Transverse spin effects in SIDIS at 11 GeV with transversely polarized target using the CLAS12 detector

(A CLAS12 experiment proposal for PAC38)

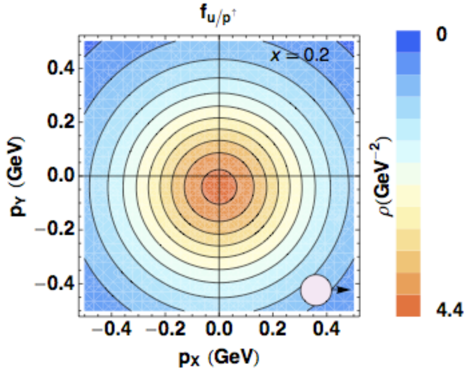
Contalbrigo Marco
INFN Ferrara

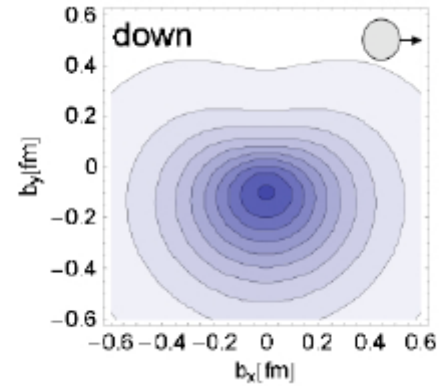
JLab PAC 38 – Open session
August 23, 2011 Newport News

Quantum phase-space distributions of quarks

$W_p^q(x,k_T,r)$ "Mother" Wigner distributions

Probability to find a quark q in a nucleon P with a certain polarization in a position r & momentum k





d^3r

d^2k_T (FT)

TMD PDFs: $f_p^u(x,k_T)$,…

Semi-inclusive measurements
Momentum transfer to quark
Direct info about momentum distribution

GPDs: $H_p^u(x,\xi,t)$, …

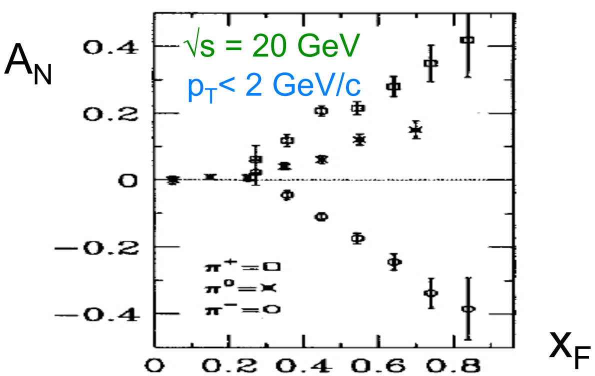
Exclusive Measurements
Momentum transfer to target
Direct info about spatial distribution

d^2k_T

$\xi=0,t=0$

PDFs $f_p^u(x)$,…

May explain SSA



LOI 11-105
Exclusive Physics: DVCS with Transverse Target

May solve proton spin puzzle

$$J_q = \frac{1}{2}\Delta\Sigma + L_q = \lim_{t\to 0}\int_{-1}^{1} dx\ x\left[H(x,\zeta,t)+E(x,\zeta,t)\right]$$

Leading Twist TMDs

Quark polarisation

Nucleon polarisation

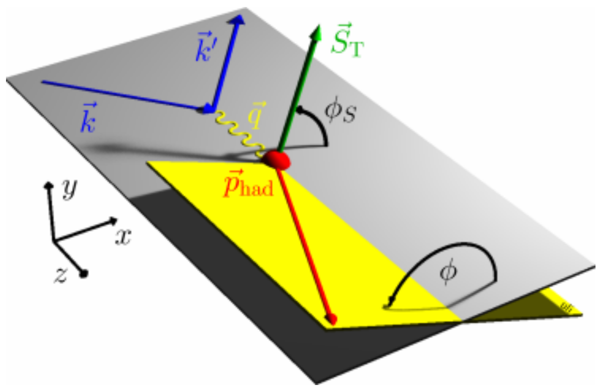
	U	L	T
U	f_1 *Number Density*		$h_1^\perp$ *Boer Mulders*
L		g_1 *Helicity*	$h_{1L}^\perp$ *Worm-gear*
T	$f_{1T}^\perp$ *Sivers*	$g_{1T}^\perp$ *Worm-gear*	h_1 *Transversity* $h_{1T}^\perp$ *Pretzelosity*

E12-09-007
Quark number and helicities

E12-06-112
E12-09-008
Boer-Mulders for pions and kaons

E12-07-107
E12-09-009
Spin-effects for pions and kaons

PR12-11-111
This proposal

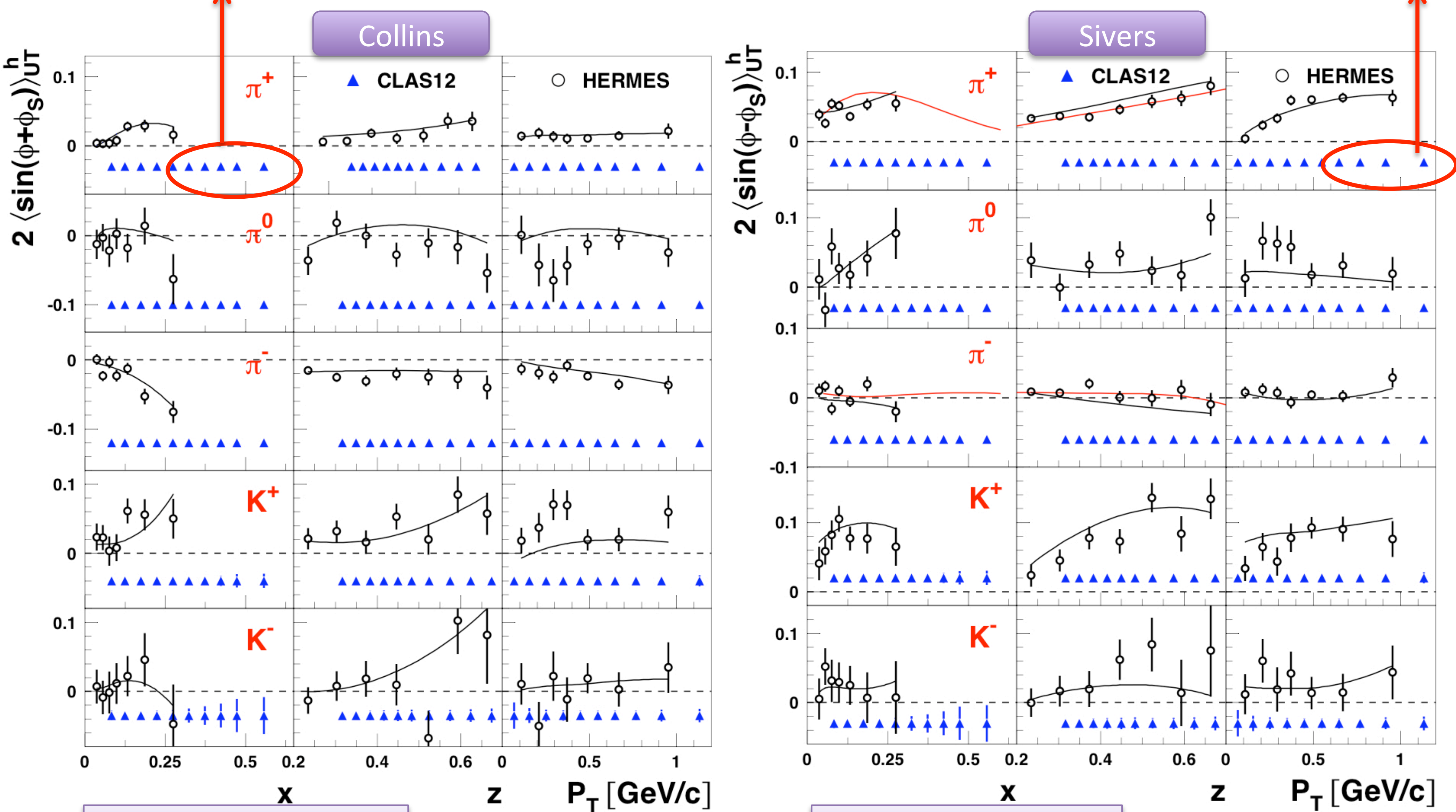


CLAS12 has access to all of them through specific azimuthal modulations (ϕ, ϕ_S) of the cross-section thanks to the polarized beam and target

