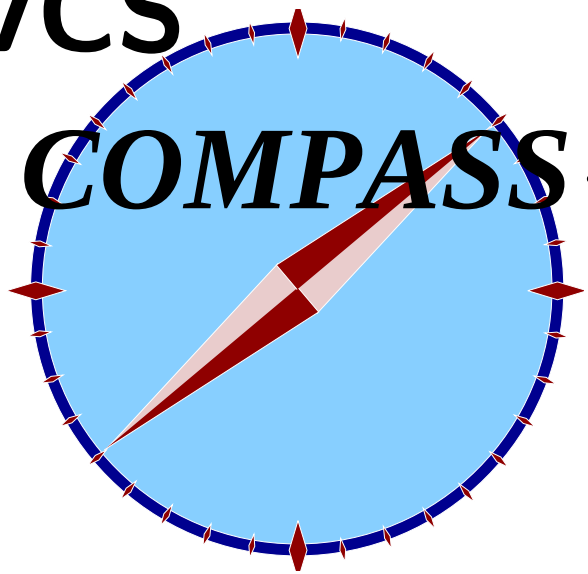
Vector-Meson & DVCS Measurements in *COMPASS*-II

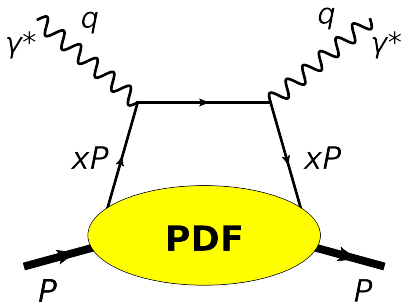
Heiner Wollny
CEA-Saclay Irfu/SPhN
on behalf of COMPASS

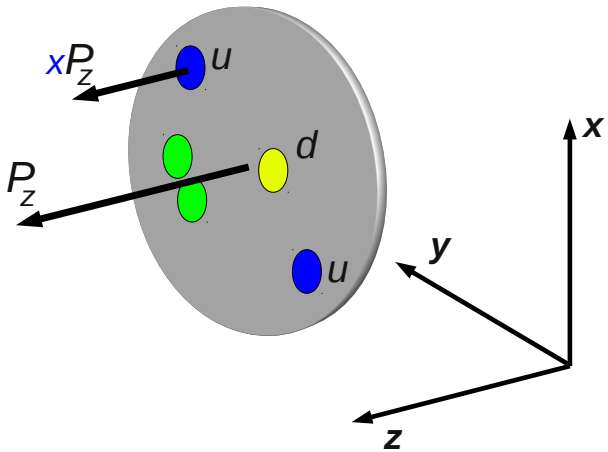


Motivation

Deep Inelastic Scattering:

$\mu p \to \mu' X$

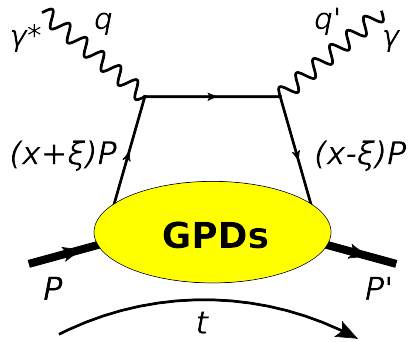


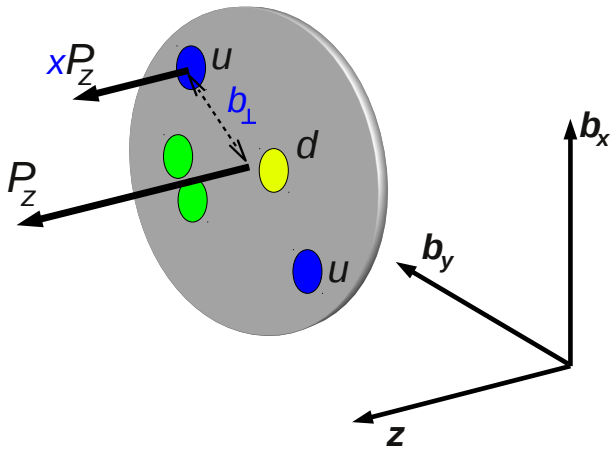


PDFs: $q(x)$, $\Delta q(x)$

Deeply Virtual Compton Scattering:

$\mu p \to \mu' p' \gamma$





GPDs: $H(x,\xi,t)$, $\tilde{H}(x,\xi,t)$

COMPASS-II @ CERN/SPS

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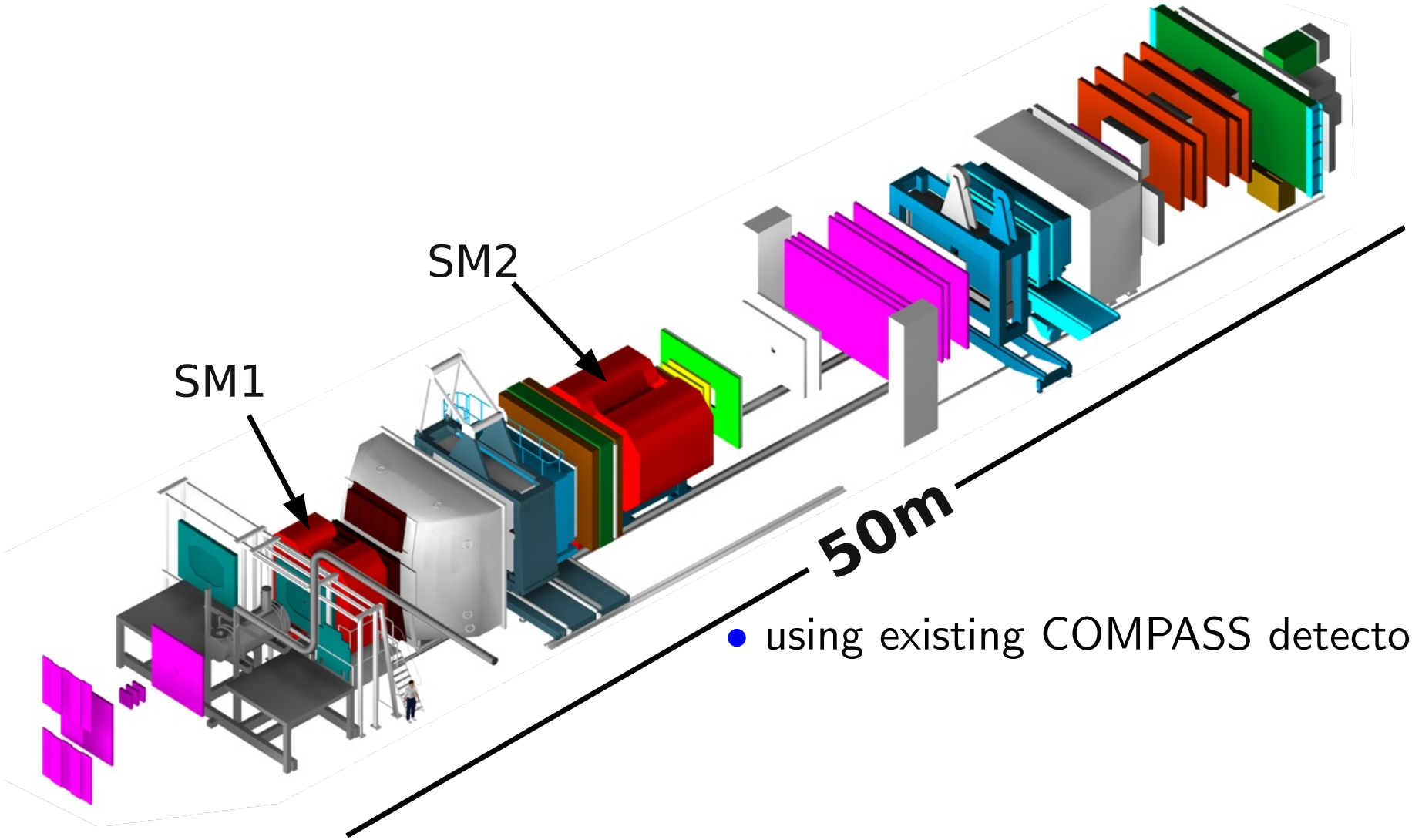
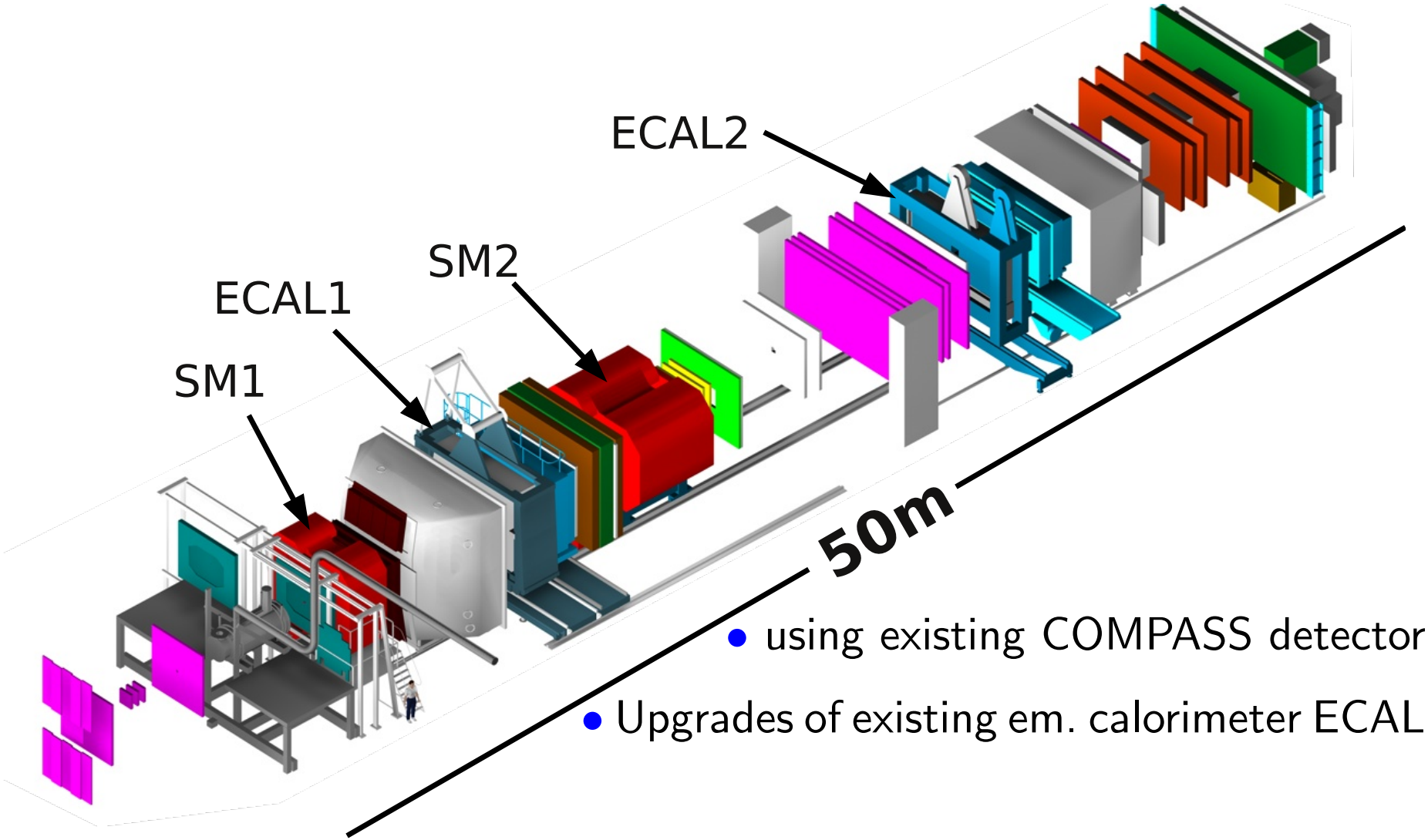


