LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

Hidden charm in the COMPASS experiment at CERN

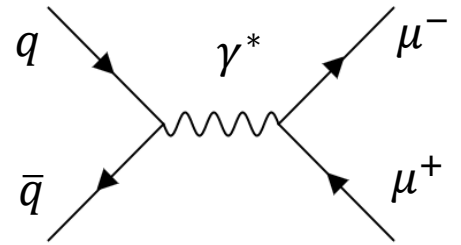
LIP

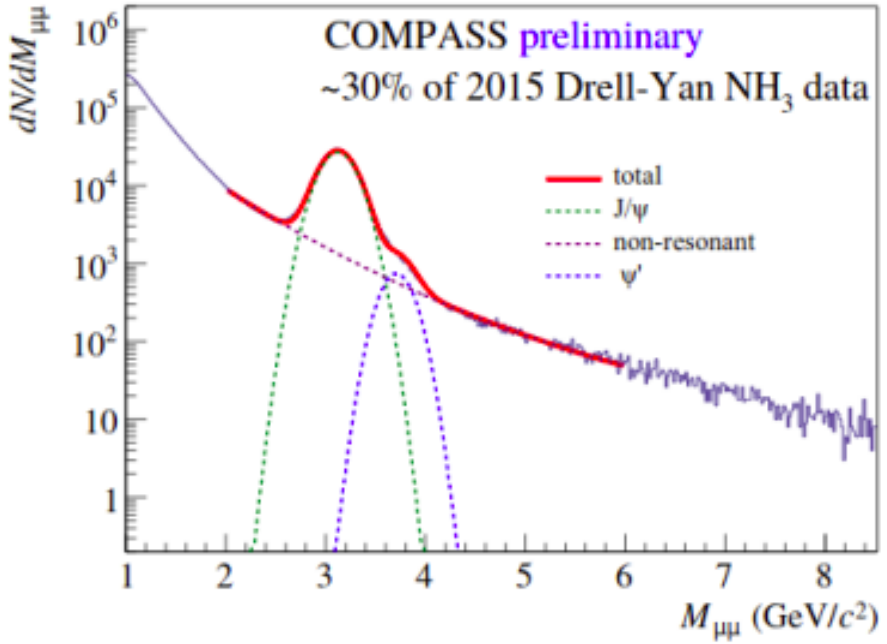
Bárbara Lopes Pereira

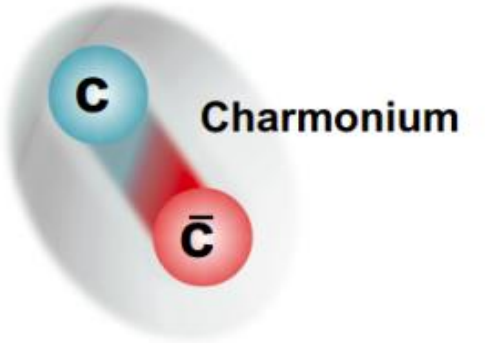
Supervisor: Catarina Quintans

The Hidden Charm

Drell-Yan







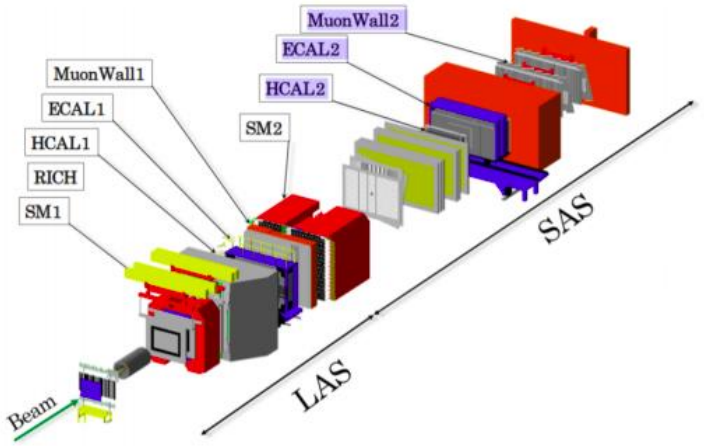
$M_{J/\psi} = 3{,}098$ GeV

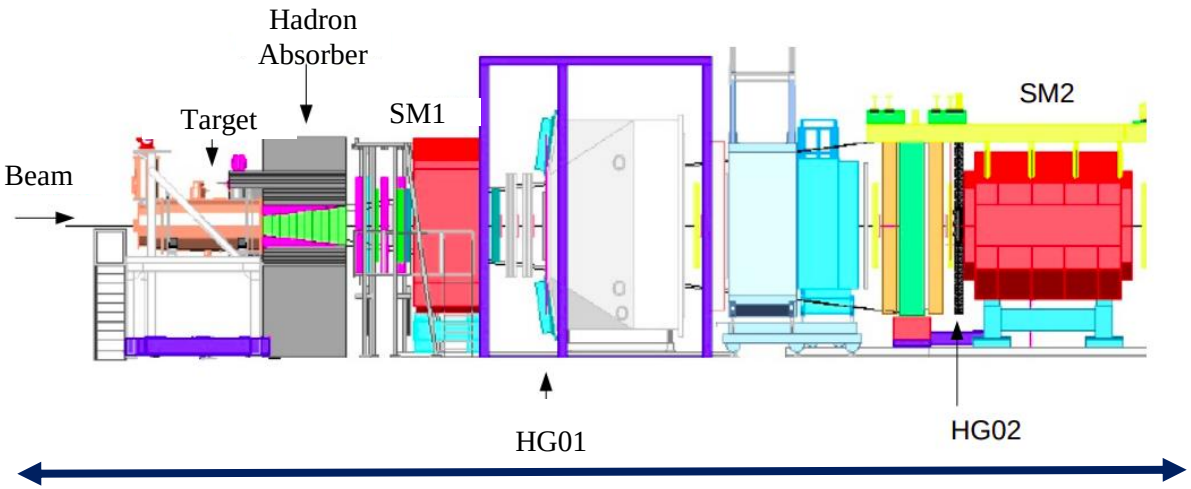
$M_{\psi'} = 3{,}686$ GeV

J/ψ production mechanism

- $gluon - gluon\ fusion$
- $q - \bar{q}\ annihilation$

COMPASS Experiment: Drell-Yan Data Taking 2018



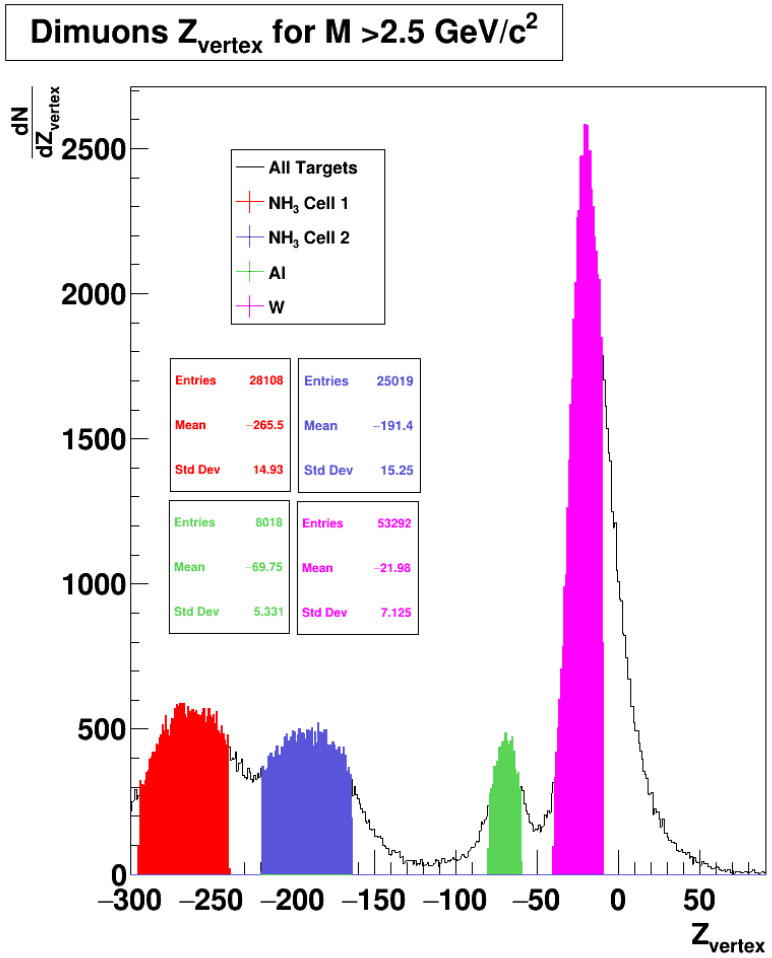


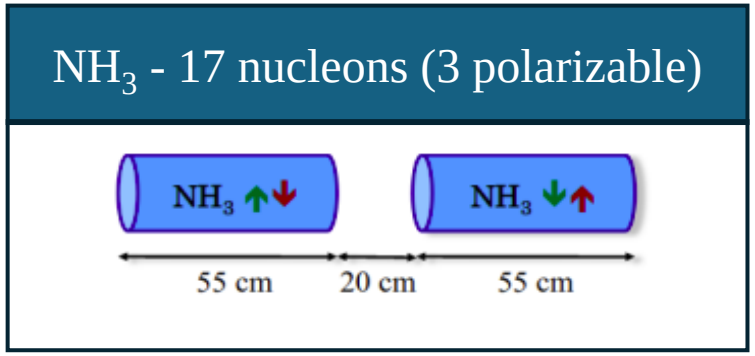
Dimuon Trigger Systems
Outer(SAS) and LAS
LAS and LAS

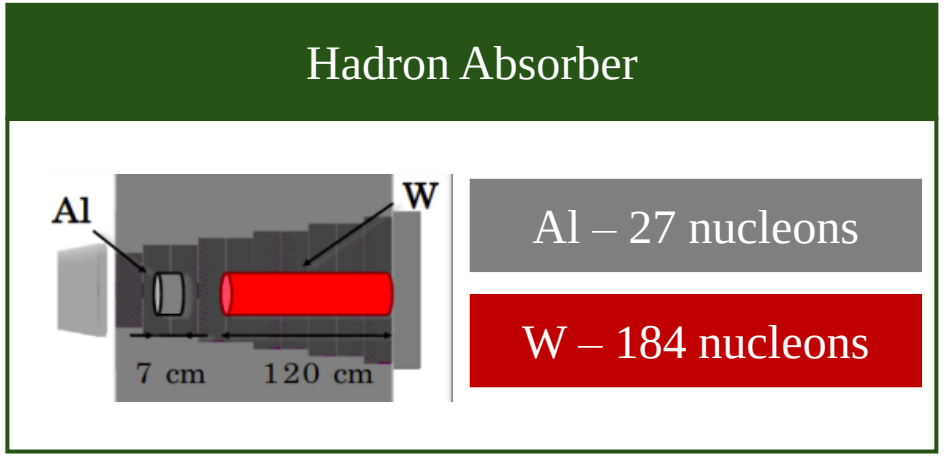
Large Angle Spectrometer
$20\ mrad < \theta < 80\ mrad$

