The Bonn Polarized Target

Exotic multi-quark states and baryon spectroscopy workshop

June 25, 2024

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Background

- DNP
- Frozen Spin
- History

Current Status

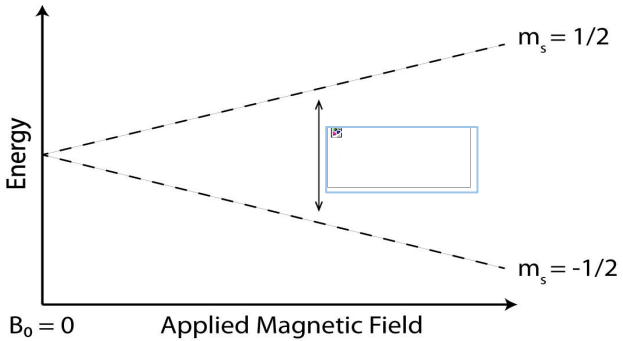
- Target Performance
- Proton Run
- Deuteron Run

Future

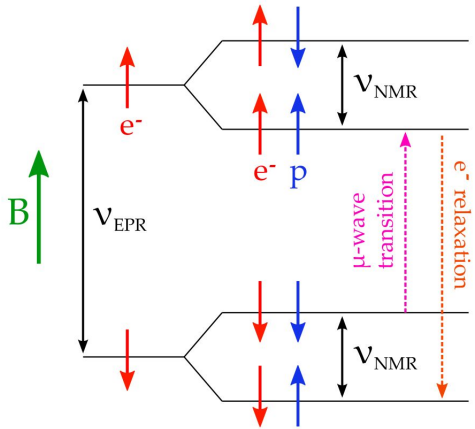
- Combined Coils
- Internal Polarization
- Cryostats

Fundamentals of Dynamic Nuclear Polarization

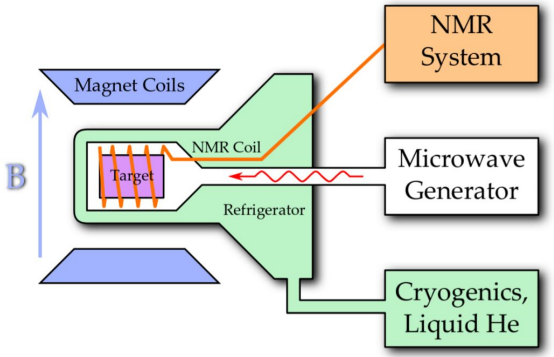
Thermal Equilibrium Polarization



Enhanced Polarization



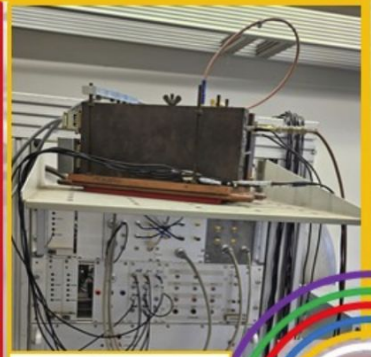
DNP Requirements

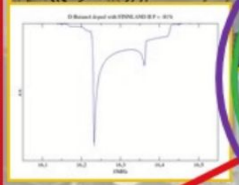


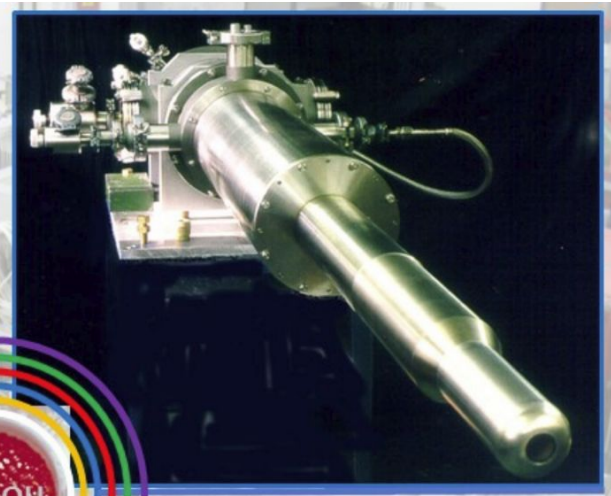
- Magnetic Field (5T)
- Low Temperature (1K)
- Paramagnetic Material
- Microwaves (140 GHz)
- Monitoring (NMR)

