

**SoLID**

SOLENOIDAL LARGE INTENSITY DEVICE

# Dilepton Physics Program with **SoLID** at **Jefferson Lab**

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**SoLID Collaboration**



**Duke**  
UNIVERSITY

**SoLID**

Jefferson Lab



# Jefferson Lab

- ▶ Newport News, Virginia, USA
- ▶ continuous polarized electron beam up to 12GeV
- ▶ Various fixed targets, both unpolarized and polarized
- ▶ *High luminosity*



# SoLID (Solenoidal Large Intensity Device)

Full exploitation of JLab 12 GeV upgrade with broad physics program

Lumi  $\sim 10^{39}/\text{cm}^2/\text{s}$  (baffled geometry)

➤ Standard Model test and hadron structure

- ❑ PVDIS on both deuterium and hydrogen

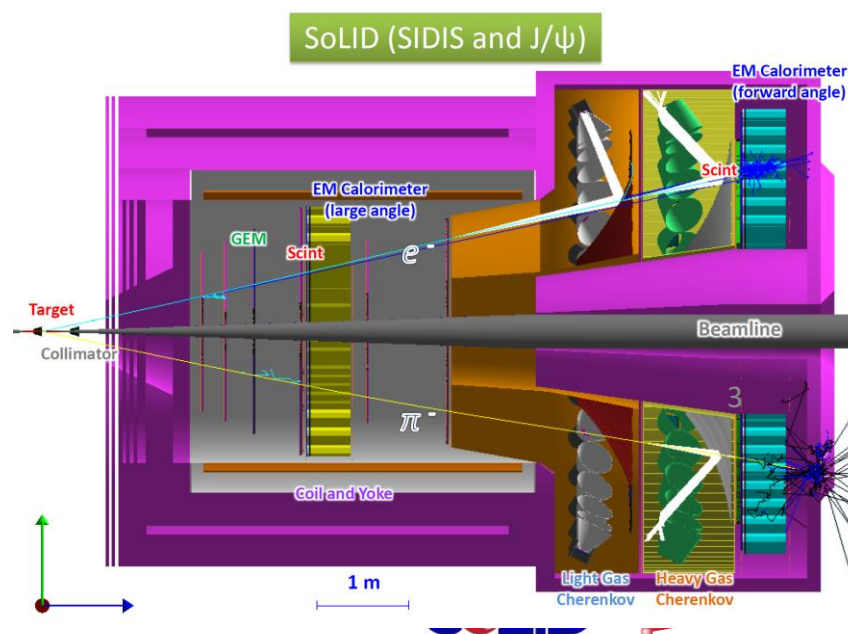
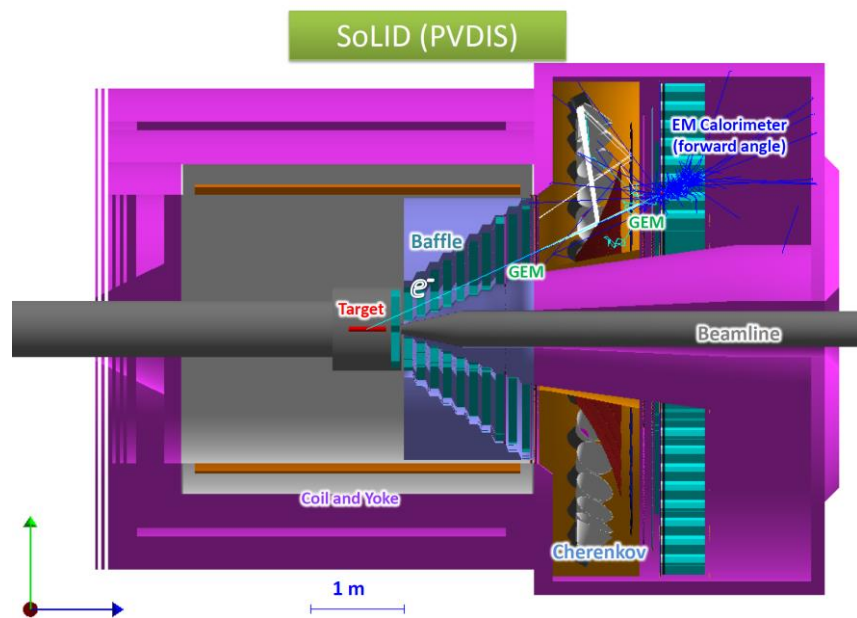
[solid.jlab.org](http://solid.jlab.org)

