Exclusivity for Spectroscopy

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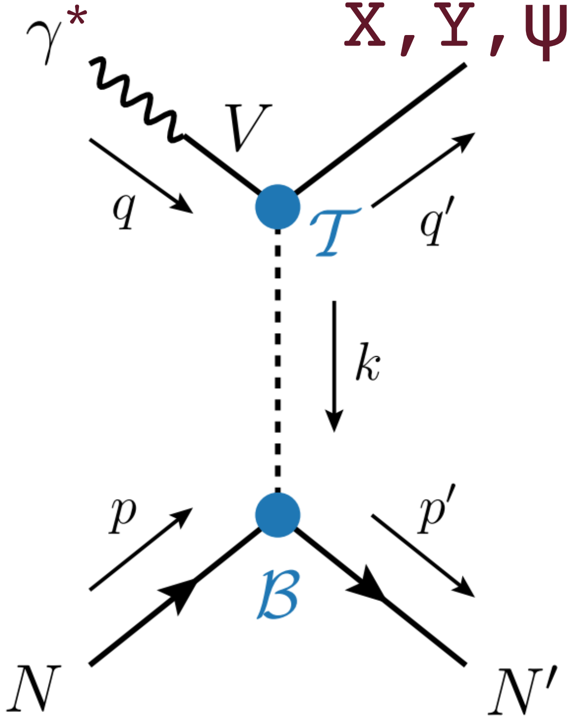
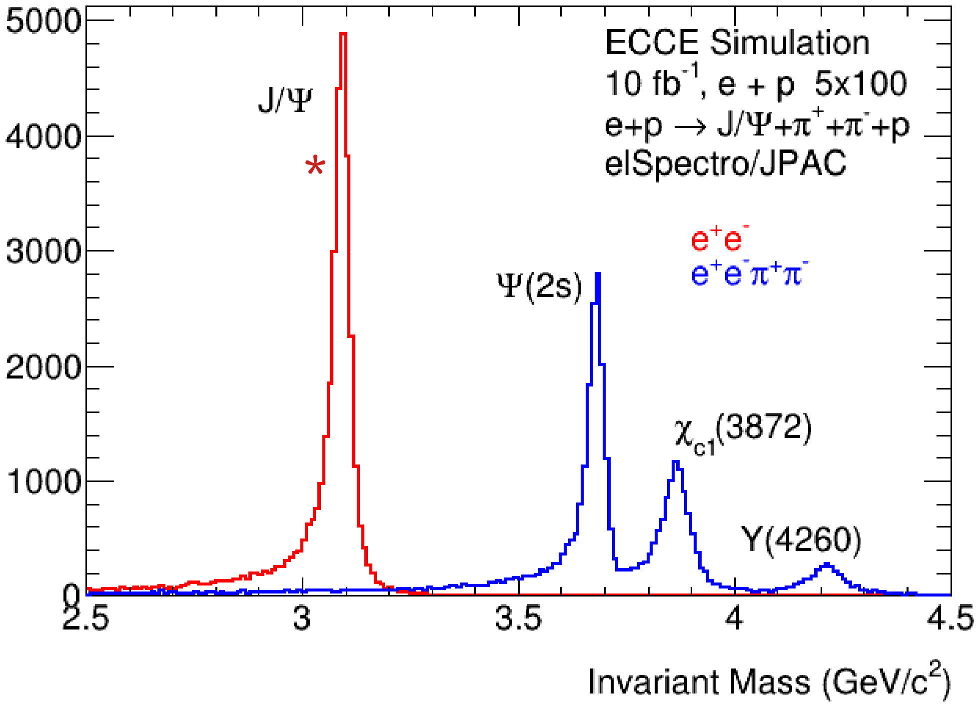
ECCE Spectroscopy Simulations

Meson → J/ψ (e^+e^-) $\pi^+\pi^-$

X,Y,ψ(2s)



