Open Discussion:
Measuring Timelike Compton Scattering (TCS)
In the Valence quarks region

Marie Boër, Virginia Tech

March 3^{d}, 2021 – “CNF mini-workshop #2”

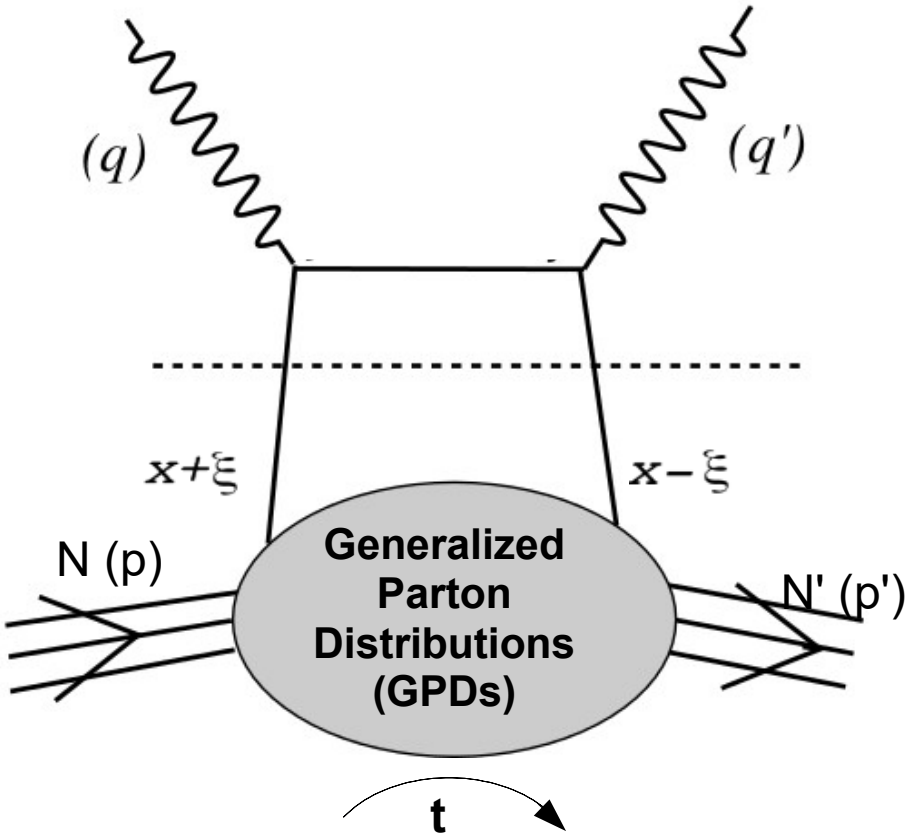
Main collaborators on these projects:

V. Tadevosyan, H.&A. Mkrtchyan, A. Camsonne, B. Wojteskhowski, S. Liuti, D. Keller, Z. Zhao, ...

& NPS / CPS collaborations (JLab Hall C) & SoLID (JLab Hall A)

Undegraduate students: M. Cassell, Z. Gao, M. Huynh, B. Lorn, E. Wrightson, C. Zindy

Timelike Compton Scattering



2 particular cases of Deeply Virtual Compton Scattering with one virtual and one real photons:

Deeply Virtual Compton Scattering (DVCS)

$e\,P \rightarrow \gamma^*(q)\,P' \rightarrow e'\,P'\,\gamma$

$q^2 < 0$ and $q'^2 = 0$

Timelike Compton Scattering (TCS)