**High Luminosity  
Large Acceptance**

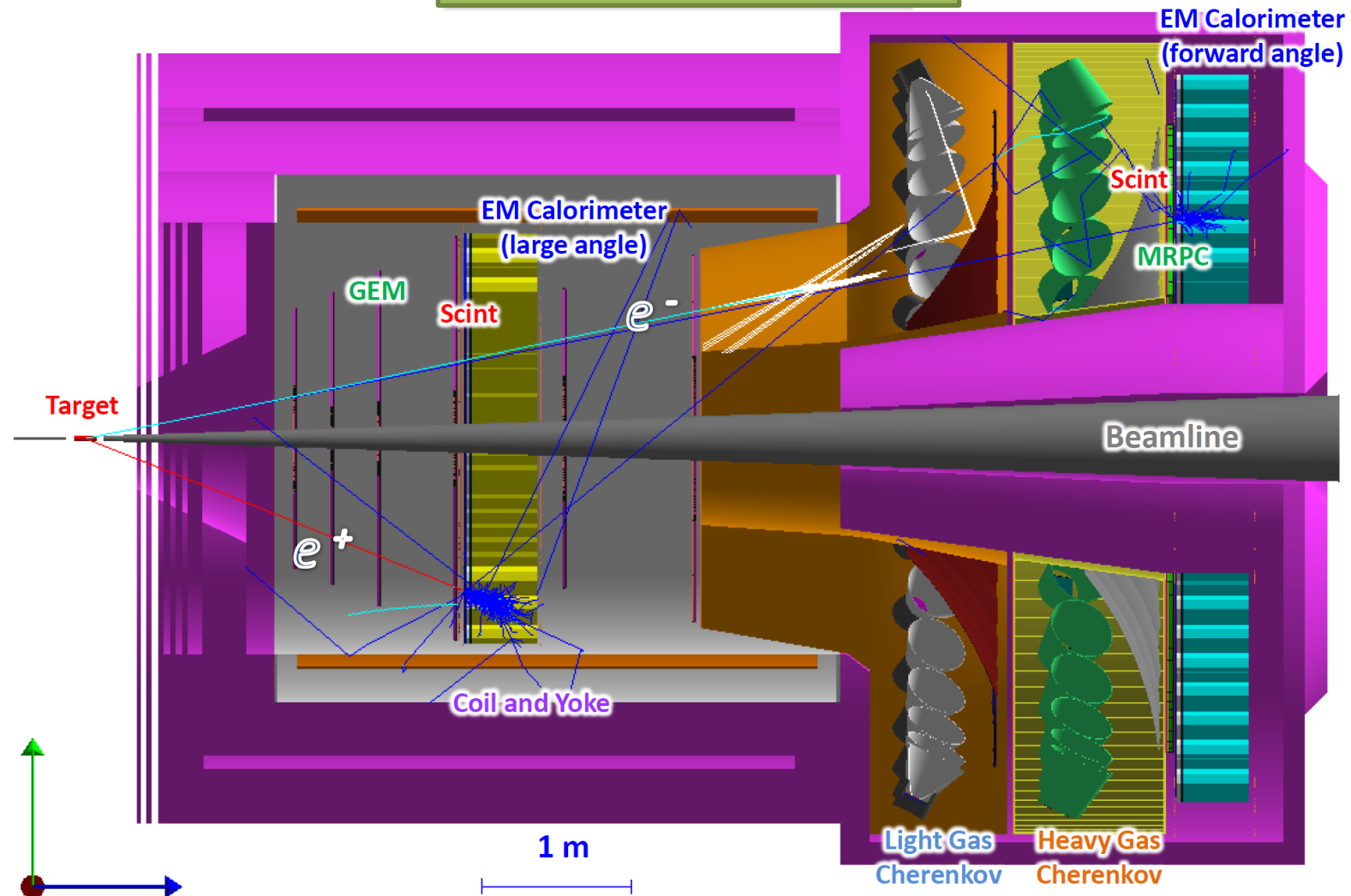
Lumi  $\sim 10^{37}/\text{cm}^2/\text{s}$  (open geometry)

➤ 3D hadron imaging

- ❑ TMD (SIDIS on both neutron and proton)
- ❑ GPD (DVCS, DEMP, TCS, DDVCS)
- proton mass and gluonic interaction
- ❑  $J/\psi$  production at threshold



# SoLID J/ $\psi$ and TCS



**E12-12-006:** Near Threshold J/ $\psi$  production on LH2 target 60 days, **rating A**  
**run group E12-12-006A: TCS**  
**Letter of Intent: DDVCS**

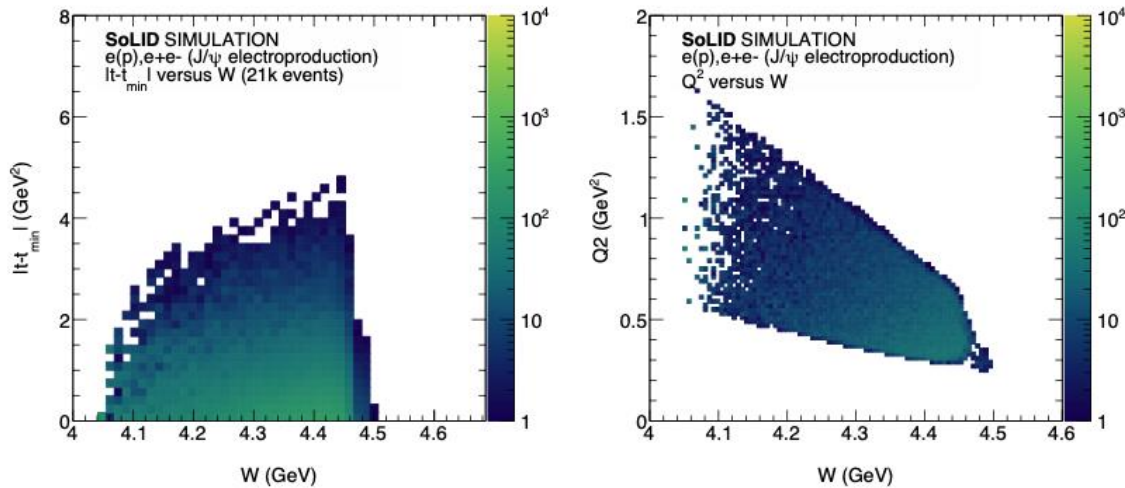
# E12-12-006: Near Threshold $J/\psi$ production on LH2 target

