GPD physics opportunities with SoLID

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Workshop at Argonne National Lab:

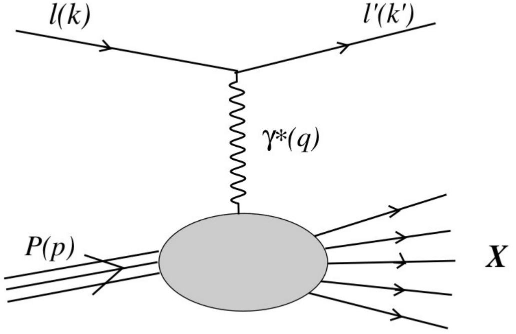
SoLID Opportunities and Challenges of Nuclear Physics at the Luminosity Frontier

VIRGINIA TECH

PaSHa

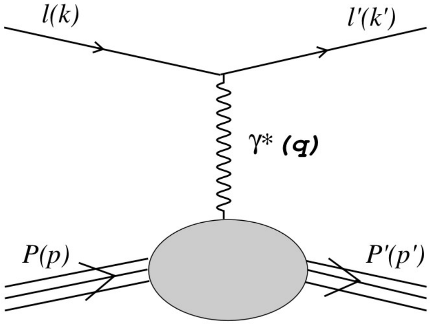
PARTONIC STRUCTURE OF THE HADRONS

Generalized Parton Distributions from exclusive reactions

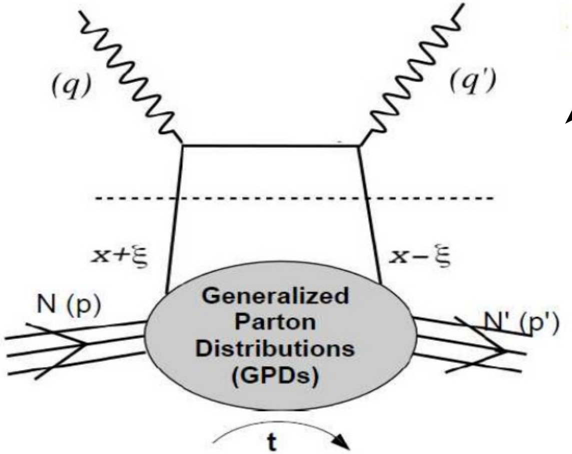


Deep Inelastic Scattering:
Probabilistic density interpretation
“x”, longitudinal momentum fraction of the partons

Hard Exclusive Scattering:
Both **“x” and “position”**
Known final state



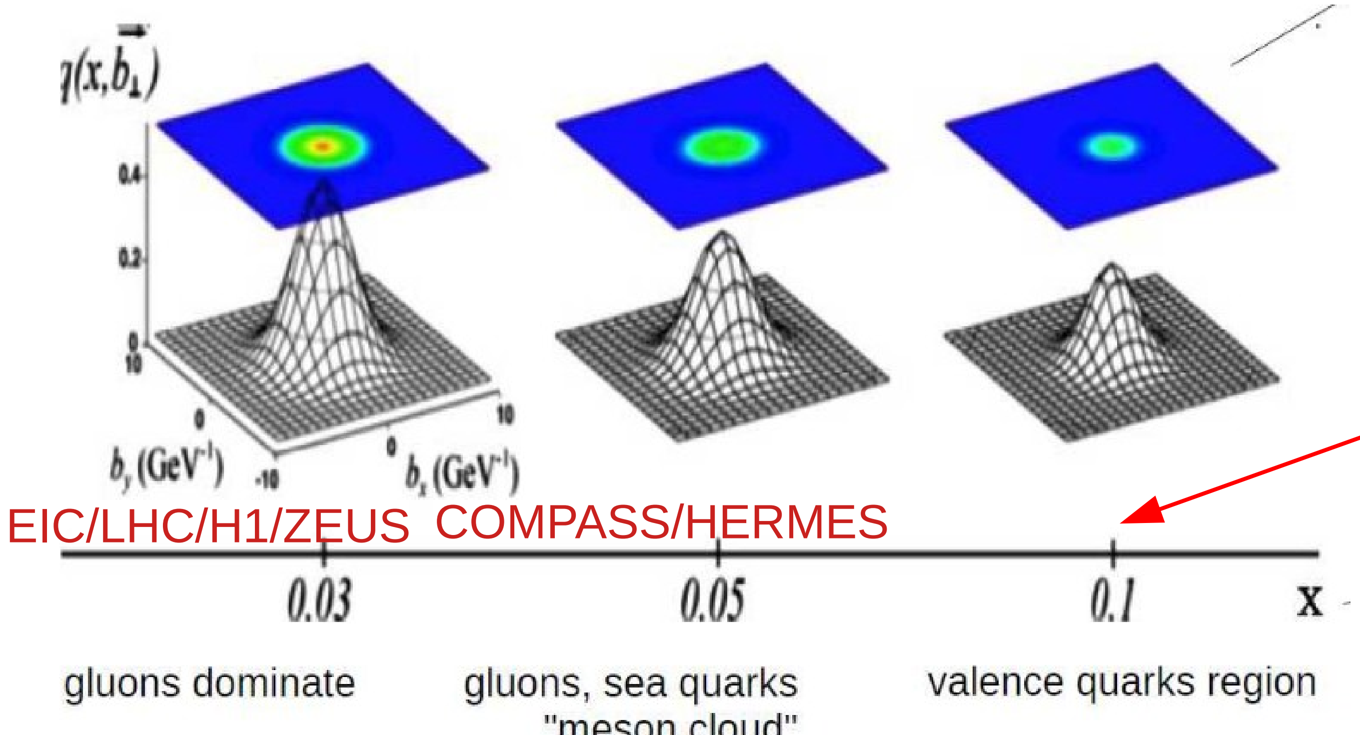
Elastic scattering:
transverse position of quarks
Access to momentum transfer t



Generalized Parton Distributions

One of the interpretation of GPDs: tomographic imaging of the nucleon
(other: spin, angular momenta correlation, “pressure”…)

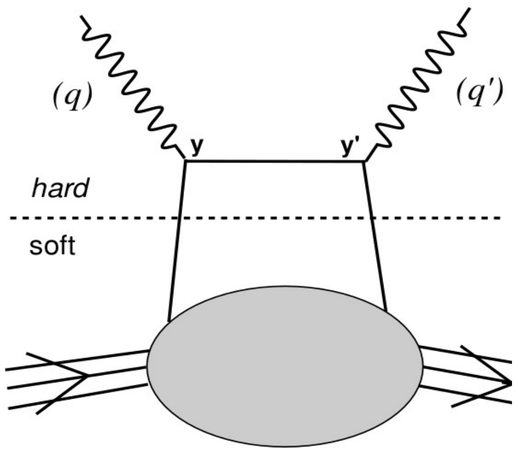
Momentum dependent impact parameter distributions
Quarks and gluons transverse position versus their longitudinal momentum

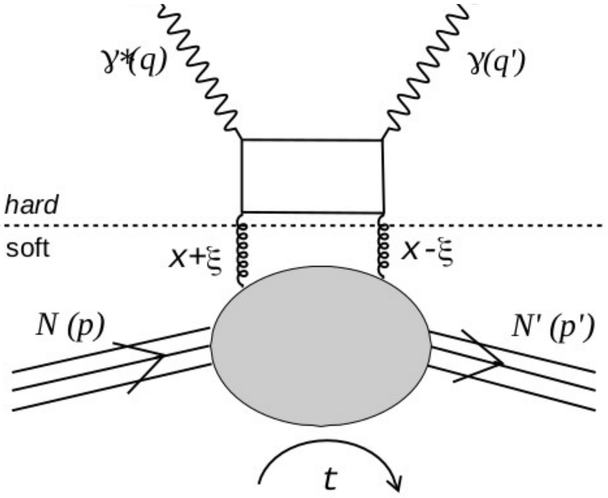


region accessed at Jlab and with SoLID

Reactions

GPDs with Compton-like reactions $\gamma(*)\ N \rightarrow \gamma'(*)\ N'$





Leading order / leading twist generic handbag diagram

DVCS: final photon is real, incoming is spacelike
(Spacelike Deeply Virtual Compton Scattering)

TCS: incoming is real, final is timelike
(Timelike Deeply Virtual Compton Scattering)

DDVCS: incoming is spacelike, outgoing is timelike
Double Deeply Virtual Compton Scattering

Other: multi-photons, photon+meson, ...

Quark GPDs; as function of x (// momentum fraction), ξ (skewness), t (squared momentum transfer)
+ Q^2, Q'^2: evolution not being taken into account in this work. Q^2/Q'^2 relevant for DDVCS

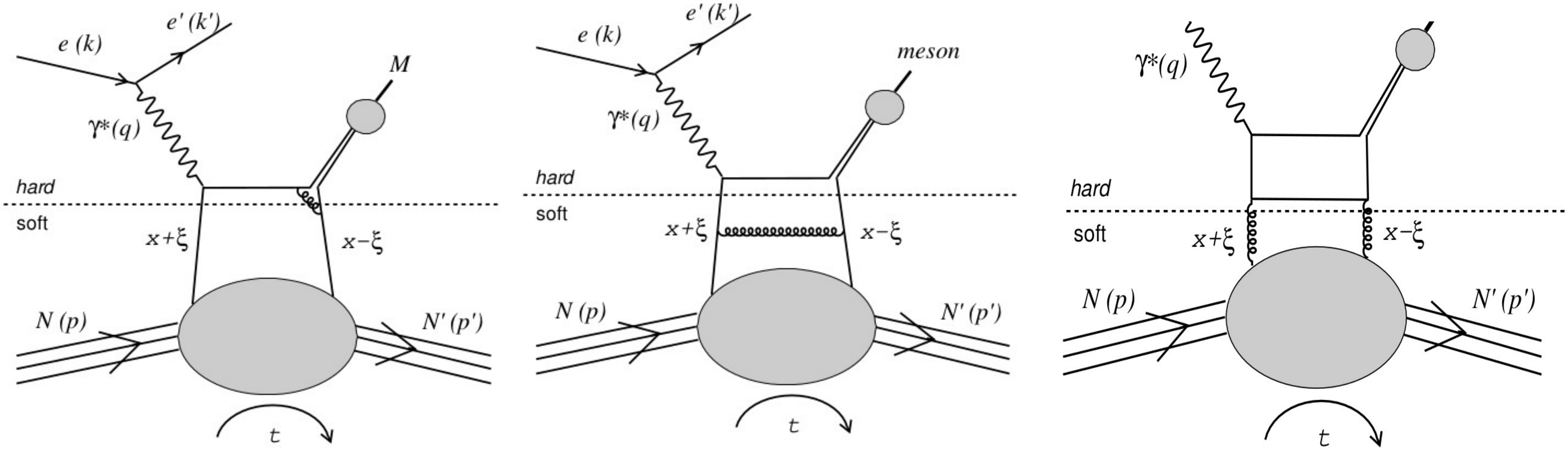
Can be seen as the "cleanest" way to access GPDs, since no meson amplitude distribution

Most measurements = DVCS; GPD models mostly constrained from DVCS data

Reactions

GPDs with Hard Exclusive Meson Production (few example of diagrams, we focus on VM)

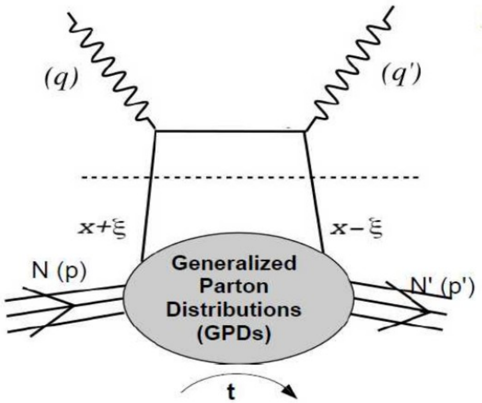
γ (*) N → (VM) N'



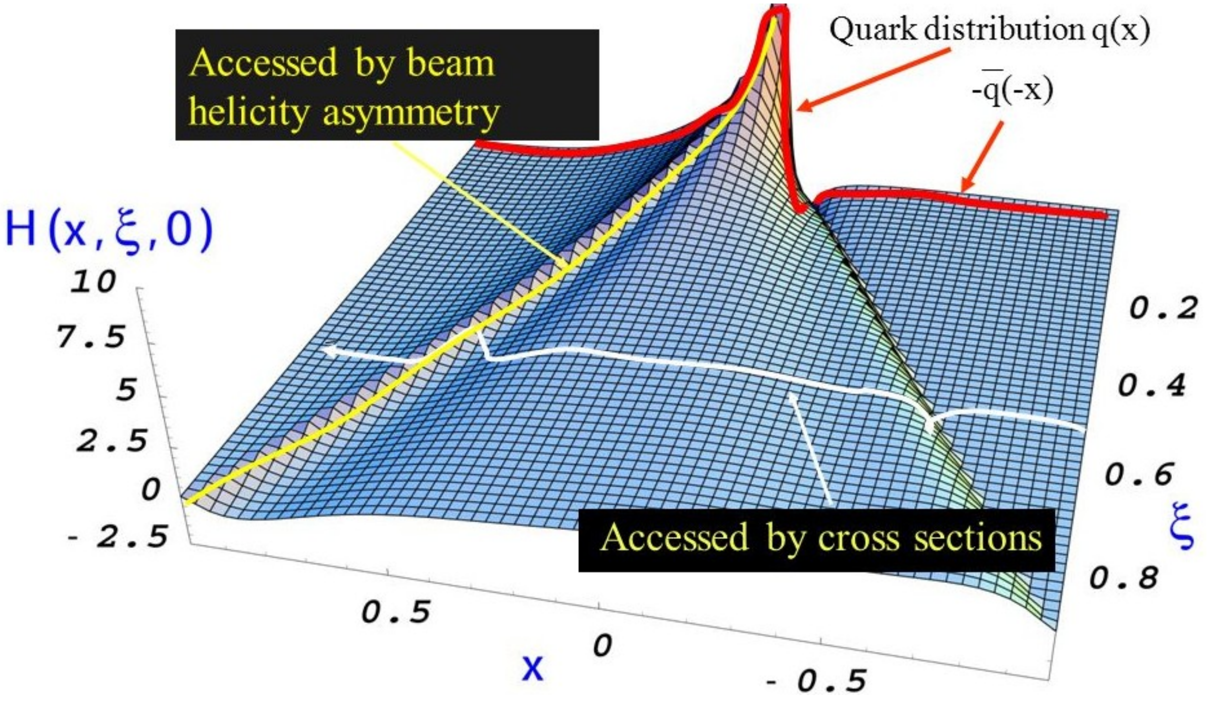
- Flavor decomposition
- Enhancement of sensitivity to certain GPDs
- Direct access to gluon GPDs with heavy mesons…

- VM: can be directly compared to Compton reactions (same spin-parity), large cross sections. Caveat: meson production, gluons at leading twist. Need more models and measurements for some mesons

Generalized Parton Distributions from CFF fits (with DVCS or TCS)



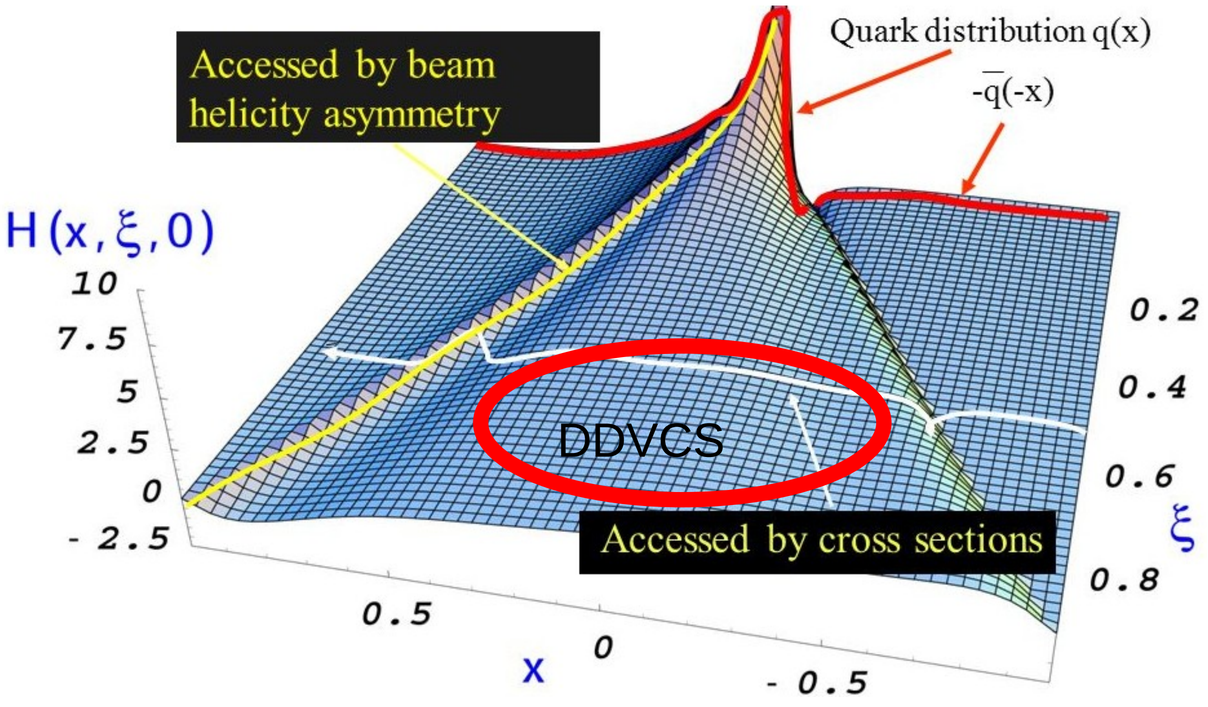
Extracted at ξ (skewness // momentum)
and t (momentum transfer ²)
from experimental data [can't access x]



$$T^{DVCS} \sim \int_{-1}^{+1} \frac{H(x,\xi,t)}{x \pm \xi + i\varepsilon} dx + \ldots \sim \underbrace{P\int_{-1}^{+1} \frac{H(x,\xi,t)}{x \pm \xi} dx}_{Re(\mathcal{H})} - \underbrace{i\pi H(\pm\xi,\xi,t)}_{Im(\mathcal{H})} + \ldots$$

