Prospects for measurements of Generalized Parton Distributions at COMPASS

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on behalf of the COMPASS collaboration

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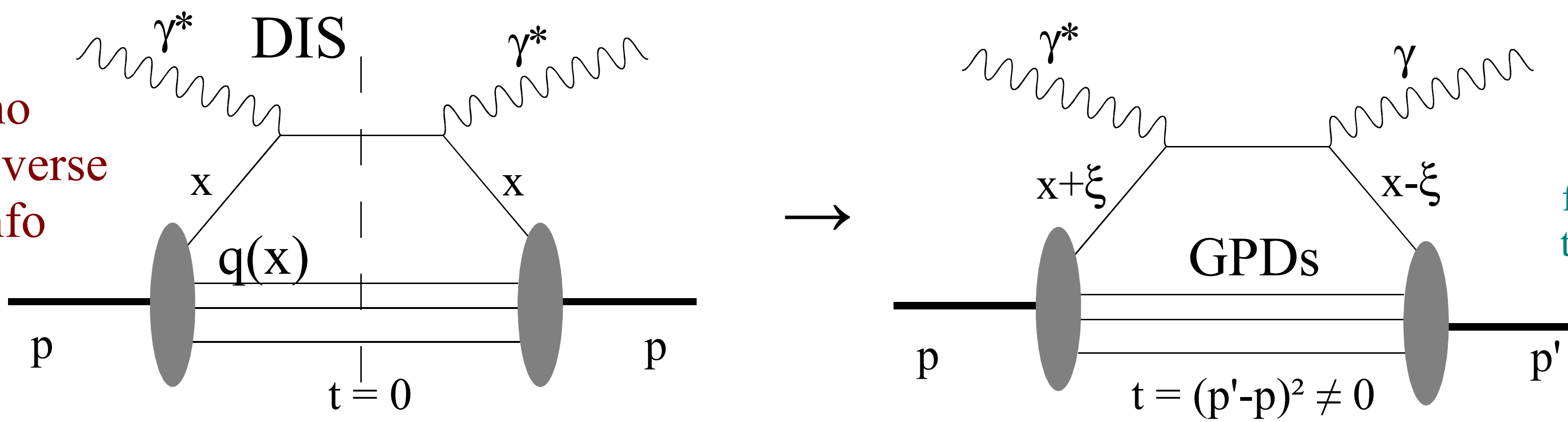
DSM/DAPNIA/SPhN

- Concept of GPDs
- DVCS measurement at Compass
- Detectors upgrades
- Results we can expect

Generalized parton distributions

no transverse info



Hard/soft parts factorisable if t not too large (<1 GeV²)

Parton transverse positions given by Fourier transform of $t_\perp=(p'-p)_\perp^2$

→ « 3D like » view of the nucleon

4 Generalized parton distribution: $H, E, \widetilde{H}, \widetilde{E}(x,\xi,t)$

GPDs linked to usual parton densities, form factors, and also q angular momentum:

$$H(x,0,0)=q(x)$$
$$\widetilde{H}(x,0,0)=\Delta q(x)$$

$$\sum_q e_q \int_{-1}^{1} dx\, H^q(x,\xi,t)=F_1(t)$$

$$\frac{1}{2}\sum_q e_q \int_{-1}^{1} dx\, x\,(H^q(x,\xi,0)+E^q(x,\xi,0))=J^{quarks}$$

Ji's sum rule

COMPASS

cea DSM - DAPNIA Service de Physique Nucléaire

"3D" nucleon description

Chiral dynamics (Strikman et al.)

Nucleon includes pion cloud at large transverse position

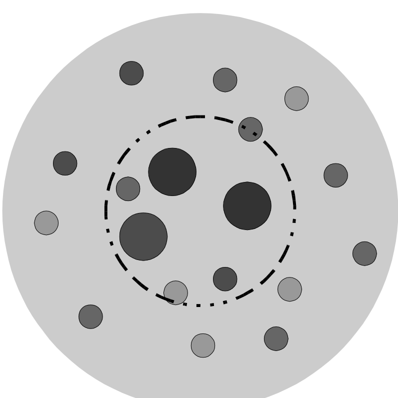
→ nucleon transverse size increases at low x_{Bj} ($< m_\pi/m_p$)

