Drell-Yan Experiment with a Polarized Proton Target

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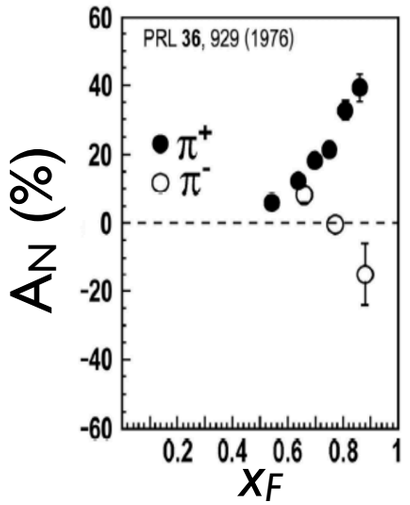
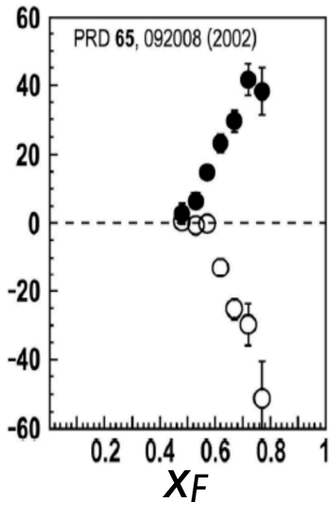
Opportunities for Polarized Physics at Fermilab, May 20-22, 2013

Transverse single-spin asymmetry

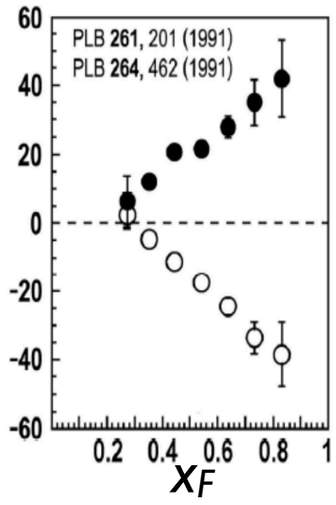
ZGS 4.9 GeV



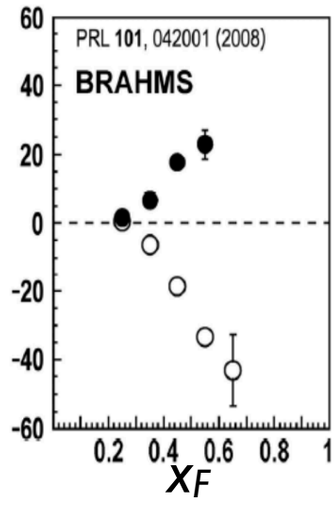
AGS 6.6 GeV



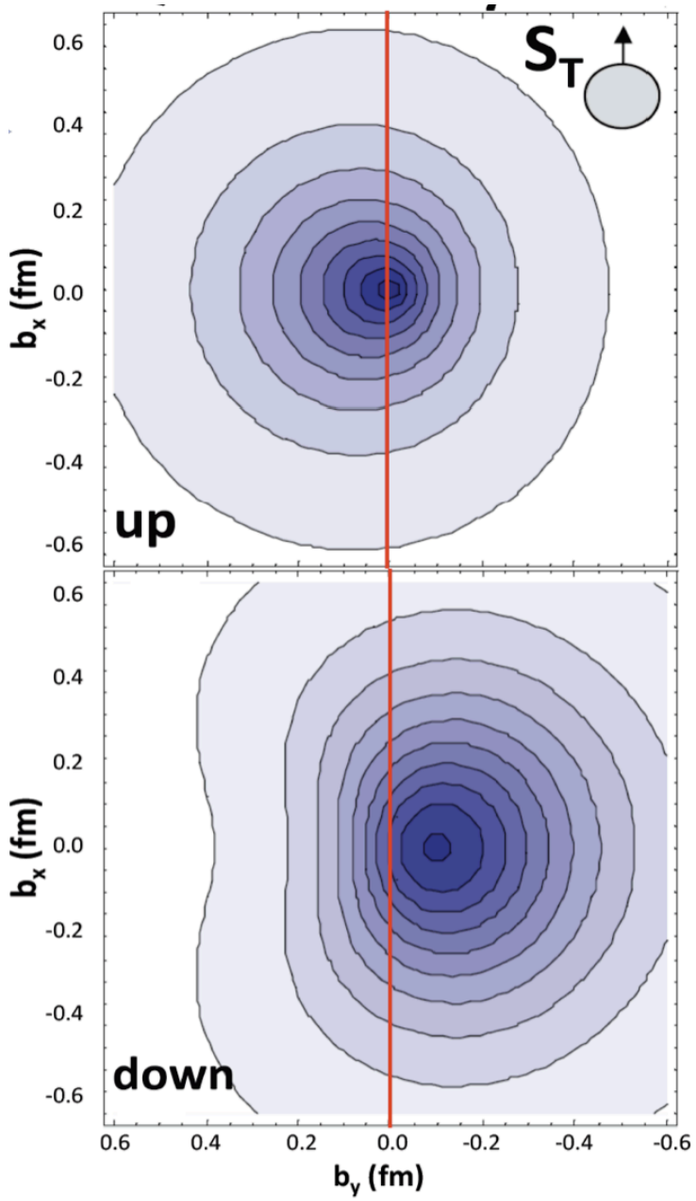
FNAL 20 GeV



RHIC 62.4 GeV



PRL 98: 222001, 2007



- Single spin asymmetry has been consistently observed for almost 40 years covering a wide range of c.m. energy
- One possible explanation (Sivers effect): quark transverse motion generates a left-right bias
- Close connection between Sivers function and quark orbital angular momentum (OAM)