Mainz - Dubna Cryostat

Polarization measurement, NMR: $\varpi_c \sim 10 - 212$ MHz







low temperature: T ~ 0.02 – 1 K

High magnetic field: B ~ 2 – 5 T

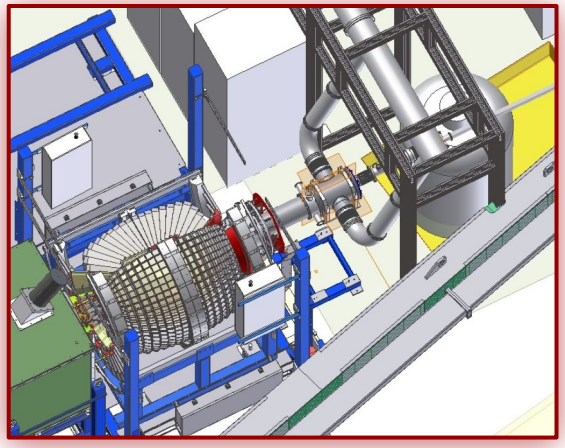
Target material

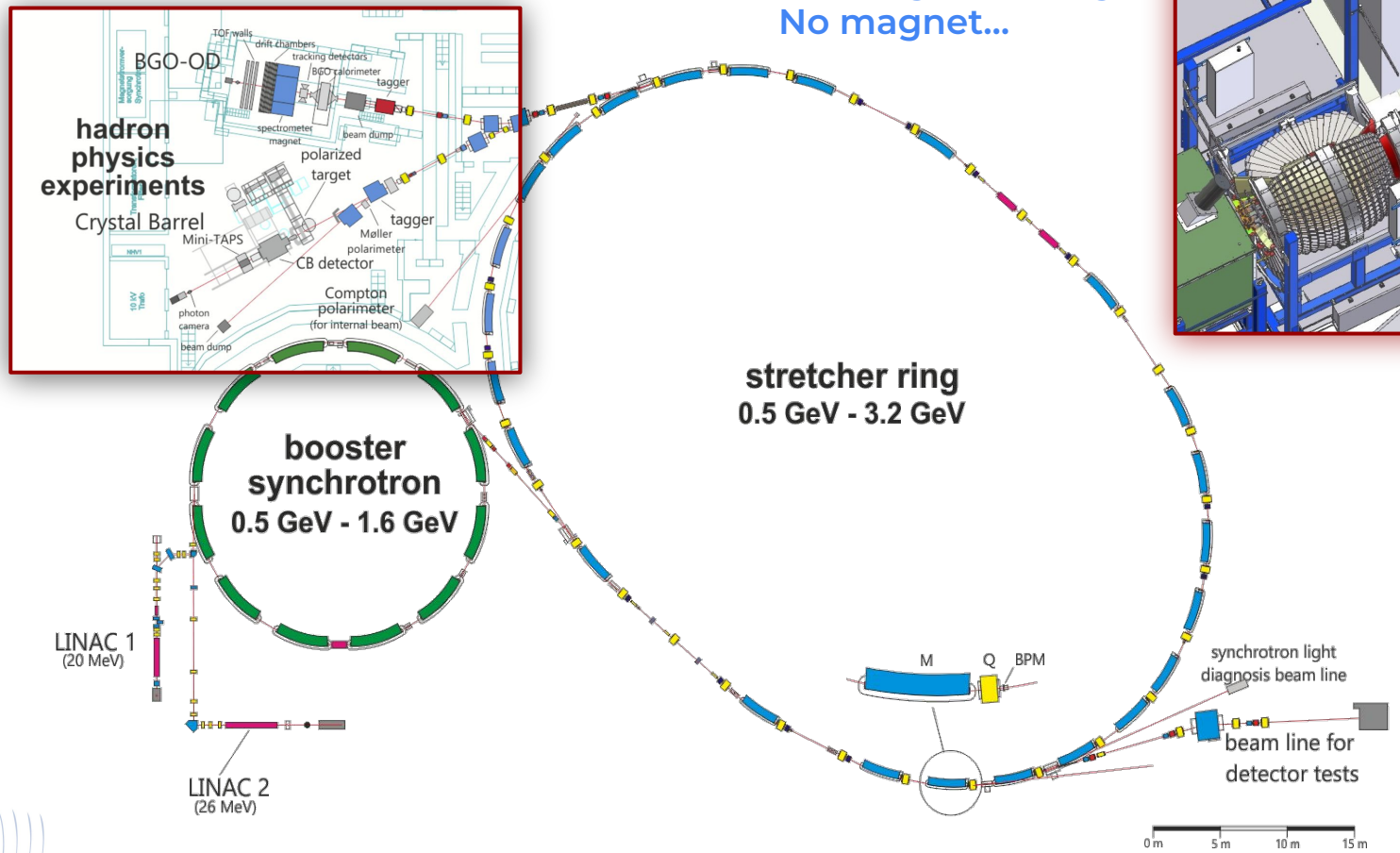
