The GPD program at COMPASS

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on behalf of the COMPASS Collaboration

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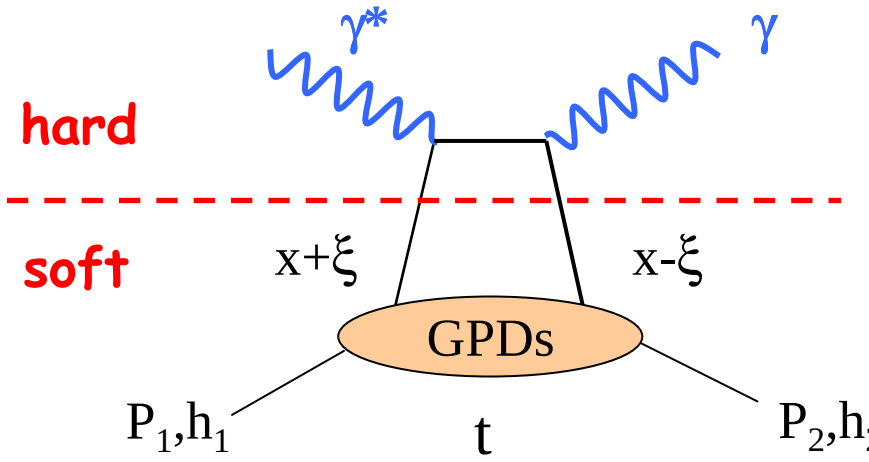
Generalized Parton Distributions and DVCS



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

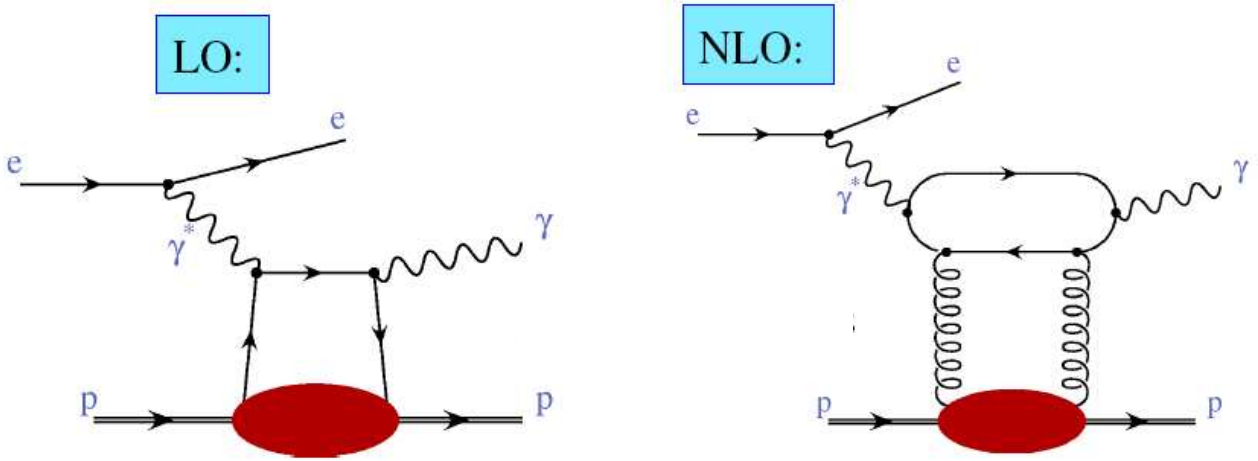
$$\xi = \frac{x_B}{2 - x_B}$$

P_i, h_i – proton momentum and helicity

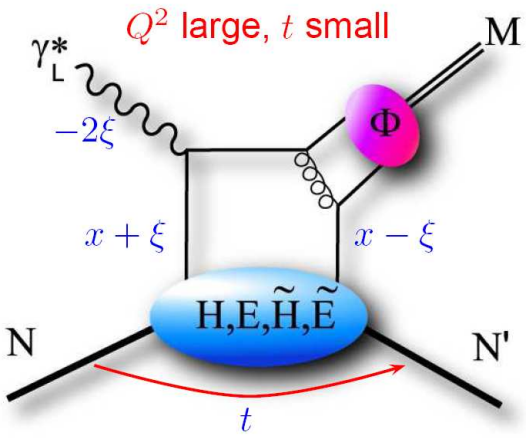
4 Generalised Parton Distributions : $H, E, \tilde{H}, \tilde{E}$ depending on 3 variables: x, ξ, t

for each quark flavour and for gluons

for DVCS gluons contribute at higher orders in α_s



GPDs and Hard Exclusive Meson Production



- factorisation proven only for σ_L
  σ_T suppressed by $1/Q^2$
  desirable to extract longitudinal contribution to observables (σ_L , …)

- allows separation $(H,E) \leftrightarrow (\tilde{H},\tilde{E})$ and wrt quark flavours

$H, \tilde{H}$ conserve nucleon helicity — Vector mesons (ρ, ω, φ)

$E, \tilde{E}$ flip nucleon helicity — Pseudoscalar mesons (π, η)

Flavour sensitivity of HEMP on the proton

π^0	$2\Delta u+\Delta d$
η	$2\Delta u-\Delta d$
ρ^0	$2u+d$, $9g/4$
ω	$2u-d$, $3g/4$
ϕ	s, g
ρ^+	$u-d$
J/ψ	g

- quarks and gluons enter at the same order of α_s

- at $Q^2 \approx$ few GeV² power corrections/higher order pQCD terms are essential

- wave function of meson (DA Φ) additional input

A glance at COMPASS GPD program activities

➢ Future GPD program of COMPASS-II

a part of approved (December 2010) COMPASS-II proposal
DVCS and HEMP with polarised μ+ and μ- beams at 160 GeV and
unpolarised and transversely polarised proton targets (LH_2 , NH_3)
optimal experimental setup for GPD program with the recoil proton detector
and large angular coverage by EM calorimetry

➢ 'DVCS test' runs in 2008 (1.5 day) and 2009 (10 days)

40 cm LH_2 target and small RPD
used also for the COMPASS hadron spectroscopy program in 2008-09
analyses of the 'DVCS test' data demonstrate feasibility to measure
exclusive γ (DVCS and BH) and π^0 production at COMPASS

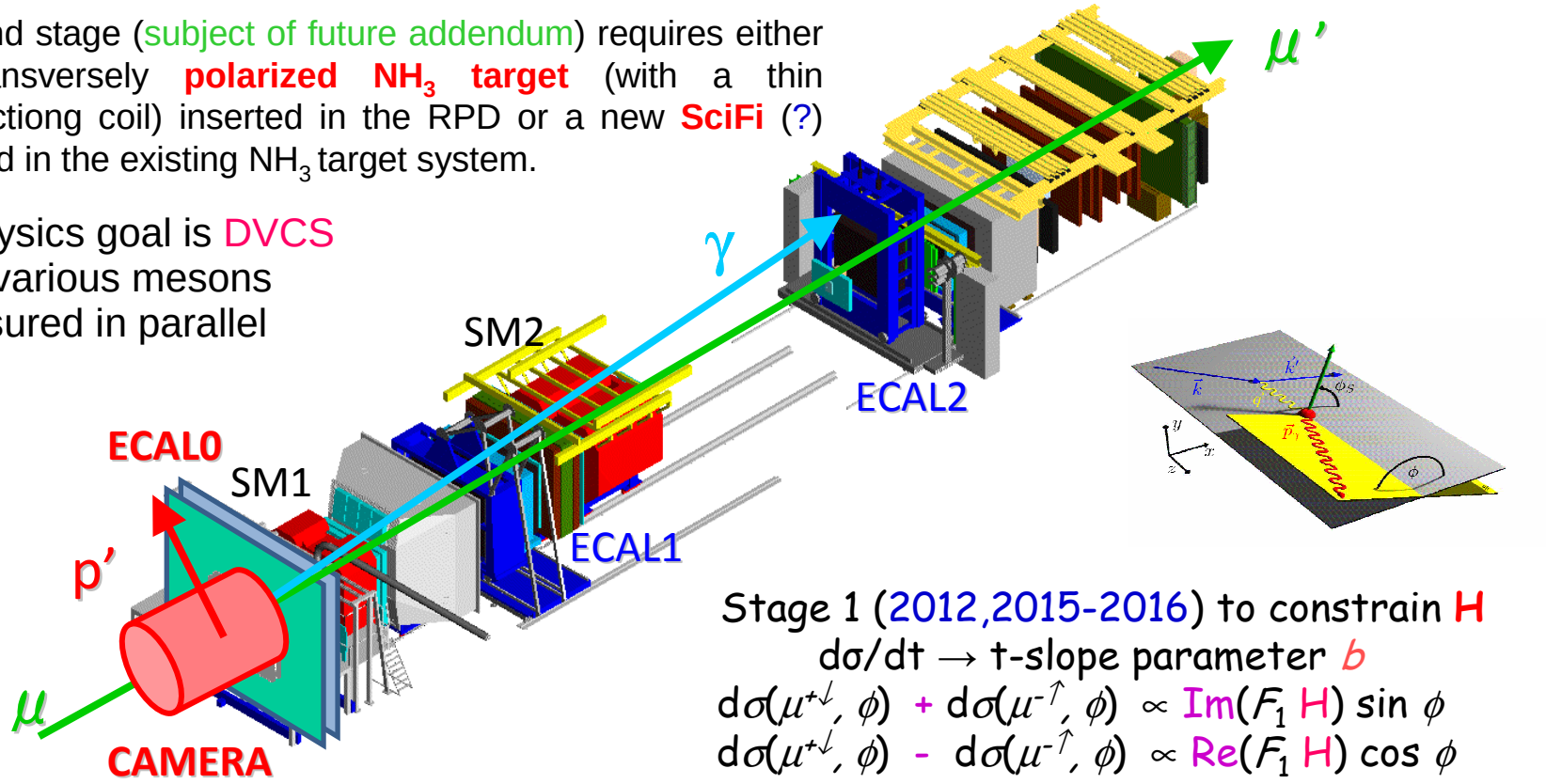
➢ Analyses of exclusive VM muo-production from 2002-2011 data

with longitudinally/transversely polarised proton/deuteron targets (^6LiD, NH_3)
experimental setup optimised mostly for DIS and SIDIS
no recoil detector ➡ disadvantage for exclusive measurements
opportunity to get early results on spin dependence for HEVMP
in particular for transversely polarised protons and deuterons
the later unique for COMPASS

Future GPD program @ COMPASS in a nutshell

- The GPDs program is part of the **COMPASS-II** proposal approved at CERN in 2010.
- The first stage (approved) of this program requires a 4 m long recoil proton detector (**CAMERA**) together with a 2.5 m long **LH target**. Upgrades of electromagnetic calorimeters to enlarge coverage at large x_B and reduce bkg (**ECAL0**).
- The second stage (subject of future addendum) requires either a new transversely **polarized NH_3 target** (with a thin superconductiong coil) inserted in the RPD or a new **SciFi** (?) **RPD** inserted in the existing NH_3 target system.

