Double Deeply Virtual Compton Scattering

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CNF Mini workshop: Experiment and Theory Intersections: Future Planning

March 3rd 2021

U.S. DEPARTMENT OF ENERGY | Office of Science

Jefferson Lab Thomas Jefferson National Accelerator Facility

JSA

Outline

- Introduction DDVCS
- DDVCS crosssection
- DDVCS kinematic and observable
- Kinematical coverage
- CLAS12 setup
- SoLID J/psi and dedicated setup
- Hall C setup
- CNF Questions
- Conclusions

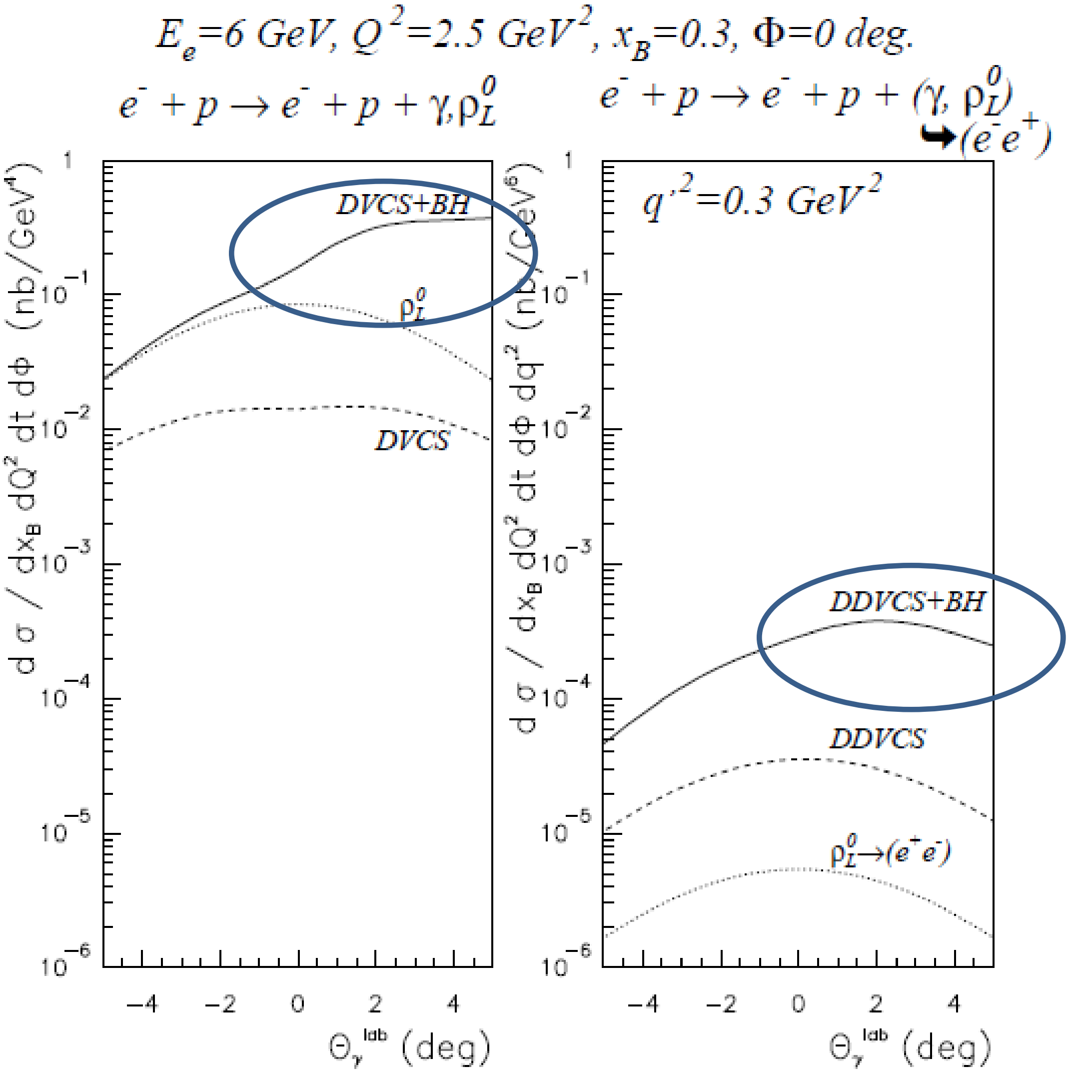
DVCS / Double DVCS

$$\gamma^* + p \longrightarrow \gamma'(*) + p'$$

$$\gamma'(*) \longrightarrow l^+ + l^-$$

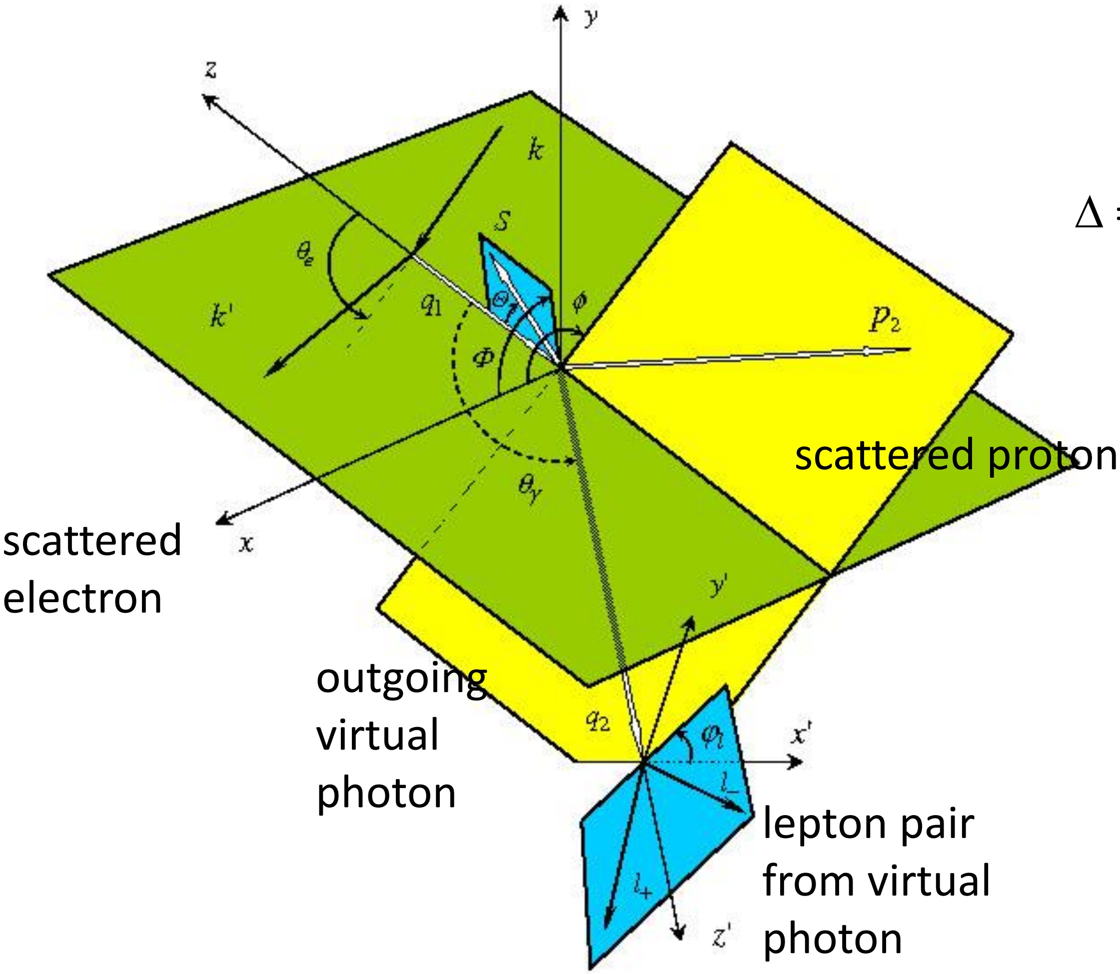
Guidal and Vanderhaegen : Double deeply virtual Compton scattering off the nucleon (arXiv:hep-ph/0208275v1 30 Aug 2002)
Belitsky Radyushkin : Unraveling hadron structure with generalized parton distributions (arXiv:hep-ph/0504030v3 27 Jun 2005)

DDVCS cross section



- VGG model
- Order of ~0.1 pb = 10^{-36}cm^2
- About 100 to 1000 smaller than DVCS
- Virtual Beth and Heitler
- Interference term enhanced by BH
- Contributions from mesons small when far from meson mass

