Transversely polarized proton

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Electron/muon beam experiments

- VEPP-3 – atomic D target, 1 kG (2 GeV)
- HERMES – atomic H/D target, 3 kG (27 GeV)
- COMPASS – solid target, 4 kG (100-200 GeV)
- JLab – ??

Challenges of transversity-SIDIS

- SBS-SIDIS: PAC38 approved E12-09-108
  - Requires refurbishing the HERMES RICH
- Enhancement of approved experiment
  - A_1^n (E12-06-122)

Some slides are from Kees's report at DOE-review of SBS

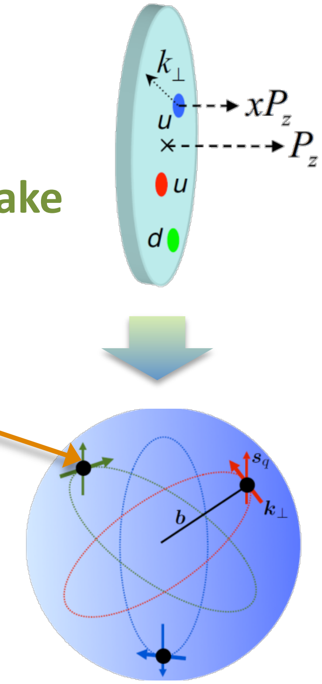
P_T-Dependent (TMD) Parton Distributions

- TMD PDFs provide a link between
  - Intrinsic motion of partons
  - Parton spin
  - Spin of the nucleon
- Multi-Dimensional structure
  - Probes orbital motion of quarks
- A new phase of study, fast developing field
  - Great advancement in theory (factorization, models, Lattice ...)
  - Not systematically studied until recent years
    - Semi-Inclusive DIS (SIDIS): HERMES, COMPASS, JLab-6GeV, ...
    - Drell-Yan process : FNAL, BNL, ...

in DIS
Nucleon -> Pancake

$L \neq^{?} 0$

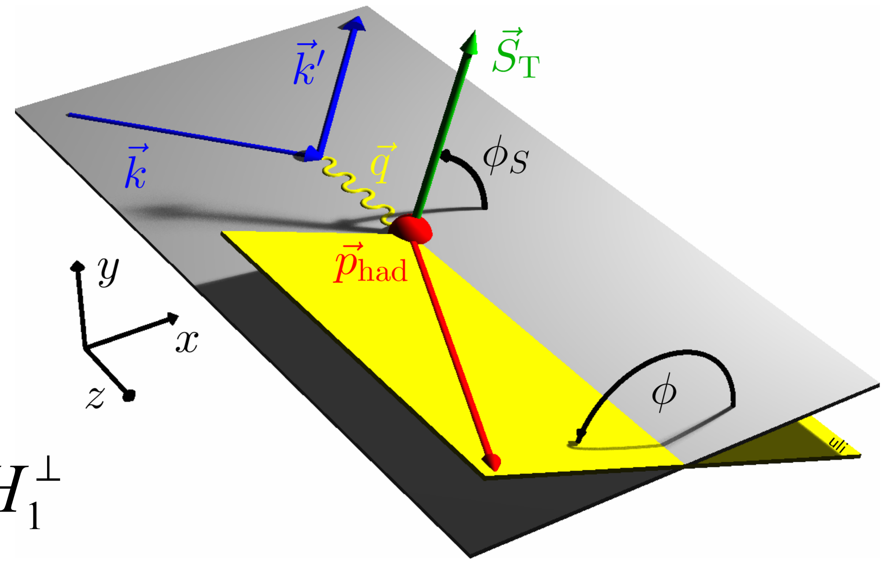
→Transverse motion



Separation of TMDs

Separate different effects through angular dependence of single-spin asymmetry from transversely polarized target

$$A_{UT}(\phi_h^l, \phi_S^l) = \frac{N^\uparrow - N^\downarrow}{N^\uparrow + N^\downarrow}$$



