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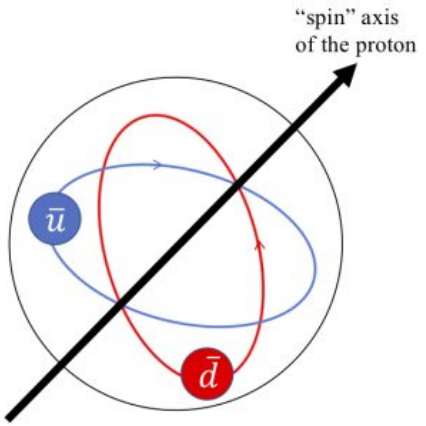
SPIN2021 The 24th International Spin Symposium

Matsue, Japan

18-22 October 2021
Matsue, Shimane Prefecture, Japan

Polarized Drell-Yan experiment at Fermilab, SpinQuest (E1039)

Y. Miyachi for the SpinQuest collaboration



Outline

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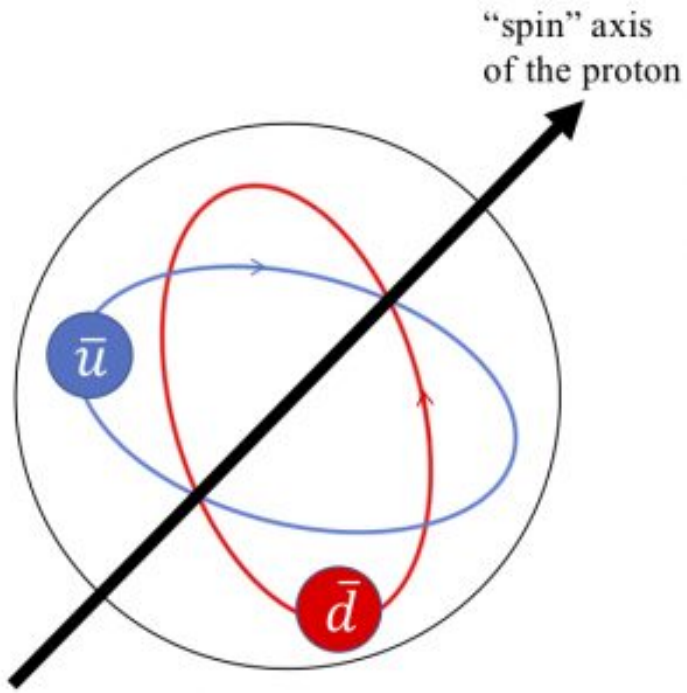
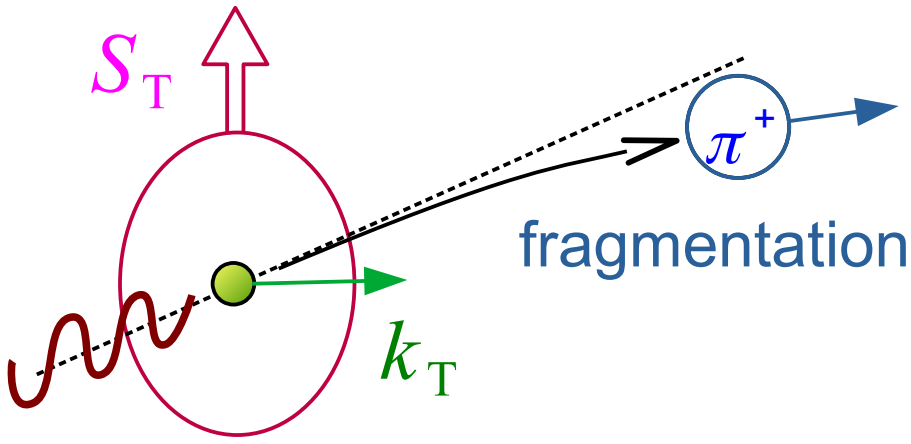
- Sivers asymmetry and distribution function
- SpinQuest experiment
  - Setup and expected Sivers asymmetries
  - Timeline
- Summary

