LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

"The hidden charm in the COMPASS and AMBER experiments at CERN"

LIP Internship Program 2023

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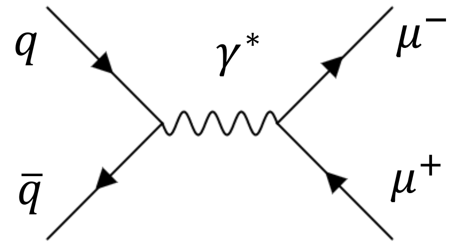
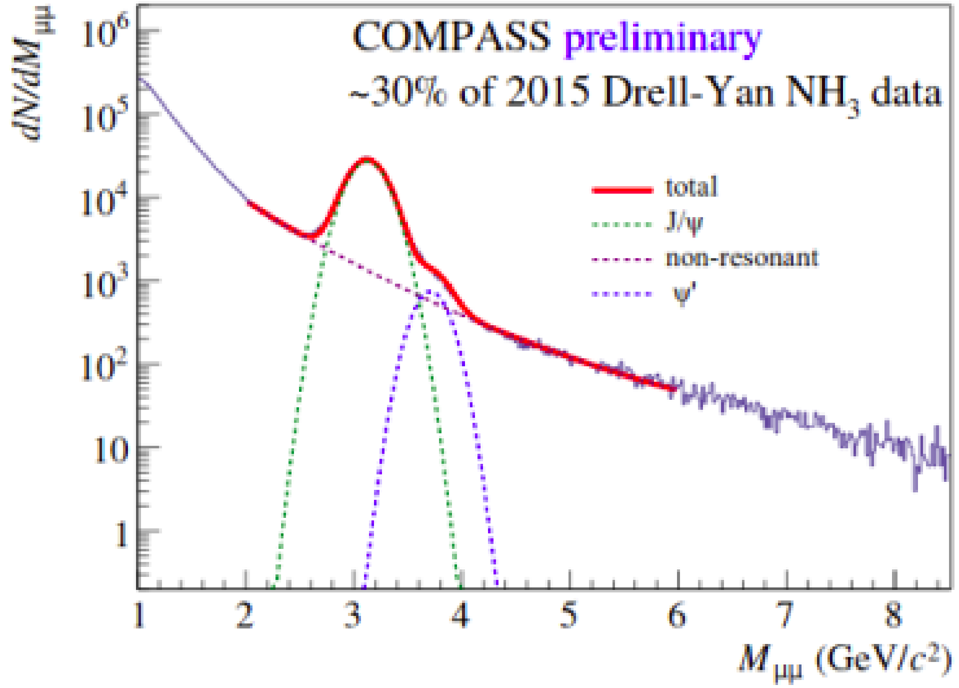
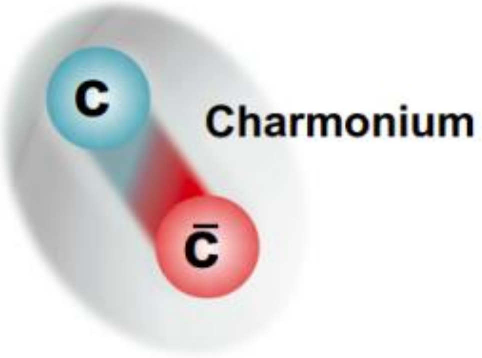
The hidden charm

