Timelike Compton Scattering and DDVCS & beyond At Jefferson Lab with high intensity beams

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ECT* Trento,
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PARTONIC STRUCTURE OF THE HADRONS

Outline

1. Timelike Compton Scattering in Hall C (see Stepan's talk for Hall B)

2. Double Deeply Virtual Compton Scattering in Hall C
(see Sebastian's talk for Hall A and Stepan's for Hall B, Victor's for theory)

3. Other directions – with Hall A, C, D
(see Nikola's talk for gamma-meson phenomenology and Garth's for Hall A)

Also see talks on complementary DVCS programs: Eric, Wassim, Maxime, Stepan…
Patrizia's for overview and 22 GeV extension
Douglas, Marija, Simonetta's talks for collaborative work with EXCLAIM and interpretations

Accessing GPDs through exclusive reactions

<u>Compton like reactions</u>

<u>Meson production</u>

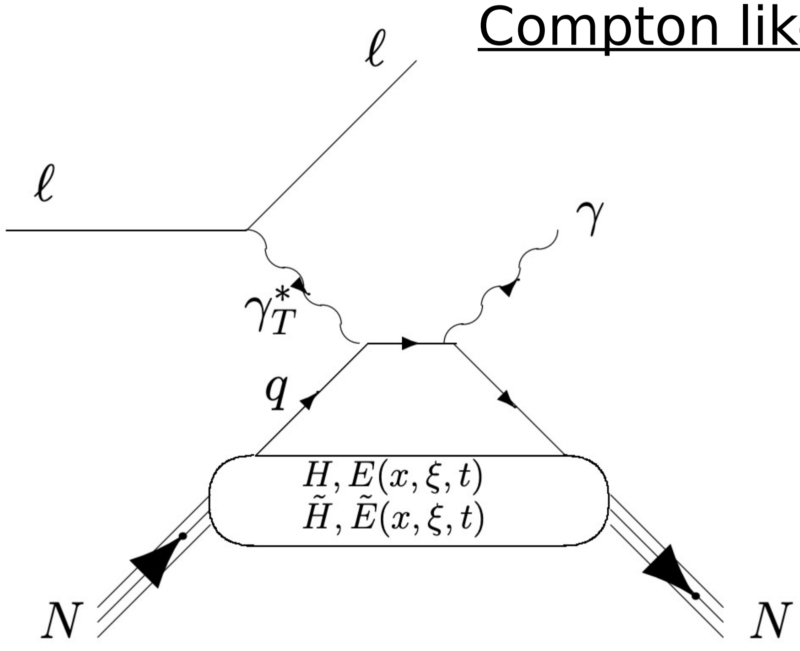


Fig : DVCS

https://arxiv.org/pdf/1511.04535.pdf

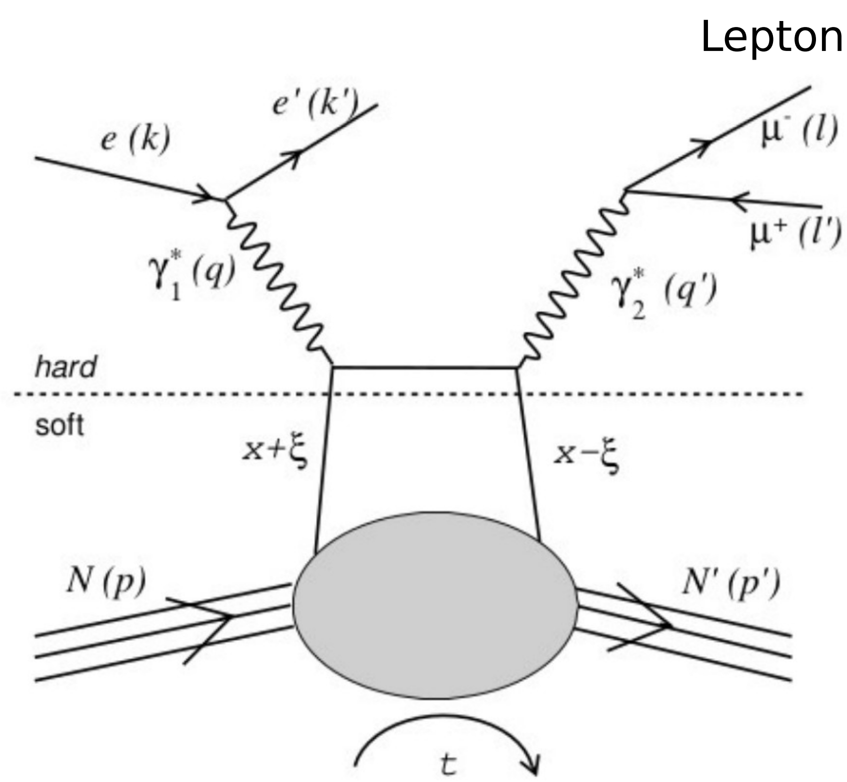


Fig : DDVCS

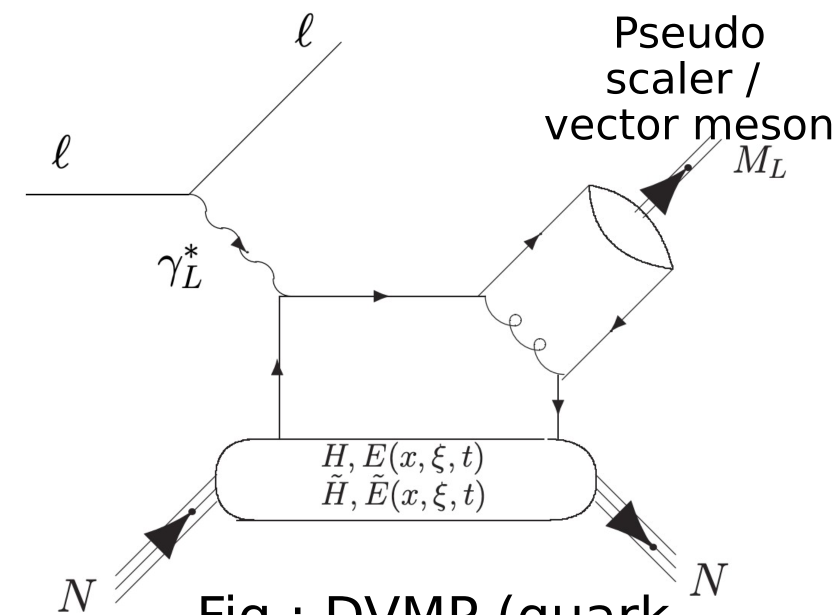


Fig : DVMP (quark Subprocess)

https://arxiv.org/pdf/1511.04535.pdf

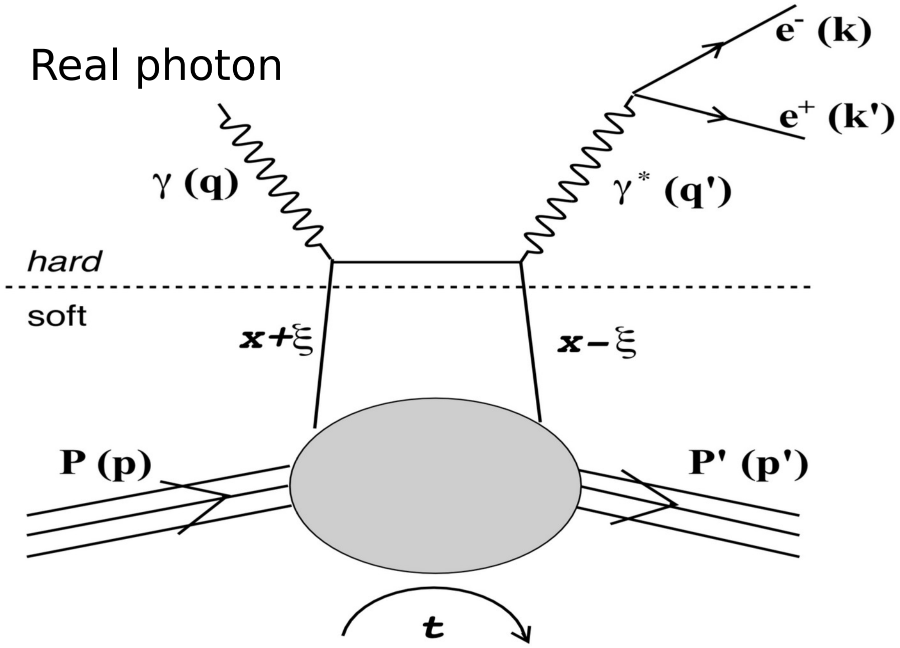


Fig : TCS

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

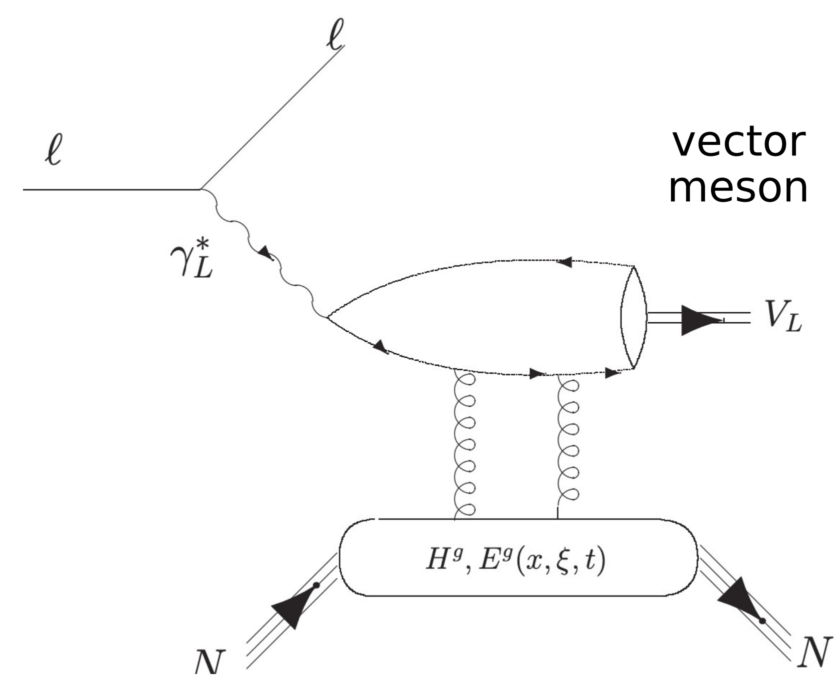


Fig : DVMP (gluon subprocess)

https://arxiv.org/pdf/1511.04535.pdf

Timelike Compton Scattering

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

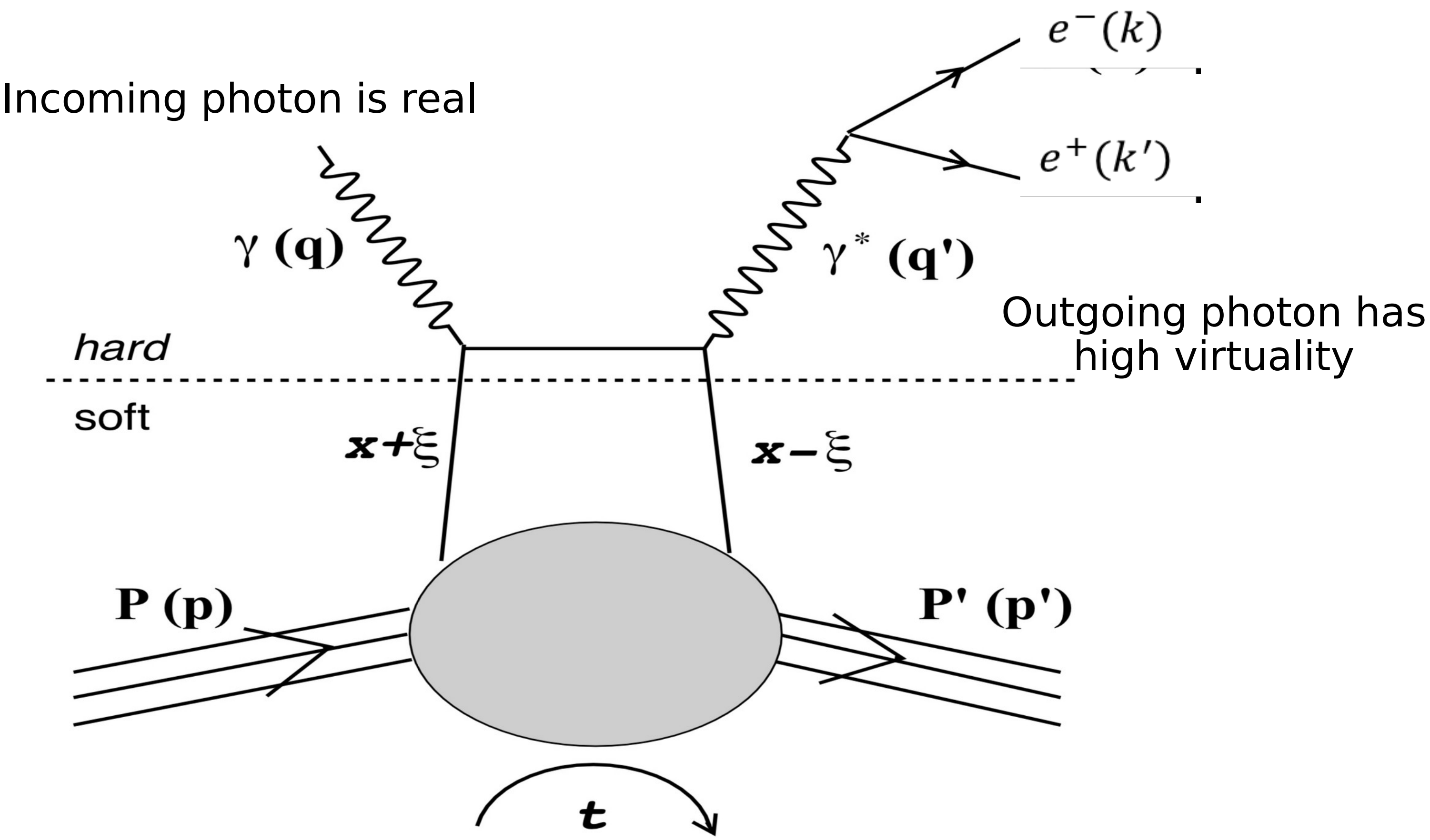


Fig : Time Like Compton Scattering

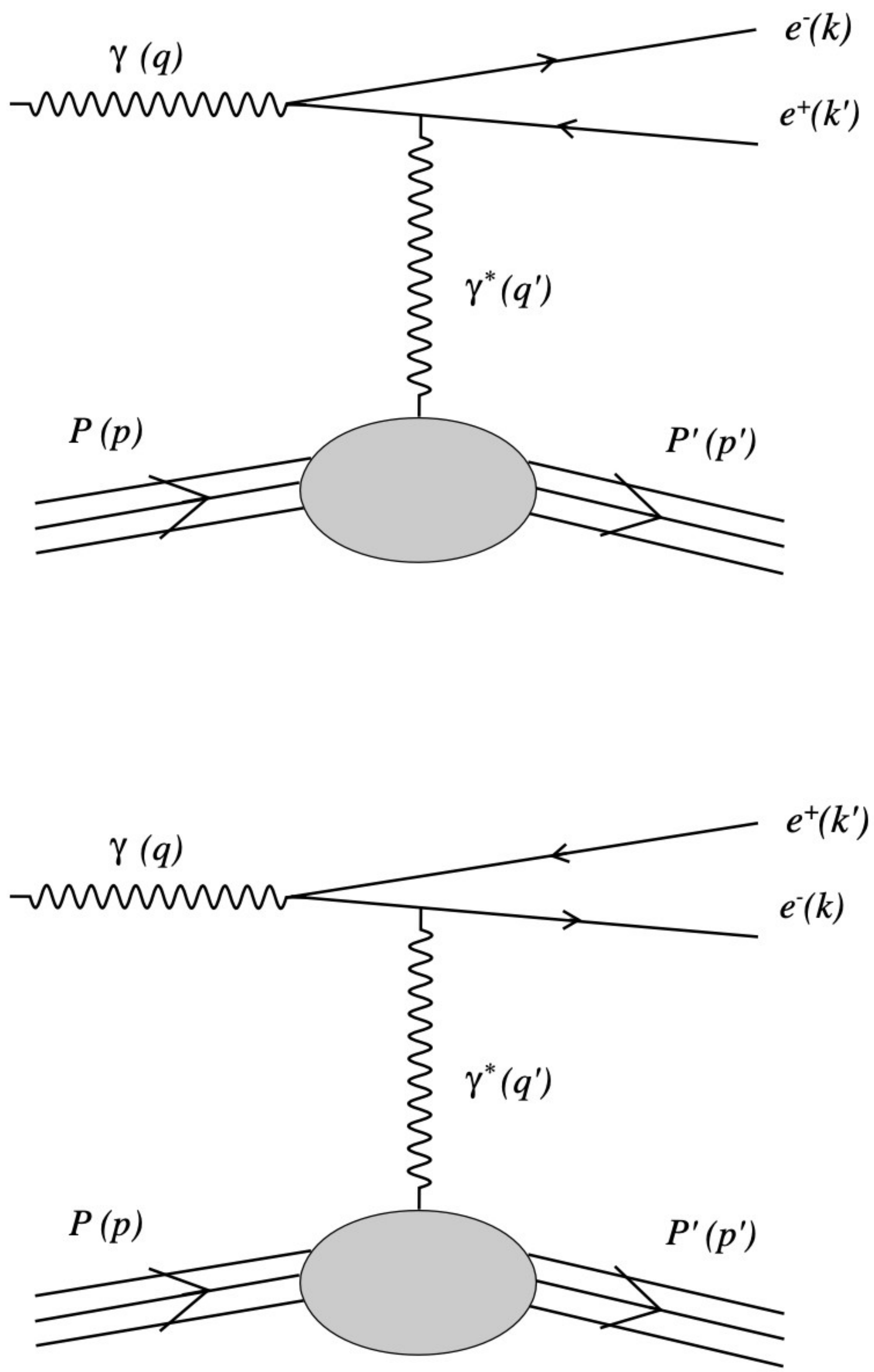
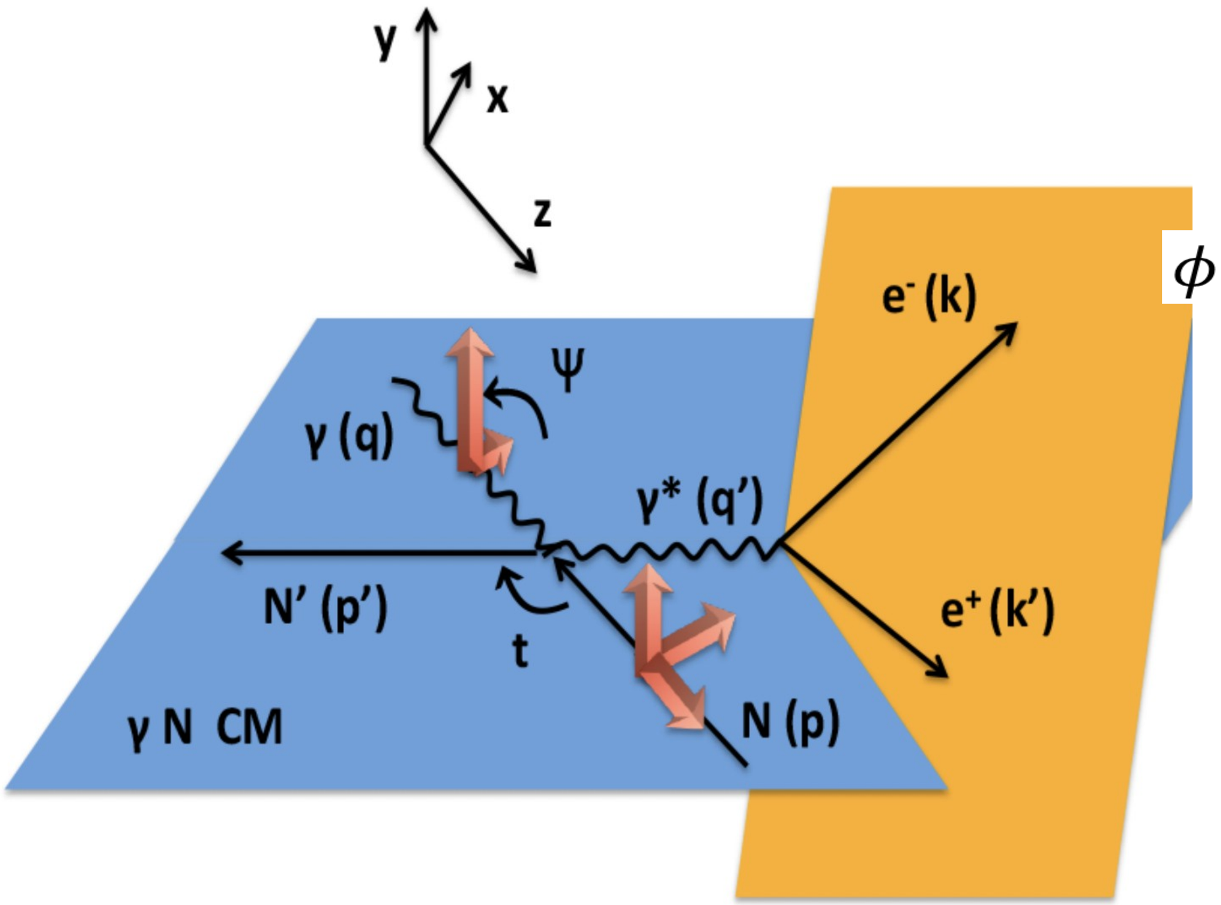


Fig : Bethe-Heitler diagrams

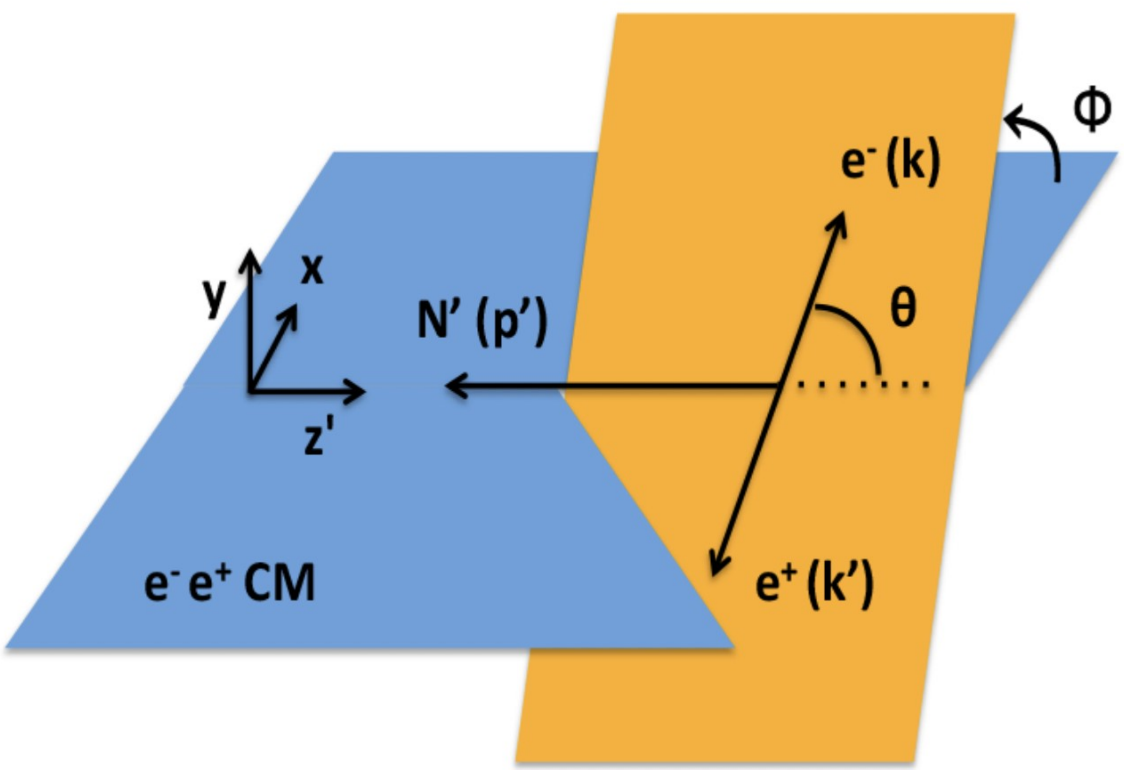
Source : M, Boer. et.al. Eur. Phys. J. A (2015) 51: 103

