The nucleon structure program at COMPASS

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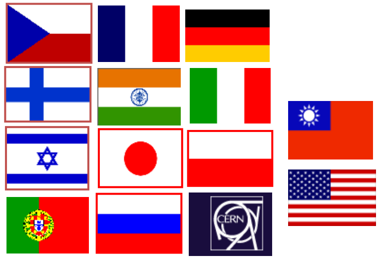
on behalf of the COMPASS Collaboration

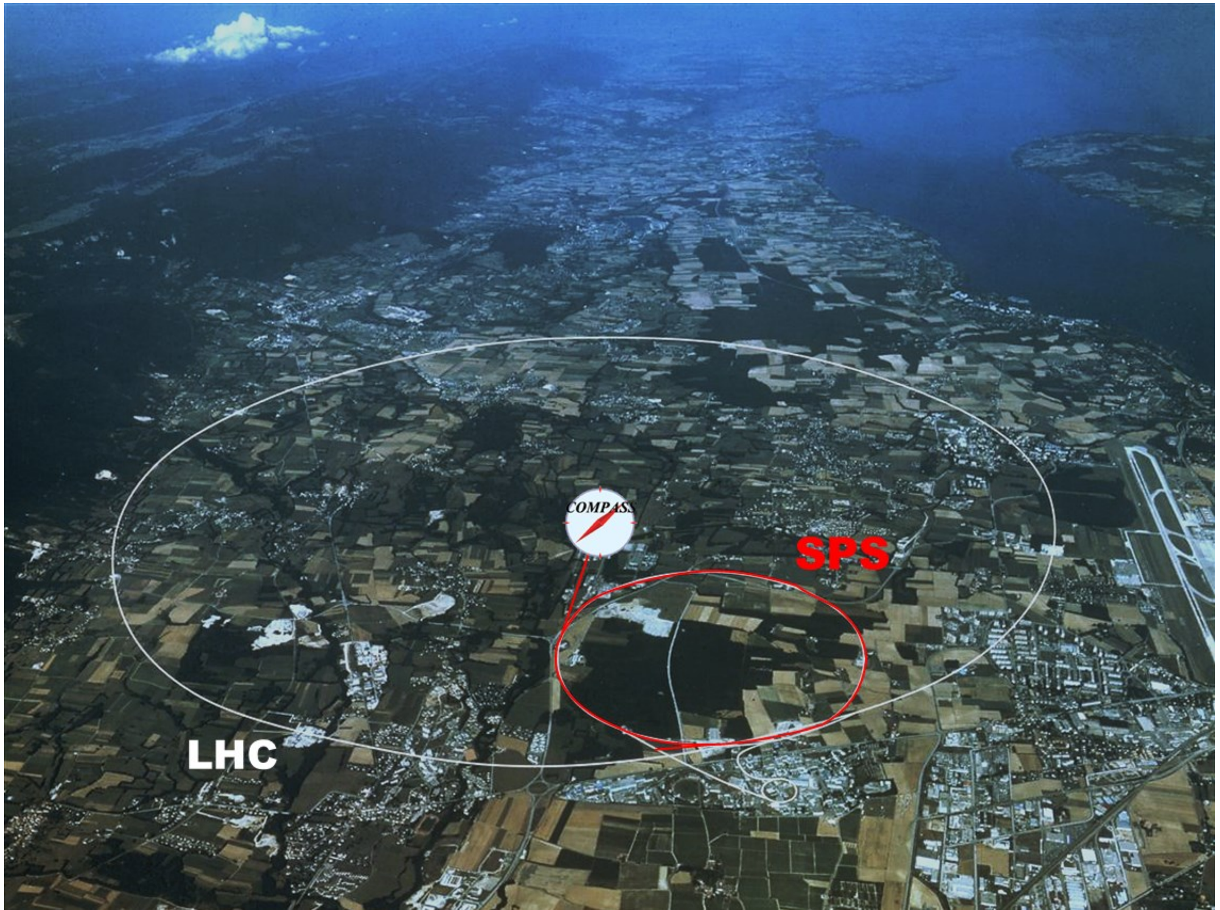
Lattice QCD and hadron physics
ECT*, 14-16 January, 2014

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

~ 230 physicists



fixed-target experiment at the CERN SPS



data-taking since 2002

approved program at least up to 2017

COMPASS physics program

installed on the M2 CERN North Area beam line

unique possibility of using different high energy beams:

$\mu^+, \mu^-, p, \pi^+, \pi^-, K^+, K^-$ → diversified physics program

several experiments using

- **muon beams**
- **hadron beams**

2002 – 2012

L and T polarised p and d targets

- nucleon spin structure
  - **gluon** and **quark helicities**
  - **transversity** & **TMD PDFs** (SIDIS)

LH and nuclear targets

- **pion polarisability**
- **light meson and baryon spectroscopy**

2015 – 2017

LH target

- nucleon structure
  - **GPDs** (DVCS and HEMP)
  - **FF** and **TMD effects** (SIDIS)

T polarised p target

- nucleon (spin) structure
  - **TMD PDFs** (Drell-Yan)

a few results on

spectroscopy

physics with hadron beams

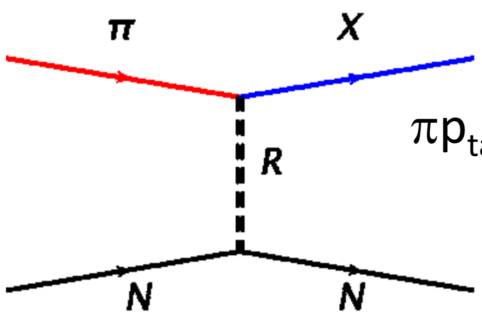
rich program on hadron spectroscopy, search for exotic mesons

π, K, p beams - 190 GeV : **large energy transfer spectrum t**
spectrometer : **flat acceptance, ECALs/ HCALs, RICH id.**
charged & neutral channels
Pb 2004, **Ni targets** 2012
LH target with p recoil detector 2008-2009

huge statistics

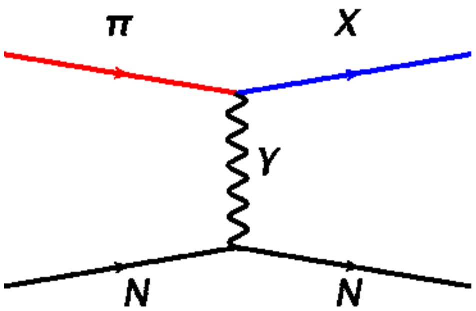
recently major progress on analysis

physics with hadron beams



$\pi p_{target} \rightarrow X + p_{recoil}$

$\rightarrow n\pi + p_{recoil}$

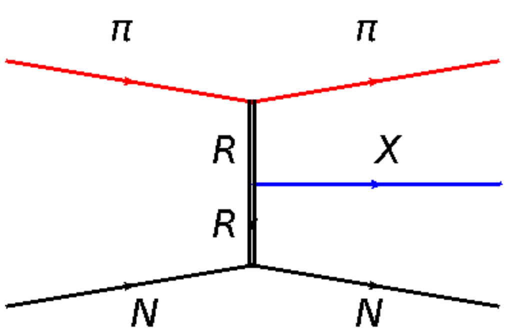


Diffractive Dissociation

- Isovector states: π_J, a_J
- Hybrids, exotics
- Scalar states as isobars

Photoproduction

- Polarizabilities: π
- Radiative couplings: a_2, π_2



$pp_{target} \rightarrow p_{fast} + X + p_{recoil}$

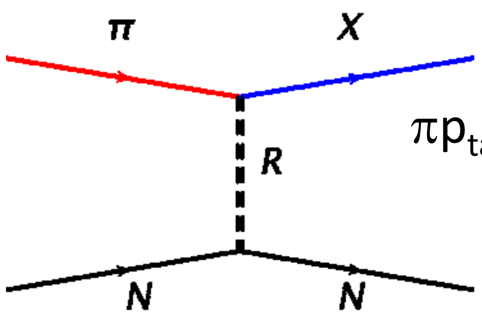
$\rightarrow p_{fast} + n\pi/K/\eta + p_{recoil}$

for a review of the new results see B. Ketzer and other COMPASS talks at Hadron2013

Central Production

- Scalar states
- Glueballs

physics with hadron beams



$\pi p_{target} \rightarrow X + p_{recoil}$

$\rightarrow n\pi + p_{recoil}$

$\pi^- \pi^+ \pi^-$

$\pi^- \pi^0 \pi^0$

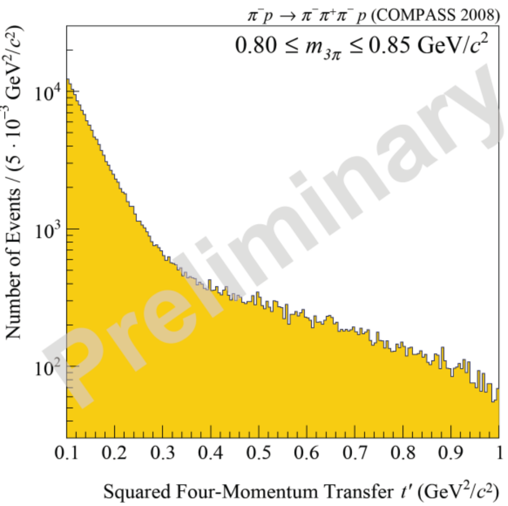
$\pi^- \eta \eta$

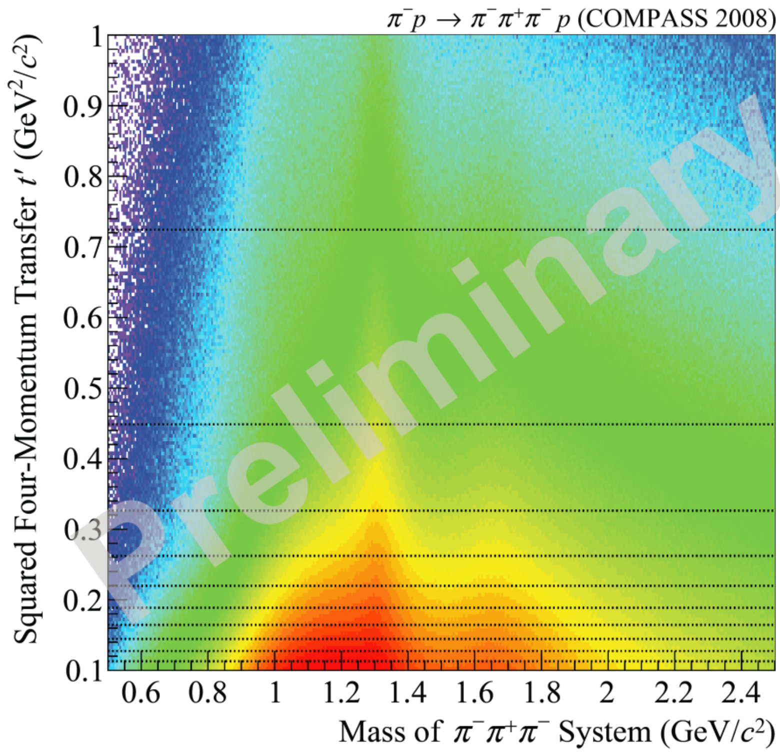
$\pi^- \pi^+ \pi^+ \pi^- \pi^-$

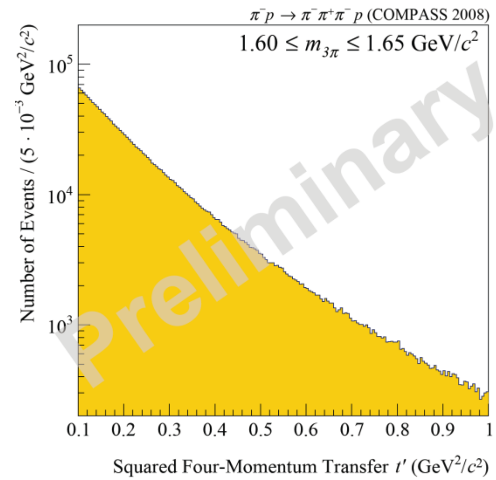
Diffractive Dissociation

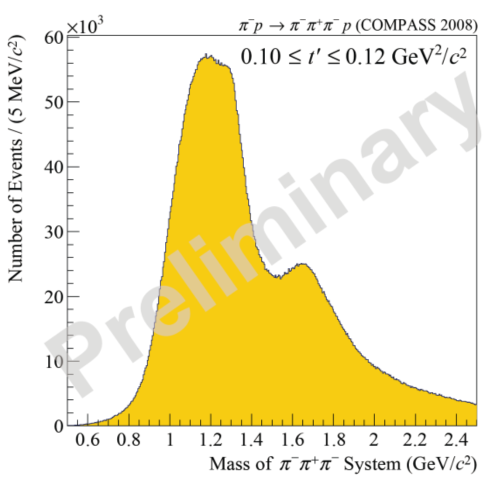
- Isovector states: π_J, a_J
- Hybrids, exotics
- Scalar states as isobars

