The COMPASS Spin Program

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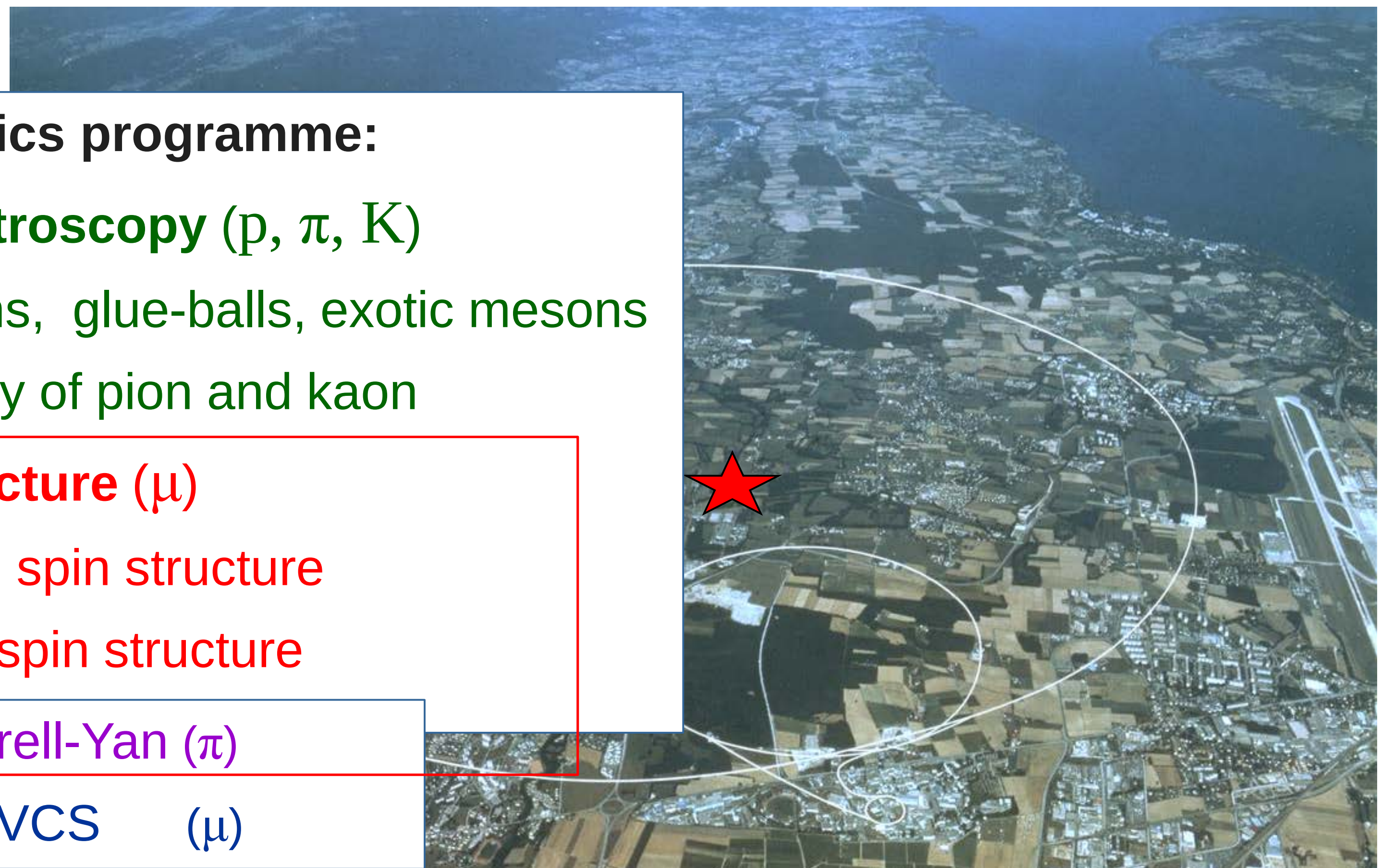
Trieste University and INFN
on behalf of the COMPASS Collaboration

Polarized light ion physics with EIC
February 5-9, 2018, Ghent University

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

fixed target experiment at the CERN SPS



proposed physics programme:

hadron spectroscopy (p, π, K)

- light mesons, glue-balls, exotic mesons
- polarisability of pion and kaon

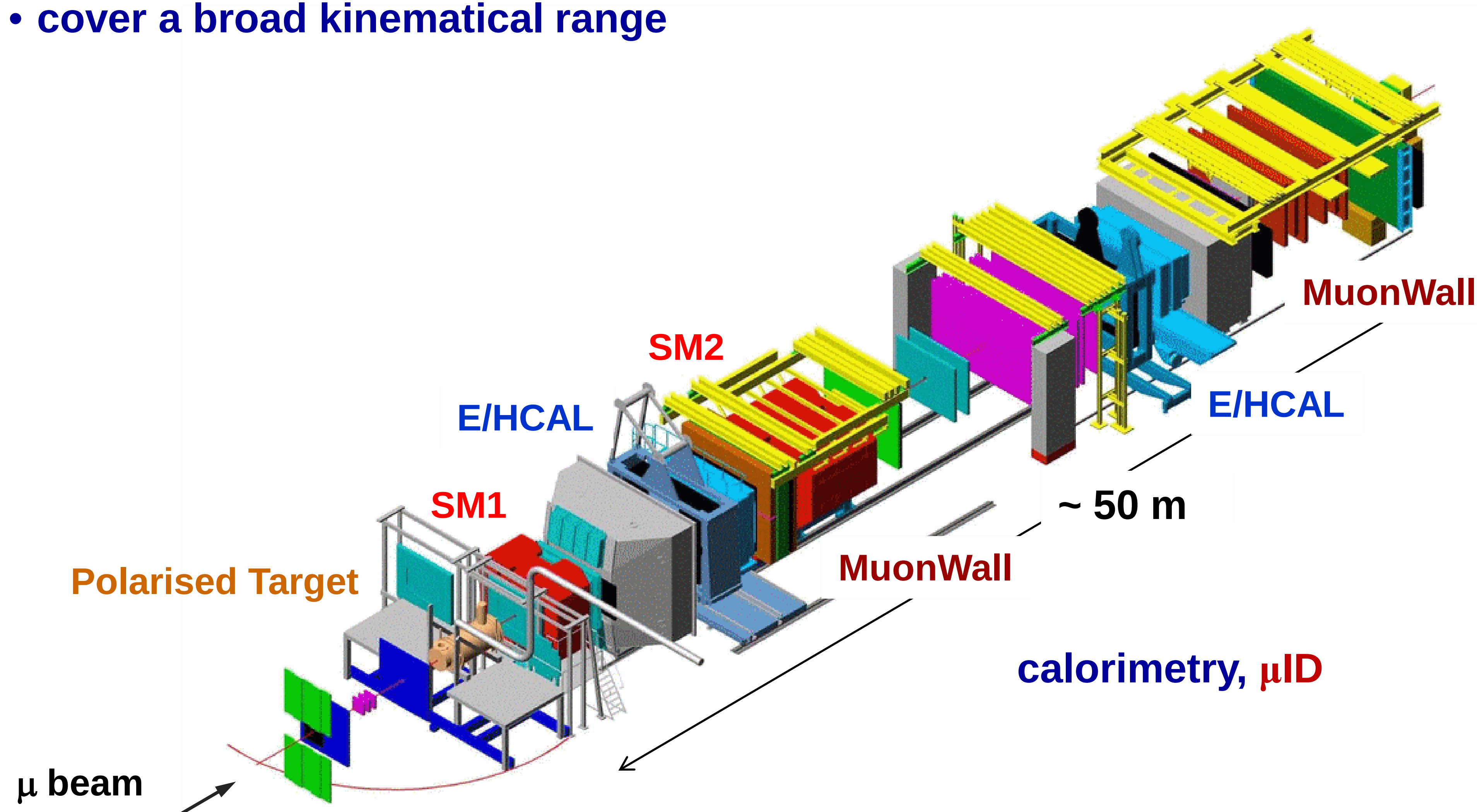
nucleon structure (μ)

- longitudinal spin structure
- transverse spin structure
- Drell-Yan (π)
- DVCS (μ)

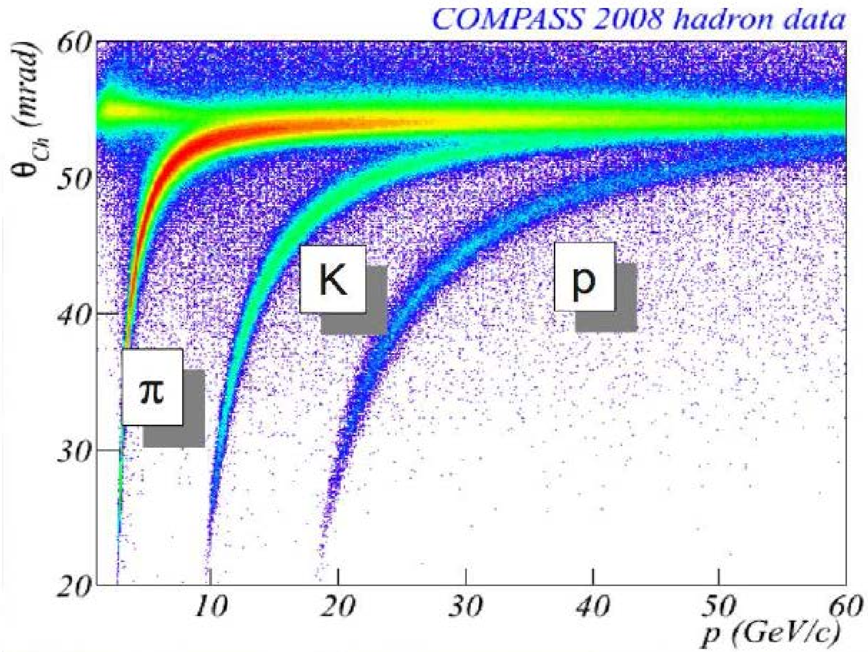
COMPASS spectrometer

designed to
- use high energy beams
- have large angular acceptance
- cover a broad kinematical range

two stages spectrometer
- Large Angle Spectrometer (SM1)
- Small Angle Spectrometer (SM2)

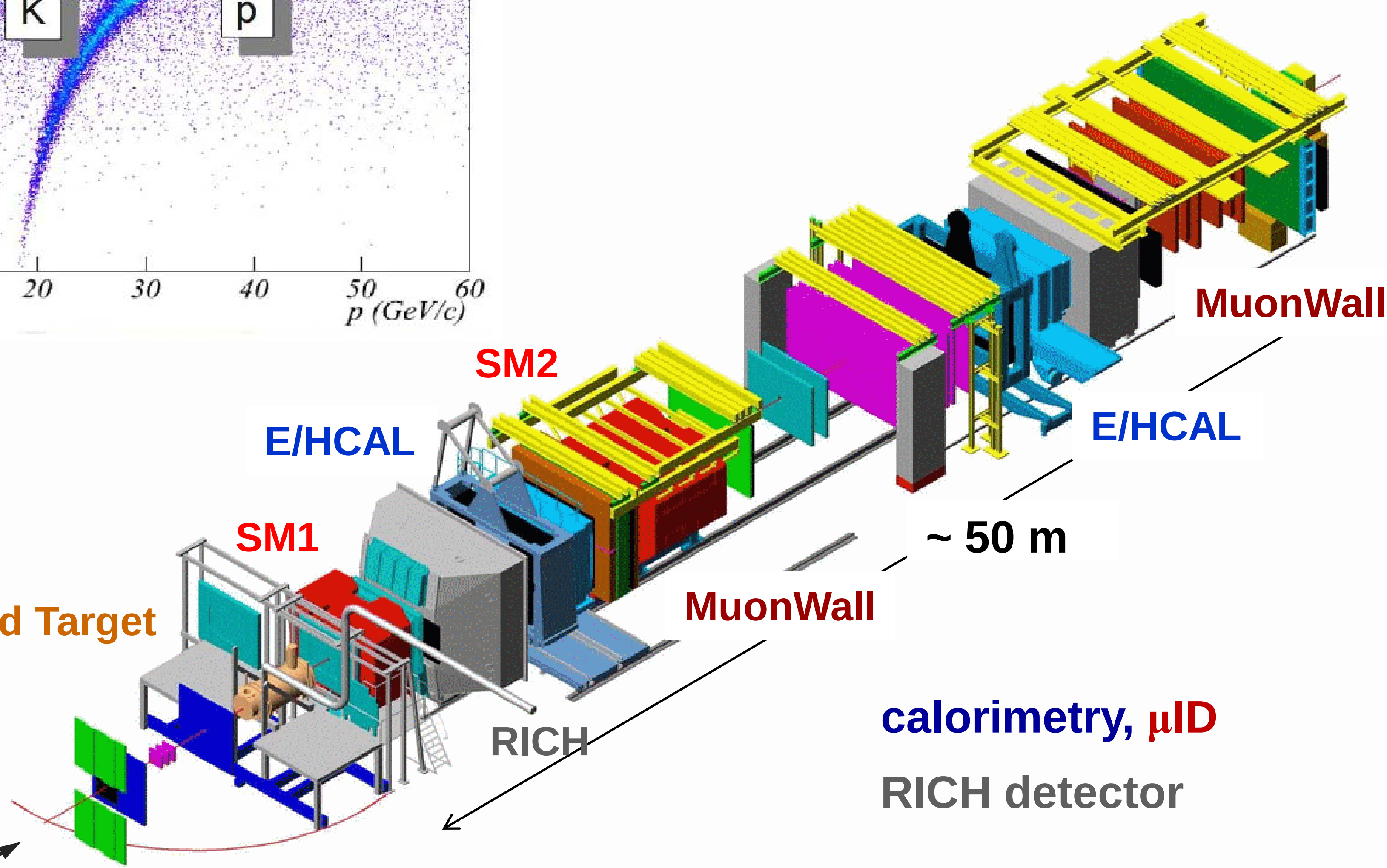


COMPASS spectrometer



two stages spectrometer

- Large Angle Spectrometer (SM1)
- Small Angle Spectrometer (SM2)



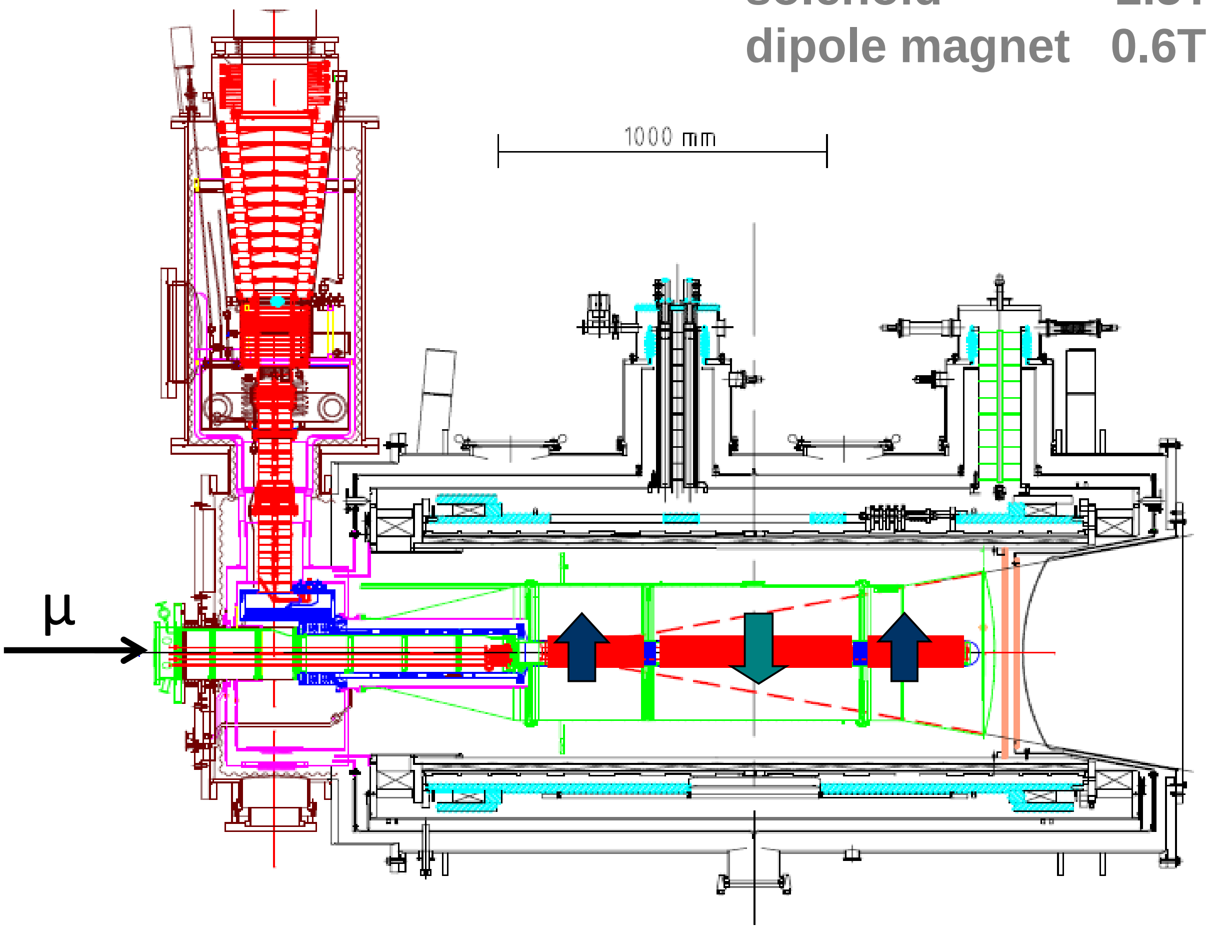
calorimetry, μID

RICH detector

the polarized target system (>2005)

