nDVCS with SBS in TDIS configuration

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Overview

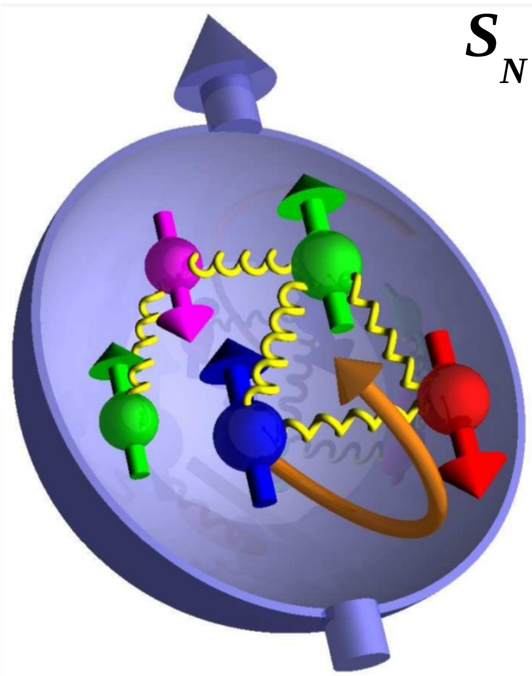
Physics case:
- Nucleon spin puzzle and GPDs;
- Experimental access to GPDs;
- DVCS on neutron: constraint on quark AM

Experimental setup:
- Advantages of TDIS-like technique;
- Existing options;

Progress on simulations:
- Acceptances;
- mTPC efficiency;
- Next steps...

Summary

Physics case:
Nucleon Spin Puzzle and GPDs

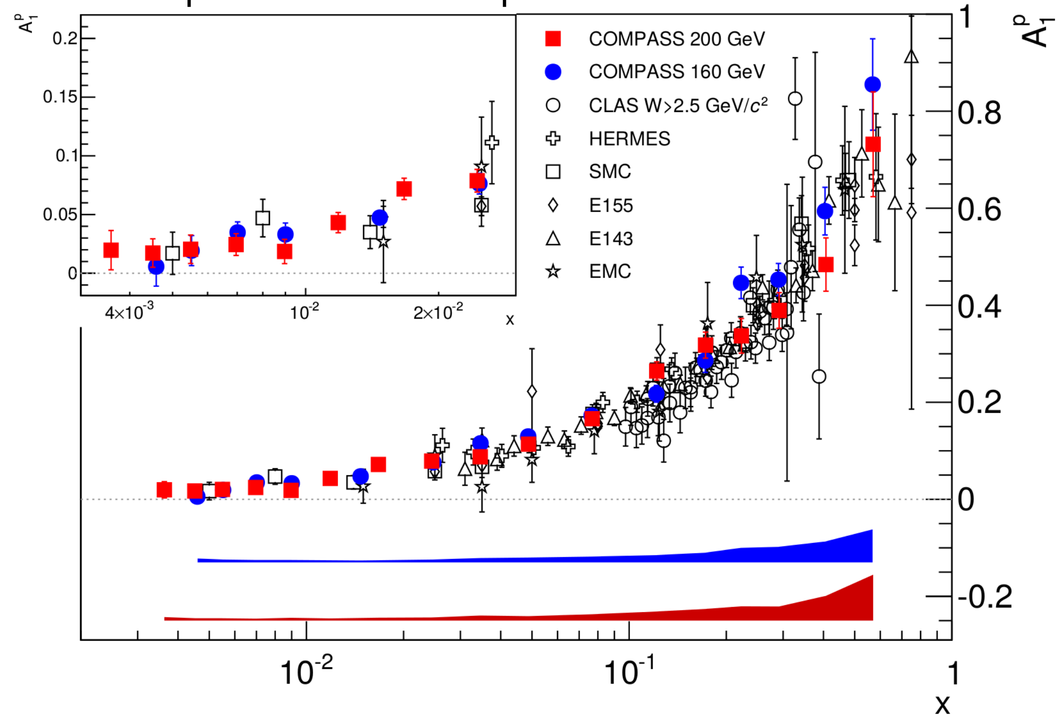


$$S_N = ½ = ½\ \Delta\Sigma + \Delta G + L_q + L_g$$

Static quark model:
$\Delta\Sigma$ = 1…

Experiments:
=> $\Delta\Sigma$ ~ 0.3

Compass coll.: arXiv:hep-ex/1503.08935



ΔG ? (phenix, compass)

$\Delta g/g$=0.113±0.038(stat.)±0.036(syst.)

[Compass coll.: arXiv:hep-ex/1512.05053]

$L_{q,g}$? => needs “3D” parameterization

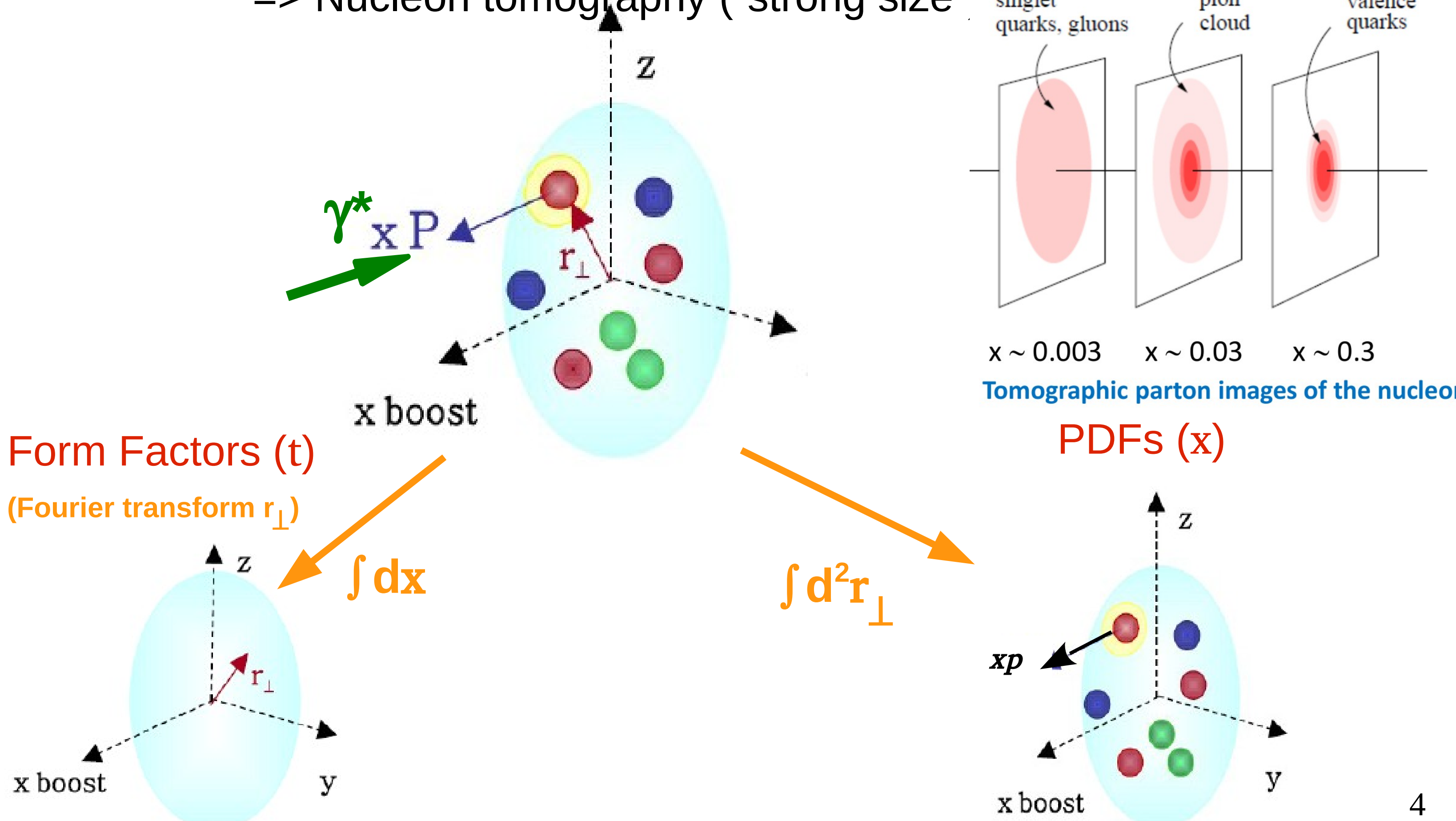
Physics case:
Nucleon Spin Puzzle and GPDs