Slow control

Microwaves for DNP: $\mu_F \sim 56 - 140$ GHz

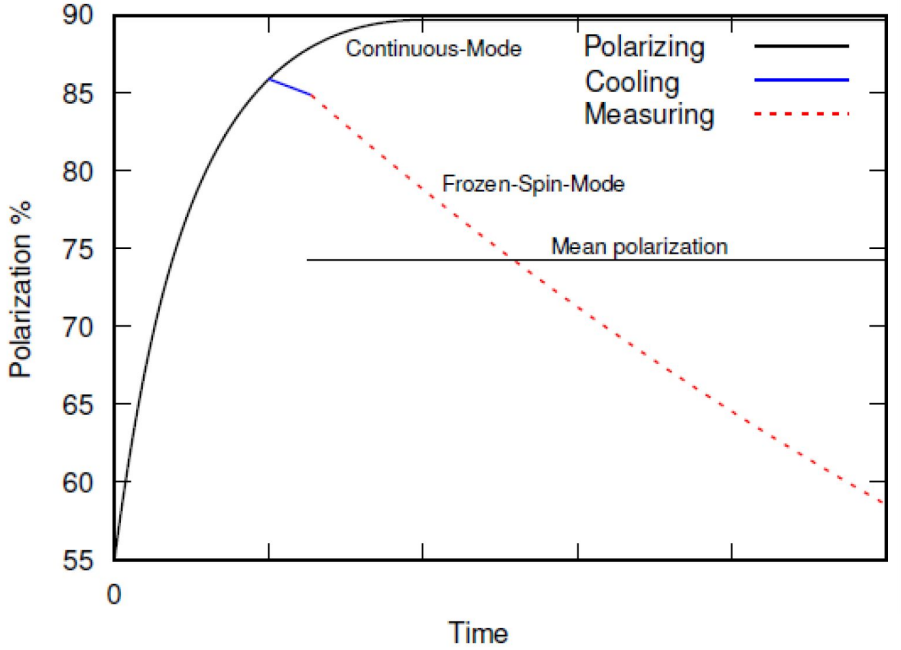
$$P_{1/2} = \tanh \frac{\mu B}{2kT}$$

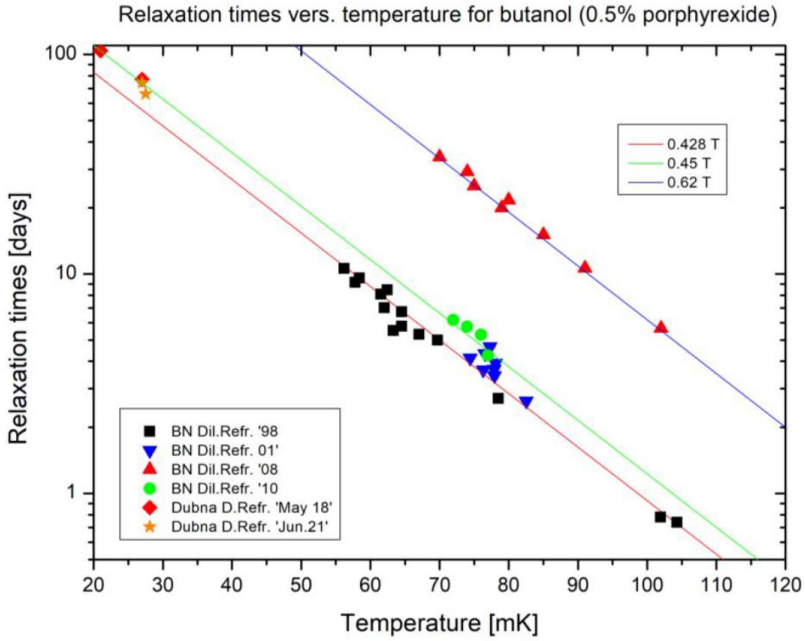
1320 CsI(Tl) crystals
97.8% solid angle coverage
No magnet...





