Unpolarized Time Like Compton Scattering in Hall C at JLab

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Timelike Compton Scattering

$$\gamma P \rightarrow e^+ e^- P'$$

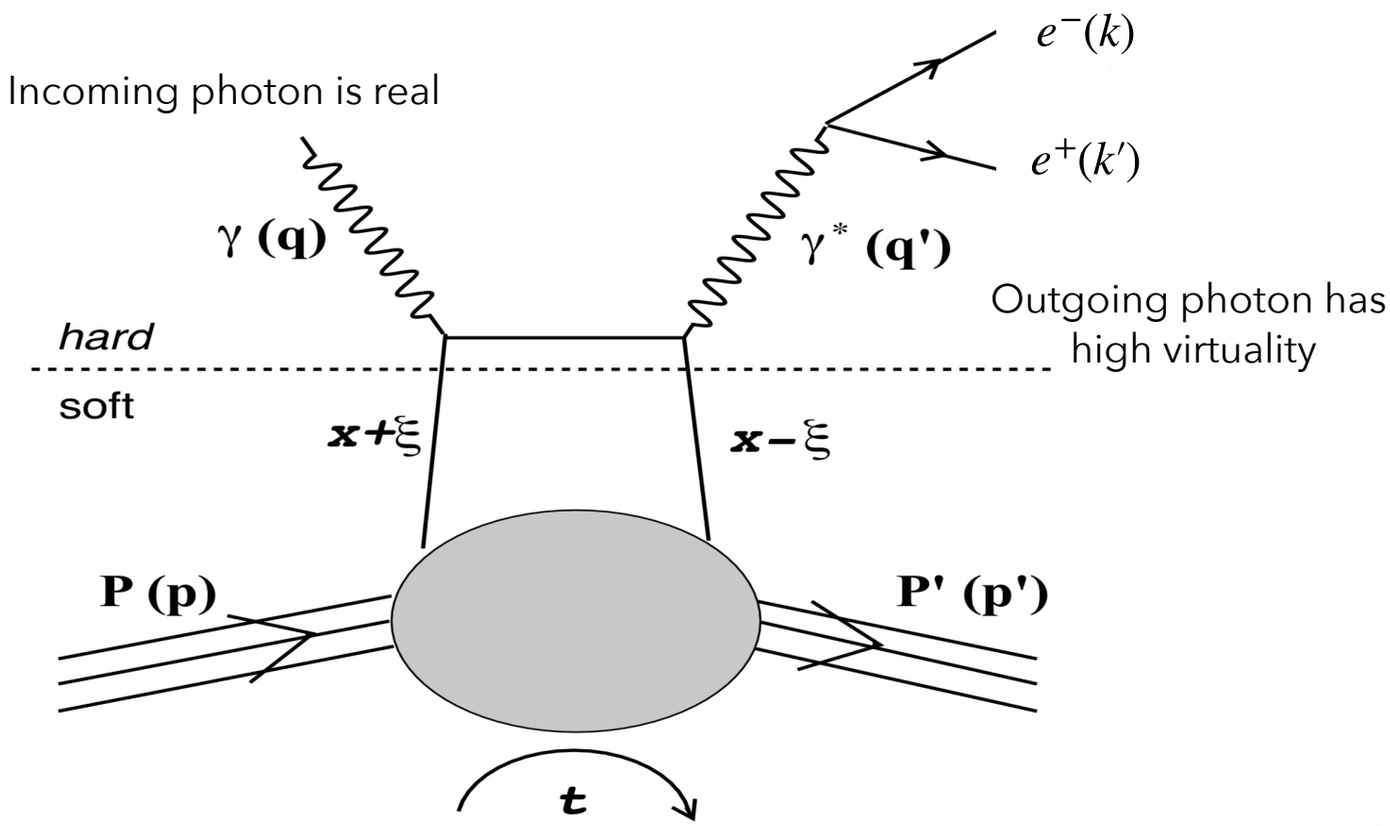
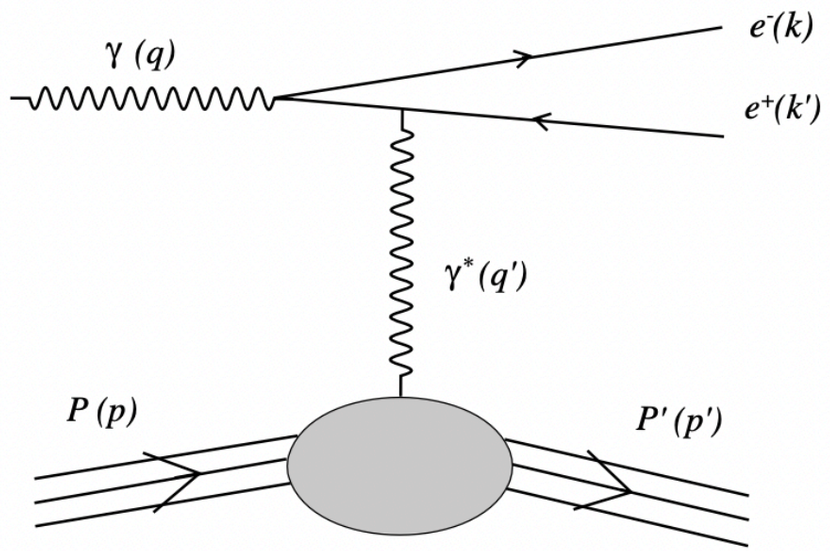


Fig : Time Like Cotton Scattering



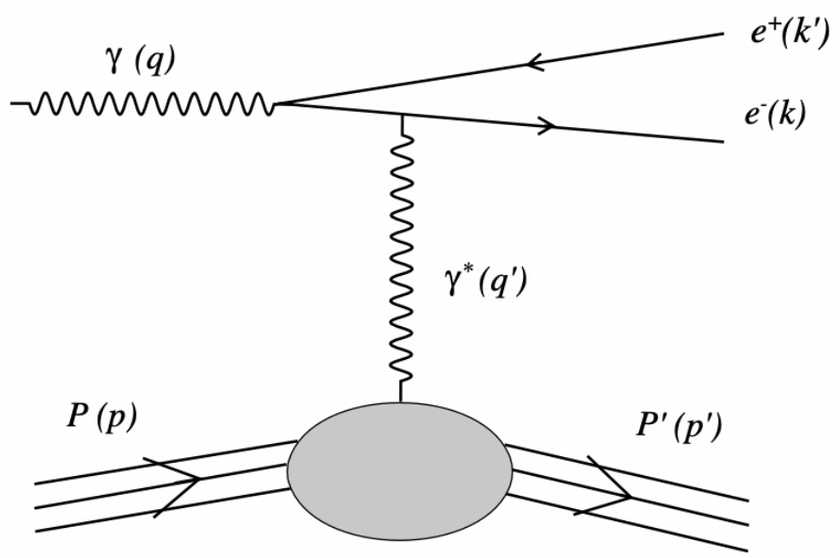
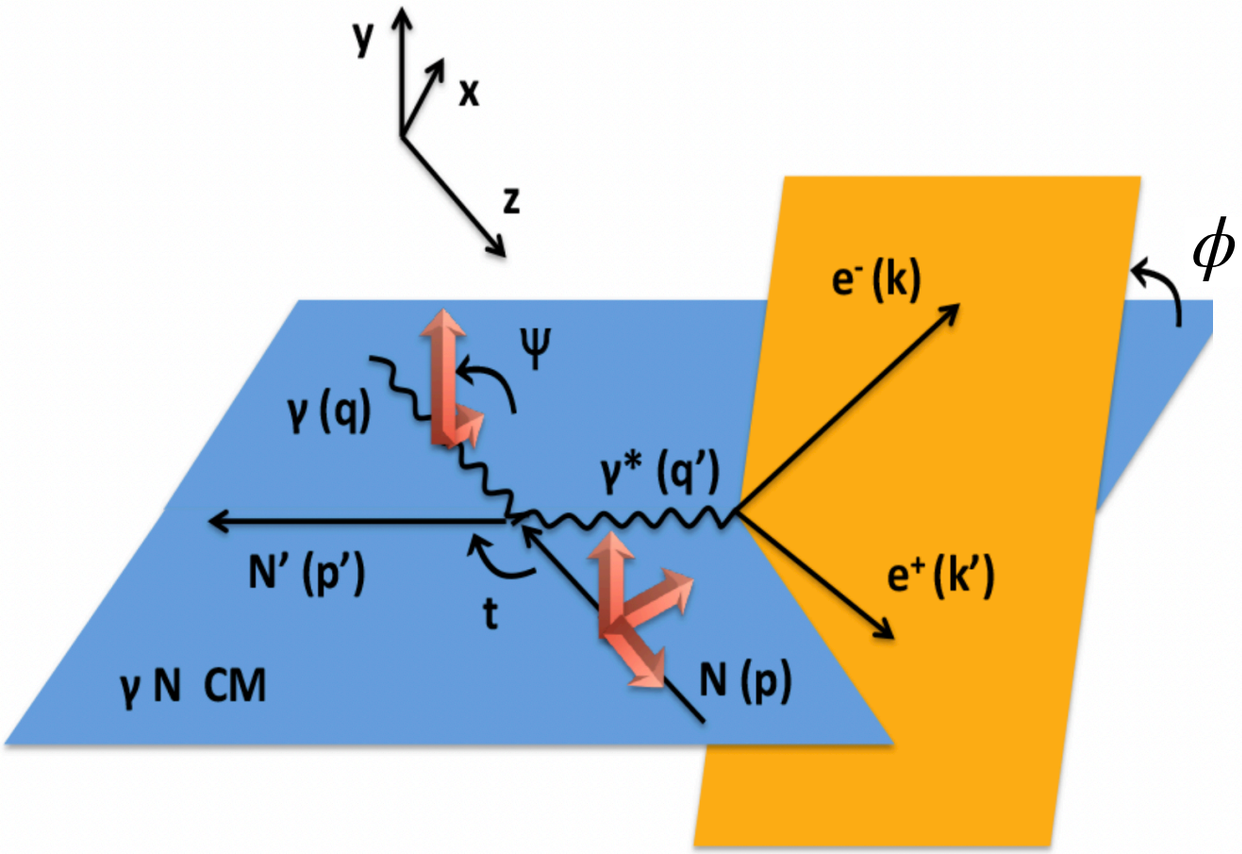


