Future Perspectives for COMPASS

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HIF05, La Biodola, May 30, 2005

- **INTRODUCTION (mostly historical)**
- **PHYSICS CASE**
- **THE COMPASS SPECTROMETER**
- **WHERE ARE WE?**
- **FUTURE PLANS**
  - **NEAR**
  - **FAR**

COmmon Muon and Proton Apparatus for Structure and Spectroscopy

NA58 @ CERN

Czech Republic, Finland, France, Germany, India, Israel, Italy, Japan, Poland, Portugal, Russia, Switzerland

Bielefeld, Bochum, Bonn, Burdwan, Calcutta, CERN, Dubna, Erlangen, Freiburg, Heidelberg, Helsinki, Lisbon, Mainz, Miyazaky, Moscow, Munich, Nagoya, Prague, Protvino, Saclay, Tel Aviv, Torino, Trieste, Warsaw

28 Institutes, more than 200 physicists

SOME HISTORY

- **experiment:**

thought of in	April ’94	Trento workshop
	Nov. ‘94	Trieste workshop
LoI	March ’95	
encouraged	June ‘95	SPSLC in Cogne
Proposal	March ’96	
recommended	Sept. ’96	
approved by RB	Feb. ‘97	as NA58
Technical run	2000	
Commissioning	2001	

- **since 2002 taking data**

with

a new spectrometer with outstanding performances

- **merging of two programmes:** **HMC** (muon beam) **CHEOPS** (hadron beam)

COMPASS Physics case

an attempt to answer some questions which have been with us since almost 40 years

- how do quarks and gluons make up a nucleon ?

  ! spin structure !

- are there non qqq or $q\bar{q}$ hadrons ?

  ! exotics !

fundamental problems of QCD

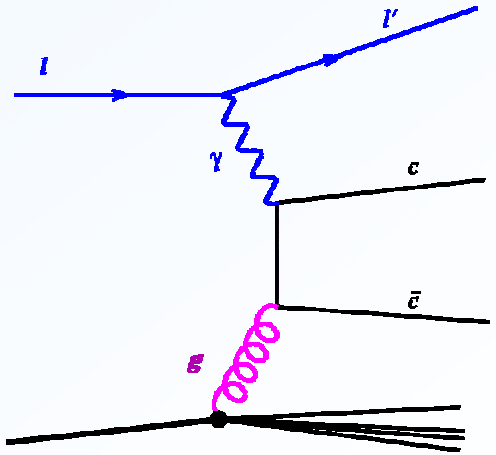
- role of the axial anomaly to the spin of the proton
- glueballs $\Leftrightarrow$ non abelian nature of QCD

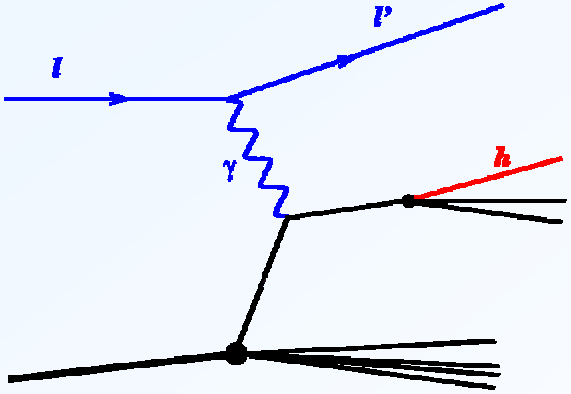
COMPASS programme with the muon beam

to determine the polarised parton density functions in a polarised nucleon from measurements of hadron asymmetries in semi-inclusive polarised DIS, both longitudinal and transverse

specifically,

- to measure the gluon polarisation ΔG through open charm (Gluk and Reya, Altarelli and Stirling, 1988)





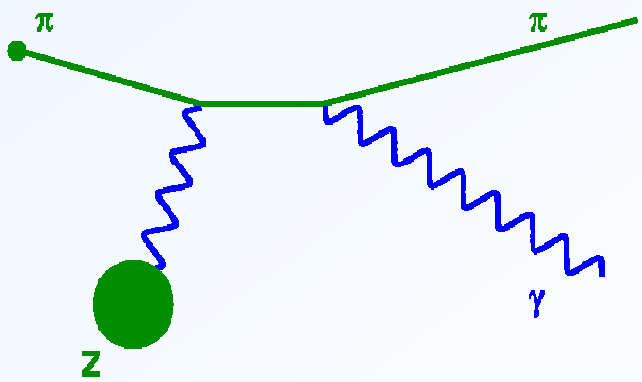
- to measure h_1, the new territory
- to measure the spin transfer in fragmentation from Λ production
- to remeasure with high statistics g_1 and g_2
- ……

COMPASS programme with hadron beams

- **charmed hadrons**
  - production phenomena (p, π, K)
  - leptonic decays
  - semileptonic decays
  - precision measurements of c-baryon lifetimes
  - production and spectroscopy of cc-baryons
- **gluonic states**
  - search for glueballs in Pomeron-Pomeron scattering
  - search for exotic states
- **hadron structure**
  - polarizability in Primakoff reactions

Primakoff scattering in COMPASS

Compton scattering
in inverse kinematics



study γ-scattering on unstable projectiles

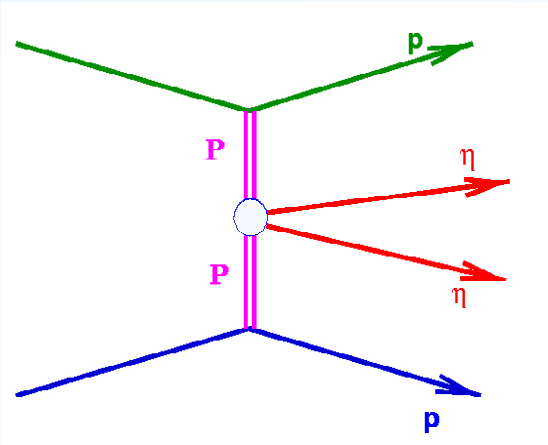
- predictions from χPT
- measure polarisabilties by deviation from $\sigma_{Compton}$
- determine polarisability α to ~5%
- measure $\pi\gamma \rightarrow \pi\pi$ (chiral anomaly)
- statistics: about 50 · present statistics

