

Polarized Drell-Yan at Fermilab

APS LRP:

Joint Town Meetings on QCD
(13-September, 2014)

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- Unpolarized Drell-Yan at Fermilab: (~70 collaborators)
 - **SeaQuest [E-906]:** (USA, Japan, Taiwan)
 - **science run:** Feb 2014 — spring/summer 2016
- **Polarized Drell-Yan** at Fermilab: (USA, Japan, Taiwan, Spain) (~80 collaborators)
 - polarized **Target [E-1039]:** 2016 (for 2 yrs) **Stage 1 approval: July-2013**
 - polarized **Beam [E-1027]:** >2018 (for 2 yrs) **Stage 1 approval: Nov-2012**
- **Present status & needs**

Planned Polarized Drell-Yan Experiments

Experiment	Particles	Energy (GeV)	x_b or x_t	Luminosity ($\text{cm}^{-2} \text{s}^{-1}$)	$A_T^{\sin\phi_3}$	P_b or P_t (f)	rFOM#	Timeline
COMPASS (CERN)	$\pi^\pm + p^\uparrow$	160 GeV $\sqrt{s} = 17$	$x_t = 0.1 - 0.3$	2×10^{33}	0.14	$P_t = 90\%$ $f = 0.22$	1.1×10^{-3}	2014, 2018
PANDA (GSI)	$\bar{p} + p^\uparrow$	15 GeV $\sqrt{s} = 5.5$	$x_t = 0.2 - 0.4$	2×10^{32}	0.07	$P_t = 90\%$ $f = 0.22$	1.1×10^{-4}	>2018
PAX (GSI)	$p^\uparrow + \bar{p}$	collider $\sqrt{s} = 14$	$x_b = 0.1 - 0.9$	2×10^{30}	0.06	$P_b = 90\%$	2.3×10^{-5}	>2020?
NICA (JINR)	$p^\uparrow + p$	collider $\sqrt{s} = 26$	$x_b = 0.1 - 0.8$	1×10^{31}	0.04	$P_b = 70\%$	6.8×10^{-5}	>2018
PHENIX/STAR (RHIC)	$p^\uparrow + p^\uparrow$	collider $\sqrt{s} = 510$	$x_b = 0.05 - 0.1$	2×10^{32}	0.08	$P_b = 60\%$	1.0×10^{-3}	>2018
fsPHENIX (RHIC)	$p^\uparrow + p^\uparrow$	$\sqrt{s} = 200$ $\sqrt{s} = 510$	$x_b = 0.1 - 0.5$ $x_b = 0.05 - 0.6$	8×10^{31} 6×10^{32}	0.08	$P_b = 60\%$ $P_b = 50\%$	4.0×10^{-4} 2.1×10^{-3}	>2021
SeaQuest (FNAL: E-906)	$p + p$	120 GeV $\sqrt{s} = 15$	$x_b = 0.35 - 0.9$ $x_t = 0.1 - 0.45$	3.4×10^{35}	---	---	---	2012 - 2015
Pol tgt DY [‡] (FNAL: E-1039)	$p + p^\uparrow$	120 GeV $\sqrt{s} = 15$	$x_t = 0.1 - 0.45$	4.4×10^{35}	0 – 0.2*	$P_t = 88\%$ $f = 0.176$	0.15	2016
Pol beam DY [§] (FNAL: E-1027)	$p^\uparrow + p$	120 GeV $\sqrt{s} = 15$	$x_b = 0.35 - 0.9$	2×10^{35}	0.04	$P_b = 60\%$	1	>2018

[‡] 8 cm NH₃ target / [§] $L = 1 \times 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$ (LH₂ tgt limited) / $L = 2 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ (10% of MI beam limited)

*not constrained by SIDIS data / # rFOM = relative lumi * P² * f² wrt E-1027 (f=1 for pol p beams, f=0.22 for π^- beam on NH₃)

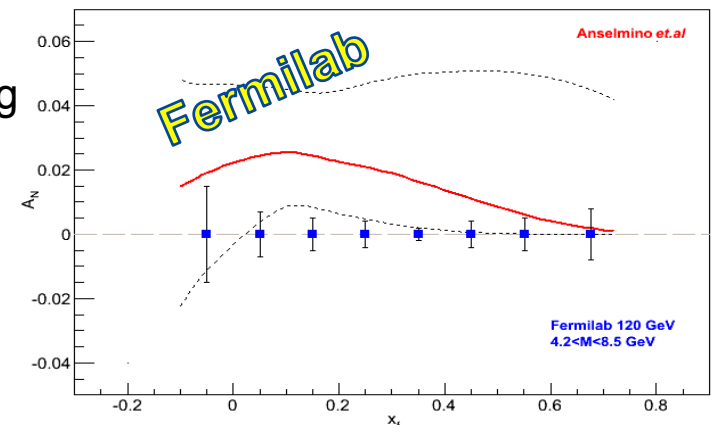
Polarized Beam Drell-Yan at Fermilab (E-1027)