## Ultimate factory for near-threshold $J/\psi$

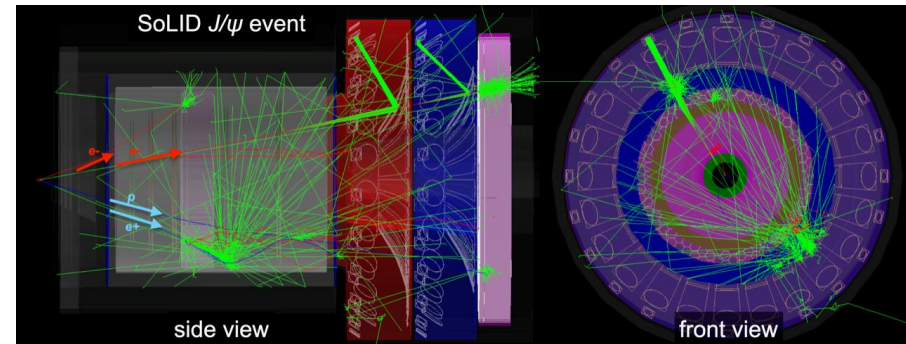
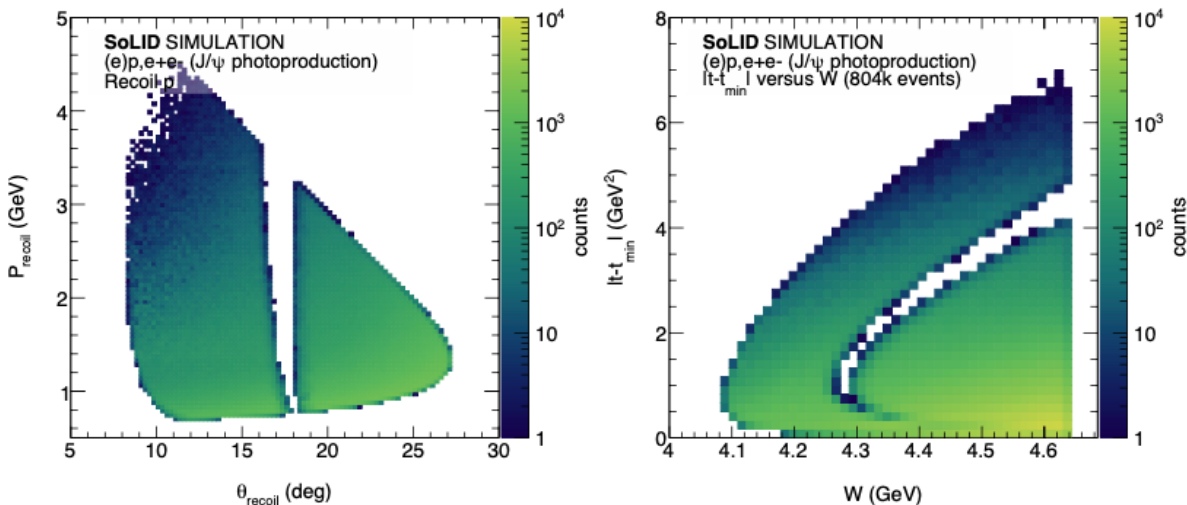
50+10 days of  $3\mu\text{A}$  beam on a 15cm long LH2 target ( $10^{37}/\text{cm}^2/\text{s}$ )

