Stony Brook University

Center for Frontiers in Nuclear Science

Event reconstruction and background subtraction for elastic J/ψ production

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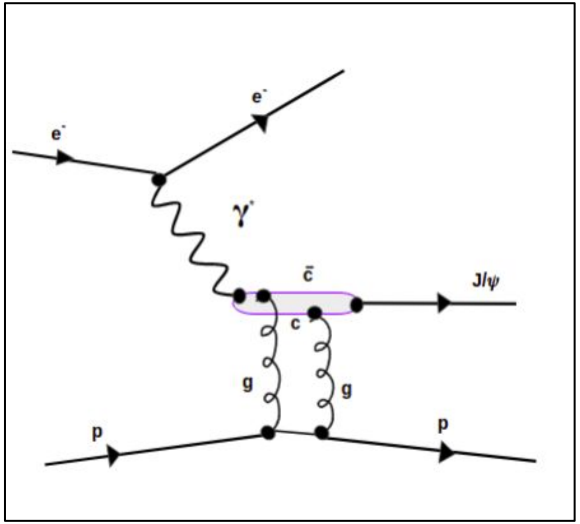
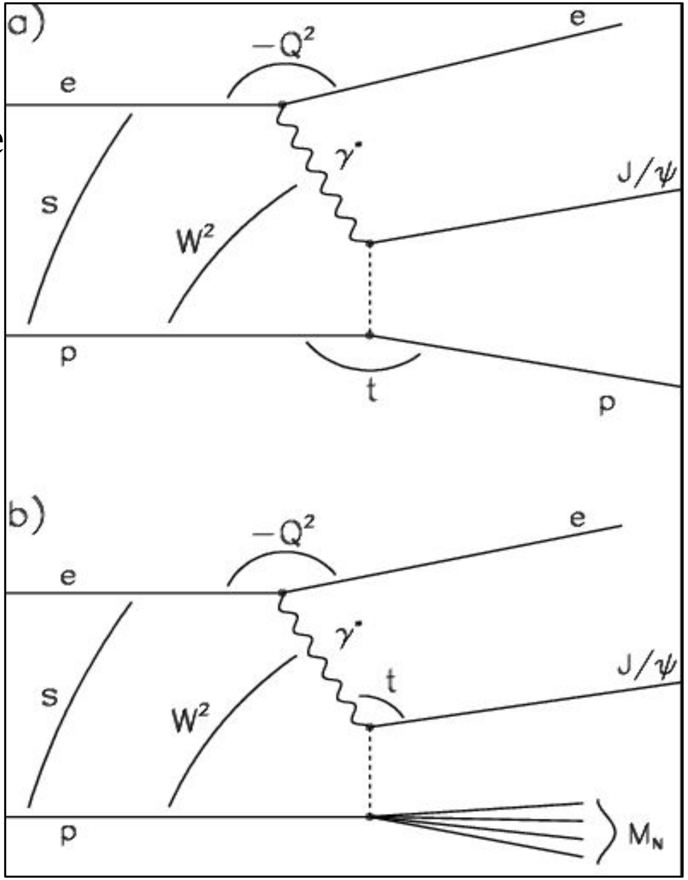
Diffractive Deep Inelastic Scattering



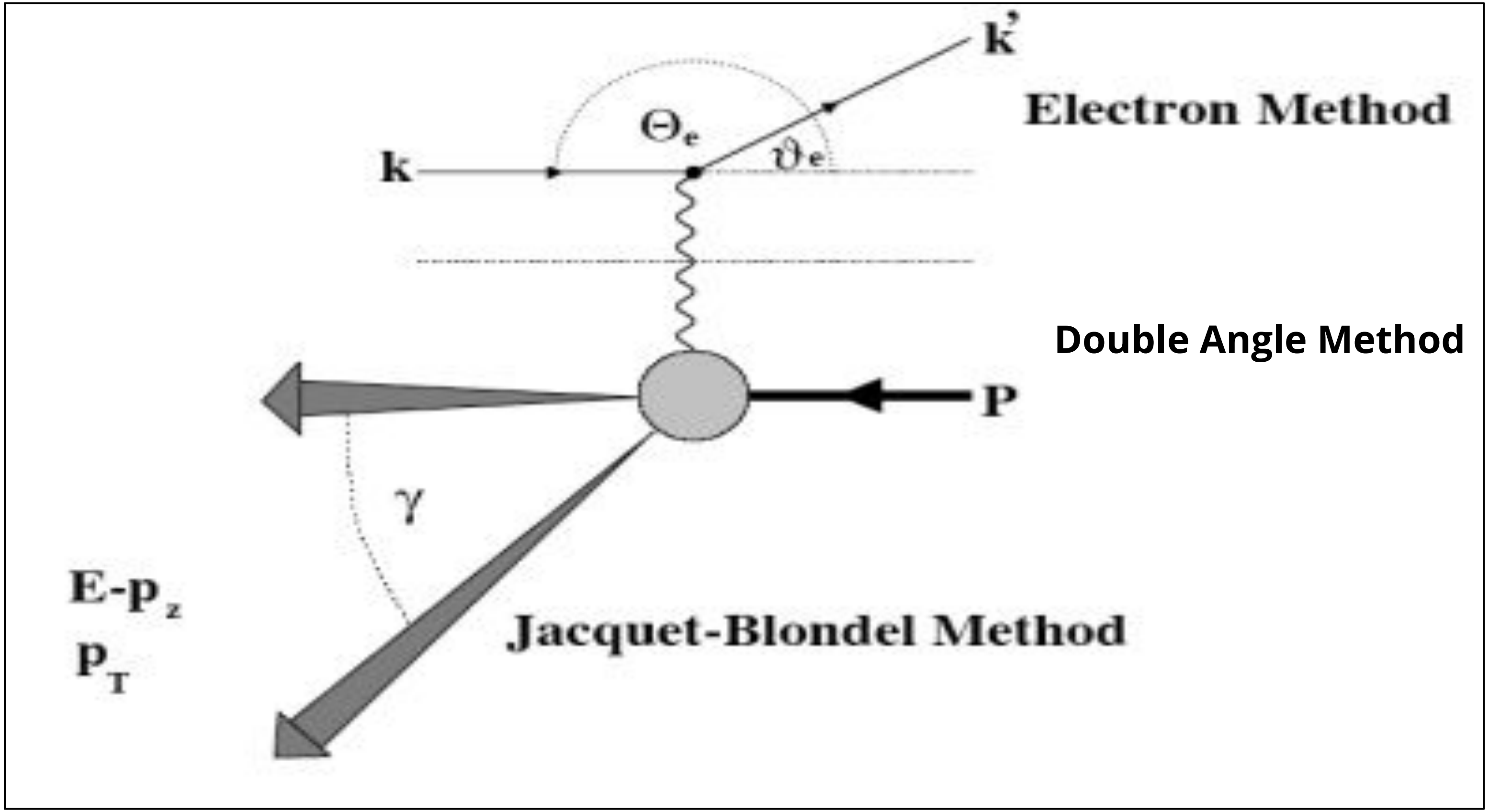
- Colorless gluon exchange
- Experimentally clean
- Sartre event generator



In today's talk:

- Kinematic reconstruction
- Background studies
- Discussion on detector constraints

Event Kinematic Reconstruction Methods



https://arxiv.org/pdf/hep-ex/9903037.pdf

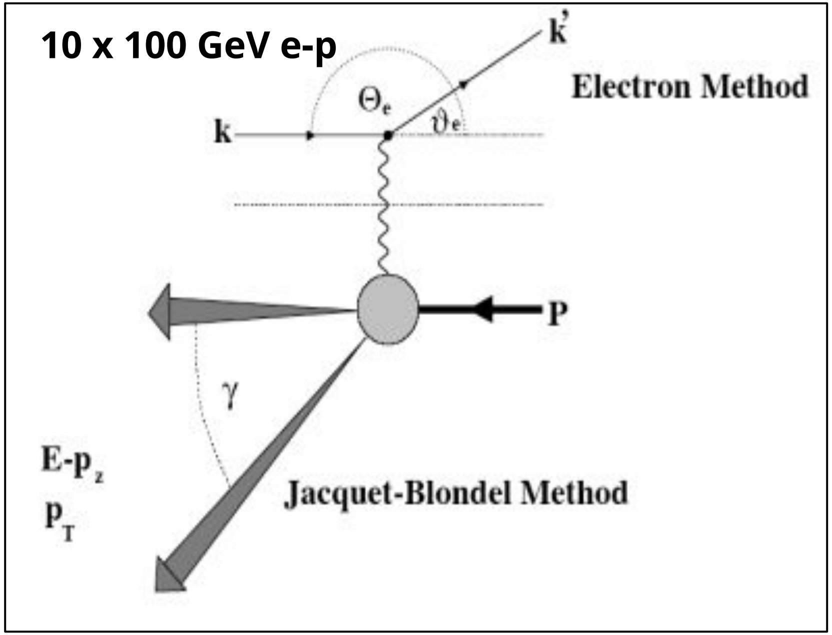
Scattered Electron Method

- E_e' and θ_e are measured to give the following variables:

$$Q_e^2 = -q^2 = 4\, E_e E_e' \cos^2 \theta_e/2$$

$$y_e = \frac{Pq}{Pk} = 1 - \frac{Pk'}{Pk} = 1 - \frac{E_e'}{2E_e}(1 - \cos\theta_e).$$

$$Q_e^2 = s.\, x_e\, .y_e$$

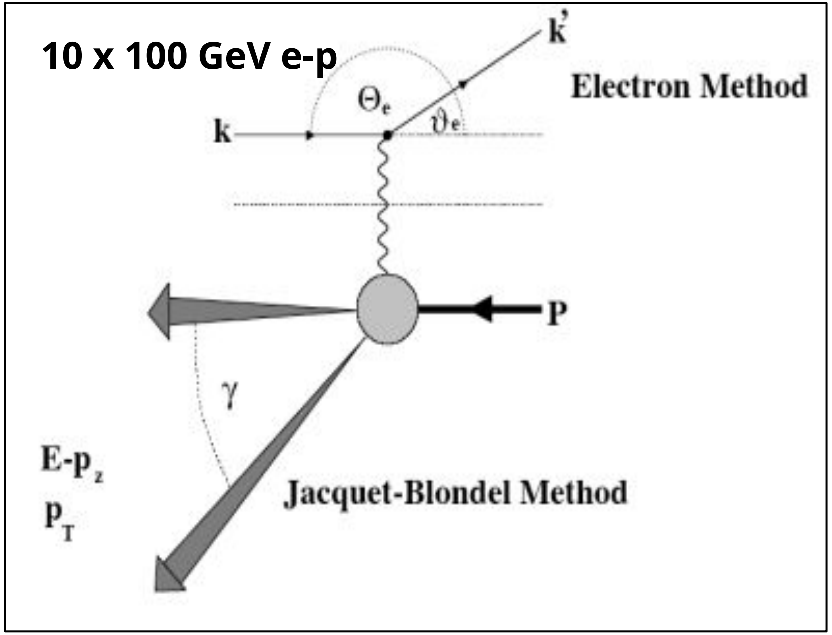


Jacquet Blondel Method

- The following equations can be derived using the energy conservation laws from the hadronic final state

$$y_h = \frac{\Sigma_h}{2E_e} \qquad Q_h^2 = \frac{p_{t,h}^2}{1 - y_h},$$

$$\Sigma_h = \sum_i (E_i - p_{z,i})$$



- VM reconstructed using the smeared lepton pair
    - When proton is detected, two final state hadrons used for reconstruction

Double Angle Method

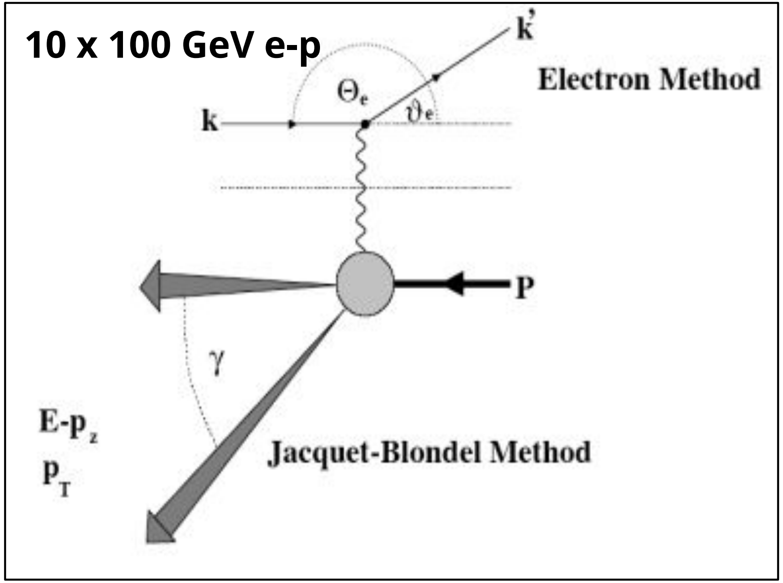
- Measuring the electron scattering angle θ_e and the effective angle γ_H of the final hadronic system give the following equations for x, Q^2 and y

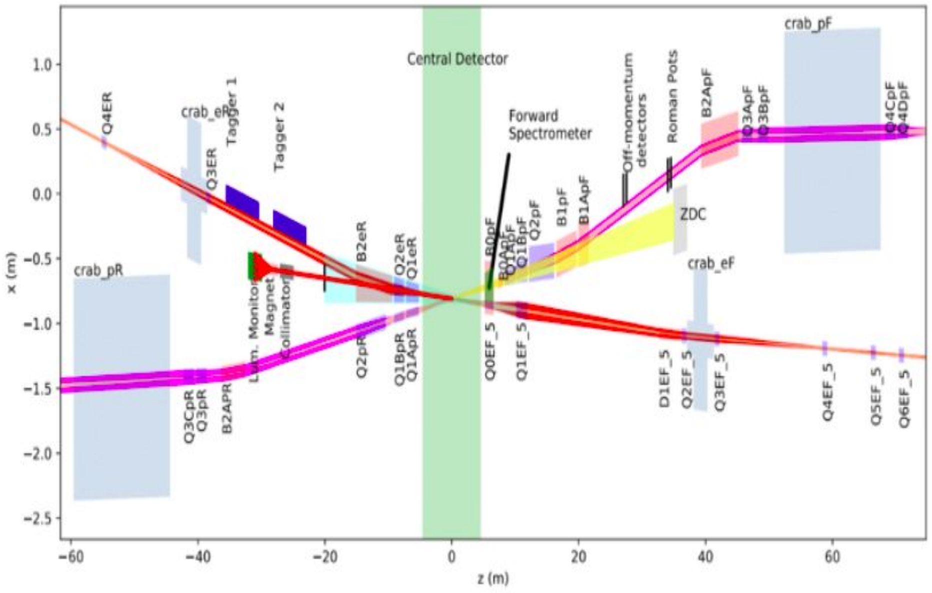
$$Q^2_{DA} = 4E^2_{e,beam}\frac{\sin\gamma_H(1+\cos\theta_e)}{\sin\gamma_H+\sin\theta_e-\sin(\theta_e+\gamma_H)}$$

$$y_{DA} = \frac{\sin\theta_e(1-\cos\gamma_H)}{\sin\gamma_H+\sin\theta_e-\sin(\theta_e+\gamma_H)}$$

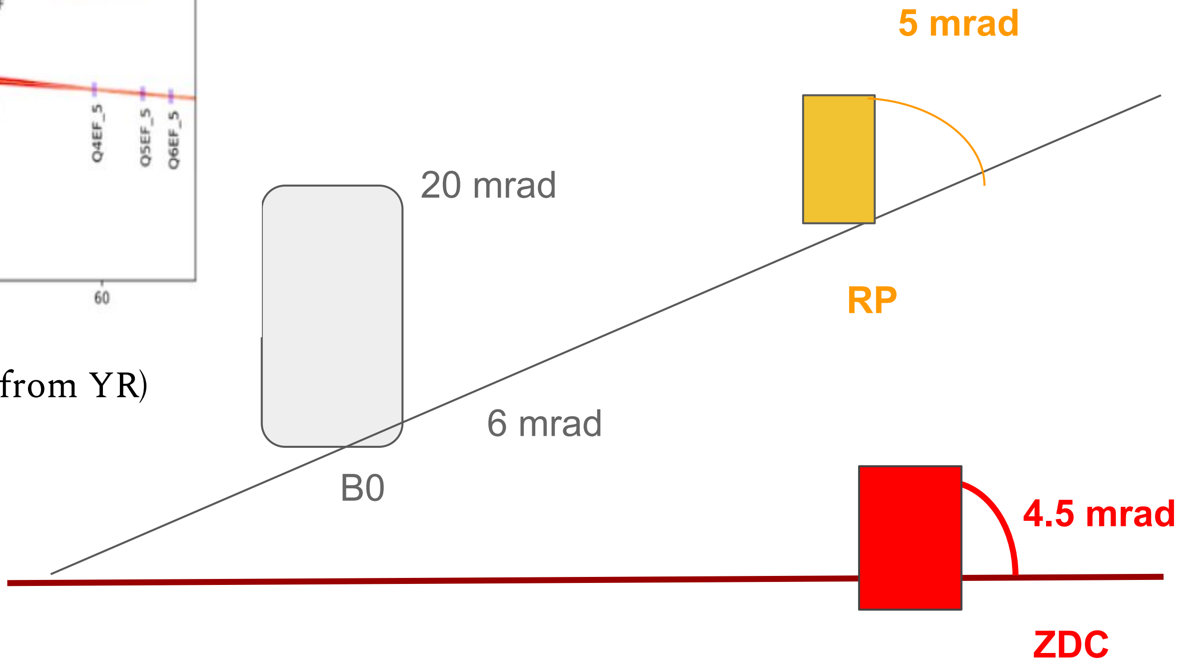
$$x_{DA} = \frac{Q^2}{ys}$$

- VM reconstructed using the smeared lepton pair
  - When proton is detected, two final state hadrons used for reconstruction





