

CLAS12 Collaboration Meeting

ϕ electroproduction on the neutron with RGB

12 March 2026

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Summary

1. Motivations
2. Events selection
3. Generator for MC simulation
4. Effect of different cuts
5. Yield extraction
6. Acceptance correction
7. Preliminary plot of differential cross section

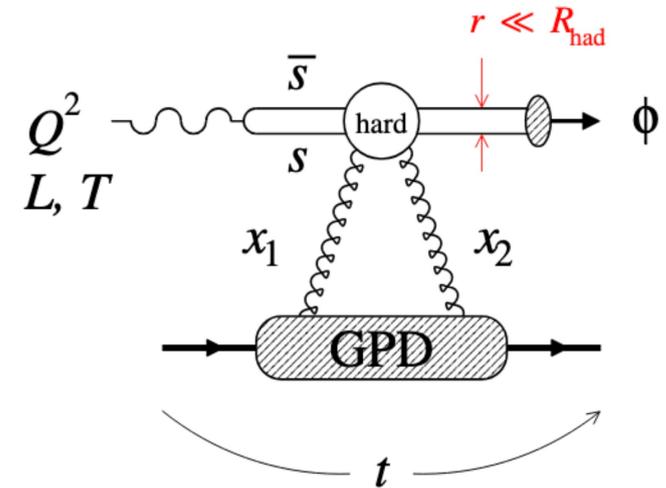
Motivations

Analysis objective :

- Measurement of the cross section of the of ϕ electroproduction on **neutron** in the **$K^+ K^-$ channel** with **RGB** data (**deuterium** target).

$e n \rightarrow e n' K^+ K^- \rightarrow$ Access to the gluon content of the neutron

- We expect that cross section measurement to be similar to that of proton. We will compare with proton bound target (RGB) and with the work on free proton target (Bhawani's work on RGA).



Change of t -dependence with Q^2
 \rightarrow gluonic radius of the neutron

Events selection

Analysis :

$e n \rightarrow e n' K^+ K^-$

Events selection :

e^-	K^+	K^-	proton	neutron
Exactly 1	Exactly 1 in FD	Exactly 1 in FD	Exactly 0	≥ 1

Datas :

- sidisdvcs **RG-B outbending fall 2019**
- with $Q^2 > 0.95 \text{ GeV}^2$, $W > 1.95 \text{ GeV}$, $P_{e^-} > 1 \text{ GeV}$.
and $-20 < v_{z_{e^-}} < 20 \text{ cm}$

select the best neutron wich minimize the angle between the **missing nucleon** and the **neutron**



$Q^2 > 1.0 \text{ GeV}^2$	$P_{\text{electron}} > 2 \text{ GeV}$	$\theta_{\text{neutron}} > 4^\circ$	$P_{\text{neutron}} > 0.25 \text{ GeV}$
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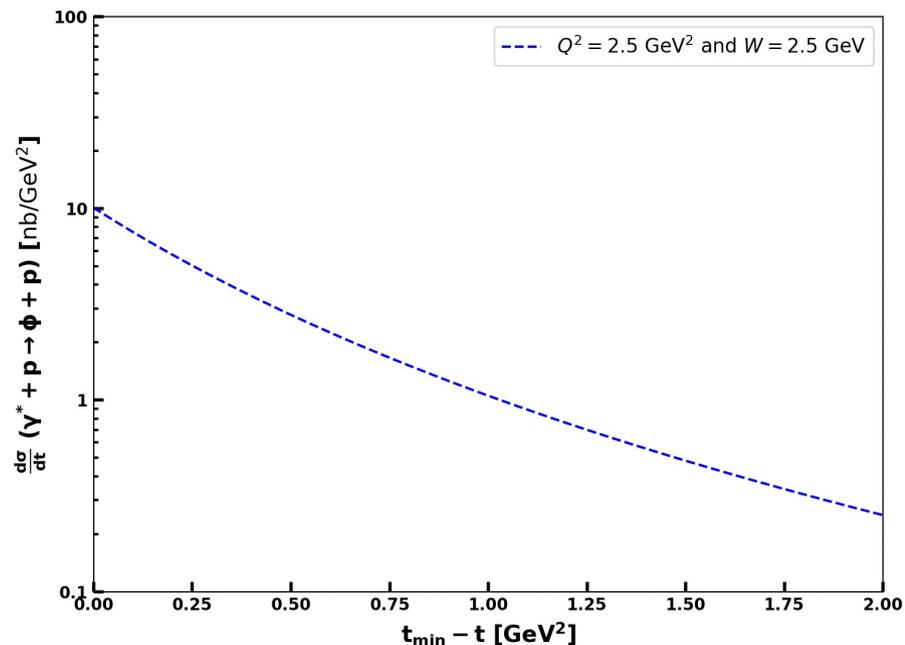
Cuts :

→ Cut on the angle between the missing nucleon and the neutron $< 5^\circ$

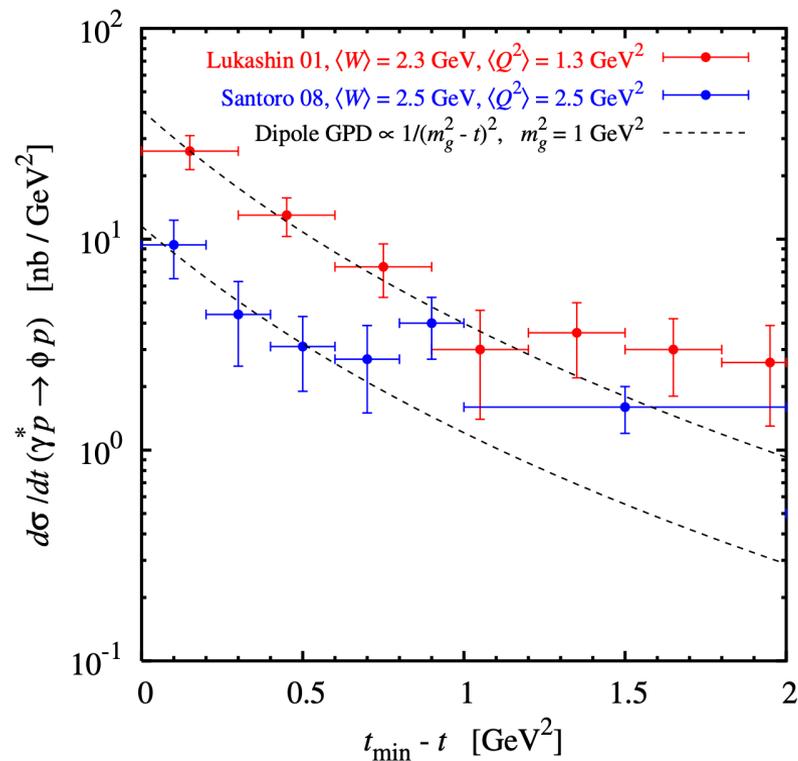
→ Cut on $-0.5 < M_{eK^+K^-nX}^2 < 0.5 \text{ GeV}^2$

The missing nucleon is use to calculate **t** with $t = (\text{target} - \text{missing})^2$

ϕ generator for MC simulation



Implemented in the generator

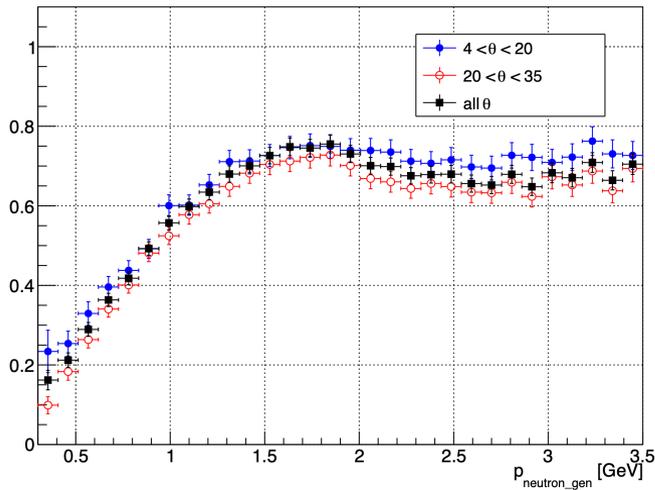


From Proposal to Jefferson Lab PAC39

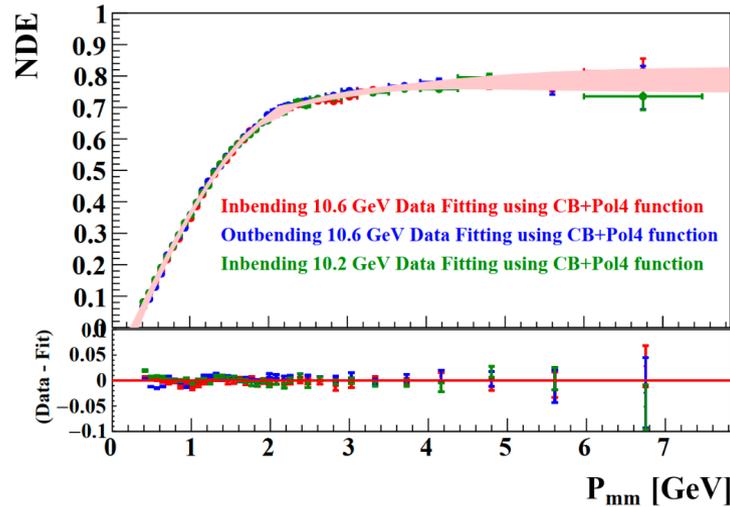
→ https://github.com/mathieuryt/phi_analysis/tree/main/electroproduction/simulation/events-generator

Efficiency correction for neutron in the FD

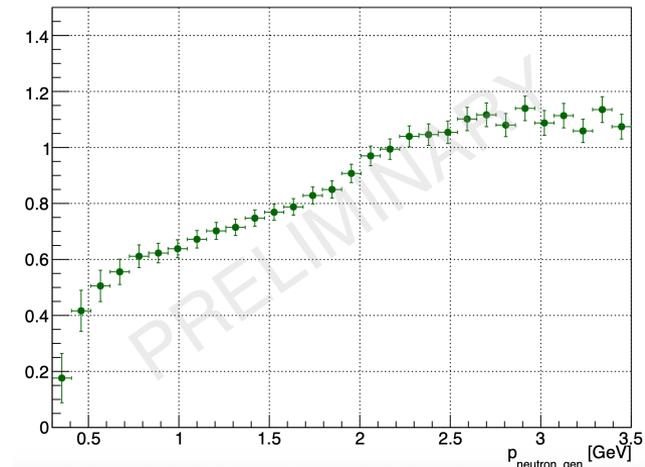
MC Efficiency vs p



Neutron Detection Eff



Data/MC Efficiency Ratio



- Neutron efficiency in **MC** :
$$\frac{N_{rec}(e^- n)}{N_{gen}(\text{with } e^- \text{ rec})}$$

- We are in the fiducial volume for reconstructed and generated event

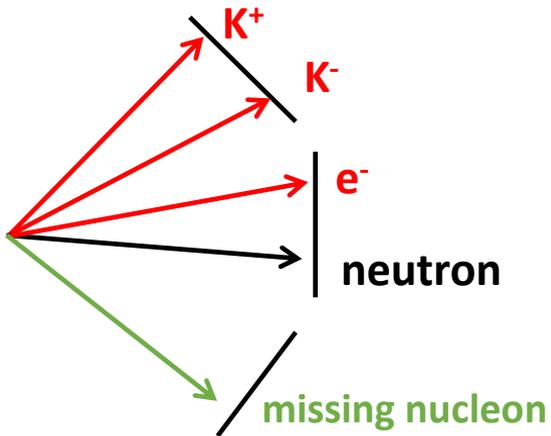
- Neutron efficiency (FD) in **data** from **Lamy Baashen** thesis

(with P_{mm} the missing momentum)

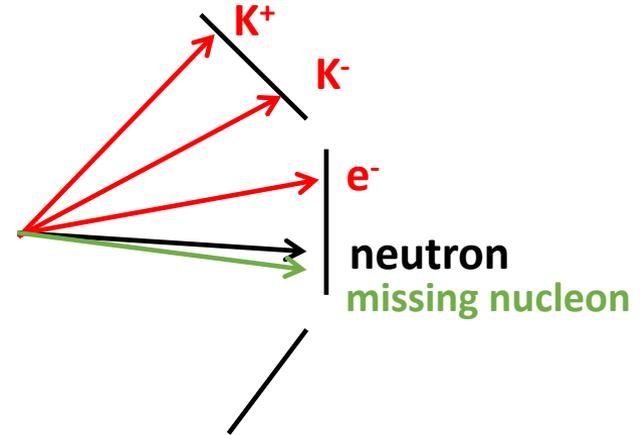
- The ratio between the **MC** and **data** efficiencies gives the **neutron efficiency correction factor**