Ultra-high luminosity:  $43.2\text{ab}^{-1}$

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



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



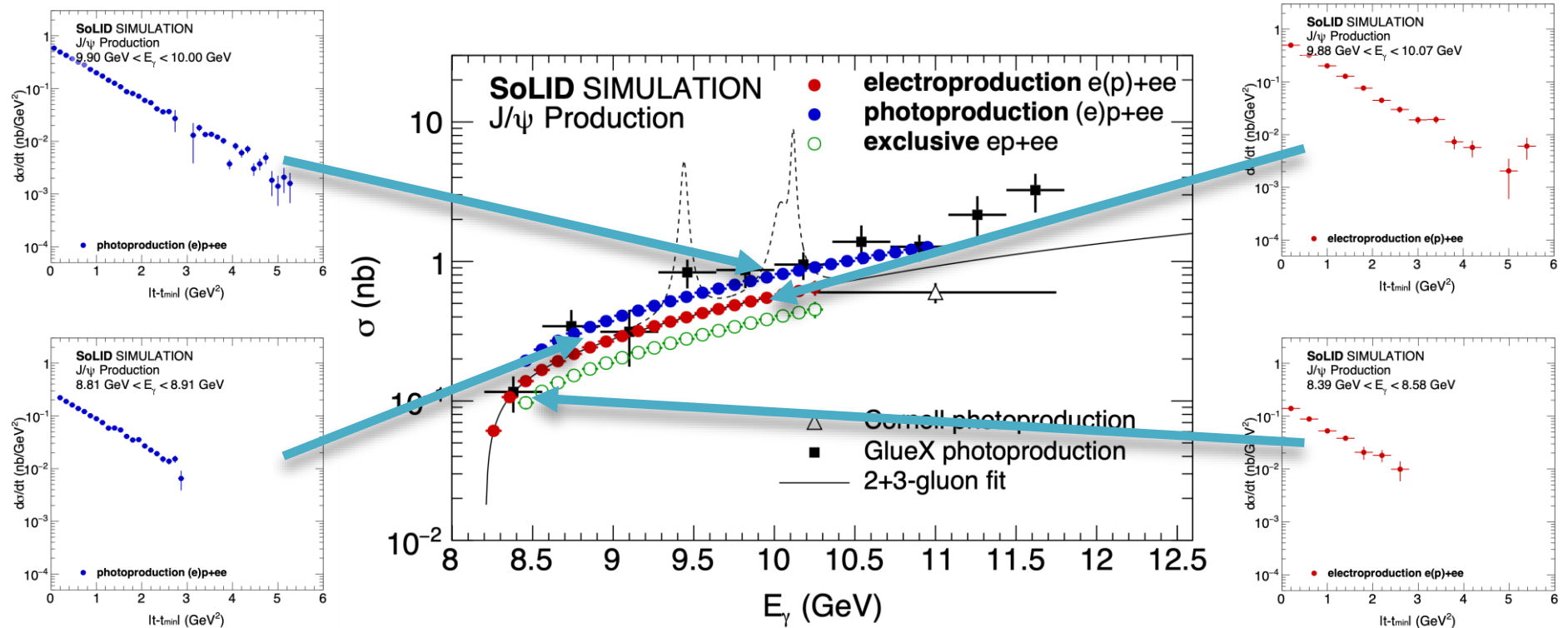
## Measurements

- **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

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# SoLID J/ψ projection

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



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# J/ψ experiments at JLab compared

	GlueX HALL D	HMS+SHMS HALL C	CLAS 12 with upgrade <sup>1</sup> HALL B	SoLID HALL A
J/ψ counts (photo-prod.)	469 published <sup>[SEP]</sup> ~10k phase I + II	2k electron channel 2k muon channel	14k	804k
J/ψ Rate (electro- prod.)	N/A	N/A	1k	21k
Features	Good reach to threshold. No high-t reach.	Can reach high-t only at higher energies. Low statistics.	No high-t reach. Electroproduction low statistics.	Enough luminosity to reach high t. High precision.
When?	Finished/Ongoing	Finished	Ongoing/Proposed	Future

<sup>1</sup>The CLAS12 projected count rates assume the proposed CLAS12 luminosity upgrade to  $2 \times 10^{35}/\text{cm}^2/\text{s}$

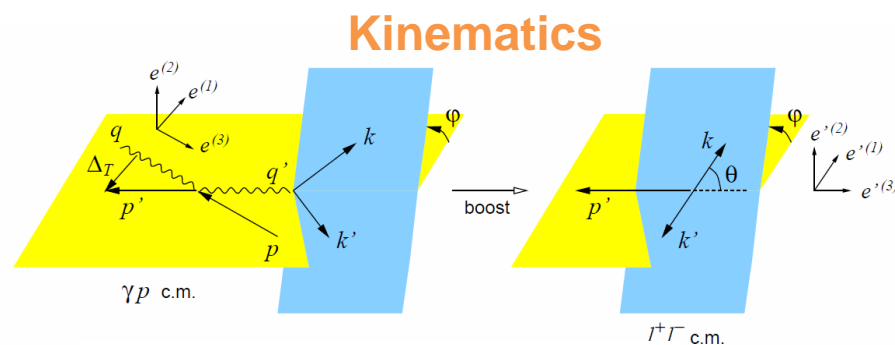
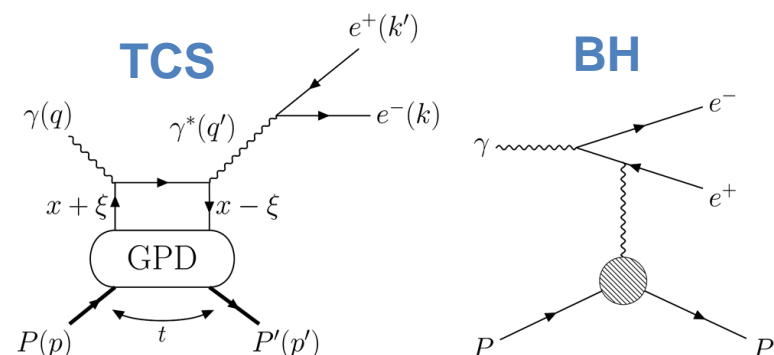


