Results of DVCS measurement at COMPASS

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on behalf of the COMPASS collaboration

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HK 14.2

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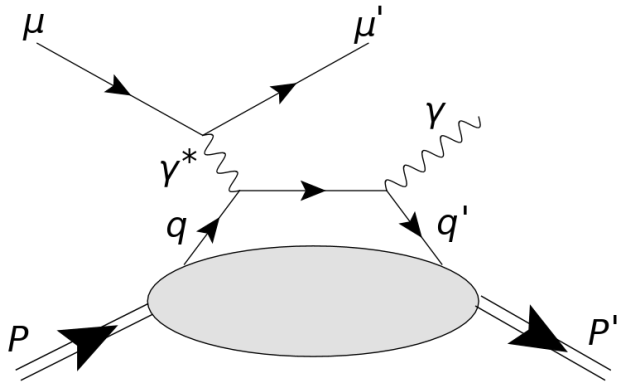
bmb+f - Förderschwerpunkt COMPASS Großgeräte der physikalischen Grundlagenforschung

COMPASS

Intro

- **COMPASS**
  → **CO**mmon **M**uon **P**roton **A**pparatus for **S**tructure and **S**pectroscopy
  → fixed target experiment at the M2 beam line of SPS
  (**S**uper **P**roton **S**ynchrotron, **CERN**)
- 2016/17 measurement of **Deeply Virtual Compton Scattering (DVCS)** was performed
  → polarized positive and negative muon beam scattered off a liquid hydrogen target
- From DVCS cross section, gain information e.g. position of a quark relative to the center of mass system of the nucleon (**Generalized Parton Distribution Functions**)

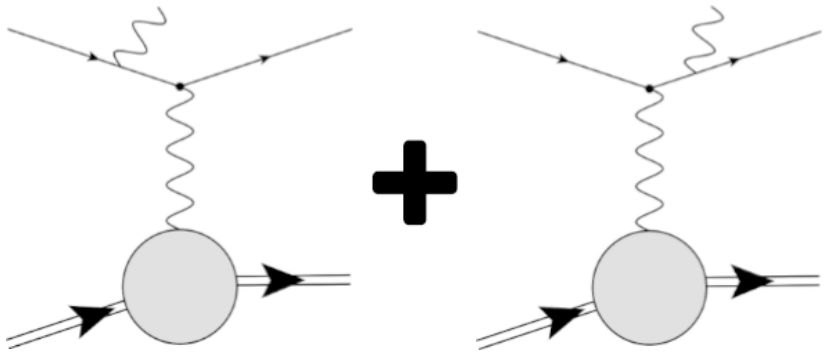
Exclusive single photon production @ COMPASS



Deeply Virtual Compton Scattering (DVCS)

$$\mu + p \rightarrow \mu' + p' + \gamma$$

Bethe-Heitler (Bremsstrahlung)
$\rightarrow$ same final state



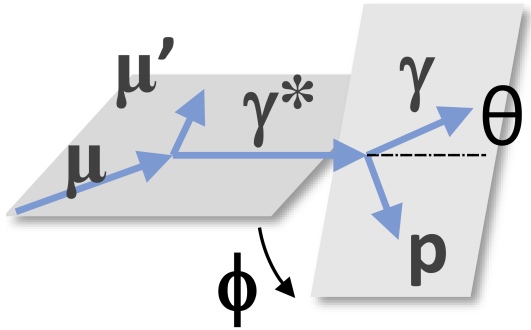
Cross section of excl. photon production:

$$\sigma(\mu p \rightarrow \mu' \gamma p') = \sigma_{DVCS} + \sigma_{BH} + \sigma_{Int.}$$

Measurement @ COMPASS

Kinematic dependencies:

- Q^2 : 4-momentum of γ^*
- ν : Energy of γ^*
- t : Momentum transfer to proton
- ϕ : Angle between scattering plane (γ^*) and production plane (γ)



$\Rightarrow$ Measure **angular distribution of real photon**

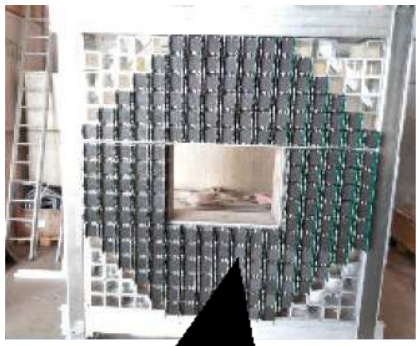
Identify exclusive photon events:

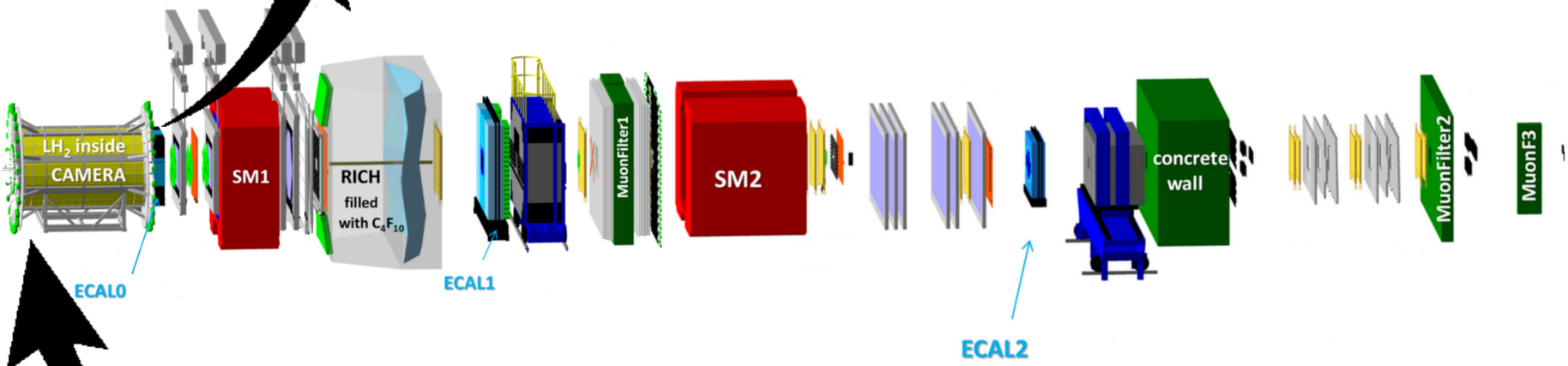
Incoming muon
Scattered muon
Recoil proton
Real photon
} overconstrained