- Polarized Drell-Yan:
 - QCD (and factorization) require sign change
 - major milestone in hadronic physics (HP13)

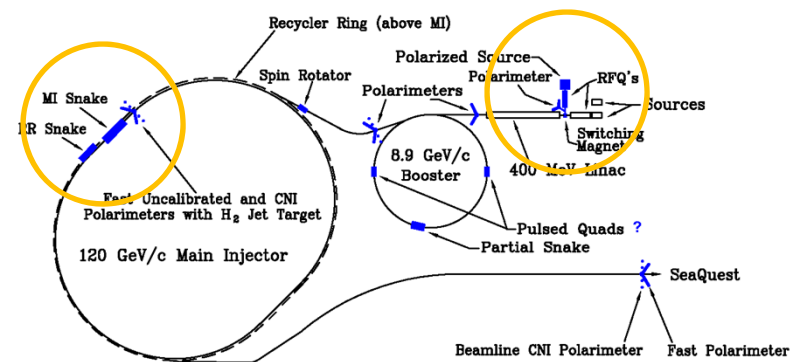
$$f_{IT}^{\perp}|_{SDS} = -f_{IT}^{\perp}|_{DY}$$

- Extraordinary opportunity at Fermilab (best place for polarized DY) :

- high luminosity, large x-coverage
- (SeaQuest) spectrometer already setup and running
- run alongside neutrino program (w/ 10% of beam)
- experimental sensitivity:
 - › 2 yrs at 50% eff, $P_b = 60%$, $I_{av} = 15$ nA
 - › luminosity: $L_{av} = 2 \times 10^{35}$ /cm²/s



- Path to polarized proton beam at Main Injector
 - perform detailed design studies
- Cost estimate to polarize Main Injector \$10M (total)
 - includes M&S, labor, 15% project management & 50% contingency
- Workshop at Hawaii 2014 Joint Mtg (7-Oct-2014)
 - *Polarized Drell-Yan Physics at Fermilab*



A Novel, Compact Siberian Snake for the Main Injector

Single snake design (6.4m long):

- 1 helical dipole + 2 conv. dipoles
 - helix: 4T / 5.6 m / 4" ID
 - dipoles: 4T / 0.2 m / 4" ID
- use one 4-twist helical magnet
 - 8π rotation of B field
- never done before in a high energy ring
 - RHIC uses snake pairs
 - 4 single-twist magnets (2π rotation ea)

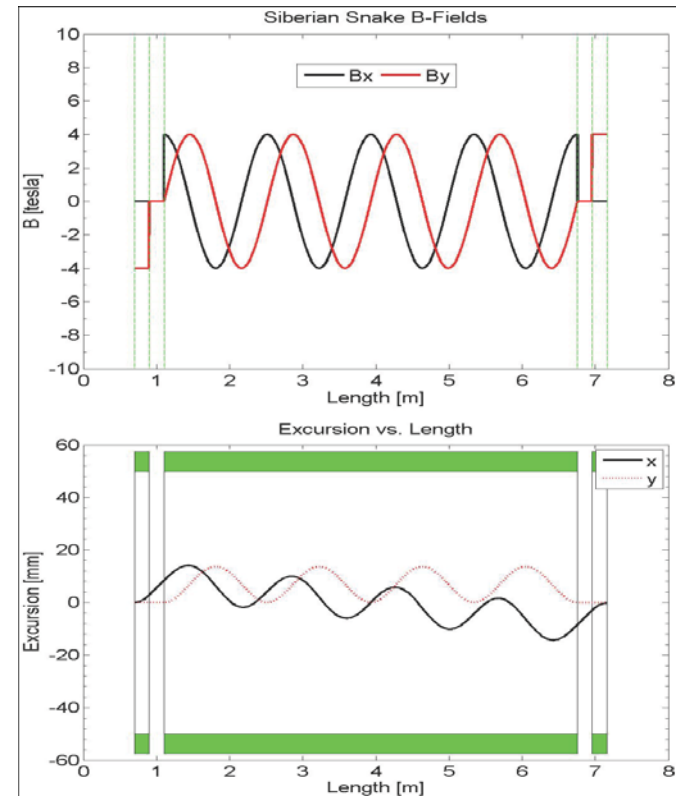
Path to polarized proton beam at MI

- detailed design studies: \$300k (short-term)
- implement modifications to MI \$10M (longer-term)

