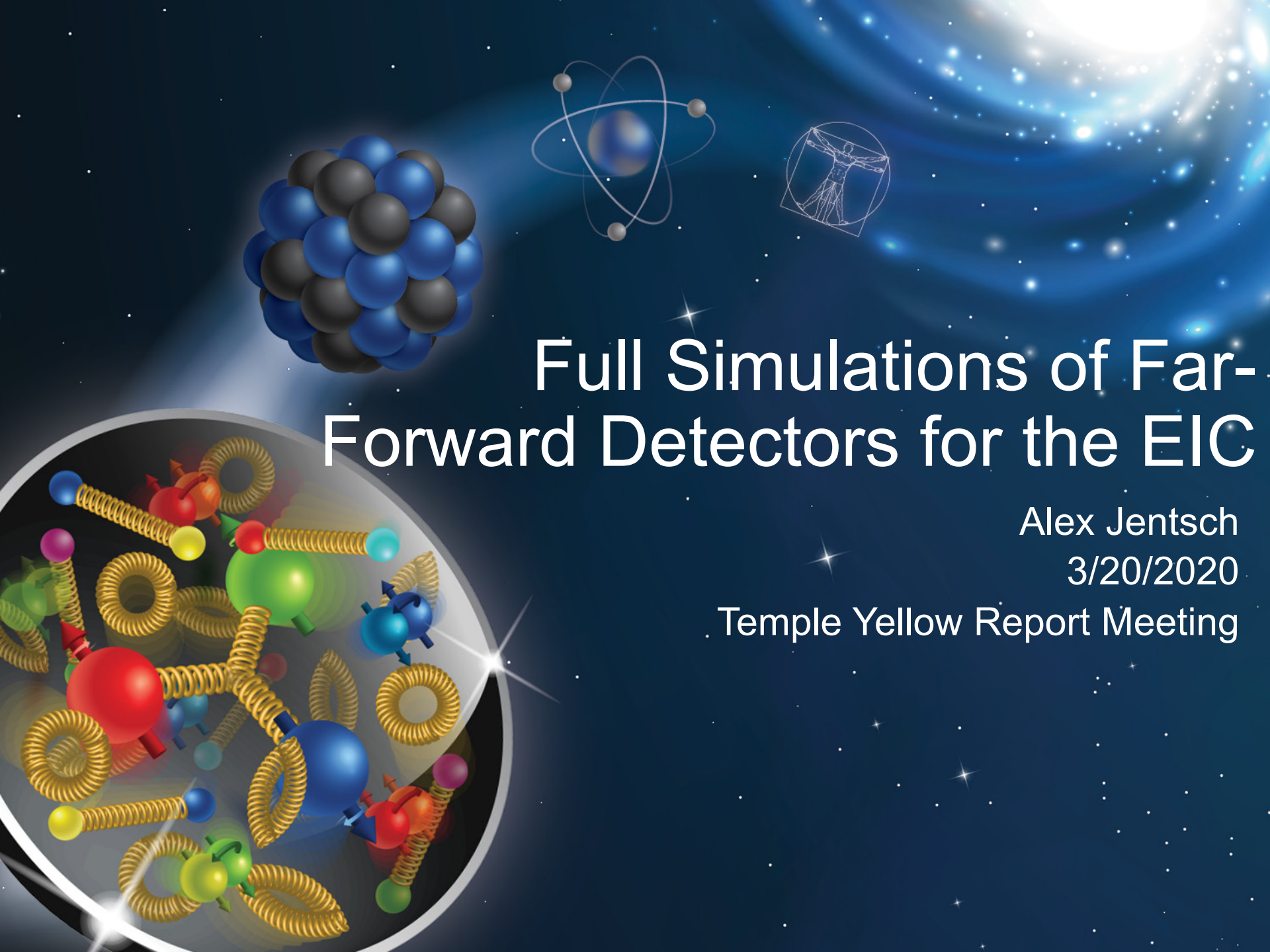


Full Simulations of Far-Forward Detectors for the EIC

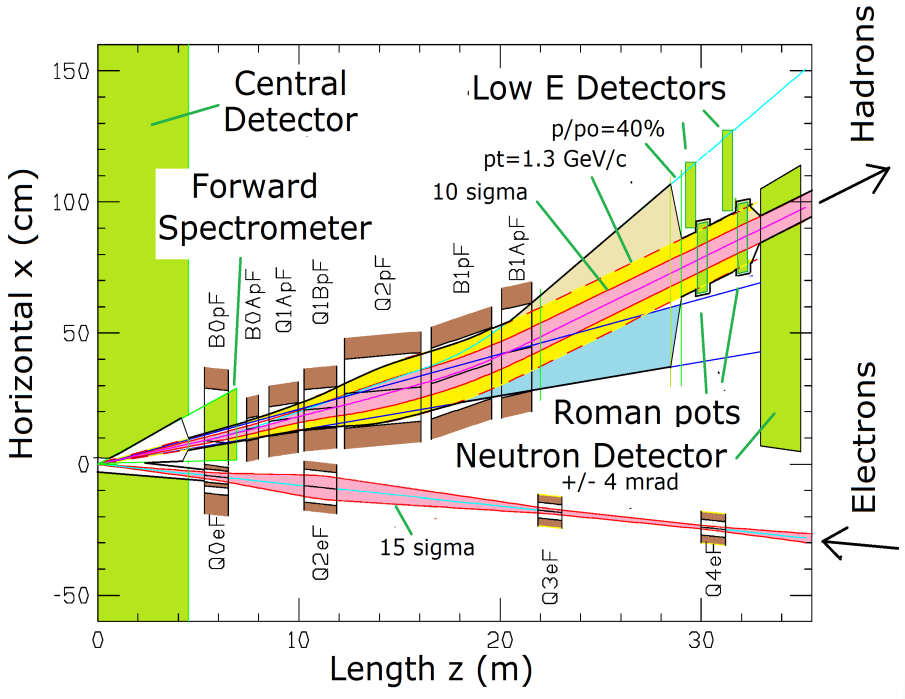
Alex Jentsch

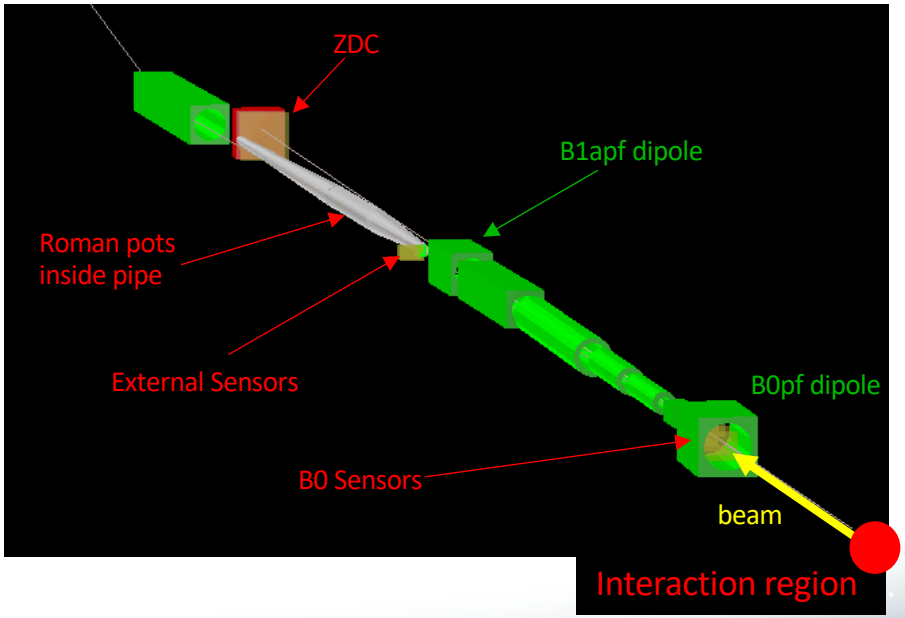
3/20/2020

Temple Yellow Report Meeting

Simulation Apparatus

- EicRoot with GEANT4
- Includes ZDC, B0 sensors, Roman Pots, and External Silicon Sensors for particles with different rigidity.





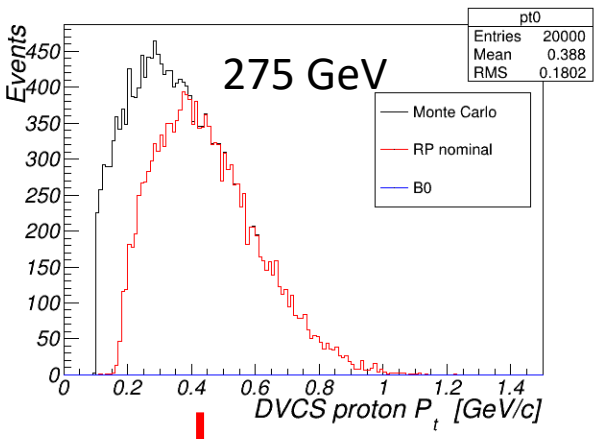
Note: beam pipe is just a placeholder.

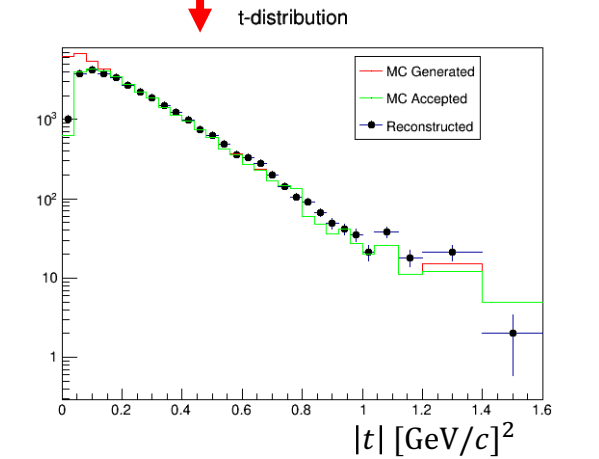
Quick Review of Proton DVCS Study

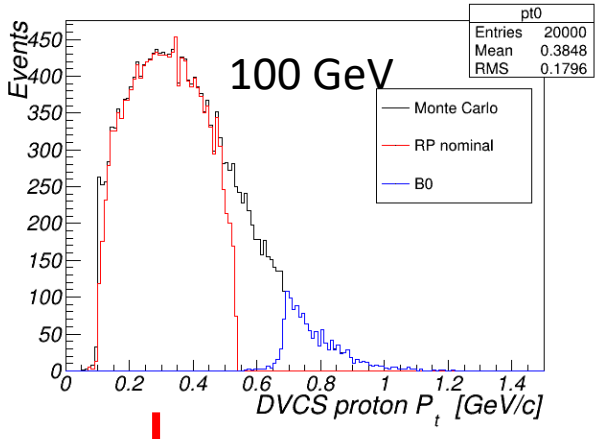
DVCS Proton Acceptance Summary

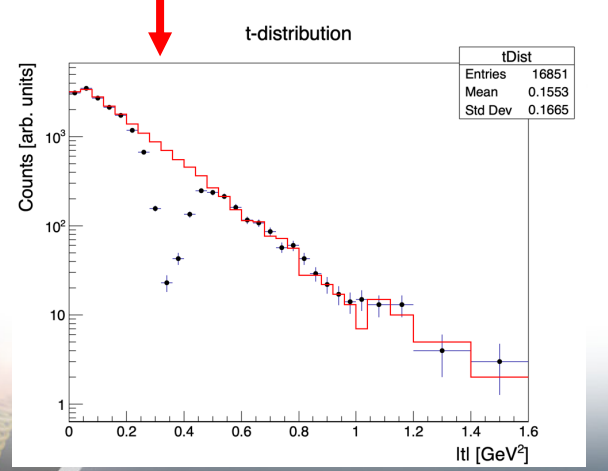
Need different detector subsystems to try and cover the acceptance and various beam energies.

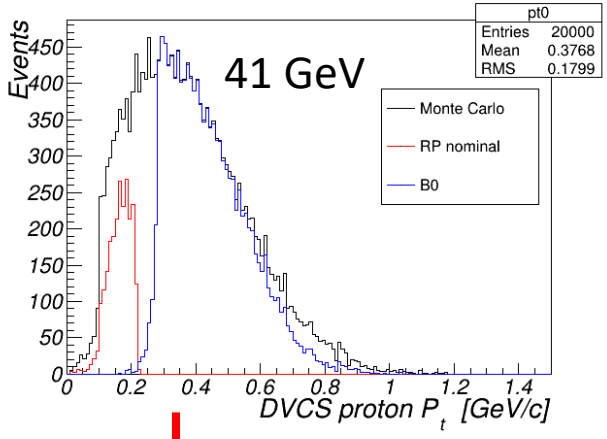
High acceptance beam configuration only.

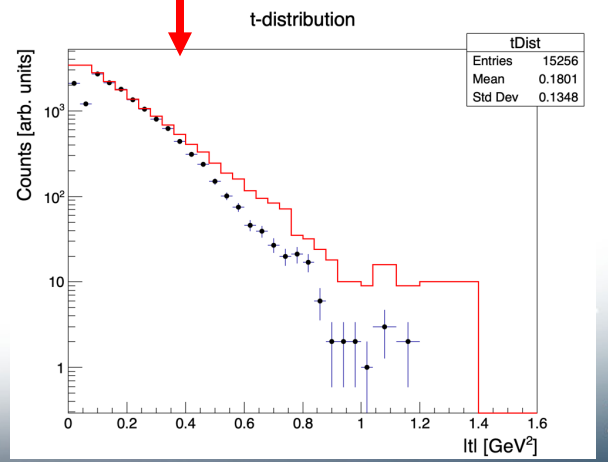






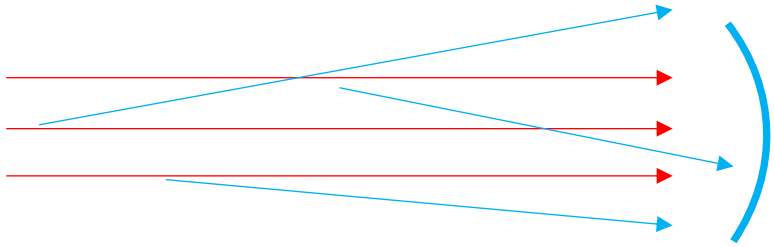


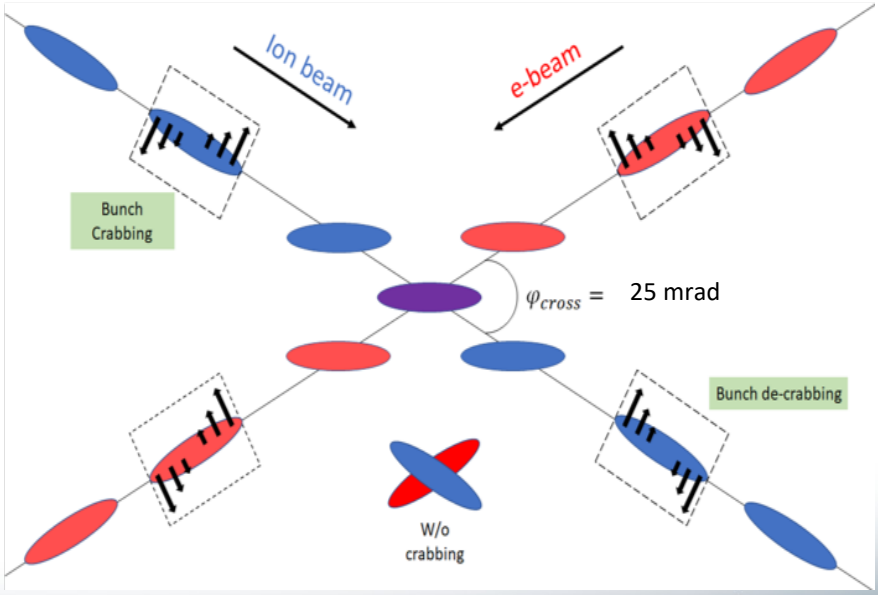




Beam-related effects

- Angular divergence
  - Angular “spread” of the beam away from the central trajectory.
  - Gives some small initial transverse momentum to the beam particles.
- Beam energy spread
  - Spread in nominal beam energy (~10^{-4})
- Crab cavity rotation
  - Can perform rotations of the beam bunches in 2D.
  - Used to account for the luminosity drop due to the crossing angle – allows for head-on collisions to still take place.
  - Included as primary vertex smearing in the simulations.





