Prospects for DVCS measurements using the COMPASS spectrometer at CERN

O.Kouznetsov CEA-Saclay/JINR-Dubna
on behalf of the COMPASS Collaboration

The DVCS program is a part of the COMPASS Phase II (5 years after 2012) proposal submitted to CERN SPS comittee (May 17,2010)

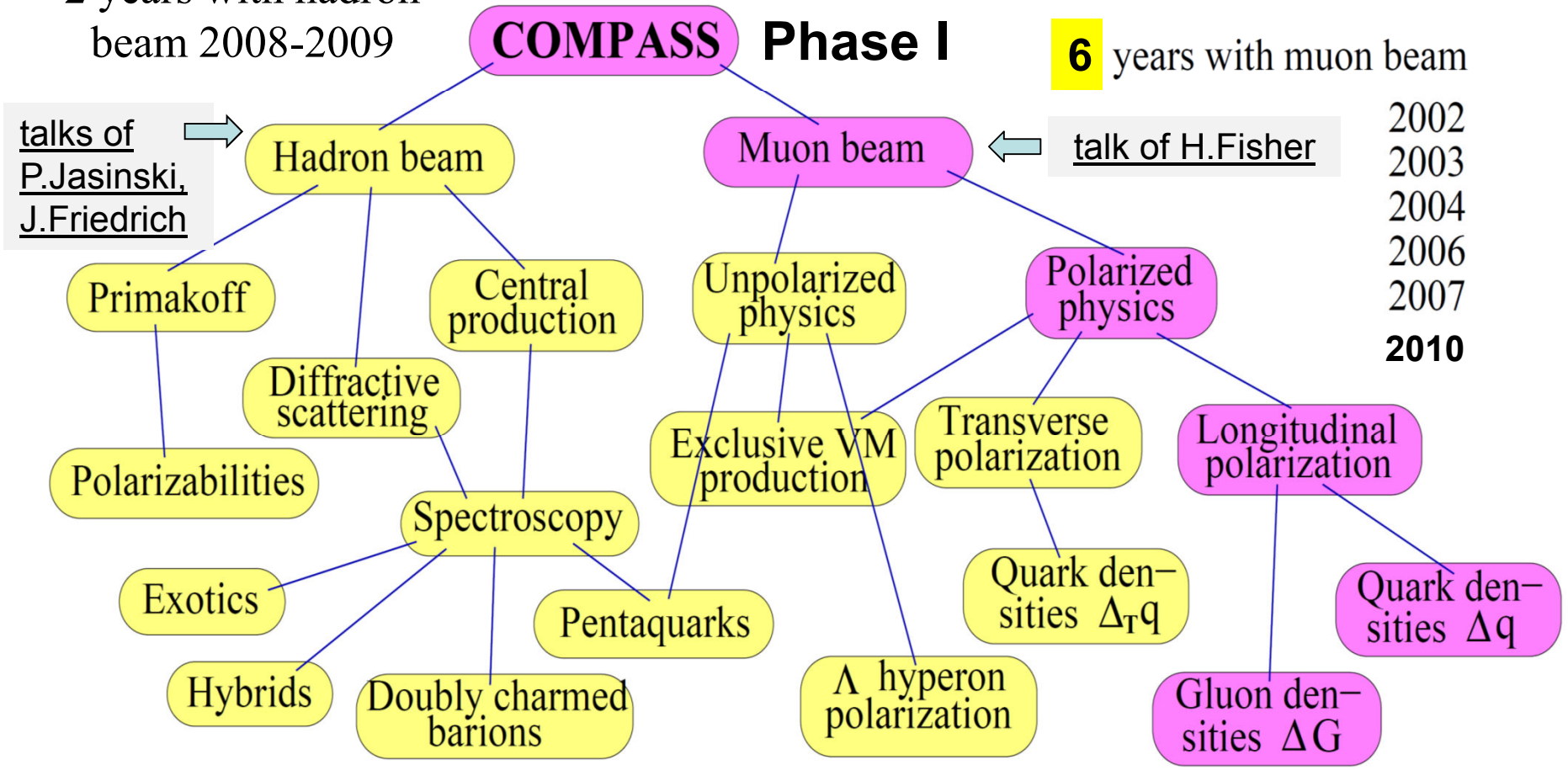
COMPASS II proposal available at : CERN-SPSC-2010-014 preprint
http://cdsweb.cern.ch/record/1265628/files/SPSC-P-340.pdf

COmmon Muon and Proton Apparatus for Structure and Spectroscopy

COMPASS in μ run
NIM A 577(2007) 455

More than 230 physicists from 20 institutes

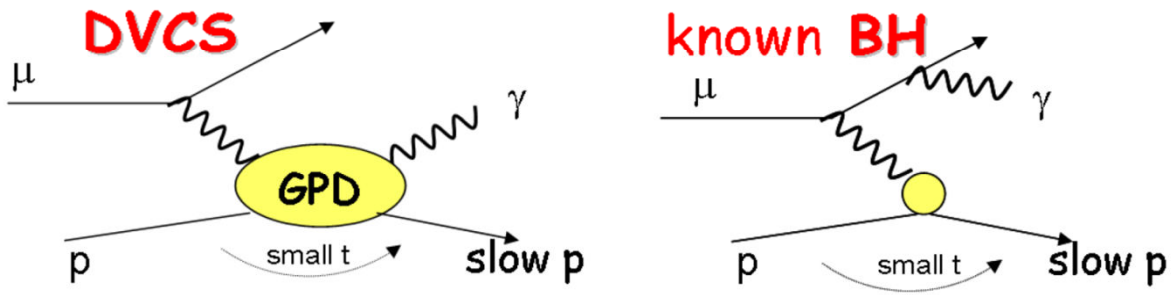
2 years with hadron beam 2008-2009



Exclusive single-photon production

Deeply Virtual Compton Scattering (DVCS) & Bethe-Heitler (BH)

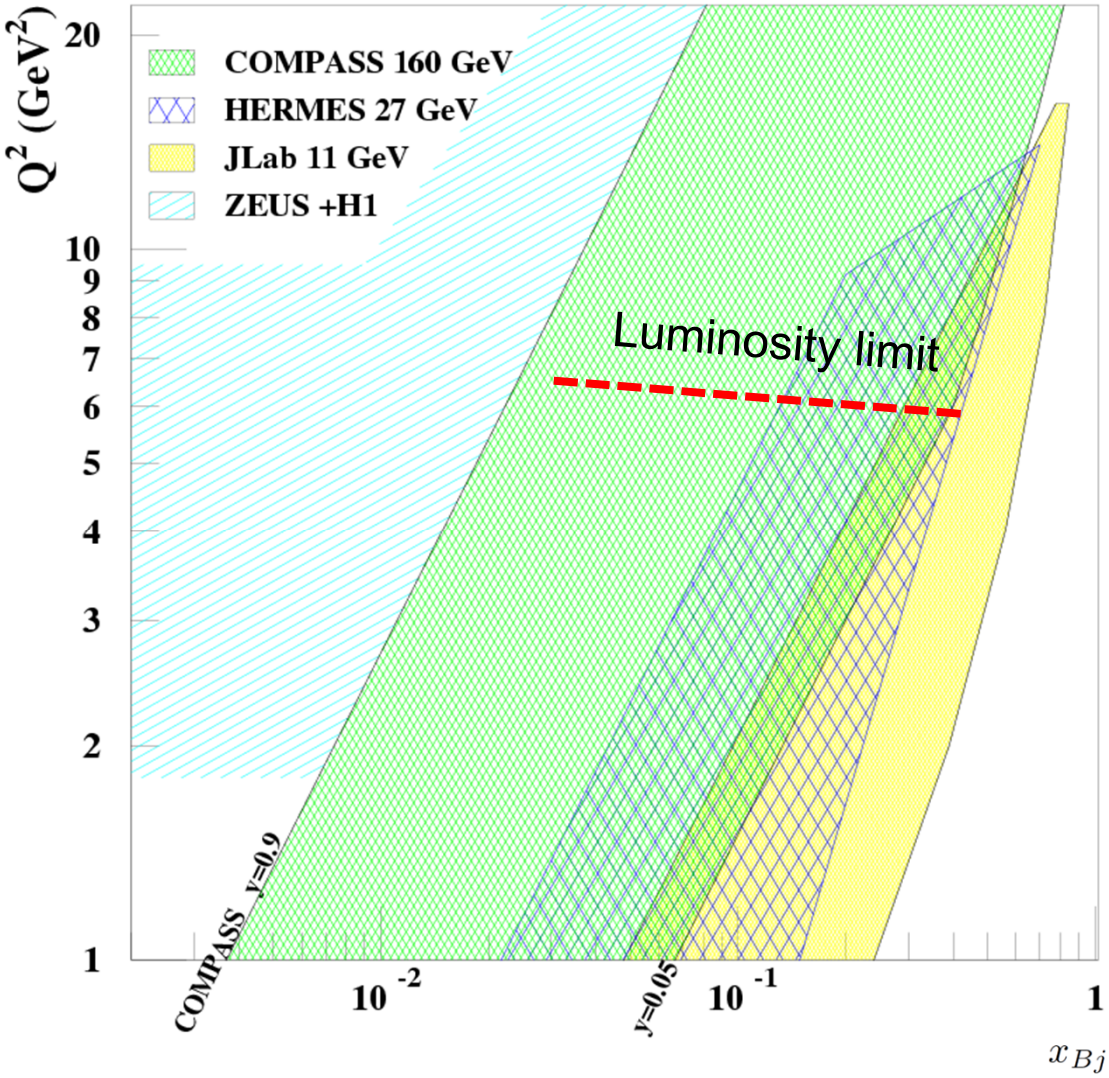
$$d\sigma(\mu N \to \mu N\gamma) \propto |\mathcal{A}_{BH}|^2 + |\mathcal{A}_{DVCS}|^2 + \underbrace{\mathcal{A}_{BH}\mathcal{A}^*_{DVCS} + \mathcal{A}^*_{BH}\mathcal{A}_{DVCS}}_{I}.$$