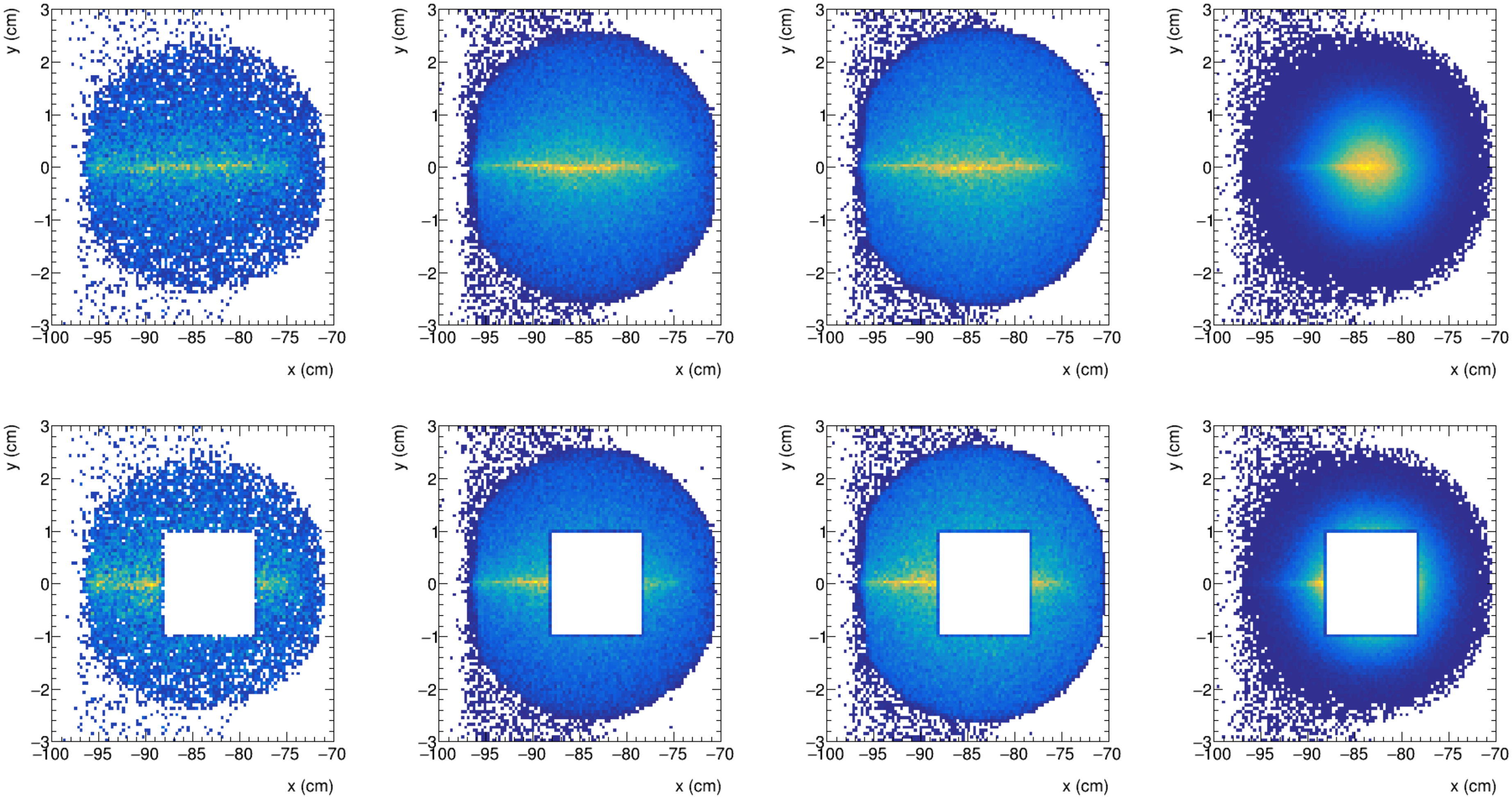
ecce-note-phys-2021-12



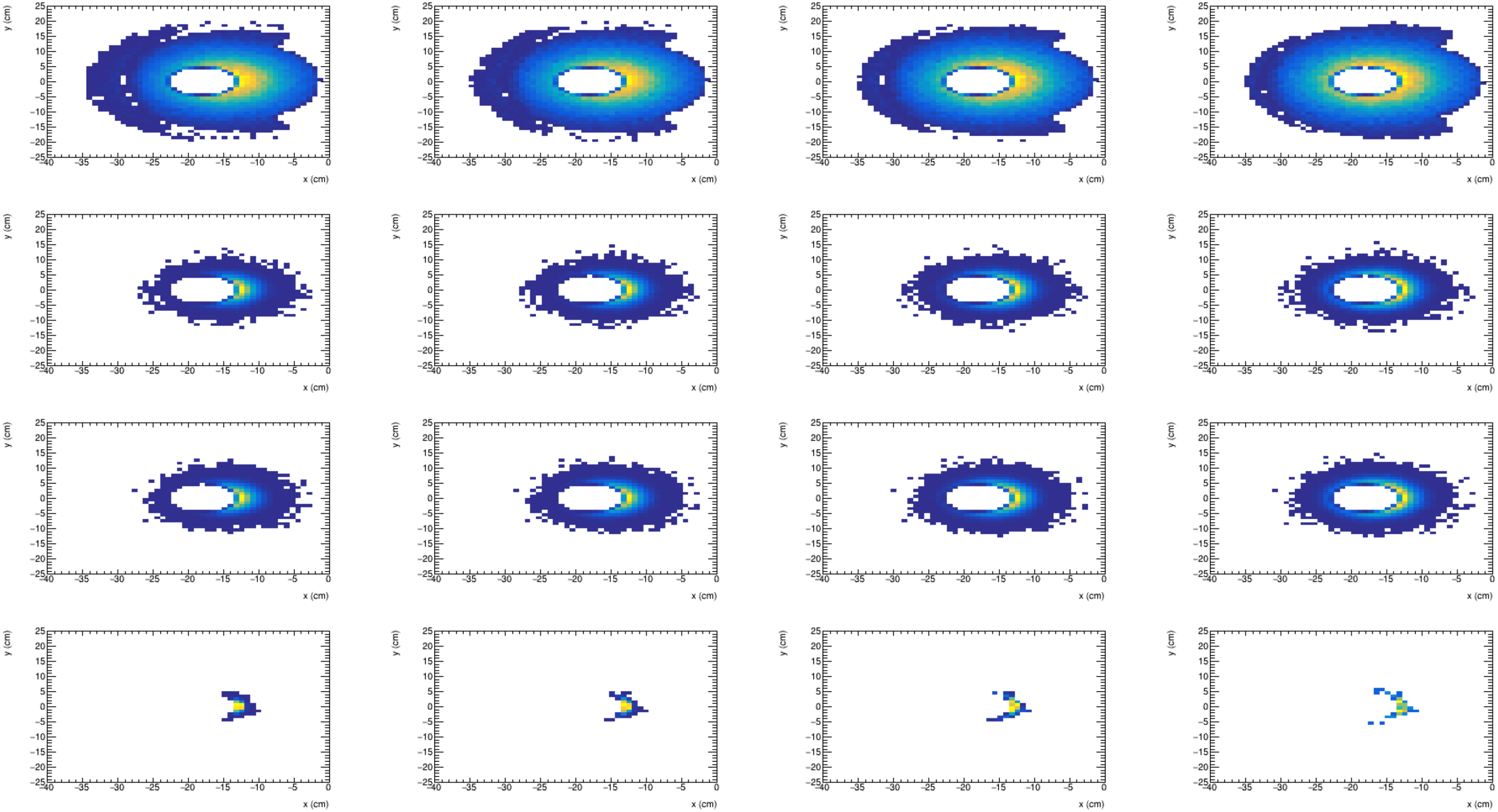
Low Q^2
Low t
=> Far *ward very important
e−′ and nucleon detection

