COMPASS (CERN-NA58) Overview

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COMPASS Collaboration
Longitudinally polarized muons $160 \text{ GeV/c}$
$2 \times 10^8 \mu^+ / \text{spill (4.8s / 16.8s)}$
$P_B = -80\%$

Longitudinally or transversely polarized deuteron target:
$^6\text{LiD}$ $P_T \sim 50\%$

Luminosity: $\sim 5 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
Physics Programmes

Muon beam programme
Polarised target (Long. & Transv.)
- Gluon contribution to nucleon spin
- Quark polarisation ($g_1, \Delta \Sigma, \Delta q$, flavor separation)
- Transversity
- Production of $\rho, \Phi, J/\Psi, \Lambda, ...$

Hadron beam programme
- Primakoff: $\pi, K$ polarisabilities
- Exotics q-states, glue balls
- Double charmed hadrons
- Drell-Yann (project)

Muon beam, LH$_2$ target, proton recoil detector
- Generalized Parton Distributions (project ~ 2010)
2002 - 2006

- 2002  160 GeV $\mu$ beam & $^6$LiD Long/Transv polarisations
- 2003  idem (~ 80/20)
- 2004  idem
- 2004  hadron beam
- 2005  NO SPS beam (Several upgrades)
- 2006  160 GeV $\mu$ beam & $^6$LiD Long/polarisation (plan)
Physics Results Overview

- $\Delta G/G$ from production of high $p_T$ hadron pairs & open charm
- $g_1^D$, new COMPASS NLO fit, $a_0$, $\Delta_s$, $\Delta \Sigma$, $\Delta G$
- Transversity: Collins, Sivers asymmetries
- ($\Lambda$ Long. & Transv. Polarisations, $\rho$ vector meson)
- Upgrades, prospects
Photon Gluon Fusion: $\gamma g \rightarrow \bar{q}q$

High $p_T$ hadron pair $\bar{q}q \rightarrow hh$

Scale $\mu^2 = Q^2$ or $\Sigma p_T^2$

Large statistics

Physical background

2 cases: $Q^2 > 1 \text{ (GeV/c)}^2$

$Q^2 < 1 \text{ (GeV/c)}^2$
$A_{\parallel} = R_{PGF} \times a_{LL}^{PGF} \times \frac{\Delta G}{G} + A_{Bkg}$

- **Photon**
- **Gluon**
- **Fusion**

- **Leading Order**

- **QCD Compton**

- **Resolved $\gamma$**
  $Q^2 < 1 \text{ (GeV/c)^2}$

- **$a_{LL}$** : calculable partonic asymmetry

- **$R_{PGF}$** : Monte Carlo is required to calculate $R_{PGF}$
\( \Delta G/G \) from high \( p_T \) hadron pairs

Two high \( p_T \) hadrons, \( p_T > 0.7 \text{ GeV}/c, \Sigma p_T^2 > 2.5 \text{ (Gev/c)}^2 \)

\( Q^2 < 1 \text{ (GeV/c)}^2 \) analysis - large statistics

- perturbative QCD scale from \( \Sigma p_T^2 \)
- PHYTIA MC used to evaluate RPGF (0.3) & physical Bkg, low \( p_T \), resolved \( \gamma \)

- 2002 - 2004 data \( Q^2 < 1 \text{ (GeV/c)}^2 \)

\[ \Delta G/G = 0.016 \pm 0.058 \text{ (stat)} \pm 0.055 \text{ (syst)} \]

@ \( x_g \sim 0.085, \mu^2 = 3 \text{ (GeV/c)}^2 \)
Two high $p_T$ hadrons, $p_T > 0.7$ GeV/c, $\Sigma p_T^2 > 2.5$ (Gev/c)²

$Q^2 > 1$ (GeV/c)² analysis - lower statistics
- perturbative QCD scale from $Q^2$,
- LEPTO MC used to evaluate RPGF (0.33) & physical Bkg

