rgB - meeting

ϕ electroproduction analysis : K^+ K^- channel

13 Feb 2026

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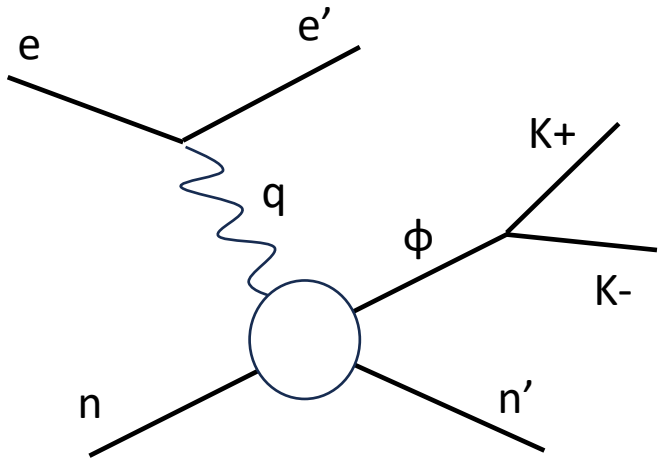
Introduction

Analysis objective :

- Measurement of the cross section and differential cross section of the electroproduction of ϕ in the K^+ K^- channel with **rgB** data (deuterium target). 3 analysis are possible :



e **n** → e **n'** K^+ K^- → Acces of gluons GPDs of the **neutron**

e **p** → e **p'** K^+ K^- → Acces of gluons GPDs of the **proton** and compare with results on rgA

(e **d** → e **d'** K^+ K^-) → Maybe possible : acces on gluons GPDs of the **deuterium**

Introduction

Analysis :

e **n** → e **n'** K^+ K^-

Datas :

sidisdvcs **RG-B outbending fall 2019**
+ spring 2019 and spring 2020 inbending

Cuts :

→ Selection of events with one e^- , K^+ , K^- , more than 1 neutron and 0 proton (select the best neutron wich minimize the angle between the missing nucleon and the neutron)

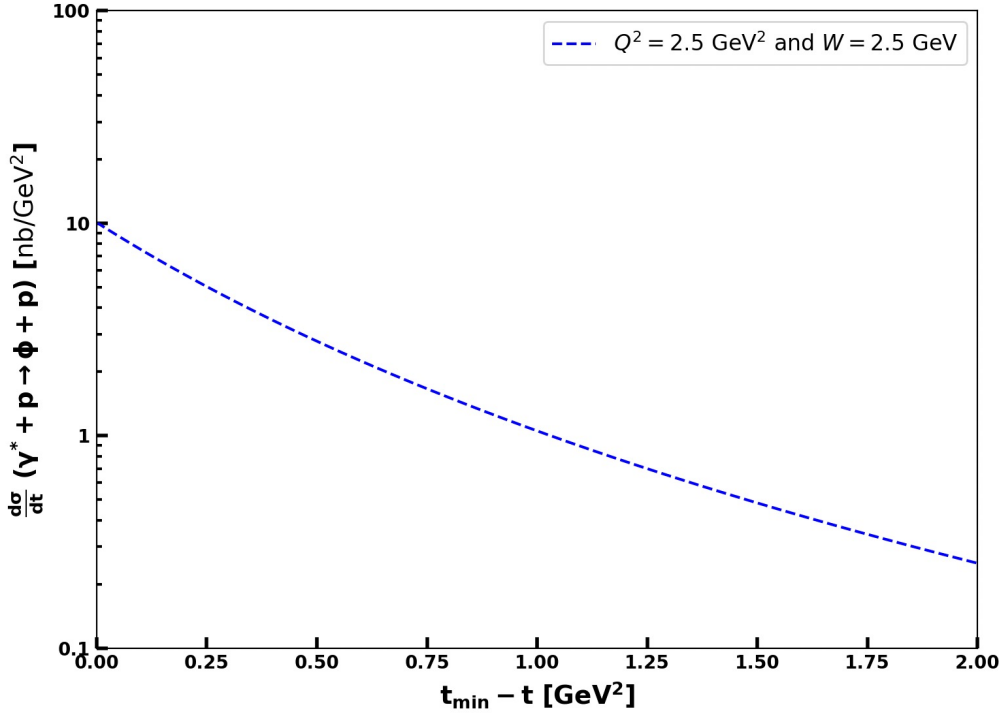
→ $Q^2 > 1.0$ GeV , $P_{electron} > 2$ GeV , $\theta_{neutron} > 4°$ and $P_{neutron} > 0.25$ GeV

→ Cut on the angle between the missing nucleon and the neutron

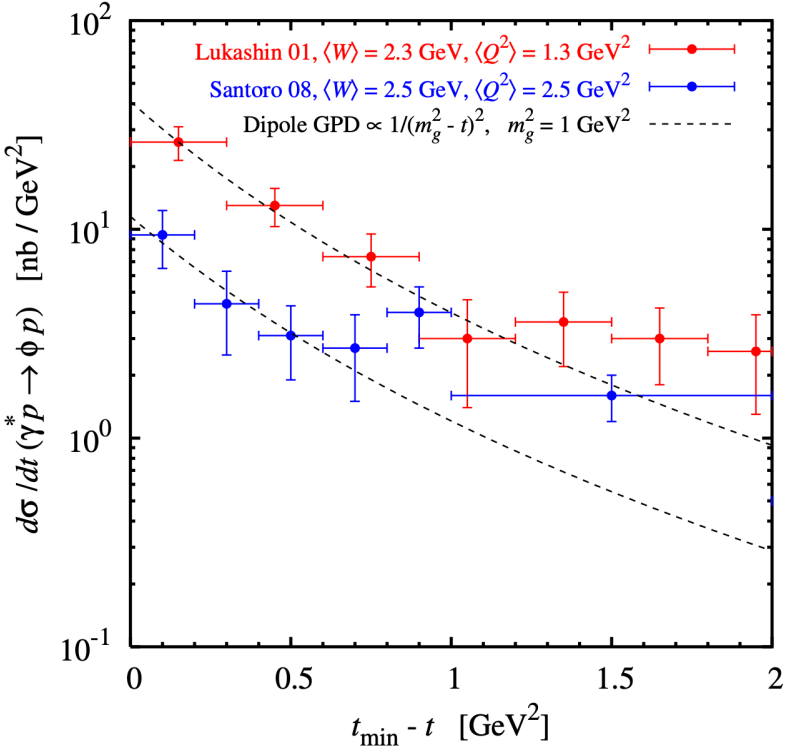
→ Cut on $-0.5 < MissingMass_{tot}^2 < 0.5$ GeV ^{2}

→ Cut on status of K^+ and K^- (keep event with both kaons in FD)

ϕ generator



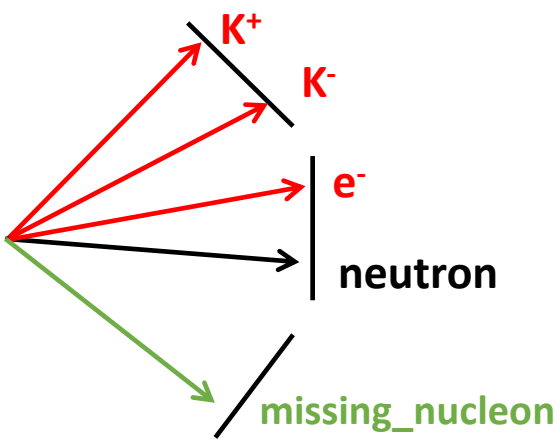
Implemented in the generator



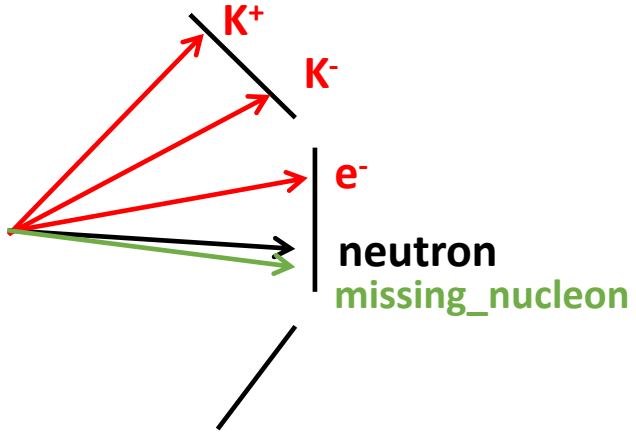
From Proposal to Jefferson Lab PAC39

Details on cuts : angle between miss nucleon and detected neutron

Missing_nucleon = beam + target - e' - K^+ - K^- (the missing particle of this reaction : e n ⟶ e' K^+ K^- X)