These effects introduce smearing in our momentum reconstruction.

DVCS Momentum Resolutions

- The various contributions add in quadrature (this was checked empirically, measuring each effect independently).

$$\Delta p_{t,total} = \sqrt{(\Delta p_{t,AD})^2 + (\Delta p_{t,CC})^2 + (\Delta p_{t,pxl})^2}$$

Angular divergence

Primary vertex smearing from crab cavity rotation.

Smearing from finite pixel size.

	Ang Div. (HD)	Ang Div. (HA)	Vtx Smear	250um pxl	500um pxl	1.3mm pxl
$\Delta p_{t,total}$ [MeV/c] - 275 GeV	40	28	20	6	11	26
$\Delta p_{t,total}$ [MeV/c] - 100 GeV	22	11	9	9	11	16
$\Delta p_{t,total}$ [MeV/c] - 41 GeV	14	-	10	9	10	12

- **Beam angular divergence**
  - Beam property, can't correct for it – sets the lower bound of smearing.
  - Subject to change (i.e. get better) – beam parameters not yet set in stone
- **Vertex smearing from crab rotation**
  - Correctable with good timing (~35ps)
- **Finite pixel size on sensor**
  - 500um seems like the best compromise between potential cost and smearing

How to included Angular Divergence and E spread?

- e+p DVCS Study
  - Outgoing protons randomly rotated in x and y by angular divergence angles given by the collider group.
  - The smearing was gaussian, with the width equal to the divergence angle.

- BeAGLE e+D Study
  - Start with "nominal" deuteron beam exactly along z in lab frame.
  - Calculate boost vector.
  - Smear nominal deuteron 4-vector in x,y (angular divergence) and z (beam energy spread).
  - Calculate "smeared" boost vector.
  - Boost final state particles to deuteron rest frame with "un-smeared" boost.
  - Boost back to lab frame with "smeared" boost.

Not shown for the e+D studies presented today. This is just for people to understand our approach.

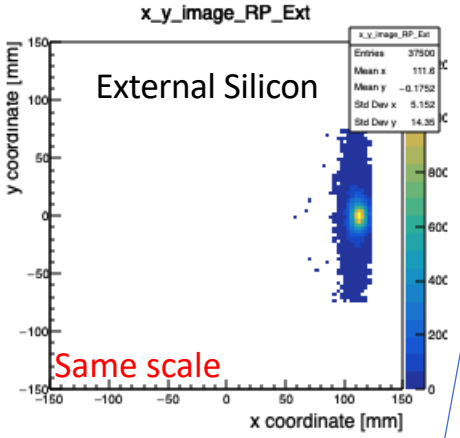

BeAGLE e+D 18x100 GeV
Neutron struck – proton spectator

Preliminary Comment

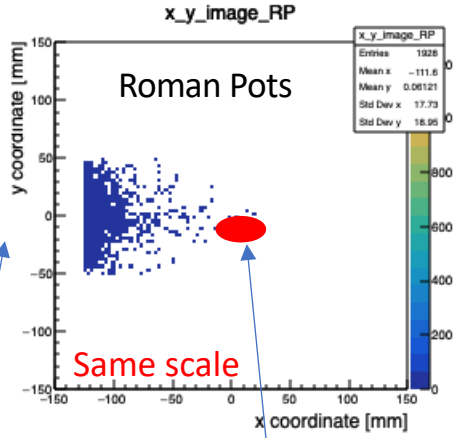
- The following simulations are for *acceptances only.* Realistic smearing effects will be added in the coming weeks as was done for the DVCS studies.

Acceptance Images (struck neutron, proton spectator)

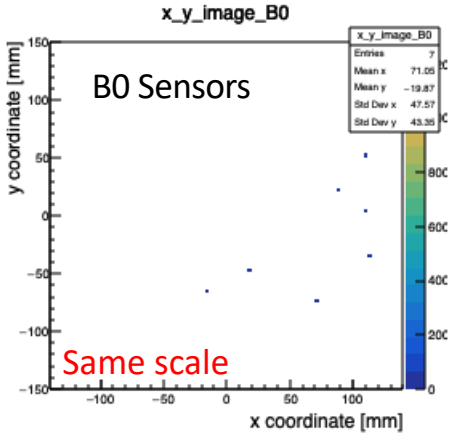
- Just the hits showing on my GEANT detectors. (~50% p+n coincidence)
- Coordinates are *local* for each sensor – not a global system here.



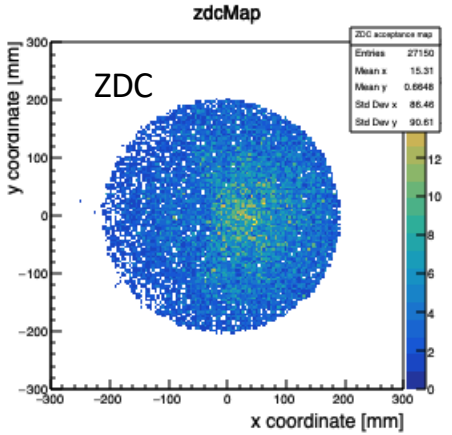
~80% of the protons



~5% of the protons



<< 1% of the protons

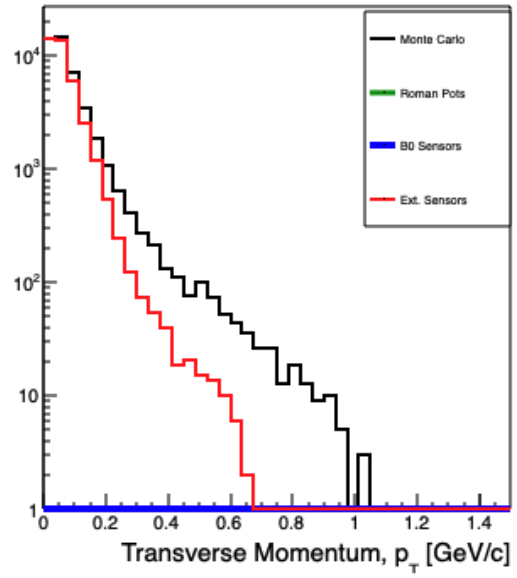


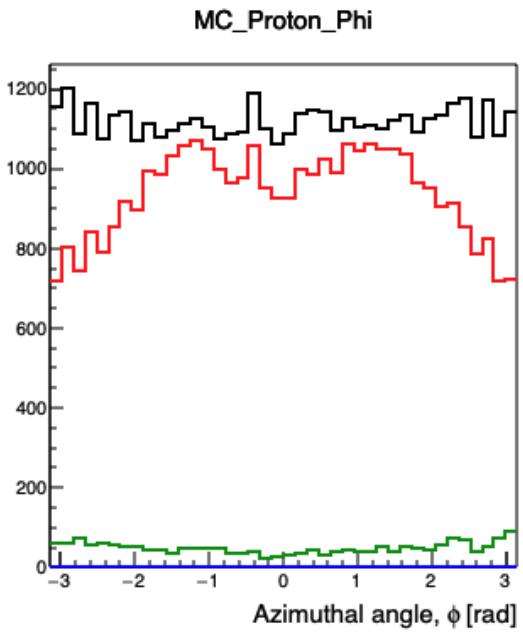
~54% of the neutrons

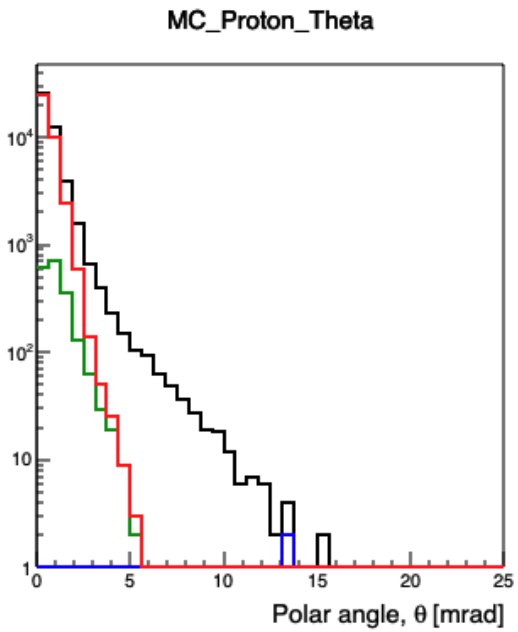
Beam pipe edge between these two detectors.

Deuteron beam (not to scale – just to guide the eye).

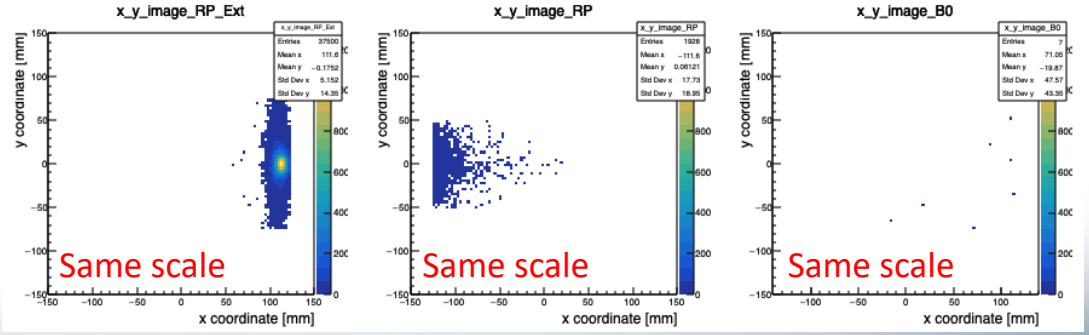
Spectator Proton Acceptance (momentum, theta, phi)







Spectator protons hardly affected from collision, as expected. Due to different rigidity compared to D, bent twice as much in the final dipole (B1apf). The external sensors do almost all of the work here.

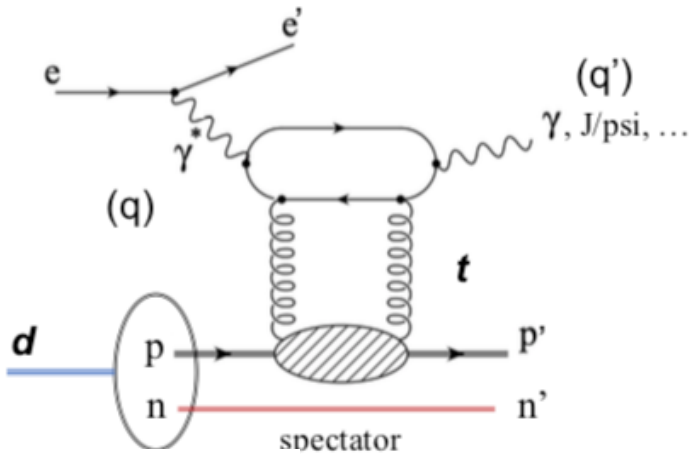


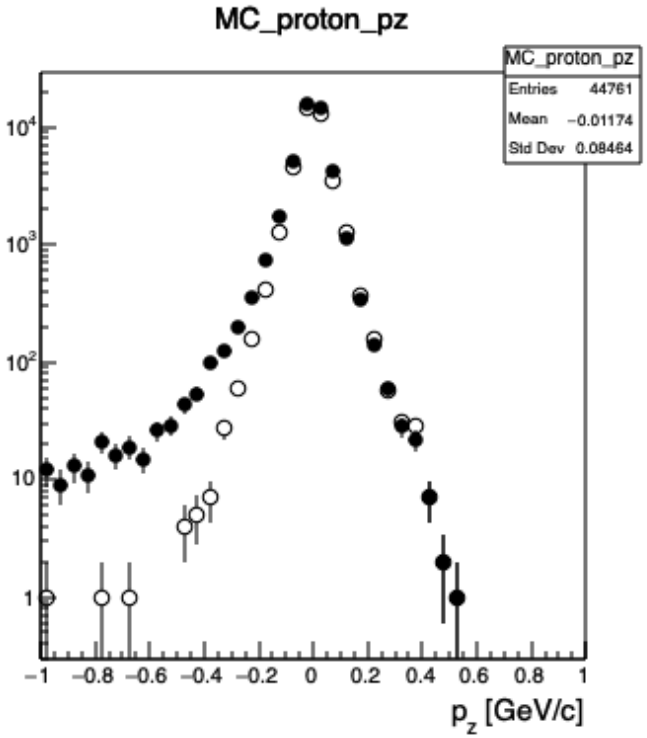
~80% of the protons ~5% of the protons << 1% of the protons

