Future plans at COMPASS

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on behalf of the
COMPASS collaboration

Bonn, September 2009

Outline

- The COMPASS experiment at CERN

  Partonic Structure of the nucleon

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- Future plans
  - Deep Virtual Compton Scattering
    Tomography of the nucleon

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  - Drell-Yan
    transverse momentum dependent
    parton distributions (TMD)

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- The COMPASS experiment at CERN
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  - Drell-Yan
    transverse momentum dependent parton distributions (TMD)
- Summary & Outlook

COMPASS

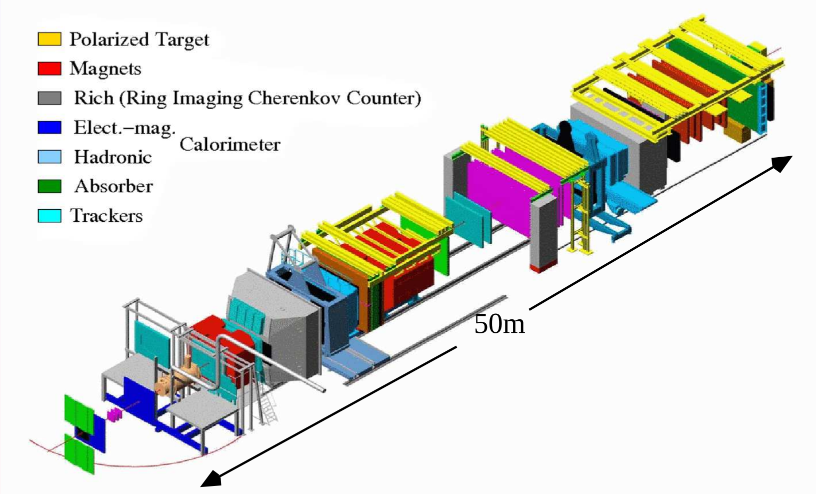
COMPASS

CO mmon
Muon and
Proton
Apparatus for
Structure and
Spectroscopy

$\approx$ 200 physicists
$\approx$ 30 institutes,
at CERN SPS


COMPASS

The COMPASS Experiment



Up to now

Spin Structure of the Nucleon

$\vec{\mu}\vec{N} \rightarrow \mu' + h + X$

quark, gluon helicity distribution

$\Delta q(x), \Delta g(x)$

transversity distribution

$\Delta_T q(x)$

...

Spectroscopy, Polarizabilities

$\pi + A \rightarrow 3\pi + A'$

PWA to study meson spectroscopy

(see talk B. Grube)

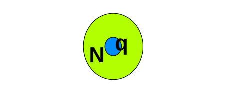
$\pi + Pb \rightarrow \pi + \gamma + Pb'$

to study polarizabilities

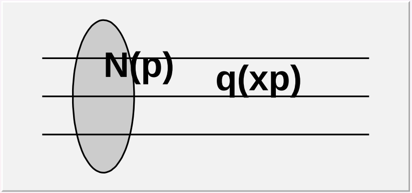
continue running up to $\approx$ 2011

Description of the Nucleon in terms of parton distribution functions

$q(x)$,
$q = u, d, s, \bar{u}, \bar{d}, \bar{s}, g$



$q(x)\mathrm{d}x =$ nb. of quarks of flavor q with momentum fraction $x \in [x, x + dx]$



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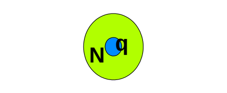
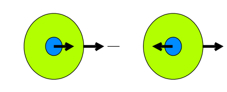


$\Delta q(x), \Delta g(x)$ (helicity)



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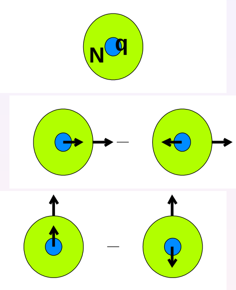
$\Delta_T q(x)$ (transversity)



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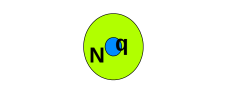

