Opportunities for spin physics with AFTER

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Fixed target projects at CERN
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Orsay

Spin physics with AFTER
Spin asymmetry and experimental requirements
Proton beam polarization at RHIC and possibility at LHC
Polarized targets at Compass and Jlab

Physics motivations

Target polarization to measure Single Spin Asymmetry (SSA): $A_{UT} = (\sigma_{+} - \sigma_{-}) / (\sigma_{+} + \sigma_{-})$

unpolarized nucleon = parton mom. distr. q(x) / long. pol. = helicity Δq(x) / trans. pol. = transversity δq(x)

- $A_{UL} \rightarrow W^{+/-}$: individual helicity distribution Δq of quarks and antiquarks
- $A_{UT} \rightarrow l^{+}l^{-}$: Sivers function (correlation between transverse momentum of a parton in the proton and the proton spin vector: link with orbital motion of partons in the nucleon - to access valence quarks, one should probe the large x_{target} region)
- $A_{UT} \rightarrow$ Quarkonium : production mechanisms, gluon Sivers function

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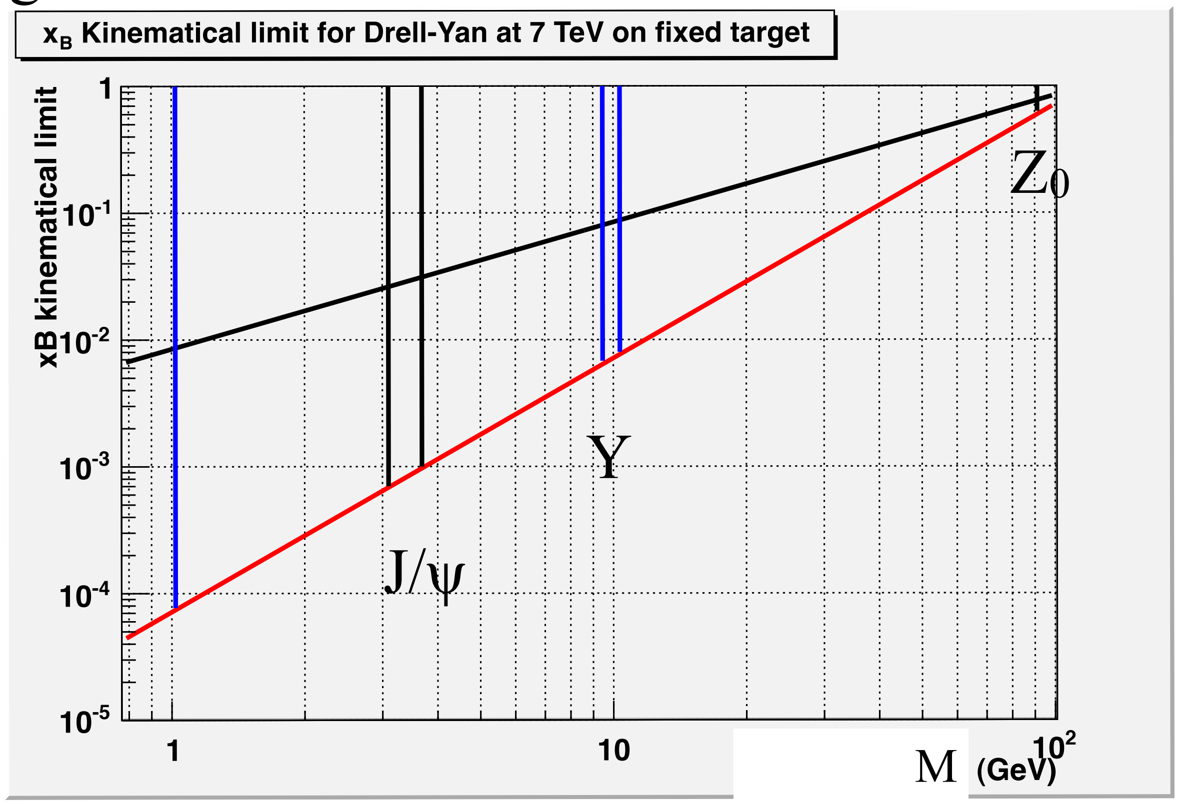
Kinematics: 7 TeV proton beam on fixed hydrogen/deuterium target

