Run 15 pp J/ψ Multiplicity Analysis

PHENIX HI PWG Meeting

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Overview

- Implement the unbinned Roofit to extract the raw yield from the fits to the invariant mass of distribution of J/ψ
- Validation of the fitting results by doing toy studies
- Report the fit parameters including the J/ψ signal raw yield and mean peak invariant mass in a differential multiplicity binning
- The codes for J/ψ raw yield extraction can be found at github: https://github.com/MYOMAO/PHENIXJPsiAna

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Roofit Framework

New framework based on ROOT to fit on dataset based on the extended maximum likelihood dedicated for high energy and nuclear physics

- Reference: https://root.cern/manual/roofit/

Extended Unbinned Maximum Likelihood

$$\mathscr{L}(m_i, \vec{\lambda}) = \prod_{i=1}^{N_{obs}} \boxed{l(m_i)} \times \frac{e^{-N} N^{N_{obs}}}{N_{obs}!}$$

S is the parameter multiplied to the single peak chosen function

B is the parameter multiplied to the background chosen function

Model

Signal Peak

Background

Advantages:

- Improve fitting performance compared to the traditional binned
- Remove potential bias due to binning
- Used in CMS heavy flavor physics analysis

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Model for J/ψ Mass Fitting

Model Function for Roofit for Nominal Results

- **Signal**

Double crystal ball function with the same mean but different width, alpha, and N to model the tail in the low dimuon mass region:

$$CB(m_{J/\psi}; \alpha, n, \mu, \sigma) = N \exp(-(x-\mu)^2/2\sigma^2) \text{ and } F_s(x; \alpha, n, \mu, \sigma) = N\, A(B - (x-\mu)/\sigma)^{-n}$$

$$F_s = c\, CB_1 + (1 - c)\, CB_2$$

- **Background**

First order polynomial:

$$F_B(m_{J/\psi}) = ax + b$$

- The model will be directly applied to fit the J/ψ invariant mass in data

$$F(m_{J/\psi}) = S \cdot F_s + B \cdot F_B$$

To extract the signal raw yield S and background raw yield B

- **Systematics:**

Signal function: vary with double Gaussian and single crystal ball functions

Background function: vary with exponential decay and quadratic functions

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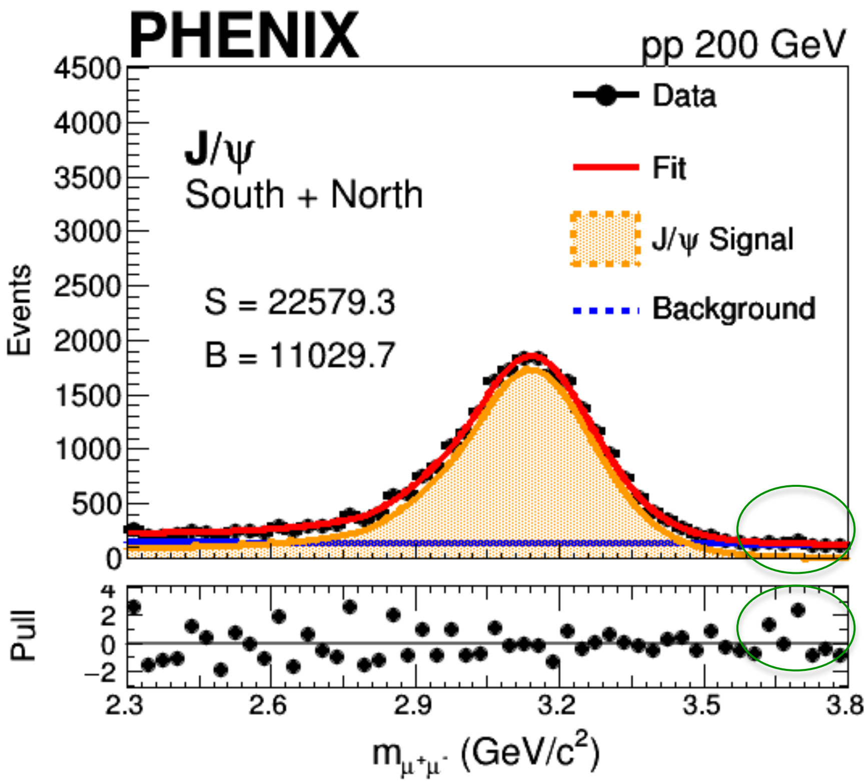
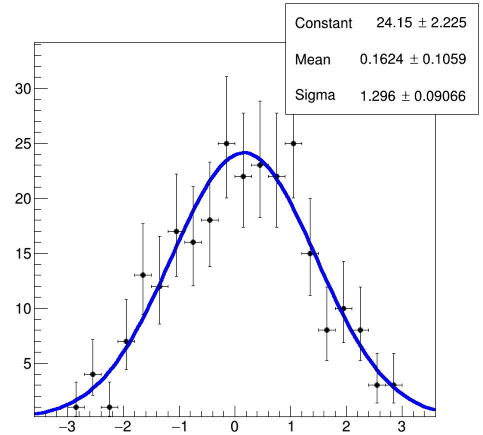
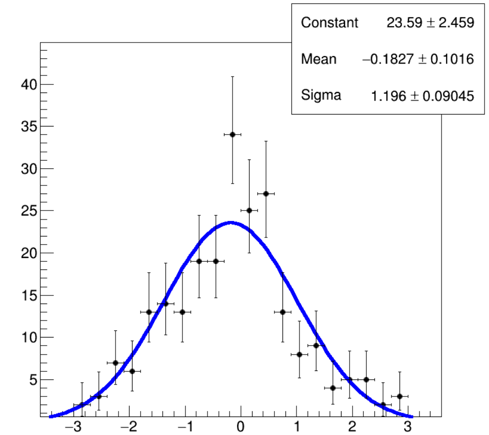
Fitting Performance for Inclusive Sample





