DVCS and Flux Determination at COMPASS

SPIN-PRAHA 2012

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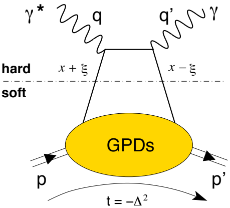
Outline

- Generalised Parton Distribution
- Deep Virtual Compton Scattering
- The COMPASS experiment
- Hardware upgrade for 2012
- Luminosity determination
- Summary

Generalised Parton Distribution



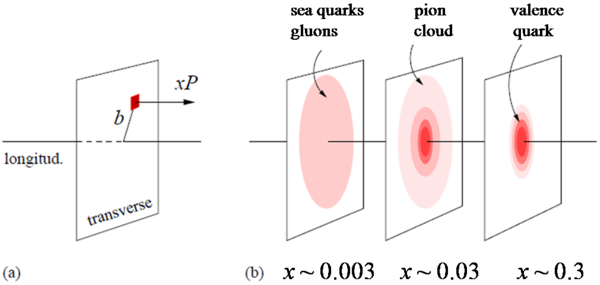
Factorisation for Q^2 large,
$t < 1\,\mathrm{GeV}^2$

- **Generalised parton distribution for quarks**:
  $H^f, E^f, \tilde{H}^f, \tilde{E}^f$
- **limits**:
  $q(x) = H(x, 0, 0)$
  $F(t) = \int dx H(x, \xi, t)$
- **Ji's sumrule**: $J^f = \frac{1}{2} \int_{1}^{-1} dx\, x[H^f(x, \xi, t) + E^f(x, \xi.t)]$

J^f: total angular momentum contribution of quark f

Nucleon Tomographie

GPDs allow measurement of longitudinal momentum and transverse spacial structure of the nucleon

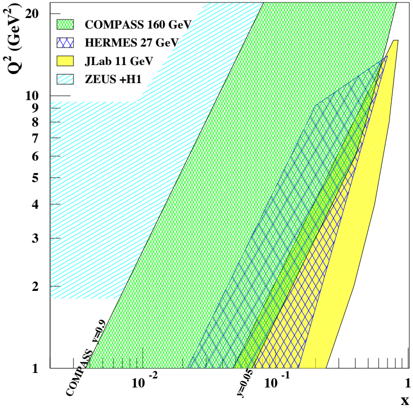


for $\xi \to 0$: $t = -\Delta_\perp^2$ purely transverse

$$q^f(x,b) = \int \frac{d^2\Delta_\perp}{(2\pi)^2} e^{-i\Delta\cdot b_\perp} H^f(x,0,-\Delta_\perp^2)$$

GPD at COMPASS

Why at COMPASS?



- High energy muon beam
  - μ^+ or μ^-
  - 160 - 200ĠeV
  - 80 % polarized
- Unique kinematic range
- good acceptance

CERN, SPS and beam

SPS proton beam: 400 GeV, $2{\cdot}10^{13}$ per spill $\rightarrow$

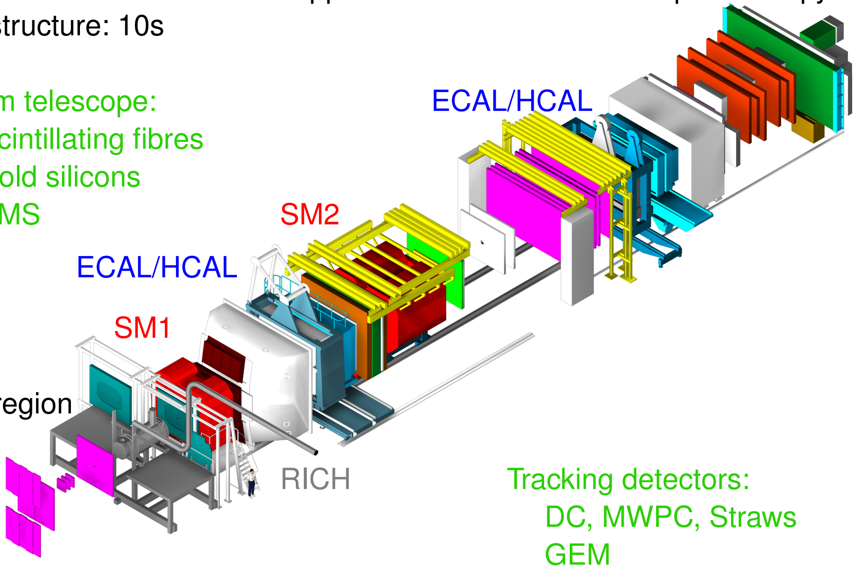
Secondary hadron beams (p, K, π) 150-270 GeV, $2{\cdot}10^{7}$ per spill

