

**The story of
TRANSVERSITY @ COMPASS**

Franco Bradamante

**Symposium in honour
of Gerhard Mallot**

CERN, February 19, 2020

The story of TRANSVERSITY @ COMPASS

My personal interest in **transverse spin phenomena** in hadronic physics

Spectacular spin effects seen at **LEAR** 1983-1992

and also at **E704** Trieste participation, A. Penzo et al.

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transversity PDF

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organized by R. Hess, to finalize the proposal
X. Artru, J. Collins, ..., A. Kotzinian

HELP (Hadronic ELection Production at LEP)

L. Dick, A. Penzo, B. Vuaridel,.....

October 1993: HELP Proposal

Transversity (no Sivers...)



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Rejected



TRY AGAIN embedding **transverse spin phenomena** in a RICHER program
with former **SMC collaborators**

First HMC **1995** flagship measurement: $\Delta g/g$ proposed by Dietrich

Then COMPASS 1996 CHEOPS+HMC

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no easy life for transverse spin there either:

many colleagues still regarded transverse spin phenomena as black magic

internal audit: Dietrich proposed Hans Siebert, from Heidelberg as referee...

ultimately a compromise was reached: **20 : 80 running time ratio for T : L**

AND A PROPOSAL WAS SUBMITTED on March 1st, 1996

editors : Gerd, Franco and Stephan

with the help of many people ... Lars, Massimo, Anna, Aram, Wojtek, Ewa ...

From my archives.....

mail from Stephan on February 20, 1996

Dear colleagues,

for your convenience you can now also find the newest version of the joint proposal (former CHEOPS/HMC) on the WEB.

Use the adress :

<http://axhyp1.cern.ch/cheops/proposal/>

There you find the proposal in different printing formats. As mentioned in the previous mail by Franco, you can of course also get it on CERNSP.

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Please read the document carefully and submit all your comments to

Gerd or Stephan or Franco

(gkm@na47sun05.cern.ch) (snp@vsnhd1.cern.ch) (bradamante@trieste.infn.it)

We still have not yet decided for the name of our common enterprise.

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COMPASS -

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The currently best suggestion is :

COMPASS - 'Charm Oriented Muon Proton Alternating Spectrometer Setup'

With best regards

The editors

The COMPASS proposal

Common Muon and Proton Apparatus for Structure and Spectroscopy



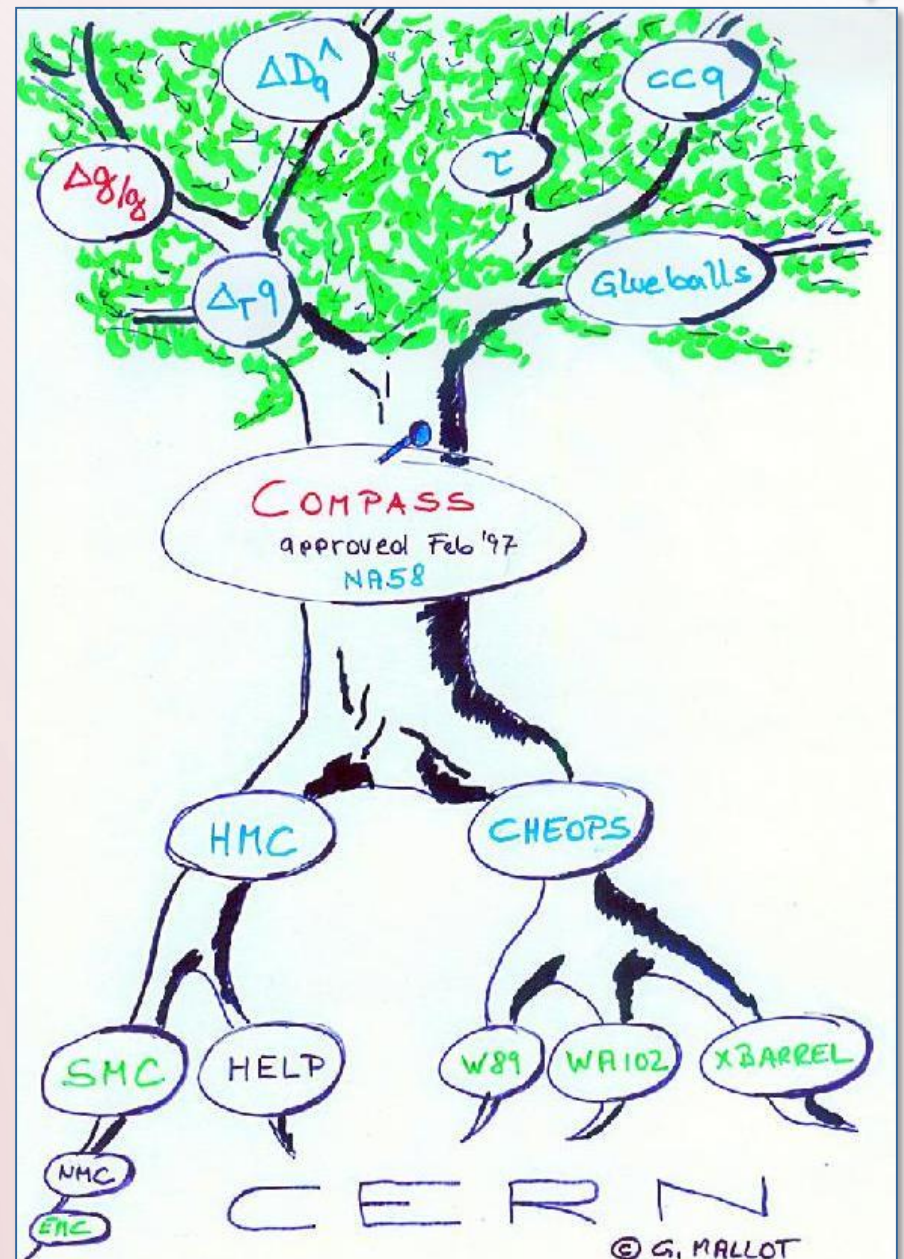
was approved in February **1997**

and data taken started in **2002**

with muon beam

and polarized deuteron target

for the measurement of $\Delta g/g$





THE DEUTERON DATA

the first SIDIS data with a transversely polarized target in COMPASS

2002: 0.5 effective weeks of data taking
in 2004 first results for the **Collins asymmetry** $A_{Coll} \sim \frac{\sum_q e_q^2 h_1^q \otimes H_{1q}^\perp}{\sum_q e_q^2 f_1^q \cdot D_{1q}}$

and for the **Sivers asymmetries** $A_{Siv} \sim \frac{\sum_q e_q^2 f_{1T}^{\perp q} \otimes D_{1q}}{\sum_q e_q^2 f_1^q \cdot D_{1q}}$
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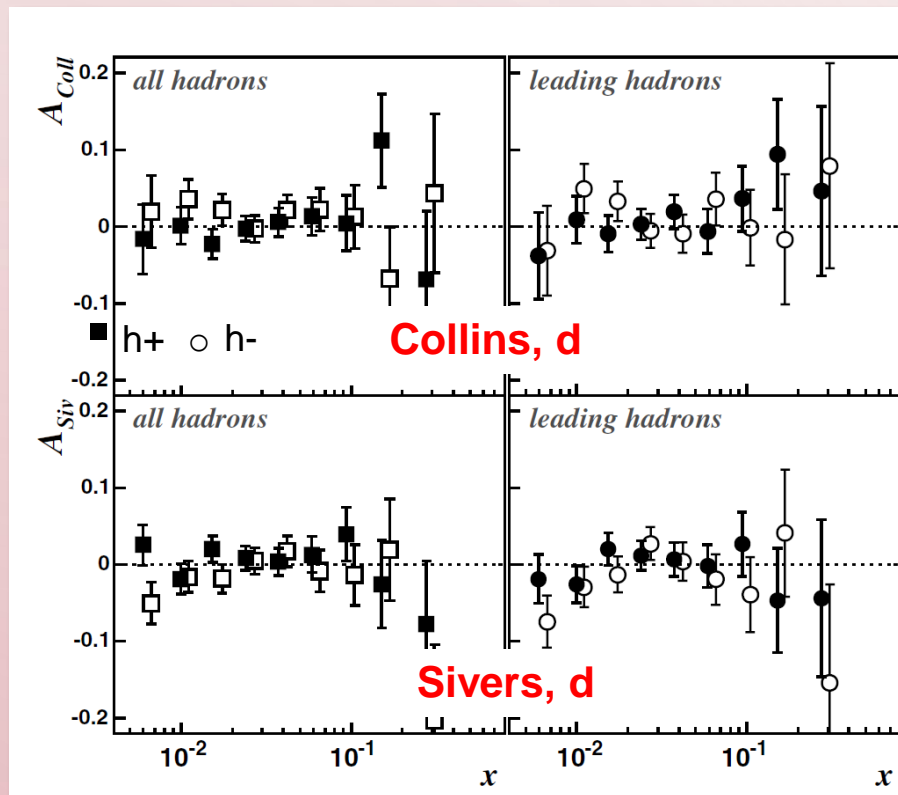
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PRL 94, 202002 (2005)

