Summary of available DVCS and GPDs impact studies in e+p at EIC

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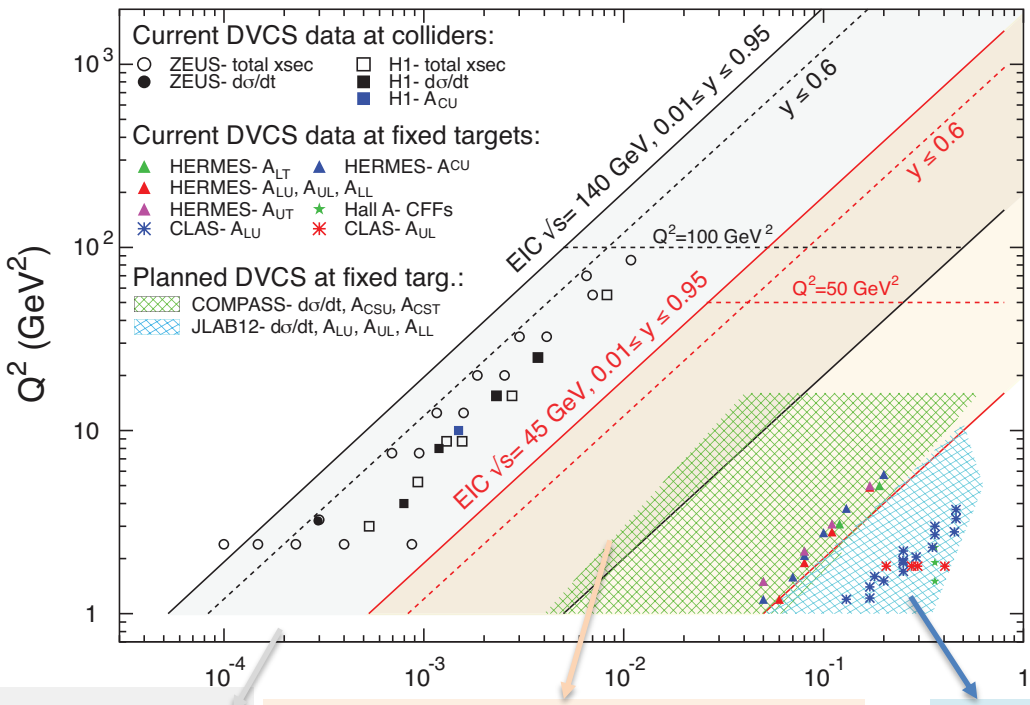
BROOKHAVEN NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY | Office of Science

DVCS at a high luminosity collider

The code MILOU by E. Perez, L Schoeffel, L. Favart [arXiv:hep-ph/0411389v1]
is Based on a GPDs convolution by: A. Freund and M. McDermott [http://durpdg.dur.ac.uk/hepdata/dvcs.html]

- **Signal extraction "a la HERA"**
- **xSec meas.: specific requirements to suppress BH → keep BH/sample below 60%**
- **Radiative Corrections evaluated**
- **detector acceptance & smearing**

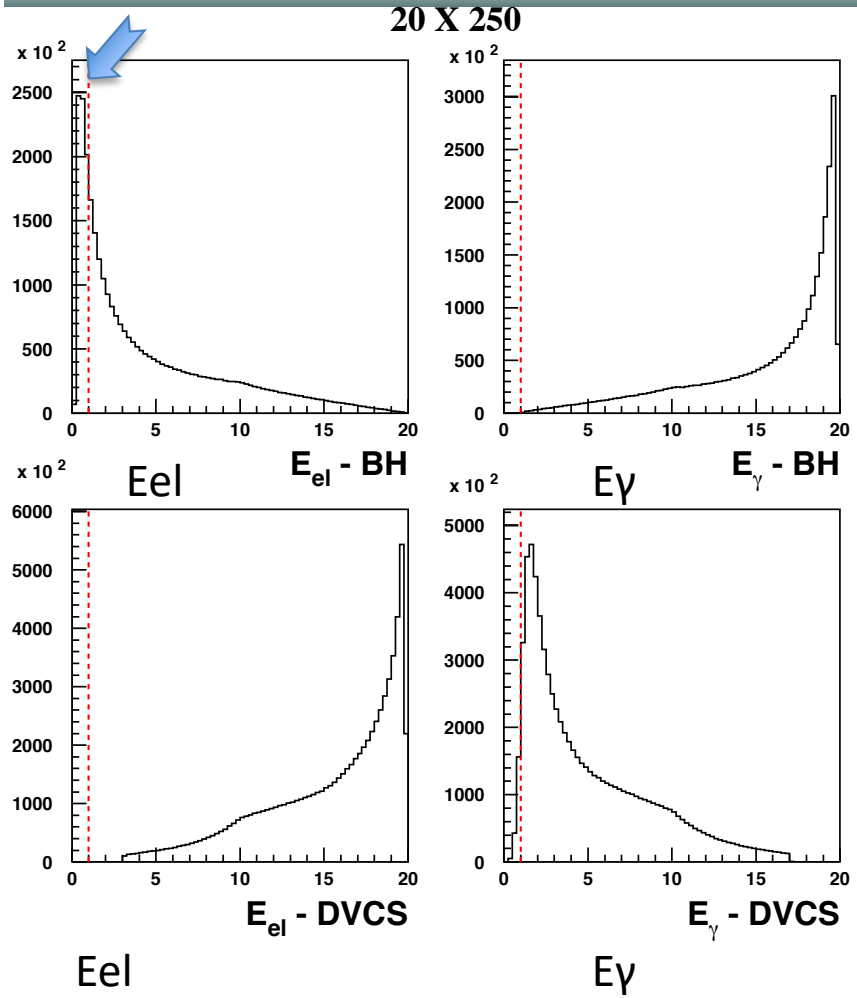


Overlap with HERA:
Large impact on current fits at low x

Intermediate region:
Fine mapping of the GPDs evolution

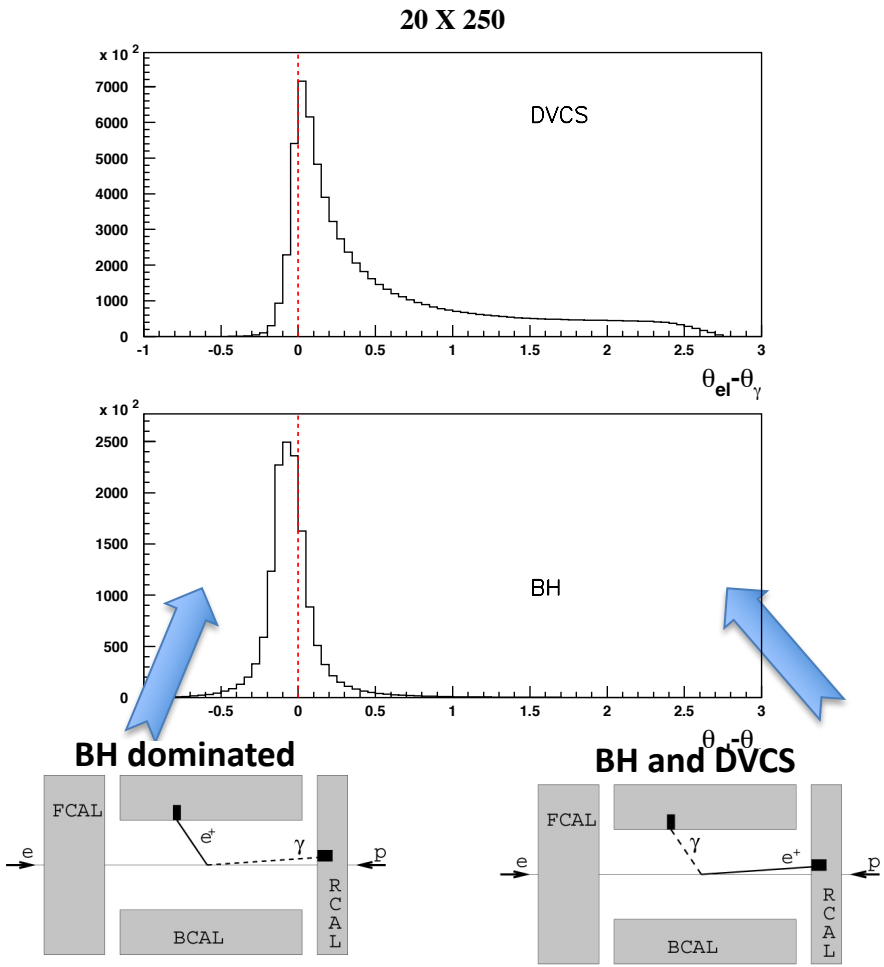
Overlap with JLAB12:
Sanity check, Q^2 evolution