CLAS12 Projections

Large x important to constrain the tensor charge

Large p_T important to link to the perturbative regime and for Bessel function analysis

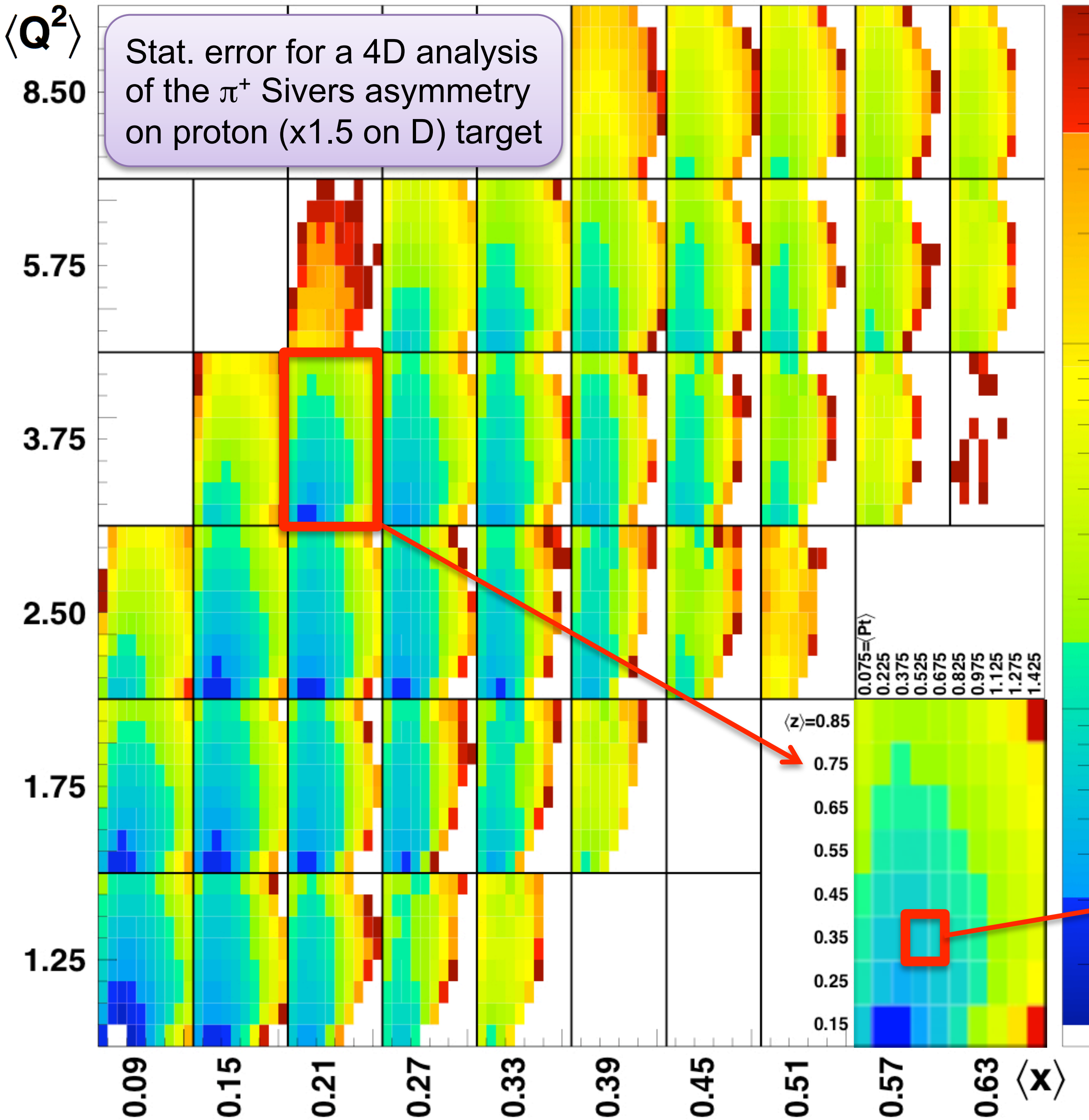


Black curve: arXiv: 0906.3918

Red curve: arXiv: 0911.3677

Statistical precision

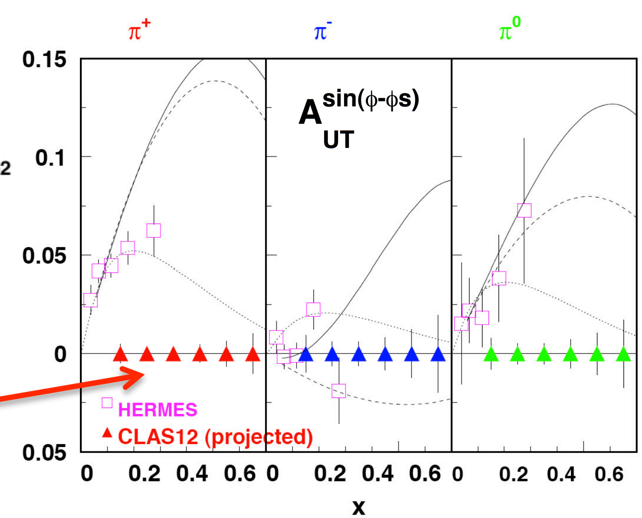
Stat. error for a 4D analysis of the π^+ Sivers asymmetry on proton (x1.5 on D) target



4D analysis is possible

Beam-time request is defined to achieve few % absolute error at the wanted high-Q^2 high-p_T

x projection in a z-p_T bin of the π^+ Sivers asymmetry



Curves from hep-ph/0507266 and hep-ph/0507181

The main goals

Transverse spin effects in SIDIS at 11 GeV with transversely polarized target using the CLAS12 detector

- Access to leading-twist poorly known or unmeasured TMDs which provide 3-dimensional picture of the nucleon in momentum space (nucleon tomography);

  - * SSA: ***Transversity, Sivers, Pretzelosity function***s;
  - * DSA: ***g_{1T} worm-gear function***;

- Multi dimensional analysis in x, Q^2, z, p_T thanks to large-acceptance and high-luminosity;

  - * ***precise mapping of the valence*** (tensor charge);
  - * ***disentangle parton distribution from fragmentation functions*** (x vs z);
  - * ***isolate sub-leading-twist effects*** from 1/Q dependence (side product: g2) ;
  - * ***flavor decomposition of pT dependence***;
  - * ***investigate perturbative to non-perturbative QCD transient*** from p_T dependence;

- Together with already approved experiments with unpolarized and longitudinally polarized targets, ***complete the mapping of the TMD table at CLAS12***.