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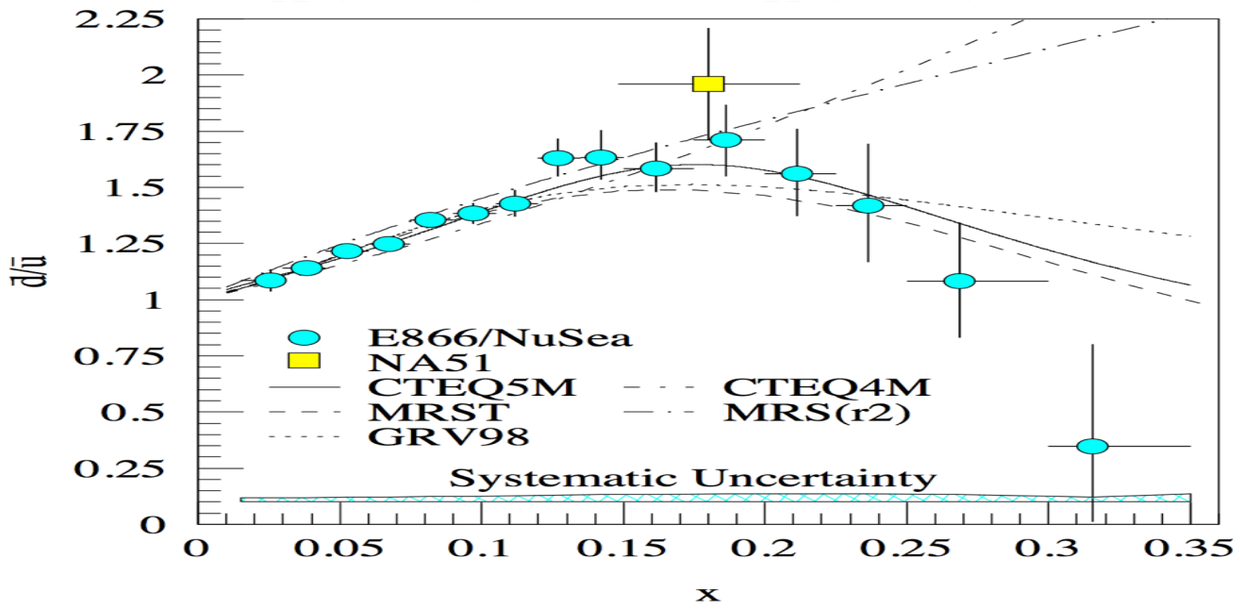
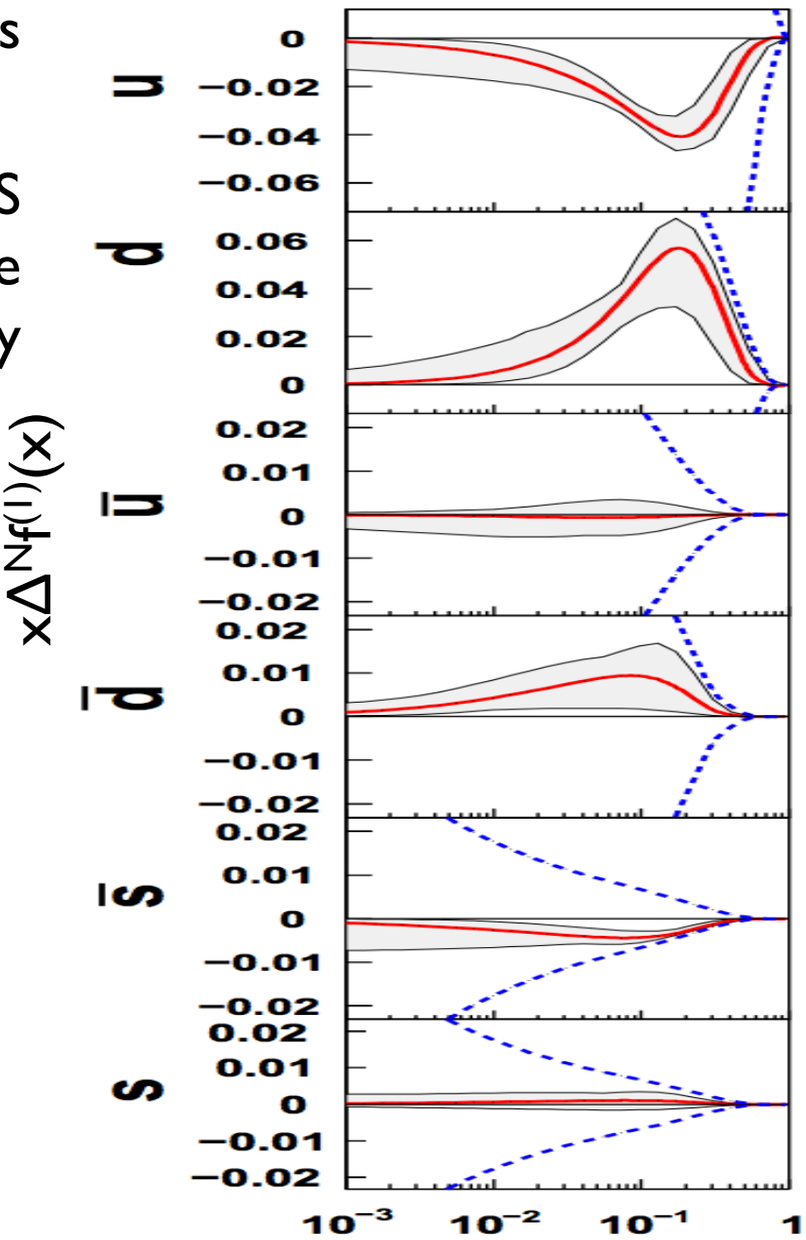
Sea quark Sivers function via DY process

- E866 observed large dbar vs. ubar excess at x ~ 0.1-0.3, provided strong hint that sea quark has significant contribution to OAM.
- In the same kinematic range, the SIDIS experiments have observed significant valence quark Sivers asymmetries, but have little sensitivity to antiquarks.
- QCD (and factorization) requires:

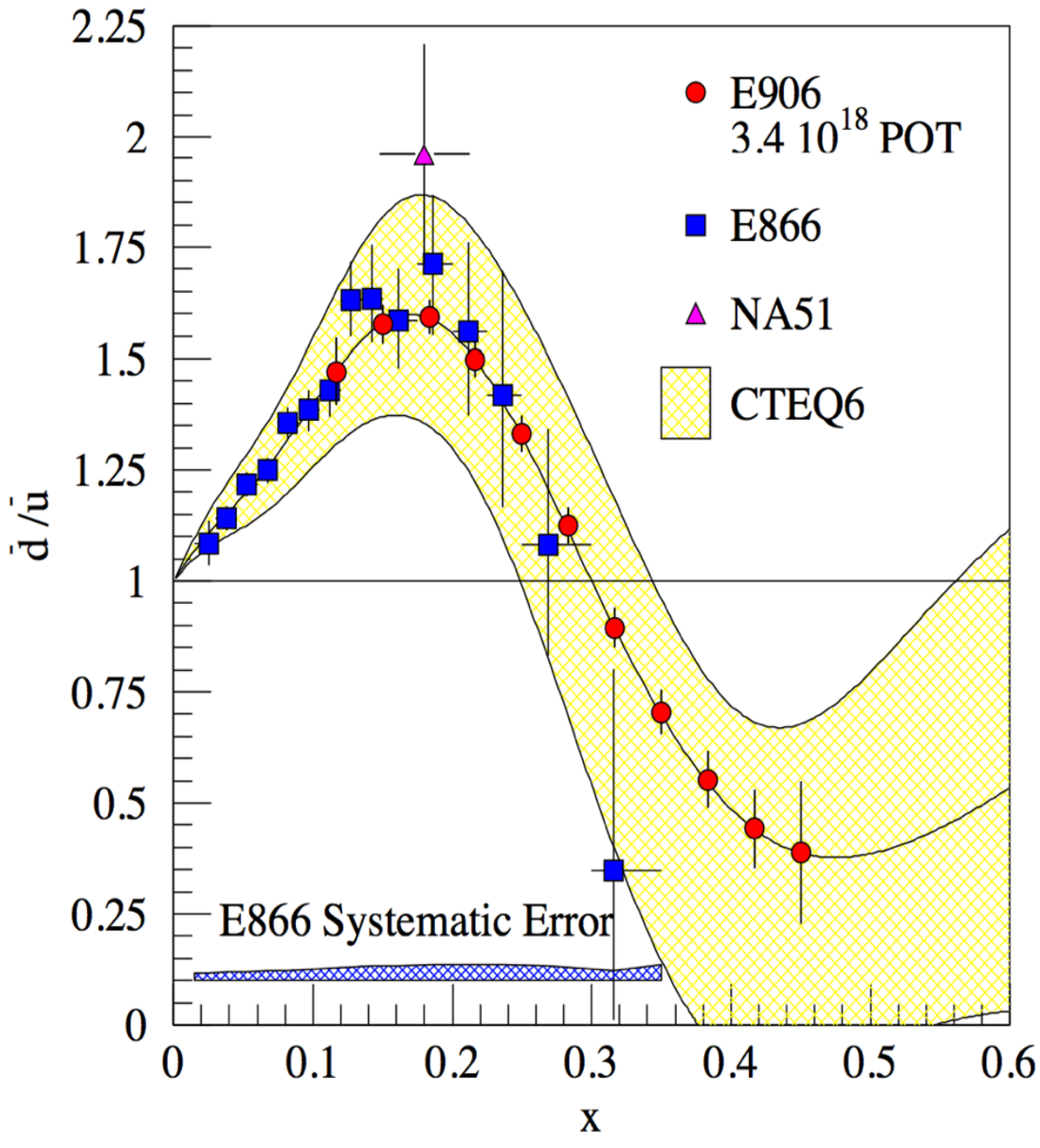
$$f_{1T}^{\perp}(x,k_{\perp})^{\mathrm{SIDIS}} = -f_{1T}^{\perp}(x,k_{\perp})^{\mathrm{DY}}$$



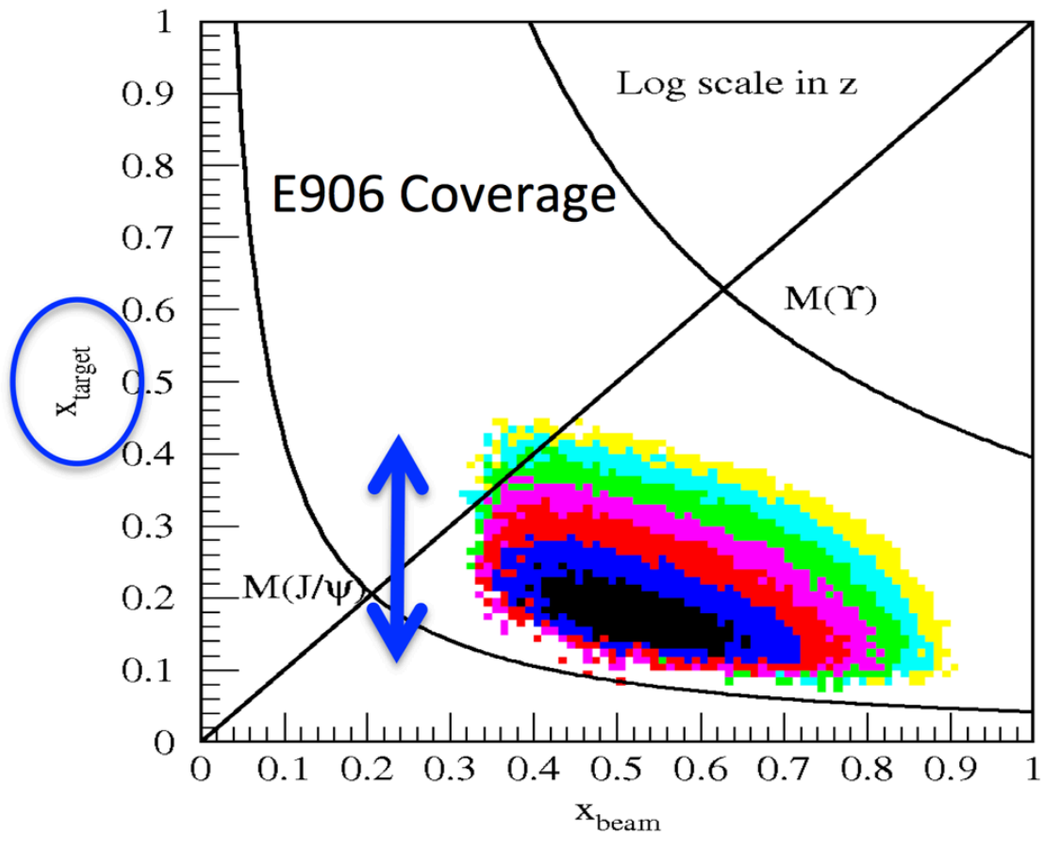
Anselmino *et al*, PRD 79 54010 (2009)



