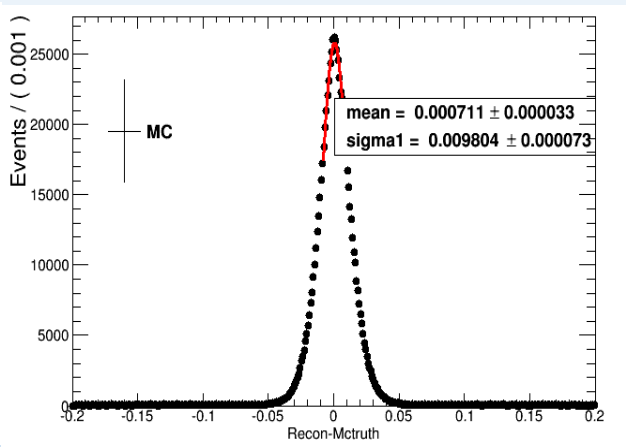
Fit chi2: 1.83021
Parameters Number: 7
sigma= 15.90 ± 0.04
Mmp= 3098.36 ± 0.04

FSR = 0.32 ± 0.05MeV

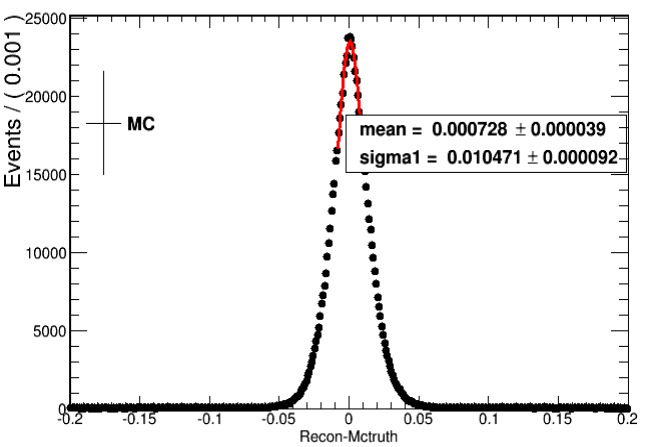
Momentum Calibration



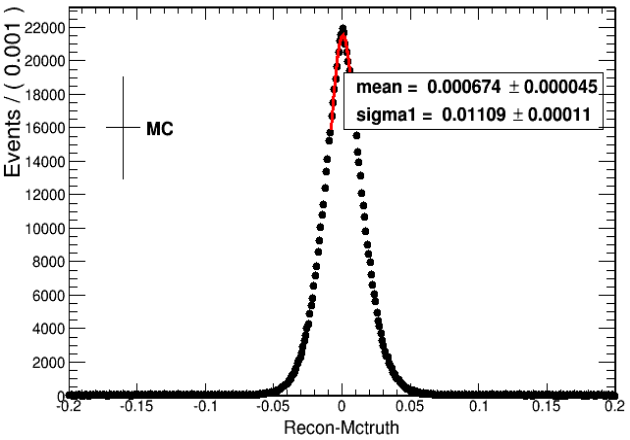
3320
mean = 0.683 +/-0.003MeV



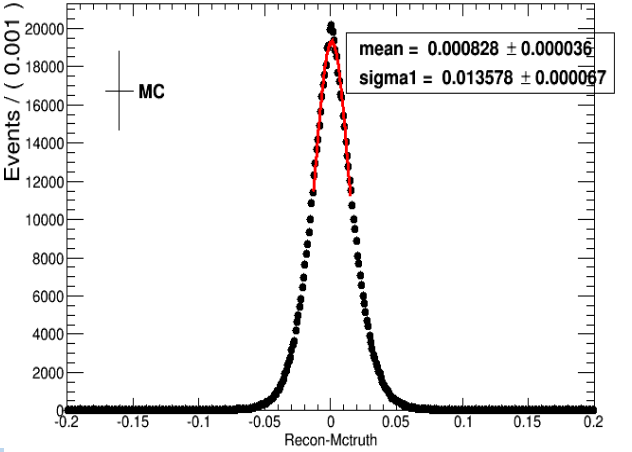
3520
mean = 0.711+/- 0.003MeV



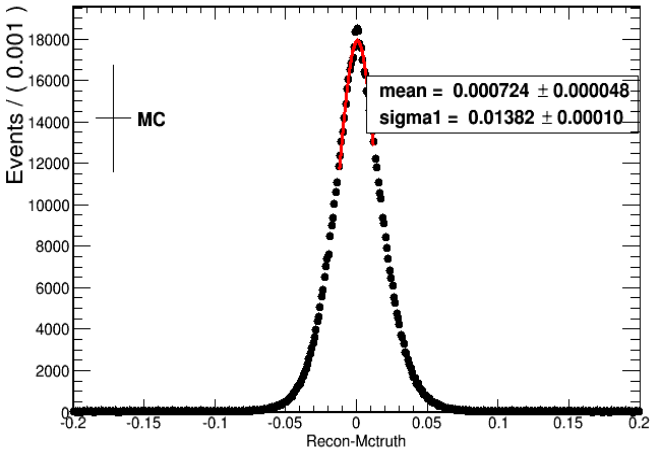
3720
mean = 0.728 +/- 0.004



3920
mean = 0.674+/- 0.005

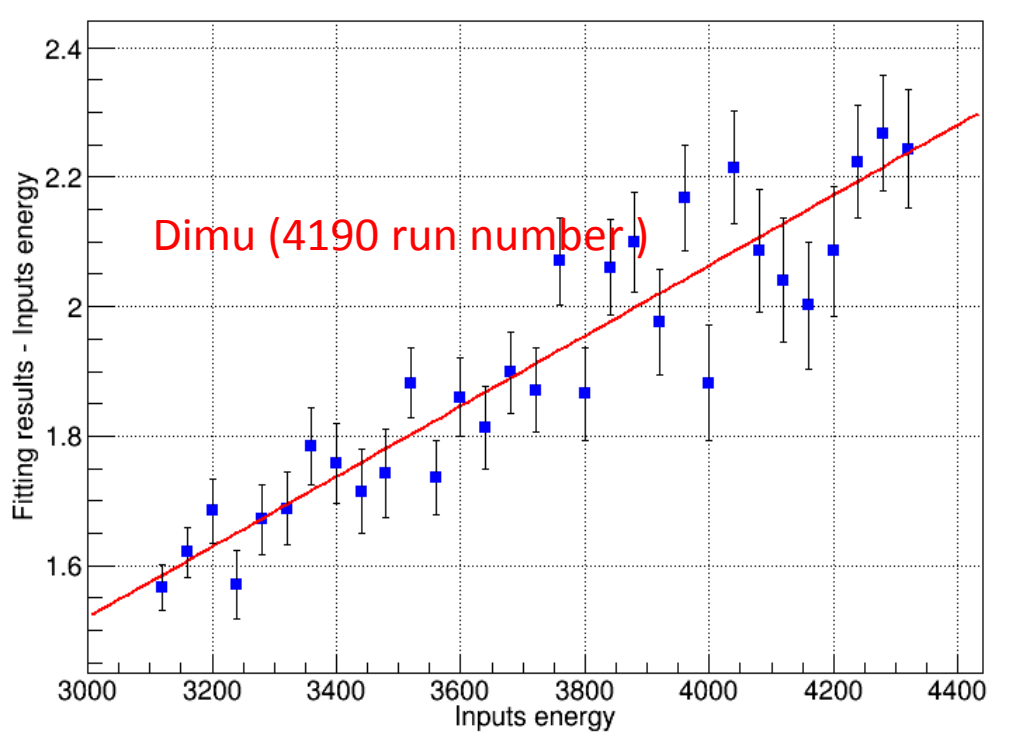


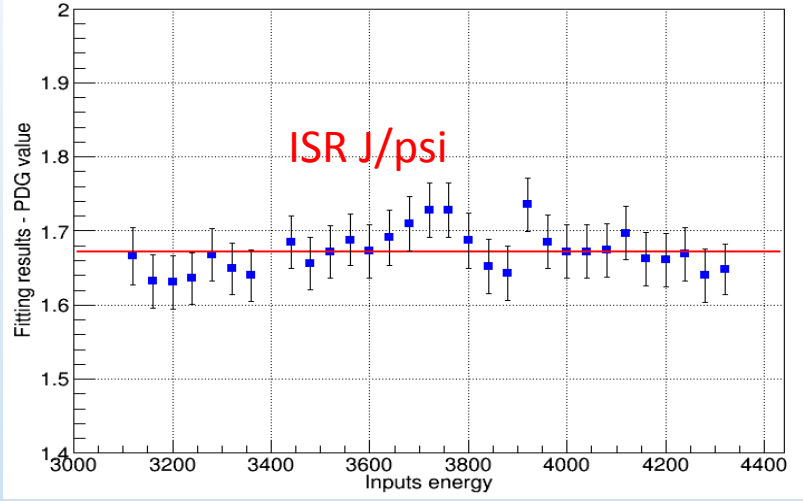
4120
mean = 0.828+/- 0.004

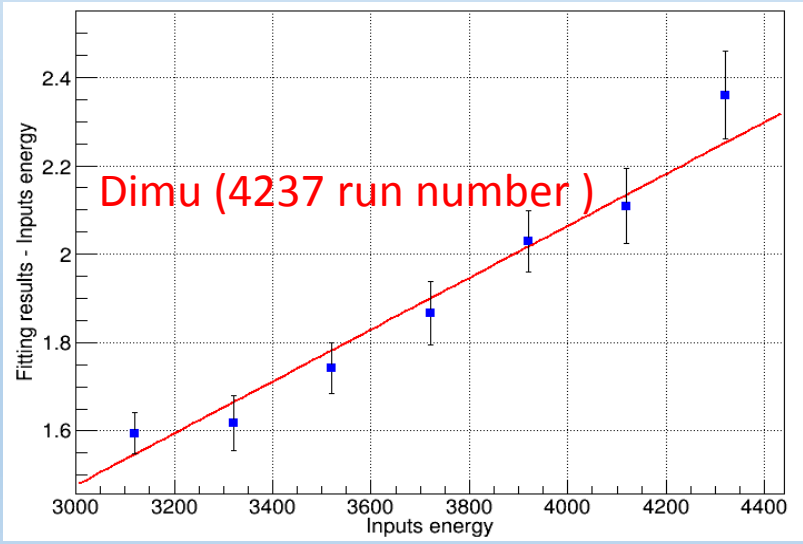


4320
mean = 0.724+/- 0.005

We simulate the Dimu and ISR J/psi (with no radiation) process, and get the difference of inputs and outputs (MeV)







