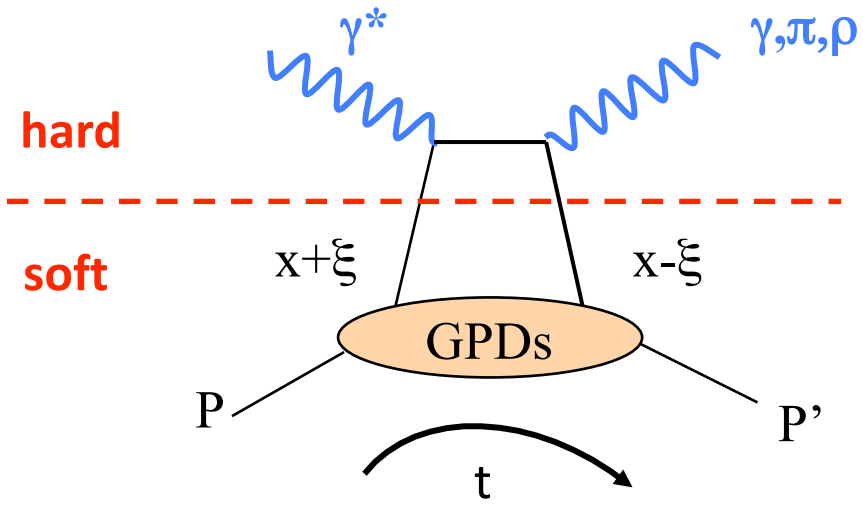
Possibilities to perform DVCS measurement at COMPASS

E. Burtin CEA-Saclay Irfu/SPhN
On Behalf of the COMPASS Collaboration
DIS 2009 - Madrid - 29 April, 2009

- Physics Motivations
- Sensitivity to physics observables using COMPASS
- Observation of exclusive photon production in 2008 test run

Generalized Parton Distributions



Factorisation:
Q^2 large, $-t<1$ GeV^2

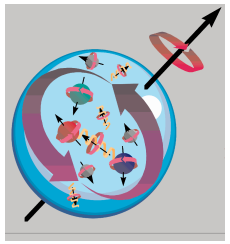
Generalized Parton Distributions

for quarks :

4 functions $H,E,\widetilde{H},\widetilde{E}(x,\xi,t)$

contains pdf
$H(x,0,0) = q(x)$
measured in DIS

contains form factors
$$F(t) = \int dx H(x,\xi,t)$$
measured in elastic scattering

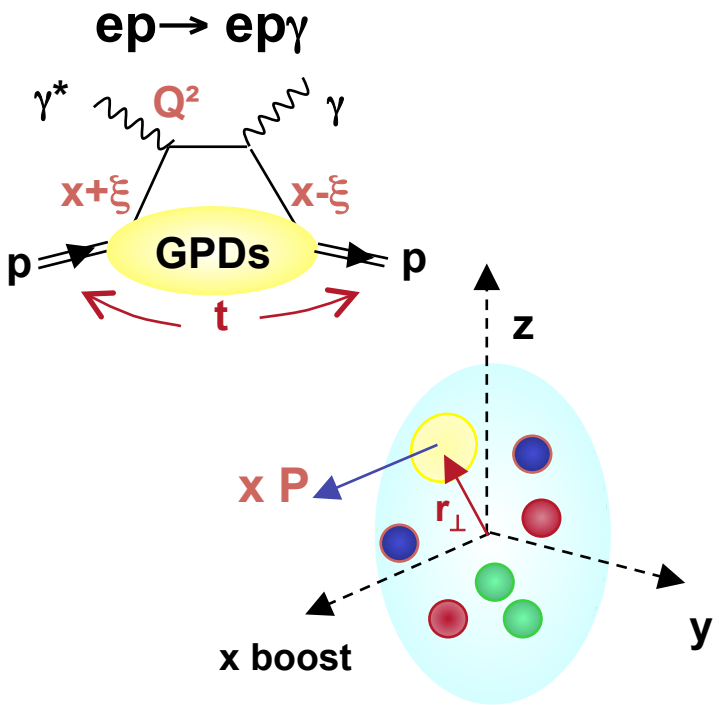


contains information on the nucleon spin :

Ji's sum rule :
$$\int x(H(x,\xi,t=0) + E(x,\xi,t=0))dx = J_z$$

Towards a 3-D nucleon picture ($P_{x}, r_{y,z}$)

Hard Exclusive Scattering
Deeply Virtual Compton Scattering



GPDs : H(x,ξ,t)

Fourier

access to correlations :

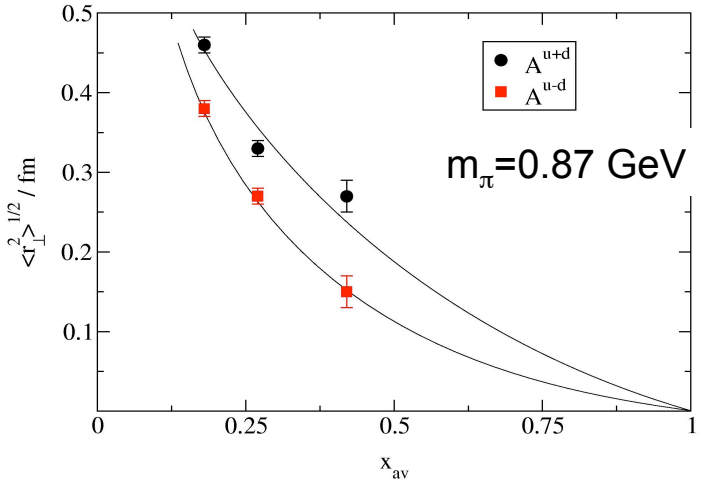
($P_{x,}$ $r_{y,z}$)

Burkardt,Belitsky,Müller,Ralston,Pire

Lattice calculation (unquenched QCD):

Negele *et al.,* NP B128 (2004) 170
Göckeler *et al.,* NP B140 (2005) 399

- **small valence quark core**
- **widely spread sea q and gluons**



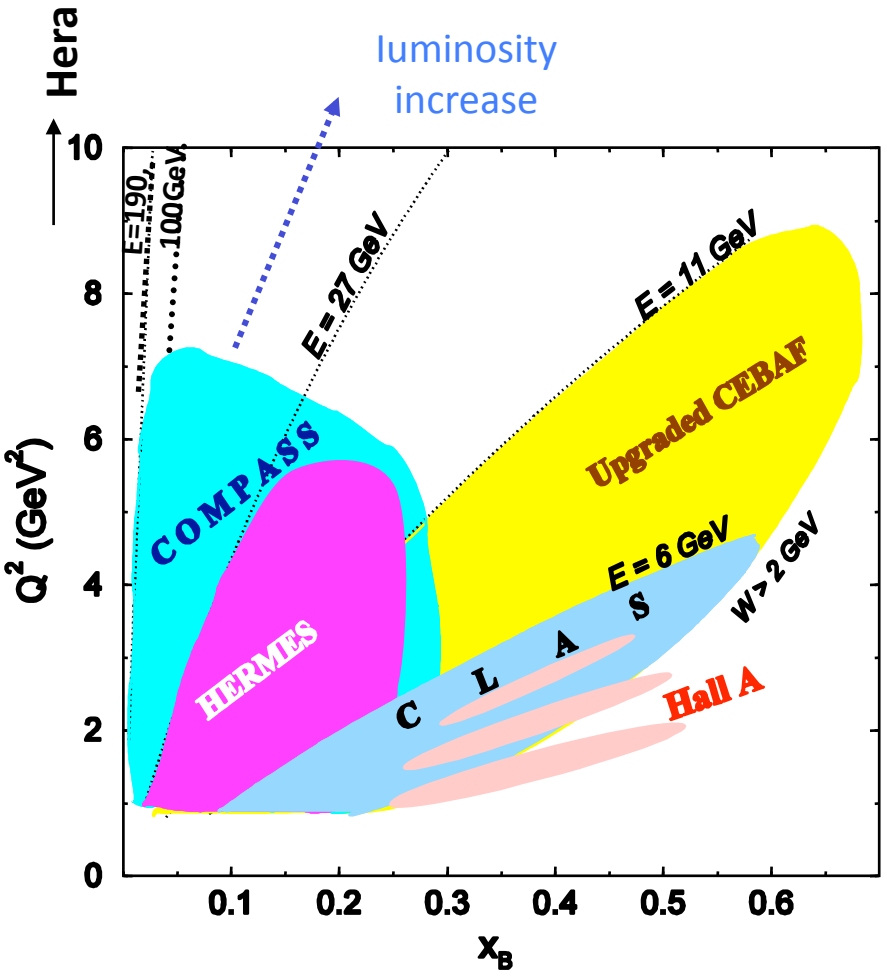
Chiral dynamics:

Strikman *et al.,* PRD69 (2004) 054012

gluon density generated by the π cloud
increase of the N transverse size
for $x_{Bj} < m_\pi/m_p$=0.14

What makes Compass a special place ?

