A Experiência COMPASS no SPS do CERN

A estrutura do protão e o seu spin

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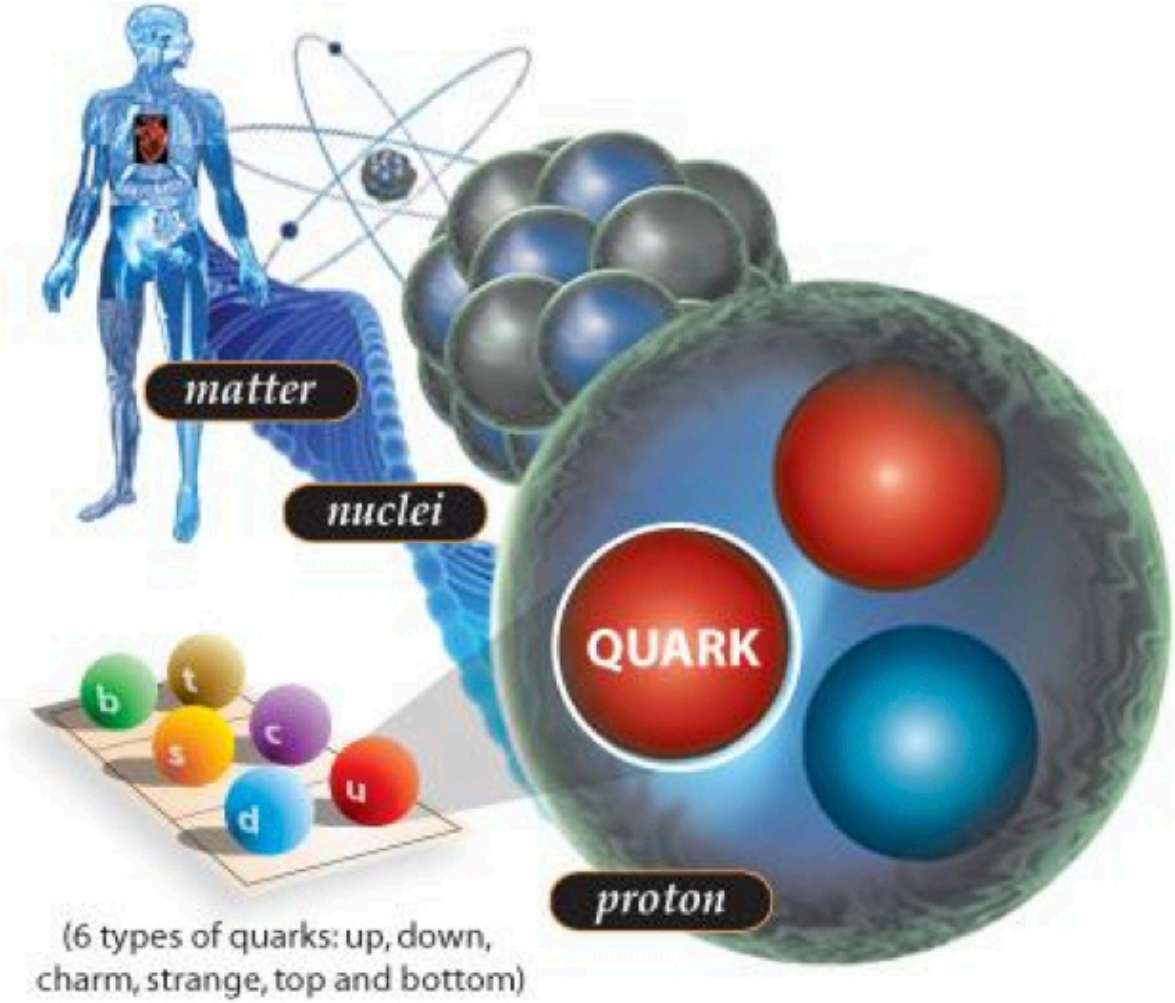
A Estrutura da Matéria



No núcleo dos átomos os nucleões - protões e neutrões - são constituídos de quarks ligados entre si por gluões

E o que é o Spin ?

As partículas constituintes da matéria - elementares (ex: quarks, electrões...) ou com estrutura (ex: protão, neutrão...) têm diferentes características.

Exemplos:

- **Massa**
- **Spin – esta característica corresponde ao movimento rotacional intrínseco**

Uma analogia clássica do spin dos nucleões (protões e neutrões) é como se fosse um pião a girar

Qual é o valor do Spin dos nucleões ?

O Spin dos protões (neutrões) = 1/2

E de onde provém ?

Sendo os nucleões constituídos por quarks e gluões, então o spin total será A soma dos spins de cada um deles

Spin do nucleão: $\frac{1}{2} = \frac{1}{2}\,\Delta\Sigma + \Delta G + L_Z$

spin dos quarks

spin dos gluões

mom. ang. orbital

A "Crise" do Spin

A primeira vez que se mediu o spin do conjunto dos 3 quarks dos nucleões foi nos anos 80 – pela experiência EMC do CERN

E o resultado foi: apenas 0.15 !!