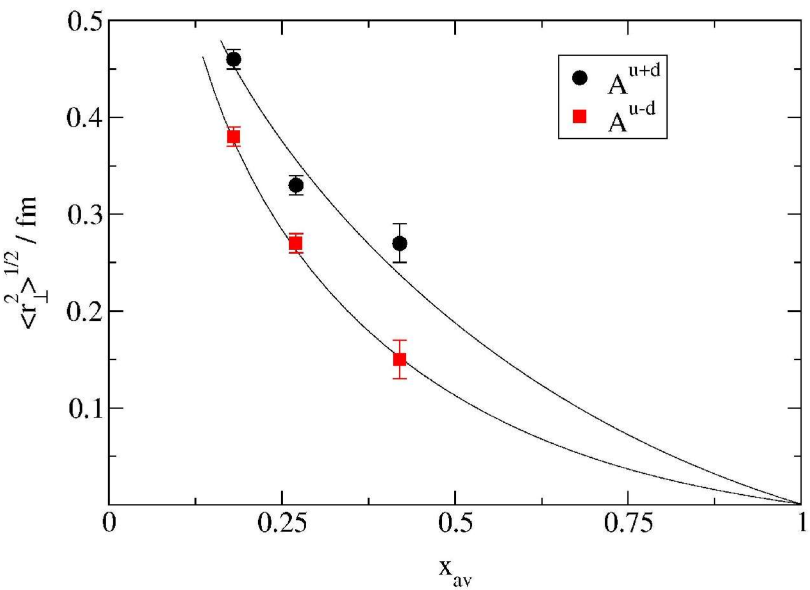
This can be tested within Compass kinematic domain

Lattice computations (Negele et al., Göckeler et al.)

nucleon = small valence quarks core (fast partons close to the center)

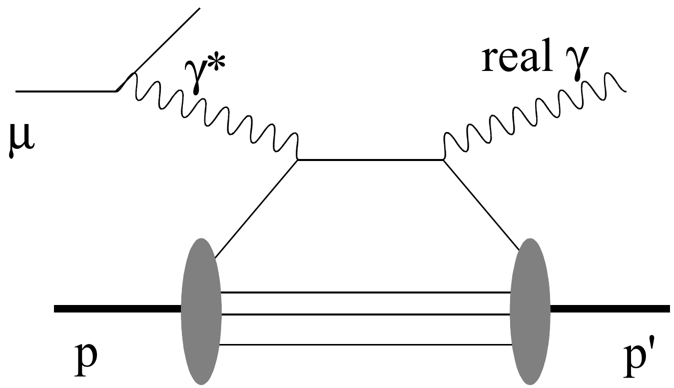
\+ large quark/gluon sea (slower partons in whole nucleon)

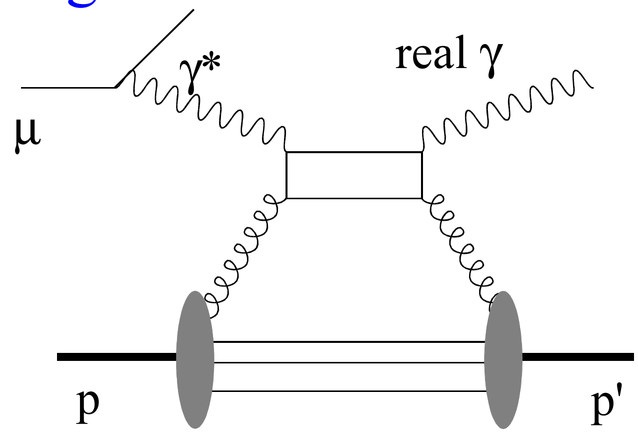




How to measure GPDs at COMPASS ?

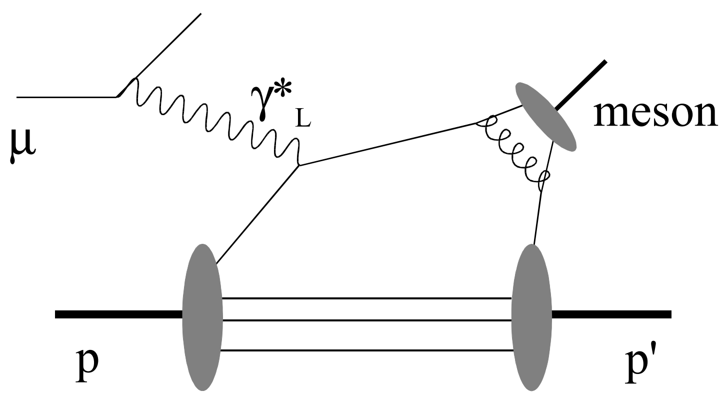
Deeply Virtual Compton Scattering:

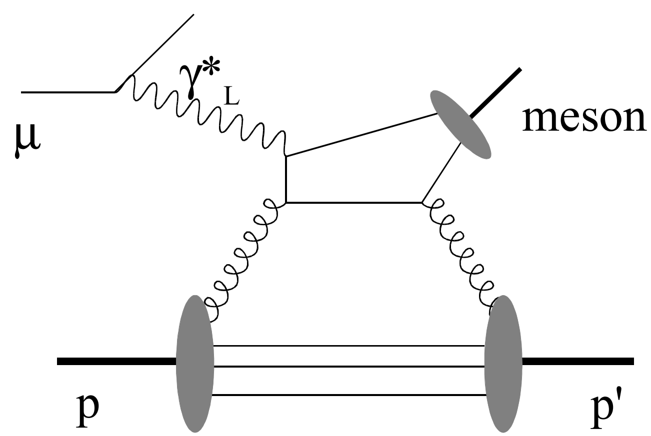




Direct and clean processes

Hard exclusive meson production:





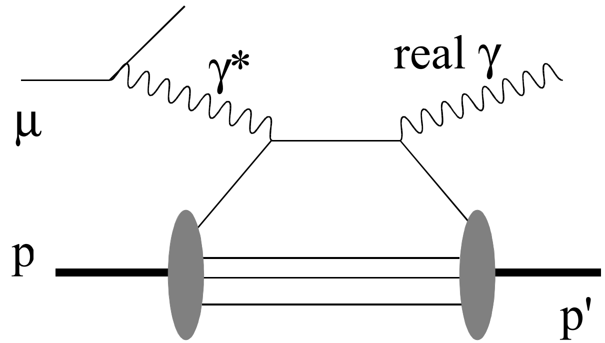
Access to GPD with vector and pseudo-scalar mesons