- **Collins asymmetry:**

$$A_{UT}^{Collins} \propto \langle \sin(\varphi_h + \varphi_s) \rangle_{UT} \propto h_1 \otimes H_1^\perp$$

- **Sivers asymmetry:**

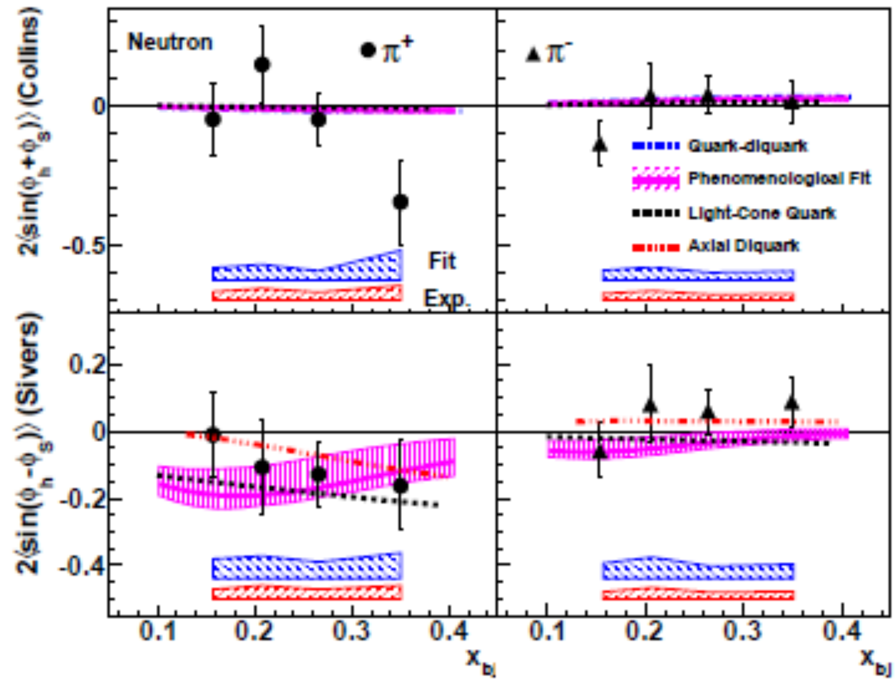
$$A_{UT}^{Sivers} \propto \langle \sin(\varphi_h - \varphi_s) \rangle_{UT} \propto f_{1T}^\perp \otimes D_1$$

- **"Pretzelosity":**

$$A_{UT}^{Pretzelosity} \propto \langle \sin(3\varphi_h - \varphi_s) \rangle_{UT} \propto h_{1T}^\perp \otimes H_1^\perp$$

