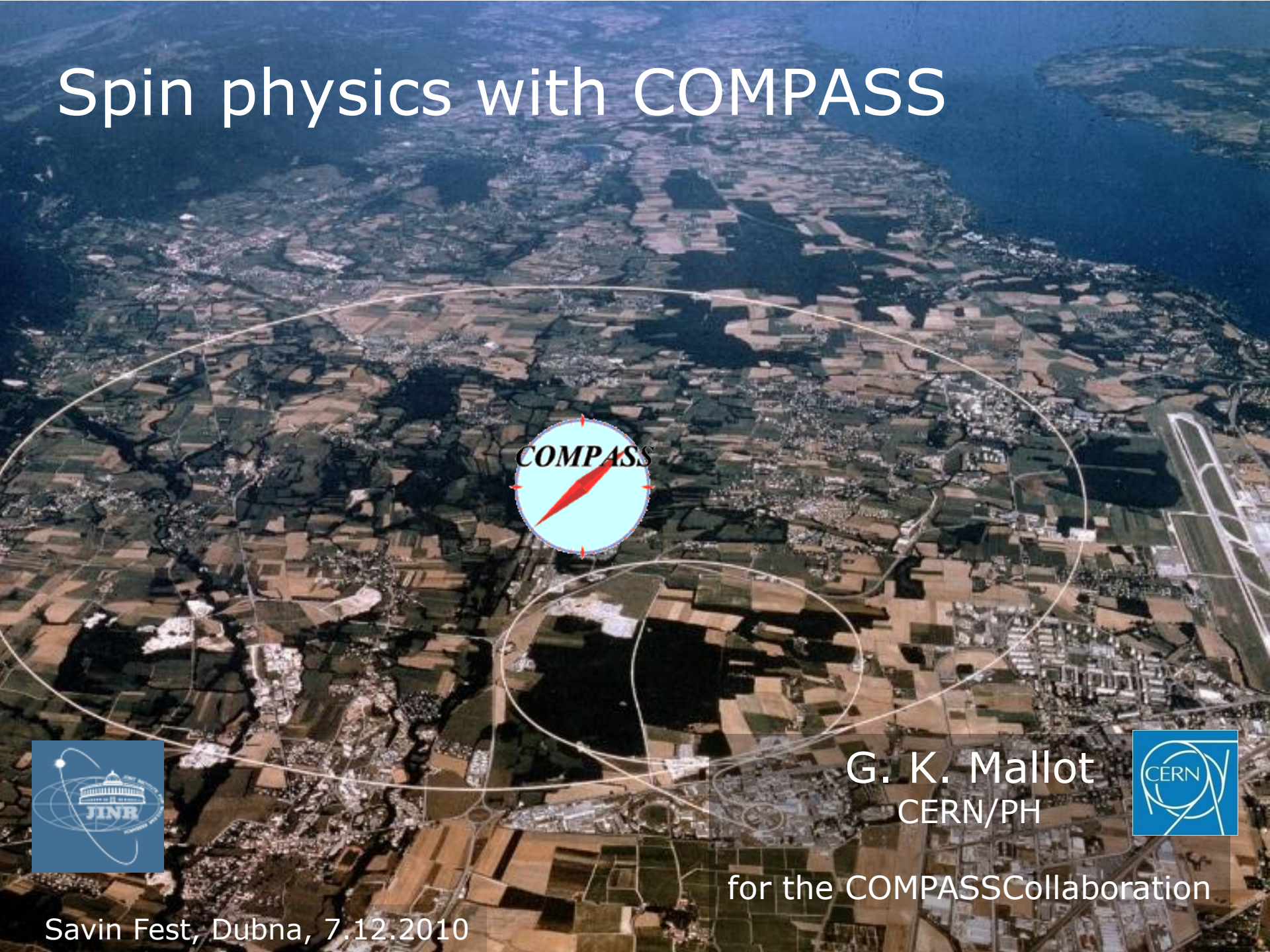
Spin physics with COMPASS



G. K. Mallot
CERN/PH

for the COMPASSCollaboration

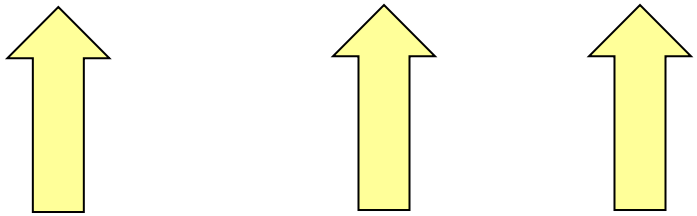
Savin Fest, Dubna, 7.12.2010

The COMPASS starting point

Smallness of ΔΣ confirmed by SMC!

Where, oh where is the proton spin? Elliot Leader

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$$



small EMC, SMC | unknown in 1997 | unknown

Theory Input 1988

CHIRAL SYMMETRY AND THE SPIN OF THE PROTON ☆

Stanley J. BRODSKY [a], John ELLIS [a,b1] and Marek KARLINER [a]
[a] *Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94305, USA*
[b] *CERN, CH-1211 Geneva 23, Switzerland*

PLB 206 (1988) 309

A crisis in the parton model: where, oh where is the proton's spin?

E. Leader[1] and M. Anselmino[2]
Birkbeck College, University of London, London, UK
Dipartimento di Fisica Teorica, Università di Torino, I-10125 Torino, Italy

Received 18 March 1988

ZPC 41 (1988) 239

E2-88-287

A.V.Efremov, O.V.Teryaev*

SPIN STRUCTURE OF THE NUCLEON AND TRIANGLE ANOMALY

THE ANOMALOUS GLUON CONTRIBUTION TO POLARIZED LEPTOPRODUCTION

G. ALTARELLI and G.G. ROSS [1]
CERN, CH-1211 Geneva 23, Switzerland

PLB 212 (1988) 391

Received 29 June 1988

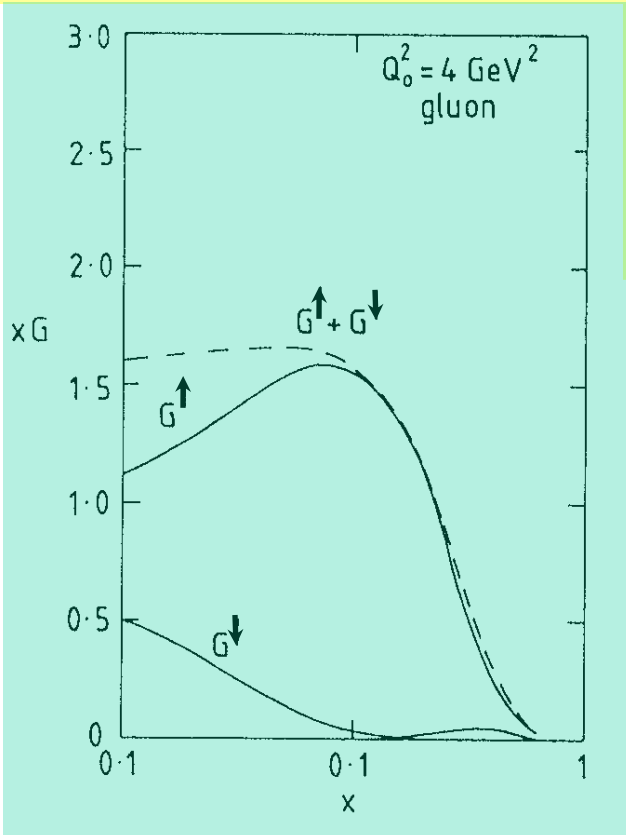
Lepton-Photon 1989

To summarise, let us return to the fit of Fig. 7 and 8. At $Q^2=10GeV^2$ this corresponds to $\Delta g=6.3$ and so the proton helicity is given by

$$\tfrac{1}{2} = \tfrac{1}{2}\Delta\Sigma + \Delta g + L_z$$

$$= 0.35 + 6.3 - 6.15$$

G. Ross 1989

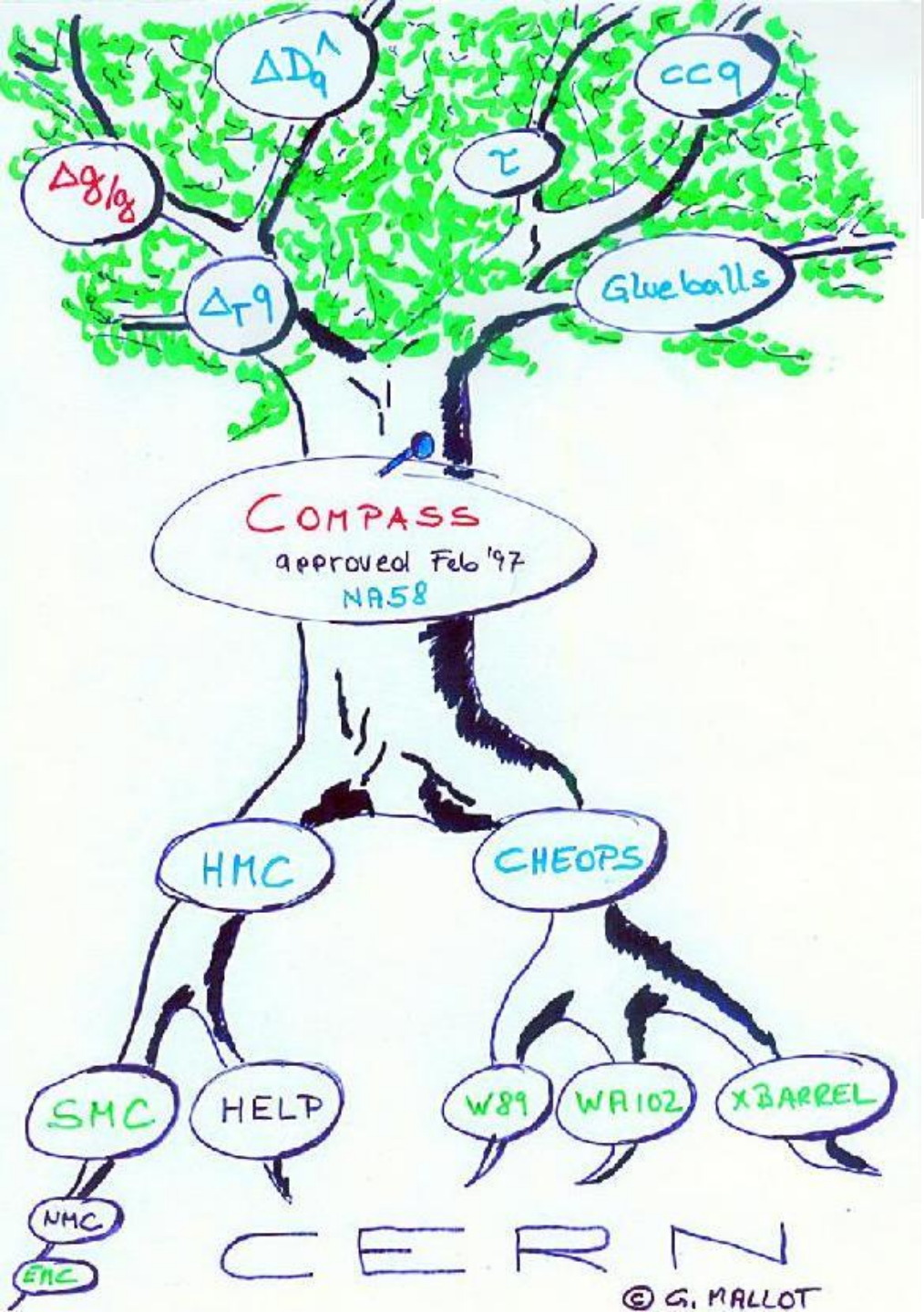


possible scenario:

$\Delta G \approx 6$ $(Q^2=10\ GeV^2)$

$\Delta g/g(x) = 1$ for $x_g > 0.1$

still unresolved after SMC & SLAC



COMPASS

Roots:

in DIS
(SMC, NMC, EMC) and
spectroscopy
(Wa89,WA102,xBarrel)

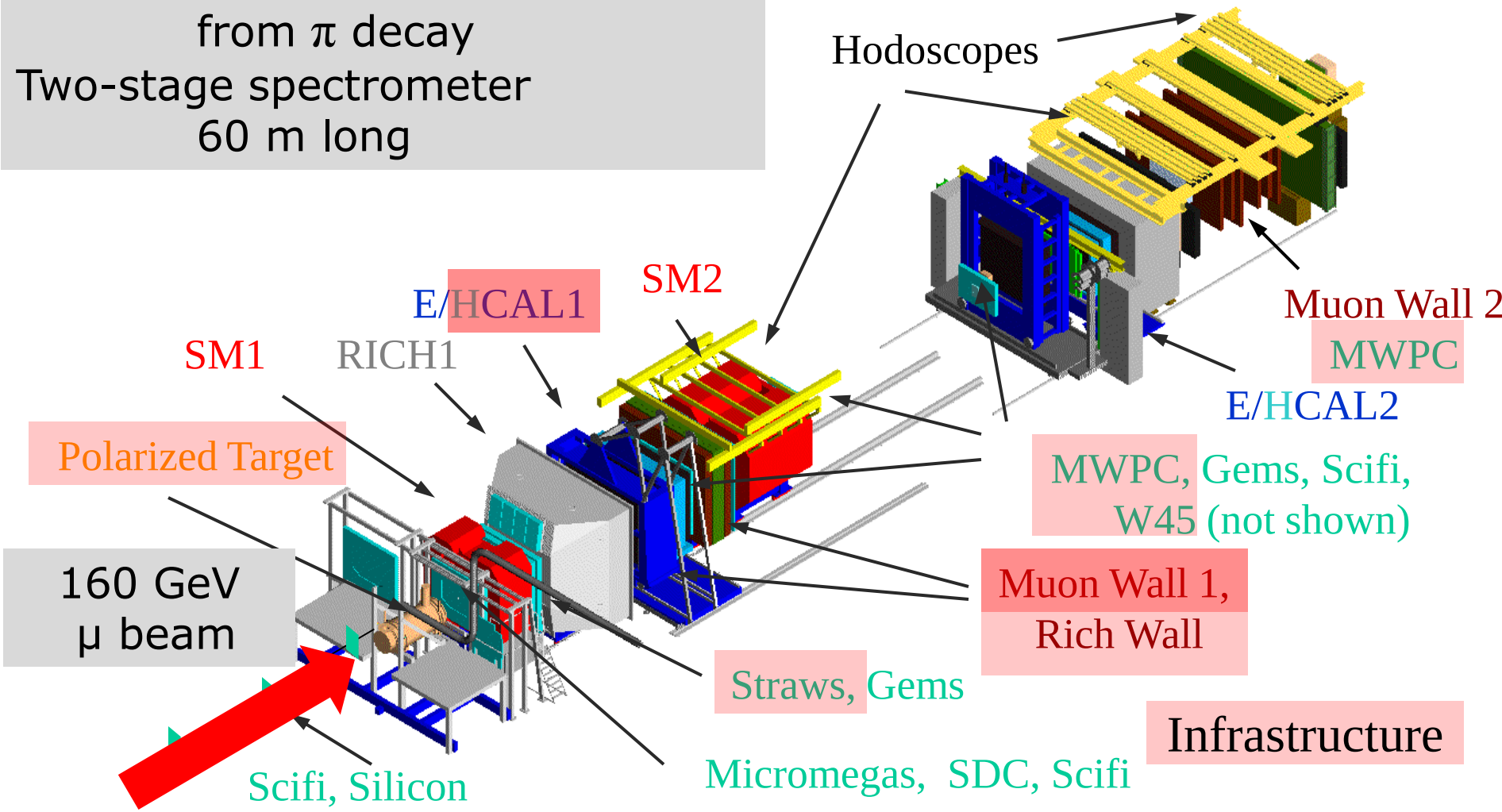
Goals:

gluon polarization,
flavour distributions,
spin transfer

meson spectroscopy,
glue balls, polarisability

COMPASS

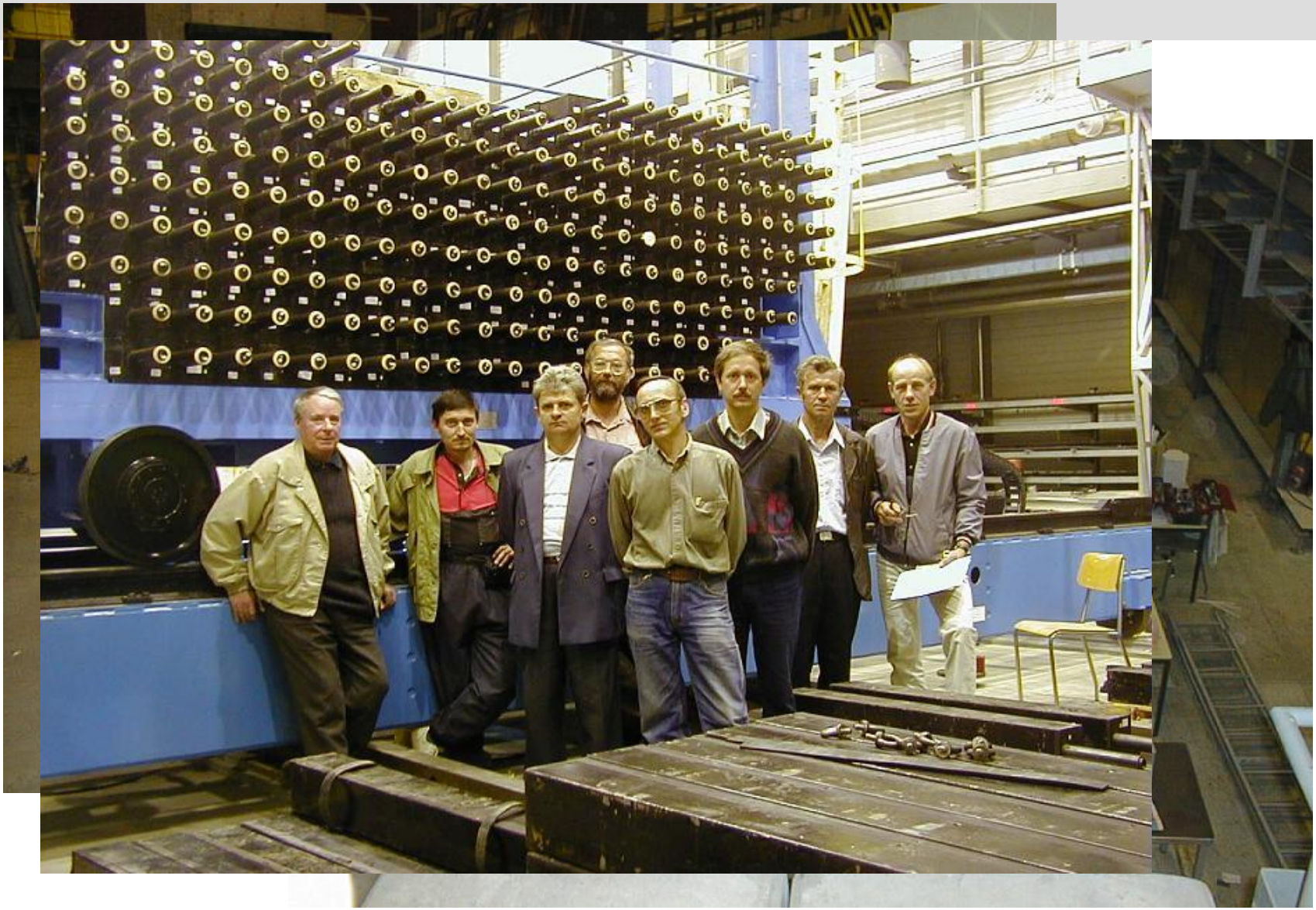
Beam: 160 GeV μ^+, pol. 80%
from π decay
Two-stage spectrometer
60 m long