* only J/ψ from Meson decays

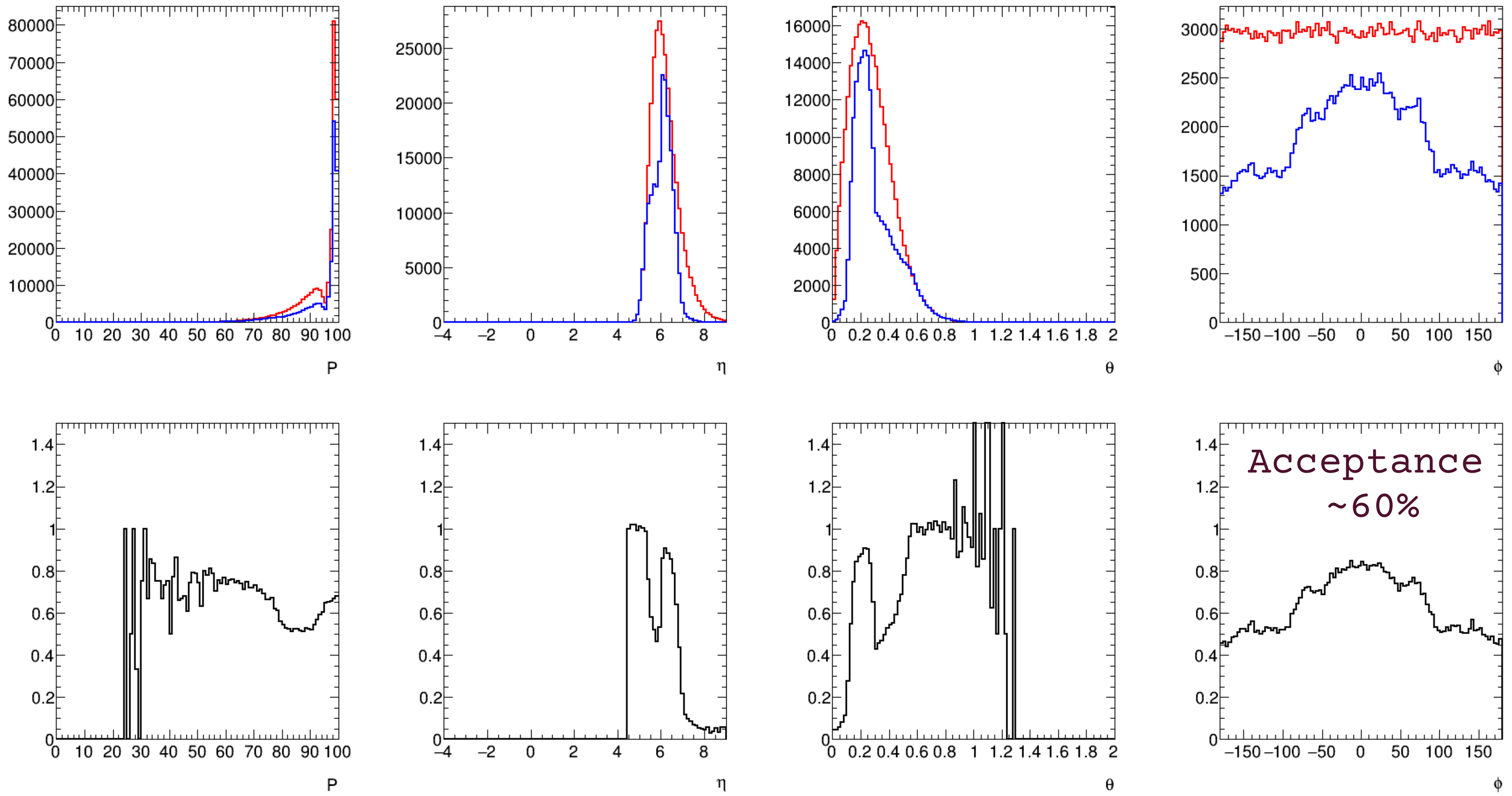
Roman Pot Acceptance



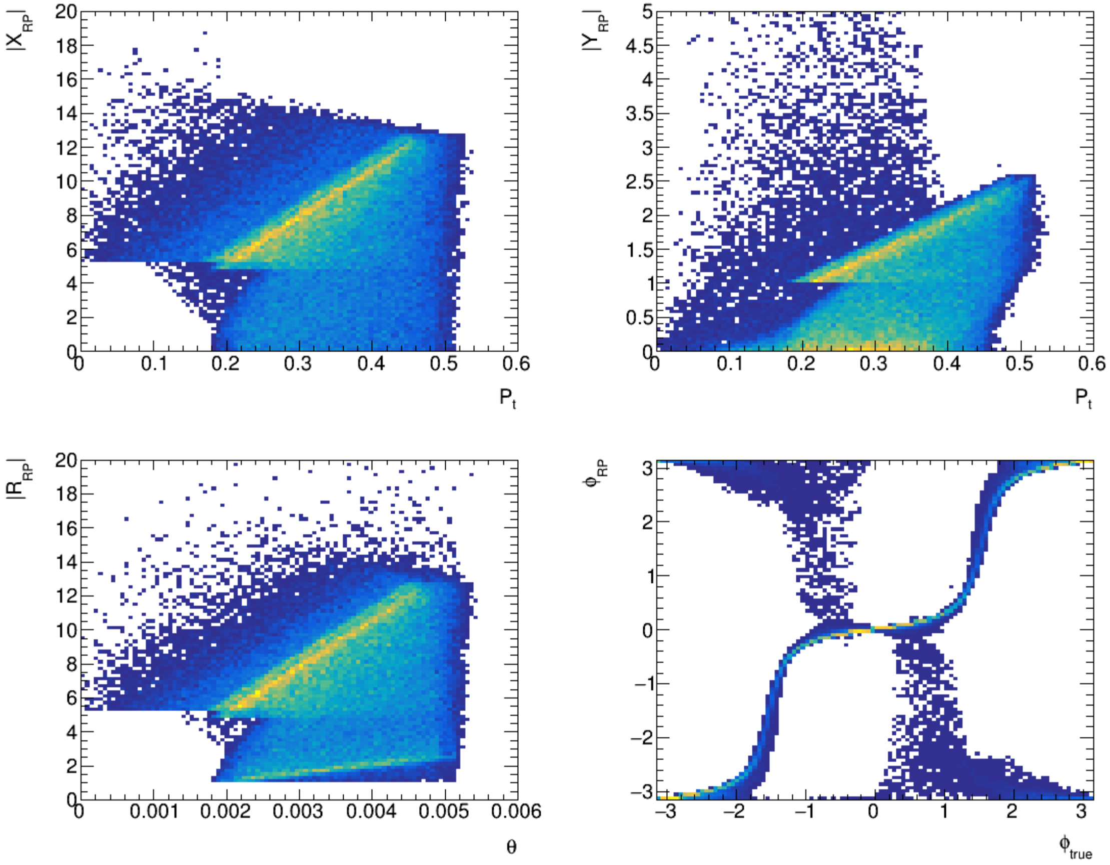
B0 Acceptance



Proton Detection B0 and RP



Roman Pot position and momentum



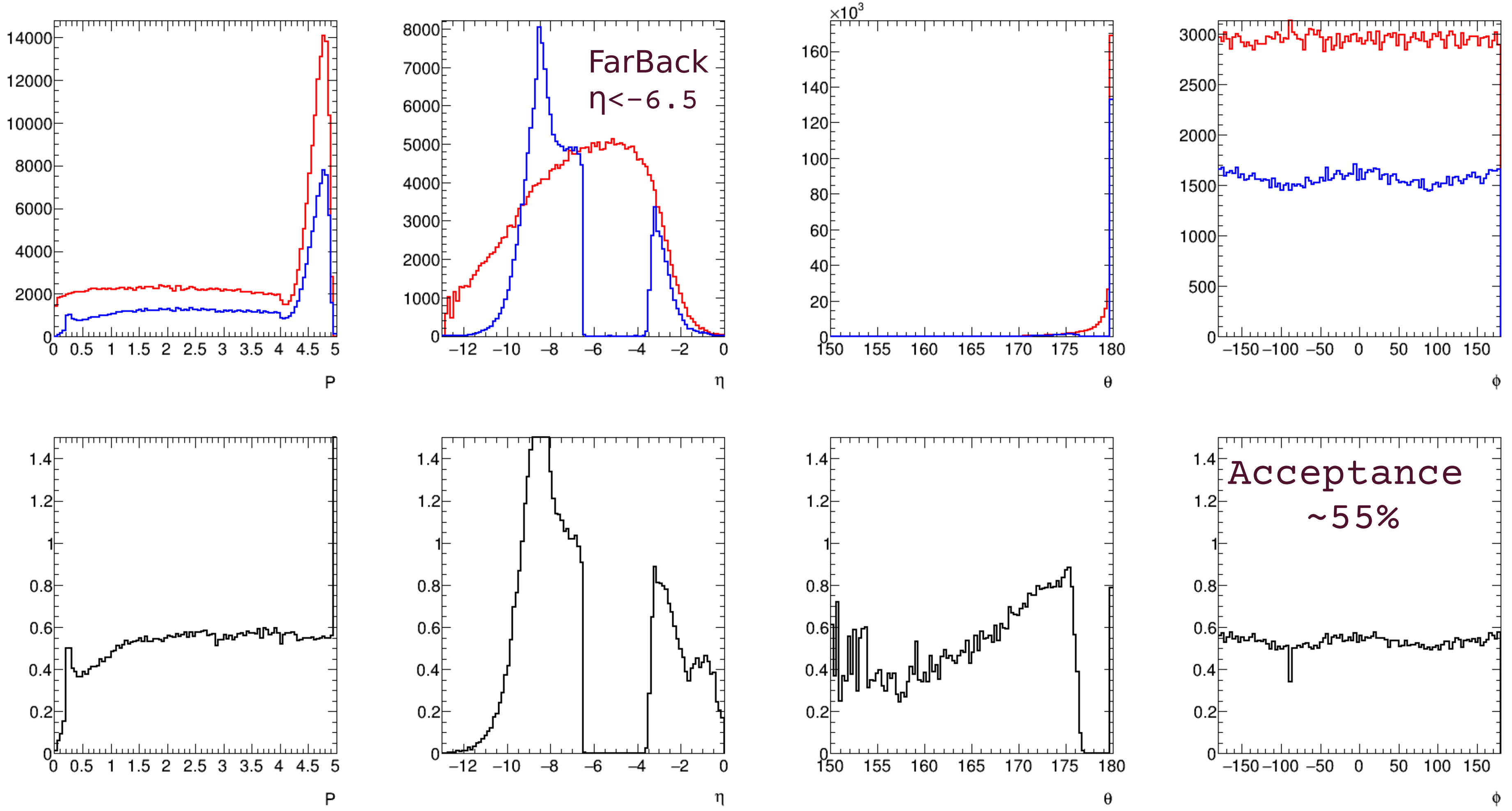
Correlation between position and P_t

But dependent on Φ

For these studies, if proton detected in RP 6% P_t resolution,
B0 3% P_t resolution

Assume (unrealistic) perfect Φ reconstruction

Electron Detection



Useful Exclusivity variables

γ= (e- beam) - (e'- scattered) Here we take e-' in Low Q2 Tagger

ΔP_t difference : Here we take proton in Far Forward

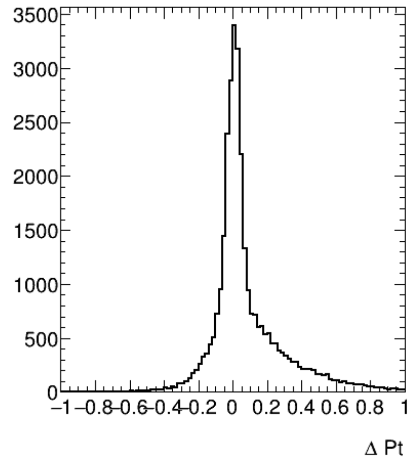
ΔPt : Pt {calculated proton - measured proton}

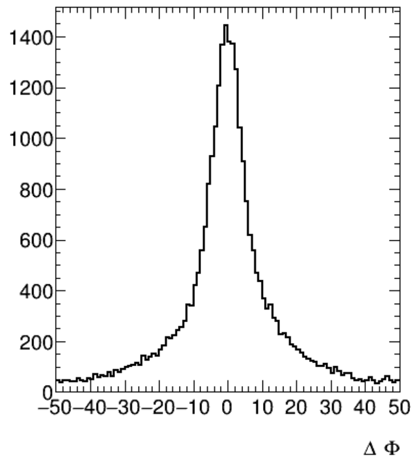
$\Delta\Phi$, Production Plane difference : $\Phi_{meson} - \Phi_{proton}$

