COMPASS results on longitudinal spin effects and future measurements

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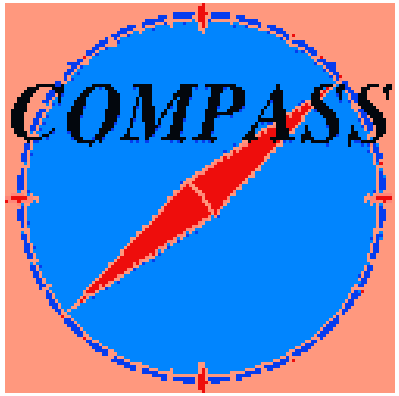
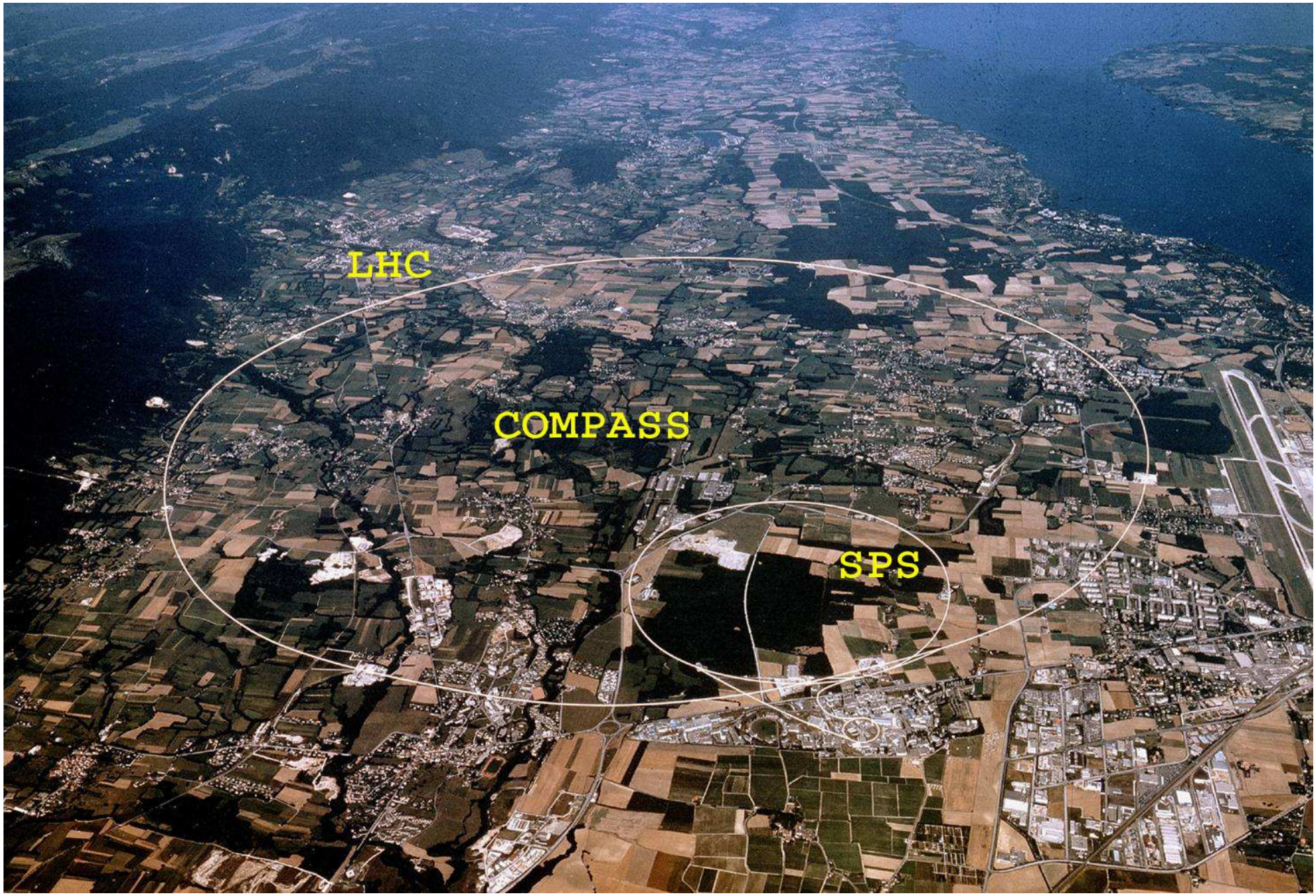
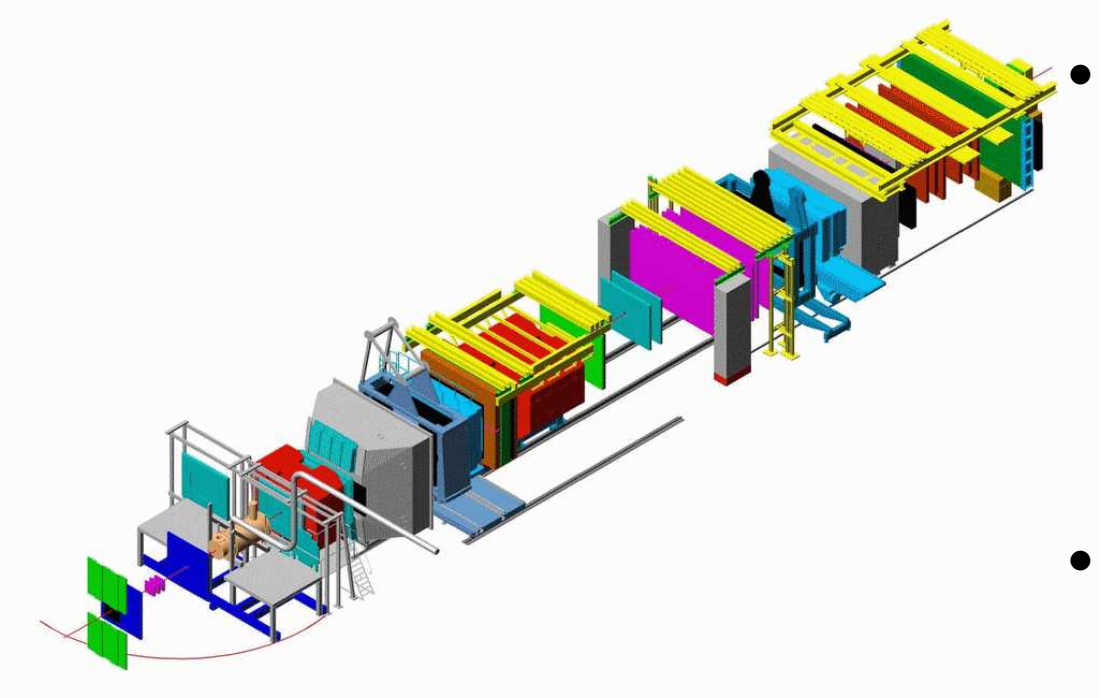
on behalf of COMPASS collaboration

