high-energy muon beams
polarised positive $\mu^{+}\downarrow$ and negative $\mu^{-}\uparrow$

COMPASS

@

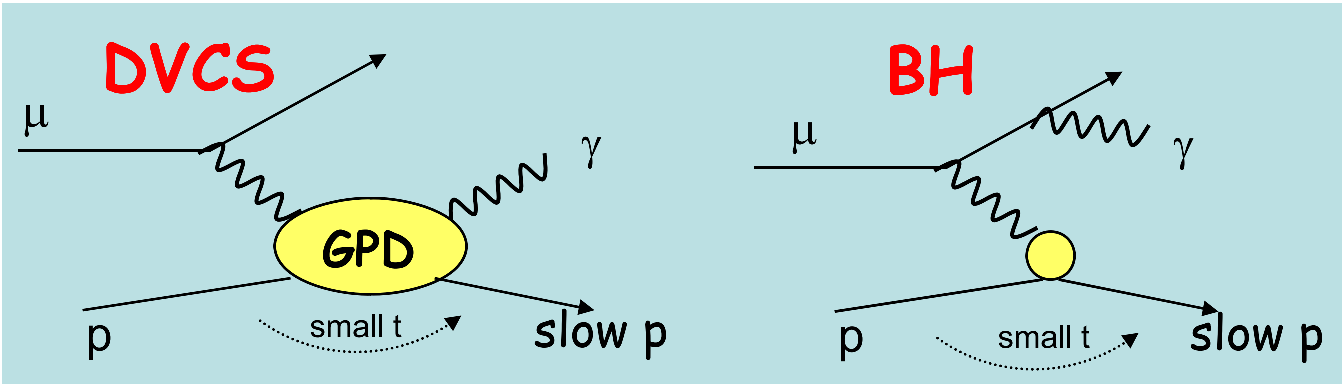
to perform DVCS measurements
for GPD study

International workshop
On Hadron Strcuture
and Spectroscopy
Mainz, 30 March 2009

Nicole d'Hose, CEA-Saclay

exclusive single-photon production

$\mu\ p \rightarrow \mu\ \gamma\ p$

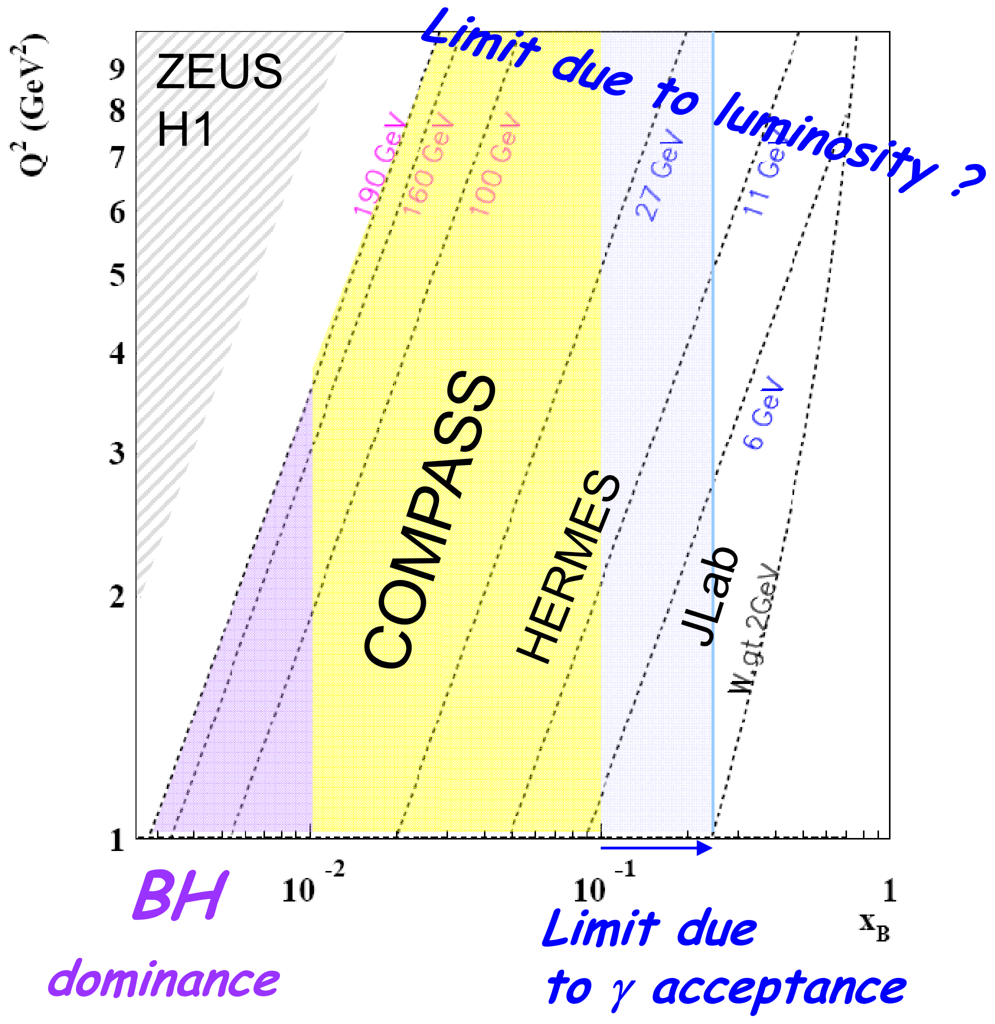


$d\sigma \propto |T_{DVCS}|^2 + |T_{BH}|^2 + \text{Interference Term}$

at COMPASS we can deal with

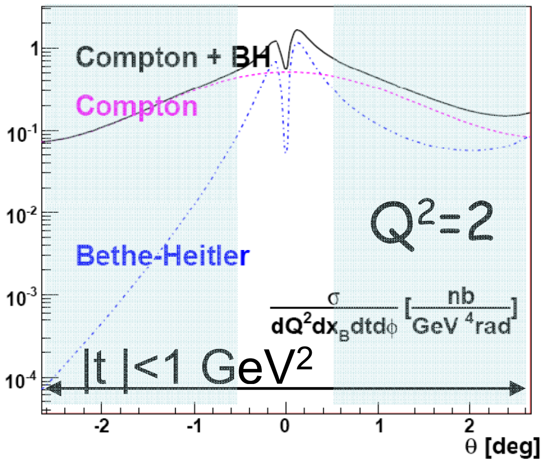
- ✓ either BH → control of the experiment
- ✓ either DVCS → $d\sigma^{DVCS}/dt$ and direct determination of α'
- ✓ or the interference → Re T^{DVCS} or Im T^{DVCS}