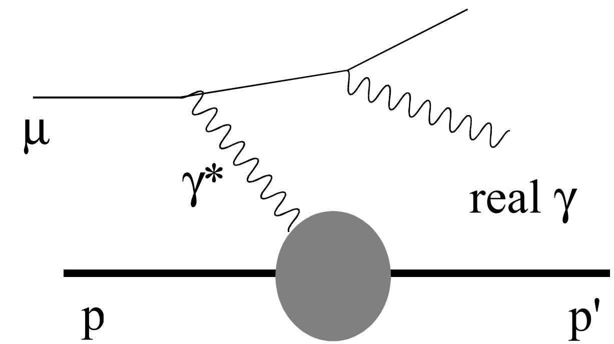
More complex

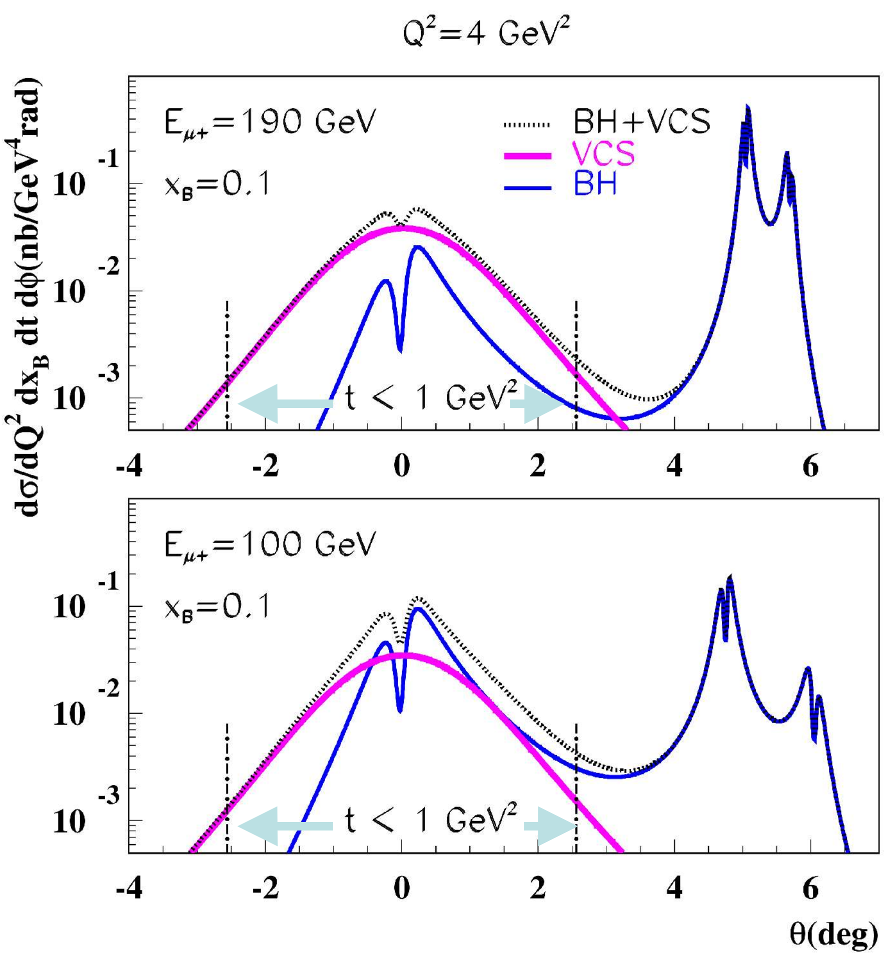
Factorizable if γ* longitudinal

GPD measurements with DVCS

2 competing processes:
DVCS and Bethe-Heitler







Relative amplitude depends of 1/y

$$1/y = 2\ mp_p E_{beam} x_B / Q^2$$

DVCS dominant at high E_{beam} = 190 GeV
→ access to DVCS cross section

DVCS-BH interference at low E_{beam} = 100 GeV
→ access to DVCS amplitude

DVCS amplitude extraction

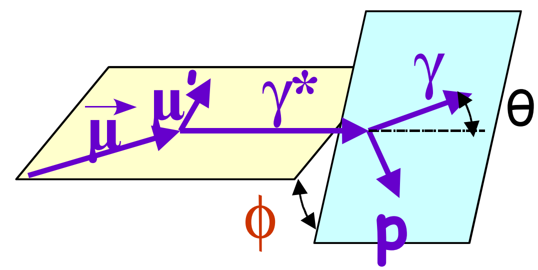
$$\frac{d\sigma(\mu p\rightarrow\mu p\gamma)}{d\phi}=A_{interf}(\cos n\phi)\left[e_\mu\left(c_1\cos\phi\,\Re e\,A^{DVCS}(\gamma^*_T)+\ldots\right)+e_\mu P_\mu\left(s_1\sin\phi\,\Im m\,A^{DVCS}(\gamma^*_T)+\ldots\right)\right]$$
$$+\frac{d\sigma_{DVCS}(\cos n\phi, P_\mu\sin\phi)}{d\phi}+\frac{d\sigma_{BH}(\cos n\phi)}{d\phi}$$

$A^{DVCS}(\gamma_T^*)$ DVCS amplitude

ϕ angle between leptonic and hadronic planes

e_μ, P_μ beam charge and polarization

$d\sigma_{BH}$, A_{interf}, c_i, s_i are known



Using $\mu^{+\rightarrow}$ and $\mu^{-\leftarrow}$ beam and ϕ dependence we can disentangle real and imaginary parts of $A(\gamma^*_T)$

E_μ=190GeV: $$\left[A^{DVCS}_{\xi\sim x_{Bj}/2}(\mu p\rightarrow\mu p\gamma)\right]^2\sim\left[P\int_{-1}^{1}dx\frac{H(x,\xi,t)}{x-\xi}-i\pi H(x=\xi,\xi,t)\right]^2$$

E_μ=100GeV: $$\sigma(\mu^{+\rightarrow})-\sigma(\mu^{-\leftarrow})\sim\Re e\,A(\gamma^*_T)\sim P\int_{-1}^{1}dx\frac{H(x,\xi,t)}{x-\xi}$$

$$\sigma(\mu^{+\rightarrow})+\sigma(\mu^{-\leftarrow})\sim\Im m\,A(\gamma^*_T)\sim-i\pi H(x=\xi,\xi,t)$$