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

$q^2 = 0$ and $q'^2 > 0$

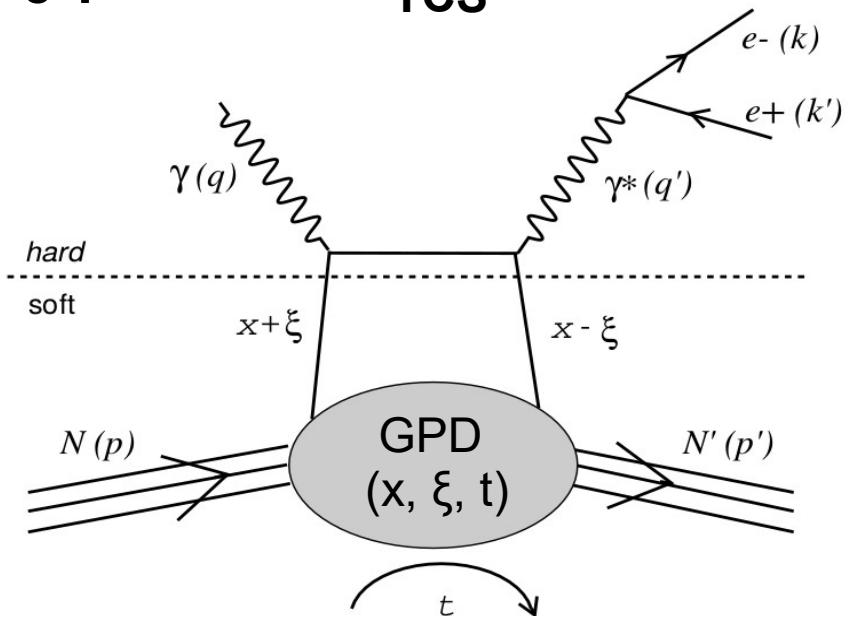
⇒ **complex conjugate at LO, twist 2**

⇒ **complementary studies, accessing the same Compton Form Factors**

Reaction, angles and kinematics

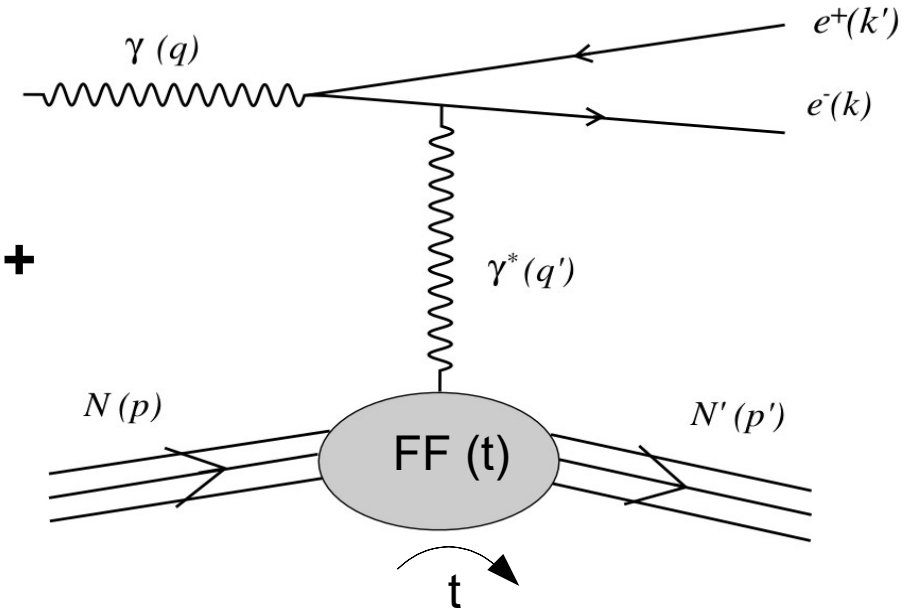
$\gamma P \rightarrow e^+e^- P'$ =

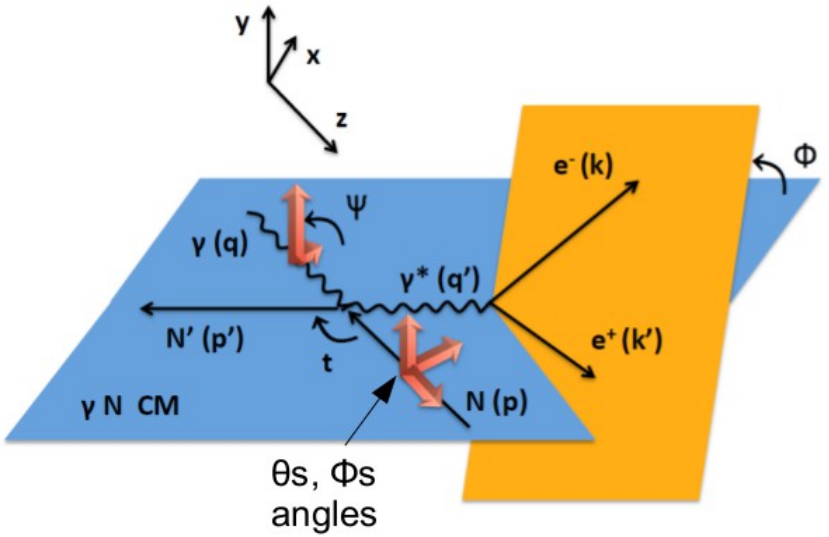
TCS

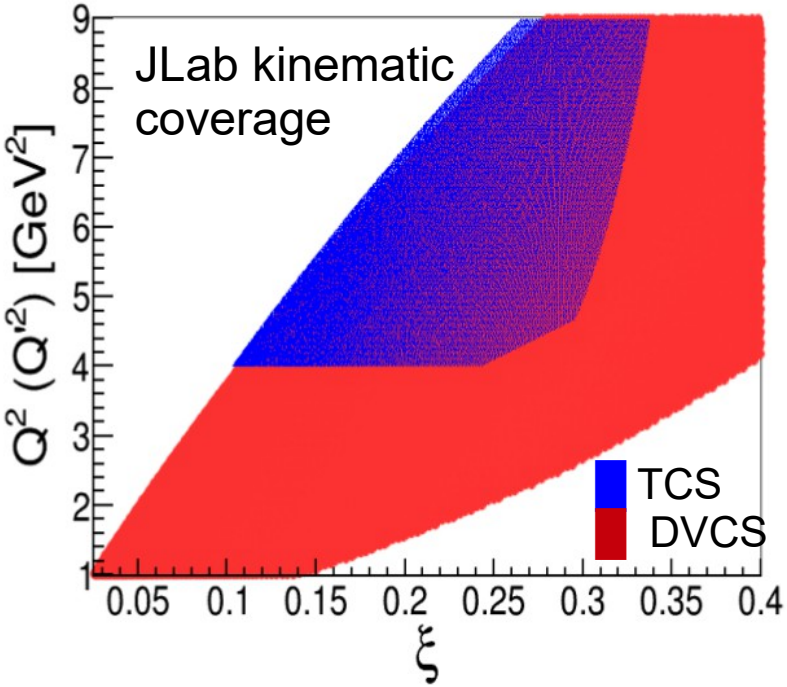


+

Bethe-Heitler







φ: e^- vs reaction plane

φ_S: P spin vs reaction plane

θ: polar angle (integrated)

E_γ (→ ξ), t, Q'²

Unpolarized TCS+BH:
5 independent variables

Observables & experiments

Observable (proton target)	Experimental challenge	Main interest for GPDs	JLab experiments
Unpolarized cross section	1 or 2 order of magnitude lower than DVCS, require high luminosity	Im + Re part of amplitude. Re(H), Im(H)	CLAS 12, SoLID approved NPS conditionnal
Circularly polarized beam	Easiest observable to measure at JLab	Im(H), Im($\widetilde{H}$) Sensitivity to quark angular momenta, in particular for neutron	CLAS 12, SoLID approved NPS conditionnal
Linearly polarized beam	Need high luminosity, at least 10x more than for circular beam, and electron tagging	Re(H), D-term. Good to discriminate models and very important to bring constrains to real part of CFF	GlueX (?)
Longitudinaly polarized target	Polarized target	Im($\widetilde{H}$)	no / "for free"?
Transversely polarized target	Polarized target, and high luminosity: binning in θs, φs	Im($\widetilde{H}$), Im(E)	NPS conditionnal
Double spin asymmetry with circularly polarized beam	Polarized target, very high luminosity, precision measurement	Real part of all CFF	no / "for free"?
Double spin asymmetry with longitudinally polarized beam	Polarized target, electron tagging, very high luminosity and precision	Not the most interesting, Im(CFFs) but difficult to measure	no