Kinematical domain :



Valence + sea + gluons

CERN High energy muon beam

- 100 / 190 GeV
- 80% Polarisation
- μ^+ and μ^- available
  - ✓Opposite polarization

Targets

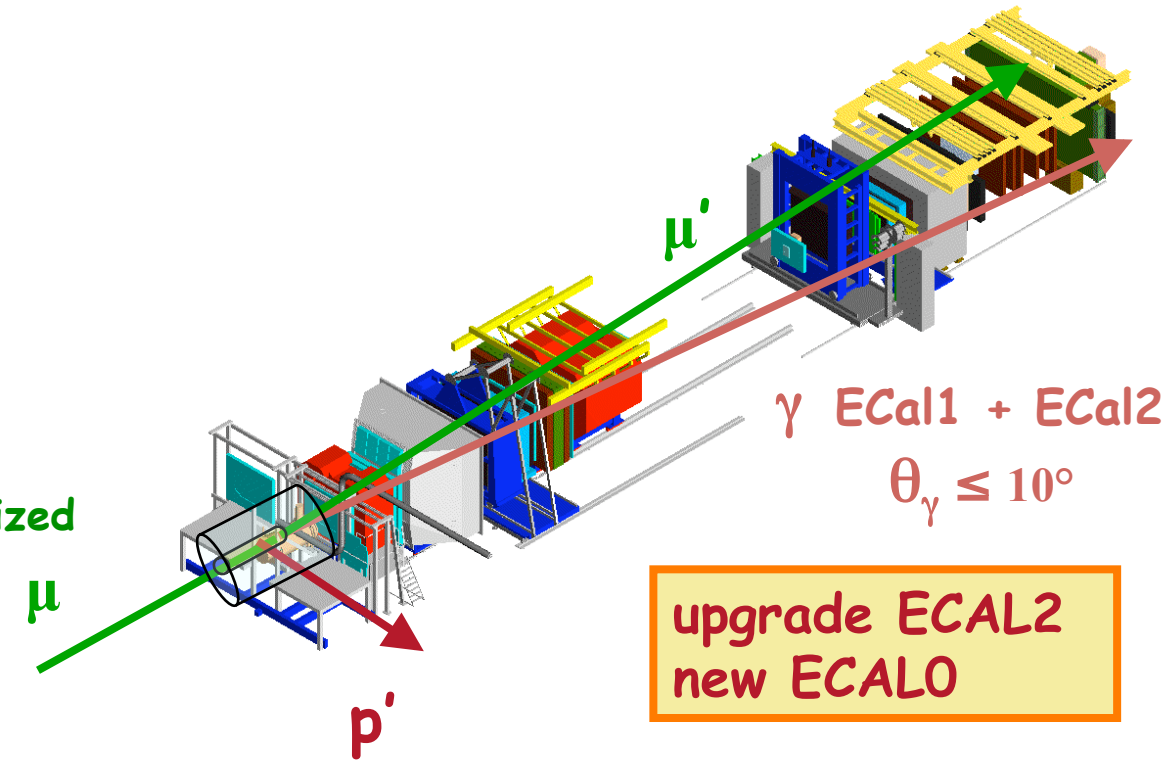
- liquid Hydrogen
- Polarised target

GPD program : experimental set-up

DVCS $\mu p \rightarrow \mu' p' \gamma$

2.5m cryogenic target
to be designed and built

- Phase 1: long H2 target
- Phase 2: transversely polarized



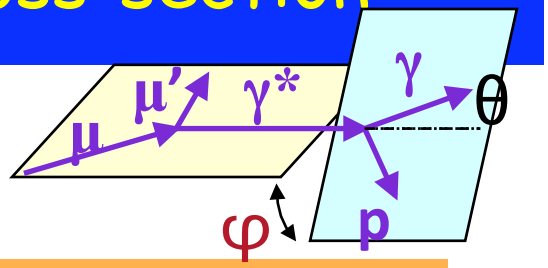
upgrade ECAL2
new ECAL0

$N\mu = 4.6\ 10^8$/SPS cycle
(duration 9.6s, every 48s)

4m long Recoil proton detector
to insure exclusivity
to be designed and built

Harmonic decomposition of the cross-section

from Belitsky, Kirchner, Müller :
polarized beam off unpolarized target



$$d\sigma_{(\mu p\to\mu p\gamma)} = d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + P_\mu\, d\sigma^{DVCS}_{pol} + e_\mu\, a^{BH}\, \mathcal{R}e\, A^{DVCS} + e_\mu P_\mu\, a^{BH}\, \mathcal{I}m\, A^{DVCS}$$

$$d\sigma^{BH} = \frac{\Gamma(x_B, Q^2, t)}{P_1(\varphi)P_2(\varphi)}\left(c_0^{BH} + c_1^{BH}\cos\varphi + c_2^{BH}\cos 2\varphi\right)$$ ← Known expression

$$d\sigma^{DVCS}_{unpol} = \frac{e^6}{y^2Q^2}\left(c_0^{DVCS} + c_1^{DVCS}\cos\varphi + c_2^{DVCS}\cos 2\varphi\right)$$

$$P_\mu \times\ d\sigma^{DVCS}_{pol} = \frac{e^6}{y^2Q^2}\left(s_1^{DVCS}\sin\varphi\right)$$

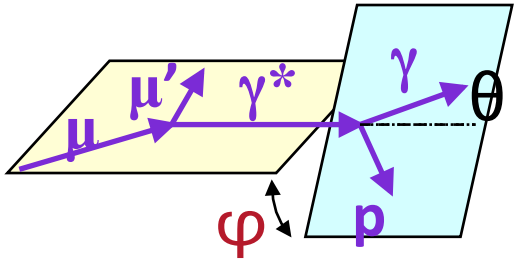
$$e_\mu \times a^{BH}\Re e A^{DVCS} = \frac{e^6}{xy^3tP_1(\varphi)P_2(\varphi)}\left(c_0^{Int} + c_1^{Int}\cos\varphi + c_2^{Int}\cos 2\varphi + c_3^{Int}\cos 3\varphi\right)$$

$$e_\mu P_\mu \times a^{BH}\Im m A^{DVCS} = \frac{e^6}{xy^3tP_1(\varphi)P_2(\varphi)}\left(s_1^{Int}\sin\varphi + s_2^{Int}\sin 2\varphi\right)$$

Twist-2 M^{11} >> Twist-3 M^{01} Twist-2 gluon M^{-11}

Harmonic decomposition : COMPASS case

Case of COMPASS : $\mu^+(P=-0.8)$ *and* $\mu^-(P=+0.8)$



$$\mathcal{D}_{U,CS} : d\sigma_{\mu^+} - d\sigma_{\mu^-} = 2\,P_\mu\, d\sigma^{DVCS}_{pol} + e_\mu\, a^{BH}\, \mathcal{R}e\, A^{DVCS}$$

$$s_1^{DVCS}\sin\varphi$$

$$c_0^{Int} + c_1^{Int}\cos\varphi + c_2^{Int}\cos 2\varphi + c_3^{Int}\cos 3\varphi$$

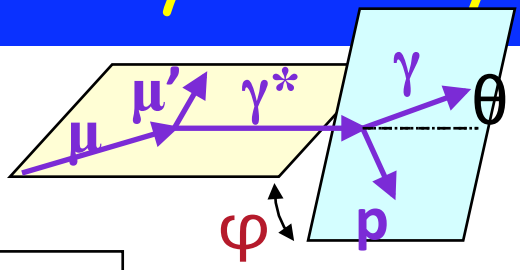
$$S_{U,CS} : d\sigma_{\mu^+} + d\sigma_{\mu^-} = 2(d\sigma^{BH} + d\sigma^{DVCS}_{unpol}) + 2\,e_\mu\, P_\mu\, a^{BH}\, \mathcal{I}m\, A^{DVCS}$$

