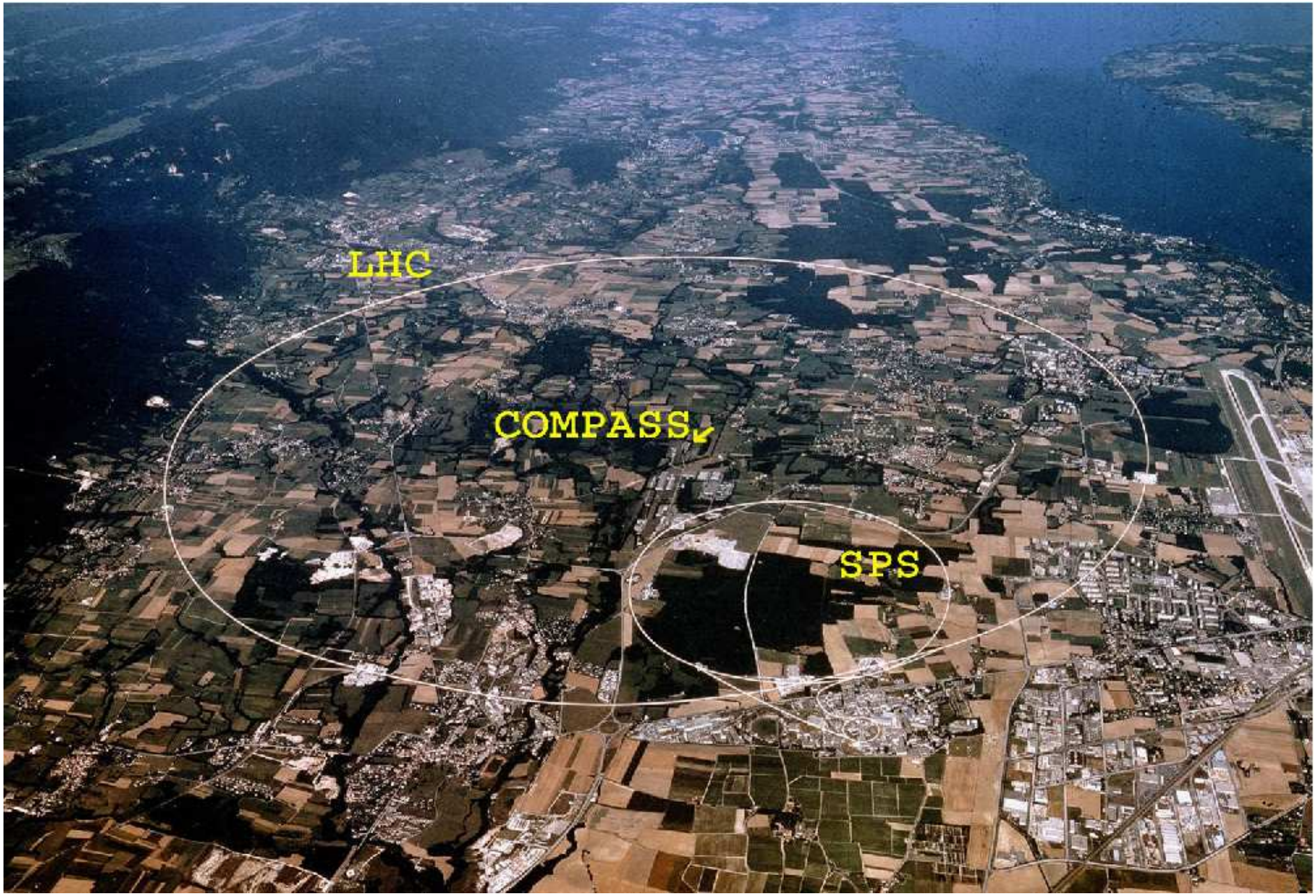
COMPASS experiment at CERN: recent LIP contributions

Marcin Stolarski

on behalf of LIP-Lisboa group

.

COMPASS at CERN



COMPASS at CERN

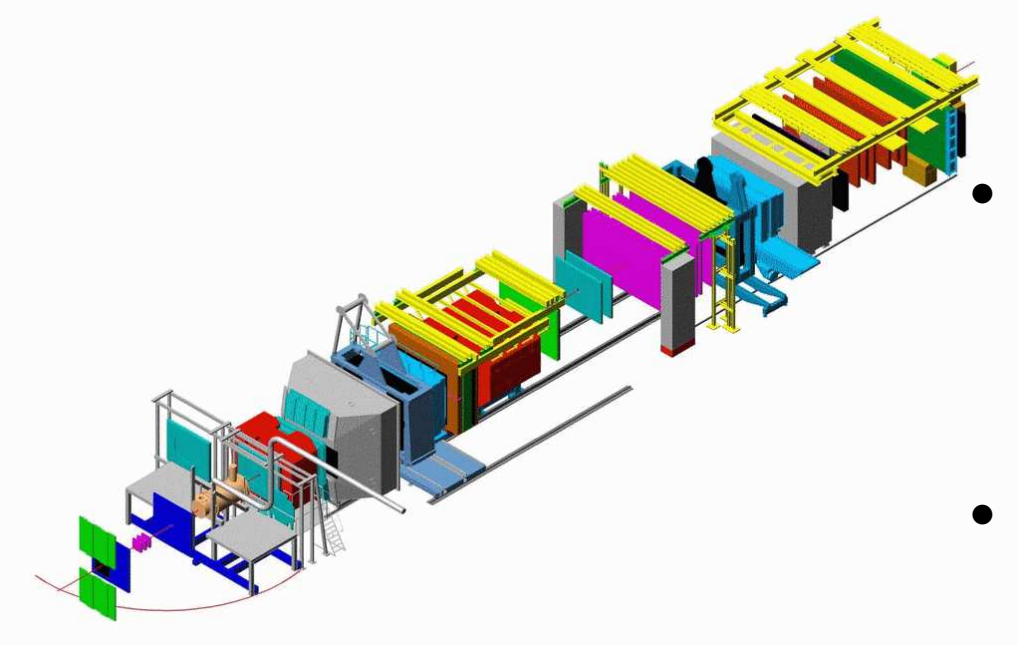
- **CO**mmon **M**uon **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

- Collaboration of 12 countries and about 210 physicists
- PHASE-I data taking in 2002-2011
- Currently PHASE-II ongoing (see talk by C.Quintans)