Spin do nucleão: $\frac{1}{2} = \frac{1}{2}\,\Delta\Sigma + \Delta G + L_Z$

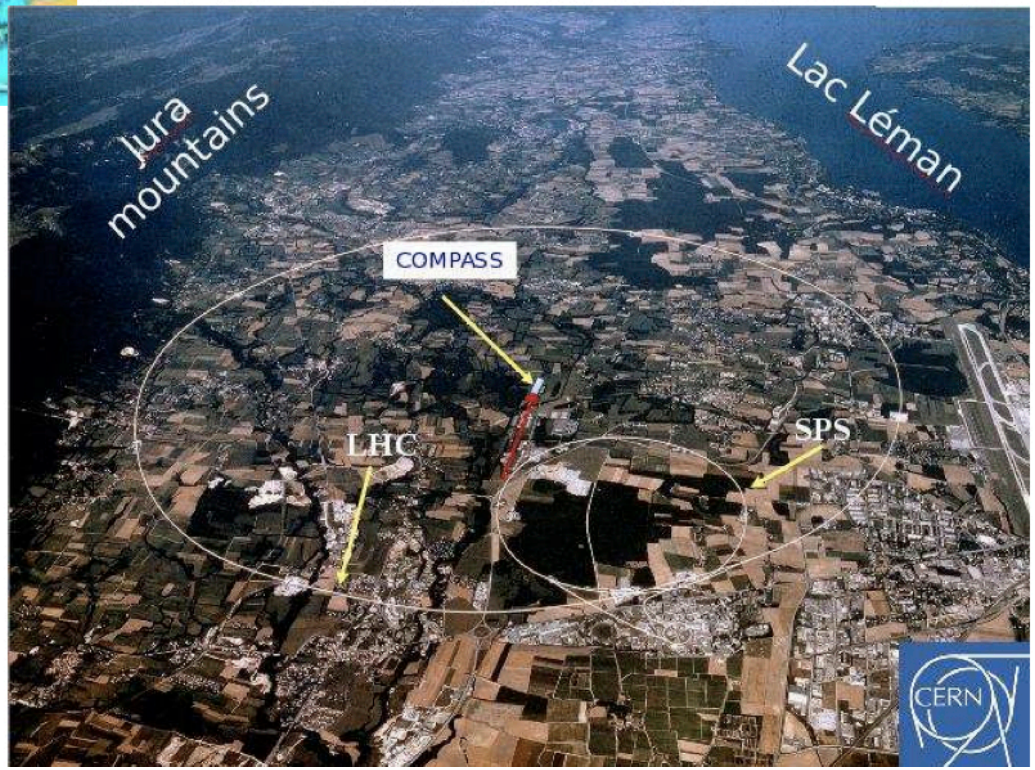
spin dos quarks — spin dos gluões — mom. ang. orbital

Um dos objectivos da experiência COMPASS do CERN é o de medir a contribuição dos gluões para o spin dos nucleões

COMPASS no CERN

COMPASS é uma colaboração de cerca de 230 físicos, de 30 institutos e 12 países.

2012

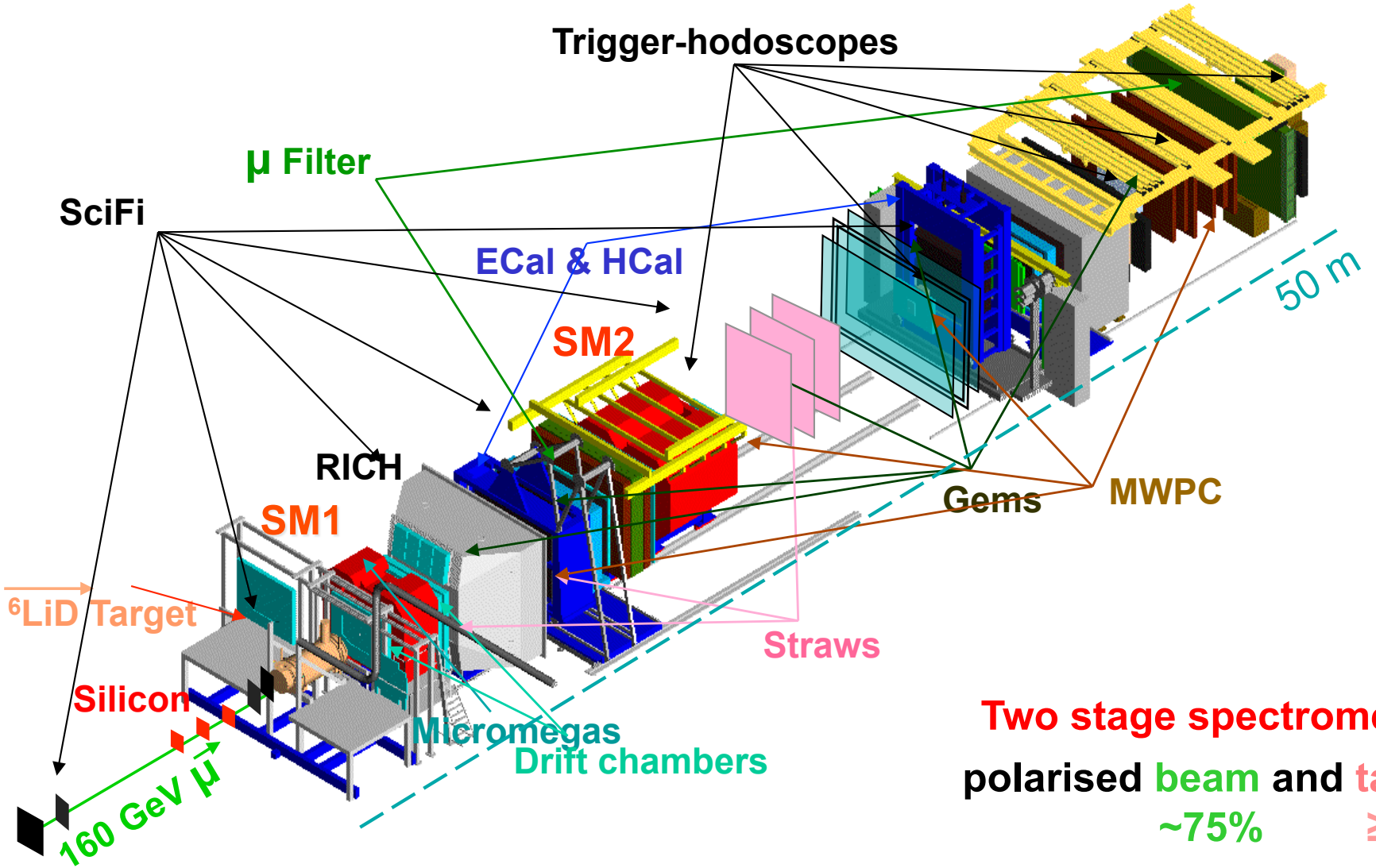


Recentemente o programa de Drell-Yan de COMPASS-II

atraiu:
2 labs USA
1 de Taiwan

A Experiência COMPASS

COmmon Muon Proton Apparatus for Structure & Spectroscopy



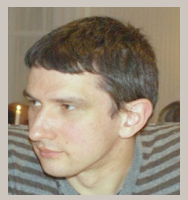
Two stage spectrometer

polarised beam and target

~75% ≥50%

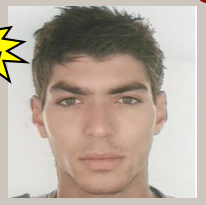
LIP-COMPASS COLLABORATORS

Seniors: Paula Bordalo  Sérgio Ramos  Catarina Quintans 

Post-Docs: Marcin Stolarski  Luís Silva  Celso Franco 

PhD Students: Márcia Quaresma new  Sofia Nunes new 

Master Student: Diogo Coutinho new 

Diploma Student: Bruno Jorge (from Paris-Sud) new 

Engineers: Gonçalo Terça, new  Christophe Pires 

THANK YOU !