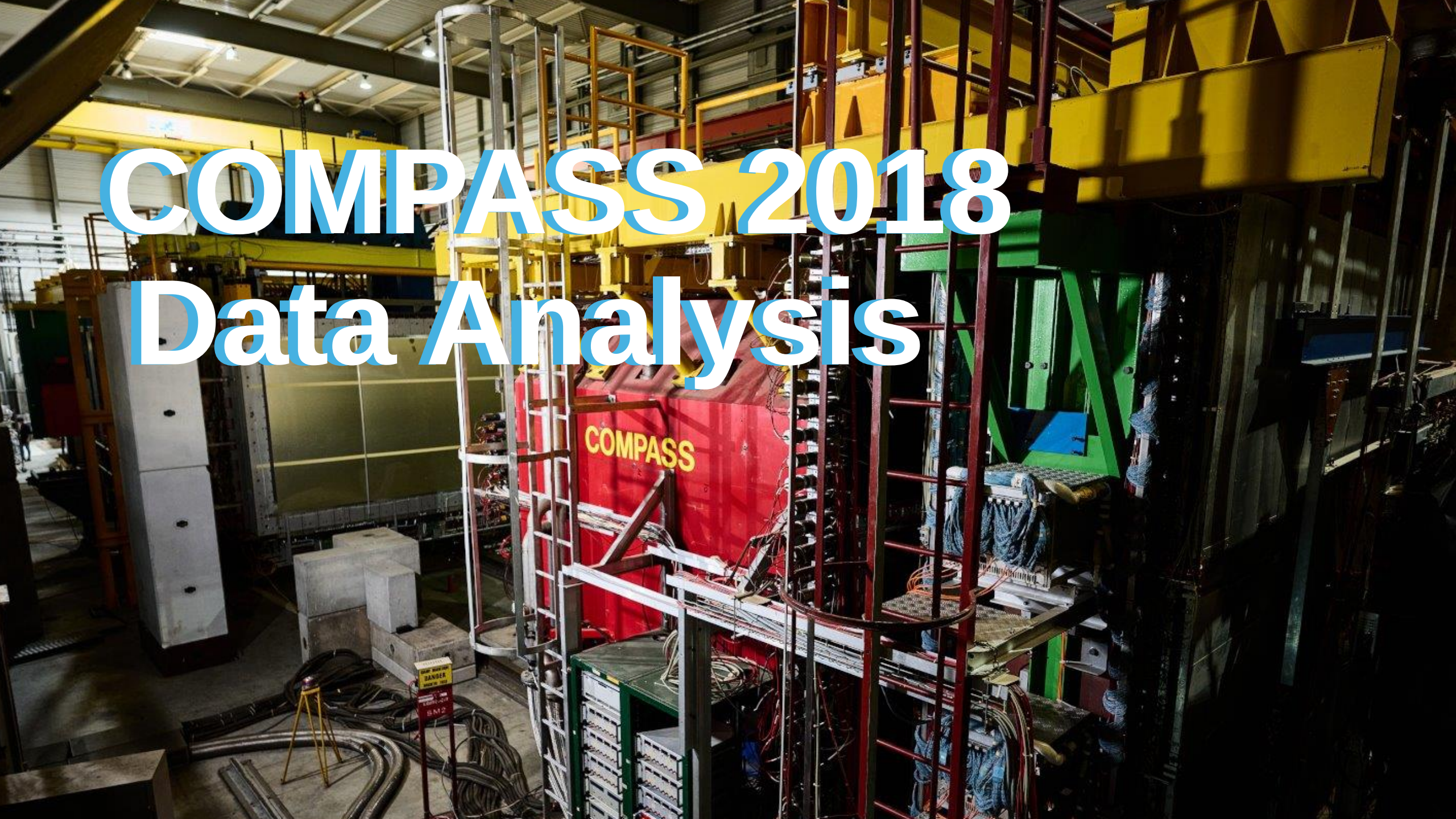
Small Angle Spectrometer
$5\ mrad < \theta < 80\ mrad$

COMPASS Experiment: Drell-Yan Data Taking 2018









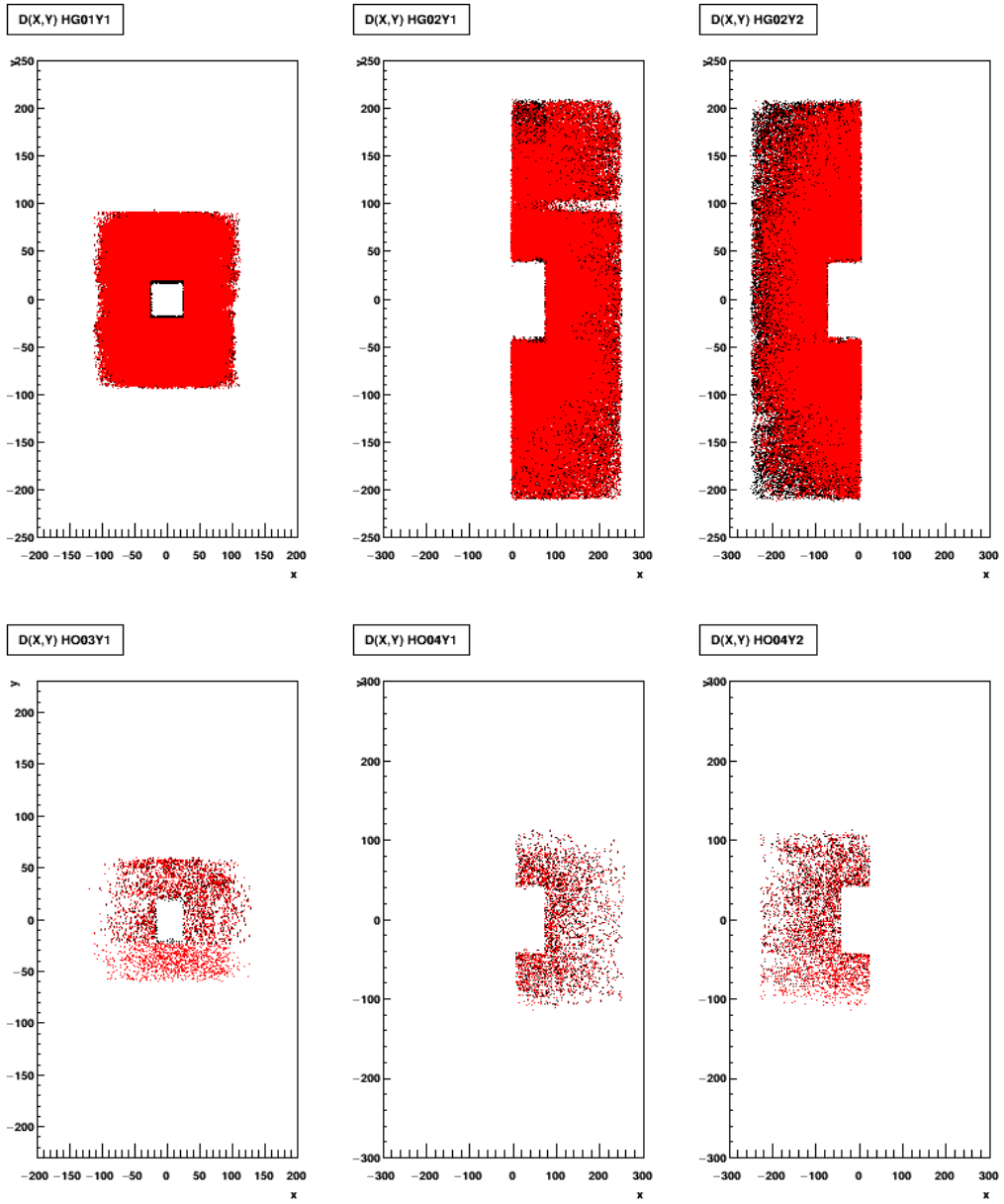
COMPASS 2018 Data Analysis

Event Selection Criteria

Variable	Condition
Mean Time of Positive Muon, t_+	$< 1000\ ns$
Mean Time of Positive Muon, t_-	$< 1000\ ns$
$\lvert t_+ - t_- \rvert$	$< 3\ ns$
Tracks χ^2/NDF	< 8
Z_{Last}	$> 1500\ cm$
Z_{First}	$< 300\ cm$
Trigger bit and Vallidation	(2 and trigvalOTLAS=1) or (8 and trigval2LAS ==1)

Variable	Condition
Time in Spill	$> 1\ s\ \ or\ \ < 5{,}6\ s$
$\lvert t_{beam} - t_+ \rvert$	$< 3\ ns$
$\lvert t_{beam} - t_- \rvert$	$< 3\ ns$
Tracks χ^2/NDF	< 10
Transverse Dimuon Momentum , $P_{t_{\mu_{+\mu-}}}$	$< 3{,}6\ \ GeV/c$
Eliptical Cut on Vertex Coordinates	$(Y_{vertex} - 1{,}5\ \ )^2/1{,}3^2 + X^2_{vertex}/1{,}9^2 = 1cm^2$
Eliptical Cut on Extrapolation coordinates in $NH_3\ Cell\ 1$	$(Y_{NH_3} - 1{,}5\ \ )^2/1{,}3^2 + X^2_{NH_3}/1{,}9^2 = 1cm^2$
Eliptical Cut on Extrapolation coordinates in W	$(Y_W - 1{,}5\ \ )^2/1{,}3^2 + X^2_W/1{,}9^2 = 1cm^2$
x_F	$< 1\ \ or\ \ > -0{,}2$

Event Selection Criteria



Trigger Validation By Hit Hodoscopes Association

The number of hits in the hodoscopes associated with one of the selected trigger must be greater than 1

Hodoscope's Active Zone Selection

Cut 2,5 cm around the Dead Zone of each hodoscope

Dimuon Mass Spectrum Fit Function

Fit Function

=

J/ψ Peak

$$\frac{N_{J/\psi}}{\sqrt{2\pi\sigma^2}} e^{\frac{-1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