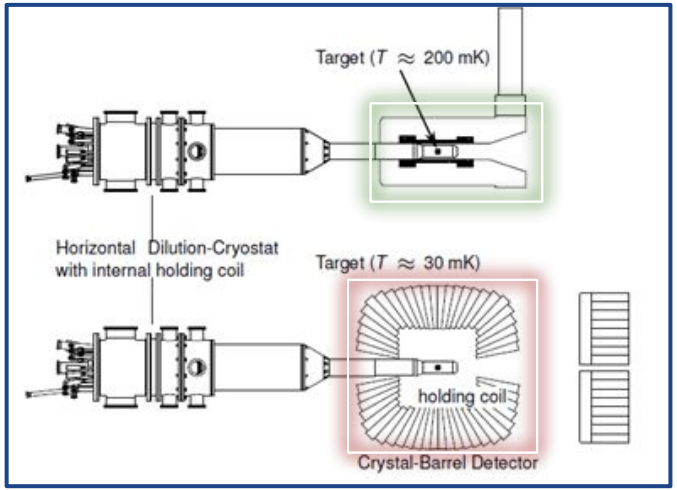
Temperature reduced to tens of mK to ‘Freeze’ in the enhanced polarization



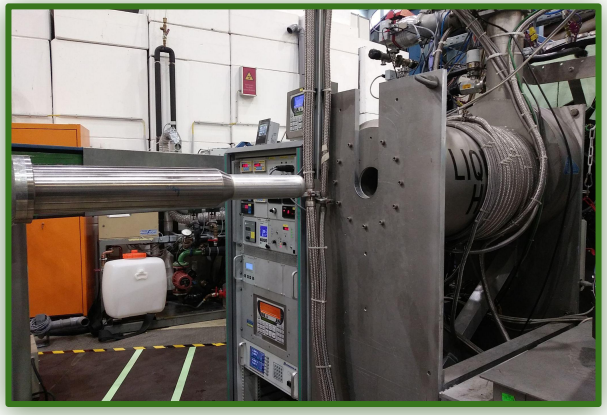


Relaxation time extended to hundreds of hours

Mainz-Dubda
Helium-3 Dilution Cryostat

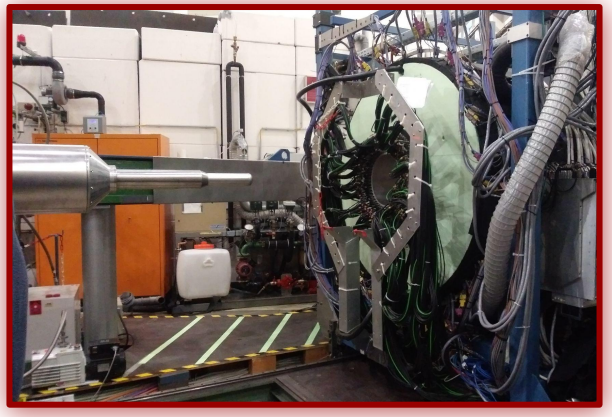


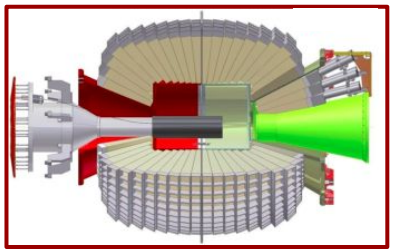
Frozen Spin Mode:
1 K → 30 mK



Saclay Magnet:
2.5 T

Holding coils:
0.5 T





CBELSA/TAPS horizontal frozen spin target with internal transverse or longitudinal holding magnet