Drell-Yan







$M_{J/\psi} = 3.098$ GeV

$M_{\psi'} = 3.686$ GeV

J/ψ production mechanism

$gluon - gluon\ fusion$

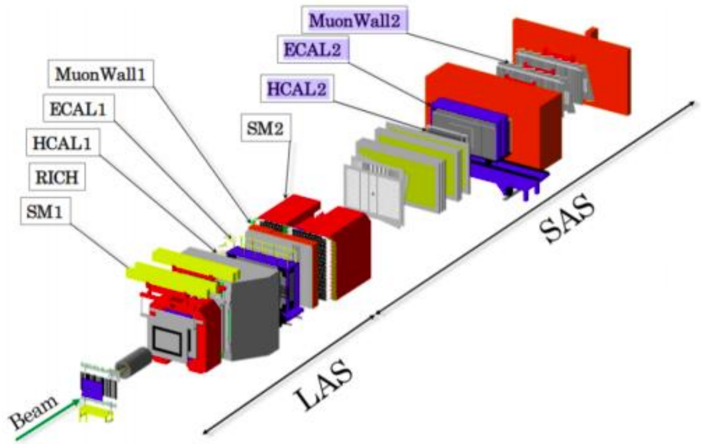
$q - \bar{q}\ annihilation$

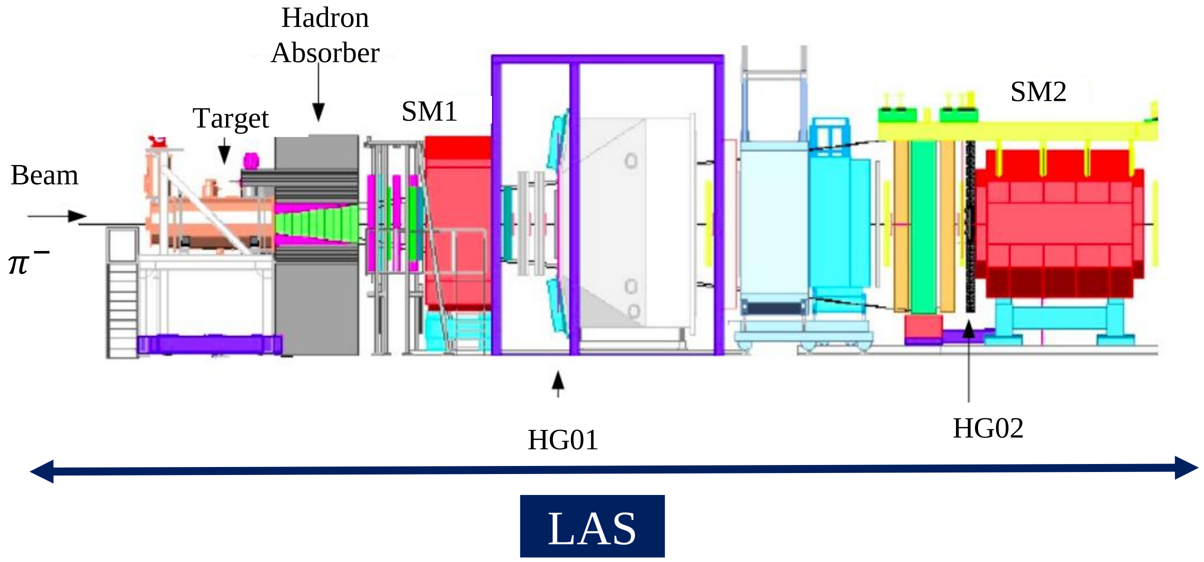
COMPASS Experiment

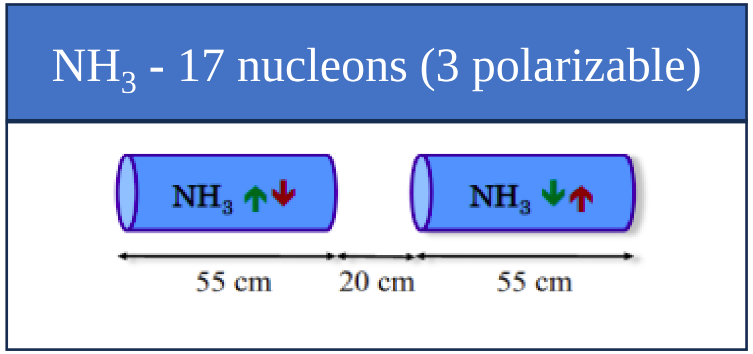
COmmon **M**uon and **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