Glueballs in COMPASS

Pomeron-Pomeron scattering in central production

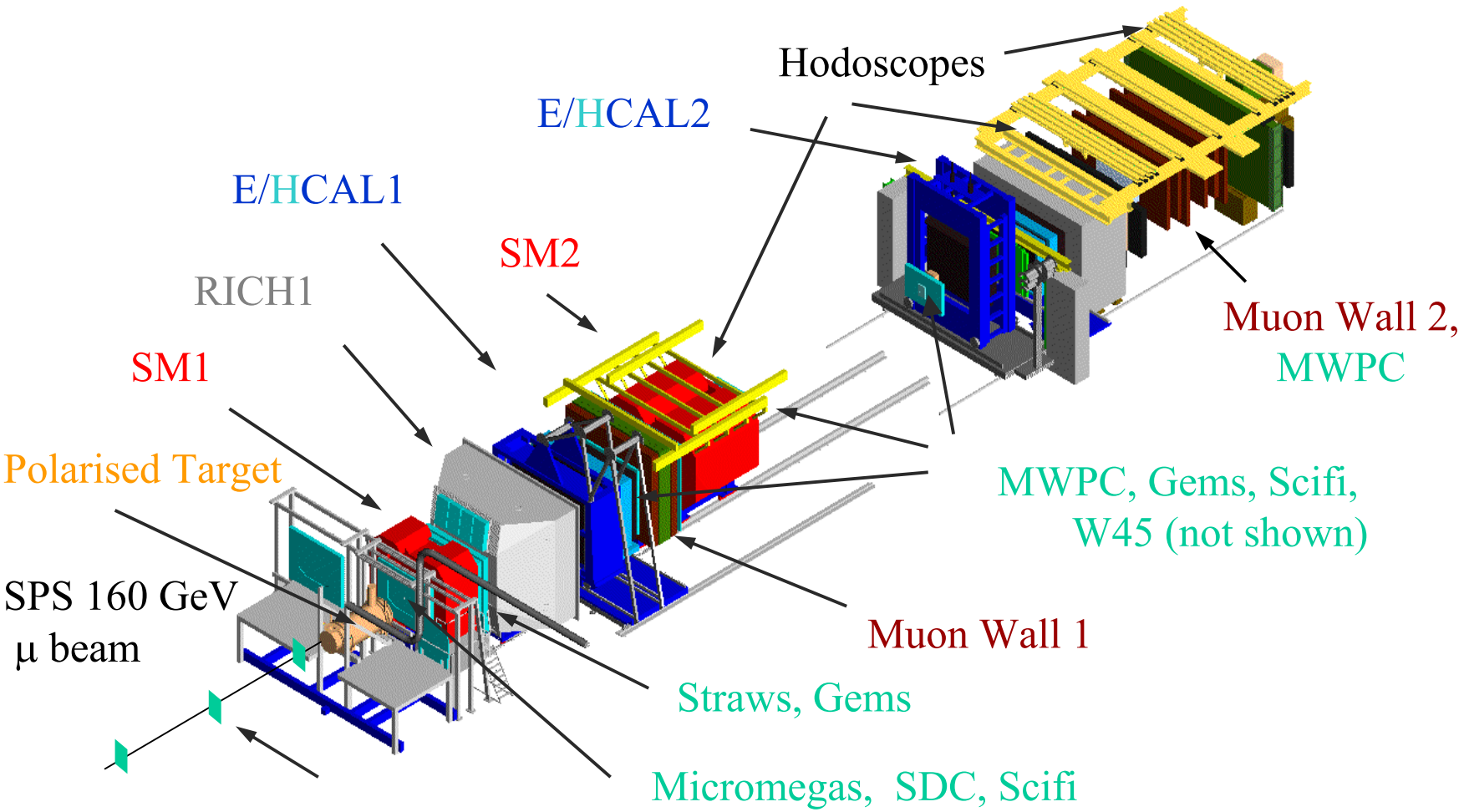
- **method: access to 0^{++}, 2^{++}, … states**
- **statistics: 10-15 · WA102**

➔ **allows exploring the mass region above 2 GeV**



in 2 SPS years (2·120 days)
we expect to detect
100000 η η
30000 η η'
15000 η'η'
decays, fully reconstructed

THE COMPASS SPECTROMETER



COMPASS – apparatus overview

High rate	10^8 μ/sec, polarised (80%)
High energy	100 – 200 GeV
Pol. target	2 oppositely polarised cells, 60 cm long proton: NH_3, P_T ~90%, f ~17% neutron: ^6LiD, P_T ~50% 75% longitudinal polarisation (ΔG, …) 25% transverse polarisation (h_1, …)
Luminosity	$5 \cdot 10^{32}$ $cm^{-2}s^{-1}$ (unpolarised)

Spectrometer (2 stages)	**Large Angle**	**Small Angle**
	180 mrad, 1 T·m	40 mrad, 5 T·m
	RICH1	RICH2
	HCAL1, ECAL1	HCAL2, ECAL2
	μ-FIL1	μ-FIL1

COMPASS – apparatus overview (cont.)

Tracking system

- Scint. Fibers Hodoscopes
- Scint. Counter Hodoscopes
- Silicon
- microMega
- Triple GEM
- Multiwire proportional Chambers
- Straw-tubes DC
- Planar DC
- Iarocci Streamer Tubes
- Drift Tubes

+ detectors specific to the hadron programme

Trigger rate 10^4 - 10^5 events/spill

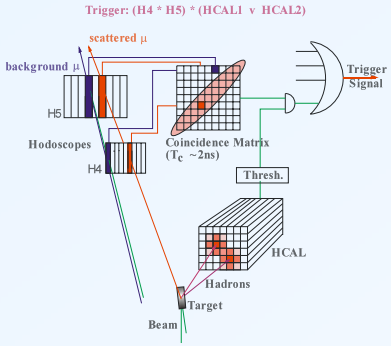
RAW event size ~ 30 kB

DAQ flux 35 MB/s (continuous)

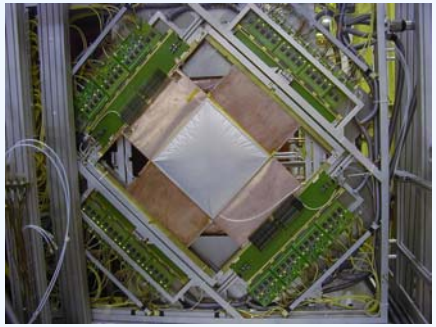
RAW Data ~300 TB per year

NEW TECHNOLOGIES

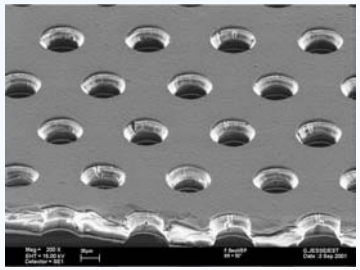
DAQ, off-line system



Trigger-System



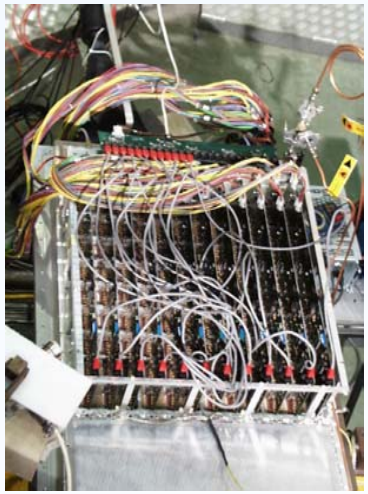
MicroMegas



GEM

Straws

Readout electronics



RICH1 readout

Scintillating fiber trackers

The COMPASS off-line system

Topical to a Workshop on

High Intensity Frontier

are the COMPASS off-line and analysis systems

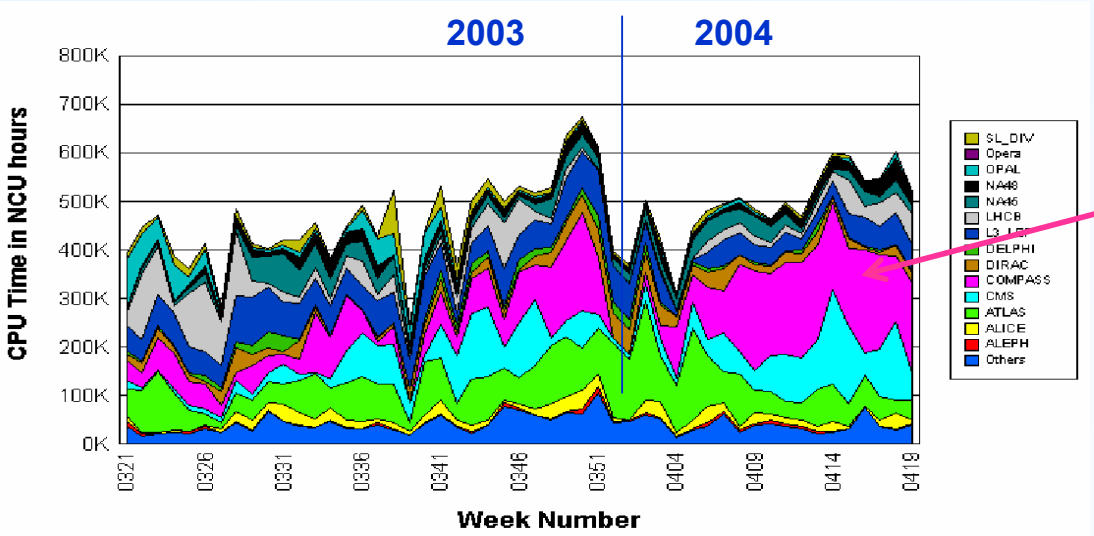
COMPASS has been the *guinea-pig* of CERN IT Division for computing in the LHC era

