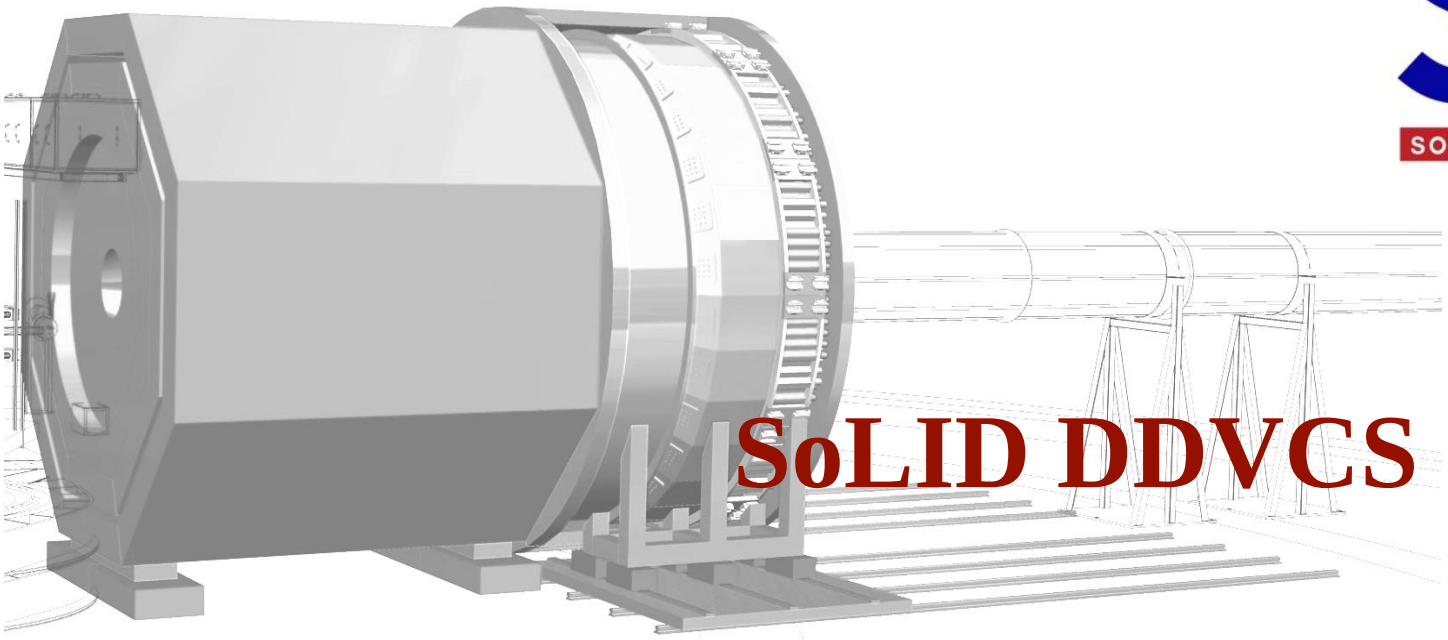


SoLID DDVCS

Zhiwen Zhao

SoLID Collaboration

Towards improved hadron femtography with hard exclusive reactions
JLab 2023/08/07-11

SoLID (Solenoidal Large Intensity Device)

Full exploitation of JLab 12 GeV upgrade with broad physics program

Lumi ~1e^{39}/cm^2/s (baffled geometry)

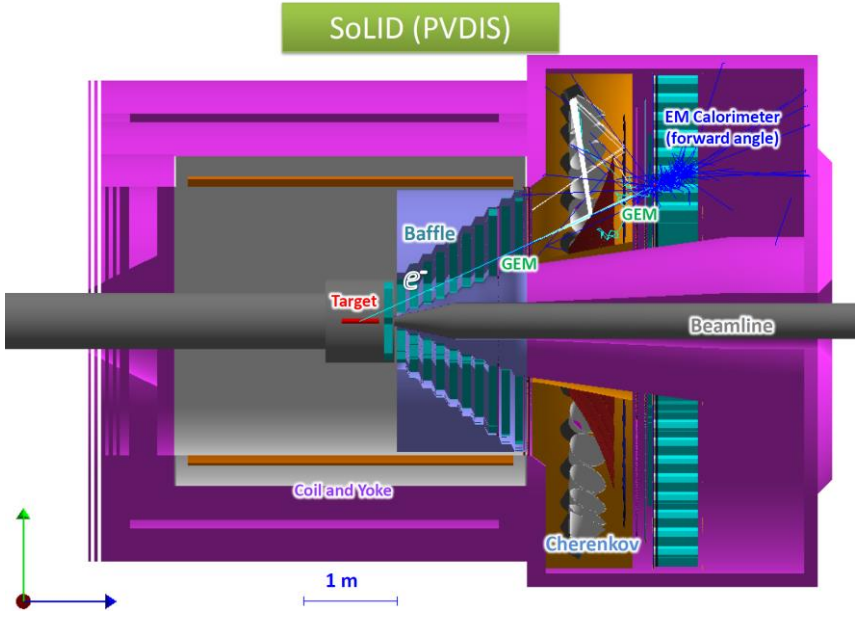
- Standard Model test and hadron structure
  - PVDIS on both deuterium and hydrogen

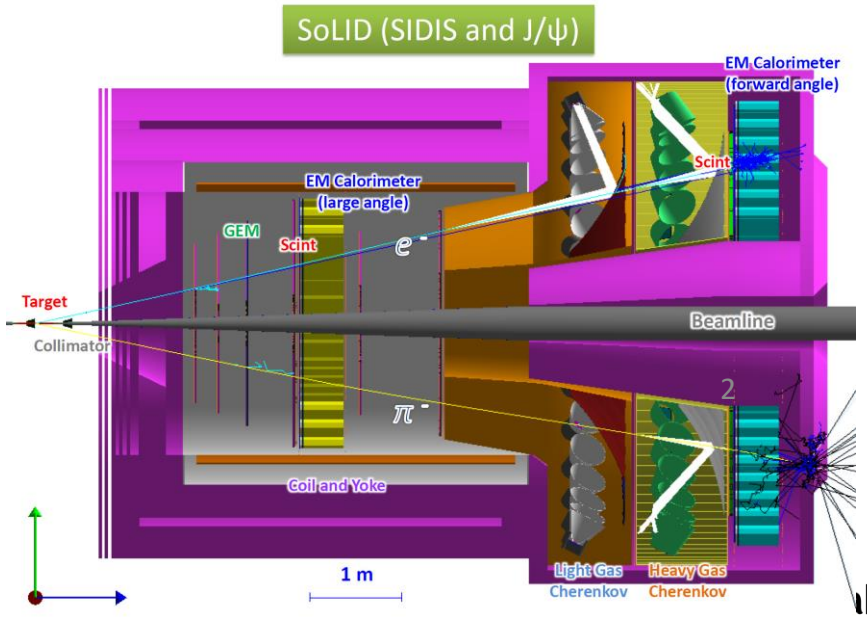
solid.jlab.org

High Luminosity Large Acceptance

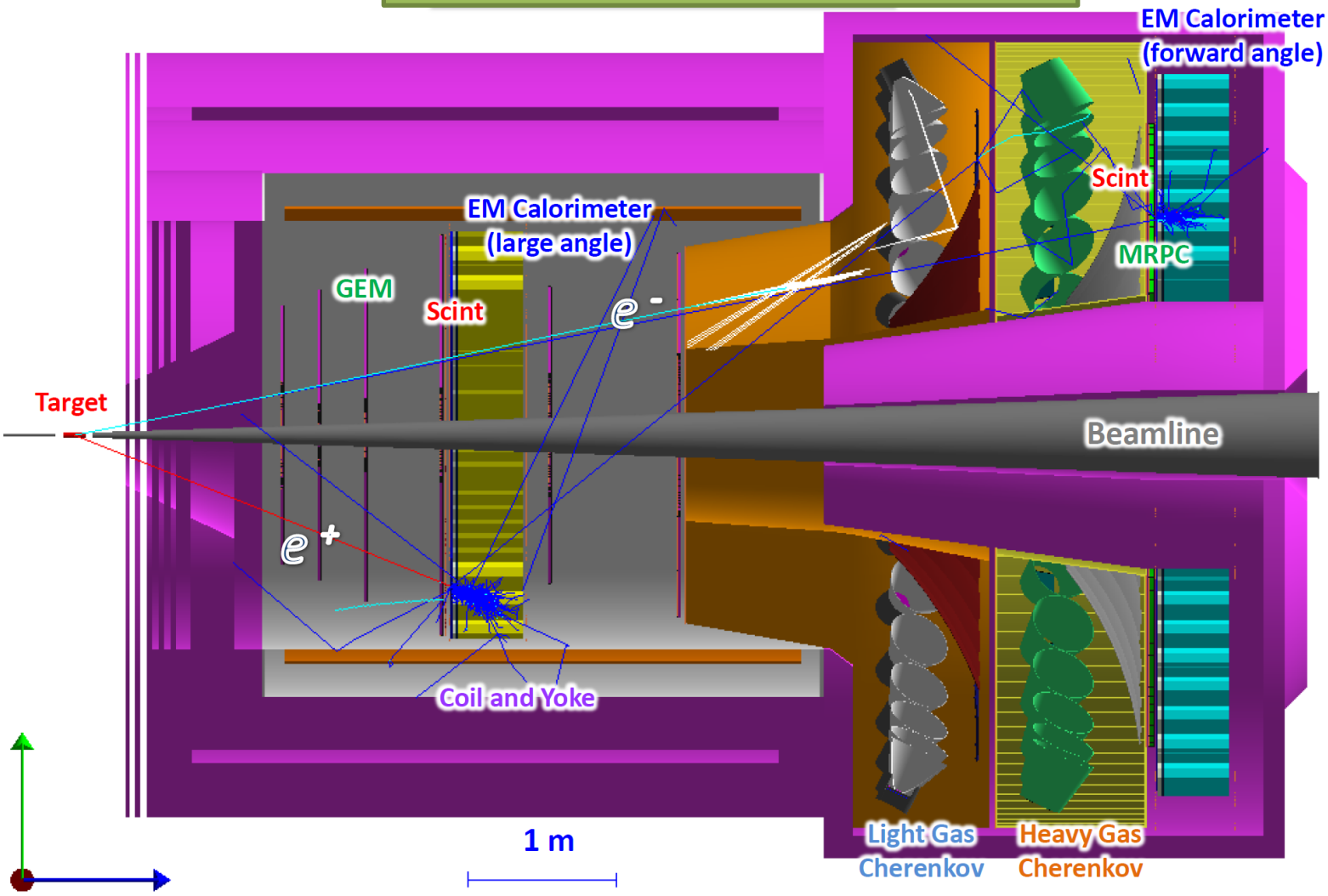
Lumi ~1e^{37}/cm^2/s (open geometry)

- 3D hadron imaging
  - TMD (SIDIS on both neutron and proton)
  - GPD (DVCS, DEMP, TCS,DDVCS)
- proton mass and gluonic interaction
  - J/ψ production at threshold