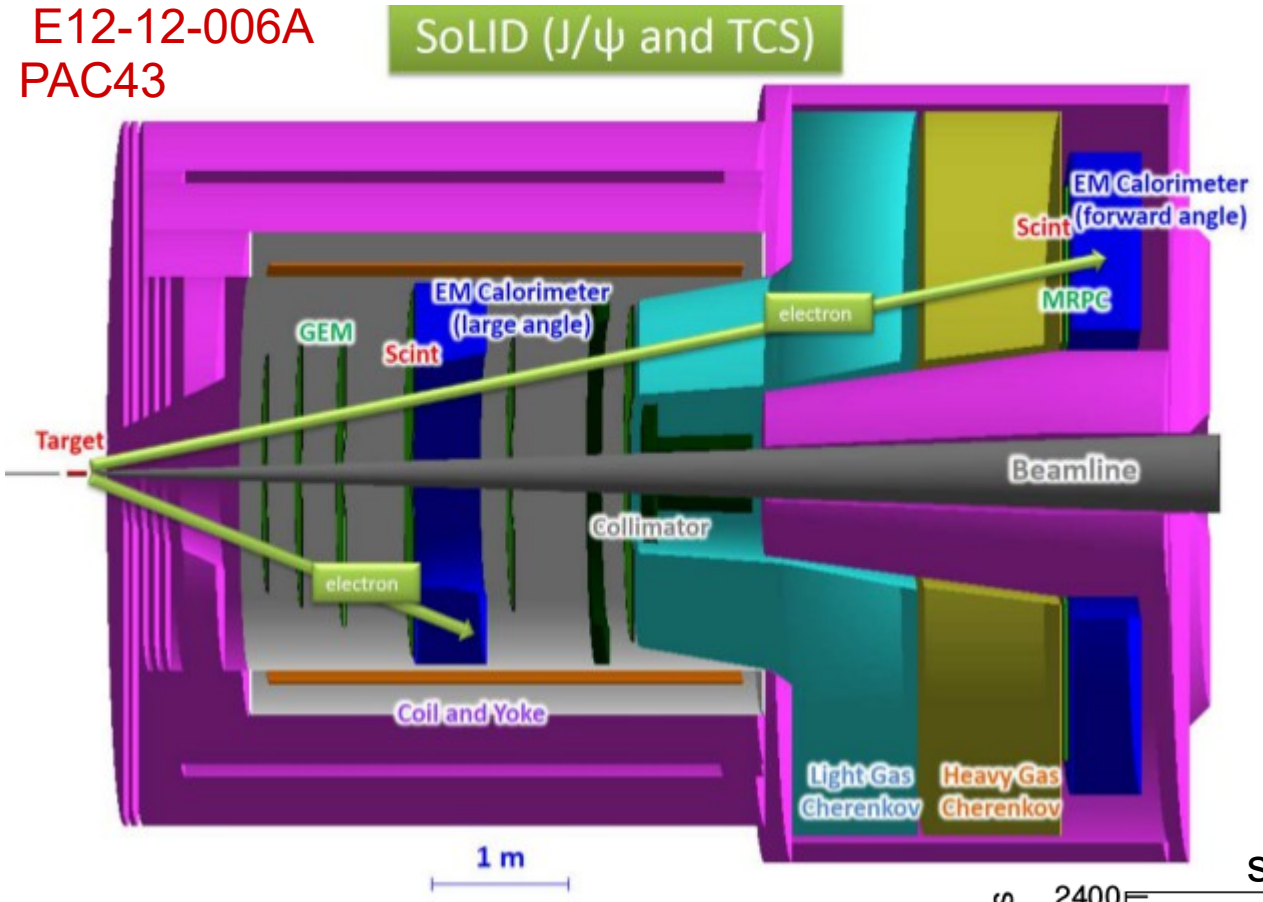
TCS off the neutron

- similar, need higher luminosity and proton or neutron tagging
- target spin asymmetries are expected to be larger, and beam spin asymmetries are smaller

This presentation: discuss only projects at JLab Hall A & C

TCS with SoLID: cross section and BSA with high luminosity

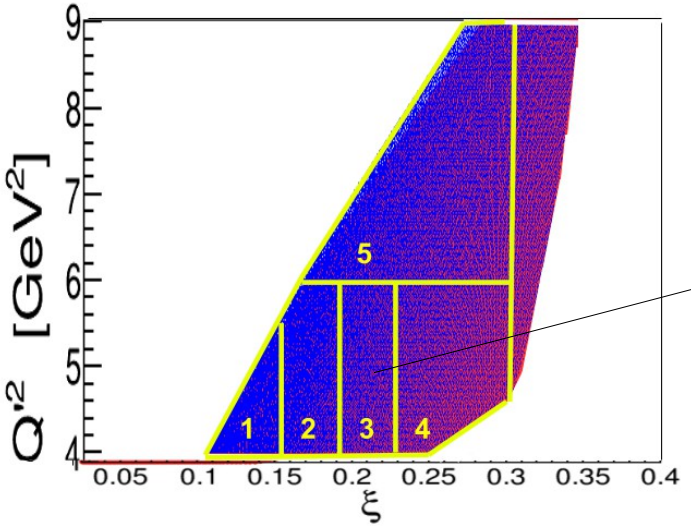
E12-12-006A
PAC43



SoLID setup for J/ψ approved exp.
50 days at flux 10^37 $cm^{-2}s^{-1}$
LH2 unpolarized target