Physics goals

- Phase I
  - muon beam program
    - gluon polarization in the nucleon
    - spin dependent structure functions
    - polarized quark distributions
    - unpolarized fragmentation functions
  - hadron beam program
    - pion polarizability
    - hadron spectroscopy
    - exotics searches (glueballs, hybrids, ...)
- Phase II
  - **T**ransverse **M**omentum **D**ependent functions (TMDs)
  - **G**eneralized **P**arton **D**istribution functions (GPDs)

COMPASS setup:



- DETECTOR
  - two stage spectrometer
  - 60 m length
  - 2 (3) magnets
  - about 350 detector planes

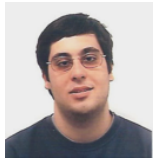
- POLARIZED TARGET
  - ^{6}LiD (NH_3) target
  - 2-3 cells (120 cm total length)
  - $\pm$ 50% (90%) polarization
  - polarization reversal every 8h-24h
- POLARIZED BEAM
  - μ^+ at 160 GeV/c
    (200 GeV/c in 2011)
  - polarization –80 %
- FEATURES
  - angular acceptance: $\pm$70 mrad
    ($\pm$180 mrad from 2006)
  - track reconstruction:
    $p > 0.5$ GeV/c
  - identification h, e, μ: calorimeters
    and muon filters
  - identification: π, K, p (RICH)
    $p > 2$, 9, 18 GeV/c respectively

LIP group in COMPASS

- Seniors:
  - Paula Bordalo (Group leader)
  - Catarina Quintans
  - Sérgio Ramos



- Post-docs:
  - Celso Franco
  - Luís Silva
  - Marcin Stolarski



- PhD students:
  - Ana Sofia Nunes
  - Márcia Quaresma


- Master students:
  - Gonçalo Terça
  - Miguel Vasco

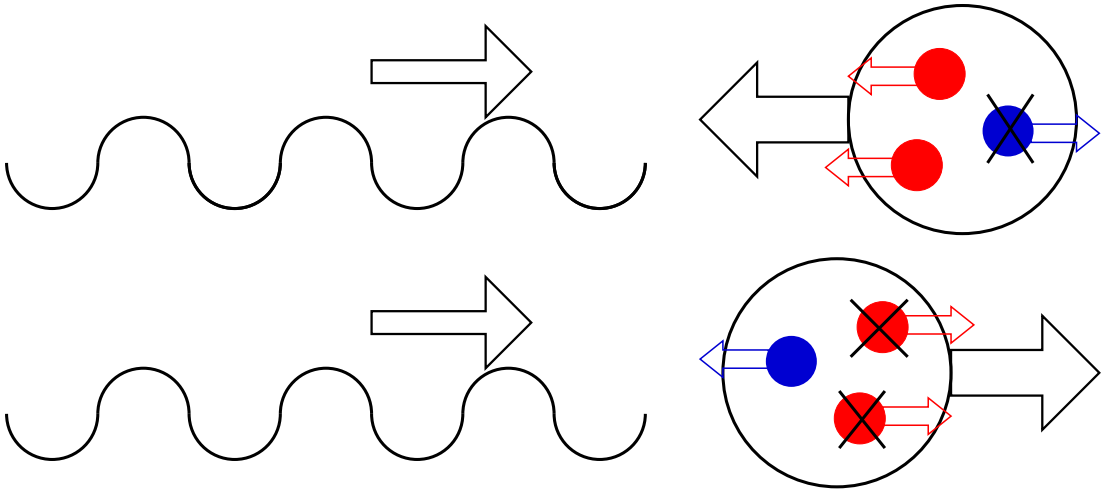

- Engineer:
  - Christophe Pires

LIP-Lisboa group activities

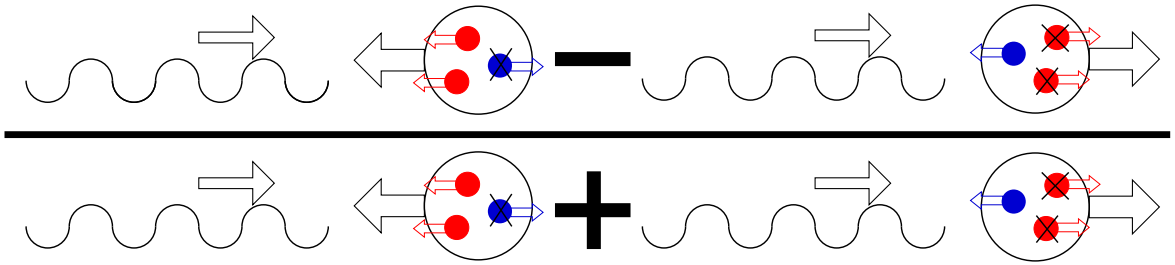
- Analysis of COMPASS-I data (content of this talk)
  - extraction of the gluon polarization from open charm events
  - extraction of the gluon polarization from high-p_T events
  - measurement of the spin asymmetry A_1 in low x and low Q^2 region
  - measurement of hadron multiplicities and fragmentation functions
- Preparation of COMPASS-II phase
  - one of the two main institutes behind the polarized Drell-Yan (DY) measurement proposal, which was approved in 2010
  - MC studies to optimize detector setup and the dimuon trigger
  - improvements in the muon tracking reconstruction efficiency and purity
  - MC analyses of possible backgrounds to DY process in COMPASS kinematic range
  - analyses of the DY test runs
- Full responsibility of the experiment's Detector Control System

Idea of spin dependent measurements

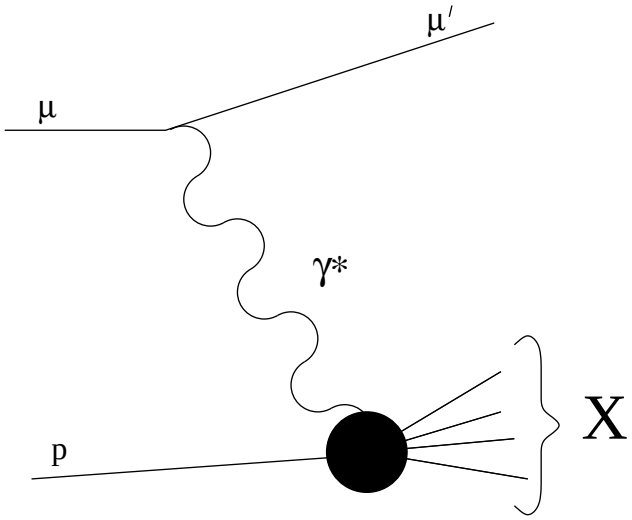
- Interaction of polarized photons with nucleon



