Double Deeply Virtual Compton Scattering Opportunities At Jefferson Laboratory

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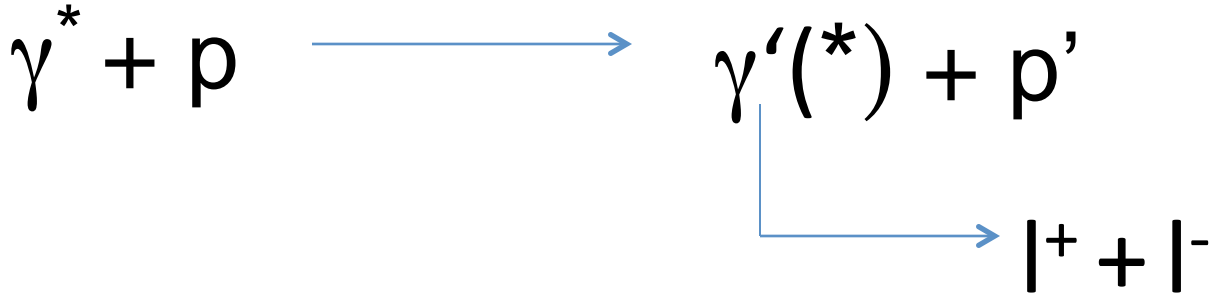
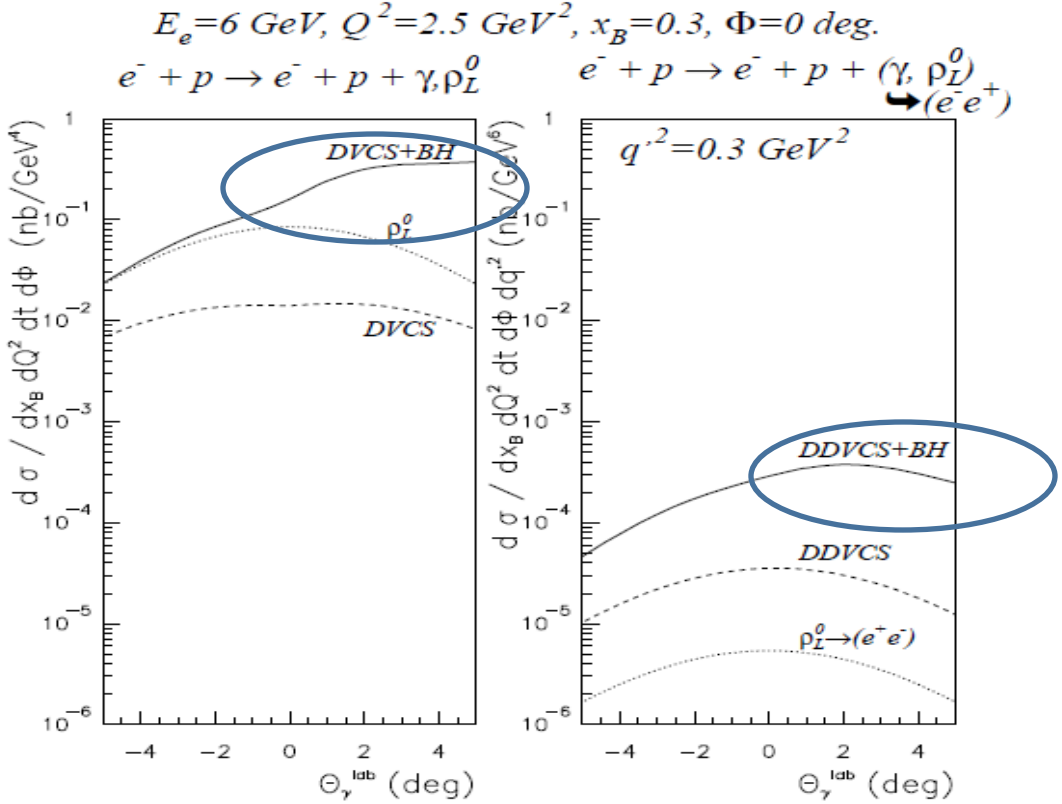
U.S. DEPARTMENT OF ENERGY | Office of Science
Jefferson Lab
Thomas Jefferson National Accelerator Facility
JSA