Fig : Bethe-Heitler diagrams

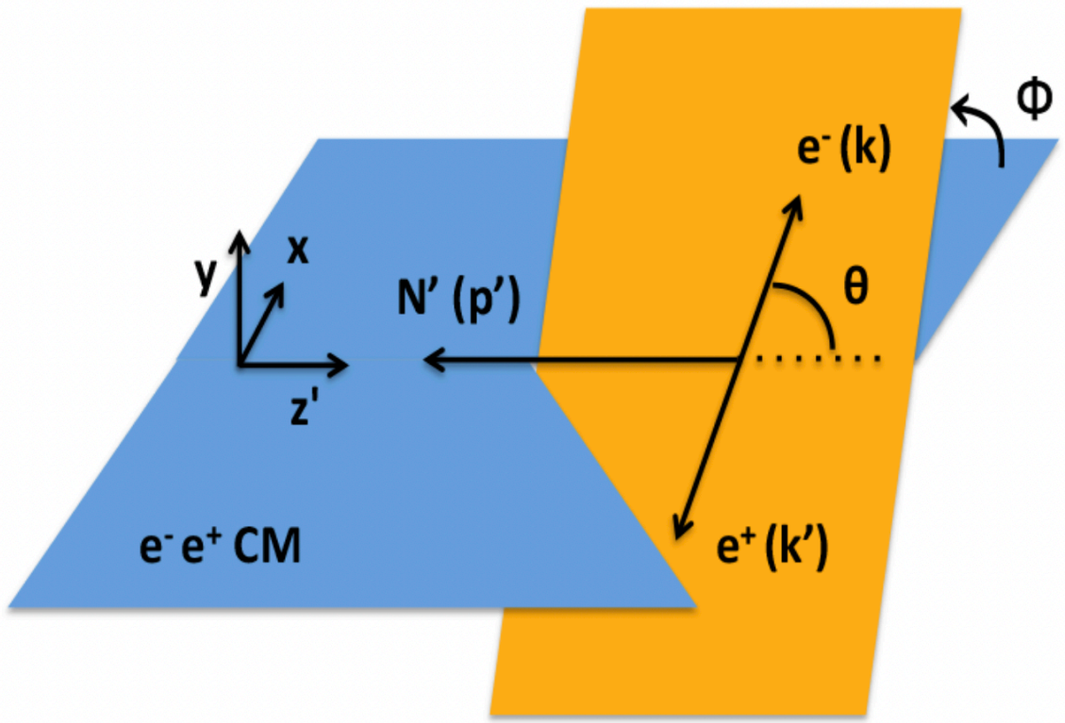
Source : M, Boer. et.al. Eur. Phys. J. A (2015) 51: 103

Timelike Compton Scattering

γP C.M. Frame



γ^* C.M. Frame



ψ : Angle between reaction plane and γ spin

ϕ : Angle between the hadronic plane (blue) and e^+e^- plane (yellow)

θ : Angle between γ^* and e^-

θ_s, ϕ_s : target and spin vector orientation

Source : M, Boer. et.al. Eur. Phys. J. A (2015) 51: 103

Physics Observables : unpolarized cross section and polarized beam spin asymmetry

Single Spin Asymmetry ($A_{\odot U}$) : circularly polarized beam and unpolarized target

$$A_{\odot U} = \frac{\sigma^{+} - \sigma^{-}}{\sigma^{+} + \sigma^{-}} \qquad \ldots(1)$$

1. $\sigma^{\pm} \equiv \frac{d^5\sigma}{dQ^2\ dt\ d\Omega\ dE_\gamma}$: 5 differential scattering cross-section TCS+BH

2. $\pm$: right (+) or left (-) handed circular polarization of the real photon

3. 5 differential cross section sensitive to both Real and Imaginary part of CFF

4. Asymmetry arises due to the interference between the TCS and BH processes

5. $A_{\odot U} \propto sin(\phi)$ moment of the $\frac{d^5\sigma^{INT}}{dQ^2\ dt\ d(cos\theta)\ d\phi\ dE_\gamma}$

6. $A_{\odot U}$ is sensible to the Imaginary part of the amplitude

7. As BH amplitude is purely Real, $A_{\odot U}$ asymmetry is due to TCS process only

Compact photon source

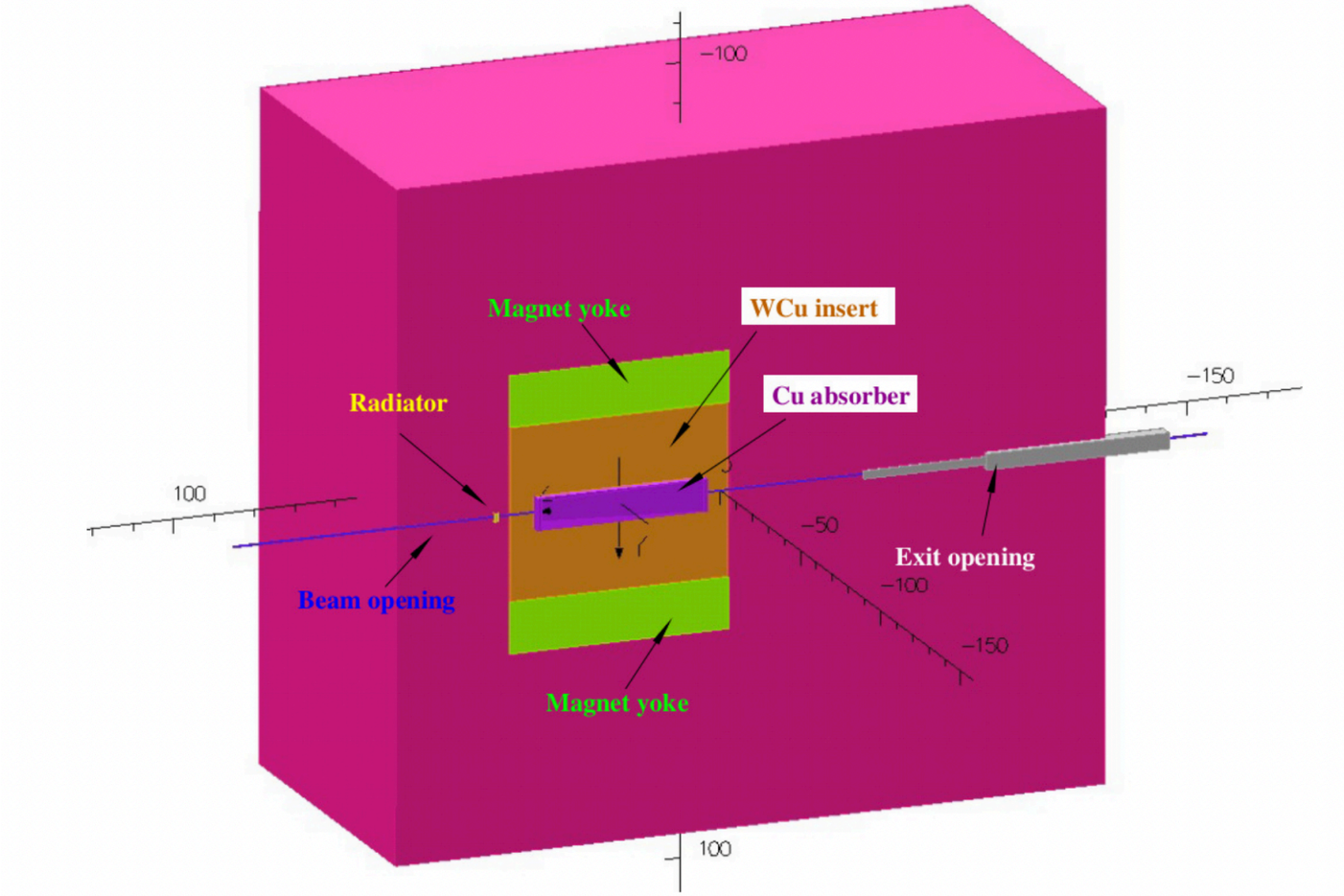


Fig : The CPS Cut off view

Source :A Conceptual Design Study of a Compact Photon Source (CPS) for Jefferson Lab