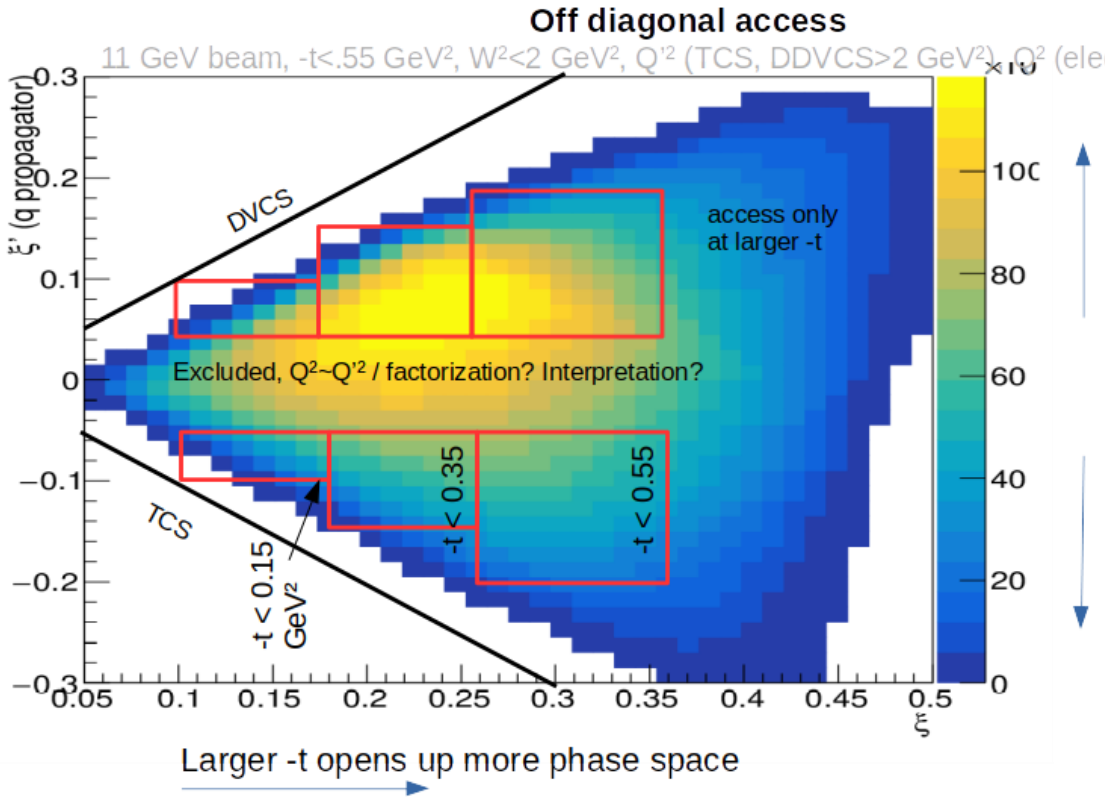
SoLID J/Psi and TCS setup



E12-12-006: Near Threshold J/Psi production on LH2 target 60 days, **rating A**

E12-12-006A: TCS with circular polarized beam and LH2 target

DDVCS with circular polarized beam and LH2 target

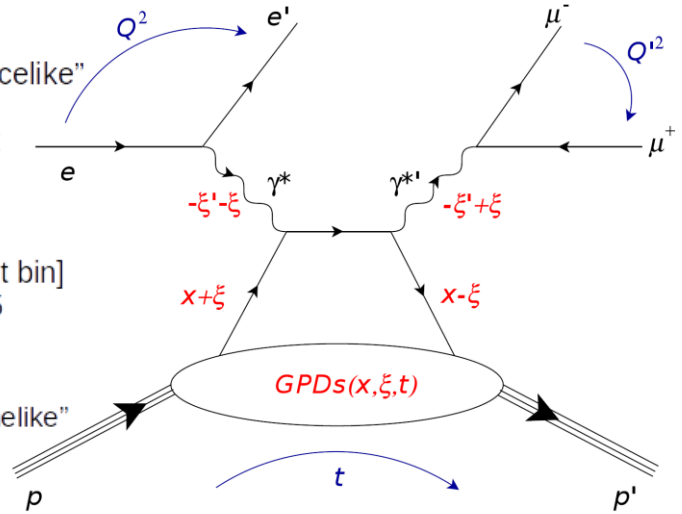


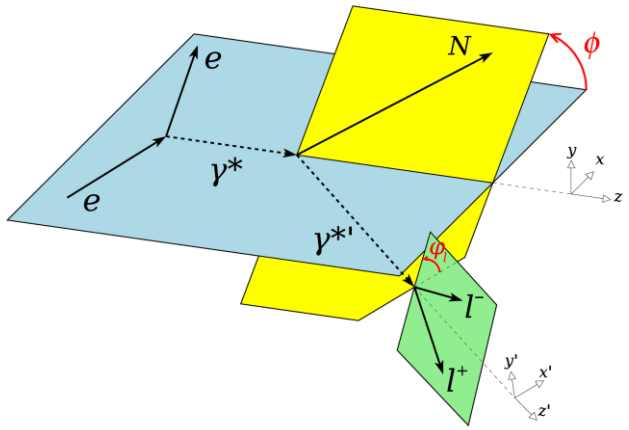
Q'² < Q² : spacelike"

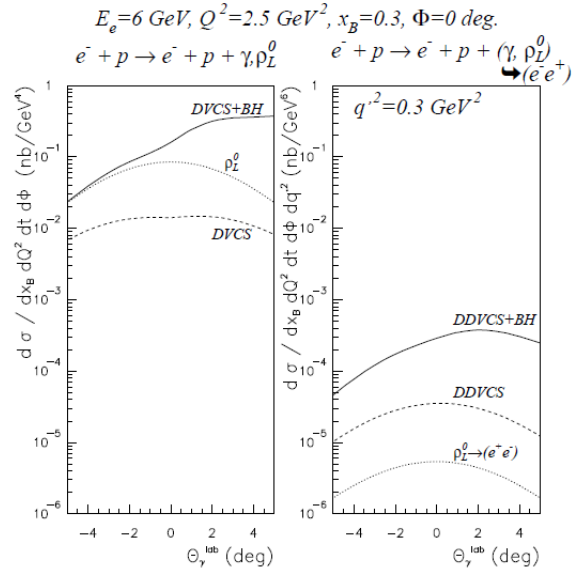
Bins in ξ, ξ', -t

-.2 < ξ' < .2
.05 < ξ < .36
[correlated to t bin]
0.05 < -t < .55

Q² < Q'² : "timelike"







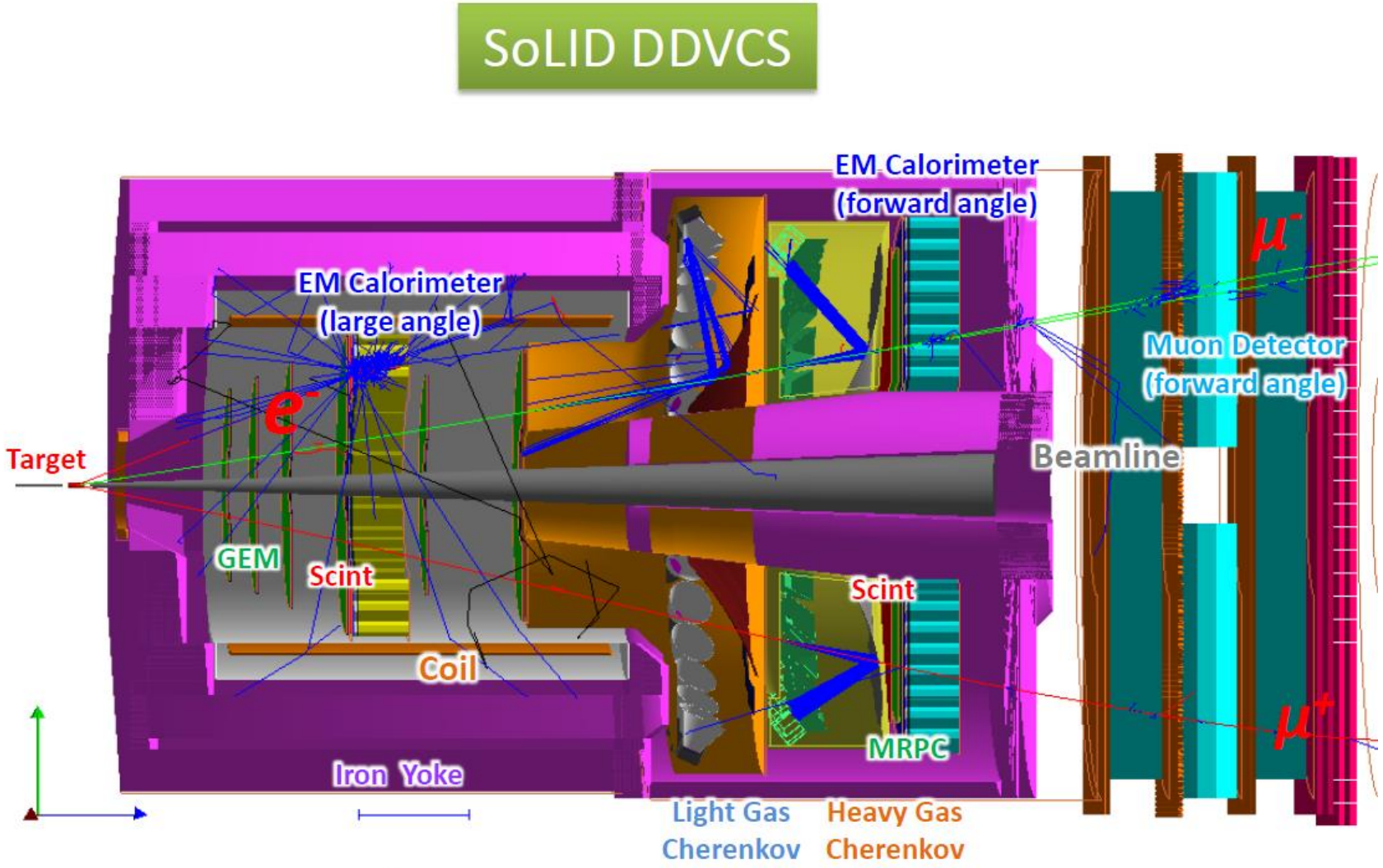
- Small DDVCS crosssection demands high luminosity and large acceptance
- Interference with Beth-Heitler helps construct observable

$$\xi' = \frac{Q^2 - Q'^2 + t/2}{2Q^2/x_B - Q^2 - Q'^2 + t}$$

$$\xi = \frac{Q^2 + Q'^2}{2Q^2/x_B - Q^2 - Q'^2 + t}$$

SoLID DDVCS Setup

- Based on the J/Psi and TCS setup with forward muon detector added
- Sharing beam time and add muon channels for approved J/Psi and TCS