- $\sqrt{s}$ = 115 GeV and y_{beam} = 4.8
- $\tau = x_{beam}\, x_{target} = (M^2/ s) = x_{min}$
- $x_{target} = x_{beam} = M/ \sqrt{s}$
- backward region: $x_{target} > x_{beam}$ to probe the target valence quarks



Physics motivations

Target and beam polarization: Double Spin Asymmetry (DSA)

- $A_{LL} \rightarrow$ hight p_T π^0, jet , Quarkonia, open charm and beauty - $\Delta G/G$
- $A_{TT} \rightarrow l^+l^-$ - transversity functions δq

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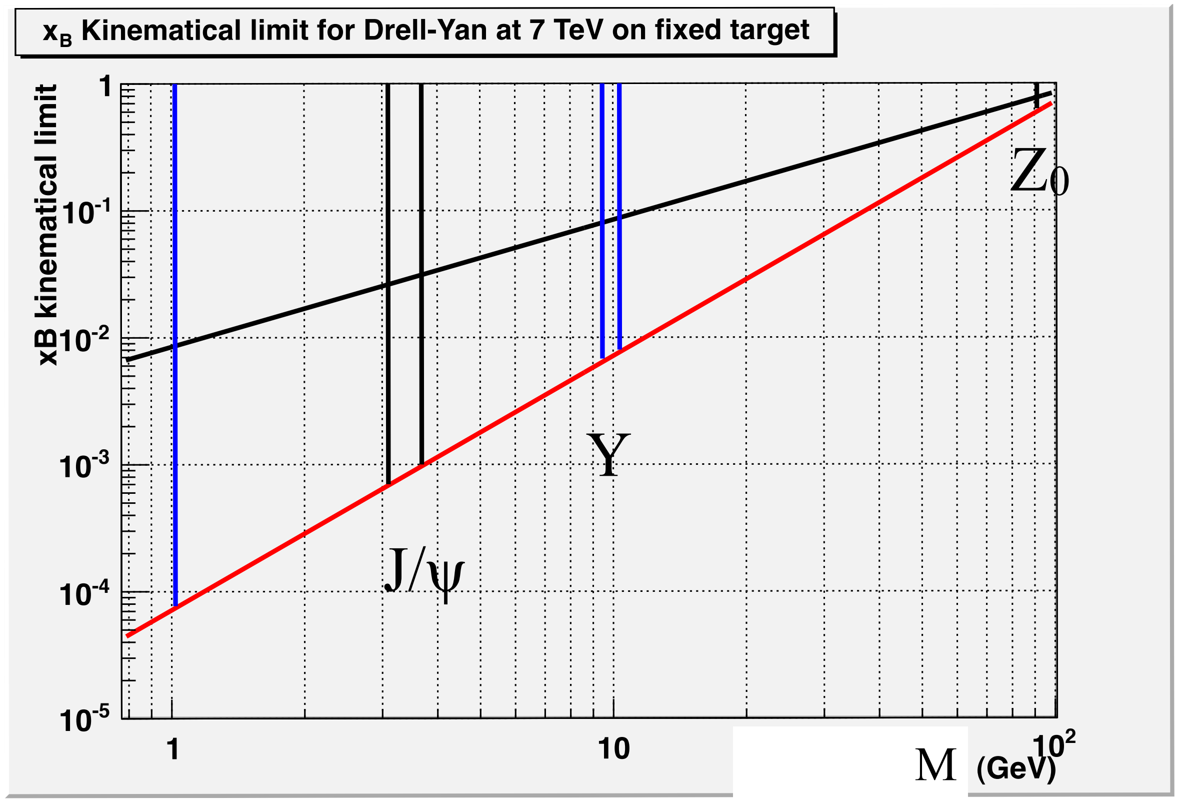
- $x_{target} = x_{beam} = M/\sqrt{s}$
- backward region: $x_{target} > x_{beam}$ and M > 10 GeV to probe the beam and target valence quarks



Measured spin asymmetry

- Definition

  $A^{th} = (\sigma_{++} - \sigma_{-+}) / (\sigma_{++} + \sigma_{-+})$

  $A^{exp} = (N_{++} - N_{-+}) / (N_{++} + N_{-+}) = P_B\, P_T\, f\, A^{th}$ (same Eff x Acc and L_{int} in ++ and -+ samples)

- What is needed experimentally?