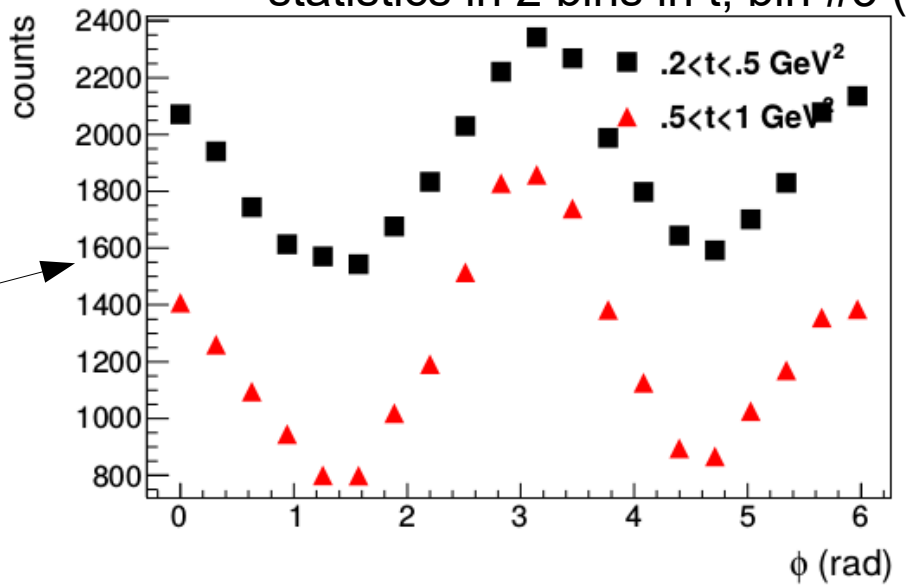
x-sec and BSA with high statistic
→binning in Q'^2: evolution...
→studies of GPD universality by comparing H extracted from TCS and DVCS

- from electron beam



bin 3

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



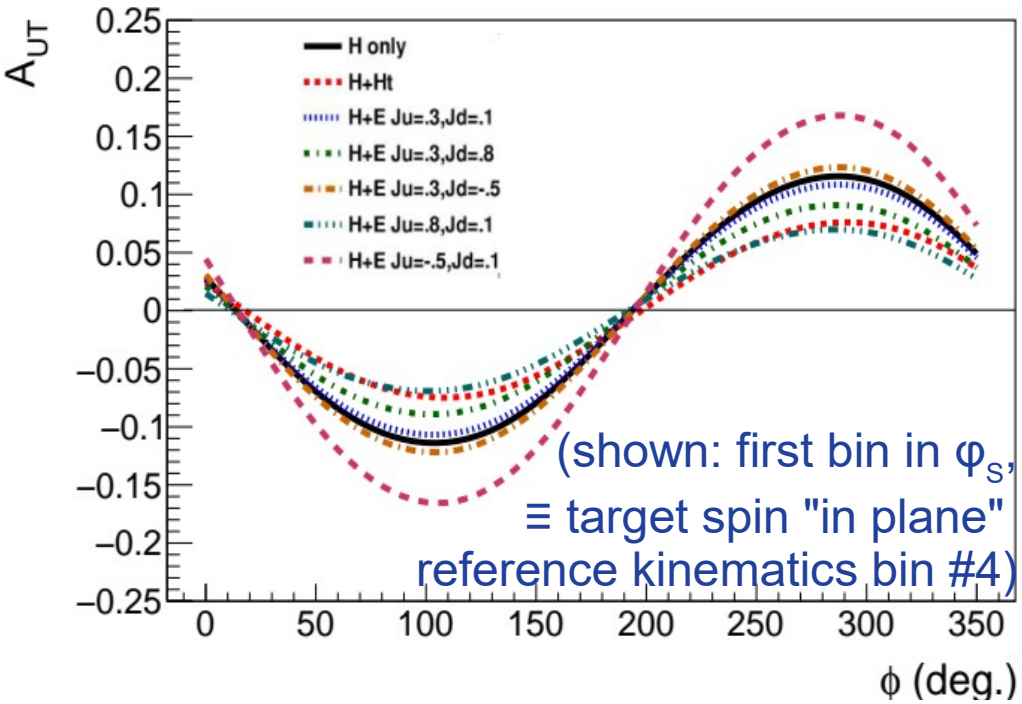
Hall C C12-18-005 Transversely polarized TCS (conditionally approved)

Why measuring TCS off a transversely polarized proton?

