Magnet and beam studies for the JLab Hall-B Frozen Spin Polarized Target

Frozen Spin Target - *FROST*

ASU, CU, FSU, Glasgow, GWU, JLab, NSU, USC, UVA.

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PST05

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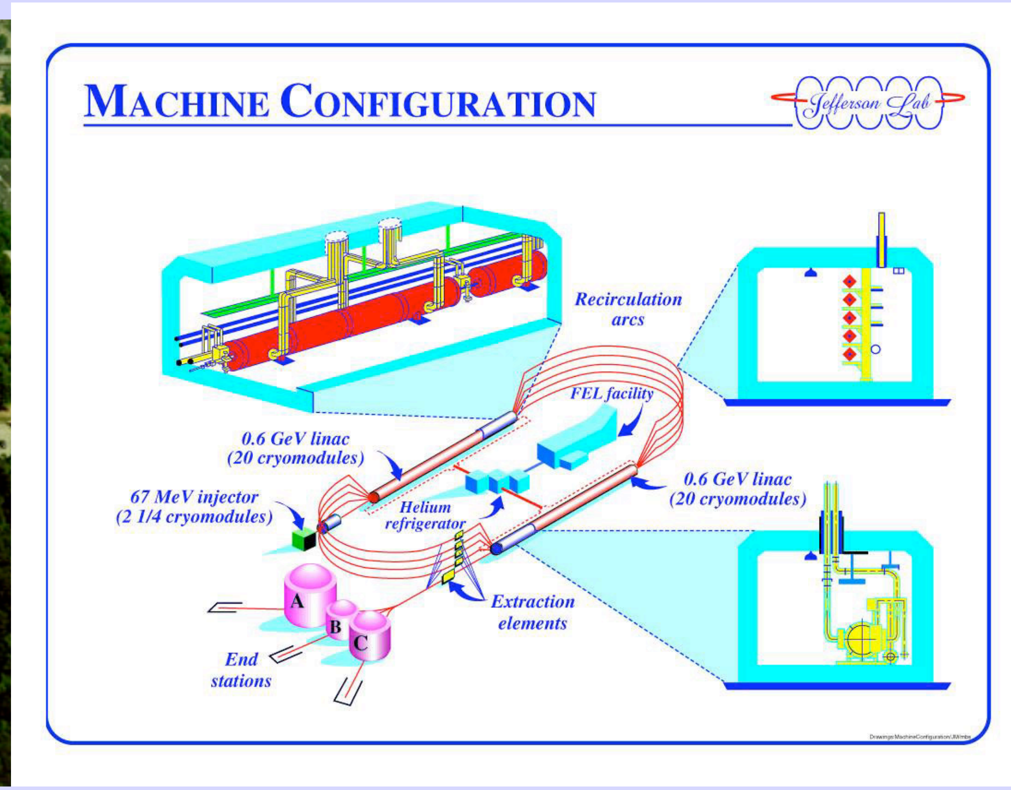
CEBAF (Continuous Electron Beam Accelerator Facility)

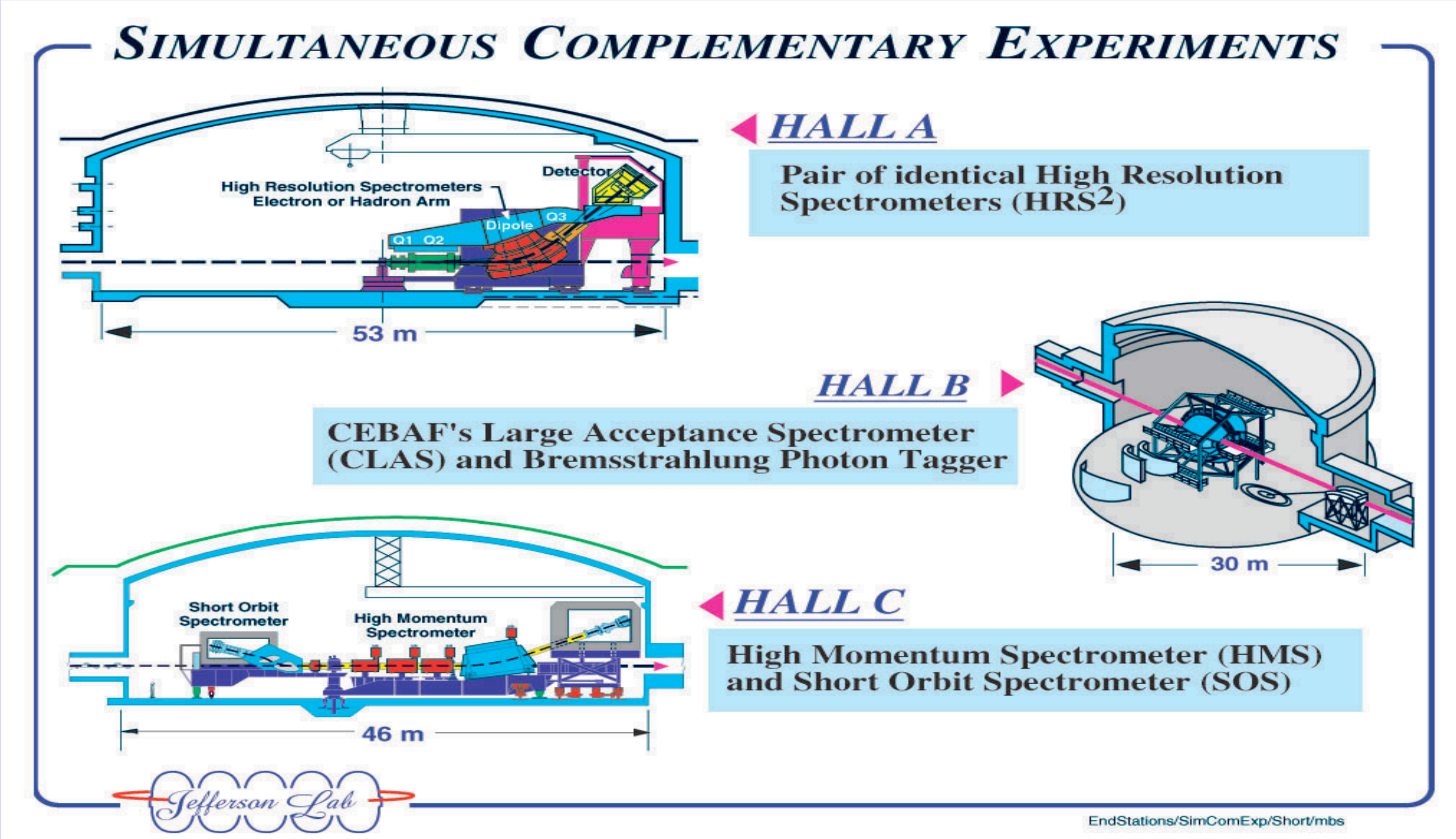
At JLab (Jefferson Laboratory) at Newport-News (VA)



Superconducting Electron Accelerator (338 cavities), 100% duty cycle, I_{max}=200 μA, E_{max}=6 GeV, $\delta E/E=10^{-4}$.

