NPS collaboration meeting – Feb. 16th, 2022

1) TCS in Hall C and impact for GPDs

2) Beyond DVCS & TCS:

how can we measure DDVCS and J/psi in Hall C with NPS

VT group : Deb Biswas (joining soon as a postdoc), Marie Boër, Brannon Semp, Erik Wrightson & new undergraduates (during spring 2022) Alexander Hamilton, Cesar Ibarra, Ge Liu, Nicholas Roush,Barbara Sanchez, Nathan Stroh

+ Vardan Tadevosyan, Alexandre Camsonne & many others

Presented by Marie Boër

TCS in Hall C and impact for GPDs

Experiment and goals : see Vardan's presentation, covering mostly everything

Here: discussing physics impact and potential extensions we explored in 2021

TCS transversely polarized & software work for PAC 50

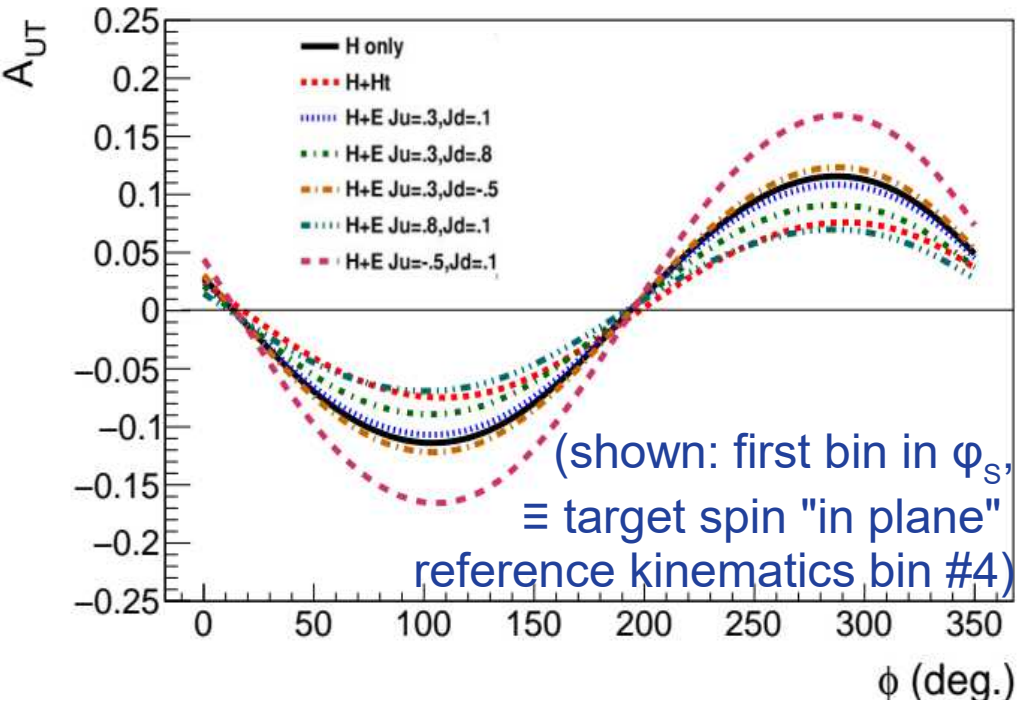
- Need of more realistic physics background simulations with fits of recent actual data
* clarifications asked by PAC48
* updated proposal will include « standard » analysis methods (as our PAC46 version) and background from fits on actual data rather than model
* in progress (Marie). Expected early April

- Update on CFF fits with more recent actual data
* requested by PAC48 and need of recent fits since new articles released (Hall B...)
* Brannon working on it with Marie to update past projections. Expected end of March

[see projections in Vardan's talk]

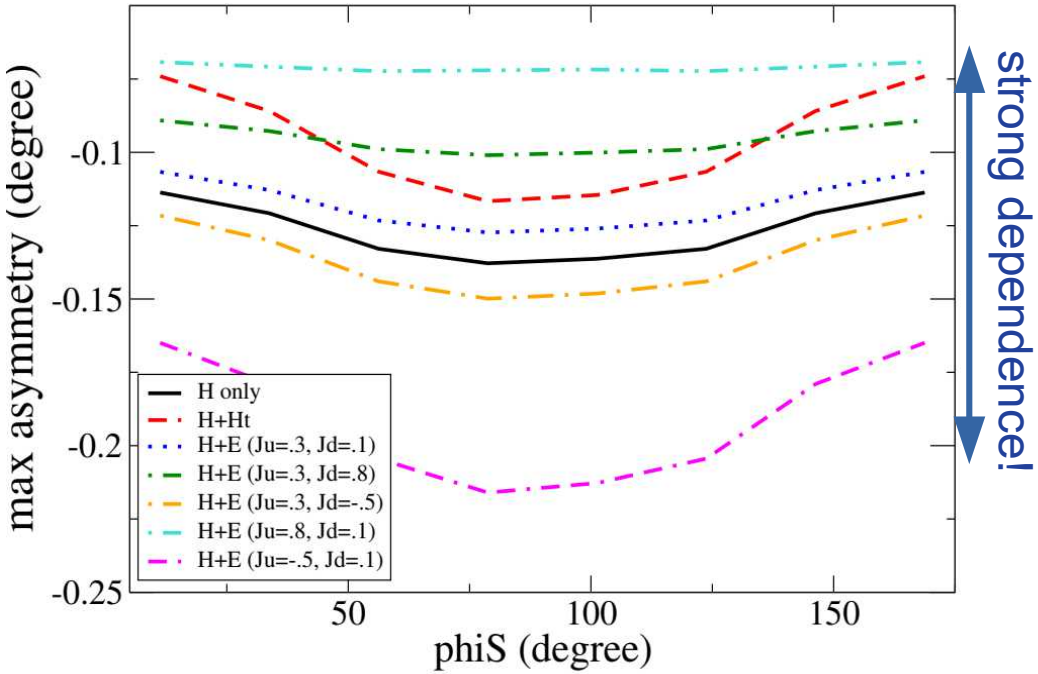
Transverse target spin asymmetry “as will be measured in Hall C”

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)



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**

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

What is needed beyond the proposed measurement for global GPD fits and interpretations of TCS data ?

*** Recent Hall B measurement**

- Not covering the same kinematic region, and low statistics = hard to use in our fits

*** Need of precision measurement for unpolarized cross section**

*** Need of proton + neutron** for flavor separation and extraction of Hu, Hd, for universality studies and comparison vs DVCS

2 options, both important

1) Extension of proposed experiment with 10 days unpolarized off NH3
- Needed for interpretation of polarized data and studies of dilution factor
- Can't be interpreted for precision measurement off proton

2) Dedicated precision LH2+LD2 measurement for GPD H
- need for high statistics and precision
- estimation 10 days each target ?