- $\Delta G/G$ measurements
- g_1^p and test of the Bjorken sum rule
- future COMPASS plans



COMPASS @ CERN





- COLLABORATION
  - about 240 physicists
  - 27 institutes
- DETECTOR
  - 60 m length
  - 2 (3) magnets
  - about 350 detector planes

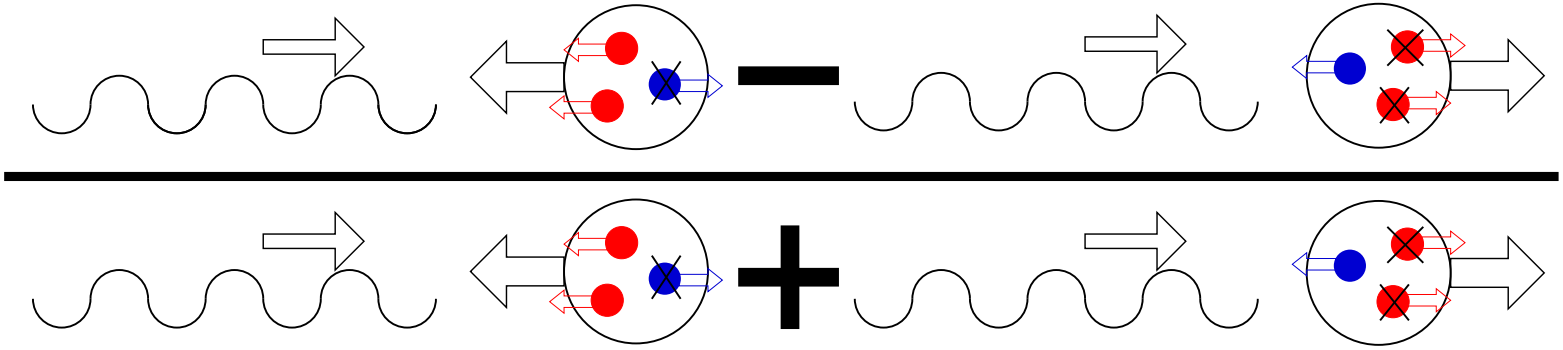
- POLARIZED TARGET
  - ^{6}LiD (NH_3) target
  - 2-3 cells (30,60 cm long each)
  - $\pm$ 50% (90%) polarization
  - polarization reversal every 8h-24h
- POLARIZED BEAM
  - positive muons at 160 GeV/c
  - polarization –80 %
- FEATURES
  - acceptance: 70 $\rightarrow$ 130 mrad
  - track reconstruction: $p > 0.5$ GeV
  - identification: π, K, p (RICH) above 2, 9, 18 GeV respectively

COMPASS scientific program with muon beam

- gluon polarization inside the nucleon
- spin dependent structure function
- polarized quark distributions
- transversity
- Lambda polarization
- vector meson production

Asymmetries

- the spin effects are small → precise methods of measurement are needed
- the asymmetry measurement is most commonly used
  - the asymmetry measurement allows to cancel a lot of parameters like acceptance, beam fluxes *etc*.
  - to obtain physical asymmetry the measured (raw) asymmetry is usually diluted by beam and target polarization, fraction of polarized nucleons in the target *etc*.
  - in COMPASS typically raw asymmetries are 10-100 smaller than the final physics asymmetries



Gluon polarization inside the nucleon

- spin of the proton ($S_p = 1/2\hbar$) can be decomposed on four parts:
  - $\Delta\Sigma$ - quark contribution to the nucleon spin
  - ΔG - gluon contribution
  - ΔL_q,ΔL_g - orbital momentum of quarks and gluons
- $S_p = 1/2\hbar = 1/2\Delta\Sigma + \Delta G + \Delta L_q + \Delta L_g$
- in the simplest QPM model: $S_p = 1/2\Delta\Sigma$
- the direct measurement: $\Delta\Sigma \approx 0.3$
- how much is then ΔG....
- possible measurement of ΔG in photon-gluon fusion
  - asymmetries in open-charm production
  - asymmetries for high transverse momenta hadrons