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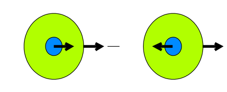
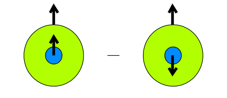
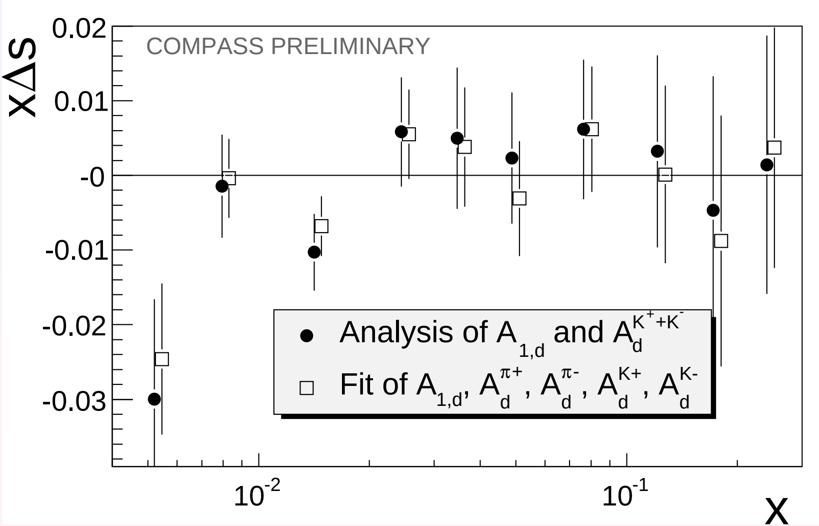


$\Delta_T q(x)$ (transversity)



All three types of distributions needed to fully describe nucleon in terms of parton distributions
(at leading twist, integrated over the transverse momentum k_T)

COMPASS results on Δq, Δg and $\Delta_T q$



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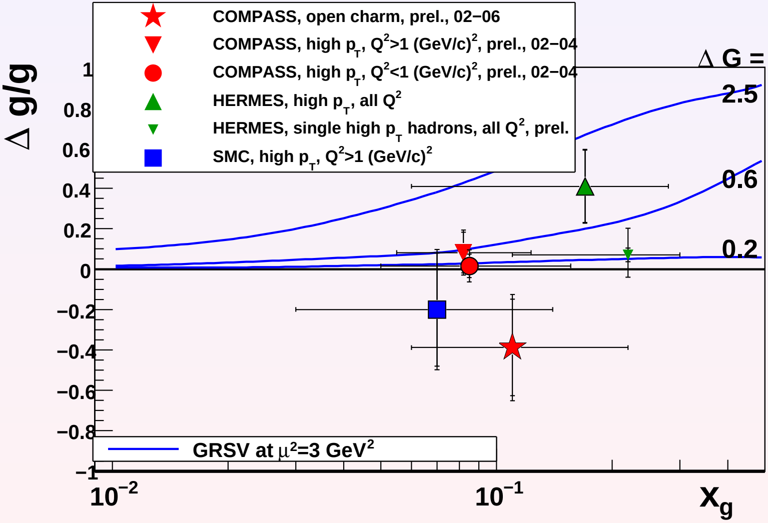

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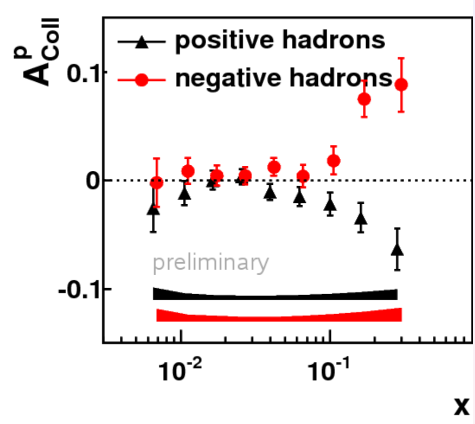
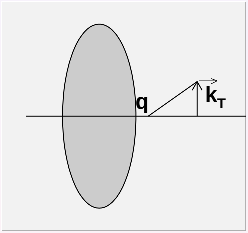


A_p^{coll} gives access to $\Delta_T q(x)$

Extend picture of parton distribution functions

- consider intrinsic transverse momentum k_T of quarks inside the nucleon
  $\Rightarrow$ Transverse momentum dependent distributions (TMD)



