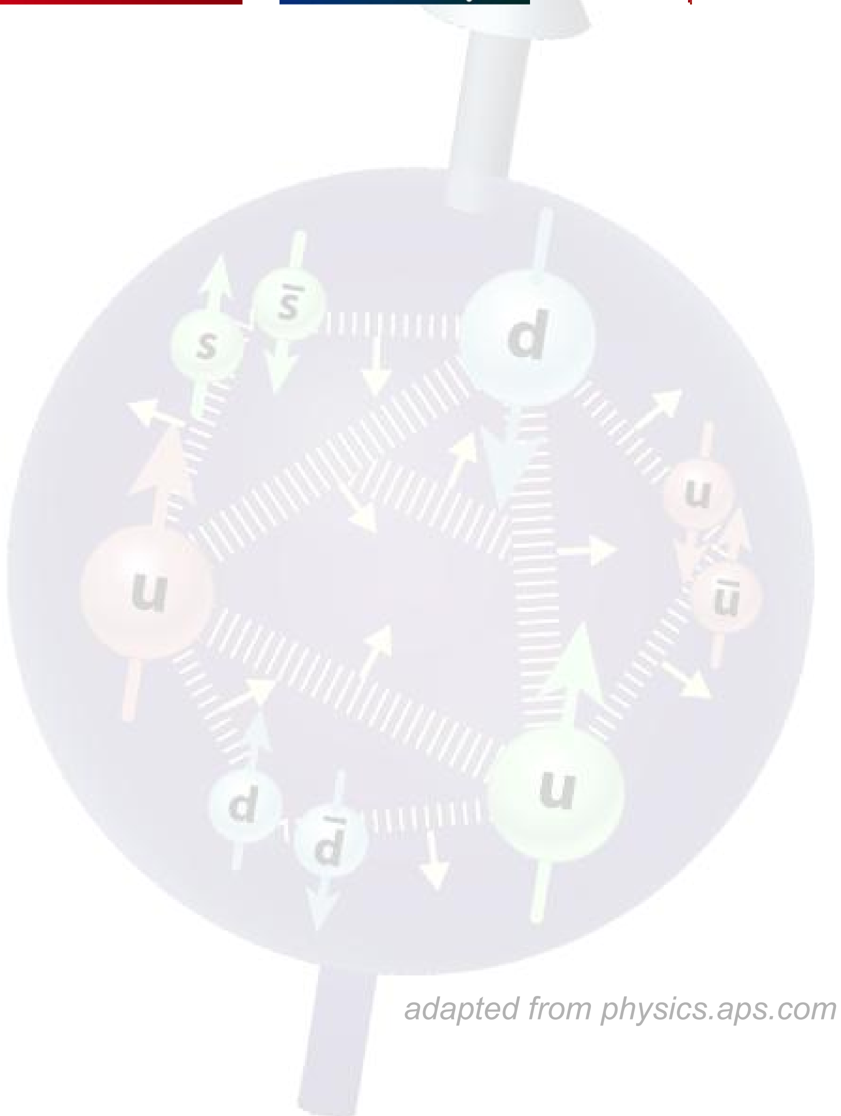
Brian Ventura,
on behalf of the COMPASS *collaboration*

Exclusive single photon muonproduction at COMPASS



adapted from physics.aps.com

DIS 2021, April 15th

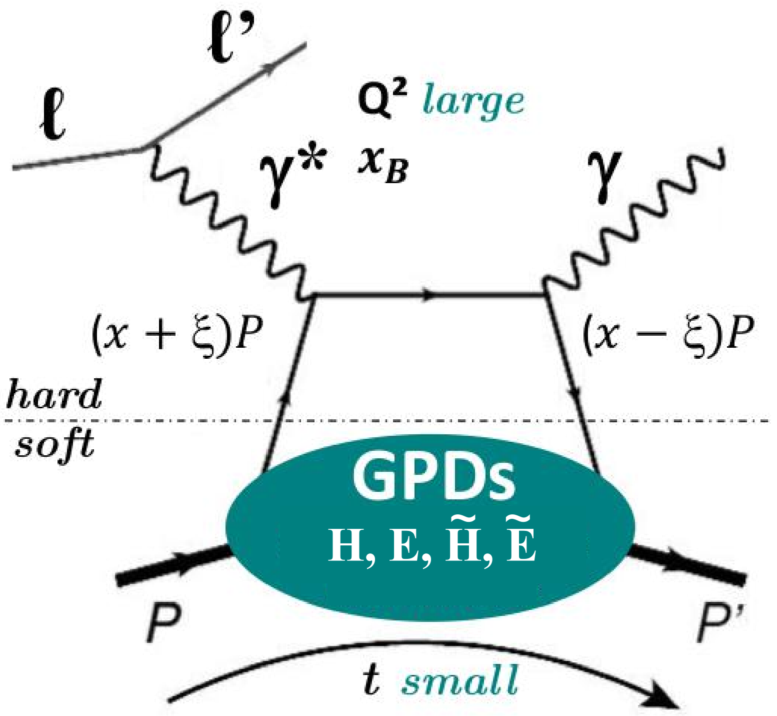
Outline

- Deeply Virtual Compton Scattering (DVCS)
- The COMPASS experiment at CERN
- The 2012 pilot run and 2016-17 run
- Summary and outlook

Deeply Virtual Compton Scattering (DVCS)

Deeply Virtual Compton Scattering (DVCS)

D. Mueller *et al*, Fortsch. Phys. 42 (1994)
X.D. Ji, PRL 78 (1997), PRD 55 (1997)
A. V. Radyushkin, PLB 385 (1996), PRD 56 (1997)

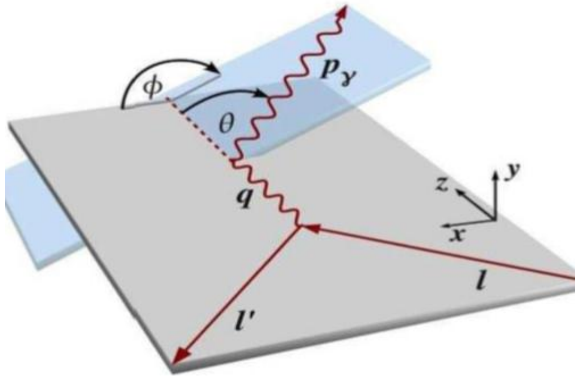


x: average longitudinal momentum
ξ: longitudinal momentum difference
t: four-momentum transfer
related to $b_\perp$ via Fourier transform

Variables measured in an experiment:

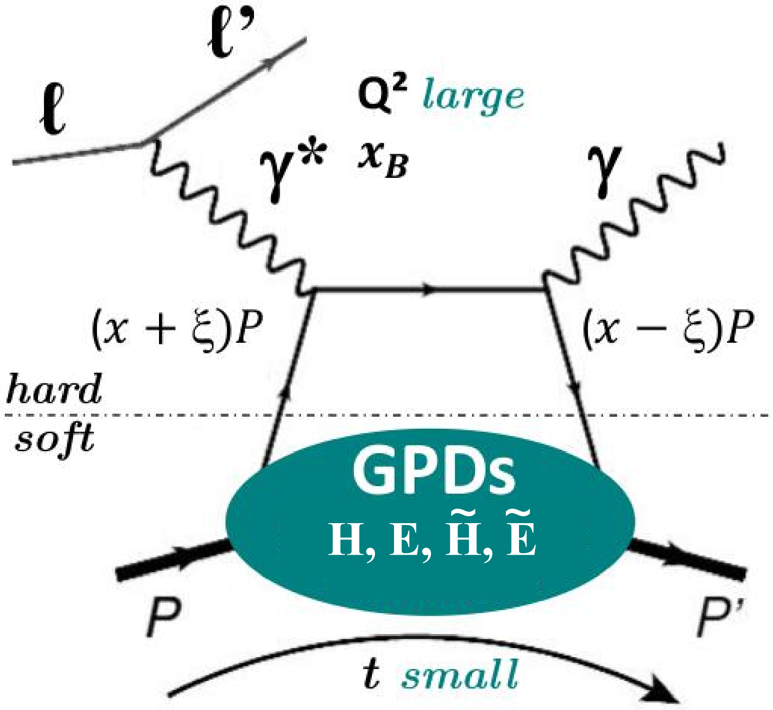
E_ℓ, Q^2, $x_B \sim 2\xi/(1+\xi)$,
t (or $\theta_{\gamma^*\gamma}$)
ϕ ($\ell\ell'$ plane/$\gamma\gamma^*$ plane)

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



Deeply Virtual Compton Scattering (DVCS)

D. Mueller *et al*, Fortsch. Phys. 42 (1994)
X.D. Ji, PRL 78 (1997), PRD 55 (1997)
A. V. Radyushkin, PLB 385 (1996), PRD 56 (1997)