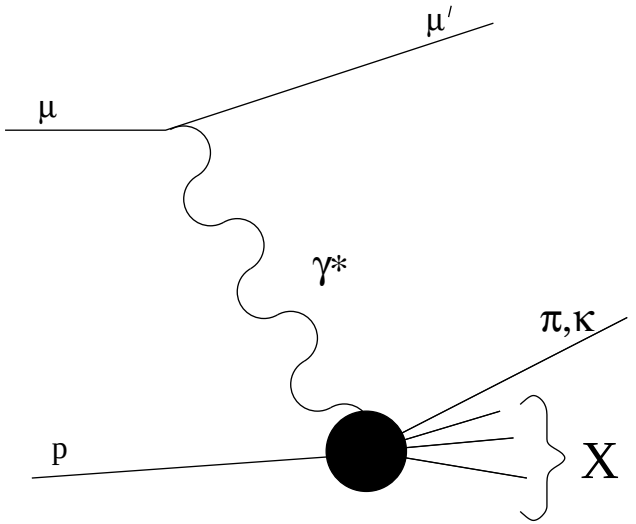
- Because of angular momentum conservation, only quarks with a spin opposite to the spin of the photon can interact with it
- Spin effects are small, precise method of extraction is needed, like asymmetry measurements



Studied processes



- **D**eep **I**nelastic **S**cattering (**DIS**)
- Incoming and outgoing muon four-momenta are measured
- The final state X is not looked at
- The cleanest measurement

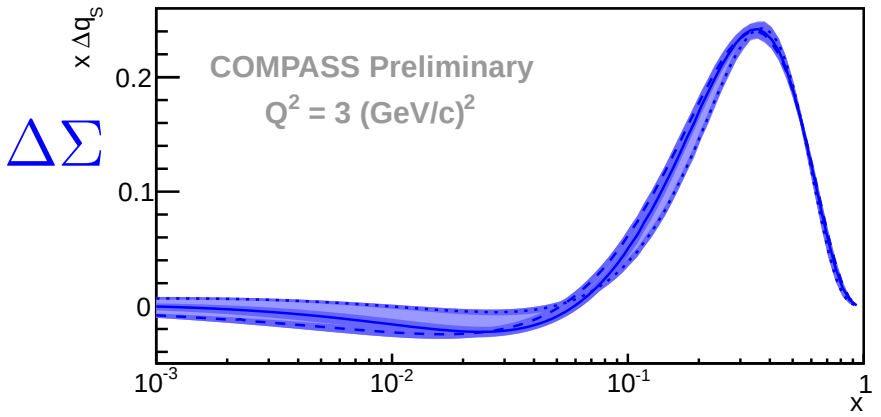


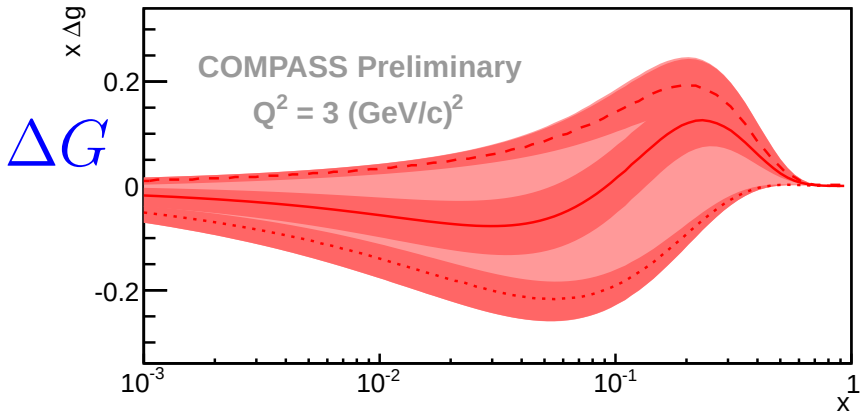
- **S**emi-**I**nclusive **D**eep **I**nelastic **S**cattering (**SIDIS**)
- The difference w.r.t. DIS: additional final state particle is detected
- More complicated: what is the probability that a quark of type q fragments into a hadron of type h?
- A new non perturbative object is needed - Fragmentation Functions (FF)

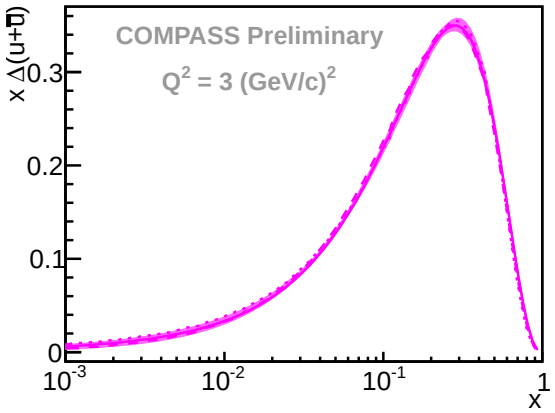
Short story of spin measurements

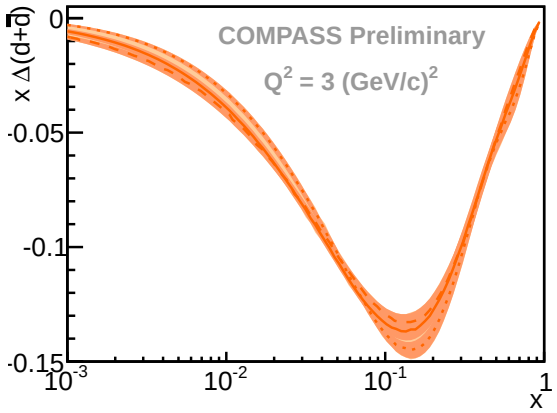
- First spin asymmetry measurement in SLAC, USA in 1975, done by Vernon Hughes et al.
- Results with large uncertainties were agreeing with the expectations
- Unexpected results of EMC (1987) started the so-called "spin crisis": quarks carry only $\Delta\Sigma = 10\% \pm 15\%$ of the proton spin $(\Delta\Sigma = \Delta u + \Delta d + \Delta s\ )$
  - **Phys. Lett. B206**(1988), 364; cited 1659 times
  - **Nucl. Phys. B328**(1989), 1; cited 1422 times
- Second generation of experiments, at CERN and USA (early-mid of 90') confirmed EMC results
- $S_p = 1/2 = 1/2\Delta\Sigma + \Delta G + L_{q,G}$
- Third generation of experiments is trying to solve the spin puzzle, COMPASS @ CERN, HERMES @ DESY, experiments at USA in RHIC and JLab laboratories
- Fourth generation is being planed