Requirements on experimental set-up
and how COMPASS can fulfill them

CERN M2 muon beam:

tunable beam energy (100 - 190 GeV ok)

μ^+ and μ^- beam with same current and opposite polarization ($|P_\mu| = 80\%$)

highest available intensity 2.10^8 μ/spill

Proton target:

liquid hydrogen target, 2.5 m long, 3 cm diameter: to be built

luminosity $L=1.3\ 10^{32}\ cm^{-2}s^{-1}$

Luminosity determination:

needed for cross section measurement

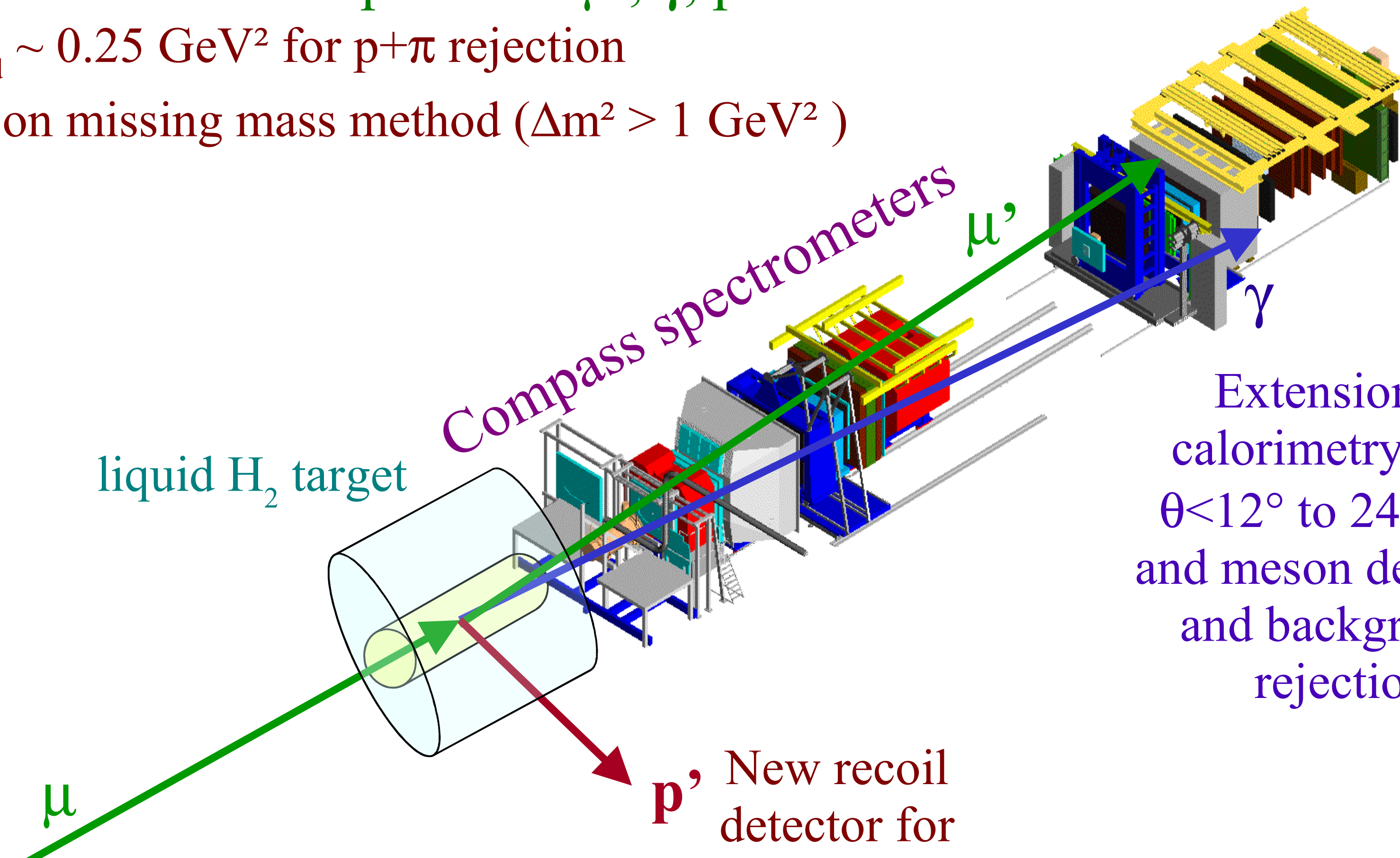
already done by NMC collab. at 1% accuracy, using random beam sampling and hodoscopes techniques