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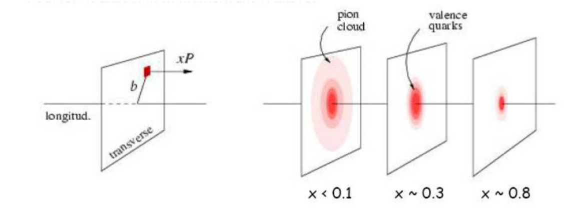


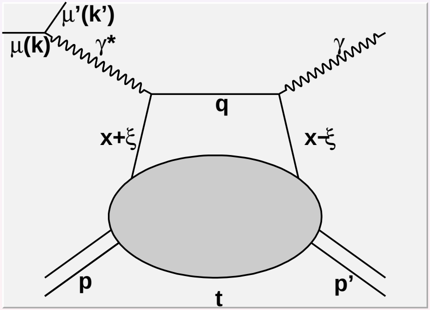
accessible in Deep Virtual Compton scattering $\mu p \rightarrow \mu' p \gamma$

Deep Virtual Compton Scattering

Generalized Parton Distributions (GPD)

Deep Virtual Compton Scattering

$$\mu + N \rightarrow \mu' + N + \gamma$$



gives access to generalized parton distributions (GPD)
H ,E, $\tilde{H}$ and $\tilde{E}$
which depend on
x, ξ and t.

GPDs are hybrids between from factors and parton distribution functions:

Generalized Parton Distributions ...

Form Factors
⇒ Spatial Distribution
$\int_{-1}^{1} H(x,\xi,t)\mathrm{dx} = \mathrm{F_1(t)}$

Parton Distributions
⇒ Momentum Distributions
$H(x,0,0) = q(x)$

⇒ GPD give access to space-momentum distribution

Generalized Parton Distributions . . .

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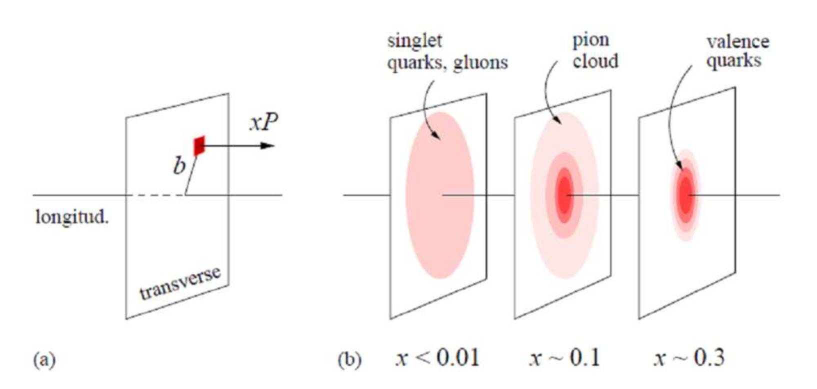
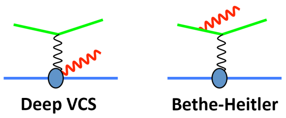


Cross Section

$d\sigma \propto |$ 

$|^2$

Bethe-Heitler contributes as background

$$\begin{aligned} d\sigma &= (d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + e_\mu a^{BH}\,\mathcal{R}e(A^{DVCS})) \times \cos(n\Phi) \\ &\quad + (P_\mu d\sigma^{DVCS}_{pol} + e_\mu P_\mu a^{BH}\,\mathcal{I}m(A^{DVCS})) \times \sin(n\Phi) \end{aligned}$$

e_μ: lepton charge, P_μ : lepton polarization, $A \propto \int_{-1}^{1} dx\, \frac{H(x,\xi,t)}{x-\xi+i\epsilon}$,

Φ : $angle(l, l' - \text{plane}, \gamma, p - \text{plane})$

difference : $d\sigma^{\mu^+\downarrow} - d\sigma^{\mu^-\uparrow} \propto \mathcal{R}e(A^{DVCS})$