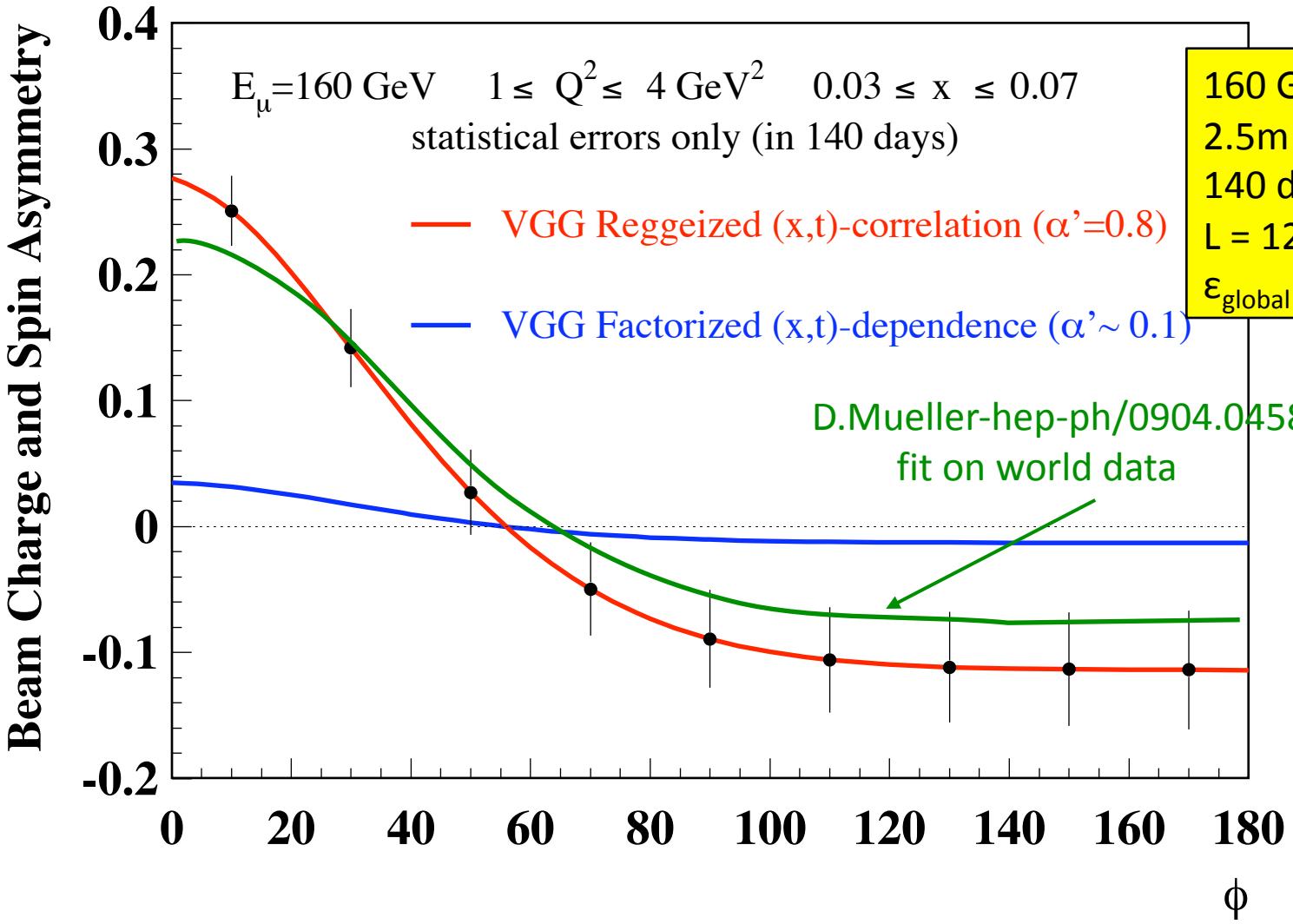
$$c_0^{DVCS+BH} + c_1^{DVCS+BH}\cos\varphi + c_2^{DVCS+BH}\cos 2\varphi$$

$$s_1^{Int}\sin\varphi + s_2^{Int}\sin 2\varphi$$

Sensitivity of Beam Charge & Spin Asymmetry

$BCSA = \mathcal{D}_{U,cs} / S_{U,cs}$





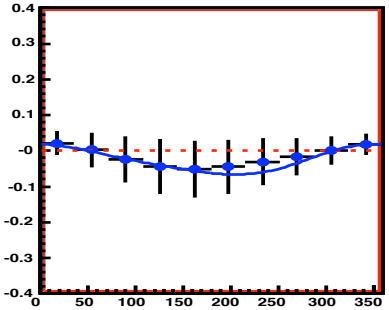
160 GeV muon beam
2.5m LH_2 target
140 days
$L = 1222\ pb^{-1}$
$\varepsilon_{global} = 10\ \%$

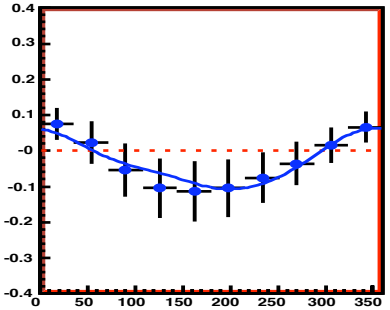
BCSA(ϕ) over the kinematical domain

Points: VGG prediction Phys. Rev. D60:094017,1999
Statistical errors only
Curves: FSS prediction Phys. Rev. D59:119901,1999

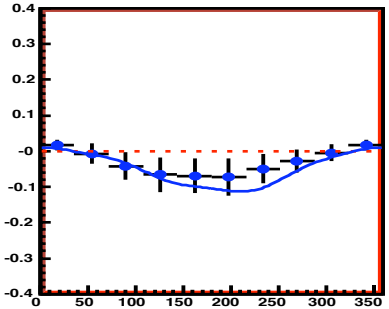
160 GeV muon beam
2.5m LH_2 target
140 days
$L = 1222\ pb^{-1}$
$\varepsilon_{global} = 10\ \%$

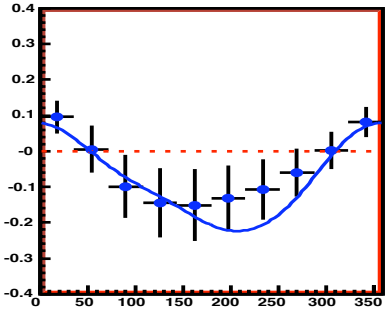
$4 < Q^2 < 8$



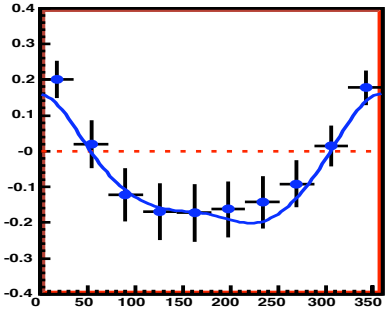


$2 < Q^2 < 4$

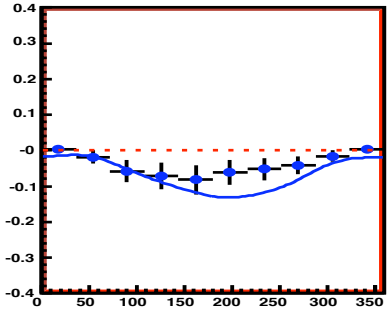


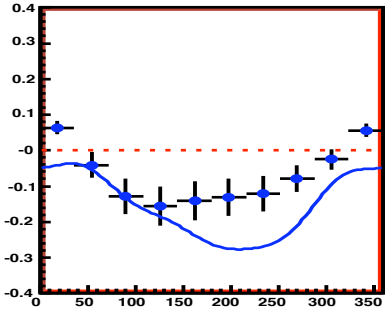


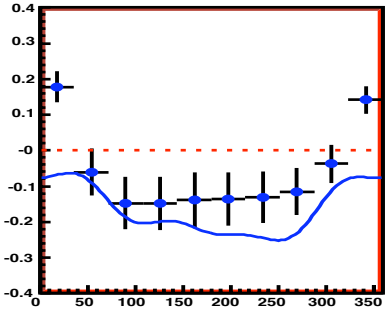
ϕ (deg)