The full EIC baseline IR layout (taken from YR)



Gaussian fitted to the percentage difference in the reconstructed variables from the true value

Generated range: $1 < Q^2 < 20$ GeV^2

	Sigma of the fitted gaussian with mean 0		
	x	Q2	y
Electron Method	5.036	1.3	3.291
JB method without proton	43.19	42.219	3.185
JB method with proton	3.699	2.443	3.177
DA method without proton	25.647	4.259	16.858
DA method with proton	3.738	1.196	2.49

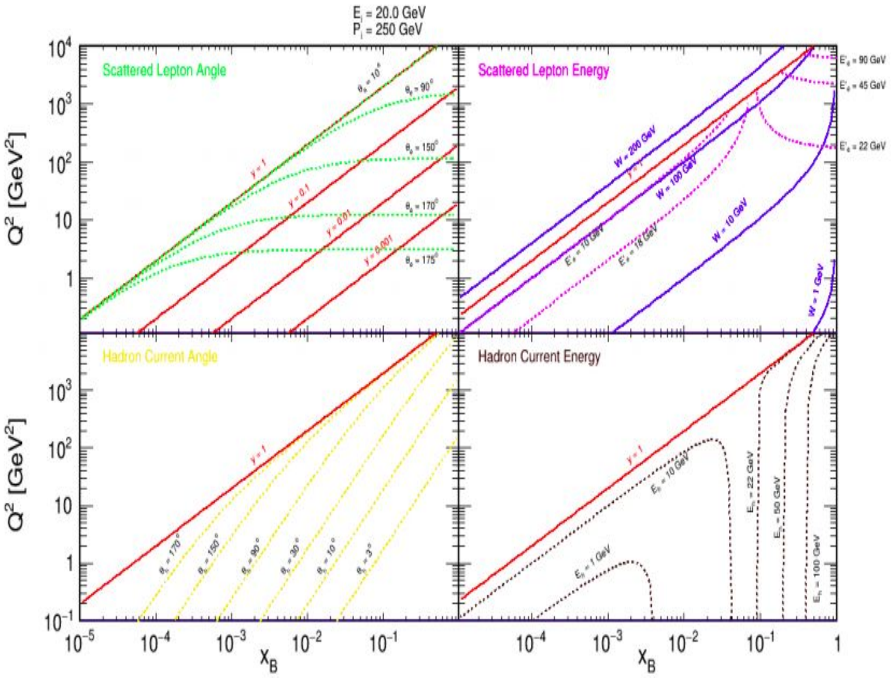
	t reconstruction using VM	t reconstruction using pOut
sigma of the fitted gaussian with mean 0	5.619	6.301

- **Reconstruct Pt of VM using the decay leptons**
- **Reconstruct Pt of the scattered electron**
- $$t \simeq -(\vec{p}_{t,\psi} + \vec{p}_{t,e})^2$$

- **Reconstruct four momenta of outgoing proton if detected**
- $$t \simeq (p_f - p_i)^2$$

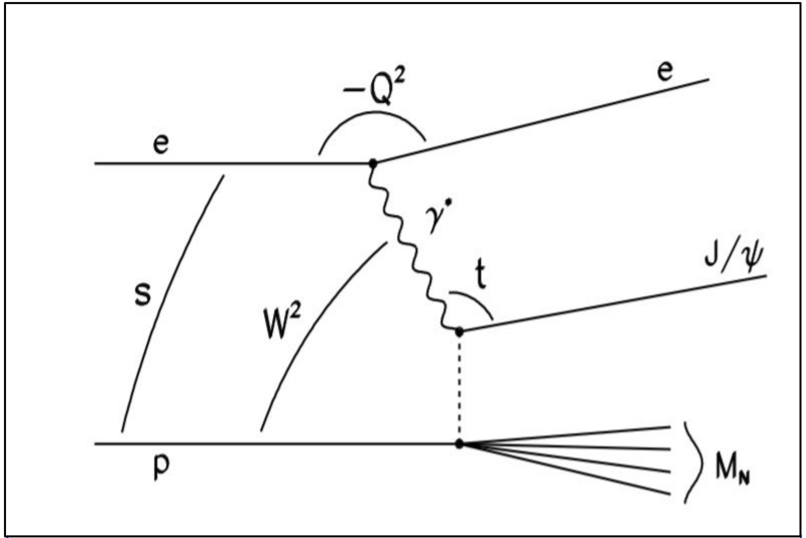
Observations

1. **Electron method** is highly correlated with the true value -**ideal at larger y** while **hadronic methods at lower y**.
2. At **lower Q^2**, very low fraction of scattered electrons get detected. Hence, rely on **JB method** resolution
3. Including the **outgoing proton** as a part of the hadronic final state, improves the accuracy of reconstruction using **JB and DA methods** to a fair amount.
4. In hadronic methods, while **JB method** gives a better reconstruction in **y**, **DA method** provides better Q^2 reconstruction in all kinematic regimes



