COMPASS 2006/2007 Status Report

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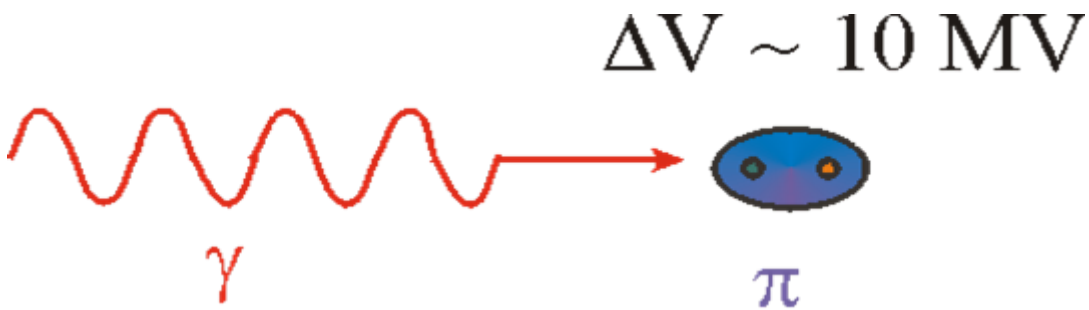
for the Collaboration

Plan

- New physics results from 2002–2004 data
  - Pion polarisability (hadron beam)
  - Inclusive and semi-inclusive DIS (long.)
  - Gluon polarisation
  - Transversity
- 2006 upgrades and performance
- Beam delivery and spectrometer performance
- 2007 goals and schedule
- Conclusion

Polarizabilities

- electric polarisability : $\vec{d} = \alpha \vec{E}$
- magnetic polarisability : $\vec{\mu} = \beta \vec{H}$



Charges oscillate ~ 0.1% π radius

From S. Paul

Polarisability: a test of χPT

- $\overline{\alpha}_\pi$ electrical , $\overline{\beta}_\pi$ magnetic polarisability
- χPT: $$\overline{\alpha}_\pi \pm \overline{\beta}_\pi = \frac{\alpha}{16\pi^2 m_\pi f_\pi^2}\left\{a_\pm + b_\pm + \mathcal{O}(\frac{m_\pi^2}{f_\pi^2})\right\}$$

1 loop

2 loop

- $a_+ = 0$, $a_- \sim$ Low Energy Constant (LEC)
- χPT:

$$\overline{\alpha}_\pi + \overline{\beta}_\pi = (0.16 \pm 0.1) \cdot 10^{-4}\ \text{fm}^3$$
$$\overline{\alpha}_\pi - \overline{\beta}_\pi = (5.7 \pm 1.0) \cdot 10^{-4}\ \text{fm}^3$$

= 0 at 1 loop

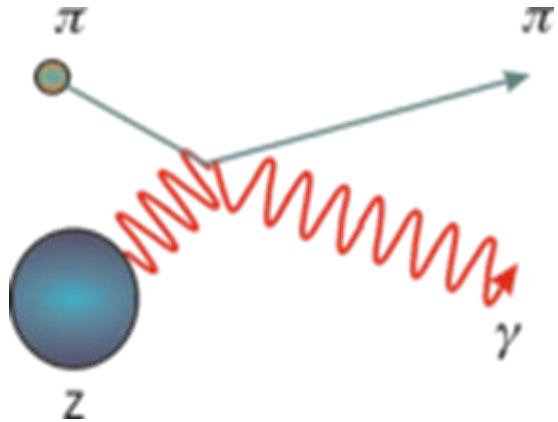
Polarisability: Primakoff

- measurable in Compton scatt.

$$\gamma\pi \to \gamma\pi$$

- Primakoff: inverse kinematics
- with $\omega = E_\gamma / E_{\text{beam}}$ and

$$\overline{\alpha}_\pi + \overline{\beta}_\pi = 0$$



$$\frac{d\sigma^{\text{Prim}}_{\gamma\pi}}{d\omega} = \frac{d\sigma^{\text{Thomson}}_{\gamma\pi}}{d\omega} + \omega\, 4Z^2\alpha^2 m_\pi \overline{\beta}_\pi \left\{ \ln\frac{Q^2_{\text{max}}}{Q^2_{\text{min}}} - 3 + 4\sqrt{\frac{Q^2_{\text{max}}}{Q^2_{\text{min}}}} \right\}$$

where $Q^2_{\text{min}} = \frac{m_\pi^2}{2E_{\text{beam}}} \frac{\omega}{1-\omega}$ and Q^2_{max} depends on analysis cuts

Polarisability: Primakoff

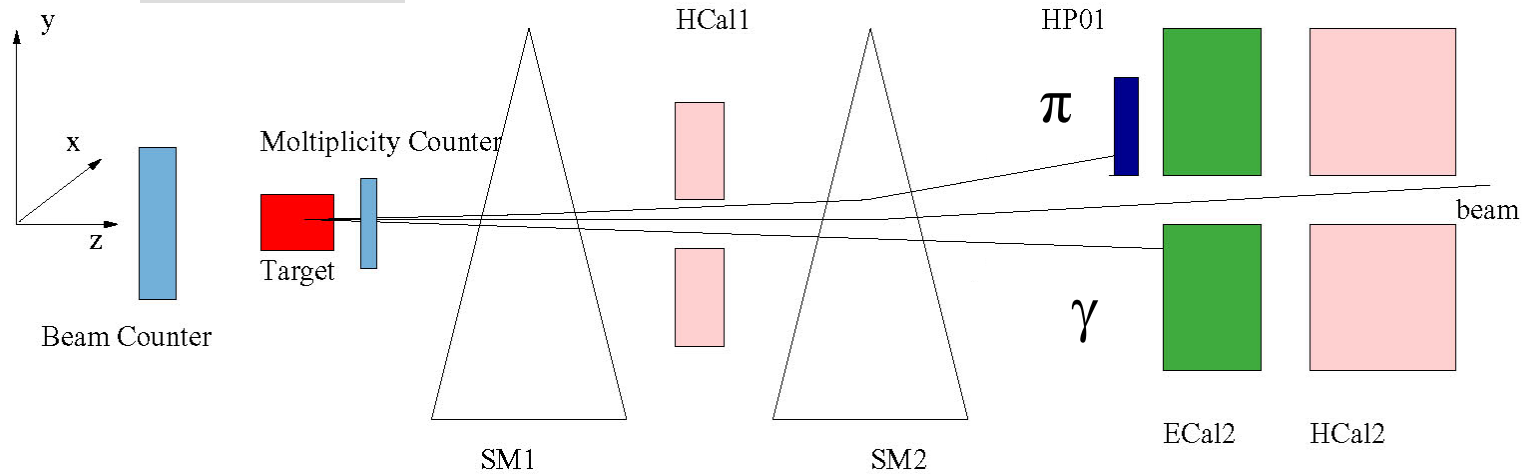
- Finally compare the shape of the measured Primakoff cross-section to a Monte Carlo simulation for the pointlike case.

$$R(\omega) = \frac{\mathrm{d}\sigma_{\gamma\pi}^{\mathrm{Prim}}}{\mathrm{d}\sigma_{\gamma\pi}^{\mathrm{Thomson}}} \simeq 1 + \frac{3}{2}\frac{m_\pi^3}{\alpha}\frac{\omega^2}{1-\omega}\overline{\beta}_\pi$$

- Note COMPASS also measured the point-like muon

Pilot hadron-beam run 2004

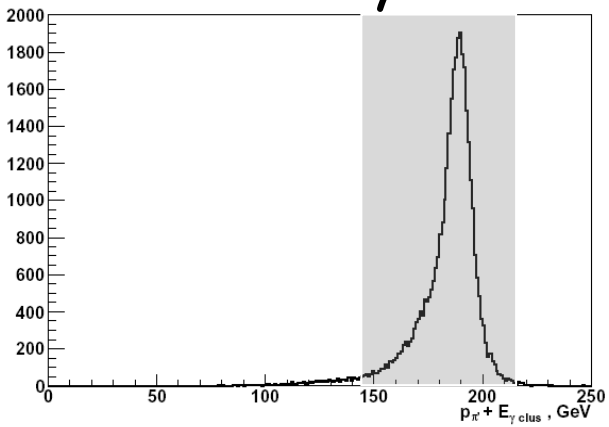
Trigger



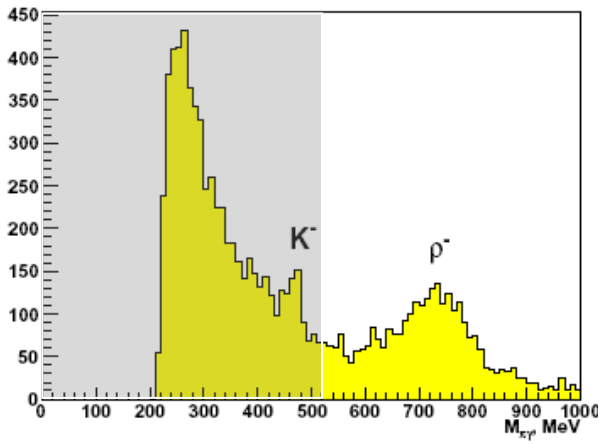
- 190 GeV π beam, low intensity: 2 ·10^6/spill
- Beam time: 7 days
- Trigger: beam, pion in hodoscope, and Eγ > 90 GeV
- Trigger rate (40-50k/spill)
- Different targets (Pb, C, Cu)