- 2002 - 2003 data $Q^2 > 1$ (GeV/c)²

$\Delta G/G = 0.06 \pm 0.31$ (stat) $\pm 0.06$ (syst)
@ $x_g = 0.13 \pm 0.08$, $\mu^2 \sim 3$ (GeV/c)²
**ΔG/G from open charm**

**Photon Gluon Fusion:** $\gamma g \rightarrow \bar{c}c$

**CHARM:** $c \rightarrow D^0 \rightarrow K\pi$

- Scale $\mu^2 = 4m_c^2$
- Theory understood
- $\sigma \sim 100$ nb, BR = 4%
- Combinatorial background
- Limited statistics
- Challenging experiment.
ΔG/G from open charm

\[ D^0 \rightarrow K + \pi \quad \text{untagged} \]

\[ D^* \rightarrow D^0 + \pi_s \rightarrow K + \pi + \pi \quad \text{tagged} \]
\[ A_{LL}/D = \frac{S}{S+B} \times a_{LL} \times \frac{\Delta G}{G}(x_g) \]

\( a_{LL} \) calculated with help of Monte Carlo and parametrized by measured quantities, (Neural Network used.)

- 2002 - 2004 data \( D^0 + D^* \)

\[ \Delta G/G = -0.57 \pm 0.41 \text{ (stat)} \pm (\text{syst} \leq \text{stat}) \]

@ \( x_g \sim 0.15, \mu^2 \sim 13 \text{ (GeV/c)}^2 \)
Direct measurements of $\Delta G/G$

\[ \int \Delta G(x) = 2.5 \]

GRSV2000
NLO fits to $g_1$
$\mu^2 = 3 \text{ GeV}^2$

\[ \int \Delta G(x) = 0.6 \]
(Grsv stdr)

\[ \int \Delta G(x) = 0.2 \]

$\Delta G/G$ is small ($x_g \approx 0.1$)

\[ \int \Delta G > 1 \text{ disfavoured} \]

LO high-$p_T$ $\Delta G/G$ results shown with GRSV NLO fits to $g_1$

Consistent also with RHIC $A_{LL} (\pi^0$ channel) measurements
COMPASS $g_1^D (2002-2004)$

Also: C. Quintans session 2A

COMPASS $g_1^D$ (2002-2004)

Also: I. Savin session 2A

NLO fits to $g_1^N$ world data (2006) & COMPASS
NLO fit to world data (2006) & COMPASS, two equally probable solutions:

\[ \Delta G > 0 \] \quad \Delta G < 0 

- \eta_G (Q^2=3(\text{GeV}/c)^2) = +0.26 \pm 0.04, -0.06 \quad -0.31 \pm 0.10, -0.14
- \eta_\Sigma (Q^2=3(\text{GeV}/c)^2) = 0.28 \pm 0.01 \quad 0.32 \pm 0.01

COMPASS data alone:

- \eta_0 (Q^2=3(\text{GeV}/c)^2) = 0.35 \pm 0.03 \text{ (stat)} \pm 0.05 \text{ (syst)}
- \Delta_s + \Delta_s^- (Q^2=3(\text{GeV}/c)^2) = -0.10 \pm 0.01 \text{ (stat)} \pm 0.02 \text{ (syst)}
Measurements of $\Delta G/G$

LO high-$p_T$ $\Delta G/G$ results shown with new NLO fits to $g_1$

$\mu^2 = 3$ GeV$^2$

$\int \Delta G(x) = 0.3$

$\int \Delta G(x) = -0.3$
Prospects

- $\Delta \Sigma \sim 0.2$ (before) $\rightarrow \sim 0.3$ (now)
- Large $\Delta G$ less and less a likely candidate
- Choose between two scenarios?

