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The COMPASS-II program

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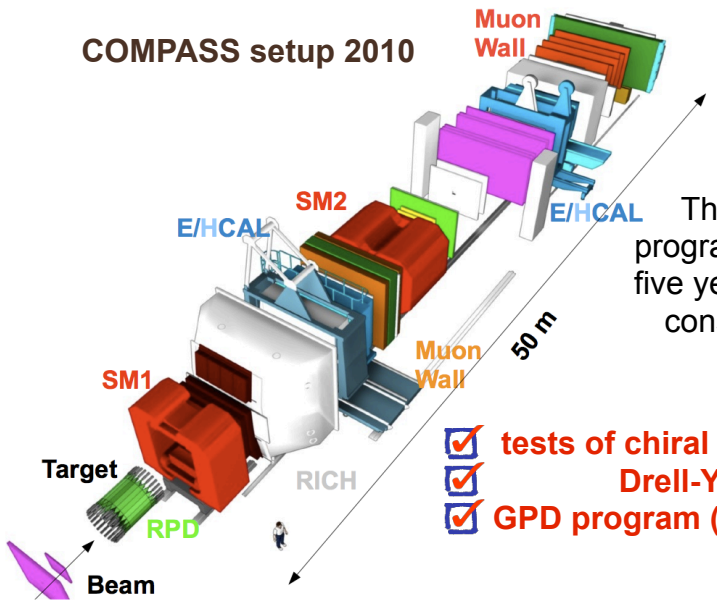
COMPASS is a high-energy physics experiment using secondary beams of Super Proton Synchrotron at CERN. The purpose of this experiment is the study of hadron structure and hadron spectroscopy. During the first phase (2003-2011) of the experiment longitudinal and transverse nucleon spin structure were studied via deep inelastic scattering with muon beam of high intensity. Production of hadron resonances via diffractive scattering, central production and photon exchange with pion and proton beams and hydrogen, tungsten, lead and nikel targets were also studied.

The COMPASS setup consists of two stages, which are open dipole spectrometers for large and small angle tracks, respectively. It's equipped with a large number of precise tracking detectors, two electromagnetic and two hadron calorimeters and particle identification system including RICH and two muon walls. Layout of a target region can be optimized for particular measurement. COMPASS operates with muon and hadron beams with momentum up to 280 GeV/c.

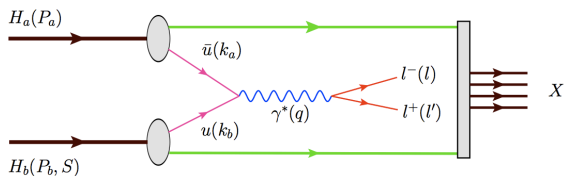
COMPASS setup 2010



The new COMPASS program covers a period of five years (2012-2016) and consists of three parts:

- ☑ tests of chiral perturbation theory
- ☑ Drell-Yan program
- ☑ GPD program (+unpolarized SIDIS)

Drell-Yan program



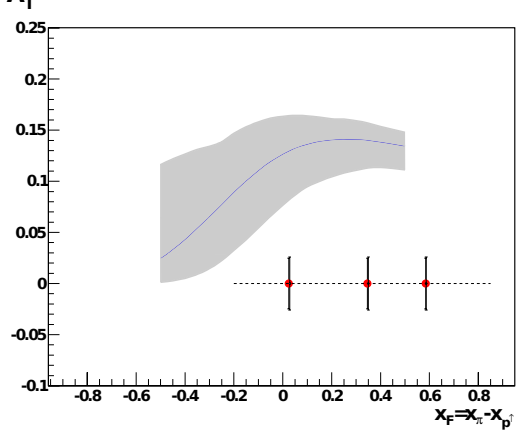
1)Unpolarized Drell-Yan (DY)

2)Transverse spin-dependent structure of the nucleon with polarized DY

$$\frac{d\sigma}{d^4q d\Omega} = \frac{\alpha^2}{Fq^2}\hat{\sigma}_U\{(1 + D_{[\sin^2\theta]}A_U^{\cos 2\phi}\cos 2\phi) + |\vec{S}_T|[A_T^{\sin\phi_S}\sin\phi_S + D_{[\sin^2\theta]}(A_T^{\sin(2\phi+\phi_S)}\sin(2\phi+\phi_S) + A_T^{\sin(2\phi-\phi_S)}\sin(2\phi-\phi_S))] + \dots\}$$