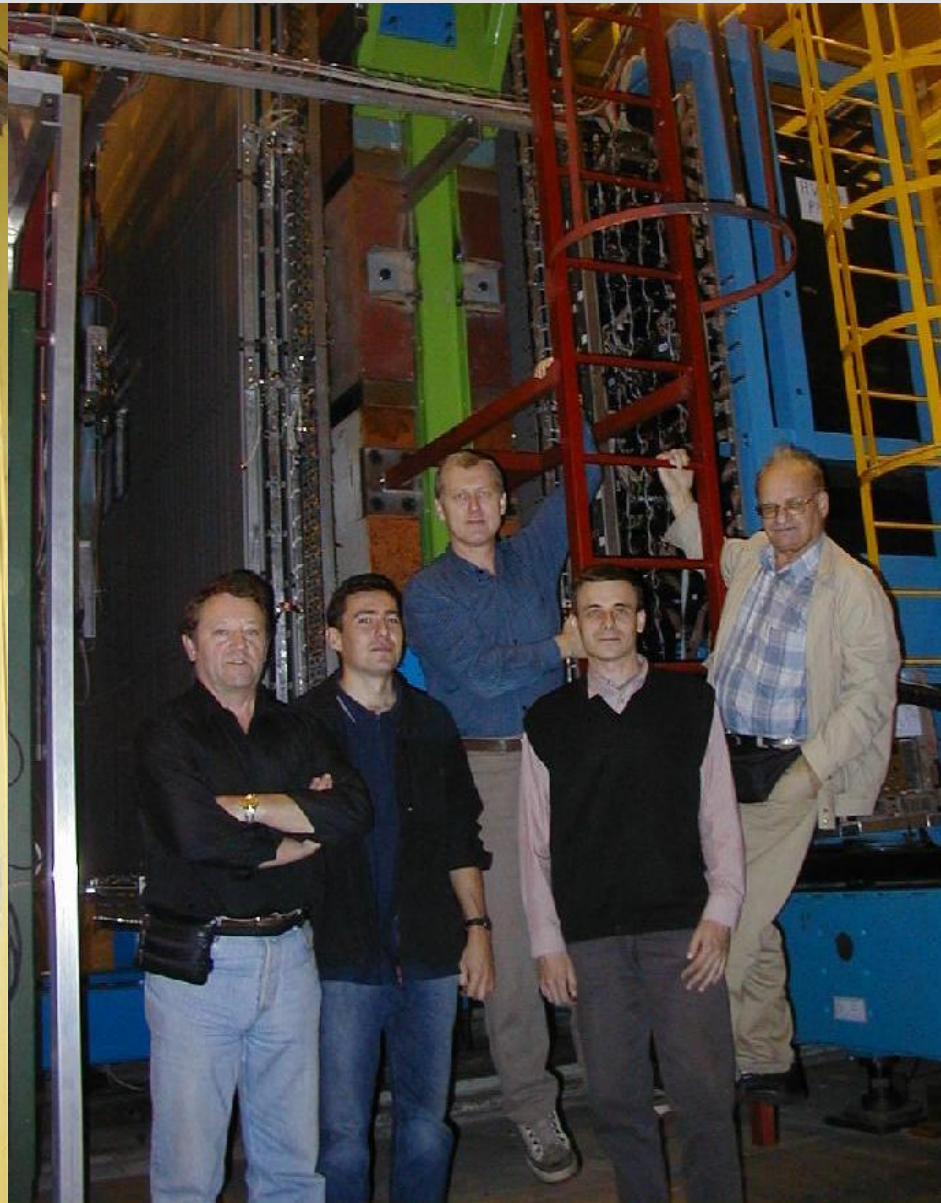
June 1998

COMPASS fully approved in October 1998

HCAL1: February 1999 - 2000

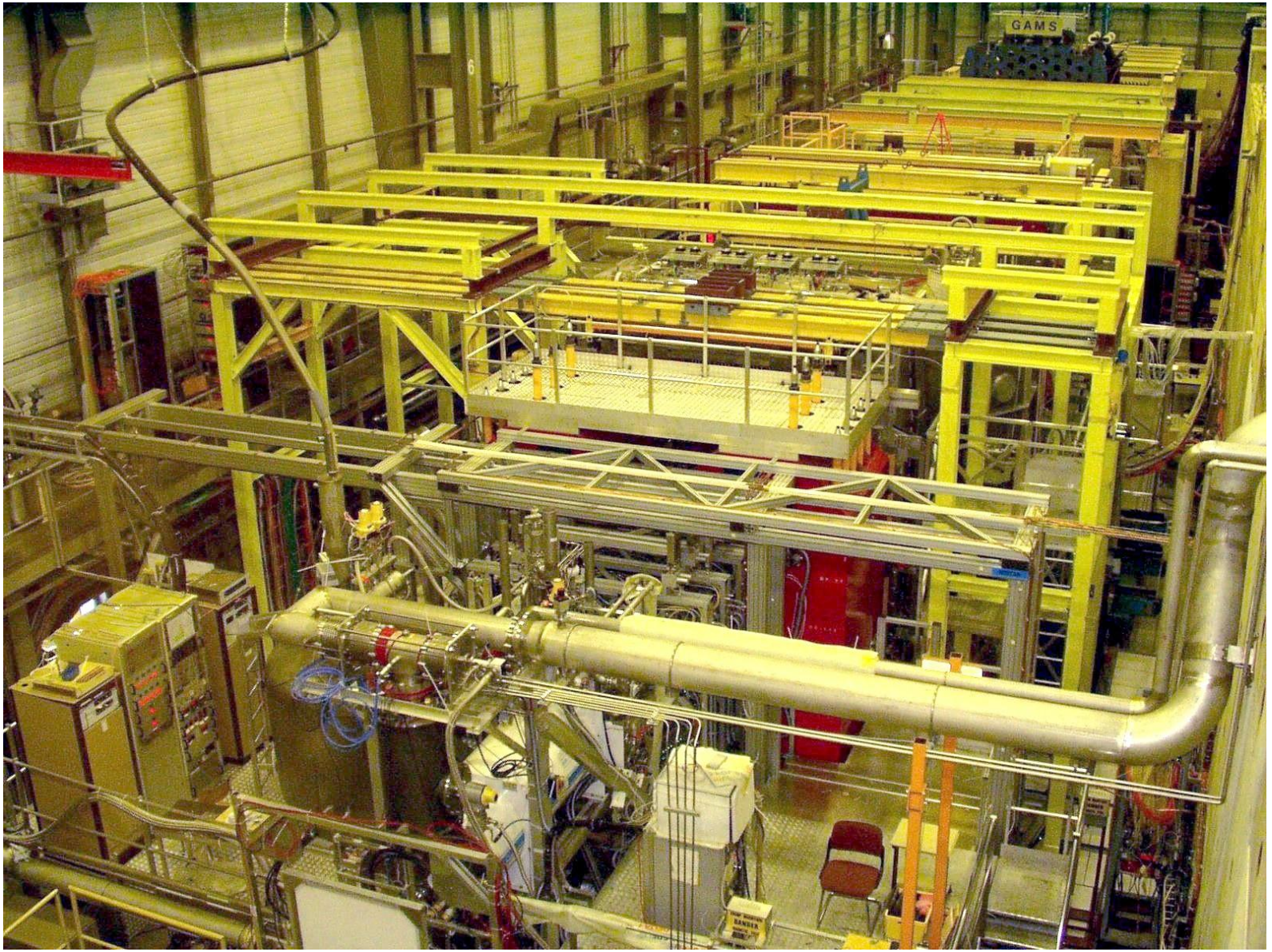


2001 HCAl1 and Muon Wall 1



Straws

COMPASS 2004



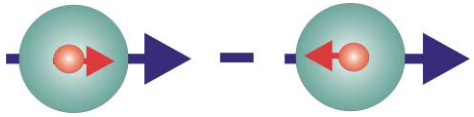
Parton Distribution Functions

Three twist-2 PDFs

q(x)
$f_1^q(x)$

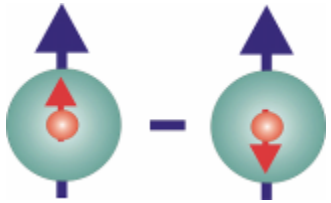
unpolarised PDF
quark with momentum *xP* in a nucleon
well known – unpolarized DIS

Δq(x)
$g_1^q(x)$



helicity PDF
quark with spin parallel to the nucleon spin in a longitudinally polarised nucleon
known – polarized DIS

$\Delta_T q(x)$
$h_1^q(x)$

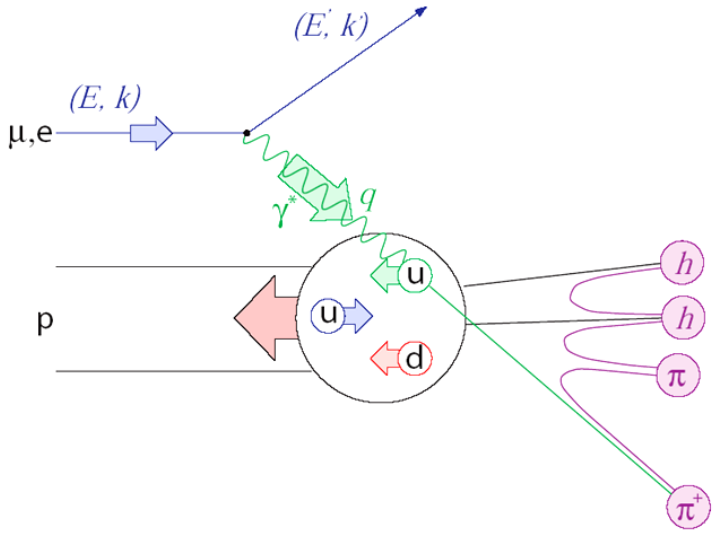


transversity PDF
quark with spin parallel to the nucleon spin in a transversely polarised nucleon
chiral odd, poorly known

Factorization & x-sect. asymmetries

Inclusive scattering

$$A_1 = \frac{\sum_q e_q^2 \Delta q(x, Q^2)}{\sum_q e_q^2 q(x, Q^2)}$$



Semi-inclusive scattering

$$A_1^h = \frac{\sum_q e_q^2 \Delta q(x, Q^2) D_q^h(z, Q^2)}{\sum_q e_q^2 q(x, Q^2) D_q^h(z, Q^2)}$$

long. double spin asymmetry

$$A_{Coll} = \frac{\sum_q e_q^2 \Delta_T q(x) \Delta_T^0 D_q^h(z, p_T^h)}{\sum_q e_q^2 q(x) D_q^h(z, p_T^h)}$$