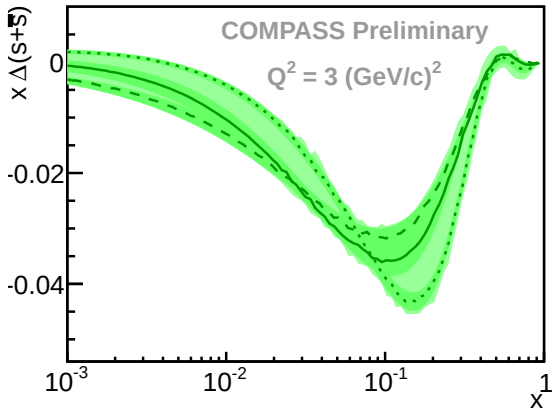
Modern Results – COMPASS NLO QCD fit







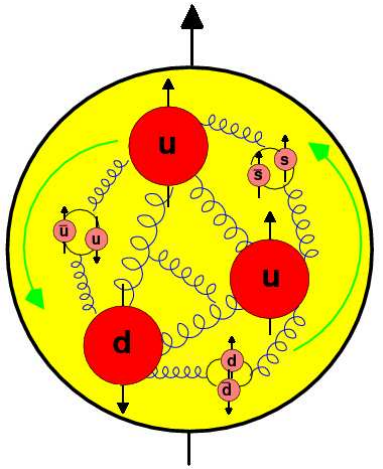


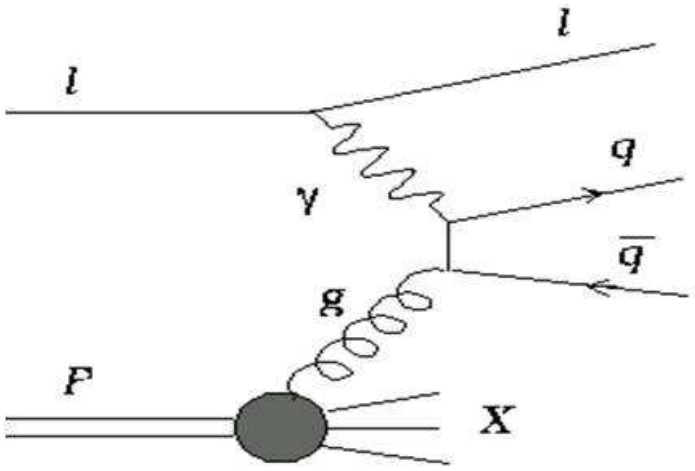


- $\Delta\Sigma \approx 0.25 - 0.30$
- ΔG not constrained
- Negative Δs in the whole x range

$\Delta g/g$ measurement

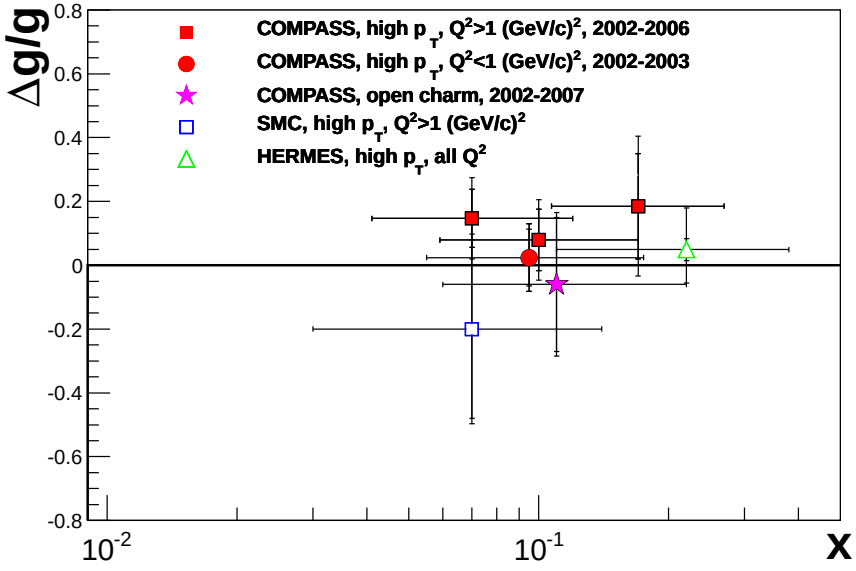
- $S_p = 1/2 = 1/2\Delta\Sigma + \Delta G + L_{q,G}$
- Gluons may carry missing spin of the proton
- Problem: photon doesn't directly interact with gluons (q=0)
- In order to measure $\Delta g/g$ higher order processes in α_s must be studied, namely photon–gluon fusion (PGF) from *e.g.*
  - open-charm events
  - high-p_T hadron pairs

