Why I am excited to Work on SpinQuest

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(On behalf of the SpinQuest Collaboration)
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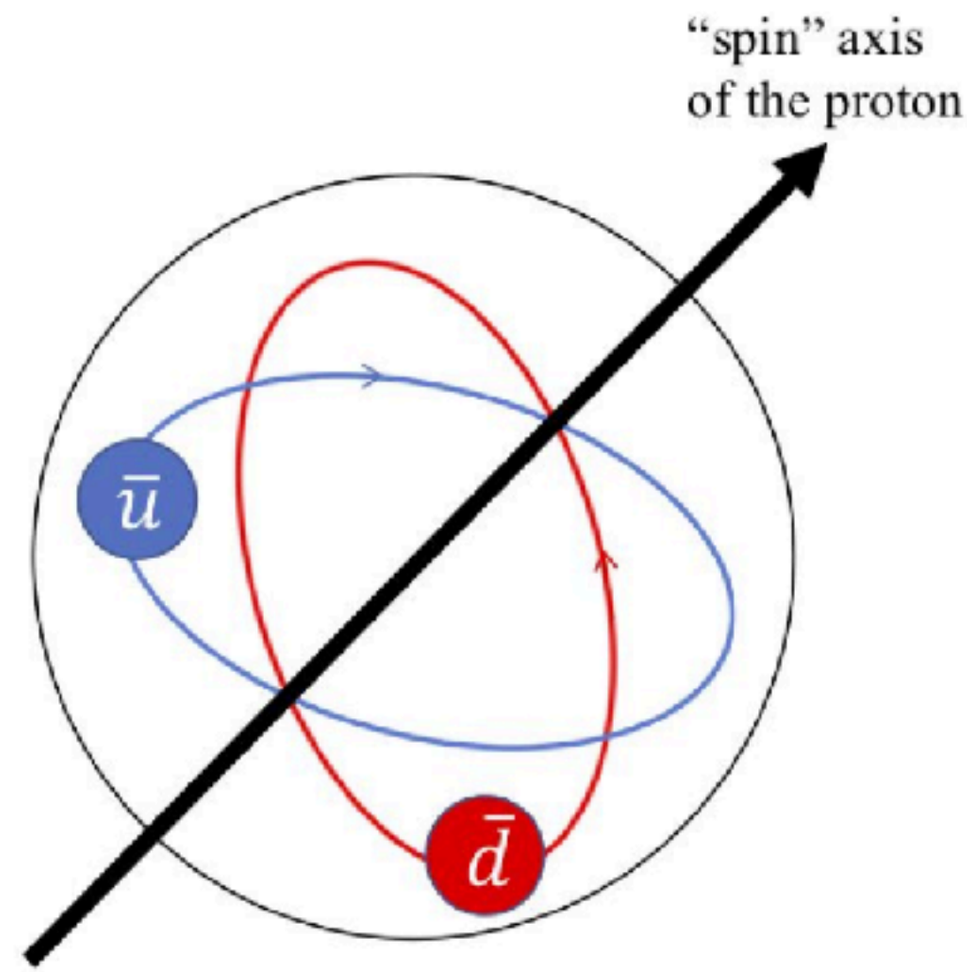
July 21, 2020
Fermilab New Perspectives

E1039/SpinQuest

Goals:

- Measure azimuthal asymmetry in Drell-Yan dimuons from protons on a polarized target.

- Extract magnitude and sign of Sivers function for ubar/dbar.



Are the anti-quarks in orbit about the spin axis of the proton?

Proton Spin Puzzle

- European Muon Collaboration studies longitudinally polarized DIS with muons.

- Violations of Ellis-Jaffe sum rules indicate little of proton spin comes from quark spins.

> Hence $(14 \pm 9 \pm 21)\%$ of the proton spin is carried by the spin of the quarks. The remaining spin must be carried by gluons or orbital angular momentum

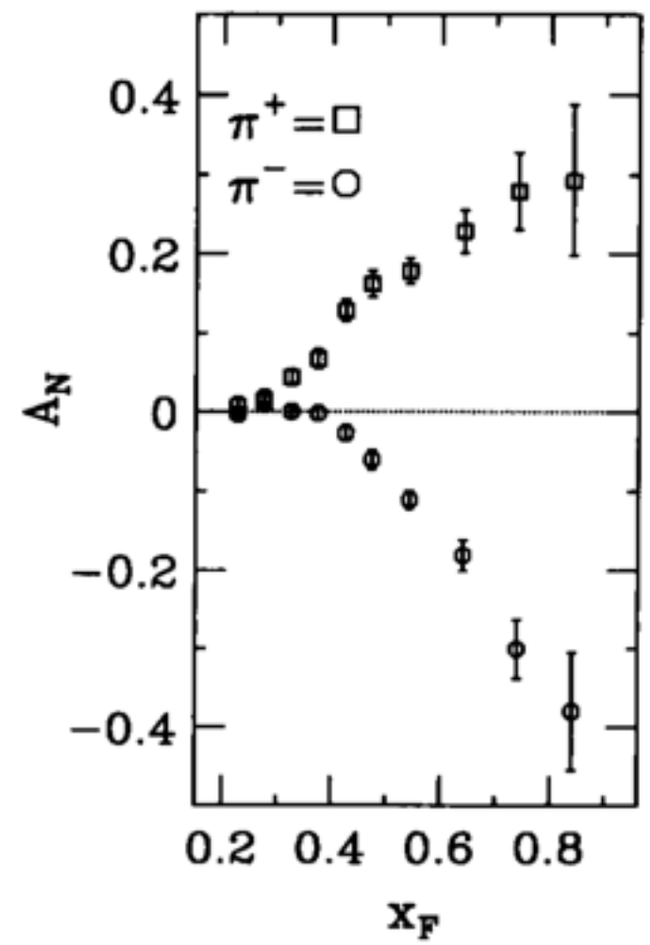
Quark OAM

- Dennis Sivers proposes transverse momenta of quarks to explain observed Transverse Single Spin Asymmetries in E704 $d\sigma(pp_{\uparrow} \to \pi X)$

$$A_N = \frac{d\sigma^{\Uparrow} - d\sigma^{\Downarrow}}{d\sigma^{\Uparrow} + d\sigma^{\Downarrow}}$$