^{3}He – ^{4}He dilution refrigerator (T~50mK)

solenoid 2.5T
dipole magnet 0.6T



acceptance > ± 180 mrad

3 target cells
30, 60, and 30 cm long

opposite polarisation

	d (^{6}LiD)	p (NH_3)
polarization	50%	90%
dilution factor	40%	16%

no evidence for relevant nuclear effects *(160 GeV)*

COMPASS data taking

muon beam 160 GeV	**deuteron (^{6}LiD) PT**	**2002** **2003** **2004**	**80% L target polarisation** **20% T**
		2005	acc. shut down / upgrade
		2006	**100% L**
	proton **(NH_3) PT**	**2007**	**50% L 50% T**
hadron beam	LH target	2008 2009	spectroscopy, Primakoff
muon beam 160,200 GeV	***proton*** **(NH_3) PT**	**2010** **2011**	**100% T** **100% L**

hadron beam	Ni target	2012	Primakoff
muon beam	LH_2 target	2012	Pilot DVCS
		2013	acc. shut down
pion beam	proton (NH_3) UT **proton (NH_3) PT**	2014 **2015**	Pilot Drell-Yan **100% T, Drell-Yan**
muon beam 160 GeV	LH_2 target	2016 2017	DVCS, unpol. SIDIS
pion beam	***proton (NH_3) PT***	***2018***	***100% T, Drell-Yan***

COMPASS data taking

muon beam 160 GeV	**deuteron (^{6}LiD) PT**	**2002 2003 2004**	**80% L target polarisation 20% T**
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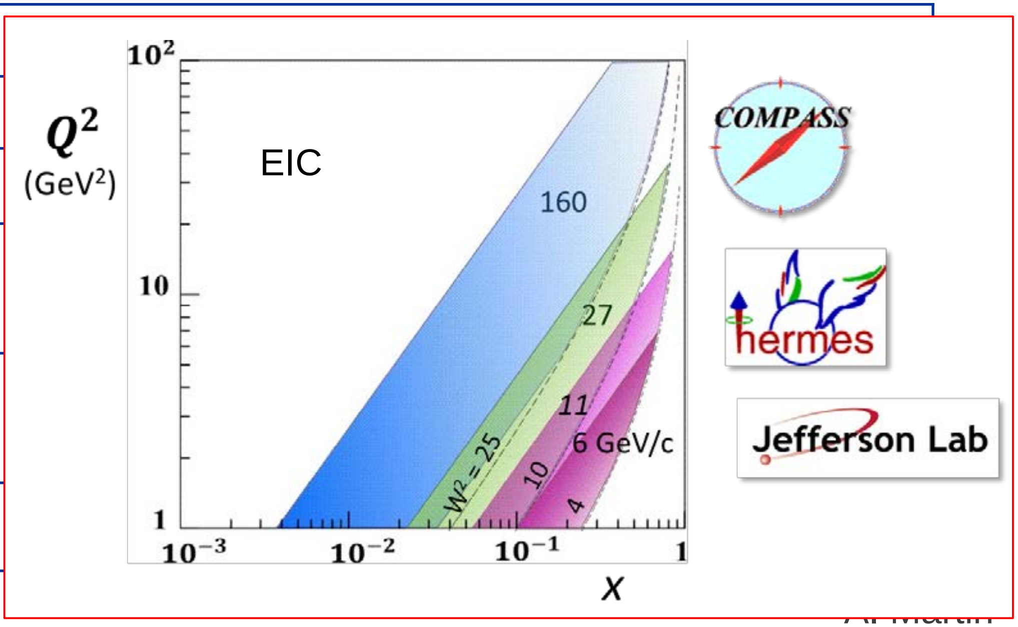
	***proton* (NH_3) PT**	**2007**	**50% L 50% T**
hadron beam	LH target	2008 2009	spectroscopy, Primakoff
muon beam 160,200 GeV	***proton* (NH_3) PT**	**2010**	**100% T**
		2011	**100% L**

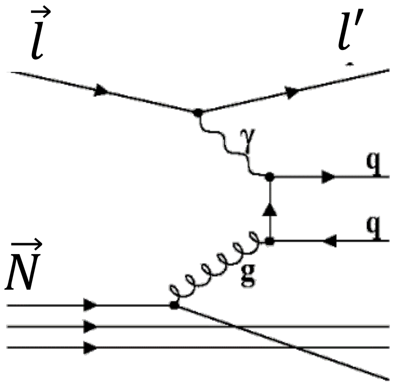
hadron beam	Ni target
muon beam	LH_2 target
pion beam	proton (NH_3) UT **proton (NH_3) PT**
muon beam 160 GeV	LH_2 target
pion beam	***proton (NH_3) PT***

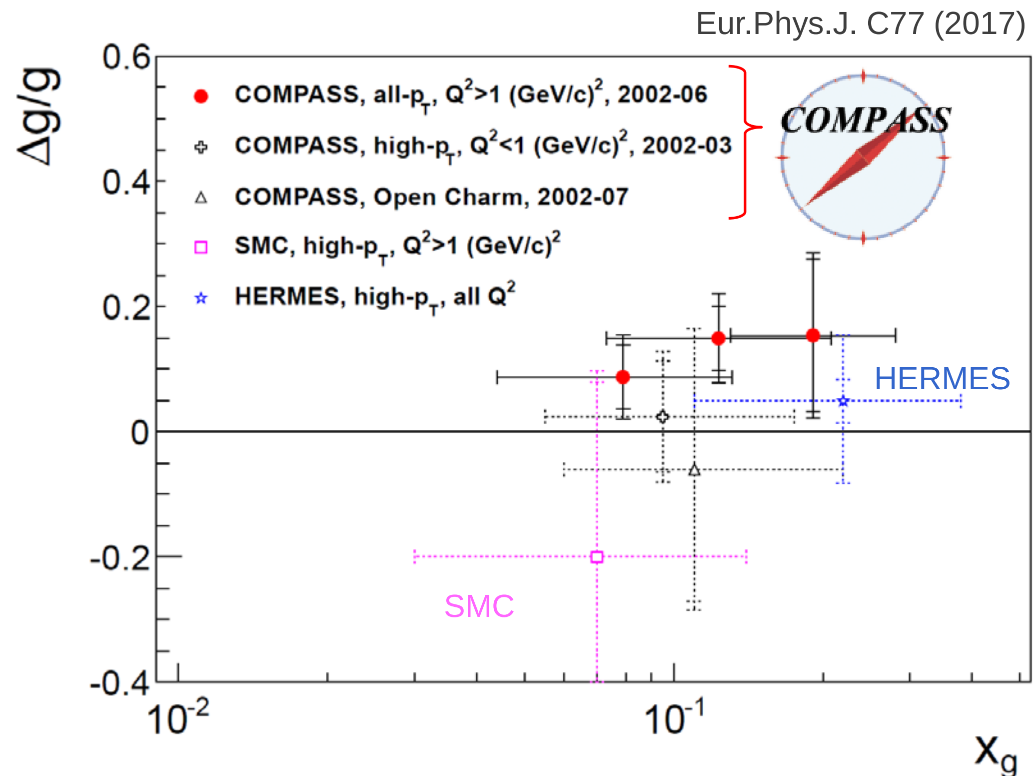


muon beam program:

LONGITUDINAL SPIN NUCLEON STRUCTURE

$\Delta g/g$ from Photon Gluon Fusion





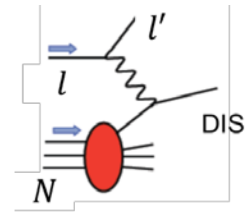
- open charm production
  $\gamma g \to c\,\bar{c} \to D^0, D^*$
- high p_T hadron pairs
  $\gamma g \to c\,\bar{c} \to 2\; jets\; or\; h^+\, h^-$

$$\Delta g/g^{LO} = 0.113 \pm 0.038_{stat} \pm 0.035_{syst}$$

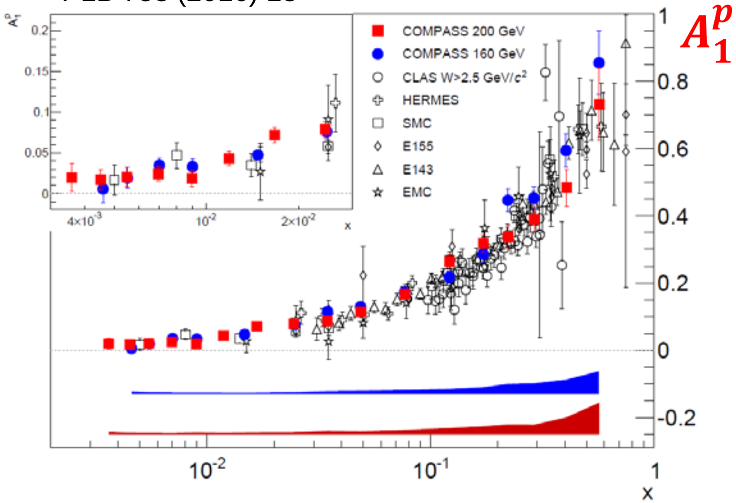
- gluon polarisation is much smaller than thought in the 1990s by many theorists
- various methods confirmed by polarised *pp* at RHIC $\quad \int_{0.05}^{1} \Delta g(x)dx \simeq 0.2$
- Δg still can make a substantial contribution to nucleon spin

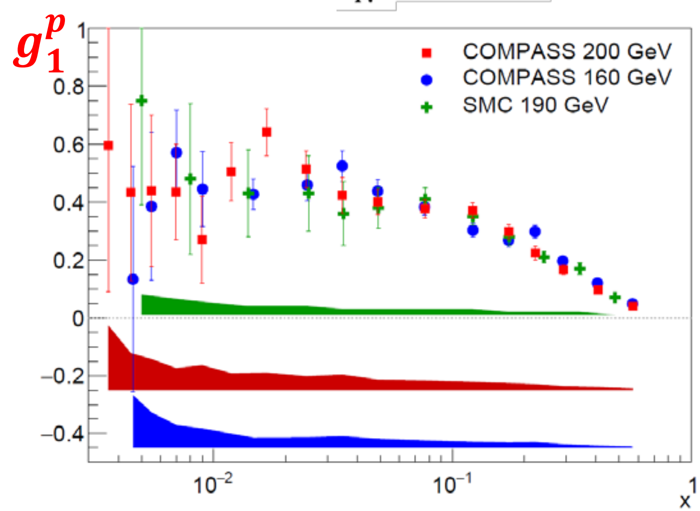
$g_1(x)$

$$A_{meas} = \frac{1}{f P_T P_B}\left(\frac{N^{\leftrightarrows} - N^{\leftleftarrows}}{N^{\leftrightarrows} + N^{\leftleftarrows}}\right) \approx D A_1 = D\,\frac{g_1(x,Q^2)}{F_1(x,Q^2)}$$

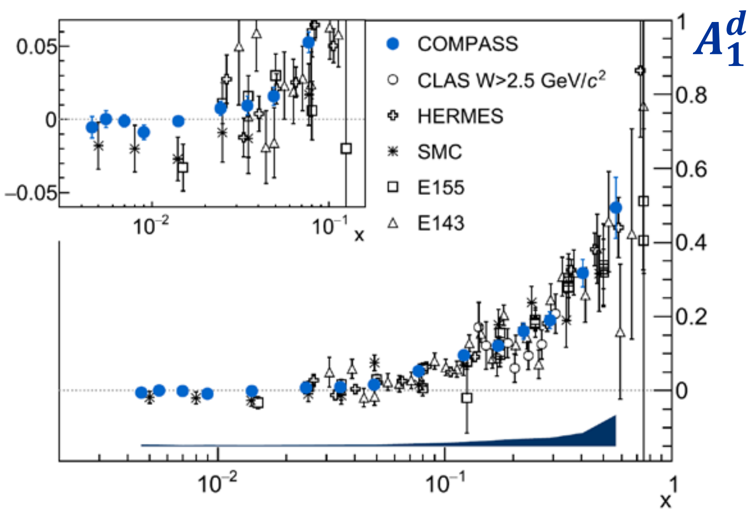


PLB 753 (2016) 18





Bjorken sum rule verified to 9%



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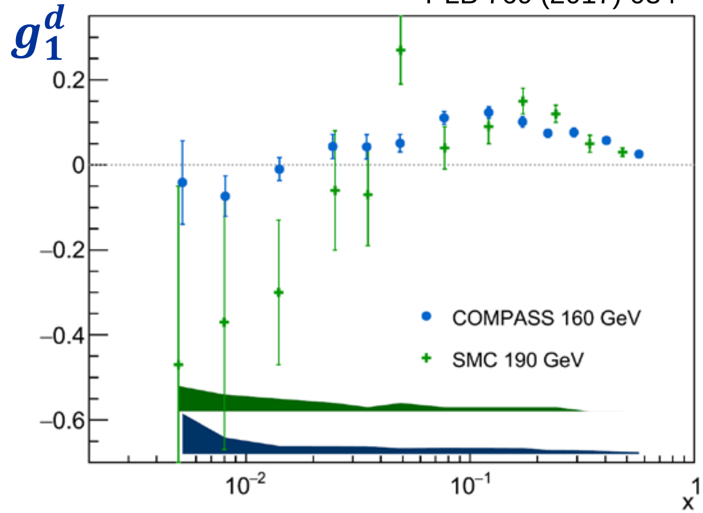
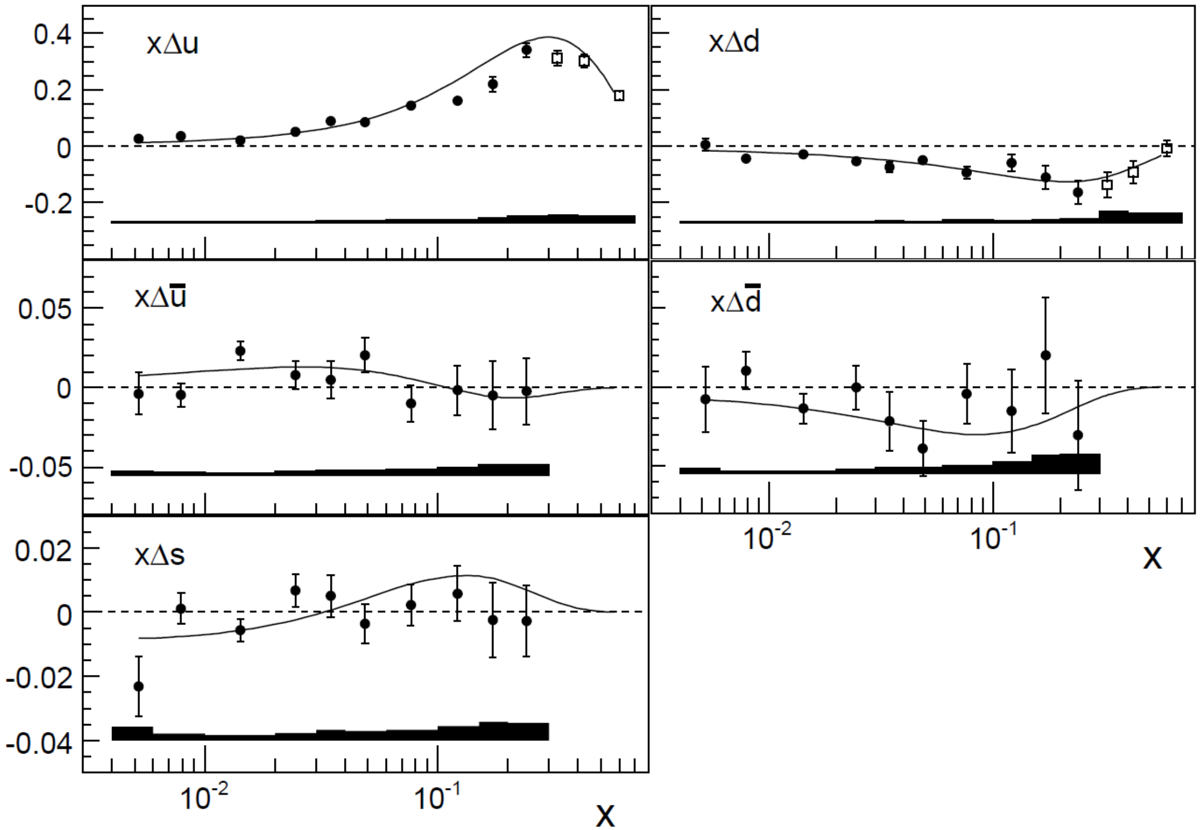
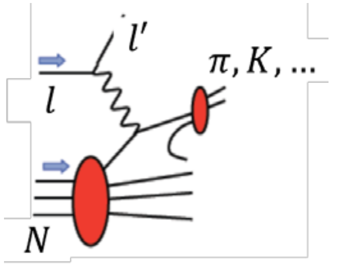


Helicity



$A_1^d, A_{1d}^{K^\pm}, A_{1d}^{\pi^\pm}$

$A_1^p, A_{1p}^{K^\pm}, A_{1p}^{\pi^\pm}$



$\Delta\mathrm{u}, \Delta\bar{\mathrm{u}}, \Delta\mathrm{d}, \Delta\bar{\mathrm{d}}, \Delta\mathrm{s} = \Delta\bar{\mathrm{s}}$

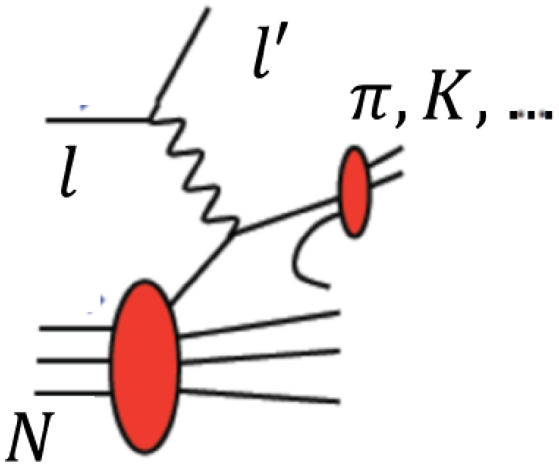
input:
unpol PDFs (MRST04),
LO FFs (DSS)

curves:DSSV param.