DVCS / Double DVCS



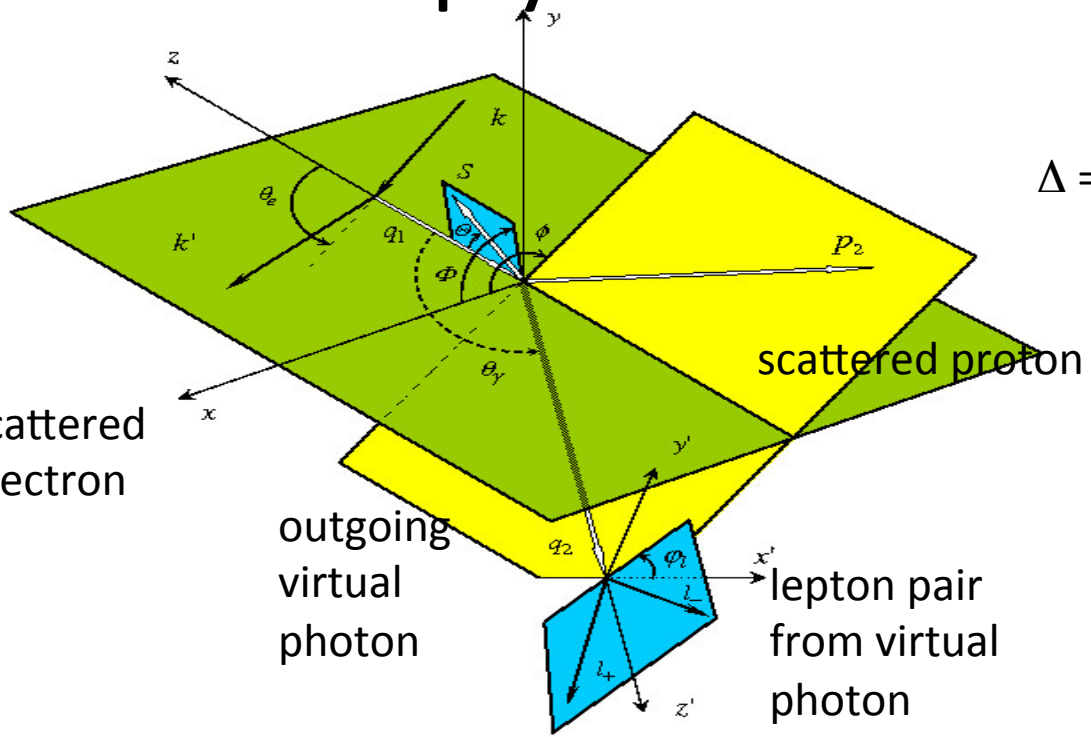
Guidal and Vanderhaegen : Double deeply virtual Compton scattering off the nucleon (arXiv:hep-ph/0208275v1 30 Aug 2002)
Belitsky Radyushkin : Unraveling hadron structure with generalized parton distributions (arXiv:hep-ph/0504030v3 27 Jun 2005)

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



scattered electron

outgoing virtual photon

scattered proton

lepton pair from virtual photon

Δ = p1-p2 = q2-q1

$Q^2 = -q^2$

p = p1+p2

q = ½ (q1+q2)