$$\frac{d^4\sigma(\mu p \to \mu p\gamma)}{dx_B dQ^2 d|t| d\phi} = d\sigma^{BH} + [d\sigma^{DVCS}_{unpol} + P_\mu\, d\sigma^{DVSC}_{pol}] + e_\mu \left[\mathrm{Re}\, I + P_\mu\, \mathrm{Im}\, I\right]$$

BH	well known (reference yield)
DVCS	t-slope measurement (nucleon tomography)
Interf. term	access to ReA^{DVCS} ImA^{DVCS}

Kinematic domain accessible at COMPASS



CERN High energy muon beam 100 - 190 GeV

μ+ and μ- available

80% Polarisation

with opposite polarization

with a 2.5m long LH_2 target

$L = 10^{32}$ cm^{-2} s^{-1}

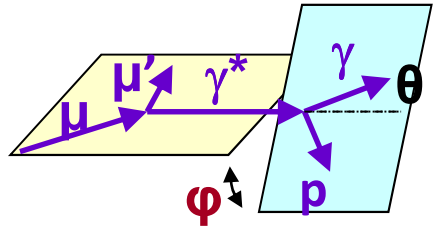
$Q^2 \rightarrow$ 8 GeV^2

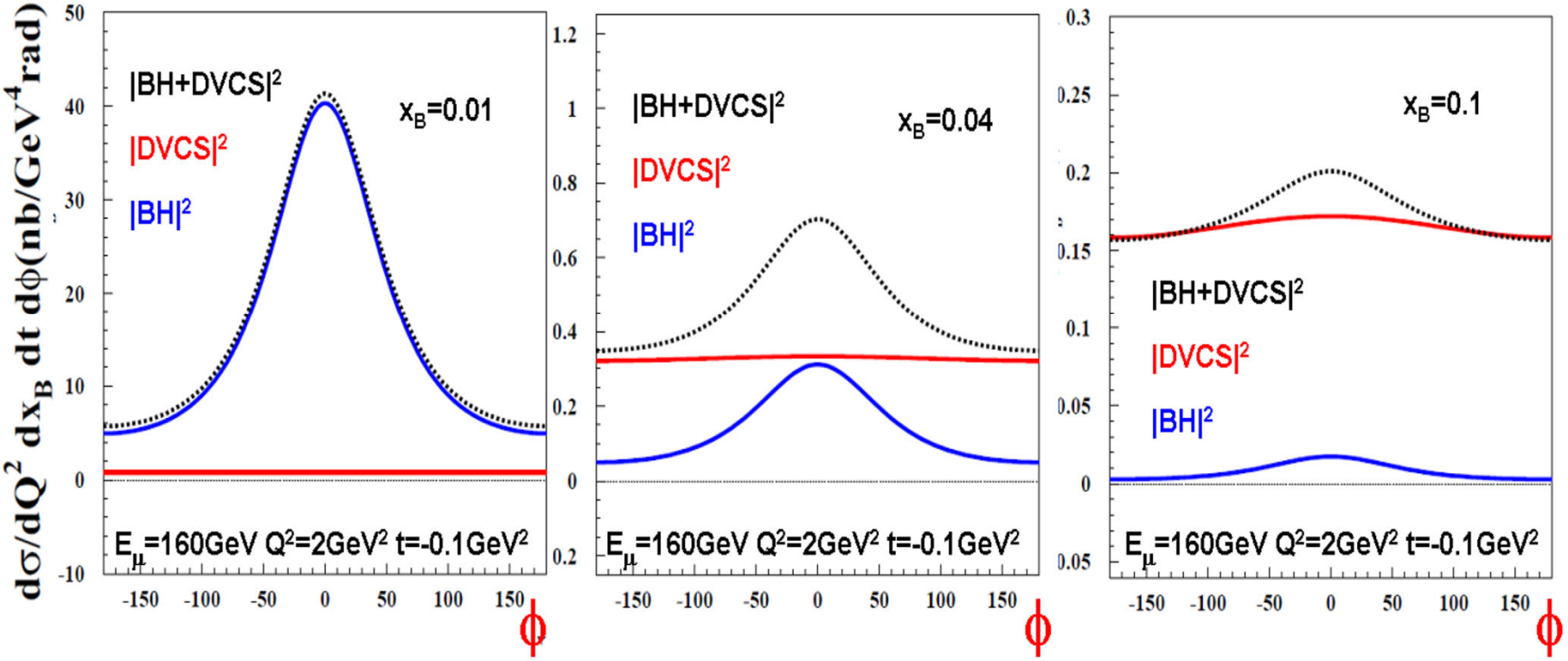
$\rightarrow$ 16 GeV^2 if luminosity increased by factor 4

$\sim 10^{-2} < x_{Bj} < \sim 10^{-1}$

$x_{Bj} \rightarrow$ 0.20 with extension of present calorimetry

Comparison of BH and DVCS at 160 GeV





BH dominates	BH and DVCS at the same level	DVCS dominates
excellent reference yield	*access to DVCS amplitude through the interference*	*study of* $d\sigma^{DVCS}/d\|t\|$

DVCS measurement with polarized μ^+ and μ^- beams

$$\mu^{+\downarrow}(P=-0.8),\ \mu^{-\uparrow}(P=0.8) \qquad \frac{\mathrm{d}^4\sigma(\mu p \to \mu p \gamma)}{\mathrm{d}x_{Bj}\mathrm{d}Q^2\mathrm{d}|t|\mathrm{d}\phi} = \mathrm{d}\sigma$$

With unpolarized LH_2 target (goal to constrain GPD H)

- Beam charge & Spin Sum: $\mathcal{S}_{CS,U} \equiv \mathrm{d}\sigma^{+\downarrow} + \mathrm{d}\sigma^{-\uparrow}$
- Beam charge & Spin Difference: $\mathcal{D}_{CS,U} \equiv \mathrm{d}\sigma^{+\downarrow} - \mathrm{d}\sigma^{-\uparrow}$
- additionally deeply virtual meson production

t-slope of the DVCS cross section from $S_{CS,U}$

$\mathrm{Im}A^{\mathrm{DVCS}}$ and $\mathrm{Re}A^{\mathrm{DVCS}}$ from
azimuthal angular dependence of interference terms in $S_{CS,U}$ & $D_{CS,U}$

DVCS measurement with polarized μ^+ and μ^- beams

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- Beam charge & Spin Difference: $\mathcal{D}_{CS,U} \equiv \mathrm{d}\sigma^{+\downarrow} - \mathrm{d}\sigma^{-\uparrow}$
- additionally deeply virtual meson production

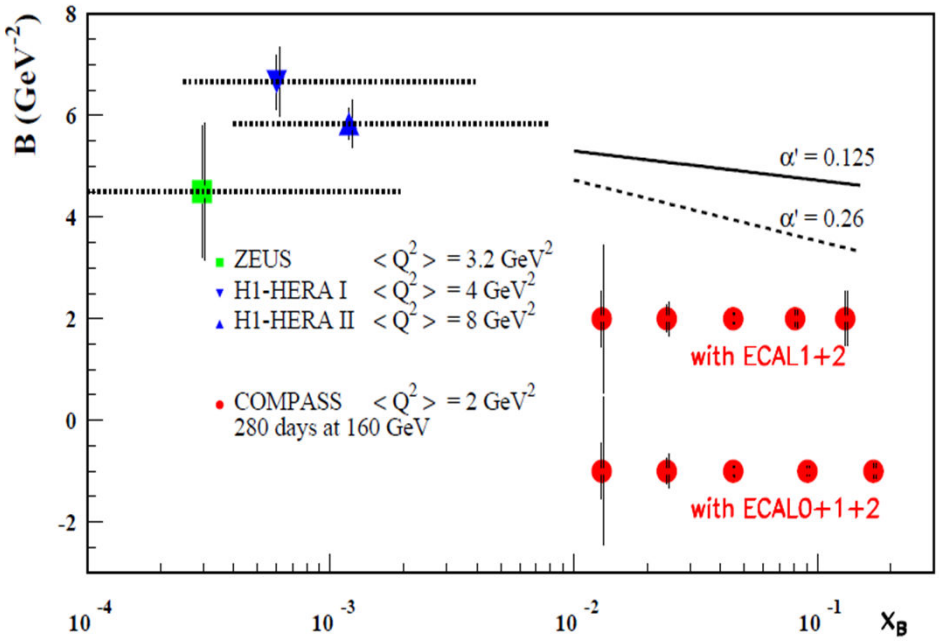
With transversely polarized NH_3 target (goal to constrain GPD E)