$\Delta s > 0$?

results for Δs depend very much on the strange quark FFs used

hadron multiplicities



unpolarased SIDIS

factorisation ansatz

$$\sigma^h \sim \sum \sigma_{hard} \otimes \mathrm{PDF} \otimes FF$$

$$q(x,Q^2) \qquad D_q^h(z,Q^2)$$

hadron multiplicities

$$\frac{dM^h(x,z,Q^2)}{dz} = \frac{d\sigma^h(x,z,Q^2)/dxdzdQ^2}{d\sigma^{DIS}(x,Q^2)/dxdQ^2}$$

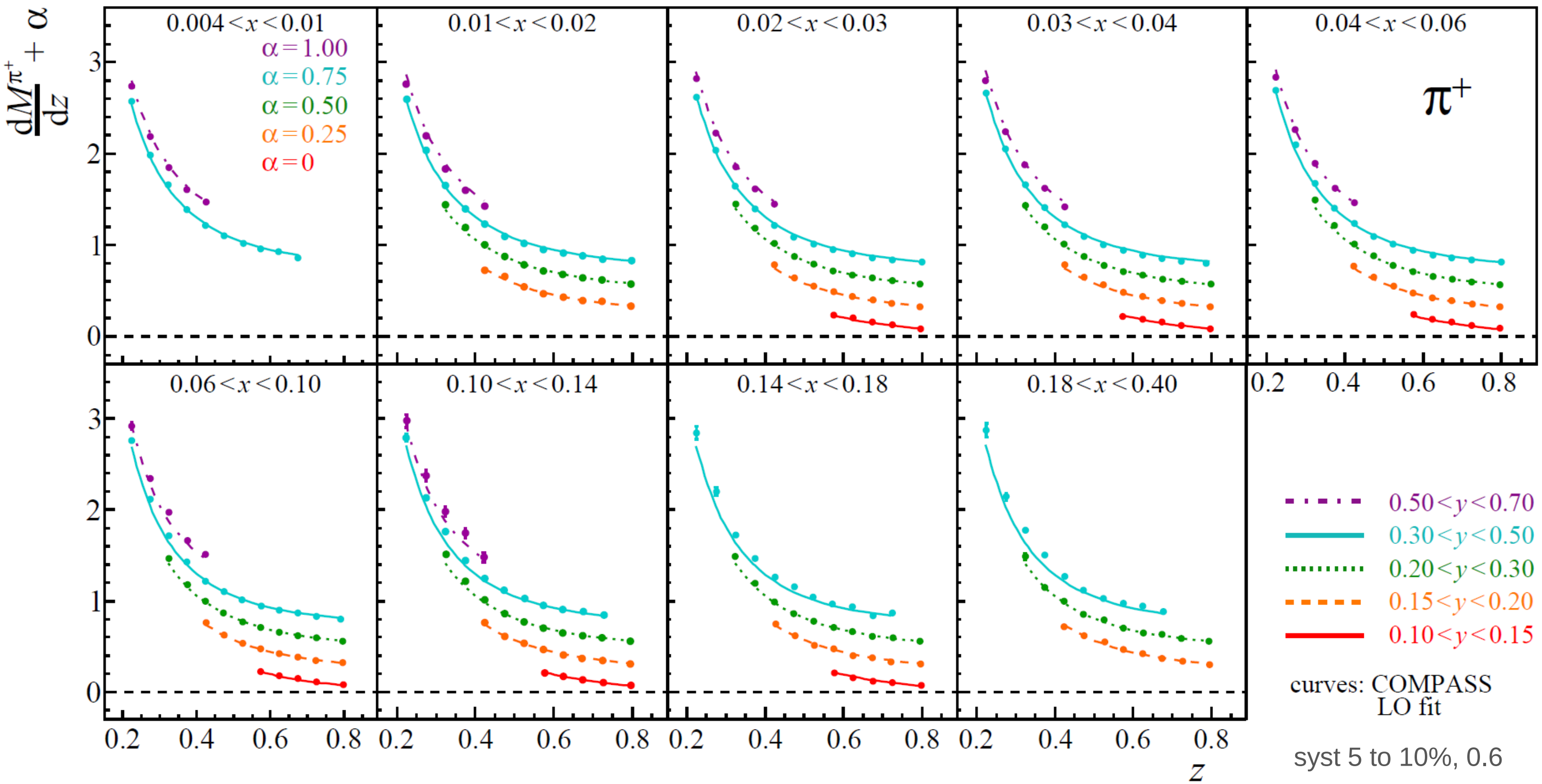
at LO pQCD

$$\frac{dM^h(x,z,Q^2)}{dz} = \frac{\sum_q e_q^2 q(x,Q^2) D_q^h(z,Q^2)}{\sum_q e_q^2 q(x,Q^2)}$$

charged pion multiplicities

160 GeV μ, unpolarised ^{6}LiD

1 (GeV/c)^2 < Q^2 <60 (GeV/c)^2, 0.004< x < 0.4,
0.1 < y < 0.7, W >5 GeV/c^2, 0.20 < z < 0.85



PLB 764 (2017) 001

syst 5 to 10%, 0.6

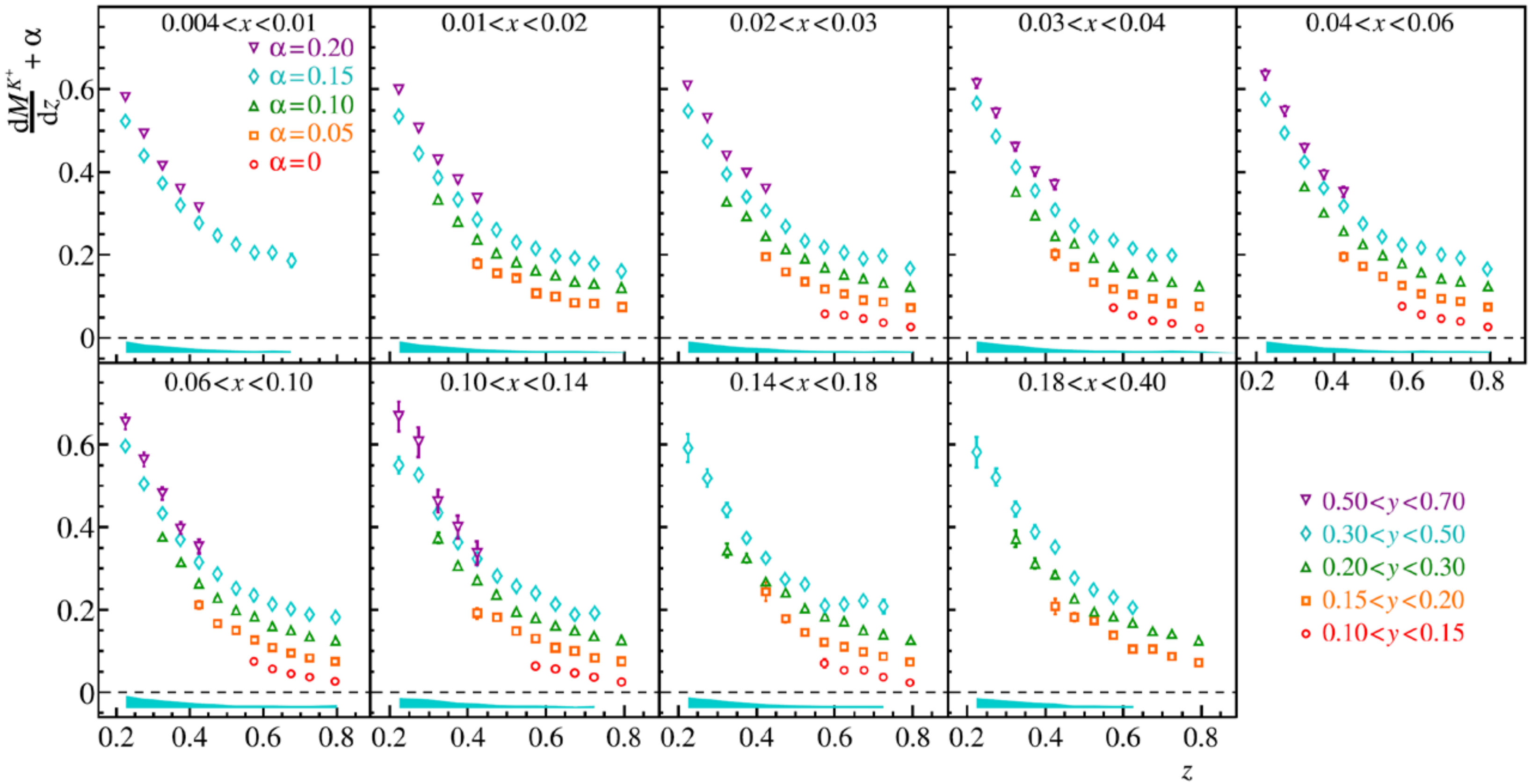
317 (x,y,z) kinematic bins

strong z dependence, ~ no dependence on y

charged kaon multiplicities

160 GeV μ, unpolarised ^{6}LiD

1 $(\mathrm{GeV}/c)^2 < Q^2 < 60\ (\mathrm{GeV}/c)^2$, 0.004< x < 0.4, 0.1 < y < 0.7, W >5 GeV/c^2, 0.20 < z < 0.85



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more than 620 data points

strong z dependence, week x dependence

MUON beam PROGRAM:

TRANSVERSITY and TMD PDFs

the structure of the nucleon

taking into account the quark intrinsic transverse momentum k_T,
at leading order other 6 TMD PDFs are needed for a full description of the nucleon structure

transversity PDF

correlation between the transverse polarisation of the nucleon and the transverse polarisation of the quark

collinear

chiral odd

Sivers PDF

sensitive to orbital angular momentum

Boer-Mulders PDF

T-odd

change of sign

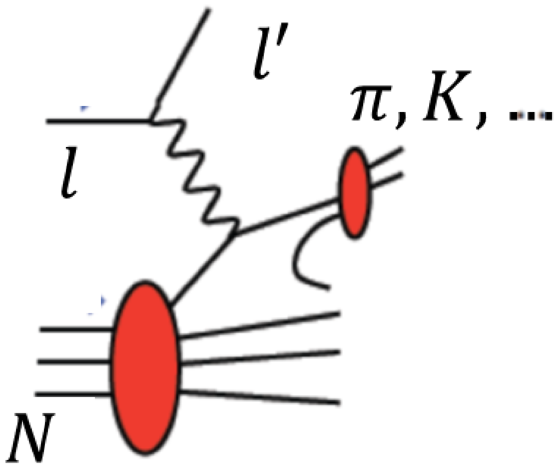
nucleon polarisation

quark 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* $h_{1T}^{\perp}$	$\Delta_T q$

SIDIS gives access to all of them

Semi-Inclusive Deep Inelastic Scattering

hard interaction of a lepton with a nucleon via virtual photon exchange

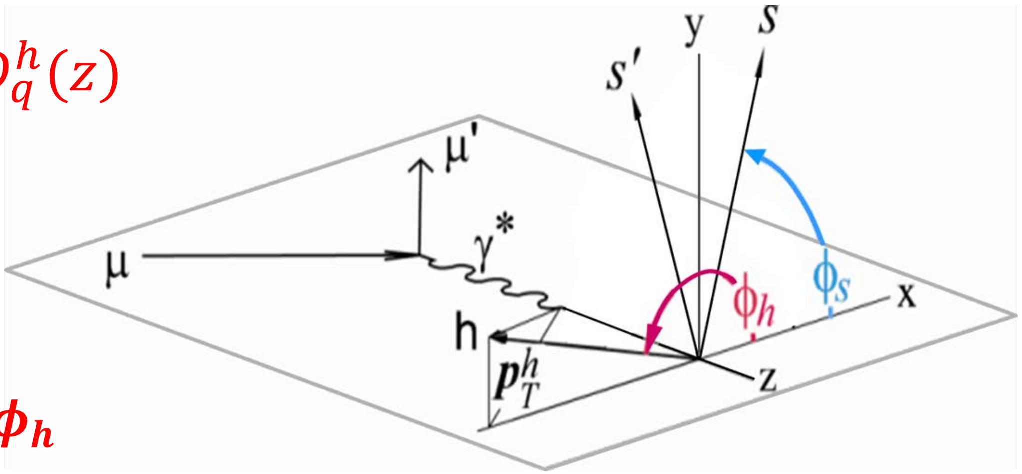


$$x = \frac{Q^2}{2P \cdot q} \qquad y = \frac{P \cdot q}{P \cdot \ell} =_{LAB} \frac{E - E'}{E}$$

$$Q^2 = -q^2 \qquad W^2 = (P + q)^2$$

$$z = \frac{P \cdot P_h}{P \cdot q} =_{LAB} \frac{E_h}{E - E'}$$

$$\sigma^{lN \to lhX} \sim \sum_q \sigma^{lq \to lq} \otimes f(x) \otimes D_q^h(z)$$



$\boldsymbol{p_T^h}$, $\boldsymbol{\phi_h}$

Semi-Inclusive Deep Inelastic Scattering

14 independent azimuthal modulations

amplitudes of the modulations
→ transversity and TMD PDFs

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

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

$h_1^\perp H_1^\perp$

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

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

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

$f_{1T}^\perp D_1$

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

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

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

$h_1 H_1^\perp$

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

$g_{1T} D_1$

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

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

Semi-Inclusive Deep Inelastic Scattering

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

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

$h_1^\perp H_1^\perp$

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

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

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

$f_{1T}^\perp D_1$

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

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

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

$h_1 H_1^\perp$

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

$g_{1T} D_1$

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

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

14 independent azimuthal modulations

amplitudes of the modulations
→ transversity and TMD PDFs

SIDIS

- **allows to disentangle the effects related to the different TMD PDFs and to access all of them**
- **by identifying the final state hadrons and using different targets allows for flavour separation**

→ ***very powerful tool***

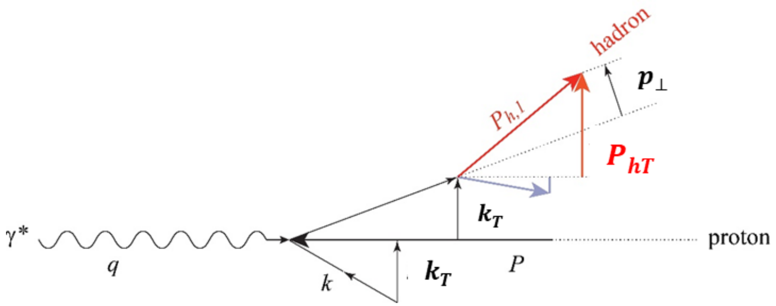
all the amplitudes (AA) have been measured in COMPASS on p and d

unpolarised SIDIS

relevance for TMDs:

- the cross-section depends on $\boldsymbol{P_{hT}}$ comes from:
  - intrinsic k_T of the quarks
  - $p_\perp$ generated in the quark fragmentation

$$\langle \boldsymbol{P_{hT}^2} \rangle = \langle \boldsymbol{p_\perp^2} \rangle + \boldsymbol{z^2} \langle \boldsymbol{k_T^2} \rangle$$