primary physics goal is DVCS
HEMP for various mesons
will be masured in parallel



Stage 1 (2012,2015-2016) to constrain **H**

$d\sigma/dt \rightarrow$ t-slope parameter b

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

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

Stage 2 (later) to constrain **E**

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

100 – 190 GeV $\mu^{+\downarrow,-\uparrow}$ 80%

Future GPD program in context of COMPASS-II time lines

Part of the COMPASS-II proposal scheduled presently by CERN

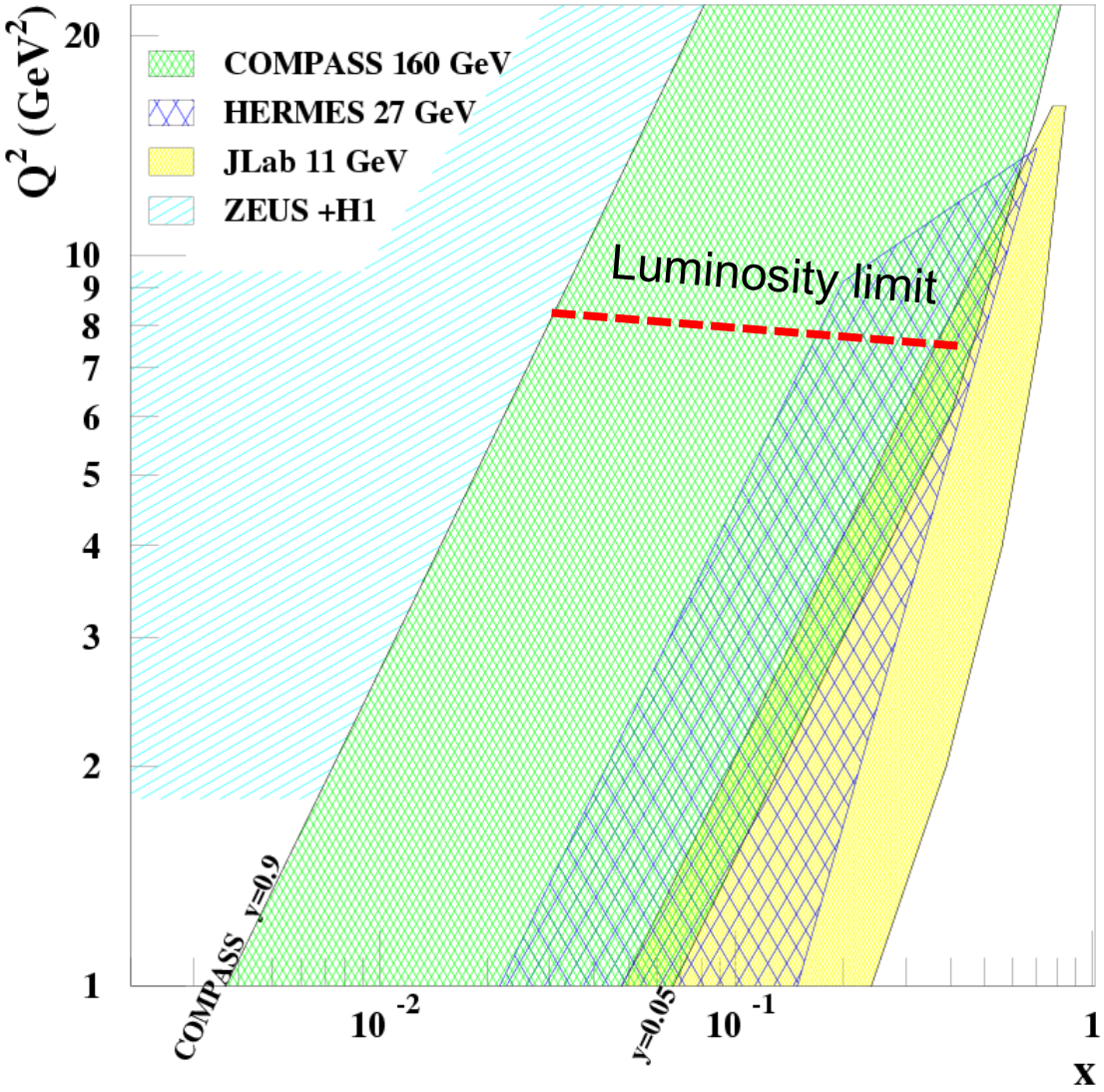
- 2012: pion and kaon polarisabilities (Primakoff) + comissioning and test run for DVCS
- 2013: long SPS shutdown
- 2014: Drell-Yann measurements with transversely polarised protons (NH_3 target)
- 2015-2016: stage 1 of GPD program and in parallel SIDIS (LH target)

Further physics subjects intended to be pursued at COMPASS-II > 2016

- ✓ additional year of Drell-Yann measurements
- ✓ stage 2 of GPD program (transversely polarised target and RPD)
- ✓ hadron program (spectroscopy in diffractive and central production)

COMPASS kinematical coverage for DVCS

CERN SPS high energy polarised muon beam 100/190 GeV



with a 2.5m long LH_2 target

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

$Q^2 \rightarrow 8\ GeV^2$

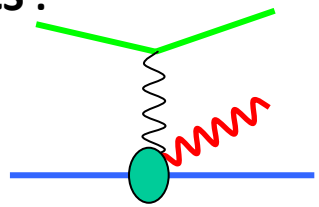
$\rightarrow 16\ GeV^2$ if luminosity increased by factor 4

$\sim 10^{-2} < x < \sim 10^{-1}$

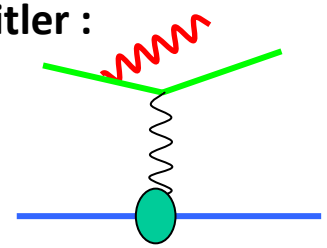
$x \rightarrow 0.20$ with extension of present calorimetry

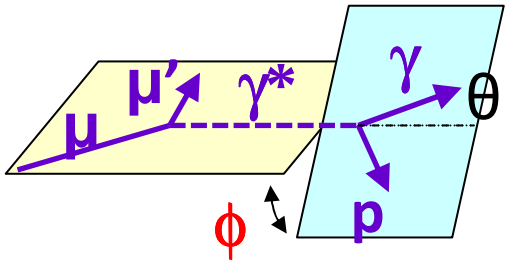
Interplay of DVCS and BH at 160 GeV

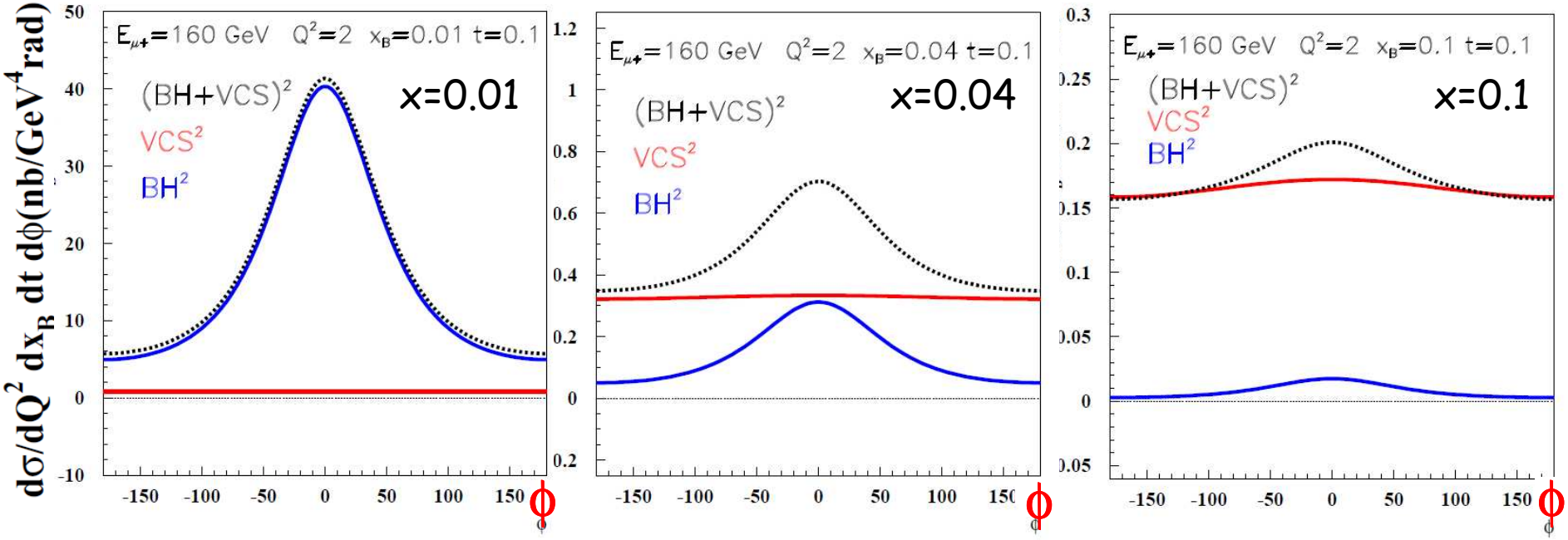
DVCS :



Bethe-Heitler :







BH dominates

excellent reference yield

BH and DVCS at the same level

access to DVCS amplitude through the interference

DVCS dominates

study of $d\sigma^{DVCS}/dt$

The GPDs in the next several years

- **H1, ZEUS, HERMES, JLab 6 GeV** are providing the first results
  significant increase of statistics expected after
  full data sets analysed

- The **energy upgrade** of the **CEBAF** accelerator will allow access
  to the **high x_B** region which requires **large luminosity**.

- The **GPD** project at **COMPASS** will explore **intermediate x_B** (0.01-0.10)
  and **large Q^2** (up to ~8(16) GeV^2) range

  COMPASS will be **the only experiment in this range** before
  availability of new colliders

  for several years COMPASS **unique** due to availability
  of lepton **beams of both charges**

‘Stage 1’ of COMPASS GPD program

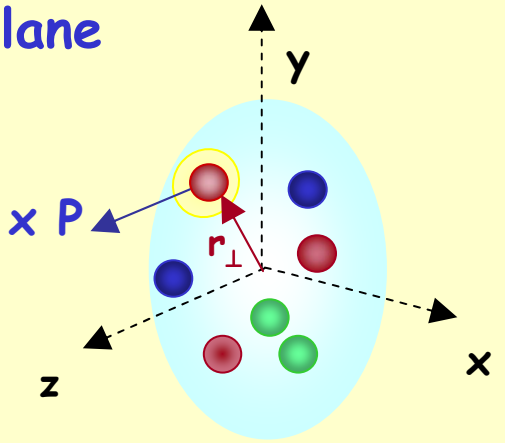
DVCS and HEMP with unpolarised proton target

to constrain GPD H

- **GPD - 3-dimensional picture of the partonic nucleon structure or spatial parton distribution in the transverse plane**

$$H(x, \xi=0, t) \rightarrow H(x, r_{x,y})$$

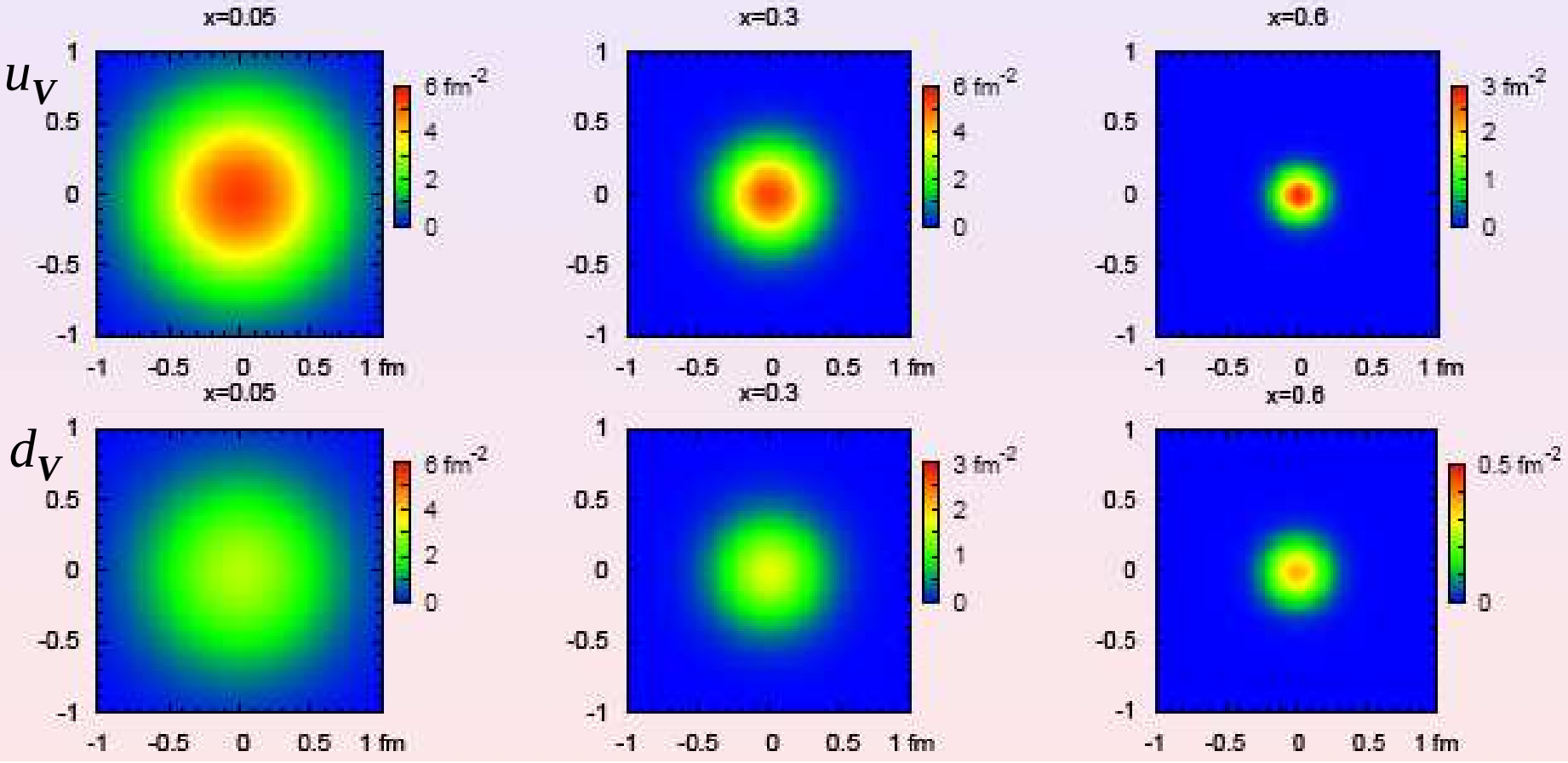
probability interpretation
Burkardt



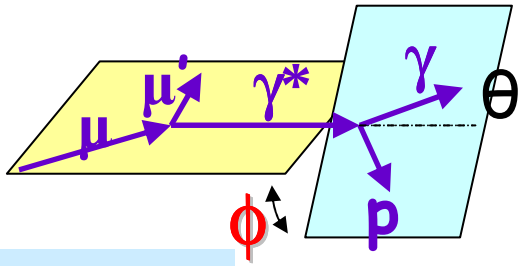
Nucleon tomography from fits to elastic form factors

from GPD fits to $F_{1,2}^{p,n}$ Diehl, Feldmann, Jakob, Kroll – (2005)

valence quarks unpolarized proton



DVCS + BH with μ+↓ and μ-↑ beams
and unpolarized proton target



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

Beam Charge & Spin Difference

$$\mathcal{D}_{CS,U} \equiv d\sigma(\mu^{+\downarrow}) - d\sigma(\mu^{-\uparrow}) = 2(e_\mu\, a^{BH}\, \mathcal{R}e\mathcal{T}^{DVCS} + P_\mu\, d\sigma^{DVCS}_{pol})$$