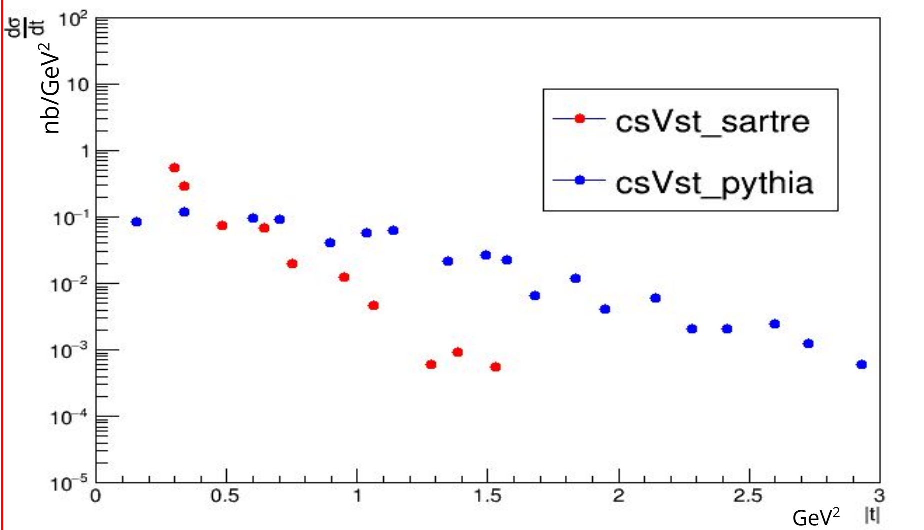
Athira Vijayakumar, CFNS

Background Analysis



Process 93 events in Pythia6

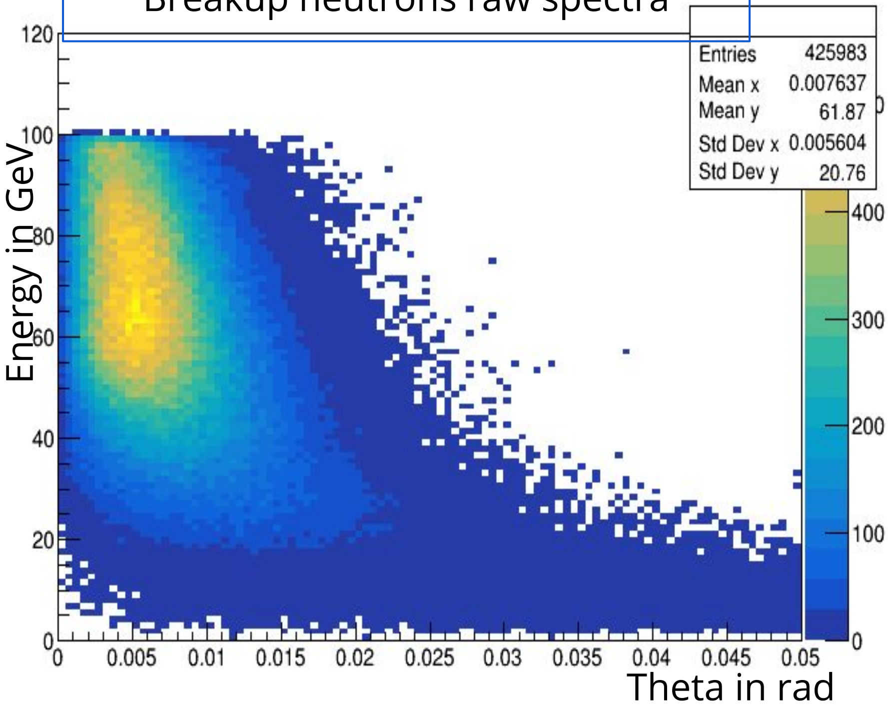
Pythia breakup events as background



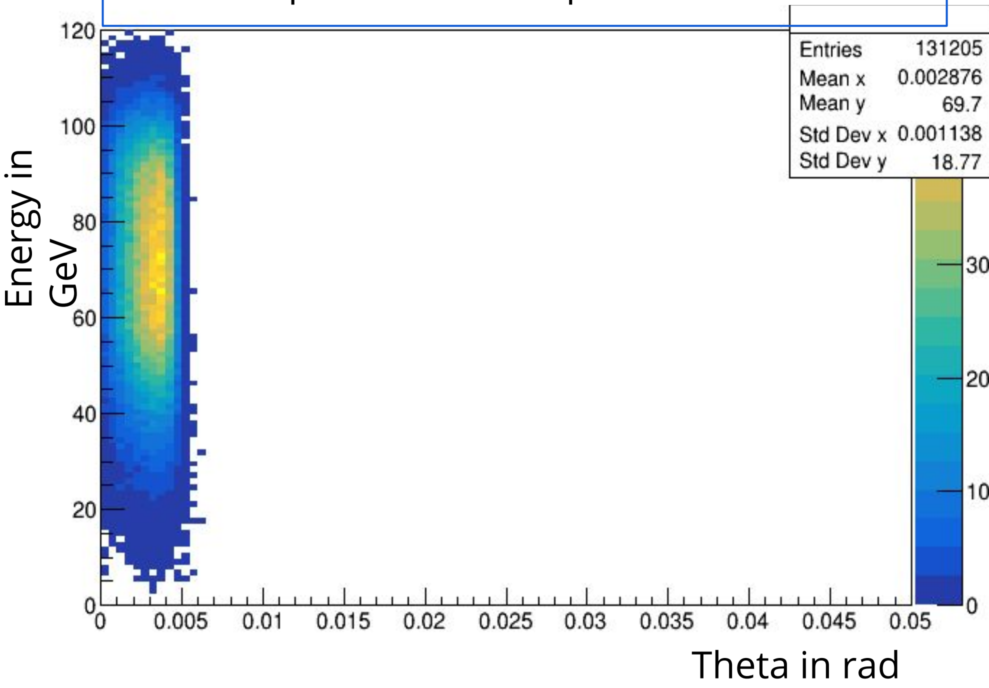
Anticipations :-

- Detecting neutrons/photons
- Detecting protons
- Detecting pions/kaons

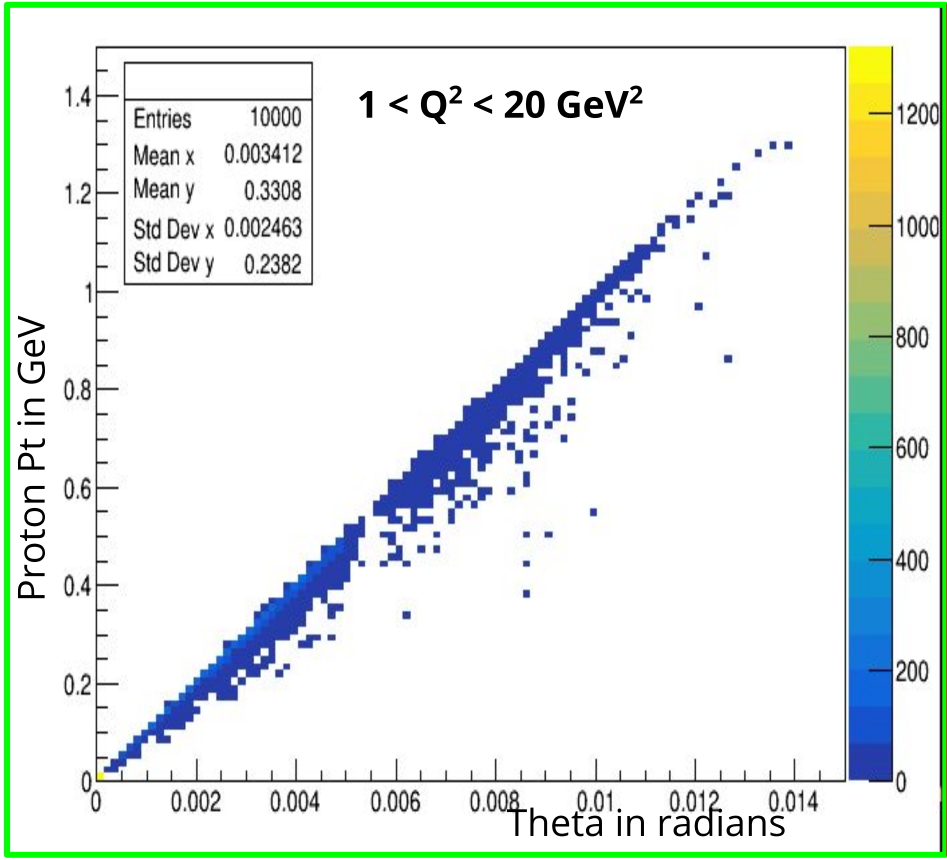
Breakup neutrons raw spectra

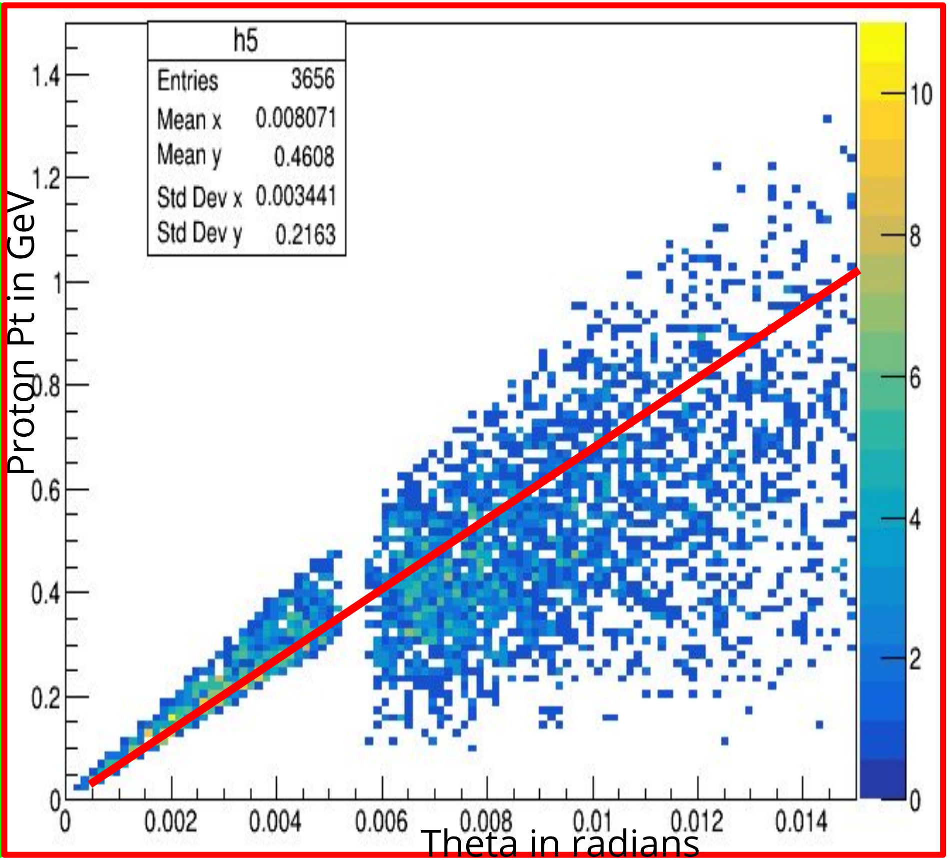


Breakup neutrons accepted and smeared



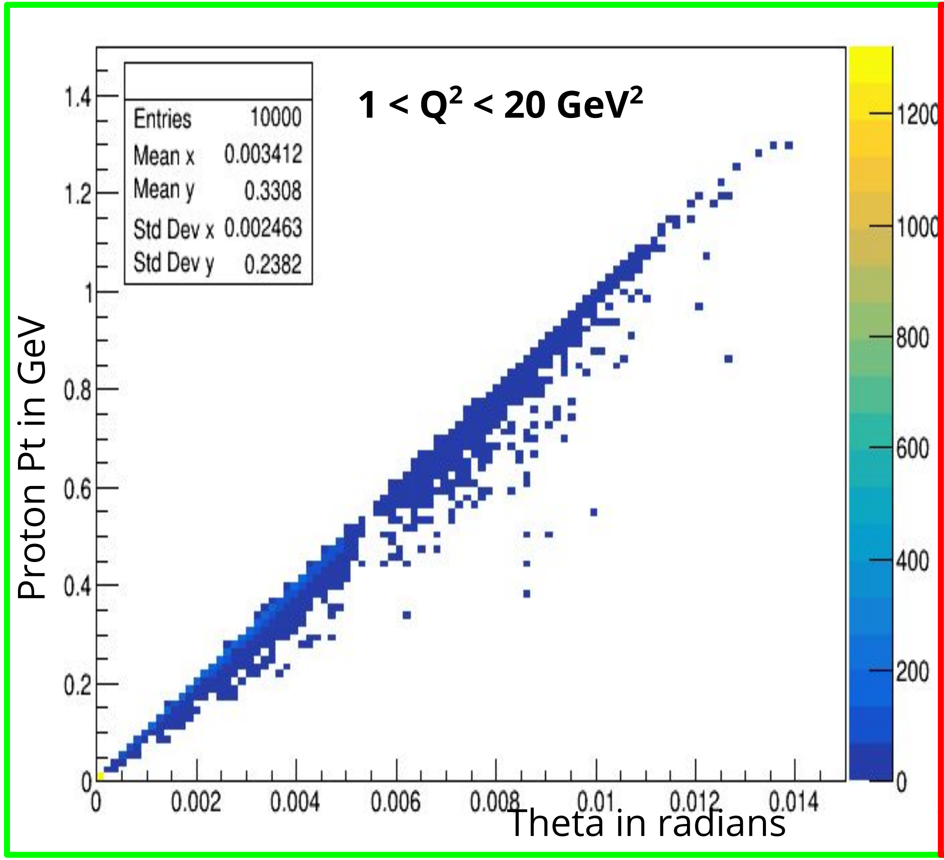
A large fraction of neutrons go undetected