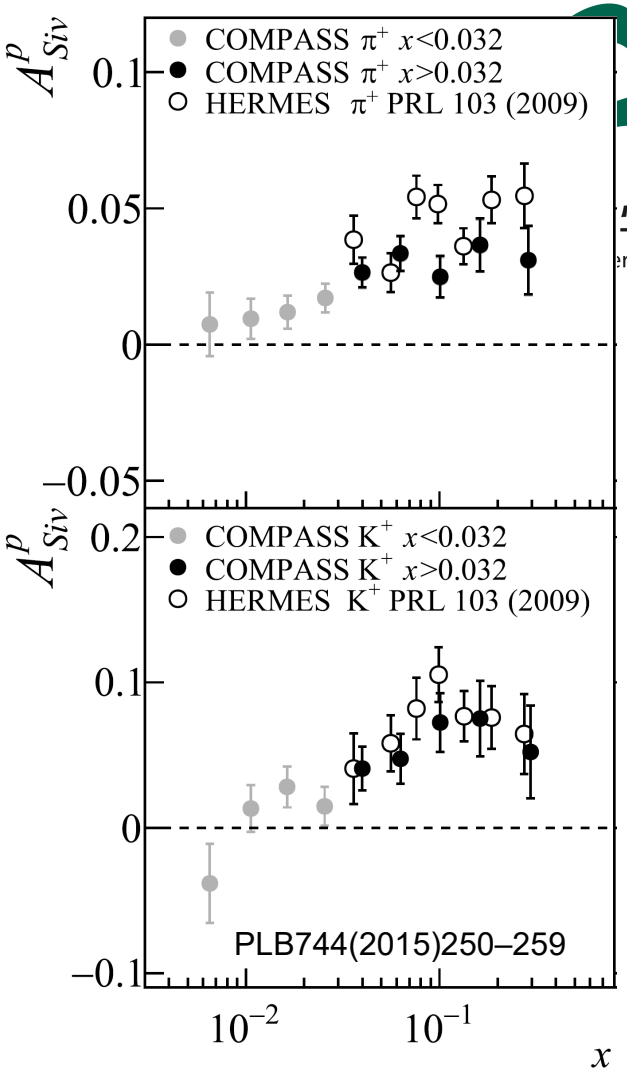


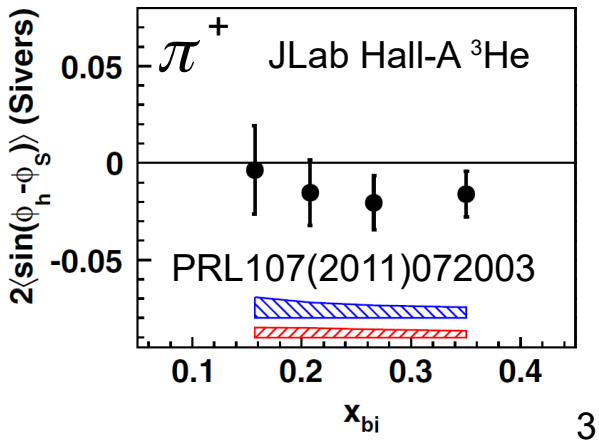
Sivers asymmetry



Azimuthal asymmetry of the **hadrons**
from **the unpolarized quark**
inside **the transversely polarized nucleon**
with respect to **the nucleon spin**

Measured in the **DIS** experiments
HERMES, COMPASS, Jlab
w/ polarized p, d, and ^{3}He





Sivers in hadron-hadron scattering

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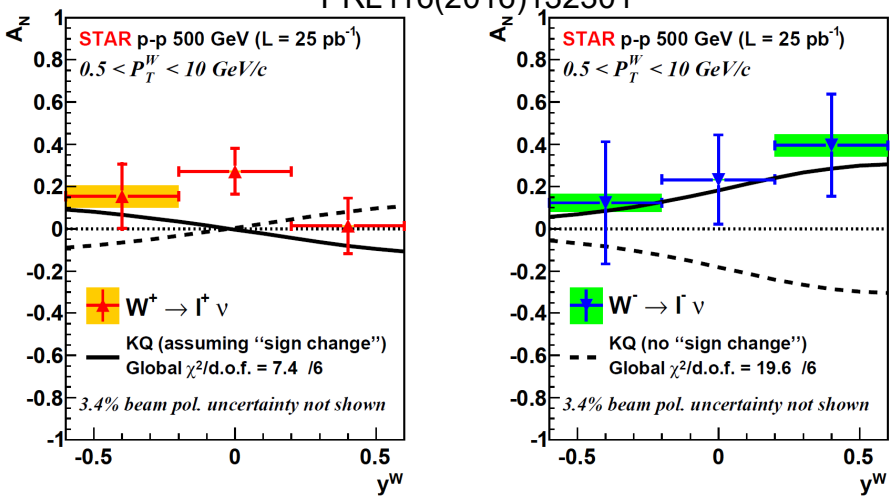
- W-prod. @RHIC and Drell-Yan @COMPASS indicate

  <u>the possible sign-change</u>

  of the Sivers distribution

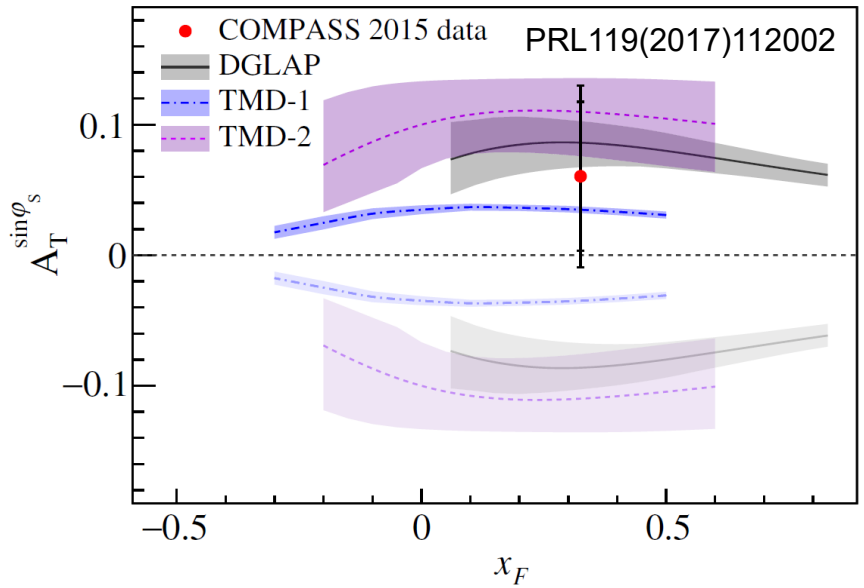
$$f_{1T}^{\perp}\Big|_{\mathrm{DIS}} = -\,f_{1T}^{\perp}\Big|_{\mathrm{DY,\,W/Z}}$$

PRL116(2016)132301

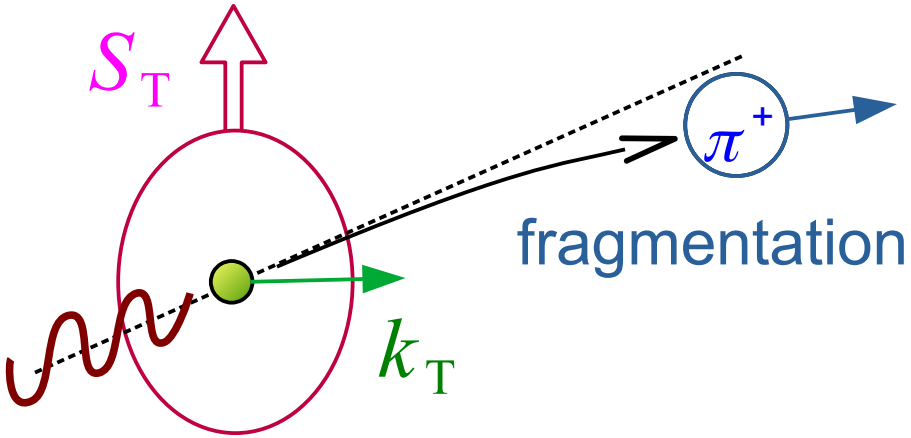


- More statistic required to understand Q^2 evolution
- TMD framework seems to be

  OK!!