Operation of the polarized target (cold cryostat) at Crystal Barrel @ ELSA (CBELSA)

2017 (long. polarization) ~ 800h b.o.t.
→ p_p = 63 %, (butanol, TEMPO), τ ~ 1300h

2018 (transv. polarization) ~ 1000h b.o.t.
→ p_p = 87 %, τ ~ 500 h

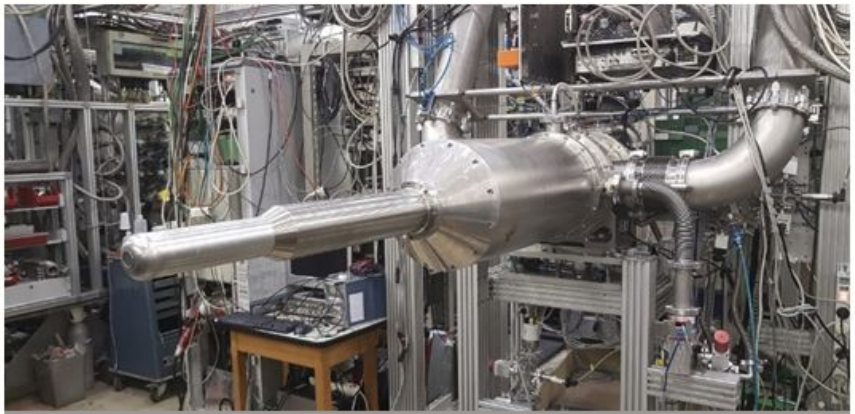
2018 (transv. polarization) ~ 800h b.o.t.
→ p_d = 76 %, τ ~ 700 h

2019 (transv. polarization) ~ 500h b.o.t.
→ p_p = 84 %, τ ~ 800 h

2021 (transv. polarization) ~ 440h b.o.t.
→ p_p = 78 %, τ ~ 700 h

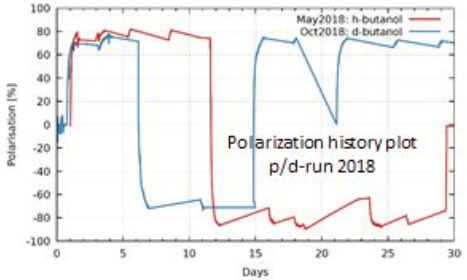
2021 (transv. polarization) ~ 500h b.o.t.
→ p_d = 75 %, τ ~ 500 h

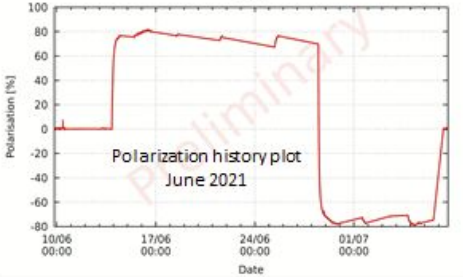
Five years of successful operation on beam in Bonn and 8 years before at A2@MAMI

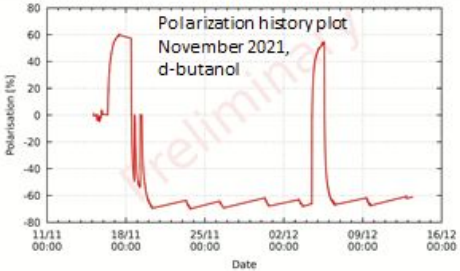


Collaborative target group: Bonn/Dubna/Mainz/Bochum (2015 – 2021)
'Mainz/Dubna frozen spin target' + internal 'holding' coil(s)