BH suppression



BH electron has very low energy (often below 1 GeV)

Important: em Cal must discriminate clusters above noise down to 1 GeV

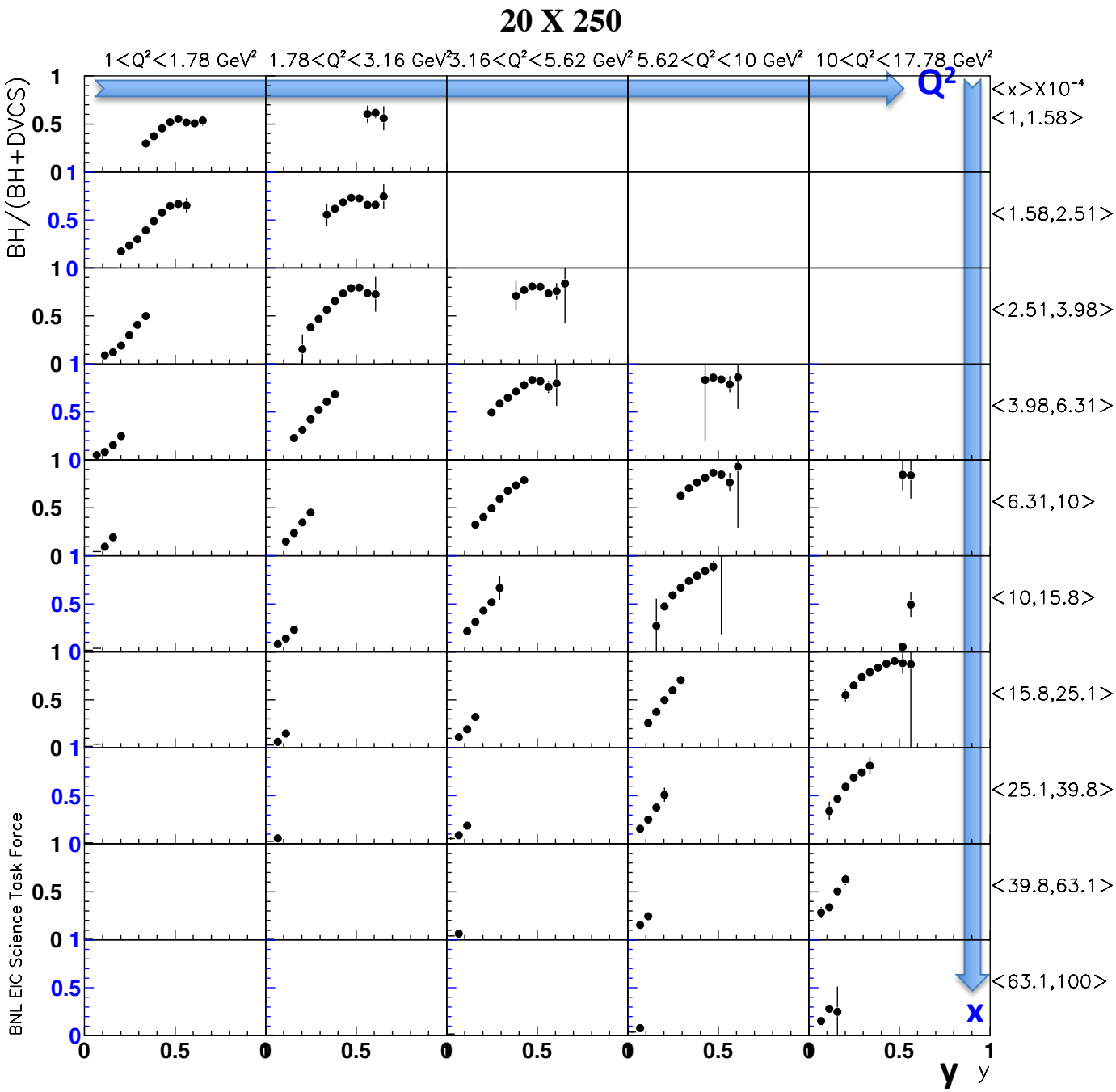


DVCS: most of the γ are less "rear" than e

(θel-θγ) > 0 → rejects most of the BH

cuts keep BH below 60% of the sample even at large y > 0.5 – at high energies

BH fraction



cuts keep BH below 60% of the sample at large y > 0.5

20 x 250 GeV²

BH subtraction will be not an issue for y<0.6

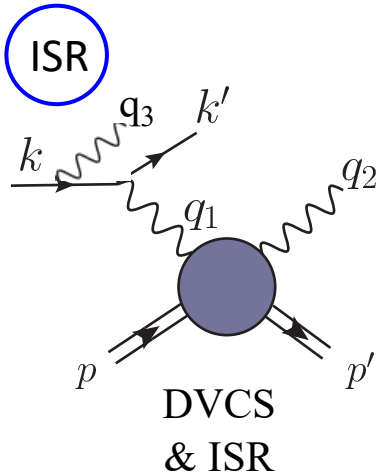
BH subtraction will be relevant at lower energies and large y, in some of the x-Q² bin