COMPASS-IT collaboration started in 1997

DataBase — **Objectivity/DB** → **Oracle**

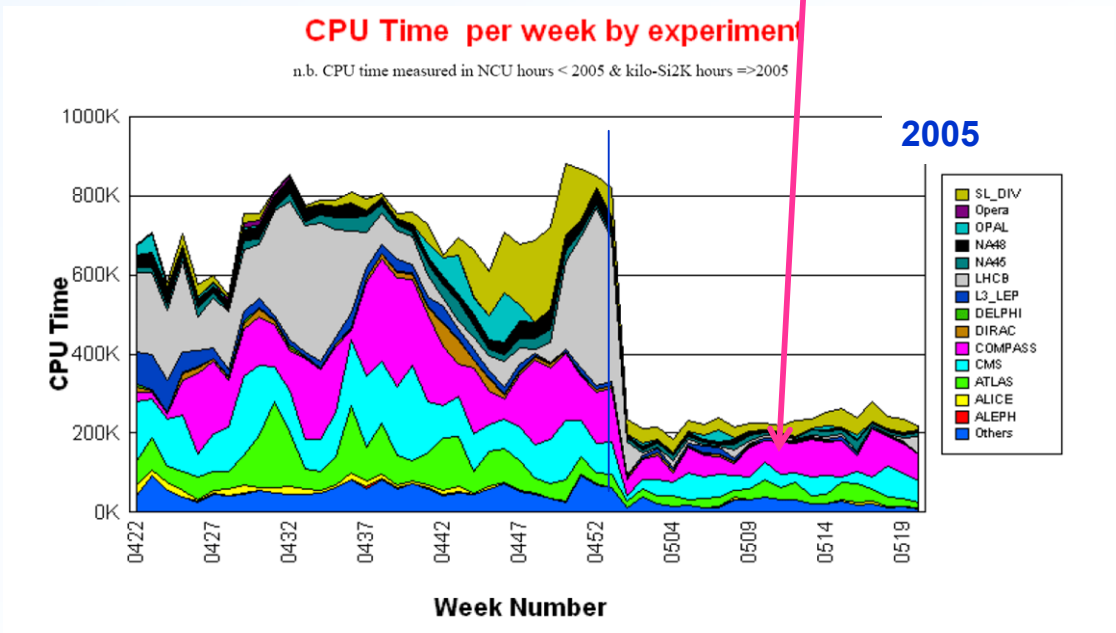
CORAL (COmpass Reconstruction and AnaLysis program) — **Object Oriented programming C++**

DATA PROCESSING at CERN

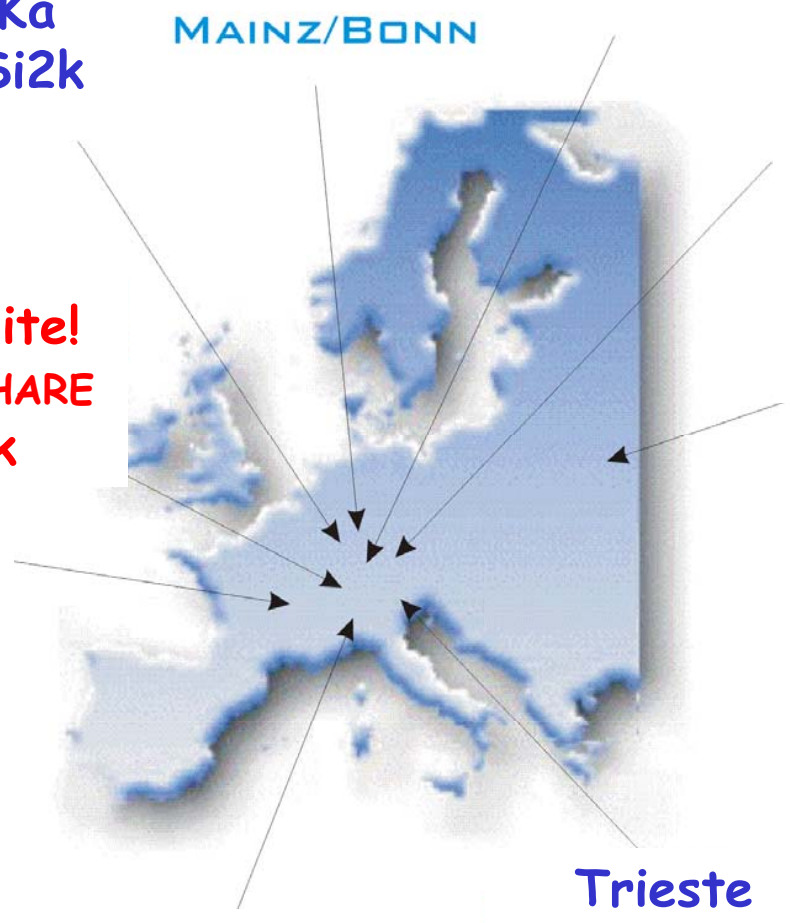


COMPASS

processing time ~
data taking time



Satellite Compass Computing



Freiburg
17 kSi2k

GridKa
45 kSi2k

TUM
26 kSi2k

CERN
production site!
LXBATCH/LXSHARE
120 kSi2k

Dubna & Protvino
43 kSi2k

Saclay/Lyon
(27 kSi2k)

Trieste
45 kSi2k

Torino
28 kSi2k

1 Pentium IV 3GHz
~ 1 kSi2k

Event reconstruction:

300 TB raw data
→ 300 000 Batch jobs
(1 GByte ~ 8 hours)

Process in parallel
as much as possible
(up to ~1000 CPUs)

WHERE ARE WE ?

- **in 2002, 2003, and 2004 COMPASS has taken data in the muon programme configuration**

  160 GeV, polarized μ beam
  ^{6}LiD polarized target (~polarized deuterons)

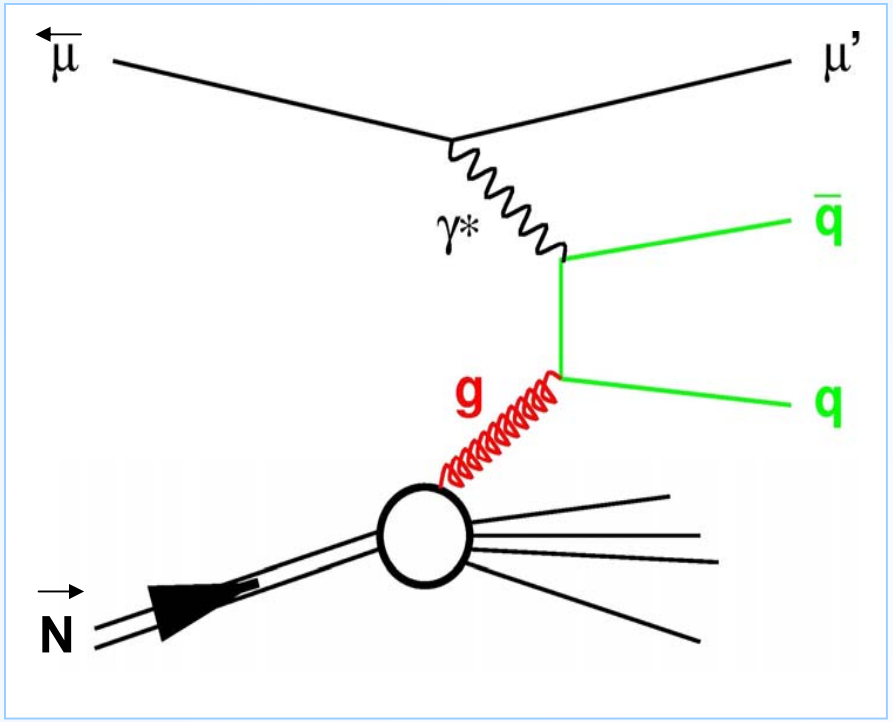
  $3 \cdot 10^{10}$ events ~ 1000 TB

- **important physics results**
  1. **$\Delta G/G$**
  2. **$\Delta\Sigma$**
  3. **Transversity**
  4. **$\Phi(1860)$**

- **pilot run in 2004 for hadron programme**

1. ΔG/G at COMPASS

Photon Gluon Fusion



q = c cross section difference in charmed meson production

→ ***theory well understood***

→ ***experiment challenging***

q = u,d,s cross section difference in 2+1 jet production in COMPASS: events with 2 hadrons with high p_T