Using 4190 energy point run number

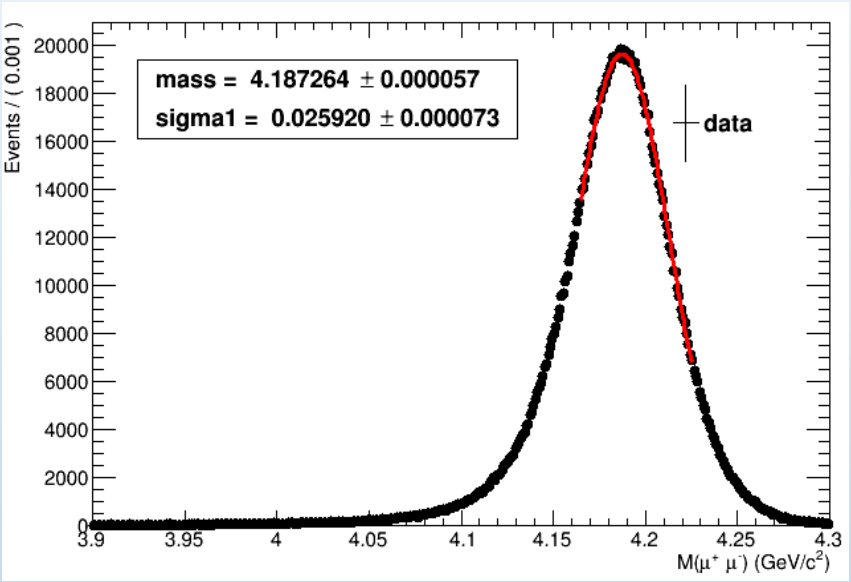
Fitting result :$Y = (5.44 \times 10^{-4} \pm 3.31 \times 10^{-5})X - (0.11 \pm 0.12)$

Momentum Calibration

(PDG value : 3096.916 +/- 0.011MeV)

Energy(MeV)	4190	4200	4210	4220	4237	4246	4270	4280
ISR J/psi	3098.67± 0.04	3098.61± 0.04	3098.665 ± 0.04	3098.61± 0.04	3098.63± 0.04	3098.61±0 .03	3098.63±0 .04	3098.59±0 .04
IFSR J/psi	3098.35 ±0.04	3098.39 ± 0.05	3098.384 ±0.04	3098.39± 0.04	3098.38± 0.04	3098.34±0 .04	3098.30±0 .04	3098.28±0 .04
ΔF	0.32±0.05	0.22±0.06	0.28±0.05	0.22± 0.05	0.25± 0.05	0.27± 0.05	0.33± 0.05	0.31± 0.05
Data fitting result	3097.51 ± 0.29	3097.80±0.2 7	3096.92 ± 0.30	3097.20± 0.27	3097.08± 0.26	3097.09±0 .26	3097.66±0 .27	3097.12±0 .49
After FSR correction	3097.83± 0.29	3098.02± 0.30	3097.20± 0.30	3097.42± 0.27	3097.33±0.2 6	3097.36±0 .26	3097.99±0 .27	3097.43±0 .49
Difference after correction	0.88±0.29	1.10±0.27	0.28±0.30	0.50± 0.27	0.41± 0.26	0.44± 0.26	1.07± 0.27	0.51±0.49
Momentum Calibration	±	±	±	±	±	±	±	±

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)

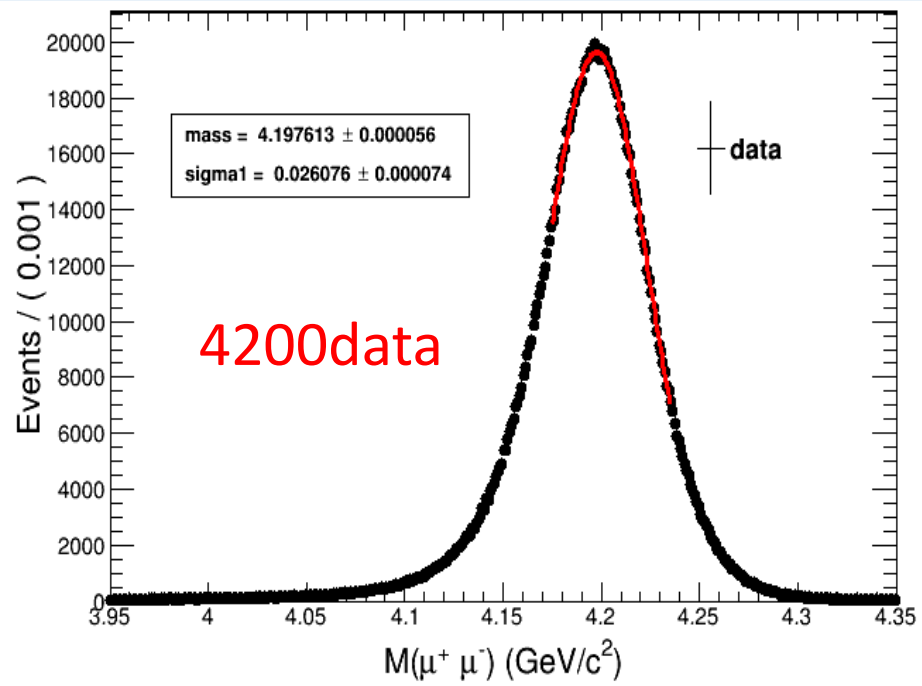
When fitting the Dimu peak with a Gaussian, we give a criterion to confirm the fitting range.

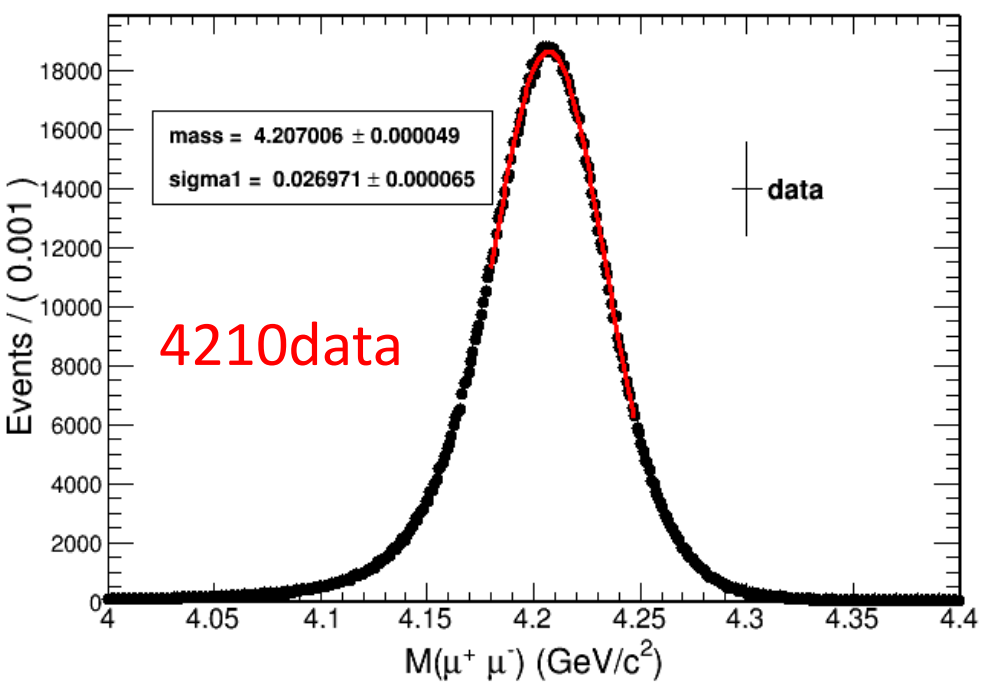
First ,we fit all data with a reasonable range to get the fitting sigma and chisquare over number of freedom degree (chis/ndf), also peak value(pv).

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





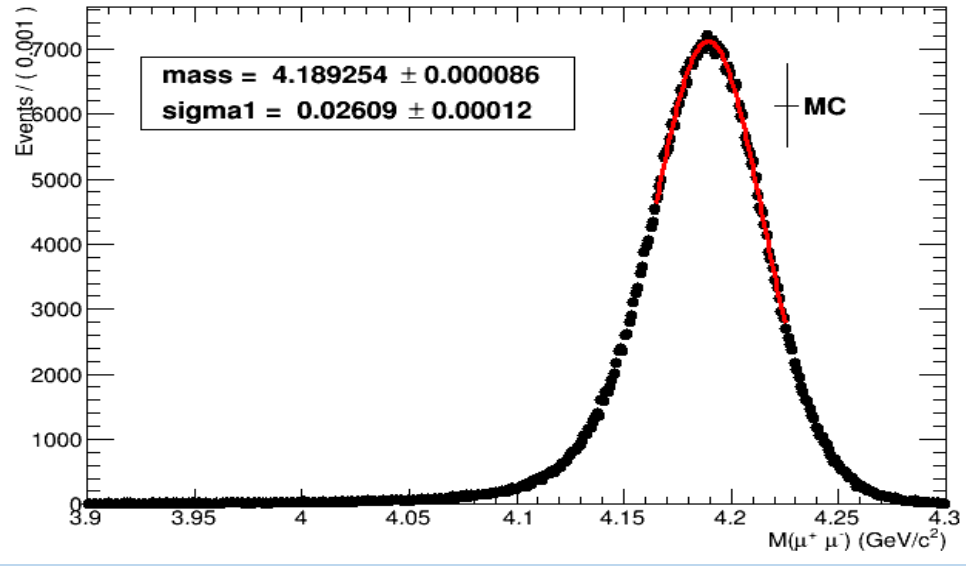
Fit chi2/ndf: 1.317

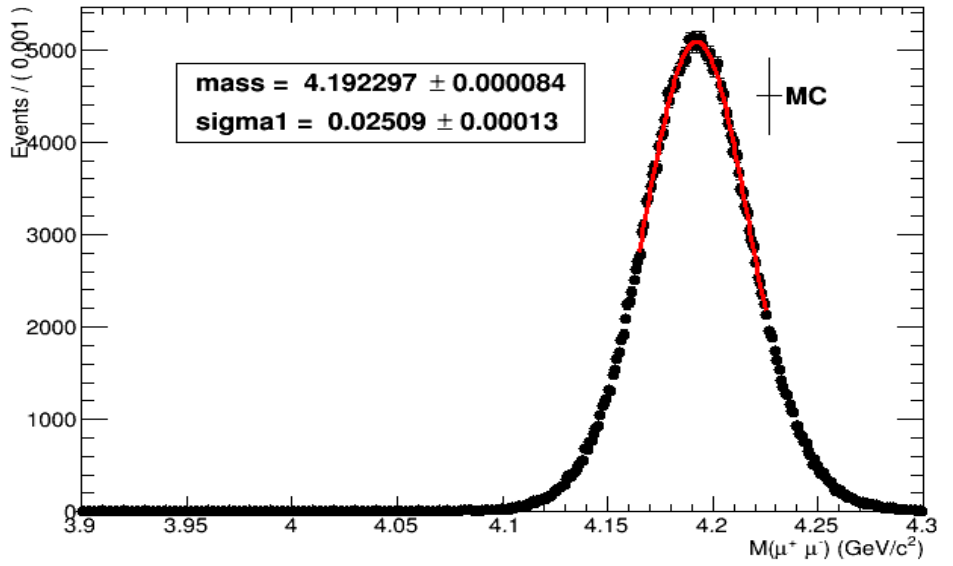
Mmp = 4197.613 ± 0.056MeV

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)(MeV)