1500 physicists, ~30 countries, operational since end of 97

The detectors



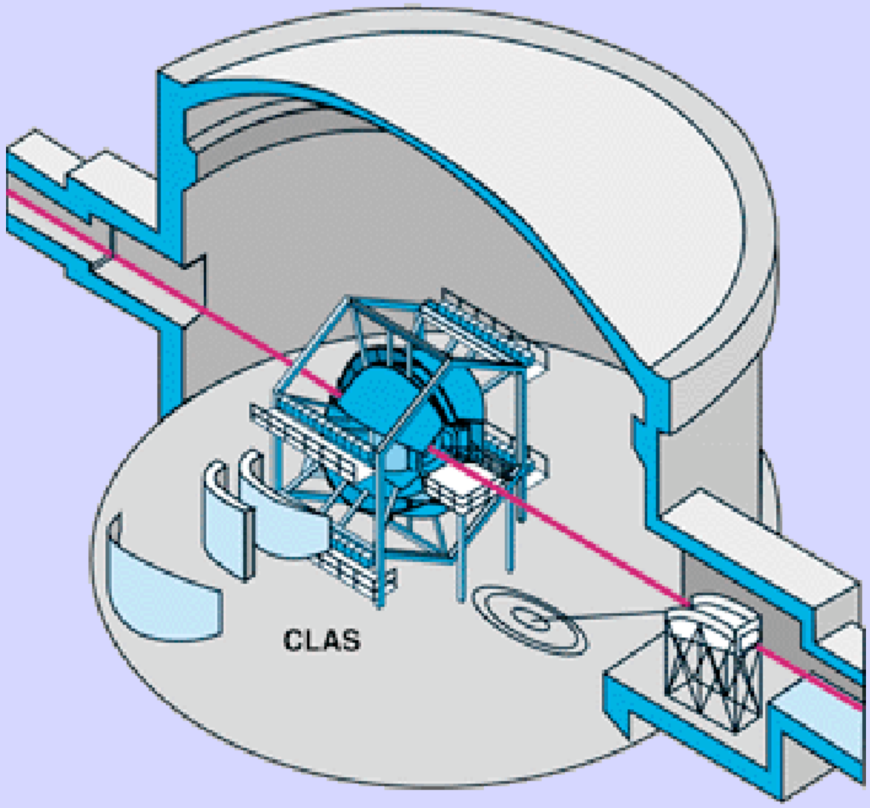
The 3 experimental halls can run simultaneously. In Hall B, the CLAS detector (CEBAF Large Acceptance Spectrometer) : Electrons and (tagged) Photon beams

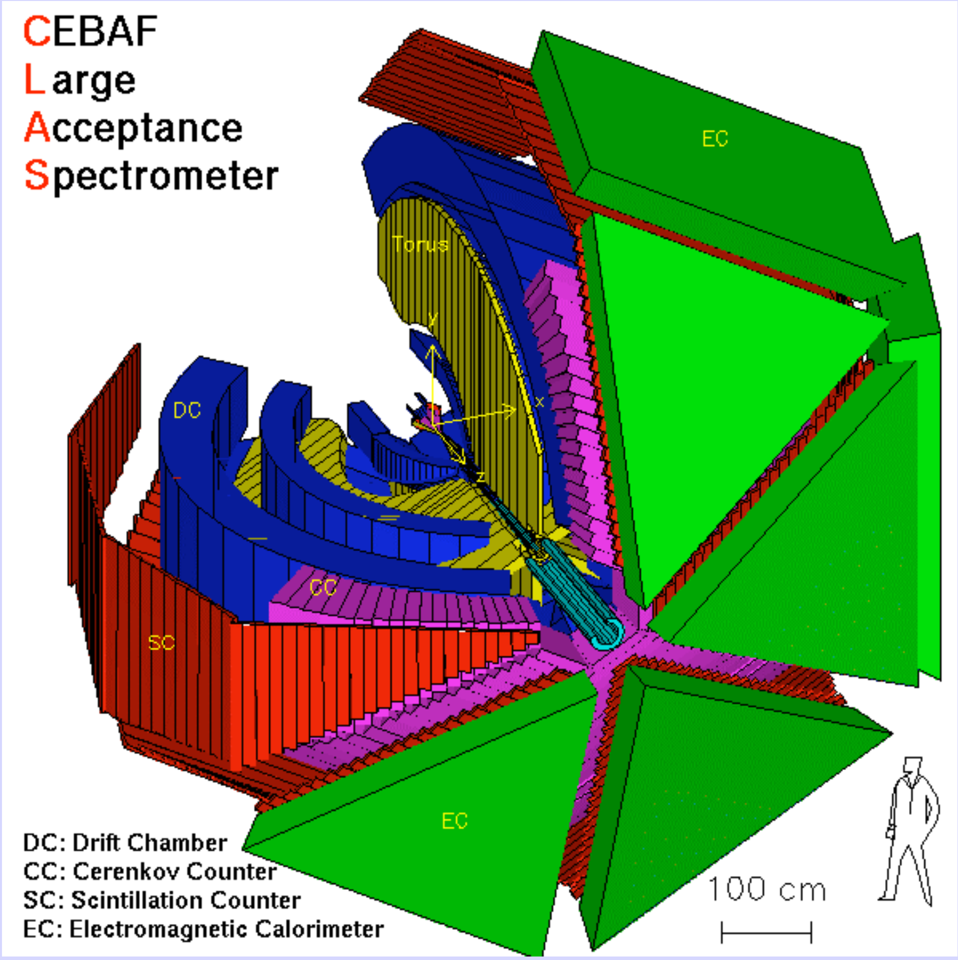
Hall B

CLAS Detector

- *Toroidal magnetic field*
  (6 superconducting coils)

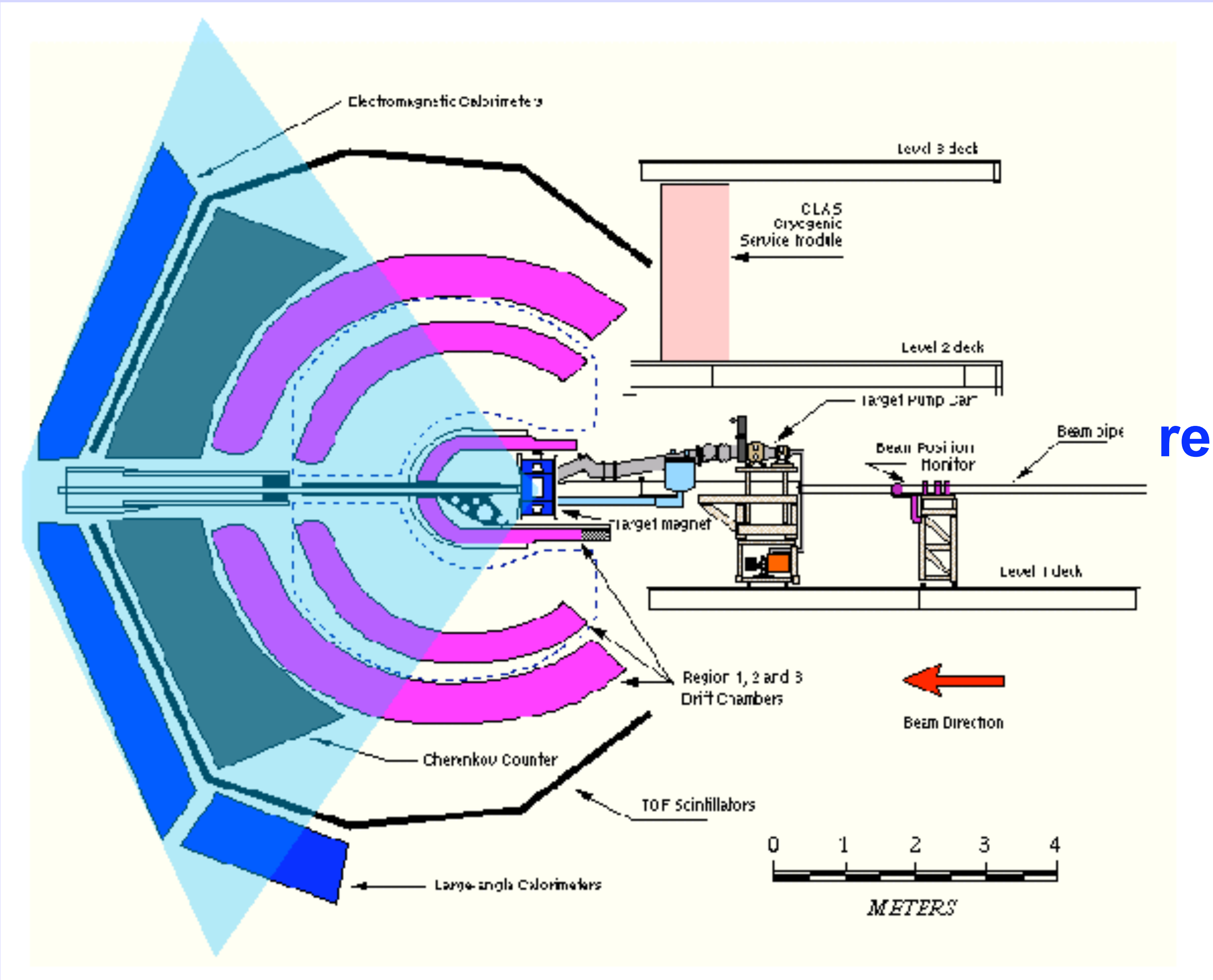
Center of CLAS is "field free" to accommodate a polarized target.