# E12-12-006A: TCS with circular polarized beam and LH2 target

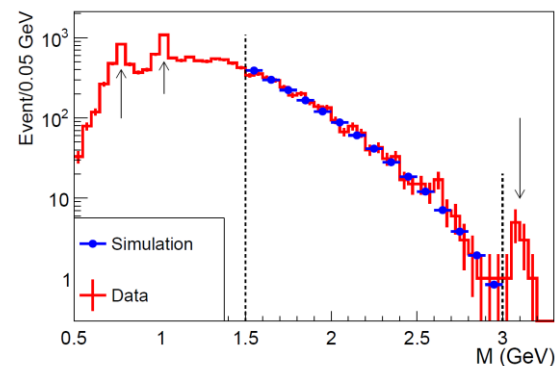
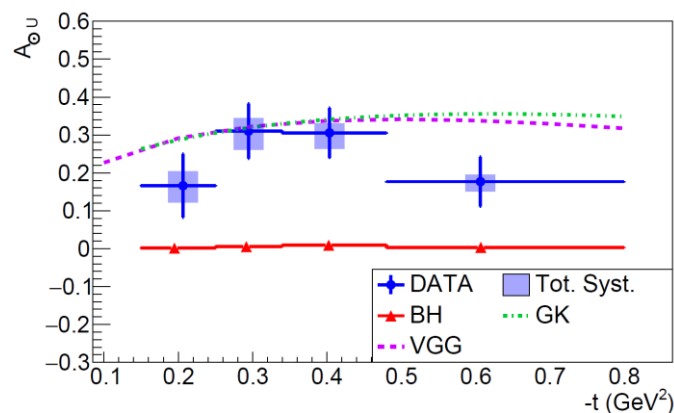
sharing beam time with J/psi run using same trigger on decay  $e^- e^+$  pair only

- Motivation
  - Timelike Compton Scattering (TCS) access the same GPDs like DVCS and test universality
  - Access real and imaginary 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

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



CLAS12  
result

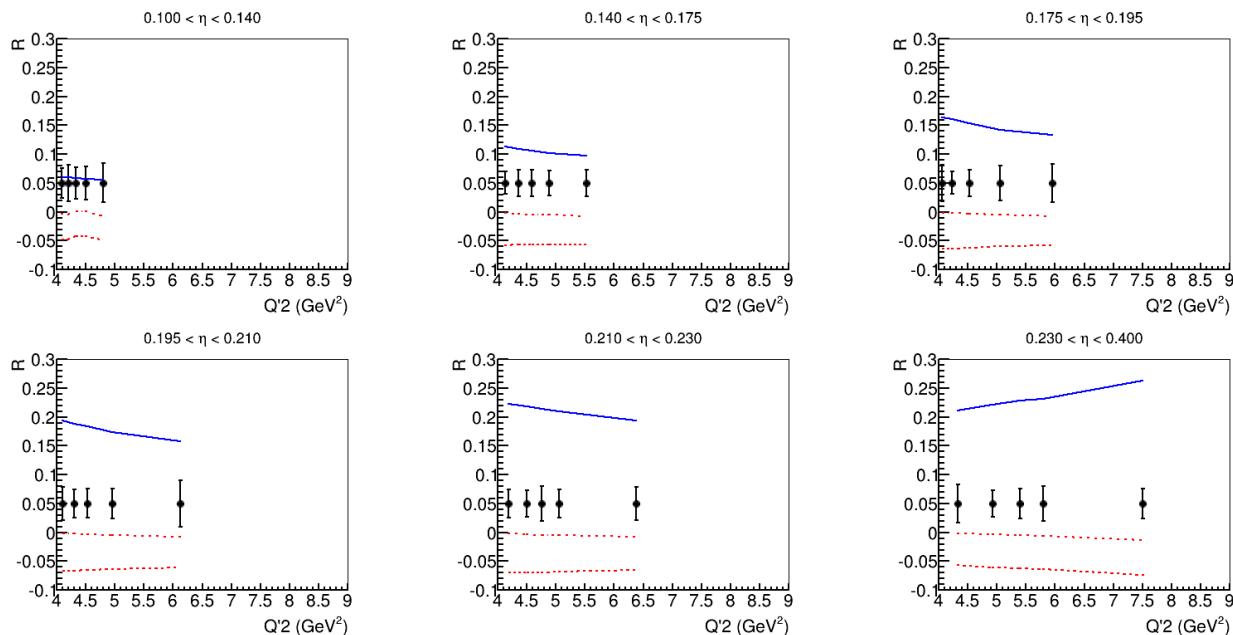
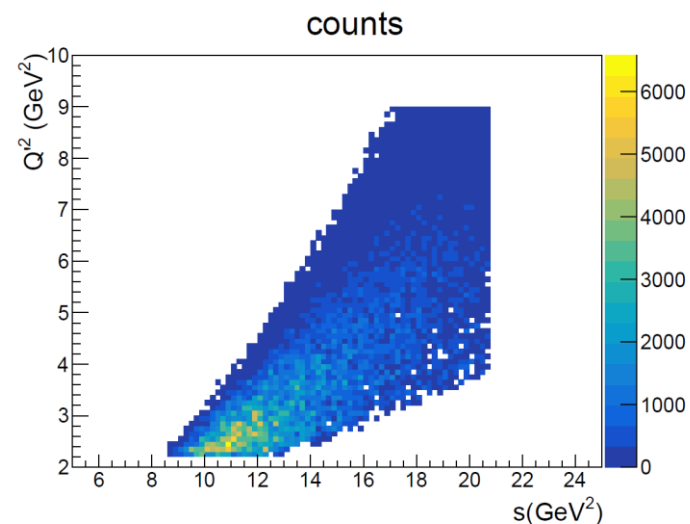
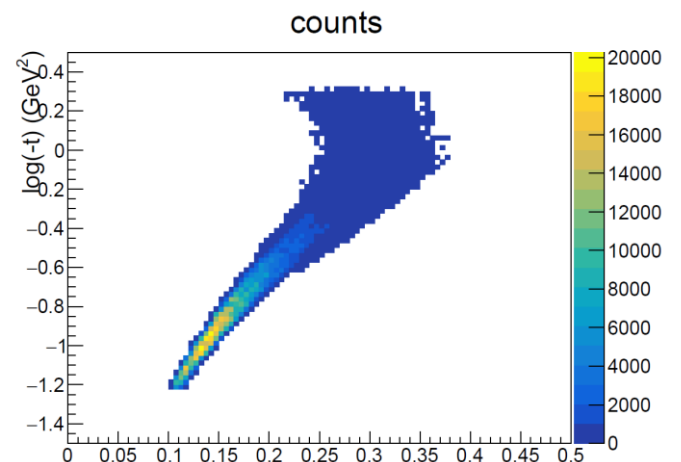