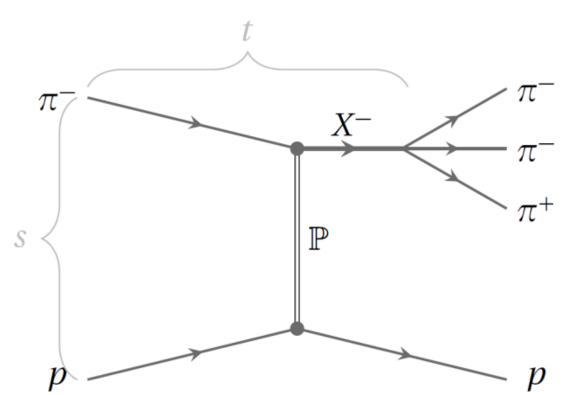
3π final state - kinematics

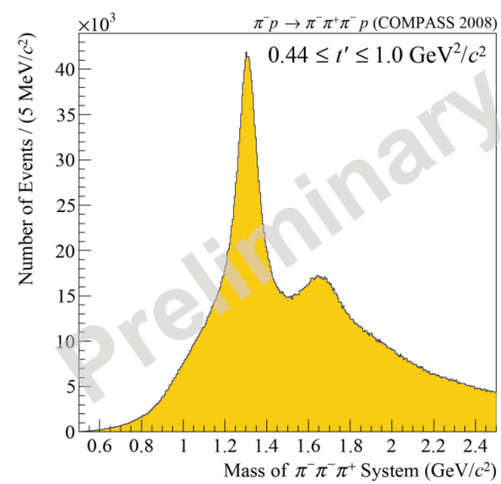




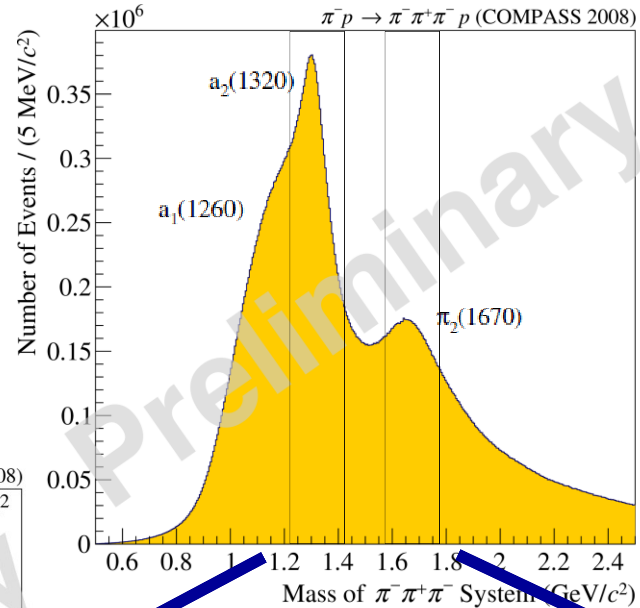


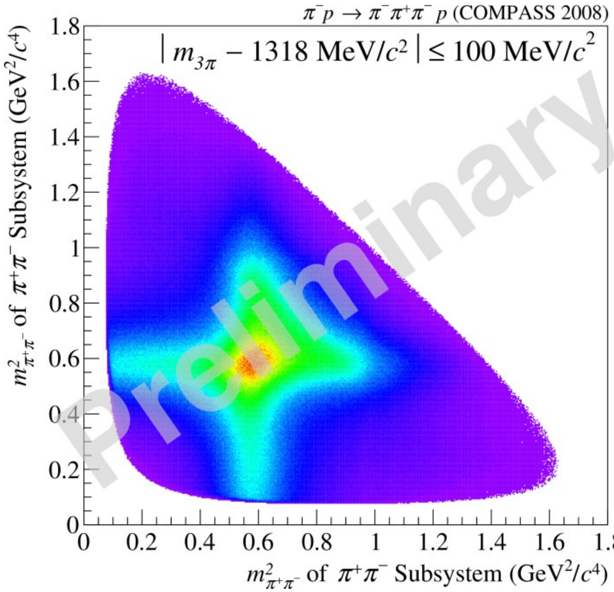


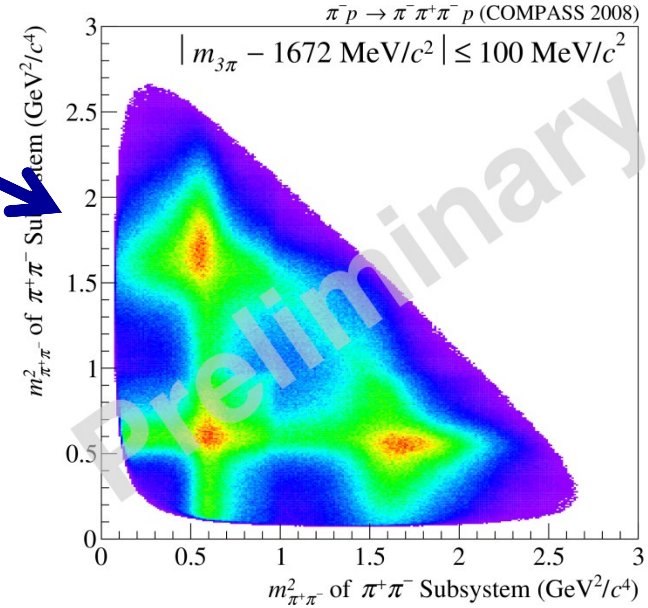


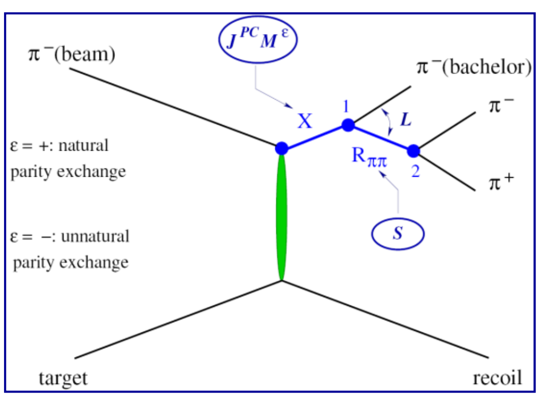


Isobar Model









2-D Partial Wave Analysis

the high 2008/2009 statistics allows and demands for improved PWA methods

new analysis method established: 2D-PWA in bins of m_X and t'

- identify resonant and non-resonant contributions to partial waves
- precise extraction of resonance parameters

1. **PWA** of angular distributions in **20 MeV mass bins** and **11 t' bins**

   88 waves, well-known states as isobars

2. **Mass-dependent χ^2 fit** to spin density matrix from step 1

total:

21 distributions x 100 mass bins x 11 t' bins,

352 free parameters

Preliminary Results of Fit to Spin-Density Matrix

Resonance	Mass (MeV/c^2)	Width (MeV/c^2)	Channel	PDG M (MeV/c^2)	PDG Γ (MeV/c^2)
			"Established" states		
$a_1(1260)$	$1260 - 1290$	$360 - 420$	$\rho\pi$	1230 ± 40	$250 - 600$
$a_2(1320)$	$1312 - 1315$	$108 - 115$	$\rho\pi$	$1318^{+0.5}_{-0.6}$	107 ± 5
$a_4(2040)$	$1928 - 1959$	$360 - 400$	$\rho\pi$	1996^{+10}_{-9}	255^{+28}_{-24}
$\pi_2(1670)$	$1635 - 1663$	$265 - 305$	$f_2(1270)\pi$	1672.2 ± 3.0	260 ± 9
$\pi(1800)$	$1768 - 1807$	$212 - 280$	$f_0(980)\pi$	1812 ± 12	208 ± 12
$\pi_2(1880)$	$1900 - 1990$	$210 - 390$	$f_2(1270)\pi$	1895 ± 16	235 ± 34
			States not in PDG summary table		
$a_1(1420)$	$1412 - 1422$	$130 - 150$	$f_0(980)\pi$		
$a_1(1930)$	$1920 - 2000$	$155 - 255$	$\rho\pi$	(1930^{+30}_{-70})	(155 ± 45)
$a_2(1950)$	$1740 - 1800$	$300 - 555$	$\rho\pi$	(1950^{+30}_{-70})	(180^{+30}_{-70})

- precise determination of resonance parameters
- mass and width ranges from systematic studies with different fit models
- final result and syst. error still under study

new axial vector meson observed: $a_1(1420) \rightarrow f_0(980)\pi$

physics with hadron beams

COMPASS has collected large data samples with hadron beams

new analysis methods have been developed

more results to come in the near future

some results on

nucleon structure

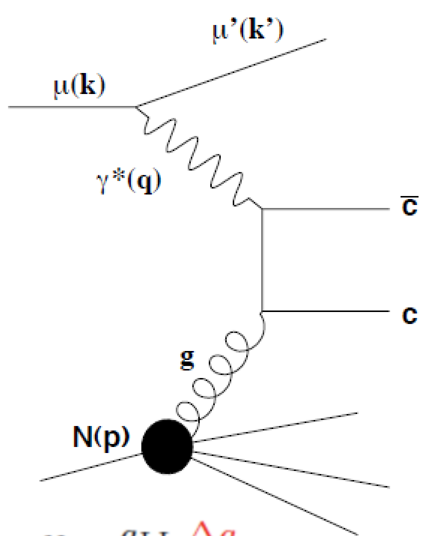
longitudinally polarised μ^+ beam

160 GeV/c	**deuteron (^{6}LiD)**	**L & T**	**polarisation**	**2002 – 2004**
		L	**polarisation**	**2006**
160 GeV/c	**proton (NH_3)**	**L & T**	**polarisation**	**2007**
		T	**polarisation**	**2010**
190 GeV/c	**proton (NH_3)**	**L**	**polarisation**	**2011**

longitudinal spin structure of the nucleon

longitudinal spin structure of the nucleon

- **direct measurement of Δg** via Photon Gluon Fusion
  COMPASS "flag-ship" measurement

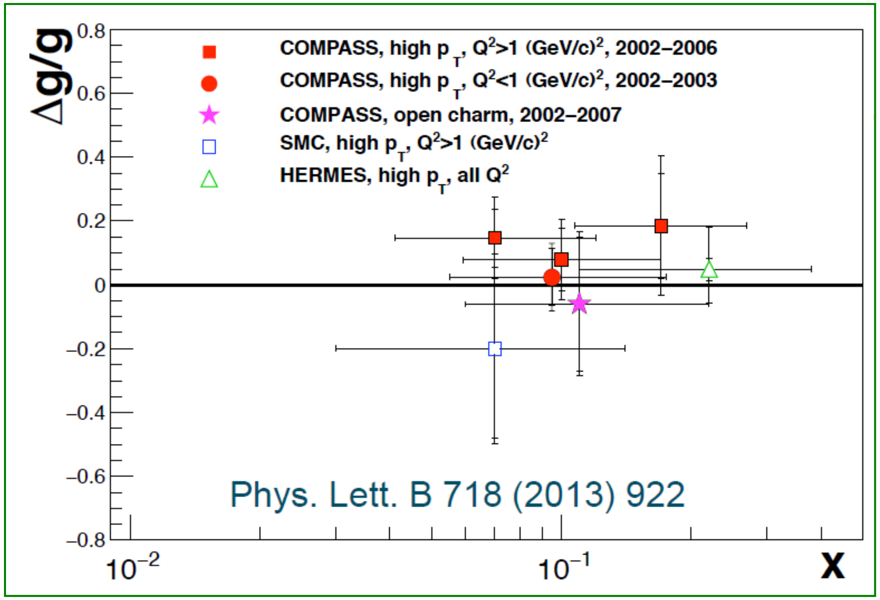


$$A^{\gamma N} = \frac{a_{LL}}{D}\frac{\Delta g}{g}$$

to select PGF process two methods are used:

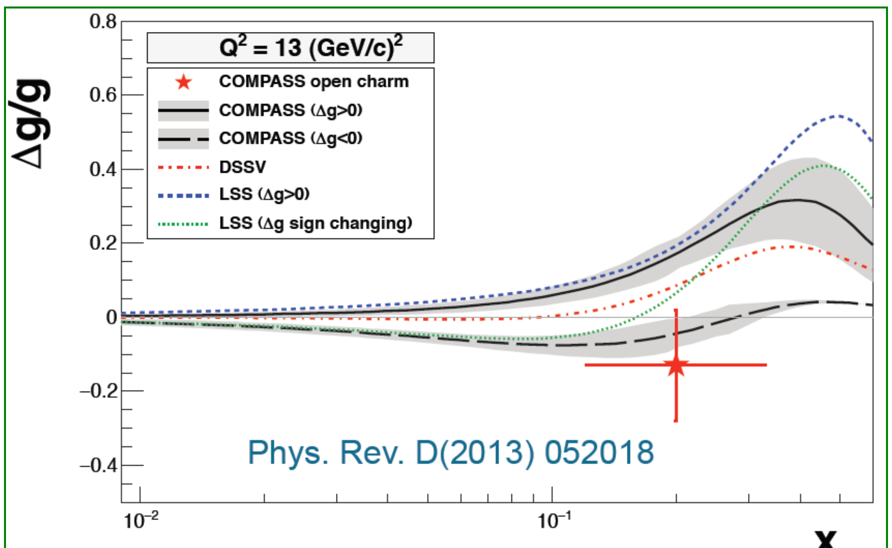
- **open-charm D meson production:**
  charm quark pairs produced in PGF
  "clean" channel
  huge combinatorial background, low statistics
- **high p_T hadron pairs production:**
  light quark pairs produced
  high statistics
  physical background; strongly model and MC dependent analysis

Δg results



LO

all results are consistent
and point toward
small gluon polarisation



$$\left\langle \frac{\Delta g}{g} \right\rangle^{\mathrm{NLO}} = -0.13 \pm 0.15\ (\mathrm{stat.}) \pm 0.15\ (\mathrm{syst.}).$$

QCD fits - Idea:

$$g_1(x,Q^2) = \tfrac{1}{2}\langle e^2\rangle \left[C_q^s \otimes \Delta\Sigma + C_q^{NS} \otimes \Delta q^{NS} + 2n_f C_G \otimes \Delta G \right]$$

DGLAP eqs

$$\frac{d}{dt}\Delta q^{NS} = \frac{\alpha_S(t)}{2\pi} P_{qq}^{NS} \otimes \Delta q^{NS} \qquad t = \log\left(\frac{Q^2}{\Lambda^2}\right)$$

$$\frac{d}{dt}\begin{pmatrix}\Delta\Sigma \\ \Delta G\end{pmatrix} = \frac{\alpha_S(t)}{2\pi}\begin{pmatrix} P_{qq}^S & 2n_f P_{qG}^S \\ P_{Gq}^S & P_{GG}^S \end{pmatrix} \otimes \begin{pmatrix}\Delta\Sigma \\ \Delta G\end{pmatrix}$$

Initial parameterization in x at fixed Q^2

$$(\Delta\Sigma, \Delta q_s, \Delta q_8, \Delta G) = \eta \frac{x^\alpha (1-x)^\beta (1+\gamma x)}{\int_0^1 x^\alpha (1-x)^\beta (1+\gamma x) dx}$$

Minimalization procedure

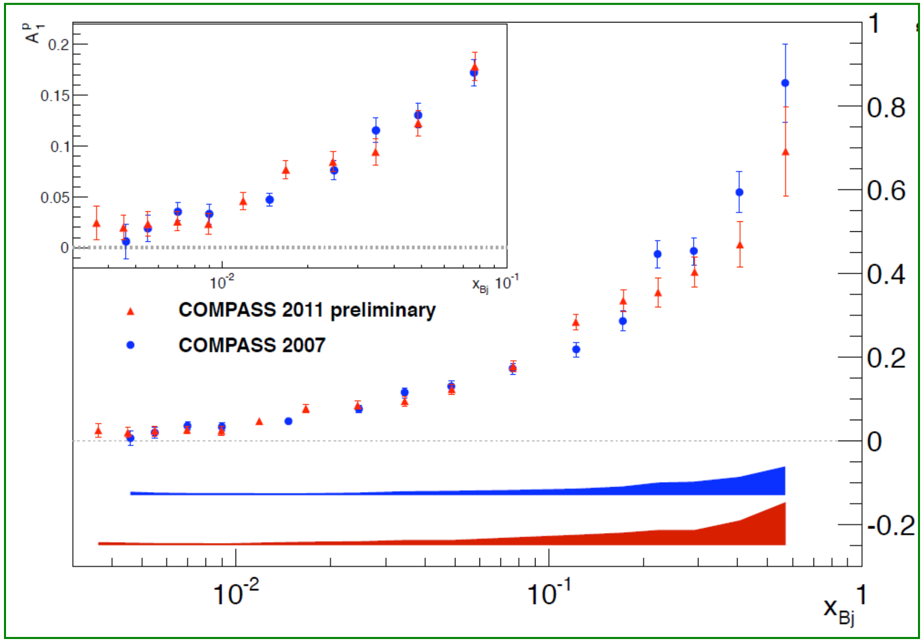
$$\chi^2 = \sum_{i=1}^{N} \frac{\left[g_1^{calc}(x,Q^2) - g_1^{exp}(x,Q^2)\right]^2}{\left[\sigma_{stat}^{exp}(x,Q^2)\right]^2}$$