Event selection

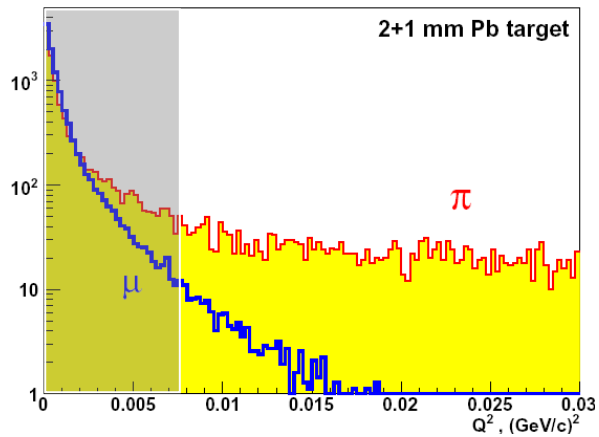
- Exclusivity



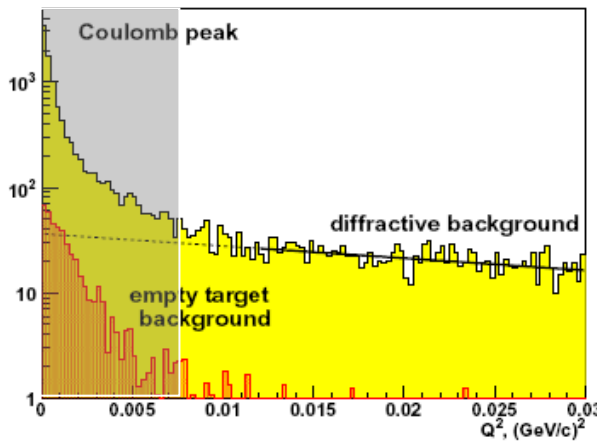
- Interference



- Diffractive background



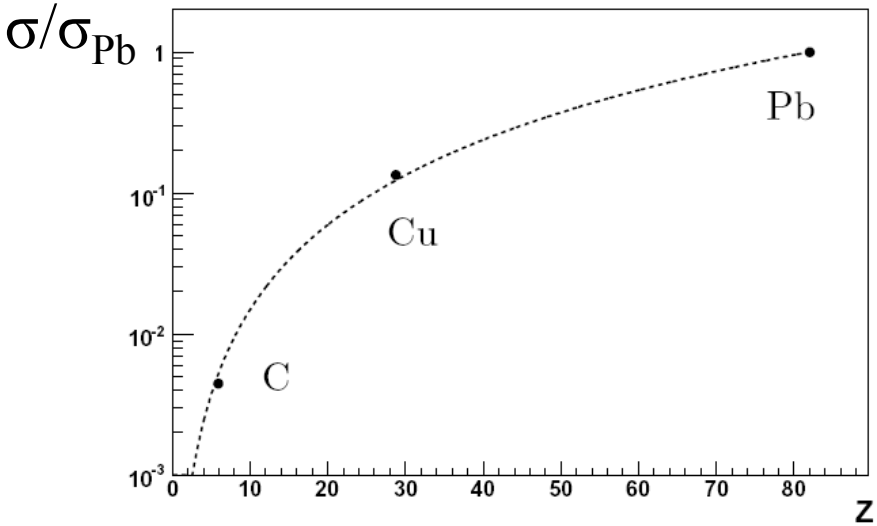
Coulomb peaks of π and μ agree



Extrapolate diffr. background

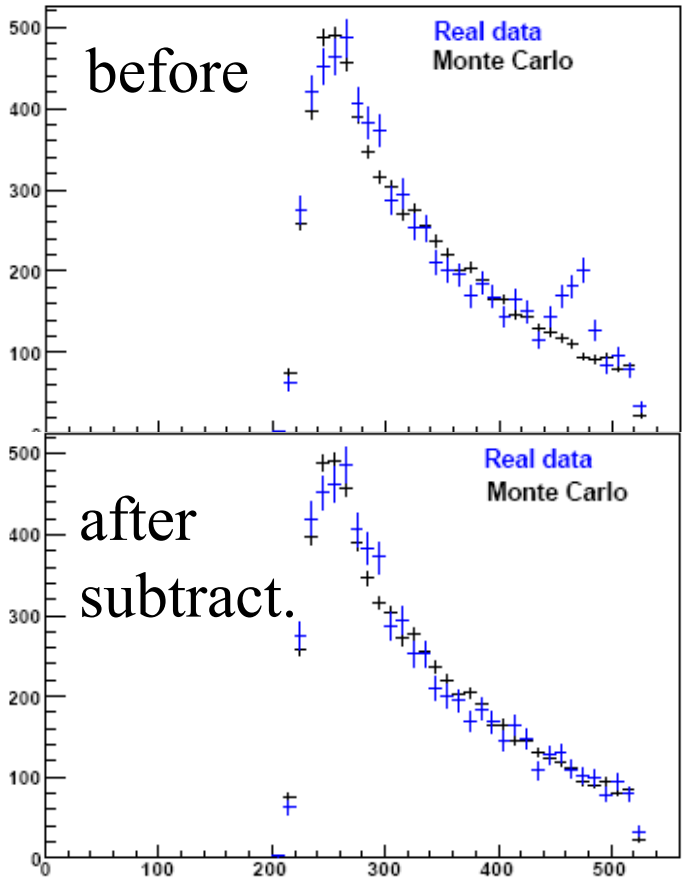
Cross checks

- Cross section ratios



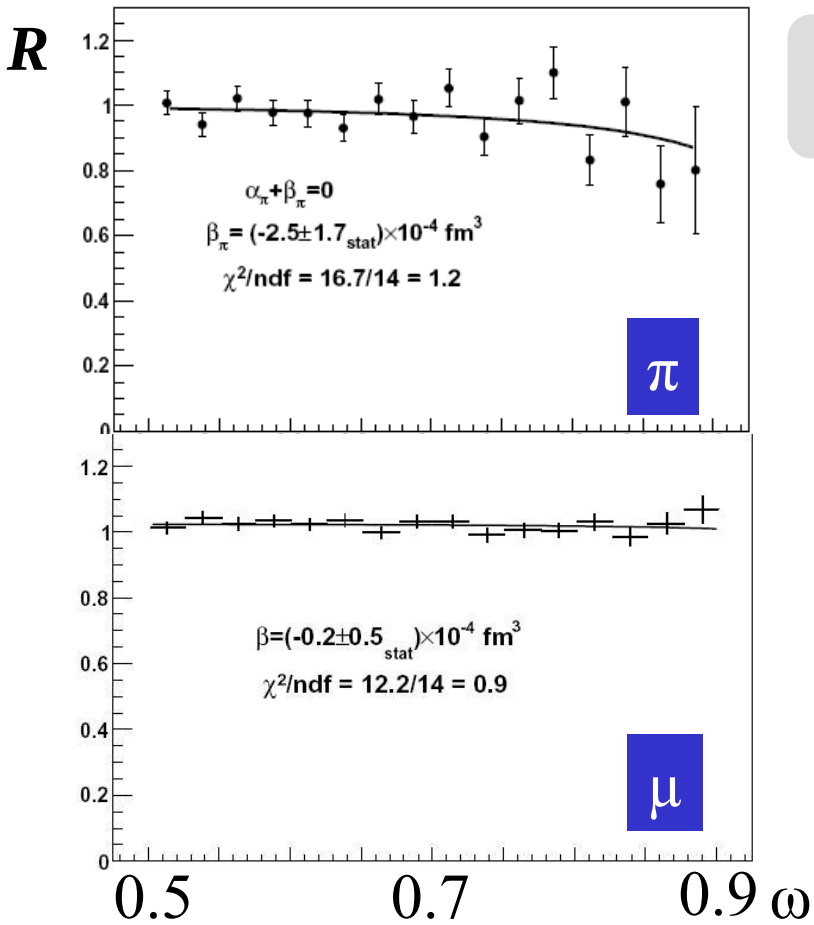
- Abs. Pb cross-section:
  estimate ~ 100 μb
  theory ~ 140 μb
- Not needed in analysis

- Empty target bkgrd



Result for $\overline{\beta}_\pi$

Ratio data/MC

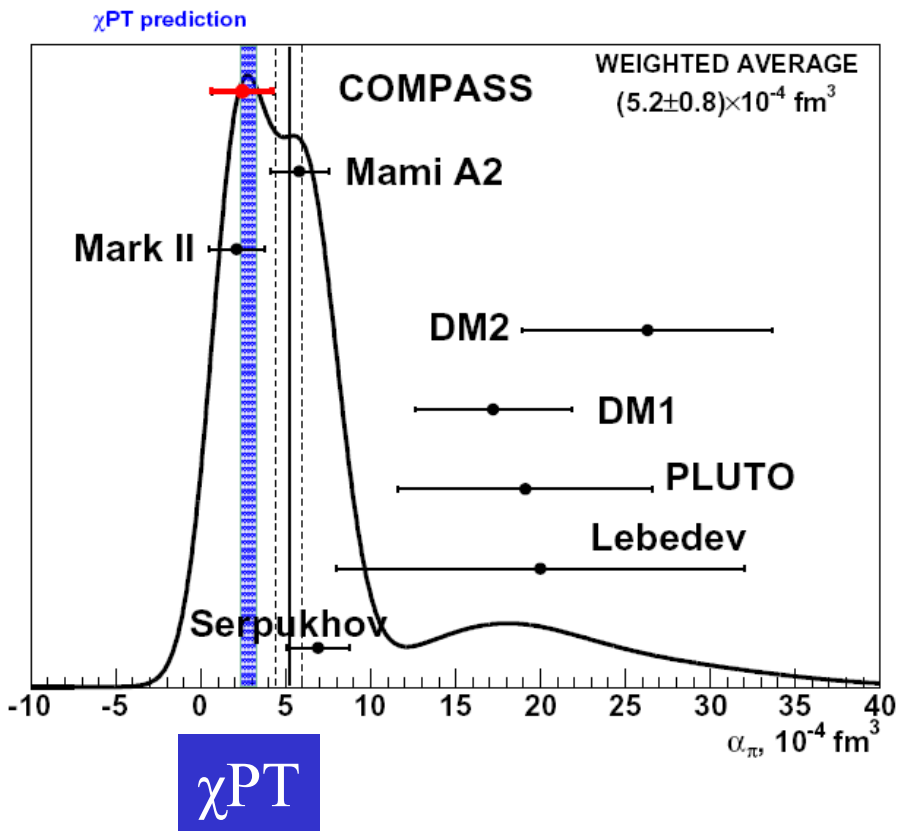


$$\overline{\beta}_\pi = (-2.5 \pm 1.7 \pm 0.6) \times 10^{-4} \text{ fm}^3$$

- Radiative corrections included
- zero result for muon
- Systematic error:

Origin	Syst. Error 10^{-4} fm^3
Setup description in MC	±0.5
Background subtraction	±0.3
Beam muons	< 0.2
Beam electrons	< 0.1
Total	±0.6

World data on $\overline{\alpha}_\pi$



- Precise result
- Good agreement with χPT
- Smaller than Serpukhov and Mainz result

Inclusive μ-DIS deuteron A_1 data

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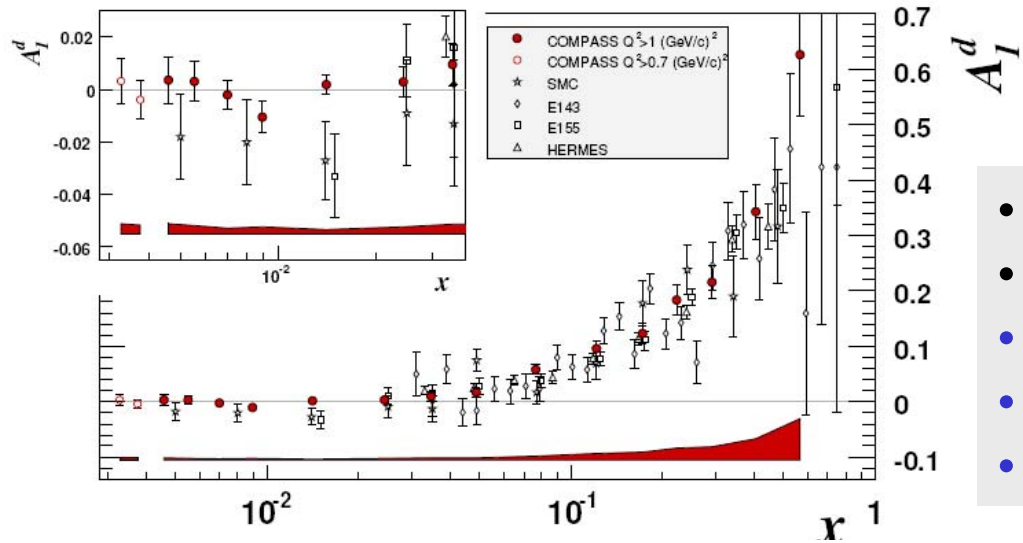