'3D' Structure of nucleon :

=> Correlation $r_\perp \leftrightarrow xP$

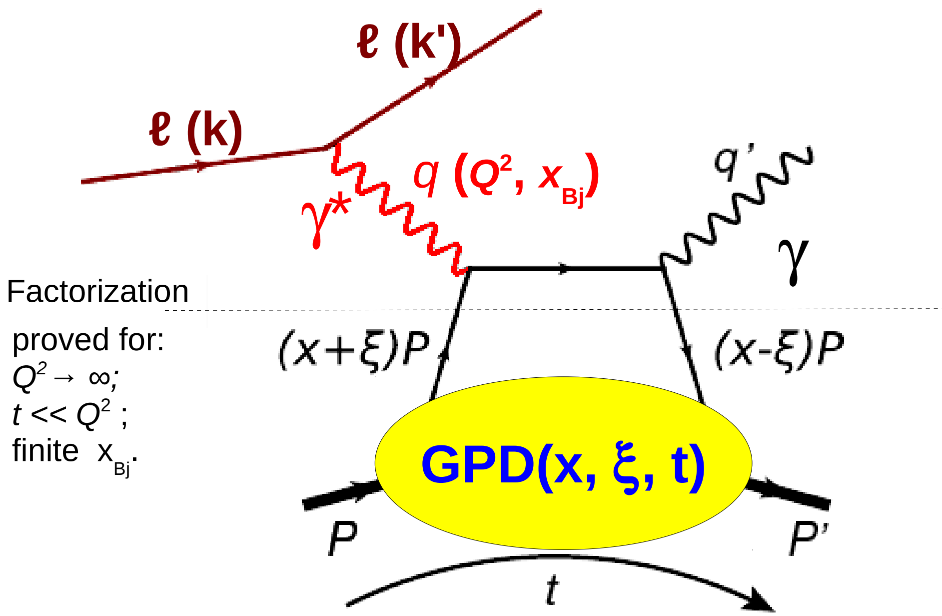
=> **Orbital Angular momentum**

=> Nucleon tomography ("strong size")



Physics case:
Experimental access to GPDs : DVCS

Exclusive reactions
(DVCS: ℓp → ℓpγ, HEMP: ℓp → ℓph)



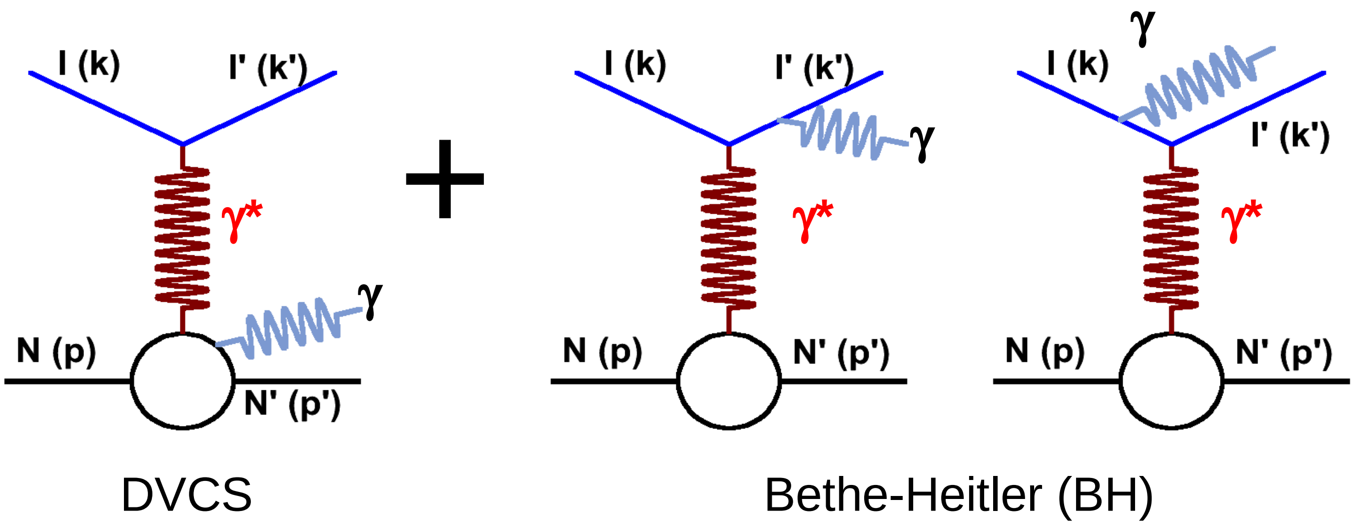
4 "chiral-even" GPD: $H, E, \tilde{H}, \tilde{E}$
+
4 "chiral-odd" GPD$_T$: $H_T, E_T, \tilde{H}_T, \tilde{E}_T$

At Leading Order:
Proton (unpolarized) : ***H***
Neutron (unpolarized): ***E***
Longitudinally polarized proton: $\tilde{H}$
Transversely polarized proton: ***E***