Tertiary muon beam (80% pol.) 160-200 GeV, $2{\cdot}10^{8}$ per spill

COmmon **M**uon and **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

Spill structure: 10s

Beam telescope:
- Scintillating fibres
- Cold silicons
- BMS



Tracking detectors:
- DC, MWPC, Straws
- GEM
- MicroMegas

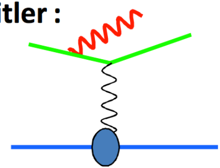
CERN-PH-EP/2007-001 hep-ex/0703049

Deep Virtual Compton Scattering

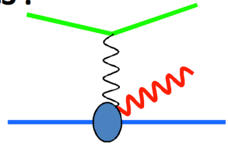
Hard exclusive exclusive photon production

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

Bethe-Heitler :



DVCS :



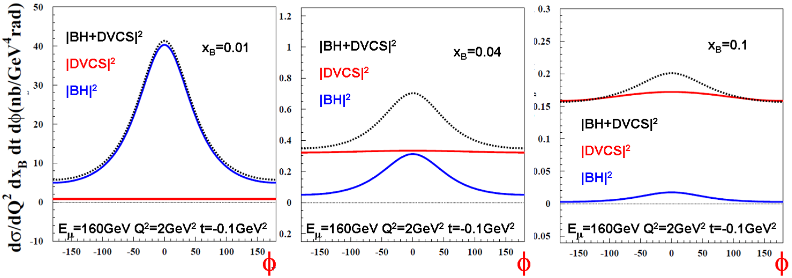
$$\sigma = \sigma_{\mathrm{BH}} + \sigma_{\mathrm{DVCS}} + \text{interference term}$$

BH	calculable
DVCS	$d\sigma^{\mathrm{DVCS}}/d\lvert t \rvert$
Interference	$Re\, A^{\mathrm{DVCS}}$ and $Im\, A^{\mathrm{DVCS}}$

BH vs. DVCS

- $Q^2 = 2\,\mathrm{GeV}^2$, $t = 0.1\,\mathrm{GeV}^2$ and 160 GeV beam energy

Azimuthal distribution of the photon



Different contributions for different X_B regions:
BH, Interference term and DVCS
How to measure the interference?

Observables

DVCS experiment to constrain GPD *H*

$$\mu^{+\downarrow}(P=-0.8),\ \mu^{-\uparrow}(P=0.8), \text{unpol. proton target } (\mathrm{lH}_2)$$

- Beam charge & Spin Sum: $\mathcal{S}_{CS,U} \equiv d\sigma^{+\downarrow} + d\sigma^{-\uparrow}$
  $\Rightarrow Im\ A^{DVCS}, \sigma^{BH}, \sigma^{\mathrm{DVCS}}$
- Beam charge & Spin Difference: $\mathcal{D}_{CS,U} \equiv d\sigma^{+\downarrow} - d\sigma^{-\uparrow}$
  $\Rightarrow Re\ A^{DVCS}, \sigma^{\mathrm{DVCS}}$
- Beam charge & Spin Asymmetry: $\mathcal{A}_{CS,U} \equiv \mathcal{D}_{CS,U}/\mathcal{S}_{CS,U}$

- Additional: Deep virtual meson production (DVMP)