Probe sea quarks via Drell-Yan process at Fermilab



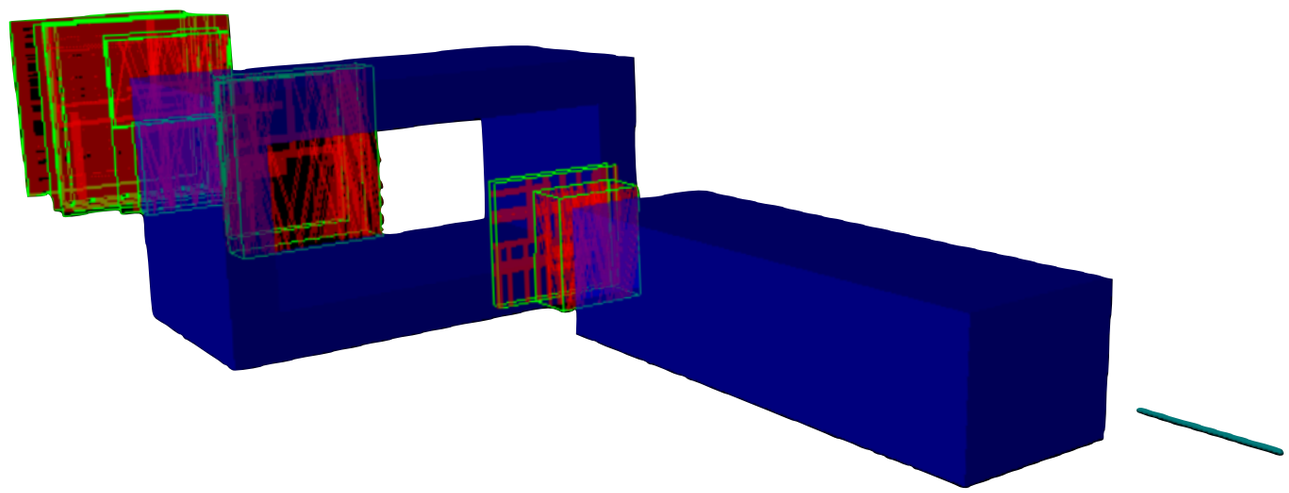
$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}x_\mathrm{b}\,\mathrm{d}x_\mathrm{t}} = \frac{4\pi\alpha^2}{9x_\mathrm{b}\,x_\mathrm{t}}\frac{1}{s}\sum_q e_q^2\,[\bar{q}_\mathrm{t}(x_\mathrm{t})q_\mathrm{b}(x_\mathrm{b}) + q_\mathrm{t}(x_\mathrm{t})\bar{q}_\mathrm{b}(x_\mathrm{b})]$$