Cut on the angle between missing nucleon and detected neutron

Missing nucleon = the missing particle of : $e n \rightarrow e' K^+ K^- X$



Not a good event

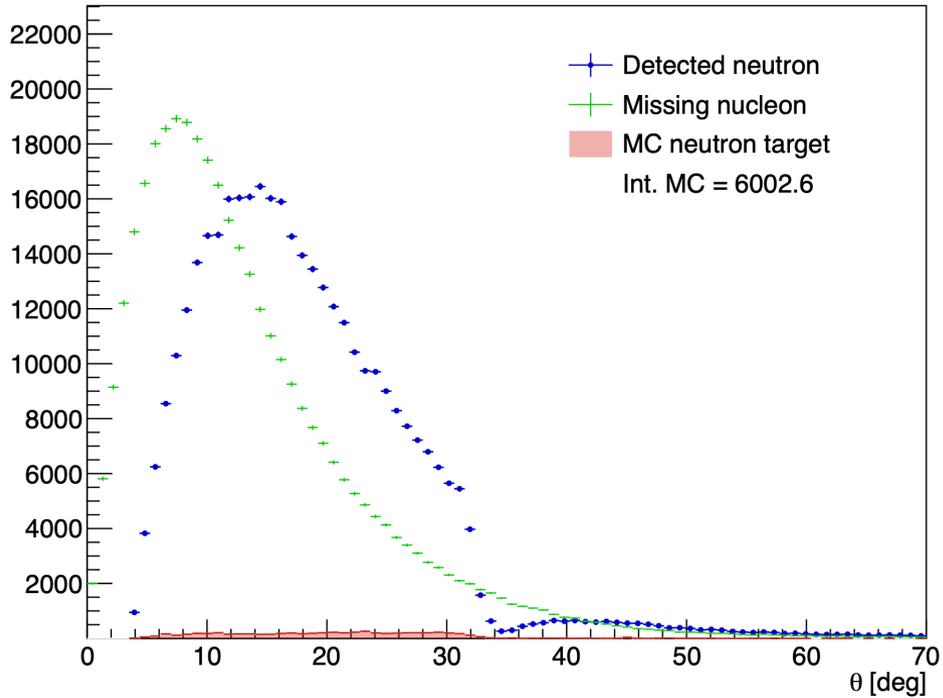


Good event

→ Cut on the angle between the missing nucleon and the neutron $< 5^\circ$

Cut on the angle between missing nucleon and detected neutron

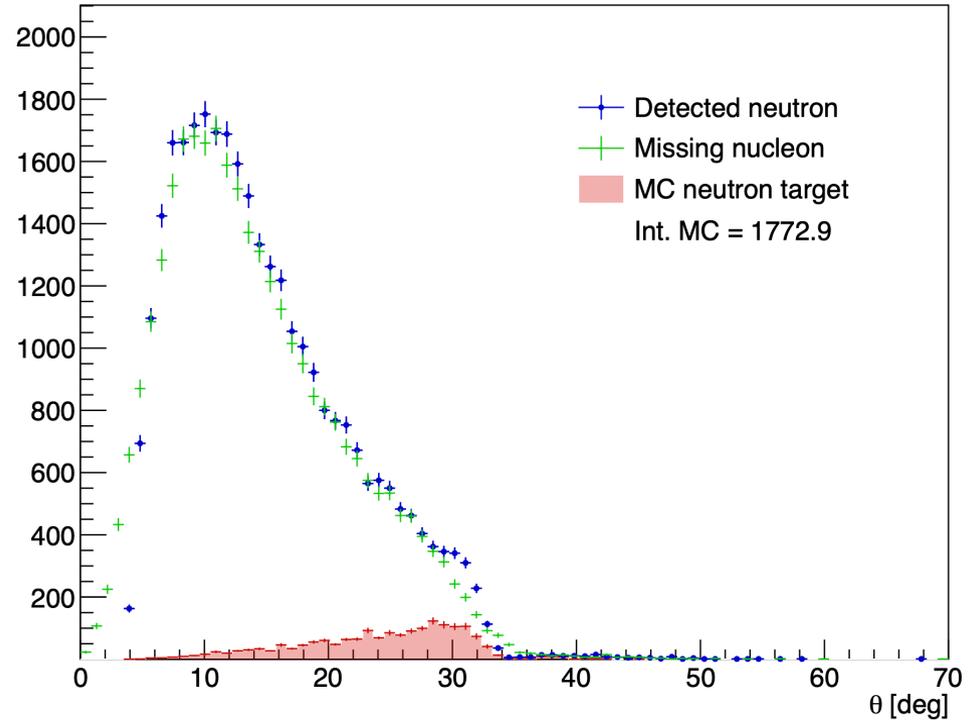
Neutron θ



Without the angle cut

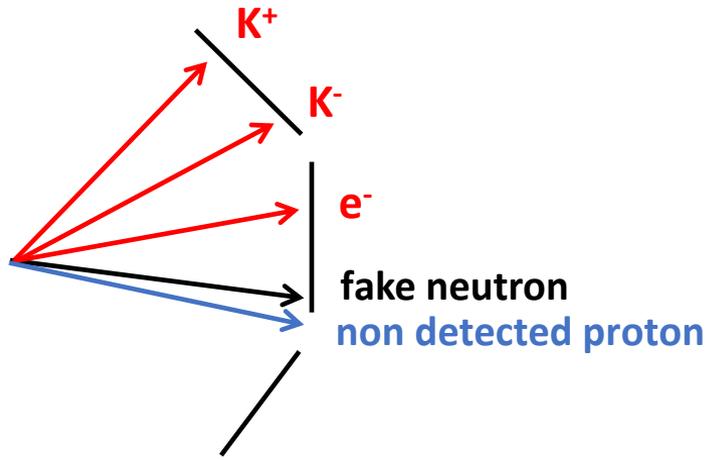


Neutron θ

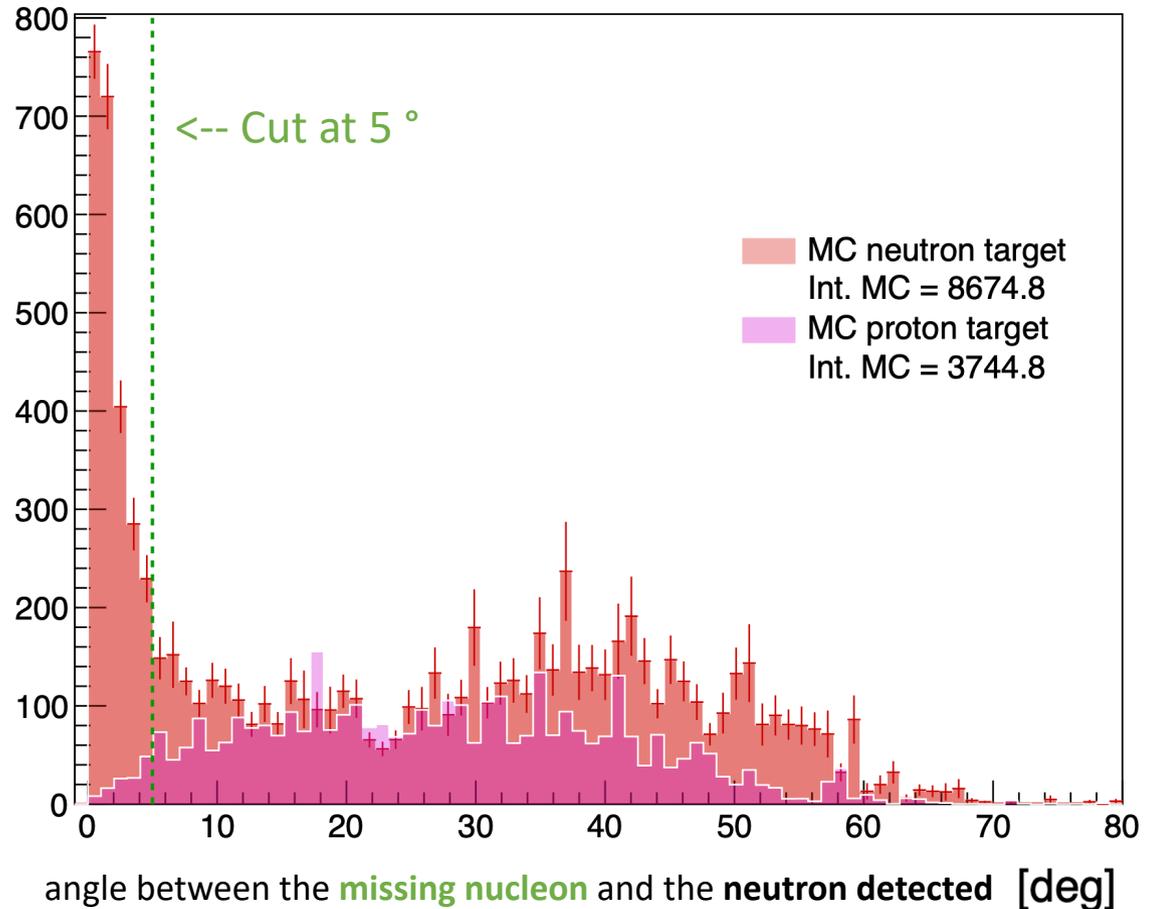


With the angle cut

Cut on the angle between missing nucleon and detected neutron



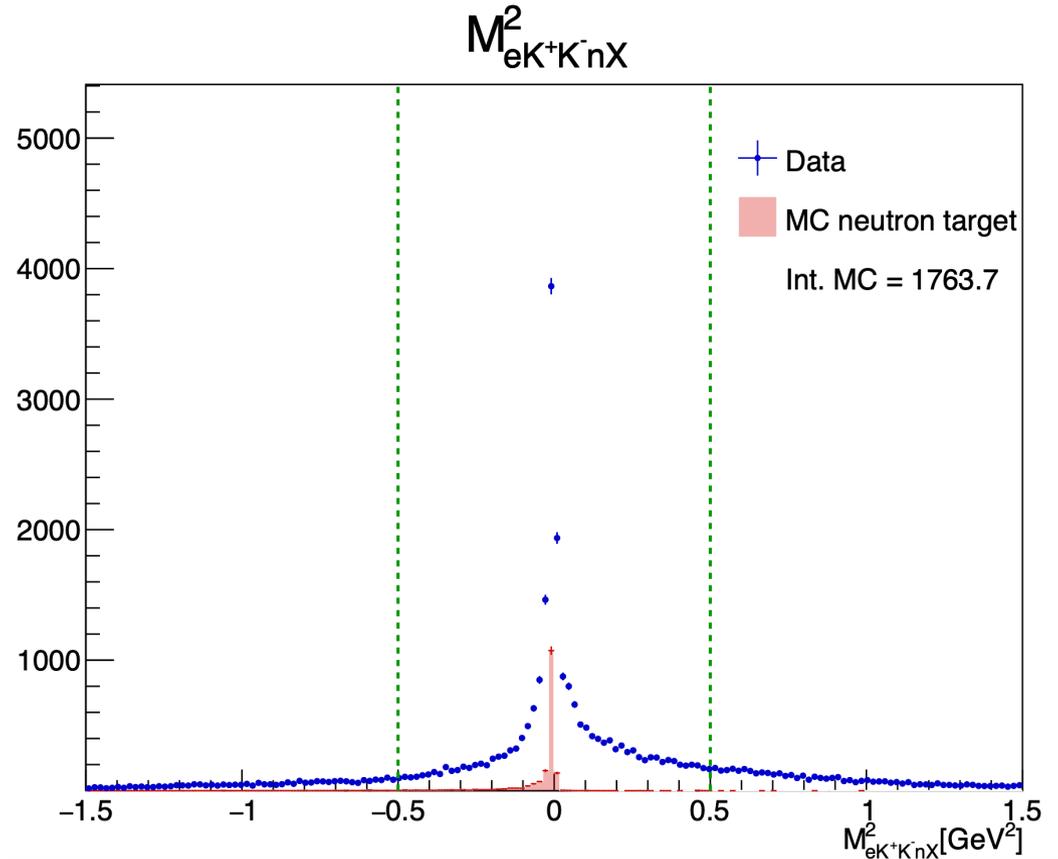
Contamination when the **missing nucleon** is a **non detected proton** and there is a fake neutron signal who pass the cut on the angle



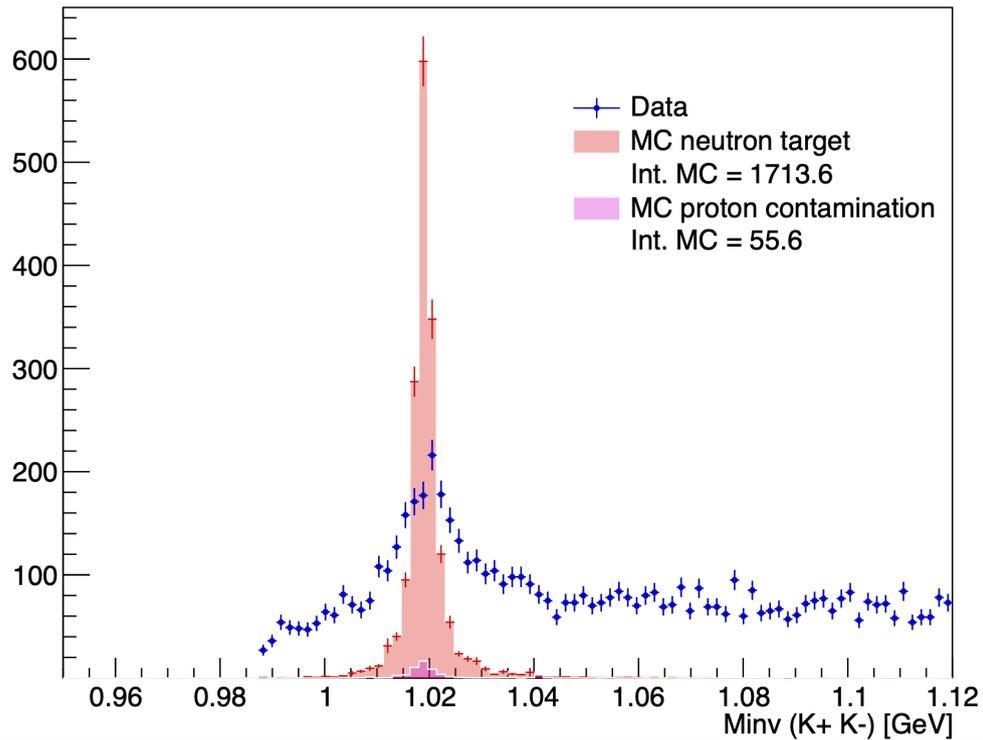
Cut on total missing mass

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

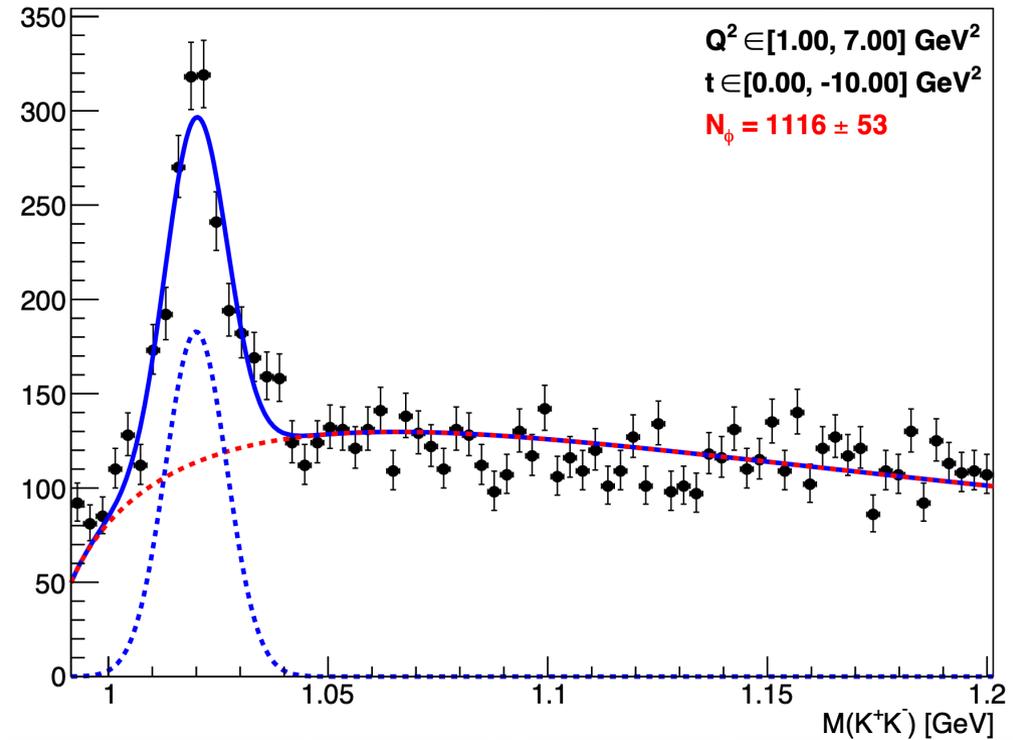
$$-0.5 < M_{eK^+K^-nX}^2 < 0.5 \text{ GeV}^2$$



Yield extraction

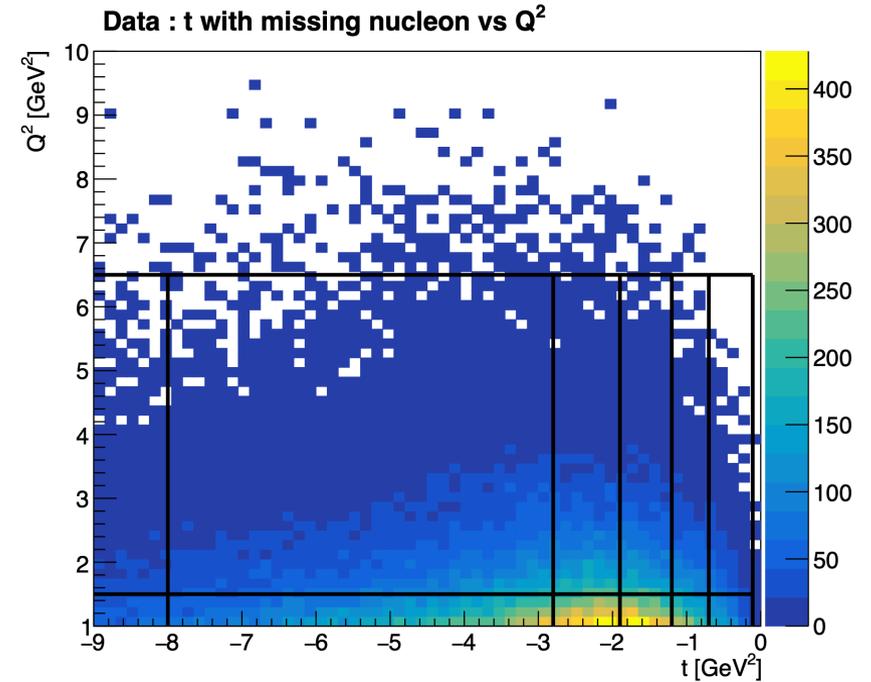
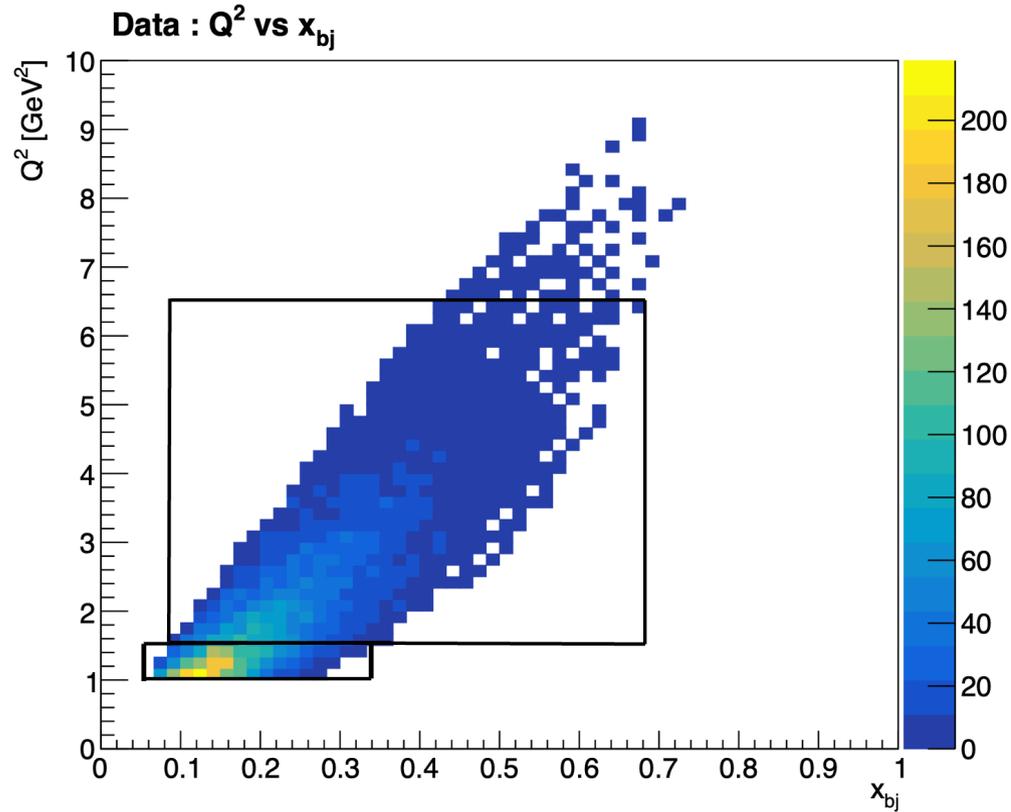