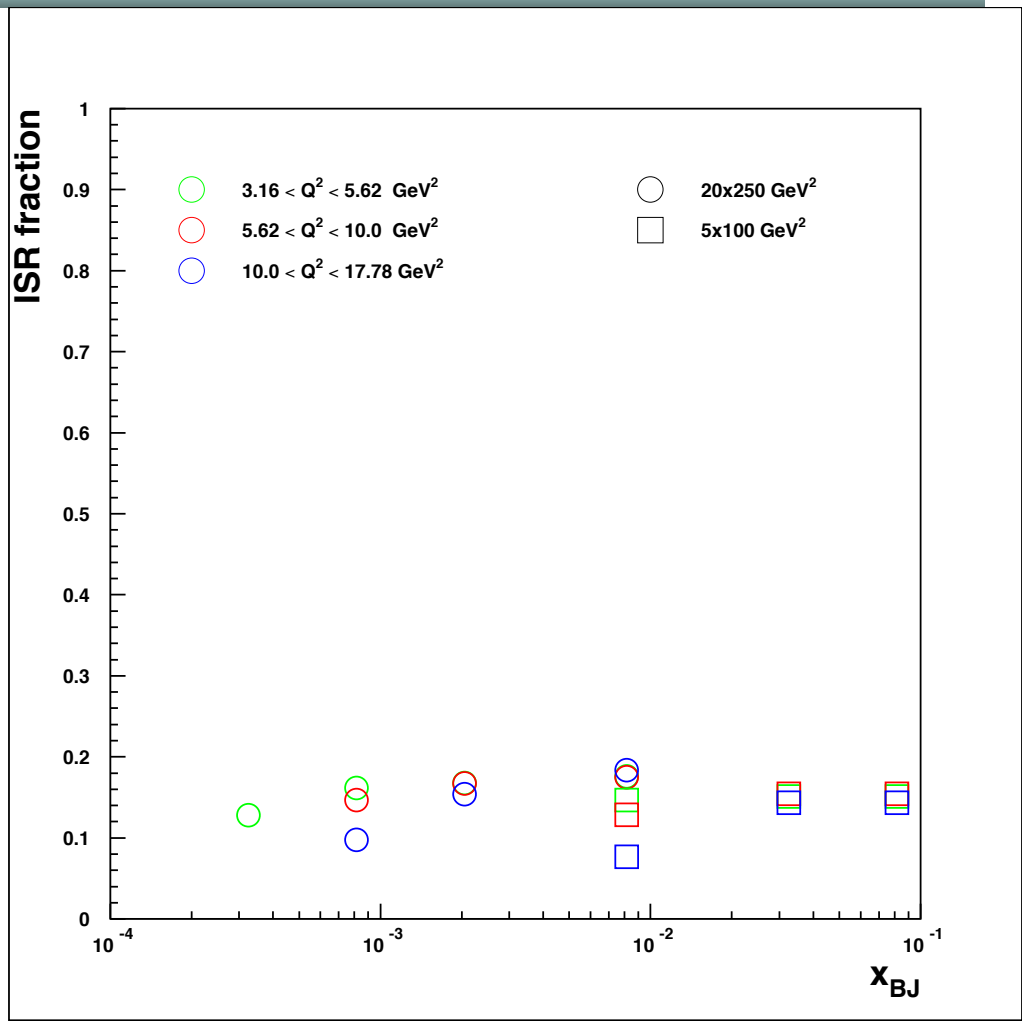
BUT…

higher-lower √s kin. overlapping:

x-sec. measurements at a higher √s at low-y can cross-check the BH subtraction made at lower √s

Radiative effects





Initial State Radiation (ISR):

photon collinear to the incoming beam and goes down the beam line

→ this contribution can only be estimated via MC

→ this causes a correction of the kinematics (x and Q^2) and some systematic uncertainty

→ **EIC: ONLY 15% of the events radiate a photon with > 2% energy of the incoming electron Independentely of C.o.M energy and Q^2 (see back up slide)**

Data simulation & event selection

Acceptance criteria

- for Roman pots: $0.03 < |t| < 0.88$ GeV^2
- for $|t| > 1$GeV2 detect recoil proton in main detector
- $0.01 < y < 0.85$ GeV^2
- $\eta < 5$

➢ BH suppression criteria (applied to x-sec. measurements)

- $y < 0.6$
- $(\theta el - \theta\gamma) > 0$
- Eel>1GeV^2; Eel>1GeV^2

➢ Events smeared for expected resolution in t, Q2, x

➢ Systematic uncertainty assumed to be ~5% (having in mind experience from HERA)

➢ Overall systematic uncertainty from luminosity measurement not taken into account

The code MILOU by E. Perez, L Schoeffel, L. Favart [arXiv:hep-ph/0411389v1] is Based on a GPDs convolution by:

A. Freund and M. McDermott

[http://durpdg.dur.ac.uk/hepdata/dvcs.html]

$0.01 < |t| < 0.85$ GeV^2

(Low-|t| sample)

- **Very high statistics**
- **Systematics will dominate!**
- **Within Roman pots acceptance**

$1.0 < |t| < 1.5$ GeV^2

(Large-|t| sample)

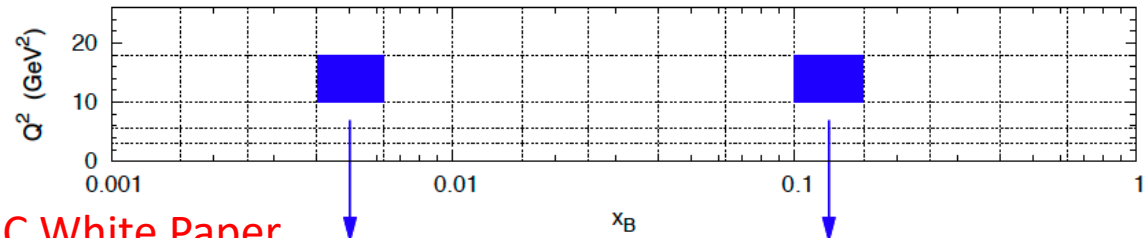
- **Xsec goes down exponentially**
- **requires much longer data taking**