- the azimuthal modulations in the unpolarized cross-sections comes from:
  - intrinsic k_T of the quarks
  - Boer-Mulders PDF

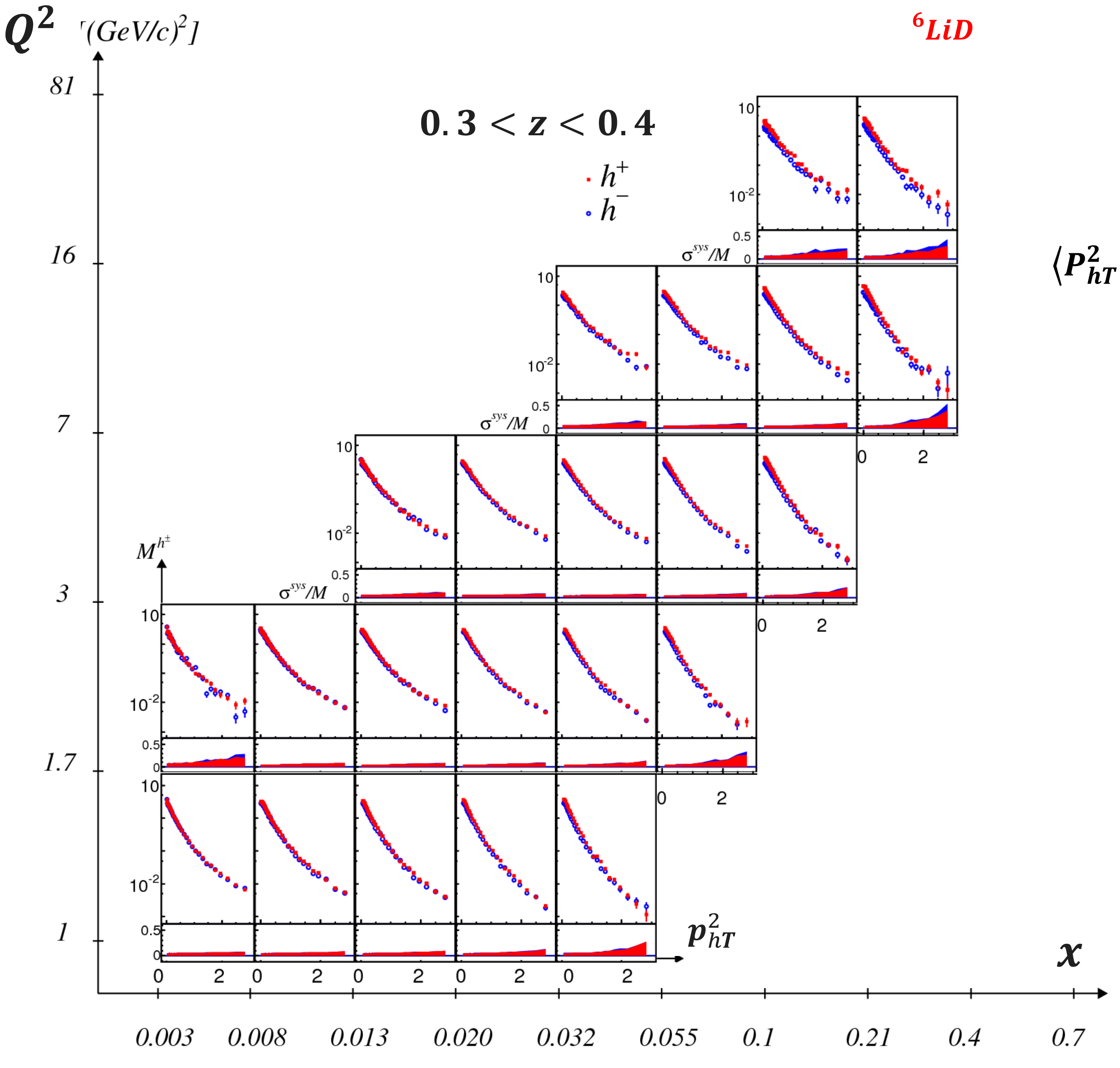
combined analysis should allow to disentangle the different effects phenomenological work is ongoing
the Boer-Mulders PDF is still unknown

COMPASS has published results on

- azimuthal asymmetries and $\boldsymbol{P_{hT}}$ distributions from 2004 ^6LiD data
- $\boldsymbol{P_{hT}}$ distributions from 2006 ^6LiD data NEW

and more results will come from 2016/17 data on LH_2

unpolarised SIDIS – P_{hT} distributions

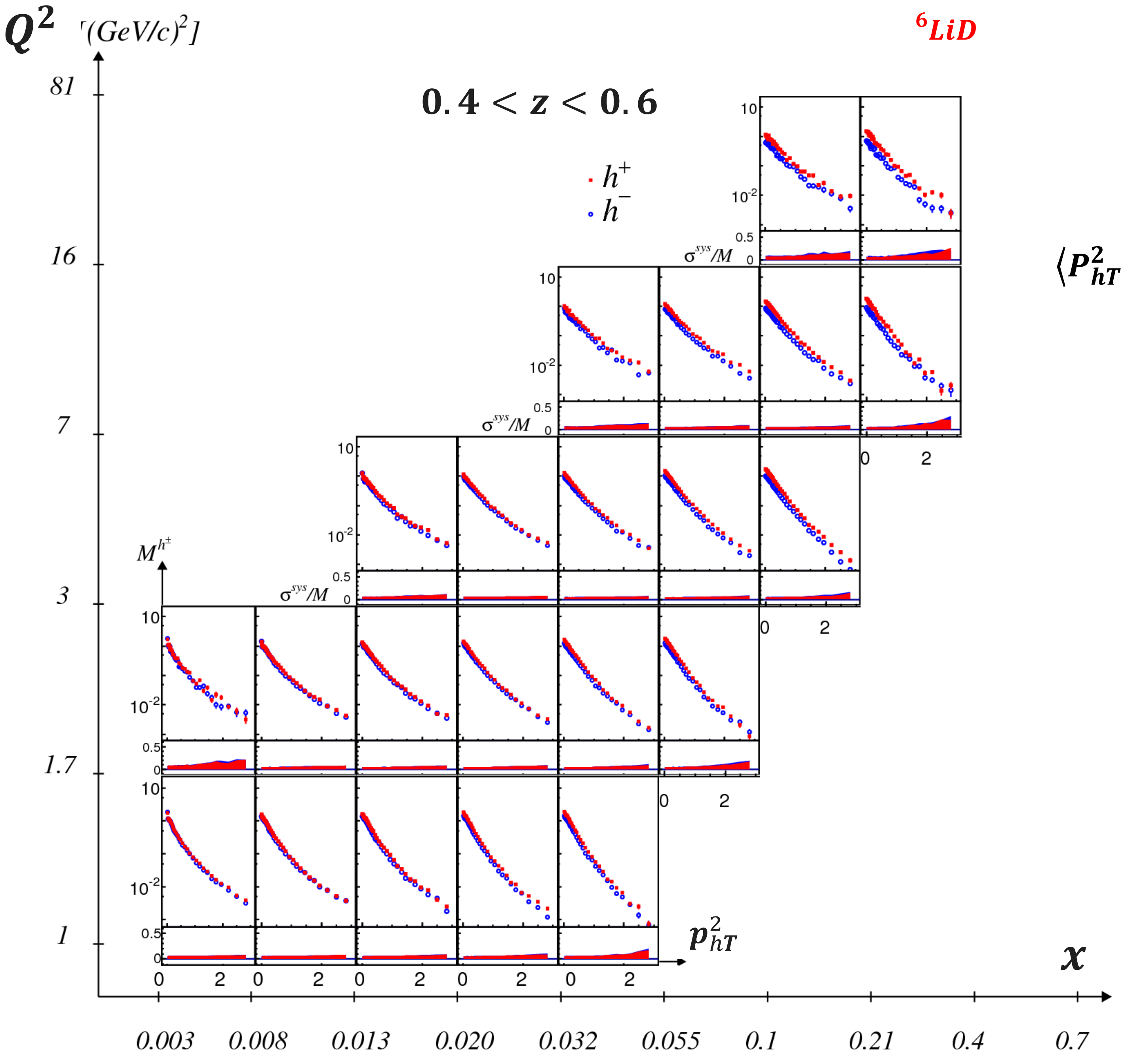


$$\langle P_{hT}^2 \rangle = \langle p_\perp^2 \rangle + z^2 \langle k_T^2 \rangle$$

NEW:
2006 data
hep-ex/1709.0737
acc. PRD

A. Martin

unpolarised SIDIS – P_{hT} distributions



$$\langle P_{hT}^2 \rangle = \langle p_\perp^2 \rangle + z^2 \langle k_T^2 \rangle$$

total:
4918 data points

NEW:
2006 data
hep-ex/1709.0737
acc. PRD

some results from
SIDIS off transversely polarised targets

TRANSVERSITY and TMD PDFs

Semi-Inclusive Deep Inelastic Scattering

MAJOR RESULT:

since 2004 two of these new PDF's have been measured and shown to be different from zero