J/ψ mean

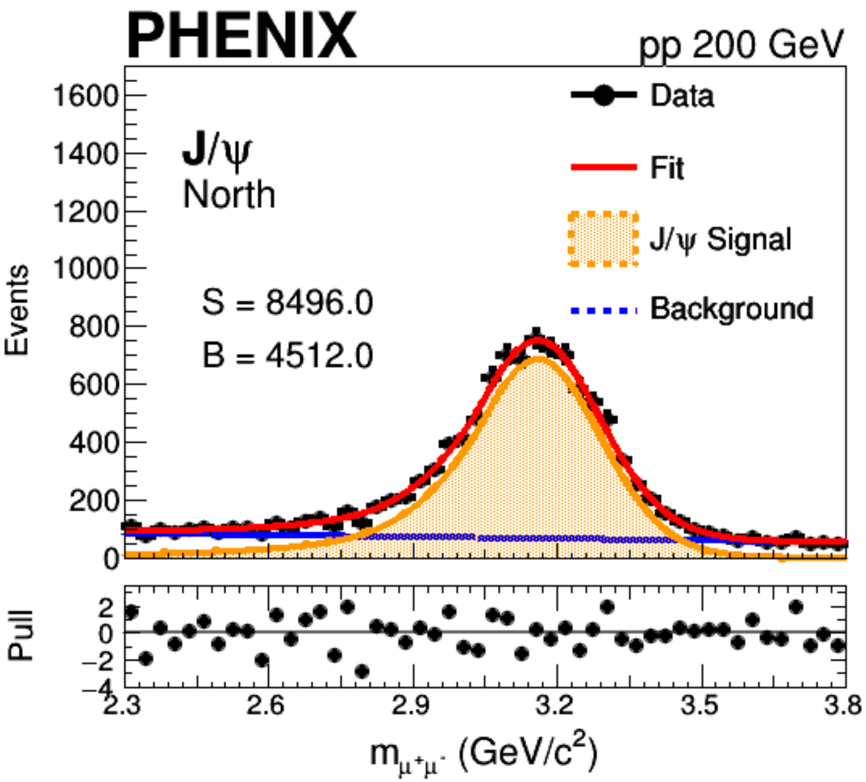


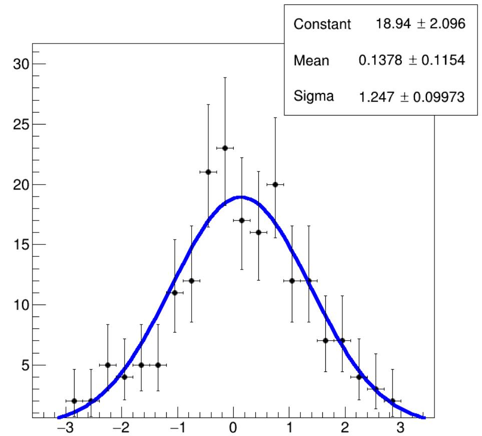
signal yield

Possible Ψ(2S) Signal

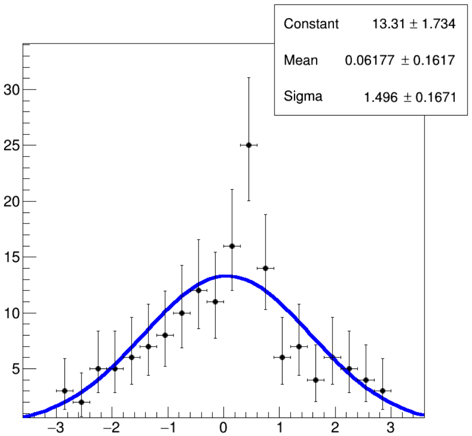
- The fits look good from a glance
- Unity pull (mean = 0 and width 1) for both signal yield and J/ψ mean -> good closure for fit -> validate the roofit model and fitting results

Fitting Performance Separated for North





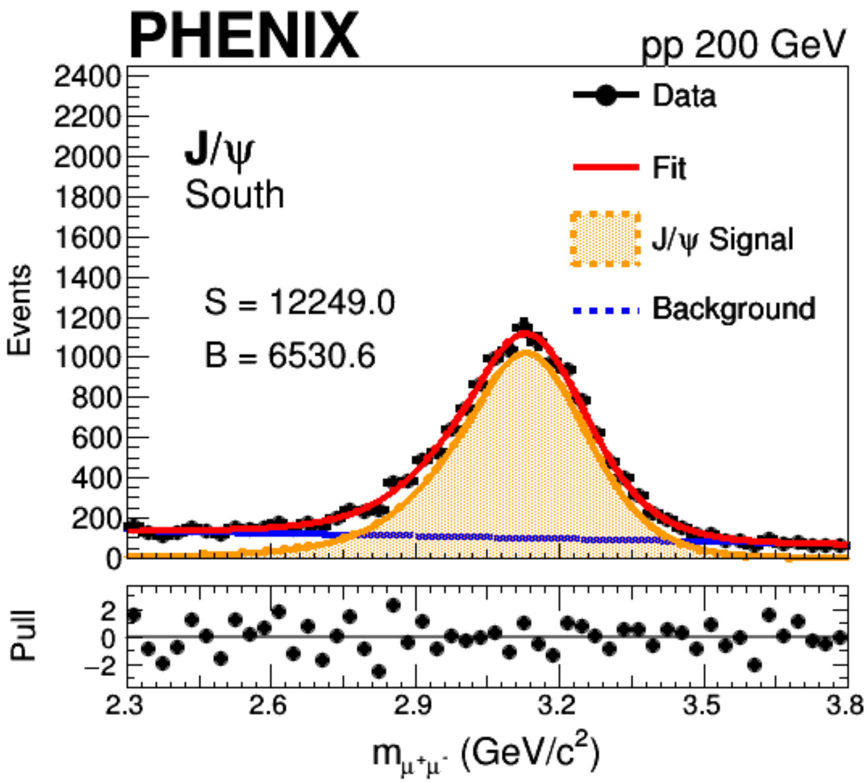
J/ψ mean

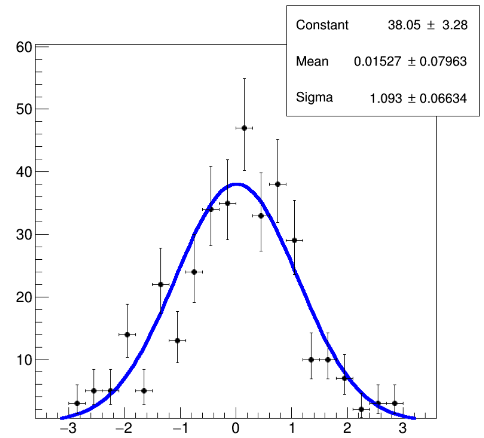


signal yield

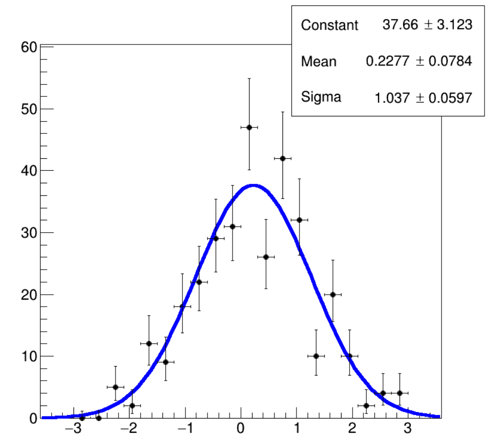
- Again, the fits look good from a glance
- Unity pull (mean = 0 and width 1) for both signal yield and J/ψ mean -> good closure for fit -> validate the roofit model and fitting results