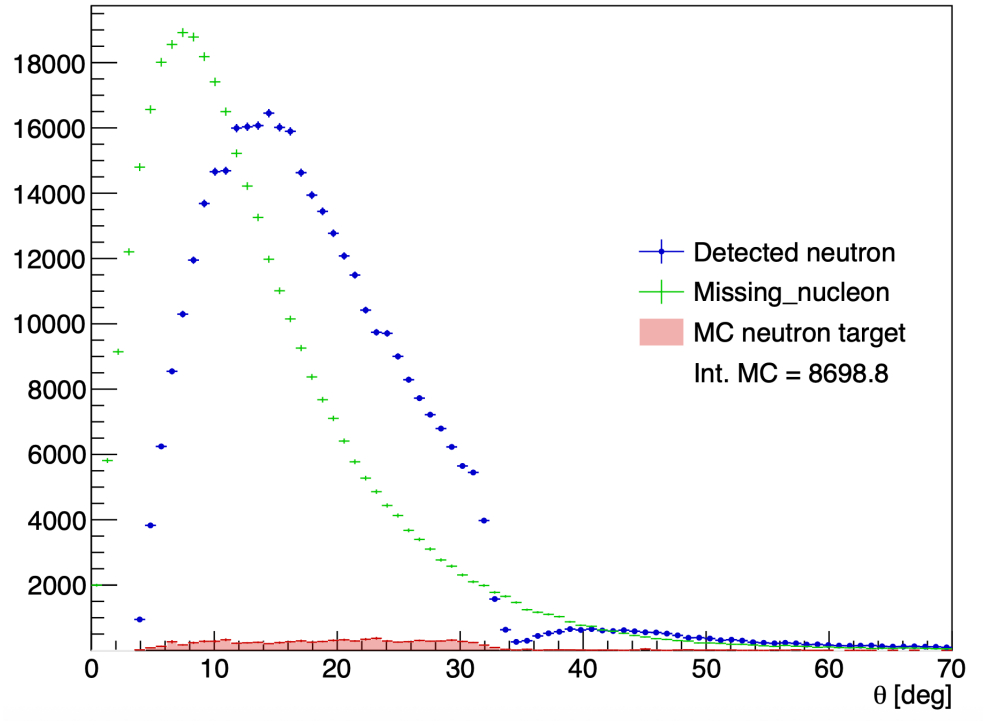
Not a good event



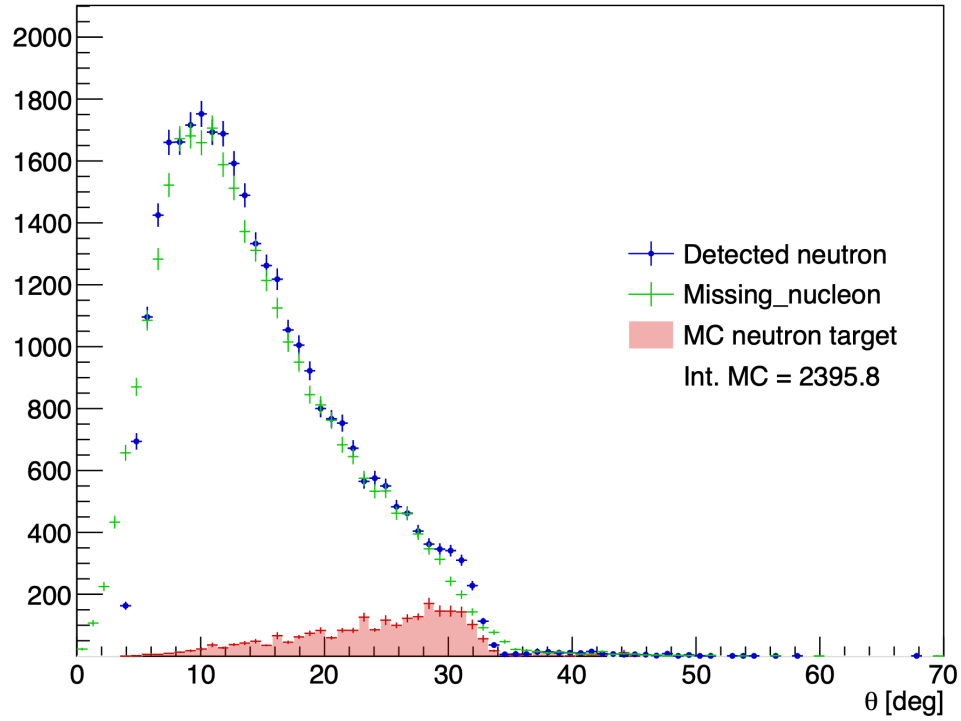
Good event

⟶ Cut on the angle between the missing nucleon and the neutron **< 5 °**

Details on cuts : angle between missing nucleon and detected neutron

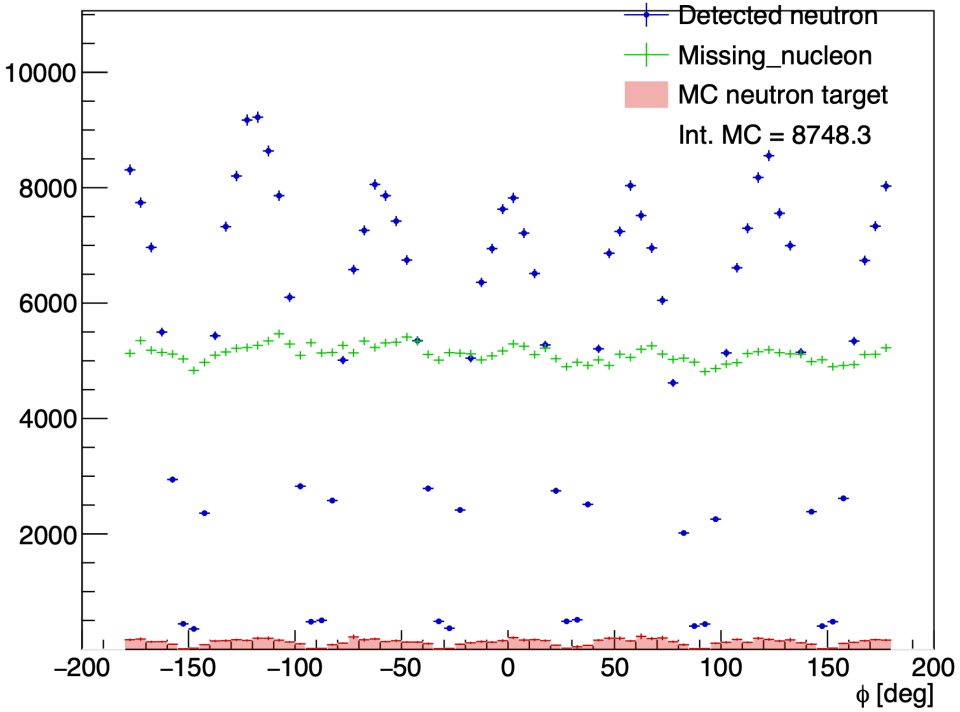


Without the angle cut

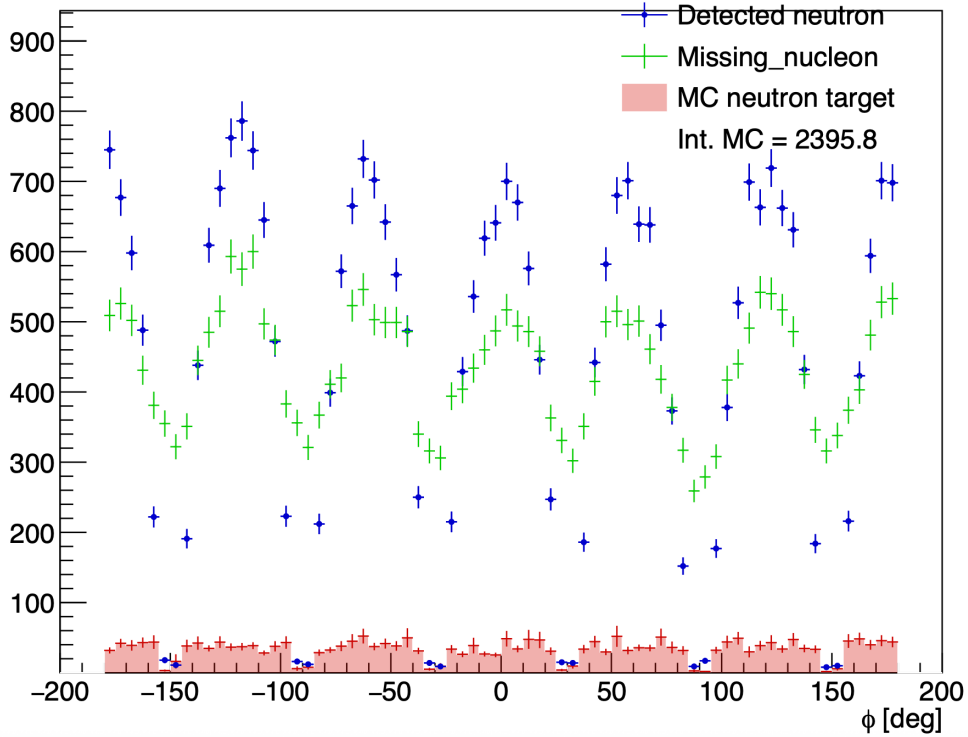


With the angle cut

Details on cuts : angle between missing nucleon and detected neutron

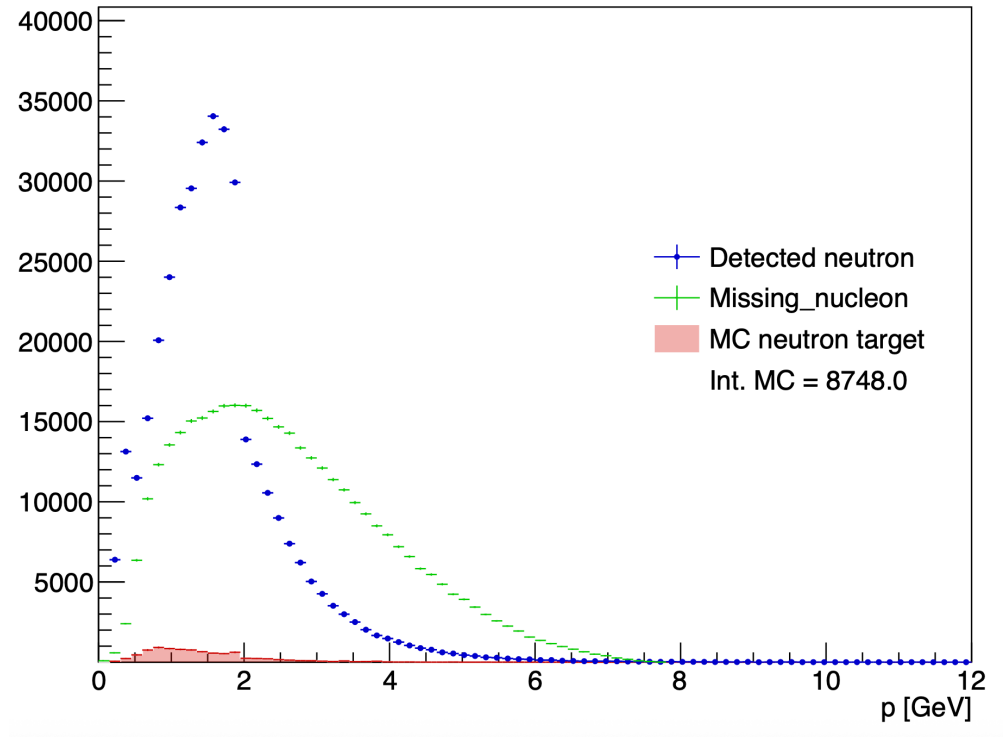


Without the angle cut

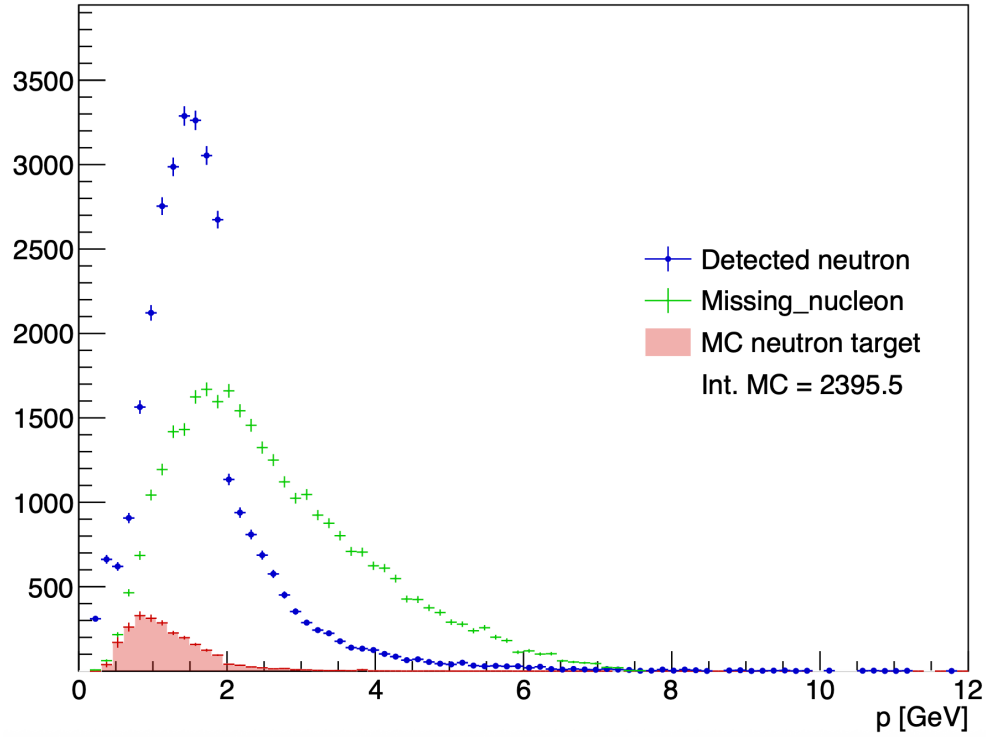


With the angle cut

Details on cuts : angle between missing nucleon and detected neutron



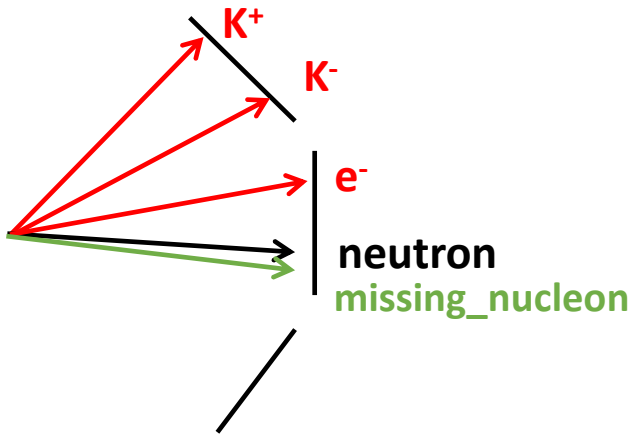
Without the angle cut



With the angle cut

Proton contamination

Missing_nucleon = beam + target - e' - K^+ - K^- (the missing particle of this reaction : e n ⟶ e' K^+ K^- X)

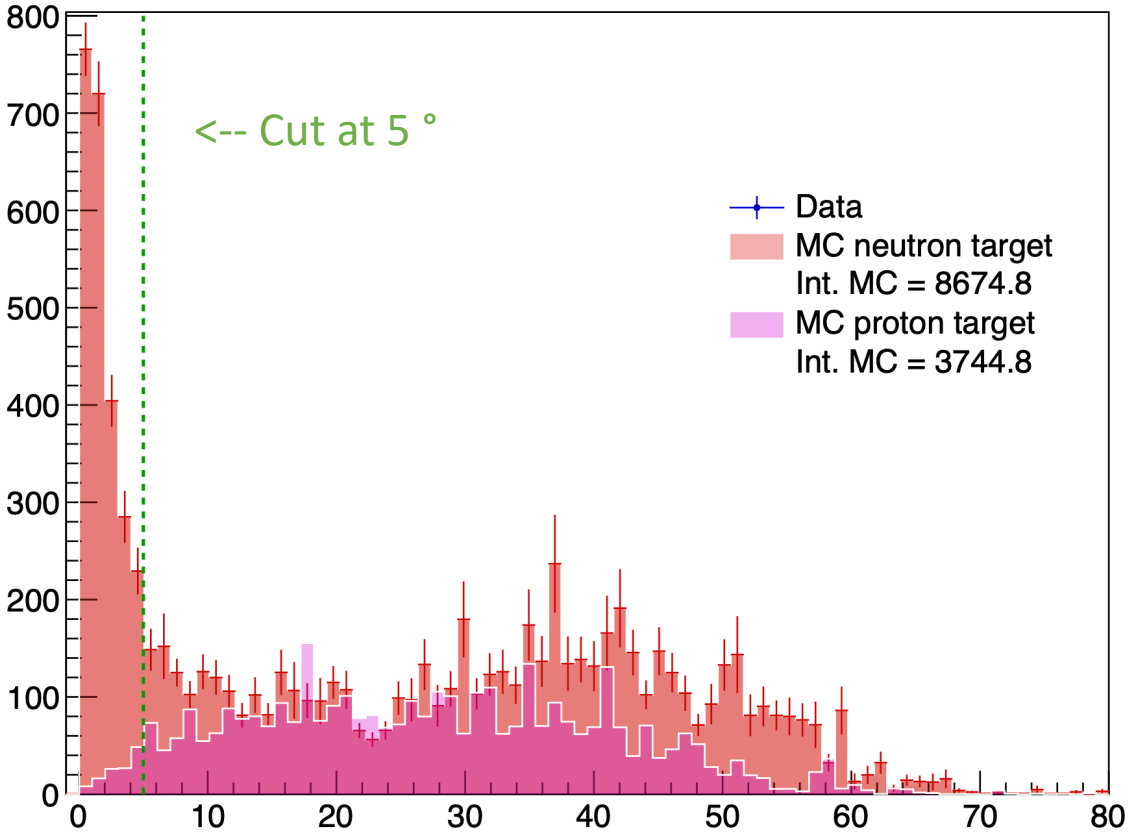


There is always a contamination when the missing_nucleon is a non detected proton and there is a **fake signal neutron** who pass the cut on the angle

⟶ Evaluate the contamination with simulation on proton target and apply the cuts of **neutron** analysis and see how many events pass the cuts

Keep event with the angle between the missing nucleon and the neutron **< 5 °**

Proton contamination : prediction of MC

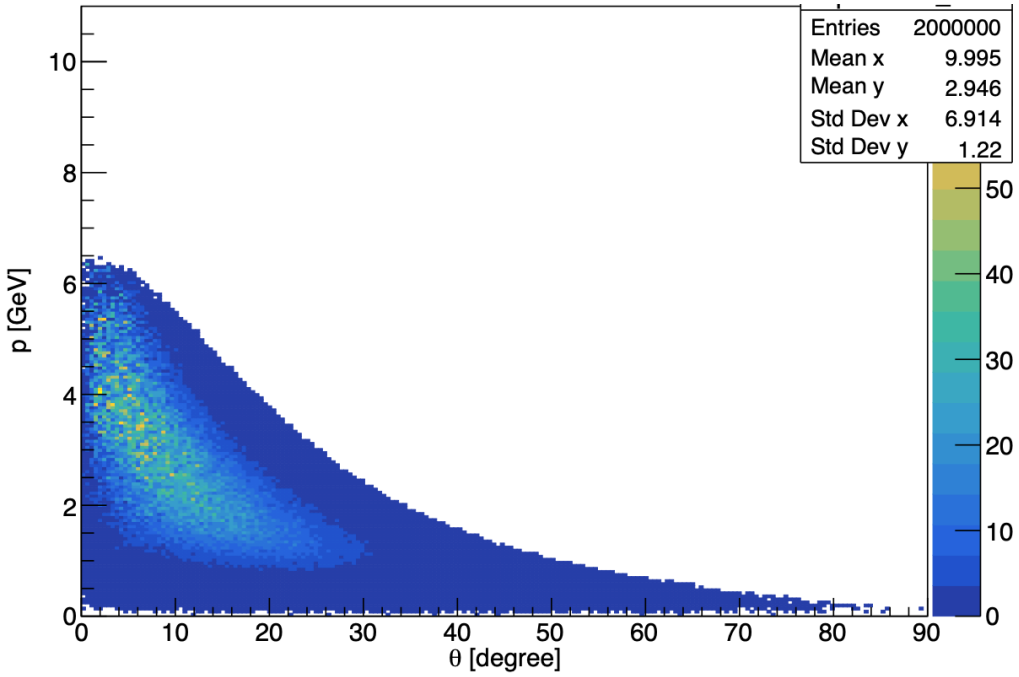


Details on cuts : keep K+ K- in FD

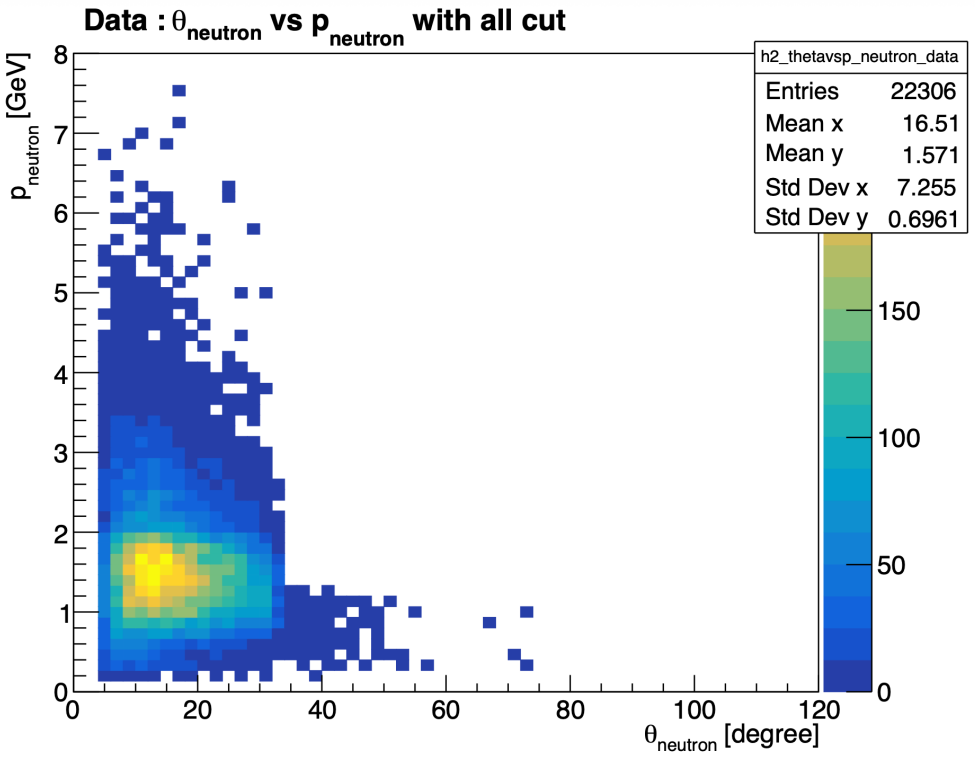
Two argument to cut K+ K- in CD :