transverse single asymmetry

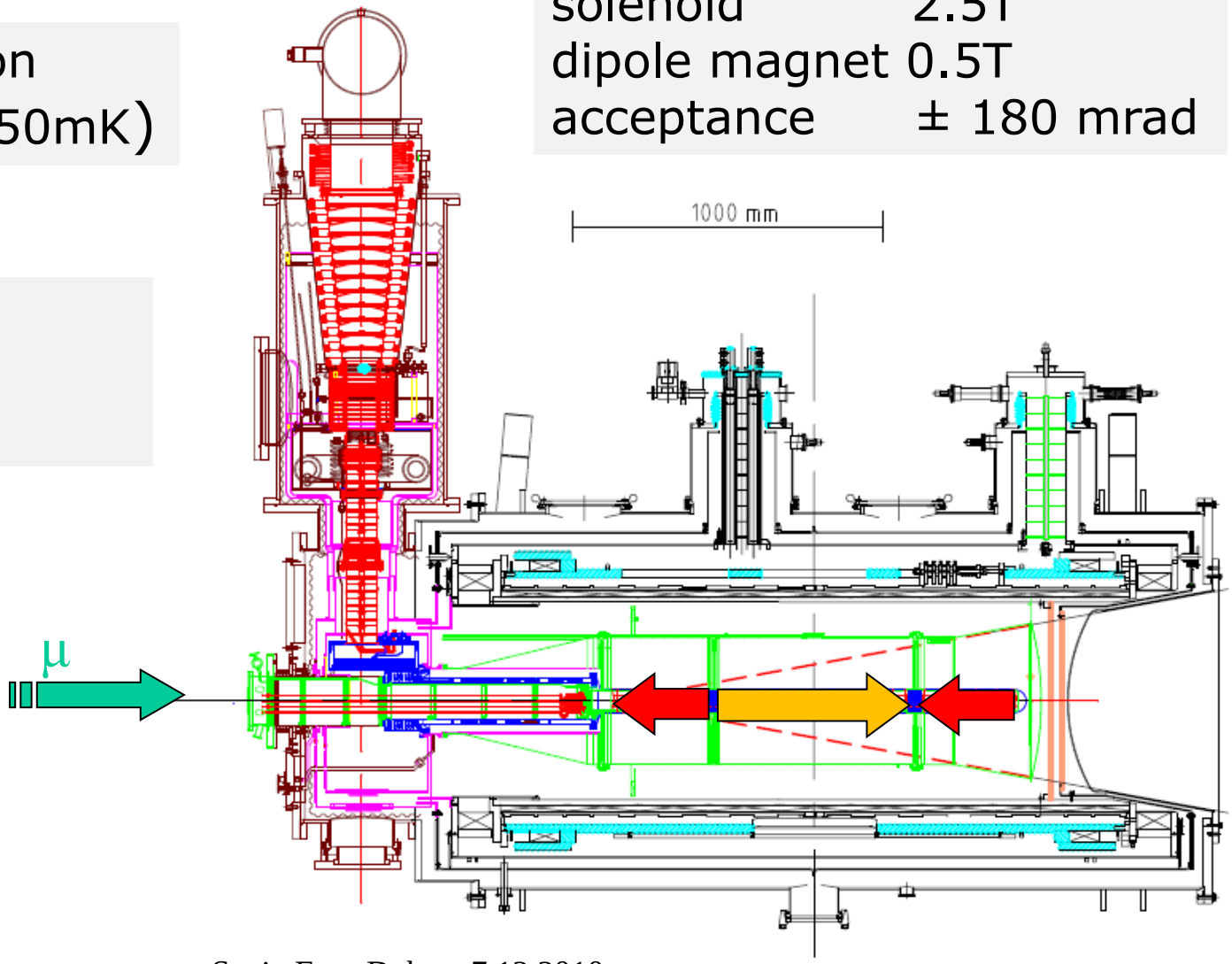
$$z = E_h/\nu$$

COMPASS Target system

^{3}He – ^{4}He dilution refrigerator (T~50mK)

^{6}LiD/NH_3
50/90% pol.
40/16% dil. f.

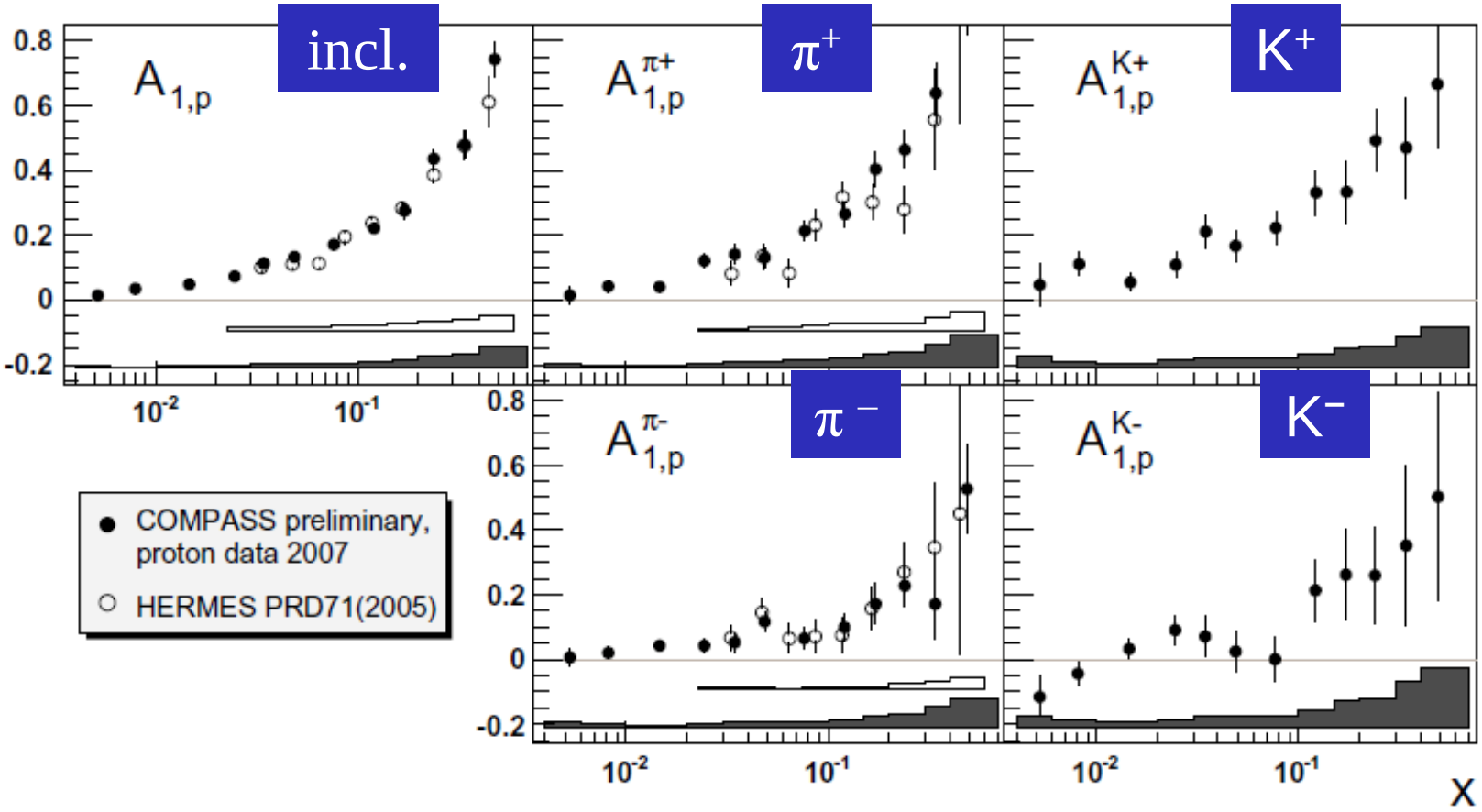
solenoid 2.5T
dipole magnet 0.5T
acceptance ± 180 mrad



Helicity structure

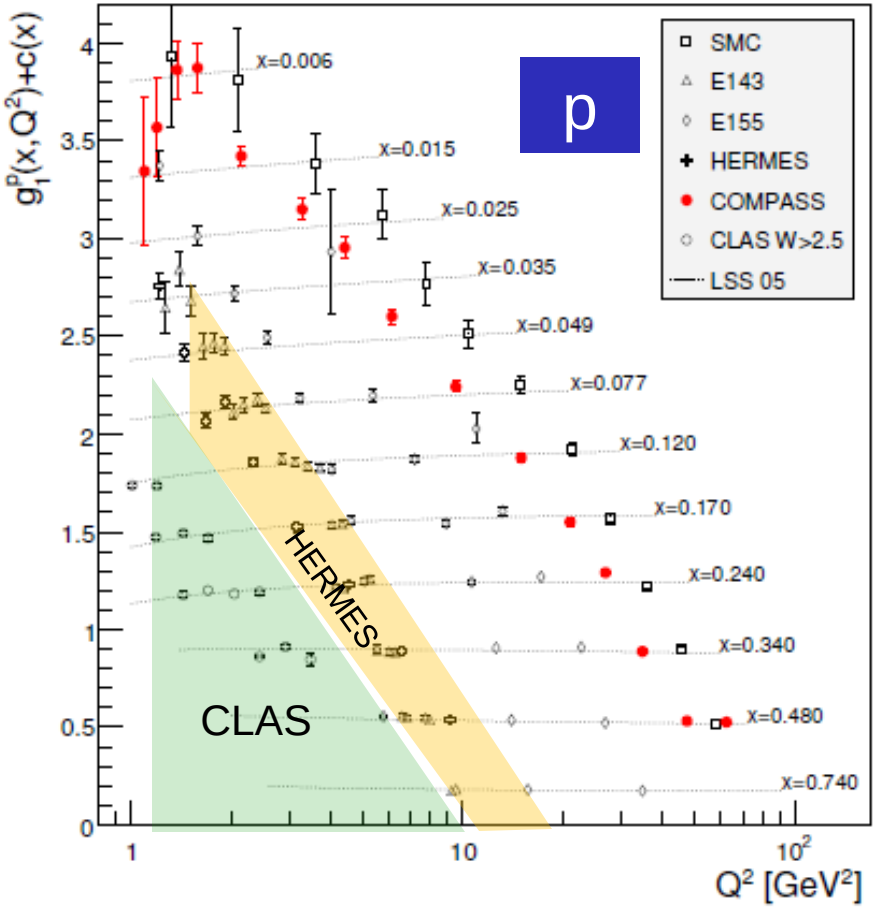
Proton asymmetries

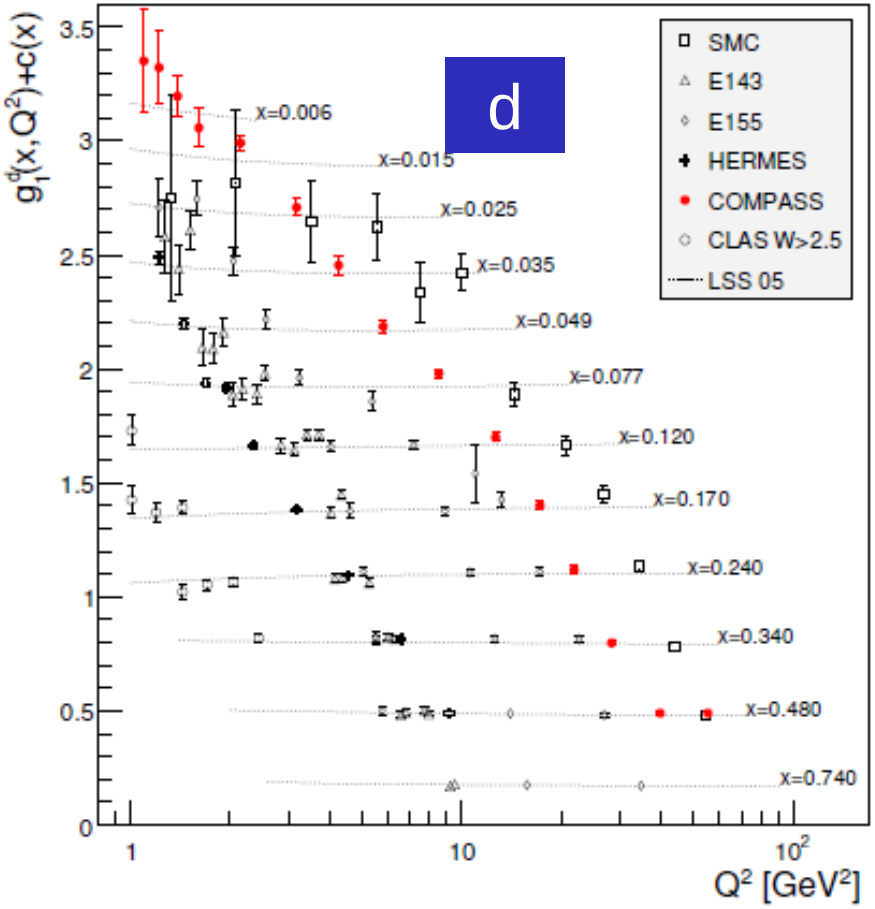
- incl. & semi-incl. asymmetries,
- similar data for deuteron