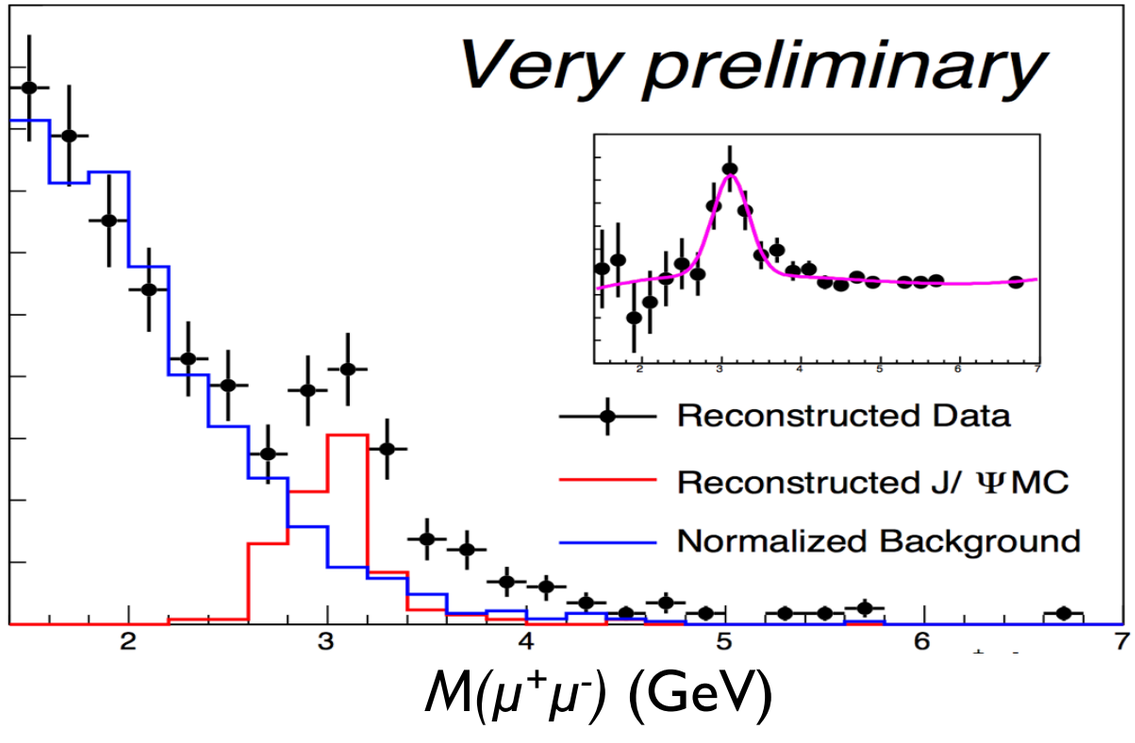


Status of E906

Commissioning Run 2012

- Brief 2-month run after many interesting diversions
- all systems worked
- Large intensity variations within spill
  - Caused entire detector to turn "on"
  - More prominent in data with dimuon trigger than single muon trigger
- DAQ TDC firmware not quite ready
  - Lacked hardware zero suppression (zero suppression in front-end CPU)
  - Large dead times, especially with large events
- PMTs at St. 1 need better rate capabilities
- Interim St. 1 and 3- Tracking





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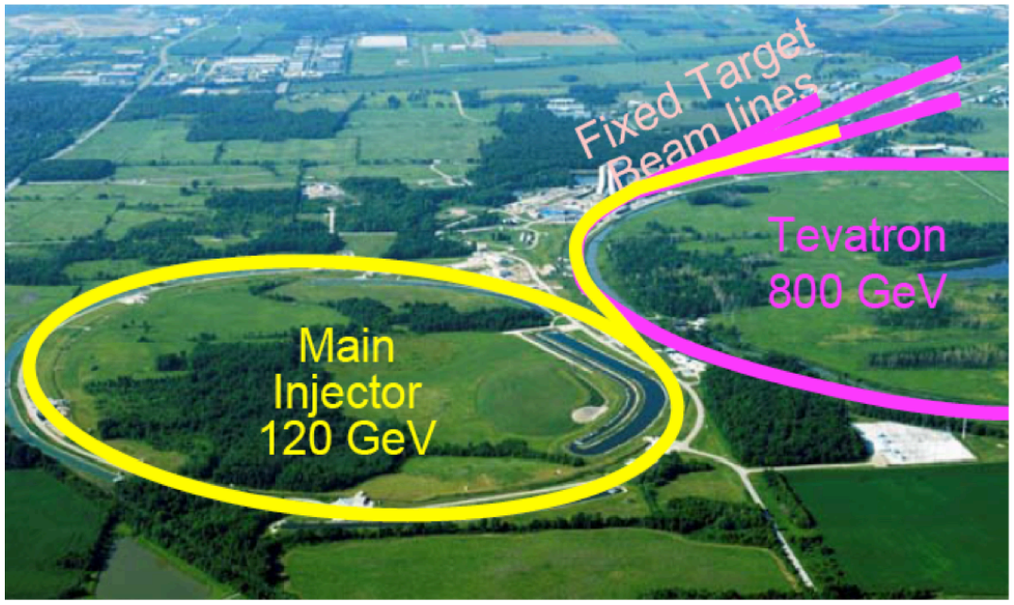
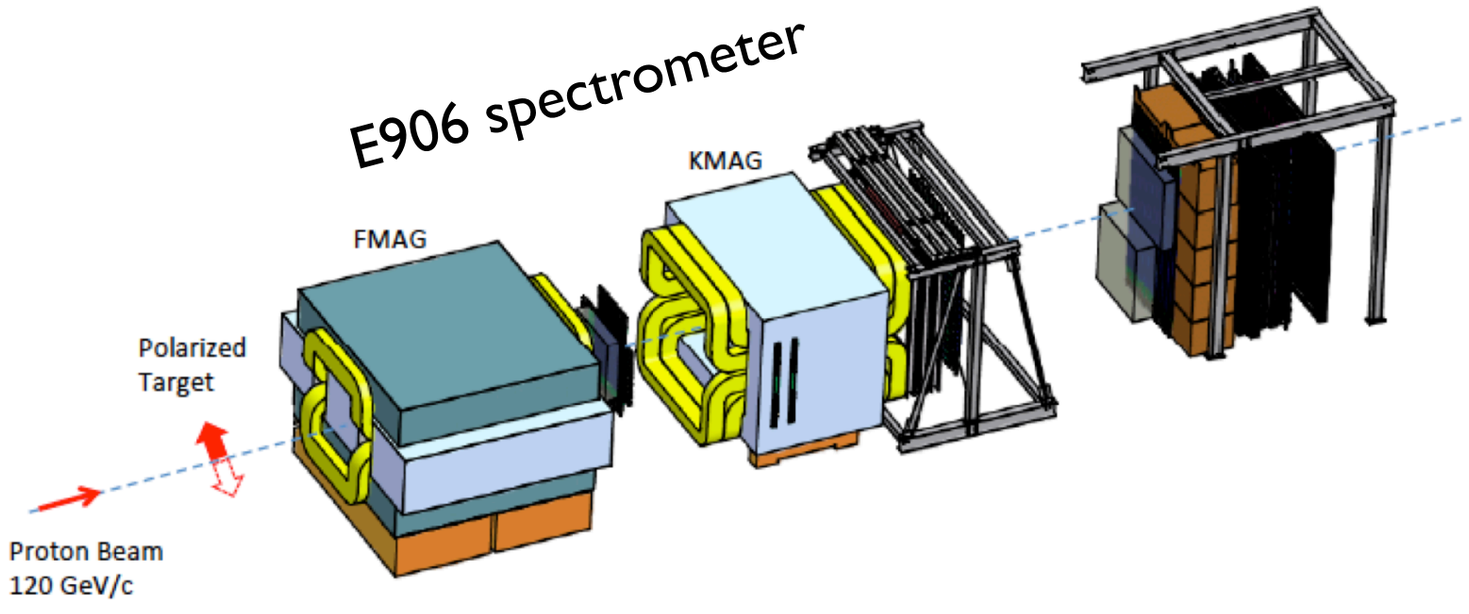
Polarized target with E906 spectrometer