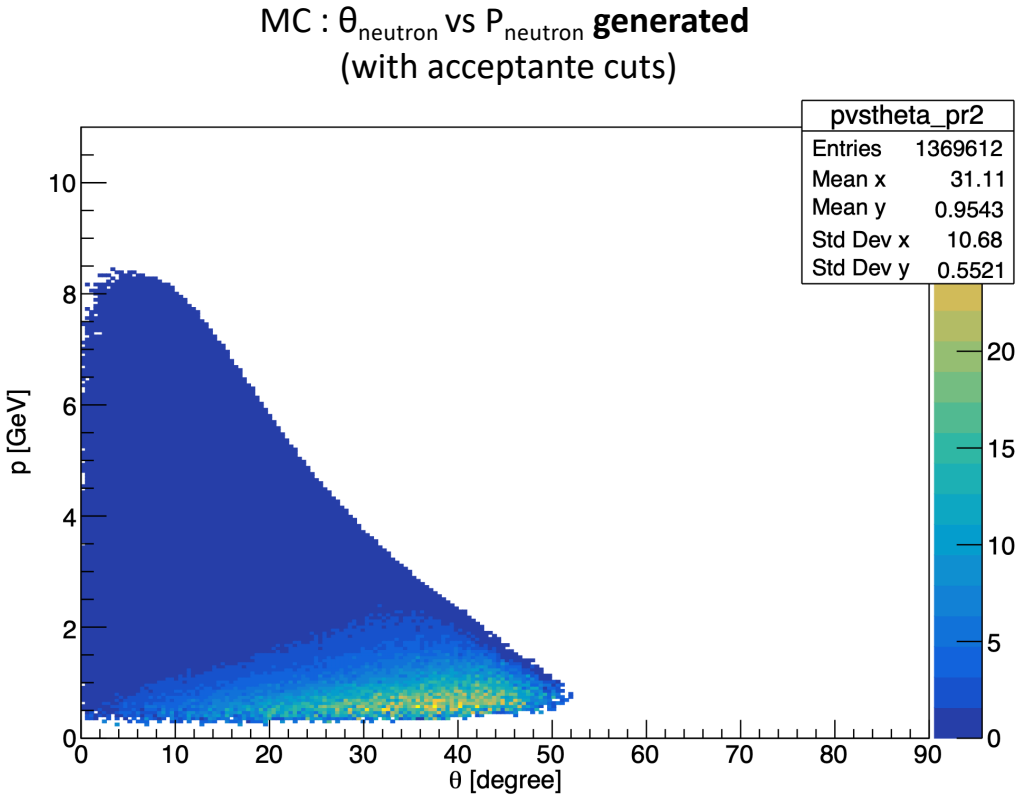
- Reconstruction of kaons in the CD is less good than in the FD
- The generator predict few events in the CD

Generated event : p vs theta for K^{+-}

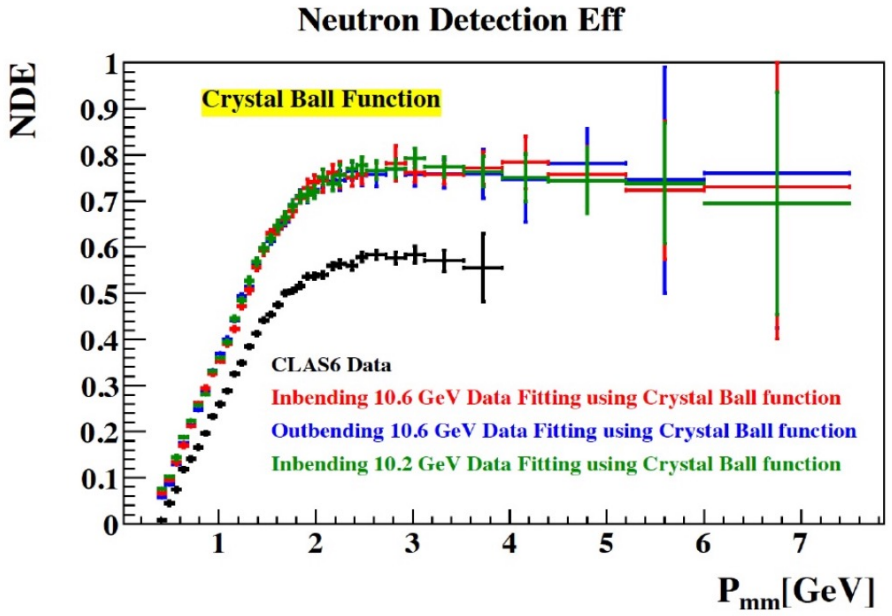


Neutron phasespace :

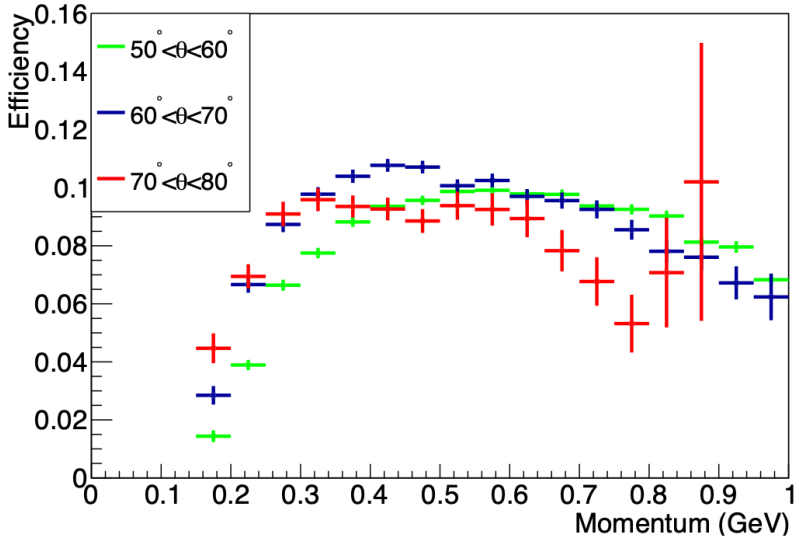




Neutron phasespace :



Neutron detection efficiency in the FD



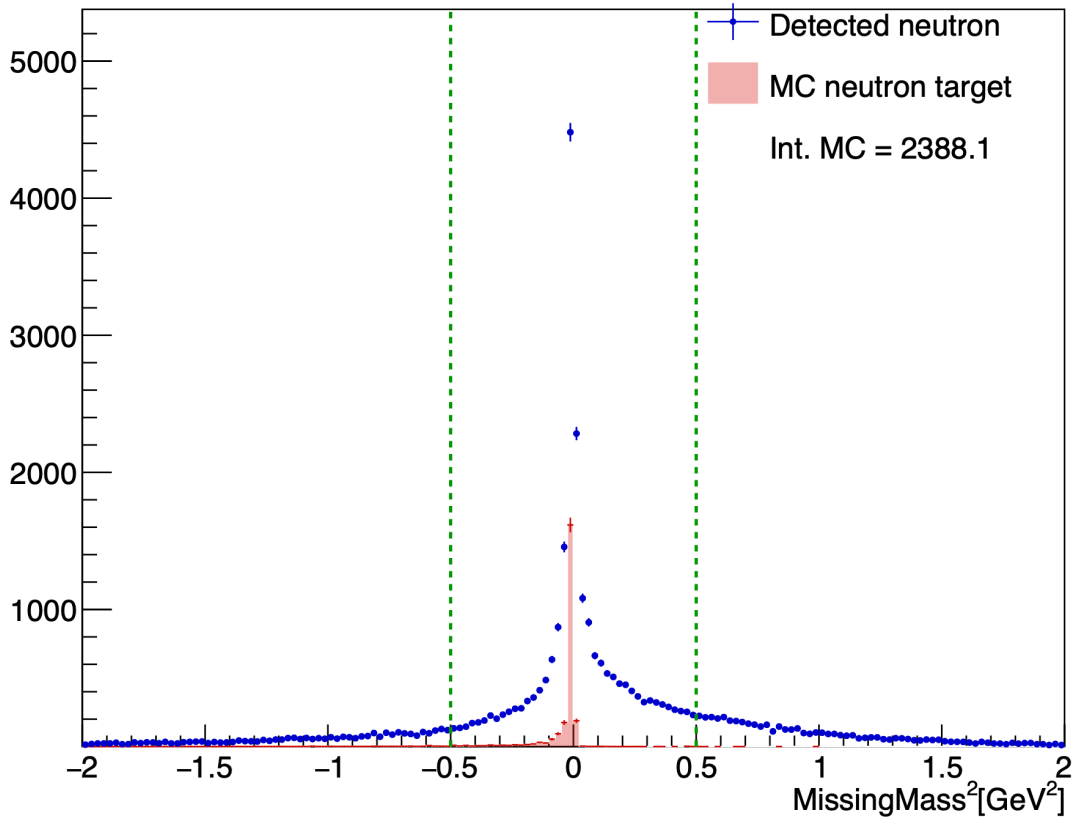
P. Chatagnon's plot

Neutron detection efficiency in the CND

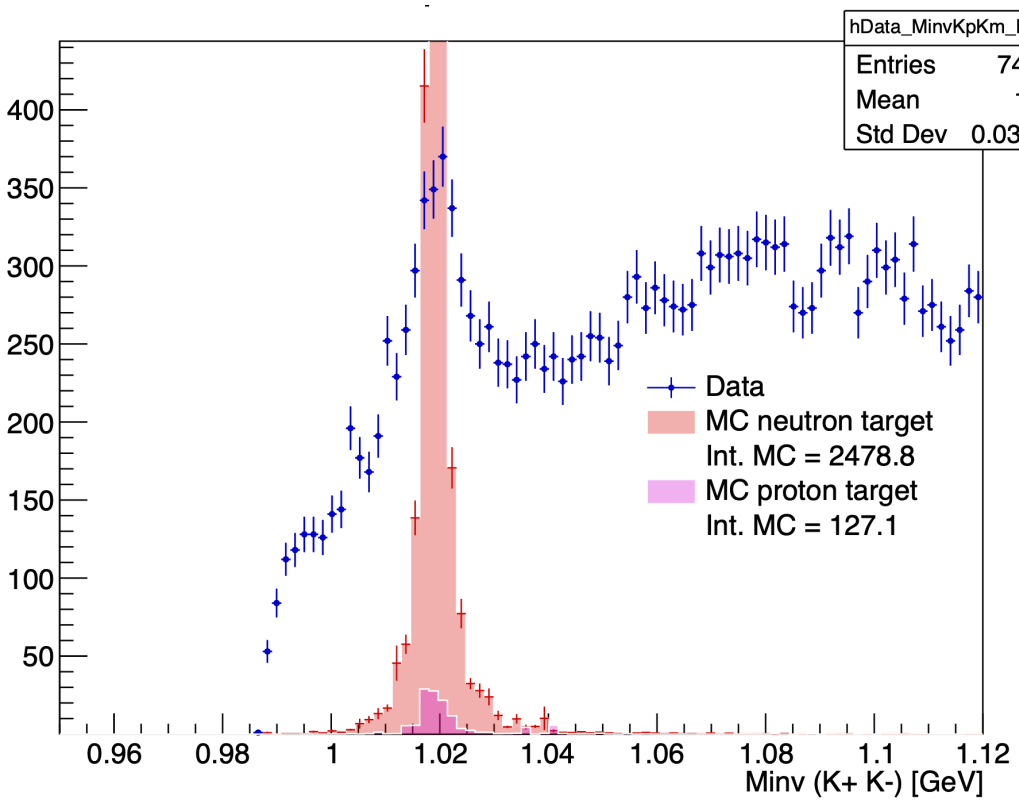
Details on cuts : Total missing mass

Total missing mass e n → e' n' K^+ K^- X
(after all the previous cut)

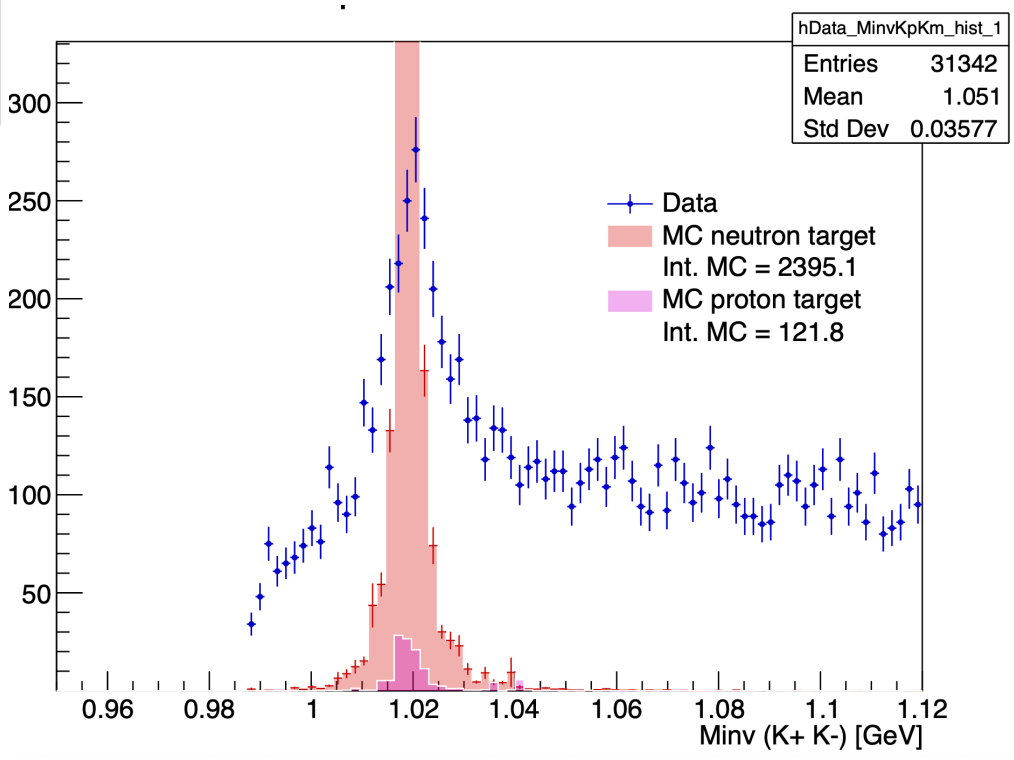
$-0.5 < \text{MissingMass}_{tot}^{\ 2} < 0.5\ \text{GeV}^2$



Invariant mass $K^+ K^-$:

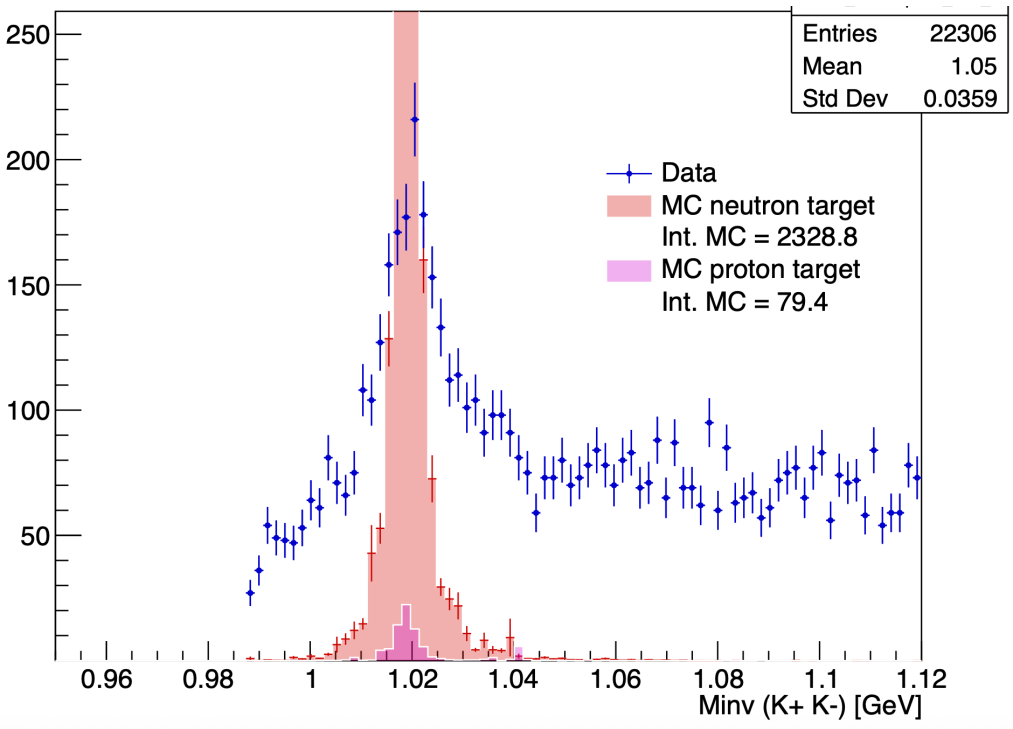


With angle cut

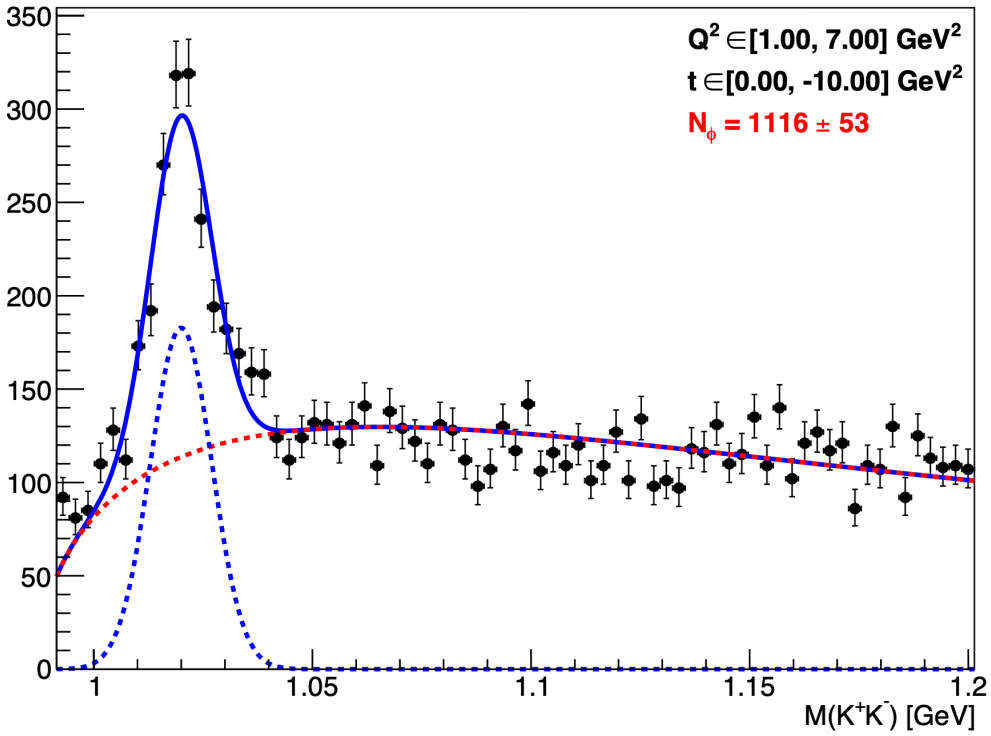


With angle cut and K+ K- in FD

Invariant mass $K^+ K^-$:

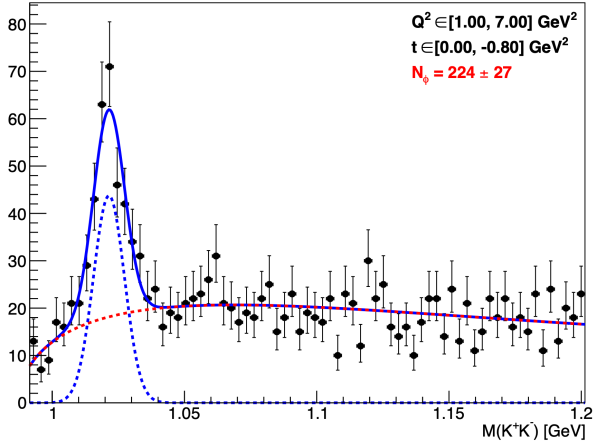


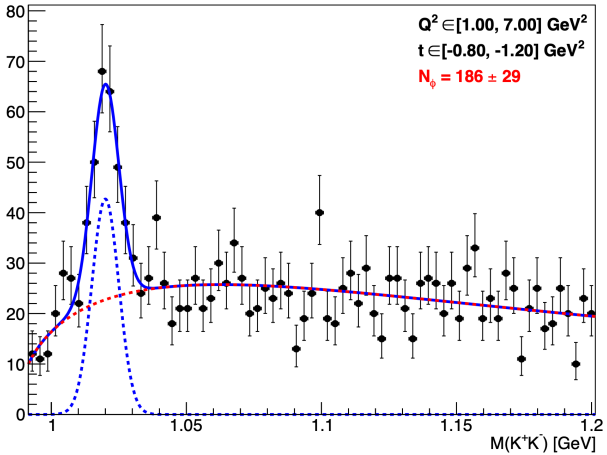
With angle cut, K+ K- in FD, and cut on MissingMass

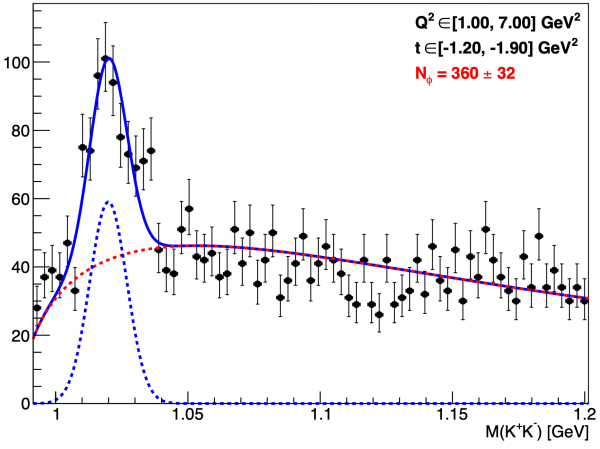


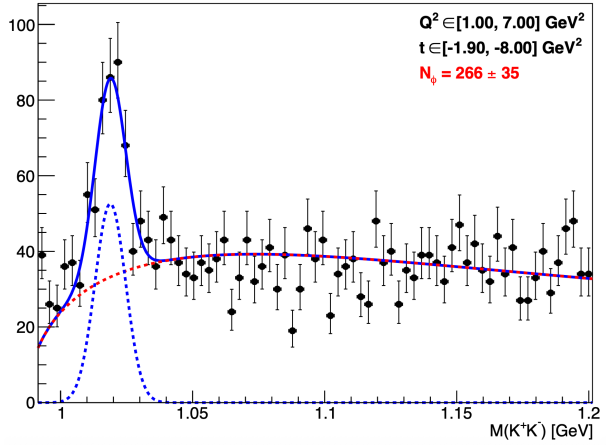
Fit all fall2019 outbending data

Invariant mass $K^+ K^-$: Fit per bins









Conclusion

Next steps :

- Improve fits for signal and background
- Evaluate the acceptance
- Run the code with the other data set

Thanks!

Update on ϕ generator

Simulation objectives :

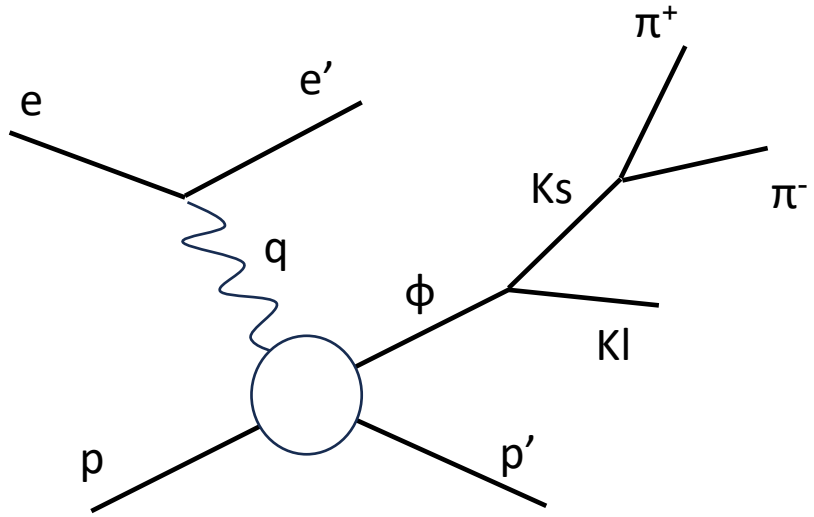
- Estimate the expected number of ϕ with

$$N_{expected} = \frac{\sum w_{rec}}{N_{gen}} * \mathcal{L}$$

- Find interresting cuts

Previously with TGenPhasespace (root module) :

- Generate automatically quadri-impulsion in the phasespace
- But problems with the weight associated with the phasespace

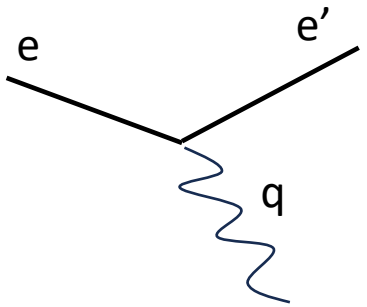


→ In the next slides the generator that we implemented without TGenPhaseSpace

Update on ϕ generator

1. Initially :

$Target = (0, 0, 0, Mp)$
$Beam = (0, 0, E_b, E_b)$
Q^2 generated in $[1, 6.5]$ GeV



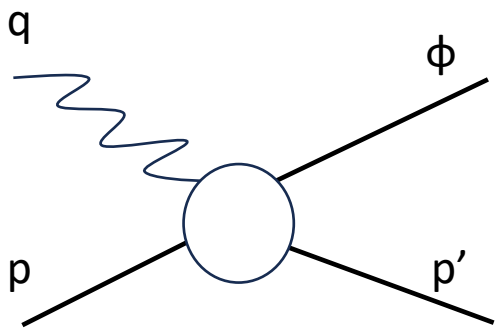
2. Scattering electron kinematics :

- Find W^2_{min} and W^2_{max}. Formula in *Byckling, E., and Kajantie, K. (1973b). Particle kinematics. Wiley-Interscience.*
- Find xb_{min} and xb_{max} (wich depend on $W^2_{min/max}$ and Q^2)
- Generate xb in $[xb_{min}, xb_{max}]$
- Find $E' = E - \nu$ with $\nu = \frac{Q^2}{2*Mp*xb}$
- Find $\theta_{e'} = 2 * arcsin(\sqrt{\frac{Q^2}{4EE'}})$
- Generate $\phi_{e'}$ in $[0, 2\pi]$

Update on ϕ generator

3. Virtual photon kinematics :

$$q = e - e'$$



4. Scattering proton kinematics :

- Find t_{min} and t_{max}
- Generate t in $[t_{min}, t_{max}]$
- Find $E_{p'} = \frac{-t+2*Mp^2}{2Mp}$
- Find $\theta_{\gamma p}$ between proton and photon
- Generate ϕ_p (relative to the photon axis) in $[0, 2\pi]$

Formula for $t_{min/max}$ and $\theta_{\gamma p}$ in *Byckling, E., and Kajantie, K. (1973b). Particle kinematics. Wiley-Interscience.*

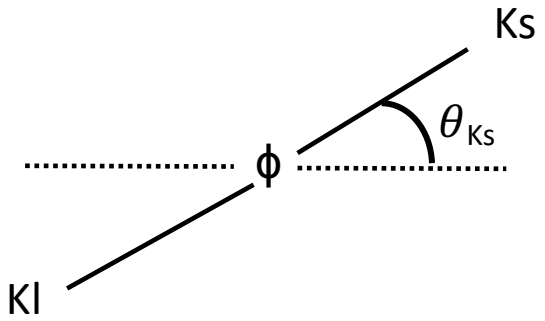
5. Meson ϕ kinematics :

$$\phi = p + q - p'$$

Update on ϕ generator

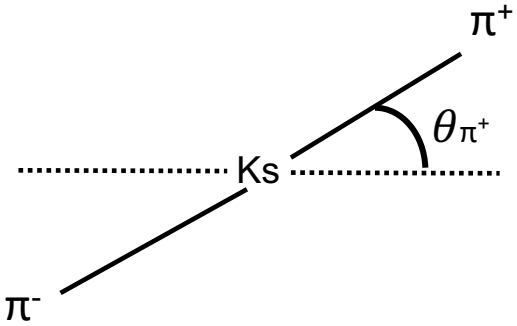
6. Kinematics of second decay ϕ → Ks Kl :

- Uniform decay in θ (and ϕ) in first approximation (in CM)
- Generate $cos(\theta_{Ks})$ in [-1 , 1]
- Generate ϕ_{Ks} in $[0, 2\pi]$
- Find $E_{Ks} = m_\phi/2$ and $p_{Ks} = \sqrt{E_{Ks}^2 - m_{Ks}^2}$
- $p_{Kl} = -p_{Ks}$ in CM
- Boost in order to find Ks and Kl in the lab



7. Kinematics of thrid decay Ks → $\pi^+ \pi^-$:

- Same method than in step 6.
- Vx Vy Vz shifted by 2.8 cm in the direction of Ks emmision to simulate the flight of Ks



ϕ generator

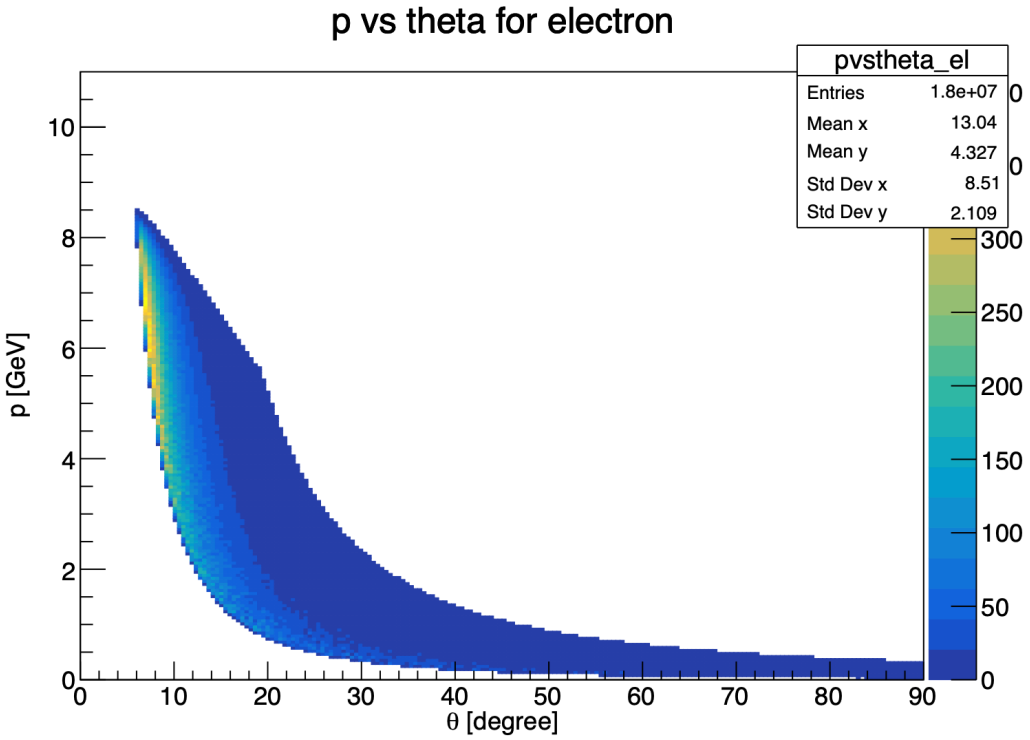
$$weight_{PhaseSpace} = |Q^2_{max} - Q^2_{min}| * |xb_{max} - xb_{min}| * |t_{max} - t_{min}|$$