+ complementary polarized measurements

Work presented by Camille summer 2021

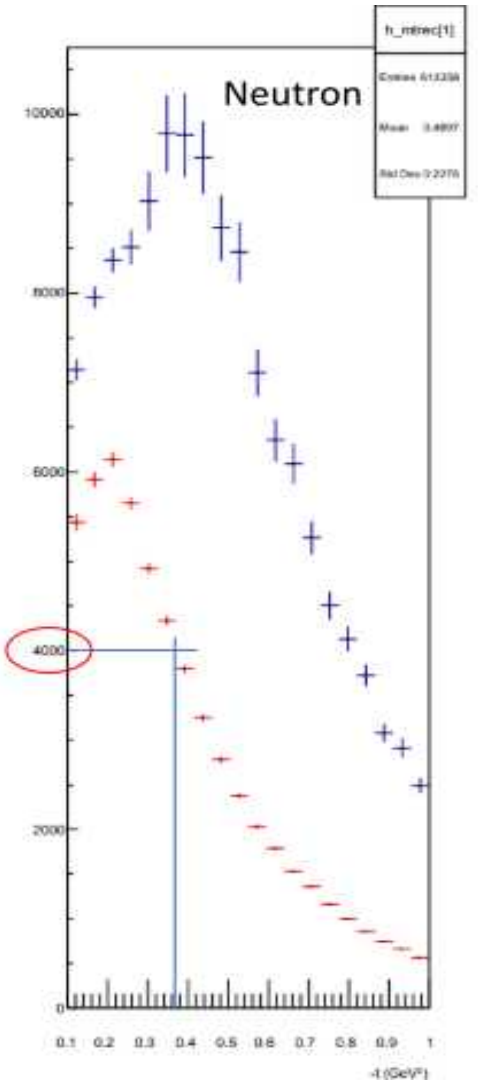
Number of reconstructed events measured for the TCS reaction depending on $-t$ weighted by the cross section

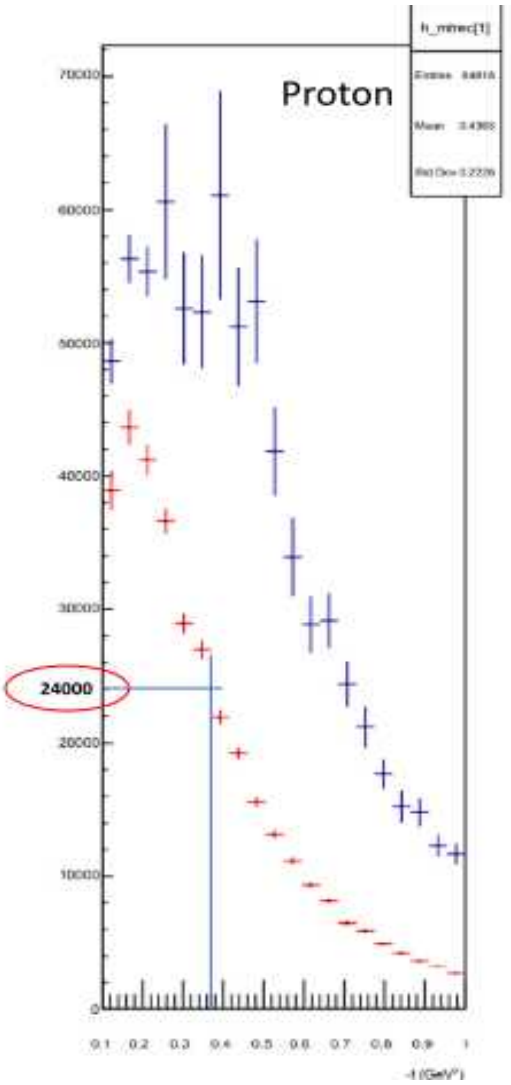
The data are normalized.

Difference between proton and neutron:

- Measured : x6

(one xi, Q2 bin)

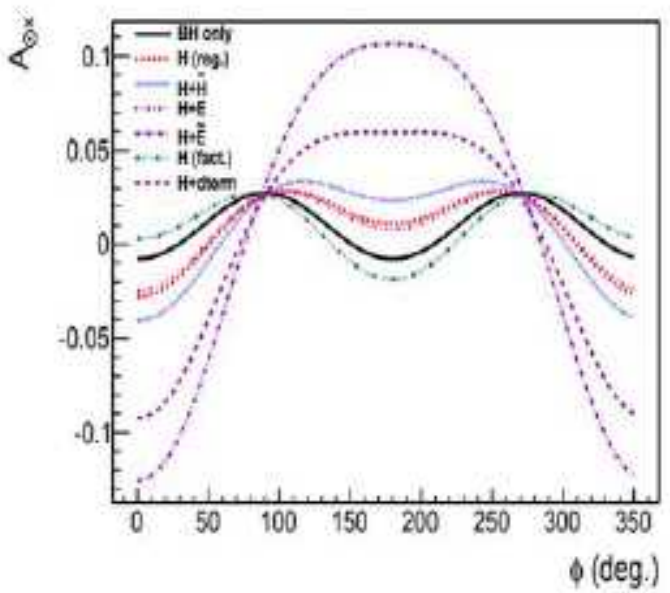


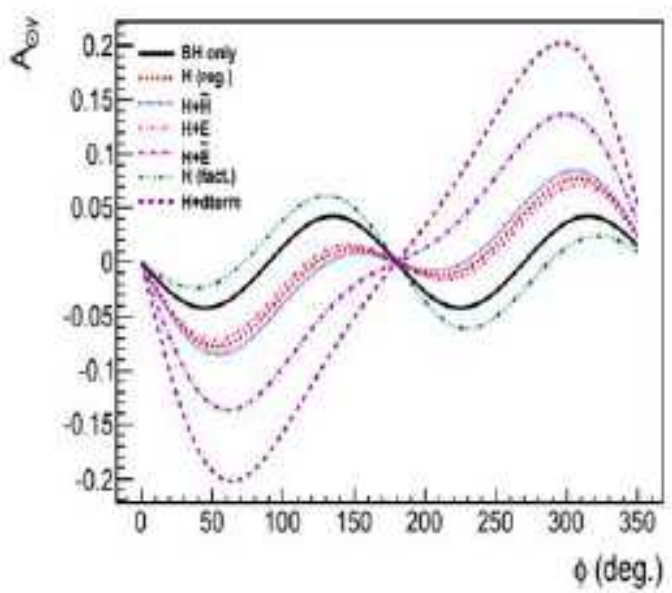


Camille's projection demonstrate
1) feasibility of measuring unpolarized proton TCS off LH2 (in terms of counting rates & impact)
2) feasibility of measuring unpolarized neutron TCS off LD2

Still to do : realistic MC with relevant targets + magnetic field

Run group proposal in preparation with Brannon Semp to be submitted at PAC50 or later (addition to single target spin asymmetries)
- credit for plots : Brannon Semp from his last presentation early 2022