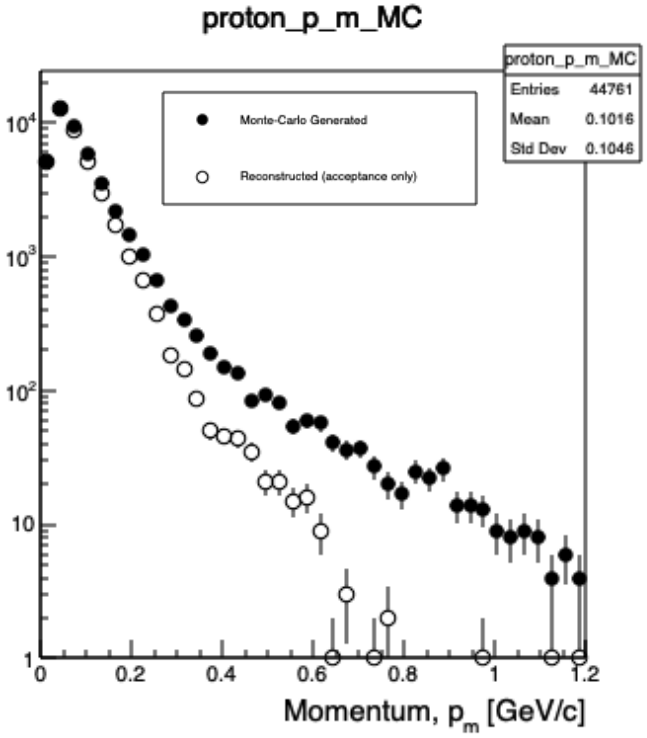
Spectator Proton Acceptance (physics variables)

p_m, p_t, p_z :

Total, transverse, and longitudinal momentum of spectator nucleon in ***d*** rest frame







Spectator Proton Acceptance (physics variables)

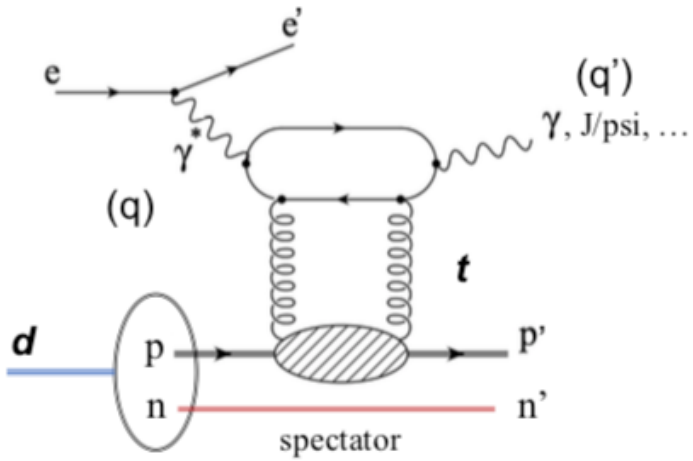
alpha:

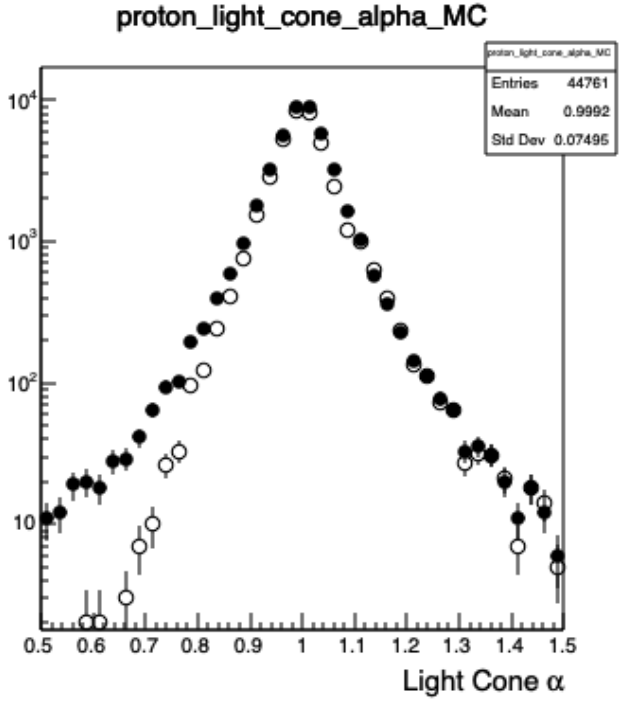
Light cone momentum fraction

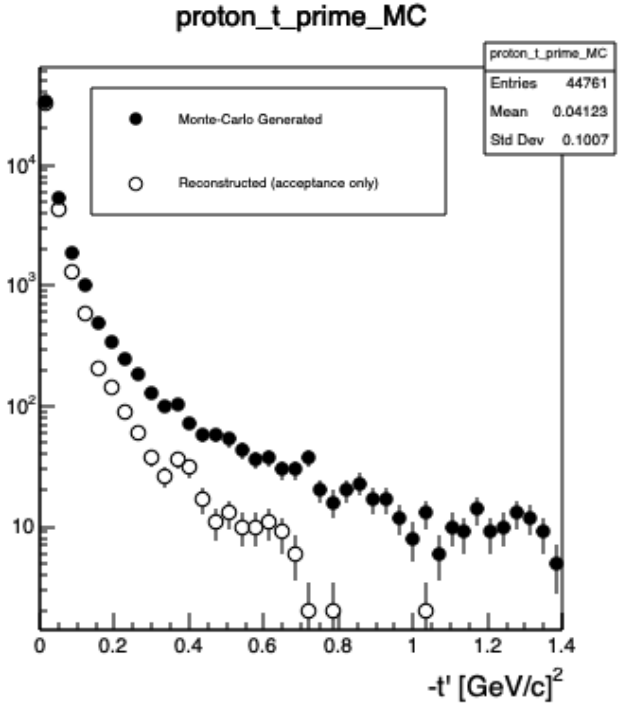
$$\alpha = \frac{2p_{n'}^{+}}{p_{d}^{+}}$$

t'= $(n'-d)^2-M^2$:

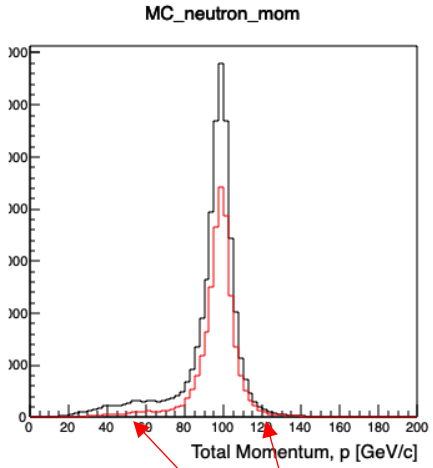
effective struck nucleon off-shellness

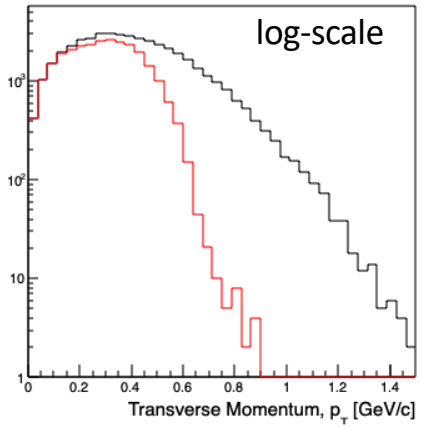


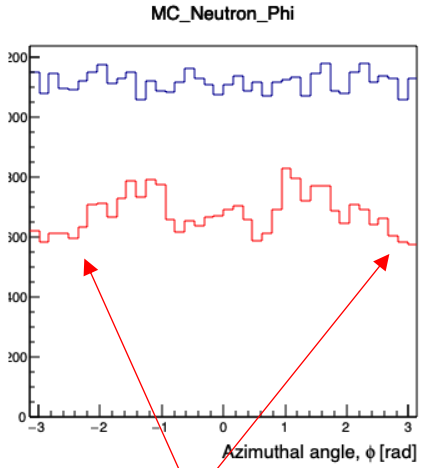


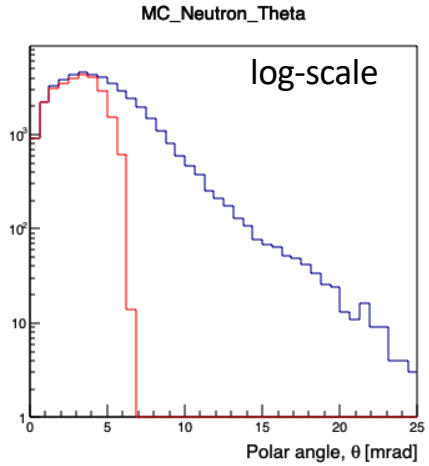


Struck Neutron Acceptance (momentum, theta, phi)



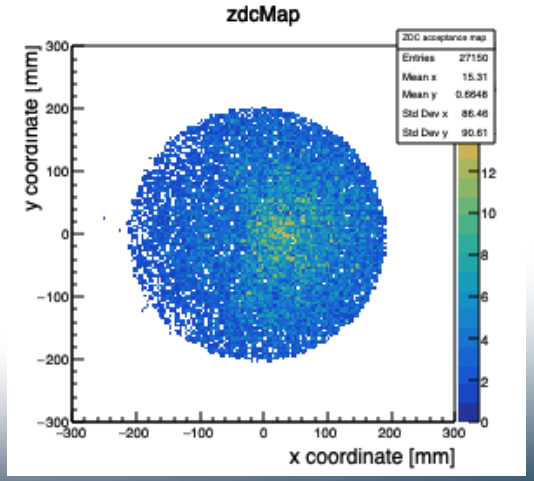




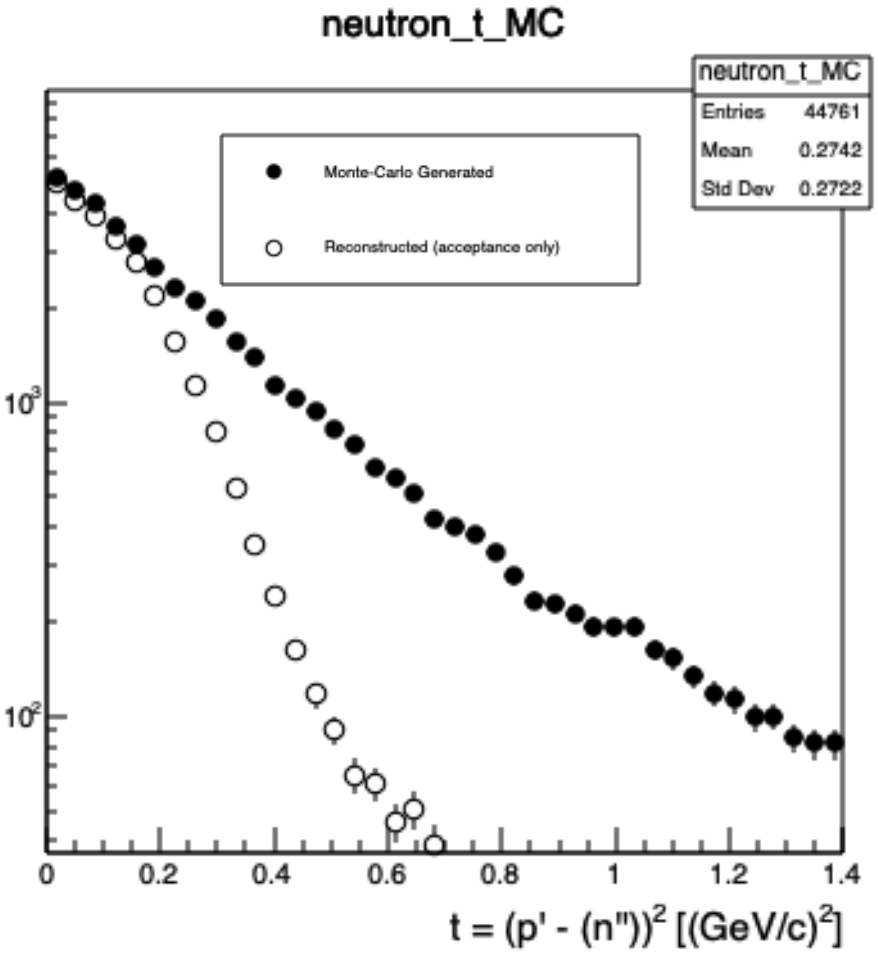


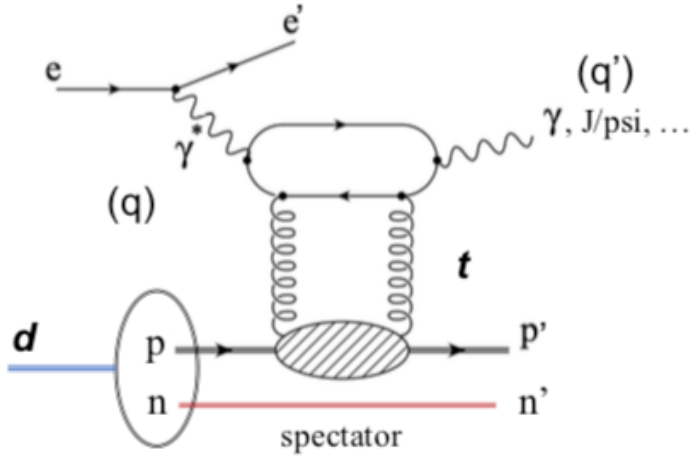
Asymmetrical tails, as it should be from the BeAGLE input (sanity check).

Neutrons hitting aperture. Currently setup to allow for roughly 5mrad cone (not perfectly uniform in phi).