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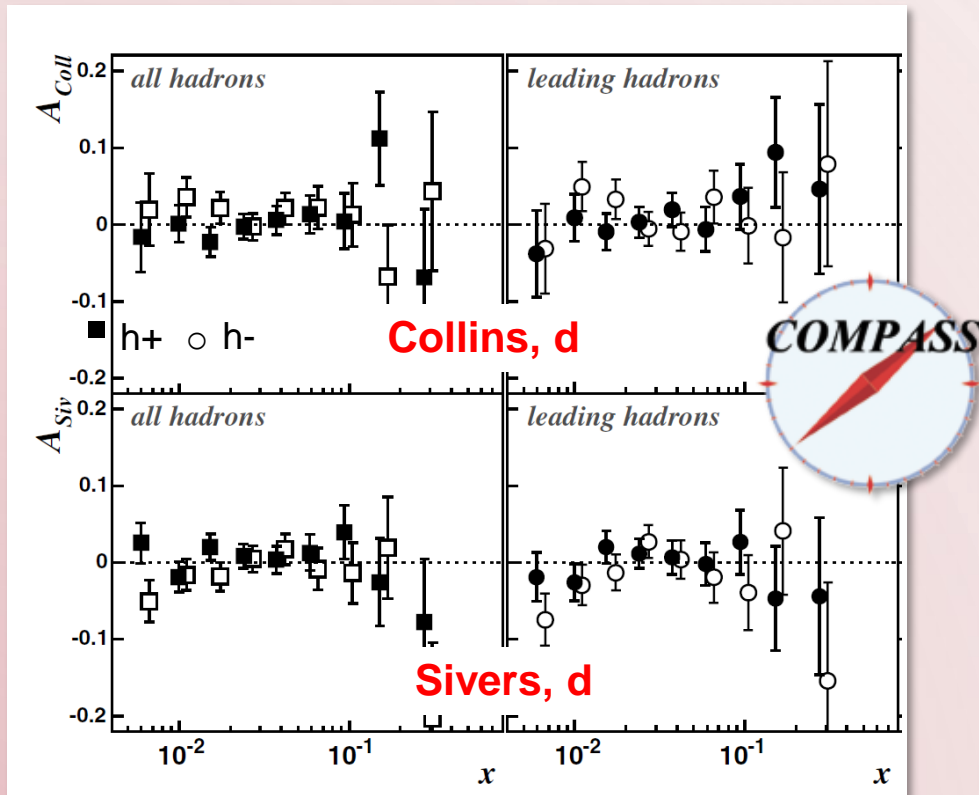
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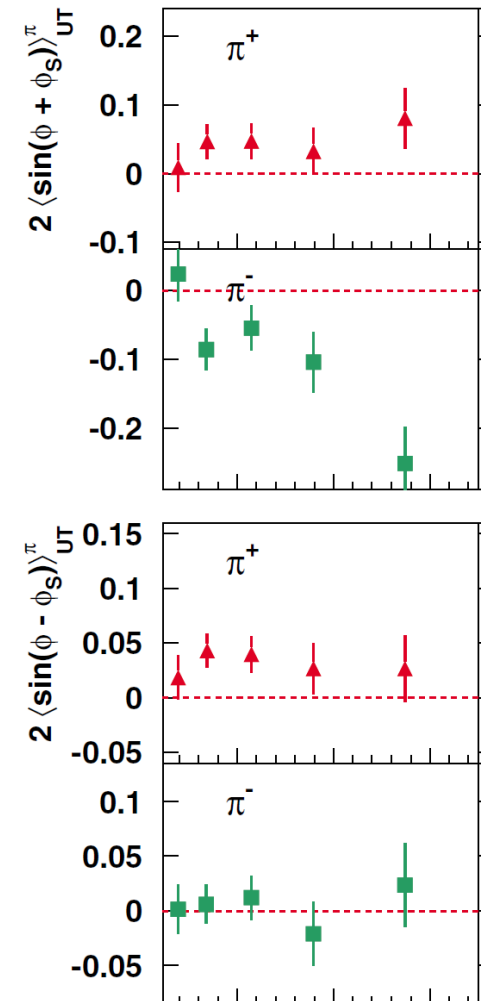


PRL 94, 202002 (2005)



Luckily, in the mean time, HERMES measurements with a proton target

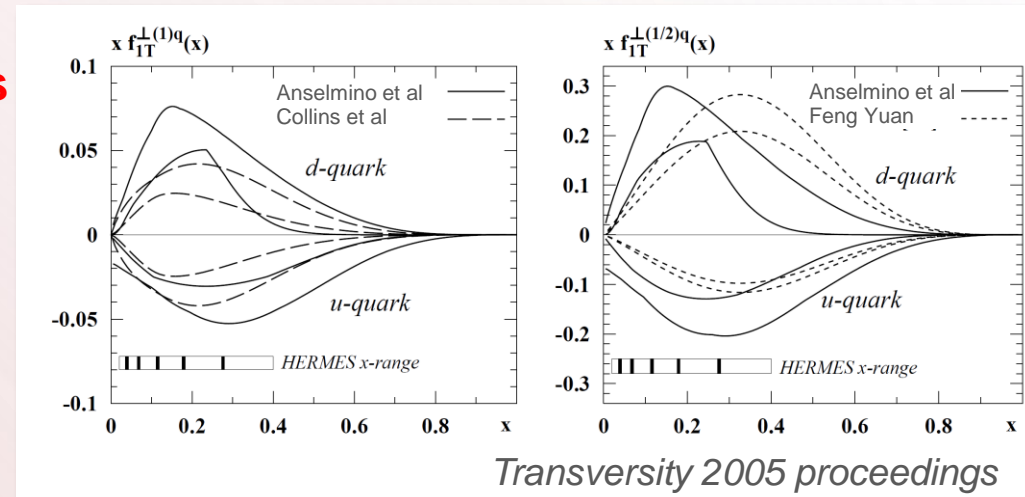
for the first time clear signals: real effects !



first extractions of the new PDFs

the first extractions of the **Sivers functions** from the p and d Sivers asymmetries came soon after

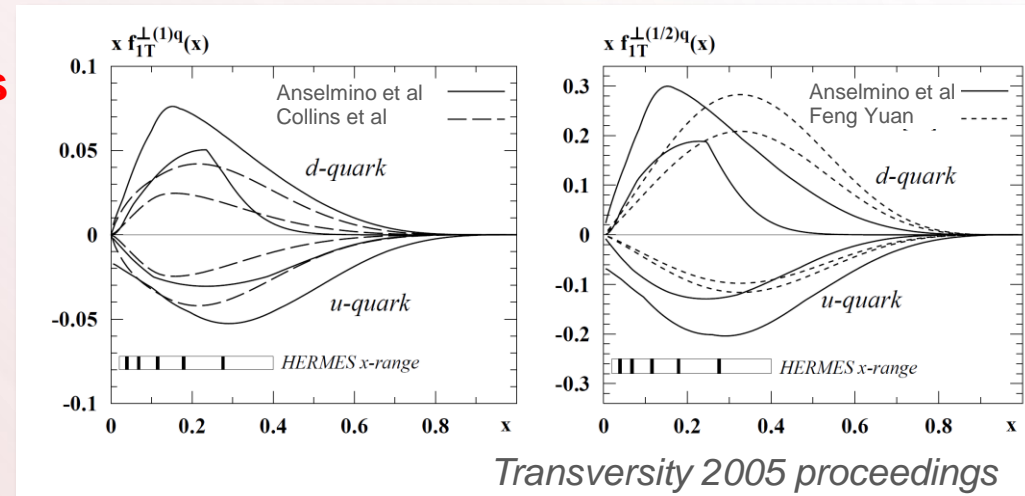
the HERMES and COMPASS data could be well described
confirmation that the COMPASS results could be due to u d quark cancellation