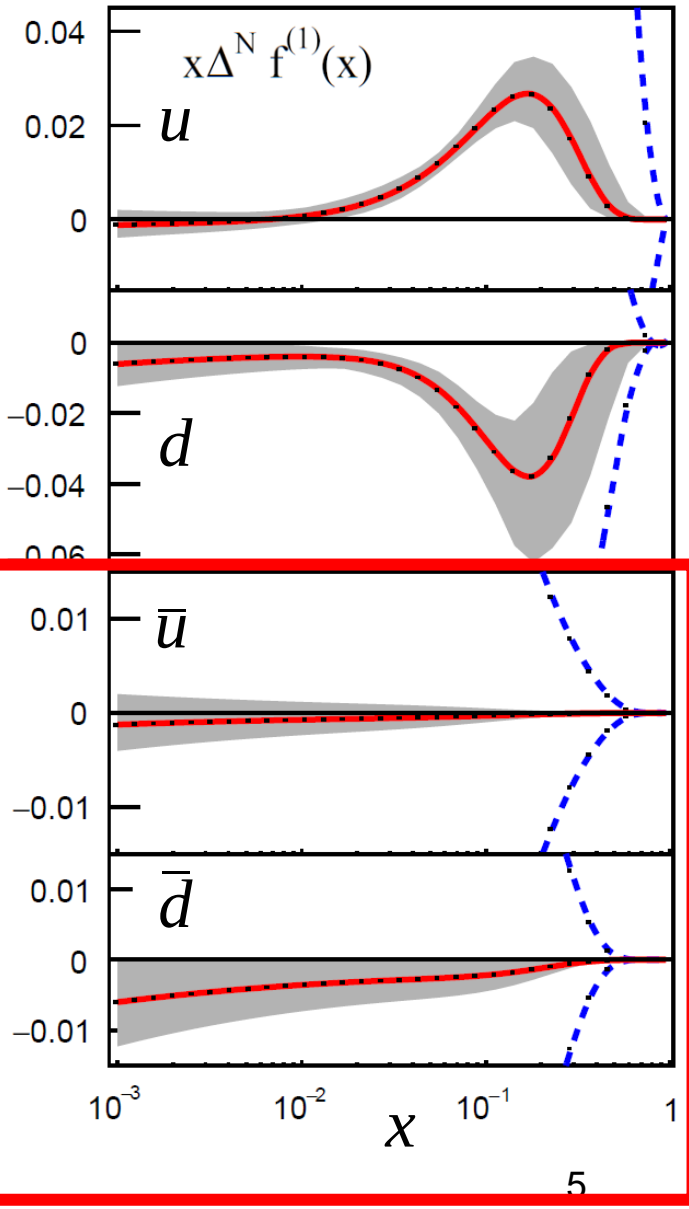
Extraction of Sivers distribution



The next challenge is **"anti-quarks"**

Global analysis of the measured symmetries

⇒ Sivers distribution



TMD2P. Sun, F. Yuan, PRD88 (2013) 114012

M. Anselmino et al., JHEP04 (2017) 046

SIDIS

A. Bacchetta, F. Delcarro, C. Pasiano, M. Radici arXiv 2004.14278 (2020)

M. Bury, A. Prokudin, A. Valadimirov, JHEP 05 (2021) 151