-Drift chambers, Scintillators, Cerenkovs, Electromagnetic Calorimeter. DAQ ~ 6kHz

Existing polarized targets



Dynamically polarized NH_3 target (1 K, 5 T):
P~80%,
(Helmholtz coils)

↓

reduces 4π acceptance

4π CLAS needs
4π target

↓

FROST

Physics Program requiring FROST

Approved experiments

- **E02-112:** Search for Missing Resonance Search in Hyperon Photoproduction (F. Klein)
- **E03-105:** Pion Photoproduction from a Polarized Target (S. Strauch)
- **E04-102:** Helicity Structure of Pion Photoproduction (D. Sober)
- **E-05-012:** Measurement of polarization observables in eta-photoproduction with CLAS (E. Pasyuk)

Proposals

- Double polarization experiment (V. Crede)

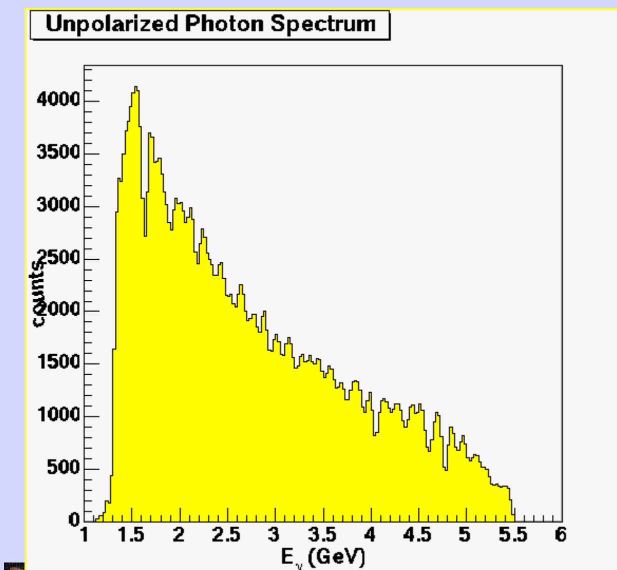
Common requirements

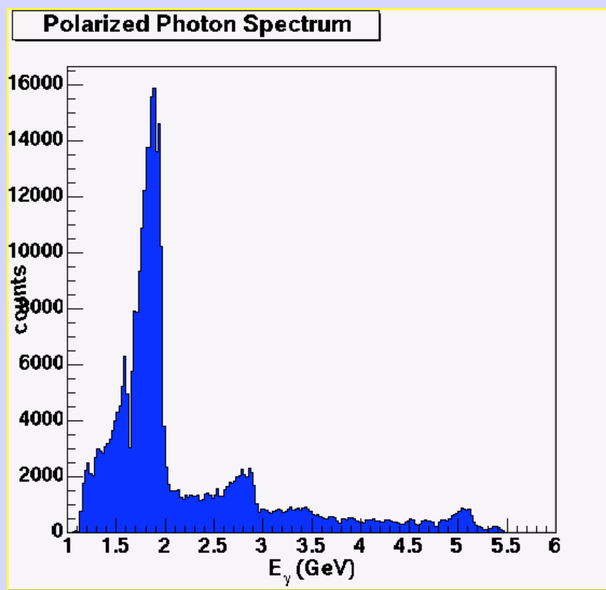
- Tagged photon beam (collimated to < 12 mm diameter)
- Frozen Spin Target

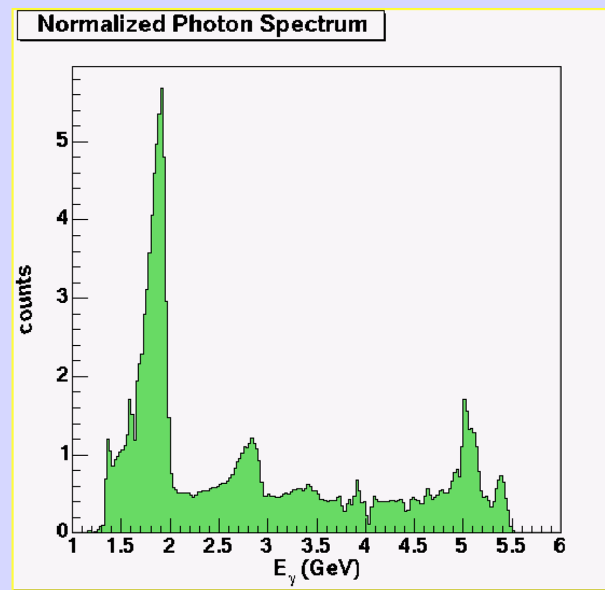
Linearly-polarized Photon Beam

<u>Coherent Bremsstrahlung Facility</u>

- **20- and 50-μm diamond radiators**
- **Goniometer oriented diamond for coherent radiation**
- **Average beam polarizations ~85%**