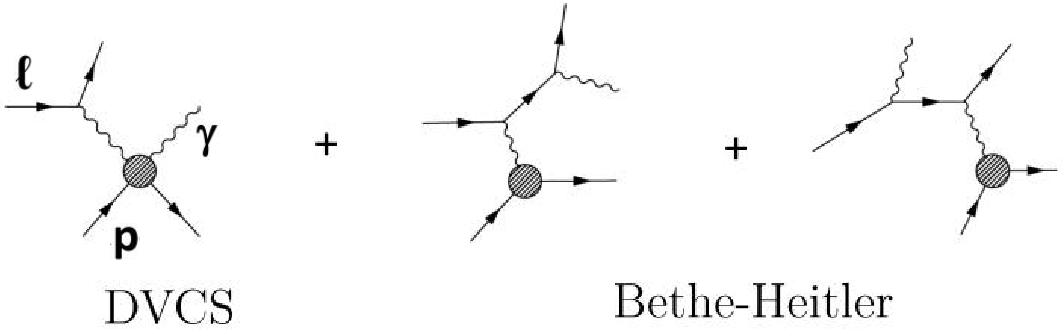
x: average longitudinal momentum

ξ: longitudinal momentum difference

t: four-momentum transfer

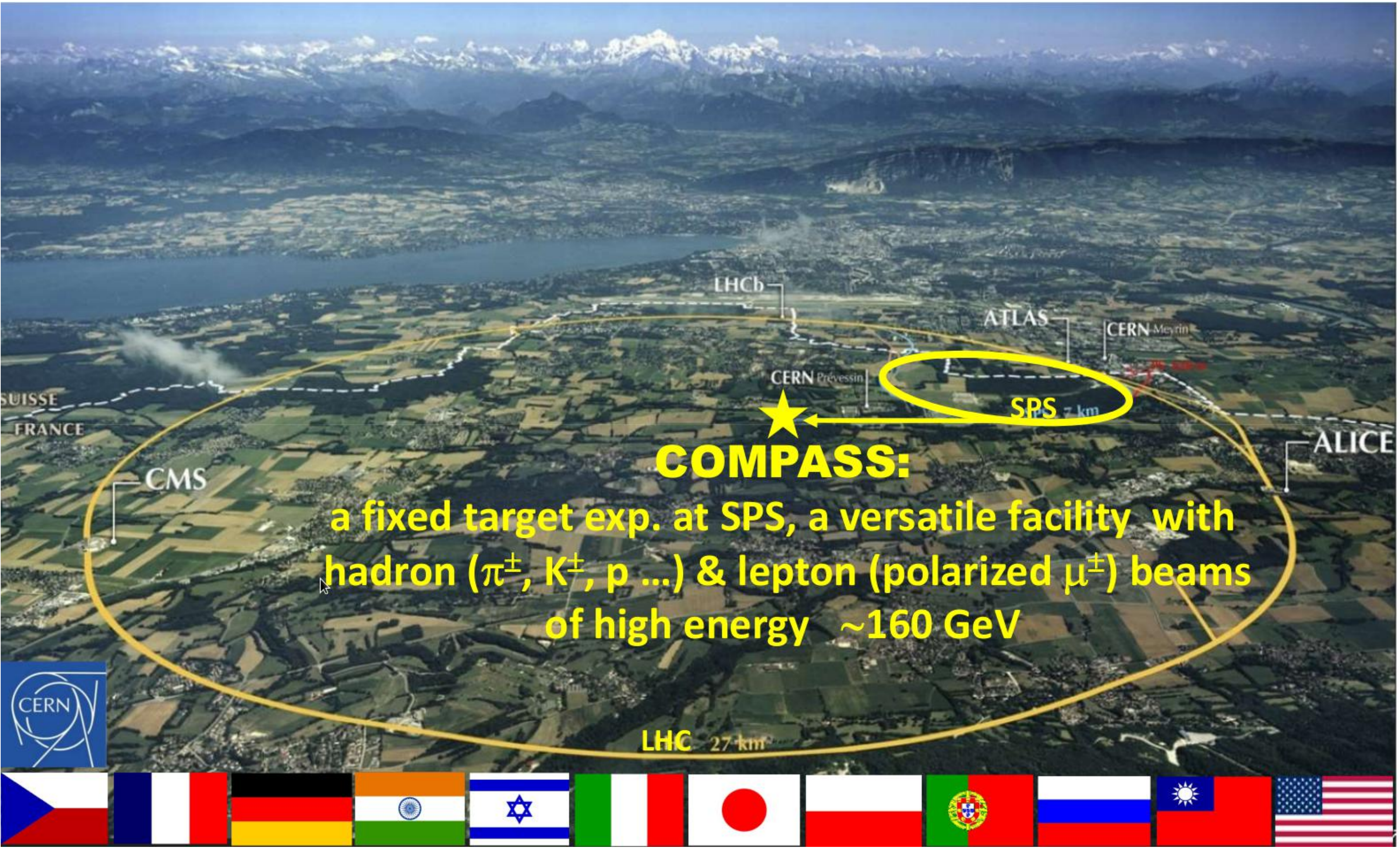
related to $b_\perp$ via Fourier transform

DVCS : ℓp→ ℓ' p' γ



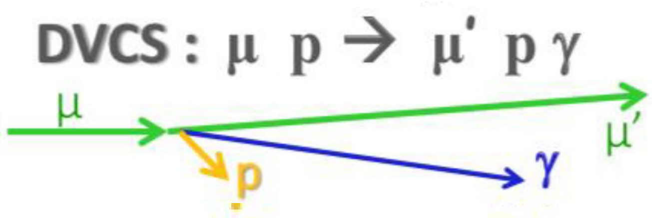
- DVCS is the golden channel to experimentally access GPDs
- Its interference with the Bethe-Heitler process gives access to more info

The COMPASS experiment at CERN

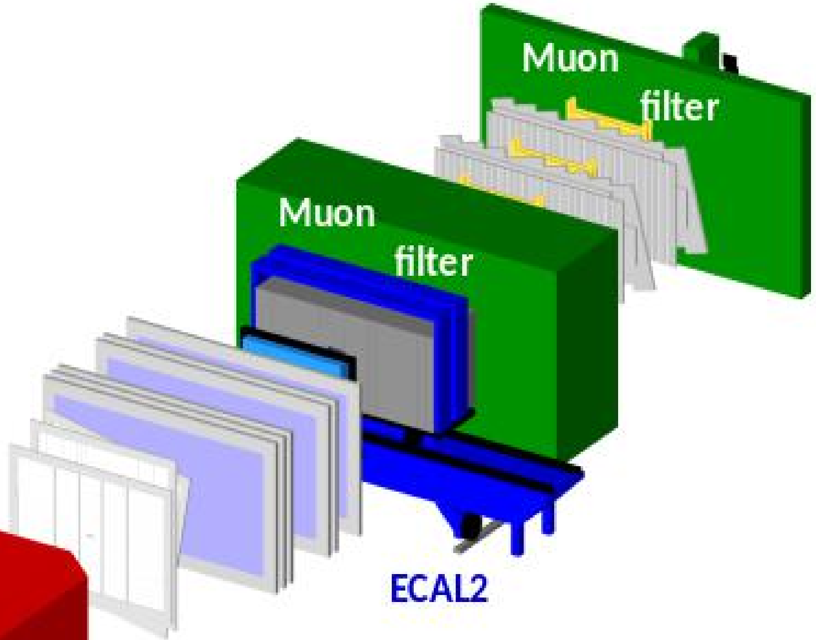


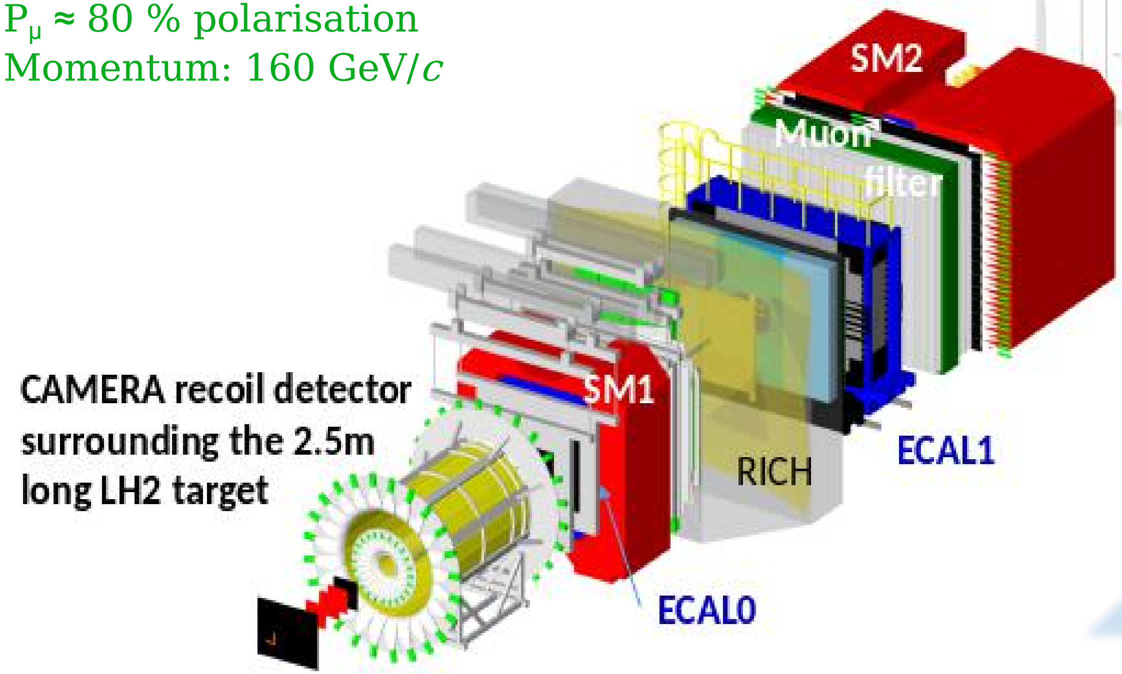
COmmon
Muon and
Proton
Apparatus for
Structure and
Spectroscopy

The COMPASS experiment at CERN



- μ^+ and μ^- beams with opposite polarisation
- $P_\mu \approx 80$ % polarisation
- Momentum: 160 GeV/c



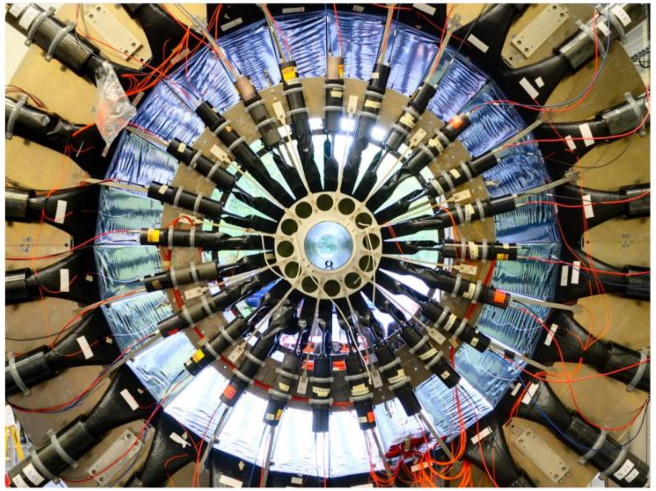


Two-stage, large angle and wide momentum range spectrometer. PID including hadron absorbers, RICH, HCALs, ECALs and muon filters.