- $\mathcal{D}_{CS,T} \equiv \left(\mathrm{d}\sigma^{+\downarrow}(\phi,\phi_S) - \mathrm{d}\sigma^{+\downarrow}(\phi,\phi_S+\pi)\right) - \left(\mathrm{d}\sigma^{-\uparrow}(\phi,\phi_S) - \mathrm{d}\sigma^{+\uparrow}(\phi,\phi_S+\pi)\right)$
- $\mathcal{S}_{CS,T} \equiv \left(\mathrm{d}\sigma^{+\downarrow}(\phi,\phi_S) - \mathrm{d}\sigma^{+\downarrow}(\phi,\phi_S+\pi)\right) + \left(\mathrm{d}\sigma^{-\uparrow}(\phi,\phi_S) - \mathrm{d}\sigma^{+\uparrow}(\phi,\phi_S+\pi)\right)$
- yielding two asymmetries $\mathcal{A}^D_{CS,T} = \frac{\mathcal{D}_{CS,T}}{\Sigma_{unpol}}$ and $\mathcal{A}^S_{CS,T} = \frac{\mathcal{S}_{CS,T}}{\Sigma_{unpol}}$

From $S_{U,CS}$: transverse imaging

integration of $\mathcal{S}_{CS,U}$ over ϕ and BH subtraction yields

$$d\sigma^{DVCS}/d|t| \propto \exp(-B|t|) \text{ with } B(x) \sim 1/2\,\langle r_\perp^2(x)\rangle$$



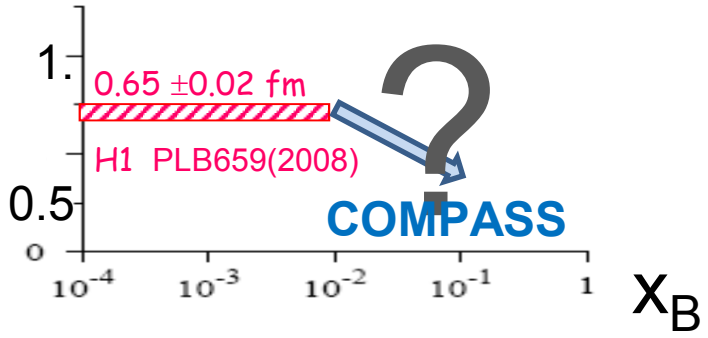
Projections: B accuracy ~0.1 GeV^{-2}
accuracy of α' ~3σ if α'>0.16

Projections for:
Eμ=160 GeV 2 years of running
L = 1222 pb^{-1}
ε_{global} = 10 %

Ansatz at small x_{Bj}:
$(x \approx x_{Bj})$

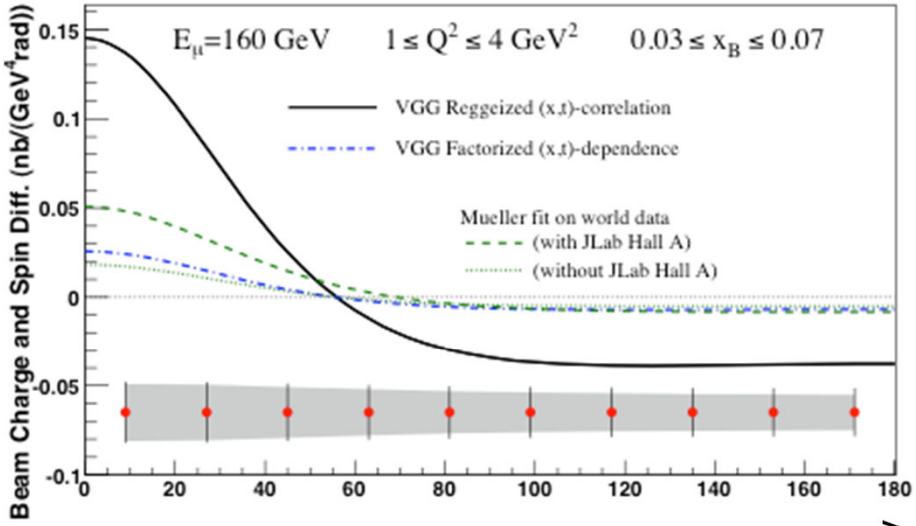
$$B(x_{Bj}) = B_0 + 2\alpha' \ln \frac{x_0}{x_{Bj}}$$

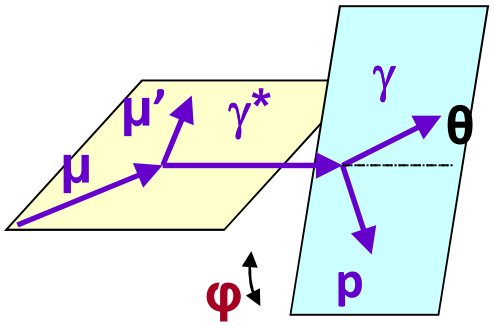
$\sqrt{< r_\perp^2 >}$



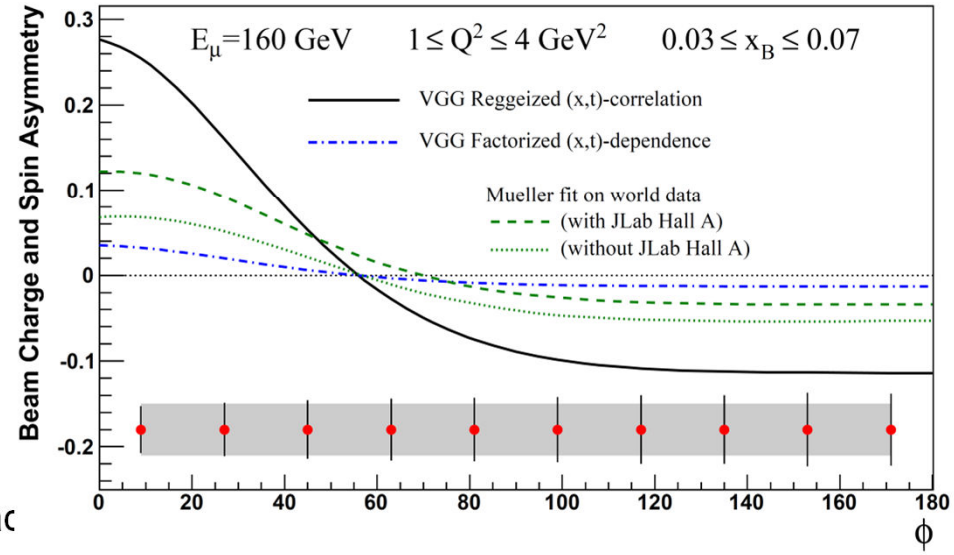
Study of the azimuthal dependence as a function of Q^2 and x_{Bj} (integration over t)