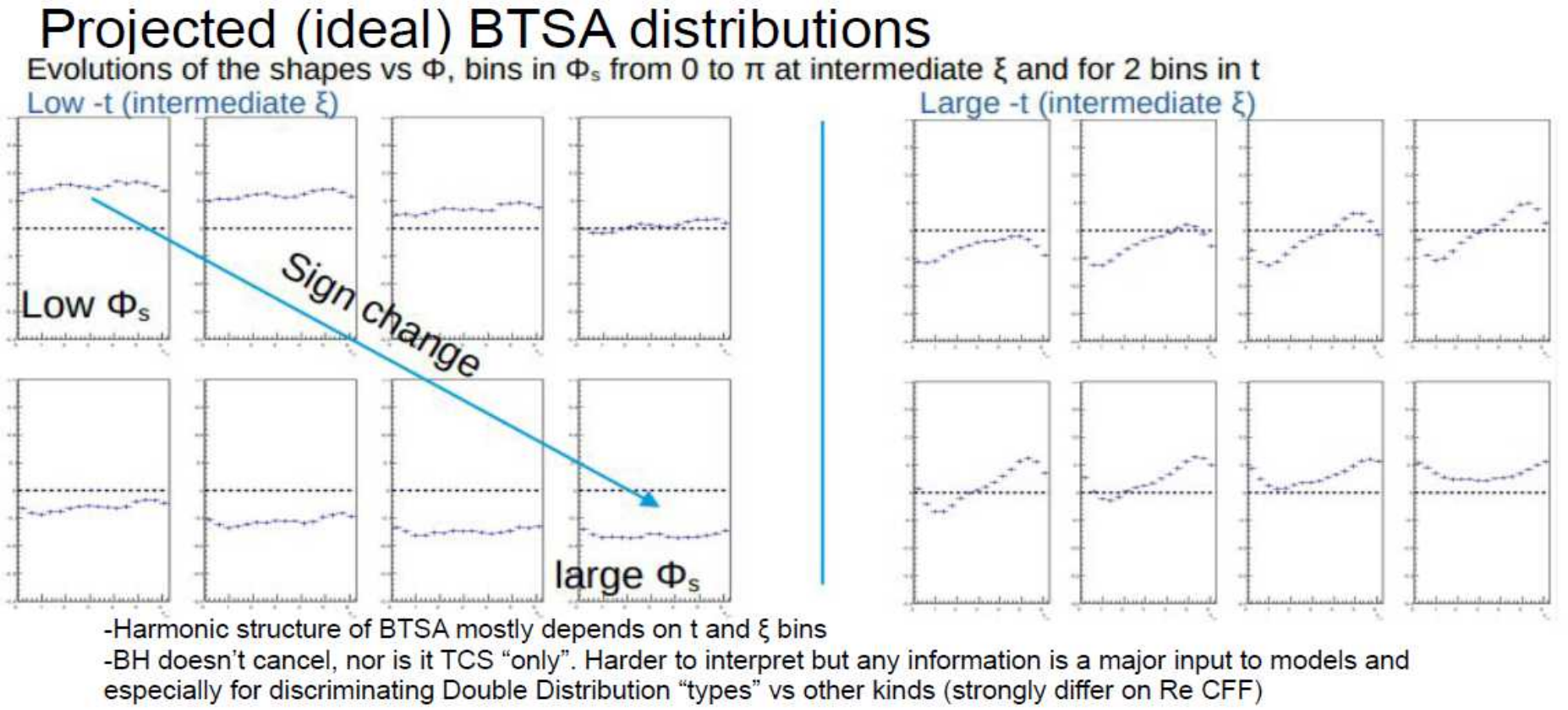
Φ=0° Φ=90°

Projection with various model's versions (different GPDs...)

We have basically no constrain on real CFFs and any measurement will have a strong impact

Not proposed in main proposal to keep it « simple » but data will be there
A bit more difficult to analyze and interpret

BTSA projections using same bins as for TSA analysis



Showing that measurement is very sensitive to TCS, despite high BH rate
+ very sensitive to GPD parametrization

== fitting these data will bring constrains

From Brannon

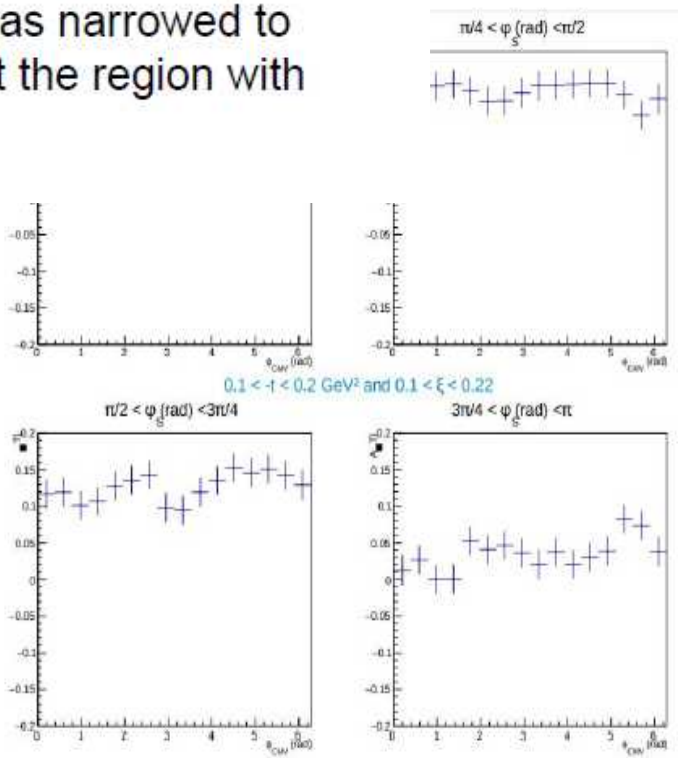
BTSA projections using same bins as for TSA analysis

Because of the large uncertainty associated with BTSA, larger bins were used then for TSA

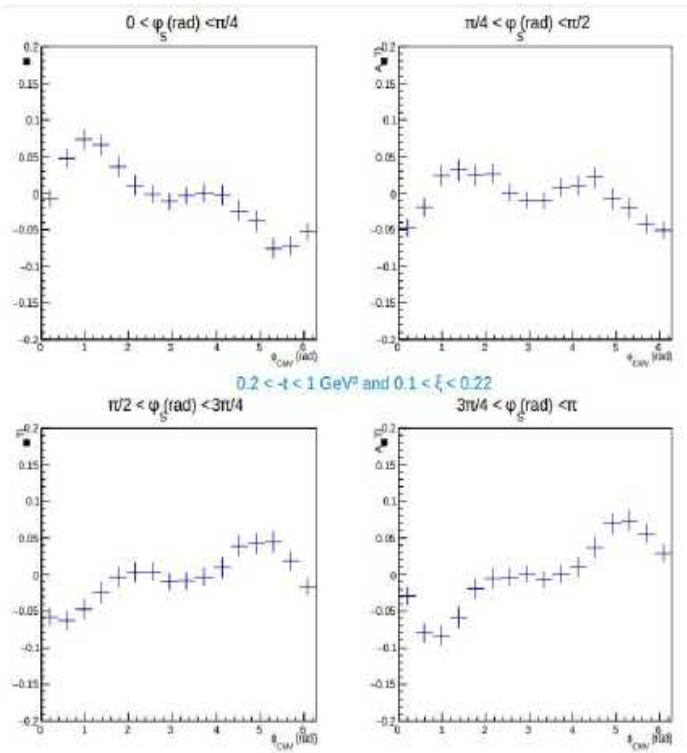
New binning still shows the evolution of harmonic structure with change in t and ξ