Fitting Performance Separated for South





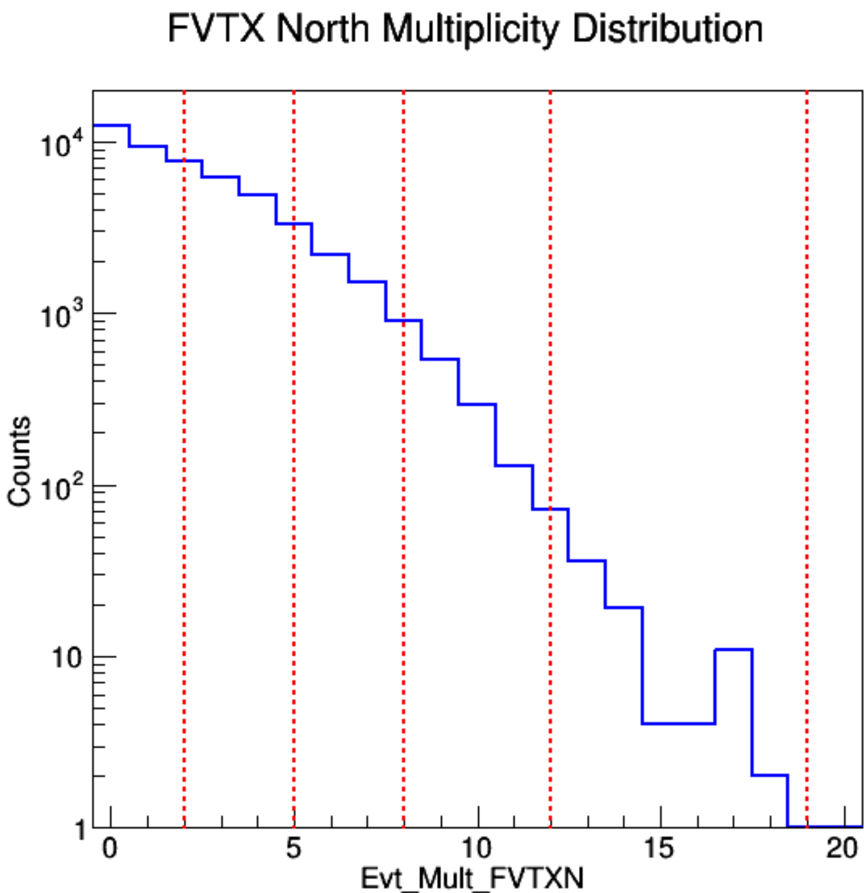
J/ψ mean

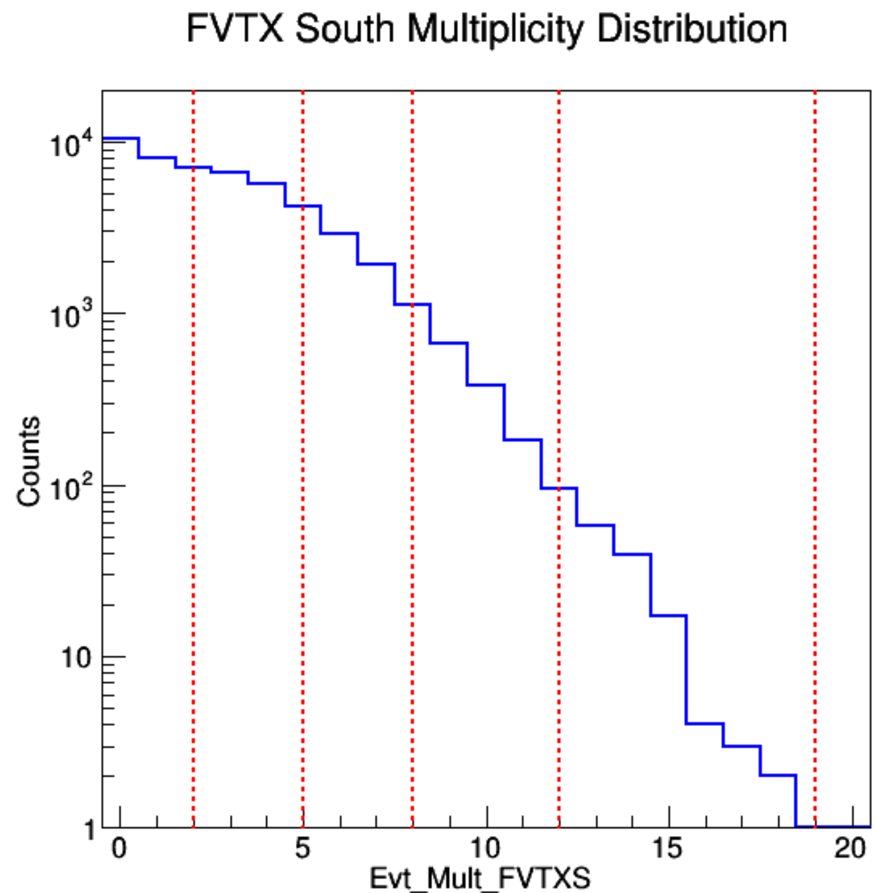


signal yield

- Again, good closure of the signal yield and J/ψ mean parameters
- In this case the signal raw yield of South and North do approximately add up compared to the inclusive case
  - South + North = 12249 + 8496= 20745
  - Inclusive = 22579

FVTX Event Multiplicity Distribution





- Total number of events:49320
- Based on the results, we decide to have a multiplicity binning of [0,2,5,8,12,18]