With angle cut, $K^+ K^-$ in FD, and cut on missing mass



Fit all fall2019 outbending data

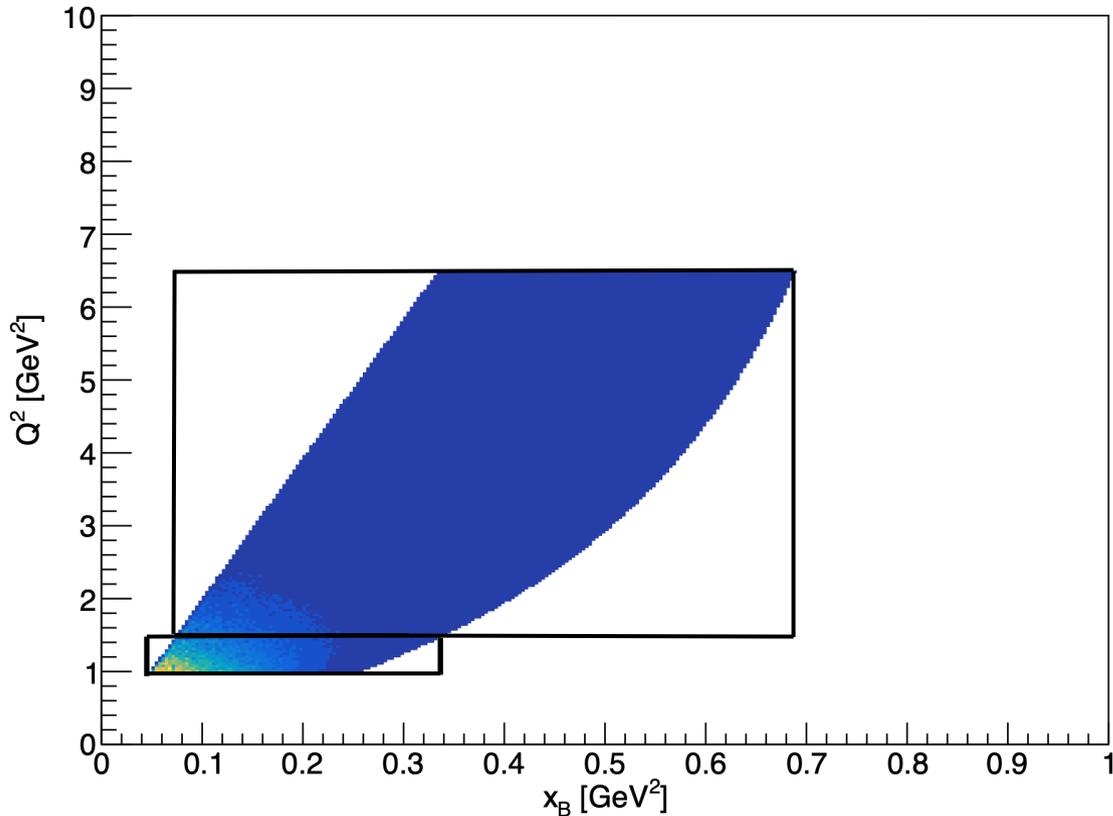
Binning of the data



• t binning for the two bins in Q^2

Binning correction

Generated events : Q^2 vs x_B



- The correction factor f is the size of the physical phase space in Q^2 and x_B divide by $\Delta Q^2 \Delta x_B$
- To determine the size of the physical phase space, we use generated events and divide the number of filled bins by the total number of bins.

bin	$1.0 < Q^2 < 1.5 \text{ GeV}^2$ $0.05 < x_B < 0.34$	$1.5 < Q^2 < 6.5 \text{ GeV}^2$ $0.08 < x_B < 0.7$
f	0.81	0.49

Yield extraction per bins

Fit performed using RooFit.

Signal model :

The signal is described by a Gaussian function :

$$S(M_{inv}) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(M_{inv}-\mu)^2}{2\sigma^2}\right)$$

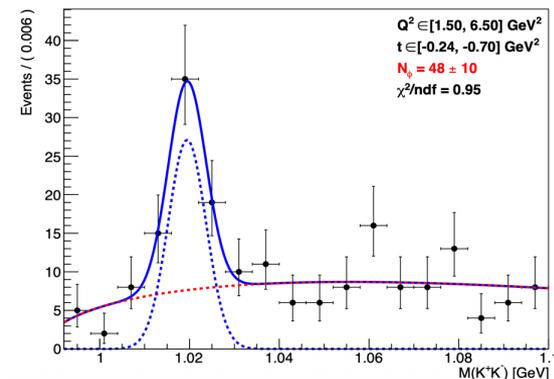
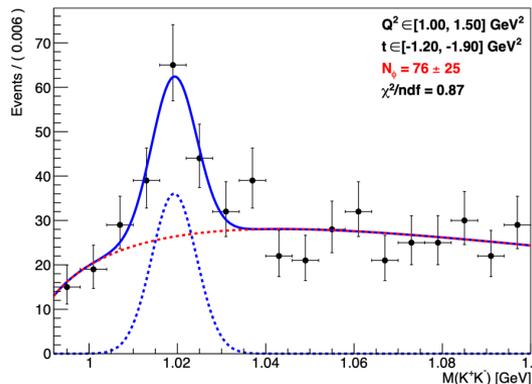
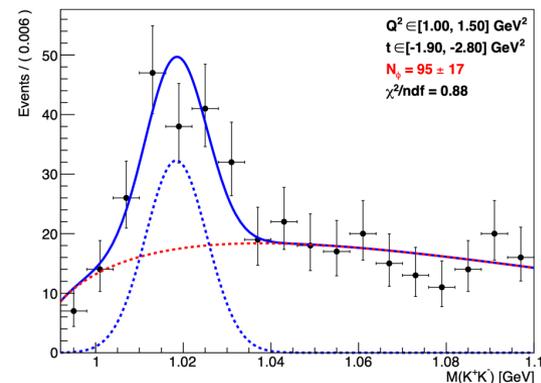
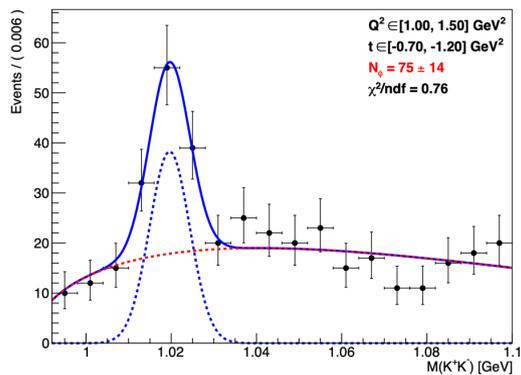
Background model :

The background is modeled using a threshold function multiplied by an exponential polynomial :

$$B(M_{inv}) = \sqrt{M_{inv}^2 - 4m_K^2} \exp(a_0 m + a_1 m^2)$$

where :

- m_K is the kaon mass,
- a_0 and a_1 are free parameters of the fit.

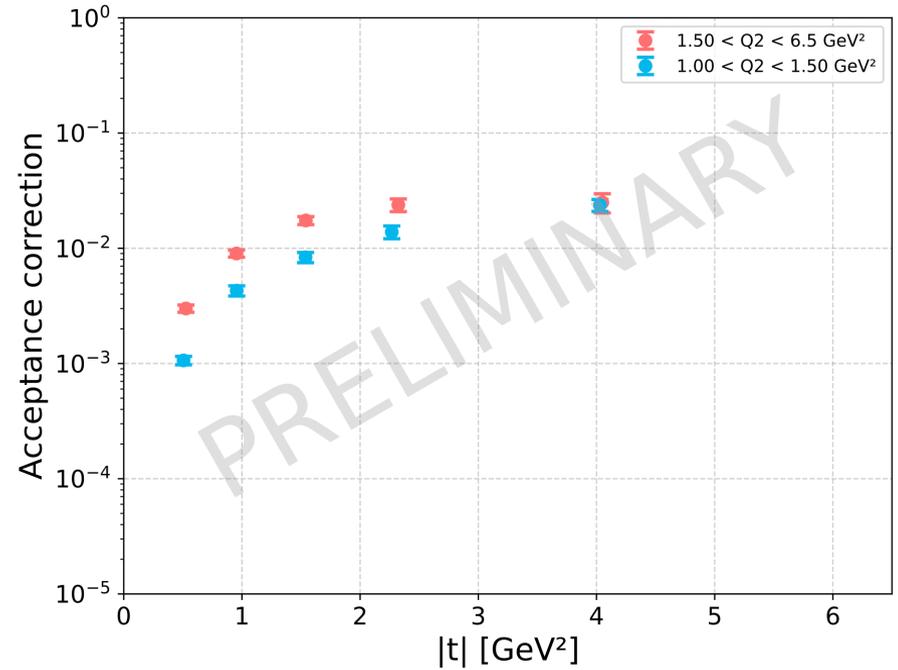
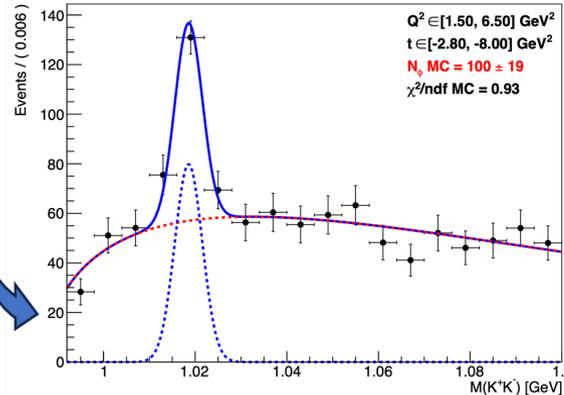
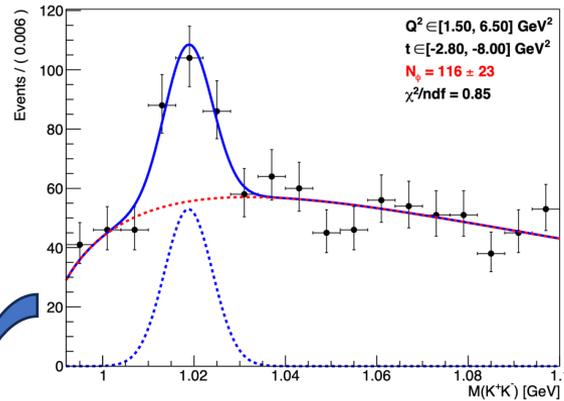


Some examples of fits

Acceptance correction

- Recover the background function from the data and perform a random fill on the MC histogram with a number of events equal to the background integral.

- The objective is to fit the MC and the data under the same conditions.



$$A = \frac{N_{rec}}{N_{gen}}$$

- with N_{rec} the number of reconstructed events in MC
- with N_{gen} the number of generated events in MC

Preliminary differential cross section

The differential cross section of this reaction $e n \rightarrow e' n' \phi$ is :

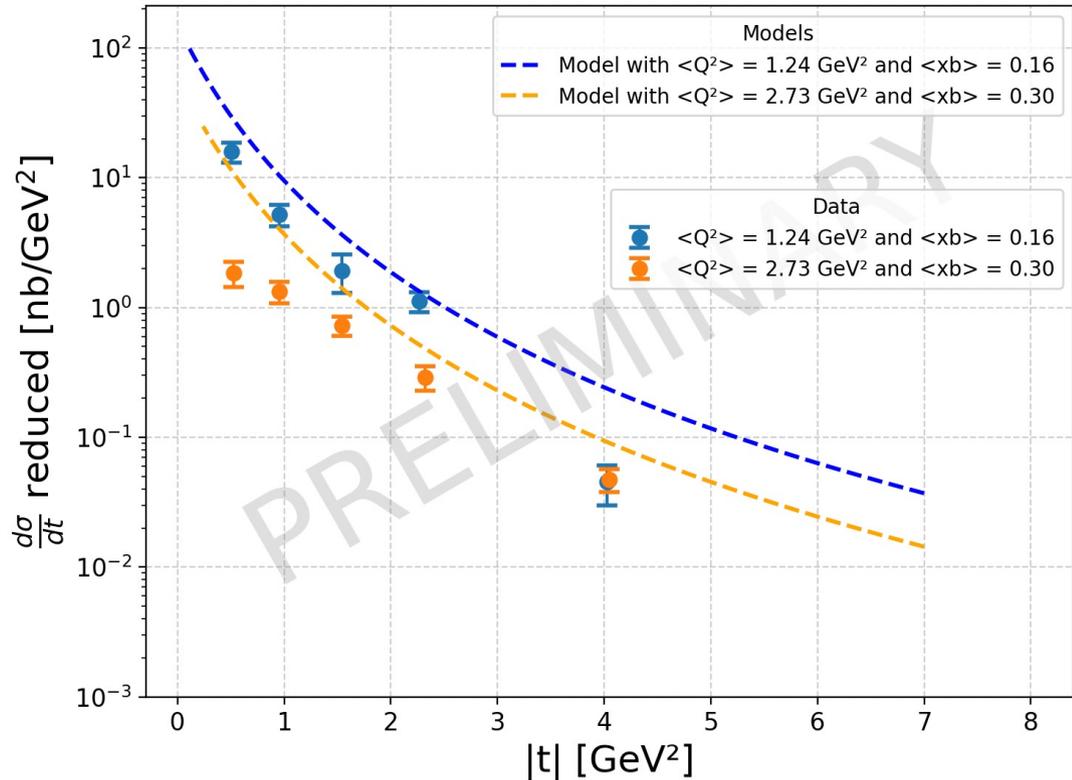
$$\frac{d^3\sigma}{dQ^2 dx_B dt} = \Gamma(Q^2, x_B, E) \left[\frac{d\sigma_T}{dt}(Q^2, x_B, t) + \epsilon \frac{d\sigma_L}{dt}(Q^2, x_B, t) \right]$$

with $\Gamma \equiv \frac{\alpha}{8\pi} \frac{Q^2}{m_N^2 E^2} \frac{1-x_B}{x_B^3} \frac{1}{1-\epsilon}$ the virtual photon flux factor.

The reduced differential cross section of this reaction $\gamma^* n \rightarrow n' \phi$ is given by :

$$\frac{d\sigma}{dt}(Q^2, x_B) = \frac{1}{\Gamma(Q^2, x_B, E)} \cdot \frac{d^3\sigma}{dQ^2 dx_B dt}$$

$$\frac{d\sigma}{dt}(Q^2, x_B) = \frac{\Delta N}{\Gamma \cdot \Delta x_B \cdot \Delta Q^2 \cdot \Delta t \cdot f \cdot L \cdot Acc \cdot Br}$$



Conclusion

Next steps :

- Do a smearing of the MC to fit the simulation in the same conditions than the data
- Run the code with the other data set.
- Implement the Fermi motion of the neutron and an non-istropic decay of the ϕ in K^+K^- in MC.
- Adapt the angle cut for events in CD.
- Add momentum corrections.

Thanks!