$D_{U,CS}$: Beam Charge & Spin Difference





$A_{U,CS}$: Beam Charge & Spin Asymmetry



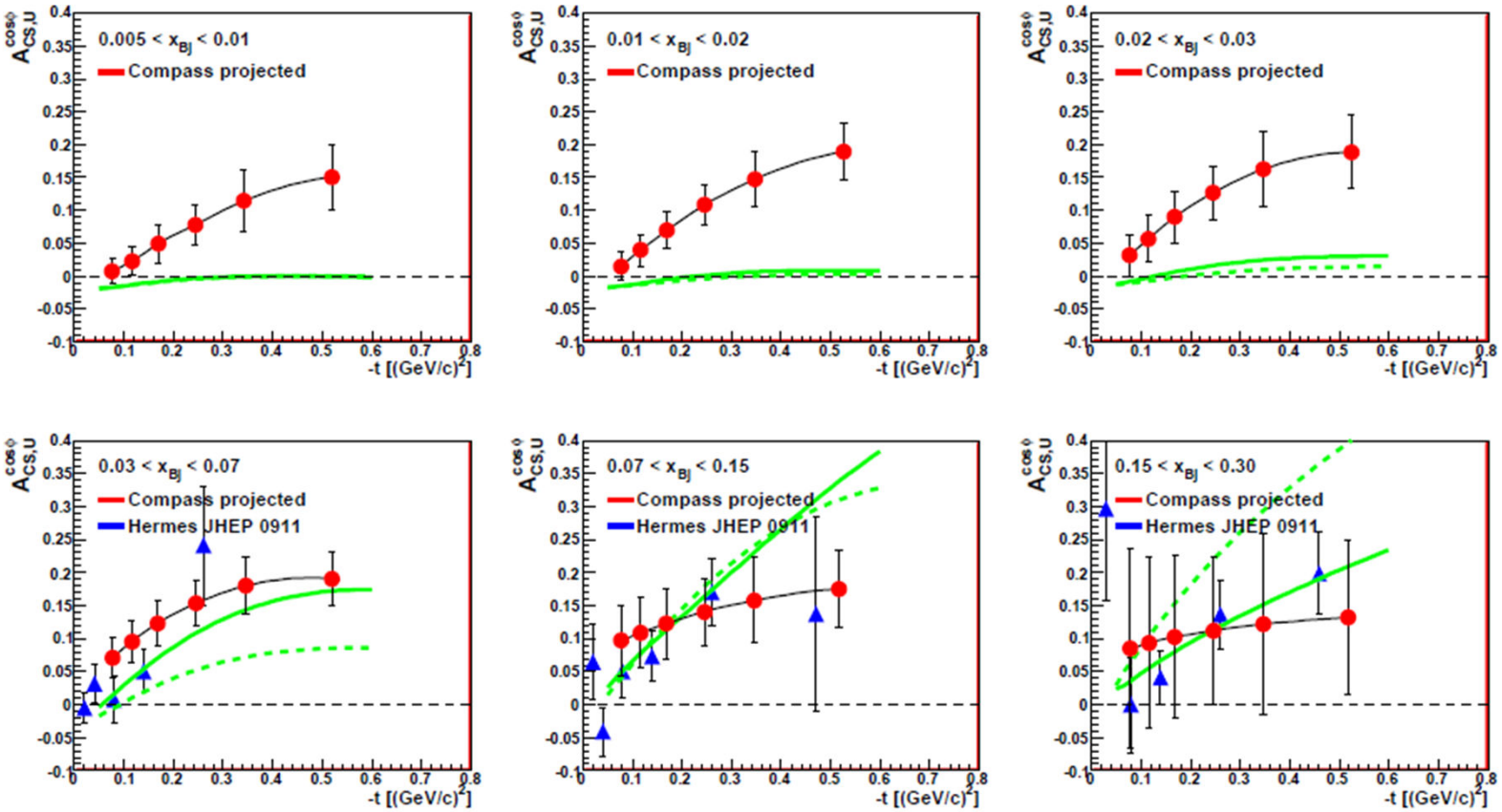
2 years of running will permit us to study a two dimensional dependence

$$Q^2, x_{Bj} \text{ or } t, x_{Bj}$$

Comparison to different models

Study of the $\cos\phi$ modulation as a function x_{Bj} and t (integration over Q^2)

Projections VGG model compared to HERMES data
Also shown D. Mueller (green)



DVCS test runs 2008 & 2009

Use COMPASS ‘hadron’ set-up

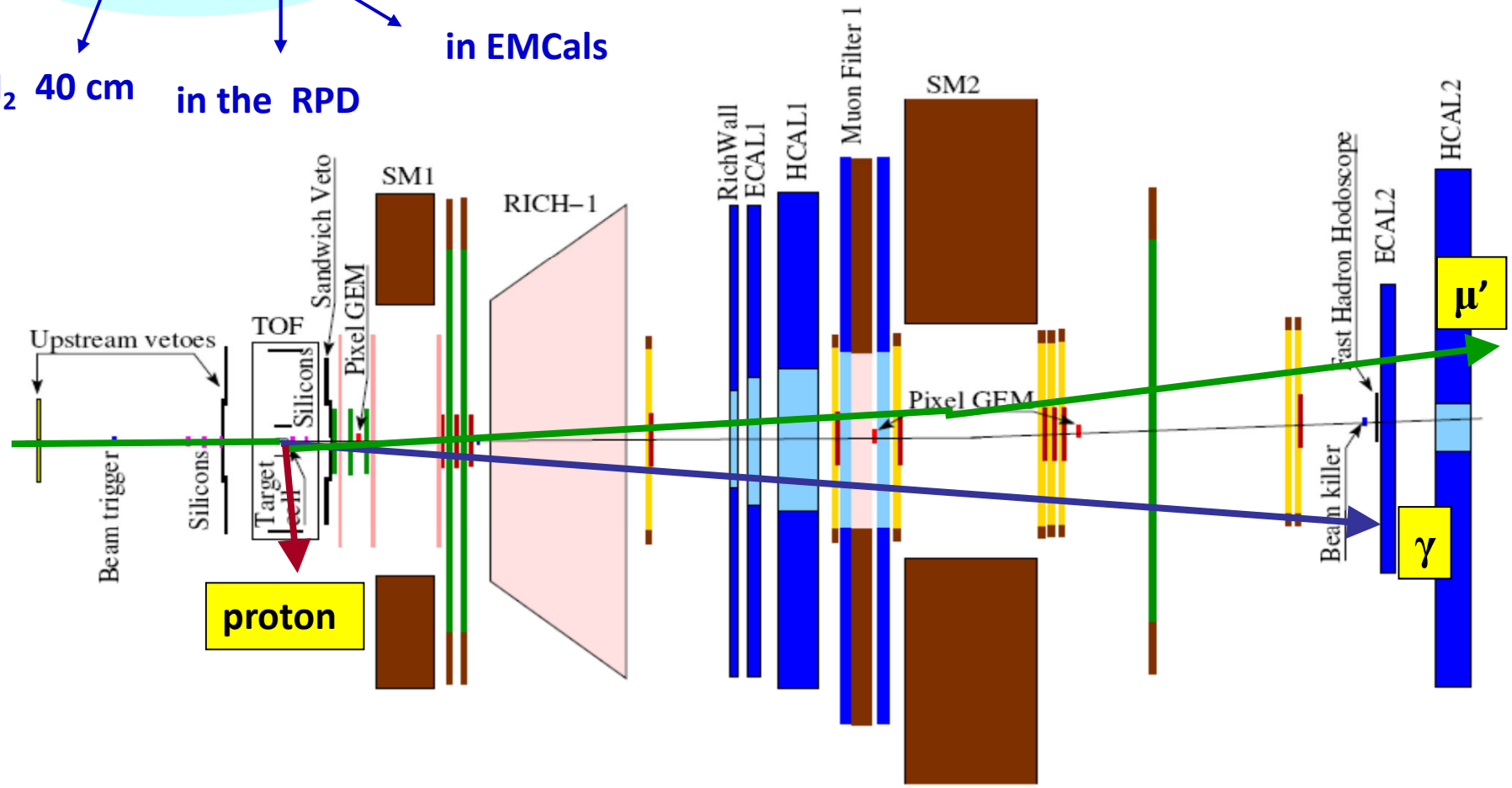
more details in the talks of P.Jasinski and J.Friedrich

