Beam Spin Asymmetry measurement of Exclusive φ production off the neutron in RGB

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CLAS12 Collaboration Meeting

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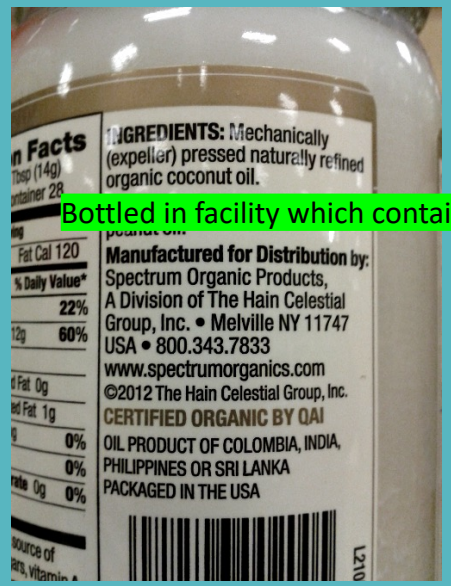
Overview

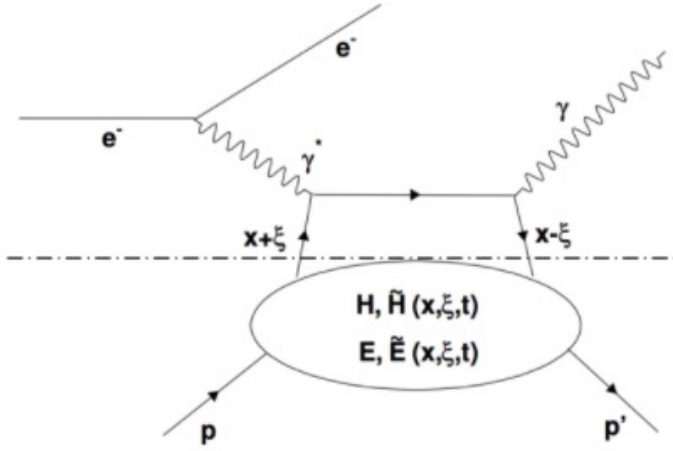
- Physics motivation for analysis of excluisve phi meson
- Basics of analysis – run group, event selection etc
- Basic calibration and quality cuts
- Deep-dive into exclusivity cut with comparison to RGA and RGB proton
- φ signal under present schematic
- A different method to do this analysis
- Summary

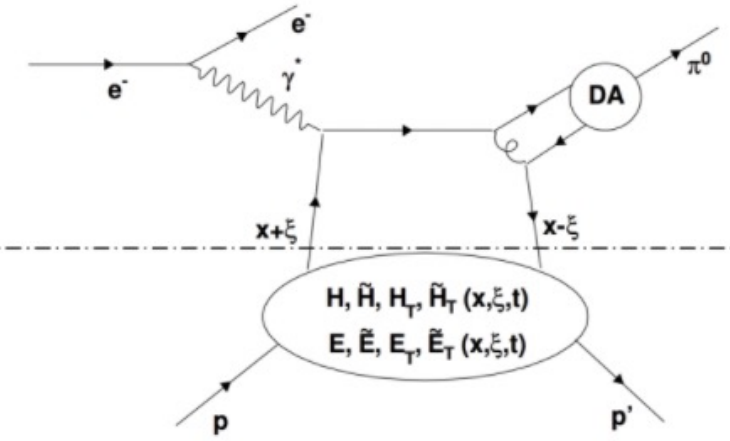
Accessing GPDs in spin ½ particle

- For each flavor of quarks, there are 8 GPDs each giving access to a specific combination of interplay between quark polorization and nucleon helicity.



Bottled in facility which contains gluon GPDS





Chiral even GPDs

+

Chiral-odd GPDs:

(helicity of the parton can flip)

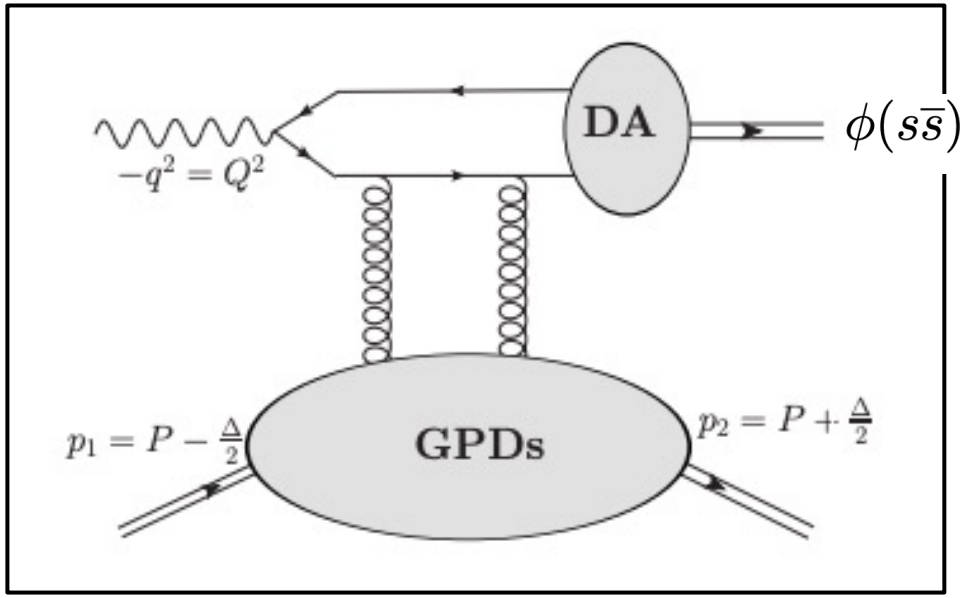
Chiral even GPDs:

(helicity of the parton is conserved)

	Nucleon Helicity	
	conserving	non-conserving
unpolarized GPD	H	E
polarized GPD	$\tilde{H}$	$\tilde{E}$

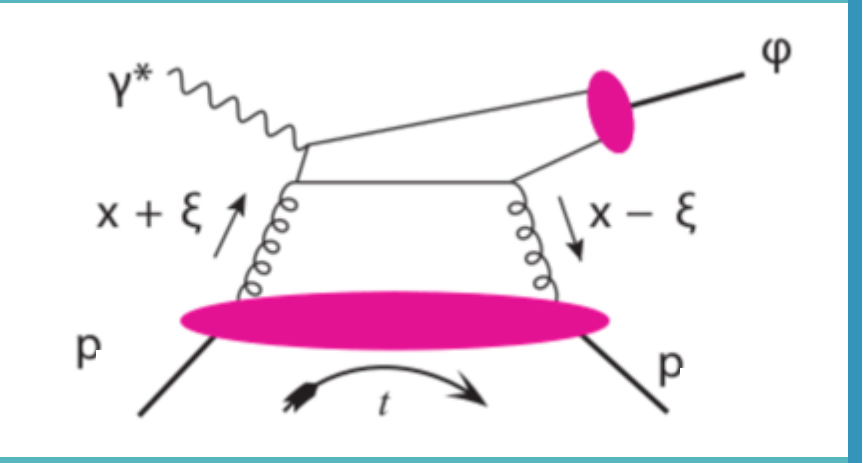
	Meson	Flavor
$\mathcal{H}_T, \mathcal{E}_T$	π^+	$\Delta u - \Delta d$
	π^0	$2\Delta u + \Delta d$
	η	$2\Delta u - \Delta d + 2\Delta s$

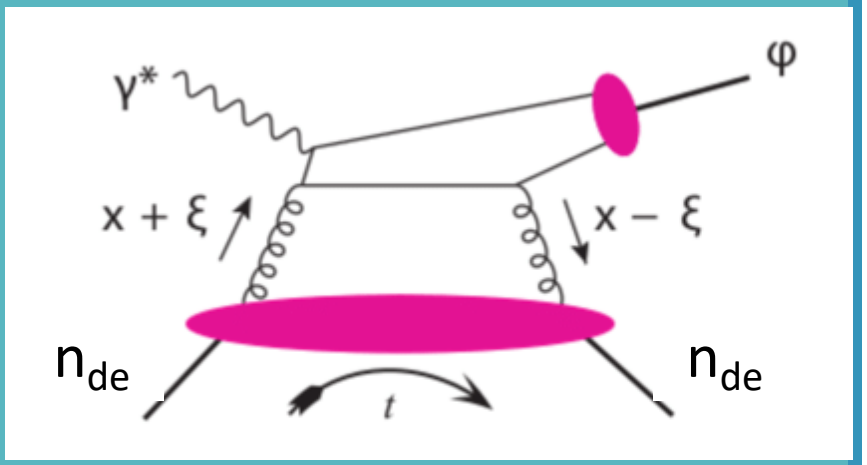
Accessing GPDs in spin ½ particle



JLab-12 plans to carry out an extensive program of "3D nucleon imaging" with exclusive and semi–inclusive processes. DVCS and elastic nucleon form factors are sensitive mostly/only to the valence quark degrees of freedom [1]. The proposed ϕ electroproduction experiment offers a unique way to access the spatial distribution of gluonic degrees of freedom and thus provides a crucial missing piece in the nucleon imaging program.

PAC39 : Exclusive Phi Meson Electroproductionhttps: //www.jlab.org/exp_prog/proposals/12/PR12- 12-007.pdf.





Why study φ off the neutron?

As the φ accesses the gluon channel, we expect any measurement of this to be similar to that of proton. It would be a good validation check

If we are sentive to differences, that makes this an even more interesting channel to study.

Additional benefits could be comparing RGB and RGA channel to understand final state interactions in heavy meson production

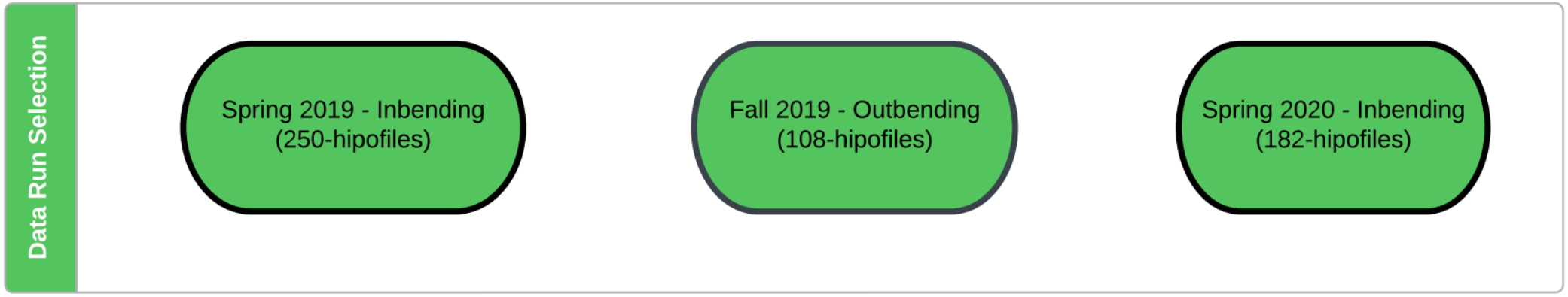
Analysis basics and run group

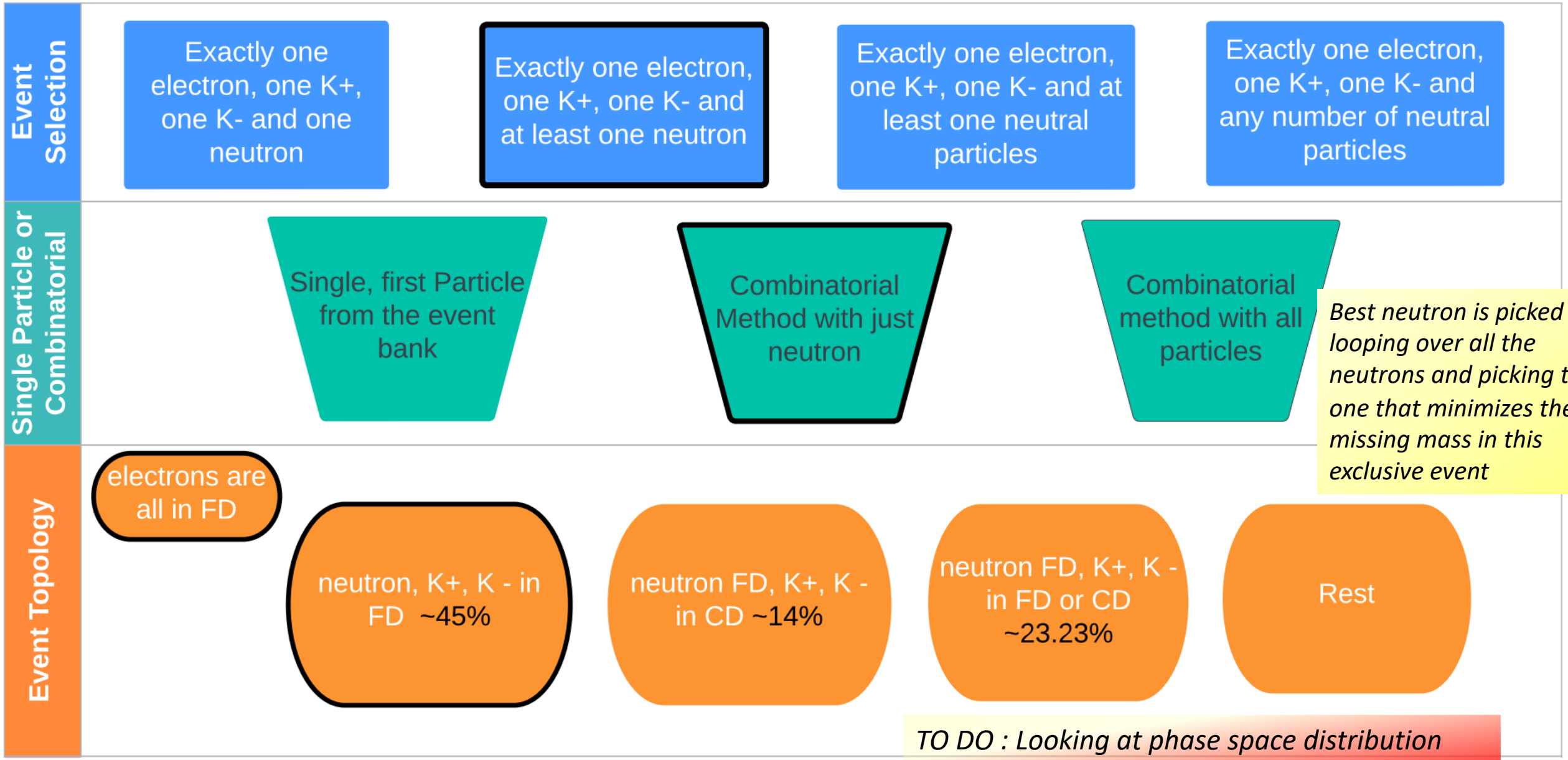
- Using RG-B data set to study φ production off of neutron
- Looking for exclusive phi production using the

$$\phi \rightarrow K^+K^-$$

- Final state particles are : scattered electron, scattered neutron, decay products of φ

decay channel	branching fraction
K^+K^-	48.9%
$K^0_L K^0_S$	34.2%
$\rho\pi + \pi^+\pi^-\pi^0$	15.32%