+

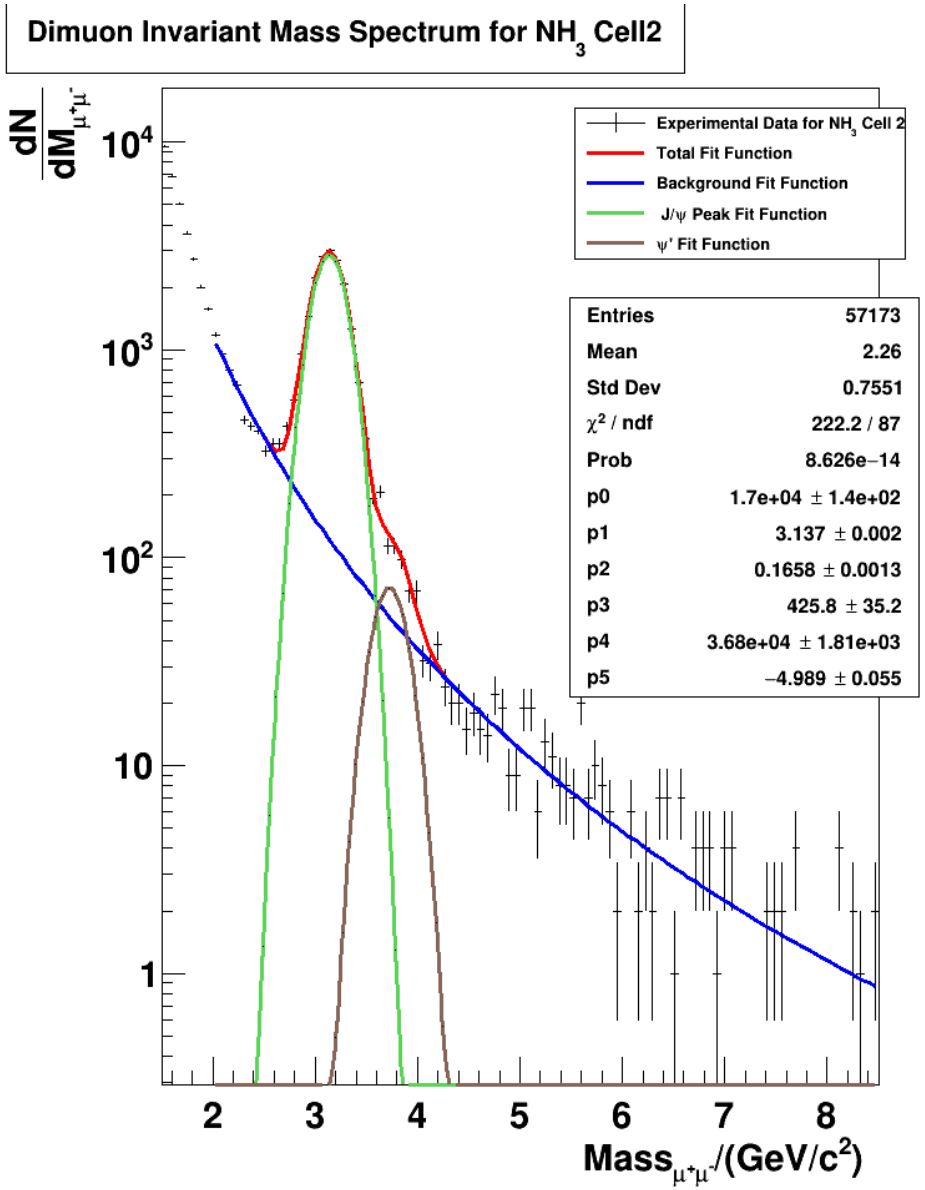
ψ' Peak

$$\frac{N_{\psi'}}{\sqrt{2\pi\sigma_{\psi'}^2}} e^{\frac{-1}{2}\left(\frac{x-\mu-d}{\sigma}\right)^2} ; d = 0{,}589\ GeV$$

