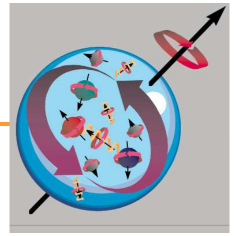


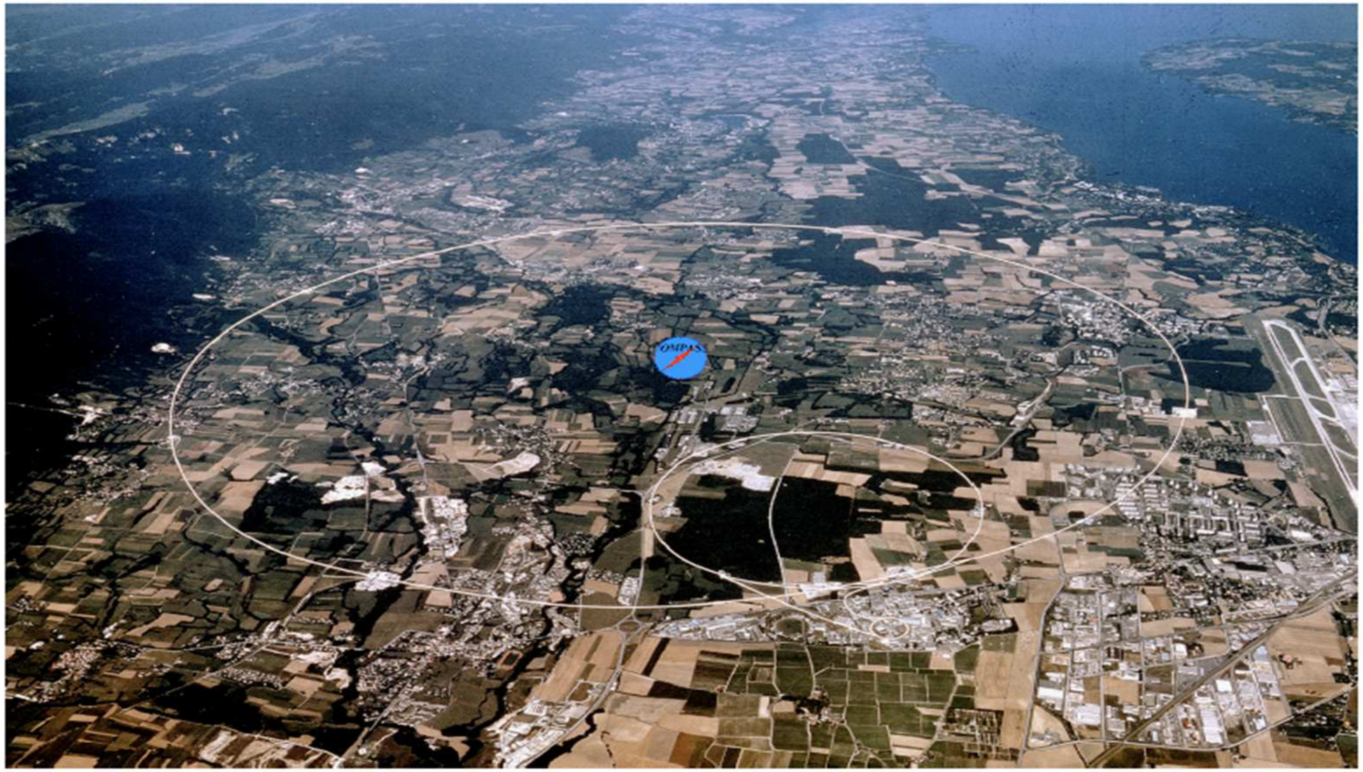
The study of the origin of nucleon spin at COMPASS

Fabienne KUNNE
CEA /IRFU Saclay, France

- **Nucleon spin:** **Gluon and quark helicities**
- **Quark Fragmentation Functions**
- **Transverse spin**
- **Ongoing and short term future studies**

EINN17, Paphos, Cyprus, Oct.31 – Nov. 4, 2017

COmmon Muon Proton Apparatus for Structure and Spectroscopy



~240 physicists, 12 countries, 24 institutions

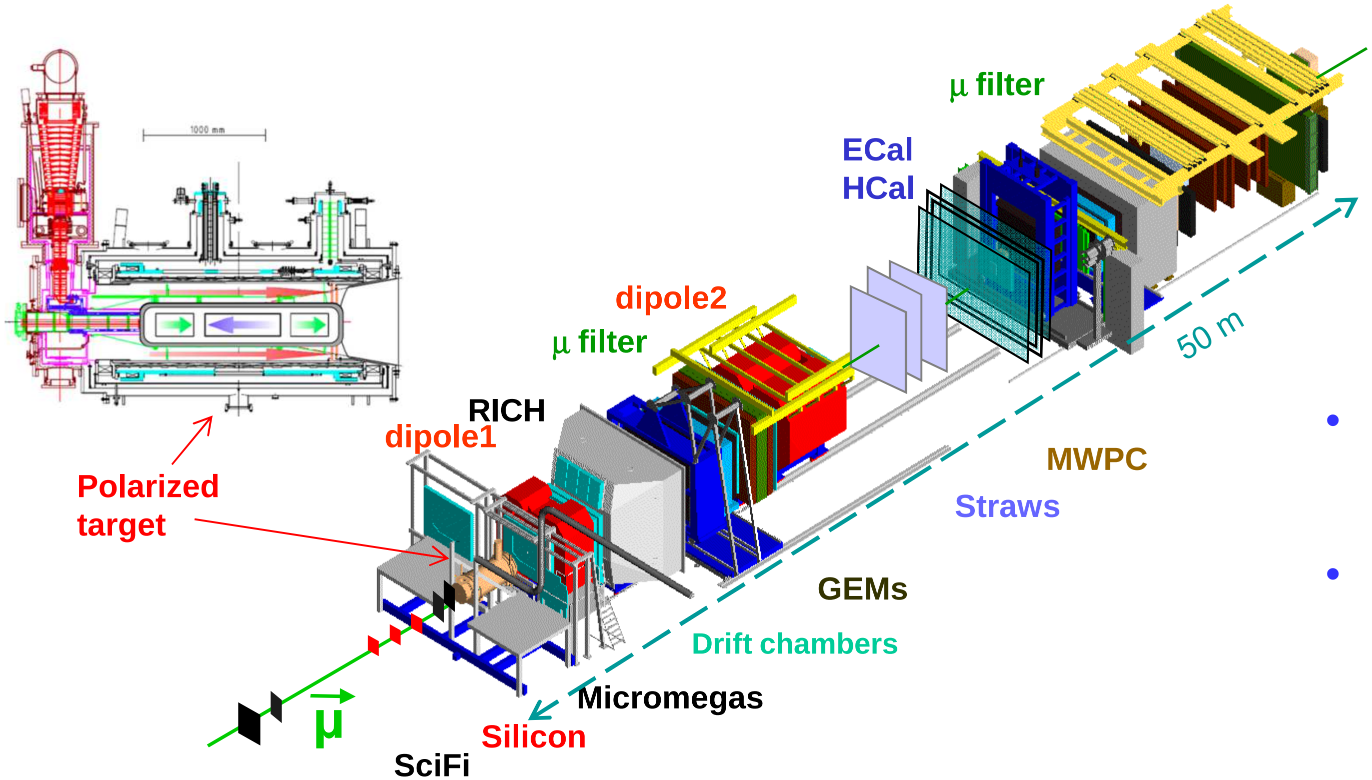
Fixed target experment, multi-purpose set-up.
Secondary ~200 GeV muon and hadron beams from CERN SPS
Various targets

COMPASS at CERN

Published results from:

Polarized muon beam & polarized target: d, p: Nucleon spin structure

Hadron beam π / K / p & LH_2 or nuclei targets: Meson spectroscopy
π, K polarisabilities



NIMA 577 (2007) 455

Ongoing program:

- Generalized Parton Distributions from DVCS
- Transverse Momentum Dependent distributions from Polarized Drell-Yan

Nucleon spin

How is the nucleon spin distributed among its constituents?

Nucleon Spin $\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$

quark gluon orbital momentum

$\Delta\Sigma$: sum over u, d, s, $\bar{u}$, $\bar{d}$, $\bar{s}$
can take non half-integer value:
superposition of several spin states

$\Delta q = \vec{q} - \overleftarrow{q}$
Parton spin parallel or anti parallel to nucleon spin

Past:

Theory: QPM estimations, with relativistic effects $\Delta\Sigma \sim 0.6$

Experiment: “Spin crisis” in 1988, when EMC measured $a_0 = \Delta\Sigma = 0.12 \pm 0.17$

$\overline{\text{MS}}$ scheme

Quark spin contribution ~ 0 ?

Today:

Precise world data on polarized DIS $g_1 + SU_f(3)$ $a_0 = \Delta\Sigma \sim 0.3$

Quark spin contribution ~ 30%

Confirmed by first results from Lattice QCD on $\Delta\Sigma_{u,d}$. (Results exist also on $L_{u,d}$)

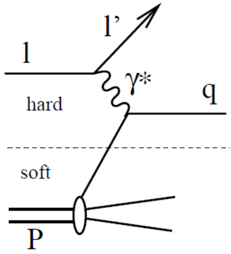
Large experimental effort on ΔG measurement

also because $a_0 = \Delta\Sigma - n_f\,(\alpha_s/2\pi)\,\Delta G$ (AB scheme)

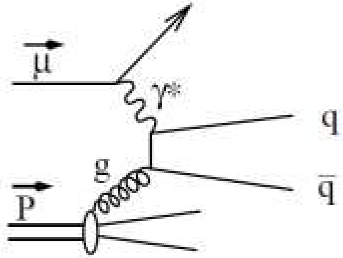
Quark and gluon helicity

Quarks and gluons from nucleon, probed with lepton beams

quarks
Deep inelastic scattering
QCD Leading order



gluons
Photon-gluon fusion: γg→qq



Helicities of partons measured via spin asymmetries using polarized beams and targets

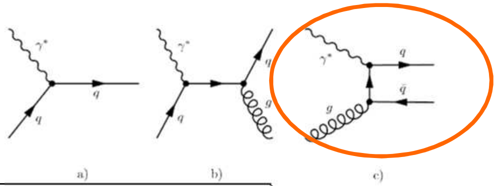
- **Acces** $\Delta\Sigma$ et ΔG : **contributions of quark and gluon spin to nuceon spin** ½= ½ $\Delta\Sigma + \Delta G + L_q + L_g$
- **Comparison to lattice QCD calculations**

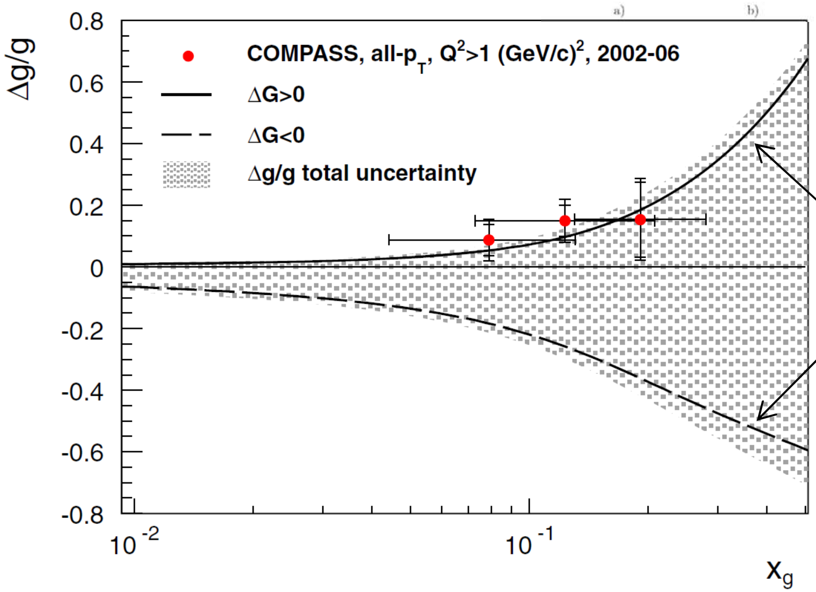
Gluon helicity ΔG/G from hadron production

Photon Gluon Fusion

(Q^2>1$(GeV/c)^2$)

$\vec{\mu}\ \overleftarrow{\vec{p}} \rightarrow \mu'$ **h + h + X**





Extraction at LO:

$\Delta g/g$ $(x=0.1)$ = 0.11 ± 0.04 ± 0.04

Solutions from COMPASS NLO QCD fit of g_1 world data (see later)