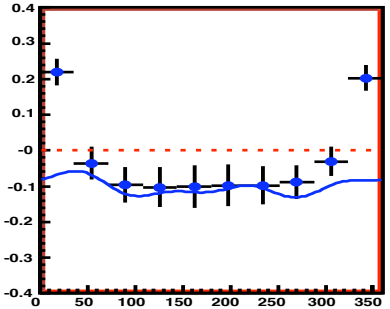


$1 < Q^2 < 2$









$0.005 < x < 0.01$

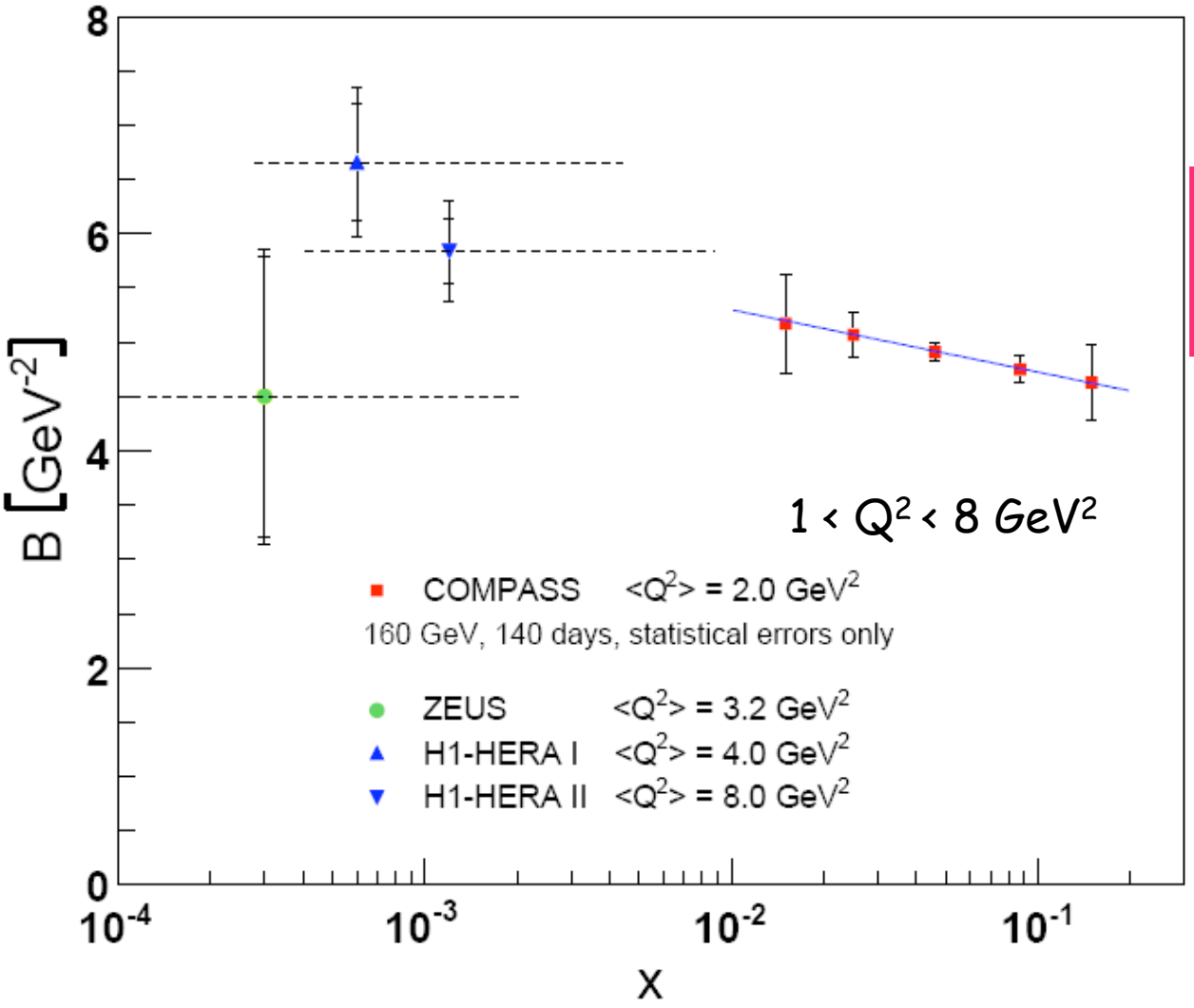
$0.01 < x < 0.02$

$0.02 < x < 0.03$

$0.03 < x < 0.07$

t-slope measurement

Using $\mathcal{S}_{U,CS}$: $d\sigma_{DVCS} / dt \sim \exp(Bt)$



Input :
$B(x) = b_0 + 2\,\alpha' \ln(x_0/x)$
$\alpha' = 0.125$ GeV^{-2} from J/Ψ

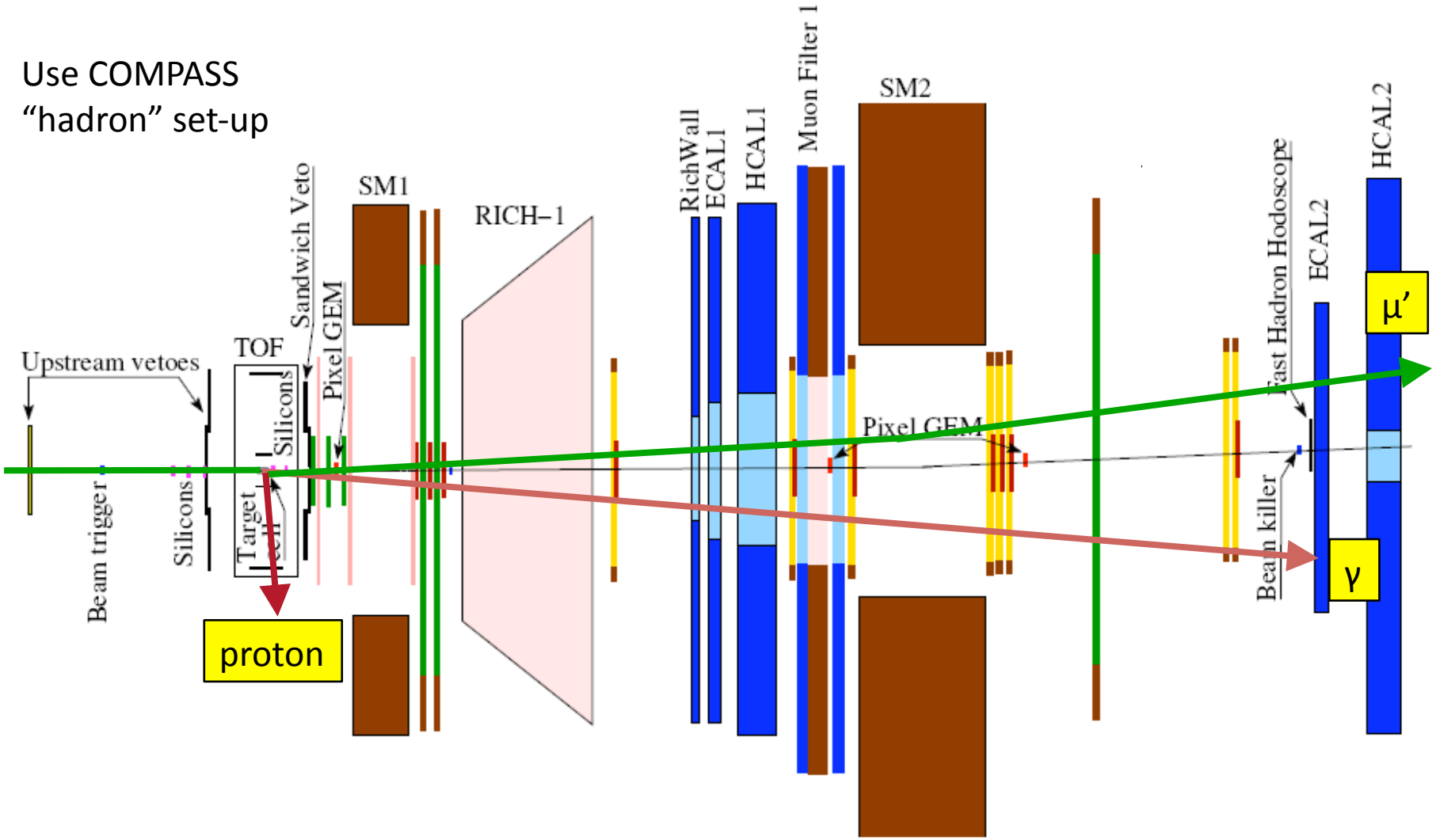
160 GeV muon beam
2.5m LH_2 target
140 days
L = 1222 pb^{-1}
ε_{global} = 10 %