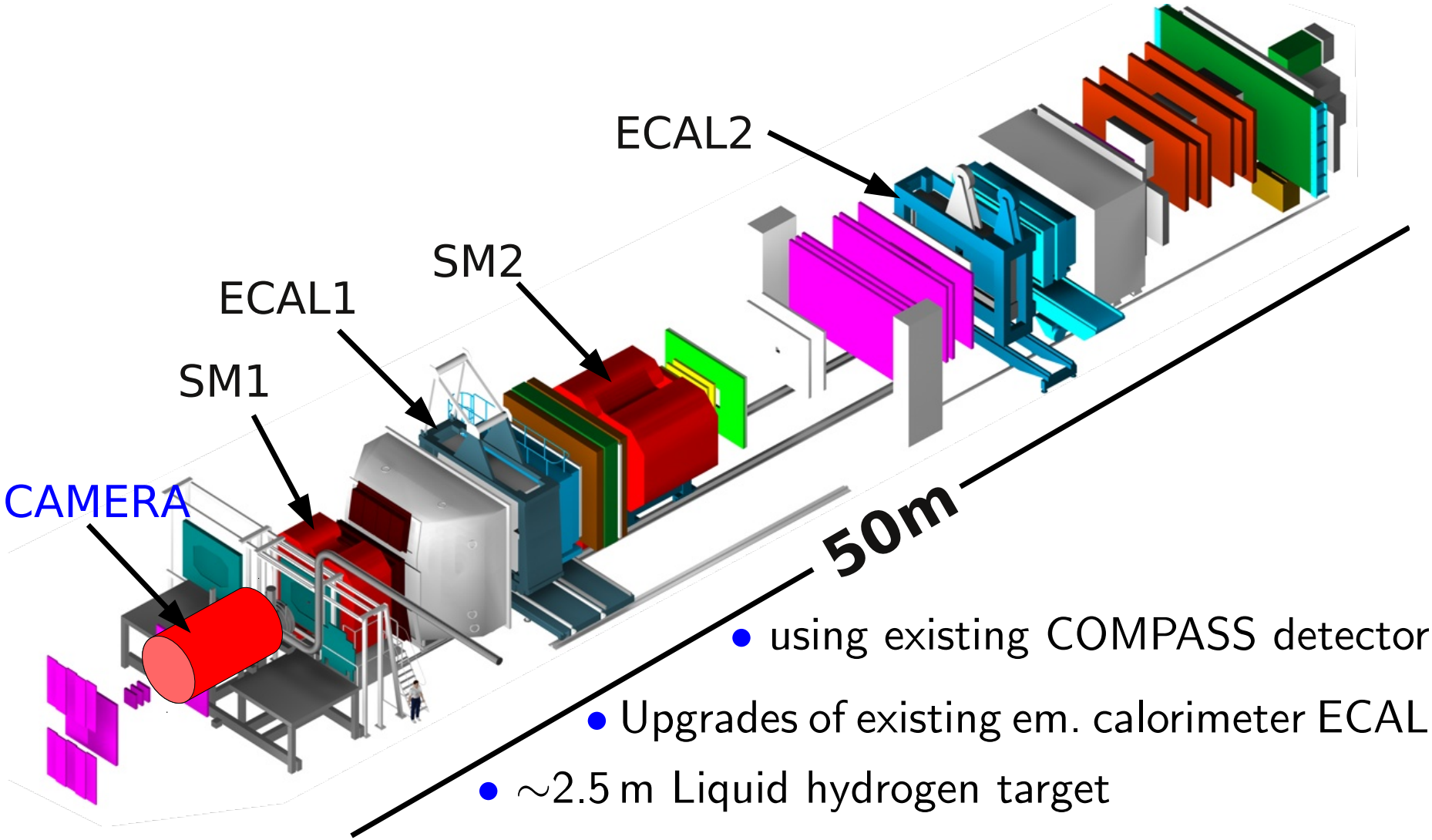
- using existing COMPASS detector

COMPASS-II @ CERN/SPS



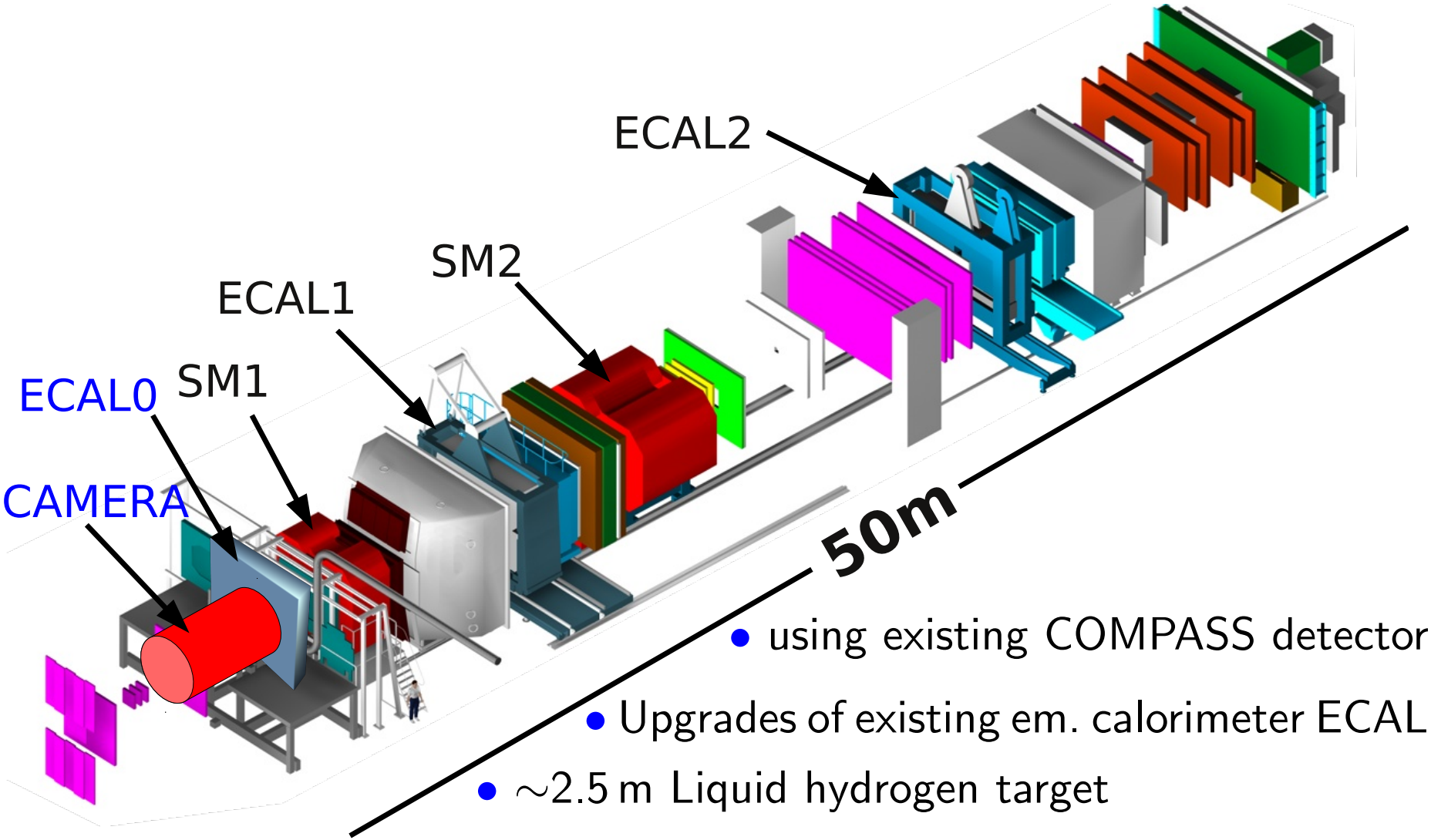
- using existing COMPASS detector
- Upgrades of existing em. calorimeter ECAL1&2