Instead of the 7 kinematic bins in (t, ξ, Q'^2) and 16 bins in Φ_s used for TSA, 3 kinematic bins in (t, ξ) and 4 bins in Φ_s were used. The same acceptance cuts were also used, with the exception of θ which was narrowed to [70°,110°] in order to target the region with more TCS

with New Binning



Low -t, low ξ



Large -t, low ξ

From Brannon

Summary

- Currently improving physics case and realism of analysis projections for proposed TCS experiment (our main priority)

- Studies with students to complement the TCS program in Hall C, with other measurements we need to interpret data in terms of GPDs, improve models and have a significant data set that can be compared to DVCS for universality studies + have impact in GPD models

* Brannon currently working on run-group proposal with BTSA + starting with fits

* Previous work from Camille for unpolarized LH2/LD2

* Other extensions in progress, but no plan to submit this year (lack of time)

- VT group also want to work on technical aspects

Beyond DVCS & TCS:

how can we measure DDVCS and J/psi in Hall C with NPS

* with minimal extensions from already approved experiments

* with dedicated setup

Goal :

- coming to a realistic setup for measuring DDVCS in Hall C
(Marie working on it, Deb joining soon)

- preparing a LOI to measure J/psi transversely polarized as extension of TCS experiment
(Erik Wrighton working on it)

J/psi : will soon be presented by Erik

- Erik updated my generator and work done by Tyler over the summer
Now has realistic projections for J/psi at JLab
Currently working on the analysis

To do : realistic MC

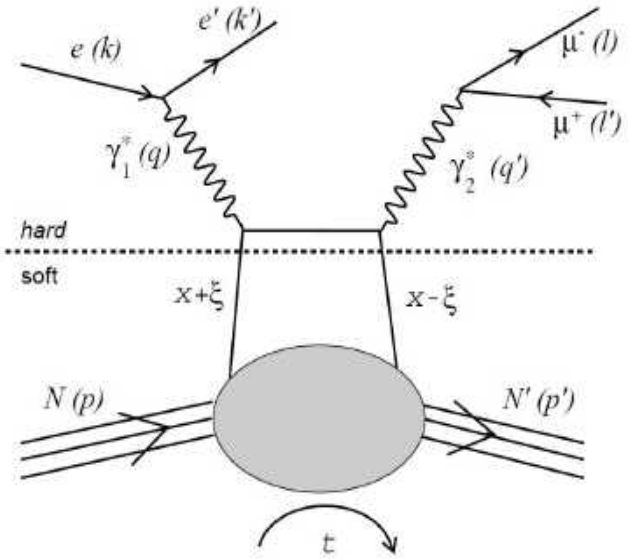
Idea :

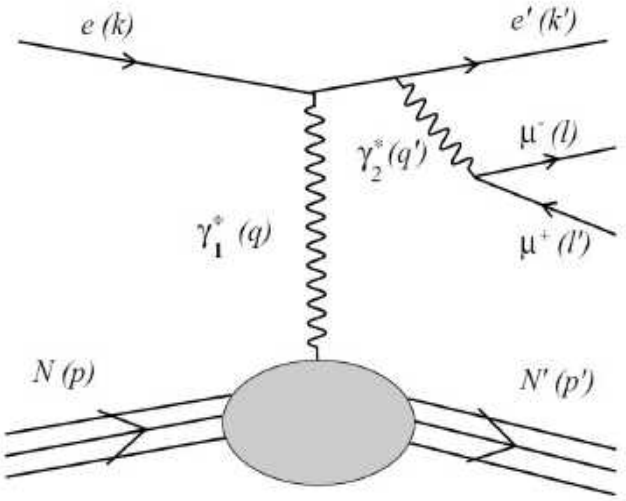
- using almost the same setup as for TCS experiment
- need to use the new magnet, due to larger scattering angles

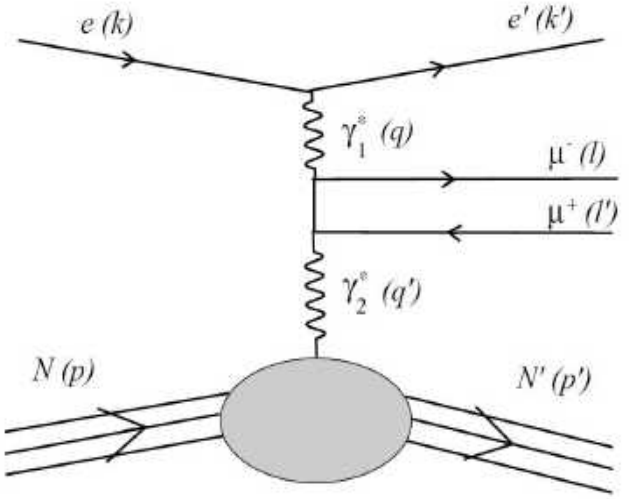
- physics motivation
* near threshold mechanisms
* gluon exchanges (asymmetries highly impacted)
* very few theoretical work on that topic for such energies, still working on it
& discussing with theorists
* GPD interpratation unclear

DDVCS

Unpolarized DDVCS. Below: Feynman diagram at leading twist/order for DDVCS & interfering BH







DDVCS
Access GPDs
$Q'^2 \neq Q^2$ & greater than 1 GeV^2
Depends on x, xi, t + evolution

BH "type I"
(behavior similar to DVCS one)

BH "type II"
(behavior similar to TCS one)

depends on Form Factors (t), calculable

- demonstrated that can't use setup availlable in Hall C for other experiments (too low statistics). Need of dedicated setup

Our goal / current work

- coming soon with realistic MC for 2 possible setup we are exploring

- prototype muon detector to be placed behind spectrometer

Why using NPS ?