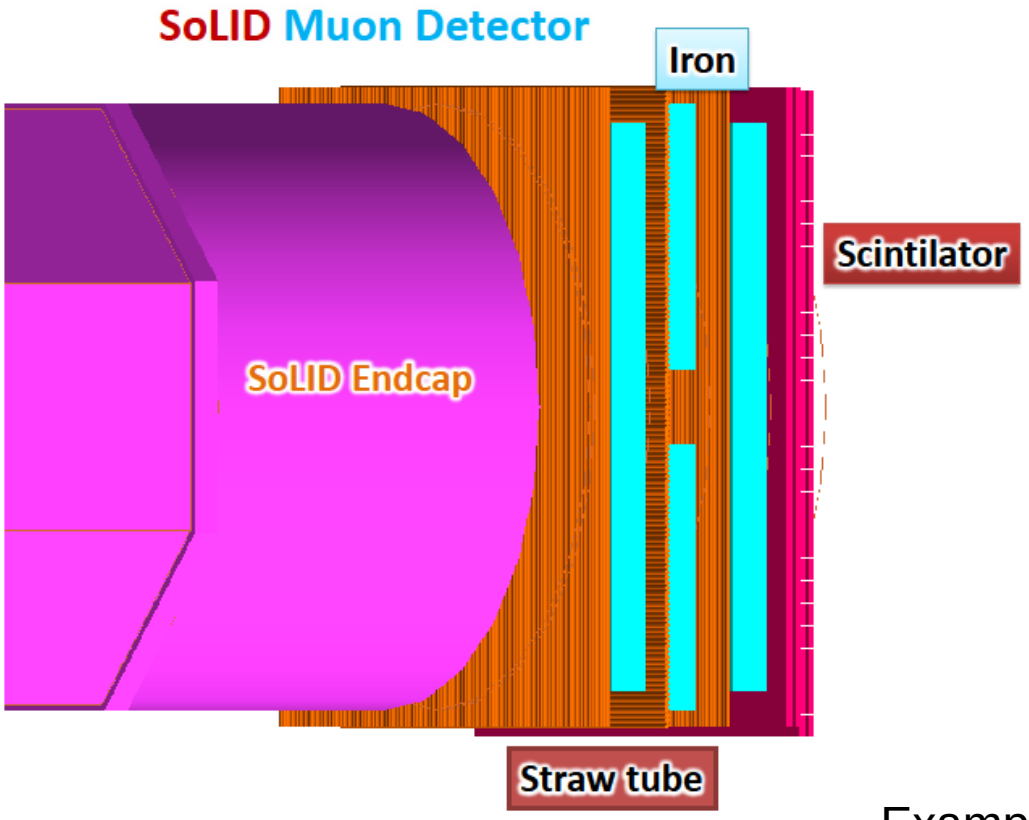


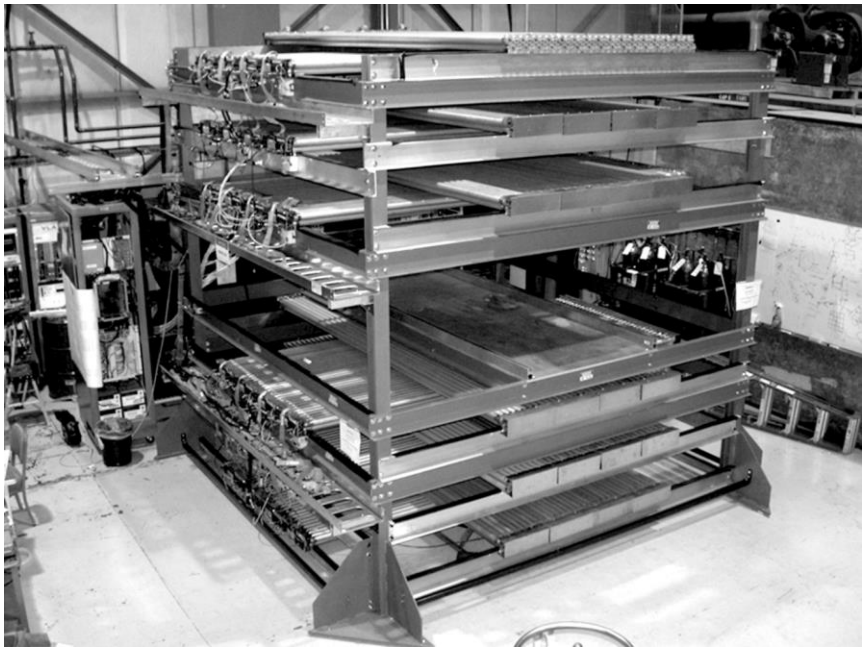
Letter of Intent 2023

Marie Boer, Alexandre Camsonne, Eric Voutier, Zhiwen Zhao

forward angle muon detector

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

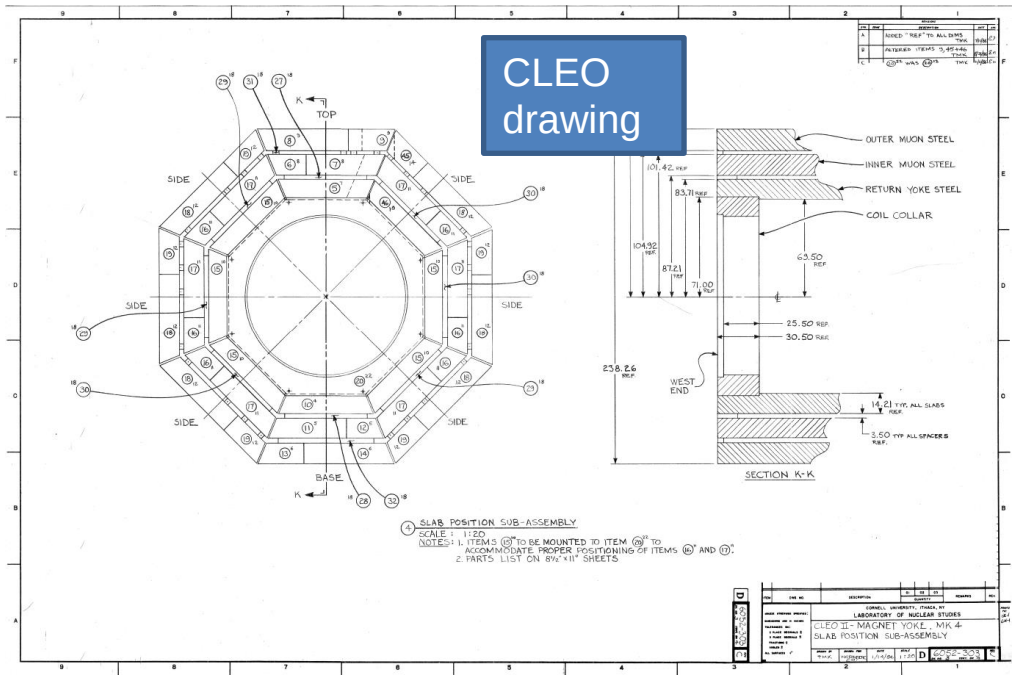


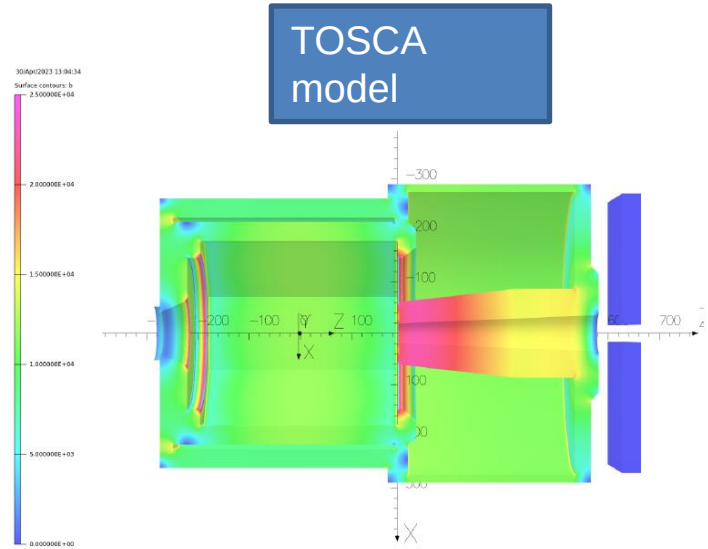


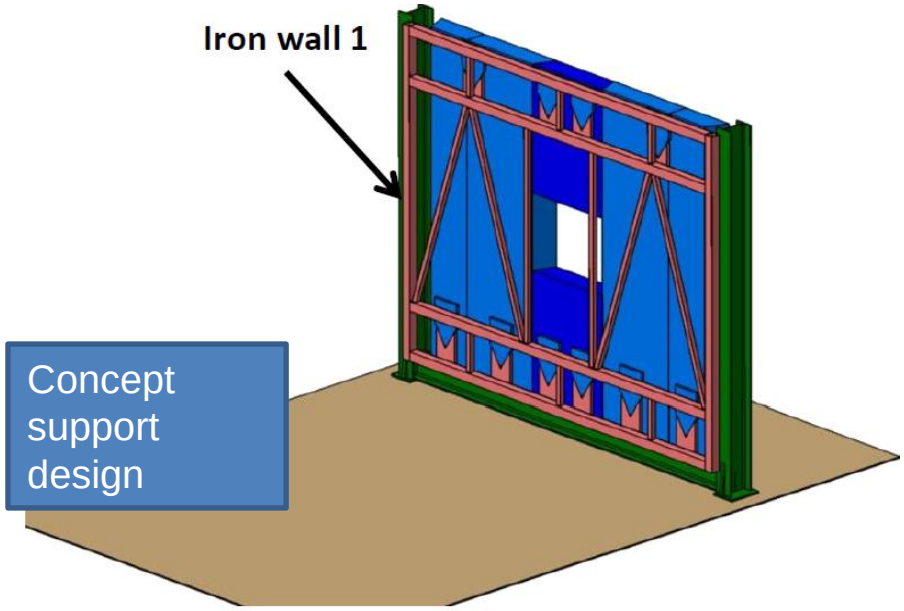
Example of straw tube chambers similar to Seaquest experiment

Iron of forward angle muon detector

Reuse 6 of 8 CLEO octagon outer layer iron
Each one is about 36x254x533cm
No problem with space
Field (<10G),force(<1N),torque(<2Nm) are small



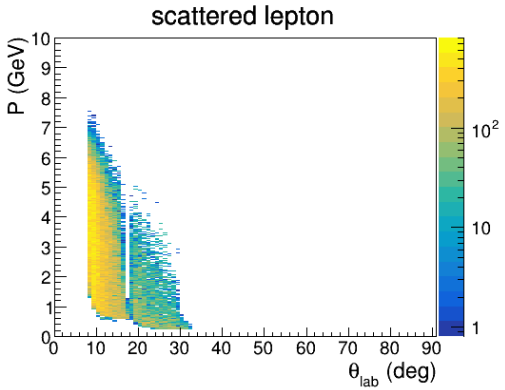


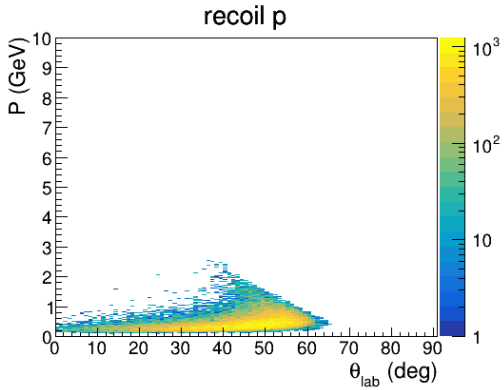


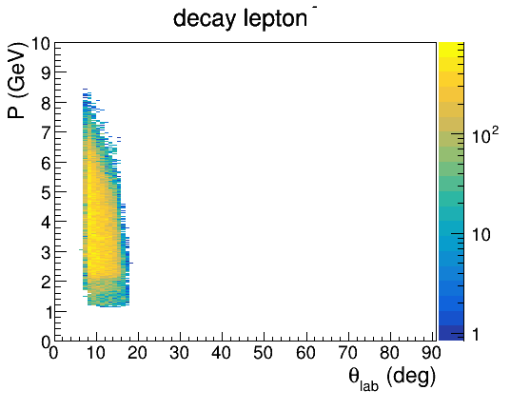
BH acceptance

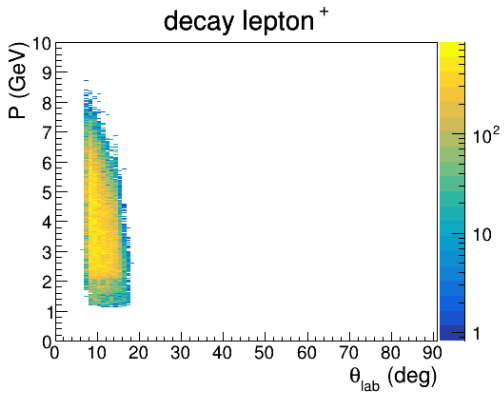
BH generator grape-dilepton

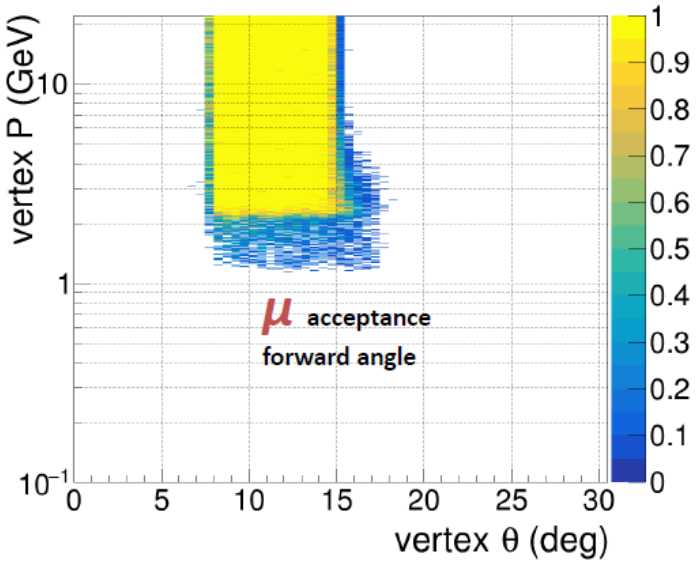
- Muon mom>2GeV is accepted
- Scattered e- and both muons are detected
- recoil proton is not required, but some can still be detected by time of flight