→ ***experiment easy***

→ ***theory difficult***

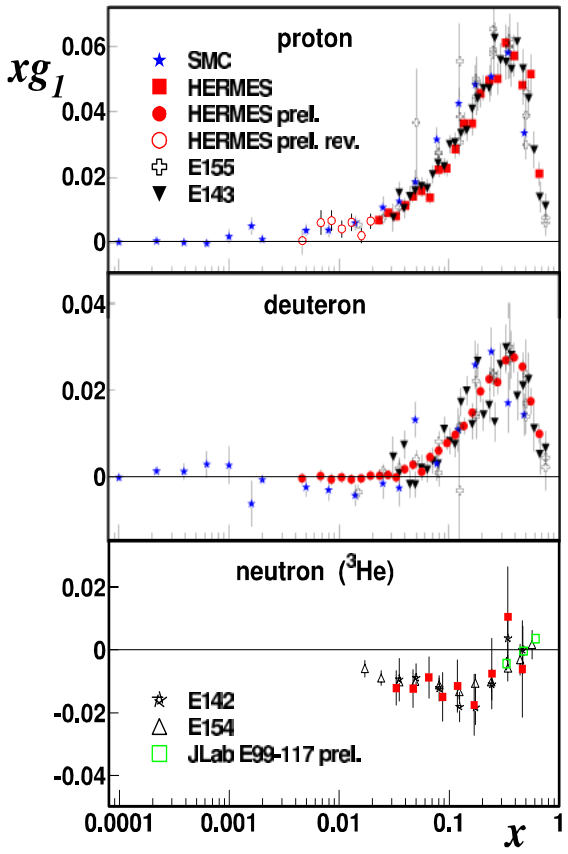
PDF AND STRUCTURE FUNCTIONS: $\Delta q(x)$

Inclusive DIS: beam and target longitudinally polarized wrt beam direction

$$\frac{d\Delta\sigma}{dx\,dy} = \lambda \cdot \frac{e^4}{4\pi^2 Q^2} \cdot \left[\left(1 - \frac{y}{2} - \frac{y^2}{4} \cdot \gamma^2 \right) \cdot g_1 - \frac{y}{2} \cdot \gamma^2 \cdot g_2 \right]$$

$$d\sigma = d\bar{\sigma} \pm d\Delta\sigma$$

beam/target helicity



g_1 measured at SLAC, EMC, SMC, HERMES:

g_2 suppressed by a factor $\gamma^2 \approx 0.01$ at 100 GeV (SMC, SLAC)

in the parton model

$$g_1(x) = \frac{1}{2} \sum_a e_a^2 \cdot \left[\Delta q_a(x) + \Delta \bar{q}_a(x) \right]$$

THE NUCLEON SPIN - $\Delta q(x)$

From $g_1(x) = \frac{1}{2}\sum_a e_a^2 \cdot [\Delta q_a(x) + \Delta\bar{q}_a(x)]$

one can determine

$$\Gamma_1 = \int_0^1 g_1(x)\,dx \qquad \text{(low x)}$$

and

$$\Delta\Sigma = \Delta u + \Delta d + \Delta s \qquad \Delta q = \int_0^1 [\Delta q(x) + \Delta\bar{q}(x)]dx$$

in the **QPM** it is the **sum of the quark contribution to the nucleon spin**

Δu, Δd, Δs are related to the matrix elements of the axial vector quark current in the nucleon, and consequently to the weak decay constants of the baryon octet

$$\Delta u - \Delta d = F + D = 1.257 \pm 0.003$$
$$\Delta u + \Delta d - 2\,\Delta s = 3F - D = \sqrt{3}\cdot[0.34 \pm 0.02]$$