Event Selection
Exactly one electron, one K+, one K- and one neutron
Exactly one electron, one K+, one K- and at least one neutron
Exactly one electron, one K+, one K- and at least one neutral particles
Exactly one electron, one K+, one K- and any number of neutral particles
Single Particle or Combinatorial
Single, first Particle from the event bank
Combinatorial Method with just neutron
Combinatorial method with all particles
Best neutron is picked b
looping over all the
neutrons and picking th
one that minimizes the
missing mass in this
exclusive event
Event Topology
electrons are all in FD
neutron, K+, K - in FD ~45%
neutron FD, K+, K - in CD ~14%
neutron FD, K+, K - in FD or CD ~23.23%
Rest
TO DO : Looking at phase space distribution using a generator

Calibration of Final State particles

Electron

|chi2| <3
total Momentum > 2.1GeV
Vz : [-8,5]
Energy deposited in PCAL >0.06GeV
U,V,W >14cm
DC-Fiducial Cut : XY

Simulation based momentum correction from Noémie Pilleux
Raditive correction

neutron

Neutron Momentum > 0.5 GeV
cone angle formed by electron and neutron >10 deg

Simualtion based beta correction from Richard Tyson

kaon +

kaon -

|chi2| <3
Kaon Momentum < 3 GeV
Vz : [-8,5]
U,V,W >14cm
DC-Fiducial Cut : theta-phi

TO DO

(yet to do) Simualtion based momentum correction

Calibration of Final State particles

Electron

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total Momentum > 2.1GeV
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Vz : [-8,5]
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DC-Fiducial Cut : theta-phi

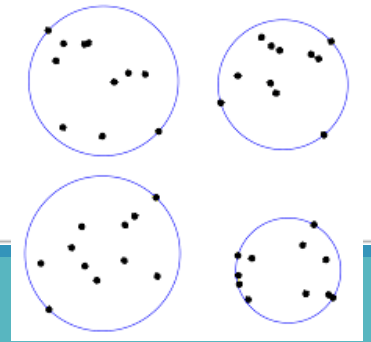
TO DO

(yet to do) Simualtion based momentum correction

Other Cuts

Vertex Cut

Miniball Algorithm



Looks for radius of the smallest sphere that encompasses all N points

Missing proton

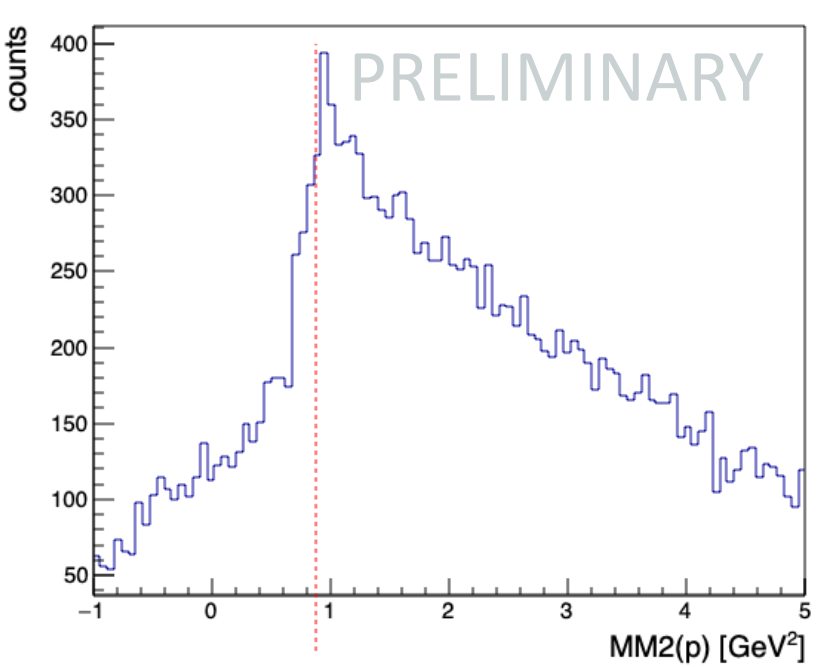
$$eD \rightarrow e'n'K^+K^-X$$

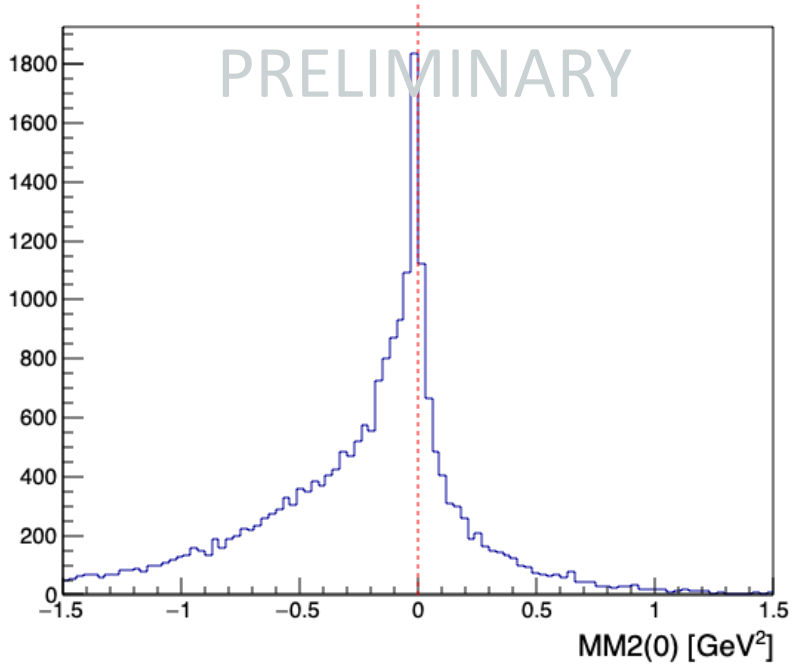
Missing Mass full event

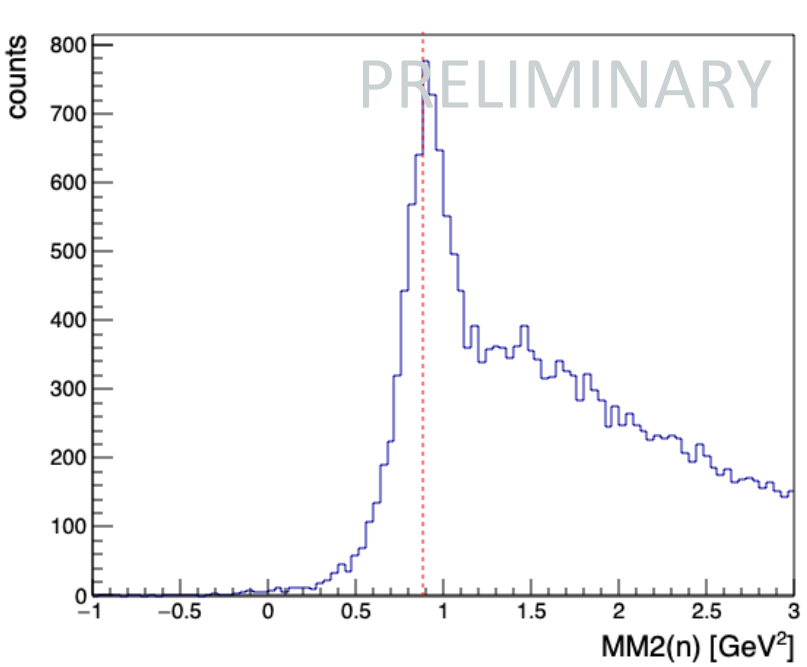
$$en \rightarrow e'n'K^+K^-X$$

Missing neutron

$$en \rightarrow e'K^+K^-X$$







All red dashed lines are an indication of where the peak should be

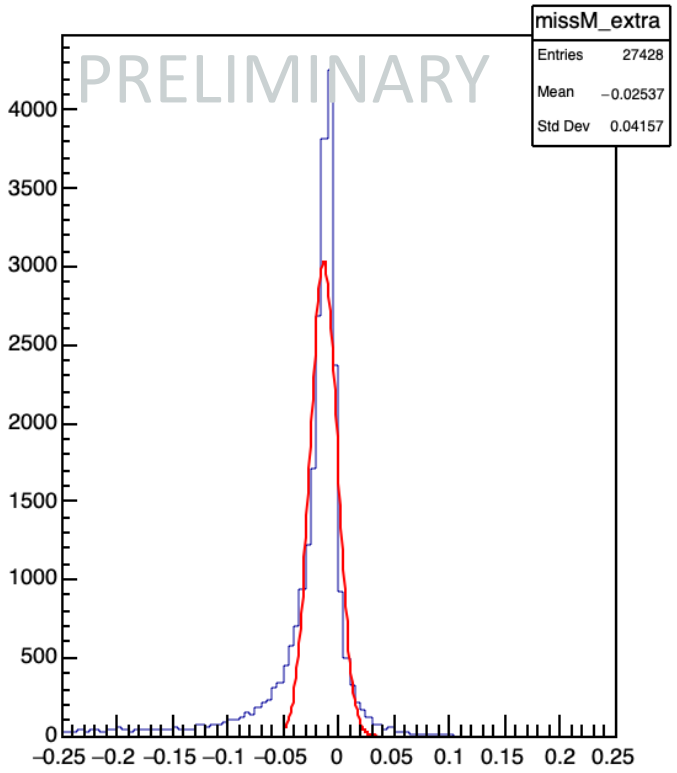
RGA

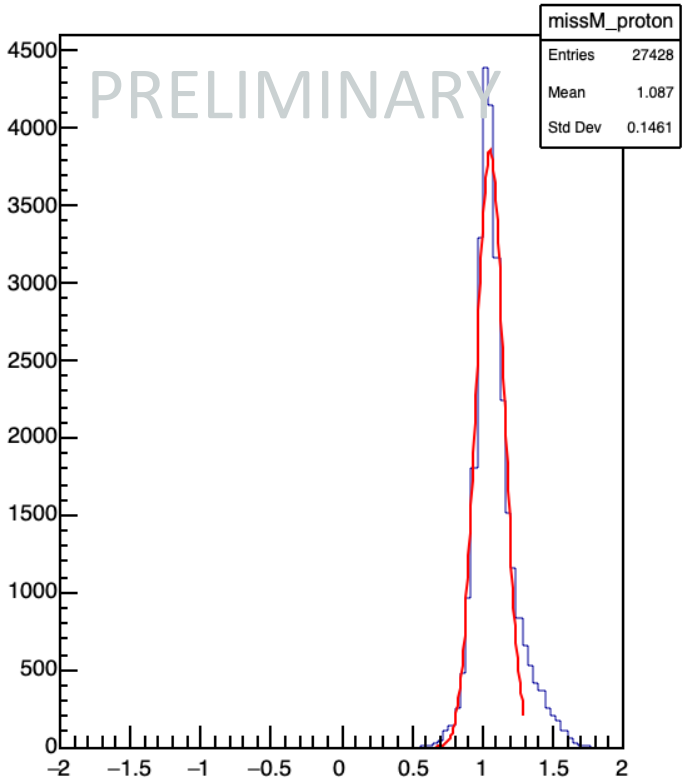
Missing Mass full event

$$ep \rightarrow e'p'K^+K^-X$$

Missing neutron

$$en \rightarrow e'K^+K^-X$$





Major difference between the two plots

- Deutron as target
- Final state interaction between spectator and target
- Neutron detection efficiency

TO DO : Efforts to understand final state interactions via simualtion is ongoing. But based on knowledge at the present moment, it is not the dominant effect.