- $Q^2 > 1$ GeV^2
- $4 \cdot 10^{-3} < x < 0.7$
- $a_0\ (\infty) = \ 0.33 \pm 0.03 \pm 0.05$
- $\Delta s\ (\infty) = -\ 0.08 \pm 0.01 \pm 0.02$
- $\overline{\text{MS}}$: $a_0 = \Delta\Sigma = \Delta u + \Delta d + \Delta s$

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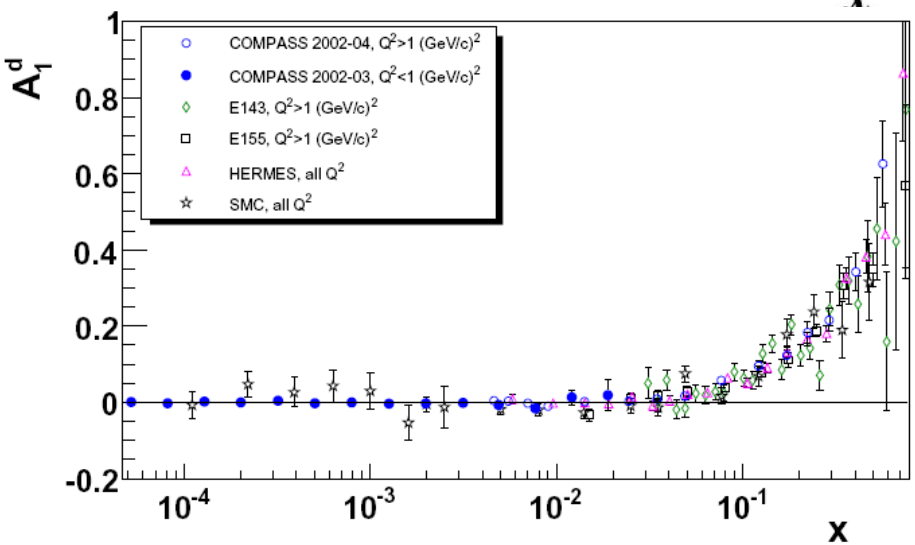


- $Q^2 < 1$ GeV^2
- $4 \cdot 10^{-5} < x < 2.5 \cdot 10^{-2}$

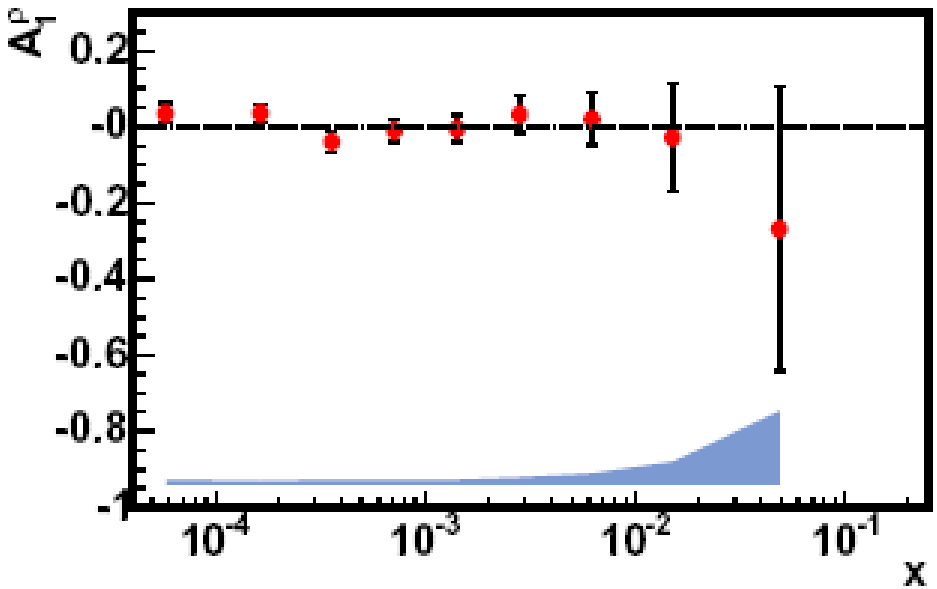
Asymmetries from SIDIS: rho

- Longitudinal double-spin asymmetry A_1^ρ in exclusive incoherent ρ production

$$\mu + N \rightarrow \mu' + \rho^0 + N'$$

- Related to spin-dependent, generalised parton distribution functions

hep-ex/0704.1863

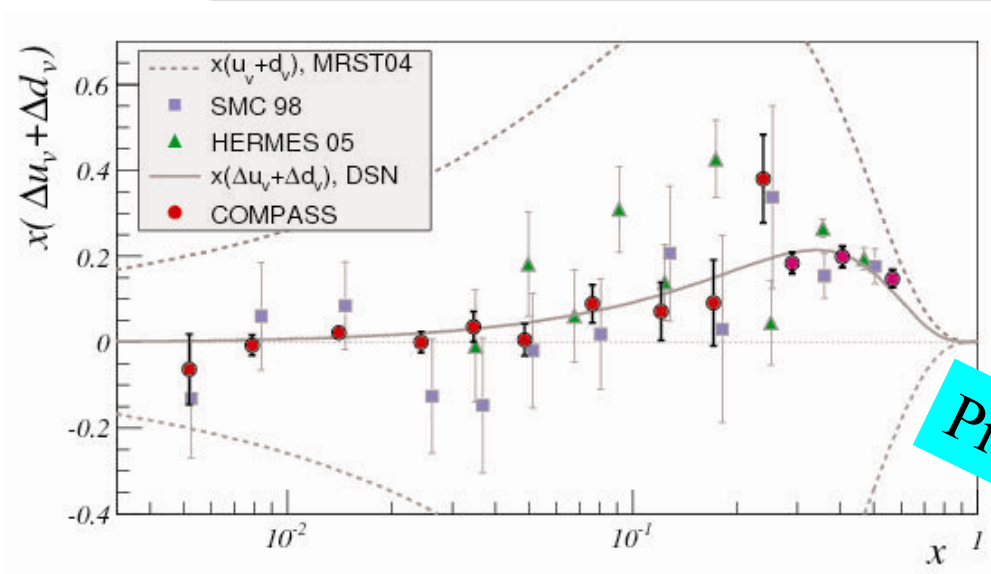


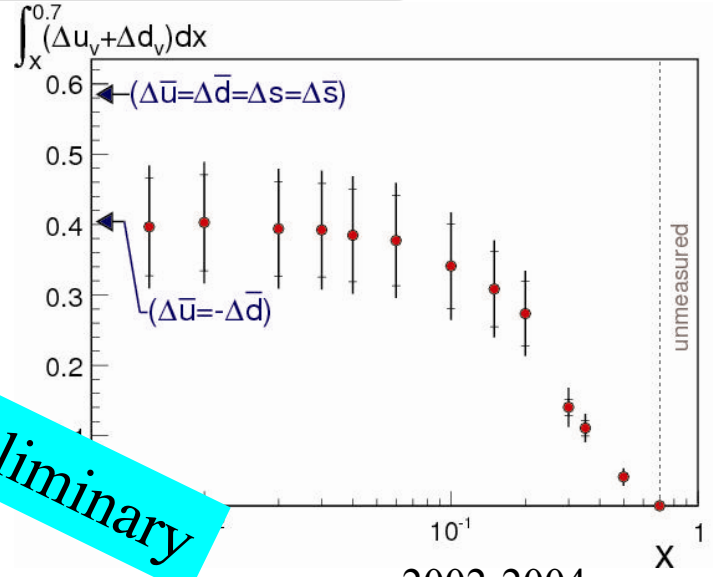
Valence quark polarisation

- Asymmetry A^{h+-h-} of $\Delta\sigma^{+-} = (\sigma^{h+} - \sigma^{h-})$
- Fragmentation functions drop out
- Flavour symmetric sea disfavoured

$$\Gamma_v^1 = \int_0^1 \mathrm{d}x\,(\Delta u_v + \Delta d_v) = 0.41 \pm 0.07 \pm 0.05$$

Ready to submit



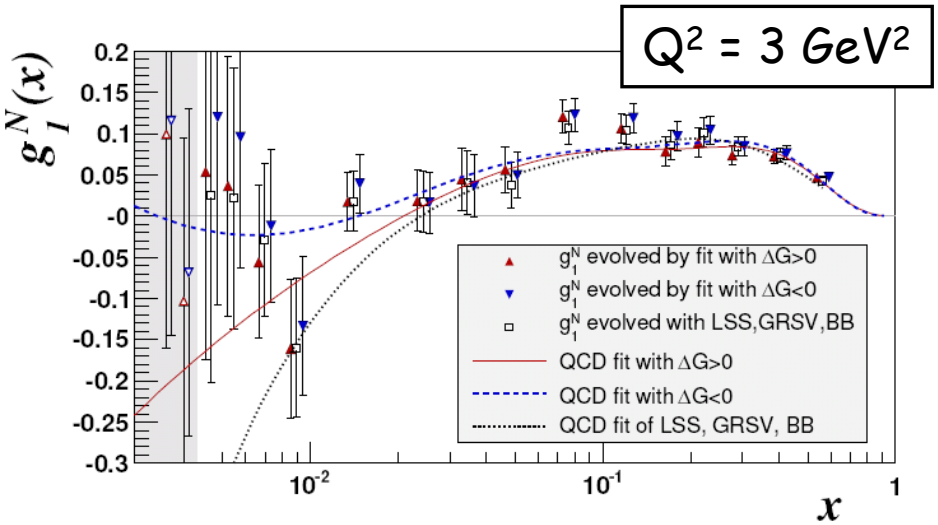


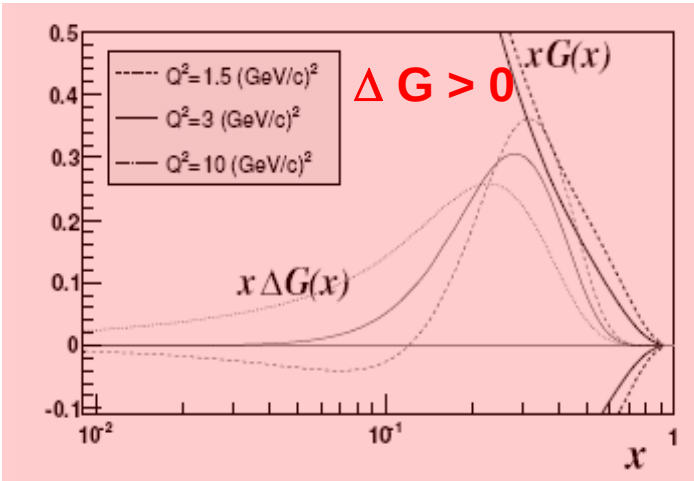
Preliminary

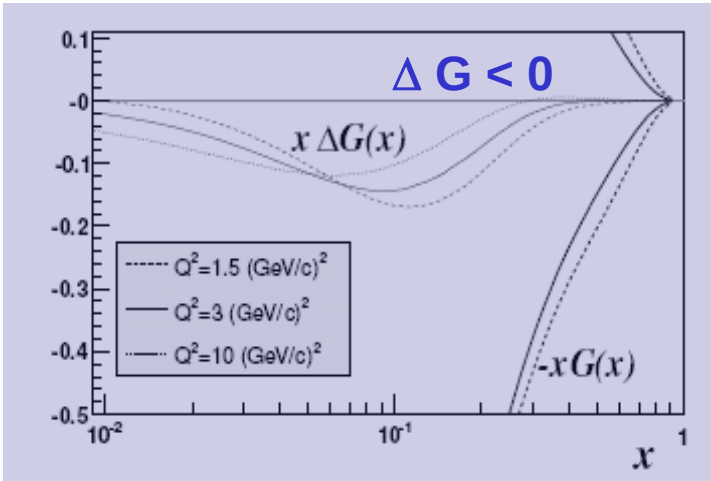
2002-2004

QCD fit

- New g_1^d data + world data
- Solutions for
  $\Delta G > 0$ and $\Delta G < 0$
- $|\Delta G| \sim 0.2$–0.3