Double Deeply Virtual Compton Scattering



Δ = p1-p2 = q2-q1

p = p1+p2

q = ½ (q1+q2)

$Q^2 = -q^2$

$\xi = \dfrac{Q^2}{2p.q}$ $\eta = \dfrac{\Delta.q}{p.q}$

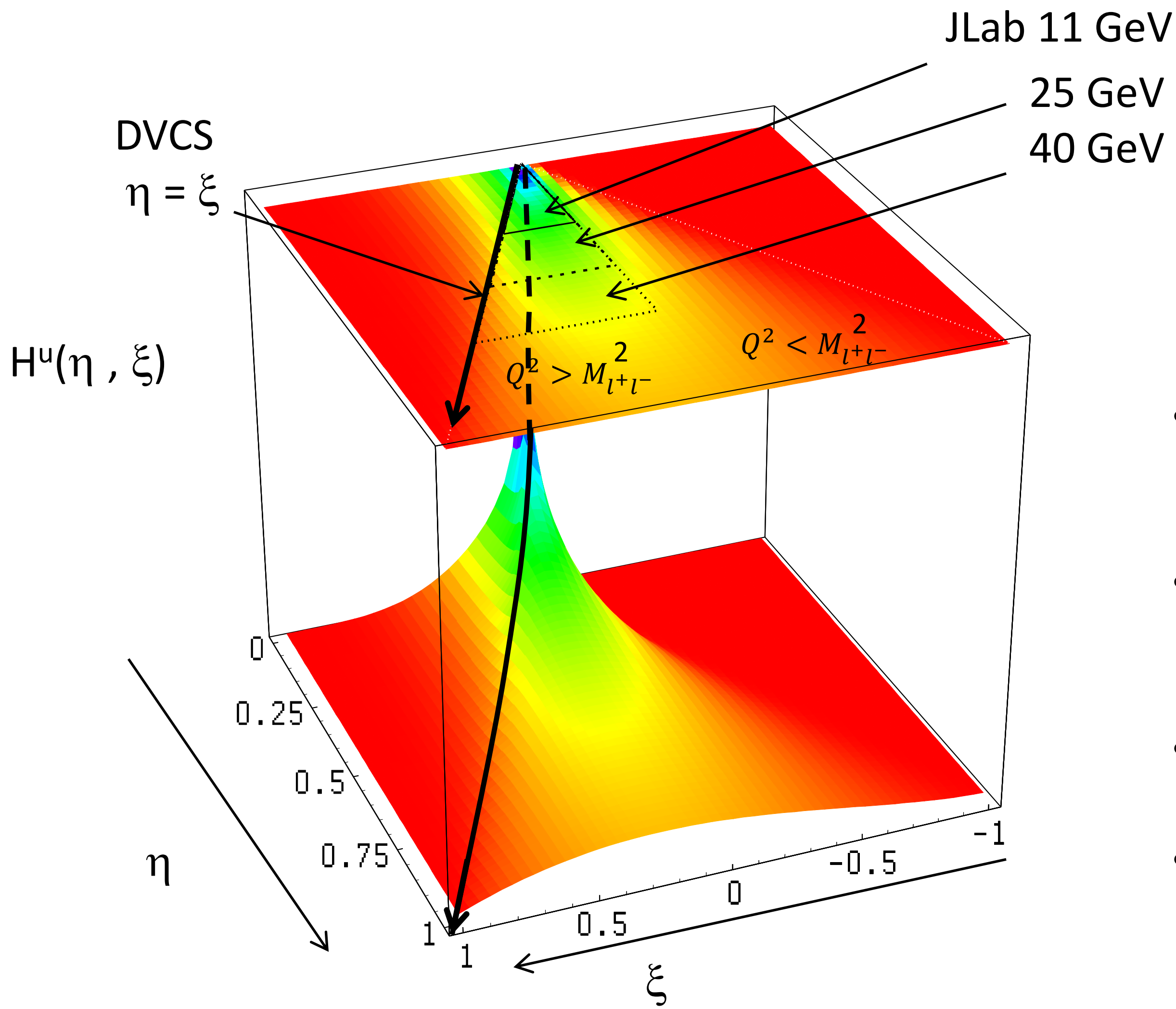
$Q^2 = -(k-k')^2$ $x_{bj} = \dfrac{Q^2}{2p_1q_1}$

Belitsky Radyushkin : Unraveling hadron structure with generalized parton distributions (arXiv:hep-ph/0504030v3 27 Jun 2005)

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

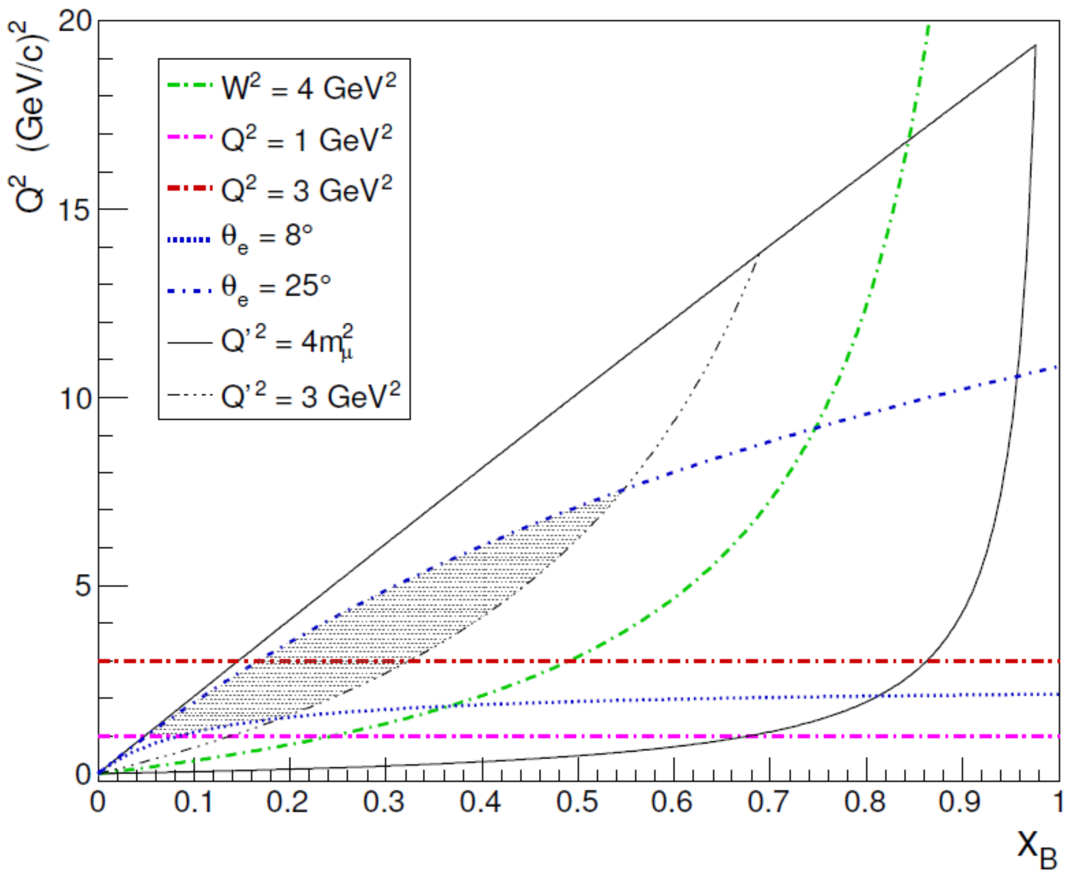
$$\propto \Im\mathrm{m} \left\{ F_1\mathcal{H} - \frac{t}{4M_N^2} F_2\mathcal{E} + \xi(F_1+F_2)\widetilde{\mathcal{H}} \right\},$$

Kinematical coverage



- DVCS only probes $\eta = \xi$ line
- Example with model of GPD H for up quark
- Jlab : $Q^2>0$
- Kinematical range increases with beam energy (larger dilepton mass)