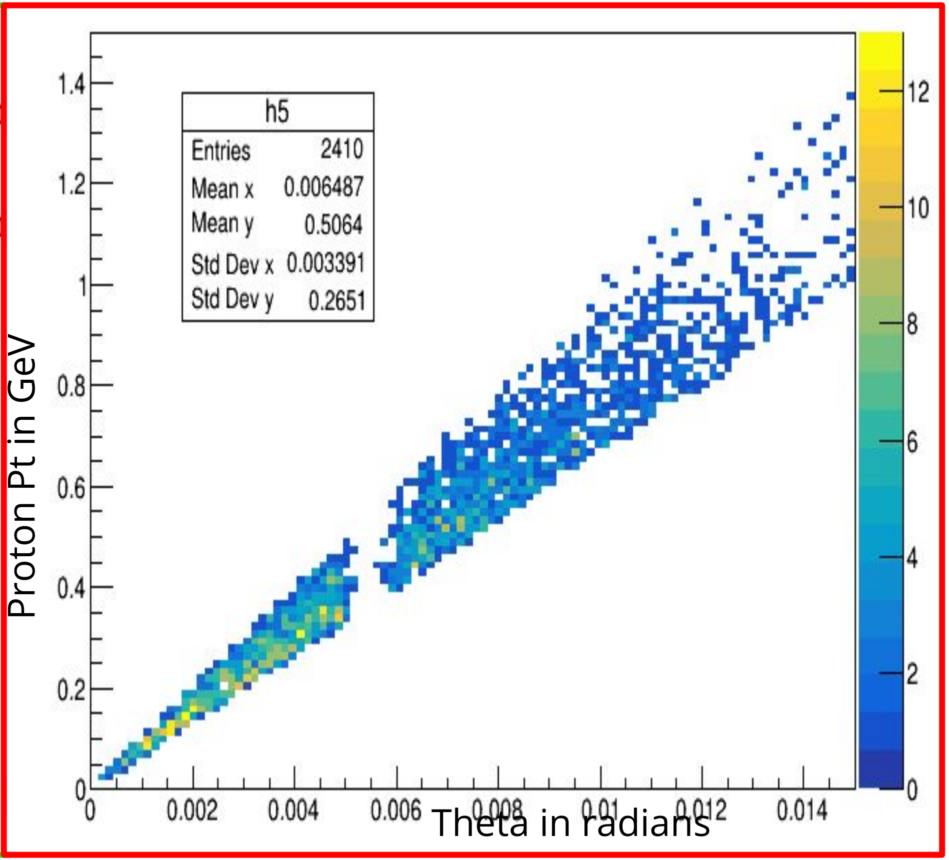


Elastic events generated using Sartre after smearing

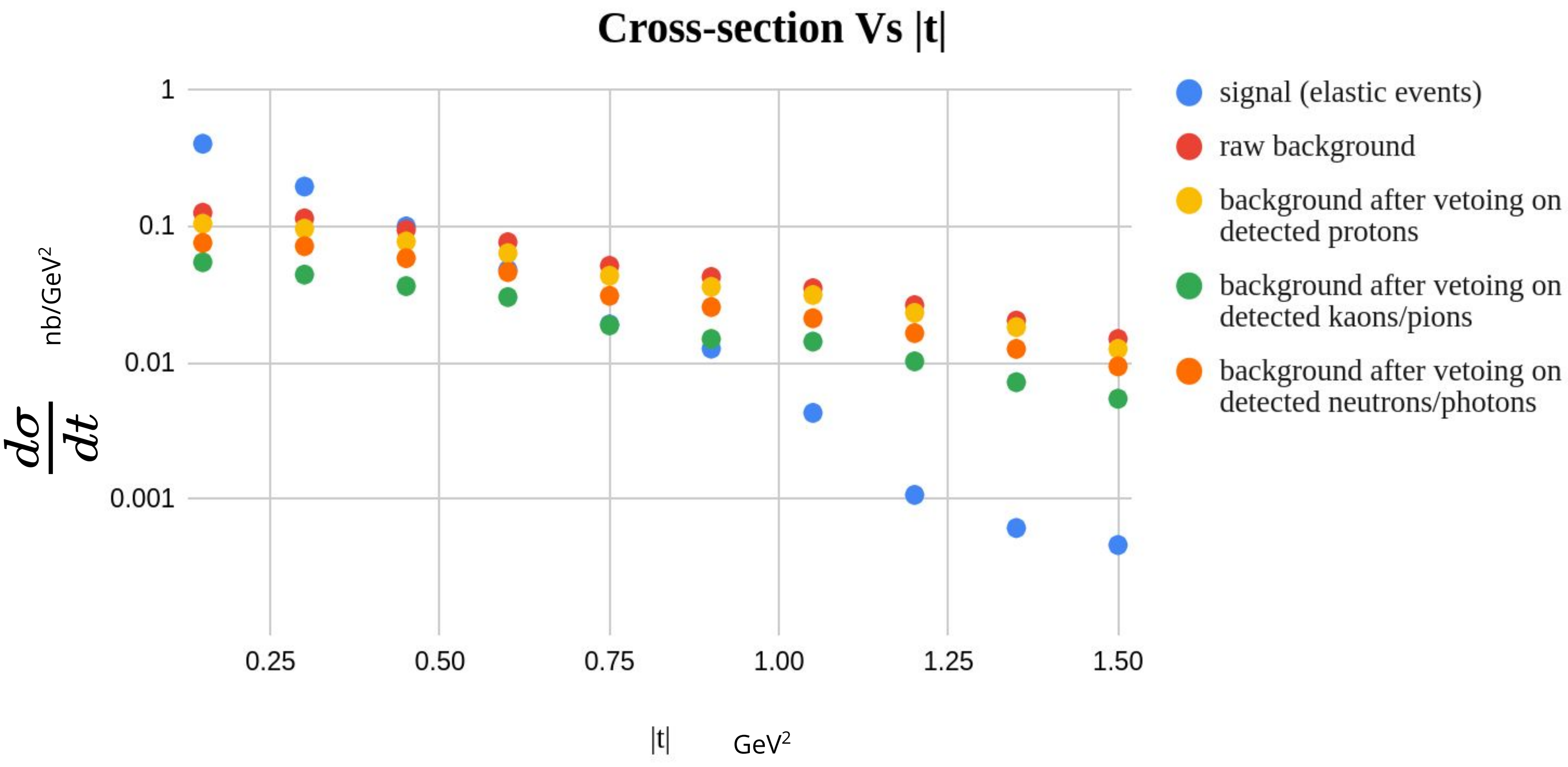
Breakup events after smearing



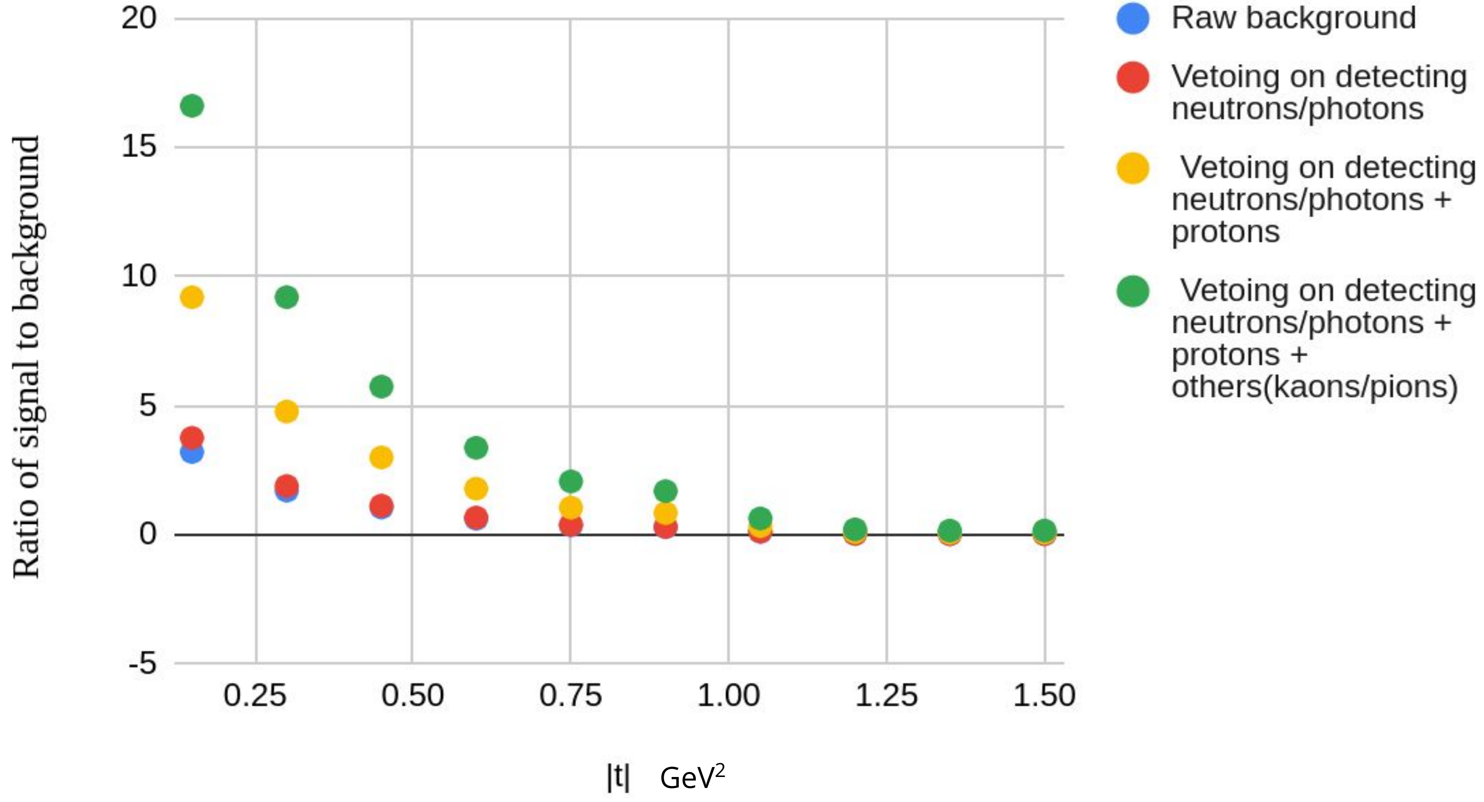
Elastic events generated using Sartre after smearing



Breakup events after smearing


Cross-section Vs |t|
1
0.1
0.01
0.001
0.25
0.50
0.75
1.00
1.25
1.50
|t|
GeV2
nb/GeV2
$\frac{d\sigma}{dt}$
signal (elastic events)
raw background
background after vetoing on detected protons
background after vetoing on detected kaons/pions
background after vetoing on detected neutrons/photons

Cross-section ratio Vs |t|



Summary

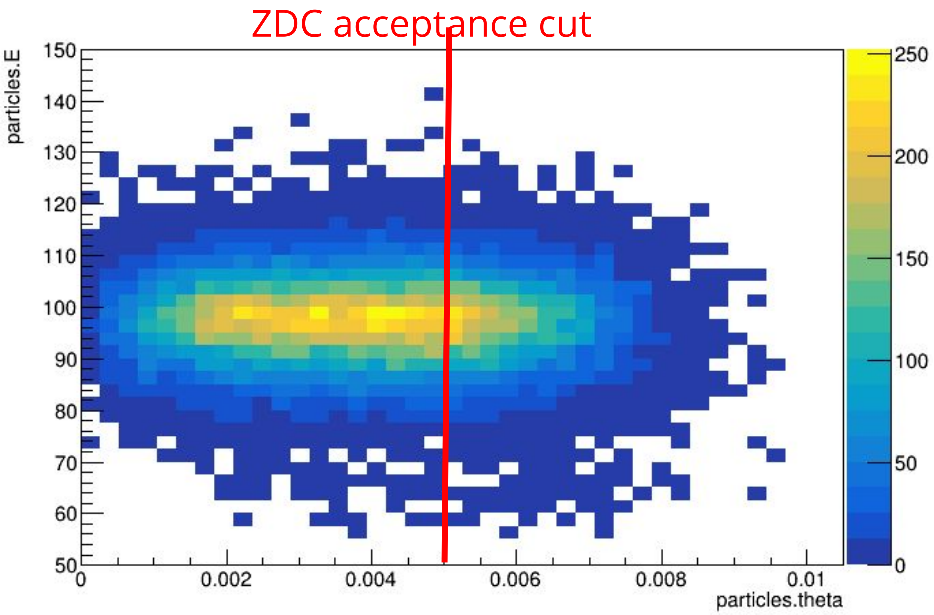
- The main background for the elastic processes is breakup events, **lower signal to background ratio at larger |t|**