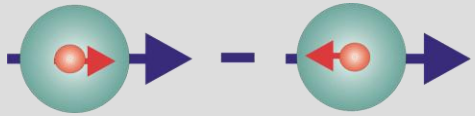
Q^2 evolution of $g_1(x,Q^2)$

- Q^2 dependence *of* g_1 data related to gluon polarization (DGLAP)
- Limited kinematic range (c.f. unpol. HERA)

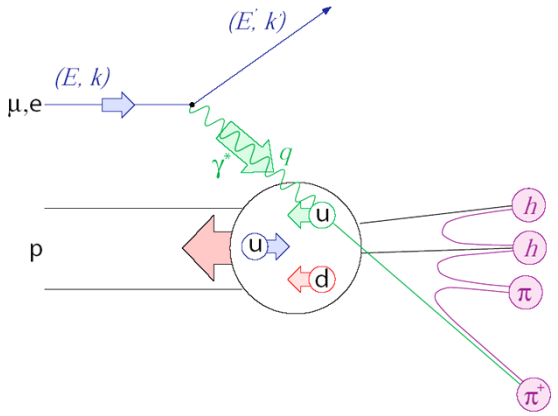


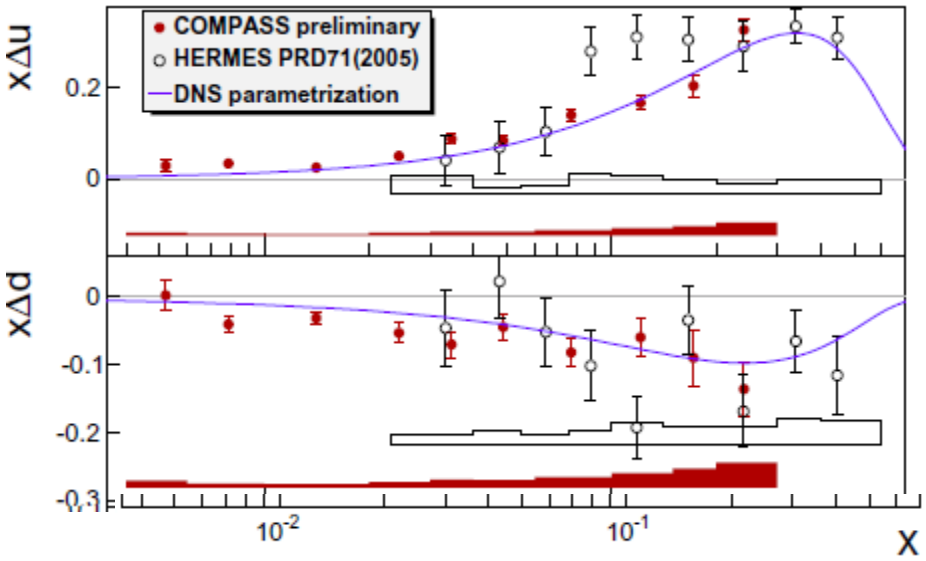


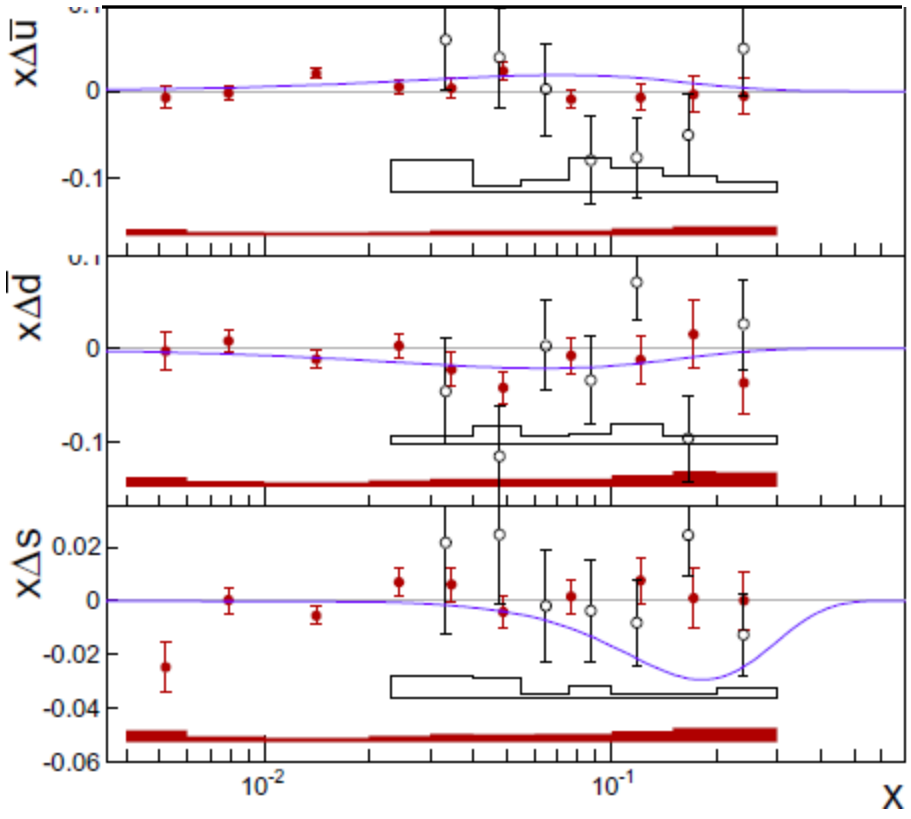
The role of quark flavours



LO semi-inclusive data analysis

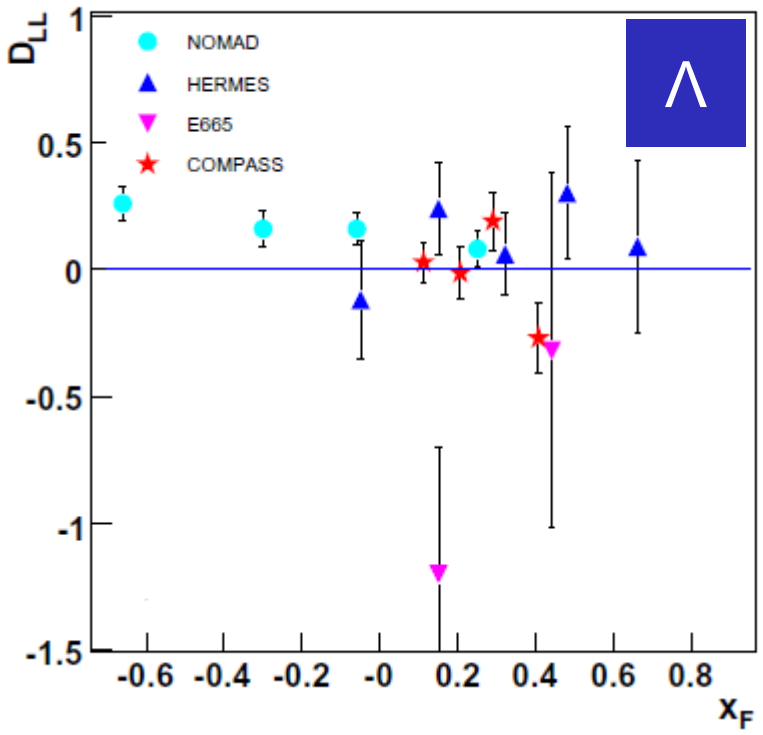


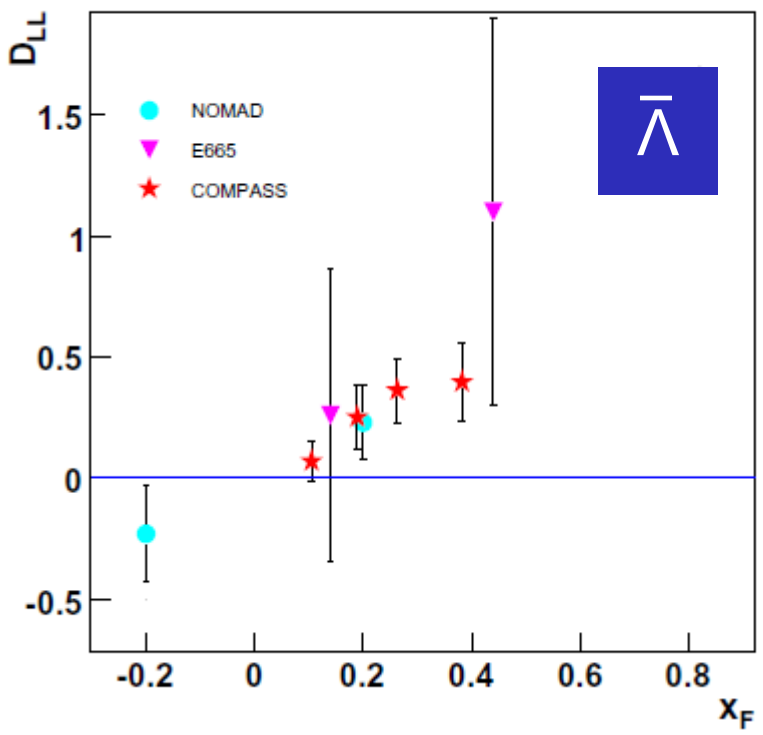




Longitudinal spin transfer to Λ & $\bar{\Lambda}$

2003/2004 data 69500 Λ 41600 $\bar{\Lambda}$