- **Unique access to GPD E of the proton**
- **GPD universality studies (TCS vs DVCS)**
- **Independent observables for GPD data sets and global fits in valence region**
- **Most knowledge on GPDs from DVCS: complex conjugate, TCS access same information**

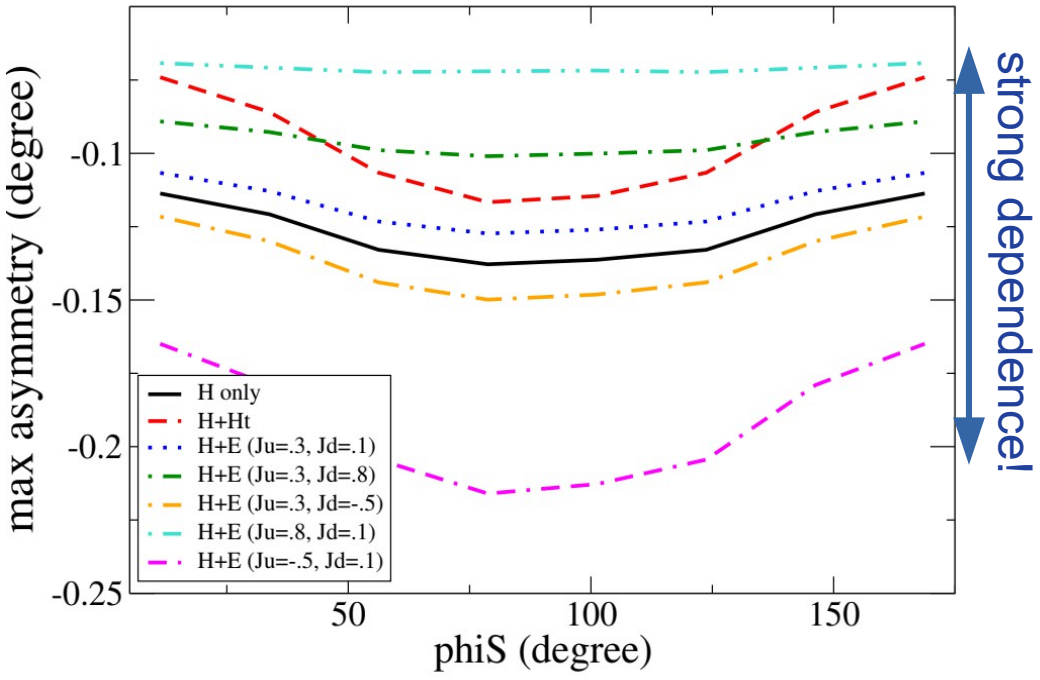
Transverse target spin asymmetry "as will be measured in Hall C"

Dependence in GPD parametrization and J_u, J_d (VGG model) vs φ and φ_S



Sin(φ) moment of transverse spin asymmetry vs φ_S

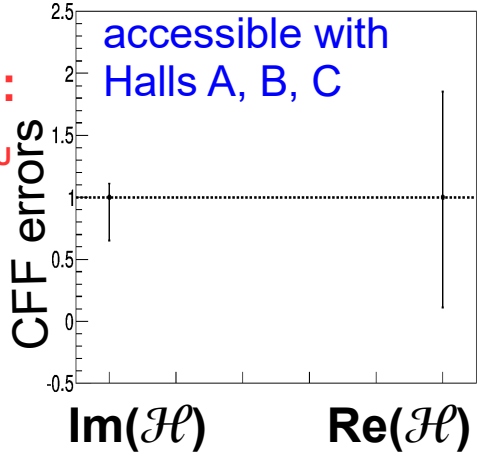
Dependence in GPD E and $J^{u,d}$ (VGG model)



Compton Form Factors from DVCS and TCS

[fit of simulations with same errors]

DVCS:
σ, $\Delta\sigma_{LU}$



- **CFFs from TCS can be extracted at same level than DVCS**
- **Im($\mathcal{E}$) extracted thanks to transverse target**
- **Precision on H greatly improved with new constraints**