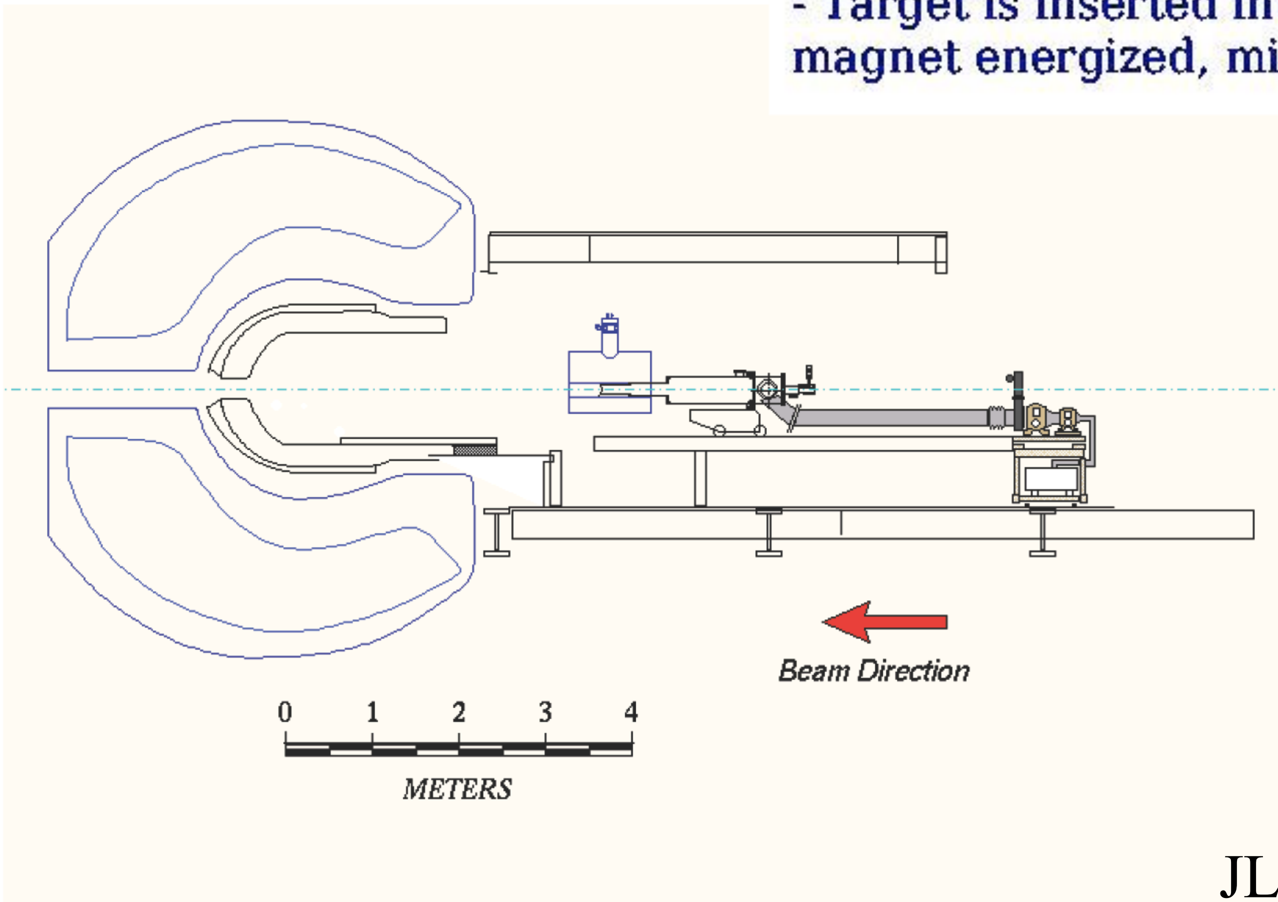


FROST Specifications

- Off beam: Polarization of target nuclei -- DNP technique
- During run: Frozen Spin Mode
- Material: Butanol with TEMPO
- **Polarizing Mode:**
    - Magnet – 5.0 Tesla (high homogeneity over target volume)
    - Temperature – 0.3 -- 0.5 K
    - Expected cooling power -- 20 mW @ 0.3 K
- **Frozen Spin Mode:**
    - Magnet – 0.5 Tesla (lower homogeneity over target volume)
    - Temperature – 50 mK
    - Expected cooling power -- 10 μW @ 50 mK
    - Expected 1.0 - 3.0 GeV photon beam (~10^7 photons/sec)

Polarization configuration

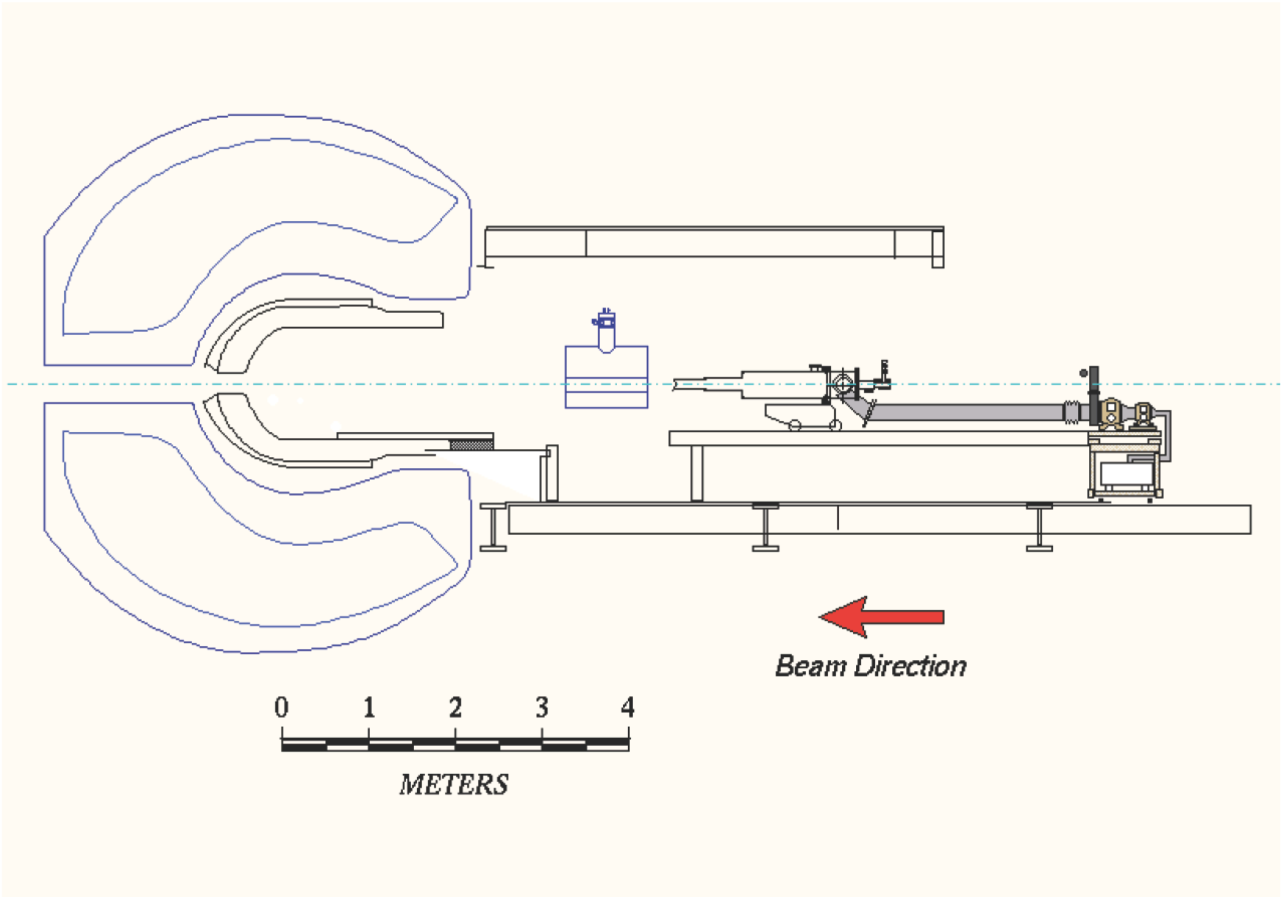
- Target is fully retracted, magnet is lifted to beam height
- Target is inserted into magnet, magnet energized, microwaves on