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 spin orientation vs reaction plane (blue)

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

TCS Program at Jefferson Lab

Observables	GPD	Target	Beam	Experiments
Unpol. cross sections vs ϕ	$\Re(H), \Im(H)$	Unpolarized (Lh2)	unpolarized	ClAS12 , SoLID (future), Unpol. TCS in Hall C
Cross sections vs ϕ	$\Im(H), \Im(\tilde{H})$	Unpolarized (Lh2)	Circularly polarized	ClAS12 , SoLID (future), Unpol. TCS in Hall C
Cross sections vs ϕ & ψ	$\Re(H), D - term$	Unpolarized (Lh2)	Linearly polarized	Possible with GlueX (student just started)
Cross sections vs ϕ	$\Im(\tilde{H})$	Longitudinally polarized target	unpolarized	In progress CLAS12
Cross section vs ϕ & ϕ_S	$\Im(E), \Im(\tilde{H})$	Transversely polarized target	unpolarized	Pol. TCS in Hall C Work in progress
Double spin asym. vs ϕ	$\Re(CFF)$	log. Polarized	Circularly polarized	Extremely interesting but very difficult
Double spin asym. vs ϕ & ϕ_S	$\Re(CFF)$	trans. Polarized	Circularly polarized	Extremely interesting but very difficult
Double spin asym. vs ϕ & ψ	$\Im(CFFs)$	log. Polarized	Longitudinally polarized	Not useful too complex and not enough info
Double spin asym. vs ϕ_S & ψ	$\Im(CFFs)$	trans. Polarized	Longitudinally polarized	Not useful too complex and not enough info

Physics Observables Polarized TCS:
cross section and transverse target spin asymmetry

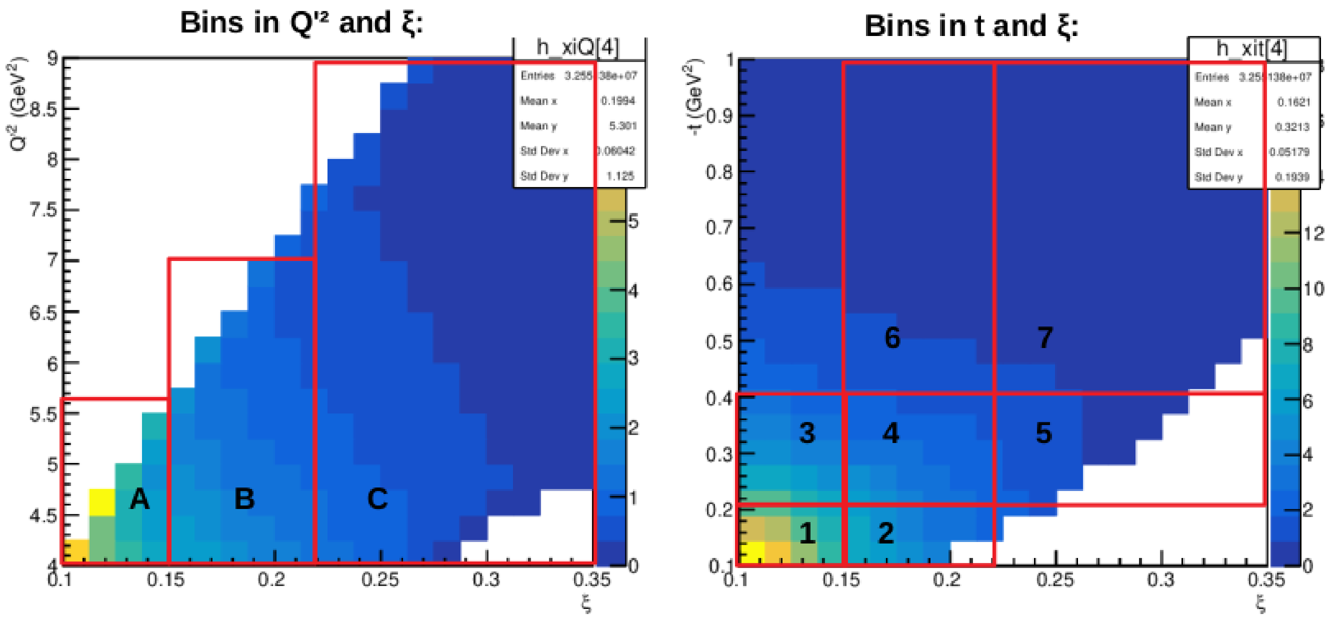
Single Spin Asymmetry (A_{UT}) : unpolarized beam and transversely polarized target

$$A_{UT} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \ldots (1)$$

1. $\sigma^{\pm} \equiv \frac{d^6\sigma}{dQ'^2 dt d\Omega d\phi_s dE_\gamma}$: 6 differential scattering cross-section TCS+BH
2. $\pm$: x direction (+) or y direction (-) of spin ϕ_s of the transversely polarized target
3. 6 differential cross section sensitive to Imaginary part of CFF
4. Asymmetry arises due to the interference between the TCS and BH processes
5. $A_{UT} \propto sin(\phi, \phi_s)$ moment of the $\frac{d^6\sigma^{INT}}{dQ'^2 dt d(cos\theta) d\phi d\phi_s dE_\gamma}$
6. A_{UT} is sensible to the Imaginary part of the amplitude
7. As BH amplitude is purely Real, A_{UT} asymmetry is due to TCS process only

Polarized TCS: kinematic coverage & CFF accuracies

Kinematic coverage



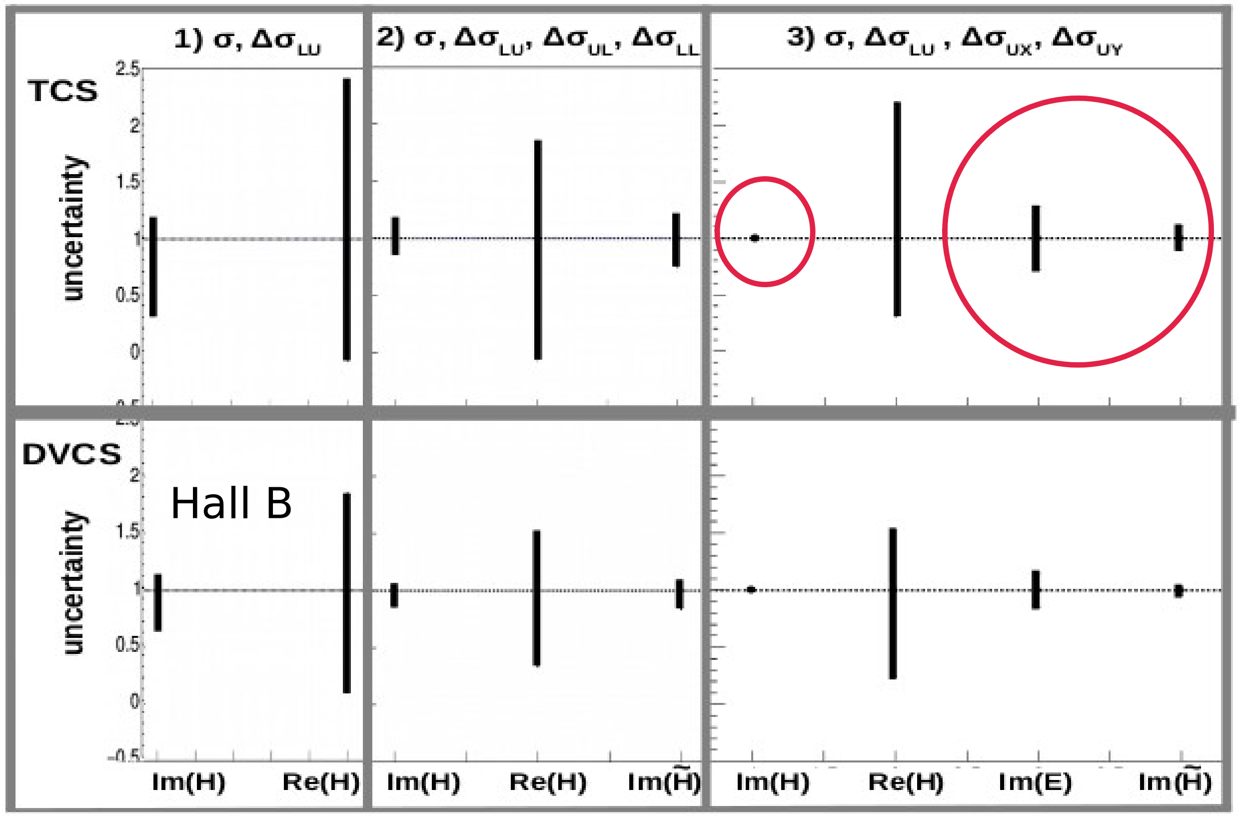
A: .10 < ξ < .15 ; 4 < Q'² < 5.5 GeV²
B: .15 < ξ < .22 ; 4 < Q'² < 7 GeV²
C: .22 < ξ < .35 ; 4 < Q'² < 9 GeV²

1, 2: .1 < -t < .2 GeV²
3, 4, 5: .2 < -t < .35 GeV²
6, 7: .35 < -t < .7 GeV²

Kinematic region out of pion resonance production

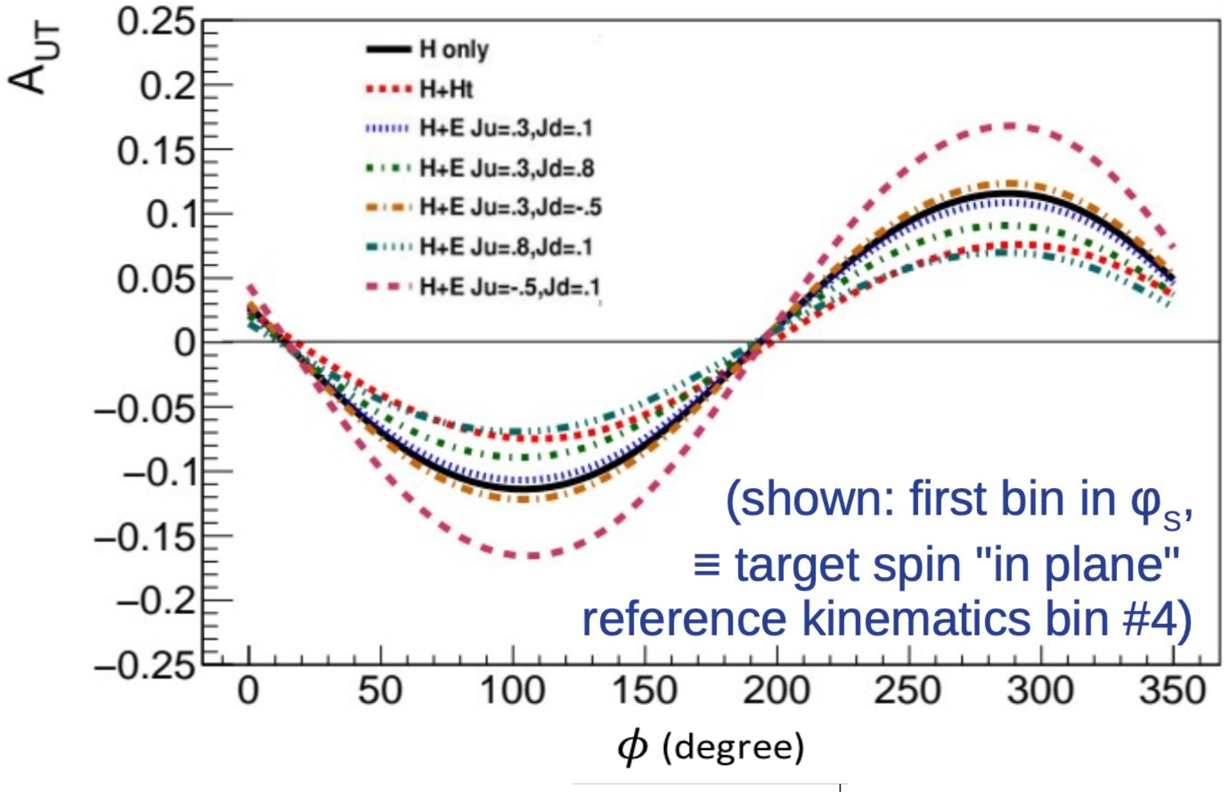
Example estimates of error propagation in extraction of CFFs (used: VGG model)
TCS with trans. pol. Target:

- Allows for extraction of **Im(E)** (**unique to this proposed experiment**)
- Allows for extraction of **Im(H) to good accuracy** (**universality tests**)

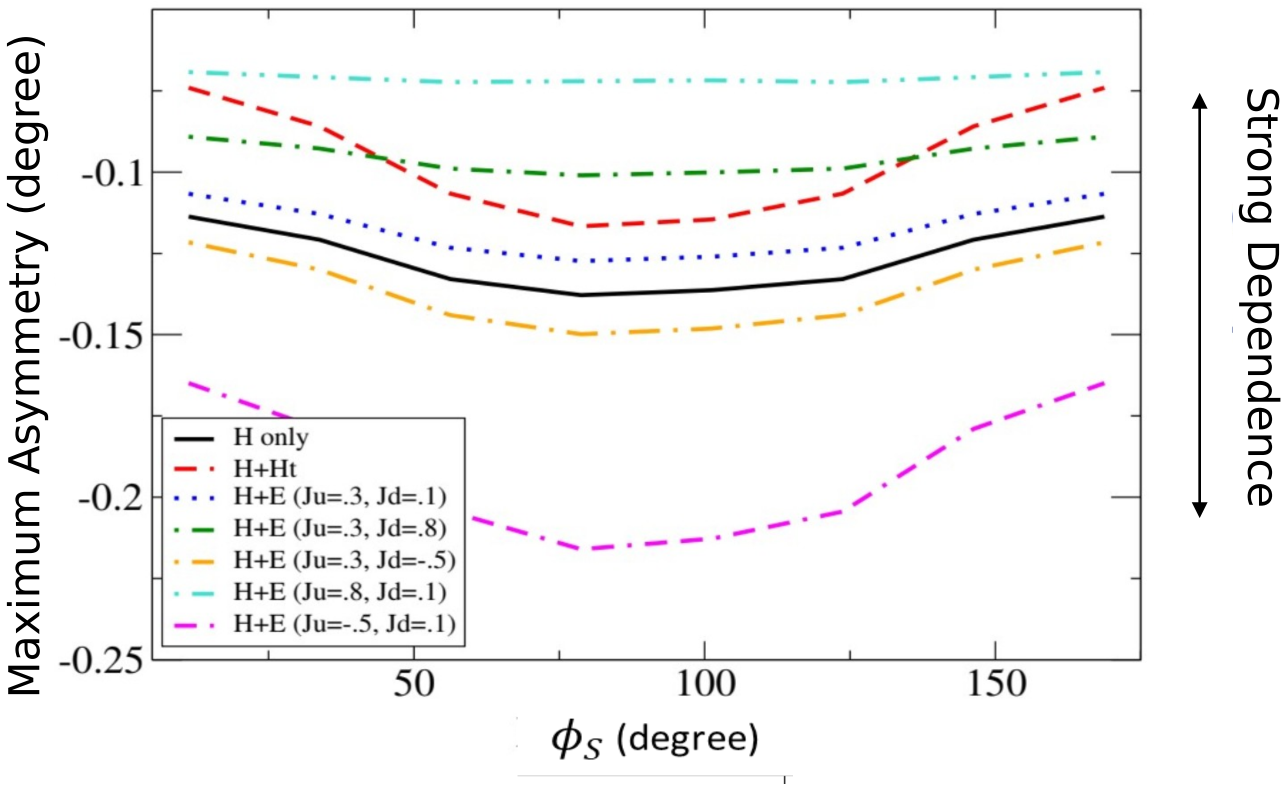


Polarized TCS: projected asymmetry

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



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



High sensitivity with spin of different quarks ($J^{u,d}$)

Polarized TCS measurement setup for Hall C

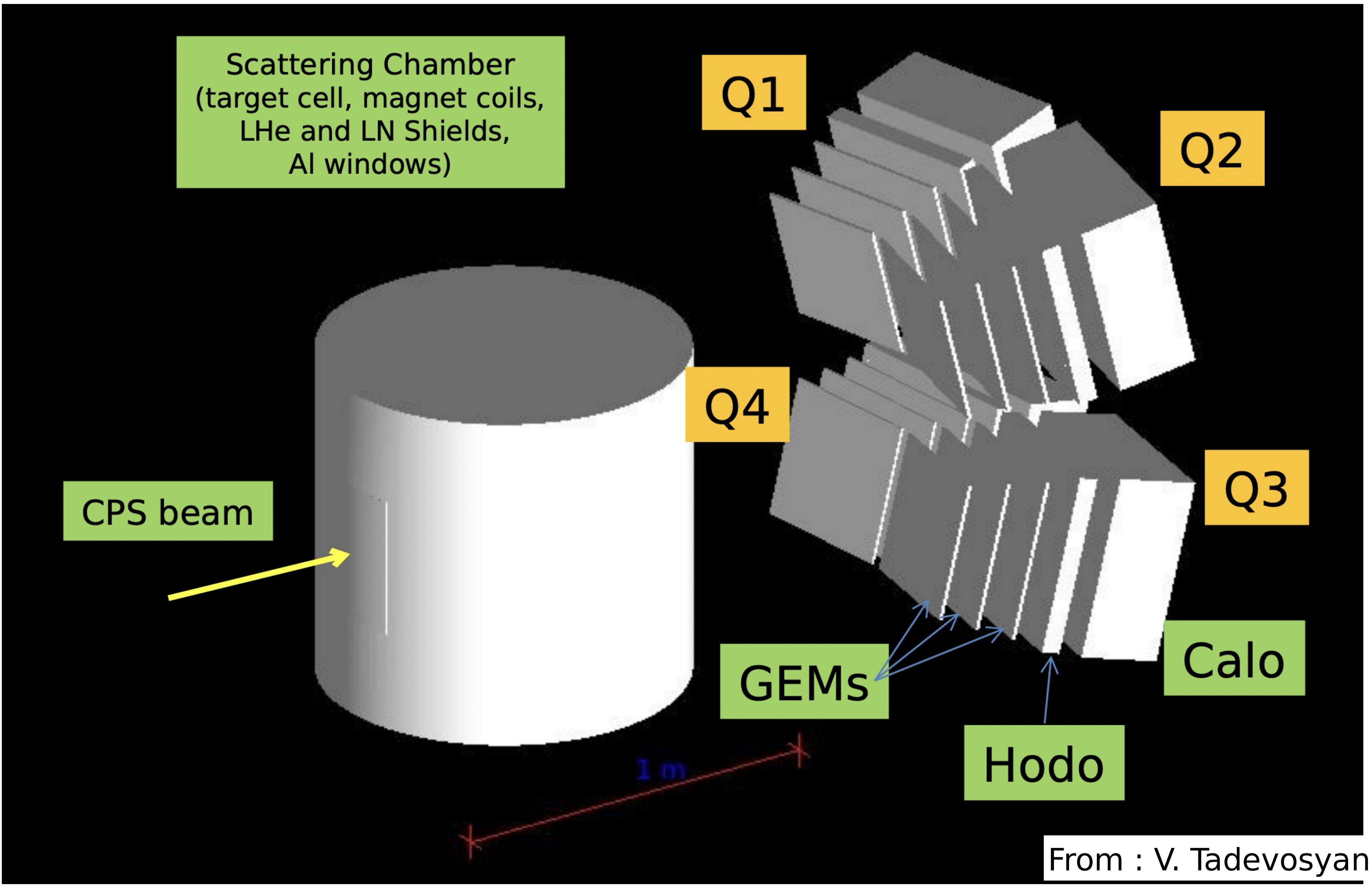


Fig : Geant4 simulation of detector setup at Hall C for proposed polarized TCS experiment

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 10^5 pb-1

Compact photon source

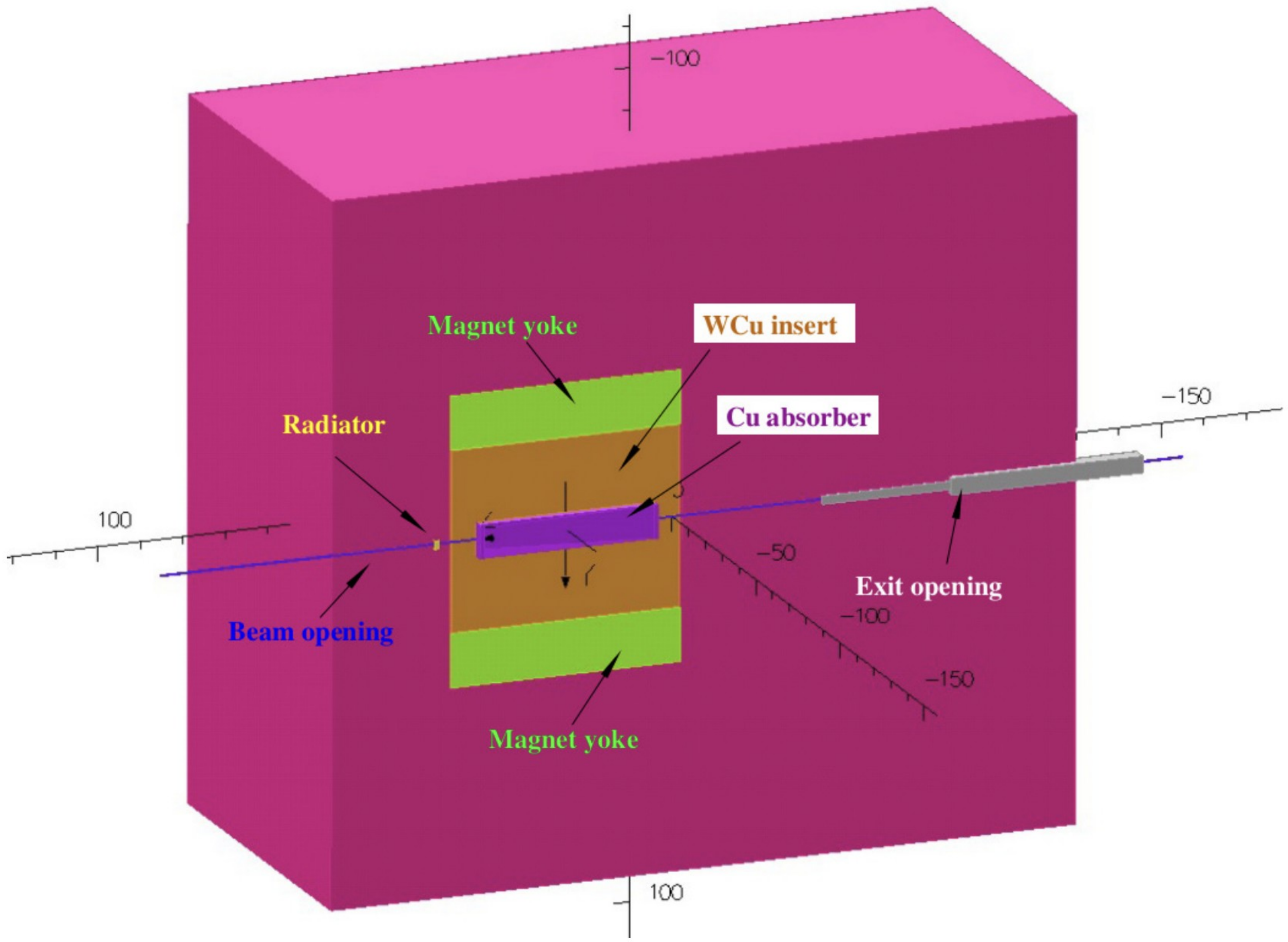


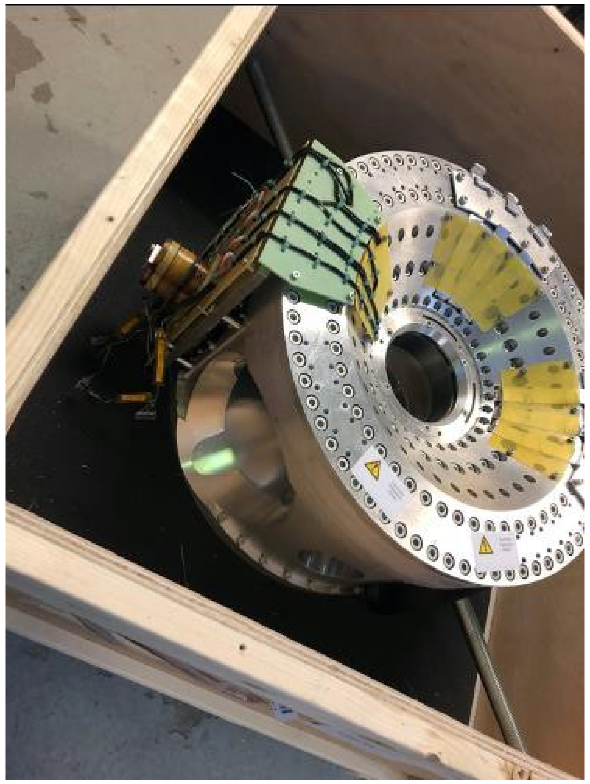
Fig : The CPS Cut off view

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

1. Spot size $\sim 0.9mm$ 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 $> 0.5E_{beam}$
4. T warm magnet to bend incoming electrons to local beam dump
5. Source : D.Day et al., NIMA 957 (2020) 163429

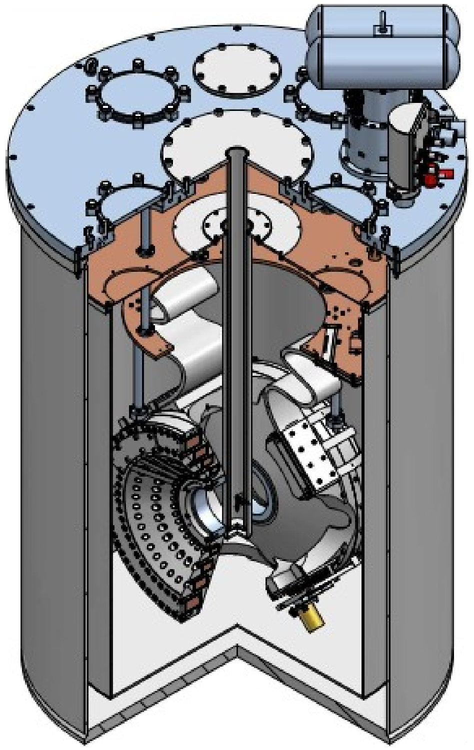
Polarized target

- Target material: $^{15}NH_3$, in LHe at 1°K.
- Packing fraction 0.6.
- Magnetic field generated by superconducting Helmhotz coils.
- DNP polarization by 140 GHz, 20 W RF field.
- Polarization monitored via NMR.
- Depolarization mitigated by combined rotation (~1 Hz) around horizontal axis and vertical up/down movement (~10 mm).