5 X 100 GeV → **10 fb^{-1}**

20 X 250 GeV → **10 fb^{-1}**

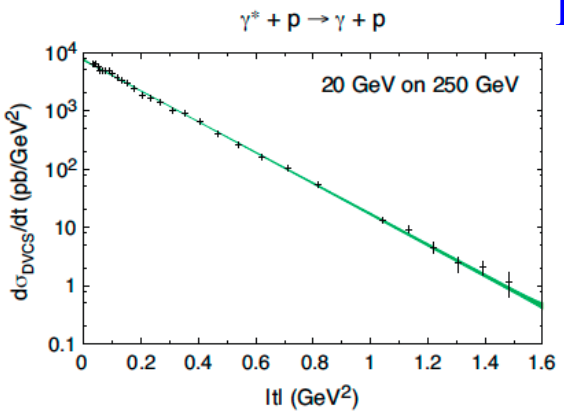
DVCS differential cross section

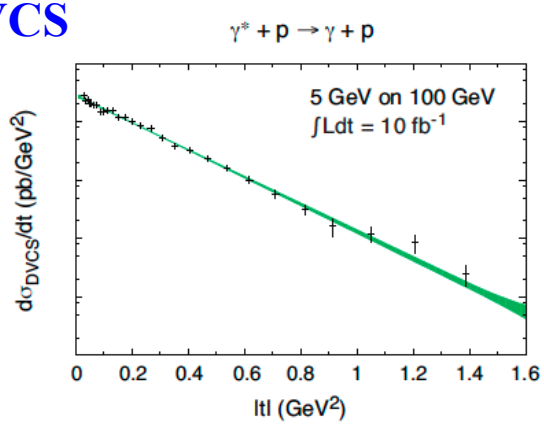
$$\int L = 10 fb^{-1}$$

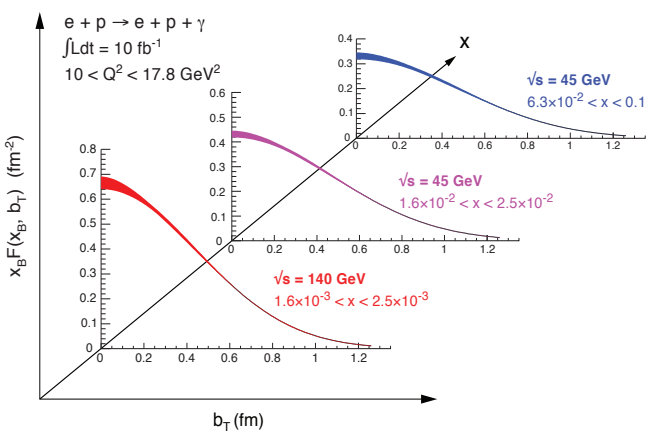


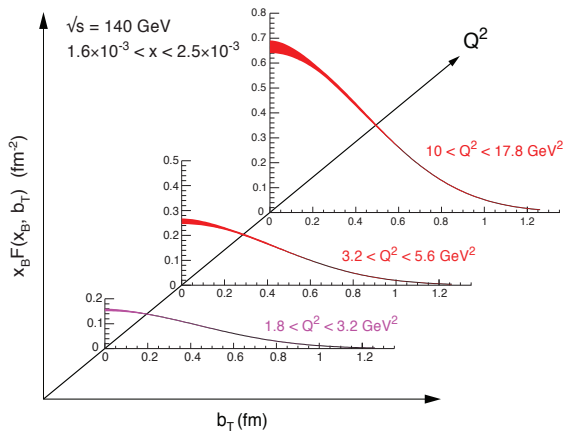
EIC White Paper

DVCS

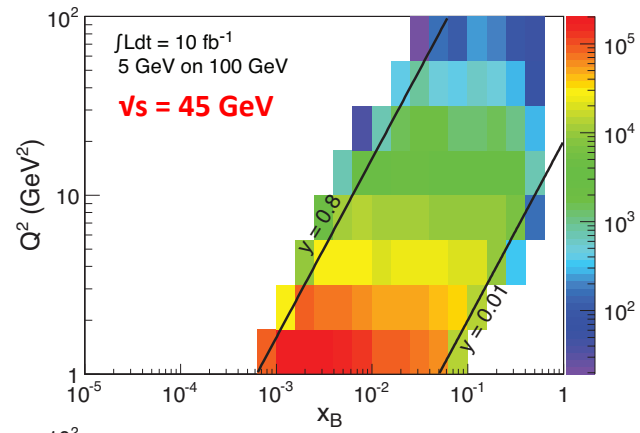


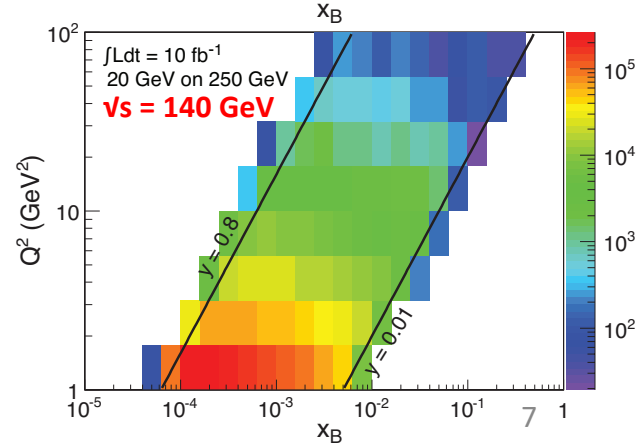






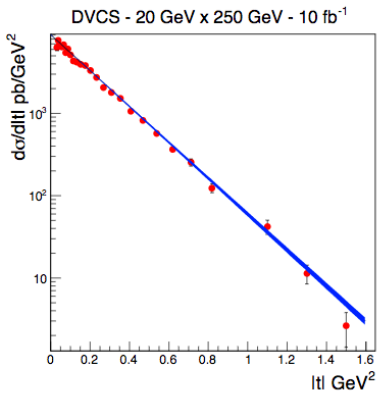
- **Measurement dominated by systematics**
- Fine binning in a wide range of x-Q^2 needed for GPDs
- Fourier transform of dσ/dt → partonic profiles





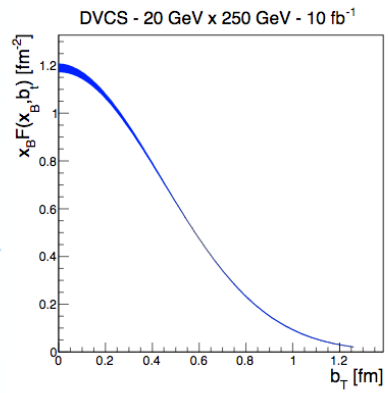
Impact of proton acceptance

Measurement | **Physics observable** (cross-section vs impact parameter)



Plots from EIC White Paper:

Fourier transform

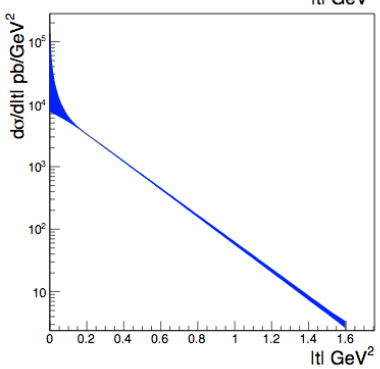


Requirement:

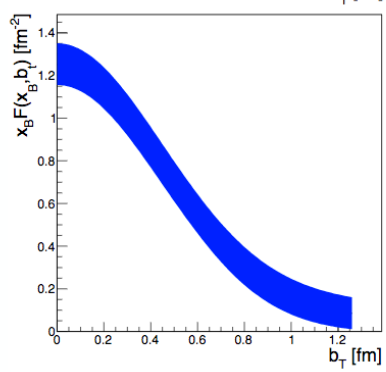
$\int L_{int} = 10 fb^{-1}$

$0.18 < p_t$ (GeV) < 1.3

$0.03 < |t|$ (GeV^2) < 1.6

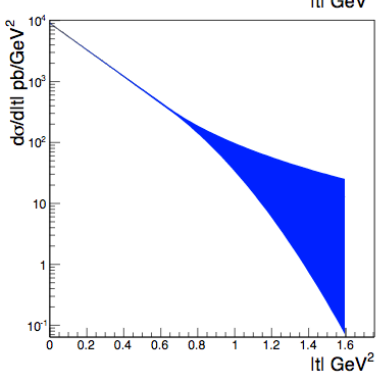


limited lower p_T-acceptance

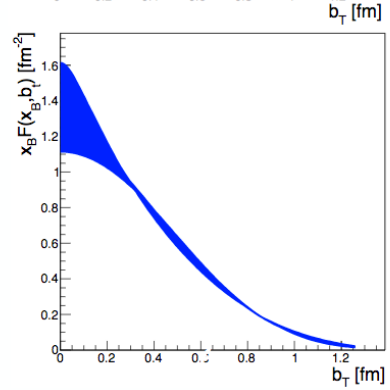


$\int L_{int} = 10 fb^{-1}$

$0.44 < p_T$(GeV) < 1.3



limited higher p_T-acceptance



$\int L_{int} = 10 fb^{-1}$

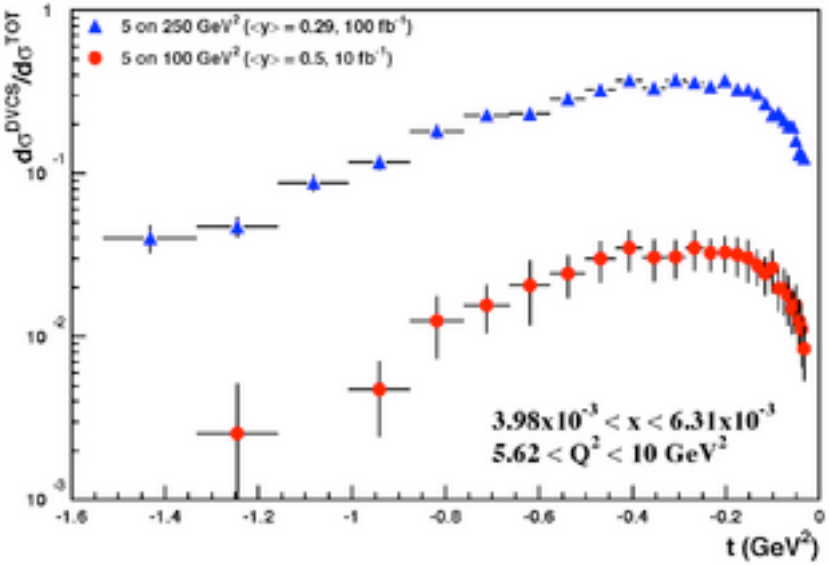
$0.18 < p_T$ (GeV) < 0.8

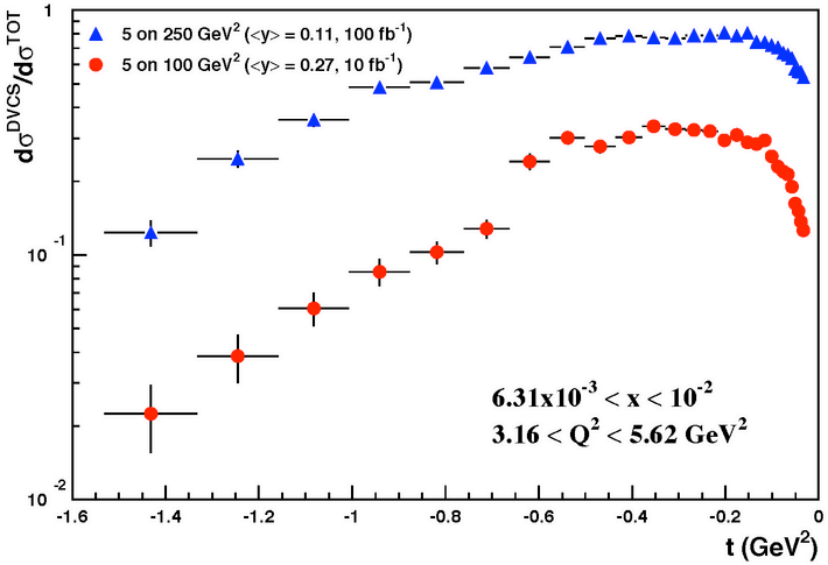
We need a proton spectrometer with large acceptance!

Rosenbluth separation

$$d\sigma = \mathrm{d}\sigma_{DVCS} + \mathrm{d}\sigma_{BH} + \mathrm{d}\sigma_{INT}$$

Rosenbluth separation of the electroproduction cross section into its parts



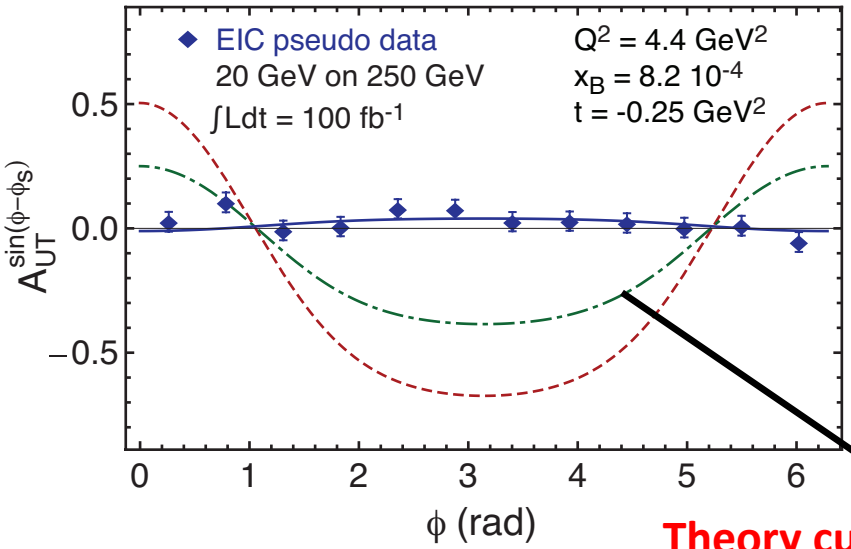


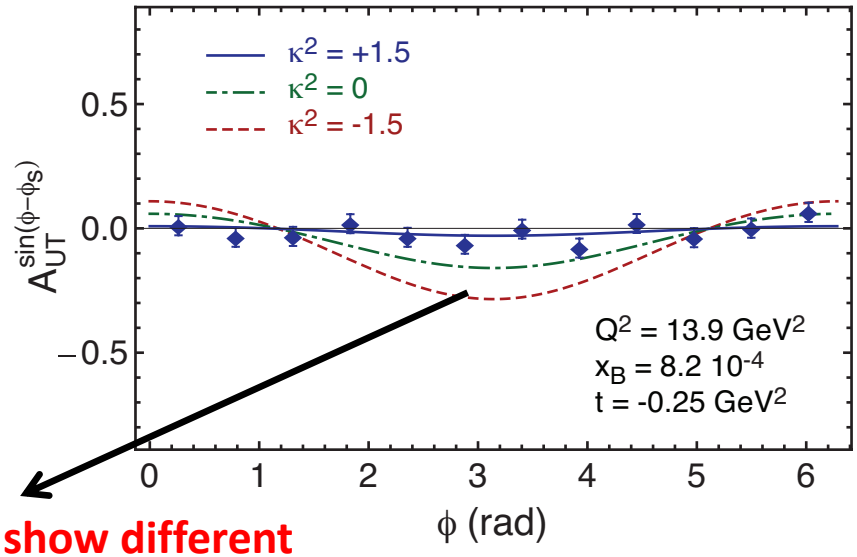
- The statistical uncertainties include all the selection criteria to suppress the BH
- exponential |t|-dependence assumed

Transverse target-spin asymmetry

$$\int L = 100 fb^{-1}$$

[E.C. Aschenauer, S. F., K. Kumerički, D. Müller JHEP09(2013)093]





Theory curves show different assumptions for E

$$A_{UT} \propto \sqrt{\frac{-t}{4M^2}}\left[F_2(t)H(\xi,\xi,t,Q^2) - F_1(t)E(\xi,\xi,t,Q^2) + \ldots\right]$$

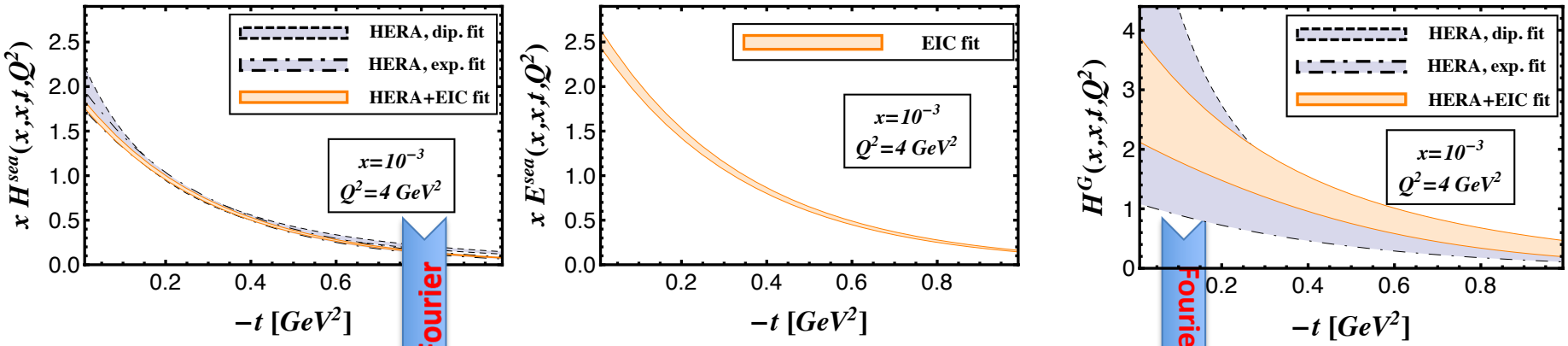
Transversely polarized protons: $\sin(\Phi_T - \phi_N)$
gives access to GPD E
Access to orbital angular momentum through "Ji sum rule"