Drell-Yan Transverse Single Spin Asymmetry

- Unpolarized 120 GeV proton beam from Fermilab's Main Injector
- Existing E906 spectrometer
- Polarized proton (NH_3) target, design and construction at LANL



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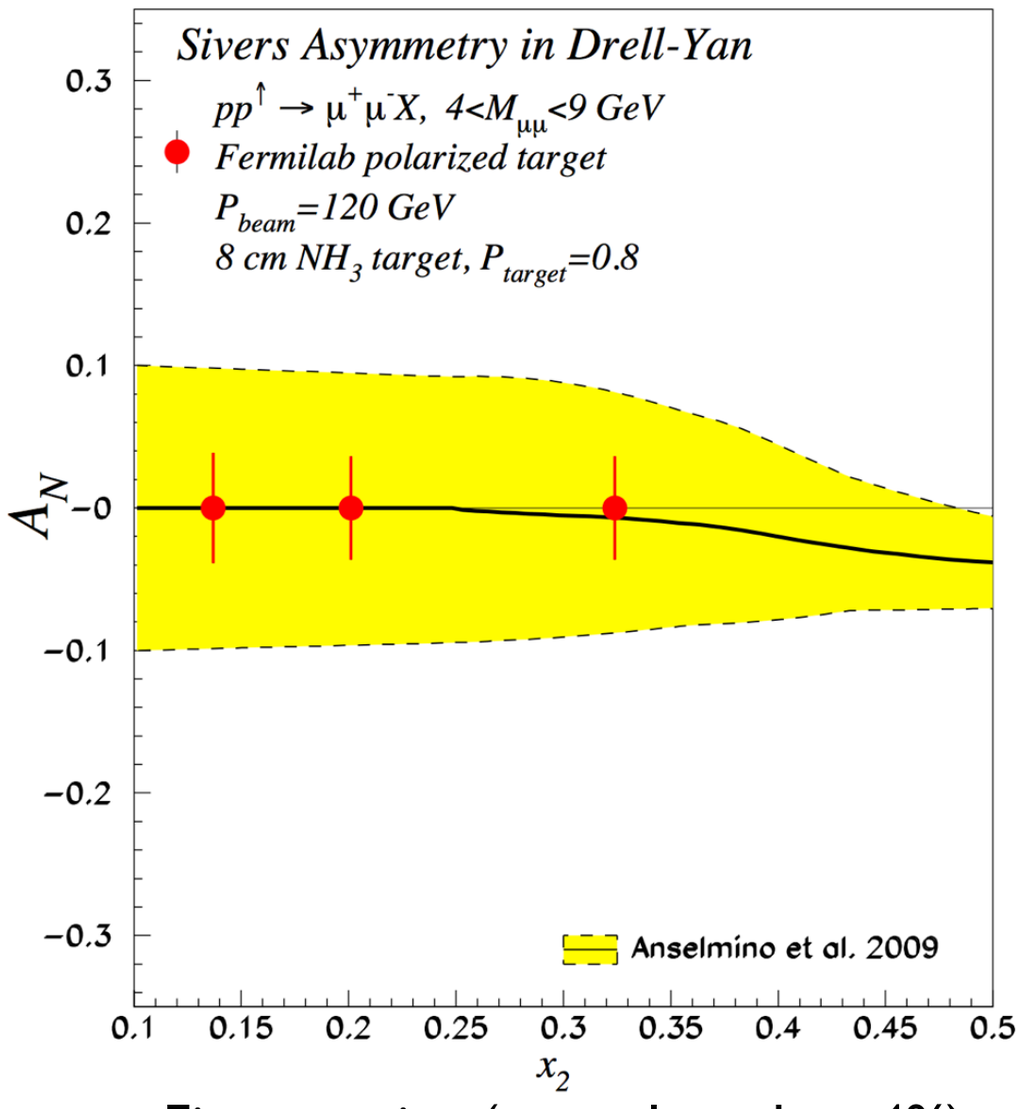
Expected precision in one year



E906 beam structure: 1E13 protons per 5 s spill, one spill per minute

- Total integrated luminosity (one year): 1.40×10^{43} cm^{-2}
- Accelerator efficiency: 50%
- Spectrometer efficiency: 80%
- Kinematic range: $4 < M < 9$ GeV, $-0.2 < x_F < 0.8$

Cuts	Efficiency	Yield
All DY in the kinematic range	100%	1.34E+08
$\mu^+\mu^-$ accepted by all detectors	2%	2.78E+06
Accepted by trigger	50%	1.39E+06
$\mu^+\mu^-$ pair reconstructed (with target/dump separation cut)	8%	1.11E+05

- First precise (error less than 4%) measurement of the sea quark Sivers distributions