- The existing IR design has **ZDC** with acceptance upto ~5 mrad -- a big fraction of **breakup neutrons go undetected** -- can't veto background
- The transverse momentum distribution of a huge fraction of **detected protons after breakup follow similar trend** as in elastic J/ψ processes -- **not** a good method to veto the background
- **Charged pions and kaons** detected in the **B0 zone** provide a major contribution to reject the background

e-Au 10x100 GeV - diffractive J/ψ production

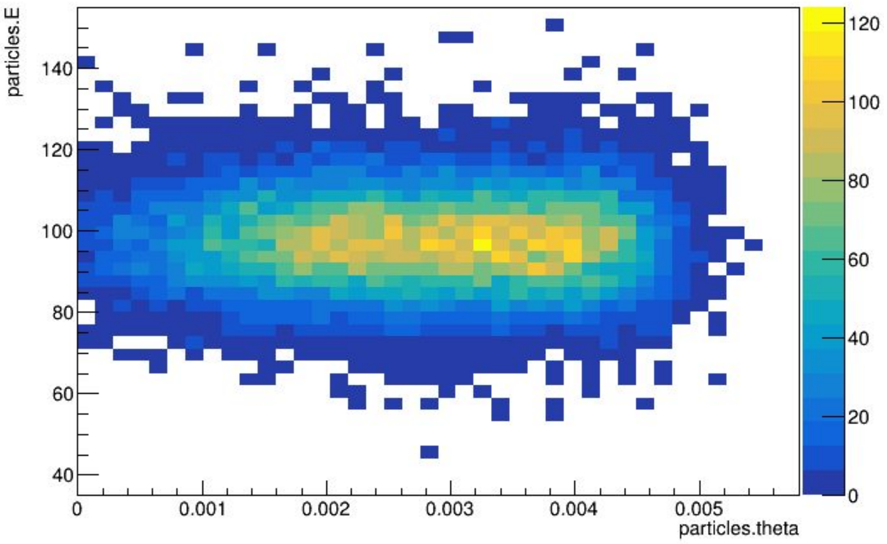
- Generated **coherent (signal)** e-Au diffractive J/ψ events using Sartre
- Generated **incoherent breakup (background)** e-Au diffractive events using Sartre
    - Breakup done using GEMINI
- Passed the events through the EIC-smear package with the far forward components
- Analysed how to veto the incoherent events

