DVCS Cross Section Measurements at COMPASS

On behalf of the COMPASS Collaboration

DIS2026

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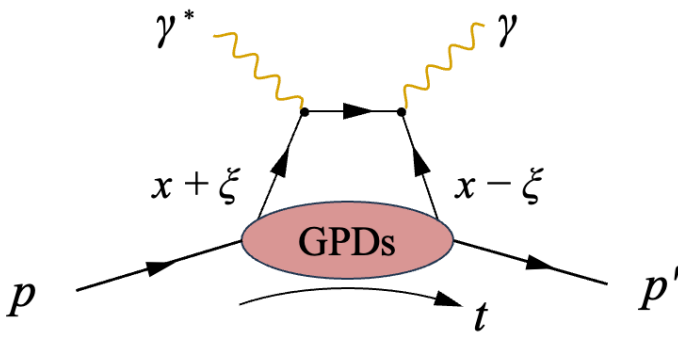
Probing Proton Structure with DVCS

Given the COMPASS kinematics and the use of a proton target, the DVCS measurements are most sensitive to the GPD H

DVCS: $\boldsymbol{l + p \rightarrow l' + p' + \gamma}$



DVCS amplitude at LO and LT in α_s:

$$\mathcal{H}_{t,\xi\ fixed} = \int_{-1}^{1} dx \frac{H(x,\xi,t)}{x-\xi+i\varepsilon} = \mathcal{P}\int_{-1}^{1} dx \frac{H(x,\xi,t)}{x-\xi} - i\pi\, H(x=\pm\xi,\xi,t)$$

$$Re\mathcal{H}(\xi,t) = \pi^{-1}\int dx \frac{Im\mathcal{H}(x,t)}{x-\xi} + \Delta(t)$$

- At COMPASS: high muon beam energy (160 GeV) and small $\xi \approx \frac{x_B}{2}$

$\frac{d\sigma_{DVCS}}{dt} \propto (Im\mathcal{H})^2$ and $Im\mathcal{H} = H(x=\xi,\xi,t)$

$\Big\langle b_\perp^2(x) \Big\rangle \approx 2B(\xi)$

- We observe $\frac{d\sigma_{DVCS}}{dt} \sim e^{-B|t|}$

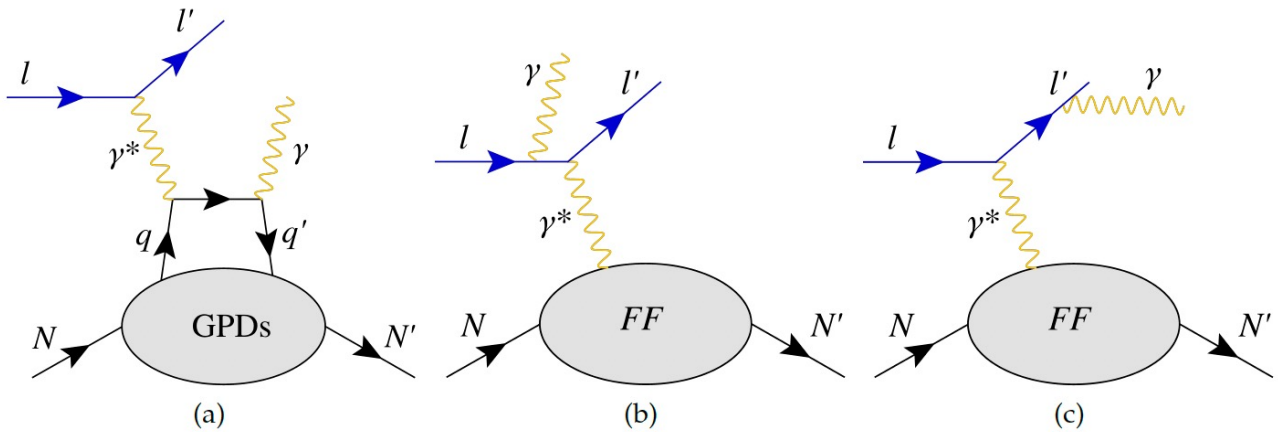
$b_\perp$ is the transverse extension of partons in the proton

