Transversely Polarized Timelike Compton Scattering Off the Proton

By Brannon Semp, Mentored by Marie Boer

General Parton Distributions (GPDs)

- Describe quark and gluon transverse position with respect to their longitudinal momentum

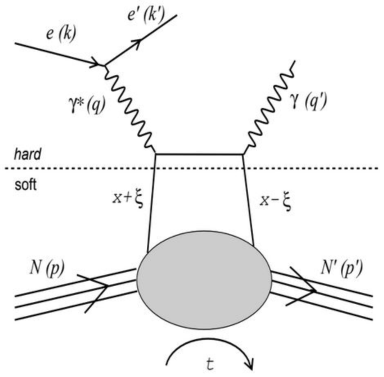
- Derived indirectly through experimental measurements of Compton Form Factors from Deep Exclusive Scattering processes

- Four independent GPDs are used in this work: H, $\tilde{H}$, E, $\tilde{E}$. These are further decomposed into real and imaginary CFFs. (ReH, ImH, etc.)

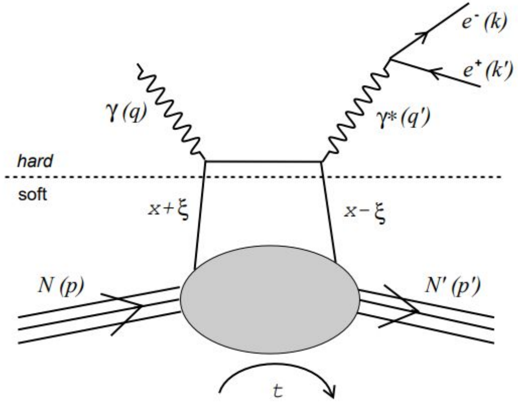
Motivations

- Past measurements primarily with done with DVCS, TCS would test for GPD universality

- Simultaneous fits of CFFs with DVCS and TCS would to lead to better constraints on all CFFs at the same time



DVCS



TCS

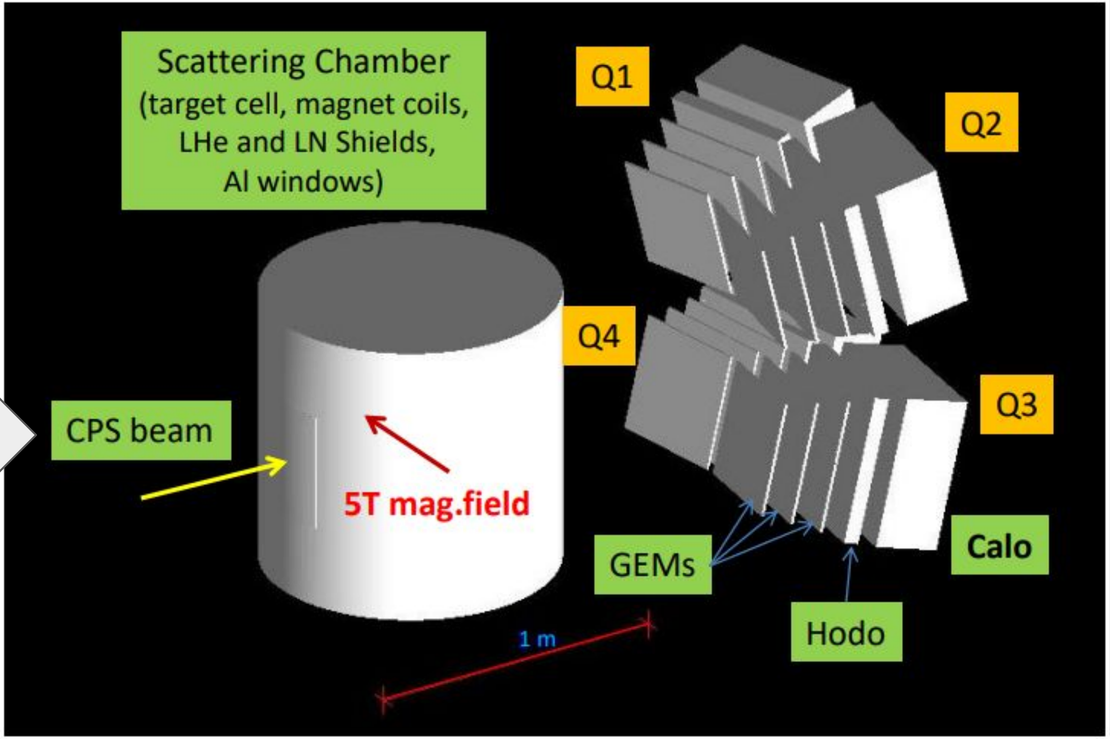
Experiment C12-18-005 at Jefferson Lab (Conditionally Approved)