- larger acceptance for electrons
- can't do with HMS/SHMS
- statistic and precision in principle ok (from toy MC) if starting from DVCS or TCS setups

2 options we are exploring

1) similar as DVCS experiment with extra muon detectors (+ shielding, dif trigger...), proton also detected

2) with 2 calo as TCS + muon detectors

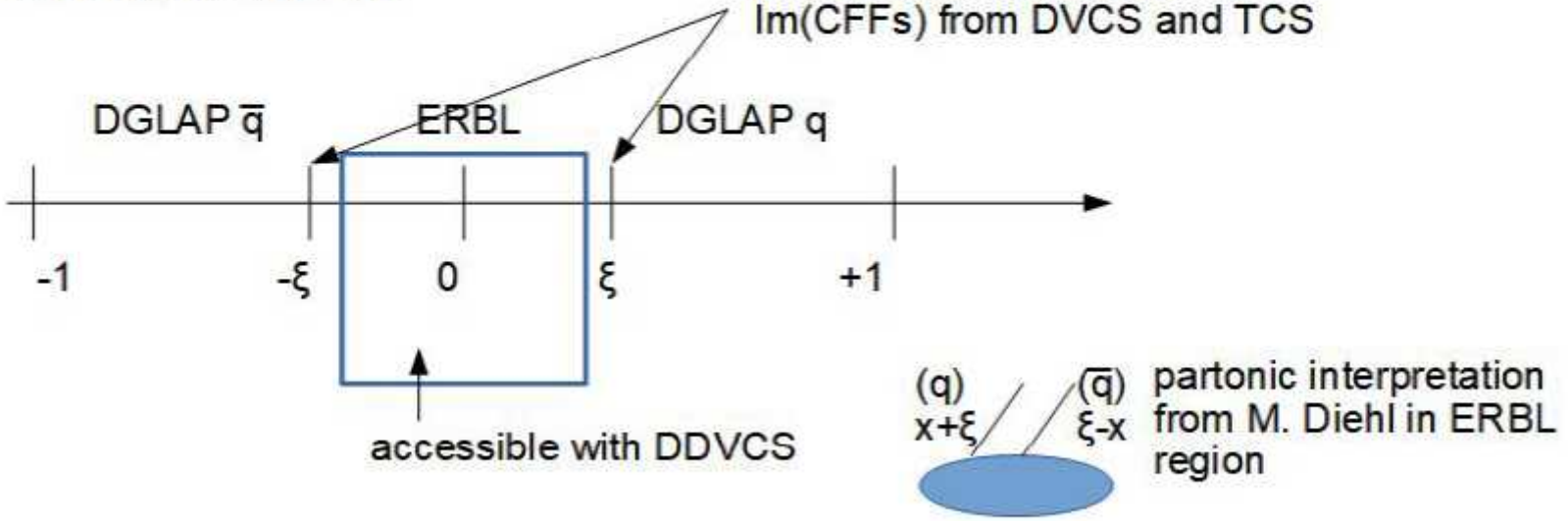
Currently
- physics case : OK, still need a bit of polishing
- MC : need to redo everything
- come with realistic projections
- need more manpower

Physics region for GPDs & impact beyond tomographic interpretations

$\xi > |\xi'|$: ERBL region; $\xi < |\xi'|$ DGLAP region

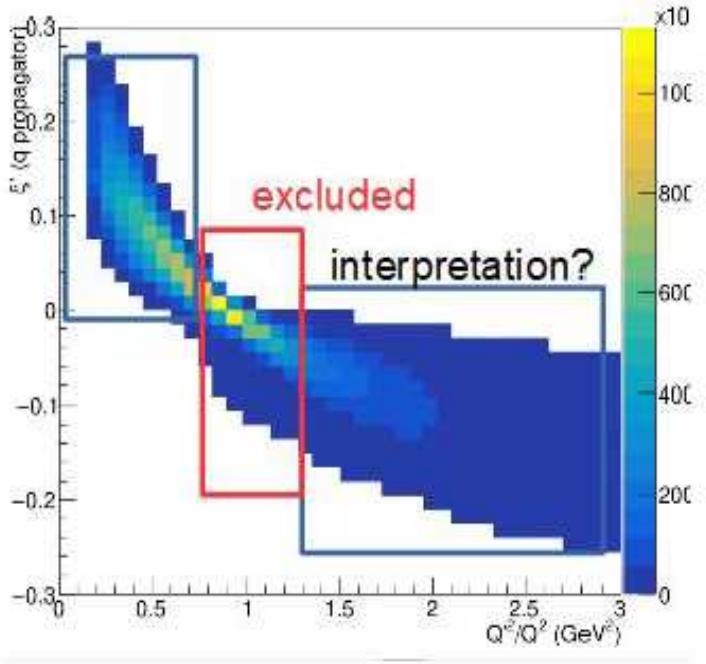
Quark propagator normalized to ξ at asymtotic limit: $(1-Q'^2/Q^2) / (1+ Q'^2/Q^2)$
→up to t/Q^2 factor, we play with respective value of Q^2 and Q'^2 to go "out of diagonal" for GPD
→neglecting t, we are restricted to $\xi > |\xi'|$

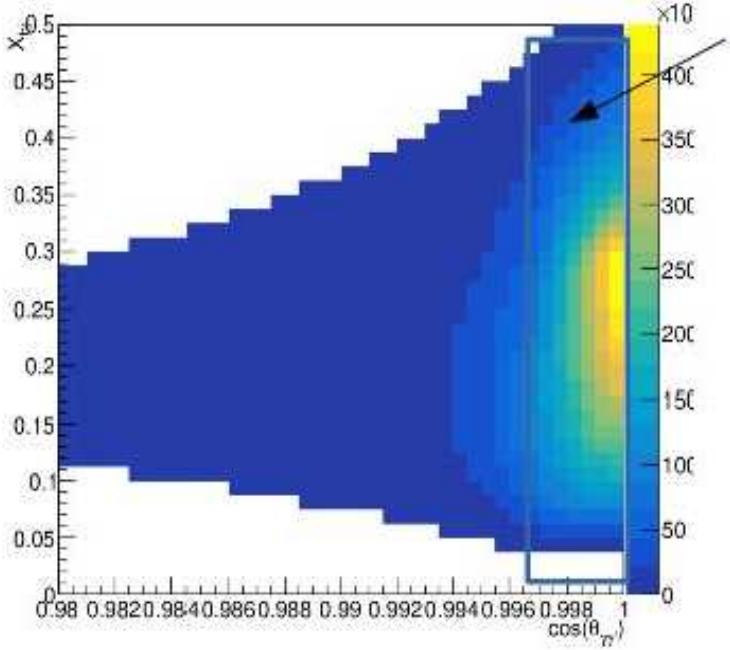
M. Diehl's representations:

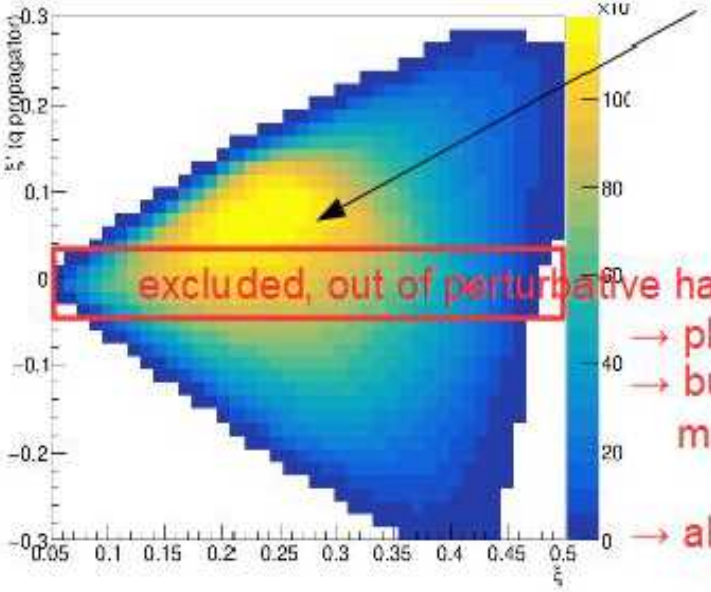


need to map this region for GPD models and extrapolations needed
for tomographic interpretations at $\xi=0$; GPD extrapolated from $\xi \to 0$

