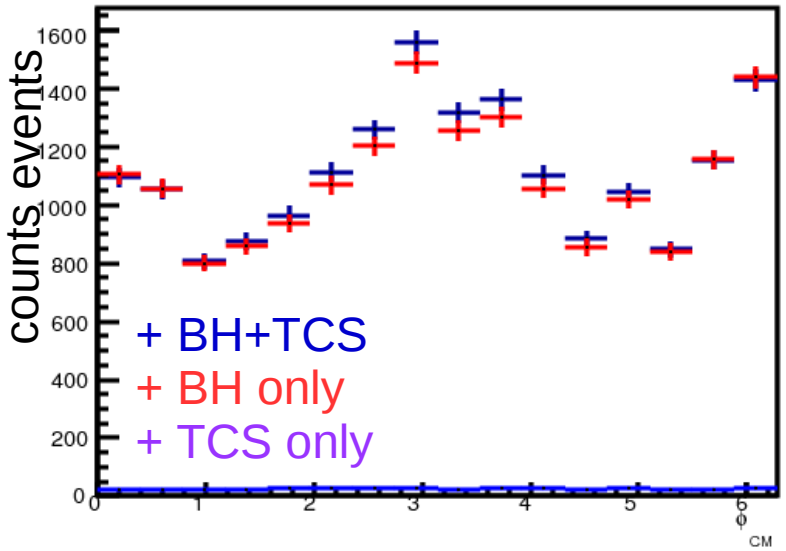
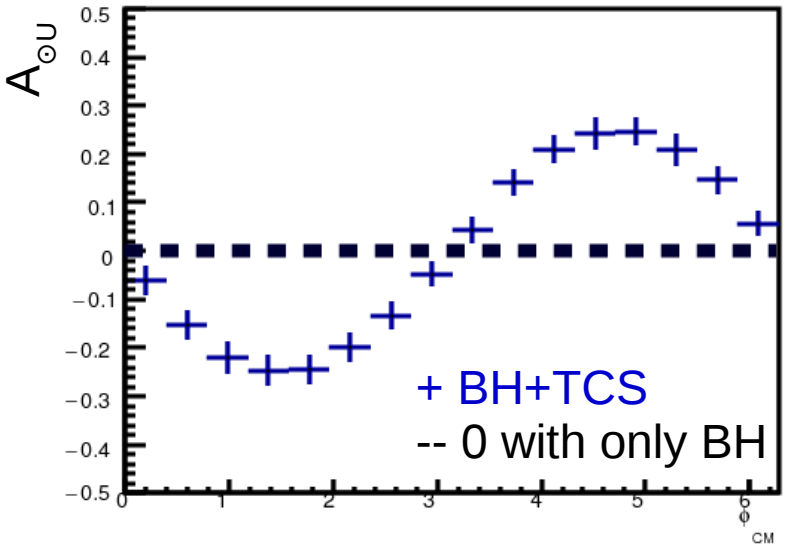
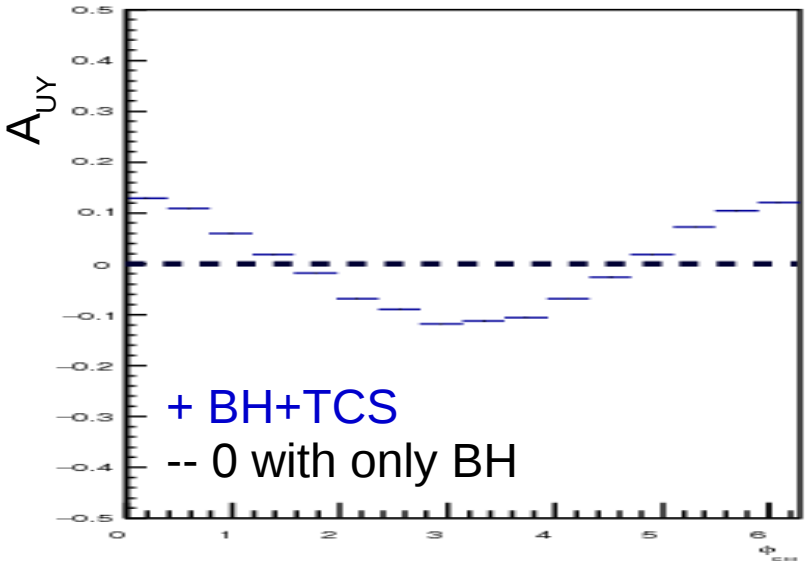
Physics case for TCS experiment at NPS using transversally polarized target and circularly polarized photon beam

Projection of TCS observables

Reference bin: .17<-t<.25 GeV², .13<ξ<.16, 4<Q'²<5.5 GeV², 7.5<Eγ<10.5 GeV
some acceptance cuts. Phase space cuts on BH peaks.







4 independent observables: σ, $\Delta\sigma_{\odot U}$, $\Delta\sigma_{UT}$.

cross section sensitive to Im and Re (amplitude) and asymmetries sensitive to Im(amplitude), BH cancels.

Proposed binning with 16 bins in φ allow for 2% to 5% statistic errors /φ bin. Asymmetries or Δσ large enough to be extracted.

⇒ I refer to past presentations this year at this meeting for details about method and binning (some slides in backup)

Fits of CFF

- Kinematic of reference bin: -t=.2 GeV², ξ=0.15, 16 bins in φ

  TCS: Q'²=4.5 GeV², θ=90° / DVCS: E=11 GeV, Q²=2.5 GeV

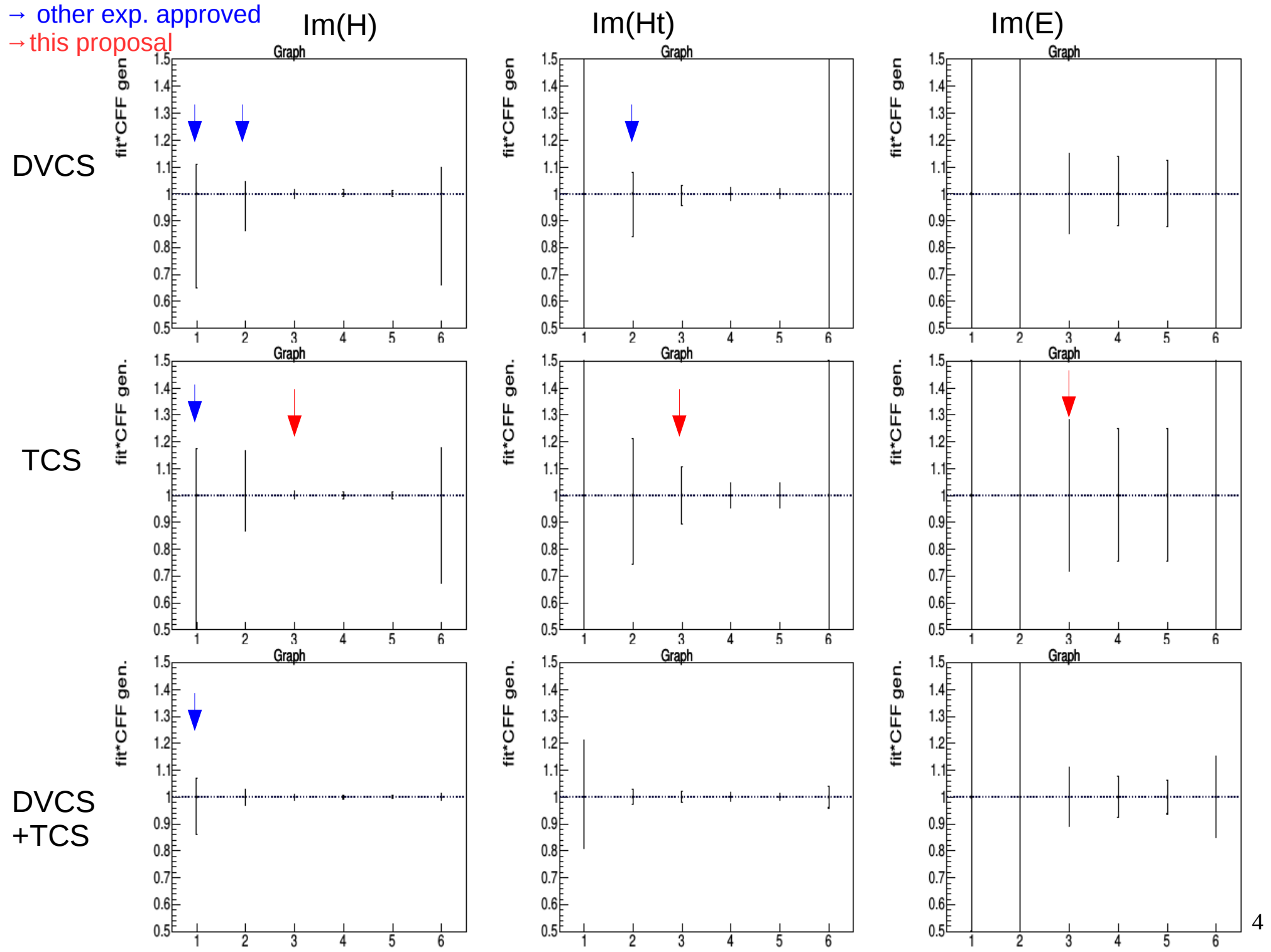
- Expected stat errors x-sec: 2% to 5% in each 16 bins in φ before polarization rescaling ⇒ for fit here, assume total errors 5% on σ and 7% on Δσ