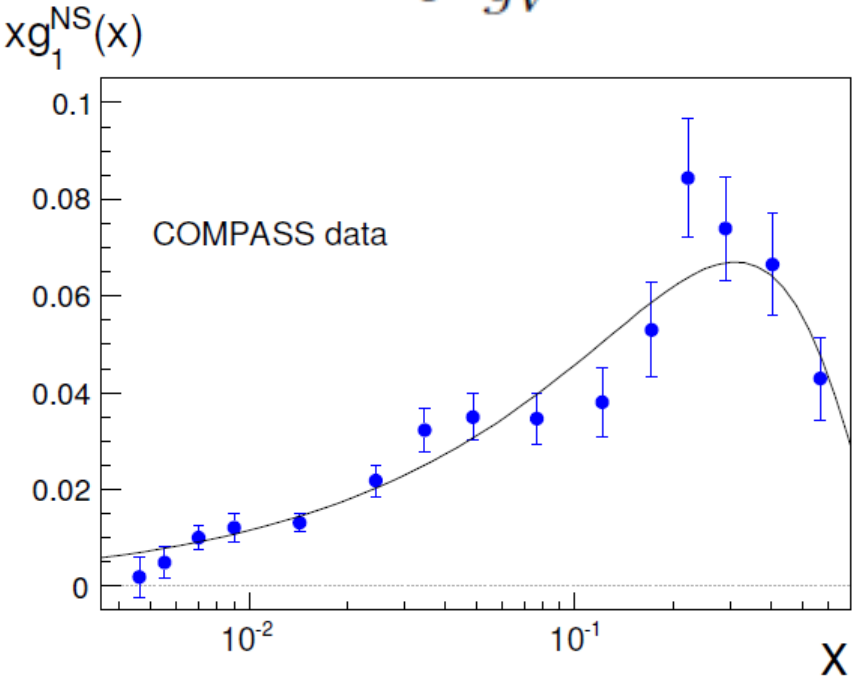


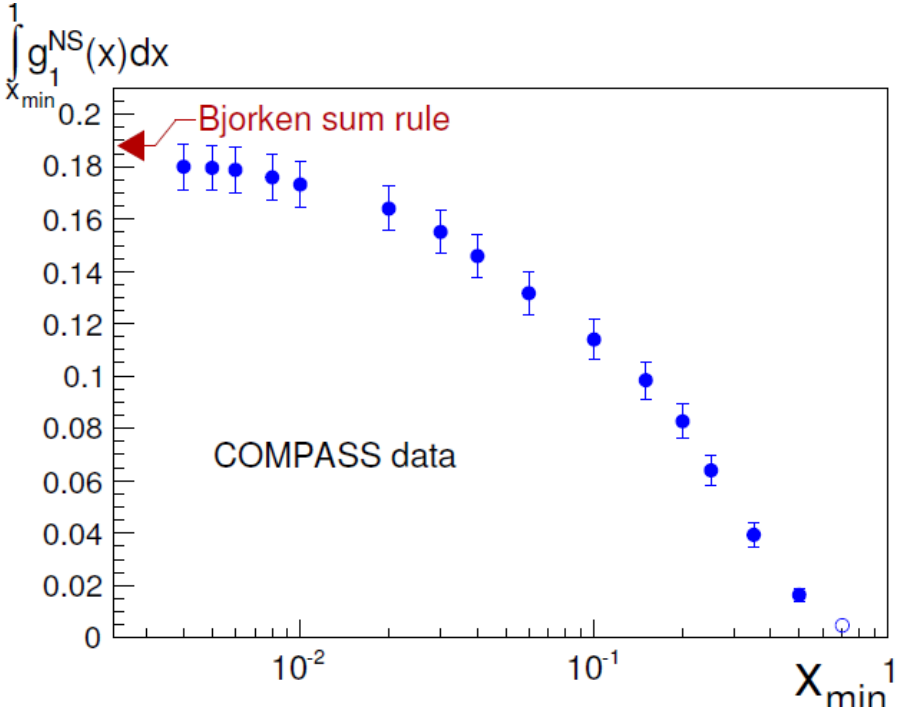
- Large (!) D_{LL} for $\bar{\Lambda}$ related to antistrange quark distribution

Bjorken sum rule

$$\Gamma_1^{NS}(Q^2) = \frac{1}{6}\left|\frac{g_A}{g_V}\right| C_1^{NS}(Q^2)$$

$$g_1^{NS}(x,Q^2) = g_1^p(x,Q^2) - g_1^n(x,Q^2)$$

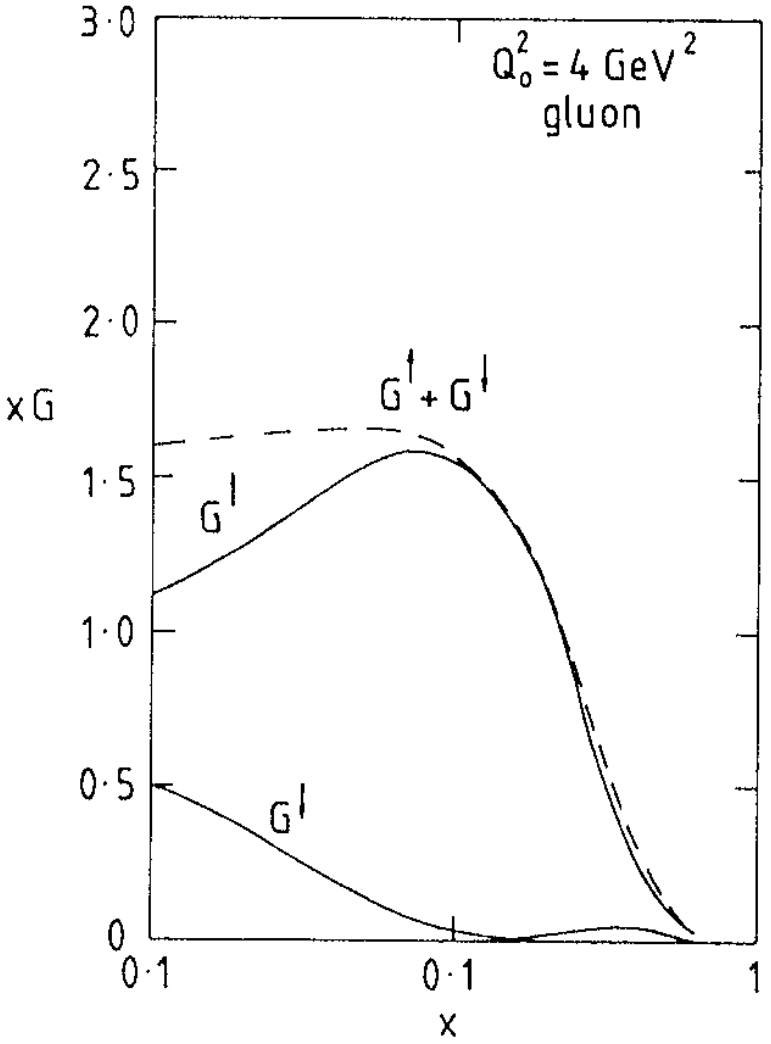


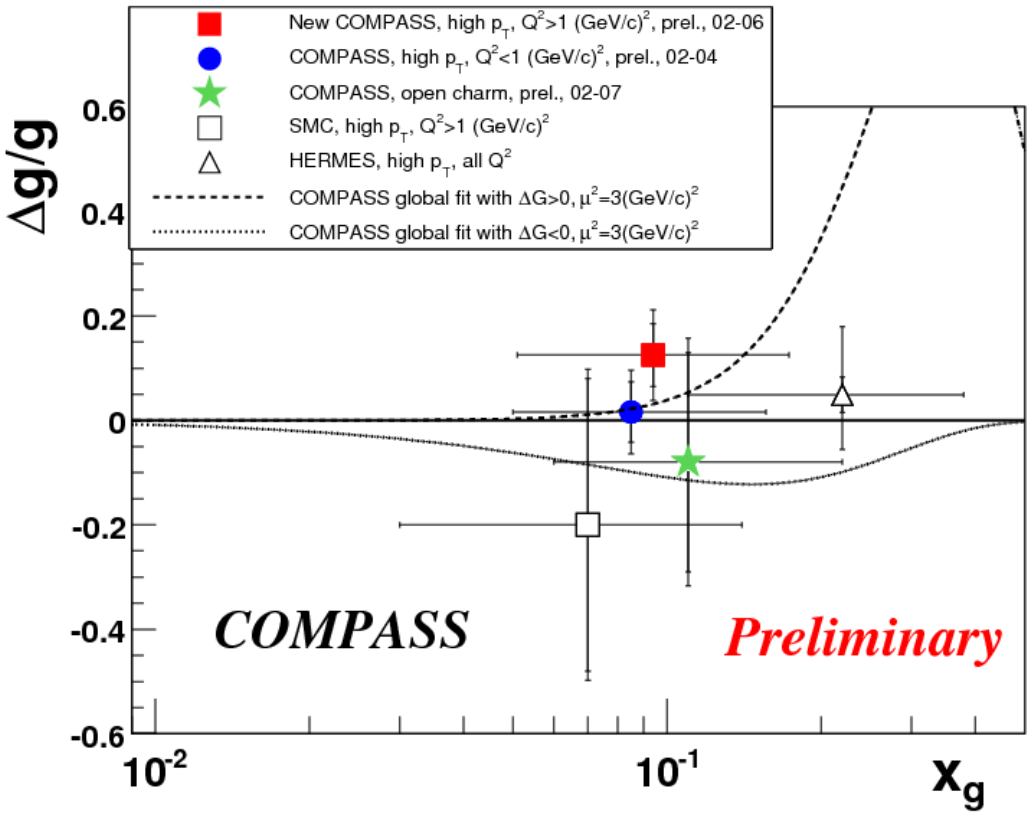


$$|g_A/g_V| = 1.28 \pm 0.07(\text{stat.}) \pm 0.10(\text{syst.})$$

$$|g_A/g_V| = 1.269$$ from neutron β decay

Gluon polarization from PGF (LO)