$\Delta G/G$ from open charm analysis 2002-2007 data

$\Delta G/G$ from open charm analysis

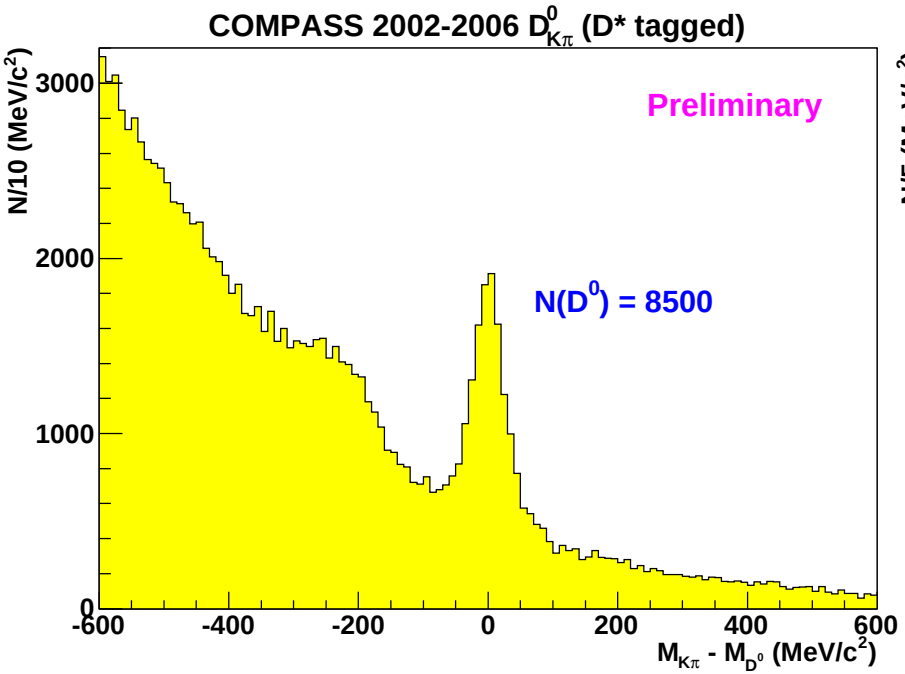
- open-charm - clean source of PGF
- hard scale $\approx 4m_c^2$, even though $Q^2 < 1$ (GeV/c)^2
- low statistics - various channels analyzed
  - $D^0 \rightarrow K\pi$
  - $D^* \rightarrow D\pi_{soft} \rightarrow K\pi\pi_{soft}$
  - $D^* \rightarrow D\pi_{soft} \rightarrow K3\pi\pi_{soft}$
  - $D^* \rightarrow K_{sub}\pi \rightarrow K_{sub}\pi\pi_{soft}$ (sub threshold Kaons)
  - $D^* \rightarrow D\pi_{soft} \rightarrow K\pi\pi^0\pi_{soft}$ (where π^0 is not observed)
  - Number of D^0 events : 65500
  - Number of total D^* 29000 (13100 in the golden channel)

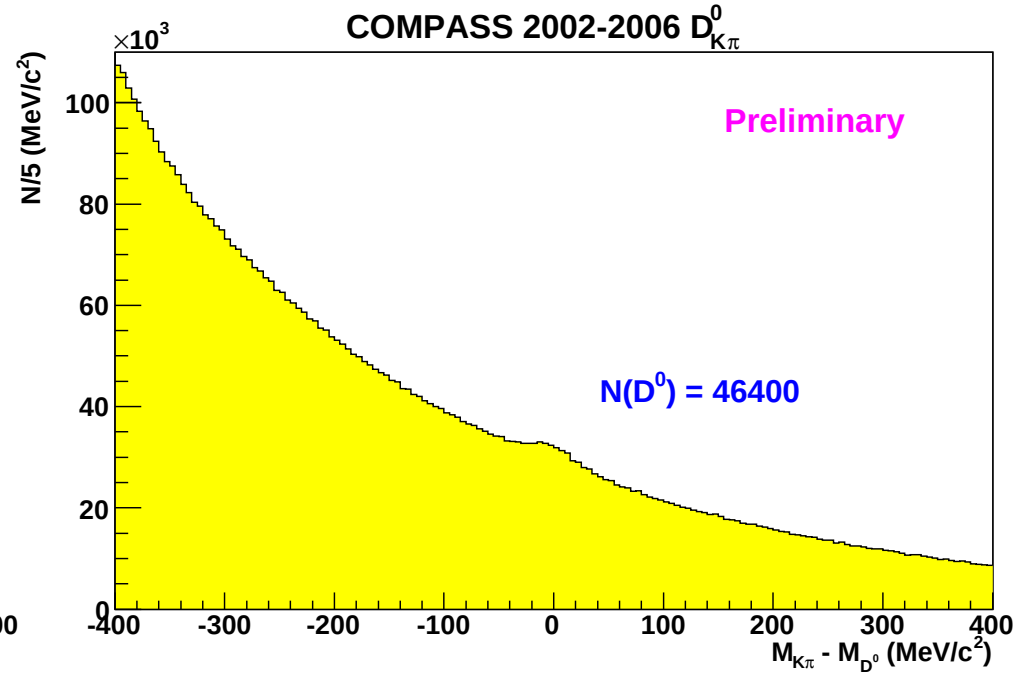
Gluon Polarization

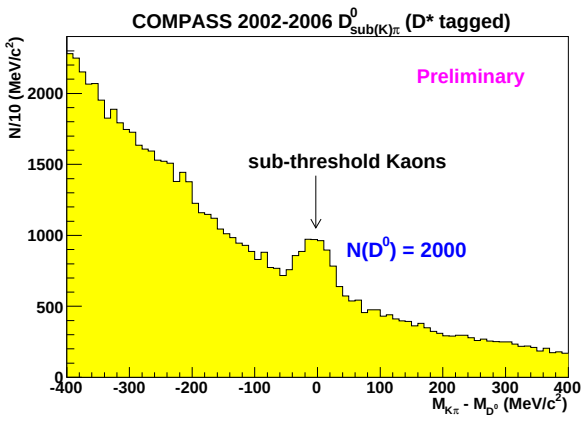
$$\frac{\Delta G}{G} = \frac{1}{P_T P_b f a_{LL} \frac{S}{S+B}} A_{raw}$$