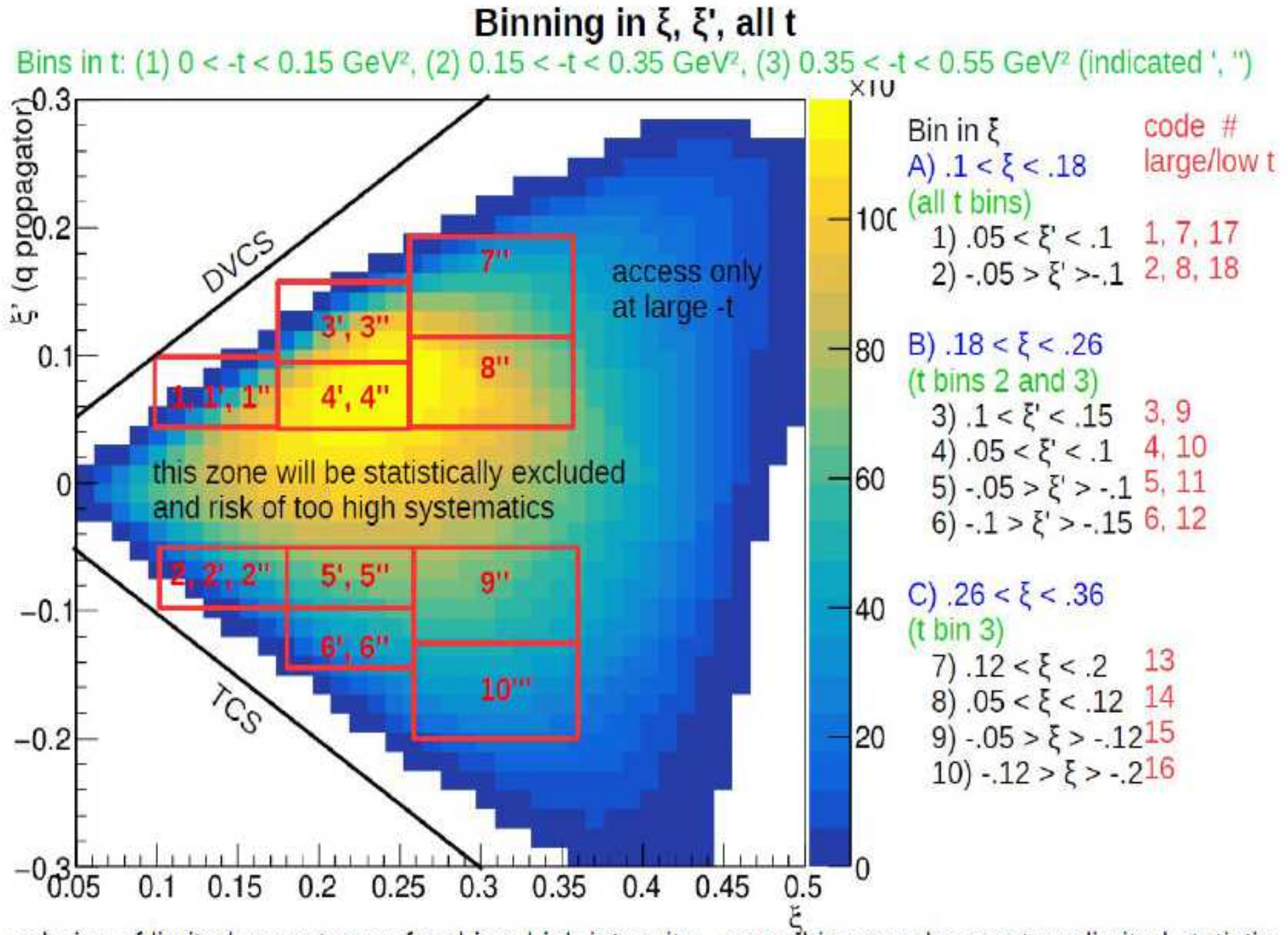
Kinematic region we access with Hall C and setups we are looking for