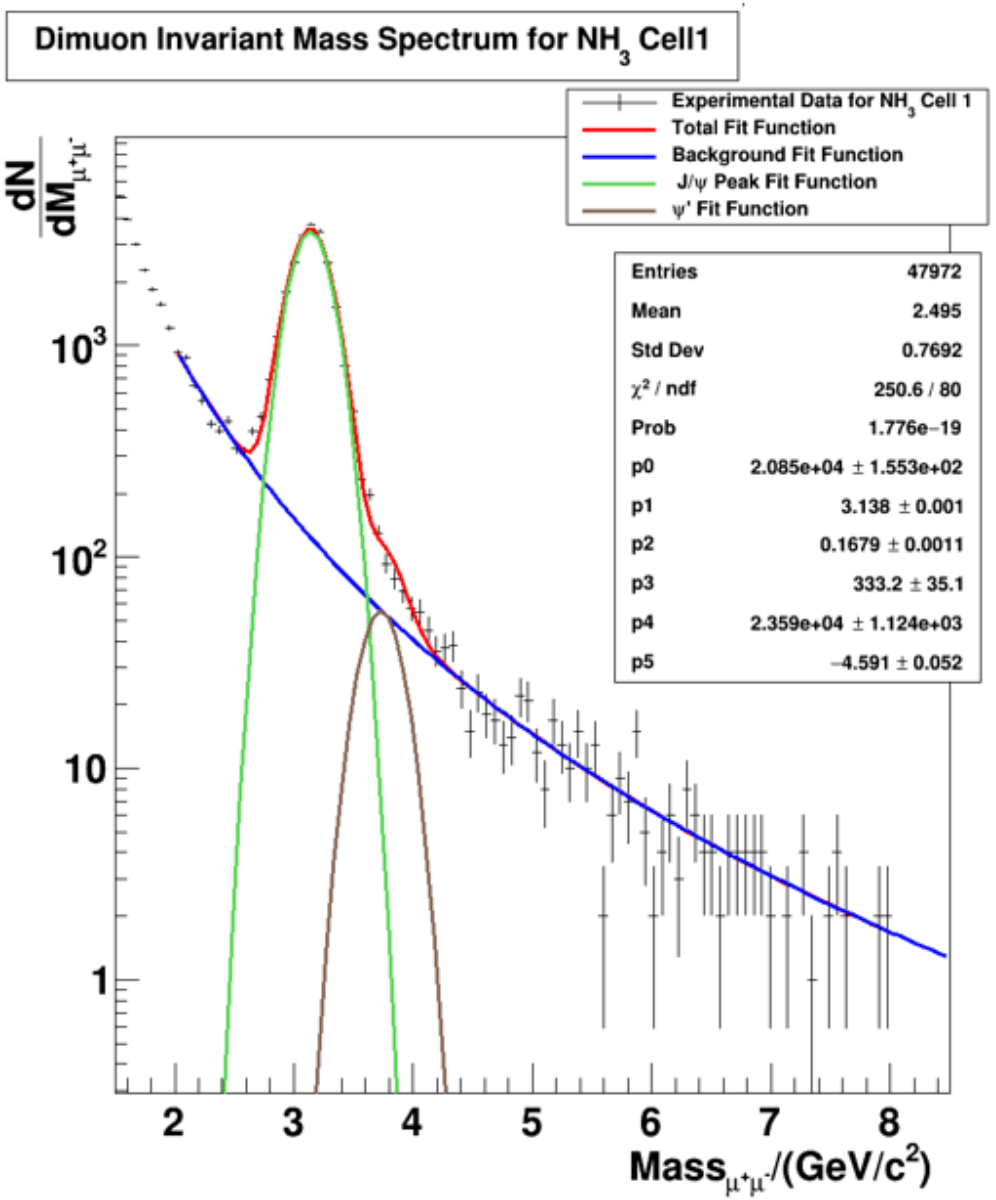
+

Background

$$ax^{-b}$$

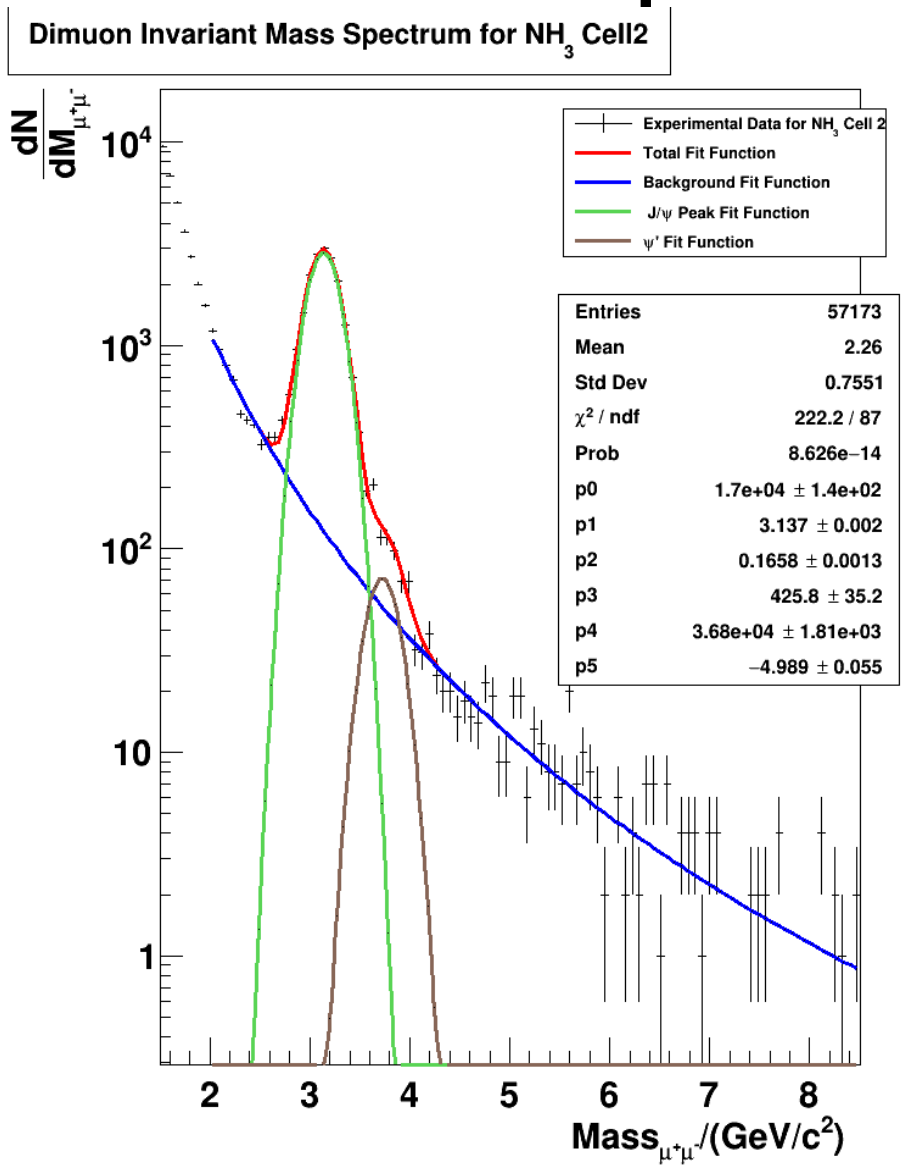


Dimuon Mass Spectrum for NH_3 Cell 1



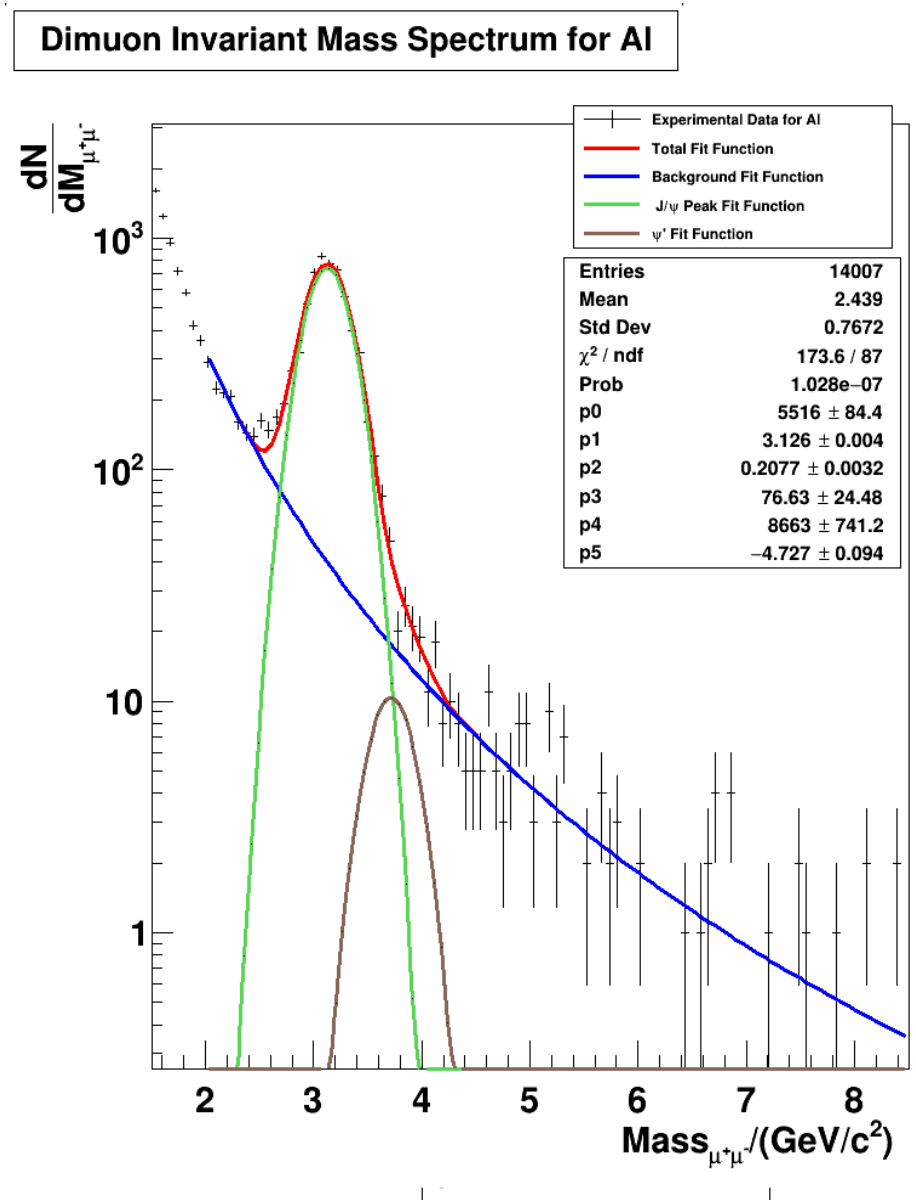
Fit Results
$\mu = 3{,}138\ \ GeV/c^2$
$\sigma = 0{,}168\ \ GeV/c^2$
$\chi^2/ndf = 3{,}13$

Dimuon Mass Spectrum for NH_3 Cell 2



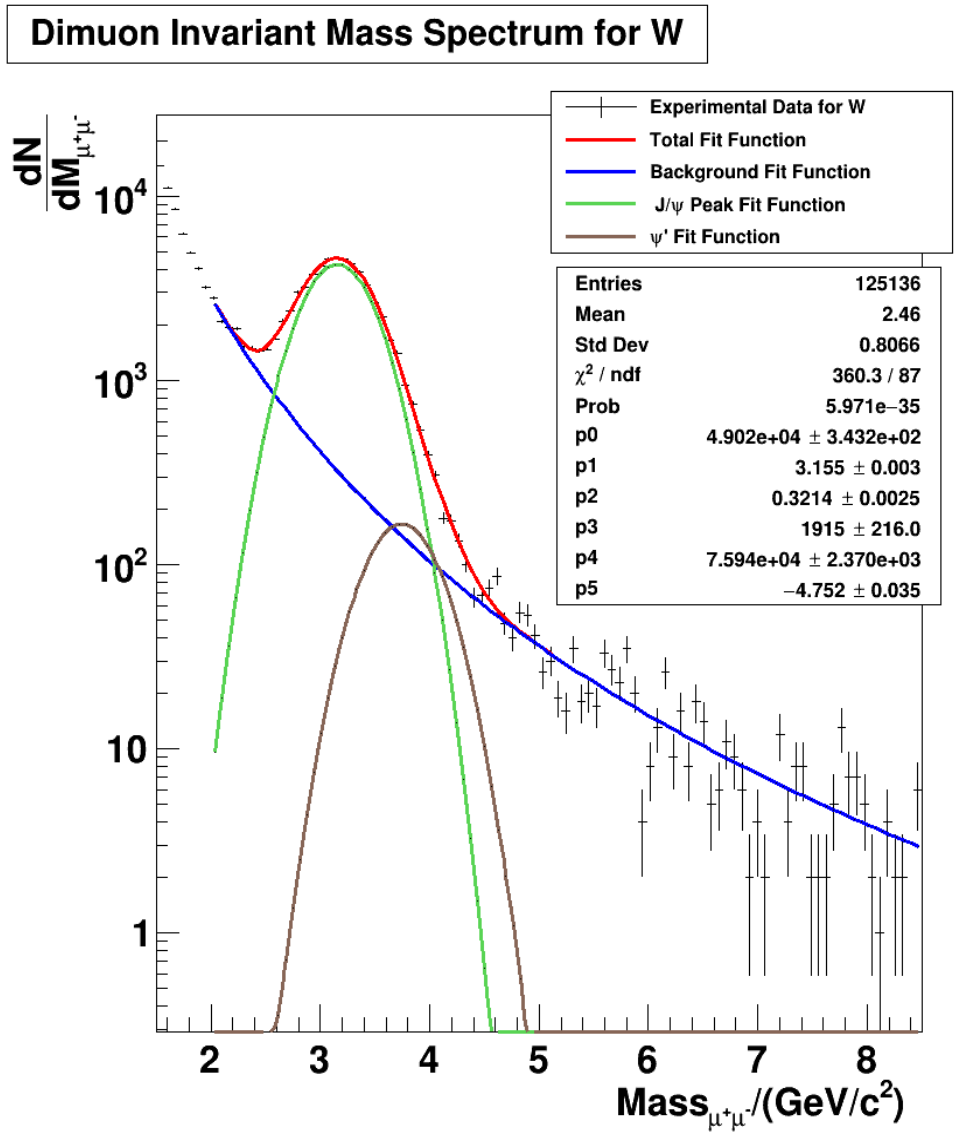
Fit Results
$\mu = 3{,}137\ GeV/c^2$
$\sigma = 0{,}165\ GeV/c^2$
$\chi^2/ndf = 2{,}55$

Dimuon Mass Spectrum for Al



Fit Results
$\mu = 3{,}138\ GeV/c^2$
$\sigma = 0{,}168\ GeV/c^2$
$\chi = 3{,}13$

Dimuon Mass Spectrum for W