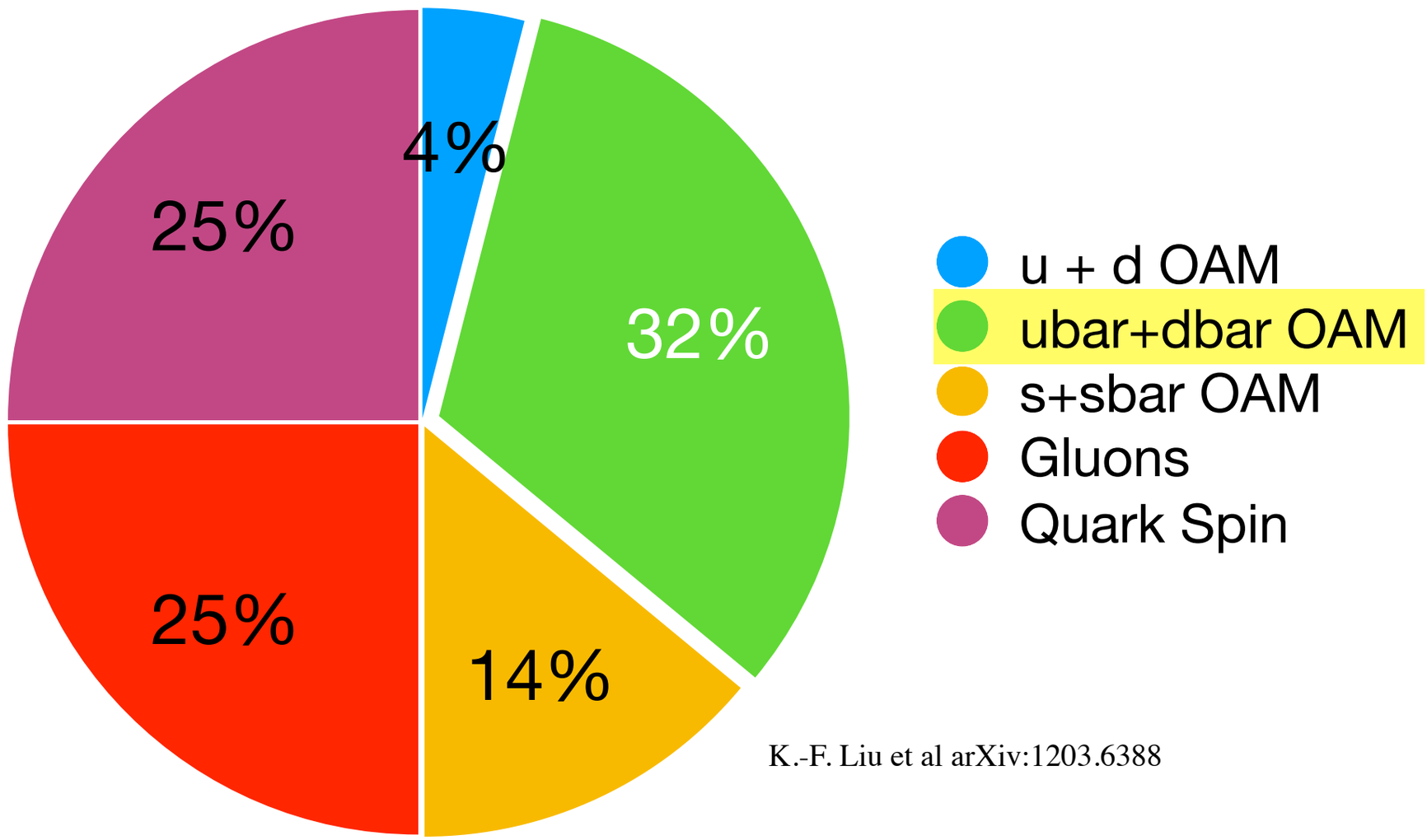
- Sivers is now one of 8 Transverse Momentum Dependent distribution functions of the nucleon.

- Correlates quarks OAM and total spin of the Proton.



Phys. Lett. B 264, 462 (1991)

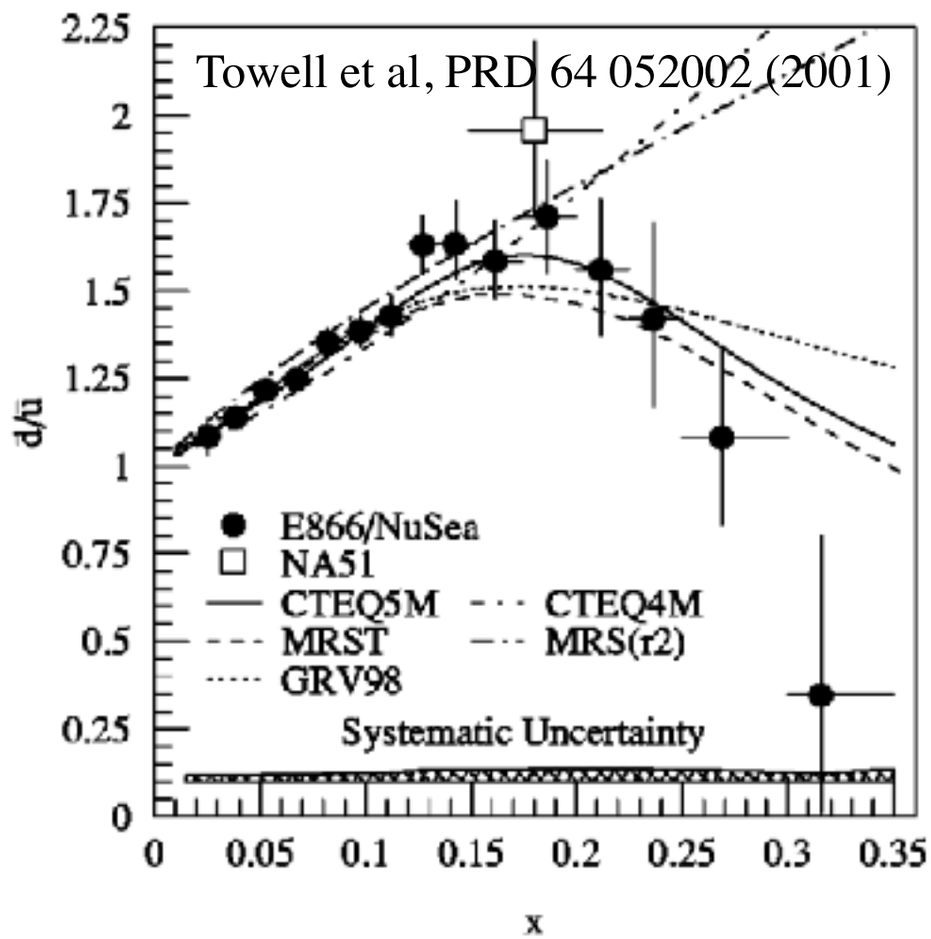
Why Sea Quarks?