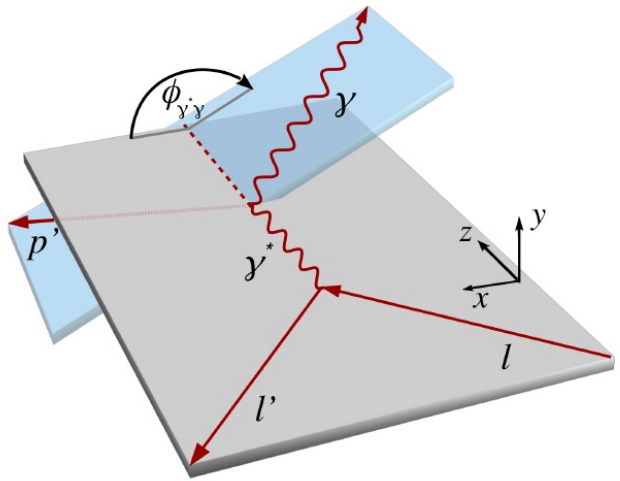
DVCS and Bethe-Heitler

DVCS and BH have the same final state, $\mathcal{A}_{lN\to l'N'\gamma} = \mathcal{A}_{DVCS} + \mathcal{A}_{BH}$; *DVCS and BH interfere at the amplitude level.*

$$\frac{d^4\sigma^{lN\to l'N'\gamma}}{dx_{bj}dQ^2d|t|d\phi_{\gamma^*\gamma}} \propto |\mathcal{A}_{lN\to l'N'\gamma}|^2 \propto |\mathcal{A}_{DVCS}|^2 + |\mathcal{A}_{BH}|^2 + \underbrace{\mathcal{A}_{DVCS}\mathcal{A}_{BH}{}^* + \mathcal{A}_{DVCS}{}^*\,\mathcal{A}_{BH}}_{\text{Interference term}}$$

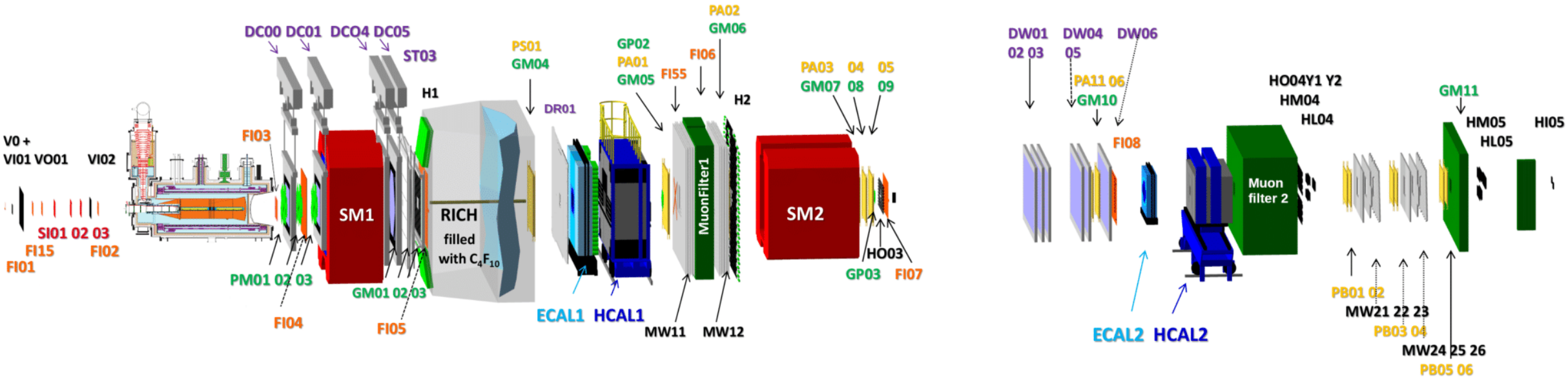
- COMPASS (160 GeV μ± beam): BH contribution is not too large; Integrating over ϕ eliminates the interference terms and allows us to isolate the ϕ-independent DVCS term





(a) Diagram of the DVCS process at LO and leading twist. (b) and (c) are diagrams for the BH process at LO, where the real photon is emitted by the lepton.