1. Spot size $\sim 0.9\ mm$ at a distance of 2m away from the radiator
2. Photon Flux $\sim 1.5 \times 10^{12}\ s^{-1}$ from electron beam current $2.5\ \mu A$ on 10% X_0 Cu radiator
3. Photon energy $> 0.5\ E_{beam}$
4. T warm magnet to bend incoming electrons to local beam dump
5. Source : D.Day et al., NIMA 957 (2020) 163429

Scattering Chamber & Target

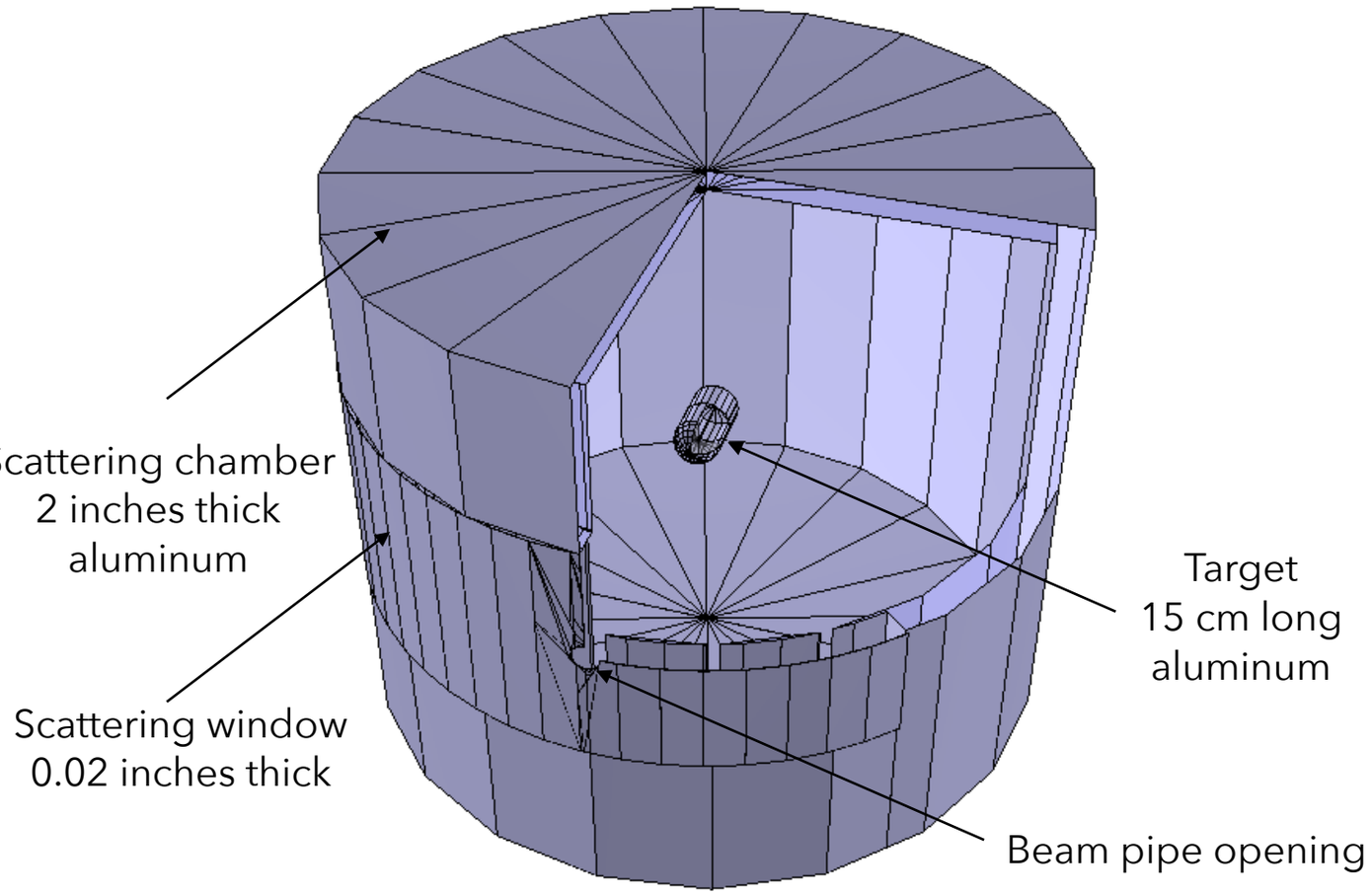


Fig : Geant4 simulation of scattering chamber and target

1. Scattering chamber inner diameter = 41 inches
2. Scattering chamber outer diameter = 45 inches
3. Angular range : horizontal HMS : 3.2 to 77.0 degrees
4. Angular range : SHMS : 3.2 to 47.0 degrees
5. Vertical angular range : ±17.3 degrees
6. Target thickness of Entrance and exit cap = 0.1778 cm
7. Target cell wall thickness = 0.0254 cm

Calorimeter

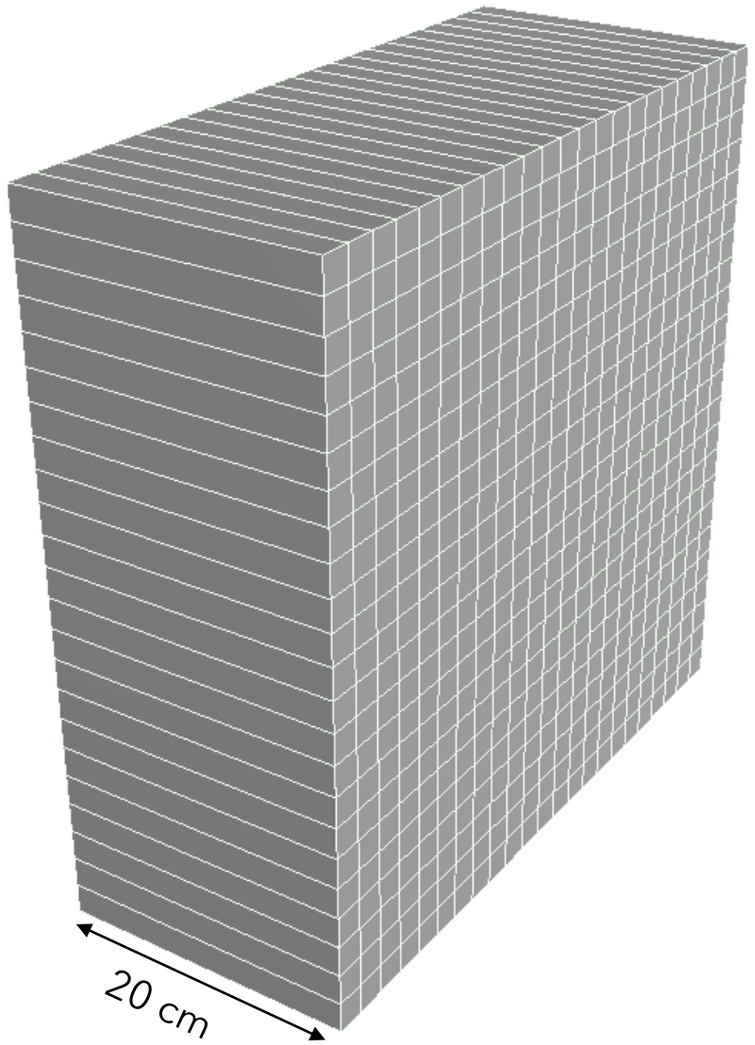


Fig : Geant4 simulation calorimeter

1. e^-, e^+, P detection and PID
2. Clones of the NPS calorimeter at Hall C
3. 2x2x20 cm^2 PBWO4 scintillator crystal
4. Expected energy resolution $\frac{2.5\,\%}{\sqrt{E}} + 1\,\%$
5. Coordinate resolution ~3 mm at 1 GeV
6. Fly's eye assembly of 23x23 matrix of total 2116 modules