Ji sum rule: $\int dx\, x\, [H+E](t=0) = 2J$

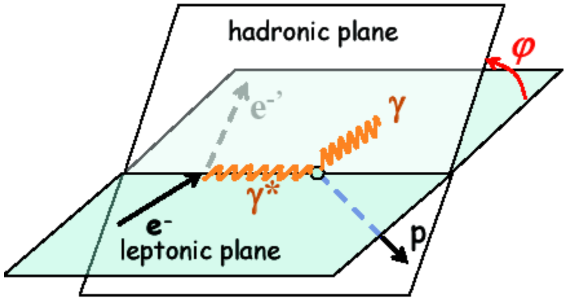
Physics case:
Experimental access to GPDs : DVCS

DVCS: interference with Bethe-Heitler



$$\sigma^{lp\to lp\gamma} \propto \left[|BH|^2 + |DVCS|^2 + 2|DVCS||BH| \right]$$

Interference: direct access to (+ enhancement of) DVCS amplitude



The interference appears as a modulation in ϕ in the beam polarization asymmetry.

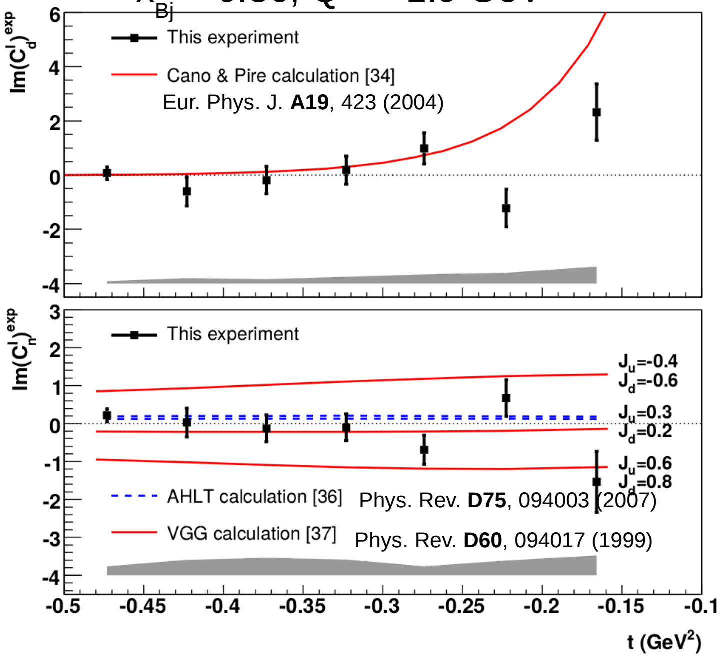
BH amplitude calculable with QED;
requires knowledge on form factors.

Physics case:
DVCS on neutron : constraint on quark AM

DVCS on neutron: => GPD *E*

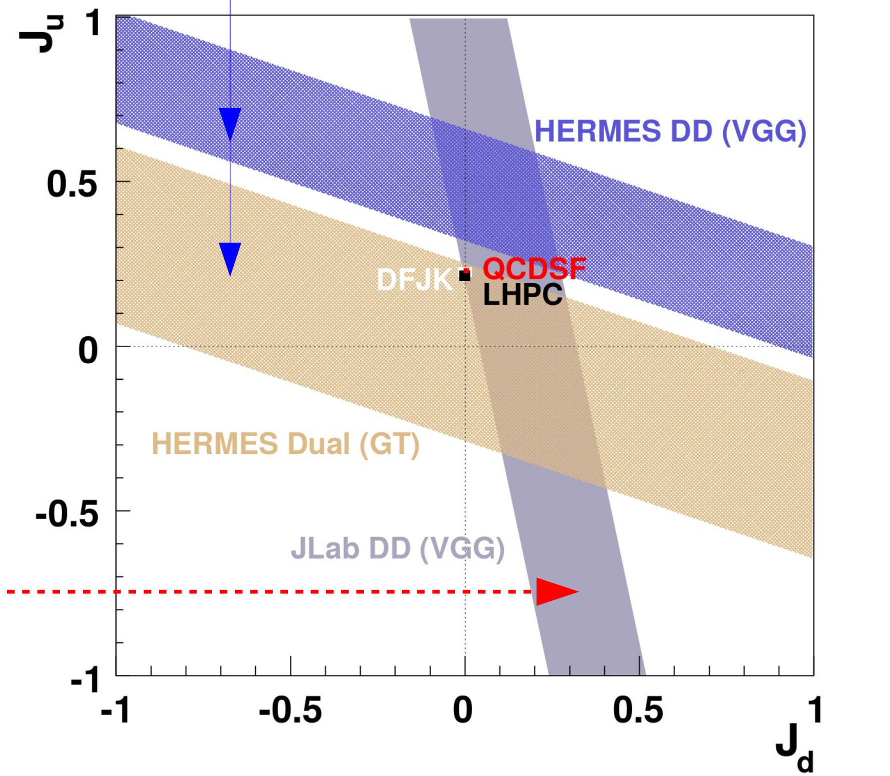
Compton Form Factors extracted from cross sections
[Mazouz and Hall A coll. : Phys. Rev. Lett. **99**, (2007) 242501]

$x_{Bj} = 0.36$, $Q^2 = 1.9$ GeV^2



constraint $J_{d,u}$

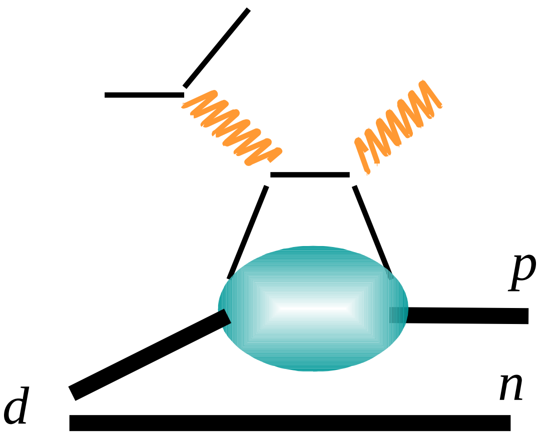
+HERMES TTSA on proton: ($J_{u,d}$)
[HERMES coll.: J. High Energy Phys. **0806** (2008) 066]



VGG: Vanderhaeghen, Guichon, Guidal, Phys. Rev. **D60**, 094017 (1999)
GT: Guzey, Teckentrup, Phys. Rev. **D74** (2006) 054027.
QCDSF/UKQCD Coll.: Eur. Phys. J. **A32** (2007) 445.
LHPC Coll.: Phys. Rev. **D77** (2008) 094502.
Diehl, Feldmann, Jakob, Kroll, Eur. Phys. J. **C39** (2005) 1.
} L-QCD