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

LH_2 40 cm

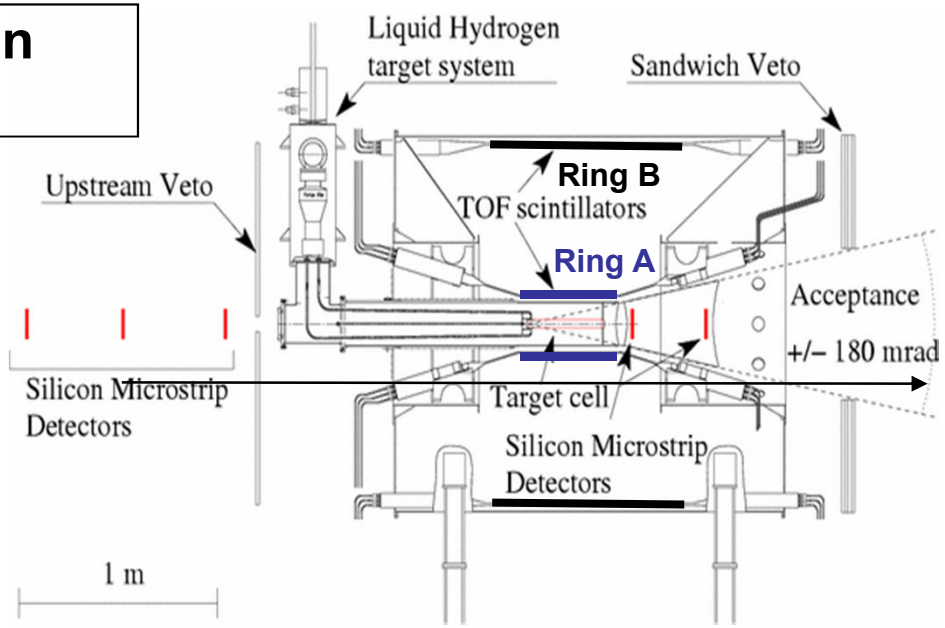
in the RPD

in EMCals

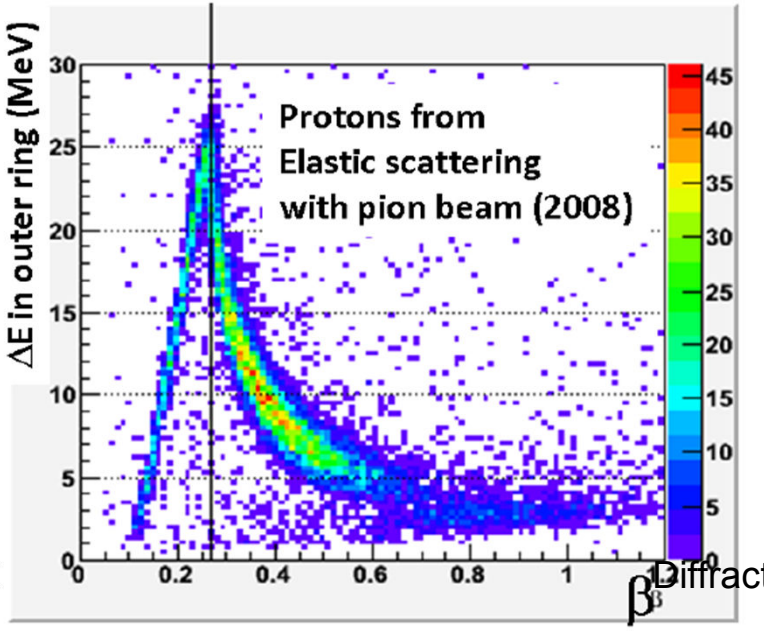


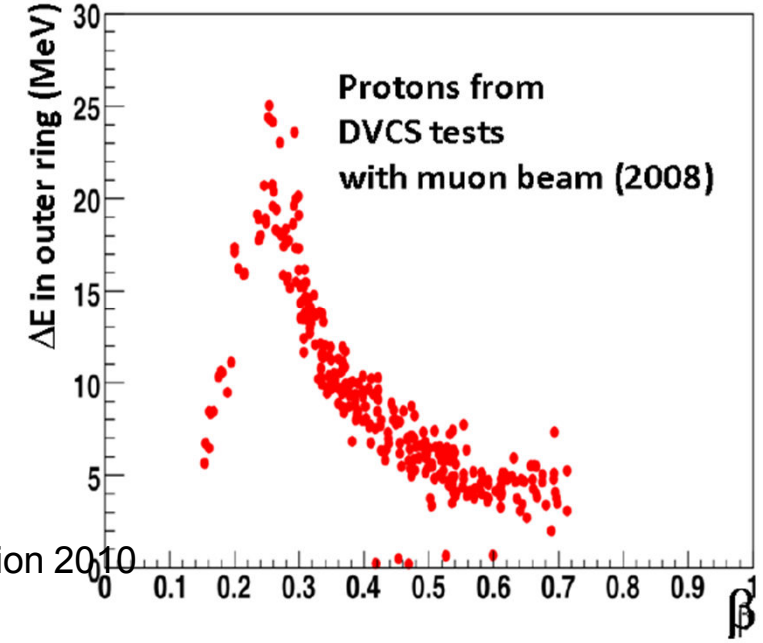
Recoil proton detector for hadron program