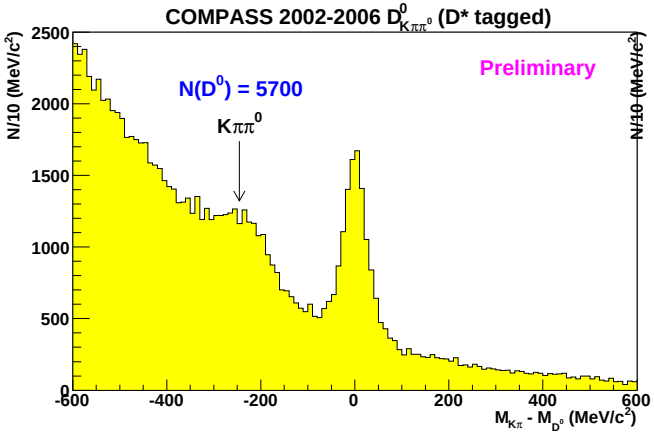
- in the analysis we use weight $P_b f a_{LL} \frac{S}{S+B}$ on the event by event basis to gain in *figure of merit*
- $\frac{S}{S+B}$ (Σ) is parametrized on data using Neural Network (NN) approach
- analyzing power, a_{LL}, is taken from MC
- f - dilution factor, fraction of polarizable material in the target, Radiative corrections included
  (NH_3; $f \approx 3/(3+14)$)
- P_b, P_T - beam and target polarizations
- NOTE: $A_{bakcgr} = \frac{1}{P_t P_b f D \frac{B}{S+B}} A_{raw}$ can be obtained simultaneously

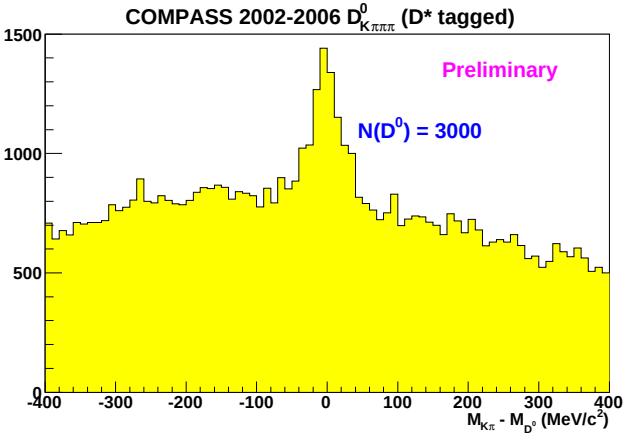
Examples of D^0 spectra (2002-2006)





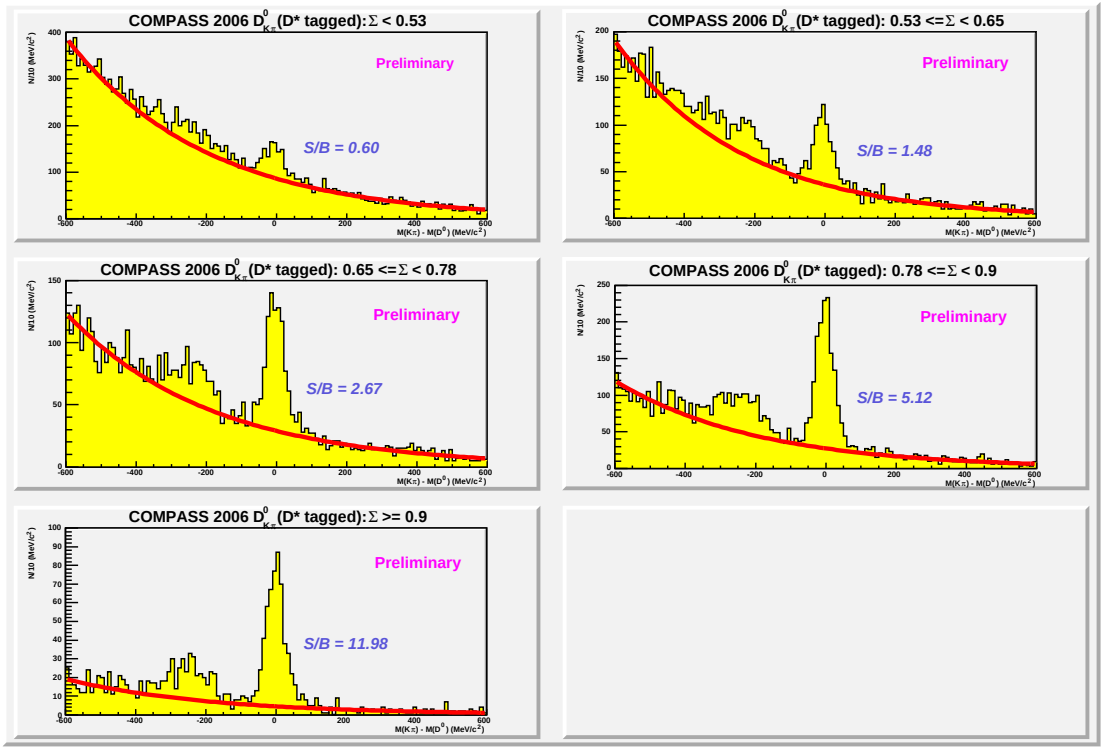






NN approach for S/(S+B) parametrization

- NN input variables: p_K, z_D, $p_{T,D}$ and 3 ratios of RICH PID likelihoods $L(K)/L(bg)$, $L(\pi)/L(bg)$ and $L(K)/L(\pi)$
- background is simulated by the wrong charge combinations
- in bins of NN output the mass spectrum is fitted and the final parametrization is done

