Status and recent updates on studies for transversally polarized TCS at NPS

- Theory status: observables and physics case
- Angular and kinematic correlations
- Consequences in lab frame and physics impact evaluation
- Setup optimization
- Status on the tools for analysis and physics interpretation

Marie Boër, Feb. 22, 2018, NPS meeting

Measurement goal: TCS with transversally polarized proton

TCS+BH in γ P → e+ e- P: 6 independent variables for polarized cross sections

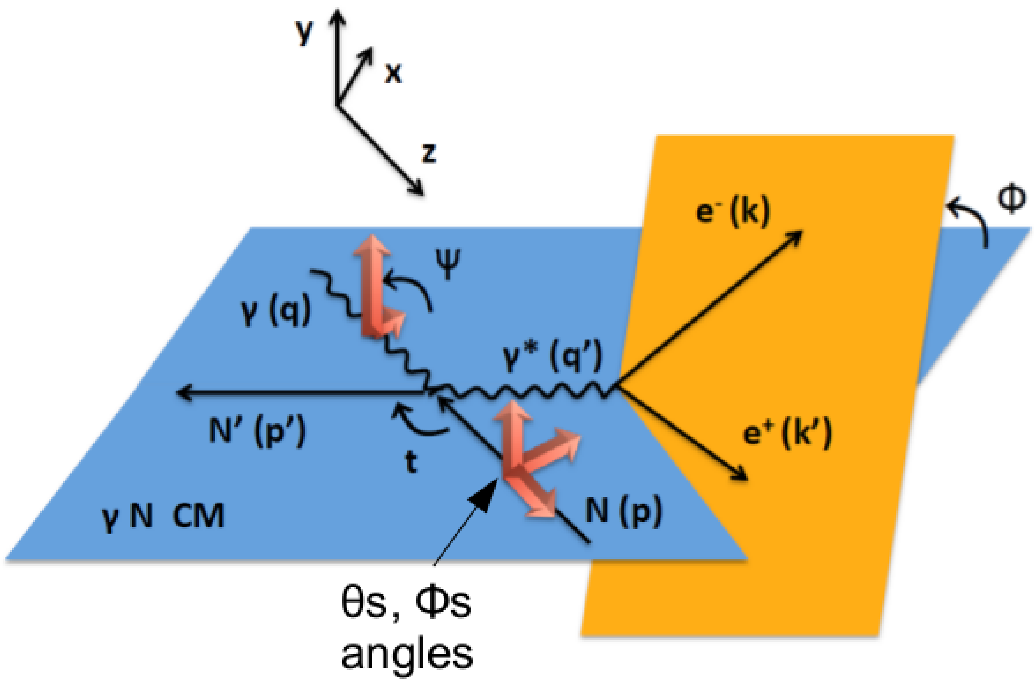
Choice: 3 kinematics (ξ, t, Q'²), 3 angles (φ_{CM}, θ_{CM}, φ_S)

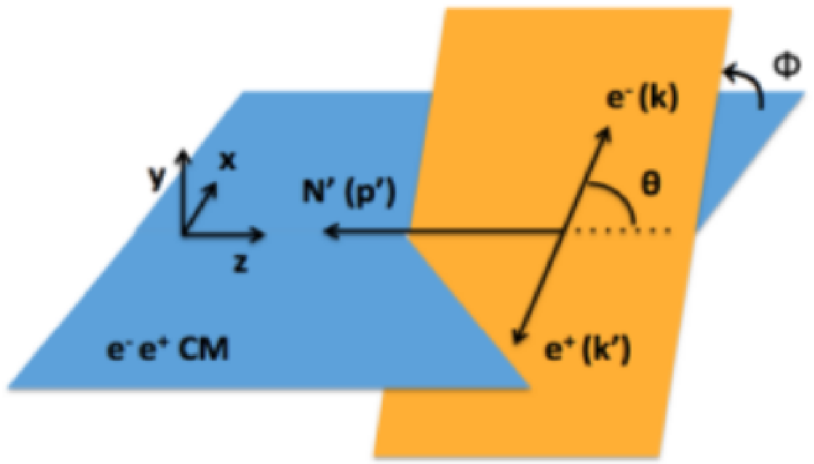
Transversally polarized target: θ_S=90° (possibly corrections at % level if small rotation of axis)

Observables to measure: 2 orthogonal asymmetries in φ_S, depending on φ and φ_S

A_{UT} = single target (transverse) spin asymmetry,

$A_{\odot T}$ = double beam (circular) and target (transverse) spin asymmetry





Theory status and physics case

Goals:

• We know/assume that transversally polarized TCS access Im part of TCS*BH polarized amplitude and is sensitive to Im($\mathcal{E}$) → quark tomography in polarized nucleon, indirectly spin physics, relation to Sivers...