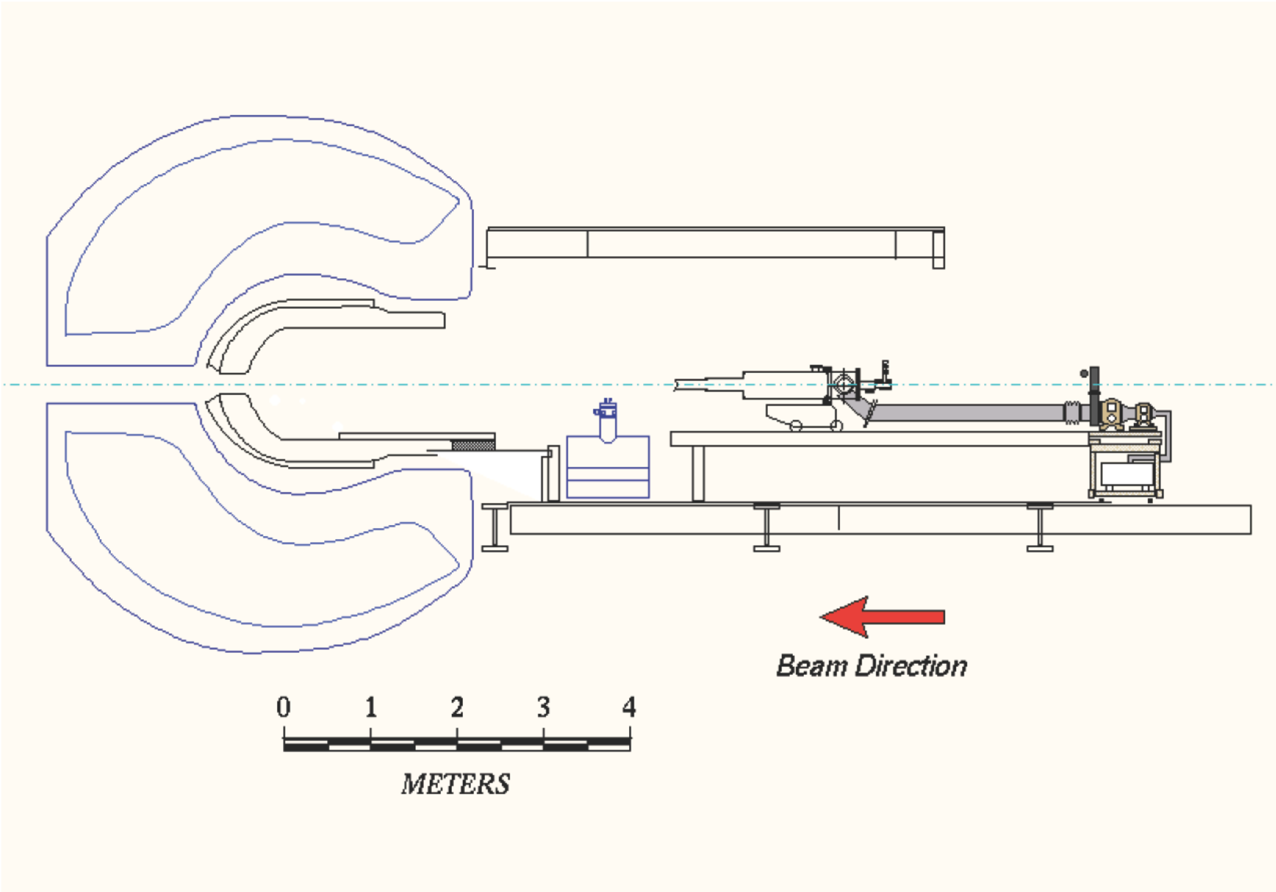
JLab, Hall-B

Dave Kashi
Pete Hemler

Target moved further back

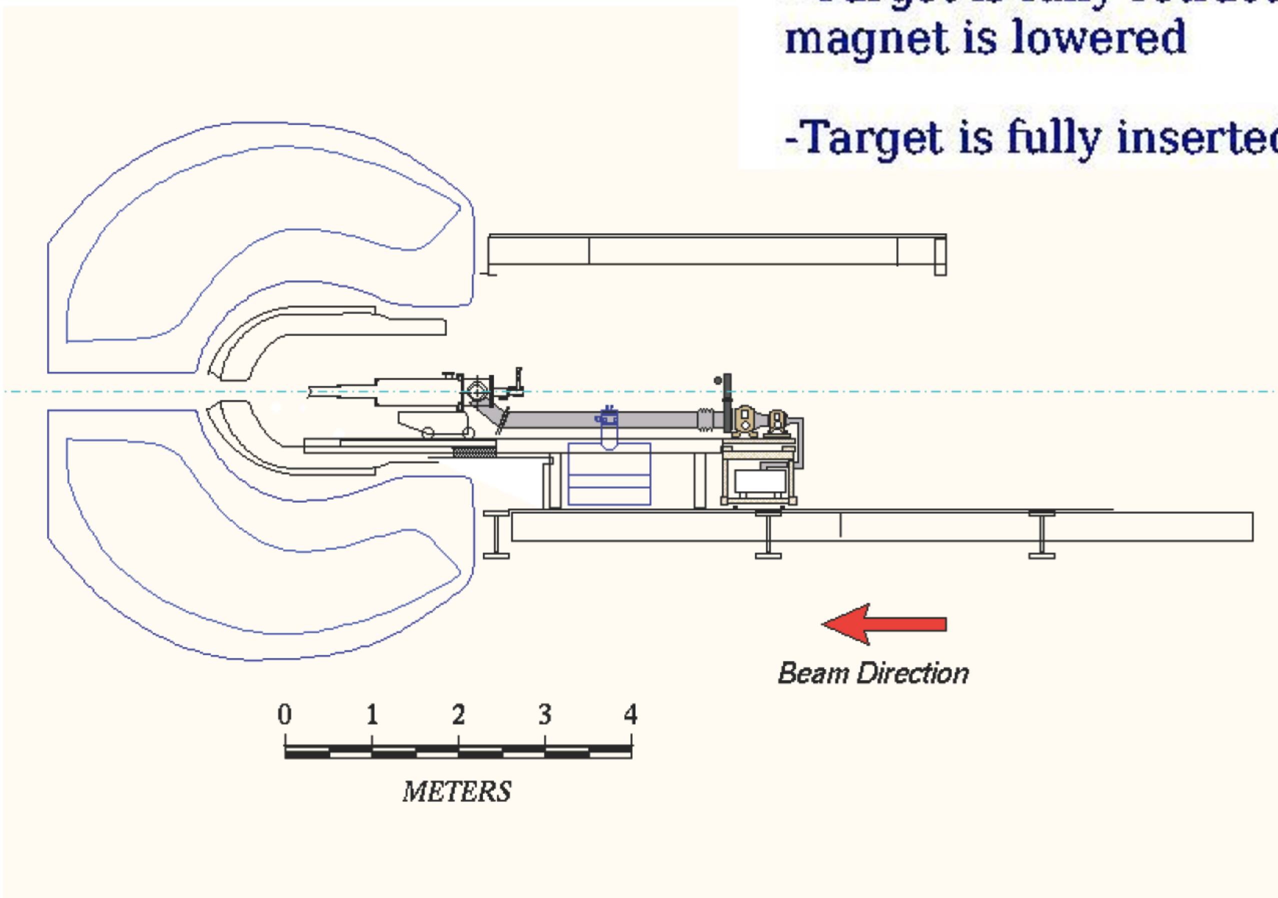


Polarization magnet lowered



Running configuration

- Microwaves off, magnet off, holding coil on
- Target is fully retracted, magnet is lowered
- Target is fully inserted into CLAS



Ongoing efforts: Calculations and Measurements

- **Polarizing Mode:**
  - Dilution cryostat (0.3- 0.5 K mode), JLab
  - Supporting infrastructure (alignment), JLab, Hall-B
  - **Magnet homogeneity measurements, USC**
  - NMR-signal calibrations (TE-measurements at 1.0 K), KIPT + USC
  - **Q-meter simulations, KIPT + USC**
- **Frozen Spin Mode:**
  - Dilution cryostat (50 mK mode), JLab
  - Supporting infrastructure (alignment), JLab, Hall-B
  - Holding Magnet – 0.5 Tesla (see Bonn, 2003), JLab + USC
  - **Photon beam heat load, USC**
  - Polarization monitoring (low field conditions), KIPT + USC

5.0 Tesla Polarizing Magnet

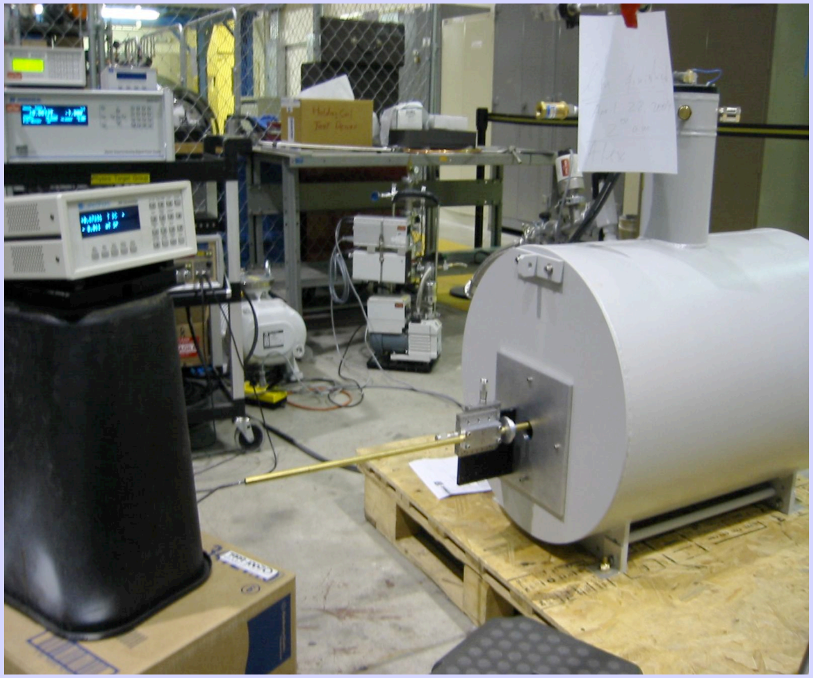
Homogeneity over target volume
Cylinder:

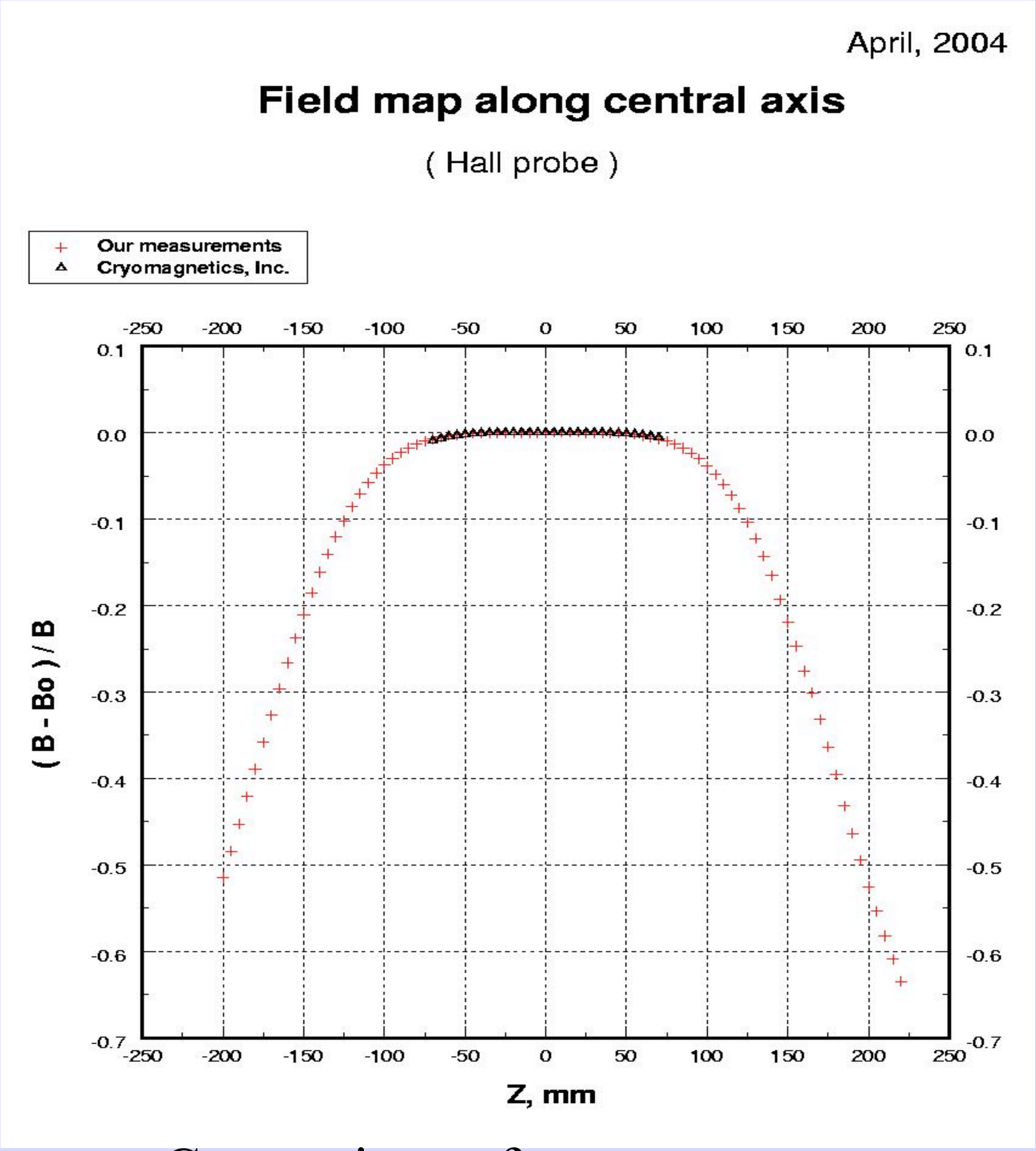
D = 15.0 mm

L = 50.0 mm

should be better than

100 ppm !

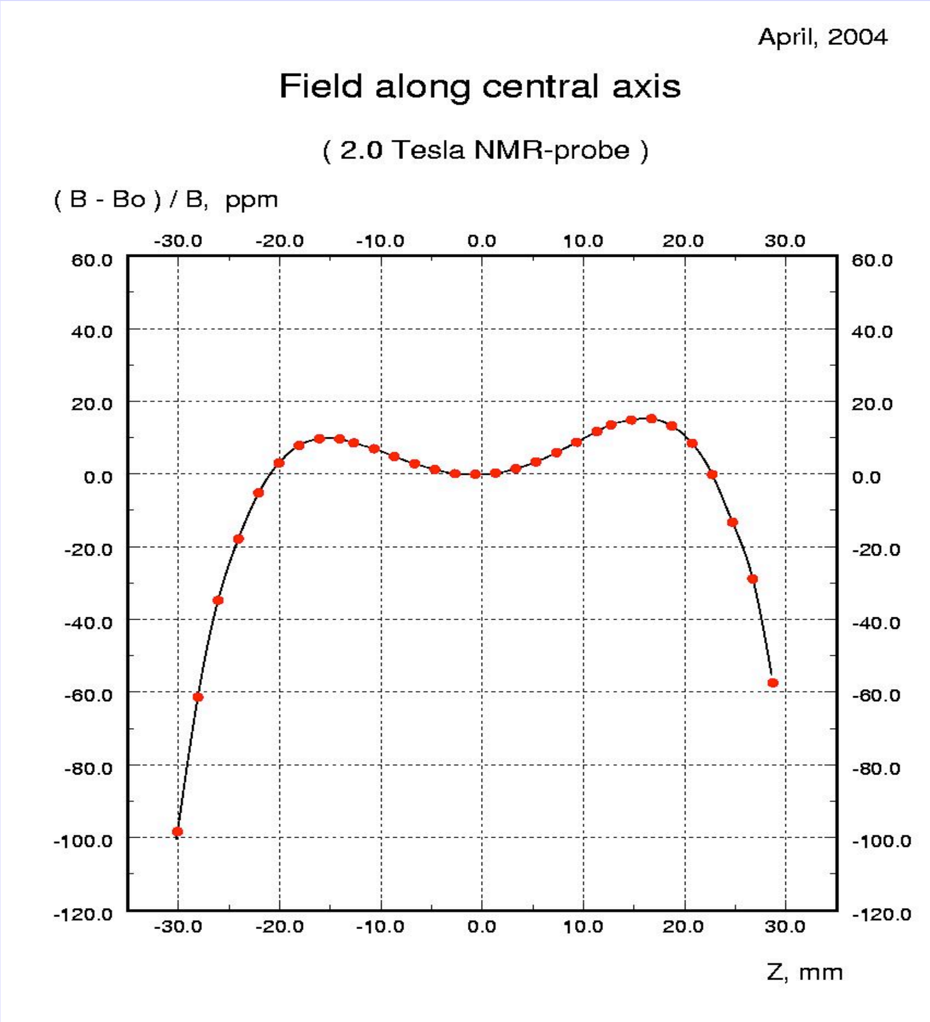




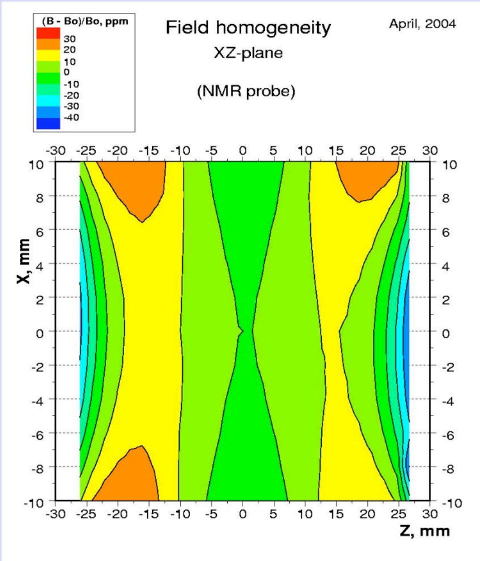
Comparison of our measurements with Cryomagnetics, Inc. ones