COMPASS-II @ CERN/SPS



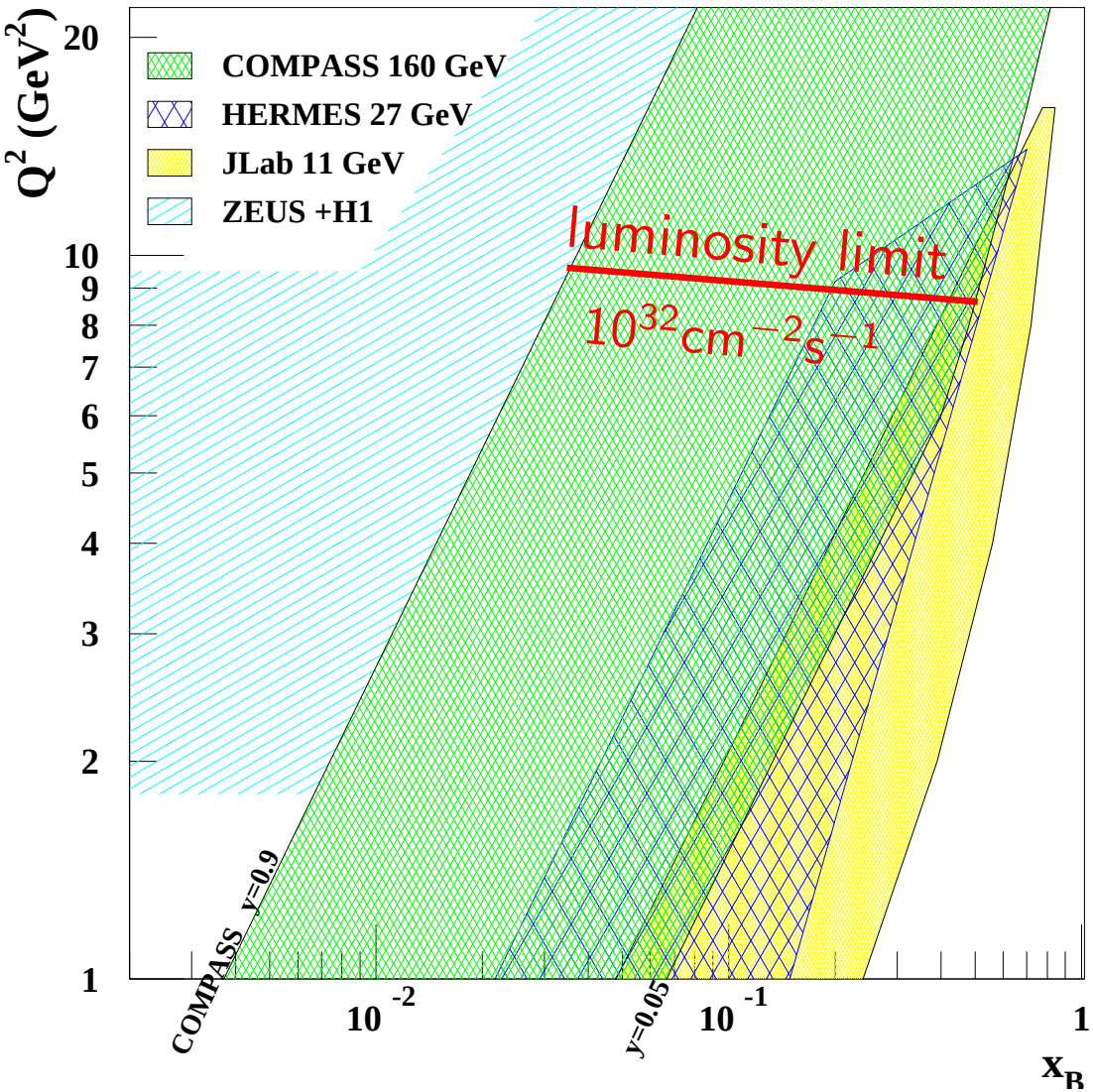
- using existing COMPASS detector
- Upgrades of existing em. calorimeter ECAL1&2
- ∼2.5 m Liquid hydrogen target
- ∼4 m Recoil proton detector (CAMERA)

COMPASS-II @ CERN/SPS



- using existing COMPASS detector
- Upgrades of existing em. calorimeter ECAL1&2
- ∼2.5 m Liquid hydrogen target
- ∼4 m Recoil proton detector (CAMERA)
- New large angle em. calorimeter in front of SM1 (ECAL0)

Unique Feature of COMPASS-II @ CERN/SPS

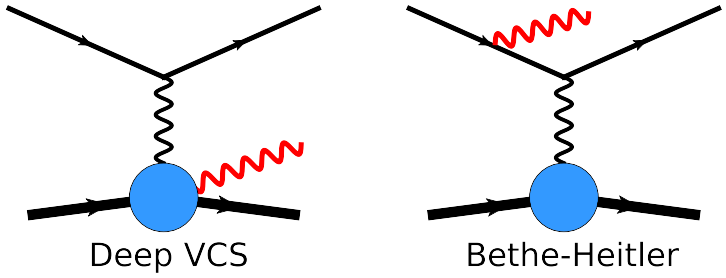


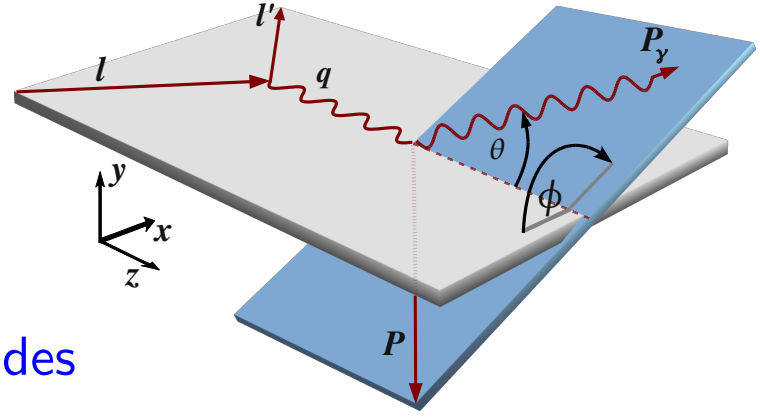
- μ^+ and μ^- beams
- momentum: $100 - 190\,\mathrm{GeV}/c$
- polarization: 80 %
  opposite for μ^+ and μ^-

- coverage of intermediate x_{Bj}

$\rightsquigarrow$ unexplored region between ZEUS+H1 and HERMES+JLab

$\mu p \to \mu' p' \gamma$: Interference with Bethe-Heitler





both processes interfere on level of amplitudes

$$\mathrm{d}\sigma_{(\mu p \to \mu' p' \gamma)} \propto |T^{BH}|^2 + \text{Interference Term} + |T^{DVCS}|^2$$

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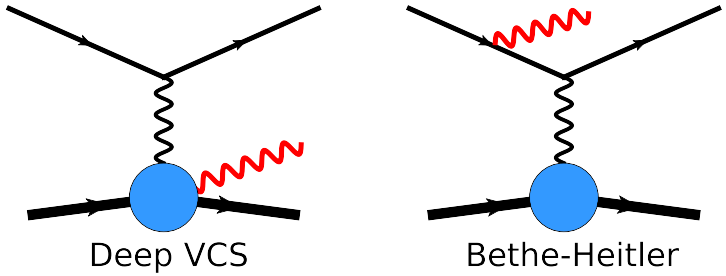

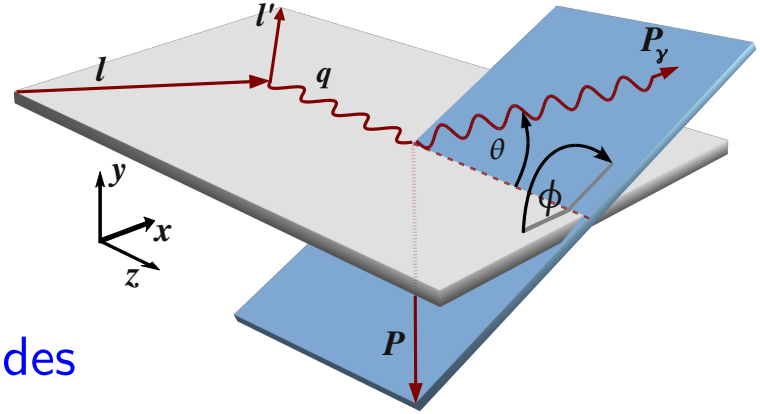

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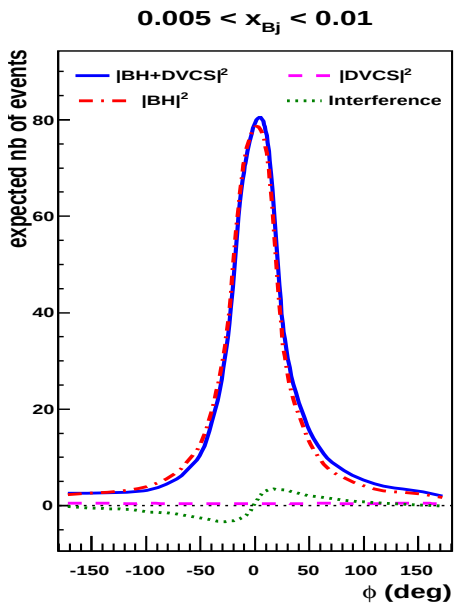
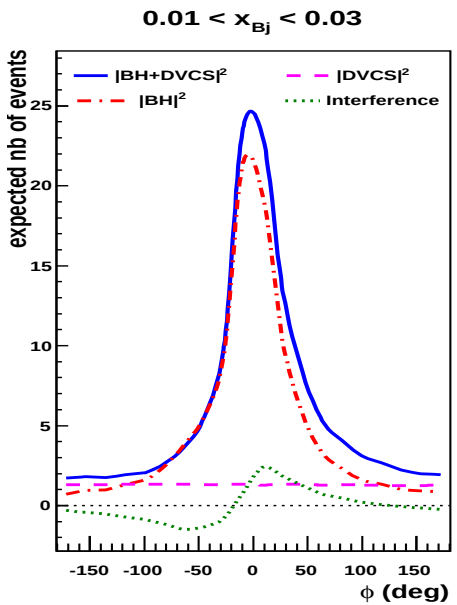
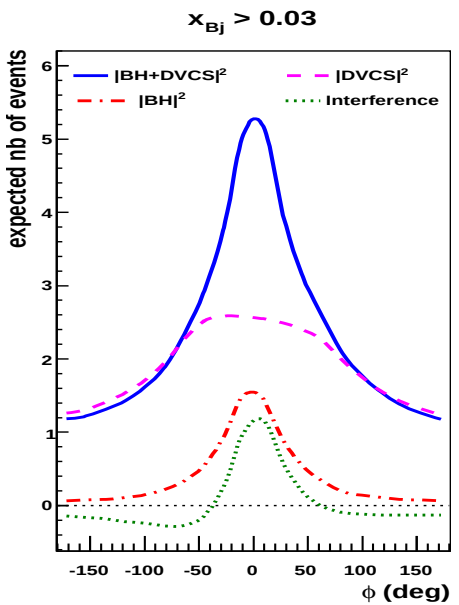