Kinematic coverage



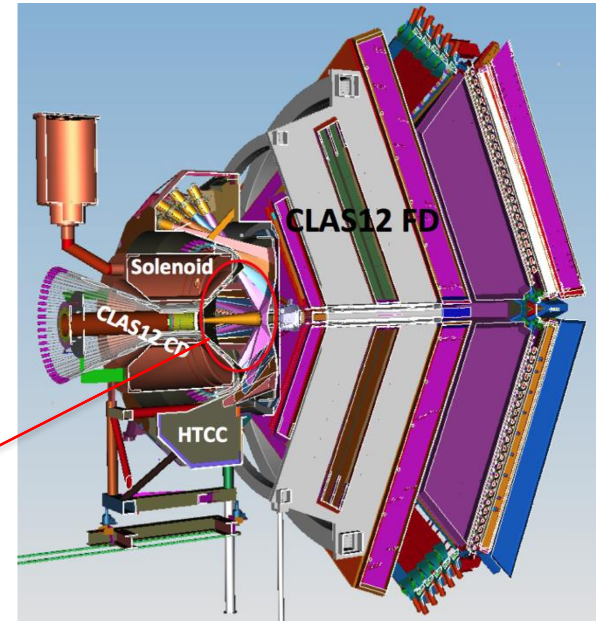
Possible measurements

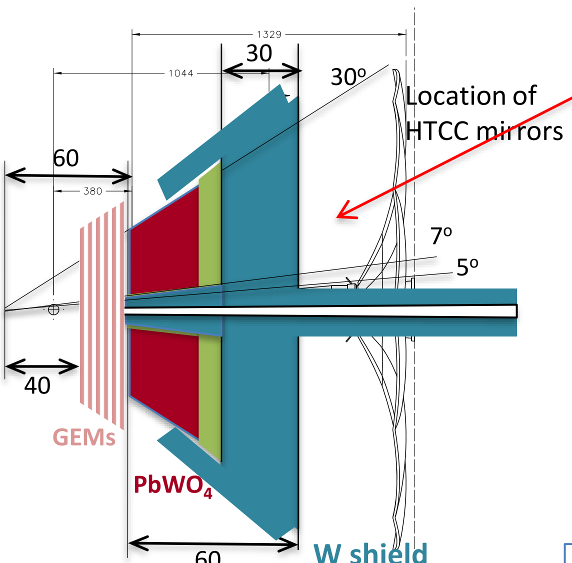
- PAC 43 : Measurement of Double Deeply Virtual Compton Scattering (DDVCS) in the di-muon channel with the SoLID spectrometer (Boer,Camsonne,Gnanvo,Sparveri,**Voutier**,Zhao)
- PAC 44 : Electroproduction of muon pairs with CLAS12: Double DVCS and J/ψ electroproduction (Boer,Guidal,**Stepanyan**,Guidal,Paremuzyan)
- Possible Hall C new detector

CLAS12 modifications for

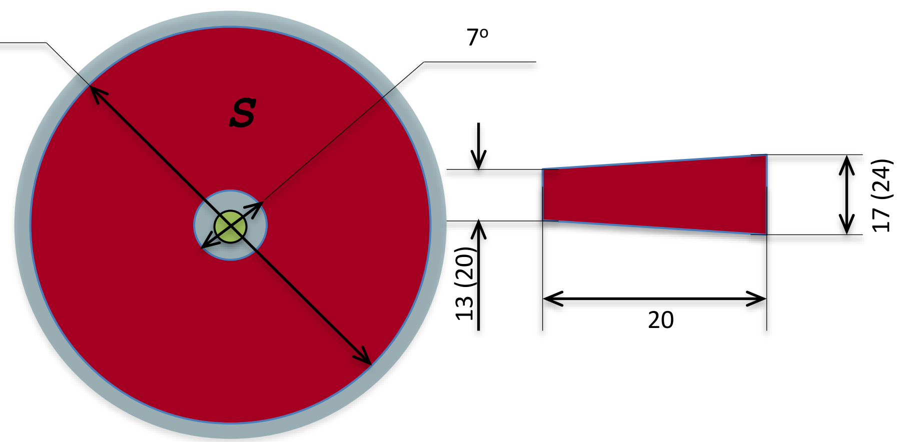
$$ep \rightarrow e'p'\mu^{+}\mu^{-} \;\; @ \;\; 10^{37}\, cm^{-2}\, s^{-1}$$

- Remove HTCC and install in the region of active volume of HTCC
  - a new Moller cone that extends up to 7º
  - a new $PbWO_4$ calorimeter that covers 7º to 30º polar angular range with 2π azimuthal coverage.
- Behind the calorimeter, a 30 cm thick tungsten shield covers the whole acceptance of the CLAS12 FD
- GEM tracker in front of the calorimeter for vertexing





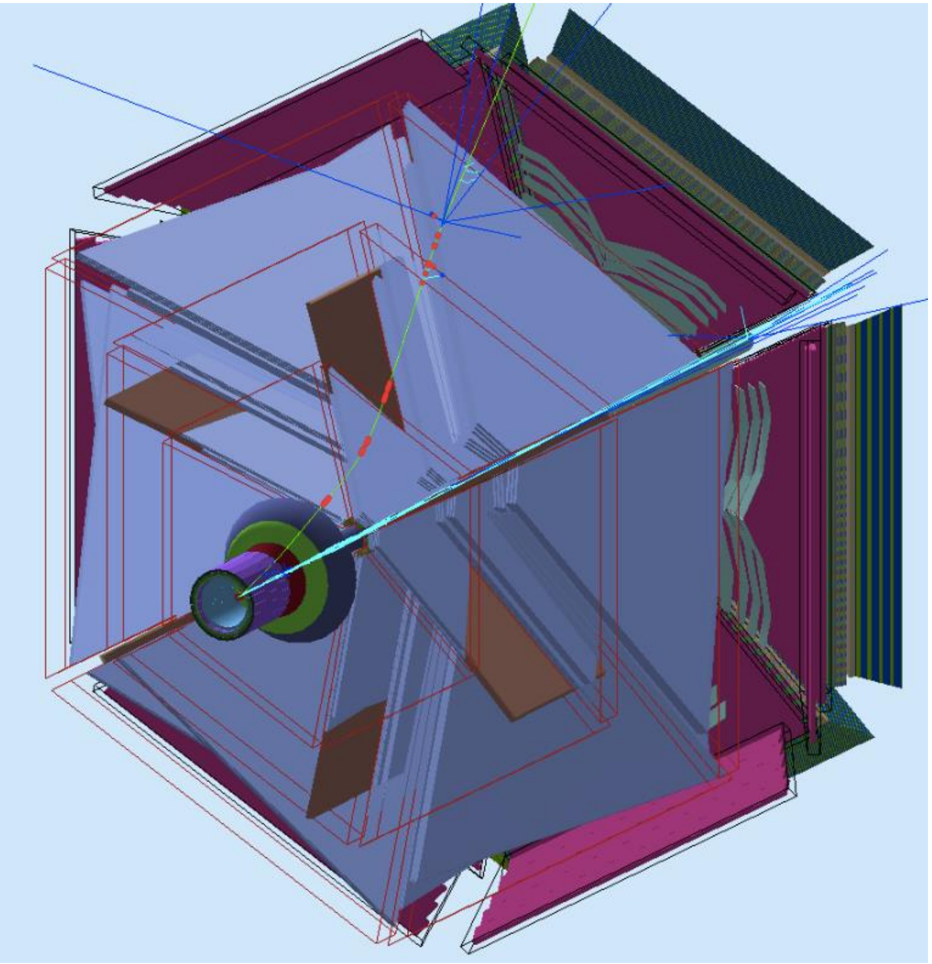
$$S = \pi l^2[(tg^2(30^o) - tg^2(7^o)] = 3600\, cm^2; \; l = 60\, cm$$