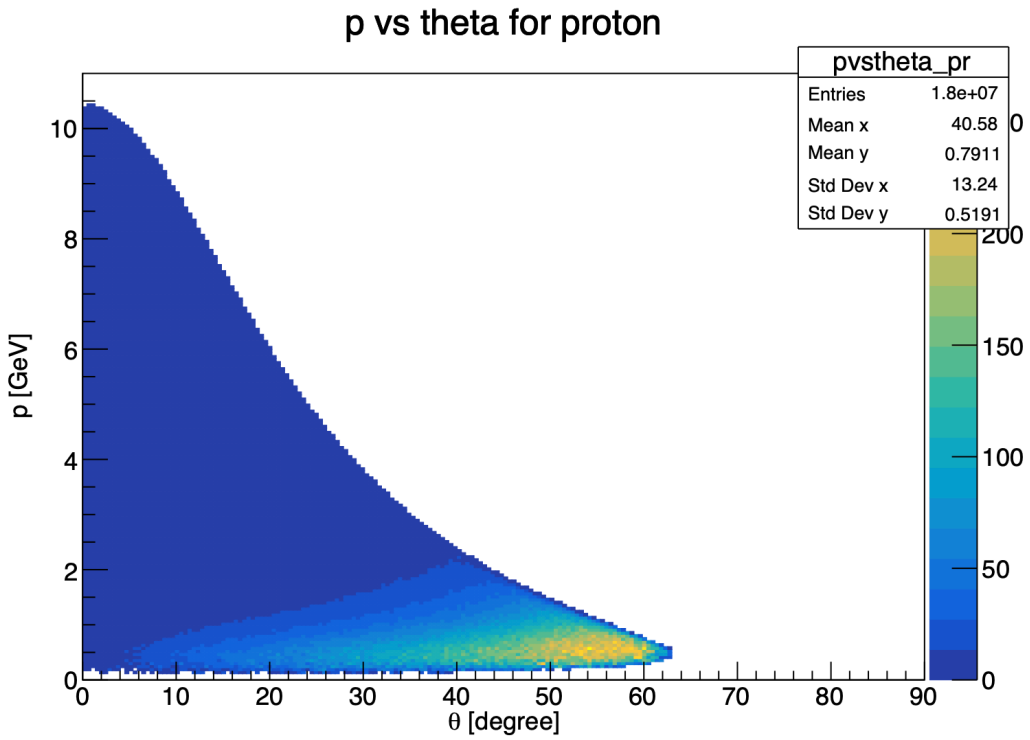
$$\frac{d^3\sigma}{dQ^2 dx_B dt}$$ *From Proposal to Jefferson Lab PAC39 Exclusive Phi Meson Electroproduction with CLAS12*

$$\mathrm{BR}(\phi \to K^+K^-) \approx 49.2\%$$

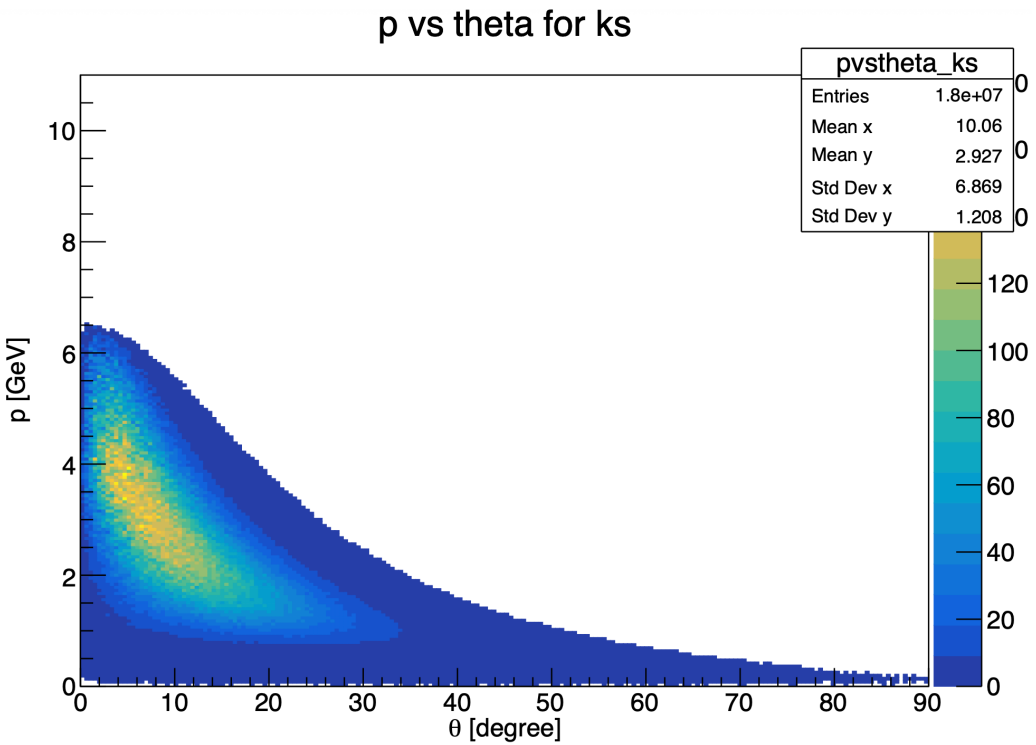
$$totalweight = weight_{phasespace} * weight_{\frac{d^3\sigma}{dtdQ^2dx_b}} * BR_{\phi \to K^+K^-}$$

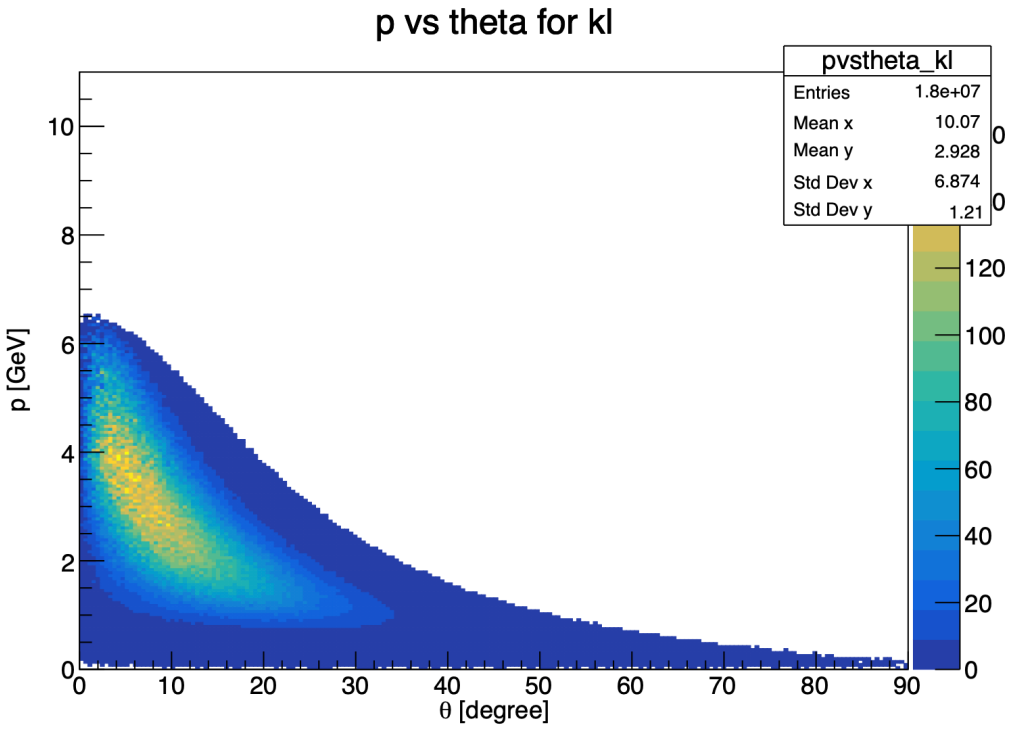
Update on ϕ generator





Update on ϕ generator





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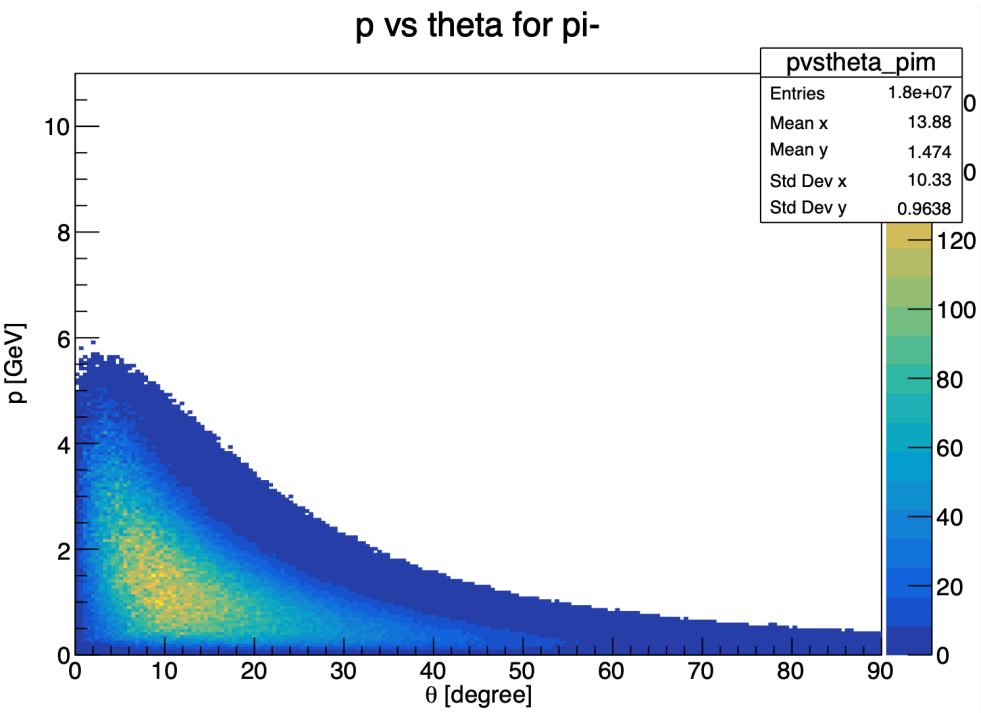
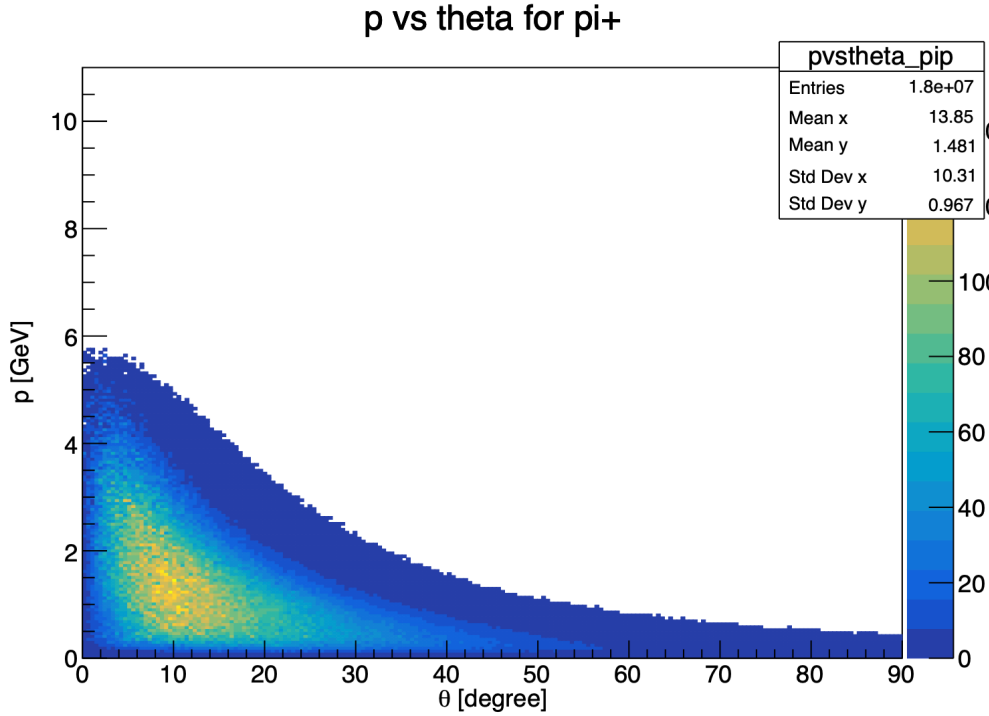
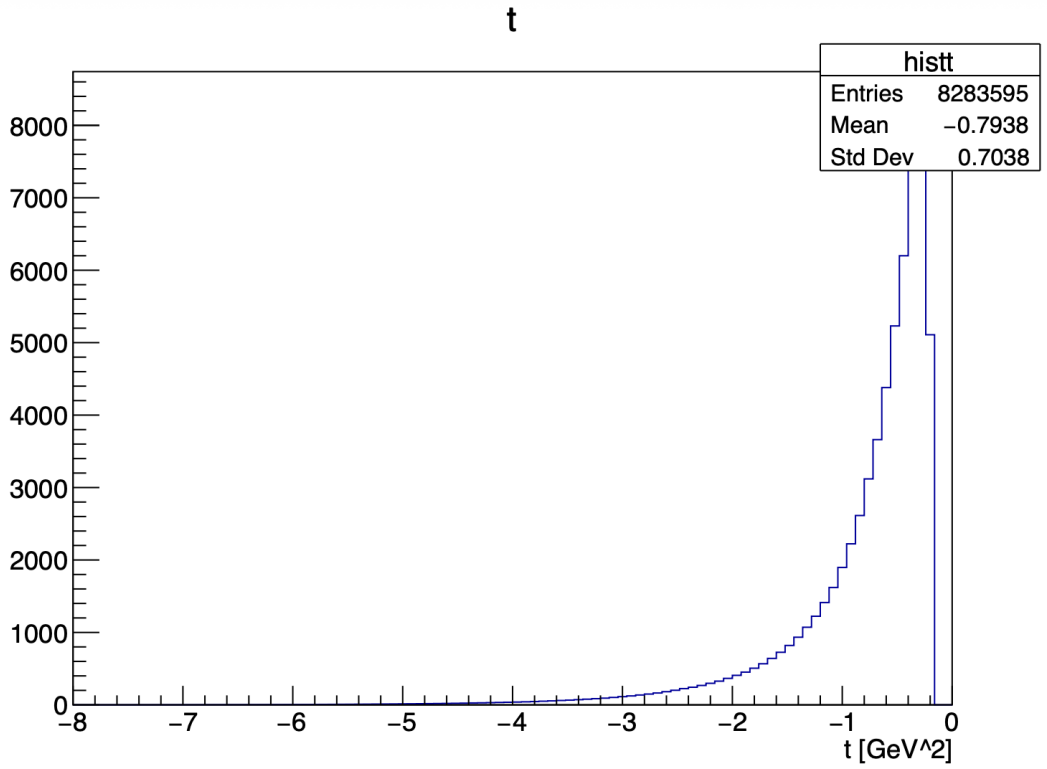
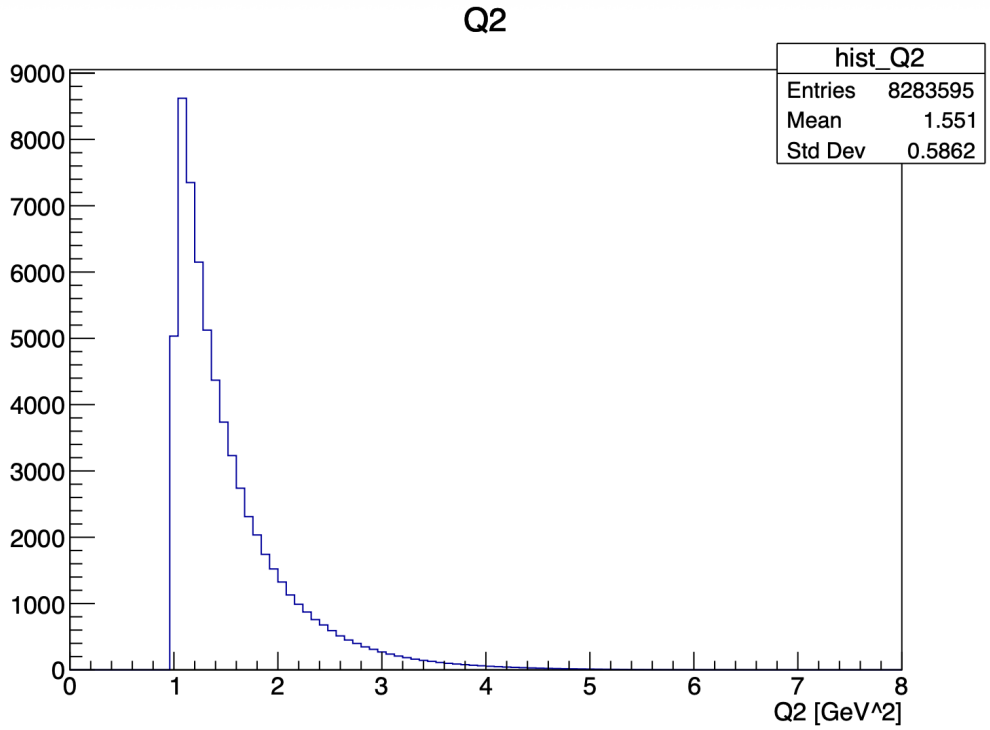