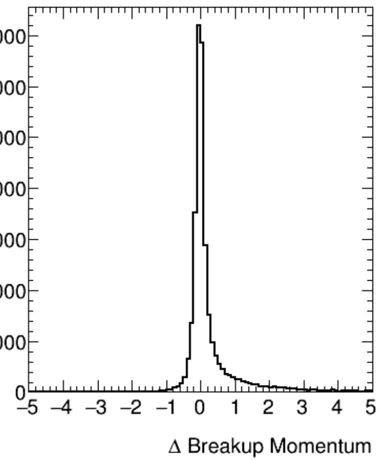
Centre of Momentum frame Δ Breakup Momentum, P_{break} :

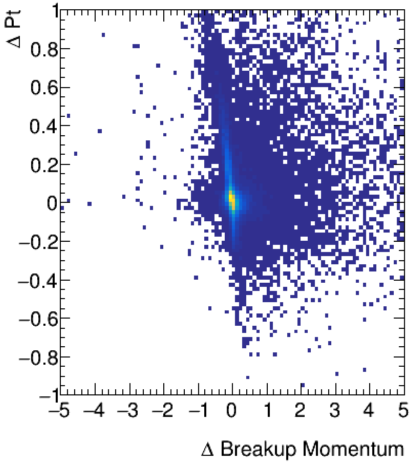
$P_{break}(E_\gamma, M_p, M_{meson}) - P_{break}(meson)$ second term boosts meson into CM

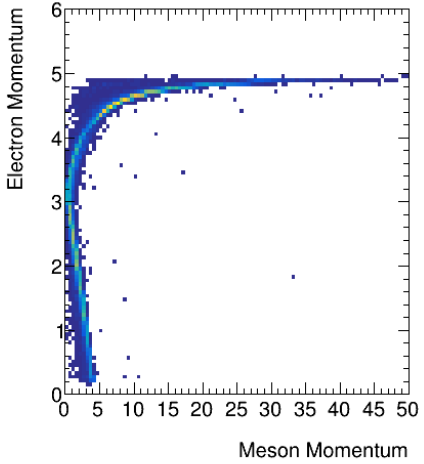
True Electron, True Proton, Realistic Meson