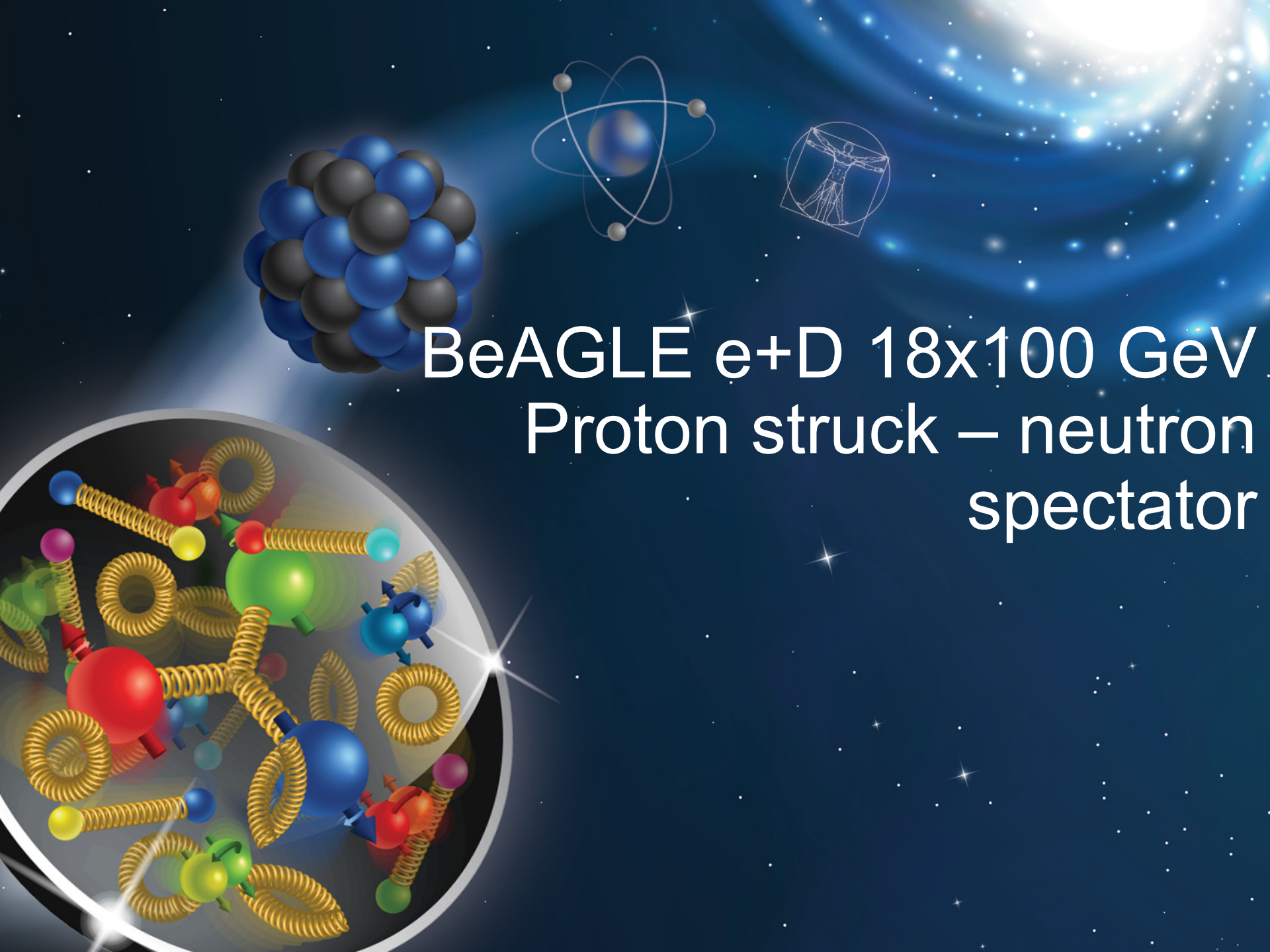
Struck Neutron Acceptance (physics variables)





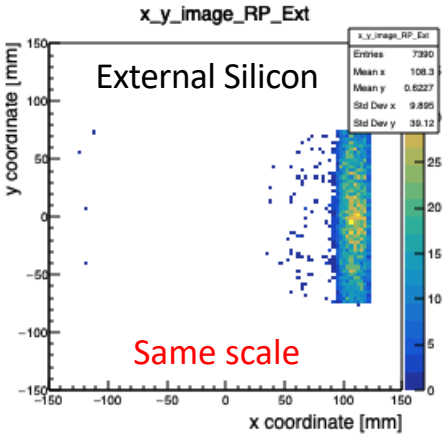
$t = (e'-e+V)^2 = (p' - (-n''))^2$

Momentum transfer from virtual photon to the struck nucleon

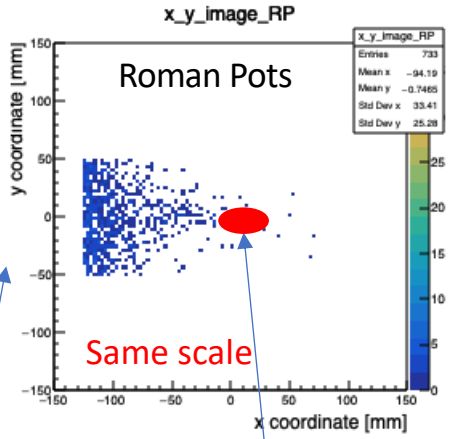

BeAGLE e+D 18x100 GeV
Proton struck – neutron
spectator

Acceptance Images (struck proton, neutron spectator)

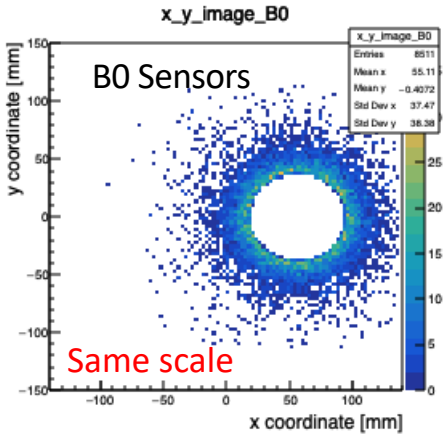
- Just the hits showing on my GEANT detectors. (~35% p+n coincidence)
- Coordinates are *local* for each sensor – not a global system here.



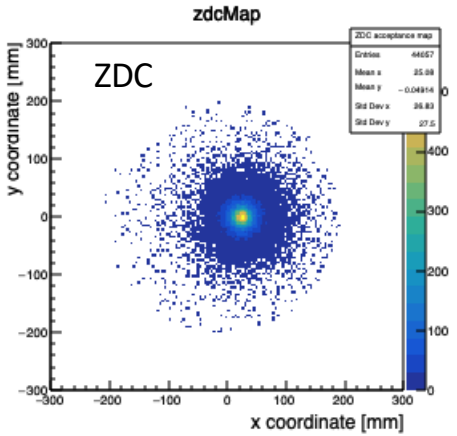
~15% of the protons



~2% of the protons



~18% of the protons



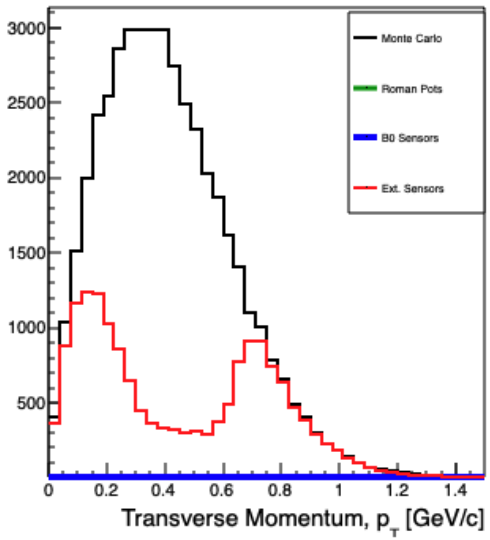
~95% of the neutrons

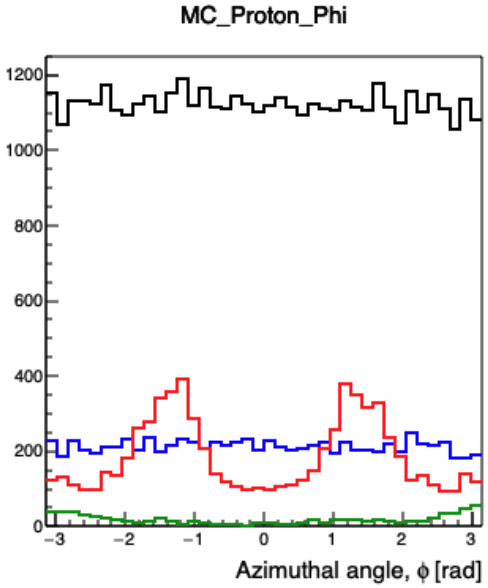
Beam pipe edge between these two detectors.

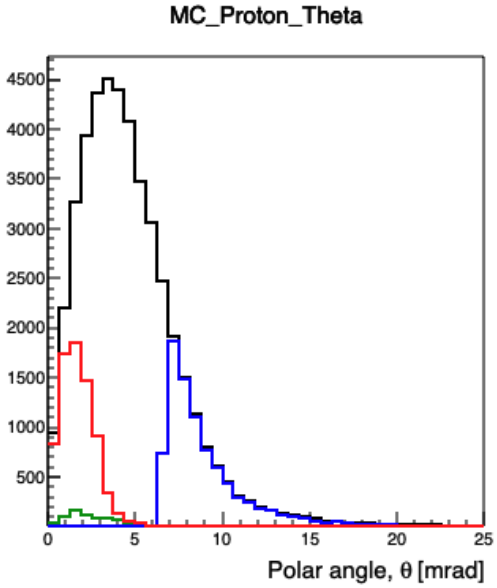
Deuteron beam (not to scale – just to guide the eye).

Last of the four sensors. The hole in the center is for the beam pipe.

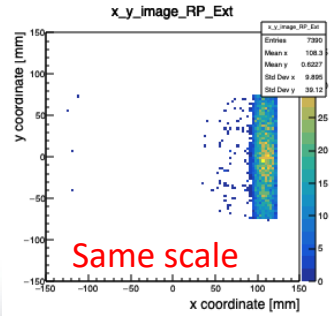
Struck Proton Acceptance (momentum, theta, phi)



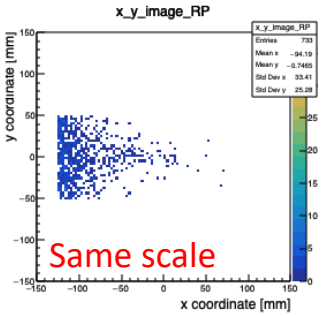




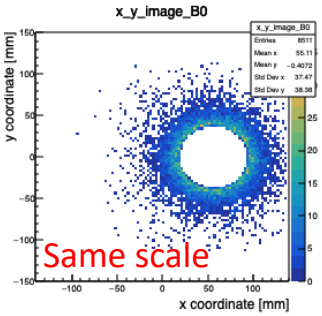
Struck protons highly affected from collision, as expected. Due to different rigidity compared to D, bent twice as much in the final dipole (B1apf). The external sensors and B0 Sensors both very important here.



~15% of the protons

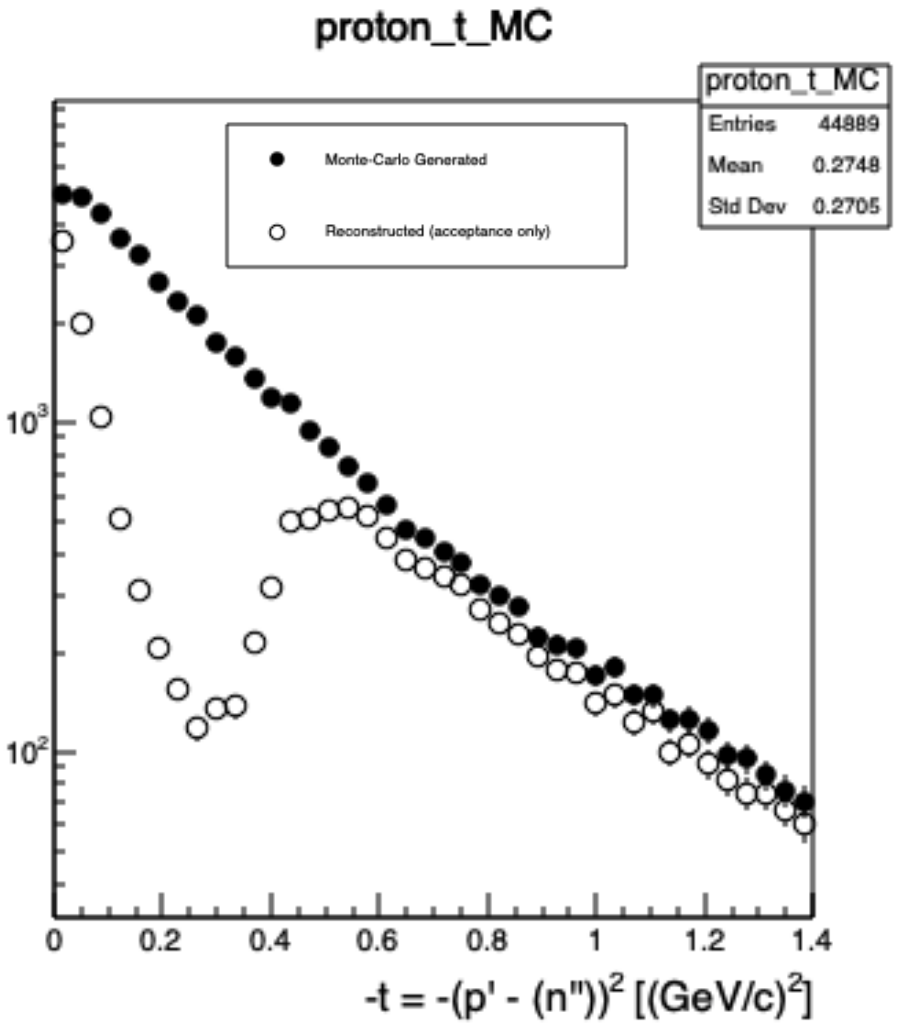


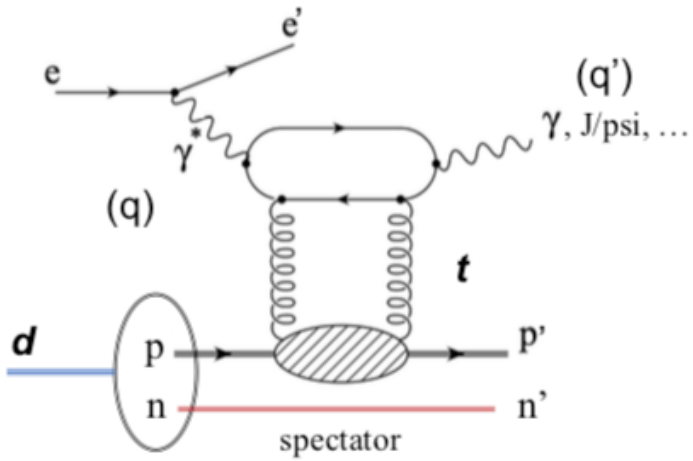
~2% of the protons



~18% of the protons

Struck Proton Acceptance (physics variables)

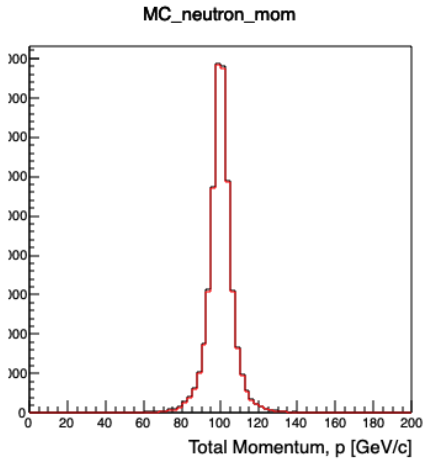


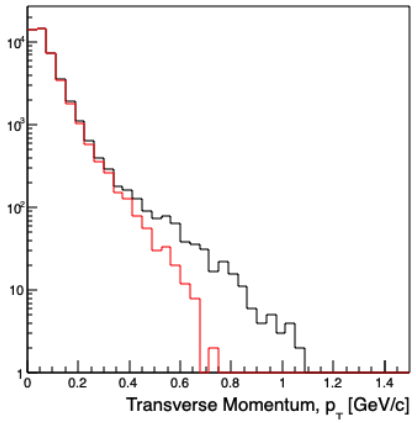


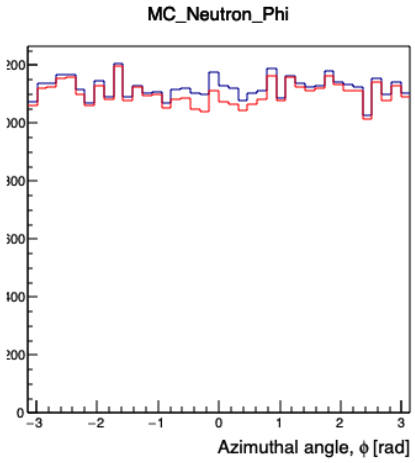
$t = (e'-e+V)^2 = (p' - (-n''))^2$

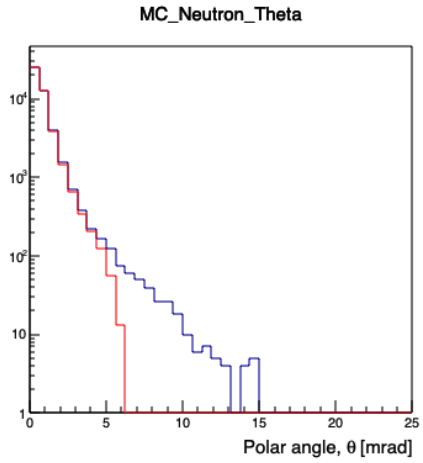
Momentum transfer from virtual photon to the struck nucleon