- Fit with 7 independent CFF on pseudo-data, VGG model, LO/LT DVCS and TCS, using MINOS with χ², systematic studies with smearing on starting point to account for correlations, limit of extracted coeff= [-5 , 5]. Extracted: "fit"*generated CFF coefficient.

Table legend: - approved / running - conditionnaly approved / future - proposed

set of observables	DVCS	TCS	DVCS+TCS	independent obs DVCS/TCS/both
1) $\sigma + \Delta\sigma_{LU(\odot U)}$	Hall A, B, C	Hall A, B, C	A, B, C	2 / 2 / 2
2) $\sigma + \Delta\sigma_{LU(\odot U)} + \Delta\sigma_{UL} + \Delta\sigma_{LL(\odot Z)}$	Hall B	no	no	4 / 4 / 4
3) $\sigma + \Delta\sigma_{LU(\odot U)} + \Delta\sigma_{UT}$	cond. Hall B	Hall C	no	4 / 4 / 4
4) = 2) + 3) $\sigma + \Delta\sigma_{LU(\odot U)} + \Delta\sigma_{UL} + \Delta\sigma_{LL(\odot L)}$, $\Delta\sigma_{UT}$	cond. Hall B	no	no	6 / 6 / 6
5) = all spin $\sigma + \Delta\sigma_{LU(\odot U)} + \Delta\sigma_{UL} + \Delta\sigma_{LL(\odot L)} + \Delta\sigma_{UT} + \Delta\sigma_{LT(\odot T)}$	no	no	no	8 / 8 / 8
6) DVCS: $\sigma + \Delta\sigma_{LU} + \Delta\sigma^{\pm}$ TCS: $\sigma + \Delta\sigma_{\odot U} + \Delta\sigma_{LU}$	no	Hall D (high luminosity)	-	3 / 3

→ other exp. approved
→this proposal



1. σ+BSA, 2. σ+BSA+long, 3. σ+BSA+trans., 4. σ+BSA+long.+trans., 5. σ+all spin, 6. σ+beam+Lbeam or charge

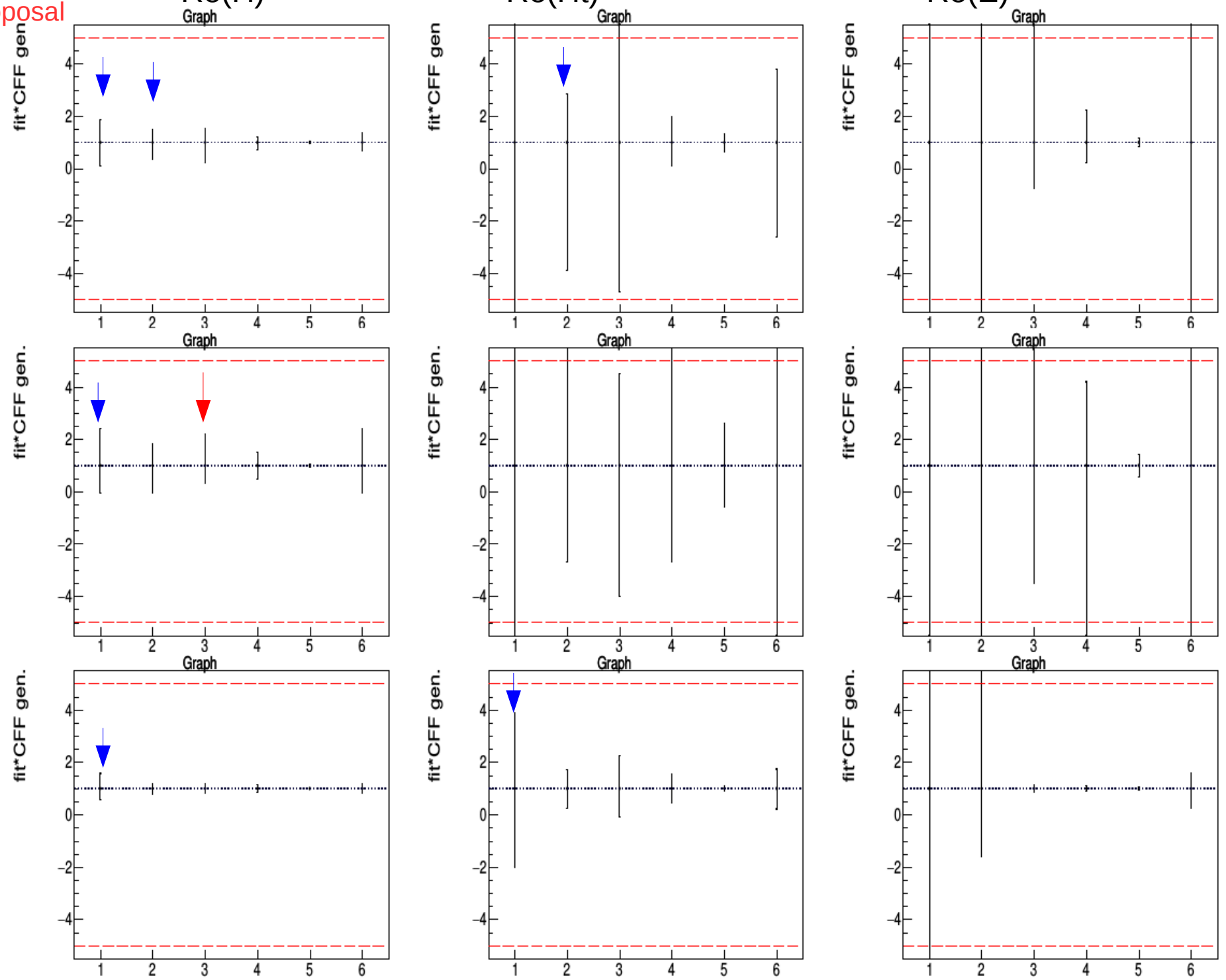
→ other exp. approved
→this proposal

Re(H) Re(Ht) Re(E)

DVCS

TCS

DVCS +TCS



1. σ+BSA, 2. σ+BSA+long, 3. σ+BSA+trans., 4. σ+BSA+long.+trans., 5. σ+all spin, 6. σ+beam+Lbeam or charge

Summary of the physics case

• TCS transverse target spin asymmetries are sensitive to Im part of amplitudes as well as beam spin asymmetry. Cross section sensitive to both Im and Re. Expected constrain on Im(CFFs).