ECM(MeV)	4190	4200	4210	4220	4237	4246	4270	4280
Radiation	4189.254±0.086	4199.310 ± 0.086	4209.210 ±0.088	4218.551±0.075	4235.355±0.083	4244.527±0.092	4268.340±0.100	4278.480±0.081
No radiation	4192.297±0.084	4202.340 ±0.085	4212.190 ±0.086	4222.263±0.077	4239.131±0.084	4248.209±0.087	4272.097±0.094	4282.268±0.082
ΔM	3.043±0.120	3.030±0.120	2.980±0.120	3.712±0.107	3.776±0.118	3.682±0.127	3.757±0.137	3.788±0.115

ΔM=No radiation dimu –radiation dimu

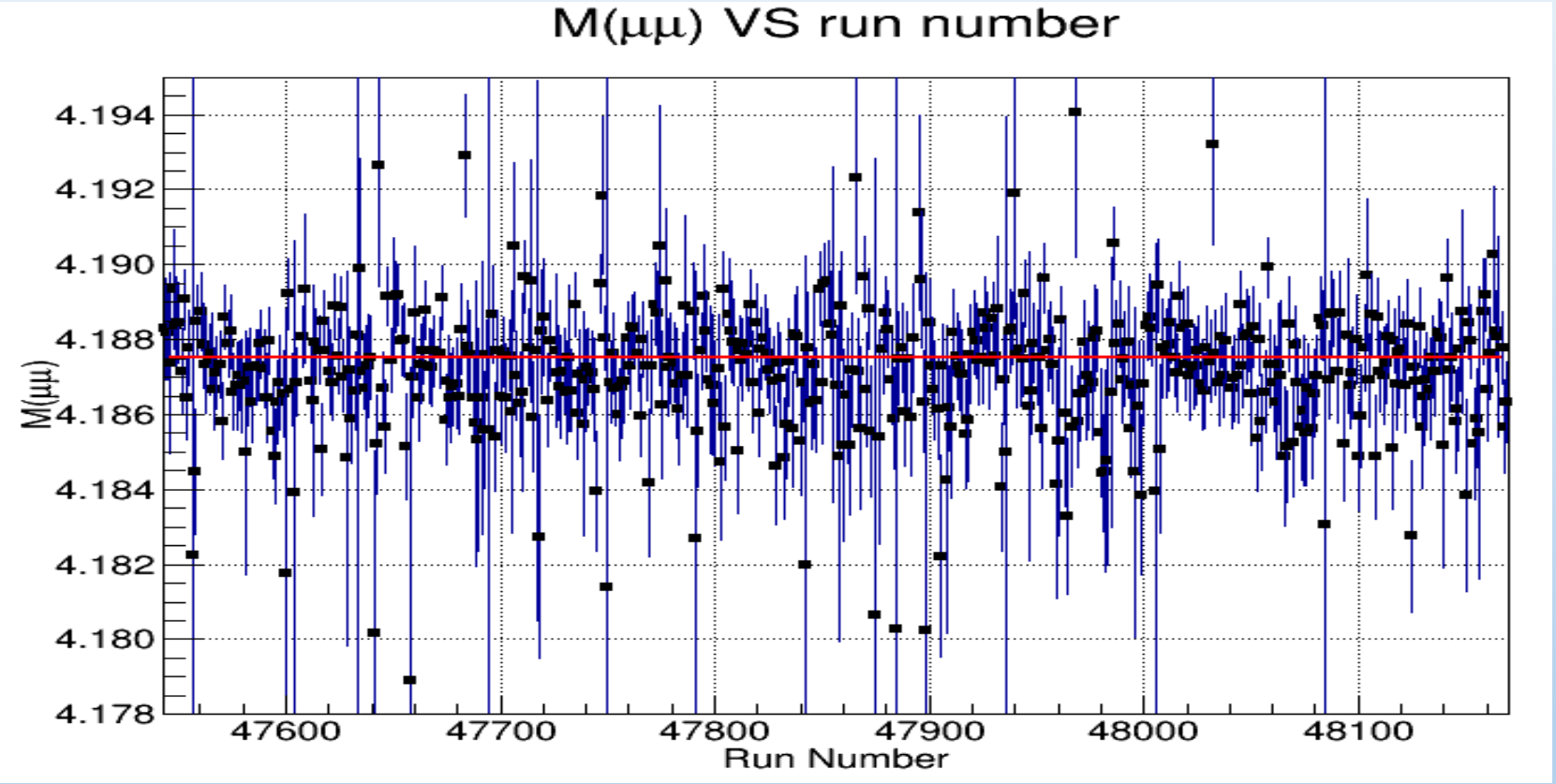
The stability of beam energy over time

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, and we also give the distribution of the difference of momentum between $\mu^+$and μ^- in the center of mass system . we use the same method to get the fitting range. Also using Gaussian as the fitting function, we can easily to fit successfully with a large data sets and more precision.

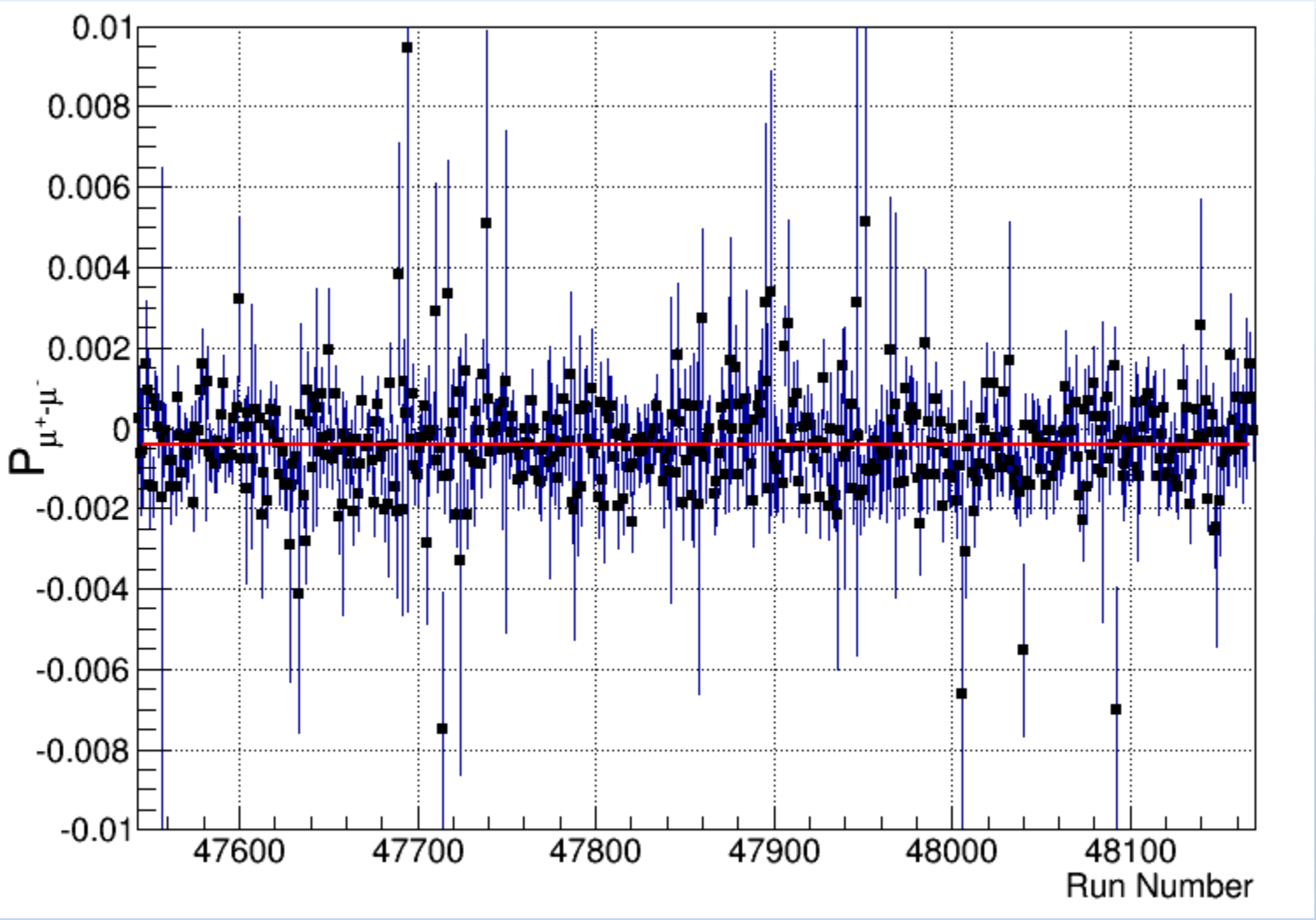
And also we will fit with subsections if it has difference obviously.