$$\sum_{q=u,d,s} J^q(Q^2) + J^G(Q^2) = \frac{1}{2}\hbar$$

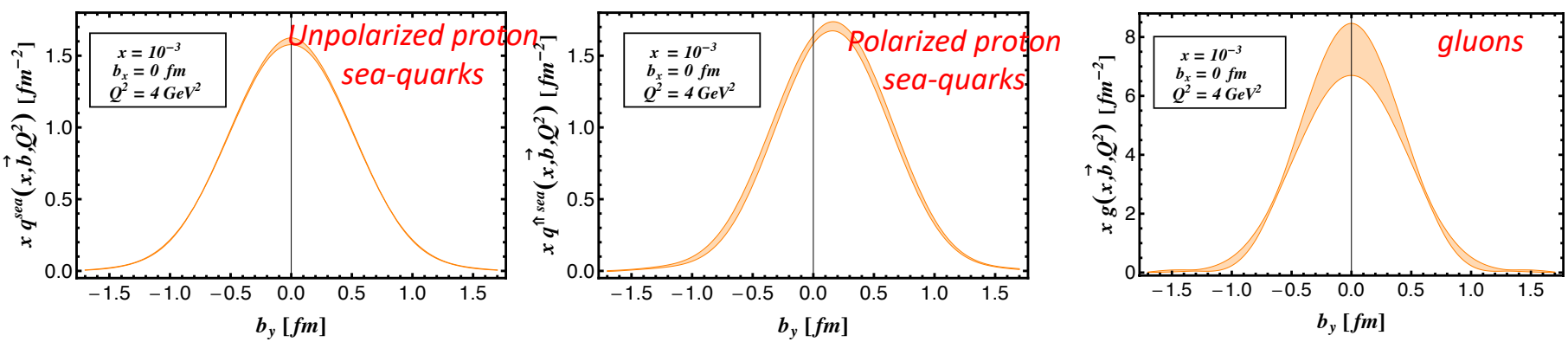
[X.D. Ji, Phys. Rev. Lett. 78, 610 (1997)]

DVCS-based imaging

- A global fit over all mock data was done, based on: [Nuclear Physics B 794 (2008) 244–323]
- Known values *q(x)*, *g(x)* are assumed for H^q, H^g (at t=0 forward limits E^q, E^g are unknown)

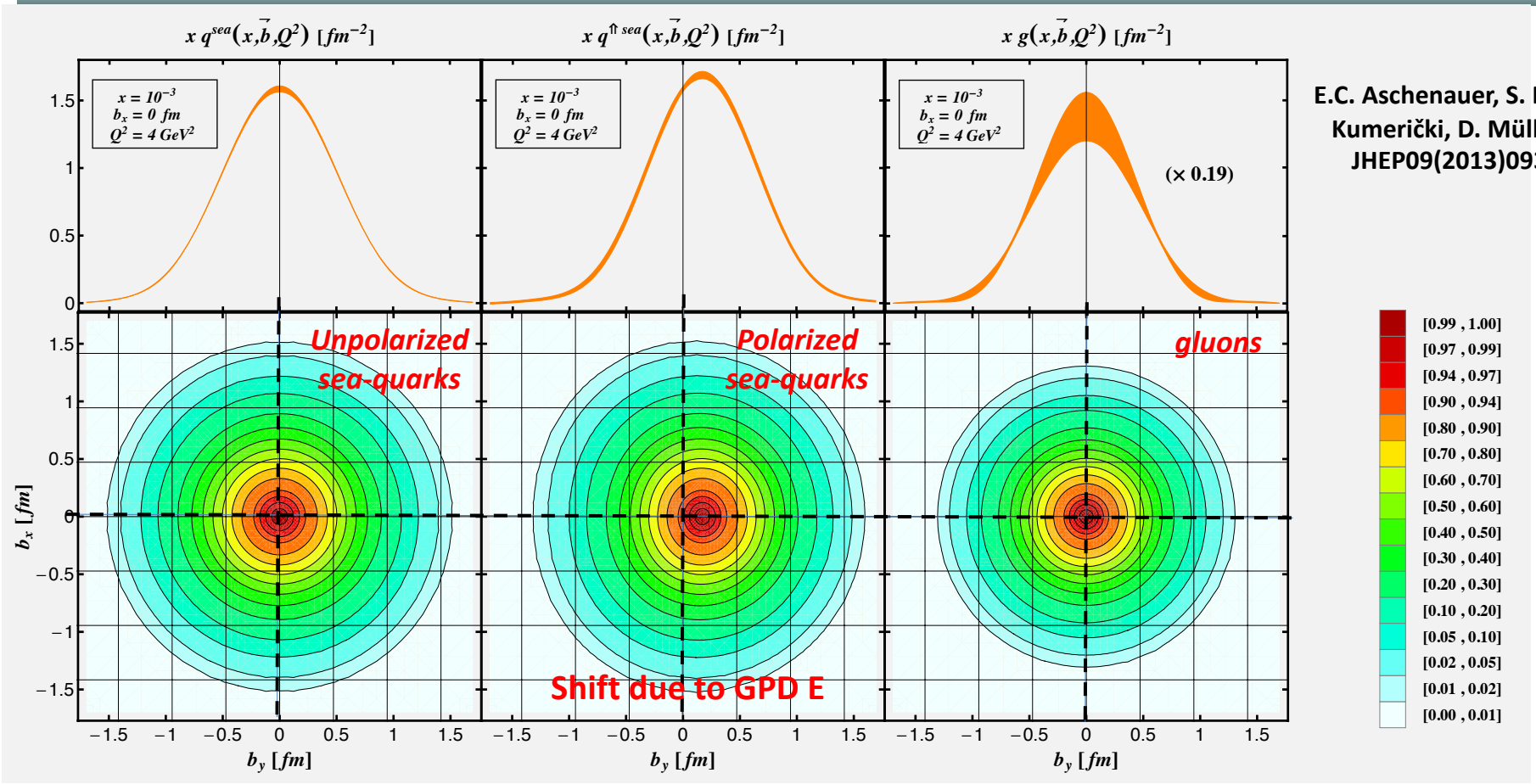


$$q\left(x,\vec{b},\mu^2\right)=\frac{1}{4\pi}\int_0^\infty d|t|J_0\left(\left|\vec{b}\right|\sqrt{|t|}\right)H\left(x,\eta=0,t,\mu^2\right)$$



E.C. Aschenauer, S. F., K. Kumerički, D. Müller, JHEP09(2013)093

Spatial Imaging – as in the EIC White Paper



E.C. Aschenauer, S. F., K. Kumerički, D. Müller, JHEP09(2013)093

Impact of EIC (based on DVCS only):

- ✓ **Excellent reconstruction of H^{sea}, and H^g (from $d\sigma/dt$)**
- ✓ **Reconstruction of sea-quarks GPD E**

Other capabilities still to be evaluated?