Propagator: only access "diagonal" part |x|=xi

Generalized Parton Distributions: “off diagonal”



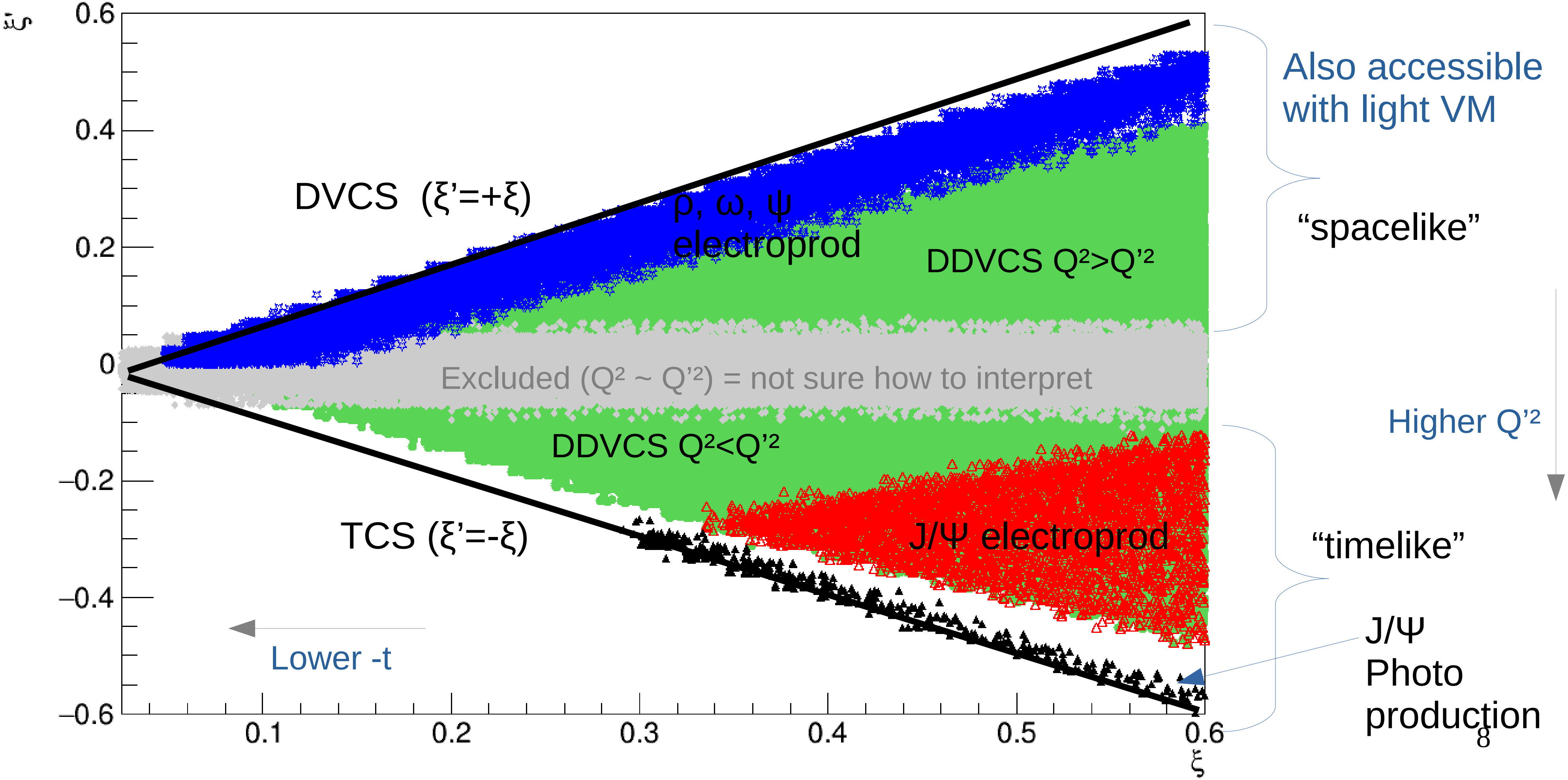
“diagonal”: $$T^{DVCS} \sim \int_{-1}^{+1} \frac{H(x,\xi,t)}{x \pm \xi + i\varepsilon} dx + \ldots \sim P\int_{-1}^{+1} \frac{H(x,\xi,t)}{x \pm \xi} dx - i\pi H(\pm\xi,\xi,t) + \ldots$$

$\underbrace{}_{\mathrm{Re}\,(\mathcal{H})}$ $\underbrace{}_{\mathrm{Im}\,(\mathcal{H})}$

“off diagonal”: $$T^{DDVCS} \sim \int_{-1}^{+1} \frac{H(x,\xi,t)}{x - (2\xi' - \xi) + i\varepsilon} dx + \ldots \sim P\int_{-1}^{+1} \frac{H(x,\xi,t)}{x - (2\xi' - \xi)} dx - i\pi H(2\xi' - \xi,\xi,t) + \ldots$$

Complementarity of GPD-sensitive exclusive reactions

11 GeV beam, -t<1 GeV², W²<2 GeV², Q'² (TCS, DDVCS>2 GeV²), Q² (electroprod. > 1 GeV²)



Which experiments with SoLID? (from webpage)

Experiments

PVDIS(E12-10-007)
Submission at PAC 34, Update at PAC 35, Update at PAC 37, Approved for 169 days (of 338 requested) with a rating of A.

SIDIS

SIDIS with Transversely Polarized ^{3}He(E12-10-006)
Submission at PAC 34, Update at PAC 35, Update at PAC 38, approved for 90 days with a rating of A

SIDIS with Longitudinally Polarized ^{3}He(E12-11-007)
Submission at PAC 37, Update at PAC 38, approved for 35 days with a rating of A

SIDIS with Transversely Polarized Proton (E12-11-108)
Submission at PAC 38, Update at PAC 39, approved for 120 days with a rating of A

J/Psi (E12-12-006)
Near Threshold Electroproduction of J/Psi at 11 GeV, Submission at PAC 39, 2012, approved 60 days;
Submission at PAC 50, 2022 - Jeopardy Experiments with a new rating of A

BNSSA (PR12-22-004)
Measurement of the Beam Normal Single Spin Asymmetry in Deep Inelastic Scattering using the SoLID Detector, Submission at PAC 50, 2022, approved 38 days with a rating of A-

Run Group Experiments

SIDIS Dihadron with Transversely Polarized ^{3}He (E12-10-006A)
Submission to SoLID TAC and PAC 42,2014, approved as a run group with E12-10-006.

SIDIS in Kaon Production with Transversely Polarized Proton and ^{3}He (E12-11-108B/E12-10-006D)
Submission to SoLID TAC and PAC46, 2018, conditionally approved as a run group experiment with E12-11-108 and E12-10-006.

Ay (E12-11-108A/E12-10-006A)
Target Single Spin Asymmetry Measurements in the Inclusive Deep-Inelastic Reaction on Transversely Polarized Proton and Neutron (^{3}He) Targets using the SoLID Spectrometer
Submission to SoLID TAC and PAC 42, 2014, approved as run group with E12-10-006 and E12-11-108.

g2n and d2n (E12-11-007A/E12-10-006E)
Measurement of Inclusive g2n and d2n with SoLID on a Polarized ^{3}He Target. Submission to SoLID TAC and PAC 48, 2020, approved as as a run group experiment with E12-11-007 and E12-10-006.

Deep Exclusive Meson Production (E12-10-006B) (DEMP)
Measurement of Deep Exclusive Pi- Production using a Transversely Polarized He3 Target and the SoLID Spectrometer,
Submission at SoLID TAC and PAC 45, 2017, approved as run group with E12-10-006.

Timelike Compton Scattering (E12-12-006A) (TCS)
TCS with circular polarized beam and unpolarized LH2 target,
Submission at SoLID TAC and PAC 43, 2015, approved as run group with J/Psi(E12-12-006).

Other Physics Channels

Conditionally approved (C2), letters of Intent, Deferred Proposals and posibilities.

EMC Effect in Parity Violating DIS (PVEMC)
Deeply Virtual Compton Scattering (DVCS)
Deferred proposals PR12-16-006 and PR12-14-007

Parity Violating DIS on polarized ^{3}He
Letter of Intent: LOI12-16-007

Deeply Virtual Compton Scattering (DVCS)
DVCS with polarized targets

Double Deeply Virtual Compton Scattering (DDVCS)
DDVCS on proton (LOI12-12-005) Letter of Intent to PAC 43, 2015. Would run first as a run group experiment with J/Psi(E12-12-006) and then as a dedicated experiment.

First Measurement of the Flavor Dependence of Nuclear PDF Modification Using Parity-Violating Deep Inelastic Scattering
C2 approved by PAC 50 (PR12-22-002).

Which experiments with SoLID? (from webpage)

Several run-group measurements proposed / approved / or possible starting from the approved J/psi setup

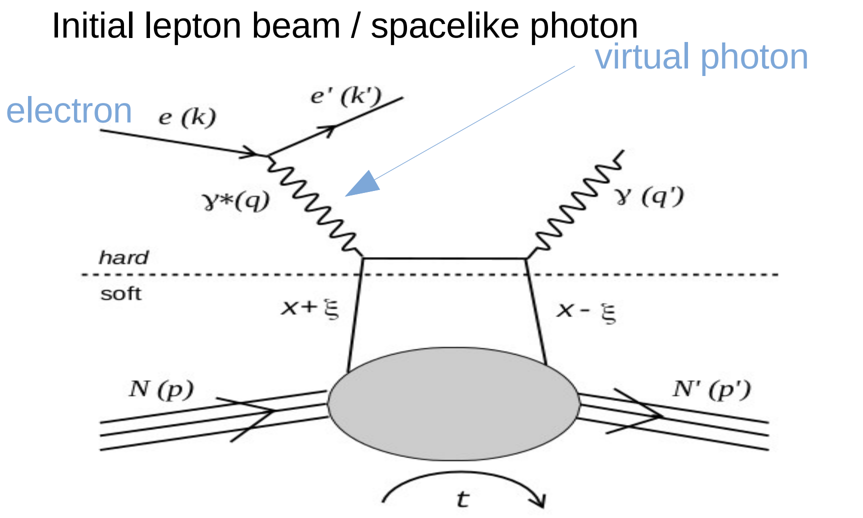
- **DVCS** program could be further developed, but measurements will be done.
* I will not talk about DVCS here since it is covered in many other talks / experiments

- **Meson** measurements proposed by Z. Ye & G. Huber: lot of potential thanks to large acceptance.

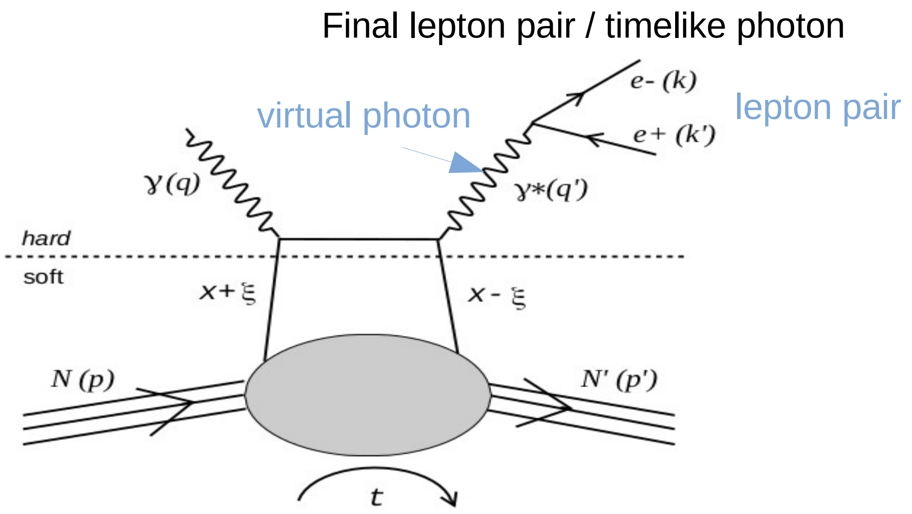
Not proposed yet in SoLID, but something to explore (large acceptance is great):
more than one particle in final state.
  * currently at exploratory stages of analyzing GlueX data for these channels.
  * potential with CLAS12 too (as well as other non-JLab experiments: COMPASS…)
  * Lot of recent progress on theory side: LDRD for JLab theory group (J. Qiu et al.), "France-group" (S. Wallon, L. Szymanowsky, S. Nabebacus et al.), UVA (S. Liuti) active in exploring these channels all with different approaches and models

- **Compton-like** complementary measurements of TCS and DDVCS proposed for SoLID

DVCS versus TCS and complementarity



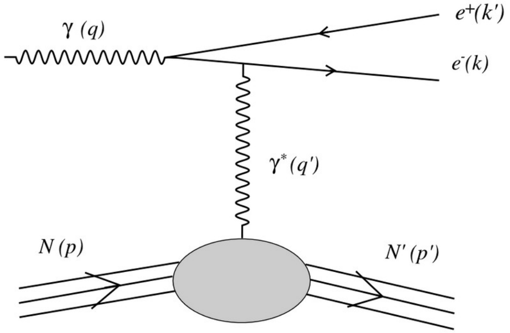
Deeply Virtual Compton Scattering (DVCS)



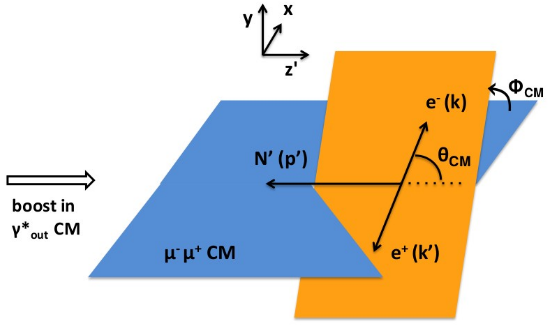
Timelike Compton Scattering (TCS)

Interference with “BH”
Harmonics in φ (φ_S)

Measuring cross section,
beam/target spin asymmetries...