longitudinal spin structure of the nucleon

- DIS, **SIDIS** on longitudinally polarised nucleons

→ Bjorken sum rule, **Δq**

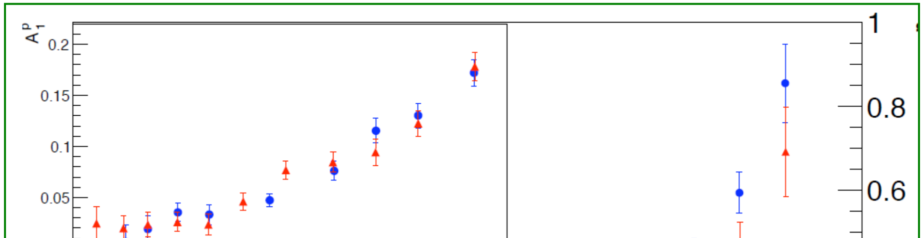
DIS results



A_1^p

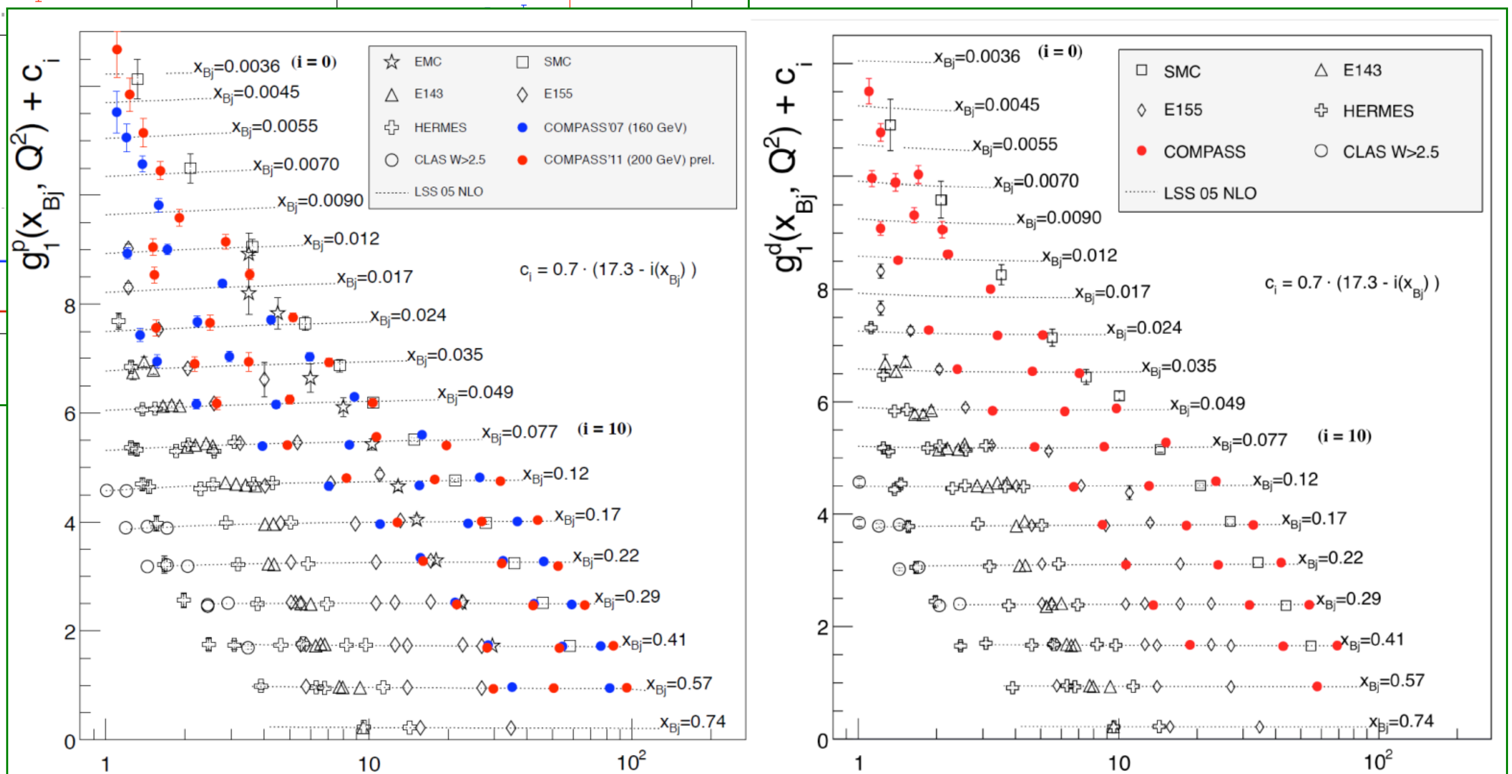
new: 2007 and 2011 p data

DIS results



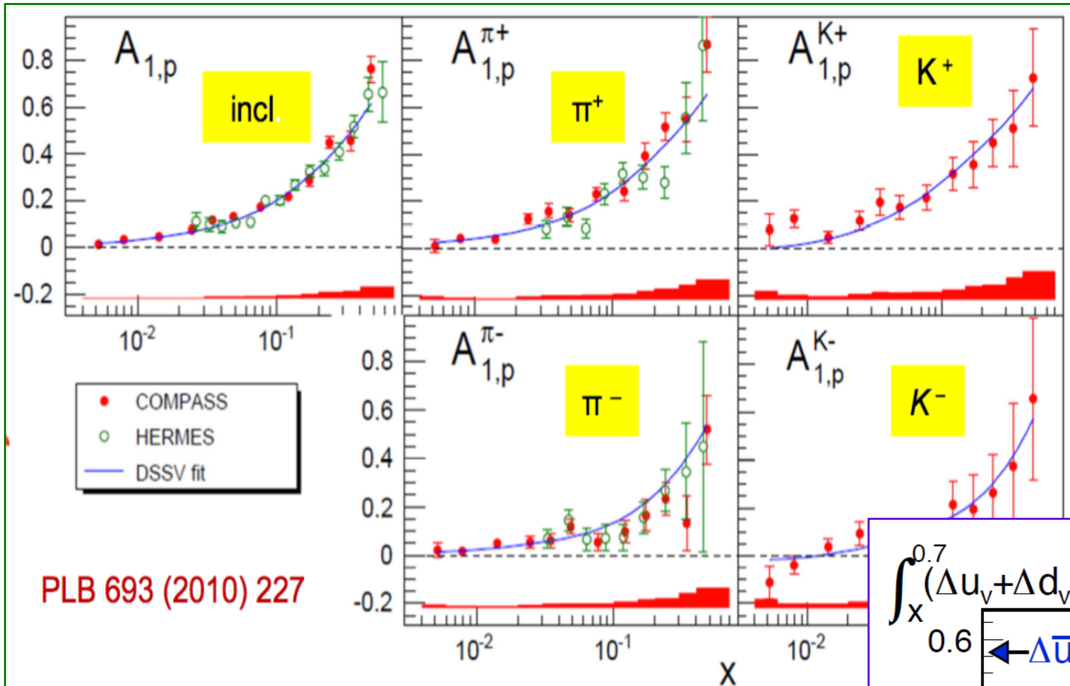
A_1^p

new: 2007 and 2011 p data



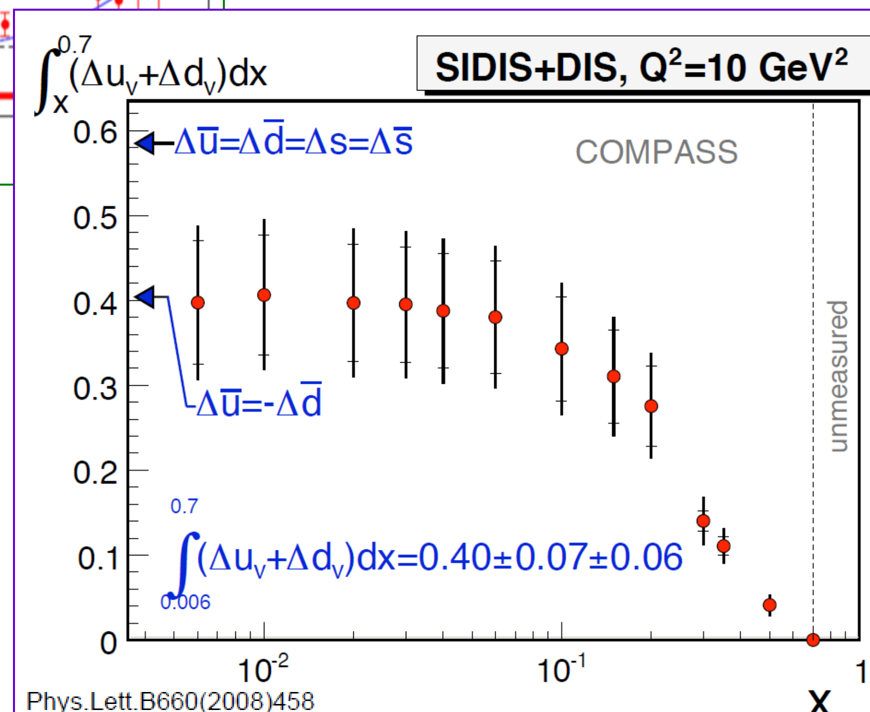
new input for global QCD fits

SIDIS results

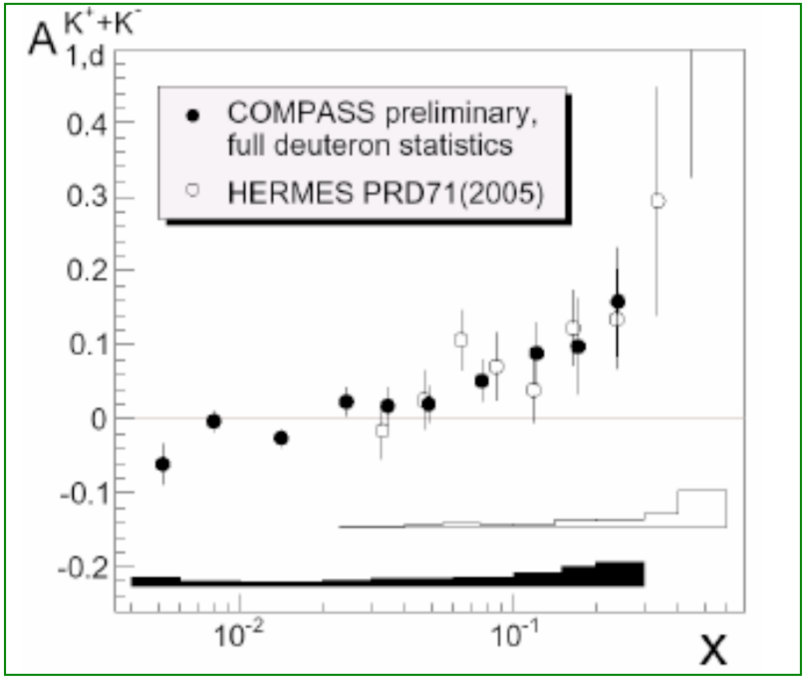


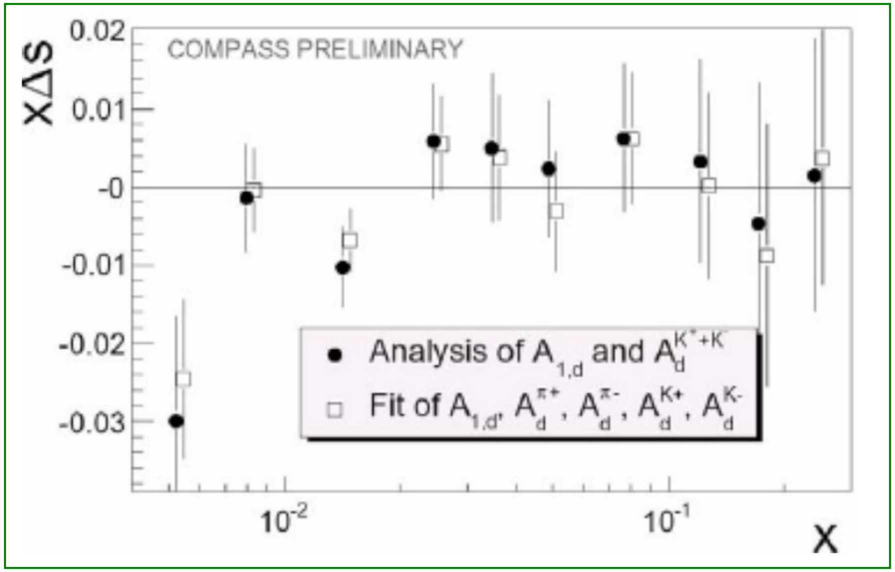
$$A_1^h = \frac{\sum e_q^2 [\Delta q(x) \int D_q^h(z)dz + \Delta\bar{q}(x) \int D_{\bar{q}}^h(z)dz]}{\sum e_q^2 [q(x) \int D_q^h(z)dz + \bar{q}(x) \int D_{\bar{q}}^h(z)dz]}$$

$$A_d^{\pi^+-\pi^-}(x) = A_d^{K^+-K^-}(x) = \frac{\Delta u_v(x) + \Delta d_v(x)}{u_v(x) + d_v(x)}$$



SIDIS results





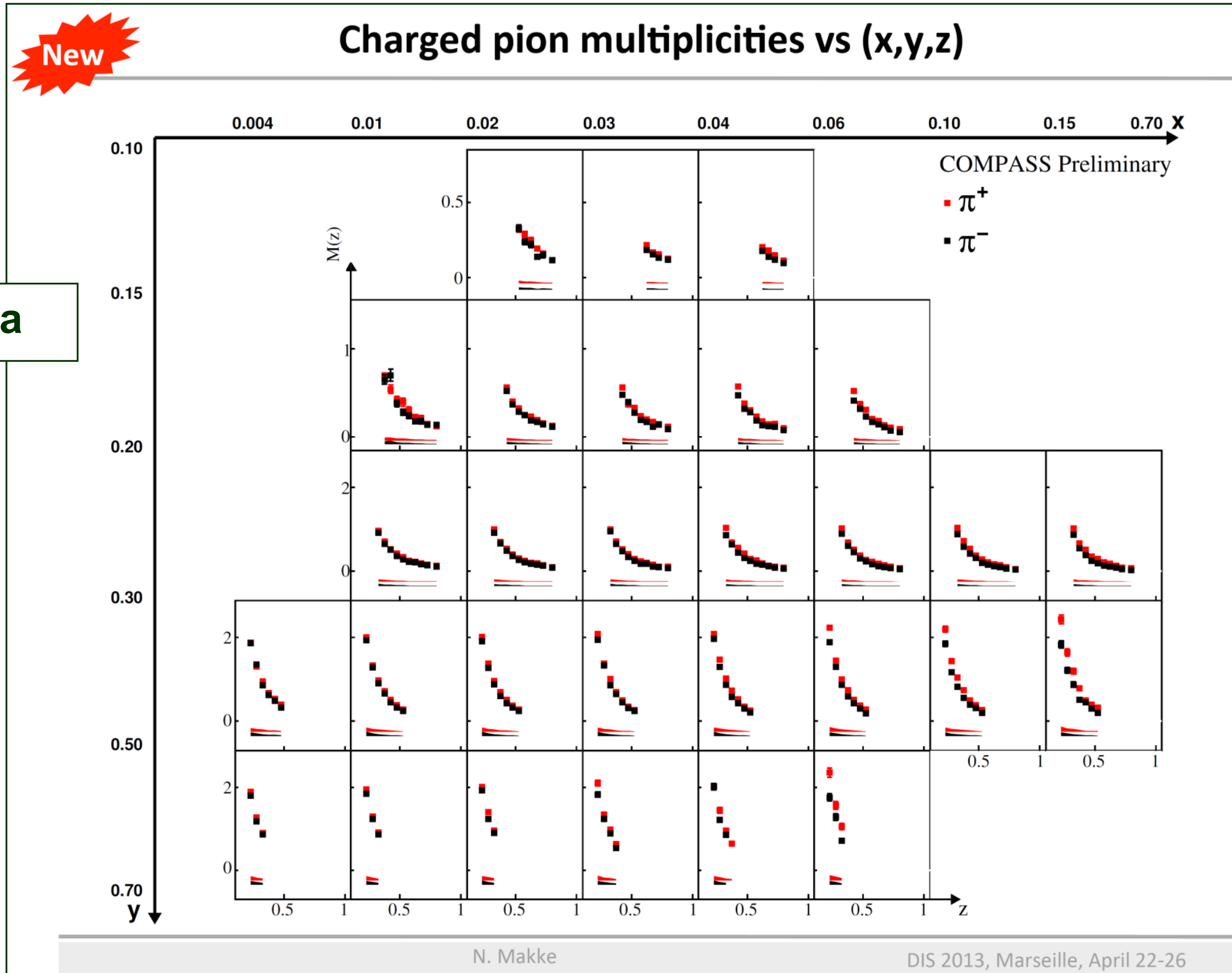
Δs (SIDIS) = –0.01 ± 0.01 ± 0.01

Δs (inclusive) = –0.045 ± 0.005 ± 0.010

large statistical uncertainties due to FFs

precise measurements of multiplicities are needed

hadron multiplicities



from 2006 ^{6}LiD data

isoscalar target

proton: from SIDIS on LH2, 2016-2017

longitudinal spin structure of the nucleon

COMPASS has produced diversified, high precision results
in DIS and SIDIS down to x ~ 0.003

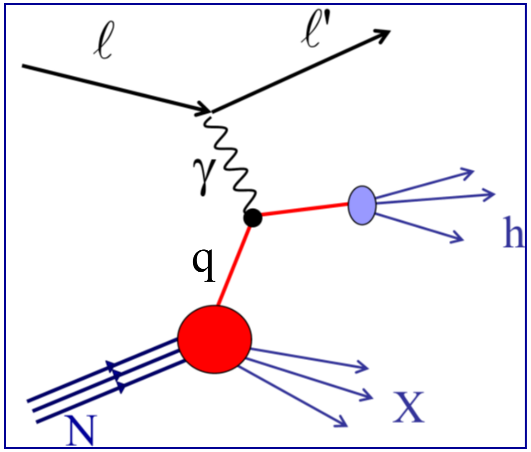
important contributions came and are coming from
HERMES, JLab and RHIC experiments

after more than 30 years the spin structure of the nucleon is understood
only qualitatively

a fast moving nucleon is a 3-dimensional complicated object
with nonnegligible orbital angular momentum contribution to its spin

unmeasured → **DVCS**

transverse spin and momentum structure of the nucleon



why SIDIS

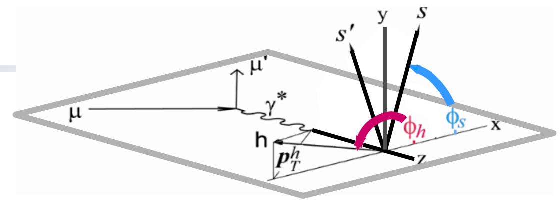
taking into account the quark intrinsic transverse momentum k_T, at leading order
8 TMD PDFs are needed for a full description of the **nucleon structure**

quark polarisation \ nucleon polarisation	U	L	T	
U	f_1 number density q		$f_{1T}^{\perp}$ - Sivers	$\Delta_0^T q$
L		g_1 - helicity Δq	g_{1T} -	
T	$h_1^{\perp}$ - Boer Mulders	$h_{1L}^{\perp}$ -	h_1 - transversity $h_{1T}^{\perp}$ -	$\Delta_T q$

new objects,
giving the correlations between
spin of the nucleon,
spin of the quark,
transverse momentum of the quark

today the only existing informations come from SIDIS, which give access to all of them

why SIDIS



cross-section

$$\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} =$$

$$\frac{\alpha^2}{xyQ^2}\,\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T}+\varepsilon F_{UU,L}+\sqrt{2\,\varepsilon(1+\varepsilon)}\,\cos\phi_h\,F_{UU}^{\cos\phi_h}$$