EMC **1989** the beginning

$\Gamma_1^p = 0.123 \pm 0.013 \pm 0.019$ $\qquad \Delta\Sigma = 0.12 \pm 0.17$

➔ **SPIN CRISIS**

$$S_z = \frac{1}{2}\Delta\Sigma + \Delta G + \langle L_z \rangle \quad ?$$

PARTON HELICITY DISTRIBUTIONS

FROM GLOBAL QCD ANALYSIS

EMC, SMC
E142, E143, E154, E155
HERMES

$A_1^{p,n,d}$, $g_1^{p,d}/F_1^{p,d}$
185 exp. points

$\Delta\Sigma = 0.32 \pm 0.06$

$\Delta u = 0.84 \pm 0.03$

$\Delta d = -0.43 \pm 0.04$

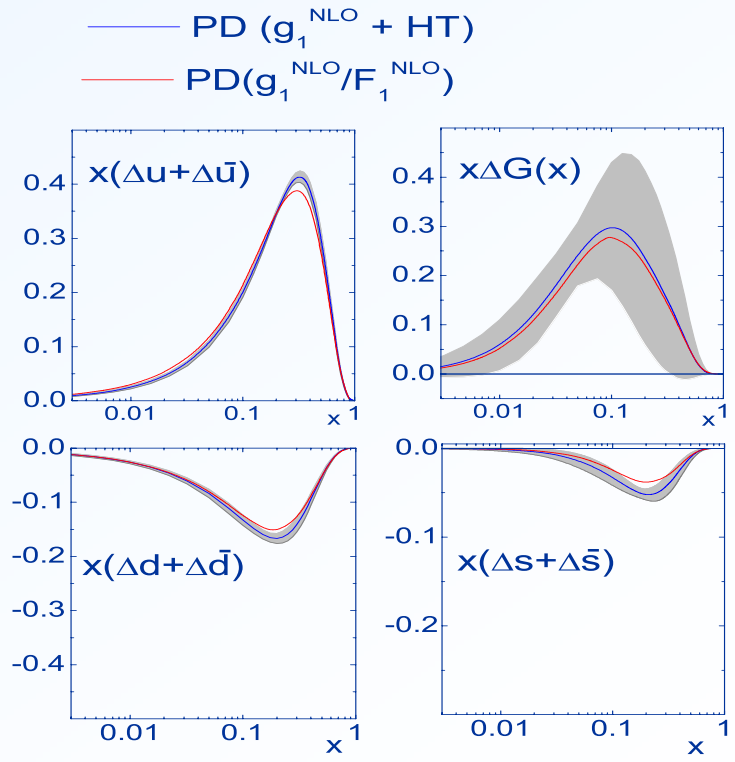
$\Delta s = -0.09 \pm 0.03$

$\Delta G = 0.80 \pm 0.43$

ΔG not well constrained
$\Delta\bar{u}$, $\Delta\bar{d}$ not extracted

$1/2 = 1/2 \cdot 0.32 + 0.80 + L_z$
$= 0.96 + L_z$

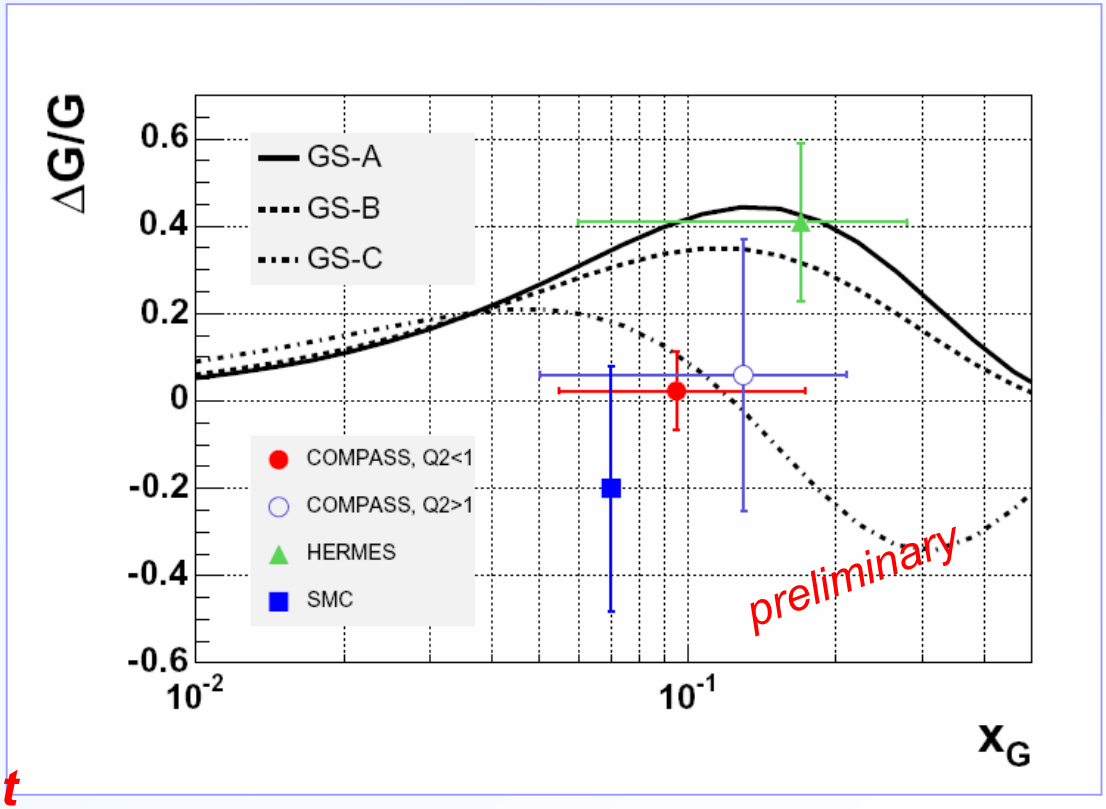
➔ L_z is ***negative***



Spin-dependent PDFs
E. Leader, A. Sidorov, D. Stamenov
Phys. Rev. D67 (2003) 074017

1. ΔG/G at COMPASS (cont.)

17 years after the onset of the spin crisis

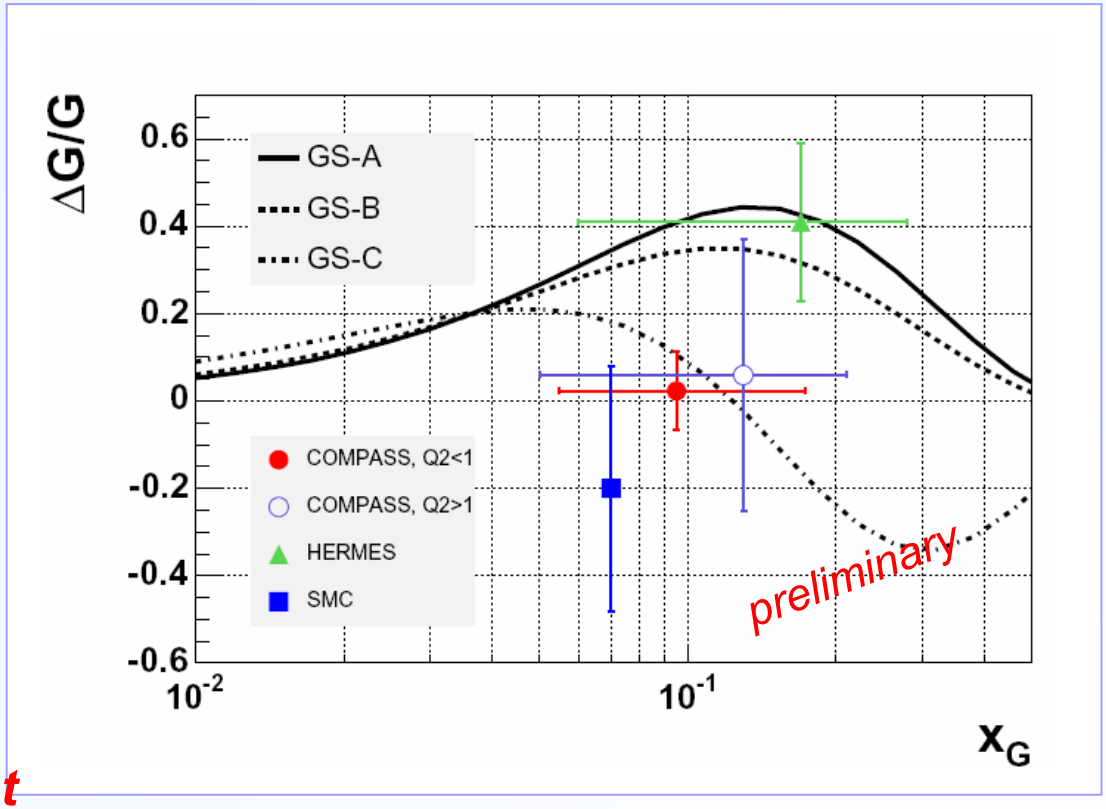


we find that

$$\Delta G \text{ is small around } x_g \approx 0.1$$

1. ΔG/G at COMPASS (cont.)

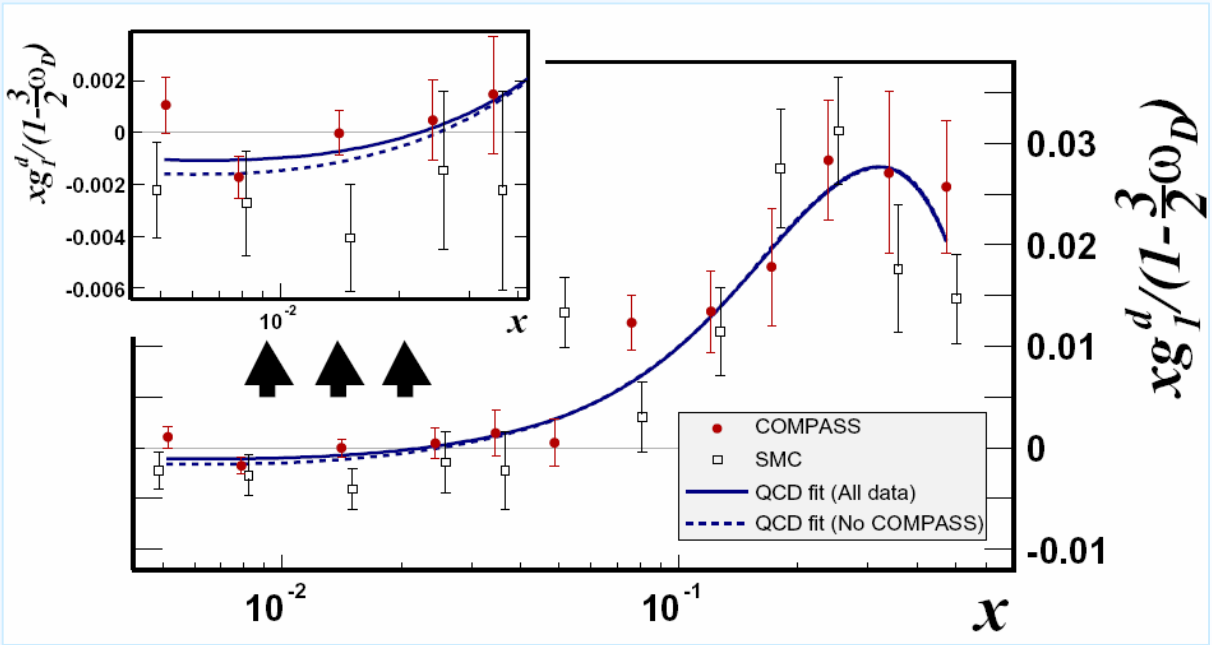
17 years after the onset of the spin crisis



we find that

$$\Delta G \text{ is small around } x_g \approx 0.1$$

2. g_1 of the deuteron



- most precise measurement for $0.004 < x < 0.03$ **PLB 612 (2005) 154**
- new NLO QCD fit, precision of a_0 improves factor 2 ($Q^2 = 4$ GeV^2)