1 m long Recoil Proton Detector and a 40cm LH_2 target in 2008/2009

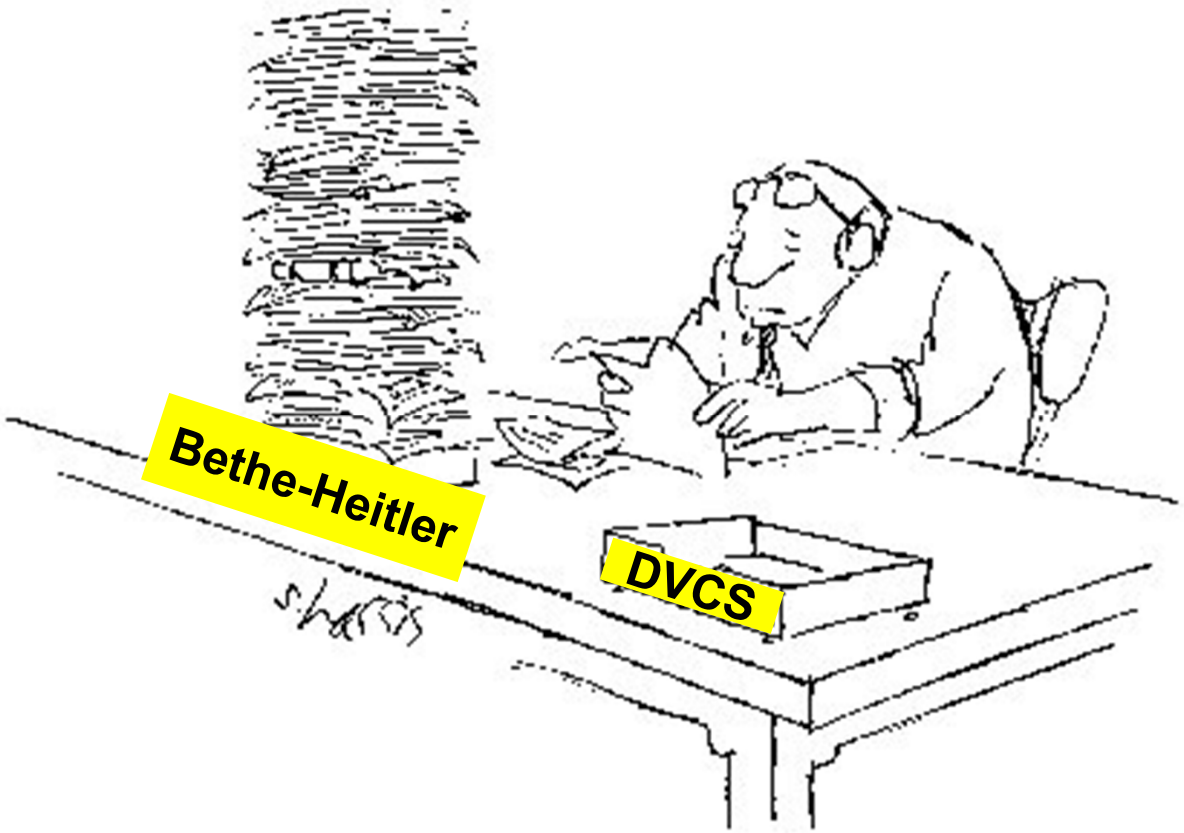


Proton identification in RPD



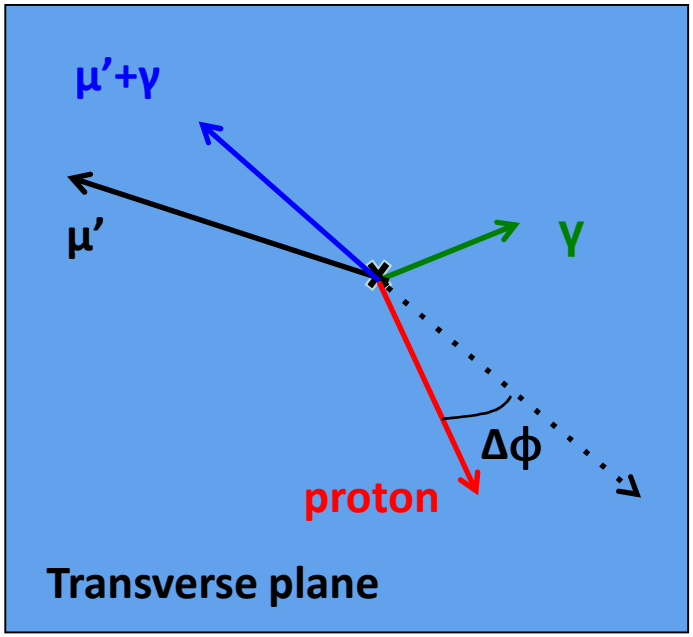


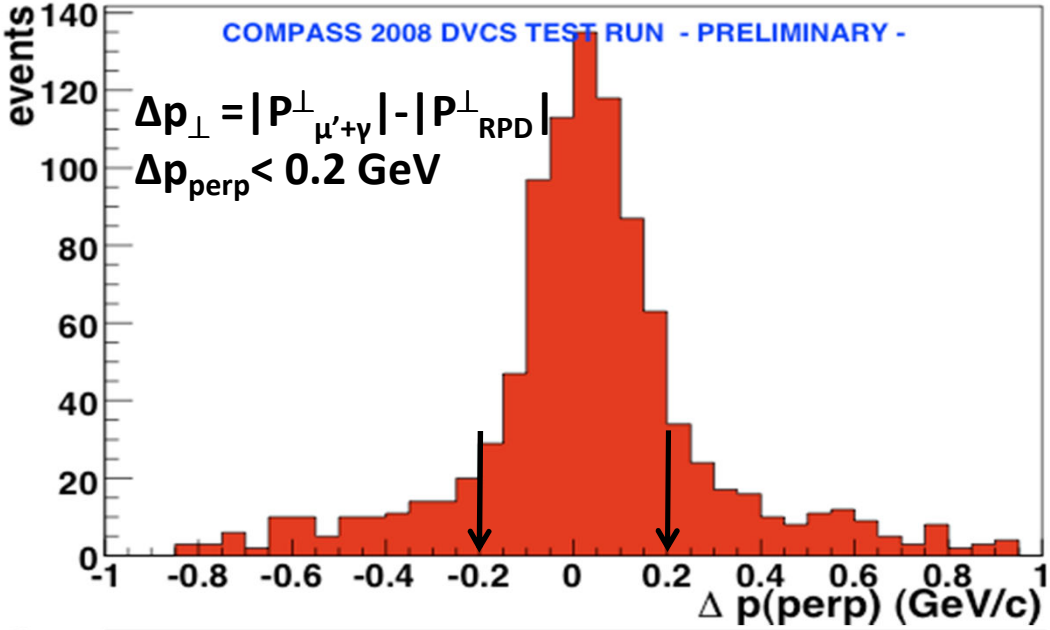
2008 DVCS test run: a first observation of exclusive single-photon production.

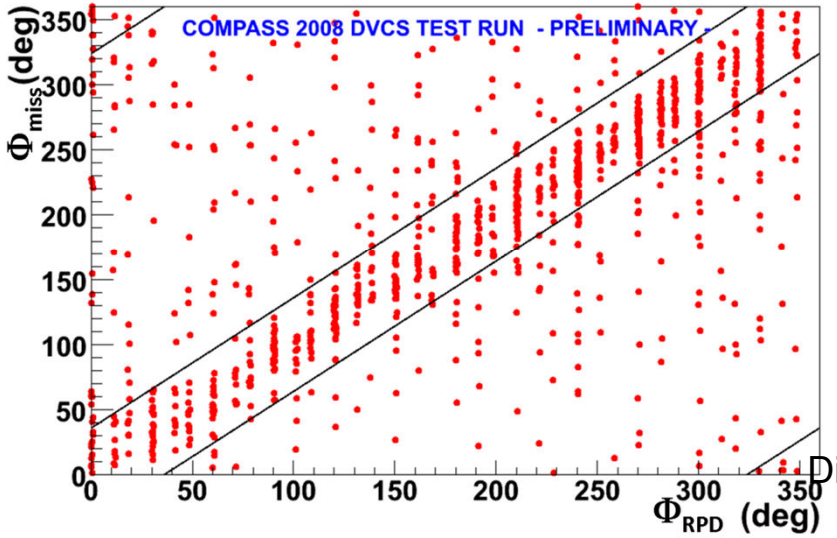


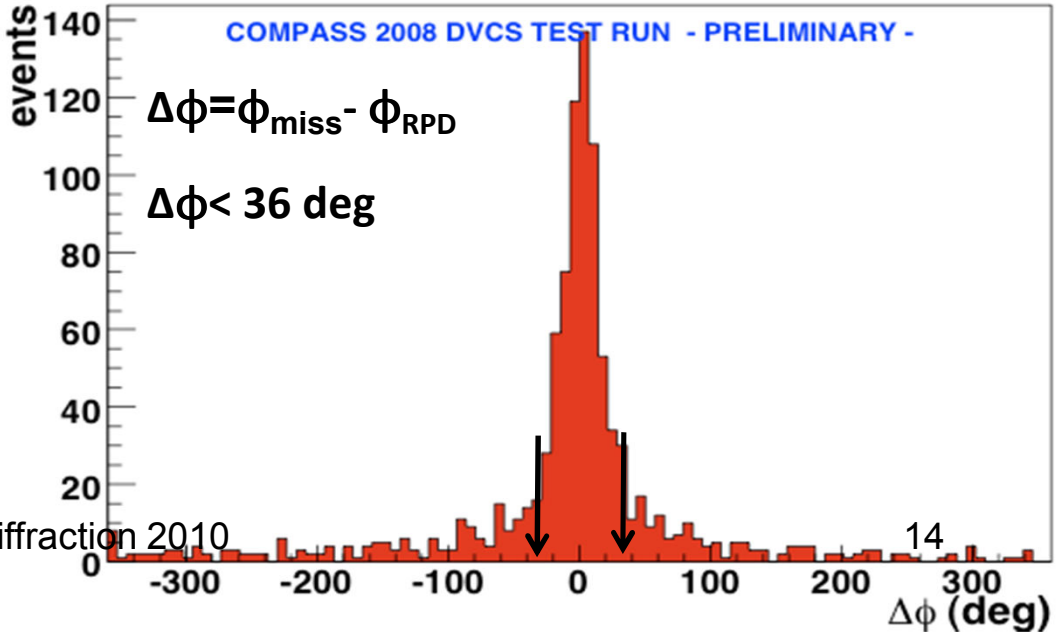
Kinematic constraints in the transverse plane