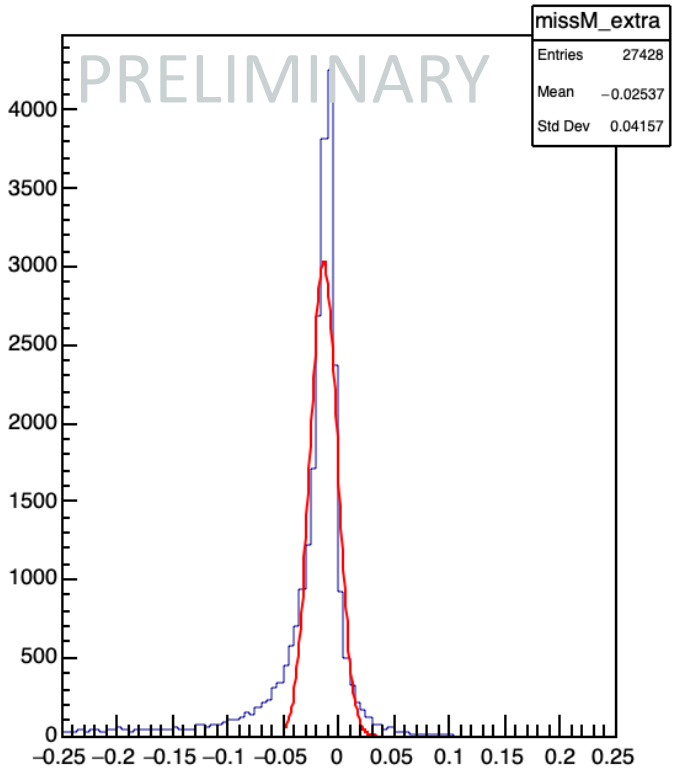
RGA

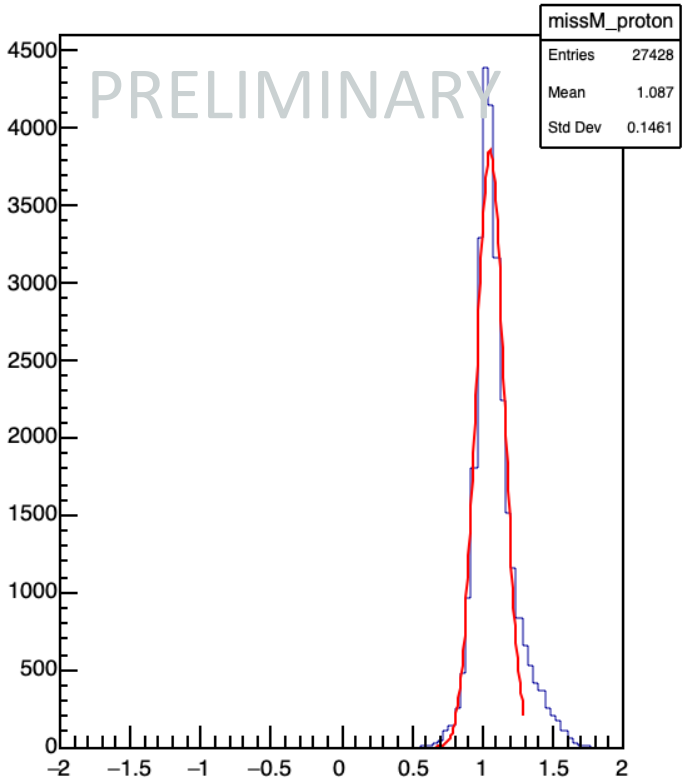
Missing Mass full event

$$ep \rightarrow e'p'K^+K^-X$$

Missing neutron

$$en \rightarrow e'K^+K^-X$$





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Missing neutron

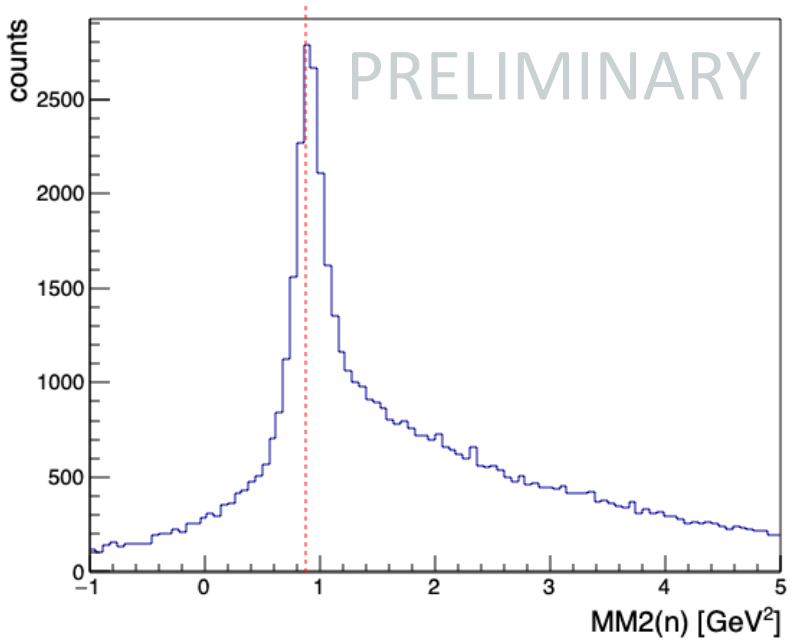
$$eD \rightarrow e'p'K^+K^-X$$

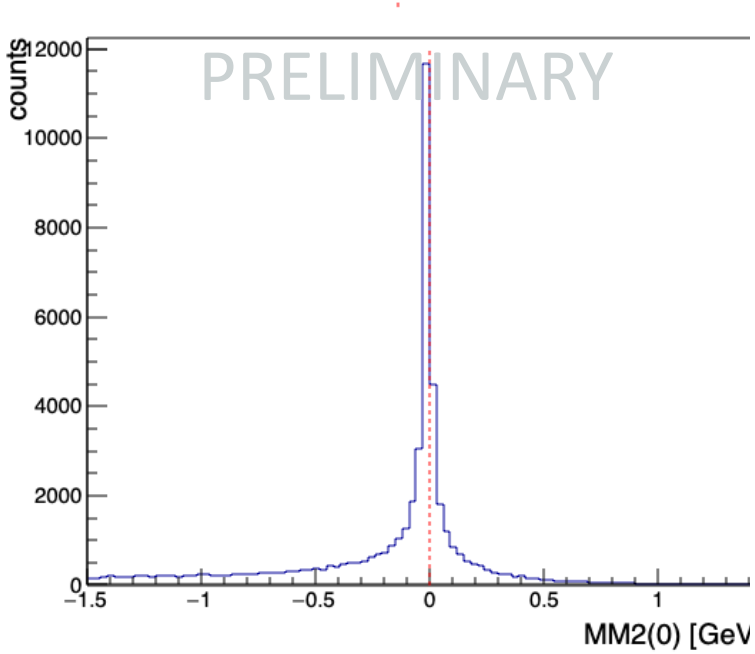
Missing Mass full event

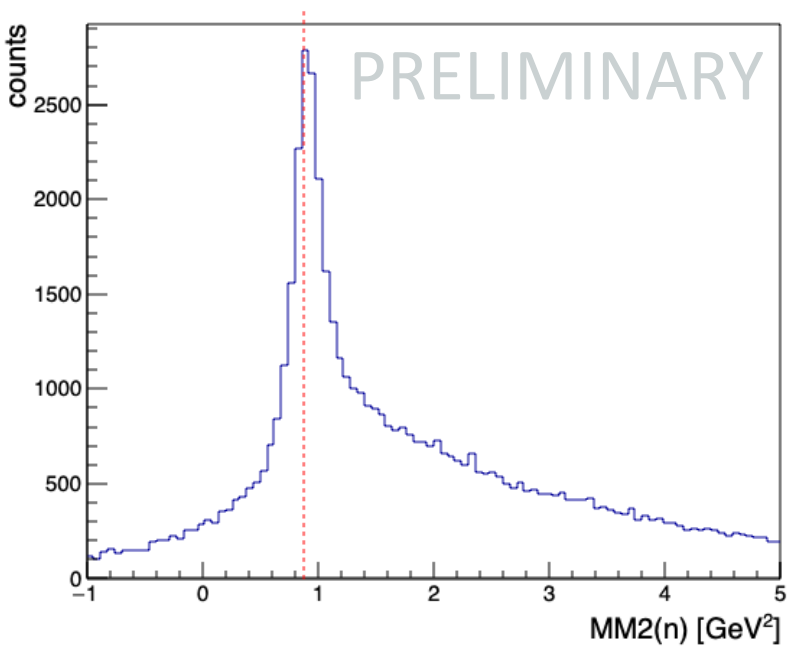
$$ep \rightarrow e'p'K^+K^-X$$

Missing proton

$$ep \rightarrow e'K^+K^-X$$

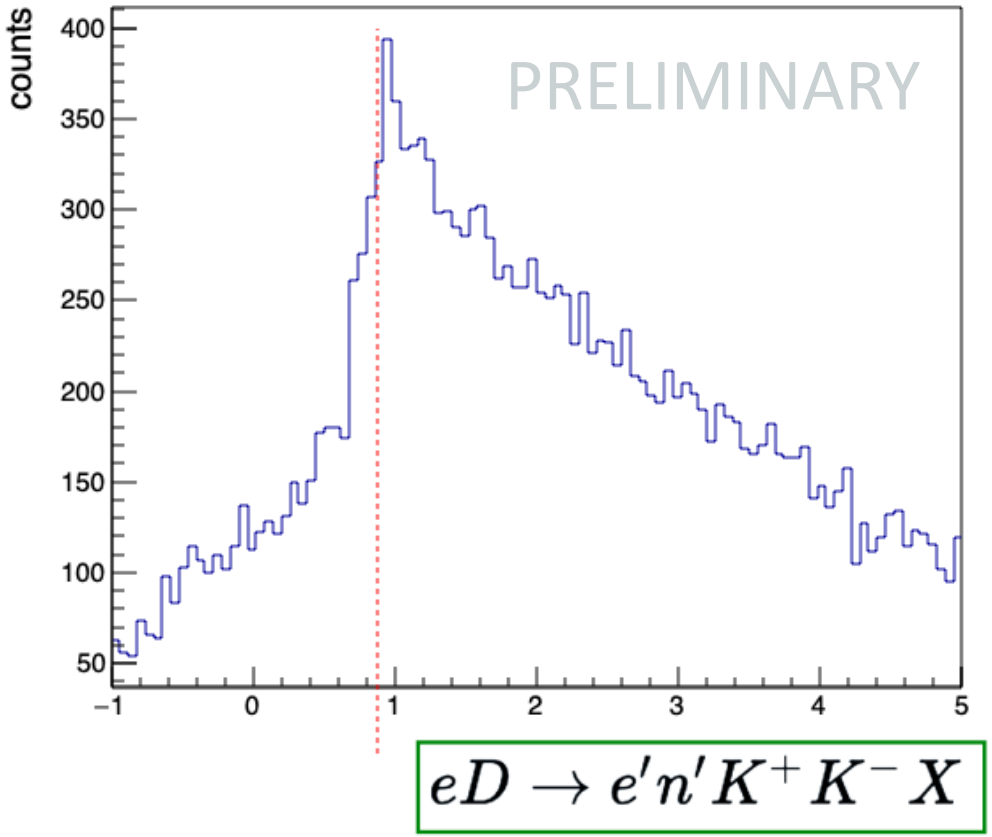


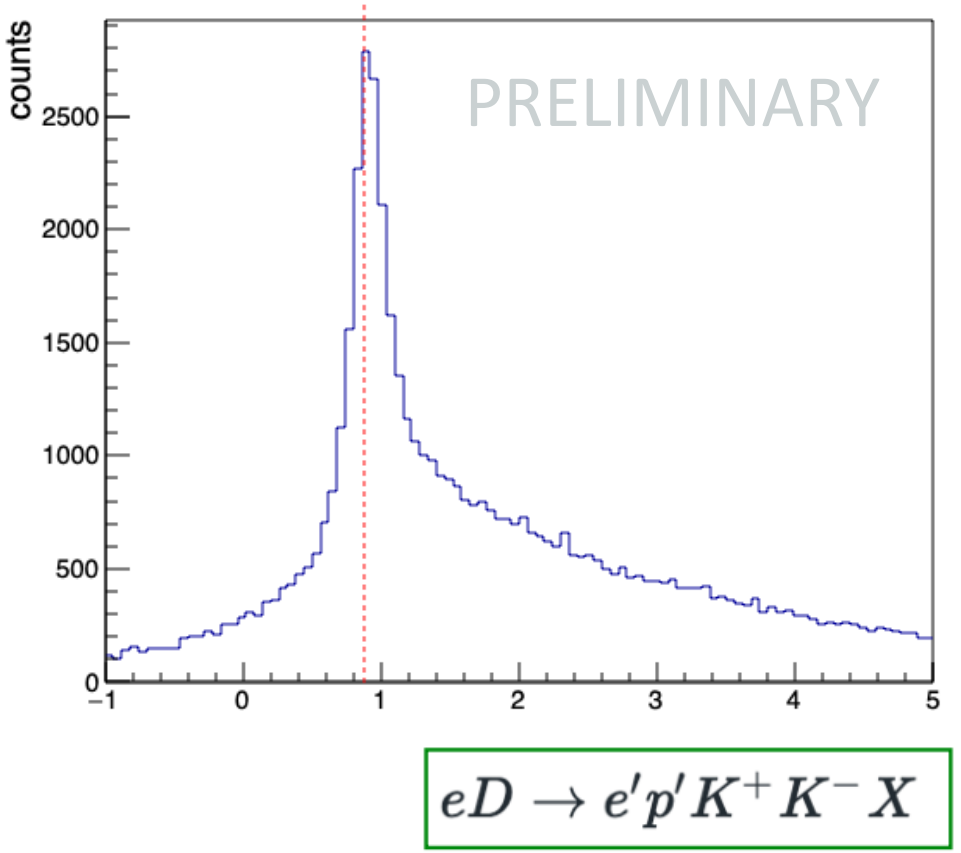




All red dashed lines are an indication of where the peak should be

Comparing excluisivity cuts off the proton vs off the neutron in RGB dataset is one good way to see how much of the effect we see in our plots is from final state interactions (which impacts both) vs how much of this comes from neutron identification

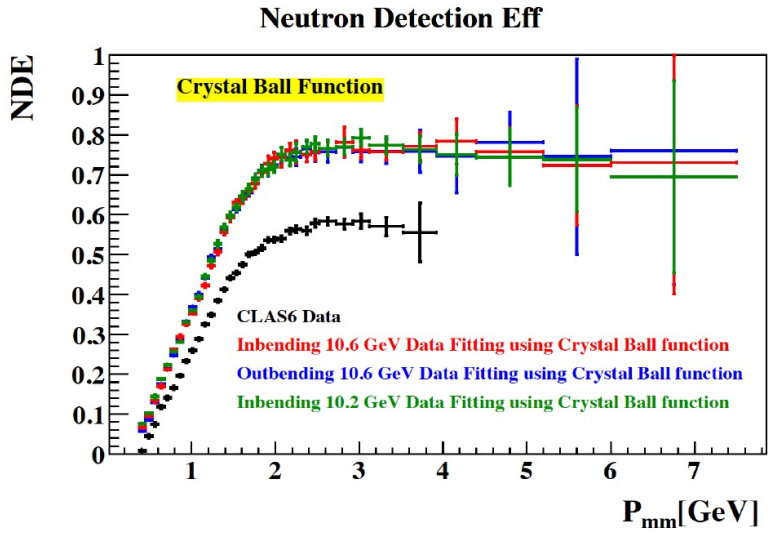


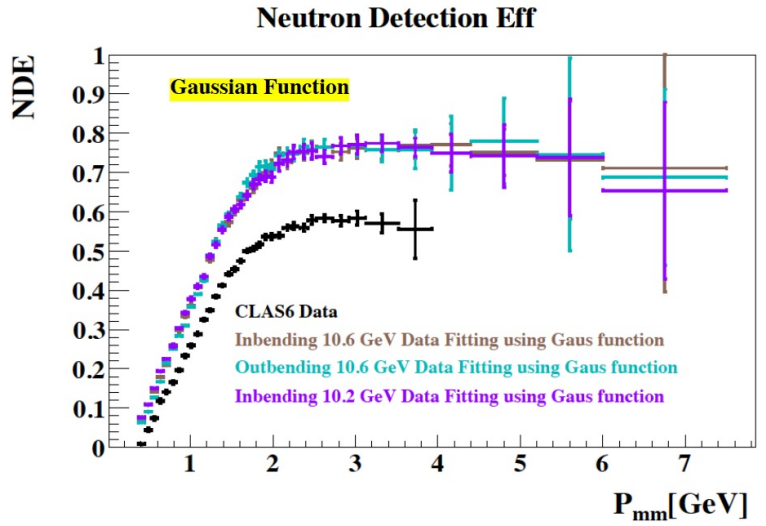


Neutron identification studies (ongoing) from Lamya Basheen

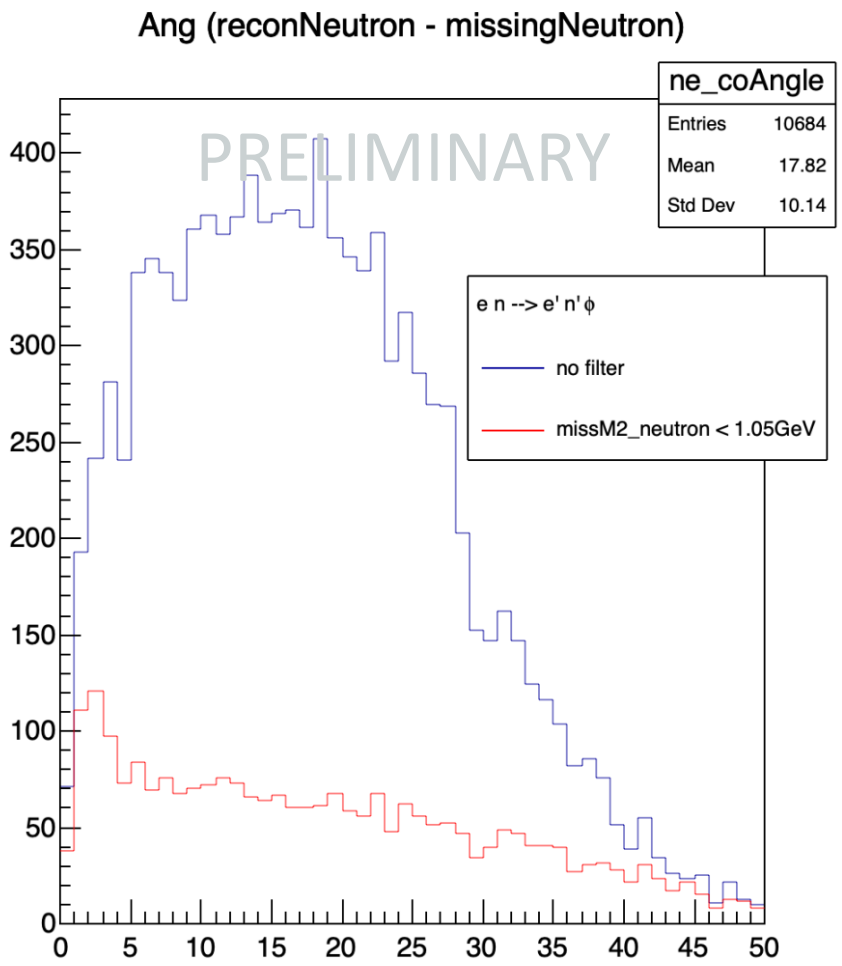
At really low momenutm, the neutron does not punch through enough for its detection to be reliable. Unfortunately most of my statistics is below 1.5GeV