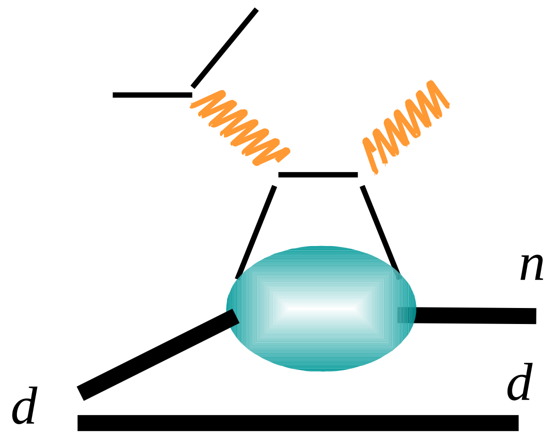
Physics case:
DVCS on neutron (measurement on deuterium)

With a Deuterium target one can have 3 different DVCS processes



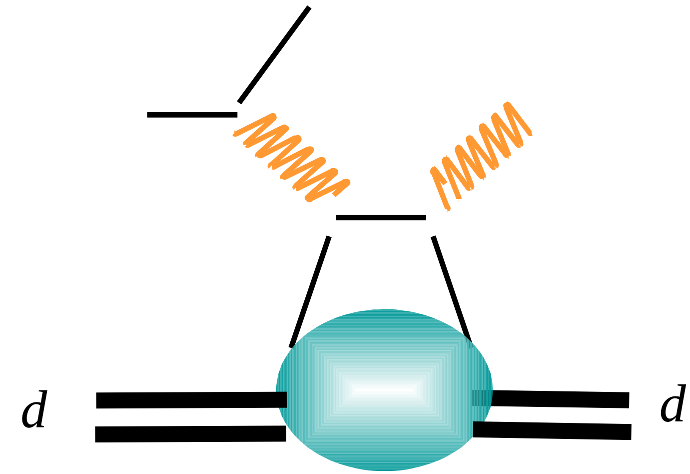
p-DVCS

(incoherent)



n-DVCS

(incoherent)



d-DVCS

(coherent)

=>

Access deuteron GPDs

Impulse approximation :

$$D(e,e'\gamma)X = d(e,e'\gamma)\,d + n(e,e'\gamma)\,n + p(e,e'\gamma)\,p + \mathrm{K}$$

Overview

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- Nucleon spin puzzle and GPDs;
- DVCS on neutron.
- Existing results.

Experimental setup:

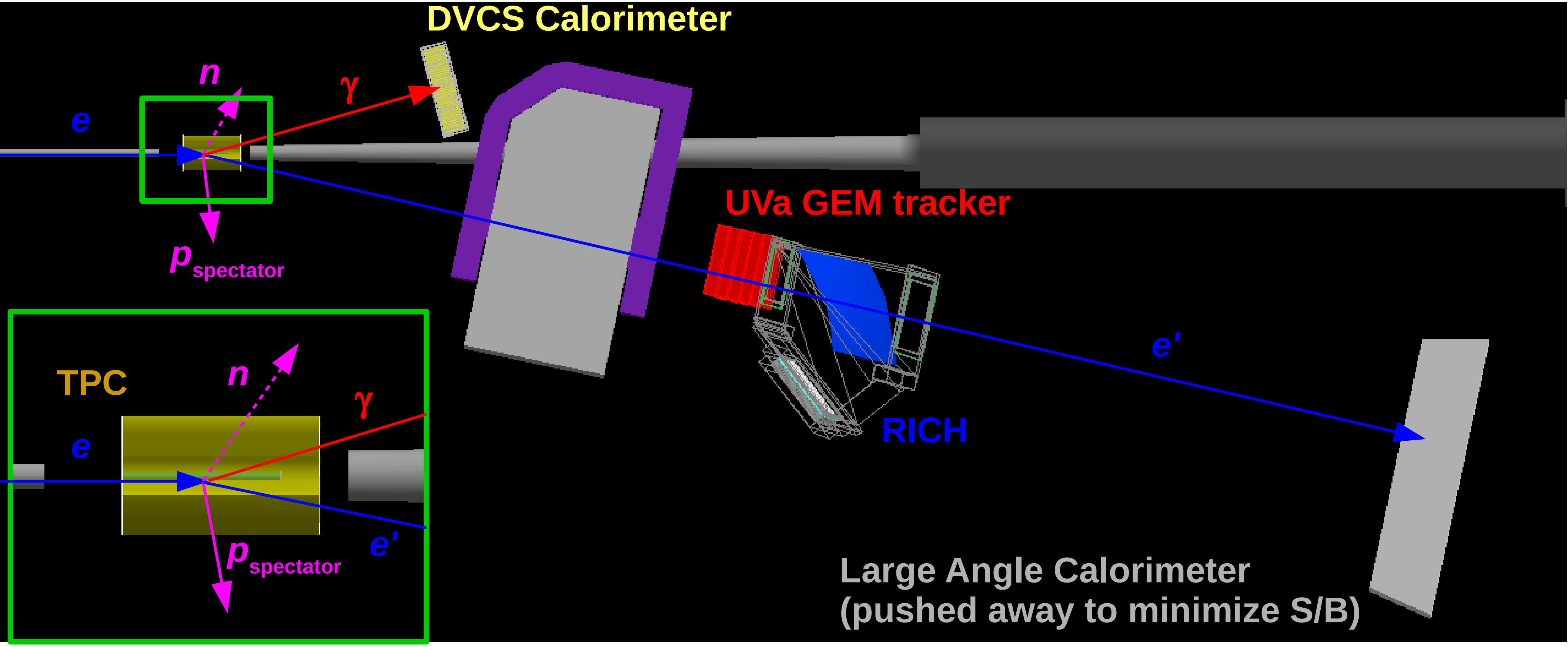
- Description;
- Existing detector options;
- Advantages of TDIS-like technique;

Progress on simulations:

- Acceptances;
- mTPC efficiency;
- Next steps...