• Azimuthal dependence of polarized cross sections $\propto \sin(\varphi \pm \varphi_S)$ with φ = lepton pair plane vs reaction plane (γ, P, γ^*) and φ_S = target spin vs reaction plane.

• Definition, **at fix φ_S: $\Delta\sigma(\varphi) = \sigma^{\uparrow}(\varphi, \varphi_S) - \sigma^{\downarrow}(\varphi, \varphi_S)$**

• 2 independent $\Delta\sigma_{UT}$ by fitting 4 sets of 2 orthogonal asymmetries: 0°/90°, 22.5°/112.5°, 45°/135°, 67.5°/157.5°. For presented results: fit 0°/90°.

• In total, experiment brings **4 independent observables in TCS: σ, $\Delta\sigma_{\odot U}$, $\Delta\sigma_{UT}$ (x2)**.

• **Fit results**:

Im(H), Im(Ht), Re(H): well constrain thanks to 4 independent obs. Level of DVCS. Combination and/or comparision possible with DVCS (assuming same uncertainties on DVCS and TCS)
⇒ check of GPD universality with H,
⇒ reduction of errors ~ factor of 2 with combination

Im(E): ~30% error on extracted coeff in presented example **⇒ unique with this experiment**

• **Conclusion regarding physics:**

Proposed experiment will bring unique constrains on Im(E). It will allow to demonstrate GPD H universality by comparison of TCS and DVCS results. Thanks to 4 independent observables for the fits, the precision on fit results on TCS side could be ~10x better than already approved experiments. In combination with DVCS in "global" DVCS+TCS fits, uncertainties on CFF "known" from DVCS can be improved up to a factor of 2. DVCS+TCS fits with new independent constrains on Im(E) will also allow for better constrains on most CFF thanks to correlations.

BACKUP

TCS with transversally polarized proton

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

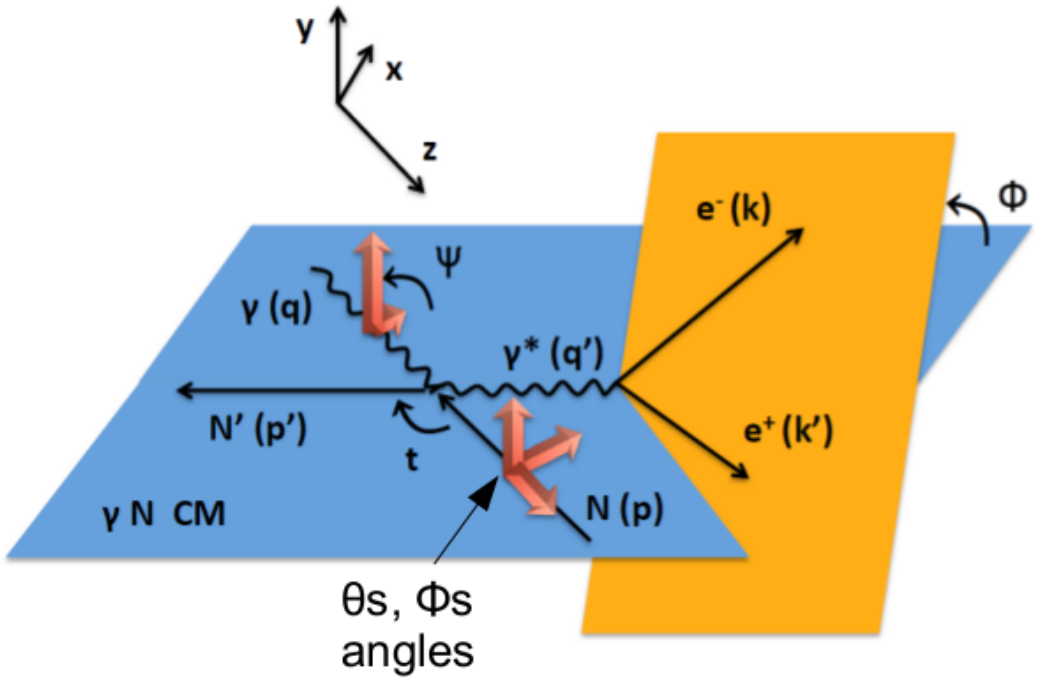
Choice: 3 kinematics (ξ, t, Q'^2), 3 angles (φ_{CM}, θ_{CM}, φ_S)

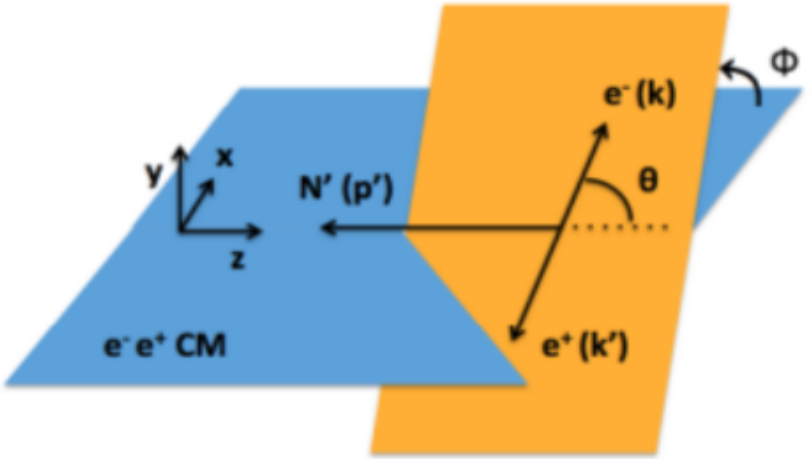
Transversally polarized target: θ_S=90°, eventual corrections at % level if small rotation of axis

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

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

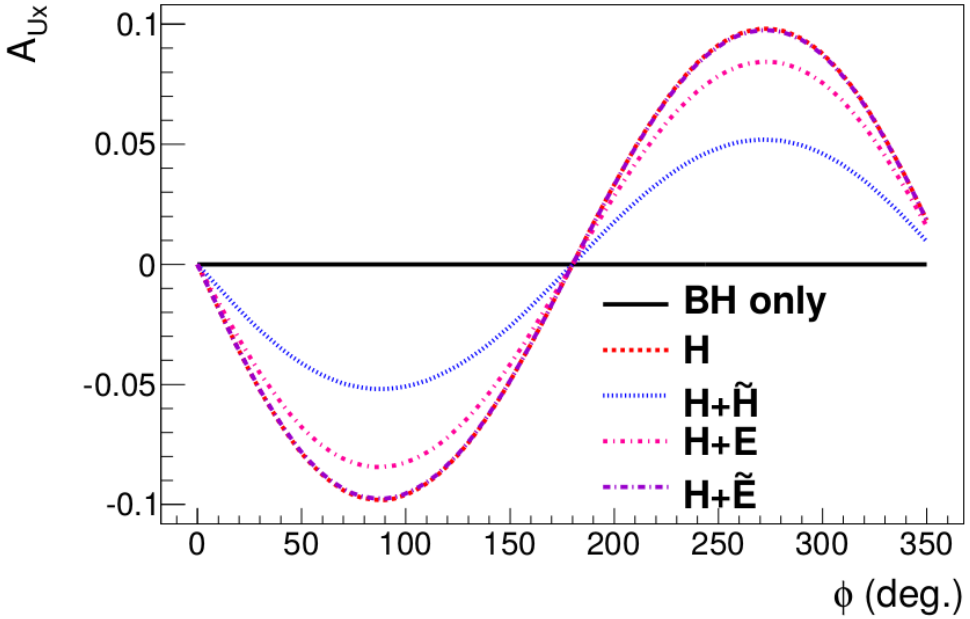
$A_{\odot T}$ = double beam (circular) and target (transverse) spin asymmetry