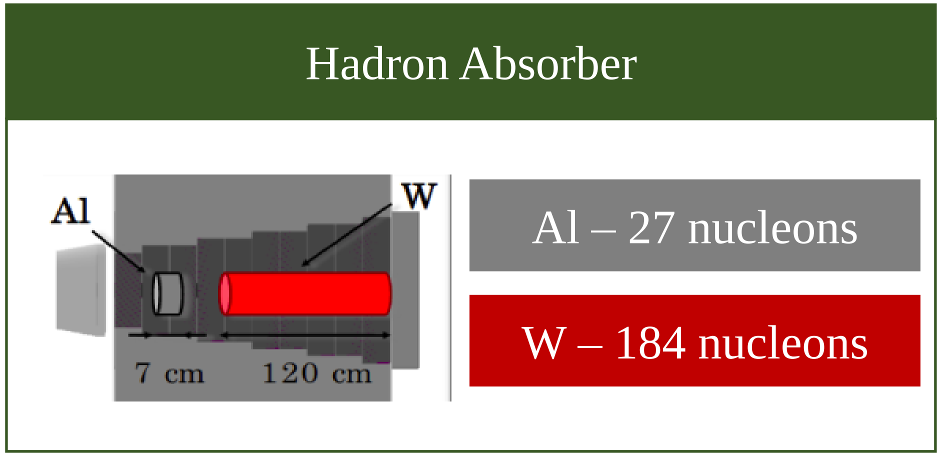
- High Energy
- Fixed Target Experiment

COMPASS Experiment: Drell-Yan Data Taking 2018

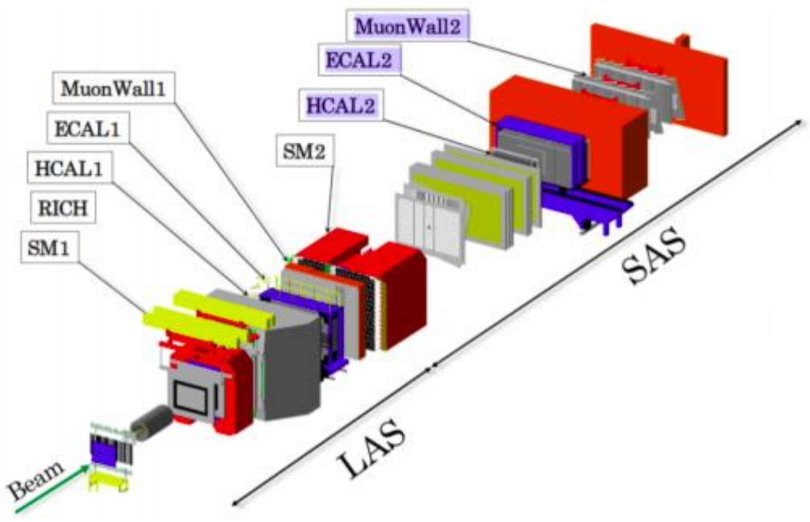








COMPASS Experiment: Drell-Yan Data Taking 2018



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

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

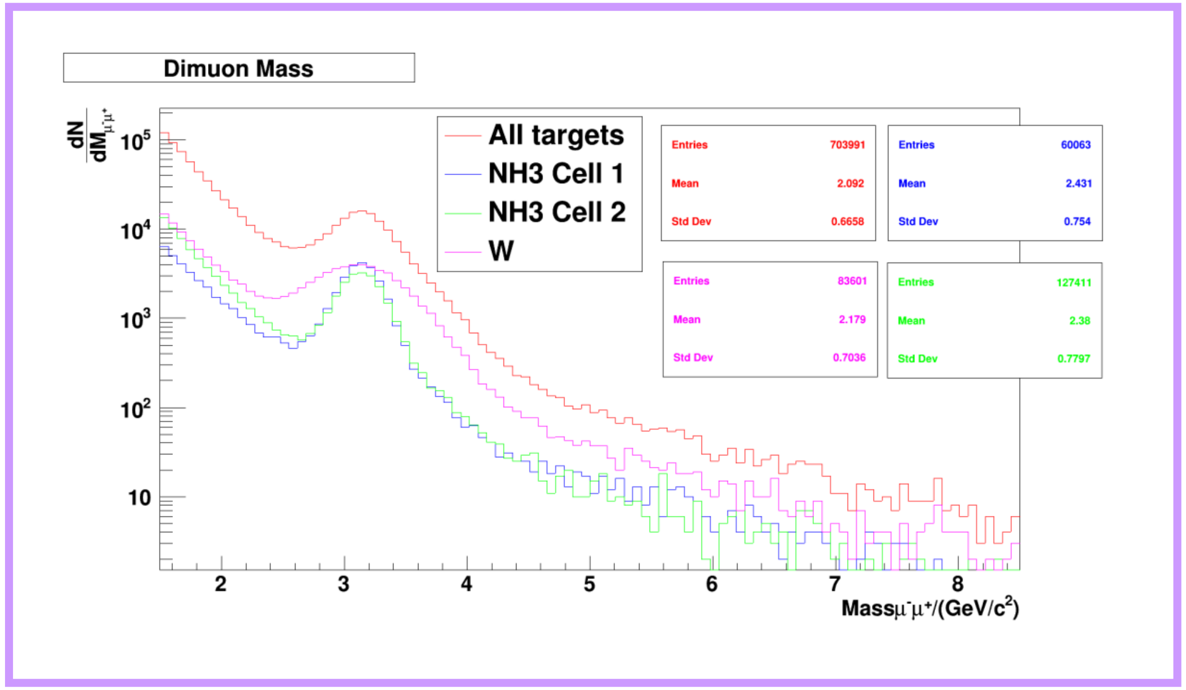
Small Angle Spectrometer
$5\, mrad < \theta < 80\, mrad$

Event Selection

Best Primary Vertex → Finding $\mu^+\mu^-$ in the same vertex → Trigger Validation

2LAS	LAS + LAS
OTLAS	Outer(SAS) + LAS

→ Applying Quality Cuts →



Kinematic Variables

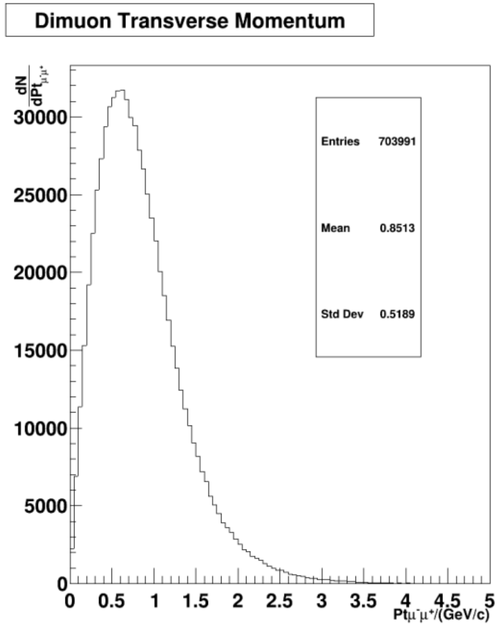
$M > 1.5\ GeV/c^2$

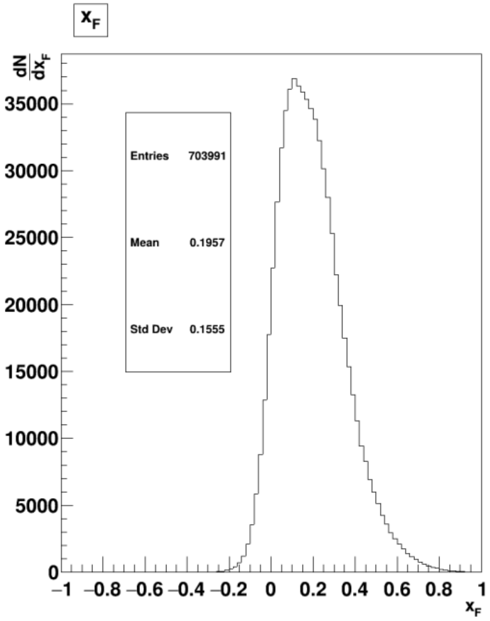
$$P_t = \sqrt{P_x^2 + P_y^2}$$

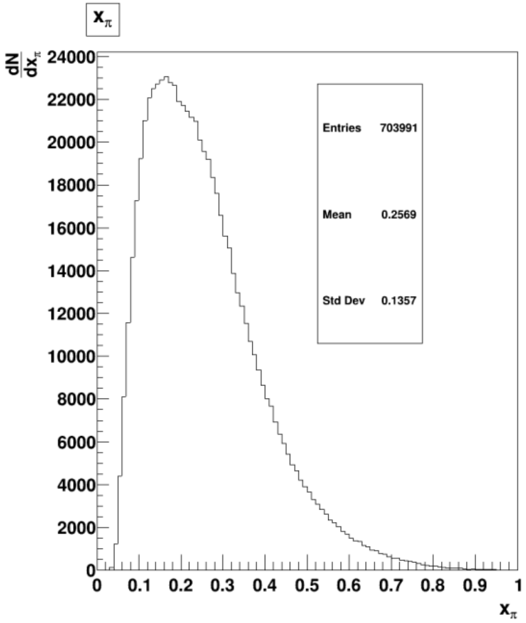
$$x_F = \frac{P_z^{\gamma^*}}{\sqrt{s}/2}|_{HCF}$$