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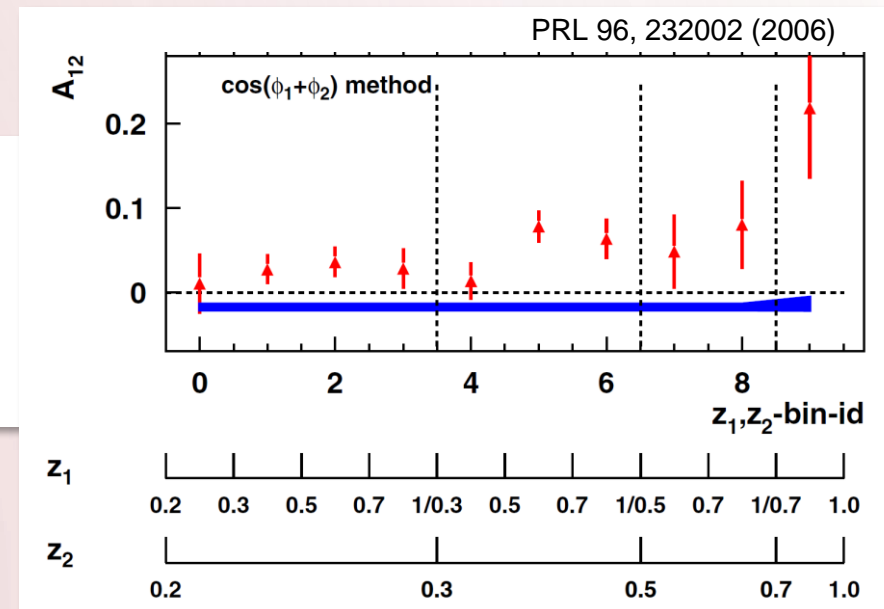


the extraction of the **transversity** distributions took some more time
 the Collins FF was the missing piece
 it was qualitatively described by the Artru 3P_0 model

$$A_{Coll} \sim \frac{\sum_q e_q^2 h_1^q \otimes H_{1q}^{\perp}}{\sum_q e_q^2 f_1^q \cdot D_{1q}}$$

first measurements of the Collins-like asymmetry in $e^+e^- \rightarrow hadrons$ at BELLE

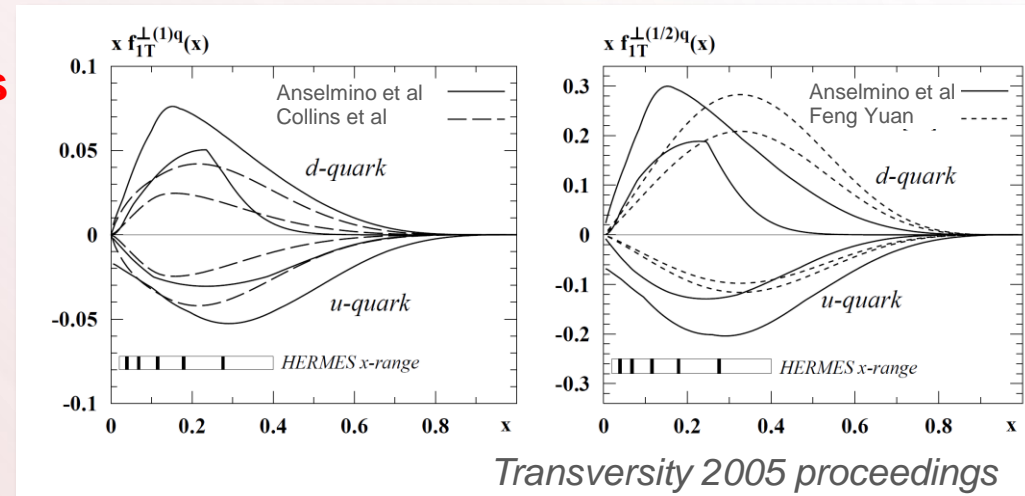
clear independent indication of non-zero Collins FFs



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first measurements at BELLE

again indication that the COMPASS result on the Collins asymmetry could be due to u d cancellation

to summarize:

- clear signals of the new transverse spin effects seen at HERMES and Belle
- a consistent picture of transverse spin effects was coming out, which could explain the both the HERMES proton and the COMPASS deuteron data

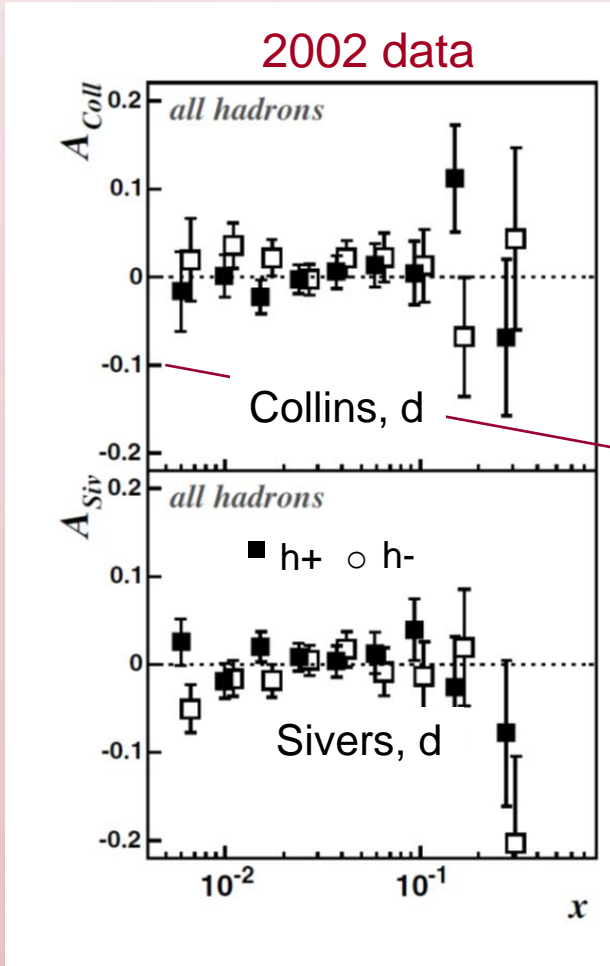
THE FINAL DEUTERON DATA



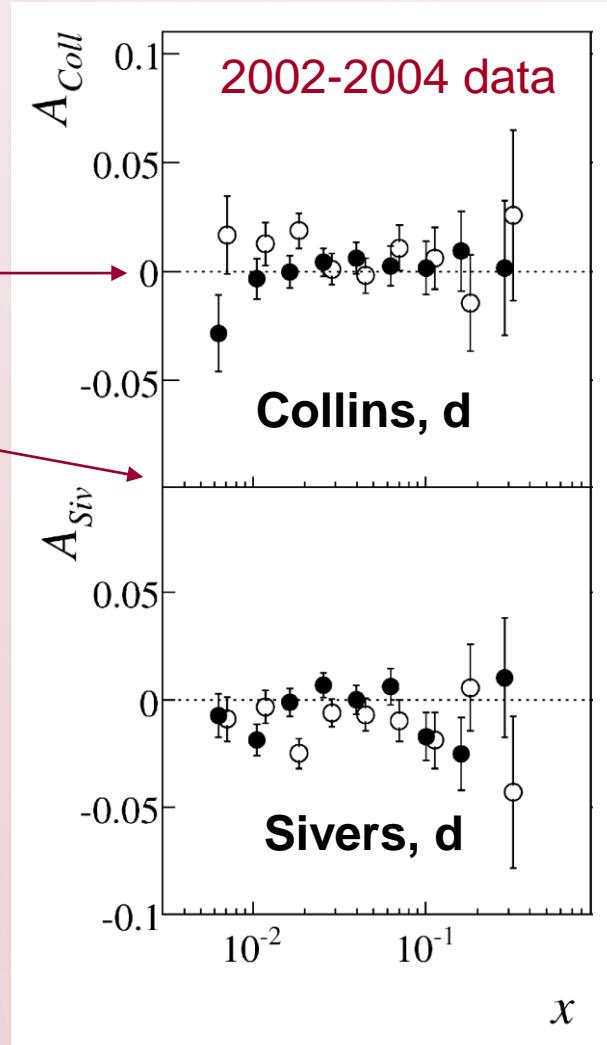
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PRL 94, 202002 (2005)