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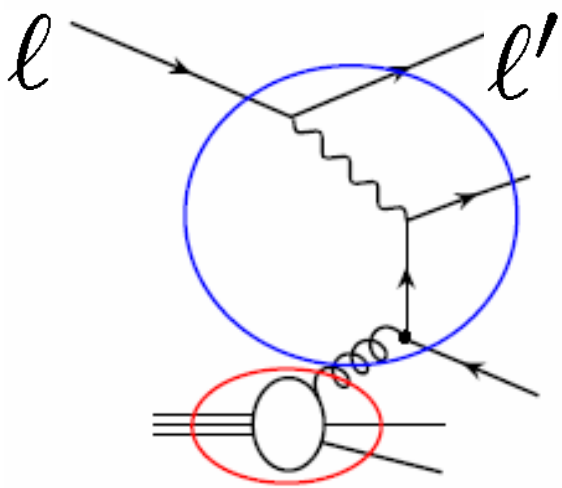
Photon-gluon fusion (PGF)

- Gluon polarisation is directly measurable in PGF



$$A_{\parallel} = R_{pgf} \langle \hat{a}_{pgf} \rangle \frac{\Delta G}{G}$$

- measure $A_{\parallel}$
- calculate R_{pgf} and $\langle \hat{a}_{pgf} \rangle$

  using Monte Carlo

Gluon polarisation

high-pT pairs; $Q^2 > 1$ GeV^2 :

2002–2003

$$\frac{\Delta G}{G} = 0.06 \pm 0.31(\text{stat.}) \pm 0.06(\text{syst.}) \qquad \langle x_g \rangle = 0.13$$

high-pT pairs; $Q^2 < 1$ GeV^2 :

2002–2004

$$\frac{\Delta G}{G} = 0.016 \pm 0.058(\text{stat.}) \pm 0.055(\text{syst.})$$

$$\langle x_g \rangle = 0.085 \qquad \langle \mu^2 \rangle = 3 \text{ GeV}^2$$

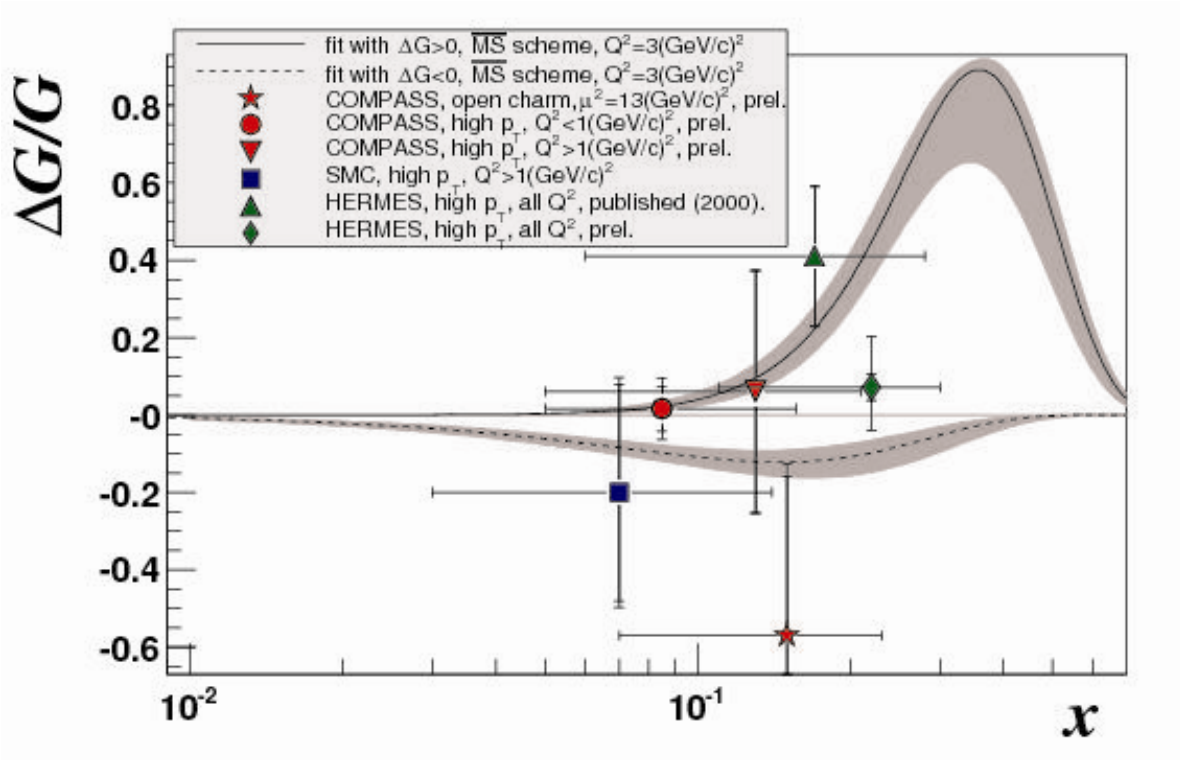
Open charm:

2002–2004

$$\frac{\Delta G}{G} = -0.57 \pm 0.41(\text{stat.}) \pm 0.17(\text{syst.})$$

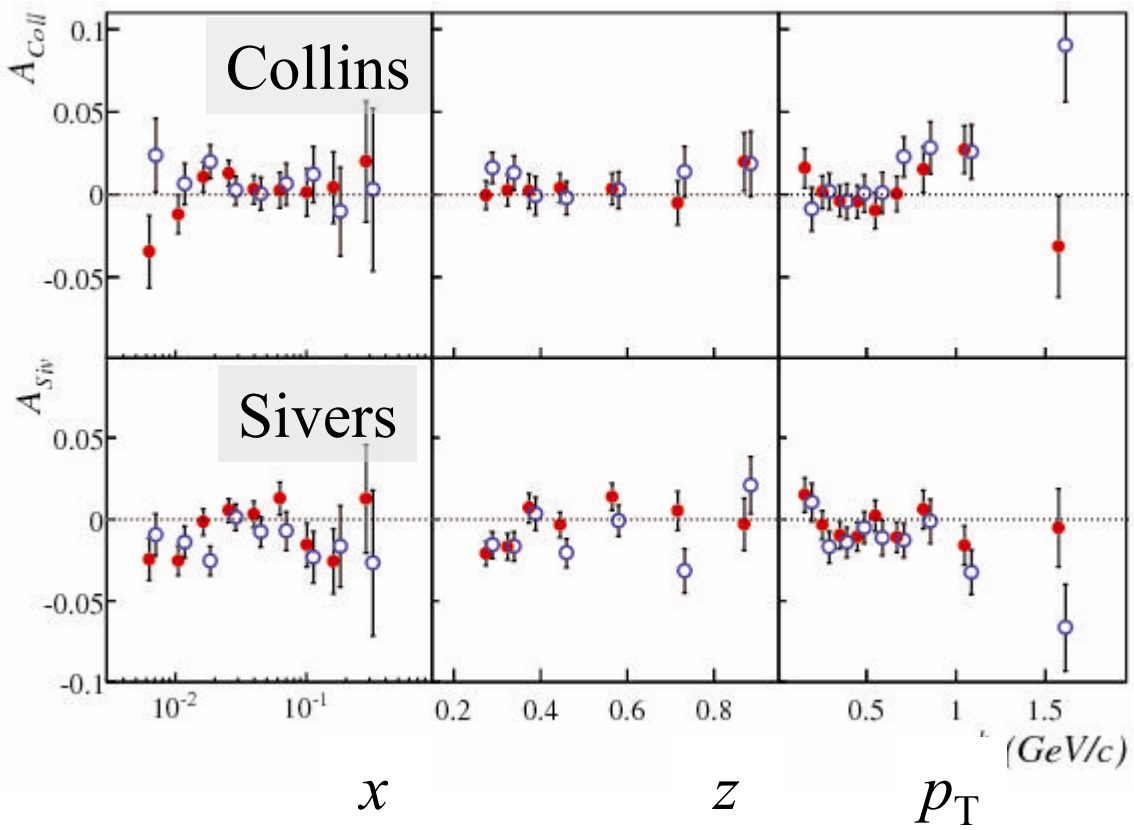
$$\langle x_g \rangle = 0.15 \quad \langle \mu^2 \rangle = 13 \text{ GeV}^2$$

Δ G/G summary



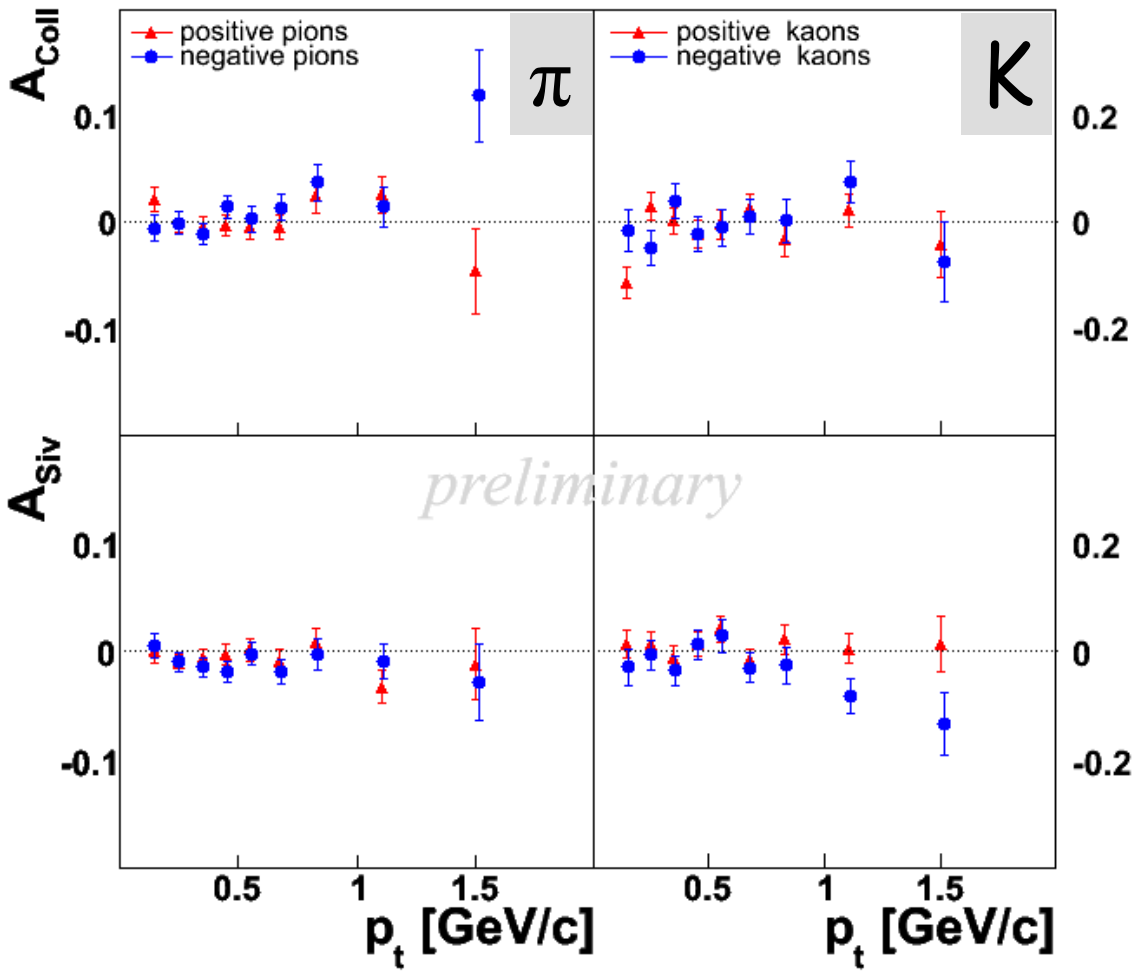
Note: not included is syst. uncertainty due to the PDF parametrisation