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

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

Beam Charge & Spin Sum

$$\mathcal{S}_{CS,U} \equiv d\sigma(\mu^{+\downarrow}) + d\sigma(\mu^{-\uparrow}) = 2(d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + e_\mu P_\mu\, a^{BH}\, Im\mathcal{T}^{DVCS})$$

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

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

Assumptions for the proposal projections

- polarised muon beam with 160 GeV energy
- 48 s SPS period with 9.6 s spill duration
- μ^+ beam intensity 4.6 x 10^8 muons / spill
- 3 times smaller intensity for μ^- beam
- running time 280 days (70 days with μ^+, 210 days with μ^-)
- a) 2.5 m LH target => $\mathcal{L}$ = 1. x 10^{32} $cm^{-2}s^{-1}$ for μ^+ beam

  b) 1.2 m NH_3 target => $\mathcal{L}$ = 3.4 x 10^{32} $cm^{-2}s^{-1}$ for μ^+ beam
- a new recoil proton detector(s) (RPD) surrounding the target(s)
- two existing electromagnetic calorimeters (ECAL1, ECAL2)

  \+ additional new large angle calorimeter (ECAL0)
- an overall global efficiency ε_{global} = 0.1

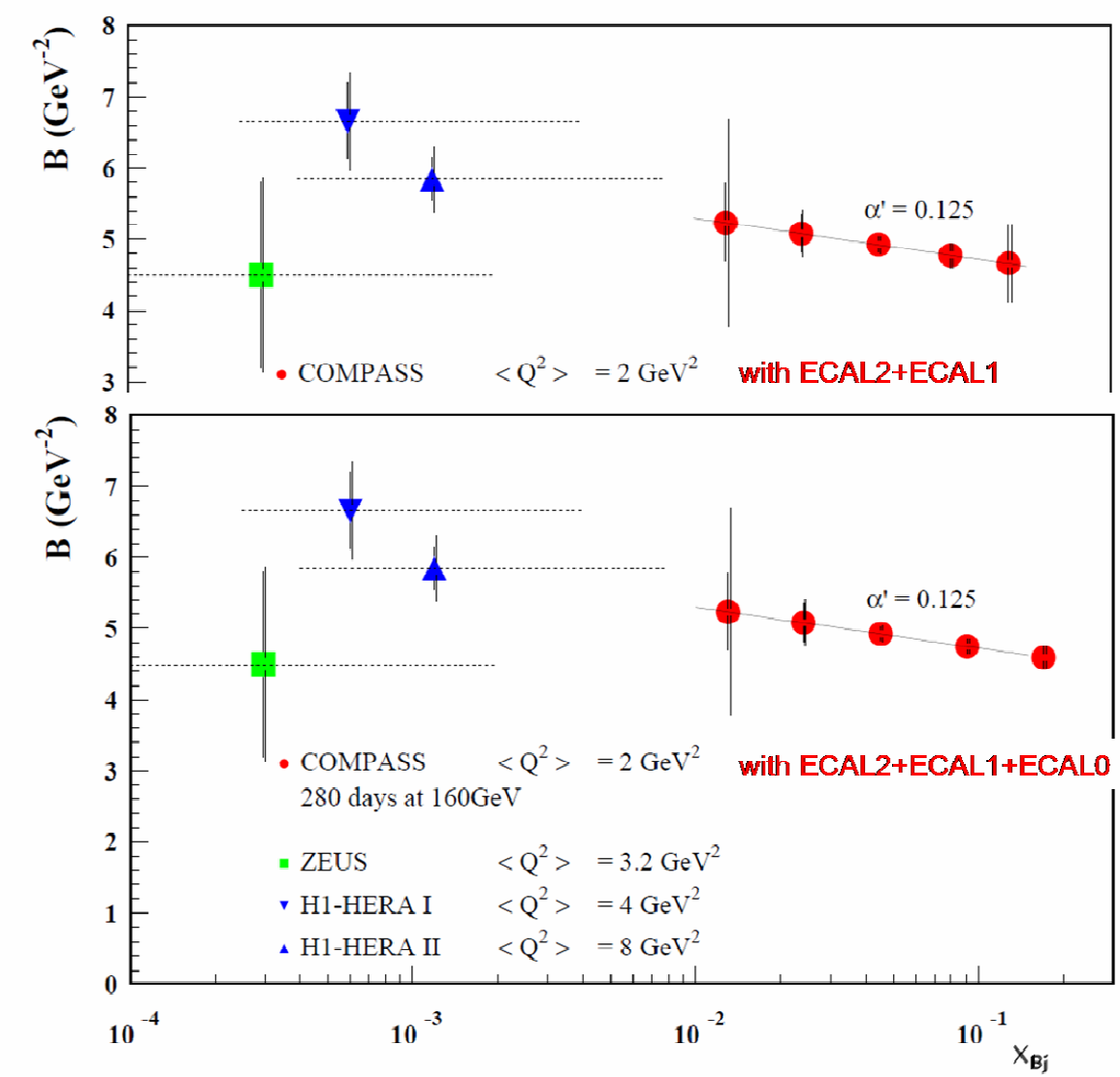
2 generators for single photon production (BH+DVCS) used:

a) VGG code b) FFS model adapted for COMPASS (by AS)

t-slope measurement for DVCS; relevant for nucleon 'tomography'

Using $\mathcal{S}_{CS,U}$, integrating over ϕ and subtracting BH $\longrightarrow$ $d\sigma_{DVCS}/dt \sim \exp(-B|t|)$

'tomography': $B(x) \Leftrightarrow \langle r_T^2 \rangle(x)$



FFS model

adapted for COMPASS (by AS)

assumed

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

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

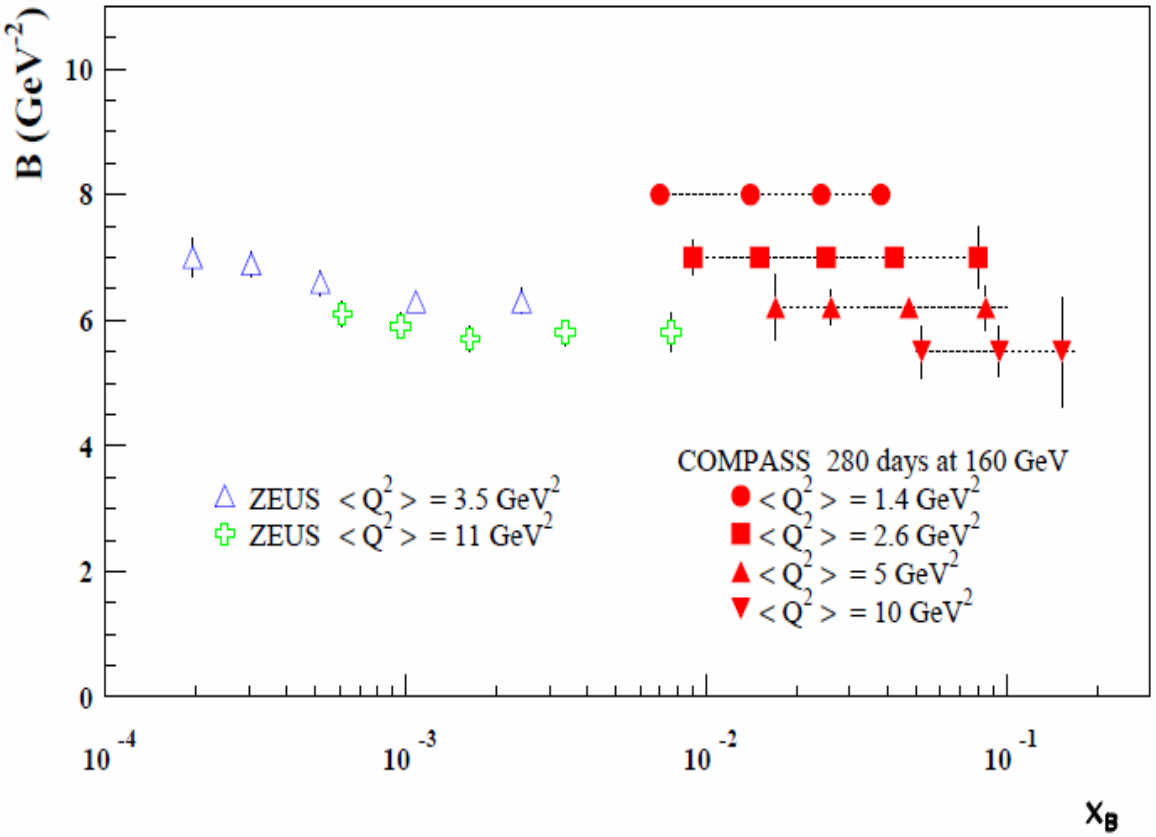
160 GeV muon beam
2.5m LH_2 target
ε_{global} = 10%, 280 days
L = 1222pb^{-1}

$0.06 < |t| < 0.64\ \text{GeV}^2$

assumed 3% systematic error on extracted DVCS c.s.

t-slope measurement for exclusive ρ^0 production

$d\sigma_{\gamma N \to \rho N}/dt \sim \exp(-B|t|)$

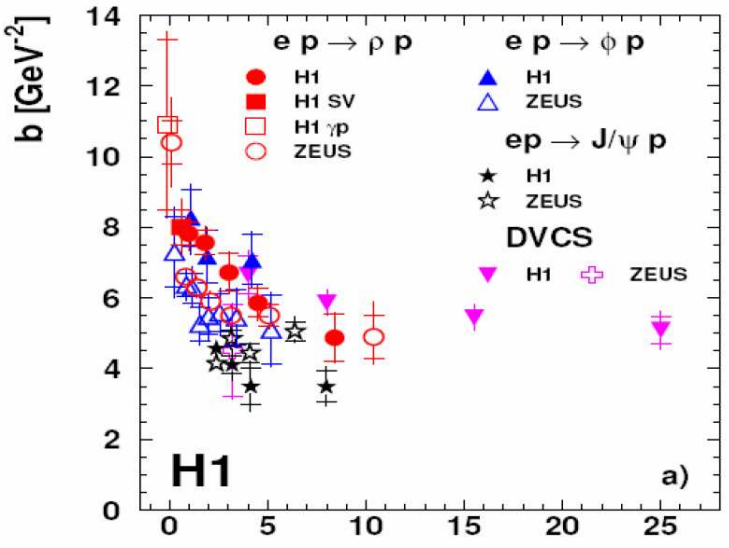


At large Q^2 slope B sensitive mostly to the nucleon size

model by AS with normalisation to Goloskokov and Kroll

160 GeV muon beam
2.5m LH_2 target
ε_{global} = 10%, 280 days
L = 1222pb^{-1}

$0.06 < |t| < 0.64$ GeV^2



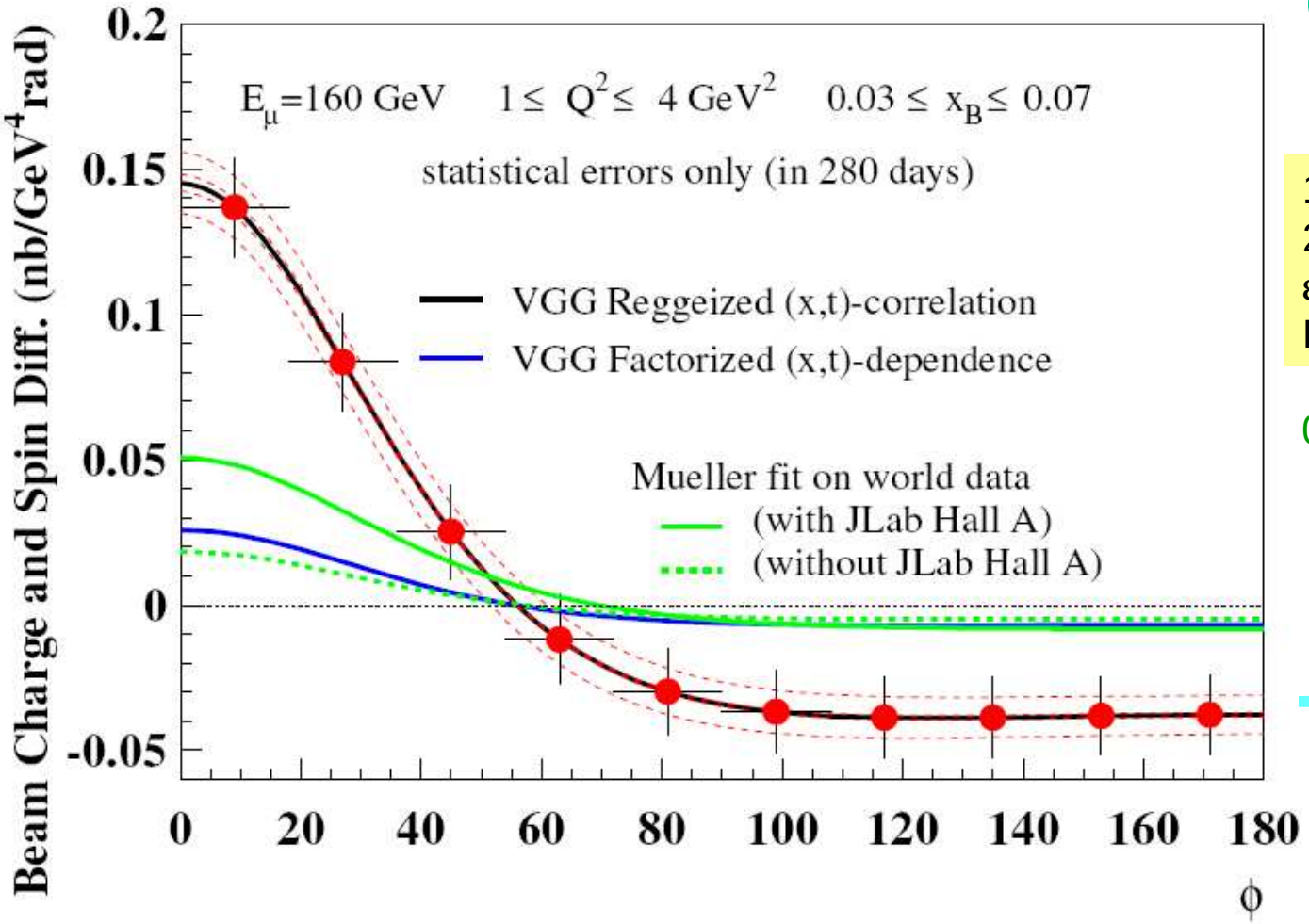
$\mu^2 = (Q^2+M_V^2)/4$
(= Q^2 for DVCS)