Data taking @COMPASS:

- 2012 test run for 4 weeks
  $\rightarrow$ Analysis finished and published
- Long runs dedicated to DVCS in 2016/17
  $\rightarrow$ Analysis ongoing

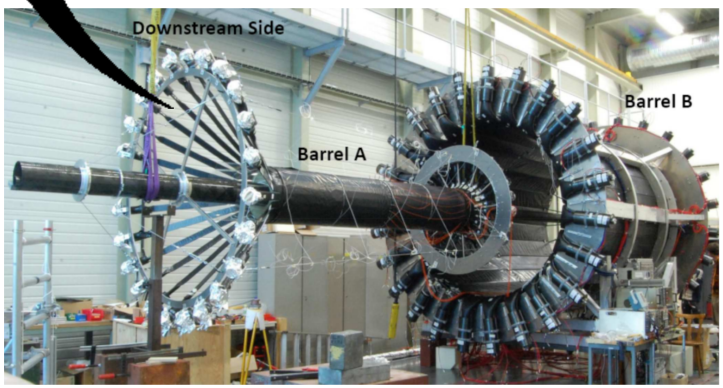
COMPASS spectrometer setup (2016/17)





Two staged forward spectrometer SM1 + SM2

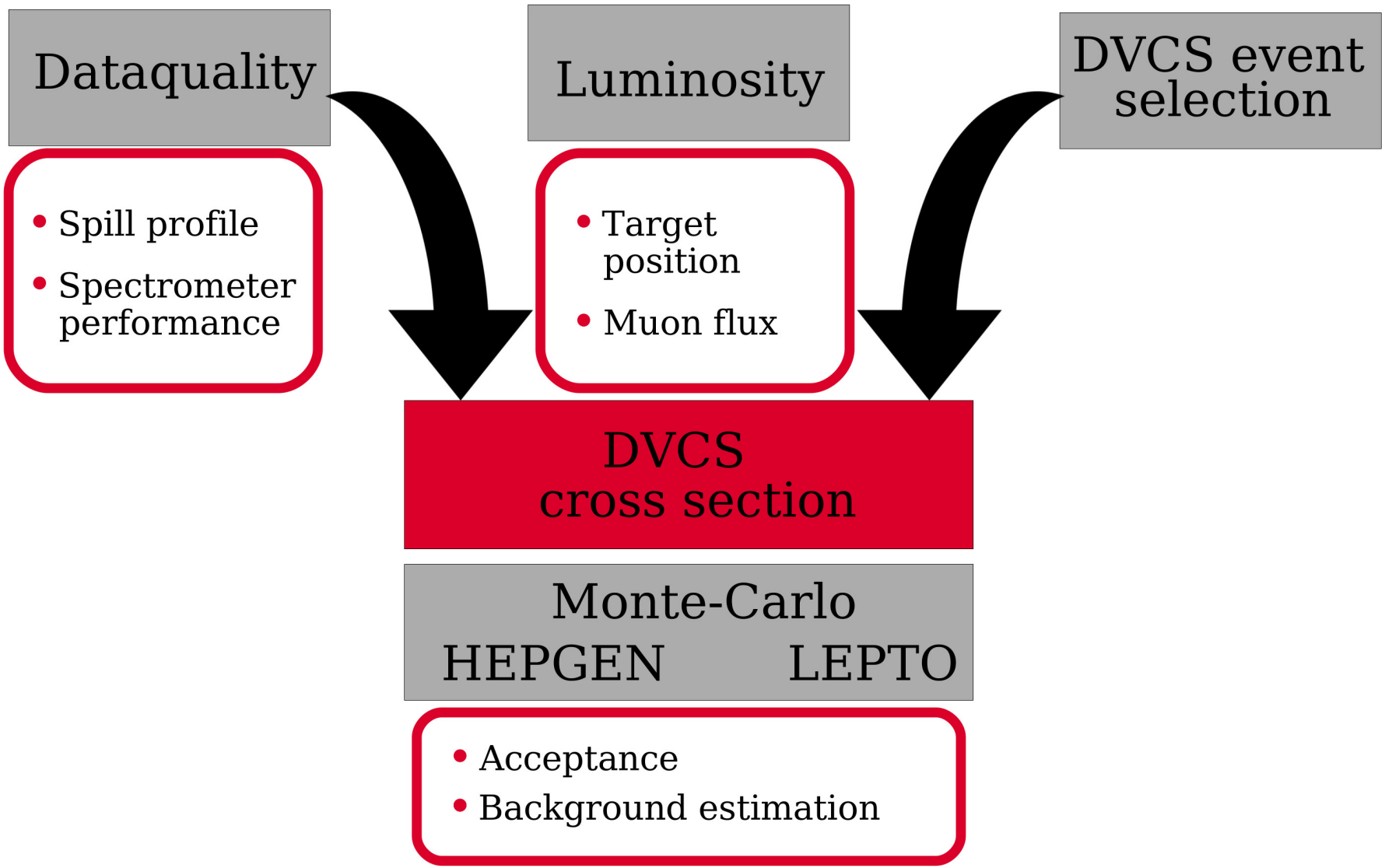
- Liquid hydrogen target (2.5m, ∅4cm)
- Proton recoil detector (CAMERA)
- ECAL0, ECAL1 and ECAL2 (Photon detection)
- Muon trigger system (μID)
  - $\sim$ 300 tracking detector planes



CAMERA:

- Inner (removed) & outer ring (in background)
- each 24 scintillators
- $\rightarrow$ TOF measurement

The road to the DVCS cross section



Selection of exclusive single photon events

Vertex selection:

- *Incoming muon*
  - Use same selection as for muon flux
    $\rightarrow$ avg. beam momentum
    160 GeV$\pm$5%,
    every single muon is measured
- *Scattered muon*
  - Sufficient momentum transfer to proton

$\Rightarrow$ Vertex

- **Real photons**
  - Photon energy above a defined threshold in one ECAL
  - Only single photon found
- **Recoil proton candidates**
  - TOF measurement
- Improve event selection by adding **"exclusivity cuts"**

Only events which have exactly one combination of:

$$\text{Vertex cand.} \times \text{Proton cand.} \times \gamma$$

Exclusivity conditions

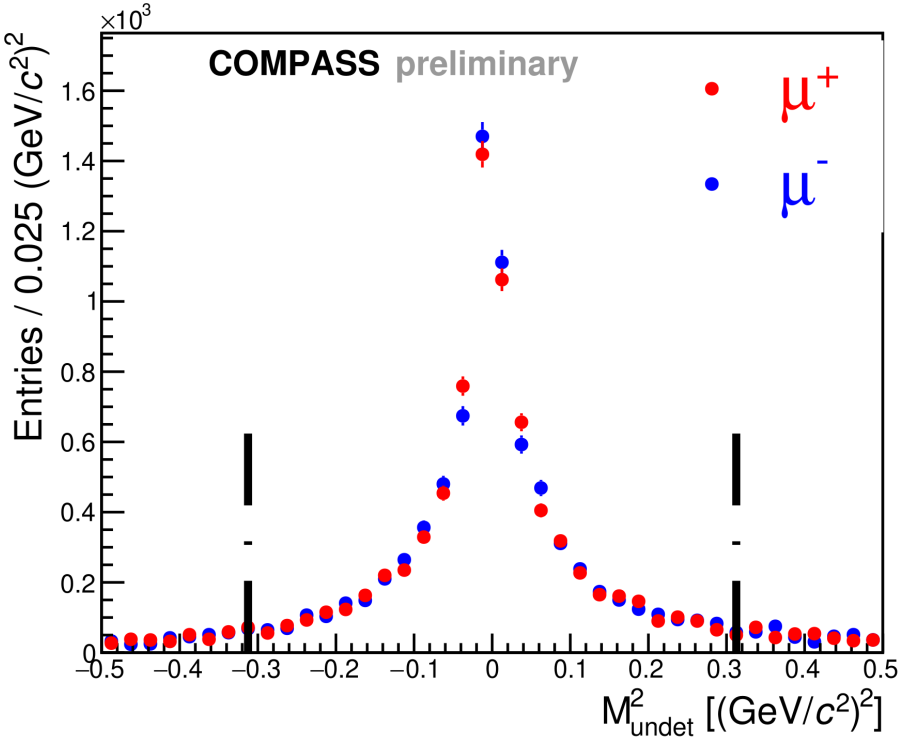
→ over constrained, due to **full exclusive measurement**

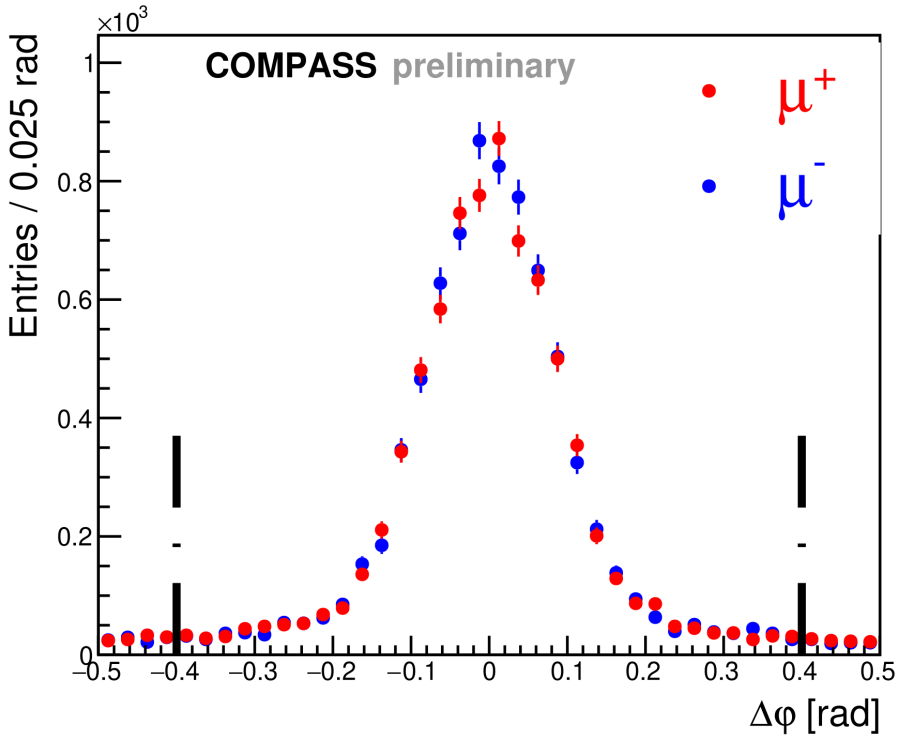
e.g. for exclusivity conditions

Missing mass: $M_x^2 = (k + p - k' - q' - p')^2$

$\Delta\phi$: $\Delta\phi = \phi_{Cam.} - \phi_{Spec.}$

Spec.: Lorentz Vector of proton calculated from 4-Momentum conservation
Cam.: Lorentz Vector of proton by CAMERA measurement