Transverse asymmetries



- 2002 – 2004 data
- all hadrons
  - positive
  - negative

Transverse asymmetries

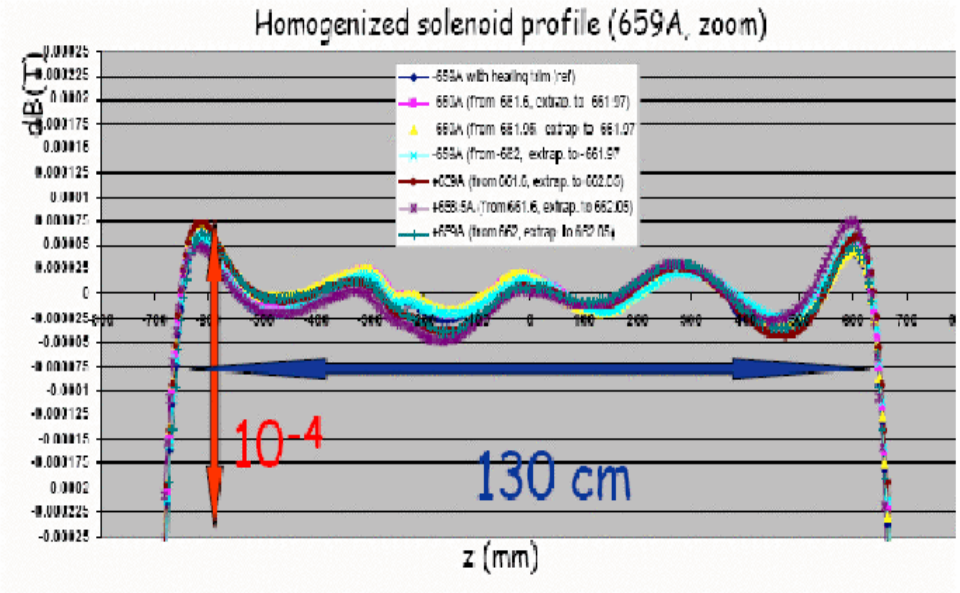


- 2003 – 2004 data
- Identified hadrons
  - positive π & K
  - negative π & K

2006 upgrades and performance

- Main projects:
  - Polarised target magnet and cavity
  - RICH photon detectors
- Not discussed:
  - RICH wall tracker & preshower
  - Drift chamber DC04
  - ECAL1

Polarized target magnet



New target magnet

SMC (70 mrad) → COMPASS (180 mrad)

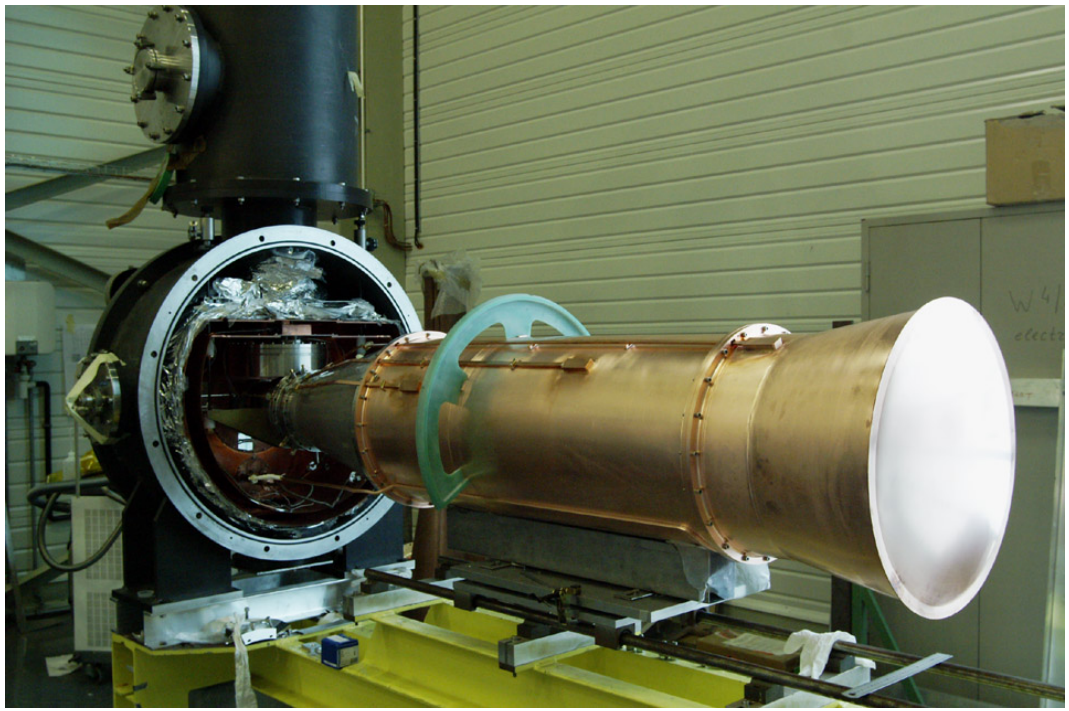
Field homogeneity of

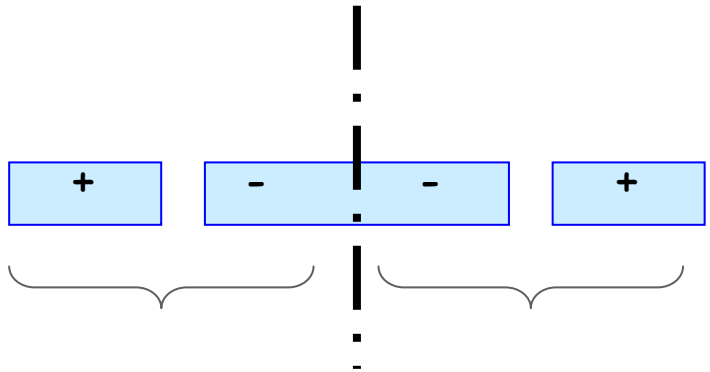
~ 3 × 10^{-5} achieved @ Saclay

Operation delicate , however reliable.