Beam Charge&Spin Difference of cross sections

$$\mathcal{D}_{CS,U} \equiv d\sigma(\mu^{+\downarrow}) - d\sigma(\mu^{-\uparrow}) = 2(e_\mu\, a^{BH}\, \mathcal{R}e T^{DVCS} + P_\mu\, d\sigma^{DVCS}_{pol})$$

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

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



160 GeV muon beam
2.5m LH_2 target
ε_{global} = 10%, 280 days
L = 1222pb^{-1}

$0.06 < |t| < 0.64$ GeV²

$$\ldots + c_1^{Int}\cos\varphi + \ldots$$

$\Rightarrow \mathcal{R}e(F_1\mathcal{H})$

Sensitivity of COMPASS; cosϕ modulation

$$BCSA = \mathcal{D}_{cs,U} / S_{cs,U} = A_0 + A^{\cos\phi}_{CS,U} \cos\phi + A_2 \cos 2\phi$$

$A^{\cos\phi}_{CS,U}$ => c_1^{Int} $\Rightarrow \mathcal{R}e(F_1\mathcal{H})$

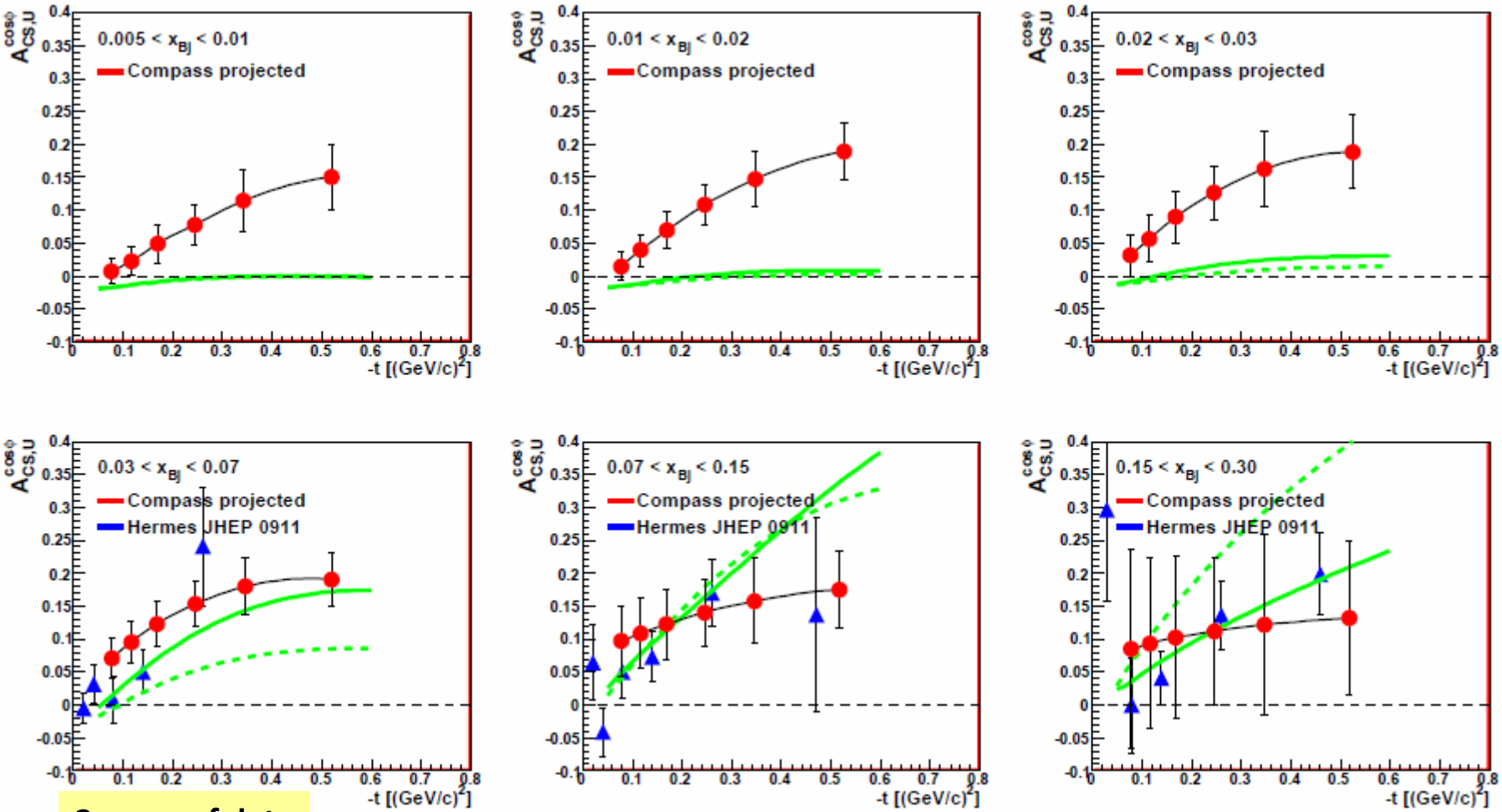
Mueller's fits to world data

VGG

$\mathcal{R}e(F_1\mathcal{H})$ > 0 at H1

< 0 at HERMES/JLab

Value of x_B for the node?



2 years of data

with ECAL2 + ECAL1 + ECAL0

‘Stage 2’ of COMPASS GPD program

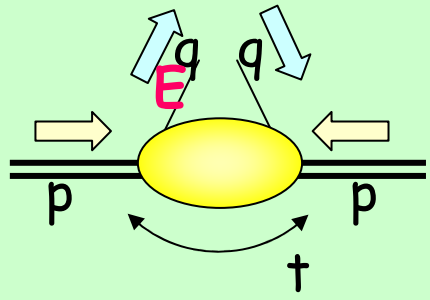
DVCS and HEMP with transversely polarised proton target (NH_3)

to constrain GPD E

- **Contribution to the nucleon spin puzzle**

  E related to the orbital angular momentum

$$J_q = \frac{1}{2} \int x \, (H^q(x,\xi,0) + E^q(x,\xi,0)) \, dx$$



Single γ production with transversely polarised target

$$d\sigma_{(\mu p \to \mu p \gamma)} = d\sigma_{U(\mu p \to \mu p \gamma)} + d\sigma_{T(\mu p \to \mu p \gamma)}$$

unpolarized target — transversely polarized target

to isolate TTS part measurements at opposite target polarisations needed

$$d\sigma_T = \tfrac{1}{2}\{d\sigma\,(S_T = +P_T) - d\sigma(S_T = -P_T)\}$$

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

$$+ S_T\, e_\mu\, a_T^{BH}\, T_T^{DVCS} + S_T\, e_\mu\, P_\mu\, a_T^{BH}\, T_T^{DVCS}{}_{pol}$$

to disentangle DVCS and Interference terms having the same azimuthal dependence

both μ+↓ and μ-↑ beams needed

cf. the next slide

measure

$$\mathcal{D}_{CS,T} \equiv d\sigma_T(\mu^{+\downarrow}) - d\sigma_T(\mu^{-\uparrow})$$

$$\mathcal{S}_{CS,T} \equiv d\sigma_T(\mu^{+\downarrow}) + d\sigma_T(\mu^{-\uparrow})$$

or/and

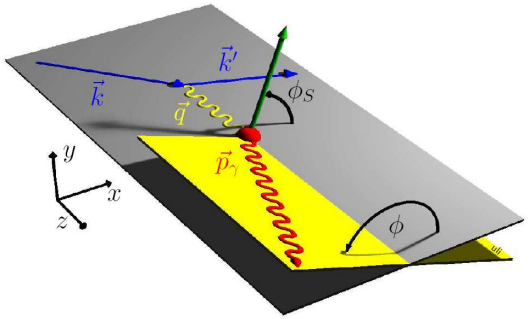
$$\mathcal{A}^D_{CS,T} \equiv \mathcal{D}_{CS,T}/d\sigma_0$$

$$\mathcal{A}^S_{CS,T} \equiv \mathcal{S}_{CS,T}/d\sigma_0$$

$d\sigma_0$ is unpolarised, charge averaged cross section

Harmonics decomposition of TTS-dependent 1 γ production cross section

Belitsky, Müller, Kirchner



$$d\sigma_T^{BH} = \frac{\Gamma(x_B, Q^2, t)}{P_1(\phi)P_2(\phi)}\left(c_{0,T}^{BH}\cos(\phi-\phi_s) + c_{1,T}^{BH}\cos(\phi-\phi_s)\cos\phi + s_{1,T}^{BH}\sin(\phi-\phi_s)\sin\phi\right) \cdot S_T\, P_\mu$$

$$d\sigma_T^{DVCS} = \frac{e^6}{y^2Q^2}\left(c_{0,T-}^{DVCS}\sin(\phi-\phi_s) + c_{1,T-}^{DVCS}\sin(\phi-\phi_s)\cos\phi + s_{1,T+}^{DVCS}\cos(\phi-\phi_s)\sin\phi + \ldots\right) \cdot S_T$$

$$d\sigma_{T,pol}^{DVCS} = \frac{e^6}{y^2Q^2}\left(c_{0,T+}^{DVCS}\cos(\phi-\phi_s) + c_{1,T+}^{DVCS}\cos(\phi-\phi_s)\cos\phi + s_{1,T-}^{DVCS}\sin(\phi-\phi_s)\sin\phi + \ldots\right) \cdot S_T\, P_\mu$$

$$a_T^{BH}T_T^{DVCS} = \frac{e^6}{xy^3tP_1(\phi)P_2(\phi)}\left(c_{0,T}^{Int}\sin(\phi-\phi_s) + c_{1,T-}^{Int}\sin(\phi-\phi_s)\cos\phi + s_{1,T+}^{Int}\cos(\phi-\phi_s)\sin\phi + \ldots\right) \cdot S_T\, e_\mu$$

$$a_T^{BH}T_{T,pol}^{DVCS} = \frac{e^6}{xy^3tP_1(\phi)P_2(\phi)}\left(c_{0,T+}^{Int}\cos(\phi-\phi_s) + c_{1,T+}^{Int}\cos(\phi-\phi_s)\cos\phi + s_{1,T-}^{Int}\sin(\phi-\phi_s)\sin\phi + \ldots\right) \cdot S_T\, e_\mu\, P_\mu$$

twist-2 terms

not shown are terms with sin(kφ) and cos(kφ) (k=2,3) dependence which are twist-3 and NLO twist-2 gluon helicity flip terms

Sensitivity to GPD E

the most promissing Transverse Target Spin asymmetry

$$A^{D}_{CS,T}\,(\text{ or } A_{UT})\ \sin(\phi\text{-}\phi s)\cos\phi \rightarrow C_{1,\mathrm{T}\text{-}}{}^{Int}$$

COMPASS HERMES

$$C^{Int}_{1,T-} \propto -\frac{M}{Q}\mathrm{Im}\left\{\frac{t}{4M^2}\left[(2-x_B)F_1\mathcal{E} - 4\frac{1-x_B}{2-x_B}F_2\mathcal{H}\right]\right.$$
$$\left. +x_B\xi\left[F_1(\mathcal{H}+\mathcal{E}) - (F_1+F_2)(\widetilde{\mathcal{H}}+\frac{t}{4M^2}\widetilde{\mathcal{E}})\right]\right\}$$