• GPDs multiparameter fits with TCS / universality by comparing with DVCS

• Assuming leading order/twist and GPDs universality: alternative to transversally polarized DVCS (technical) / DVCS+TCS complementarity (fits)

• Studies of higher twist and NLO effect in DVCS versus TCS

Theory status for the physics case:

• Predictions for A_{UX}, A_{UY} asymmetries [published in 2015]: serve as a reference, I use an updated version of this work for all calculations entering the proposal

• Correlations with target spin, extension to "experimental conditions" (angular corrections in φ_S, θ_S, lab variables...) [final since early 2016]

• Observables: $\sin(\varphi-\varphi_S)$ moment at fix φ or φ_S and "2D" moments vs (φ, φ_S) and φ

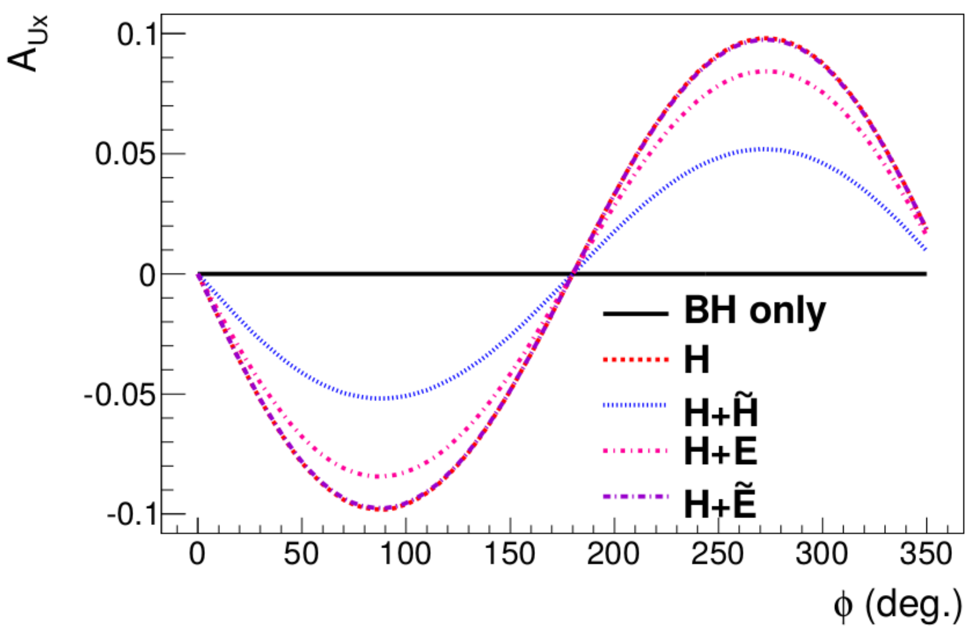
• No existing "nice" analytic equations showing GPDs vs angular dependence for TCS, but alternatively:

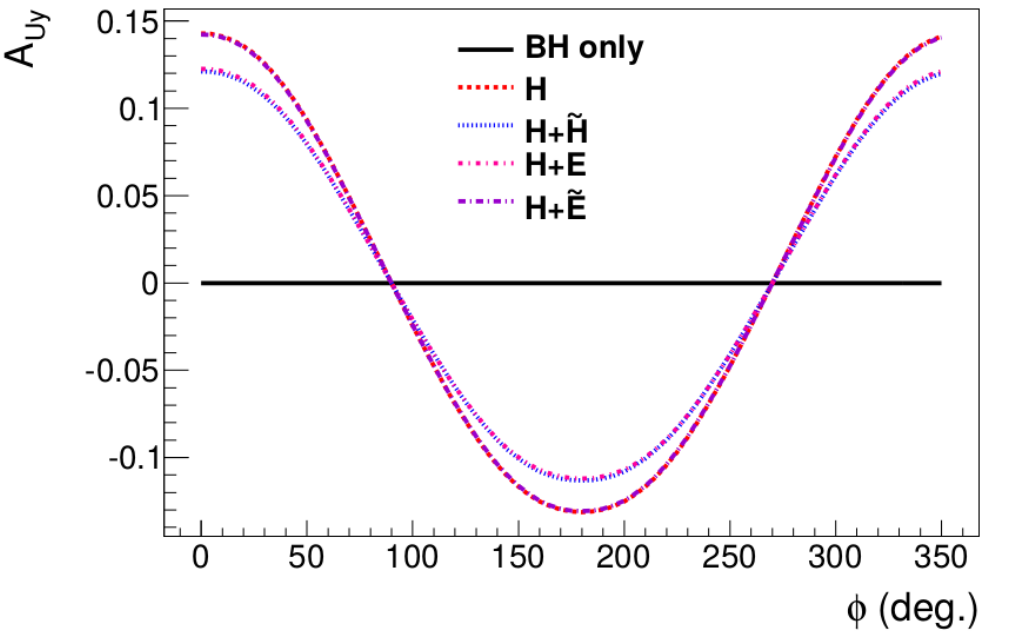
- Impact evaluation from CFF fitting
- Analogy is possible with DVCS, comparison of 2 approachs (fix φ_S, moments "a la HERMES")

⇒ Physics case will be updated after quantifying the potential physics impact in regards of the expected statistics and kinematic coverage on CFF extraction