Requirements on detection

Need to detect the 3 final particles μ', γ, p

$\Delta m_p{}^2{}_{required}$ ~ 0.25 GeV² for p+π rejection

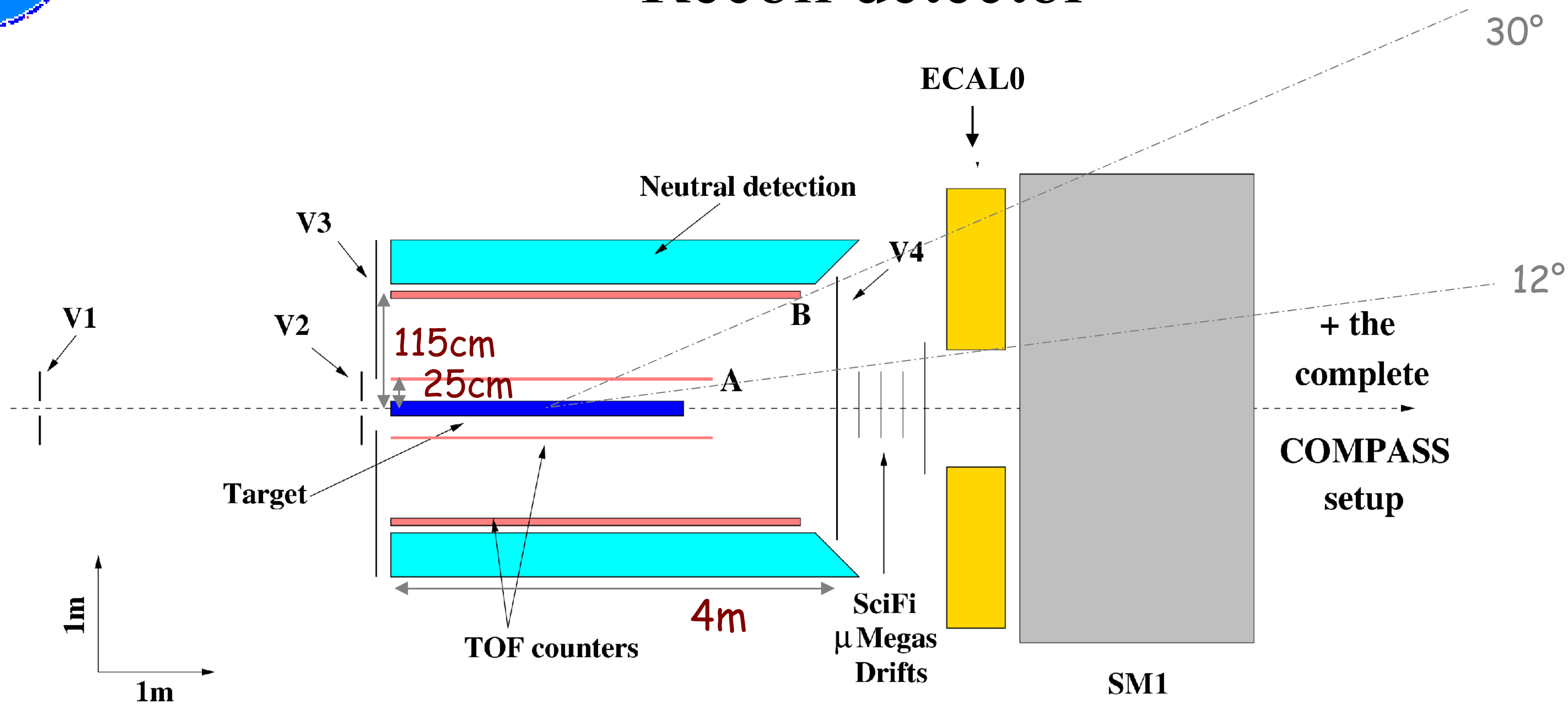
can't rely on missing mass method (Δm^2 > 1 GeV²)



Extension of calorimetry from θ<12° to 24° for γ and meson detection and background rejection