Proton Spin Components from Lattice QCD

Why Sea Quarks?

Observation of flavor asymmetry in nucleon sea by fixed target DY experiments at Fermilab- E866, E906

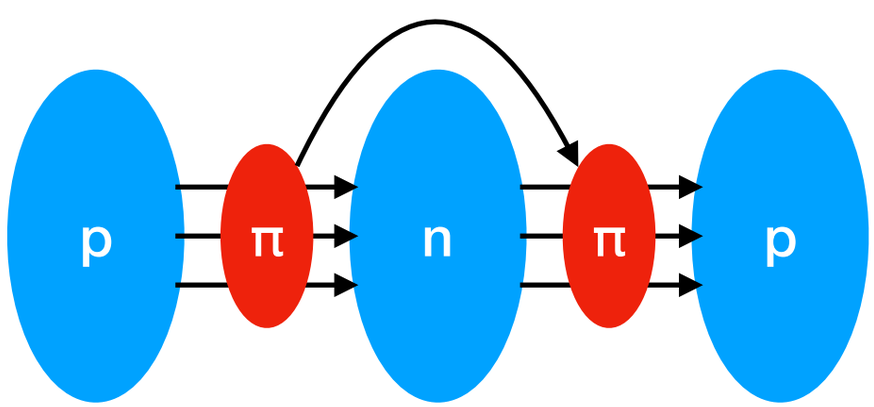


E906 publication coming soon!

Meson cloud models:

Predicts dbar/ubar.

Pion is 0^-, needs L = 1 for proton to be $J^P=1/2^+$



Fixed Target DY at Fermilab

NAL PROPOSAL # 288

Scientific Spokesman:

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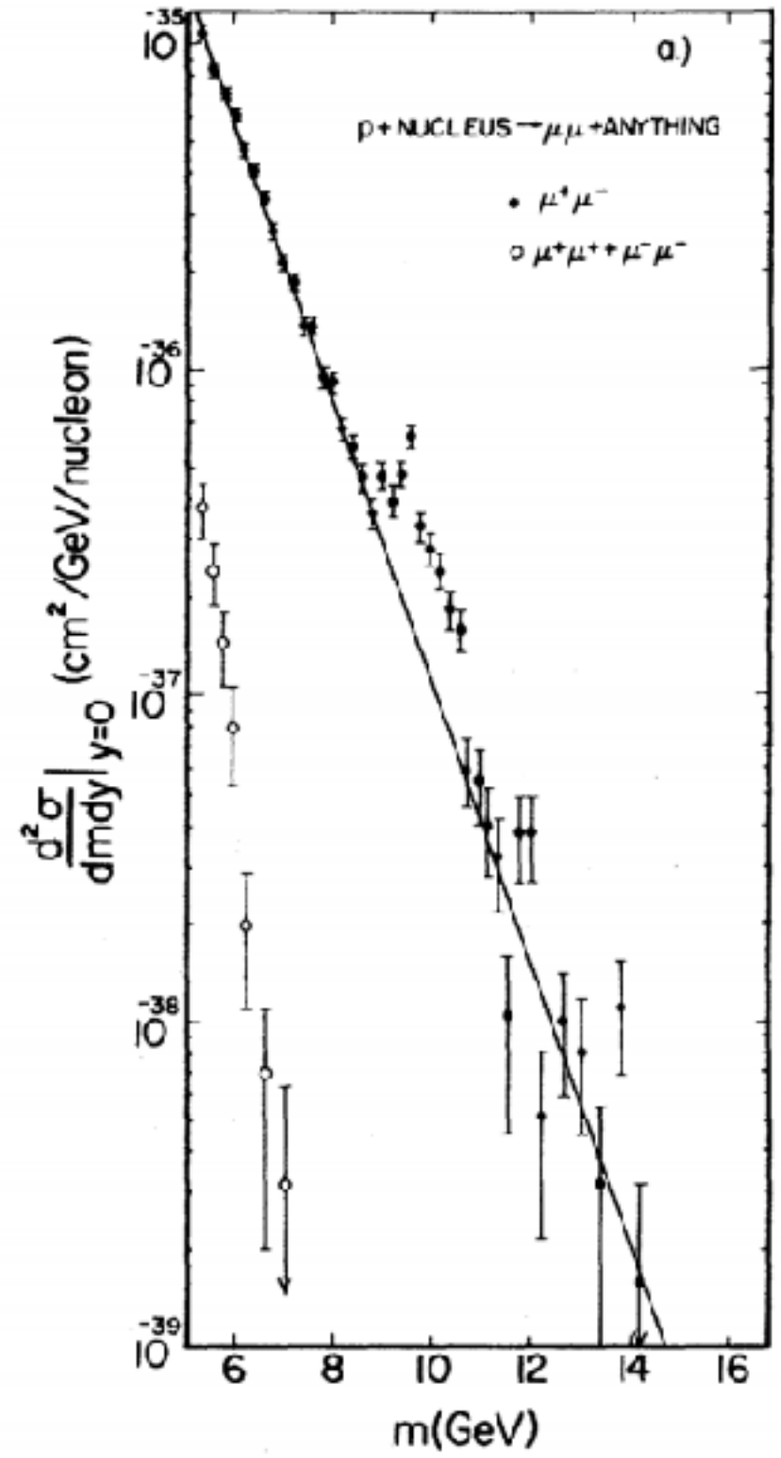
0 1160 0012577 7

A Study of Di-Lepton Production in Proton Collisions at NAL

J. A. Appel, M. H. Bourquin, D. C. Hom, L. M. Lederman, J. P. Repellin, H. D. Snyder, J. K. Yoh (Columbia University); B. C. Brown, P. Limon, T. Yamanouchi (NAL).