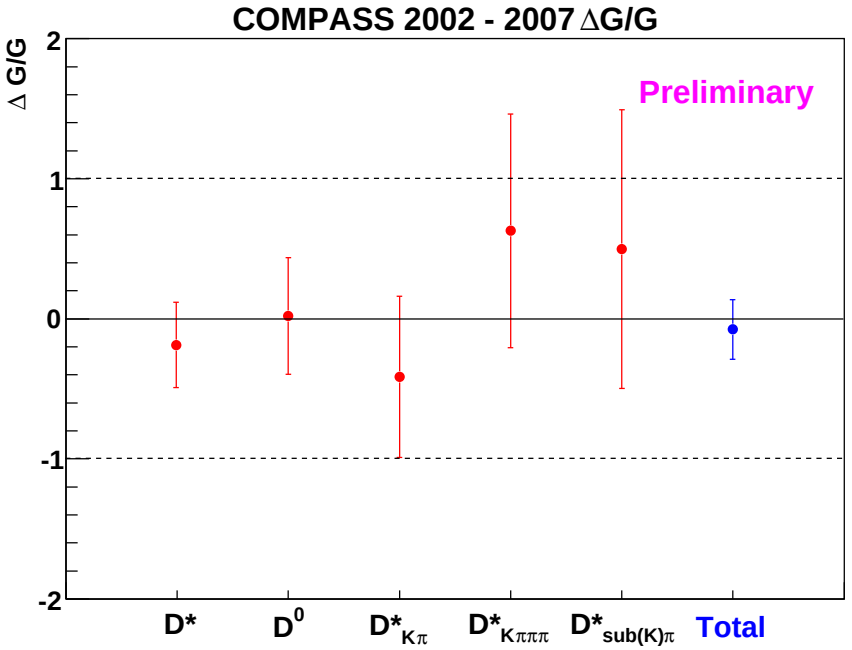


The $\Delta G/G$ Results

$$\Delta G/G = -0.08 \pm 0.21 \pm 0.11$$

$$< x_G >= 0.11^{+0.11}_{-0.05} \quad < \mu^2 > = 13 \text{ (GeV/c)}^2$$

channel	results
$D^* \rightarrow K\pi\pi_{slow}$	-0.19 ± 0.30
$D^0 \rightarrow K\pi$	0.02 ± 0.42
$D^* \rightarrow K\pi\pi^0 pi_{slow}$	-0.41 ± 0.58
$D^* \rightarrow K3\pi\pi_{slow}$	0.63 ± 0.83
$D^* \rightarrow K_{subth}\pi\pi_{slow}$	0.5 ± 1.0

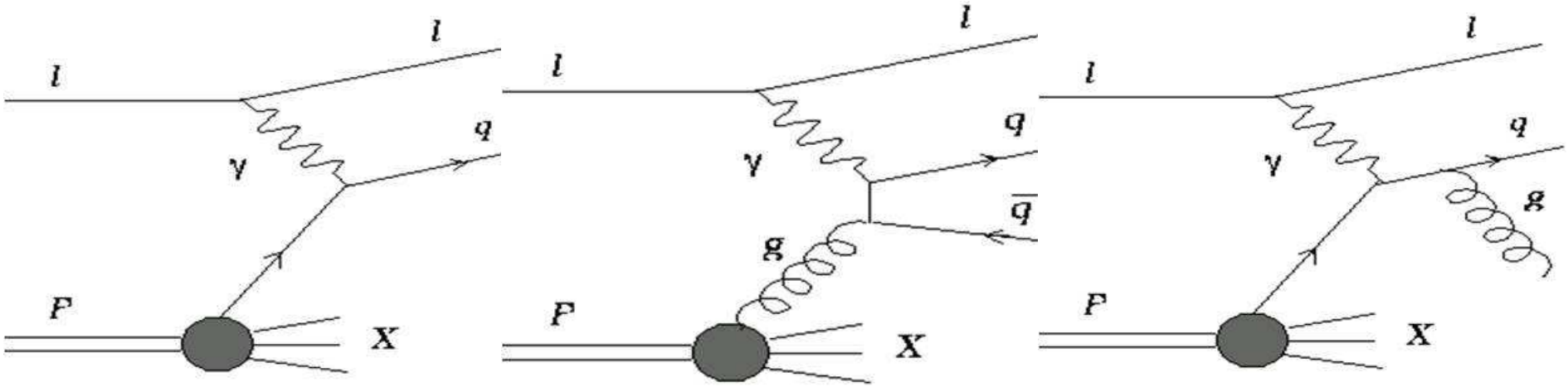


- large part of the systematic error is proportional $\delta\Delta G/G_{stat}$
- key point $\sigma_{stat} >> \sigma_{sys}$

High-p_T hadron pairs analysis 2002-2004 data

High-p_T hadron pairs analysis 2002-2004 data

- in LO three processes are contributing: LP, PGF and QCDC
- the fraction of PGF in the sample has to be estimated based on MC
- in general, higher p_T larger fraction of PGF is expected
- key point of the analysis is good data over MC agreement
- much larger statistics than for open charm sample