EPJC 77 (2017) 209

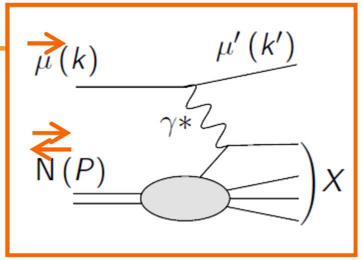
COMPASS data indicate ΔG >0 at x ~0.1

Results are in agreement with fits from NNPDF and DSSV++ using RHIC $\vec{p}\vec{p}$ data, which give

$$\int_{0.05}^{0.2} \Delta g(x)\mathrm{d}x \simeq 0.20$$

QCD fits- World data on g_1^p and g_1^d

DIS

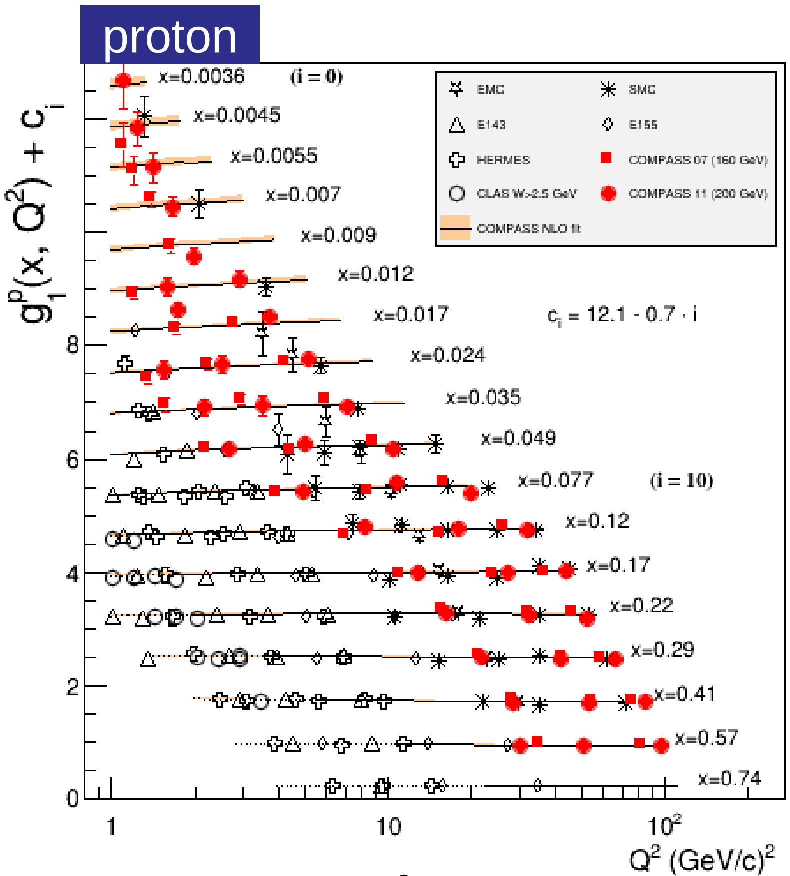


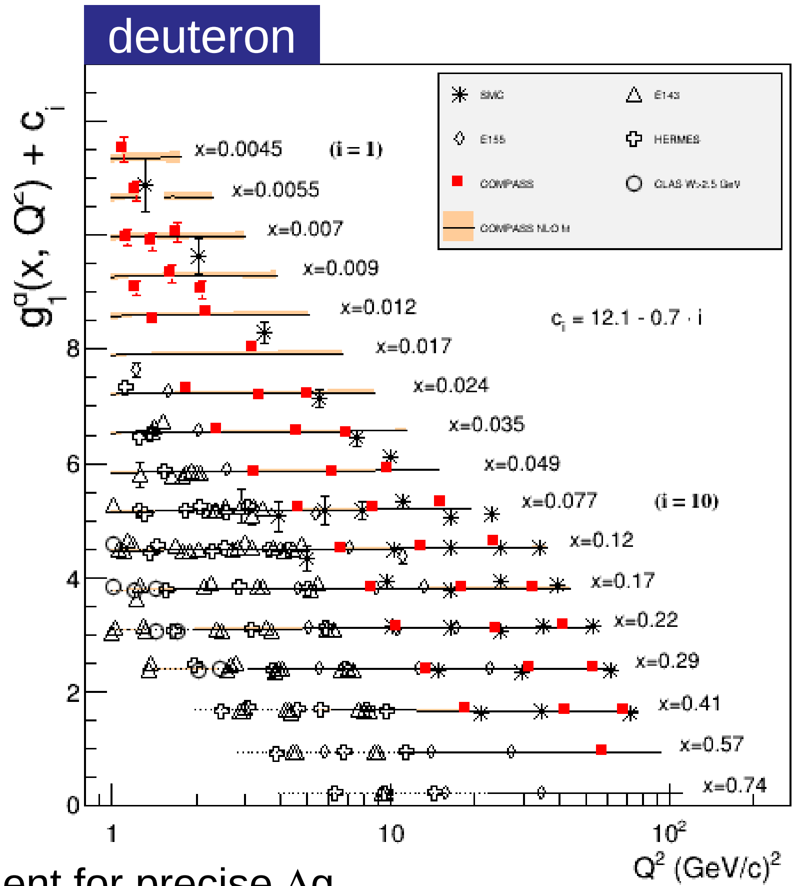
Polarized Deep Inelastic Scattering

➔ Nucleon spin structure functions g_1

➔ g1 (x,Q2) as input to global QCD fits for extraction of **$\Delta q_f(x)$** and **$\Delta g(x)$**

$$\frac{d\, g_1}{d\, Log(Q^2)} \propto -\Delta g(x, Q^2)$$





However x and Q^2 coverage not yet sufficient for precise Δg

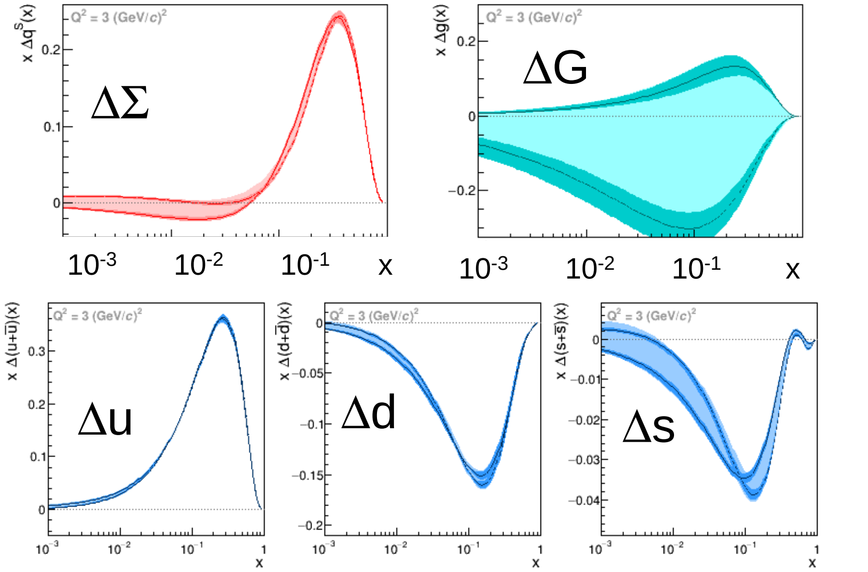
Would need to use constraint from pp data (as DSSV, NNPDF…)

PLB753 (2016) 18

COMPASS NLO pQCD fit to g_1 DIS world data

- Assume functional forms for $\Delta\Sigma$, ΔG and Δq^{NS} , and assume SU3 symmetry
- Use DGLAP equations, relating $\Delta\Sigma$, ΔG evolutions .
- Fit g_1^p, g_1^d, g_1^n DIS world data
- Extract $\Delta\Sigma$ Quarks ΔG Gluons

→ Solutions $\Delta G>0$ and $\Delta G<0$



$0.82 \leq \Delta U \leq 0.85$ $\quad -0.45 \leq \Delta D \leq -0.42$ $\quad -0.11 \leq \Delta S \leq -0.08$

→ Quark spin contribution :

$\Delta\Sigma$= 0.31 (5) at Q^2=3 $(GeV/c)^2$

Largest uncertainty comes from the bad knowledge of functional forms.

Results in fair agreement with other global fits

PLB 753 (2016) 18

→ Gluon spin contribution: ΔG not well constrained, even the sign, using DIS only

Solution with $\Delta G>0$ agrees with result from DSSV++ using RHIC pp data

Summary on nucleon spin from COMPASS

$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$

Quarks $\frac{1}{2}\Delta\Sigma \sim 0.15$ (3), from g_1 measurements and global analysis at NLO.
Largest uncertainty on $\Delta\Sigma$ due to uncertainty on ΔG

Gluons $\Delta G/G$ positive at $x \sim 0.1$ (from data of γ-g fusion process, at LO).
Agrees with precise RHIC result ($\Delta G \sim 0.2$ for integral $0.05<x<0.2$)
Low x contribution to integral still unknown.
Not enough constrain from g_1 global analysis at NLO.

Orbital momenta Lq, Lg: Ongoing studies of GPDs.

Promising results from lattice QCD calculations:
Confirm already $\Delta\Sigma$, and predictions for $\mathbf{L_u}$ et $\mathbf{L_d}$.

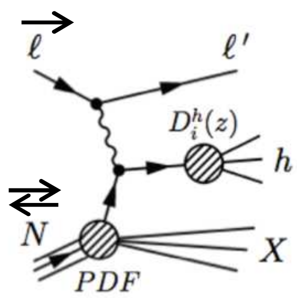
→ The main question raised in 'Nucleon spin crisis' is resolved:

- Quark spin represents a non zero fraction (0.3) of nucleon spin **(measurements and lattice QCD calculations)**
- The hypothesis of very large ΔG (2 to 3, associated to L~ -2 ou -3) rejected (COMPASS 2005)
- **Puzzle still pending:** share between ΔG and L

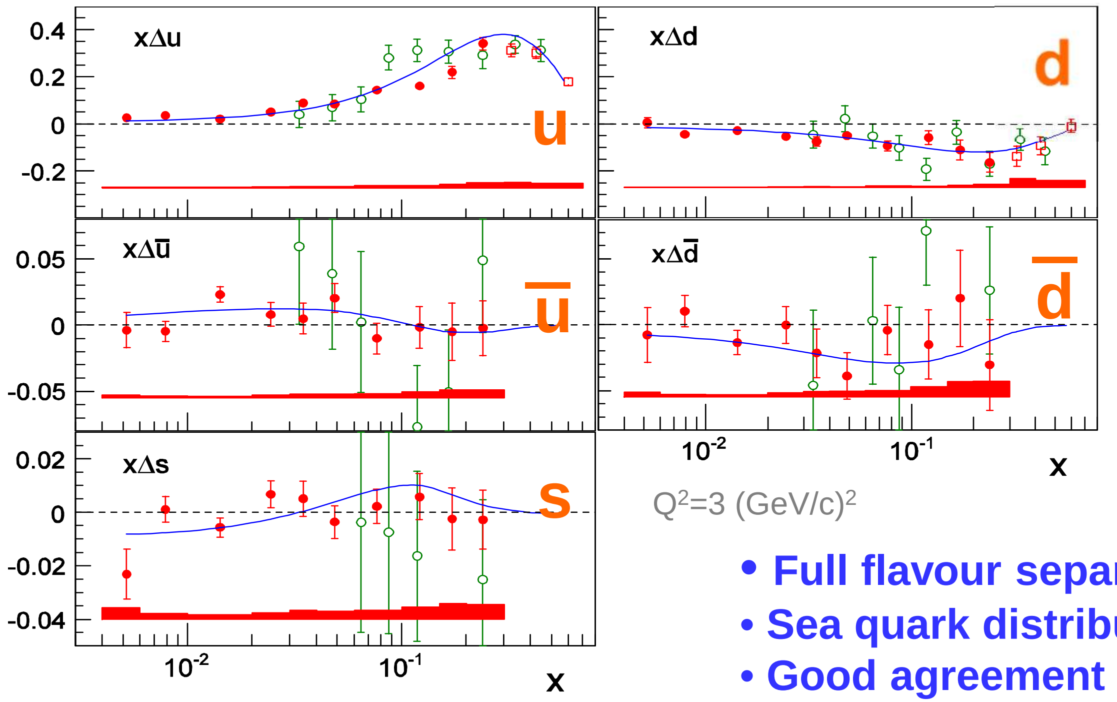
Quark helicities from semi-inclusive DIS

$\vec{l}\,\vec{p} \rightarrow l\,h^{+/-}\,x$

Outgoing hadron tags quark flavor (quark fragmentation functions)



Leading order extraction of quark helicities from spin asymmetries:



• **COMPASS**
PLB693(2010)227 *using DSS FFs*

o **HERMES**
PRD71(2005)012003

__ DSSV at NLO

- **Full flavour separation → x~0.004**
- **Sea quark distributions ~ zero**
- **Good agreement with global fits**

What about Δs? Integral is found negative from ***inclusive*** data, when imposing SU3 while here from ***semi-inclusive*** data, x> ~0.005, Δs is compatible with zero.