Proposed by: M. Boer, V. Tadevosyan, D. Keller, et. al.

Compact Photon Source and Neutral Particle Spectrometer collabs, JLab Hall C

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

High Intensity 5-11 GeV Photon Beam



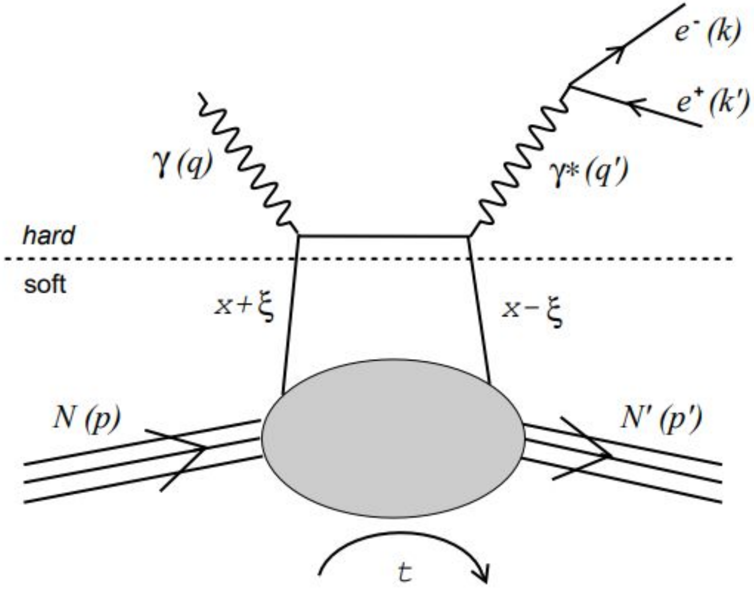
- Detect e^+, e^-, recoil p in coincidence
- CPS bremsstrahlung photon beam
- UVA/Jlab NH_3 target, transversely polarized
- Detectors arranged in 4 quarters, oriented to target
- Triple-GEMs for e^+, e^-, p tracking
- Hodoscopes for recoil proton detection/PID
- $PbWO_4$ calorimeters for e^+, e^-, p detection/PID

Slide Credit: V. Tadevosyan

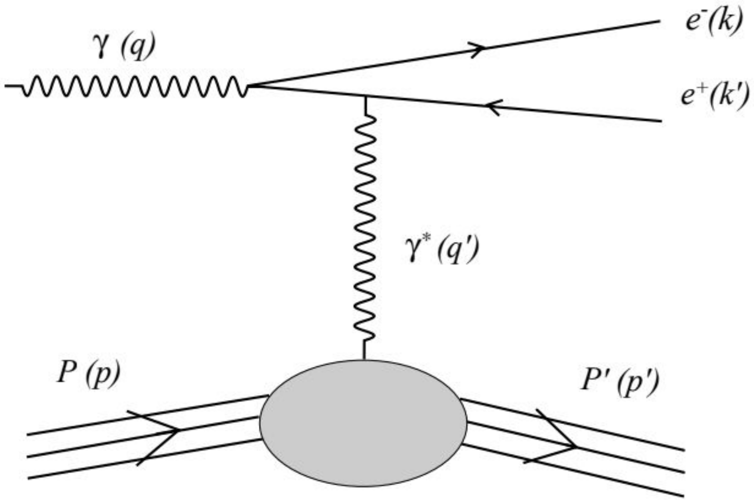
Beam Target Spin Asymmetry (BTSA) →

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($\tilde{H}$) 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($\tilde{H}$)	no / "for free"?
Transversely polarized target	Polarized target, and high luminosity: binning in θs, φs	Im($\tilde{H}$), 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