Magnet ：Separate the outgoing particles

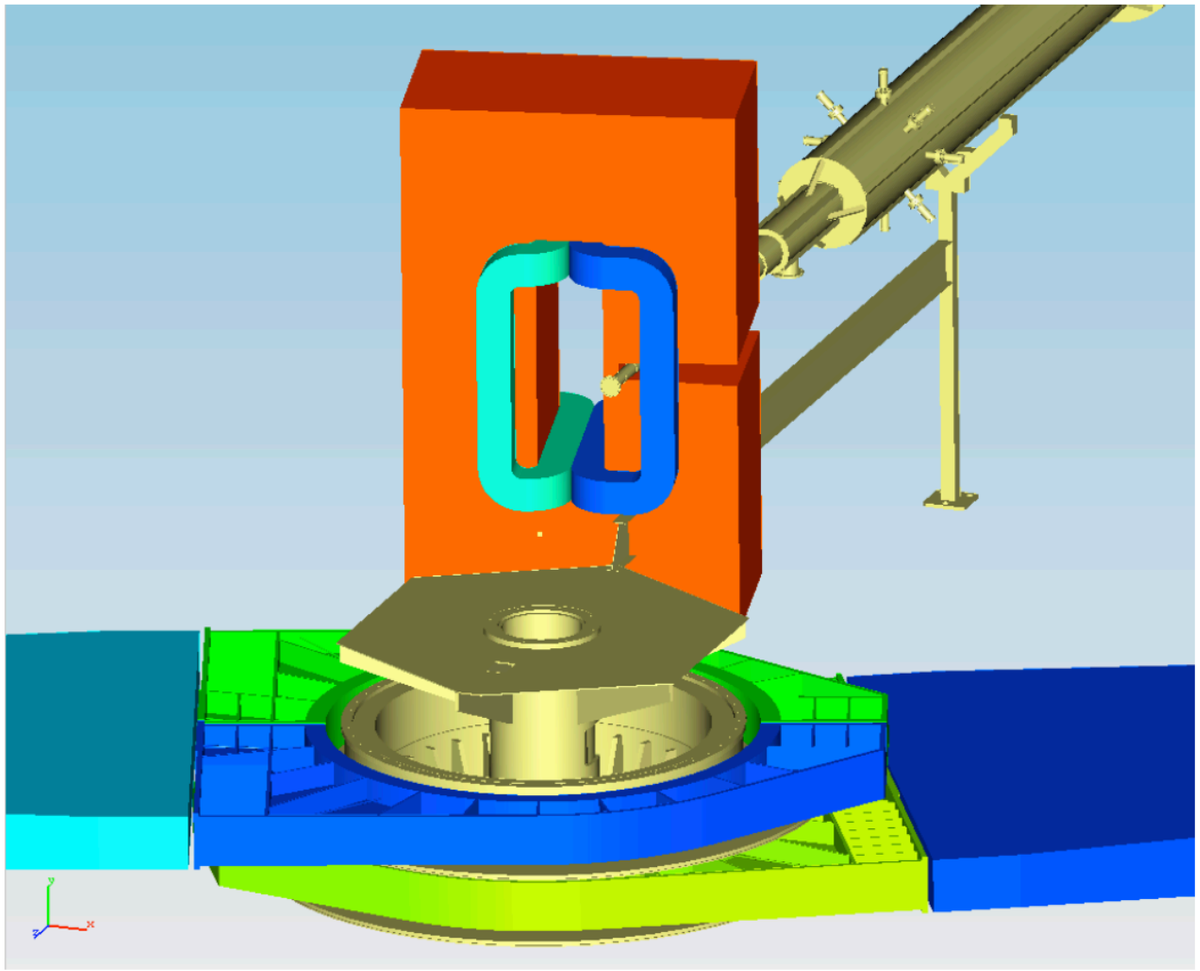


Fig : CAD Drawing for Super Bigbite Magnet

Source : https://userweb.jlab.org/~bogdanw/SBS-general.pdf

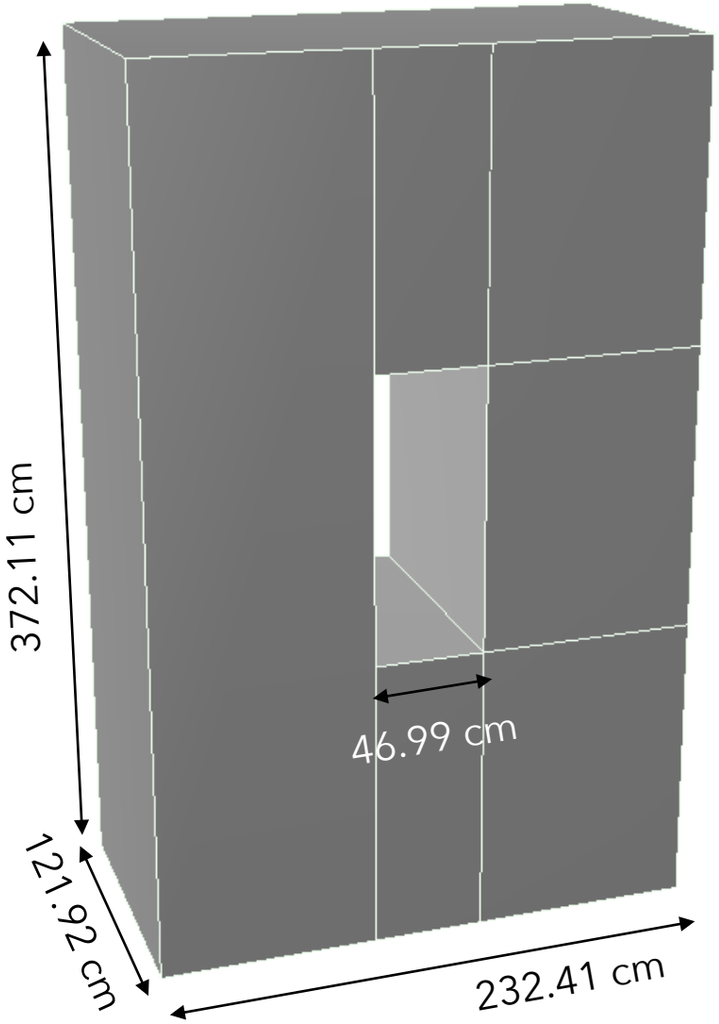
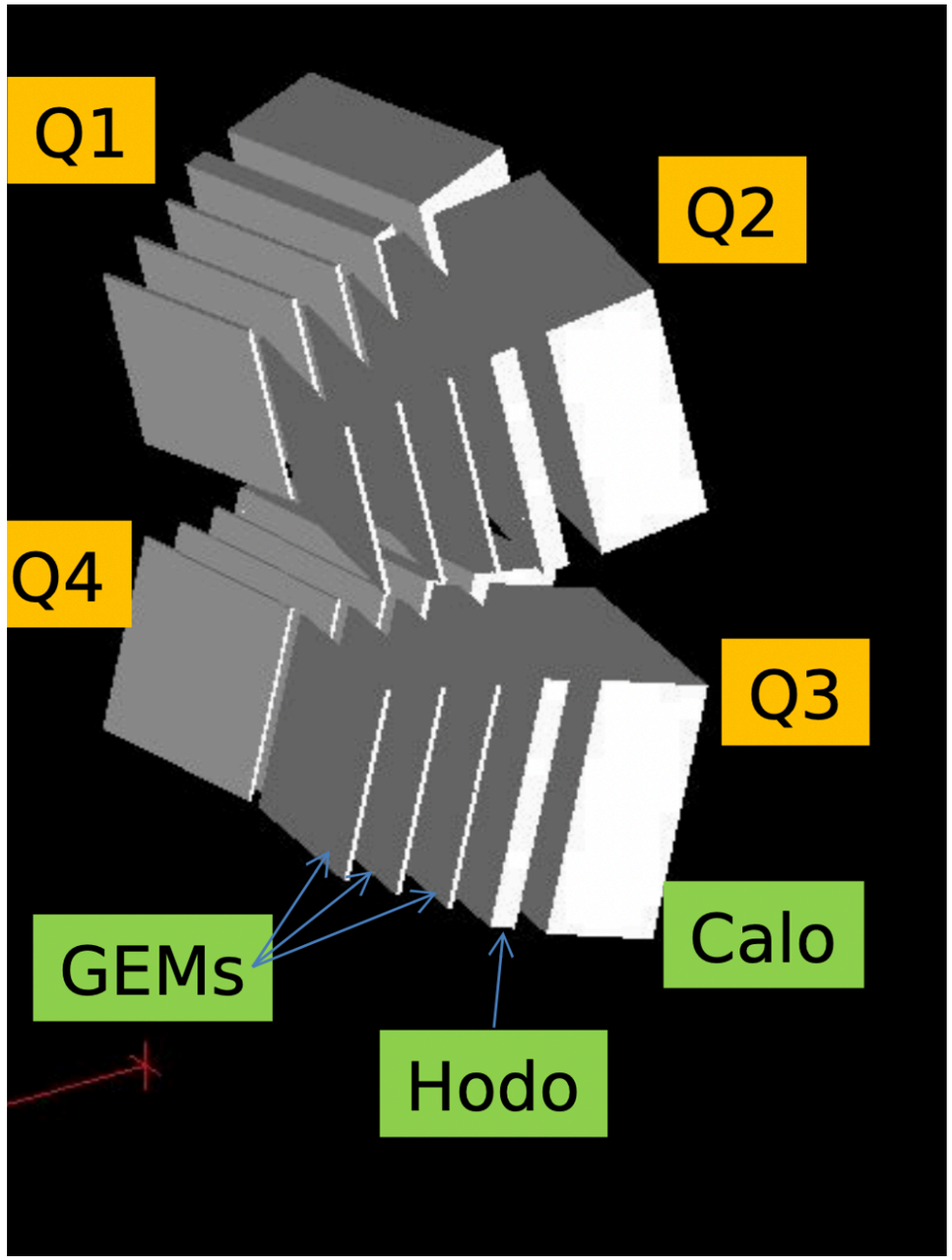