The CLAS12 Spectrometer

Luminosity up to 10^{35} cm^{-2} s^{-1}

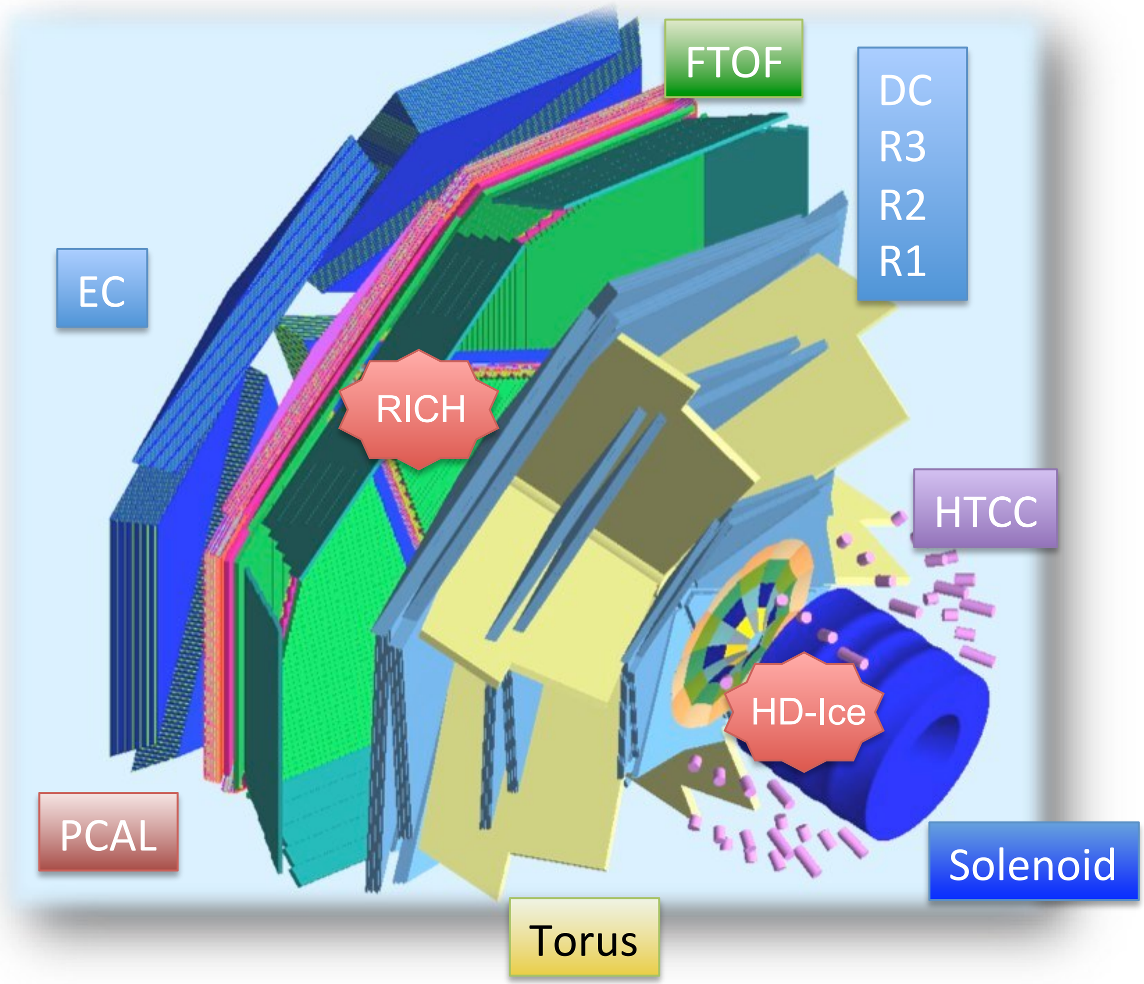
Highly polarized electron beam

H and D polarized targets

Broad kinematic range coverage (current to target fragmentation)

HD-Ice: Transverse Target new concept (commission with CLAS at 6 GeV common to LOI 11-105)

RICH: Hadron ID for flavor separation (common to SIDIS approved exp.)



PAC30 report (2006): Measuring the kaon asymmetries is likely to be as important as pions …. The present capabilities of the present CLAS12 design are weak in this respect and should be strengthened.

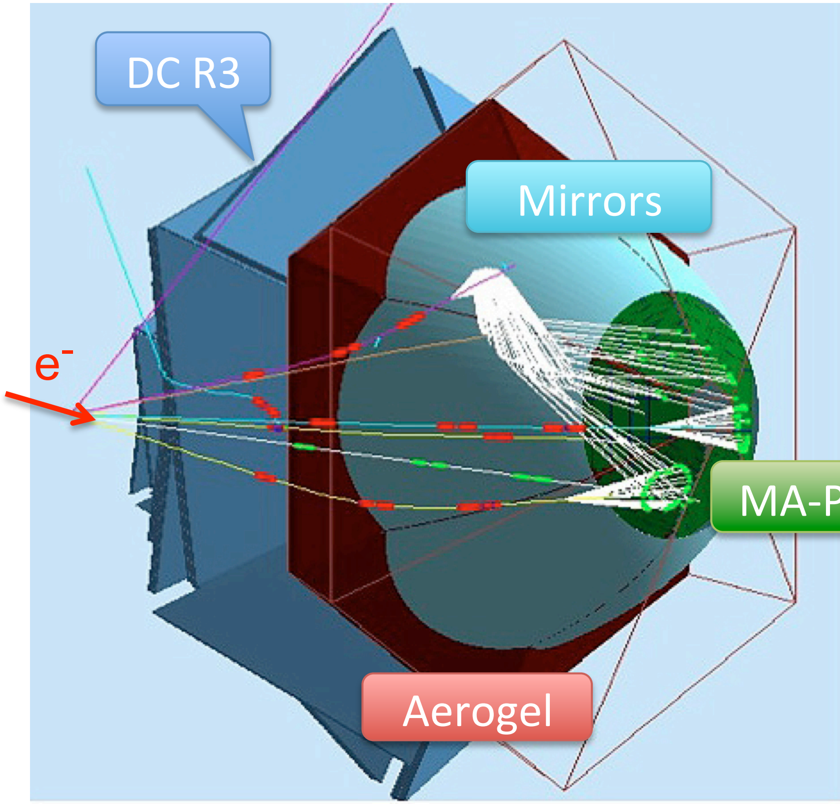
PAC38 requirements

Measurement and Feasibility: Using CLAS12 with a transversely polarized HD-Ice target and a longitudinally polarized 11 GeV electron beam, data for pions and kaons will be taken simultaneously in a 4-dimensional scan, aiming at a substantially improved statistical precision compared to previous HERMES and COMPASS data. The proposed 100 days include 80 days of data taking and 20 days for calibration, test and set-up. For part of the program flavor tagging is required. The low-threshold Cherenkov detector has to be replaced by a RICH. Tests of the target in a high-intensity electron beam are planned in early 2012. The impact of Moeller scattering on the detector performance has to be well controlled. A combined analysis of unpolarized and longitudinally polarized data will constrain different TMDs and will provide an important contribution to nucleon tomography.

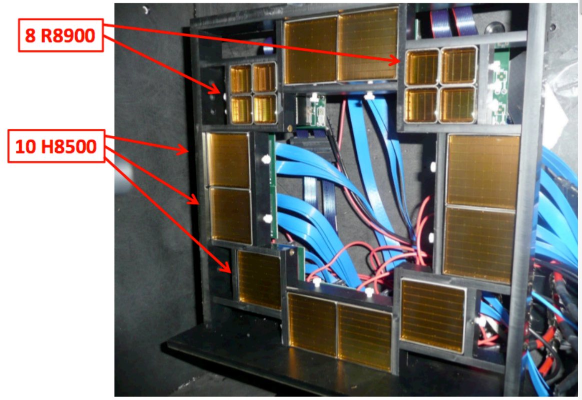
Issues: The measurement requires incorporation of the transversely polarized HD-Ice target into the 3-5 Tesla field of the CLAS12 solenoid. The transverse holding field is applied in the region where the longitudinal field of the main solenoid has to be compensated by an additional small solenoid leaving 60^0 acceptance and requiring some central trackers to be removed. In such a difficult configuration one needs to be sure about the proper magnetic and mechanical design and a sufficiently precise track reconstruction in the complicated field arrangement.