2008 DVCS beam test

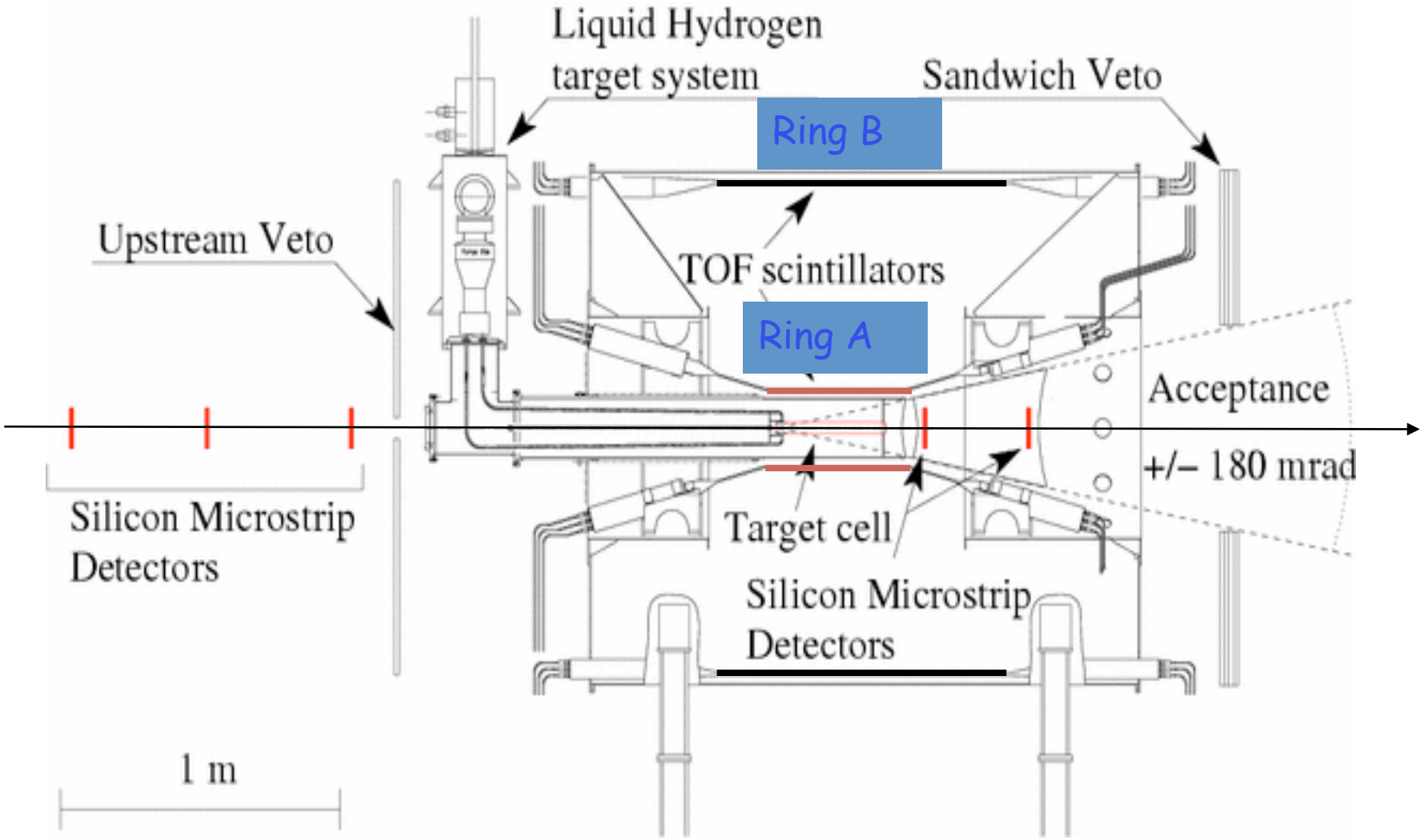
Goal : Evaluate feasibility of DVCS detection in the Compass environment

160 GeV μ on a 40cm long Liquid H2 target & RPD - 2 days of beam (μ+ and μ-)

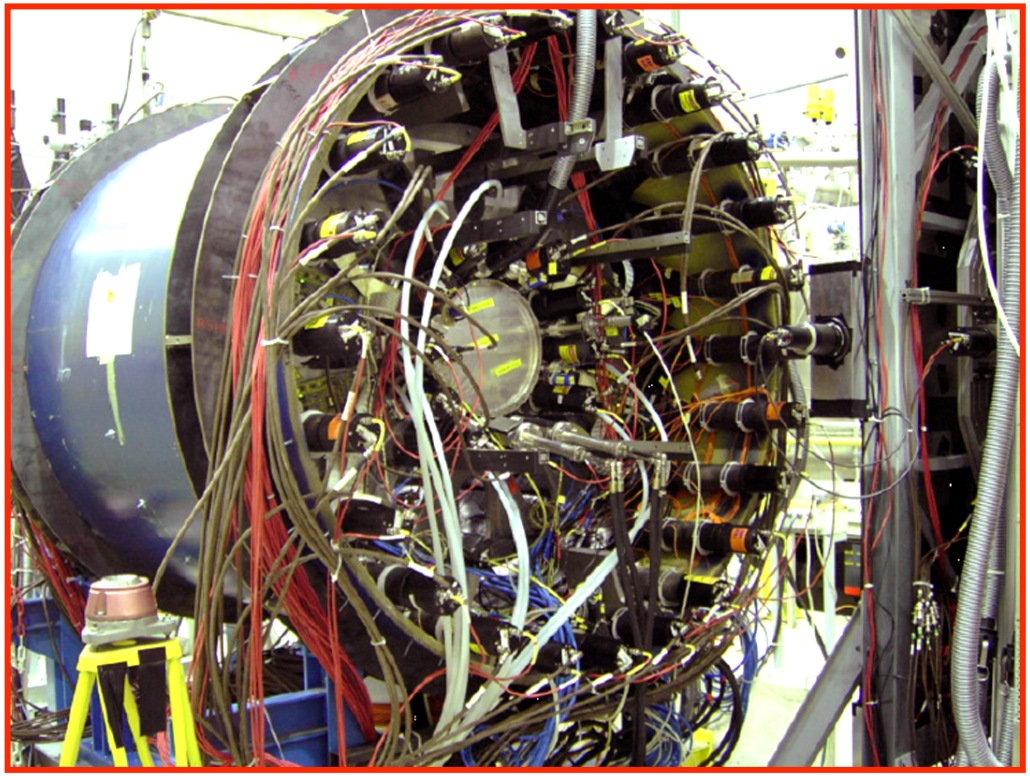
Use COMPASS
"hadron" set-up

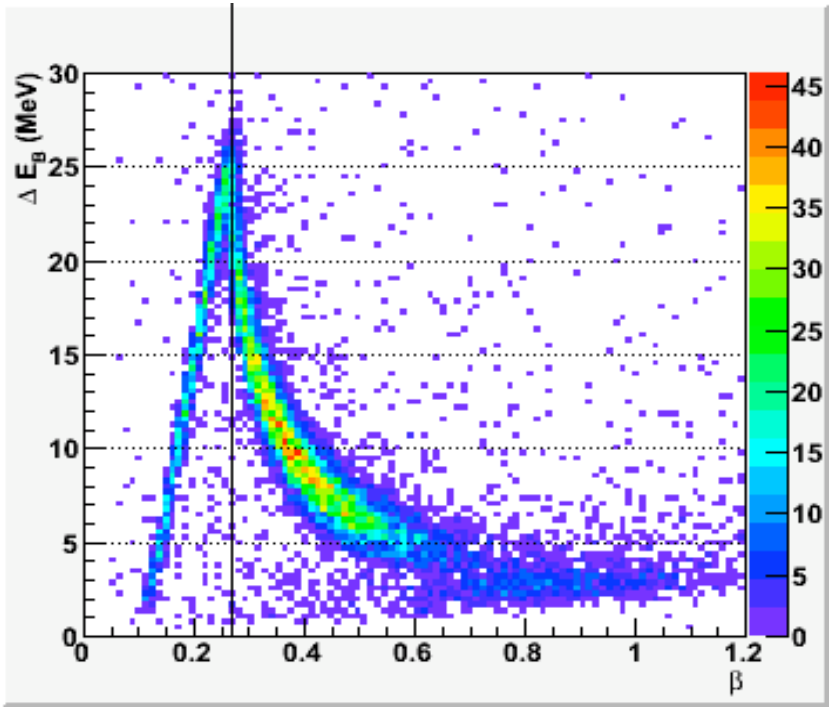


Liquid H_2 Target & RPD



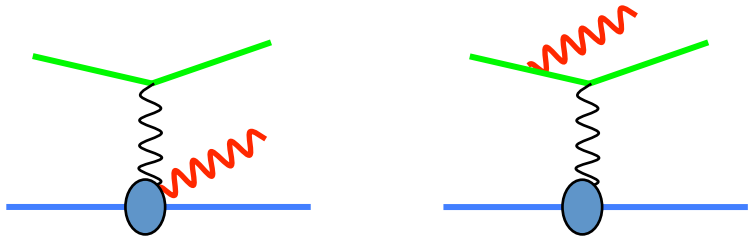
Recoil Proton Detector





Proton identification in RPD
Elastic scattering (hadron beam)