BH interferes with TCS

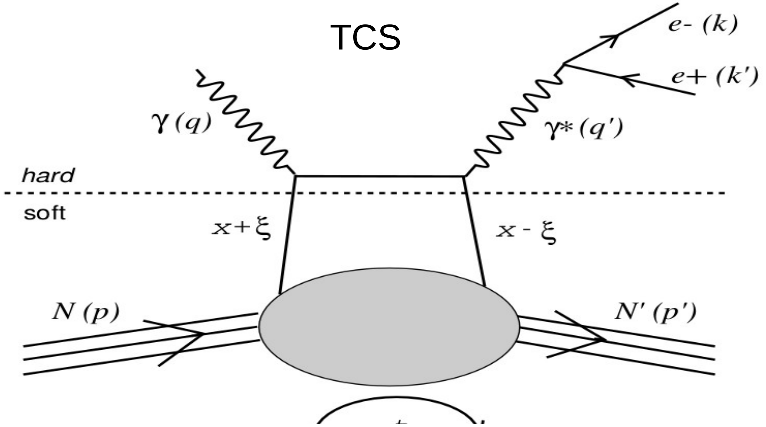


Measuring TCS in exclusive di-electron photo-production

$\gamma N \rightarrow e^+e^- N$

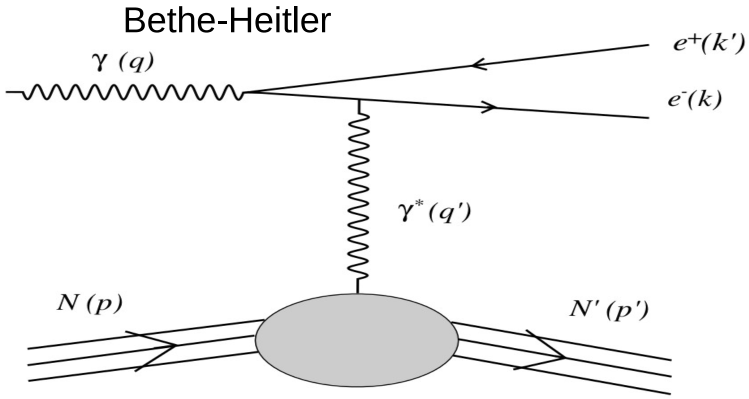
=

TCS



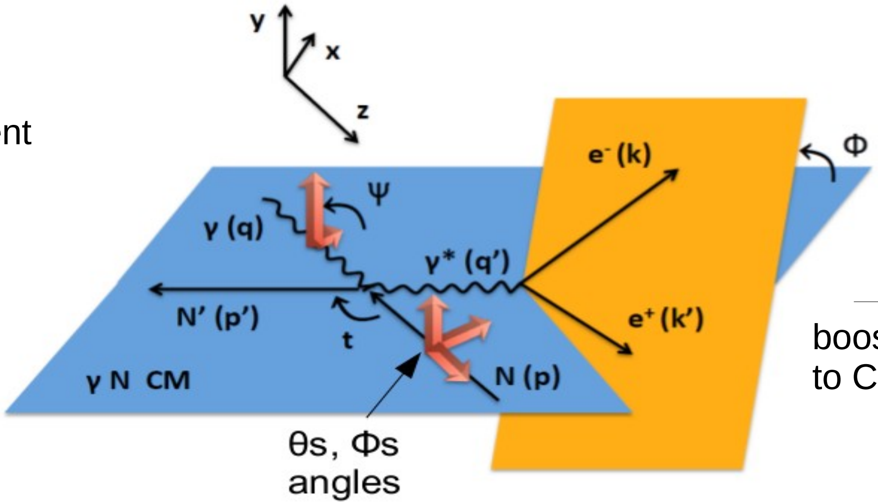
+

Bethe-Heitler

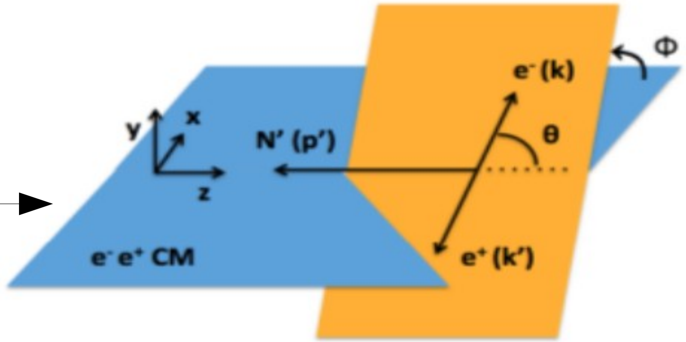


dσ: 5 or 6 independent variables

choice:
E or ξ,
t, Q^2, φ, θ,
if spin: φ_s or Ψ_s



boost
to CM

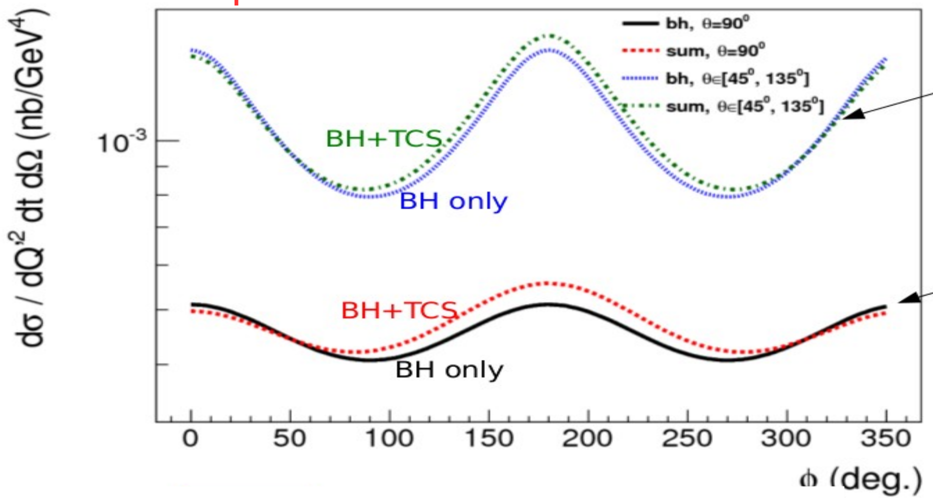


φ: (hadronic plane, pair)
θ: (γ*, e⁻)

φ_S, θ_S: (hadronic plane, target spin)
Ψ: (hadronic plane, γ spin)

Interesting TCS observables and GPD sensitivity (calculations)

Unpolarized cross section



Integrated over polar decay angle

45°<θ<135°

θ=90°

- **Unpolarized σ:**

- sensitivity to Im + Re (amplitude)
- difficult, BH dominant

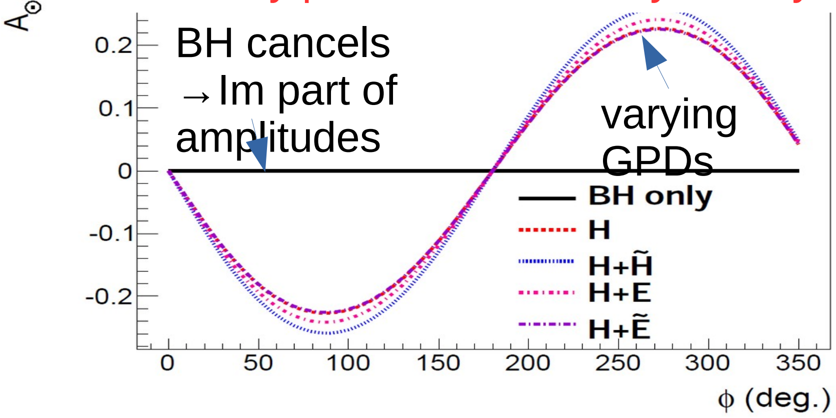
- **Beam or target polarized σ:**

- BH cancel, reflect interference (Im)
- easier to measure, quite large
- access Im($\mathcal{H}$), Im($\tilde{H}$), Im($\mathcal{E}$)

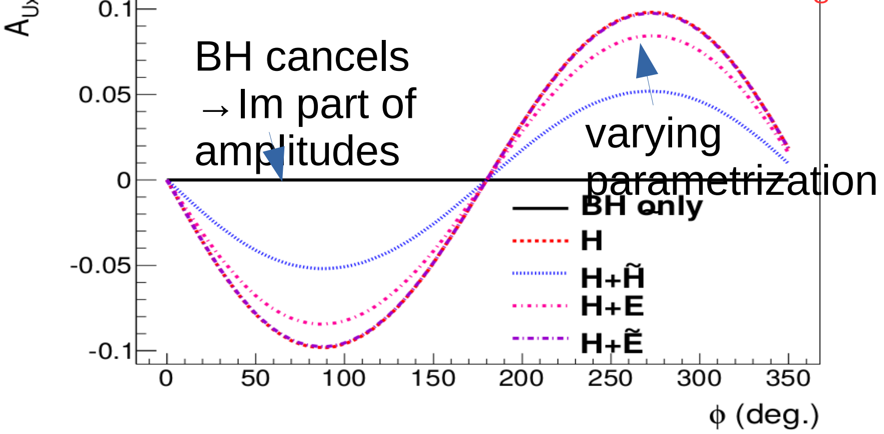
- **Double spin asym. or linear beam:**

- strong constrains on Re
- very hard, dominated by BH

Circularly polarized beam asymmetry



Transversely polarized target asym at φ_S=0°

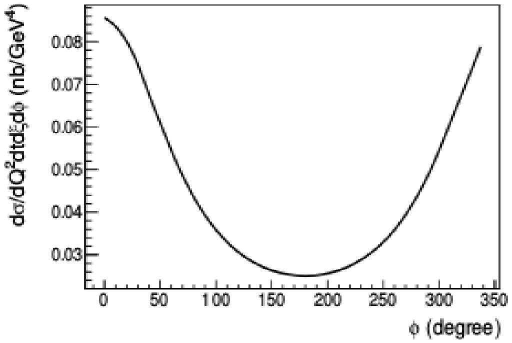


from Boer, Guidal, Vanderhaeghen, Eur. Phys. J. A51 (2015) 8, 103

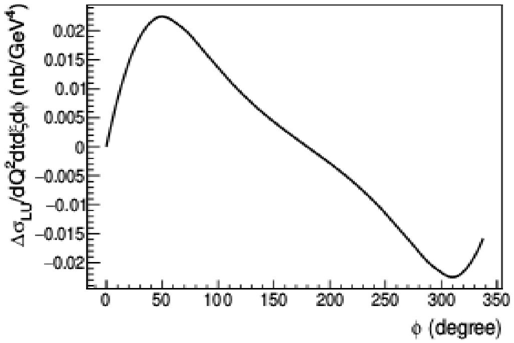
Extract of some work on fits from complementary channels “multidimensional approach”

DVCS

unpolarized cross section



polarized beam: $\Delta\sigma_{LU}$



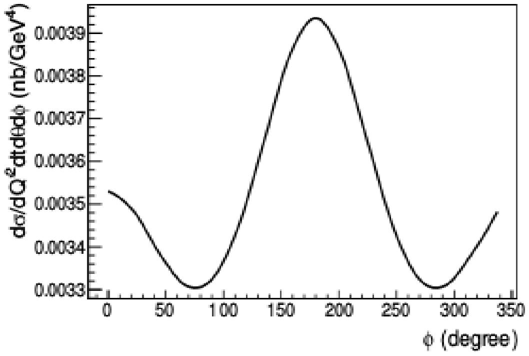
+ 7 more distributions of polarized cross section differences:

// pol target: $\Delta\sigma_{UL}$
⊥ pol target: $\Delta\sigma_{UX}$ (φ_S=0°), $\Delta\sigma_{UY}$ (φ_S=90°)
double pol beam+ target: $\Delta\sigma_{LX}$, $\Delta\sigma_{LY}$, $\Delta\sigma_{LL}$
beam charge: $\Delta\sigma_{C}$

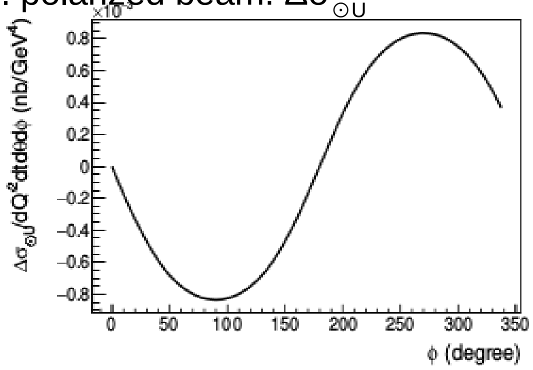
At Q^2 = 2.5 GeV², E = 11 GeV

TCS

unpolarized cross section



circ. polarized beam: $\Delta\sigma_{\odot U}$



+ 7 more distributions of polarized cross section differences:

// pol target: $\Delta\sigma_{UL}$
⊥ pol target: $\Delta\sigma_{UX}$ (φ_S=0°), $\Delta\sigma_{UY}$ (φ_S=90°)
double pol beam+ target: $\Delta\sigma_{\odot X}$, $\Delta\sigma_{\odot Y}$, $\Delta\sigma_{\odot L}$
linearly pol beam: $\Delta\sigma_{LU}$

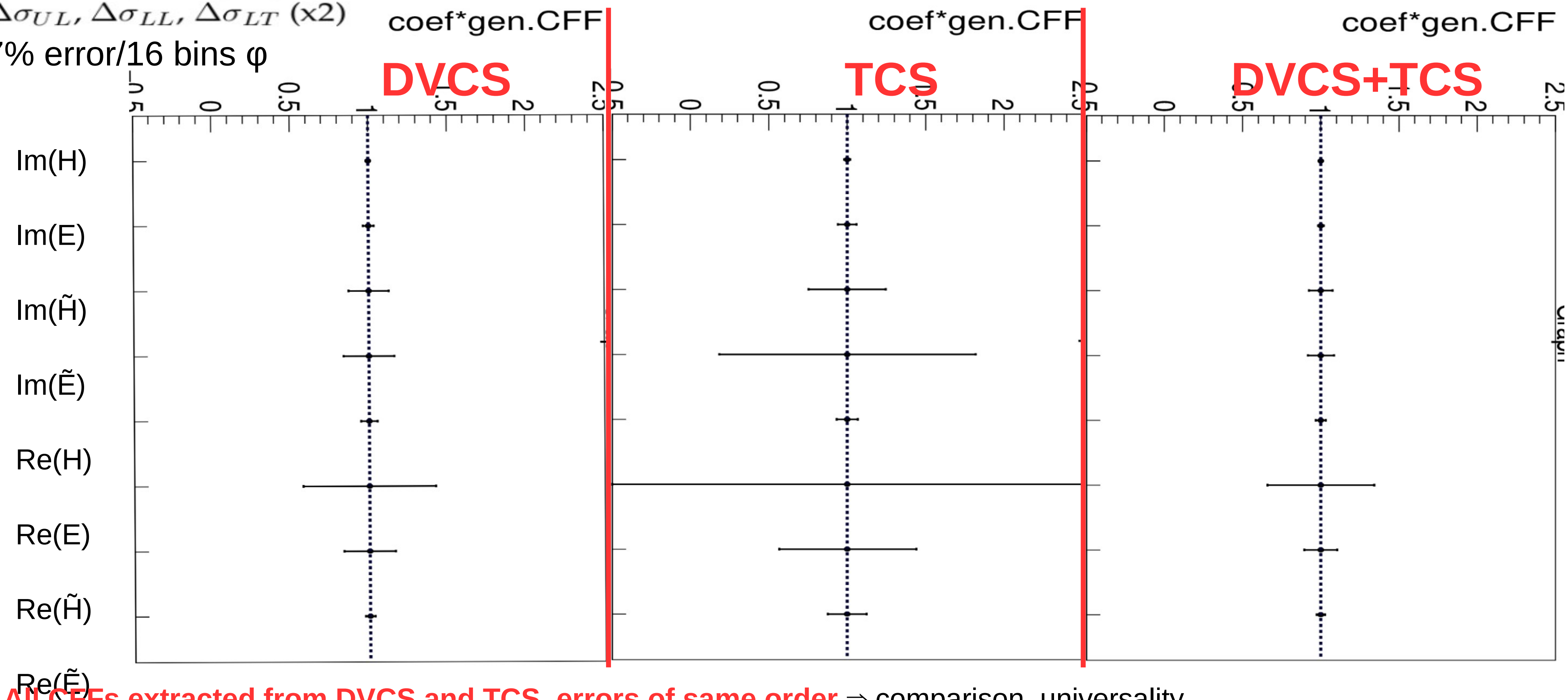
At Q^2 = 4.5 GeV², θ = 90°

In following example shown here, in both cases: ξ = 0.15, -t = 0.2 GeV²

Results: 8 parameters, 8 independent observables

5) σ, $\Delta\sigma_{LU}$, $\Delta\sigma_{UT}$ (x2)
$\Delta\sigma_{UL}$, $\Delta\sigma_{LL}$, $\Delta\sigma_{LT}$ (x2)