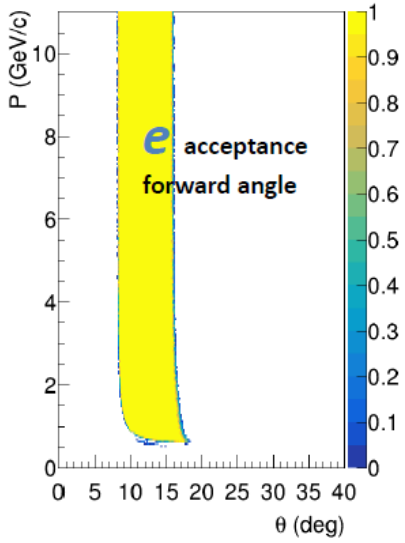


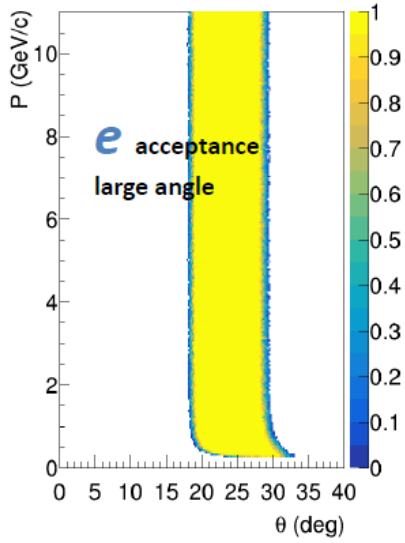




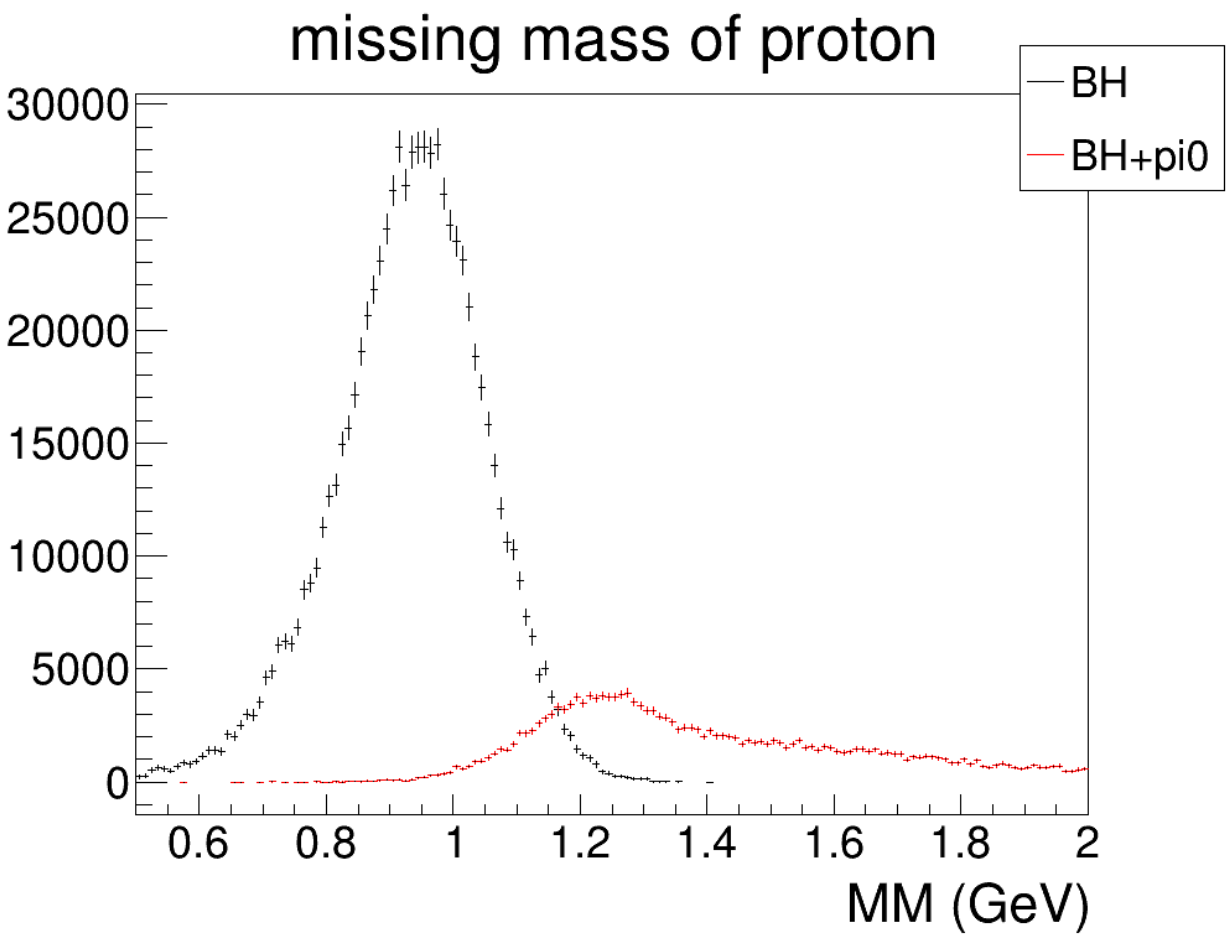








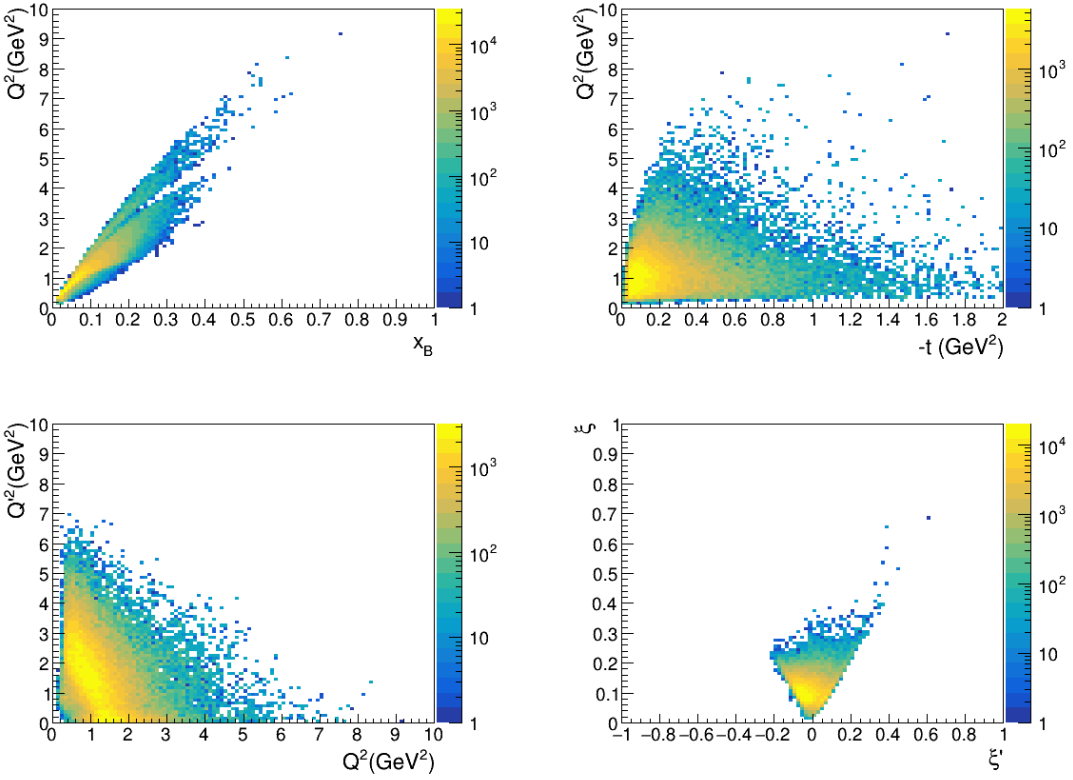
Exclusive cut

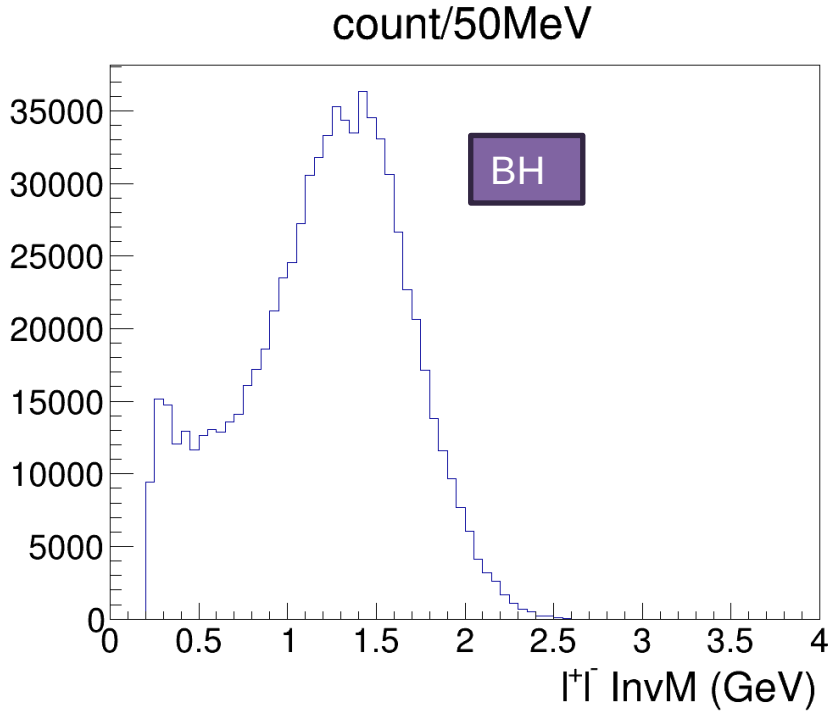


- BH and BH+pi0 from generator grape-dilepton
- Missing mass resolution good enough to separate exclusive events