- A: azimuthal asymmetries – $A_U^{\cos 2\phi}$, $A_T^{\sin\phi_S}$, $A_T^{\sin(2\phi+\phi_S)}$ and $A_T^{\sin(2\phi-\phi_S)}$
- $\hat{\sigma}_U$: part of the cross-section surviving integration over ϕ and ϕ_S
- D: depolarization factor
- S: target spin components
- $F = 4\sqrt{(P_a \cdot P_b)^2 - M_a^2 M_b^2}$

COMPASS can directly perform Important test of QCD prediction: Sivers asymmetries in **SIDIS** and **DY** should have opposite signs and the same magnitude



Theoretical prediction and expected total error for a measurement of the Sivers asymmetry at COMPASS for $4<Q^2<9$ GeV^2/c^2

3)Study of the J/ψ production mechanism

- determination of q-qbar and g-g contributions
- J/ψ-DY duality test

Experimental conditions:

- transverse polarized NH_3 target (2 cells)
- π^- beam of 190 GeV/c, up to 10^8 π/s
- High luminosity L=10^{32} cm^2 s^{-1}
- Beam dump
- J/ψ as monitoring signal
- Expected rate of Drell-Yan events:
  2 GeV<M<2.5 GeV - ~5000 day^{-1}
  4 GeV<M<9 GeV - ~800 day^{-1}

Required modification for the apparatus:

- Hadron absorber (2.4 m of alumina+steel with tungsten beam plug
- Two large angle hodoscopes for organization of dimuon trigger in the first spectrometer

GPD program

Generalized Parton Distributions → 3D structure of the nucleon

Program with unpolarized LH_2 target to constrain GPD H

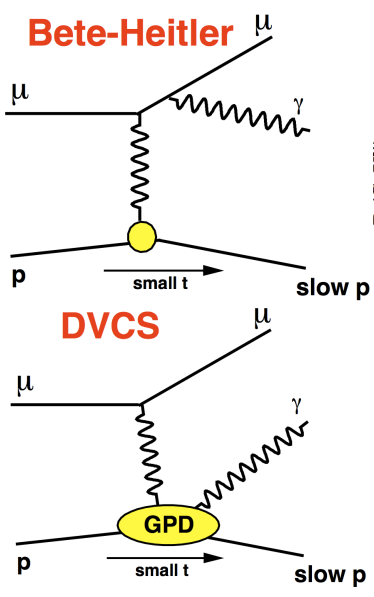
1) Deeply virtual Compton scattering (DVCS)

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

BH	well known (reference yield)
DVCS	t-slope measurement (nucleon tomography)
Interf. term	access to $\mathrm{Re}A^{\mathrm{DVCS}}$ $\mathrm{Im}A^{\mathrm{DVCS}}$

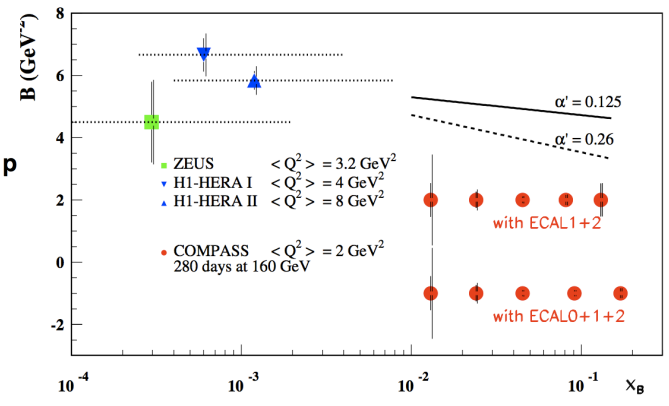
$$\mu^{+\downarrow}(P=-0.8),\ \mu^{-\uparrow}(P=0.8) \qquad \frac{\mathrm{d}^4\sigma(\mu p \to \mu p\gamma)}{\mathrm{d}x_{Bj}\mathrm{d}Q^2\mathrm{d}|t|\mathrm{d}\phi} = \mathrm{d}\sigma$$

Bete-Heitler



DVCS

- **Beam charge & Spin Sum:** $S_{CS,U} \equiv d\sigma^{+\downarrow} + d\sigma^{-\downarrow}$
- **Beam charge & Spin Difference:** $D_{CS,U} \equiv d\sigma^{+\downarrow} - d\sigma^{-\downarrow}$
- **t-slope of DVCS cross section**



Projections for measuring the x_B dependence of the t-slope parameter $B(x_B)$ of the DVCS cross section calculated for $1<Q^2<8$ GeV^2/c^2