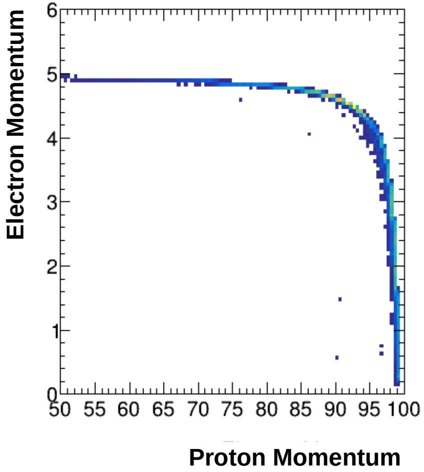


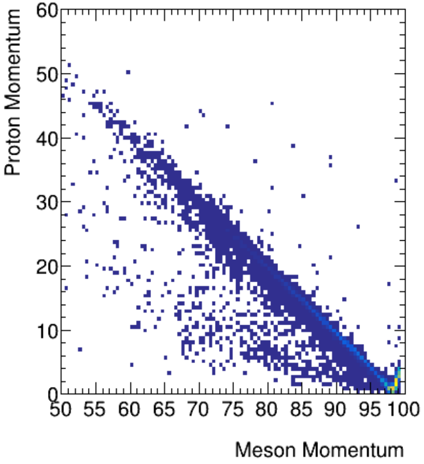


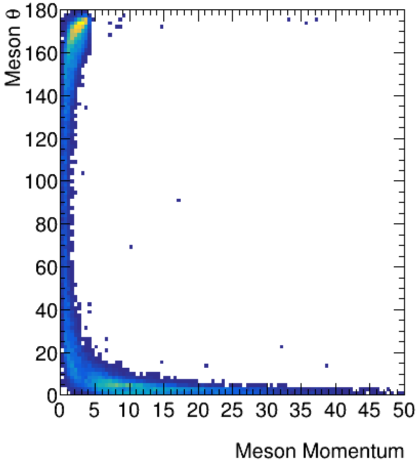




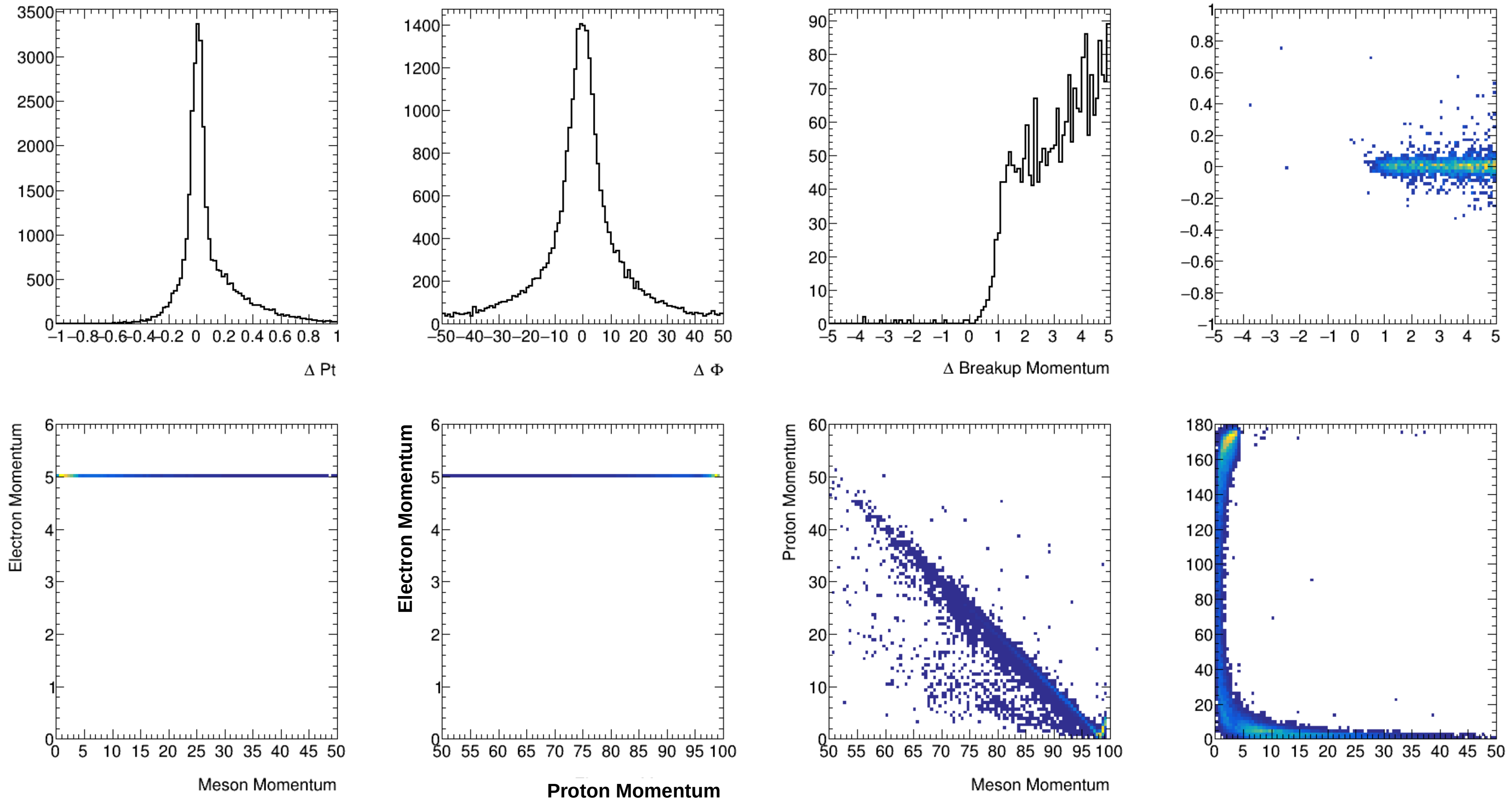




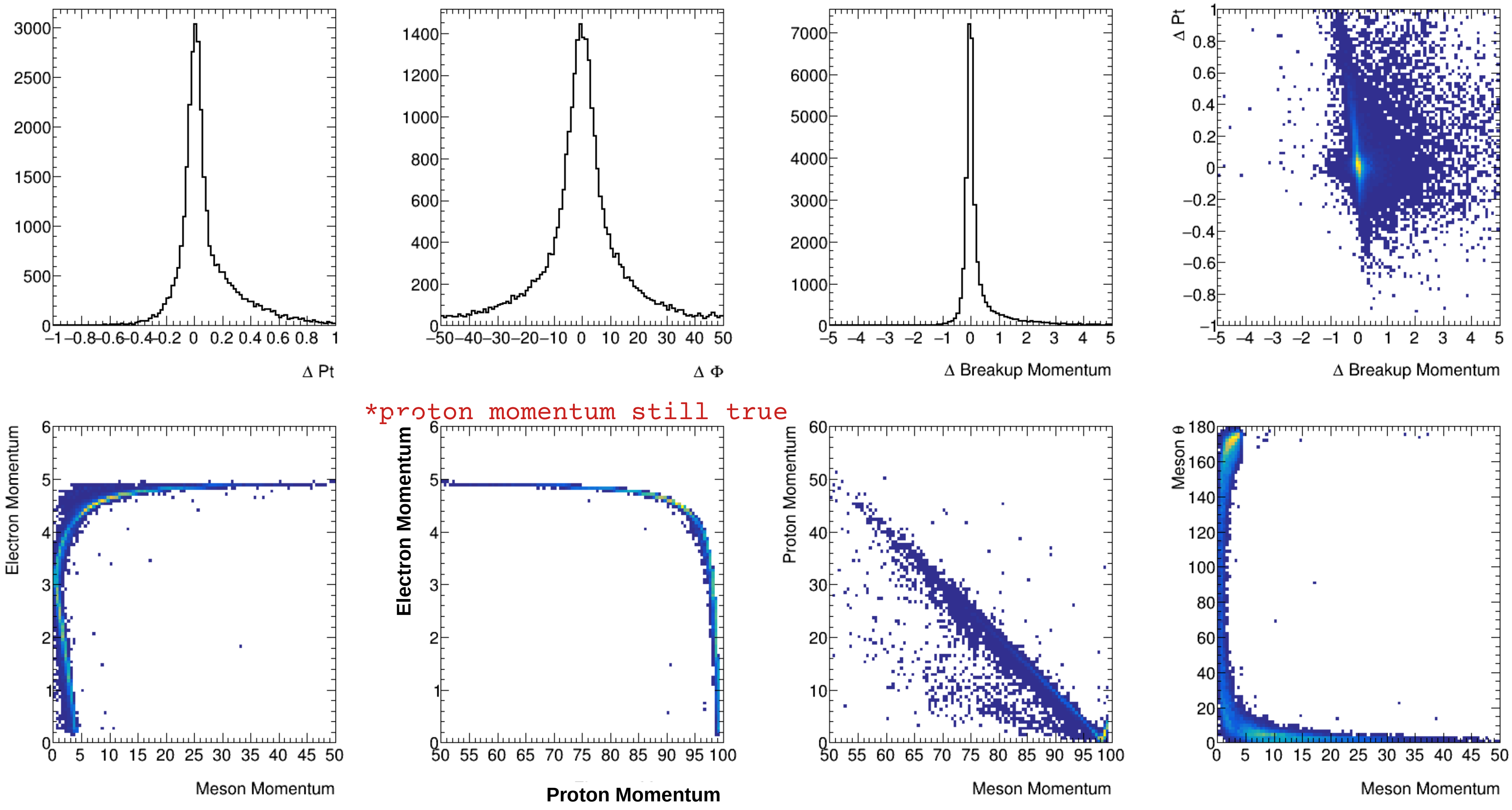




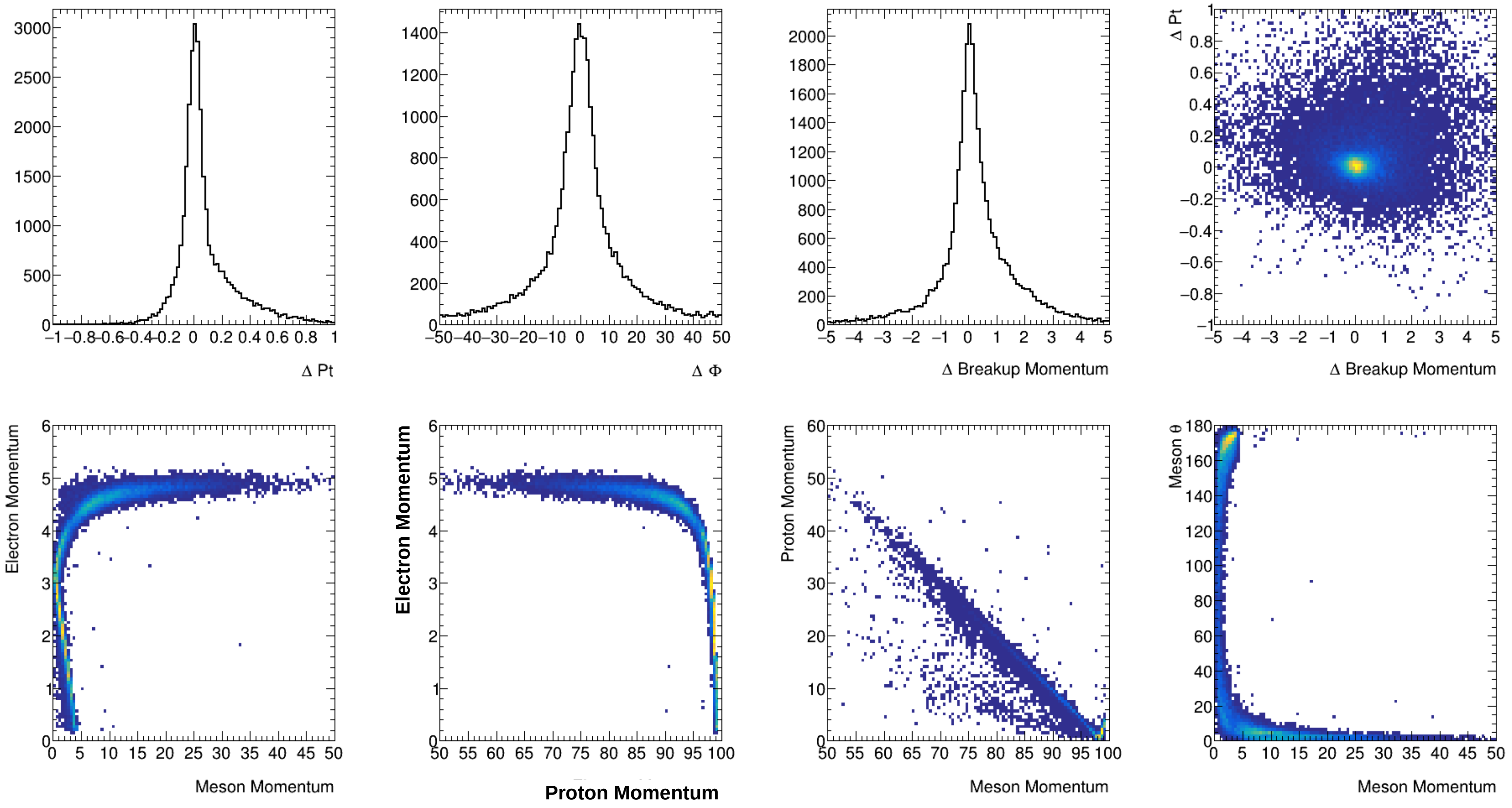
No Electron, True Proton, Realistic Meson