# E12-12-006A: TCS with circular polarized beam and LH2 target

- SoLID TCS will have at least 1 order higher 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  $\frac{1}{4}$  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

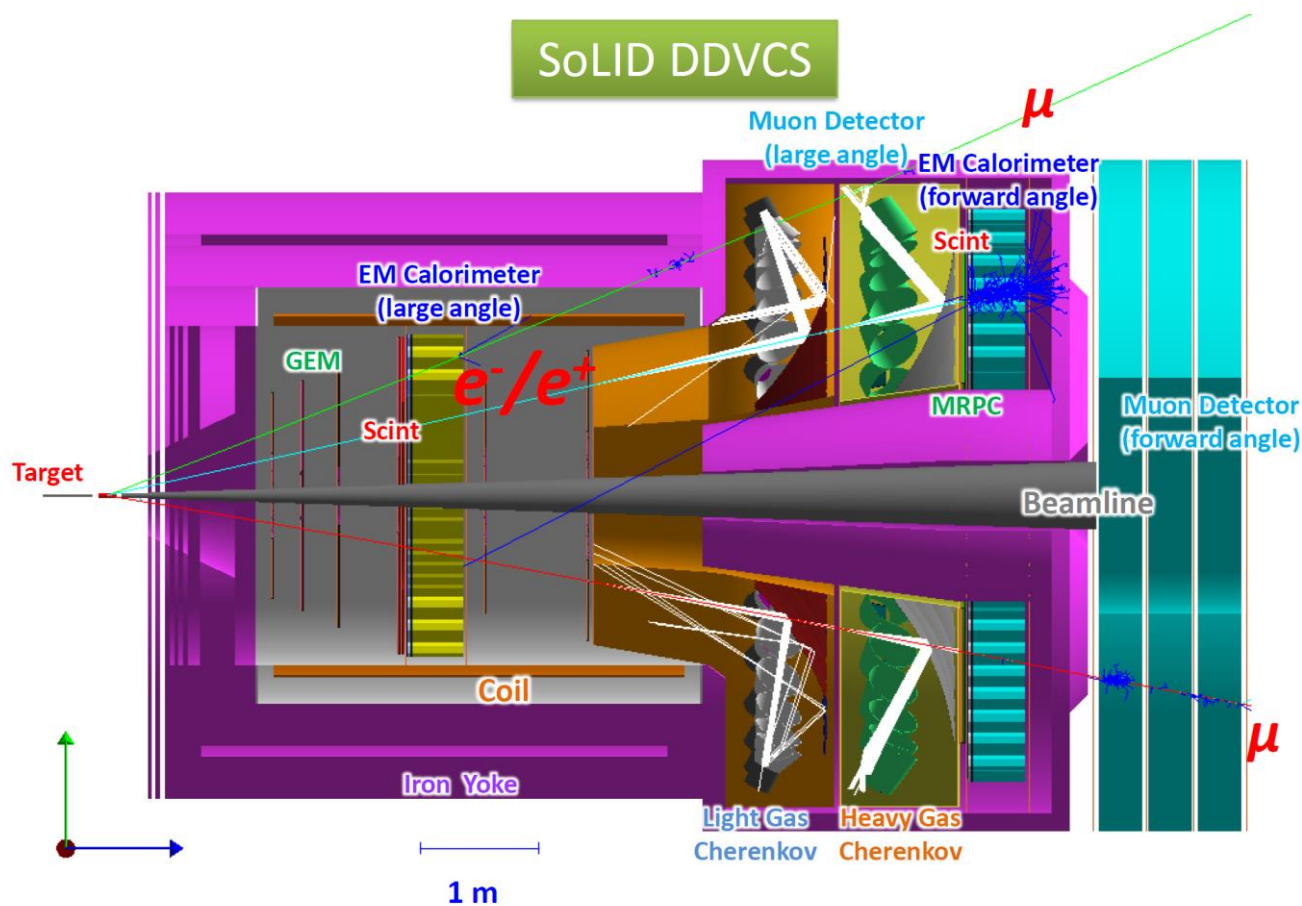
## SoLID TCS coverage



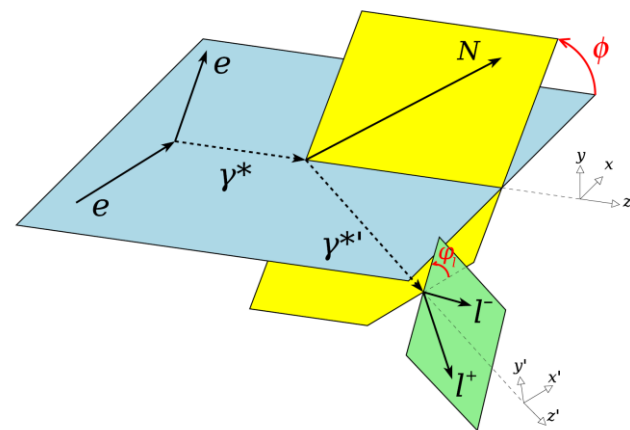
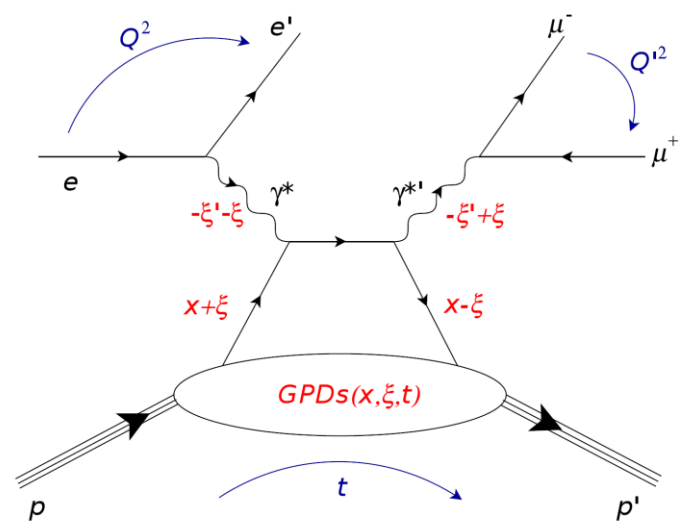
$$R = \frac{2 \int_0^{2\pi} d\varphi \cos \varphi \frac{dS}{dQ^2 dt d\varphi}}{\int_0^{2\pi} d\varphi \frac{dS}{dQ^2 dt d\varphi}}$$