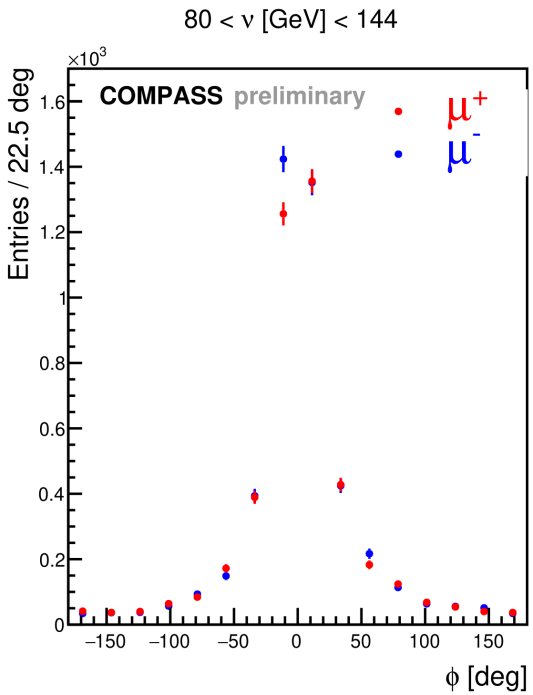


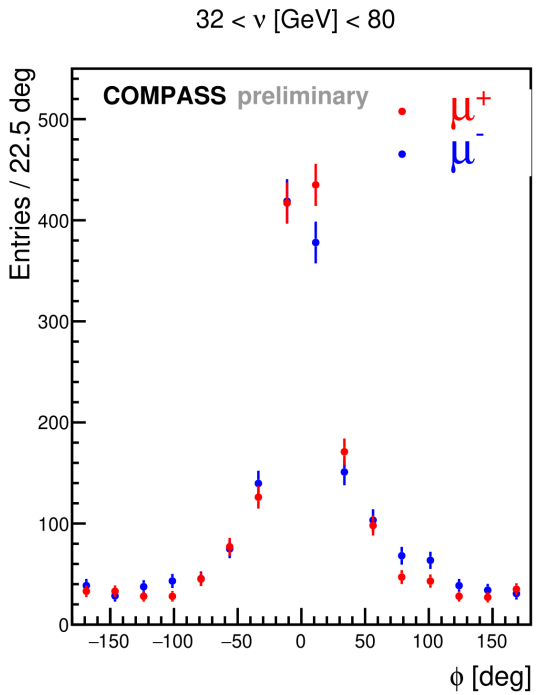


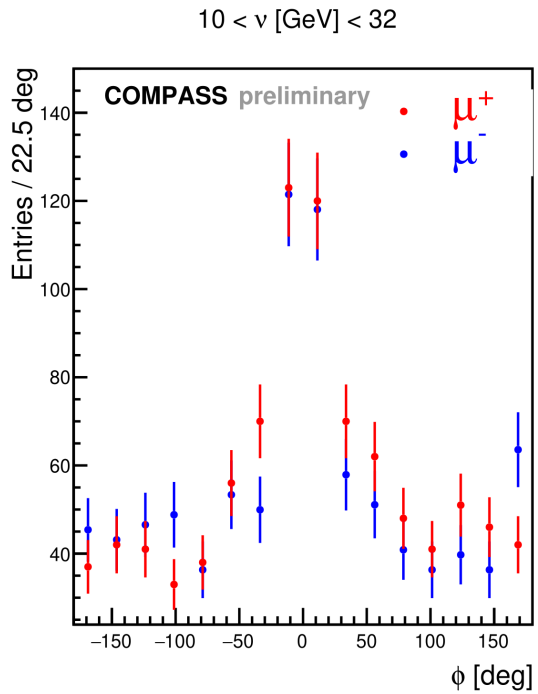
$\phi_{\gamma\gamma*}$ distribution

High beam energy

$\rightarrow$ Possibility to choose 3 different ν ranges







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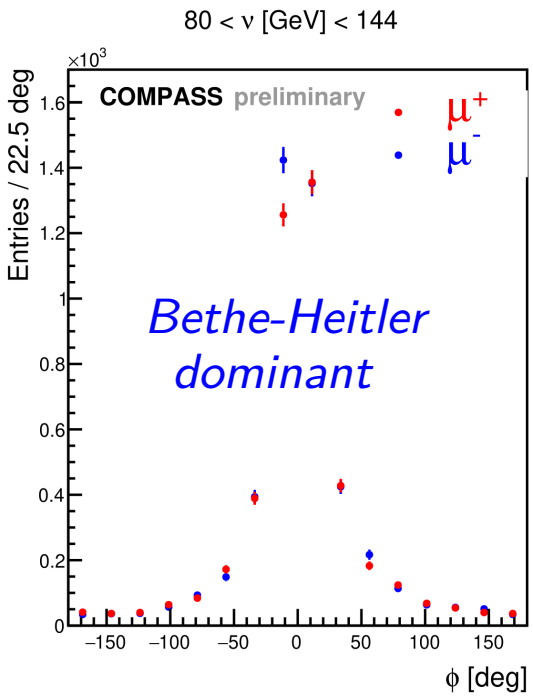