Update on ϕ generator





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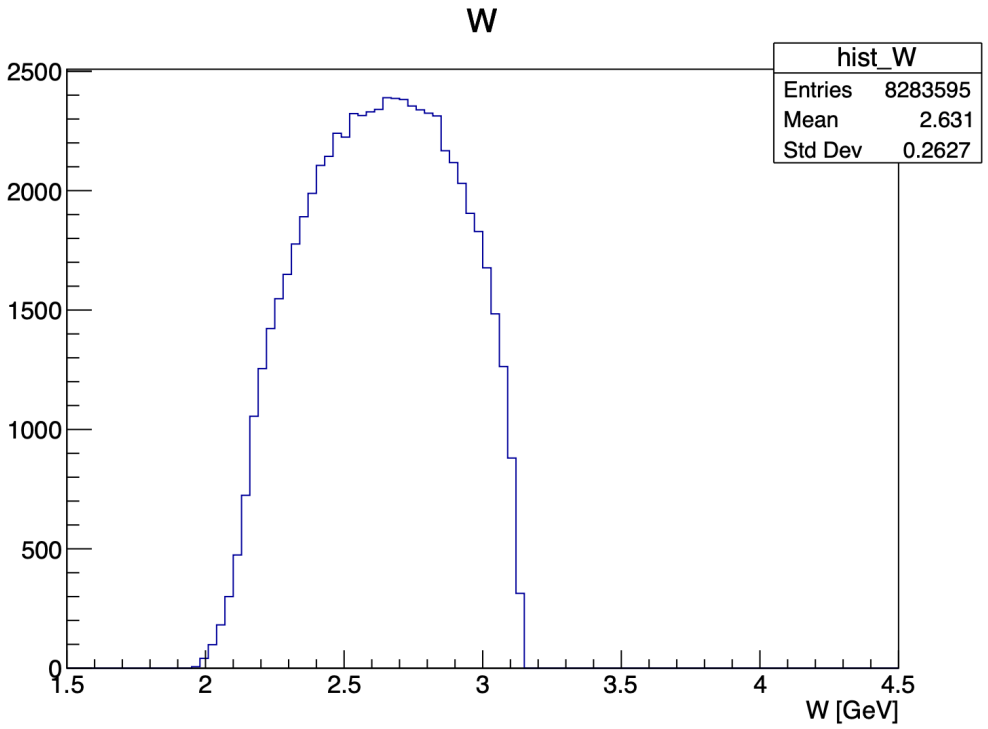
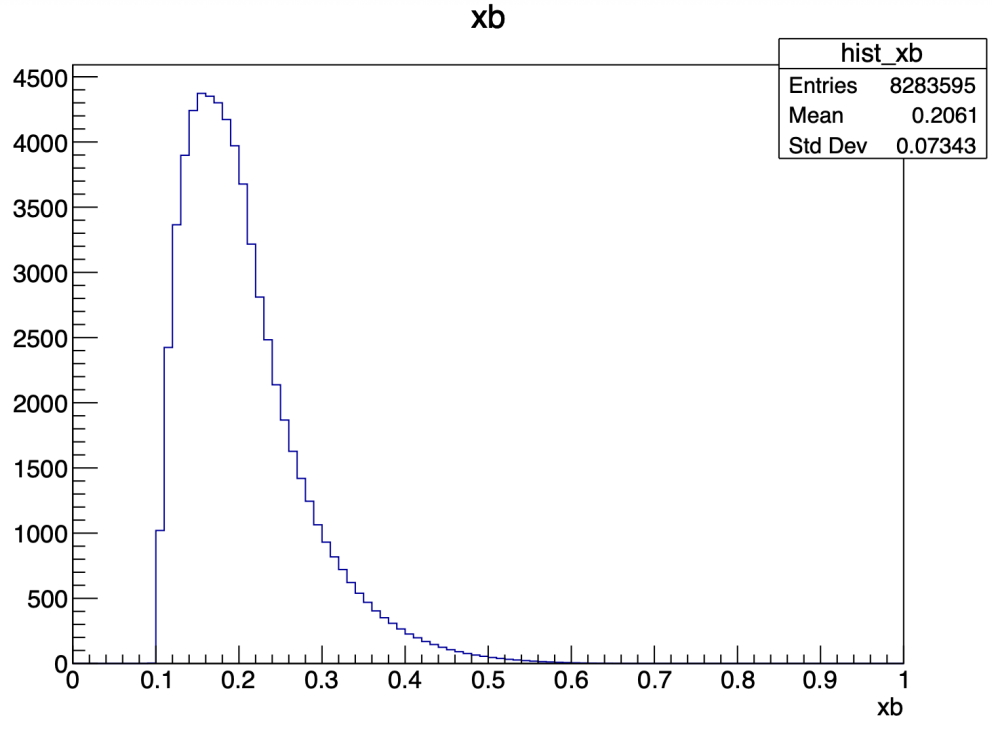
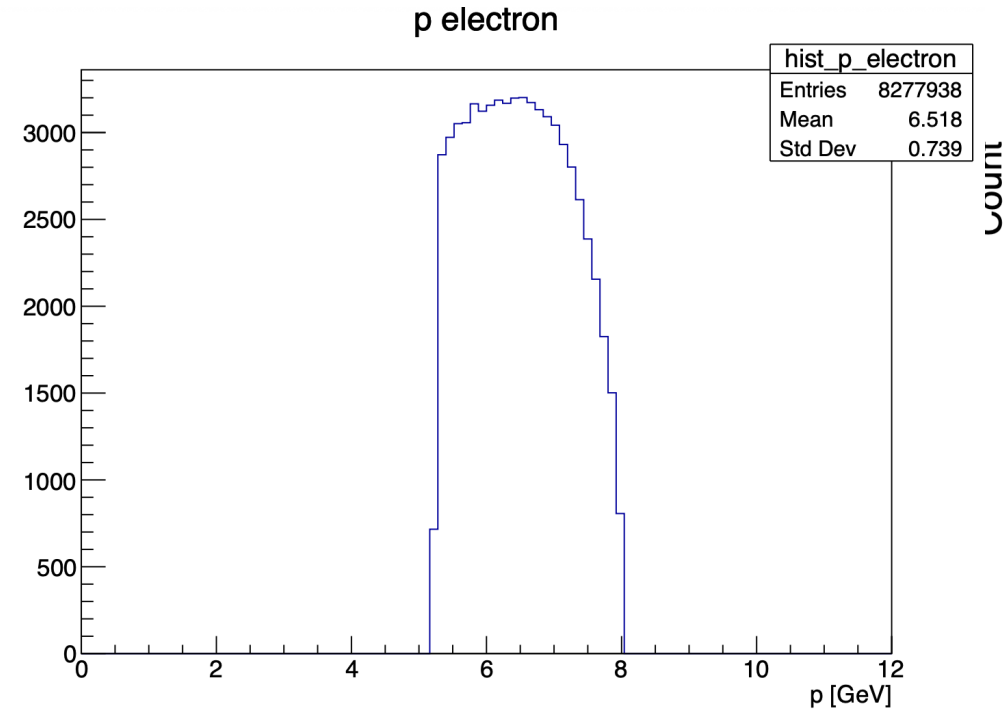