Spectator Neutron Acceptance (momentum, theta, phi)

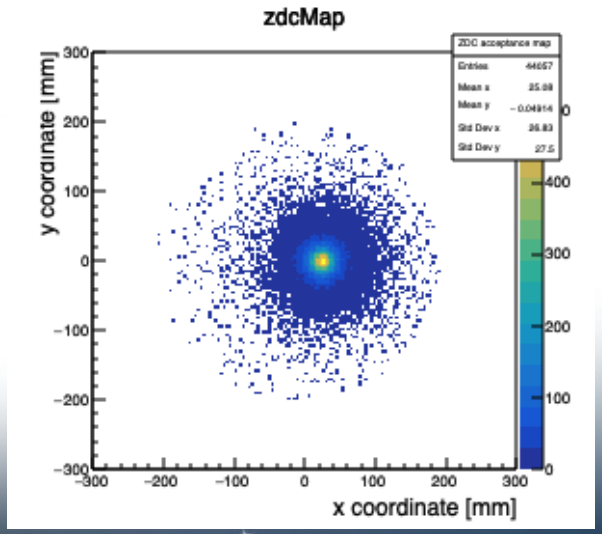








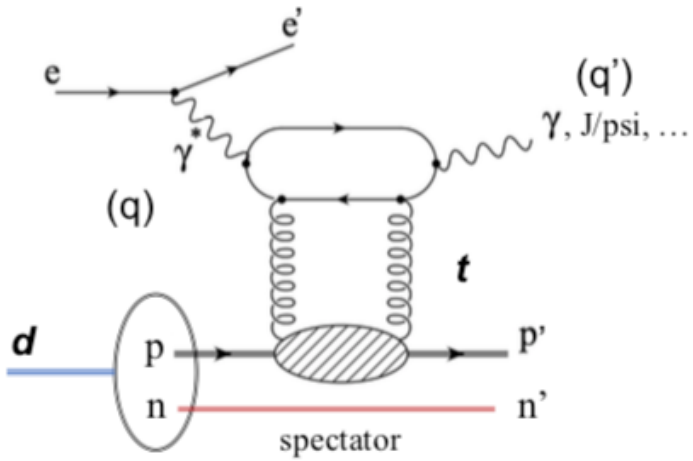
Spectator neutrons essentially unaffected by collision. Most of them fall into the ZDC acceptance and pass the aperture. The cone is much more tightly confined (generally within 2.5 mrad).

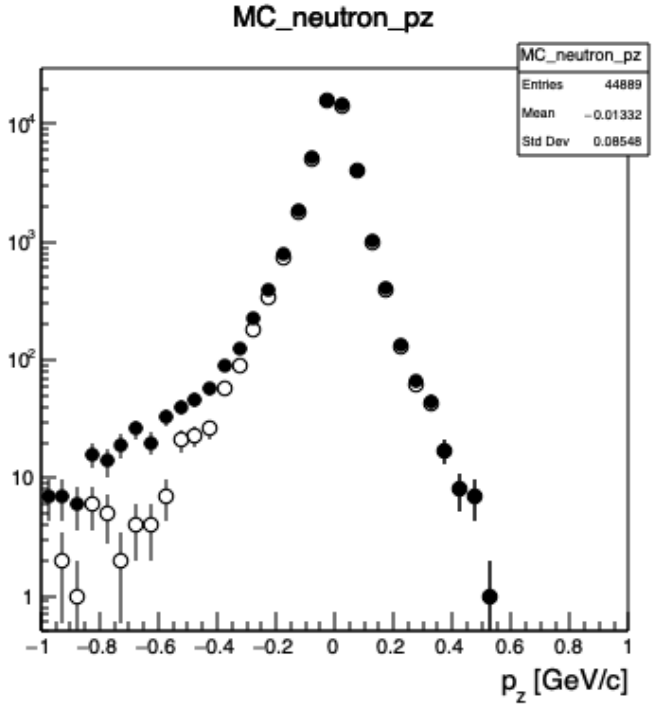


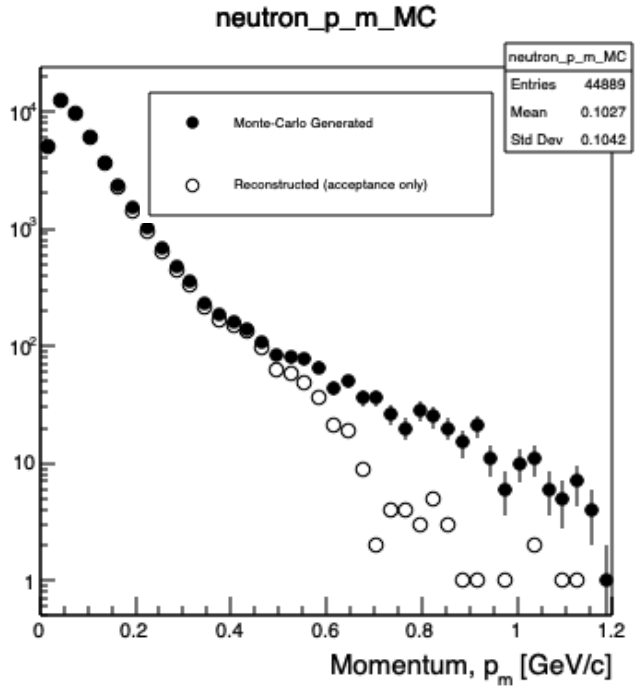
Spectator Neutron Acceptance (physics variables)

p_m, p_t, p_z :

Total, transverse, and longitudinal momentum of spectator nucleon in ***d*** rest frame







Spectator Neutron Acceptance (physics variables)

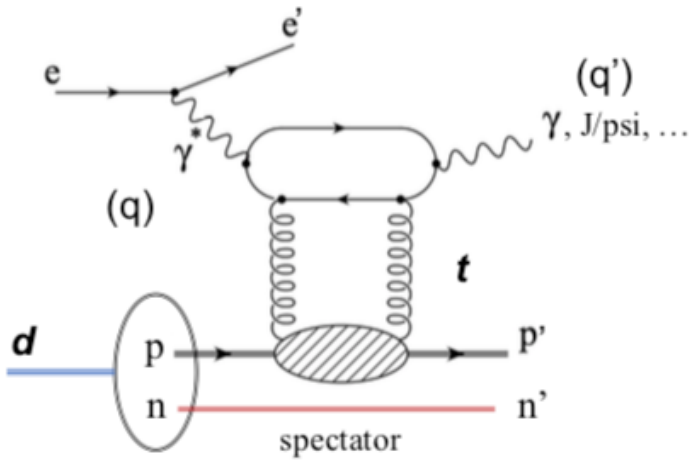
alpha:

Light cone momentum fraction

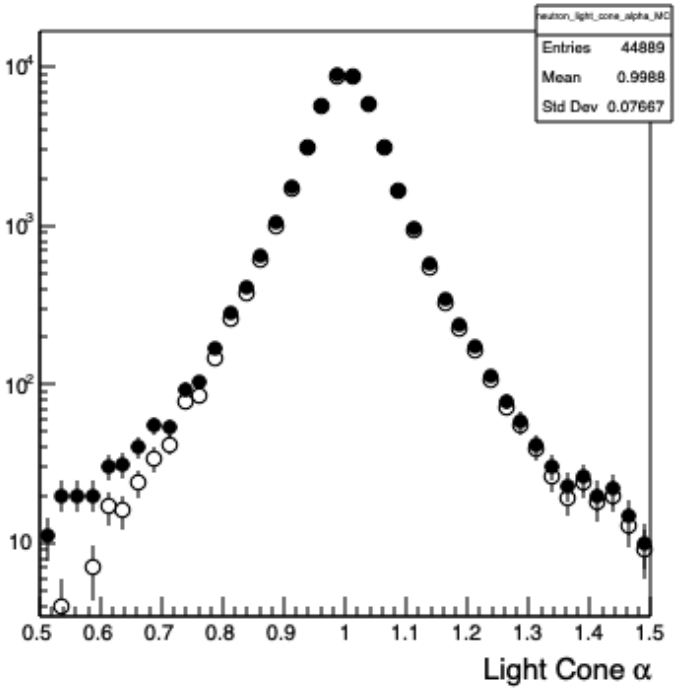
$$\alpha = \frac{2p_{n'}^{+}}{p_{d}^{+}}$$

t'= $(n'-d)^2-M^2$:

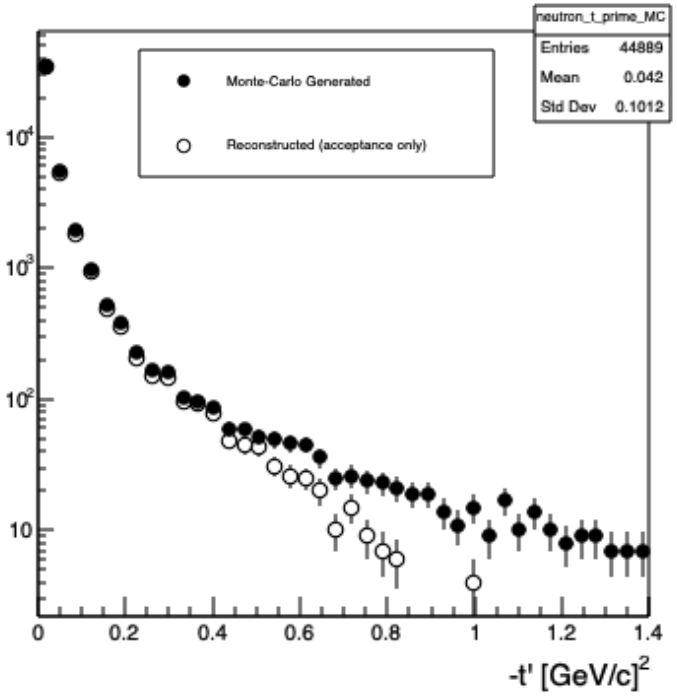
effective struck nucleon off-shellness



neutron_light_cone_alpha_MC



neutron_t_prime_MC



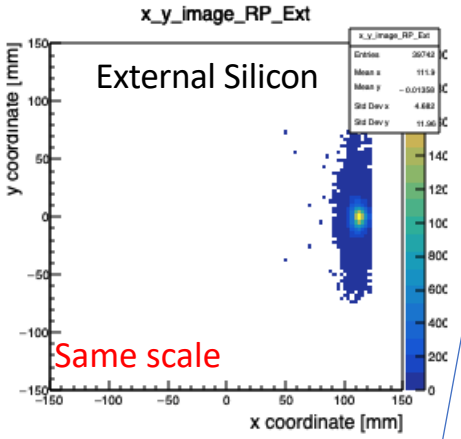
Conclusions & takeaways

- Acceptance limits now understood for the e+D collisions at two (18x135 in backup) energies.
  - Need to do a few more checks – external sensor placement not finalized – will need to redo study with inclusion of vacuum system when available.
  - Both neutron and proton spectators studied separately.
  - Low energy configuration will be studied in the coming weeks.
- Angular divergence & beam energy spread included in the smearing thus far (not shown today, still need to do some checks).
  - Detector effects will be added in the coming weeks.

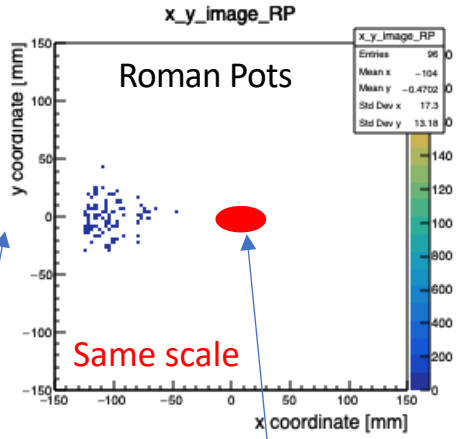

BeAGLE e+D 18x135 GeV
Neutron struck – proton spectator

Acceptance Images (struck neutron, proton spectator)

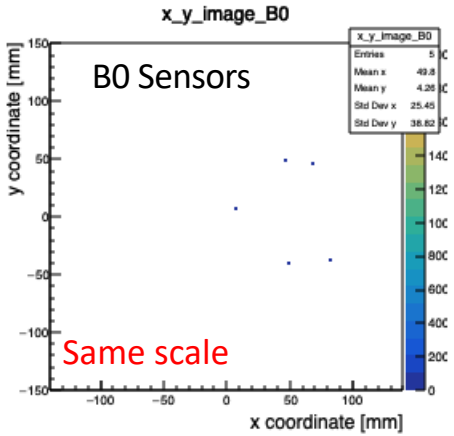
- Just the hits showing on my GEANT detectors. (~60% p+n coincidence)
- Coordinates are *local* for each sensor – not a global system here.