$h_1^\perp H_1^\perp$

$$+\,\varepsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h}+\lambda_e\,\sqrt{2\,\varepsilon(1-\varepsilon)}\,\sin\phi_h\,F_{LU}^{\sin\phi_h}$$

$h_{1L}^\perp H_1^\perp$

$$+\,S_\parallel\left[\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_h\,F_{UL}^{\sin\phi_h}+\varepsilon\sin(2\phi_h)\,F_{UL}^{\sin 2\phi_h}\right]+S_\parallel\lambda_e\left[\sqrt{1-\varepsilon^2}\,F_{LL}+\sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_h\,F_{LL}^{\cos\phi_h}\right]$$

$f_{1T}^\perp D_1$

$$+\,|\boldsymbol{S}_\perp|\Big[\sin(\phi_h-\phi_S)\left(F_{UT,T}^{\sin(\phi_h-\phi_S)}+\varepsilon\,F_{UT,L}^{\sin(\phi_h-\phi_S)}\right)$$

$h_{1T}^\perp H_1^\perp$

$$+\,\varepsilon\sin(\phi_h+\phi_S)\,F_{UT}^{\sin(\phi_h+\phi_S)}+\varepsilon\sin(3\phi_h-\phi_S)\,F_{UT}^{\sin(3\phi_h-\phi_S)}$$

$h_1 H_1^\perp$

$$+\,\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin\phi_S\,F_{UT}^{\sin\phi_S}+\sqrt{2\,\varepsilon(1+\varepsilon)}\,\sin(2\phi_h-\phi_S)\,F_{UT}^{\sin(2\ldots}$$

$g_{1T} D_1$

$$+\,|\boldsymbol{S}_\perp|\lambda_e\Big[\sqrt{1-\varepsilon^2}\,\cos(\phi_h-\phi_S)\,F_{LT}^{\cos(\phi_h-\phi_S)}+\sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos\phi_S\,F_{LT}^{\cos\phi_S}$$

$$+\,\sqrt{2\,\varepsilon(1-\varepsilon)}\,\cos(2\phi_h-\phi_S)\,F_{LT}^{\cos(2\phi_h-\phi_S)}\Big]\Big\},$$

18 structure functions
14 azimuthal modulations

all measured at COMPASS on d, or on p and d

A Bacchetta et al., 2006

why COMPASS

transversity and the TMD PDFs are new objects,
their properties have to be studied, the different effects disentangled
→ to be measured in a kinematical range as wide as possible

the **high energy beam** available at COMPASS ensures the
hardness of the process

- **large W**
  current jet and target fragmentation well separated
- **small x**
  PDF parameterizations and their 1st moments
- **large Q^2 coverage**
  higher twist effects

COMPASS

$p_\mu = 160$ GeV/c

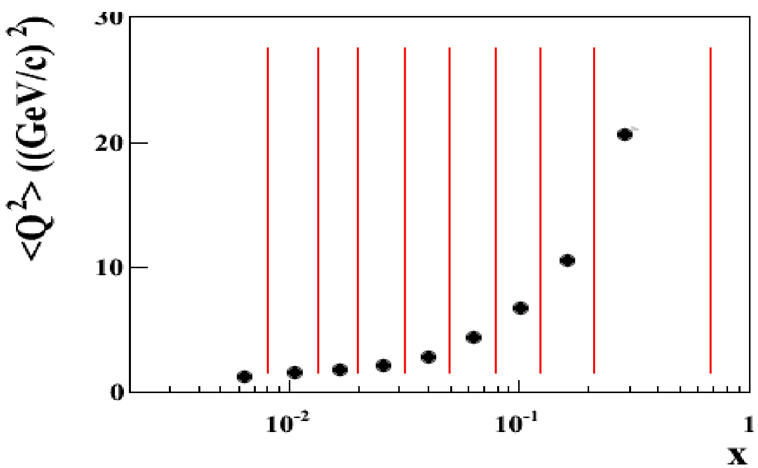
DIS event selection: $Q^2 > 1\ (\mathrm{GeV}/c)^2$

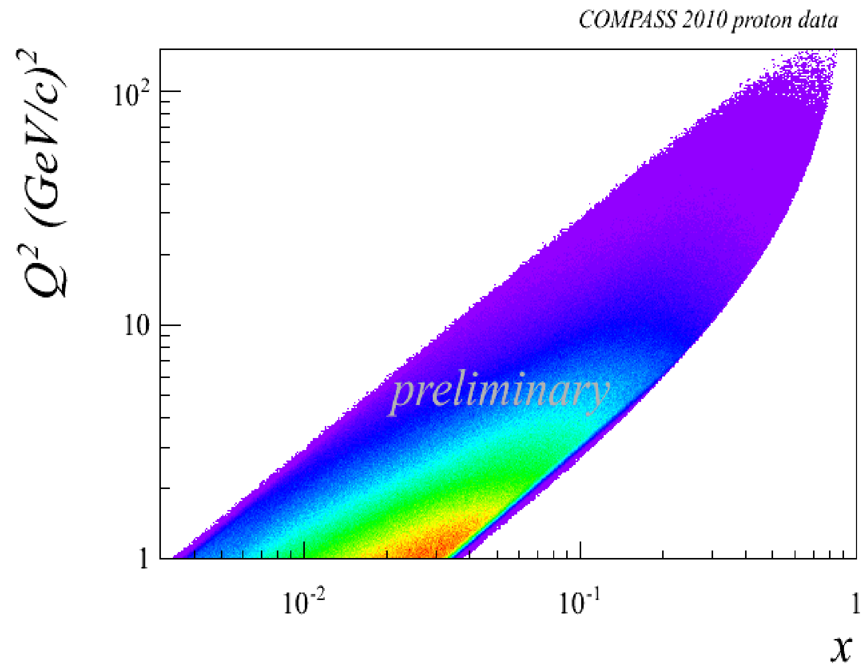
$0.1 < y < 0.9$

$W > 5\ \mathrm{GeV}/c^2$

h± selection: $p_t^h > 0.1$ GeV/c

$z > 0.2$ + low y low z



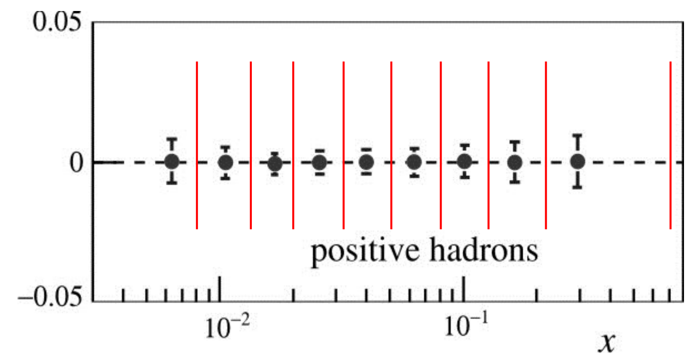


complementary to

HERMES, JLab, JLab12

high x, high Q^2 :

luminosity limit



statistical error (raw asymmetry corrected for f)

6 months of data taking (June-November 2010)

TRANSVERSITY

one of the main goals of COMPASS

three distribution functions are necessary to describe the structure of the nucleon at LO in the collinear case:

$q(x)$: **number density** or **unpolarised distribution**	$f_1^q(x)$
$\Delta q(x) = q^{\rightrightarrows} - q^{\leftrightarrows}$: **longitudinal polarization** or **helicity distribution**	$g_1^q(x)$
$\Delta_T q(x) = q^{\uparrow\uparrow} - q^{\downarrow\uparrow}$: **transverse polarization** or **transversity distribution**	$h_1^q(x)$

ALL OF EQUAL IMPORTANCE !

TRANSVERSITY

one of the main goals of COMPASS

it has different properties than helicity
tensor charge of the N

$$\int_0^1 \mathrm{d}x[h_1^q(x) - \bar{h}_1^q(x)] = \delta q.$$

it survives after integration over the intrinsic transverse momentum

it is chiral-odd, more difficult to measure than helicity (DIS)

$\Delta_T q(x) = q^{\uparrow\uparrow} - q^{\downarrow\uparrow}$: **transverse polarization** or **transversity distribution** $h_1^q(x)$

SIDIS off transversely polarised nucleons:

$$A_{Coll} \approx \frac{\sum_q e_q^2 \; h_1^q \otimes H_1^{\perp q}}{\sum_q e_q^2 \; f_1^q \otimes D_q}$$

"Collins FF"
Belle Babar

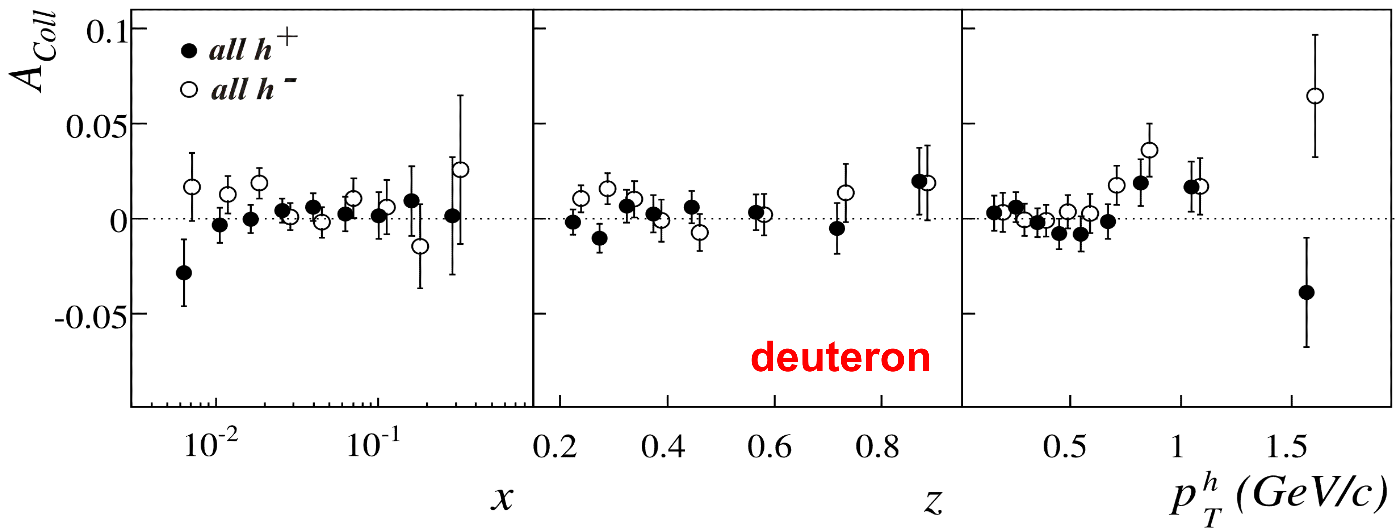
COMPASS

Collins asymmetry

- clear non-zero effects first seen by HERMES on p in 2005
- ~ zero asymmetries measured by COMPASS on d

$h_1^u \approx - h_1^d$ $H_1^{\perp fav} \approx - H_1^{\perp unf}$

2002-2004 NPB 765 (2007) 31, PLB 673 (2009) 127

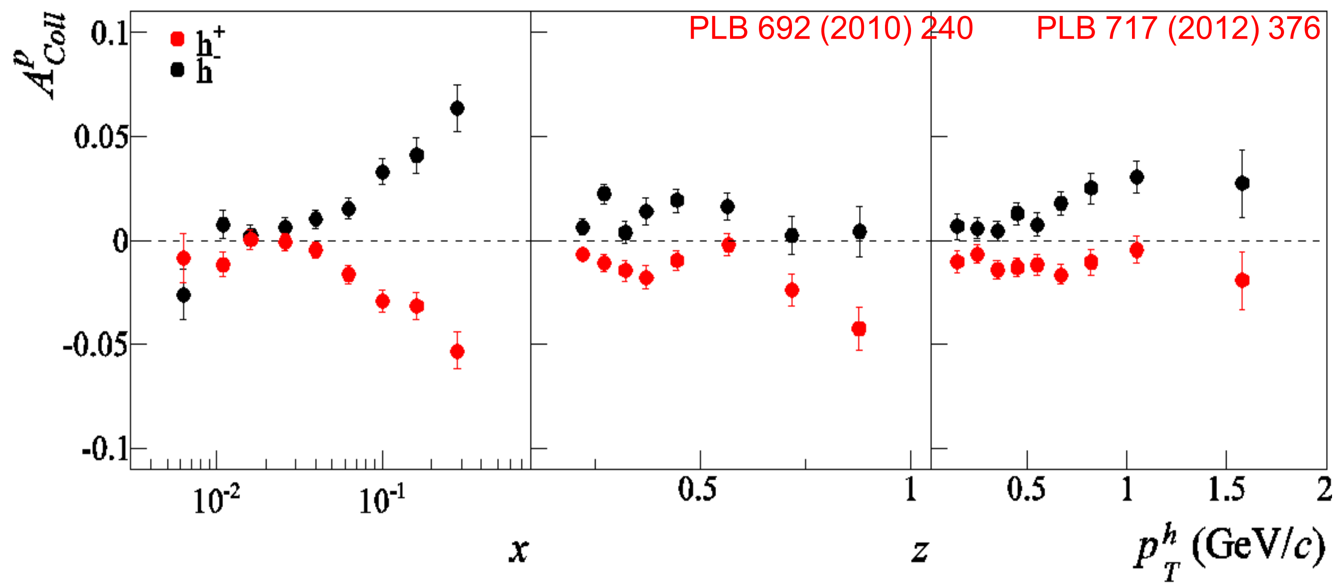


still only measurements on d

JLab : n (He3)

Collins asymmetry

- **clear non-zero effects first seen by HERMES on p in 2005**
- **~ zero asymmetries measured by COMPASS on d**
- **COMPASS results on proton target** (2007, 2010 data)