<u>New polarizing magnet arrived in September 2021!</u>

- Drop-in replacement for old Jlab-UVA target
- 5 T magnetic field, 100 ppm uniformity
- ±25° horizontal opening angle in transverse field configuration (increase from ±18° --> increase of TCS acceptance, help with background rates.)



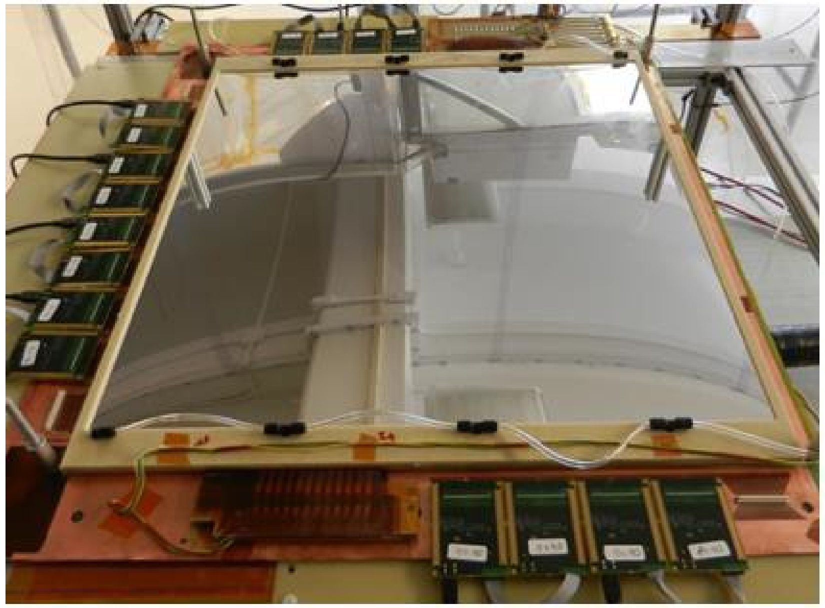
Horizontal field orientation

GEM Tracker , Hodoscope & Calorimeter

<u>GEM trackers:</u>

- Coordinate reconstruction accuracy $\sim 80\mu m$
- Background rate tolerance up to $10^6 Hz/mm^2$
- Minimum material thickness along particle pass
- Big size manufacturing

Use at JLab: SBS, SoLID DDVCS, Prad



SBS BT GEM prototype
(K.Gnanvo et al., NIMA 782 (2015) 77-86)

<u>Hodoscopes:</u>

- To provide dE/dX signal from low momentum recoil protons
- 2x2x5 cm^3 scintillators arranged in "Fly's eye" hodoscopic construction

<u>Calorimeters, clones of the NPS calorimeter:</u>

- 2x2x20 cm^2 $PBWO_4$ scintillator crystals, optically isolated
- Modules arranged in a mesh of carbon fiber/μ-metal
- Expected energy resolution 2.5%/√E + 1%
- Expected coordinate resolution ~3 mm at 1 GeV
- Modules arranged in 4 "fly's eye" assemblies of 23x23 matrix

Total number of modules needed 2116.

Assembling of NPS calorimeter (June 2022)

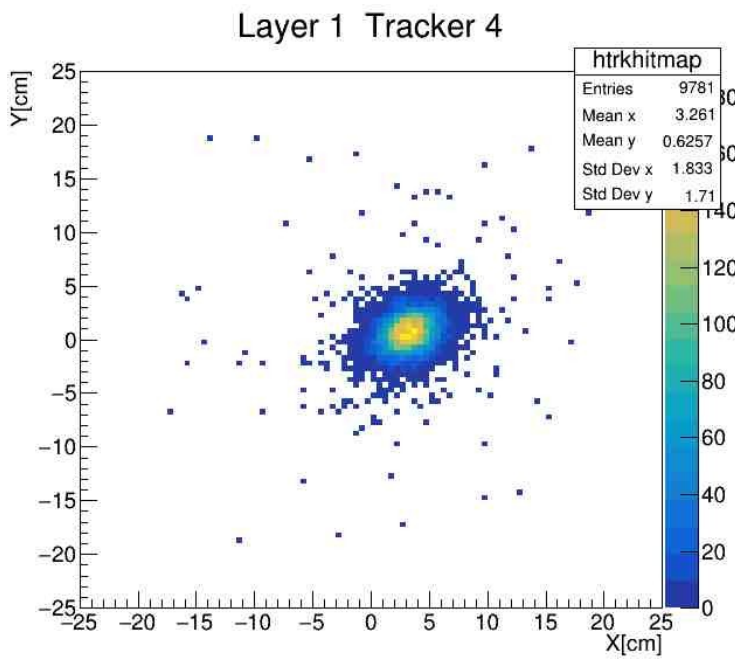
Polarized TCS : Recoil proton ID

Low energy protons : E_{kin} ~ 30 MeV - 450 MeV

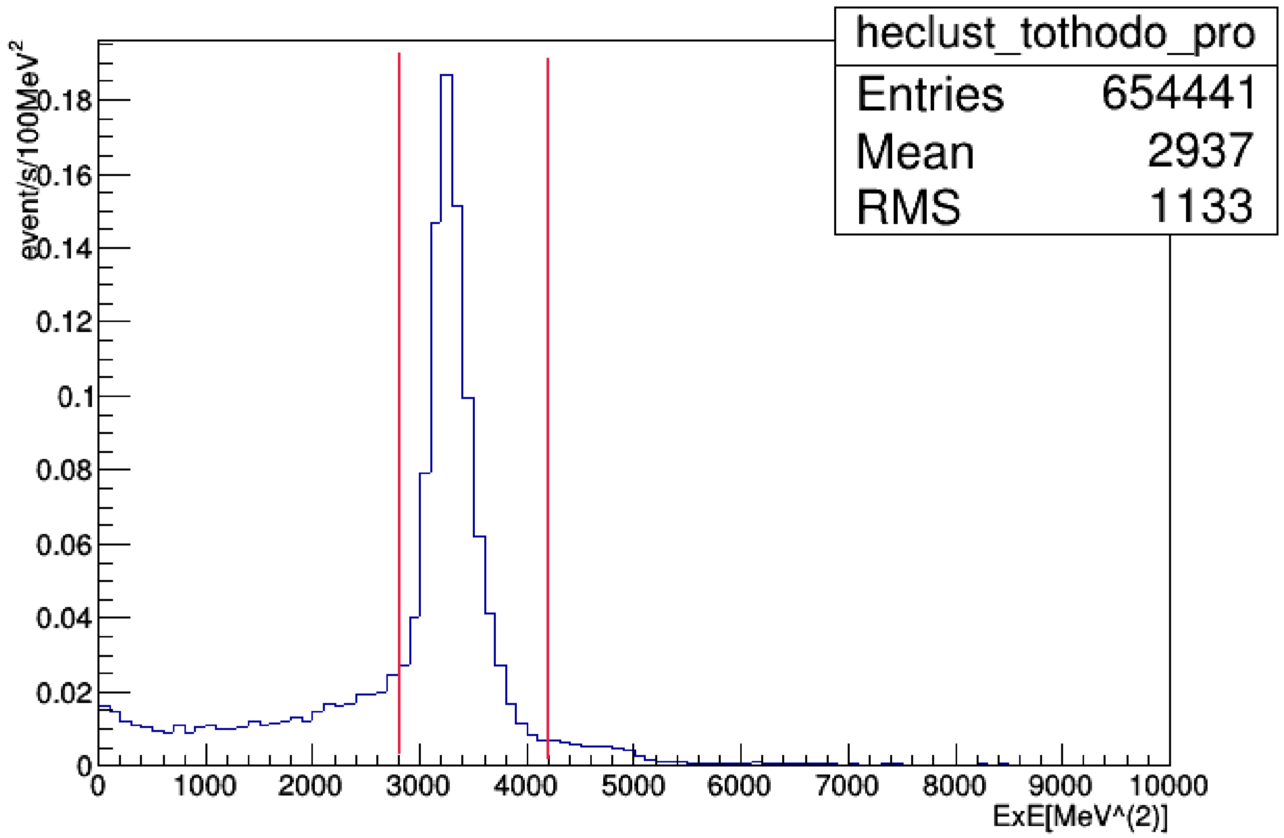
Cuts to select good protons :

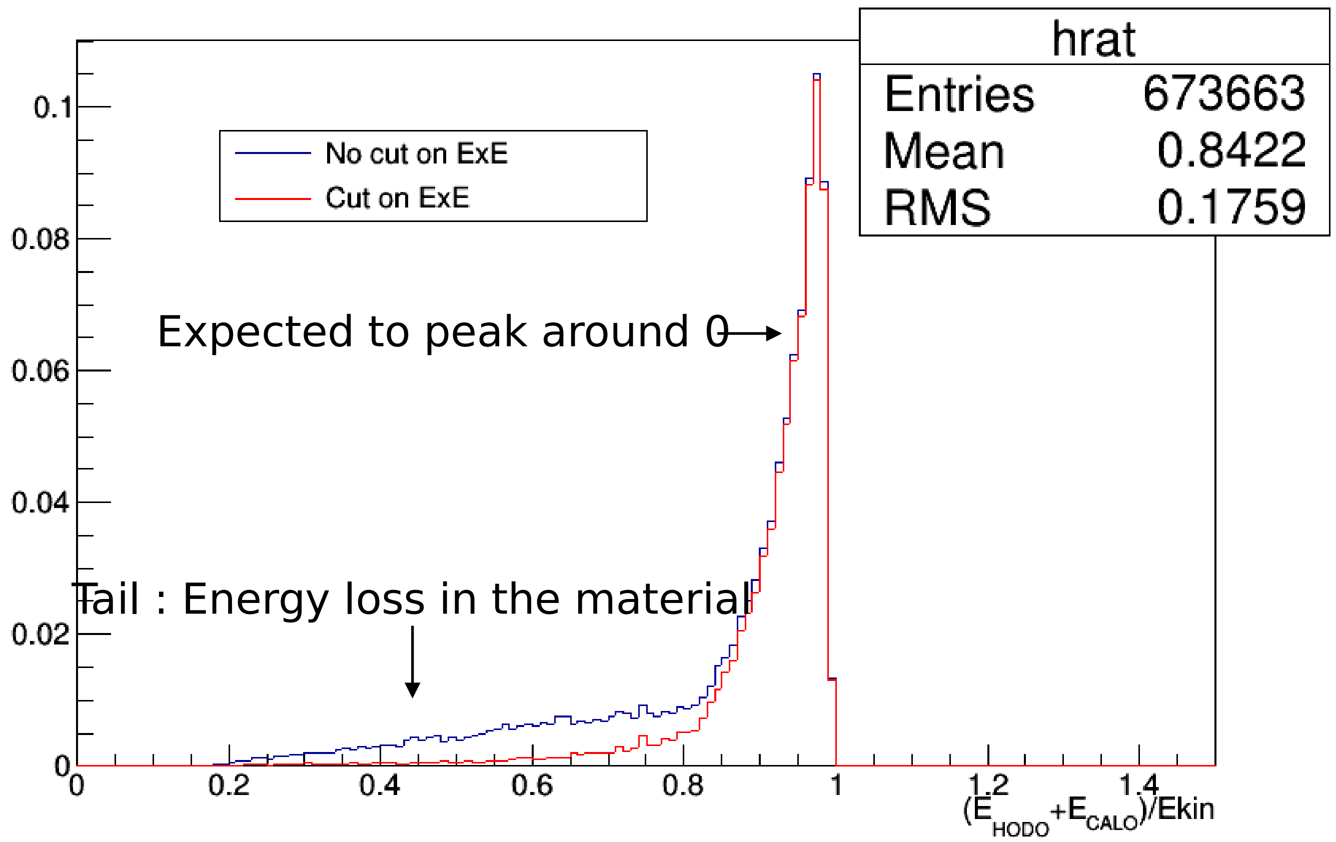
1. $E_{HODO} > 15$ MeV
2. 90 MeV $< E_{HODO} + E_{CALO} <$ 450 MeV
3. 2800 $MeV^2 < E.E <$ 4200 MeV^2

Where $E.E = (E_{HODO} + E_{CALO} - 12).(E_{HODO} - 7)$



GEM hit patter from 400 MeV/C protons





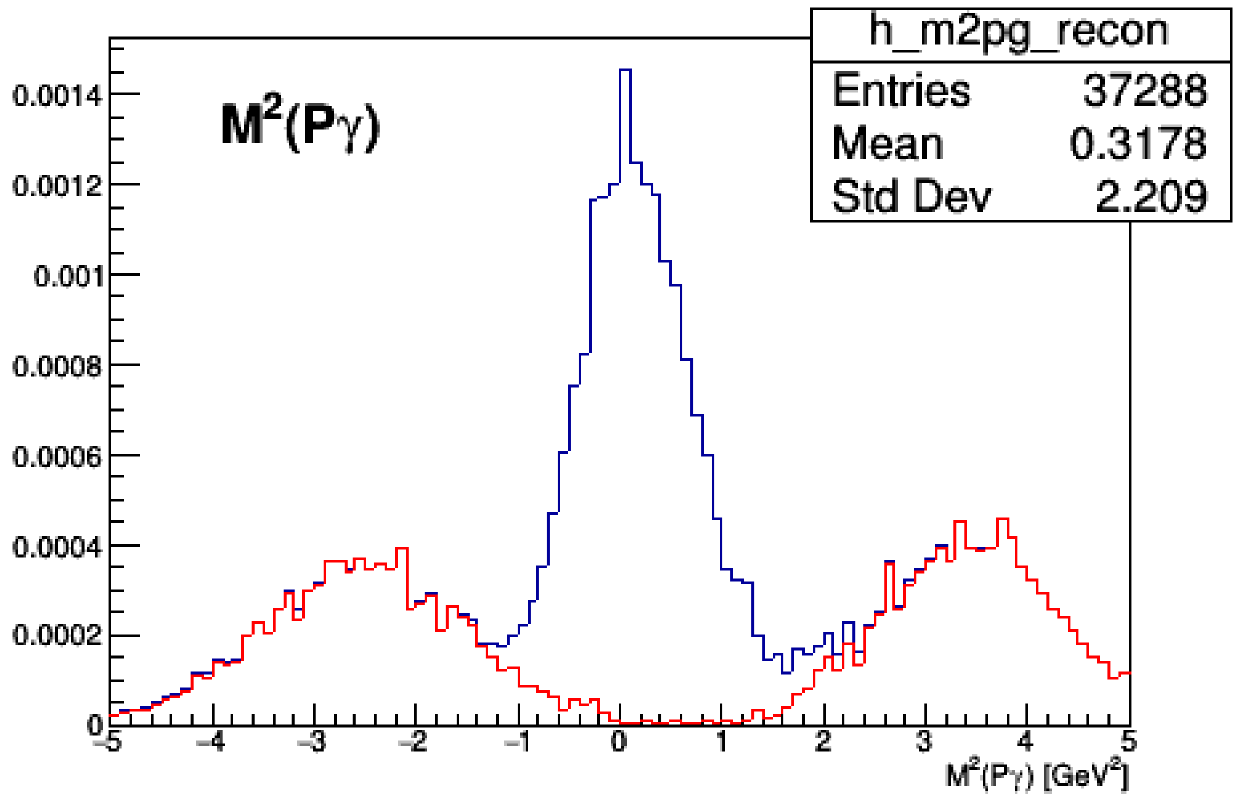
From : Vardan Tadevosyan

Polarized TCS : Lepton charge assignment

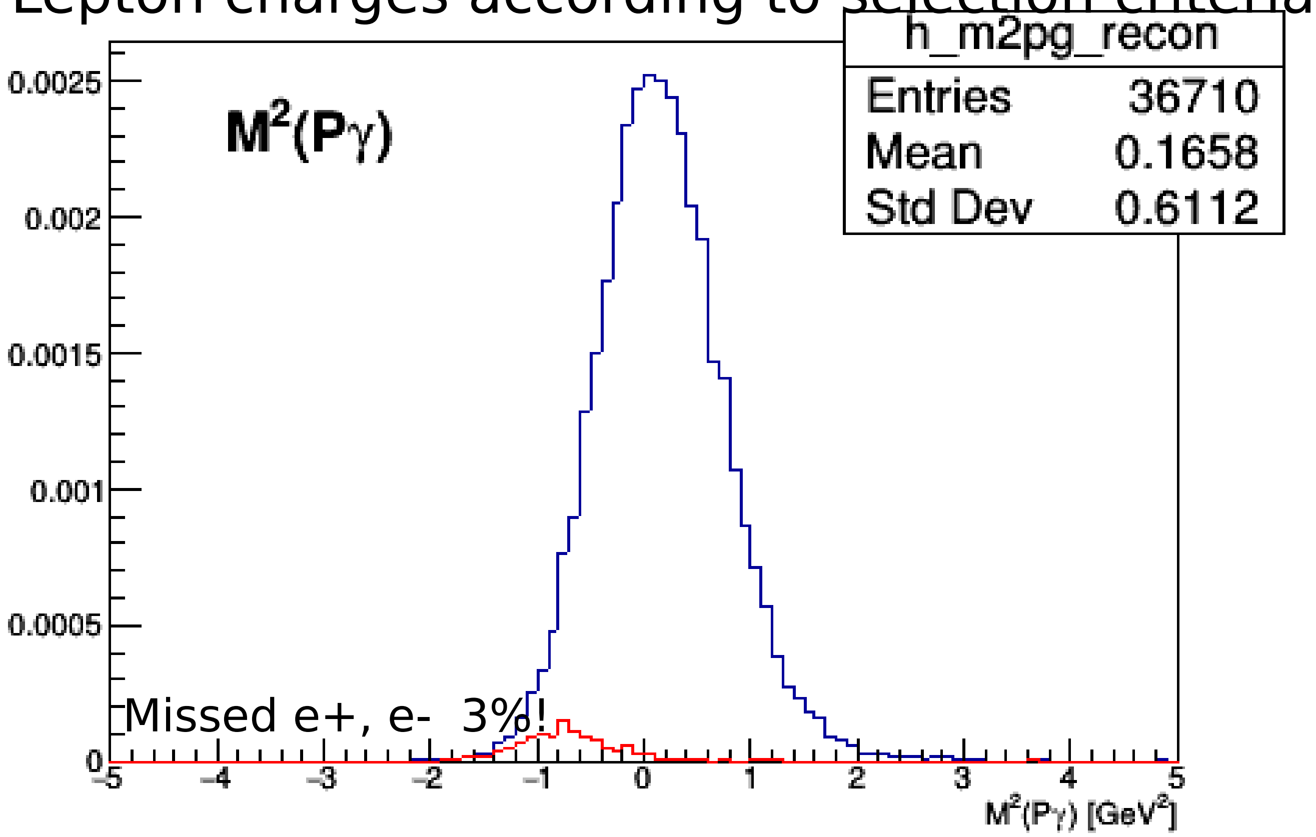
5T target field localized at target cell
Field behind scattering chamber too weak to distinguish pos. and neg. tracks.
Alternative: use reconstructed incident photon mass:

- Reconstruct recoil proton;
- Reconstruct leptons twice, by assigning (+,-) and (-,+) charges;
- Combine with reconstructed proton to get 2 masses, choose smaller one.