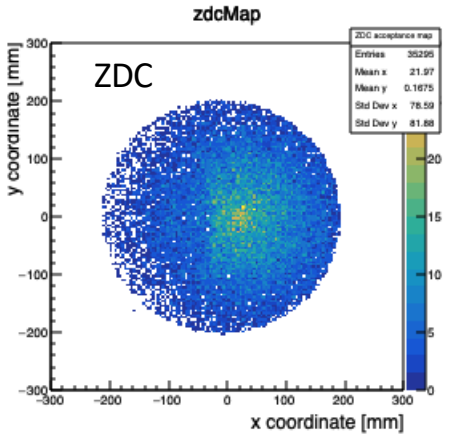
~55% of the protons



~1-2% of the protons



<< 1% of the protons

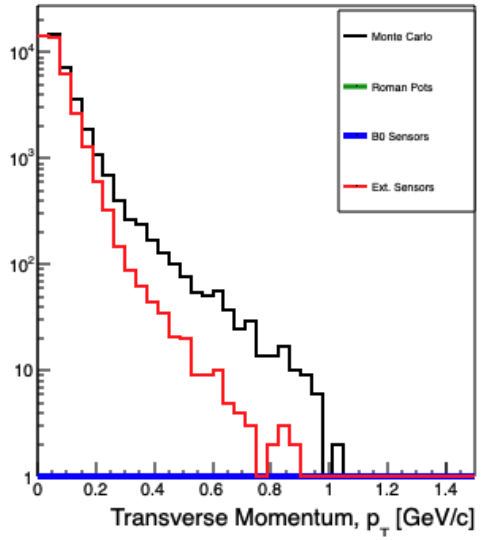


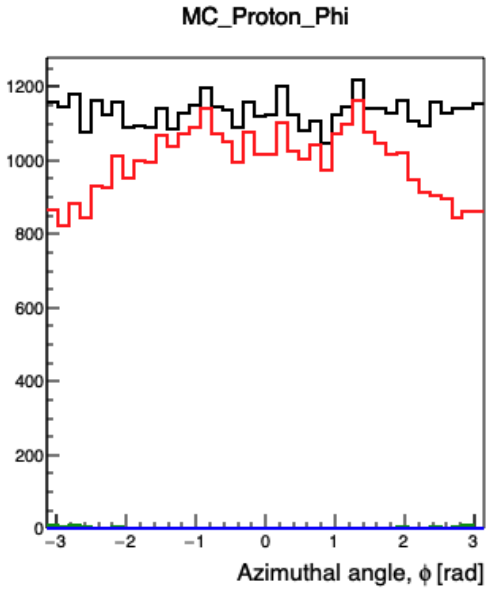
~70% of the neutrons

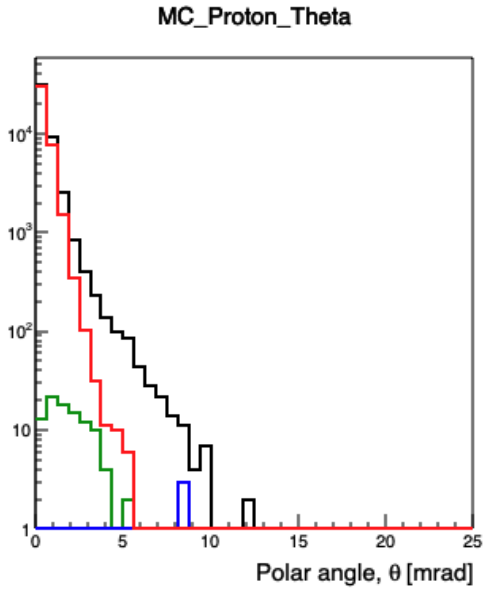
Beam pipe edge between these two detectors.

Deuteron beam (not to scale – just to guide the eye).

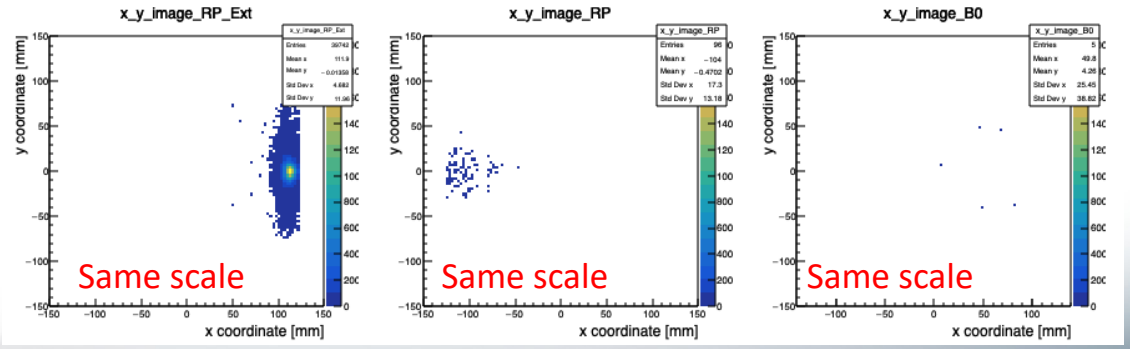
Spectator Proton Acceptance (momentum, theta, phi)







Spectator protons hardly affected from collision, as expected. Due to different rigidity compared to D, bent twice as much in the final dipole (B1apf). The external sensors do almost all of the work here.

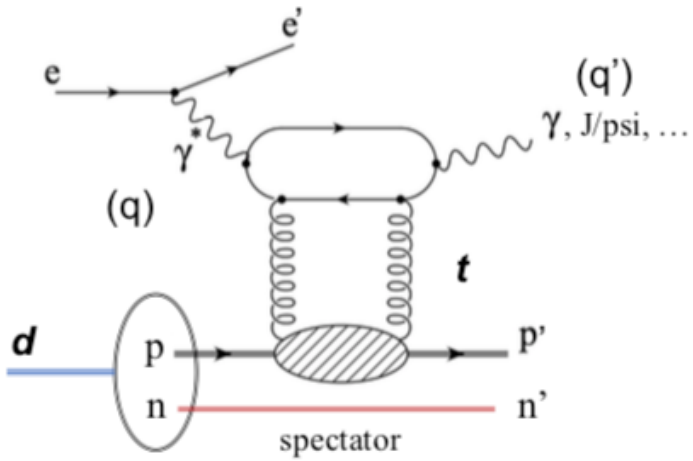


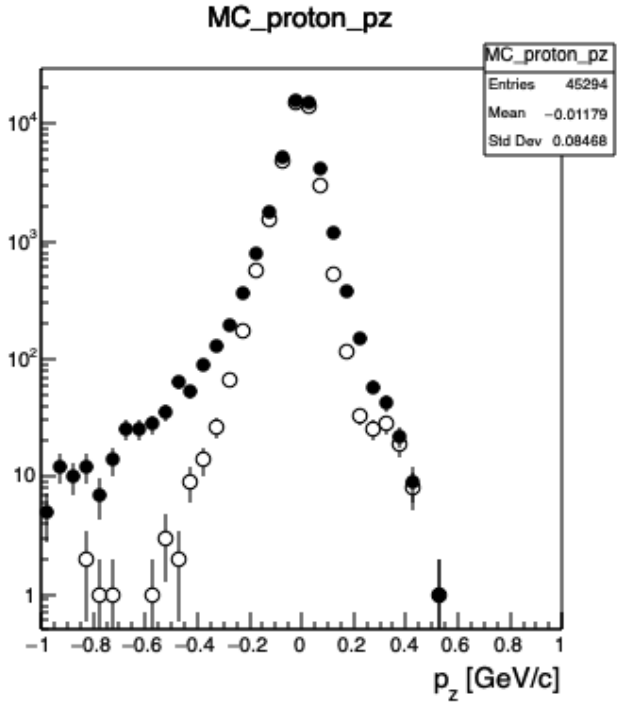
~55% of the protons ~1-2% of the protons << 1% of the protons

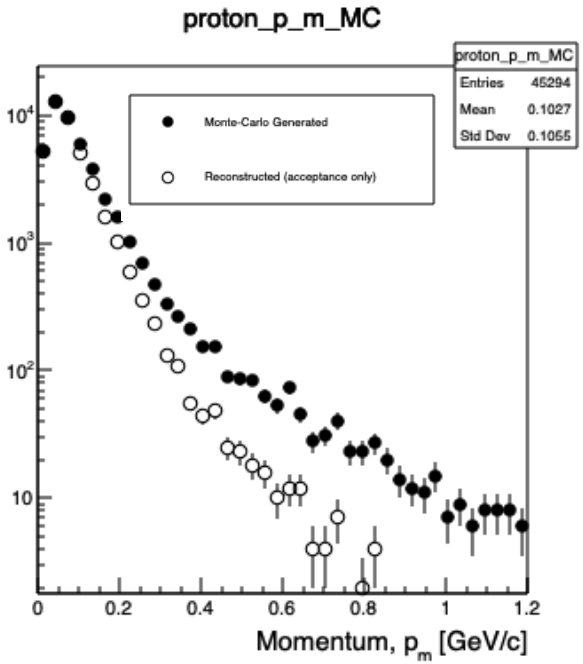
Spectator Proton Acceptance (physics variables)

p_m, p_t, p_z :

Total, transverse, and longitudinal momentum of spectator nucleon in ***d*** rest frame







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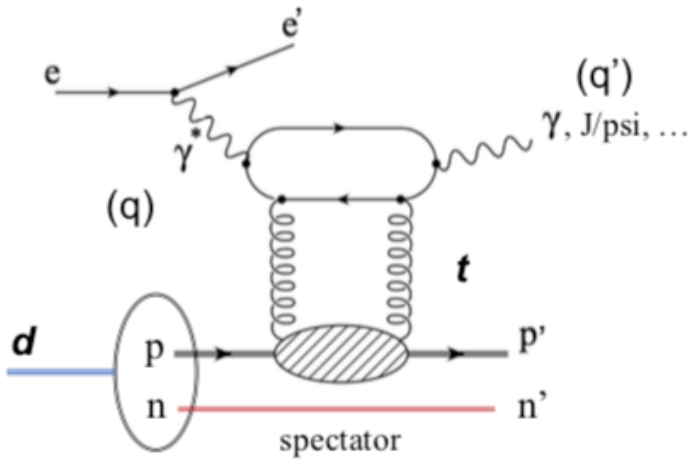
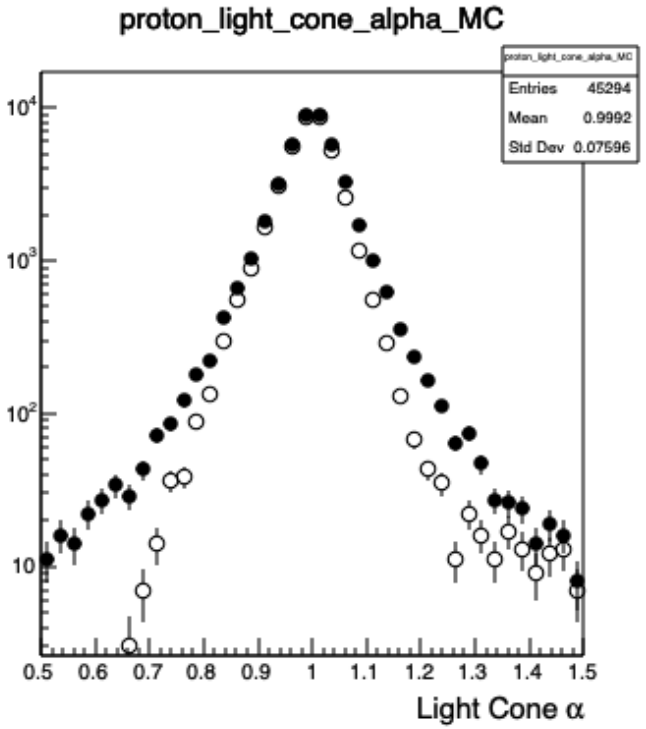
Light cone momentum fraction

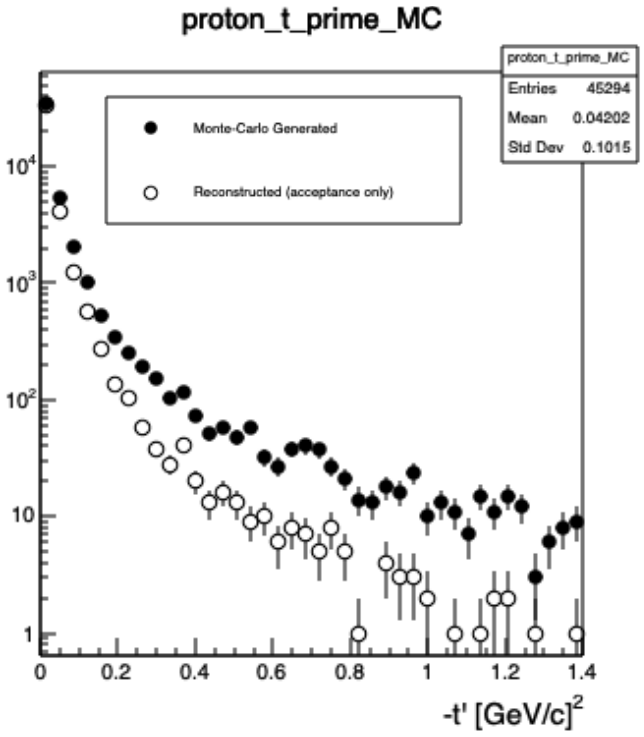
$$\alpha = \frac{2p_{n'}^{+}}{p_{d}^{+}}$$

$t' = (n'-d)^2 - M^2$:

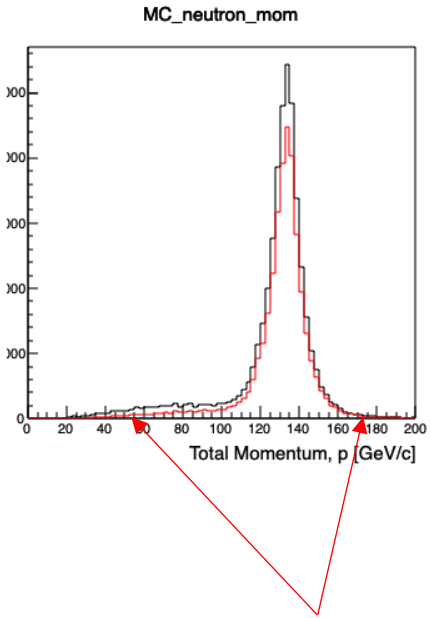
effective struck nucleon off-shellness

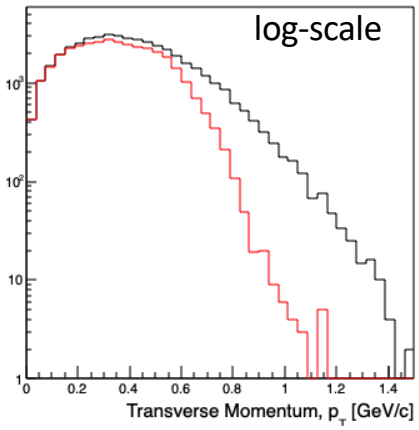


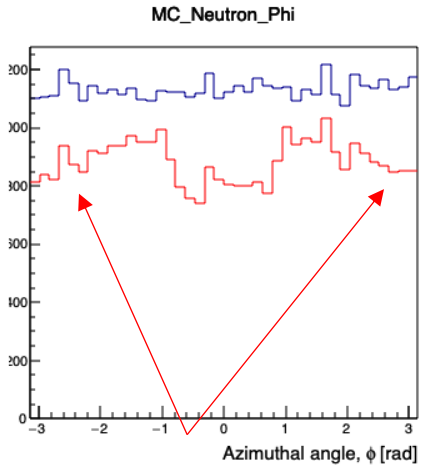


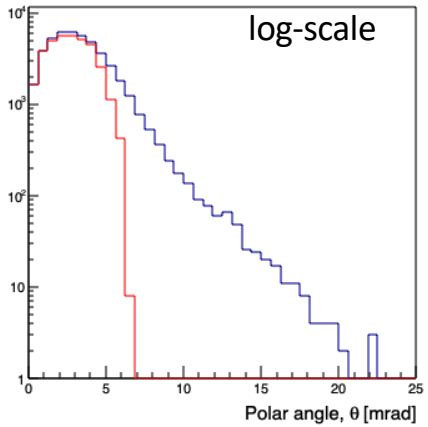


Struck Neutron Acceptance (momentum, theta, phi)