JLab E06-010: $^3He/n(e,e'\pi^{\pm})X$ TSSA

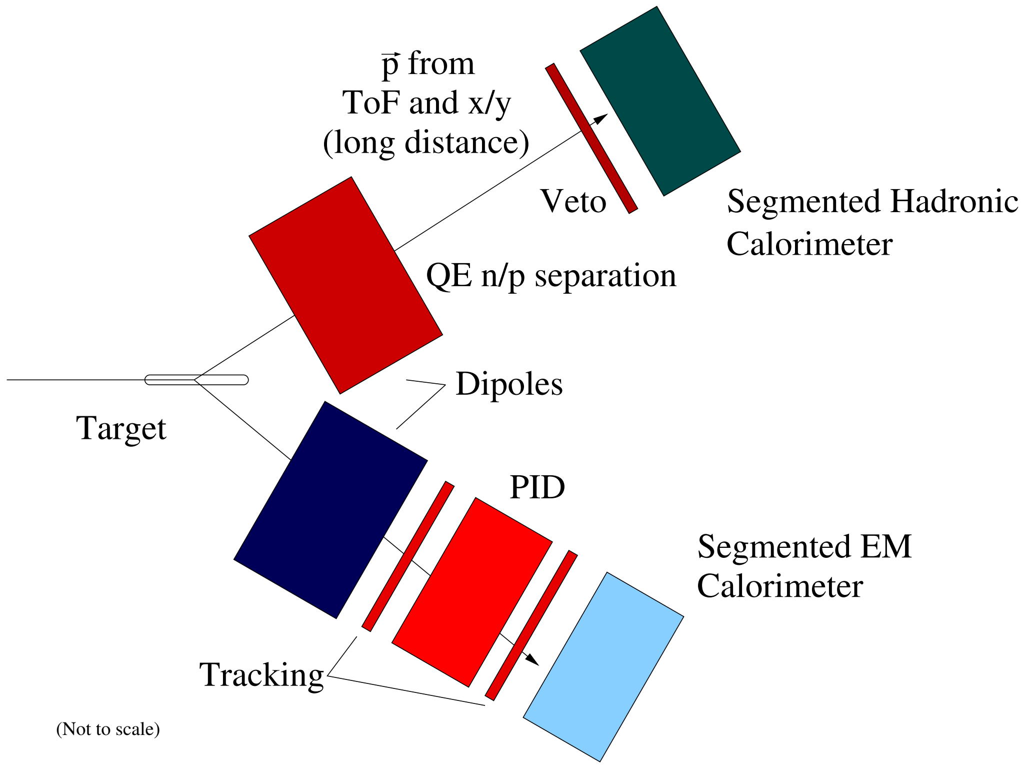
- Pioneering experiment, studying for first time neutron TMDs with polarized ^3He target
- Key instrumentation achievements:
  - BigBite as open-geometry electron arm
  - Rotation of target spin polarization provides full coverage for Collins and Sivers angles
- X. Qian et al., PRL 107, 072003 (2011)

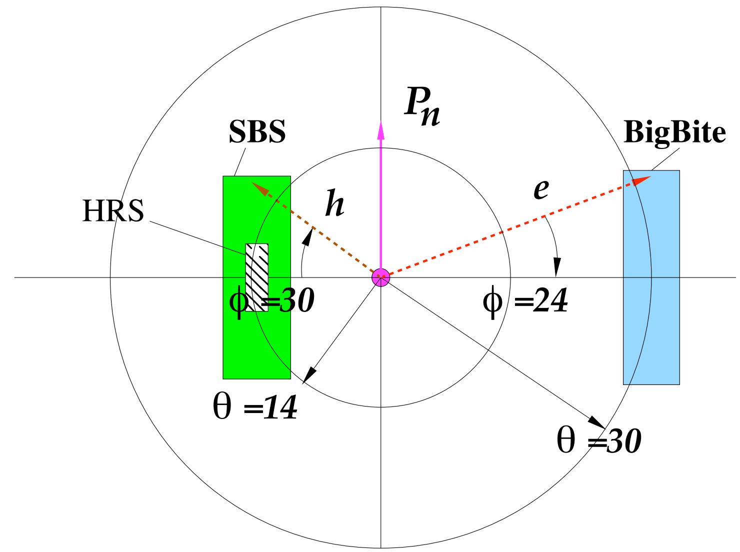


→ E12-09-018 will provide ~1000X more statistics for neutron asymmetries than E06-010

Systematic of the target polarization !!