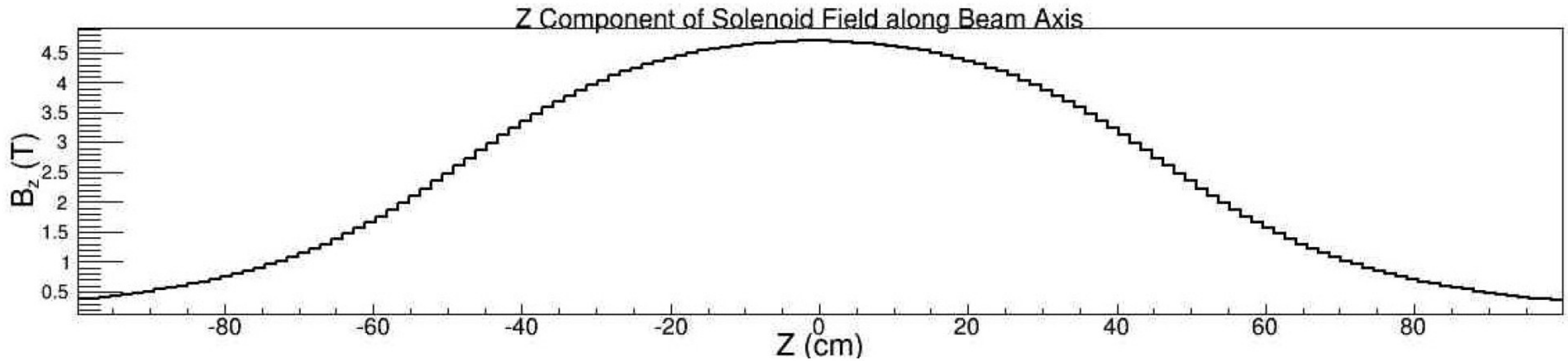
Summary

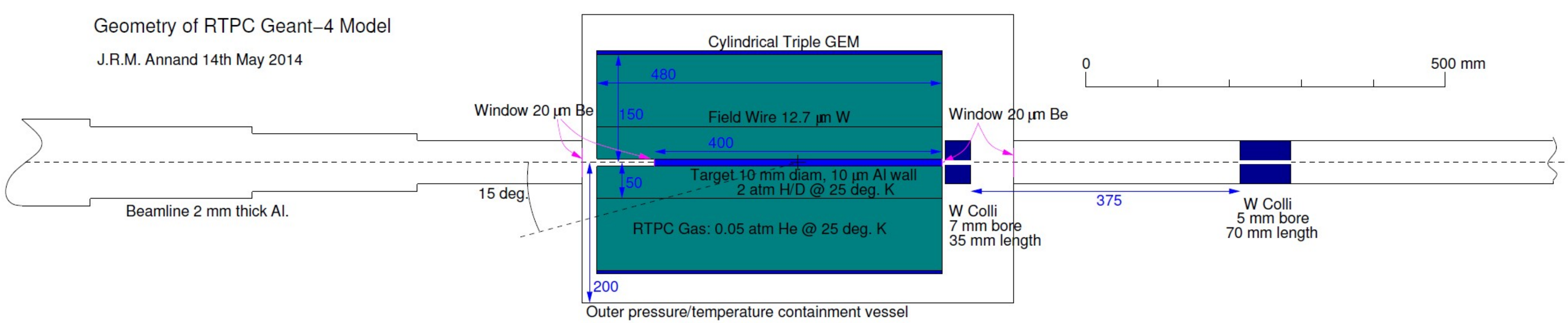
Experimental setup:
Description



Experimental setup:
Description

TPC inside a solenoid:
=> magnetic field profile





Experimental setup:
Detector options

DVCS Calorimeter:

* NPS calorimeter
Pros:
- Sufficient size/coverage (63.6 x 73.8 cm^2);
Cons:
- Likely unavailable at time of run.

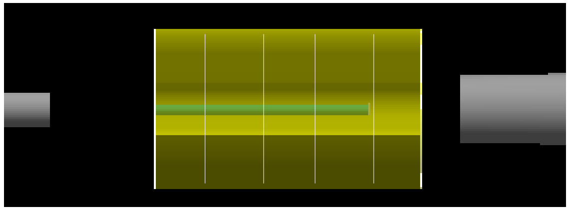
* DVCS Hall A PbF2 calorimeter
Pros:
- already exists;
- will be available;
Cons:
- way too small (39 x 48 cm^2);

In any case, *those will need to be readout by SiPM, because of SBS magnet proximity.*

TPC:

* RTPC
Pros:
- already being developed
Cons:
- slow response: might not be compatible with experiment rates

* mTPC (modular)
Pros:
- faster response than a TPC in one chunk;
Cons:
- brand new detector: to be developed



Experimental setup:
Advantages of TDIS like technique

* Detecting the spectator proton (instead of recoil neutron) as in Tagged DIS is much more efficient than detecting the recoil neutron directly;

* The TPC will also provide some PID with track q/M:
=> coherent DVCS on deuteron identified unambiguously; can be measured for itself instead of being treated as background;