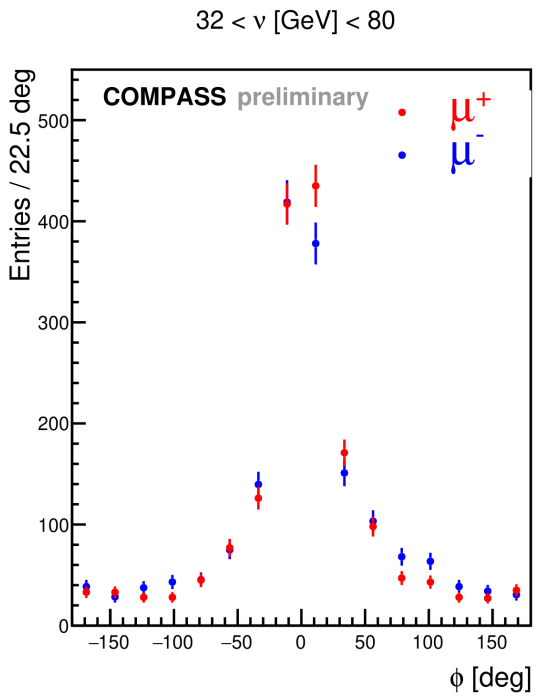

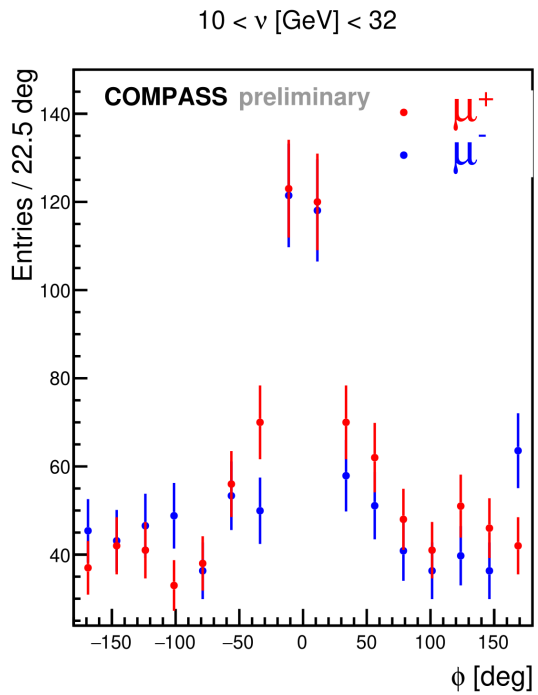

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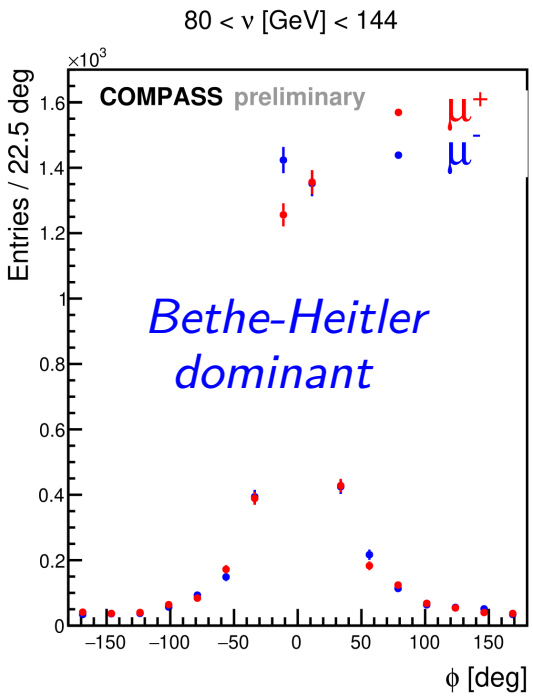