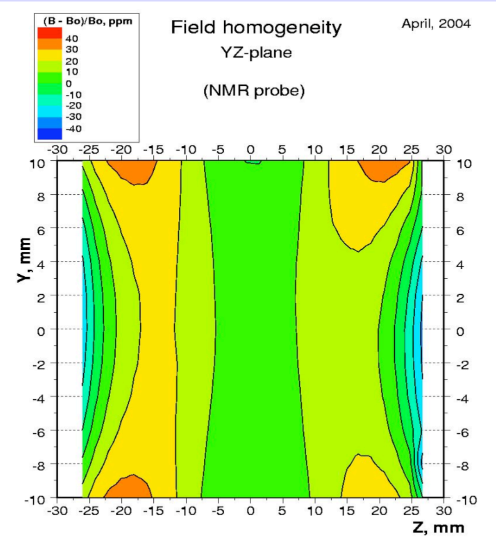
Polarizing Magnet Field homogeneity over target cell area

Field along central axis

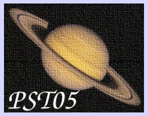


20 x 52 mm^2 area (NMR-probe)



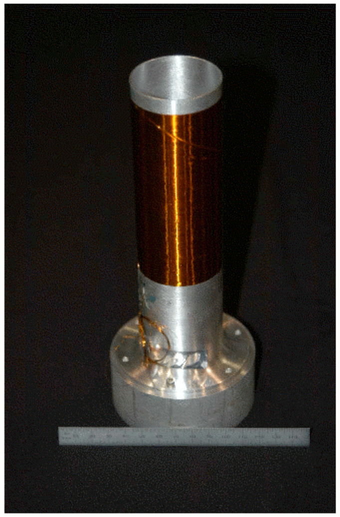


- **Homogeneity over target area better than 40 ppm**
- **3mm tolerance in positioning target and polarizing magnet**

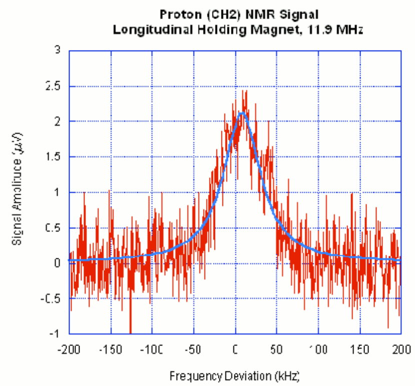


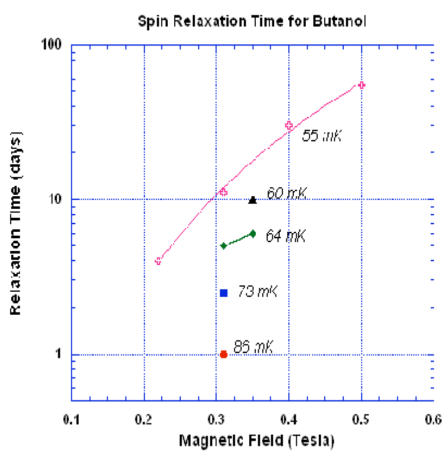
Holding Magnet (M. Seely, Jlab)

Longitudinal polarization:
solenoidal coil (0.5T; ΔB/B~0.2%)



size: Ø5cmx11cm



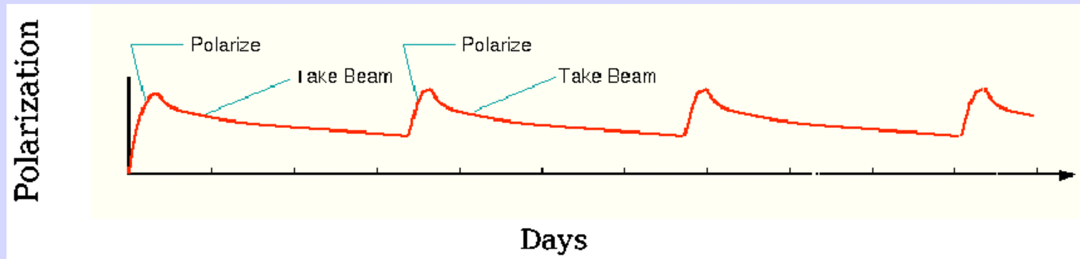


Ch. Bradtke
PhD Thesis, Univ. Bonn, 1999

Transverse polarization:
"racetrack" coil (0.3+ T; ΔB/B~0.5%)

NEW DEVELOPMENT!