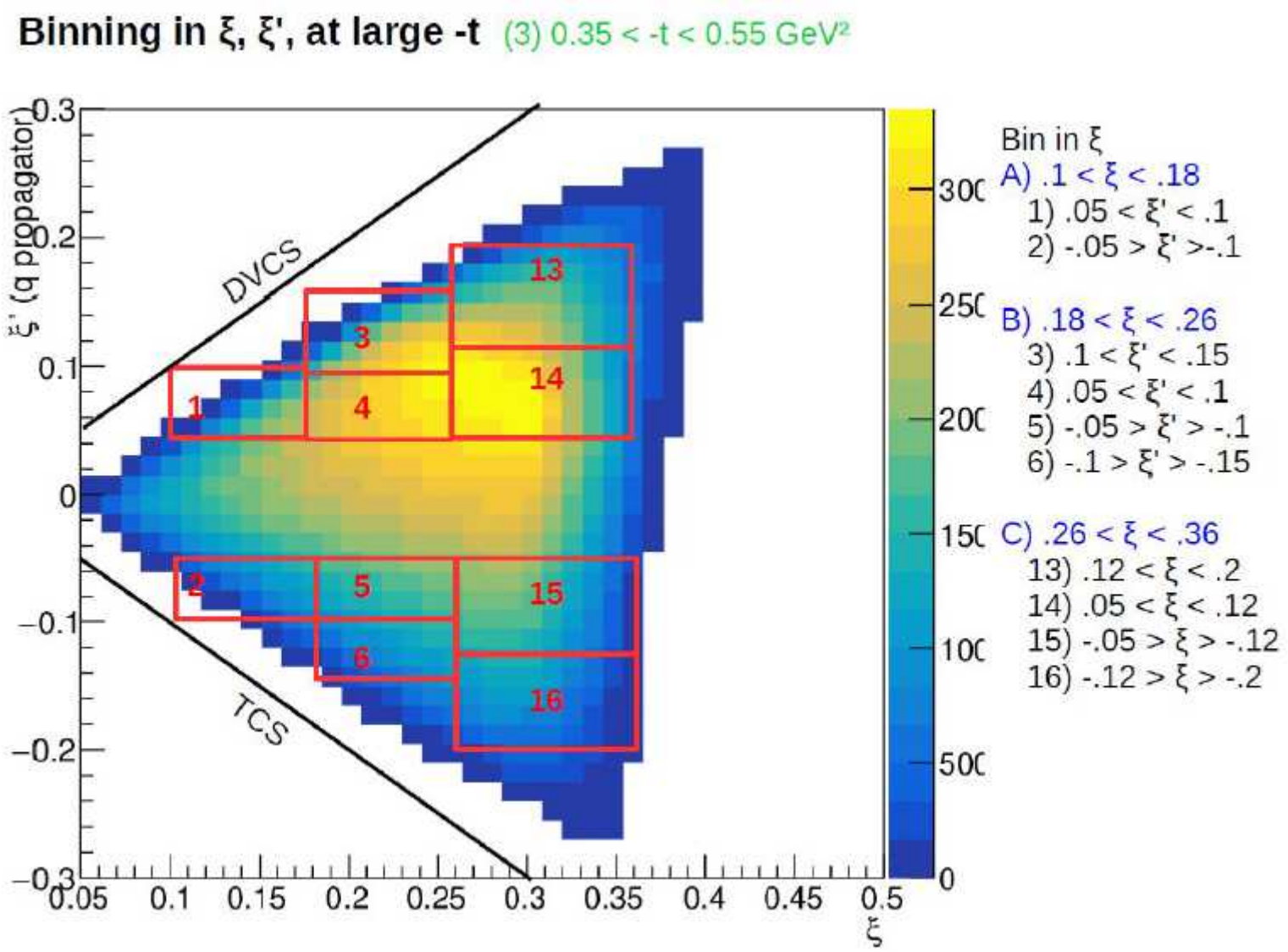


Kinematic region we access with Hall C and setups we are looking for



- choice of limited acceptance: few bins, high intensity → some bins may be empty or limited statistic
- no binning in Q^2 and Q'^2: the above selections are cutting bands in the Q^2 vs Q'^2 distribution

Kinematic region we access with Hall C and setups we are looking for



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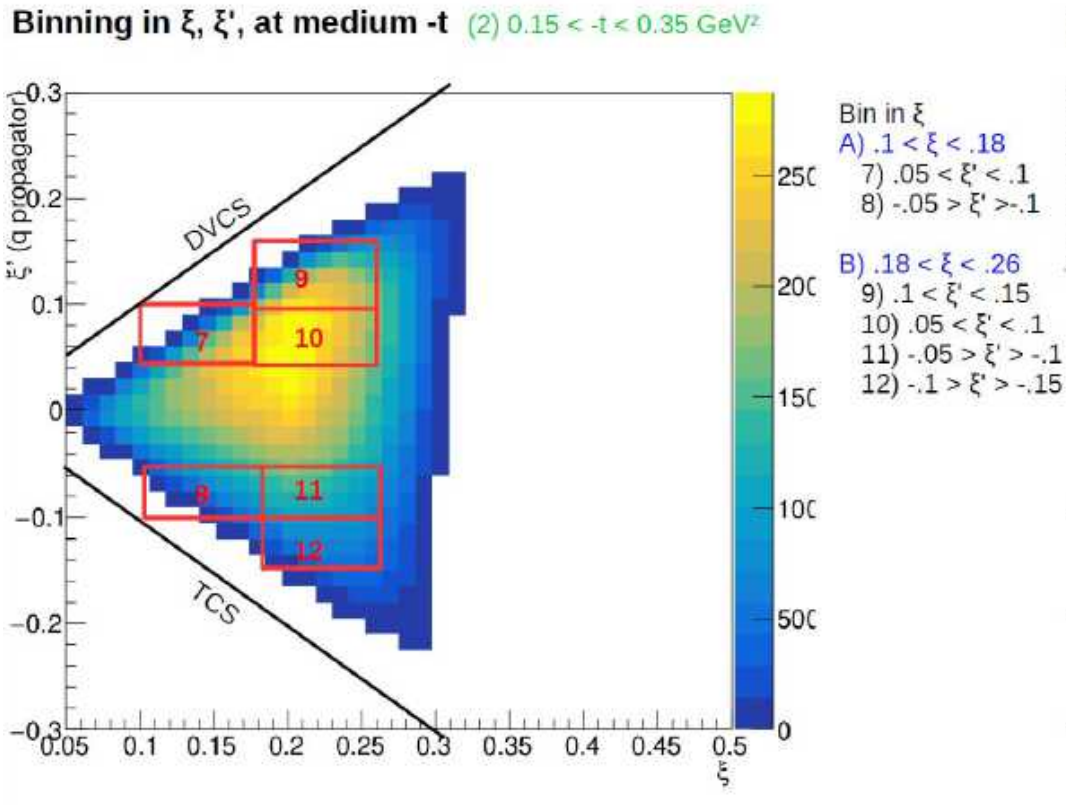
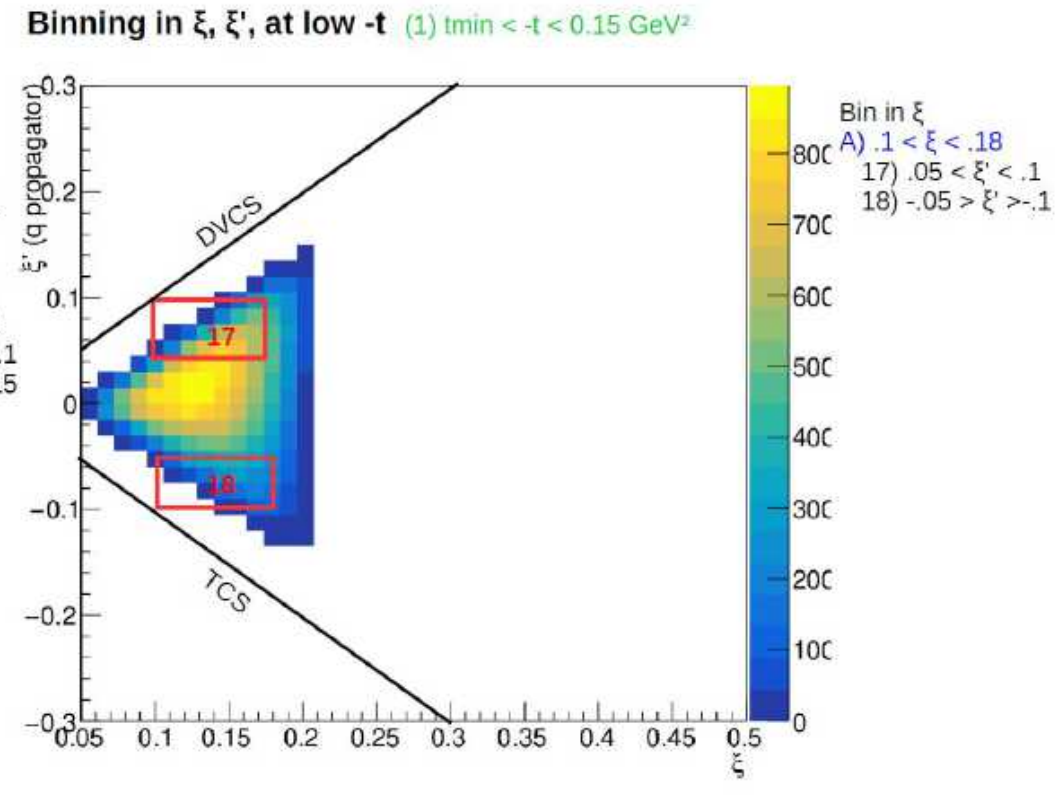