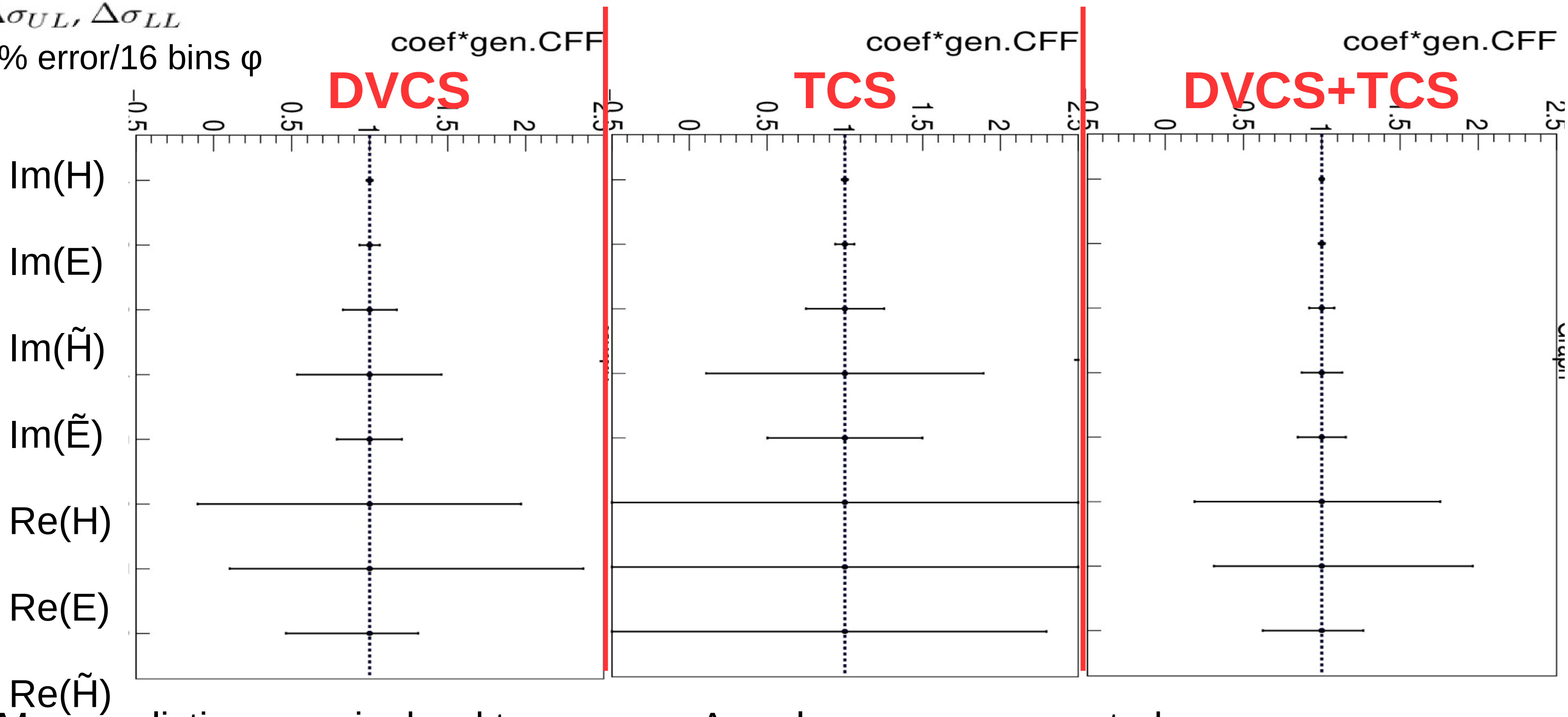
7% error/16 bins φ



- **All CFFs extracted from DVCS and TCS, errors of same order** ⇒ comparison, universality
- Lower errors with DVCS vs TCS: TCS/BH < DVCS/BH. "real": higher statistics with DVCS
- DVCS+TCS: "real" scenario expect shift to direction of DVCS solution if shift to opposite directions from higher twists ⇒ combining fits assume GPDs universality + low higher twist/order

Results: 8 parameters, 6 independent observables

4) σ, $\Delta\sigma_{LU}$, $\Delta\sigma_{UT}$ (x2)
$\Delta\sigma_{UL}$, $\Delta\sigma_{LL}$
7% error/16 bins φ



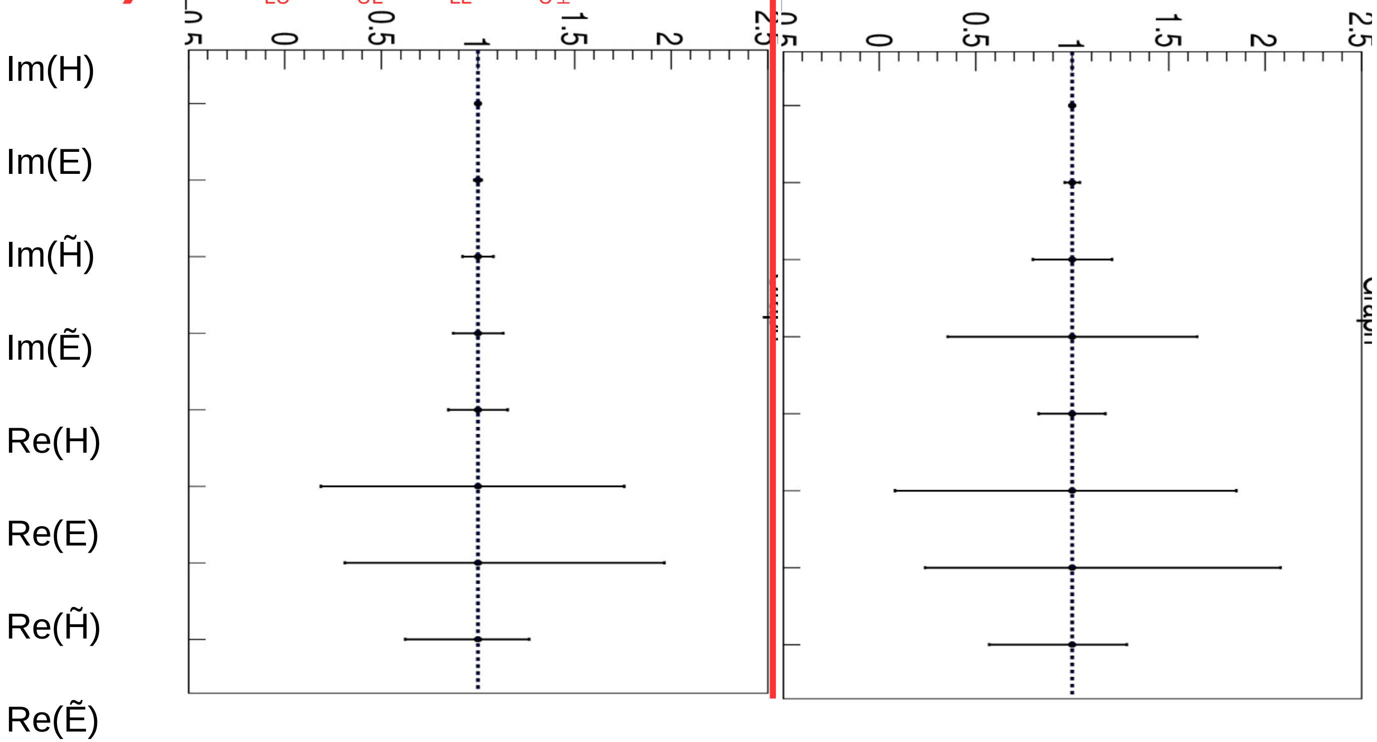
More realistic scenario: hard to measure $\Delta\sigma_{LT}$, large errors expected

- Problem is underconstained → asymmetric errors for Re(CFFs)
- Still possible to **extract all CFFs** (errors larger than scale for TCS real parts)

Combining independent observables from DVCS and TCS

DVCS+TCS (previous slide, 6 obs.): σ, $\Delta\sigma_{LU}$, $\Delta\sigma_{UL}$, $\Delta\sigma_{LL}$, $\Delta\sigma_{U\perp}$

DVCS (4 obs.): σ, $\Delta\sigma_{LU}$, $\Delta\sigma_{UL}$, $\Delta\sigma_{LL}$
+ TCS (4 obs.): σ, $\Delta\sigma_{\odot U}$, $\Delta\sigma_{U\perp}$



4+4 independent observables → 6 independent when combined

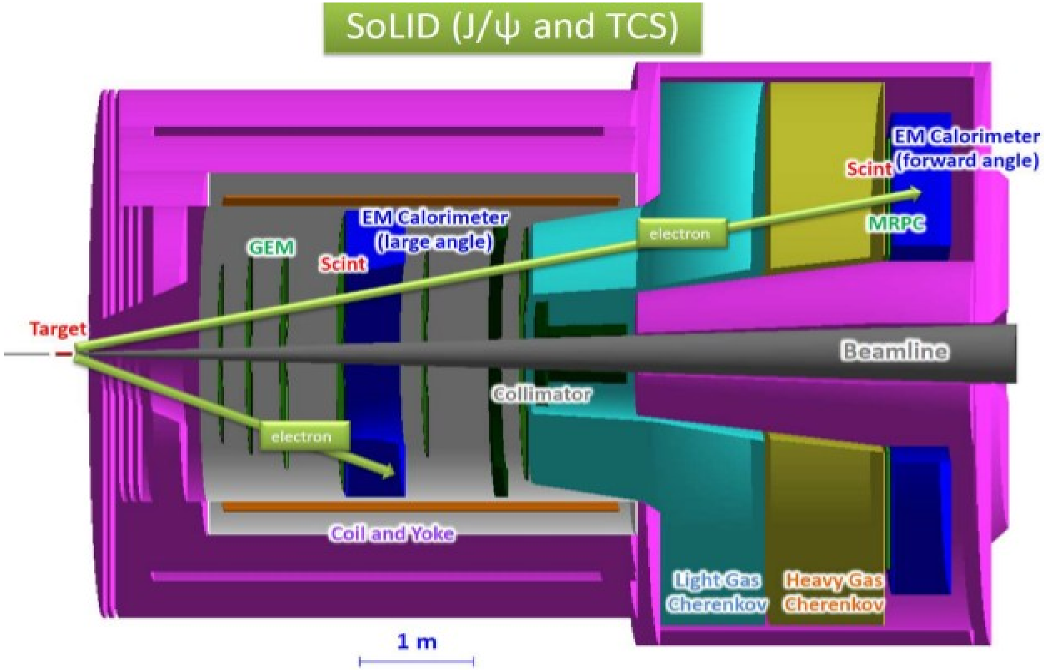
Realistic scenario: longitudinal target single+double asym with DVCS, transverse target with TCS

- Similar result combined fits with 4+4 observables than 6+6 observables → **all CFFs extracted**, thanks to independent information brought by the 2 processes

Caveat: assume low higher twist effects, and GPD universality

TCS run-group proposal

E12-12-006A PAC43

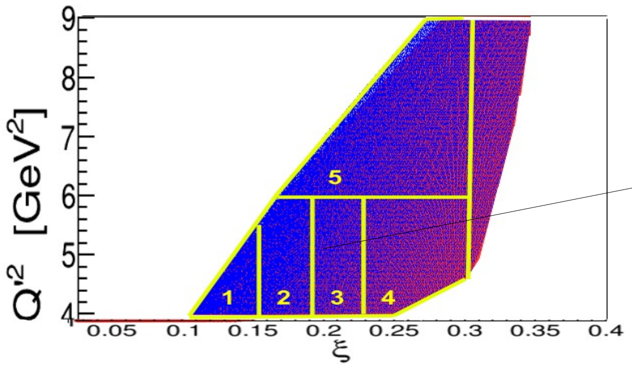


SoLID setup for J/ψ approved exp.

- no beam time request for TCS
- 50 days approved up to 10^37 cm^{-2}

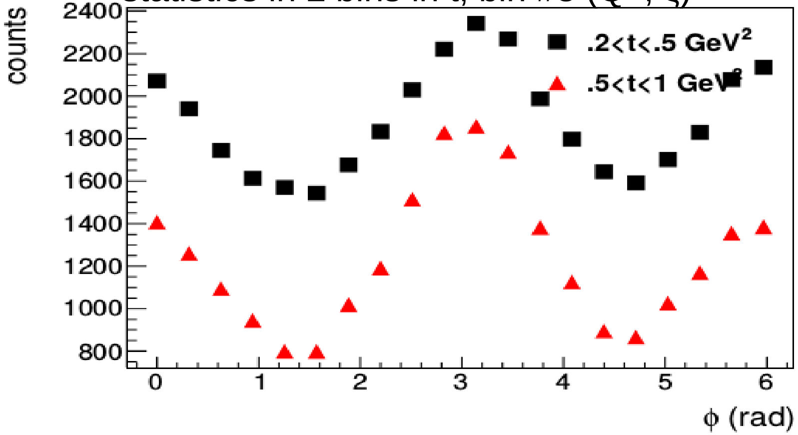
Similar as CLAS12, with larger statistic, narrower acceptance
→ binning in Q'^{2}: evolution...
→ studies of GPD universality by comparing H extracted from TCS and DVCS

Note: potential for polarized measurements too



bin 3

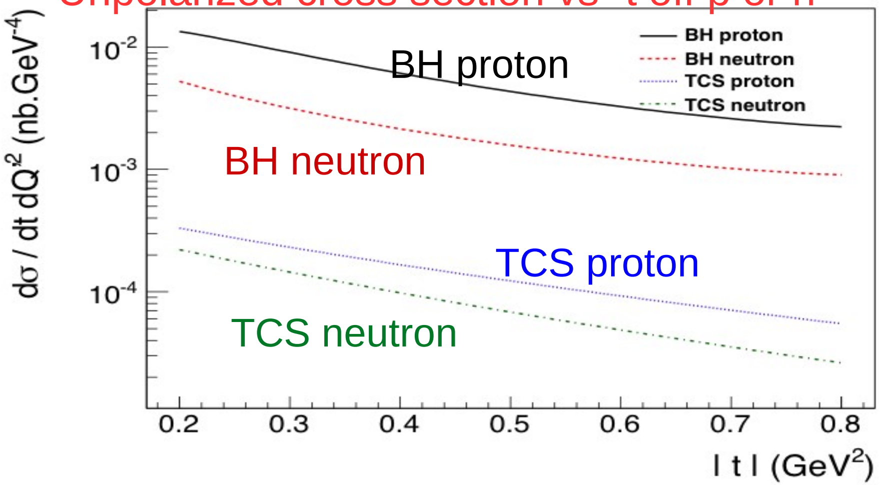
statistics in 2 bins in t, bin #3 (Q'², ξ)



TCS program possible extensions

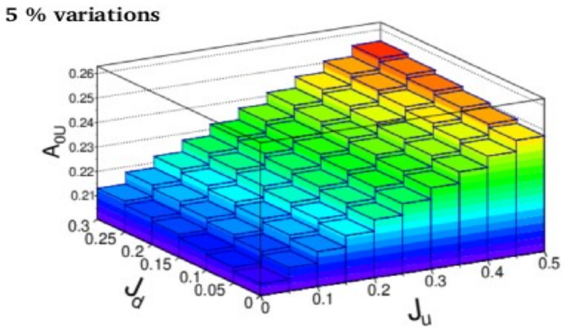
- **Neutron: flavor separation and spin**

Unpolarized cross section vs -t off p or n

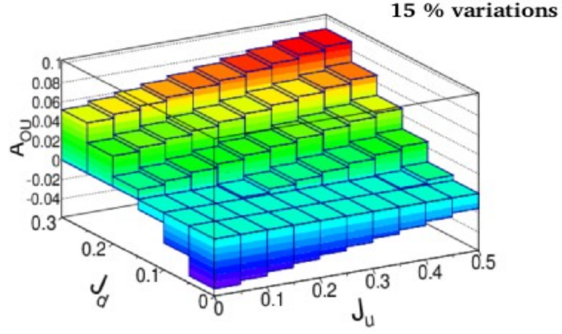


- σ off neutron not suppressed, sizeable asymmetries
- similar sensitivities to GPDs expected
- strong sensitivity to J_u, J_d

BSA proton



BSA neutron



- **Nuclear targets** :

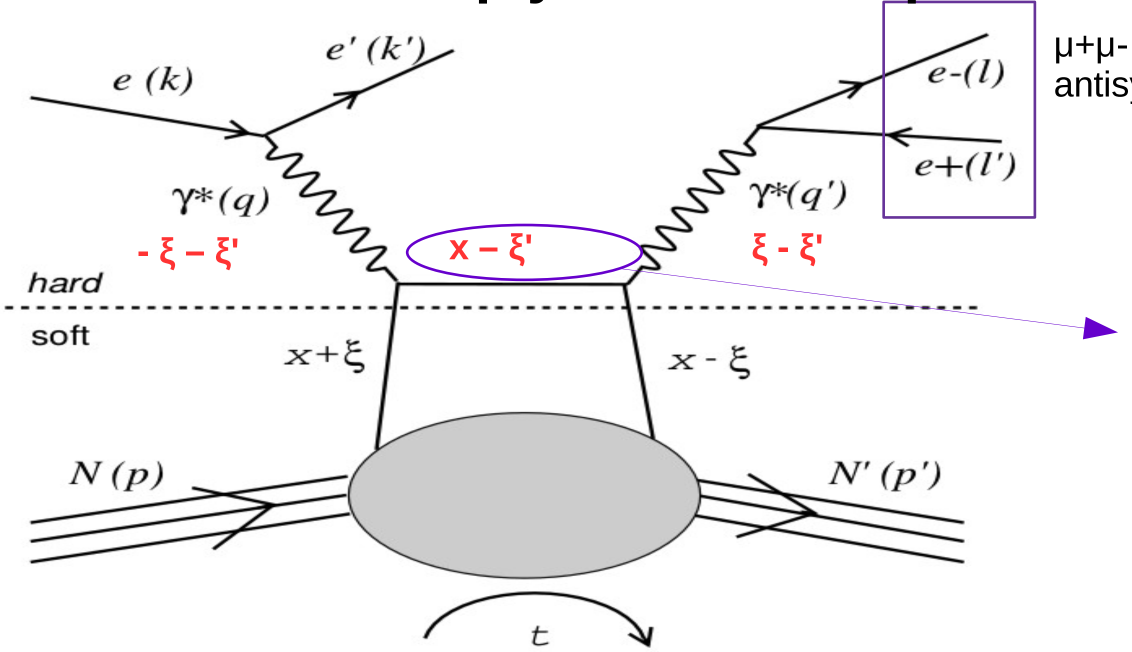
- needed to complement polarized experiments + extra-measurement of GPDs off N (coherent)

- **Precision unpolarized measurement:** off LH2, same setup
- **Longitudinally polarized target:** single and double spin asymmetries
- **Linearly polarized beam**: Re(H)

Here: complementarity in what can be done with SoLID and in other experiments (Halls A, C, D)

Figs from Boer, Guidal, Vanderhaeghen, EPJA 52 (2016) 33

Double Deeply Virtual Compton Scattering (status=LOI 2023)



μ+μ- → avoid antisymmetrisation

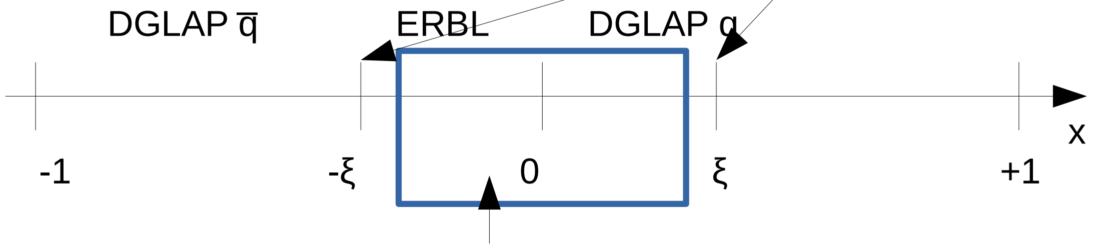
- ξ = + component of P=(p+p') in light cone frame. GPDs depend on it. "skewness"
- ξ' = + component of q̄=(q+q')/2 in light cone frame. quark propagator can be related to x_{bj}

Special cases (at asymp. limit):
DVCS: ξ'=ξ; TCS: ξ'=-ξ

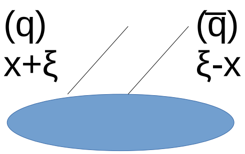
What do we learn?