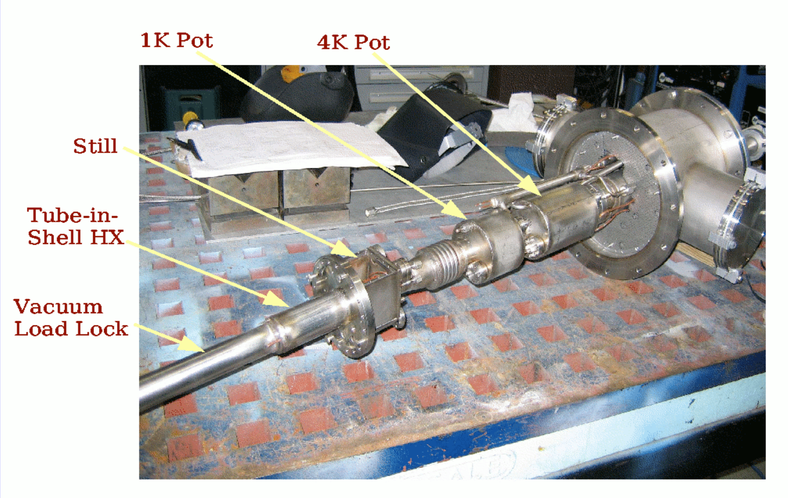
size:
Ø5cmx20cm



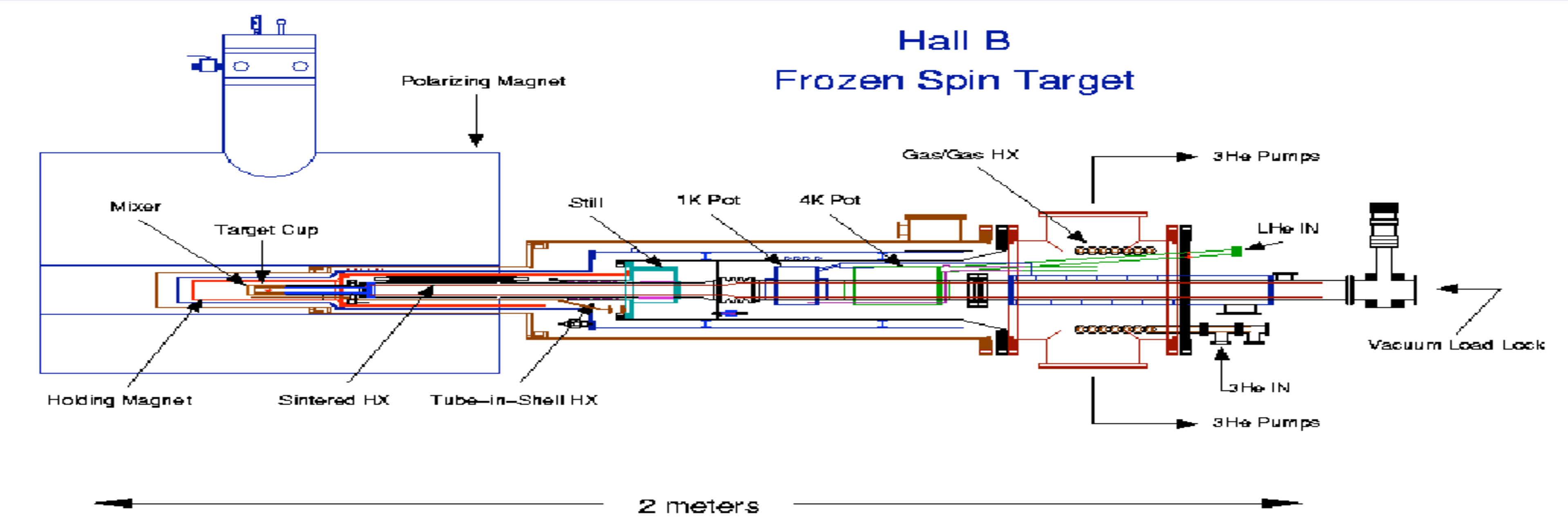
Average Pol ~80-85%, repolarize every 2-3 days?

Cryostat (C.Keith, JLab)

Target Cell: Ø15mm x 50mm
butanol C_4H_9OH+TEMPO
dilution factor 10/74
eff. density: 0.611 g/cm^3



Expected Operation
20 mW @ 300 mK
10 μW @ 50 mK,



Target Cryostat as of November 2005

Status of Target Cryostat as of Nov. 3, 2005
Shown at Hall Collaboration meeting (V. Burkert)

- 2nd cooling test of refrigerator completed with dummy target sample inside the mixing chamber of the dilution refrigerator and attempting to cool it to approximately 1K by circulating He-4 through dilution unit.

- Massive vacuum leak prevented cool down to 1K but limited cool down to 10K

- Identified serious misalignment of holding magnet heat shield that requires serious repair.

- 4He precooling system for the circulating 3He/4He mixture operates reasonably well;
  - -the heat shields operate better than expected;
  - -the insertion of the target stick into a "cold" (20K) mixing chamber works;

- Need to dismantle cryostat to identify vacuum leak.

- Misalignment issue and internal leak in dilution unit will require re-design and re-fabrication.

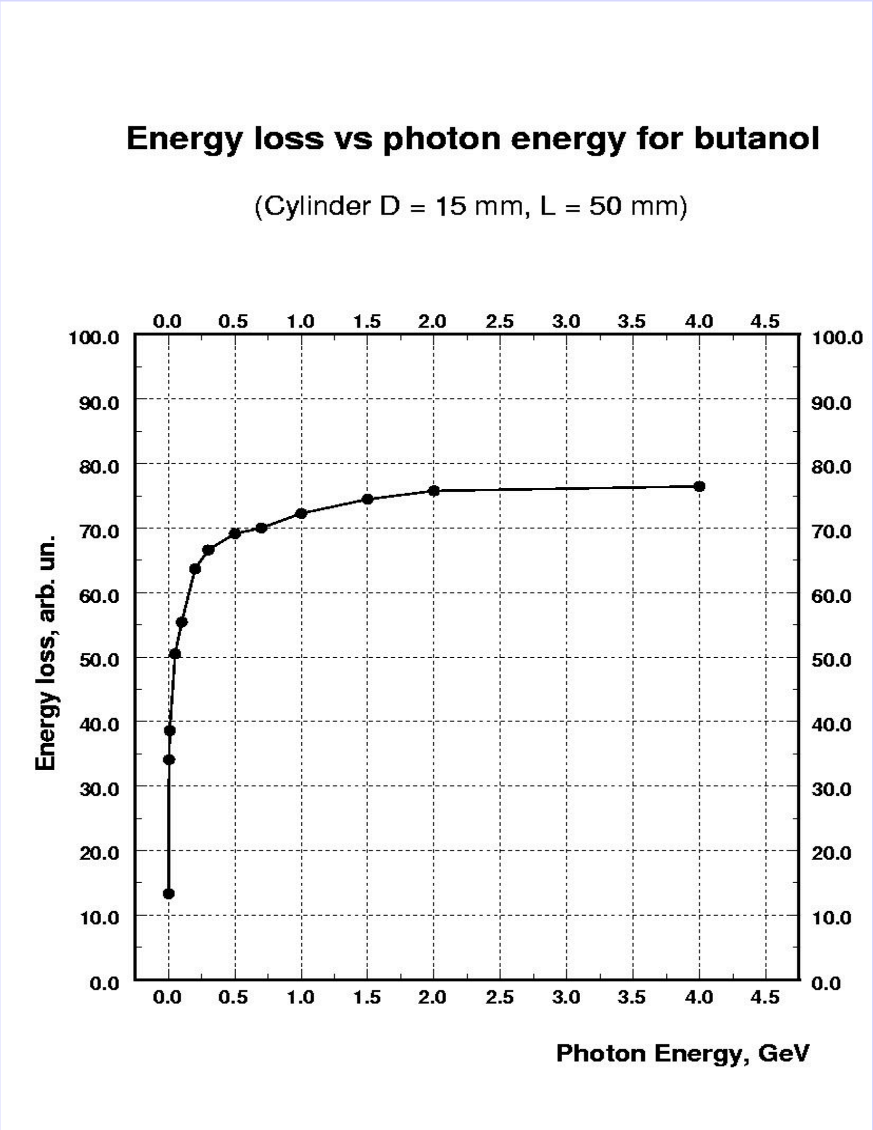
- Testing will resume early ‘06

Beam heat load

Conditions:

1) one target cell;
2) target material – beads immersed into L He;
3) appropriate packing factor used.
4) 10^7 gammas (1 GeV)

Material	Packing Factor	Photon beam heat, μW
Butanol, C_4H_9OH + He	0.62	0.51
Ammonia, NH_3 + He	0.58	0.40
LiH + He	0.55	0.14



Calculated additional heat load caused by photon beam is less than 1.0 μW

USC and KIPT collaboration

The target polarization value is measured by the NMR technique.
Accuracy of measurements is affected by many factors such as:

- Temperature (stability and accuracy)
- Magnetic field
- Q-meter stability
- Dispersion of NMR-signal, etc.

USC in collaboration with KIPT (Kharkov, UKRAINE) is working on design and optimizations for NMR-signal measurements using Liverpool type of Q-meter.

USC and KIPT collaboration

This collaboration includes the work on

- TE-signal measurements at 1.0 K
- Hardware and software optimizations for NMR-measurements
  - Polarizing Mode
  - Holding Mode

The following types of Q-meters have been studied:

- Amplitude detector with resonant cable
- Phase detector with resonant cable
- Phase detector with non-resonant cable

Preliminary <u>simulations</u> of the errors caused by the dispersion of NMR signal have been completed. Contrib to error ~ 1 %

Summary and Conclusions

- Hall-B polarizing magnet is very reliable.
- Homogeneity over the target area is better than 40 ppm.
- This polarizing magnet can be used for a large variety of target materials. For now choice is Butanol + TEMPO
- Calculated additional heat load caused by photon beam is less than 1.0 μW which is only10% *of expected cooling power.*
- Goals :

  Test full target in Summer 2006

  Run with FROST in Fall 2006

VERY TIGHT SCHEDULE!