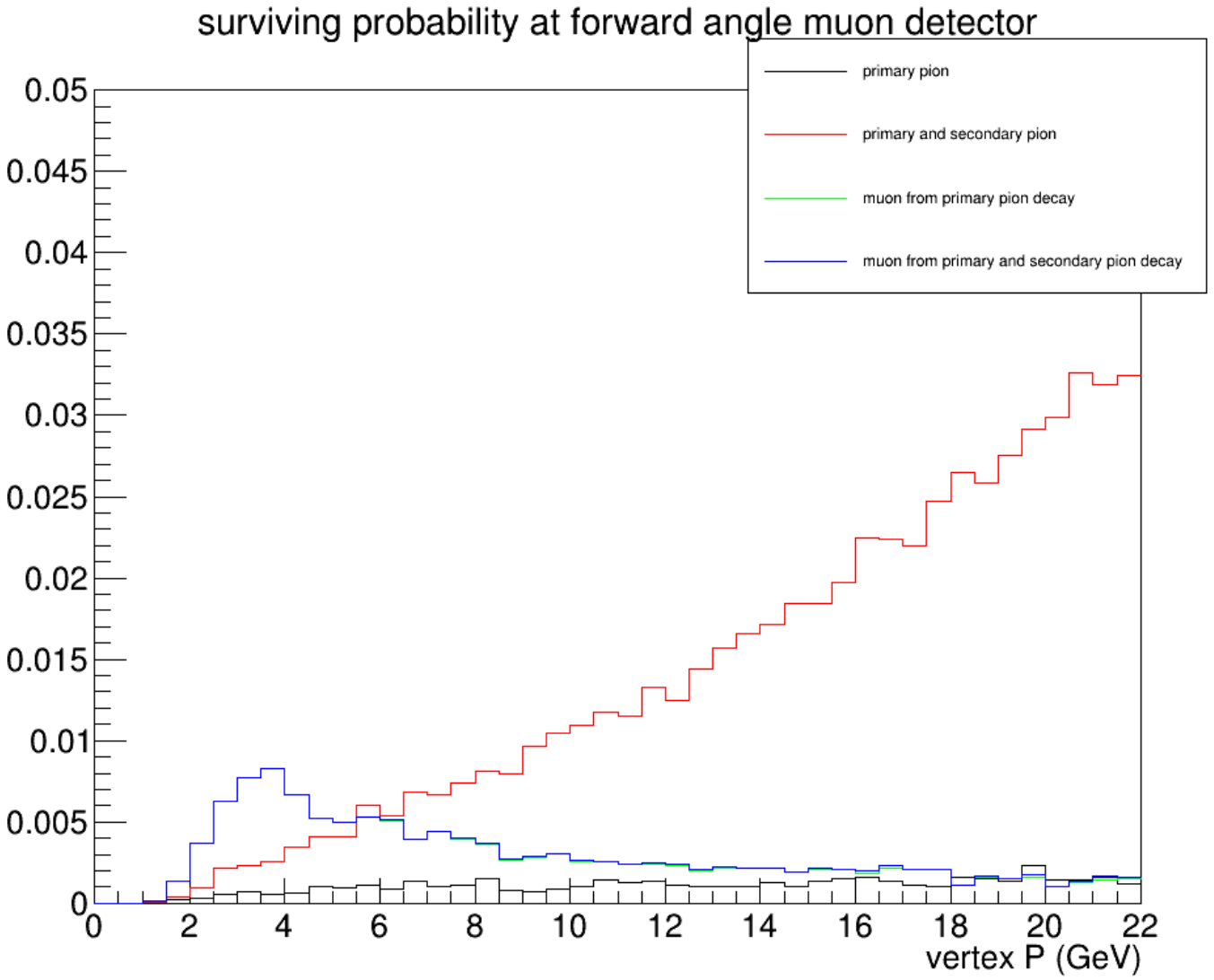
BH kinematics and counts

- 30k events for 2GeV< InvM, 600k events for 1GeV<InvM, 800k events in total
- Enough for ~500bins in 5D with 1000 events per bin





Pion blocking at back of forward angle muon detector



Single pion background at muon detector

- Start from “evgen_bggen” generator based on resonance fit and pythia
- go through full SoLID simulation for pion blocking and muon decay including both primary and secondary particles
- pi-/pi+ rate 9khz, mu-/mu+ rate 26khz, total 70khz
- Two charge particle coincidence rate 70e3*70e3*100ns<1khz

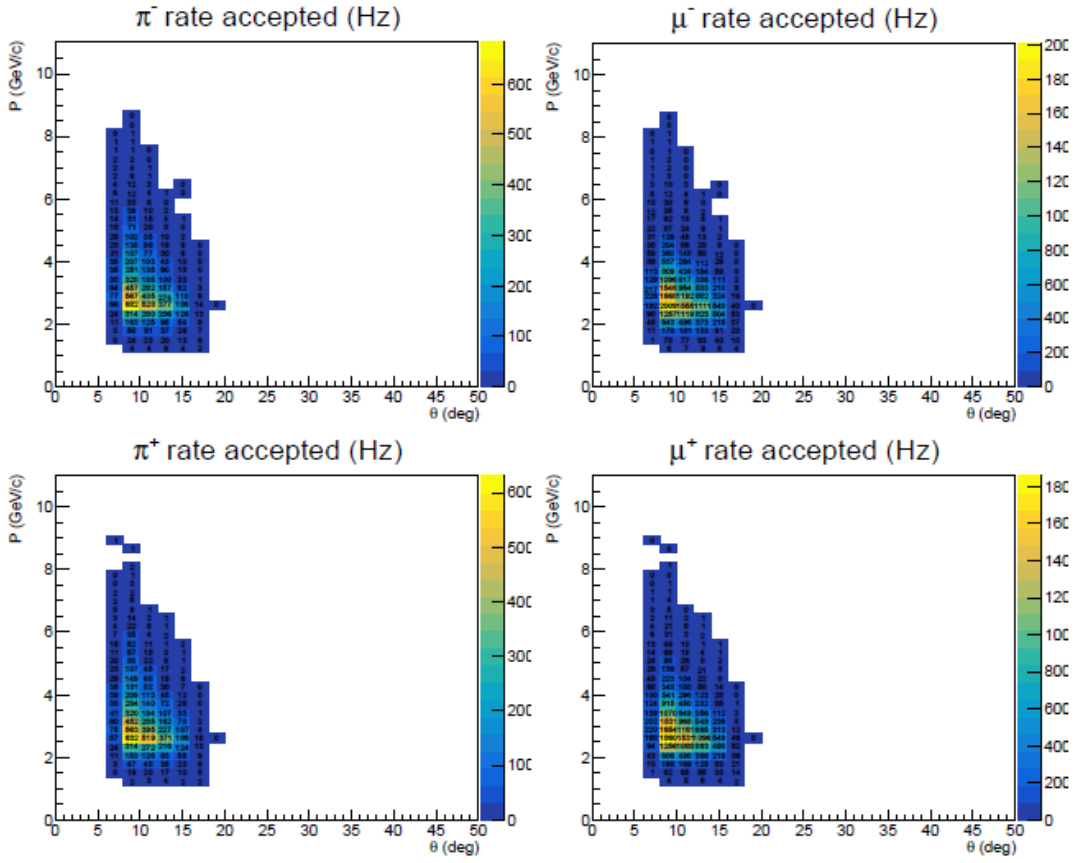
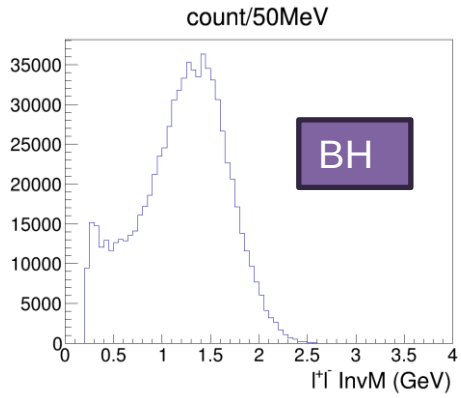


Figure 22: Single particles rate of pion and muon from pion decay at the back of forward angle muon detector. They include both pions directly from target and all secondaries and muons from their decay.

Two pion exclusive background



- Start from “twopeg” generator based on CLAS data fit and extrapolation to 11GeV beam kinematics
- go through full SoLID simulation for pion blocking and muon decay including primary particles only
- Left with counts about 10% of BH counts, mainly from both pions decay into muons.
- Tracking with vertex cut could reduce it further

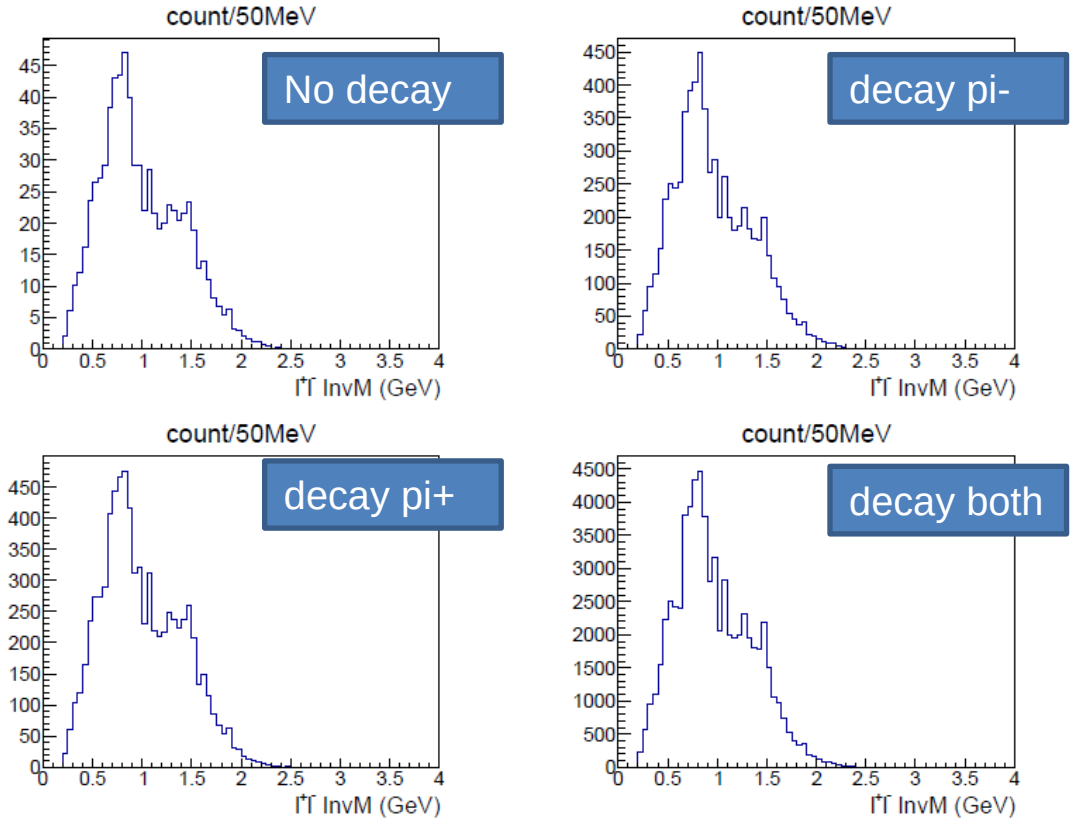
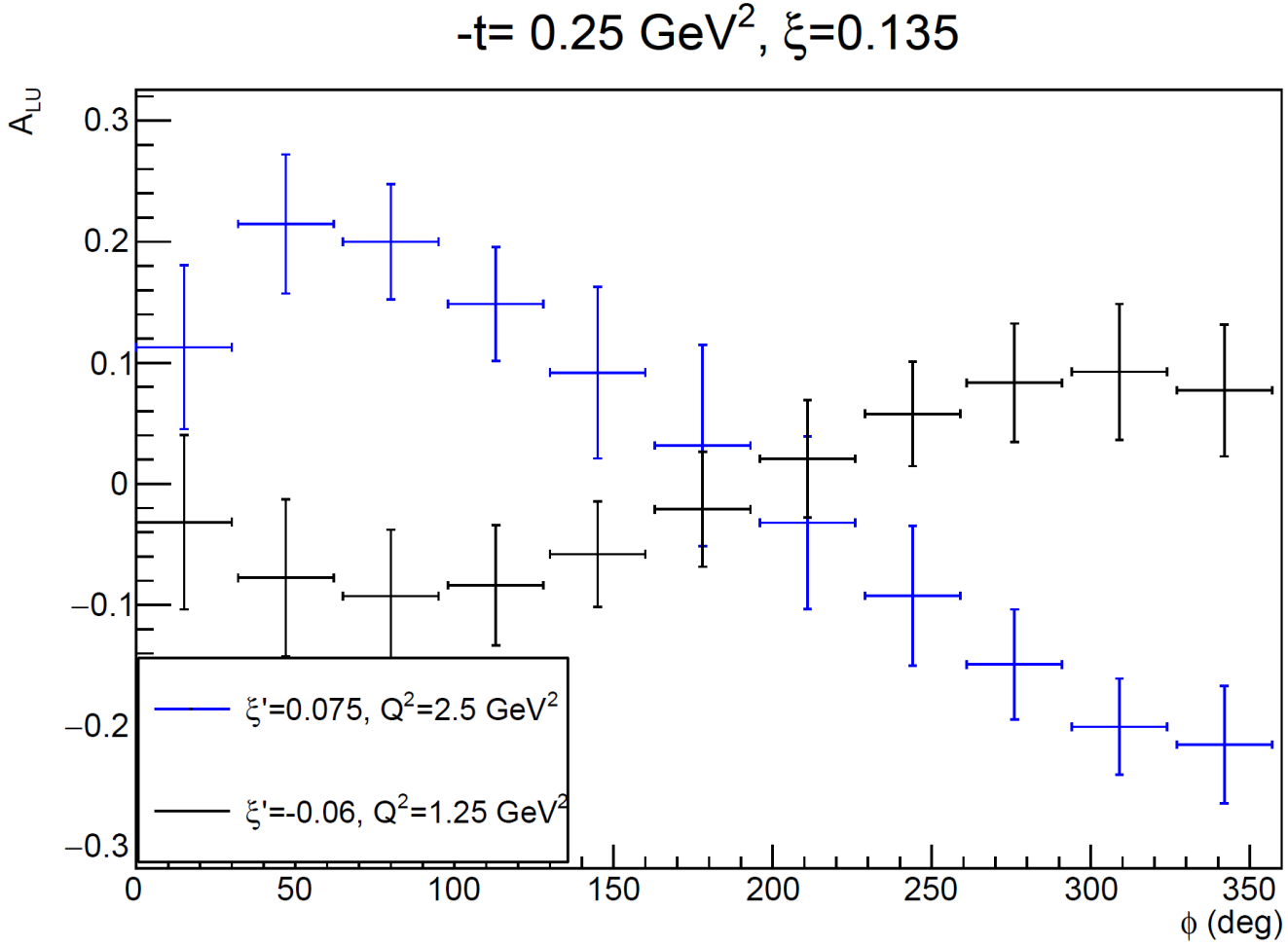


Figure 23: From left to right and top to bottom, the counts from the two pion exclusive channel contamination are shown in 4 cases, neither pion decay, negative pion decays into muon, positive pion decays into muon, and both pions decay.