Collins asymmetry

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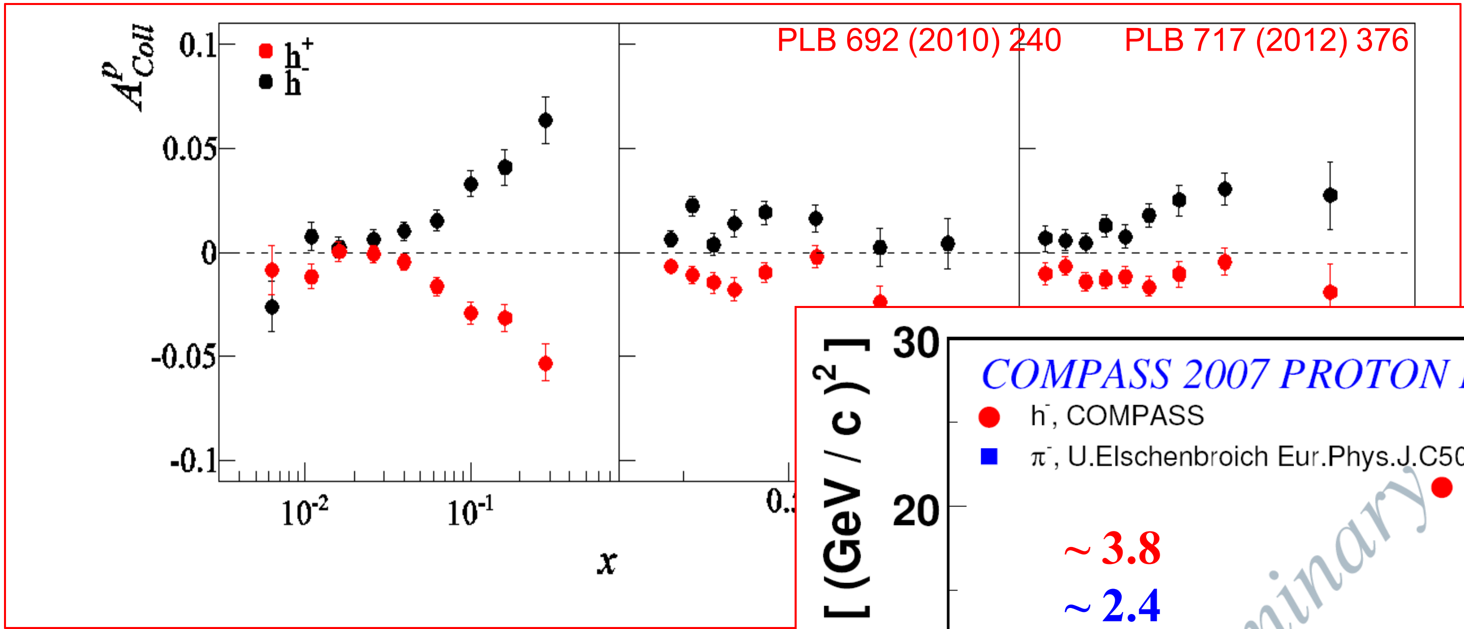
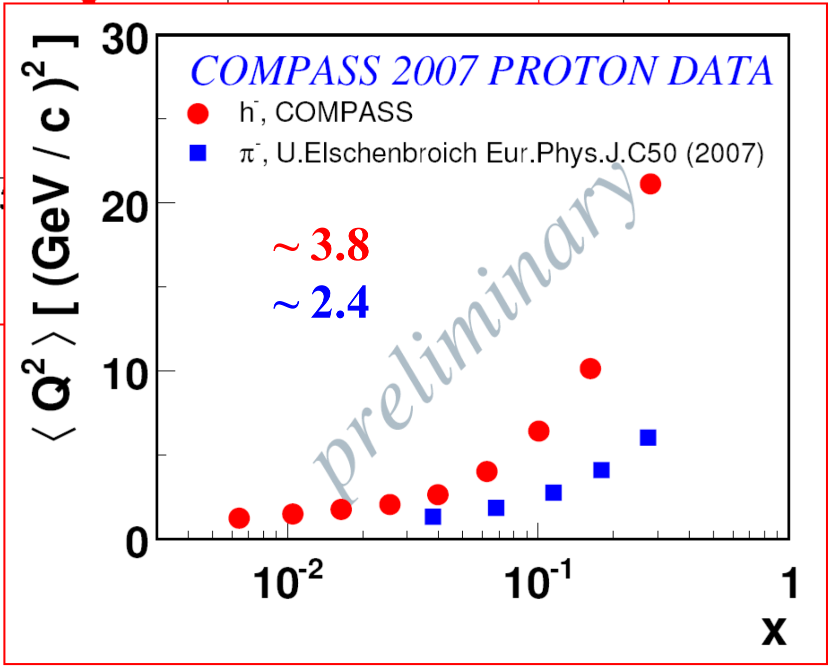
- **~ zero asymmetries measured by COMPASS on d**
- **COMPASS results on proton target** (2007, 2010 data)



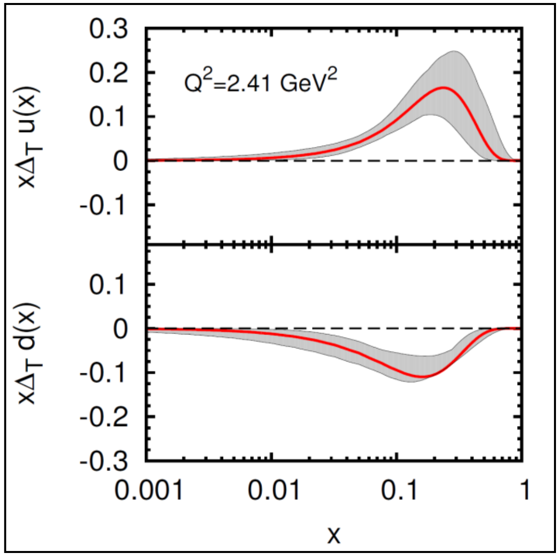


good agreement with HERMES in the x overlap region

same for pions

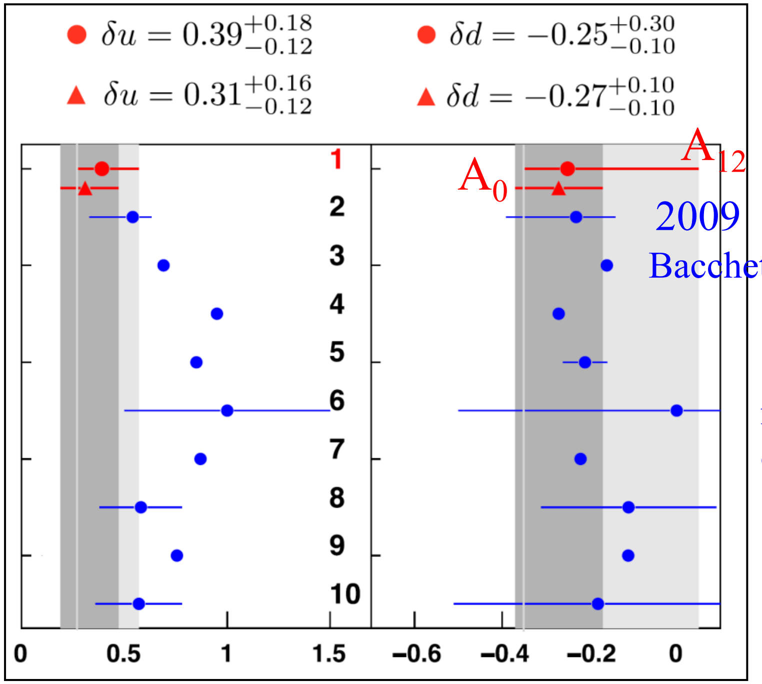
Transversity

transversity is different from zero and
can be measured in SIDIS thanks to the "Collins effect"



M. Anselmino et al., PRD87 (2013) 094019
simultaneous fit of
HERMES p, COMPASS p & d, and Belle data
very good χ^2

$$\int_0^1 dx[h_1^q(x) - \bar{h}_1^q(x)] = \delta q.$$



more data
large and small x, p & d / n, PID
are needed

dihadron asymmetry

independent channel to access transversity in SIDIS on transversely polarised nucleons

Collins

$$A_{Coll} \approx \frac{\sum_q e_q^2 \; h_1^q \otimes H_1^{\perp q}}{\sum_q e_q^2 \; f_1^q \otimes D_q}$$

"Collins FF"

Belle Babar

dihadron

$$A_{RS} \approx \frac{\sum_q e_q^2 \; h_1^q \cdot H_q^{\angle}}{\sum_q e_q^2 \; f_1^q \cdot D_q^{2h}}$$

"Interference / Di-hadron FF"

Belle Babar

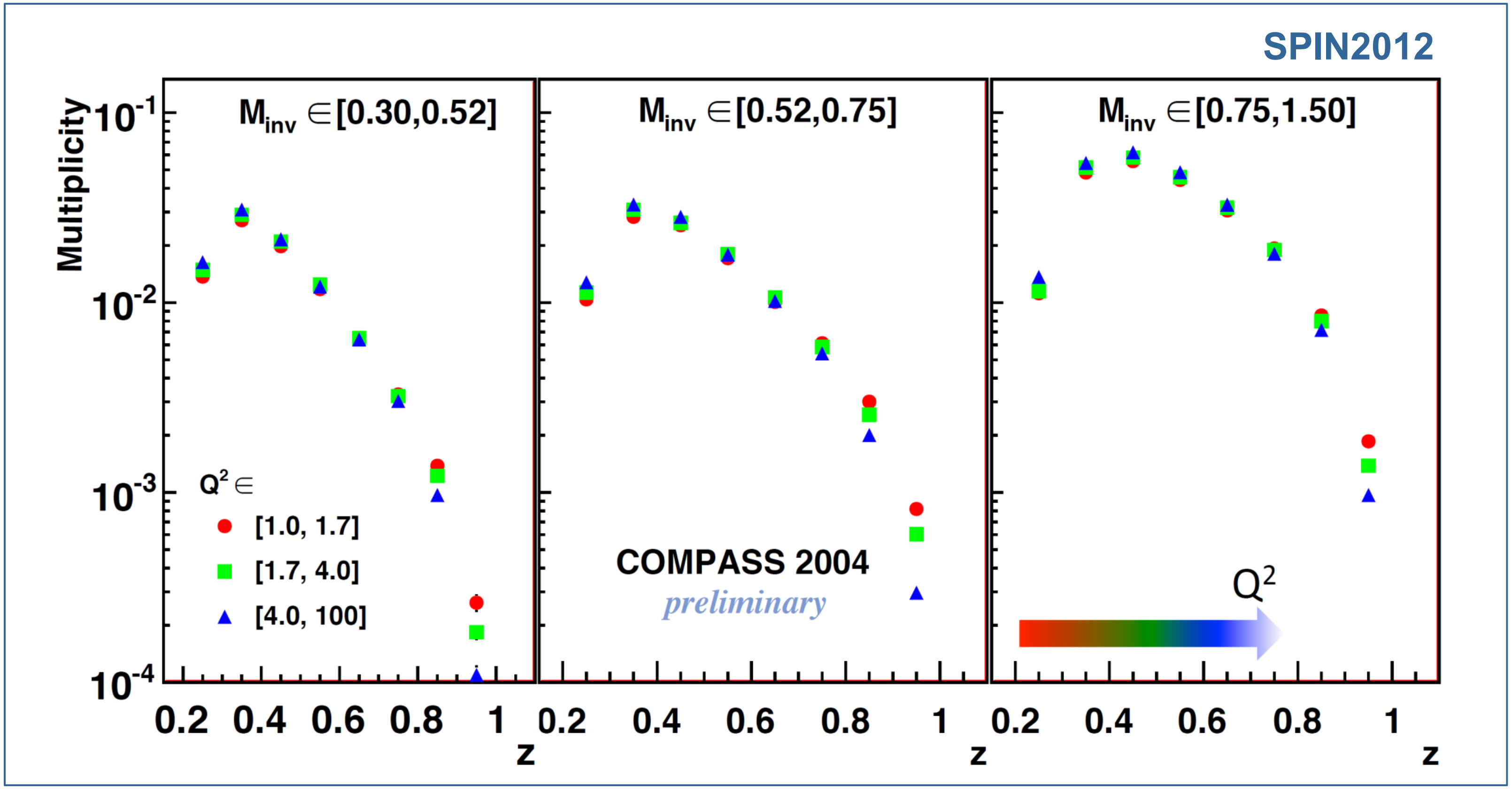
"spin independent di-hadron FF"

being measured at COMPASS

dihadron multiplicities in SIDIS

hadron pair multiplicities

in M_{inv}, $z=z_1+z_2$, Q^2 bins

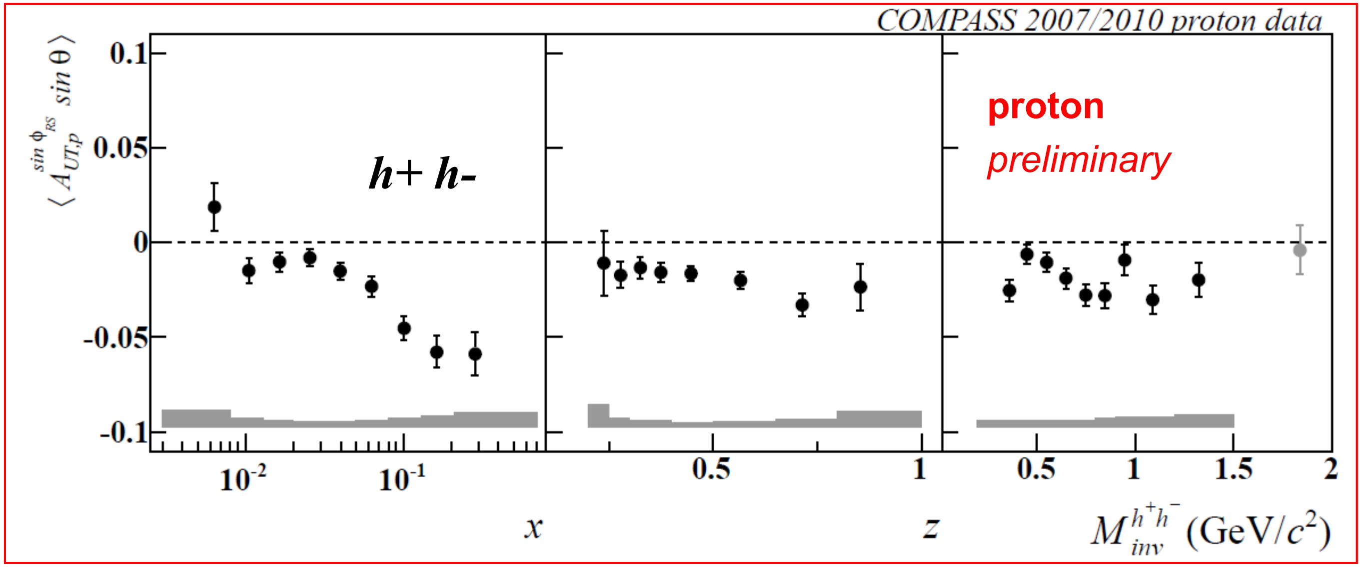


dihadron asymmetry

all d data: asymmetries compatible with zero PLB 713 (2012) 10

all p data

PLB 713 (2012) 10 & Transversity 2011



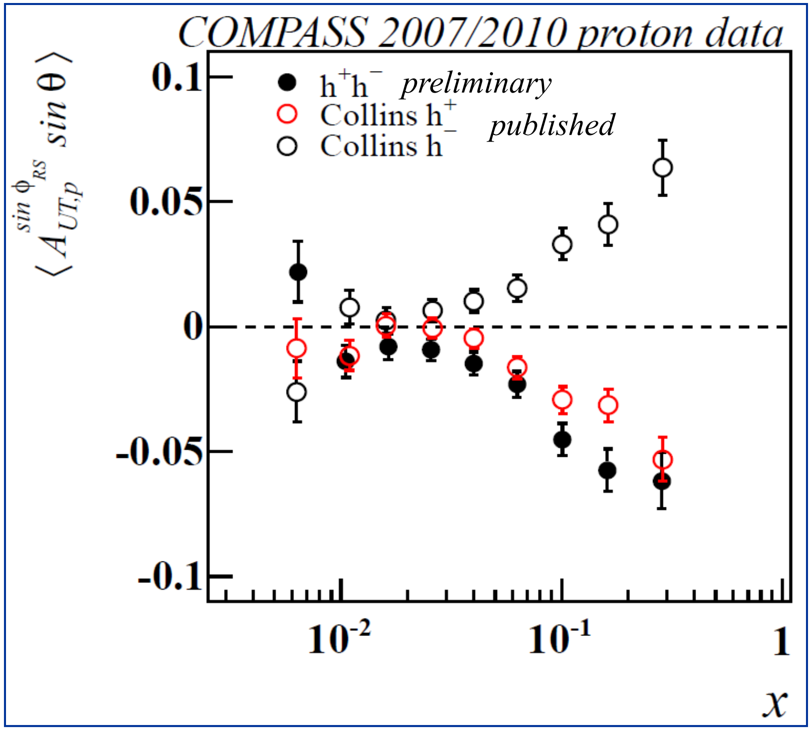
high statistics over a wide x range

clear signal

dihadron asymmetry and Collins asymmetries

“intriguing” results

- **Collins asymmetry for h+ and for h-**
  “mirror symmetry”
- **dihadron asymmetry vs Collins asymmetries**
  only somewhat larger



further investigation:

correlations between the relevant azimuthal angles and the corresponding asymmetries

→ information on the nature of the fragmentation of transv polarised q
Collins vs 2h interference mechanism

F. Bradamante , Como2013, D-SPIN2013

conclusion:
hints for a common physical origin for the Collins mechanism and the polarised dihadron fragmentation function