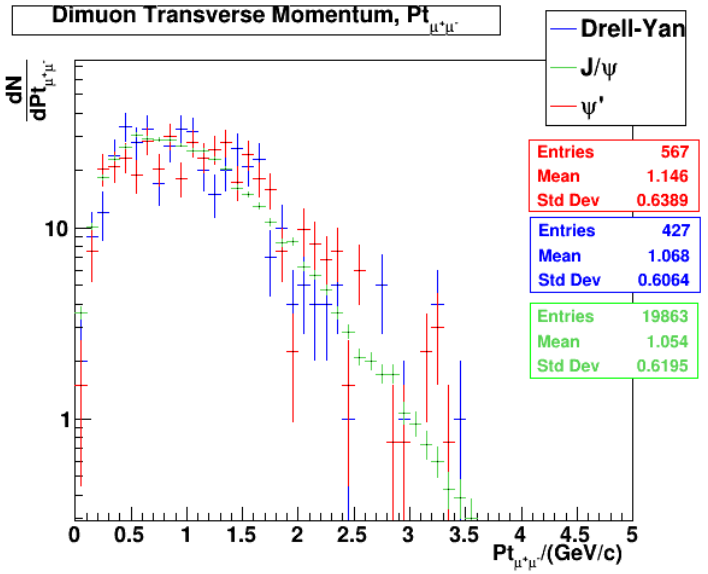


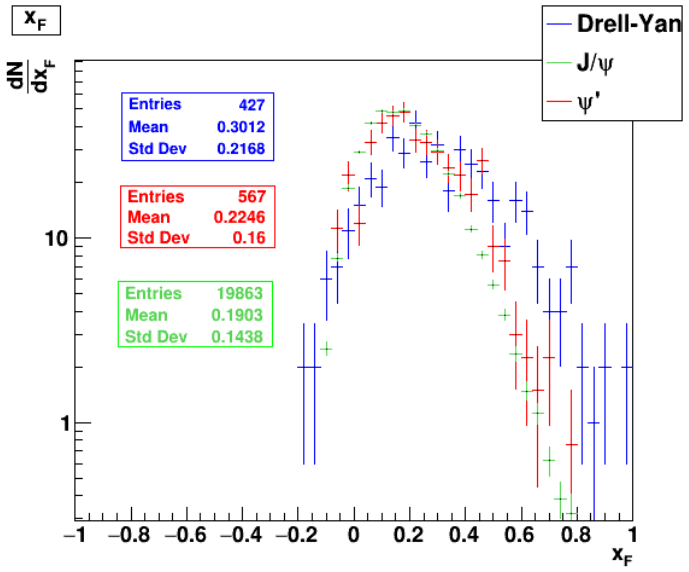
Fit Results
$\mu = 3{,}155\ GeV/c^2$
$\sigma = 0{,}321\ GeV/c^2$
$\chi^2/ndf = 4{,}14$

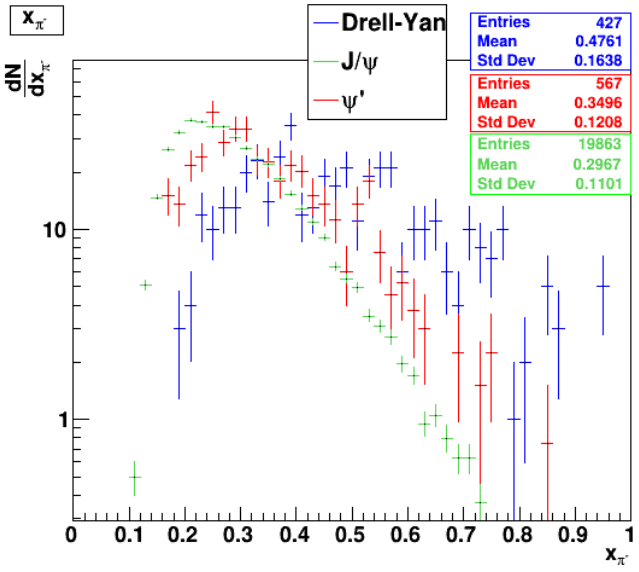
Summary of Results

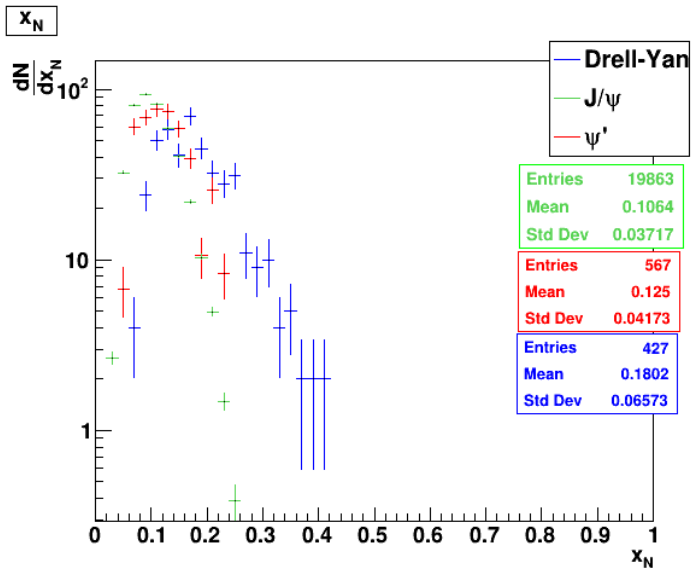
Target	$\#J/\psi$	$\#\psi(2S)$	$^{\#\psi(2S)}/_{\#J/\psi}$ (%)	$^{\#J/\psi}/_{Total}$(%)	χ^2/ndf	$\mu/(GeV/c^2)$	$\sigma/(GeV/c^2)$
NH_3 Cell 1	20851±155	333±35	1,6±0,2	95±1	3,13	3,14	0,168
NH_3 Cell 2	17003±141	425±35	2,4±0,2	94±1	2,55	3,14	0,166
Al	5516±84	76±24	1,4±0,4	88±2	2,00	3,13	0,208
W	49020±343	1914±215	3,9±0,4	86,3±0,7	4,14	3,15	0,321