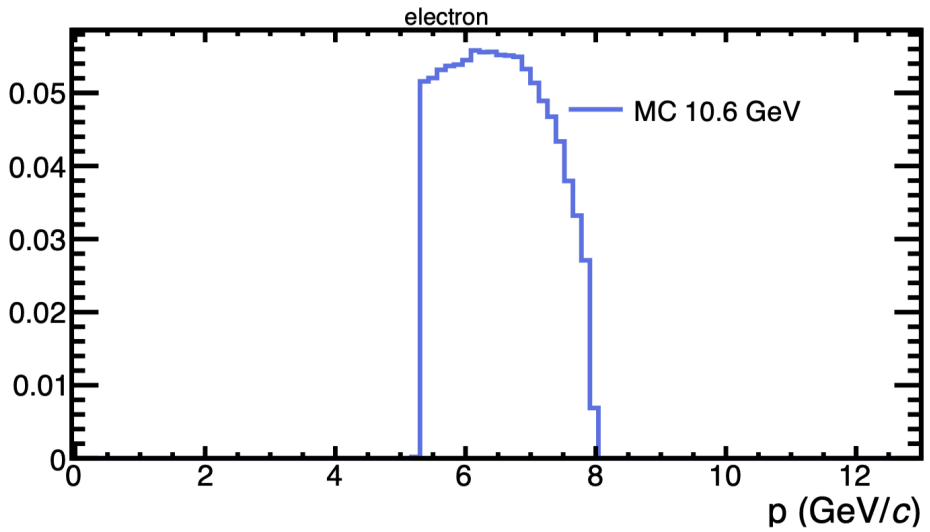


Update on ϕ generator

With this cuts : 5.25 < $P_{electron}$ < 8 GeV and P_{proton} > 0.45 GeV



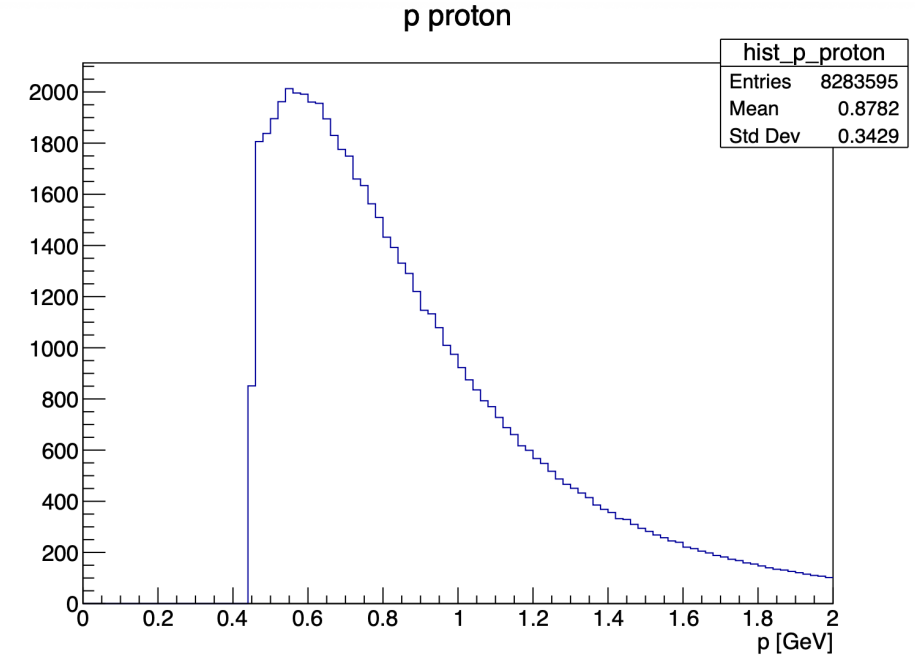
my generator



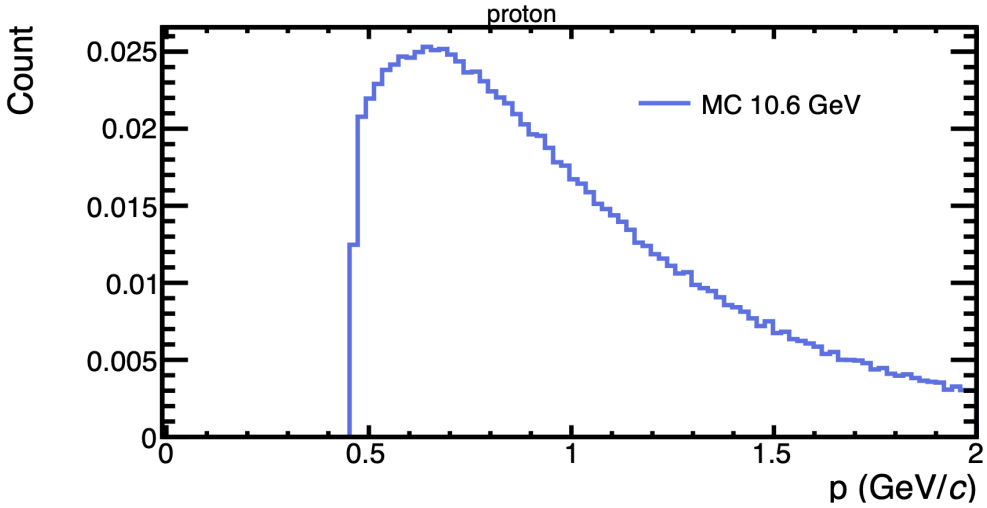
Bhawani plot

Update on ϕ generator

With this cuts : 5.25 < $P_{electron}$ < 8 GeV and P_{proton} > 0.45 GeV



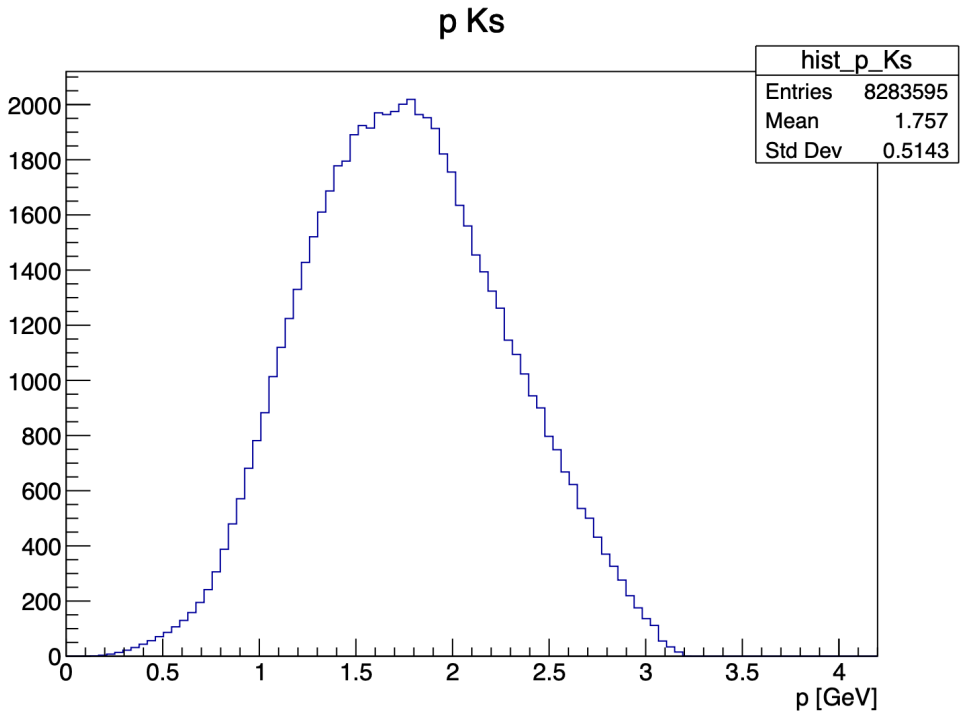
my generator



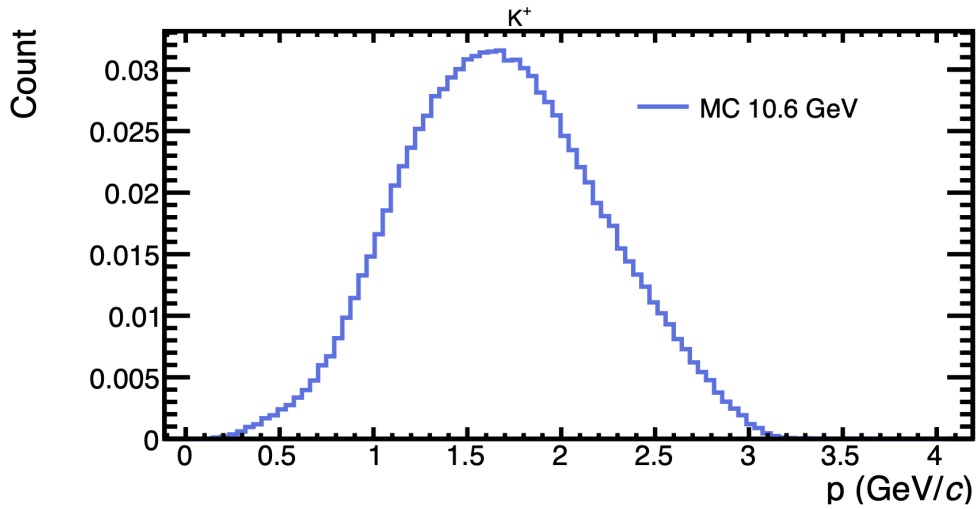
Bhawani plot

Update on ϕ generator

With this cuts : 5.25 < $P_{electron}$ < 8 GeV and P_{proton} > 0.45 GeV



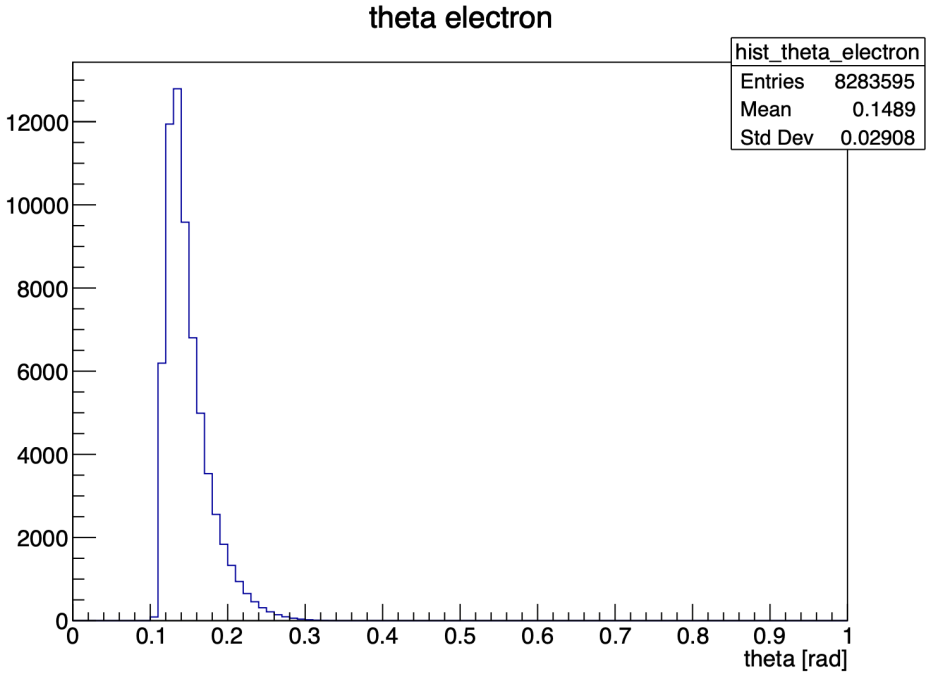
my generator



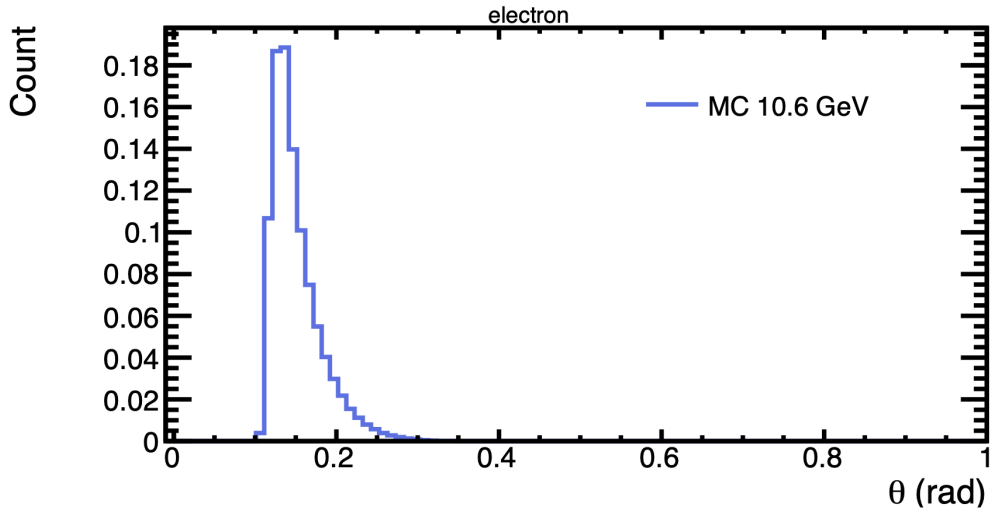
Bhawani plot

Update on ϕ generator

With this cuts : 5.25 < $P_{electron}$ < 8 GeV and P_{proton} > 0.45 GeV



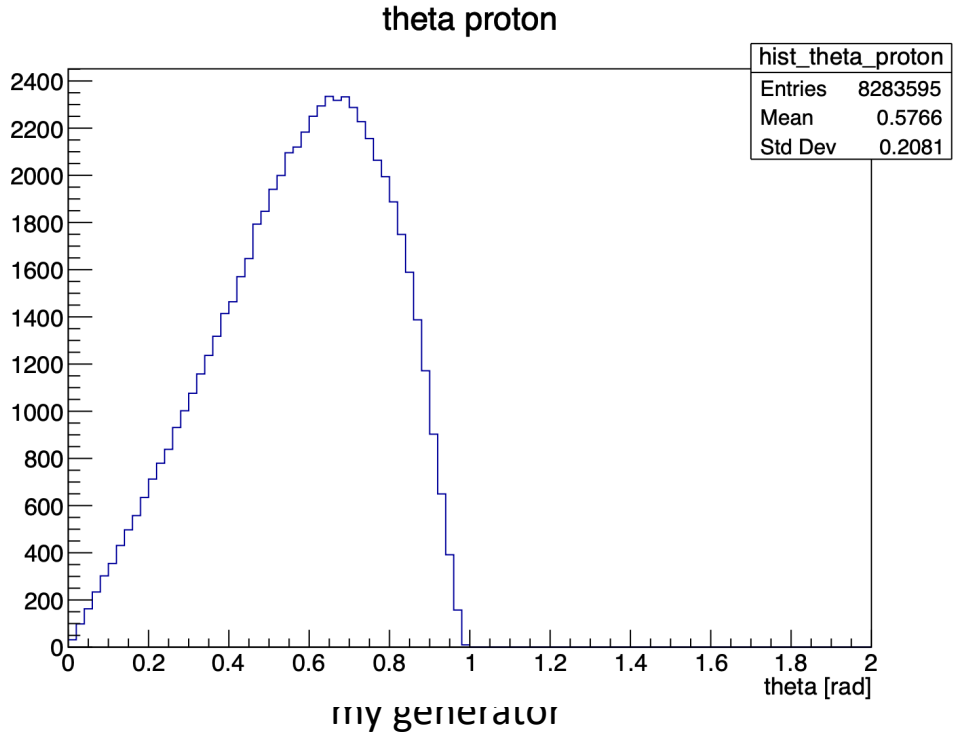
my generator

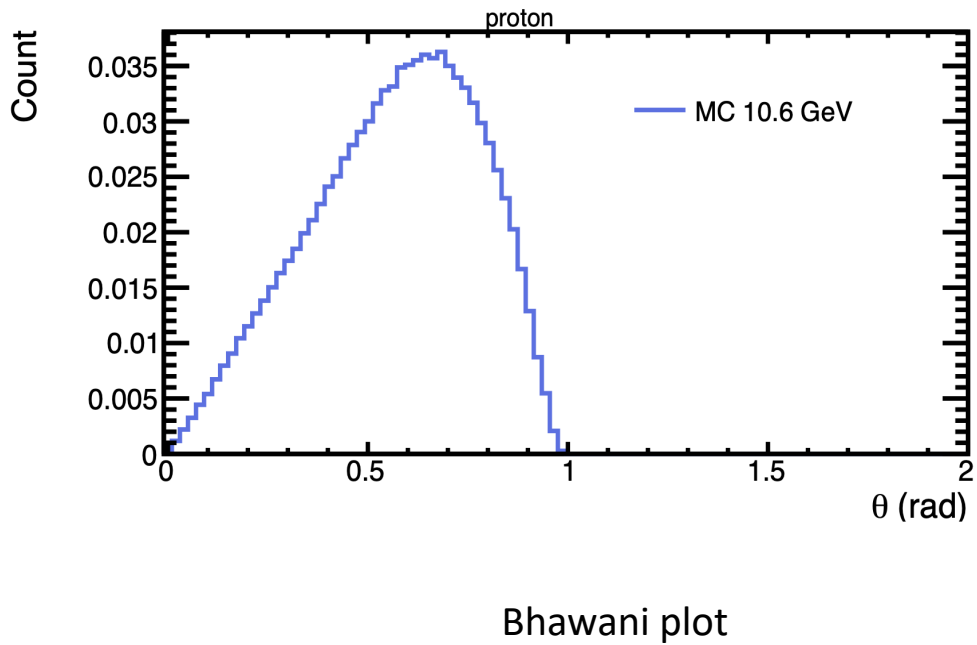


Bhawani plot

Update on ϕ generator

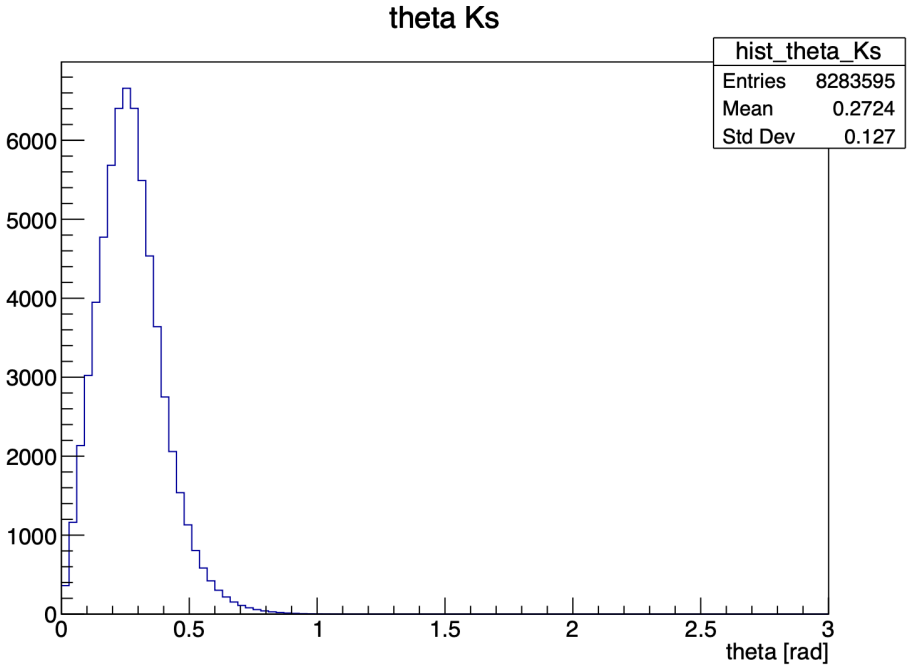
With this cuts : 5.25 < $P_{electron}$ < 8 GeV and P_{proton} > 0.45 GeV



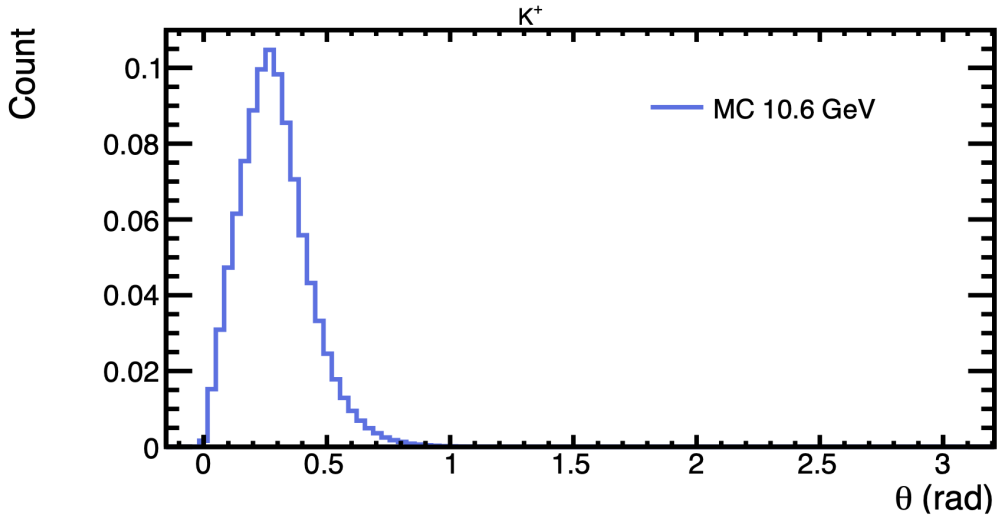


Update on ϕ generator

With this cuts : 5.25 < $P_{electron}$ < 8 GeV and P_{proton} > 0.45 GeV



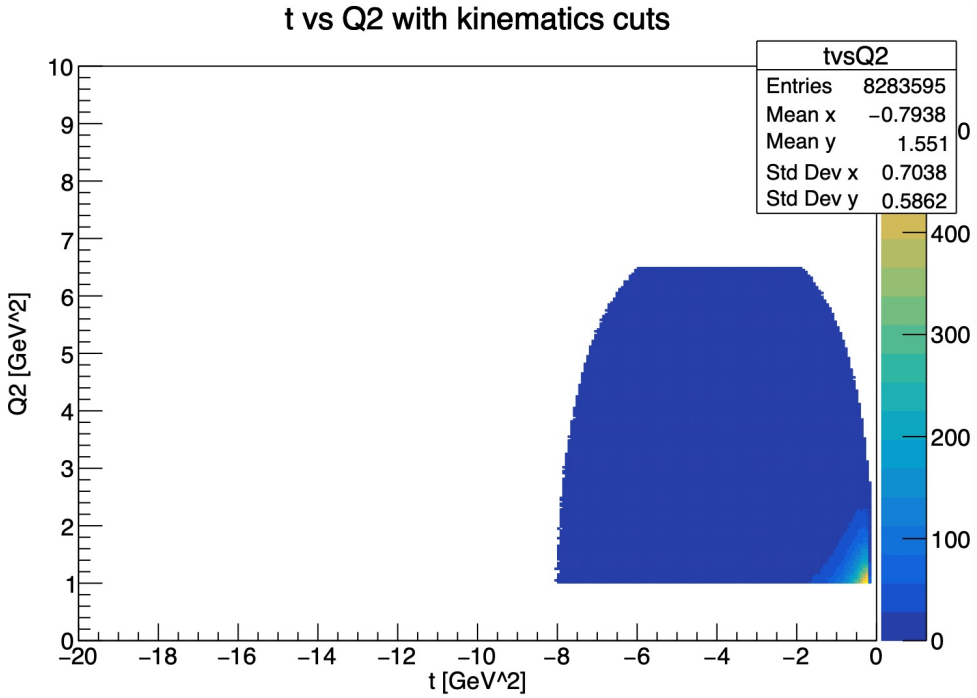
my generator



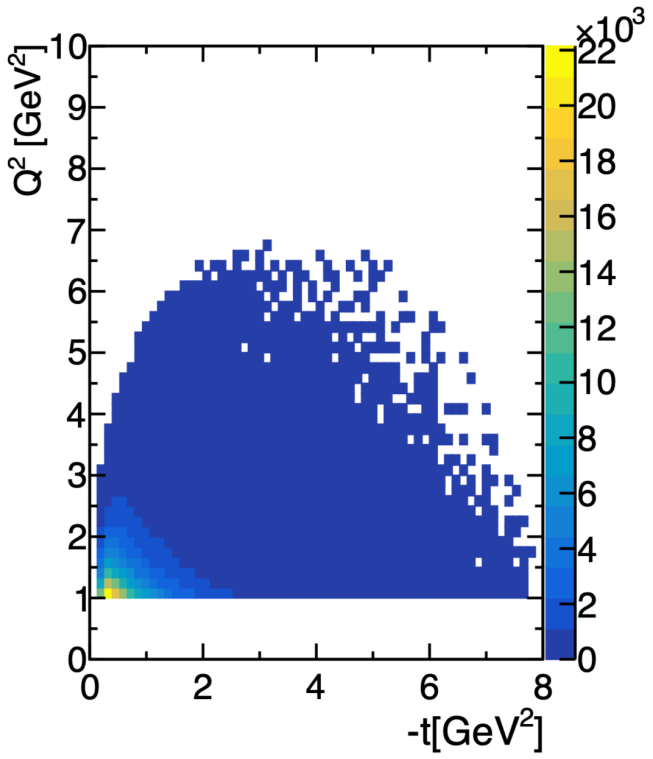
Bhawani plot

Update on ϕ generator

With this cuts : $5.25 < P_{electron} < 8$ GeV and $P_{proton} > 0.45$ GeV



my generator



Bhawani plot

Update on ϕ generator

Backup cross section

Update on ϕ generator

Details on cross section :