  Proton beam with polarization P_B

  Proton/deuterium target with polarization P_T

  Dilution factor f = ratio of polarizable nucleons / total number of nucleons in the target

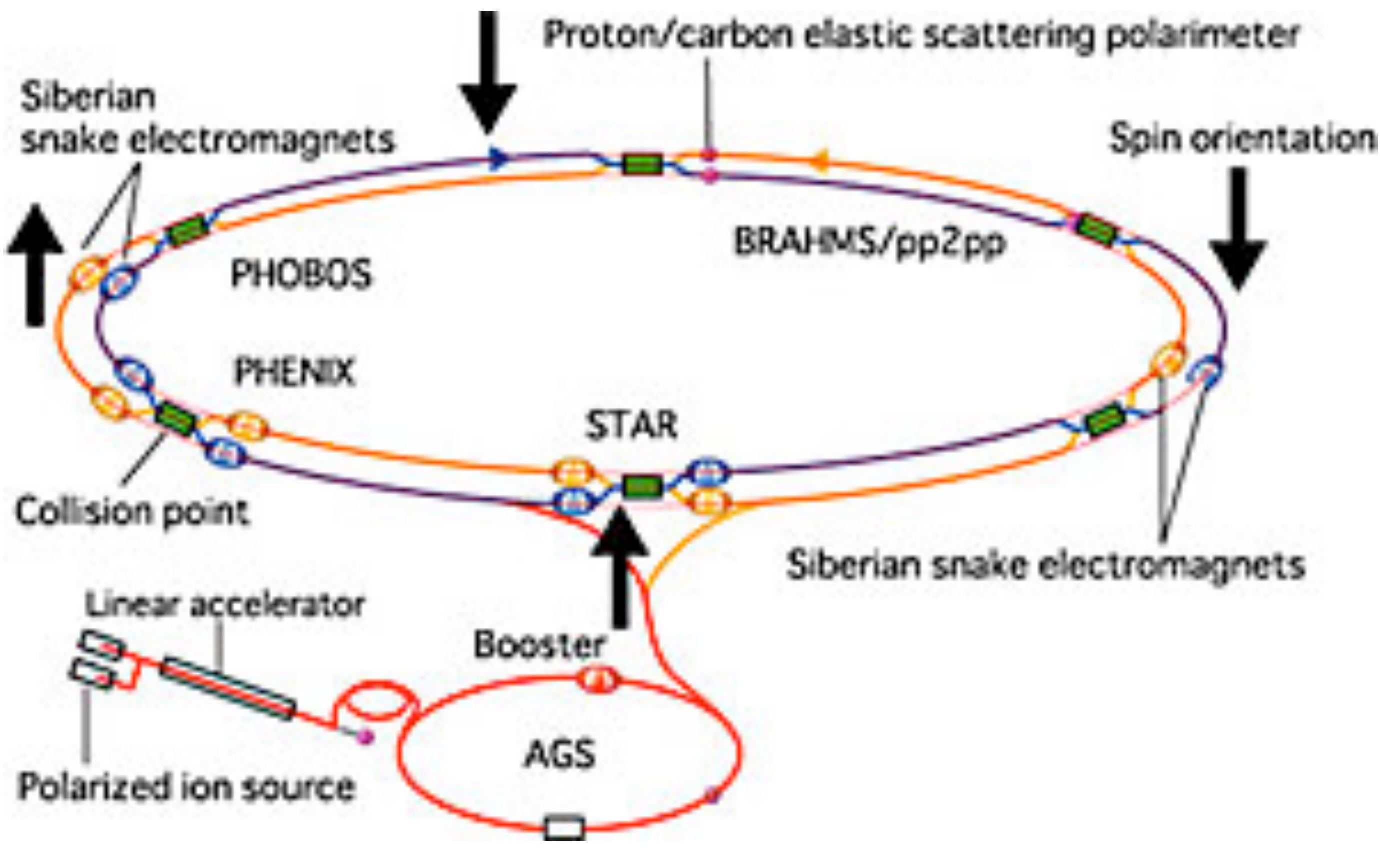
  Gas target: fraction of recombined gas atoms may reduce the polarization f~1 but low density (used in collider)

  Solid target: Figure of Merit $= \rho\, k\, (f\, P_T)^2$ (target = grains filled by refrigerator; k = packing factor: composition of pol. material /tot. volume)