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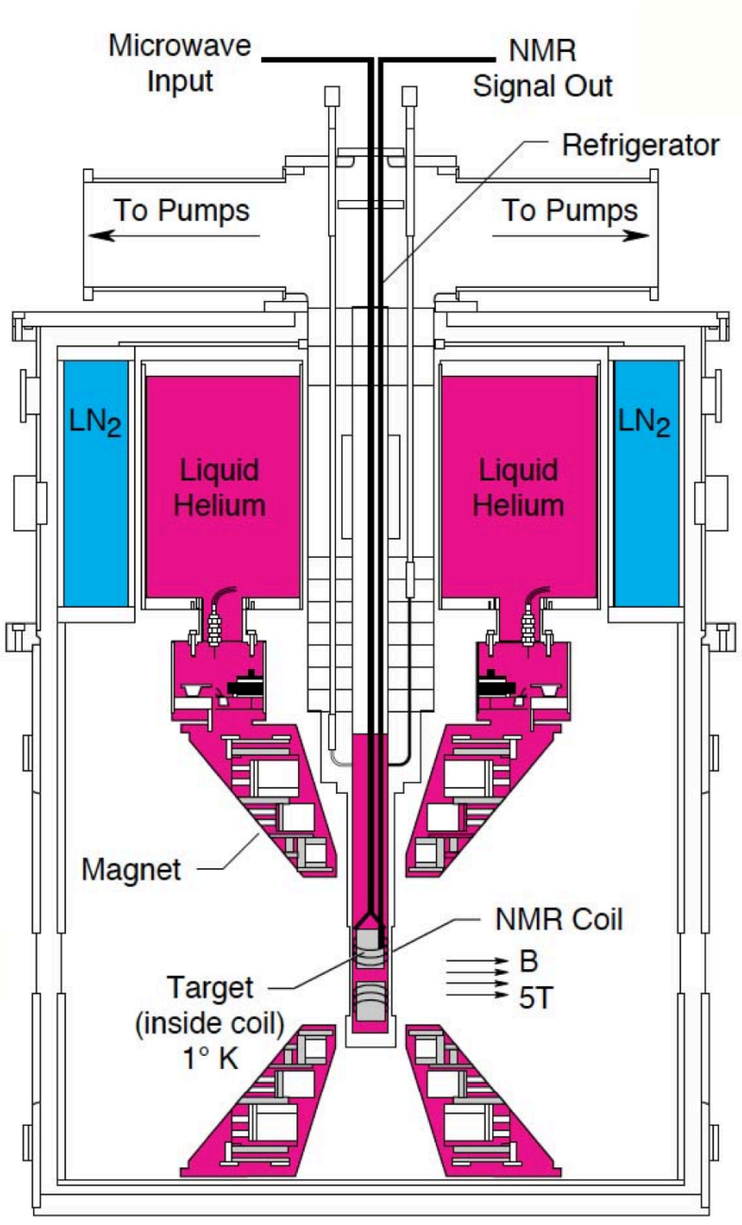
LANL high density polarized proton (neutron) target



Super conducting dipole magnet:

- Use liquid helium to reach 1 K
- Magnetic field: 5 Tesla
- 8 cm long NH_3 target irradiated by NIST
- Same design used at Jlab Hall C, proved to be capable of handling high luminosity up to 10^{35}

- Target is polarized by Dynamic Nuclear Polarization to 80%
- Re-commissioned at full field at UVa in Feb. 2013
- Original design was polarizing at longitudinal direction

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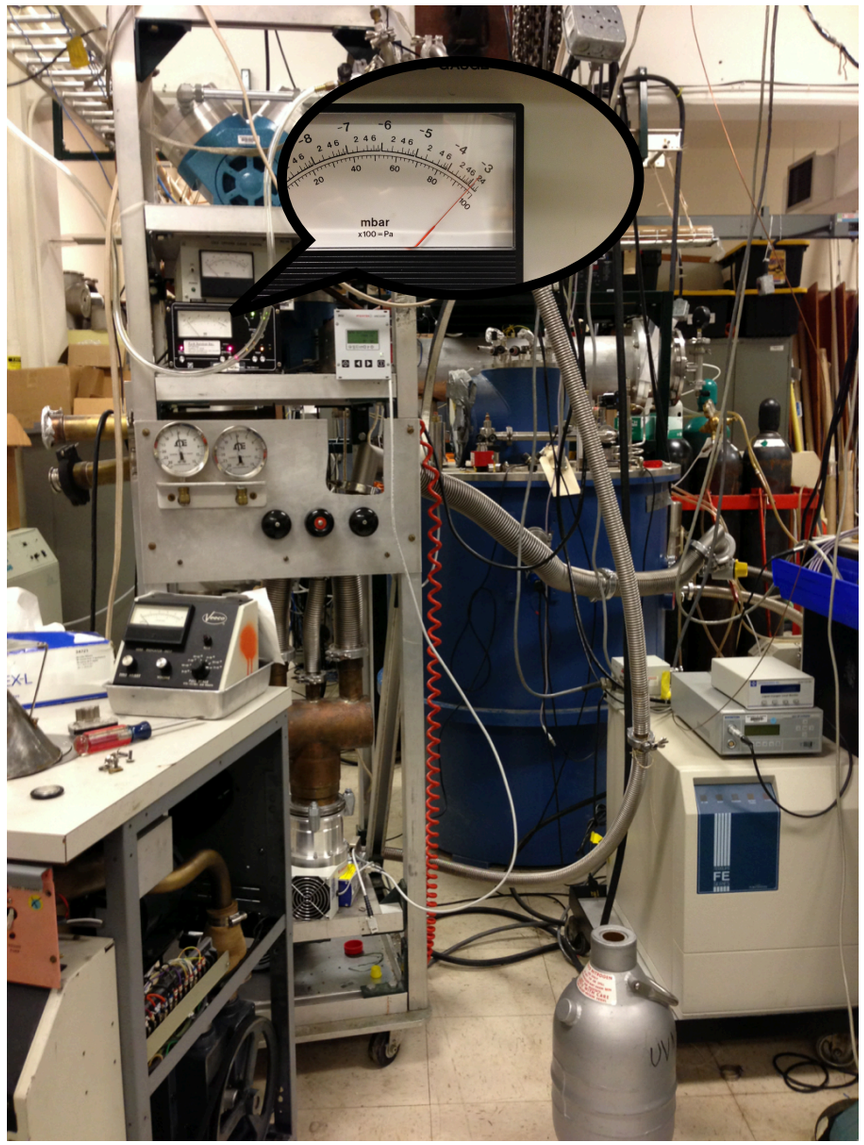
Re-commissioning at UVa