Fig : Geant4 simulation of simple magnet geometry

1. The field integral is 2.4 Tesla-meter with 1.2 m long pole

GEM Tracker

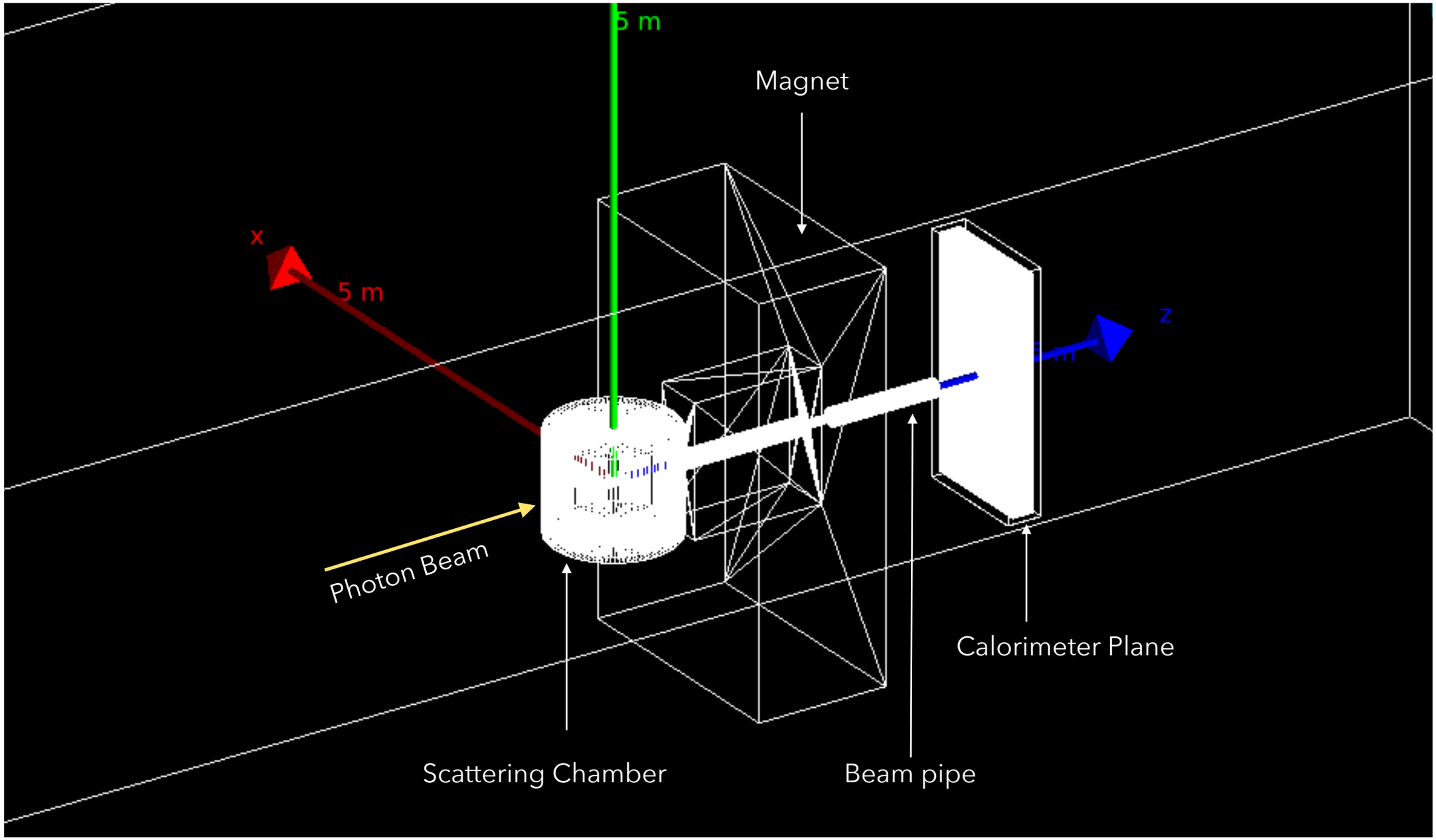
1. GEM tracker will be used to track e^-, e^+, P
2. Coordinate reconstruction accuracy ~80 μm
3. Background rate tolerance up to 106 Hz/ mm^2
4. Minimum material thickness along particle pass
5. Big size manufacturing Use at Jlab: SBS, SoLID DDVCS, Prad



Hodoscopes

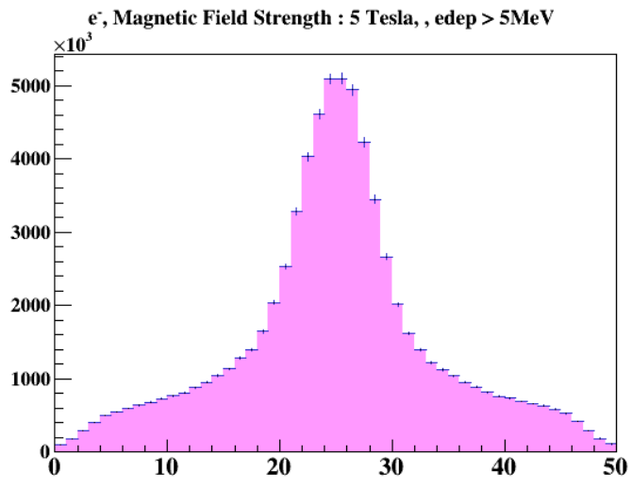
1. For recoil proton detection and and PID
2. To provide dE/dX signal from low momentum recoil protons
3. 2x2x5 cm^3 scintillators arranged in “Fly’s eye” hodoscopic construction