Selection of the events

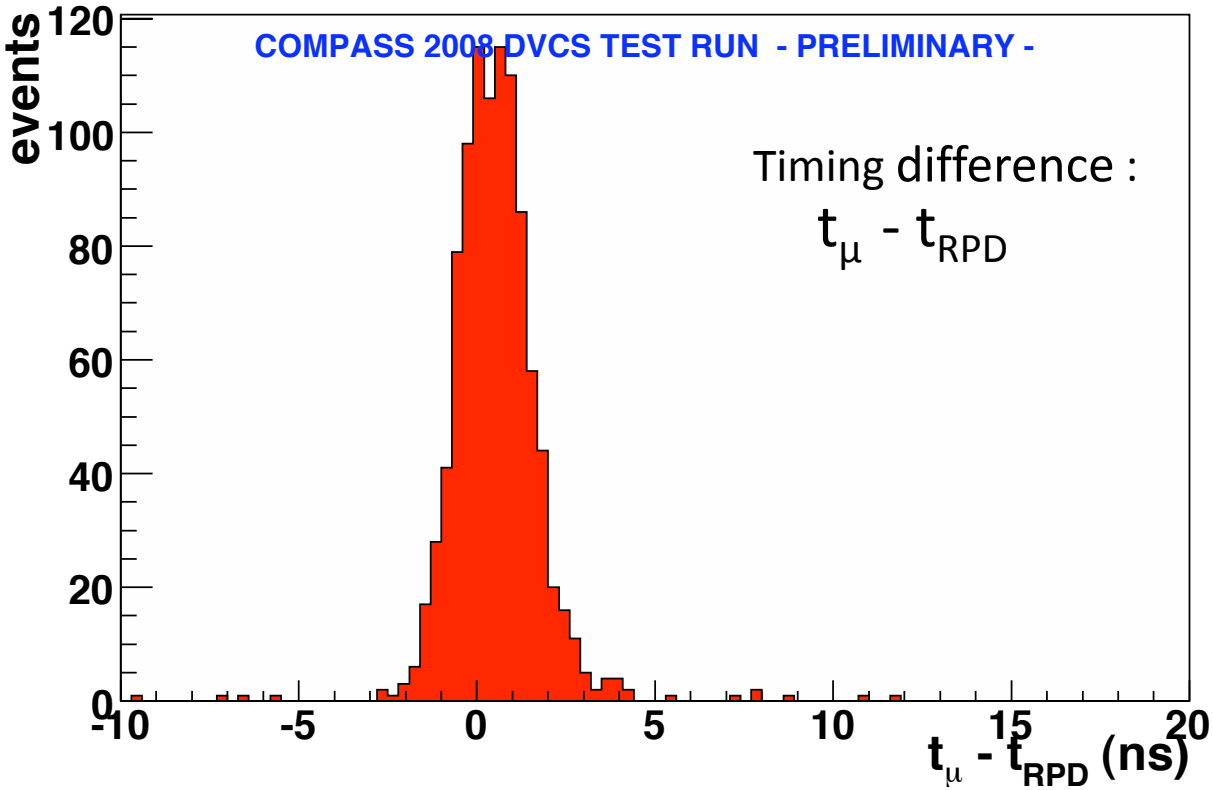


DVCS

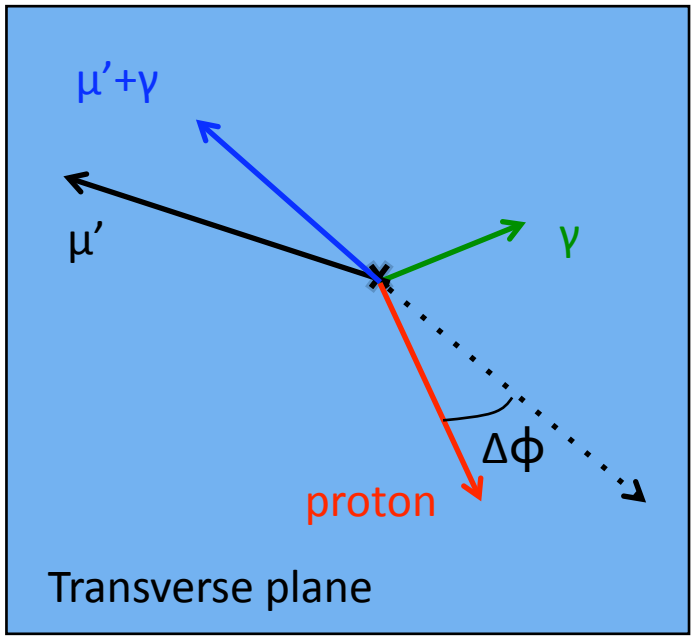
Bethe-Heitler

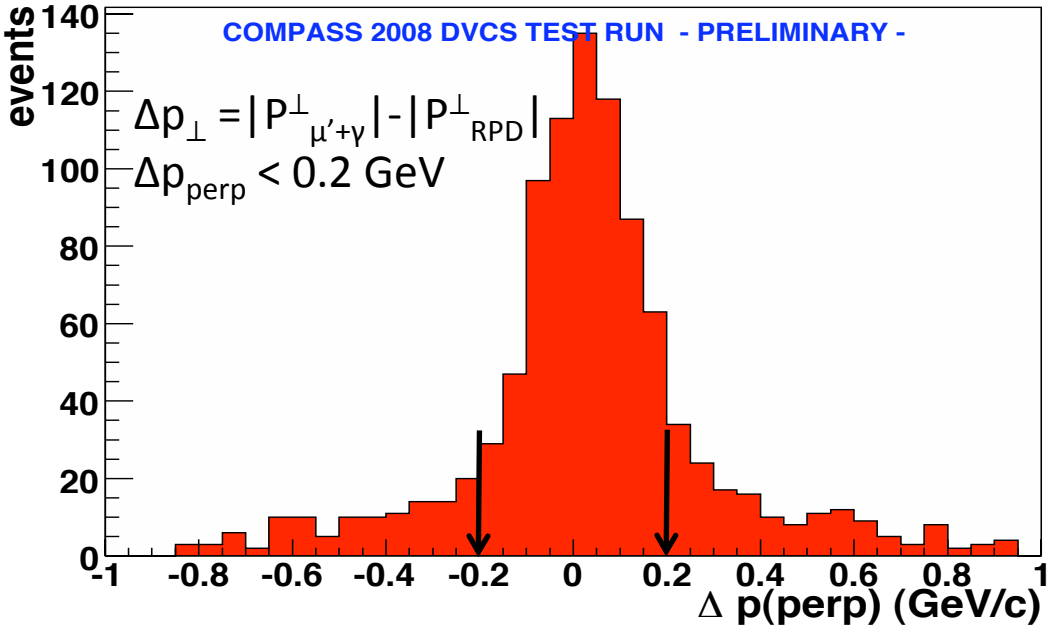
Selection of events :

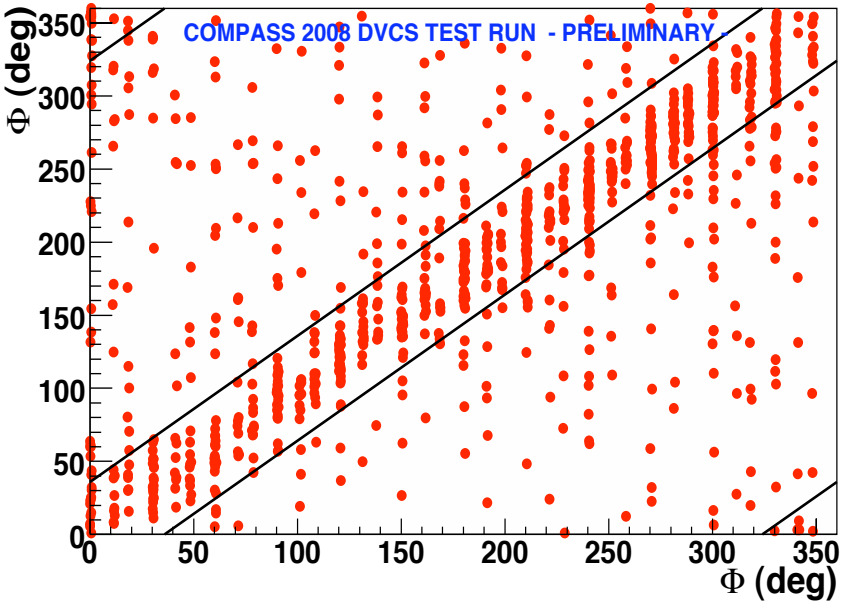
- one vertex with μ and μ'
- no other charged tracks
- only 1 high energy photon
- 1 proton in RPD with p < 1. GeV/c