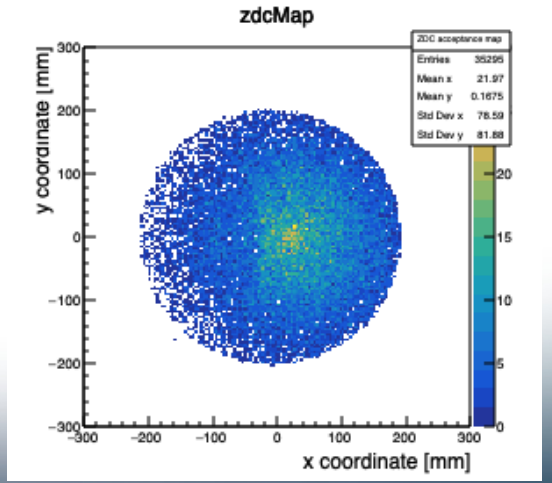




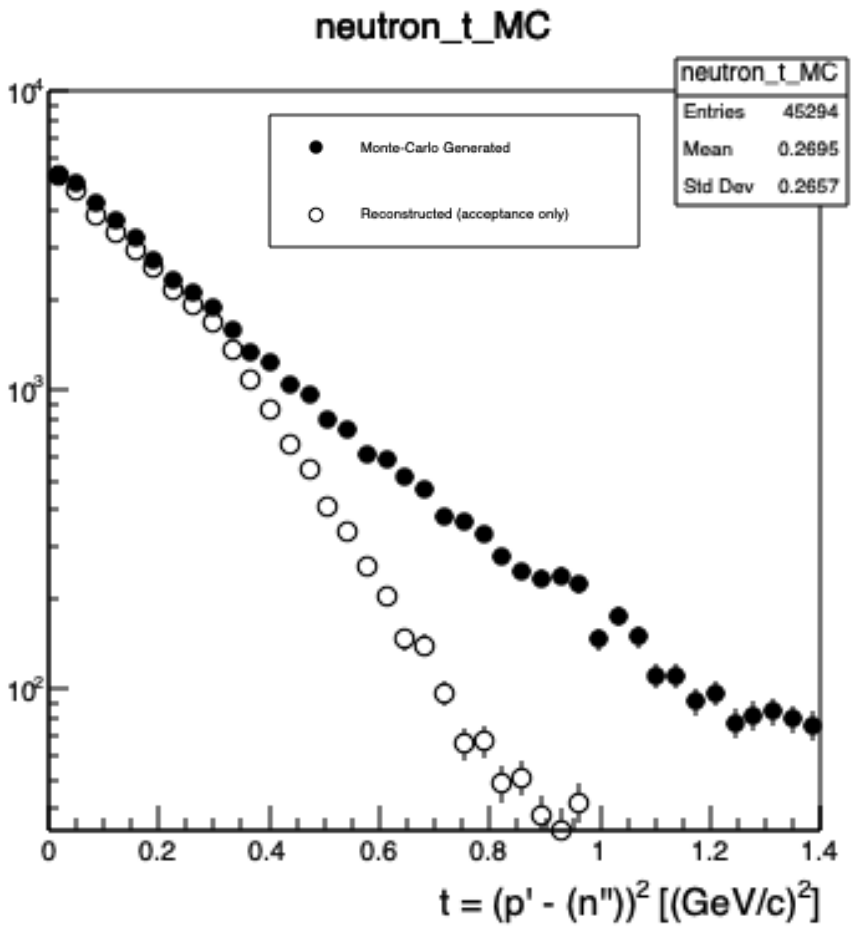


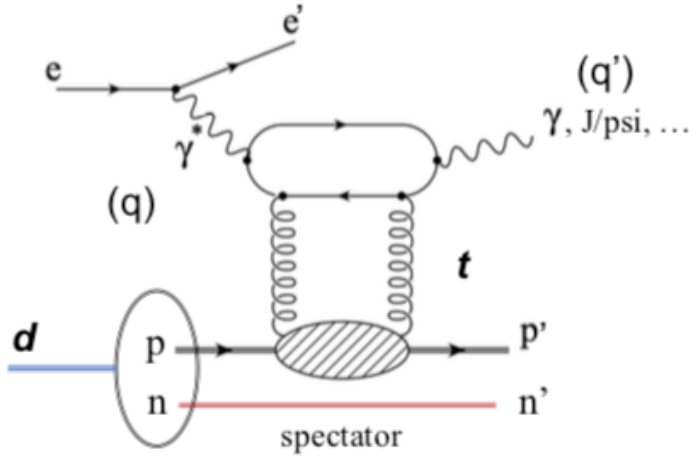
Asymmetrical tails, as it should be from the BeAGLE input (sanity check).

Neutrons hitting aperture. Currently setup to allow for roughly 5mrad cone (not perfectly uniform in phi).



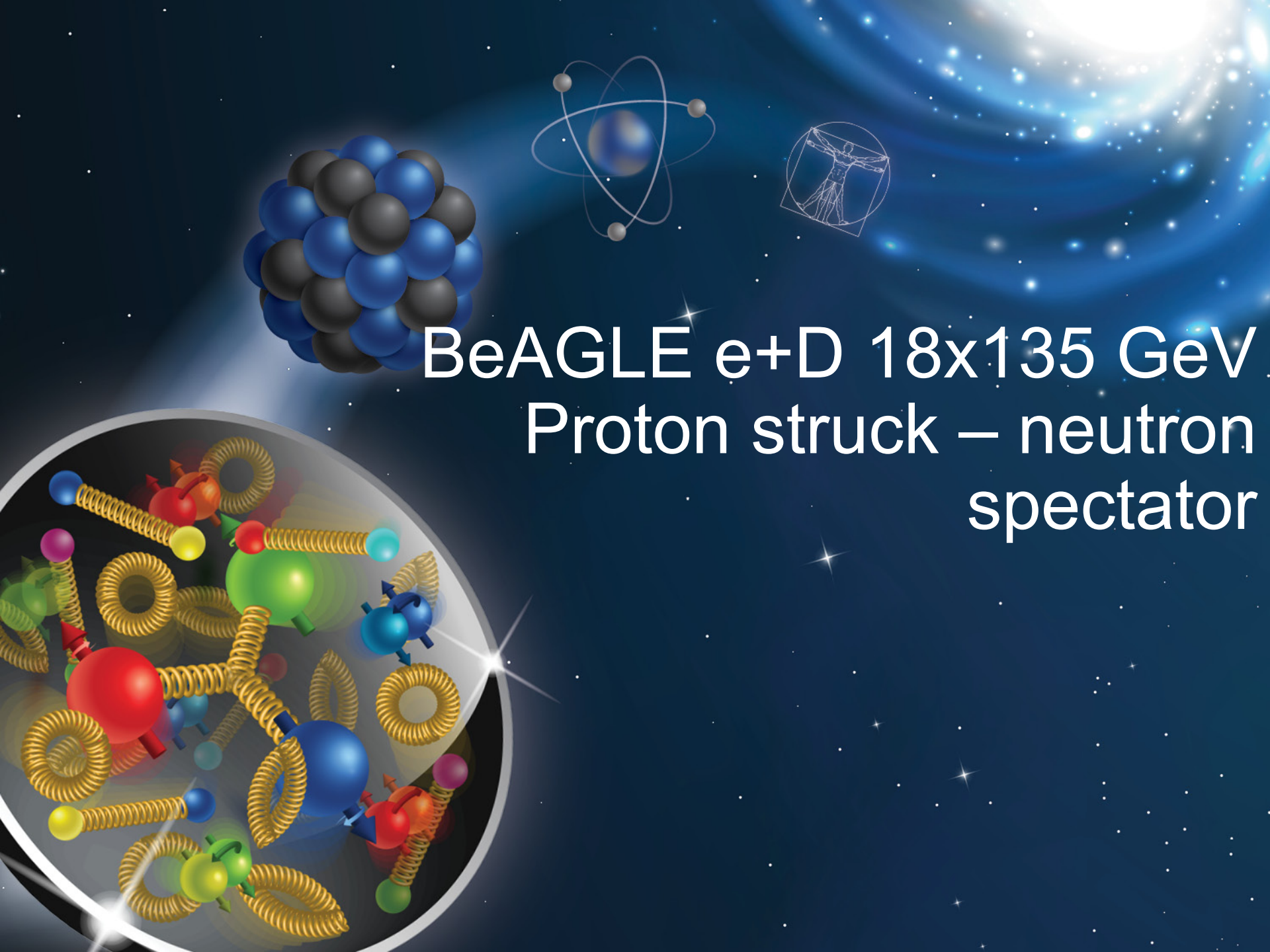
Struck Neutron Acceptance (physics variables)





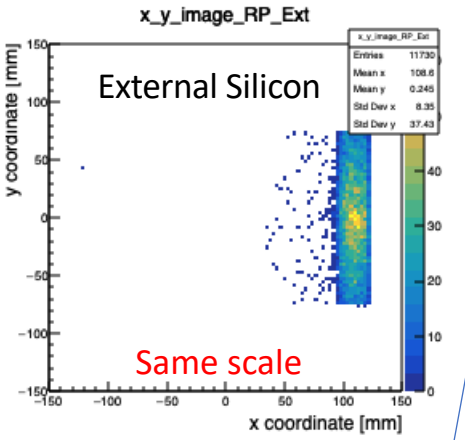
$t = (e'-e+V)^2 = (p' - (-n''))^2$

Momentum transfer from virtual photon to the struck nucleon

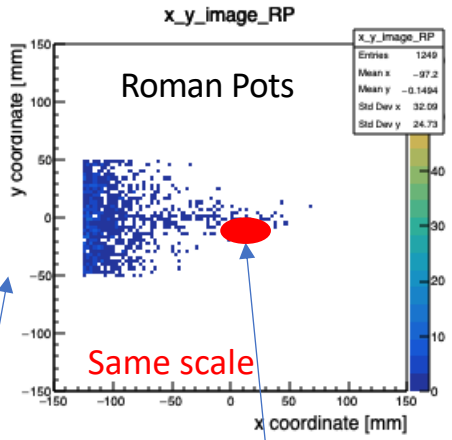

BeAGLE e+D 18x135 GeV
Proton struck – neutron
spectator

Acceptance Images (struck proton, neutron spectator)

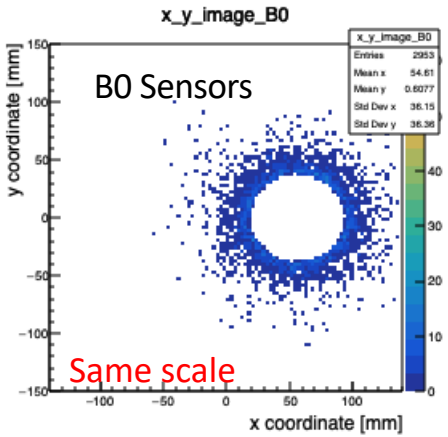
- Just the hits showing on my GEANT detectors. (~30% p+n coincidence)
- Coordinates are *local* for each sensor – not a global system here.



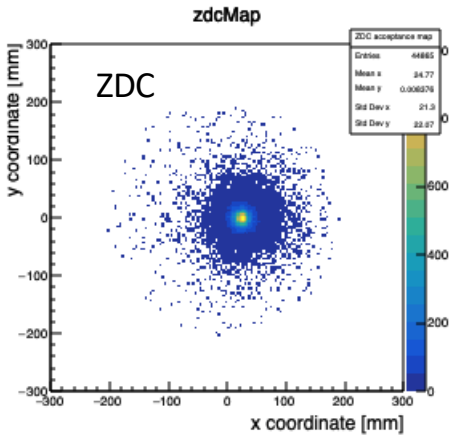
~22% of the protons



~2% of the protons



~6% of the protons



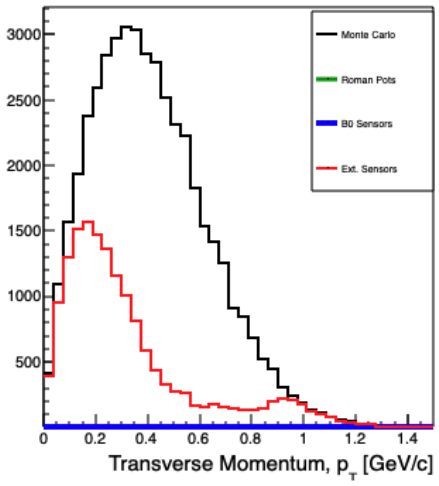
~95% of the neutrons

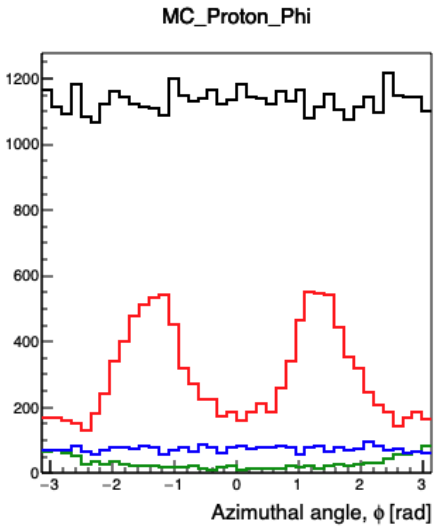
Beam pipe edge between these two detectors.

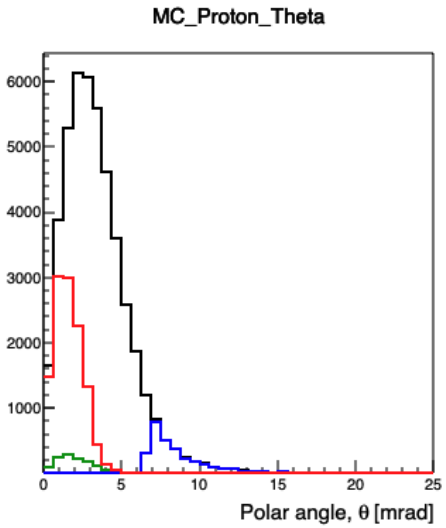
Deuteron beam (not to scale – just to guide the eye).