New recoil detector for reaction exclusivity

Recoil detector



Proton detection on 250-750 MeV

- TOF measurement on 2 barrels of 24 scintillators read at both sides
- time resolution needed 200 ps with analog ring sampler or multi-sample ADC
- veto scintillators on not covered angular regions for hermeticity

Prototype actually under test (financed by European FP6)

Electromagnetic Calorimetry

2 existing calorimeter ECAL1 and ECAL2

- cover θ from 0.4° to 12° (ECAL2 0.4-2°, ECAL1 2-12°)
- lead glass blocks, 90% signal in 50 ns
- good energy resolution $\sigma E/E = 0.055/\sqrt{E} + 0.015$ with ~20MeV threshold
- good position resolution $\sigma_x = 6/\sqrt{E} + 0.5$ mm

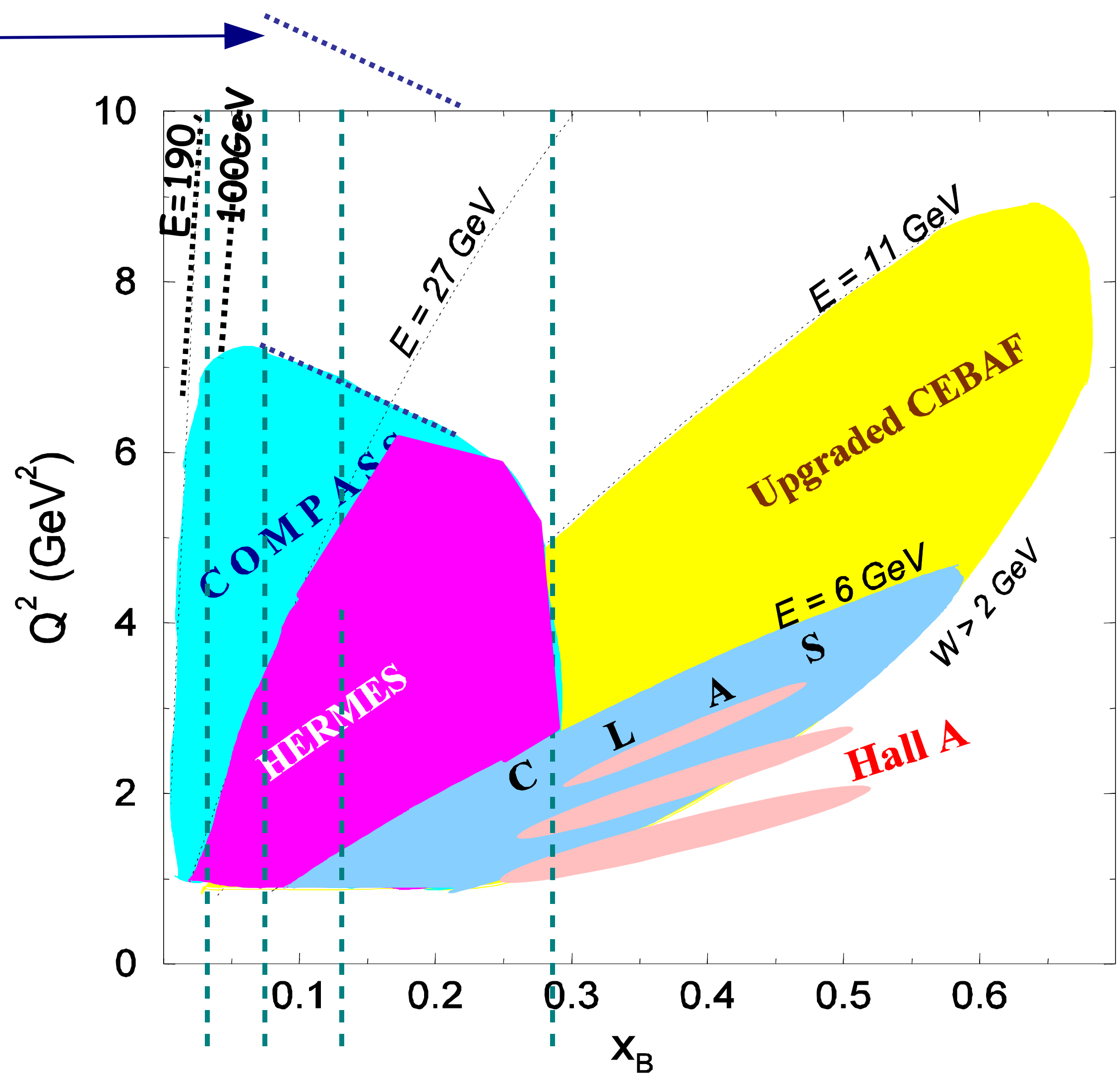
New calorimeter ECAL0 foreseen for large angle particles (up to 24°)