Study of azimuthal asymmetries from transversely polarized NH_3 target is a part of Phase 2 of COMPASS GPD program

example: COMPASS projections for

$$A^{D}_{CS,T}\ \sin(\phi\text{-}\phi s)\cos\phi$$

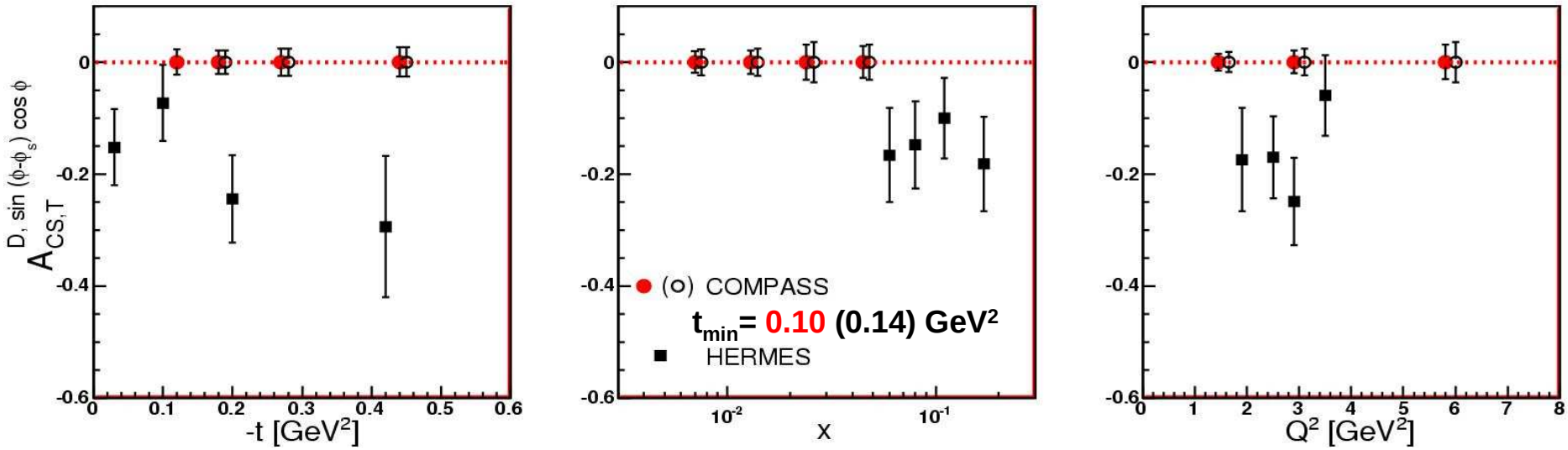
FFS model

adapted for COMPASS (by AS)

160 GeV muon beam
1.2m NH_3 target
ε_{global} = 10%, 280 days
ECAL1+ECAL2 only

for $\mu\, p^{\uparrow} \rightarrow \mu\, \gamma\, p$
dilution factor f=0.26

0.10 (0.14) < |t| < 0.64 GeV²



Typical statistical errors of TTS azimuthal asymmetries:

projections for COMPASS ≈ 0.03

for HERMES ≈ 0.08

TTS asymmetry $A_{UT}^{\sin(\phi-\phi_S)}$ for ρ^0 production from COMPASS

see talk by P. Sznajder this afternoon

$\mu\ N \to \mu'\ \rho^0\ N'$

$$\left[\frac{\alpha_{em}}{8\pi^3}\frac{y^2}{1-\epsilon}\frac{1-x_B}{x_B}\frac{1}{Q^2}\right]^{-1}\frac{d\sigma}{dx_B dQ^2 d\phi d\phi_s} \simeq$$

$$\underbrace{\frac{1}{2}\left(\sigma_{++}^{++}+\sigma_{++}^{--}\right)+\epsilon\sigma_{00}^{++}}_{\text{unpolarised cross section}} - S_T \sin\left(\phi-\phi_s\right)\mathrm{Im}\left(\sigma_{++}^{+-}+\epsilon\sigma_{00}^{+-}\right)+\ \ldots$$

$$A_{UT}^{\sin(\phi-\phi_S)} = -\frac{\mathrm{Im}(\sigma_{++}^{+-}+\epsilon\,\sigma_{00}^{+-})}{\frac{1}{2}(\sigma_{++}^{++}+\sigma_{++}^{--})+\epsilon\,\sigma_{00}^{++}}$$

M. Diehl's notation:

$$\sigma_{mn}^{ij} \propto \sum_{spins}\left(A_m^i\right)^* A_n^j$$

A^k_l amplitude for $\gamma^* N \to \rho^0 N'$

l (k) – helicity of γ^* (N)

at leading twist :

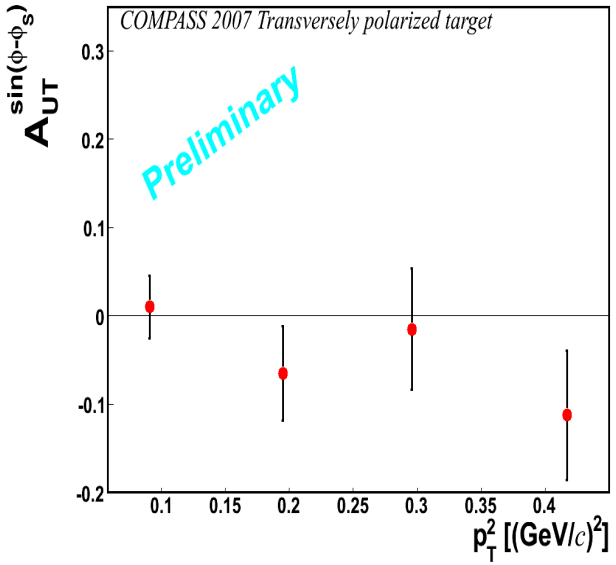
$$A_{UT}^{\sin(\phi-\phi_s)}(LT) = -\frac{\mathrm{Im}\,\sigma_{00}^{+-}}{\sigma_{00}^{++}} \approx -\frac{\sqrt{-t'}}{M_p\sqrt{1-\xi^2}}\frac{\mathrm{Im}(E_M^* H_M)}{\left|H_M^2\right|}$$

access to 'elusive' GPD E

H_M, E_M are weighted sums of convolutions of GPDs $H^{q,g}$, $E^{q,g}$ with hard scattering kernel and meson GDA

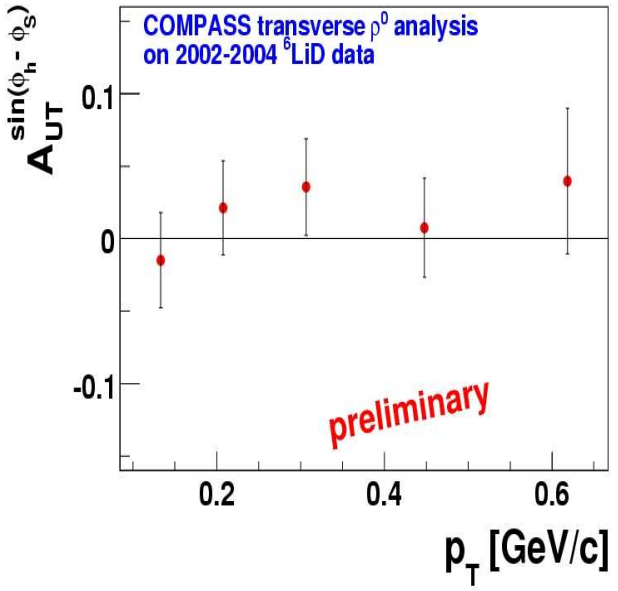
TTS asymmetry $A_{UT}^{\sin(\phi-\phi_S)}$ for ρ^0 production from COMPASS

COMPASS $p^\uparrow$



$< Q^2 > \approx 2.2$ (GeV/c)^2 , $< x_{Bj} > \approx 0.04$

COMPASS $d^\uparrow$



$< Q^2 > \approx 2.0$ (GeV/c)^2 , $< x_{Bj} > \approx 0.03$

$E^u_{val} \approx -E^d_{val}$ as indicated by anomalous magnetic moments of quarks κ^q

$E_{\rho 0} \sim \frac{2}{3} E^u + \frac{1}{3} E^d + \ldots$ for p

$E_{\rho 0} \sim E^u + E^d + \ldots$ for incoherent production on d

- Small asymmetries – approximate cancellation of contributions from GPDs E^u and E^d
- Unique COMPASS data for $d^\uparrow$ provide additional constrains on modelling GPDs E

Comparison to a GPD model

see the next talk by S. Goloskokov

- Goloskokov-Kroll

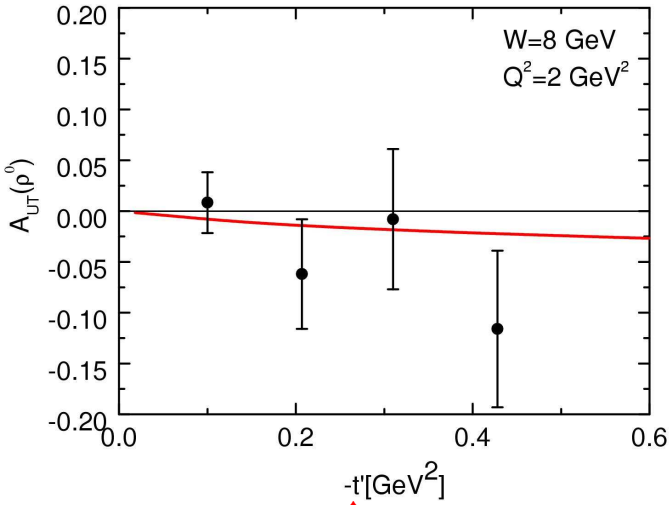
  [EPJ C53 (2008) 367]

'Hand-bag model';

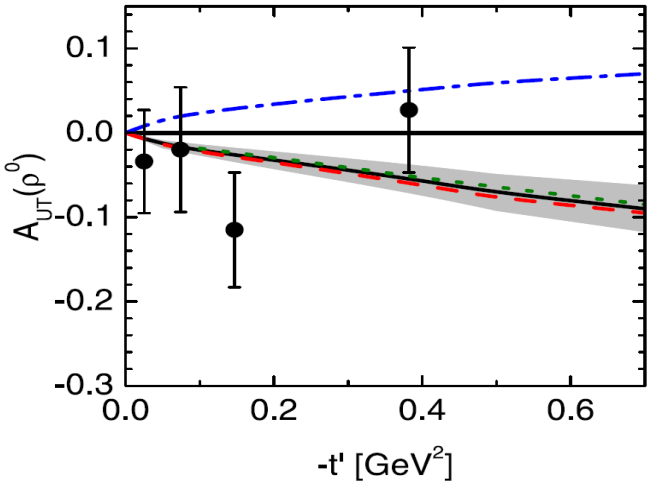
power corrections due to k_t of quarks

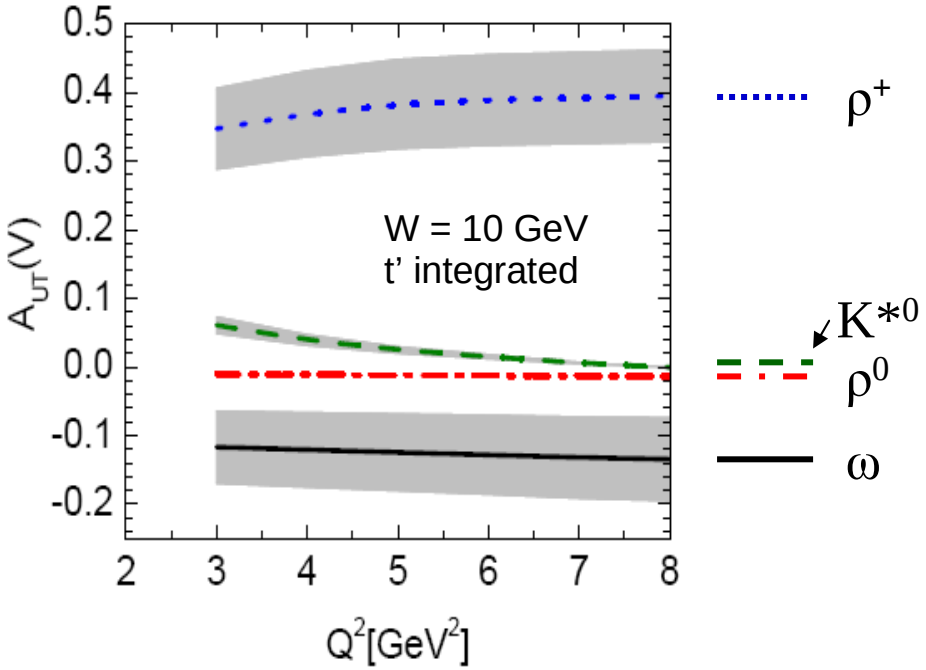
→ both contributions of γ^*_L and γ^*_T included