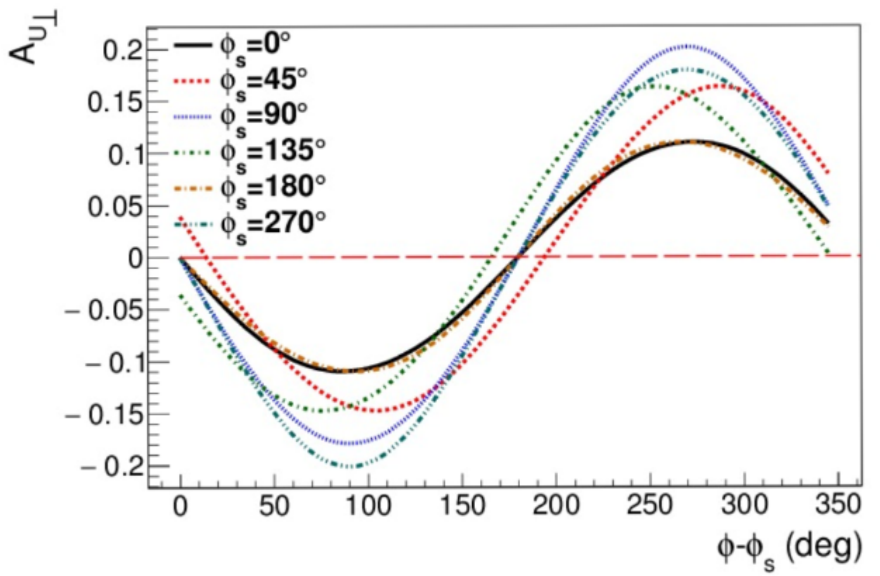
What observables do we want to extract?

Approach 1 (single TSA): $A_{UT} = -\sin(\varphi-\varphi_S)$, at 2 fix orthogonal φ_s or φ values → 2 independent observables sensitive to different combination of GPDs in the nucleon





Approach 1-bis (single TSA): iterative CFF extraction at various values of 2 orthogonal φ or φ_s



What observables do we want to extract?

Approach 2 (single TSA): by analogy with DVCS, "a la HERMES"; (φ-φ_S) and φ moments

A_{UT} = [$d\sigma(\varphi,\varphi_S) - (\varphi,\varphi_S+90°)$] / $\Sigma d\sigma$

$\approx F[t, \xi, Im(\mathcal{H}), Im(\mathcal{E})] \sin(\varphi-\varphi_S) \cos(\varphi) + F[t, \xi, Im(\tilde{\mathcal{H}}), Im(\tilde{\mathcal{E}})] \sin(\varphi-\varphi_S) \sin(\varphi)$

⇒ 2 dimensionnal approach with moments in φ. Analytic development exist only for DVCS. Same observables can be extracted for TCS

- In this approach, the interest of keeping the full angular range
- same physics content from approach 1 (1bis) and 2, same impact expected for CFF fits

Double spin asymmetry:

- Same 2 approachs, similar needs. But needs higher counting rates due to BH asymmetry doesn't cancel
- Important physics impact: Re(CFF), strong model dependence

Proposed:

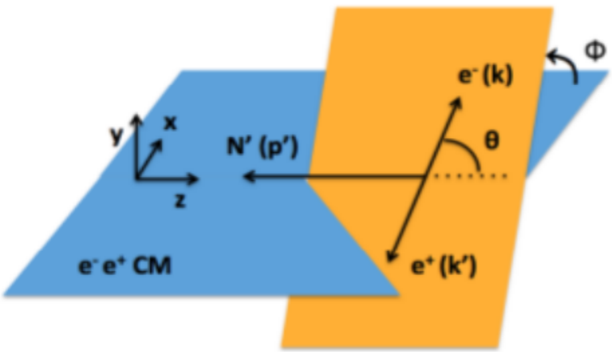
- Approach 1 and 1-bis: extraction of A_{UT} from $\sin(\varphi-\varphi_S)$ momenta at different values of φ and φ_S. Weighting in $\cos(\varphi)$ and $\sin(\varphi)$ is duable from data to get results from the different approaches
- Similarly, extraction of $A_{\odot T}$ at different values of φ and φ_S.

Experimental requirements for interpretation:

- acceptance: good coverage in φ, φ_S
- sufficient statistics for 2D binning. re-evaluation of observables: sums instead of integrals / cuts...