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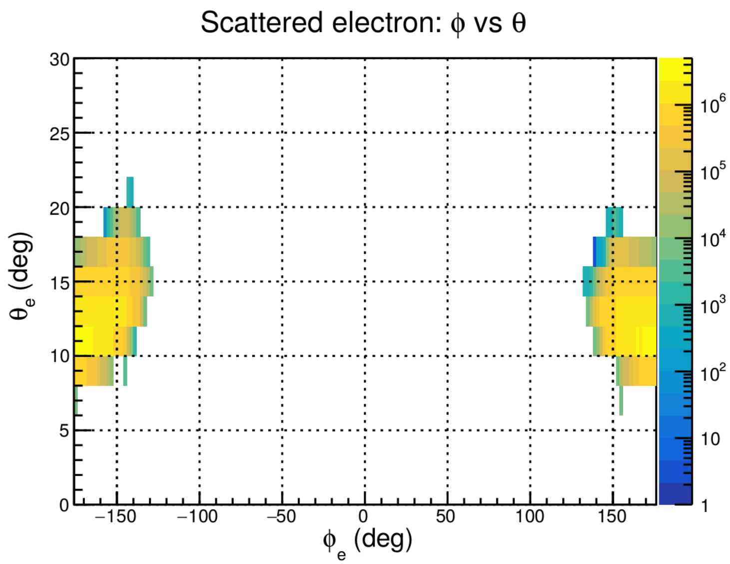
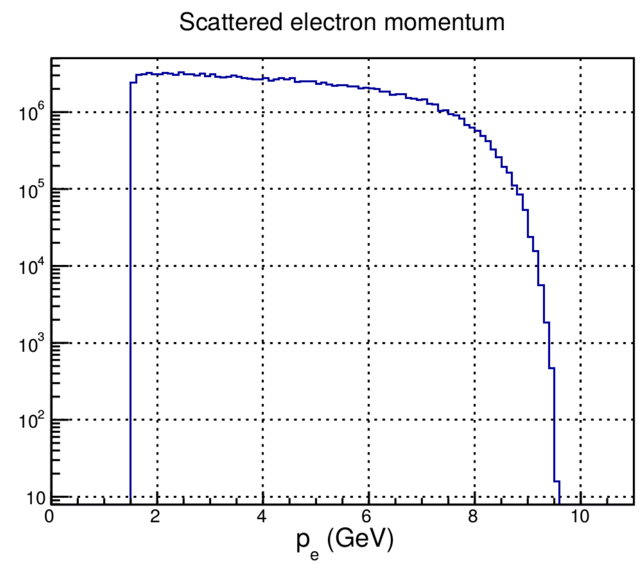
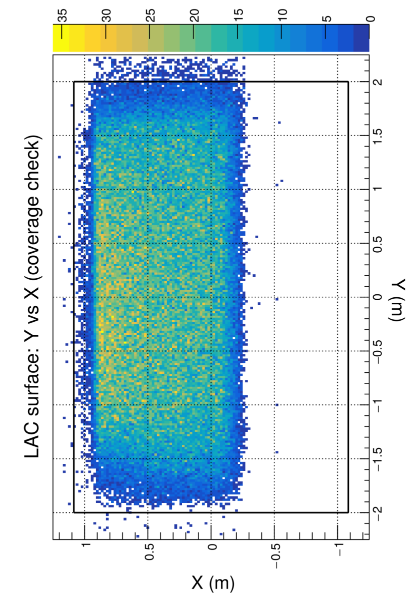
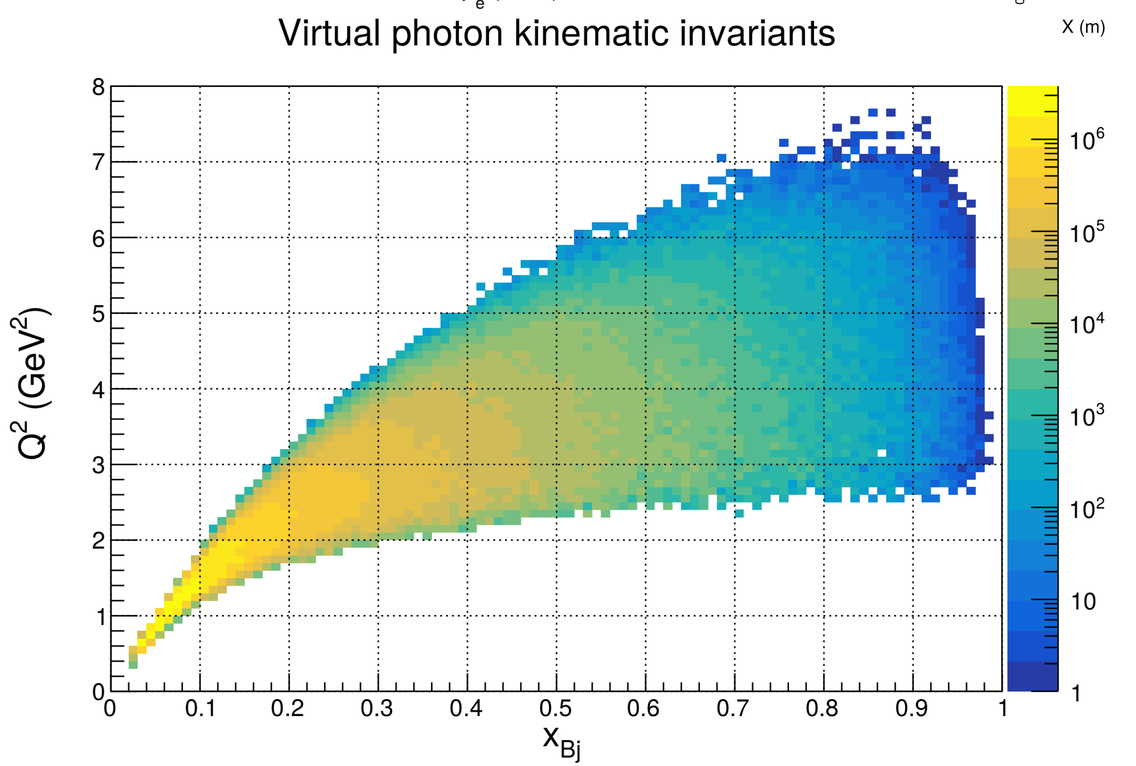
Progress on simulations:
Acceptances









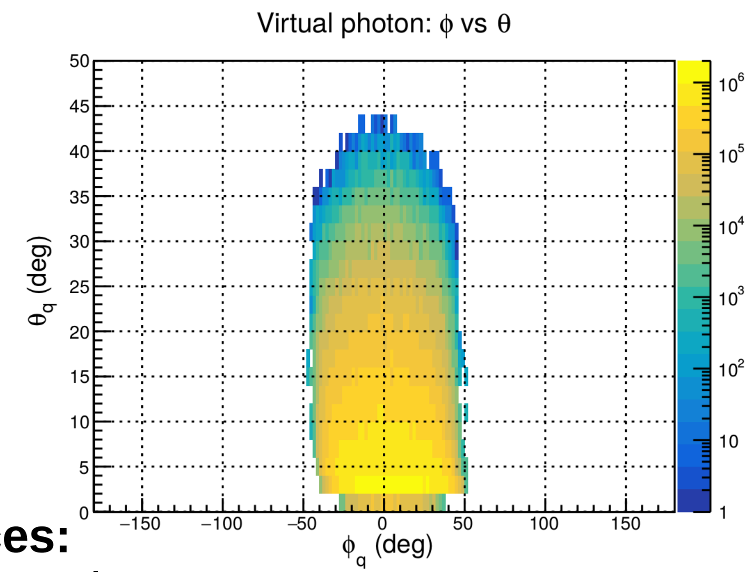
Scattered electron acceptances:

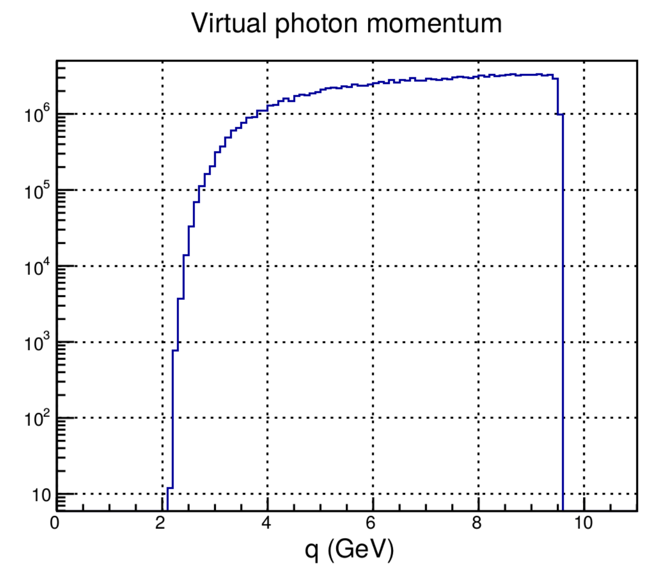
* Electron through all 5 GEM planes;
* at least 2 PMT hits in RICH;
* E_e>1.5 GeV.