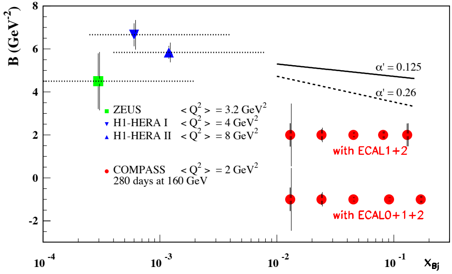
GPD E more challenging:

$$\mu^{+\downarrow}(P=-0.8),\ \mu^{-\uparrow}(P=0.8), \text{transversely pola. proton target } (\mathrm{NH}_3)$$

Parametrisation and Transverse Imaging

Prediction with different models for t dependence :

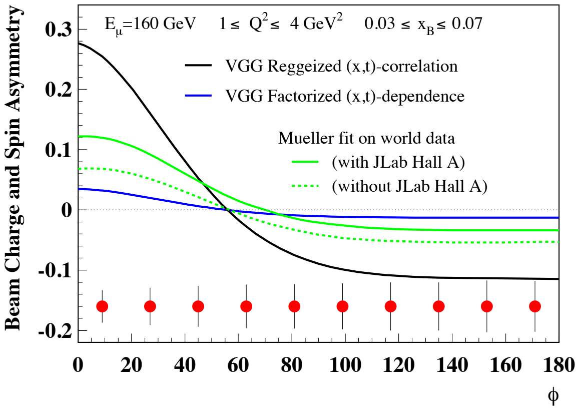
- factorisation: $H(x,\xi,t) \propto q(x)F(t)$
- Regge motivated t dependence: $x - t$ correlation
  $H(x,0,t) \propto q(x)\exp(-B(x)\,|t|)$
  For x dependency: simple Ansatz
  $B = 1/2\ < b^2 >= B_0 + 2\alpha' ln\frac{x_0}{x}$



$r_\perp = b/(1-x)$: transverse size of nucleon

BCSA Projections

With 2 years of data taking $\equiv$ 1222pb^{-1}



Uncertainties small enough for model comparison

2012 DVCS Dress Rehearsal

6 weeks of test run this years
Studies of principles and checks of equipment for the main run in 2015/2016

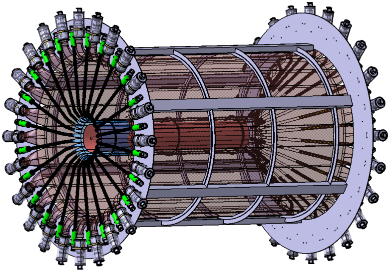
Experimental challenges:

- New recoil proton detector (CAMERA)
- New 2.5 m long lH_2 target by CERN
- Good acceptance for photons (Upgrades and ECAL0)
- Extension of trigger acceptance towards higher Q^2
- Well known acceptance
- High precision luminosity determination

160 GeV $\mu^{\pm}$ beam with a flux of $\approx 2 \cdot 10^7 \frac{1}{\mathrm{s}}$

CAMERA

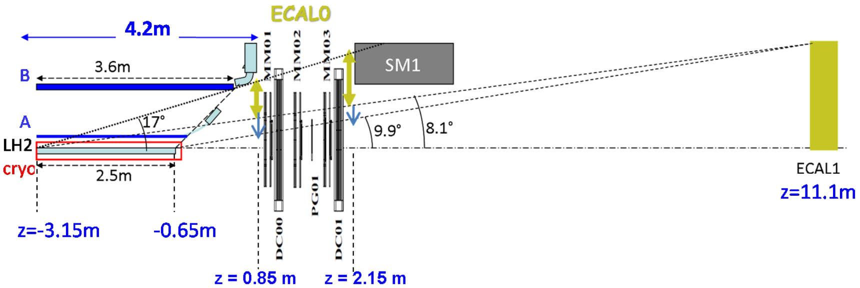
Exclusivity via recoil proton detection
Used for triggering and proton PID



- 2.5 m long lH_2 target
- 40 mm diameter
- TOF detector with two layers of scintillator
- high time resolution (300 ps)
- Readout with GANDALF board with 1 GHz digitalisation