BH dominates



Interference



DVCS dominates

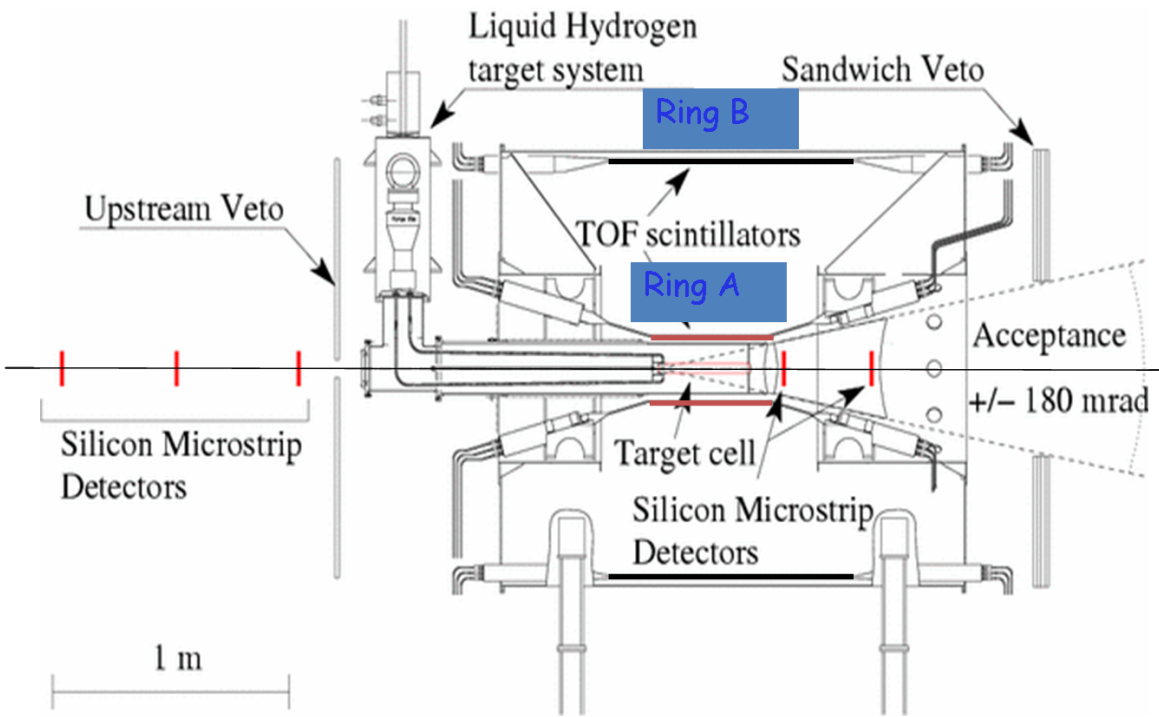
MC simulation for COMPASS without ECAL0

$\rightsquigarrow$ reference yield

DVCS: Testrun 2008 and 2009

Beam Tests @ COMPASS during hadron programme:

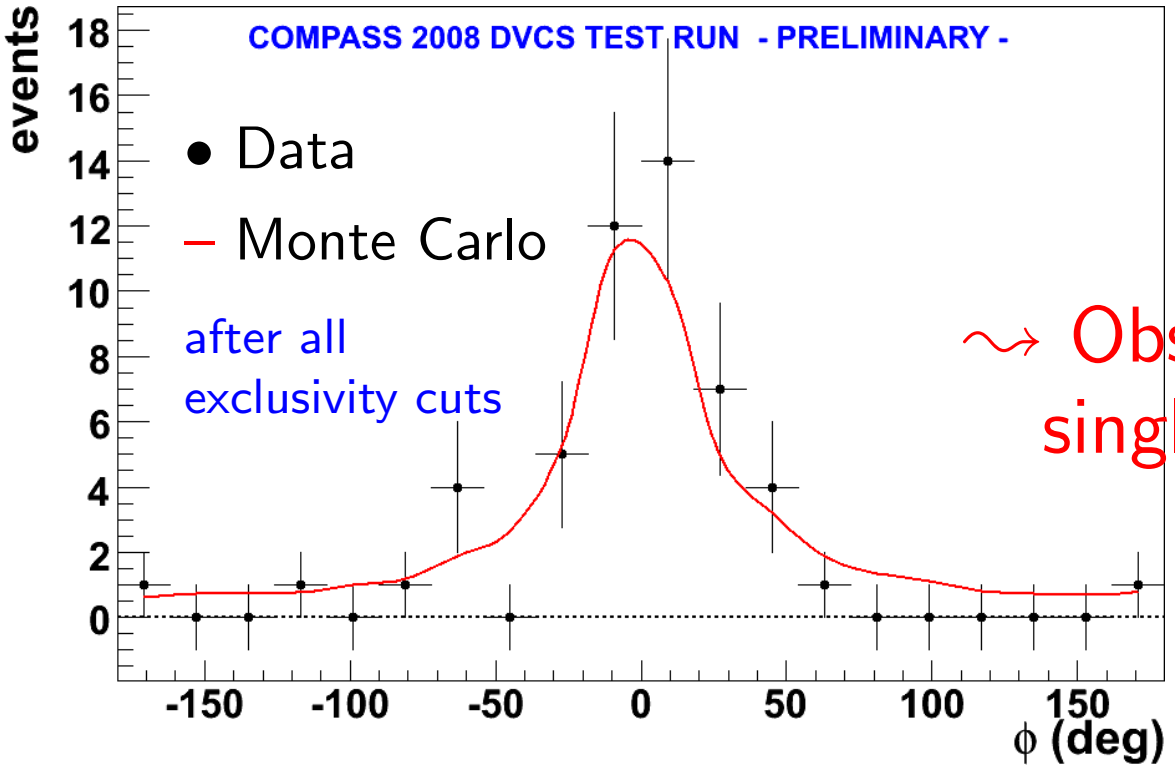
- 2008 (8 hours)
- 2009 (10 times statistics of 2008)



Target Setup for the Hadron Programme (2008-2009):

- Target: 40 cm LH_2
- Recoil Detector (1 m long)
- ECAL1 & ECAL2

2008 test: Bethe-Heitler Signal

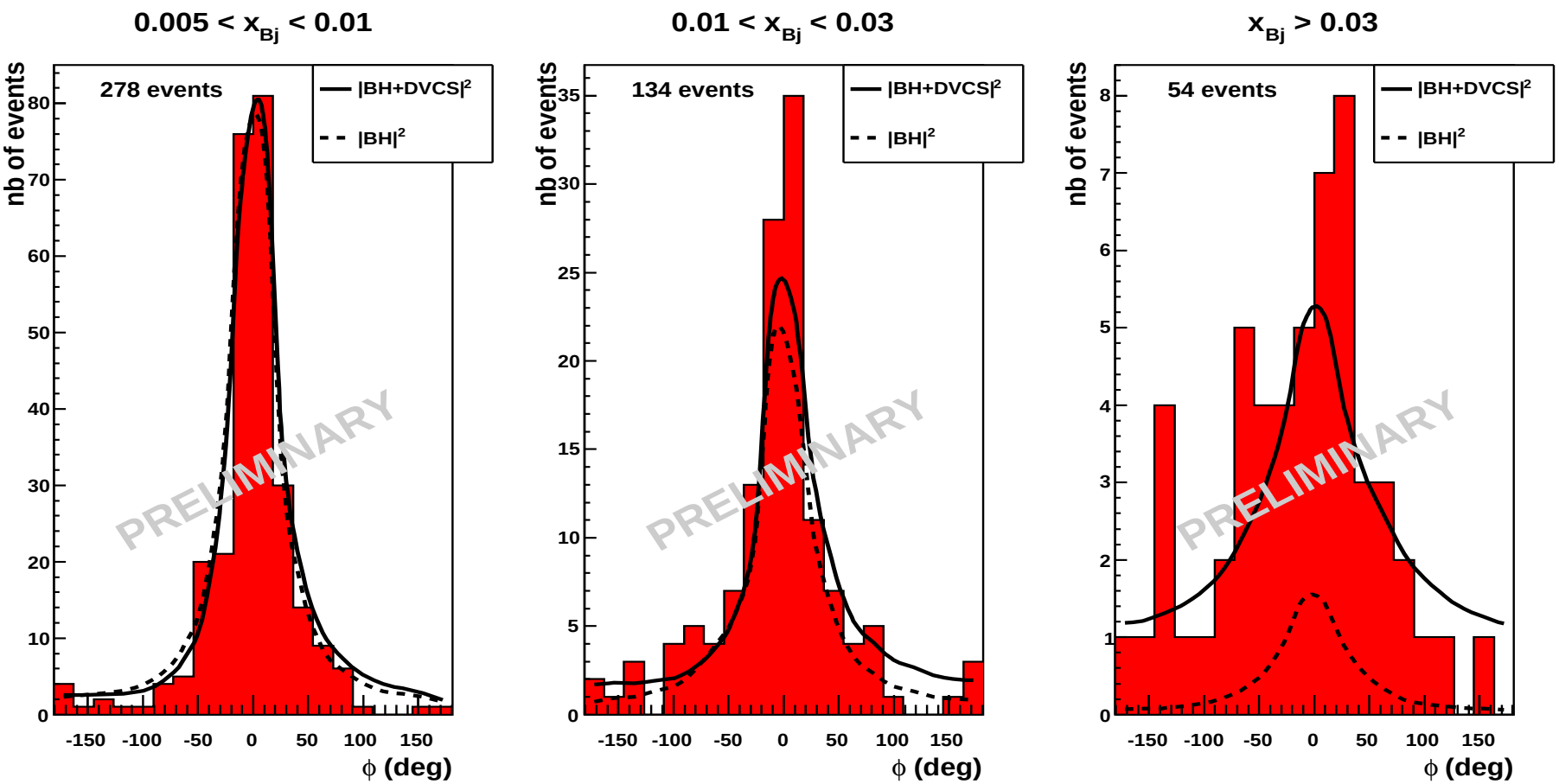


$\rightsquigarrow$ Observation of exclusive single photon production

- $\epsilon_{\mu p \to \mu' p' \gamma} = 0.32 \pm 0.13$
- SPS & COMPASS availability
- DAQ dead time
- Trigger efficiency