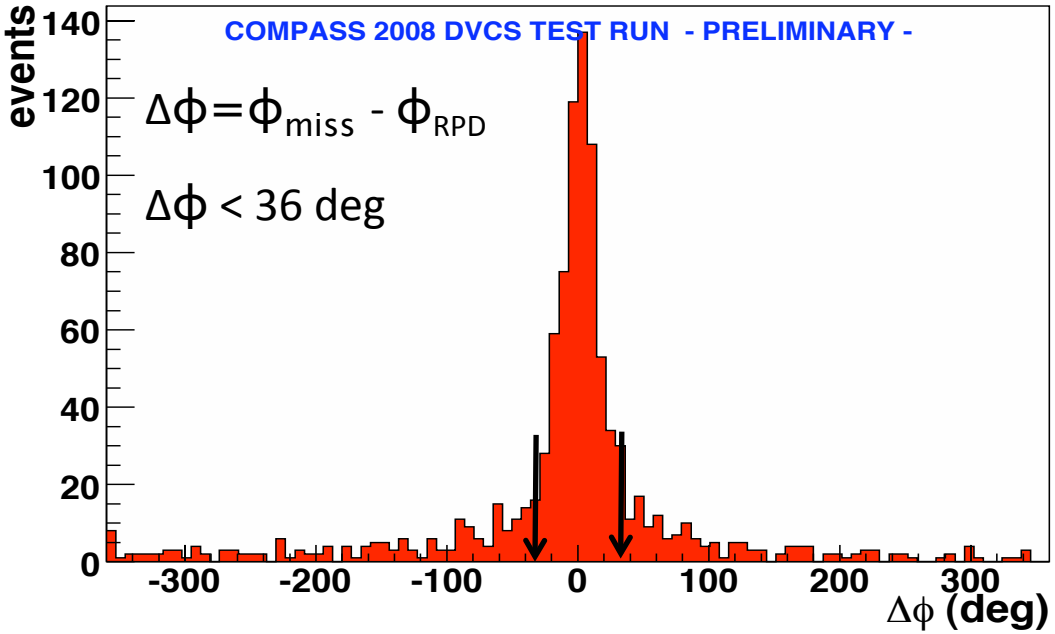


Exclusivity cuts

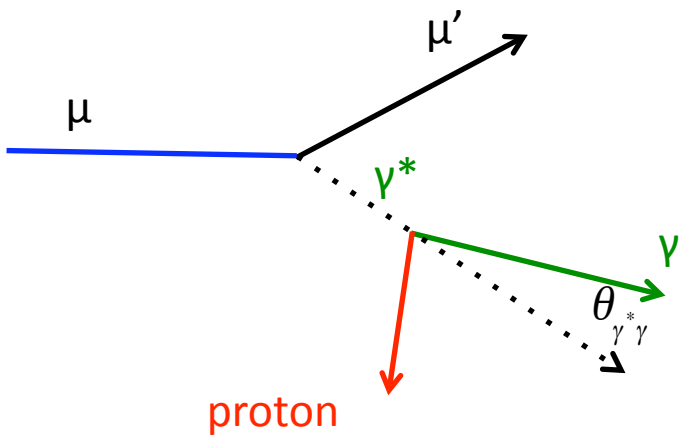








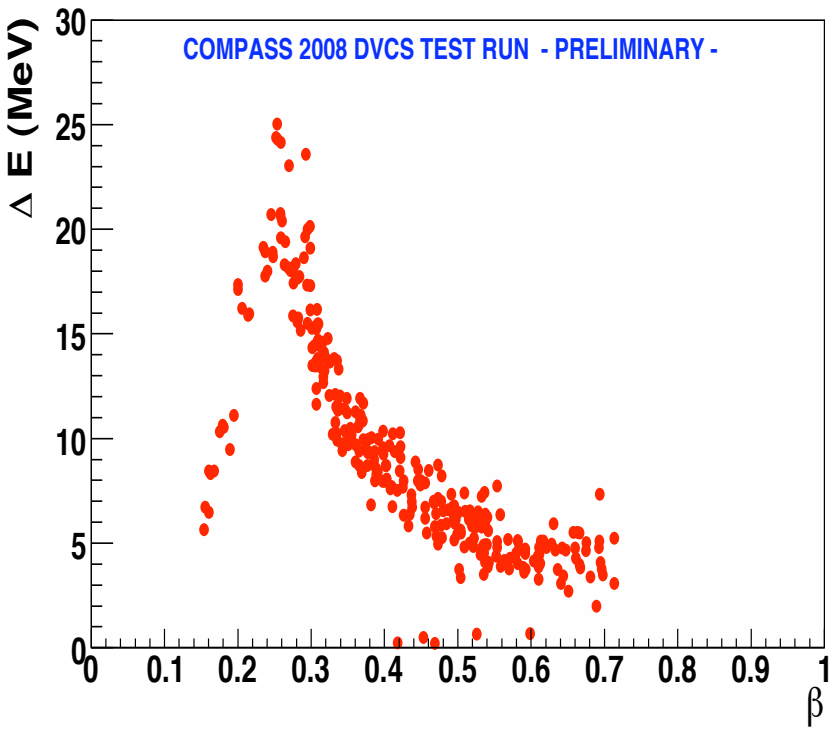
Kinematical consistency : $\vartheta_{\gamma^*\gamma}$

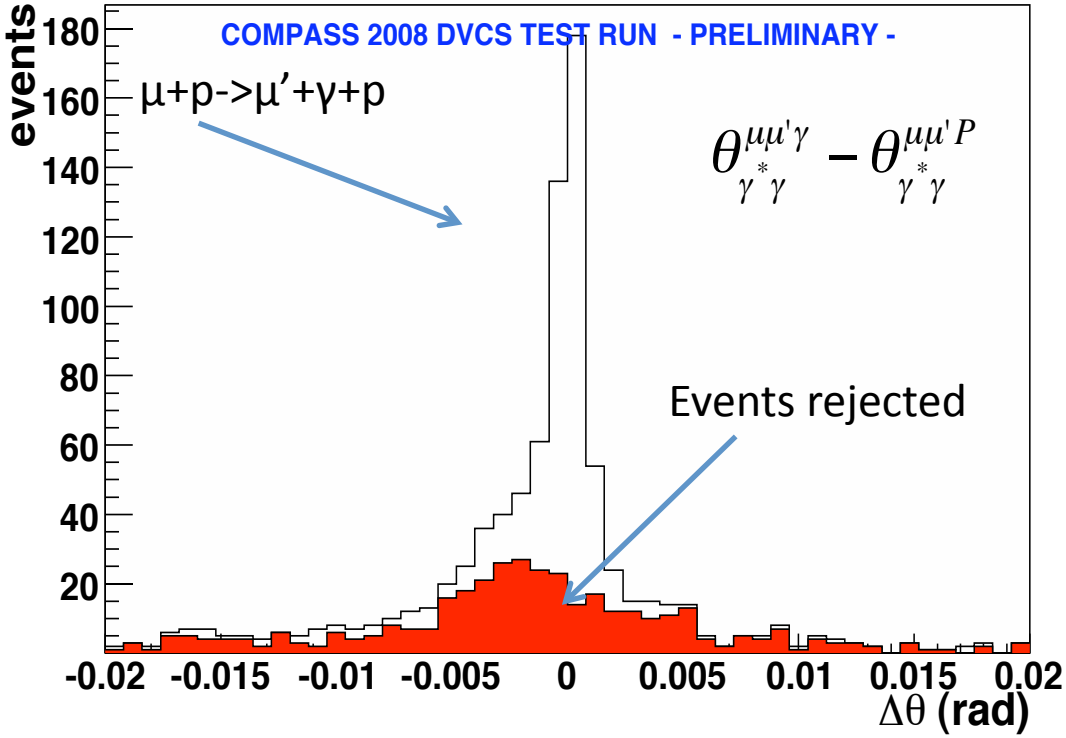


With μ, μ' and γ : $\theta^{\mu\mu'\gamma}_{\gamma^*\gamma}$

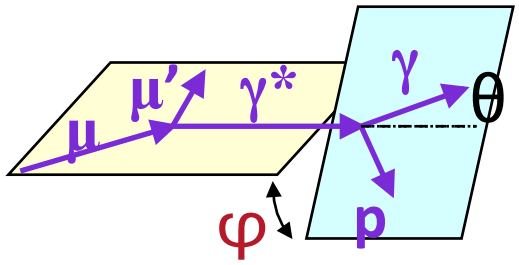
With μ, μ' and proton :