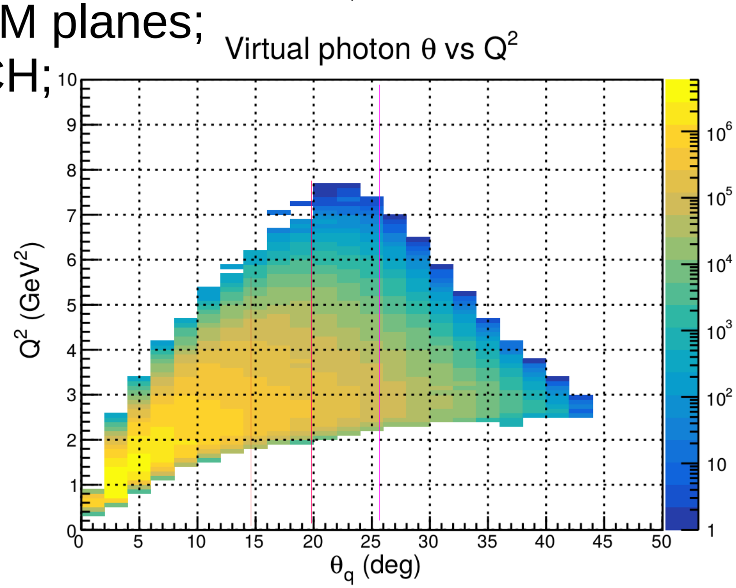
Progress on simulations:
Acceptances

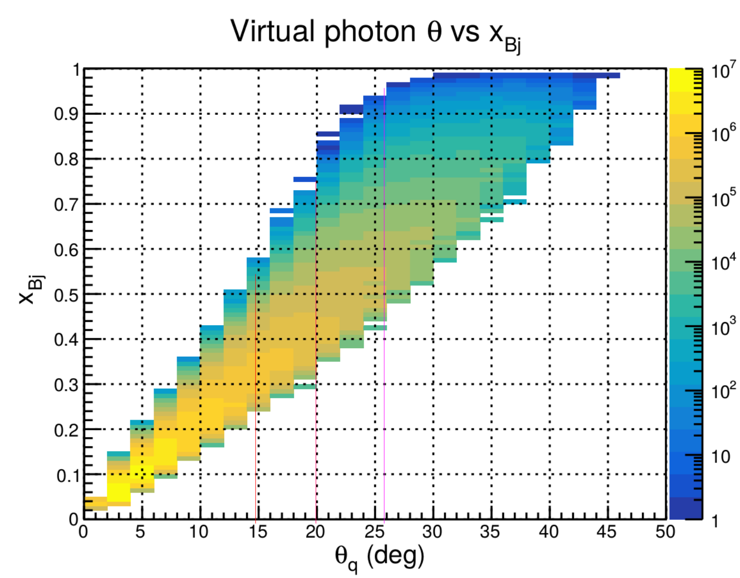
Virtual photon acceptances:

* Electron through all 5 GEM planes;
* at least 2 PMT hits in RICH;
* E_e>1.5 GeV.





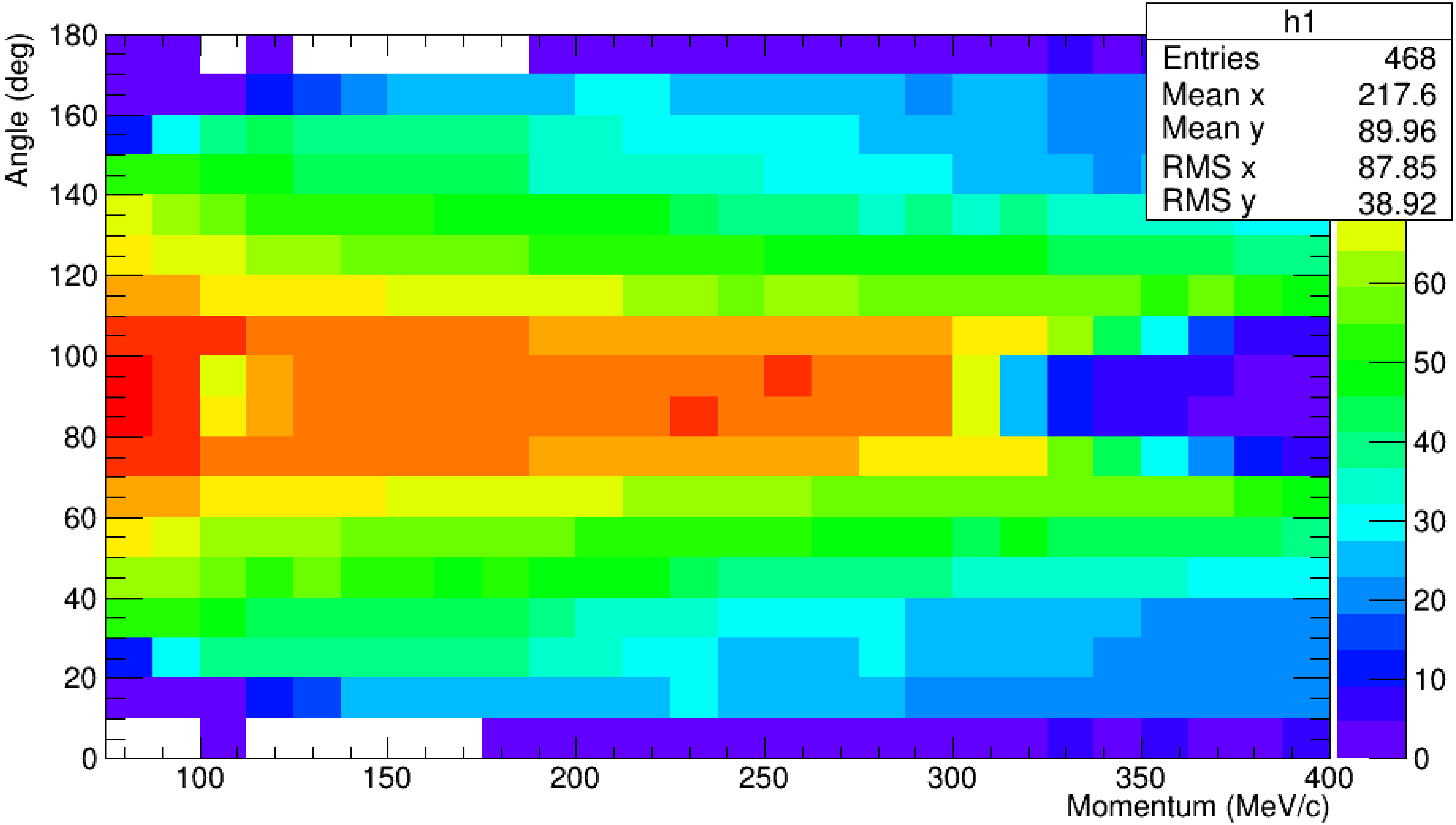




x_{Bj}, Q^2 decided by calorimeter angle

Progress on simulations:
mTPC efficiency

Semi-empirical efficiency:
proportion of protons reaching active gas volume and reconstructed within 10 % of generated momentum



Progress on simulations:
Next steps...