$$\vec{p}_{miss} = \vec{p}_{\mu} - \vec{p}_{\mu'} - \vec{p}_{\gamma}$$

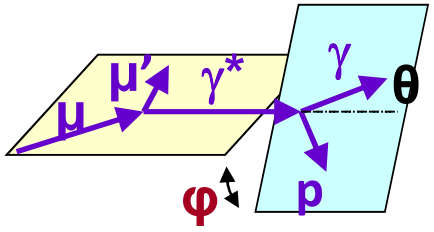






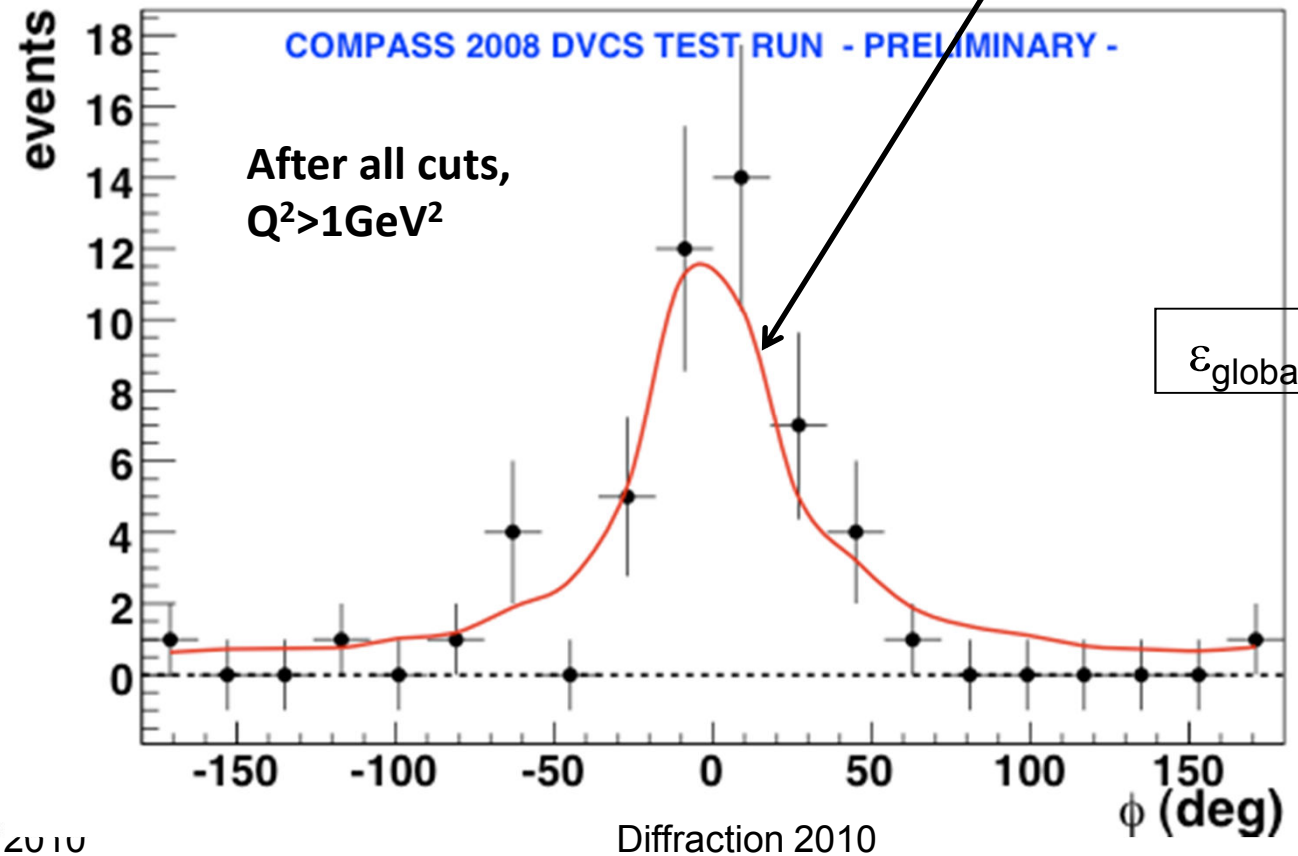


Azimuthal distribution for exclusive single photon events



Clear BH signal observed at $Q^2>1$ GeV^2

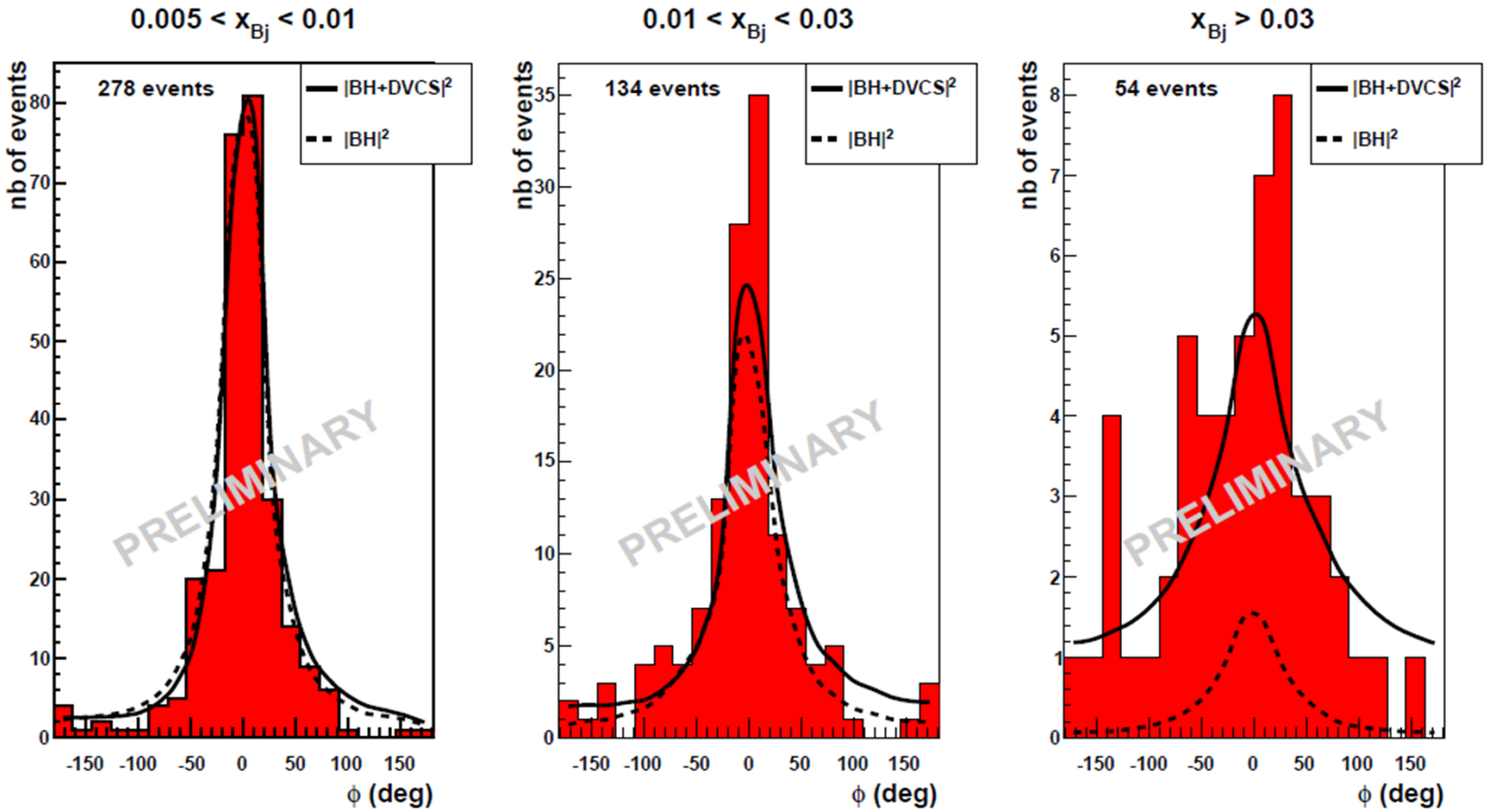
Monte-Carlo simulation of BH (dominant) and DVCS



ε_{global} = 13%±5%

2009 DVCS test run: first estmation of pure DVCS, pure BH and DVCS-BH interference relative contributions

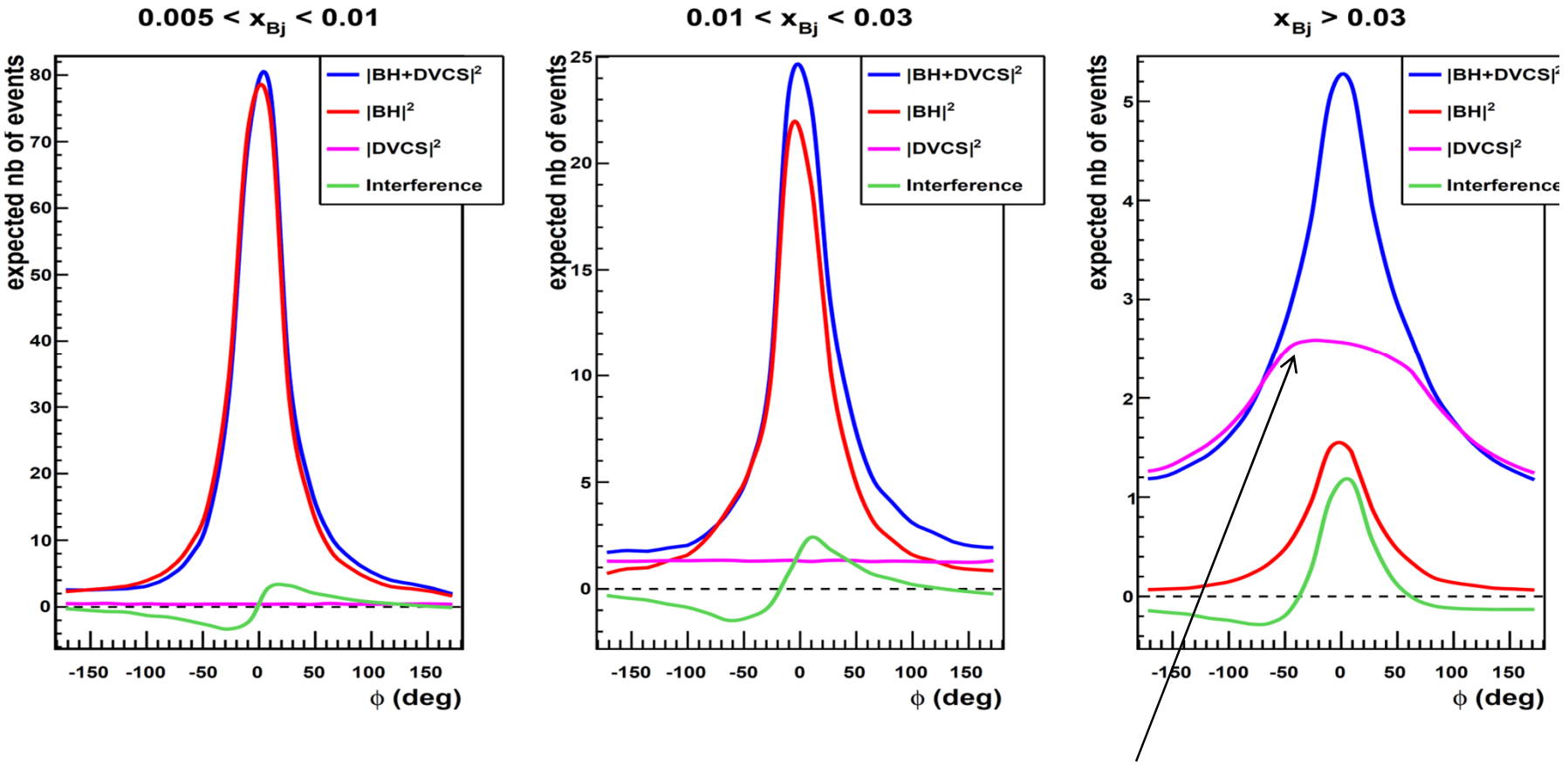
2009 beam test : DVCS signal



excess of events for x_{bj}>0.03 is a clear sign for DVCS

- evaluation an exclusive π^0 background is in progress
- question of the acceptance uniformity