  Polarimeters both for beam and target

  Luminometer as $A^{exp} = (N_{++} / L_{++} - N_{-+} / L_{-+}) / (N_{++} / L_{++} + N_{-+} / L_{-+})$

Polarized proton beam at RHIC



- Polarized H− ion source
- Challenging because the produced polarized proton beam is accelerated: external magnetic field depolarizes the beam.
- Use of Siberian Snake (=180˚ spin rotator about a horizontal axis) to maintain the beam polarization of P_B=60-70%

- Spin rotator to switch the pol.
- Polarimeter: 5 μm diameter carbon fiber fixed targets and polarized atomic gas jet target - polarisation measurement with 5% accuracy
- Possible sources of systematics: luminosity variation, crossing angle variation: different bunch polarization pattern and flip of the polarization

Polarized Proton beam at LHC?

Extraction of proton beam with particles channelling in a bent crystal
The beam extraction induces a transverse polarization of the beam depending on the analyzing power of the crystal A_0
Successive collisions in the crystal amplify the polarization

M. Ukhanov, Nucl. Instrum. Meth. A 582 (2007) 378

A = analyzing power of the crystal nucleus

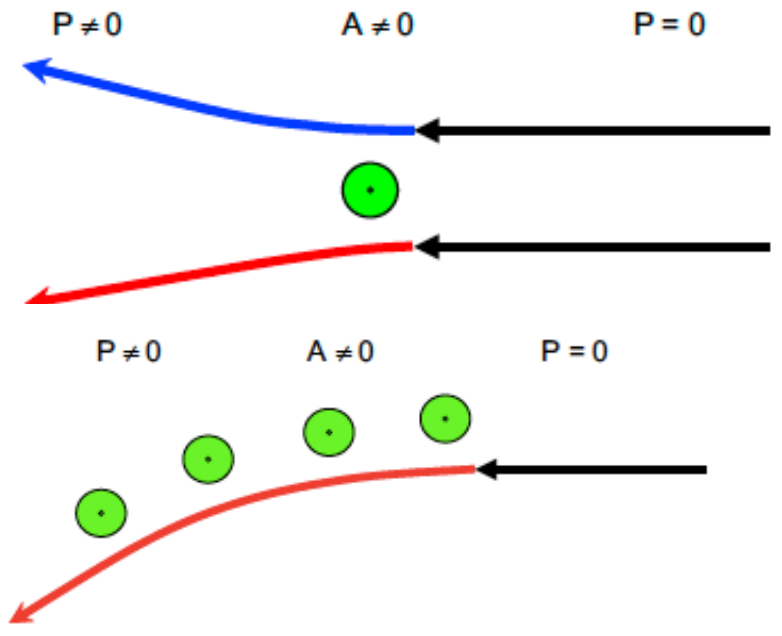


Fig. 2. Channeling in a bent crystal as a sequence of scatterings.