Random lepton charge assignment

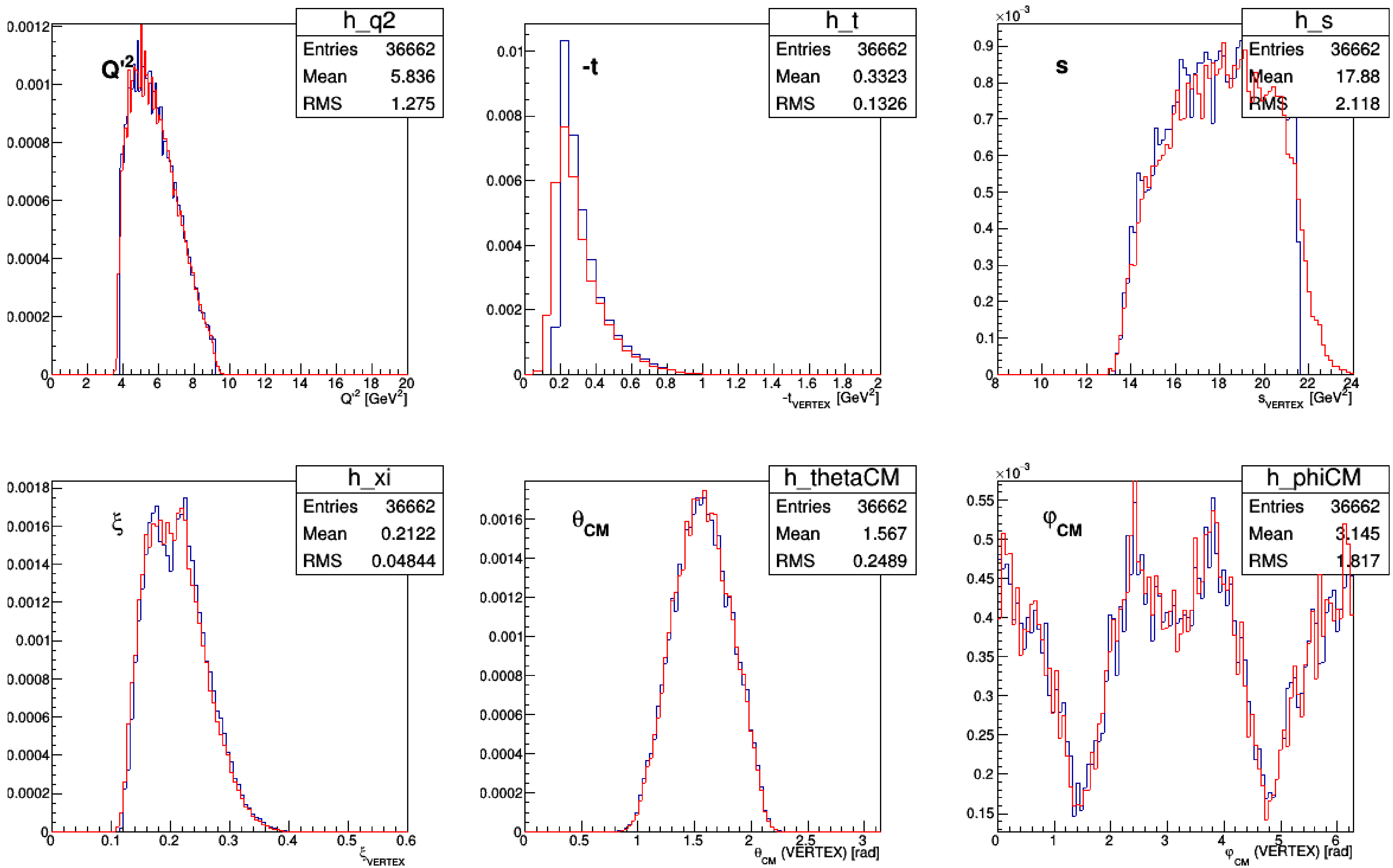


Lepton charges according to selection criteria



From : Vardan Tadevosyan

Polarized TCS : reconstructed vs true quantities



From : Vardan Tadevosyan

Physics Observables Unpolarized TCS :
unpolarized cross section and polarized beam spin asymmetry

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

$$A_{\odot U} = \frac{\sigma^{+} - \sigma^{-}}{\sigma^{+} + \sigma^{-}} \ldots (2)$$

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

Scattering Chamber & Target

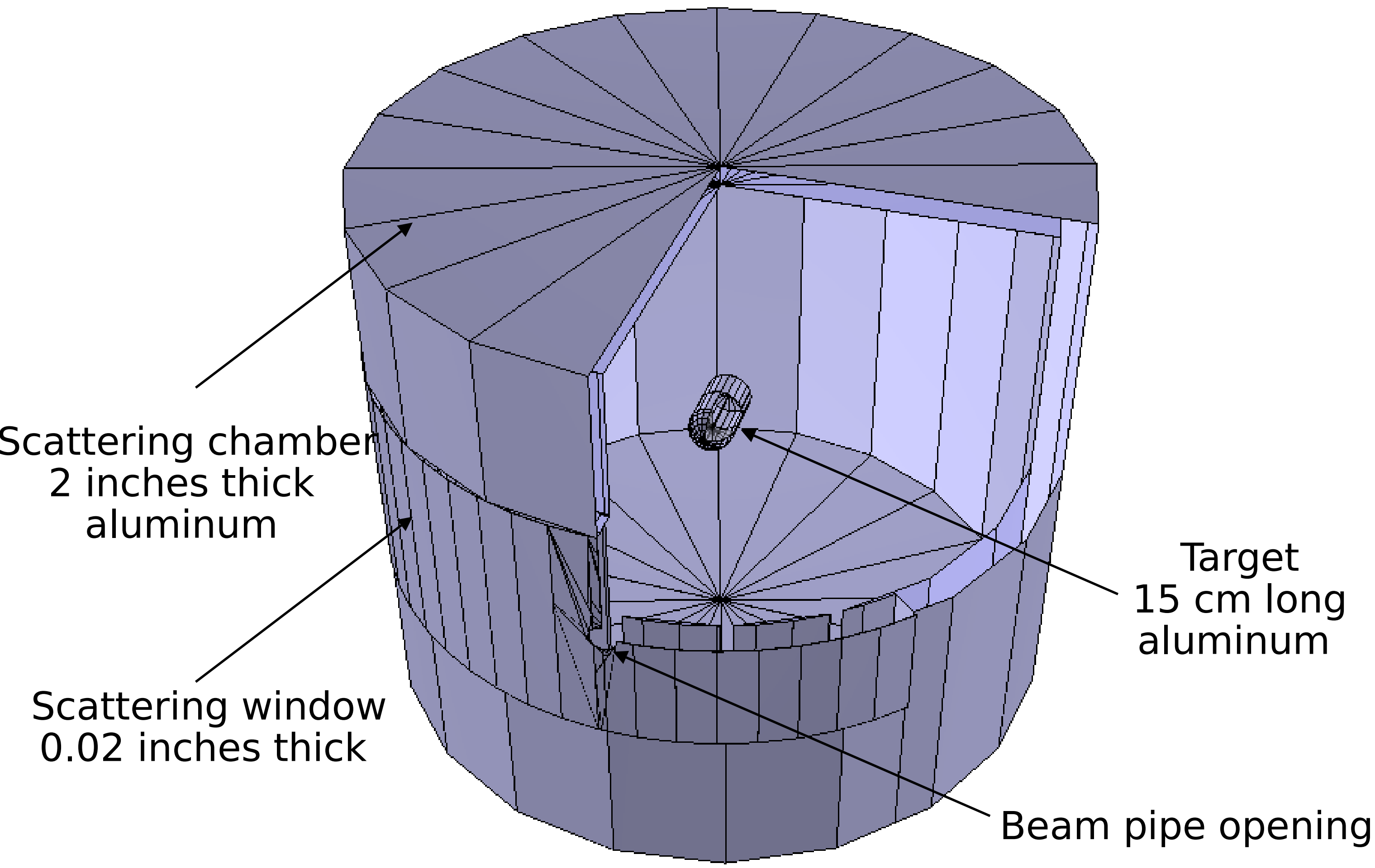


Fig : Geant4 simulation of scattering chamber and target

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 : $\pm$17.3 degrees
6. Target thickness of Entrance and exit cap = 0.1778 cm
7. Target cell wall thickness = 0.0254 cm

Calorimeter

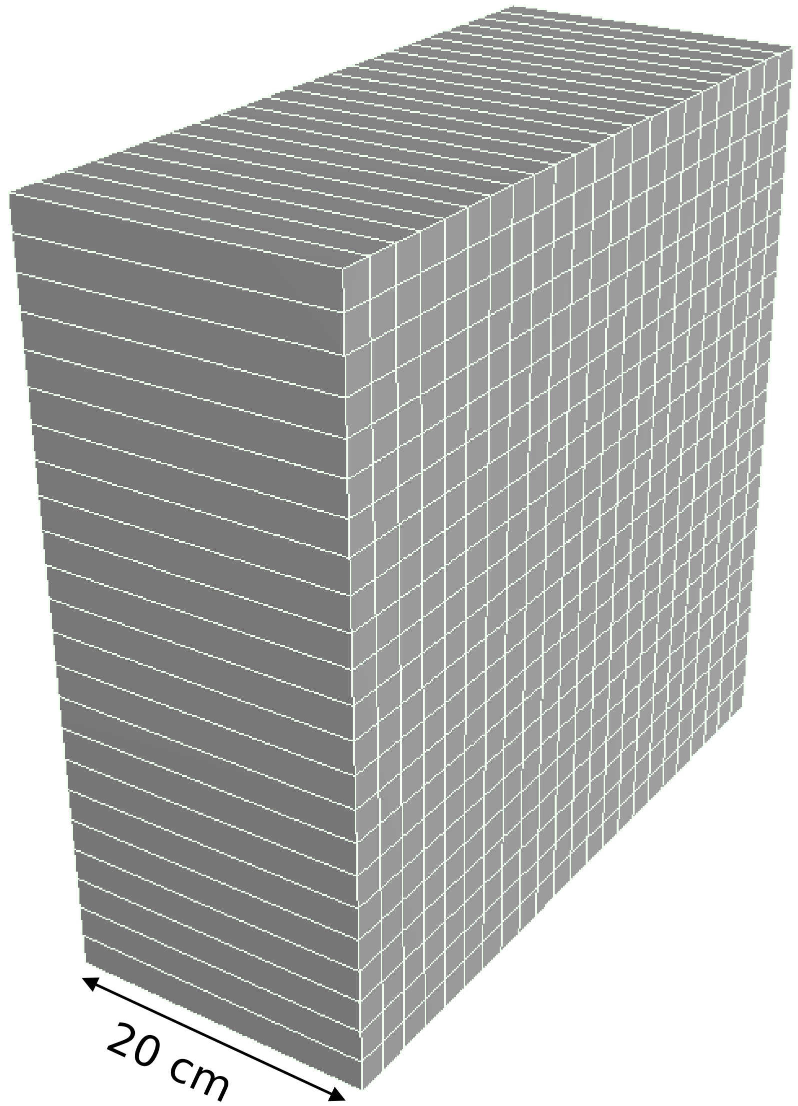


Fig : Geant4 simulation calorimeter

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

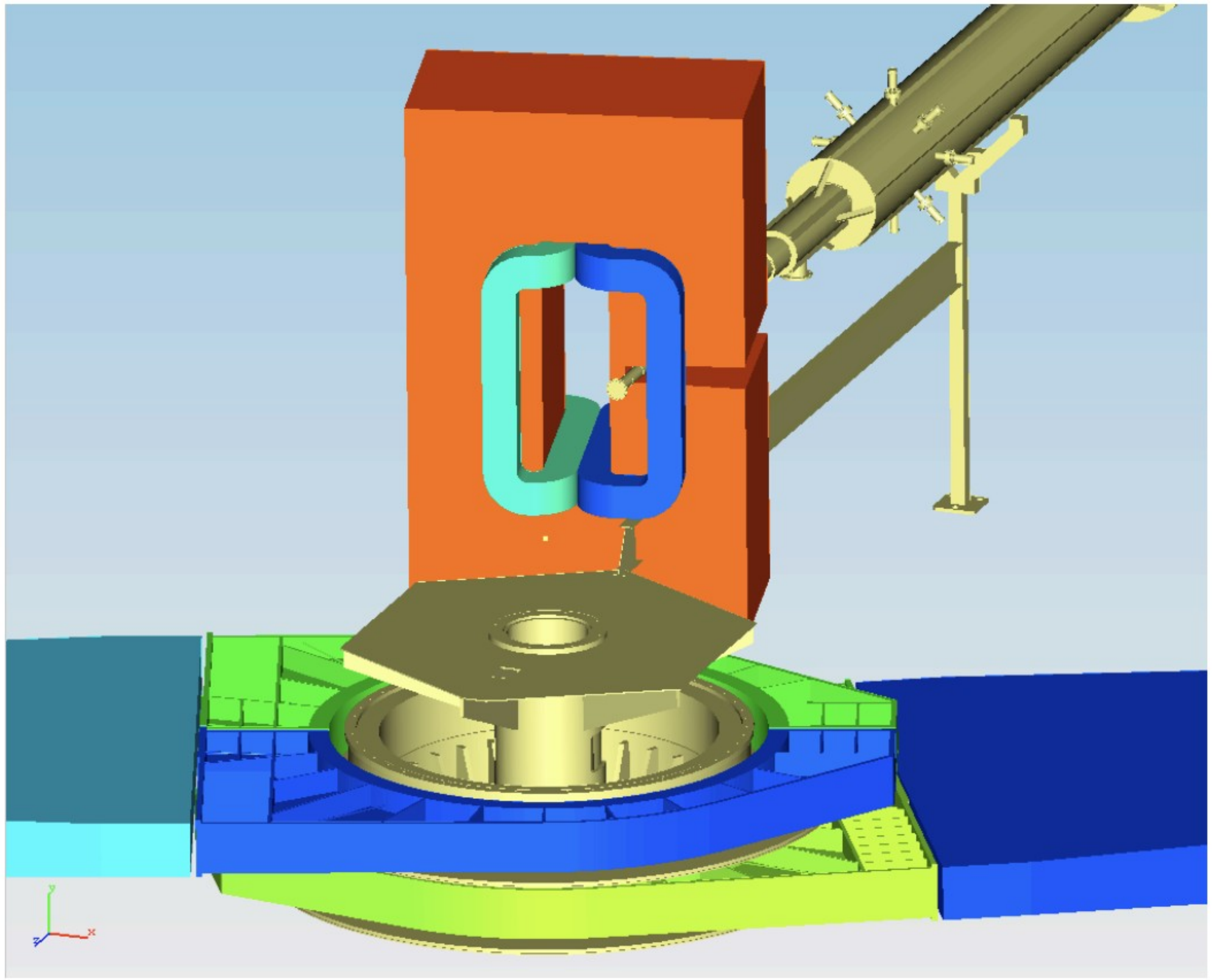


Fig : CAD Drawing for Super Bigbite Magnet

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

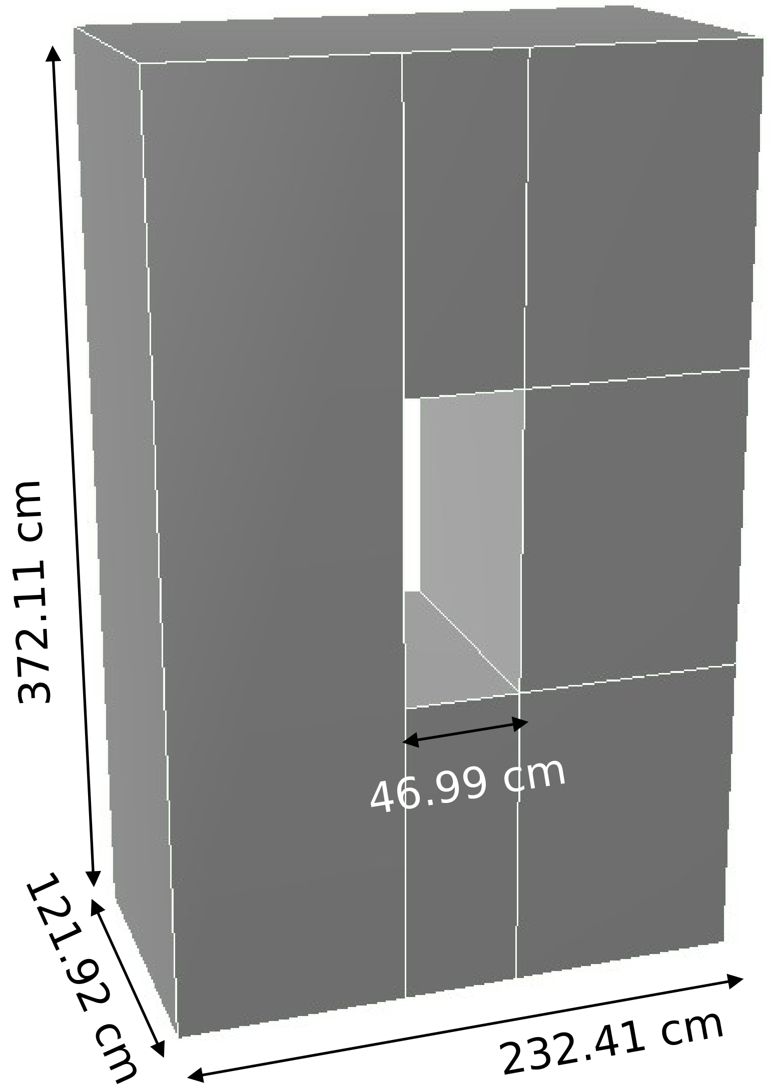
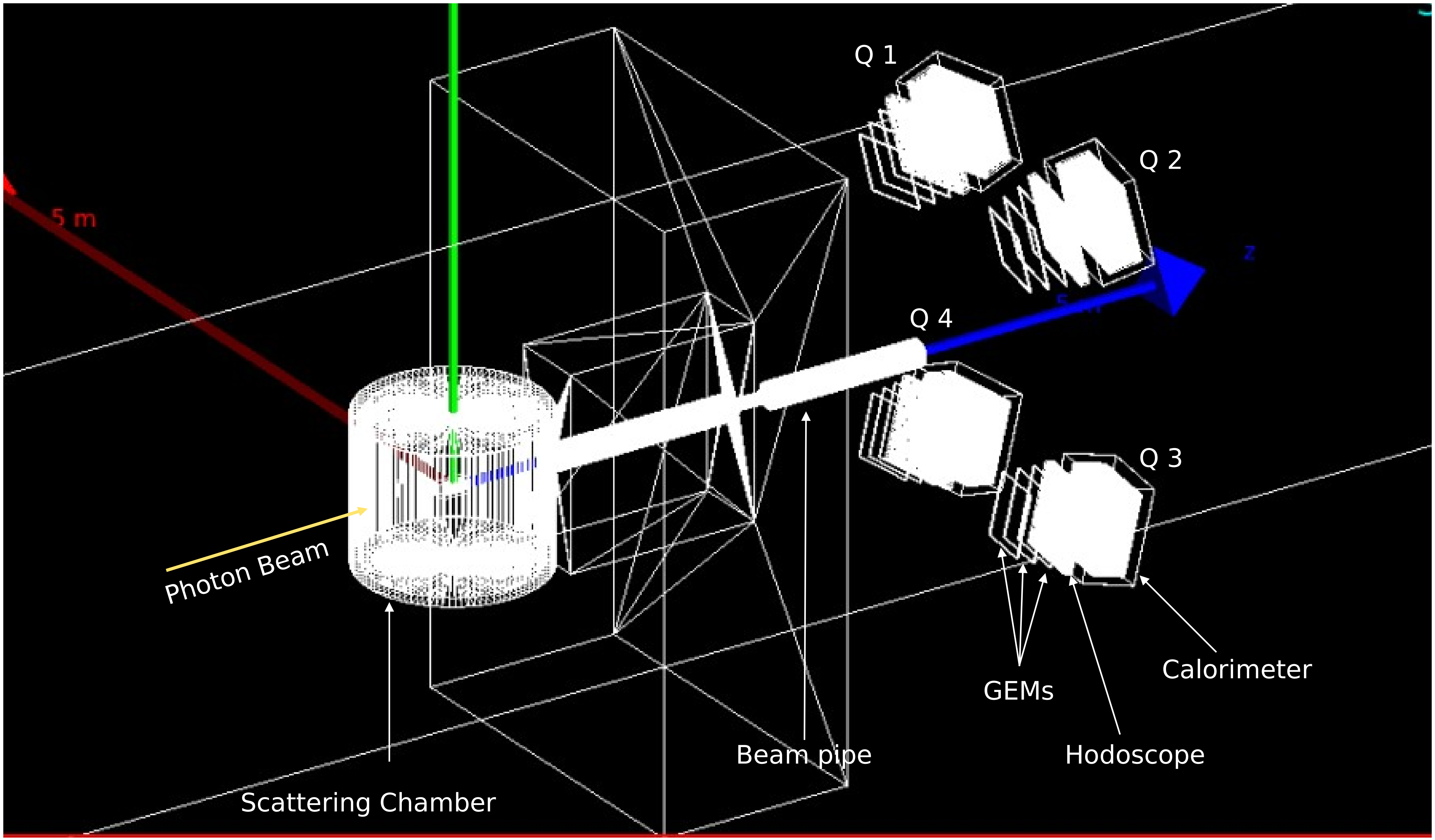


Fig : Geant4 simulation of simple magnet geometry

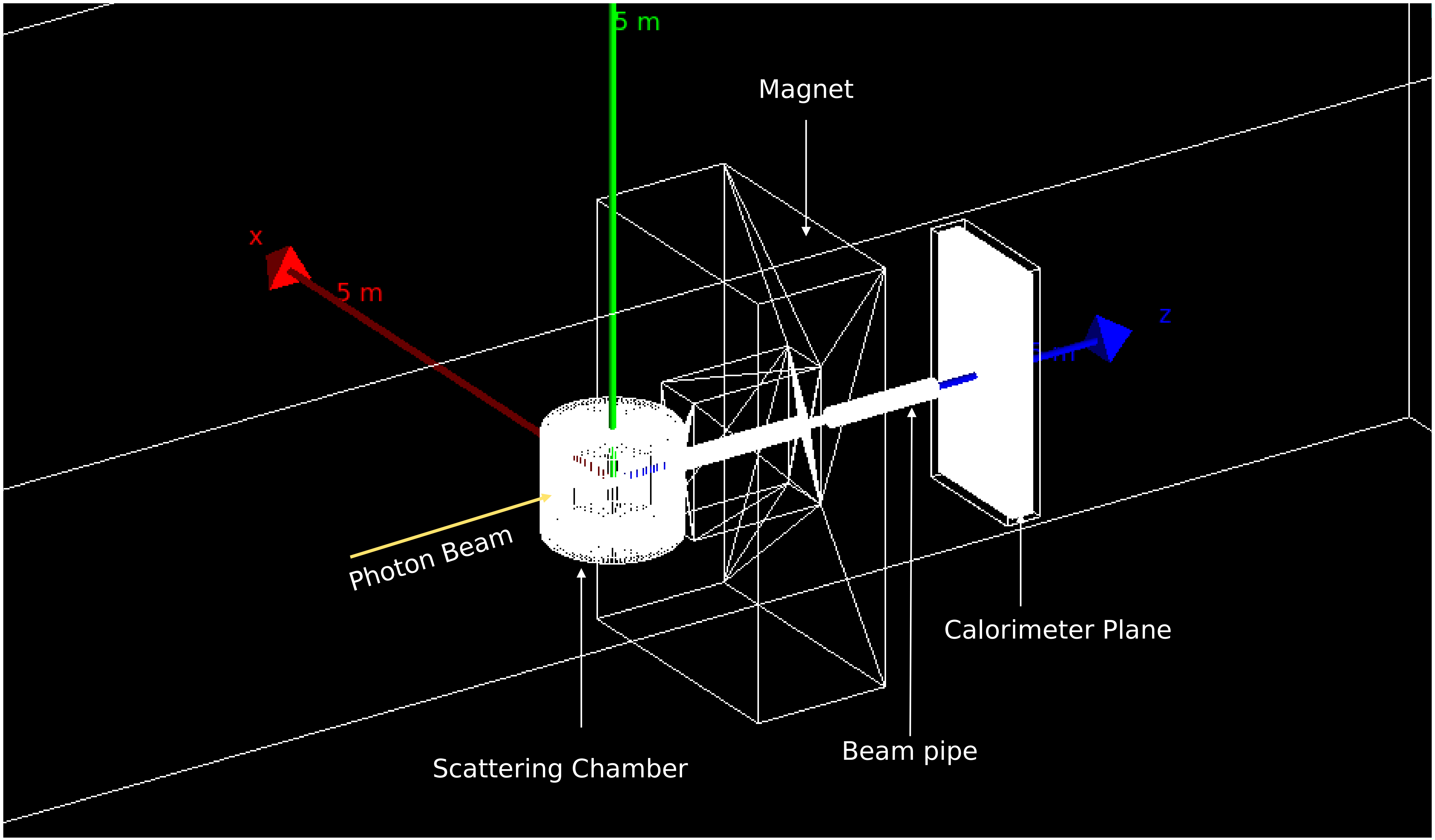
1. The field integral is 2.4 Tesla-meter with 1.2 m long pole

Unpolarized TCS measurement setup for Hall C



Based on proposed polarized setup, changed target and using SBS magnet(2.4T)

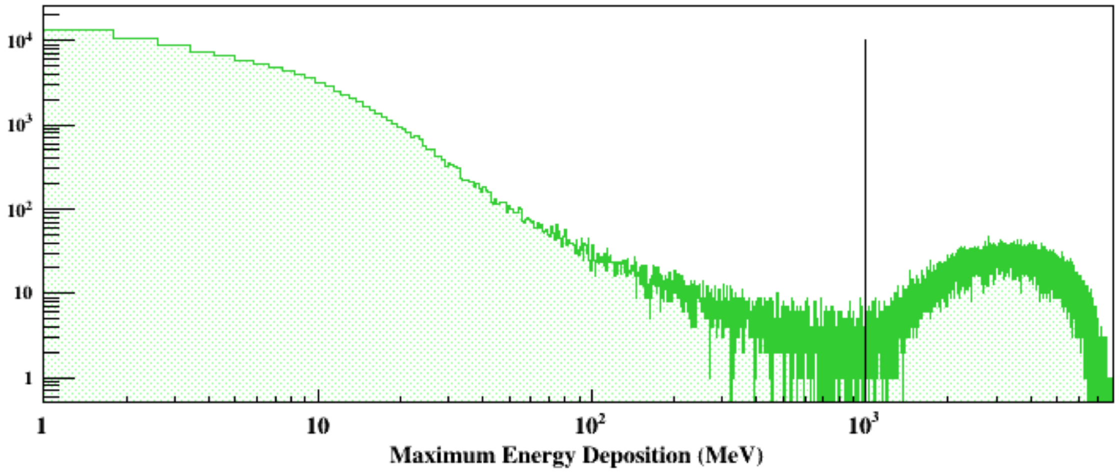
Geant4 Simulation :Simple One Calorimeter Plane Setup