M. Diehl's representations:

limit between the 2 regions:
Im(CFFs) from DVCS and TCS

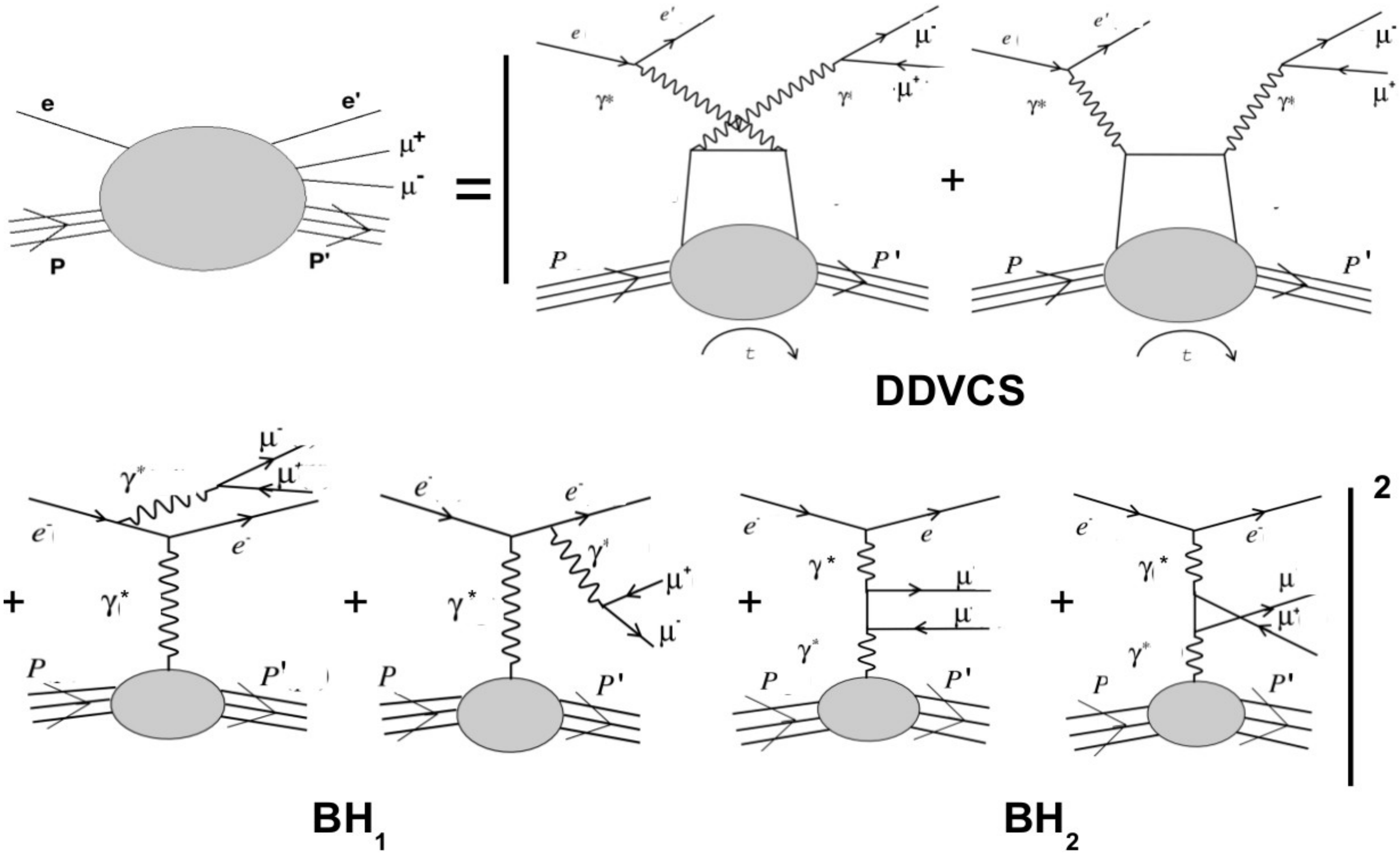


accessible with DDVCS



partonic interpretation from M. Diehl in ERBL region

Interference with Bethe-Heitler

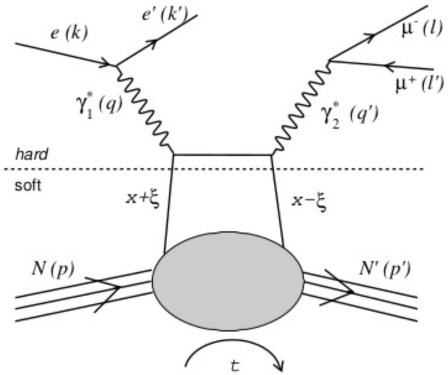


BH1: understood from DVCS+BH ; BH2: understood from TCS+BH (“peaks” in thetaCM)

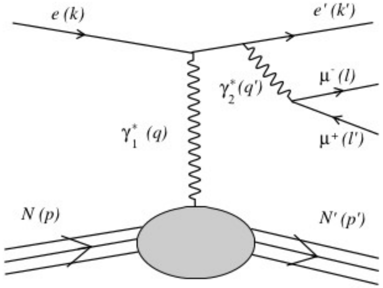
Phenomenology of DDVCS

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

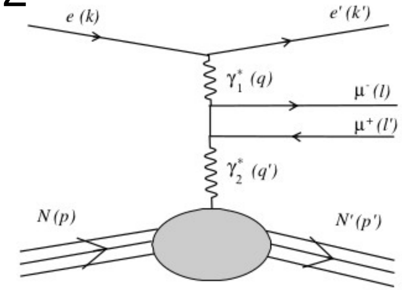
DDVCS



"BH1"



"BH2"



Variables definition/notations:

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

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

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

"skewness":

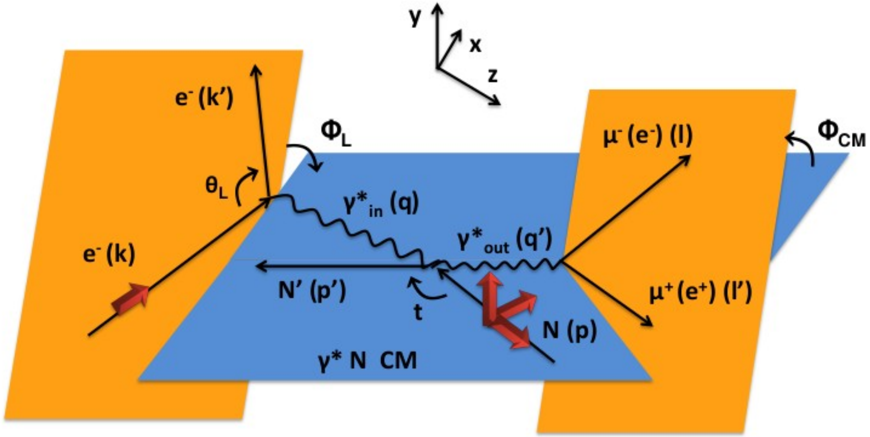
$$\xi = \frac{Q^2 - Q'^2 + (\Delta^2/2)}{2(Q^2/x_B) - Q^2 - Q'^2 + \Delta^2}$$

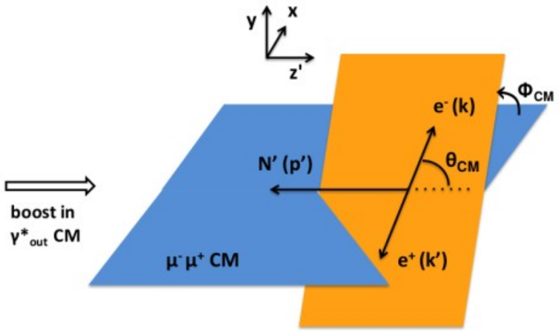
$$\xi' = -\frac{Q^2 + Q'^2}{2(Q^2/x_B) - Q^2 - Q'^2 + \Delta^2}$$

7-independent variables for cross section.

Choice: E_e, ξ (or x_{bj}), t, Q^2, Q'^2, Φ_L, Φ_{CM}, θ_{CM}

Angles and correlations





$$\frac{d^7\sigma}{dx_B\, dy\, dt\, d\phi_{LH}\, dQ'^2\, d\Omega_{CM}} = \frac{1}{(2\pi)^3}\,\frac{\alpha^4}{16}\,\frac{y x_{bj}}{Q^2\sqrt{1+\varepsilon^2}}\sqrt{1-\frac{4m_\mu^2}{Q'^2}}\;|\mathcal{T}|^2$$

with:

$$|\mathcal{T}|^2 = |\mathcal{T}_{DDVCS}|^2 + \mathcal{I}_1 + \mathcal{I}_2 + |\mathcal{T}_{BH_1}|^2 + |\mathcal{T}_{BH_2}|^2 + \mathcal{T}_{BH_{12}}$$

7-independent variables for cross section.
Choice: E_e, ξ (or x_{bj}), t, Q^2, Q'^2, Φ_L, Φ_{CM}, θ_{CM}

3 angles: azimuthal angle for incoming and outgoing lepton / polar for outgoing lepton

"BH1" influences strongly ϕ_L distribution

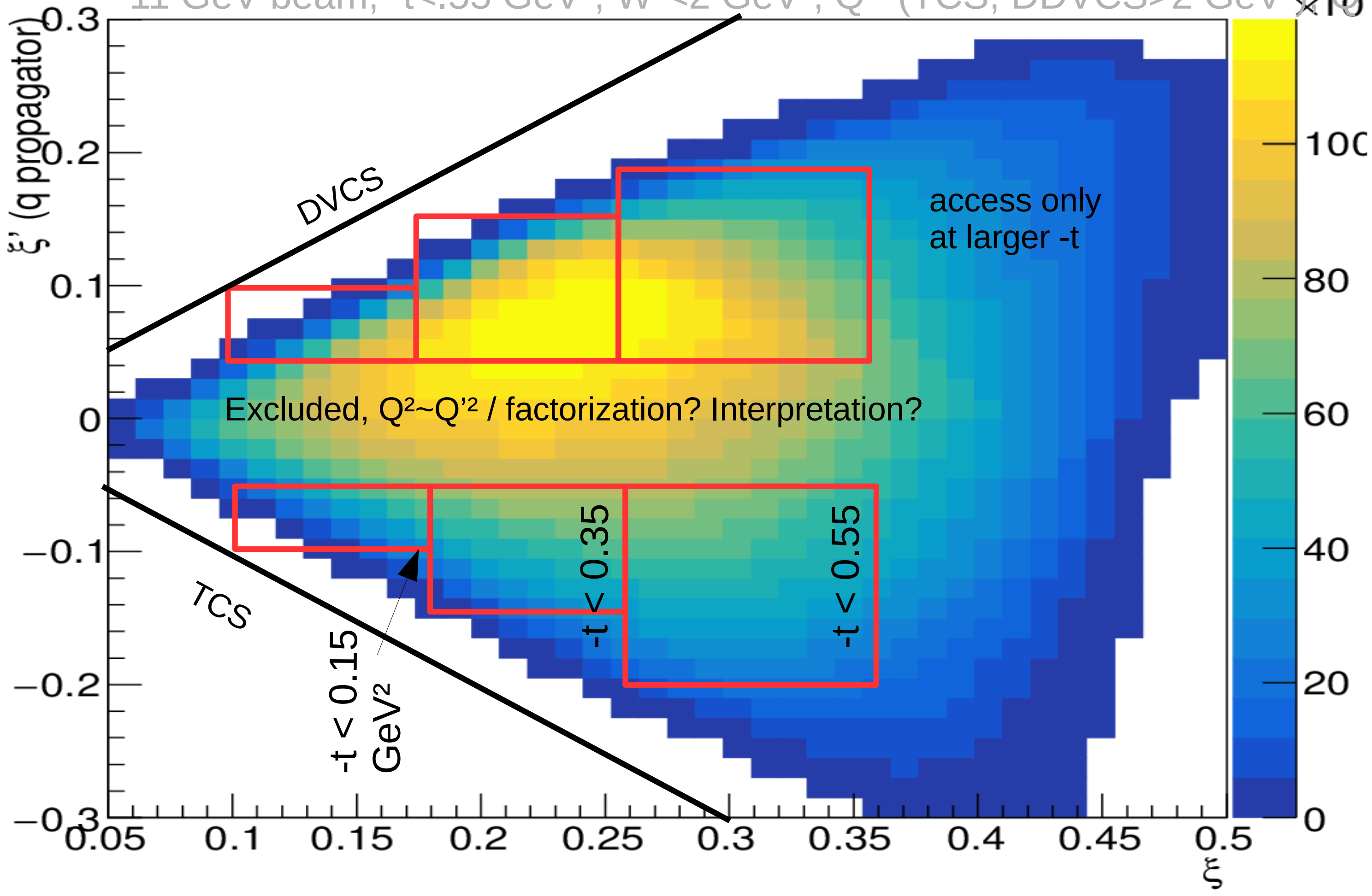
"BH2" influences strongly ϕ_{CM} distribution

θ: mostly rate of DDVCS/"BH2"

Study of angular correlations is essential to define obserbables, interpret projections, and design an experiment

Off diagonal "lever arm": phase space for JLab, 11 GeV electron

11 GeV beam, -t<.55 GeV², W²<2 GeV², Q'² (TCS, DDVCS>2 GeV²), Q² (electroprod. > 1 GeV²)



Q'² < Q² : spacelike"

Bins in ξ, ξ', -t

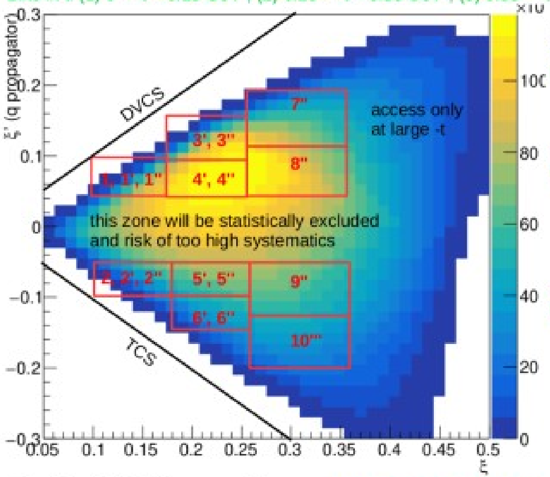
-.2 < ξ' < .2
.05 < ξ < .36
[correlated to t bin]
0.05 < -t < .55

Q² < Q'² : "timelike"