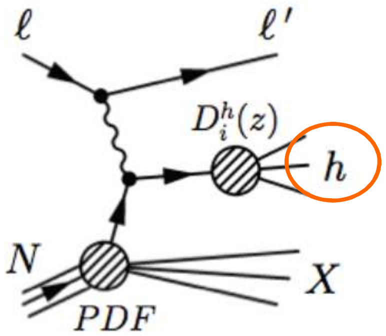
NB: - The extraction assumes quark Fragmentation Functions known (DSS here)
- No measurement at lower x

Quark Fragmentation Functions (FF)

FFs : - Non perturbative object; needed to describe various reactions
- Strange quark FF= **largest uncertainty in Δs extraction** from polarized SIDIS.

Data exist from e^+e^- and pp reactions, but unsufficient and at too high Q^2

→ Measure hadron multiplicities in **SIDIS:** $\mu^+ d \to \mu^+ h^\pm X$ $h = \pi, K, p$



$z = E_h/(E_\mu - E_{\mu}')$

PDFs FFs

$$\frac{dM^h(x,Q^2,z)}{dz} \underset{\text{at LO}}{=} \frac{\sum_q e_q^2 f_q(x,Q^2) D_q^h(z,Q^2)}{\sum_q e_q^2 f_q(x,Q^2)}$$

PDFs depend on x, while FFs depend on z

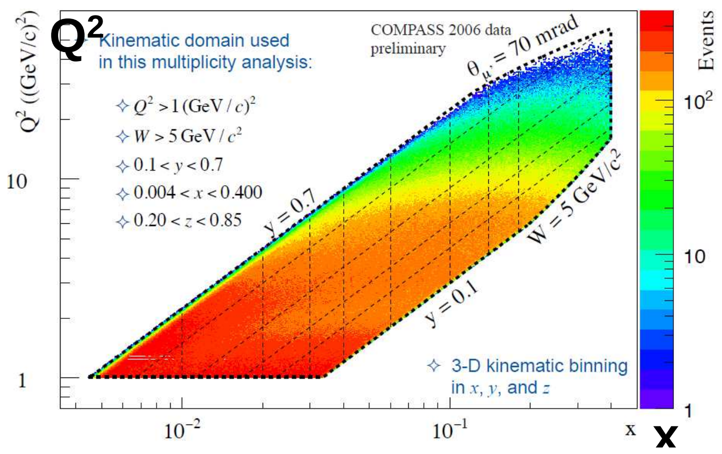
→ With kaons, access typically : $s(x,Q^2)$. $D_s^K(z,Q^2)$

Corrections for : acceptance, RICH purity & efficiency, radiative effects and vector meson contamination

Data obtained in a fine binning in x, z, Q^2

→ **π and *K* multiplicities constitute an input to global NLO QCD analyses to extract quark FFs,**

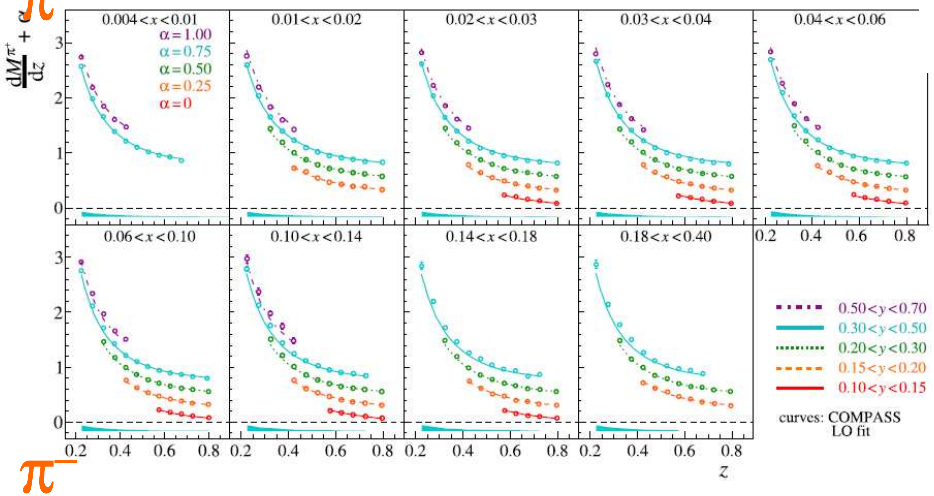
→ **Especially, *K* will constrain strangeness**



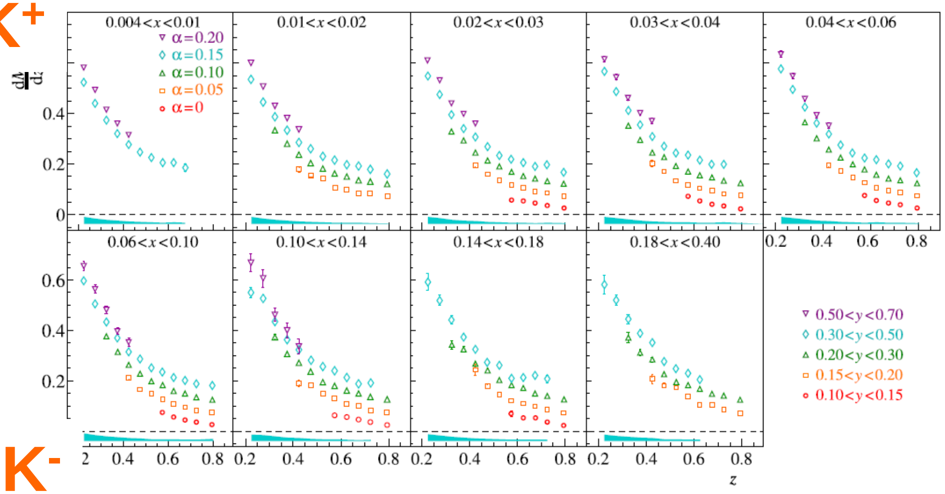
F. Kunne

COMPASS π and K multiplicities vs z in (x,y) bins

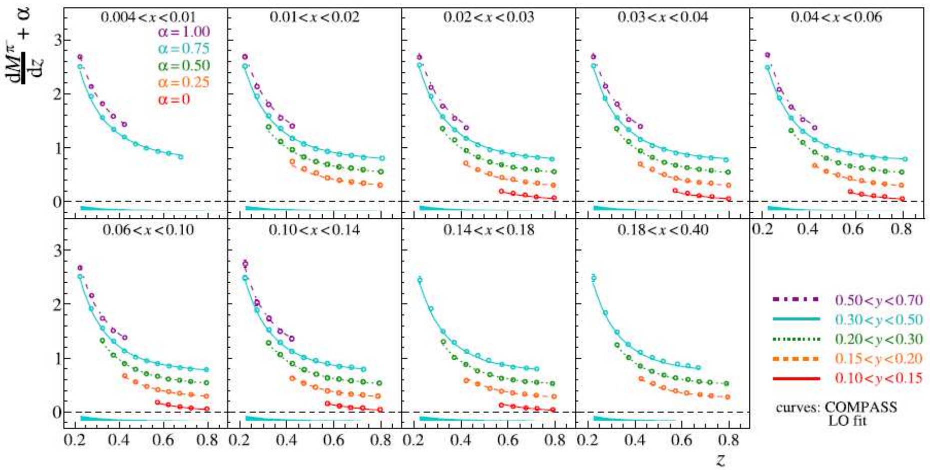
π^+



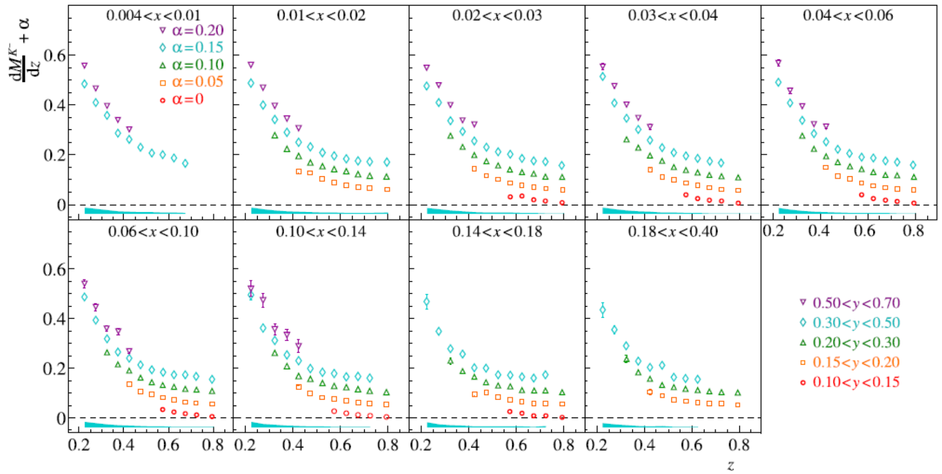
K^+



π^-



K^-



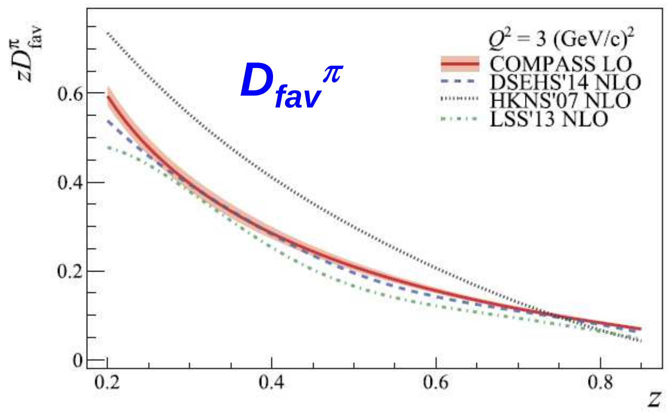
- More than 1200 points in total, various Q^2 staggered vertically for clarity
- Strong z dependance
- $M\pi^+ \sim M\pi^-$ and $MK^+ > MK^-$

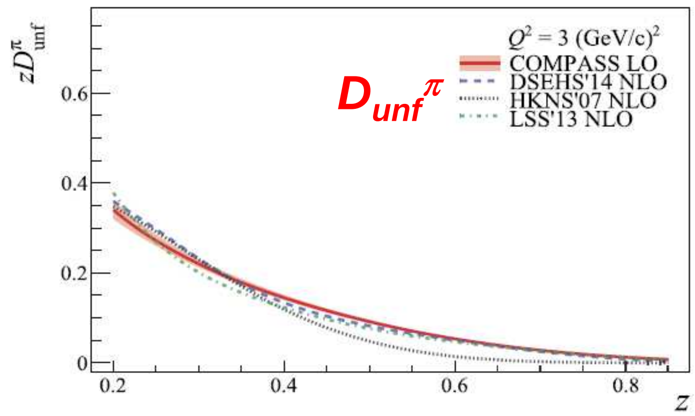
PLB 764 (2017) 001
PLB 767 (2017) 133

From multiplicities to quark Fragmentation functions

Pions

Results from COMPASS LO fits assuming 2 independent FFs: D_{fav}^{π} D_{unf}^{π}





- As expected, $D_{fav}^{\pi} > D_{unf}^{\pi}$.
- COMPASS LO fit results ~agree with DSEHS and LSS NLO.