(Formerly #70 Phase III)

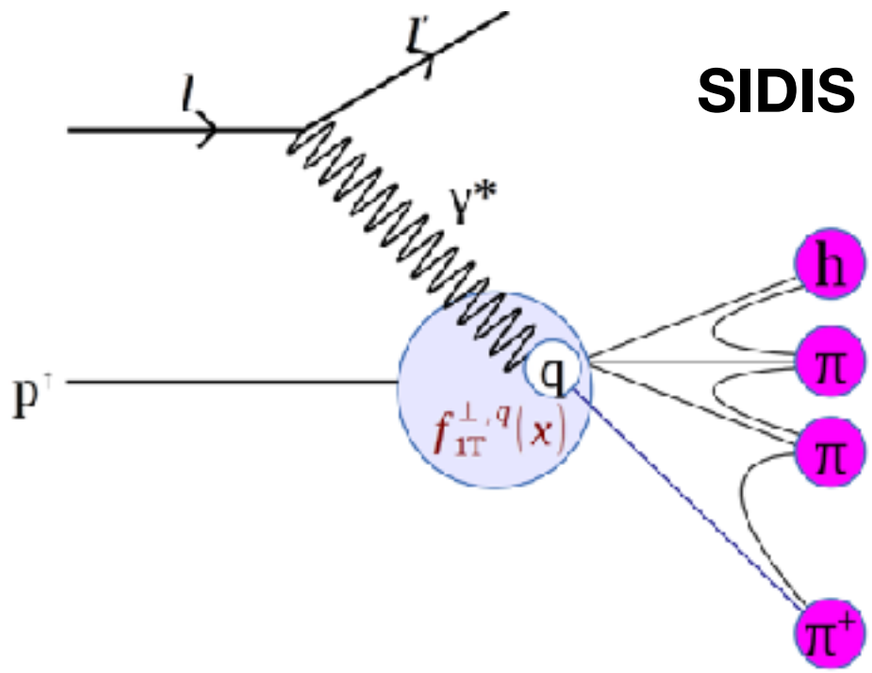
Discovery of Upsilon



Herb et al, PRL 39 (1977)

Accessing Sivers

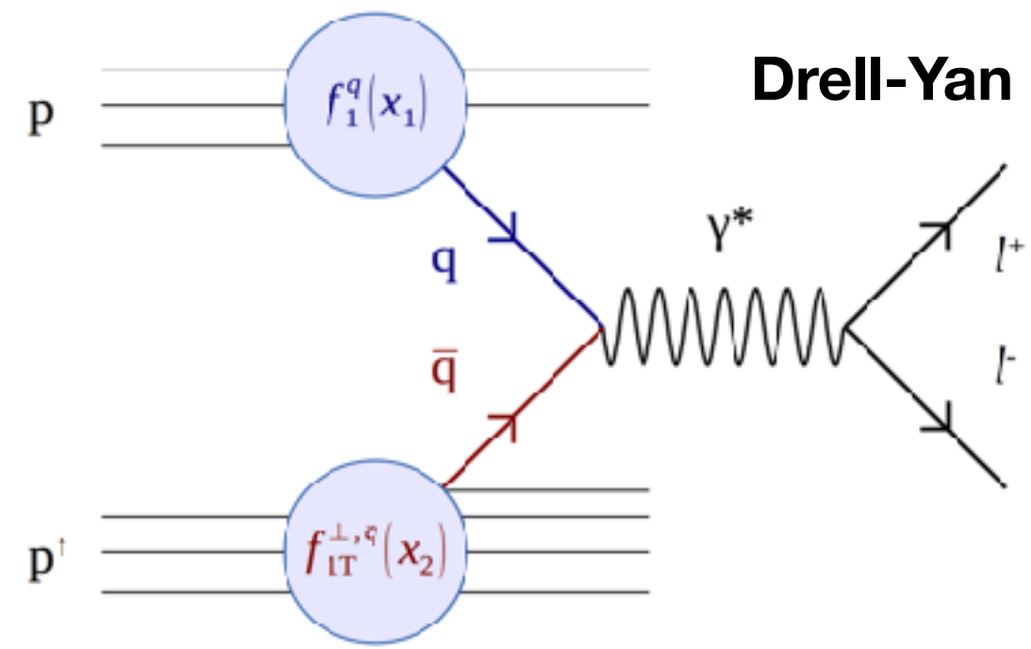
$$e + p^{\uparrow} \rightarrow e' \pi X$$



$$A_{UT}^{SIDIS} \propto \frac{\sum_q e_q^2 f_{1T}^{\perp,q}(x) \otimes D_1^q(z)}{\sum_q e_q^2 f_1^q(x) \otimes D_1^q(z)}$$

- Complicated Fragmentation Function.
- Valence and Sea quarks participate.

$$p + p^{\uparrow} \rightarrow \mu^+ \mu^- X$$



$$A_N^{DY} \propto \frac{\sum_q e_q^2 \left[f_1^q(x_1) \cdot f_{1T}^{\perp,\bar{q}}(x_2) + 1 \leftrightarrow 2 \right]}{\sum_q e_q^2 \left[f_1^q(x_1) \cdot f_1^{\bar{q}}(x_2) + 1 \leftrightarrow 2 \right]}$$