e-Au 10x100 GeV - diffractive J/ψ production

Neutron Energy Vs Theta



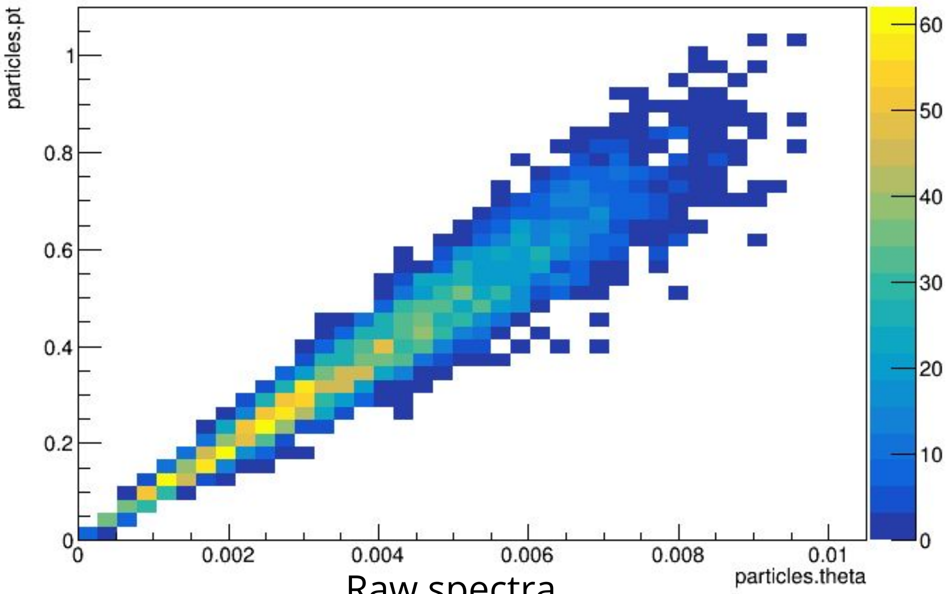
Raw spectra



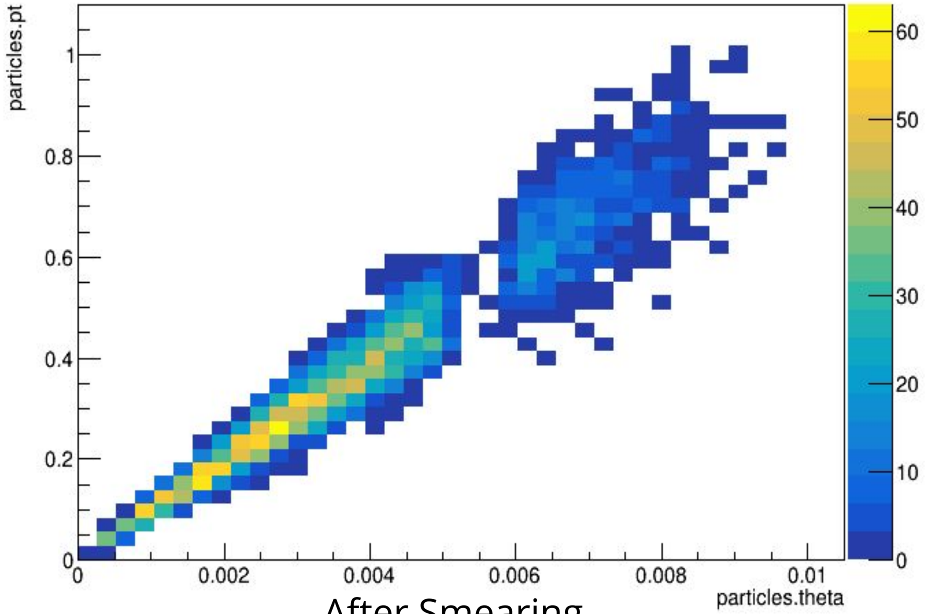
After Smearing

e-Au 10x100 GeV - diffractive J/ψ production

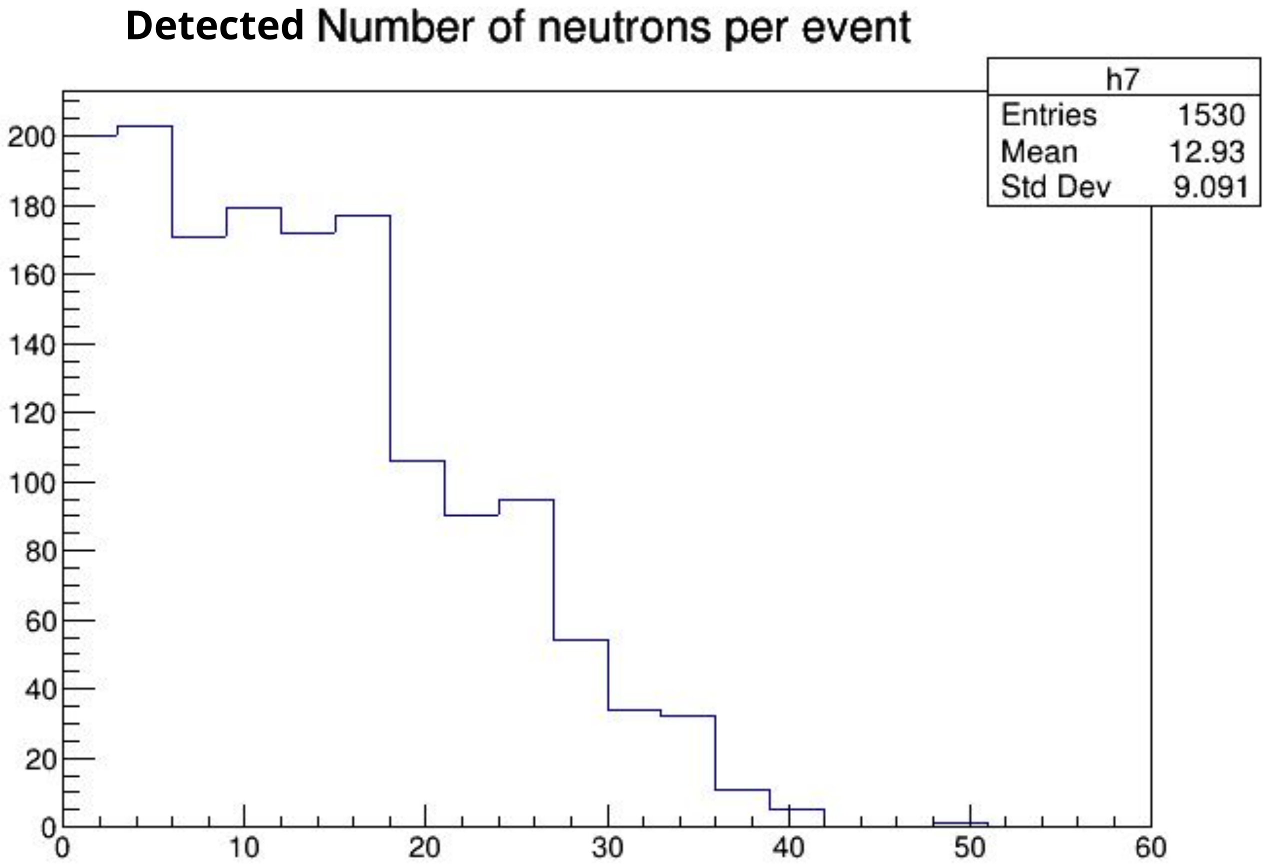
Proton Pt Vs Theta



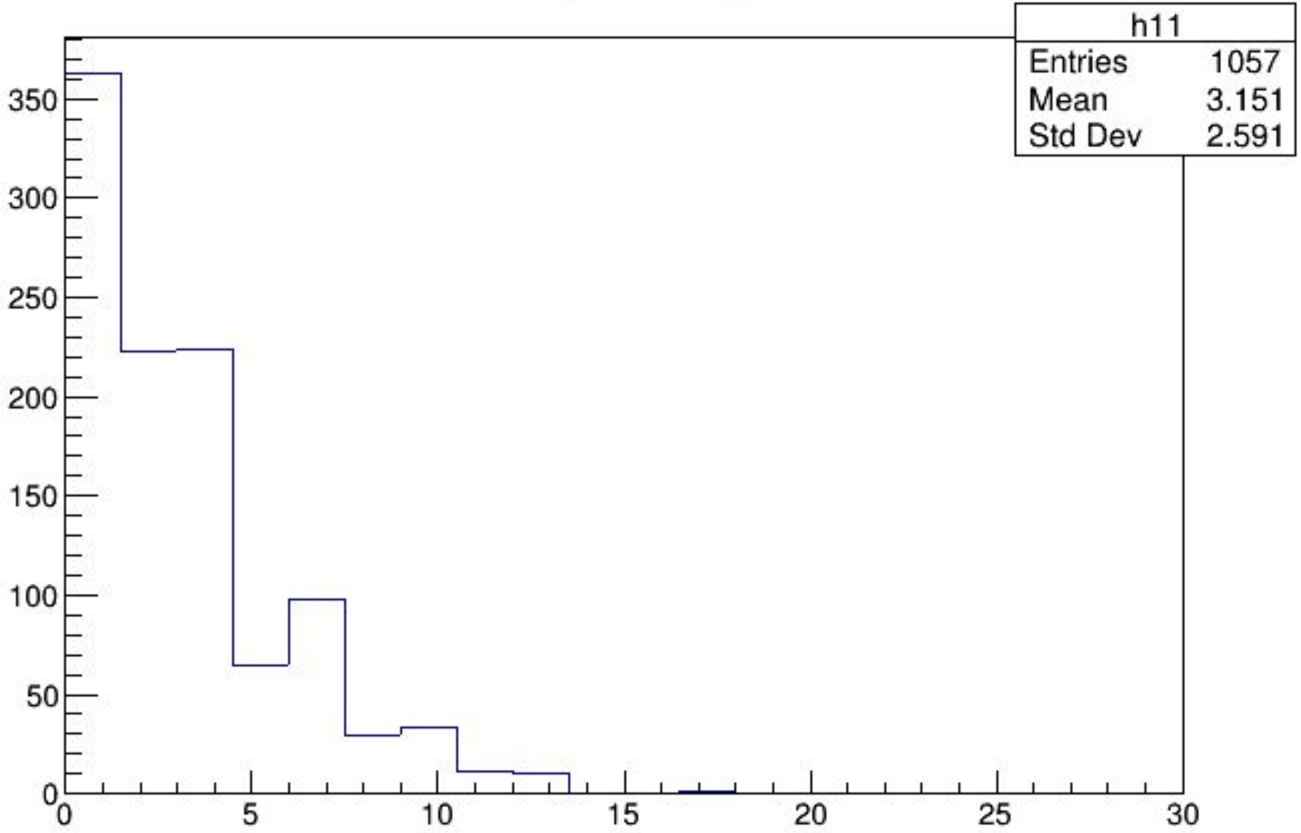
Raw spectra



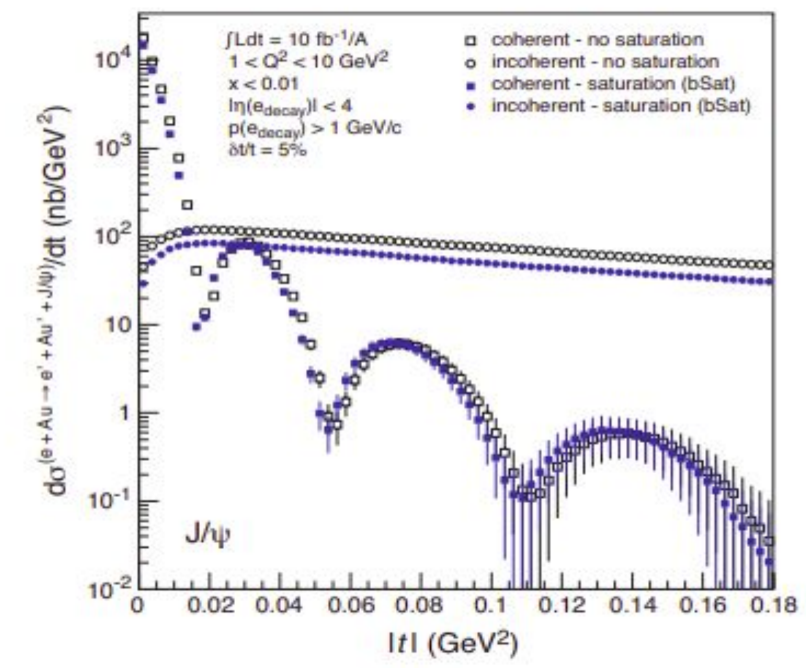
After Smearing

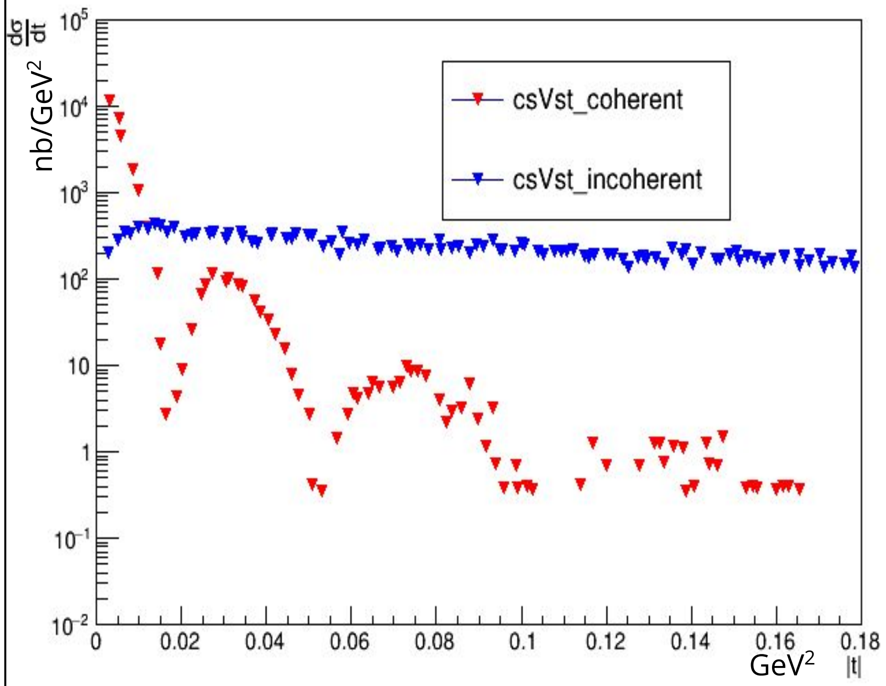

Detected Number of neutrons per event
h7
Entries 1530
Mean 12.93
Std Dev 9.091
0
20
40
60
80
100
120
140
160
180
200
0
10
20
30
40
50
60

Detected Number of protons per event

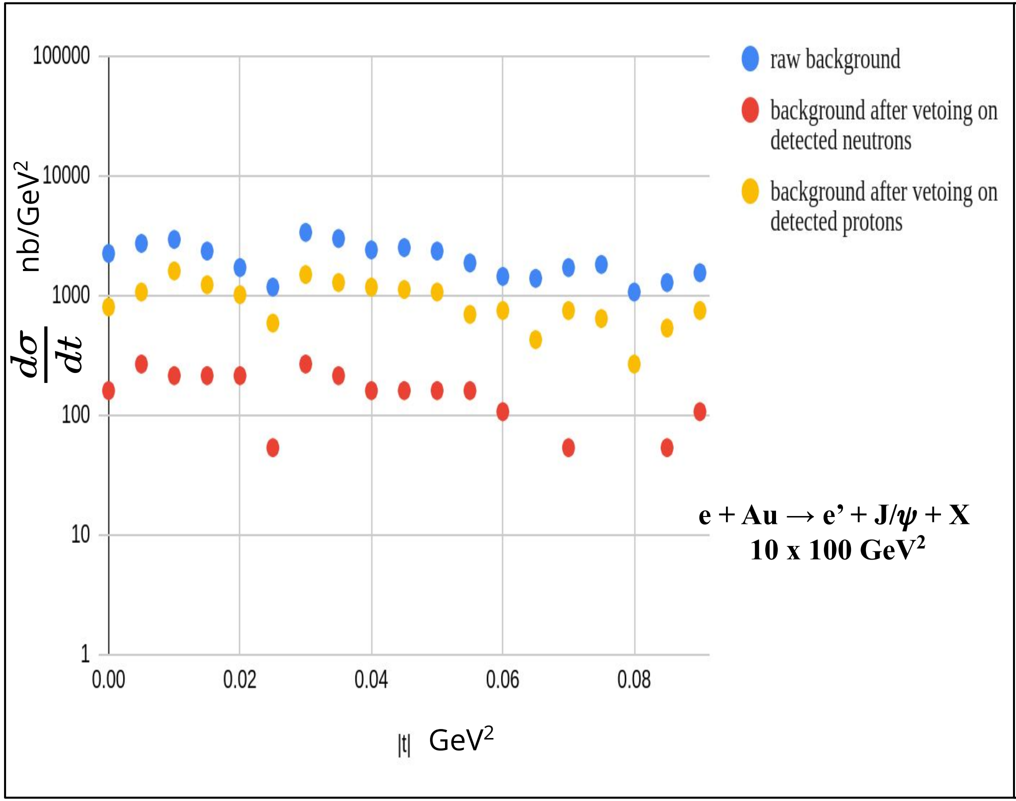