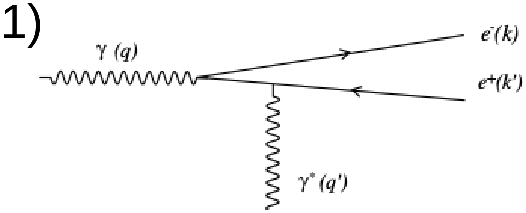
Angular correlations (CM)

CM angles

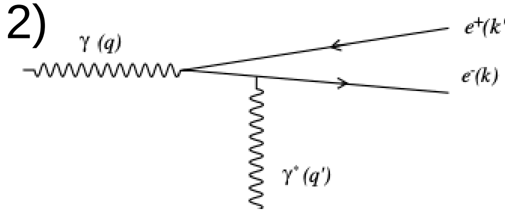


BH propagators

1)



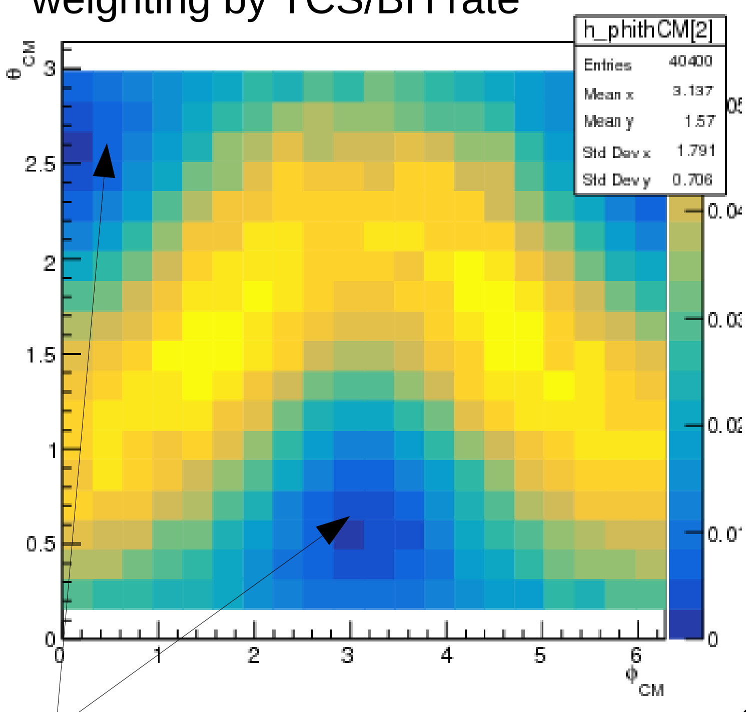
2)



- singularities when e- or e+ collinear to incoming γ
- strong kinematic dependence at JLab energy
- one diagram becomes largely dominant / very asymmetric decays

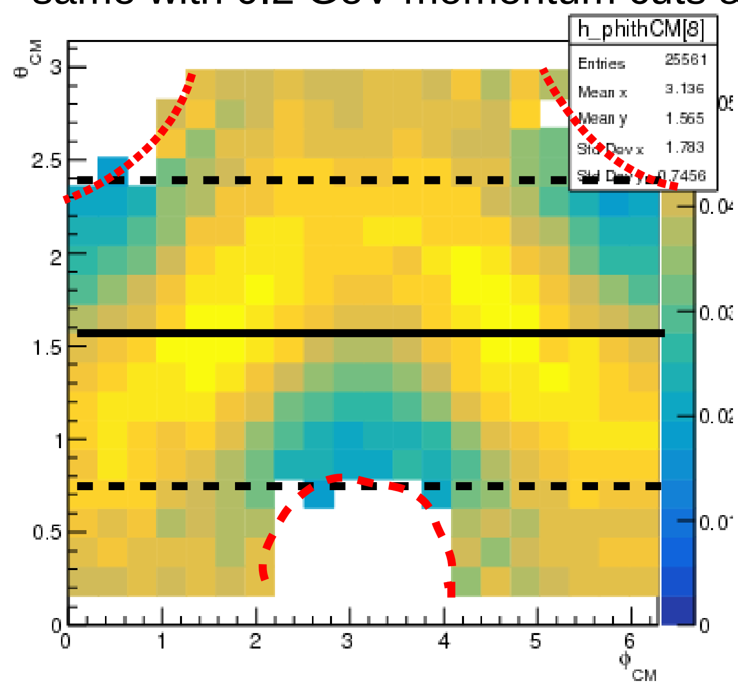
θ_{CM} vs φ_{CM} weighted distributions

weighting by TCS/BH rate



regions next to BH singularities
very large cross section
low TCS/BH rate, low A_{UT}