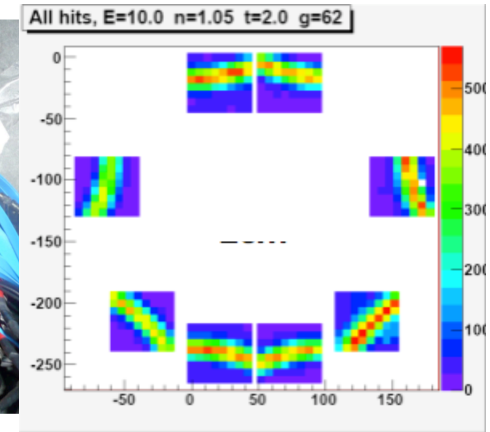
Conditions: The operation of the HD-Ice target in an electron beam with the requested beam current has to be proven. The magnetic field and detector configuration has to be optimized and the track reconstruction code has to be developed including the final configuration.

The RICH Detector



Test beam results at CERN, July 2011





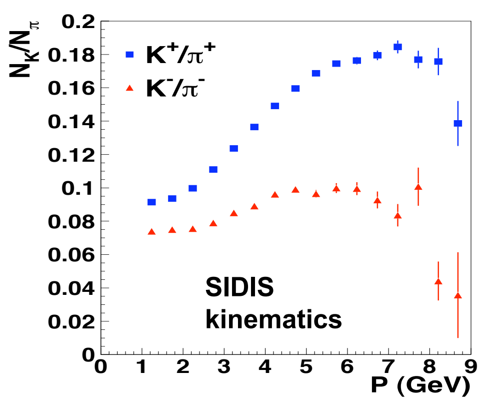
Simulation of n=1.05 aerogel + H8500:

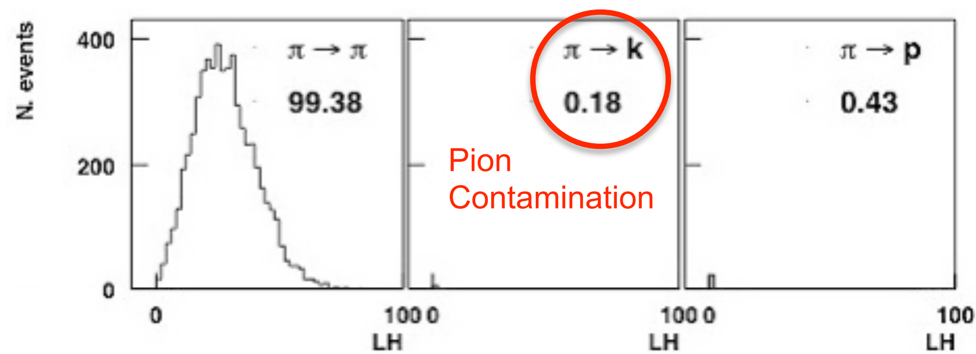
≥ 10 p.e. for direct rings
(confirmed by preliminary test-beam results)

≥ 5 p.e. for reflected rings

≥ 500 pion rejection factor @ 99% kaon eff.

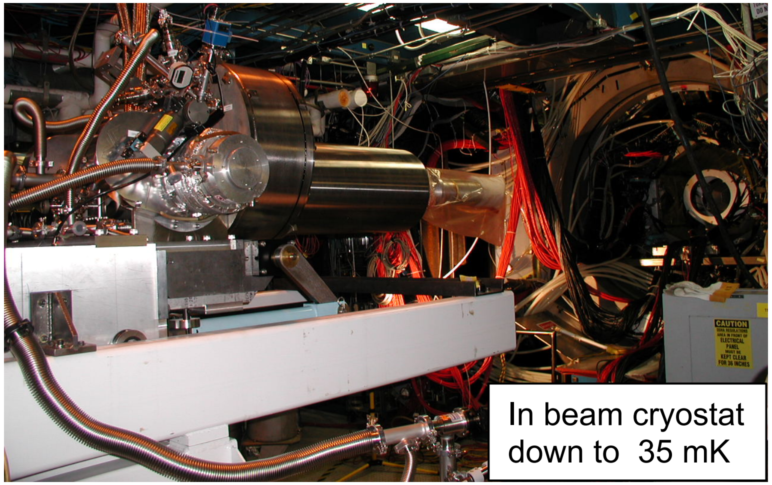
RICH goal:
π/K/p separation
of **4-5 σ @ 8 GeV/c**
for a pion rejection
factor **1:1000**

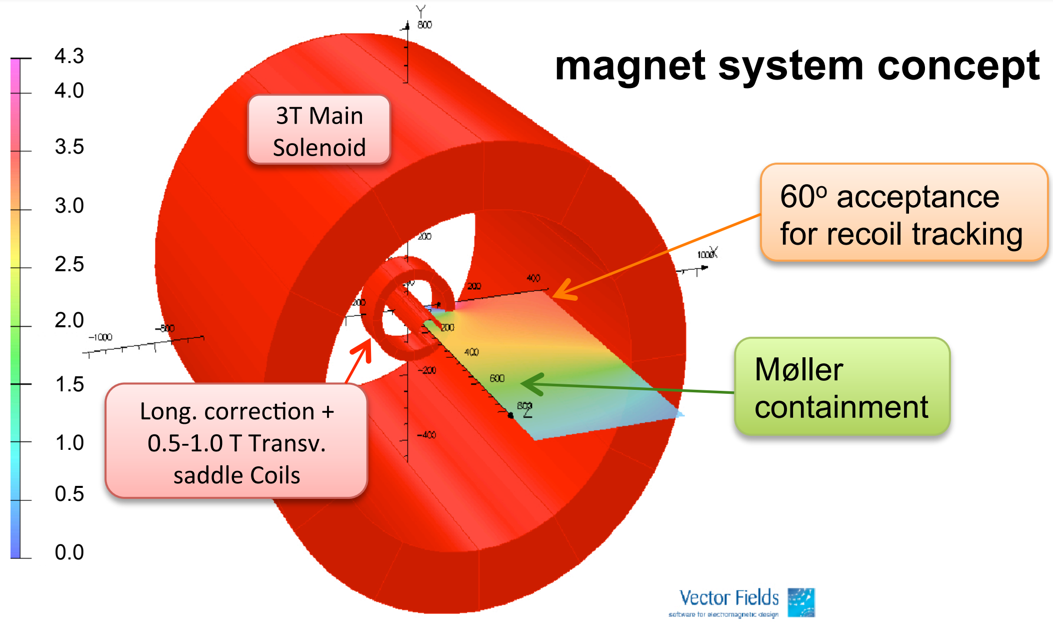




Transversely Polarized HD-Ice Target

Up to 75% H and 40 % D polarization independently controlled

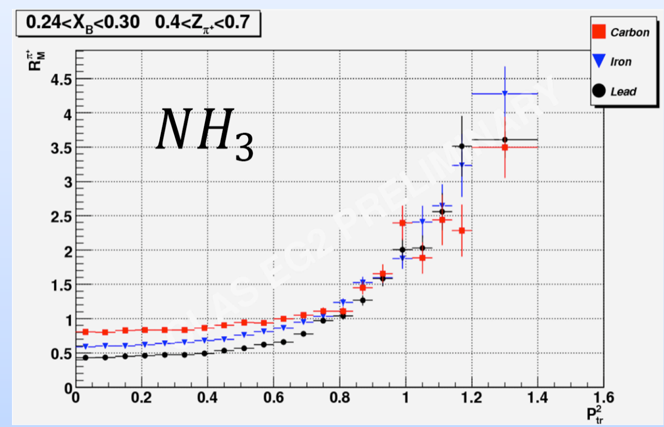




HD-Ice target vs standard nuclear targets

Advantages:

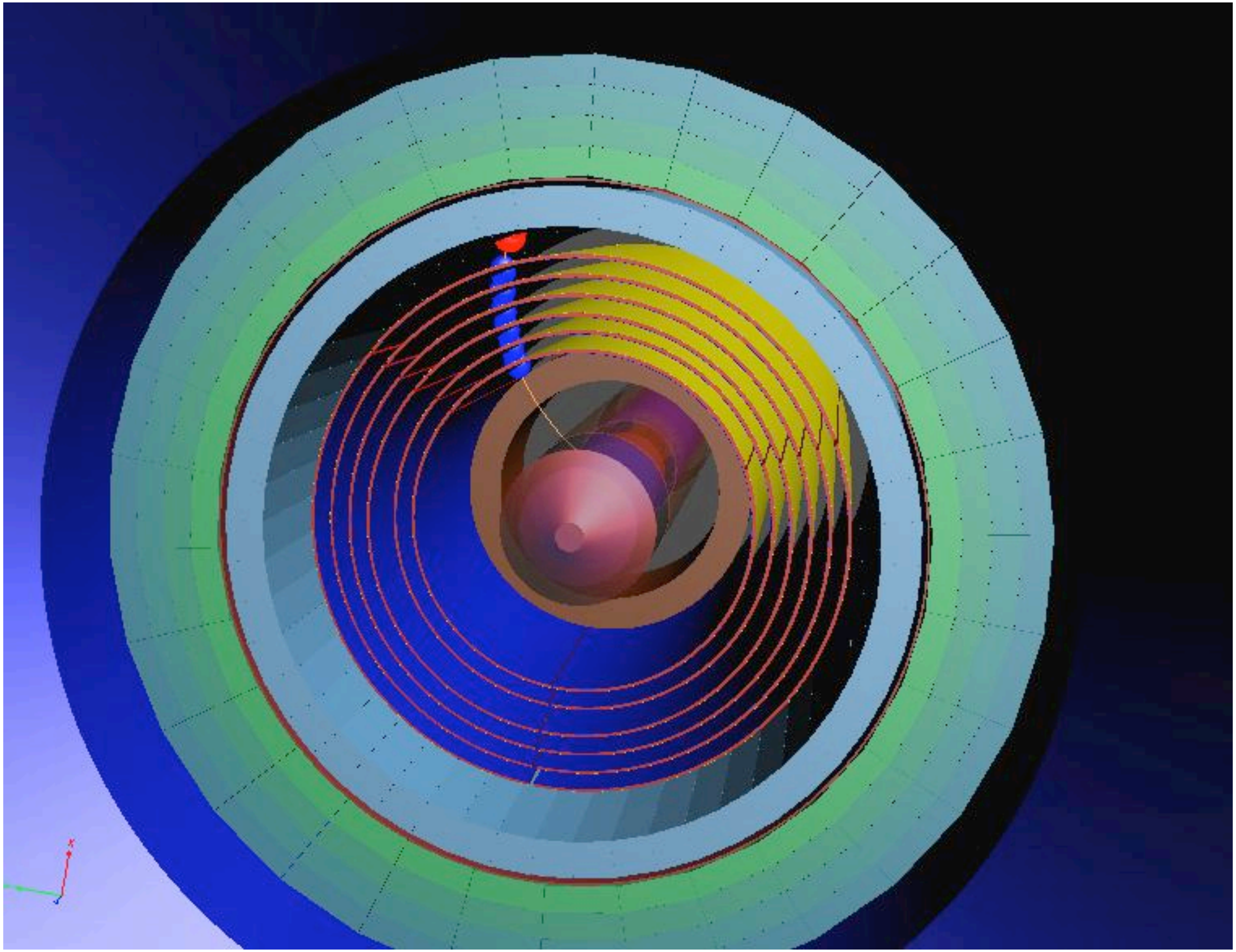
- Minimize nuclear background
  small dilution and nuclear effets at large p_T
- Weak holding field (BdL ≤ 0.1 Tm)
  wide acceptance, negligible beam deflection, viable field inversion



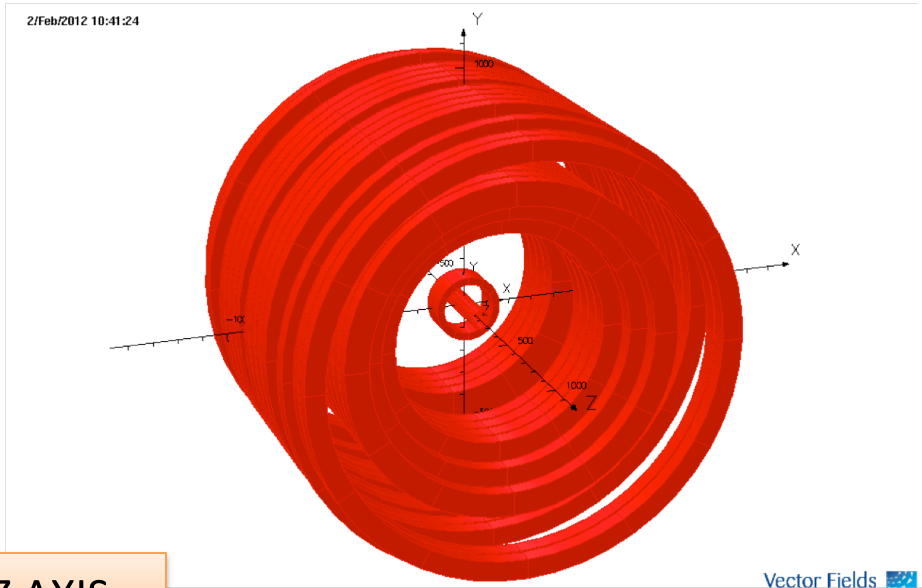
Disadvantages:

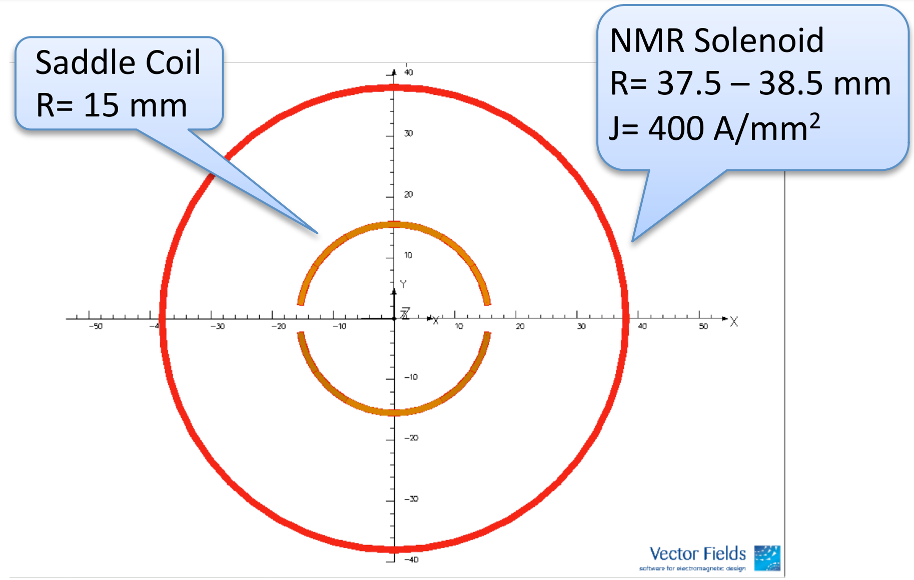
- Very long polarizing times (months)
- Need to demonstrate that can remain polarized for long periods with an electron beam: as consevative approach we consider 1/10 of full luminosity (compensated by better dilution)