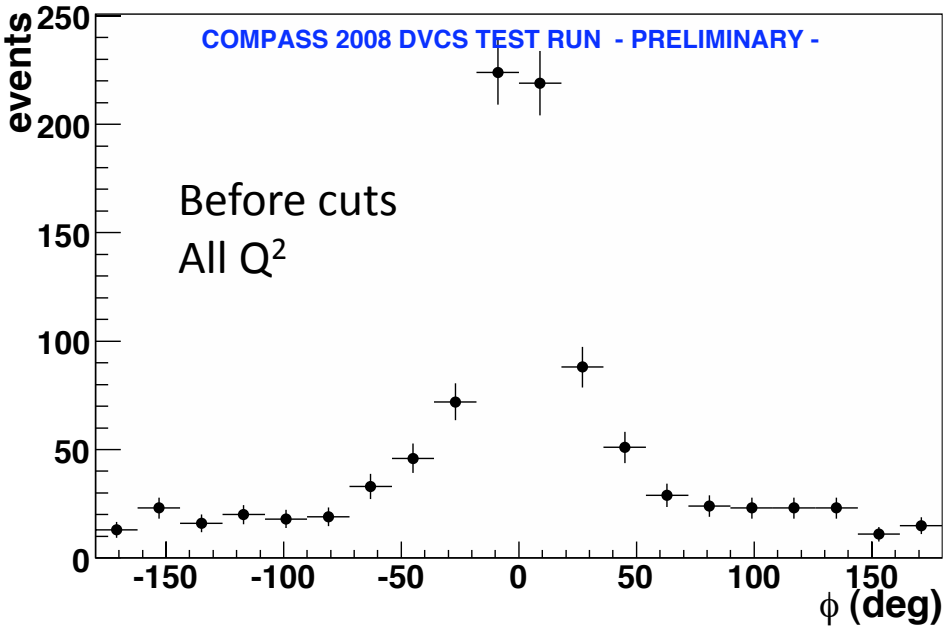
$$\cos\theta^{\mu\mu'P}_{\gamma^*\gamma} = \frac{1}{\sqrt{1+4M_P^2x^2/Q^2}}\left(1+\frac{2M_P^2x}{Q^2}\frac{t+Q^2}{t+Q^2/x}\right)$$

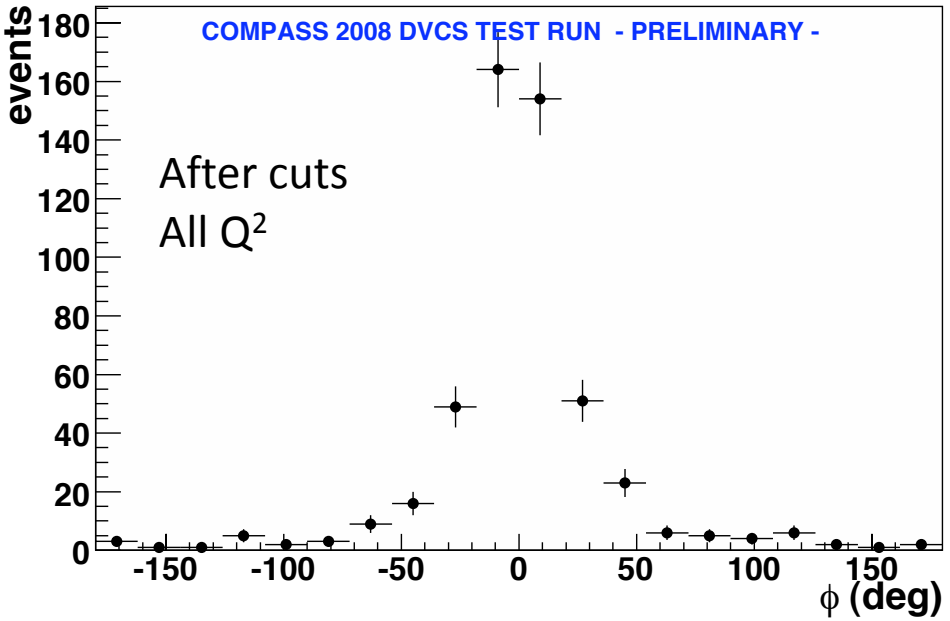




Exclusive photon production signal

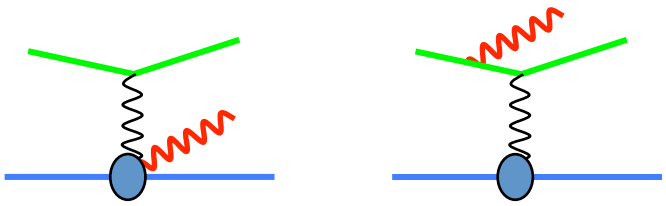






A flat background contribution in ϕ is suppressed
The peak at ϕ=0 remains => identified as BH

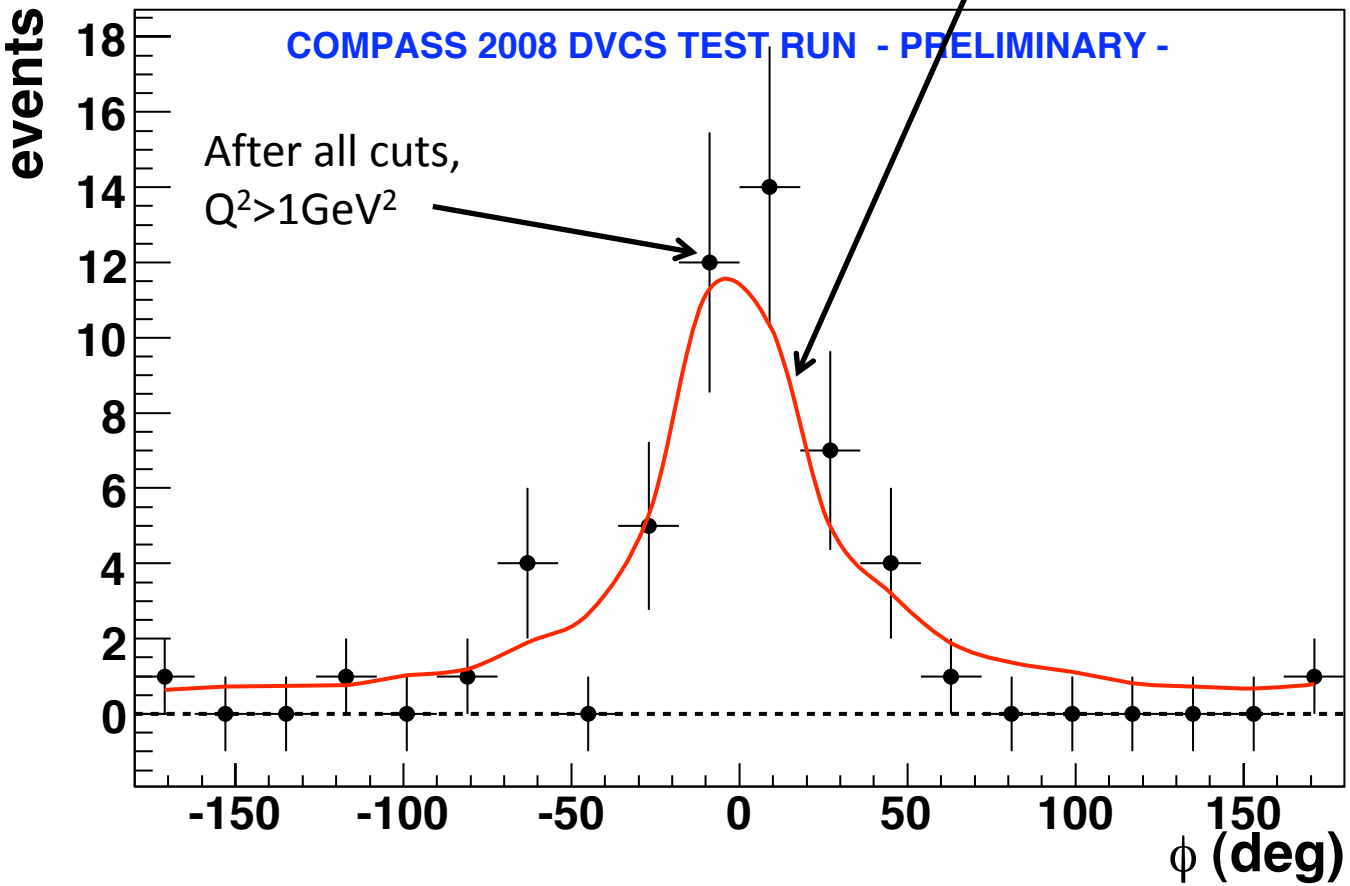
Bethe-Heitler signal



Deep VCS

Bethe-Heitler

Monte-Carlo simulation
of BH (dominant) and DVCS



Conclusions & perspectives

COMPASS has a great potential in GPDs physics – Proposal in preparation

- Phase 1 2011/12 : study of the GPD H with a LH2 target
  measurement ot t-slopes – transverse size of the nucleon
  measurement of Beam Charge and Spin differences & asymmetries
- Phase 2 2013/14 : study of the GPD E with a transv. polarized target
  measurement of Beam Charge and Spin differences & asymmetries
- Equipements needed :
  4m long RPD, 2.5m LH2 target, Extended & improved calorimetry,
  RPD with polarized Target

2008 DVCS test Run preliminary analysis

Observation of Exclusive Photon Production

In agreement with Bethe-Heitler contribution

2009 : 2 weeks of DVCS tests approved by SPSC

Goals : Observe DVCS and measure BH precisely
Evaluate background level