➢ M(μμ) of 4190 data Run by Run



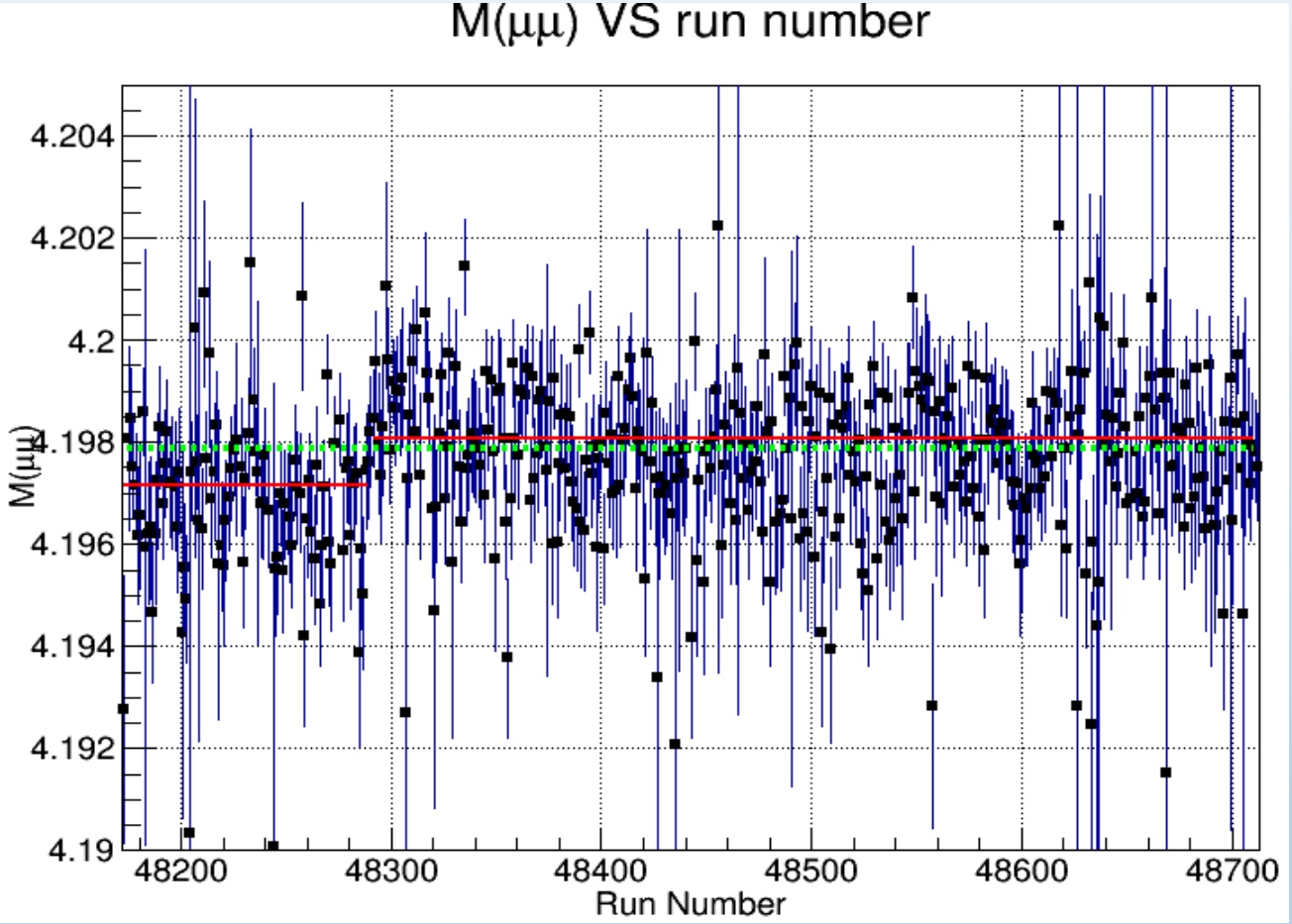
Value:4187.520 $\pm$ 0.056MeV

- The difference of momentum between $\mu^+$and μ^- in the center of mass system of 4190 data Run by Run



Value: -0.041 $\pm$ 0.004MeV

➢ M(μμ) of 4200 data Run by Run(MeV)

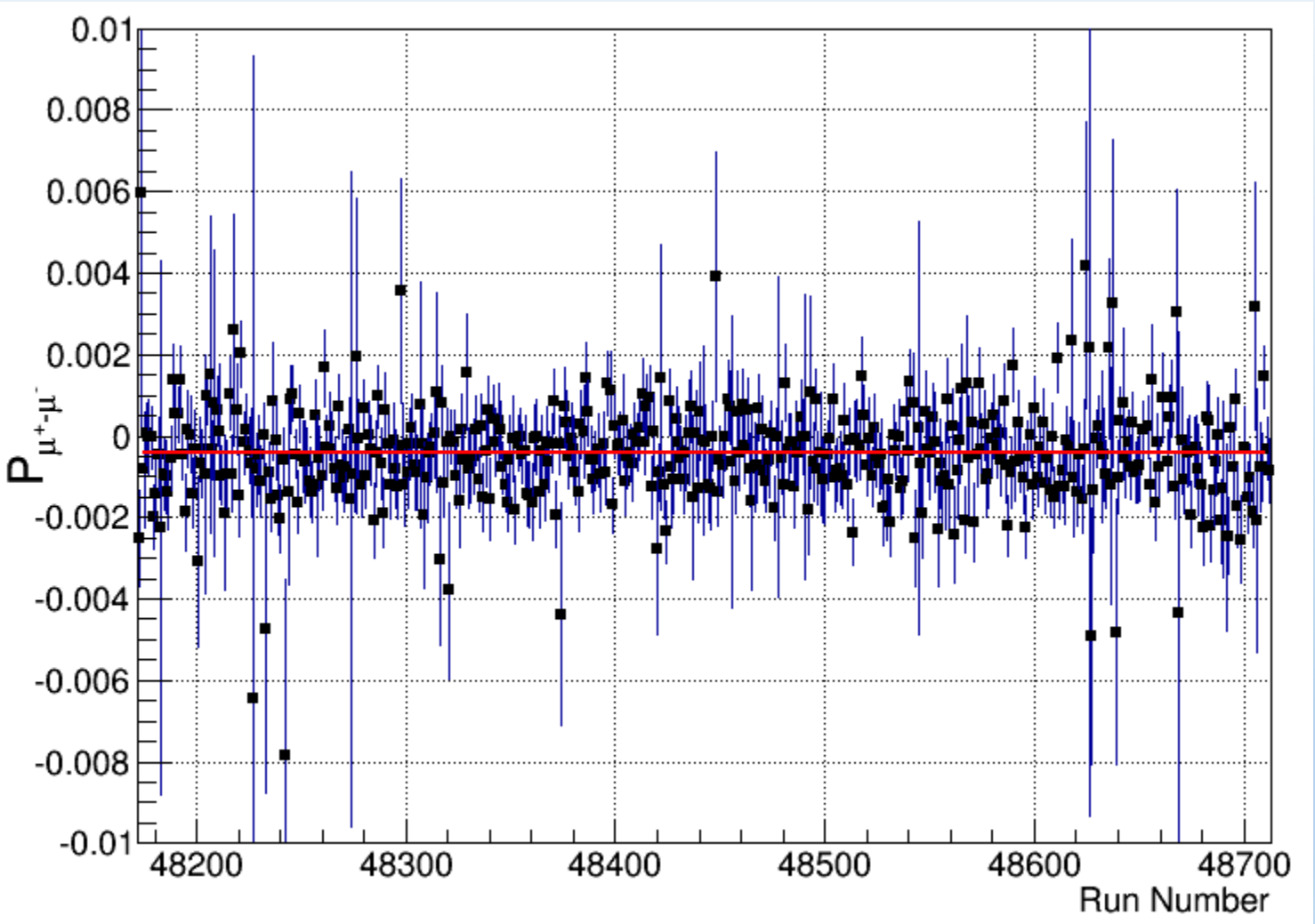


Range (48172, 48290)
Value: 4197.14 ± 0.12MeV

Range (48291, 48713)
Value: 4198.07 ± 0.06MeV

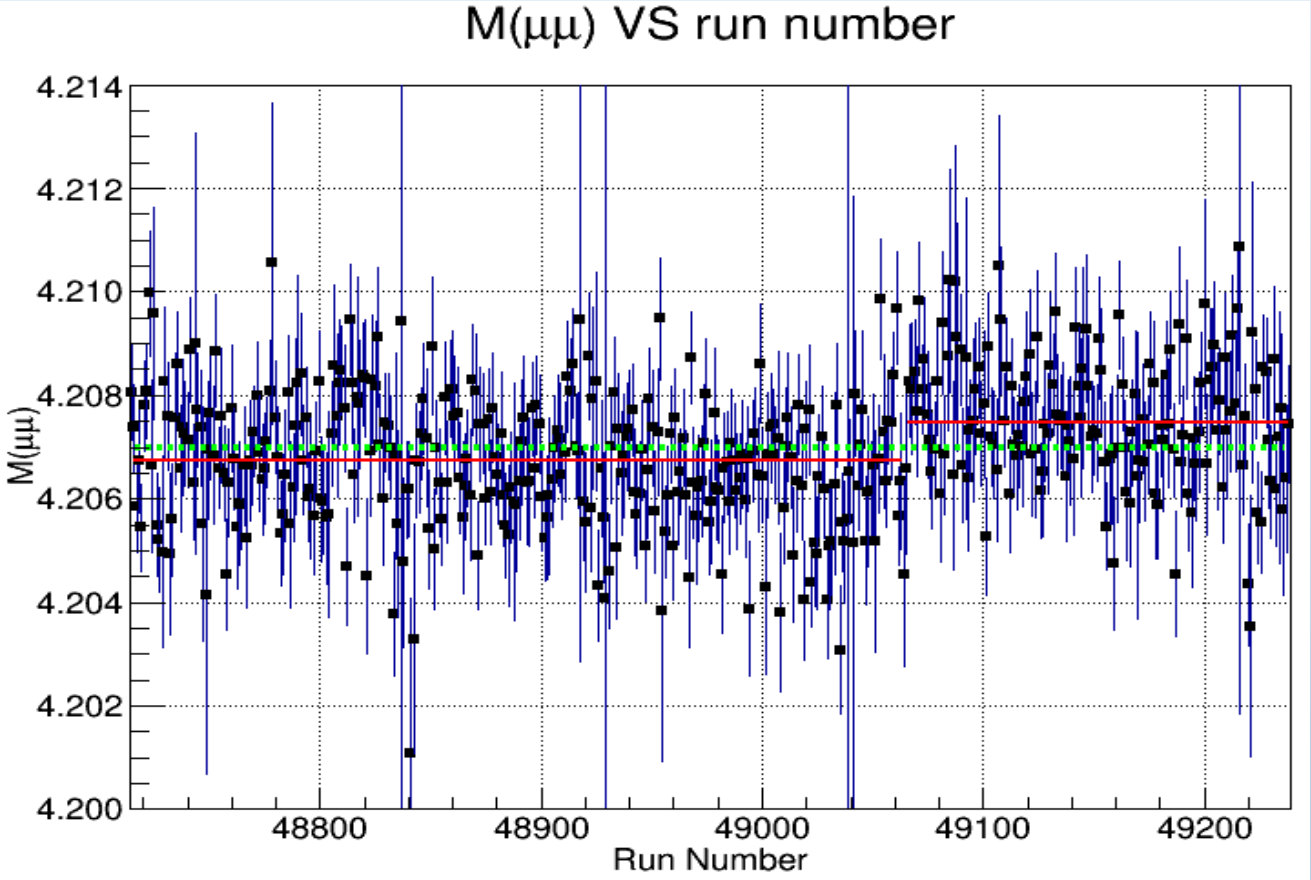
Range(48172,48713)
Value: 4197.88 ± 0.06MeV

- The difference of momentum between $\mu^+$and μ^- in the center of mass system of 4200 data Run by Run