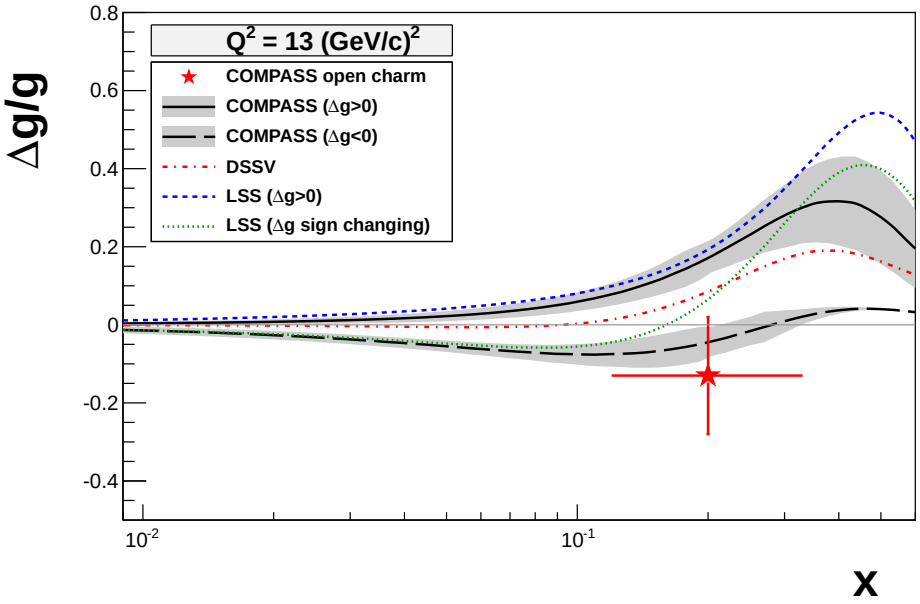




$\Delta g/g$ measurement: COMPASS results

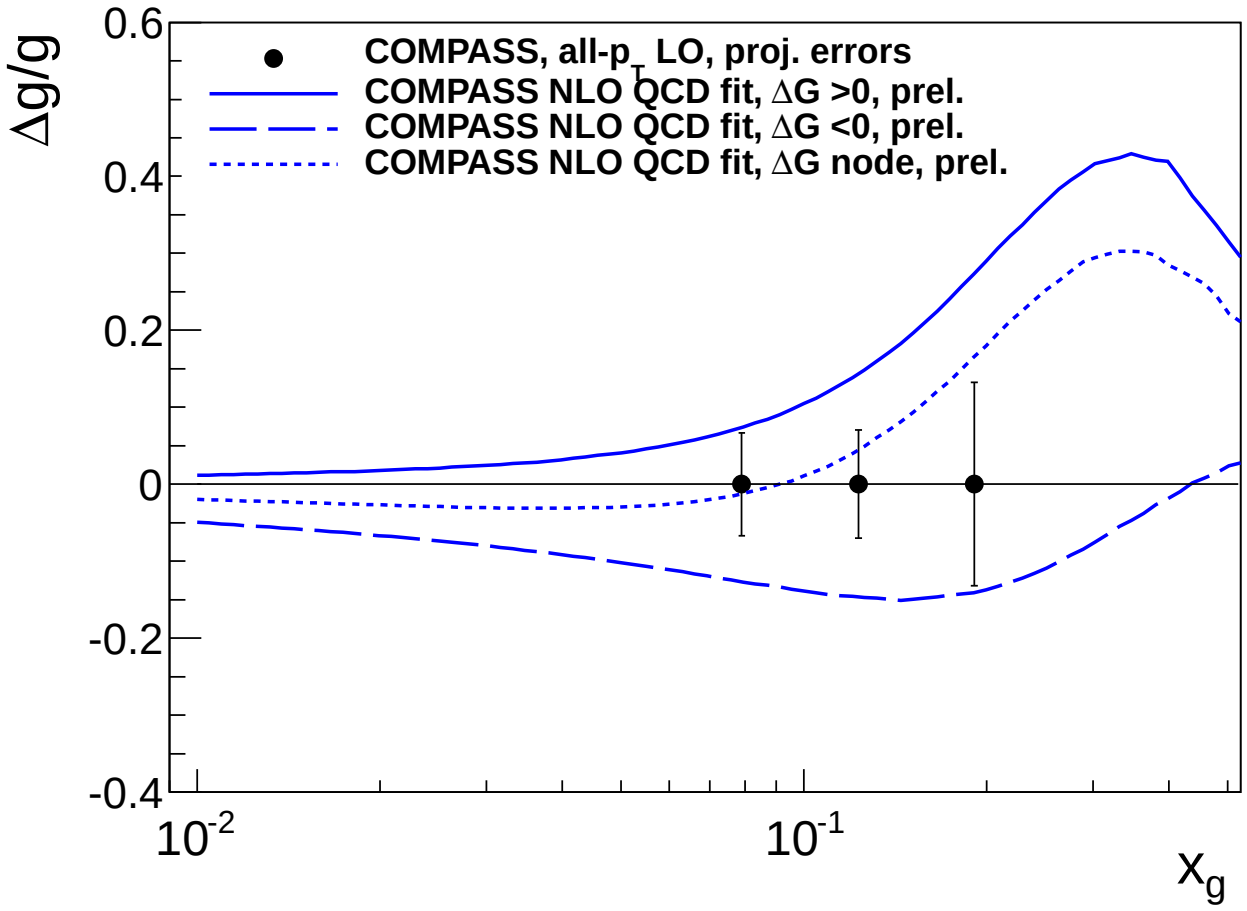
- Both analyses were published last year (with outstanding contribution from LIP)
  - High-p_T - PLB **718** (2013) 922 (LO analysis)
  - Open Charm - PRD **87** (2013) 052018 (LO and NLO analyses)
- Results:





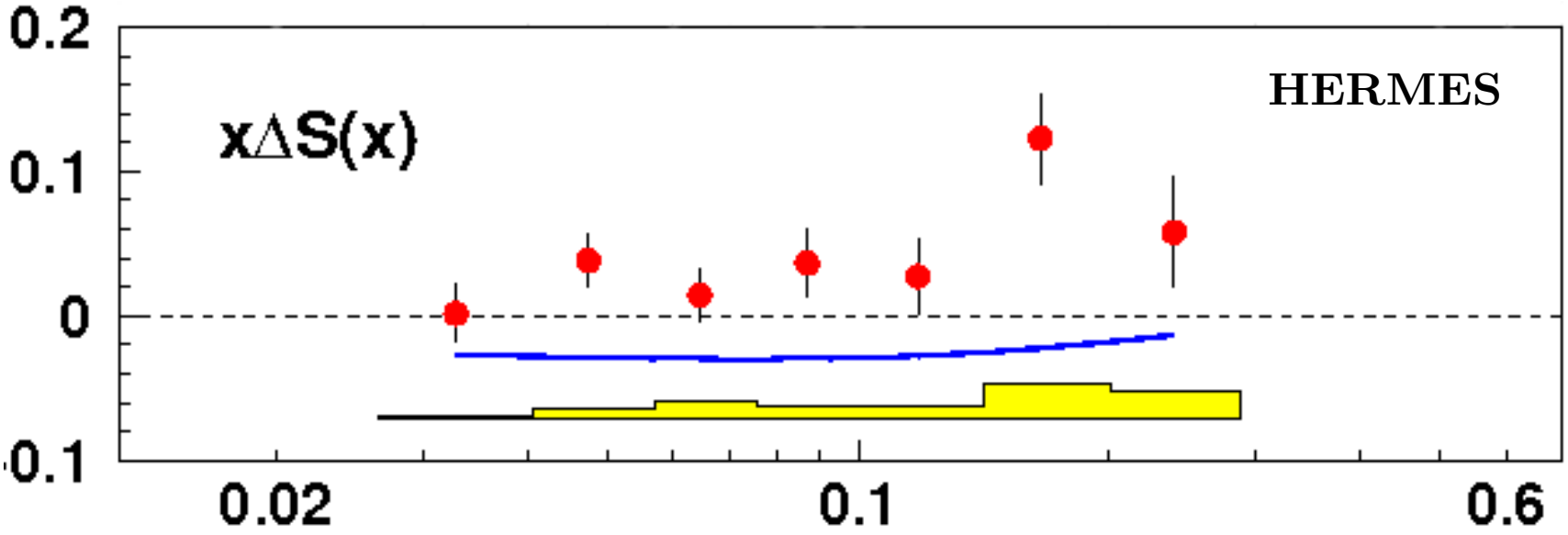
$\Delta g/g$ measurement: method improvement