NPB 765 (2007) 31

final results for deuteron

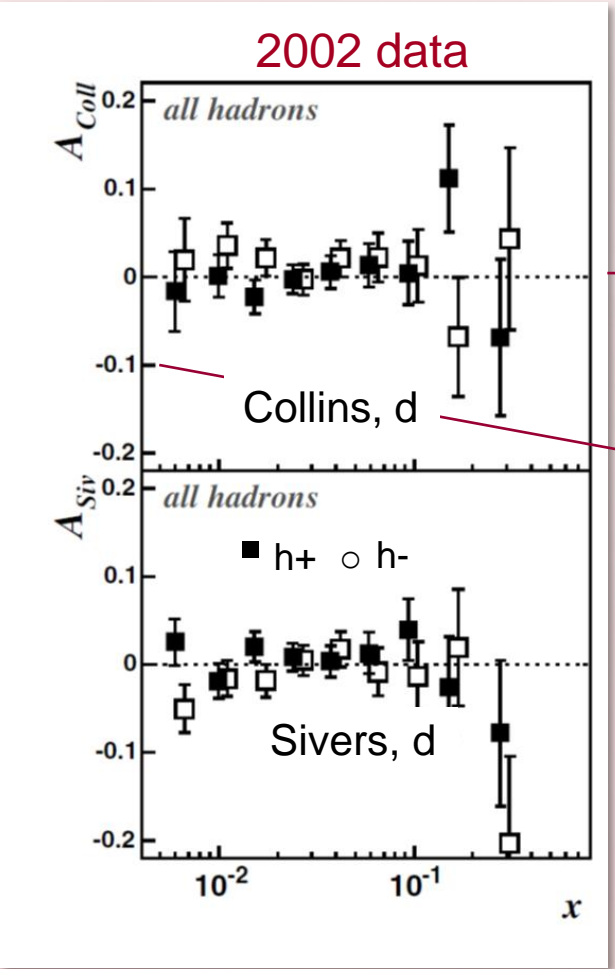
a much more precise
measurements of zero

still, large statistical
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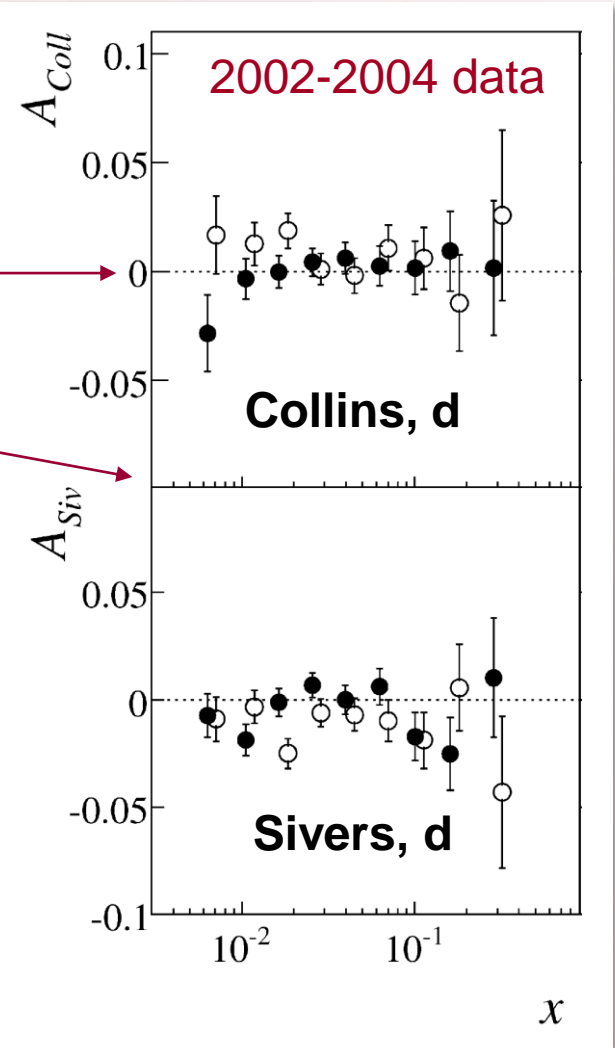


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PRL 94, 20202 (2005)



NPB 765 (2007) 31

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still, large statistical uncertainties

today, these are the only existing deuteron data

JLab6: ^3He , statistically limited

→ 2021 run

THE FINAL DEUTERON DATA



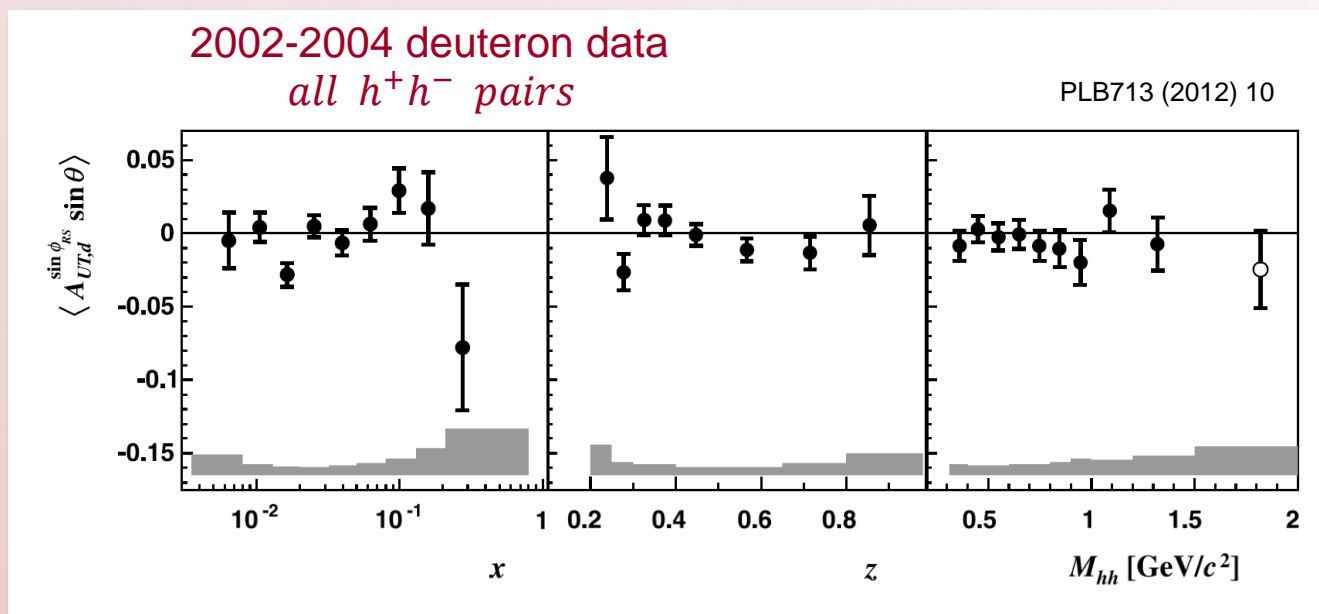
looking for a signal

di-hadron asymmetries:

a different approach to transversity

$$A_{hh} \sim \frac{\sum_q e_q^2 h_1^q \cdot H_{1q}^{\zeta}}{\sum_q e_q^2 f_1^q \cdot D_{1q}^{hh}}$$

Belle



many tests measurements:

- z ordering, leading + or - with sub-leading like or unlike sign
- particle identification
-

a lot of expectation for the
COMPASS proton results
(higher energy)