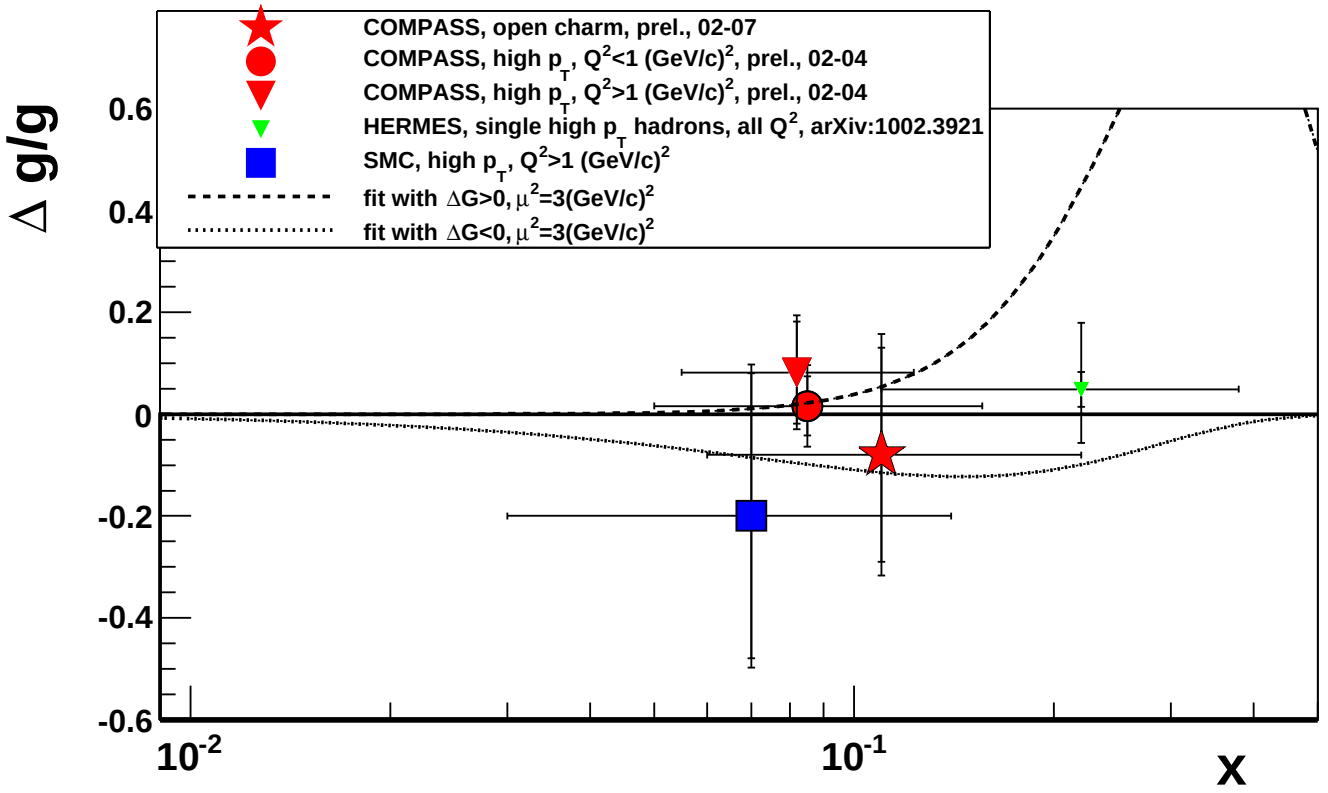


LP PGF QCDC

Results from High-p_T hadron pairs analysis

- preliminary result for $Q^2 > 1$ (GeV/c)^2 2002-2004
  - $\Delta G/G = 0.08 \pm 0.10 \pm 0.05$
- preliminary result for $Q^2 < 1$ (GeV/c)^2 2002-2004
  - additional contribution from resolved photons
  - $\Delta G/G = 0.016 \pm 0.058 \pm 0.014 \pm 0.052 \pm 0.013$
- published results 2002-2003, $Q^2 < 1$ (GeV/c)^2
  - PLB 633 (2006) 25-32
  - $\Delta G/G = 0.024 \pm 0.089 \pm 0.014 \pm 0.052 \pm 0.018$

Summary of $\Delta G/G$ from COMPASS



In progress:

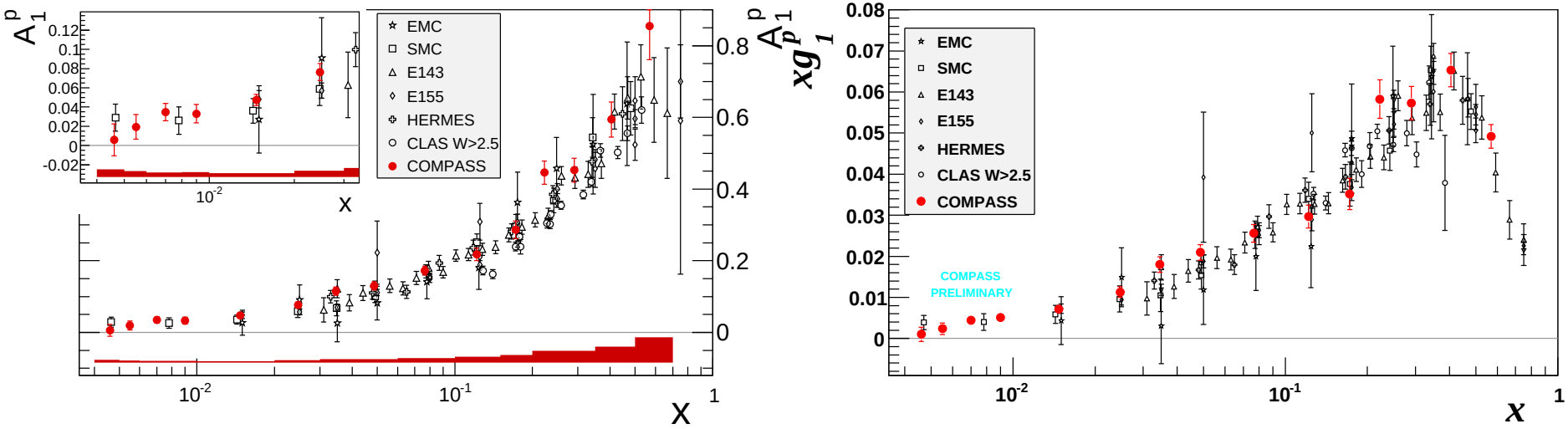
- NLO results for open–charm analysis
- updated and extended HipT analysis $Q^2 > 1$ (GeV/c)^2
- NLO analysis of 1hadron large p_T sample with $Q^2 < 0.1$ (GeV/c)^2