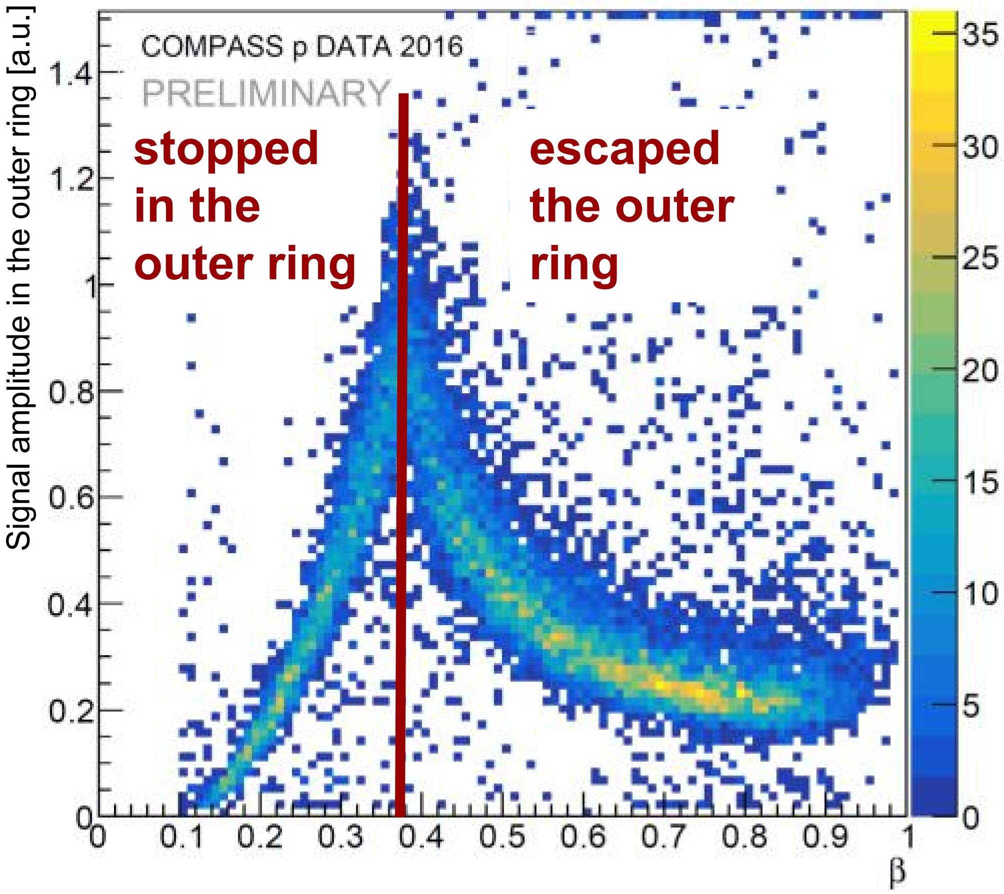
❖NIM A 577 (2007) & NIM A 779 (2015) 69

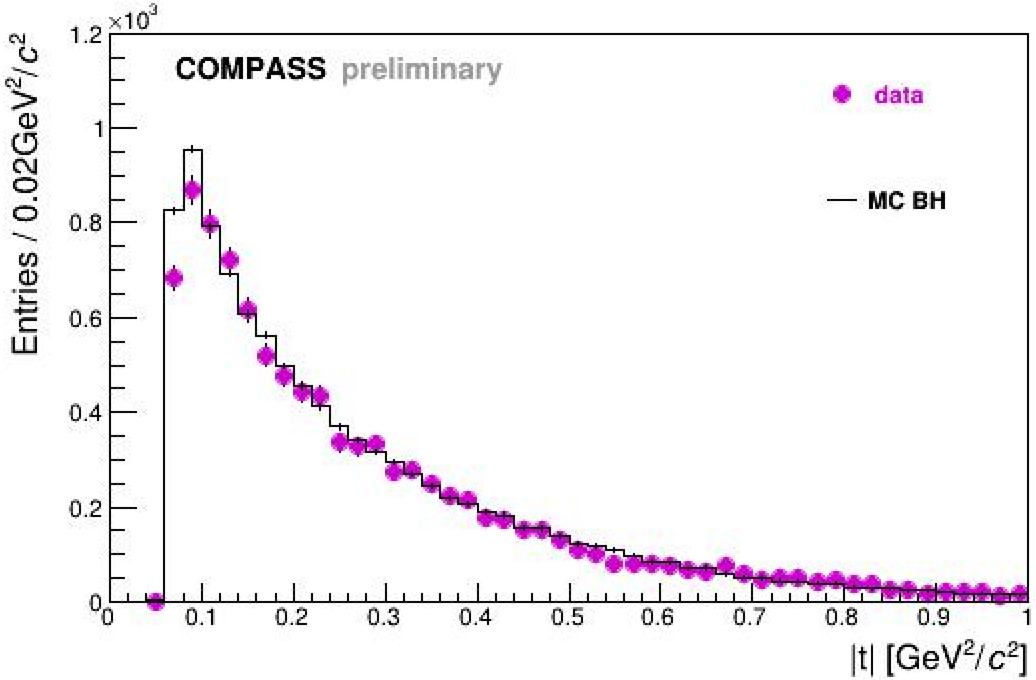
- 2012 pilot run with 4-week data taking
- 2016-17 dedicated runs of 2×6 months

The COMPASS experiment at CERN



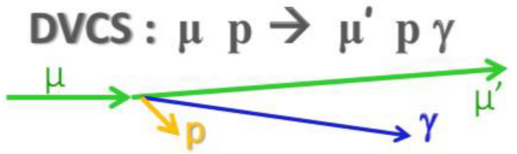
Protons detected in CAMERA: L = 4m ; Ø = 2m
24 inner & outer scintillators separated by about 1m
1 GHz SADC readout, 330ps ToF resolution



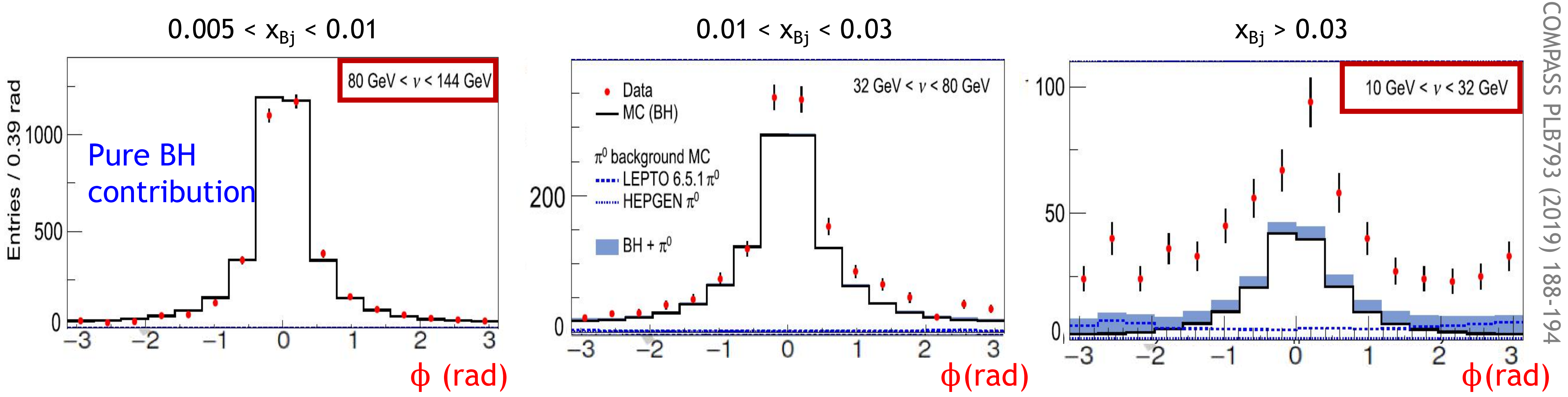


COMPASS 2012 Pilot run results

E_μ = 160 GeV



$$d\sigma \propto |T^{BH}|^2 + \text{Interference Term} + |T^{DVCS}|^2$$



DVCS > BH

MC: — BH normalisation based on integrated luminosity
π° background contribution from inclusive and exclusive production

COMPASS 2012 Pilot run results

At COMPASS using polarized positive and negative muon beams:

$$S_{CS,U} \equiv d\sigma^{\overset{+}{\leftarrow}} + d\sigma^{\overset{-}{\rightarrow}} = 2[d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + \mathrm{Im}\, I]$$

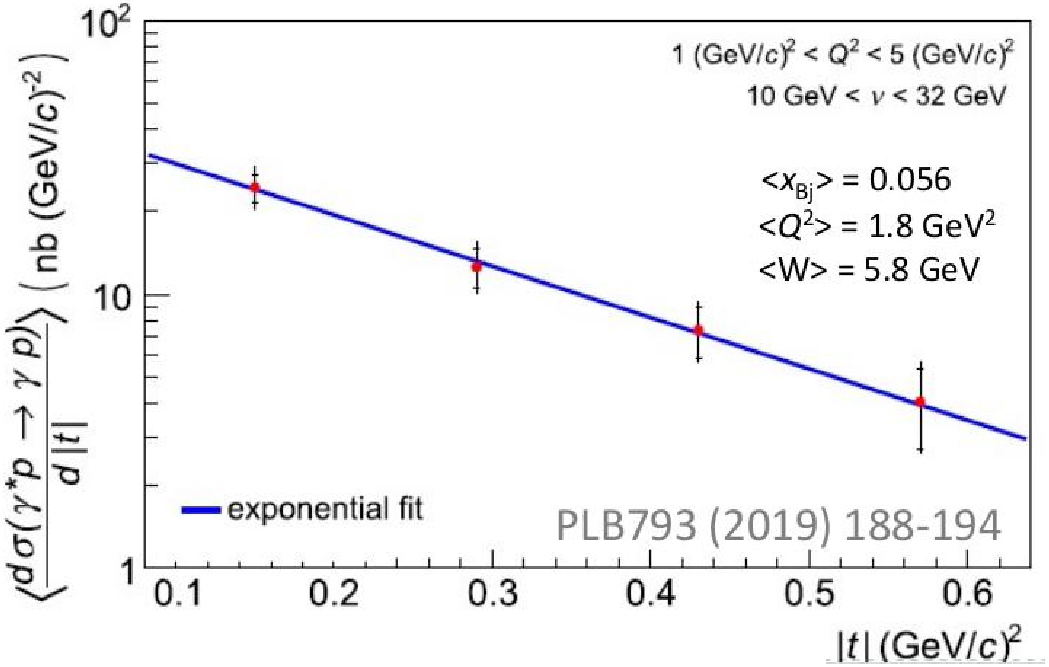
$$= 2[d\sigma^{BH} + c_0^{DVCS} + c_1^{DVCS} \cos\phi + c_2^{DVCS} \cos 2\phi + s_1^I \sin\phi + s_2^I \sin 2\phi\,]$$

calculable
can be subtracted

All the other terms are cancelled in the integration over ϕ

$$\frac{d^3\sigma_T^{\mu p}}{dQ^2 d\nu dt} = \int_{-\pi}^{\pi} d\phi\, (d\sigma - d\sigma^{BH}) \propto c_0^{DVCS}$$