Excellent uniformity

Polarized target new μW cavity

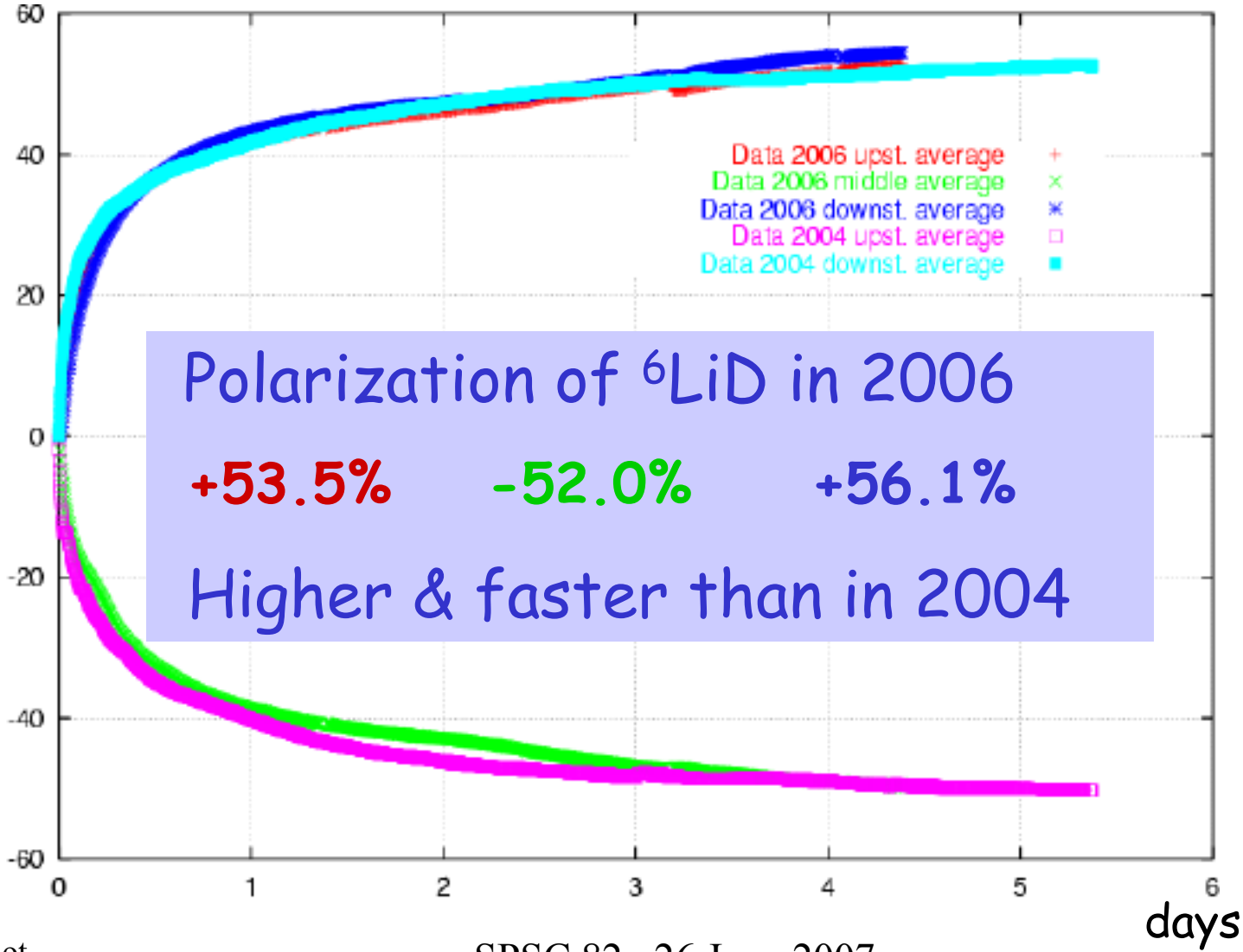




New 3-cell system & microwave cavity matched for larger acceptance

reduces false asymmetries

Polarized target performance



Polarization of ^{6}LiD in 2006

+53.5% **-52.0%** **+56.1%**

Higher & faster than in 2004

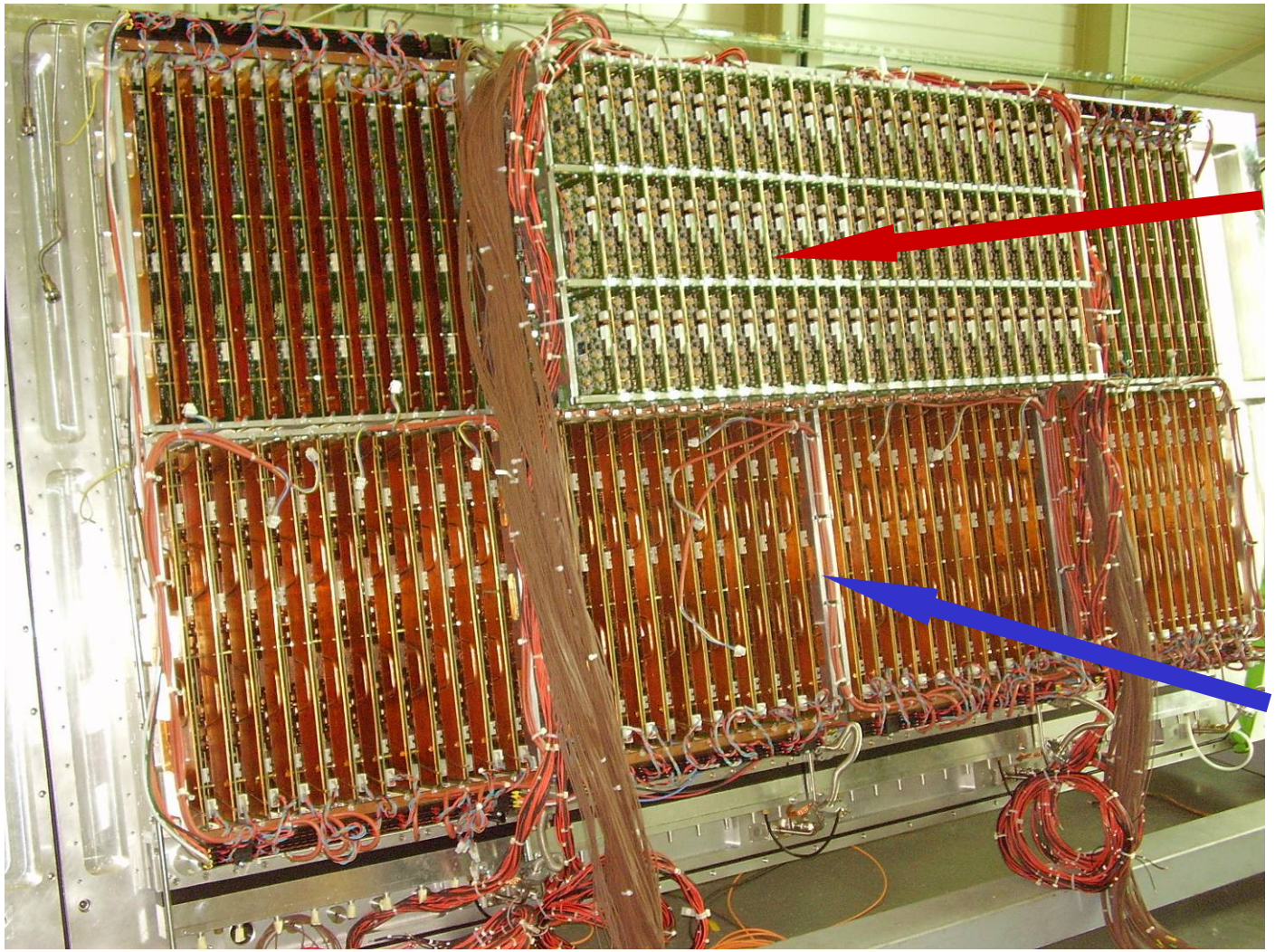
RICH upgrade

- Central photodetectors (1/4) replaced by MAPMTs
- Significant increase in nb of photons, no dead time, excellent timing.

- Outer (CsI MWPC) photodetectors read by APV25S1
- Nb of photons as with previous electronics, no dead time, uncorrelated background is at least 6 times smaller.

INFN + 8 COMPASS Institutes

RICH upgrade



Lens system

+ MAPMTs

+ MAD4

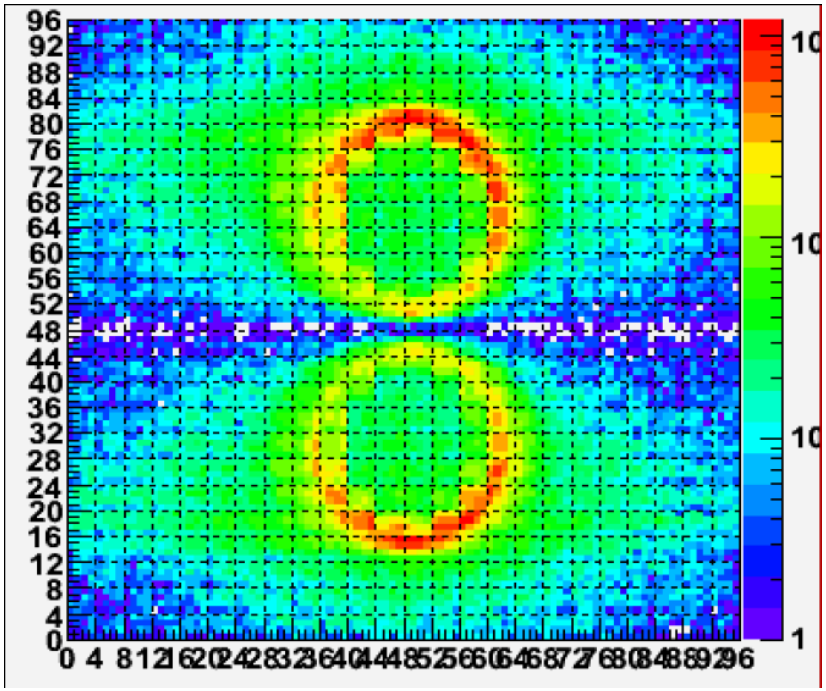
+ F1

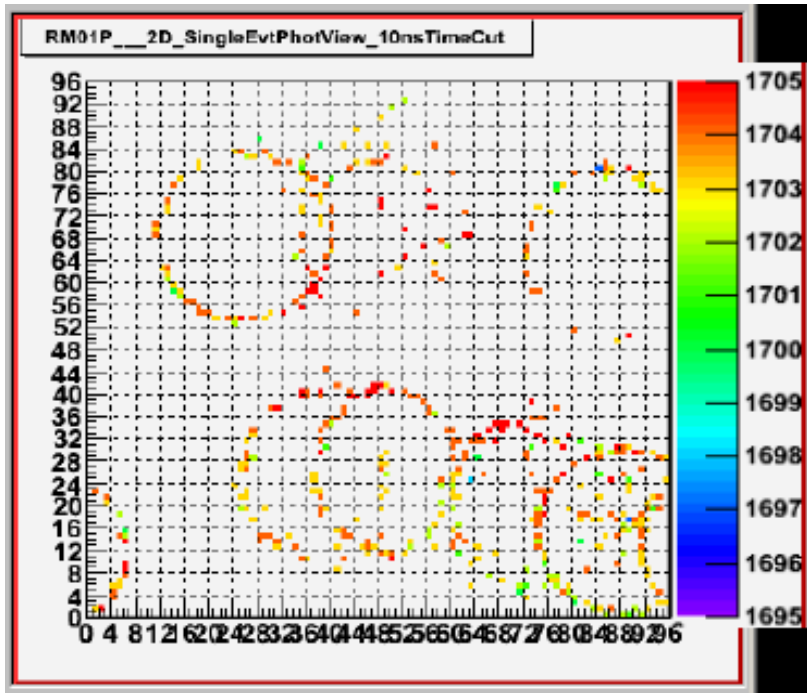
CsI MWPC

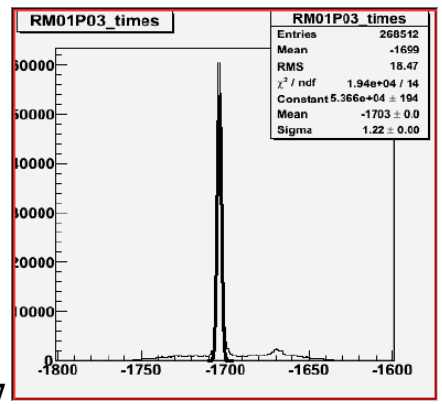
+ APV25S1

+ ADC

RICH upgrade, MAPMTs "on-line"





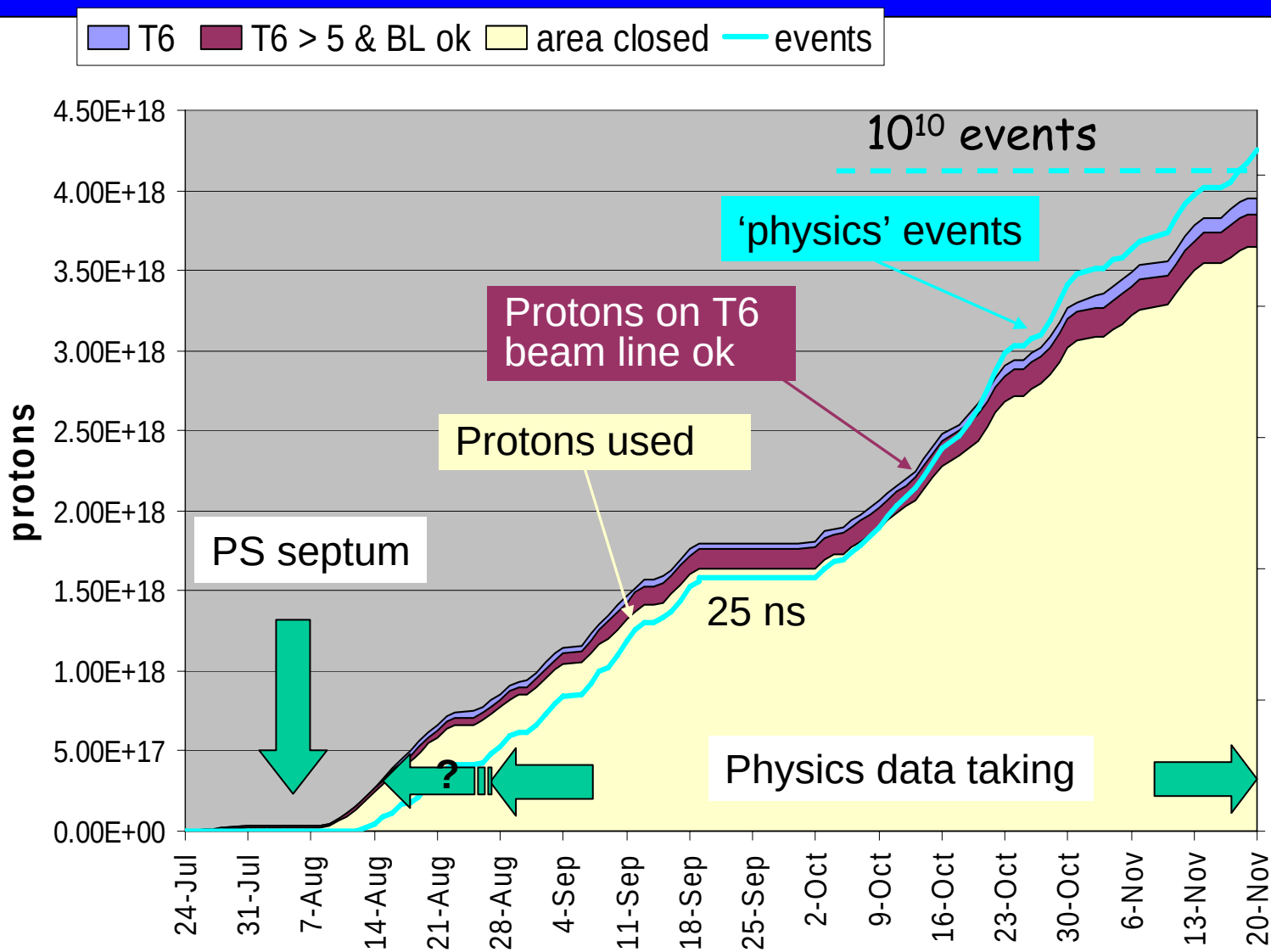


Very promising results !