Geant4 Simulation :Simple One Calorimeter Plane Setup

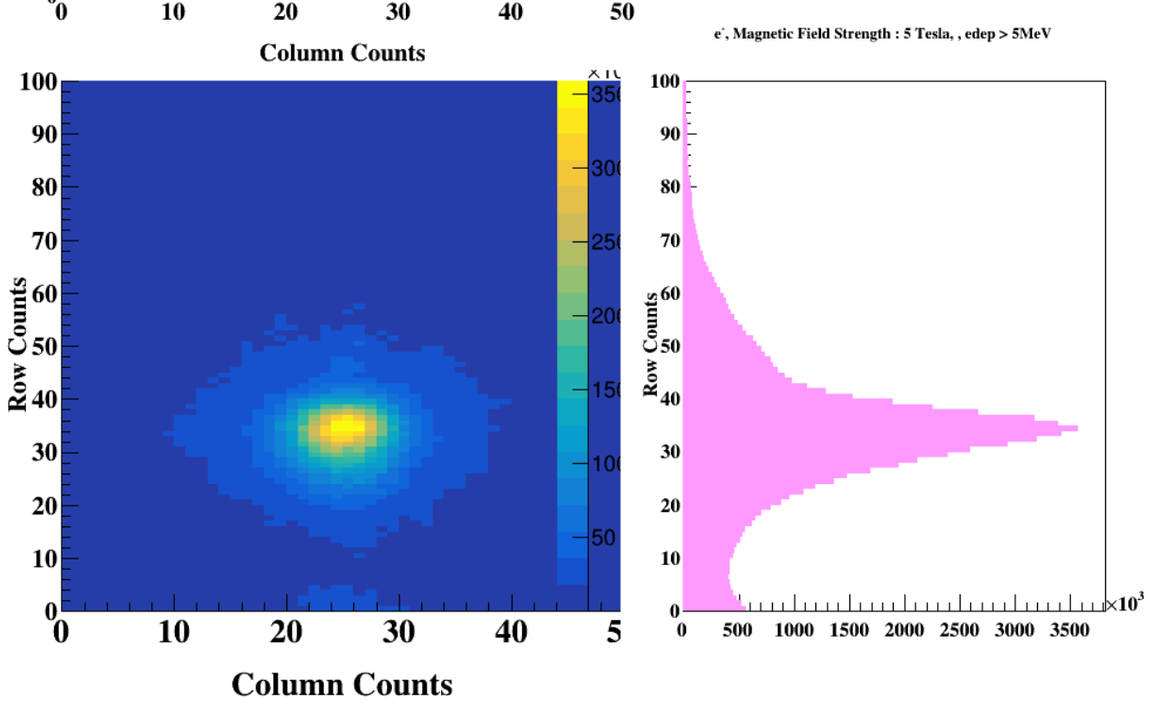


Geant4 Simulation : towards more realistic setup

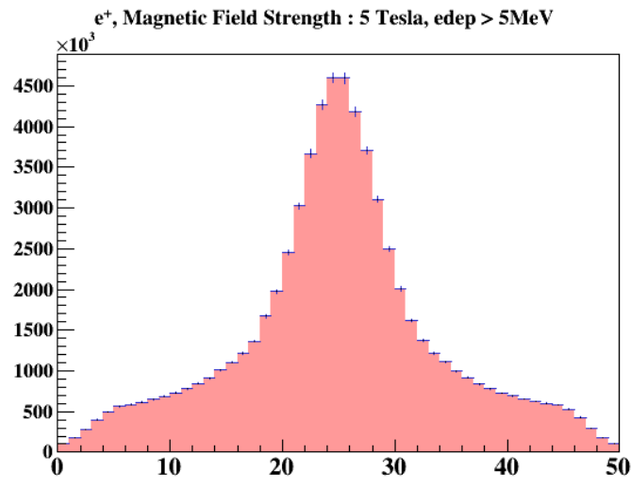
Projection of electron on calorimeter plane



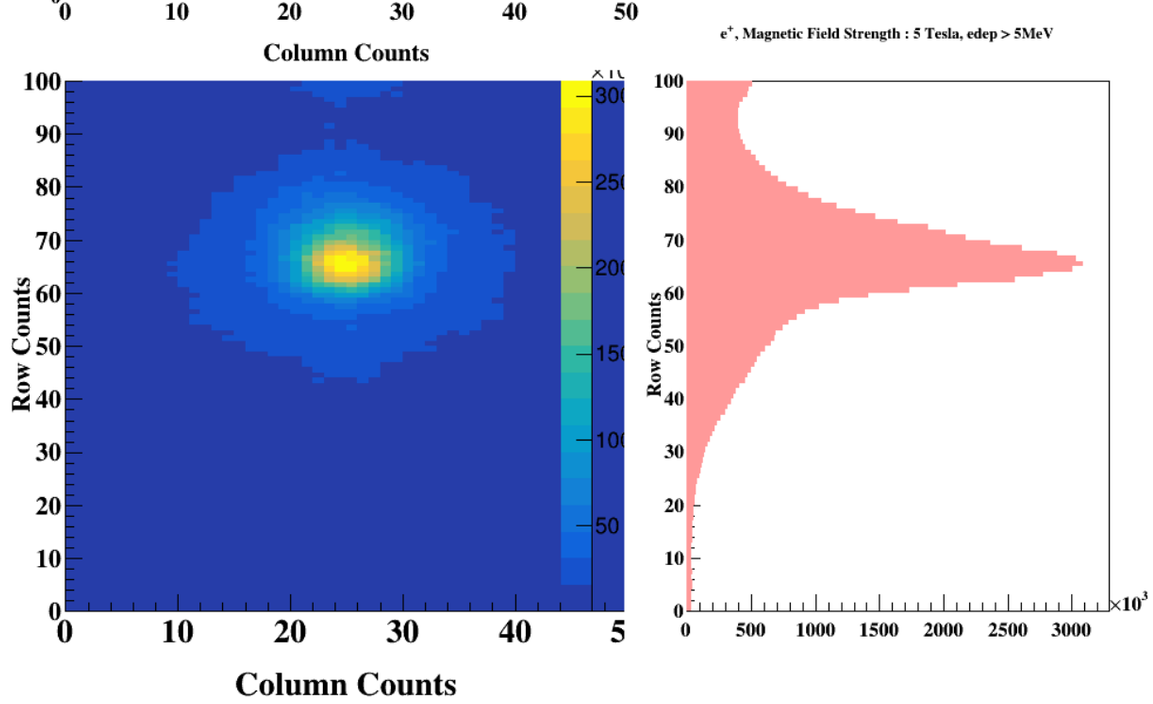
1. Magneti fiels : 5 T
2. Energy deposition > 5 MeV
3. For each event only the hit with maximum energy deposition is considered



Projection of positron on calorimeter plane



1. Magneti fiels : 5 T
2. Energy deposition > 5 MeV
3. For each event only the hit with maximum energy deposition is considered



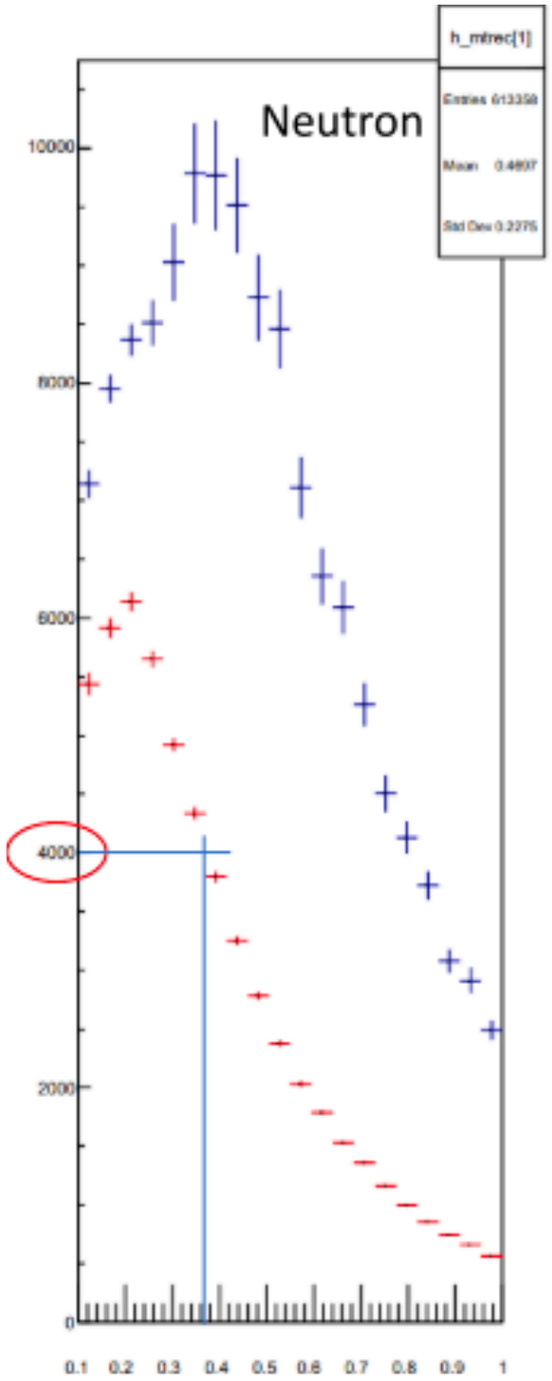
Possible extension to measure TCS for neutron