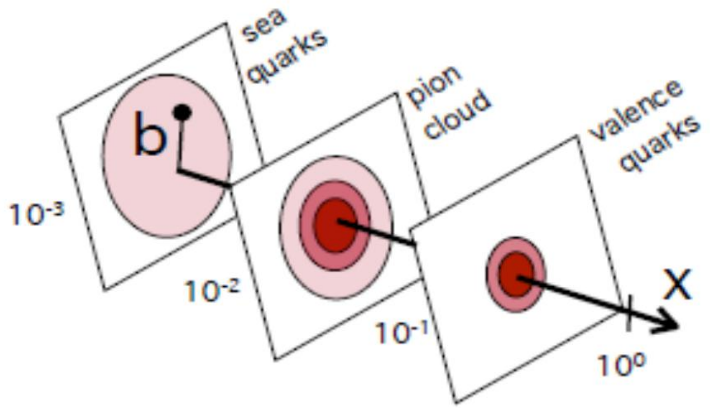
$$d\sigma^{DVCS}/dt = e^{-B|t|} = c_0^{DVCS}$$

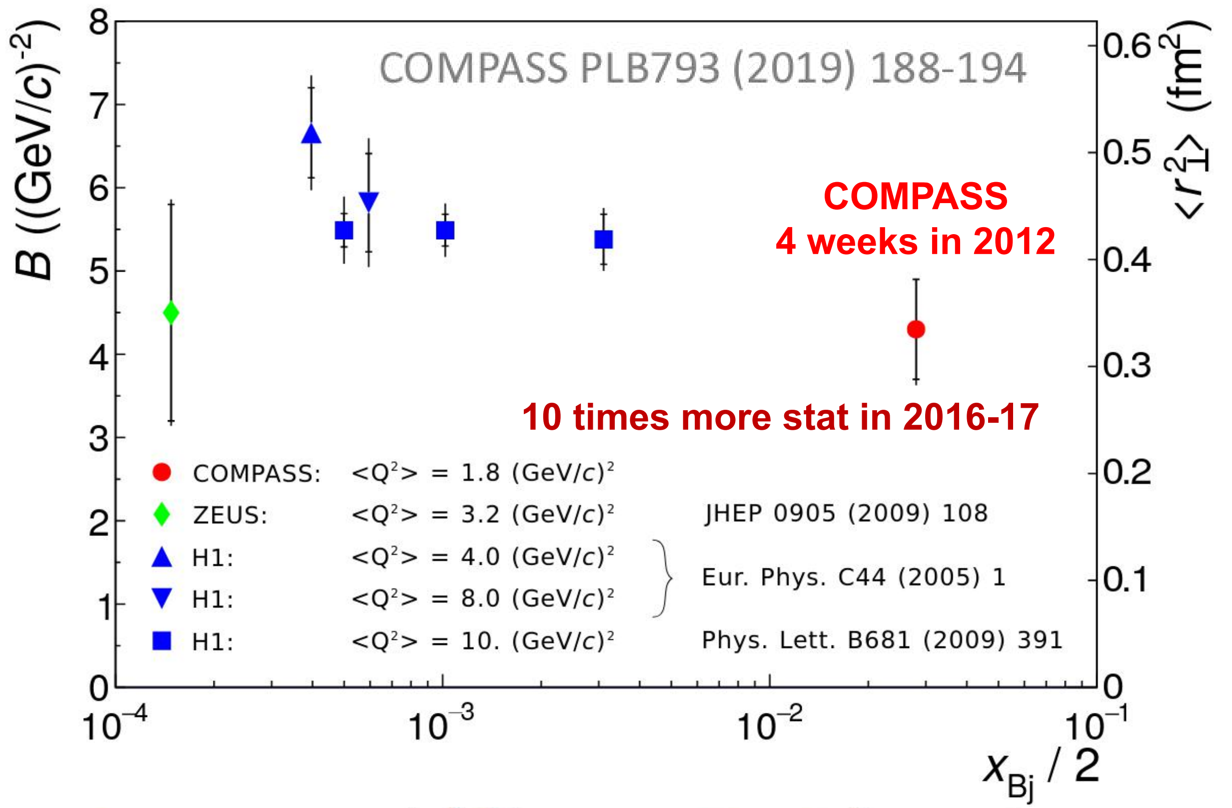


COMPASS 2012 Pilot run results

$d\sigma^{DVCS}/dt = e^{-B|t|} = c_0^{DVCS}$

$\langle r_\perp^2(x_B)\rangle \approx 2B(x_B)$



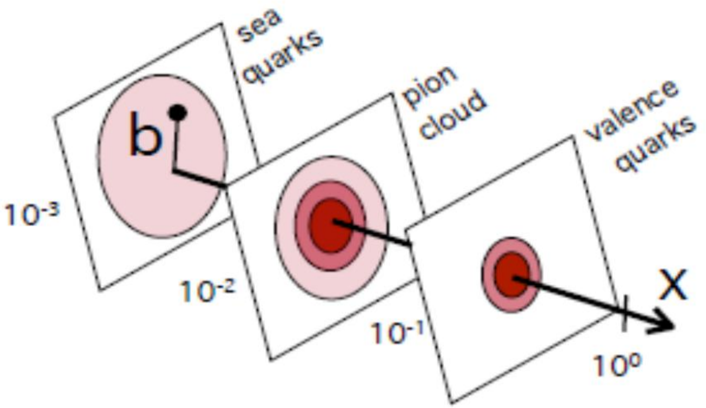


$$B = (4.3 \pm 0.6_{\text{stat}} \,{}^{+0.1}_{-0.3}\big|_{\text{sys}})\ (\text{GeV}/c)^{-2}$$

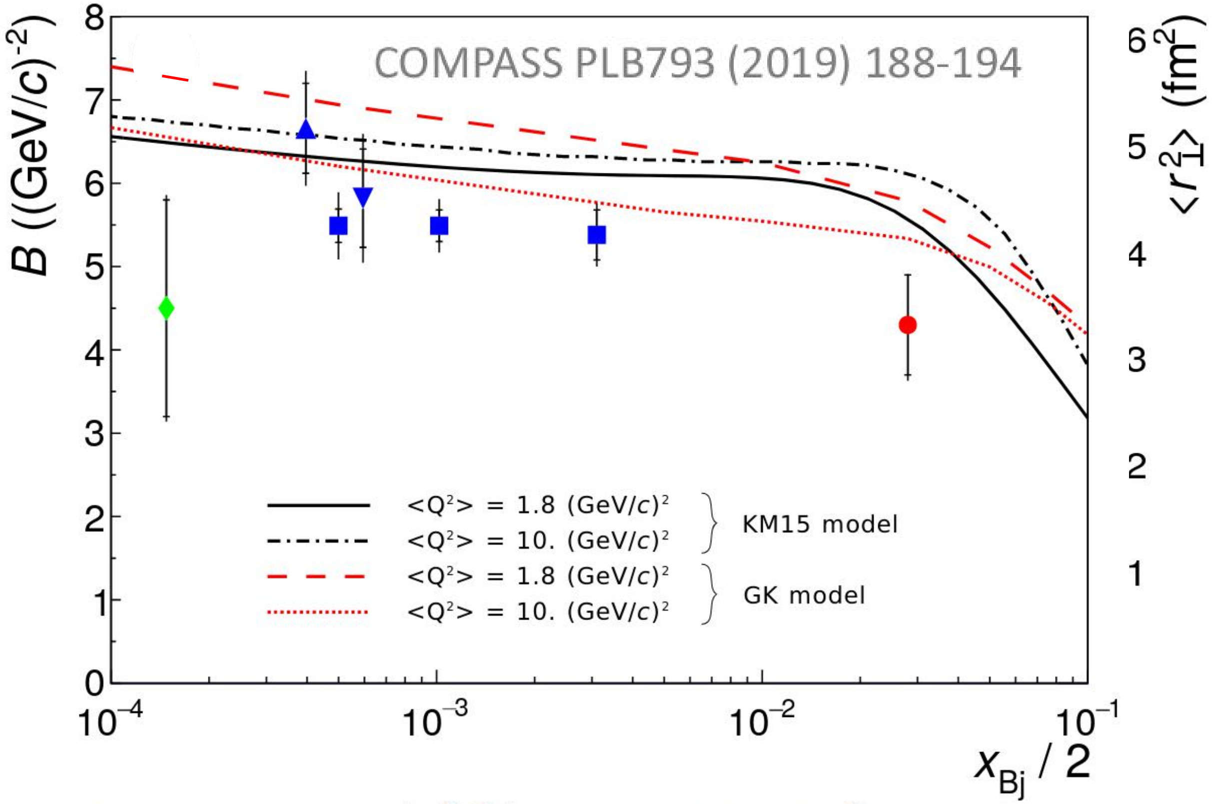
$$\sqrt{\langle r_\perp^2\rangle} = (0.58 \pm 0.04_{\text{stat}} \,{}^{+0.01}_{-0.02}\big|_{\text{sys}} \pm 0.04_{\text{model}})\ \text{fm}$$

COMPASS 2012 Pilot run results

$d\sigma^{DVCS}/dt = e^{-B|t|} = c_0^{DVCS}$



$\langle r_\perp^2(x_B)\rangle \approx 2B(x_B)$



$$B = (4.3 \ \pm \ 0.6_{\rm stat} \ {}^{+\,0.1}_{-\,0.3}\big|_{\rm sys}) \ ({\rm GeV}/c)^{-2}$$

$$\sqrt{\langle r_\perp^2\rangle} = (0.58 \pm 0.04_{\rm stat} \ {}^{+\,0.01}_{-\,0.02}\big|_{\rm sys} \ \pm 0.04_{\rm model})\ {\rm fm}$$