by COMPASS and HERMES

the transversity PDF amplitude of the sine modulation in $\phi_h + \phi_s - \pi$

Collins asymmetry $\sim h_1 \otimes H_1^{\perp}$

the Sivers PDF amplitude of the sine modulation in $\phi_h - \phi_s$

Sivers asymmetry $\sim f_{1T}^{\perp} \otimes D_1$

A STEP TOWARDS
THE 3-D STRUCTURE OF THE NUCLEON

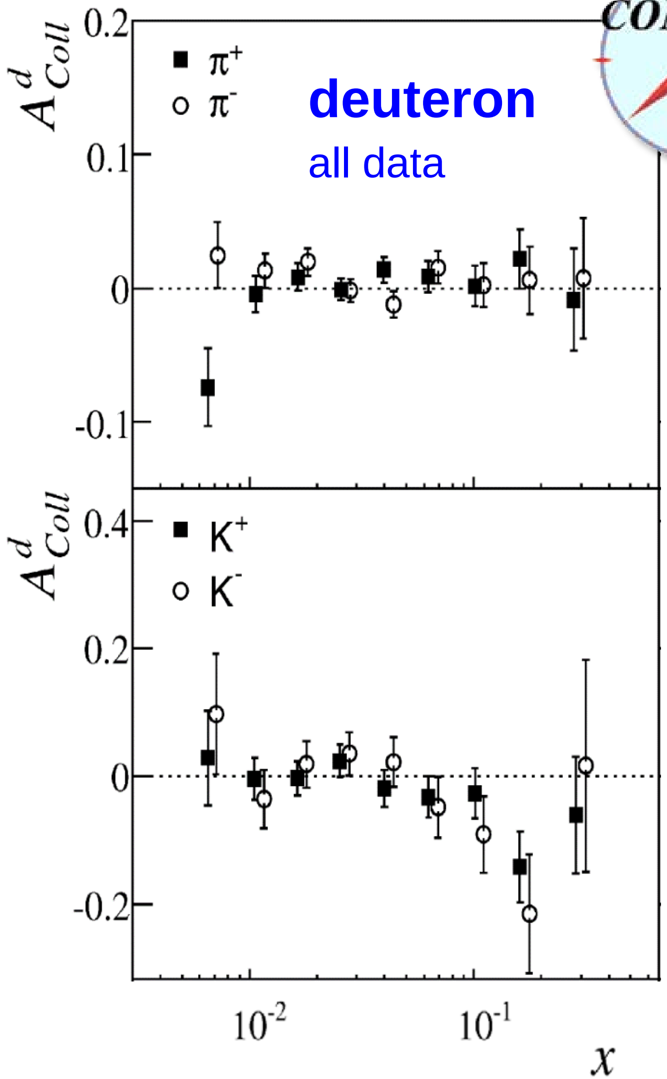
TRANSVERSITY PDFs

Collins asymmetry

$\sim\; h_1 \otimes H_1^{\perp}$

2004: first evidence for non-zero Collins asymmetry on p from HERMES

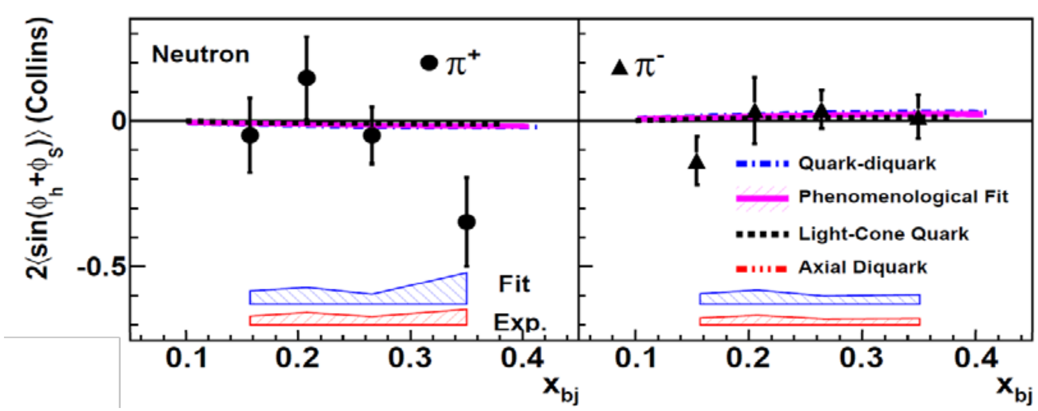
COMPASS results



PRL94 2005
NPB765 2007
PLB673 2009

neutron

Hall A PRL107, 2011

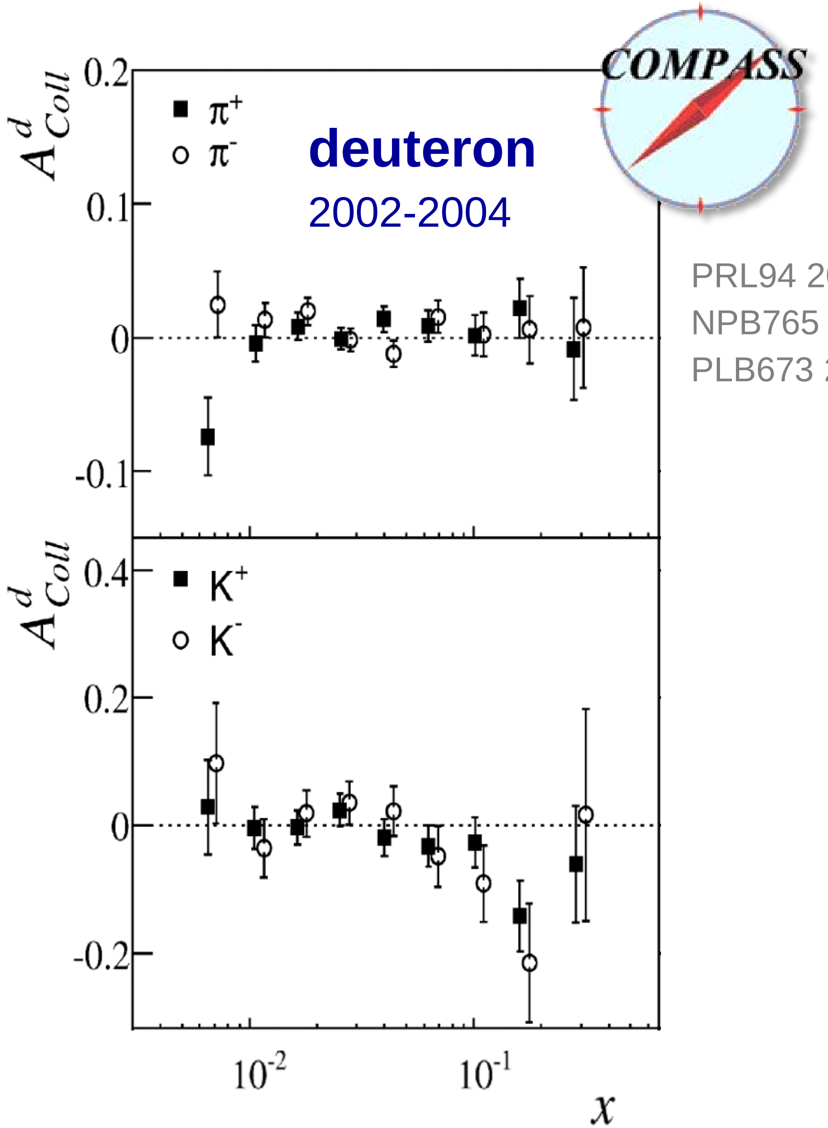


Collins asymmetry

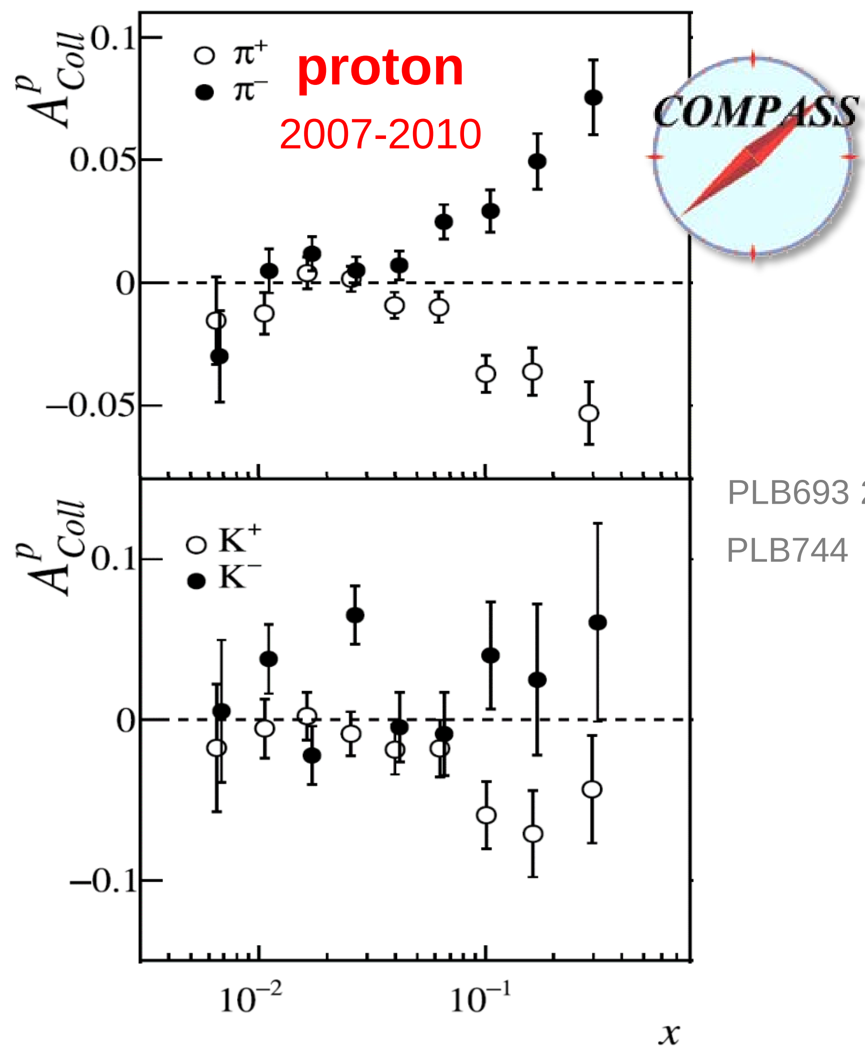
$\sim h_1 \otimes H_1^{\perp}$

2004: first evidence for non-zero Collins asymmetry on p from HERMES

COMPASS results



PRL94 2005
NPB765 2007
PLB673 2009

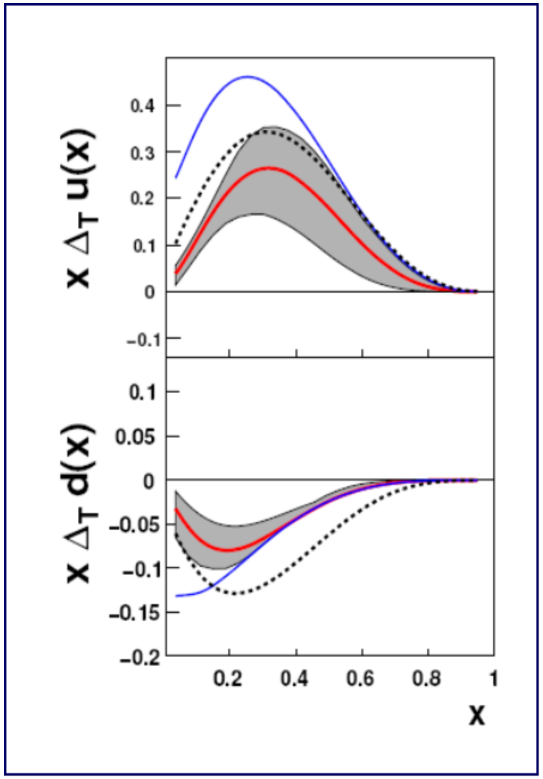


PLB693 2010
PLB744 2015

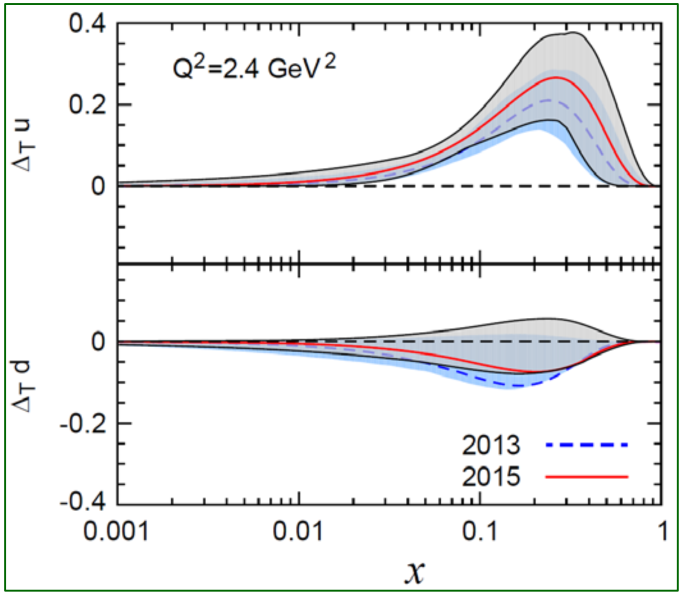
transversity from SIDIS

M. Anselmino et al., Nucl. Phys. Proc. Suppl. 2009

fit to HERMES p, COMPASS d, Belle e+e- data



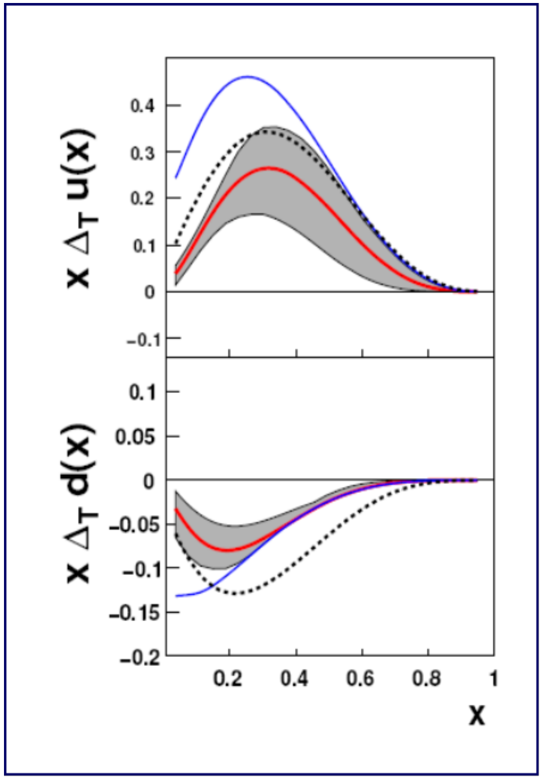
M. Anselmino et al.,
PRD 2015

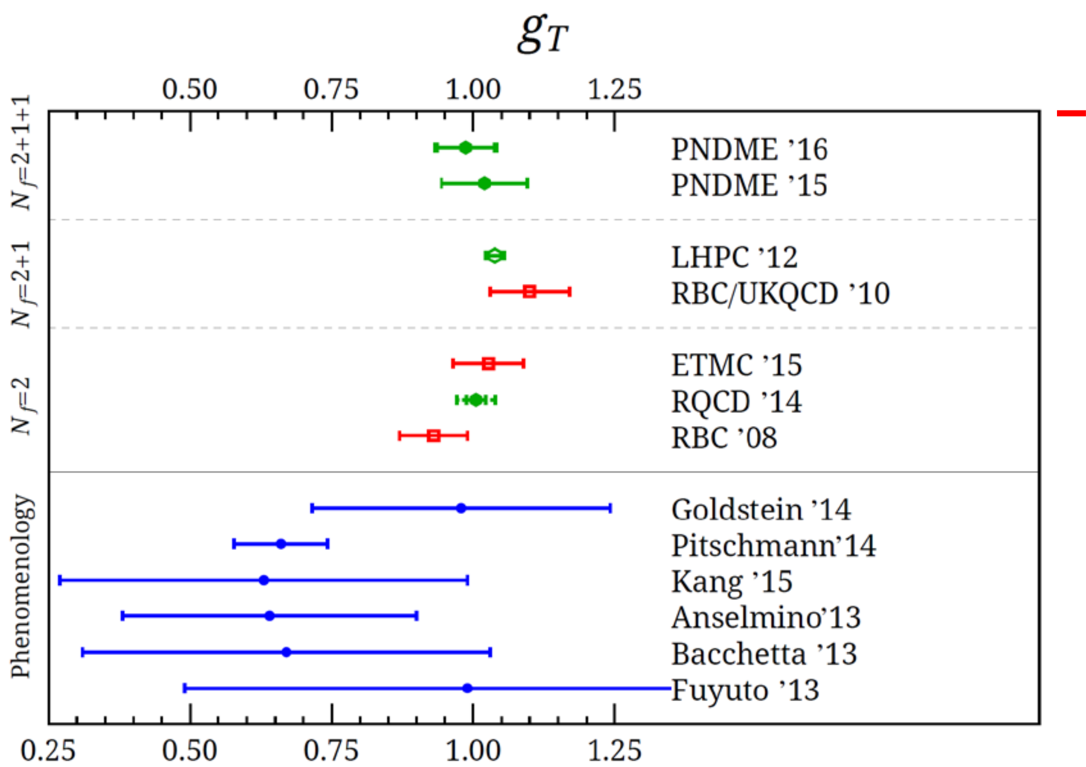


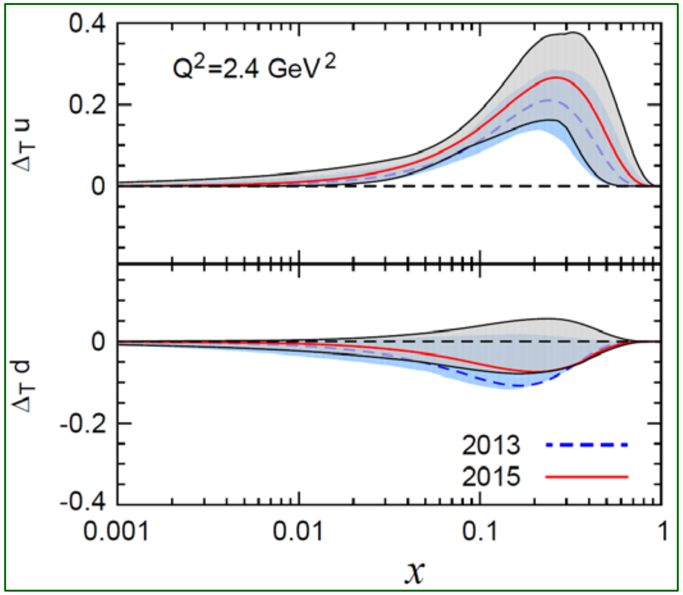
transversity from SIDIS

M. Anselmino et al., Nucl. Phys. Proc. Suppl. :

fit to HERMES p, COMPASS d, Belle e







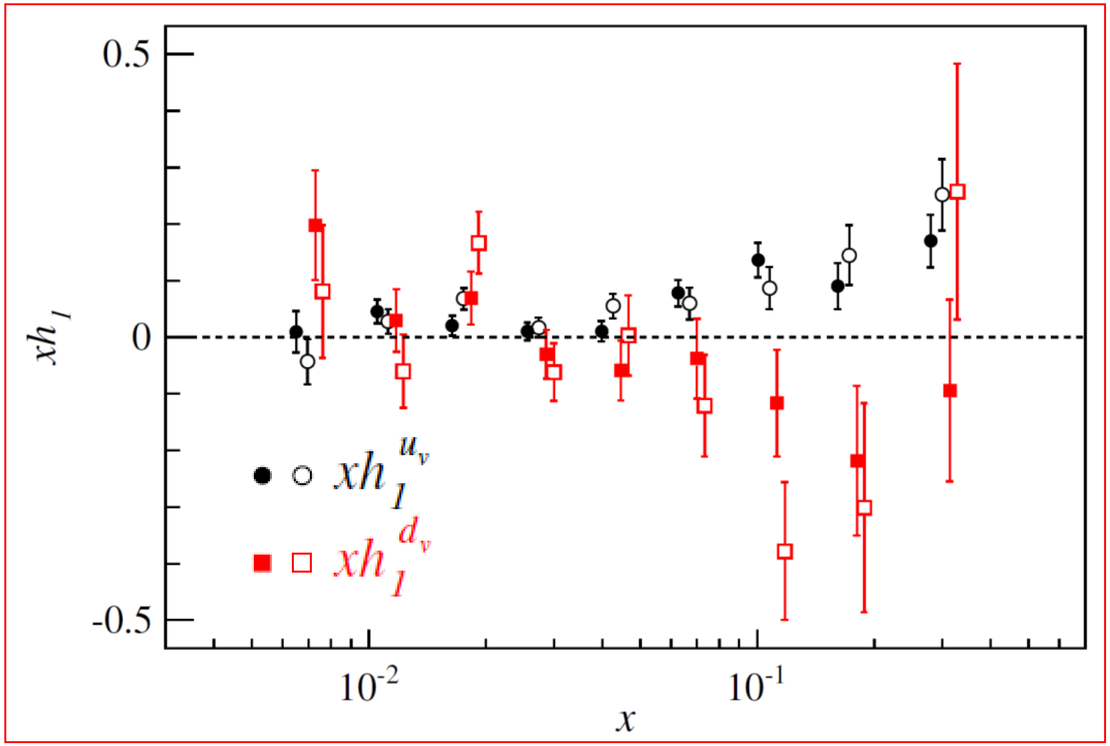
M. Anselmino et al., PRD 2015

Transversity from Collins and di-hadron asymmetries

point by point extraction

one can use directly the COMPASS p and d asymmetries,
and the Belle data to evaluate the analysing power
(with some "reasonable" assumption)

advantage: no Monte Carlo
nor parametrisation is needed



open points: dihadron

closed points: Collins

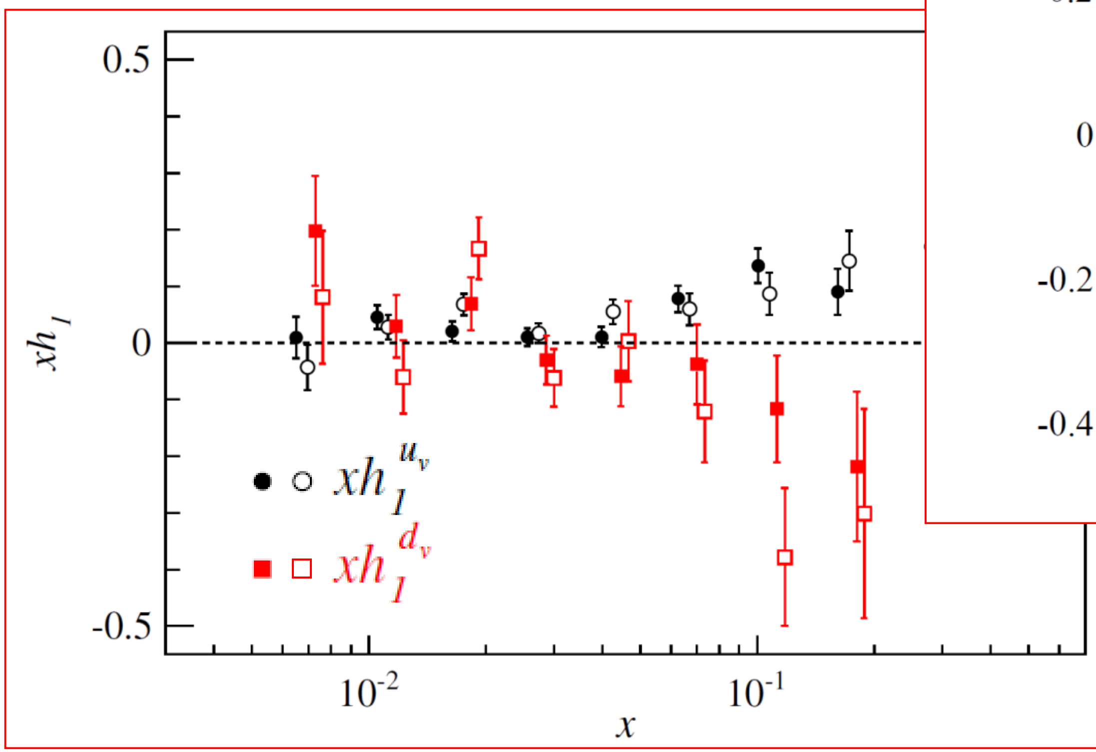
A.M., F. Bradamante, V. Barone
PRD 2015

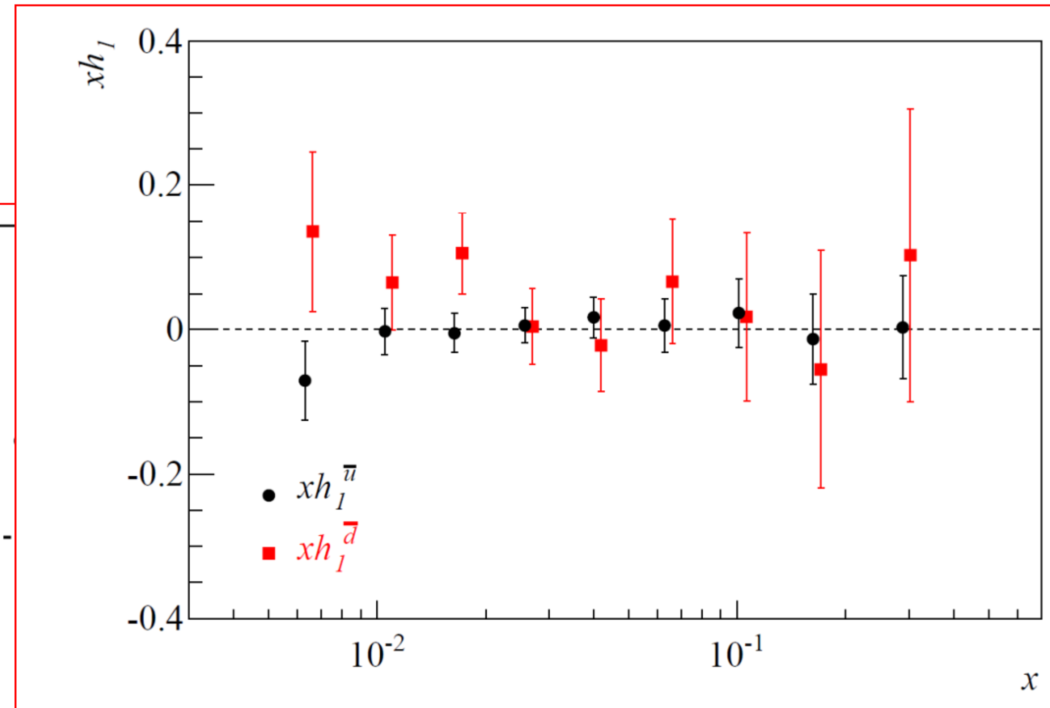
Transversity from Collins and di-hadron asymmetries