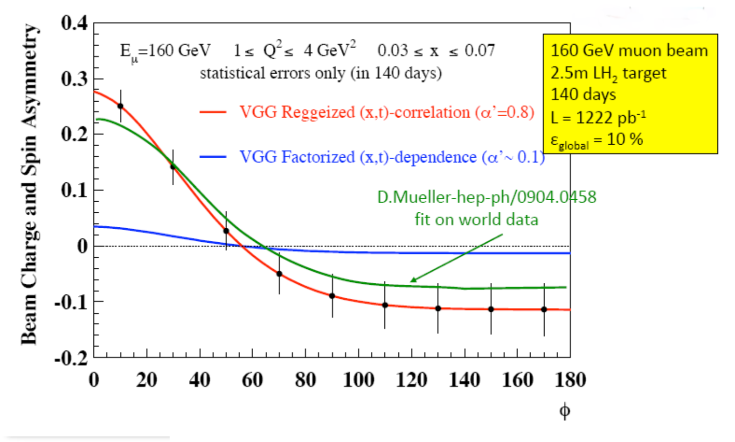
sum : $d\sigma^{\mu^+\downarrow} + d\sigma^{\mu^-\uparrow} \propto \mathcal{I}m(A^{DVCS})$

in addition exploit angular dependence

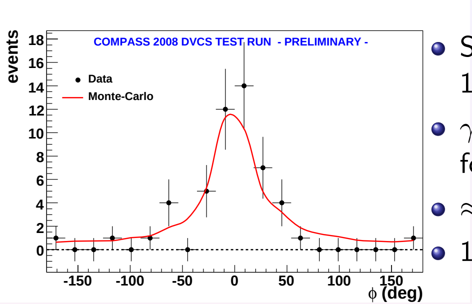
$\Rightarrow$ access to various contributions

Beam charge spin asymmetry

Beam charge spin asymmetry $= \frac{\text{difference}}{\text{sum}}$



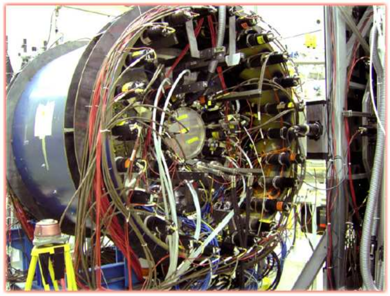
Results from a test run



- Single day of running with 1/3 nominal intensity
- γ azimuthal distribution follows expected behavior
- $\approx$ 100 BH events
- 13% efficiency

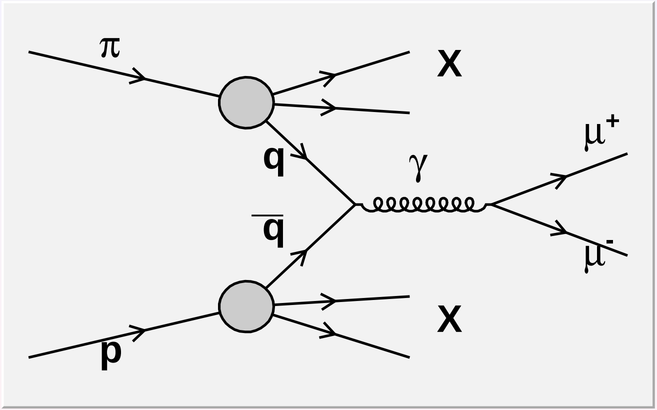
Experimental Requirements

- Phase I
  - 2.5m Liquid Hydrogen Target
  - 4m Recoil Detector
  - ECAL upgrade
- Phase II
  - Polarized target
  - corresponding RPD



Drell-Yan

Measurement of TMD: Drell-Yan



Drell-Yan cross section

Unpolarized DY:

$$d\sigma^{DY} \propto \quad \bar{h}_1^{\perp}(x_1, k^2_{T,1}) \quad \times \quad h_1^{\perp}(x_2, k^2_{T,2}) \cos(2\Phi)$$

Boer-Mulders × **Boer-Mulders**

Single polarized DY:

$$d\sigma^{DY} \propto \quad \bar{f}_1(x_1, k^2_{T,1}) \quad \times \quad f_{1T}^{\perp}(x_2, k_{T,2}) \sin(\Phi - \Phi_{S2}) +$$