COMPASS 2016 preliminary results

COMPASS 2016 preliminary results

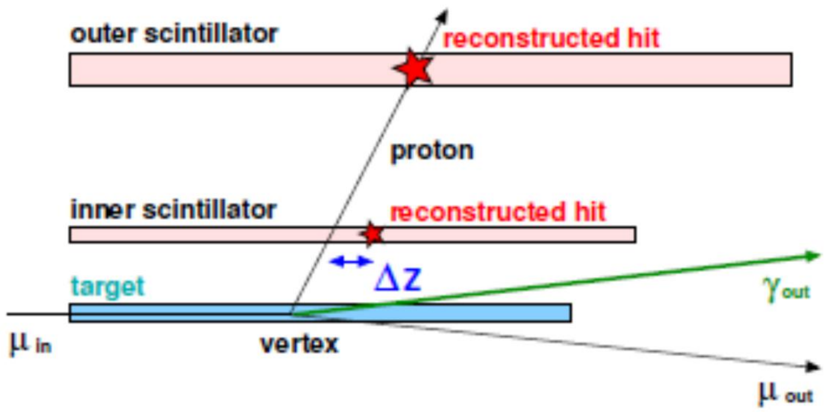
2 × 2012 statistics
22% of 2016-17 statistics

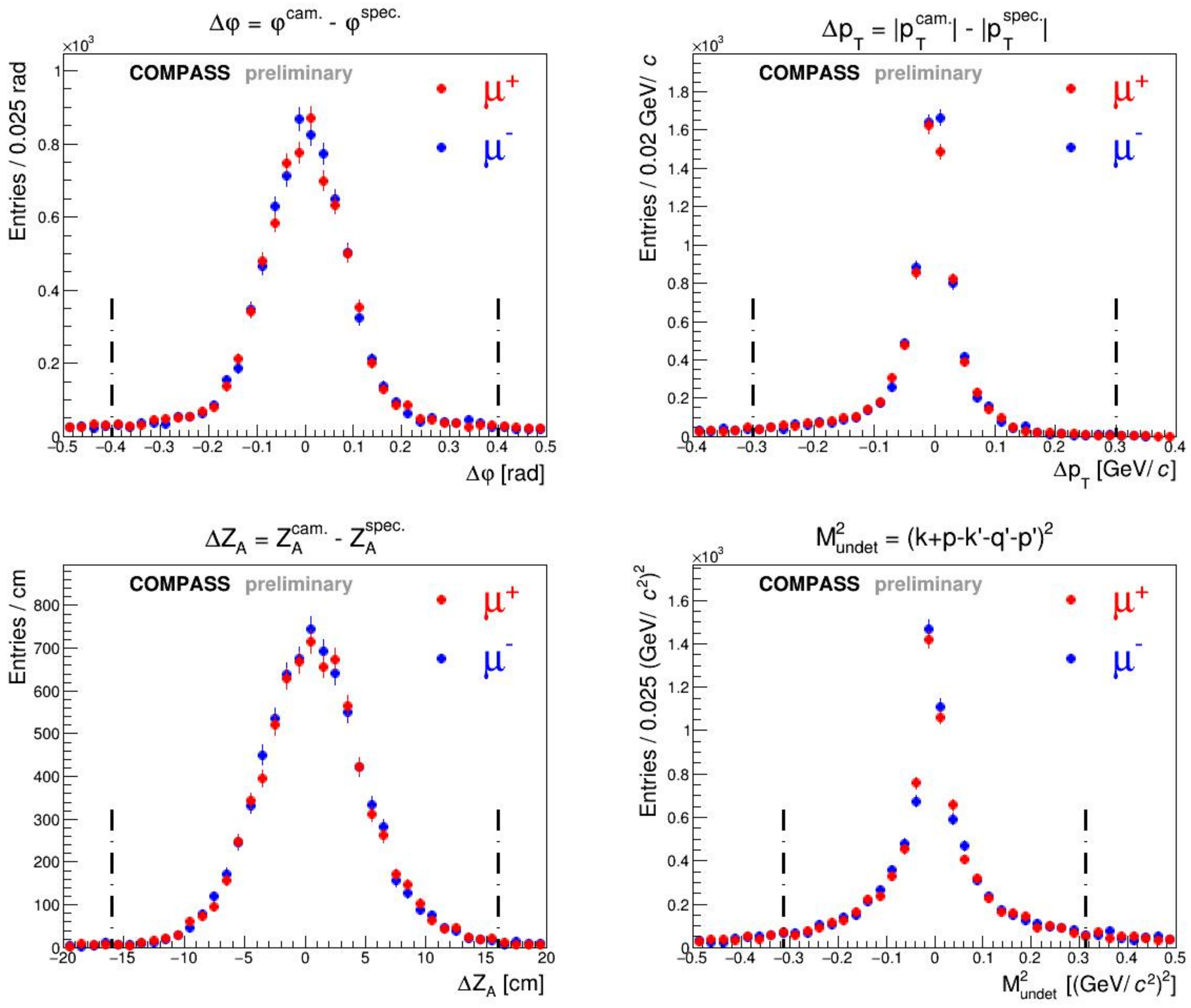
$\Delta\varphi = \varphi^{cam.} - \varphi^{spec.}$

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

$\Delta z_A = z_A^{cam.} - z_A^{spec.}$

$M^2_{undet} = (k + p - k' - q' - p')^2$





COMPASS 2016 preliminary results

2 × 2012 statistics
22% of 2016-17 statistics

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

$\Delta p_T = |p_T^{\text{cam.}}| - |p_T^{\text{spec.}}|$

$\Delta z_A = z_A^{\text{cam.}} - z_A^{\text{spec.}}$

$M^2_{\text{undet}} = (k + p - k' - q' - p')^2$

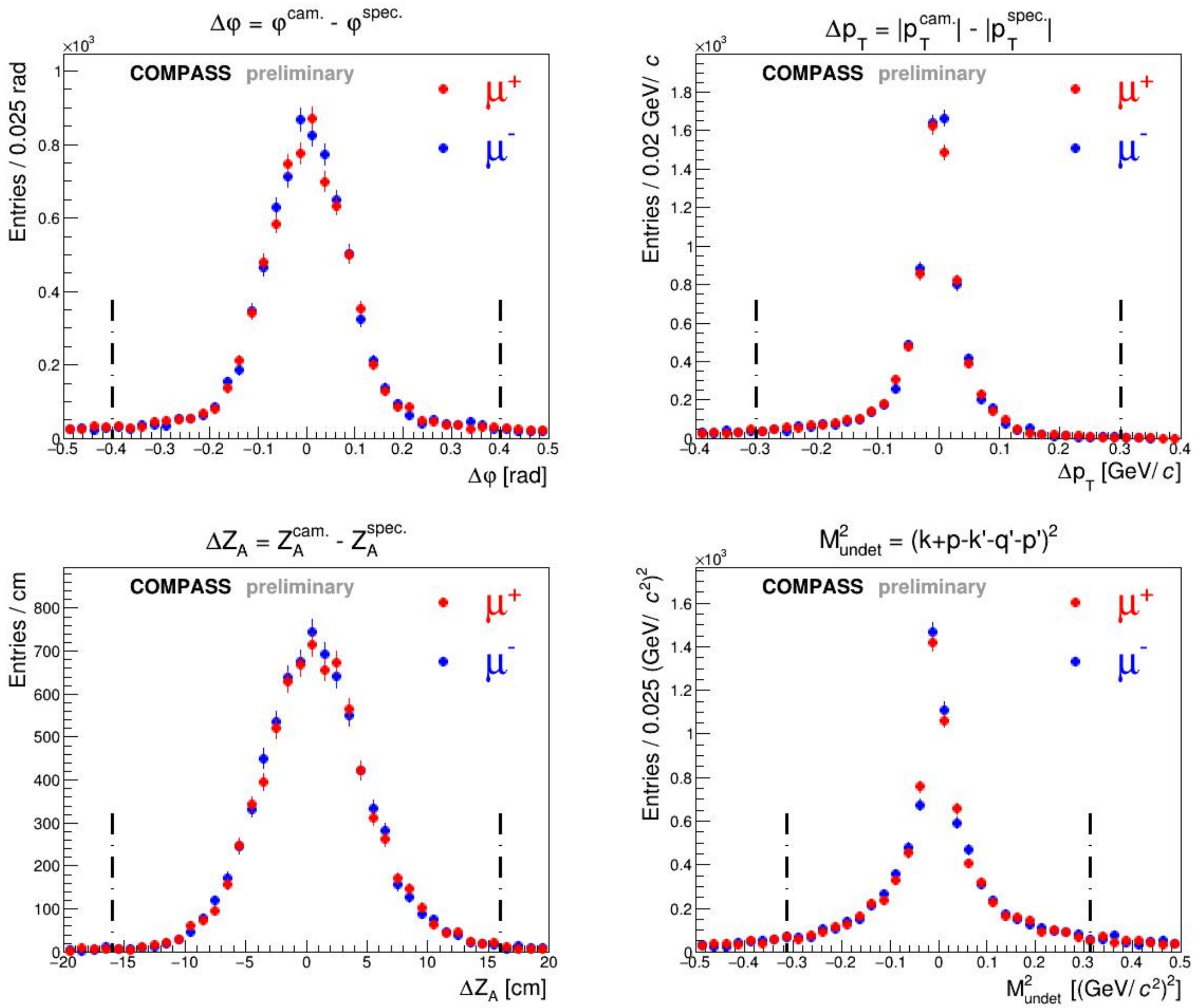
Good agreement between $\overleftarrow{\mu}^{+}$ **and** $\overrightarrow{\mu}^{-}$ yields
Important achievement for:

$$\boxed{\mathcal{D}_{CS,U} \equiv d\sigma^{\overset{+}{\leftarrow}} - d\sigma^{\overset{-}{\rightarrow}}}$$

Challenging

$$\boxed{\mathcal{S}_{CS,U} \equiv d\sigma^{\overset{+}{\leftarrow}} + d\sigma^{\overset{-}{\rightarrow}}}$$