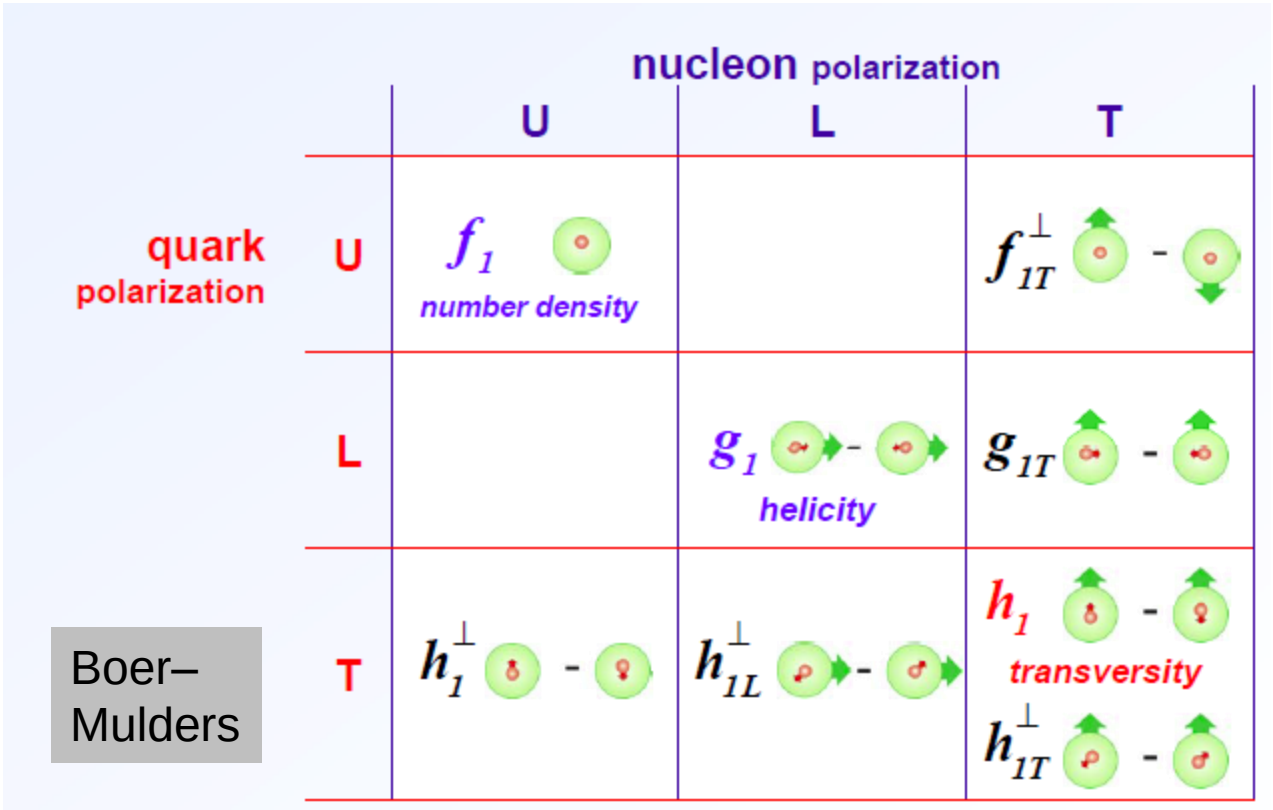


Data not yet in global fits

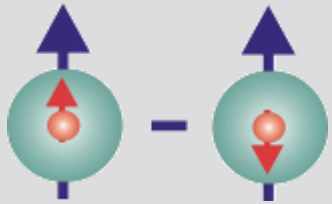
Transverse spin structure

TMD parton distributions

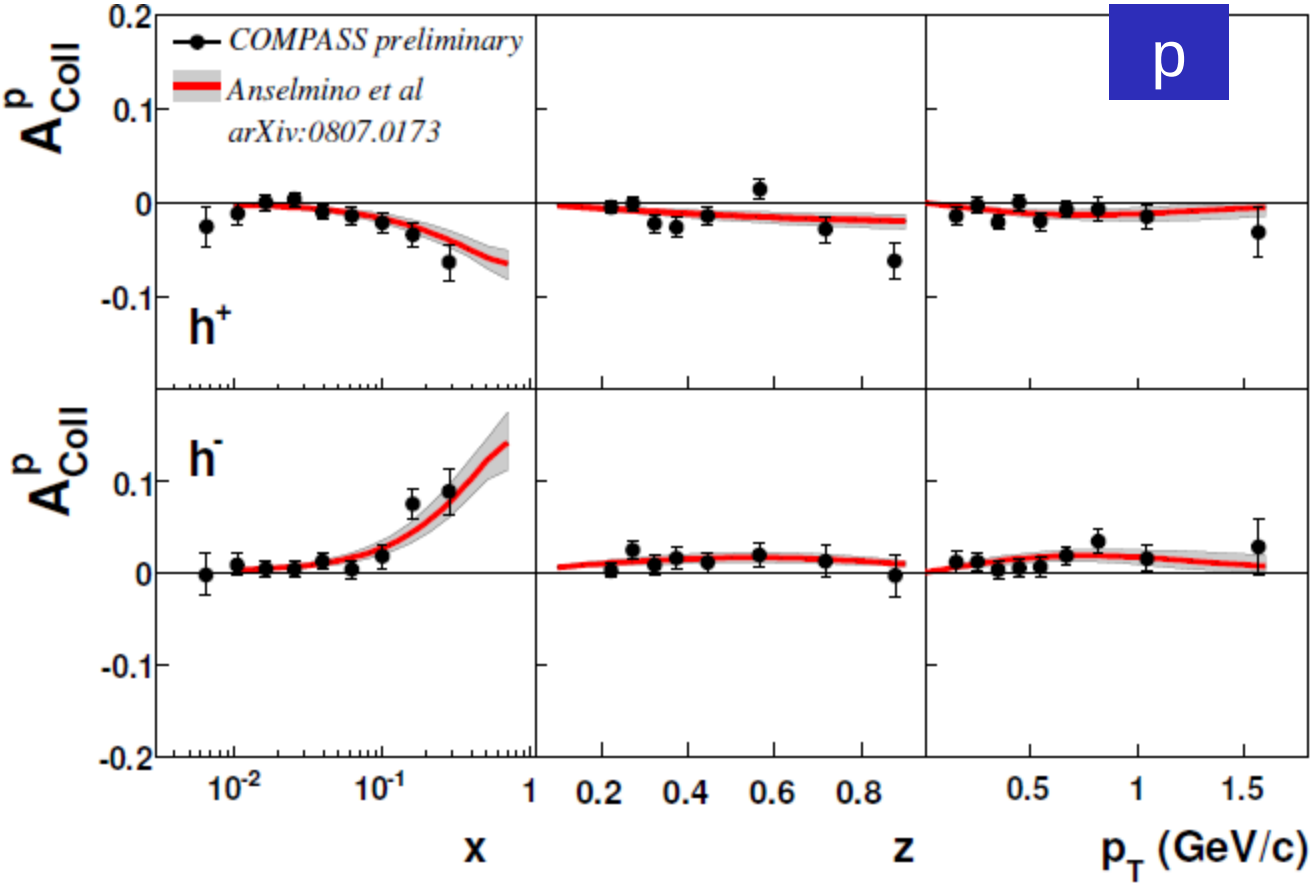
- 8 intrinsic transverse-momentum dependent PDFs at LO
- Azimuthal asymmetries with different angular modulations in the hadron and spin azimuthal angles, Φ_h and Φ_s

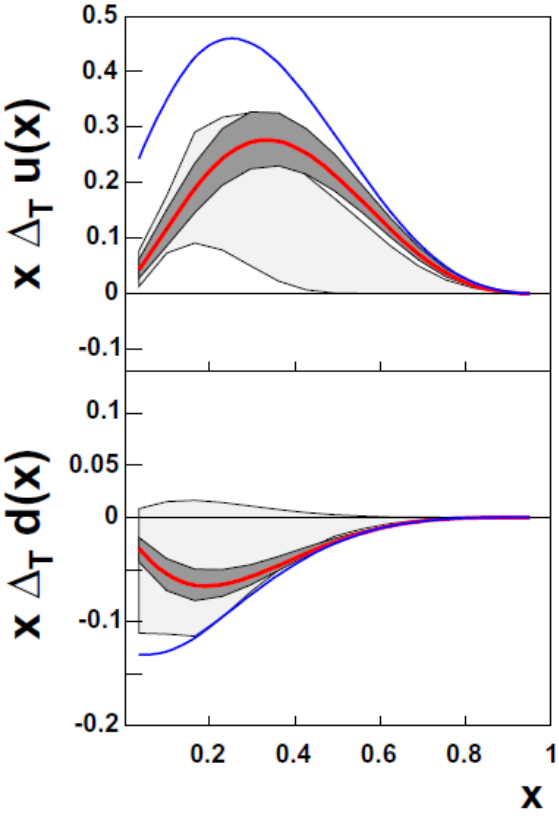


Proton Collins asymmetry

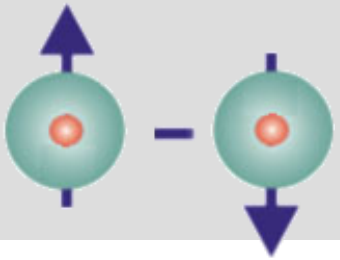


Fit to COMPASS *d*, HERMES, BELLE (Collins FF, e^+e^-)
in good agreement with new proton data



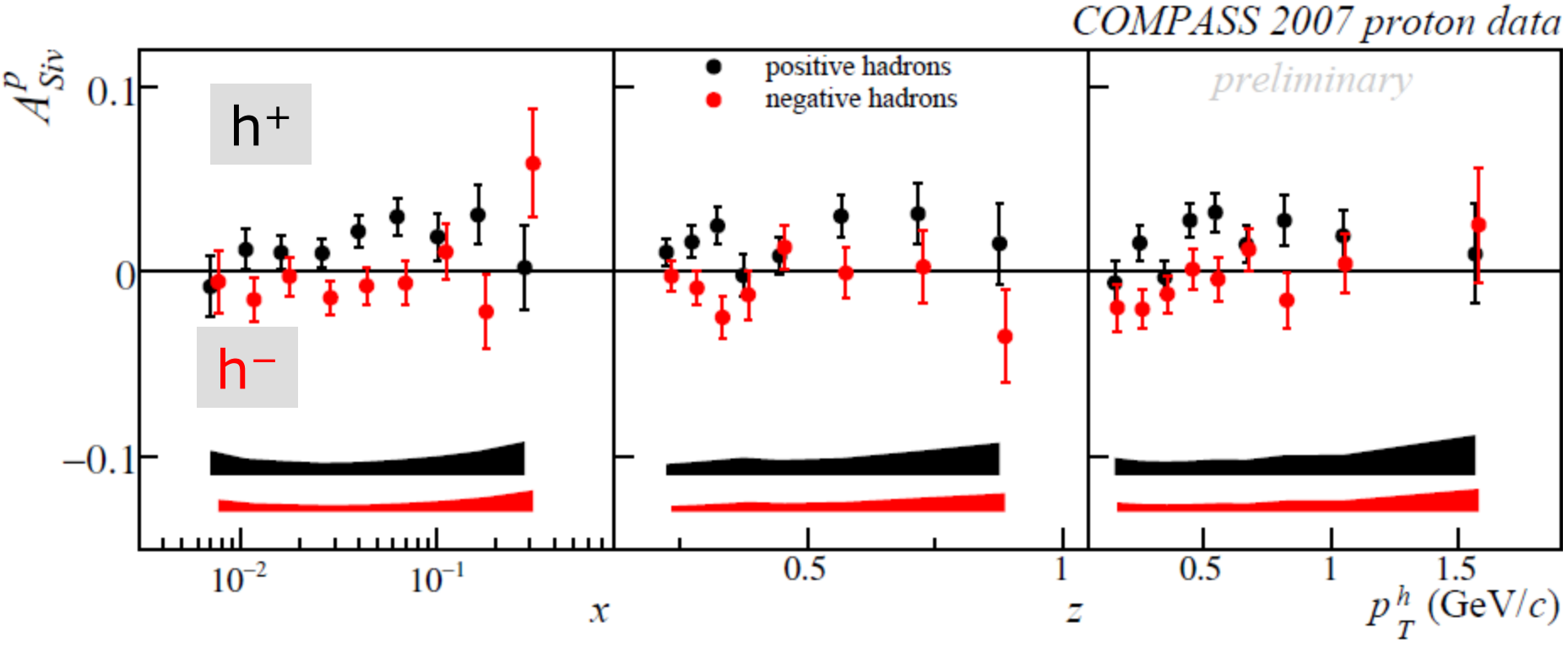


Proton Sivers asymmetry



- compatible with zero for the deuteron
- non-zero asymmetry for pos. hadrons

COMPASS



What's next: COMPASS-II

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN–SPSC–2010–014
SPSC-P-340
May 17, 2010

- Polarised Drell-Yan
- Generalized Parton Distributions (GPD)
- Pion (and kaon) Polarisabilities