same with 0.2 GeV momentum cuts & θ_{lab}>6°

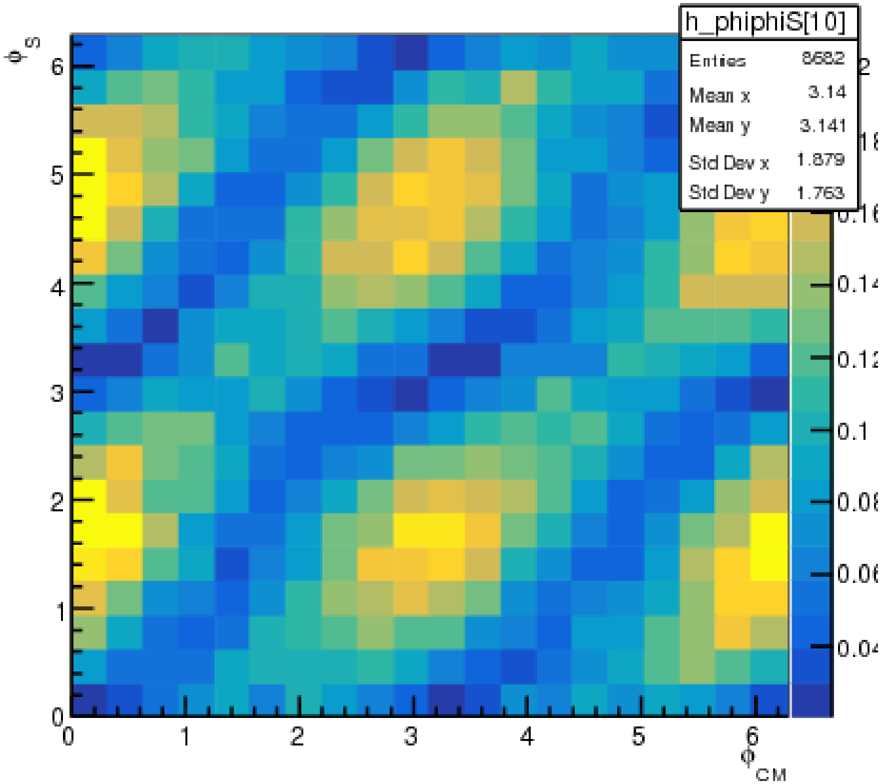


-- cut at 45°; 135°
-- acceptance cut
not included: cut of some bins next to singularities if not experimentaly "solvable" due to limited statistics (example 2 orders of magnitude increase of σ within a bin)

singularities: lepton 1 goes 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

Angular correlations (spin)

φ_S vs φ_{CM} weighted distribution $\propto|A_{UT}|$



⇒ This 2D distribution reflects $\sigma^{pol} \propto [\xi, t, Q'^2, \theta_{CM}, \varphi_{CM}] * \sin(\varphi_{CM}-\varphi_S)$

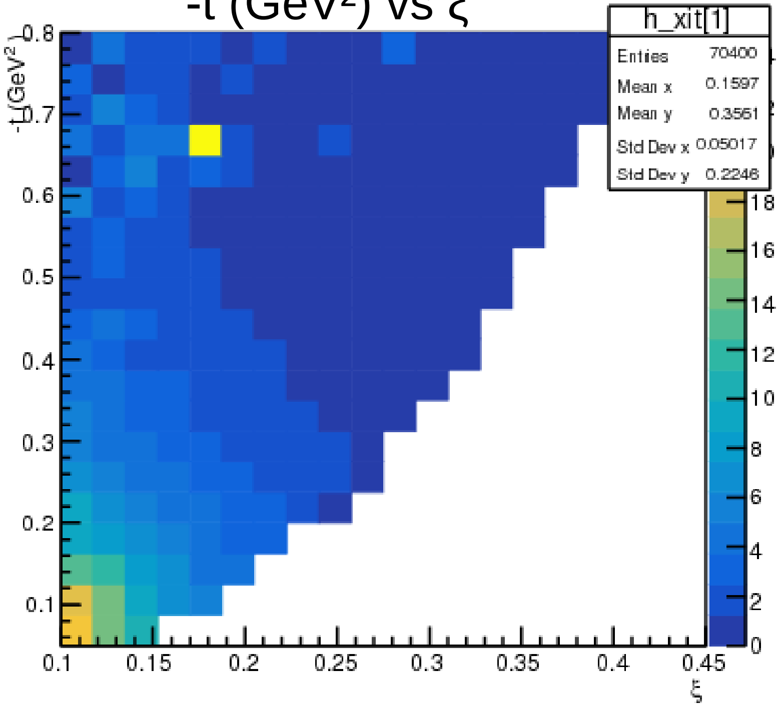
- 2D fit of such distribution to extract physics information

Correlations between "physics" angles and kinematic variables

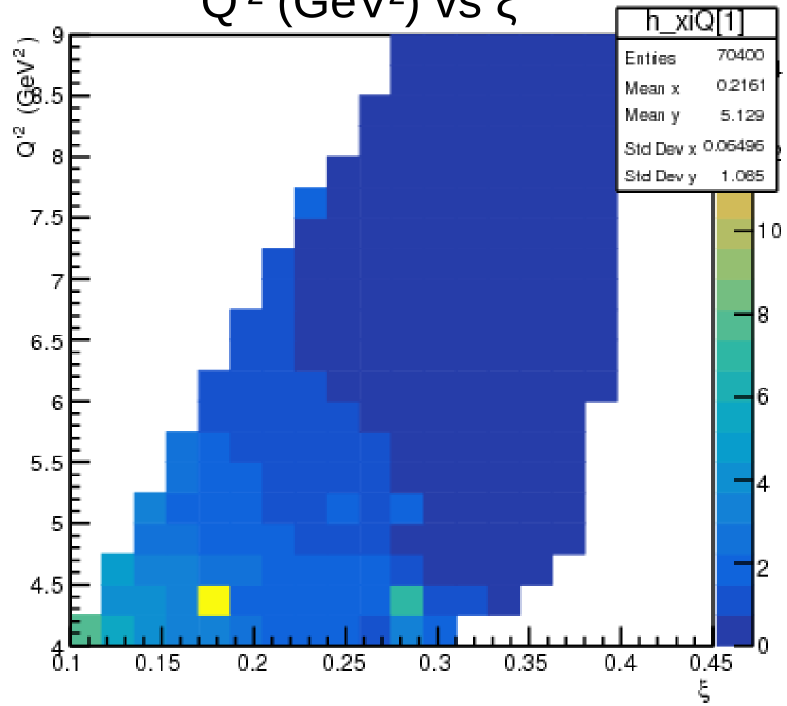
- Considerations on physics valid at forward limit ($-t \rightarrow 0$; i.e. $\Theta_{\gamma\gamma^*} \rightarrow 0$)
- JLab kinematic: all proposed cuts and extracted asymmetry binning are kinematic dependent in (E_γ, t, Q'^2)
- No detail here, presented during dedicated dilepton meetings