Layout for Experiment E12-09-018

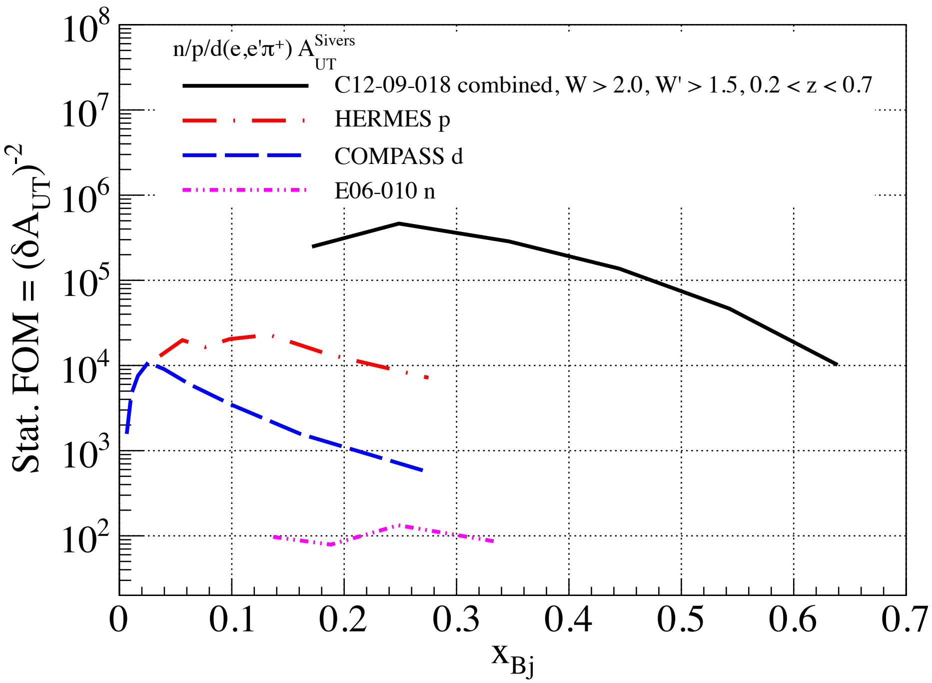


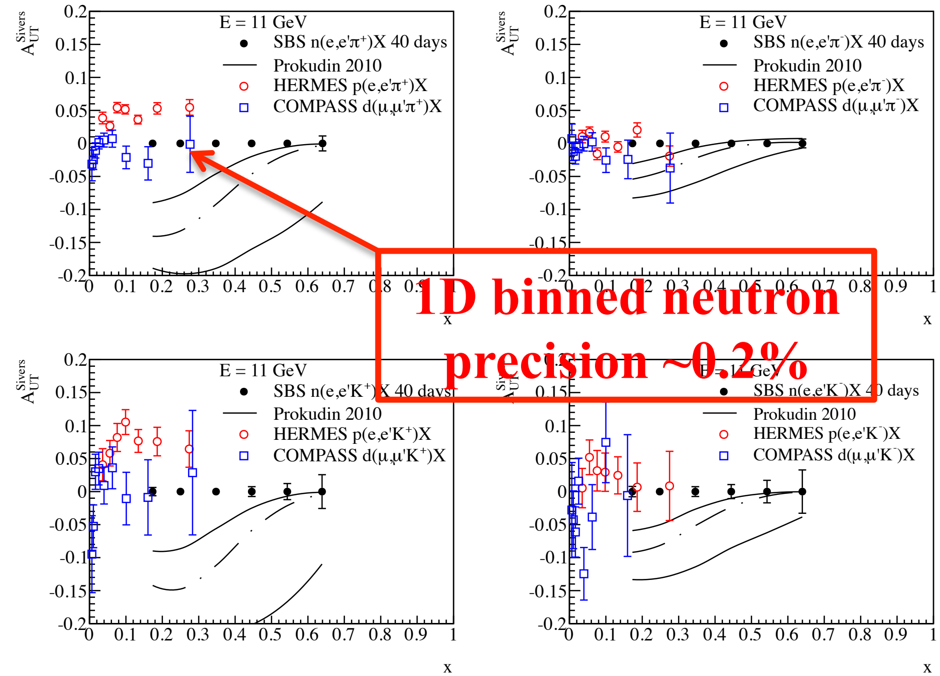


Angular coverage viewed along beam

- Electron arm (BigBite) at 30° and hadron arm (SBS) at 14°
- Both arms: large solid angle and "infinite" momentum bite
- Upgraded high-luminosity ^{3}He target, 60 cm long; target spin can be oriented in any transverse direction, we will use 8, sufficient to cover the full azimuthal phase space
- 10X larger angular acceptance compared to E06-010, 20X larger useful momentum acceptance, 4X higher useful luminosity → 800X greater FOM