COMPASS : domain $10^{-2} < x < 10^{-1}$



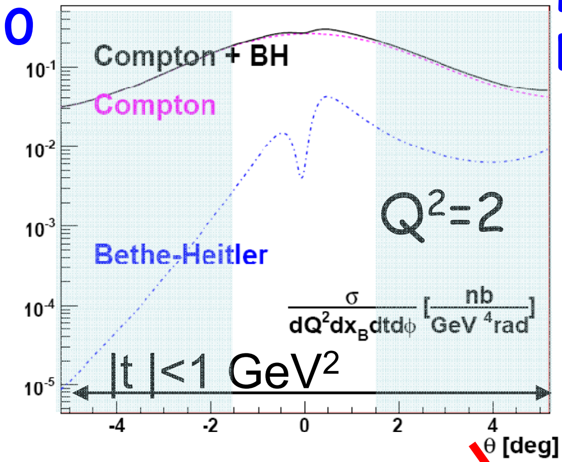
Comparison BH and DVCS at 160 GeV

x_B=0.05



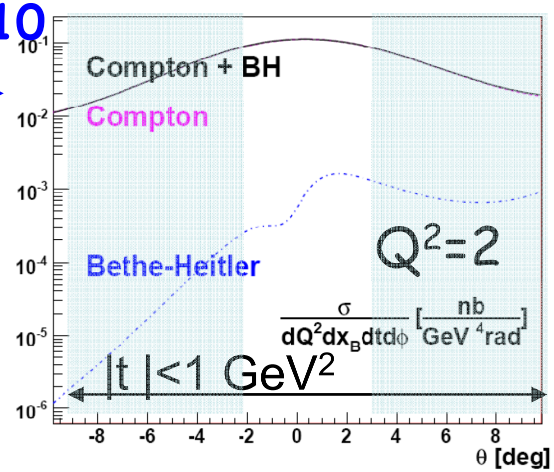
DVCS /2
BH/10

x_B=0.1

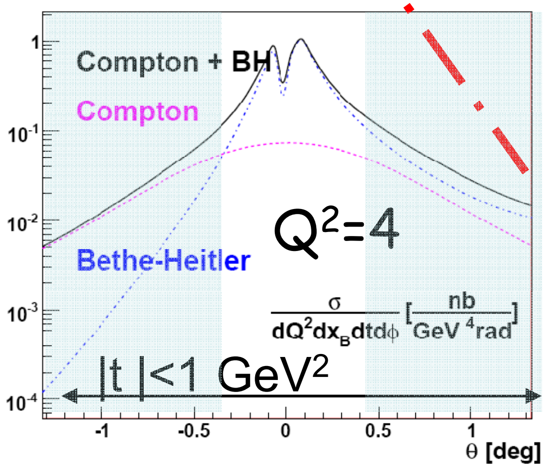


DVCS /2
BH/10

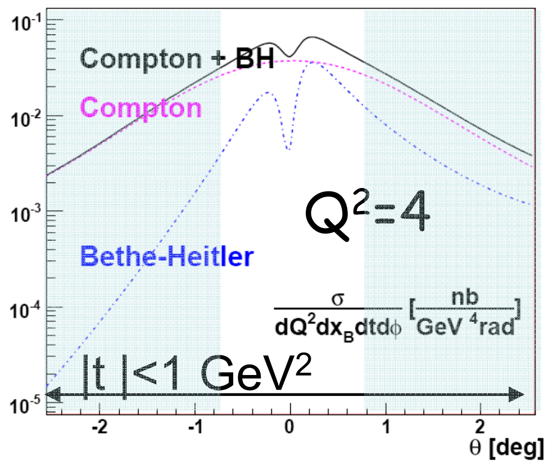
x_B=0.2



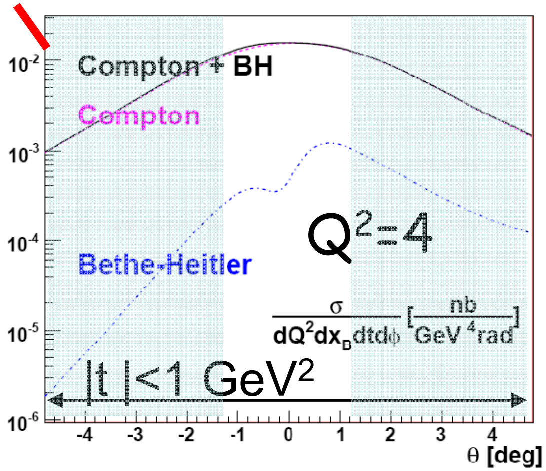
BH important



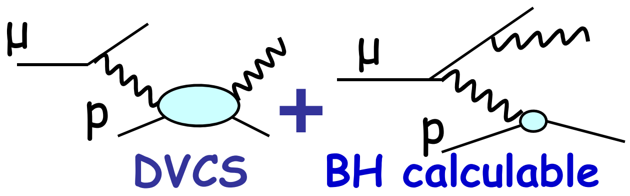
BH < 10 × DVCS

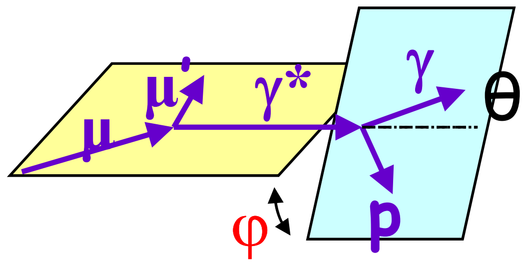


DVCS dominates



DVCS + BH with $\mu+\downarrow$ and $\mu-\uparrow$ beam and unpolarized target





$$d\sigma_{(\mu p\to\mu p\gamma)} = d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + P_\mu\, d\sigma^{DVCS}_{pol}$$

$$+\, e_\mu\, a^{BH}\, \mathcal{Re}\, T^{DVCS} + e_\mu\, P_\mu\, a^{BH}\, \mathcal{Im}\, T^{DVCS}$$

Beam Charge & spin difference

$$\mathcal{D}_{U,CS} \equiv d^4\sigma^{\uparrow +} - d^4\sigma^{\downarrow -} = 2[P_\ell d\sigma^{DVCS}_{pol} + e_\ell \mathrm{Re}\, I]$$

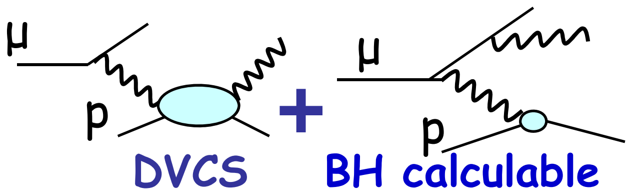
$$= 2P_\mu \times \frac{e^6}{y^2Q^2}\left(s_1^{DVCS}\sin\varphi\right)$$

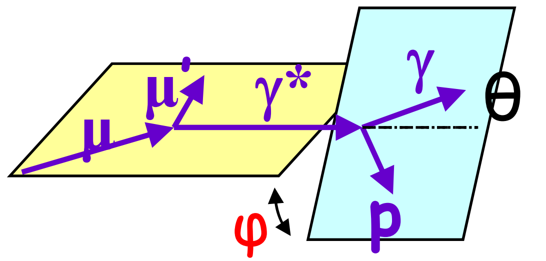
$$+\, 2e_\mu \times \frac{e^6}{xy^3tP_1(\varphi)P_2(\varphi)}\left(c_0^{Int} + c_1^{Int}\cos\varphi + c_2^{Int}\cos 2\varphi + c_3^{Int}\cos 3\varphi\right)$$

This is the good way to get rid of the large BH contribution
if we are able to control the $\mu+\downarrow$ and $\mu-\uparrow$ fluxes and efficiencies

→ *we can get Re T^{DVCS} and c_0^{Int} and c_1^{Int}*

DVCS + BH with $\mu+\downarrow$ and $\mu-\uparrow$ beam and unpolarized target





$$d\sigma_{(\mu p\to\mu p\gamma)} = d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + P_\mu\, d\sigma^{DVCS}_{pol}$$

$$+\, e_\mu\, a^{BH}\, \mathcal{R}e\, T^{DVCS} + e_\mu\, P_\mu\, a^{BH}\, \mathcal{I}m\, T^{DVCS}$$

$$S_{U,CS} \equiv d^4\sigma^{\uparrow +} + d^4\sigma^{\downarrow -} = 2[d\sigma^{BH} + d\sigma^{DVCS}_{unpol} - e_\ell P_\ell \mathrm{Im}\, I]$$

Beam Charge & spin sum

$$= 2 \frac{\Gamma(x_B, Q^2, t)}{P_1(\varphi)P_2(\varphi)} (c_0^{BH} + c_1^{BH} \cos\varphi + c_2^{BH} \cos 2\varphi)$$