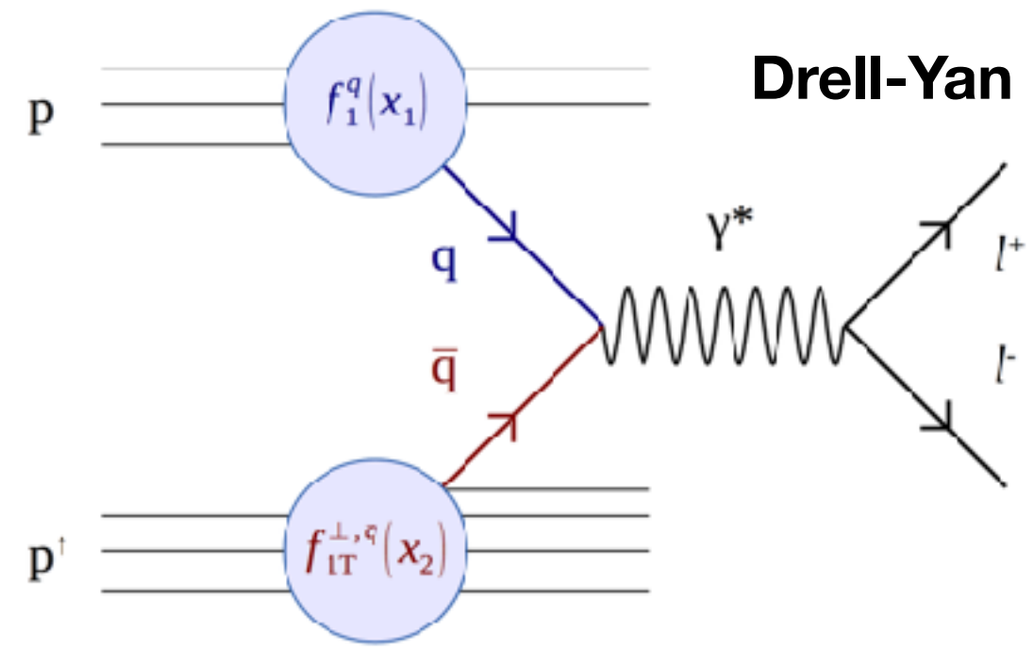
- Convolution of Sivers and unpolarized PDF.
- Isolate sea quarks in target.

Accessing Sivers

- First DY measurement of Sea Quark Sivers.
- Parallel measurement of NH_3 and ND_3 separates ubar and dbar.
- Intensity frontier: highest planned, instantaneous intensity proton beam on a polarized target with 4.4×10^{12} protons over 4.4 s spill.

- Nonzero Sivers would be "smoking gun" evidence for nonzero sea quark OAM.