PLB 764 (2017) 001

Kaons

Assuming 3 independent FFs: D_{fav}^{K} D_{unf}^{K} D_{str}^{K}

- LO fit not conclusive. Some difficulty in fitting high z data even at NLO (see later)
- Global NLO fit *DSS17*, half of data from COMPASS→ **Smaller D_{str}^{K}** than previously; also ongoing study of strange PDF and FF via iterative study *BSS arXiv:1708.01630*
- Some contrains on FFs from sum of K^+ and K^- multiplicities (see next slide)

Sum of z integrated multiplicities $\pi^+ + \pi^-$ & $K^+ + K^-$

For isoscalar target, simple dependence on FFs:

$$M^{\pi^+ + \pi^-} = (1-2S/(5Q+2S))\, D_{fav} + D_{unf}$$

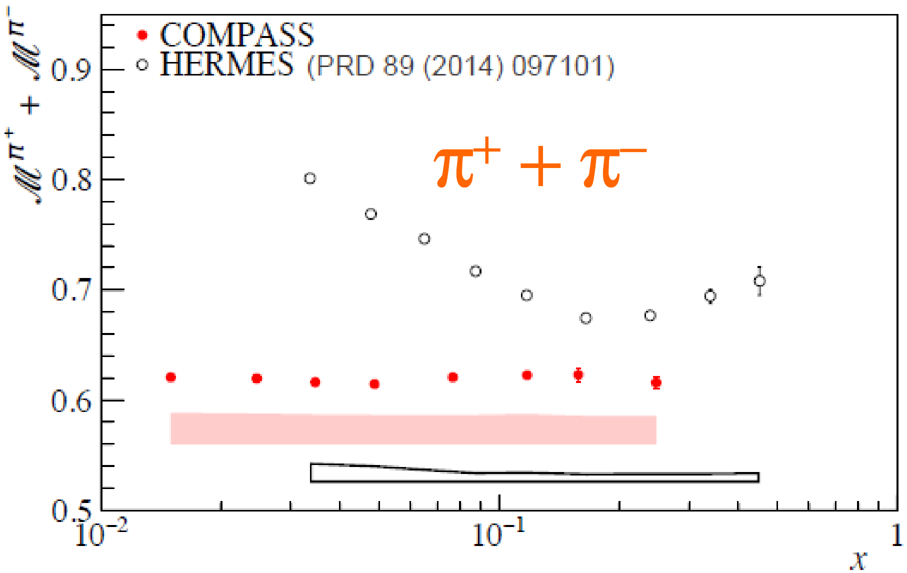
$$5M^{K^+ + K^-} = D_Q^K + S/Q\ D_S^K$$

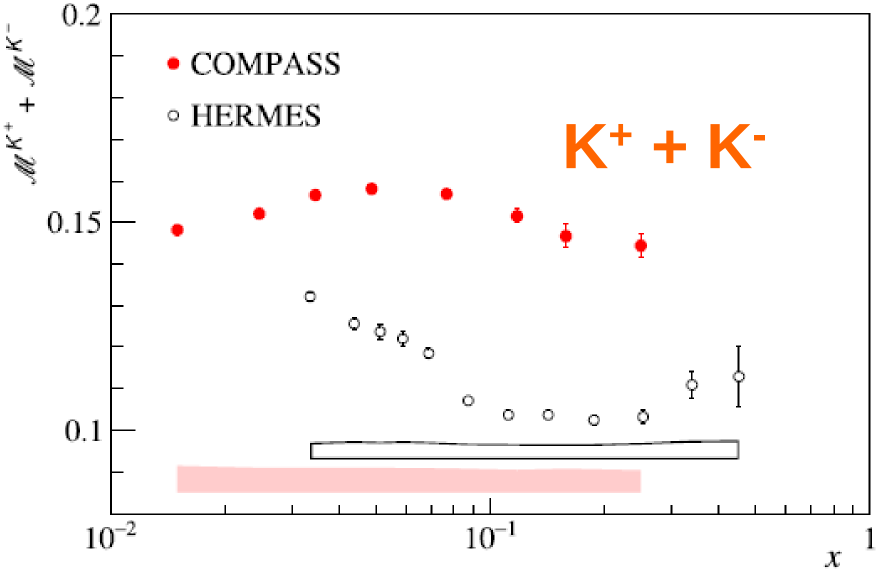
high x data ***low x data***

At high x, ~no *x* dependence expected

where:

$$\begin{cases} Q = u + \bar{u} + d + \bar{d}, \\ S = s + \bar{s}, \\ D_Q^K = 4D_{fav}^K + 6D_{unf}^K \end{cases}$$





COMPASS pion data:

- **significantly below HERMES ones**
- **no x dependence**

(as in EMC h, but not shown here)

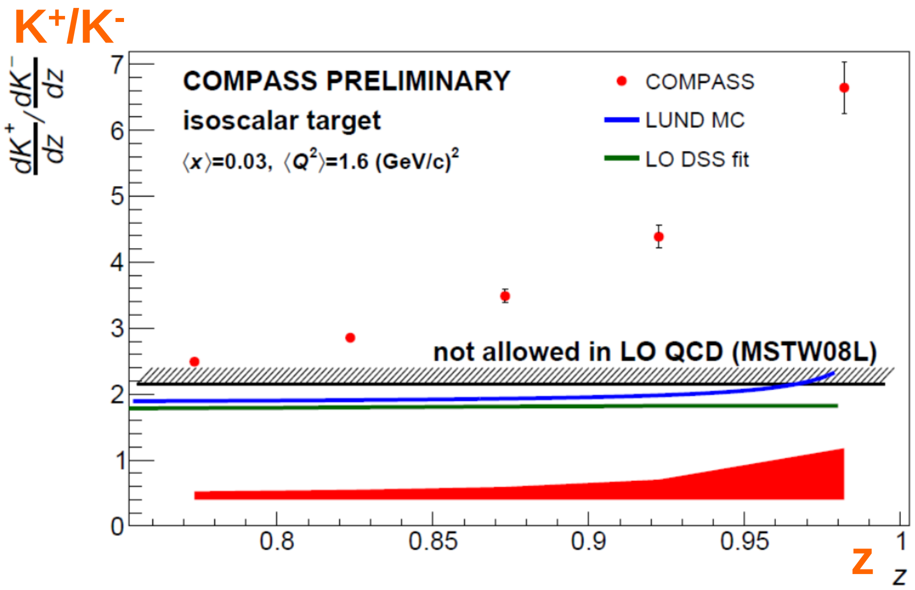
PLB 764 (2017) 001

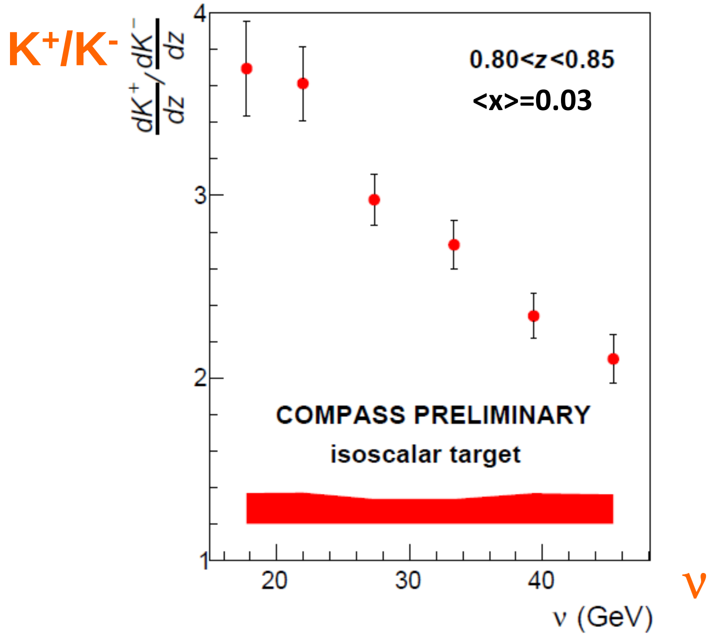
COMPASS kaon data:

- **significantly above HERMES ones**
- **Indicate smaller D_S^K, and larger D_Q^K than previous NLO fits**

PLB 767 (2017) 133

Ratio of K^+ to K^- multiplicity at high z





- Ratio of K^+/K^- multiplicities satisfies simple relation at LO, when assuming D_{unf} negligible at z>0.5, and s=sbar:

$$\frac{dM^{K^+}}{dz} \Big/ \frac{dM^{K^-}}{dz} < \frac{u+d}{\bar{u}+\bar{d}}$$

- **Data well above LO pQCD expectation**
- Could suggest non applicability of factorization in cross-section or non universality of (kaon) FFs in that region.
- Further calculations at higher orders welcome

- **Observe strong dependence on ν = E - E',** also not expected at LO
- Could it explain part of discrepancy between HERMES & COMPASS?

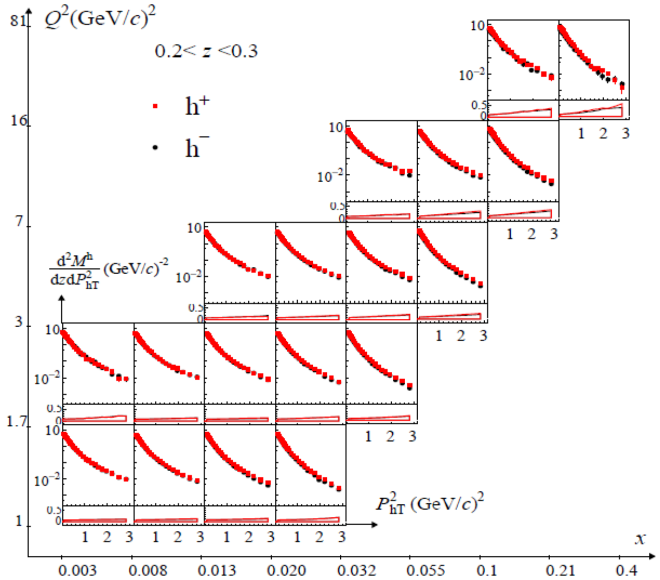
DIS2017, M.Stolarski, COMPASS

p_T dependent hadron multiplicities in SIDIS

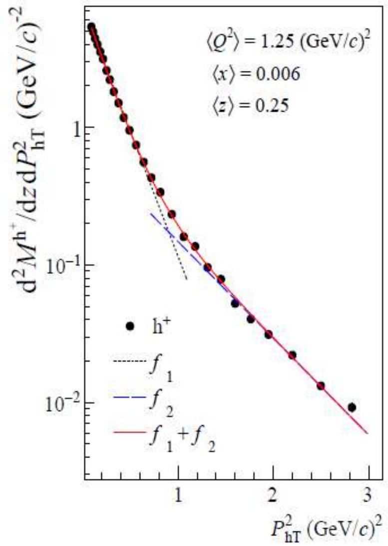
Measure $M_{h+/-}(x,Q^2,z,p_T^2)$

~5000 data points, e.g. results for lowest z bin:

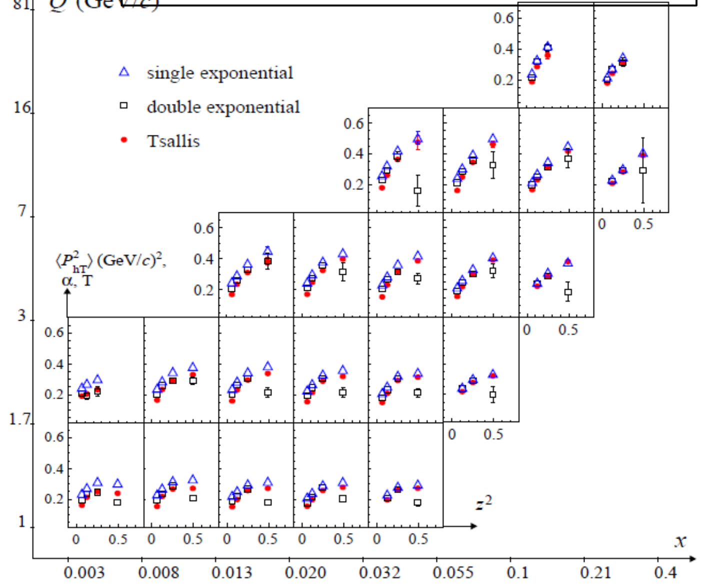
hep-ex/1709.07374, subm. to PRD



M_h vs p_T^2
with 2 exponentials



p_T^2 vs z^2, various (x,Q^2)bins



	EMC [11]	HERMES [15]	JLAB [31]	COMPASS [16]	COMPASS (This paper)
Target	p/d	p/d	d	d	d
Beam energy (GeV)	100-280	27.6	5.479	160	160
Hadron type	$h^\pm$	$\pi^\pm$,K$^\pm$	$\pi^\pm$	$h^\pm$	$h^\pm$
Observable	$M^{h^+ + h^-}$	M^h	σ^h	M^h	M^h
Q^2_{min} $(\mathrm{GeV}/c)^2$	2/3/4/5	1	2	1	1
W^2_{min} $(\mathrm{GeV}/c^2)^2$	-	10	4	25	25
y range	[0.2,0.8]	[0.1,0.85]	[0.1,0.9]	[0.1,0.9]	[0.1,0.9]
x range	[0.01,1]	[0.023,0.6]	[0.2,0.6]	[0.004,0.12]	[0.003,0.4]
P^2_{hT} range $(\mathrm{GeV}/c)^2$	[0.081, 15.8]	[0.0047,0.9]	[0.004,0.196]	[0.02,0.72]	[0.02,3]

Transversity- Collins and Sivers asymmetries

- Access via **SIDIS**, transversely polarized target $\mu p^{\uparrow} \rightarrow \mu h^{+/-} X$

- Measure simultaneously several azimuthal asymmetries, out of which :

  - Collins: Outgoing hadron direction & quark transverse spin
  - Sivers: Nucleon spin & quark transverse momentum k_T

  Sivers function = one of the TMDs = Transverse Momentum Dependent PDFs

at LO:

Collins

q transverse spin distr.

$$A_{Coll} = \frac{\sum_q e_q^2 \cdot x \cdot h_1^q \otimes H_{1q}^{\perp}}{\sum_q e_q^2 \cdot x \cdot q \otimes D_{1q}^h}$$