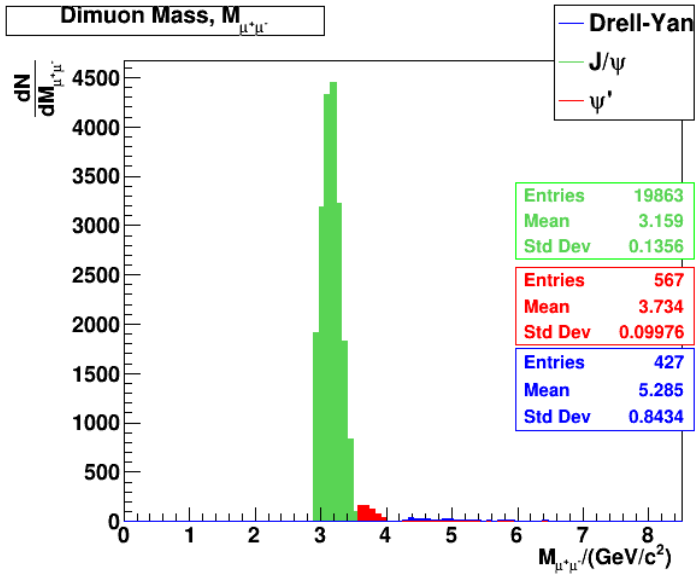
Kinematic Variables for NH_3 Cell 1



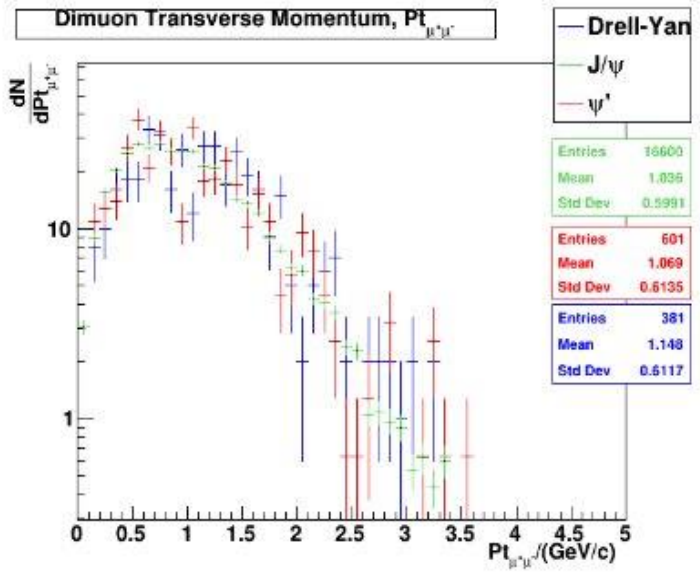


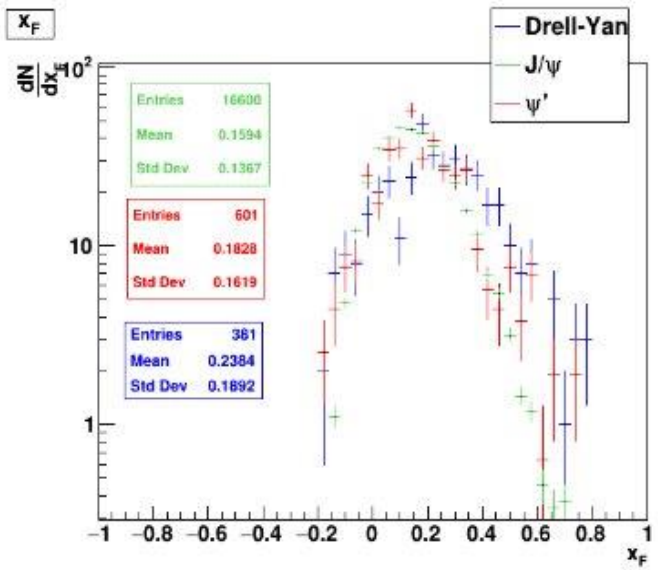


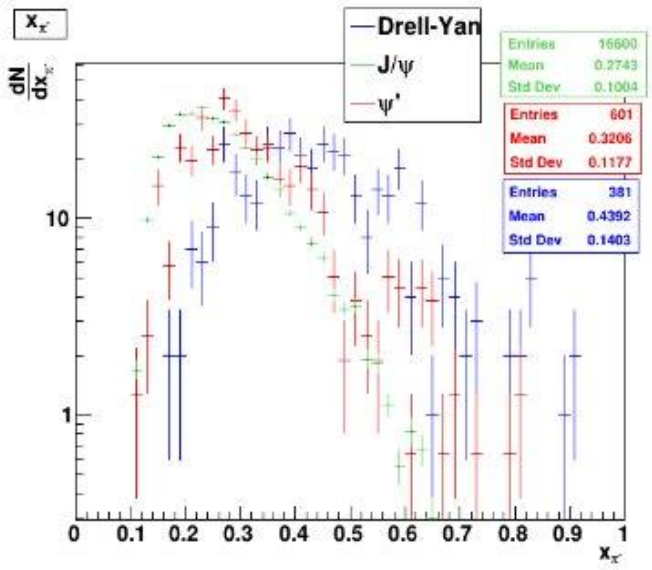


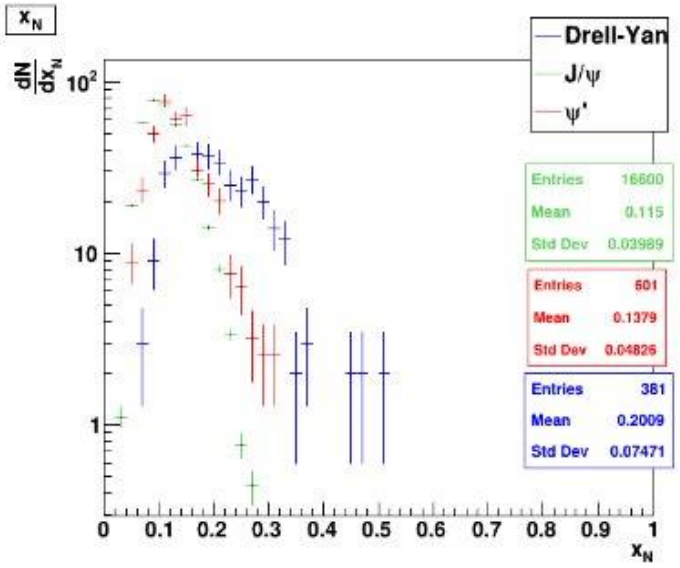


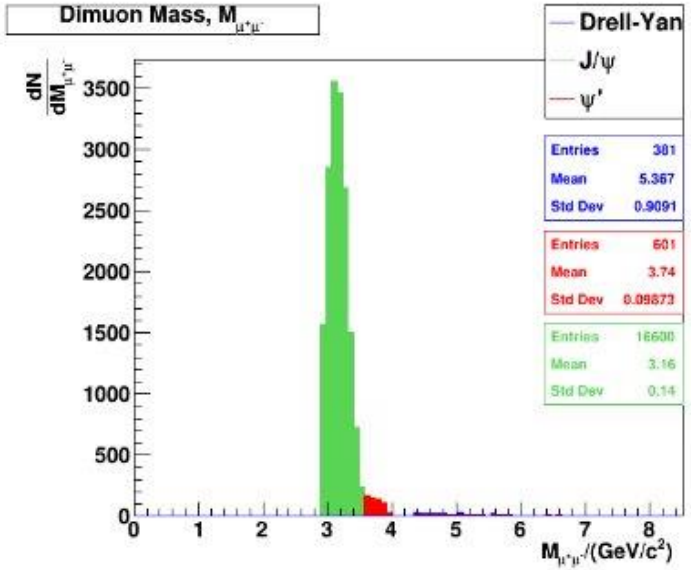
Kinematic Variables for NH_3 Cell 2



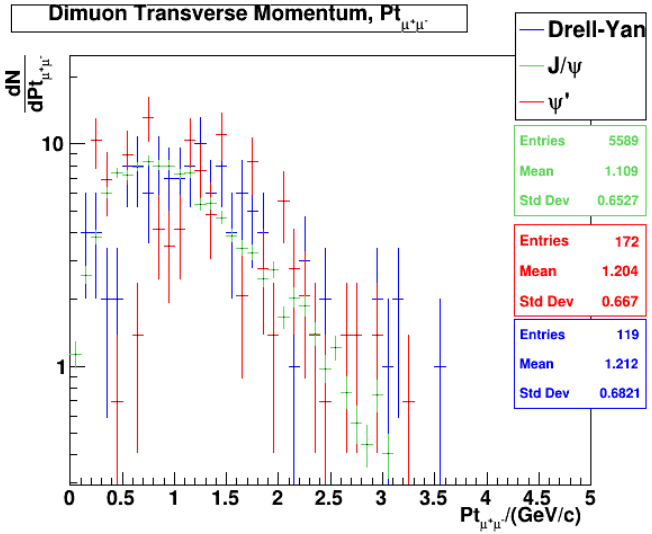


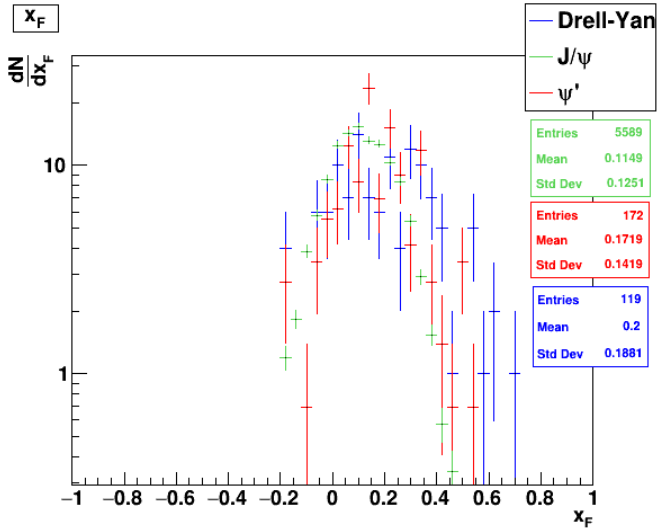


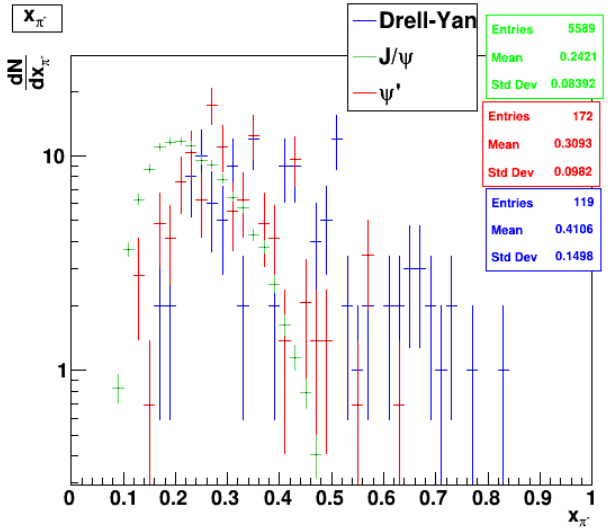


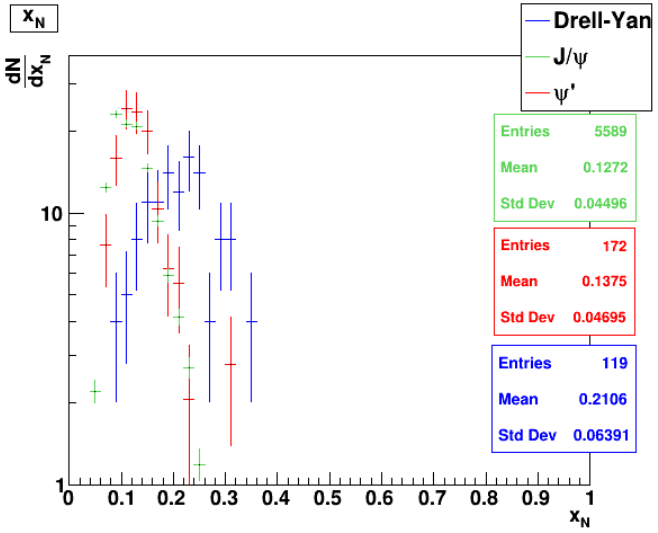


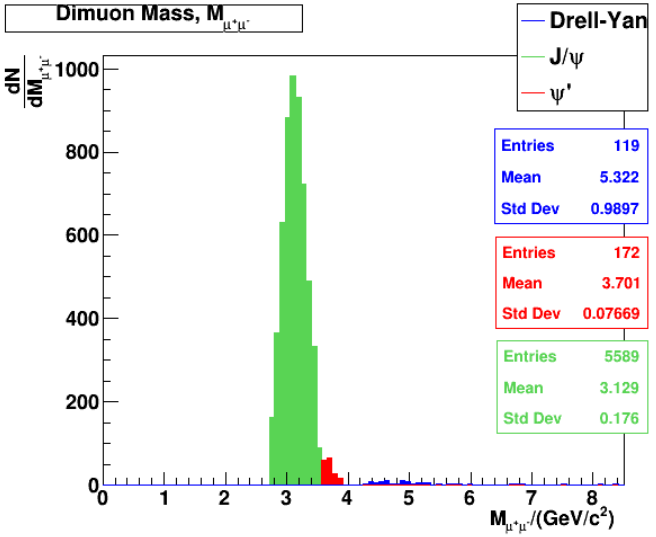
Kinematic Variables for AI



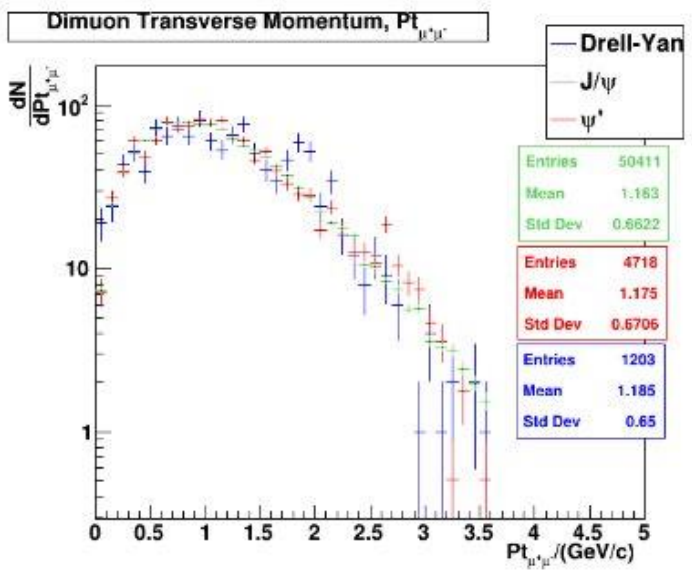


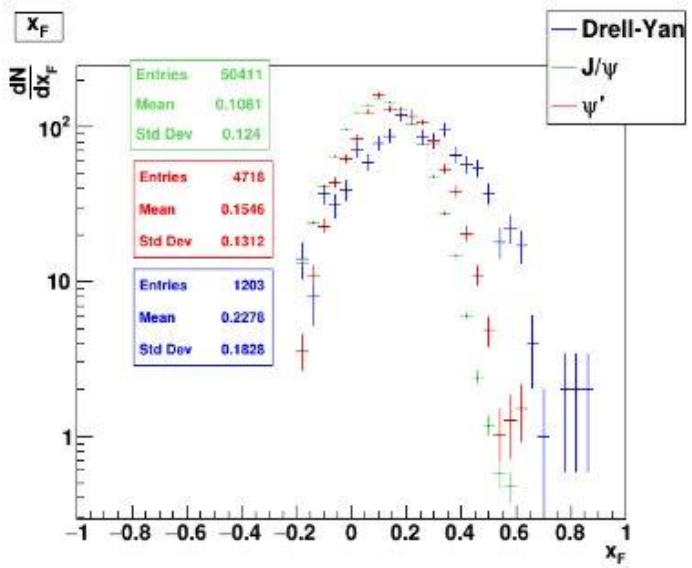


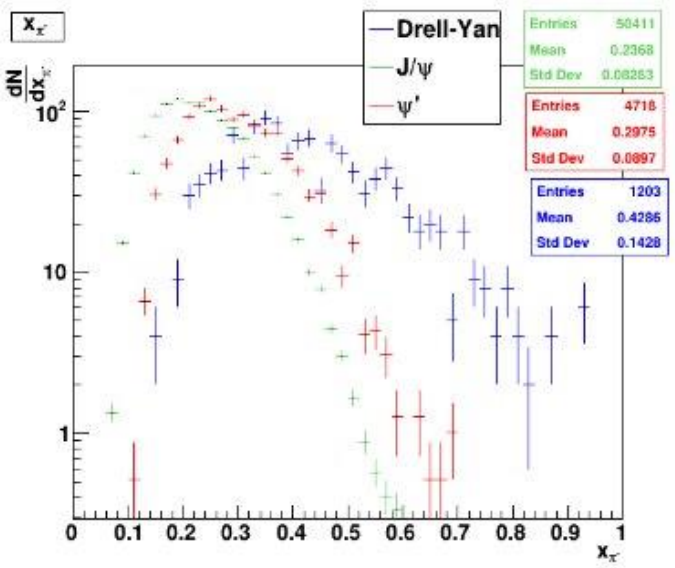


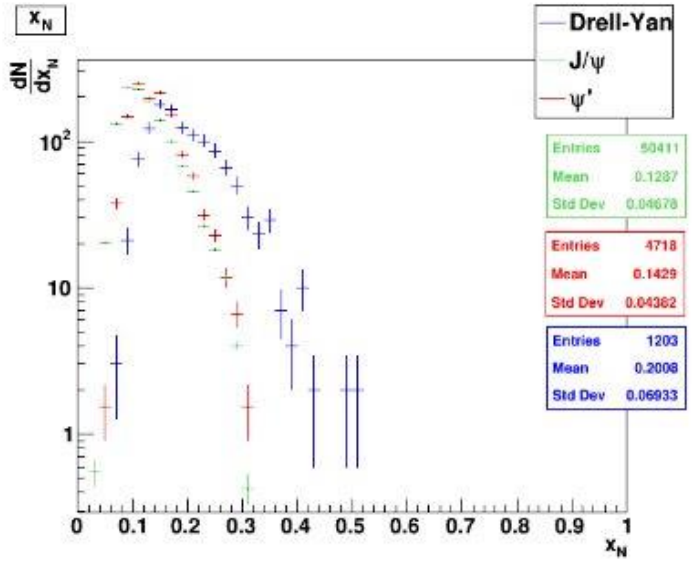


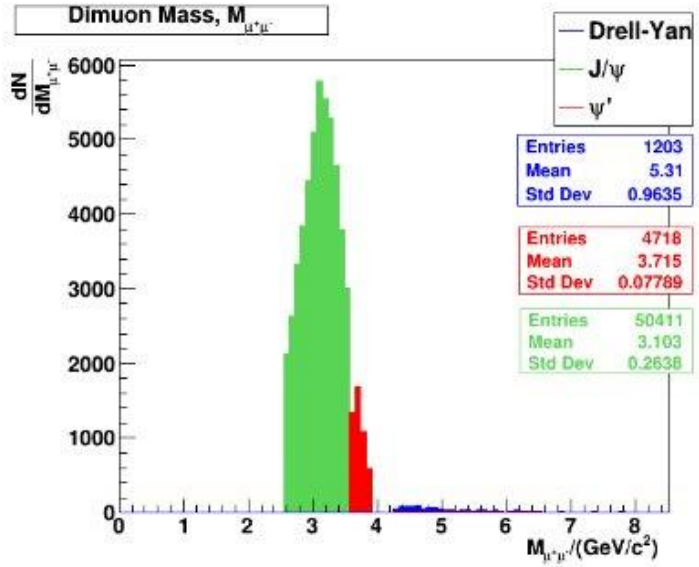
Kinematic Variables for W











Conclusions

When the Bjorken-X and Feynmann-X of momentum tend to values closer to 1, the dominant process is Drell-Yann.