Value: -0.044 $\pm$ 0.004MeV

➢ M(μμ) of 4210 data Run by Run

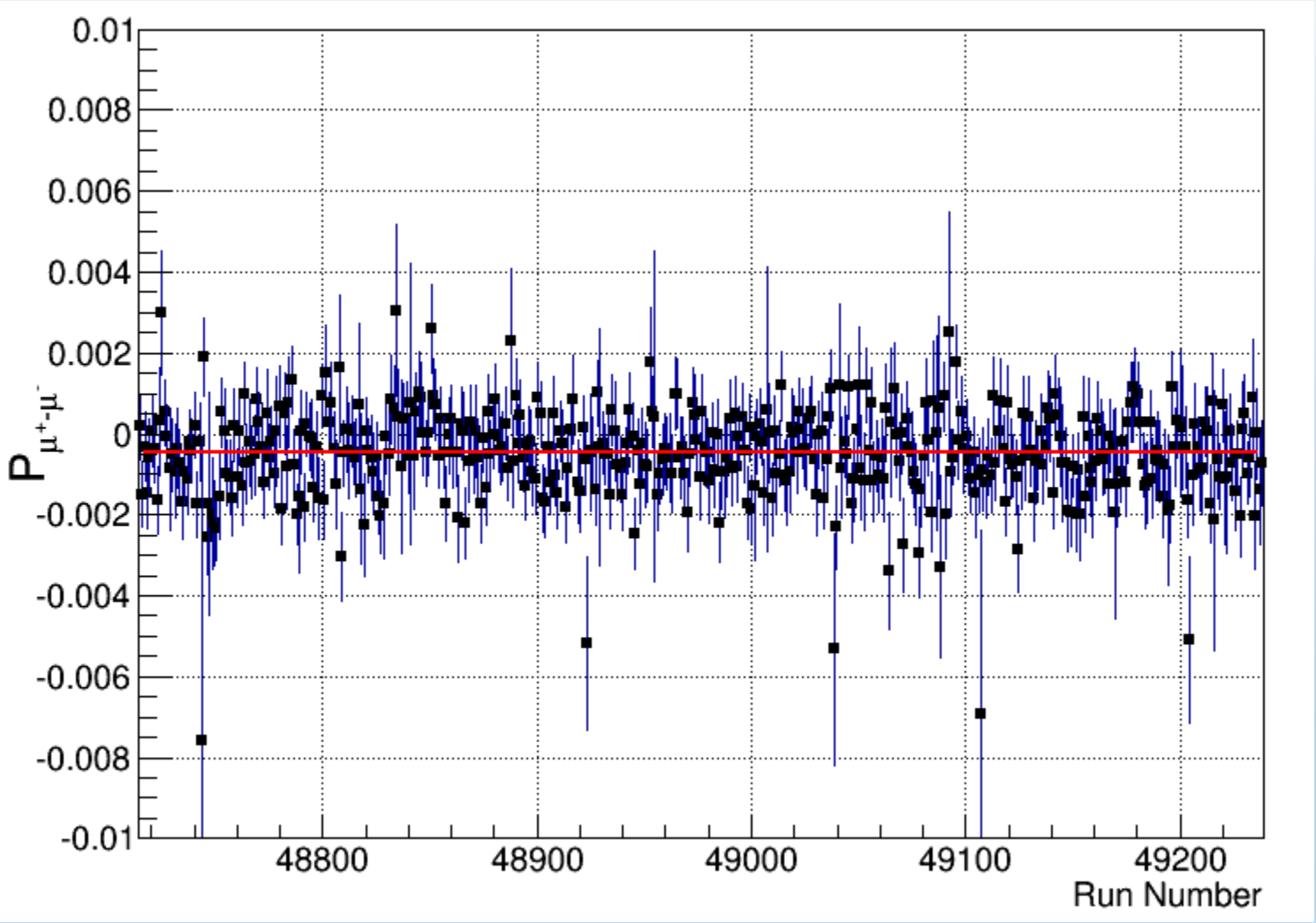


Range (48174, 49065)
Value: 4206.75 ± 0.06MeV

Range (49066, 49239)
Value: 4207.49 ±0.09MeV

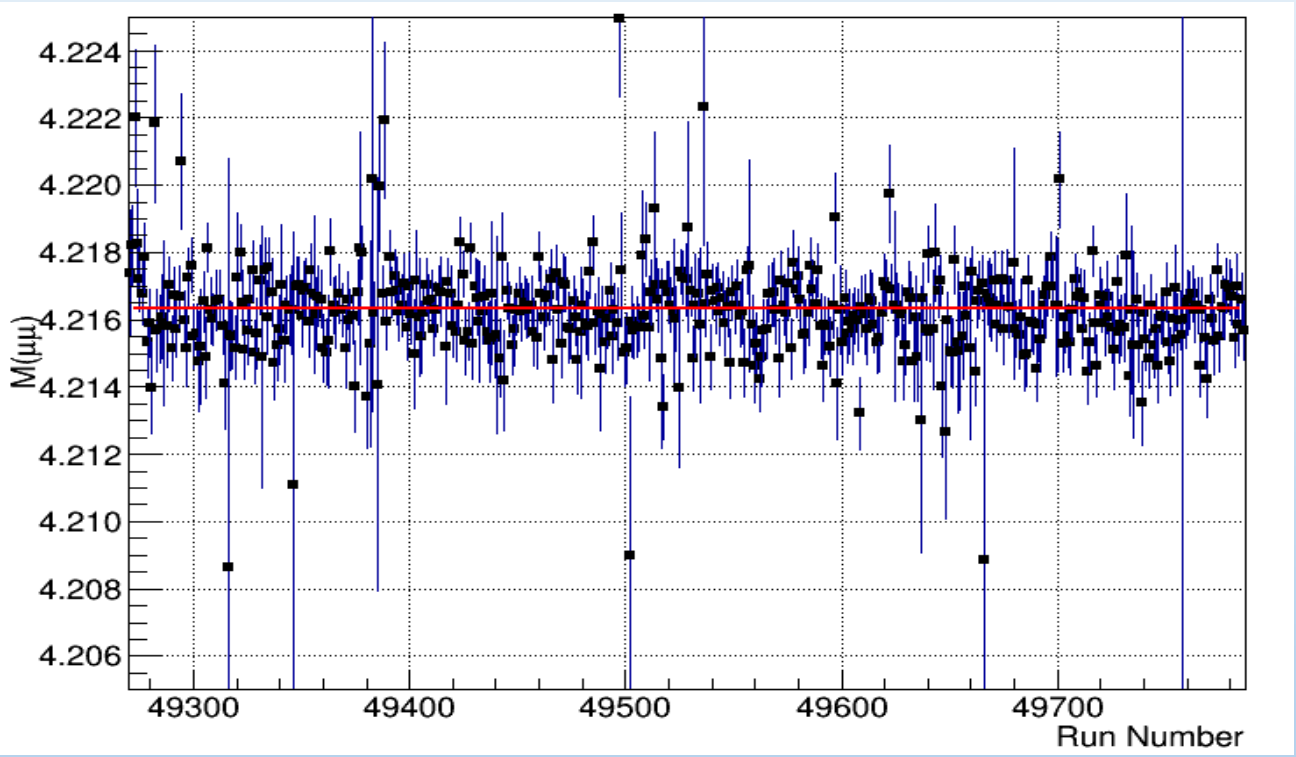
Range (48174, 49239)
Value: 4206.98 ± 0.05MeV

- The difference of momentum between $\mu^+$and μ^- in the center of mass system of 4210 data Run by Run