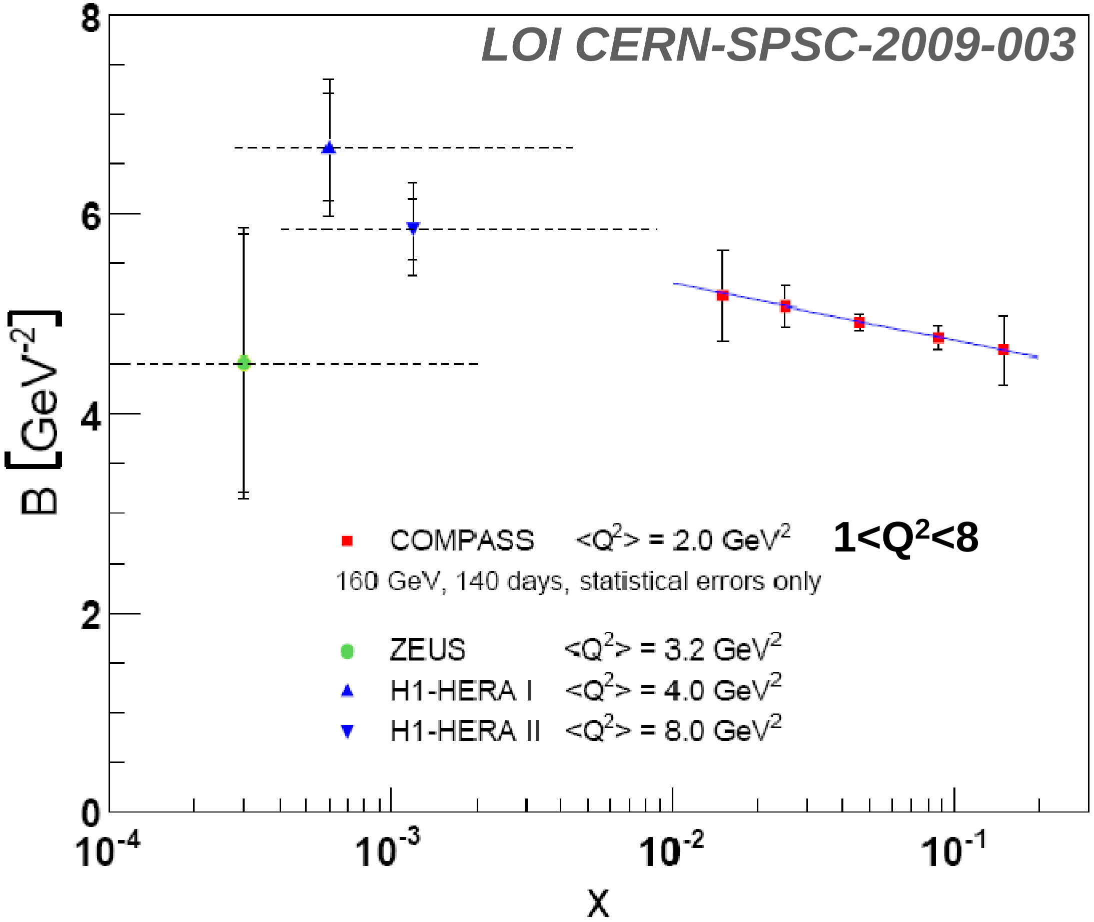
$$+ 2 \frac{e^6}{y^2 Q^2} (c_0^{DVCS} + c_1^{DVCS} \cos\varphi + c_2^{DVCS} \cos 2\varphi)$$

$$+ 2\, e_\mu\, P_\mu \times \frac{e^6}{x y^3 t P_1(\varphi) P_2(\varphi)} (s_1^{Int} \sin\varphi + s_2^{Int} \sin 2\varphi)$$

After subtraction of BH and integration over φ in all the acceptance
→ *we can get DVCS contribution , i.e.* C_0^{DVCS}

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

Projections for the t-slope measurement at COMPASS



FFS model

Adapted by Sandacz

$$\boxed{B(x) = b_0 + 2\,\alpha' \ln(x_0/x)}$$

$\alpha' = 0.125\ GeV^{-2}$

$b_0 = 5.83 \pm 0.5\ GeV^{-2}$

$x_0 = 0.0012$ ($Q^2=8, W=82$)

for valence quark $\alpha' \sim 1\ GeV^{-2}$ to reproduce FF $\cong$ meson Regge traj.

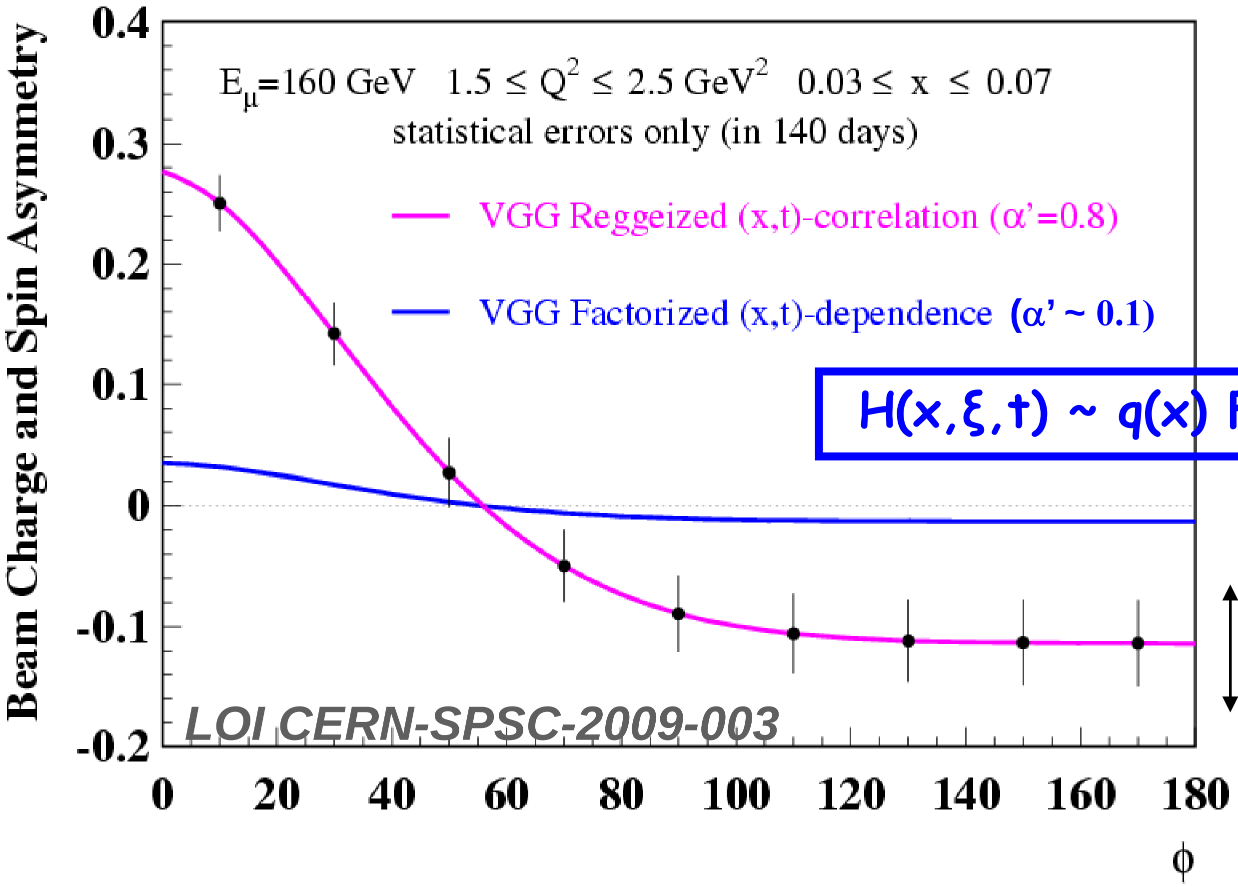
for gluon $\alpha' \sim 0.164\ GeV^{-2}$ (J/Ψ at $Q^2=0$)