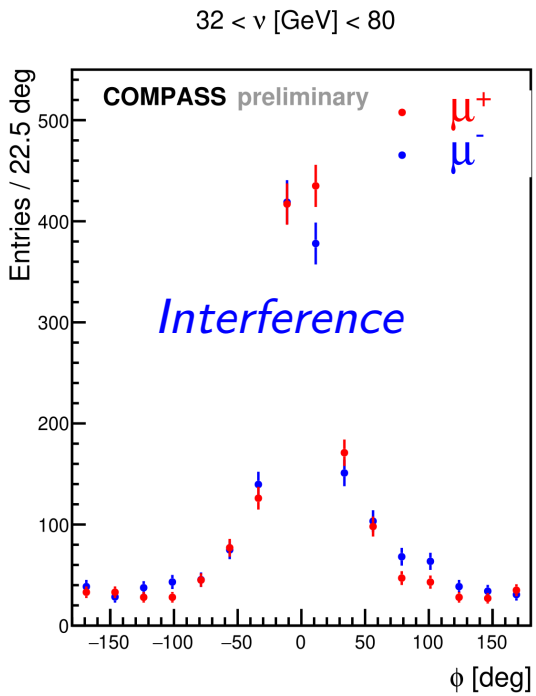

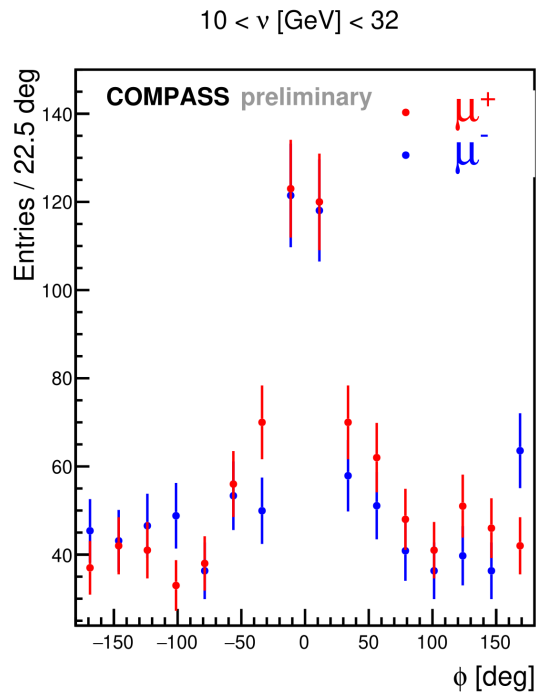

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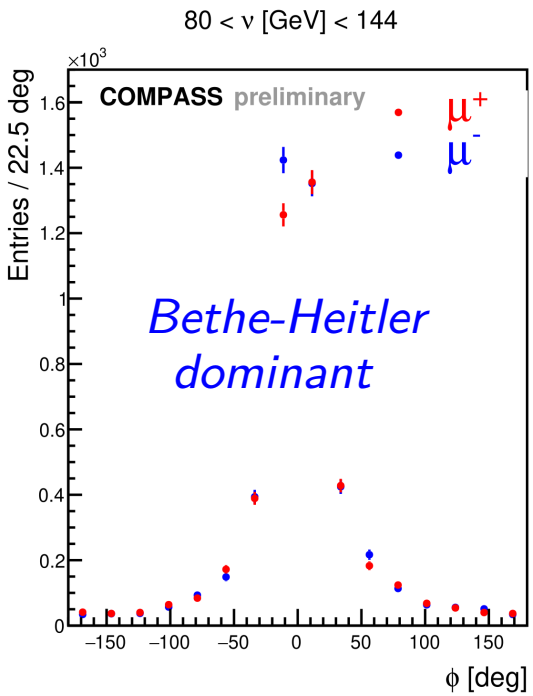
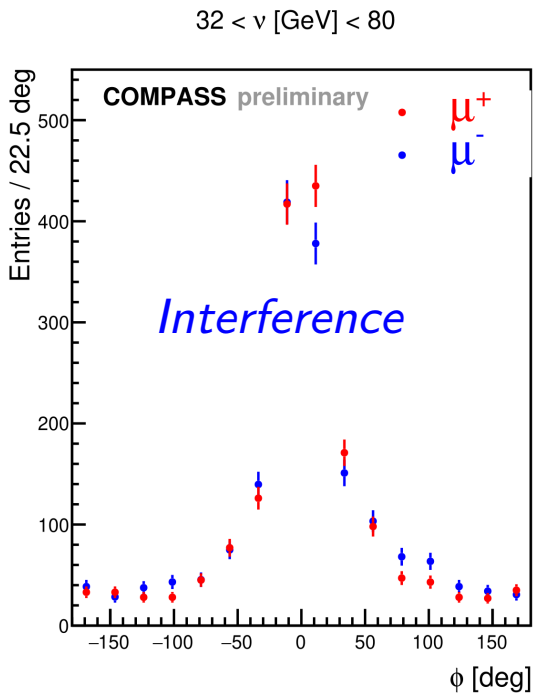
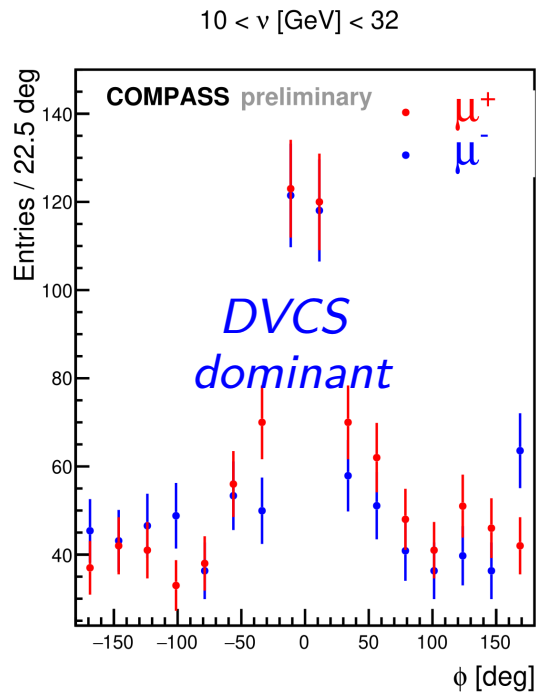






The t-dependency of the DVCS cross section

DVCS cross section:

$$\left\langle \frac{d\sigma_{DVCS}}{d|t|} \right\rangle^{\pm}_{t_n} =$$

$$\frac{1}{\mathcal{L}\Delta t_n \Delta Q^2 \Delta \nu} \sum^{Q_i,\nu_j} \left[(a^{\pm}_{ijn})^{-1} \left(\text{data} - c^{\pm}_{BH} \text{BH}_{MC} - c^{\pm}_{\pi^0} \pi^0_{MC} \right) \right]$$

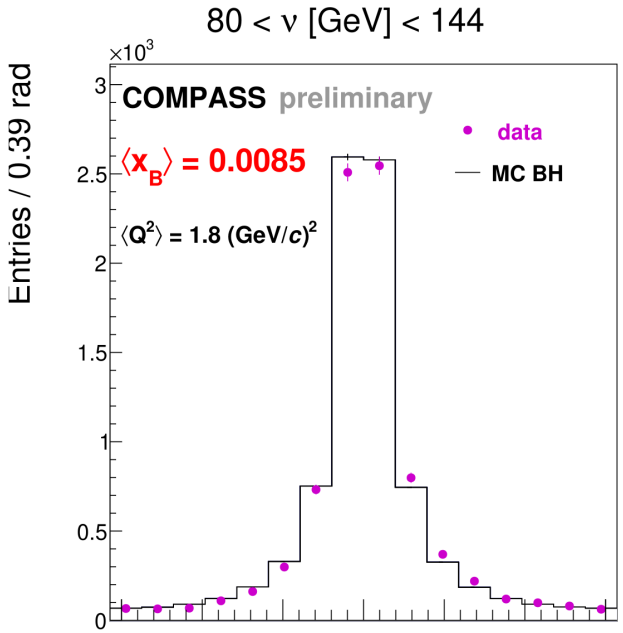
- data
- BH_{MC}: exclusive single photon MC sample
- π^0_{MC}: π^0 MC sample (background)
- c: Normalization factors

Binning

Integrated over $\phi_{\gamma\gamma*}$
4 bins: $1 < Q^2[(\text{GeV/c})^2] < 5$
4 bins: $0.08 < |t|[(\text{GeV/c})^2] < 0.64$
11 bins: $10 < \nu[\text{GeV}] < 32$

Contribution of the Bethe-Heitler

BH process **very well known** over a wide kinematic range
$\rightarrow$ MC sample for the BH (HEPGEN)



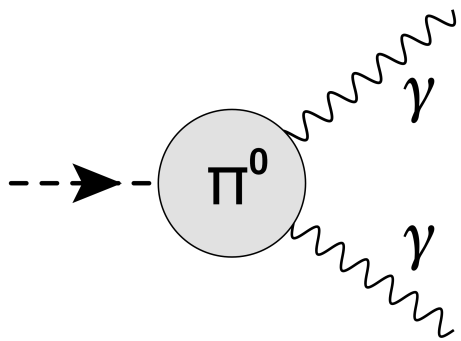
Handling BH contribution:

- Kinematic range where **BH is dominant**
  $\rightarrow$ Normalize real and MC data according their luminosity
  $\Rightarrow$ $c_{BH}^{\pm}$ ratio of data to MC luminosity
- **BH** subtracted from the data in extraction region ($10 < \nu[GeV] < 32$)