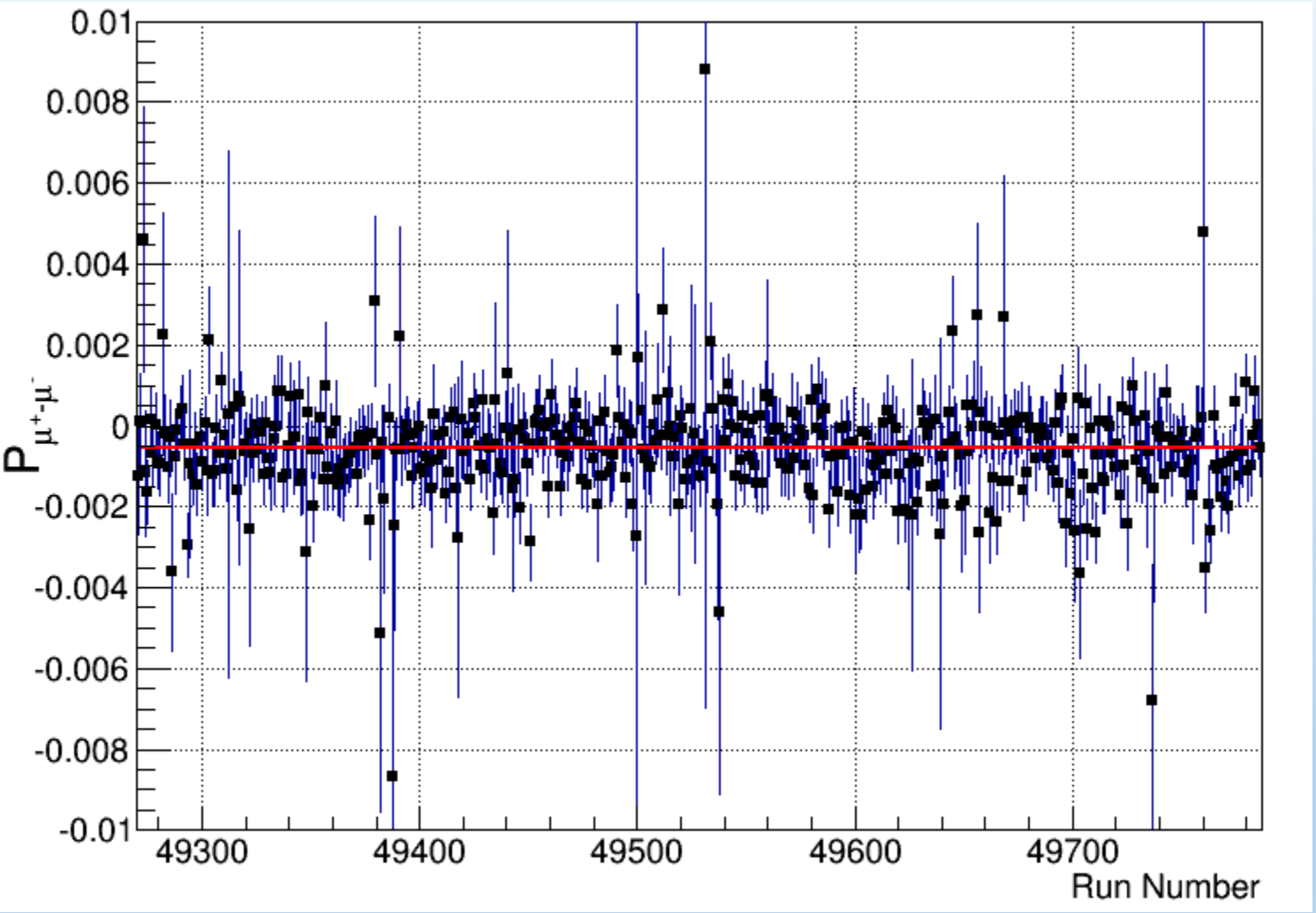
Value : -0.044 $\pm$0.004MeV

➢ M(μμ) of 4220 data Run by Run



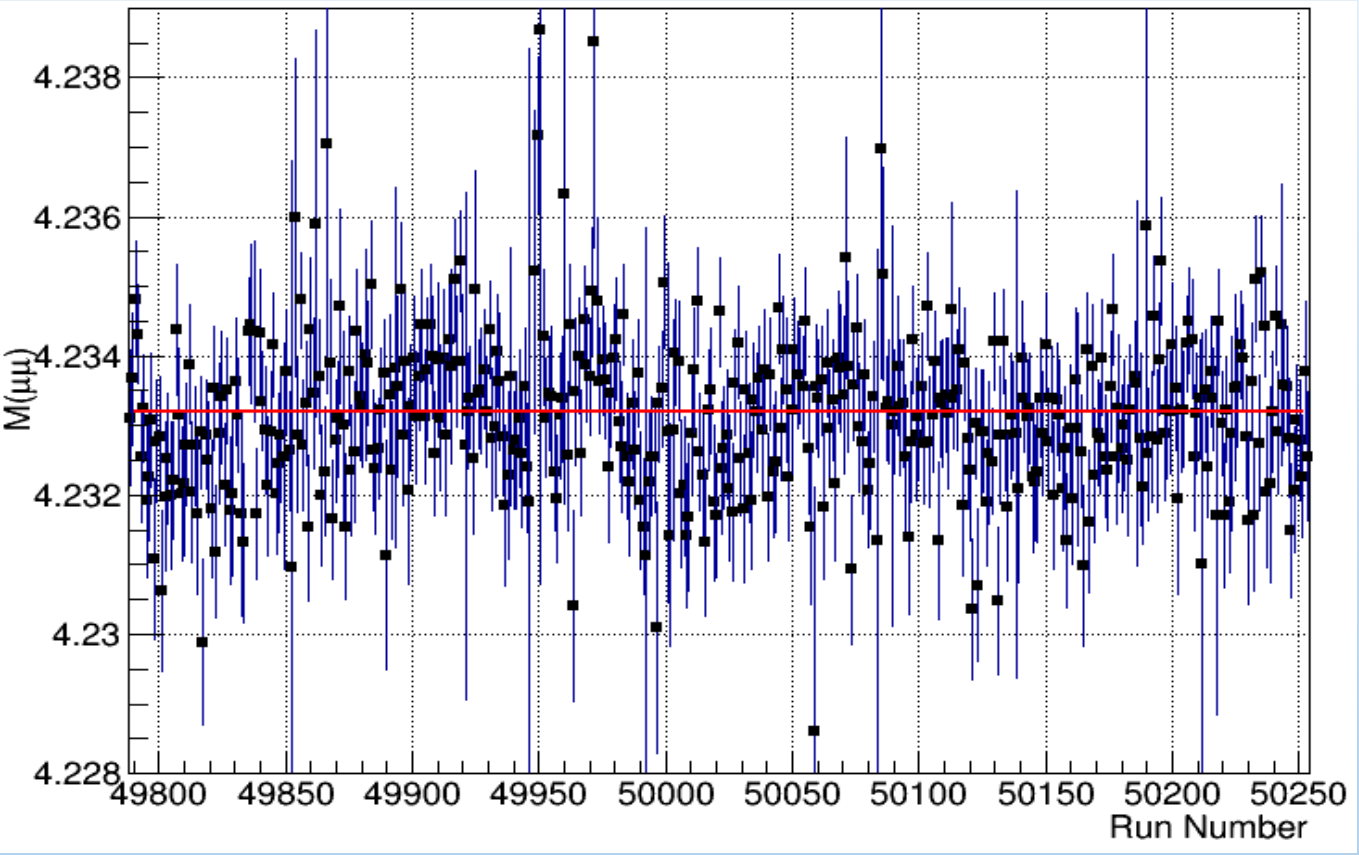
Value: 4216.33 ± 0.05(MeV)

- The difference of momentum between μ^+ and μ^- in the center of mass system of 4220 data Run by Run



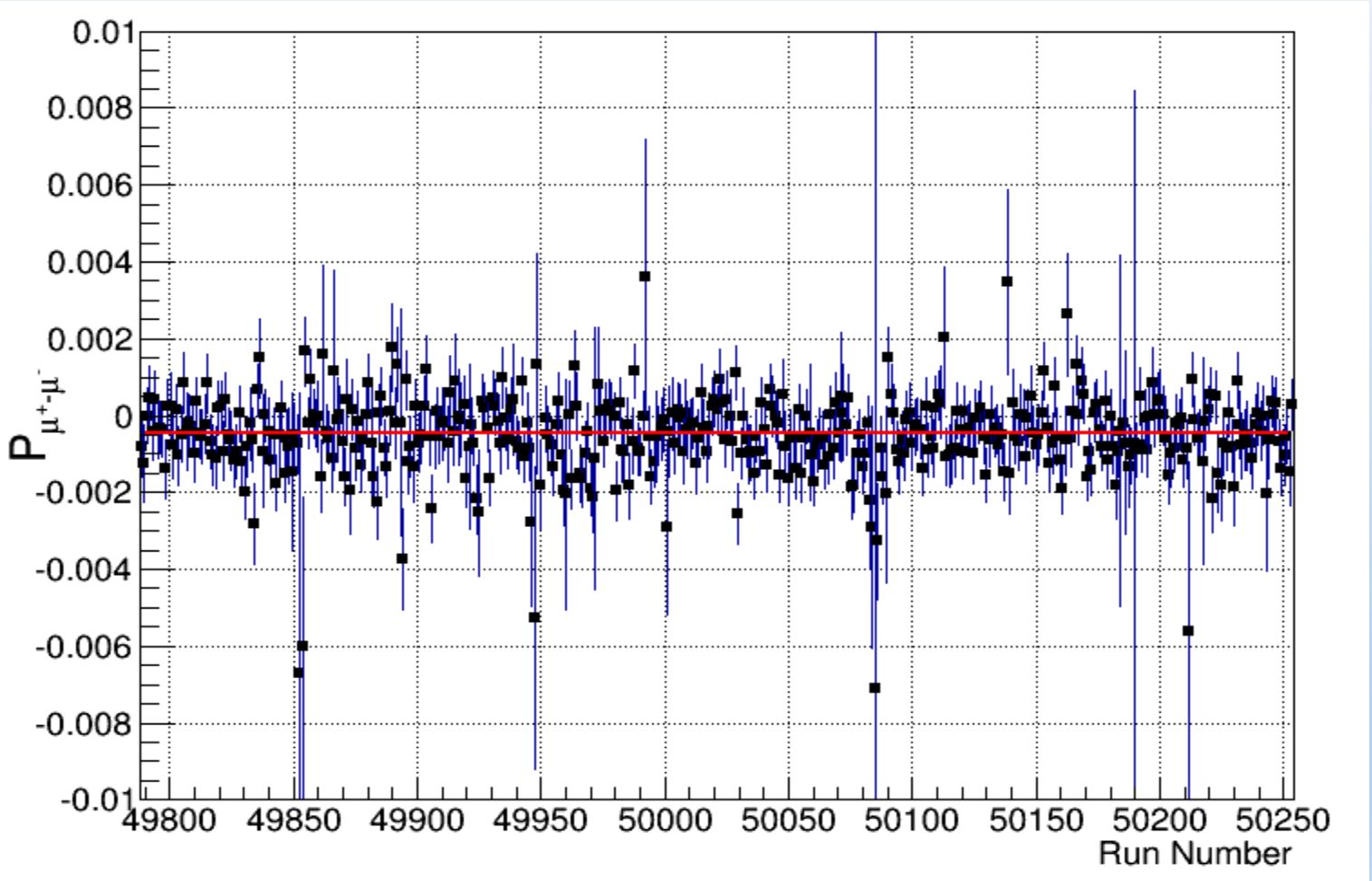
Value: -0.054 $\pm$ 0.004MeV

➢ M(μμ) of 4237 data Run by Run



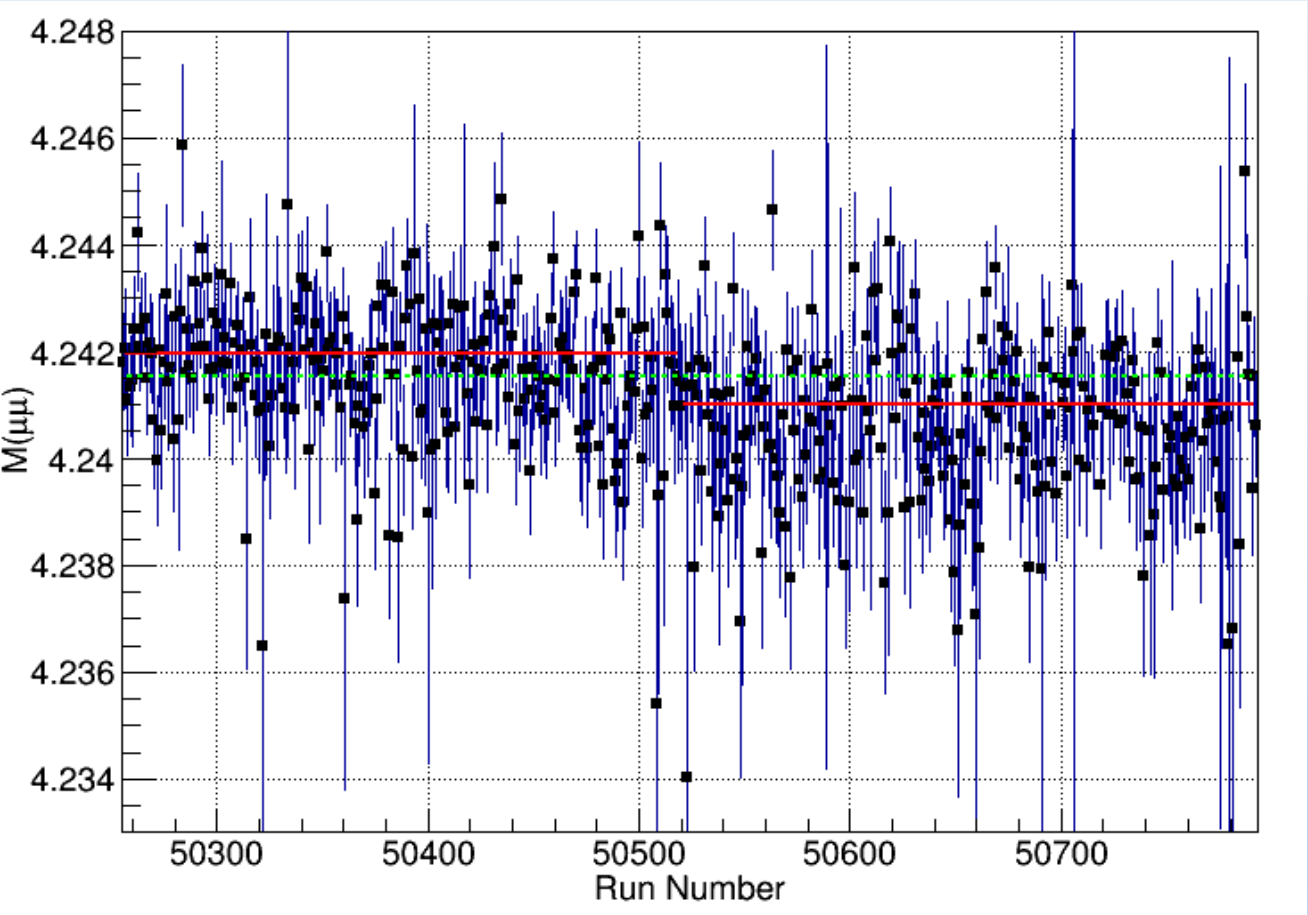
Value: 4233.21± 0.04(MeV)