COMPASS-II Proposal

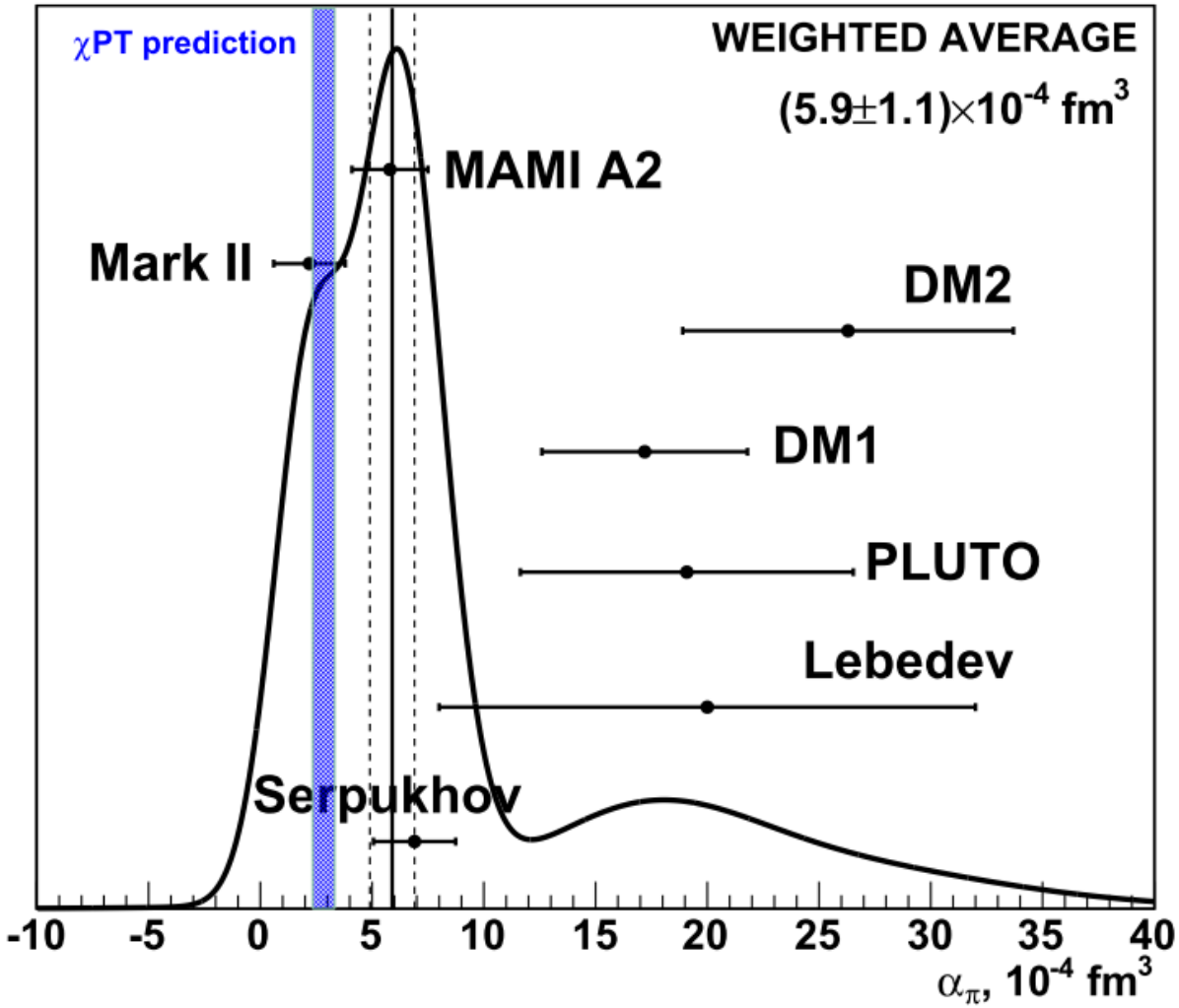
recommended by Programme Committee (SPSC)

The COMPASS Collaboration

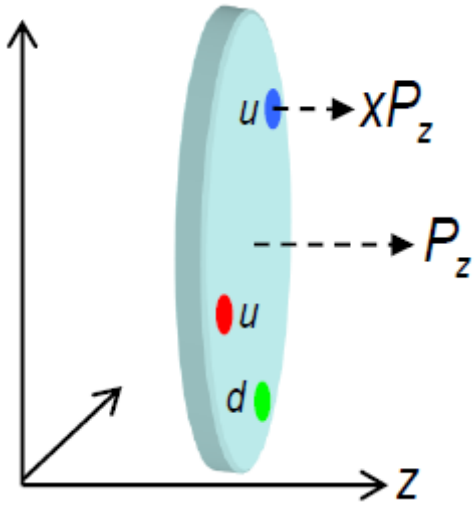
Pion Polarisability experimental situation $\alpha_\pi - \beta_\pi$

Planned measurement better than χPT-prediction.

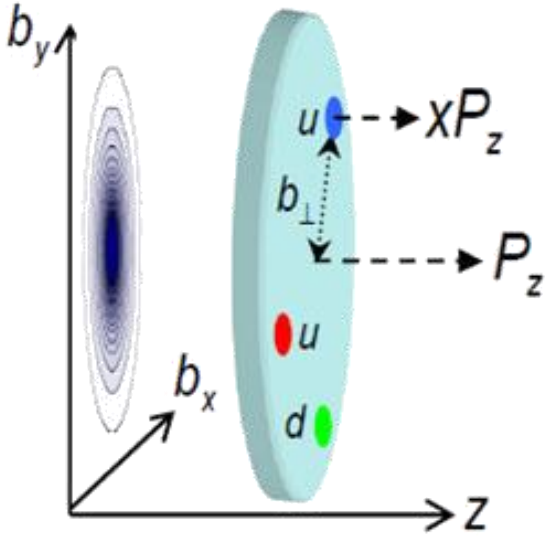
Strong JINR participation



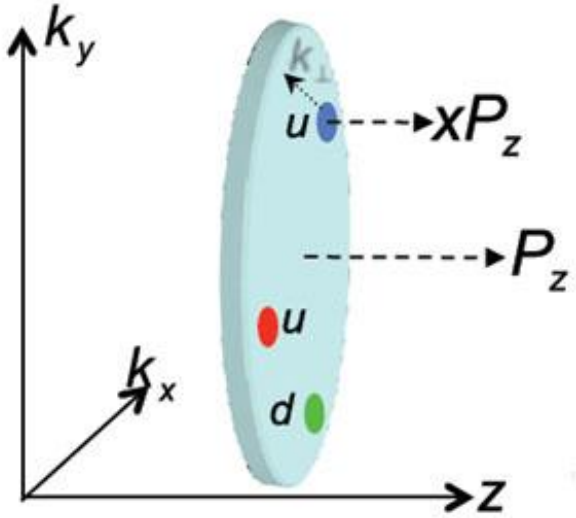
PDF, GPD, TMD



PDF



GPD

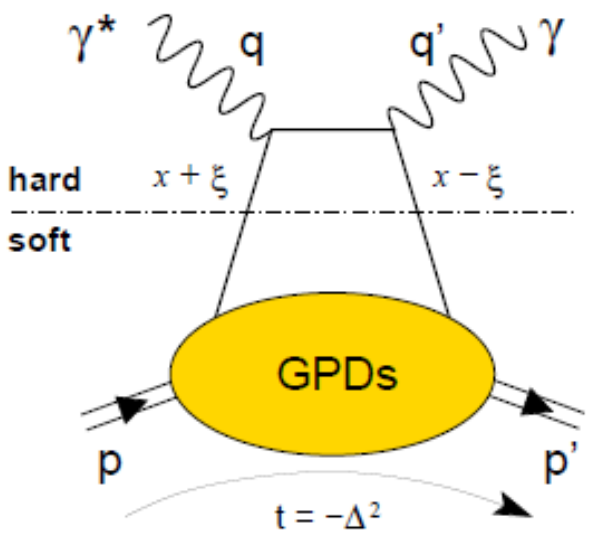


TMD

Ji, PRL 2003, Belitsky, Ji, Yuan PRD 2004
Meissner, Metz, Schlegel, JHEP 0908:056 2009

Generalized Parton Distribution Functions

- Novel concept, universal, H, $\tilde{H}$, E, $\tilde{E}$
- H (E) nucleon helicity (non)conservation
- Nucleon form factors and PDFs as limiting cases
- Correlating transverse spatial and longitudinal momentum degrees of freedom ('tomography')
- DVCS & DVMP



Total orbital momentum:

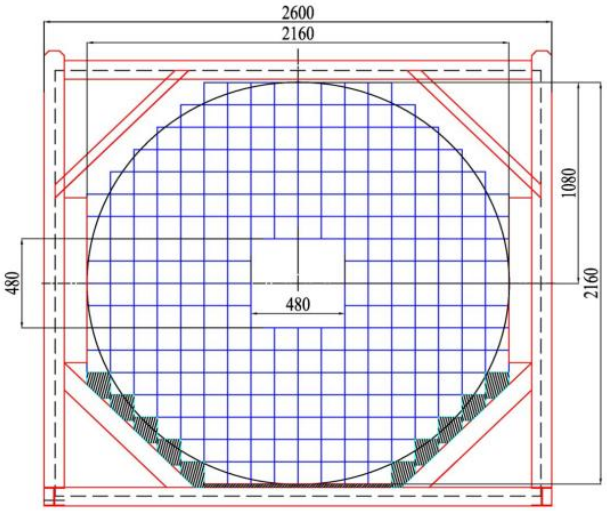
$$J^f(Q^2) = \frac{1}{2} \lim_{t\to 0} \int_{-1}^{1} \mathrm{d}x \; x \left[H^f(x,\xi,t,Q^2) + E^f(x,\xi,t,Q^2)\right]$$

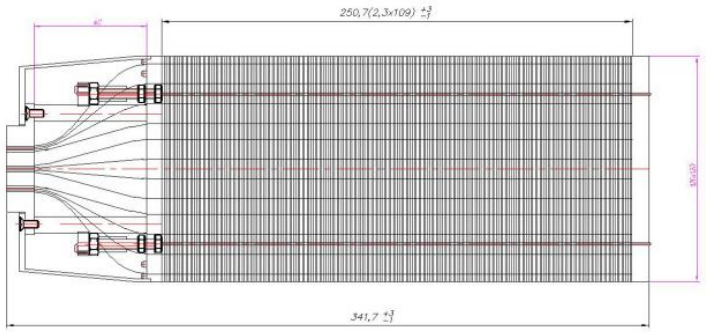
X.-D. Ji, Phys. Rev. Lett. 78 (1997) 610

x is not x-Bjorken

GPDs need ECAL0

- ECAL0 essential for GPD programme
- led by JINR, promising novel technology MAPDs





- looking forward for another decade of fruitful collaboration with JINR & Igor

EoR 2001

Savin Fest, Dubna, 7.12.2010