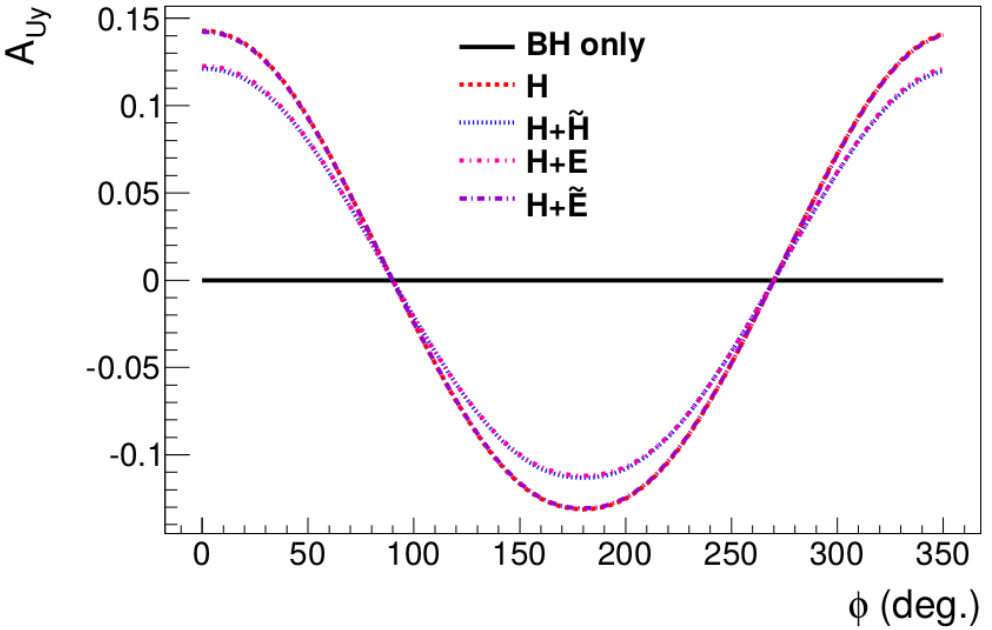




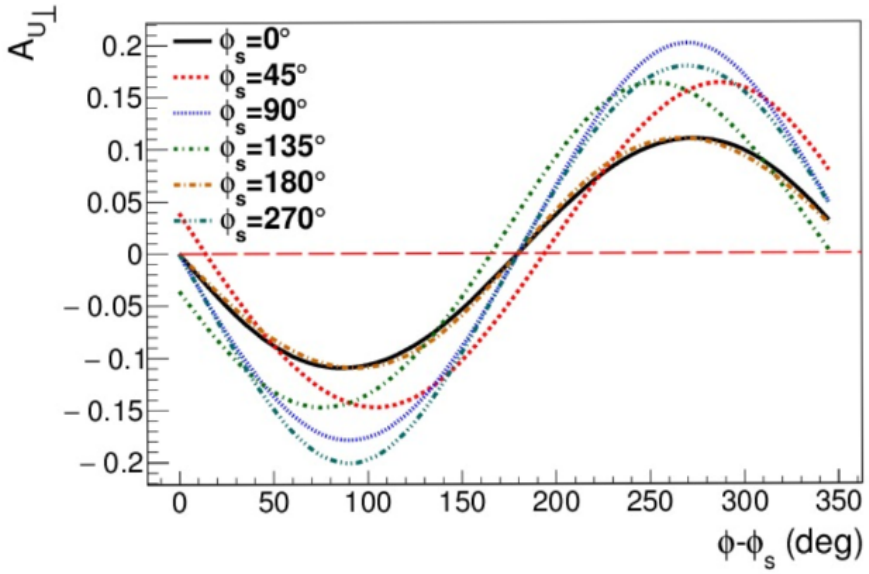
Observables: calculated

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

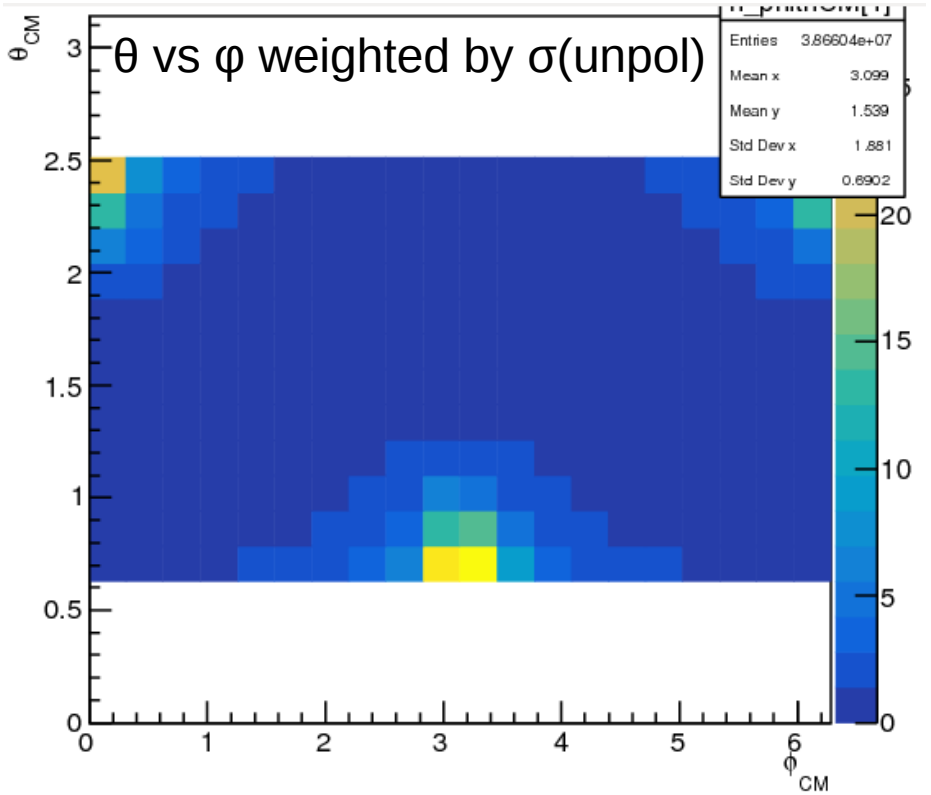




Approach 1-bis (single TSA): iterative CFF extraction at various values of 2 orthogonal φ or φ_S