$\alpha' \sim 0.02\ GeV^{-2}$ (J/Ψ at $Q^2=2\text{-}80\ GeV^2$)

$\ll$ $\alpha' \sim 0.25\ GeV^{-2}$ for soft Pomeron

Using $\mathcal{D}_{U,CS} / \mathcal{S}_{U,CS}$: Beam Charge and Spin Asymmetry

Comparison to different models from VGG



$H(x,\xi,t) \sim q(x)\, F(t)$

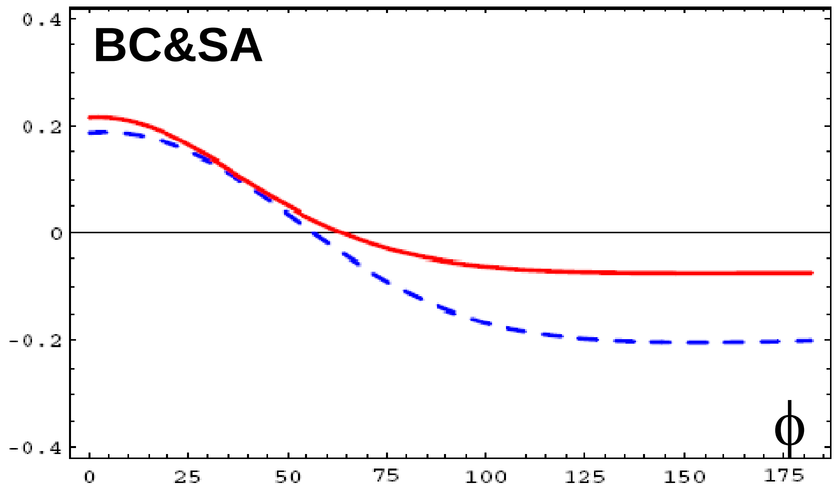
$\langle b^2_\perp \rangle \sim \alpha' \ln 1/x$

$H(x,0,t) = q(x)\, e^{t \langle b_\perp^2 \rangle}$

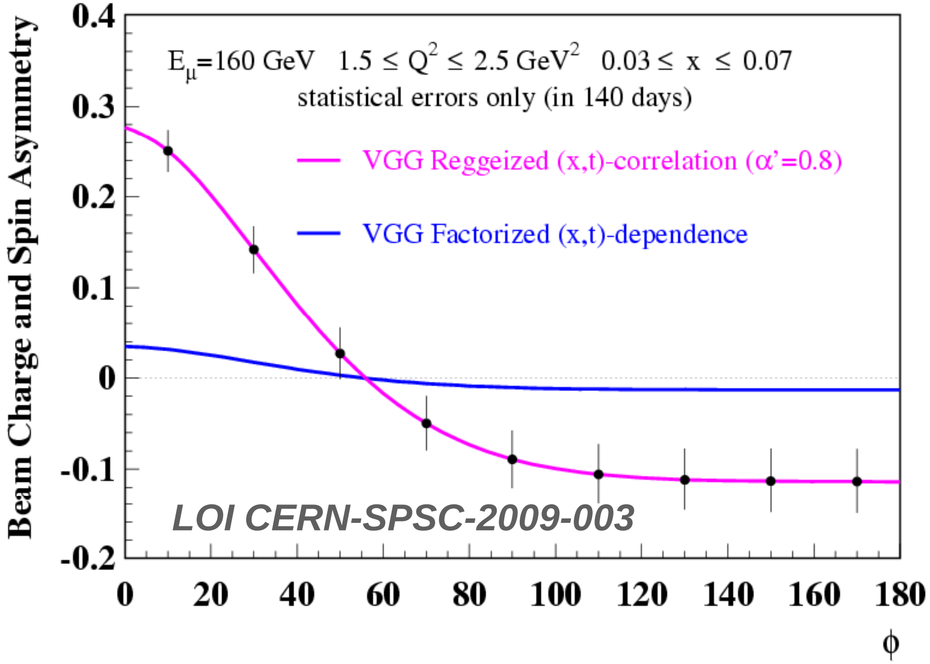
$\sim q(x) / x^{\alpha' t}$

error bars still underdebate

New predictions from Dieter Mueller



Dieter Mueller uses **a Global Fit**
on H1/ZEUS, HERMES, CLAS
and JLab Hall A
and no JLab Hall A



several questions

- ✓ on FoM
- ✓ on systematic effects

while the complete proposal is underpreparation

DVCS tests are made in parallel (in 2008-9)