Backup slides

ϕ generator for MC simulation

$$weight_{PhaseSpace} = |Q_{max}^2 - Q_{min}^2| * |x_{b,max} - x_{b,min}| * |t_{max} - t_{min}|$$

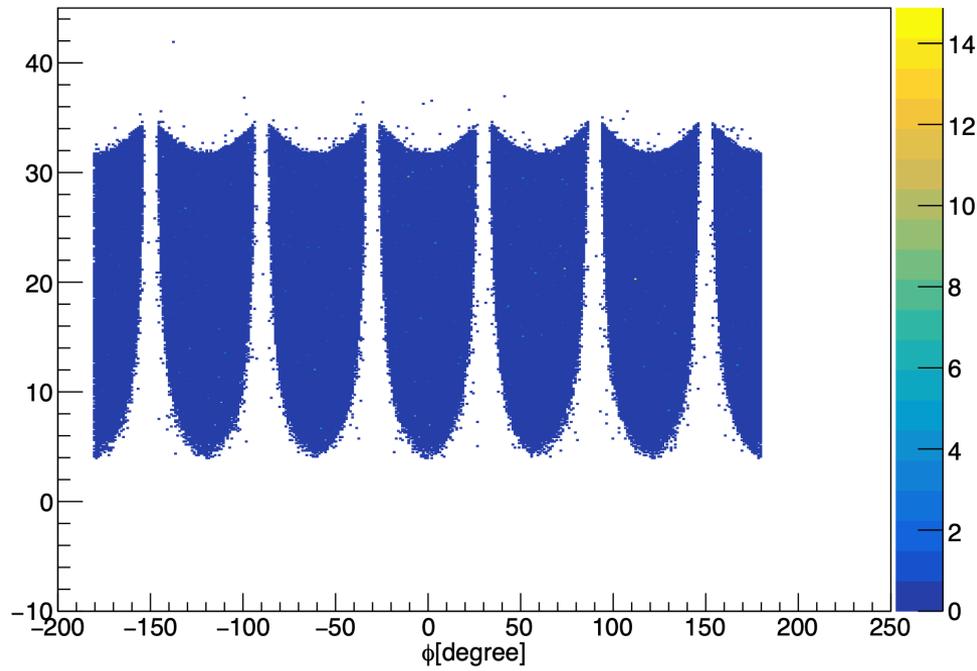
$$\frac{d^3\sigma}{dQ^2 dx_B dt} \quad \text{From Proposal to Jefferson Lab PAC39 Exclusive Phi Meson Electroproduction with CLAS12}$$

$$BR(\phi \rightarrow K^+ K^-) \approx 49.2\%$$

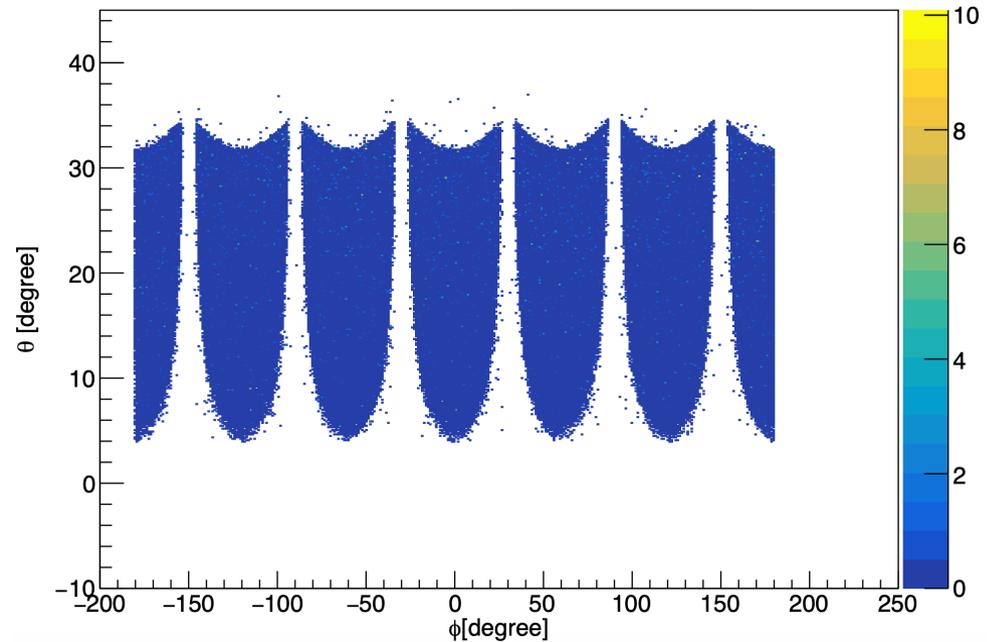
$$totalweight = weight_{phasespace} * weight_{\frac{d^3\sigma}{dt dQ^2 dx_b}} * BR_{\phi \rightarrow K^+ K^-}$$

Neutron efficiency correction additional plots

theta vs phi neutron REC

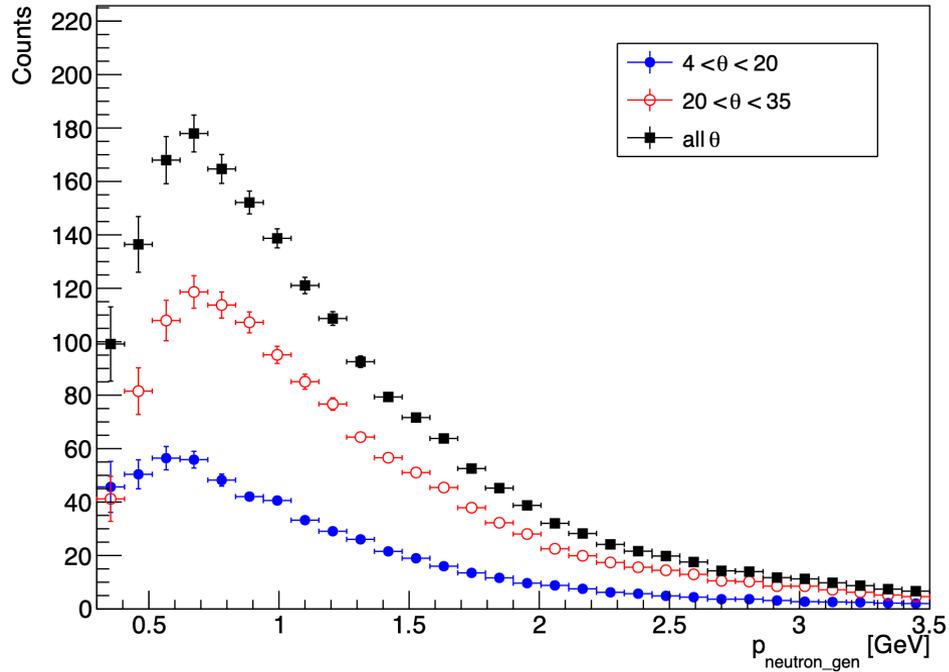


theta vs phi neutron GEN

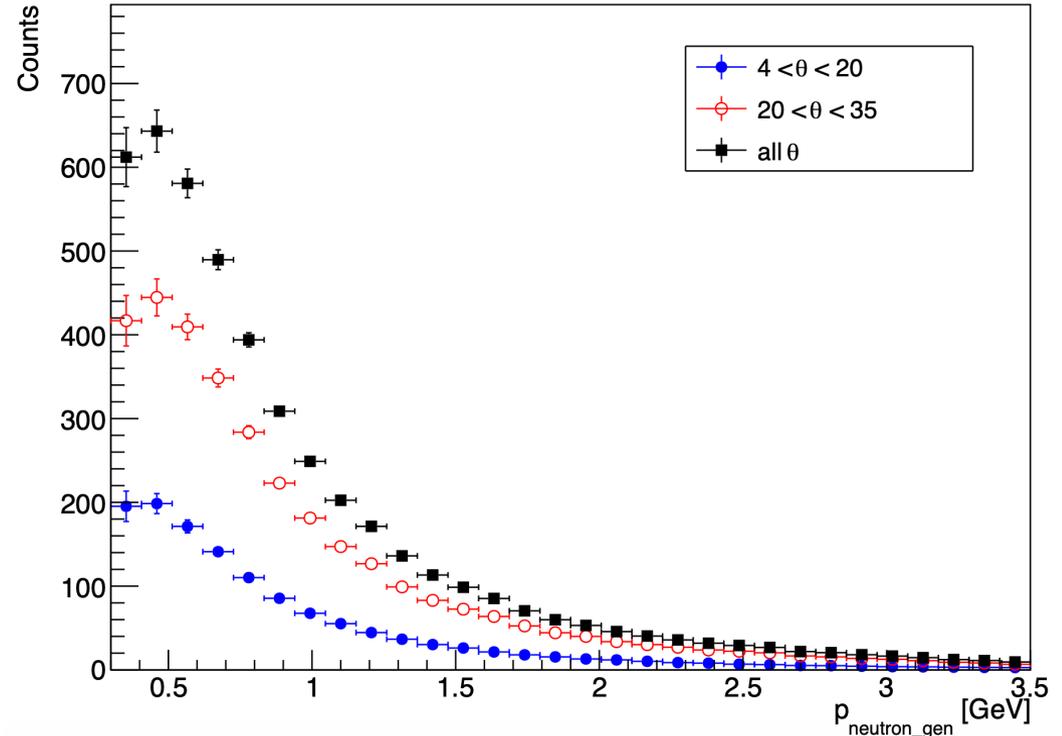


Neutron efficiency correction additional plots

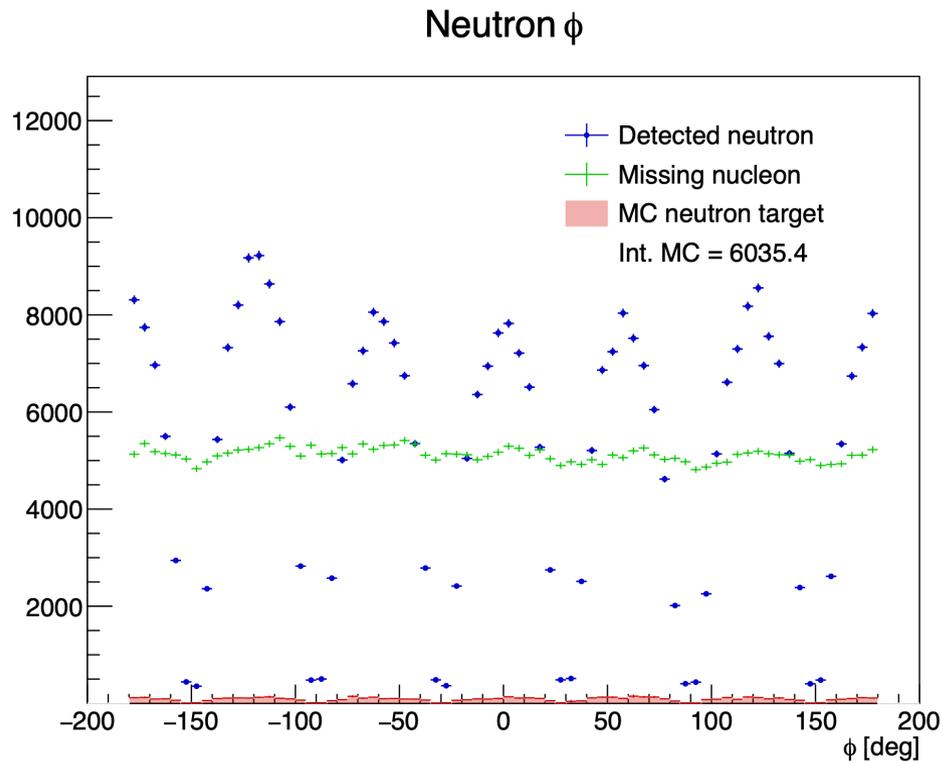
p neutron REC



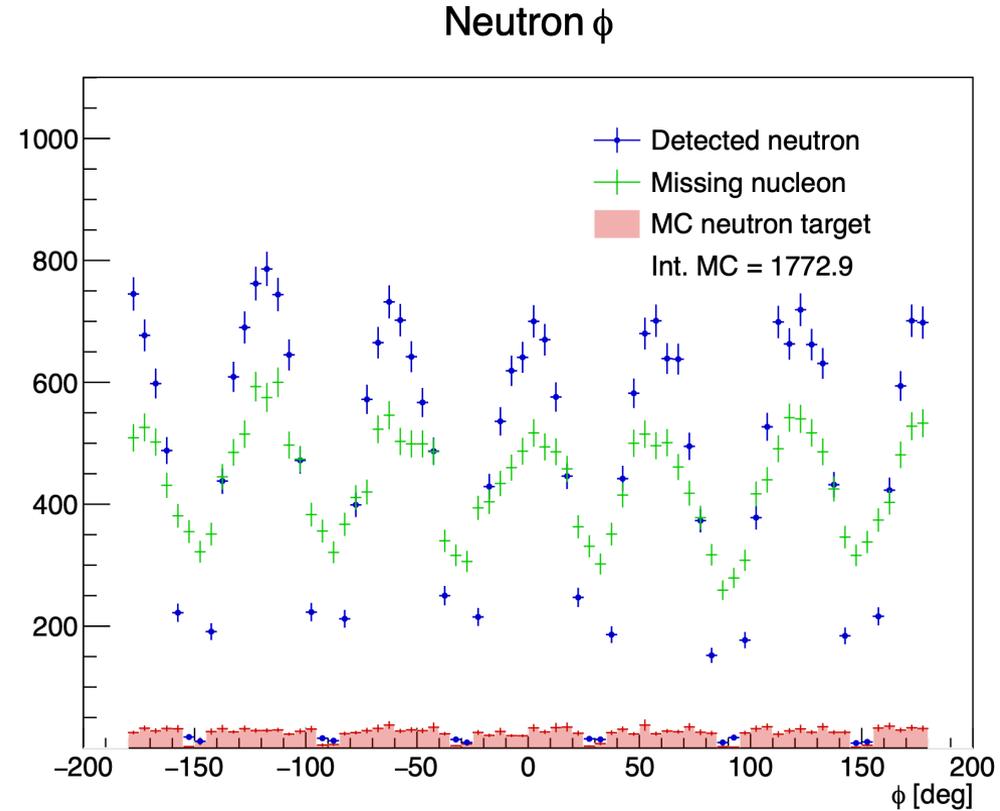
p neutron GEN



Cut on the angle between missing nucleon and detected neutron



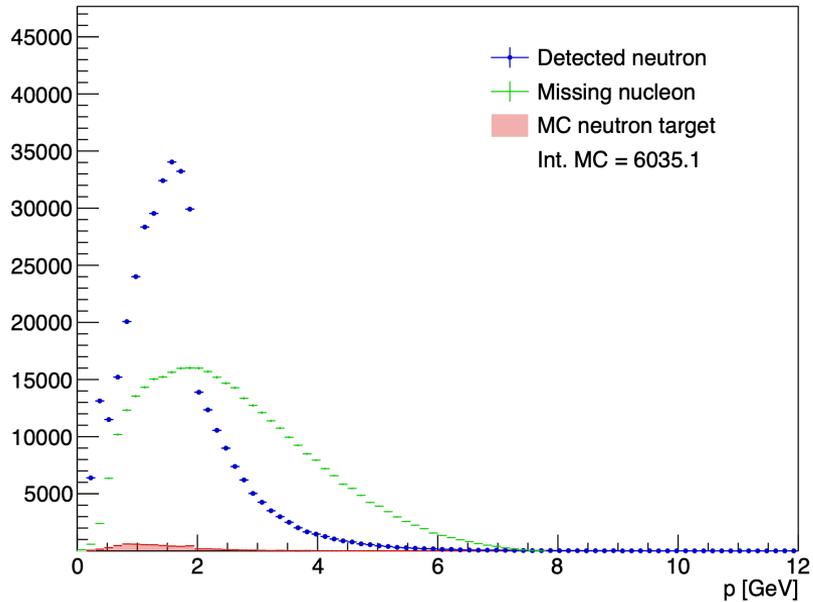
Without the angle cut



With the angle cut

Cut on the angle between missing nucleon and detected neutron

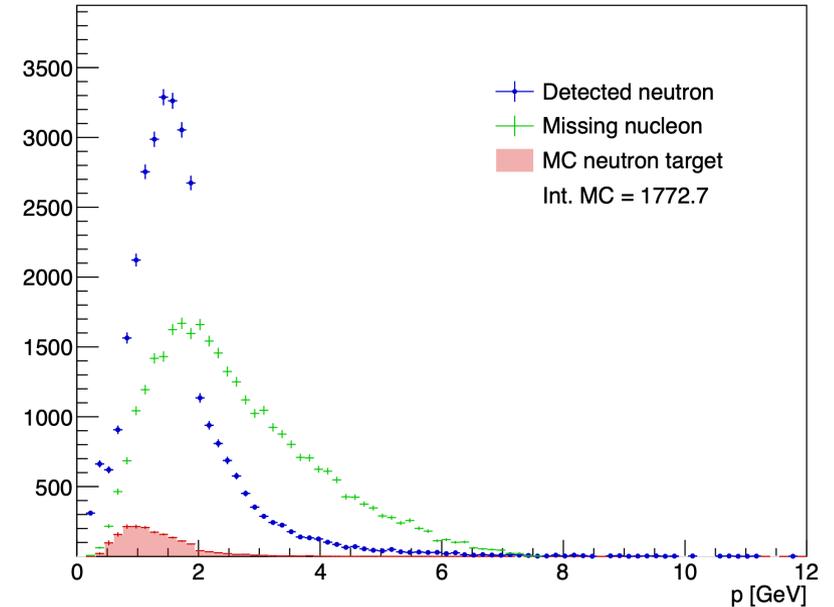
Neutron momentum



Without the angle cut



Neutron momentum



With the angle cut

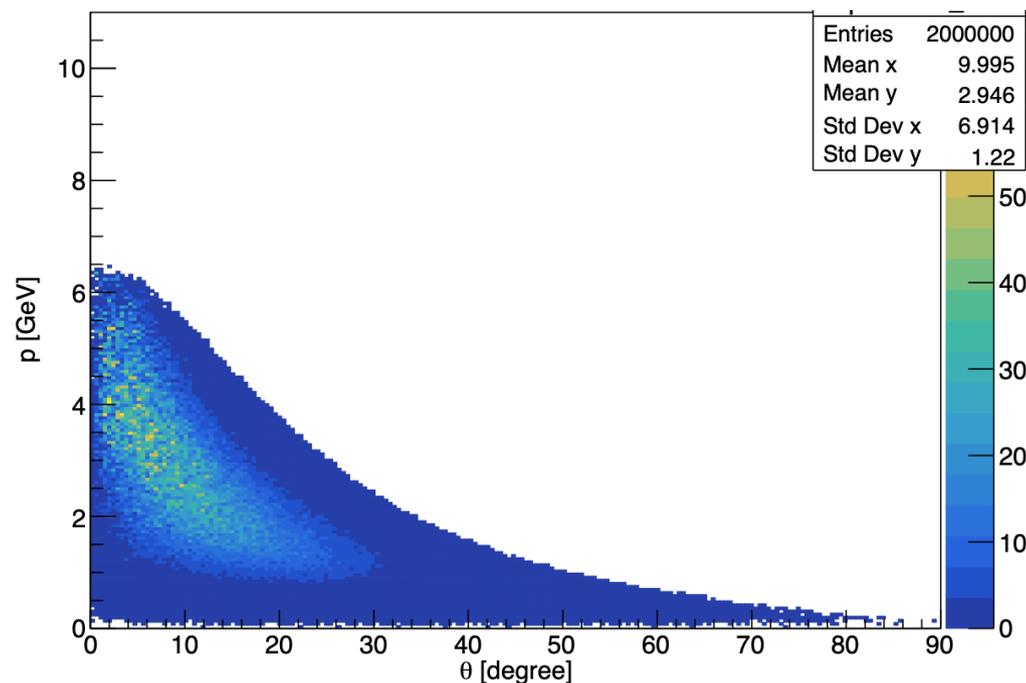
- I do not have a neutron momentum correction yet