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

$Q^2 = -(k-k')^2$

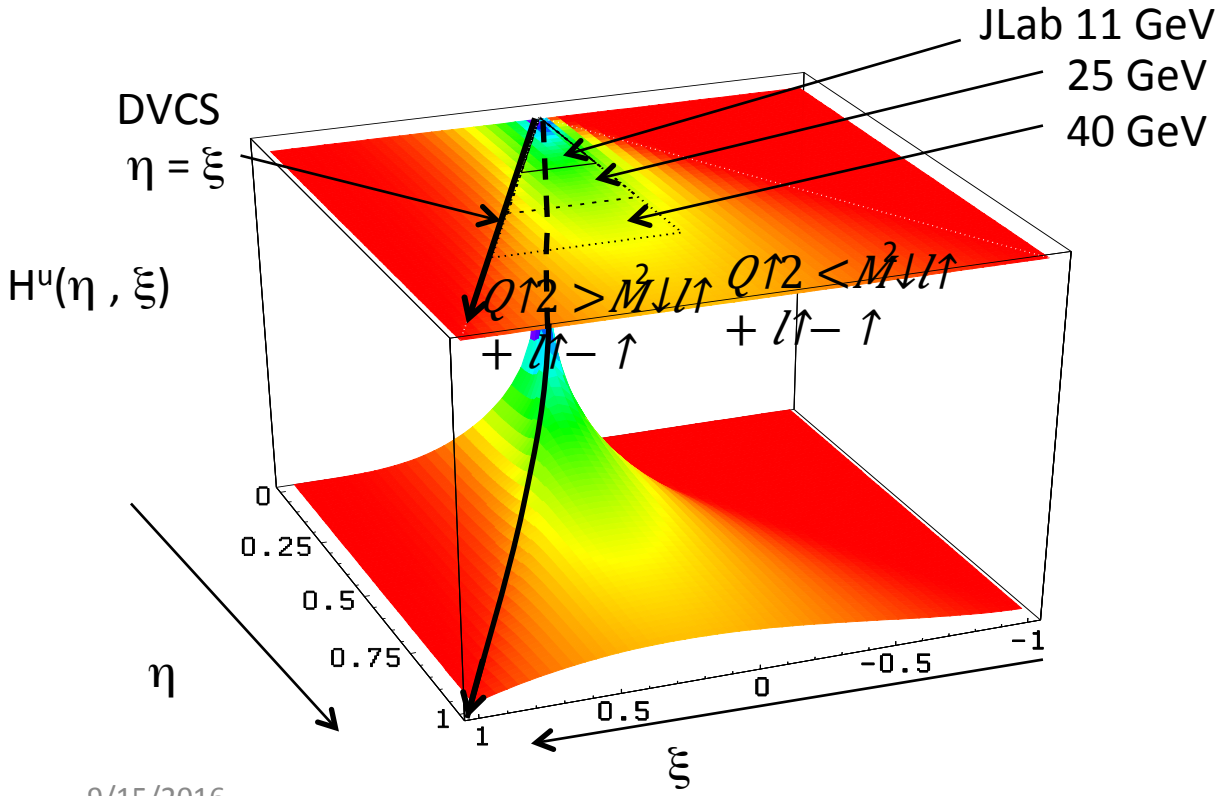
$$x_{bj} = \frac{Q^2}{2p_1q_1}$$

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

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

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

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)

Two letters of intent at JLab

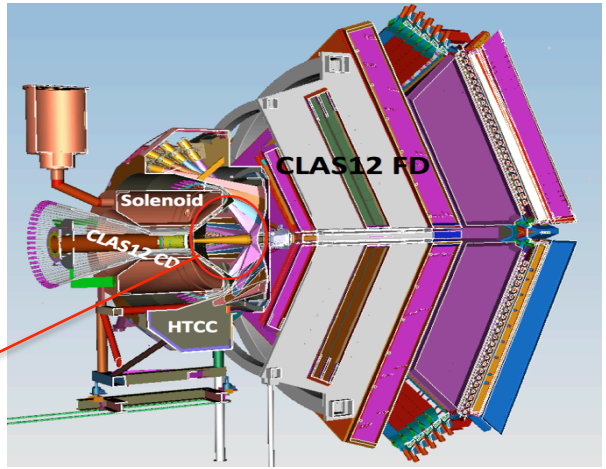
- PAC 43 : Measurement of Double Deeply Virtual Compton Scattering (DDVCS) in the di-muon channel with the SoLID spectrometer (Boer,Camsonne,Gnanvo,Sparveri,**Voutier**,Zhao)

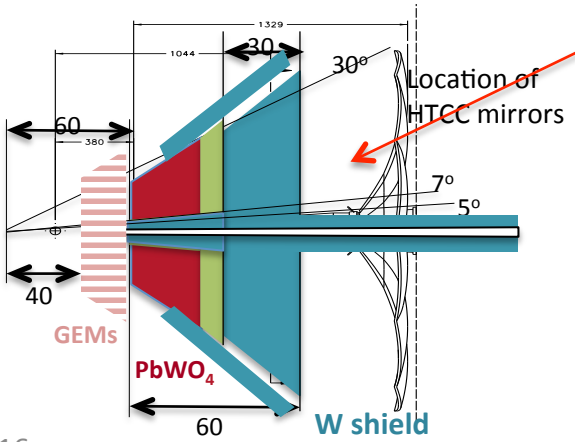
- PAC 44 : Electroproduction of muon pairs with CLAS12: Double DVCS and J/ψ electroproduction (Boer,Guidal,**Stepanyan**,Guidal,Paremuzyan)

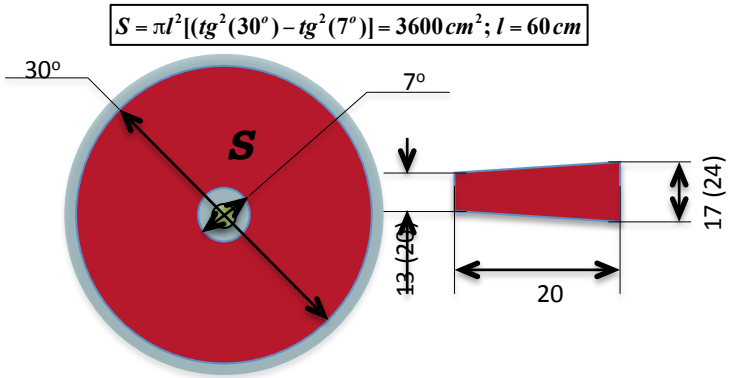
CLAS12 modifications for

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

- Remove HTCC and install in the region of active volume of HTCC
  - a new Moller cone that extends up to 7°
  - a new $PbWO_4$ calorimeter that covers 7° to 30° 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