Easier, done first



COMPASS 2016 preliminary results

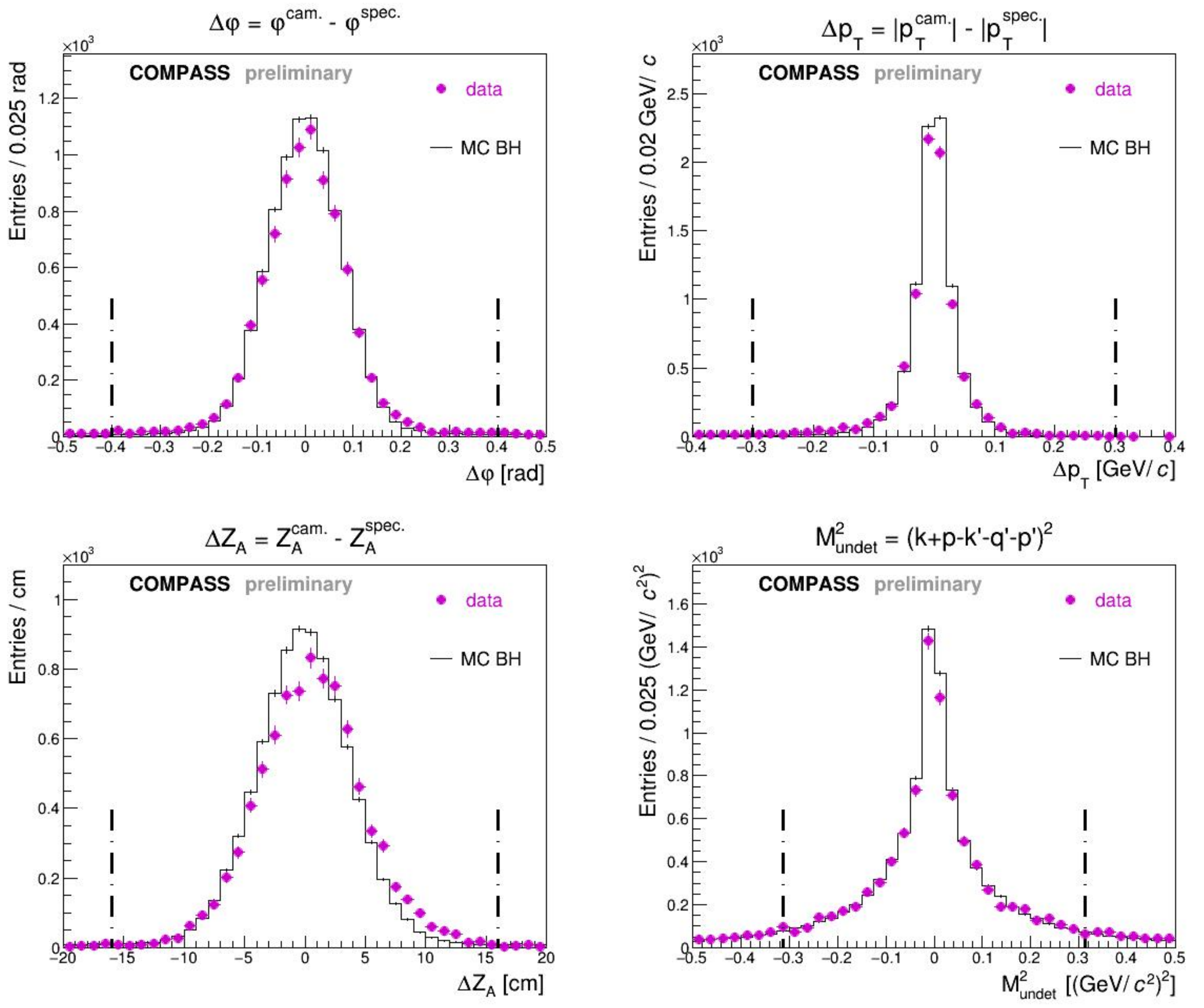
BH domain $0.005 < x_B < 0.01$
or $80\ \text{GeV} < \nu < 144\ \text{GeV}$

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

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

$\Delta z_A = z_A^{cam.} - z_A^{spec.}$

$M^2_{undet} = (k + p - k' - q' - p')^2$



Good agreement between $\overleftarrow{\mu}^{+}$ **and** $\overrightarrow{\mu}^{-}$ yields
Important achievement for:

$\boxed{\mathcal{D}_{CS,U} \equiv d\sigma^{\overleftarrow{+}} - d\sigma^{\overrightarrow{-}}}$ Challenging

$\boxed{\mathcal{S}_{CS,U} \equiv d\sigma^{\overleftarrow{+}} + d\sigma^{\overrightarrow{-}}}$ Easier, done first

COMPASS 2016 preliminary results

π^0 are one of the main background sources for exclusive photon events

Two possible cases:

Visible (both γ detected) $\rightarrow$ subtracted

the DVCS photon after exclusivity cuts is combined with all detected photons below the DVCS threshold: 4,5 GeV in Ecal0,1 respectively

Invisible (one γ lost) $\rightarrow$ estimated by MC

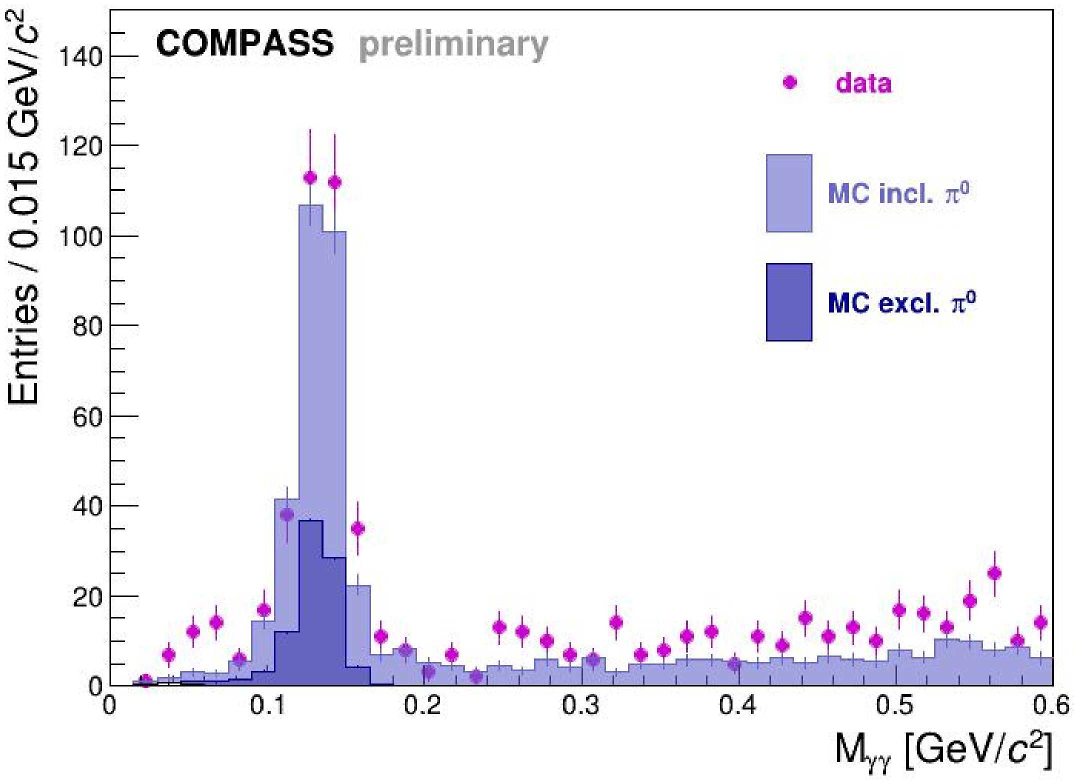
Semi-inclusive LEPTO 6.1

Exclusive HEPGEN π^0

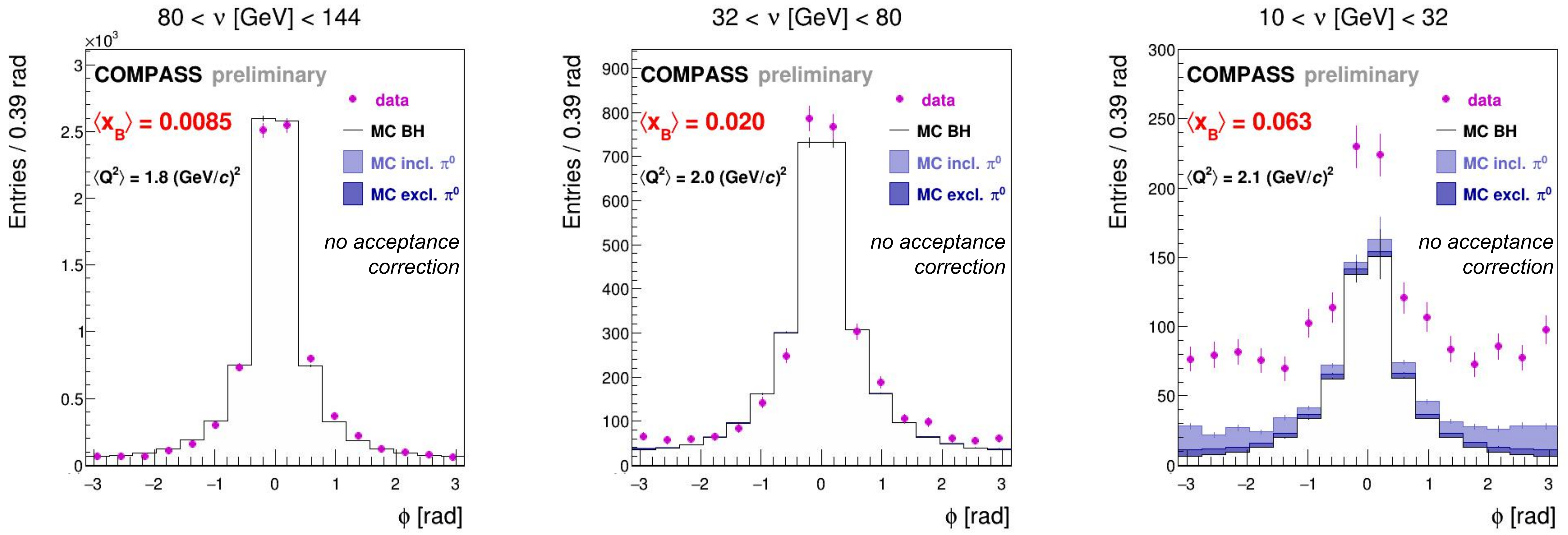
(Goloskokov-Kroll model)

The sum of the 2 contributions LEPTO and HEPGEN is normalised to $M_{\gamma\gamma}$ peak in real data