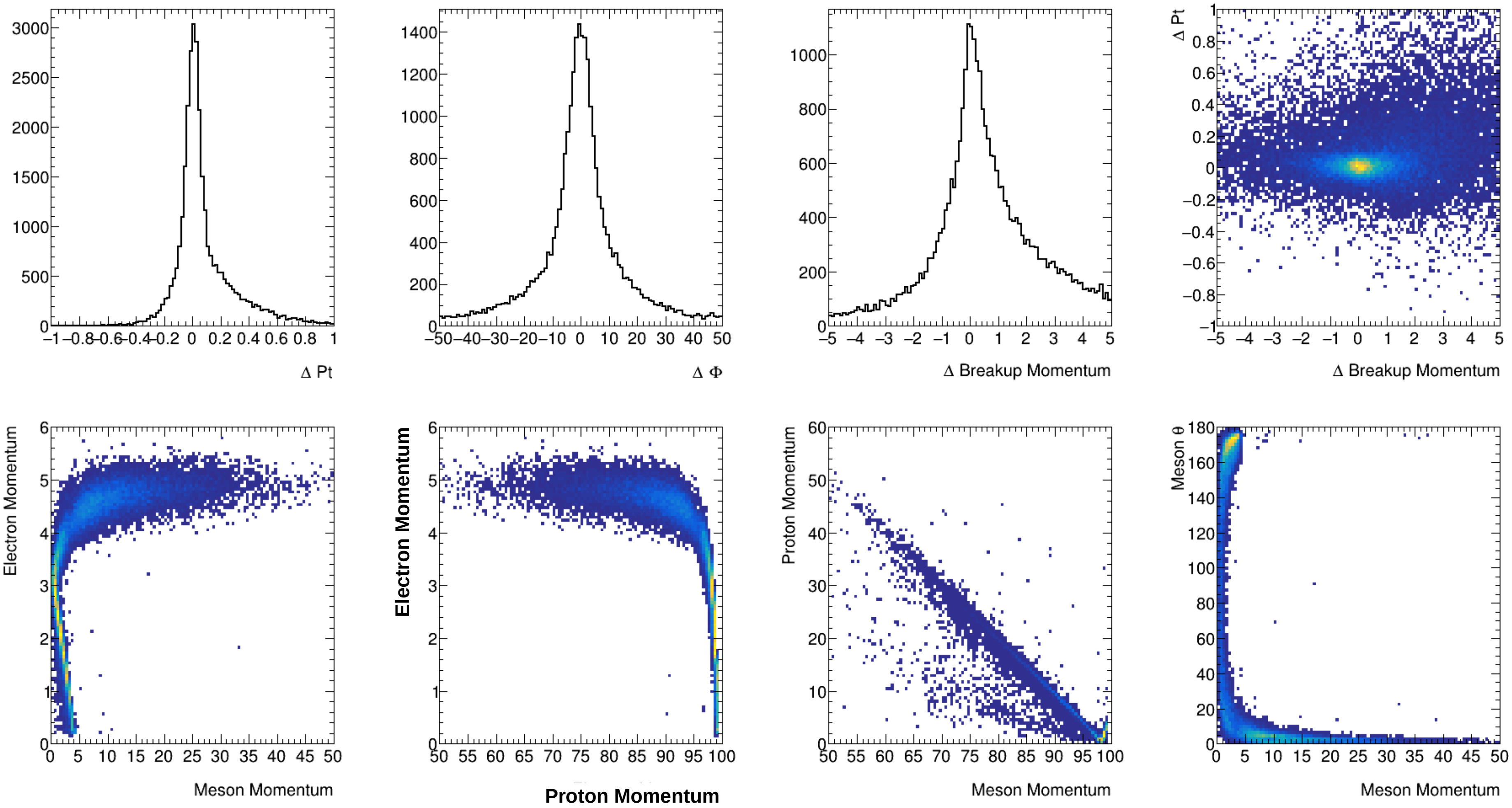
True Electron, “Realistic” Proton



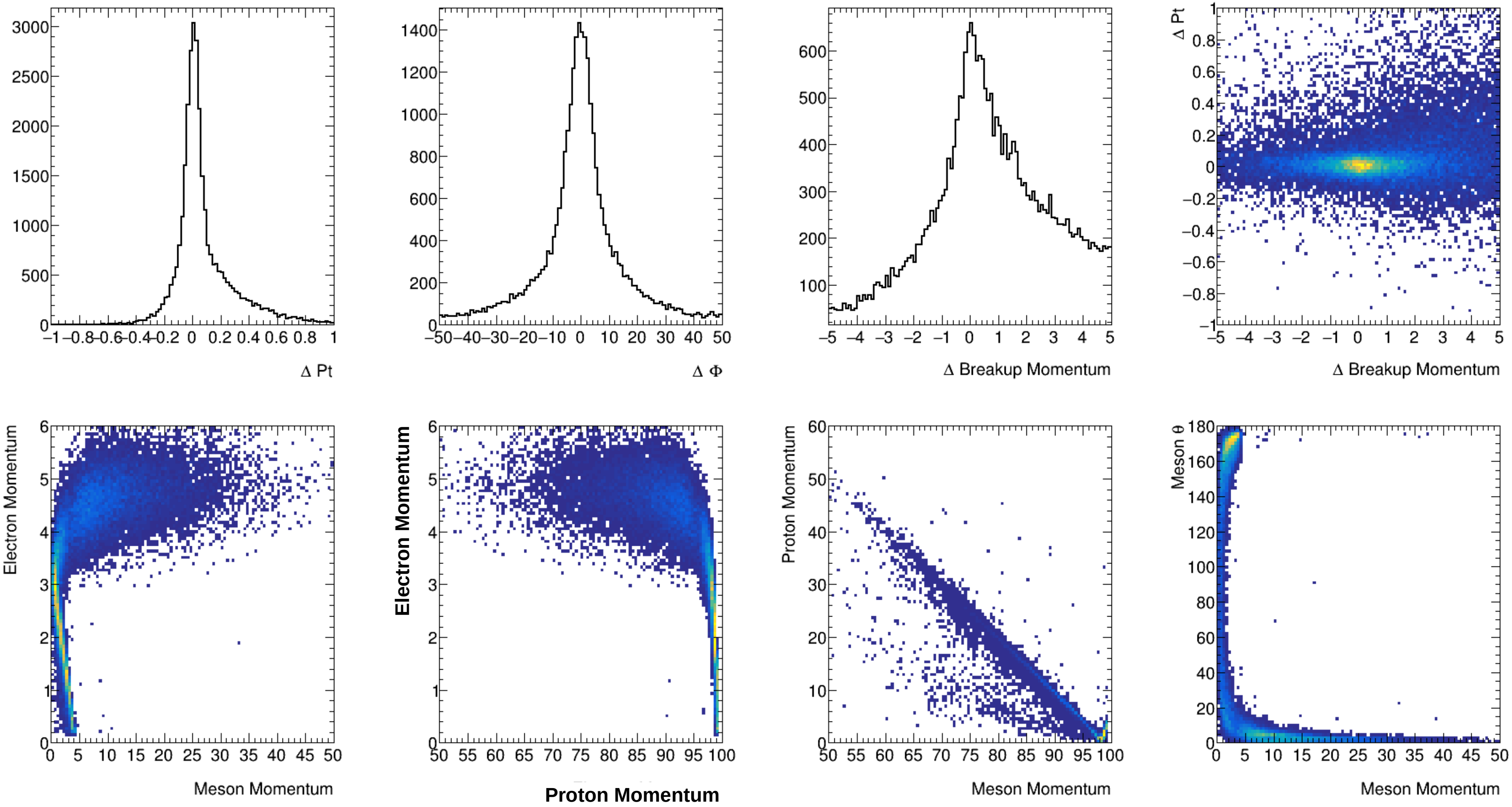
+ Electron 2% energy resolution



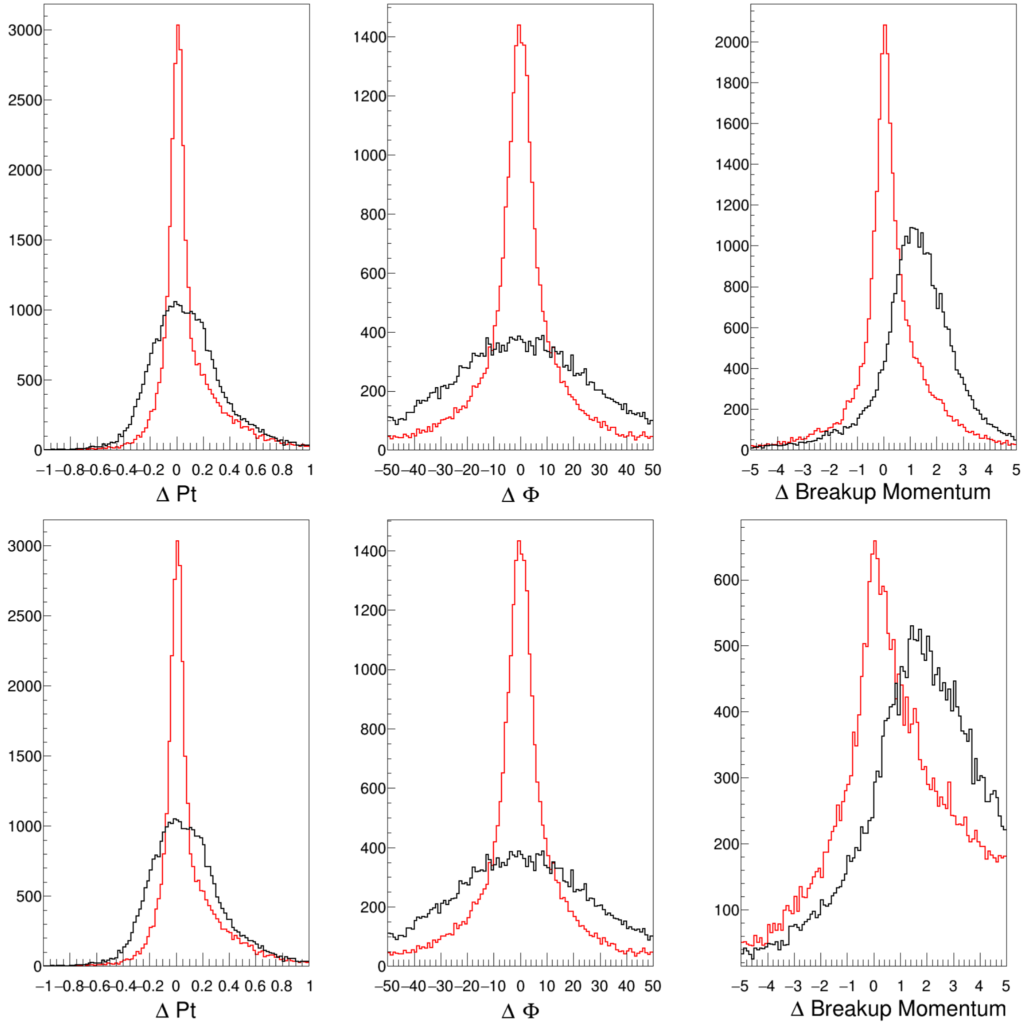
+ Electron 5% energy resolution



+ Electron 10% energy resolution



Missing Pion Background



No simulations of background Channels

Instead create exclusivity variables with missing pion

Top 2% electron resolution
Bottom 10% electron resolution

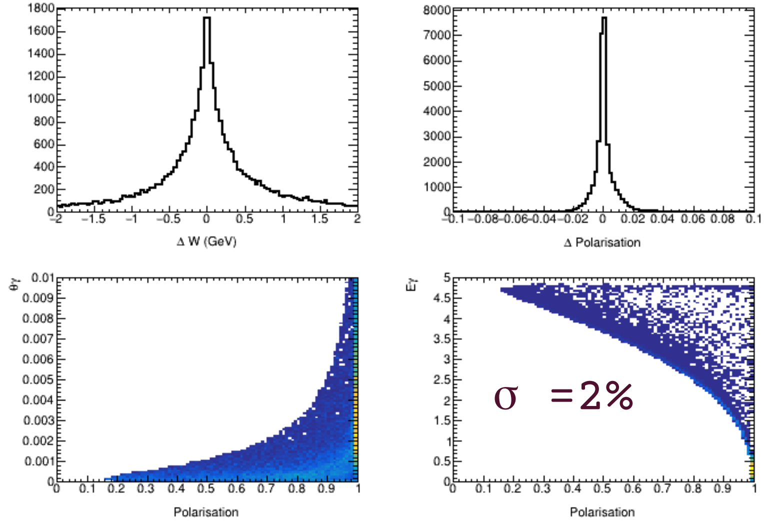
Fully Exclusive
Missing Pion

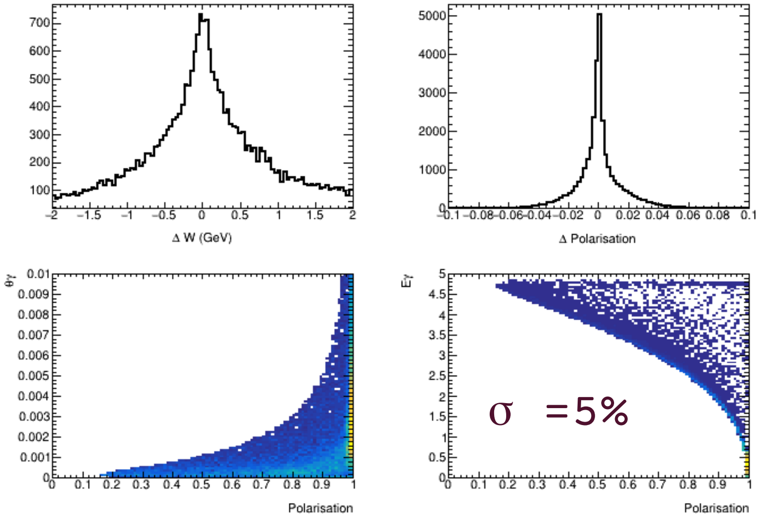
Other Useful Kinematics

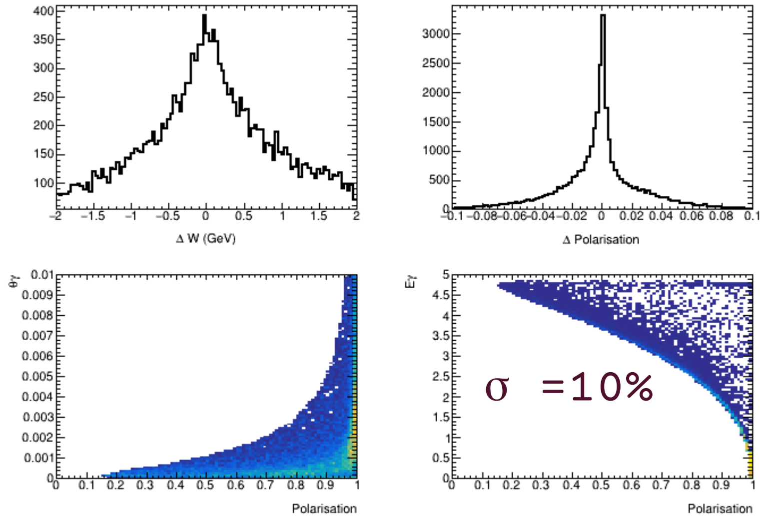
Tagger can also provide
Reaction W

Electron scattering plane
-requires excellent tracking

Transverse Polarisation
=> extra observables
(photon asymmetries, polarised SDMEs)







Conclusions

Spectroscopy measurements will be greatly aided by :

- Good exclusivity variables
- Determination of W and t
- Transverse photon polarisation (~ Linear Polarisation)

A Low Q2 tagger can provide these with

- Accurate energy reconstruction of around 2%
- Determination of the electron scattering azimuthal angle(say to 10°)
- Moderate angle resolution for the degree of polarisation
- Large acceptance in electron energy
  (close to beam energy as possible)

Such features could be possible with a high resolution pixel tracker

Exclusive Photoproduction (Quasi-real)

Observation of XYZ states in photoproduction
- independent confirmation

Different production mechanism, different kinematics

Measurement of polarisation observables and photocouplings
- insights into production mechanisms and internal structure

XYZ spectroscopy at electron-hadron facilities: Exclusive processes

M. Albaladejo, A. N. Hiller Blin, A. Pilloni, D. Winney, C. Fernández-Ramírez, V. Mathieu, and A. Szczepaniak
(Joint Physics Analysis Center)
Phys. Rev. D **102**, 114010 – Published 7 December 2020

See D.Winney
Exotic Spectroscopy
at the EIC

- qualitative behaviour and order of magnitude estimates

X(3872)