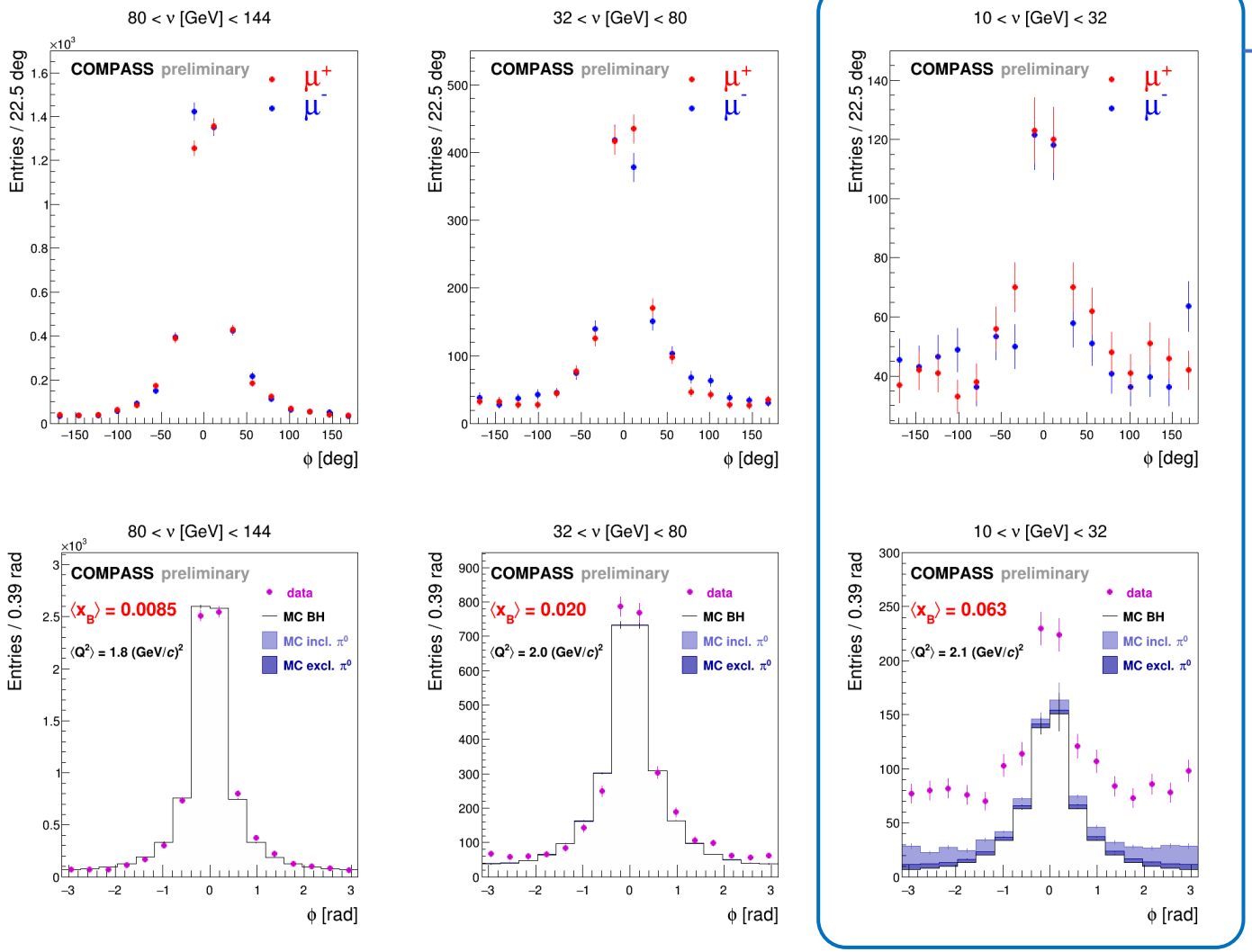
Spectrometer setup in 2016/17



- Beam: Longitudinally polarized 160 GeV $\mu^{\pm}$ beams (polarization $\sim \mp 80\%$)
- Target: 2.5m long unpolarized liquid H_2

- Muons: Identified via radiation length (X/X_0) in muon filters/walls across spectrometer stages
- Photons: Detected in ECALs (ECAL0/1/2); ECAL0 added after CAMERA in 2016/17 setup
- Recoil protons: Detected with CAMERA surrounding the target; identified by time-of-flight and energy loss