- Precise timing
- High photon statistics

Beam delivery and spectrometer performance in 2006

Beam delivery 2006



2006 beam

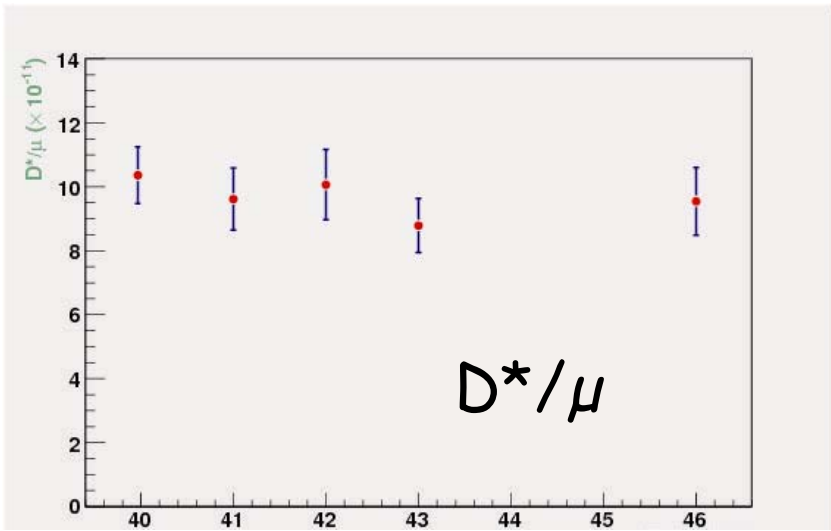
- Data taking August 13 – November 21
- Basically no CNGS running
- SC 16.8s → 14.4s and higher intensity recovered equivalent of 13 days, thanks to the SPS crew
- Total beam delivered 3.8 10^{18} protons
- Got 10 days commissioning and
  - 71% of beam expected for longitudinal run, but
  - 0% for transverse run (postponed to 2007)
  - 56% of total from 2005 projection, i.e. 140 days at 14.4s SC and 1.2 10^{13} ppp (10/100/30 days)
- 56% of total
- (note the 2005 projection was assuming a longer SPS run)

Spectrometer performance

- Evaluate effectiveness of upgrade for open charm channel

$$D^* \rightarrow D^0 \pi_{slow} \rightarrow K\pi\ \pi_{slow}$$

- total > 10^{10} raw events, > 400 TB
- 86 % of data reconstructed
- Study based on 50 % of data taken
- Extrapolate to full statistics



2006 D* statistics (prelim.)

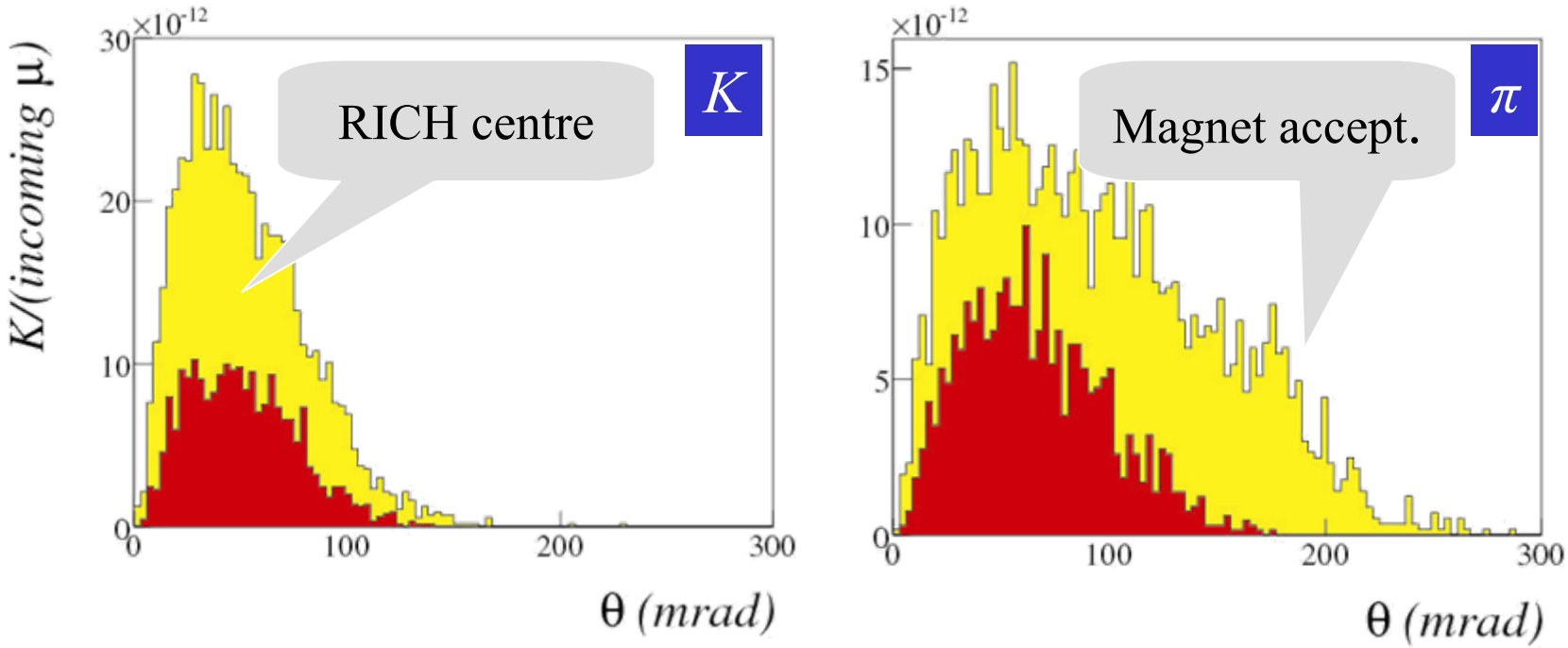
- Compare: number of D* and effective signal S_{eff}

$$S_{\text{eff}} = \frac{S^2}{S+B} \propto \delta^{-2} \frac{\Delta G}{G}$$

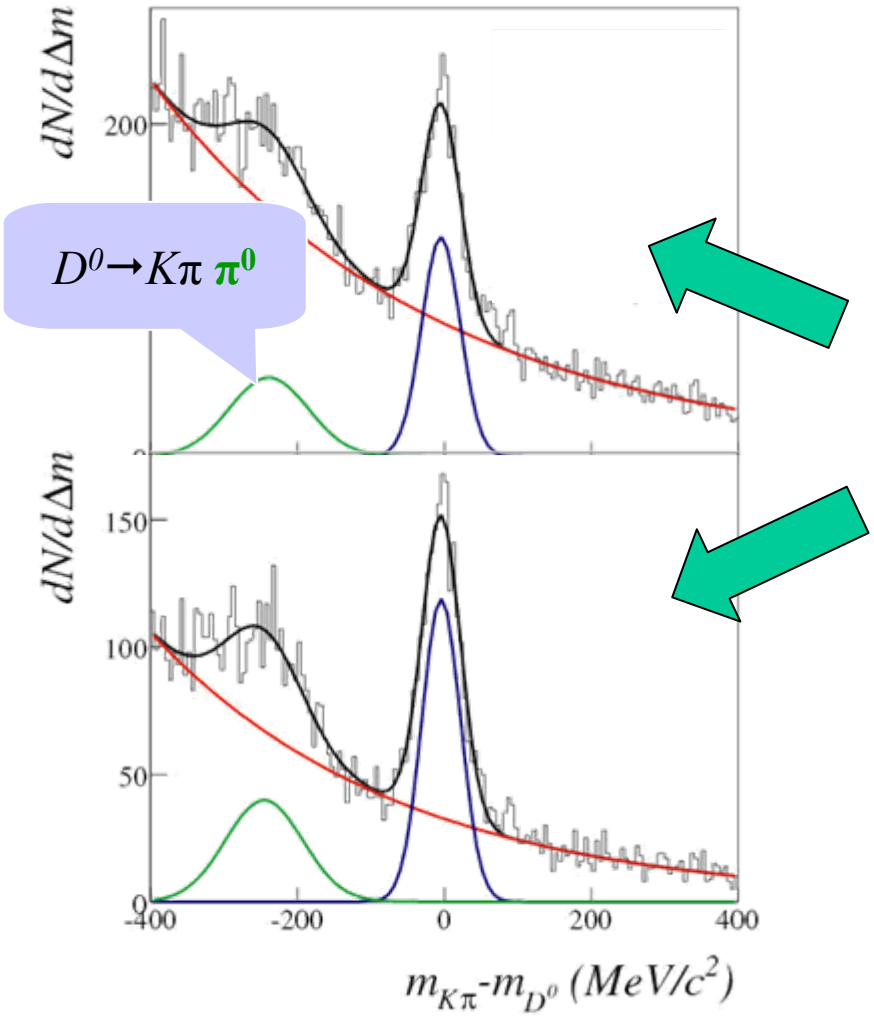
- Caveat: slightly different kinematics may influence event weight

	2006	2004	2006/2004
D*	3660	2084	1.76
D*/(10^{12} μ)	98	52	1.9
S_{eff} /(10^{12} μ)	46	26	1.8

Event gains in 2006 wrt 2004



Signal-to-background ratio



- Slow π_s not identified
- Larger acceptance in 2006 → larger combinatorial bg
- Large e^- bg found in π_s sample
- rejected by RICH
- S/B: 0.99 → 2.17!
- S_{eff} increases by 25 % despite of loss of 10 % of events.