$$p + p^{\uparrow} \rightarrow \mu^{+}\mu^{-}X$$



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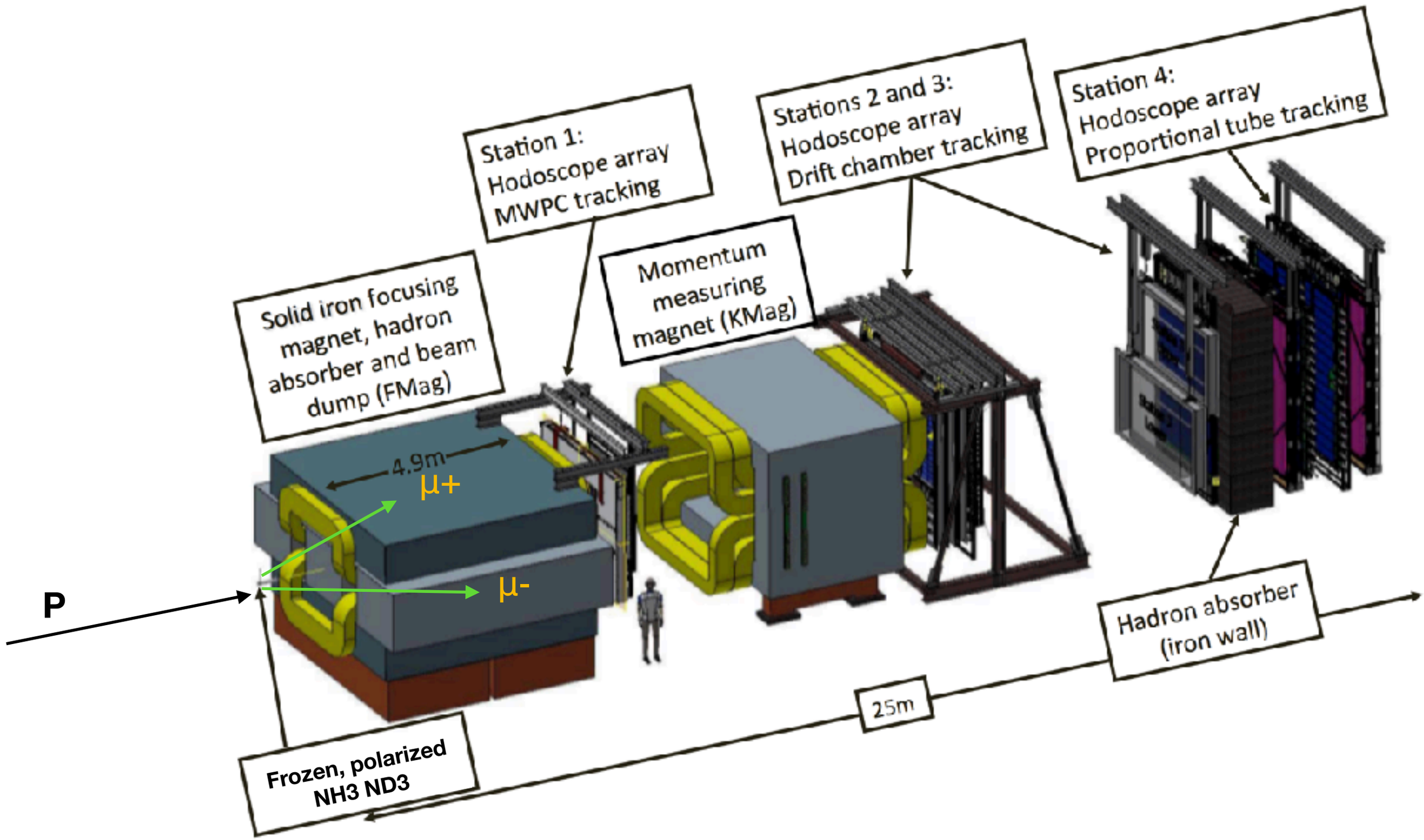
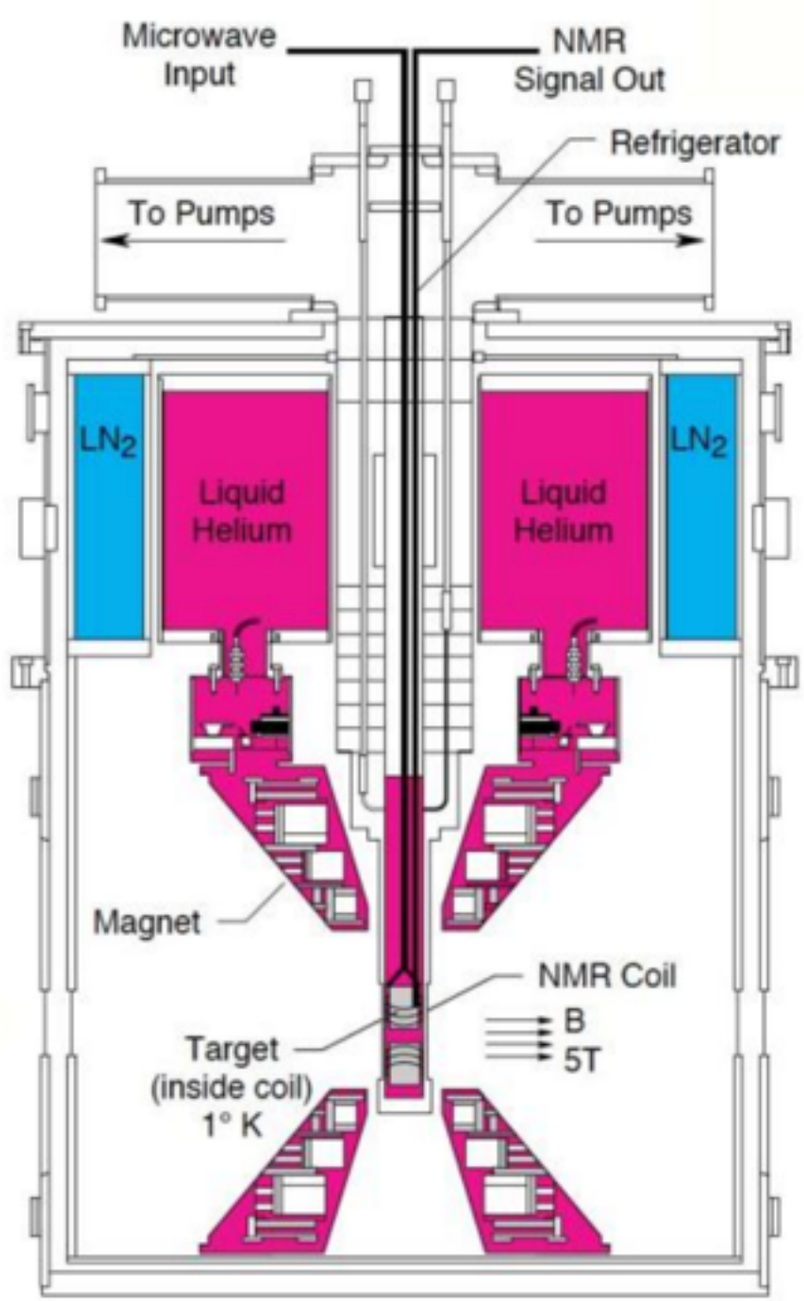
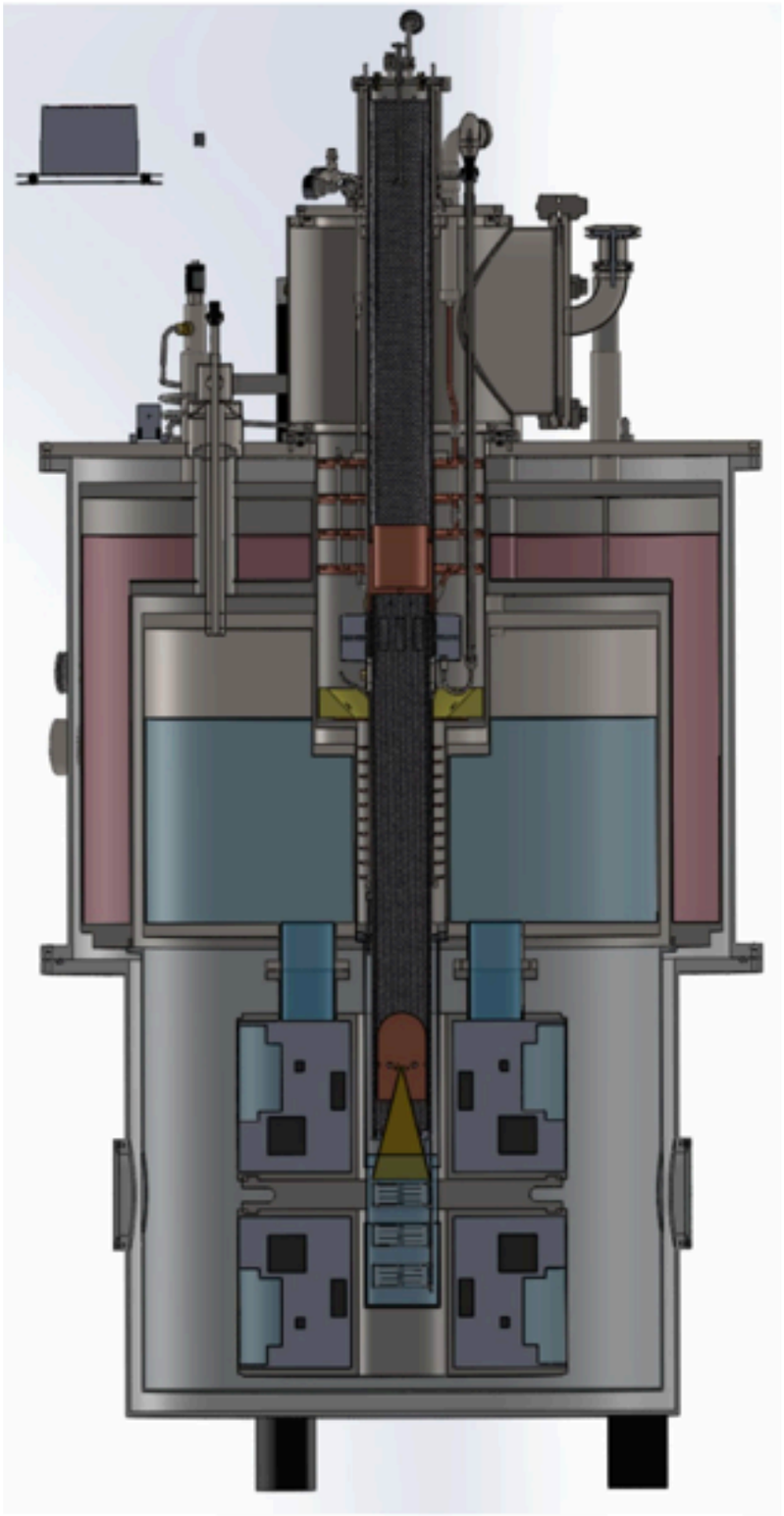
E-1039 Spectrometer