# DDVCS with circular polarized beam and LH2 target

Letter of Intent 2015, under study



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



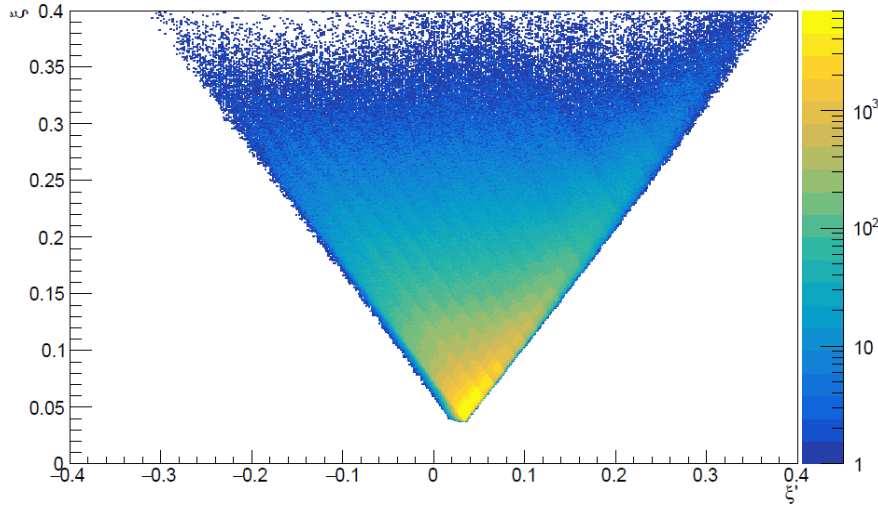
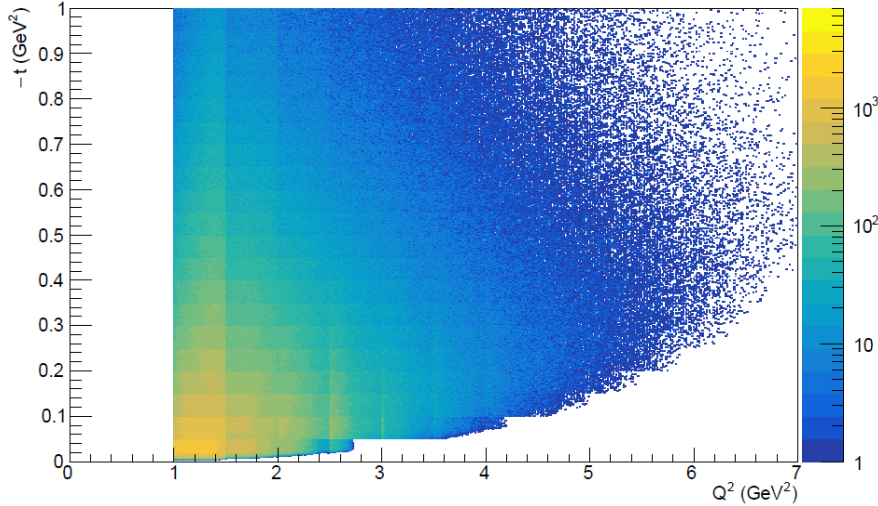
- Double Deeply Virtual Compton Scattering (DDVCS) explores wide off-axis kinematic region of GPDs, beyond DVCS and TCS
- **SoLID** with **muon detectors** at forward and large angle, enables DDVCS measurements with both polarized electron and positron beams at 11 GeV
- Sharing running time and increase statistics for  $J/\psi$  and TCS