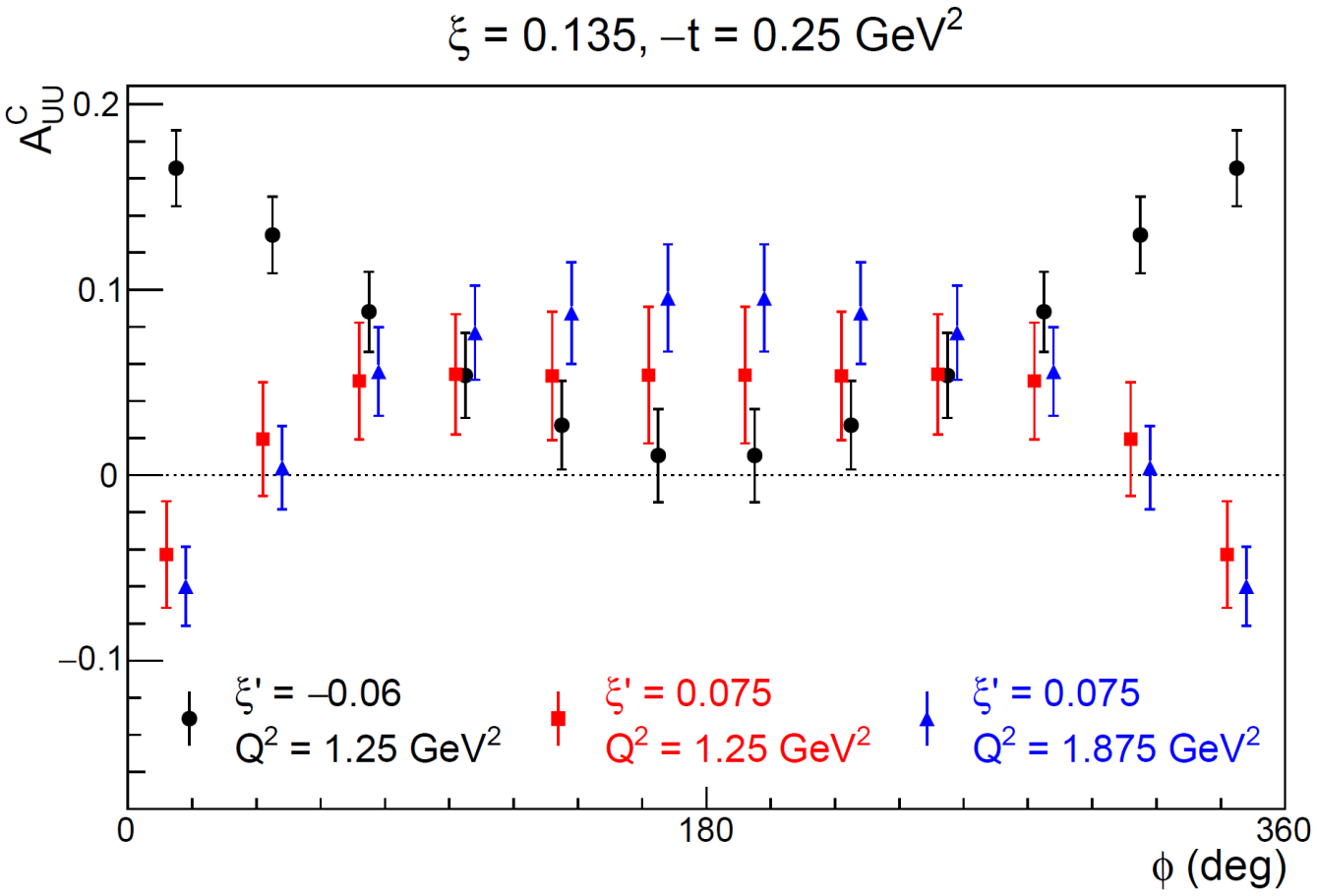
An example of projection with e- beam



$$A_{LU}^{\pm}(\phi) = \frac{1}{\lambda^{\pm}} \frac{d^5\sigma_+^{\pm} - d^5\sigma_-^{\pm}}{d^5\sigma_+^{\pm} + d^5\sigma_-^{\pm}} \qquad (15)$$

$$= \frac{d^5\widetilde{\sigma}_{DDVCS} \mp d^5\widetilde{\sigma}^{\mathrm{INT1}}}{d^5\sigma_{BH_1} + d^5\sigma_{BH_2} + d^5\sigma_{DDVCS} \mp d^5\sigma_{INT_1}}$$

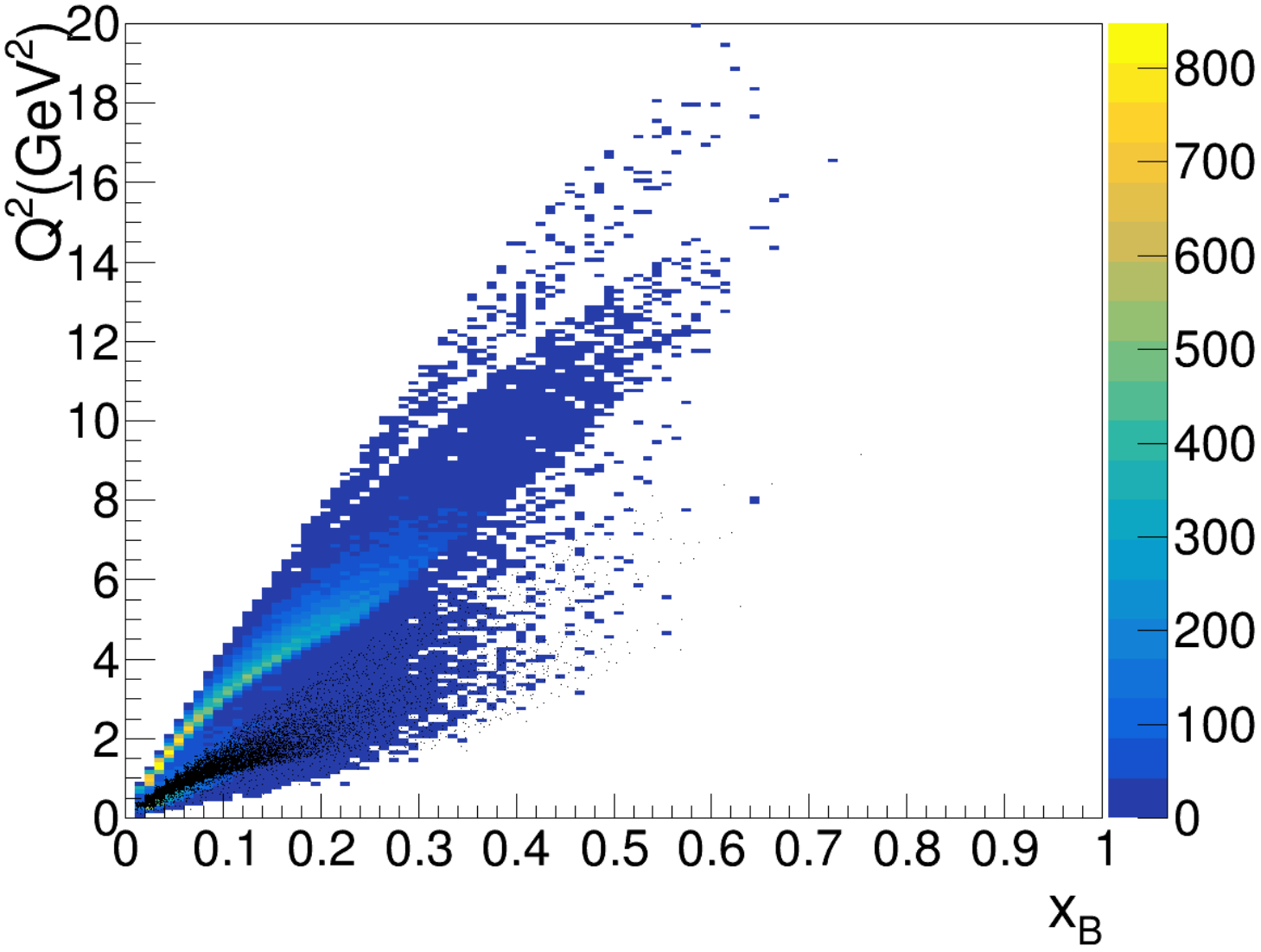
An example of projection with e- and e+ beam



$$A_{UU}^{C}(\phi) = \frac{(d^5\sigma_+^+ + d^5\sigma_-^+) - (d^5\sigma_+^- + d^5\sigma_-^-)}{d^5\sigma_+^+ + d^5\sigma_-^+ + d^5\sigma_+^- + d^5\sigma_-^-}$$
$$= \frac{d^5\sigma_{INT_1}}{d^5\sigma_{BH_1} + d^5\sigma_{BH_2} + d^5\sigma_{DDVCS}}$$

EPJA 57, 240 (2021)

11GeV and 22GeV



22GeV (colored) has about 10% event rate of 11GeV (black), but much larger kinematic coverage

EPJA 57, 240 (2021)

Summary

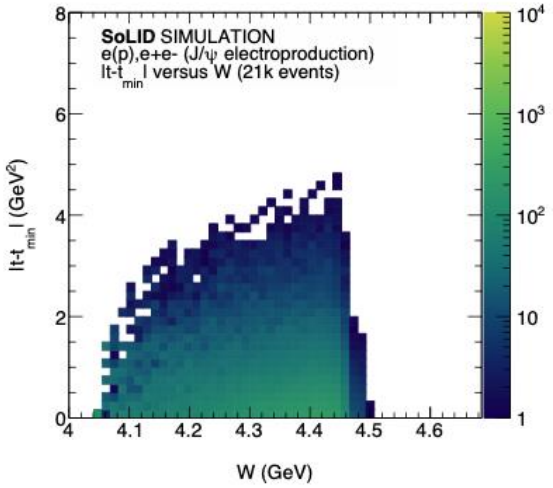
- SoLID DDVCS experiment will add a forward muon detector
- Measure exclusive DDVCS by detecting scattered electron and dimuon pair
- Unique opportunity to measure DDVCS in dimuons channel without additional beam request in parallel to the approved J/Psi and TCS experiment
- Add dimuon channels for J/Psi and TCS experiment as well
- Large kinematic Q^2 and Q'^2 range allows to check the scaling range for DDVCS
- First measurement of H Compton Form Factor for x different from xi
- Crucial measurement for future program with dedicated detector and with future positron beam and 22 GeV upgrade