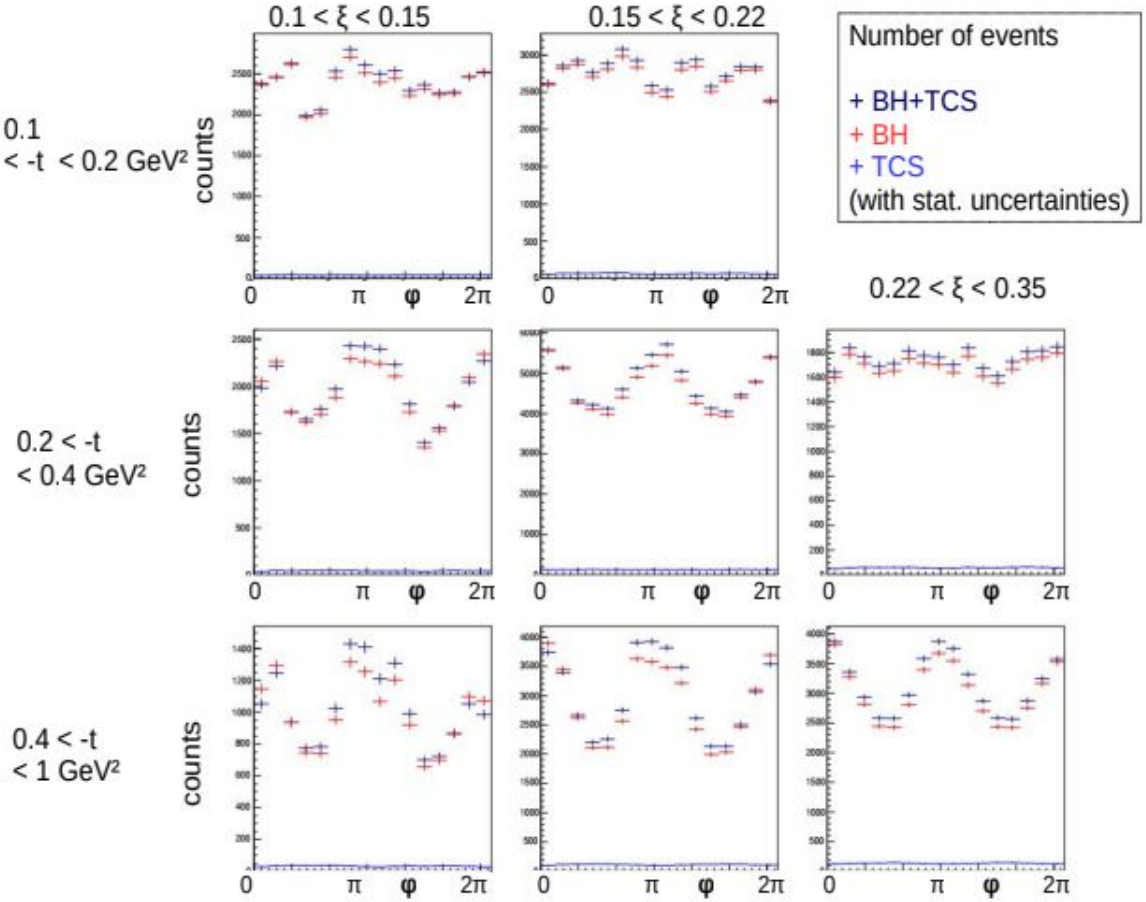
Bethe-Heitler



TCS



BH

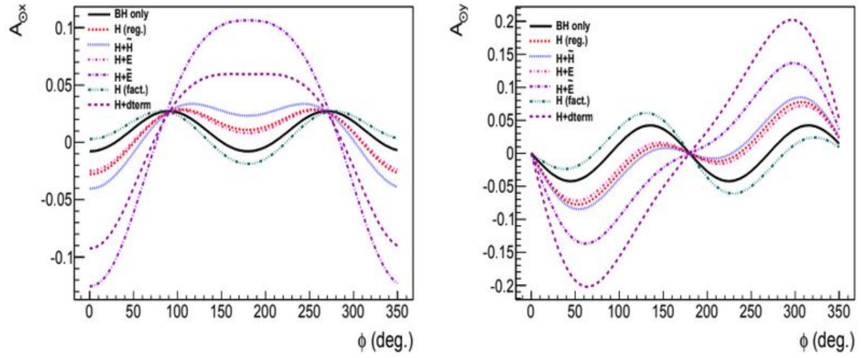


Distribution provided by Dr. Boer

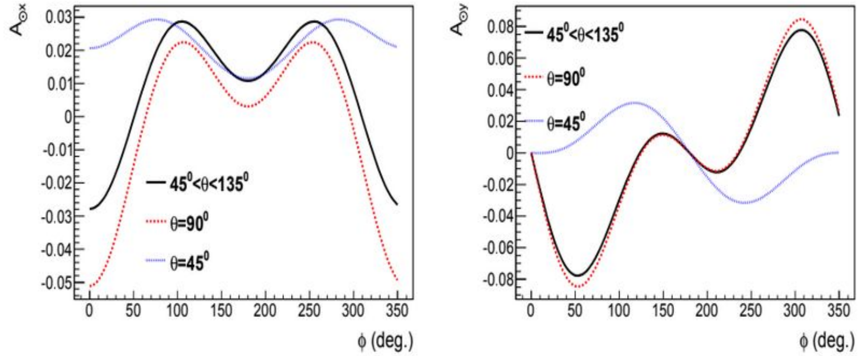
BTSA

BTSA shows access to all real CFFs. Extraction is difficult, but is currently poorly constrained so any measurements could be useful

Note that the integrated asymmetry is very similar to the asymmetry at 90° (Highest TCS vs BH). This allows us to use the integrated asymmetry to measure TCS.