Correlation between kinematic variables

-t (GeV²) vs ξ

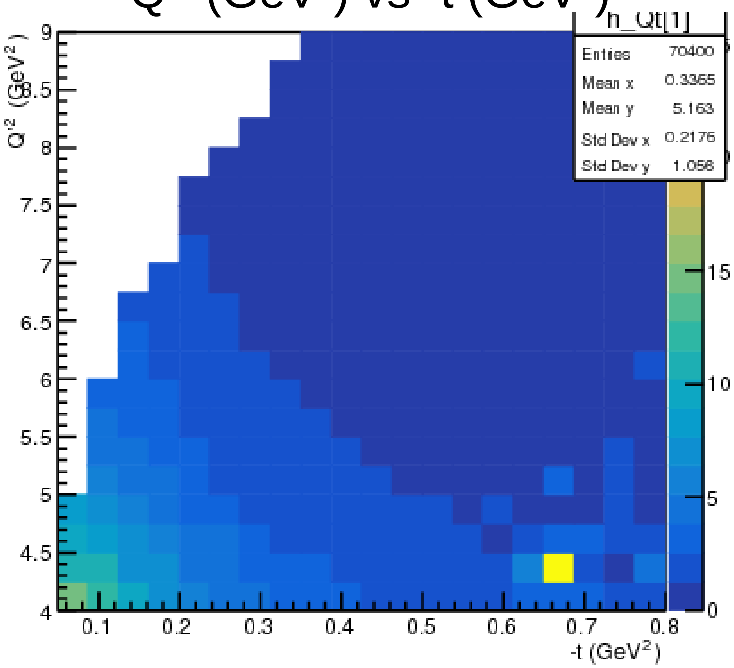


Q'² (GeV²) vs ξ



weighting ∝ cross section

Q'² (GeV²) vs -t (GeV²)



Here = temporary cuts, will be updated according to final cuts and binning, defined from counting rates

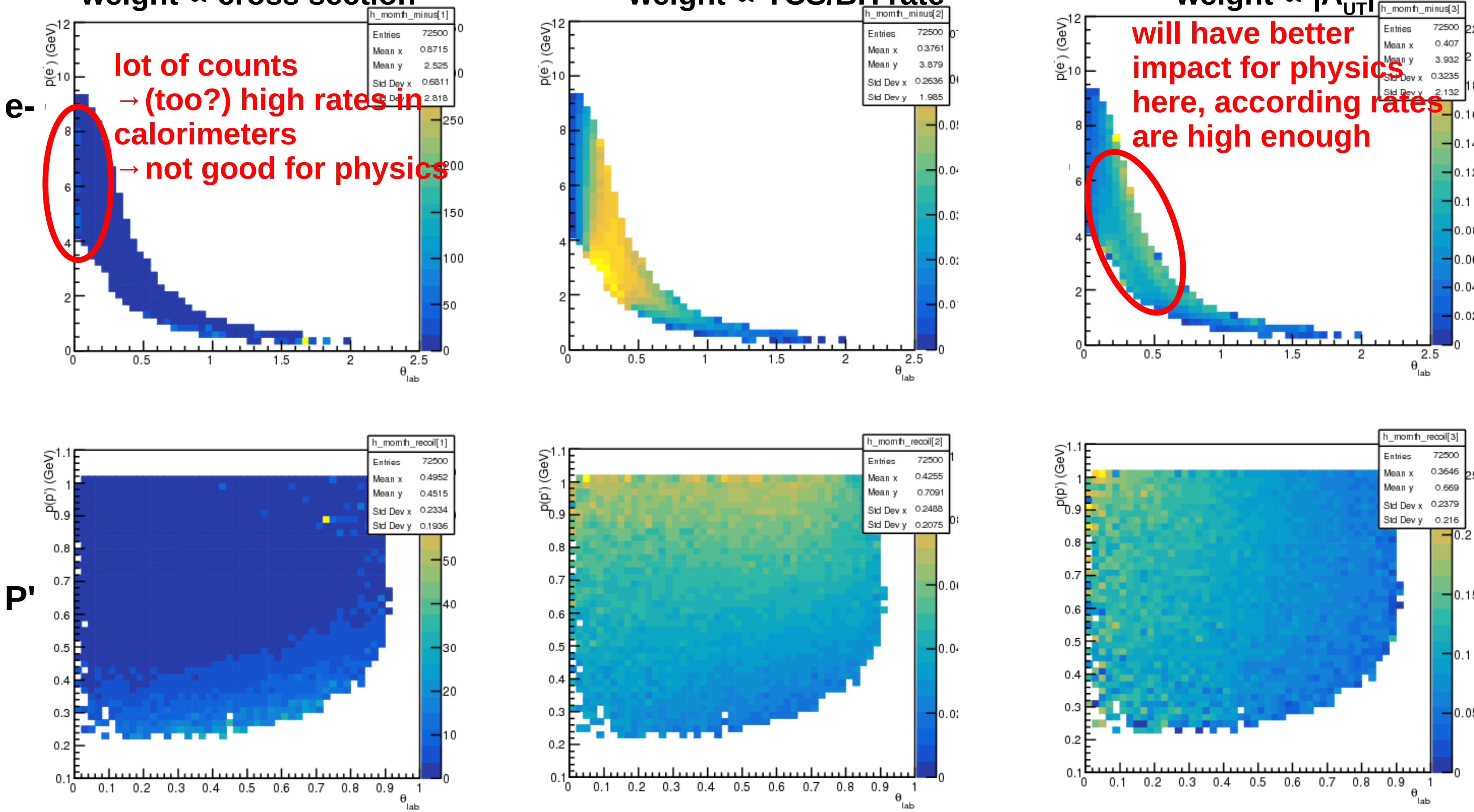
Important for the binning: narrow in ξ and t