Larger -t opens up more phase space

Projections and bins

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



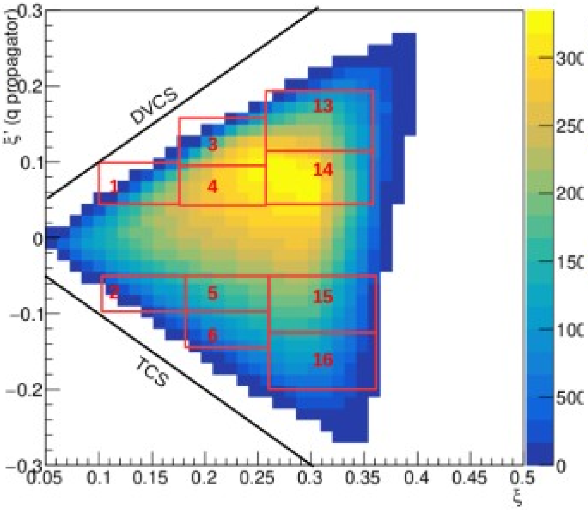
Bin in ξ | code # large/low t

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

Binning in ξ, ξ', at large -t (3) 0.35 < -t < 0.55 GeV²



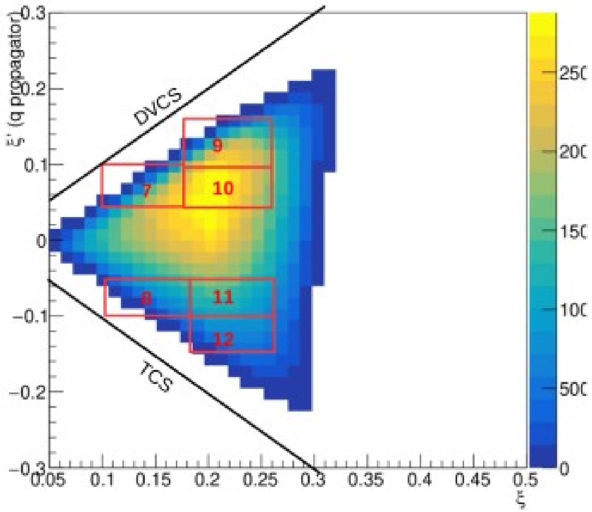
Bin in ξ

A) .1 < ξ < .18
- 1) .05 < ξ' < .1
- 2) -.05 > ξ' >-.1

B) .18 < ξ < .26
- 3) .1 < ξ' < .15
- 4) .05 < ξ' < .1
- 5) -.05 > ξ' > -.1
- 6) -.1 > ξ' > -.15

C) .26 < ξ < .36
- 13) .12 < ξ < .2
- 14) .05 < ξ < .12
- 15) -.05 > ξ > -.12
- 16) -.12 > ξ > -.2

Binning in ξ, ξ', at medium -t (2) 0.15 < -t < 0.35 GeV²

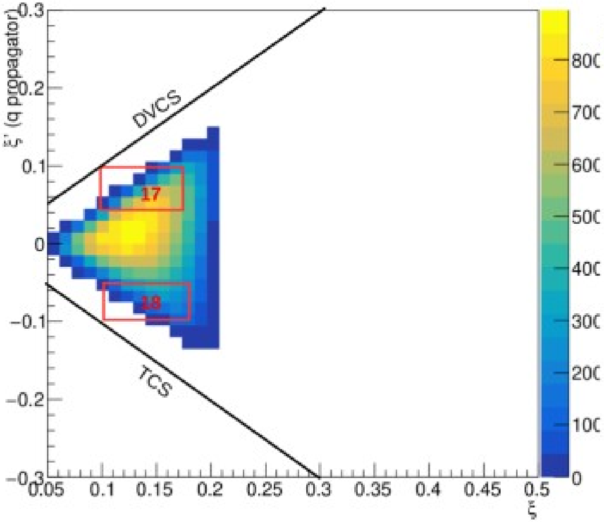


Bin in ξ

A) .1 < ξ < .18
- 7) .05 < ξ' < .1
- 8) -.05 > ξ' >-.1

B) .18 < ξ < .26
- 9) .1 < ξ' < .15
- 10) .05 < ξ' < .1
- 11) -.05 > ξ' > -.1
- 12) -.1 > ξ' > -.15

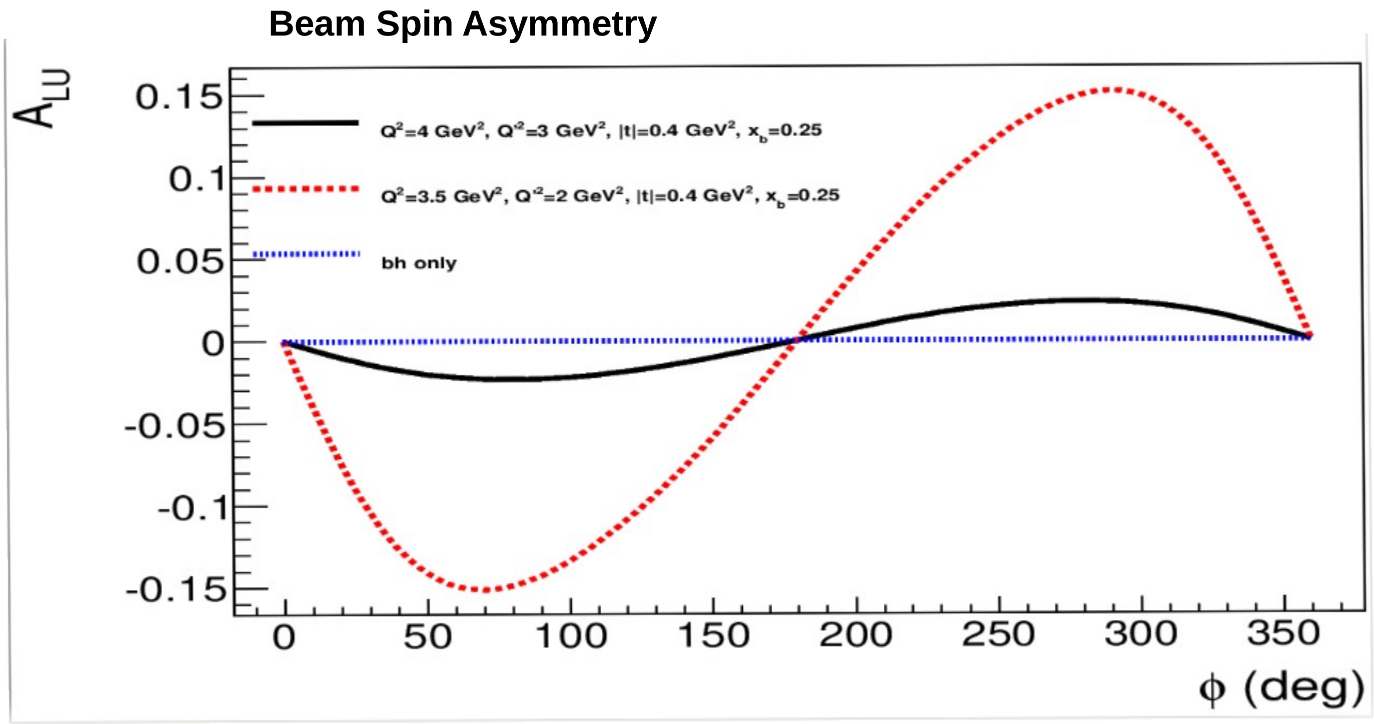
Binning in ξ, ξ', at low -t (1) tmin < -t < 0.15 GeV²



Bin in ξ

A) .1 < ξ < .18
- 17) .05 < ξ' < .1
- 18) -.05 > ξ' >-.1

DDVCS +BH Beam Spin Asymmetry



purely coming from interference between BH(1+2)*DDVCS
asymmetries are sizeable.

Change of sign to be observed in different kinematic regions

Imaginary part of amplitude

BH cancels, comes from interference. Sizeable asymmetry and counts thanks to interference

Evolution of the beam spin asymmetry

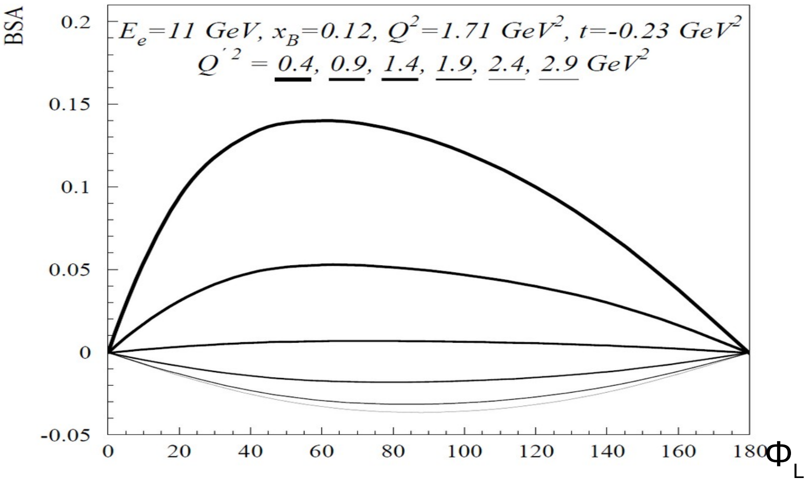
Sign change in BSA and interplay "spacelike" and "timelike" regions

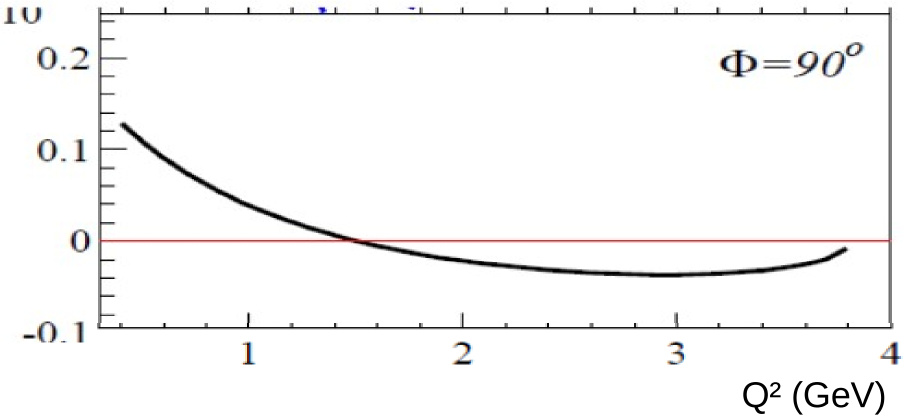
Calculations from M. Guidal (Trento, 2016)

→ scan of BSA in Q'^2 at fixed Q^2

→ sign change in BSA vs Φ_L and vs φ_{CM} when $Q'^2 \approx Q^2$

asymmetry Q^2 scan

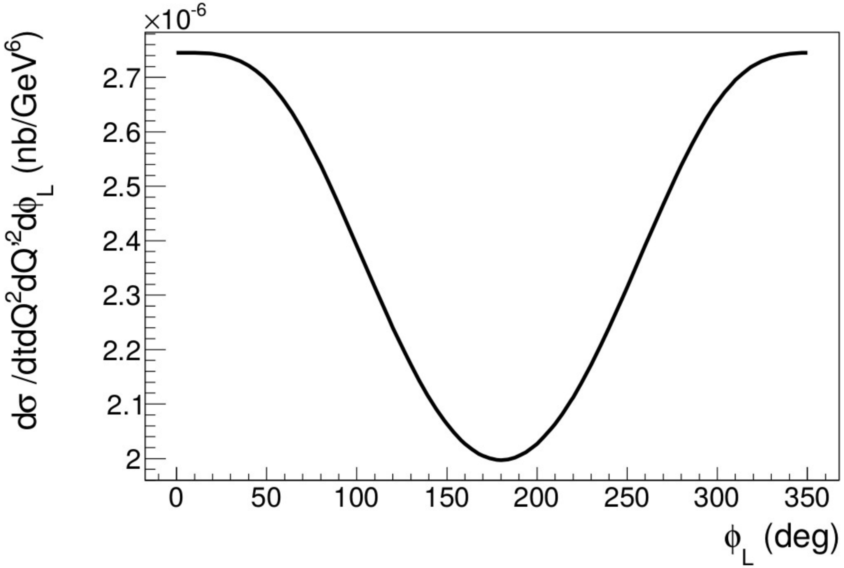


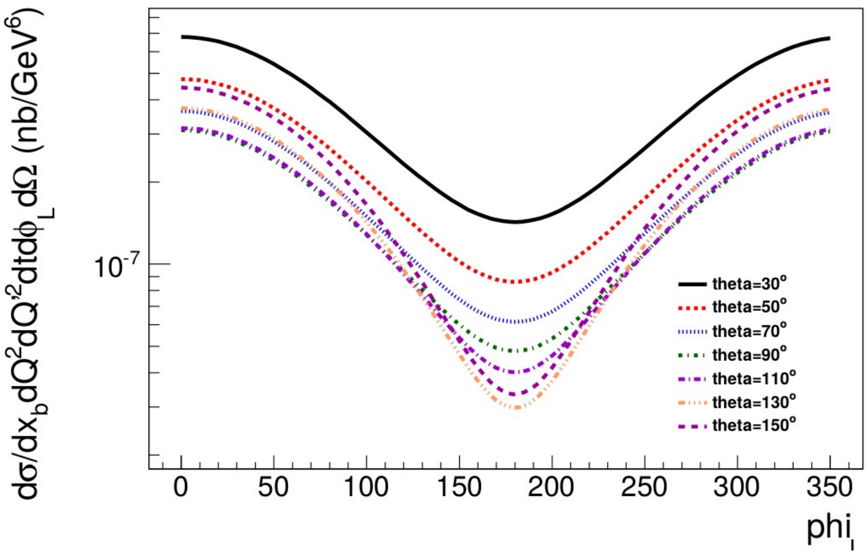


- Probing GPDs at $x \neq \xi$ → tomographic interpretations....
- Expectation of sign change for observables sensitive to Im (DDVCS) when moving from « spacelike » to « timelike » region

→ this reaction is unique for probing effects between these 2 regions.

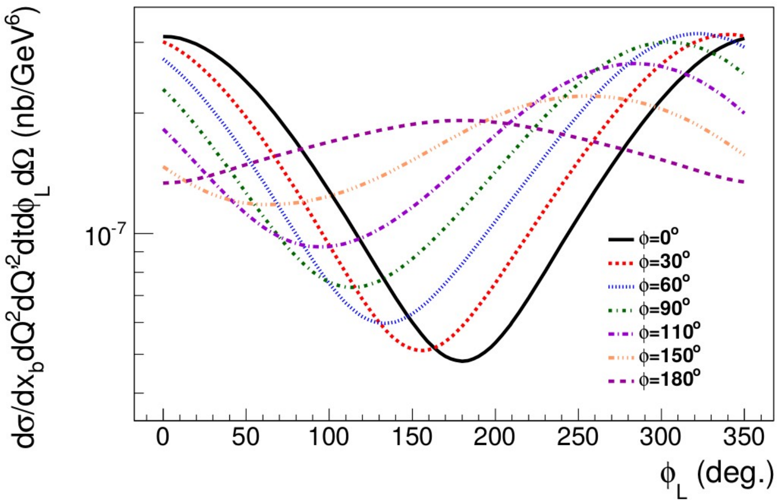
Cross sections versus angles



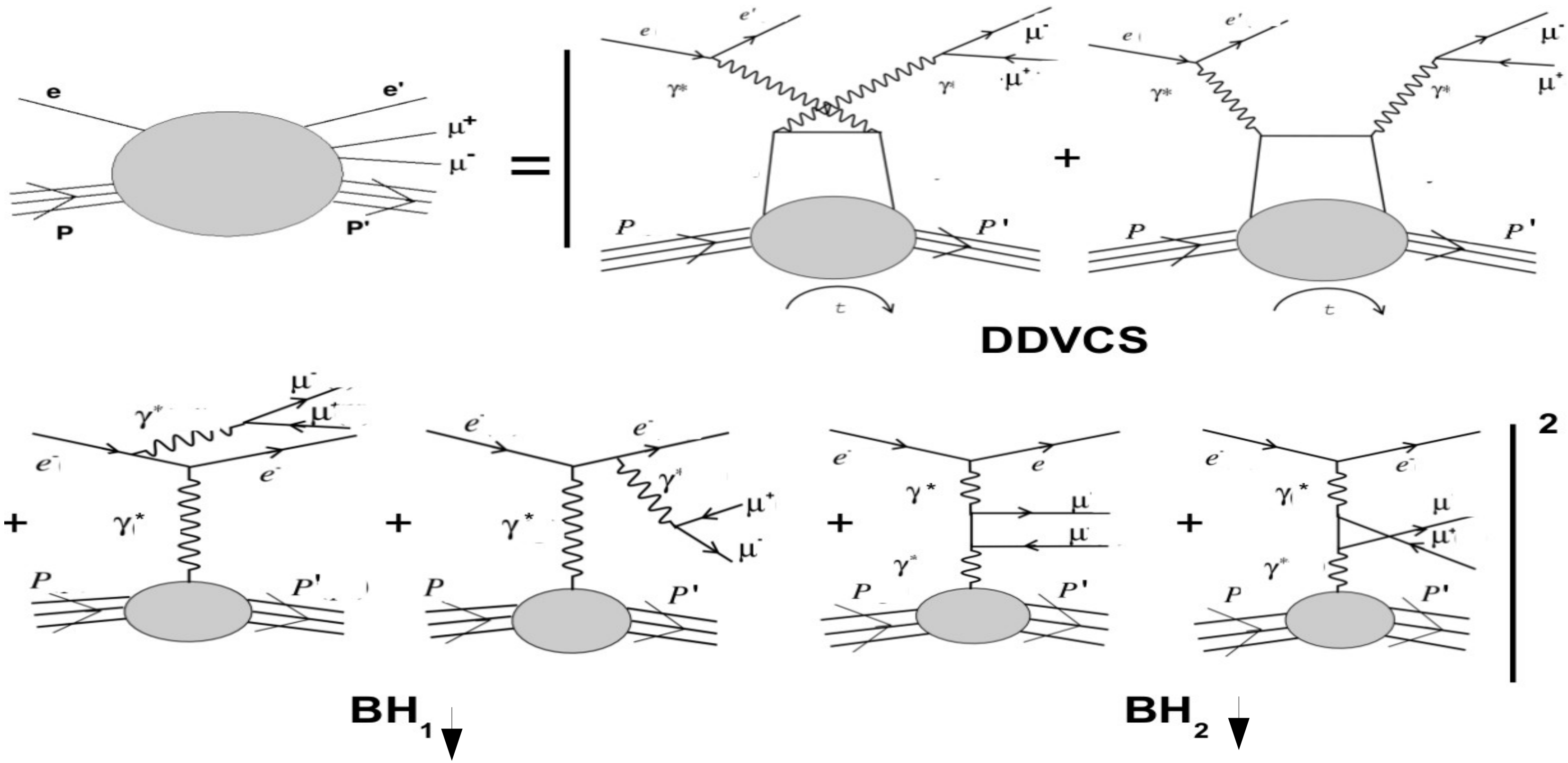


Due to strong angular dependence in 3 angles:

CFFs: 2D fits in φ_{CM}, φ_{LH}, as a function of ξ, ξ', t only Im($\mathcal{H}$) (ξ', ξ, t) will be possible to extract with unpolarized cross section and beam asym.