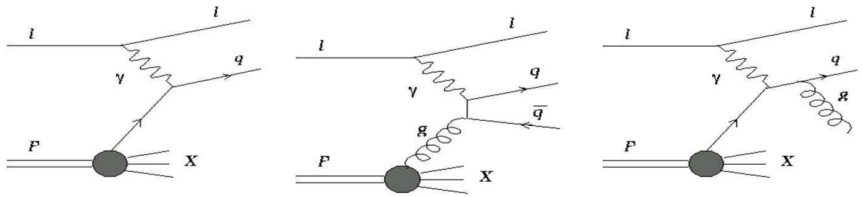
Thanks also to Catarina Quintans who provided some slides

LIP work and responsibilities

in COMPASS Experiment

Gluon Polarisation – LIP results
High-p_T Analysis, $Q^2 > 1$ GeV^2

In helicity asymmetries measurement with 2 high-p_T hadron events, 3 processes contribute in LO:



LP PGF QCDC

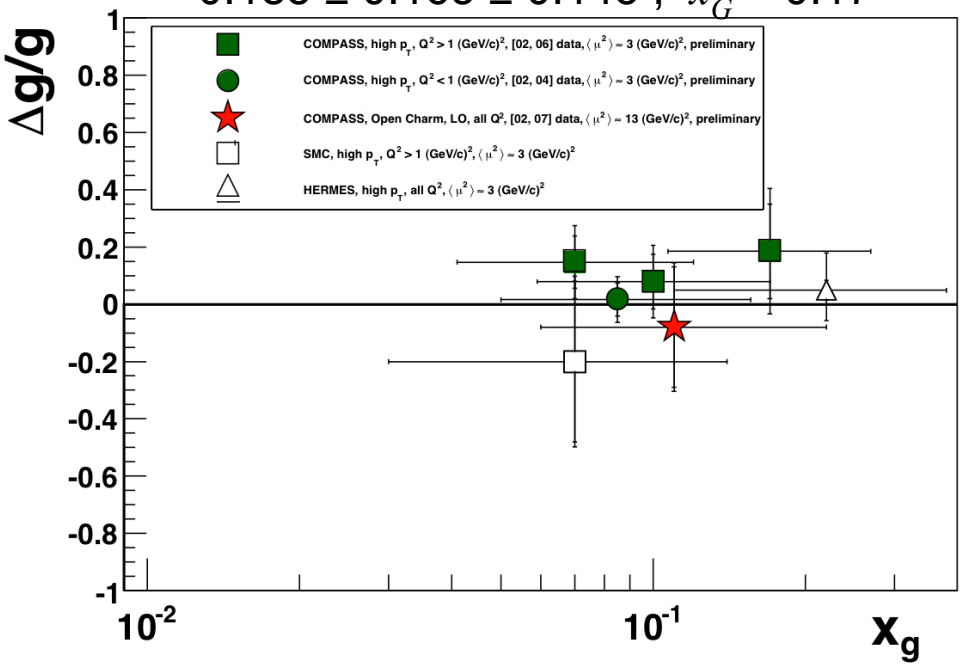
$$A_{LL}^{2h} = a_{LL}^{PGF} R_{PGF} \Delta G/G(x_G) + D R_{LP} A_1(x_{Bj}) + a_{LL}^{QCDC} R_C A_1(x_C)$$

a_{LL}s and Rs are taken from MC

Higher p_T ⇒ higher PGF probability

COMPASS is the **first experiment** providing measurement of $\Delta G/G$ in bins of x_G :

0.147 ± 0.091 ± 0.088 , x_G = 0.07
0.079 ± 0.096 ± 0.082 , x_G = 0.10
0.185 ± 0.165 ± 0.143 , x_G = 0.17