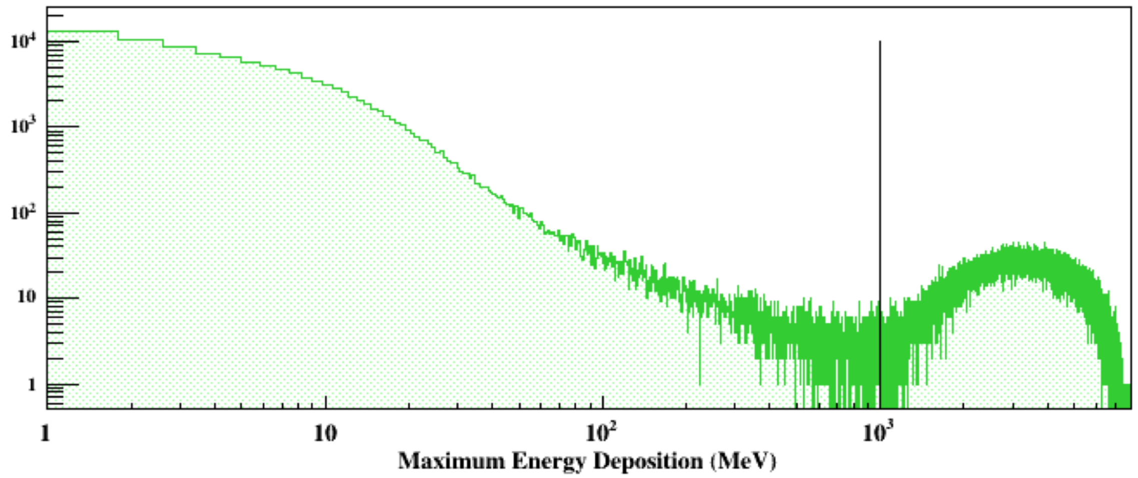
(we use for systematic studies and some done by undergrad students)

Geant4 Simulation : maximum energy distribution

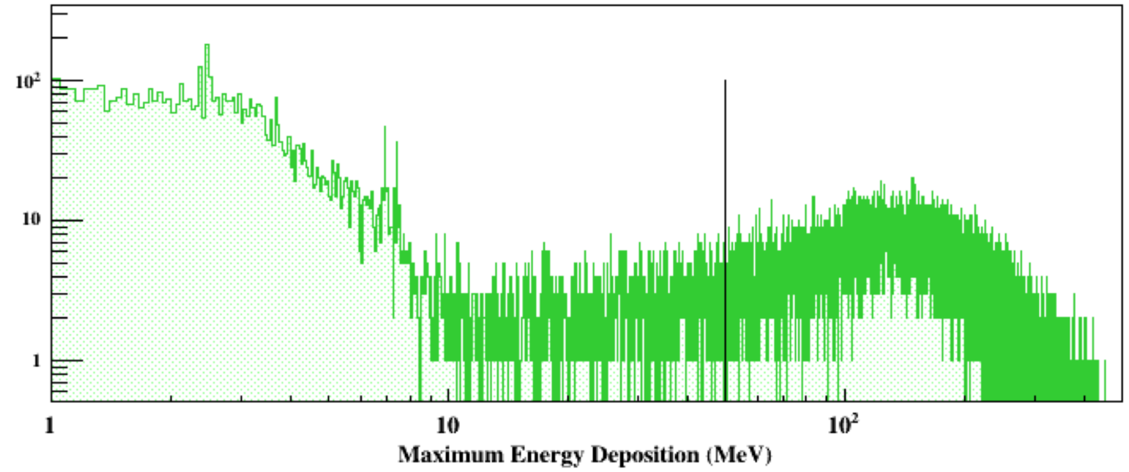
Electron



Positron

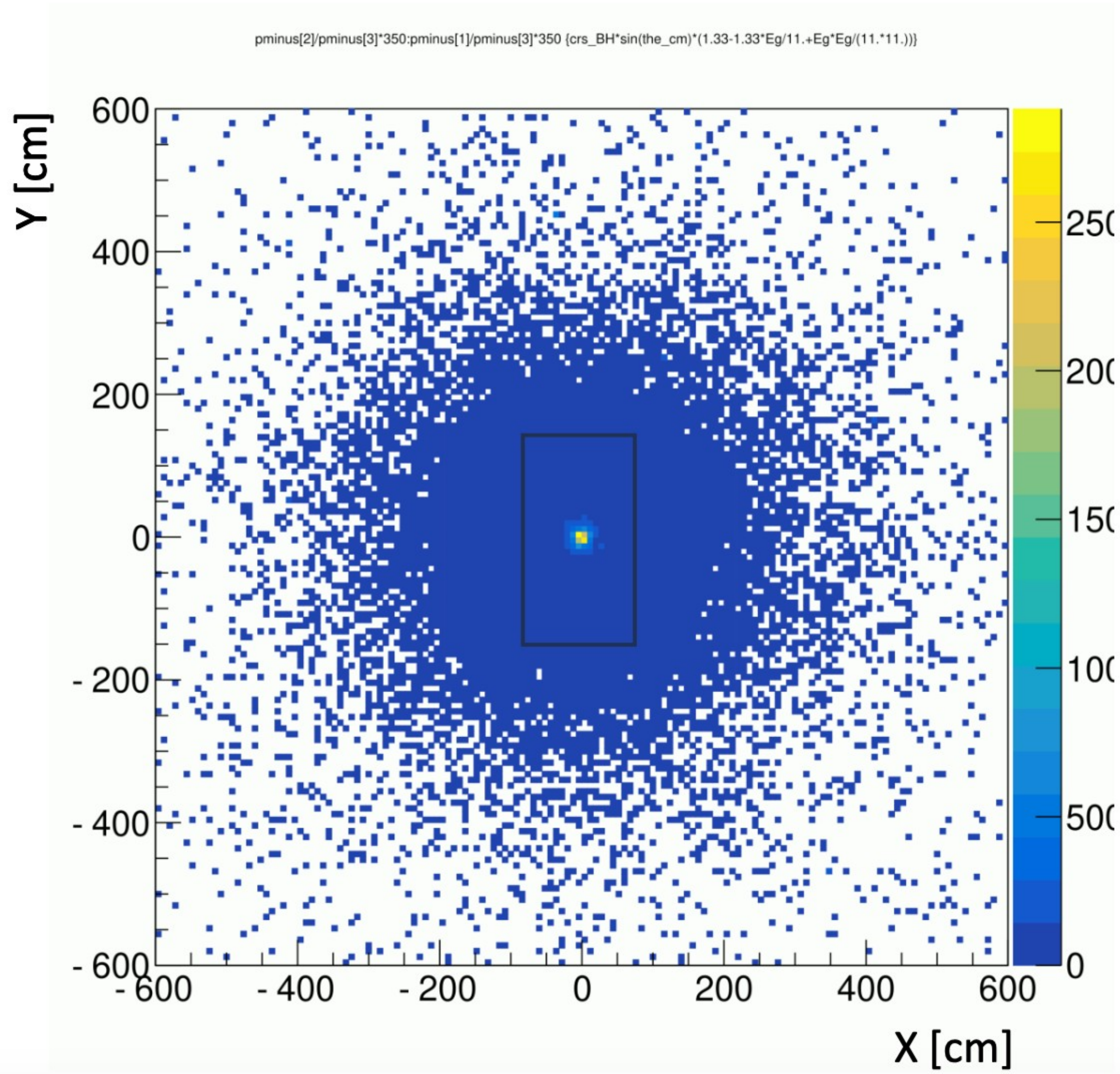


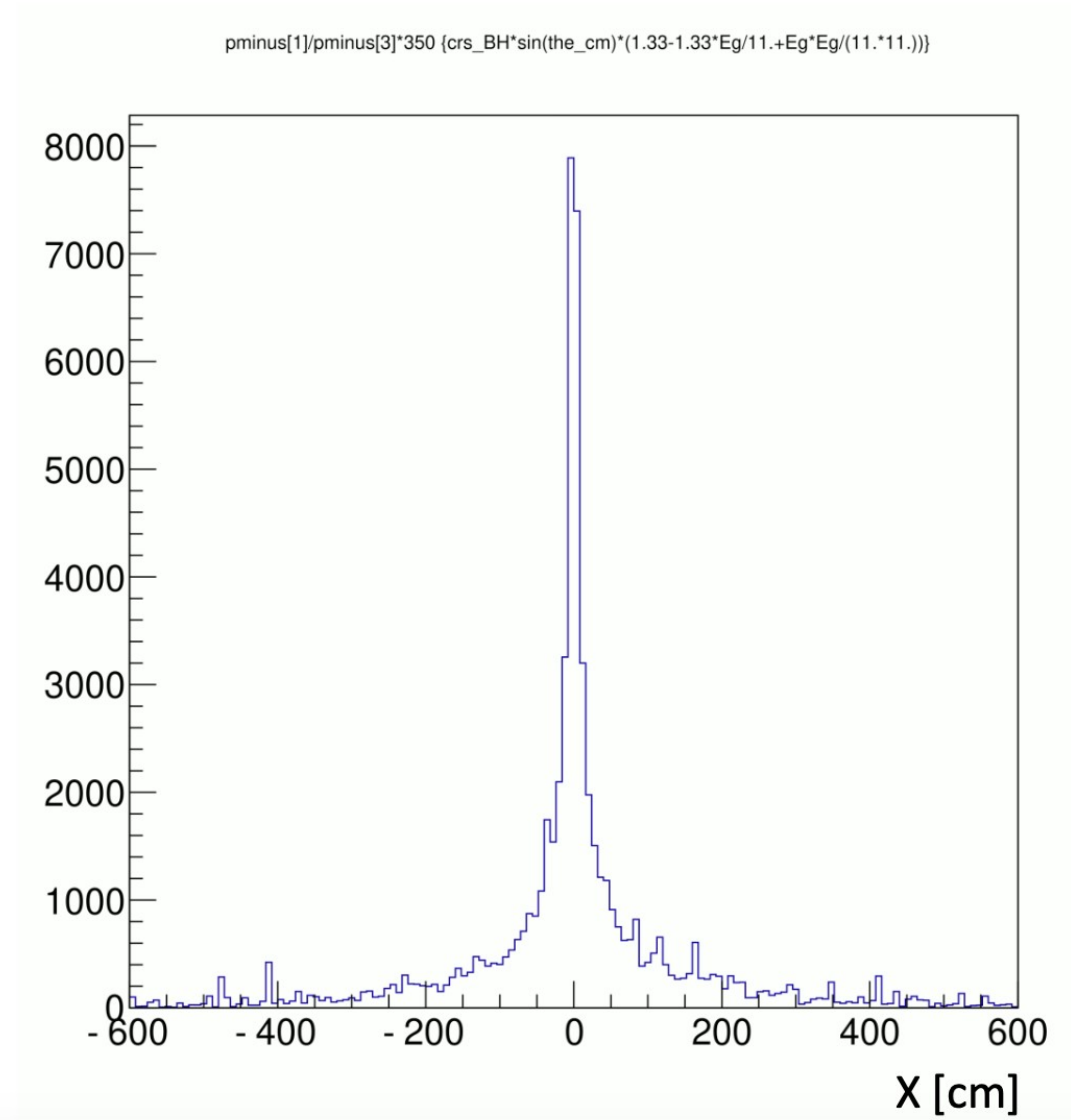
Proton



Geant4 Simulation : projection of electrons w/o magnetic field

1. TCS weighted events (from DEEPGen event generator) for electrons
2. Projected to Z = 350 cm plane (face of the calorimeter)
3. No magnetic Field (for now)
4. Rectangle at the center of the 2D plot encompasses the events passing through the magnetic bore
5. Expect Similar for positrons

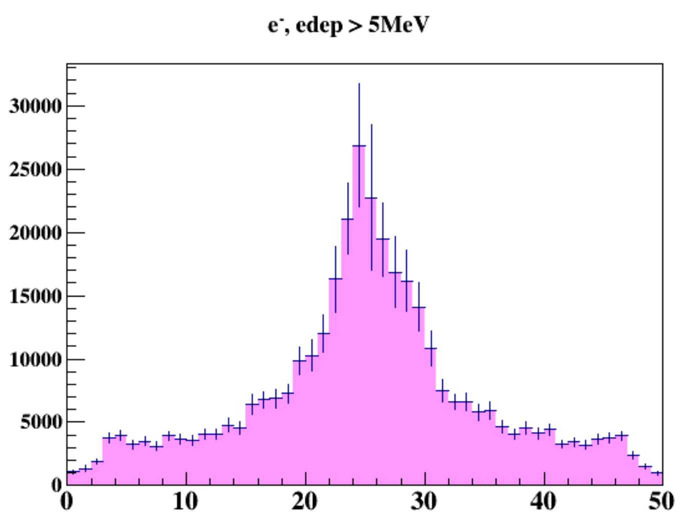




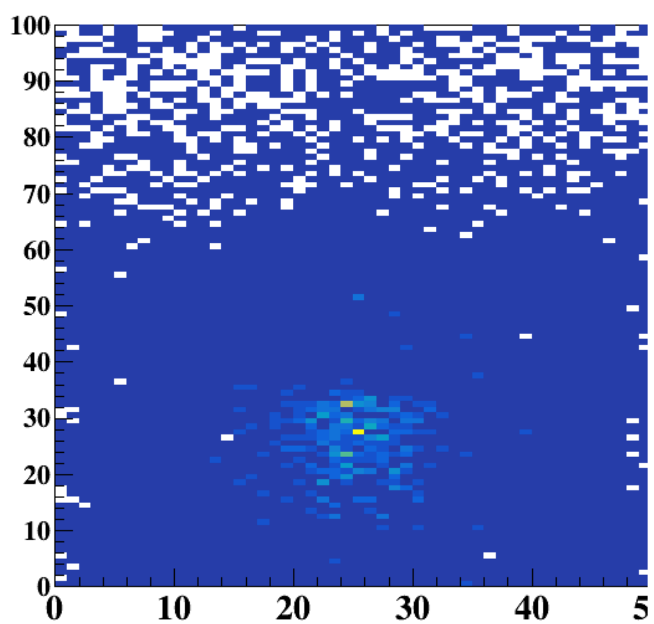
From : Vardan Tadevosyan

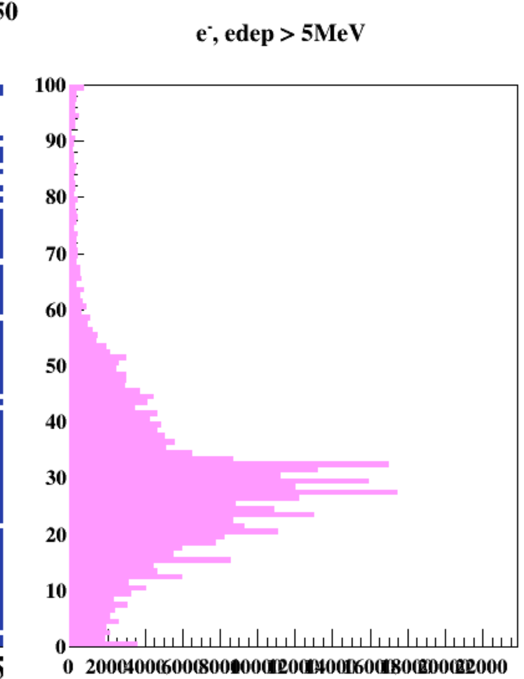
Geant4 Simulation : charge assignment to leptons

Projection of electron on calorimeter plane

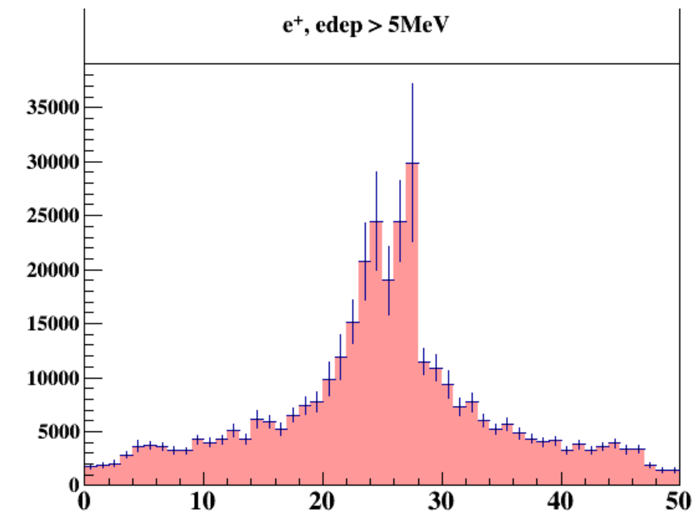


1. Magneti fiels : 2.4 T-m
2. For each event only the hit with maximum energy deposition is considered





Projection of positron on calorimeter plane



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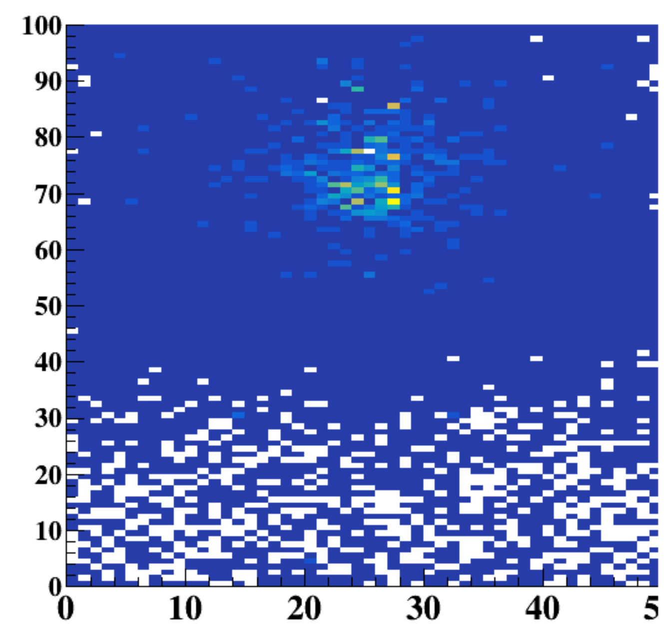

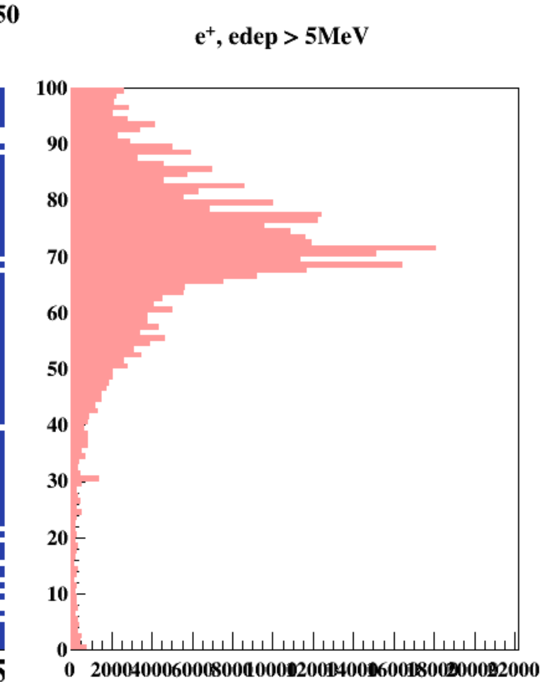

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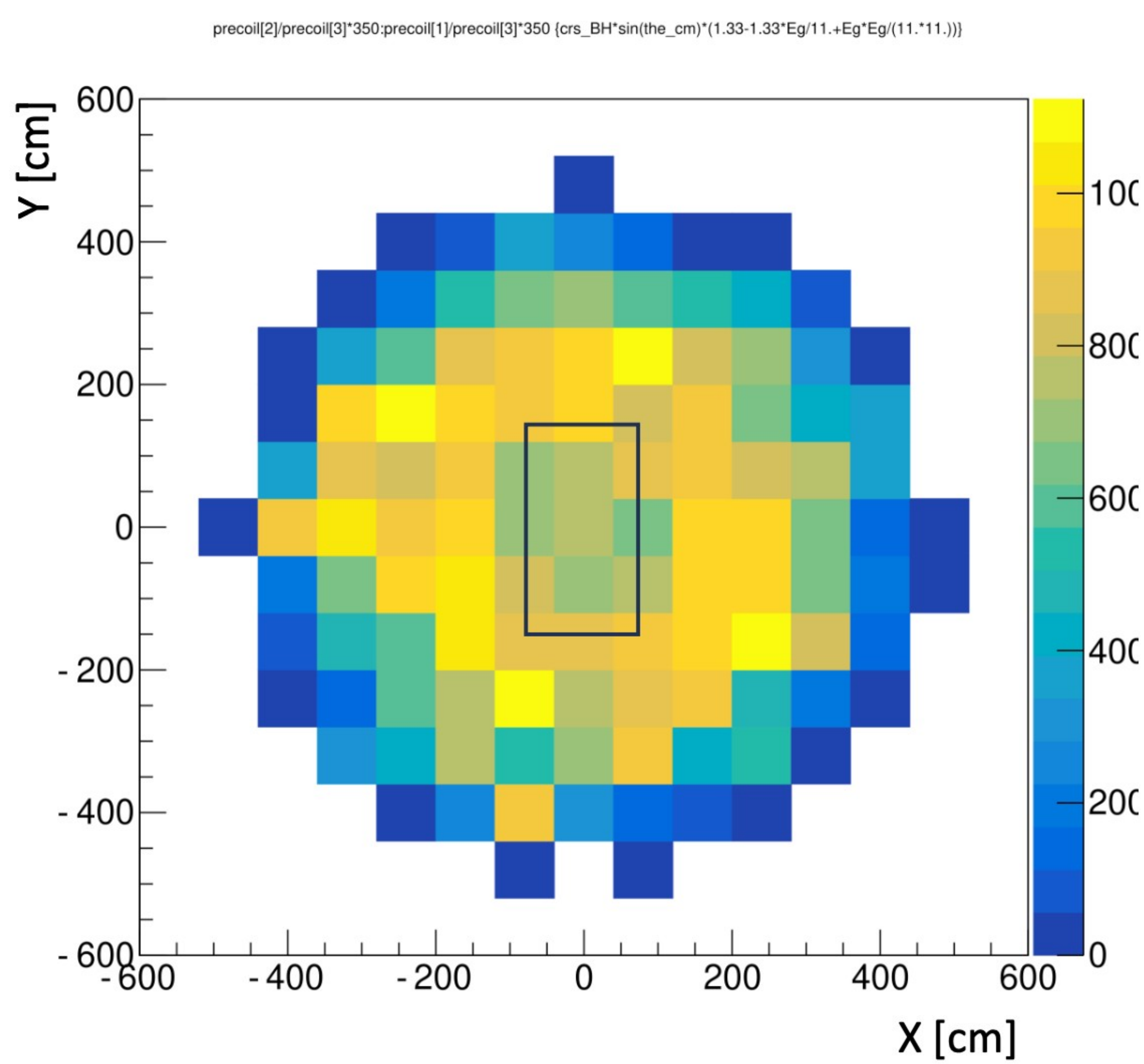
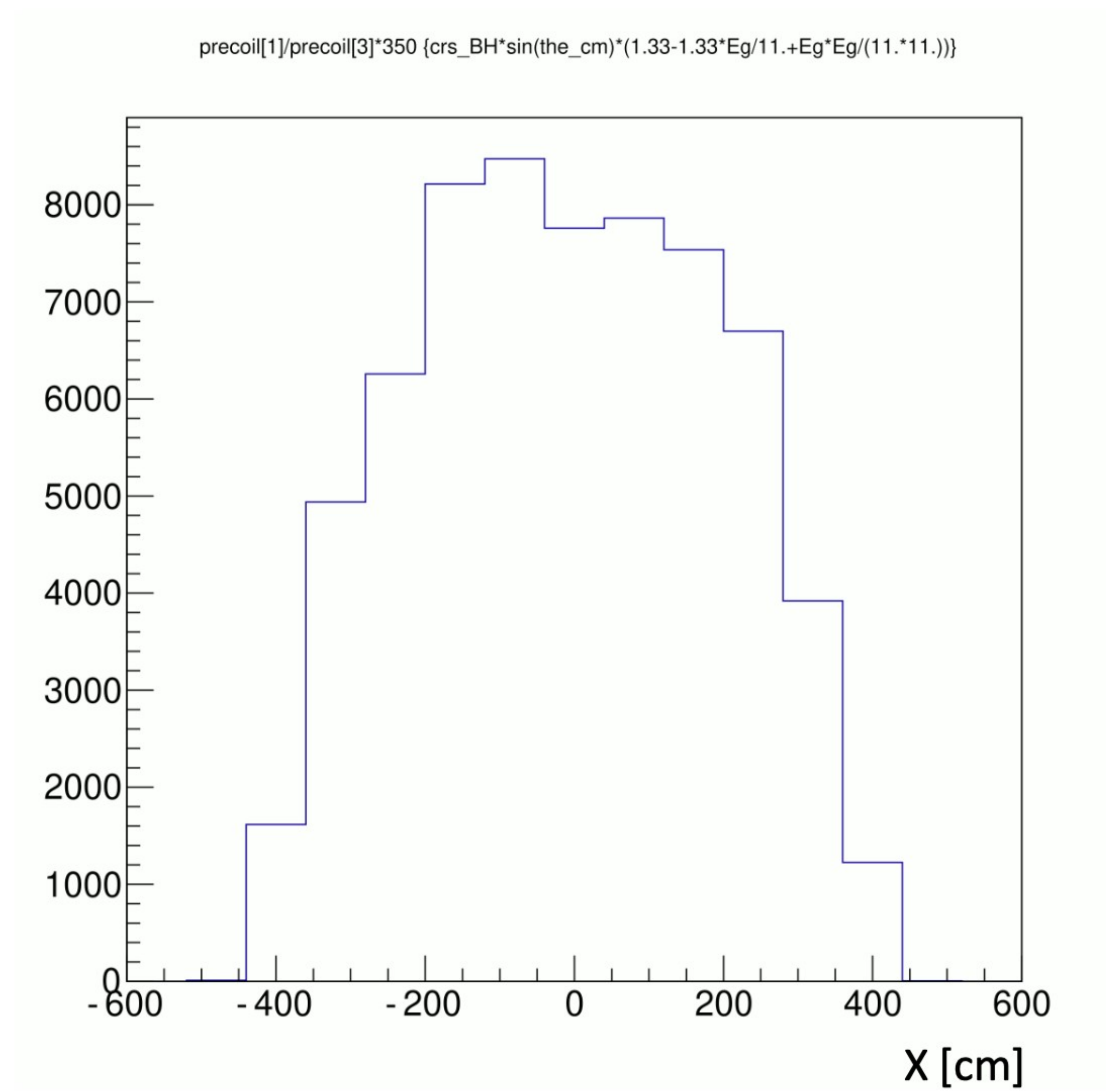
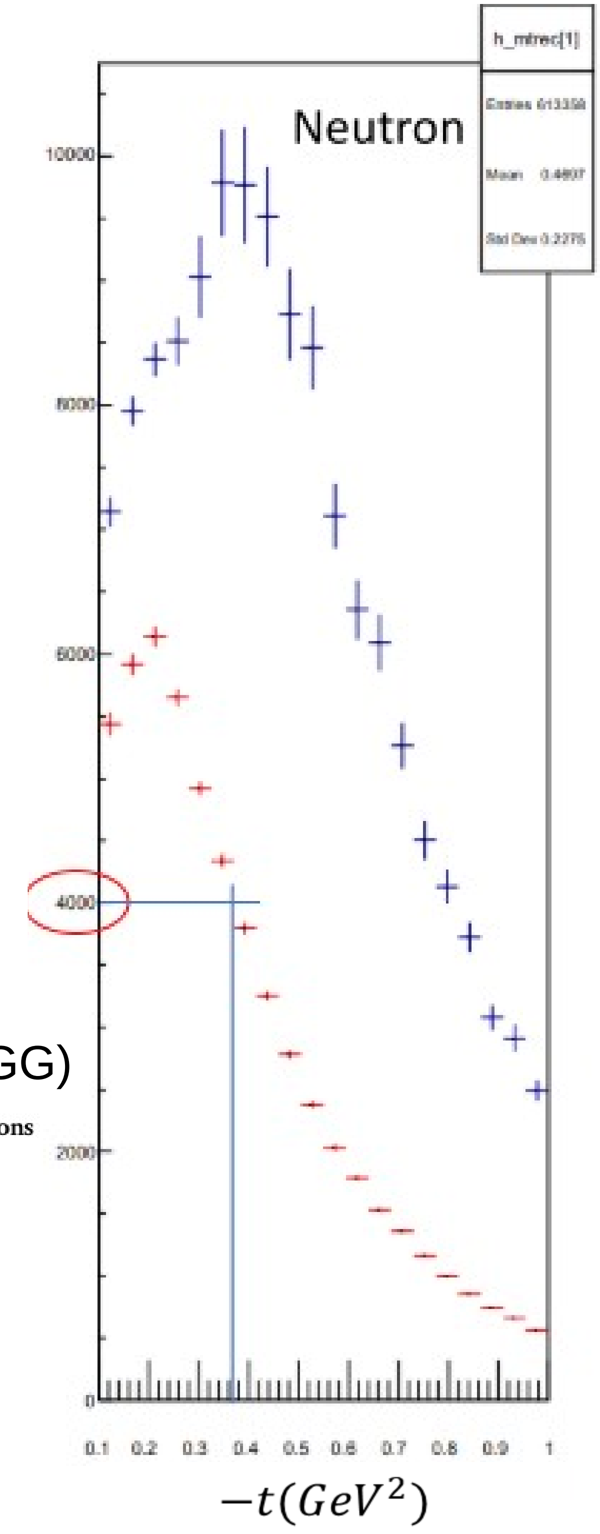