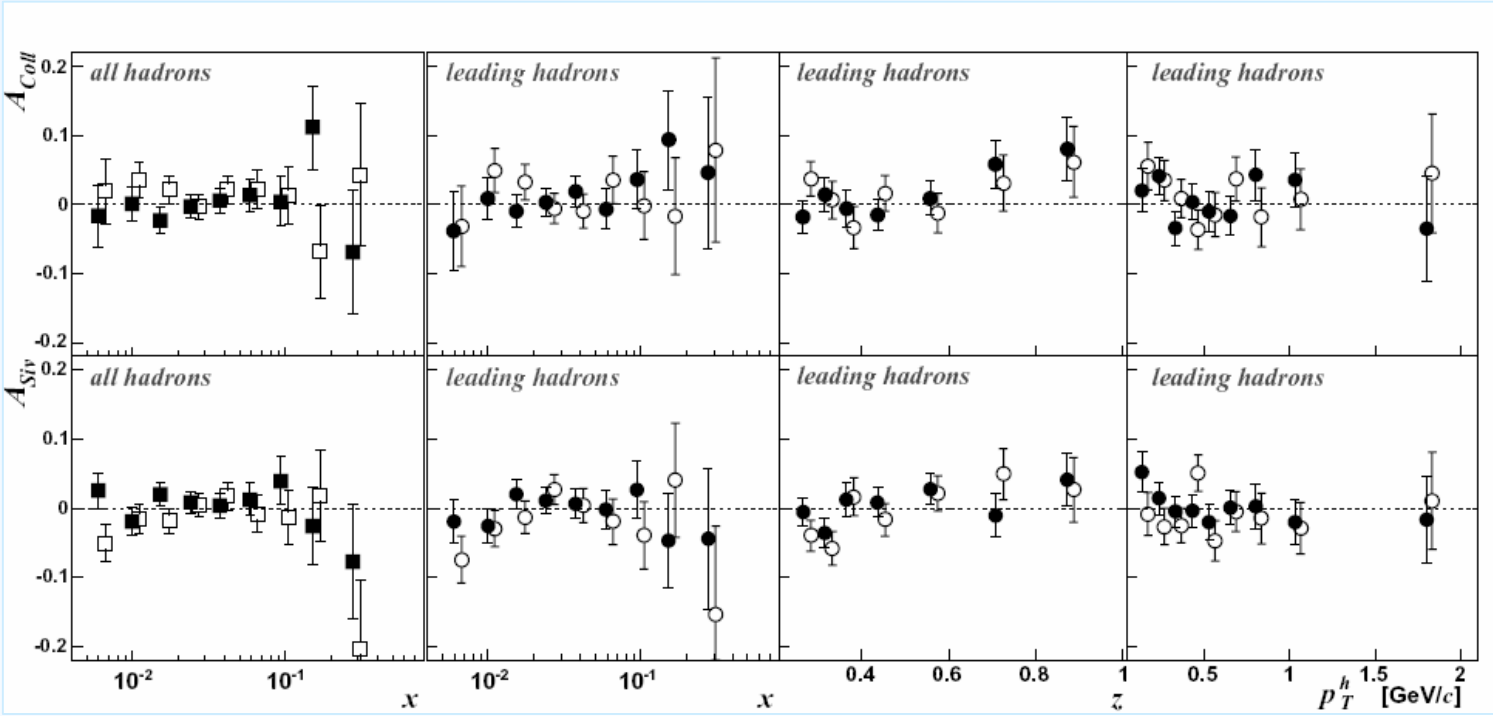
$$a_0 = \Delta\Sigma(\overline{MS}) = 0.237^{+0.024}_{-0.029}$$

3. Transversity

first measurements of transverse spin asymmetries in DIS of high energy muons (160 GeV) on a transversely polarized deuteron target

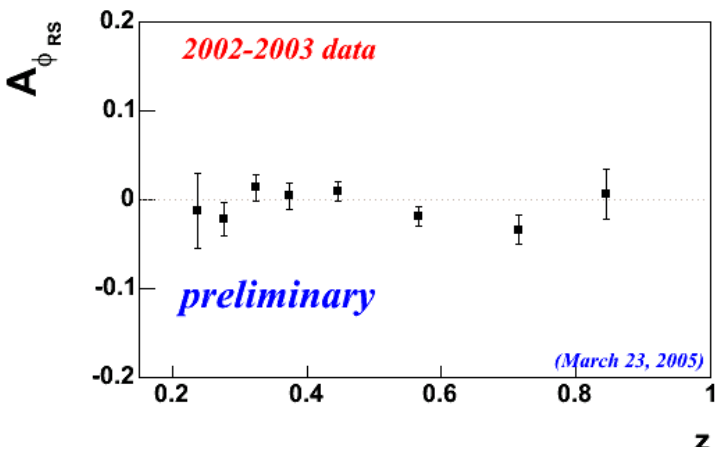
published single hadron asymmetries from 2002 run

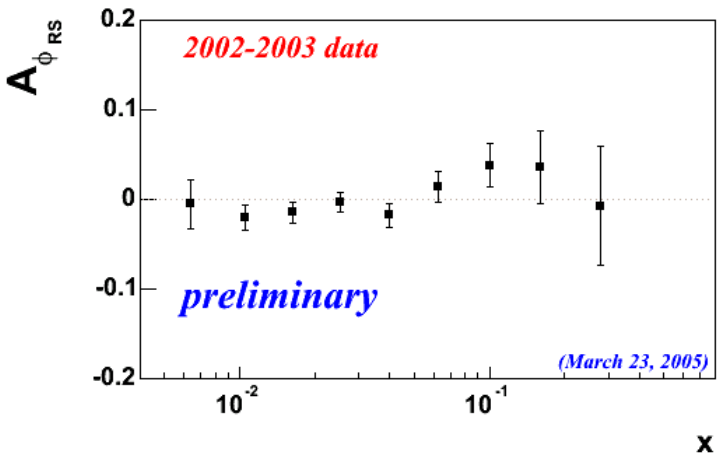
- **Collins: related to transverse quark distributions**
- **Sivers: related to intrinsic k_T**

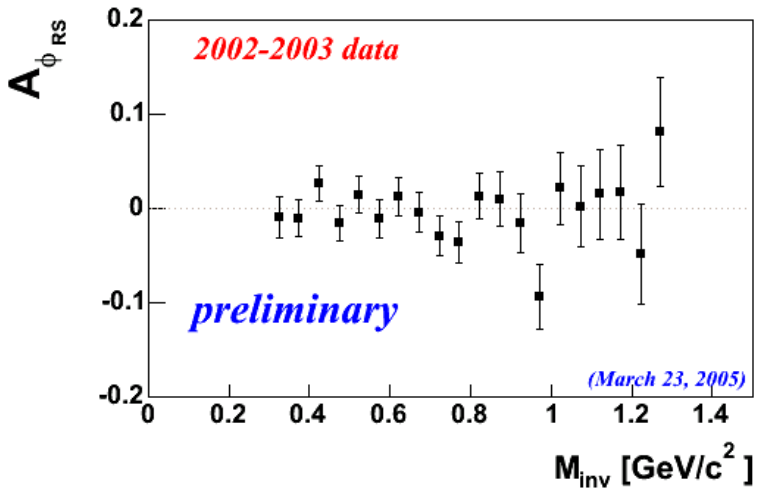


CERN-PH-EP/2005-003; hep-ex/0503002; PRL

3. Transversity: two hadron asymmetries







- precise measurement of few %
- systematics seems well under control
- also compatible with zero
- interesting to see proton in 2006