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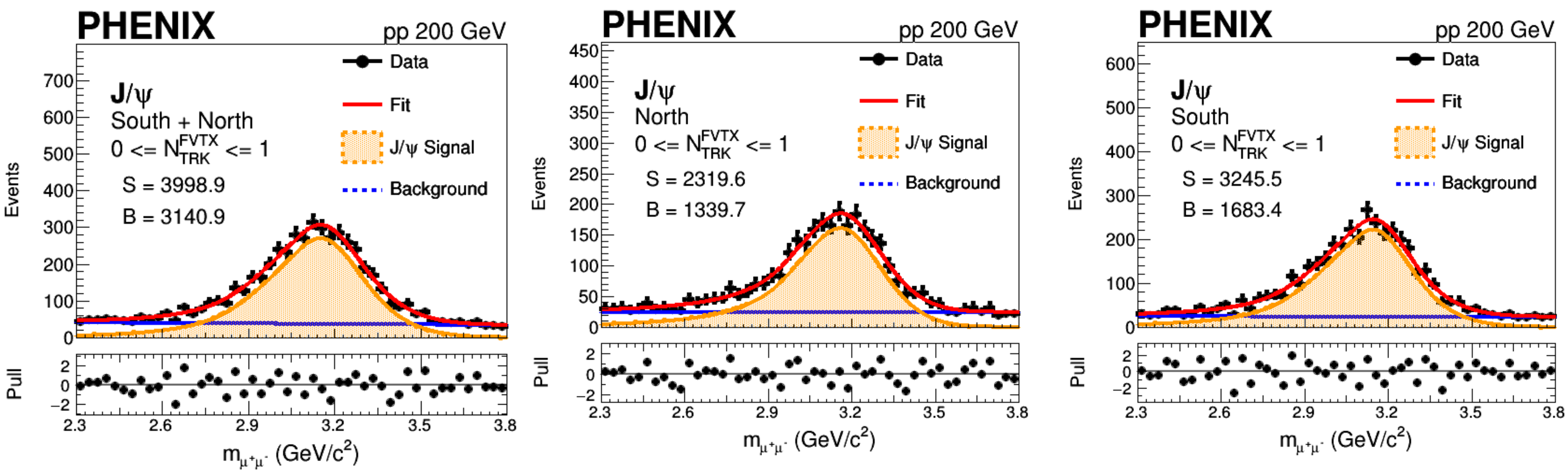
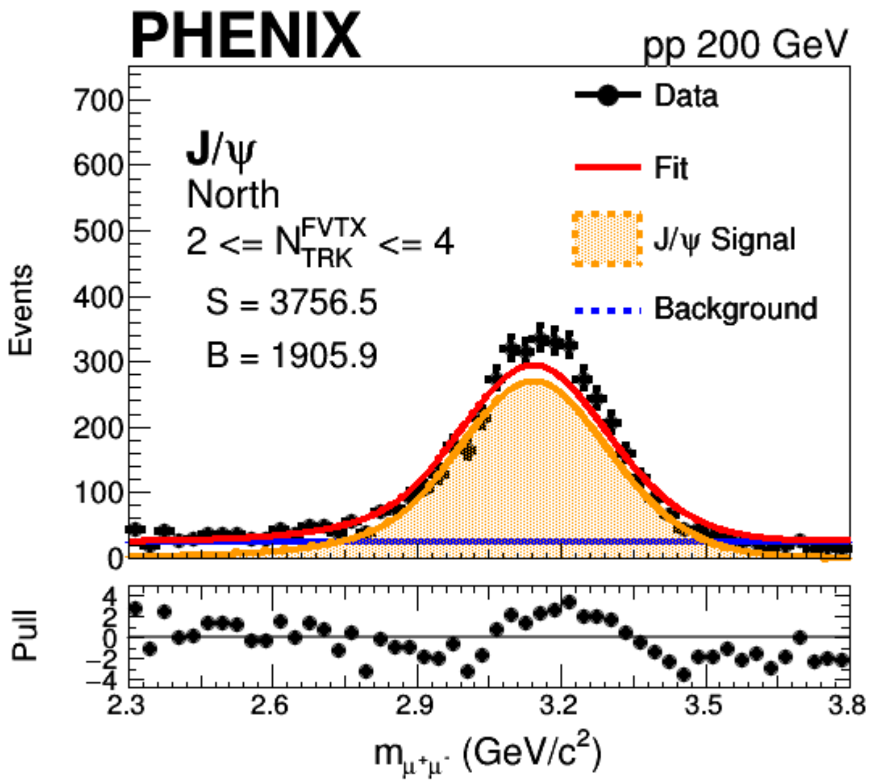
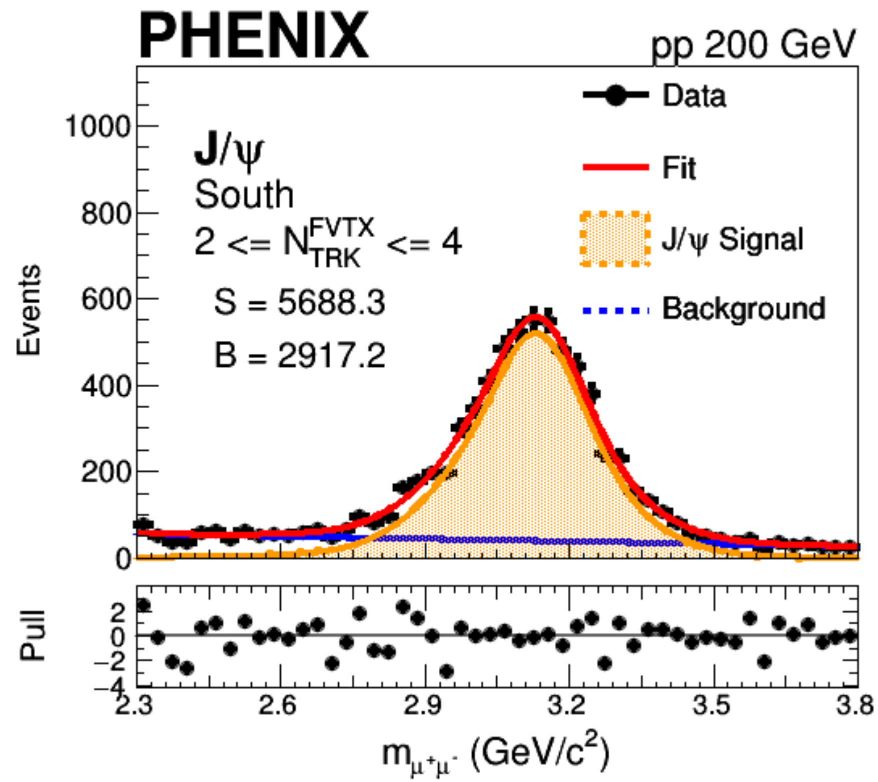
Fitting Performance for Multiplicity [0,2)



- The fits all look great
- Here the signal region is defined as J/ψ PDG mass ± 0.4 GeV/c^2
- S and B are obtained from the fit parameters and integrating the F_s and F_B over the signal region
- The event multiplicitySouth + North = FVTX_N + FVTX_S
- The event multiplicity for North = FVTX_N
- The event multiplicity for South = FVTX_S
- In this case they do not add up because of the multiplicity cut