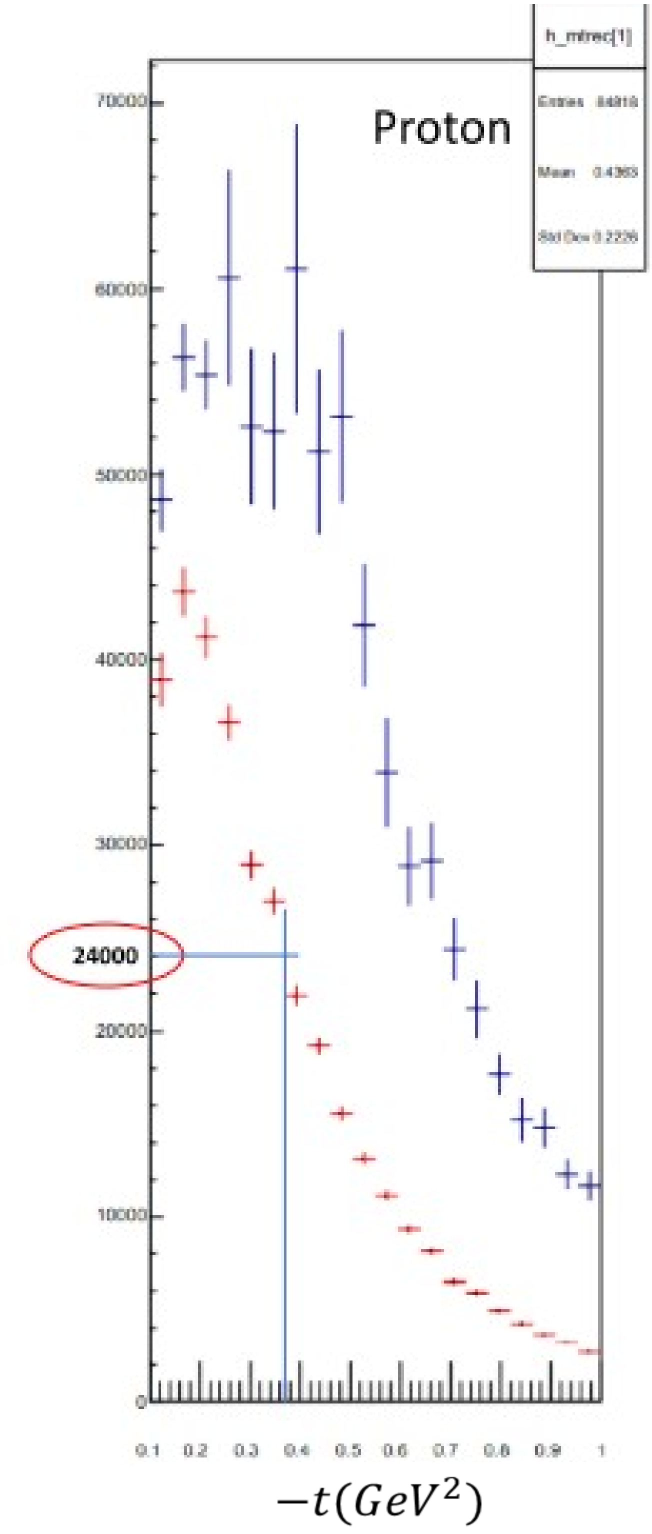


From :

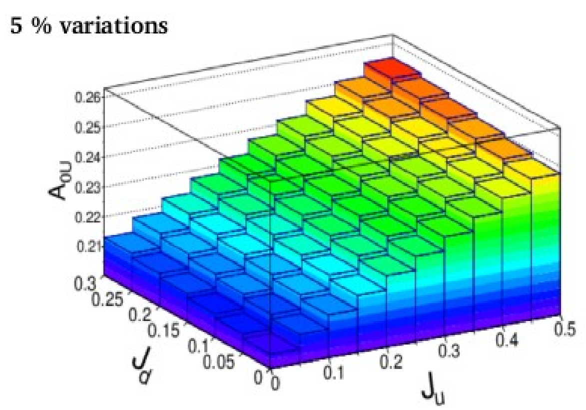
Possible extension to measure TCS for neutron

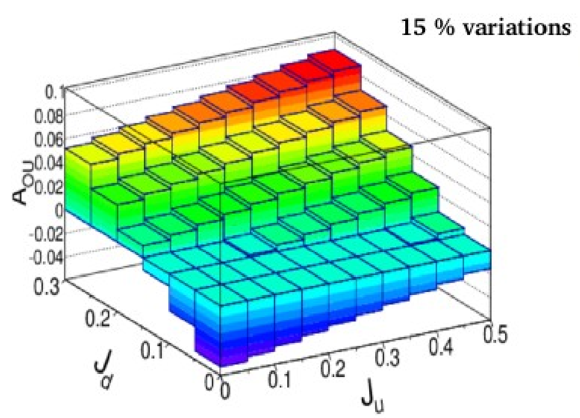
1. Preliminary study to show the feasibility of the measuring TCS for neutron
2. Number of reconstructed TCS events plotted against -t weighted by cross-section
3. Study before having the full Geant4 simulation
4. In principle it is possible to do the measurement on neutron, provided we have a neutron detector (because we don't detect the beam photon/electron)





proton versus neutron BSA off the neutron vs Ju, Jd (VGG)





From : Camille Zindy & M. Boer, 202

Our plans for TCS in Hall C

We proposed since first LOI in 2015, then proposals in 2018 a dedicated "dilepton spectrometer" dedicated setup to measure TCS at high intensity, using a photon source (CPS, dump in magnet) and new calorimeters with tracking provided by GEMs+hodoscope. Reconstruction of all final state particles.

Started with the (almost) most difficult: transversely polarized off proton (NH3, DNP technique)

Necessary (physics and baseline): unpolarized off LH2

Complementary (in progress for proposing experiments):

- unpolarized off neutron: flavor separation, universality studies – need to detect neutron
- long. polarized off neutron (ND3): similar, flavor separation
- long polarized off proton (NH3) / measurements off nuclear targets

} Hall C, dedicated

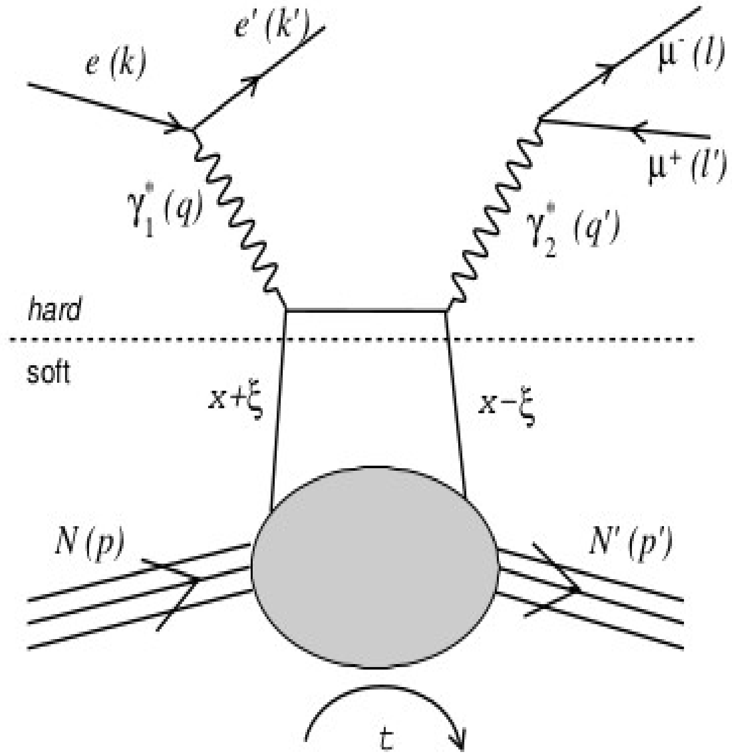
- long. beam polarized off LH2 with GlueX: real part – analysis in progress

From unpolarized TCS to DDVCS

Phenomenology of DDVCS

$$e(k) - e'(k') + p(p_1) \equiv \gamma^\star(q_1) + p(p_1) \to p'(p_2) + \gamma^\star(q_2) \to p'(p_2) + \mu^+(l^+) + \mu^-(l^-)$$

DDVCS



Variables definition/notations:

$$Q^2 = -q^2; \quad Q'^2 = q'^2$$

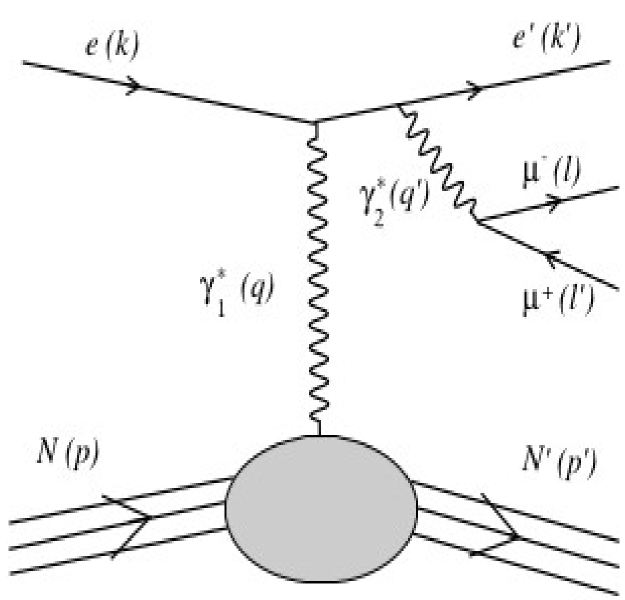
$$q = \frac{1}{2}(q + q'); \qquad p = p + p'$$

$$\Delta = p - p' = q - q' \text{ with } t = \Delta^2$$

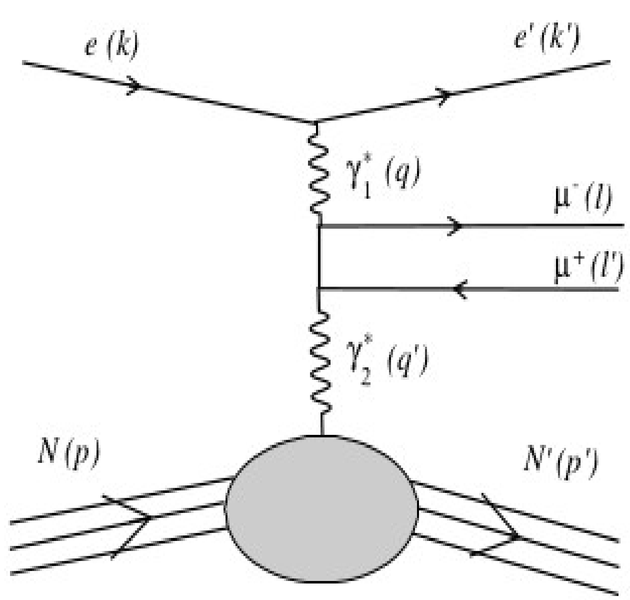
$$x_B = -\frac{1}{2}\frac{q_1 \cdot q_1}{p_1 \cdot q_1}; \qquad \xi' = -\frac{q \cdot q}{p \cdot q}; \qquad \xi = \frac{\Delta \cdot q}{p \cdot q}$$

"skewness":

"BH1"



"BH2"

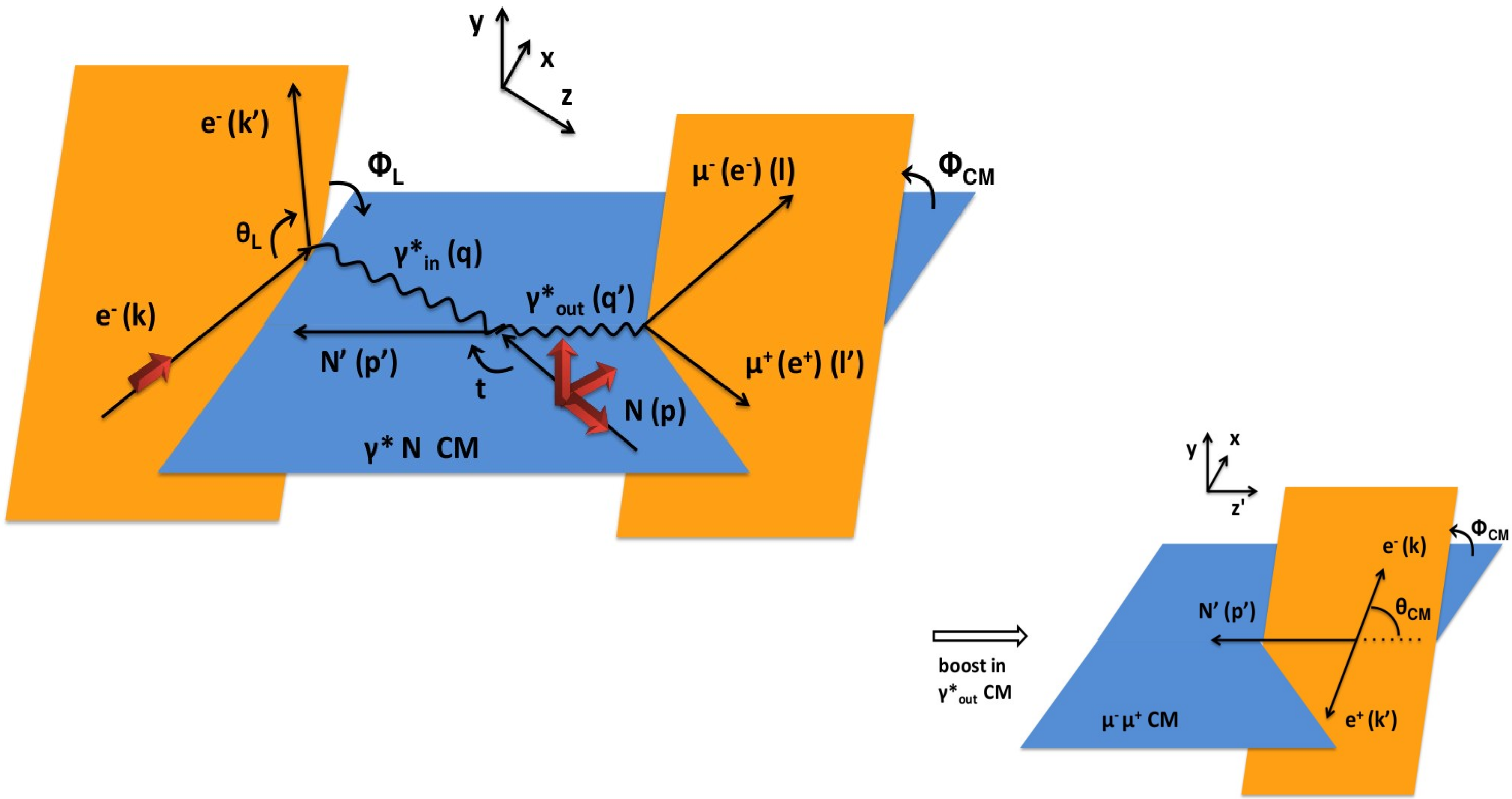


$$\xi = \frac{Q^2 - Q'^2 + (\Delta^2/2)}{2(Q^2/x_B) - Q^2 - Q'^2 + \Delta^2}$$

$$\xi' = -\frac{Q^2 + Q'^2}{2(Q^2/x_B) - Q^2 - Q'^2 + \Delta^2}$$

see Victor's talk for more

Angles and our notations



Observables to be measured in DDVCS+BH

Unpolarized cross section and beam spin asymmetries:

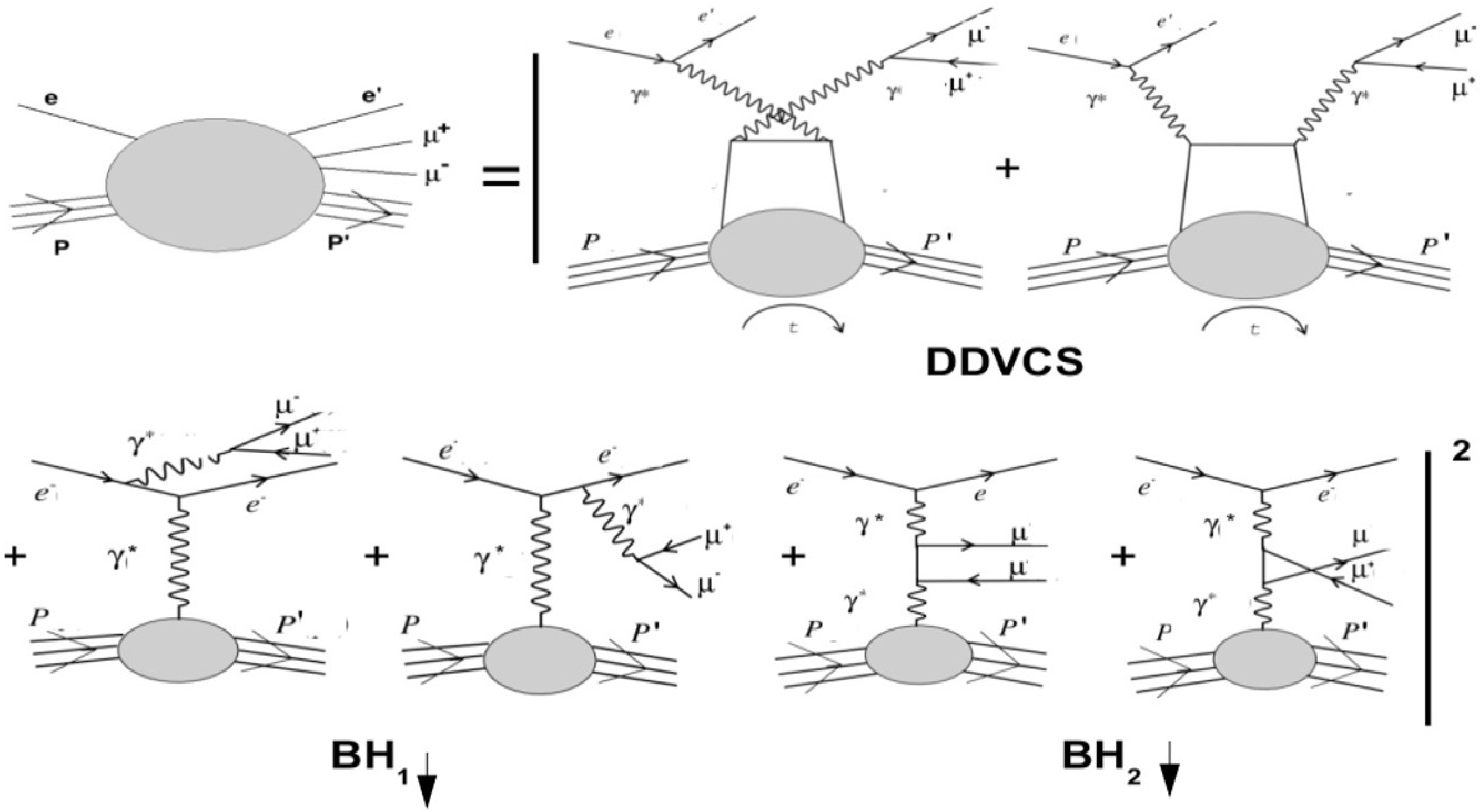
$$\left\{ \begin{array}{c} A_{\mathrm{LU}}^{\sin\phi_{LH}} \\ A_{\mathrm{LU}}^{\sin\phi_{CM}} \end{array} \right\} = \frac{1}{\mathcal{N}} \int_{\pi/4}^{3\pi/4} d\theta_{CM} \int_0^{2\pi} d\phi_{CM} \int_0^{2\pi} d\phi_{LH} \left\{ \begin{array}{c} 2\sin\phi_{LH} \\ 2\sin\phi_{CM} \end{array} \right\} \frac{d^7\overrightarrow{\sigma} - d^7\overleftarrow{\sigma}}{dx_{bj}\, dy\, dt\, d\phi_{LH}\, dQ'^2\, d\Omega_{CM}}$$

$$\propto \Im\mathrm{m} \left\{ F_1 \mathcal{H} - \frac{t}{4M_N^2} F_2 \mathcal{E} + \xi'(F_1 + F_2)\widetilde{\mathcal{H}} \right\},$$