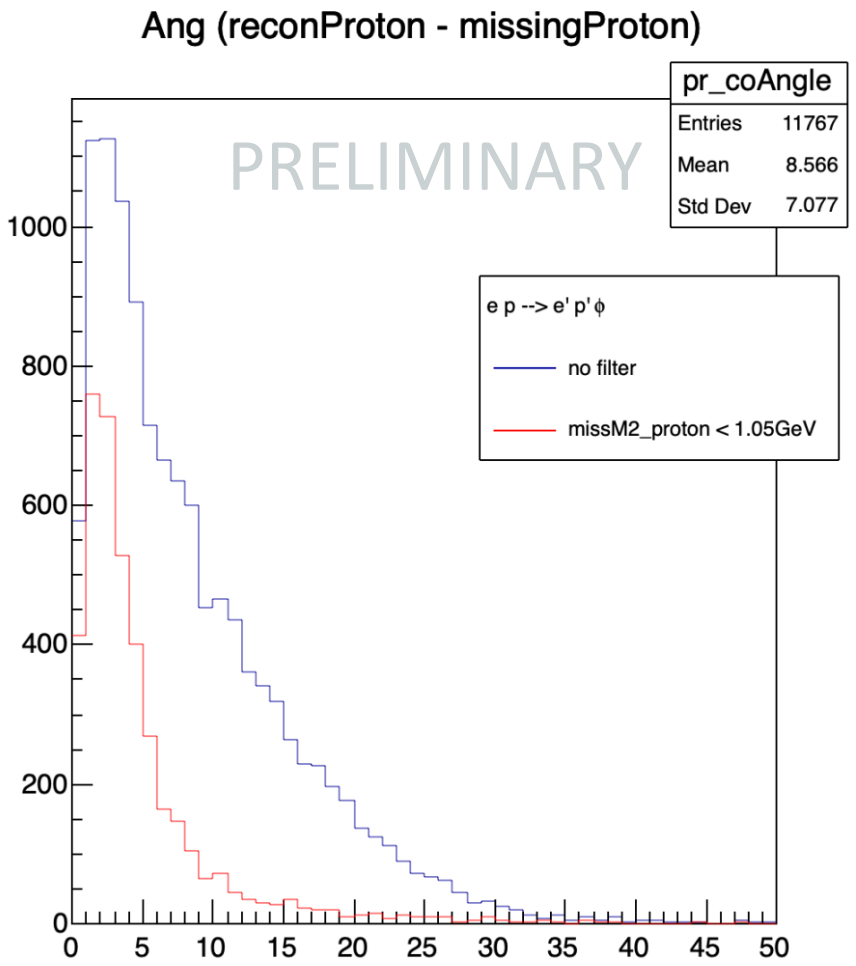
NDE Results from Fitting with background





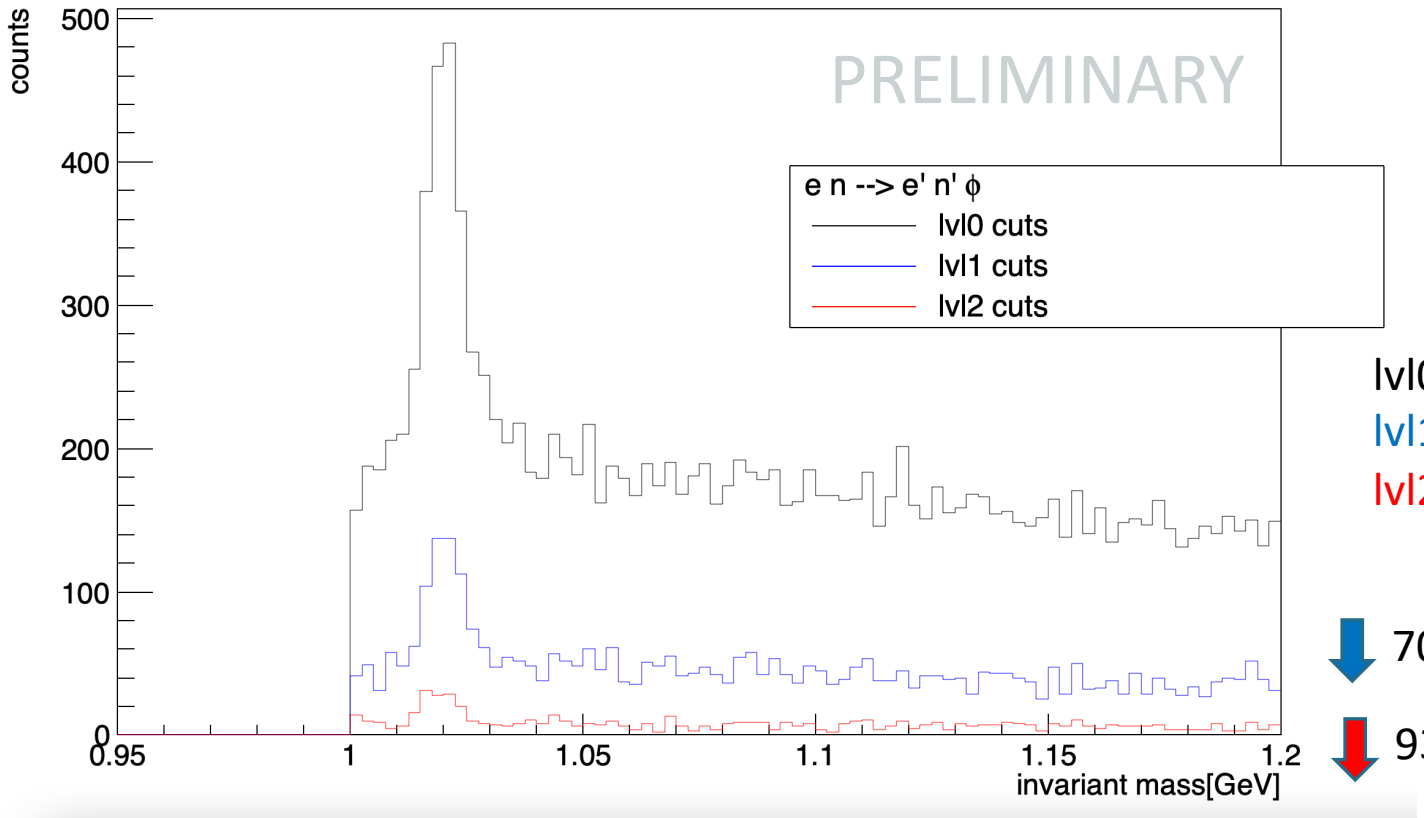
Angle between missing nucleon and reconstructed nucleon

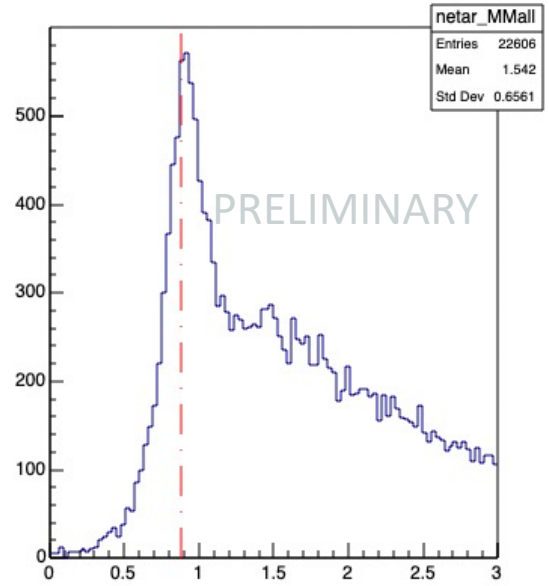




35% statistics

φ meson signal – neutron target





$en \rightarrow e' K^+ K^- X$

lvl0_cuts : $Q^2>2$ $W^2>4$

lvl1_cuts : lvl0_cuts + 0.75 < miss mass of neutron <1.15

lvl2_cuts : lvl1_cuts + coAngle_neutron<=5deg

70%

93%

Summary #1 – the end?

- Studying φ is a very interesiting channel giving us access to the gluon GPDs of nucleons

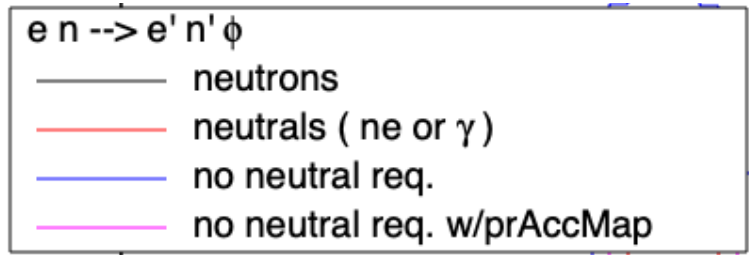
- there are minor improvements that can be done to the analysis such as correction to kaon momentum

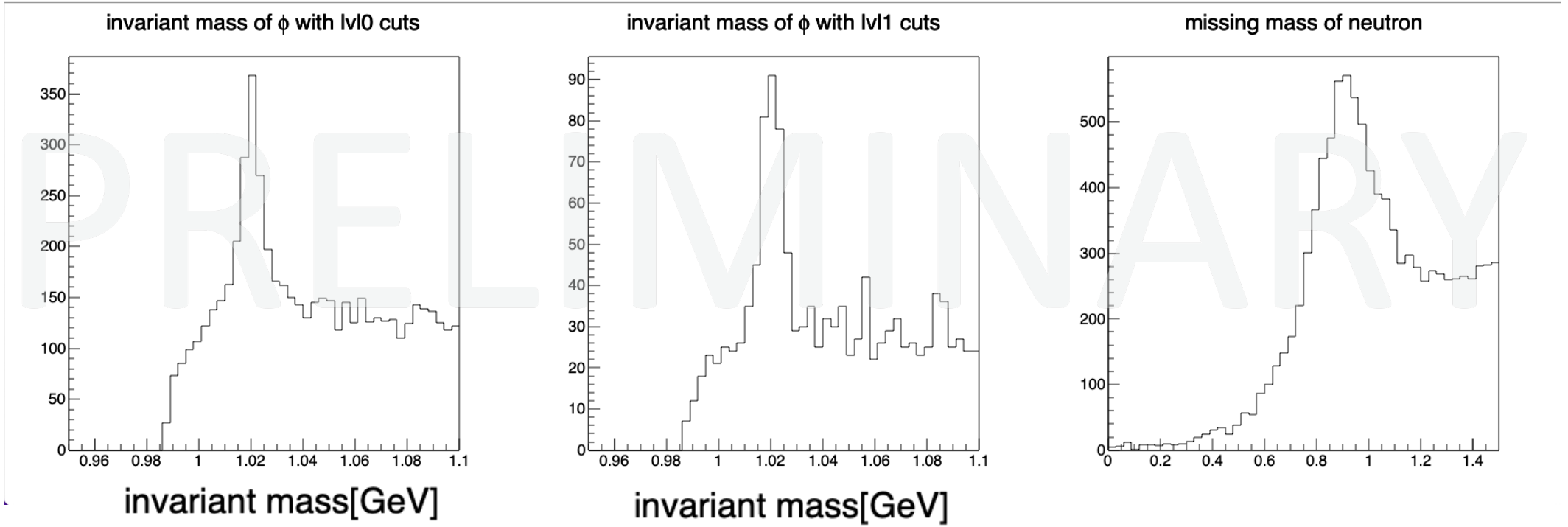
- the major difficulty for this analysis is he low momentum of neutrons in the forward detector which makes their reconstruction difficult

- This, combined with the limited cross-section of φ meson production, results in a small signal that can hinder obtaining accurate beam-spin asymmetry (BSA) measurements.

Let’s try one more thing…..

How about loosening the requirements on neutron?

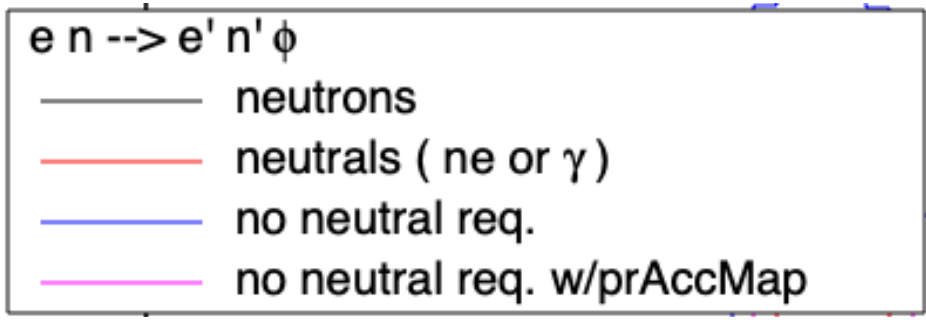




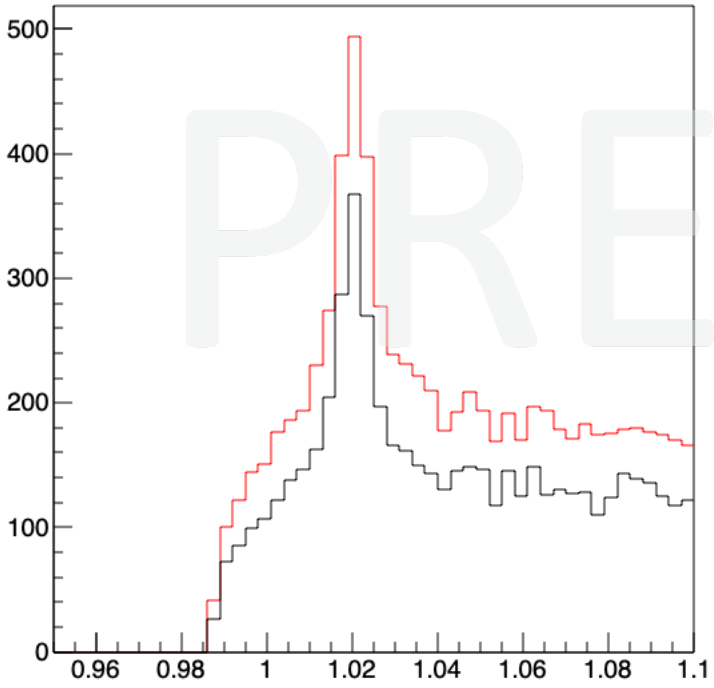
Event Selection

Exactly one electron, one K+, one K- and one neutron	**Exactly one electron, one K+, one K- and at least one neutron**	Exactly one electron, one K+, one K- and at least one neutral particles	Exactly one electron, one K+, one K- and any number of neutral particles