THE PROTON DATA



2007 half year of data taking - the signals are there **but**

THE PROTON DATA



2007 half year of data taking - the signals are there **but**

Collins asymmetry ok

Sivers asymmetry first part of data taking
compatible with zero, at variance with HERMES
second part of data taking
positive for positive hadrons

a long a difficult analysis, without understanding the reason of the discrepancy

results published with large systematic uncertainties

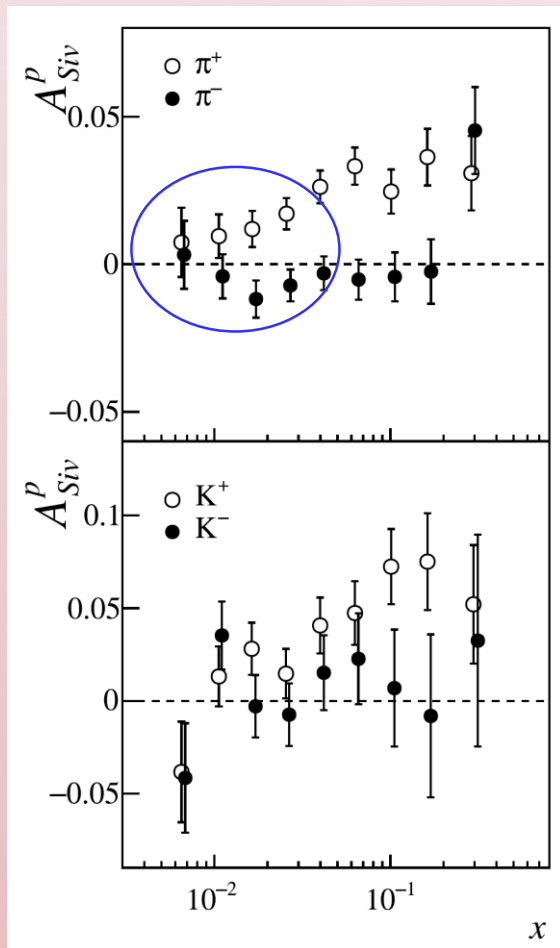
→ strong motivation to ask for one year of data taking
asked in June 2009, approved soon after (.. Elke)
data taking in 2010

THE PROTON DATA



2007 half year, 2010 one year of data taking - the signals are there!

Sivers asymmetry all proton data

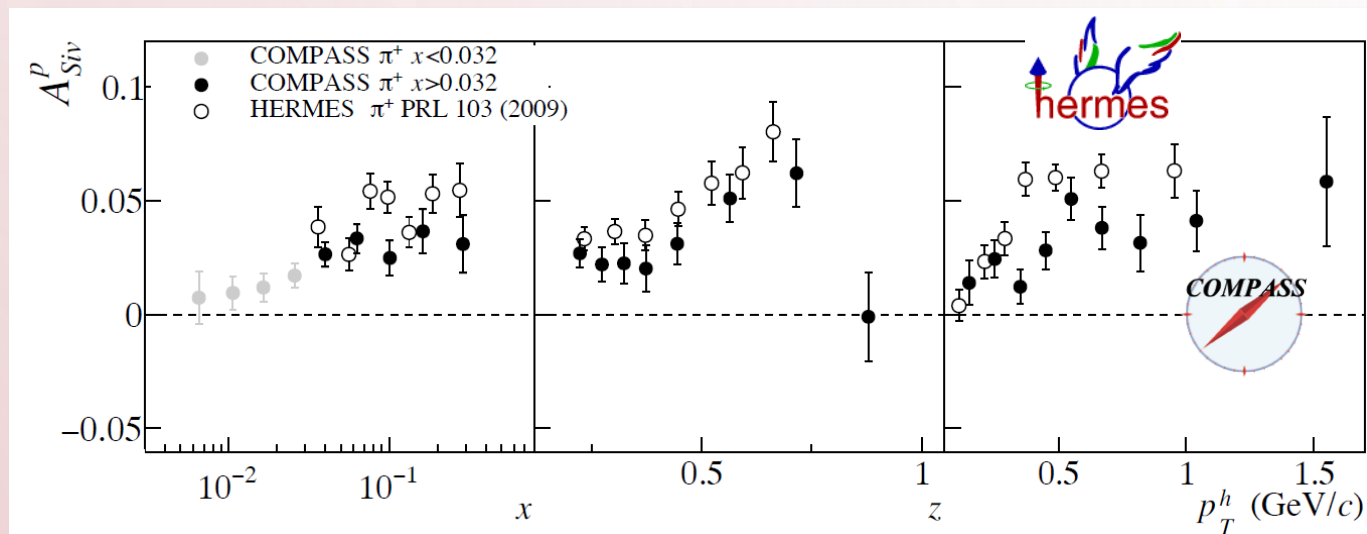
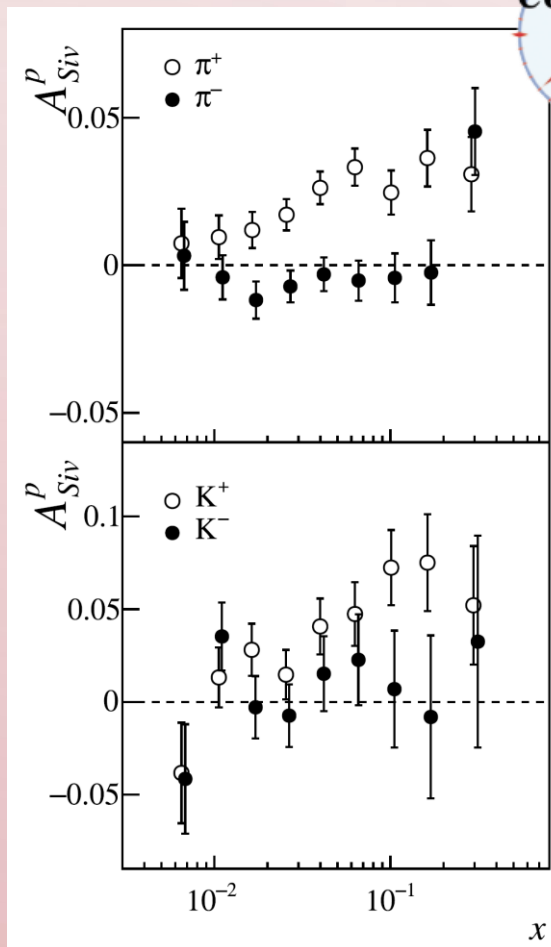


PLB 744 (2015) 250
PLB 717 (2012) 383

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all proton data



smaller values at COMPASS:
TMD evolution ...