point by point extraction

one can use directly the COMPASS p and d asymmetries,
and the Belle data to evaluate the analysing power
(with some “reasonable” assumption)

advantage: no Monte Carlo
nor parametrisation is needed





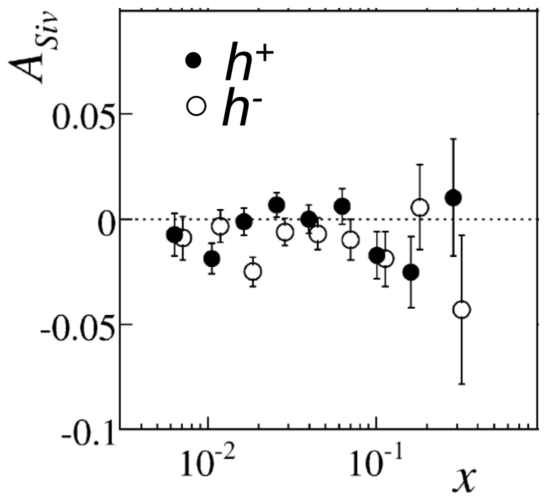
A.M., F. Bradamante, V. Barone
PRD 2015

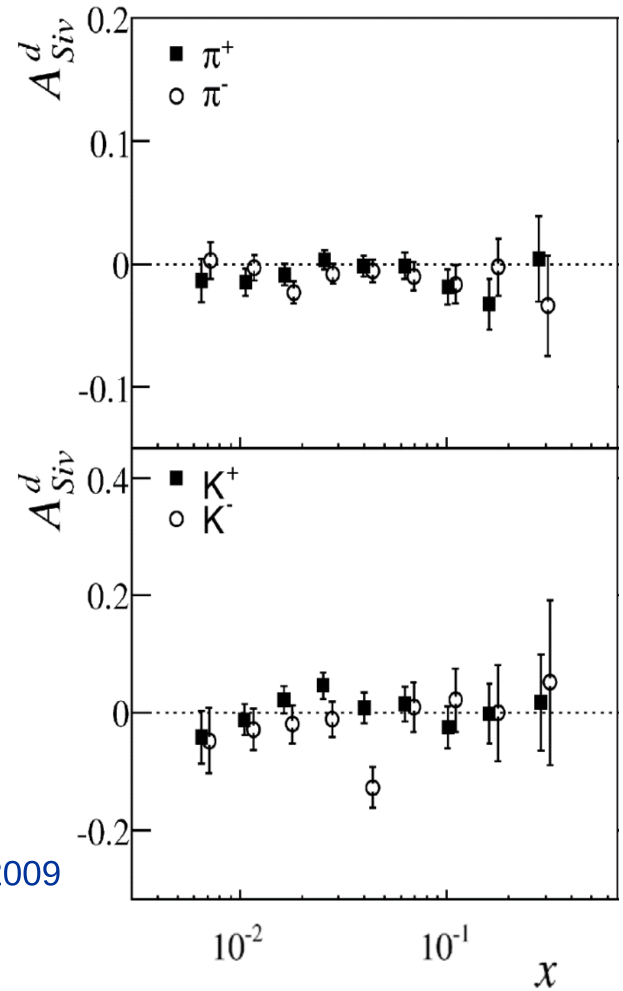
Sivers function

Sivers asymmetry

$$A_{Siv} \sim \frac{\sum_q e_q^2 \, f_{1T}^{\perp\, q} \otimes D_{1q}}{\sum_q e_q^2 \, f_1^q \cdot D_{1q}}$$

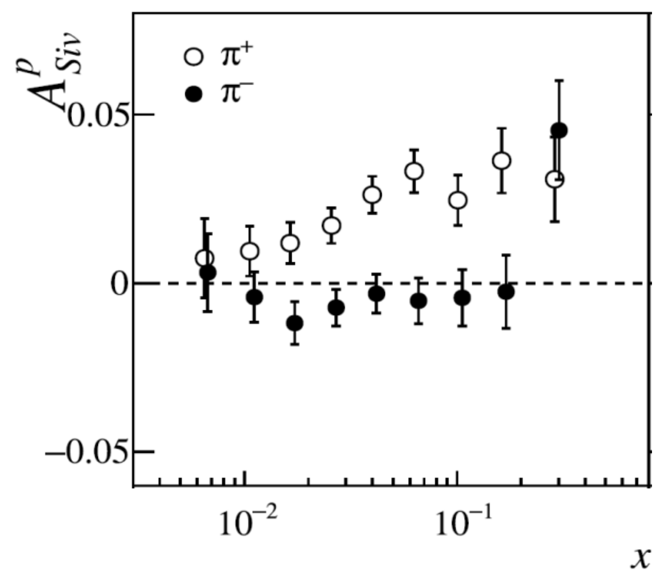
deuteron





2002-2004 data
NPB765 2007, PLB673 2009

proton



clearly positive for π^+
down to $x \sim 10^{-2}$
slightly lower than
HERMES results

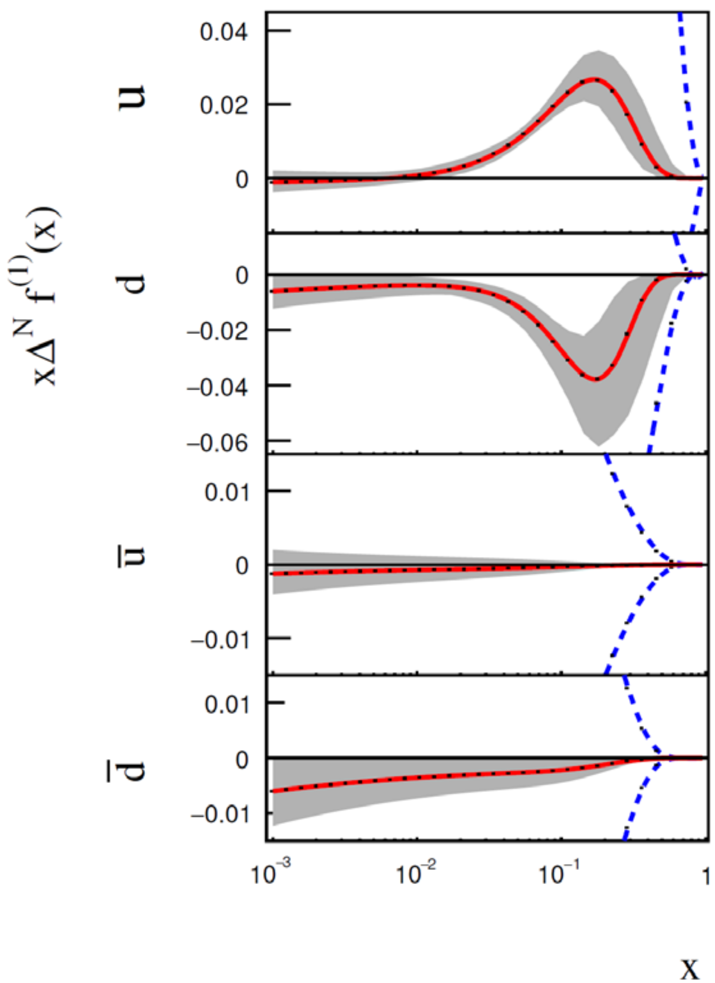
PLB 2010, 2012

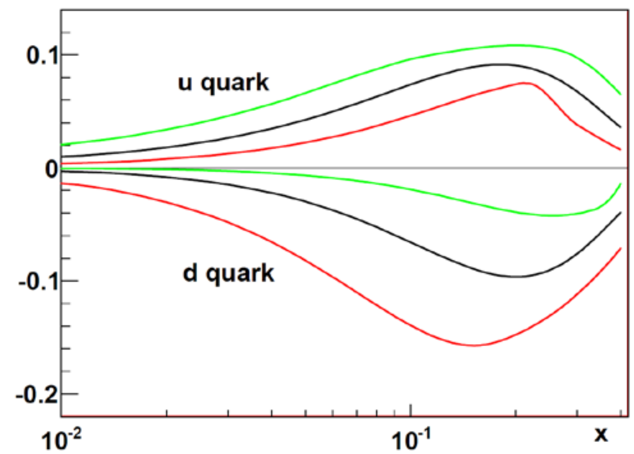
Sivers function

$$A_{Siv} \sim \frac{\sum_q e_q^2\, f_{1T}^{\perp\,q} \otimes D_{1q}}{\sum_q e_q^2\, f_1^q \cdot D_{1q}}$$

fits to COMPASS and HERMES data since 2005

Anselmino et al., JHEP04 **2017**

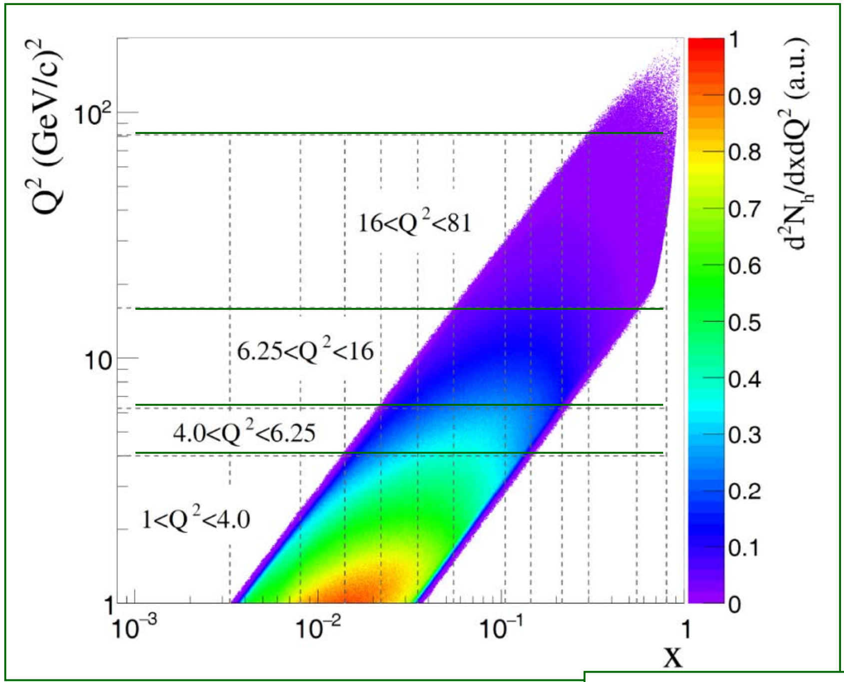




Sun and Yuan
PRD88 **2013**

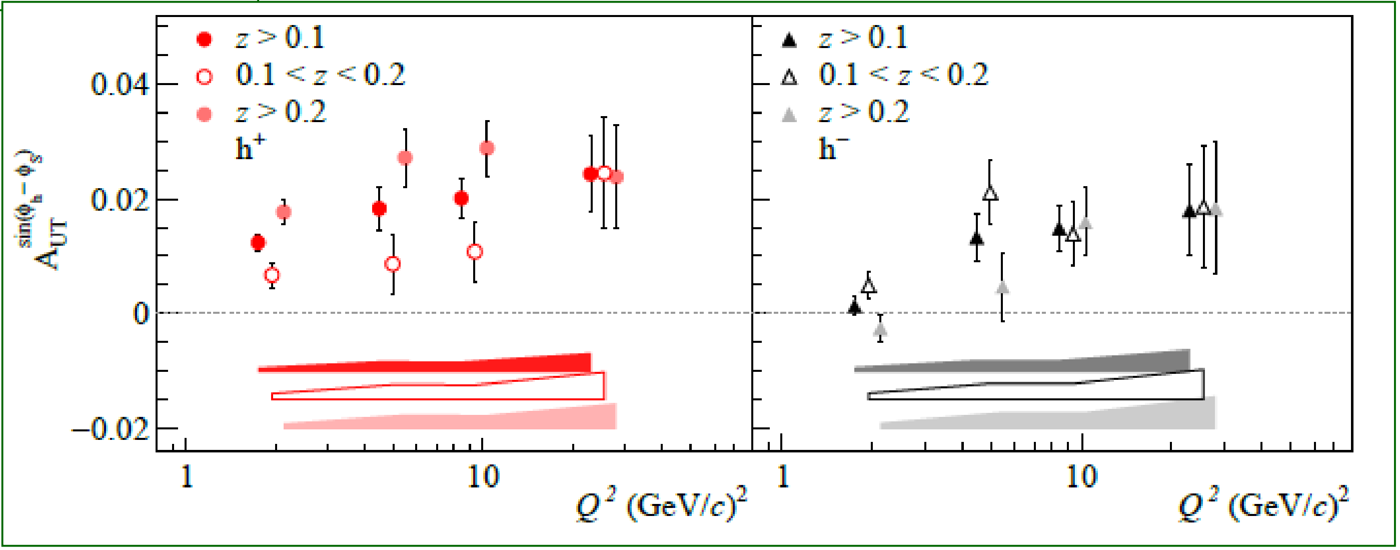
large uncertainties, in particular for the d-quark

Sivers asymmetry on **proton**



Drell-Yan Q^2 range at COMPASS
no evolution SIDIS → DY

PBL770 2017



clearly positive test of change of sign feasible

the weighted Sivers asymmetry

$$A_{Siv} \propto \frac{\sum_q e_q^2 \cdot f_{1T}^{\perp q} \otimes D_{1q}^h}{\sum_q e_q^2 \cdot f_1^q \cdot D_{1q}^h}$$

convolution

→ non negligible uncertainties in extractions

$\vec{k}_T$!

a possible way out: use of the P_T weighted asymmetries

obtained by weighting the spin dependent part of the cross-section

$$w = P_T / zM \qquad A_{Siv}^w = \frac{\sigma_S^w}{\sigma_U} = 2\frac{\sum_q e_q^2 \cdot f_{1T}^{\perp(1)q} \cdot D_{1q}^h}{\sum_q e_q^2 \cdot f_1^q \cdot D_{1q}^h}$$

easier to extract $f_{1T}^{\perp(1)q}$

proposed a long time ago …

A. Kotzinian and P. J. Mulders, PLB 406 (1997) 373
D. Boer and P. J. Mulders, PRD 57 (1998) 5780
J. C. Collins et al. PRD 73 (2006) 014021