Looking at neutrons + photon

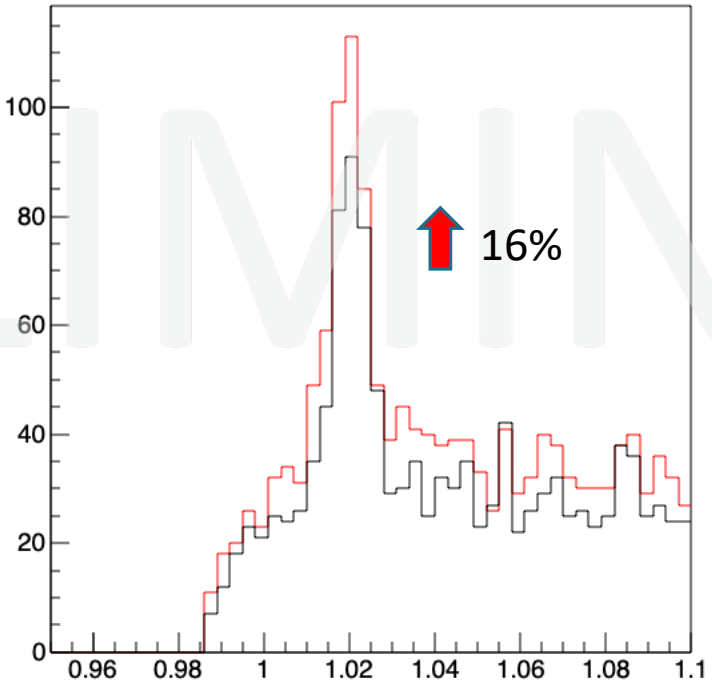


invariant mass of ϕ with lvl0 cuts



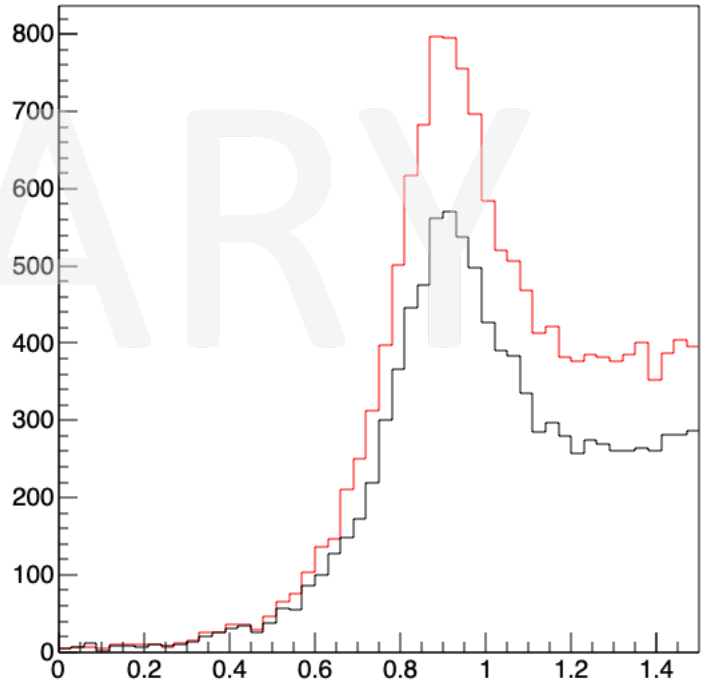
invariant mass[GeV]

invariant mass of ϕ with lvl1 cuts



invariant mass[GeV]

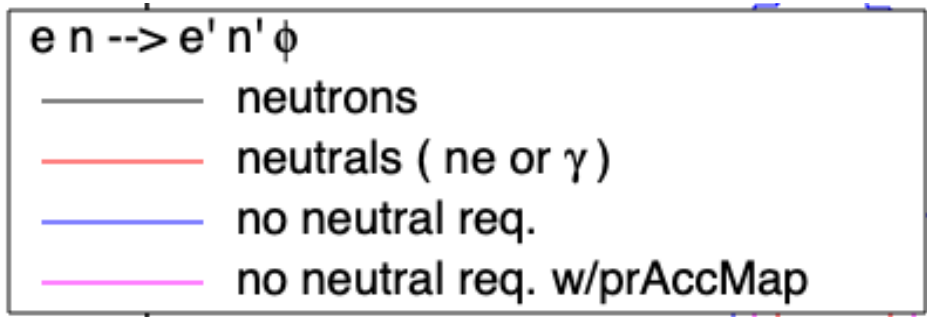
missing mass of neutron

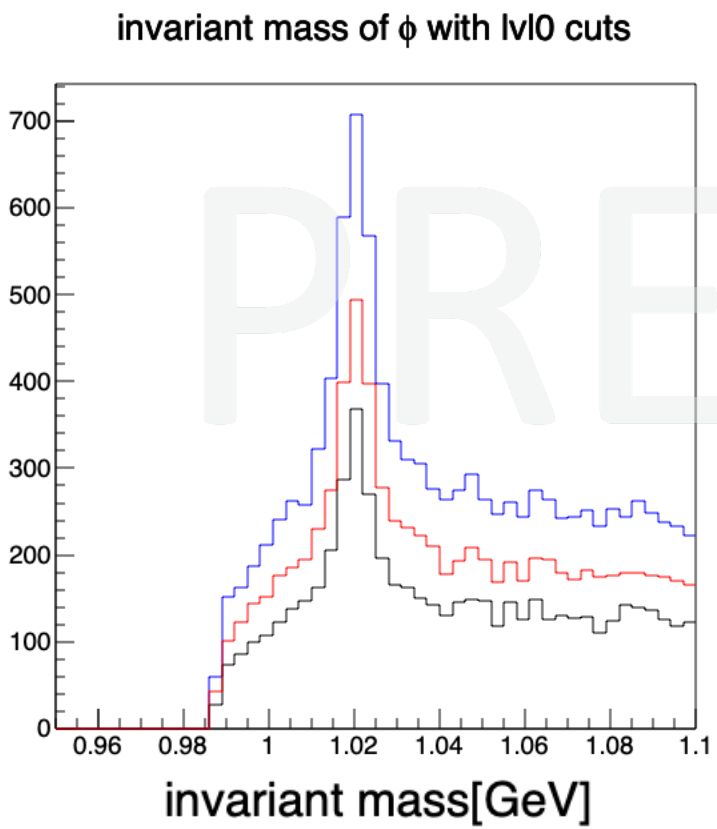


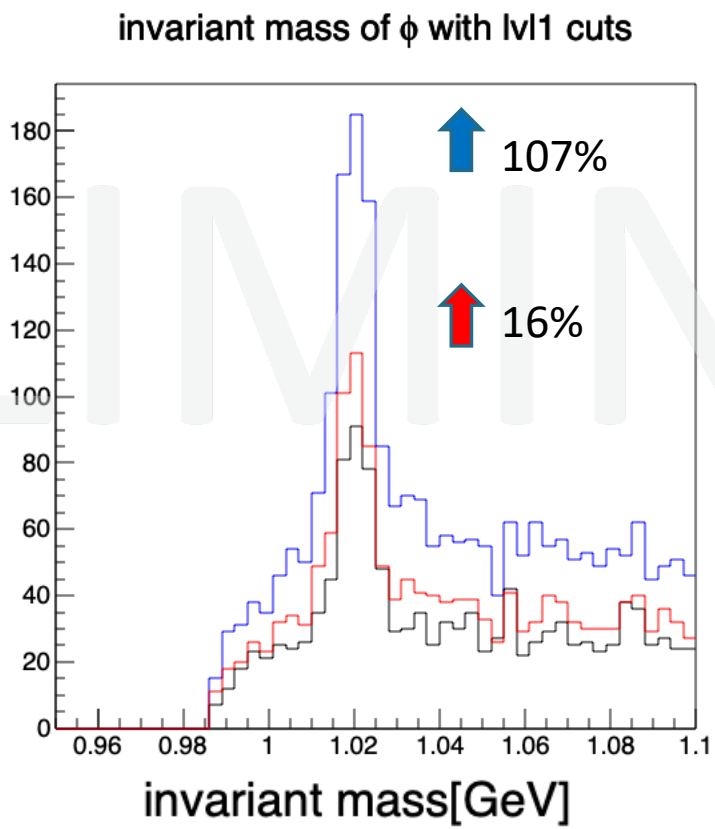
Missing neutron

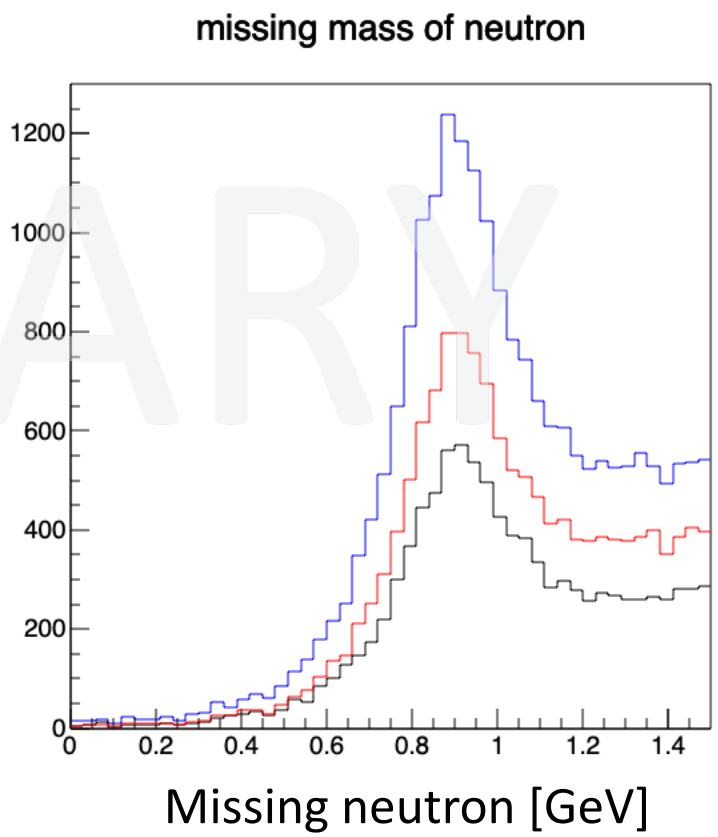
35% statistics

No Req. on neutral particle.







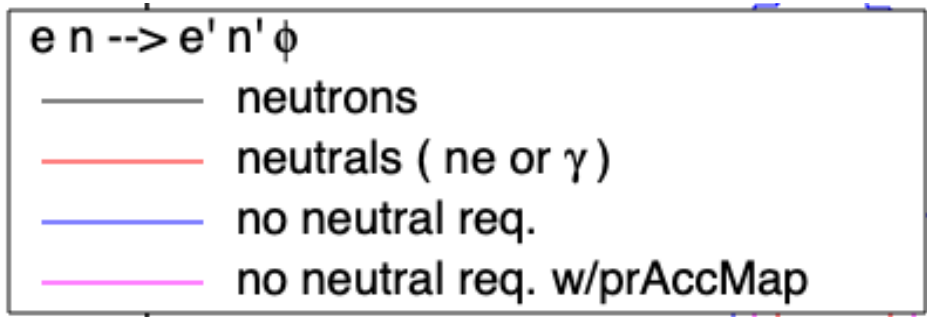


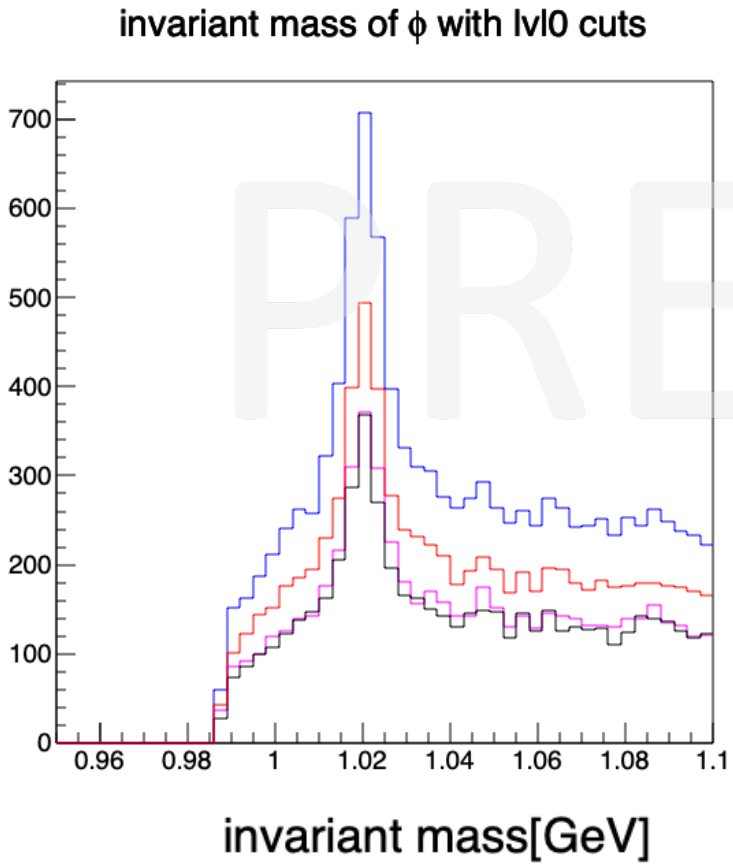
But ofc, ignoring events which has reconstructed proton.
There are two issues with this

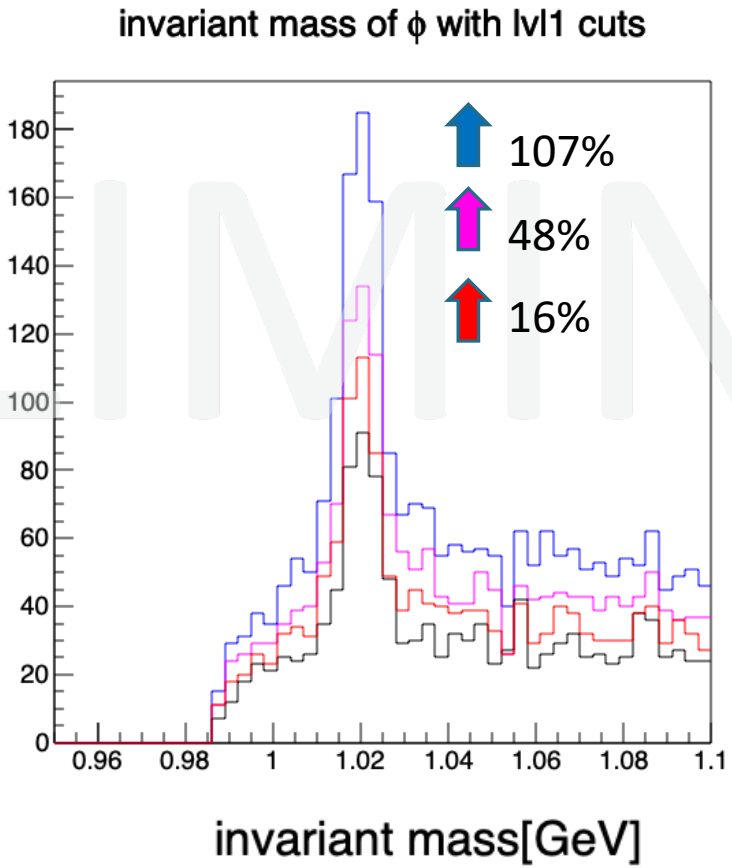
35% statistics

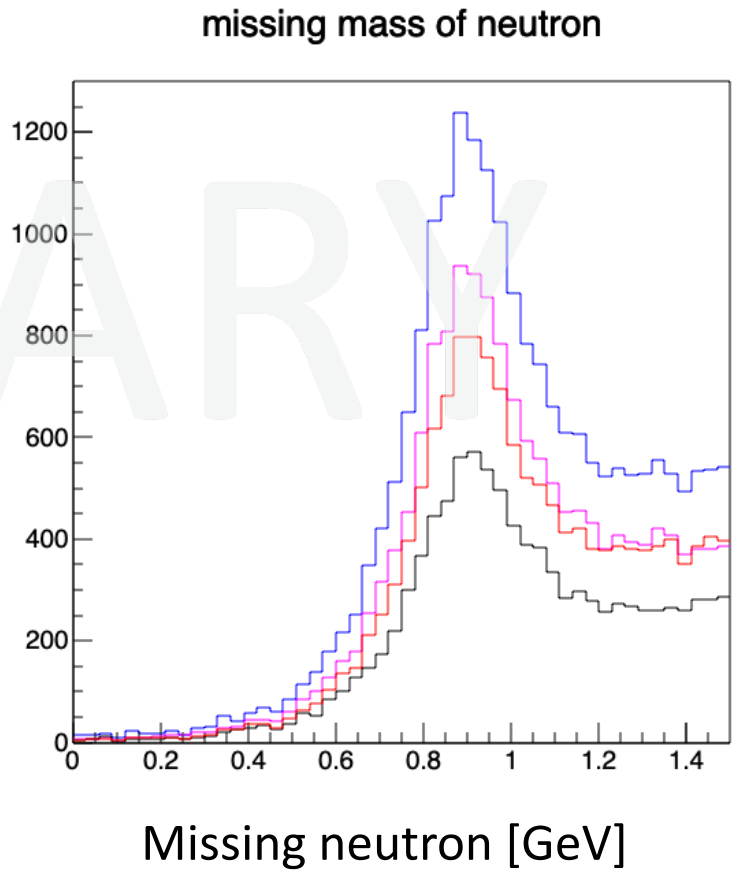
1) protons which are outside acceptance
2) proton within acceptance, but not yet reconstructed.