$PbWO_4$ modules with APD readout - ~ 1200 modules

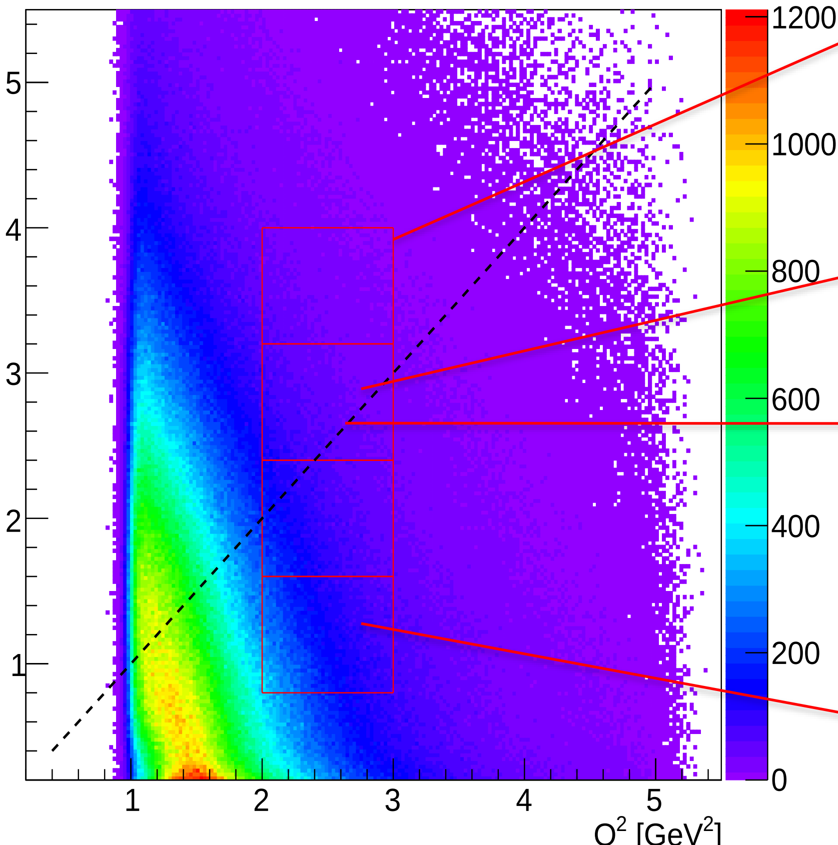
CLAS12 FD new configuration

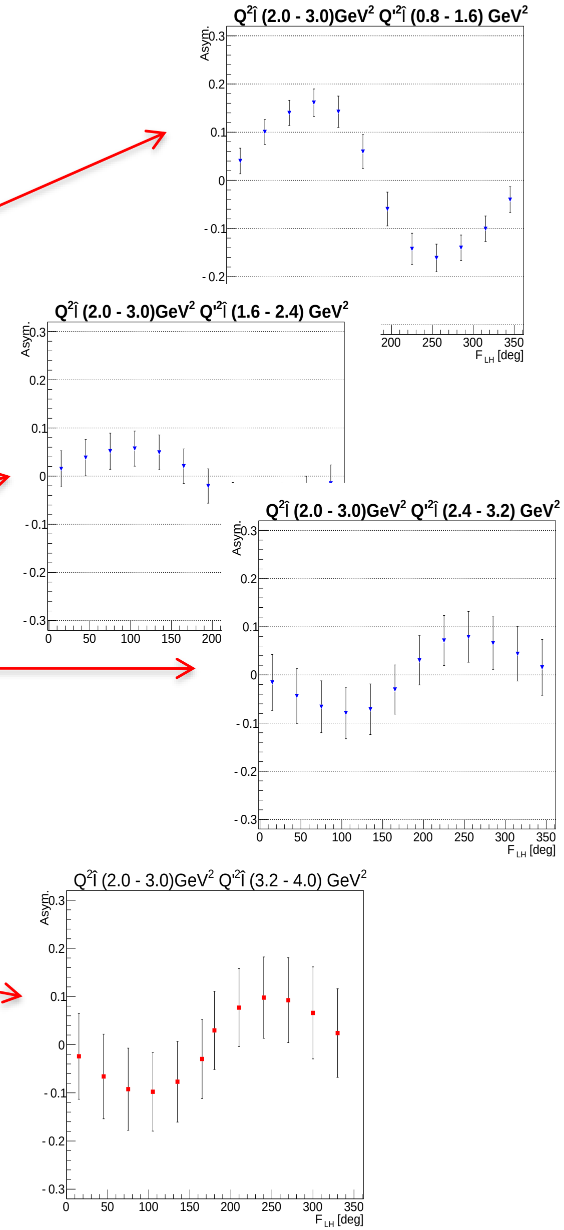
- In this configuration the forward drift chambers are fully protected from electromagnetic and hadronic background
- Calorimeter/shield configuration will play a role of the absorber for the muon detector, i.e. the CLAS12 FD
- The scattered electrons will be detected in the calorimeter
- GEM based tracking detectors will aid reconstruction of vertex parameters (angles and positions) of charged particles.



DDVCS beam spin asymmetry

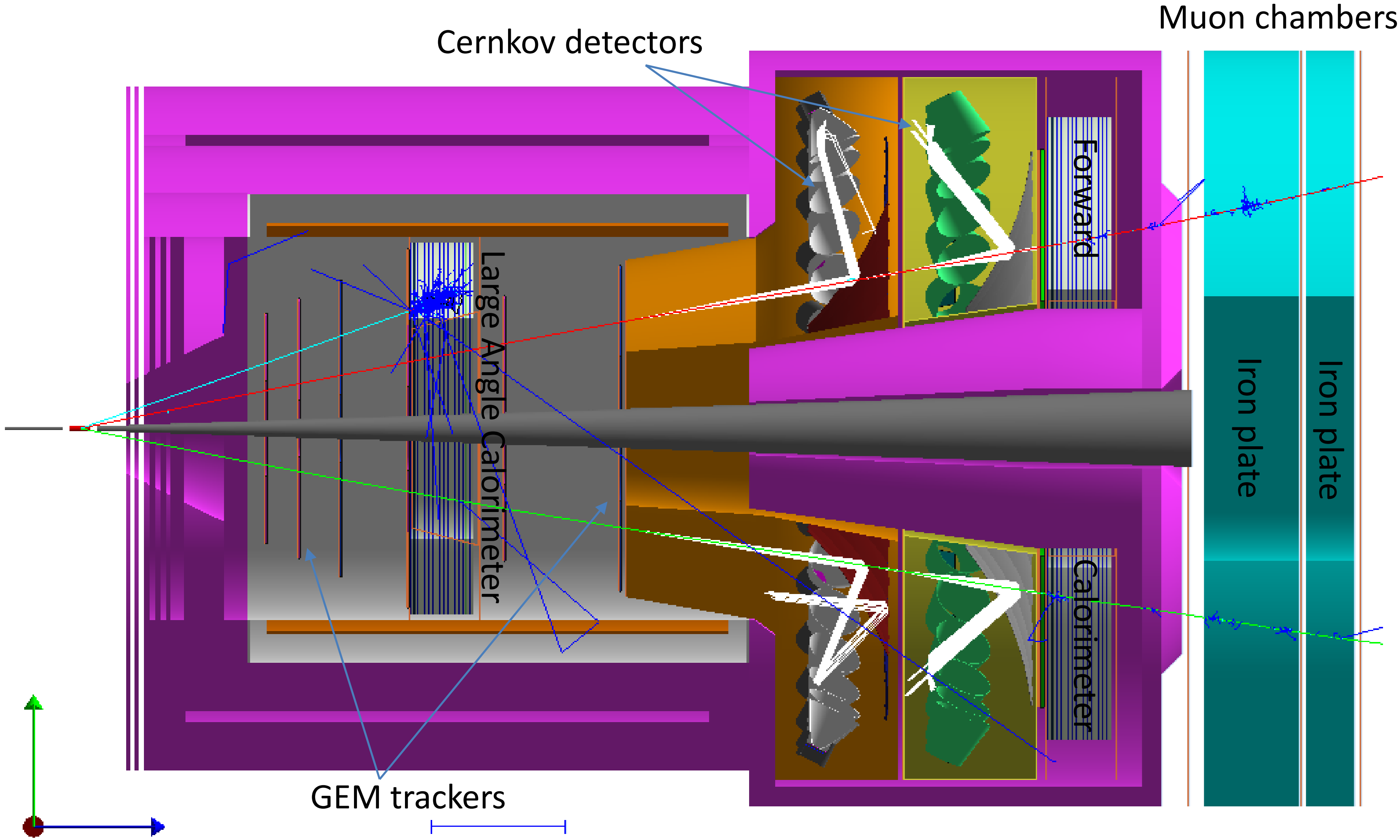
Sign change with change of kinematics – from Space-like to Time-like dominance region



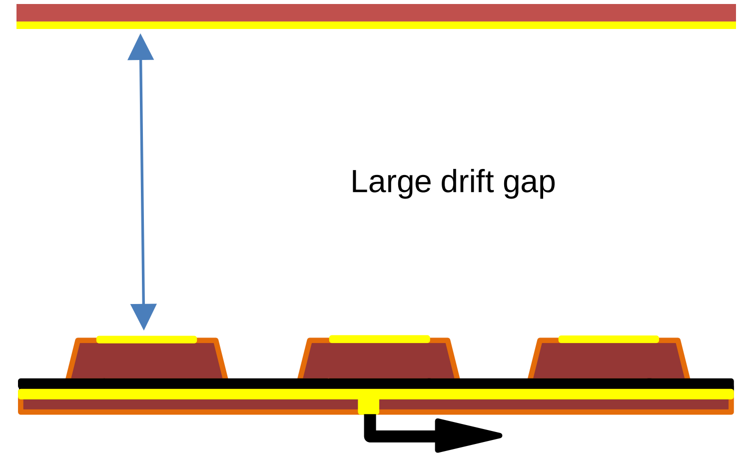


- The VGG code was used for DDVCS BSA
- GRAPE-dilepton event generator was used to estimate rates