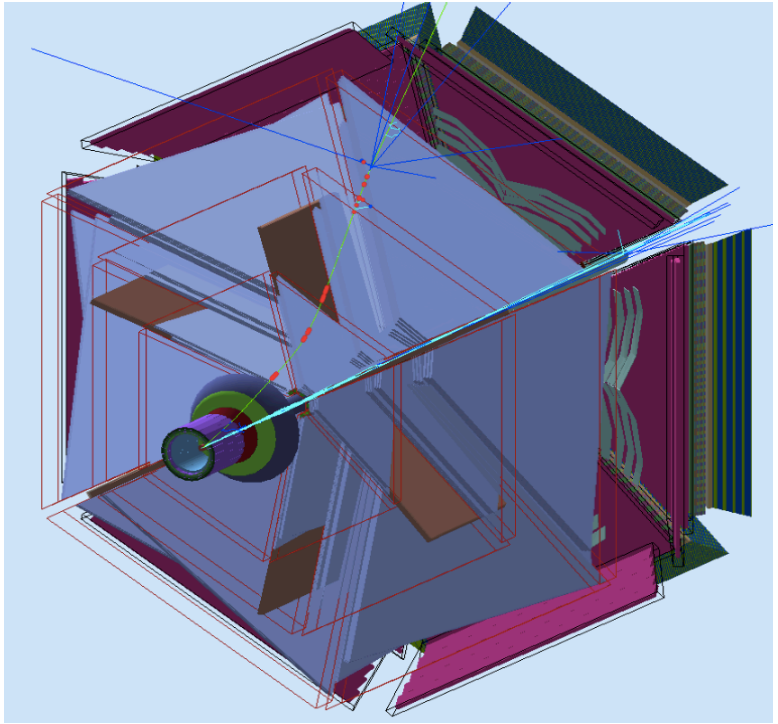




$PbWO_4$ modules with APD readout - ~ 1200 modules

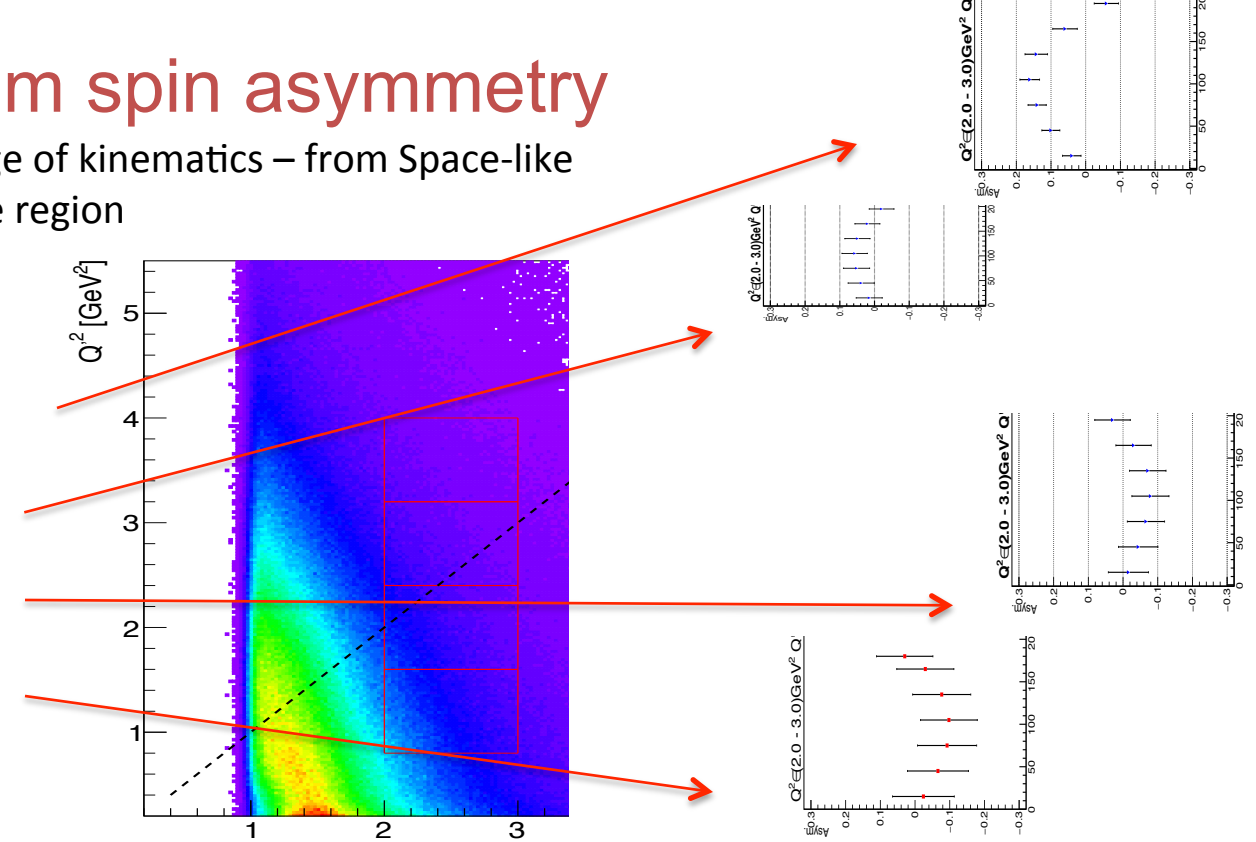
CLAS12 FD new configuration

- 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.