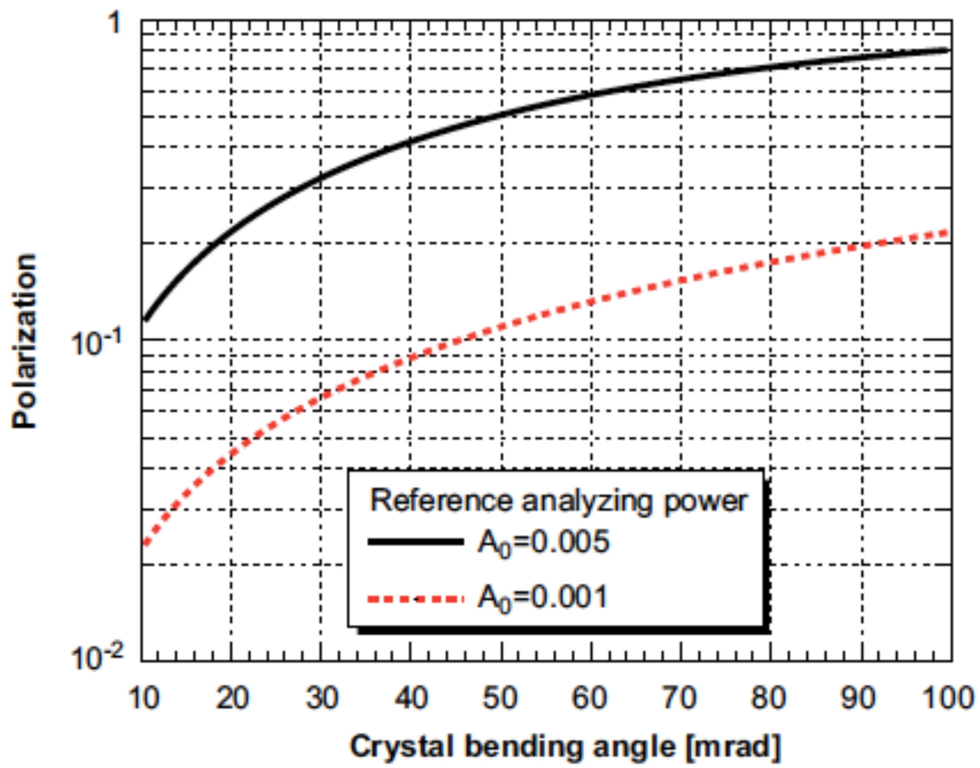


Fig. 3. Dependence of a polarization on the crystal bending angle.

Polarization reach>50% depending on A_0
No experimental tests performed

Polarized deuterium target at Compass

Figure of Merit $= \rho\, k\, (f\, P_T)^2$

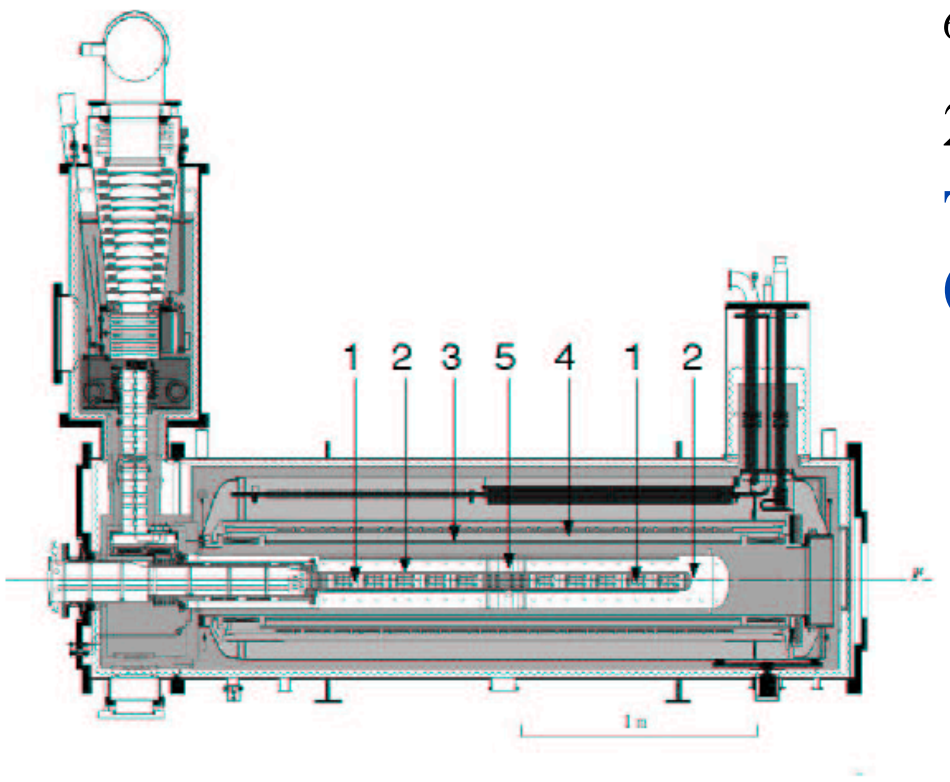


Figure 1. Side view layout of the target system. The muon beam enters the cryostat from the left. (1) target cells, (2) microwave cavity, (3) solenoid, (4) dipole, (5) microwave stopper

^{6}LiD with $P_T = 50\%$, $k = 0.55$, $\rho = 0.84 g/cm^3$, $f = 0.4$

2 cells of 60 cm each separated by 10 cm

Technique of polarization = Dynamic Nuclear Polarisation (DNP)