M. Echevarria, Z. Kang, J. Terry, JHEP01(2021)126

SIDIS, DY/W

Estracted Sivers functions

M. Echevarria, Z. Kang, J. Terry, JHEP01(2021)126

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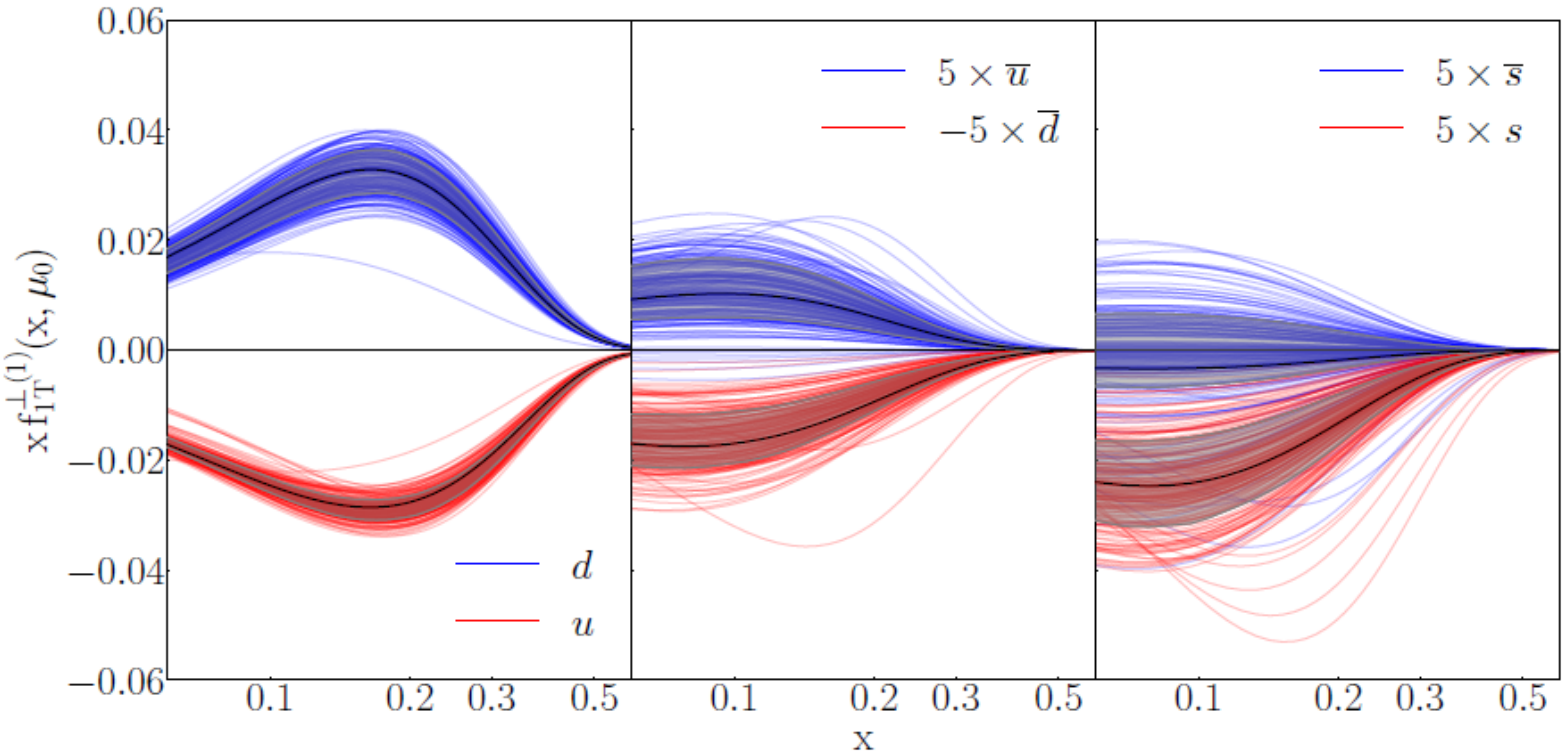
SIDIS, DY



Proton Spin Puzzle

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

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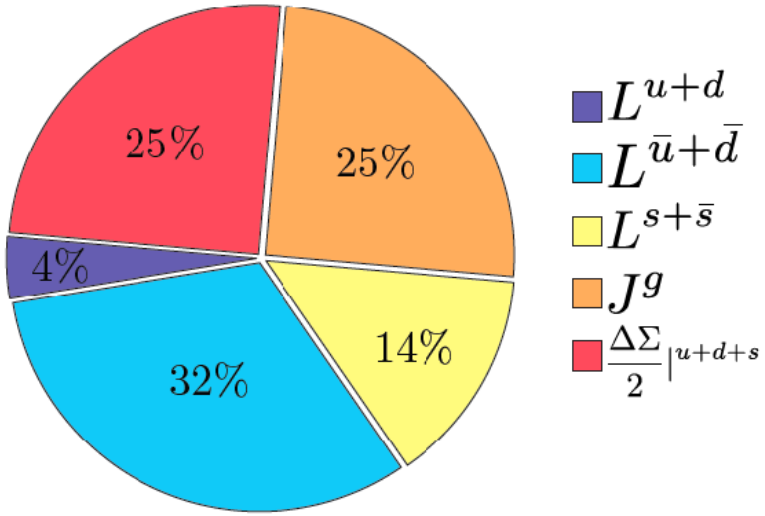
Proton Spin Budget from Lattice QCD