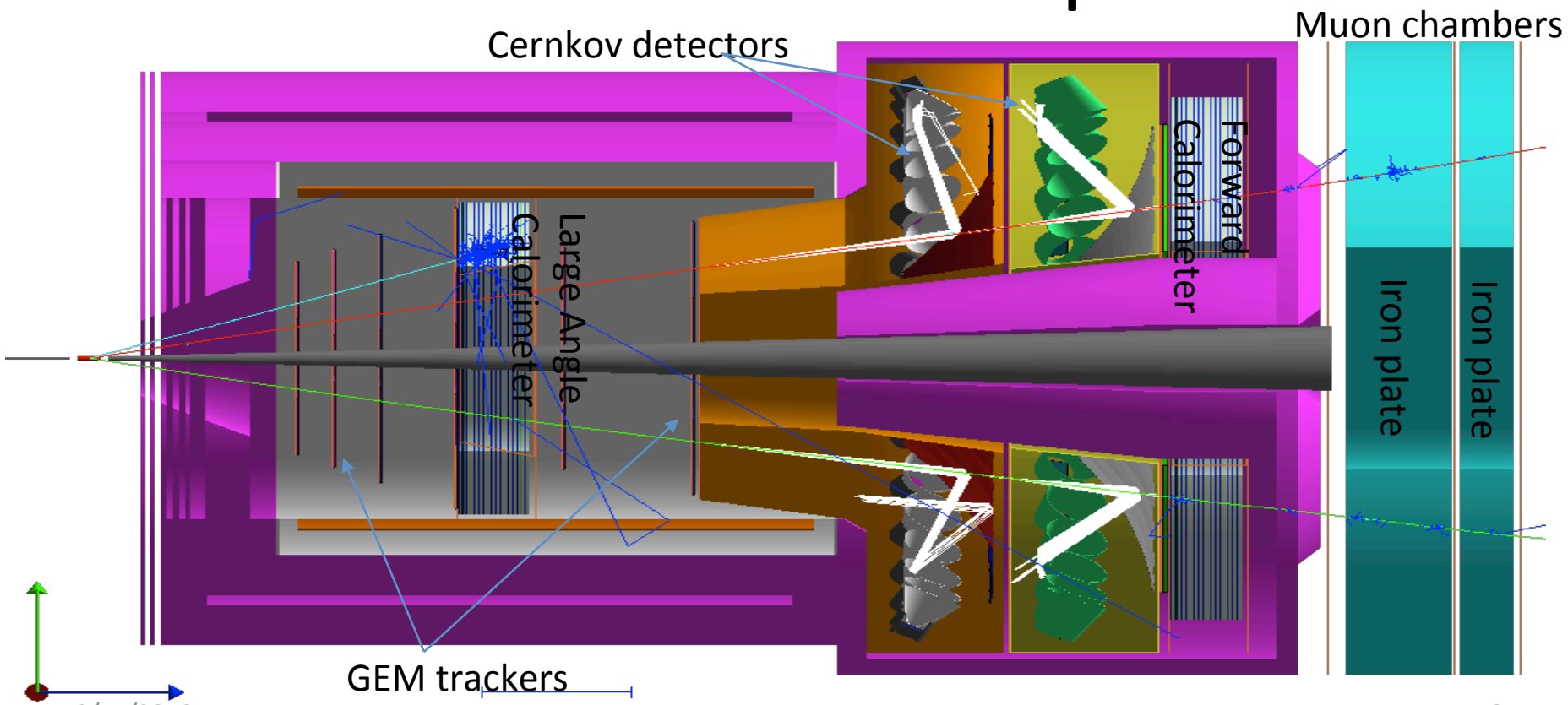
DDVCS beam spin asymmetry

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

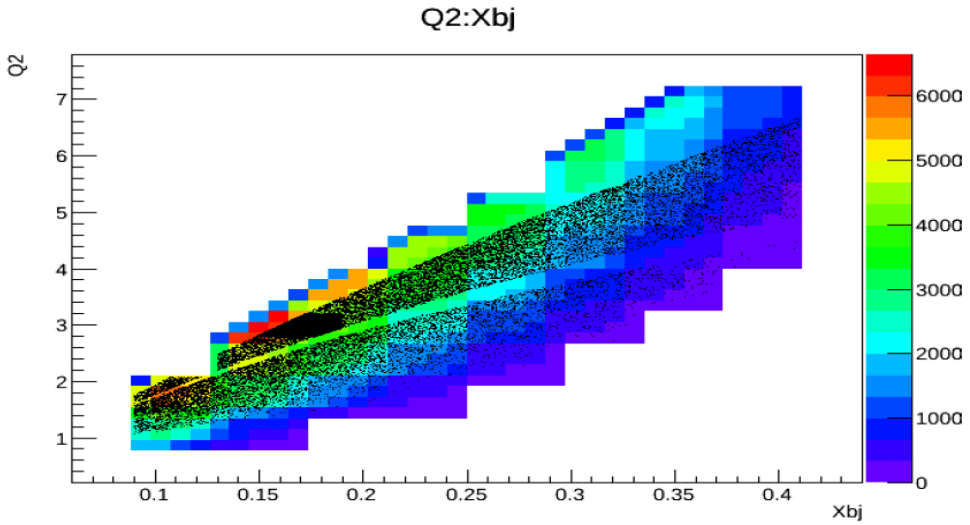


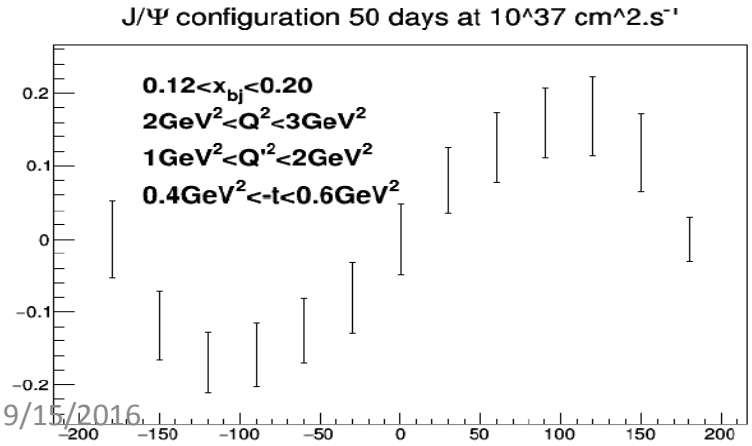
- The VGG code was used for DDVCS BSA