\[
\begin{align*}
\Delta \Sigma & \quad \Delta G & \quad L_q & \quad L_g \\
\frac{1}{2} & = 1/2 \times 0.3 & + & 0.35 & + & 0 & + & 0 \\
\frac{1}{2} & = 1/2 \times 0.3 & + & 0.0 & + & 0.35
\end{align*}
\]

COMPASS/RHIC \quad JLab/HERMES/COMPASS
Transverse spin: Collins & Sivers asymmetries

\[ A_\Phi^{\text{Coll}} = \frac{\sum q e^2 \times \Delta T \frac{q}{q} \times \Delta^0 T D^h \frac{q}{q}}{\sum q e^2 \times q \times D^h \frac{q}{q}} \]

spin dependent fragmentation of transversely polarized quarks into hadrons

\[ A_\Phi^{\text{Siv}} = \frac{\sum q e^2 \times \Delta T \frac{q}{q} \times D^h \frac{q}{q}}{\sum q e^2 \times q \times D^h \frac{q}{q}} \]

Intrinsic \( k_T \) dependence of the quark distribution
$A_{\text{Coll}}$ (deuteron) $\pi, K$

Also: F. Bradamante session 2B
$A_{Siv}$ (deuteron)

Anselmino et. al hep-ph/0507181

positive hadrons

2002-2004 data

COMPASS

negative hadrons
More polarimeters for transversity:
- Two-hadrons T spin asymmetries (R. Joosten 2B)
- $\Lambda$ & $\bar{\Lambda}$ T polarisations (A. Ferrero 2A)

Prospects:
- Precise transversity deuteron COMPASS data: hint for p & n cancellation for deuteron?
- Strong case for transversity proton data with COMPASS in 2007.
Polarized target upgrade, in 2006

- New COMPASS target magnet
  - \(\rightarrow 180 \text{ mrad}\)

- New 3-cell system & microwave cavity
  - Matched for larger acceptance,
  - Reduces false asymmetries

Also: F.Gautheron session 9A
Polarized target performances

Polarization of $^6$LiD in 2006

+53.5%  -52.0%  +56.1%

Higher & faster than in 2004
RICH-1 upgrade, in 2006

Lens system
+ MAPMTs
+ MAD4
+ F1

CsI MWPC
+ APV25S1
+ ADC
RICH-1 upgrade, MAPMTs “on-line”

Very promising results!
- Precise timing
- High photon statistics
1/σ(ΔG/G)^{1/2} = FoM

In 2006, apparatus will have reached optimum performances allowing us to make the most productive use of SPS beam.

Beam delivered in 2006 will be ~ 0.5 of our expectation.
Prospects

- Proton target
  - with Transverse polarisation (planned in 2007)
  - with Longitudinal polarisation (beyond 2007)
    - SIDIS
    - Particle ID
    - Flavor separation
    - Revisiting Bjorken SR?
Additional slides
Longitudinal $\Lambda$ & $\bar{\Lambda}$ polarisations

- Statistics of $\sim 31000$ $\Lambda$ and $\sim 18000$ $\bar{\Lambda}$ from 2003 data
- 2004 data will at least double statistics
- Access to $s$ and $\bar{s}$ quarks, also $\Delta s$? Need dedicated studies with Monte Carlo

Also: M. Sapozhnikov session 2A
Transverse $\Lambda$ polarization

\[ P_T^\Lambda = \frac{\sum_q e_q^2 \Delta T q \times \Delta D_q^\Lambda}{\sum_q e_q^2 q \times D_q^\Lambda} \]

Also: A. Ferrero session 2A

All 2002–2004 transversity data
- $Q^2 > 1$ (GeV/c)$^2$
- $0.1 < y < 0.9$
Hard exclusive $\rho^0$ meson production

- Large statistics on diffractive production of $\rho, \phi, J/\Psi$
- Large $x, Q^2$ range
- Measure spin density matrix elements and L-double spin asymmetries
- $A_1$ for $\rho^0$ compatible with zero, more data needed