K.-F. Liu et al, LATTICE2011 (2011) 164

J^g
$\frac{\Delta\Sigma}{2}|^{u+d+s}$

Consistent with the experimental results

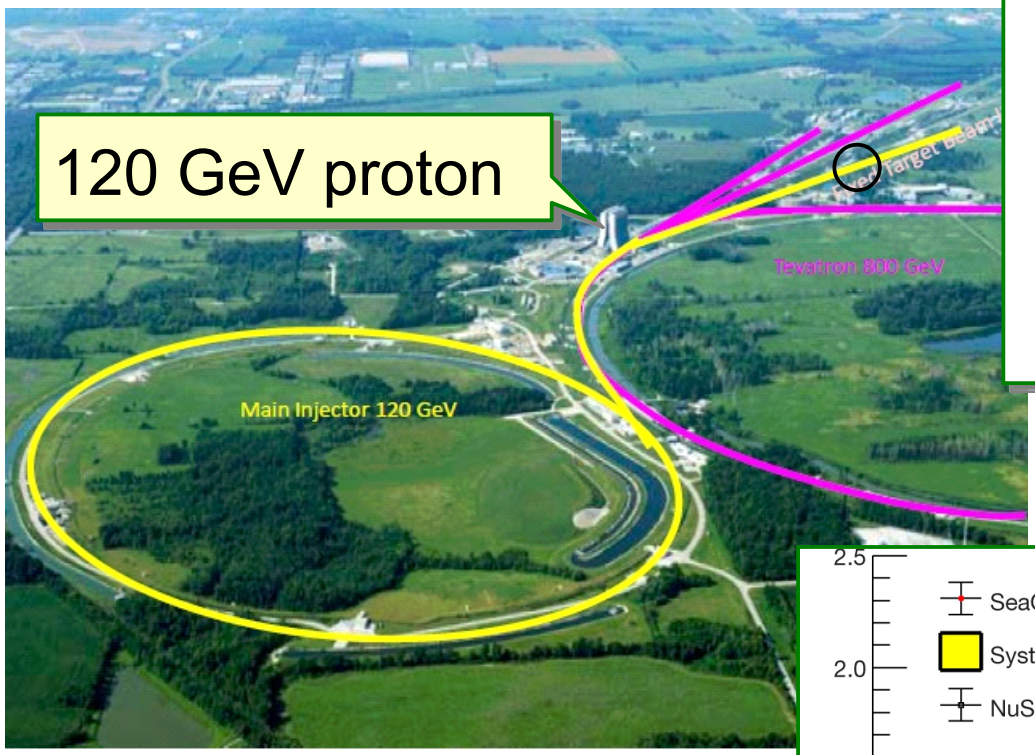


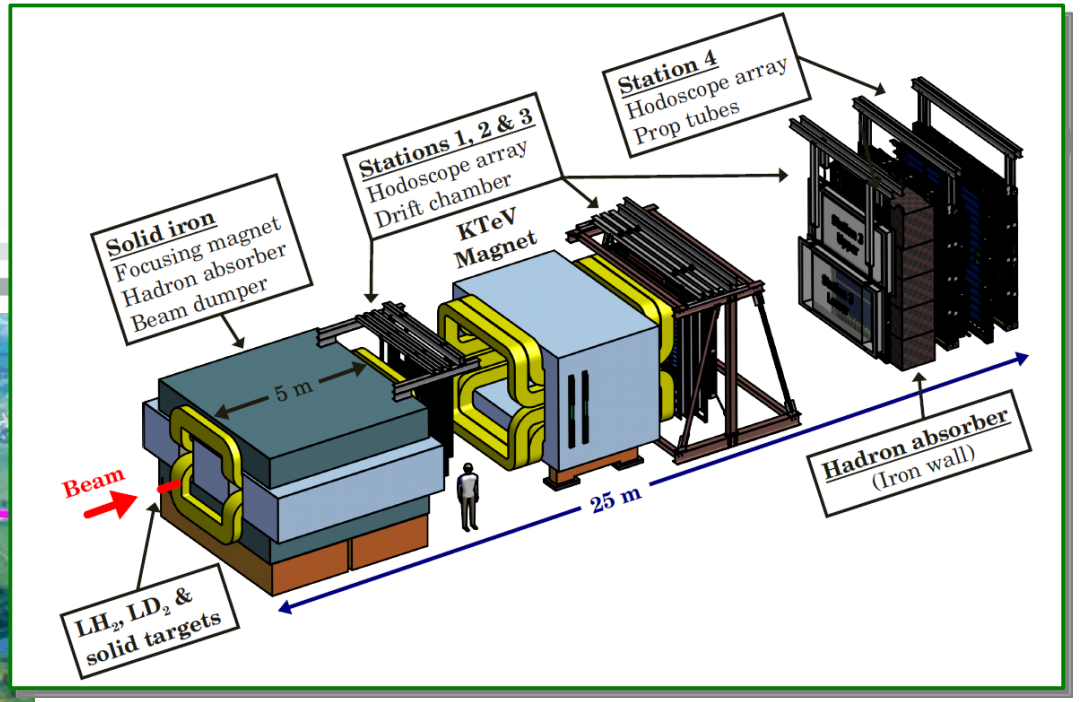
Siverse function ↔

L^{u+d}
$L^{\bar{u}+\bar{d}}$
$L^{s+\bar{s}}$

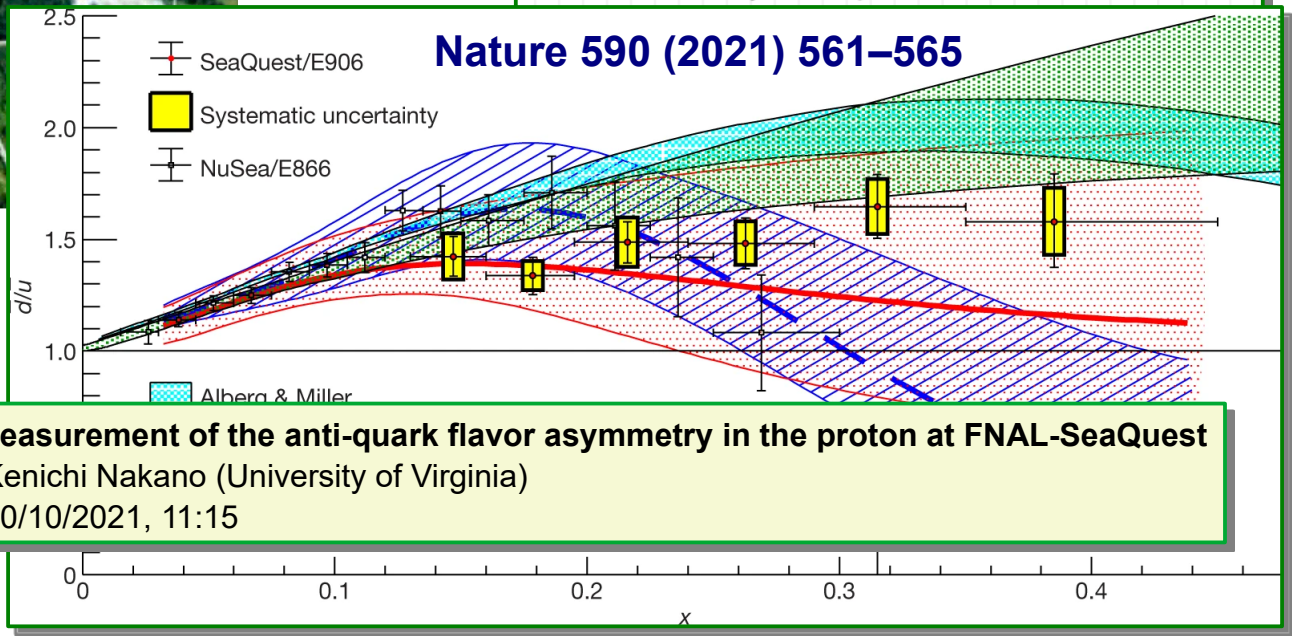
Large contribution to the proton spin, especially from “sea”-quarks.