Main goal: **GPD E (proton) → unique, not measured in other ex**

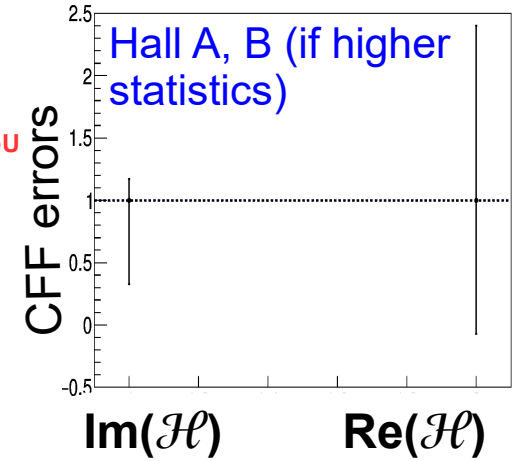
Secondary goal: **complement universality studies**

→universality or breaking? Higher twist/NLO effects?

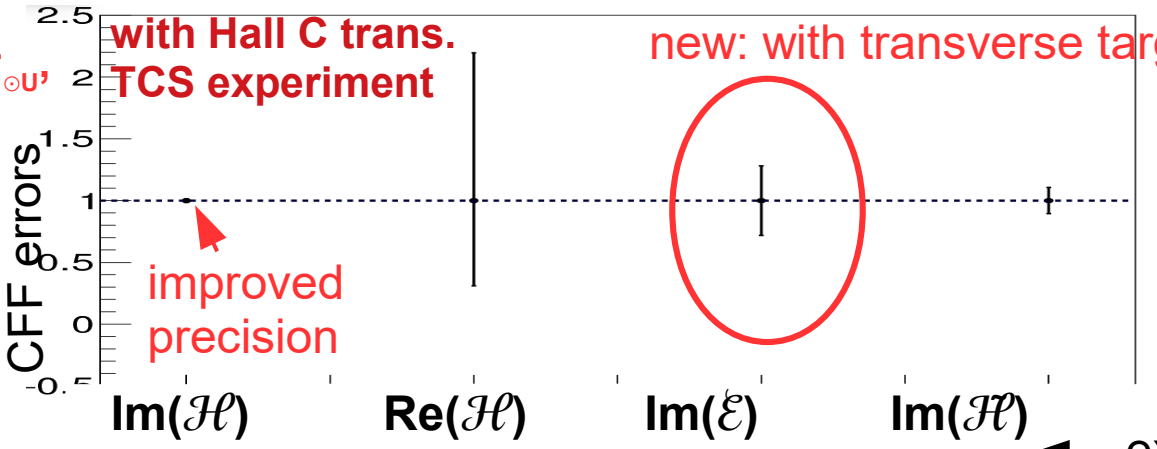
- Studied with Q^2 evolution in other experiments
- Comparison of fit results DVCS only, TCS, TCS+DVCS