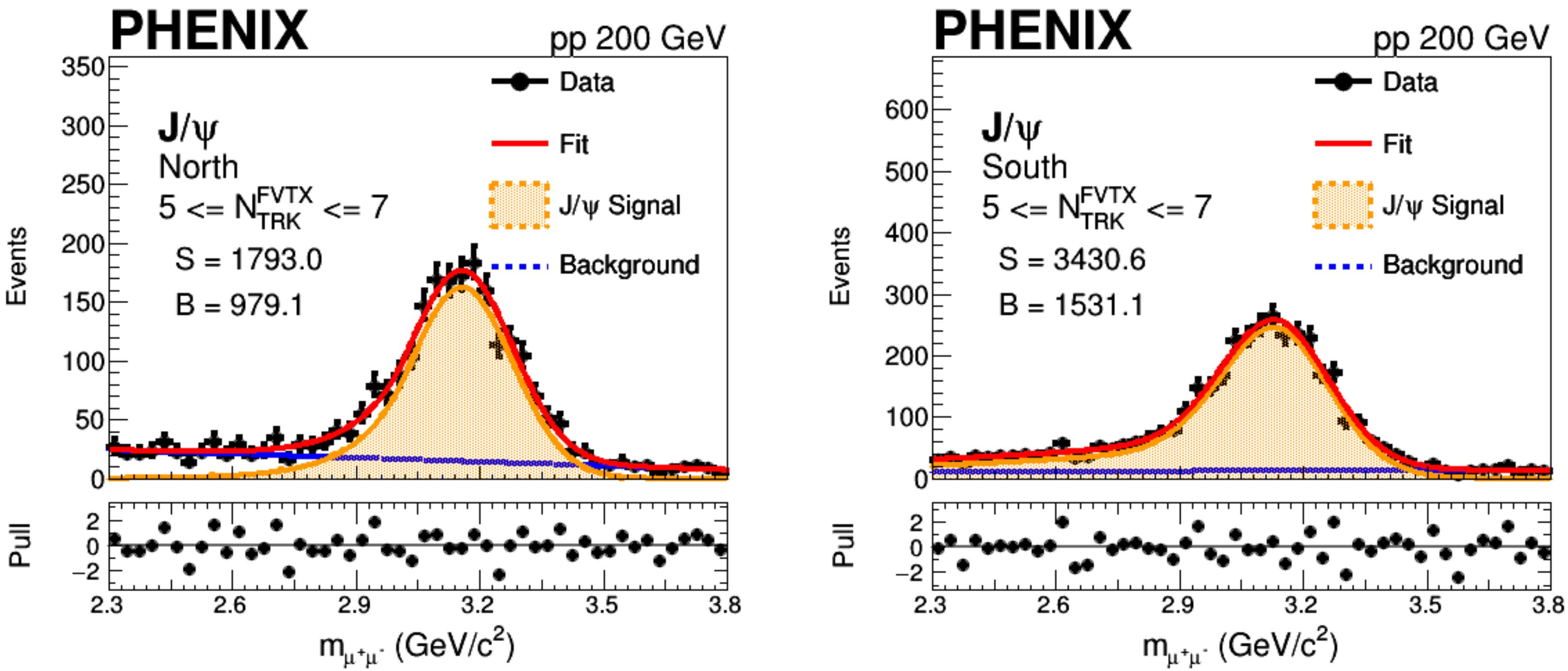
Fitting Performance for Multiplicity [2,5)





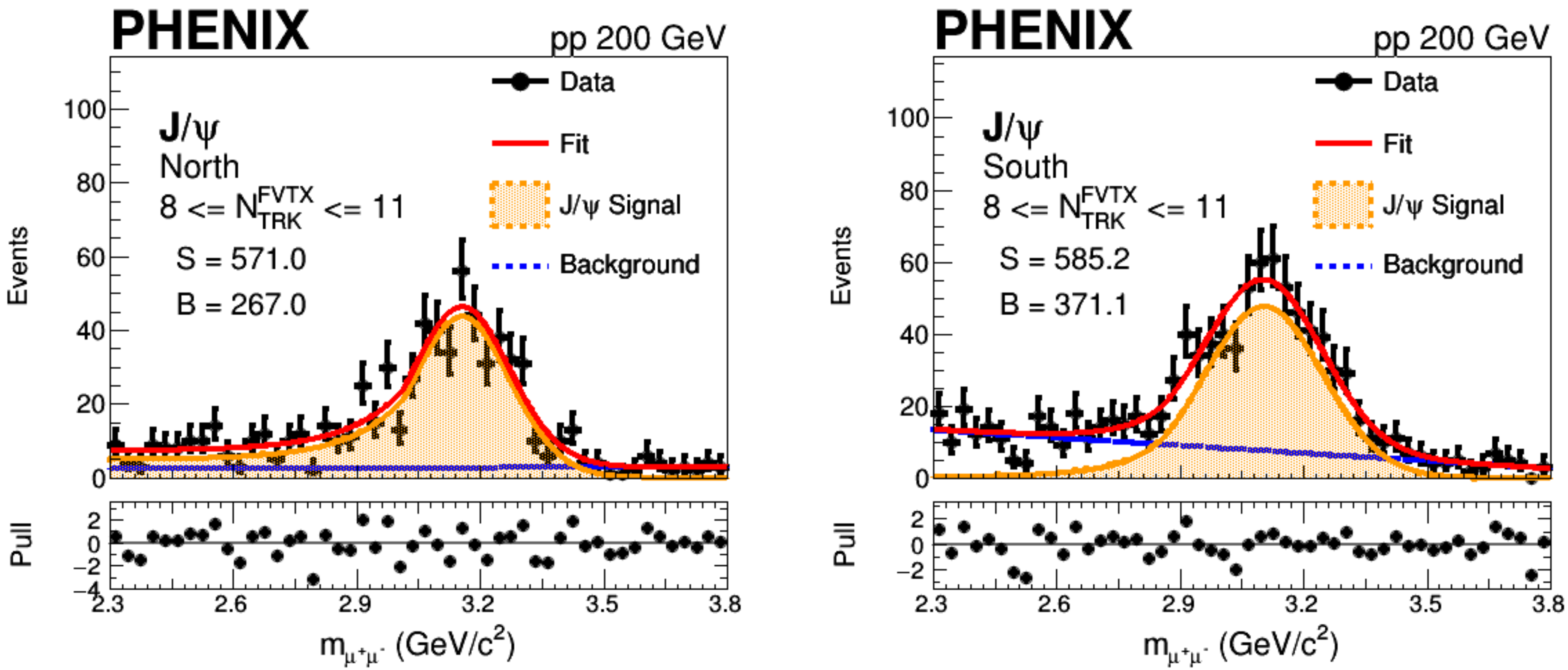
- Again, the fits look great

Fitting Performance for Multiplicity [5,8)