Geometry / detector:
- TPC magnetic field;
- LAC implementation (started);
- mTPC implementation;
- Straw target;
- beamline;

Background studies:
- LAC trigger rates: standalone, combined with RICH;
- RICH background, pion rejection;
- DVCS calorimeter: Møller;

Signal:
- DVCS event generator; ideally, include fermi momentum;
- study missing mass resolution;
- DVCS counting rates and observables:
  - ϕ distribution;
  - cross section with unpolarized and polarized electrons.

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* nDVCS with TDIS setup seems doable

* Could study both nDVCS and dDVCS (coherent DVCS on deuterium)

* Straightforward experimental setup:
  → we will try to put a proposal this year.

* Still a fair amount of tasks to do

Thank you for your attention !

Generalized Parton Distributions (GPDs) :
'3D' Structure of nucleon

In practice: GPDs encapsulated in Compton Form Factors (CFFs)

Factorization scale

$$\mathcal{F}(\xi, t, Q^2) = \int_{-1}^{+1} dx\, C\left(x, \xi, \alpha_S(\mu_R), \frac{Q}{\mu_F}\right) F(x, \xi, t, \mu_F)$$

CFF
(complex quantity)

Integration kernel
(calculated up to NLO)

GPD

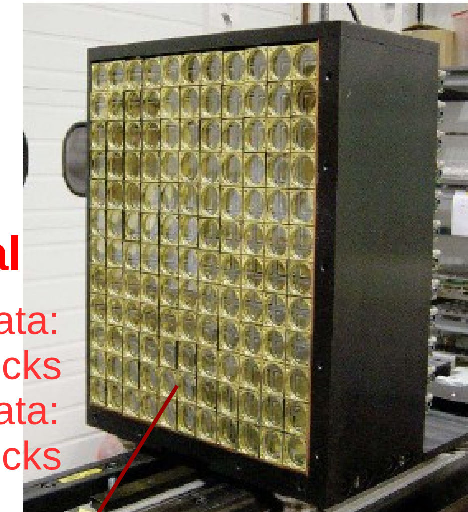
Sometimes *effective* CFFs: combinations of CFFs with same kinematic dependence

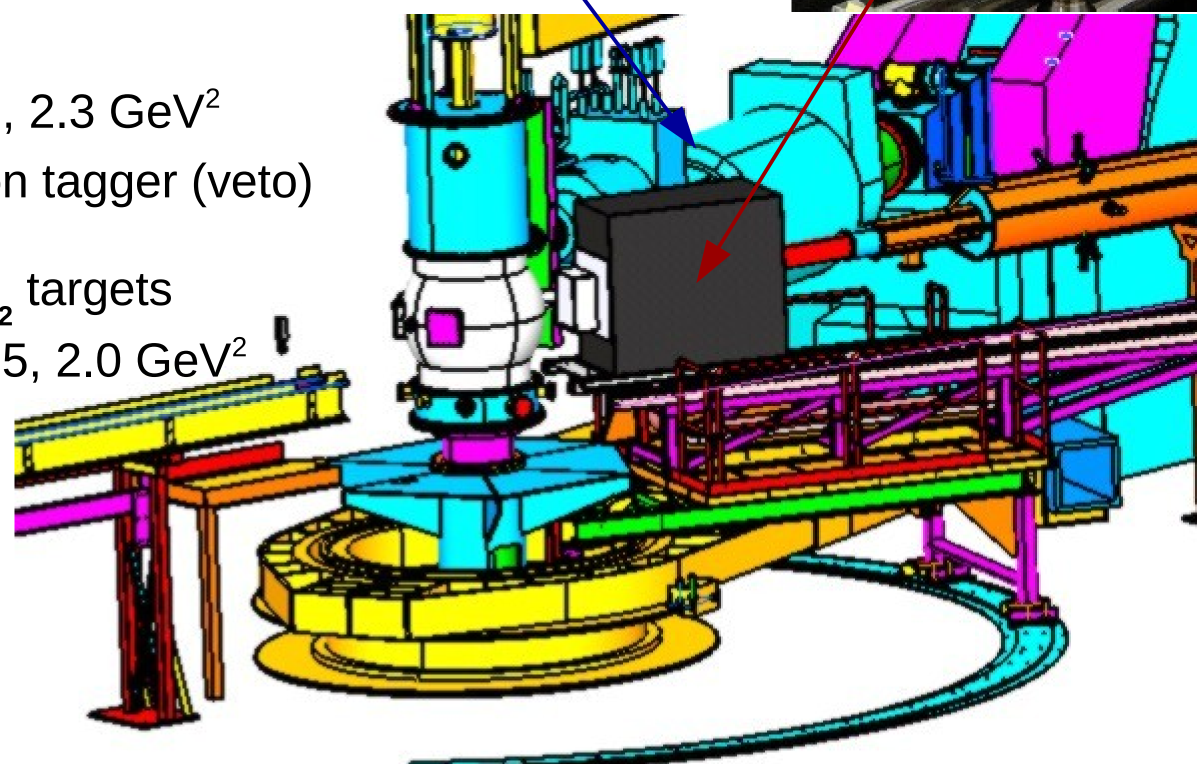
Jefferson Lab GPD program : Hall A setup

Hall A: **valence** region
High Resolution Spectrometer+Calorimeter
Polarized e^- beam (≤ 6 GeV), fixed target:
Hydrogen, deuterium
- **High luminosity**: ($\mathcal{L}$ ~10^{37} cm^{-2} s^{-1})
- **High resolution equipements**

=> **High precision measurements**

2 runs during 6 GeV era:
2004 data:
E_{beam} **= 5.75 GeV, LH_2, LD_2** targets
3 kinematics: x_{Bj} **= 0.36**, Q^2 = 1.5, 1.9, 2.3 GeV^2
Proton array around PbF_2, with neutron tagger (veto)
2010 data:
E_{beam} **= 5.55, 4.55, 3.55 GeV**, **LH_2, LD_2** targets
3 kinematics: x_{Bj} **= 0.36**, Q^2 = 1.5, 1.75, 2.0 GeV^2
2 E_{beam} / kin: **Rosenbluth separation**
($DVCS^2$/DVCS-BH, σ_T/σ_L)





Analysis method

$$eD \rightarrow e\gamma X$$