Spin dependent asymmetry A_1^p and structure function g_1^p

analysis published in: hep-ex/1001.4654, accepted by PLB

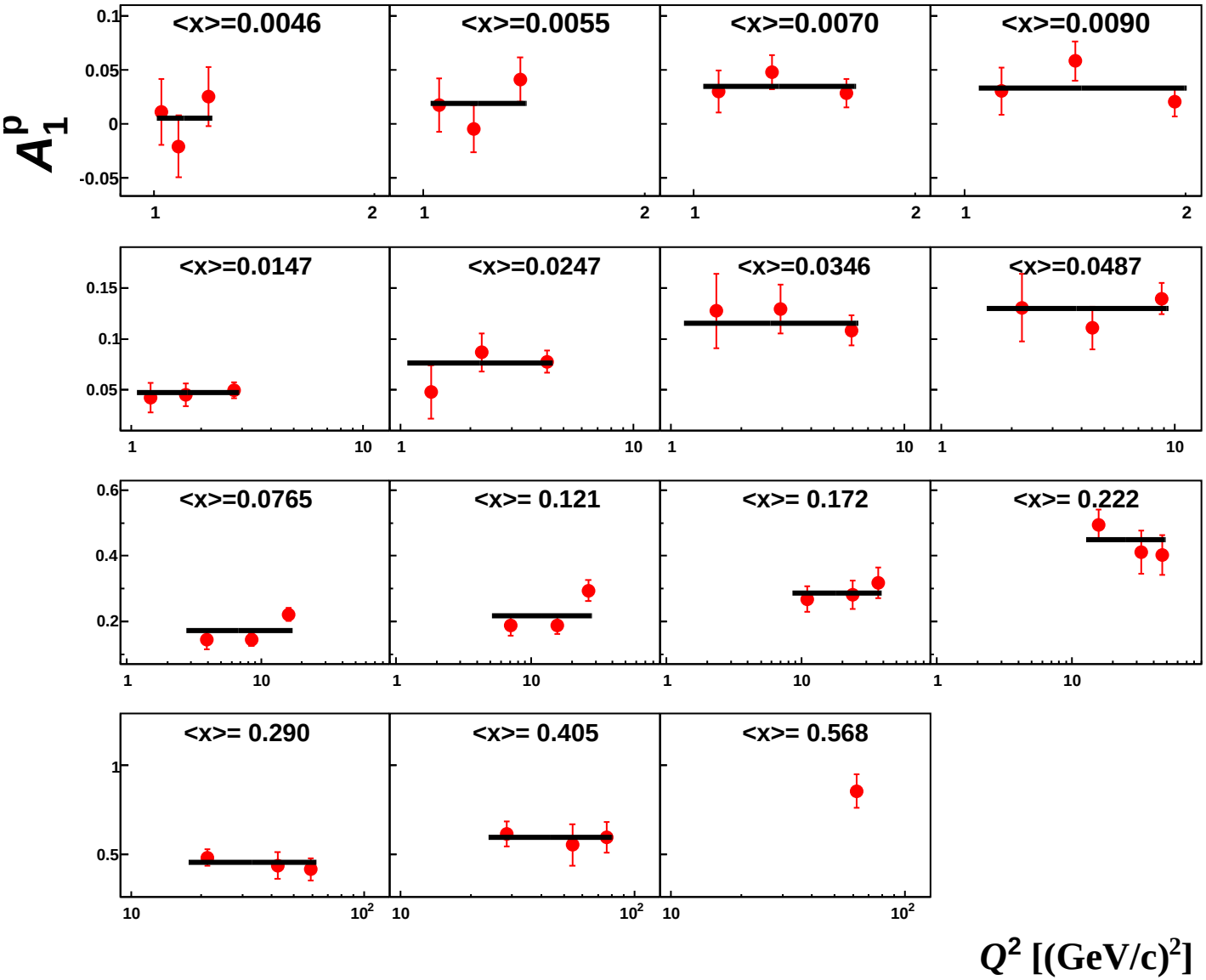
Asymmetry A_1^p and structure function g_1^p

- 2007 data sample $Q^2 > 1$ (GeV/c)^2
- reconstruction of μ and μ' and additional hadron for SI triggers
- $A_{raw} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}}$ $\qquad A_1^p = \frac{1}{fDP_bP_T} A_{raw}$ $\qquad g_1^p = \frac{F_2^p}{2x(1+R)} A_1^p$