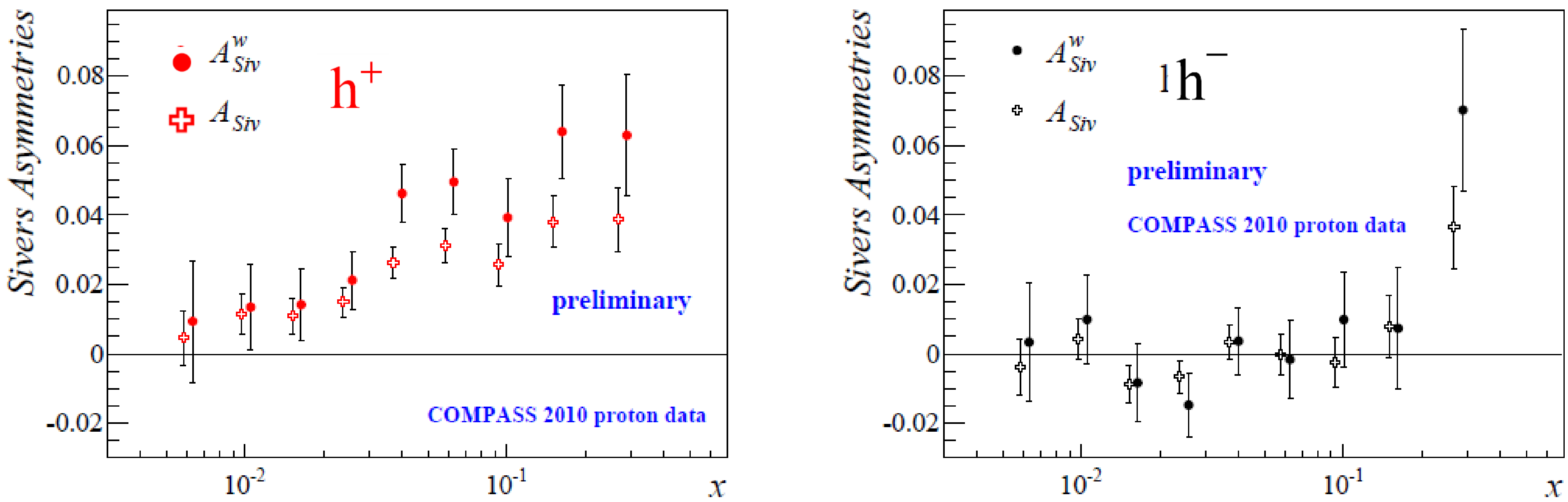
reconsidered recently

Zhong-Bo Kang et al., Phys.Rev. D87 (2013)
….

preliminary results by HERMES in 2005

the weighted Sivers asymmetry

$$A^{w}_{Siv}(x) = 2\frac{\sum_q e_q^2 x f_{1T}^{\perp(1)q}(x) \int D_{1q}(z)dz}{\sum_q e_q^2 x f_1^q(x) \int D_{1q}(z)dz} \qquad w = P_T/zM$$



u-dominance:

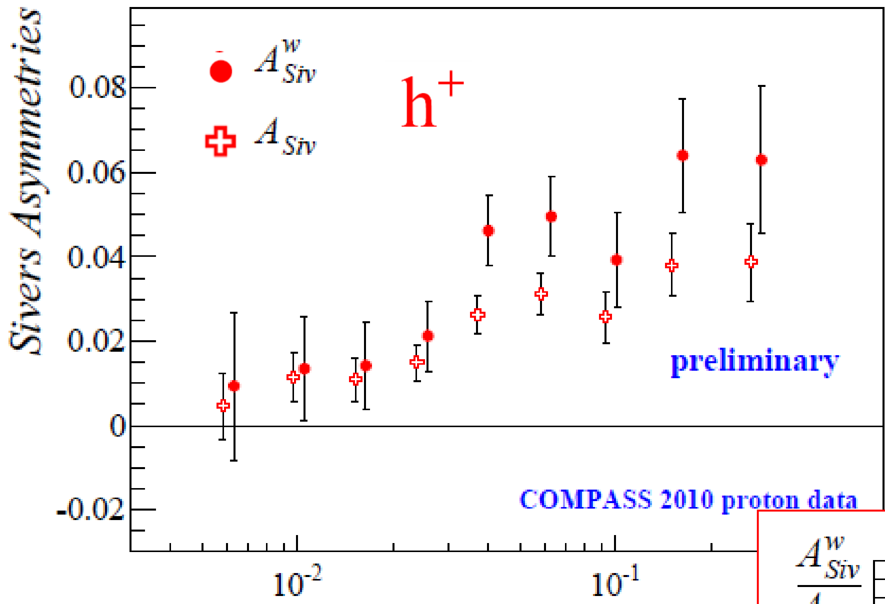
$$A^{w}_{Siv} \sim 2 f_{1T}^{\perp(1)u}(x)/f_1^u(x)$$

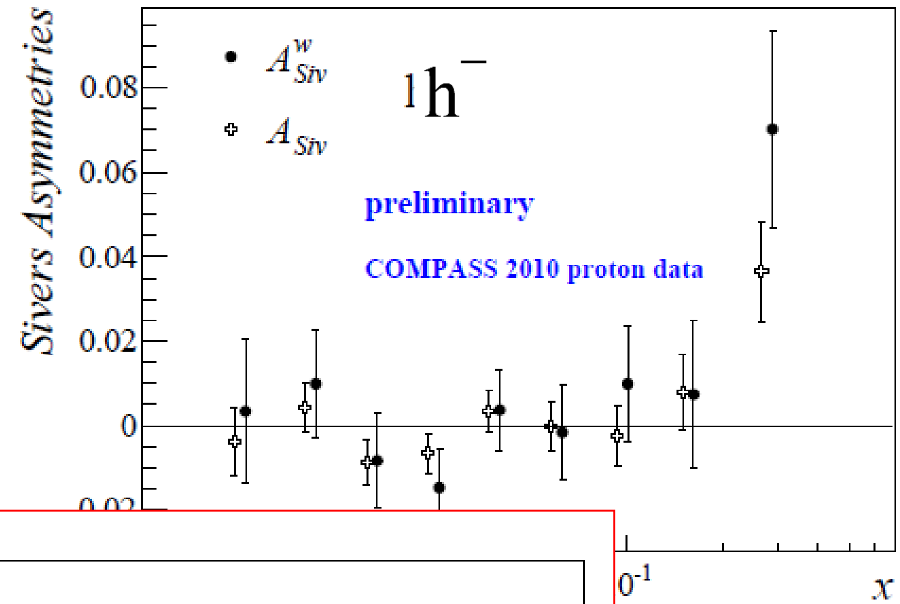
A^{w}_{Siv} SPIN2016,arXiv:1702.00621

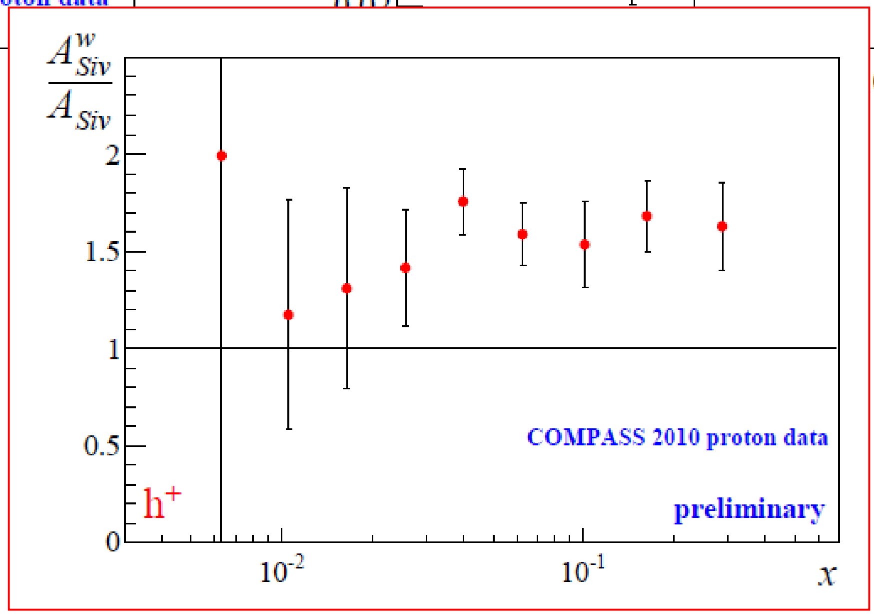
A_{Siv} PLB717 (2012) 383

the weighted Sivers asymmetry

$$A_{Siv}^{w}(x) = 2\frac{\sum_q e_q^2 x f_{1T}^{\perp(1)q}(x)\int D_{1q}(z)dz}{\sum_q e_q^2 x f_1^q(x)\int D_{1q}(z)dz} \qquad w = P_T/zM$$







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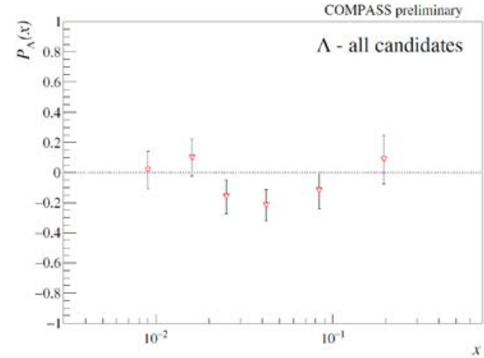
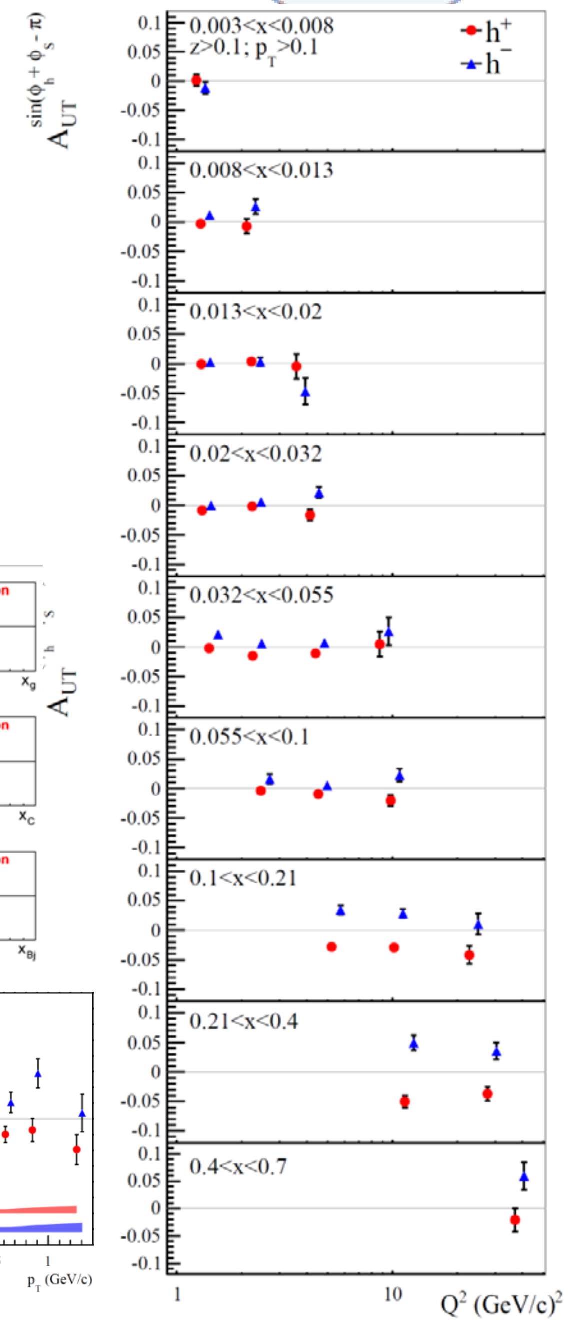
A_{Siv}^{w} SPIN2016,arXiv:1702.00621

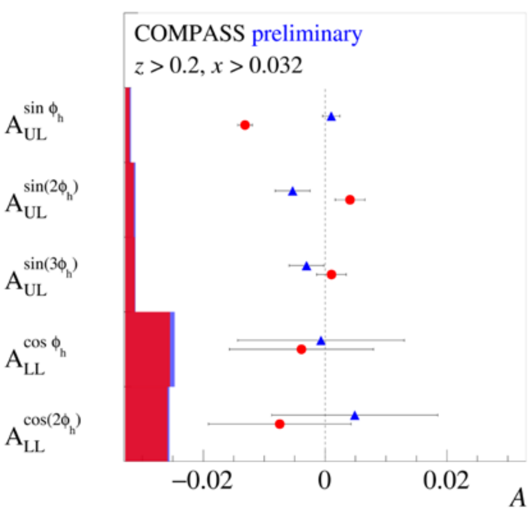
A_{Siv} PLB717 (2012) 383

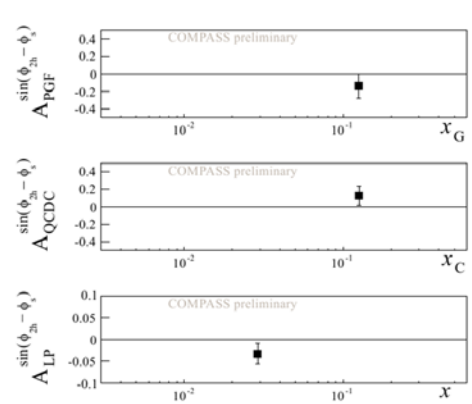
other SIDIS results

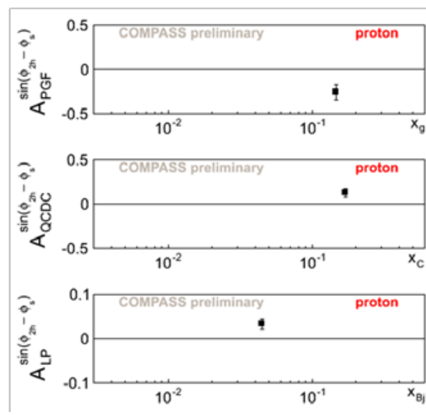
- 2h TSAs
- interplay Collins asymmetry – 2h asymmetry
- multidimensional analysis of p TSAs
- transversity induced Λ polarisation
- gluon Sivers asymmetries
- LSAs

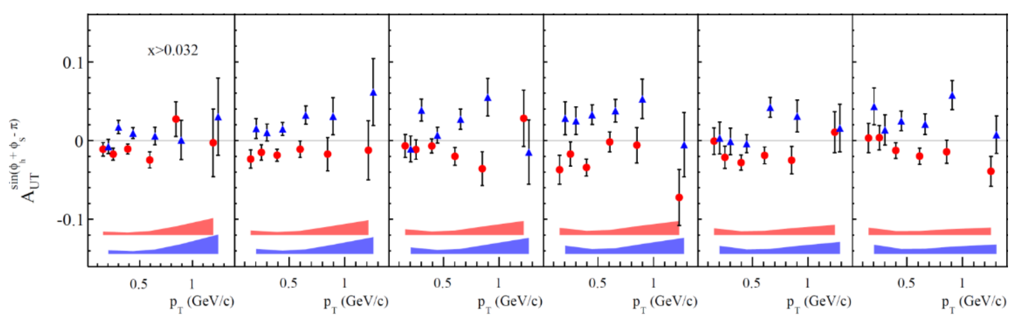






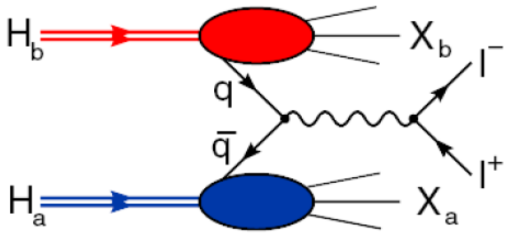






Drell-Yan at COMPASS

DRELL-YAN PROCESS



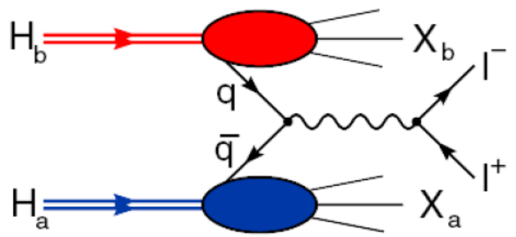
COMPLEMENTARY APPROACH TO SIDIS

COMPASS is measuring for the FIRST TIME

the Drell-Yan process $\pi^- p \rightarrow \mu^+ \mu^- X$
with a transversely polarized proton target

aim: test the fundamental prediction che change of sign of the Sivers function from SIDIS to Drell-Yan

DRELL-YAN PROCESS



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$$\frac{d\sigma^{LO}}{d^4q\, d\Omega} = \frac{\alpha_{em}^2}{F q^2} \hat{\sigma}_U^{LO} \Big\{ \Big(1 + D^{LO}_{[\sin^2\theta]} A_U^{\cos 2\phi} \cos 2\phi \Big)$$
$$+ \quad S_L D^{LO}_{[\sin^2\theta]} A_L^{\sin 2\phi} \sin 2\phi$$
$$+ \quad |\vec{S}_T| \Big[A_T^{\sin\phi_S} \sin\phi_S + D^{LO}_{[\sin^2\theta]} \Big(A_T^{\sin(2\phi+\phi_S)} \sin(2\phi+\phi_S)$$
$$+ \quad A_T^{\sin(2\phi-\phi_S)} \sin(2\phi-\phi_S) \Big) \Big] \Big\},$$