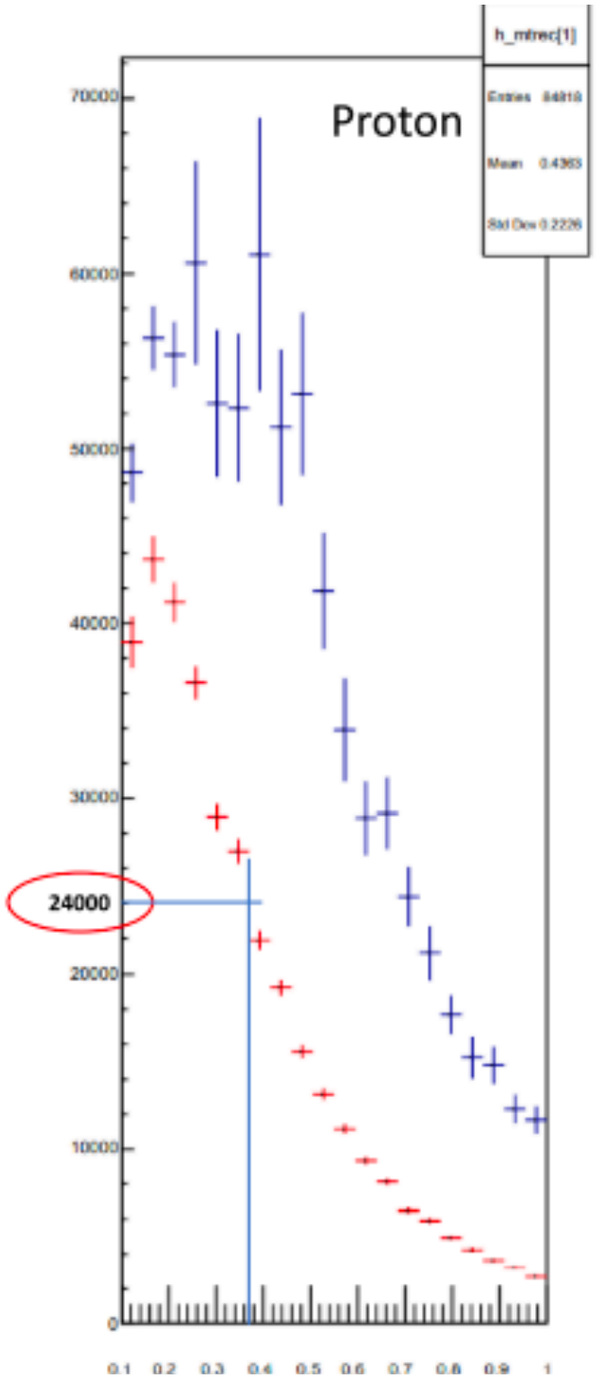
1. Preliminary study to show the feasibility of the measuring TCS for neutron

2. Number of reconstructed TCS events plotted against -t weighted by cross-section

3. Study before having the full Geant4 simulation

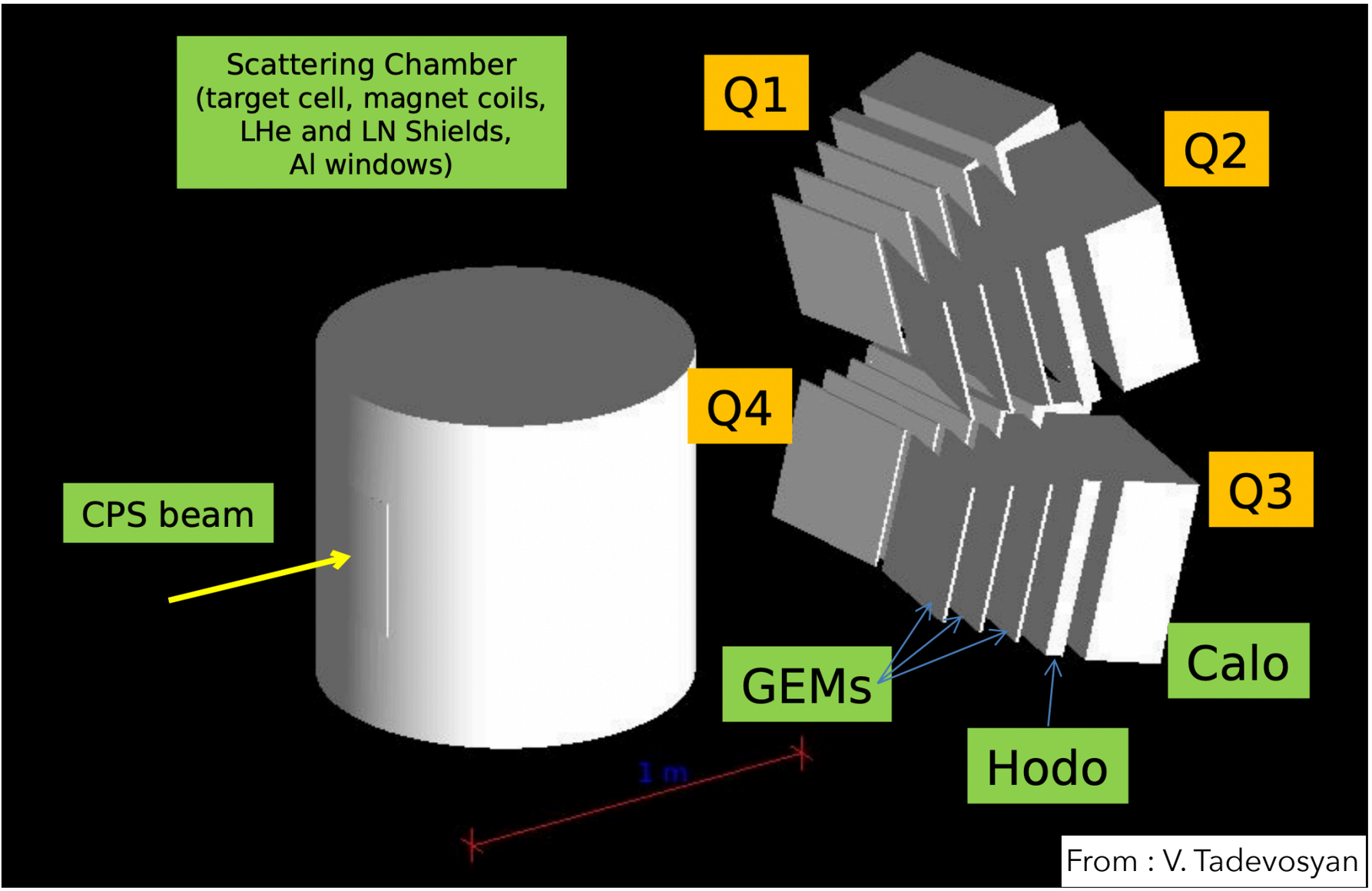
4. In principle it is possible to do the measurement on neutron, provided we have an neutron detector





From : Camille Zindy & M. Boer, 2021

Polarized TCS measurement setup for Hall C



1. High intensity photon source 1.5 x 1012 γ/sec (CPS)

2. Target chamber: NH3, 3cm Polarized via DNP

3. Tracking: GEM+hodoscopes, 4 symmetric quadrants

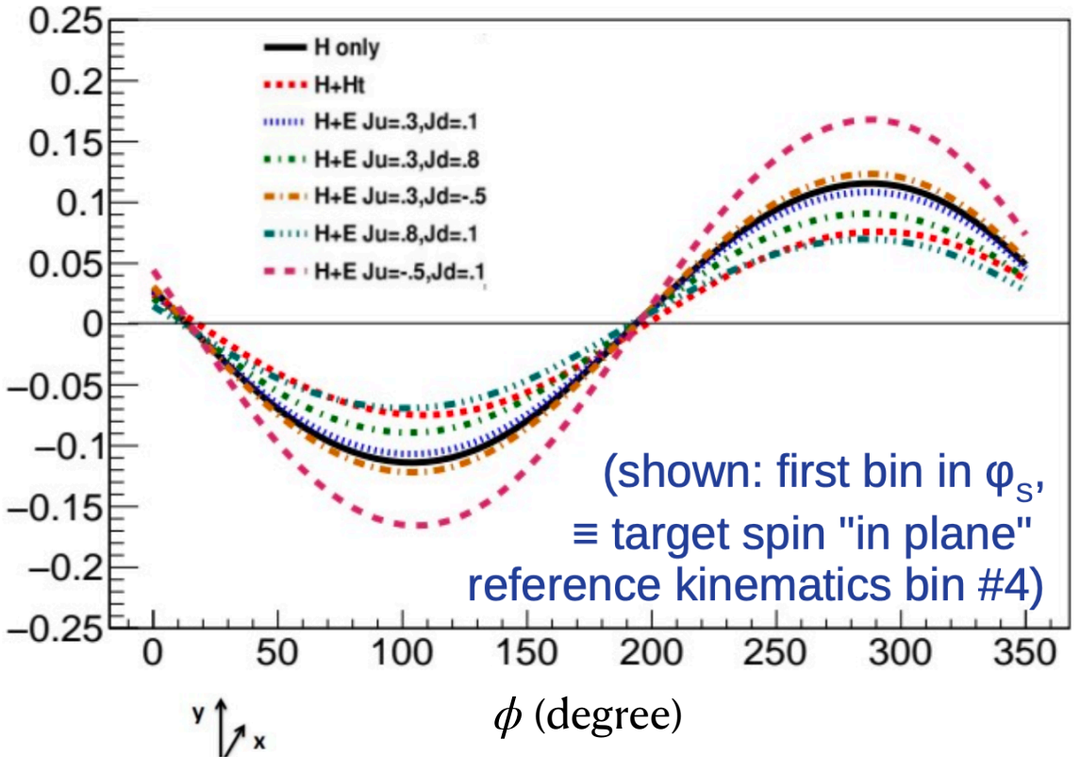
4. Calorimeters: 4 symmetric quadrants, equivalent of 2 NPS ~ 6° to 27° aperture