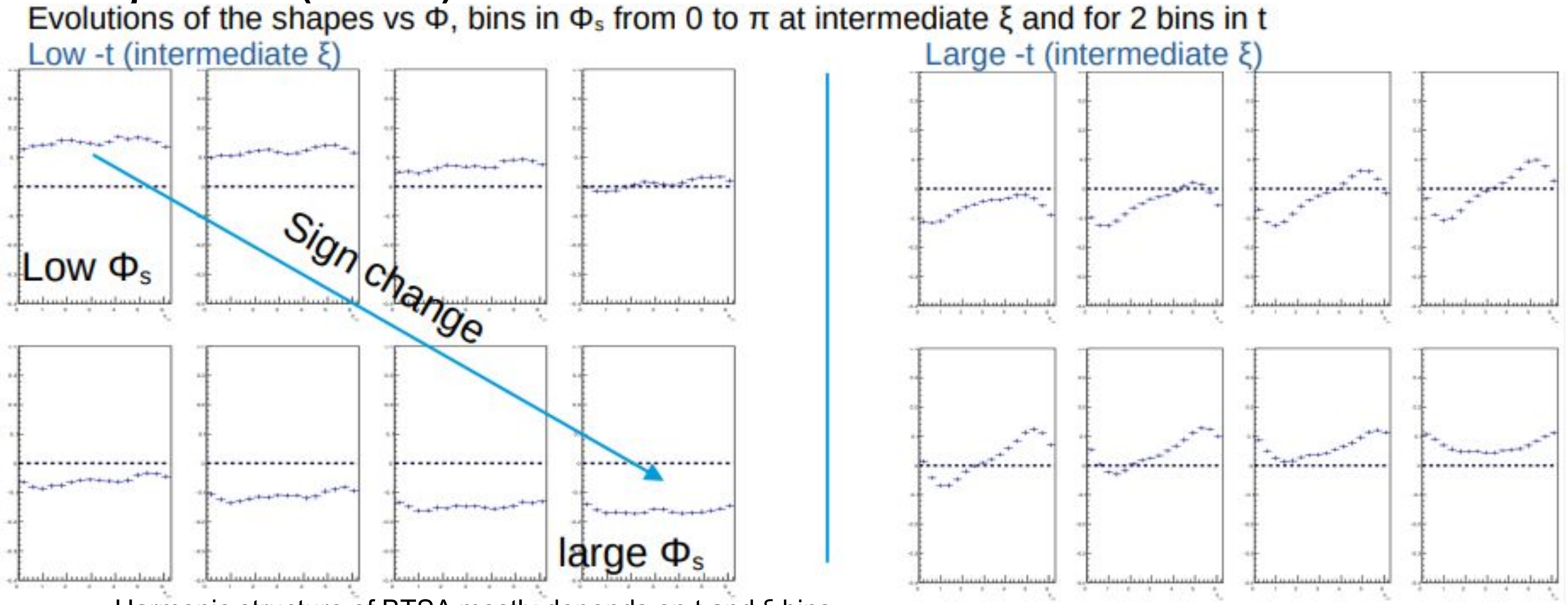


Φ=0° Φ=90°

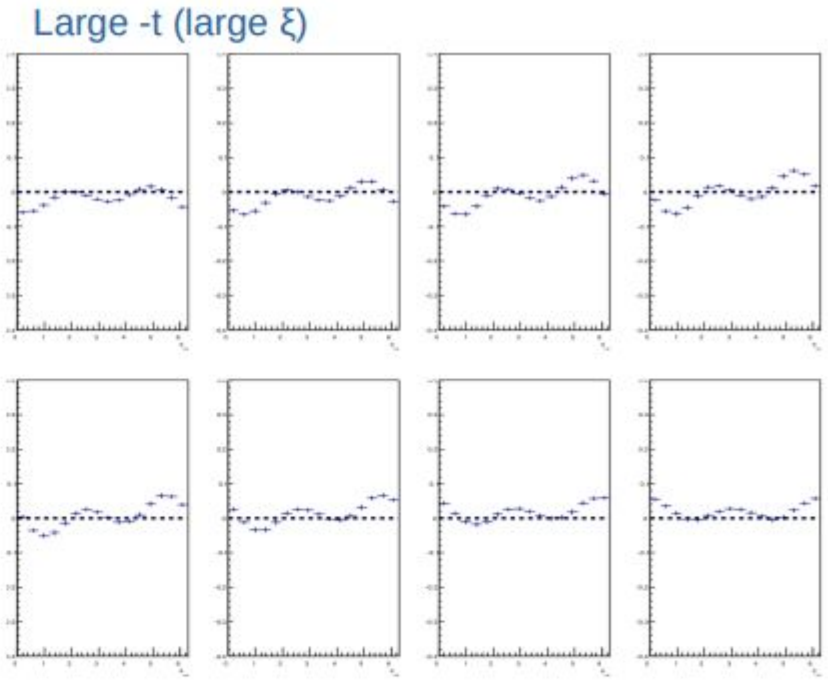


$\xi = 0.2$, $-t = 0.4$ GeV² and $Q'^2 = 7$ GeV²

Projected (ideal) BTSA distributions



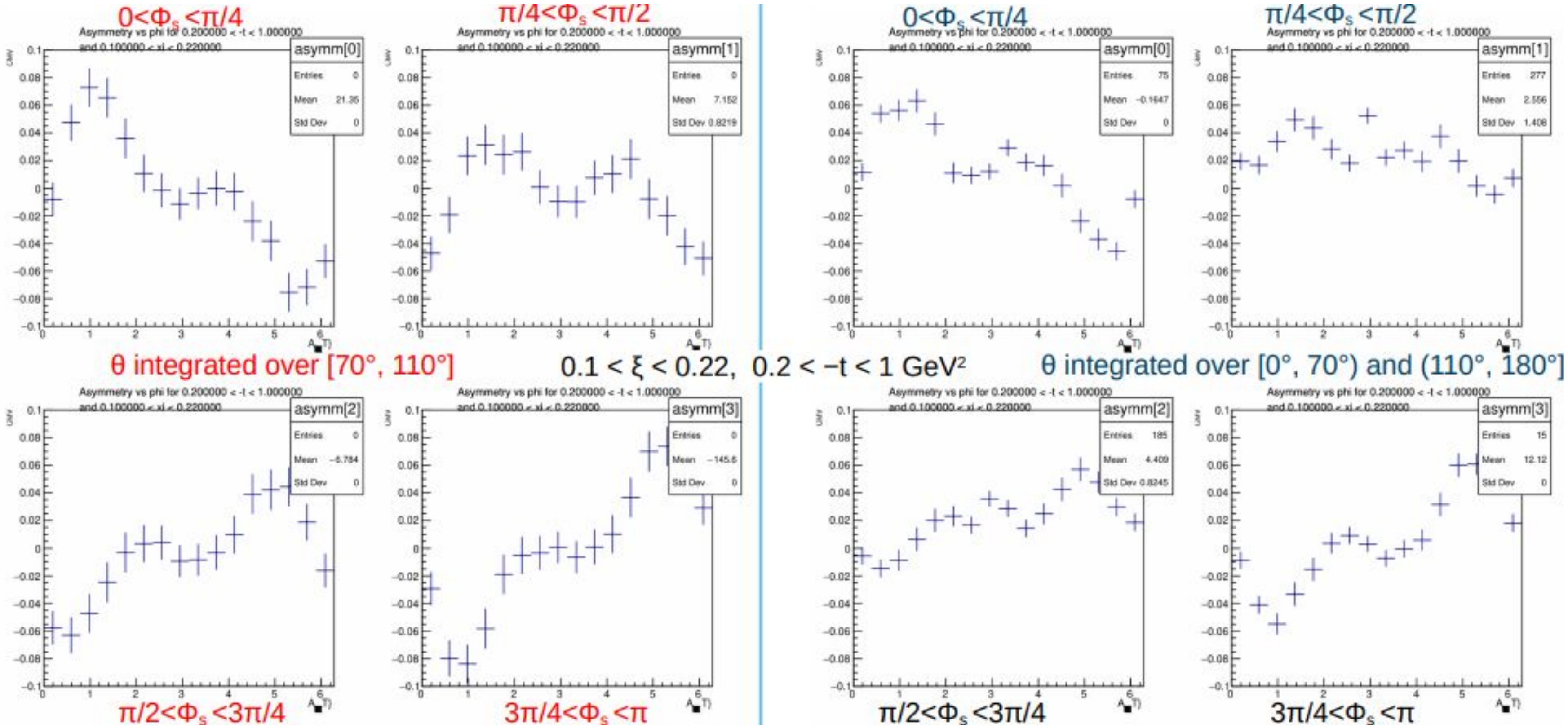
- -Harmonic structure of BTSA mostly depends on t and ξ bins
- -BH doesn't cancel, nor is it TCS "only". Harder to interpret but any information is a major input to models and especially for discriminating Double Distribution "types" vs other kinds (strongly differ on Re CFF)



-Shape also strongly dependent on ξ (compares to right panel of last slide)
-Very fast evolution of real part of amplitudes with ξ, unlike for the imaginary part
-Importance of selecting the right binning in ξ & t

Comparing results integrated inside [70°,110°] vs Integrated outside range

TCS+BH Interference | Dominated by BH



Asymmetries integrated inside [70°, 110°] show more extreme negative values compared to outside, which is only BH