ECAL 0

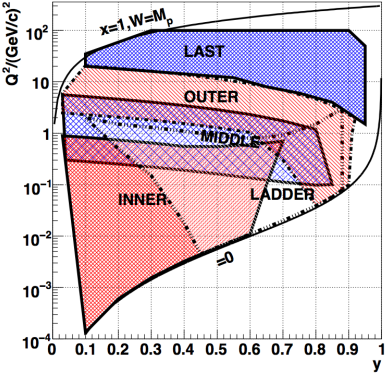
Large angle photons detected by ECAL0



- Shashlyk modules with MAPD readout
- Energy range: 0.1- 30 GeV
- Energy resolution $\frac{0.05}{\sqrt{E}}$
- Time resolution 0.5-0.6 ns

LAST

Large Angle Spectrometer Trigger
Scintillator trigger hodoscope consisting of 2 planes (H1/ H2)
Principle of target pointing with coincidence matrix
$Q^2 > 10\,\mathrm{GeV}$



H1 and H2

H1: 230 cm $\times$ 190 cm, 64 channels and 1 cm thick
H2: 500 cm $\times$ 420 cm, 128 channels and 2 cm thick

Cross section and Luminosity

$$\frac{d^2\sigma}{dQ^2\,dx\,d\xi\,dt} = \frac{N}{\int L\,dt \;\cdot\; A \;\cdot\; \delta Q^2\,\delta x\,\delta\xi\,\delta t \cdot \text{corrections}}$$

with N = number of selected events, A = acceptance
and $\int L\,dt$ = integrated luminosity

Cross section measurement
$\Rightarrow$ precise luminosity determination

Fixed target experiment:

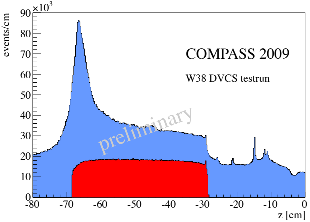
$$L[cm^{-2}s^{-1}] = \text{flux} \times \text{target density}$$

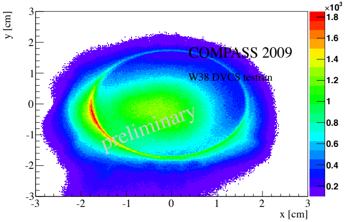
2009 Test Run

- Two weeks of data taking
- Small RPD
- 40 cm lH_2 target
- Only intermediate Q^2 trigger
- 160 GeV $\mu^{\pm}$ beam

Using one run of 2009 test data for illustration

Target Density





2009 DVCS test run:

- Liquid hydrogen target
- 40 cm long target cell
- Radius of 1.6 cm
- Density LH: 0.0745 $\frac{\text{mol}}{\text{cm}^3}$ at 1020 mbar and 18 K
- $1.77 \cdot 10^{24} \frac{1}{\text{cm}^2}$

Random Trigger Method

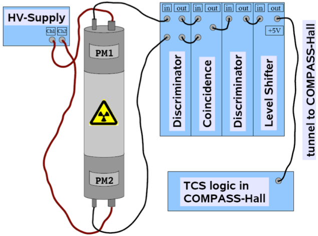
High flux $\approx 10^7 s^{-1}$
Using random trigger for flux measurement
Hardware and offline analysis
Beam track reconstruction with beam telescope (FI,SI)

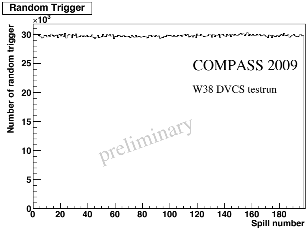
$$\text{Flux} = \frac{\text{number of reconstructed beam tracks}}{\text{number of random trigger} \times \text{time gate } \Delta t}$$

- DAQ dead time free
- Effective flux
- Unbiased measurement

Random Trigger

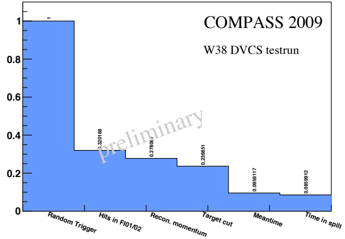
- Radioactive β^+source
- Decay of ^{22}Na measured
- $^{22}Na \rightarrow ^{22}Ne + e^+ + \nu_e$
- Away from experiment
- Very stable over the run
- Coincidence rate $\approx$ 3kHz in 2009