Pythia Simulations

Pythia Generator

General Purpose Monte Carlo Event Generator

- Generation of high-energy physics collision events
- The generator contains physical models

- hard and soft interactions
- multiparton interactions
- parton distributions
- fragmentation and decay
- initial- and final-state parton showers

Pythia Simulations

Prompt J/ψ

Charmonium:gg2ccbar(3S1)[3S1(1)]g = on,off
Charmonium:gg2ccbar(3S1)[3S1(8)]g = on,off
Charmonium:qg2ccbar(3S1)[3S1(8)]q = on,off
Charmonium:qqbar2ccbar(3S1)[3S1(8)]g = on,off
Charmonium:gg2ccbar(3S1)[1S0(8)]g = on,off
Charmonium:qg2ccbar(3S1)[1S0(8)]q = on,off
Charmonium:qqbar2ccbar(3S1)[1S0(8)]g = on,off
Charmonium:gg2ccbar(3S1)[3PJ(8)]g = on,off
Charmonium:qg2ccbar(3S1)[3PJ(8)]q = on,off
Charmonium:qqbar2ccbar(3S1)[3PJ(8)]g = on,off

443:onMode = off
443:onIfAll = 13 -13
J/ψ → μ+μ-

Prompt ψ'

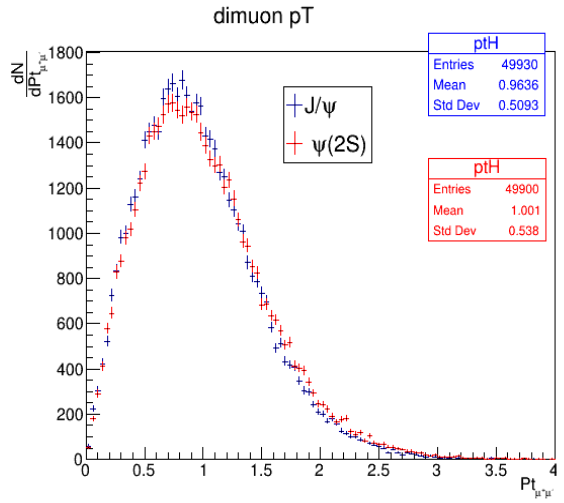
Charmonium:gg2ccbar(3S1)[3S1(1)]g = off,on
Charmonium:gg2ccbar(3S1)[3S1(8)]g = off,on
Charmonium:qg2ccbar(3S1)[3S1(8)]q = off,on
Charmonium:qqbar2ccbar(3S1)[3S1(8)]g = off,on
Charmonium:gg2ccbar(3S1)[1S0(8)]g = off,on
Charmonium:qg2ccbar(3S1)[1S0(8)]q = off,on
Charmonium:qqbar2ccbar(3S1)[1S0(8)]g = off,on
Charmonium:gg2ccbar(3S1)[3PJ(8)]g = off,on
Charmonium:qg2ccbar(3S1)[3PJ(8)]q = off,on
Charmonium:qqbar2ccbar(3S1)[3PJ(8)]g = off,on

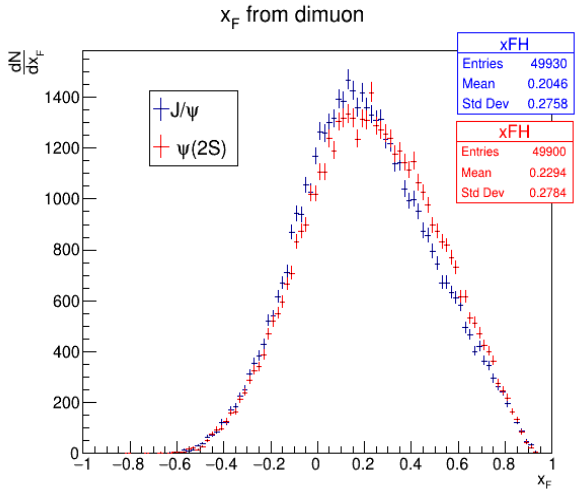
100443:onMode = off
100443:onIfAll = 13 -13
ψ' → μ+μ-

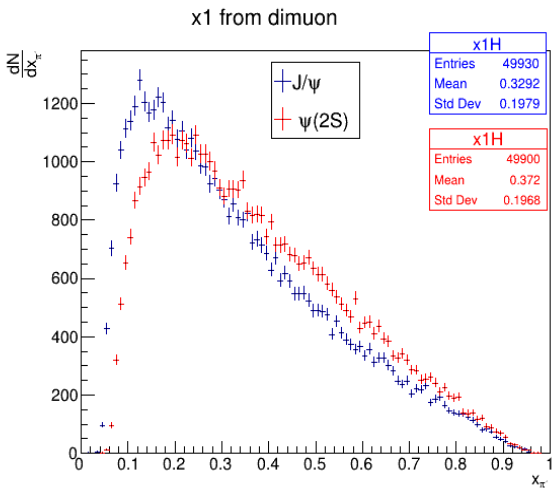
Pythia Simulations Results

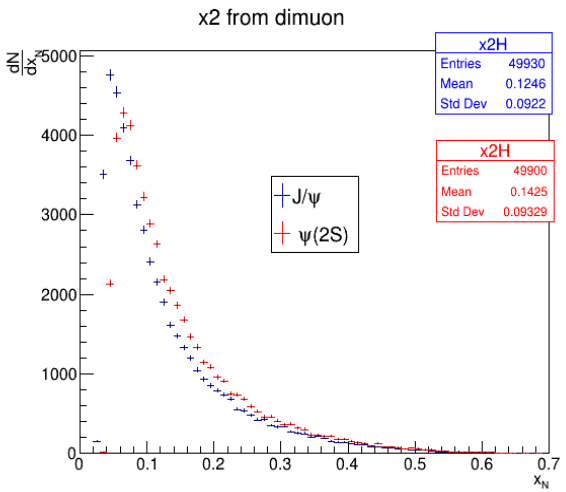
J/ψ
$\sigma = (126{,}1 \pm 0{,}3)nb$

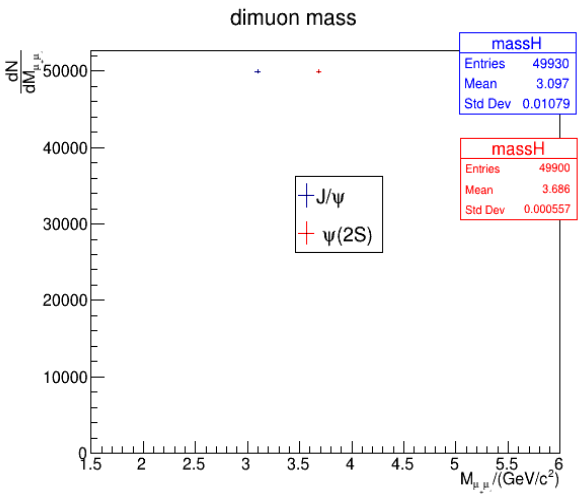
ψ'
$\sigma = (15{,}35 \pm 0{,}04)nb$











Pythia Simulations

J/ψ

Charmonium:all = on

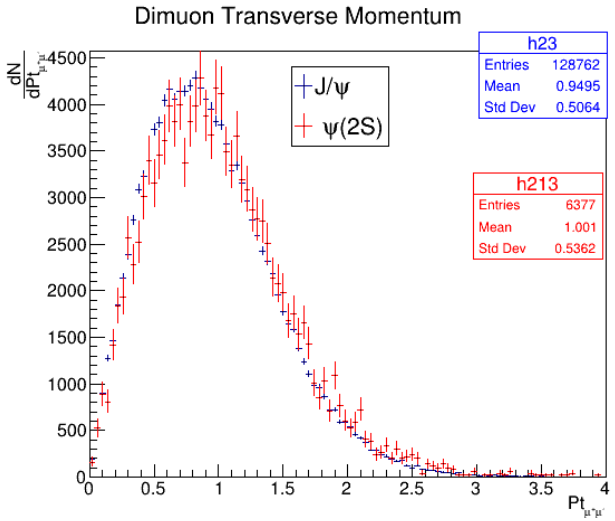
443:onMode = off
443:onIfAll = 13 -13
J/ψ → μ+μ-

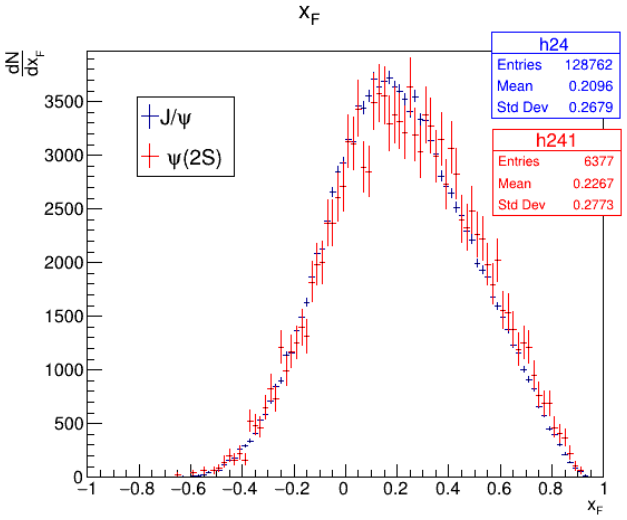
ψ’

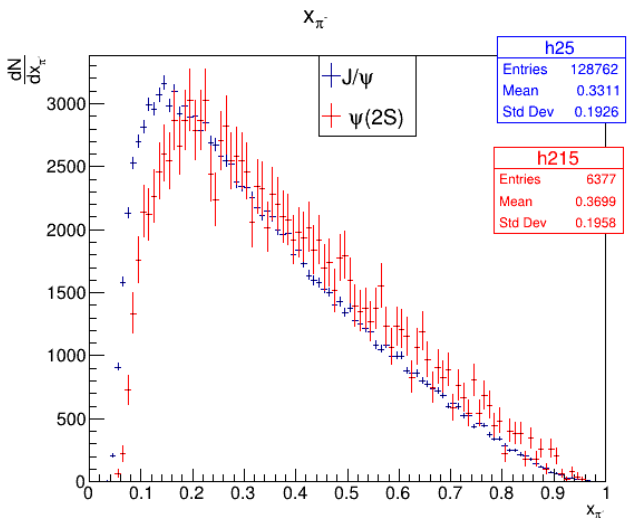
Charmonium:all = on

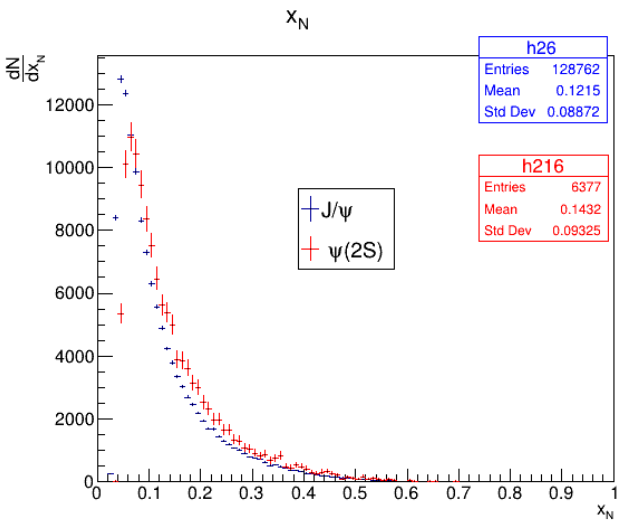
443:onMode = off
443:onIfAll = 13 -13
ψ’ → μ+μ-