TCS+BH Interference

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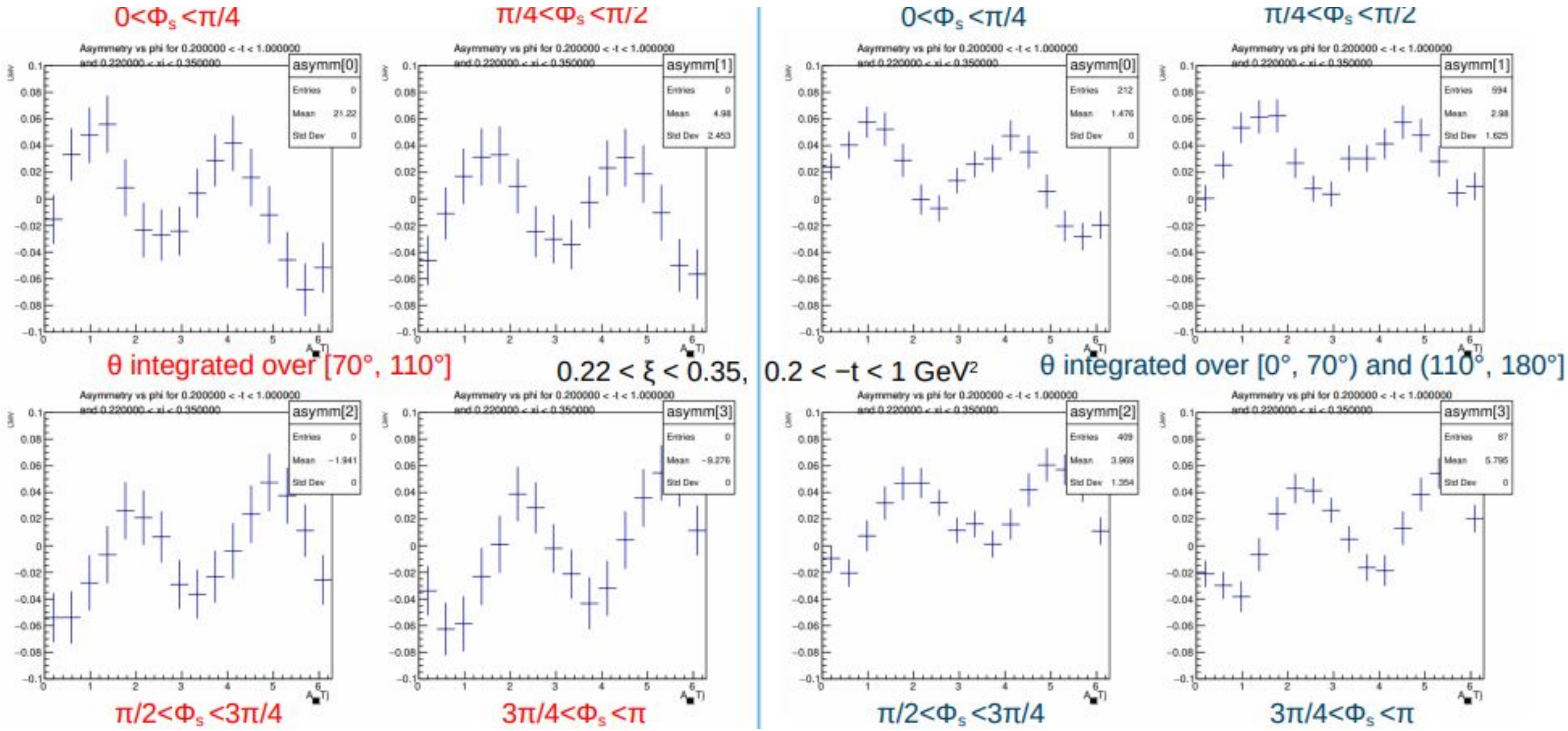

Asymmetries integrated inside [70°, 110°] show more extreme negative values compared to outside, which is only BH

CFF Extraction at -t=0.4, Q’^2 = 7 with 7% error

Average	Real	Imaginary
H	1.019	1.011
E	0.908	0.6917
H̃	0.9805	0.933
Ẽ	1.016	0.2156

Standard Deviation	Real	Imaginary
H	0.6466	0.07964
E	2.522	0.6226
H̃	2.021	0.2633
Ẽ	0.6858	2.953

Conclusion

- Extraction of real parts of all GPDs is possible but difficult with BTSA

- Complementary to Experiment C12-18-005, would require no additional beam time

- Current models strongly disagree in this area, so any data could help discriminate between different models (just the sign of a CFF could have a large impact)

- Further research will focus on experimental uncertainties and uncertainties in the extracted CFFs