Vast Improvement over Current Knowledge



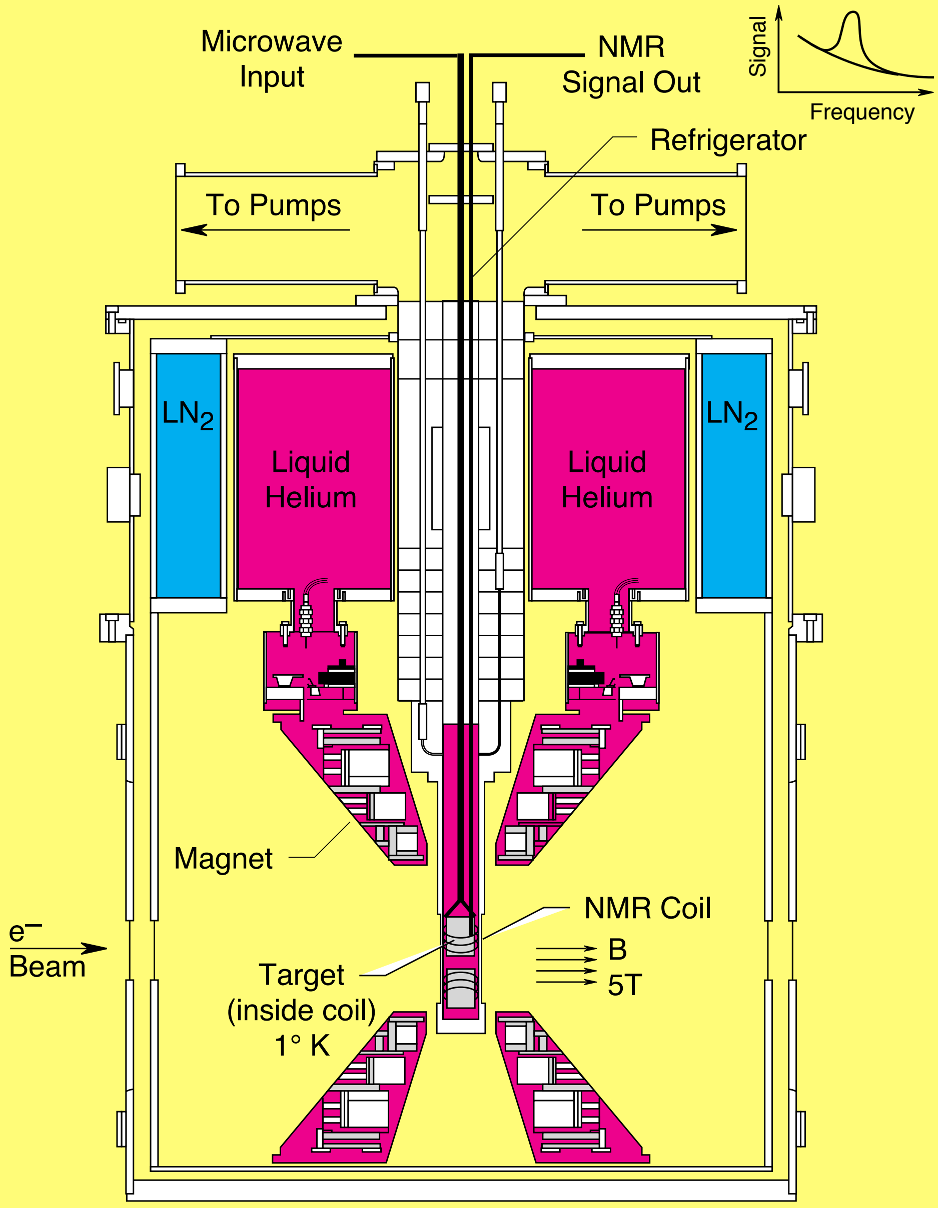


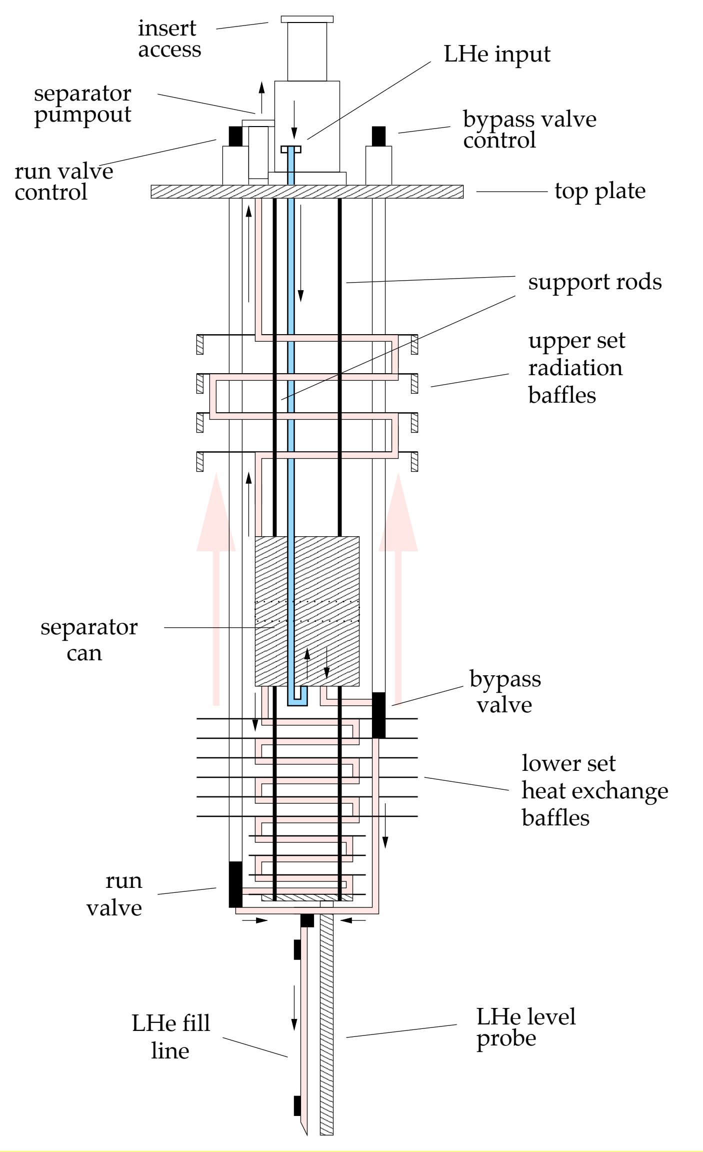
FOM: Improvement on existing data by 2+ orders of magnitude

$\pi^{\pm}$, $K^{\pm}$ Sivers compared to HERMES, COMPASS, theory fit

- E12-09-018 will achieve statistical FOM for the neutron ~100X better than HERMES proton data and ~1000X better than E06-010 neutron data
- Kaon and neutral pion data will aid the flavor decomposition, and provide a better understanding of reaction-mechanism effects