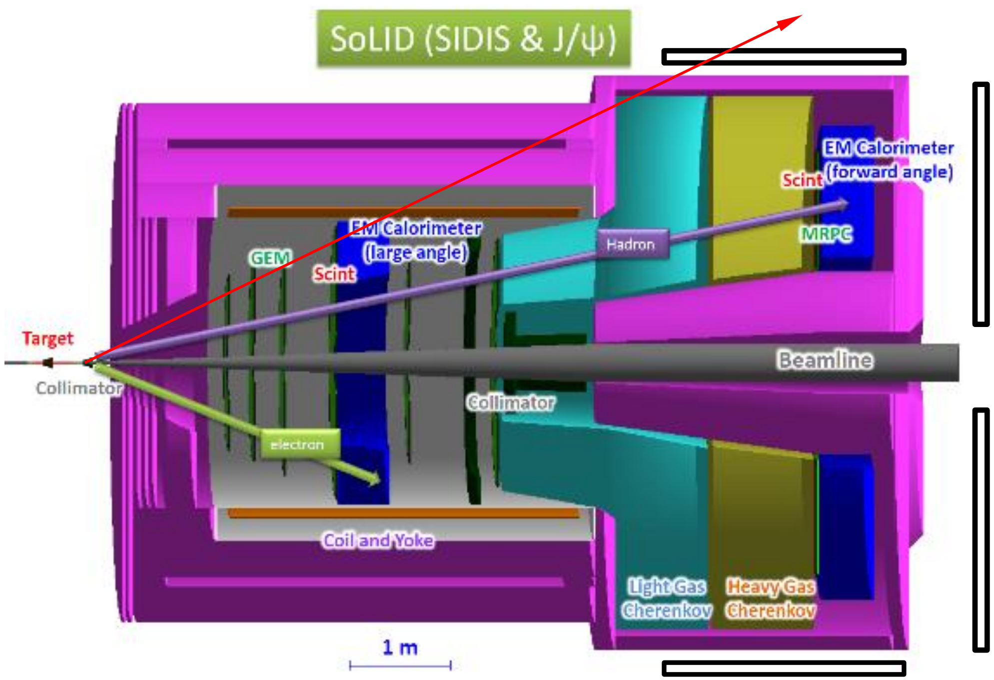
SoLID JPsi Setup



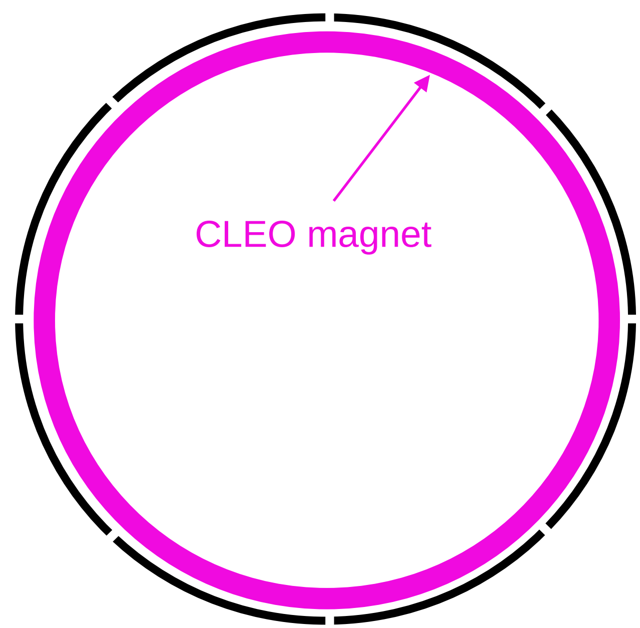
mini-drift μ-RWELL detector



- ✓ Muons hitting the chambers at vary large incident angle
- ✓ **Using μ-RWELL in mini drift mode** ⇨ Excellent tracking capability with one detector layer at very low overall cost