Beam Track Selection

Selection of reconstructed beam tracks:

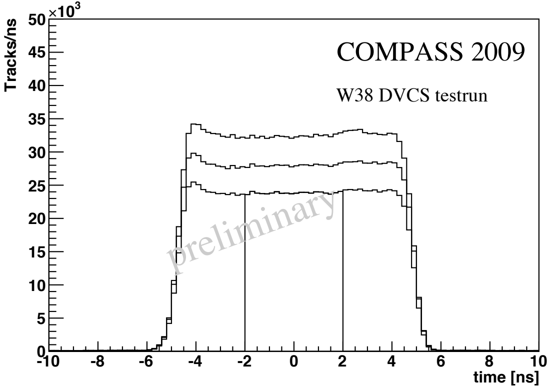


- Random Trigger Events
- Hits in FI01/FI02
- Reconstructed momentum
- Target cut (1.6 cm)
- Track time cut $\pm$ 2 ns
- Time in spill cut

$\approx$10% of the random trigger events contain at least one good beam track

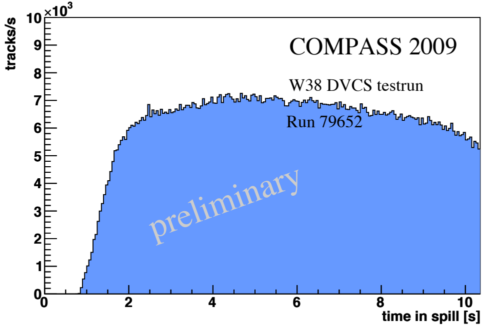
Track Time for Δt

Time of the beam track with respect to trigger time
Physics trigger have a time peak at 0 ns
Flat distribution because of the Random Trigger



Time in spill

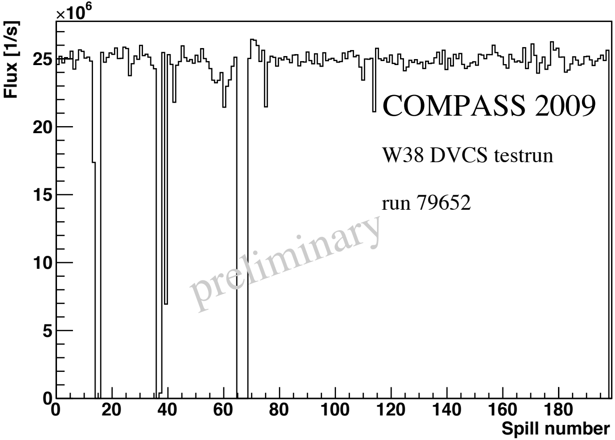
Beam tracks over time in spill



- Spill structure
- Flat beam track distribution
- Constant detector load
- Veto dead time correction easier
- Time in spill cut: $>2\,\mathrm{s}$ and $<10\,\mathrm{s}$

Estimated Flux

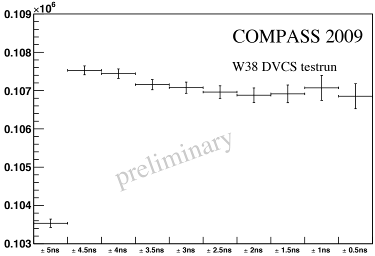
Time in spill cut applied
Random trigger attempts scaled with time window



Estimate of Precision

The statiscal errors are small: 2.1% per spill
Systematic uncertainties to be estimated ⇒ Goal: 1%!

- Track time cut
- Target density
- Veto dead time
- $\mu^{\pm}$ differences



Studies are ongoing but not yet released

Summary and Outlook

- COMPASS has great potential to study GPDs
- GPDs are accessable via hard exclusive photon production
- Experimental challenges
- 6 Week of dress rehearsal in 2012
- Main physics run in 2015/2016
- Hardware upgrades:
  - CAMERA
  - ECAL0
  - Large Angle Spectrometer Trigger
- High precision luminosity determination with the Random Trigger method

Thanks for the attention