- GRAPE-dilepton event generator was used to estimate rates

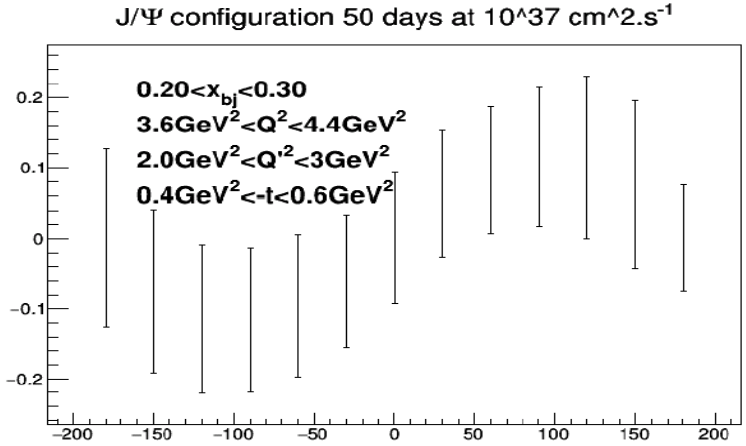
SoLID JPsi Setup



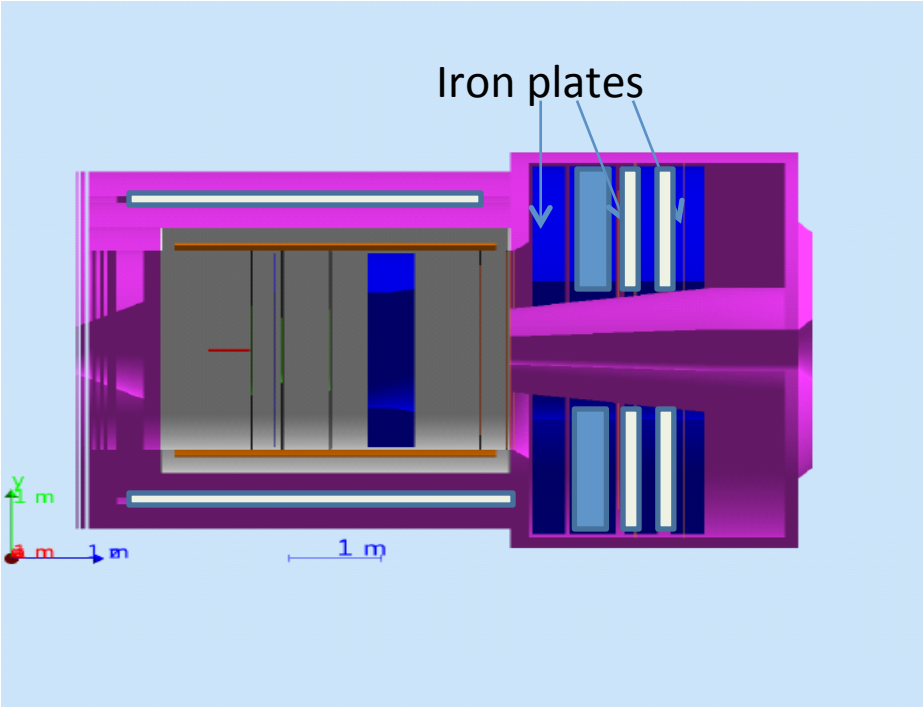
Counts J/psi setup 60 days at 10^37 $cm^{-2}s^{-1}$