TT magnet N80

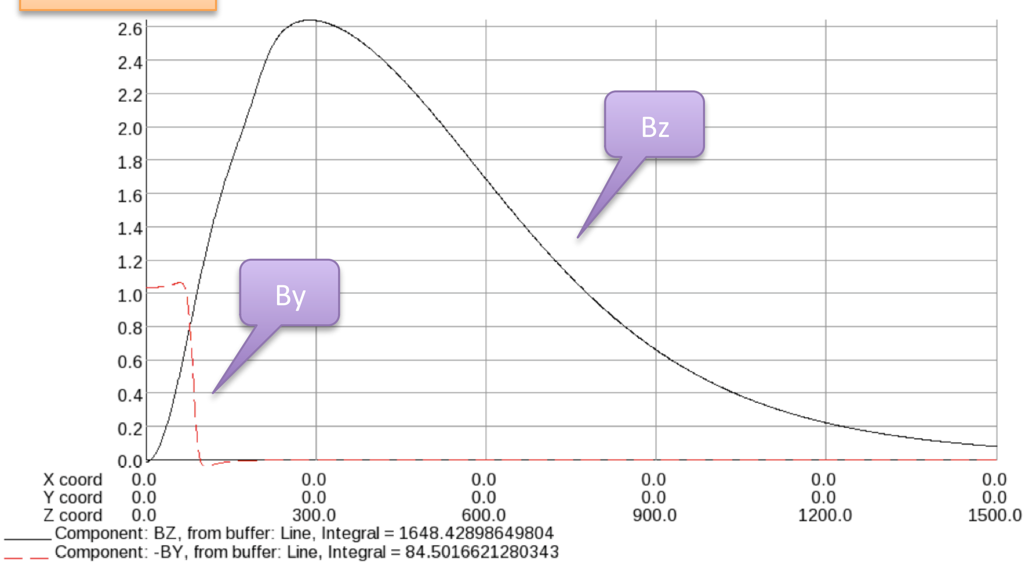


TT magnet N81

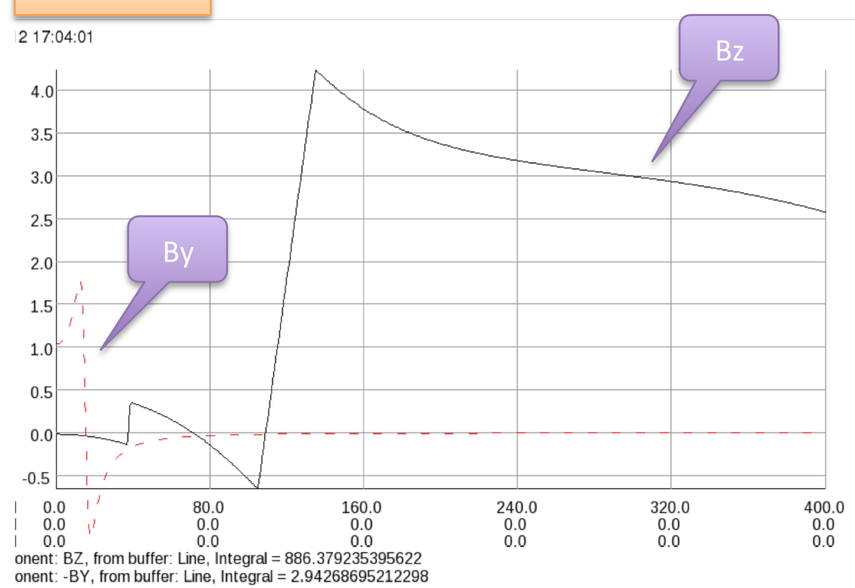




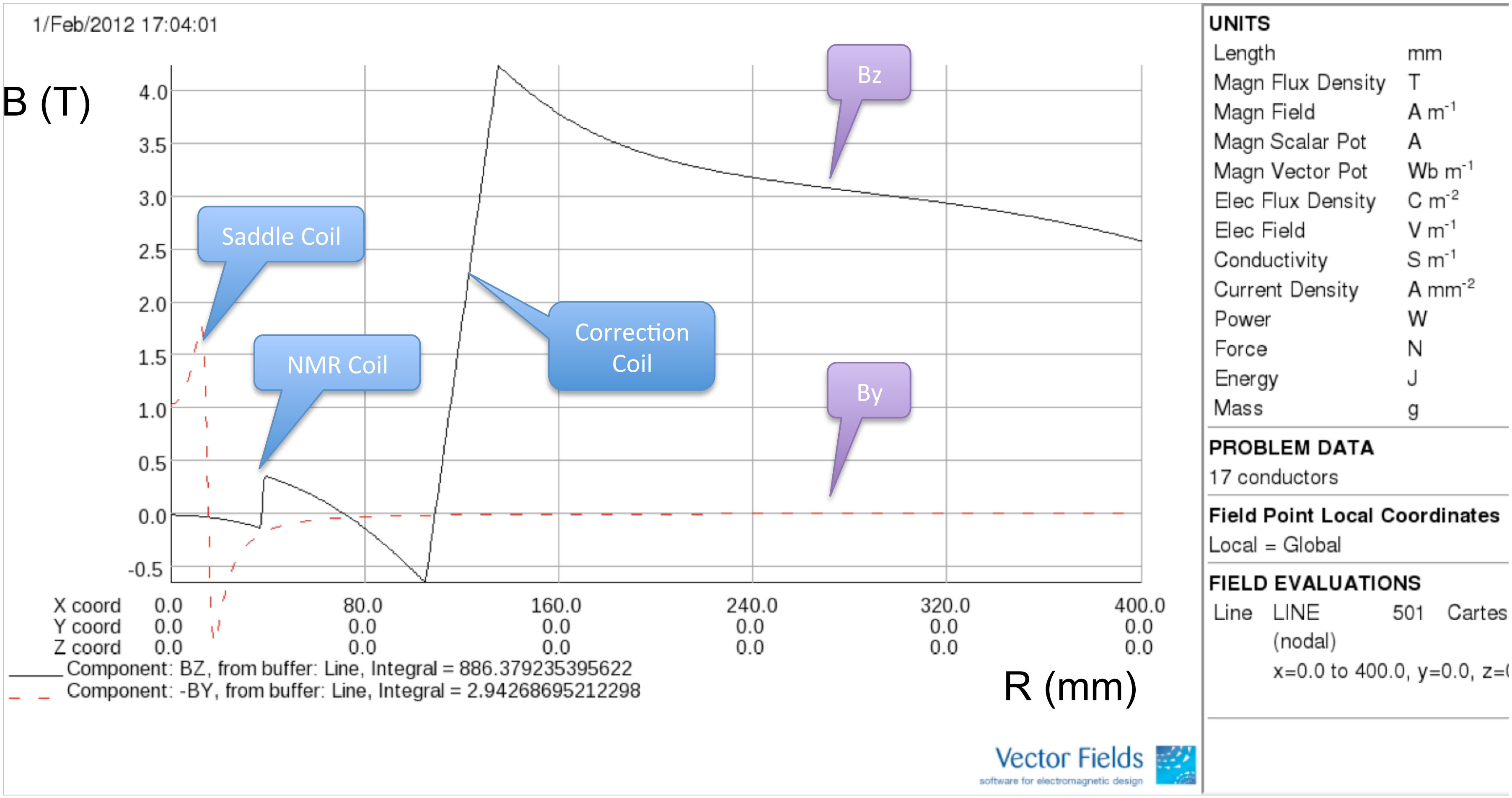
Z AXIS



X AXIS

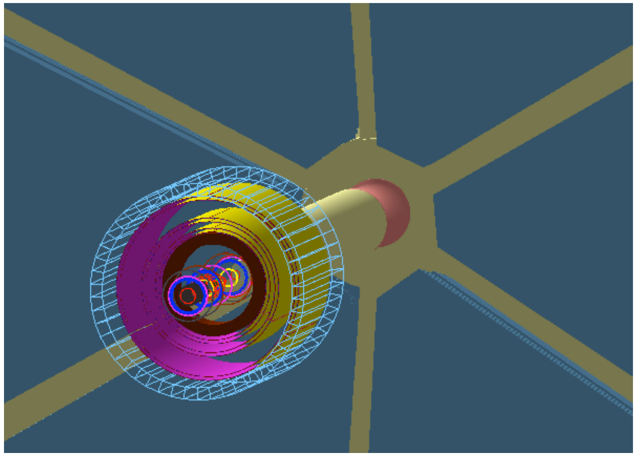


TT magnet N81



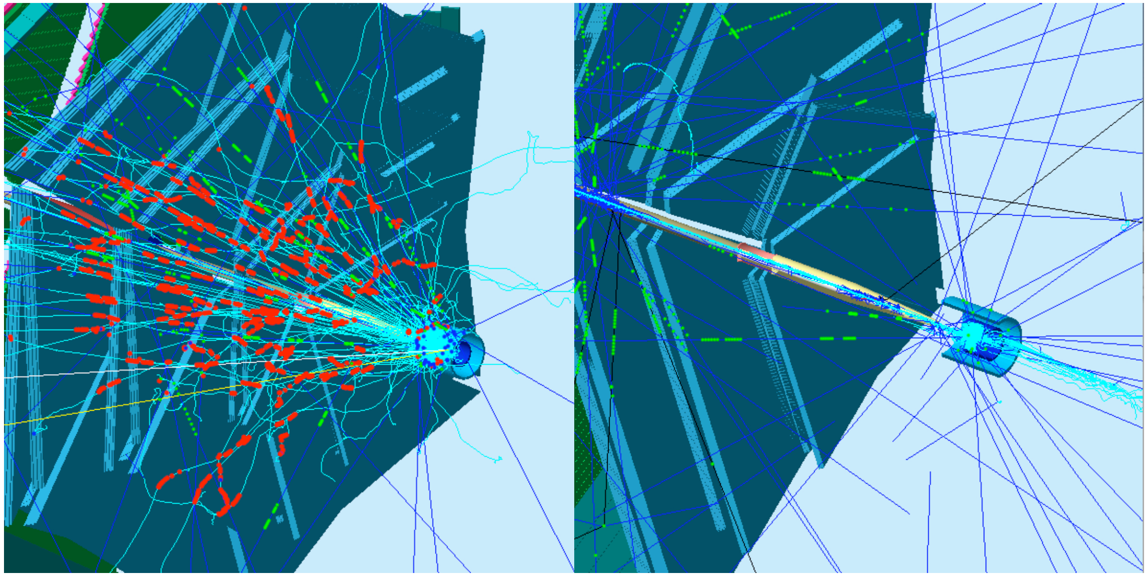
TT Magnet: Configuration

- The HD-Ice target transverse polarization is mantained with a transverse magnet (saddle coil, 0.5 – 1 T)