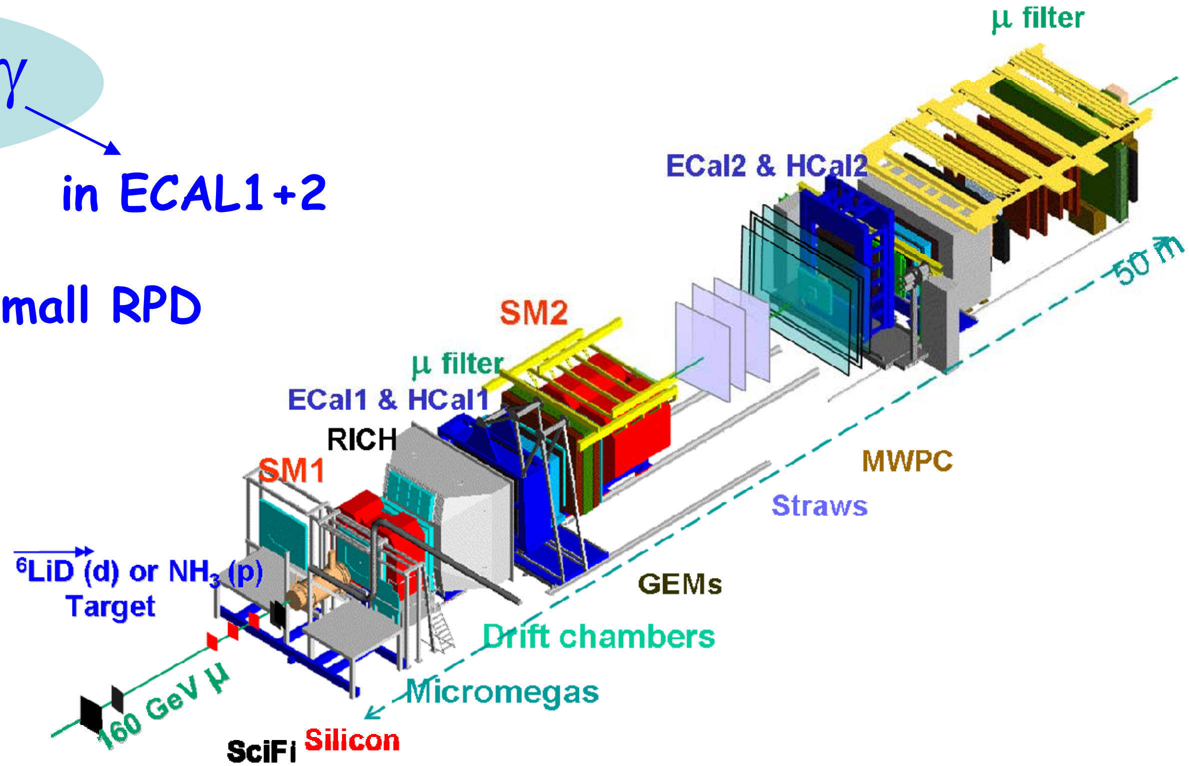
in 2008

$\mu\ p \rightarrow \mu\ p\ \gamma$

LH2
40cm

in the small RPD

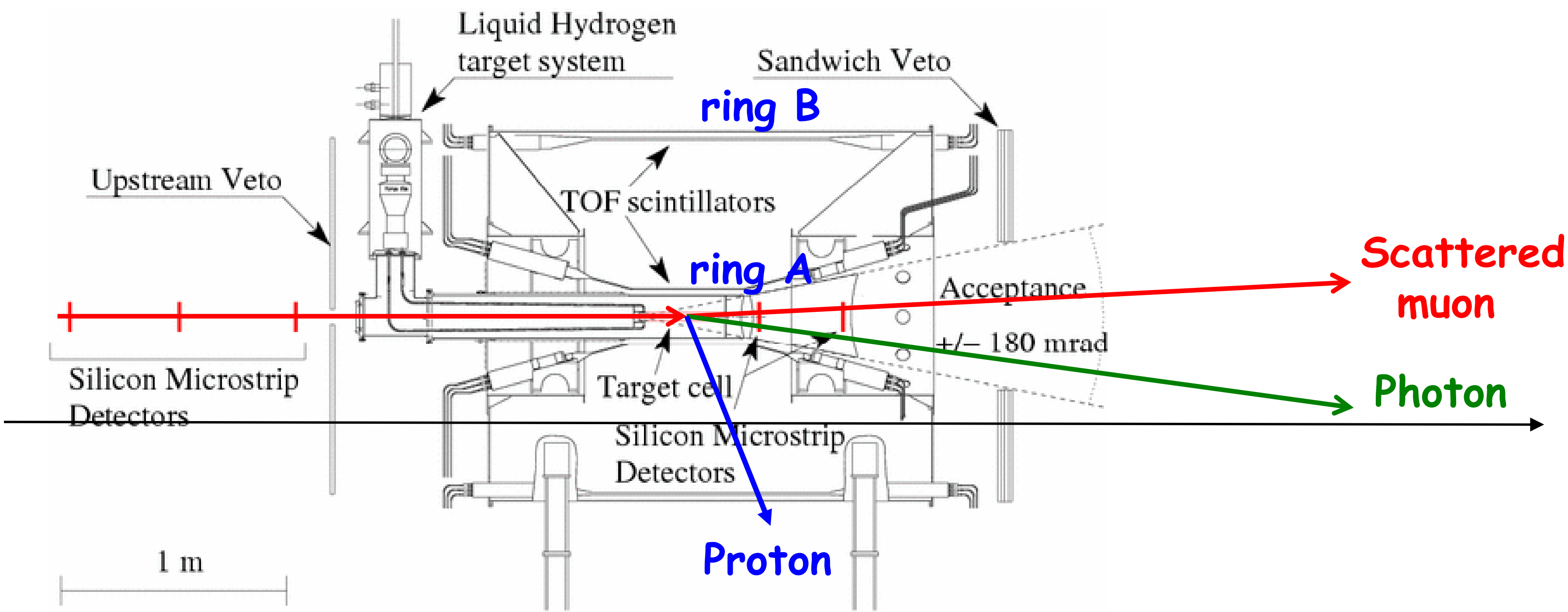
in ECAL1+2



1.5 days of beam of low intensity
done in a rush before the shut down
(LHC incident)

Selection of single photon production

$$\mu\ p \rightarrow \mu\ p\ \gamma$$

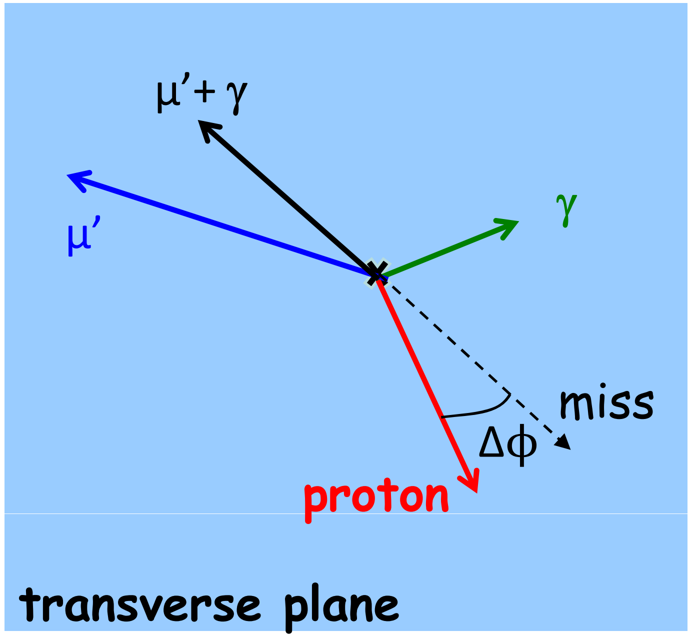


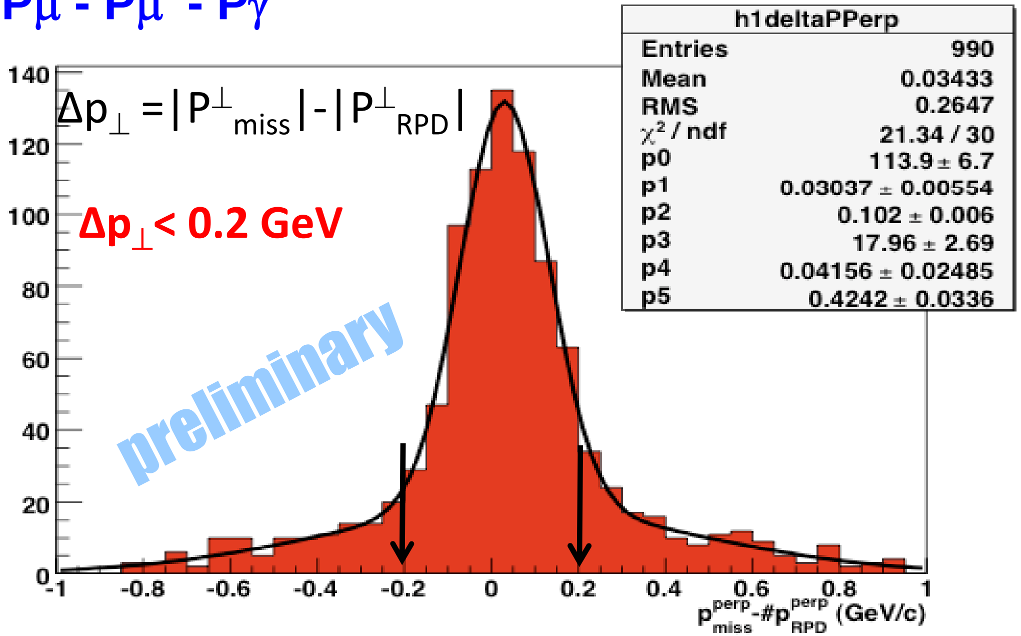
See more detail:

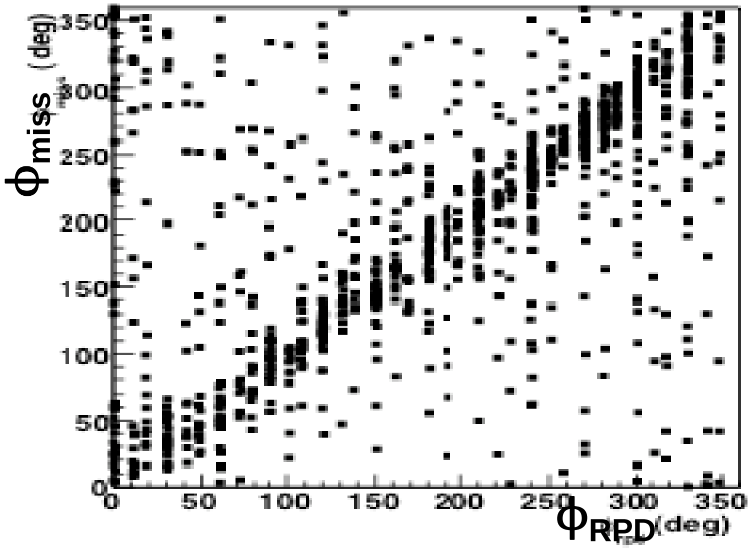
- ✓ *Oleg Kouznetsov's presentation on Thursday*
- ✓ *COMPASS-note 2009-xxx*