Fermilab- SeaQuest E906





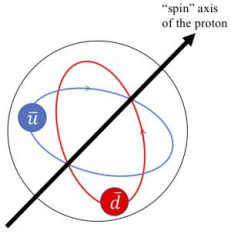
$$h_1 + h_2 \rightarrow q + \bar{q} + X$$
$$\rightarrow \mu^+ + \mu^- + X$$



Proton induced Drell-Yan with H/D target
→ **asymmetric anti-quarks** in the proton

Measurement of the anti-quark flavor asymmetry in the proton at FNAL-SeaQuest
Kenichi Nakano (University of Virginia)
20/10/2021, 11:15

Fermilab-SpinQuest (E1039)



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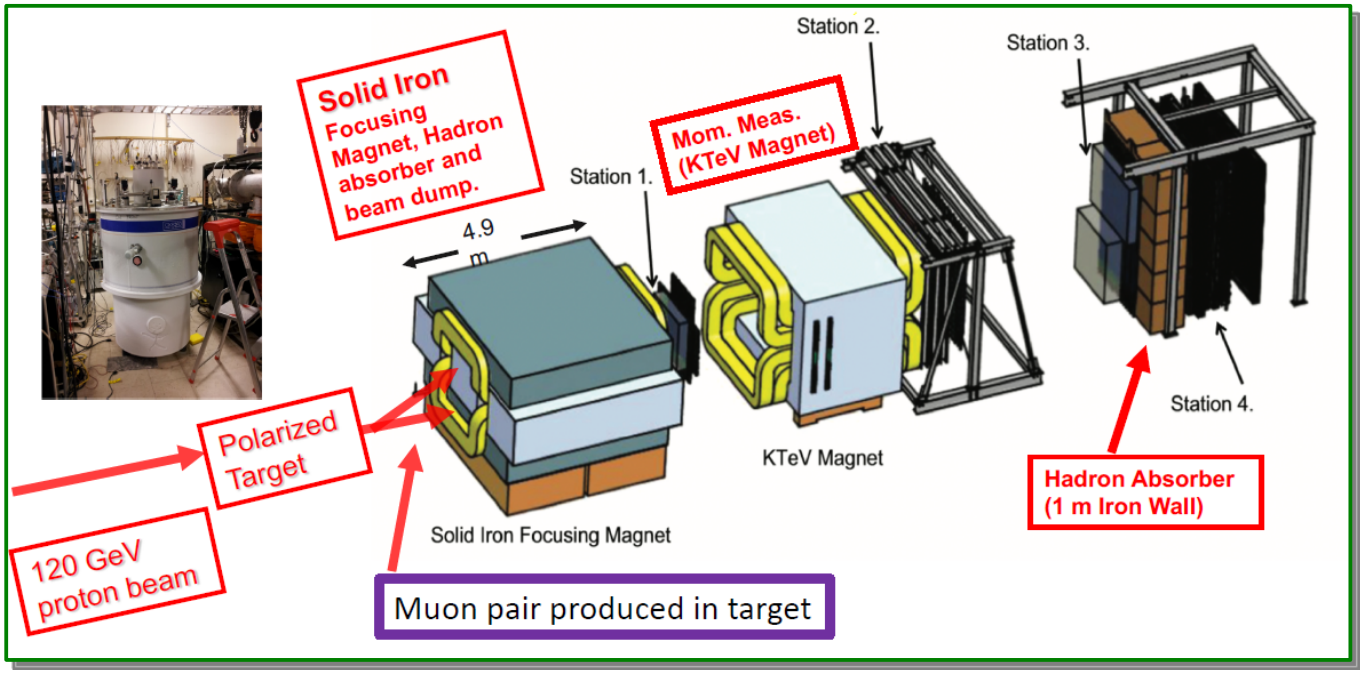
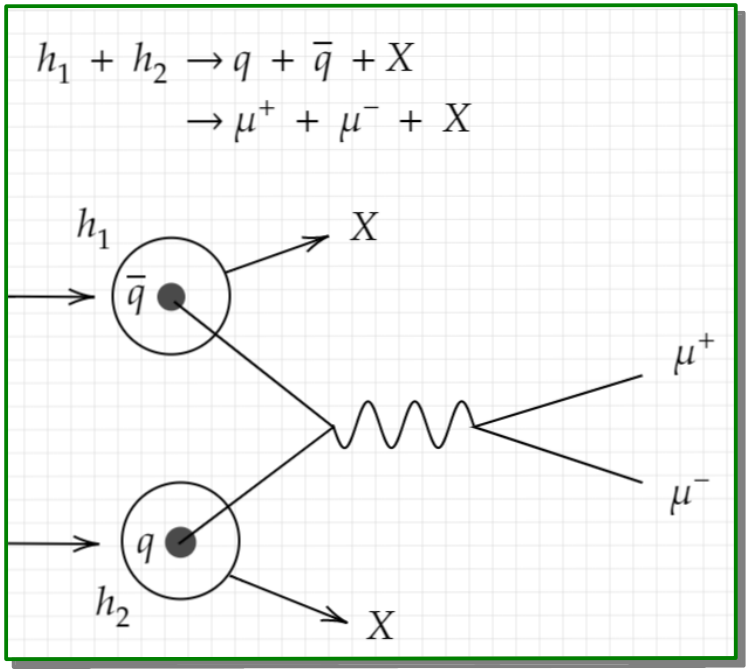
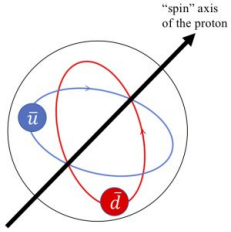




Quark from the beam proton and
anti-quark from the transversely "polarized" nucleon
Polalized NH_3, → $\bar{u}$ and ND_3 targets → $\bar{d}$