- Operation with a transversely polarized target requires shielding from the longitudinal magnetic field provided by the main solenoid

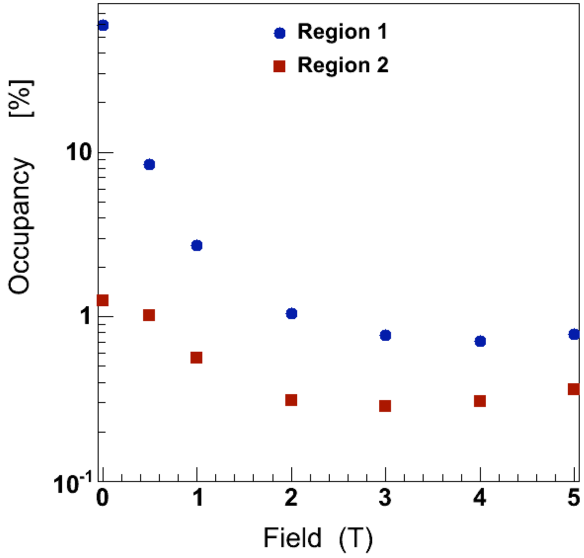


parameter	Central detector solenoid	compensating solenoid	NMR coil
inner radius (mm)	471	105	37.5
outer radius (mm)	650	135	38.5
length (mm)	1225	121	400
current density @ 3 T (A/mm^2)	18.2	148	400

- Minimum field for main solenoid:
  - maximum current allowed by HD-Ice
  - Moeller background