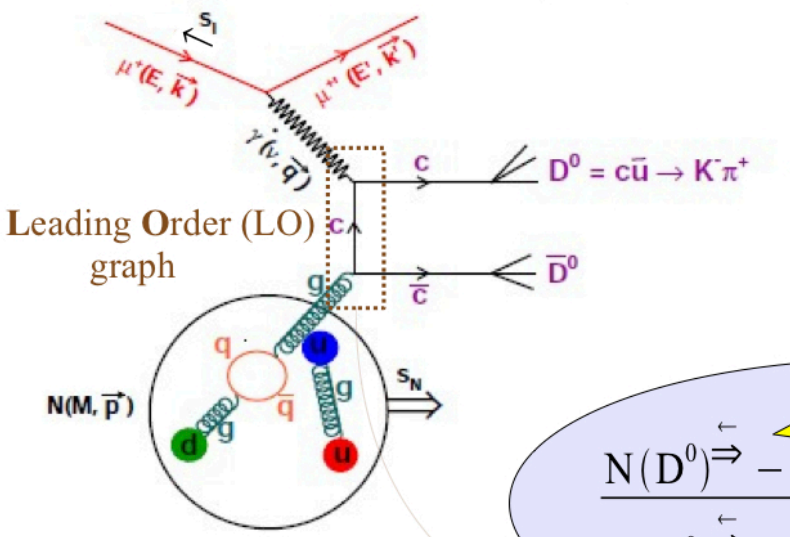


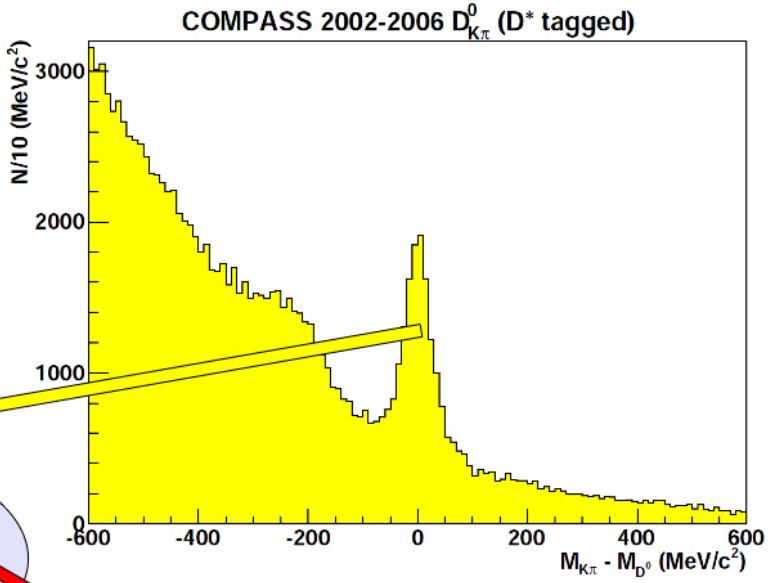
We are developing a new method of $\Delta G/G$ extraction from all p_T sample

- expected $\Delta G/G$ error reduction by a factor of 1.5 – 1.8
- easier way to deal with systematics
- allows tests of the MC models used in the analysis

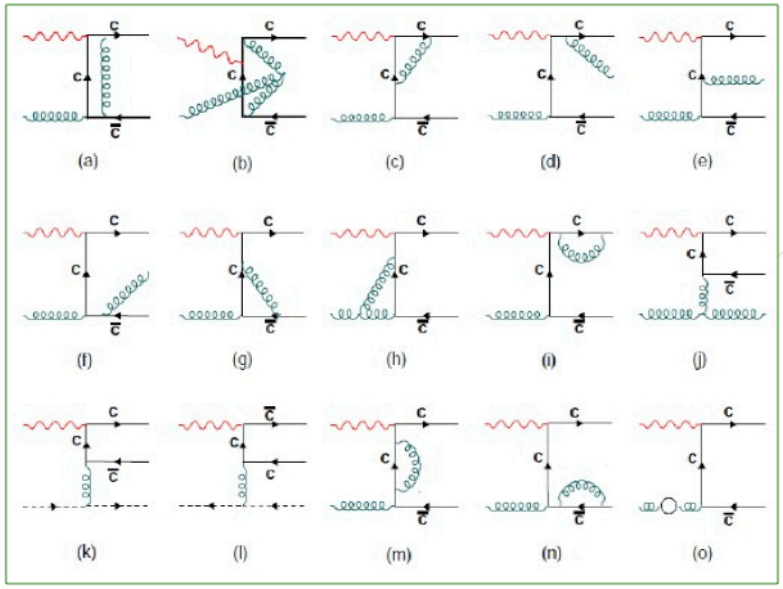
ΔG/G from open charm - LIP results (First world NLO analysis)

Polarised Photon-Gluon Fusion (PGF)





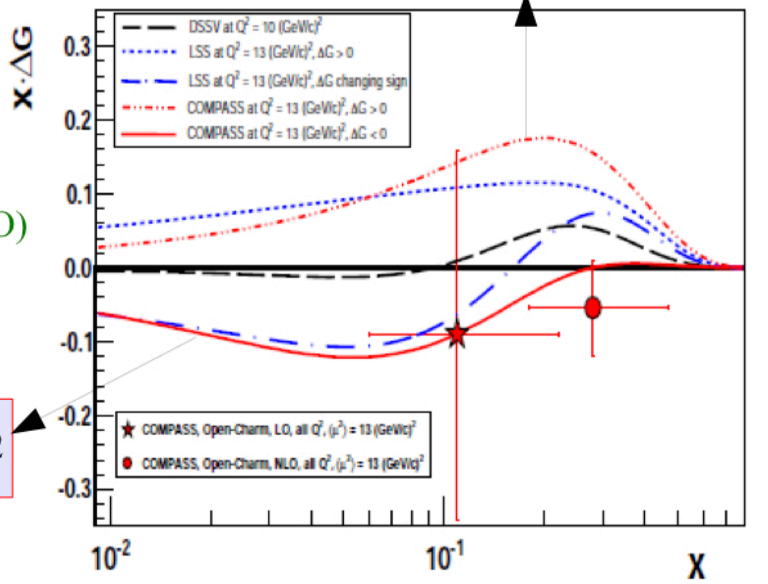
$$\frac{N(D^0)^{\Rightarrow}_{\Leftarrow} - N(D^0)^{\Rightarrow}_{\Leftarrow}}{N(D^0)^{\Rightarrow}_{\Leftarrow} + N(D^0)^{\Rightarrow}_{\Leftarrow}} \propto \frac{\Delta\sigma^{\Rightarrow}_{\Leftarrow}}{\sigma^{\Rightarrow}_{\Leftarrow}} \frac{\Delta G}{G}$$



Next-to-Leading Order (NLO) corrections to PGF

$$\int_0^1 \Delta G dx = 0.27 \pm 0.09$$

$$\int_0^1 \Delta G dx = -0.34 \pm 0.12$$



A_1^p Helicity Asymmetry in the low x_{Bj} and low Q^2 region

The photon-nucleon interaction is theoretically well explained in 2 regimes:

- ✓ real photons ($Q^2=0$)
- ✓ virtual photons in the perturbative region $Q^2 > 1$ GeV^2/c^2