UVA/SLAC/JLAB Target

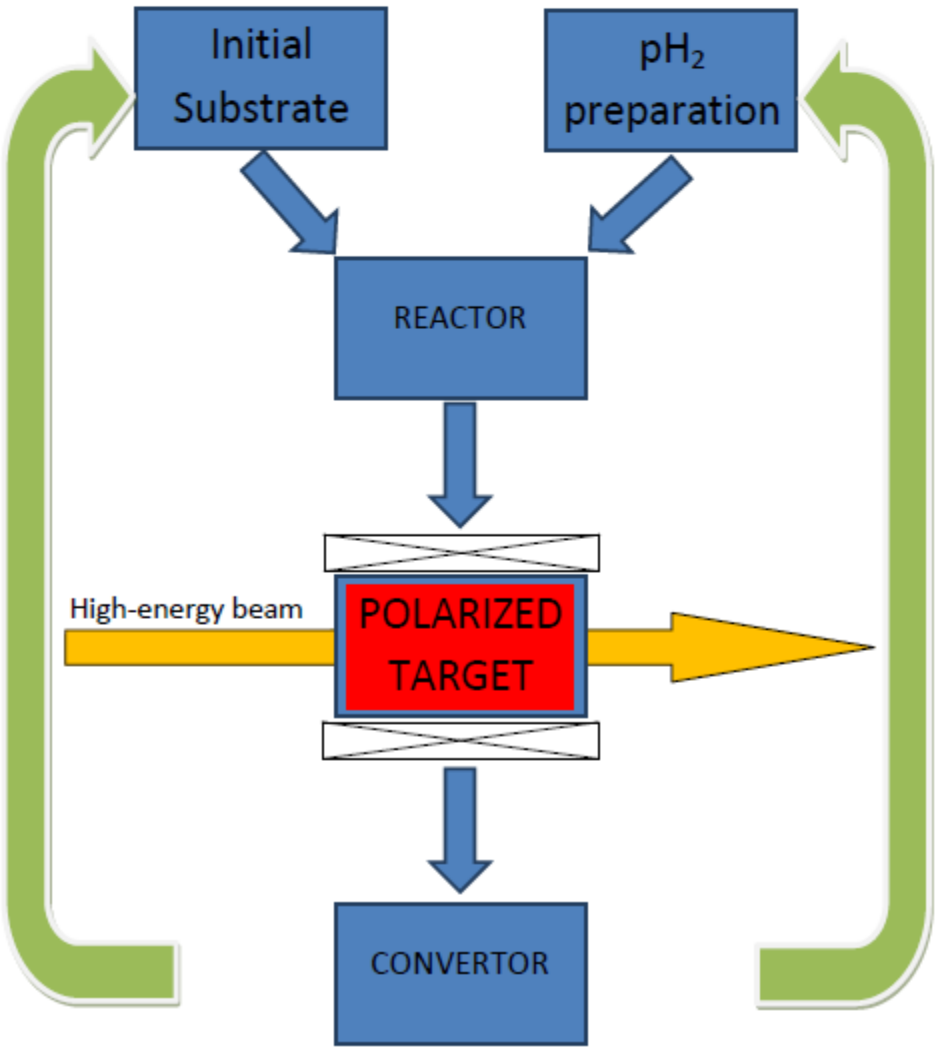




Polarized nuclear target based on parahydrogen induced polarization

D. Budker[1,2], M. P. Ledbetter[1], S. Appelt[3], L. S. Bouchard[4], and B. Wojtsekhowski[5]

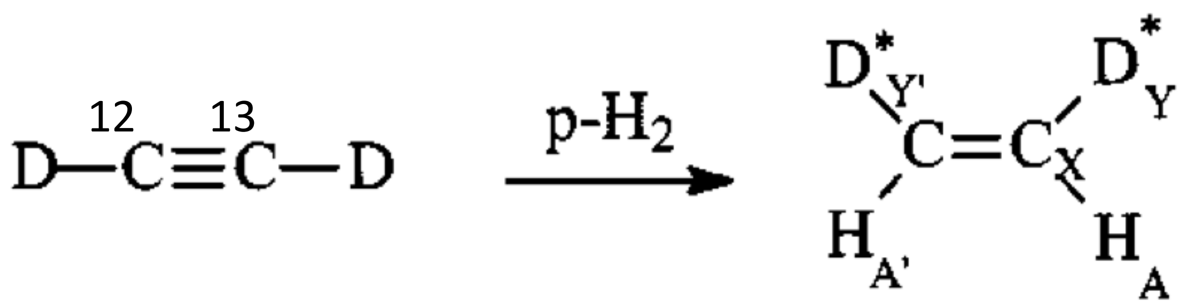
nima.2012.08.007 NIMA54679



- Novel concept for polarized nuclear targets
- Fast reversal (~100 Hz)
- Near-zero magnetic field
- Based on a revolutionary NMR technique
- Competitive FOM