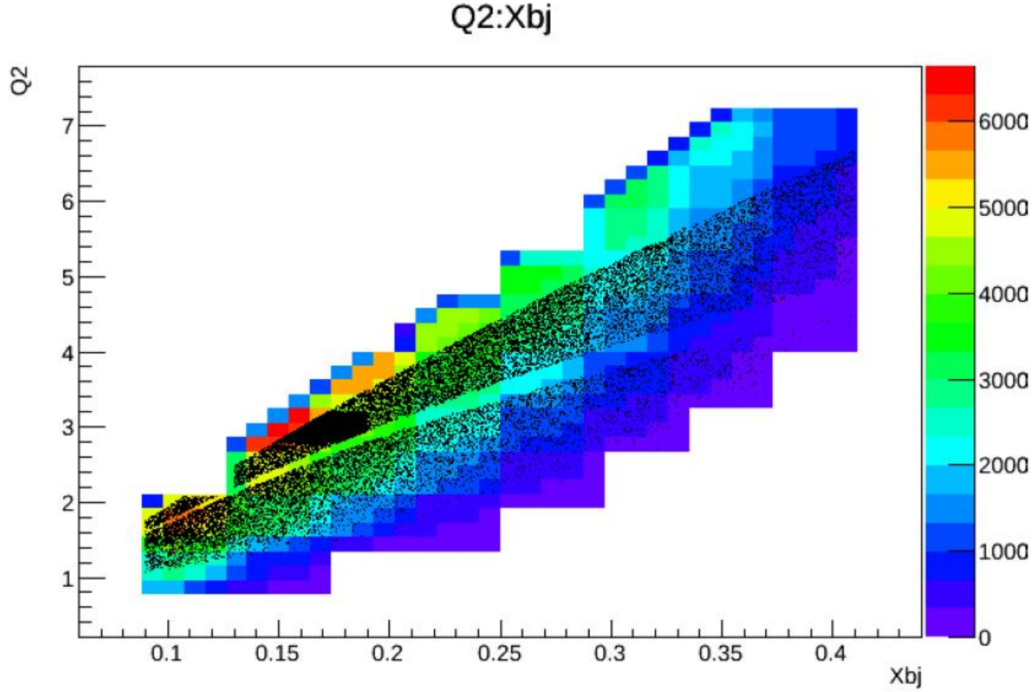


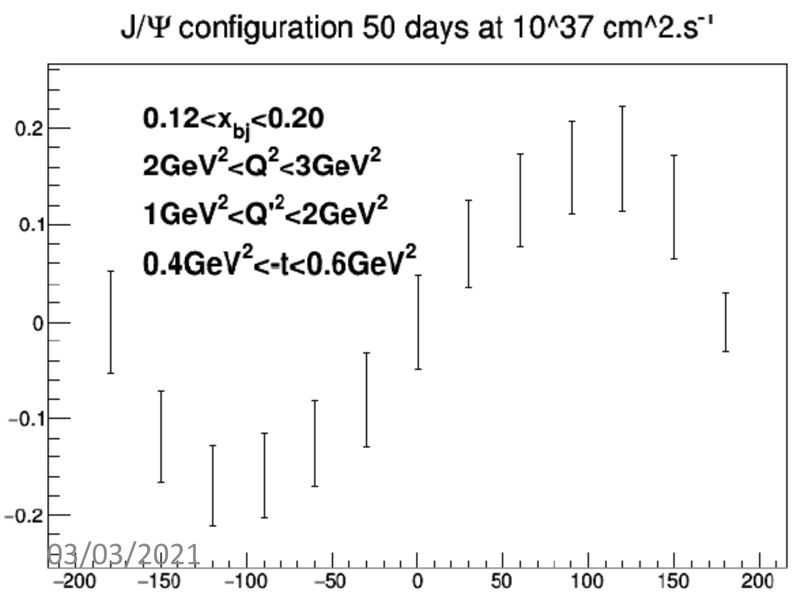
Slide from Kondo Gnanvo

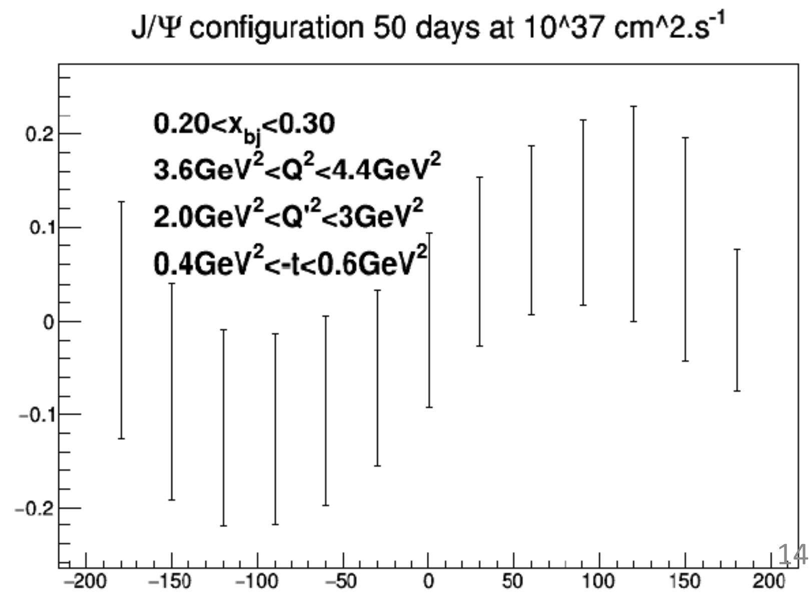


Curved mini drift μ-RWELL

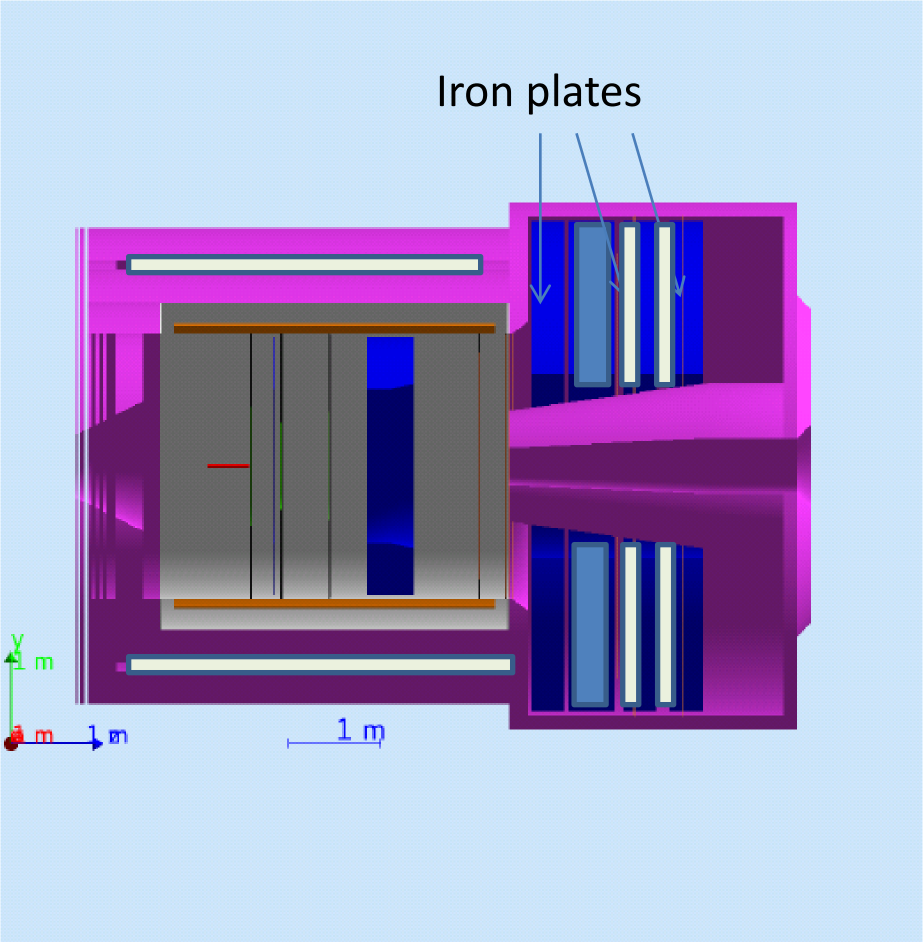
Counts J/psi setup 60 days at 10^37 cm^{-2}s^{-1}







Dedicated setup for muon detection only



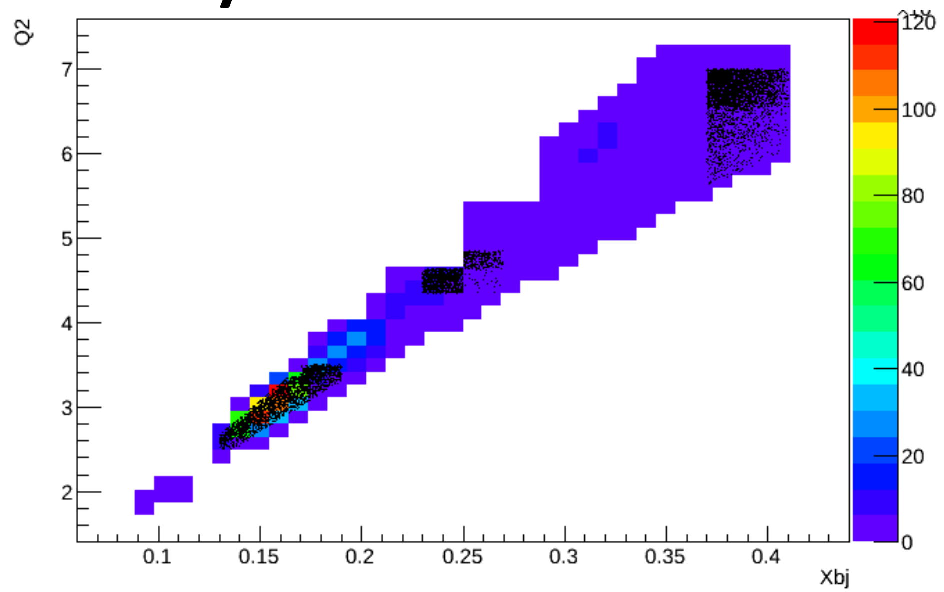
- In addition to muon detector

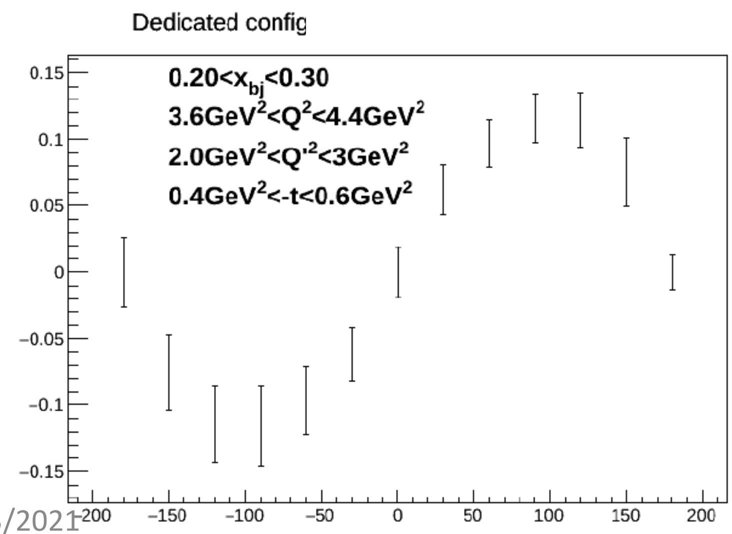
- Target moved 2m from Jpsi position inside and switch to 45 cm target
- Iron plate from 3rd layer yoke in front and behind calorimeter (low resolution e for trigger)