Sivers asymmetry from anti-quarks

Fermilab-SpinQuest (E1039)



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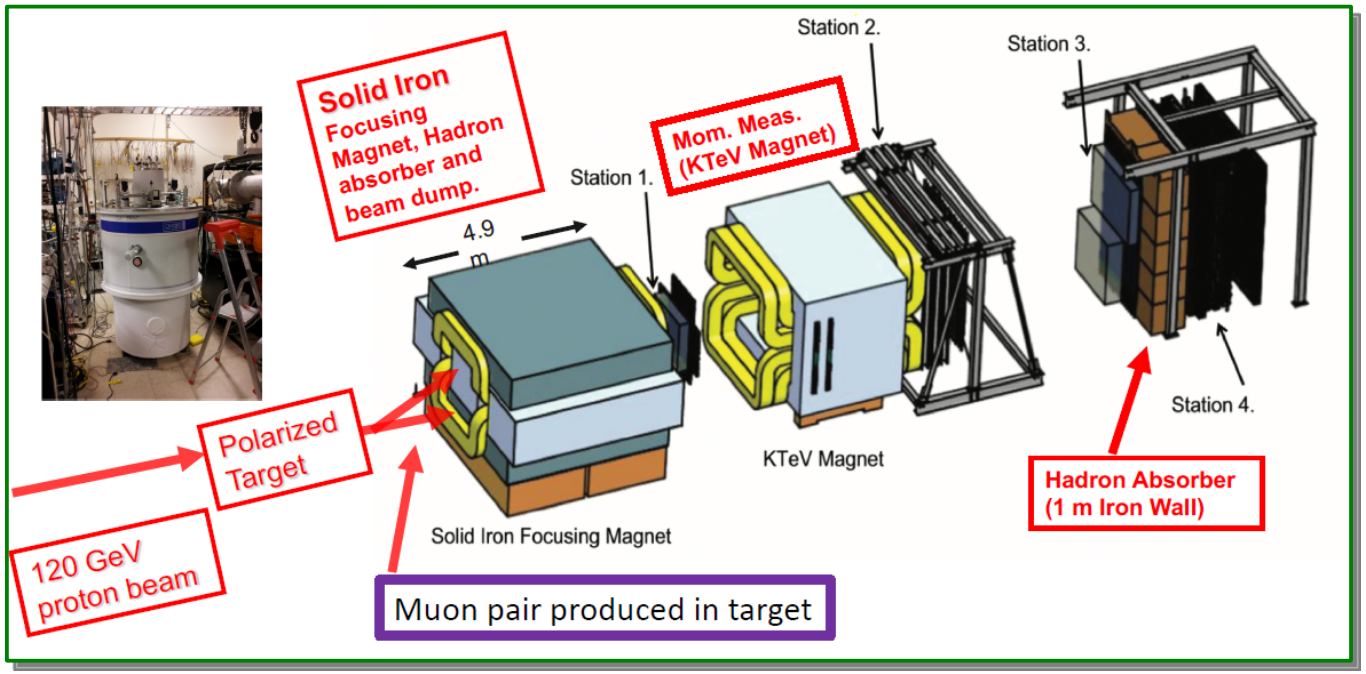


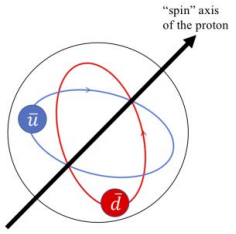
Spectrometer

- Inherit from SeaQuest
- newly installed
  - 90° beam monitor
  - fiber scinti. between St1 & St2
- DAQ & Trigger upgrade

Polarized NH_3/ND_3 target

- P_H~90%, P_D~50% by DNP (1 K, 5 T, 140 GHz μ-wave)
- **Big challenge** under the high proton intensity

SpinQuest talks @ SPIN2021



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Future facilities and experiments

Machine Learning Online Monitoring for the SpinQuest experiment at Fermilab
Arthur Conover (University of Virginia)
22/10/2021, 07:25

Online Reconstruction on GPUs for J/ψ TSSA Study at SpinQuest
Catherine Ayuso (Mississippi State University)
22/10/2021, 07:50

Polarized Sources and Targets

SpinQuest Polarized Target: An Overview
Ishara Fernando (University of Virginia)
22/10/2021, 08:40

Dynamical Behavior of the SpinQuest Target Polarization due to Beam Heating and Radiation Damage
Zulkaida Akbar (University of Virginia)
22/10/2021, 09:00

Dilution factor calculation and its contribution to SpinQuest systematic error
Anchit Anchit Arora (University of Virginia)
22/10/2021, 09:20