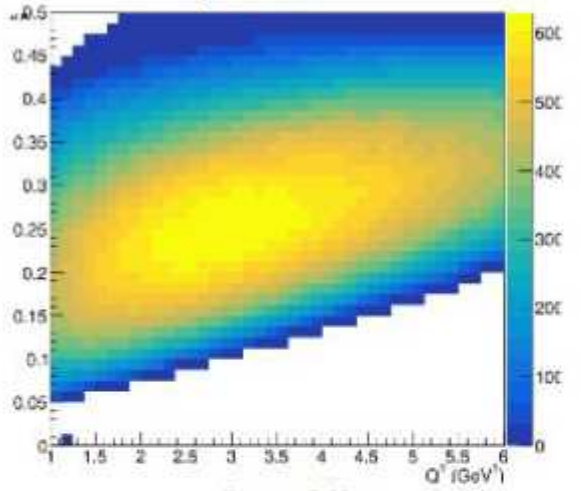


Kinematic region we access with Hall C and setups we are looking for

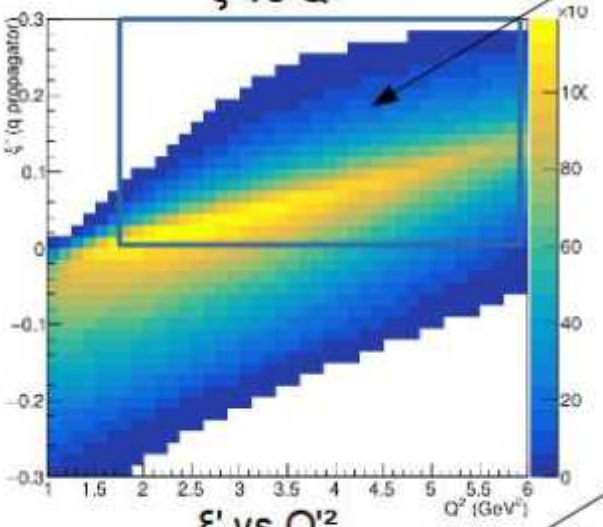
Few projections from generated MC : phase space « out of diagonal »

Q^2 and Q'^2 not correlated
correlation with other kinematic variables

ξ vs Q^2

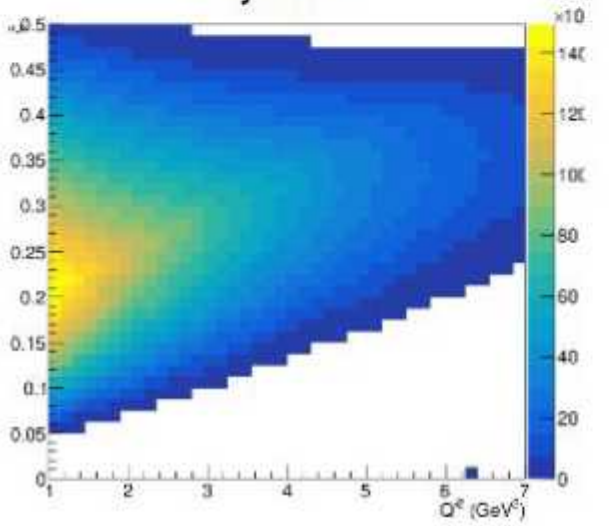


ξ' vs Q^2

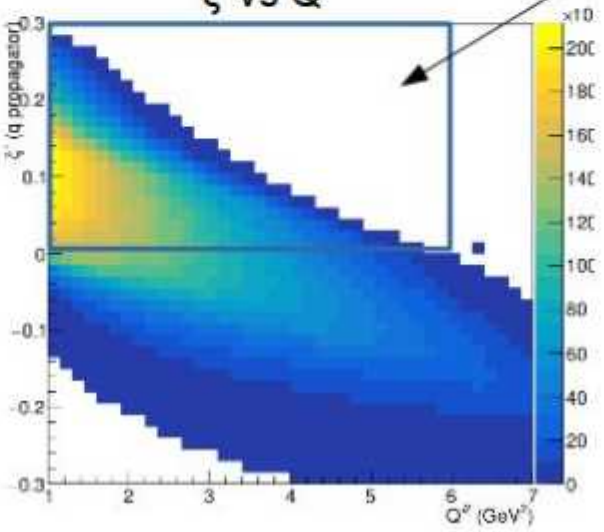


Q^2>2 GeV² if we want to stay at ξ'>0

ξ vs Q'^2



ξ' vs Q'^2



in this case,
Q'^2<6 GeV²
question about resonances and interferences

Summary for DDVCS

Physics:

- Motivations, strong case: Access ERBL region of GPDs & tomographic interpretations
- Approach of current work (and presented here) differs from previously done by various groups
- Physics case mostly ready, will update with CFF fits and more impact studies

Need also realistic MC prior to select kinematic region

Technical

- currently working on simulations starting from DVCS or TCS proposed setups
- lot of work still to be done there

Goal : develop muon detector to make this measurement feasible

Other reactions we are currently exploring and doing impact studies
- may lead to new measurement with existing setups or new ideas
- still very preliminary

Undergraduate students (just starting) to perform analysis and impact studies
For their senior project this semester

- Barbara Sanchez : unpolarized rho (analysis)
- Nathan Stroh : omega, (eta), mesons decaying to multiple states (pheno)
- Ge Liu: phi_s
- Nicholas Roush : J/psi hadronic modes
-
- Cesar Ibarra : TCS longitudinally polarized
- Alexander Hamilton : TCS off the neutron

- Goal is for students to learn the tools and how to analyse data
- Some studies can trigger further studies next summer to complete a « GPD » program with mesons, possible extensions of science that can be achieved with NPS

Simulated data will soon be available and (Marie) will perform some parallel impact studies
- update expected ~May/june : which of these studies worth to continue ?

- Deb Biswas, joining soon as a postdoc will work on DDVCS and light mesons

Why looking at several mesons together for GPDs ?

Goal : global GPD fits from mesons + Compton-like channels all together

Measurements of vector mesons ($J^p=1^-$ like photon) for complementarity with Compton & flavor decomposition
- factorization proven (caveat : near threshold not clear)
- high energy enhancement / pomeron exchange

Light vector mesons
- flavor decomposition
- « some » out of diagonal access x vs xi
- complementarity with Compton and already made measurements
- feasible in short term

Heavy mesons, quarkonia
- flavor decomposition + gluons
- not sure of interpretation : non perturbative region near threshold
- possibility to go off diagonal if light meson measuruments prove that we have a way to incorporate meson measurements within Compton-like fits
- photon & electron beam, possibility to demonstrate lepton pair equivalence (or not) + if feasible to reconstruct ee pairs