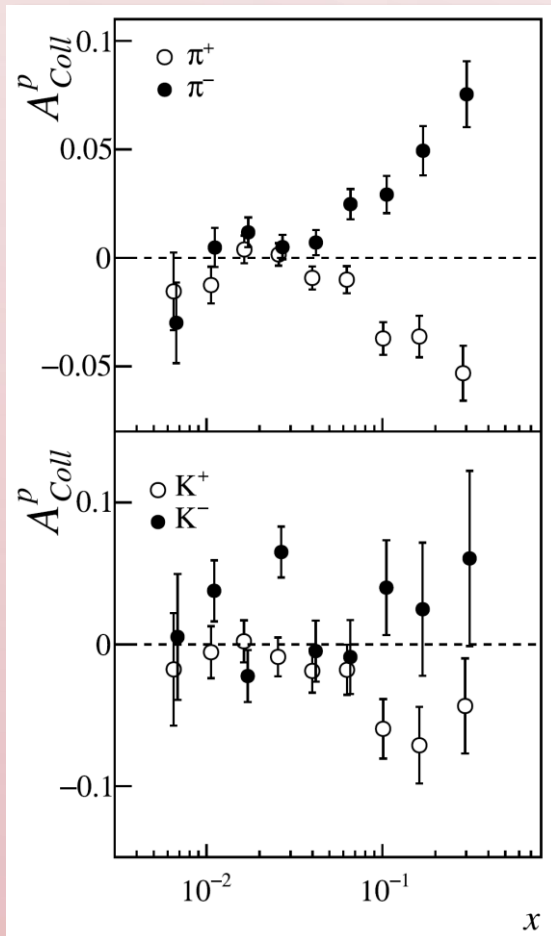
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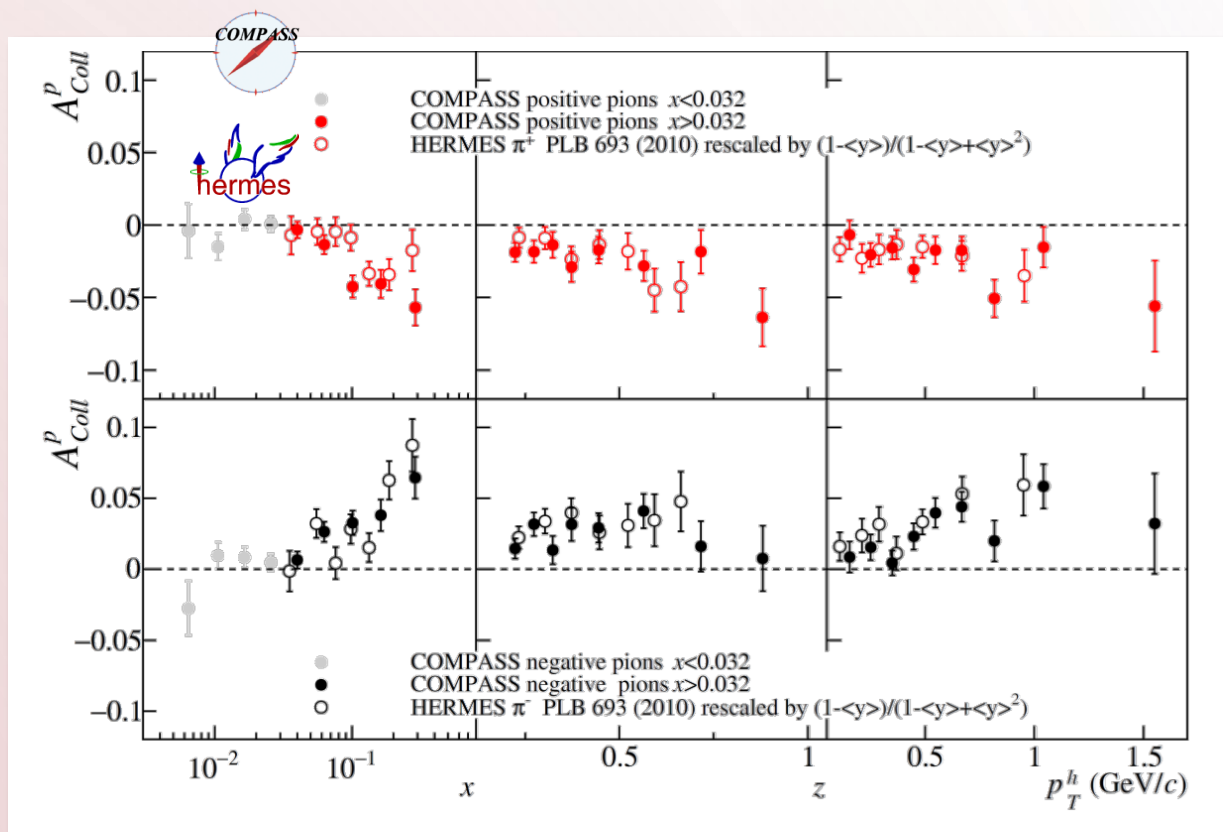
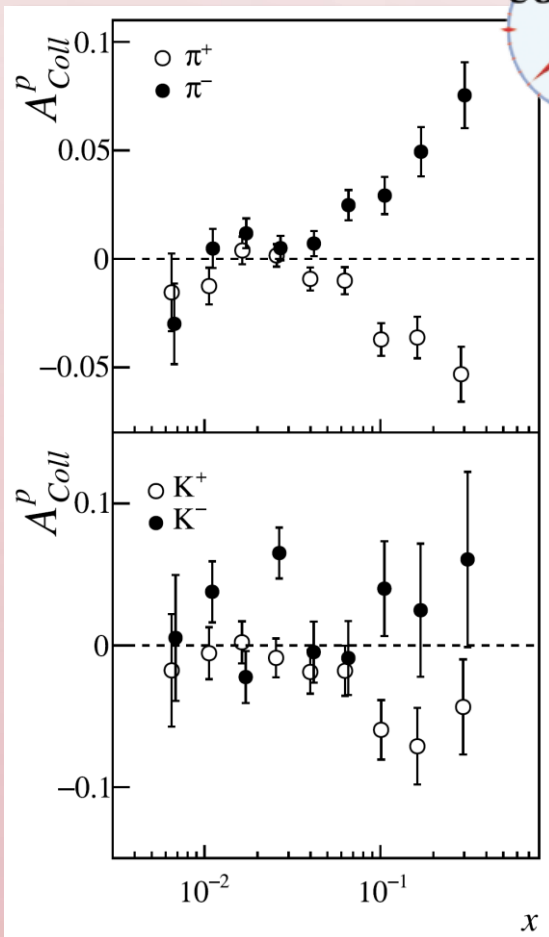


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very good agreement !

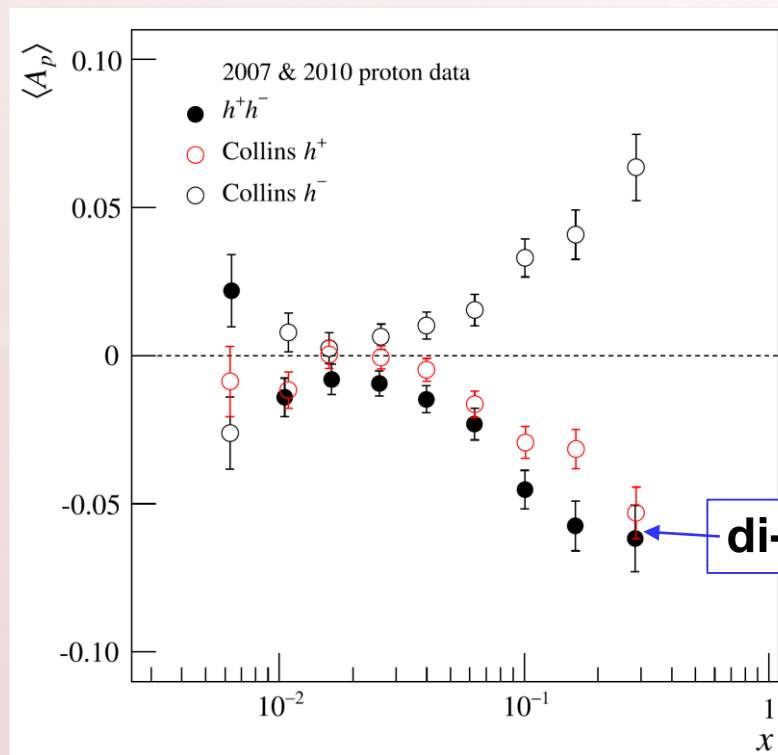
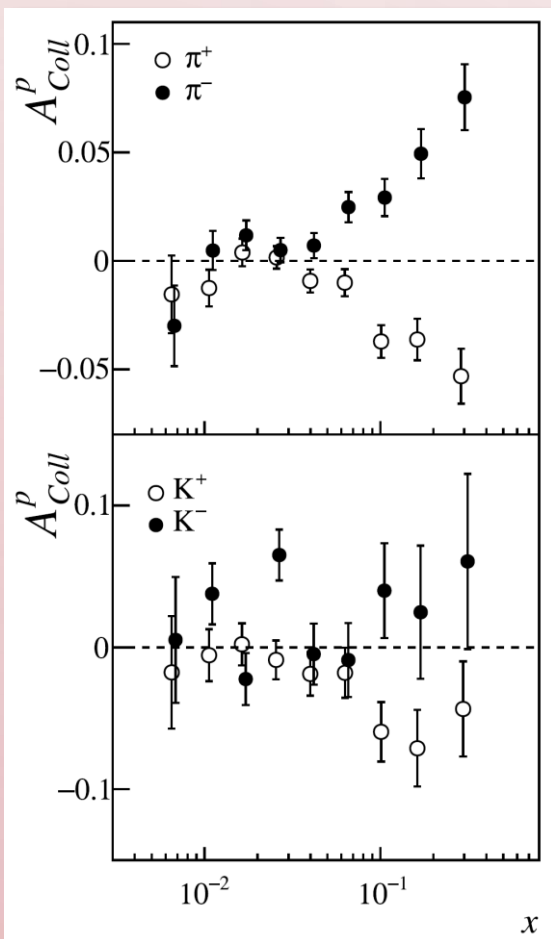
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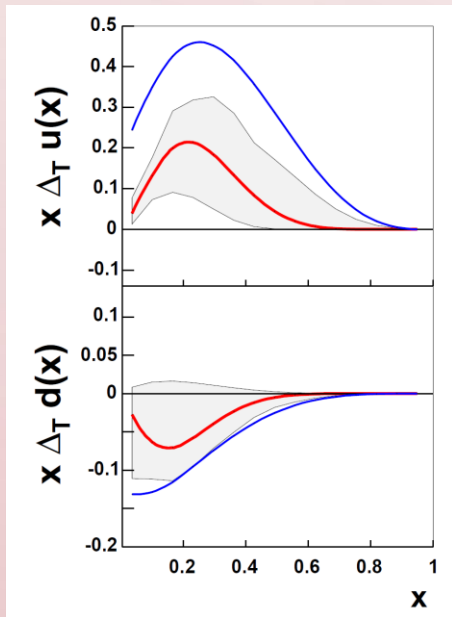
study of the interplay between
Collins and di-hadron asymmetries
– not independent