} global efficiency: $\epsilon_{global} = 0.13 \pm 0.05$

2009 test: DVCS and BH Signal



- confirmation of global efficiency

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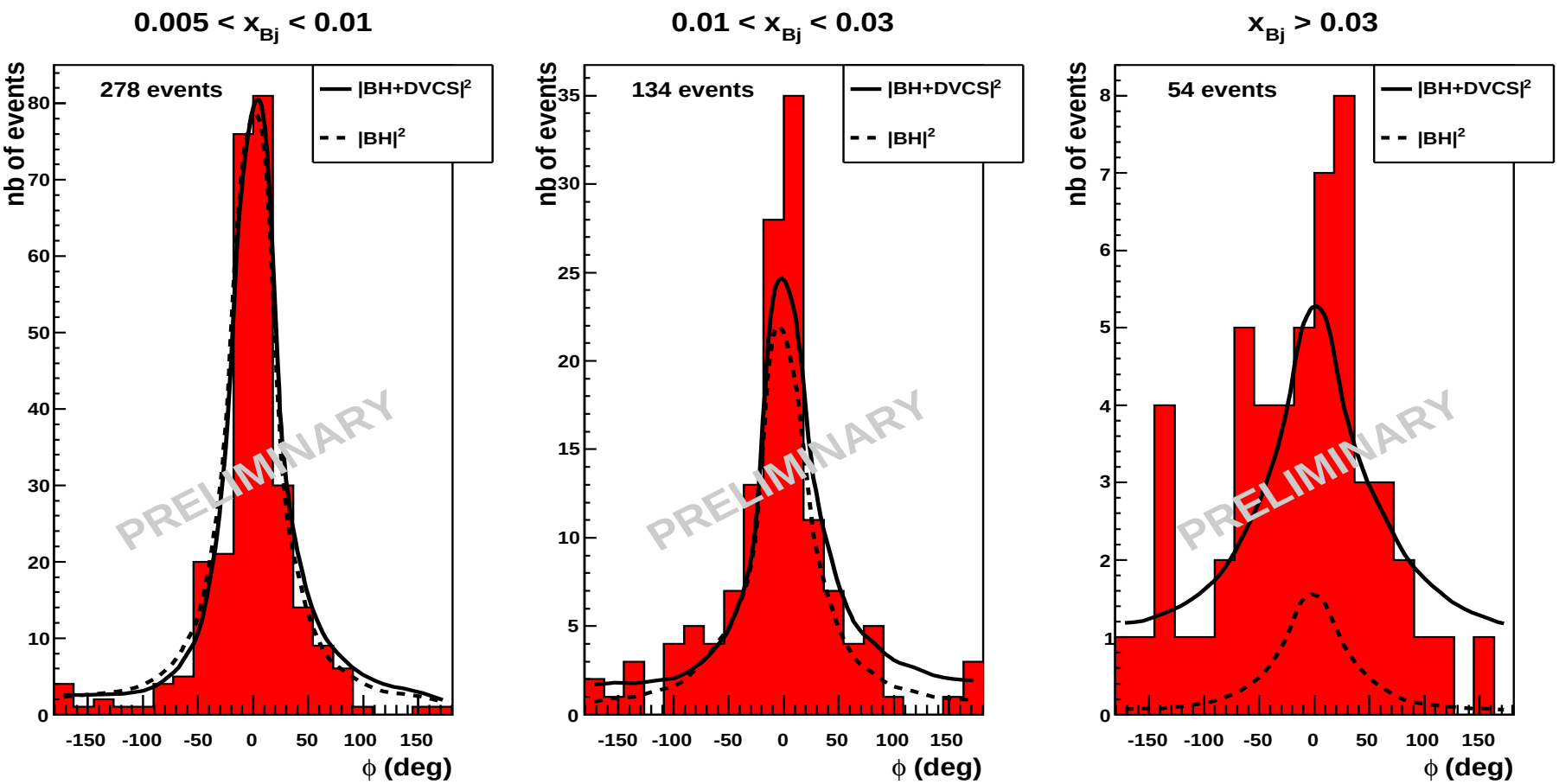
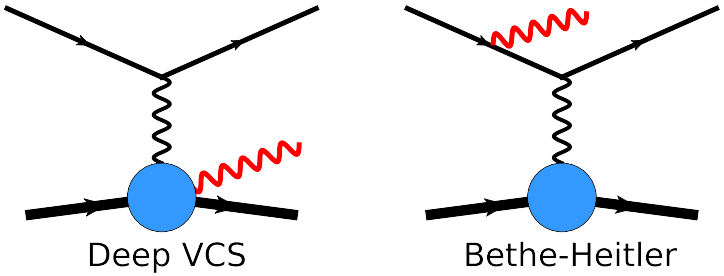
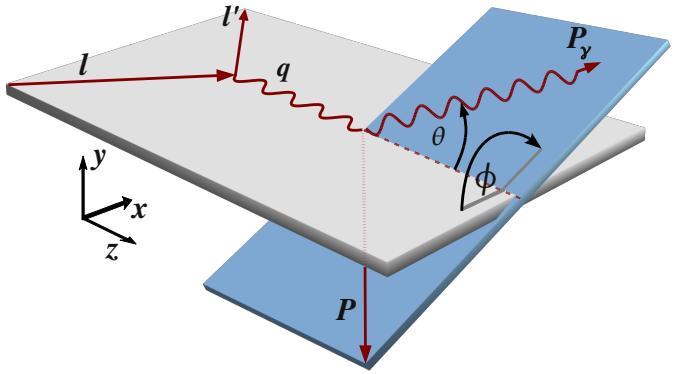


- confirmation of global efficiency

$\rightsquigarrow$ realistic projection of errors

Deeply Virtual Compton Scattering





$$d\sigma_{(\mu p \to \mu' p' \gamma)} = d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + P_\mu d\sigma^{DVCS}_{pol} + e_\mu a^{BH} \mathrm{Re}(T^{DVCS}) + e_\mu P_\mu a^{BH} \mathrm{Im}(T^{DVCS})$$

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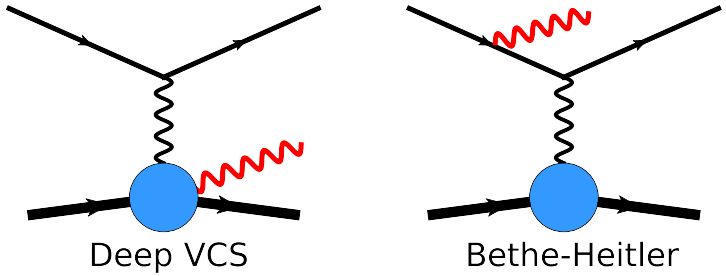

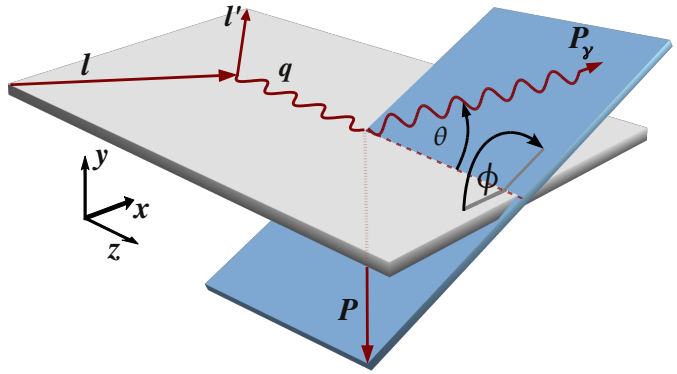

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- Beam charge and Spin sum:

$$\mathcal{S}_{CS,U} = d\sigma^{+\leftarrow} + d\sigma^{-\rightarrow} = 2\left(d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + e_\mu P_\mu a^{BH} \mathrm{Im}(T^{DVCS})\right)$$

- ϕ dependence gives access to GPD H

$\propto \sin\phi$

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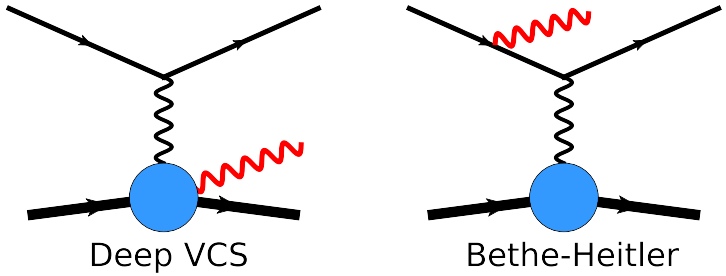