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

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

# DDVCS with circular polarized beam and LH2 target

coverage

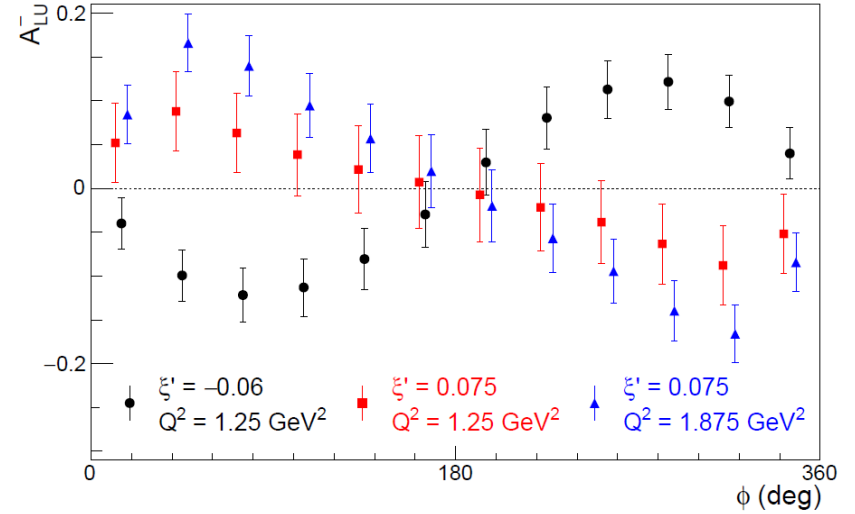


$$A_{LU}^{\pm}(\phi) = \frac{1}{\lambda^{\pm}} \frac{d^5\sigma_{+}^{\pm} - d^5\sigma_{-}^{\pm}}{d^5\sigma_{+}^{\pm} + d^5\sigma_{-}^{\pm}} \quad (15)$$

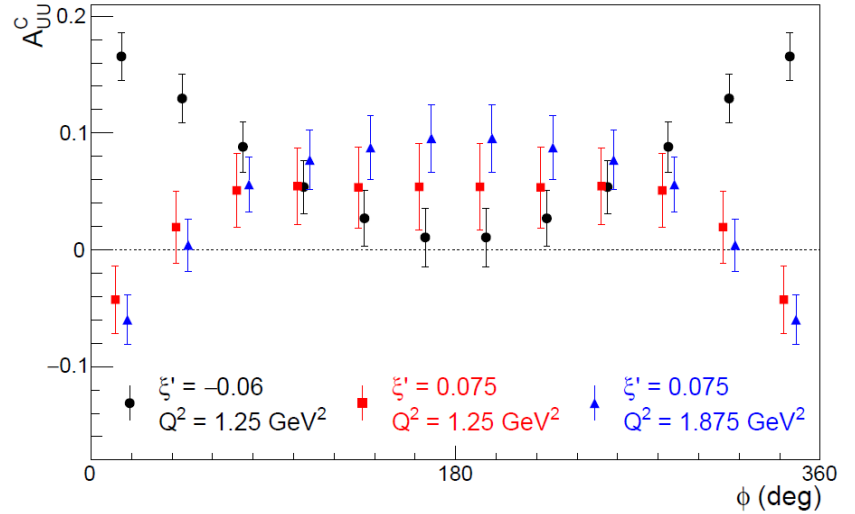
$$= \frac{d^5\tilde{\sigma}_{DDVCS} \mp d^5\tilde{\sigma}^{INT1}}{d^5\sigma_{BH1} + d^5\sigma_{BH2} + d^5\sigma_{DDVCS} \mp d^5\sigma_{INT1}}$$

projection

$\xi = 0.135, -t = 0.25 \text{ GeV}^2$



$\xi = 0.135, -t = 0.25 \text{ GeV}^2$



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

$$= \frac{d^5\sigma_{INT1}}{d^5\sigma_{BH1} + d^5\sigma_{BH2} + d^5\sigma_{DDVCS}}$$

EPJA 57, 240 (2021)



# Summary

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- SoLID with **open geometry** has a broad dilepton physics program
  - $J/\psi$  near threshold (approved)
  - TCS (approved)
  - DDVCS (under study)
- **High luminosity and large acceptance** are keys to make those next generation experiments possible with multidimensional binning
- More ideas (e.g. deuterium and other nuclei target)

*Thank you!*

## Strong Collaboration

- 270+ collaborators, 70+ institutes from 13 countries
- Strong theory support
- Active development and validation of the pre-conceptual design and physics programs