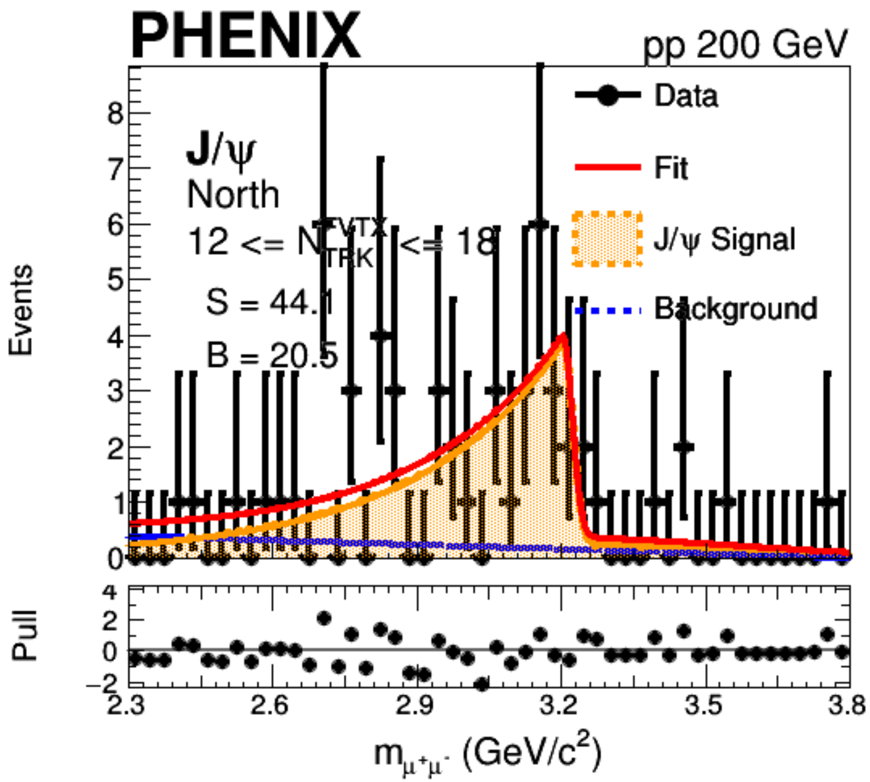
- Again, the fits look great

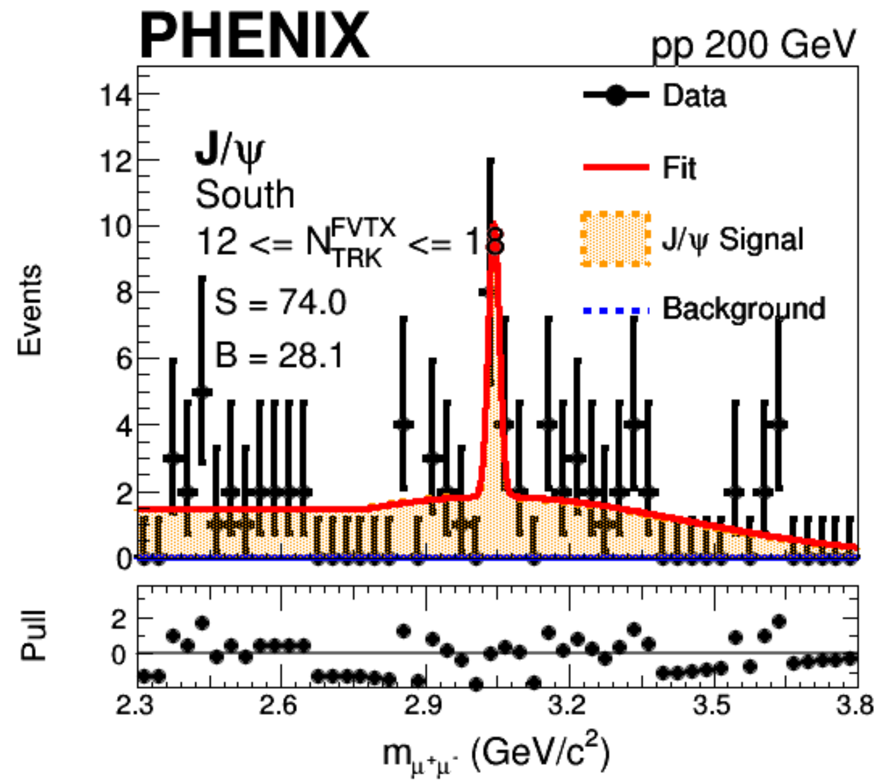
Fitting Performance for Multiplicity [8,12)



- Again, the fits look great

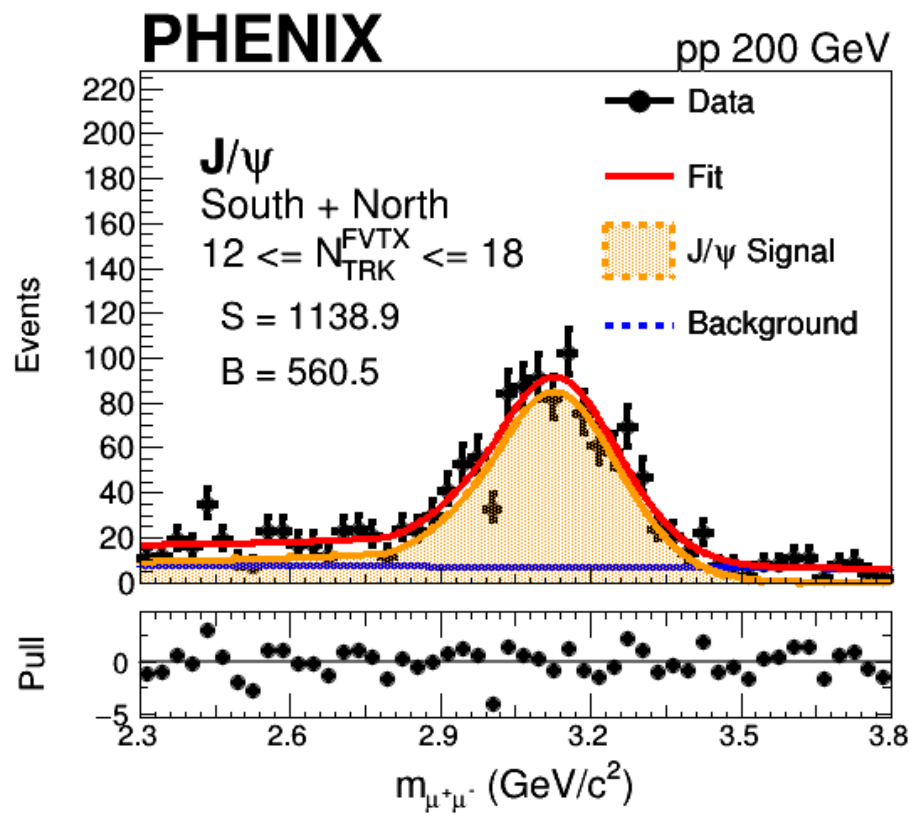
Fitting Performance for Multiplicity [12,19)