Angular behavior and “effective” observables



no favored direction for γ* emission or decay leptons

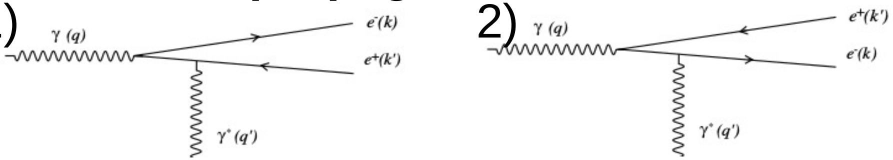
peak when γ' becomes collinear to e
related to φ_{LH}=0,
and depends $\cos\theta_{\gamma\gamma}$ (kinematics)
and "y"→e' angle

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 correlations ("as for TCS")

BH propagators

1) 2)

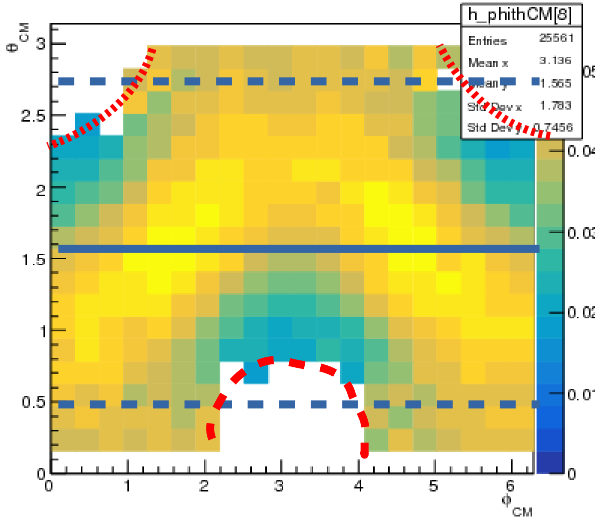


- BH peaks when e- or e+ collinear to incoming γ (from BH II)
- strong kinematic dependence at JLab energy
- one diagram becomes largely dominant / very asymmetric decays

- 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



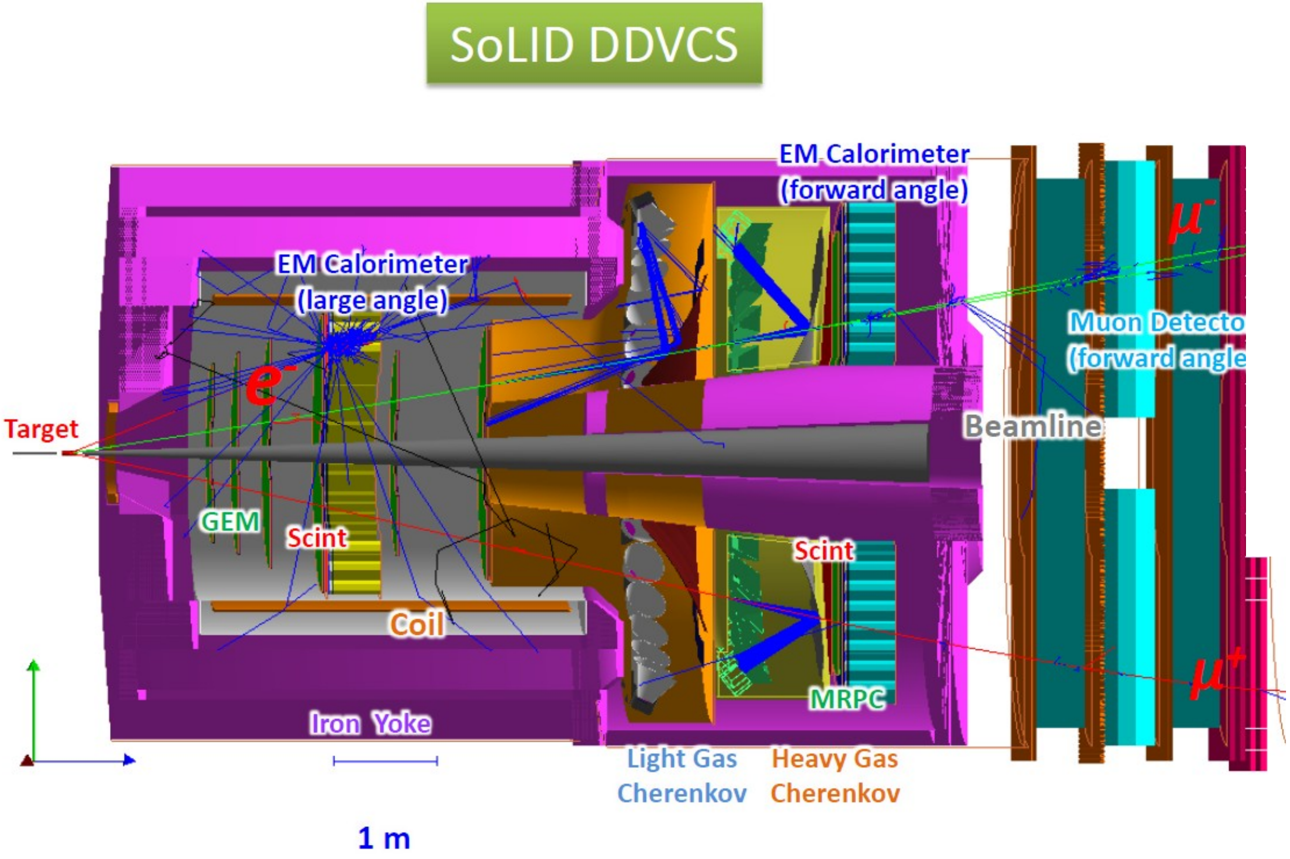
-- cut at 30°; 150°

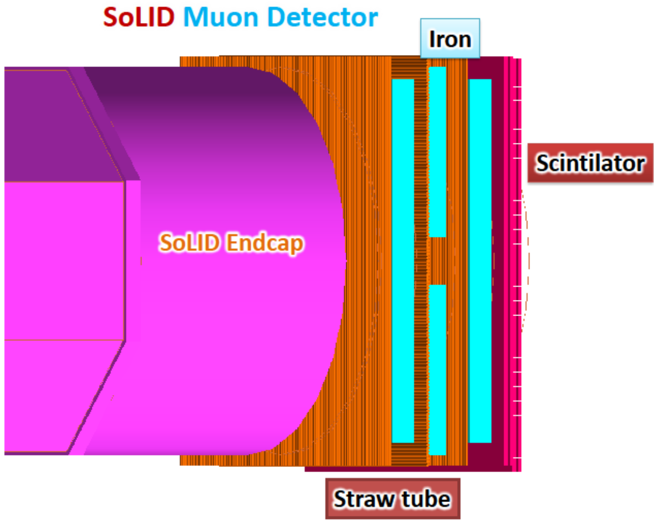
-- acceptance cut

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)

SoLID Setup

Using similar setup as J/psi experiment E12-12-006, with additional muon detector



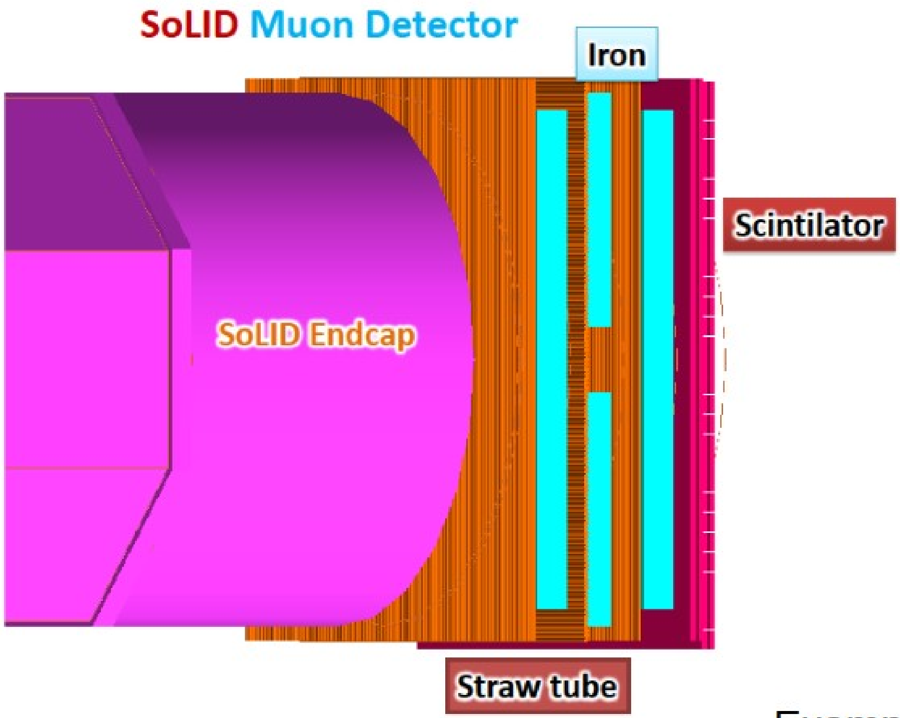


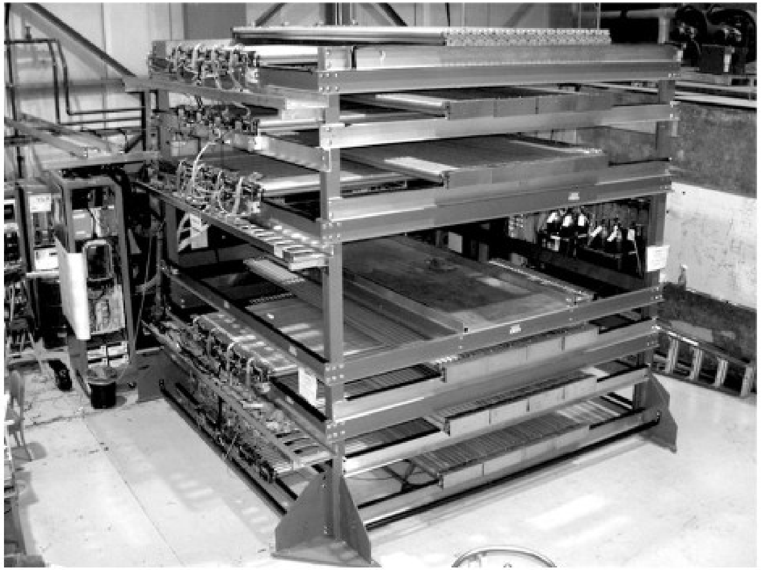
3 layers iron (shielding)
3 layers straw tubes (tracking)
2 layers scintillators (trigger)

Boër, Camsonne, Voutier, Zhao, et al. LOI submitted 2023

Forward muon detector (proposed addition)

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



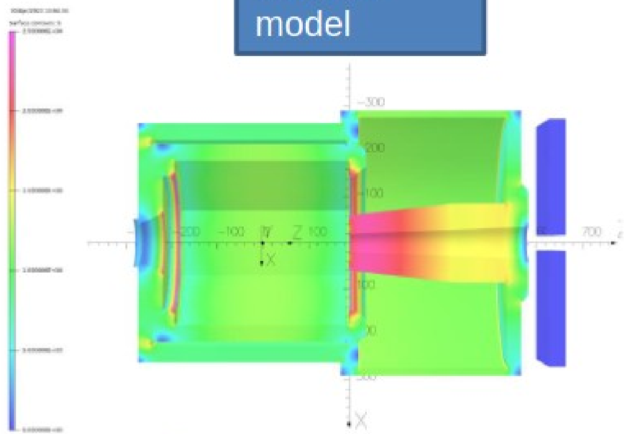


Example of straw tube chambers similar to Seaquest experiment

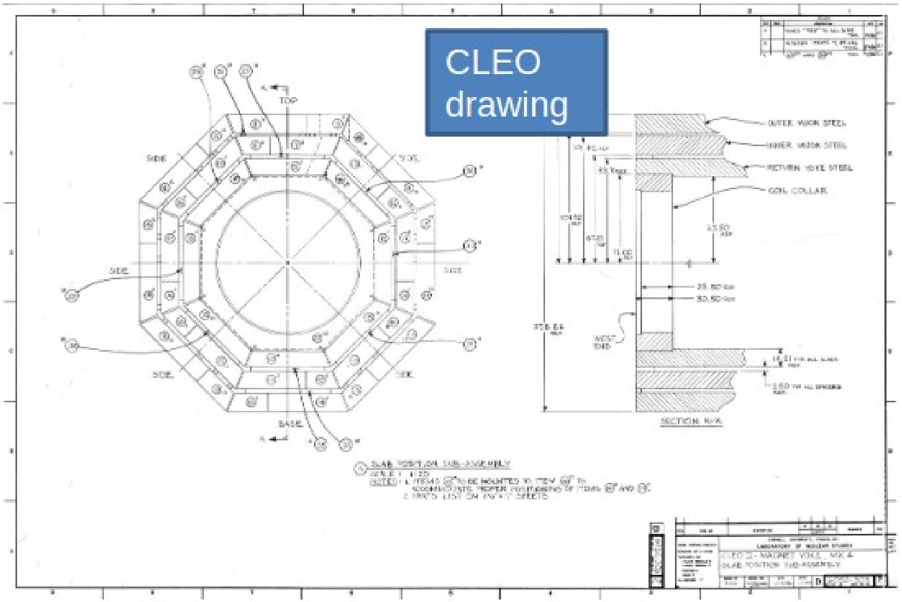
Iron Shielding: from CLEO

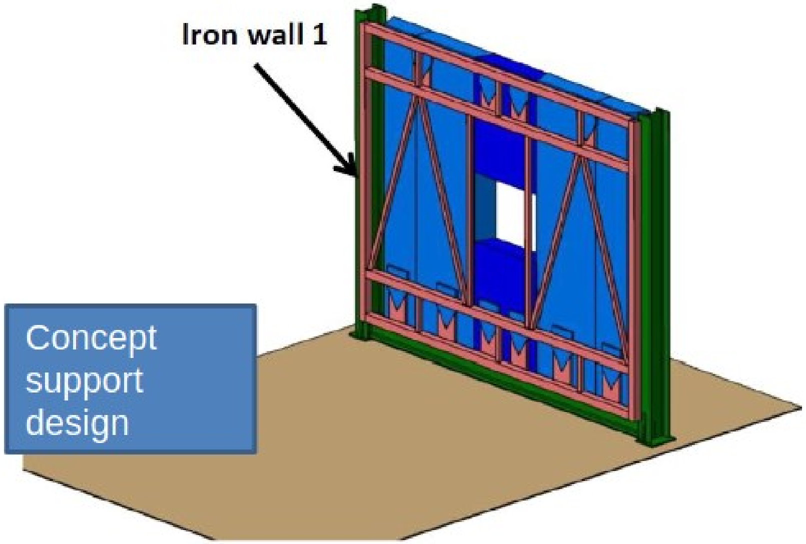
Reuse 6 of 8 CLEO octagon outer layer iron
Each one is about 36x254x533cm
No problem with space
Field (<10G),force(<1N),torque(<2Nm) are small

TOSCA model



CLEO drawing





Concept support design

Software

- Projections from VGG model
- Effective observables calculated with VGG model for GPDs and DEEPGen generator
- Angular studies with DEEPGen
- Acceptance studies with Grape
- Work in progress to add EPIC, will be able to compare models
- Currently phenomenology work ongoing in 2 different approaches: IJCLab and VT

(+S. Zhao 2021).