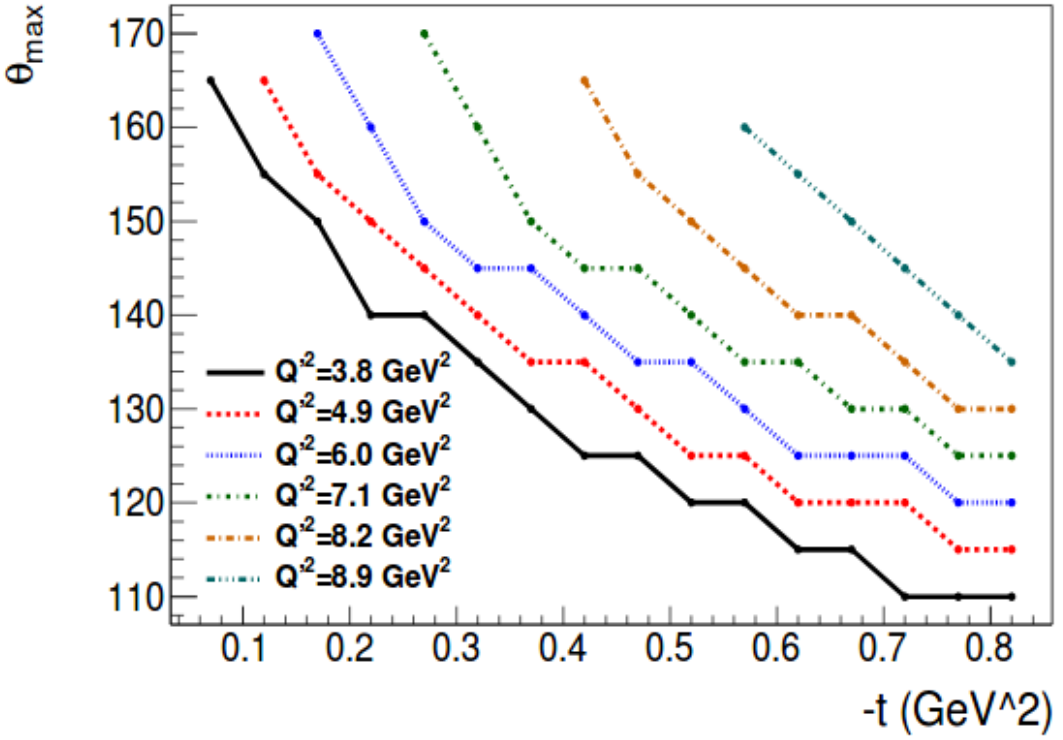


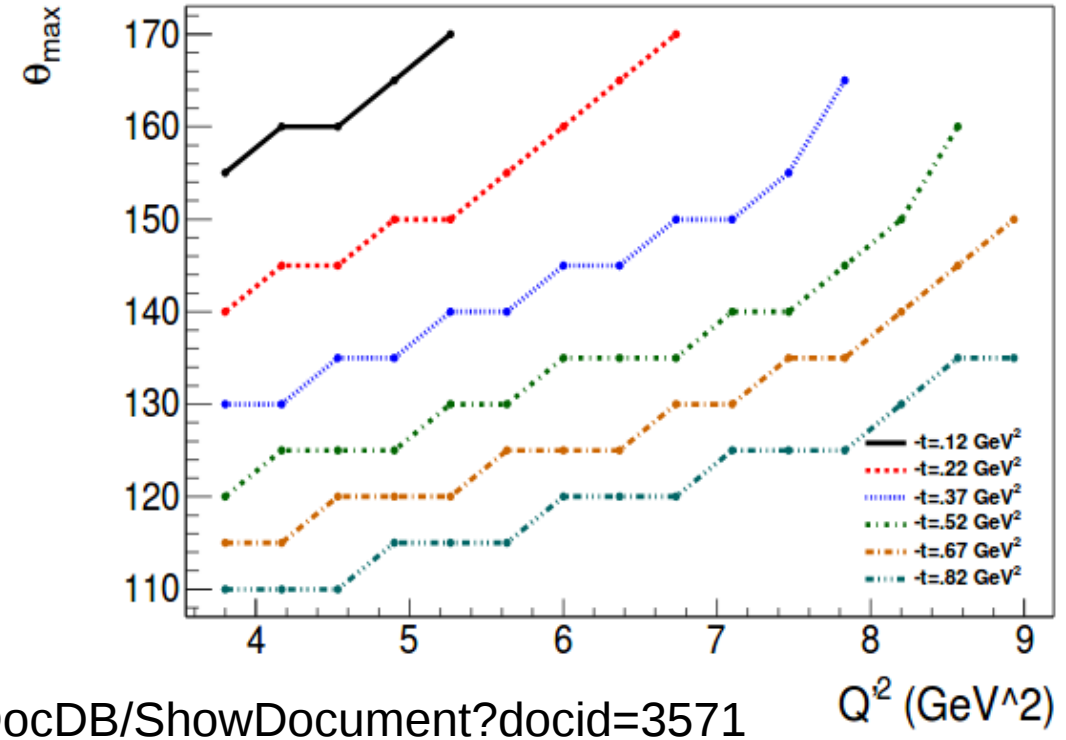
2D kinematic cut



BH peaks in yellow, mostly out of acceptance (small θlab for one lepton, low momentum for the other one) →cut as a function of (E, Q'², t)

2 figs on right: θmax cut, all what is above is rejected in case φ=0±30° or φ=180°±30°



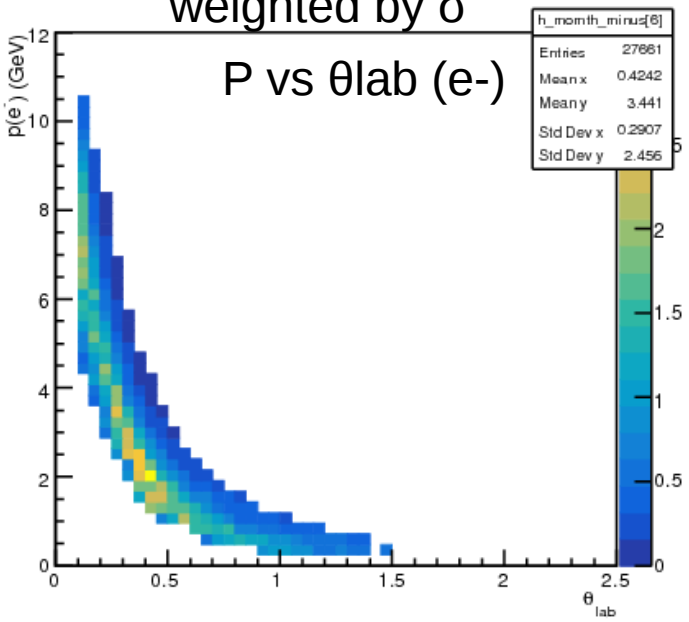


cf note: https://halldweb.jlab.org/doc-public/DocDB/ShowDocument?docid=3571

Lab frame correlation (without deflection)

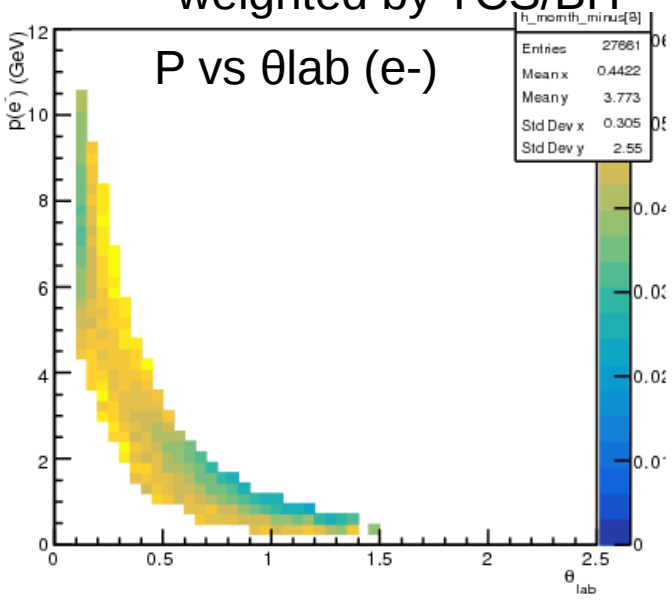
weighted by σ

P vs θlab (e-)