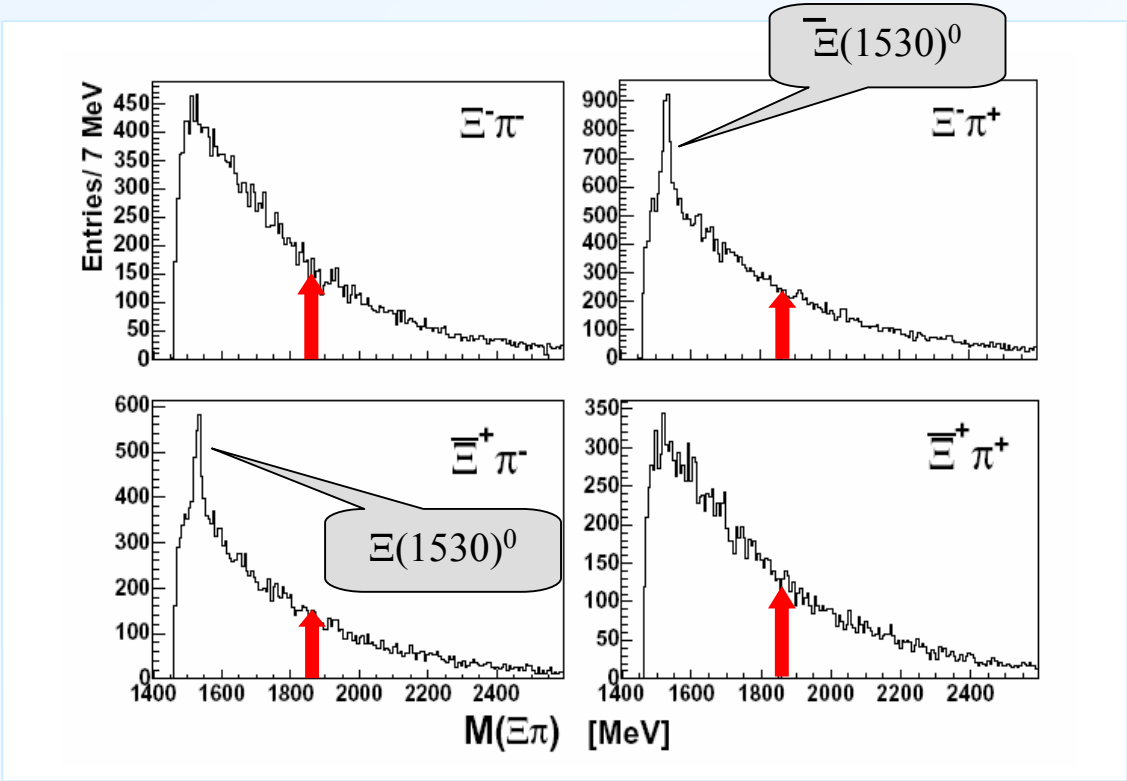
4. Φ(1860) Pentaquark search

motivated by NA49 report of pentaquark candidate

- COMPASS has large sample of the double-strange Ξ^- baryon (18000 Ξ^-, 11000 Ξ^+) from 2002/3 data
- search for $\Xi^- \pi^-$ resonance

$$\Phi(1860)^{--} \rightarrow \Xi^- \pi^- \rightarrow \Lambda\pi^- \pi^- \rightarrow p\, \pi^- \pi^- \pi^-$$

4. Φ(1860) Pentaquark search (cont.)



compare to yields

- **opposite-sign pairs: $\Xi(1530)^0 \rightarrow \Xi^- \pi^+$, 1700 and 920 evts**
- **like-sign pairs: evts <79 and <89 at 99% CL**

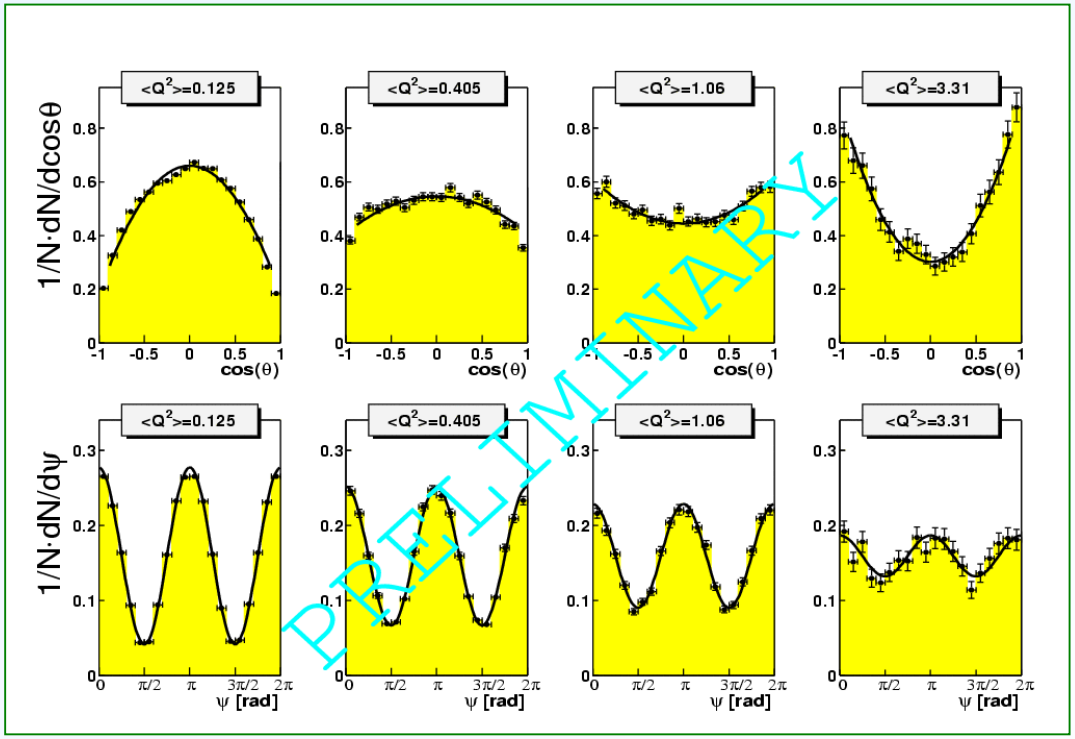
(expected ~400)

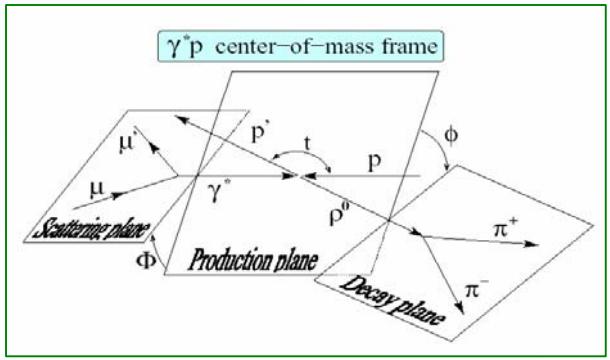
CERN-PH-EP/2005-009; hep-ex/0503033; epj

5. Other Physics Analysis

EXCLUSIVE ρ and ϕ PRODUCTION

ANGULAR DISTRIBUTIONS





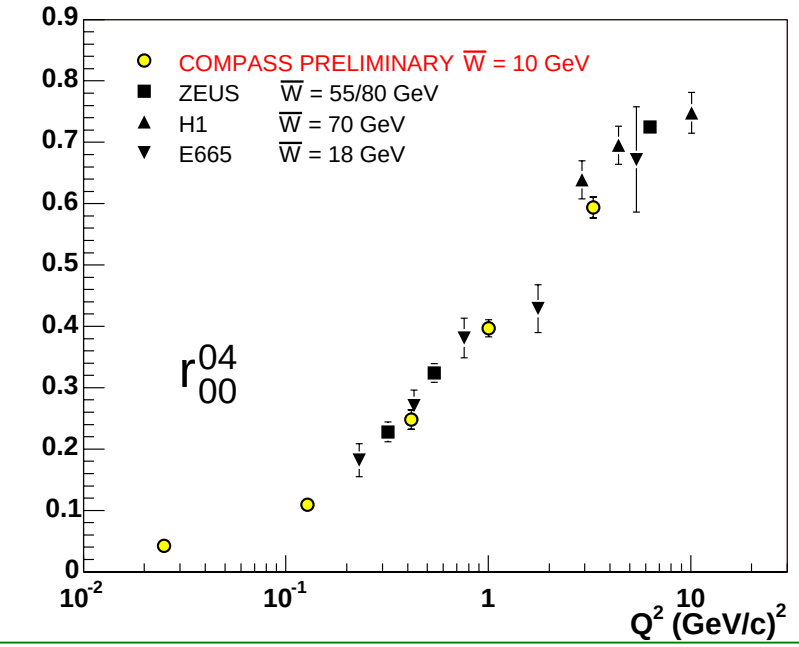
$p_T > 0.15$ GeV $\qquad Q^2 > 0.05$ GeV^2