Can be integrated over Q'² if not enough statistics

Physics impact versus lab angles (at vertex)

momentum vs θ_{lab} distributions (generated sample / no acceptance cuts)

weight ∝ cross section | **weight ∝ TCS/BH rate** | **weight ∝ $|A_{UT}|$**



- Lepton angles between ≈15° to ≈40° to enhance TCS/BH rate and size of asymmetry
- Proton acceptance is mostly providing binning in t
- Balance of physics impact/size of asymmetries versus counting rates → in progress (more jobs on ifarm)

Question: technical feasibility to go to larger angles?

Experimental setup optimization

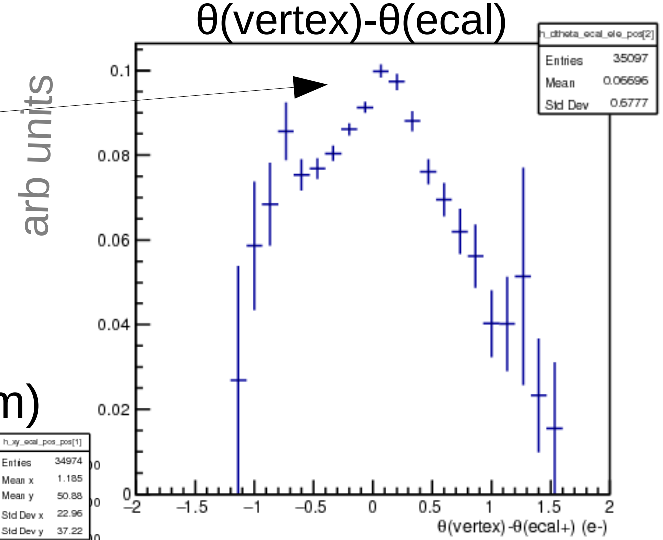
- We are playing with a scenario "very wide" detectors (ecal, hodo, trackers) to optimize sizes and positions
- Goal: counts and asymmetries for various subrange of the acceptance → ongoing, jobs still running on ifarm

1) optimization of calorimeters position

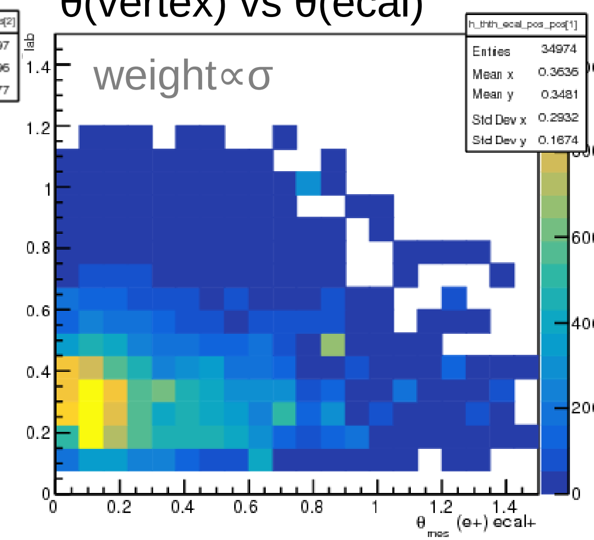
Deflection of e+/e- θ_{lab}: ≈3° with wide tail at ECAL and HODO positions

In progress...