Dedicated setup

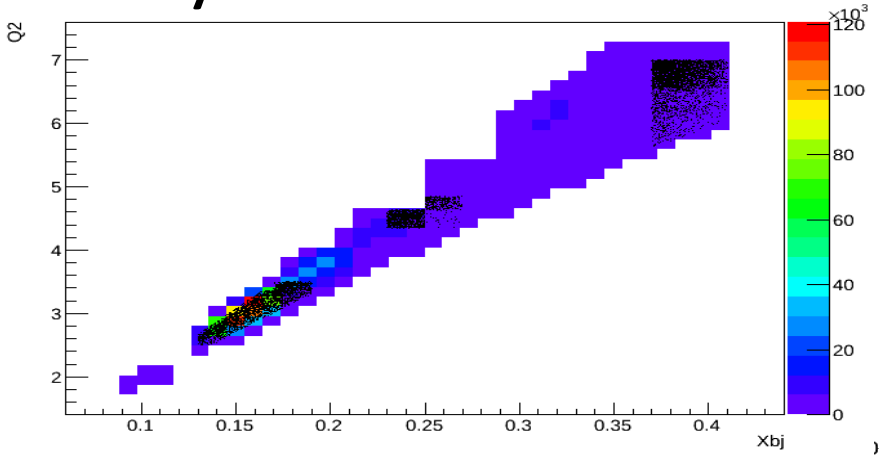


- Target moved 2m from Jpsi position inside and switch to 45 cm target
- Iron plate from 3rd layer yoke in front and behind calorimeter

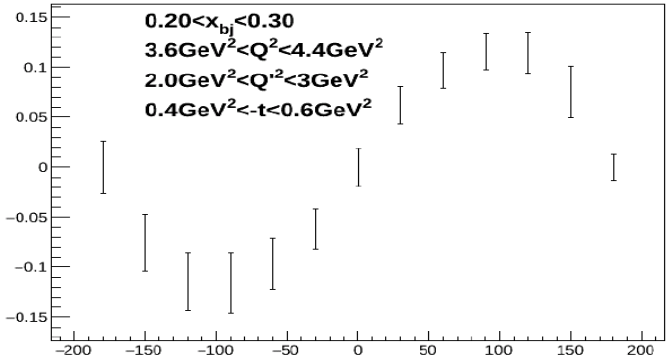
- Remove Gas Cerenkov

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

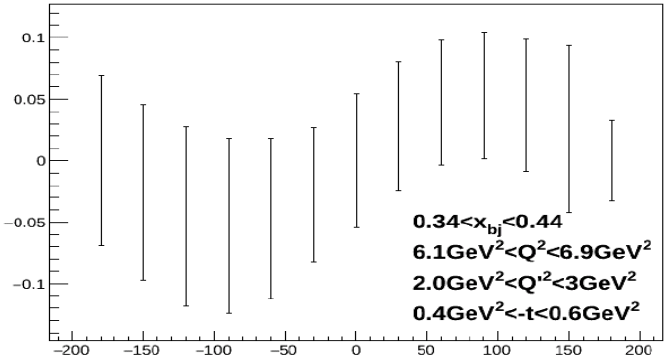
Expected accuracy dedicated setup
90 days at 10^{38} $cm^{-2}s^{-1}$