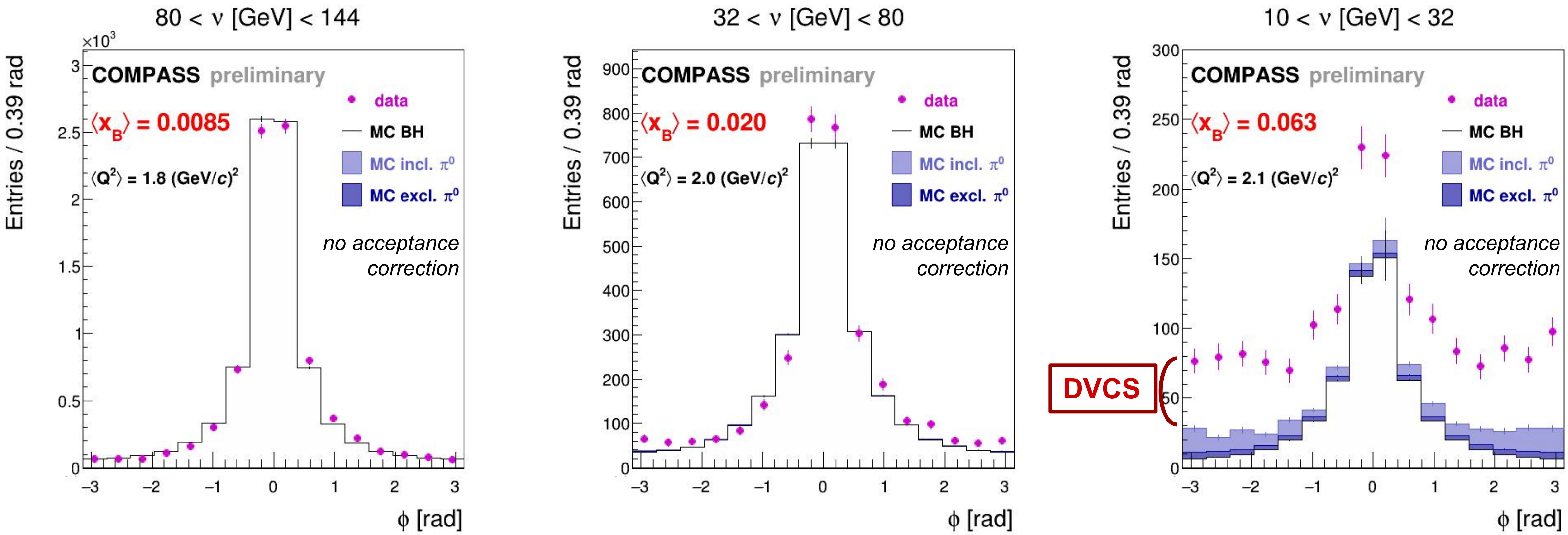
Visible π^0 candidates



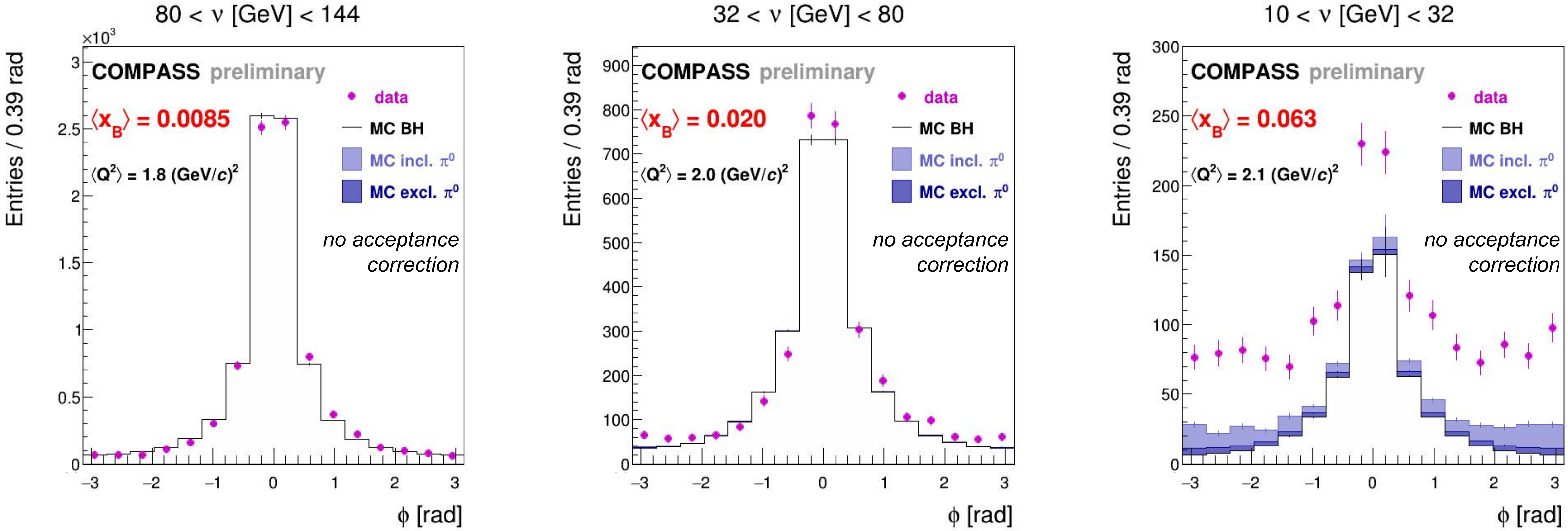
COMPASS 2016 preliminary results



COMPASS 2016 preliminary results

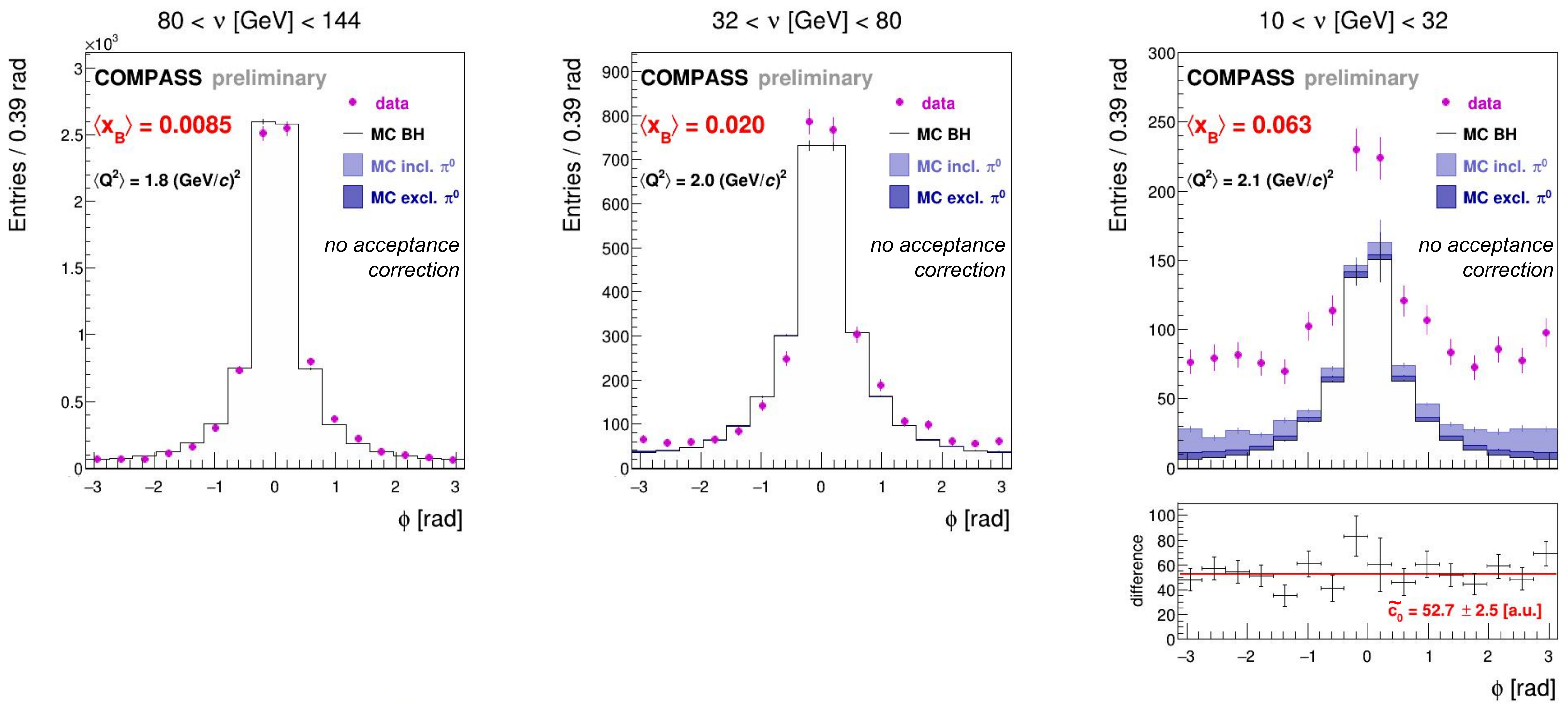


COMPASS 2016 preliminary results



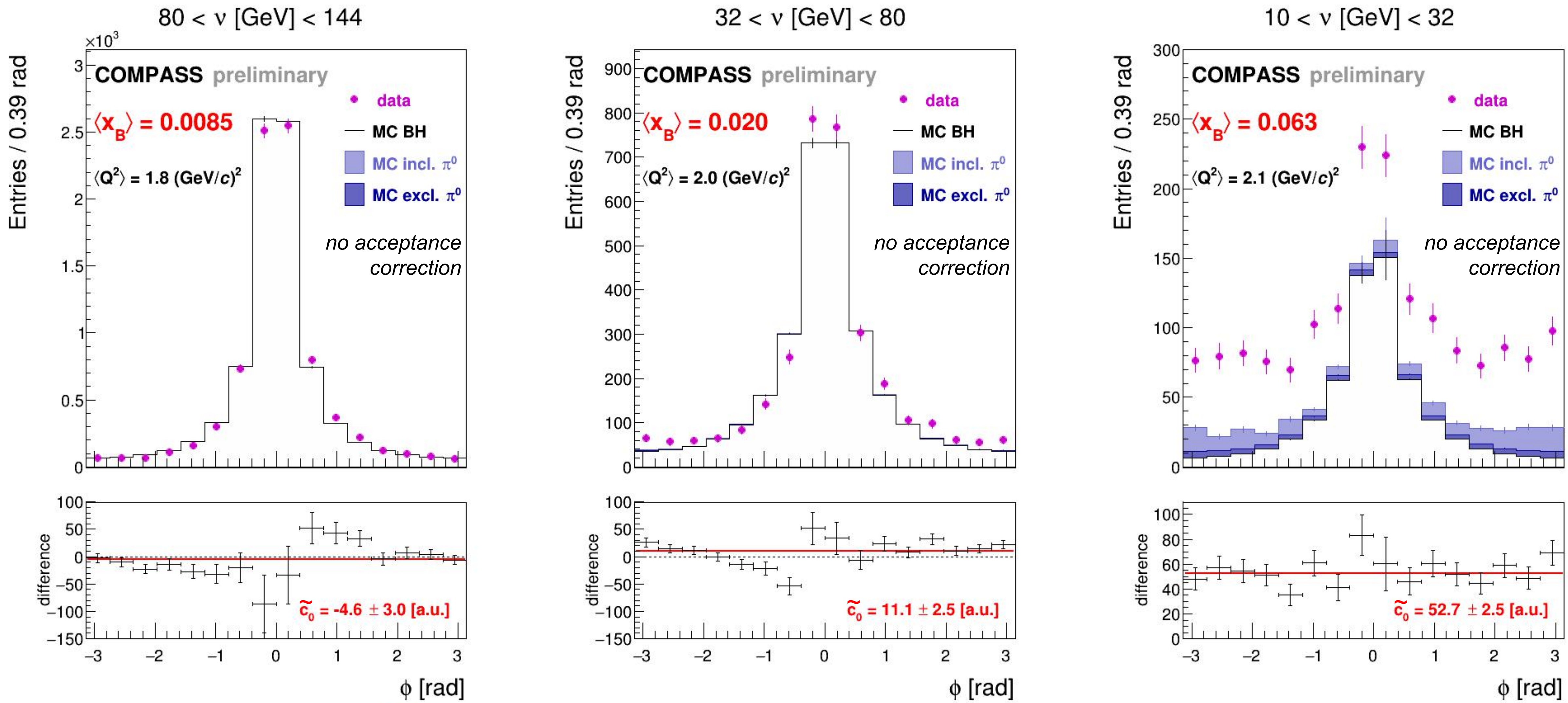
$$S_{CS,U} = 2[d\sigma^{BH} + c_0^{DVCS} + c_1^{DVCS}\cos\phi + c_2^{DVCS}\cos 2\phi + s_1^I \sin\phi + s_2^I \sin 2\phi]$$

COMPASS 2016 preliminary results



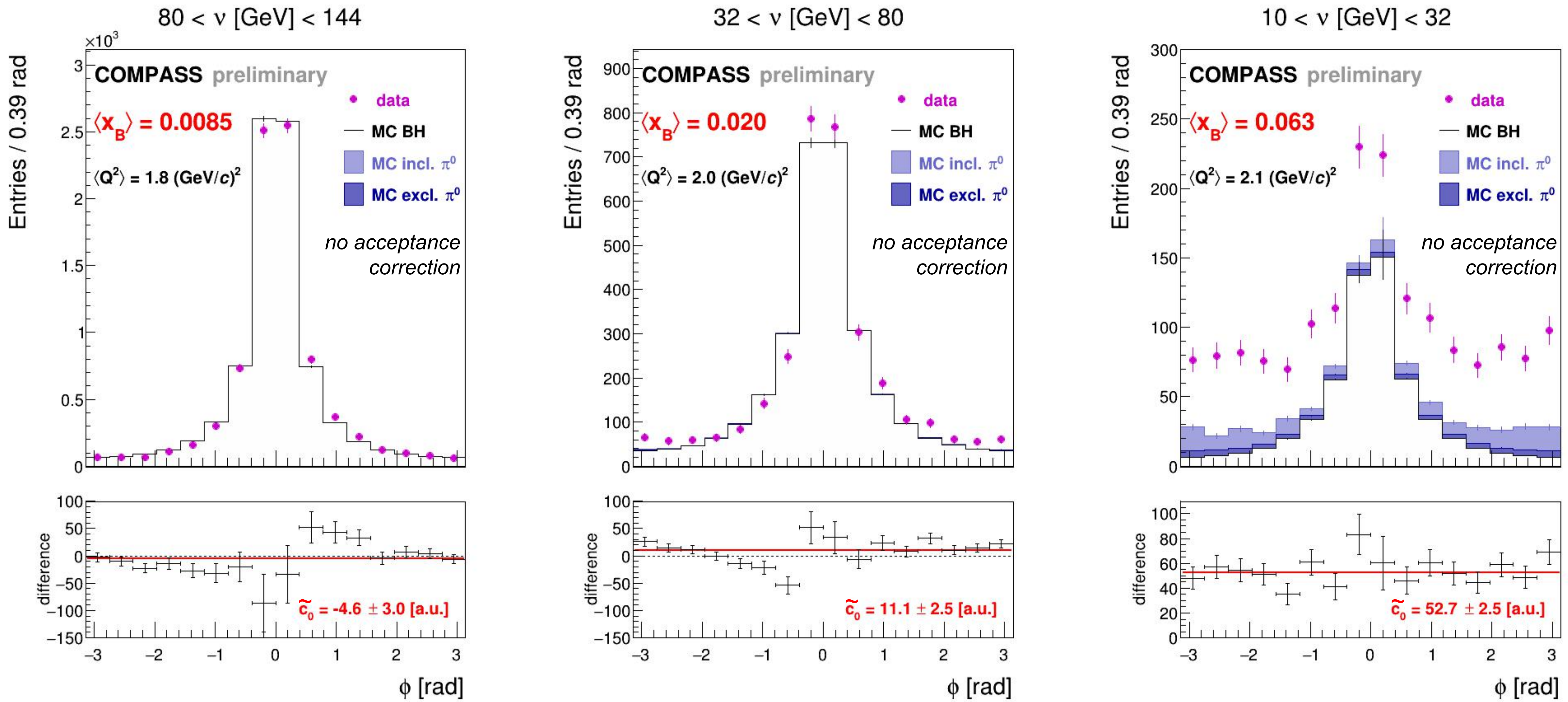
$$S_{CS,U} = 2[d\sigma^{BH} + c_0^{DVCS} + c_1^{DVCS}\cos\phi + c_2^{DVCS}\cos 2\phi + s_1^I \sin\phi + s_2^I \sin 2\phi]$$

COMPASS 2016 preliminary results