No Req. on Neutral particle + proton acceptance map









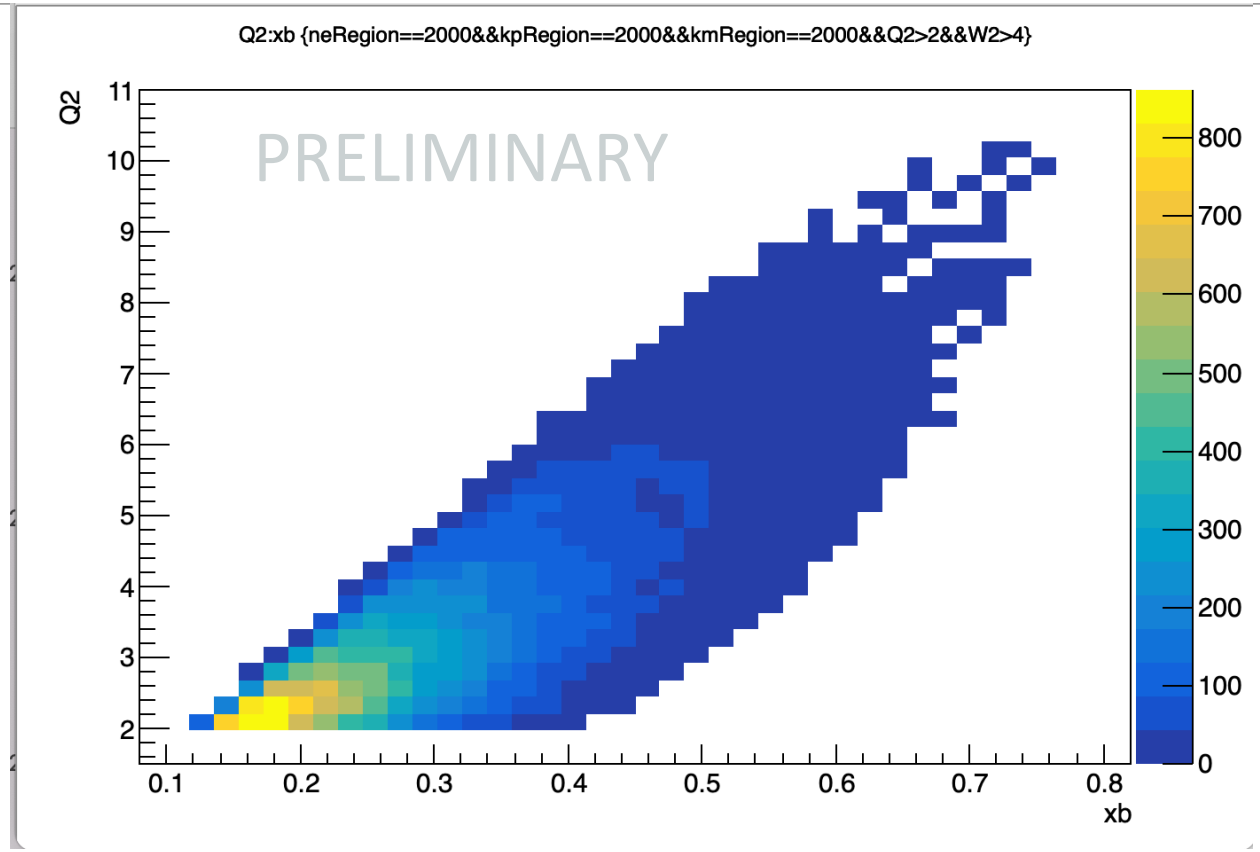
35% statistics

Summary 2 : All isn’t lost, yet.

- Maybe this analysis can be done even without requiring a neutron
- This will present with some challenges in understading and constraining contamination from the proton channel
- Studying small sample of Pass 2 indicates a significant improvement in statistics in this channel..
- We may not get a finely binned BSA measurement. But with some effort, it might be possible to see a very small signal
- Nevertheless, this effort will be written up and submitted as an analysis note within collaboration for future reference.

Backup

Q2 vs XB

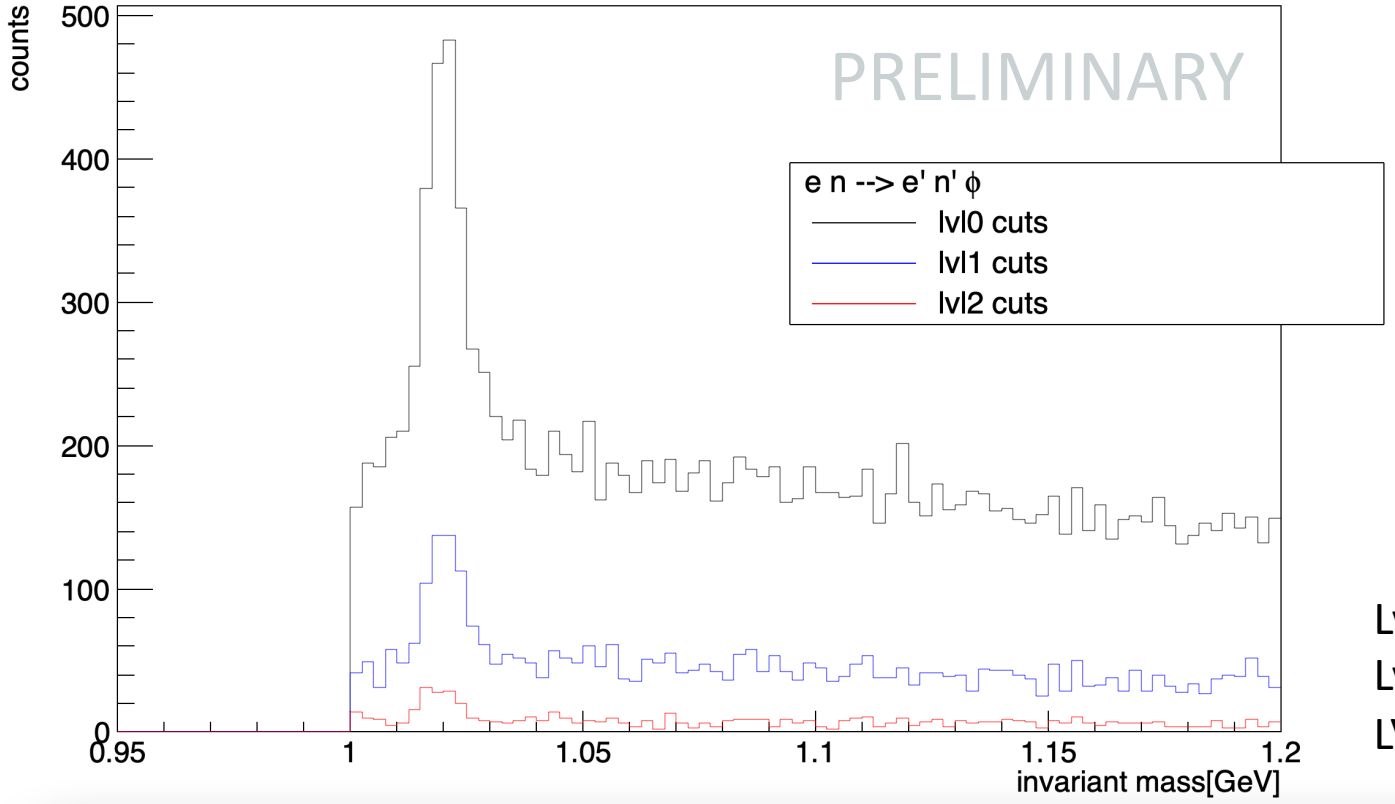

Q2:xb {neRegion==2000&&kpRegion==2000&&kmRegion==2000&&Q2>2&&W2>4}
PRELIMINARY
Q2
11
10
9
8
7
6
5
4
3
2
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
xb
800
700
600
500
400
300
200
100
0

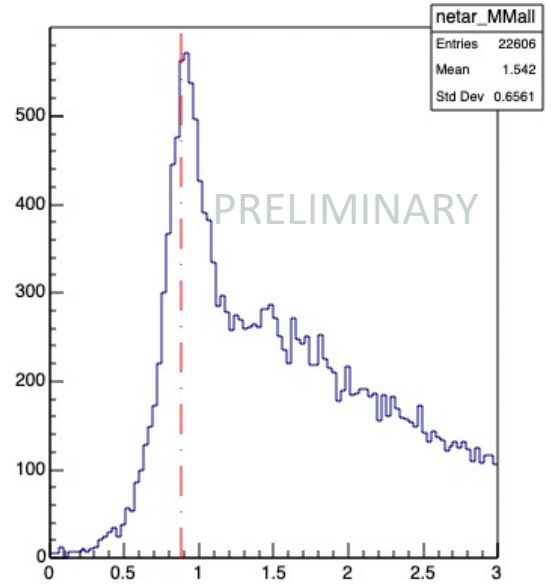
lvl0_cuts : $Q^2>2$ $W^2>4$

lvl1_cuts : lvl0_cuts + 0.75 < miss mass of neutron <1.15

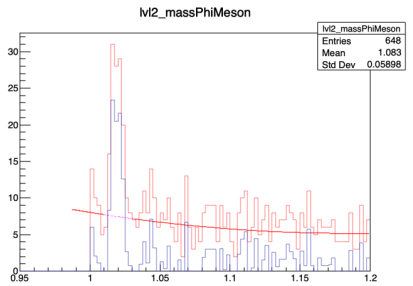
lvl2_cuts : lvl1_cuts + coAngle_neutron<=5deg