- S_{eff} (D*) = 1.25 x 1.8 = 2.25

2006 performance

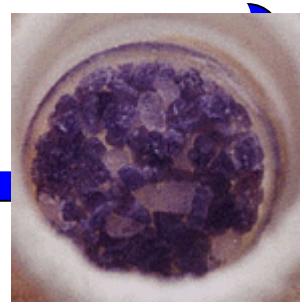
- RICH and target upgrade fully successful
- Almost as many D^*s in 2006 as in 2002-2004
- Full data set to be evaluated
  - impact of combinatorial background on untagged D^0s?
  - Possible influence of changed kinematics

- If no surprises:

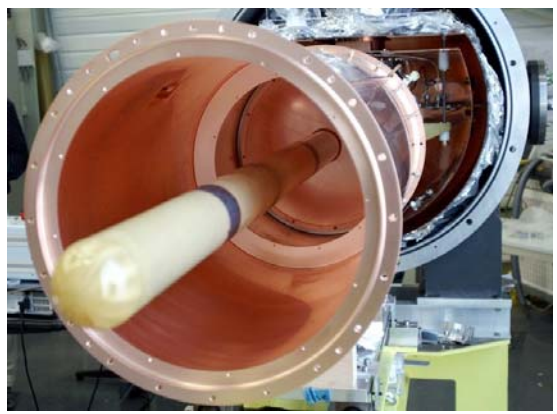
  Goal for longitudinal running in 2006 largely achieved

2007

2007 Target



- Different target material NH_3 (proton)
  - Fragile and difficult to handle
  - Successfully loaded
  - Very long relaxation time (~ 4000 h), important for transverse run
  - Magnetic field rotation without polarisation loss (no superradiance)



Goals of 2007 muon-proton run

- 2008 : measurements with hadron beam
- 2007: dedicated to muon-proton DIS
- Physics goal: flavour separation of PDFs,
  requires proton and deuteron (or n) data
- 2007 p data complement the 2002-2006 d data
- Proton target is twice harder:

	^{6}LiD	NH_3
Polarisation (P_T)	0.515	0.89
Dilution factor (f)	0.37	0.14
Density (ρ)	0.84	0.87
Filling factor (k)	0.55	0.60
FOM	0.0168	0.0081

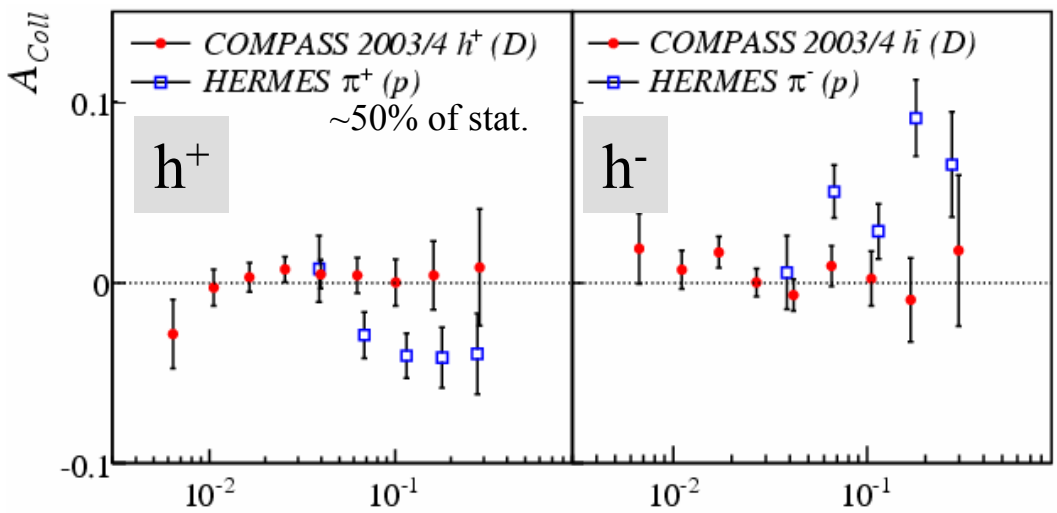
- Partly compensated by
  2006 spectrometer upgrade
  (channel dependent)

More info SPSC-2007-015/M754

Proton Collins asymmetry A_{Coll}

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

- Proton: only HERMES data at lower Q^2
- Non-zero HERMES results transversity or HT?
- Goal: comparable statistics for:
  - HERMES p
  - COMPASS d
  - COMPASS p
- Sivers asymmetry



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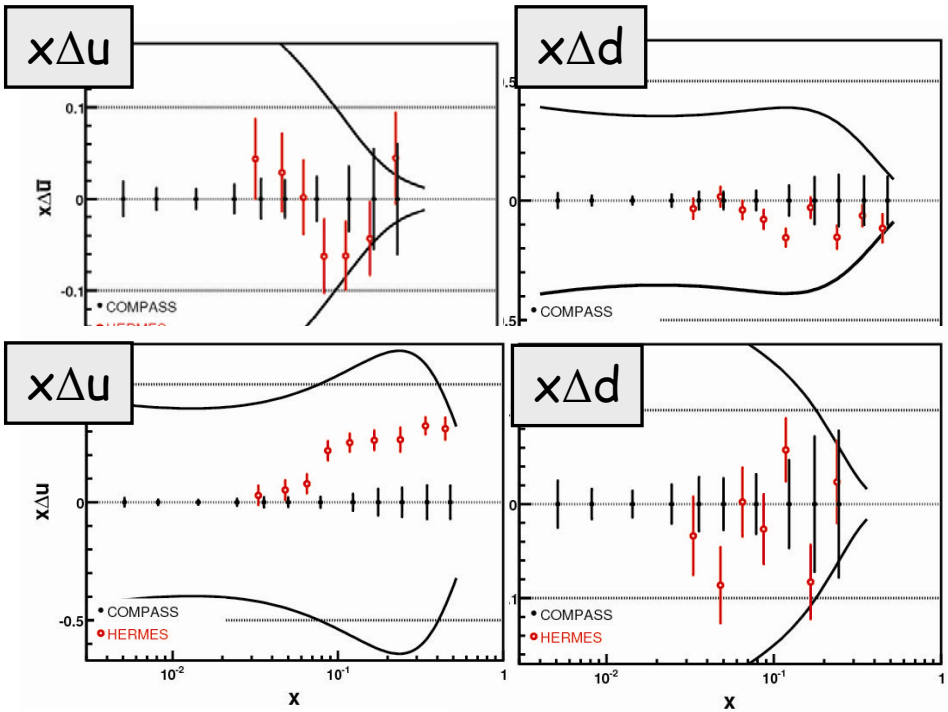
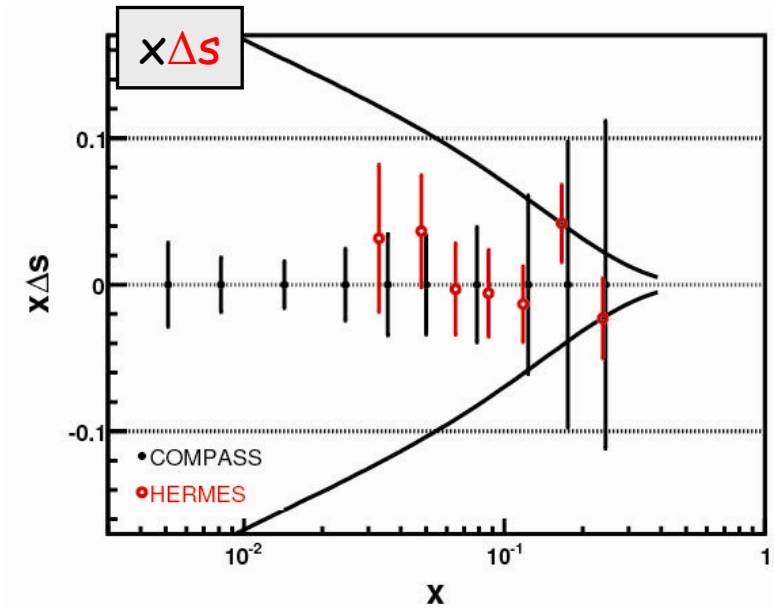
Flavour separated PDFs

- Goal for 2007 p and 2002-2006 d data
- What is the sign of $\int \mathrm{d}x\, \Delta s(x)$?
- COMPASS is unique at small x

<0 from incl. data;
>0 from Hermes SIDIS data





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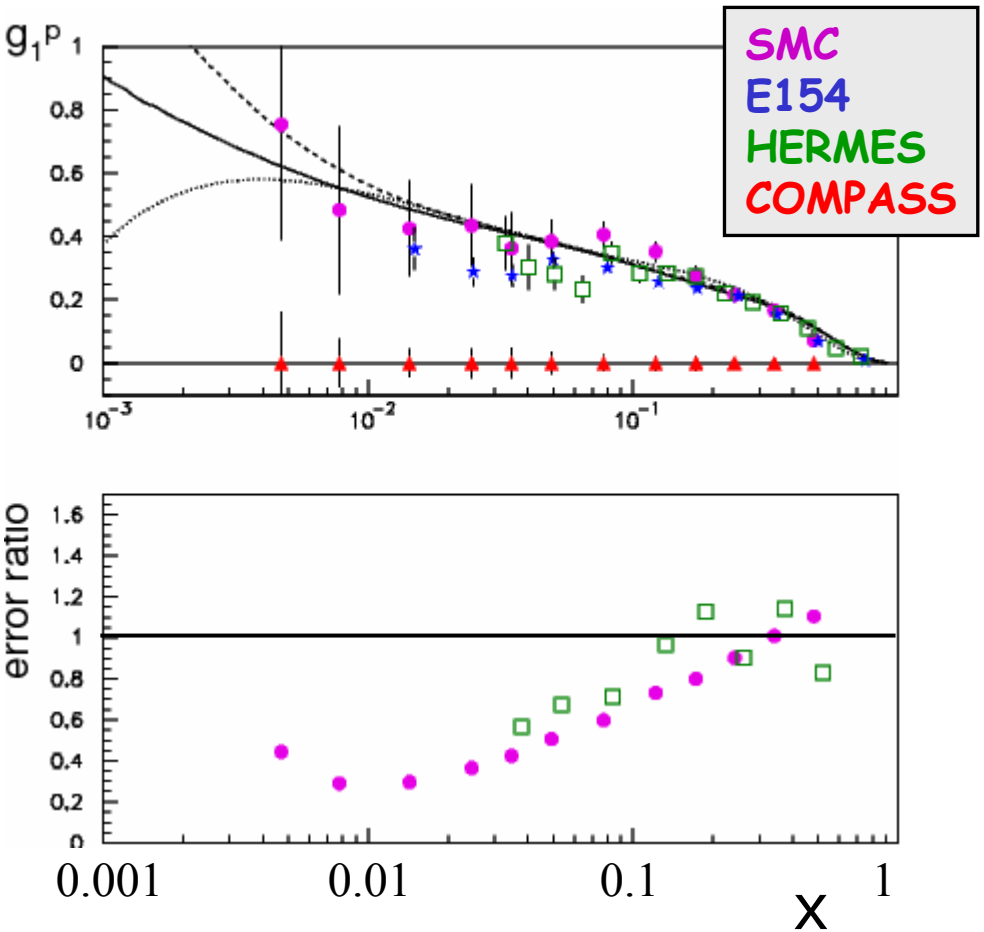
g_1 of the proton at small x



- Shape of g_1 at small x unknown
- Reduce SMC error by about a factor 3
- Fade of g_1 at small x depends on gluon polarisation
- But good precision needed
- x range unique to COMPASS
- Bjorken sum rule

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2007 schedule

- The discussed physics goals require
  - Excellent spectrometer performance, similar to 2006
  - Stable beam conditions for asymmetry measurements
  - ~10^{19} protons on T6 (see SPSC-2007-015/M754, 9.5 10^{18})
- Optimistically we can expect
  - About 8.4 10^{18} protons in 2007
  - Maybe more, if SPS/PS effi > 80 %
- Spectrometer tuned and calibrated
- Start with transversely polarised proton target
- Then switch to longitudinal proton polarisation