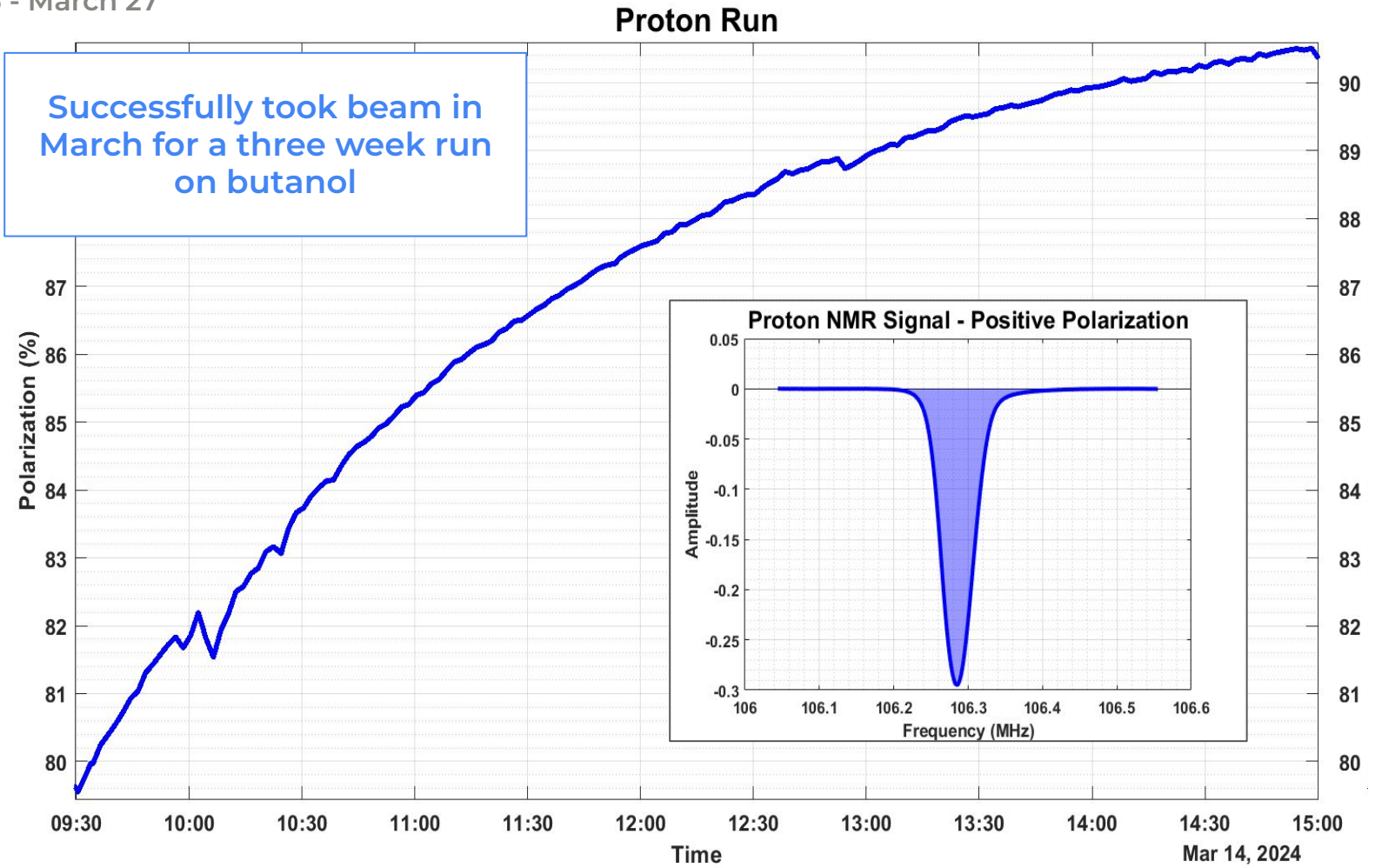
All activities stopped in March 2022, because of the Russian invasion of the Ukraine
- → No refrigerator for the CryPTA-project for CryPTA:ScM and CryPTA:APT
- → No working refrigerator for the experiment
- → No reliable planning was (is) possible
- → Since no one (all) of us has operated the refrigerator in the past
- → Nevertheless we decided to cool down the system