Sivers PDF

the most famous of the TMD PDFs

correlation between the transverse spin of the nucleon and the transverse momentum of the quark

sensitive to orbital angular momentum

T-odd

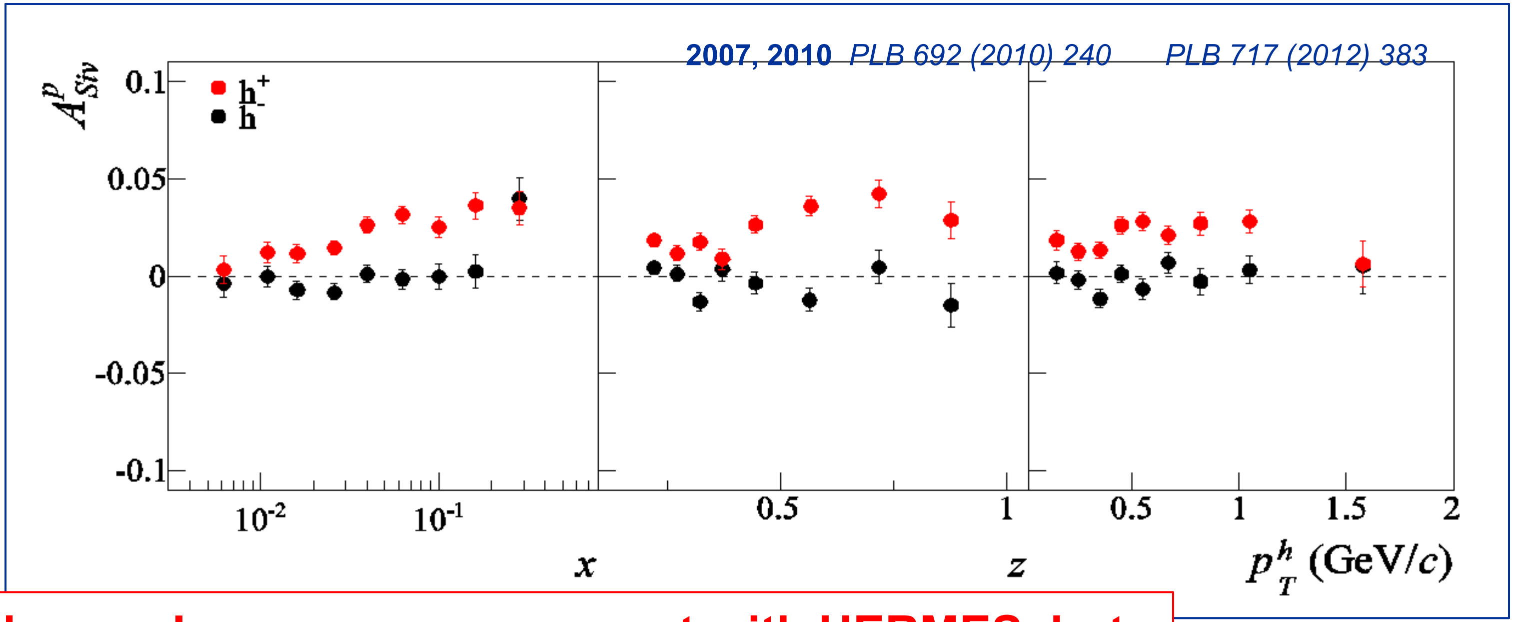
SIDIS on transversely polarised nucleons

Sivers asymmetry

$$A_{Siv} \approx \frac{\sum_q e_q^2 \, f_{1T}^{\perp q} \otimes D_q}{\sum_q e_q^2 \, f_1^q \otimes D_q}$$

Sivers asymmetry

- strong signal seen by HERMES in π^+ production on p in 2005
- no signal seen by COMPASS on d u ~ - d
- COMPASS results on proton:
  clear signal for h+
  down to low x, in the previously unmeasured region



in the overlap x range, agreement with HERMES, but clear indication that the strength decreases:
Q^2 evolution

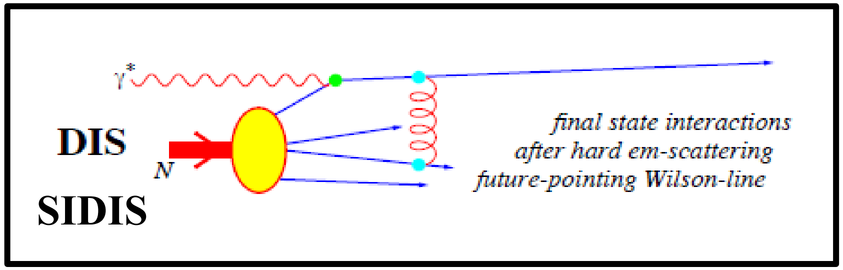
Sivers PDF

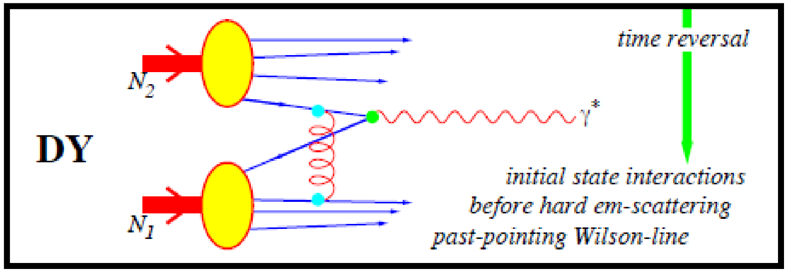
- from SIDIS, clear evidence that it is different from zero
- all the existing data can be well described in the present theoretical framework

being T-odd, it should be process-dependent

it is expected to change sign if measured in Drell-Yan

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





→ future measurements of Drell-Yan at COMPASS

Boer-Mulders PDF

- **correlation between the transverse spin and the transverse momentum of the quarks in unpolarised nucleons**
- **T-odd**
- **can be accessed in SIDIS on unpolarised nucleons**

Cahn effect, k_T
Boer-Mulders PDF

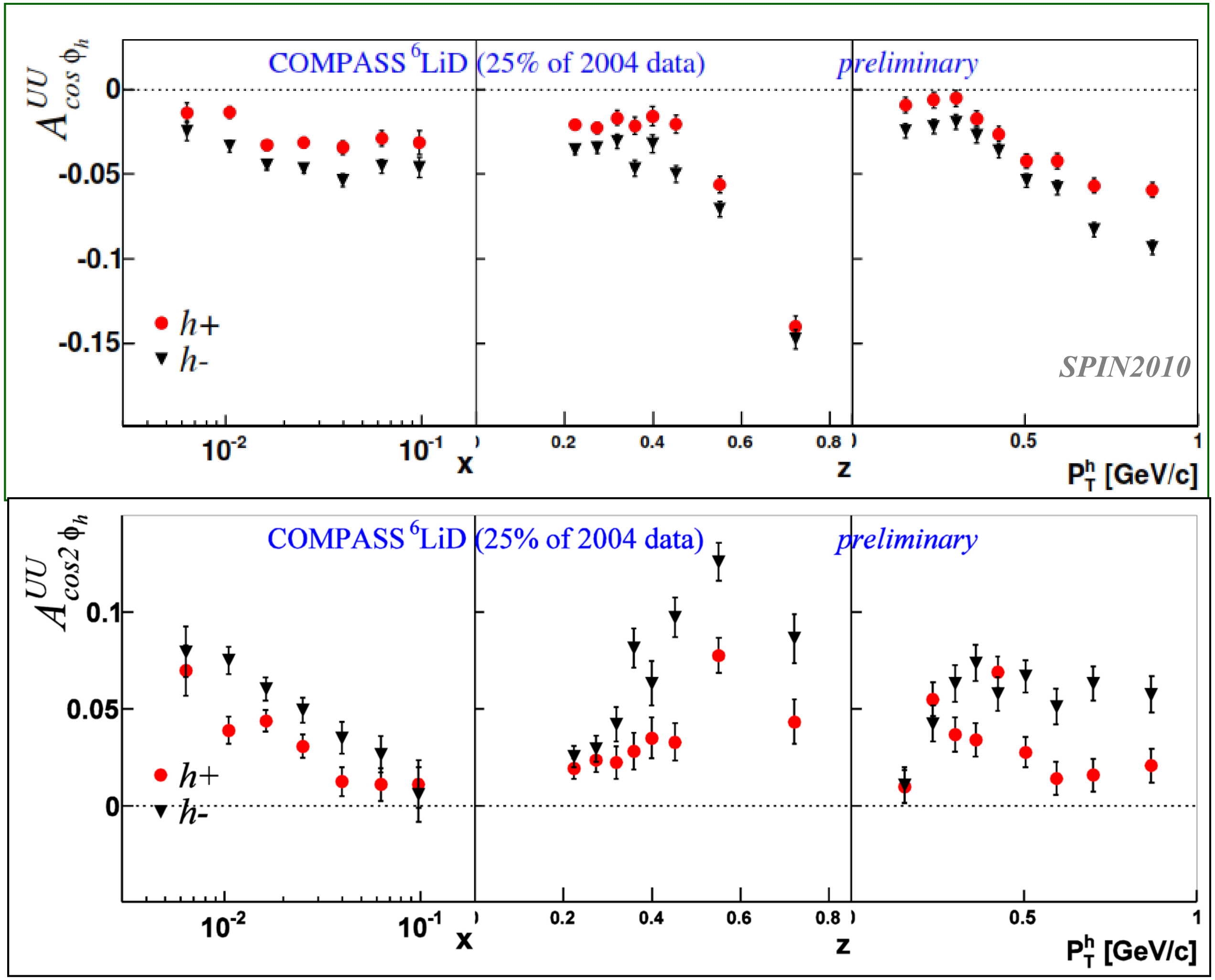
$$\frac{d\sigma}{dx\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2\,(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\left\{F_{UU,T}+\varepsilon F_{UU,L}+\sqrt{2\,\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} + \varepsilon\cos(2\phi_h)F_{UU}^{\cos 2\phi_h} + \lambda_e\sqrt{2\,\varepsilon(1-\varepsilon)}\sin\phi_h F_{LU}^{\sin\phi_h} + \dots\right.$$

twist3

Boer-Mulders PDF x Collins FF
+ Cahn effect (twist 4, $1/Q^2$)

measured by COMPASS using combined data taken with oppositely polarised ^{6}LiD target

unpolarised deuteron - azimuthal asymmetries



$\cos\phi$

- large signals over all the x range

$sys \approx 2 \cdot stat$

$\cos 2\phi$

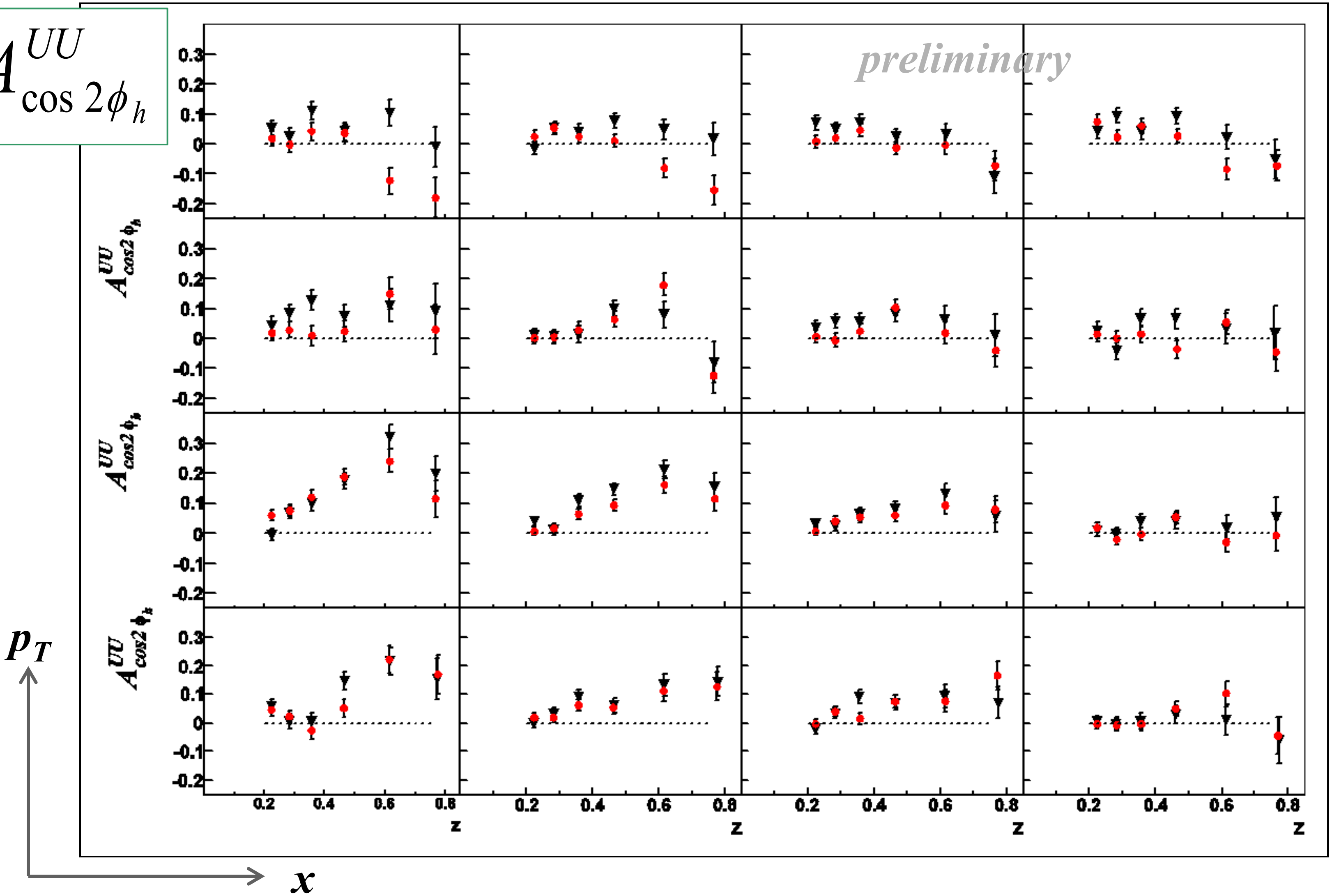
- large signals at small x

different for h^+ and h^-

strong unexpected dependence on x, z, P_T^h

unpolarised deuteron - azimuthal asymmetries

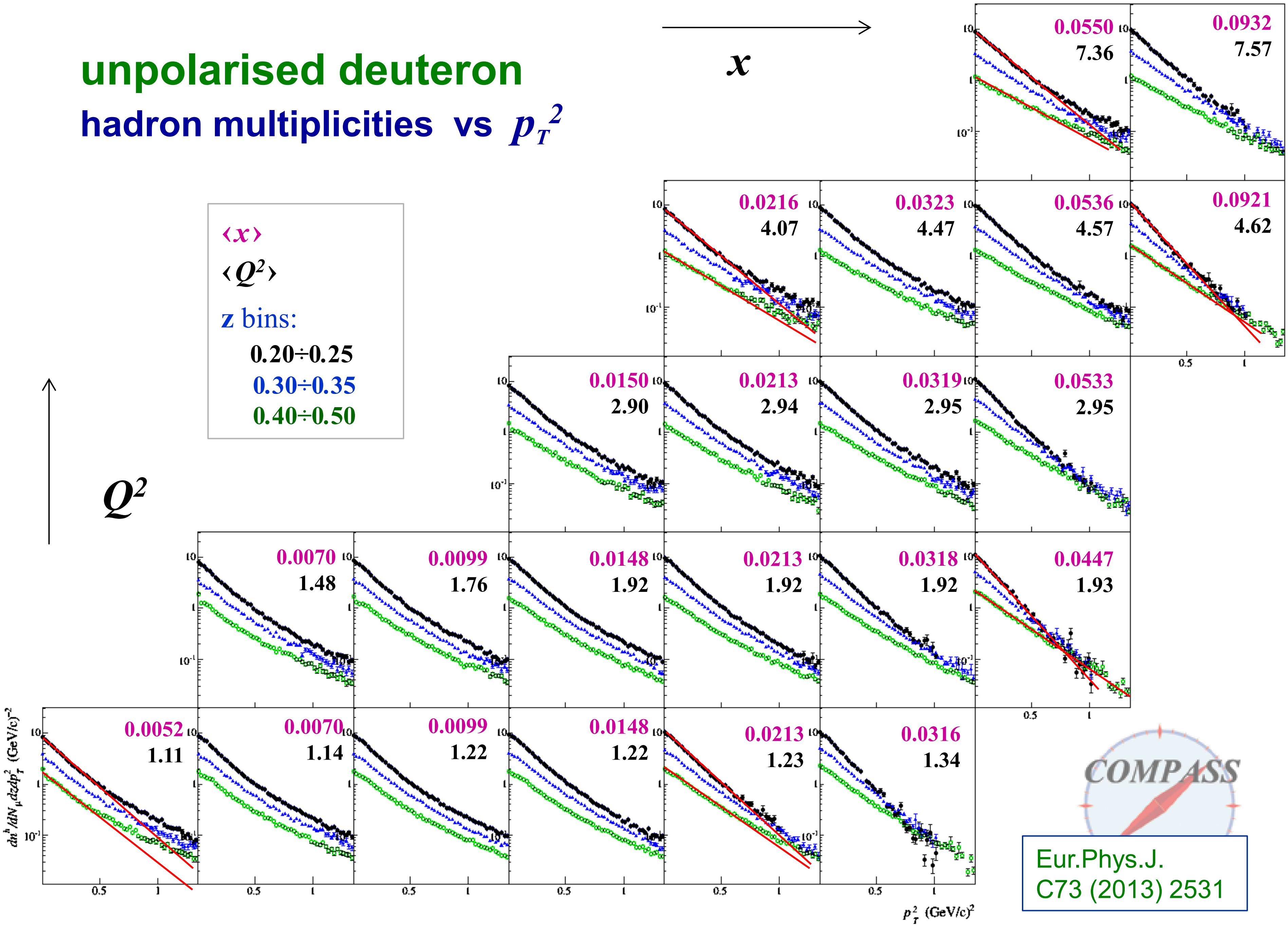
$A_{\cos 2\phi_h}^{UU}$



sys $\approx$ $2 \cdot stat$

unpolarised deuteron

hadron multiplicities vs p_T^2



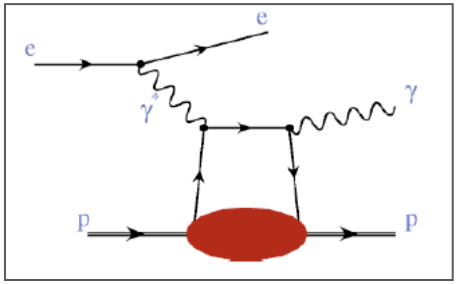
Eur.Phys.J.
C73 (2013) 2531

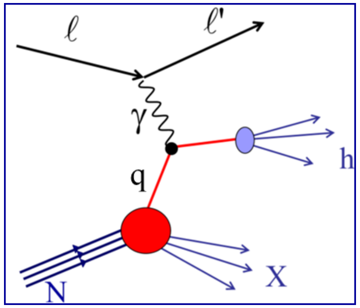
nucleon structure
future COMPASS contribution