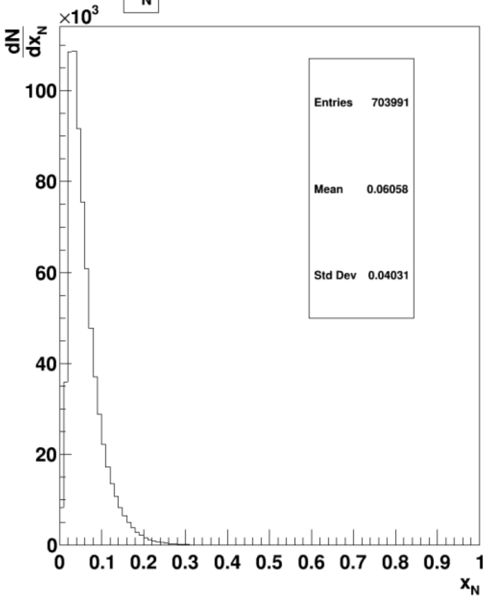
$$x_\pi = \frac{1}{2} \times \left(\sqrt{x_F^2 + \frac{4Q^2}{s}} + x_F \right)$$

$$x_N = \frac{1}{2} \times \left(\sqrt{x_F^2 + \frac{4Q^2}{s}} - x_F \right)$$









Invariant Mass Spectrum for NH_3 Cell 1

Total Fit Function

=

J/ψ Peak

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

+

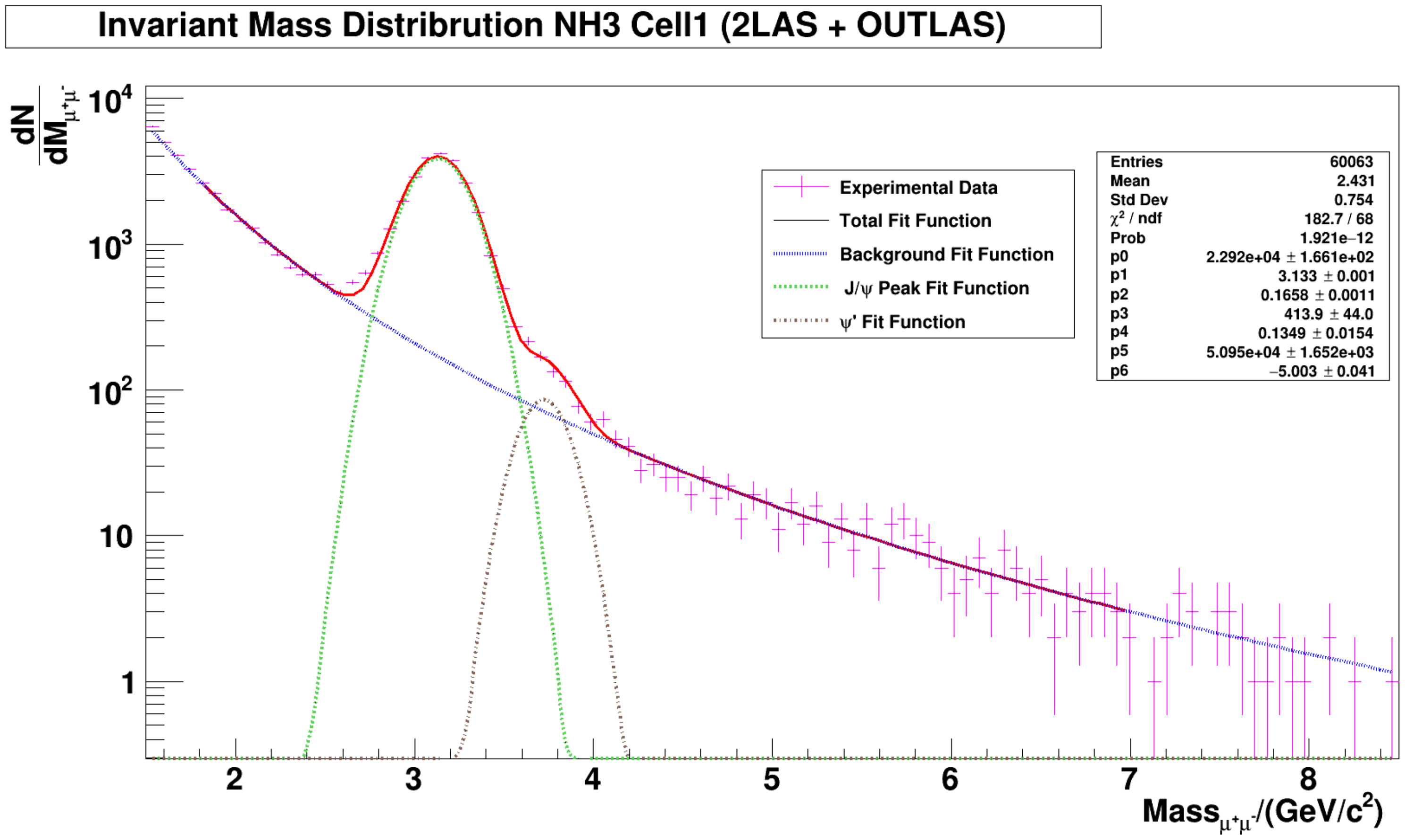
ψ' Peak

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

+

Background

$$ae^{bx}$$



Invariant Mass Spectrum for NH_3 Cell 2

Total Fit Function

=

J/ψ Peak

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

+

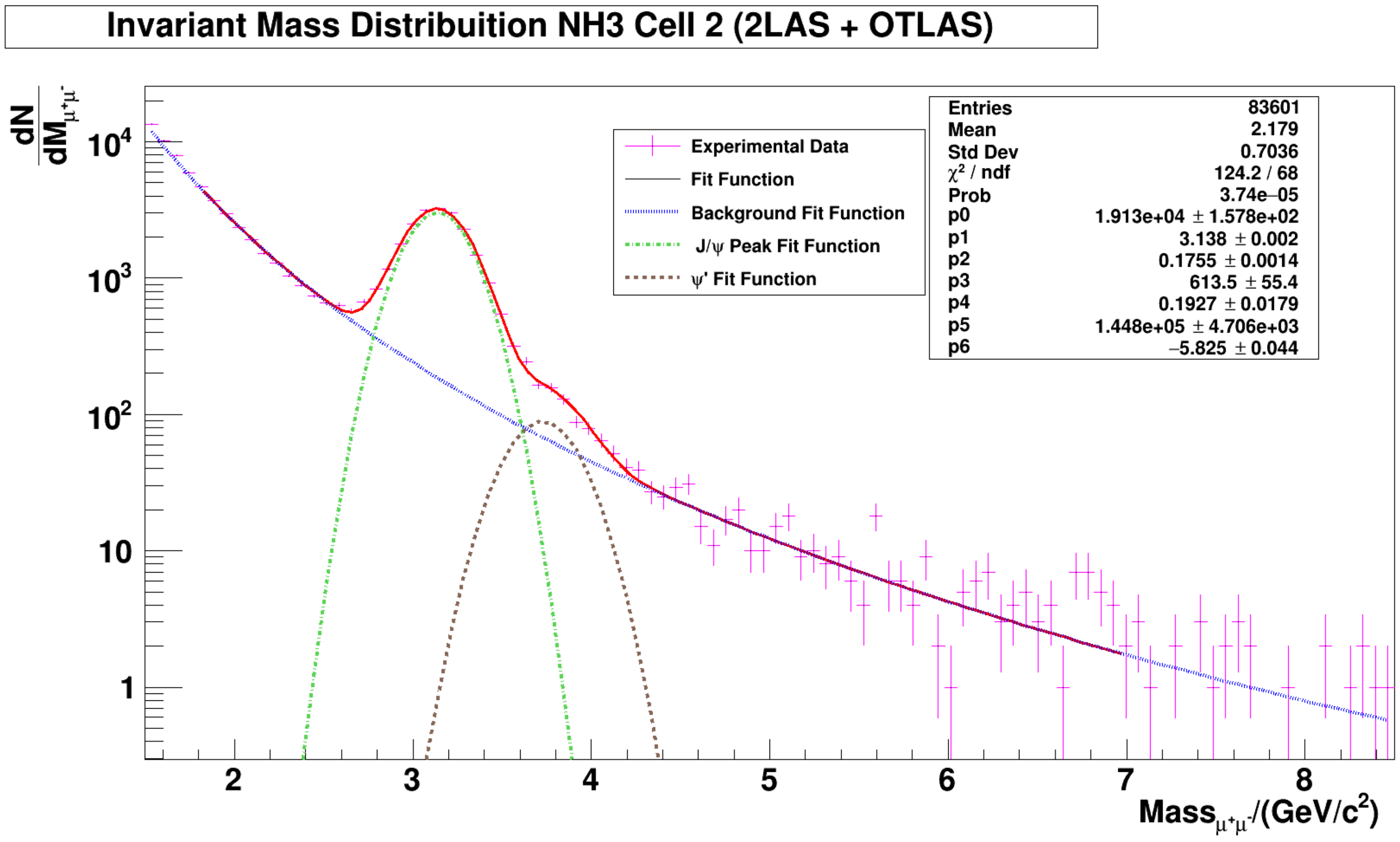
ψ' Peak

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

+

Background

$$ae^{bx}$$



Invariant Mass Spectrum for W

Total Fit Function

=

J/ψ Peak

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

+