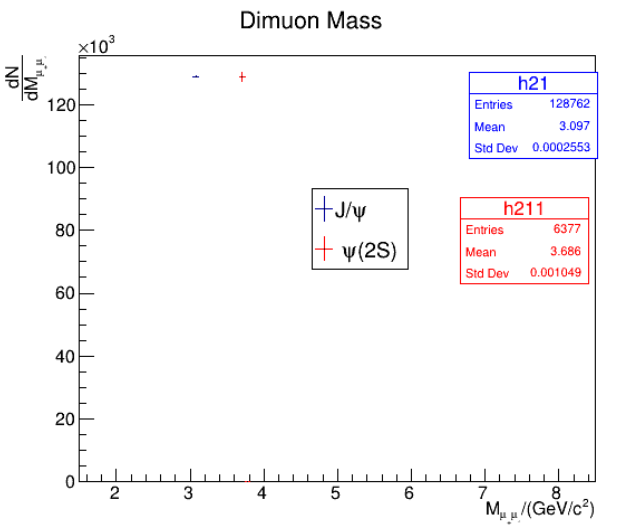
Pythia Simulations Results



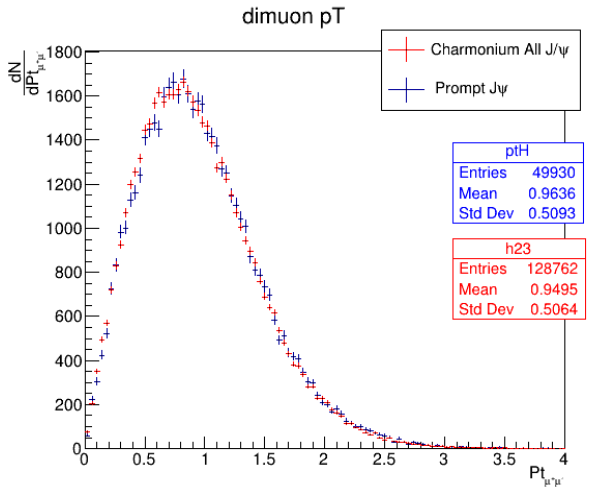


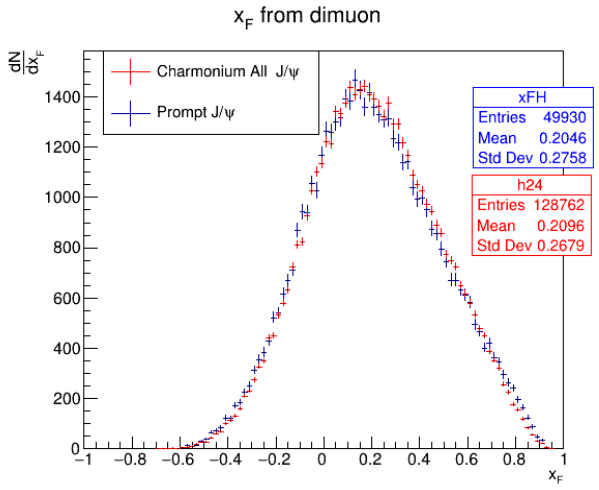


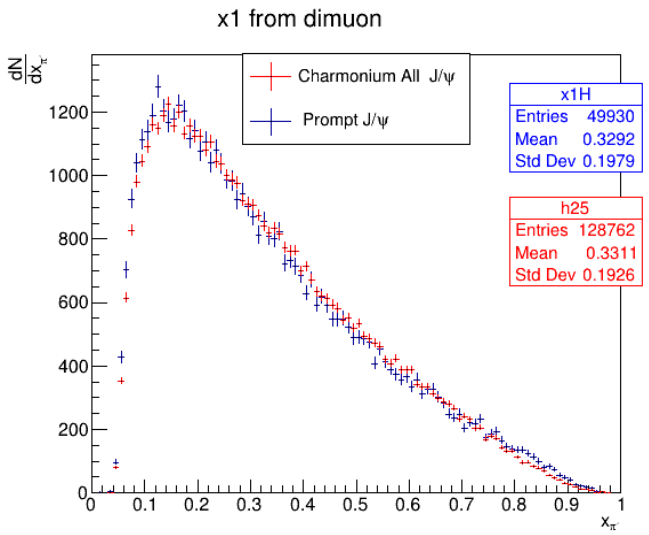


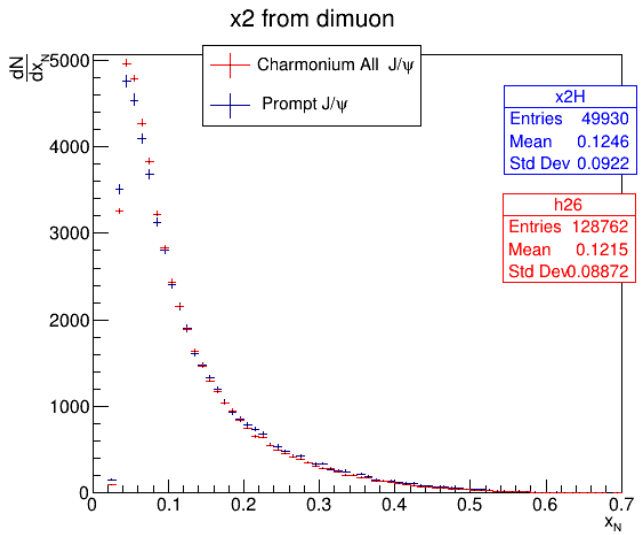


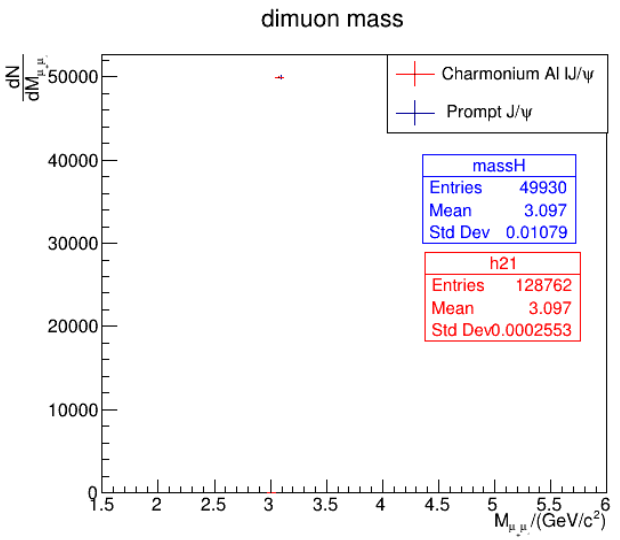
Pythia Simulations – Charmonium:all J/ψ vs. Prompt J/ψ



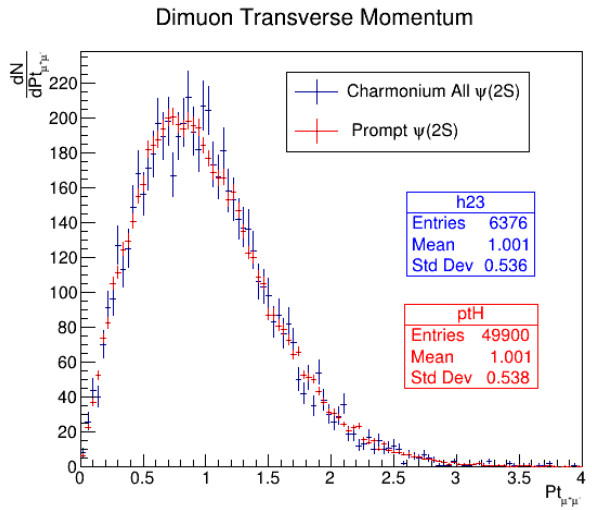


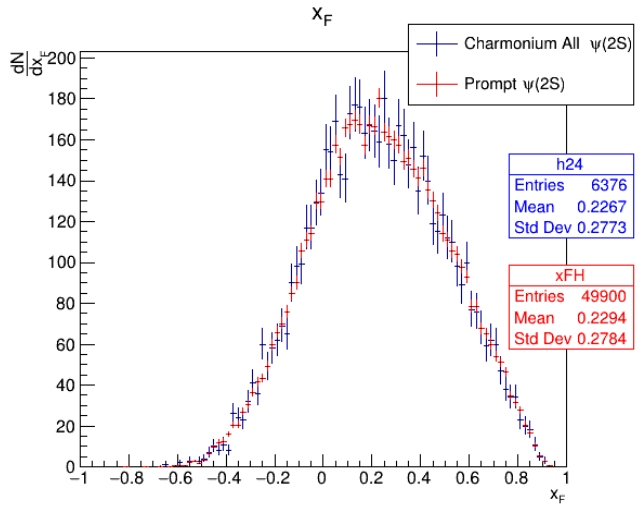


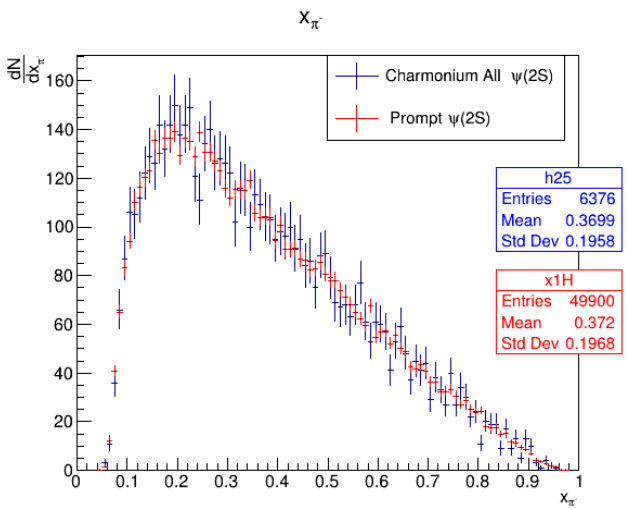


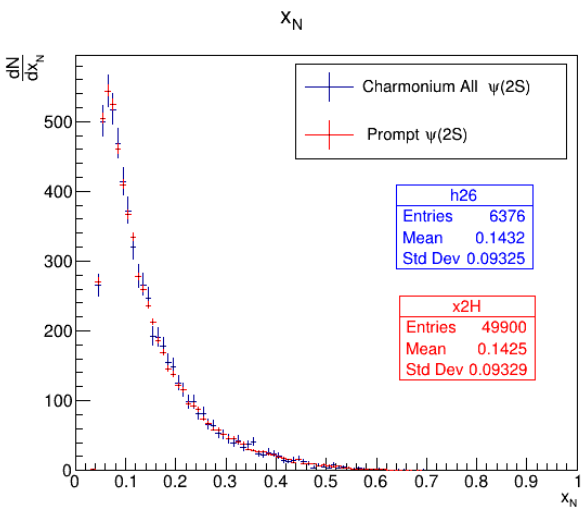


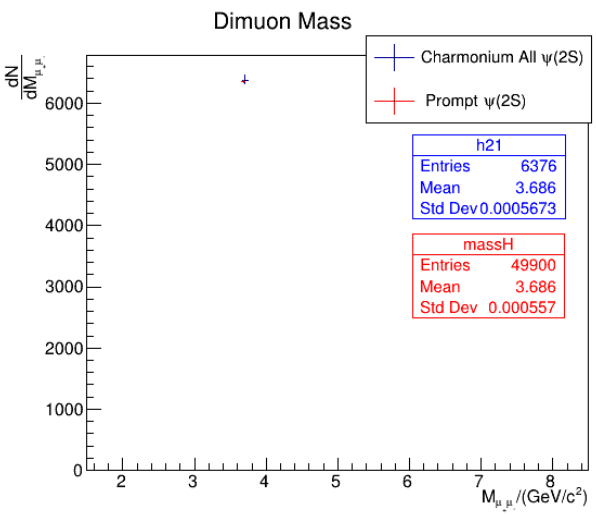
Pythia Simulations – Charmonium:all $\psi(2S)$ vs. Prompt $\psi(2S)$











Conclusions

- Generation Chamonium:all and Generation Prompt of J/ψ and $\psi(2S)$ produce similar results.
- Generation of J/ψ and $\psi(2S)$ produce similar Kinematic Distirbuitions.