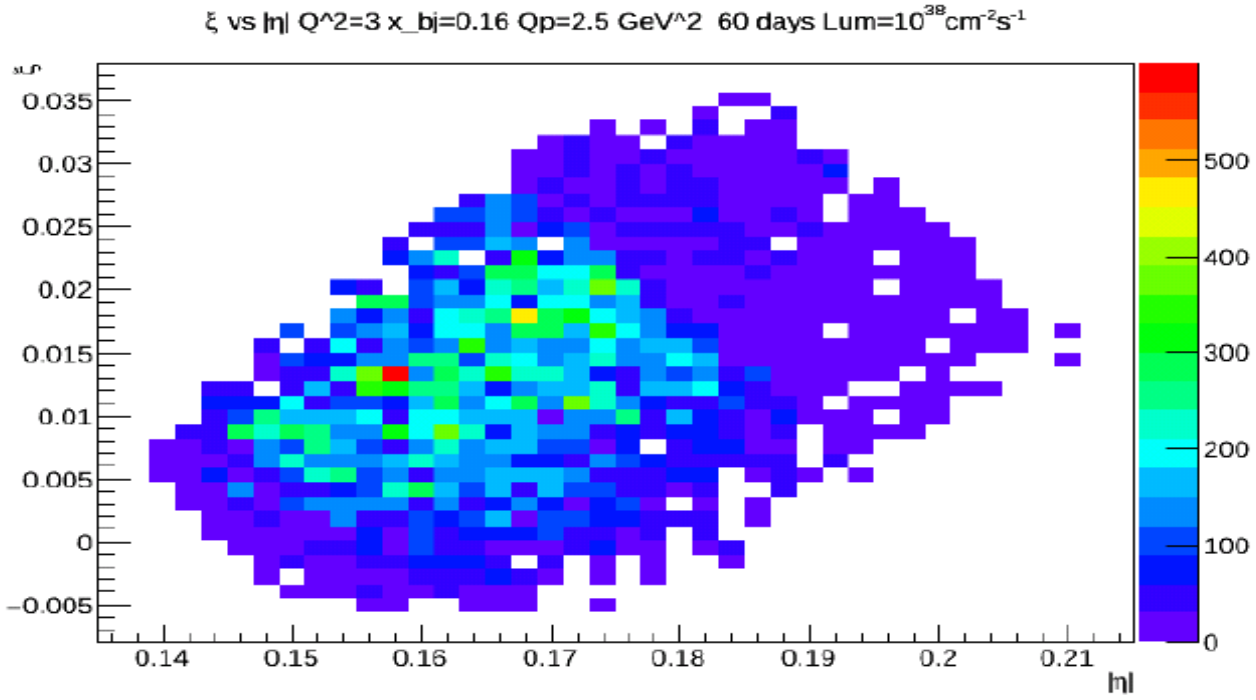
Dedicated con



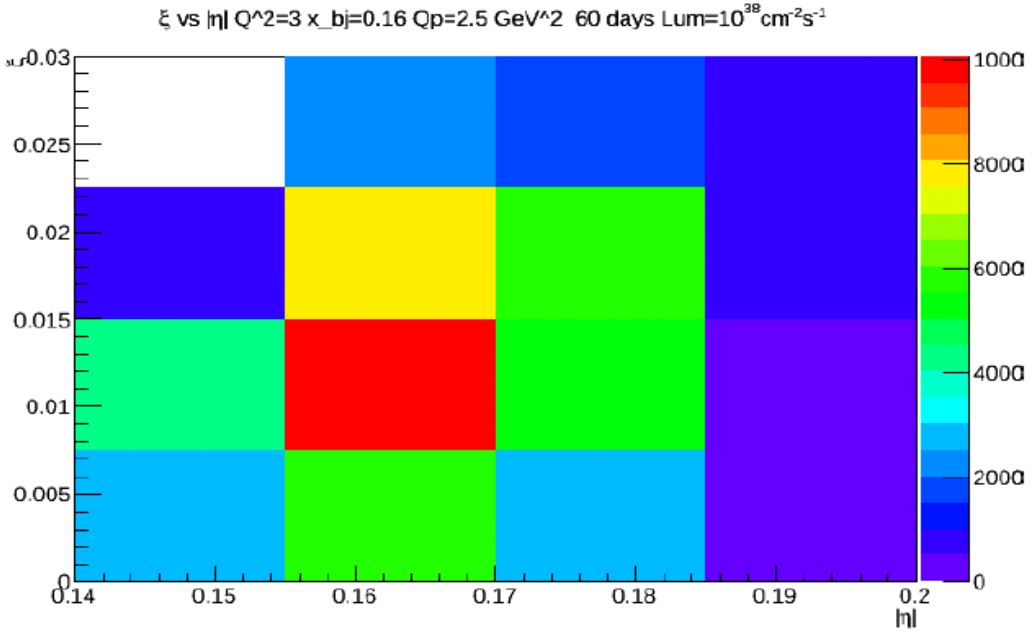
) days at 10^38 cm^2.s^-1



Eta and xi coverage



Eta Xi coverage large bin



Higher luminosity ?

- Current could go up to 80 uA
- Target length up to 1 meter
- Tracker occupancy and photon background
  - Reduce amount of Copper in GEM
  - Micromegas option
  - Build smaller chambers and add more channels
  - Study complement with 2D pad readout
  - Superconducting tracker option
- Calorimetry
  - Study liquid scintillator and cryogenics calorimeter option
  - Superconducting detector to replace PMT (1 ns width pulse to increase rate capability)
- Cerenkov
  - Superconducting detector to replace PMT (1 ns width pulse to increase rate capability)
  - HBD type Cerenkov for Large Angle calorimeter

6. 10^38 $cm^{-2}s^{-1}$

Technically doable mostly matter of cost

Conclusion

- Jlab 12 GeV beam along with high power target offers a unique opportunity to study DDVCS
- Muon detection is interesting to distinguish from incoming electron and to increase luminosity
- Hall B DDVCS or SoLID Parasitic measurement on J/Psi could give a first measurements of DDVCS
- 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

ECT Trento workshop on dilepton production
October 24th to 28th 2016