Extraction of the DVCS Cross Section

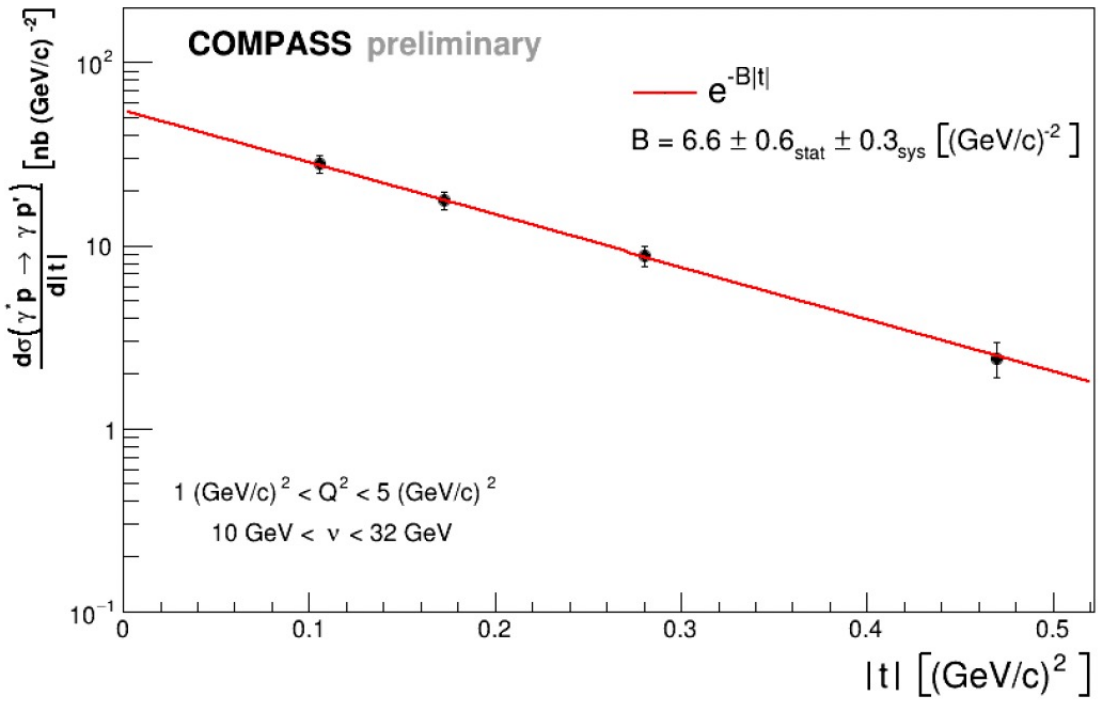


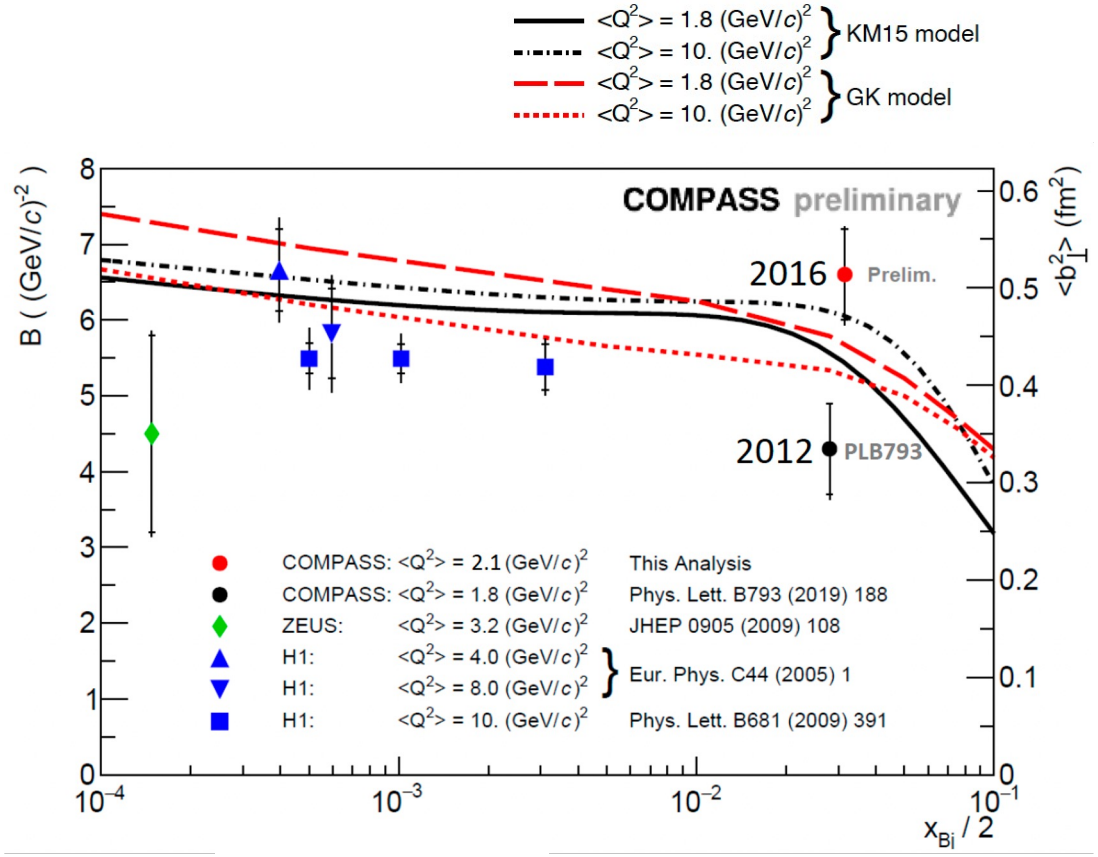
Extraction is done in the low ν region where the DVCS contribution is most dominant