$$S_{CS,U} = 2[d\sigma^{BH} + c_0^{DVCS} + c_1^{DVCS}\cos\phi + c_2^{DVCS}\cos 2\phi + s_1^I \sin\phi + s_2^I \sin 2\phi]$$

COMPASS 2016 preliminary results



Only 22% of the 2016-17 statistics

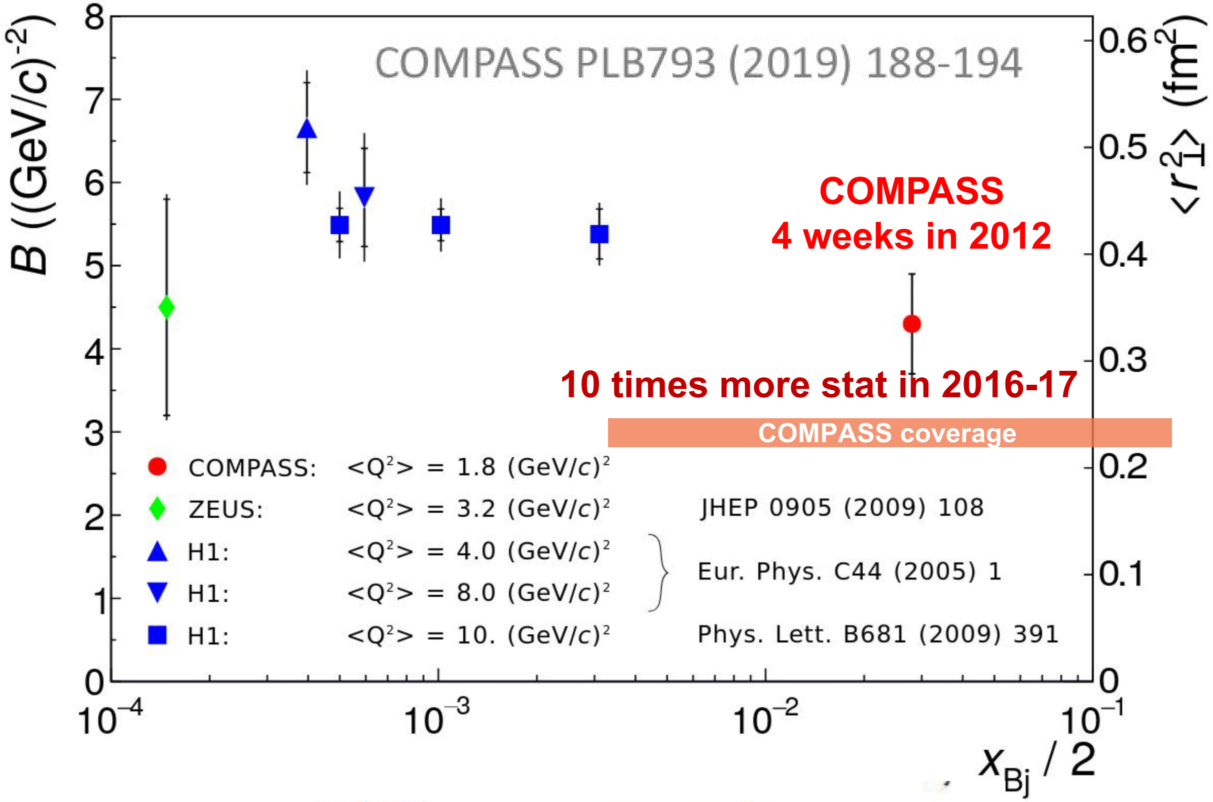
Summary and Outlook

$$d\sigma^{DVCS}/dt = e^{-B|t|} = c_0^{DVCS}$$

$$\langle r_\perp^2(x_B)\rangle \approx 2B(x_B)$$

- Measurement of $S_{CS,U}$ gives access to c_0^{DVCS}
  → transverse extension of the proton

- With full 2016-17 statistics, expect 3 bins in x_B around the 2012 result



$$B = (4.3 \pm 0.6_{\text{stat}} \,{}^{+0.1}_{-0.3}\big|_{\text{sys}})\ (\text{GeV}/c)^{-2}$$

$$\sqrt{\langle r_\perp^2\rangle} = (0.58 \pm 0.04_{\text{stat}} \,{}^{+0.01}_{-0.02}\big|_{\text{sys}} \pm 0.04_{\text{model}})\ \text{fm}$$