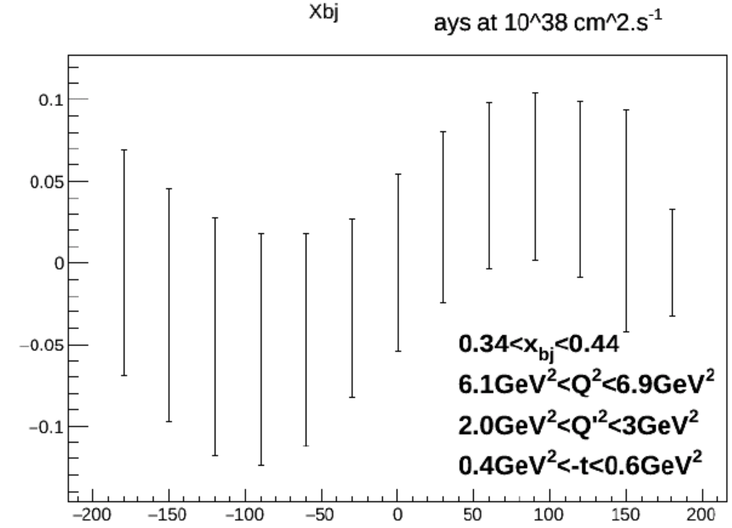
- Remove / Upgrade Gas Cerenkov

- Try to reach 10^{38} cm^{-2}s^{-1}
- 10 uA on 45 cm target

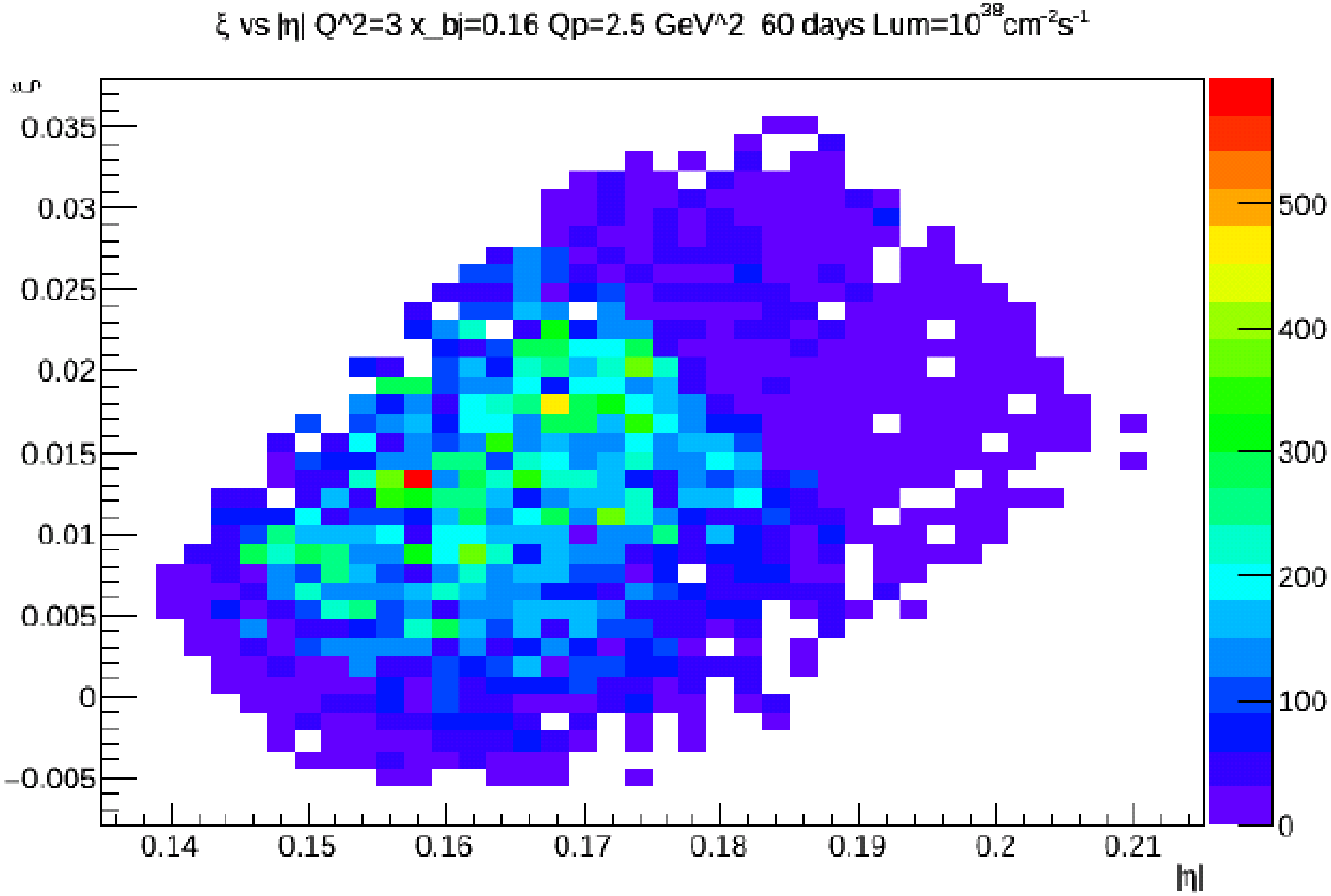
Expected accuracy dedicated setup 90 days at 10^{38} cm^{-2}s^{-1}