Cut on the status of K^+K^-

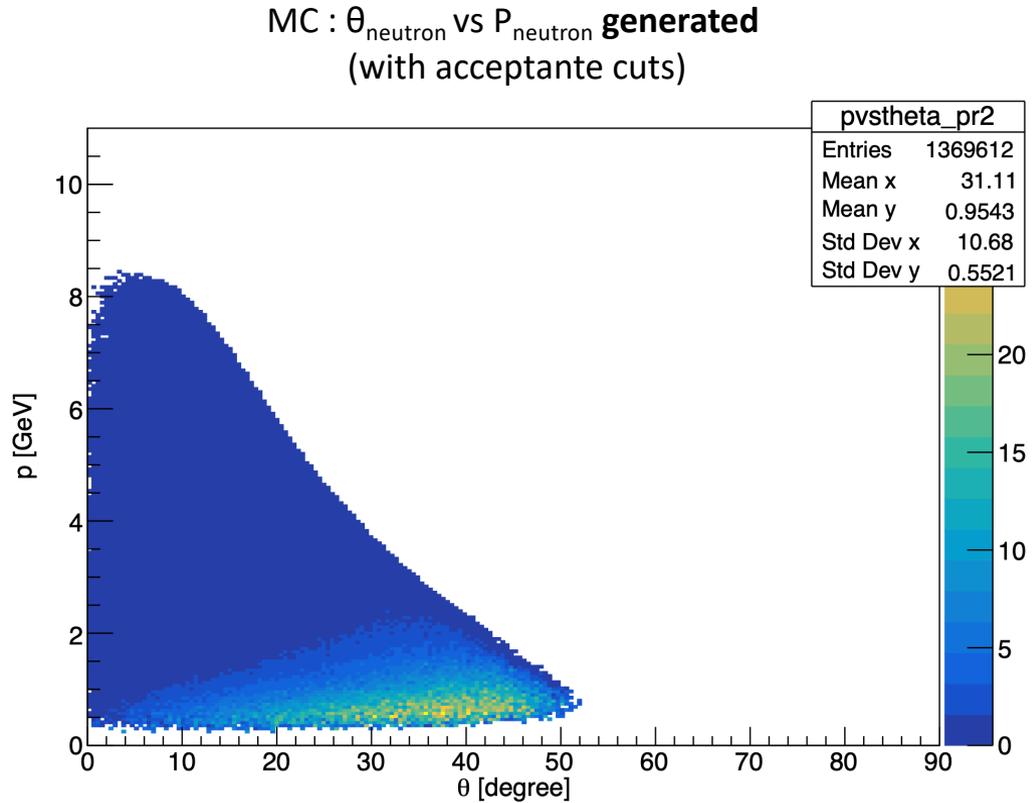
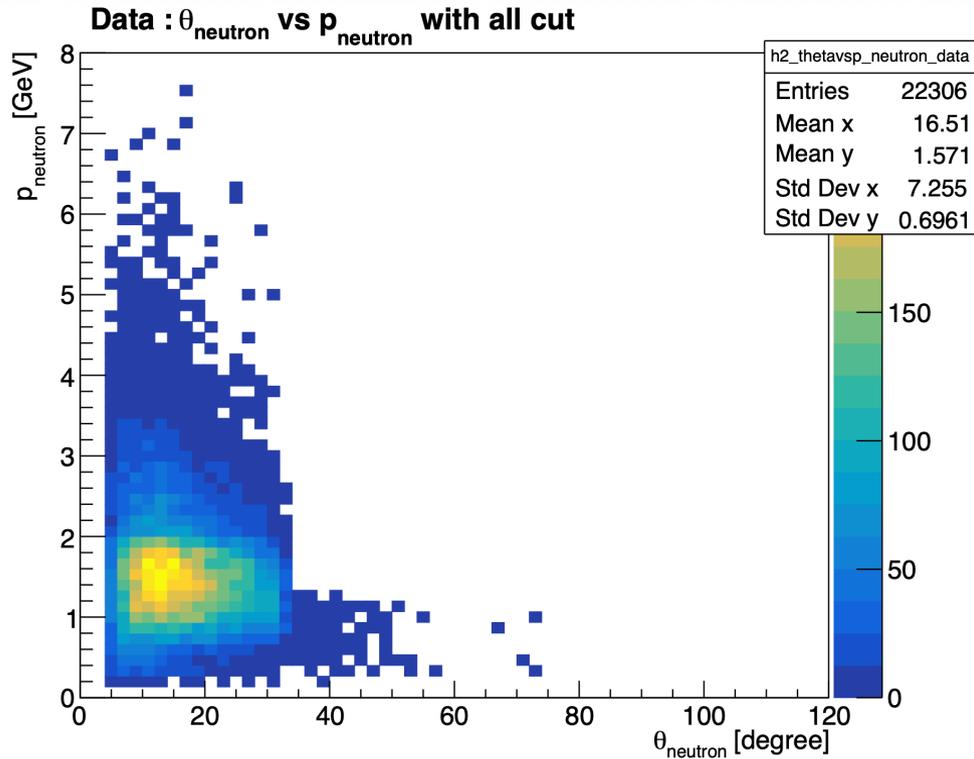
Two justifications to cut $K^+ K^-$ in CD :

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

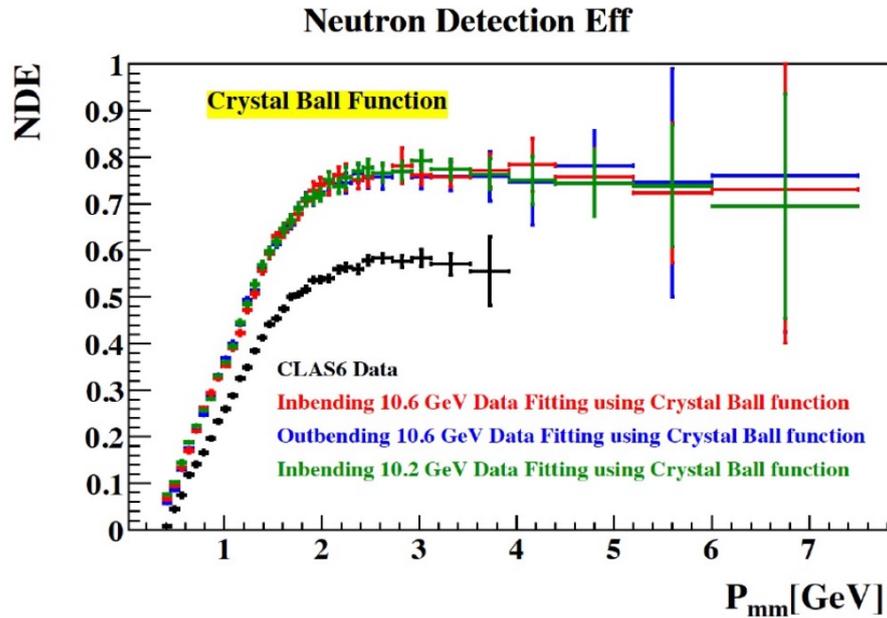
Generated event : p vs theta for K^+



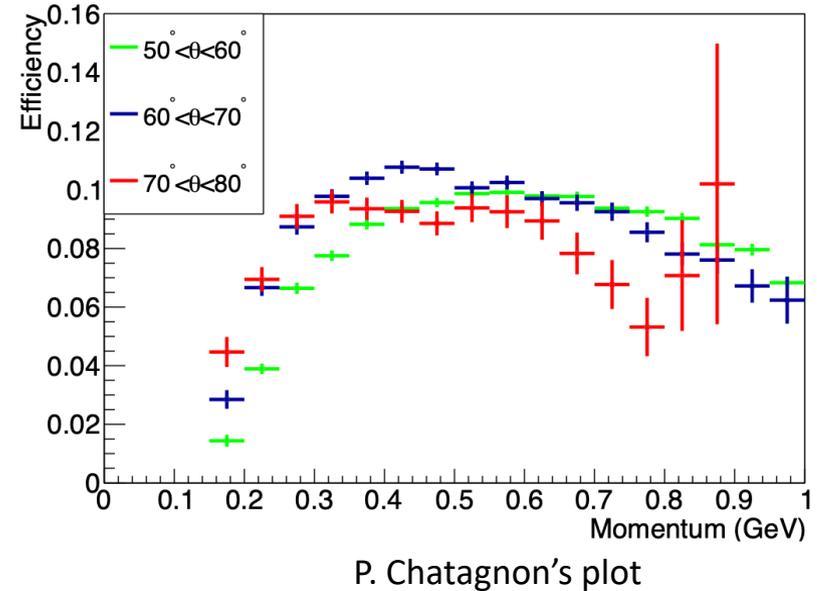
Neutron phasespace :



Neutron phasespace :



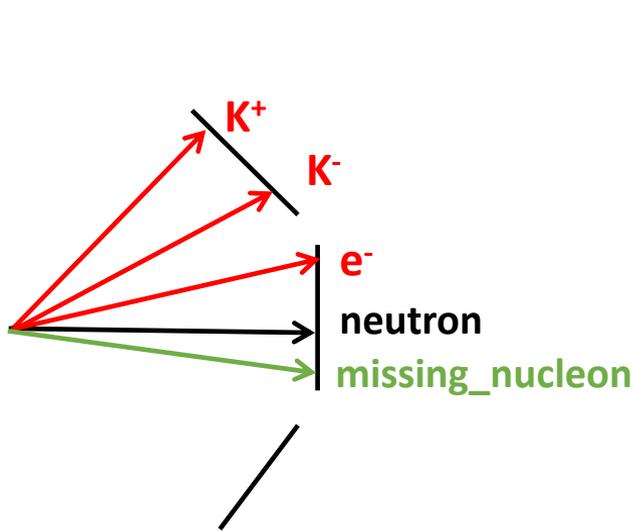
Neutron detection efficiency in the FD



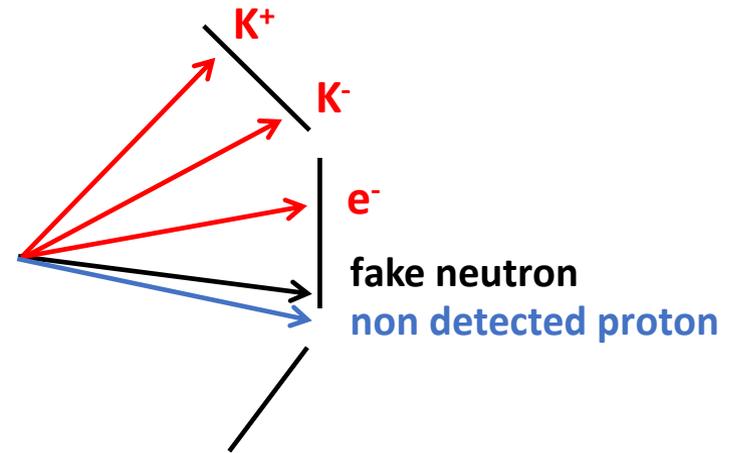
Neutron detection efficiency in the CND

Proton contamination

Missing_nucleon = the missing particle of this reaction : $e n \rightarrow e' K^+ K^- X$



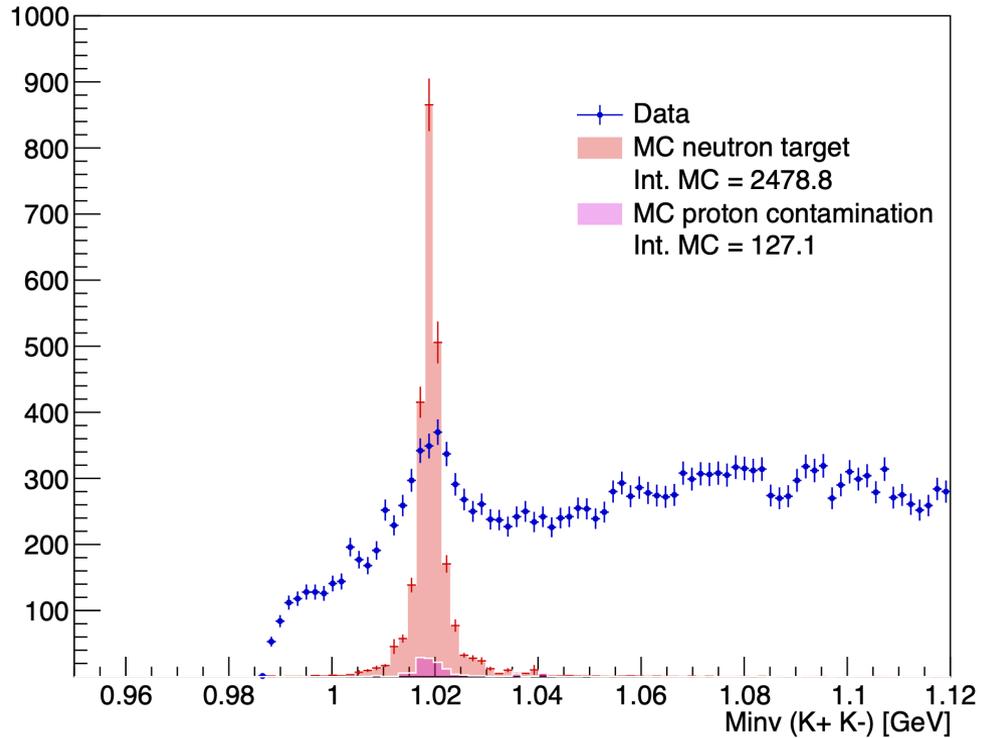
Good event with the angle between the missing nucleon and the neutron $< 5^\circ$



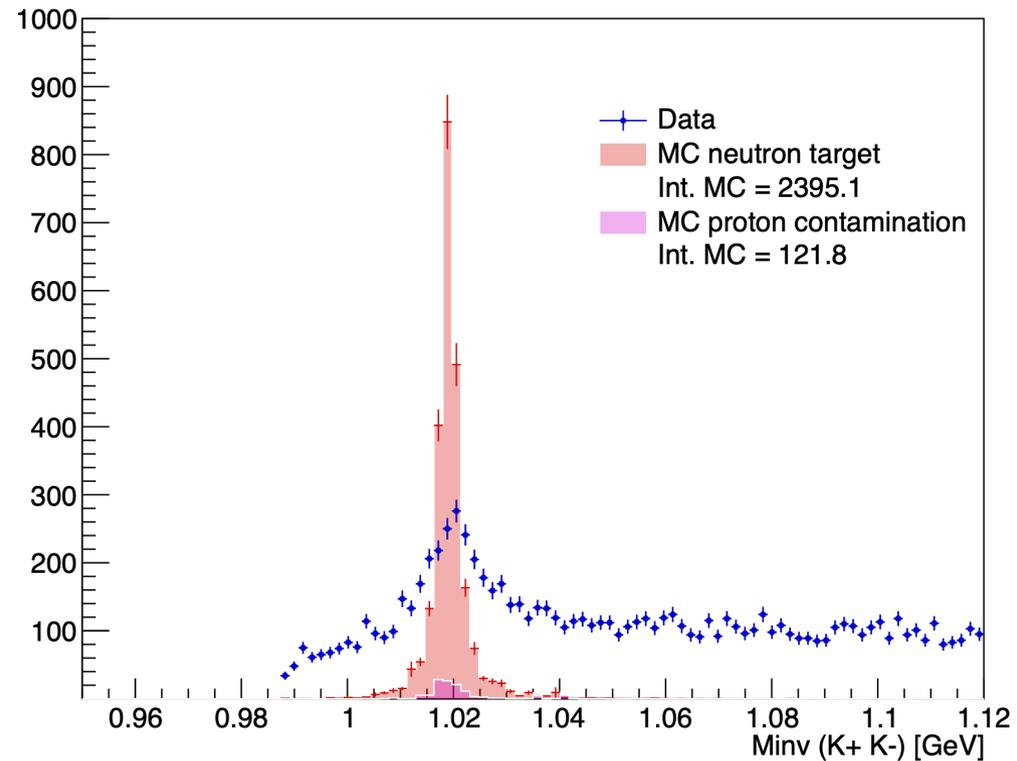
There is still a contamination when the **missing_nucleon** is a **non detected proton** and there is a **fake signal neutron** who pass the cut on the angle

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

Influence of cuts on the invariant mass $K^+ K^-$:



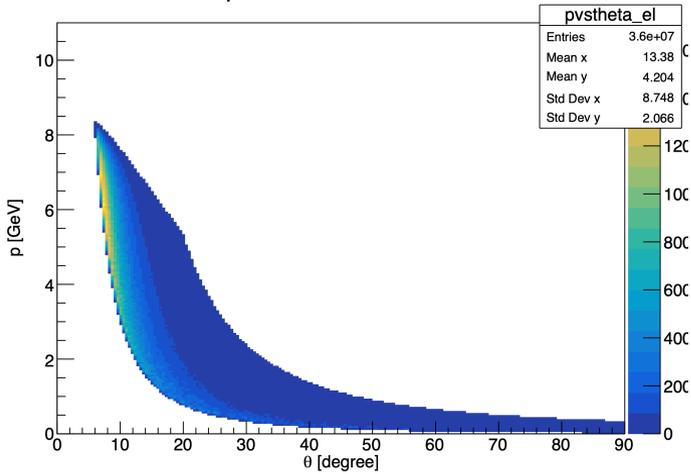
With angle cut



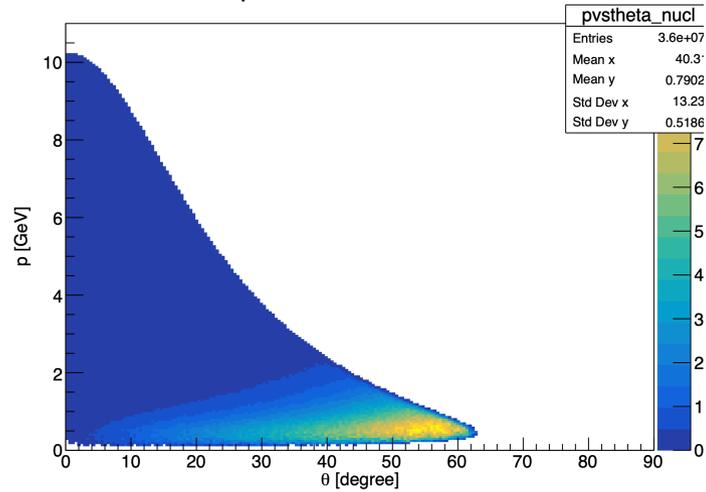
With angle cut and $K^+ K^-$ in FD

Generator plots

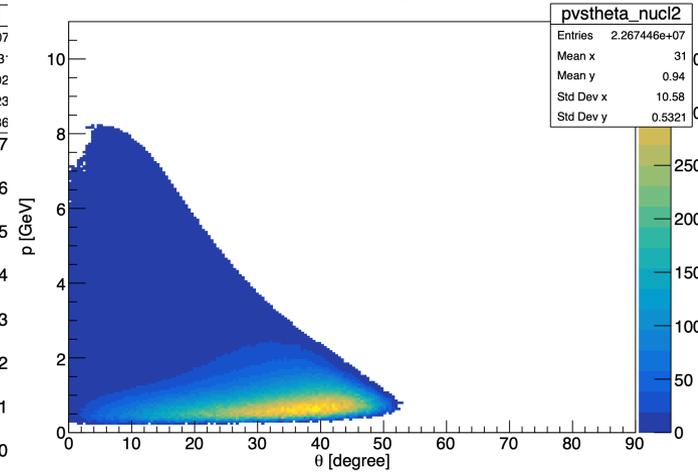
p vs theta for electron



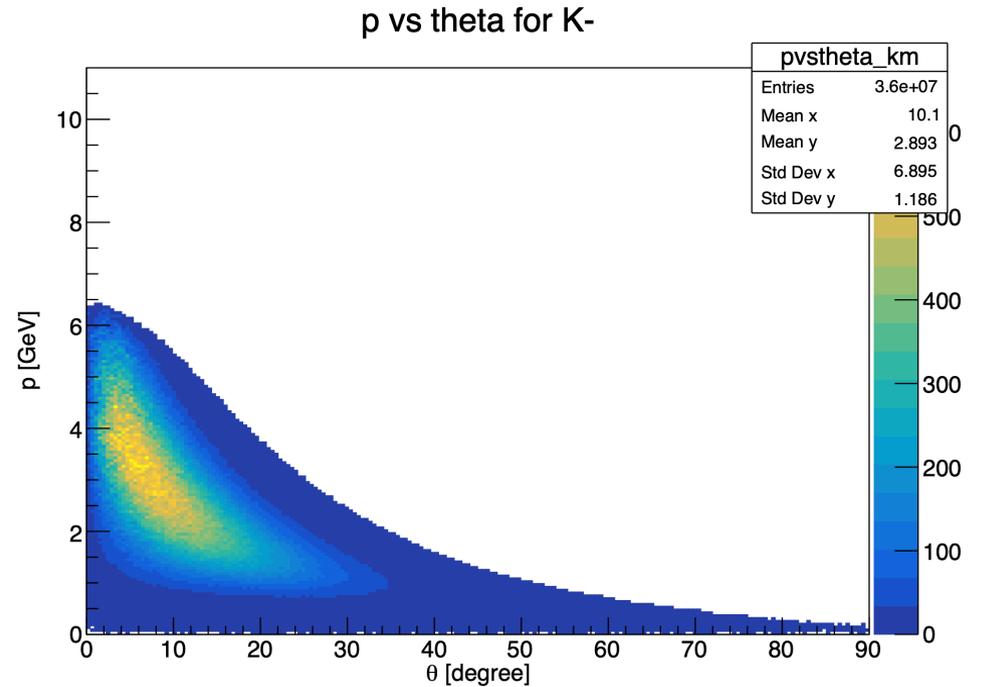
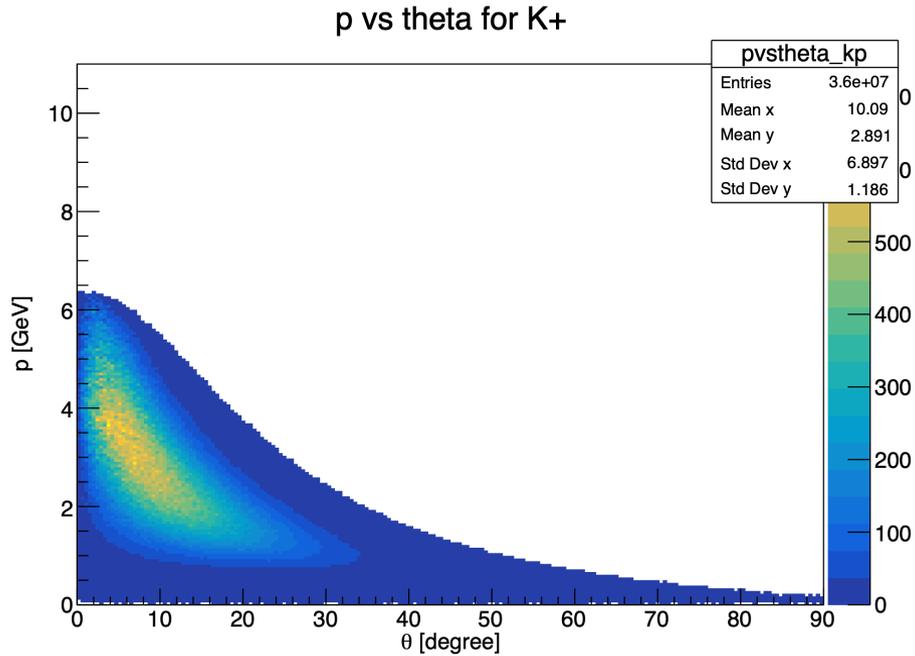
p vs theta for nucleon



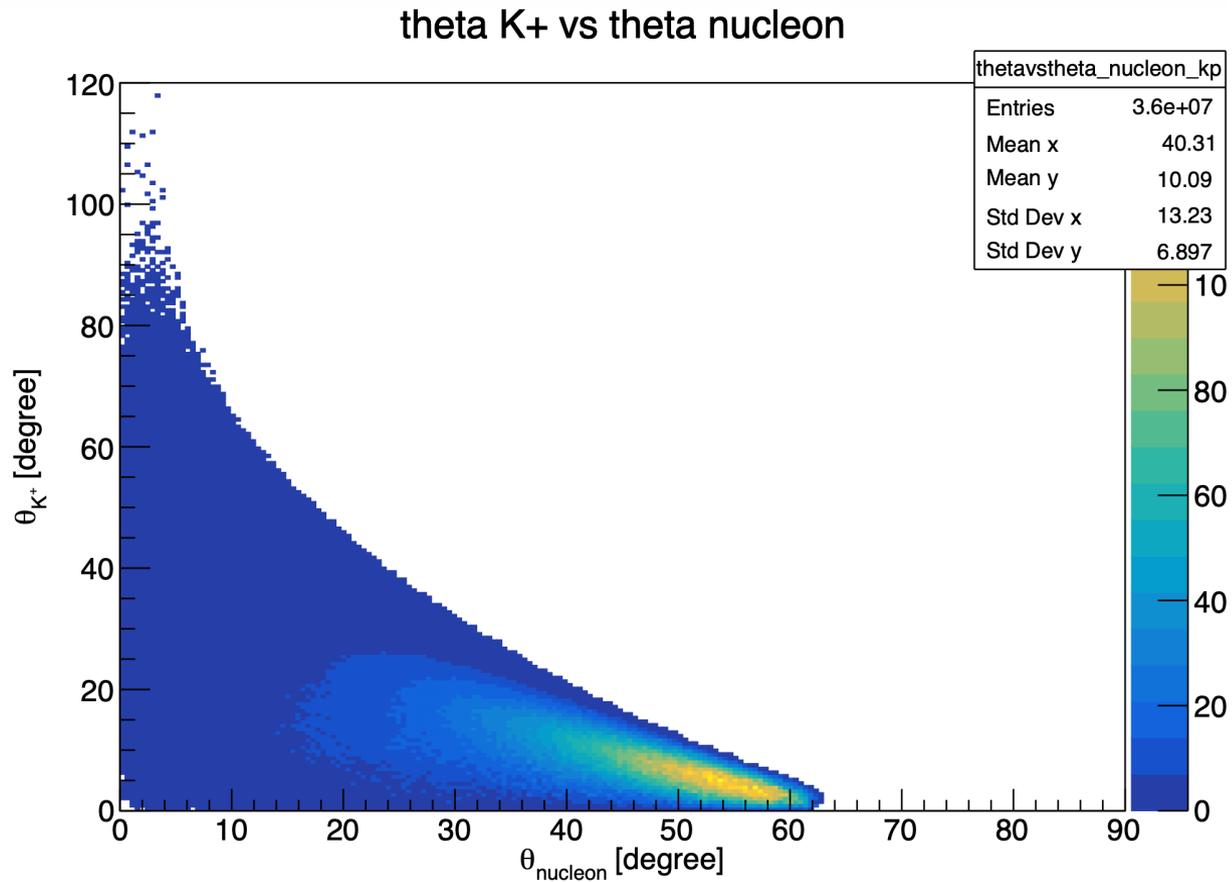
p vs theta for nucleon with large acceptance cuts