- At LIP we developed a new method of $\Delta g/g$ extraction - all$-p_T$ method
  $\Rightarrow$ Reduction of the statistical error of $\Delta g/g$ by about 60% with respect to the last COMPASS publication PLB 718 (2013) 922



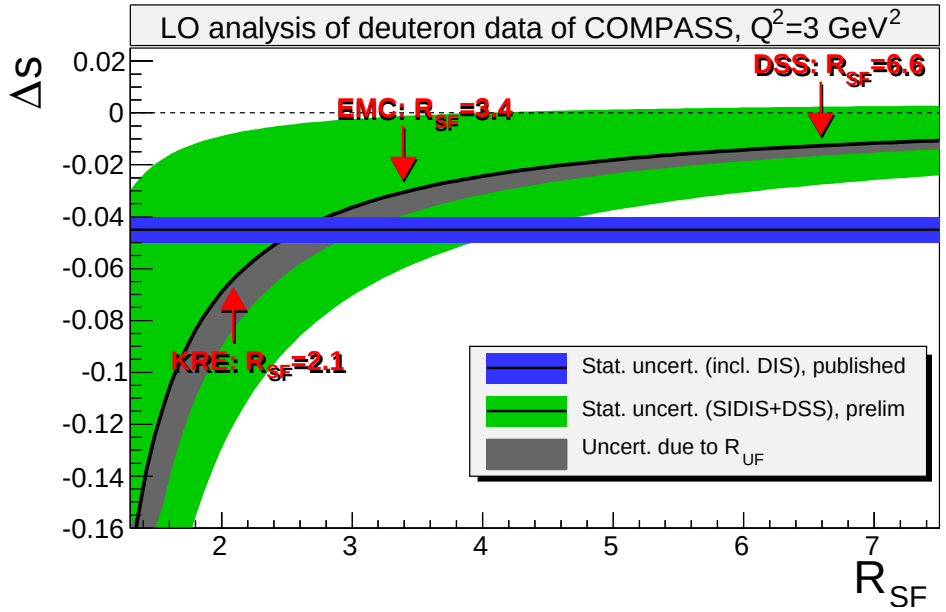
ΔS puzzle

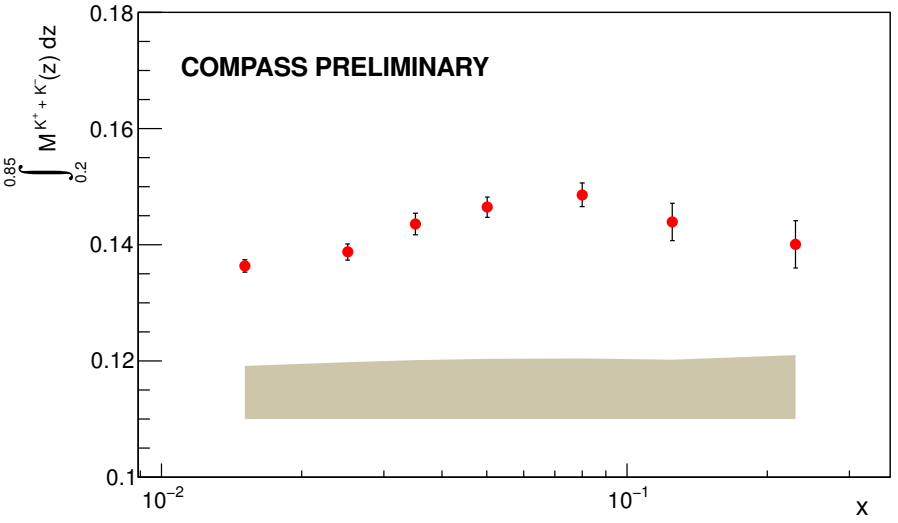
- From NLO QCD fits, a negative ΔS is expected in the whole x range
- However, by selecting kaons in the final state, one enhances the contribution of strange quarks
- Examples of previous analyses:
  - HERMES analysis, **PLB 666** (2008) 446
  - the curve from LSS group NLO QCD **PRD** 73 034023
- Clear disagreement of HERMES data with global NLO QCD fit is visible



ΔS studies at COMPASS

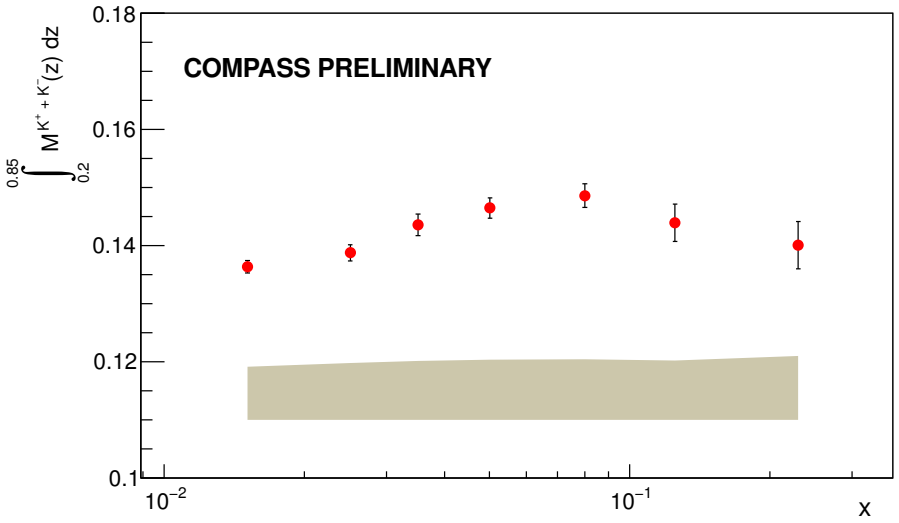
- The results of the SIDIS-type analysis depend on the choice of the Fragmentation Functions (FF),
  - $D_{str}(z)$: $\bar{s} \rightarrow K^+$ and c.c.
  - $D_{fav}(z)$: $u \rightarrow K^+$ and c.c.
  - $D_{unf}(z)$: $\bar{u}, d, \bar{d} \rightarrow K^+$ and c.c.
- FF can be studied by analysing hadron multiplicities, *e.g.*, kaon multiplicity sum
- $5\frac{dN^K(x)}{dN^{DIS}(x)} \approx \int D_Q^K(z)dz + S(x)/Q(x) \int D_S^K(z)$