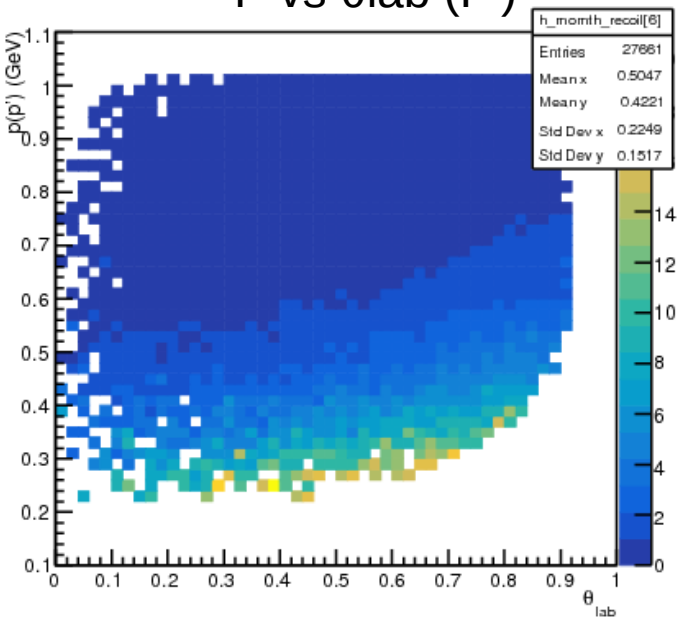


weighted by TCS/BH

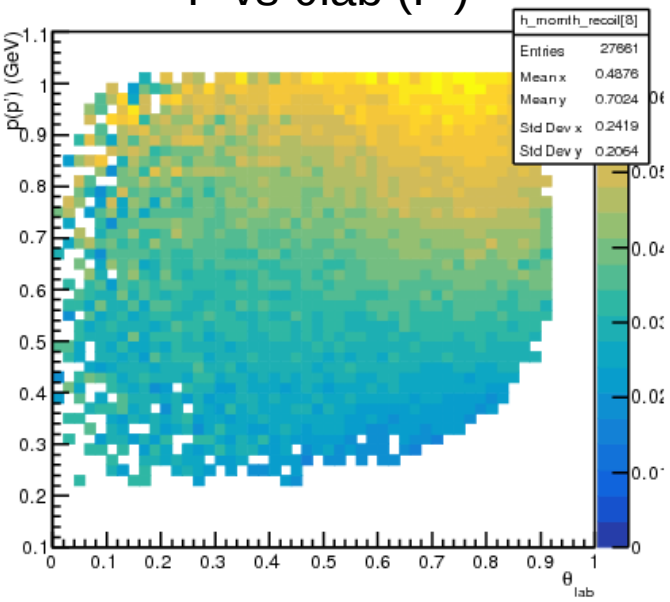
P vs θlab (e-)



P vs θlab (P')



P vs θlab (P')



yellow: most of the counts

yellow: higher sensitivity to TCS

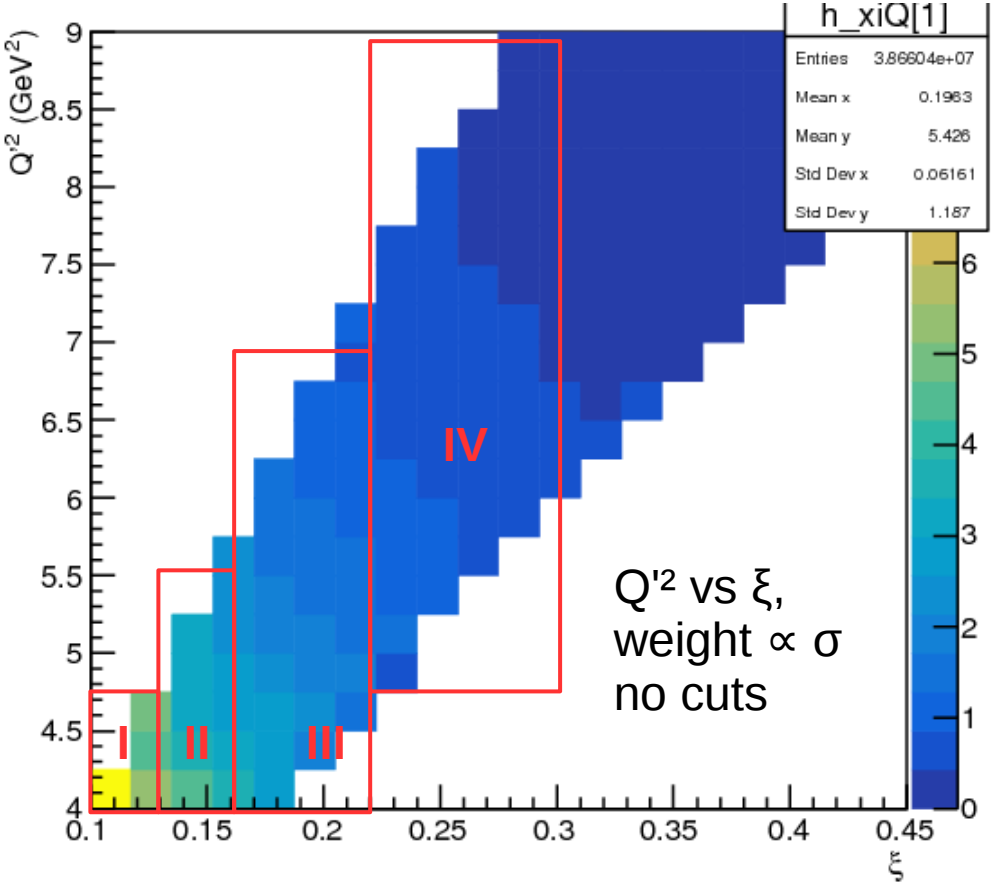
Optimization with balance between error bars, TCS and size of asymmetries