- The difference of momentum between $\mu^+$and μ^- in the center of mass system of 4237 data Run by Run



Value: -0.044 ±0.004MeV

➢ M(μμ) of 4246 data Run by Run

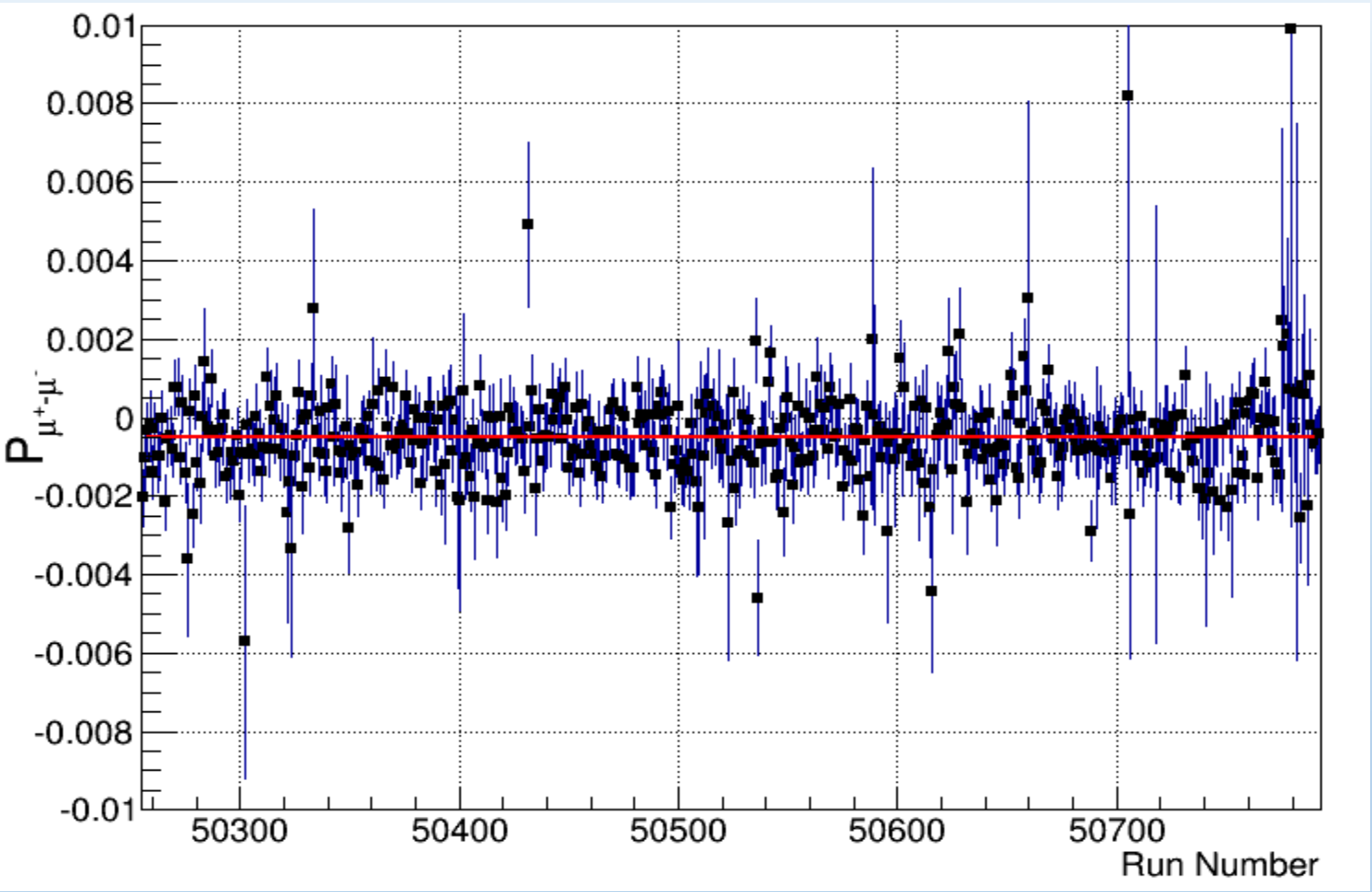


Range (50255,50793)
Value: 4241.95± 0.07MeV

Range (50255,50520)
Value: 4241.01 ± 0.08MeV

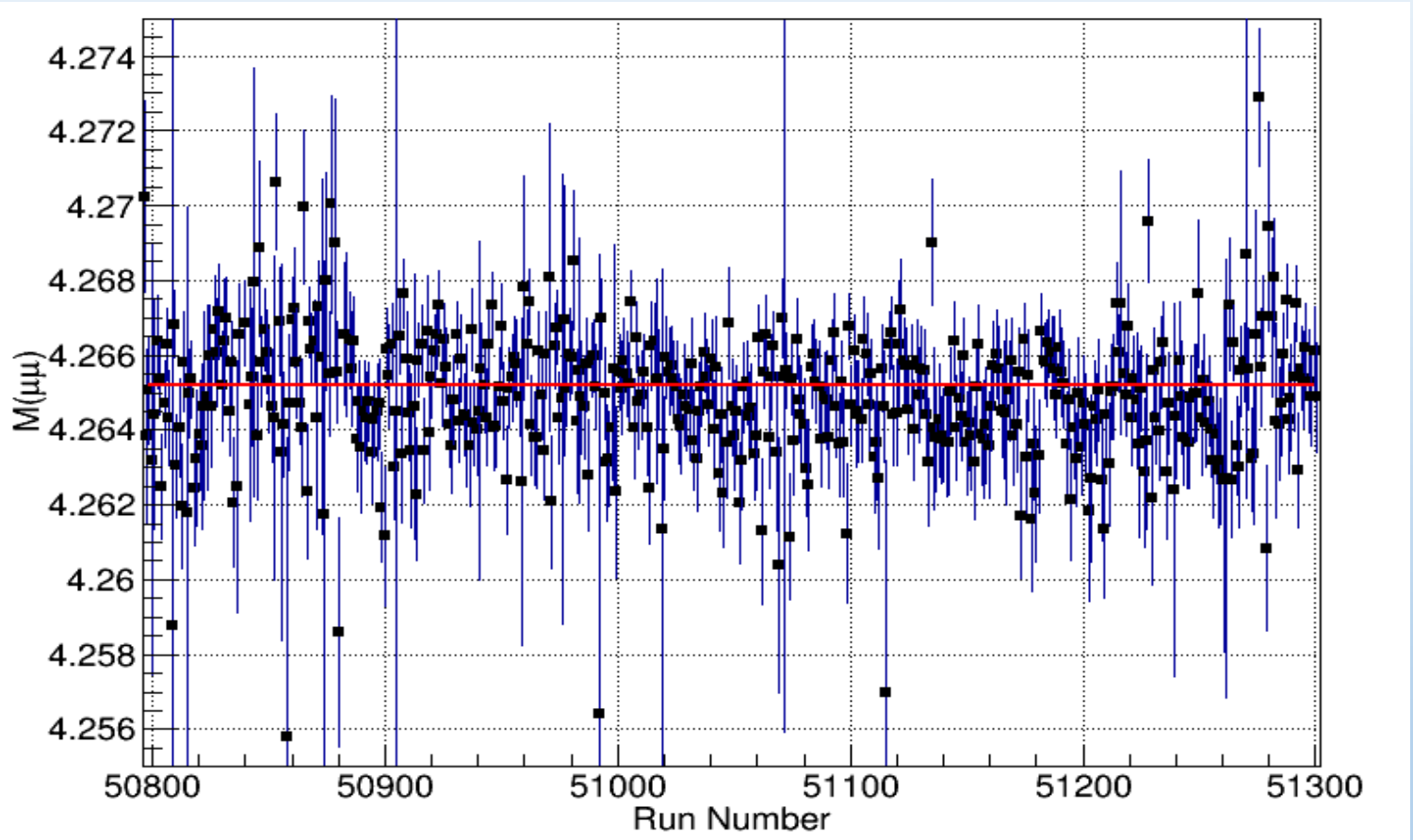
Range (50520,50793)
Value: 4241.55 ± 0.05MeV

- The difference of momentum between μ^+ and μ^- in the center of mass system of 4246 data Run by Run