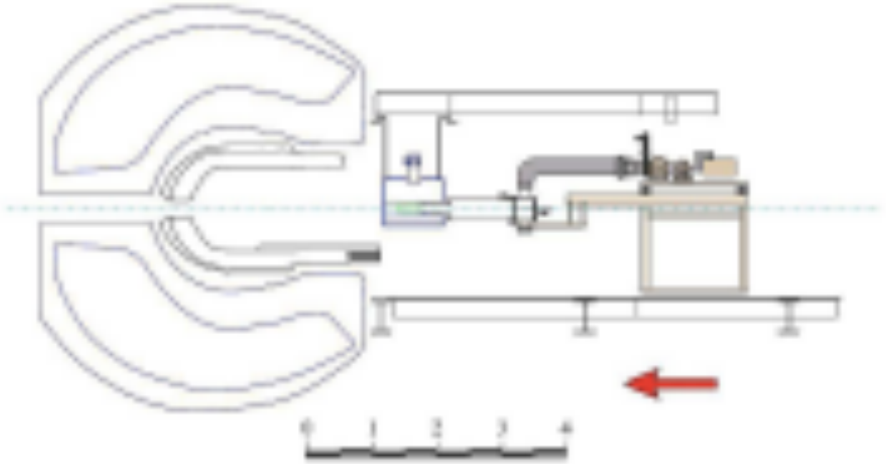
1. Need high homogeneous longitudinal (vs beam line) magnetic field (B=2.5 T and $\Delta B/B = 3.5\ 10^{-5}$)-supra conductor solenoidal magnet system refrigerated at T = 60 mK (^{3}He/^{4}He dilution refrigerator)
2. Polarization transfer from electron to deutons by means of microwave irradiation for a few hours / days (^{6}LiD)
3. Target kept at T=50 mK to increase the time relaxation (~1000 hours) in longitudinal or transverse holding magnetic field (B=0.5T)

- Target pol. measurement = system of nuclear magnetic resonance
- Possible sources of systematics: acceptance from long target size, beam intensity, spectrometer efficiency, ...: possibility to reverse the target spin orientation
- Ongoing developments: R&D for thinner holding magnetic field system (allowing a larger angular aperture)

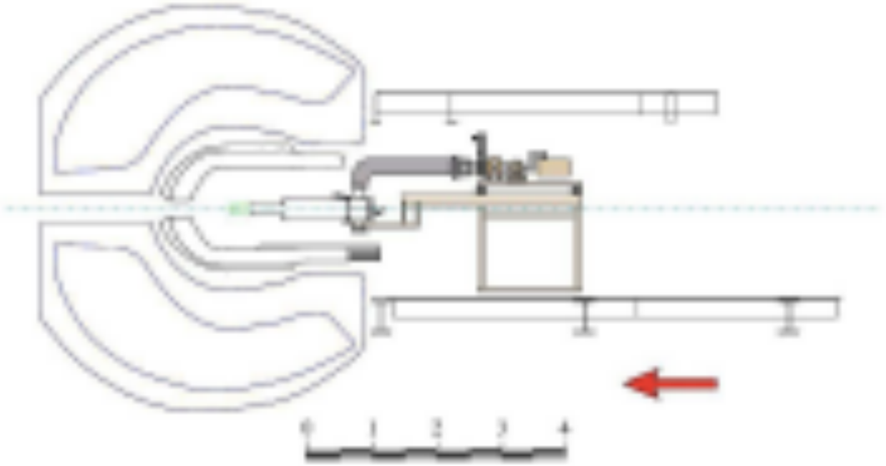
Polarized targets at Jlab

- NH_3 solid target - few cm
  with $P_T \sim 80\%$
  DNP technique (B=5 T and $\Delta B/B < 10^{-4}$; T=1K) using permanent microwave irradiation

FROST @ CLAS



- FROzen Spin Target FROST
  with $P_T \sim 85\%$
  Polarized (DNP technique with T=0.3K and B=5T) and then move (T=30mK, B=0.56T with relaxation time = 1000 h) to the nominal position to allow a larger angular aperture for particle detection
  Relaxation time depends on the beam intensity.



- HD target: almost no dilution, f~1, polarization carried out before the experiment. Large relaxation time expected.
  Attempt last year, ongoing tests

Conclusion

- Spin physics opportunities with the extracted 7 TeV LHC proton beam
- Polarized solid targets are under control: SSA measurements
- Proton beam polarization at LHC may be possible: DSA measurements