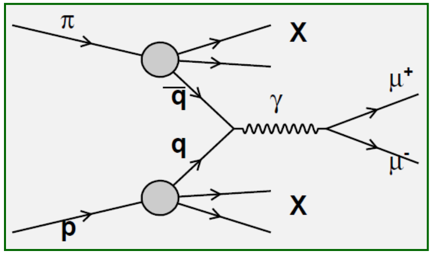
- **the analysis of the SIDIS is not over**
  - further investigation of single hadron and dihadron asymmetries
  - multidimensional analysis of transverse spin asymmetries
  - more d and p results on longitudinal spin azimuthal asymmetries
  - more on azimuthal asymmetries and multiplicities from unpolarised d data (PID)
  - ….

new results coming soon

- **future measurements**

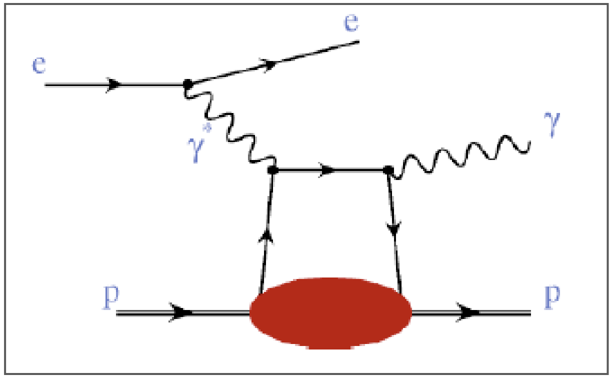






GPDs from DVCS and HEMP

2016 - 2017



GPD program at COMPASS

- **transverse target spin asymmetry for exclusive ρ^0 production on d and p**

2002-2004, 2007, 2010 data

NPB 865 (2012) 1, CERN-PH-EP/2013-191

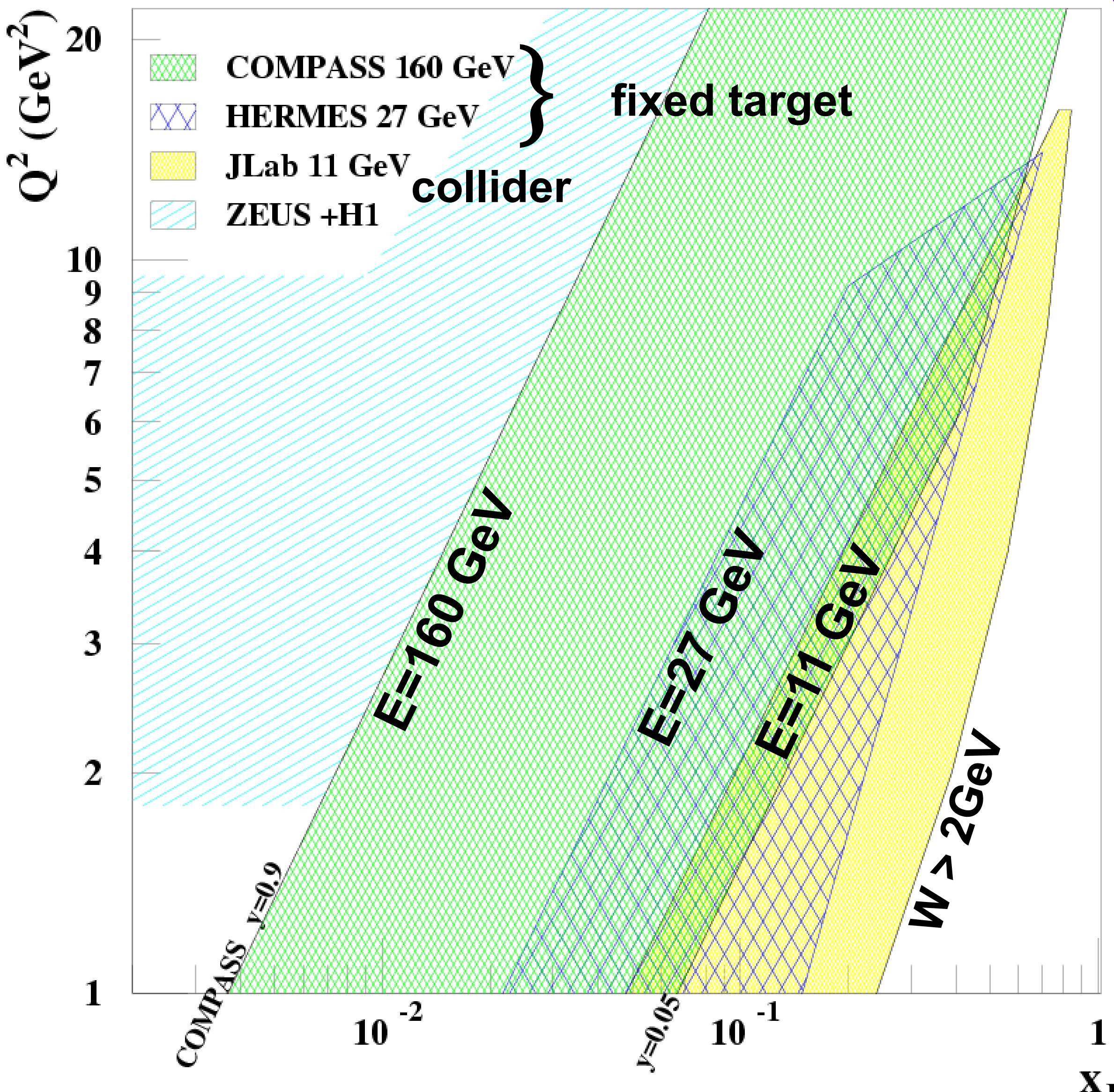
- **DVCS and Hard Exclusive Meson Production with LH_2 target and $\mu^{+\downarrow}$, $\mu^{-\uparrow}$ 160 GeV beams**

test runs 2009,2012

to constrain GPD H
to study the transverse proton structure

data taking 2016-2017

kinematic domain (Q^2, x_B) for DVCS



COMPASS unique facility

CERN muon beam

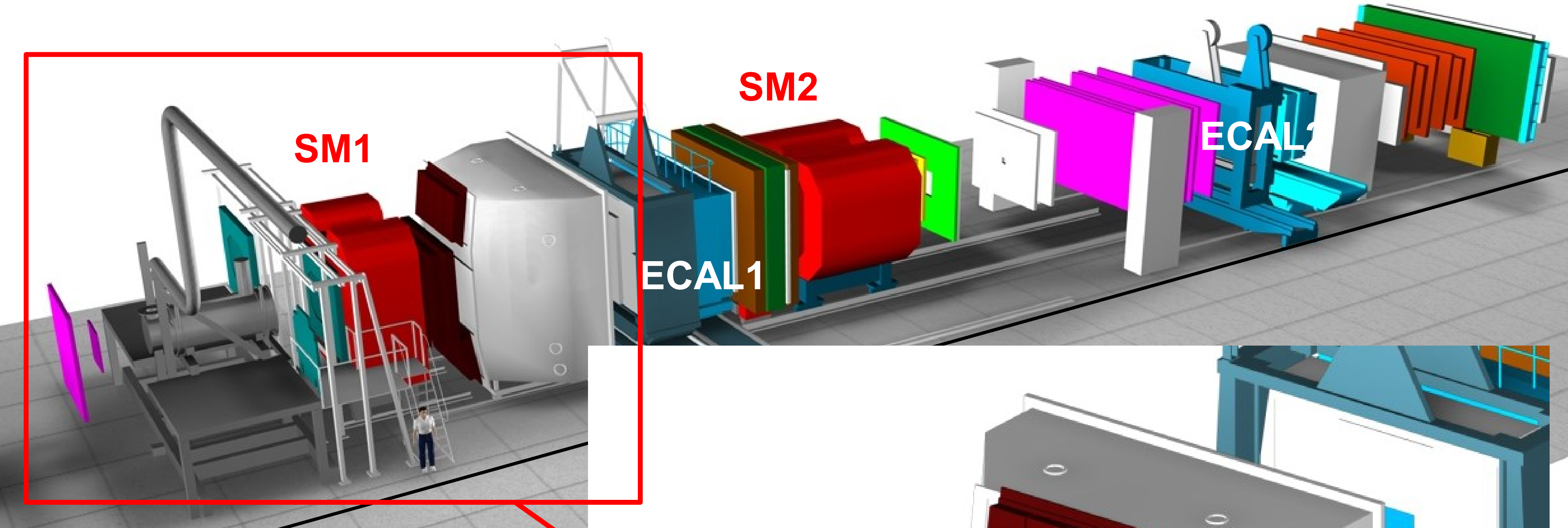
- 100 - 190 GeV
- $\mu^{+\downarrow}$ and $\mu^{-\uparrow}$ available
- 80% Polarisation
- 4.6 10^8 μ^+

→ Lumi= 10^{32} cm^{-2} s^{-1}
with 2.5m LH2 target

explore the intermediate x_{Bj} region

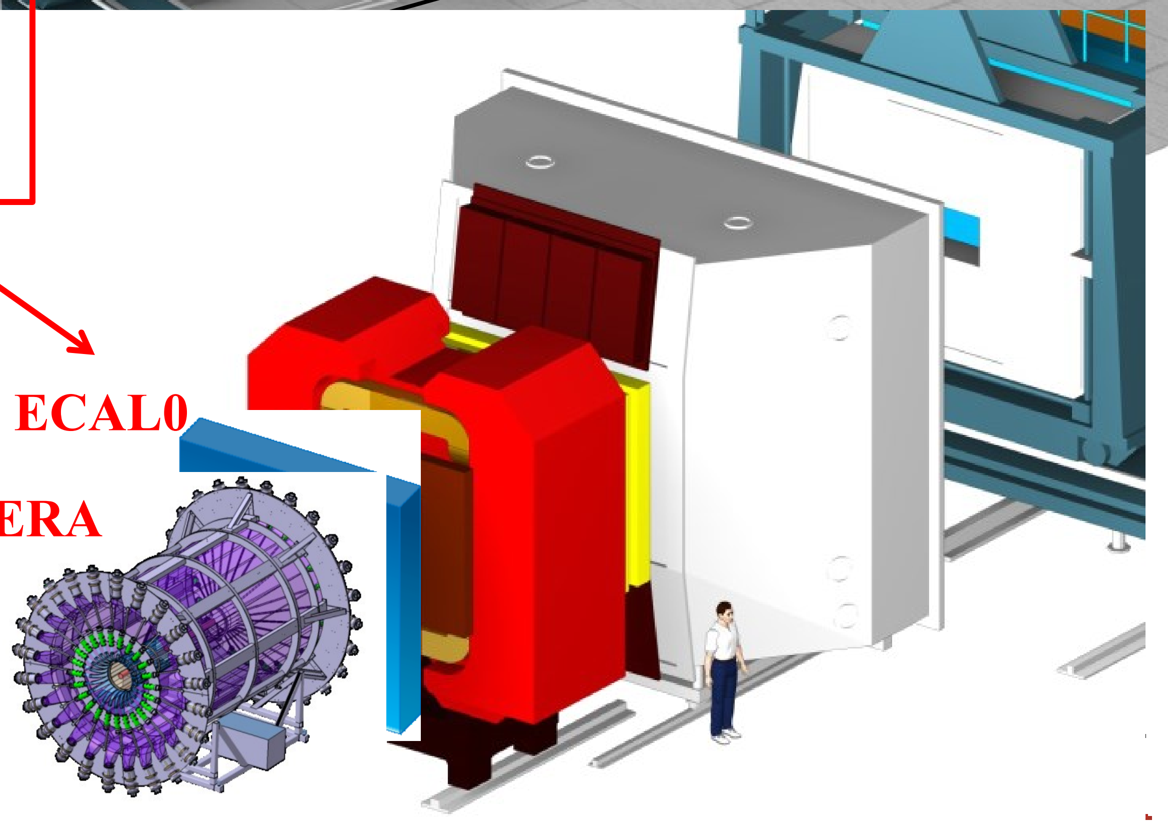
uncovered region between ZEUS+H1 & HERMES + JLab before new colliders may be available