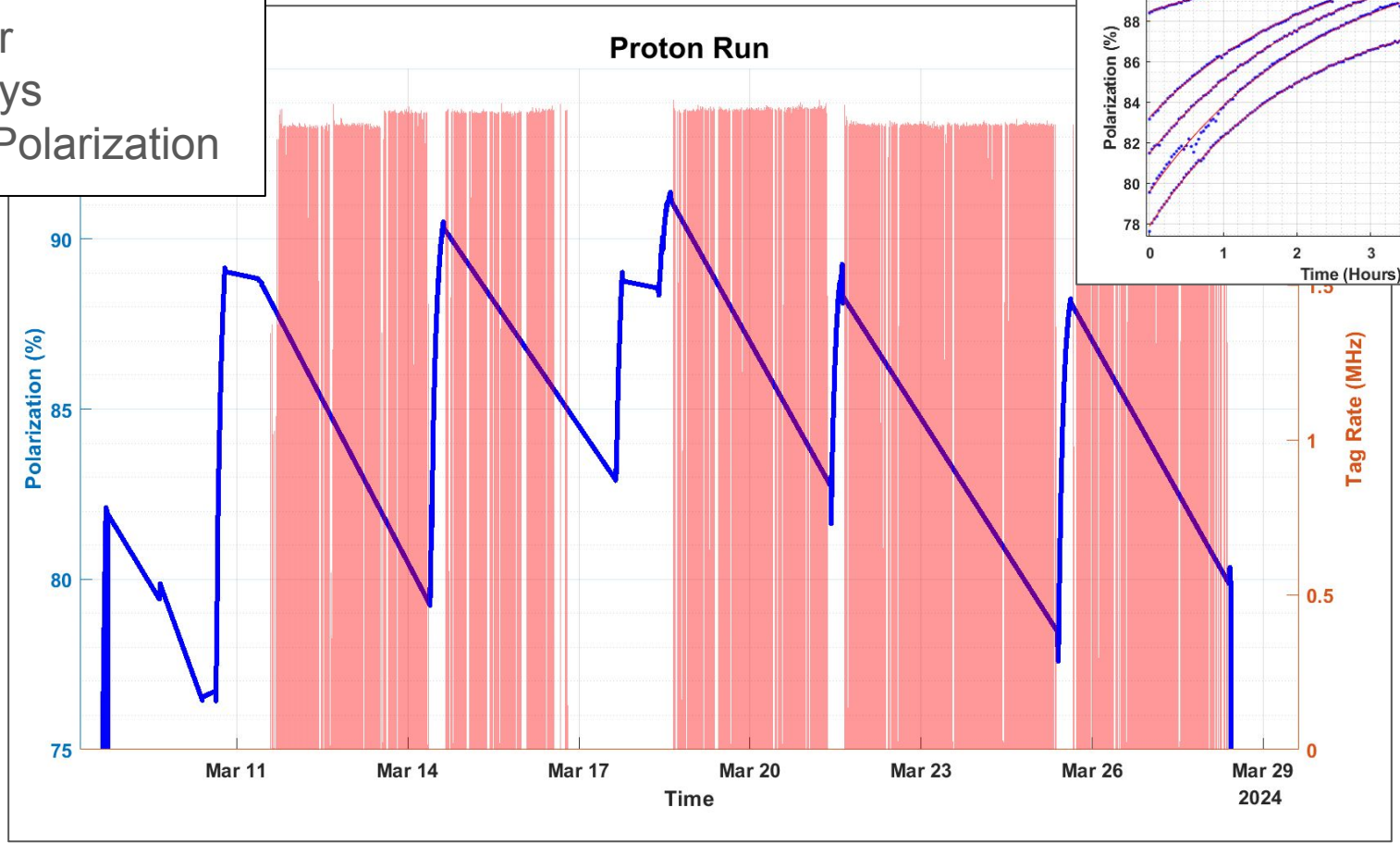


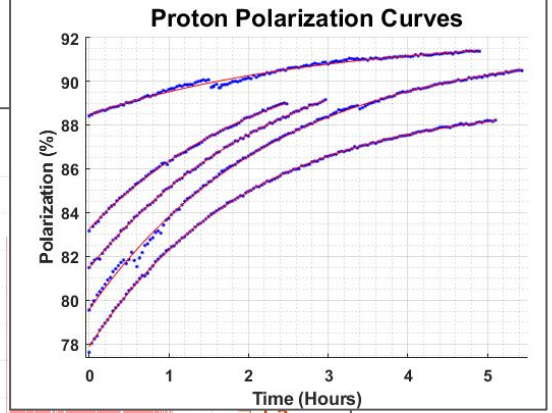


Successfully took beam in March for a three week run on butanol

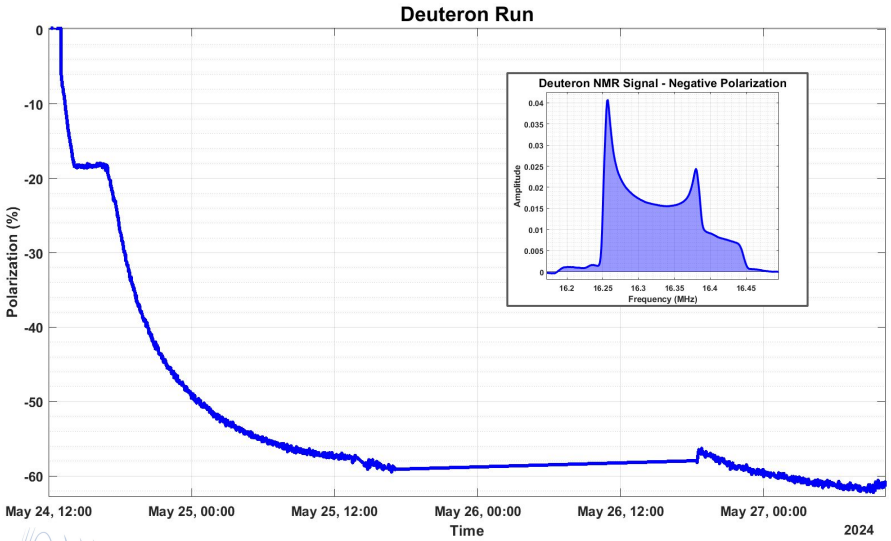