Needs

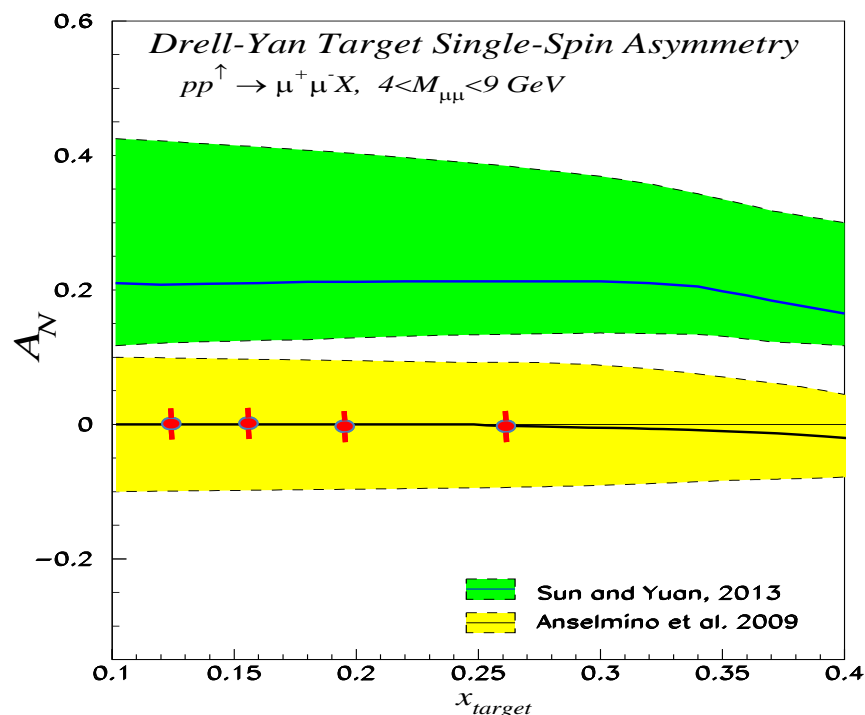
- recommendation in LRP document

initial design studies



Polarized Beam Drell-Yan at Fermilab (E-1039)

- Probe **Sea-quark Sivers Asymmetry** with a polarized proton target at SeaQuest



- Statistics shown for one calendar year of running:
- $L = 7.2 \cdot 10^{42} / \text{cm}^2 \leftrightarrow \text{POT} = 2.8 \cdot 10^{18}$
- Running will be two calendar years of beam time

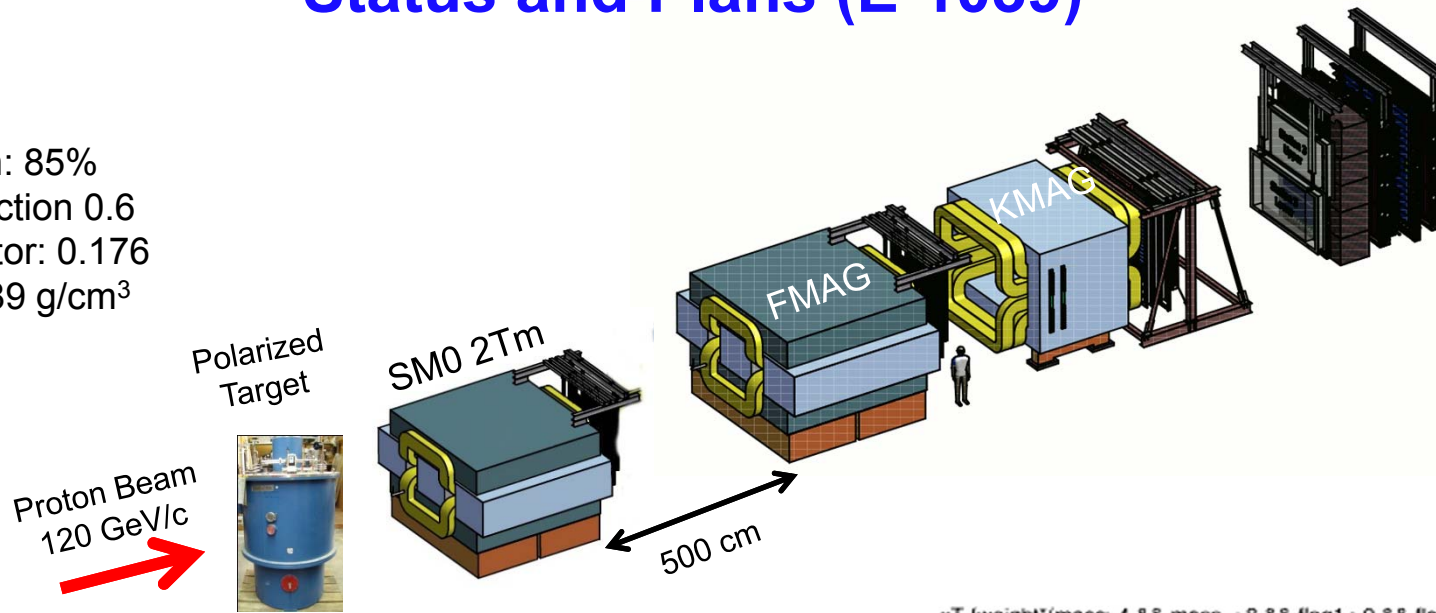
- existing SIDIS data poorly constrain sea-quark Sivers function
- significant Sivers asymmetry expected from meson-cloud model
- **first Sea Quark Sivers Measurement**
- **determine sign and value of \bar{u} Sivers distribution**