Collins TMD fragmentation function, depends on spin, and hadron p_T

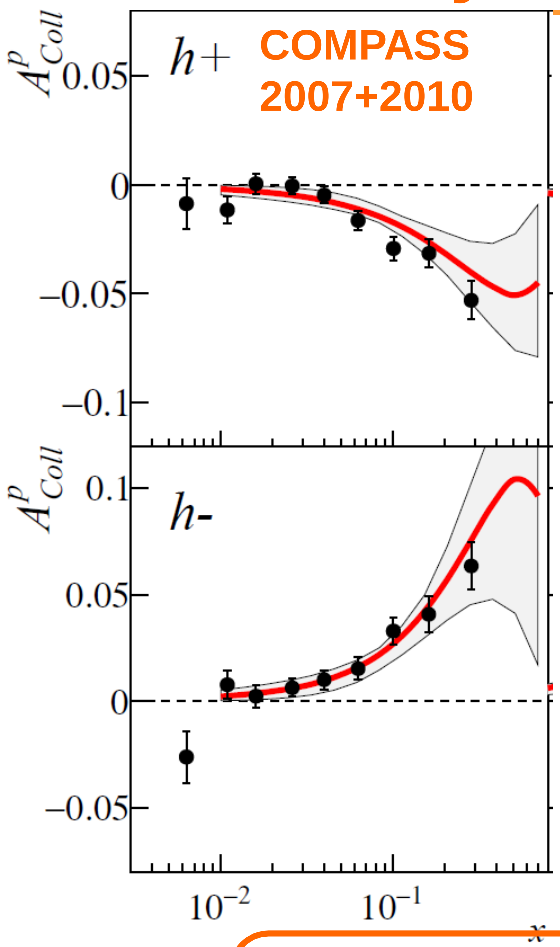
Sivers

Unpolarized quark TMD fragmentation function

$$A_{Siv} = \frac{\sum_q e_q^2 \cdot f_{1Tq}^{\perp} \otimes D_q^h}{\sum_q e_q^2 \cdot q \otimes D_q^h}$$

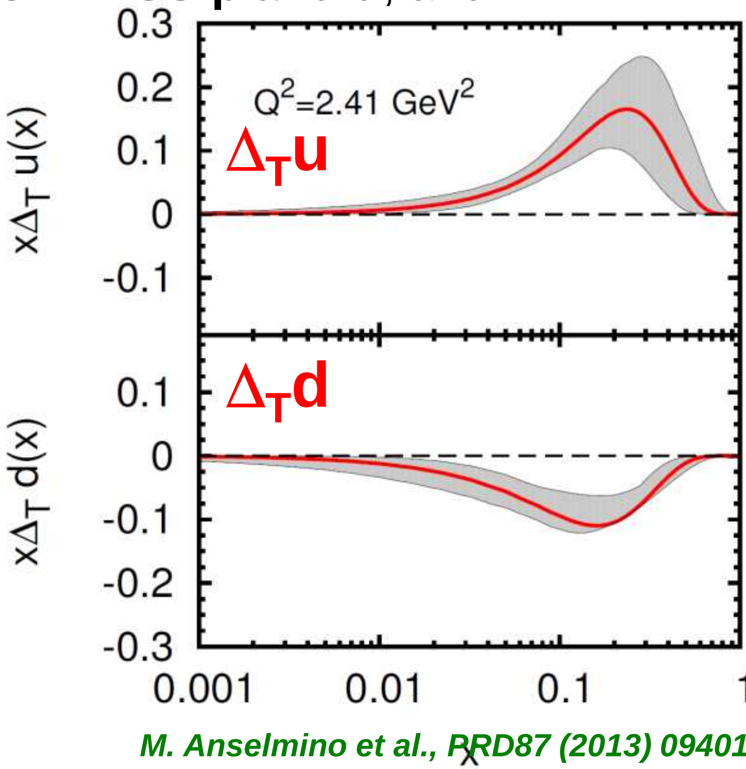
note: $\Delta_T q$ also measured in SIDIS using ''Two hadron'' fragmentation function

Collins asymmetry → Transversity $\Delta_T u$ $\Delta_T d$



- **Large signal for proton target.**
  (compatible with zero for deuteron target)
- **Same signal strength seen by HERMES and COMPASS, although different Q^2 (times 4)**

Several combined analyses of polarized SIDIS data
HERMES p, COMPASS p and d, and **BELLE FF**



- **$\Delta_T u > 0$ and $\Delta_T d < 0$**
- Smaller than helicity
- Derived also from di-hadron

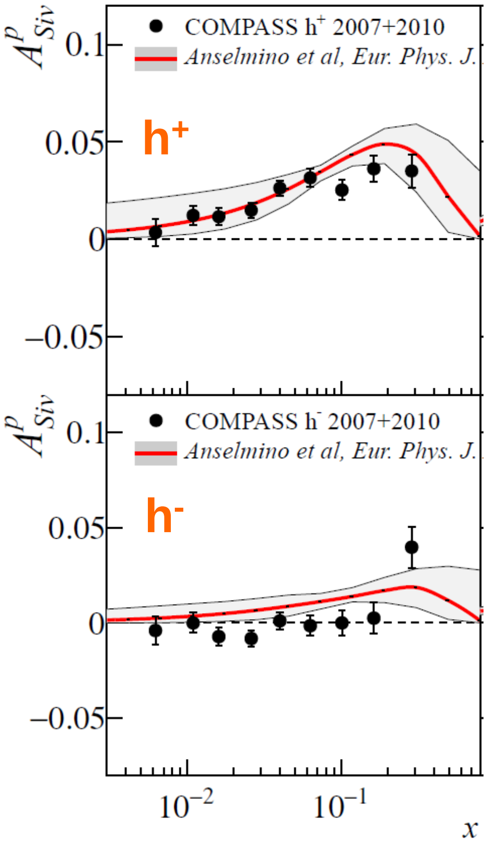
Nb: Asymmetry also measured for π and K

PLB 744 (2015) 250

M. Anselmino et al., PRD87 (2013) 094019

Sivers asymmetry → Sivers function

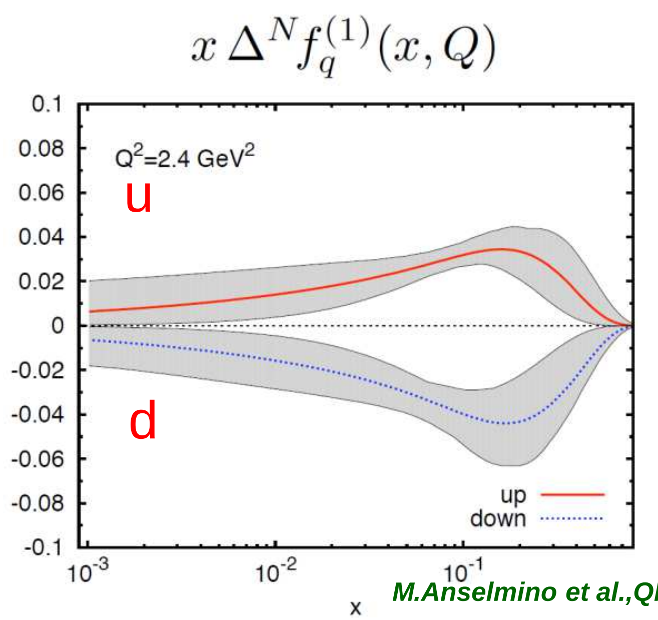
Correlation between Nucleon spin & quark transverse momentum k_T



Large signal with proton target and h+

Was measured compatible with zero on deuteron

When compared to HERMES, smaller strength at larger Q^2



M.Anselmino et al.,QNP2012

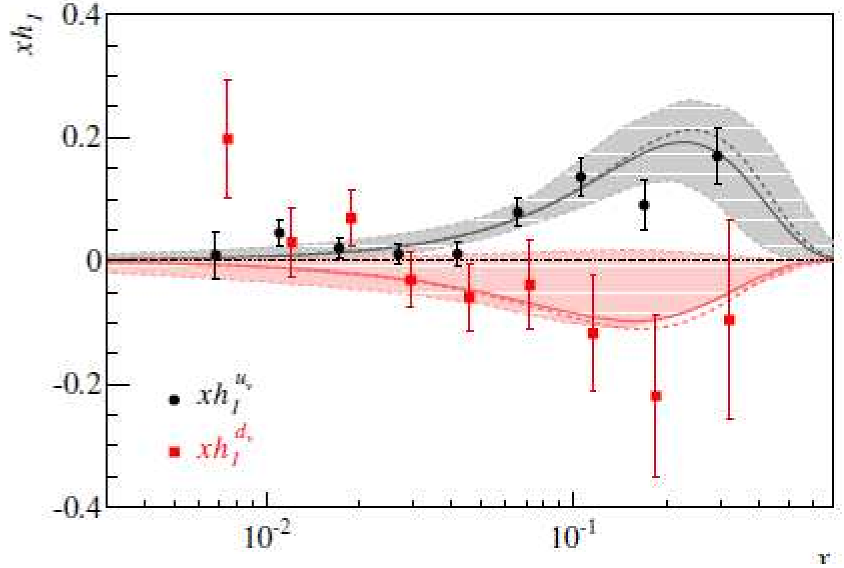
→ **Opposite sign for u and d quark Sivers function**

Nb: Asymmetry also measured for π and K ***PLB 744 (2015) 250***

Direct extraction of Transversity h_1 and Sivers function

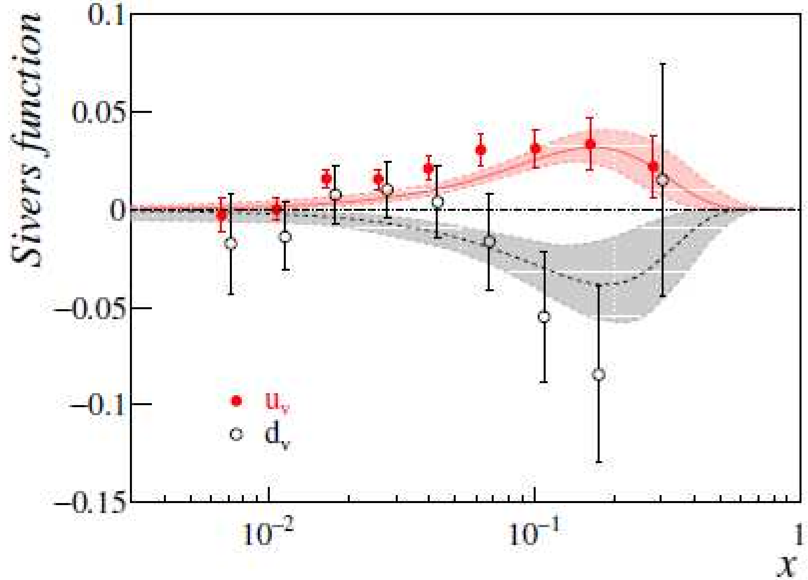
Direct extractions using COMPASS proton and deuteron data
on both single hadron and dihadron azimuthal asymmetries.

xh_1



More data needed on deuteron

Sivers

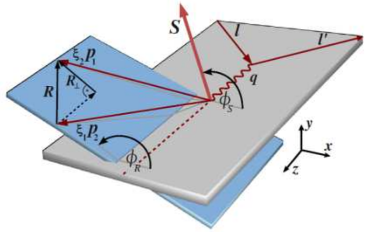


A.Martin et al. PRD91(1) (2015) 014034 and PRD95(9) 2017) 094024

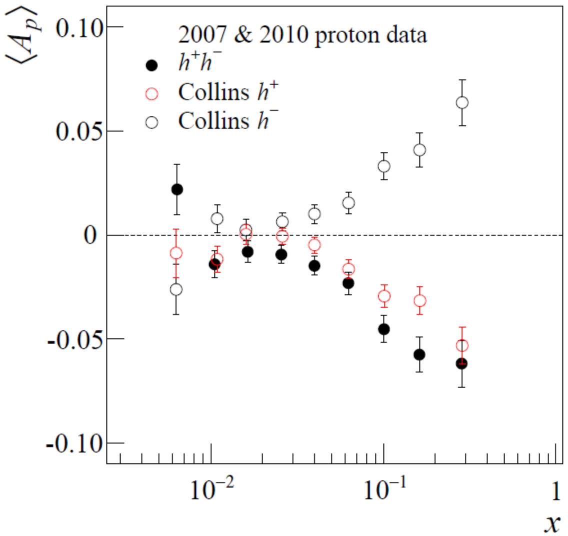
Global fits of COMPASS and HERMES data
M. Anselmino et al. PRD 87 (2013)094019