- GPD H-Gluon is nice but can be much better by including J/ψ
- Access to GPD E-gluon → orbital momentum (Ji sum rule)
- Flavor Separation of GPDs (VMP and/or DVCS on deuteron)
- Nuclear imaging (modification of GPDs in p+A collisions)

Summary on GPDs

e+p(A) physics program at EIC provides an unprecedented opportunity to study quarks and gluons in free protons and nuclei

The studies from the EIC WP era… (DVCS)

- Accurate 2+1D imaging of the polarized and unpolarized quarks and gluons inside the hadrons, and their correlations
- Investigate proton-spin decomposition (total orbital angular momentum)

Luminosity Requirements

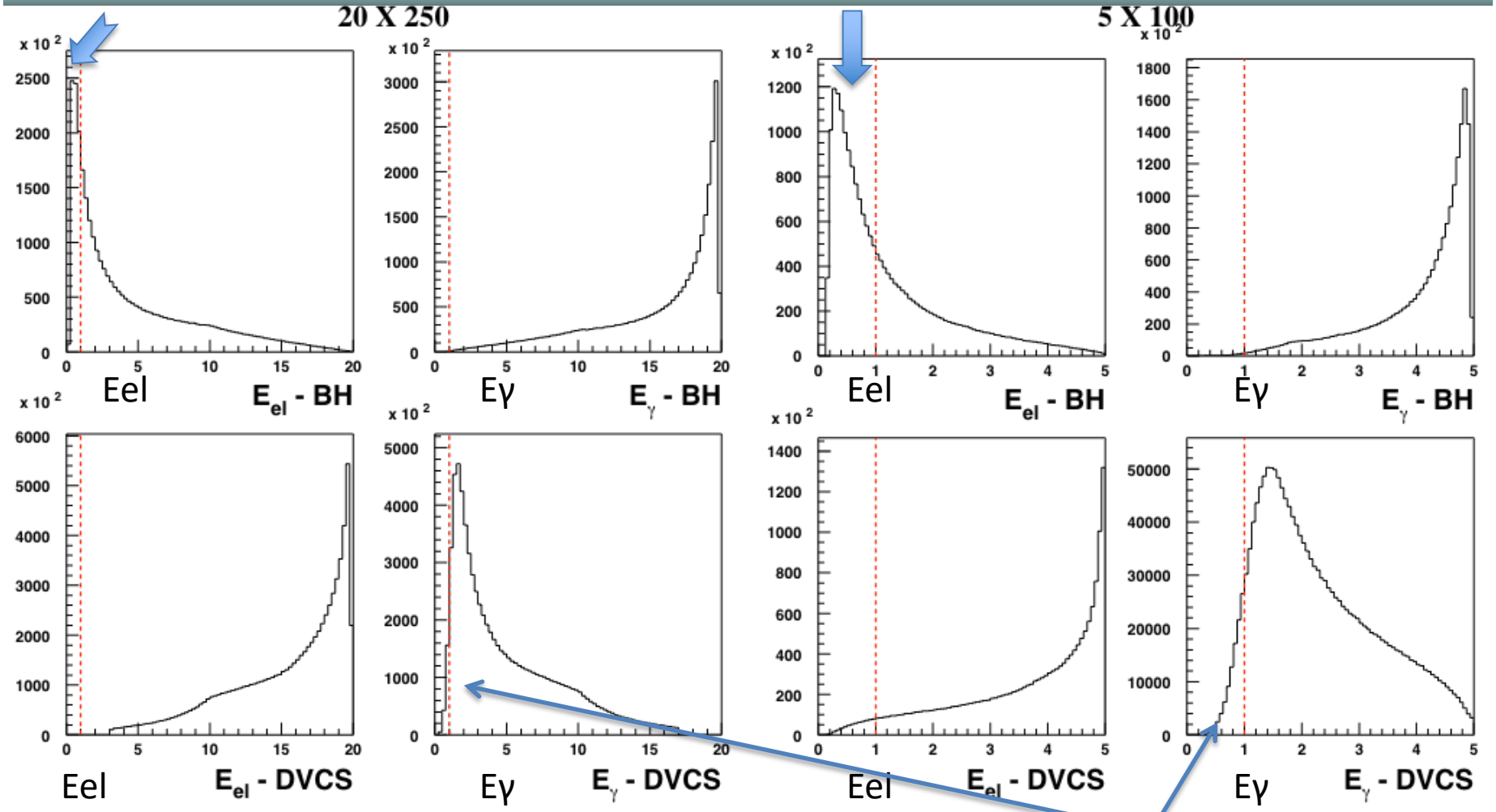
- A total of 200fb^{-1} collected at a lower and a top √s energy needed cover the W.P.'s GPDs program on e+p.

New excitement ahead

- Fully develop common framework platforms
- Include mesons in global fits (flavor separation, precision on gluons)
- Study of GPDs in nuclei (and possible gluon saturation effects)
- Extract the much-discussed *D*-term - the last "global unknown property" of a hadron, related to radial pressure distribution inside a nucleon

Back up

BH rejection

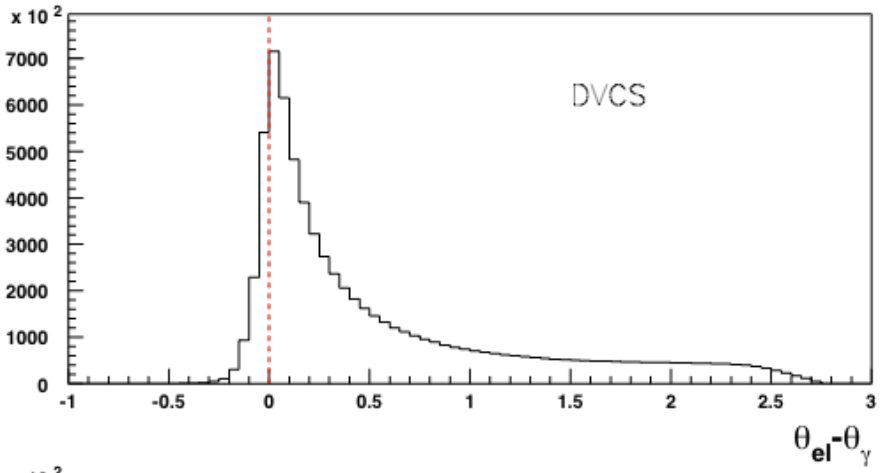


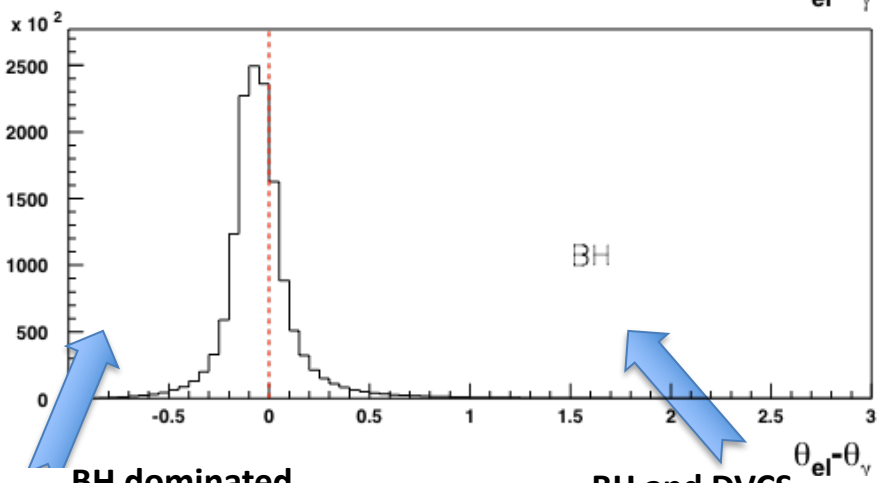
1. **BH electron has very low energy (often below 1 GeV)**
2. **Photon for BH (ISR) goes often forward (trough the beam pipe)**