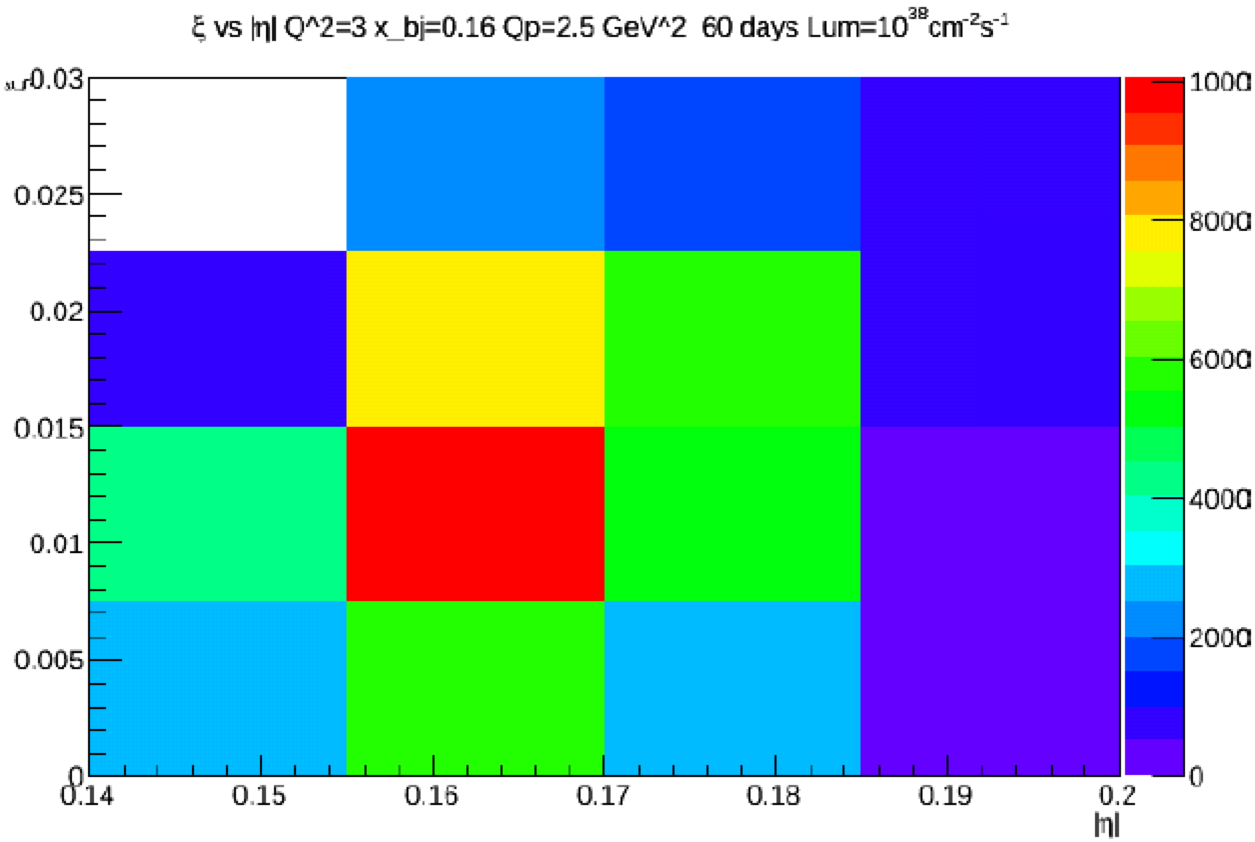




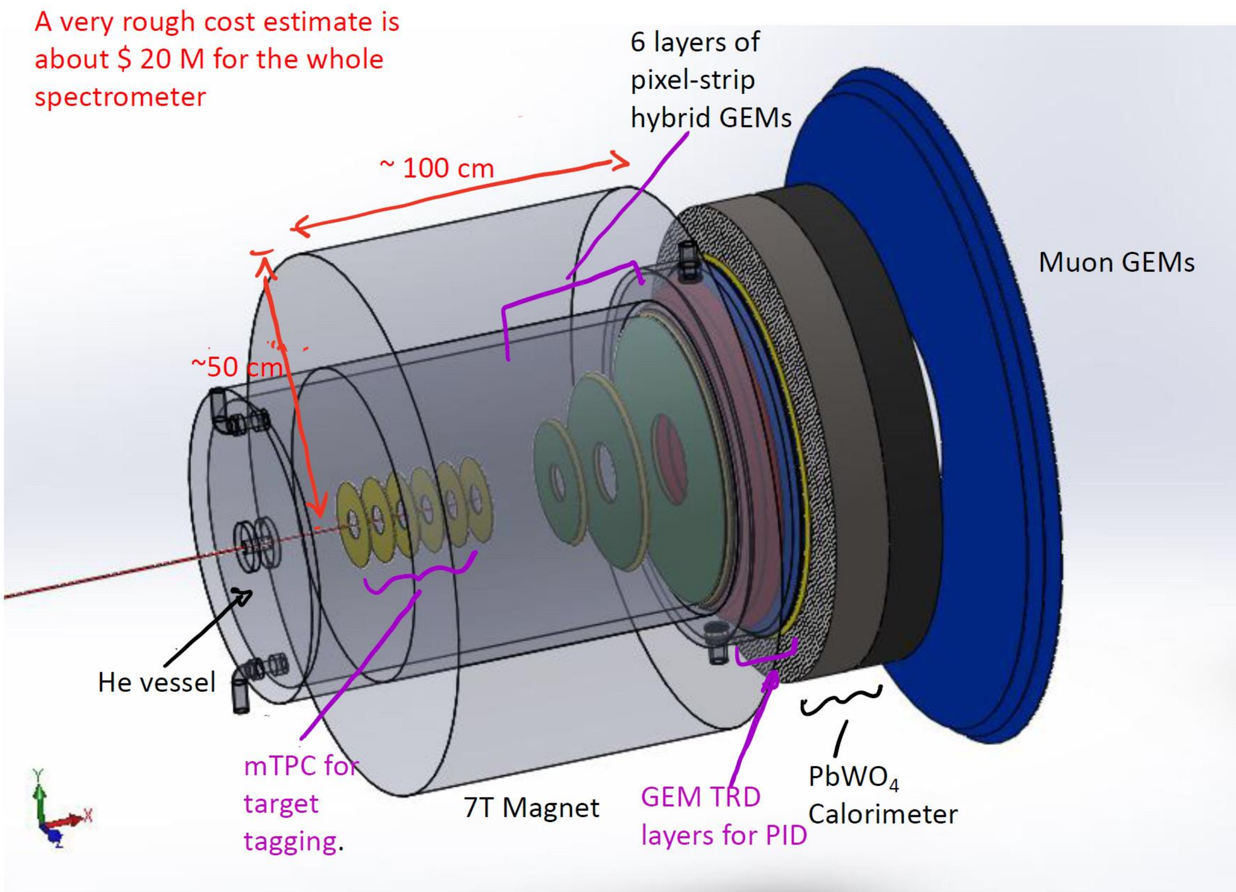
Eta and xi coverage



Eta Xi coverage large bin



Hall C proposal



Higher luminosity ?

- Current could go up to 80 uA on 40 cm target ~ 7.10^38 to $cm^{-2}s^{-1}$
- Muon detector using GEM or uRWell should be ok since after material
- Tracker occupancy and photon background
  - Reduce amount of Copper in GEM
  - 2D MGPD readout
  - Micromegas option
  - Pixellized MAPS
  - Superconducting tracker option
- Calorimetry
  - Study liquid scintillator and cryogenics calorimeter option
  - Faster PMT or LAPPD/MCP PMT (1 ns width pulse to increase rate capability)
- Cerenkov
  - Faster PMT or LAPPD/MCP PMT (1 ns width pulse to increase rate capability)
  - HBD type Cerenkov for Large Angle calorimeter

Technically doable mostly matter of cost

CNF Question sheet

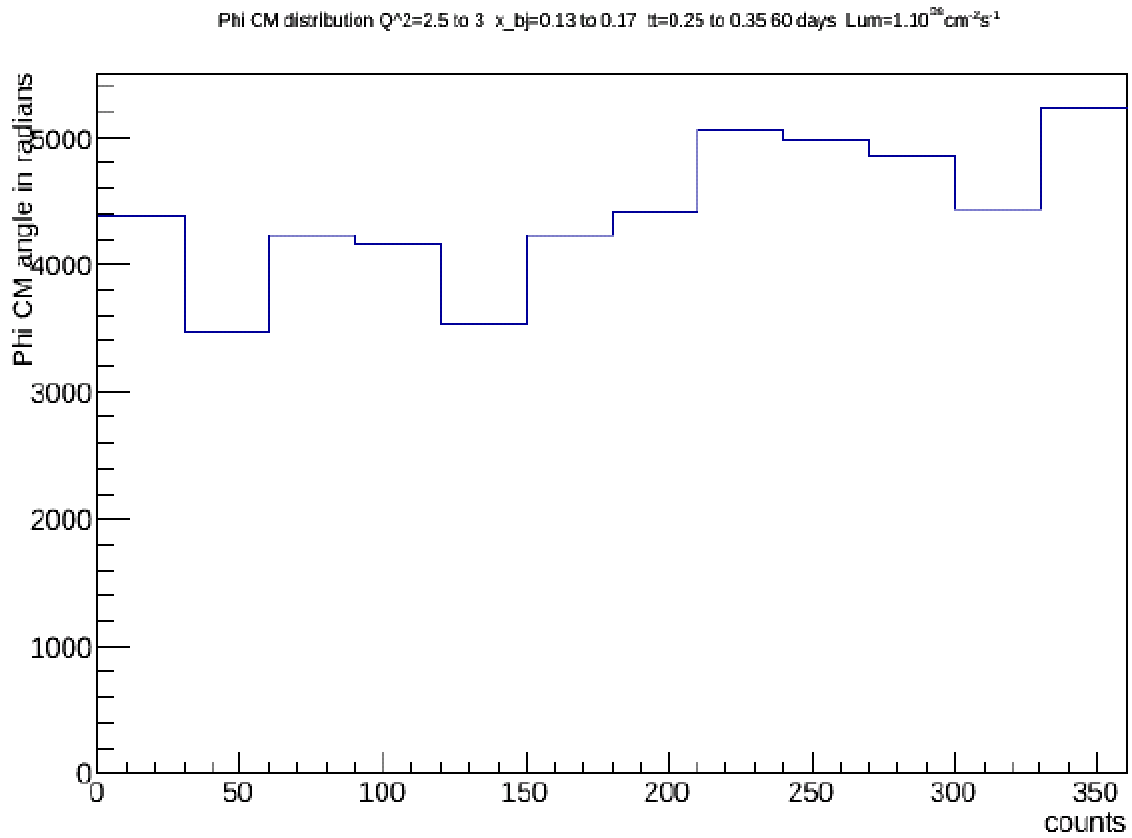
- what can be extracted from data, is it cross sections, asymmetries, both, CFFs?
  - Asymmetries : 5 %
  - Crossections : 10 % need to be studied
- what has been done to get to the CFFs?
- Looking into the future, what information is used to get: AM and similar mechanical properties, and the spatial structure?
  - Azimuthal asymmetry
- How can theory help, what and where is it needed, what tools?
  - Impact on CFF and GPD fits
  - What accuracy is required for
  - Scheme for inclusion of data
- In particular, how are data going to be shared by the community, can we plan on designing a public website?
- Are pseudo data going to be available?
  - VGG model
- What level of model-independence can we reach in the extraction of Compton form factors?
  - Not model dependent
- Skewdness dependence gives access to D-term

Conclusion

- Jlab 12 GeV beam along with high power target offers a unique opportunity to study DDVCS
- Higher energy would give higher kinematical reach
- Muon detection is interesting to distinguish from incoming electron and to increase luminosity
- Hall B DDVCS and SoLID Parasitic measurement on J/Psi could give a first measurements of DDVCS
- Hall C high luminosity detector proposal
- Dedicated setup could increase luminosity by a factor of 10 up to 10^{38} $cm^{-2}.s^{-1}$ for improved statistical accuracy
- High statistics would allow binning in different variables to look a binning in Q'^2 to probe xi eta surface with xi different of eta of GPDs
- Need develop physics case for proposals and funding requests

Backup

Counts SoLID dedicated setup 10^38 $cm^{-2}s^{-1}$



~2 % statistical error