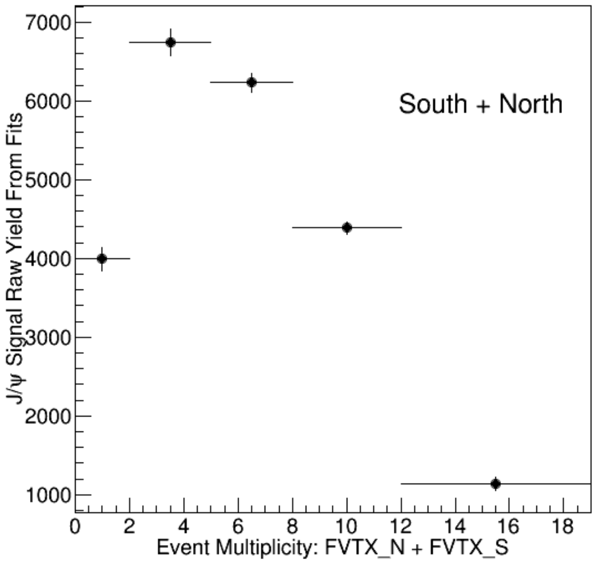
- Marginal signal is observed at this multiplicity bin – very low statistics for either FVTX North or South with >= 12 tracks

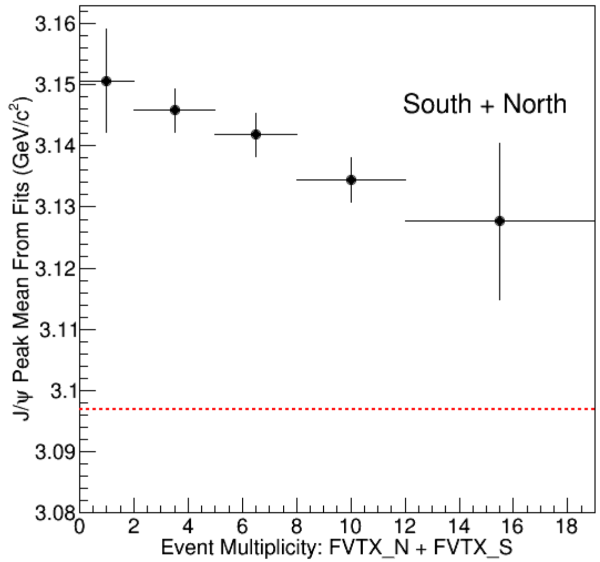
Inclusive Multiplicity at [12,19)

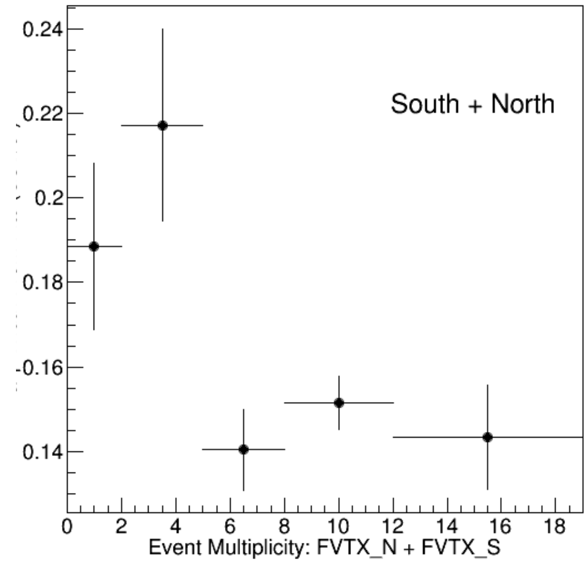


- The fits look great
- We can see clear signal event at the highest multiplicity bin up to about 18 for 12 <= FVTX_N + FVTX_S <= 18