- increase angular coverage
- $\pi^0 \rightarrow 2\gamma$ background rejection
- crowded environment, magnetic fringe field

New ECAL0 calorimeter under study

Kinematic domain covered for DVCS

Kinematic limit if $N_\mu \times 2$



Large range of Q² (1.5 – 7.5 GeV²) in 6 bins for E_μ = 100 GeV

x_{Bj} from 0.03 to 0.27 in 3 bins

Q² range can be extended to 11 GeV² if beam intensity × 2

DVCS beam charge (μ^+-μ^-) asymmetry measurements

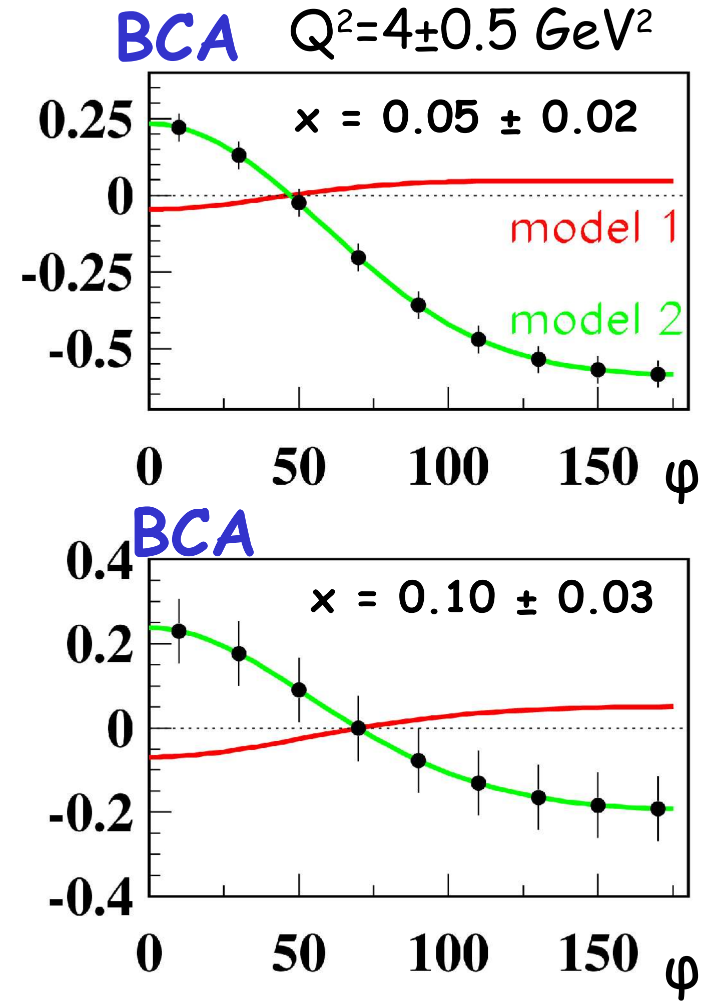
Projected results with 150 days of data taking at E_μ=100 GeV with 25% efficiency
3 bins in x, 6 bins in Q^2

Model 1: simple model using form factor
$H(x, \xi, t) \sim q(x) F(t)$

Model 2: more realistic model, with fast partons in small valence core
$H(x, 0, t) \sim q(x)\, e^{t \langle b_\perp^2 \rangle}$ where $\langle b_\perp^2 \rangle = \alpha \ln 1/x$

Models from Vanderhaeghen, Guichon, Guidal, with inputs from Goeke, Polyakov, Vanderhaeghen

Comparisons with more sophisticated models are under study



Project roadmap

2005	expression of interest SPSC-EOI-005
2006	test of a prototype of the recoil detector
2007	proposal submitted
2007-9	construction of recoil detector, ECAL0, liquid H_2 target
2010	first DVCS data taking (also used for HEMP)
ongoing:	analysis of ρ^0 production, Φ,...