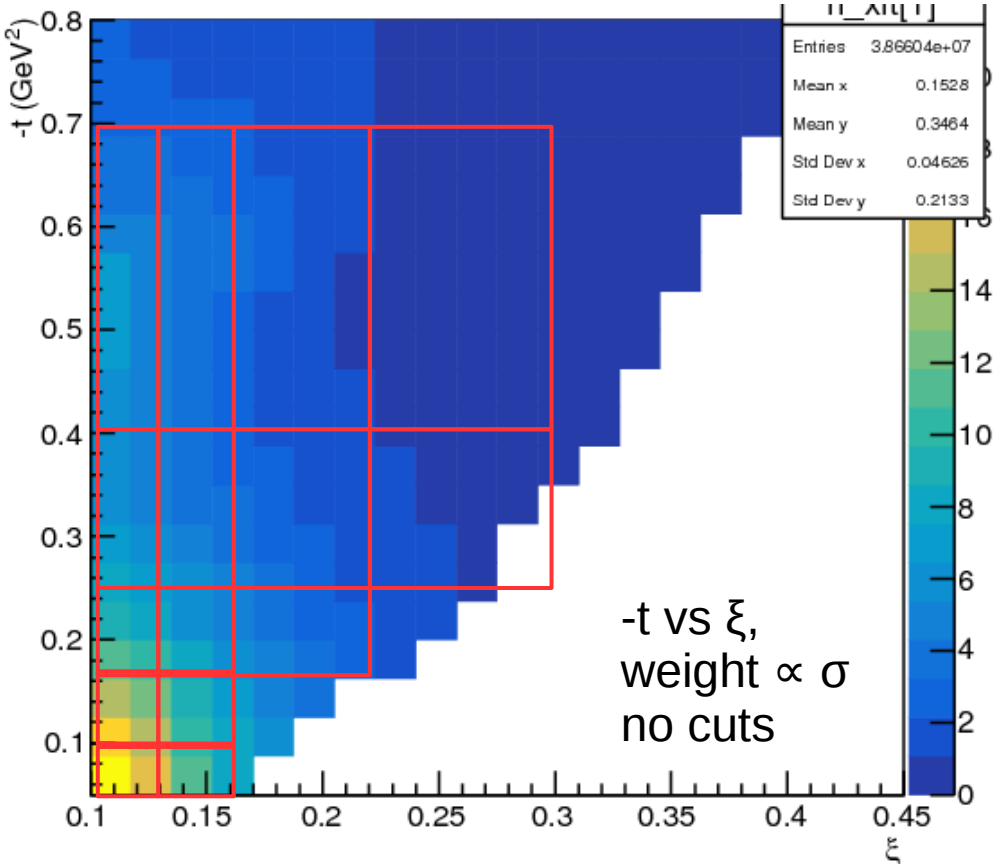
Choice of binning

Proposed binning for current studies, will be updated after setup optimization and more studies

Important for GPDs and target spin asymmetries: thin ξ and t bins

Option for unpolarized cross section and beam spin asymmetry: $Q'^2 \rightarrow$ not in presented approach





4 bins in ξ, Q'^2 (GeV²)

I) .1 <ξ<.13, 4<Q'^2<4.5
II) .13<ξ<.16, 4<Q'^2<5.5
III) .16<ξ<.22, 4<Q'^2<7
IV) .22<ξ<.3, 4.5<Q'^2<9

5 bins in -t (GeV²)

1) .04<-t<.1, 2) .1<-t<.17, 3) .17<-t<.25, 4) .25<t<.4 5) .4<-t<.7
1) .04<-t<.1, 2) .1<-t<.17, 3) .17<-t<.25, 4) .25<t<.4 5) .4<-t<.7
3) .17<-t<.25 4) .25<t<.4 5) .4<-t<.7
4) .25<t<.4 5) .4<-t<.7

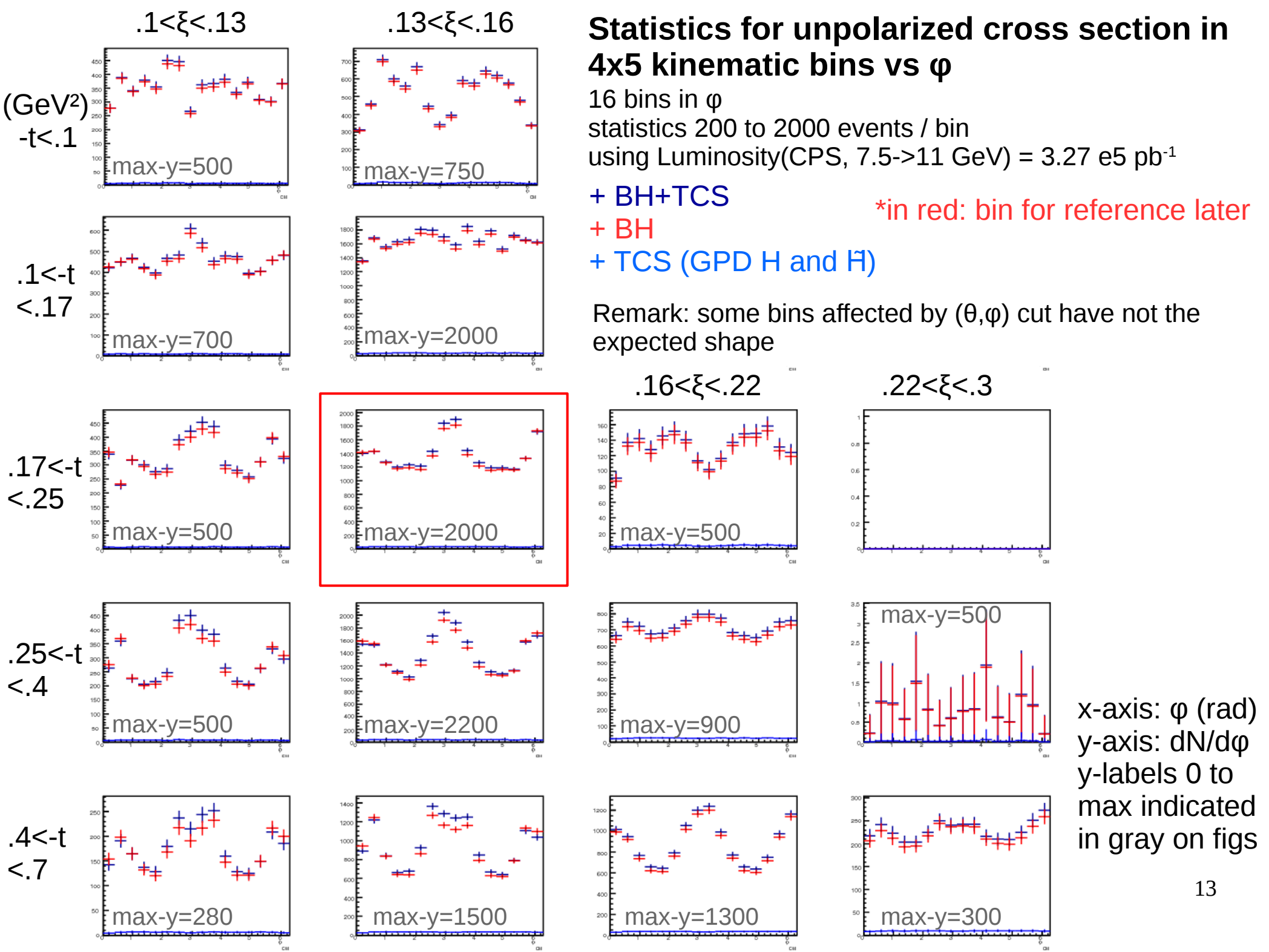
Statistics for unpolarized cross section in 4x5 kinematic bins vs φ

16 bins in φ
statistics 200 to 2000 events / bin
using Luminosity(CPS, 7.5->11 GeV) = 3.27 e5 pb^{-1}