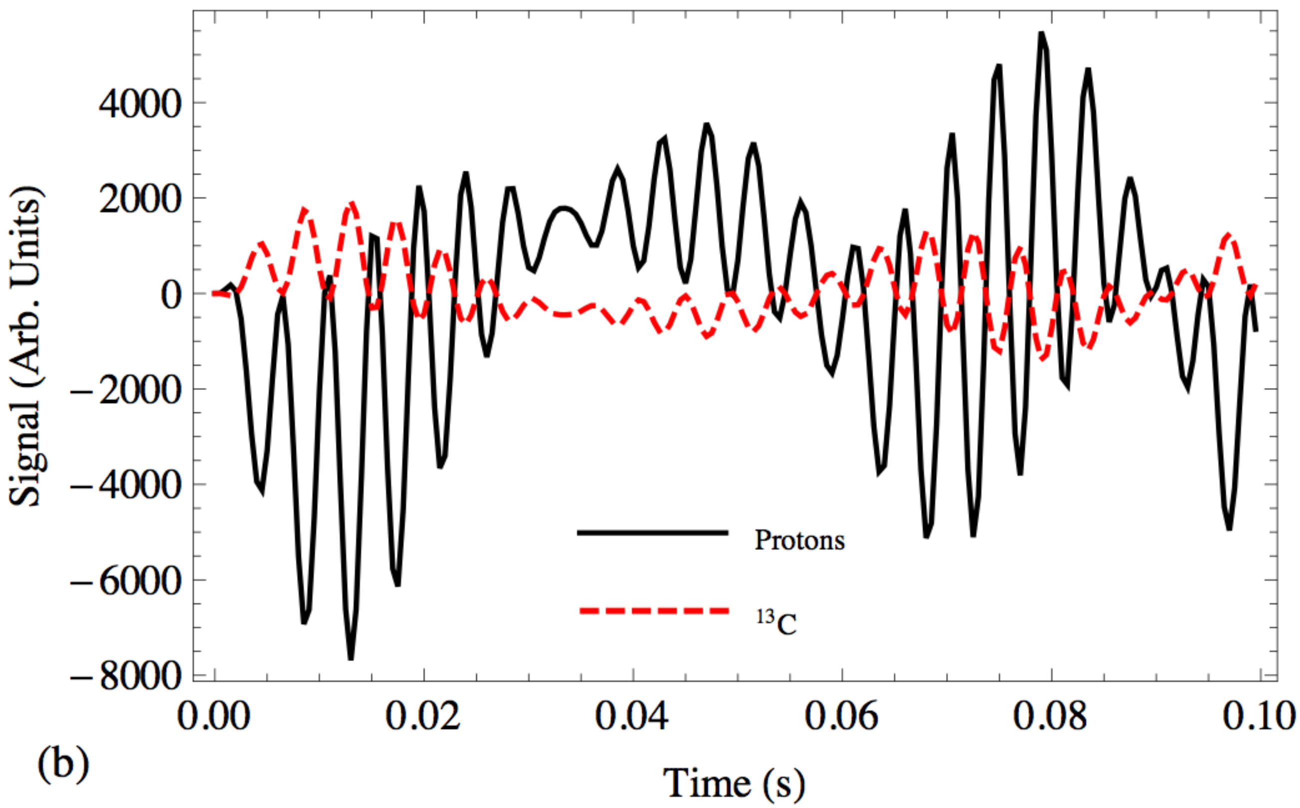
NIMA, 2012.08.007

Hyperpolarization transfer from parahydrogen



Magnetic field values at $H_{A'}$ and H_A are different!

Combined proton polarization is oscillating with a well defined frequency



Neutron polarization is opposite to one of C-13