π^0 background contamination

Photons via **decay of**

$$\pi^0 \rightarrow \gamma\gamma$$

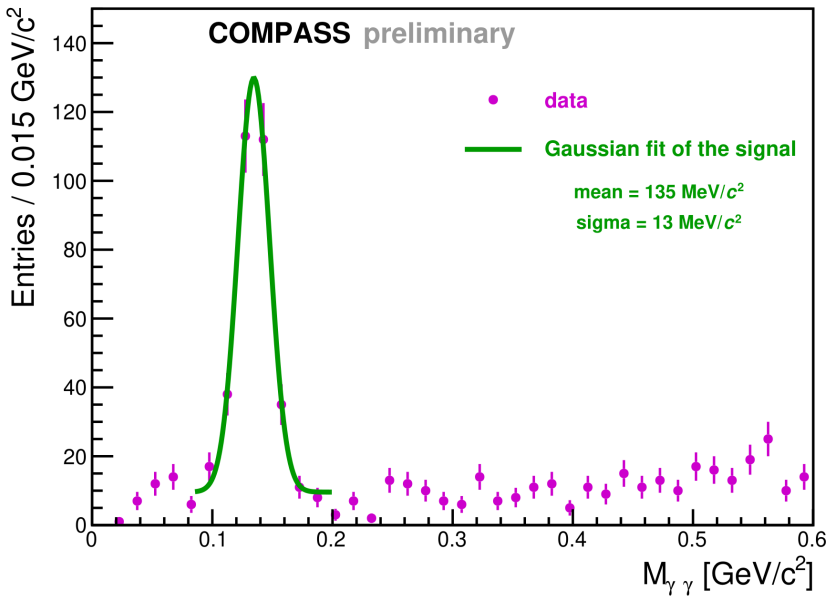


π^0 contamination:

- Visible π^0 contamination
  - Combine photon with other low energy photons in the event (below ECAL threshold)

  $\rightarrow$ Remove the events which contribute to π^0 peak
- Invisible π^0 contamination
  - 2nd photon was not detected
  - Monte-Carlo study needed

  π^0 production channel:
    - Exclusive (HEPGEN):
      $\mu + p \rightarrow \mu + p + \pi^0$
    - Semi inclusive (LEPTO):
      $\mu + p \rightarrow \mu + \pi^0 + X$



$\Rightarrow$ For normalization of HEPGEN and LEPTO use visible π^0 peak

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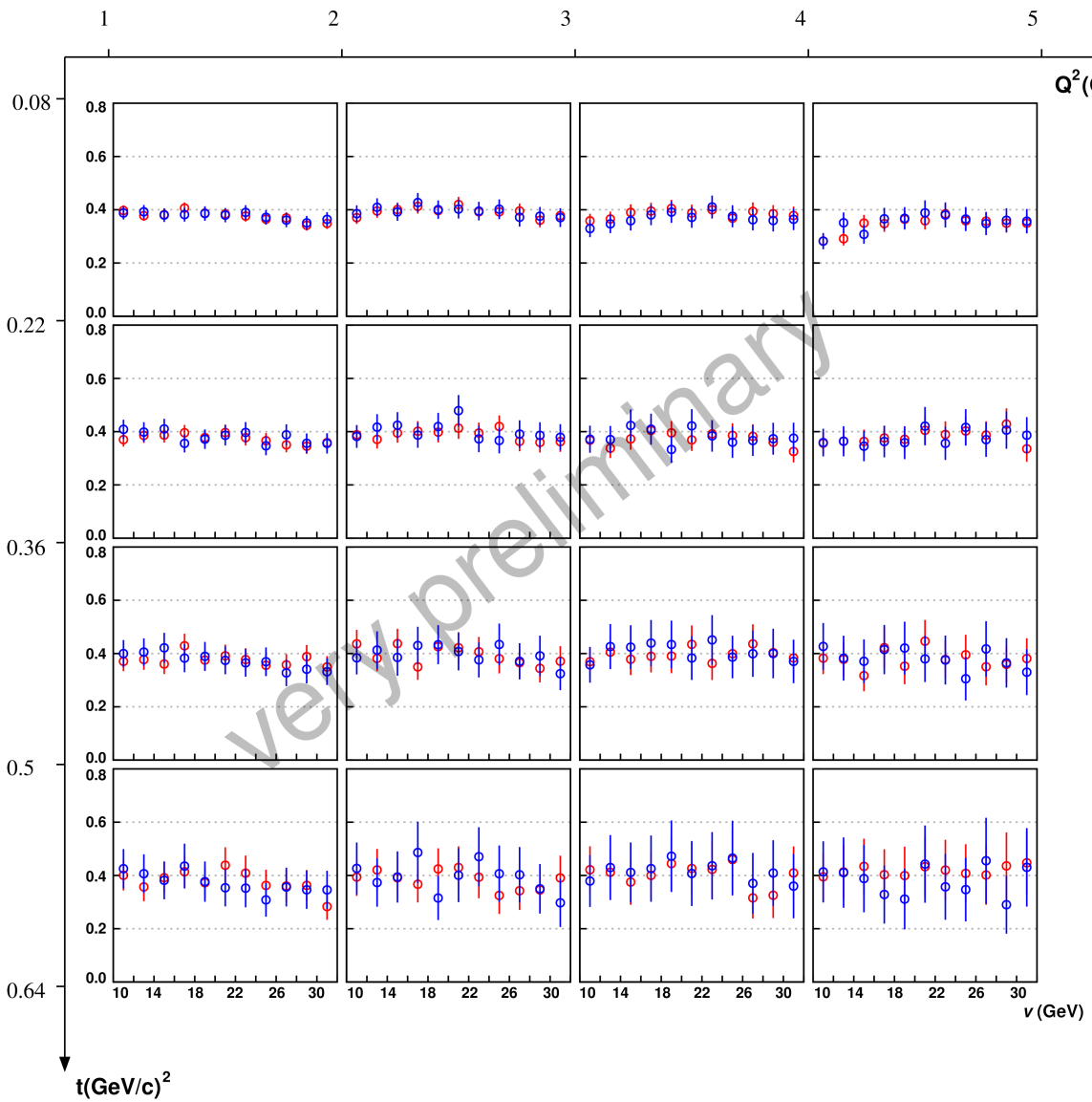
$$c^{\pm}_{\pi^0} \pi^0_{MC} = c^{\pm}_{HEPGEN} \cdot R \cdot \pi^0_{HEPGEN} + c^{\pm}_{LEPTO} \cdot (1 - R) \cdot \pi^0_{LEPTO}$$