J/ψ Fit Parameters - Inclusive

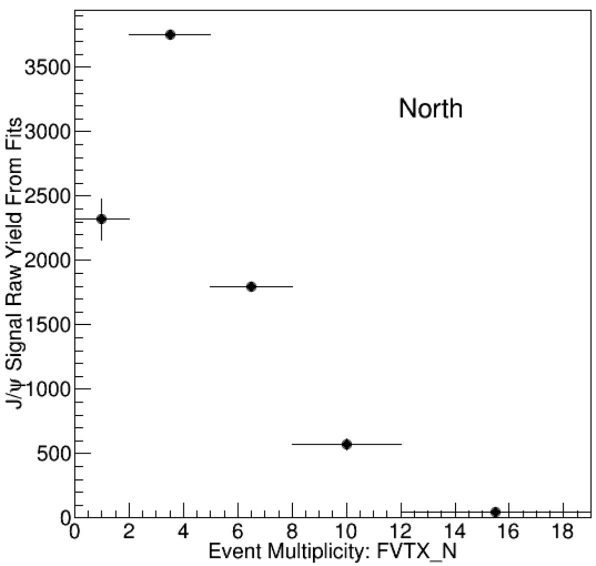


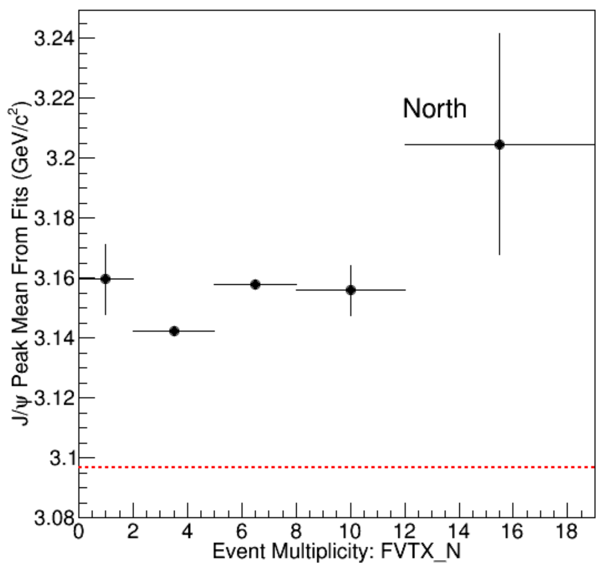


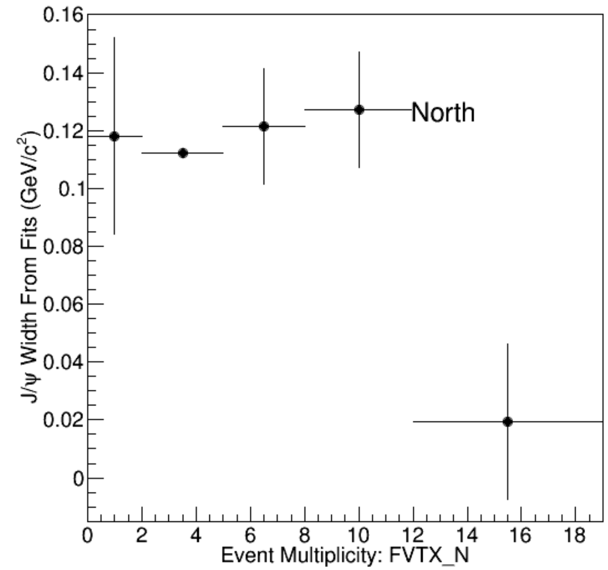


- The value of J/ψ mean peak of the combined FVTX North and South is stable within about 20 MeV/c^2, ranging from 3.13 GeV/c^2 to 3.15 GeV/c^2, close to but systematically above the J/ψ mass: 3.096 GeV/c^2 from PDG
- The width varies rom 0.14 to 0.22 GeV/c^2, which is about the expected mass resolution of J/ψ 0.15 GeV/c^2

J/ψ Fit Parameters - North

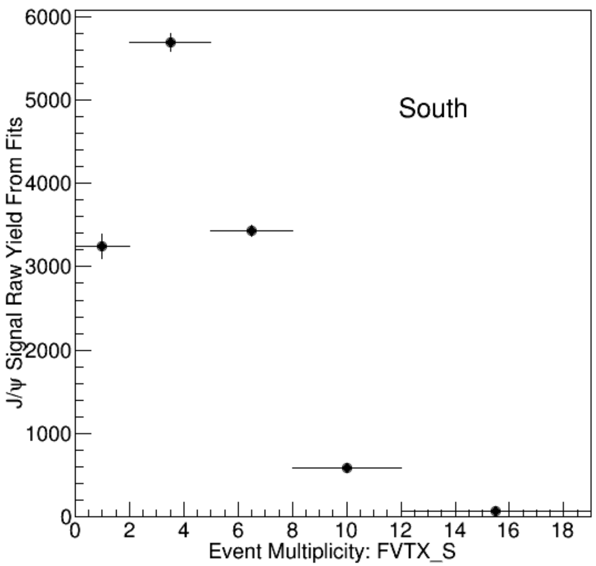


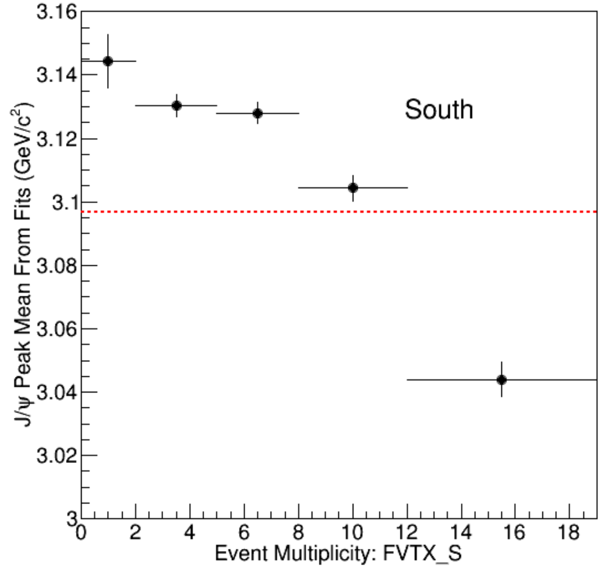


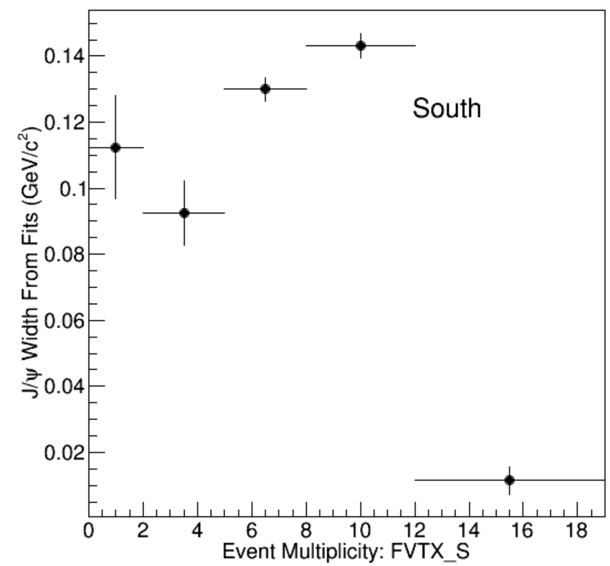


- The value of J/ψ mean peak from the FVTX North is stable within about 60 MeV/c^2, ranging from 3.14 GeV/c^2 to 3.20 GeV/c^2, close to but systematically above the J/ψ mass: 3.096 GeV/c^2 from PDG. However, the highest multiplicity bin deviates a lot from other bins due to the poor statistics
- The width varies rom 0.11 to 0.13 GeV/c^2 (excluding the 0.02 GeV/c^2 due to the poor fit at the highest multiplicity bin), which is about the expected mass resolution of J/ψ 0.15 GeV/c^2
- No significant multiplicity dependence on the J/ψ signal width

J/ψ Fit Parameters - South







- The value of J/ψ mean peak from the FVTX South is stable within about 100 MeV/c^2, ranging from 3.14 GeV/c^2 to 3.04 GeV/c^2, close to the J/ψ mass: 3.096 GeV/c^2 from PDG. However, the highest multiplicity bin deviates a lot from other bins due to the poor statistics
- The width varies rom 0.09 to 0.14 GeV/c^2 (excluding the 0.01 GeV/c^2 due to the poor fit at the highest multiplicity bin), which is about the expected mass resolution of J/ψ 0.15 GeV/c^2
- No significant multiplicity dependence on the J/ψ signal width

To Do List

- Optimize our fitting results with the best mass window
- Complete the systematic studies and estimate the systematic uncertainties of the J/ψ signal raw yield extraction
- Complete the studies to estimate the trigger efficiency ratios
- Present our final results in abscissae manners rather than a bin format (bin center) for the x-axis (asymmetric X center for the multiplicity in the x-axis)
- Produce the preliminary results for J/ψ corrected yield ratio as a function of event multiplicity
- Complete the documentation and prepare for the presentation in QM 2022