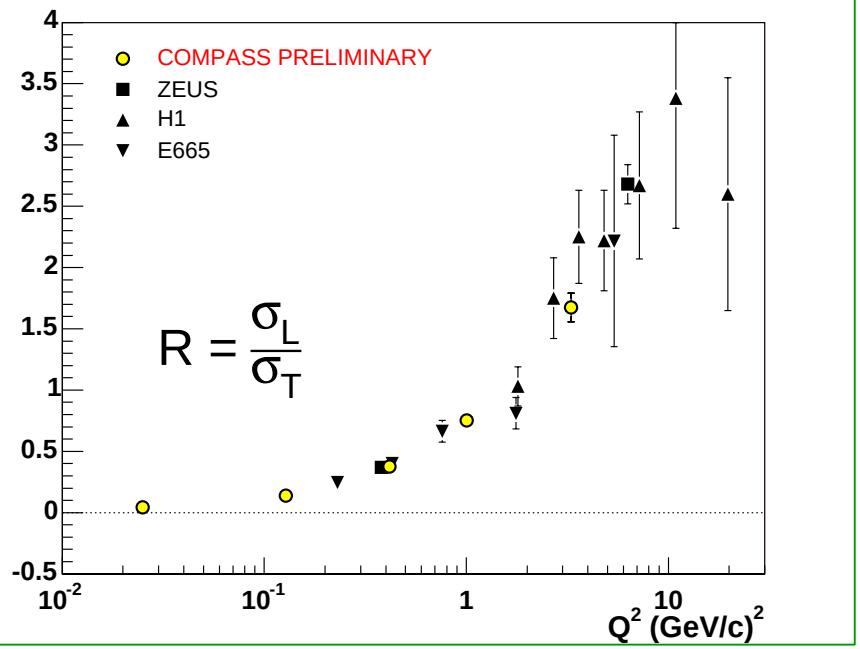
EXCLUSIVE ρ PRODUCTION

High precision measurement of spin density matrix element

if SCHC →

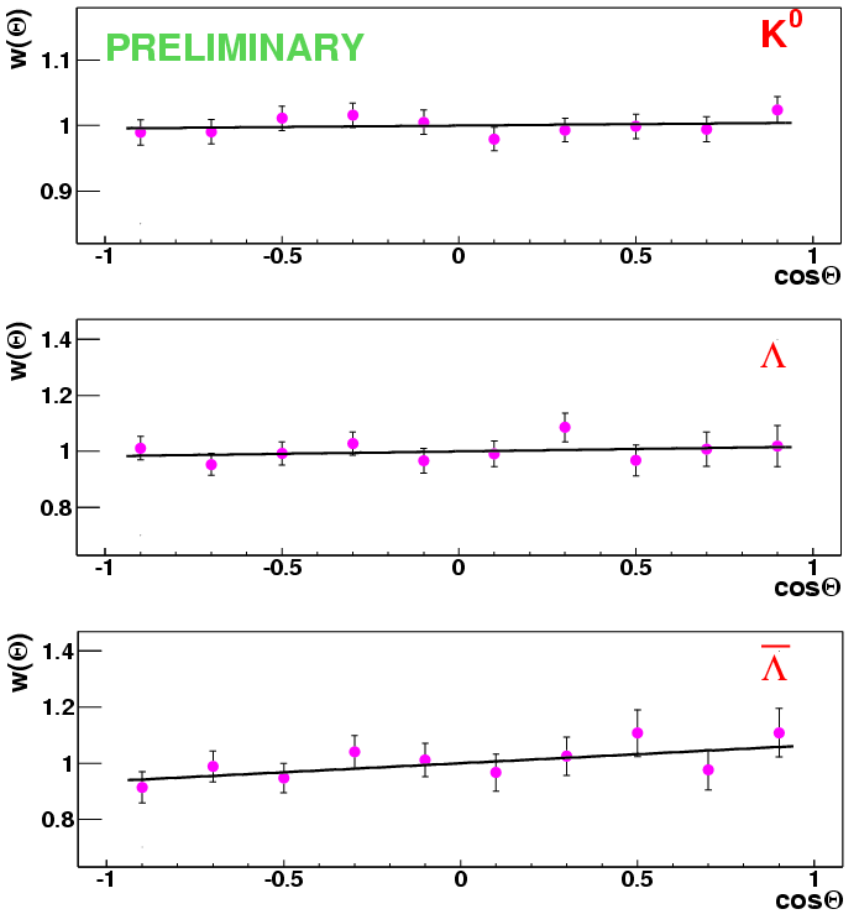
$$R = \frac{\sigma_L}{\sigma_T} = \frac{1}{(\epsilon+\delta)} \frac{r_{00}^{04}}{(1-r_{00}^{04})}$$

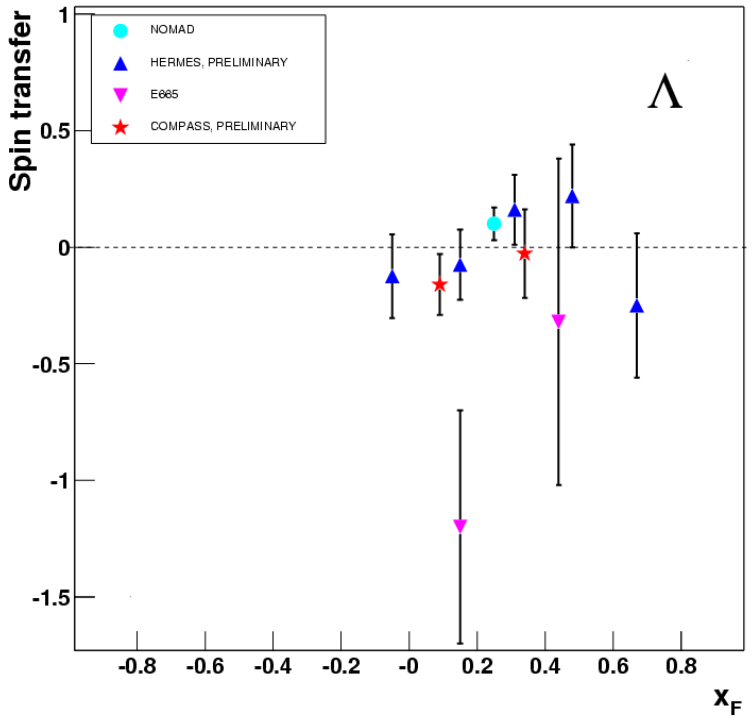




2002 data (only)

Λ POLARIZATION





NEAR FUTURE (2006-2010)

Workshop on Future Physics @ COMPASS
Yellow Report CERN-2004-011, 22 Nov. 2004

- **IMPORTANT UPGRADE of the SPECTROMETER ONGOING**
  - **RICH**
  - **TRACKING**
  - **E.M. CALORIMETERS**
  - **O. D. P.T. MAGNET**
  - **Veto System**
- **2006 MUON RUNNING**
  - **100 days 6LiD Longitudinal Polarization**
  - **30 days NH3 Transverse Polarization**
- **2007 HADRON RUNNING**
  - **CENTRAL PRODUCTION**
  - **with 300 GeV hadron beam and LH2 target**
- **2008- 2010 COMPLETE THE APPROVED MUON and HADRON PROGRAMME**

FAR FUTURE (after 2010)

DEPENDS ON

- **Beam availability and properties**
  (muon programme)
- **Spectrometer response**
  (hadron programme)
- **Physics outcome from COMPASS-1**

In Villars 2004 COMPASS declared great interest in

- **glueballs and exotics**
- **DG/G and Transversity (statistically limited)**
- **GPD to address the contribution of the quark and gluon orbital angular momentum to the nucleon spin**
  Expression of Interest to SPSC after Villars
  (CERN-SPSC-EOI-005)

SUMMARY AND OUTLOOK

- **a technically challenging new experiment is IN OPERATION SINCE 2002**

  "LHC" technologies *detectors*
  read-out
  data handling

- **a privileged situation at CERN**

- **FIRST PHYSICS RESULTS have been produced**
  MANY MORE IN THE PIPE-LINE

- **COMPASS is foreseen to run up to the end of the present mid-term plan of CERN (2010)**

  BIG DISCOVERY POTENTIAL

- **with some upgrade COMPASS might be an interesting option even in the second decade of this century**