If $A_N \neq 0$, **major discovery:**
“Smoking Gun” evidence for $L_{\bar{u}} \neq 0$

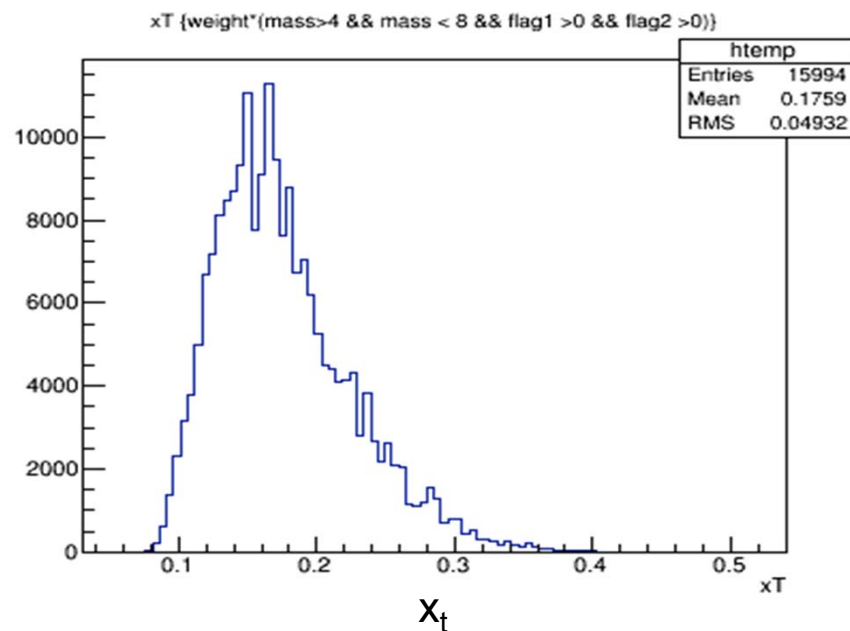
Status and Plans (E-1039)

Target

Polarization: 85%
 Packing fraction 0.6
 Dilution factor: 0.176
 Density: 0.89 g/cm³



- use current SeaQuest setup, a polarized proton target, unpolarized beam
- add third magnet SM0 ~5m upstream
 - improves dump-target separation
 - moves $\langle x_t \rangle$ from 0.21 to 0.176
 - reduces overall acceptance
 - adds shielding challenges



COMPASS, E-1027, E-1039 (and Beyond)

	Beam Pol.	Target Pol.	Favored Quarks	Physics Goals			
				(Sivers Function)			L_{sea}
				sign change	size	shape	
COMPASS $\pi^- p^\uparrow \rightarrow \mu^+ \mu^- X$	✗	✓	valence	✓	✗	✗	✗
E-1027 $p^\uparrow p \rightarrow \mu^+ \mu^- X$	✓	✗	valence	✓	✓	✓	✗
E-1039 $p p^\uparrow \rightarrow \mu^+ \mu^- X$	✗	✓	sea	✗	✓	✓	✓
E-10XX $p^\uparrow p^\uparrow \rightarrow \mu^+ \mu^- X$ $\vec{p} \vec{p} \rightarrow \mu^+ \mu^- X$	✓	✓	sea & valence	Transversity, Helicity, Other TMDs ...			

Proposed Polarized Drell-Yan Recommendation Text for the QCD Town Meeting

- A high-luminosity polarized Drell-Yan program at the Fermilab Main Injector with both polarized beams and targets is endorsed by the U.S. QCD community.