- Identify exclusive single-photon events in μ^+ and μ^- data
- Remove visible π^0 contamination
- At large ν: distribution dominated by BH
  - good agreement with BH expectation
- At small ν: subtract BH (and invisible π^0) contribution to isolate DVCS contribution
- Apply 4D acceptance and luminosity corrections
- Integrate over ϕ to obtain dσ/dt
  - extract slope parameter B

|t|-dependence of the Cross Section

$$\frac{d\sigma_{DVCS}}{dt} \sim e^{-B|t|}$$





- $d\sigma/d|t|$ is evaluated in 4 |t| bins (only the statistical errors are shown)
- |t|-dependence is well described by $e^{-B|t|}$
- Extract B using a binned maximum-likelihood method

Thank you!

Exclusivity variables for proton selection

Difference in values measured by camera and spec.

- Azimuthal angle:

$$\Delta\varphi = \varphi^{cam} - \varphi^{spec}$$

- Transverse momentum:

$$\Delta p_T = p_T^{cam} - p_T^{spec}$$

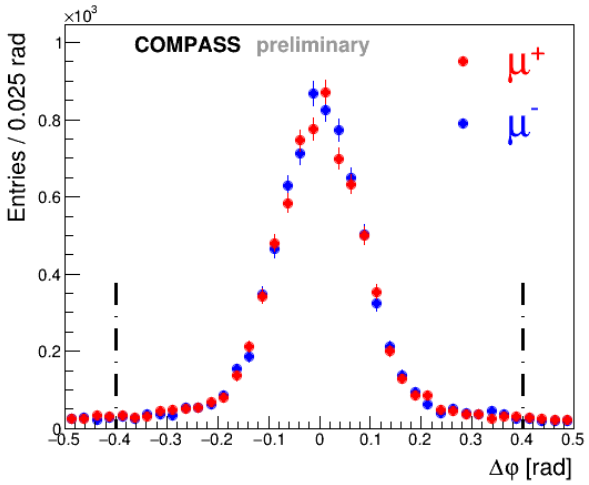
- Track hit position:

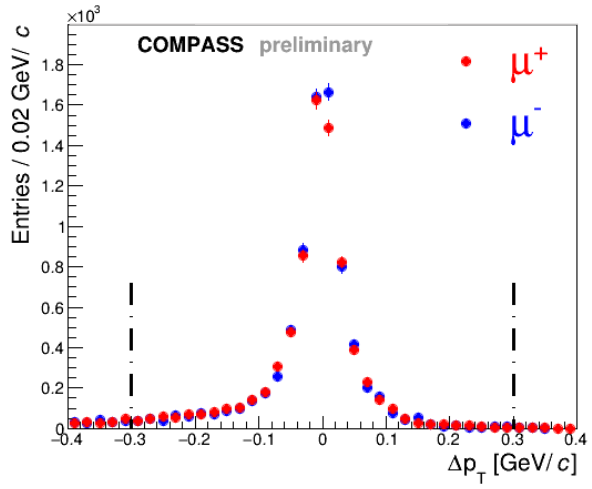
$$\Delta Z_A = Z_A^{cam} - Z_A^{interp}$$

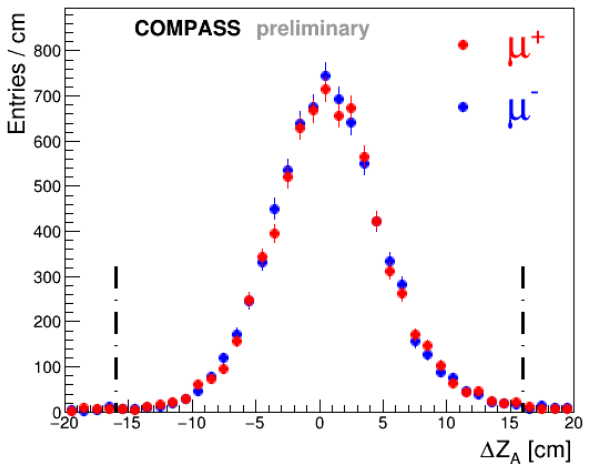
- Energy-momentum balance:

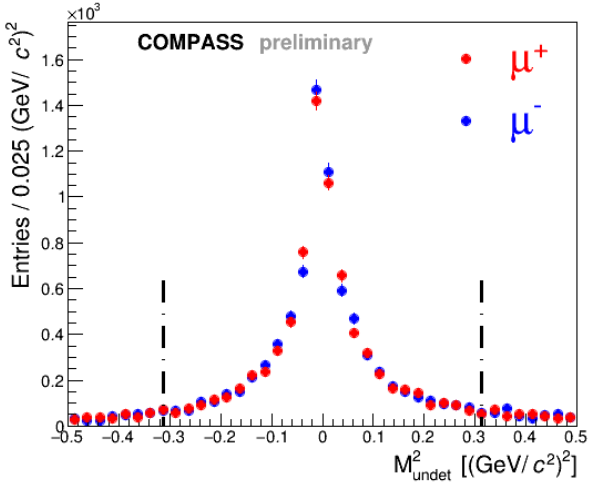
$$\Delta M_x^2 = (k + p - k' - q' - p')^2$$

Good agreement in $\overleftarrow{\mu^+}$ and $\overrightarrow{\mu^-}$ is imperative for,
$\Sigma \equiv d\sigma^{\overleftarrow{+}} + d\sigma^{\overrightarrow{-}}$