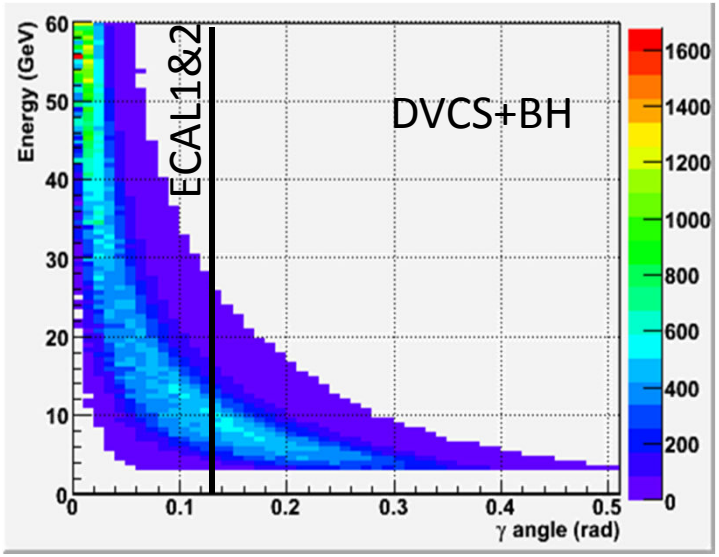
Simulation using VGG for DVCS



Current spectrometer acceptance (non-uniformity for DVCS)

Normalised to the integrate luminosity of the 2009 DVCS test run

Detectors to be built:
new large-angle electromagnetic calorimeter ECAL0

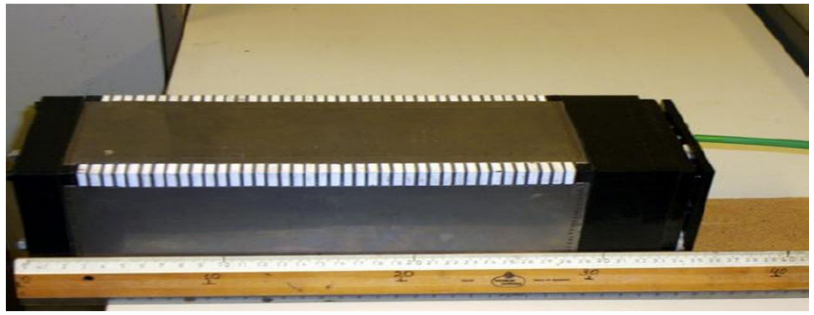


Requirements
- Photon energy range 0.2- 30 GeV
- Size: 360cm x 360cm ;
- Granularity 4x4 – 6x6 cm^2
- Energy resolution < 10.0%/√E (GeV)
- Thickness < 50 cm,
- Insensitive to the magnetic field.

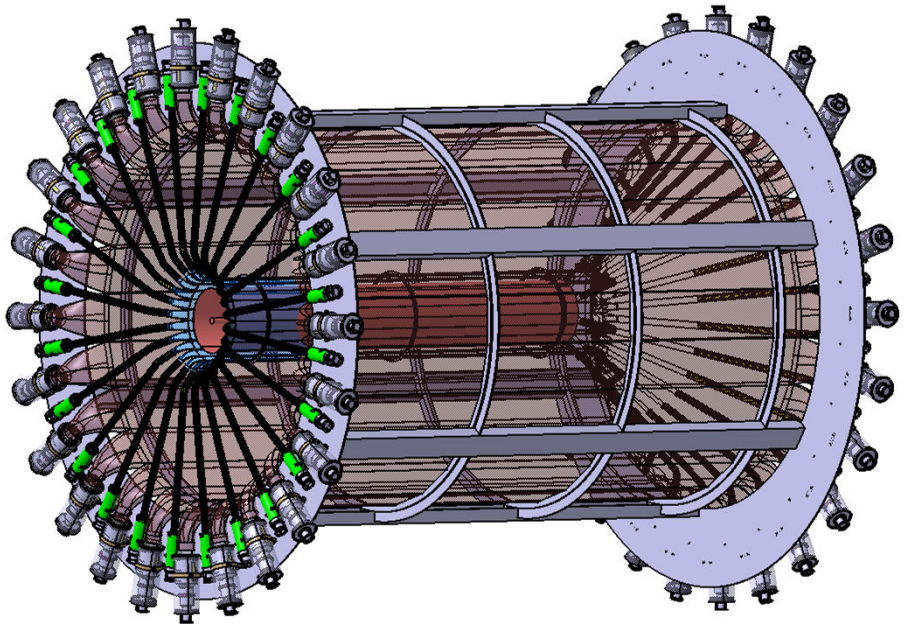
Avalanche Micropixel Photo Diodes

Need temp. stability <0.2K

Prototype under studies
Shaschlyk module with AMPD readout



Detectors to be built:
recoil proton detector for 2.5 m long LH_2 target



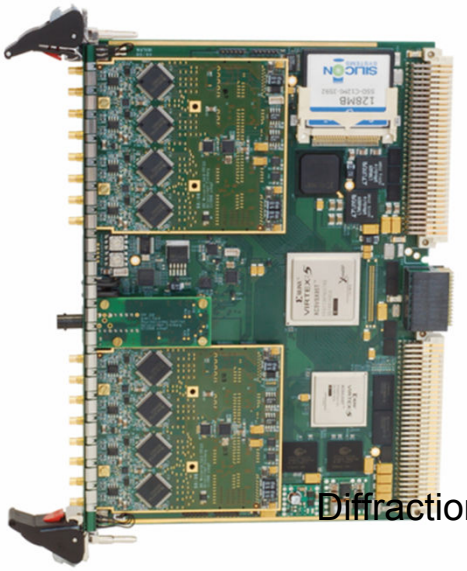
- 4 m long scintillator slabs
- ~ 300 ps timing resolution
- 30º prototype tested successfully

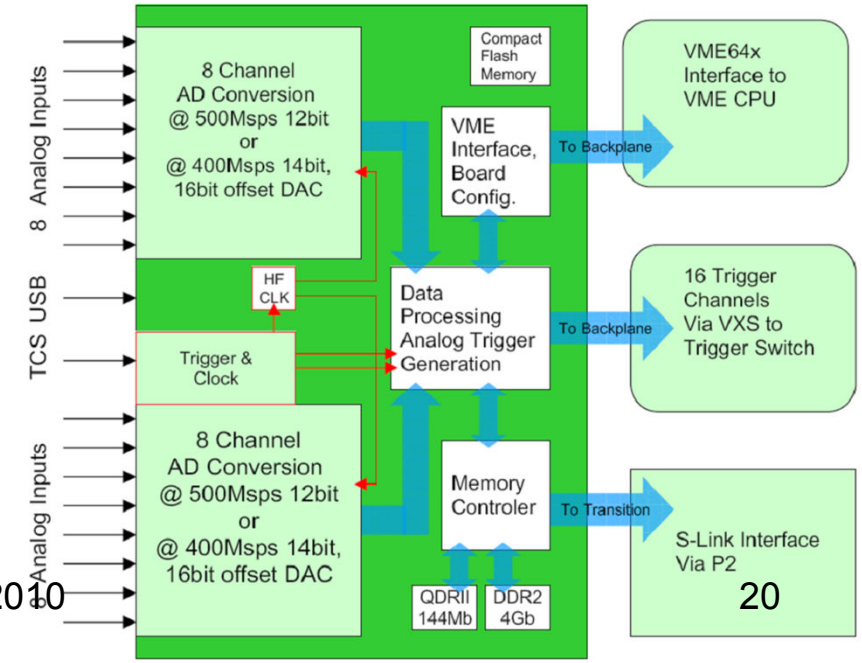
Momentum resolution (3-9)%
in the interval 0.26-0.7 GeV

high occupancy

⇩

Gandalf Project:
1 GHz digitalisation of the PMT signal to cope with high rate





Conclusions

- The strategic location of COMPASS – on the highly energetic polarized $\mu^{\pm}$ beams – provides with a great potential in GPDs physics
- For exclusive measurements detection of the recoil proton is mandatory

  - First phase: GPDs H study with unpolarized LH_2 target
  - measurement of t-slopes – transverse partonic structure of the nucleon
  - measurement of Beam Charge and Spin differences & asymmetries

  Upgrade of spectrometer

  4m long RPD, 2.5m LH_2 target, extended & improved calorimetry

  is under the way

  - At a later stage a study of GPDs E requires a recoil detector integrated with a transversely polarized target.