5.Lumi request: 5.85 x 105 pb-1

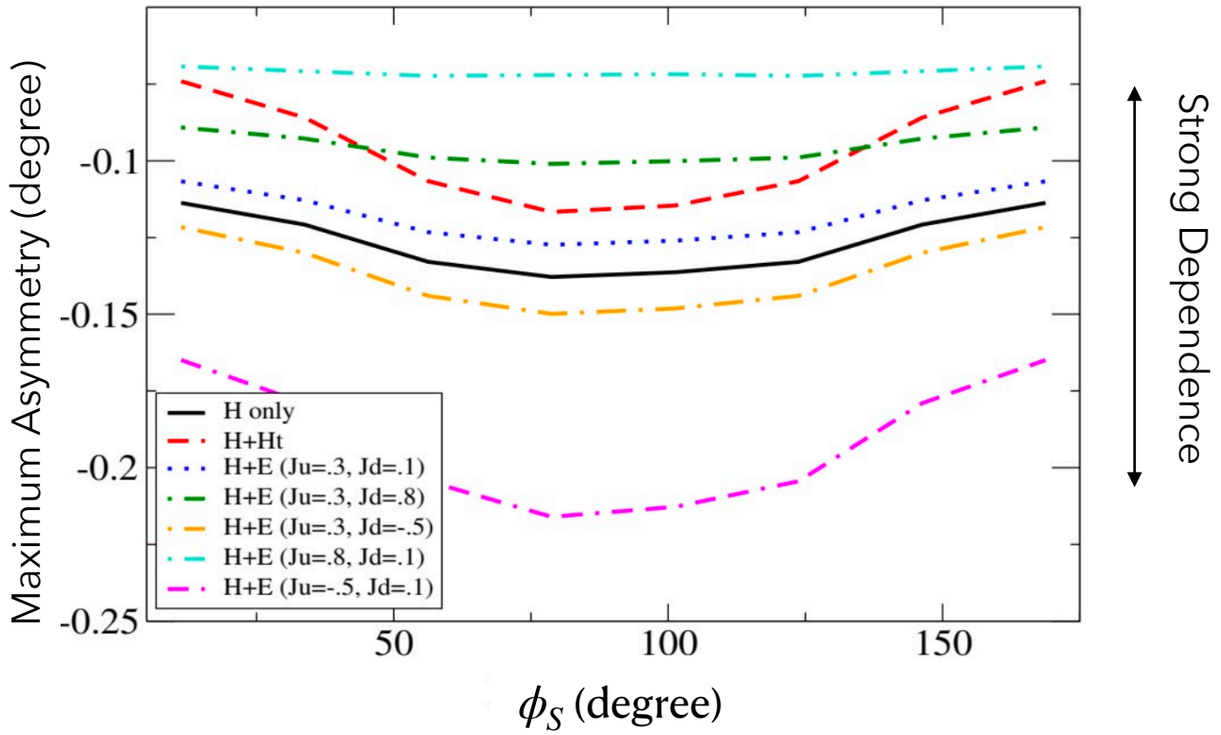
Fig : Geant4 simulation of detector setup at Hall C for proposed polarized TCS experiment

Polarized TCS measurement setup for Hall C

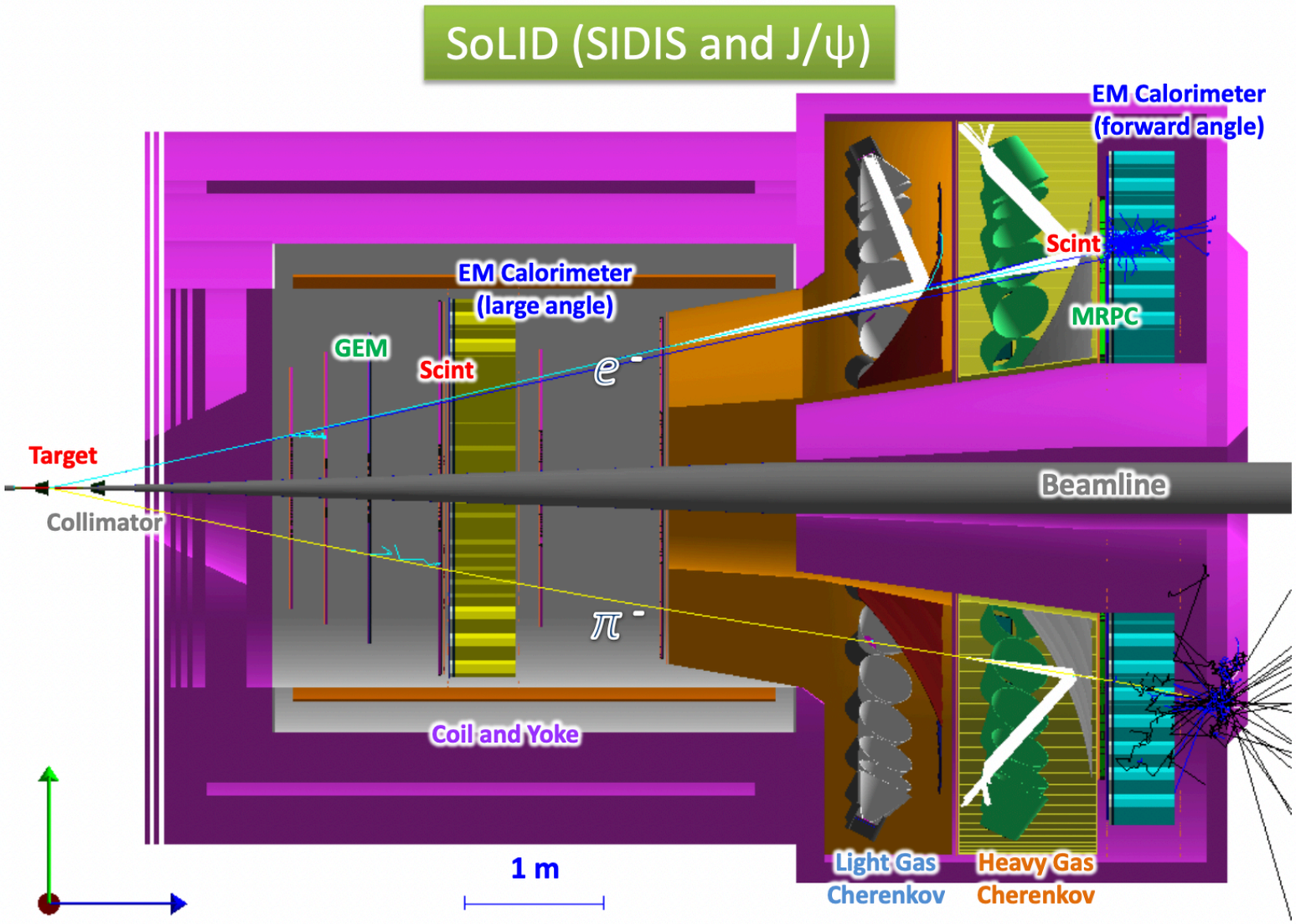
Dependence in GPD parametrization and J_u, J_d (VGG model) vs ϕ and $\phi_S = 0$



$sin(\phi)$ moment of transverse spin asymmetry vs ϕ_S, Dependence in GPD E and $J^{u,d}$ (VGG model)



Unpolarized TCS measurement setup for Hall A



1. Measures unpolarized TCS asymmetry
2. Large Kinematic coverage
3. Not a dedicated Experiment : Run parallel with j/ψ
4. Not as high luminosity compared to Hall C unpolarized
5. Runs in Hall A after Moller
6. Quasi real unpolarized photon beams

Fig: The SIDIS configurations of SoLID setup

Source : https://arxiv.org/pdf/2209.13357.pdf

For Hall B TCS results : see Pierre C. Talk from Monday :
https://indico.jlab.org/event/663/contributions/12955/attachments/10250/15331/Slides_Spin2023_Chatagnon.pdf

Summary

1. DEEPGen simulator (written by M.Boer) is used to generated Unpolarized TCS events
2. Geant4 Simulation for the detector setup is ready
3. Propose to measure both asymmetry and cross-sections
4. Can set a bench mark for the future asymmetry measurements at Hall C
5. This measurement will be dedicated TCS measurement at Hall C
6. Also, can run sooner than SoLID unpolarized TCS proposed experiment
7. Higher statistics compared to SoLID
8. Working on full background simulations for a new PAC proposal
9. In principle it is possible to measure both proton and neutron TCS