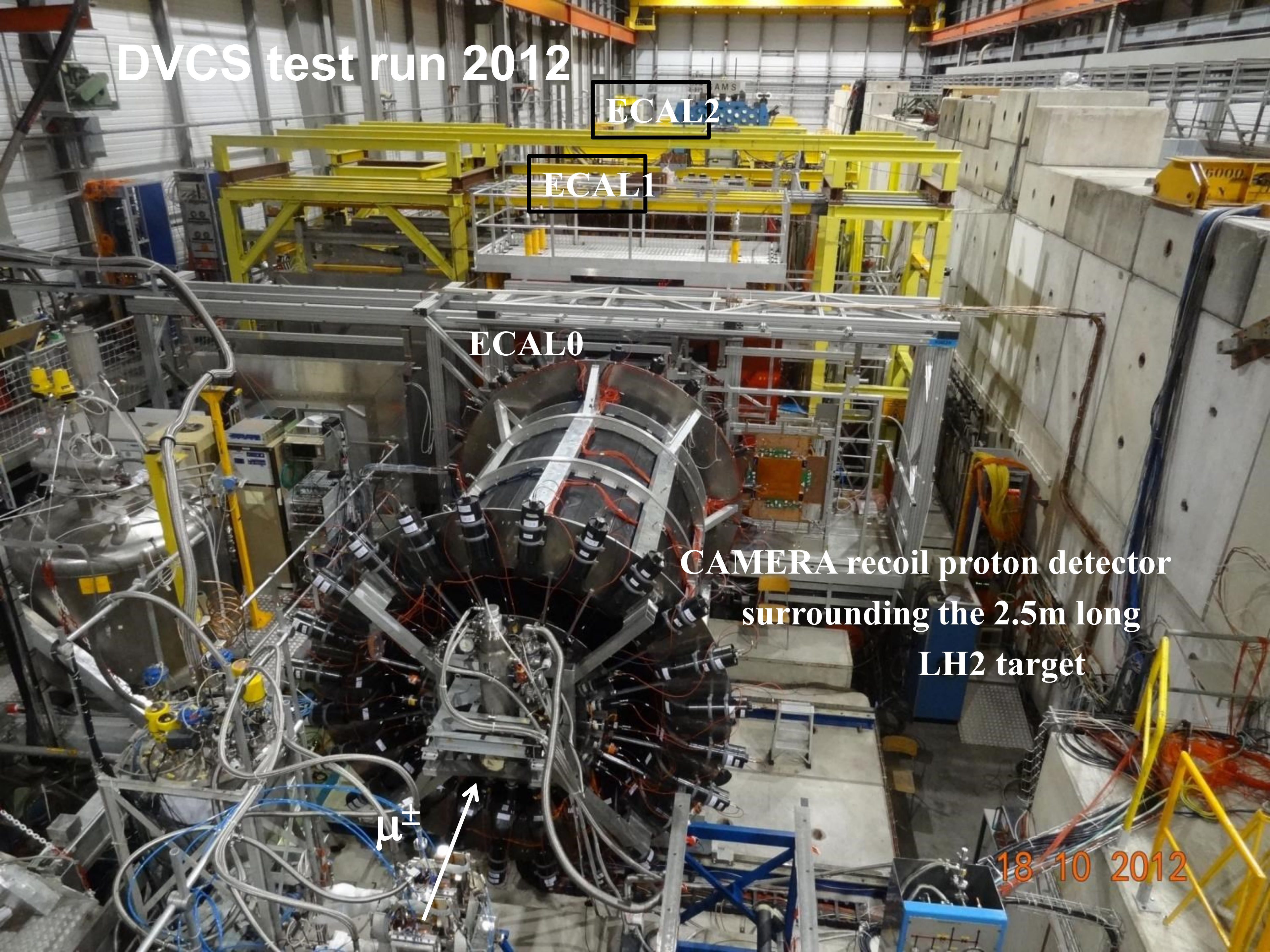
experimental apparatus



new equipements

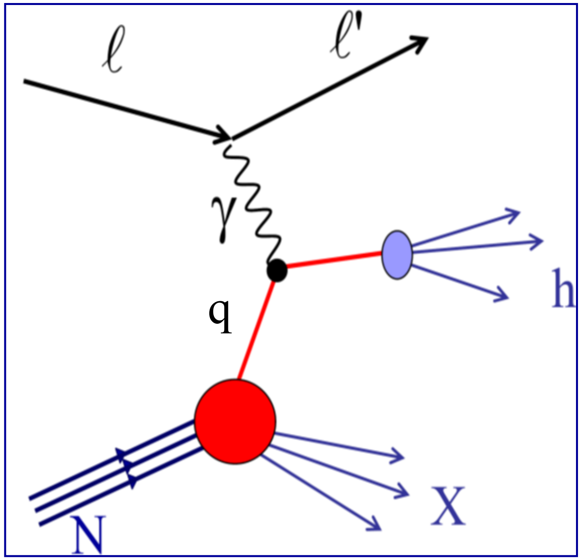
- 2.5m LH2 target
- 4m ToF Barrel CAMERA
- ECAL0
- tracking detectors




DVCS test run 2012
ECAL2
ECAL1
ECAL0
CAMERA recoil proton detector
surrounding the 2.5m long
LH2 target
μ±
18 10 2012

SIDIS

in parallel to DVCS
2016 - 2017



SIDIS

on the 2.5 m long LH_2 target with the 160 GeV/c muon beam

taking advantage of the spectrometer consolidation and upgrades which are ongoing *trackers, RICH*

- **hadron multiplicities vs z → FFs → s quark PDFs**
- **dihadron multiplicities → transversity**
- **TMDs**

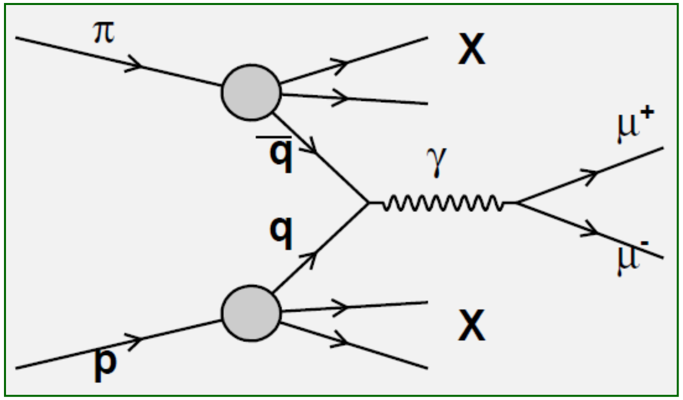
  hadron multiplicities vs p_t^2 → k_T

  azimuthal asymmetries → BM PDF

all relevant measurements

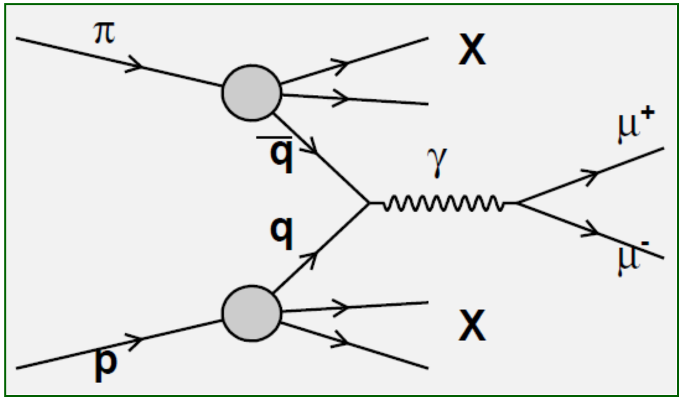
polarised Drell – Yan 2015

test run in 2009

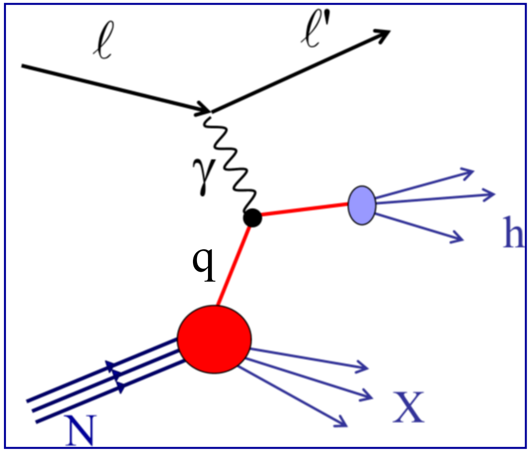


Drell - Yan

$\pi^- p \to \mu^+ \mu^- X$



complementary to **SIDIS**



cross-sections:

SIDIS: convolution of a TMD PDFs with FFs

DY: convolution of 2 TMD PDFs $\sigma^{DY} \propto f_{\bar{u}|\pi^-} \otimes f'_{u|p}$

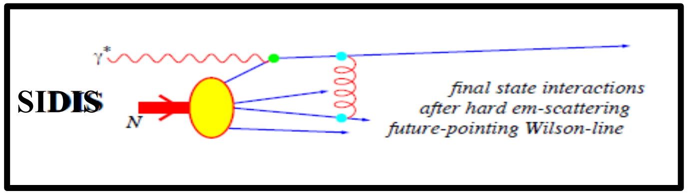
Drell – Yan at COMPASS

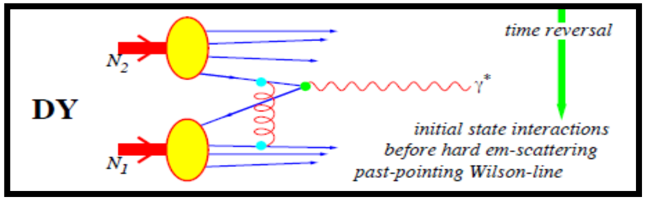
$\pi^- p^\uparrow \rightarrow \mu^+ \mu^- X$ **transversely polarised p target**

aim: test for the first time the expected change of sign of the Sivers function

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

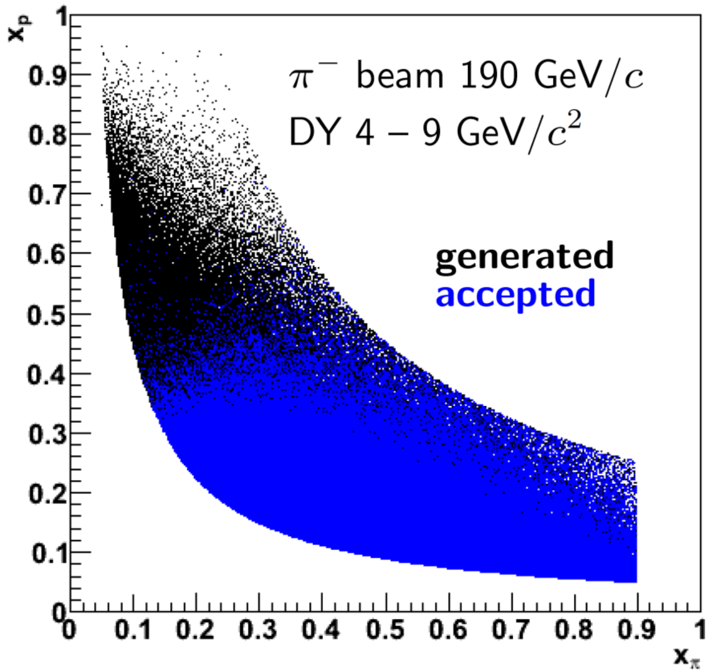
clearly positive *never measured*



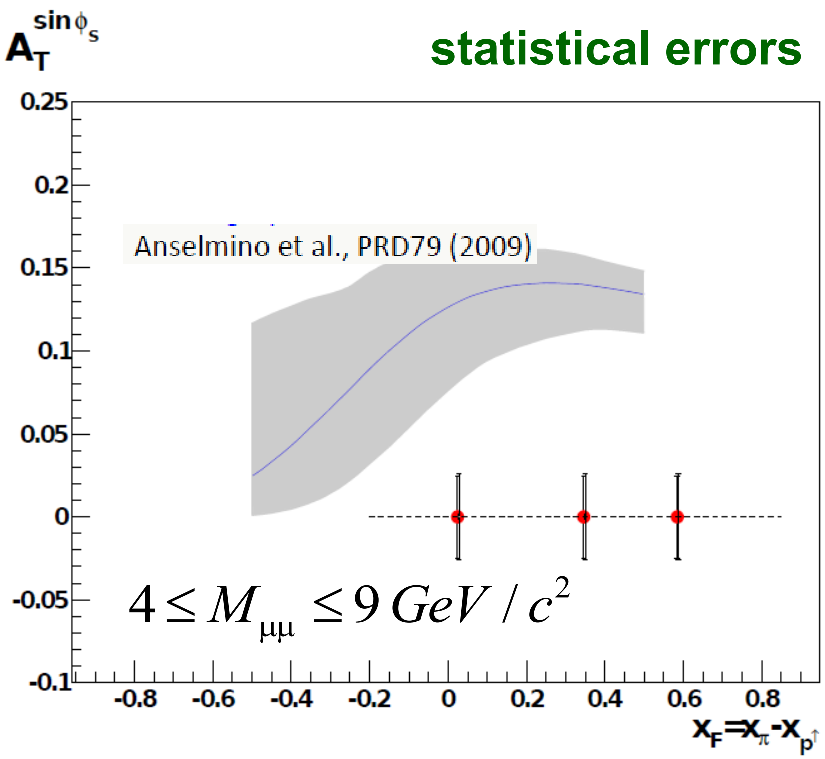


polarised Drell - Yan $\pi^- p^\uparrow \rightarrow \mu^+ \mu^- X$

acceptance

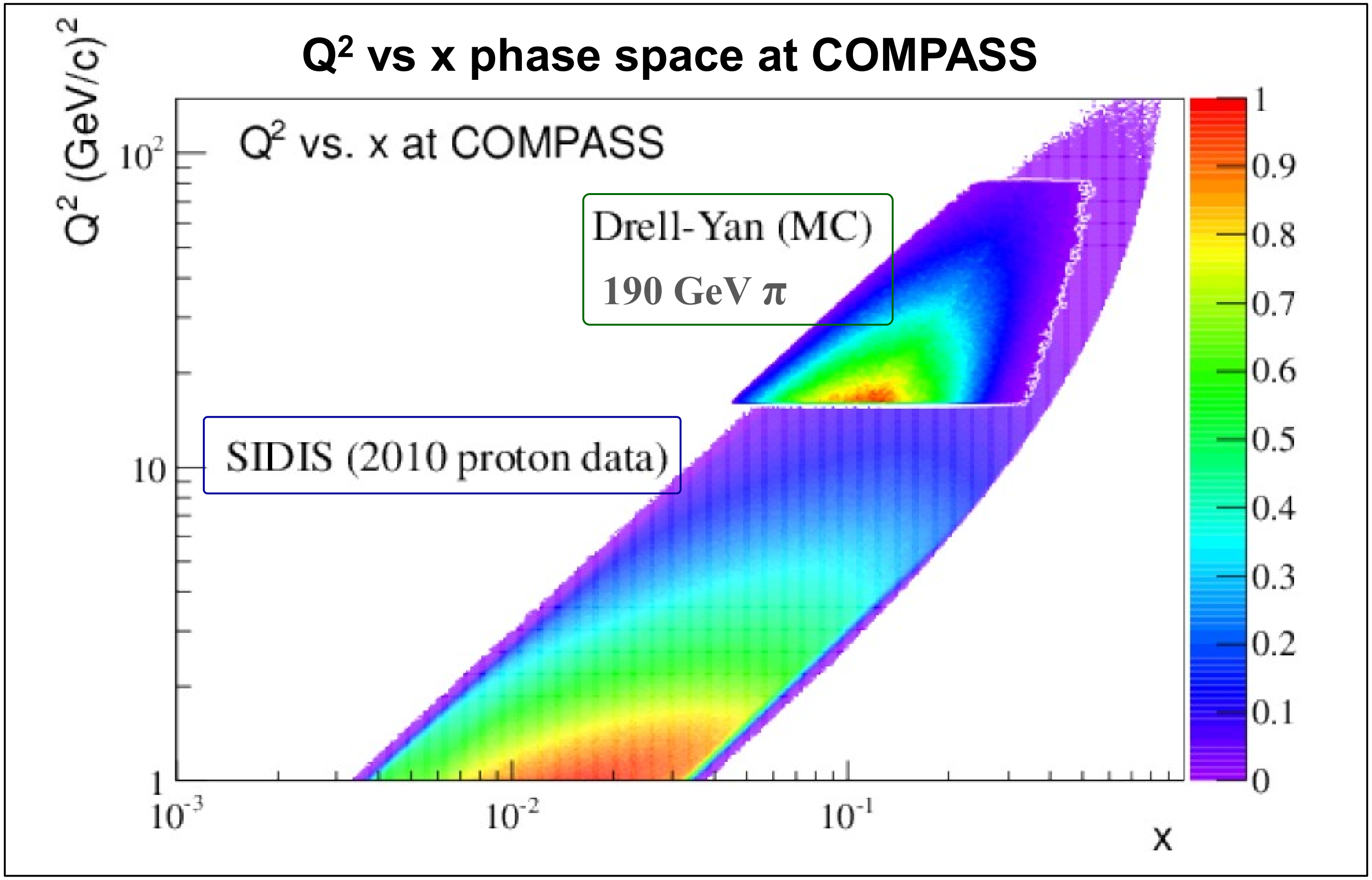


statistical errors



2 years data taking (1y = 140d)
$6 \cdot 10^8$ π/spill (9.6s/48s duty cycle)
1.1m transv pol. NH_3 target
Lumi=$1.2 \cdot 10^{32}$ cm^{-2}s^{-1}

polarised Drell - Yan $\pi^- p^\uparrow \rightarrow \mu^+ \mu^- X$



overlap of the x-Q^2 region covered in the two processes overlap

→ consistent extraction of TMD PDFs

COMPASS

great impact results
on nucleon structure and spectroscopy
have already been obtained and
new ones are expected in the next few years

more can be done later on - from 2018

first ideas

	physics item	key aspects of the measurement
Hadron	glueballs	280 GeV beam, higher intensity, π, K and $\bar{p}$ separation
GPD	E	transversely polarized proton target
SIDIS	h_1^d with same accuracy as h_1^u $f_1^\perp$ evolution	transversely polarized deuteron target 100 GeV and transversely polarized proton target
DY	universality of TMD PDFs flavor separation test of the Lam-Tung relation EMC effect in DY	higher statistics with transversely polarized proton target transversely polarized deuteron target hydrogen target different nuclear targets

submitted to European Strategy Preparatory Group, 2012

Thank you