PLB 744 (2015) 250
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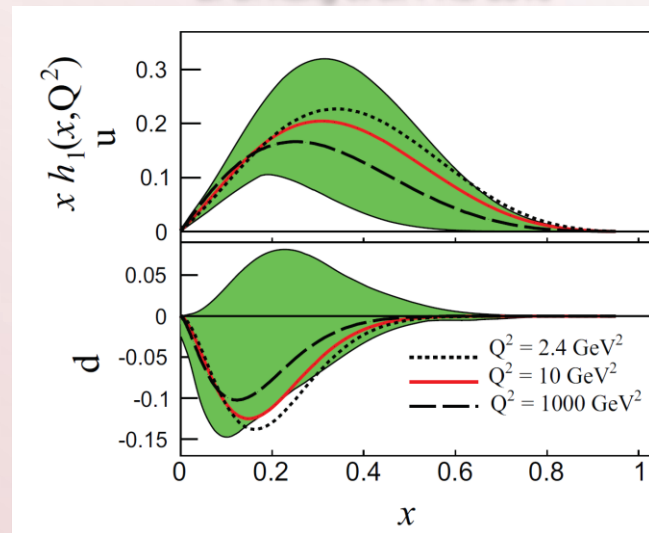
extractions of transversity

global fits of
Collins asymmetries
SIDIS, e^+e^- data

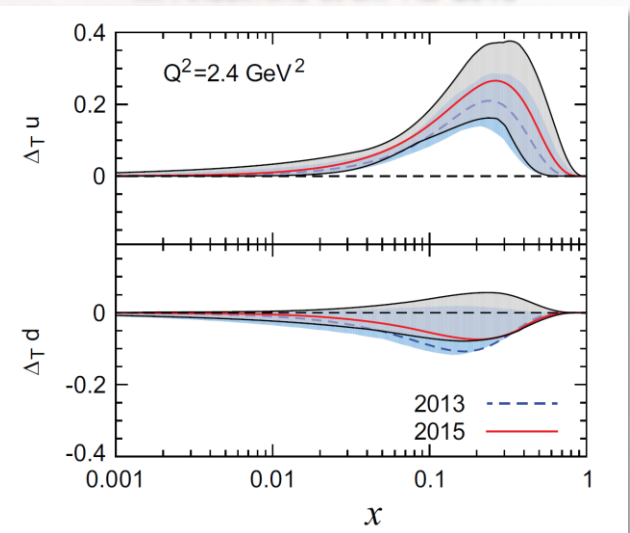
Anselmino et al PRD 2007



Z.-B. Kang et al. PRD 2016

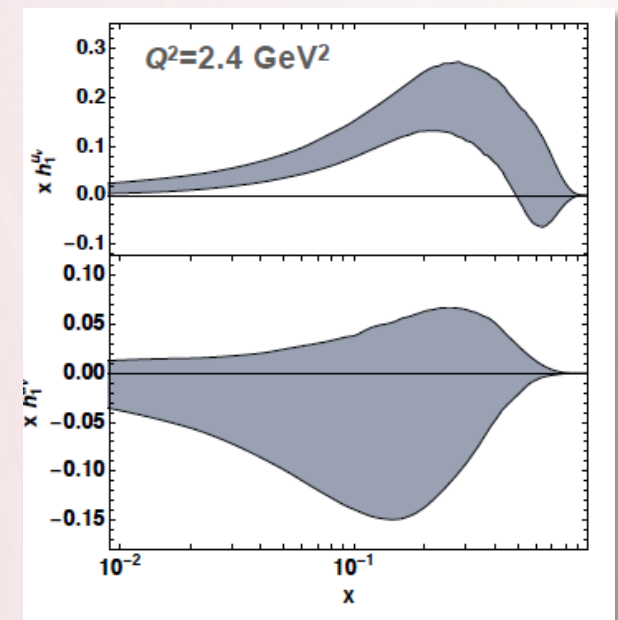


M. Anselmino et al. PRD 2015



global fits of
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SIDIS, e^+e^- , pp data

Radici Bacchetta PRL 2018

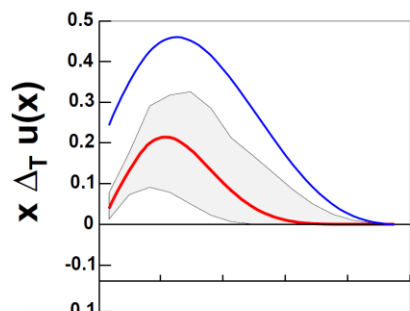


Franco Bradamante

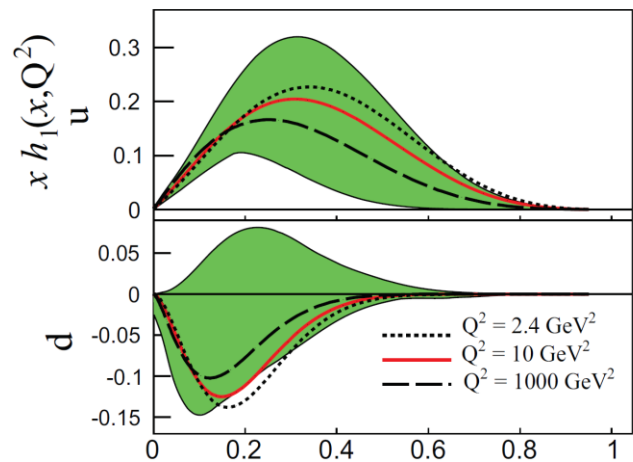
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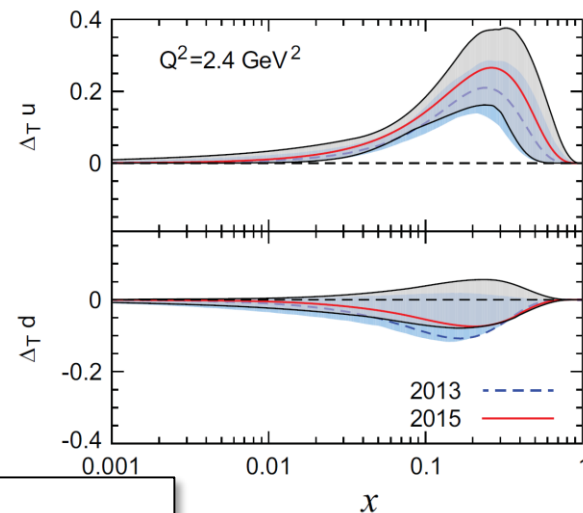
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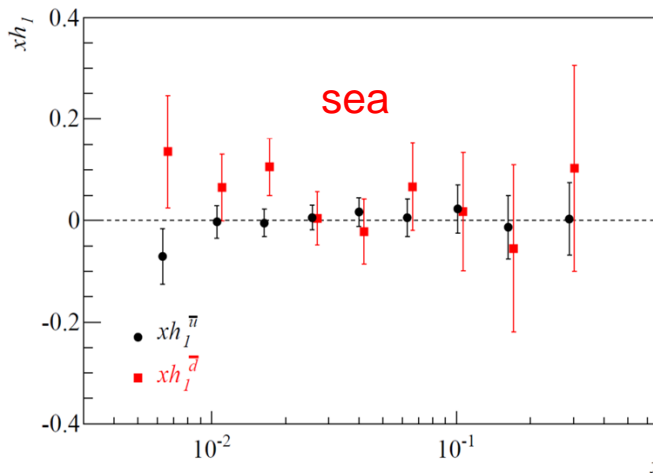
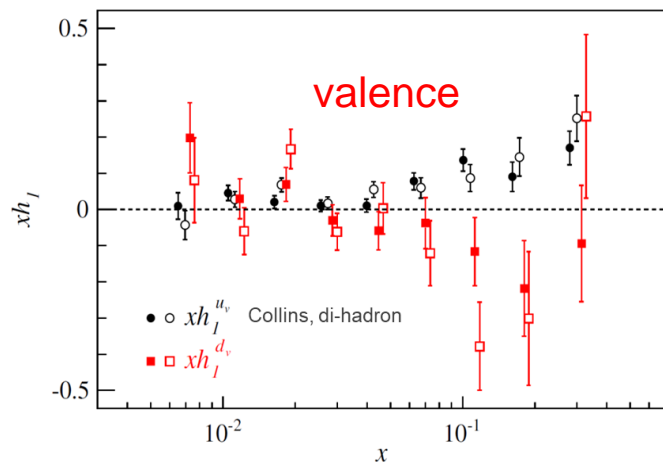
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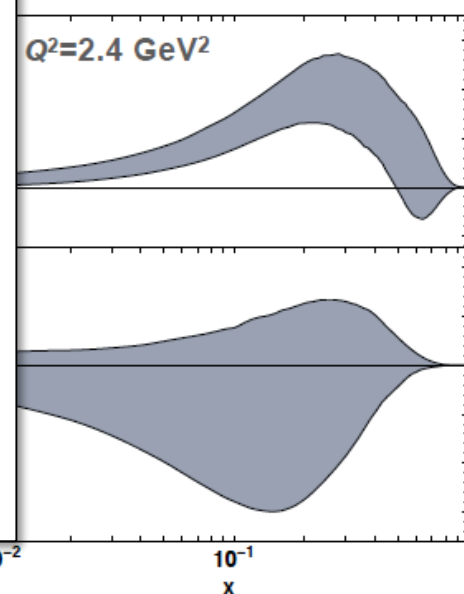
M. Anselmino et al. PRD 2015