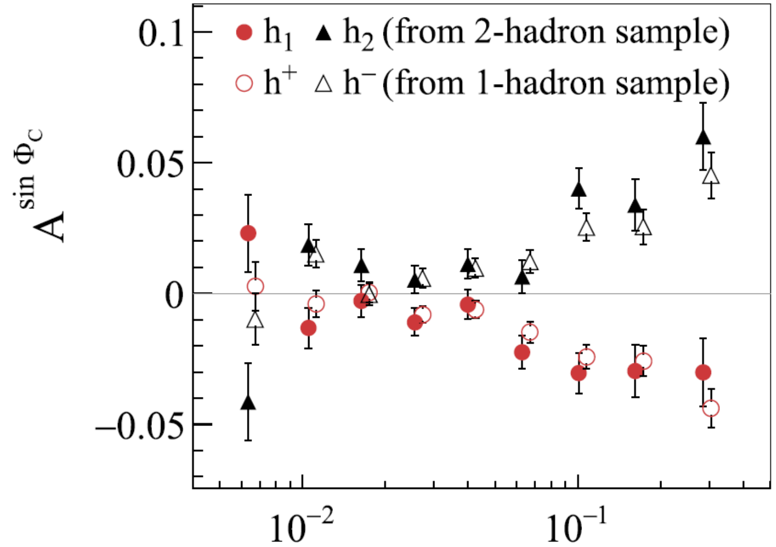
Transversity from di-hadrons. Interplay with Collins

Fragmentation of a transversely polarized quark



Azimuthal asymmetries from production of :
- di-hadron (oppositely charged pair)
- single hadron (+ and -, mirror symmetric Collins asymmetries)





→ Observe similar behaviour … and establish correlation between the three

PLB 736 (2014) 124

PLB 753 (2016) 406

- **First experimental indication for a common physical origin to the two processes, di-hadron and Collins, as originally suggested by different models.**
- **Results for 'transversity' from the two measurements are NOT independent**

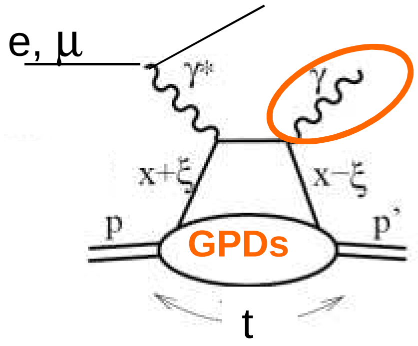
COMPASS ongoing program 2015 - 2018:

- **GPDs** **(Generalized Parton Distributions)**
  via **Deep Virtual Compton Scattering** $\mu\, p \rightarrow \mu\, p'\, \gamma$

- **TMDs (Sivers and other transverse Momentum Dependent distributions)**
  via spin dependent Drell-Yan $\pi\, p\uparrow \rightarrow \mu^{+} \mu^{-}$

DVCS- t-slope of Cross-section, first result

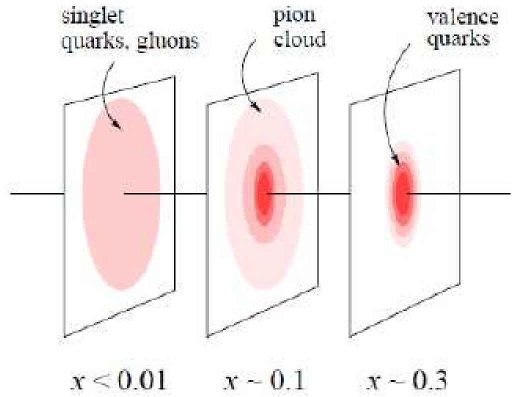
$\mu\ p \to \mu\ p\ \gamma$



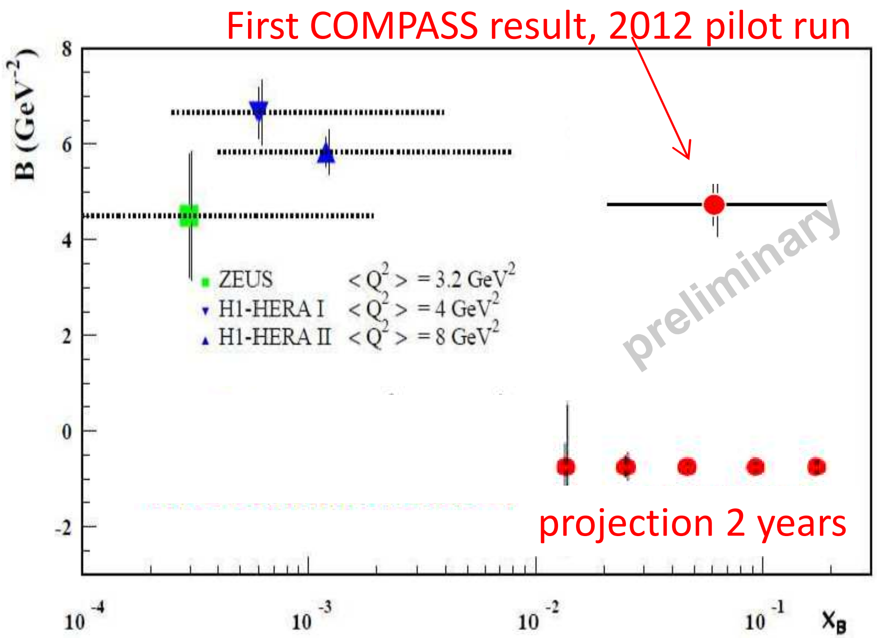
x dependence of transverse size of the nucleon

$\sigma^{DVCS}/dt \sim \exp^{-B|t|}$

$B(x_B) = \frac{1}{2} \langle r_\perp^2(x_B) \rangle$

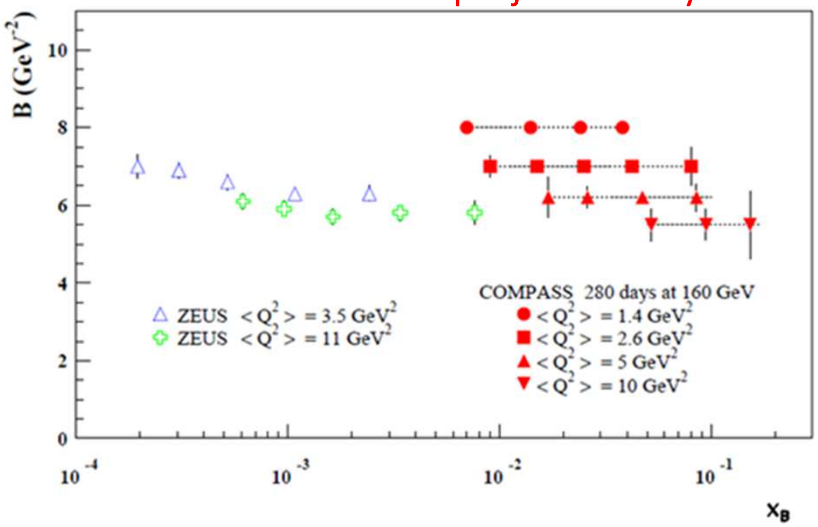


Deep Virtual Compton Scattering (γ)



Deep Virtual Meson Prod. (ρ)

COMPASS projection 2 years

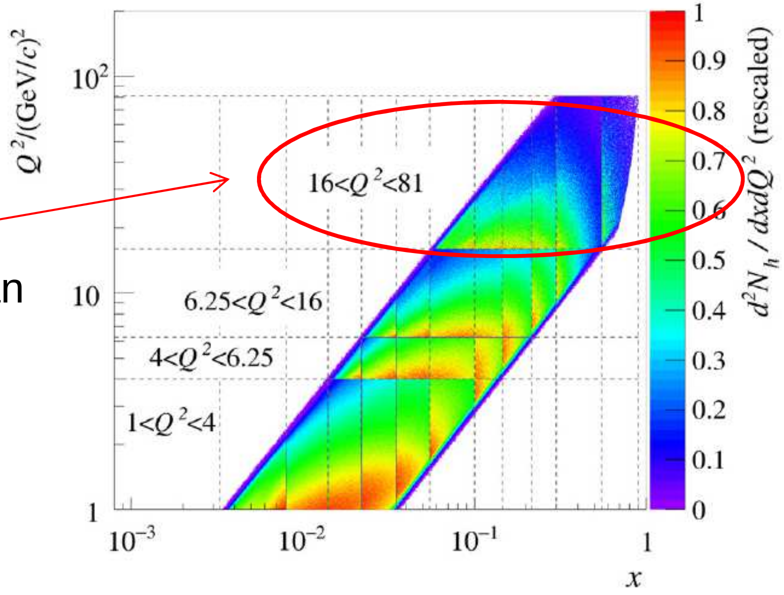


Sivers from SIDIS (at Drell-Yan scale)

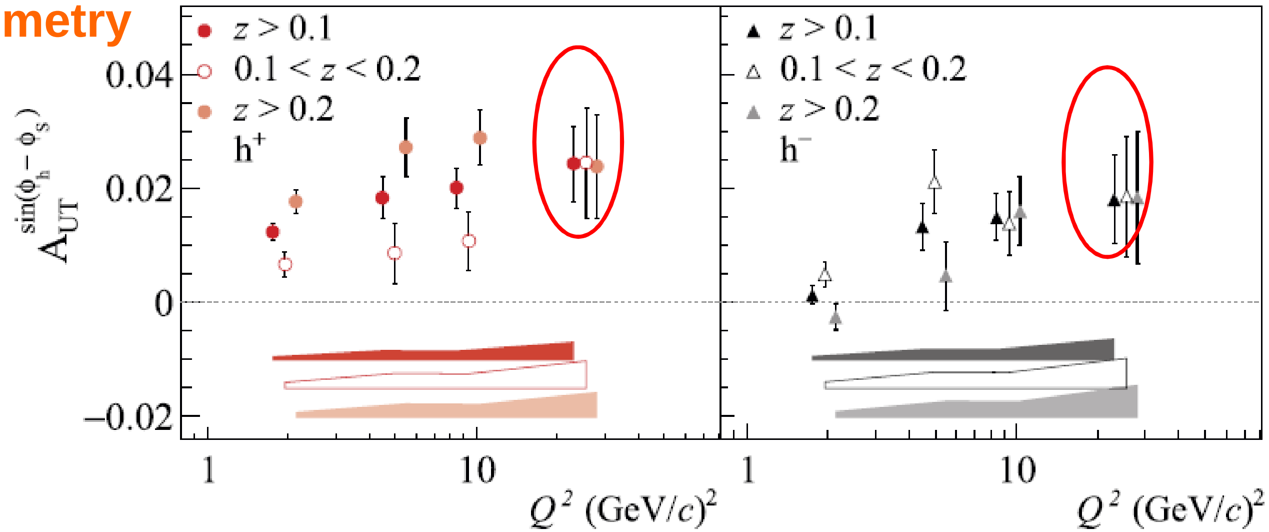
SIDIS x-Q^2 range divided in 4 Q^2 bins:

highest Q^2 bin corresponds to Drell-Yan Q^2 region

PLB 770 (2017) 138



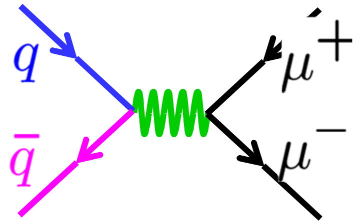
Sivers asymmetry



Clear signal from Sivers, test of sign change feasible

COMPASS- Spin dependent Drell-Yan (2015 and 2018)

Polarized Drell-Yan: π beam on transversely polarized nucleon $\pi\, p\uparrow \rightarrow \mu^+ \mu^-$



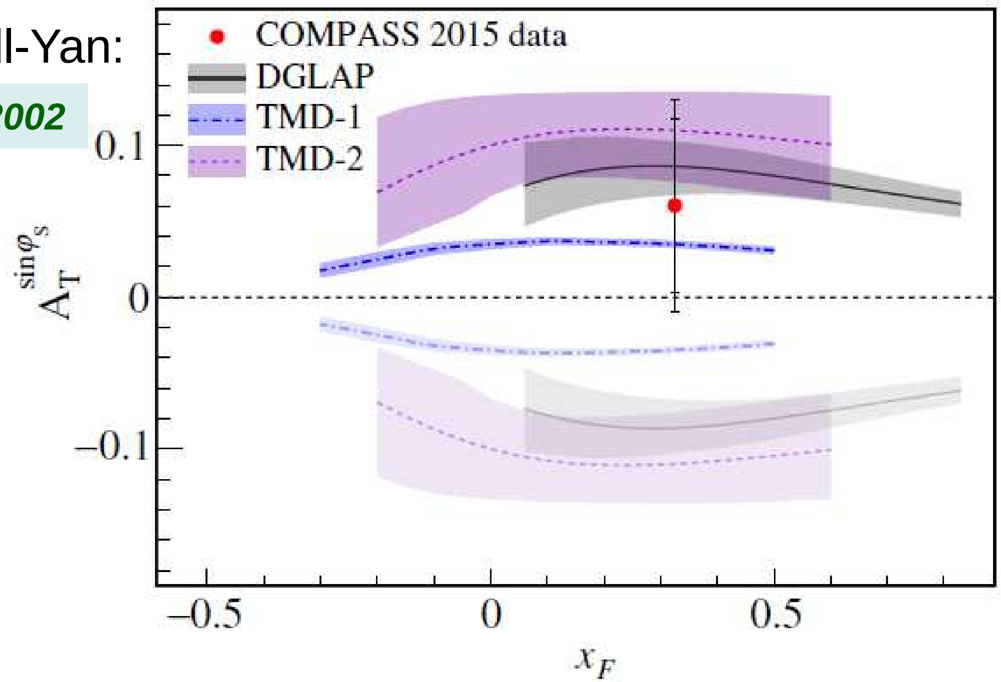
Test **change of sign in Sivers** between Drell-Yan and SIDIS