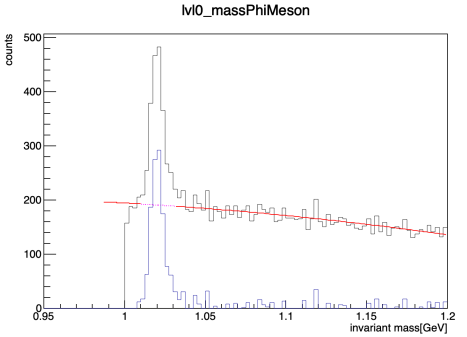
φ meson signal – neutron target





$$en \rightarrow e' K^+ K^- X$$

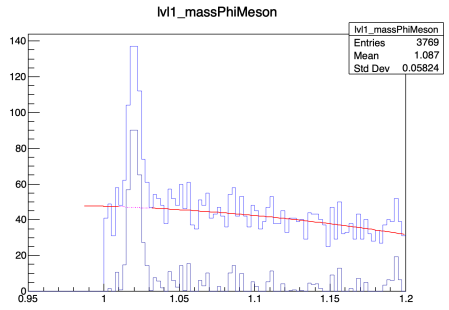




Lvl0 : 1160

Lvl1 : 370

LV2 : 85

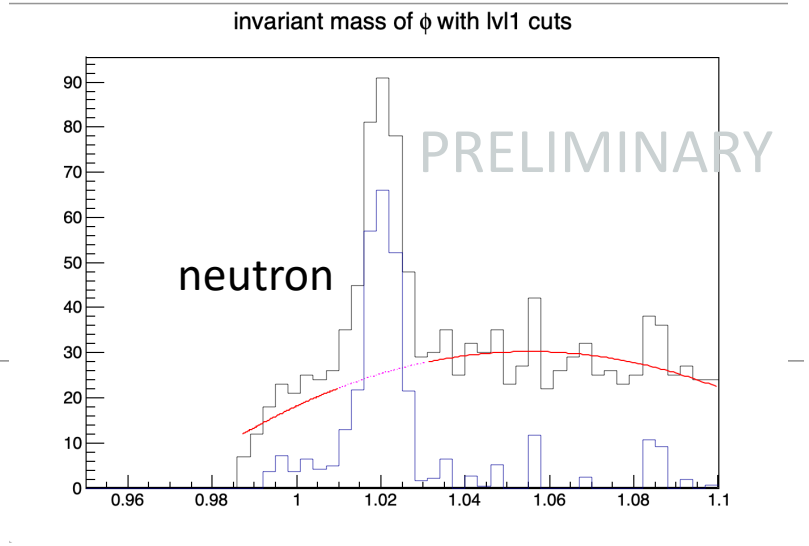


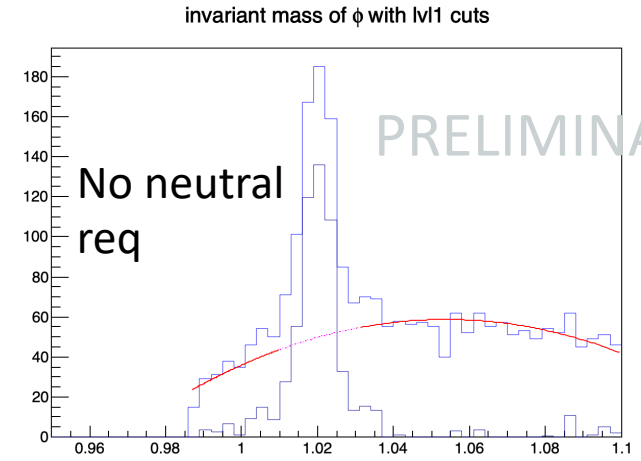
1) neutrons : 235.97

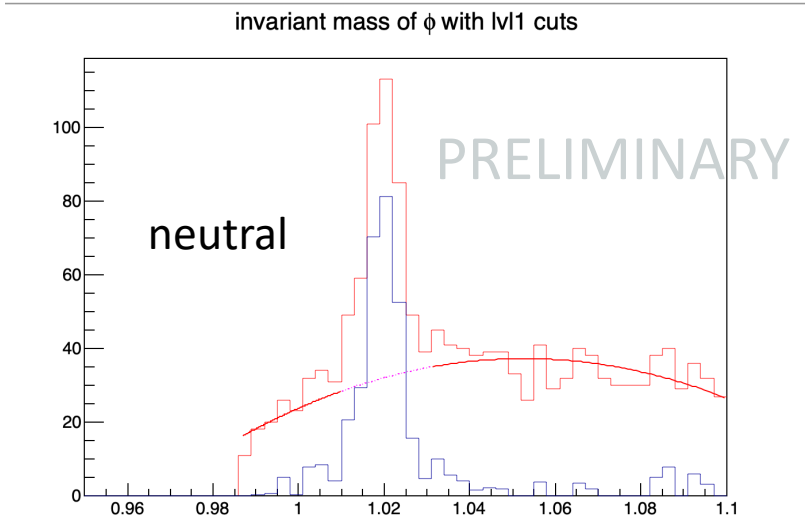
2) neutrals : 273

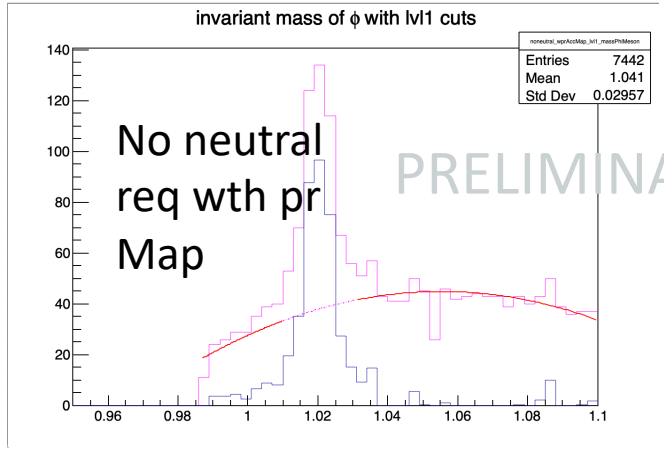
3) no neutral req : 487

4) no neutral req with proton map : 349





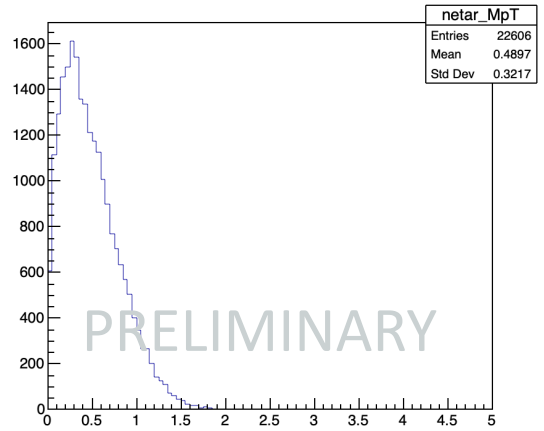


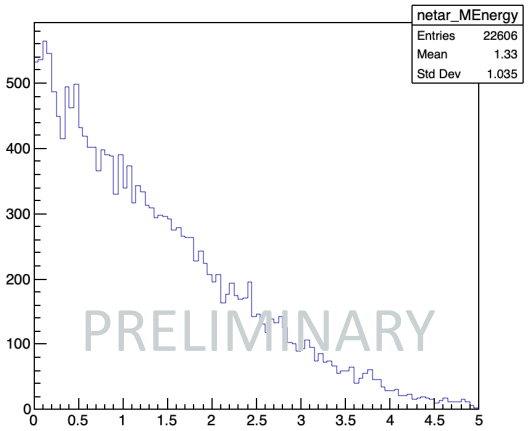


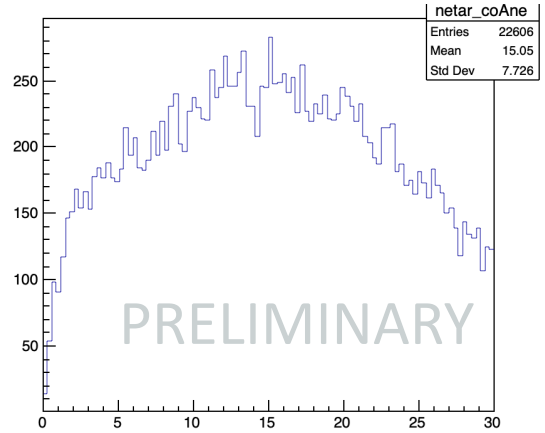
Other possible exclusivity cuts

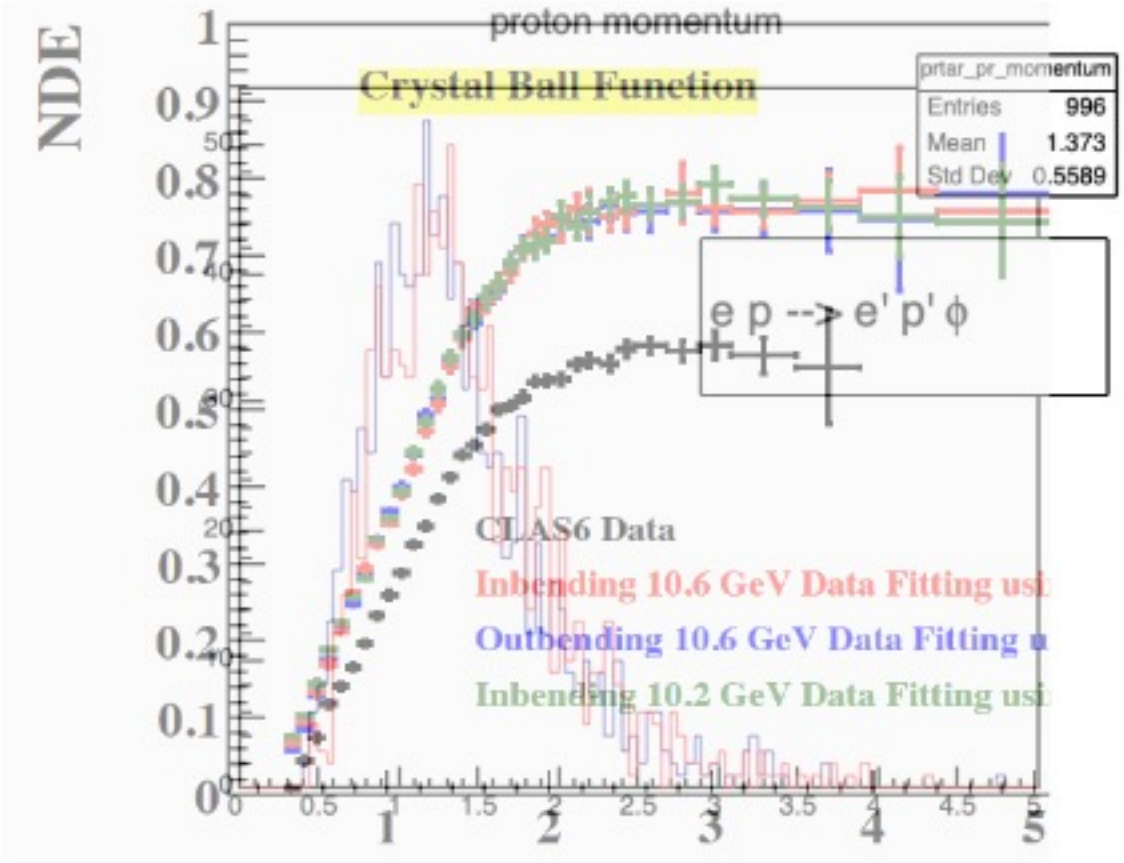
Exclusivity Cuts - Others

- missing pT
- missing energy
- Angle between Hadron Plane defined two different ways
- Angle between missing particle and the reconstructed particle

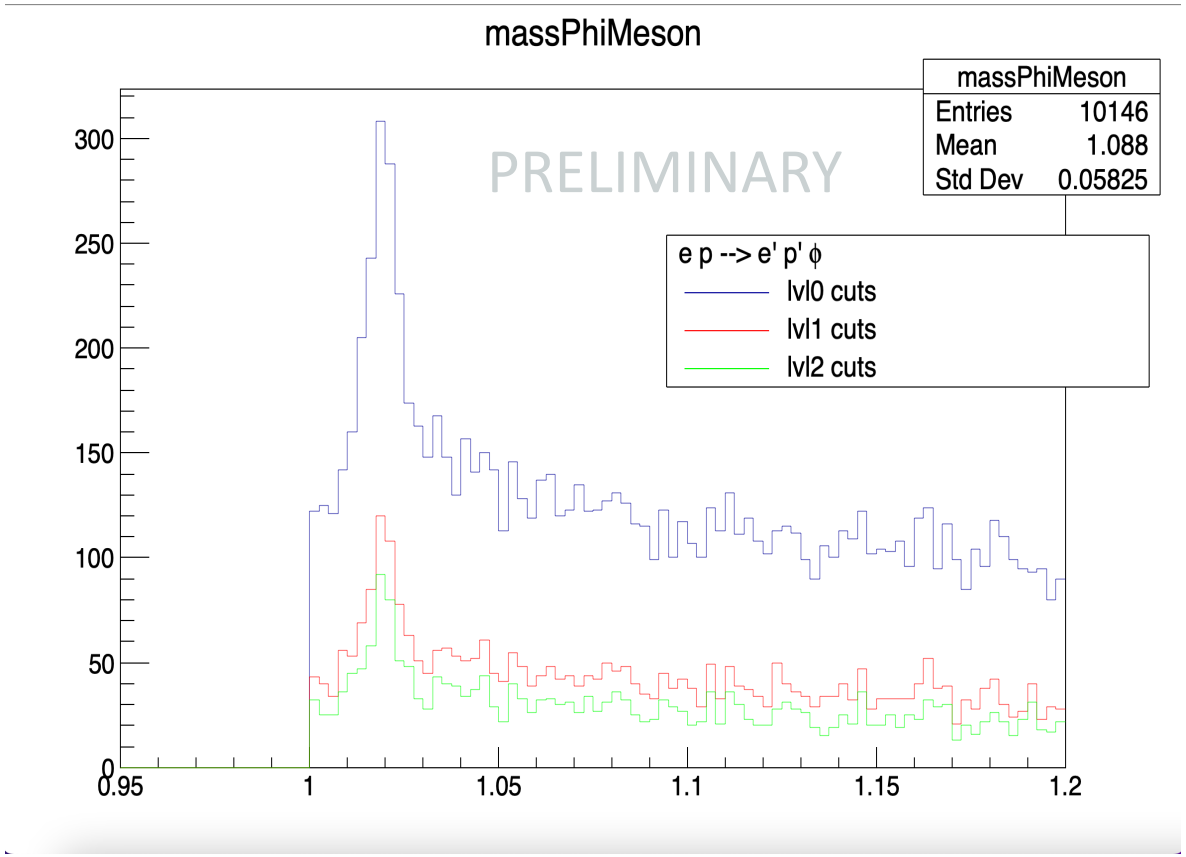


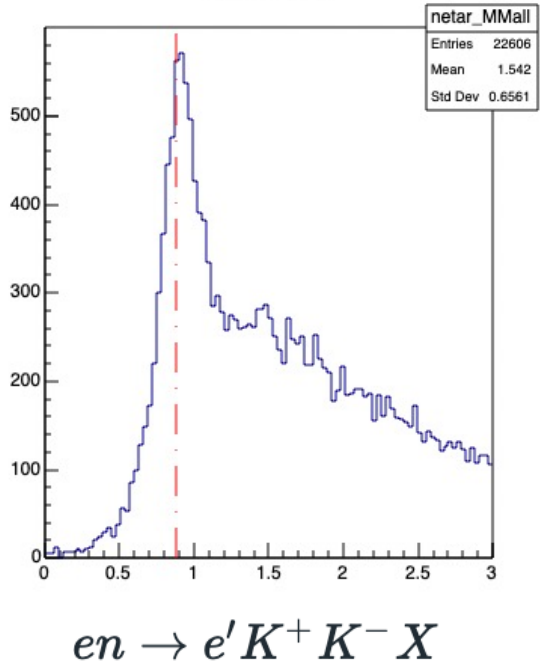





proton momentum
Crystal Ball Function
NDE
prtar_pr_momentum
Entries 996
Mean 1.373
Std Dev 0.5589
e p --> e' p' ϕ
CLAS6 Data
Inbending 10.6 GeV Data Fitting usi
Outbending 10.6 GeV Data Fitting u
Inbending 10.2 GeV Data Fitting usi

φ meson signal – proton target





$en \rightarrow e' K^+ K^- X$

lvl0_cuts : $Q^2>2$ $W^2>4$

lvl1_cuts : lvl0_cuts + 0.75 < miss mass of neutron <1.15

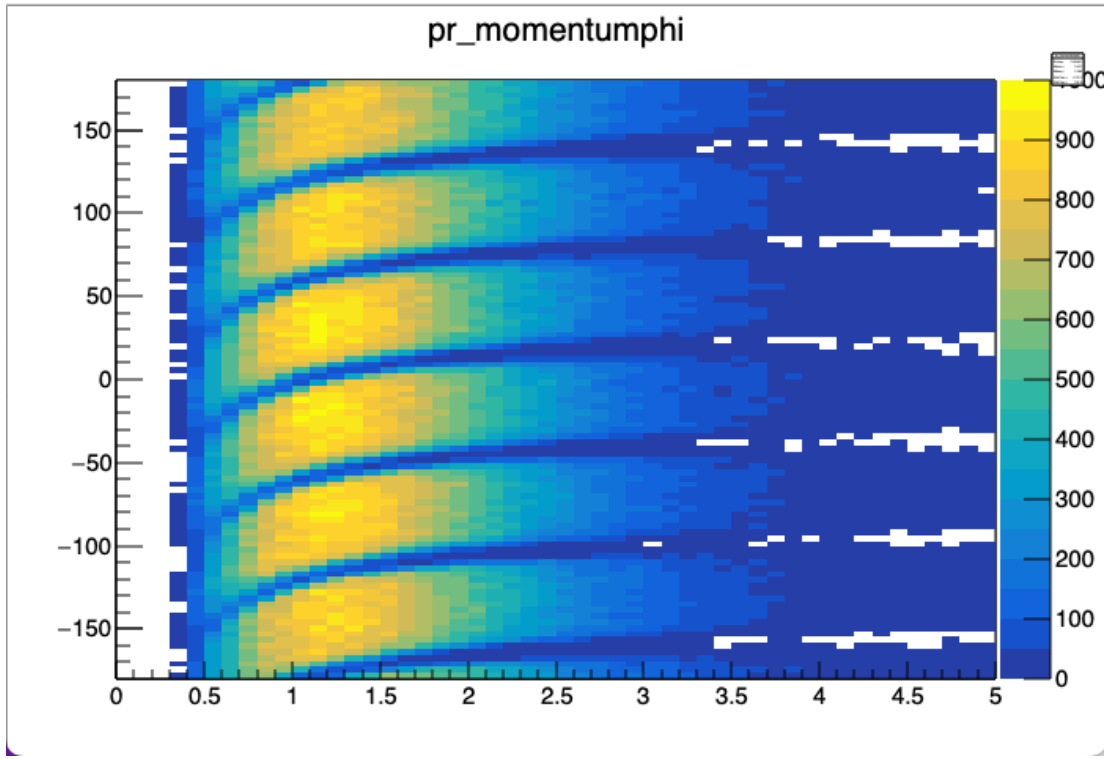
lvl2_cuts : lvl1_cuts + coAngle_neutron<=5deg

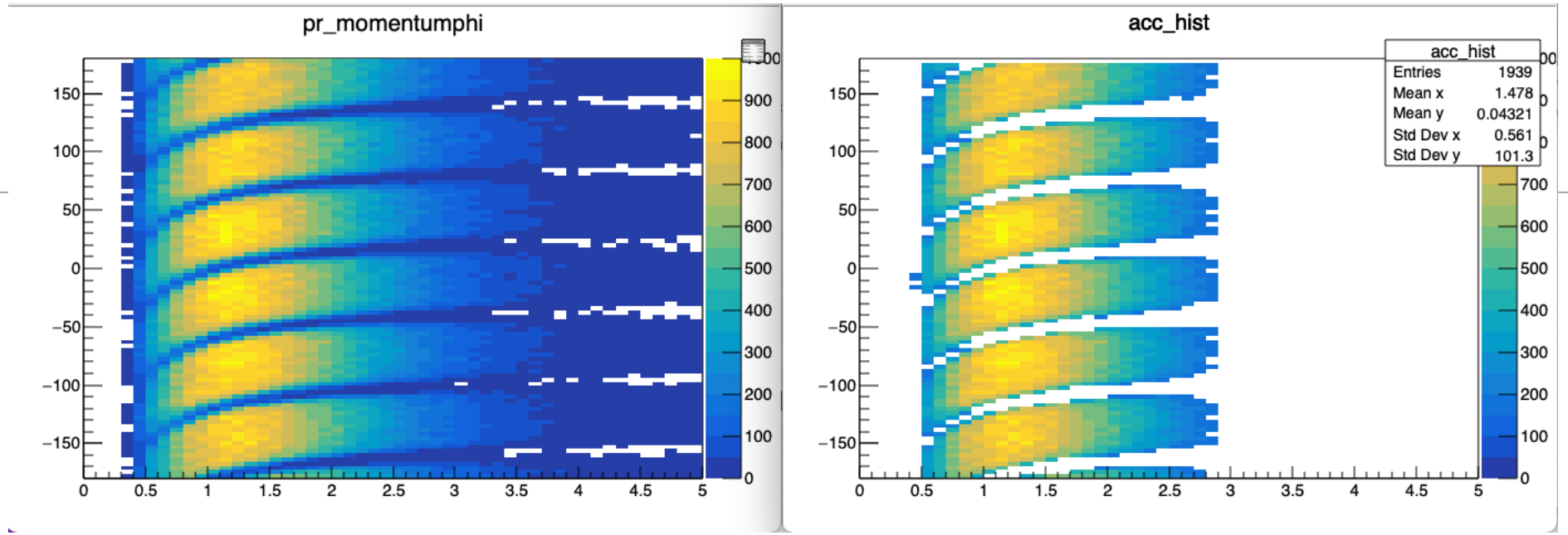
Simulation of proton to get acceptance map

I can't just look at all filled bins and call that within acceptance. Needed an edge cut.