- Unpolarized cross section gives access to Re and Im of amplitudes

- BSA gives access to Im(H)
We need to define “2D” ϕ_L versus ϕ_{CM} asymmetries.
We can integrate over polar angle

Angular behavior and "effective" observable



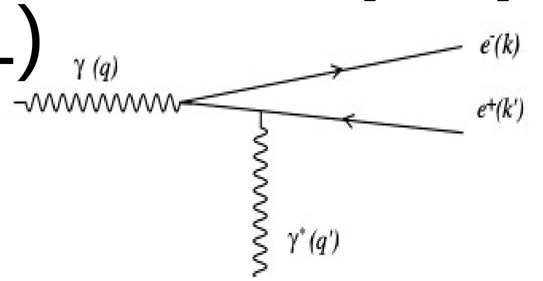
no favored direction for γ* emission or decay leptons

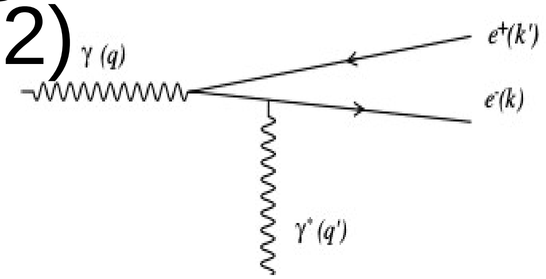
peak when γ' becomes collinear to e
related to φ_{LH}=0,
and depends $\cos\theta_{\gamma\gamma}$ (kinematics)
and "γ"→e' angle

2 peaks when μ+ or μ- become collinear to γ
related to φ_{LH}=0 and 180°,
and depends $\cos\theta_{\gamma\gamma}$ (kinematics) which position the value of θ_{CM} for the peaks

Angular behavior and "effective" observable

BH propagators

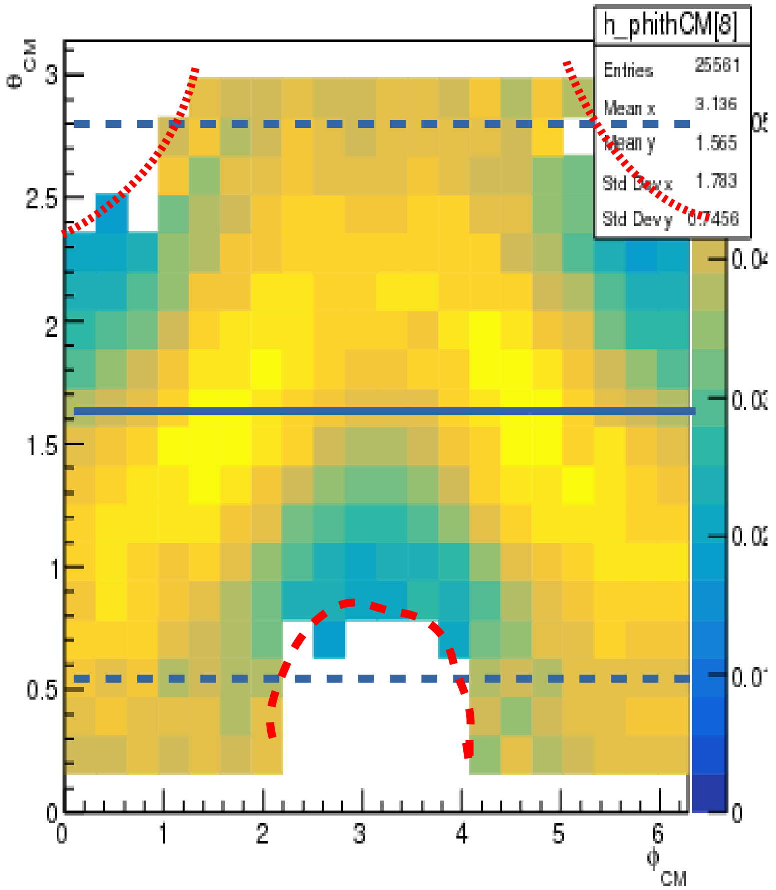
1) 

2) 

- BH peaks when e- or e+ collinear to incoming γ (from BH II)
- strong kinematic dependence at JLab energy
- one diagram becomes largely dominant / very asymmetric decays

- Momentum and θ_{lab} cuts help already
- Q^2, Q'^2, xb, t dependent angular cut for “effective” observables

BH peaks: lepton 1 to beam direction, other almost "at rest"
⇒ momentum threshold and geometrical acceptance mostly prevent for too high rates and singularitie regions.
Angular + momentum acceptance is important



-- cut at 30°; 150°
-- acceptance cut
not included: cut of some bins next to singularities if not experimentaly "solvable" due to limited statistics (example 2 orders of magnitude increase of σ within a bin)

Projected observables for experiment at JLab and studies of angular correlations

Still need to work on: 2D fits of CFFs on the 2 azimuthal angle with all GPDs included

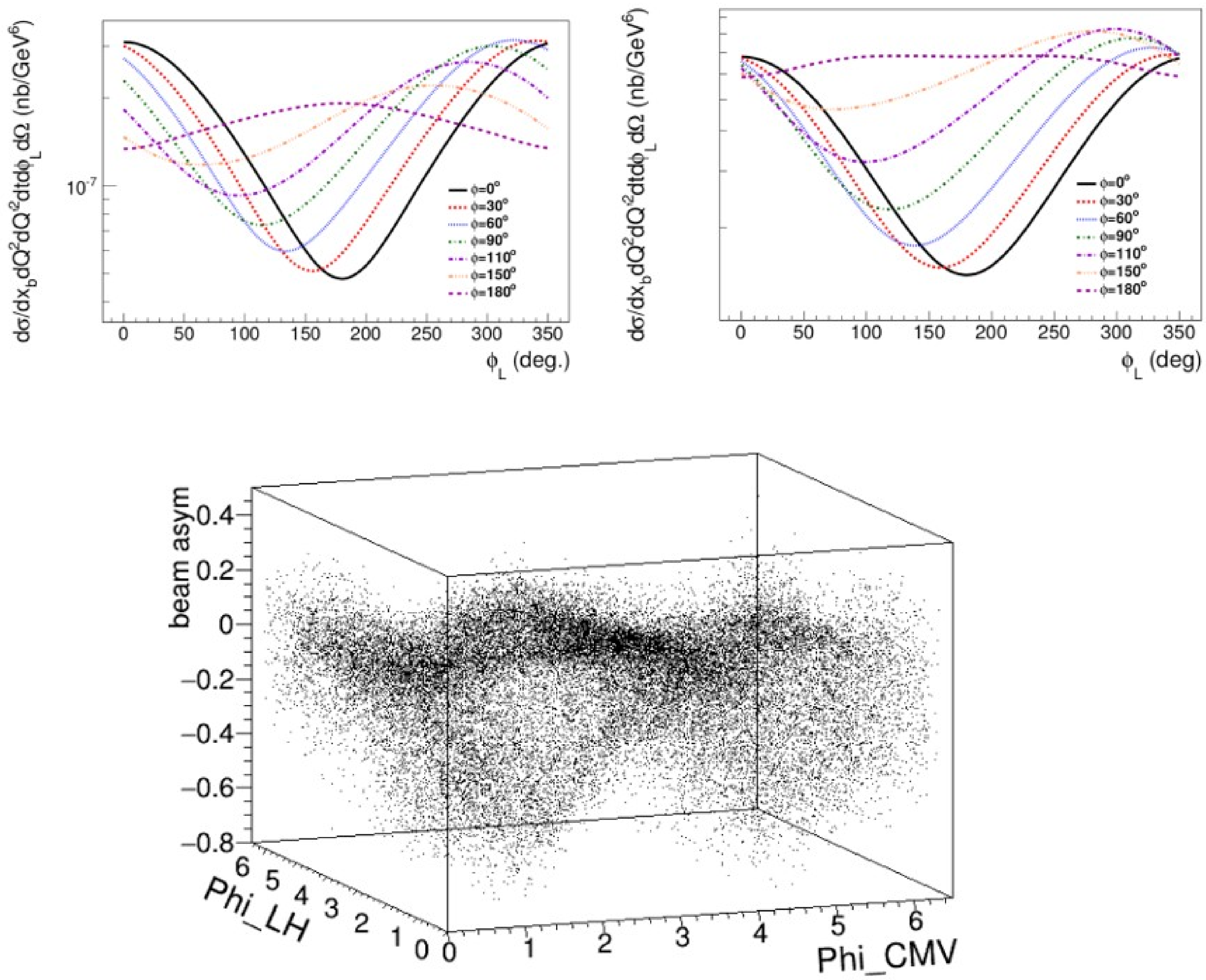


Figure 6: Top row: ϕ_{LH} dependencies of the unpolarized DDVCS+BH cross section for different fixed values of ϕ_{CM}. On the left, we selected a region ($\theta_{CM} = 90^o$) where the DDVCS/BH rate is the highest, and on the right, we selected a region where "BH2" largely dominates ($\theta_{CM} = 30^o$). Bottom: 2-D ϕ_{LH} versus ϕ_{CM} dependencies of the beam spin asymmetries. This is showing that the 2 angles must be measured independently and was can't integrate over one of them.

Projected observables for experiment at JLab and studies of angular correlations

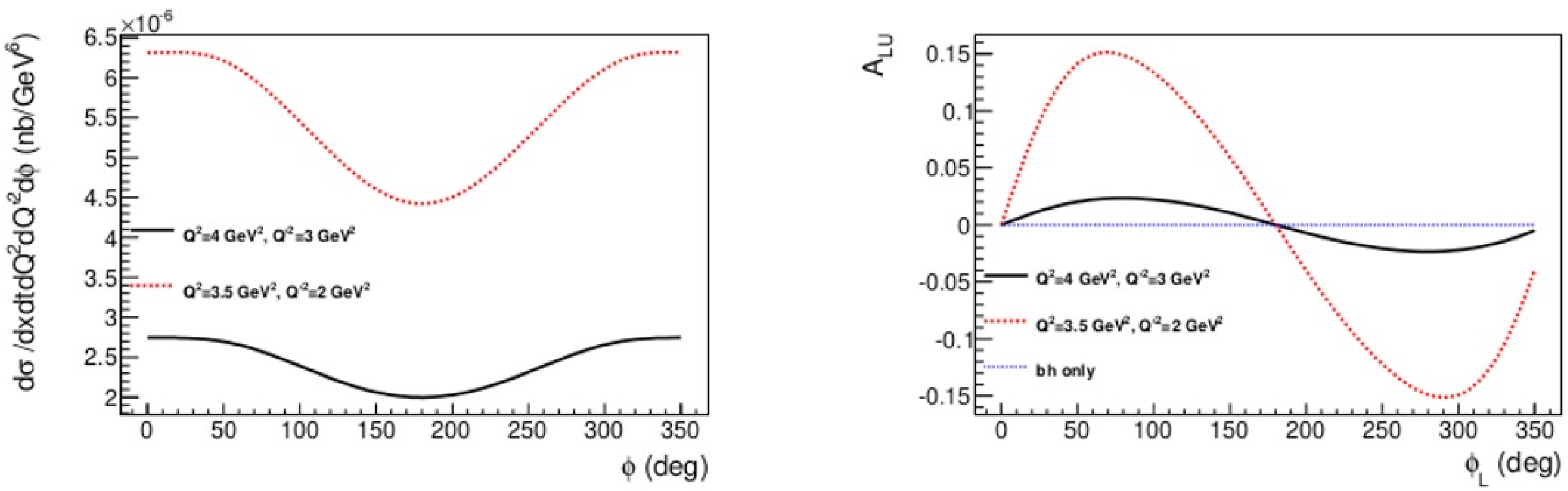


Figure 7: Out-of-plane ϕ_{LH} angular dependence of the differential cross section (left) and the beam spin asymmetry (right) for the $eP \to e'p\mu^+\mu^-$ process at E=11 GeV, x_{bj}=0.25, t=-0.4 GeV^2, and different virtual photon masses.

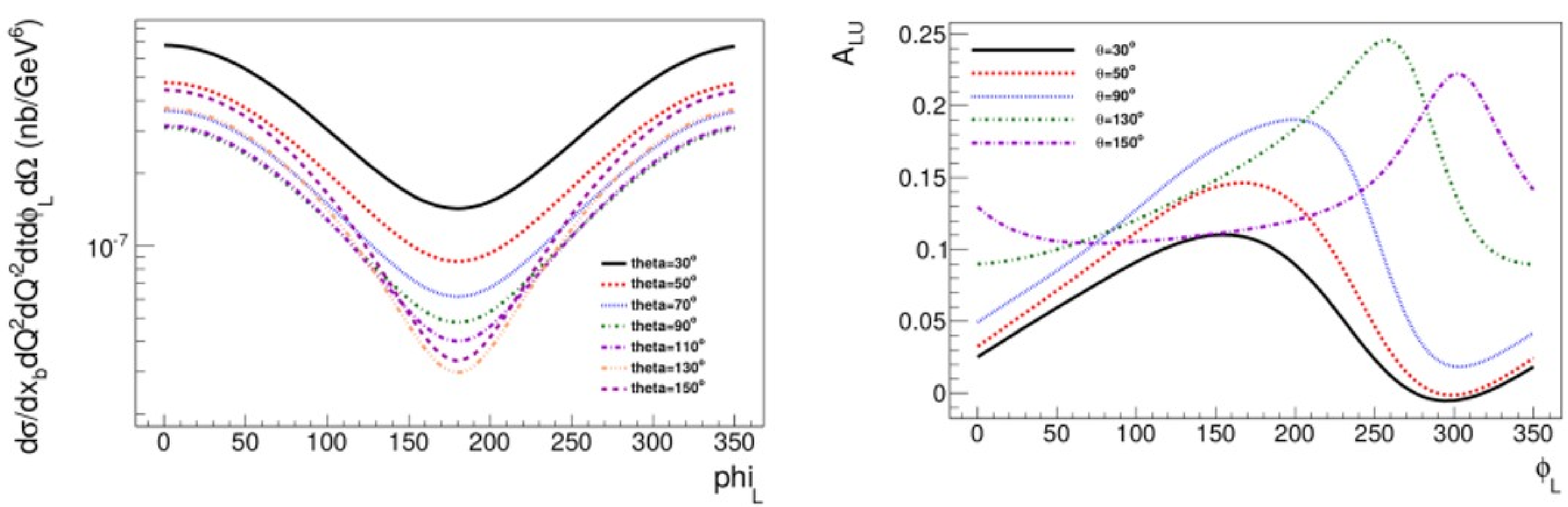
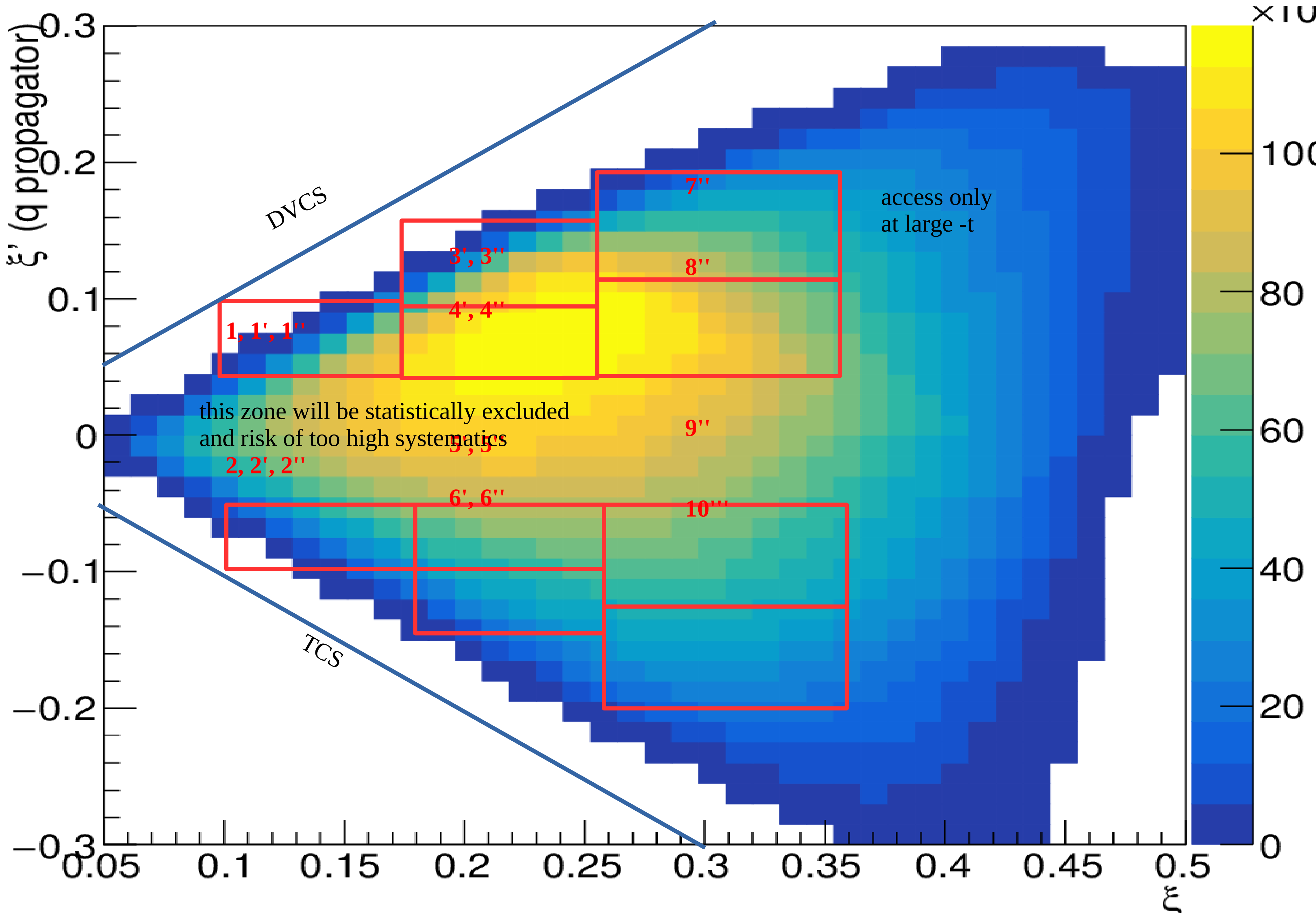


Figure 8: Out-of-plane angular dependence of the differential cross section for various polar angles of the muon (left) and for the differential beam spin asymmetry (right)

Kinematic coverage

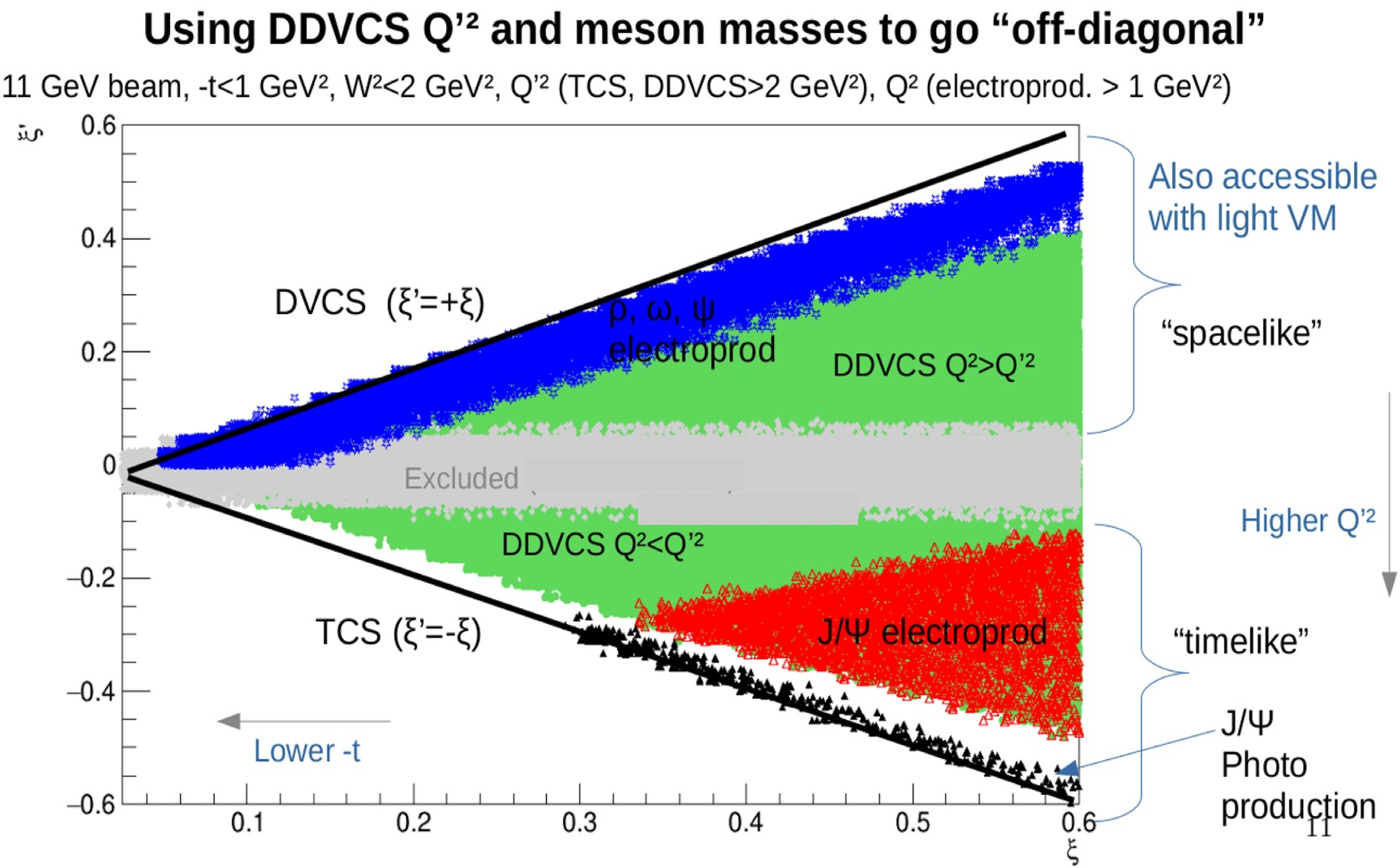
Binning in ξ, ξ', all t: going "off-diagonal" for tomographic views