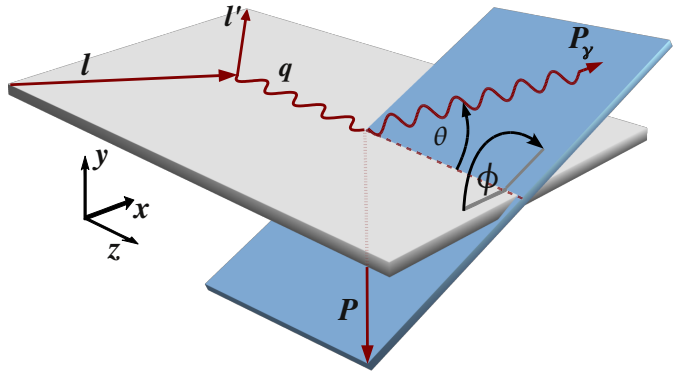

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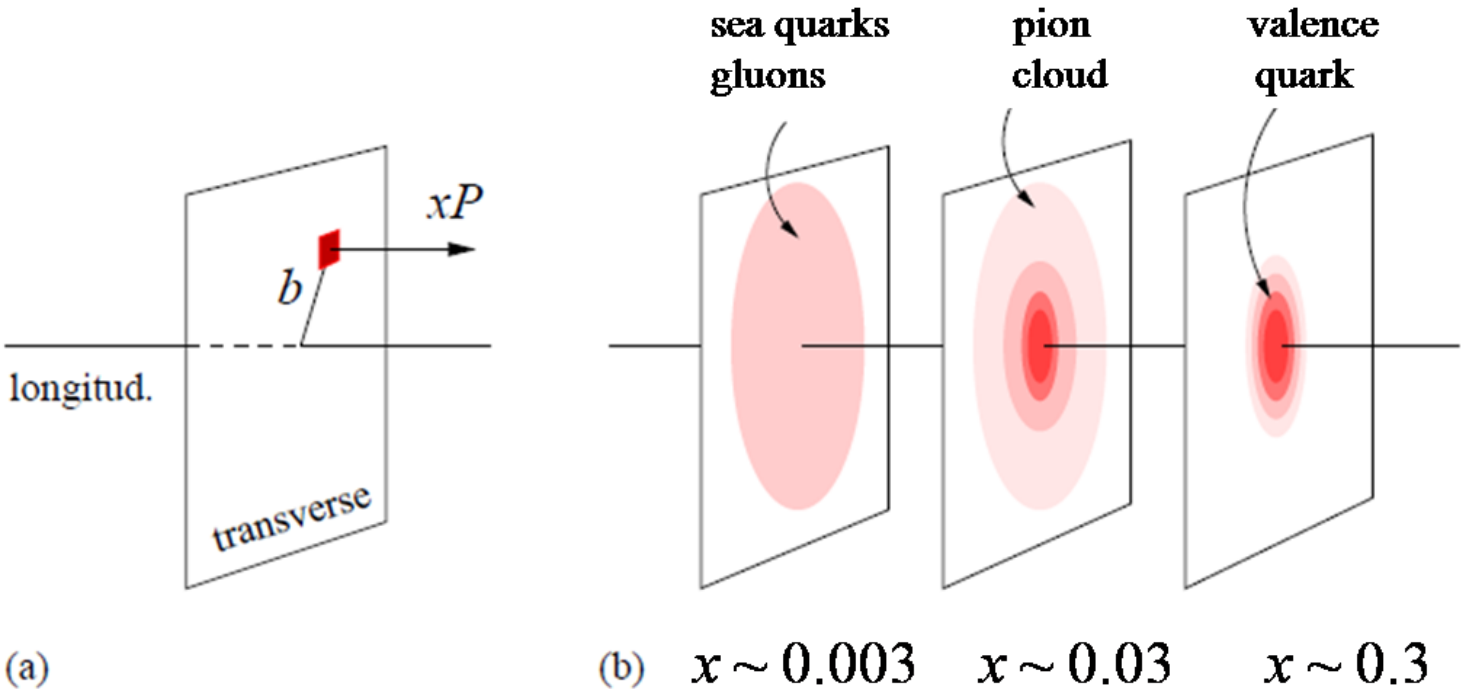
$\propto \sin\phi$

- ϕ dependence gives access to GPD H
- Integration over ϕ and subtracting BH:

$d\sigma^{DVCS}/dt \sim exp(-B|t|)$

DVCS: Transverse Size of the Nucleon



- Integration over ϕ and substracting BH:

  $d\sigma^{DVCS}/dt \sim exp(-B|t|)$

  $B(x_B) \sim \frac{1}{2}\langle r_\perp^2(x_B)\rangle$

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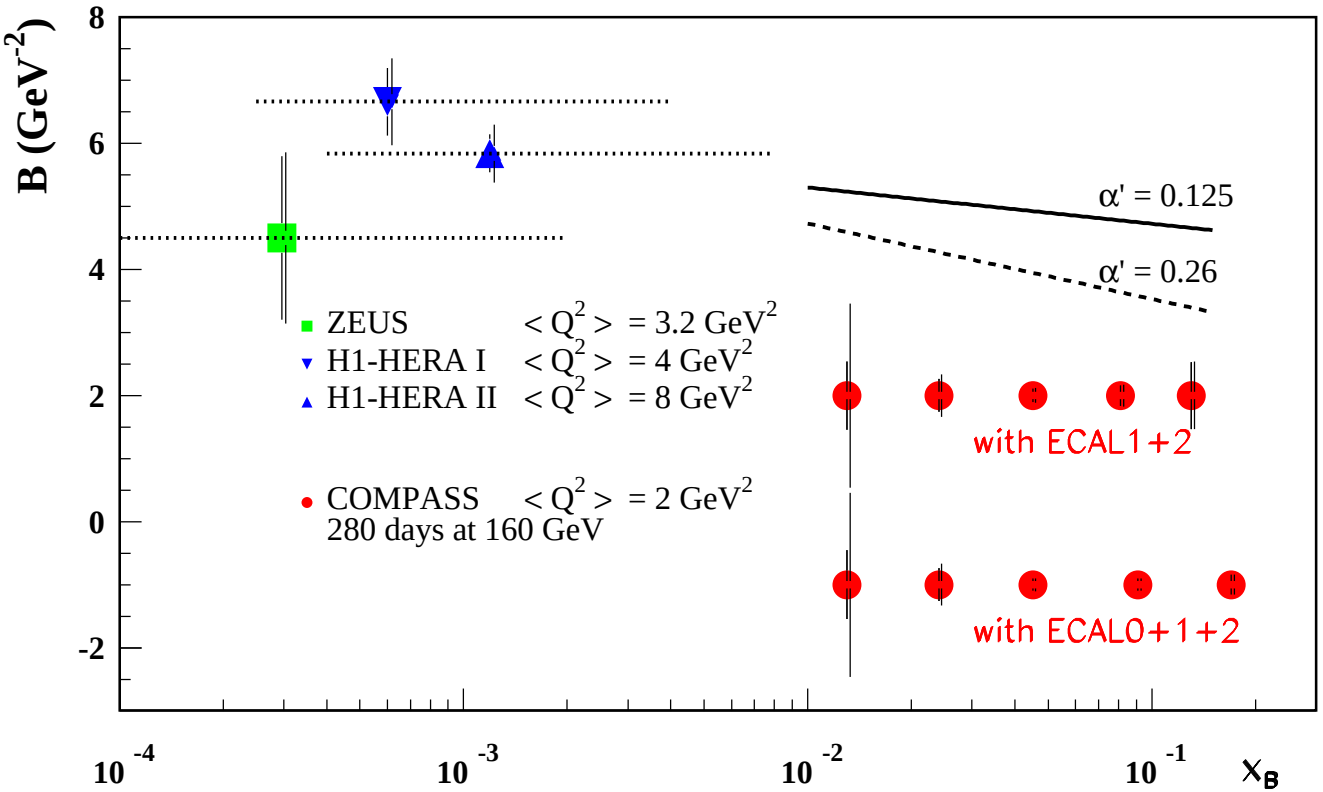

Input for projections:

- L=1222 pb^{-1}
  2 years of data
- $\epsilon_{global} = 10\,\%$
- 160 GeV/c muon beam
- 2.5 m LH_2 target

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  $d\sigma^{DVCS}/dt \sim exp(-B|t|)$

  $B(x_B) \sim \frac{1}{2}\langle r_\perp^2(x_B)\rangle$

- Ansatz at small x_B: $(x \sim x_B)$

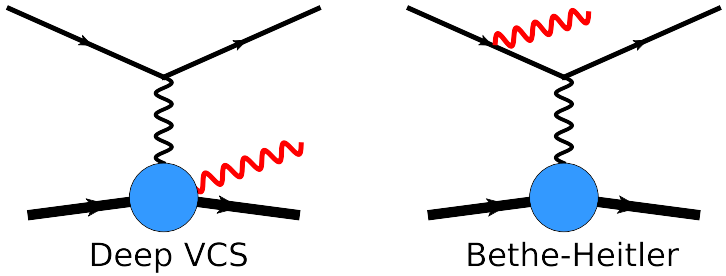
  $B(x_B) = b_0 + 2\alpha' ln(x_0/x_B)$

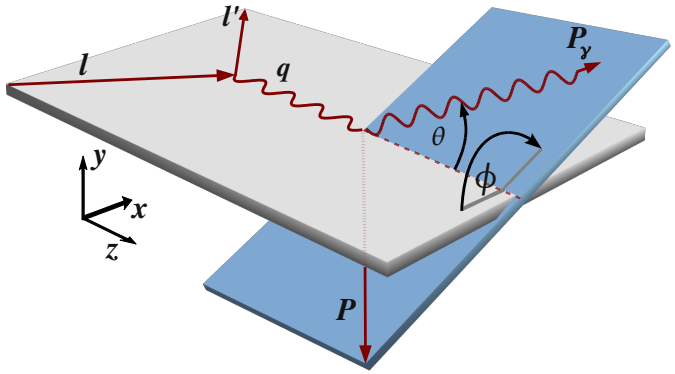
Accuracy $> 2.5\,\sigma$

for: $\alpha' > 0.26$ (with ECAL 1+2)

for: $\alpha' > 0.125$ (with ECAL 0+1+2)