Last of the four sensors. The hole in the center is for the beam pipe.

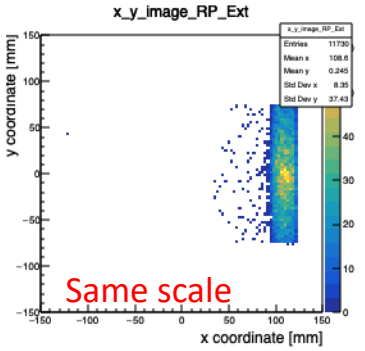
Struck Proton Acceptance (momentum, theta, phi)

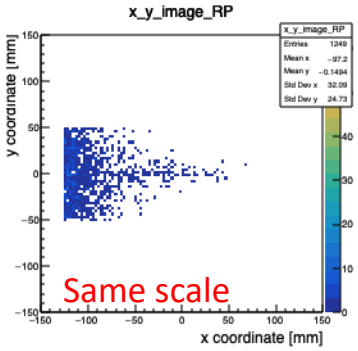


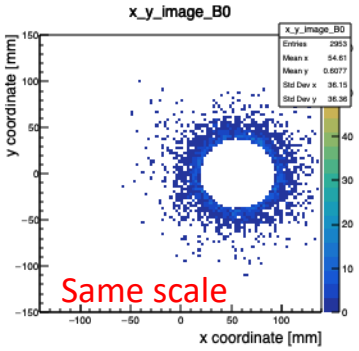




Struck protons highly affected from collision, as expected. Due to different rigidity compared to D, bent twice as much in the final dipole (B1apf). The external sensors and B0 Sensors both very important here.





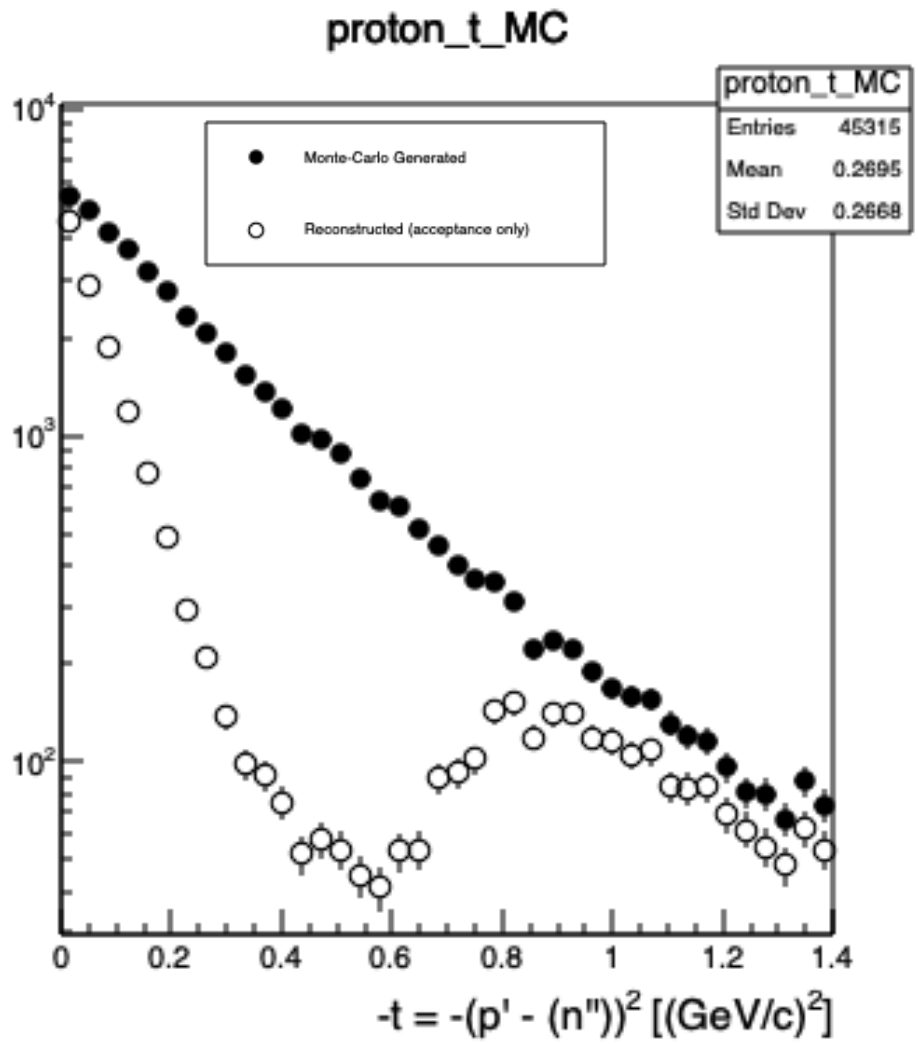


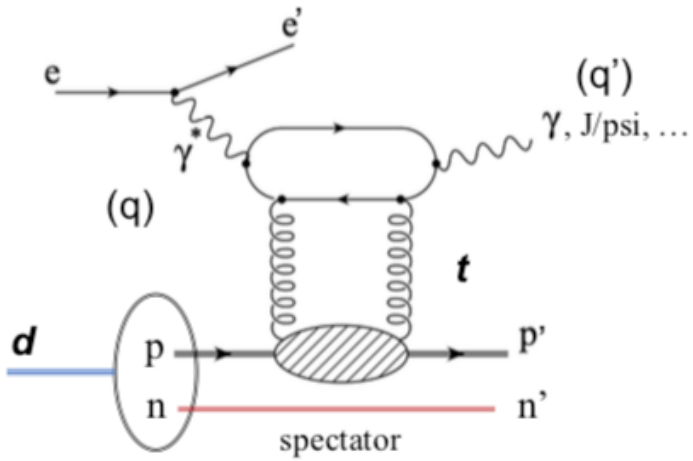
~15% of the protons

~2% of the protons

~18% of the protons

Struck Proton Acceptance (physics variables)

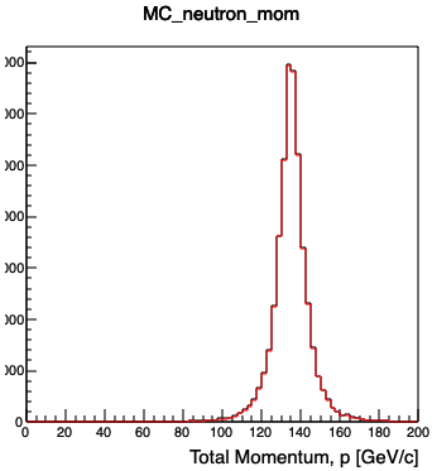


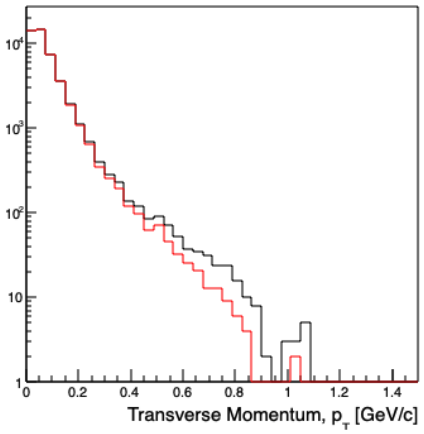


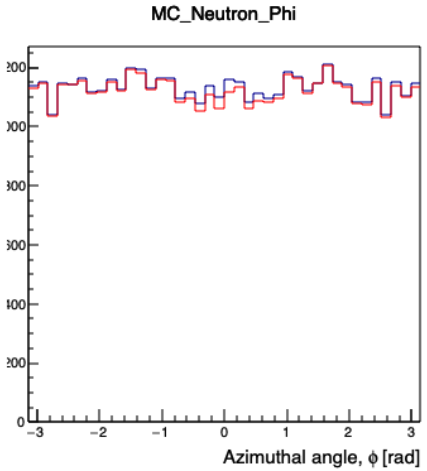
$t = (e'-e+V)^2 = (p' - (-n''))^2$

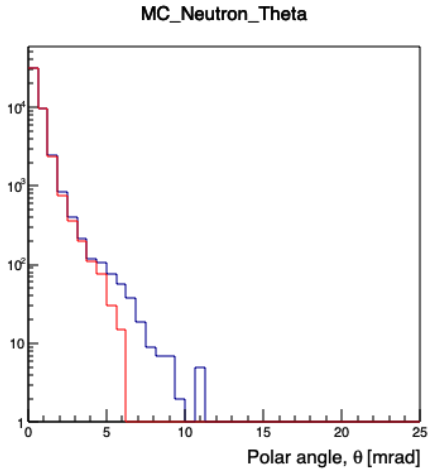
Momentum transfer from virtual photon to the struck nucleon

Spectator Neutron Acceptance (momentum, theta, phi)

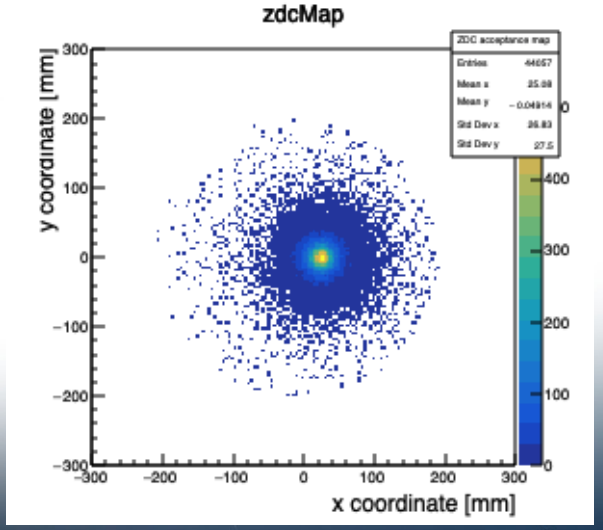








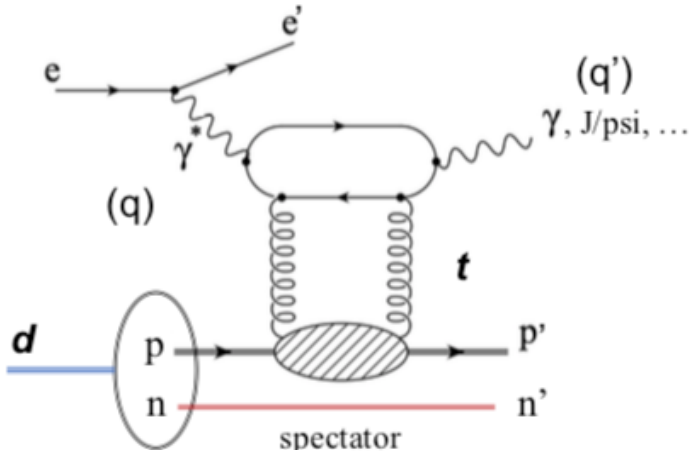
Spectator neutrons essentially unaffected by collision. Most of them fall into the ZDC acceptance and pass the aperture. The cone is much more tightly confined (generally within 2.5 mrad).



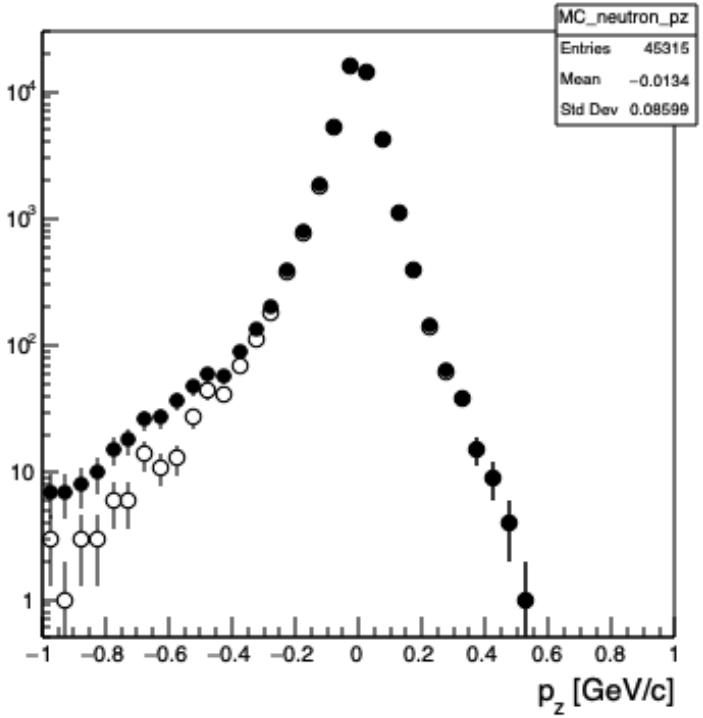
Spectator Neutron Acceptance (physics variables)

p_m, p_t, p_z :

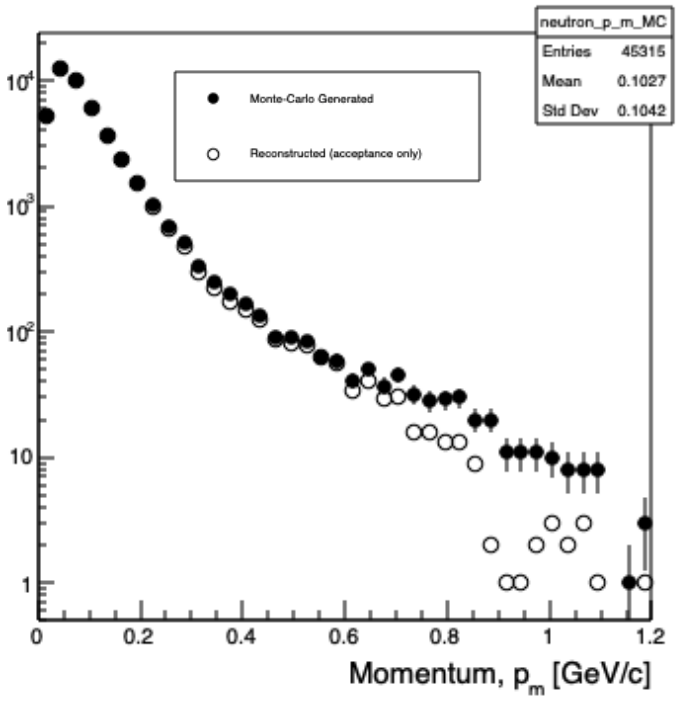
Total, transverse, and longitudinal momentum of spectator nucleon in ***d*** rest frame



MC_neutron_pz



neutron_p_m_MC



Spectator Neutron Acceptance (physics variables)

alpha:

Light cone momentum fraction

$$\alpha = \frac{2p_{n'}^{+}}{p_{d}^{+}}$$

t'= $(n'-d)^2-M^2$:

effective struck nucleon off-shellness