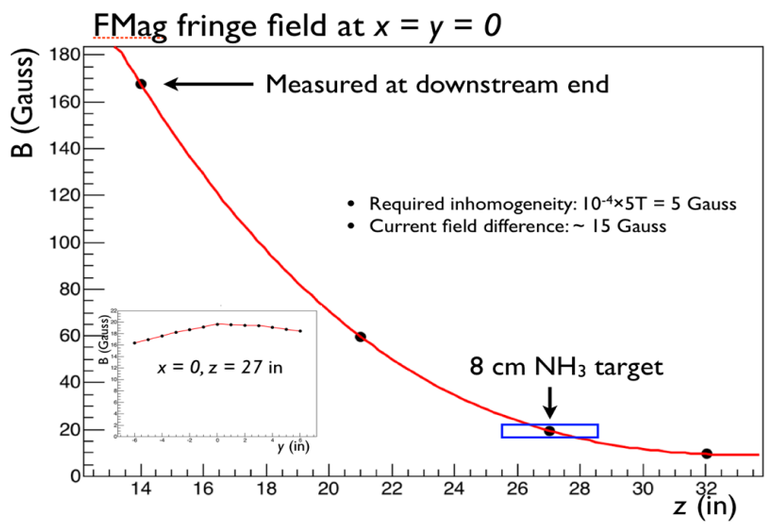


Fit into E906 target cave

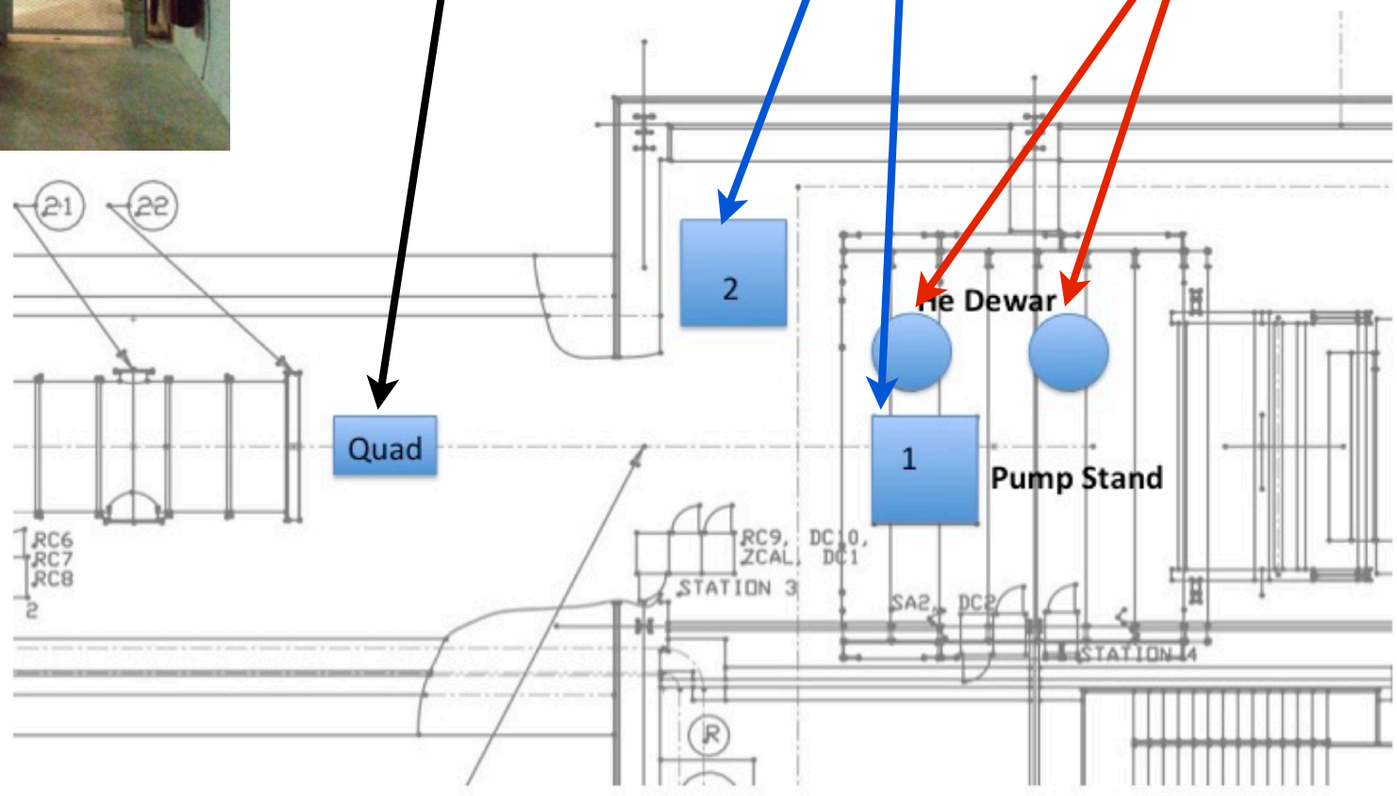
Add quadruple to improve the beam focus from ~ 1 cm to ~ 1 mm

Root pump system at either inside or outside the cave

1000 liter dewar to provide liquid helium



Beam



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Roadmap towards physics

LANL approved LDRD project: FY13-FY16

- A (3+1/2)-year project to have preliminary polarized DY spin asymmetry measurement at E906/Fermilab by the end of FY16; also including a significant theoretical effort on data interpretation within pQCD and LQCD framework
- FY13:
  - ➢ A LOI of fixed target polarized Drell-Yan to Fermilab, followed by a full proposal
  - ➢ Polarized target development
  - ➢ *LOI submitted to Fermilab PAC, invited to make presentation in June 2013*
- FY13-FY14:
  - ➢ Fermilab's approval of the full proposal
  - ➢ Re-build the LANL polarized proton target, in collaboration with UVa, JLab and Oxford
  - ➢ Be ready for installation and beams in FY15
- FY15-FY16:
  - ➢ First physics run with the polarized target at E906
  - ➢ Preliminary results by the end of FY16

Summary

- By performing Drell-Yan experiments with polarized proton target at E906/Fermilab, we will be enabled to:

  ➢ make the first measurement of Sivers function of sea quarks at *x* ~ *0.1 - 0.5*

  ➢ if it is non-zero, we will determine its sign

- This measurement will be complementary to the recently approved E-1027 (polarized proton beam).

- A polarized proton (NH_3) target was re-commissioned at full field recently at University of Virginia

- We've secured funding from LANL LDRD project and hope to have the first physics results in FY16.

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Thank you!