Deeply Virtual Compton Scattering





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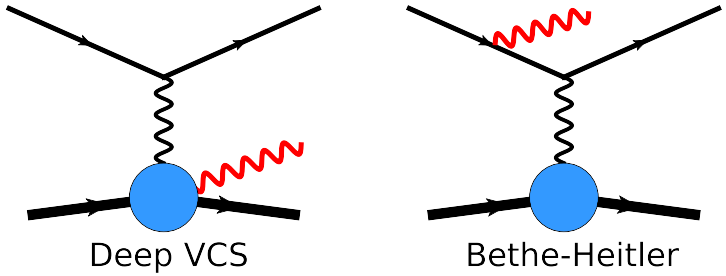

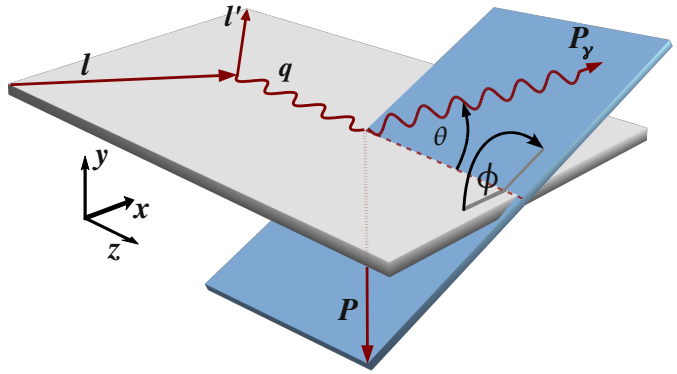

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$\Rightarrow$ BH contribution cancels

$\rightsquigarrow$ control detector acceptance and beam flux with high precision

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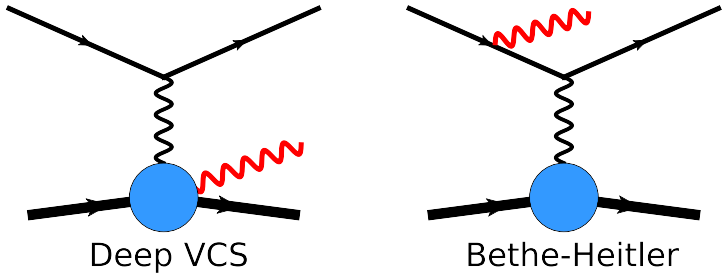

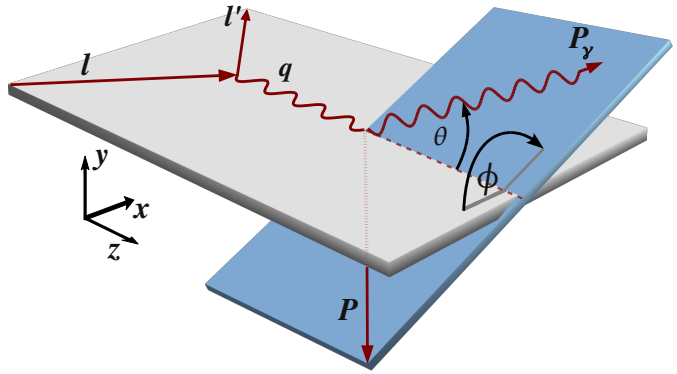

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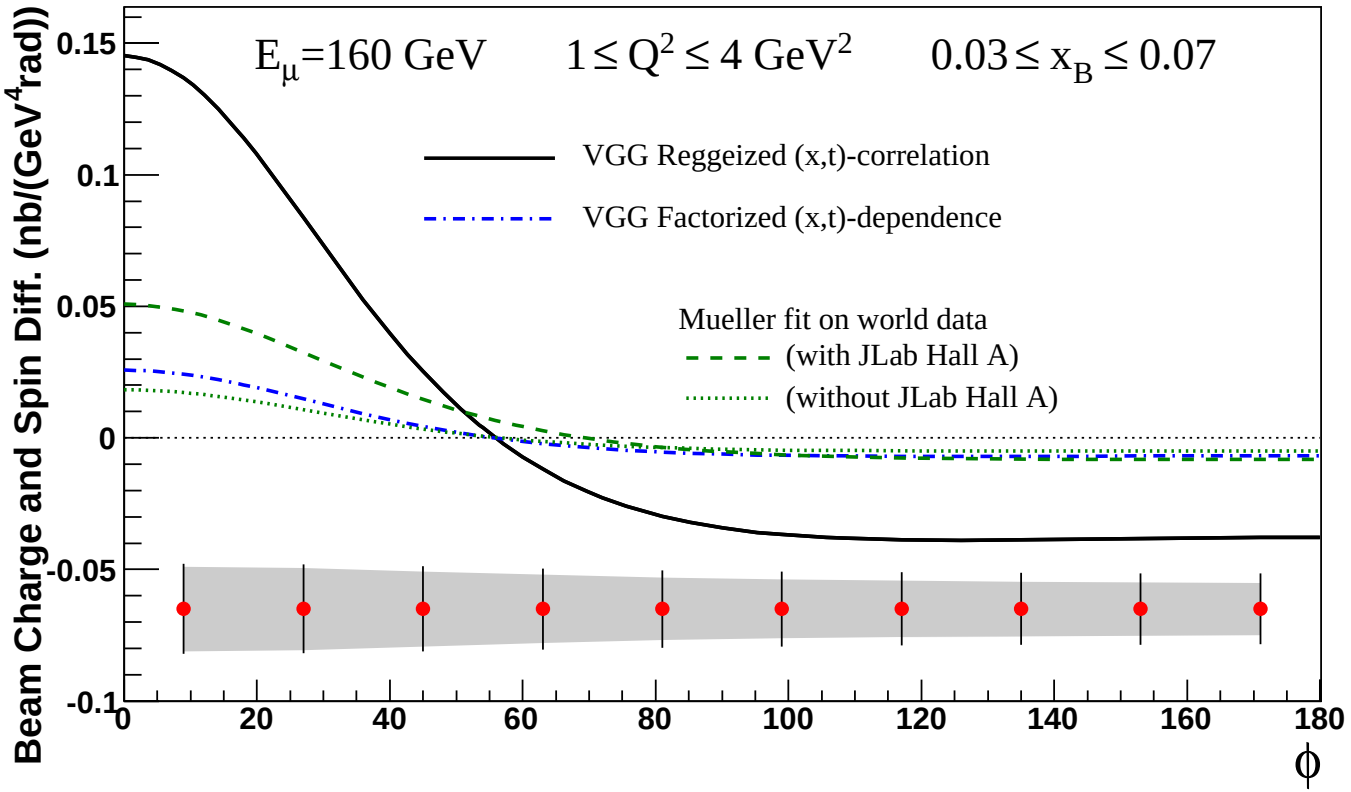
$$\propto c_0^{Int} + c_1^{Int} \cos\phi$$

$$c_{0,1}^{Int} \propto \mathrm{Re}(F_1 \mathcal{H})$$

DVCS: Beam Charge and Spin Difference



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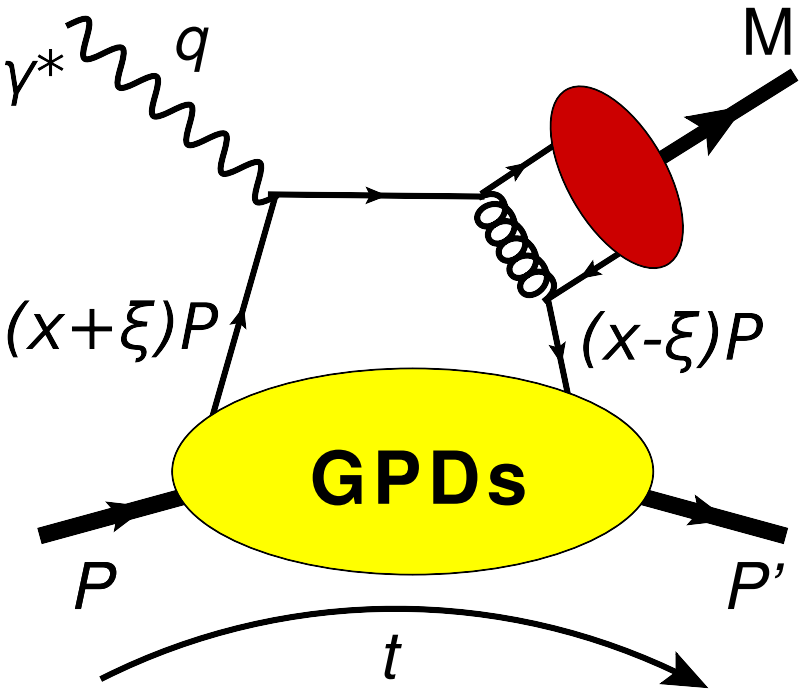
- 2.5 m LH_2 target

$$\mathrm{Re}(\mathcal{H}(\xi,t)) = \sum_f e_f^2 \left[\mathcal{P} \int \mathrm{d}x\, \mathrm{H}^f(x,\xi,t) \left(\frac{1}{x-\xi} \mp \frac{1}{x+\xi} \right) \right]$$

Hard Exclusive Meson Production



Cross section measurements:

- Pseudo-scalar: $\pi, \eta, .. \Rightarrow \tilde{\mathrm{H}}$
- Vector meson: $\rho, \omega, \phi, .. \Rightarrow \mathrm{H}$

Allow for flavour separation:

$$\mathrm{H}_{\rho^0} = \frac{1}{\sqrt{2}}\left(\frac{2}{3}\mathrm{H}^u + \frac{1}{3}\mathrm{H}^d + \frac{3}{8}\mathrm{H}^g\right)$$

$$\mathrm{H}_{\omega} = \frac{1}{\sqrt{2}}\left(\frac{2}{3}\mathrm{H}^u - \frac{1}{3}\mathrm{H}^d + \frac{1}{8}\mathrm{H}^g\right)$$