Generator plots

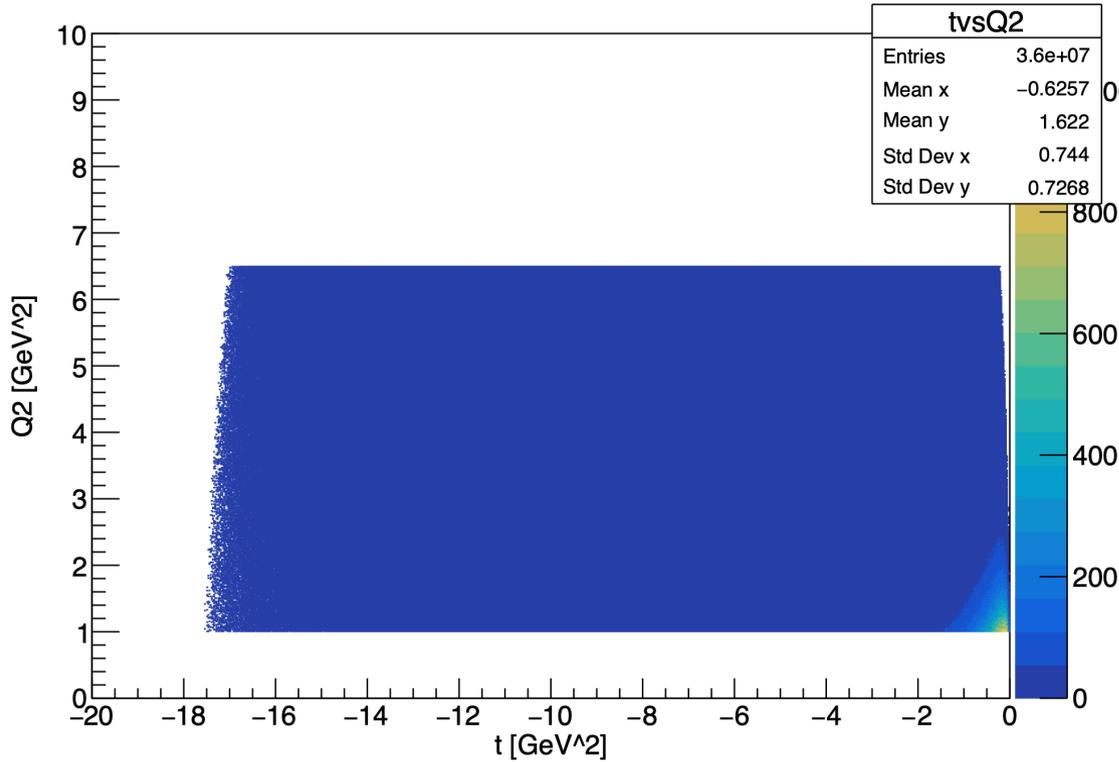


Generator plots

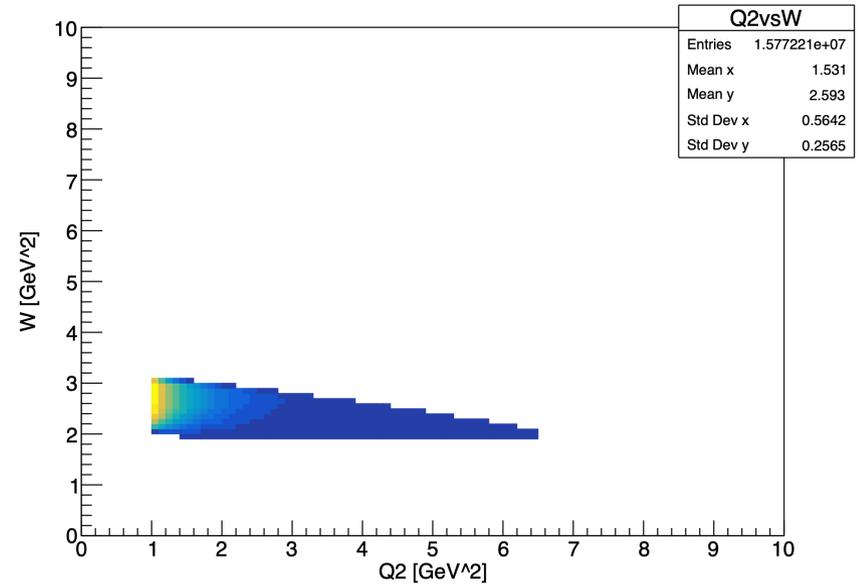


Generator plots

t vs Q2 with kinematics cuts

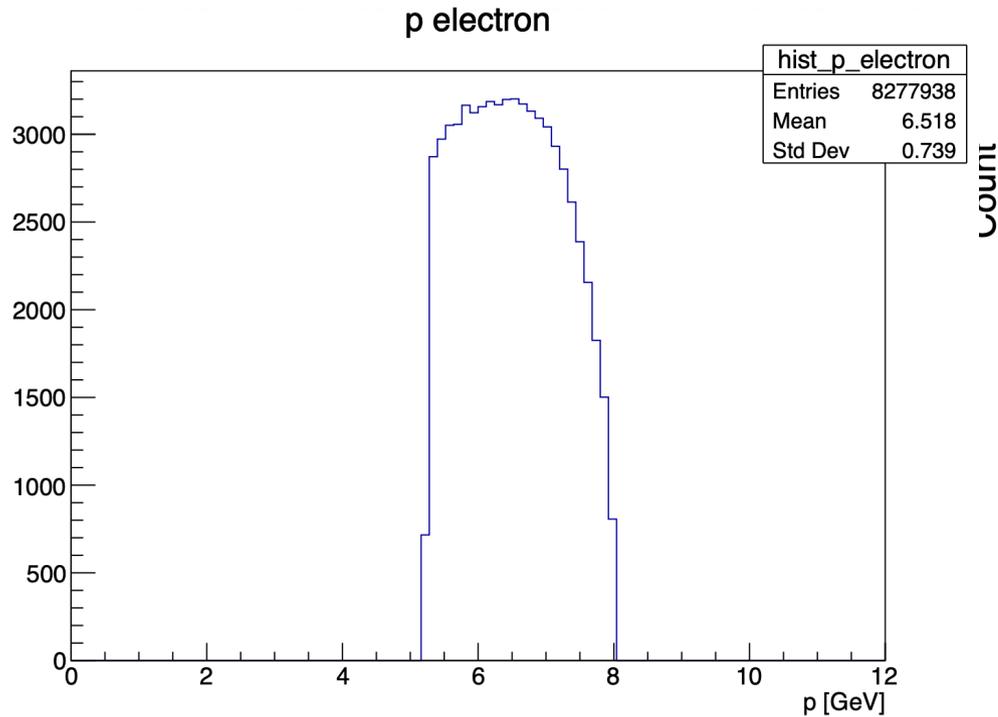


Q2 vs W

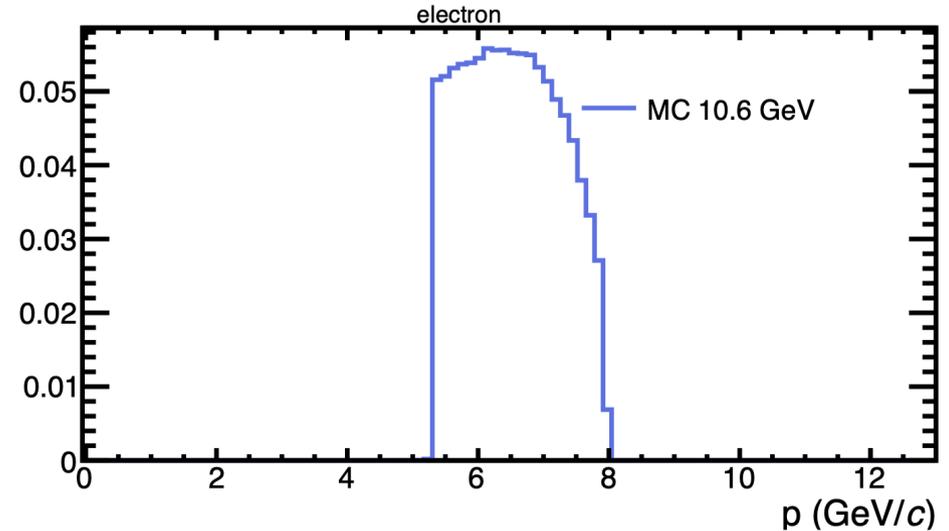


Generator plots

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



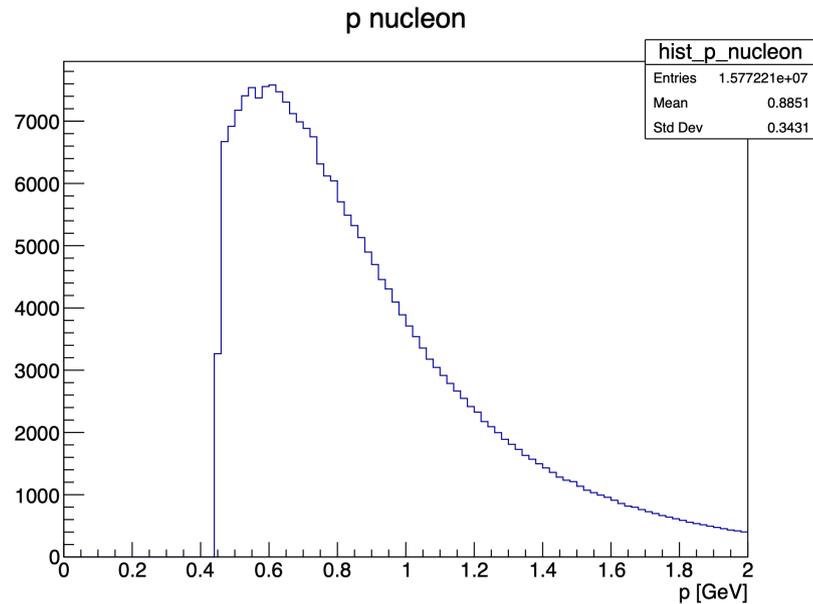
my generator



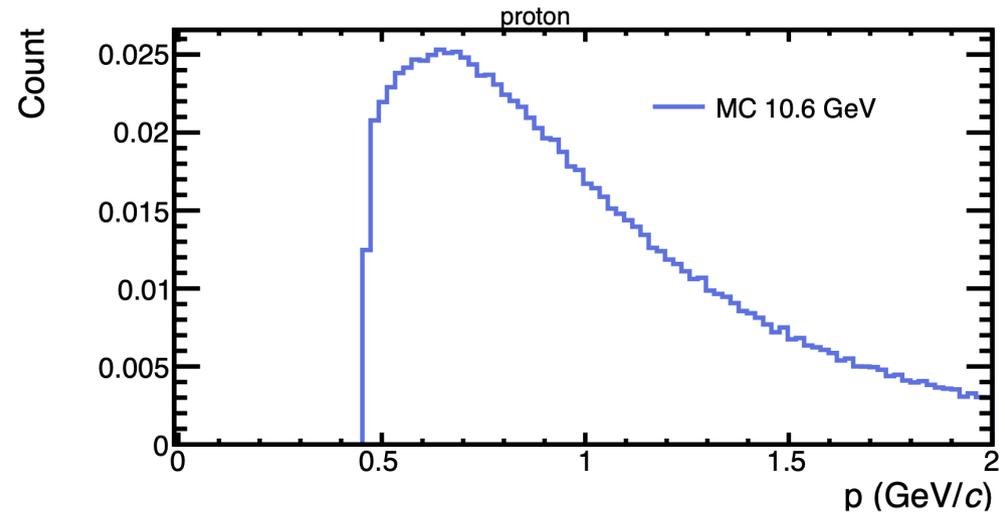
Bhawani plot

Generator plots

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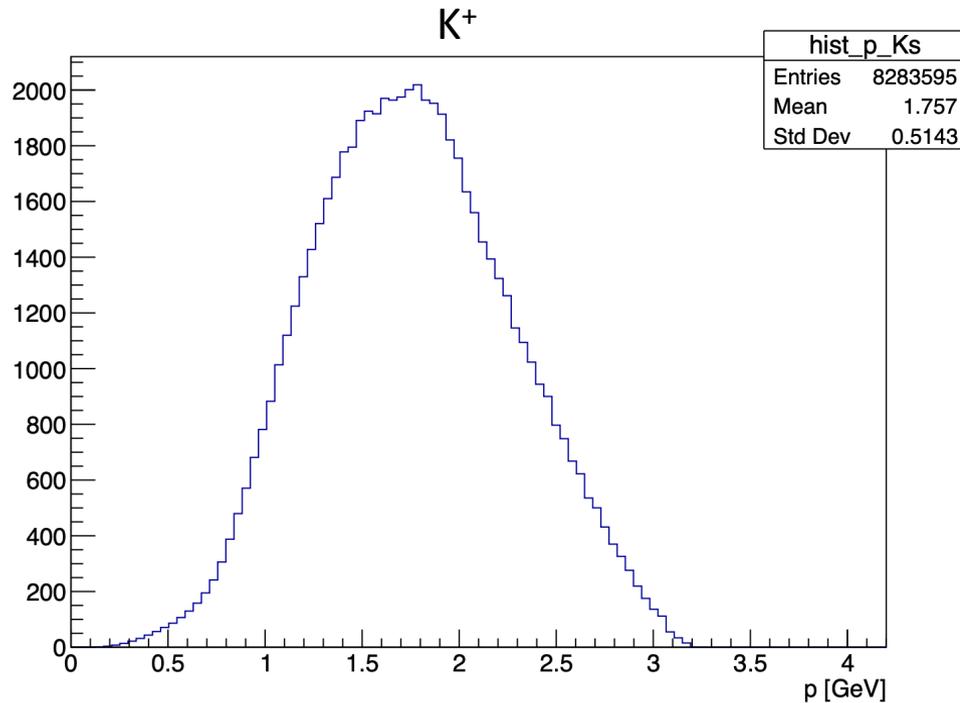
my generator



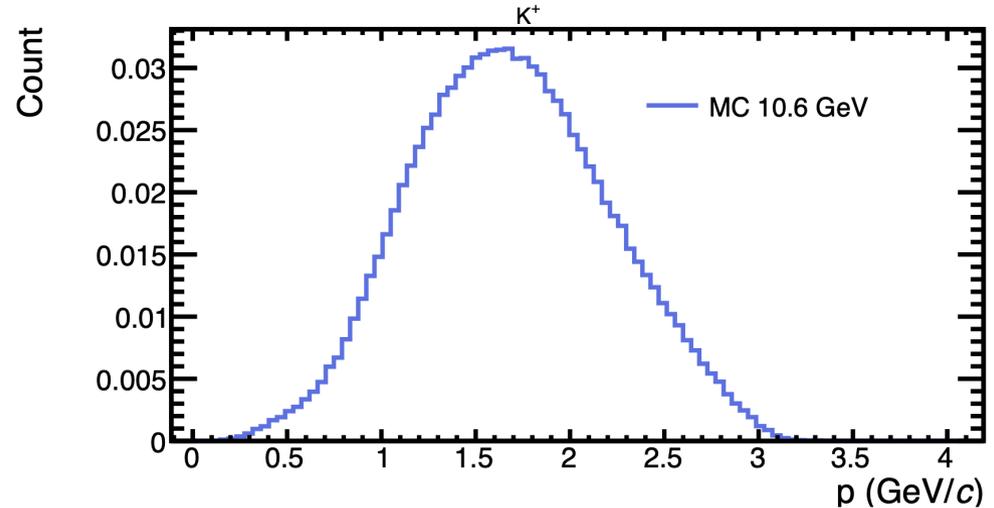
Bhawani plot

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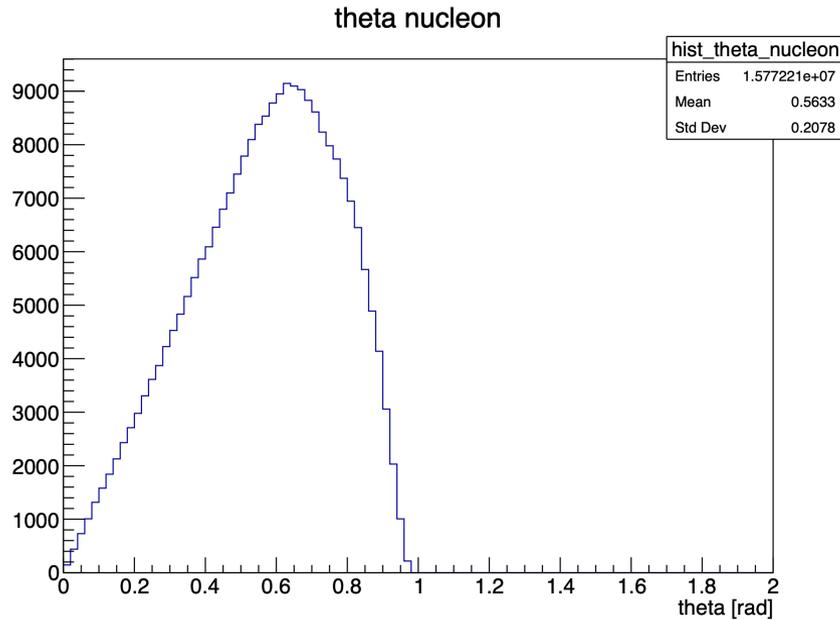
my generator



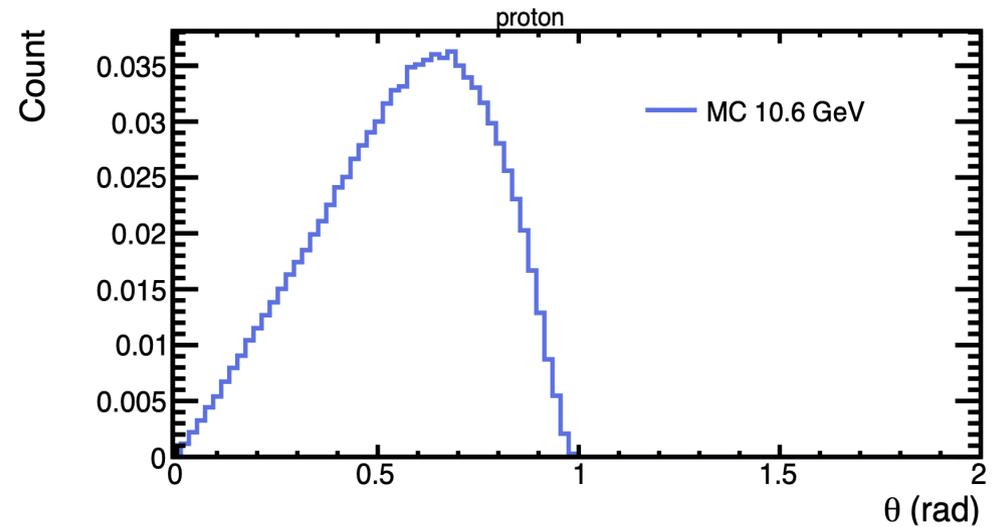
Bhawani plot

Generator plots

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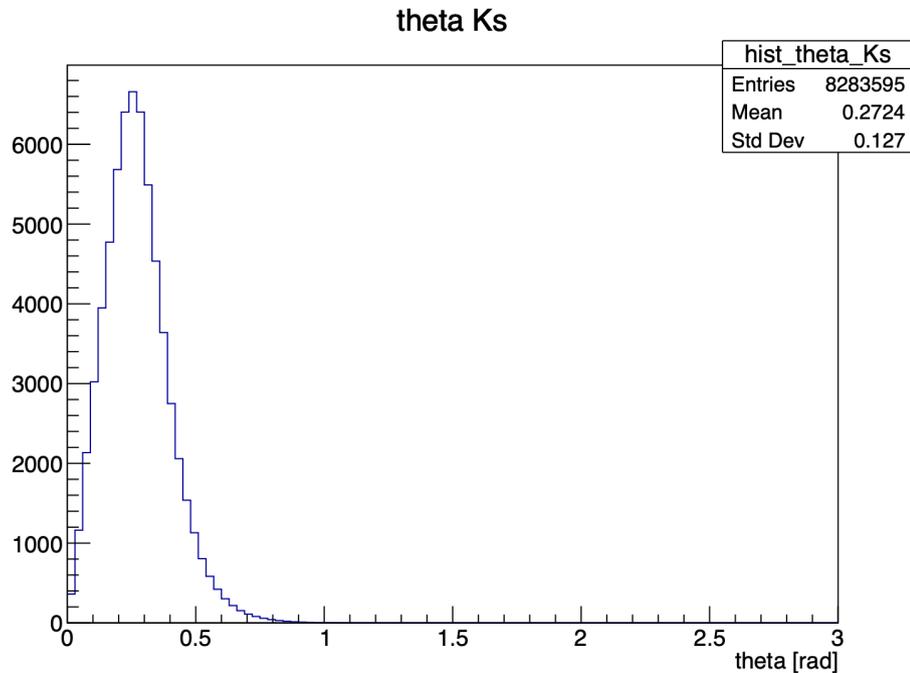
my generator