In the region $0< Q^2 <1$ GeV^2/c^2 only models exist ⇒ they needed to be tested

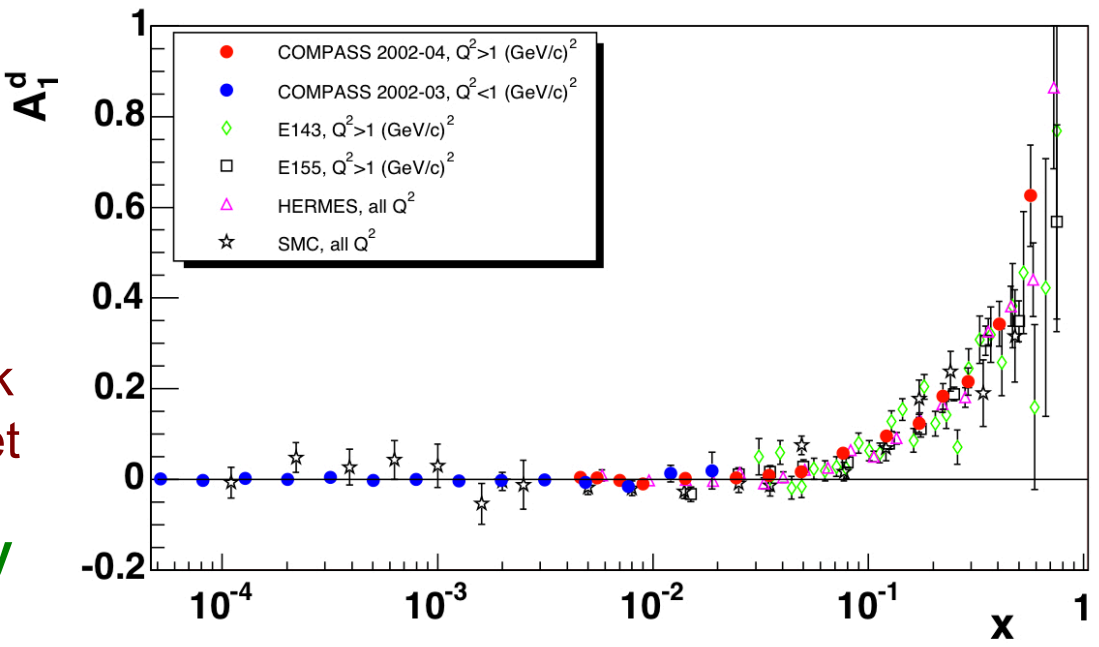
Advantages:

- high statistics: 90% of the μ–N interactions are in $Q^2 < 1$ GeV^2/c^2
- low x_{Bj} region is very interesting - it is the region with very high parton densities

➢ So far, COMPASS has measured A_1^d asymmetry for the deuteron target with an increased precision of a factor of 10 w.r.t. previous measurements

➢ A_1^p measurements are not at the same level of precision; COMPASS took data in 2007 and 2011 w/ a proton target

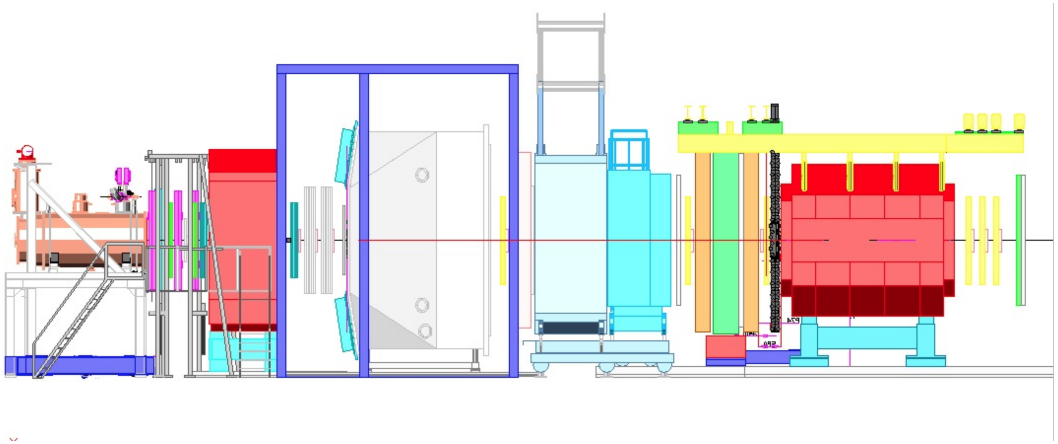
➢ **d & p analyses are complementary and allow to discriminate theoretical models**

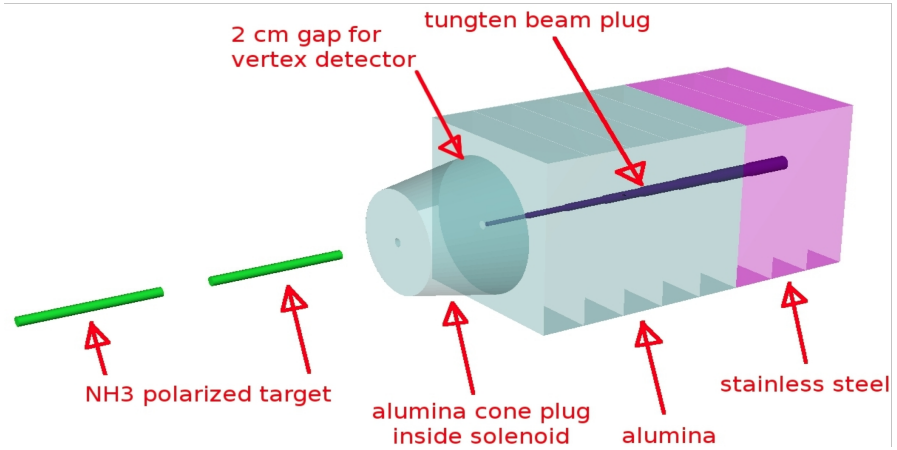


COMPASS DRELL-YAN & LIP

- **CERN has approved DY and DVCS program of the COMPASS-II proposal for the period 2012-2016**

- The present setup must be modified to include a **hadron absorber** and a **dimuon trigger** with large angular coverage





- **LIP group is strongly involved in the Drell-Yan project**

- The DY measurement is planned for 2014 – setup modifications **must start to be prepared immediately**, including equipments/detectors and manpower

- COMPASS can become **the first experiment to do polarised Drell-Yan**, and check the QCD change predictions in T-odd TMDs