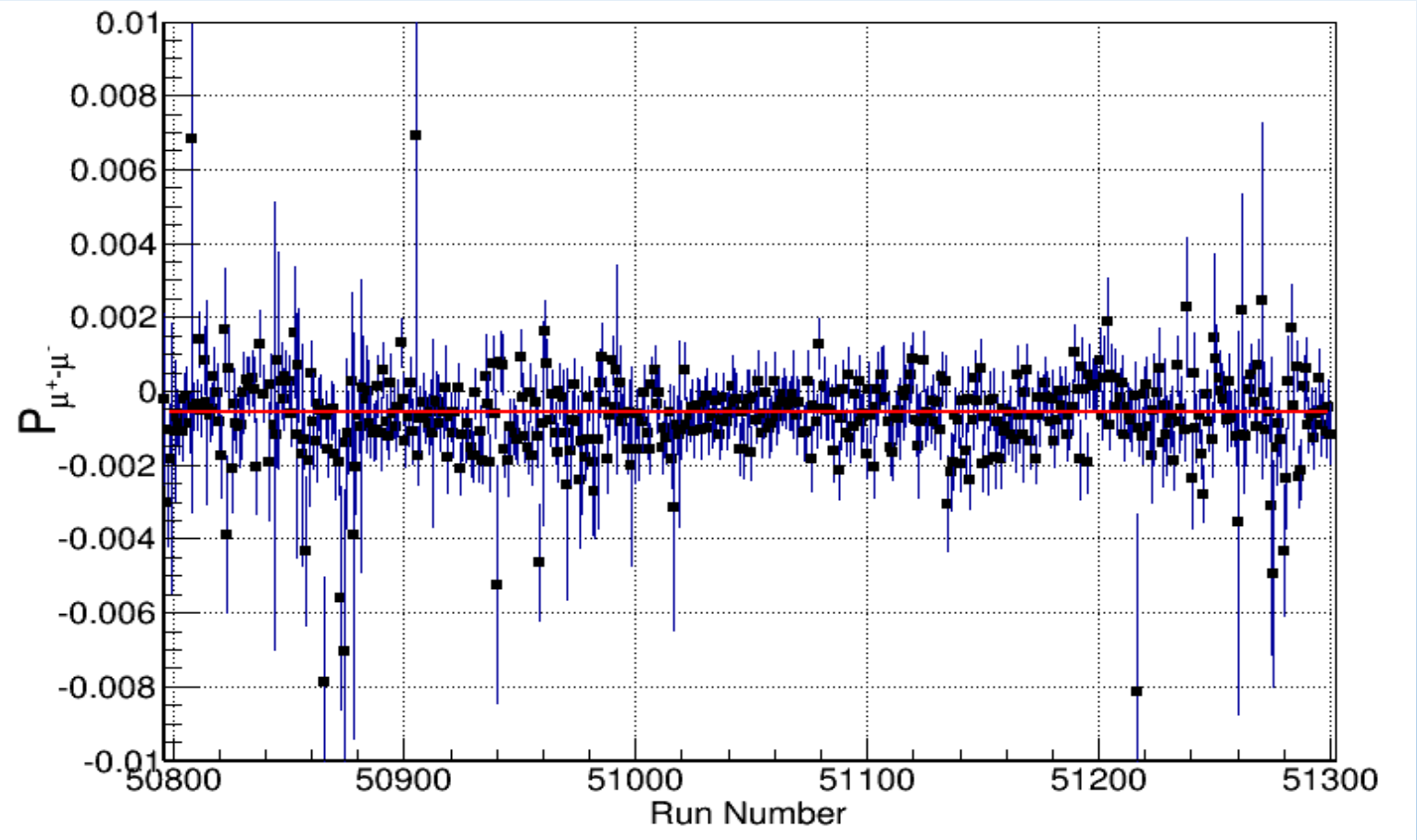
Value: -0.051 $\pm$ 0.004MeV

➢ M(μμ) of 4270 data Run by Run



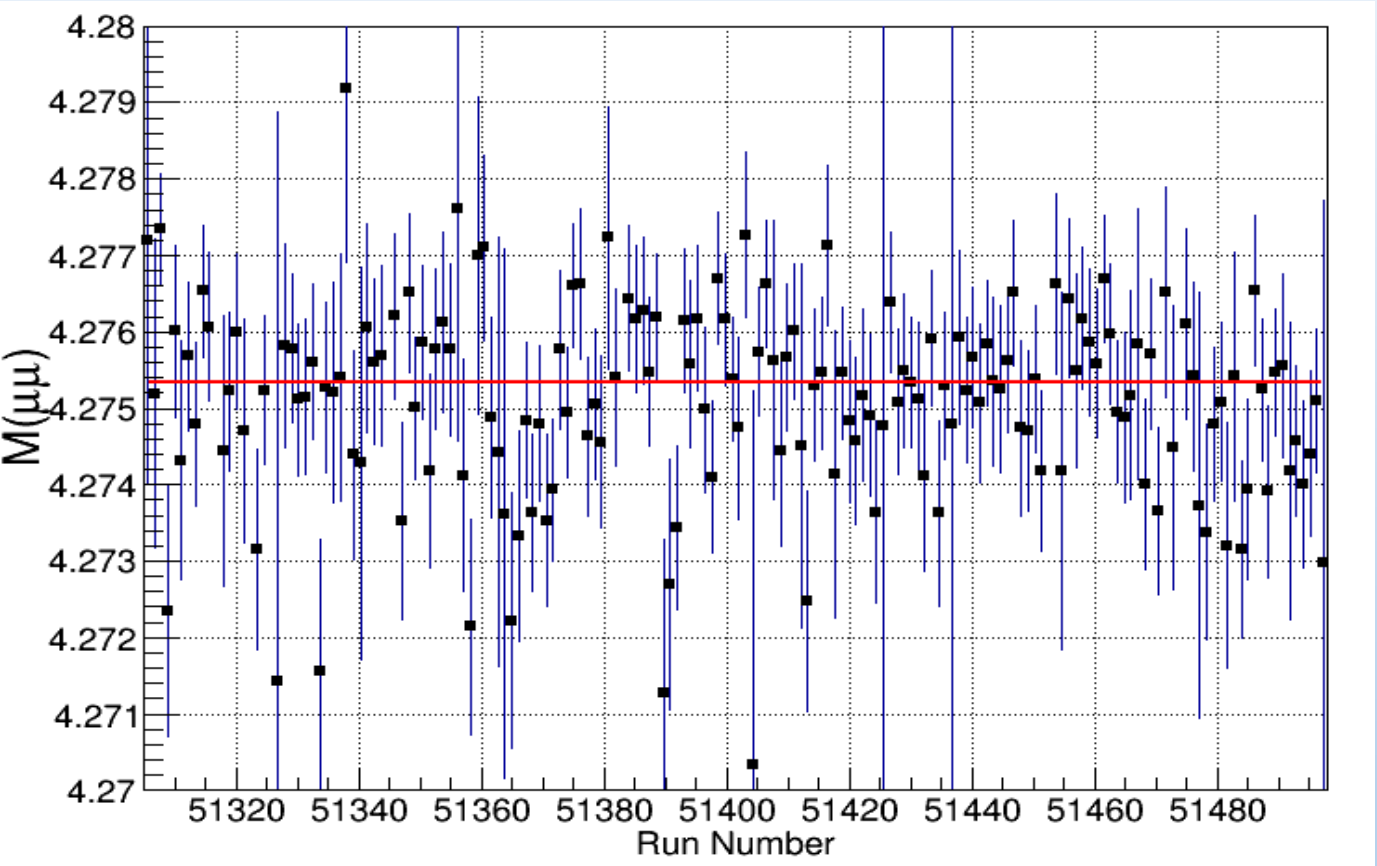
value: 4265.20 ± 0.06MeV

- The difference of momentum between $\mu^+$and μ^- in the center of mass system of 4270 data Run by Run



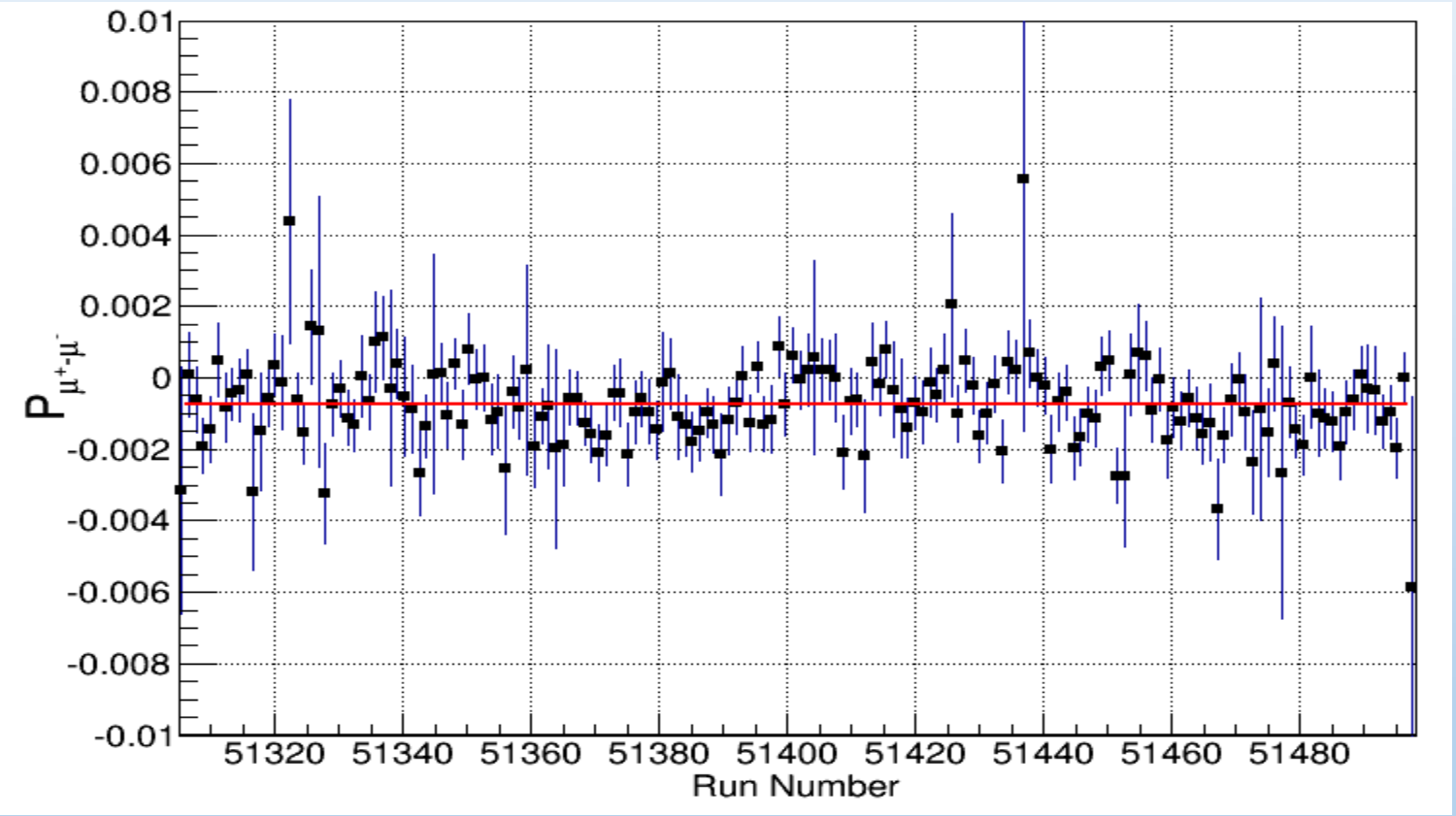
Value: -0.059 $\pm$ 0.004MeV

➢ M(μμ) of 4280 data Run by Run



Value: 4275.34 ± 0.09MeV

- The difference of momentum between $\mu^+$and μ^- in the center of mass system of 4280 data Run by Run



Value: -0.074± 0.007MeV

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(MeV)
4190		3.04±0.12	4187.26 ±0.06	
4200		3.03±0.12	4197.61 ± 0.06	
4210		2.98±0.12	4207.01 ±0.05	
4220		3.71±0.11	4216.21±0.05	
4237		3.78±0.12	4233.08±0.04	
4246		3.68±0.13	4241.28 ±0.05	
4270		3.76±0.14	4264.88 ±0.06	
4280		3.79±0.12	4275.15 ±0.09	

Thank you !!!