Please find the details from the slides on indico

Projection of Sivers Asymmetry

in proton induced polarized Drell-Yan

$$pp^{\uparrow}(d^{\uparrow}) \rightarrow \mu^{+}\mu^{-}X$$

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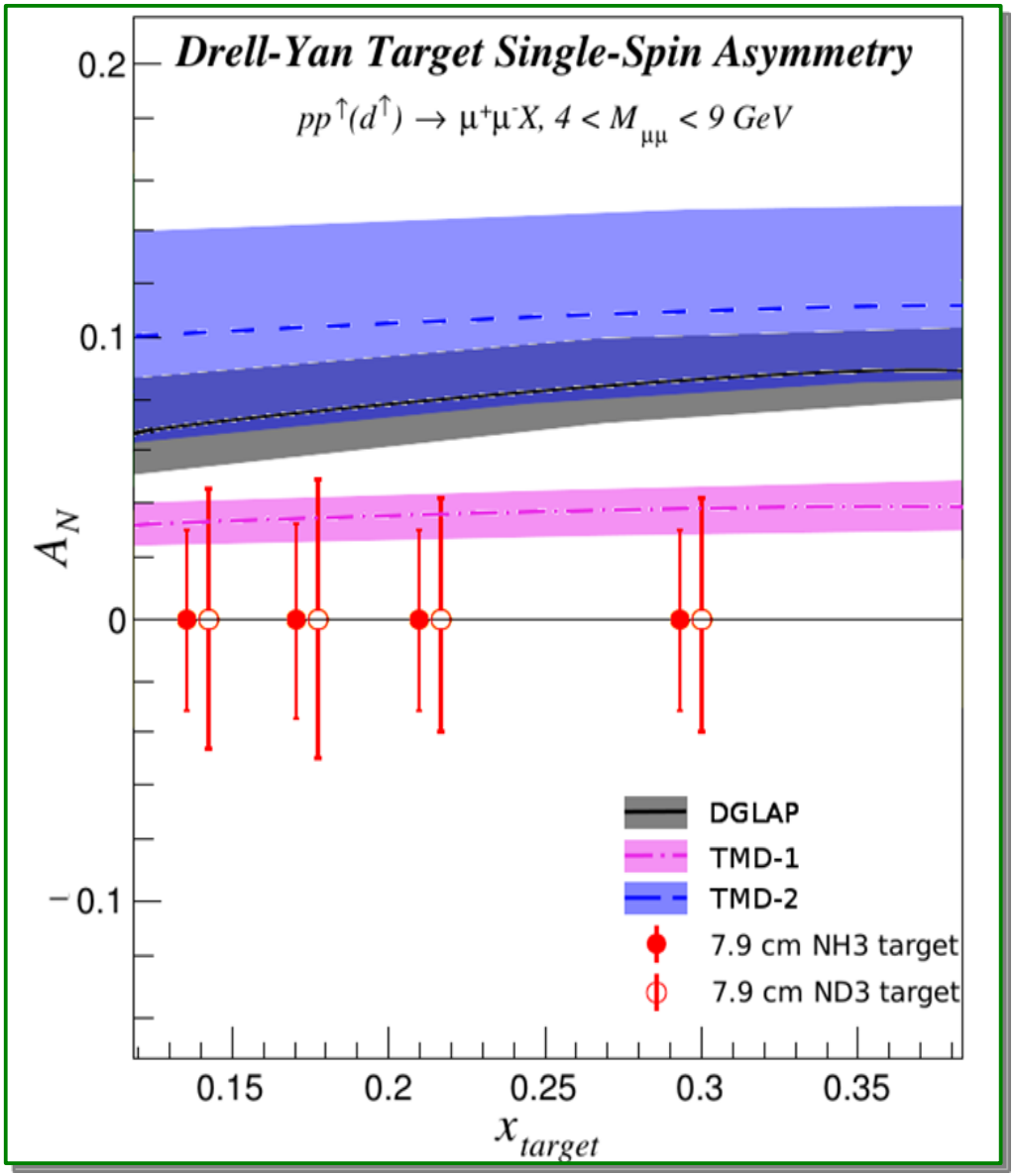
- **Proton Beam**
  - Energy: 120 GeV (√s=15 GeV)
  - Instant luminosity: $4*10^{35}$ cm^{-2} s^{-1}
  - Integrated luminosity: $1.1*10^{43}$ cm^{-2} $year^{-1}$
  - Beam time: 2 years
- **Mass range 4 < M < 8 GeV/c²**
- **Polarized p(d) targets**
  - Upstream by ~ 2 m by SeaQuest
    - Lower x_{target} acceptance
    - Better target and dump separation
- **Drell-Yan Target Single Spin Asymmetry**

$$A_N \propto \frac{f_{1T}^{\perp,\bar{u}}}{f_1^{\bar{u}}}$$



SpinQuest Timeline

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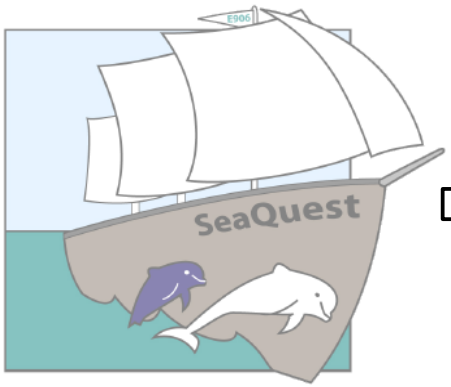
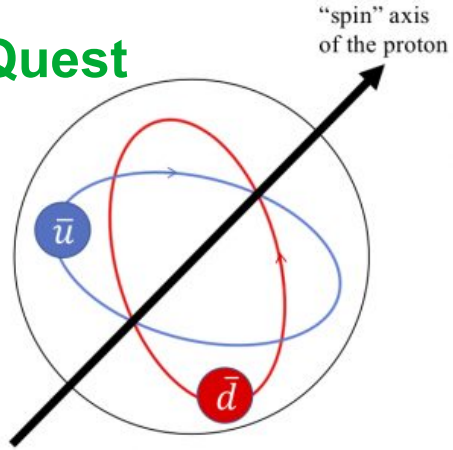
- 2018 DOE approval (March)
  Fermilab stage-2 approval (May)
  SeaQuest decommissioned (June)
- 2019 Transferred PT from UVA to Fermilab (May)
- 2021 Spectrometer Commissioning using cosmic rays
- 2022 PT installation (~ Spring)
  Commissioning starts in the beginning of 2022
  Physics Run (2 years) starts

Summary

- Fermilab-**SpinQuest** (E1039)
  - SeaQuest (anti-quark) + Polarized Targets (spin)
  - Sivers asymmetry in proton induced polarized Drell-Yan
  - Proving orbiting u-bar, or d-bar inside the polarized nucleon
- Successful transition from



SpinQuest



- Physics Run in 2022
  - Commissioning on-going (~2022)
  - ”Physics Run” (2 years)
  - **Proton induced DY with PT for the first time!!**

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