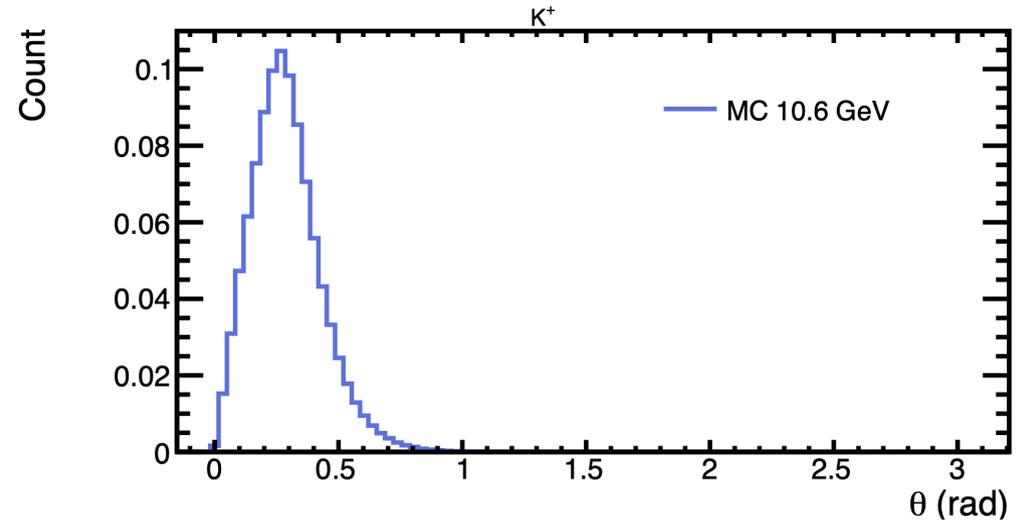
Bhawani plot

Generator plots

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



my generator

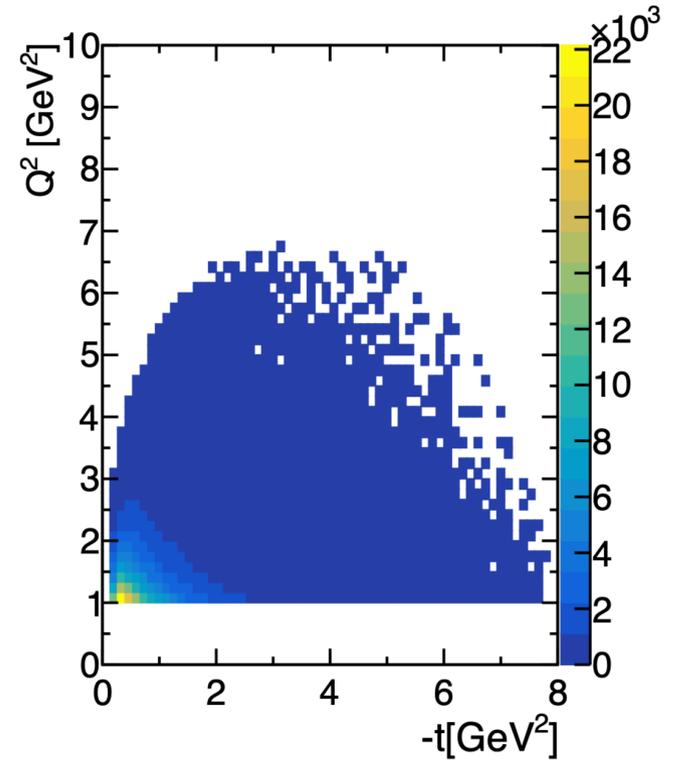
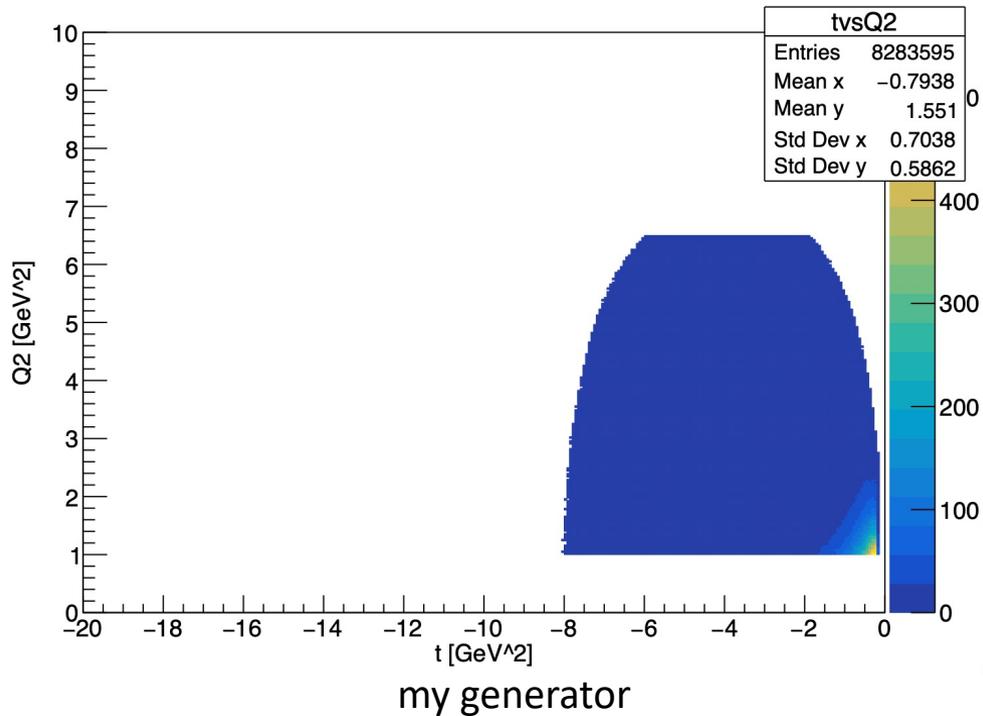


Bhawani plot

Generator plots

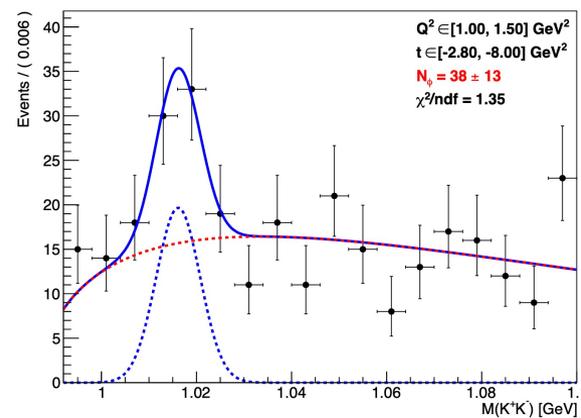
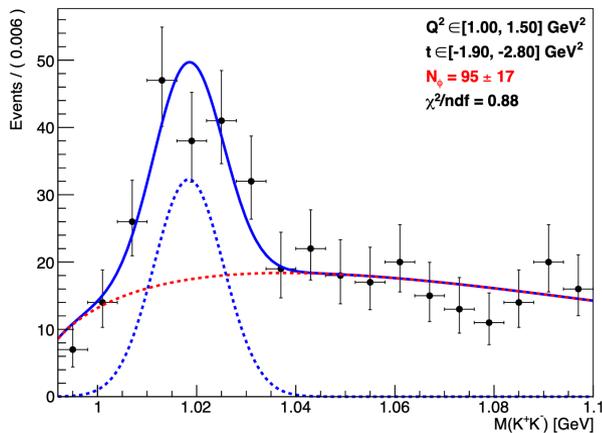
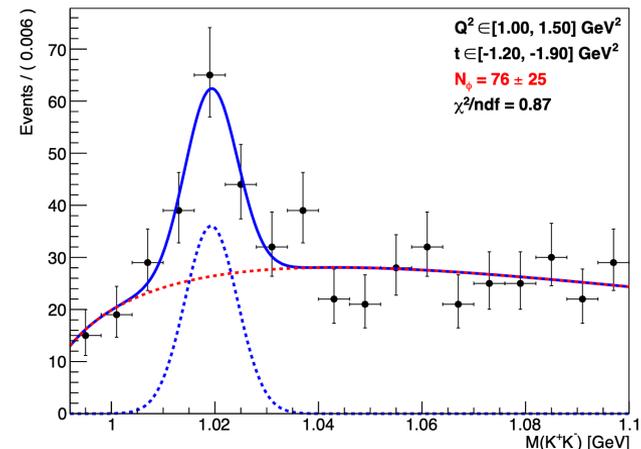
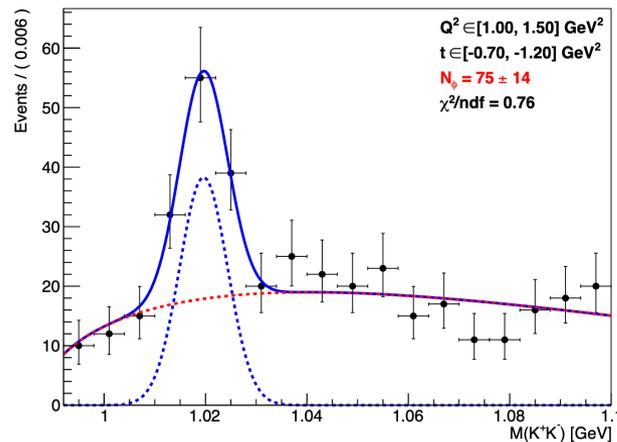
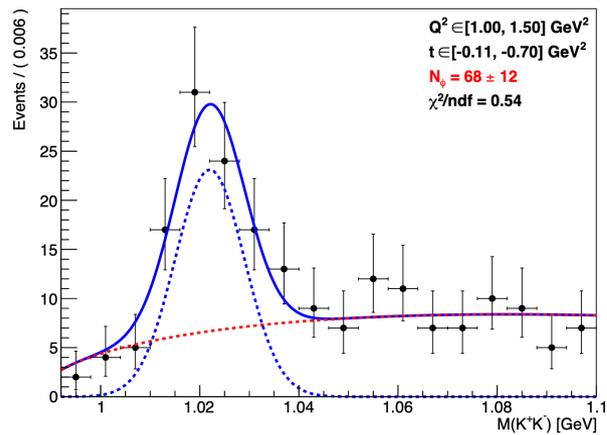
With this cuts : $5.25 < P_{\text{electron}} < 8 \text{ GeV}$ and $P_{\text{proton}} > 0.45 \text{ GeV}$

t vs Q2 with kinematics cuts

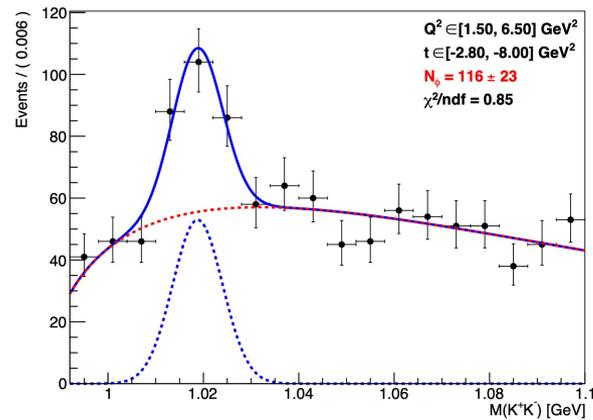
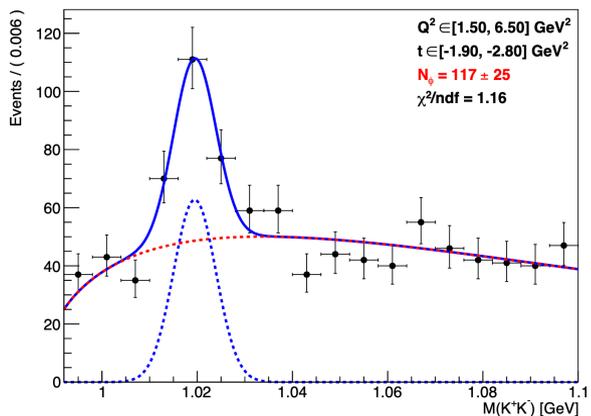
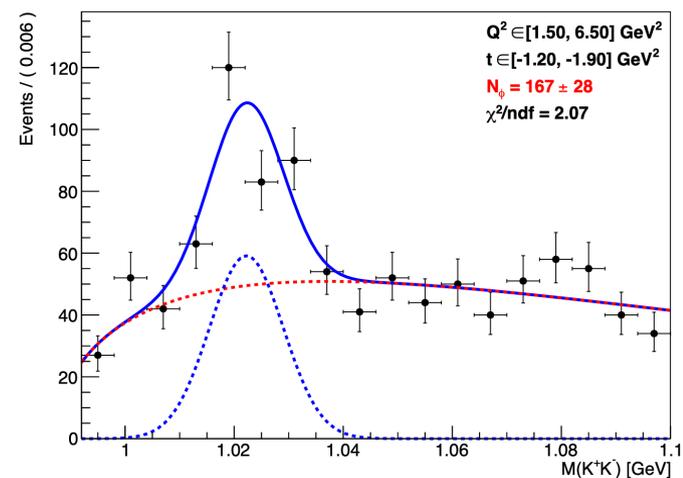
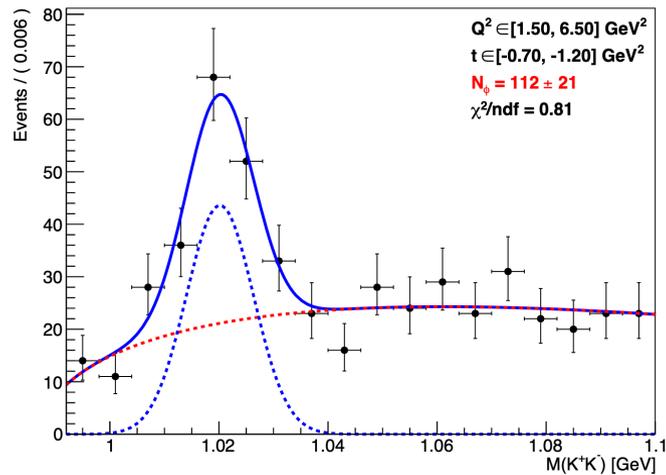
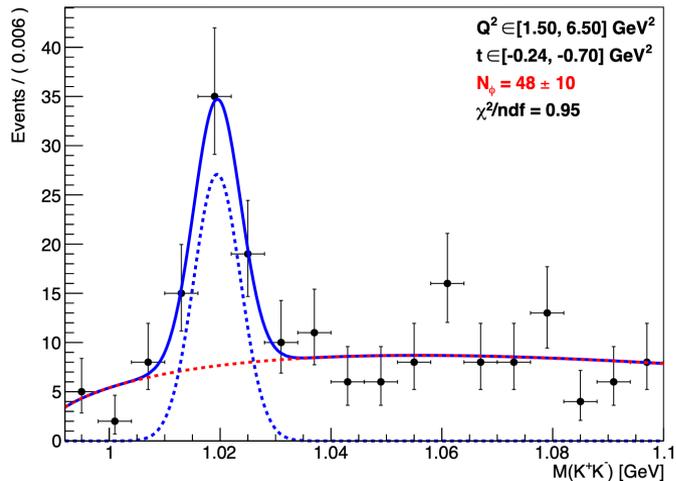


Bhawani plot

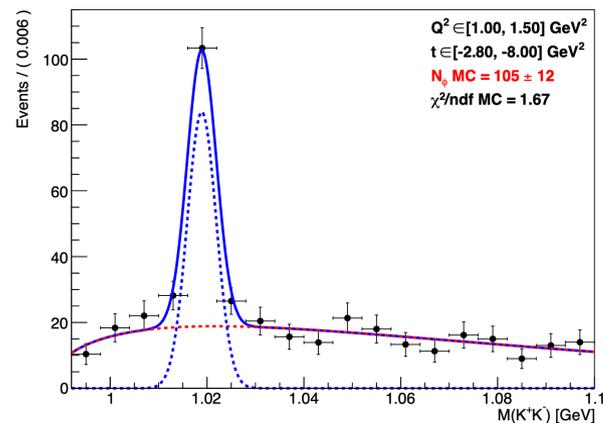
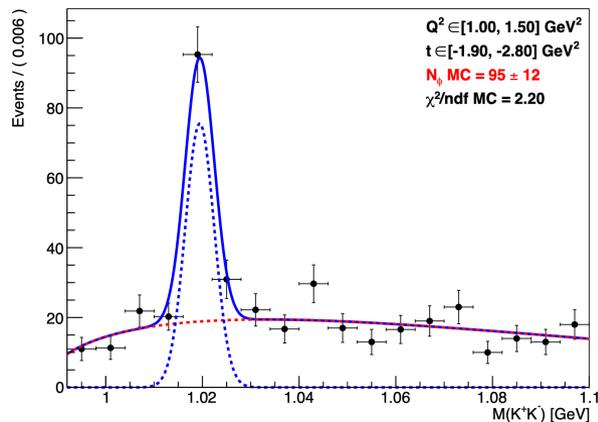
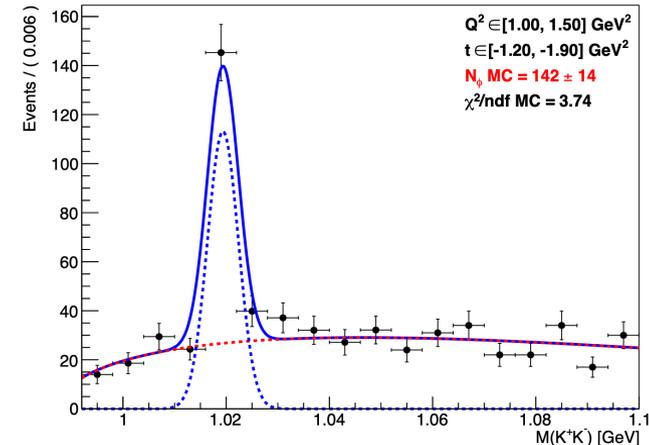
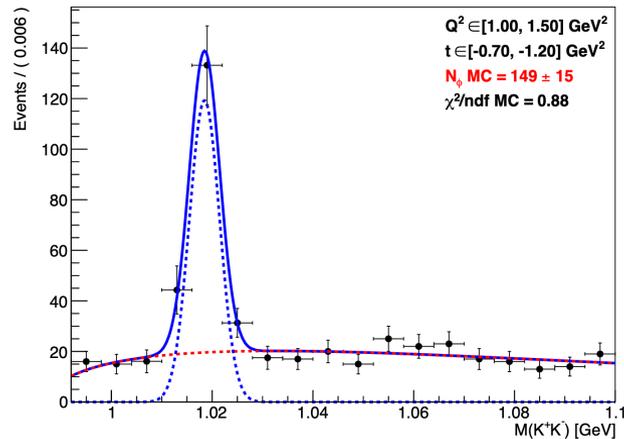
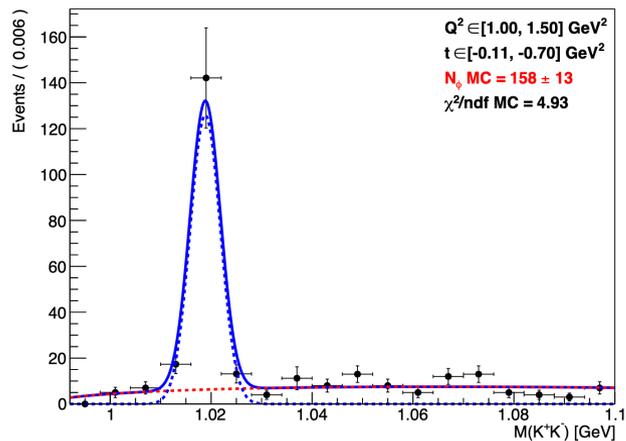
All fit data bin1 Q^2



All fit data bin2 Q^2



All fit mc bin1 Q²



All fit mc bin2 Q^2