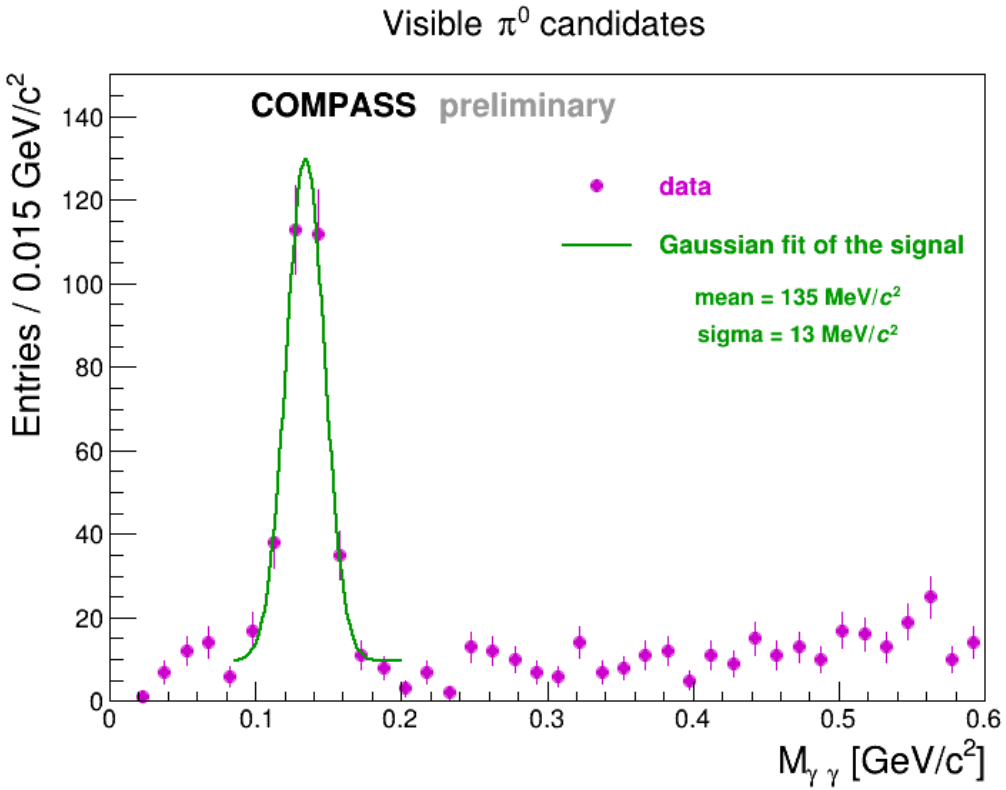


π^0 contamination

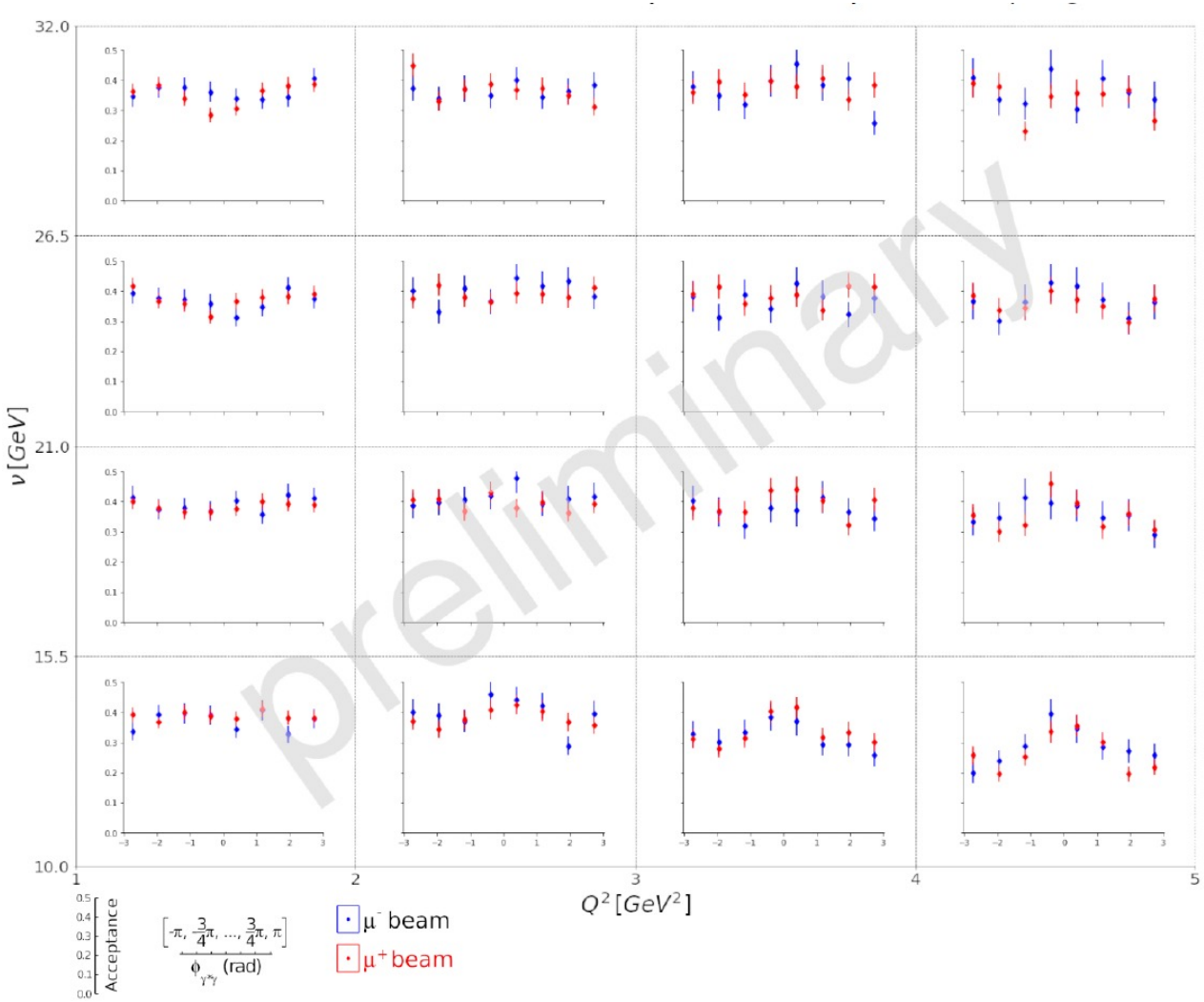
$\pi^0 \rightarrow \gamma\gamma$

Visible π^0:
- Both photons are detected
- Directly removed from data
- Identified by combining the high energy photon with those with energy below the DVCS energy thresholds

Invisible π^0:
- Only one photon is detected
- Estimated using dedicated MC samples
  - Inclusive: LEPTO π^0
  - Exclusive: HEPGEN π^0
- MC samples are normalized to the visible π^0 in data