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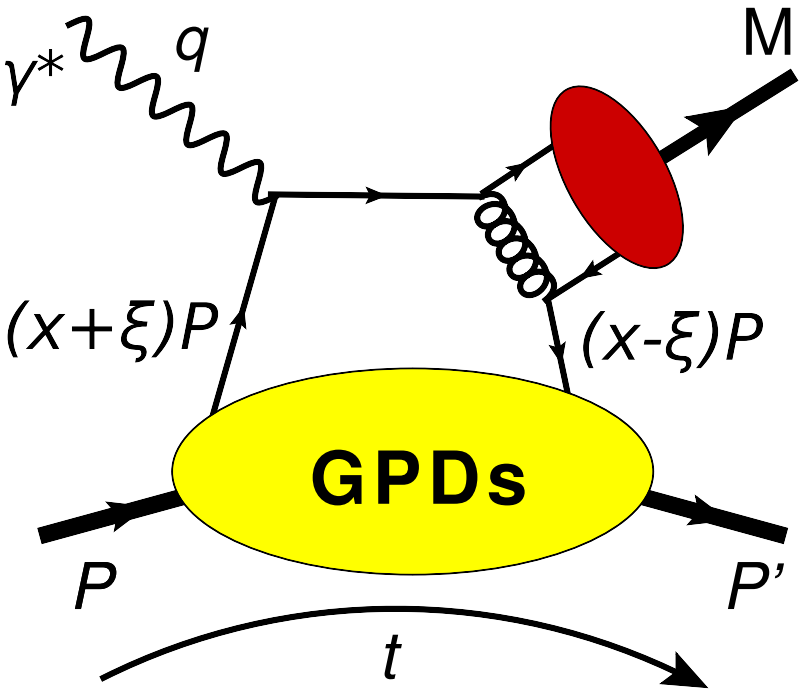

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Vector meson production from transversely polarized target:

- Asymmetry $\propto E/H$

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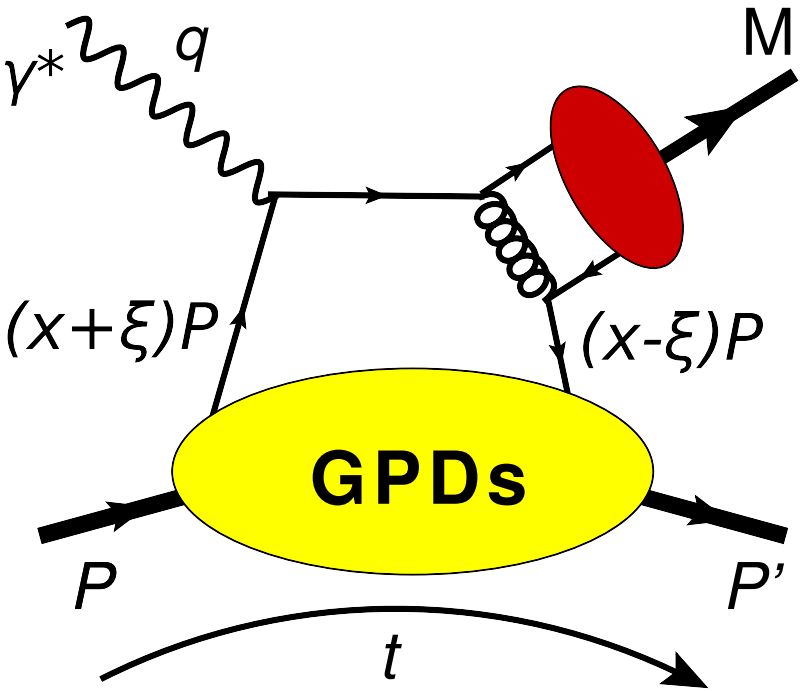

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$$H_{\phi} = -\frac{1}{3}H^s - \frac{1}{8}H^g$$

Also studied without RPD

used data with transversely polarized targets:

^{6}LiD: 2002-2004

NH_3: 2007 & 2010

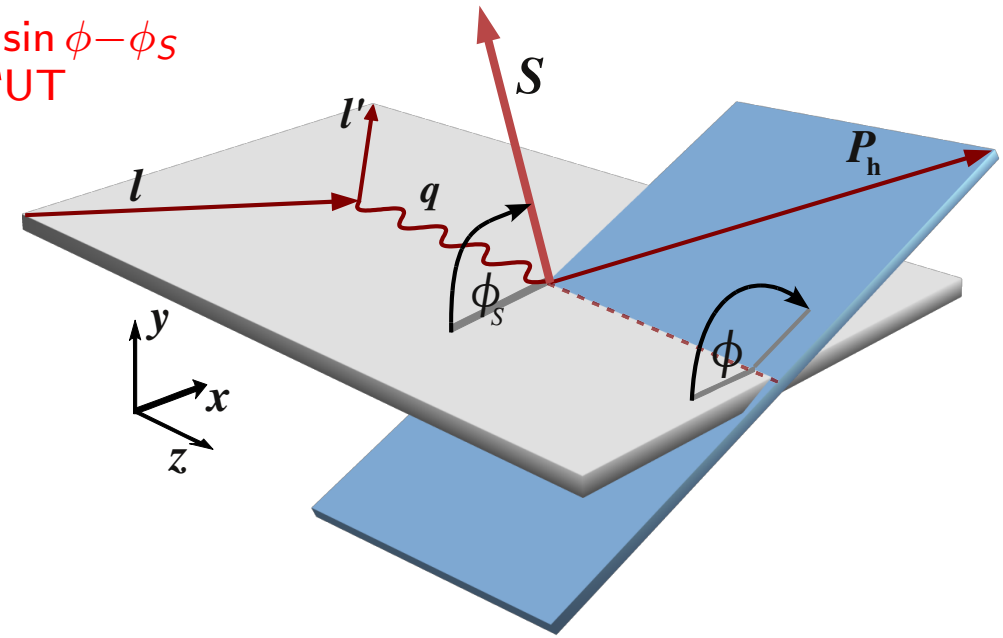
HEMP: Transversely Polarized Target

Transverse target spin asymmetry: $A_{UT}^{\sin\phi-\phi_S}$

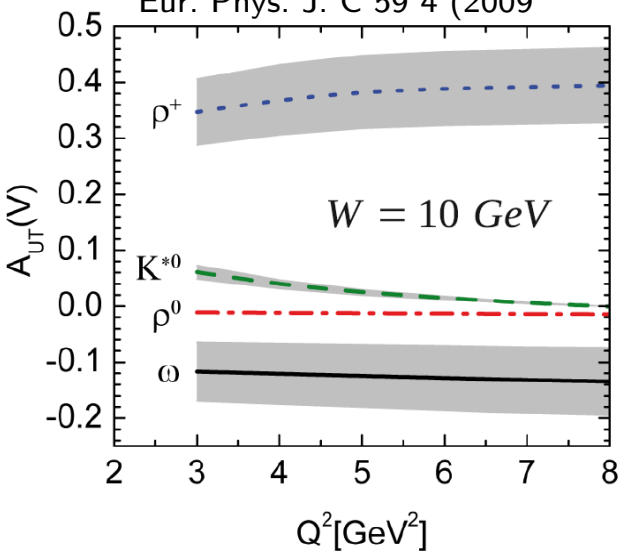
$$A_{UT}^{\sin\phi-\phi_S}(\rho^0) \propto \sqrt{|-t'|}\,\frac{\mathrm{Im}(\mathcal{E}\,\mathcal{H})}{|\mathcal{H}|^2}$$

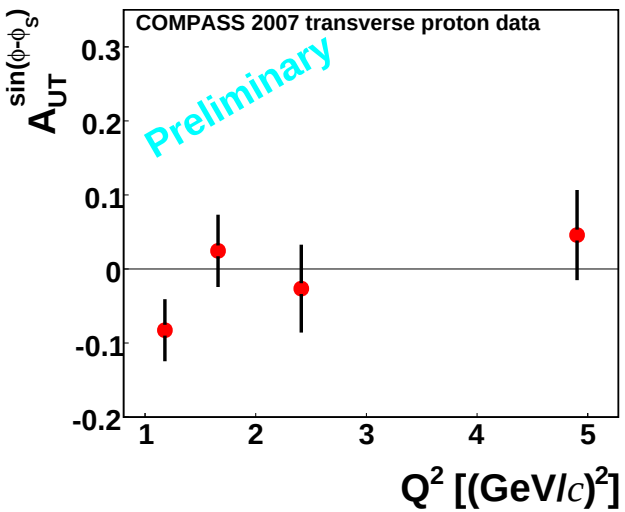
- $\mathcal{E}$ and $\mathcal{H}$ are weighted sums of GPDs $E^{q,g}$ and $H^{q,g}$

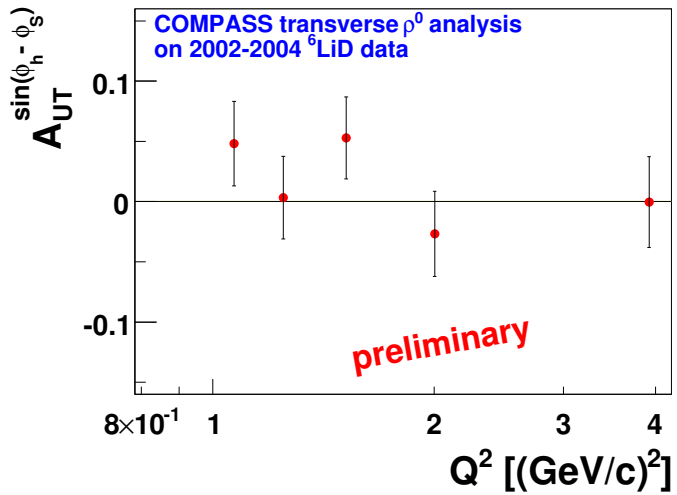
  $\rightsquigarrow$ provide access to GPD E



Goloskokov and Kroll
Eur. Phys. J. C 59 4 (2009







Summary

- COMPASS-II will investigate quark GPDs with DVCS
  - Covered x_B/Q^2 regime not accessible to any other experiment in the near future
  - Change of beam charge and polarization - UNIQUE
  - Study nucleon transversal dimension as function of x_B (Tomography)
  - Constrain GPD H through ϕ dependence of $\mathcal{D}_{CS,U}$ and $\mathcal{S}_{CS,U}$
- Complementary information from hard exclusive meson production
- In a second phase measurement with transversely polarized target and RPD

Thank You!

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