COMPASS assets

- Large acceptance, same spectrometer for both processes
- Hadron beam (π, K, p) with valence antiquarks
- Transversely polarized target

Sivers from Drell-Yan:

PRL119 (2017) 112002



COMPASS Plans

2018	**Polarized Drell-Yan- Sivers sign change**	**π p↑ → $\mu\mu$**
2019 2020	*CERN Long Shutdown-2*	
2021	**SIDIS Transverse spin**	**μ d↑ → μ' h X**
2022	tbd **Proton radius**	**μ p elastic**
2023	tbd	
2024 2025	*CERN Long Shutdown-3*	

Letter of Intent for 2022 and beyond in preparation:

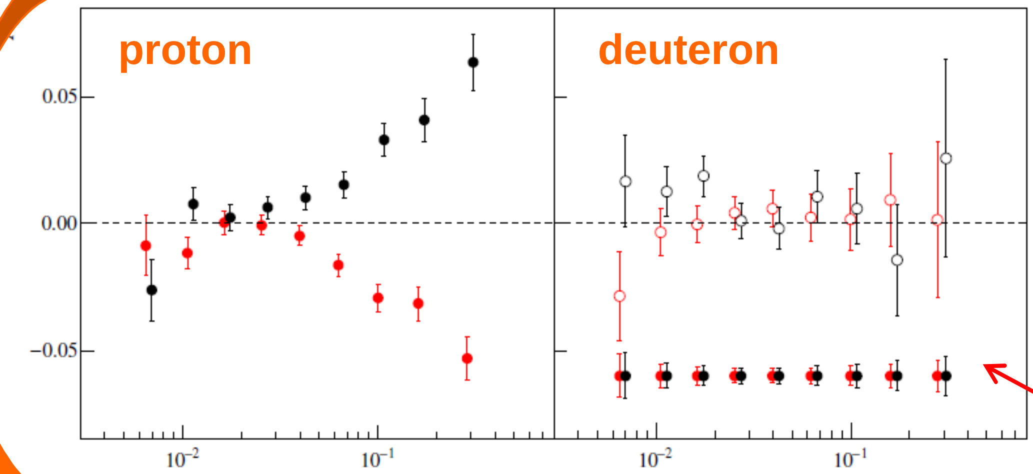
- Proton radius
- Pion PDFs
- kaon & p-bar beams (Kaon PDFs; Meson Spectroscopy)
- …

COMPASS 2021projections – Transversity

Proposal for Transversity measurements in 2021 $\mu\, d\uparrow \rightarrow \mu'\, h\, X$

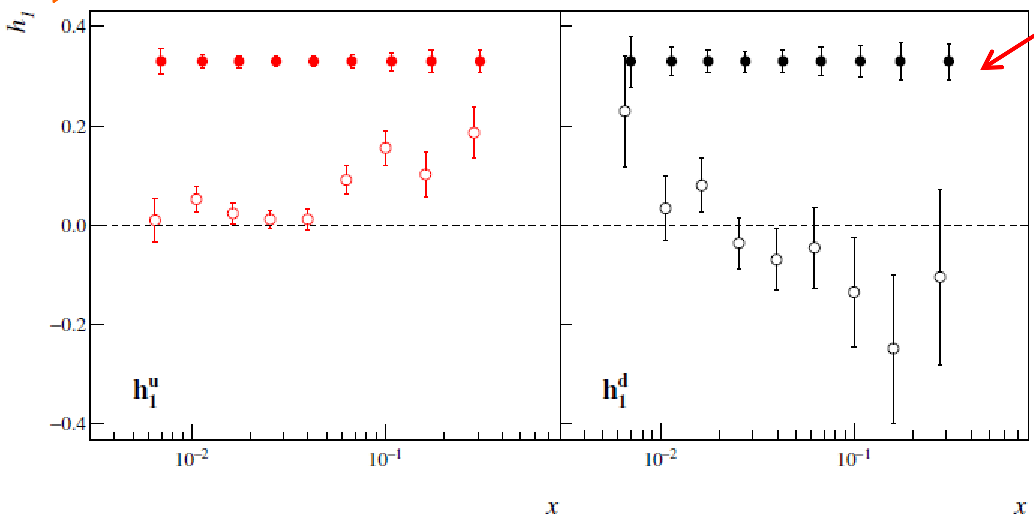
Current COMPASS results for h^+ and h^-:

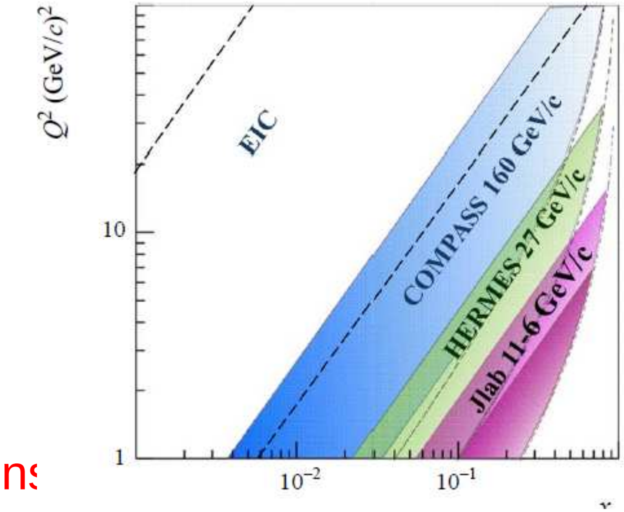
Collins asymmetry

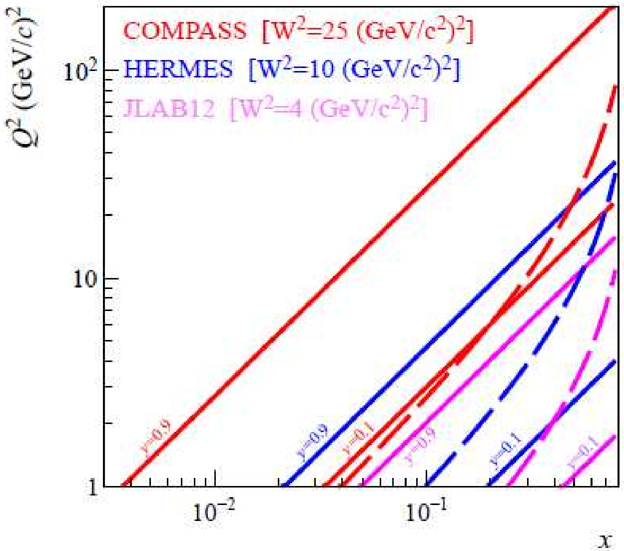


projections 2021

h_1^u **h_1^d**







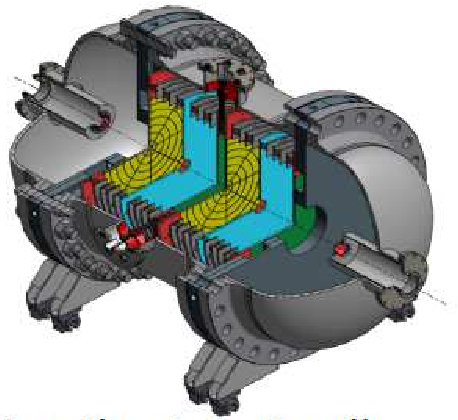
Proton Radius measurement

COMPASS Proposal **μ p elastic**

High energy muon beam : 100 GeV
Target: high pressure hydrogen
active target cell (PNPI development)

Q^2 range for fit: 0.001 to 0.02

Precision : 0.03 fm (low beam intensity),
with goal of 0.01 fm



IKAR active target cell
A. Vorobyev, St. Petersburg

Summary

Gluon and quark contribution to nucleon spin

Gluon $\Delta G/G = 0.1$ at $x=0.1$ from measurement in PGF 2 hadrons

Quarks : Sum $0.26 < \Delta\Sigma < 0.34$ from global QCD fit of g_1 world data

Largest uncertainty comes from functional shape (of ΔG also)

Extraction for all flavours from SIDIS measurements, down to x ~0.004.

Towards agreement with Lattice QCD calculation

Pion and kaon multiplicities in semi-inclusive DIS:

Large discrepancies between COMPASS and HERMES data

Transversity and Transverse Momentum Dependent parton distributions

Precise results on Collins and Sivers asymmetries

Interplay Collins effect / di-hadron

Much progress on all azimuthal asymmetries for TMDs

Sivers : sign change Drell-Yan vs SIDIS

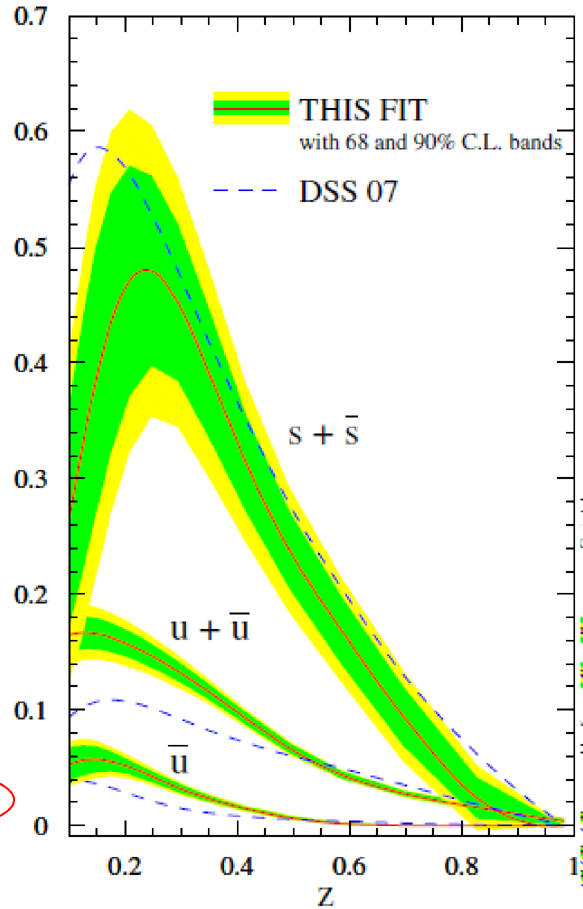
and more data to come

GPDs via DVCS: First result on proton transverse size

Backup slides

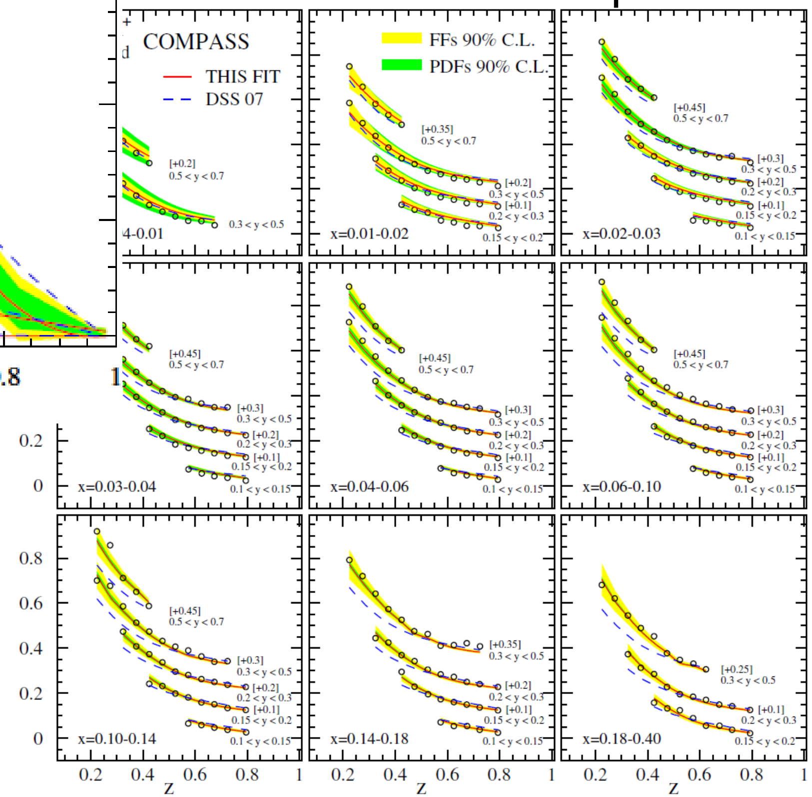
Strange quark FF. DEHSS global fit of kaon data