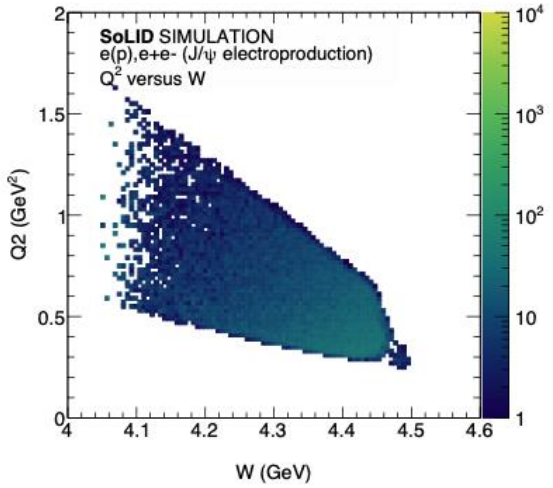
Supported in part by U.S. Department of Energy under contract number DE-FG02-03ER41231

backup

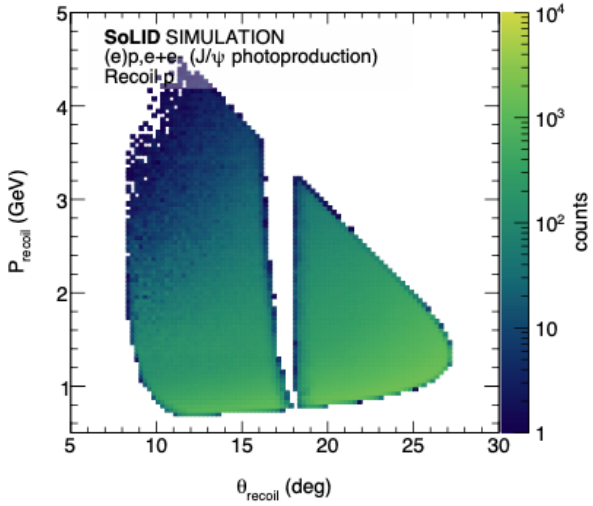
E12-12-006: Near Threshold J/Psi production on LH2 target

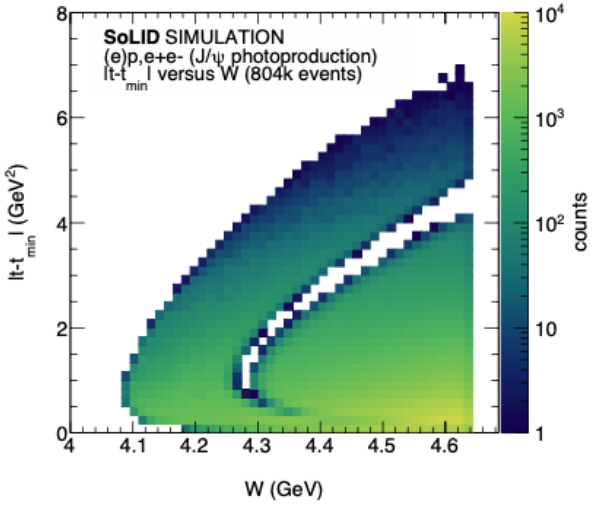
$e\,p \rightarrow e'\,p'\,J/\psi(e^-\,e^+)$





$\gamma\,p \rightarrow p'\,J/\psi(e^-\,e^+)$





Measurements

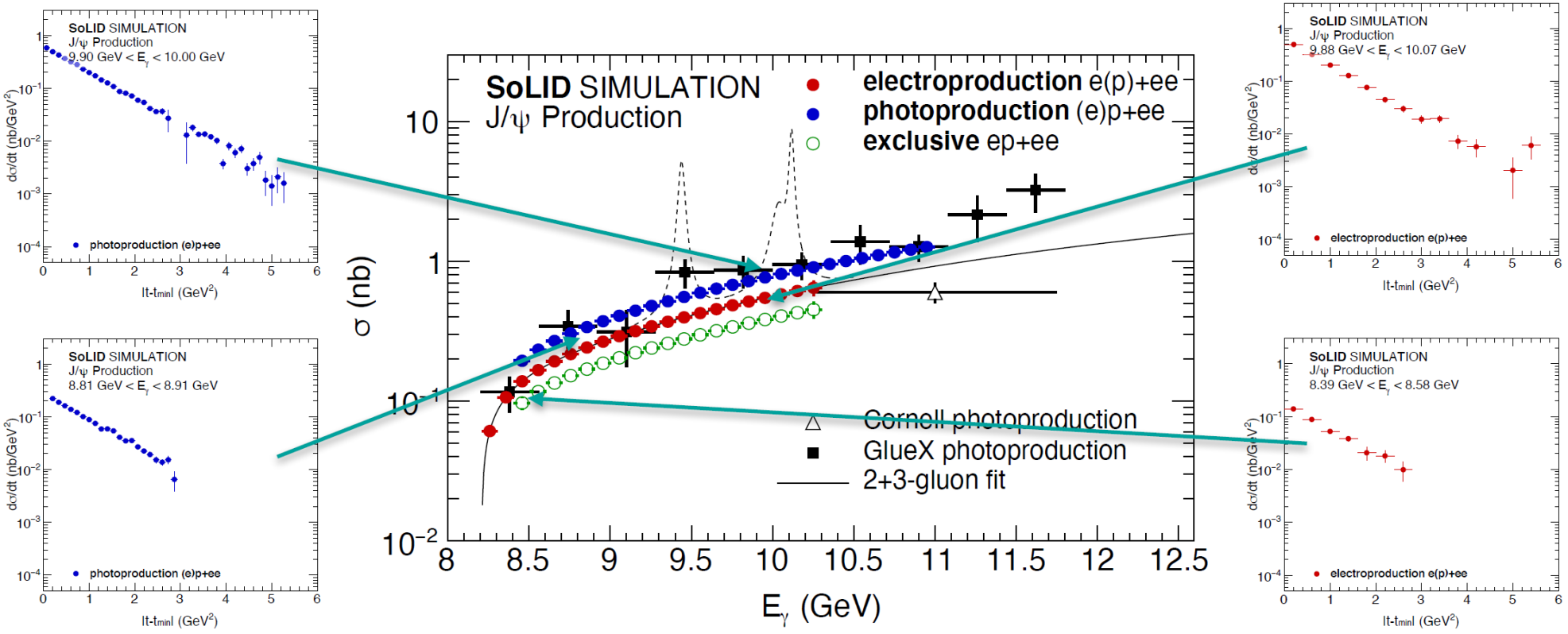
- Electro-production:
  - 4-fold: detect decay e^- e^+ pair, scattered e^- and recoil proton
  - 3-fold: detect decay e^- e^+ pair, scattered e^- or recoil proton
- Photo-production:
  - 3-fold: detect decay e^- e^+ pair and recoil proton
- Trigger on decay e^- e^+ pair only
- Wide kinematic coverage

E12-12-006: Near Threshold J/Psi production on LH2 target

Most precise measurement near threshold

SOLID-J/Ψ PROJECTIONS

Precision at high t crucial for extrapolations to the forward limit (exponential, dipole, triple, …)

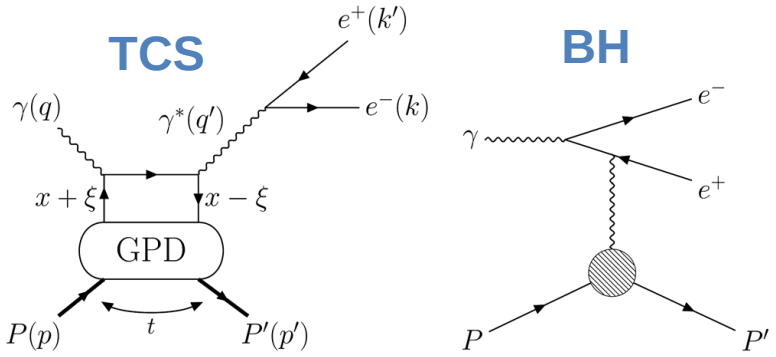


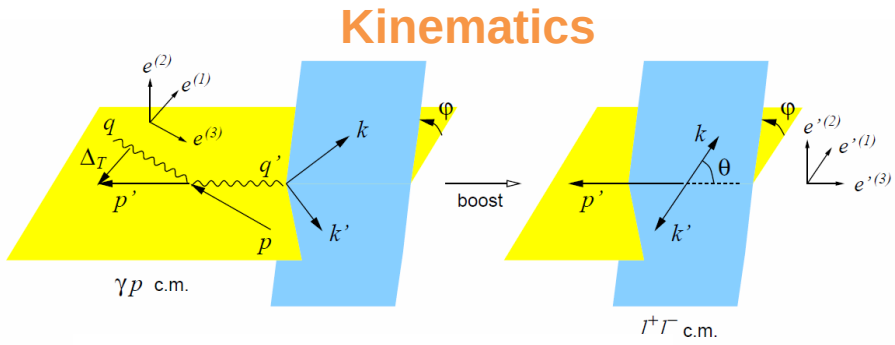
E12-12-006A: TCS with circular polarized beam and LH2 target

sharing beam time with J/psi run using same trigger on decay e^- e^+ pair only

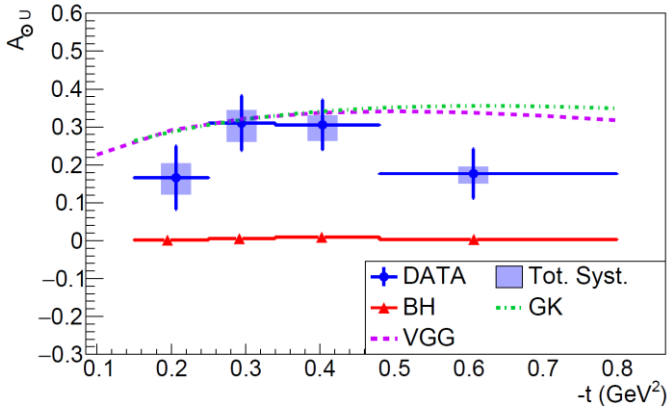
$$\gamma\, p \rightarrow \gamma^*(e^-\, e^+)\, p'$$

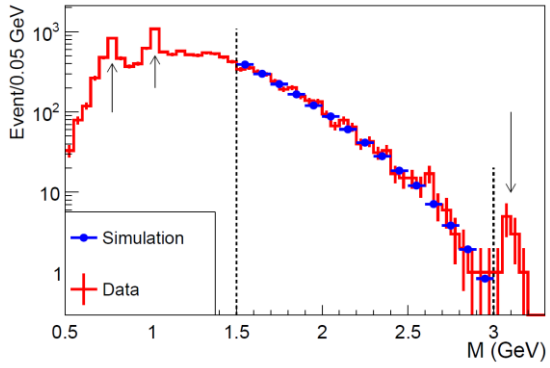
- Motivation
  - Access the same GPDs like DVCS and test universality
  - Access real and imgginary part of GPD H through CFF
  - New observables for global GPD fits
- Status
  - exploration at CLAS 6GeV
  - First result at CLAS12 published at PRL, 127, 262501 (2021) obtain **nonzero** beam polarized asymmetry A_{LU} and forward backward asymmetry A_{FB}
  - Limited by low statistics