E-1039 Target

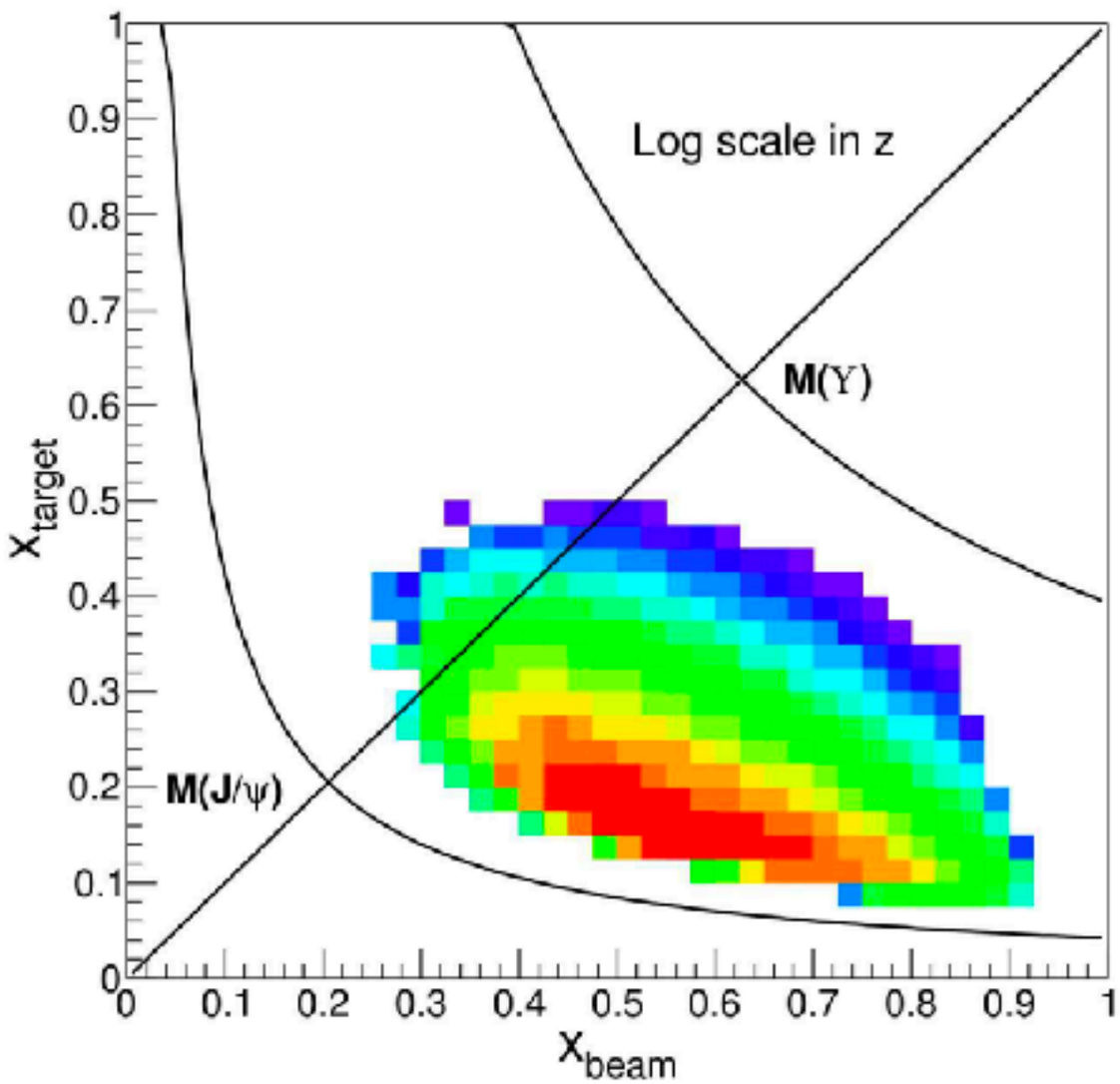
- Dynamic nuclear polarization yields ~80% proton target polarization at ~4% uncertainty.
- Target maintained at 1K in 5 T field, polarization flip every 8 hours.
- NH_3, ND_3, and Background target.