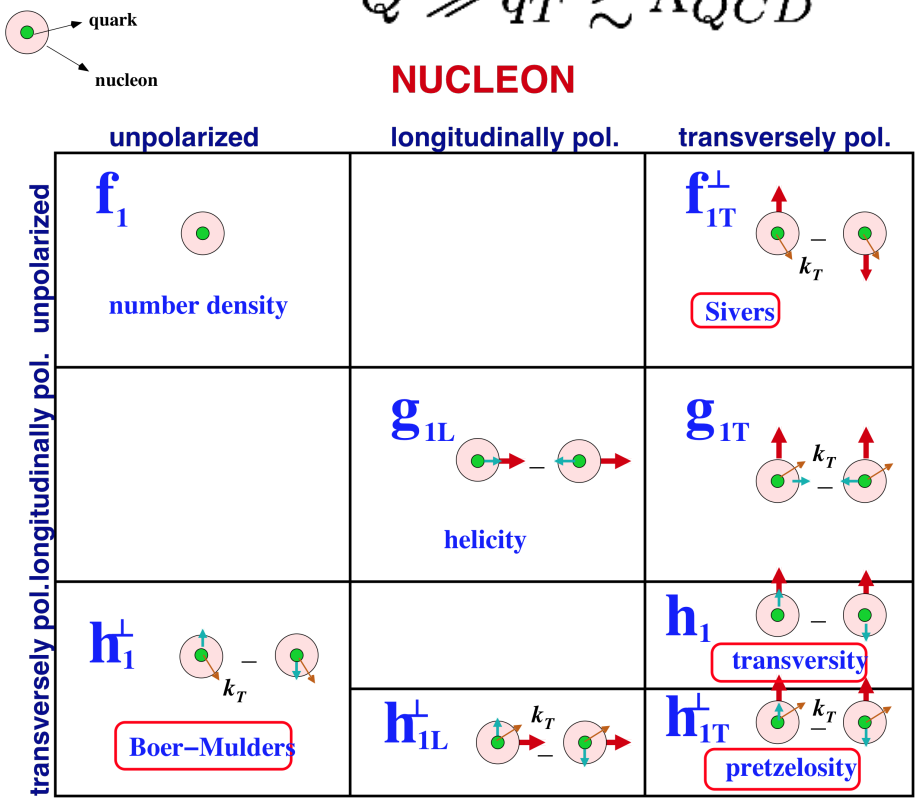
TMD Parton Distribution Functions

Transverse Momentum Dependent (TMD) PDFs give us a dynamic picture of the nucleon spin dynamics.

In LO and if k_T of quarks is not neglected, 8 PDFs are needed to fully describe the nucleon.

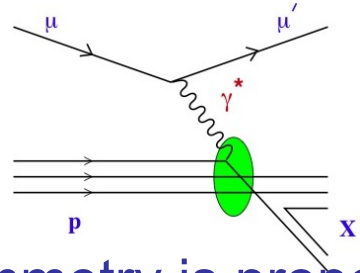
TMDs approach is valid when

$$Q \gg q_T \gtrsim \Lambda_{QCD}$$



In COMPASS TMD PDFs are accessed by measuring azimuthal asymmetries, in 2 ways:

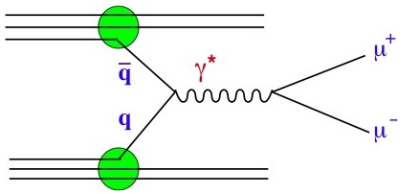
➢ **SIDIS**



The spin asymmetry is proportional to PDF ✪ FF:

$$A_{Sivers} \propto \frac{\sum_q e_q^2 f_{1T}^{\perp(1)}(x) D_q^h(z)}{\sum_q e_q^2 f_1(x) D_q^h(z)}$$

➢ **Drell-Yan**



The spin asymmetry is proportional to PDF_{Beam} ✪ PDF_{Tgt} . If unpolarised beam and transversely polarised target:

$$A_{Sivers} \propto 2 \frac{\sum_q e_q^2 \bar{f}_{1q}(x_1) f_{1Tq}^{\perp(1)}(x_2)}{\sum_q e_q^2 \bar{f}_{1q}(x_1) f_{1q}(x_2)}$$

COMPASS DRELL-YAN Program

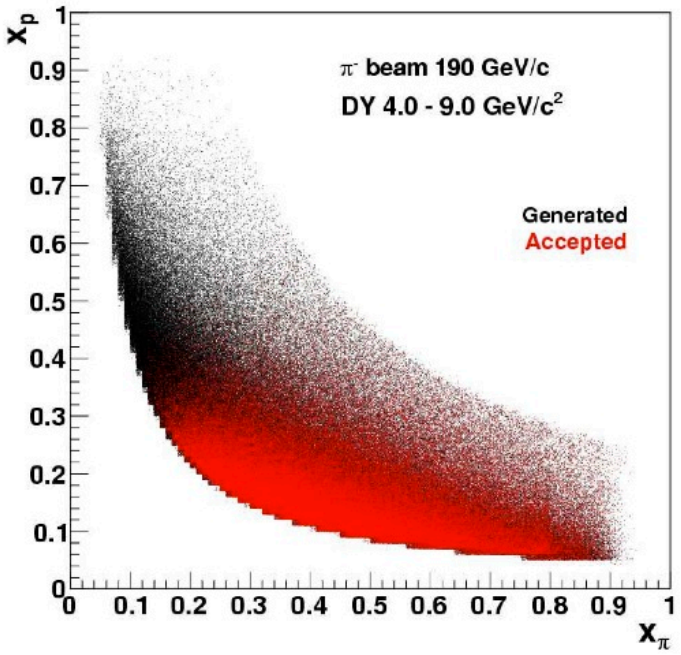
As Sivers and Boer-Mulders are T-odd PDFs:

Sivers: $f_{1T}^{\perp}(DY) = -f_{1T}^{\perp}(SIDIS)$

Boer-Mulders: $h_1^{\perp}(DY) = -h_1^{\perp}(SIDIS)$

✓An important test of non-pertubative QCD and of TMDs approach

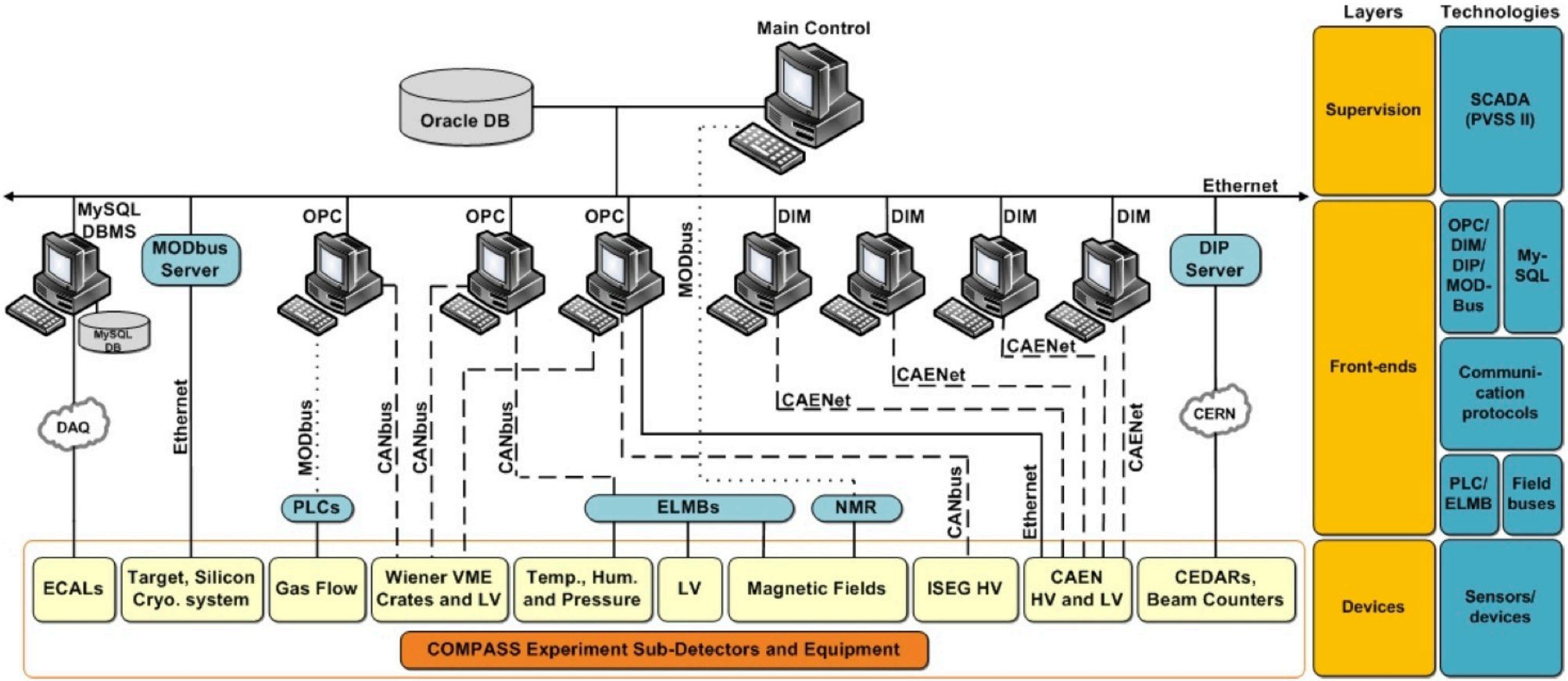
Collisions of π^- **@ 190 GeV/c on NH3 transversely polarised target** give access to 4 azimuthal modulations related to Boer-Mulders, Sivers, pretzelosity and transversity PDFs



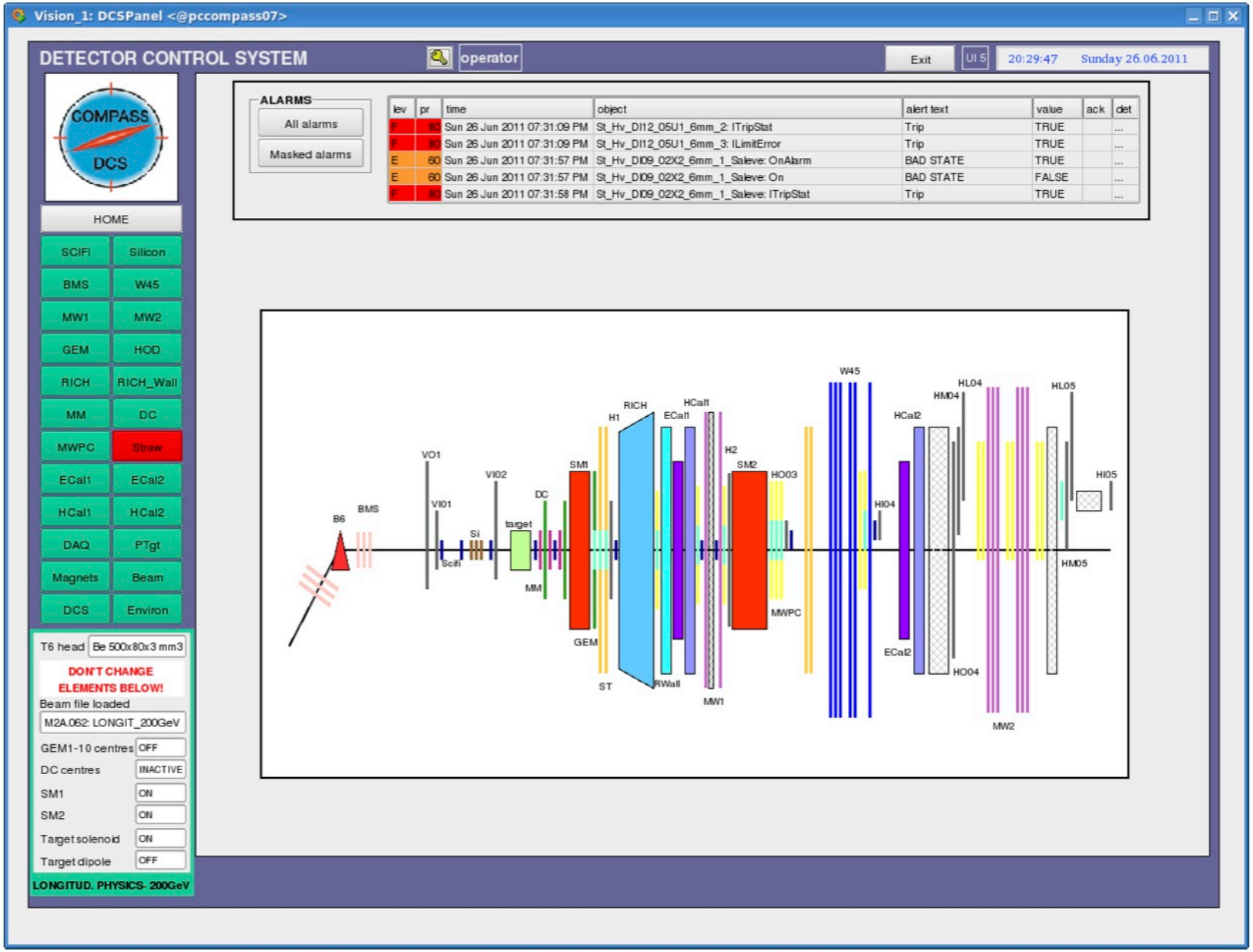
- All 4 asymmetries predicted to be sizable in the valence quarks region.
- COMPASS acceptance is very favorable: $x_p > 0.05$.
- Study Drell-Yan in $4 < M_{\mu\mu} < 9$ GeV/c^2, where background is negligible.
- TMD approach validity guaranteed by $M_{\mu\mu} \gg p_T^{\mu\mu} \approx 1$ GeV.