→**interpretation depends on size of observed effects**

TCS:
σ, $\Delta\sigma_{\odot U}$



TCS:
σ, $\Delta\sigma_{\odot U}$,
$\Delta\sigma_{UX}$,
$\Delta\sigma_{UY}$



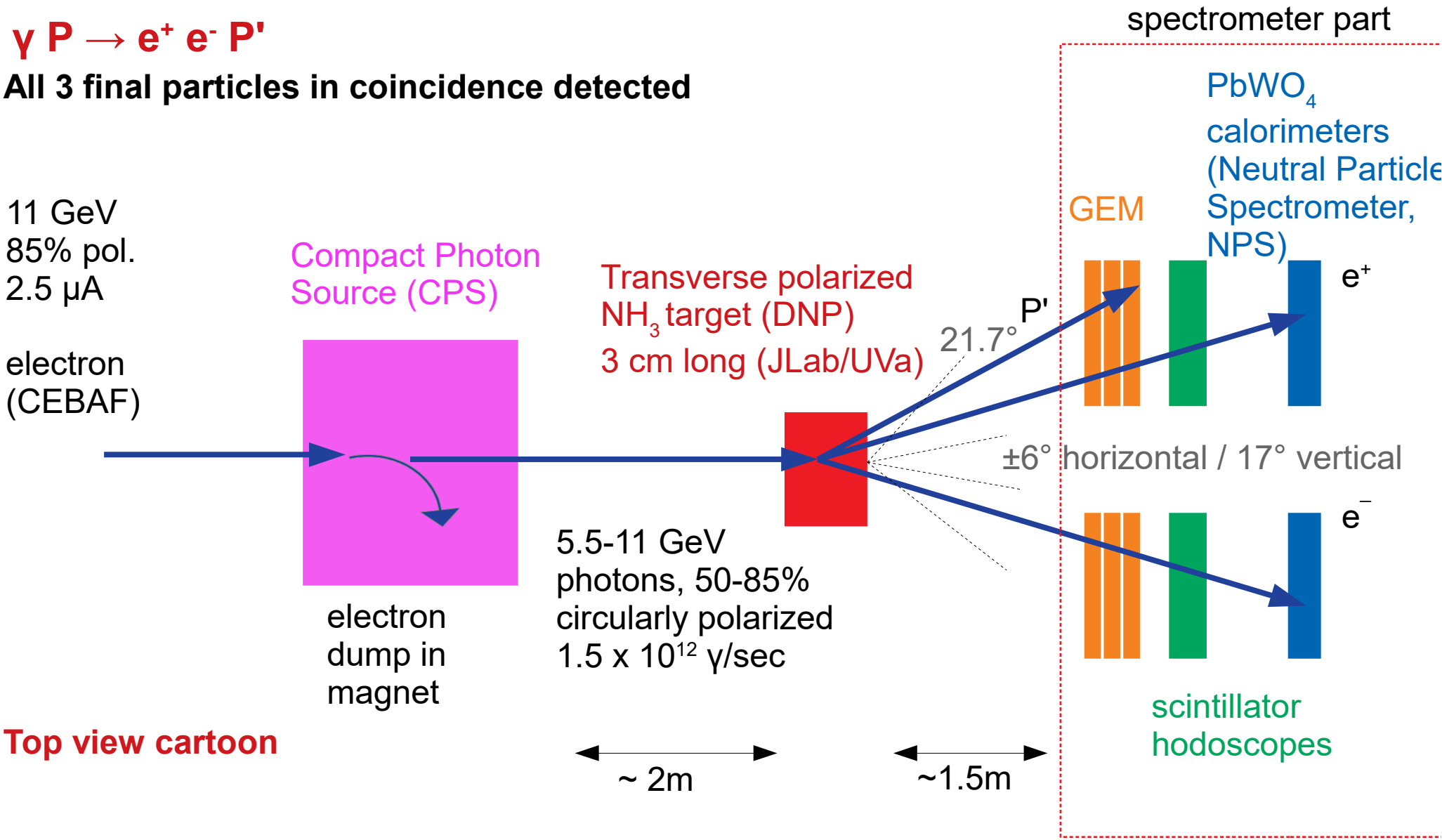
← extracted CFFs (generated at value=1)

Caveat: for comparison purpose and sensitivity studies; assuming same uncertainties for all cases (based on Boër, Guidal...)

Experimental setup

$\gamma P \rightarrow e^+ e^- P'$

All 3 final particles in coincidence detected



Top view cartoon

Trigger: GEMs, hodoscopes, calorimeters (all 3 particles)

Integrated luminosity: 5.85 x 10^5 pb^{-1} for 30 PAC days of "physics"
Condition PAC: trigger system, will be re-submitted this year (2021)

Our future: (my soccer team)

GO VT HOKIES!!

Zeyu G.
TCS longitudinal asymmetries
off proton & neutron

Mitchell C.
TCS off
the neutron

Mai H. TCS off the proton,
Unpolarized
and transversely polarized

Erik W. :
light mesons
event generator

Brendan L.
Polarized
J/psi event
generator

Camille Z.
Unpolarized TCS
Low Q'2 vs large

Goals: what is feasible (or not) in Hall C in near future?

Discussion

- Main physics goals: GPD universality, complementarity with DVCS & meson studies... ?

  - universality

  - fits of TCS, combined fits... methods/ complementarity / data sets...

  - NLO, higher twists

  - angular momenta through sum rules (transverse TCS...) ?

  - uniqueness of TCS

- Observables to measure ?
- Proton & neutron, nuclei ?
- Q'2 range, xi range (limited to JLab kinematics)... ?
- JLab Hall A/B/C/D pros & cons ?
- Other experiments: COMPASS, EIC (not discussed here), … feasibility with lower intensity ?