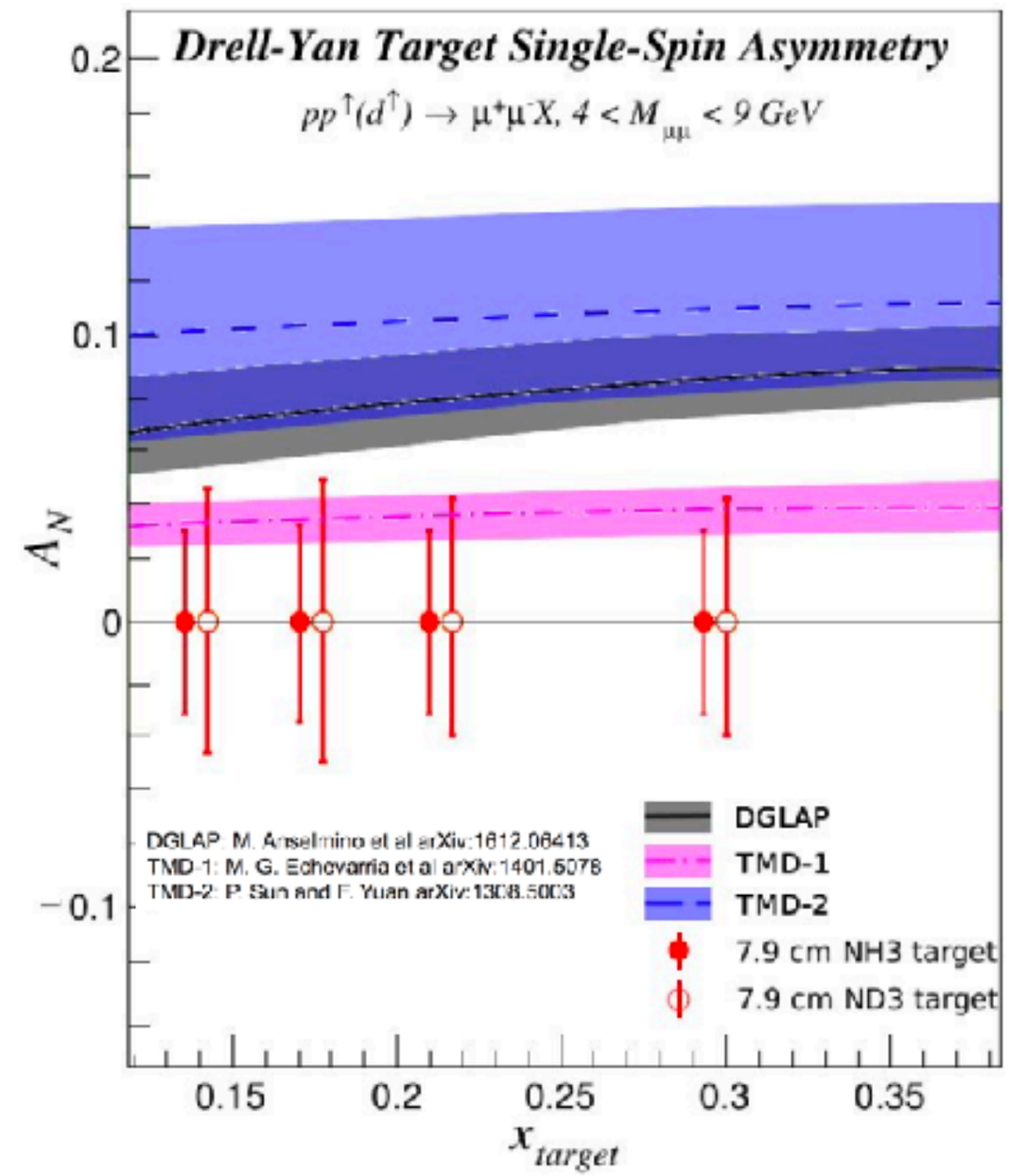


Kinematics and Sensitivity

- Optimized for X target between 0.1 and 0.5 where target antiquark sea dominates.
- Avoid target valence contribution by choosing $X_F = X_{beam} - X_{target} > 0$



Spectrometer Acceptance



Anticipated Sensitivity

Conclusion

- SpinQuest will run for 2 years, alternating NH_3, ND_3 and background subtraction targets.

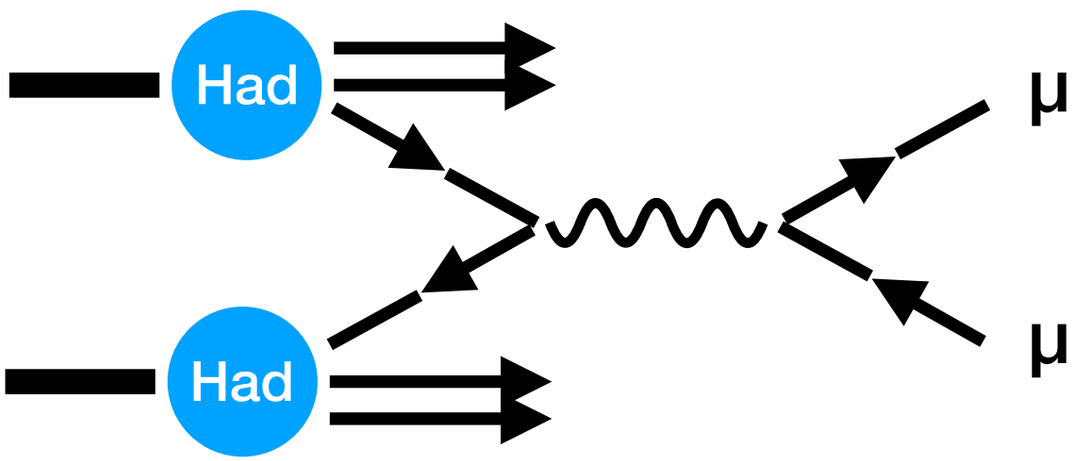
- Projected Statistical uncertainty ~ 3-5%.

Range x_2	Mean x_2	N events p	ΔA % p	N events n	ΔA % n
0.1-0.16	.139	5.0×10^4	3.2	5.8×10^4	5.4
0.16-0.19	0.175	4.5×10^4	3.3	5.2×10^4	5.7
0.19-0.24	0.213	5.7×10^4	2.0	6.6×10^4	5.0
0.24-0.6	0.295	5.5×10^4	3.0	6.4×10^4	5.1

- SpinQuest takes part in a rich history of fixed target DY at Fermilab.

- Quark OAM likely contributes to nuclear spin, polarized Drell-Yan can confirm it is nonzero. Major Discovery!

The Drell Yan Process at LO



$$\frac{d^2\sigma}{dx_1\,dx_2} = \left(\frac{4\pi\alpha^2}{9M^2}\right)\sum Q^2[q_B(x_1)\bar{q}_T(x_2) + \bar{q}_B(x_1)q_T(x_2)].$$

Negligible at forward rapidities

- QCD-improved DY makes verifiable predictions about dilepton production spectrum.
- Factorization makes DY an attractive process for theory.
- Clean final state for experiment.
- Fixed target experiments with forward detectors are sensitive to target sea quark distributions.