CLAS12 result

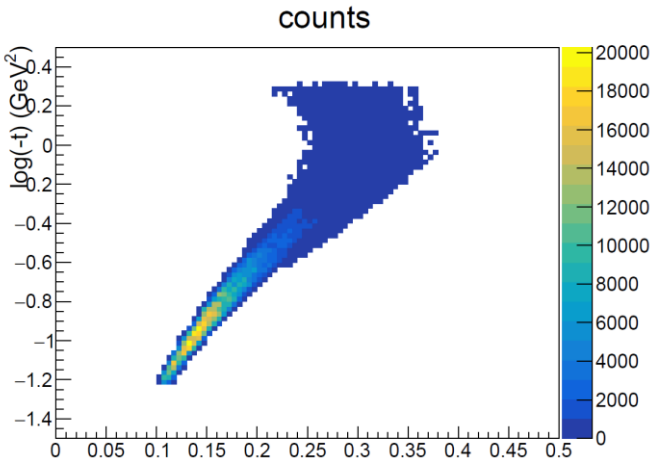


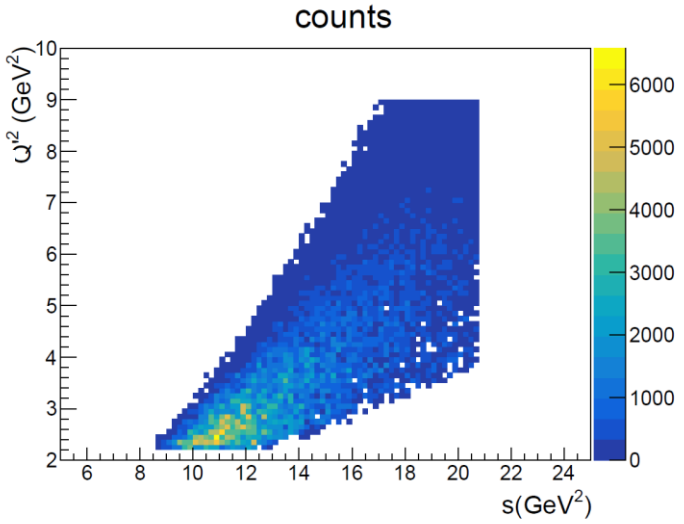


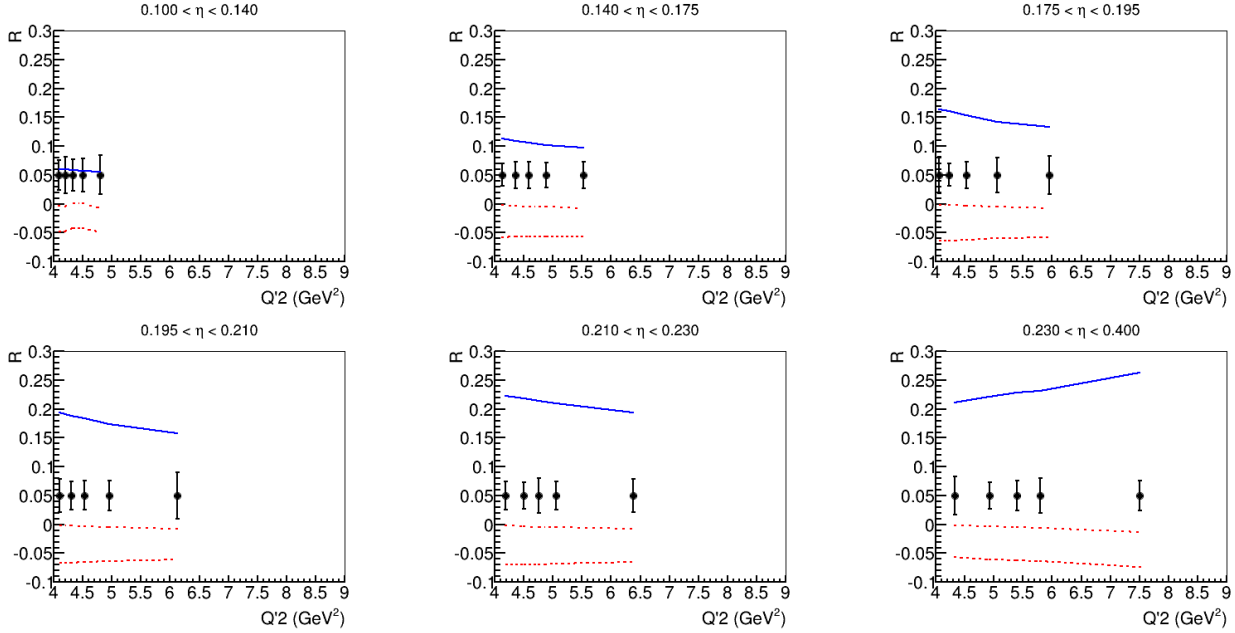
E12-12-006A: TCS with circular polarized beam and LH2 target

- SoLID TCS will have at least 1 order larger statistics than CLAS12 and usher TCS study into precision era with multi-dimensional binning
  - SoLID has 250 times more integrated luminosity than the CLAS12 TCS published result
  - SoLID acceptance to TCS events is about ¼ of CLAS12. But with full azimuthal coverage, (ideal for the forward backward asymmetry)
  - Crosssection measurement (moment)
- SoLID TCS could lead to study of NLO correction

SoLID TCS coverage



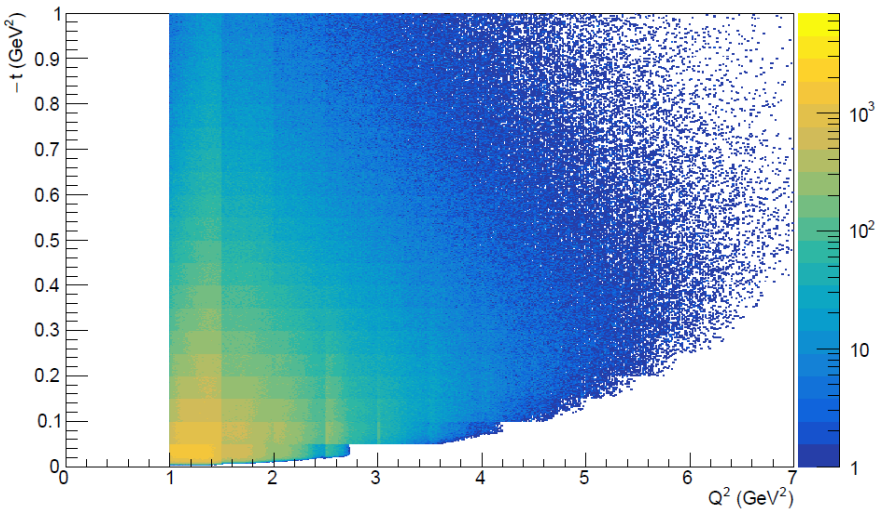


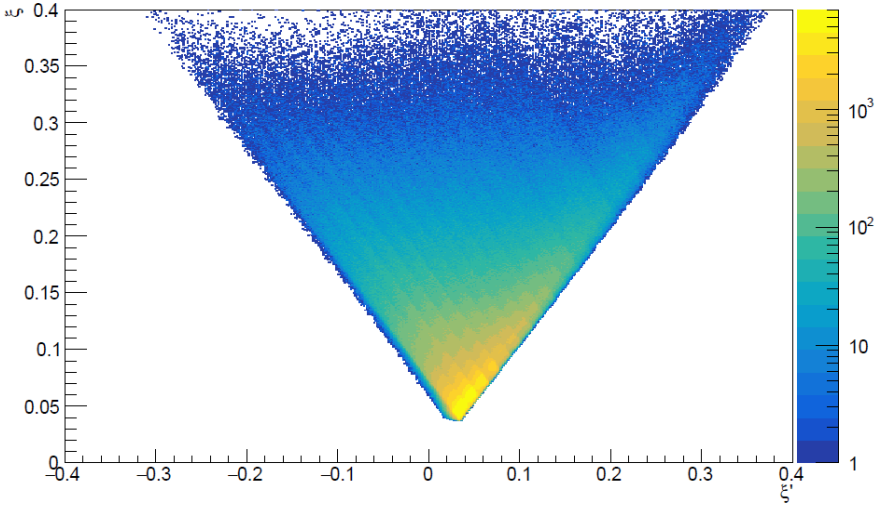


$$R = \frac{2\int_0^{2\pi} d\varphi \cos\varphi \frac{dS}{dQ^2\, dt\, d\varphi}}{\int_0^{2\pi} d\varphi \frac{dS}{dQ^2\, dt\, d\varphi}}$$

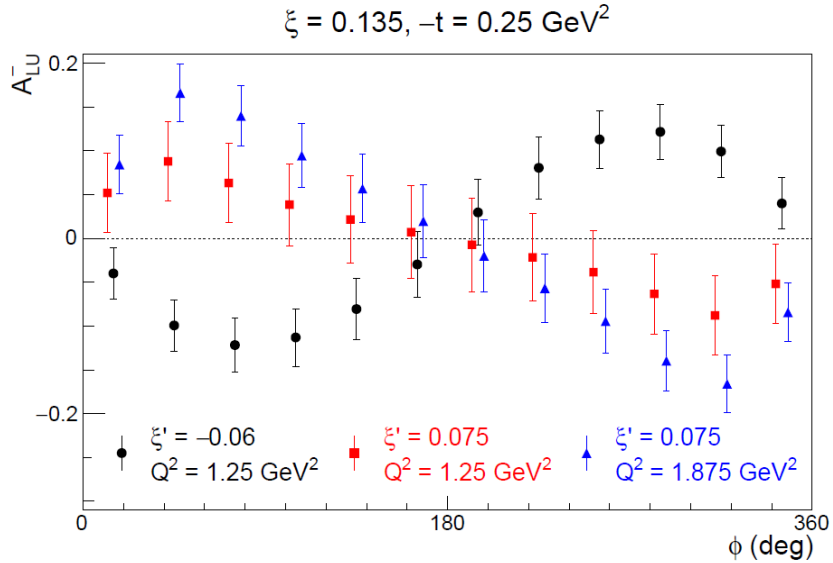
DDVCS with circular polarized beam and LH2 target

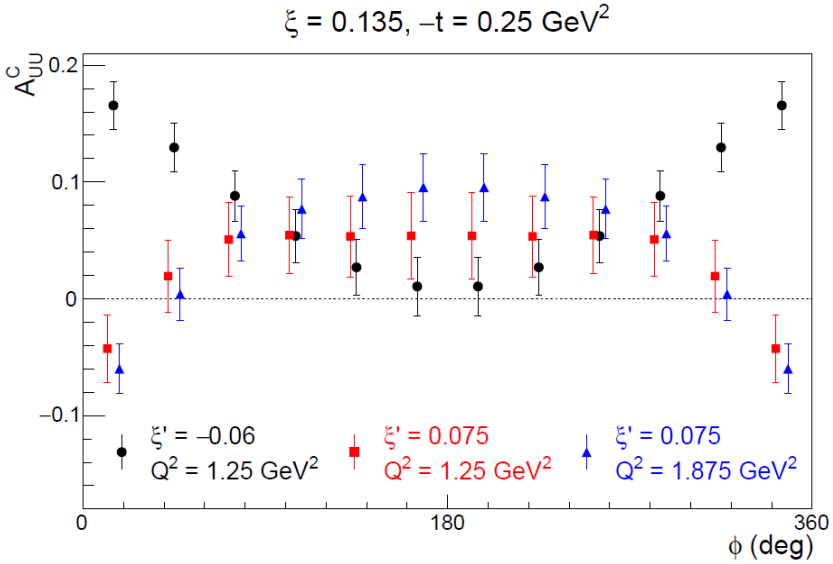
coverage





projection





$$A_{LU}^{\pm}(\phi) = \frac{1}{\lambda^{\pm}} \frac{d^5\sigma_+^{\pm} - d^5\sigma_-^{\pm}}{d^5\sigma_+^{\pm} + d^5\sigma_-^{\pm}} \qquad (15)$$

$$= \frac{d^5\widetilde{\sigma}_{DDVCS} \mp d^5\widetilde{\sigma}^{\mathrm{INT1}}}{d^5\sigma_{BH_1} + d^5\sigma_{BH_2} + d^5\sigma_{DDVCS} \mp d^5\sigma_{INT_1}}$$

$$A_{UU}^{C}(\phi) = \frac{\left(d^5\sigma_+^+ + d^5\sigma_-^+\right) - \left(d^5\sigma_+^- + d^5\sigma_-^-\right)}{d^5\sigma_+^+ + d^5\sigma_-^+ + d^5\sigma_+^- + d^5\sigma_-^-}$$

$$= \frac{d^5\sigma_{INT_1}}{d^5\sigma_{BH_1} + d^5\sigma_{BH_2} + d^5\sigma_{DDVCS}}$$

EPJA 57, 240 (2021)

Surviving rate of pion and muon from pion decay at back of forward muon detector