θ(vertex)-θ(ecal)

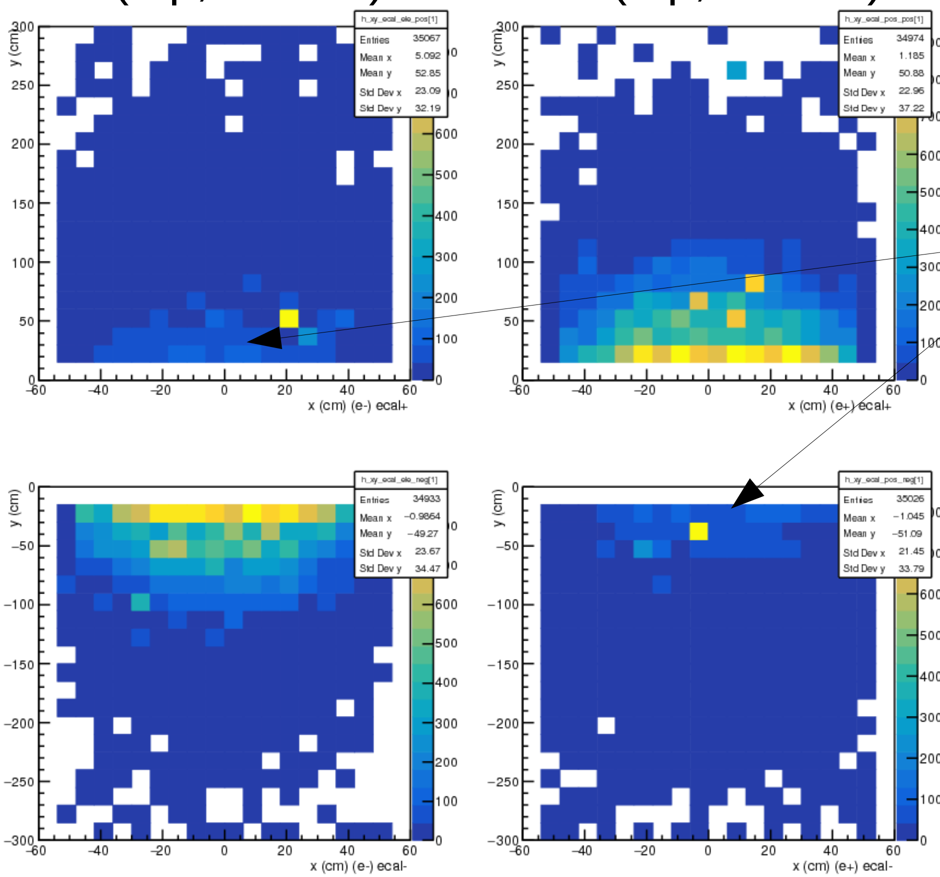


θ(vertex) vs θ(ecal)



calorimeters hits (arbitrary units)

e- (top, bottom) e+ (top, bottom)



presence of halo of e-/e+ on the "wrong" side:
- another argument to go to larger angle?
- discrimination by tracking?

2) Once done with optimization of calorimeters and hodoscope angles/position/size, we will optimize proton acceptance to maximize the rates in various t bins

3) next step is to extract asymmetries for several scenario of the setup. Needs more MC statistics

Status: tools for analysis and interpretation

• **Calculations**:

- we can fit data with appropriate function accounting "experimental" conditions.

- re-definition of observables and integrated cross sections to match kinematic range that can be actually measured (details were shown at some dileptons meetings / mostly angular cuts)

• **Simulations**:

- generator: https://hallaweb.jlab.org/wiki/index.php/DDVCS_and_TCS_event_generator

- GEANT4 or fast MC (current studies with full GEANT4)

→full chain: generator→reconstruction→analysis→observables→fits (we have the first 3 steps done)

→comparison of different setup (ongoing)

→physics: generator provides event/event TCS, BH, polarized and unpolarized rates... for systematic studies. Also include spin orientations and dilution factors to analyze events "like actual data"

• **Analysis tools:**

- Analysis classes with physics cuts (physics variable, background reduction, exclusivity, acceptance...) and reconstruction code [mostly done on simulations – in progress for the analysis of actual data]

- Current analysis of Hall B & D existing data are helping for this project. Current studies with MC, soon with data.

• **CFF fits:**

- codes and simulation chain installed, work to finalize. Will be included in the physics case.

Summary

• Physics observables: moments in φ and φ_S. Requires quite large statistics and good angular coverage

• Behavior of BH next to singularities and correlation with lab angles: some regions to avoid, mostly cut-out with acceptance

• Binning optimization: balance between counting rates, size of asymmetries and TCS rates

• Optimization of setup: going to larger angles?

• Tools needed are in our hands to finalize the work, still few steps in progress. Benefits of input from current Hall B & D analysis.

• In progress:
- finalizing setup optimization
- background rate

• Next:
- asymmetry and counting rates for final binning (needs more statistics in MC),
- CFF extraction for expected experimental uncertainties

Any comment / input is welcome