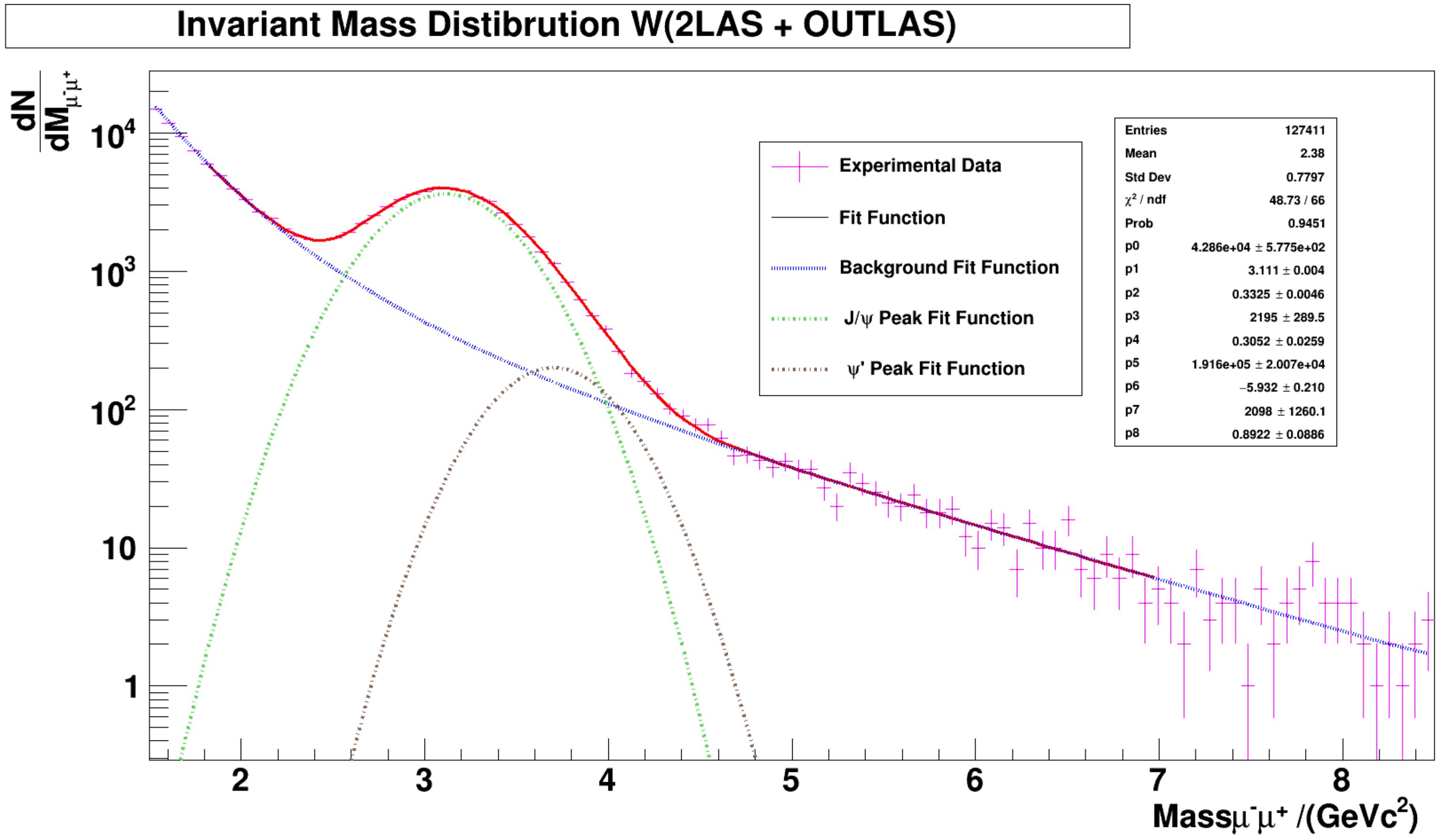
ψ' Peak

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

+

Background

$$ae^{-bx} + ce^{-dx}$$



J/ψ and ψ' Ratios for NH_3 Cell 1

2LAS + OTLAS	2LAS	OTLAS
$[2.9\ GeV/c^2, 3.53 GeV/c^2]$	$[2.9\ GeV/c^2, 3.53 GeV/c^2]$	$[2.9\ GeV/c^2, 3.53 GeV/c^2]$
J/ψ(%) =93.74	J/ψ(%) =94.75	J/ψ(%) =92.46
# J/ψ =22919	# J/ψ =14792	# J/ψ =9858
$[3.6 GeV/c^2, 3.95 GeV/c^2]$	$[3.6 GeV/c^2, 3.95 GeV/c^2]$	$[3.6 GeV/c^2, 3.95 GeV/c^2]$
ψ'(%) =45.02	ψ'(%) =48.22	ψ'(%) =43.87
J/ψ Contamination(%) = 7.81	J/ψ Contamination(%) = 9.11	J/ψ Contamination(%) = 6.12
$Background$(%) = 41.7	$Background$(%) = 42.62	$Background$(%) = 50.01

J/ψ and ψ' Ratios for NH_3 Cell 2

2LAS + OTLAS
$[2.9\ GeV/c^2, 3.53 GeV/c^2]$
$J/\psi(\%)$ =91.78
J/ψ =19131
$[3.6 GeV/c^2, 3.95 GeV/c^2]$
$\psi'(\%)$ =48.74
J/ψ Contamination(%) = 10.36
$Background(\%)$ = 40.90