COMPASS $p^\uparrow$ preliminary



HERMES $p^\uparrow$





predictions for COMPASS

$A_{UT}(\rho) \approx -0.02$

$A_{UT}(\omega) \approx -0.10$

$E_{\rho 0} \sim \frac{2}{3} E^u + \frac{1}{3} E^d + \frac{3}{8} E^g$

$E_{\omega} \sim \frac{2}{3} E^u - \frac{1}{3} E^d + \frac{1}{8} E^g$

DVCS test runs in 2008-2009

Goal: evaluate feasibility to detect DVCS/BH in the COMPASS setup

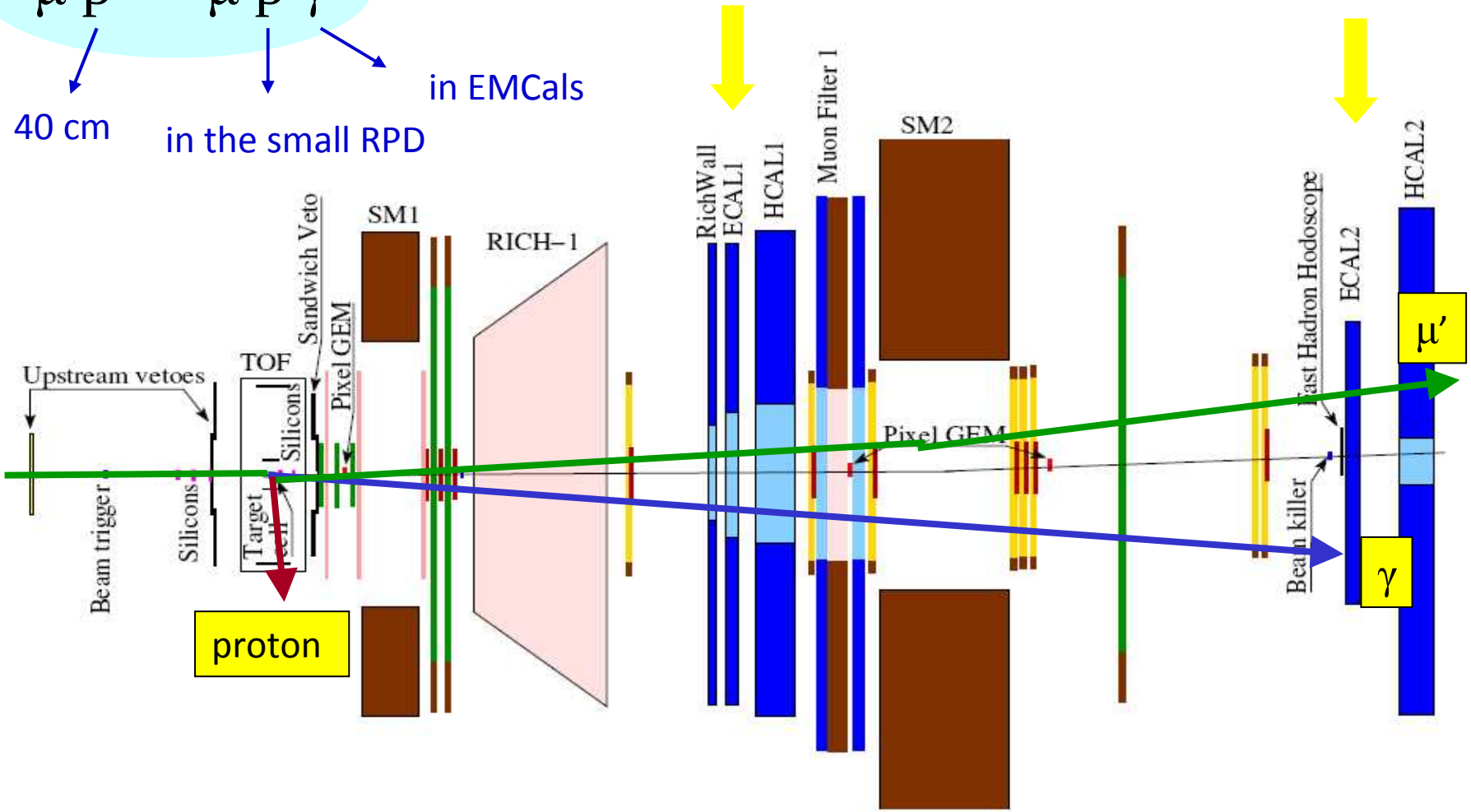
$\mu\, p \rightarrow \mu\, p\, \gamma$

LH 40 cm

in the small RPD

in EMCals

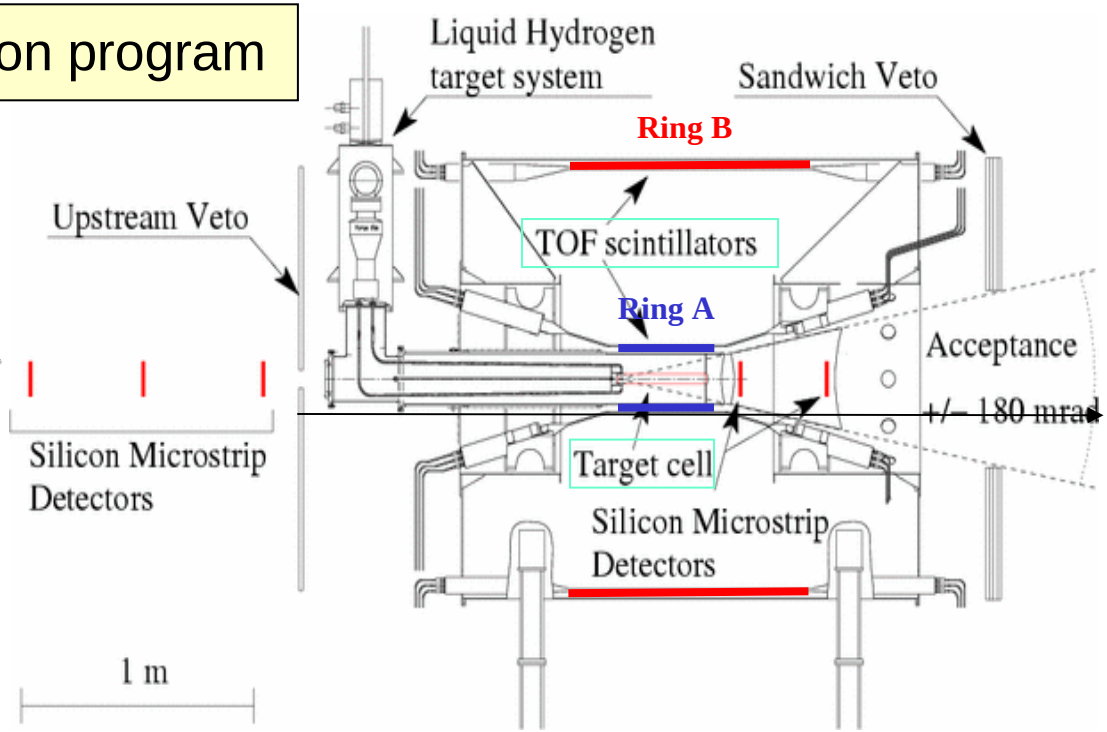
COMPASS 'hadron' set-up



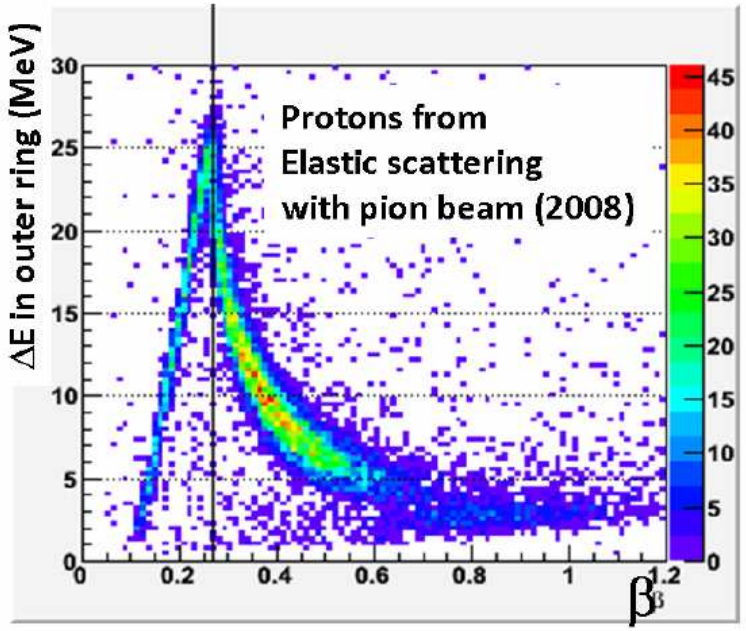
Short: 1.5 day in 2008 and 10 days in 2009 of 160 GeV muon beam (μ^+ and μ^-)

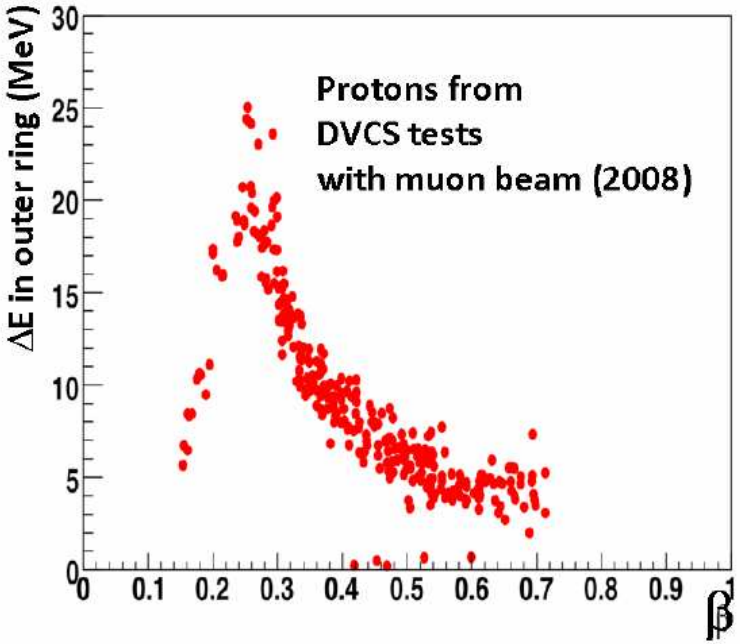
Recoil proton detector for hadron program

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



Proton identification in RPD





Selection of single γ events

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

- 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 in transverse plane

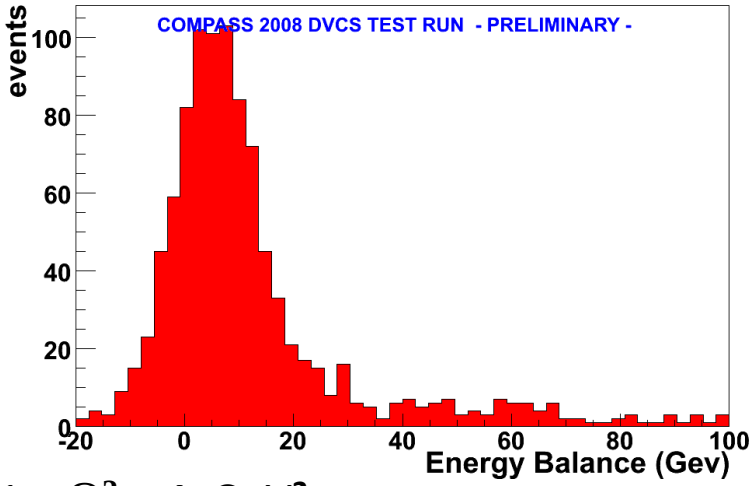
  $|\Delta p_{\perp}| < 0.2$ GeV

  $|\Delta\phi| < 41$ deg

- exclusivity cut on energy ballance (E_{miss})

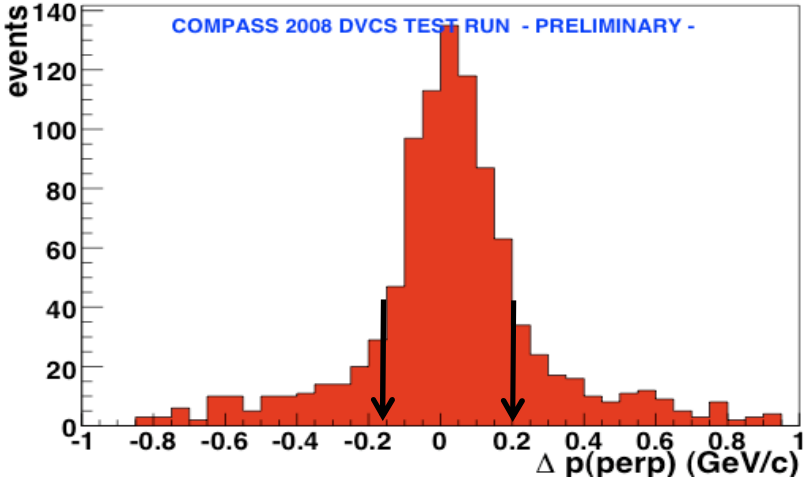
  $E_{miss} = E_{\mu} + M_p - (E_{\mu'} + E_p + E_{\gamma})$