σ_T and σ_L ($\gamma^* p \rightarrow \phi\, p$) :

$$\sigma_T(W, Q^2) = \frac{c_T(W)}{(1 + Q^2/m_\phi^2)^{\nu_T}}$$

$$R = \sigma_L(W, Q^2)/\sigma_T(W, Q^2)$$

$$R(W, Q^2) = \frac{c_R Q^2}{m_\phi^2}$$

t-dependence (dipole) :

$$\frac{d\sigma_{L,T}}{dt} = \frac{\sigma_{L,T}\, F(t)}{F_{\text{int}}}$$

$$F(t) = \frac{m_g^8}{(m_g^2 - t)^4}$$

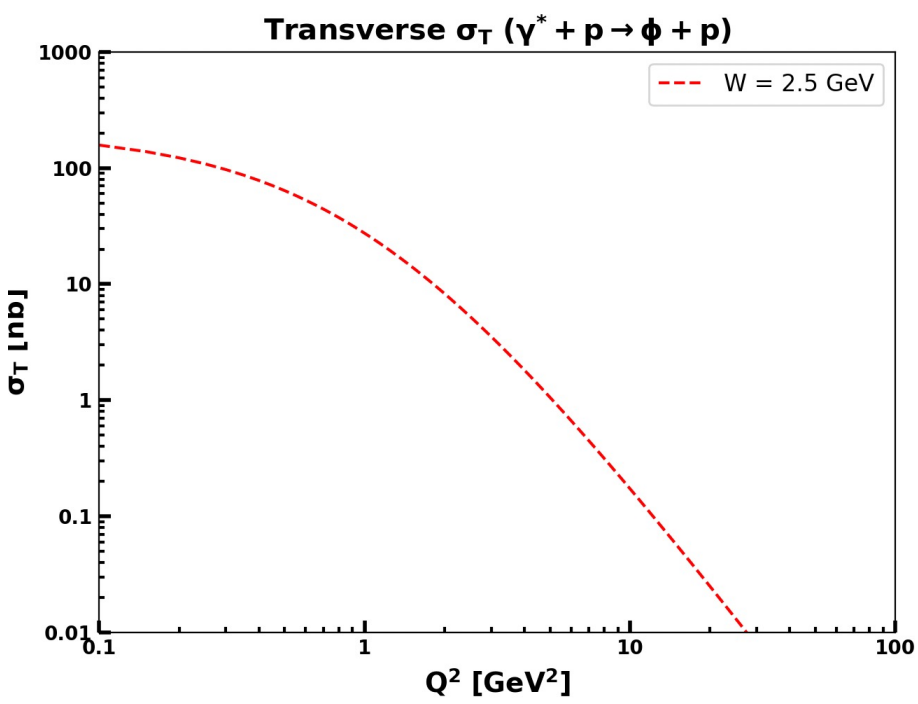
Update on ϕ generator

Cross section (ep → ϕ p) :

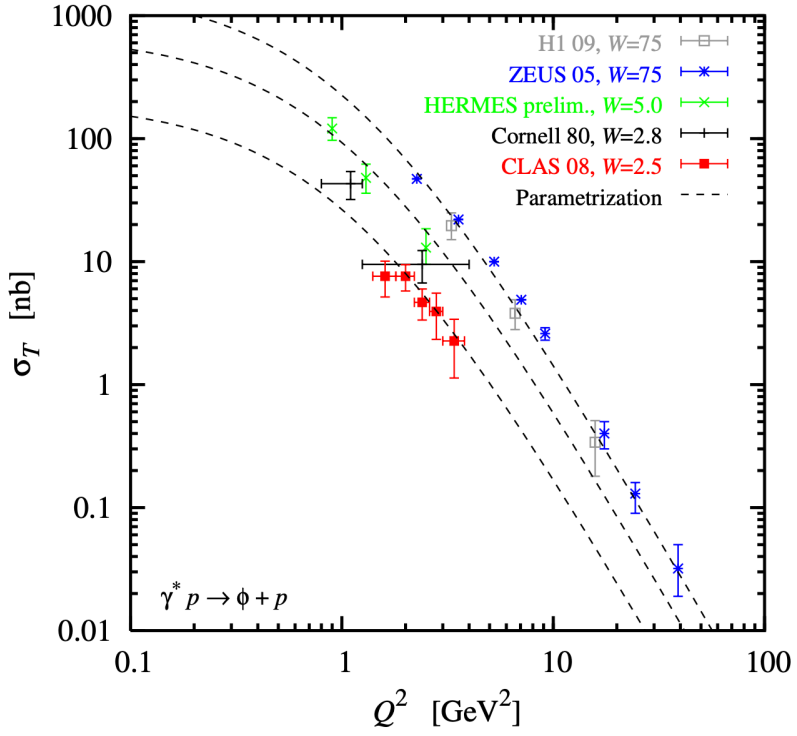
$$\frac{d^3\sigma}{dQ^2 dx_B dt} = \Gamma(Q^2, x_B, E)\left[\frac{d\sigma_T}{dt}(Q^2, x_B, t) + \epsilon\frac{d\sigma_L}{dt}(Q^2, x_B, t)\right]$$

The virtual photon flux : $\Gamma \equiv \frac{\alpha}{8\pi}\frac{Q^2}{m_N^2 E^2}\frac{1-x_B}{x_B^3}\frac{1}{1-\epsilon}$

Update on ϕ generator

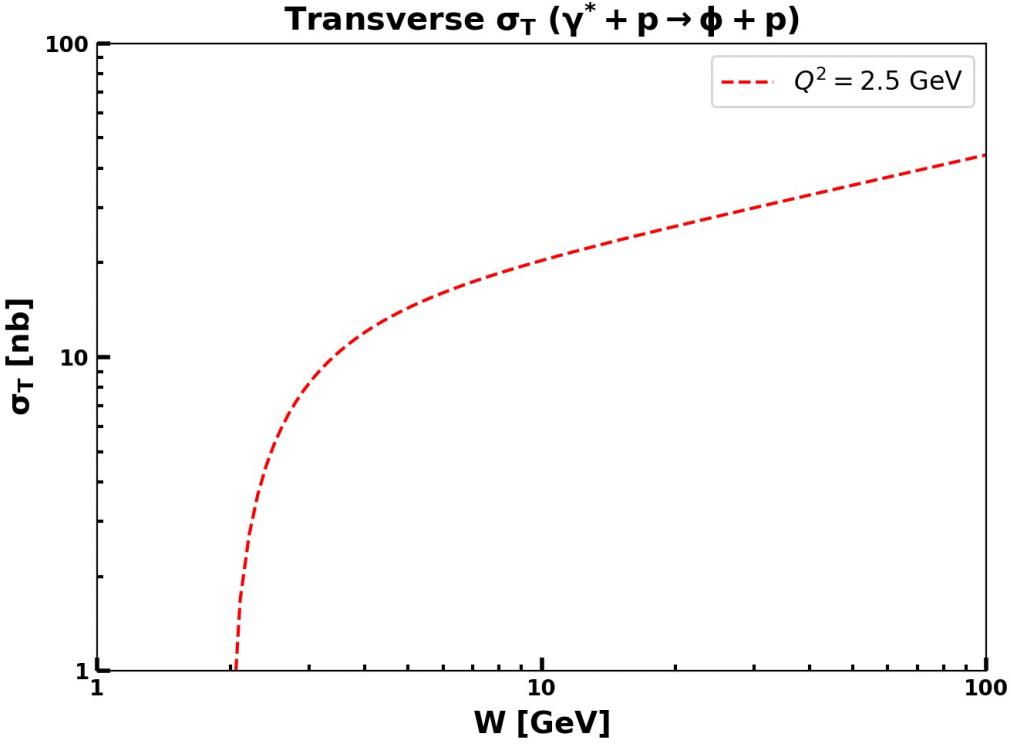


Implemented in the generator

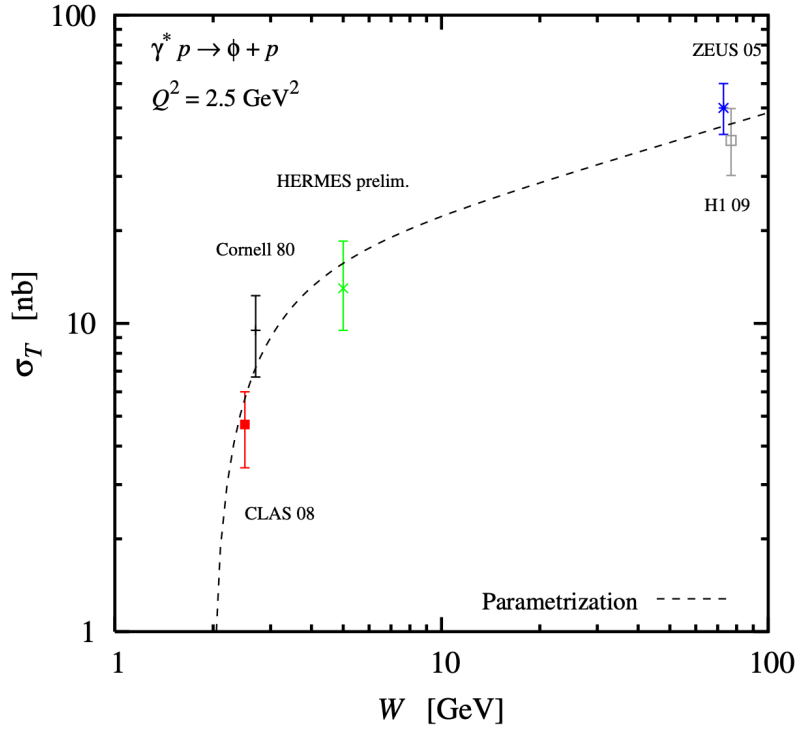


From Proposal to Jefferson Lab PAC39

Update on ϕ generator

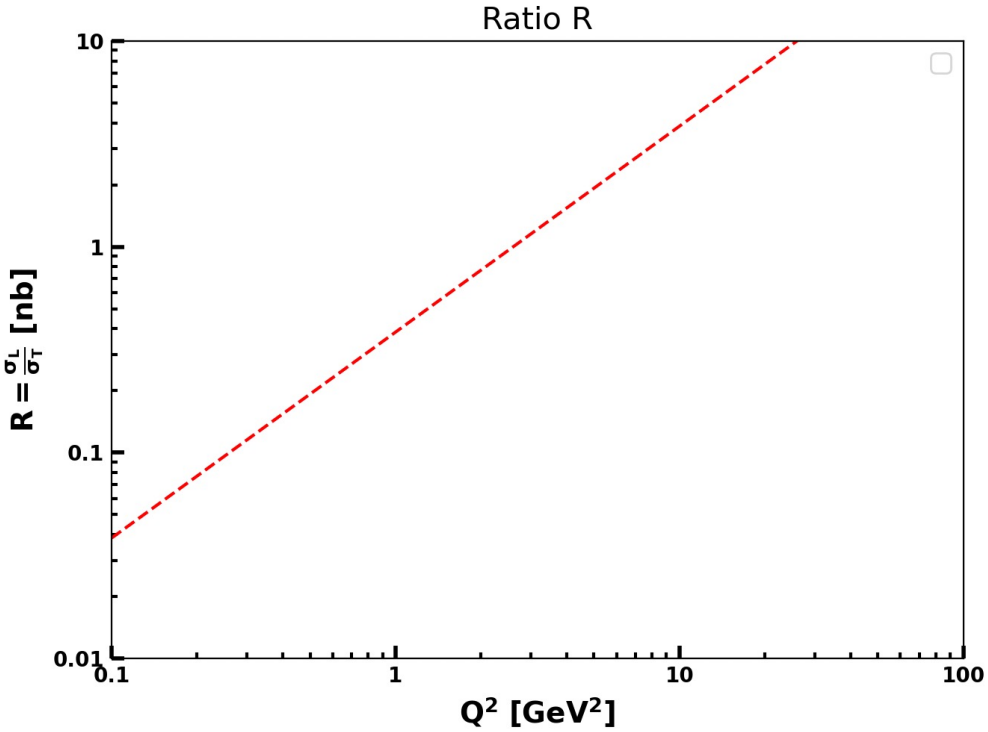


Implemented in the generator

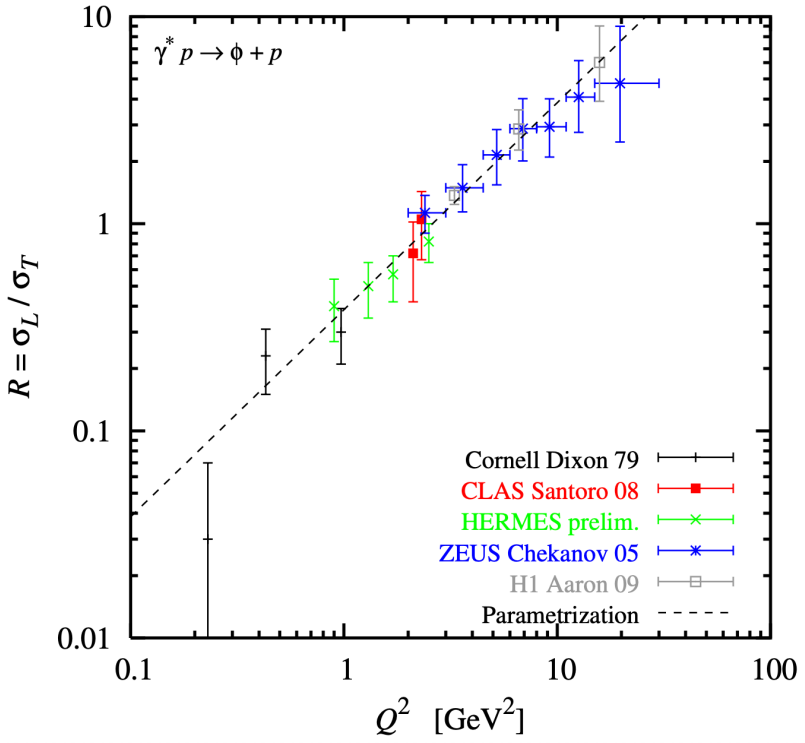


From Proposal to Jefferson Lab PAC39

Update on ϕ generator



Implemented in the generator



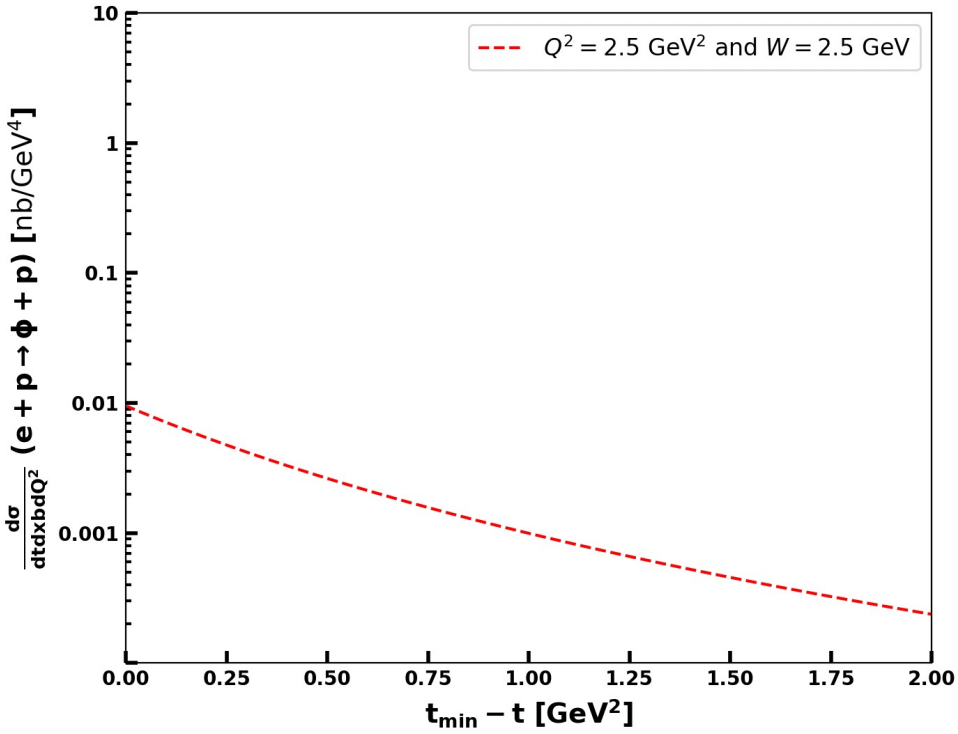
From Proposal to Jefferson Lab PAC39

Update on ϕ generator

Cross section (ep → ϕ p) (with the virtual photon flux) :

$$\frac{d^3\sigma}{dQ^2 dx_B dt} = \Gamma(Q^2, x_B, E)\left[\frac{d\sigma_T}{dt}(Q^2, x_B, t) + \epsilon\frac{d\sigma_L}{dt}(Q^2, x_B, t)\right]$$

$$\Gamma \equiv \frac{\alpha}{8\pi}\frac{Q^2}{m_N^2 E^2}\frac{1-x_B}{x_B^3}\frac{1}{1-\epsilon}$$



Implemented in the generator