2) Deeply virtual meson production (DVMP) π,η,ρ,ω,ϕ,J/ψ

Measurement of cross section for exclusive meson production, which in combination with DVCS will allow quark flavour separation and determination of gluon GPD H

Program with transversely polarized NH_3 target to constrain GPD E

Studies of azimuthal asymmetries for DVCS and DVMP on transversely polarised protons (this part will be subject of a future addendum to the proposal)

Measurements of unpolarised PDFs and TMD effects in SIDIS

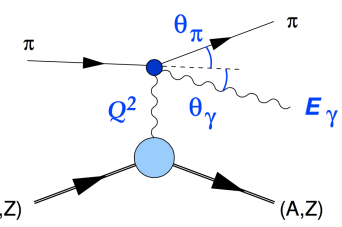
High-statistics data on semi-inclusive deep inelastic scattering (SIDIS) on the proton will be recorded simultaneously with the DVCS and DVMP measurements

Experimental conditions and required changes in the apparatus:

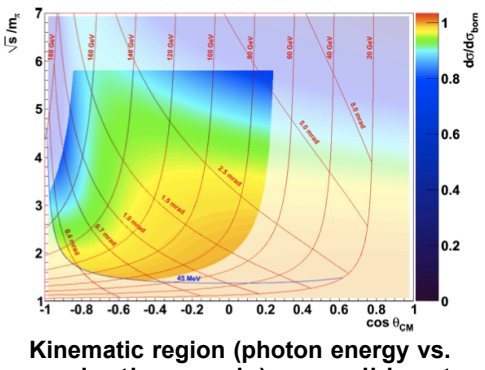
- Polarized muon beam with qP =±160 GeV/c
- New liquid hydrogen target
- New recoil proton detector around the target
- New large aperture electromagnetic calorimeter
- 70 days of data taking with μ$^+$ and 210 days with μ$^-$ beam to have equal integrated luminosity L=10^{32} cm^{-2} s^{-1}

Tests of chiral perturbation theory

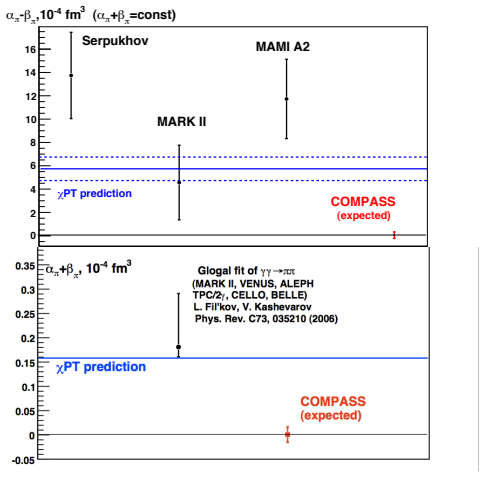
1) Precise measurement of pion electrical and magnetic polarizabilities



- Pion beam of 190 GeV/c
- Muon beam of 190 GeV/c for study of systematic effects
- Ni target (0.3 X_0)
- Up to 10^6 events in the range $0.5<E_\gamma/E_{beam}<0.9$
- Expected total error for $\alpha_\pi-\beta_\pi$ is $<0.3\times10^{-4}$ fm^3 (χPT prediction is 5.7×10^{-4} fm^3)
- Expected total error for $\alpha_\pi+\beta_\pi$ is $<0.02\times10^{-4}$ fm^3 (χPT prediction is 0.16×10^{-4} fm^3)
- Access to quadrupole polarizabilities



Kinematic region (photon energy vs. production angle) accesible at COMPASS. Influence of polarization effects on the cross section is shown in colors



Expected accuracy of $\alpha_\pi-\beta_\pi$ and $\alpha_\pi+\beta_\pi$ measurement at COMPASS in comparison with the best previous experimental results

2) First measurement of kaon polarizabilities

- ~3% of kaons in pion beam
- Beam kaons identification by threshold Cherenkov detectors
- About 4000 events in the range $0.5<E_\gamma/E_{beam}<0.9$
- Expected total error for $\alpha_K-\beta_K$ is $<0.1\times10^{-4}$ fm^3 (χPT prediction is 1.0×10^{-4} fm^3)

3) Primakoff reactions with neutral mesons in the final state

$\pi^- Z \to \pi^- Z\, \pi^0$		chiral anomaly amplitude $F_{3\pi}$ (10 000 events)
$\pi^- Z \to \pi^- Z\, \pi^0\pi^0$		strong test of χPT at tree level (2 500 events)
$\pi^- Z \to \pi^- Z\, \eta$		direct observation of $1^-(1^{-+})$ exotics created in photoproduction