Collaborators / Hardware R&D

Main collaborators: JLab, IJCLab, Duke, Virginia Tech, Rutgers, ...

- muon detector first tests to be done at soon, all groups work together to develop a realistic experiment,

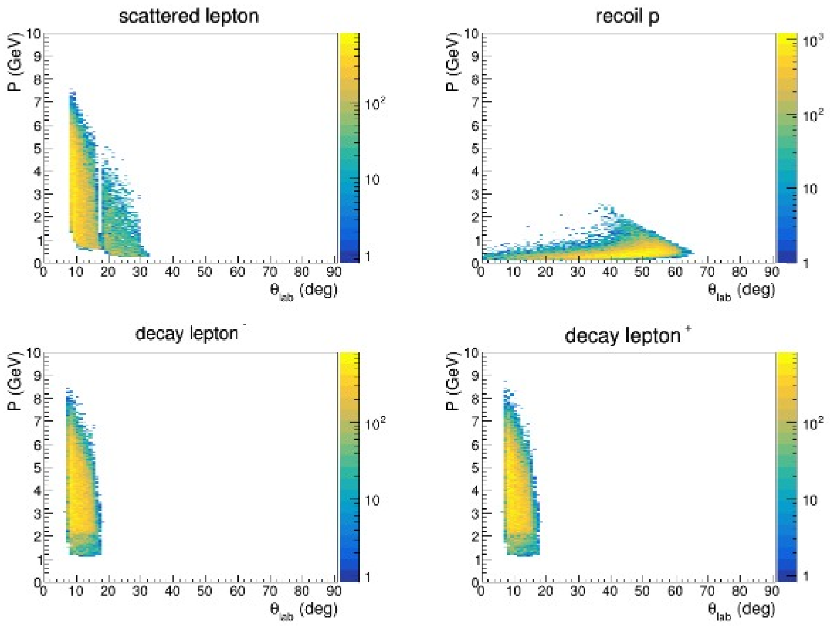
- exploring various options for muon detector

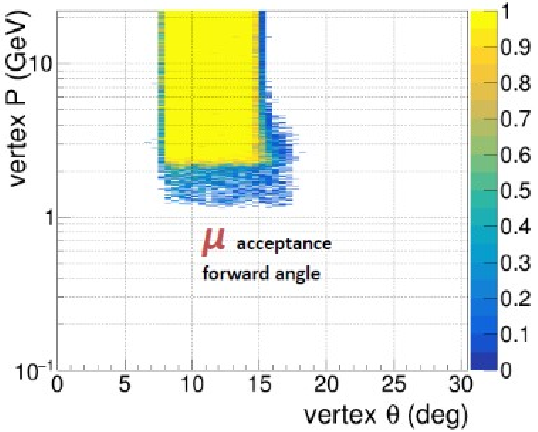
- also exploring shorter scale experiment(in Hall C, see backup slide)

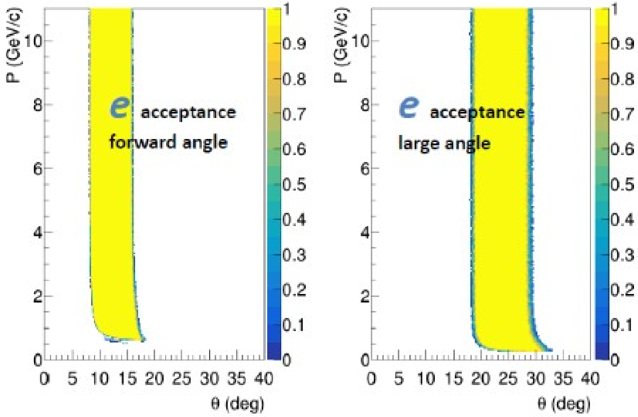
SoLID Acceptance studies

BH generator grape-dilepton

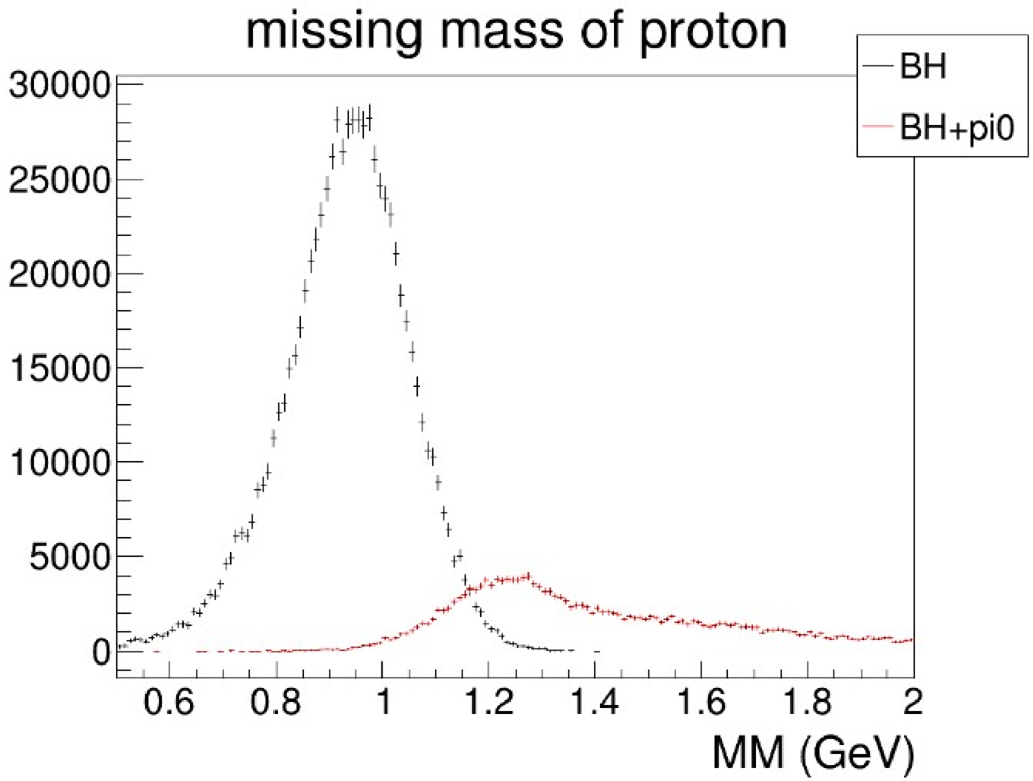
- Muon mom>2GeV is accepted
- Scattered e- and both muons are detected
- recoil proton is not required, but some can still be detected by time of flight

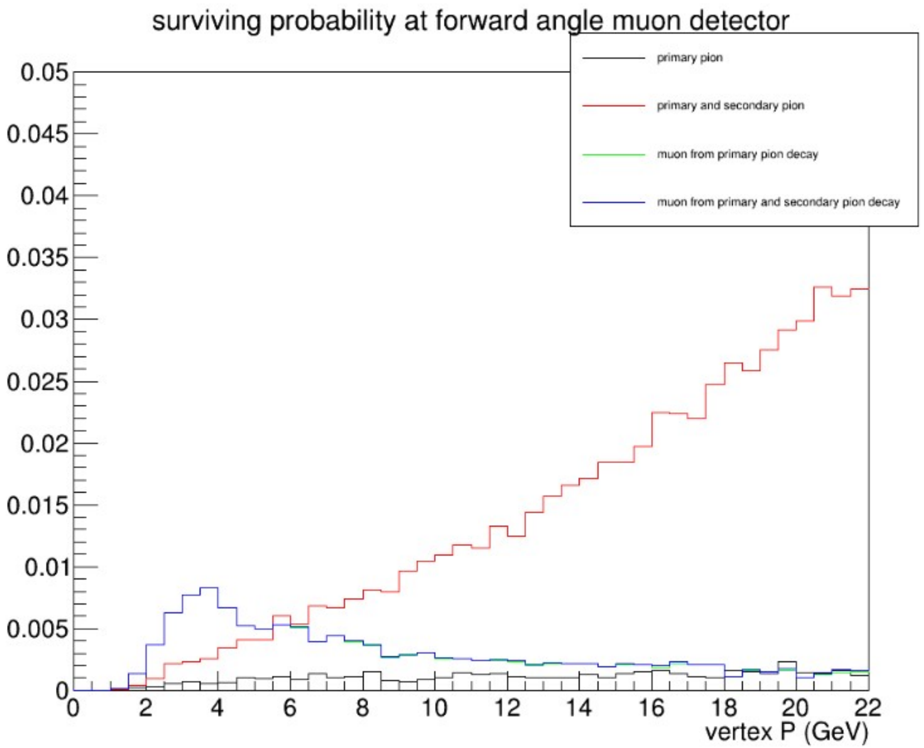






Exclusivity and background rejection





fine enough resolution to select DDVCS+BH

high rate of pion rejection after muon detector

Single pion rates 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

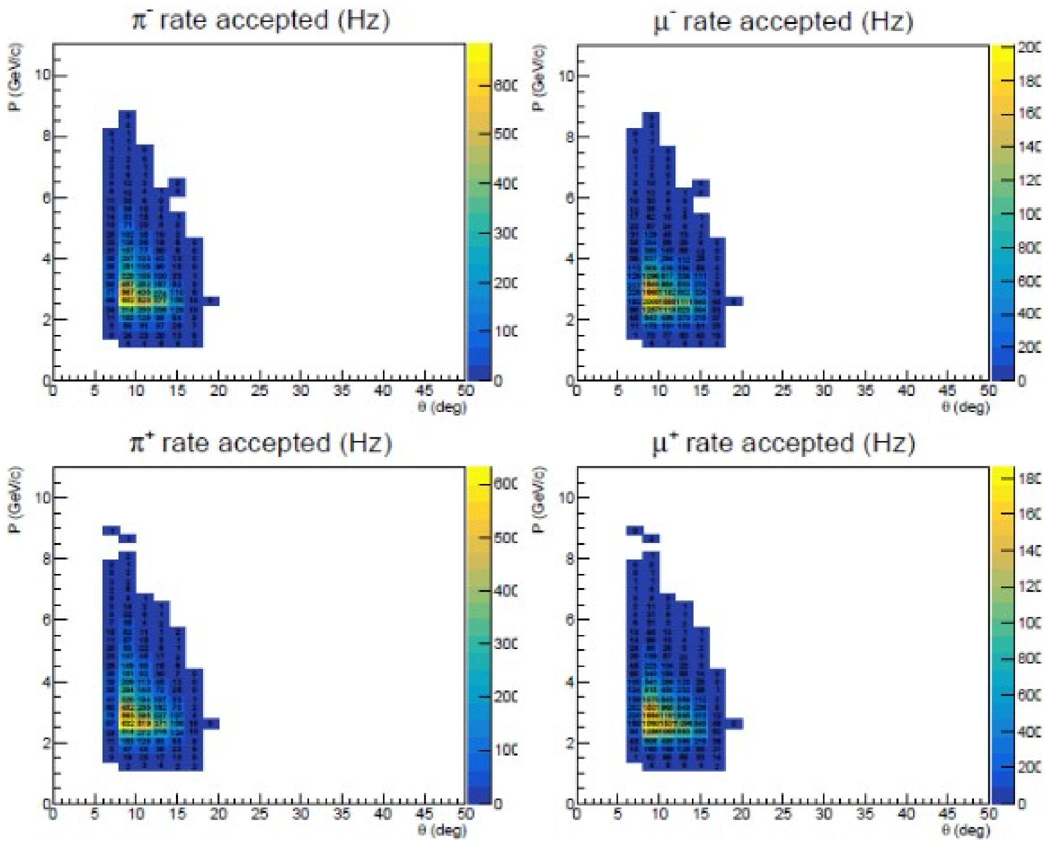
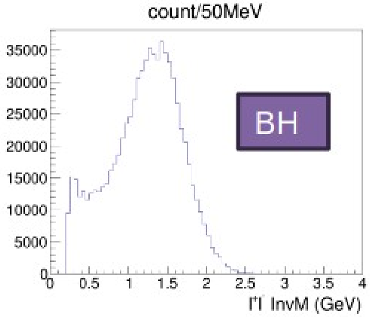


Figure 22: Single particles rate of pion and muon from pion decay at the back of forward angle muon detector. They include both pions directly from target and all secondaries and muons from their decay.

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

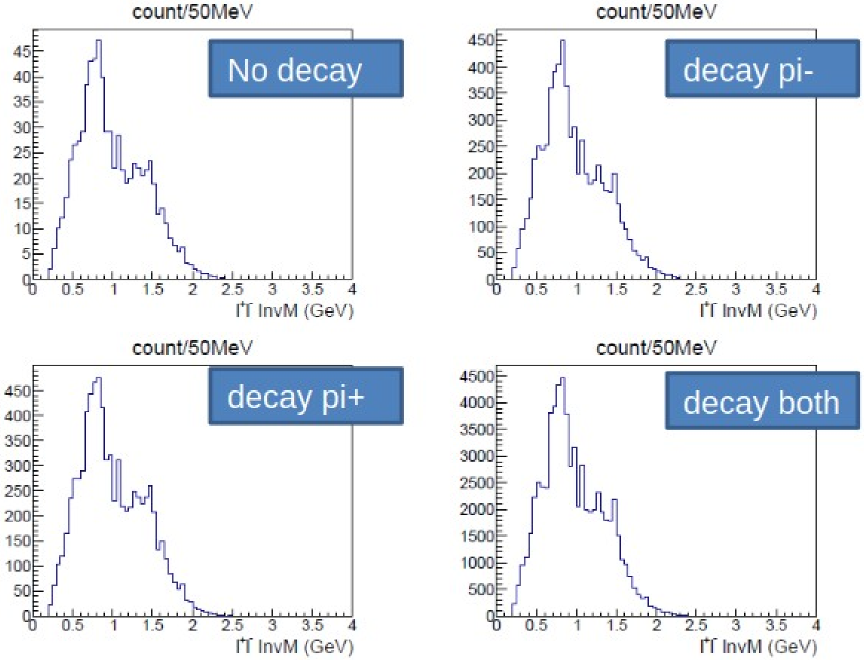


Figure 23: From left to right and top to bottom, the counts from the two pion exclusive channel contamination are shown in 4 cases, neither pion decay, negative pion decays into muon, positive pion decays into muon, and both pions decay.

Complementarity with Hall C: recently submitted LOI to JLab PAC 52

Letter of Intent to PAC 52: Generalized Parton Distributions from Double Deeply Virtual Compton Scattering at Jefferson Lab Hall C

Debaditya Biswas[*], Marie Boër[†],
Dipangkar Dutta[‡],
David Gaskell[§],
David Hamilton[¶],
Hamlet Mkrtchyan[‖], Vardan Tadevosyan[**]

May 1^{st}, 2024

Abstract

This letter of intent presents our prospects for a first measurement of Double Deeply Virtual Compton Scattering (DDVCS) unpolarized cross sections and beam polarized spin asymmetries at Jefferson Lab Hall C, in the reaction $eP \to e'P'\mu^+\mu^-$, where two virtual photons are being exchanged between quarks and leptons. The scientific goal of this new experiment is to constrain the so-called Generalized Parton Distribution (GPDs) in the "ERBL" region, that is not accessed in any other Compton-like experiment, but is accessible in DDVCS thanks to a lever arm provided by the relative virtuality of the two photons. Constraining GPDs in this region is essential for tomographic interpretations, as it enables the deconvolution of momenta and extrapolation of the GPDs to "zero-skewness". A new muon detector, dedicated to this experiment, which could also open perspectives for other future measurements, will be developed and installed. The spectrometer and tracking for this experiment is derived from the setup we proposed in the past for a measurement of Timelike Compton Scattering (TCS), and intend to submit to the next PAC (in 2025) for both this target polarized measurement a complementary unpolarized TCS measurement.

Also see presentation D. Biswas JLab user's group for more details on muon detector R&D

SUMMARY

- Lot of potential for GPD sensitive measurements in SoLID, still can be really extended

- Complementarity with Hall B and C “in-between” in terms of acceptance/luminosity

- DDVCS: extration of CFF and deconvolution x, xi for tomographic interpretations

  * LOI 2023 following earlier work (first LOI) in 2015 / currently efforts theory

- Muon detector for DDVCS:

question for collaboration, should be pursue R&D and submit full proposal?

- Would need more effort on DVCS and exclusive mesons + multi-particles

- Theory progress in recent years and growing interest for multi-particle final states