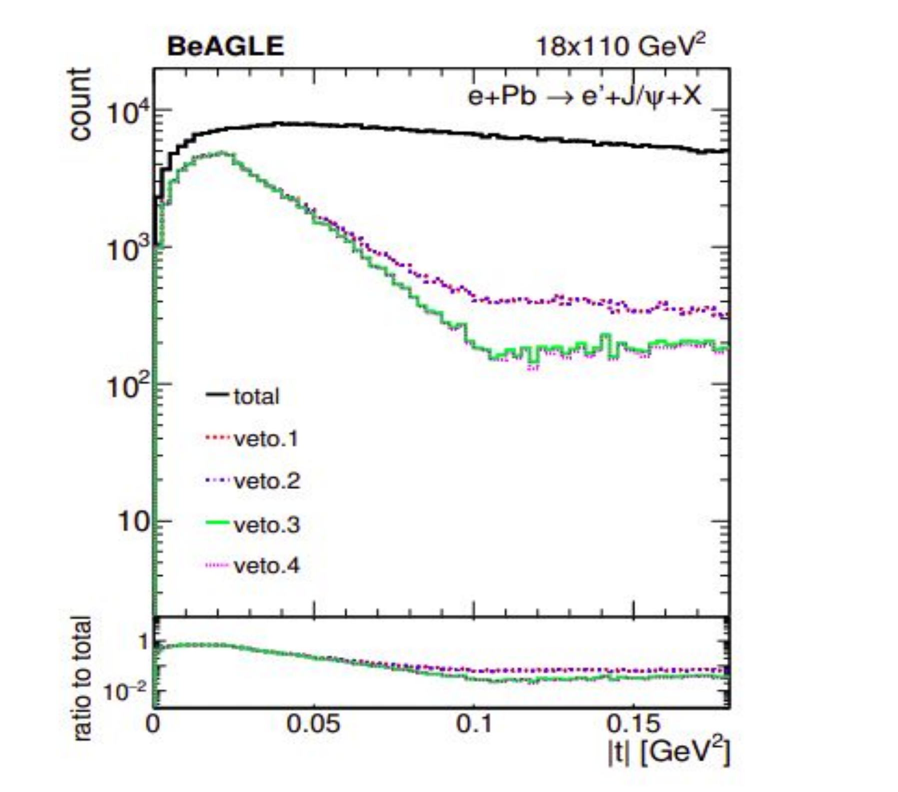
Comparison with the White Paper plot





The same cuts have been applied





Assuming a 30% efficiency for the ZDC

From YR

Outlook

- All of the studies were done using EIC-smear fast smearing package with Far forward detector Implementation - No beam effects
- Assumed 30% efficiency for the ZDC
- We would like to repeat these studies using the ATHENA + IR6 full simulation
- Differences in the nuclear breakup in Sartre and BeAGLE
    - The entire nucleus absorbs the four momentum exchange that leads GEMINI to explode the nucleus in Sartre
    - In BeAGLE, the interaction is assumed to happen on one nucleon