Acceptance

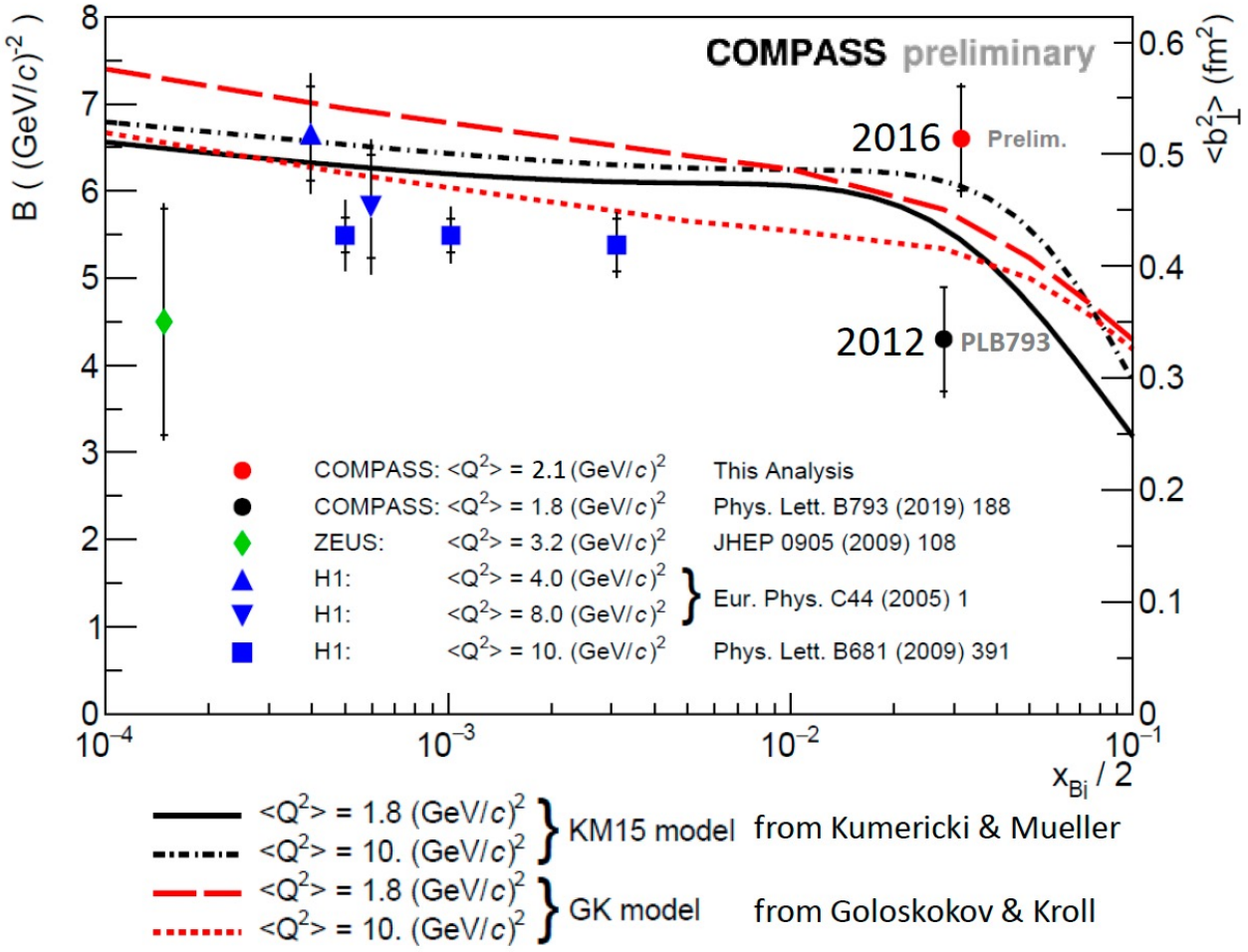


- Determined using the HEPGEN BH MC sample

$$A(\Delta\Omega) = \frac{N_{rec}}{N_{gen}}$$

- Use 4D binning (t, ϕ, Q^2, ν) in the cross-section calculation
- Similar acceptance between $\overleftarrow{\mu^+}$ and $\overrightarrow{\mu^-}$ $\sim$ 40%

Comparison between 2012 and 2016



Improvements in 2016 compared to 2012:

- Same intensity μ^+ and μ^- beams in 2016
- More detailed analysis in 2016, still ongoing
- π^0 contamination with different thresholds
- Better MC description of evolution in ν
- Binning in 4 variables, (t, ϕ, Q^2, ν) vs. 3 variables (t, Q^2, ν)
- Different binning in t

DVCS and BH processes interfere at the amplitude level; the ϕ-dependence of the cross section is sensitive to their interference.