$h_1^{\perp\bar{u}} \otimes h_1^{\perp u}$

Boer-Mulders of the π

Boer-Mulders of the p

$h_1^{\perp\bar{u}} \otimes h_{1T}^{\perp u}$

Boer-Mulders of the π

pretzelosity of the p

$f_1^{\bar{u}} \otimes f_{1T}^{\perp u}$

nr density of the π

Sivers of the p

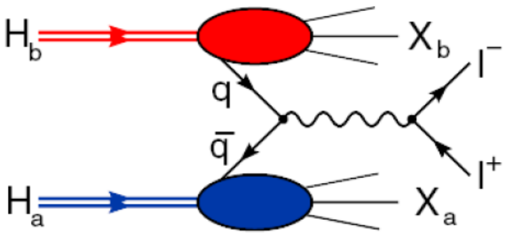
$h_1^{\perp\bar{u}} \otimes h_1^{u}$

Boer-Mulders of the π

transversity of the p

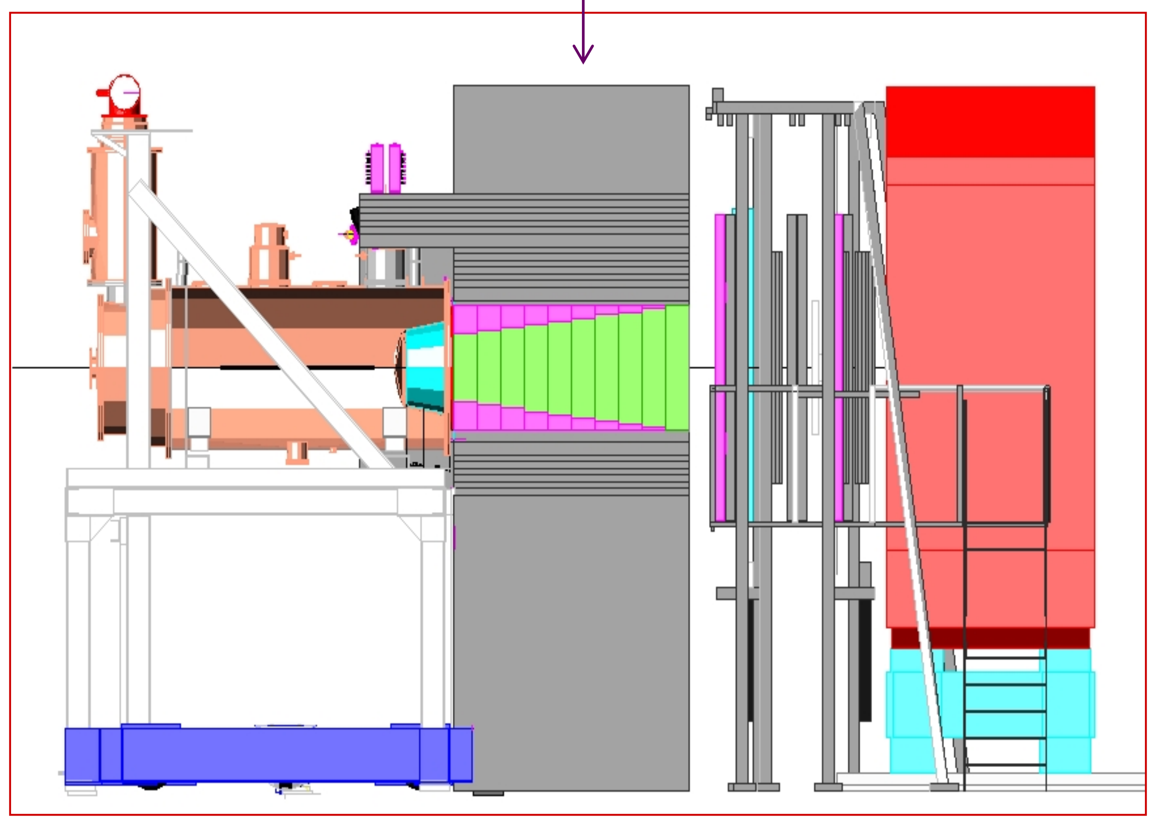
Drell-Yan

190 GeV π^- beam, transversely polarised proton (NH_3) **target**



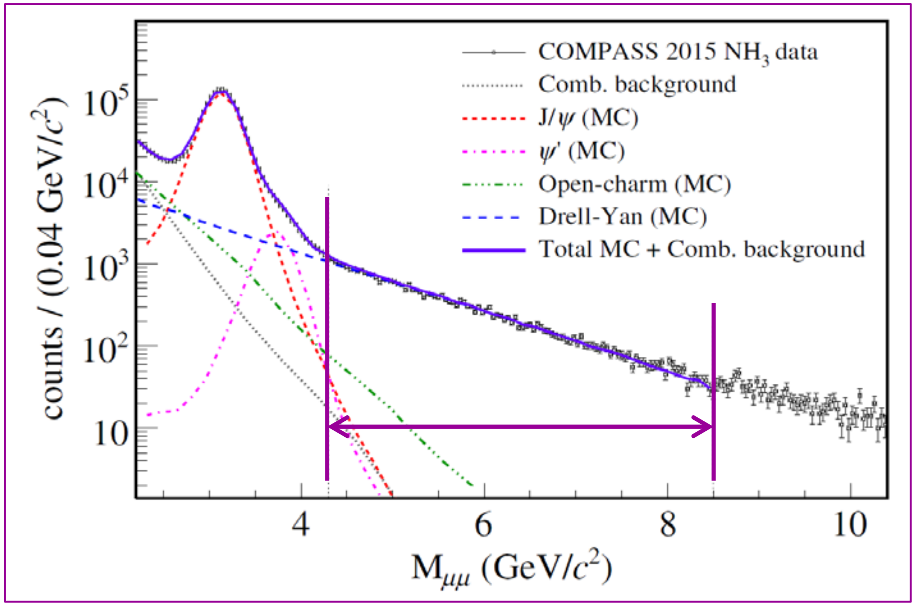
2015 run:

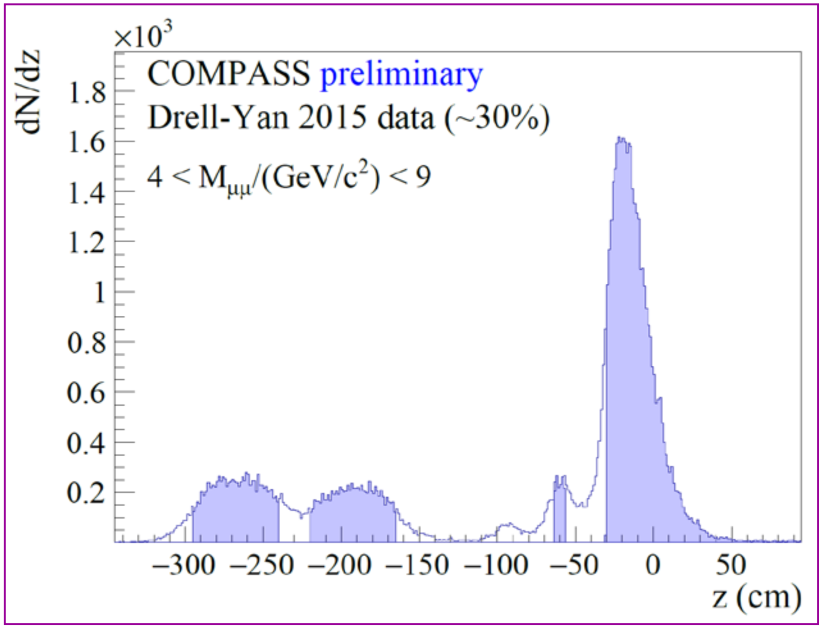
thick hadron absorber



Drell-Yan

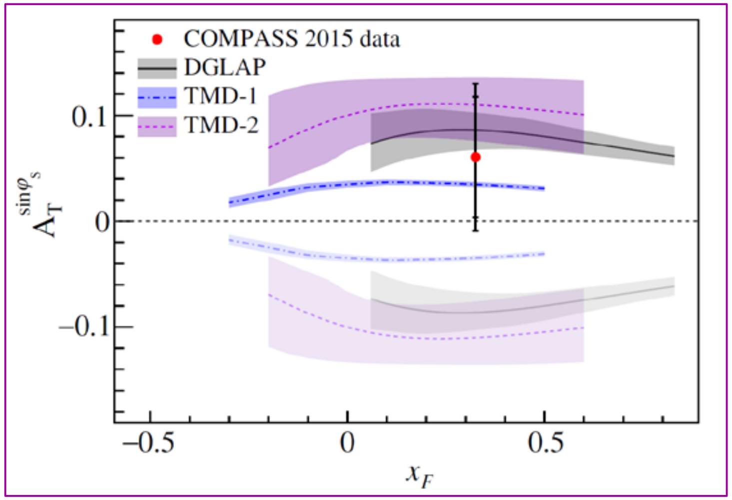
190 GeV π^- beam, transversely polarised proton target





Drell-Yan

190 GeV π^- beam, transversely polarised proton target



PRL 119 (2017)

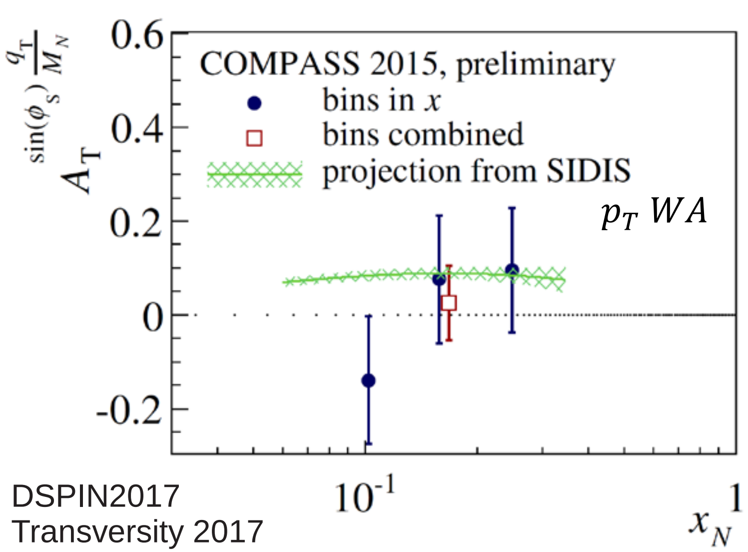
change of sign

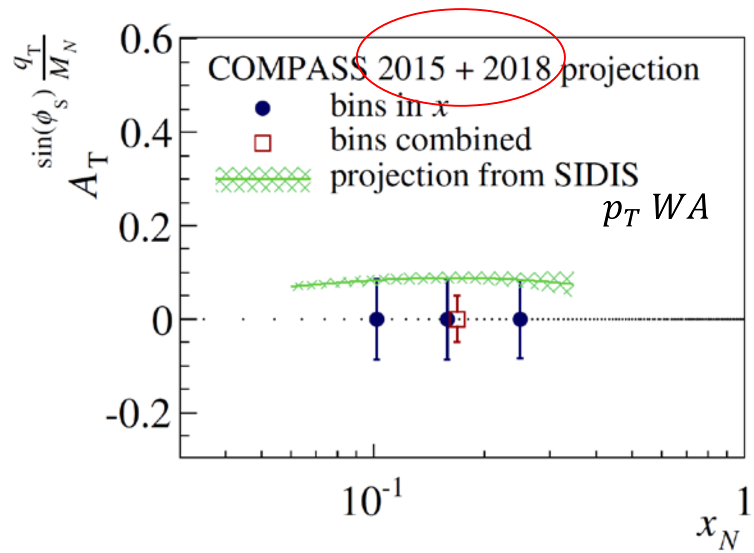
same sign

$$A_T^{std} \sim \frac{f_1^{\bar{u}} \otimes f_{1T}^{\perp u}}{f_1^{\bar{u}} \, f_1^{u}}$$

convolution
evolution
pion PDFs

q_T weighted Sivers asymmetry $A_T^w \sim \frac{f_{1T}^{\perp(1)u}}{f_1^u}$





future

future

LoI is open for new ideas/proponents

A.) RF separated kaon and anti-proton beam:
- 1. Hadron spectroscopy ✔
- 2. Drell-Yan physics ✔
- 3. Primakoff with kaon beam
- 4. Direct Photons with kaon ✔
- 5. RF separated beam

B.) Standard muon beam:
- 1. DVCS with trans. polarised proton target
- 2. Elastic muon proton scattering ✔

C.) Standard hadron beam:
- 1. Polarised/Unpolarised DY with various targets ✔
- 2. Absolute cross-section measurements p + He -> pbar X ✔
- 3. Hadron spectroscopy with antiprotons

D.) Spectrometer upgrades – hardware

For the moment it is ~50 pages long document

12/12/2017 Oleg Denisov 9

near future

proposal for

one year of run with 160 GeV muons to measure SIDIS off transversely polarised d

the missing piece of information to complete our programme

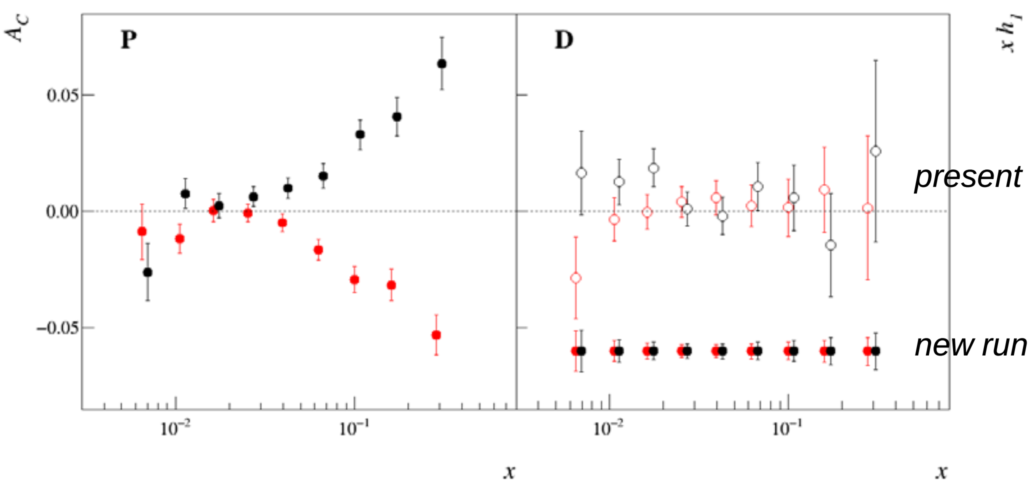
to EPS in 2012

with these data, the d asymmetries would have a statistical uncertainty

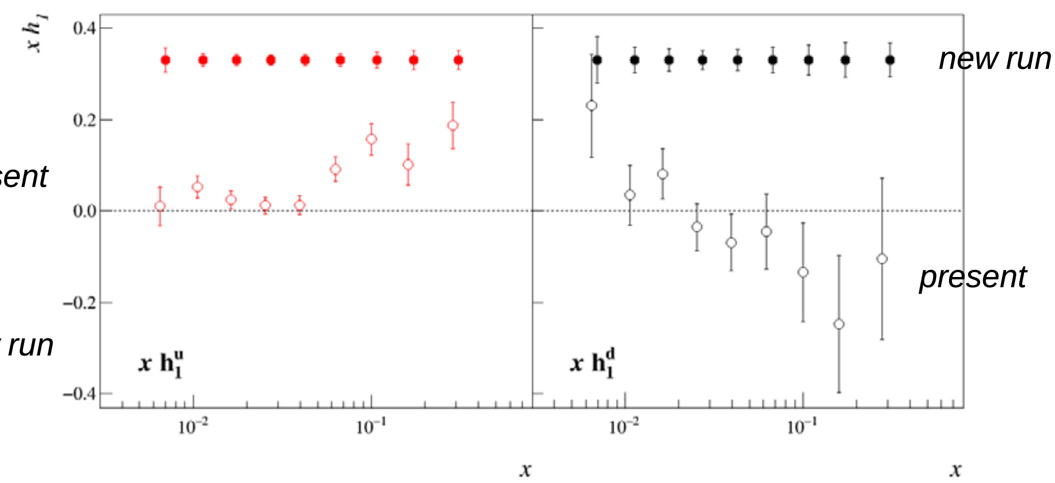
$$\sigma_d \cong 0.6\, \sigma_p$$ or smaller

an example

Collins asymmetry



transversity from COMPASS p and d data



→ tensor charge

we will gain knowledge in a kinematic range that only COMPASS can cover,
as long as EIC will not start

Conclusions

SIDIS gave and is giving fundamental contributions to the study of the spin structure of the nucleon

helicity

Sivers PDF, transversity, Collins FFs different from zero

to progress further

- comparison with different processes, e+e-, Drell-Yan, pp hard scattering
- more from SIDIS
  - precision measurements at new facilities with different energies

    JLab12, EIC
  - COMPASS can still do a lot in the “consolidation” phase

    from existing data

    Λ polarisation, weighted asymmetries, … new ideas and tests

    and with new data

    LH_2, the future d↑ run

still a long way, a lot to be learned, and a lot of fun!

Thank you!