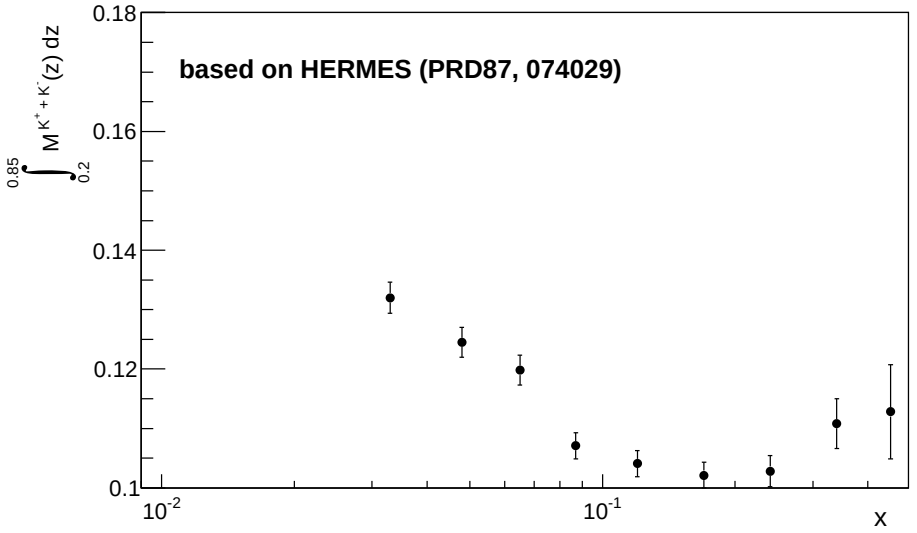




ΔS puzzle: comparison of experimental results

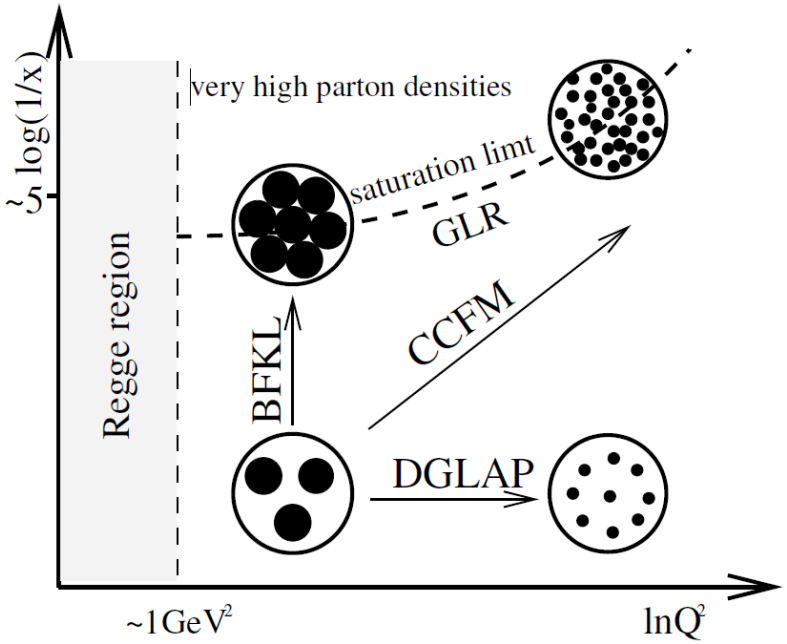
- Clear disagreement is seen between preliminary COMPASS results and HERMES published data
- The discrepancy between the two experiments is being investigated

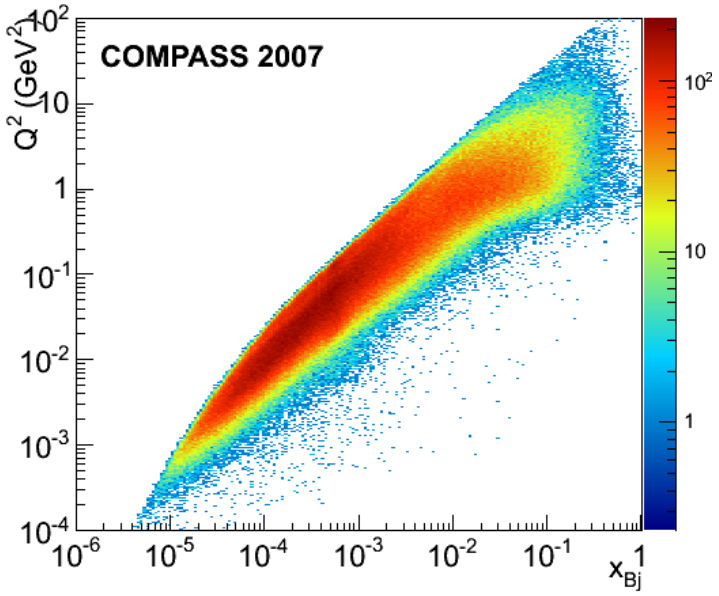




Asymmetry A_1^p at low x and low Q^2

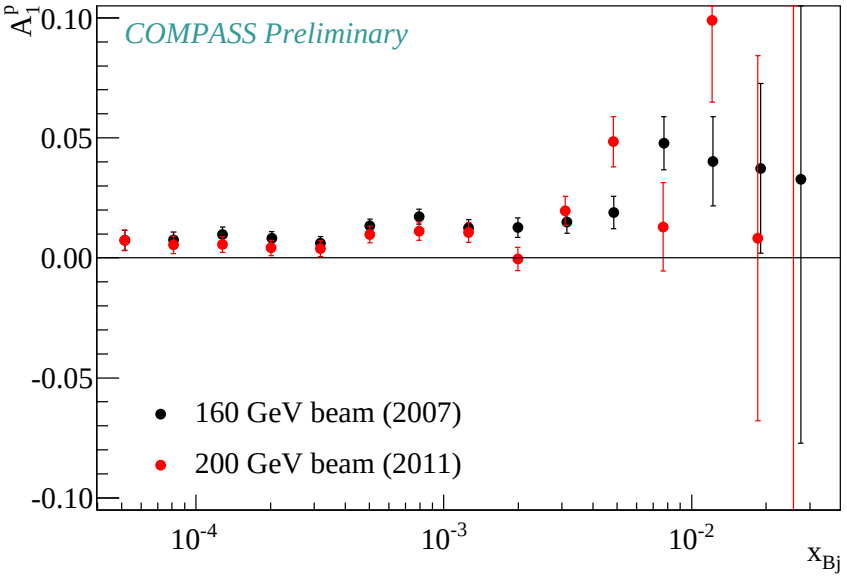
- The low x region is very interesting because of high parton densities in the nucleon
- However, in COMPASS there is a strong correlation between x and Q^2
- Low x measurement is in the non-perturbative region of QCD