  $|E_{miss}| < 20$ GeV

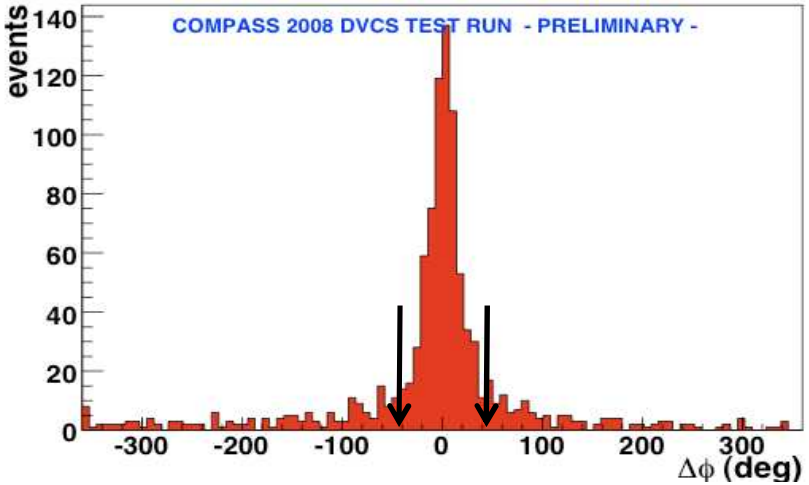


- $1 < Q^2 < 4$ GeV²

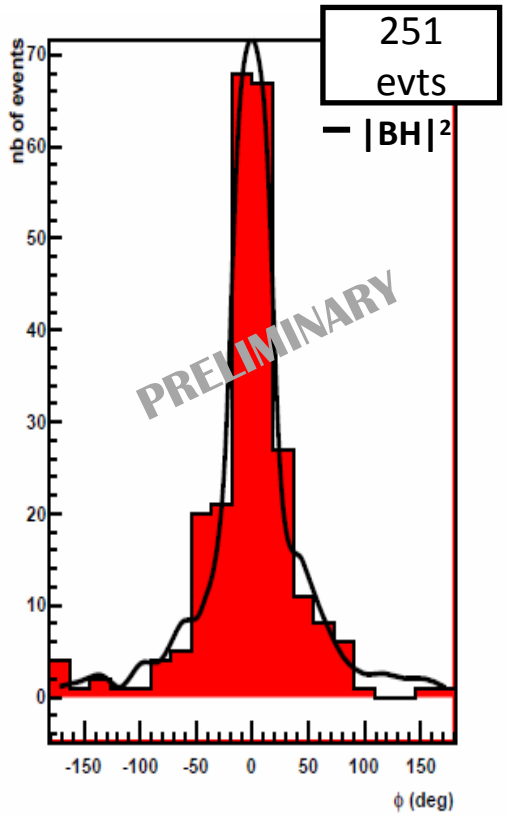
$\Delta p_{\perp} = |P^{\perp}_{miss}| - |P^{\perp}_{RPD}|$

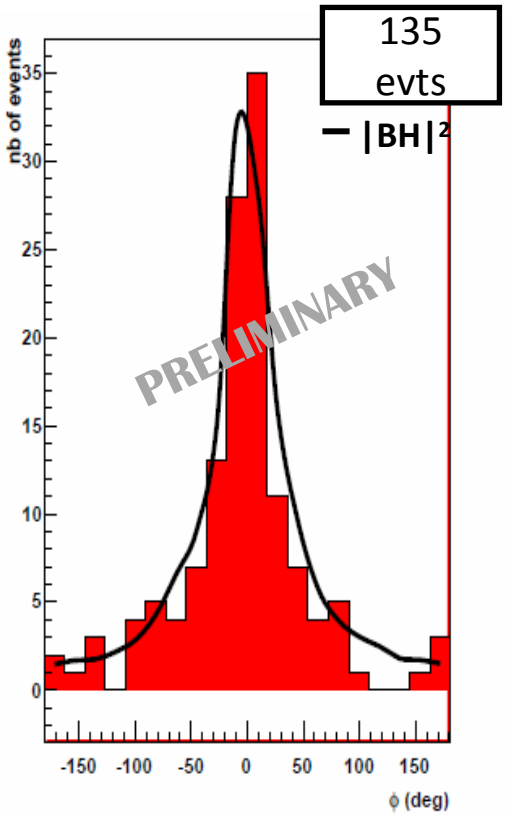


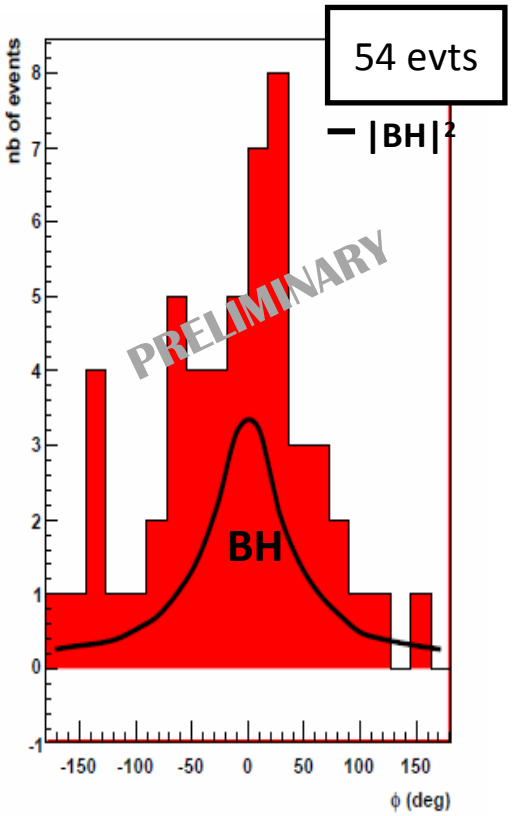
$\Delta\phi = \phi_{miss} - \phi_{RPD}$



Exclusive γ production from 2009 DVCS test run







$0.005 < x_B < 0.01$ | **$0.01 < x_B < 0.03$** | **$x_B > 0.03$**

$\epsilon_{\mu p \to \mu' \gamma p} \approx 35\%$

$\times (0.8)^4$ for SPS + COMPASS avail. + trigger eff + dead time

$\epsilon_{global} \approx 0.14$ confirmed $\epsilon_{global} = 0.1$

assumed for COMPASS-II projections

54 evts ≈ 20 BH

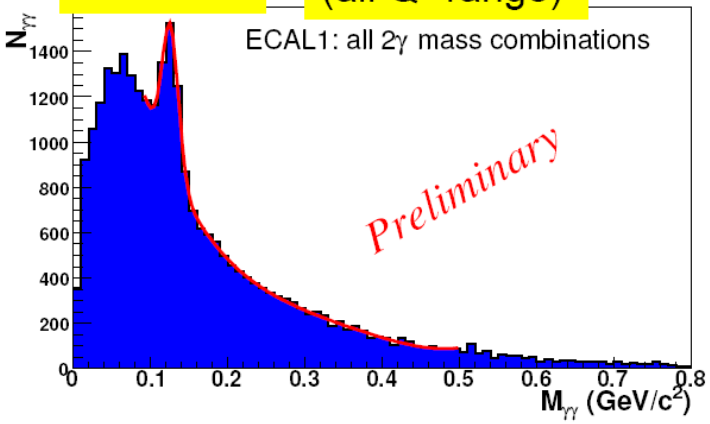
+ 22 DVCS

+ about 12 γ from π^0

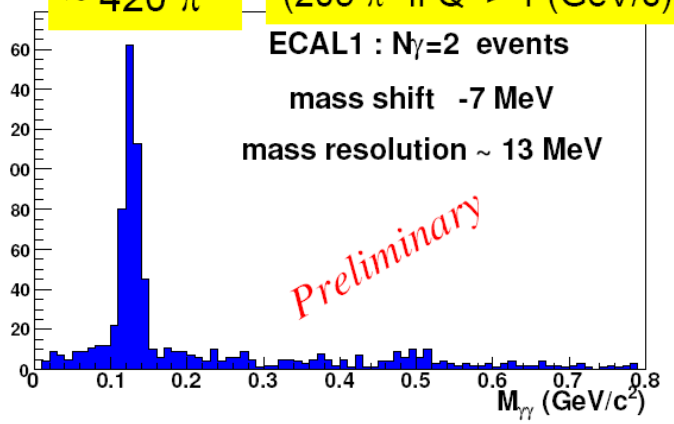
upper limit

Exclusive π^0 production from 2009 DVCS test run

~1700 π^0 (all Q^2 range)

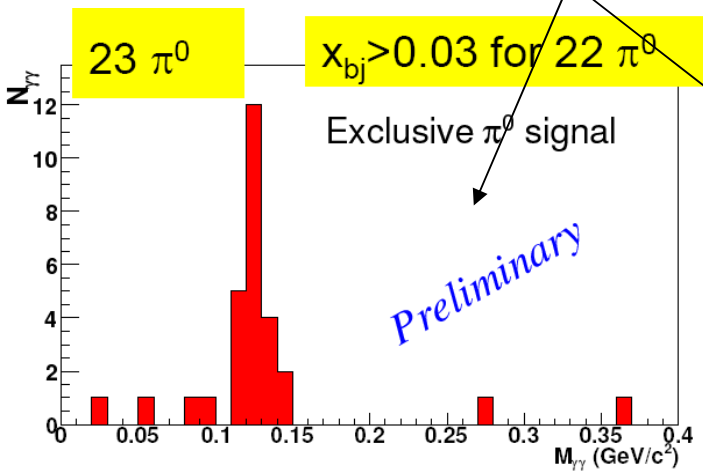


~ 420 π^0 (205 π^0 if $Q^2 > 1$ (GeV/c)^2)

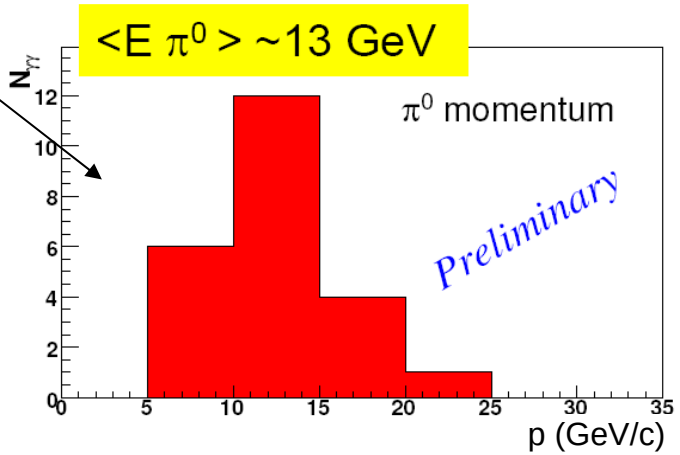


after exclusivity cuts (similar as for DVCS) and $Q^2 > 1$ GeV^2

23 π^0 x_{bj}>0.03 for 22 π^0



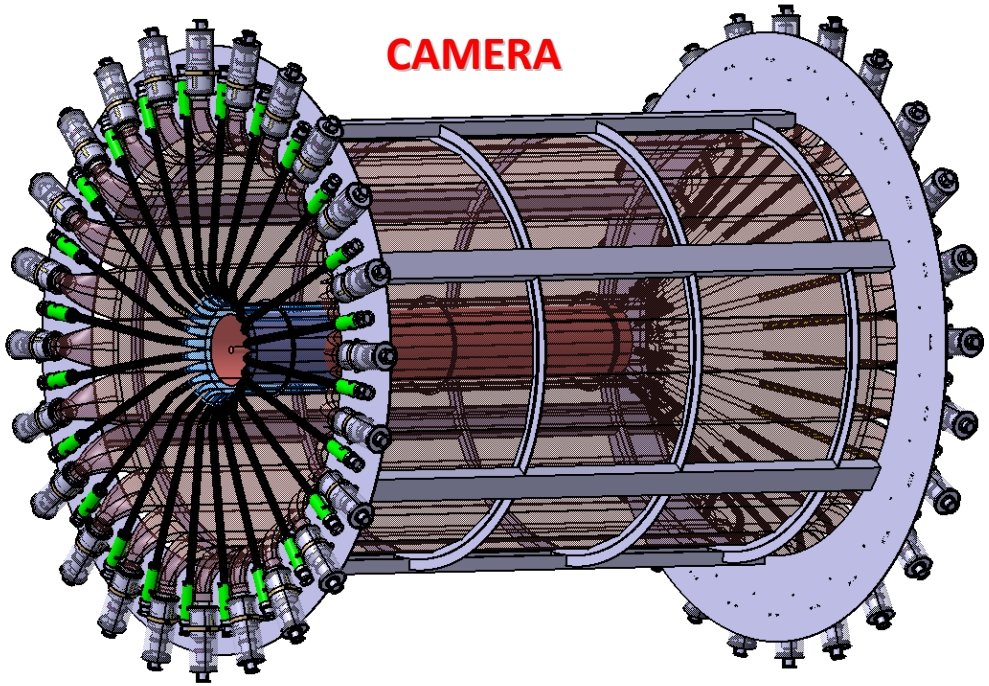
<E π^0 > ~13 GeV



ongoing work to give an estimate of cross section and t distribution

✓ Production of π^0 → sensitivity to GPDs $\tilde{E}$ and $\bar{E}_T$ ($\equiv 2\tilde{H}_T + E_T$)