2LAS
$[2.9\ GeV/c^2, 3.53 GeV/c^2]$
$J/\psi(\%)$ =94.44
J/ψ =12292
$[3.6 GeV/c^2, 3.95 GeV/c^2]$
$\psi'(\%)$ =56.91
J/ψ Contamination(%) = 8.37
$Background(\%)$ = 34.72

OTLAS
$[2.9\ GeV/c^2, 3.53 GeV/c^2]$
$J/\psi(\%)$ =87.91
J/ψ =7684
$[3.6 GeV/c^2, 3.95 GeV/c^2]$
$\psi'(\%)$ =38.64
J/ψ Contamination(%) = 14.73
$Background(\%)$ = 46.63

J/ψ and ψ' Ratios for W

2LAS + OTLAS

$[2.55GeV/c^2, 3.6GeV/c^2]$
$J/\psi(\%)$ =85.18
J/ψ =42681

$[3.67GeV/c^2, 3.95GeV/c^2]$
$\psi'(\%)$ =22.46
J/ψ Contamination(%) = 59.34
$Background(\%)$ = 18.20

2LAS

$[2.77GeV/c^2, 3.6GeV/c^2]$
$J/\psi(\%)$ =90.81
J/ψ =25880

$[3.67GeV/c^2, 4.02GeV/c^2]$
$\psi'(\%)$ =28.37
J/ψ Contamination(%) = 53.38
$Background(\%)$ = 18.25

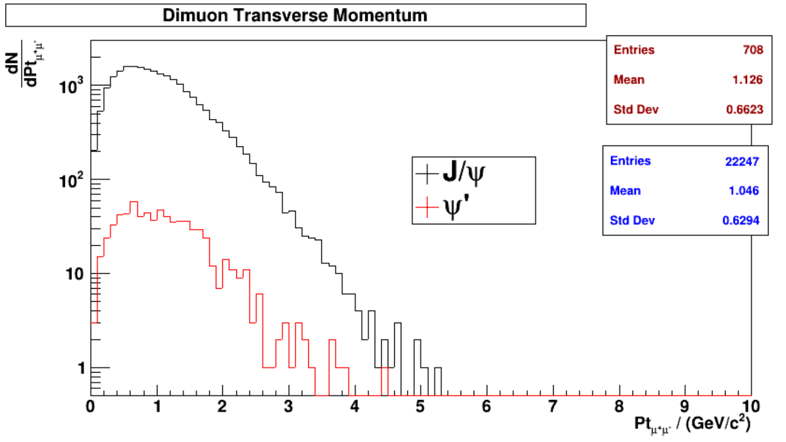
OTLAS

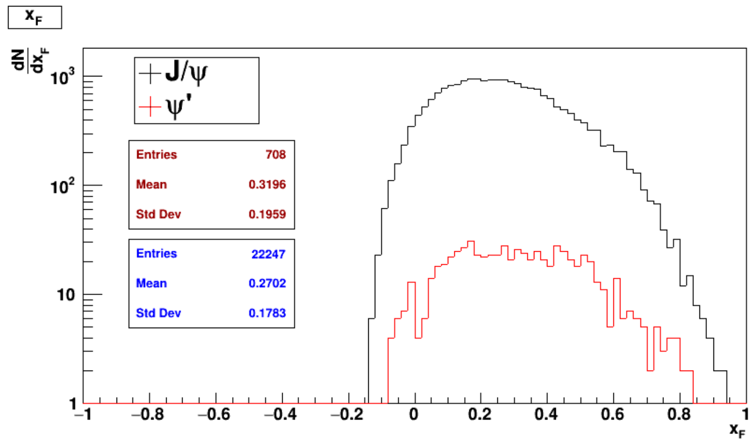
$[2.77GeV/c^2, 3.6GeV/c^2]$
$J/\psi(\%)$ =80.63
J/ψ = 19945