Important: em Cal must discriminate clusters above noise down to 1 GeV

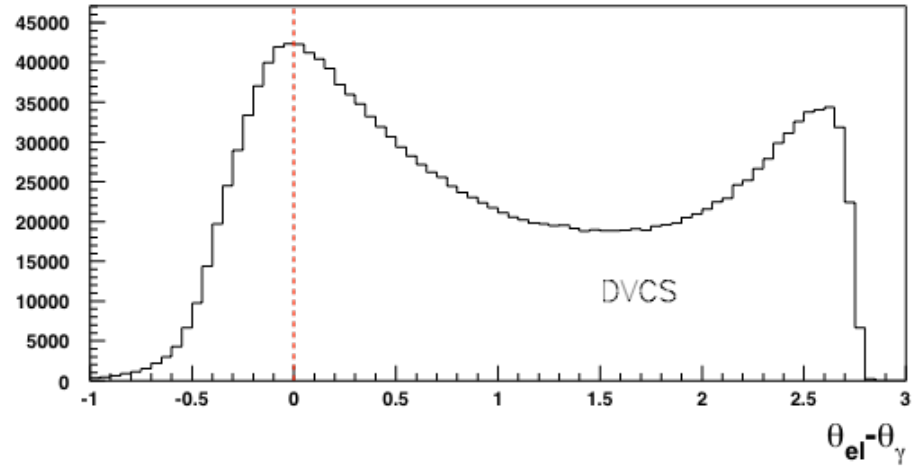
BH rejection

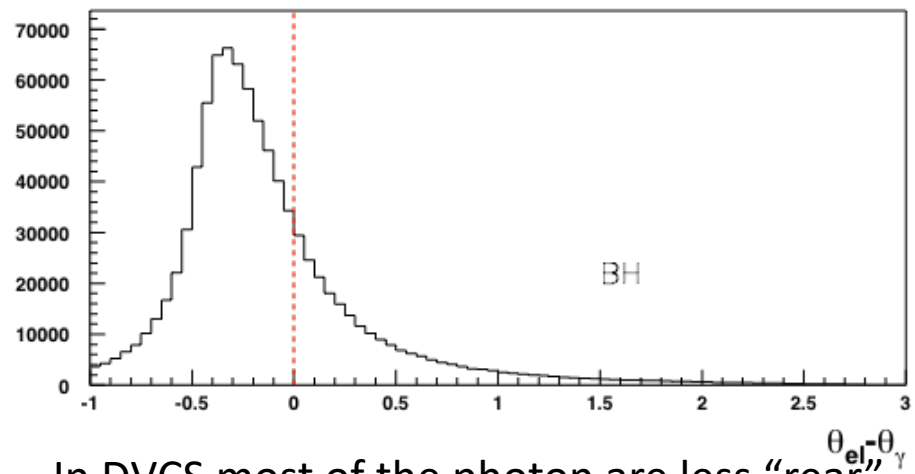
20 X 250



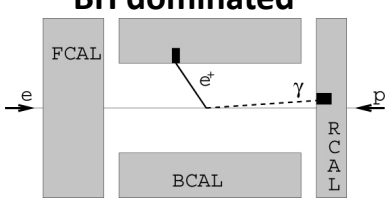


5 X 100

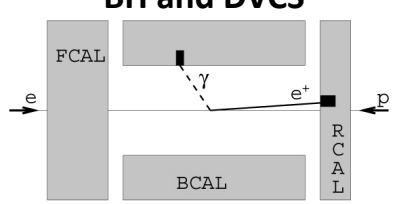




BH dominated



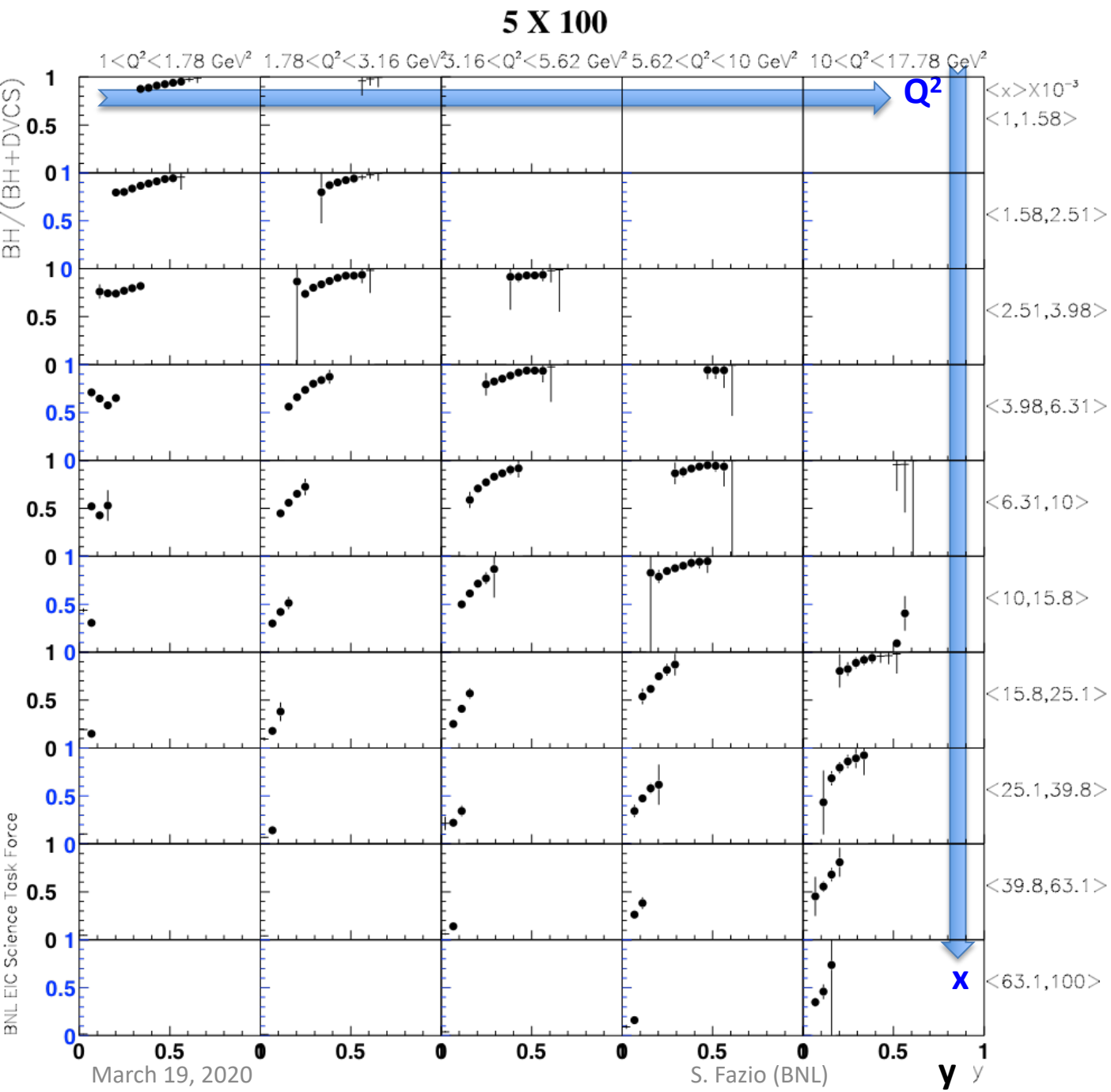
BH and DVCS



In DVCS most of the photon are less "rear" Than the electrons:

$(\theta el-\theta\gamma) > 0$ → rejects most of the BH

BH fraction



5 x 100 GeV²

BH subtraction will be relevant at low beam-energies, at large y, depending on the x-Q² bin