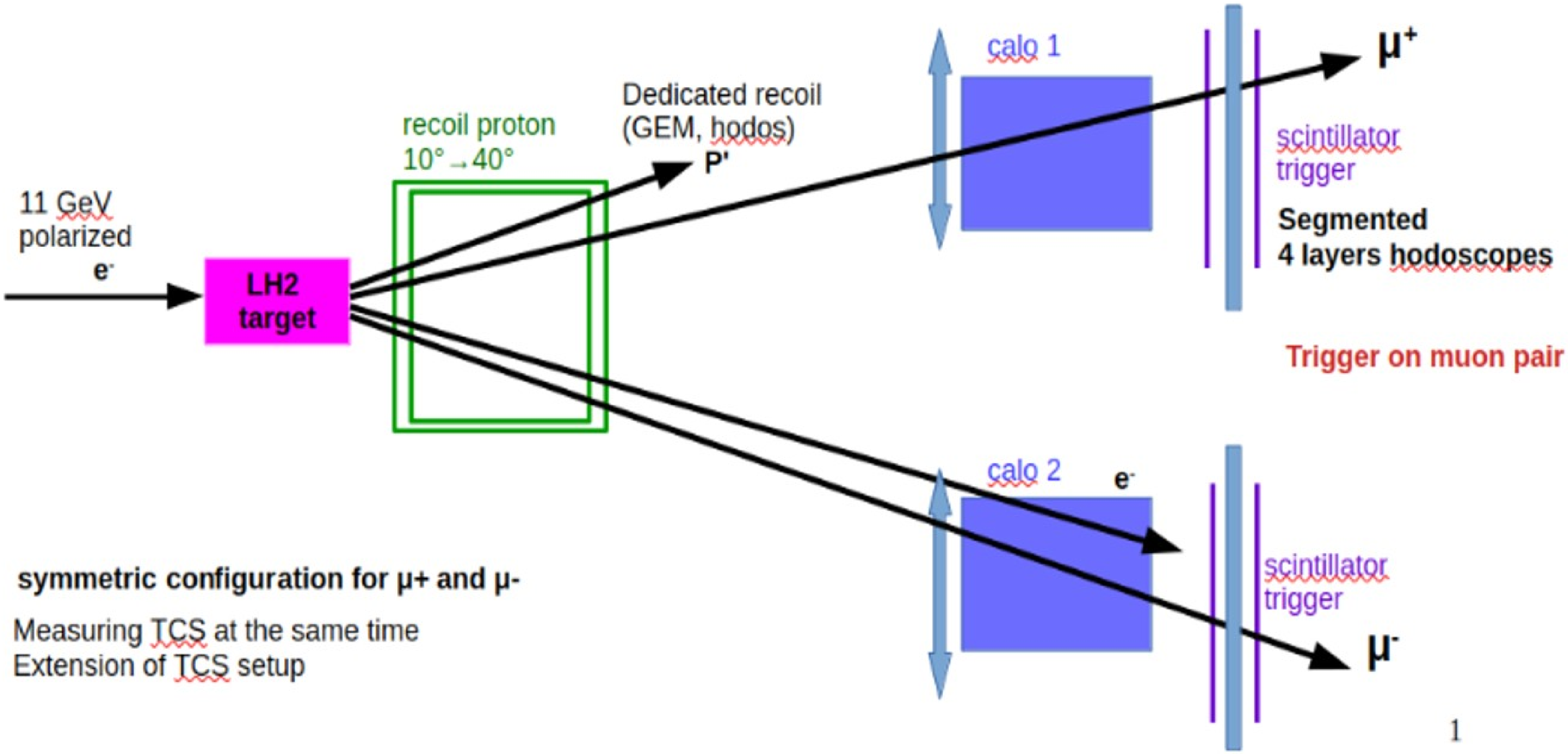
Bin in ξ	code # large/low t
A) .1 < ξ < .18	
(all t bins)	
1) .05 < ξ' < .1	1, 7, 17
2) -.05 > ξ' >-.1	2, 8, 18
B) .18 < ξ < .26	
(t bins 2 and 3)	
3) .1 < ξ' < .15	3, 9
4) .05 < ξ' < .1	4, 10
5) -.05 > ξ' > -.1	5, 11
6) -.1 > ξ' > -.15	6, 12
C) .26 < ξ < .36	
(t bin 3)	
7) .12 < ξ < .2	13
8) .05 < ξ < .12	14
9) -.05 > ξ > -.12	15
10) -.12 > ξ > -.2	16

Bins in t: (1) 0 < -t < 0.15 GeV², (2) 0.15 < -t < 0.35 GeV², (3) 0.35 < -t < 0.55 GeV² (indicated ', '')

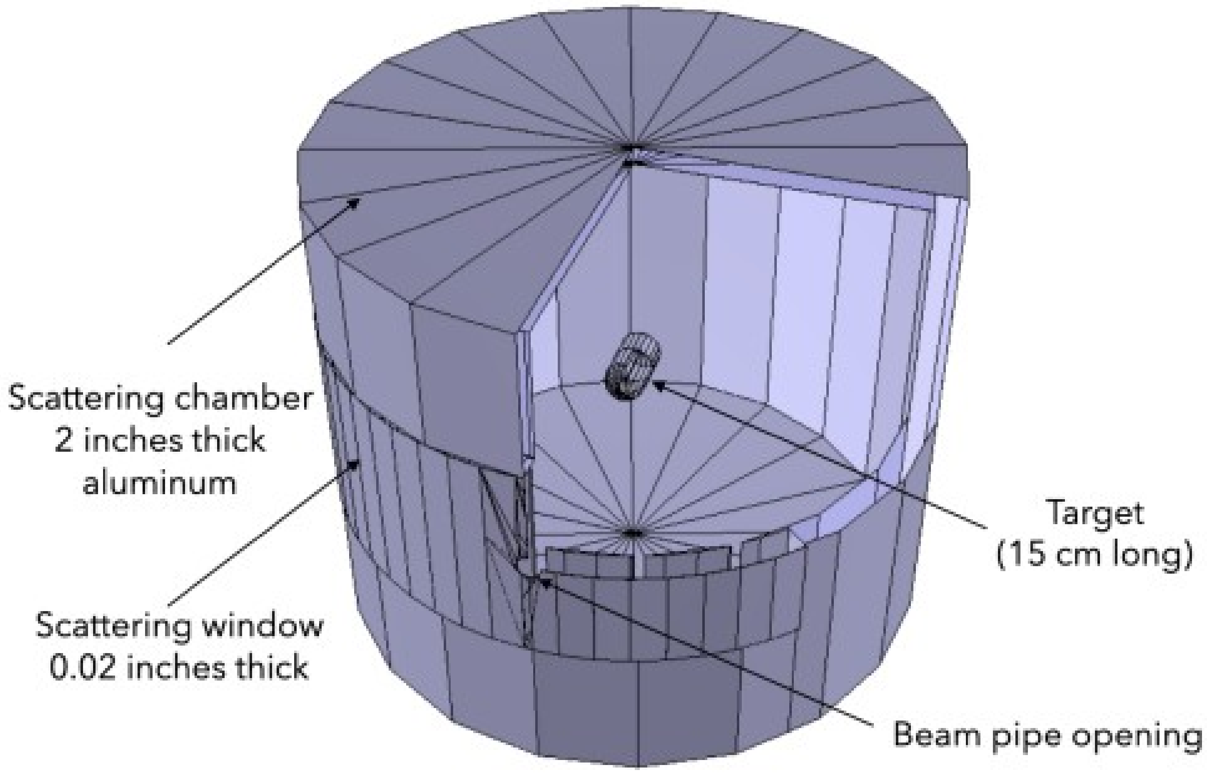
Using DDVCS Q'² and meson masses to go "off-diagonal"

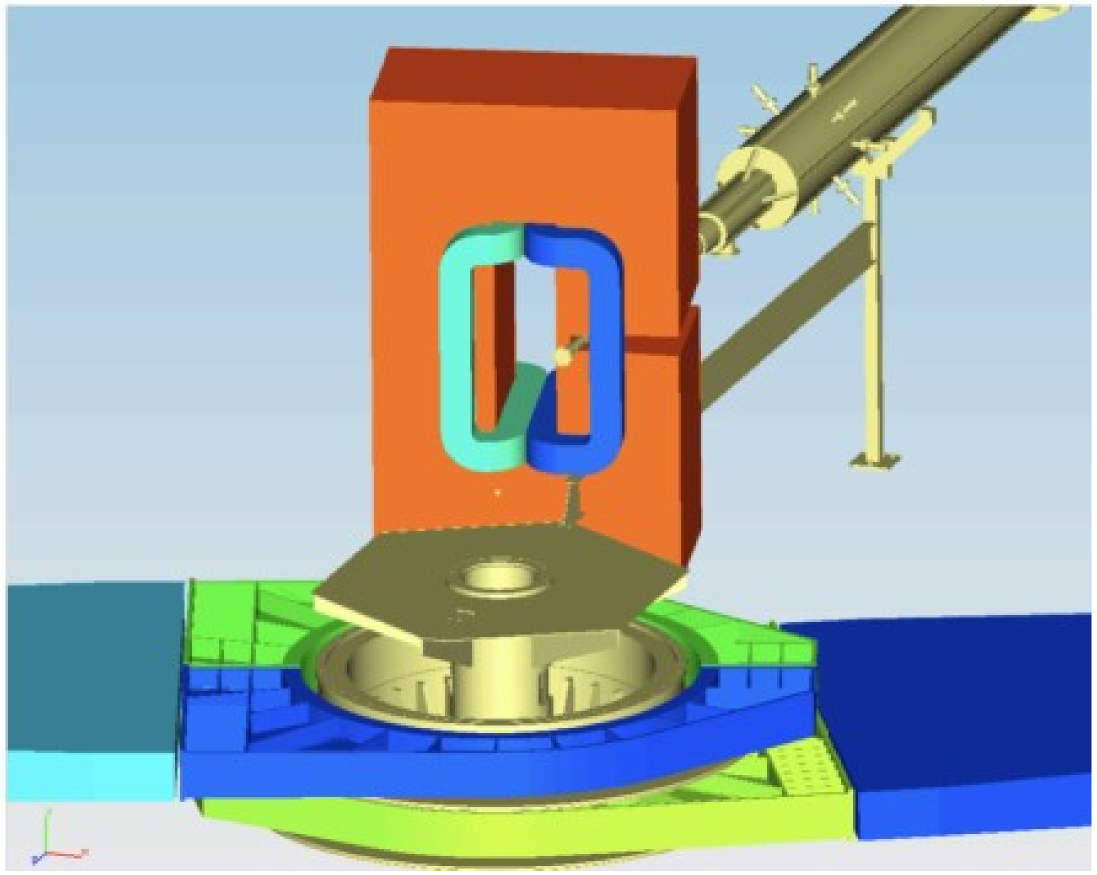


Dedicated setup proposed for Hall C



Dedicated setup proposed for Hall C



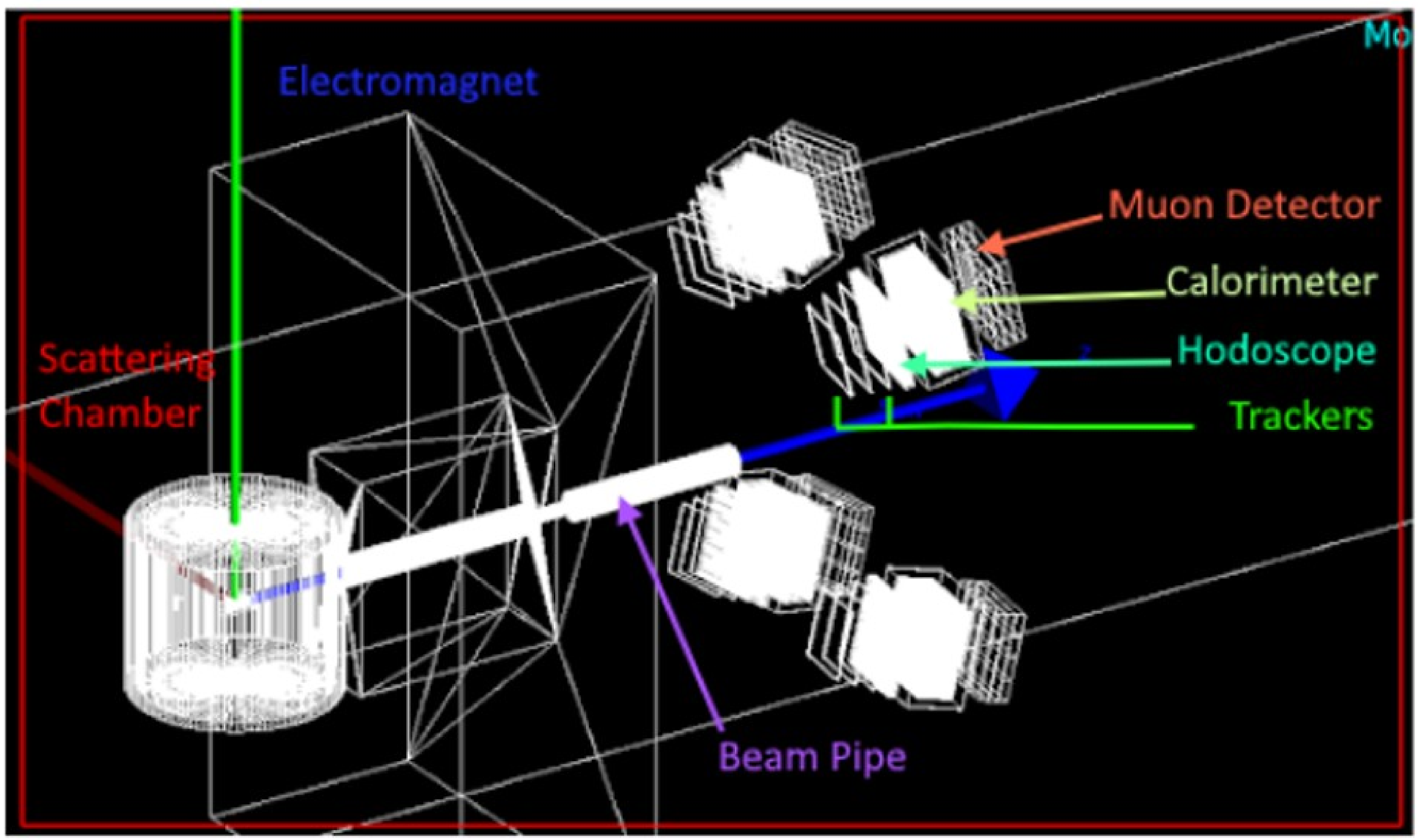


target and scattering chamber

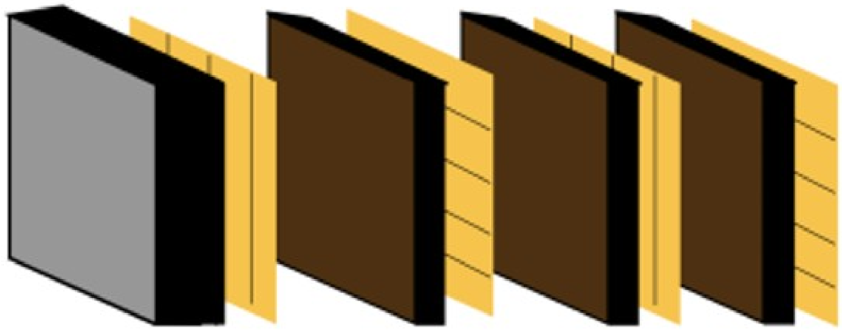
SBS magnet (in Hall A now)

this is what we are proposing in parallel for unpolarized TCS

Genat4 Simulation : New Muon Detector



(a) Geant4 simulation of the full di-lepton spectrometer for DDVCS experiment in Hall C. Each of the four quadrants of detectors consists of trackers, hodoscopes, calorimeter and muon detector.



(b) Conceptual design of the muon detector. Two segmented scintillator planes are sandwiched between three absorber planes. The segmentation of the first and second scintillator planes offers spatial information along the x and y axes, respectively.

New Muon Detector : Studying different material and thickness for the absorber

combined total hits in all four scintillators				
particle	1 GeV	2 GeV	4 GeV	6 GeV
mu-	19992	39987	39983	39985
pi+	1359	2237	3476	5314

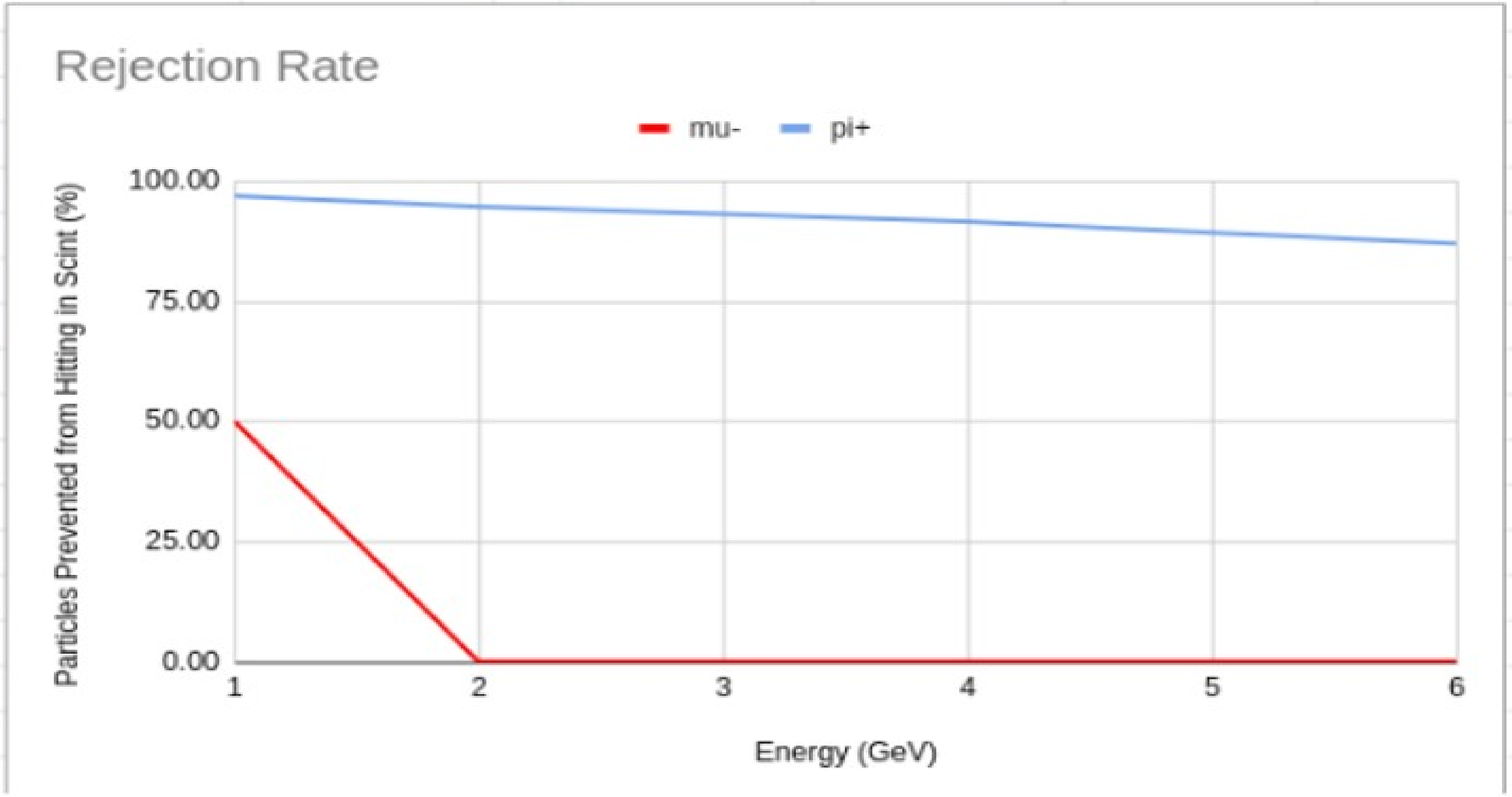
hits in each layer of scintillator				1 GeV
particle	scint 1	scint 2	scint 3	scint 4
mu-	9998	9993	1	0
pi+	1080	279	0	0

hits in each layer of scintillator				2 GeV
particle	scint 1	scint 2	scint 3	scint 4
mu-	9998	9998	9998	9993
pi+	1485	536	186	40

hits in each layer of scintillator				4 GeV
particle	scint 1	scint 2	scint 3	scint 4
mu-	9997	9996	9996	9994
pi+	2100	919	349	108

hits in each layer of scintillator				6 GeV
particle	scint 1	scint 2	scint 3	scint 4
mu-	9997	9997	9997	9994
pi+	3011	1428	631	244

rejection rate		
energy (GeV)	mu-	pi+
1	50.02	96.60
2	0.03	94.41
4	0.04	91.31
6	0.04	86.72



Building DAQ in parallel

Here is the basic setup we started with in our lab at VT.
DAQ/CODA based on JLab software – plan to test at JLab during another run.

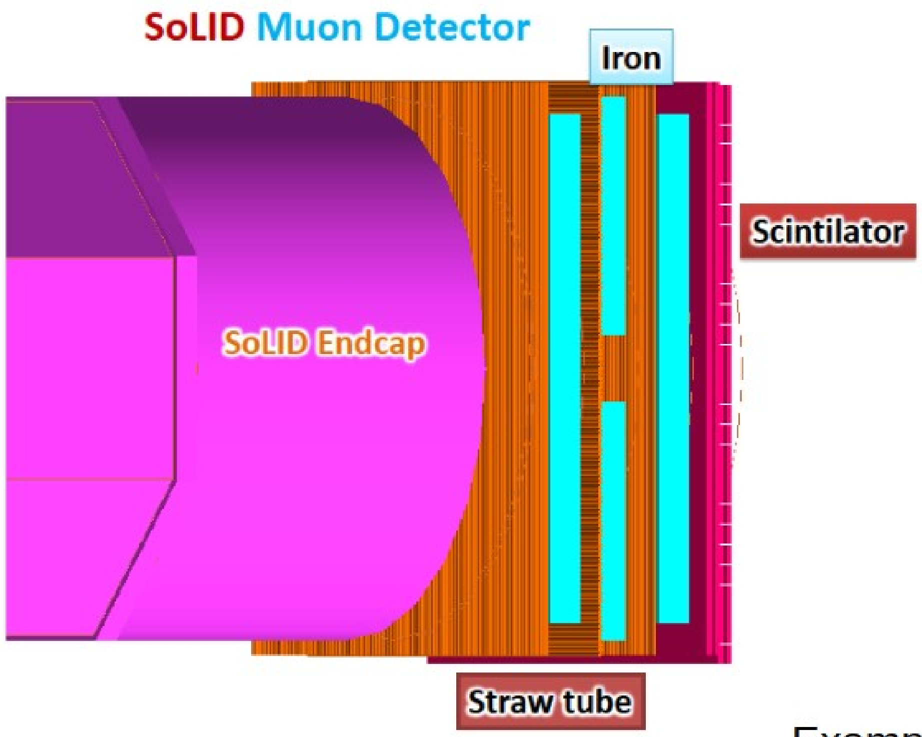
(a) (b)

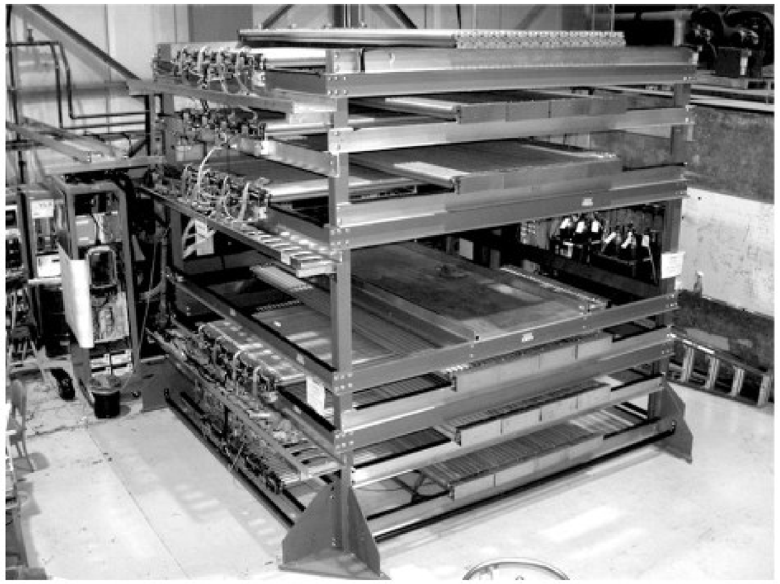
We are setting up DAQ, then we plan to move towards building a simple prototype.
We are making funding requests for a larger scale prototype that can be tested at JLab

Some directions for Hall C muon detector

3 layer iron to block charged pions, 3 layer straw tubes for tracking, 2 layer scintillators for trigger

SoLID: see Sebastian's talk





Example of straw tube chambers similar to Seaquest experiment

Hall C: principle is absorbers and scintillators. Also exploring use of scintillating fibers (in progress, in touch with LANL to test things done by FERMILAB in SeaQuest experiment)

Reconstruction/PID: also exploring use of AI/ML for improving techniques

== Deb got SURA postdoc prize on this project and is actively working on muon detector R&D

Other directions

- TCS with linearly polarized beam: GlueX – student (Gyang Chung) started the analysis

Access to Real part of amplitudes

- photoproduction of gamma+meson: once TCS analysis is done, Gyang will extend to that analysis, starting with gamma-rho

Access chiral odd GPDs, other combinations and kinematics (like DDVCS)…
Started to collaborate with Saad N., Samuel W, Lech S. but still need to work on our side to find measurable kinematics

- extension of the DDVCS/TCS/DVCS program to combination of vector mesons to “play” with the meson masses and perform multi-channel fits

New postdoc in the group Kemal Tezgin currently implementing phi meson / work done in collaboration with EXCLAIM
(see Douglas, Simonetta, Marija’s talks)

Summary

- TCS program in Hall C: some proposed, some still to propose. Get high intensity TCS measurement off polarized
and unpolarized target. Still some experimental challenge. Physics goals clear: universality, GPD E…

- DDVCS program in Hall C: complementary to CLAS12 and SoLID / enables higher intensity and precision dedicated
measurement. Currently working on muon detector R&D

- Extension to other channels: VM, gamma+meson… Started to collaborate with GlueX for linearly polarized beam and
wide acceptance spectrometer enabling some new measurement

- Goal = multi-channel access to CFFs for universality studies, higher twist and NLO studies,
flavor combination and extension to ERBL region for modeling extension to zero skewness.