Short Drell-Yan beam tests performed in 2007, 2008 and 2009 have shown the feasibility of the Drell-Yan measurement in COMPASS.

Full LIP Responsibility – DCS Detector Control System



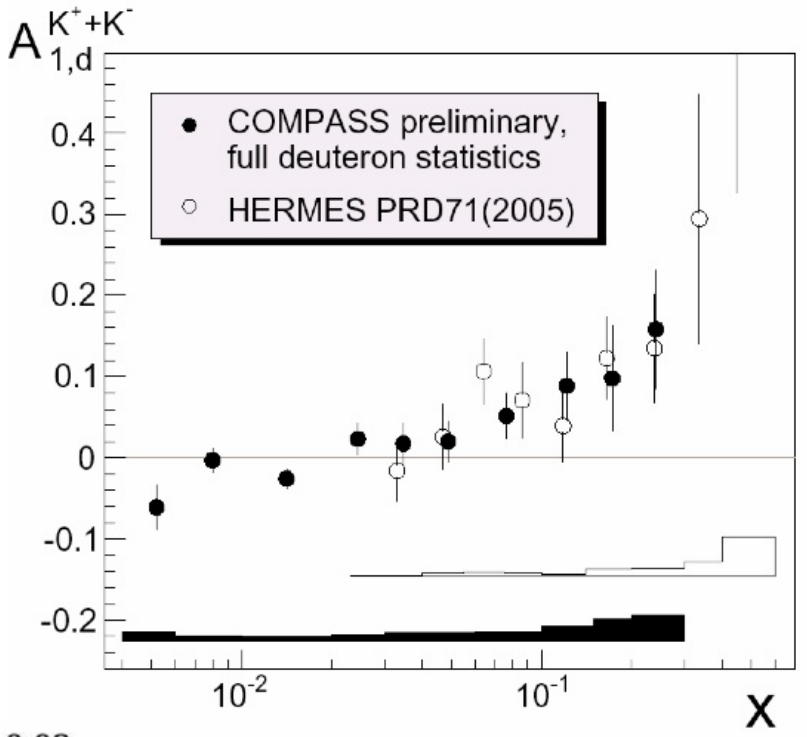
Full LIP Responsibility – DCS
COMPASS DCS User Interface

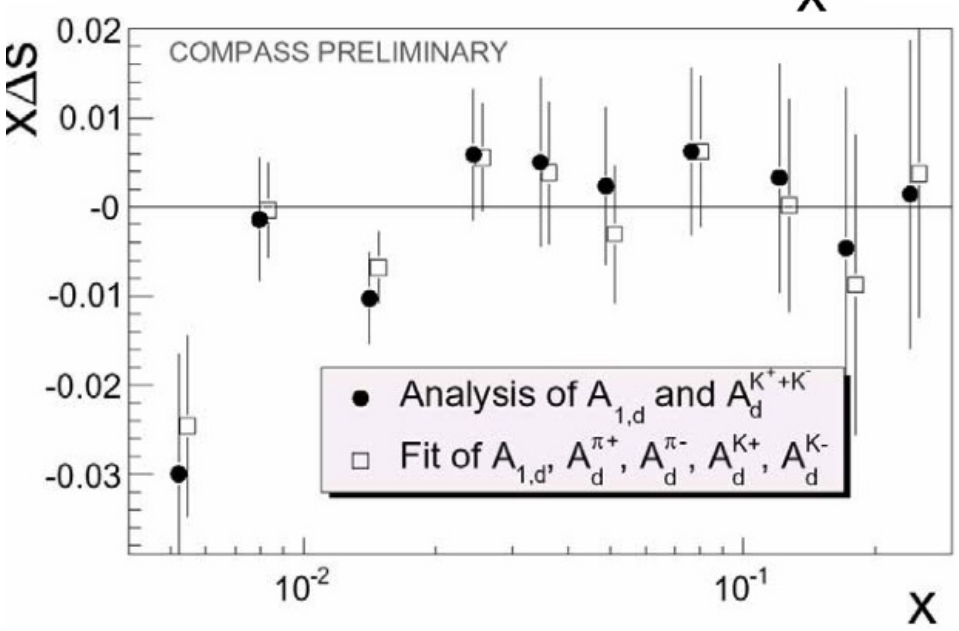


COMPASS DCS – new features 2010-2012

	Polarized target monitoring	DAQ monitoring	Beam line monitoring	Trigger rates monitoring	Calorimeters monitoring	General experimental status
DIP	X		X			
mySQL/Oracle	X			X	X	
CONTROL script(s)	X		X	X	X	X
ELMB					X	
DIM		X				
S7	X					

Δs from charged kaon asymmetry





$$\frac{\Delta s}{s} = A_1^d + \left(A_1^{K^+ + K^-} - A_1^d\right)\frac{Q/s + \alpha}{\alpha - 4/5}$$

$$\alpha = \frac{2R_{UF} + 2R_{SF}}{3R_{UF} + 2} \qquad Q = u + \bar{u} + d + \bar{d}$$

$$R_{UF} = \frac{\int D_d^{K^+}(z)dz}{\int D_u^{K^+}(z)dz} \qquad R_{SF} = \frac{\int D_{\bar{s}}^{K^+}(z)dz}{\int D_u^{K^+}(z)dz}$$

From the first moment of g_1^d and semi-inclusive asymmetries, we extract the Δs contribution to the nucleon spin :

Δs (inclusive) = –0.045 ± 0.005 ± 0.010

Δs (SIDIS) = –0.01 ± 0.01 ± 0.01