A. Martin, F. B., V. Barone PRD 2015



Radici Bacchetta PRL 2018



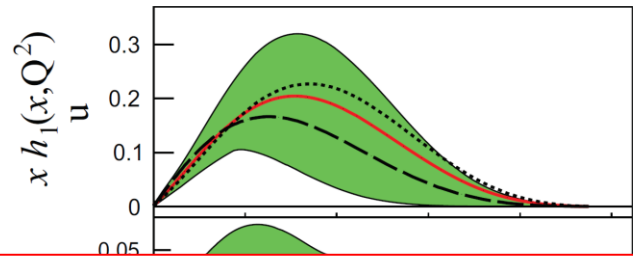
point by point extraction

using COMPASS p and d asymmetries, and e^+e^- data, no Soffer bound
advantage: no Monte Carlo nor parametrisation is needed

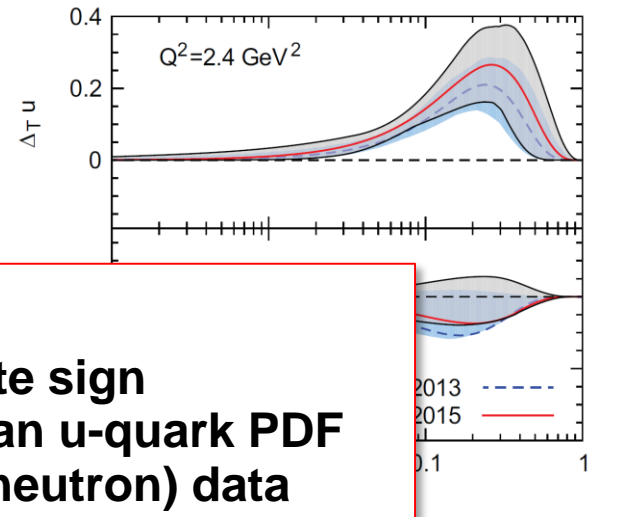
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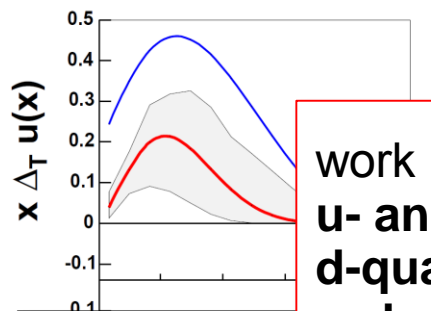
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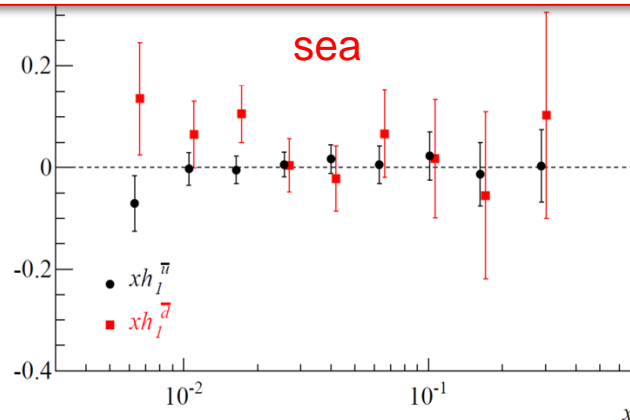
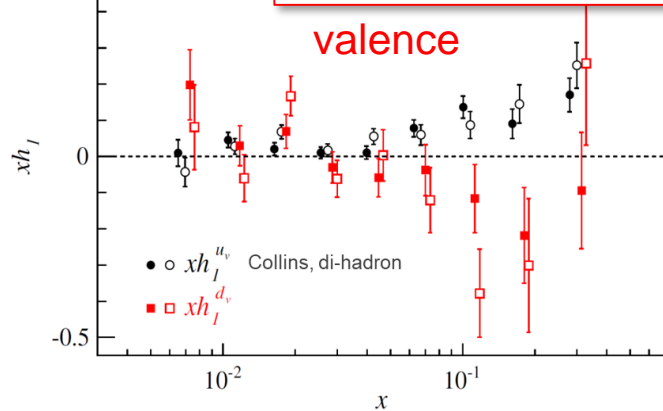


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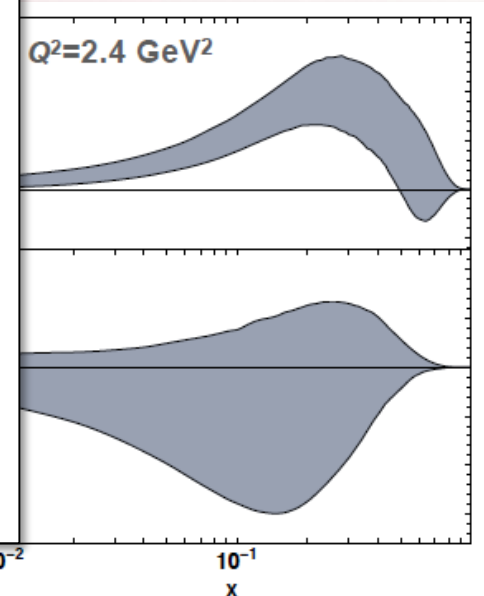
work still ongoing ...
u- and d-quark transversity have opposite sign
d-quark PDF much worse determined than u-quark PDF
 because of the scarcity of deuteron (neutron) data
 → 2021 run

Radici Bacchetta PRL 2018



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SOME PERSONAL MEDITATIONS

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it was a logical decision, since we were the majority shareholders
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we could get ONE CERN position, and Stephan and me
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25 years dedicated to COMPASS, and it is not over

AND ... what about Gerd and transversity?

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AND ... what about Gerd and transversity?



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we made a special investment on him at Transversity 2011
he did his best, but the result was disappointing



AND ... what about Gerd and transversity?

STILL, transverse spin physics owes much to Gerd

It is fair to say that COMPASS could perform so well over so many years thanks to the

great technical expertise and the careful watching of Gerd



Franco
on behalf of the
Transversity Group

AND ... what about Gerd and transversity?