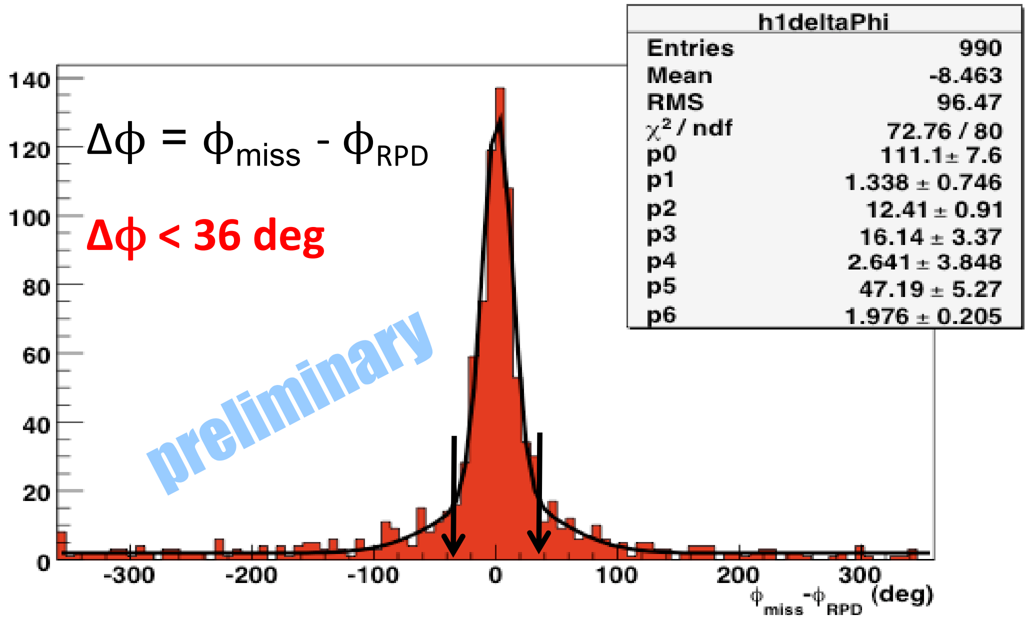
Kinematic constraints in the transverse plane

$$\vec{P}miss = \vec{P}\mu - \vec{P}\mu' - \vec{P}\gamma$$

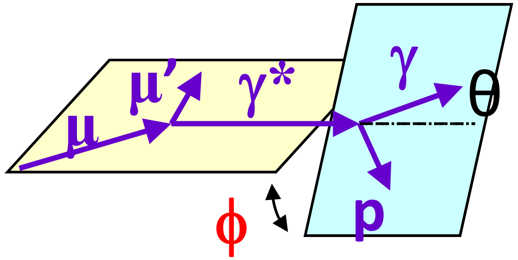


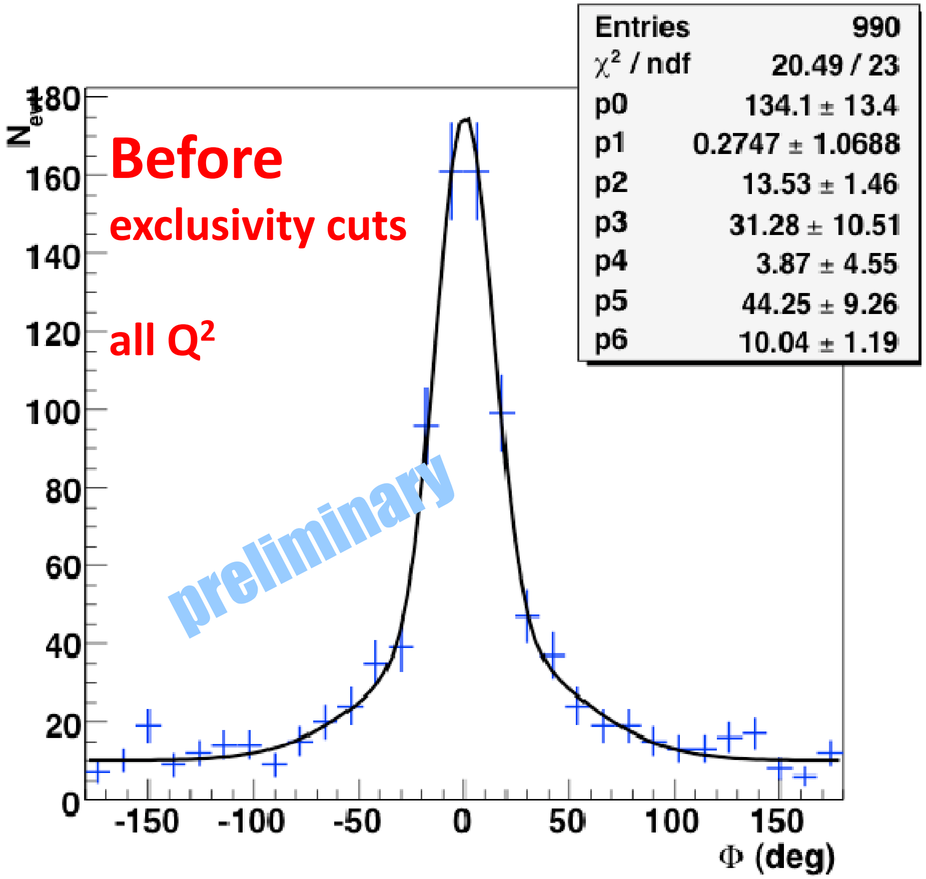


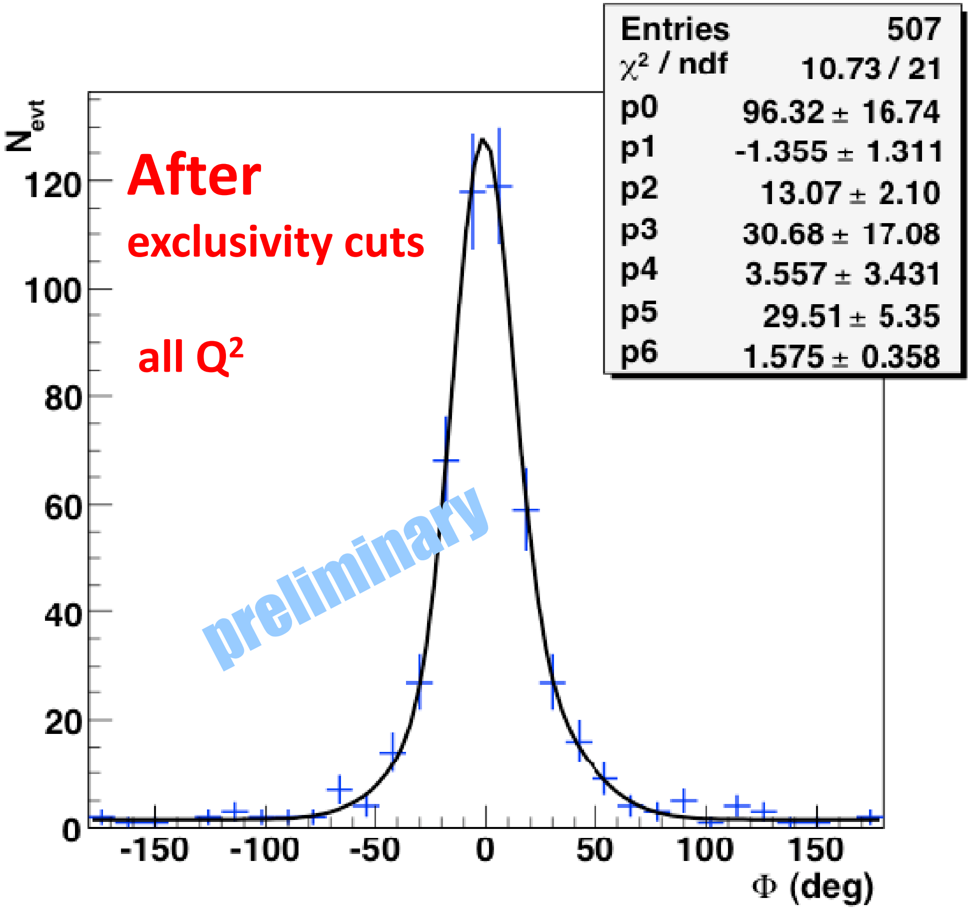




angular distribution for ϕ







clear signature of BH events

DVCS events are expected with a flat distribution

Conclusion from 2008 – Goal for 2009

At $Q^2 > 1$ GeV^2 ~100 Exclusive single photon production observed in 2008

identified to BH due to their distribution in ϕ

provide a realistic estimate of the FoM

More data are needed to measure DVCS events
and to disentangle it from background