New developments – target and recoil detector

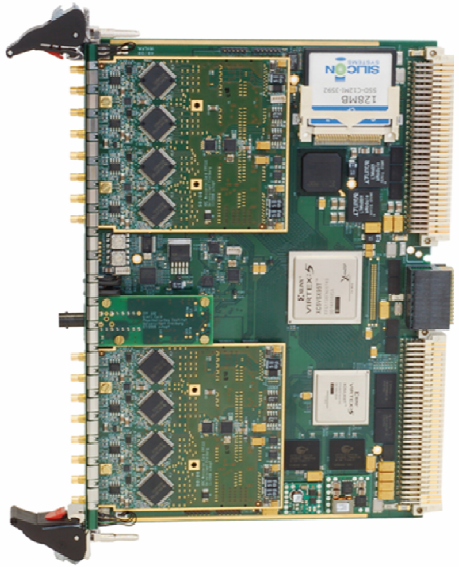


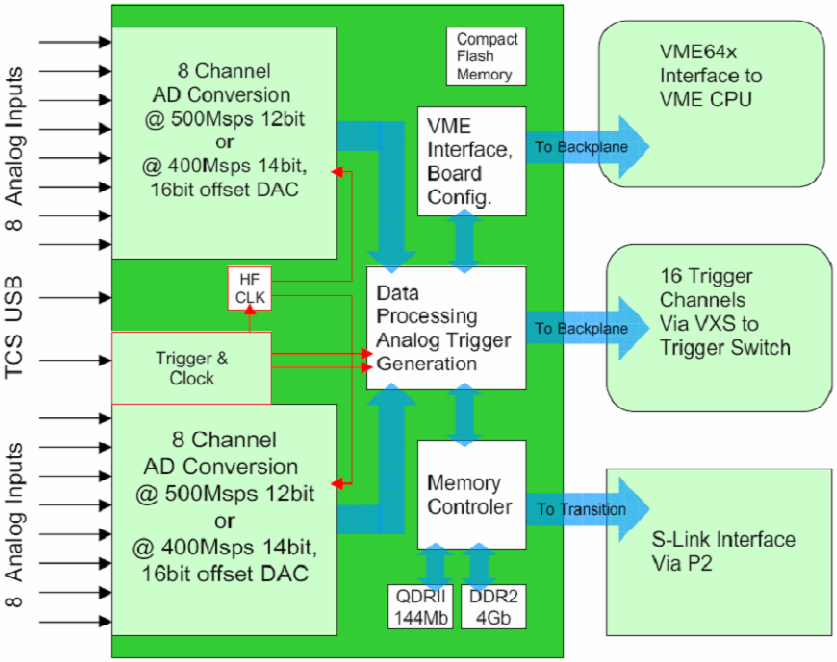
- 2.5m long LH target
- 4m long ToF barrel
  of 2 scintillator layers
- recoil proton ID by ToF and dE/dx
- ≈ 300 ps time resolution
- full scale prototype tested

high occupancy due to δ rays

GANDALF project:

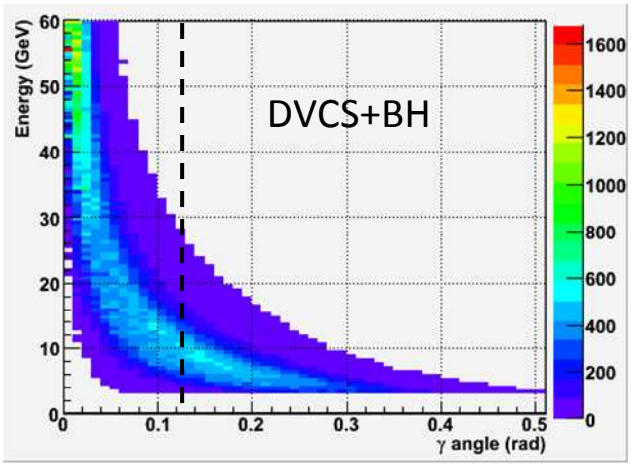
- 1 GHz digitsation of PMT signal to cope with high rate
- resolution > 10 ENOB
- self triggered

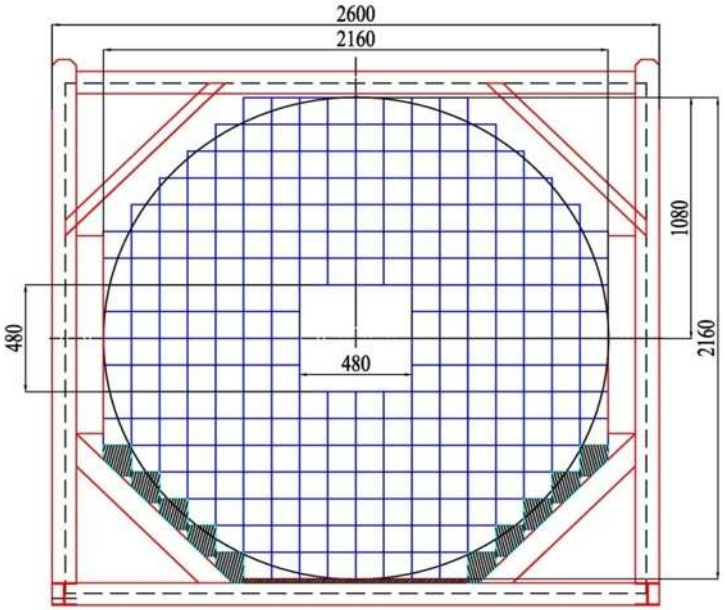




New developments - large-angle electromagnetic calorimeter ECAL0

existing
ECAL1&2





ECAL0 location and specifications

ECAL0 located downstream of CAMERA

- transverse size 216x216 cm^2 (approx.)
  modules arranged in a circular array of 1.08 m radius
- hole size 48x48 cm^2 (or 84x60 cm^2)
  decision to be taken soon
- granularity 4x4 cm^2
- energy range 0.1 - 30 GeV
- polar angle range 0.15-0.6 rad.
- energy resolution ~ (5-7)%/sqrt(E)
- time resolution 0.5-0.6 ns
- thickness $\lesssim$ 50 cm
- insensitive to magnetic field

Total:	248	9-cell modules
	2232	MAPDs
	the weight about 6-7 tons	

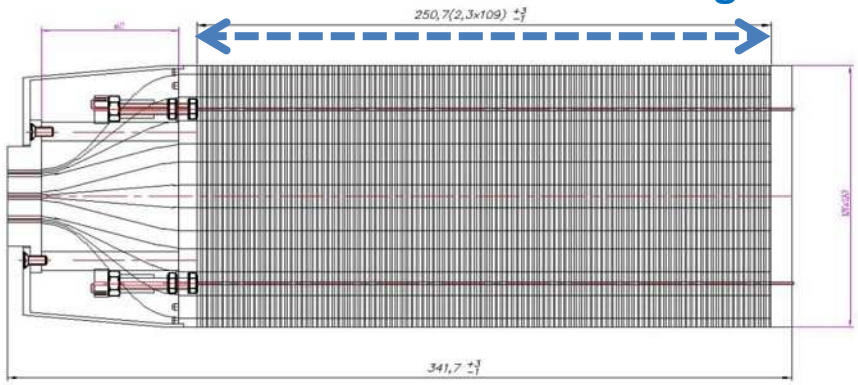
ECAL0 module

Module:

- size is 12x12 cm^2
- 9 cells, size is 4x4 cm^2
- 9 light collection systems
- 9 MAPDs
- 9 MSADC channels
- Temperature stabilization system (Peltier element, electronics)
- 9 Amplifiers
- Control system (LED, Laser)
- Power supply

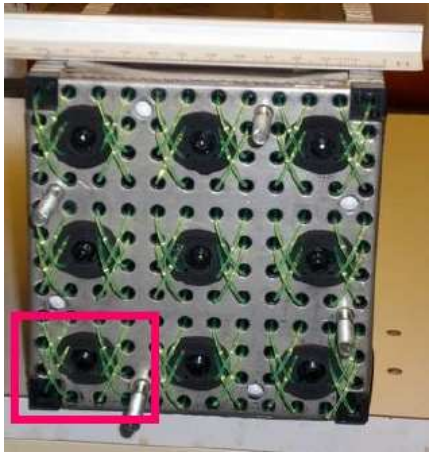
ECAL0 cell

252mm or 15 radiation length

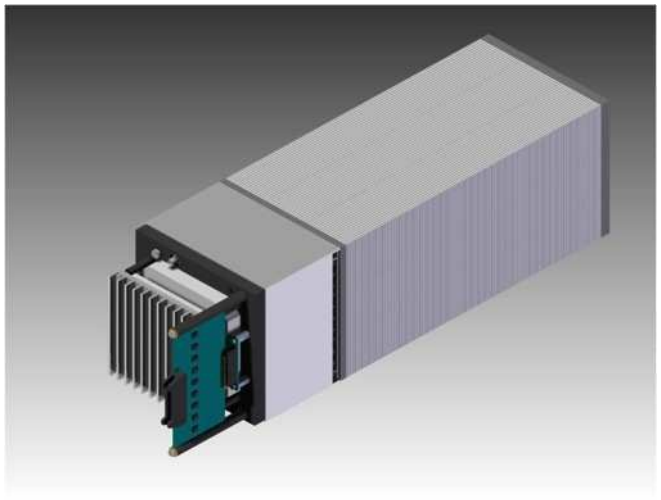


shashlyk technology
109 plates made of Sc 1.5 mm /Pb 0.8 mm

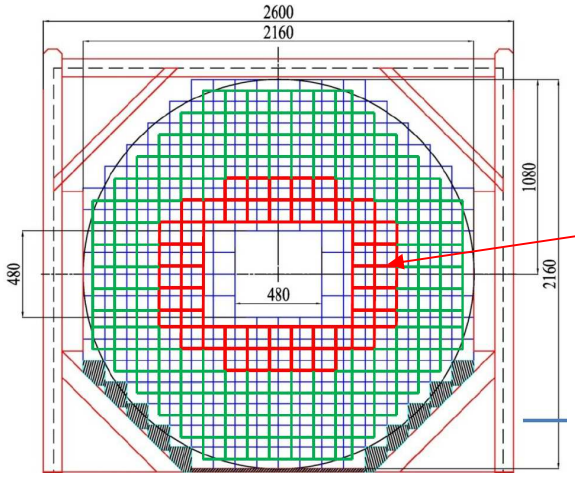
Micropixel Avalanche Photo Diodes
3 x 3 mm^2, number of pixels ~ 135 000



new module for tests in 2011



Start of GPD program of COMPASS-II in 2012 - 'dress rehearsal'

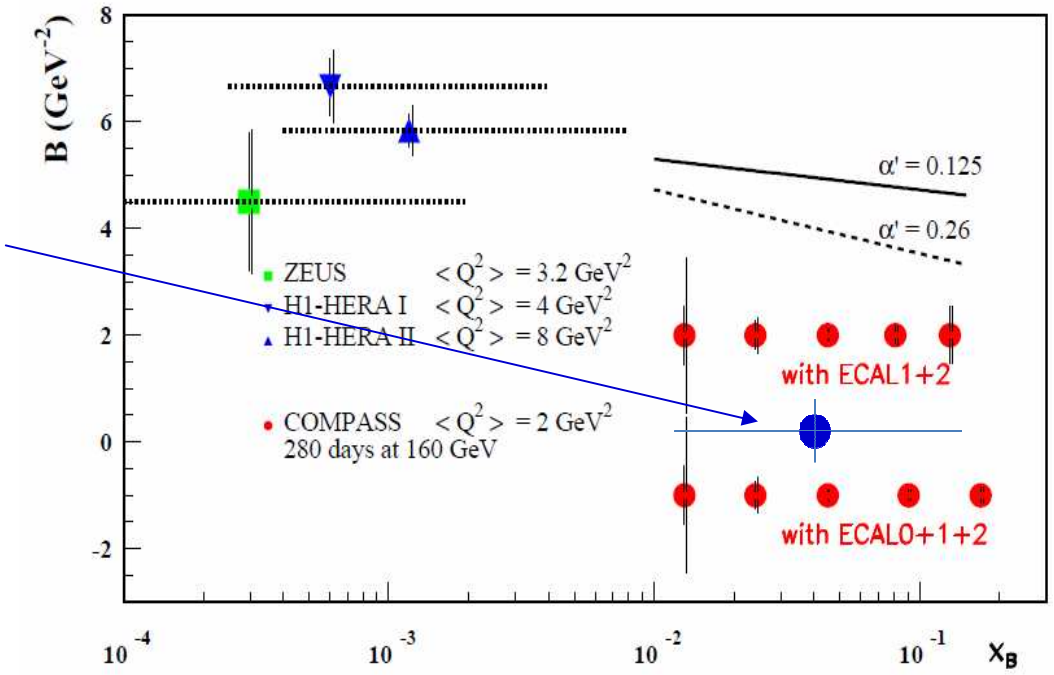


- 2.5m LH target and CAMERA ready by August 2012
- reduced ECAL0 (48 modules) ready by August 2012
- 3 weeks of comissioning and DVCS data taking

after 18 weeks of Primakoff measurements
which is the main goal in 2012

- projection for a physics result

from 1 week of DVCS test in 2012
1/40 of the complete statistics



Complete GPD program of Stage 1 with complete ECAL0 is scheduled for 2015-2016

Summary

- COMPASS has a great potential for GPD physics
  - ✓ unique polarised μ^+ and μ^- beams
  - ✓ favourable kinematic domain (x_{Bj})
- Large projects for new apparatus to be build
  - ✓ 4m RPD + large angle ECAL0 (phase 1)
  - ✓ recoil proton detector incorporated into a large polarised target (phase 2)
- Investigation of GPDs with both DVCS and HEMP on unpolarised nucleons
  - ✓ t-slope of DVCS and HEMP cross section
    → transverse distribution of partons
  - ✓ Beam Charge&Spin sum and difference of DVCS cross sections
    → $\mathcal{R}e\, T^{DVCS}$ and $\mathcal{I}m\, T^{DVCS}$ for the GPD H determination
  - ✓ Production of vector mesons ρ^0, ω, φ … → flavour separation for GPD H
  - ✓ Production of π^0 → sensitivity to GPDs $\tilde{E}$ and $\bar{E}_T$ ($\equiv 2\tilde{H}_T + E_T$)
- Transverse Target Spin Asymmetries for DVCS and hard exclusive VM production
  → GPD E and angular momentum of partons