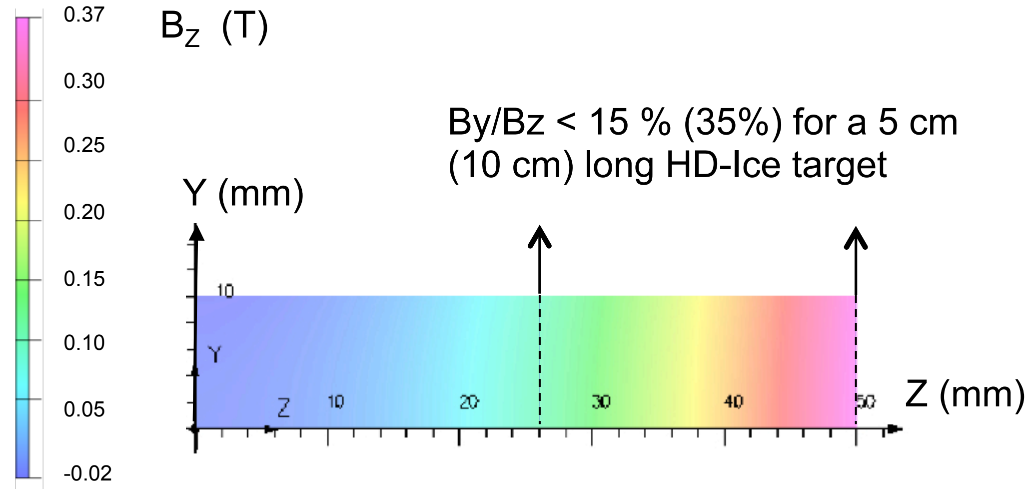


Drift Chamber Occupancy

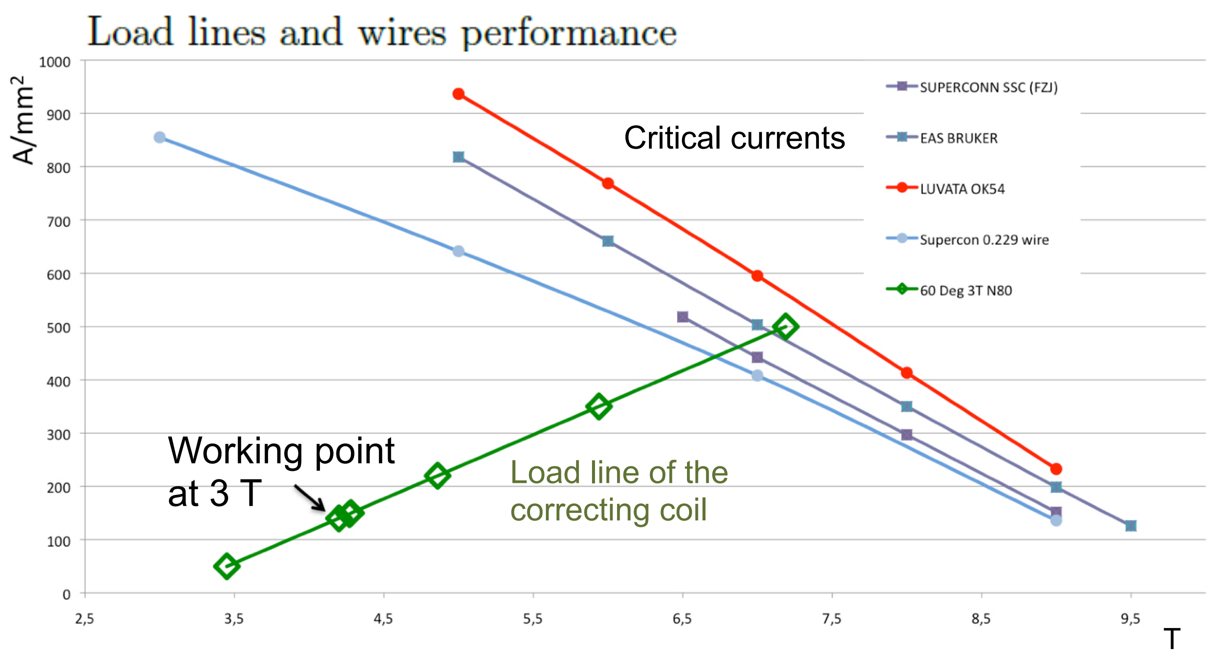


TT magnet Working Point

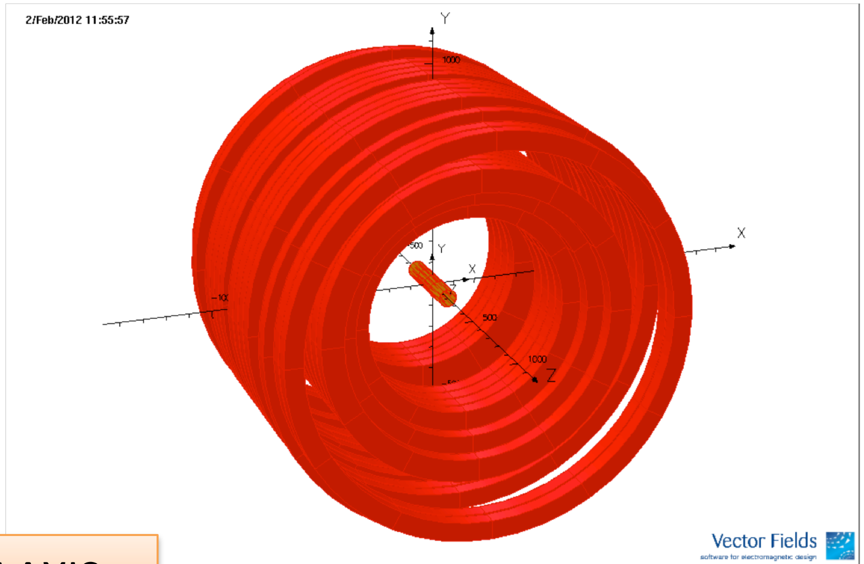
- Comparable with mixing due to polarization transverse to beam
- Compromise with
  - target dimensions
  - acceptance requirements
  - beam induced depolarization ?

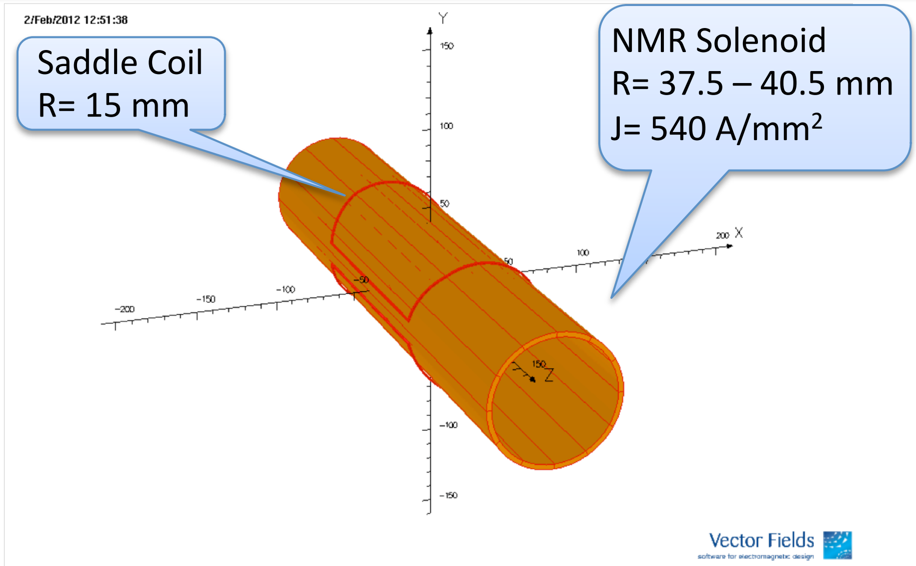


- Safety margin for standard SC wires
- Quenching:
  - termal stress
  - magnetic forces

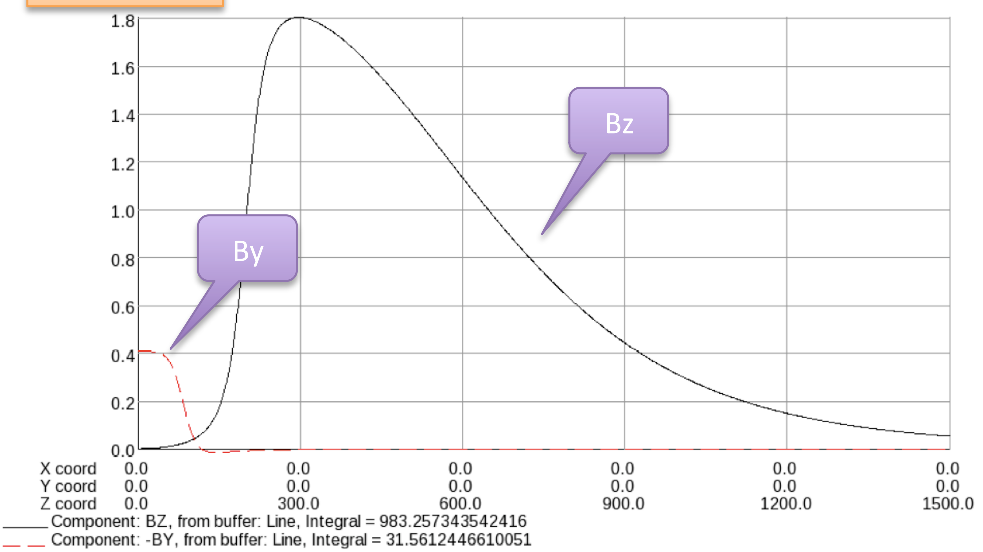


TT magnet N91

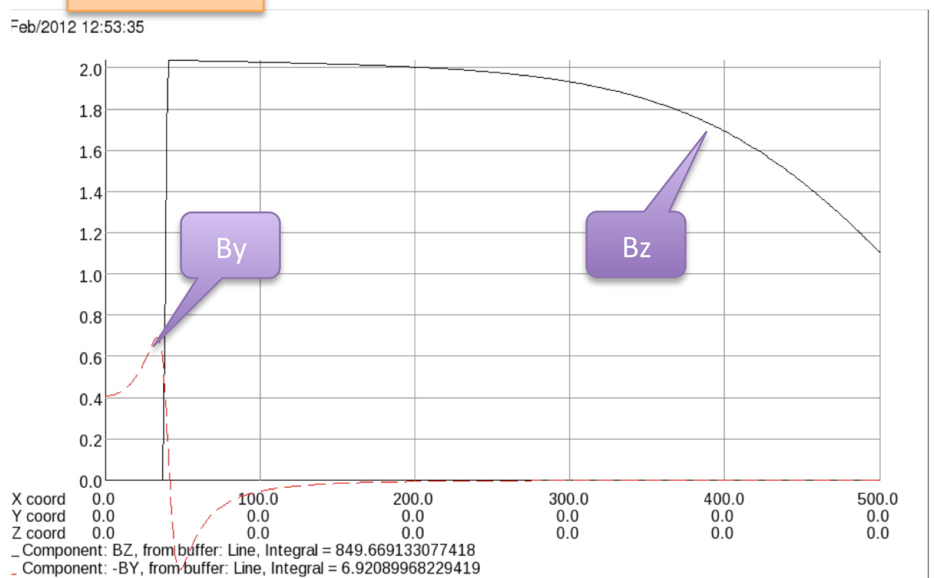




Z AXIS



X AXIS



Conclusions

- **N91: solution internal to the HD-Ice cryostat**

  - * Better from magnetic/mechanical point of view;
    - field homogeneity
    - compactness
    - Moeller containment
  - * Impact of material budget critical;
  - * Compatible with current CLAS12 tracking ?

- **MN81: solution with external compensation coil**

  - * better material budget;
  - * Complex from mechanical point of view;
  - * Large volume with zero field (Moeller ?);

- **Saddle coil not trivial**