→ this is the essential goal of 2009 tests

roadmap

- "Letter of Intent" CERN-SPSC-2009-003 submitted in Jan 2009
- demonstration of the feasibility of such an experiment 2008-9
- in parallel preparation of the complete proposal for June 2009
  - ✓ phase 1 in ~2011/12
    DVCS with unpolarised proton target
  - ✓ phase 2 in ~2013/14
    DVCS with polarised proton target

→ new equipments needed

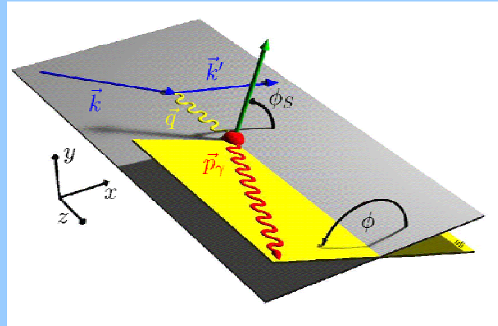
Proposal to study "GPDs @ COMPASS" in 2 phases

Phase 1: DVCS experiment in ~2011/12 to constrain GPD H

with $\mu^{+\downarrow}$, $\mu^{-\uparrow}$ beam + unpolarized long LH2 (proton) target
+ recoil detector + ECAL1,2 (possibly 0) + all COMPASS equipment

$d\sigma/dt$ → *impact parameter b*

$$d\sigma(\mu^{+\downarrow},\phi) + d\sigma(\mu^{-\uparrow},\phi) \propto \mathrm{Im}(F_1\mathcal{H})\sin\phi$$
$$d\sigma(\mu^{+\downarrow},\phi) - d\sigma(\mu^{-\uparrow},\phi) \propto \mathrm{Re}(F_1\mathcal{H})\cos\phi$$



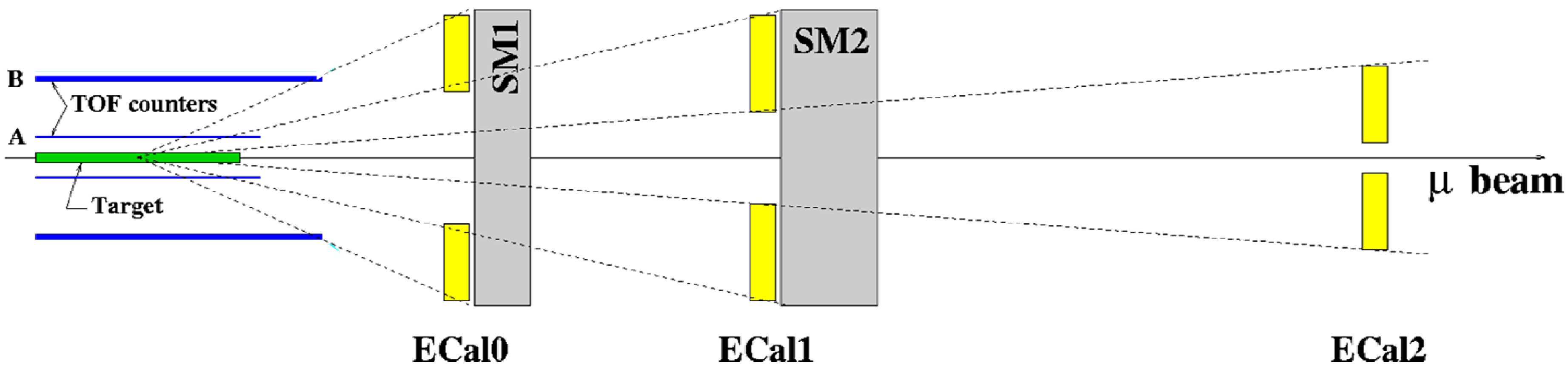
Phase 2: DVCS experiment in ~2013/14 to constrain GPD E

with μ^{+} and transversely polarized NH3 (proton) target
+ recoil detector + ECAL1,2 (possibly 0) + all COMPASS equipment

$$d\sigma(\phi,\phi_S) - d\sigma(\phi,\phi_S+\pi) \propto \mathrm{Im}(F_2\mathcal{H} - F_1\mathcal{E})\sin(\phi-\phi_S)\cos\phi$$

Detectors to be built

- ✓ Recoil detector and a long LH2 target (phase 1)
  specific read out electronics with 1 GHZ sampling
- ✓ Recoil detector with a transversely polarised target (phase 2)
- ✓ Trigger adapted to $Q^2 > 1 GeV^2$
- ✓ Monitoring of muon flux
- ✓ ECAL1+2 to be supplemented
- ✓ ECAL0 to be designed and built to increase the range of xBj



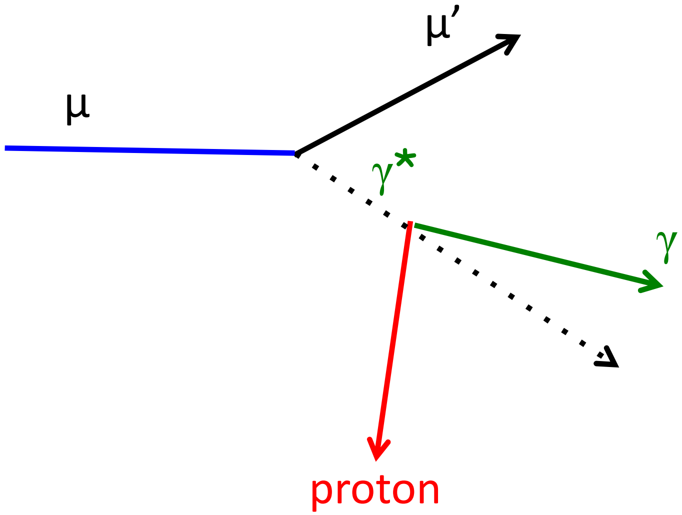
Conclusion

the high energy polarised $\mu+\downarrow$ and $\mu-\uparrow$ beams
are the determining assets for the COMPASS experiment

- unique and large domain $10^{-2} < x < 10^{-1}$
- BH, DVCS and Re T^{DVCS} or Im T^{DVCS}

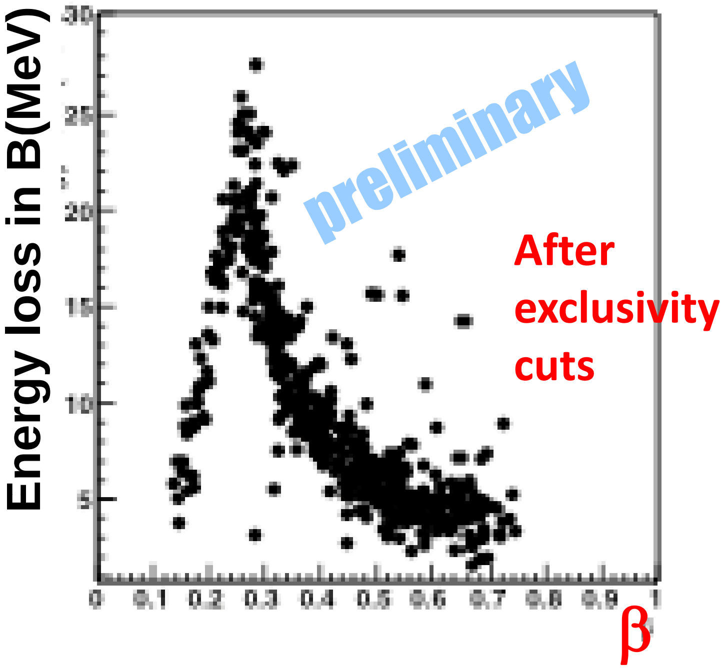
could be nicely completed by a substantial increase of luminosity to get a comfortable domain up to $Q^2 > 10$ GeV^2 (upgrade SPS and muon beam line ?)