Option 1 : FitSliceX, and 5sigma away from it…

Option2: Look at each phi bin, look for a minimum value and cut certain value above the minimum value





Now created a boolean function which takes in particular momentum and phi and sees if that bin is filled or not.

Exclusivity Cuts - Missing Mass

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

Missing proton

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

Missing Mass full event

$en \rightarrow e'K^+K^-X$

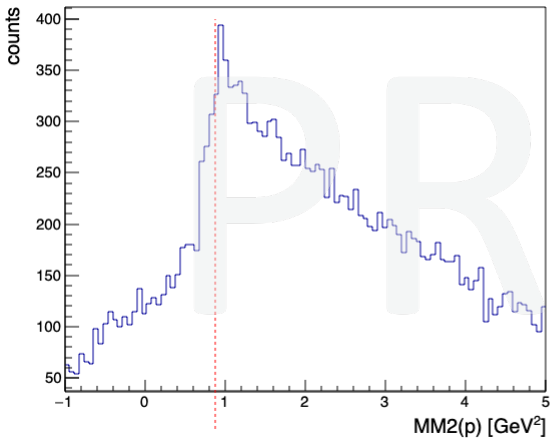
Missing neutron

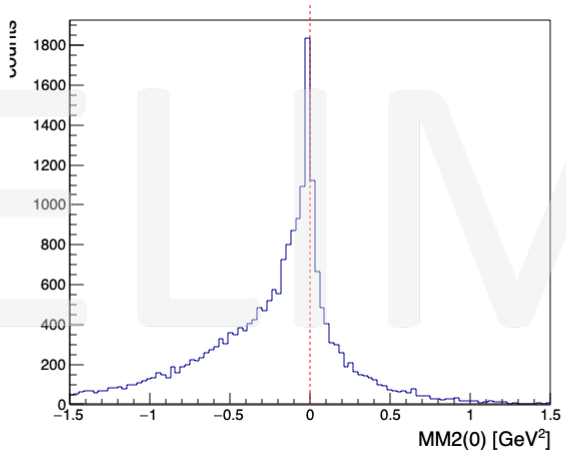
Missing Kaon +

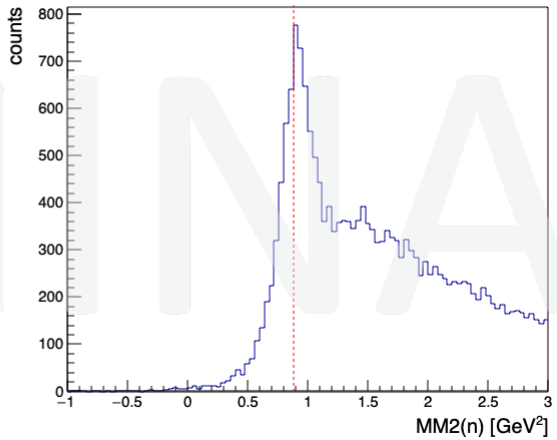
$en \rightarrow e'n'K^-X$

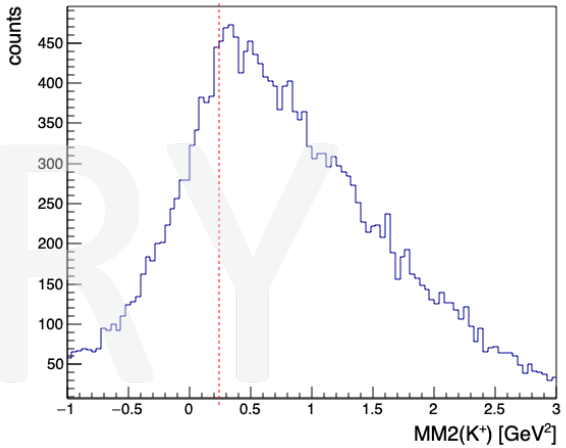
$en \rightarrow e'n'K^+X$

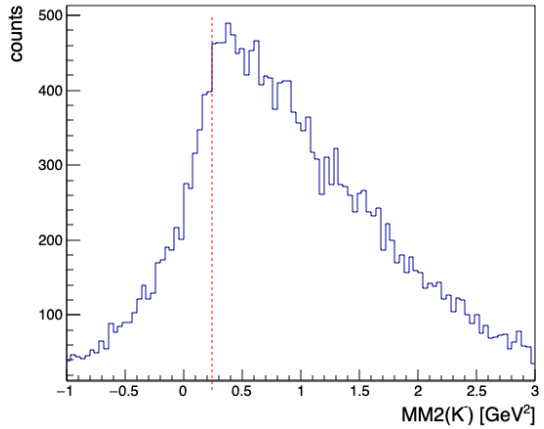
Missing Kaon -











All red dashed lines are an indication of where the peak should be

Exclusivity Cuts - Missing Mass

RGA

$ep \rightarrow e'p'K^+K^-X$

Missing Mass full event

$ep \rightarrow e'K^+K^-X$

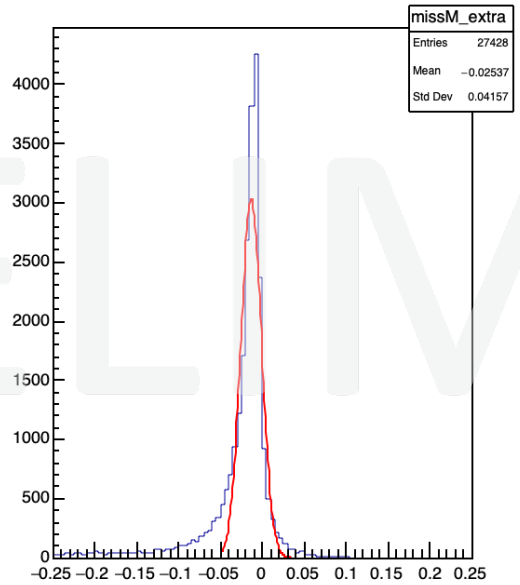
Missing proton

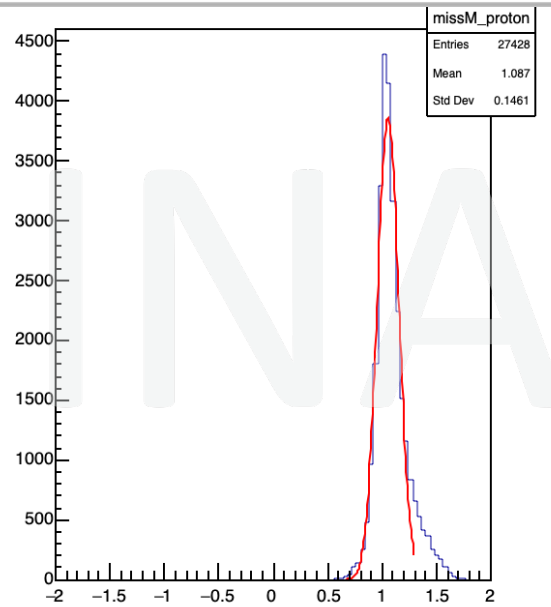
Missing Kaon +

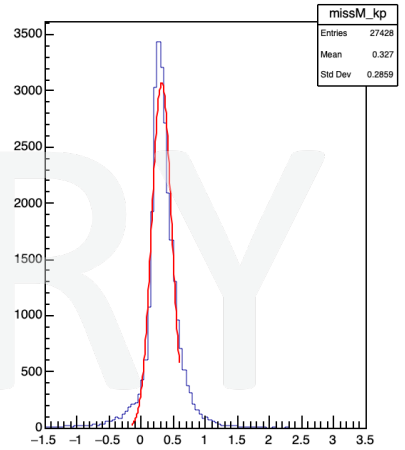
$ep \rightarrow e'p'K^-X$

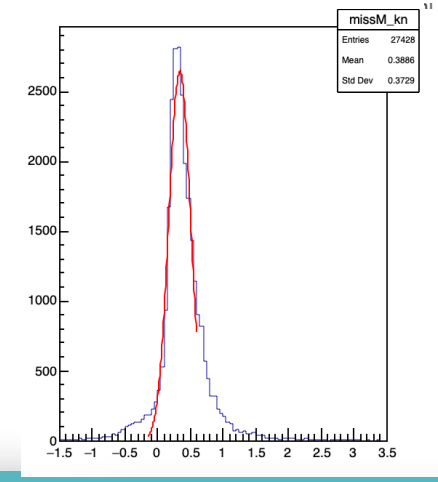
$ep \rightarrow e'p'K^+X$

Missing Kaon -









<u>Major difference between the two plots</u>

- Deutron as target
- Final state interaction between spectator and target
- Neutron detection efficiency

TO DO : Efforts to understand final state interactions via simualtion is ongoing. But based on knowledge at the present moment, it is not the dominant effect.

Exclusivity Cuts - Missing Mass

$eD \rightarrow e'p'K^+K^-X$

Missing neutron

$ep \rightarrow e'p'K^+K^-X$

Missing Mass full event

$ep \rightarrow e'K^+K^-X$

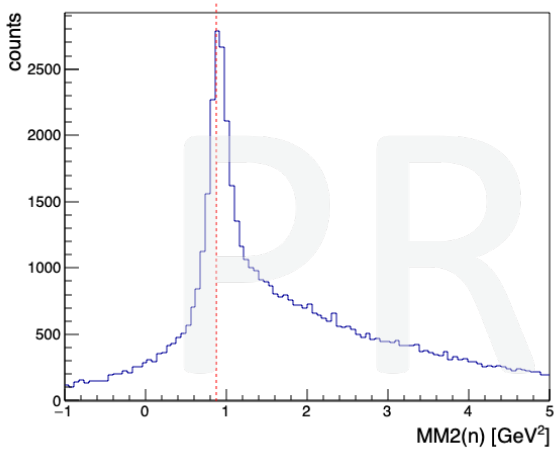
Missing proton

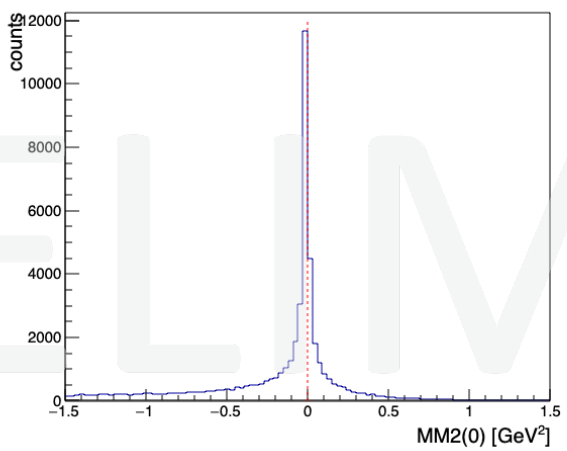
Missing Kaon +

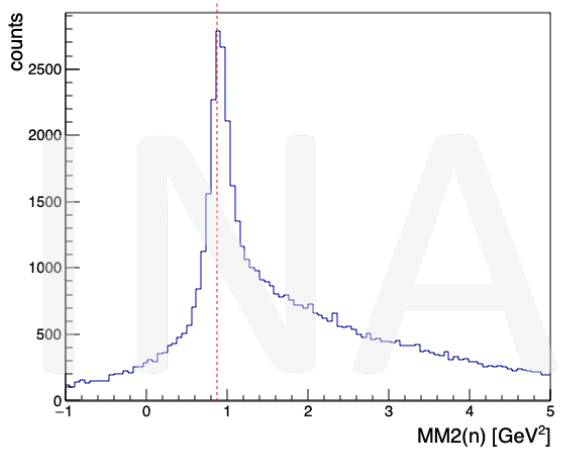
$ep \rightarrow e'p'K^-X$

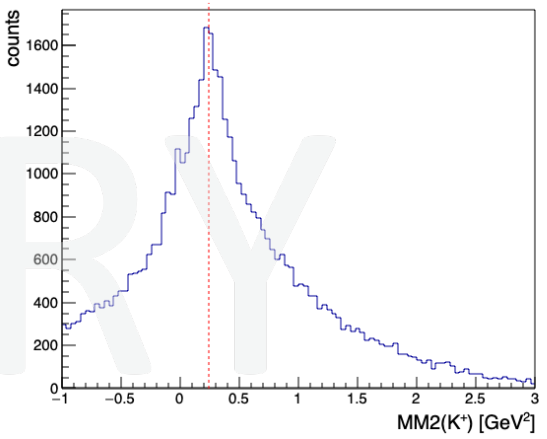
$ep \rightarrow e'p'K^+X$

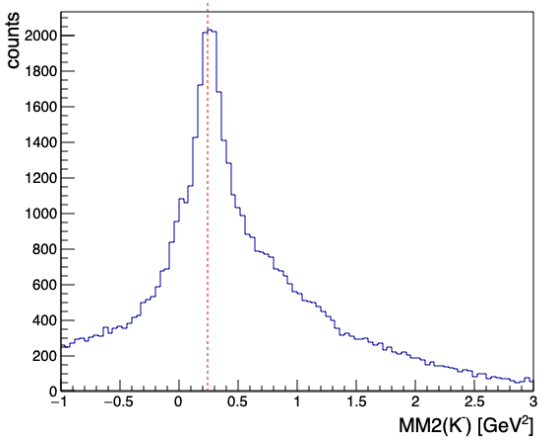
Missing Kaon -











Comparing excluisivity cuts off the proton vs off the neutron in RGB dataset is one good way to see how much of the effect we see in our plots is from final state interactions (which impacts both) vs how much of this comes from neutron identification