Experiment	Data type	$\mathcal{N}_i$	# data in fit	χ^2
Tpc [38]	Inclusive	1.003	12	13.4
Sld [35]	Inclusive	1.014	18	17.2
	uds tag	1.014	10	31.5
	c tag	1.014	10	21.3
	b tag	1.014	10	11.9
Aleph [32]	Inclusive	1.026	13	29.7
Delphi [33]	Inclusive	1.000	12	6.9
	uds tag	1.000	12	13.1
	b tag	1.000	12	11.0
Opal [39]	*u* tag	0.778	5	9.6
	d tag	0.778	5	7.7
	s tag	0.778	5	23.4
	c tag	0.778	5	42.5
	b tag	0.778	5	16.9
BABAR [19]	Inclusive	1.077	45	30.6
Belle [20]	Inclusive	0.996	78	15.6
Hermes [21]	K^+ (p) Q^2	0.843	36	61.9
	K^- (p) Q^2	0.843	36	29.6
	K^+ (p) x	1.135	36	75.8
	K^- (p) x	1.135	36	42.1
	K^+ (d) Q^2	0.845	36	44.7
	K^- (d) Q^2	0.845	36	41.9
	K^+ (d) x	1.095	36	48.9
	K^- (d) x	1.095	36	44.4
Compass [24]	K^+ (d)	0.996	309	285.8
	K^- (d)	0.996	309	265.1
Star [26]	$K^+,K^-/K^+$	1.088	16	7.6
Alice [25] 2.76 TeV	K/π	0.985	15	21.6
Total			1194	1271.7



DEHSS, PRD95, 094019 (2017)

COMPASS K+ multiplicities



- Half of entries from COMPASS
- D_s^K smaller than in DSS07

Simultaneous study of PDF and FF

Borsa, Sassot & Stratmann arXiv:1708.01630v

Iterative procedure; fitting SIDIS charged kaon multiplicities from COMPASS and HERMES.

Concluding on NNPDF3.0 PDF set for s(x).

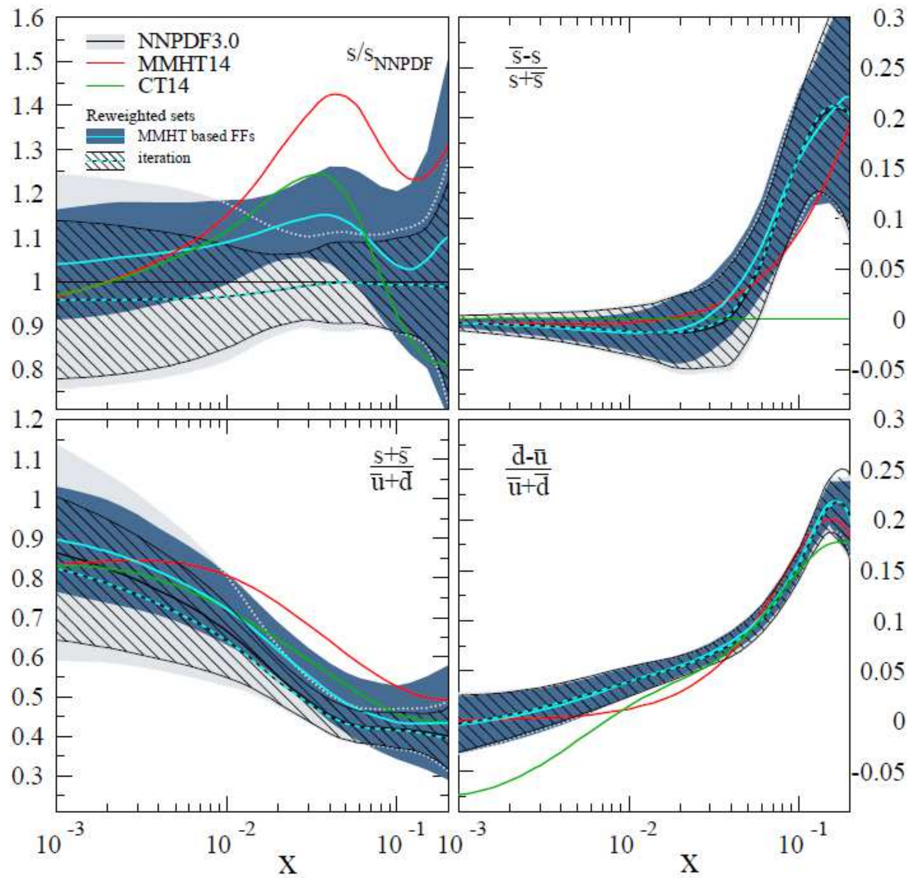


FIG. 5: Reweighting of the strange quark distribution (upper left panel) and for the PDF combinations sensitive to charge (upper right panel) and flavor (lower panels) symmetry breaking using the DSS 17 set of kaon FFs that is based on the MMHT 14 set of PDFs; see text. The dashed light blue and black lines and the hatched areas represent the results of one iteration of the reweighting procedure and the corresponding uncertainty bands, respectively; see text. All results are shown at a scale of $Q^2 = 5\,\mathrm{GeV}^2$.

Six Transverse Target spin asymmetries

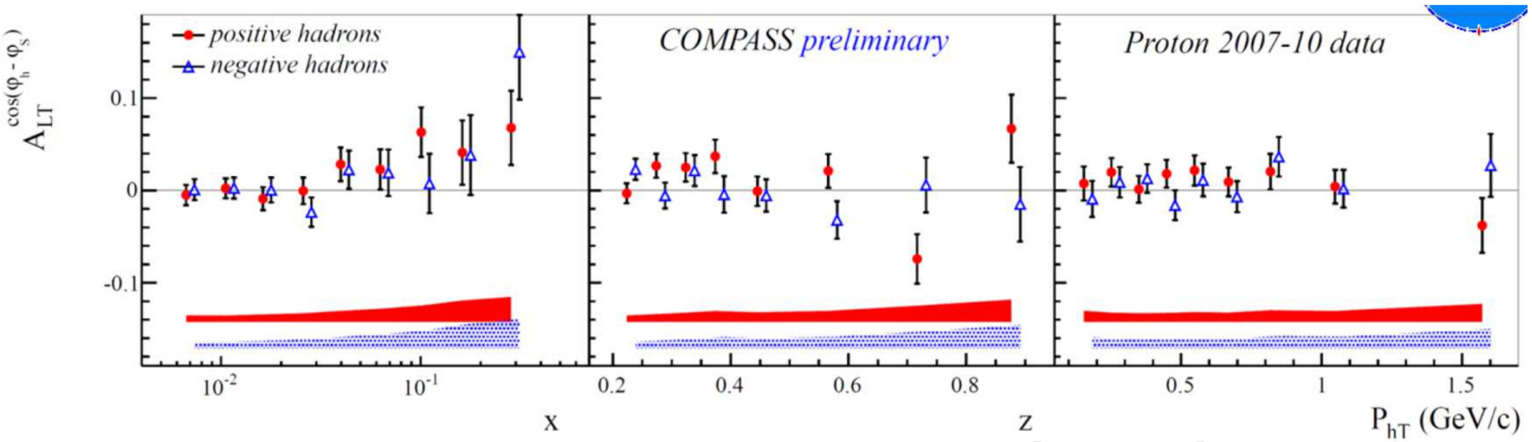
beyond Collins & Sivers, access TMDs

$\mu\, p^{\uparrow} \rightarrow \mu\, p\, h^{+/-}$

k_T effects → modulations in SIDIS cross-section

- **Major progress in TMD measurement**
- **Powerful tool to understand correlations**

$A_{LT}^{\cos(\varphi_h - \varphi_s)}$ shown as example



$A_{LT}^{\cos(\phi_h - \phi_s)} \propto g_{1T}^q \otimes D_{1q}^h$, "Worm Gear" PDF g_{1T}^q :

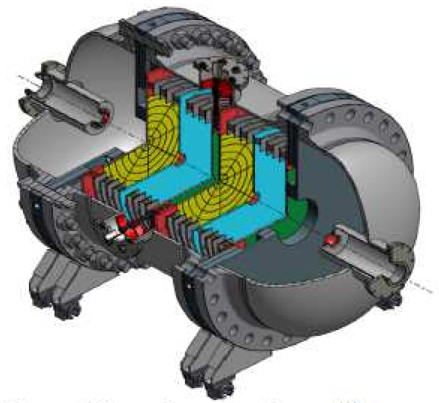
In agreement with HERMES prelim., and with theoretical predictions

Proton Radius measurement–COMPASS Proposal

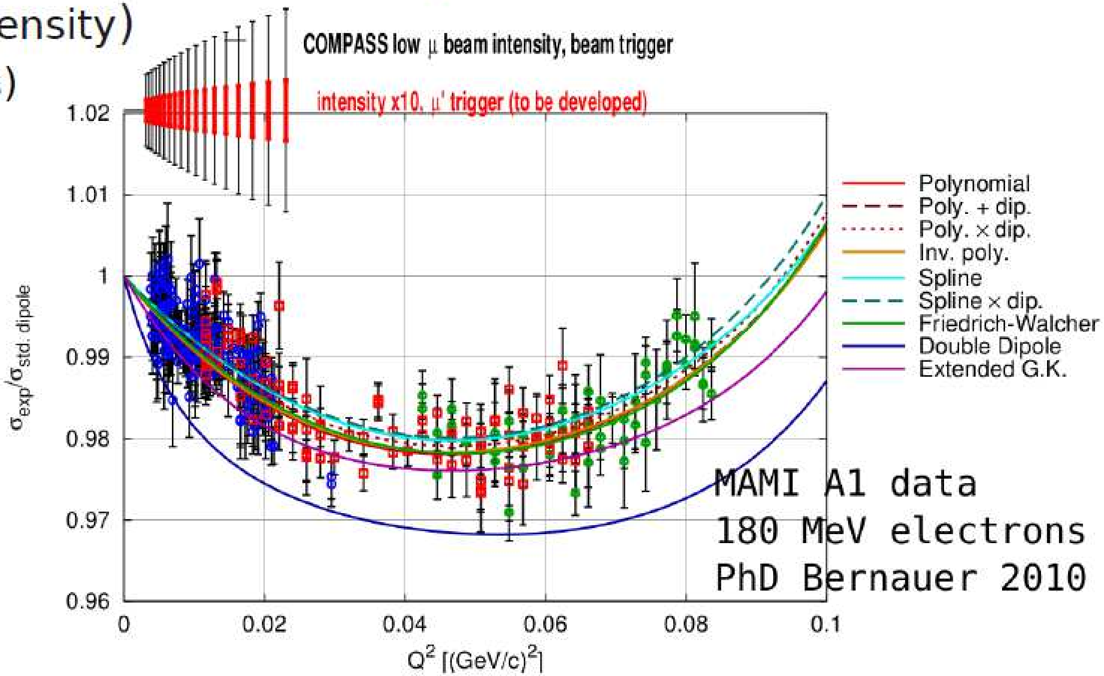
- 100 GeV SPS muon beam (M2)
- Hydrogen high-pressure active TPC target cell (PNPI development)
- Measure the cross-section (shape) over broad Q^2 range 10^{-4} ... 10^{-1}
- From 10^{-3} ... $2*10^{-2}$ fit the proton radius (slope of electric form factor)
  - Precision 0.03 fm with conservative beam trigger (0.5% beam intensity)
  - Goal: 0.01 fm (from 180 days) trigger concept to be solved

unique because...

- muon beam requires a factor 10 smaller radiative corrections than e^- beams (vs. Mainz, Jlab)
- high-energy muon beam, very small scattering angles: practically no Coulomb correction (vs. MUSE)
- *best systematics control*



IKAR active target cell
A. Vorobyev, St. Petersburg



COMPASS proposal to CERN SPSC Oct.2017
Slide from J.Friedrich

Ratio of K^+ to K^- multiplicity at high z (1/2)

Study **ratio of K^+ to K^-** multiplicities at high z:

These are the first SIDIS multiplicity data at **z> 0.85**
No contributions from diffractive production of ϕ
Many systematic uncertainties cancel

Ratio has simple expression in pQCD LO for independent FFs:

$$\frac{dM^{K^+}}{dz} \Big/ \frac{dM^{K^-}}{dz} = \frac{4uD_{fav}+\bar{s}D_{str}}{4\bar{u}D_{fav}+sD_{str}}$$

Gives a simple limit within some assumptions
(D_{unf} negligible at z>0.5, s=sbar):

$$\frac{dM^{K^+}}{dz} \Big/ \frac{dM^{K^-}}{dz} < \frac{u}{\bar{u}}$$ for proton target

$$\frac{dM^{K^+}}{dz} \Big/ \frac{dM^{K^-}}{dz} < \frac{u+d}{\bar{u}+\bar{d}}$$ for deuteron target