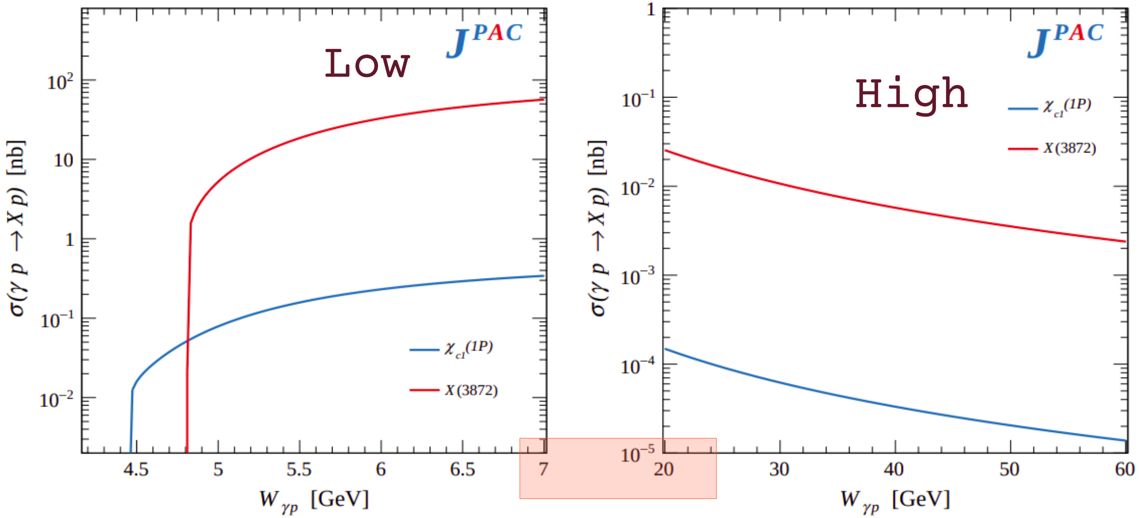
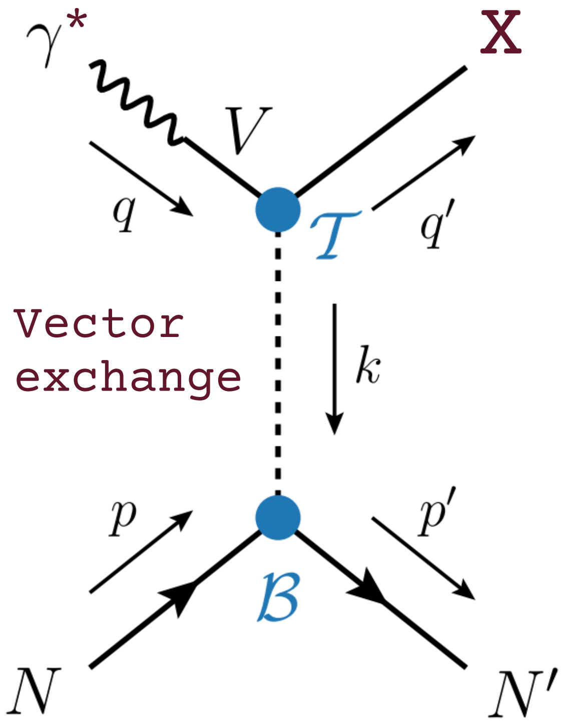


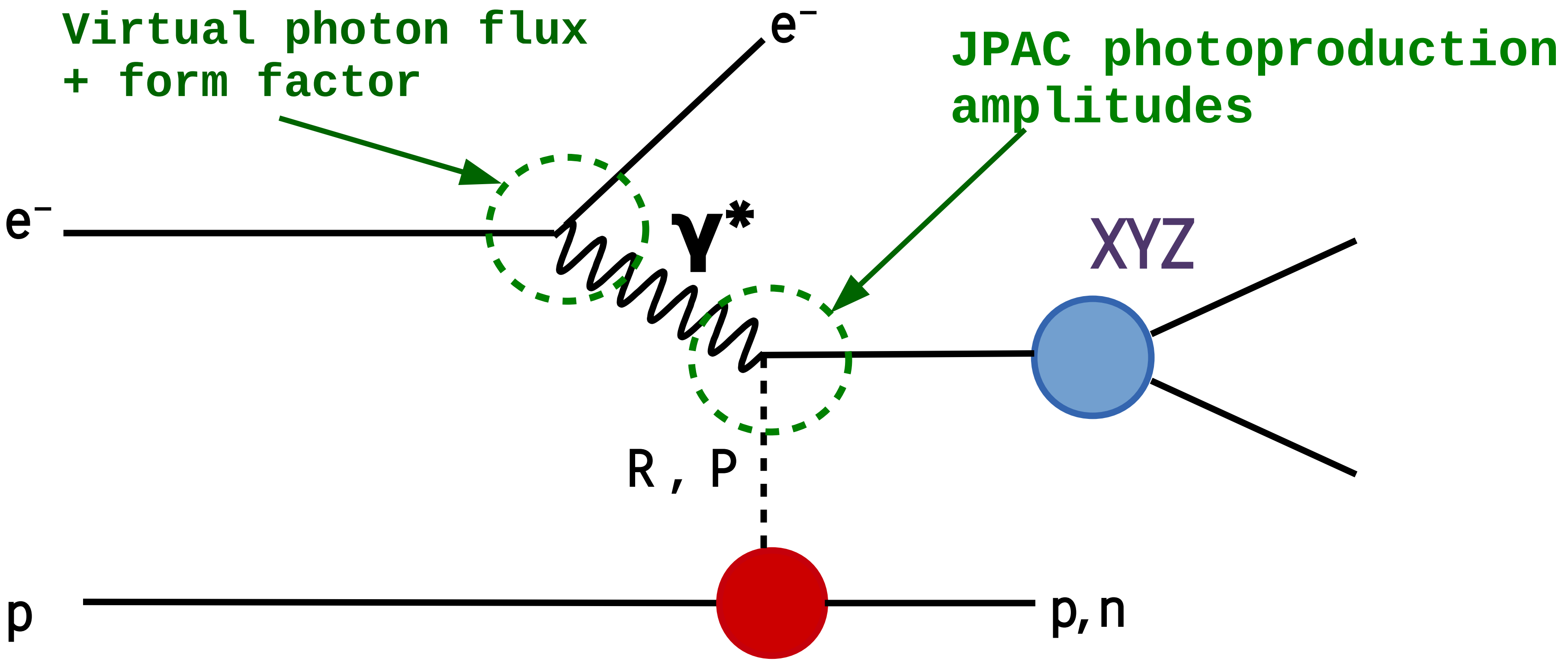
FIG. 3. Integrated cross sections for the axial $\chi_{c1}(1P)$ and $X(3872)$. Left panel: predictions for fixed-spin exchange, valid at low energies. Right panel: predictions for Regge exchange, valid at high energies.



Larger model uncertainty

Event Generator (Pictorial)

Factorise 2 photon vertices



Event Generator (Formal)

$$\frac{d^4\sigma}{ds\,dQ^2\,d\phi\,dt} = \frac{d^2\sigma_{e,\gamma*e'}}{dsdQ^2}\frac{d^2\sigma_{\gamma*+p\to V+p}(s,Q^2)}{d\phi\,dt}$$

→ Integrate for event rate

$$\frac{d^2\sigma_{e,\gamma*e'}}{dsdQ^2} = \frac{\alpha}{2\pi}\cdot\frac{K.L}{E}\cdot\frac{1}{Q^2}\cdot\frac{1}{(s-M^2+Q^2)}$$

$$Q^2 = 2EMxy$$

$$W^2 = M^2 + 2EMy - Q^2$$

$$L = \frac{1+(1-y)^2}{y} - \frac{2m_e^2 y}{Q^2}$$

$$K = \frac{W^2-M^2}{2M} = \nu(1-x) = Ey(1-x) = \nu - \frac{Q^2}{2M}$$

$$\frac{d^2\sigma_{\gamma*+p}}{d\phi\,dt} = \frac{d\sigma^T(Q^2,s)}{d\phi\,dt} + (\epsilon+\delta)\frac{d\sigma^L(Q^2,s)}{d\phi\,dt}$$

$$\frac{d^2\sigma^T(Q^2,s)}{d\phi\,dt} = \frac{d^2\sigma_{\gamma+p\to V+p}}{d\phi\,dt}F(Q^2)$$

$$\frac{d^2\sigma^L(Q^2,s)}{d\phi\,dt} = 0$$

$$\frac{d^2\sigma_{\gamma+p\to V+p}}{d\phi\,dt} = \frac{1}{128\pi^2 s}\frac{1}{|\mathbf{p}_{\gamma*cm}|^2}|M(s,t)|^2$$

→ $|M(s,t)|^2$ JPAC Photoproduction Amplitudes