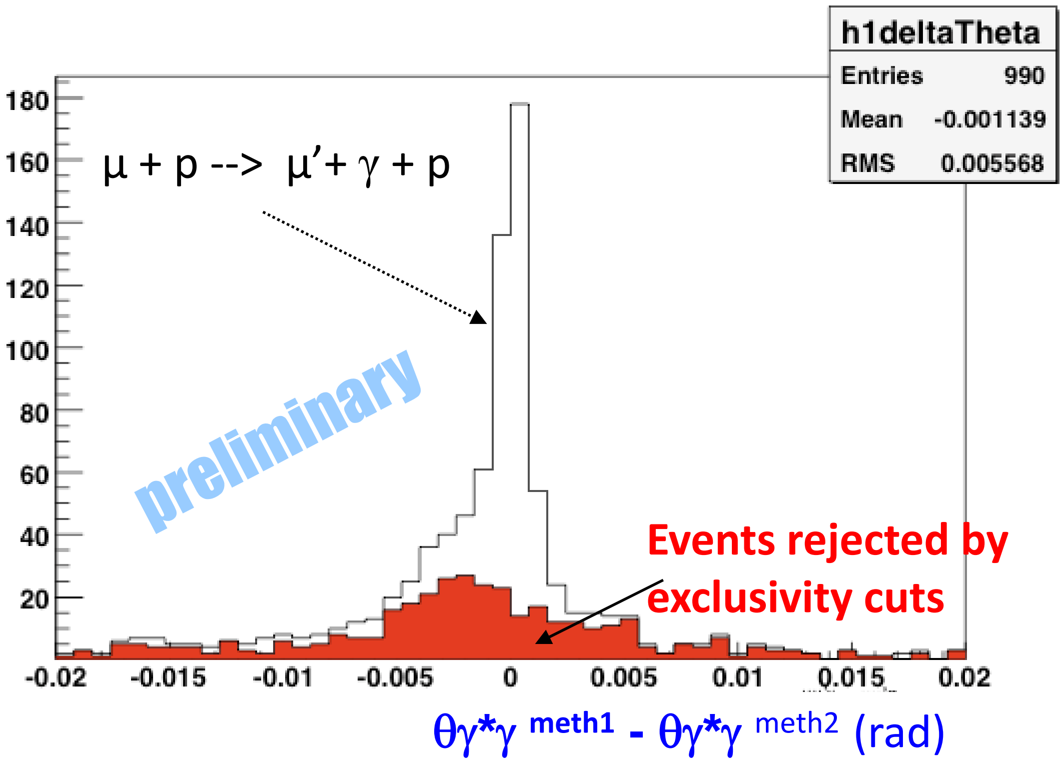
kinematic consistency



meth1: cos $\theta_{\gamma^*\gamma}$ from $(\vec{P}_\mu - \vec{P}_{\mu'}) \cdot \vec{P}_\gamma$

meth2: cos $\theta_{\gamma^*\gamma}$ from (Q^2, E_γ, E_p) using the proton information





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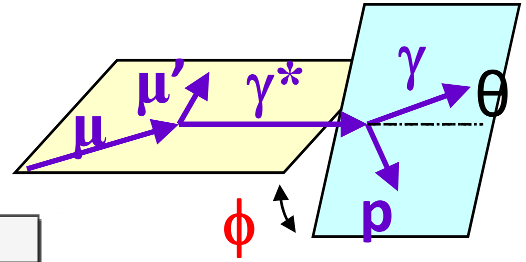

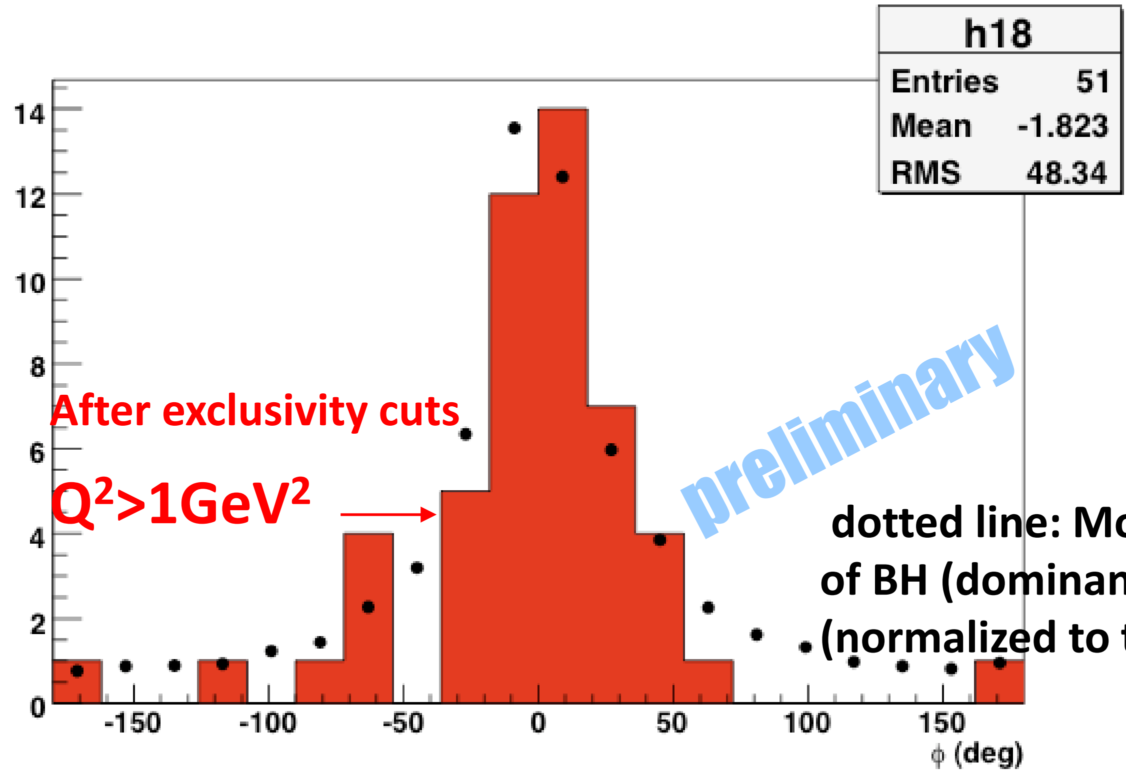

dotted line: Monte-Carlo simulation of BH (dominant) and DVCS. (normalized to the central peak)

clear signature of BH events

DVCS events are expected with a flat distribution

Rough estimate of the FoM

Nb of events corrected for prescaling $\sim$ 131+/-25 for $3.3\ 10^{11}\ \mu$ (i.e. 0.4 day at $4.6\ 10^{8} \mu$/sp) (and 40cm LH2)

→ Global **FOM = 0.16 $\pm$ 0.06** in the LOI : **FOM=0.1**