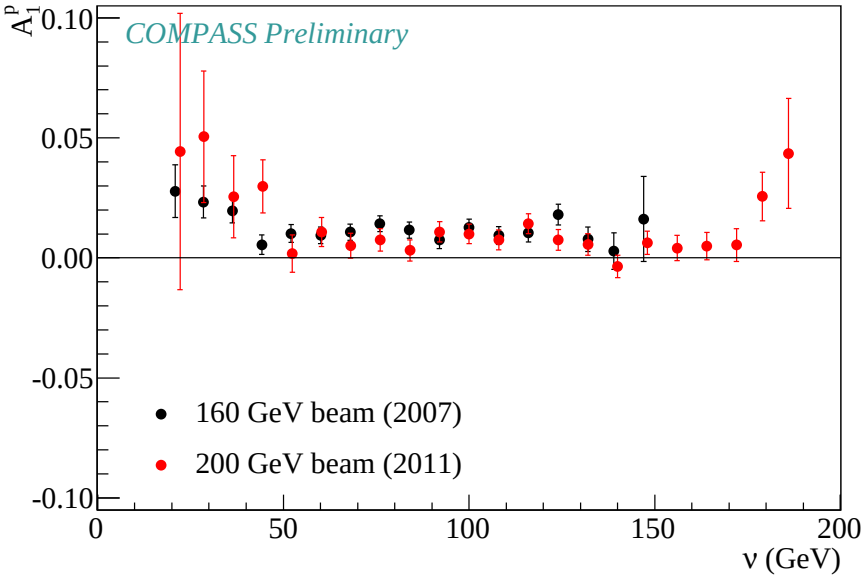




A_1^p at low x and low Q^2 - COMPASS results

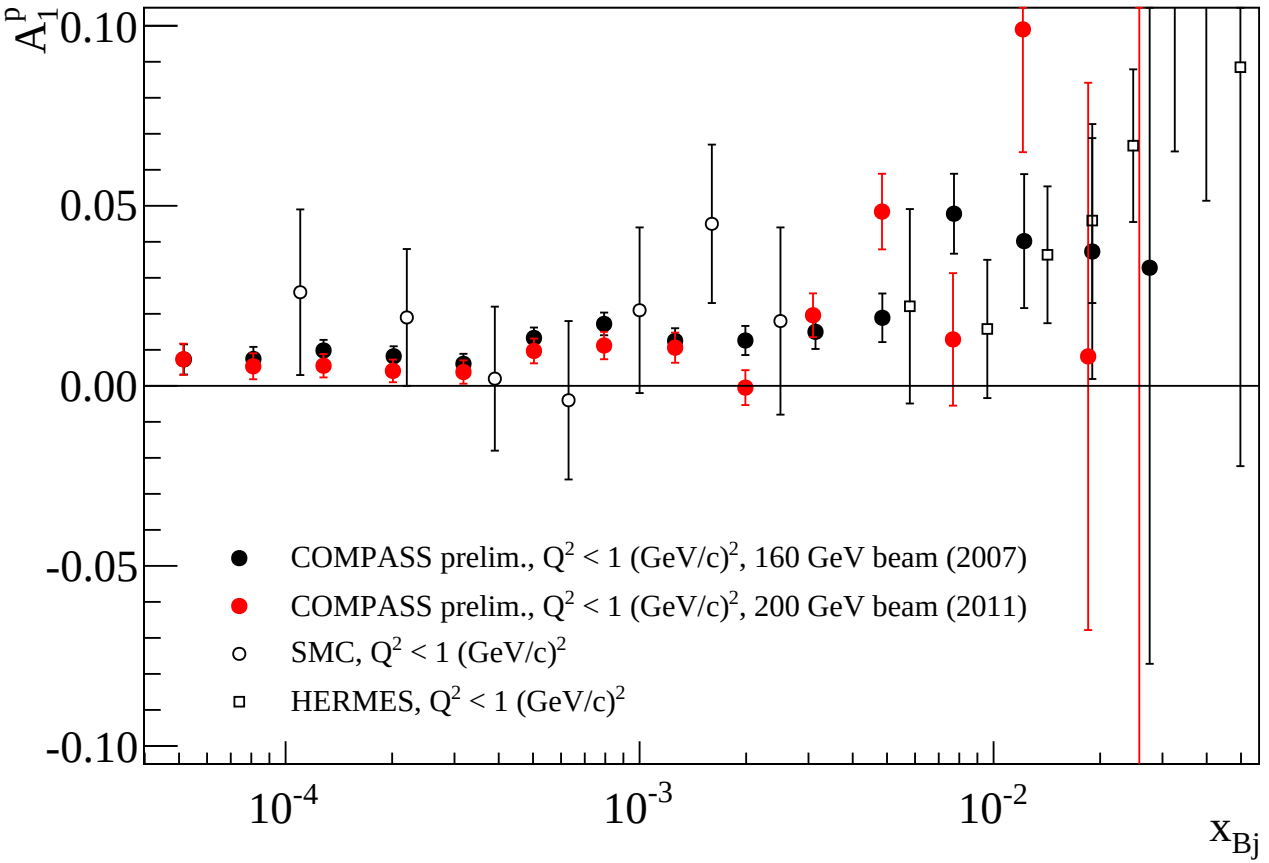
- The A_1^p is positive, about 1% in the low x region
- For the first time non zero spin effects are observed for so low x_{Bj}
- Measurements at the two beam energies give similar results as functions of x_{Bj} and ν





A_1^p at low x and low Q^2: comparison of experimental results

- The statistical precision obtained at COMPASS is by a factor of 10-20 better than in the previous experiments



Summary & Conclusions

- COMPASS Phase I data taking is finished
- However,
  - new results are being published
  - analysis methods are being improved
- LIP group has an important role in COMPASS data analyses and in the preparation of the following physics program
  $\Rightarrow$ At the next International Conference DIS2014, 3 members of LIP group will give oral presentations of their work on behalf of the COMPASS Collaboration