- data
- BH_{MC}: exclusive single photon MC sample
- π^0_{HEPGEN}: exclusive π^0 MC sample
- π^0_{LEPTO}: semi-inclusive π^0 MC sample
- $c^{\pm}_{BH}$: Ratio of data and MC luminosity
- $c^{\pm}_{HEPGEN}$: HEPGEN normalized to vis. π^0-peak
- $c^{\pm}_{LEPTO}$: LEPTO normalized to vis. π^0-peak
- R: Ratio of HEPGEN to LEPTO
  → Estimated by fitting kin. distributions of both MC to real data
- $a^{\pm}_{ijn}$: Acceptance

Acceptance



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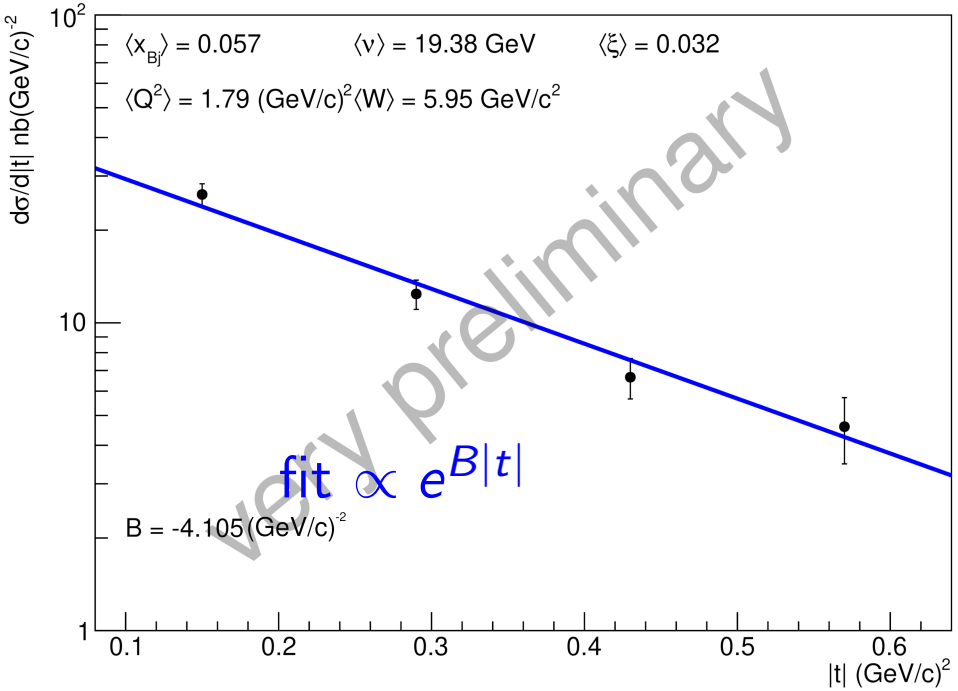
Mostly flat acceptance (app. 35-40%)

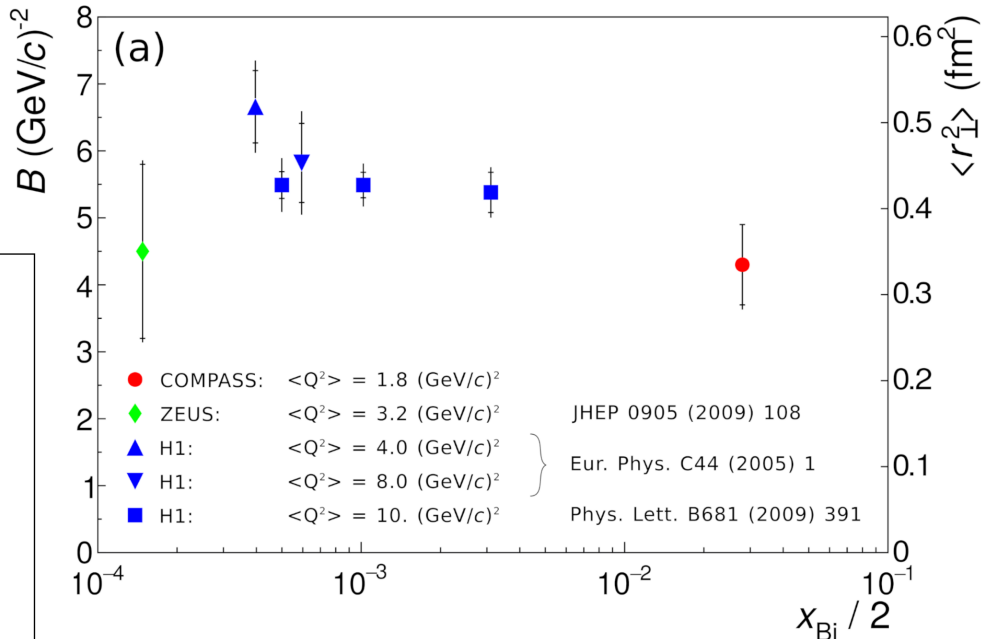
Analyse the t-slope of the cross section

DVCS cross section in each t bin:

$$\left\langle \frac{d\sigma_{DVCS}}{d|t|} \right\rangle_{t_n} = \frac{1}{2}\left(\left\langle \frac{d\sigma_{DVCS}}{d|t|} \right\rangle^{+}_{t_n} + \left\langle \frac{d\sigma_{DVCS}}{d|t|} \right\rangle^{-}_{t_n} \right)$$

Only two weeks of 2016 data taking





2012 results PLB 793 (2019) 188

$\langle r_\perp^2 \rangle = 2\langle B(x_{Bj})\rangle \hbar^2$

$\sqrt{\langle r_\perp^2 \rangle} = (0.58 \pm 0.04_{stat}|_{sys} \pm 0.04_{model})\text{fm}$

Outlook

Honorable mentions:

- Use a kinematic fit to improve the values of kinematic variables

In the future ...

- Analysis is progressing well (but still ongoing)
- Hope to present a new value on B in autumn

Thank you for your attention.