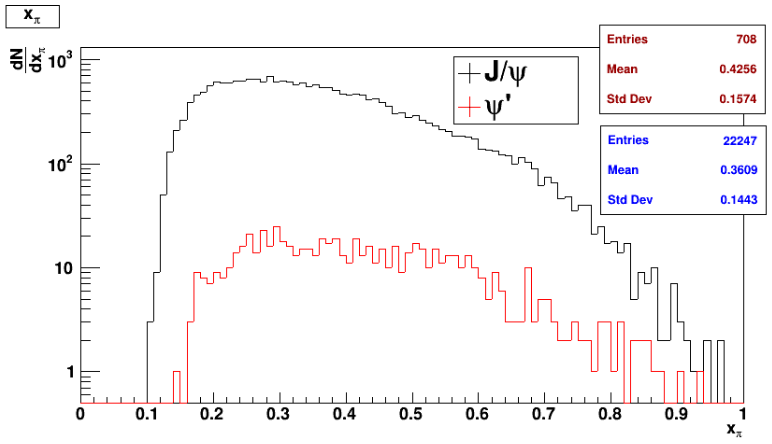
ψ Peak
The fit doesn't find ψ'

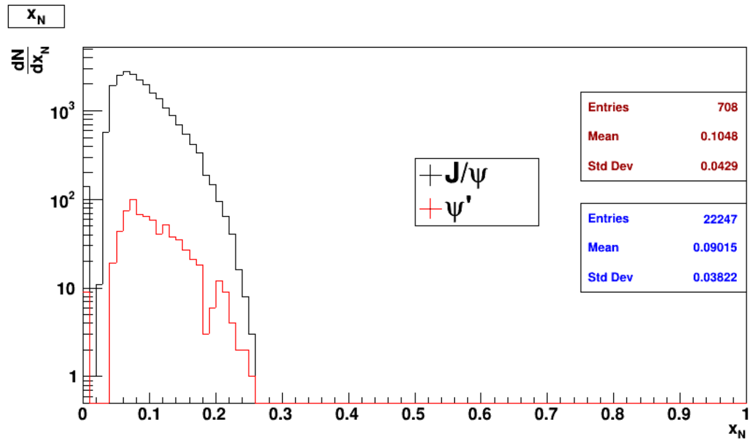
Kinematic Variables for NH_3 Cell 1

$M > 1.5\ GeV/c^2$



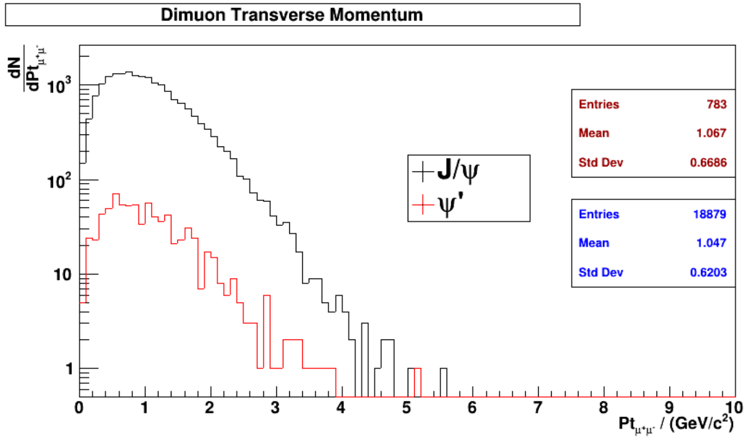


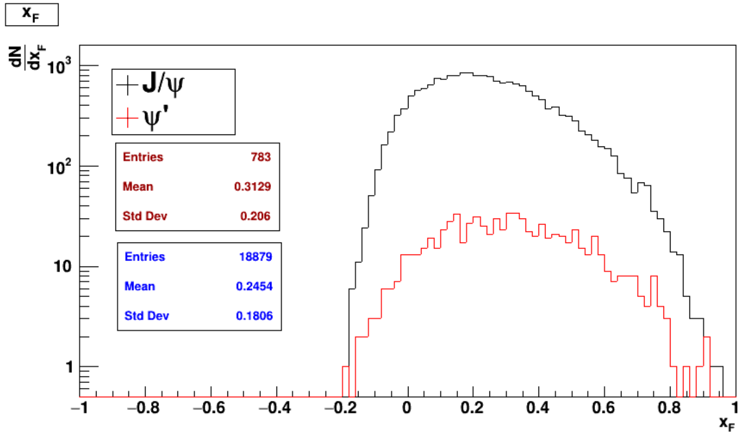


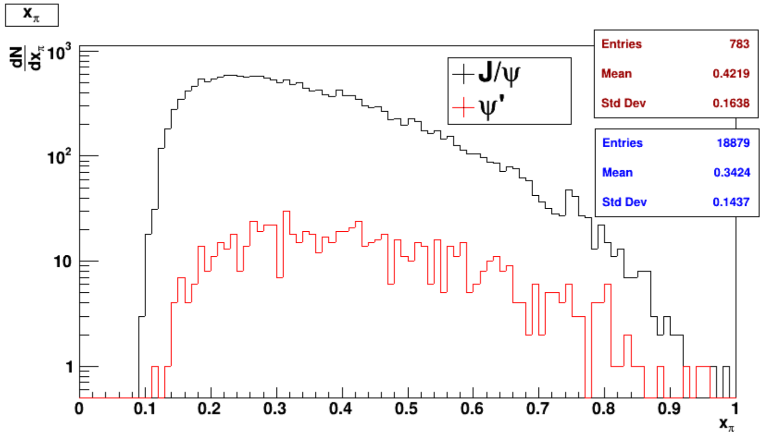


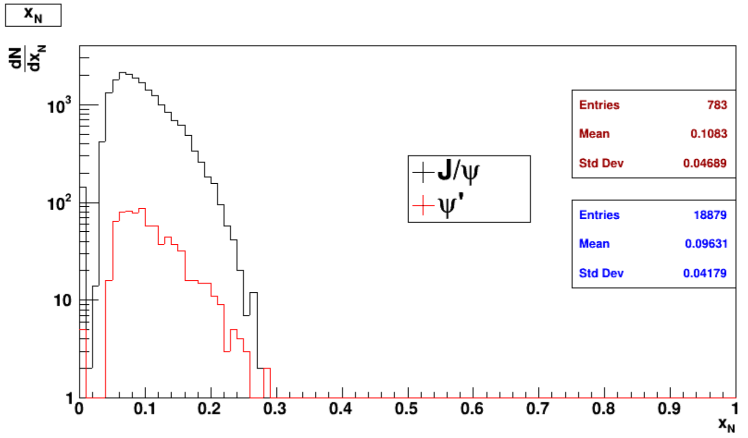
Kinematic Variables for NH_3 Cell 2

$M > 1.5\ GeV/c^2$



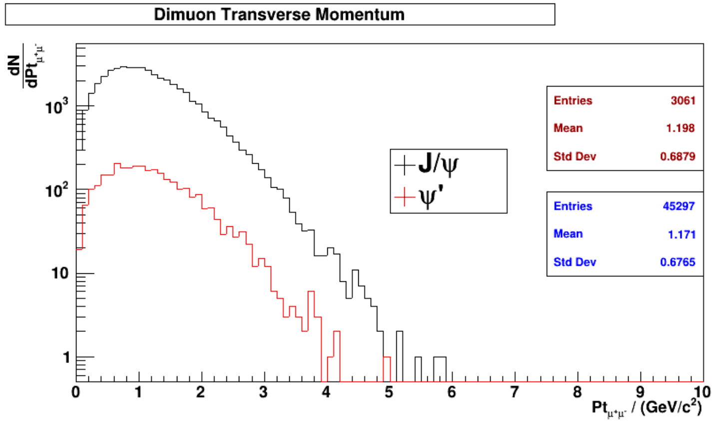


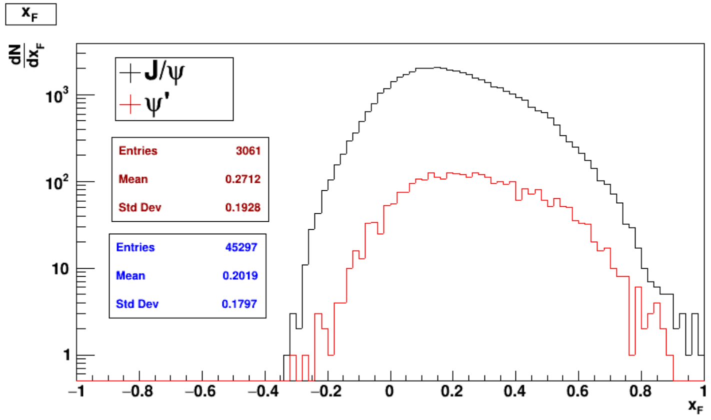


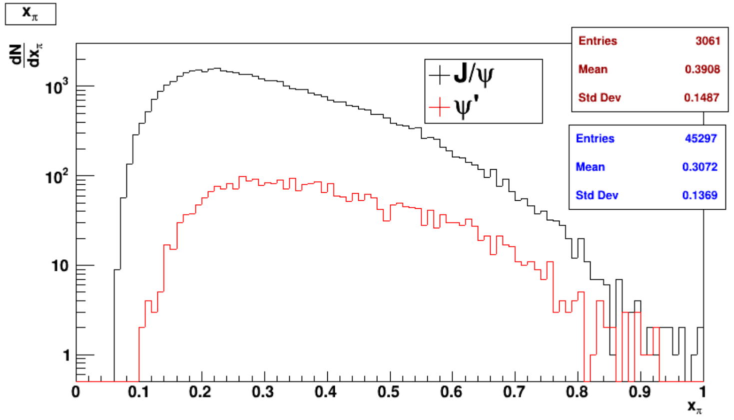


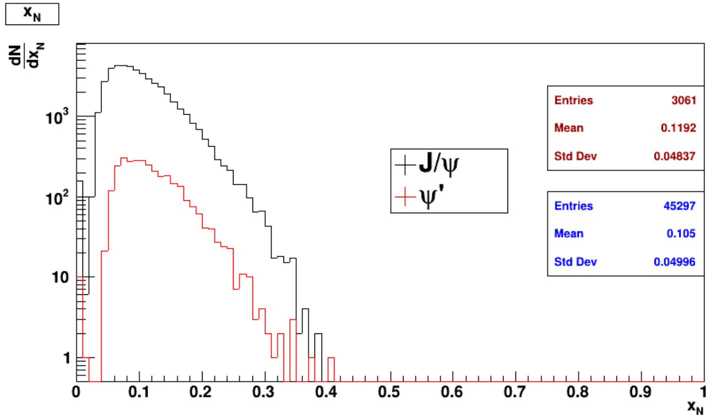
Kinematic Variables for W

$M > 1.5\, GeV/c^2$









Conclusions

- The J/ψ resonance can be observed in NH_3 target and W target in both trigger systems considered (2LAS and OTLAS);
- The ψ' resonance can be observed in NH_3 target in both trigger systems considered (2LAS and OTLAS), however ψ' can be observed in the W target, only by considering 2LAS;
- We cannot make rigorous conclusions from the comparison of the kinetic variables of J/ψ and ψ', considering the ratio of Background in the selected intervals is still too elevated to be neglected.