$\bar{q}$ × **Sivers**

$$\bar{h}_1^{\perp}(x_1, k^2_{T,1}) \quad \times \quad h_1(x_2, k_{T,2}) \sin(\Phi + \Phi_{S2}) +$$

Boer-Mulders × **Transversity**

$$\bar{h}_1^{\perp}(x_1, k^2_{T,1}) \quad \times \quad h_{1,T}^{\perp}(x_2, k_{T,2}) \sin(3\Phi - \Phi_{S2})$$

Boer-Mulders × **Pretzelosity**

at leading twist, integrated over k_T: 3 pdfs

5 more w/o integration, 3 appear in DY cross section

Interesting Relations

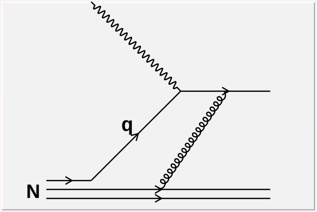
Sivers: $f_{1T}^{\perp}(DY) = -f_{1T}^{\perp}(SIDIS)$

Boer-Mulders: $h_1^{\perp}(DY) = -h_1^{\perp}(SIDIS)$

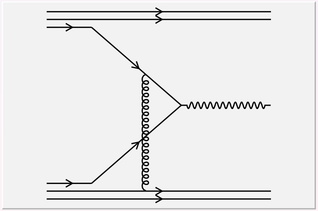
(SIDIS=semi-inclusive deep inelastic scattering)

"−" comes form T (time reversal) -odd character of distributions function

SIDIS



DY

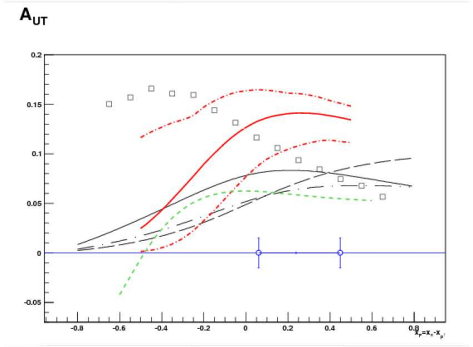


test factorization of k_T dependent processes
(J. Collins, PLB536, 43 (2002))

Observable

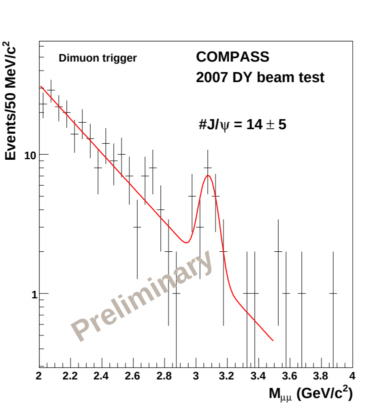
To access Sivers function, measure:

$$A_{UT} = \frac{\int_0^{2\pi} \mathrm{d}\sigma^{\uparrow} - \mathrm{d}\sigma^{\downarrow} \sin(\Phi_{S2} - \Phi)\mathrm{d}\Phi}{\int_0^{2\pi} \mathrm{d}\sigma^{\uparrow} + \mathrm{d}\sigma^{\downarrow} \mathrm{d}\Phi}$$



- Expected statistical error on A_{UT} assuming 2 years of running
- curves: various models: Anselmino, Bacchetta, Bianconi, Collins, Efrimov

Results from test measurements



- 2007 test run:
- 160 GeV/c π^- beam on NH_3 target, 12 hours of data taking:
- expected $J/Psi = 20 \pm 8$

Experimental Requirements

- hadron absorber downstream of polarized target
- new trigger system for $\mu^+\mu^-$ pairs

longer term:

- RF separated $\bar{p}$ - K beam
- beam of $10^7\bar{p}$/s

Summary & Outlook

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COMPASS studies partonic structure of matter
PRESENT and near FUTURE:

- helicity distributions ($\Delta q, \Delta g$)
- transverse asymmetries leading to $\Delta_T q$, Sivers function (in SIDIS)
- Spectroscopy, Polarizabilities using hadron beams

FUTURE ($>$ 2011)

- Generalized Parton Distributions
  Deep Virtual Compton Scattering
- Transverse momentum distributions (TMDs)
  Drell-Yan

Spare