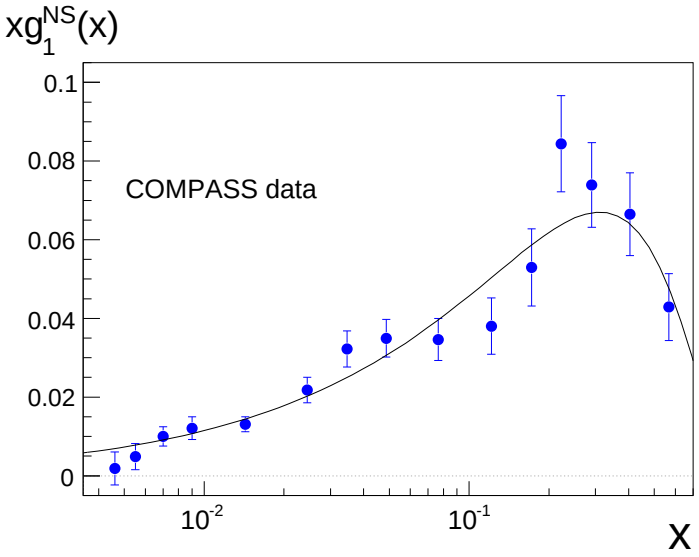
Q^2 dependence of A_1^p

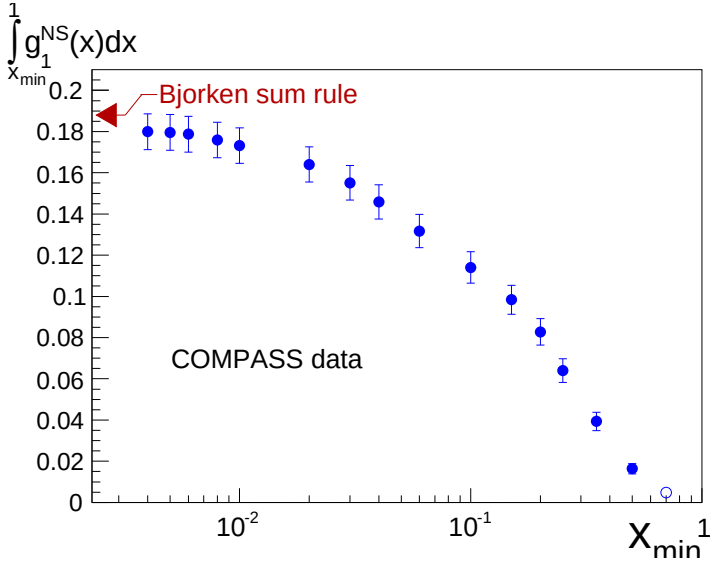
- within statistical precision the $A_1^p(x = const, Q^2)$ is flat



Test of Bjorken sum rule

- $g_1^{NS}(x,Q^2) = g_1^p(x,Q^2) - g_1^d(x,Q^2)$
- $g_1^{NS}(x,Q^2)$ is interesting because its Q^2 dependence decouples from the singlet and gluon densities
- $\int_0^1 g_1^{NS}(x,Q^2) = \Gamma_1^{NS} = \frac{1}{6}\frac{g_A}{g_V} C_1^{NS}(Q^2)$,
  where $C_1^{NS}(Q^2)$ has been calculated in pQCD up to $\alpha_s^3(Q^2)$
- $\frac{g_A}{g_V}$ can be obtained from neutron beta decay, $\frac{g_A}{g_V} = 1.2694 \pm 0.0028$





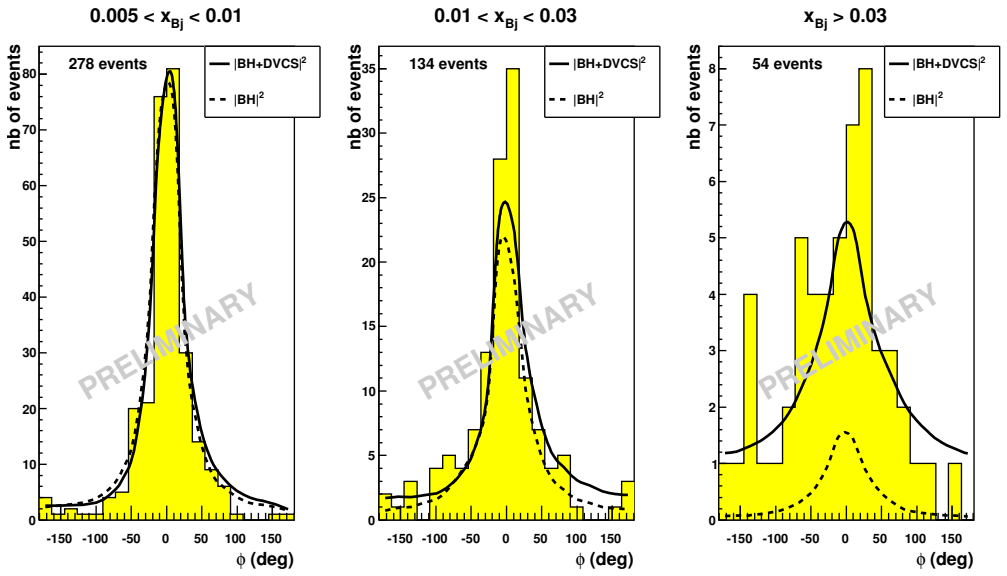
COMPASS results $\frac{g_A}{g_V} = 1.28 \pm 0.07 \pm 0.10$

COMPASS II

- proposal for COMPASS II phase has been submitted to CERN
- GOALS:
  - Transverse momentum dependent structure functions (TMDs) measurement in Drell-Yann process
  - General Parton Distribution (GPDs) measurement via DVCS process
  - time scale if accepted >= 2013
- new equipments
  - 3m long LH target, with 4.5m long Recoil Proton Detector
  - new ECAL0
  - 40t hadron absorber for DY physics
- successful test runs in 2008-2009

Results from test runs for COMPASS II

- example from DVCS test, $Q^2 > 1$ (GeV/c)^2 sample
- exclusive events with $\mu p \to \mu' p' \gamma$
- distribution of the events as a function of the azimuthal angle between photon and $\mu\mu'$ scattering place
  - BH can be calculated analytically
  - DVCS is flat
- clear signal from DVCS events are observed in COMPASS



Summary

- updated result for $\Delta G/G$ from open charm LO analysis was presented
  - $\Delta G/G = -0.08 \pm 0.21 \pm 0.11$
- updated results for other methods of $\Delta G/G$ extraction are expected soon
- results of A_1^p, g_1^p were shown, the Bjorken sum rule is confirmed within the measured precision

- COMPASS II proposal has been submitted, GOALS: TMDs and GPDs