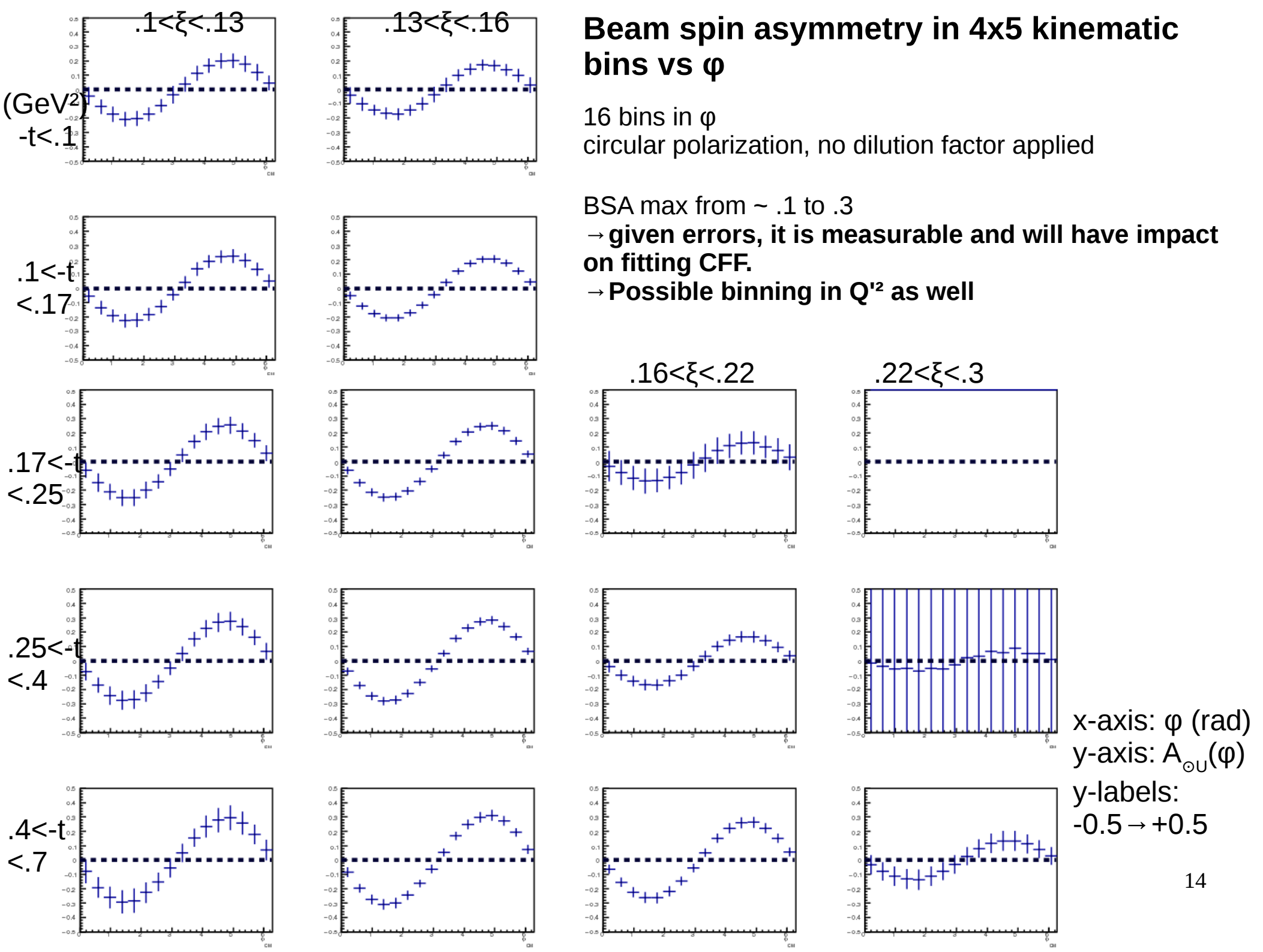
+ BH+TCS
+ BH
+ TCS (GPD H and Ħ)

*in red: bin for reference later

Remark: some bins affected by (θ,φ) cut have not the expected shape



x-axis: φ (rad)
y-axis: dN/dφ
y-labels 0 to max indicated in gray on figs



Beam spin asymmetry in 4x5 kinematic bins vs φ

16 bins in φ
circular polarization, no dilution factor applied

BSA max from ~ .1 to .3
→**given errors, it is measurable and will have impact on fitting CFF.**
→**Possible binning in Q'² as well**

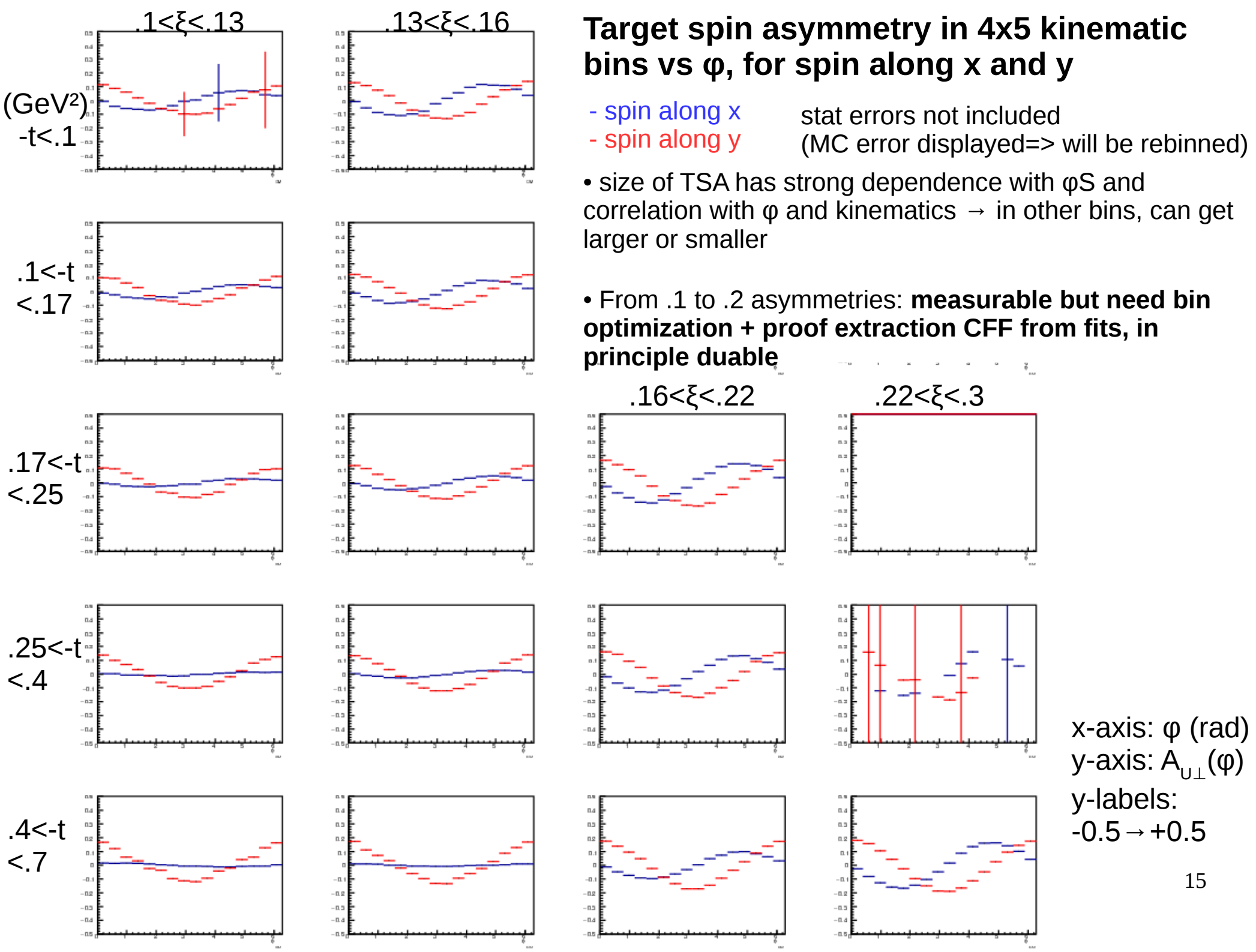
Target spin asymmetry in 4x5 kinematic bins vs φ, for spin along x and y

- spin along x
- spin along y

stat errors not included
(MC error displayed=> will be rebinned)

• size of TSA has strong dependence with φS and correlation with φ and kinematics → in other bins, can get larger or smaller

• From .1 to .2 asymmetries: **measurable but need bin optimization + proof extraction CFF from fits, in principle duable**



x-axis: φ (rad)
y-axis: $A_{U\perp}(\varphi)$
y-labels:
-0.5 → +0.5