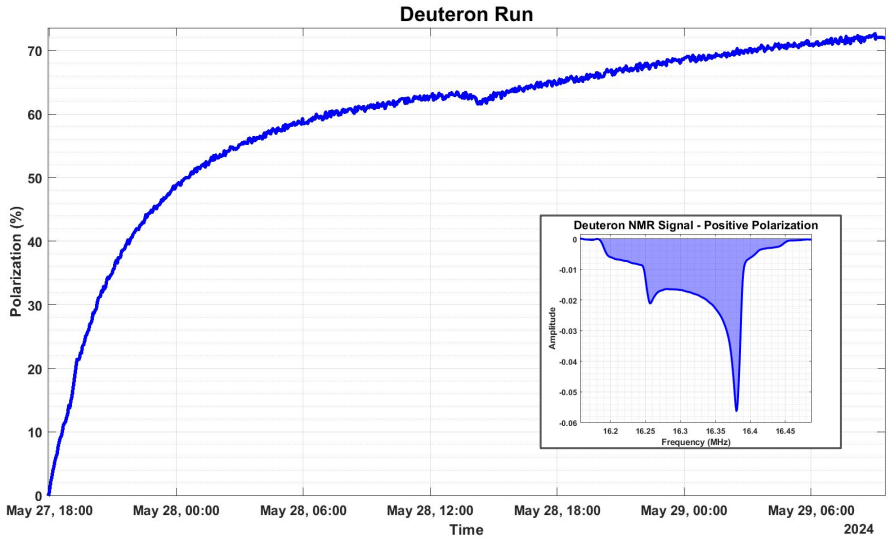
320 hr
17 days
92% Polarization

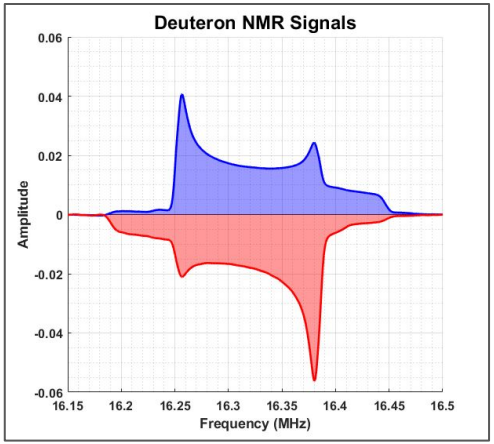




Followed up in April with a carbon run then in May / June with deuterated butanol

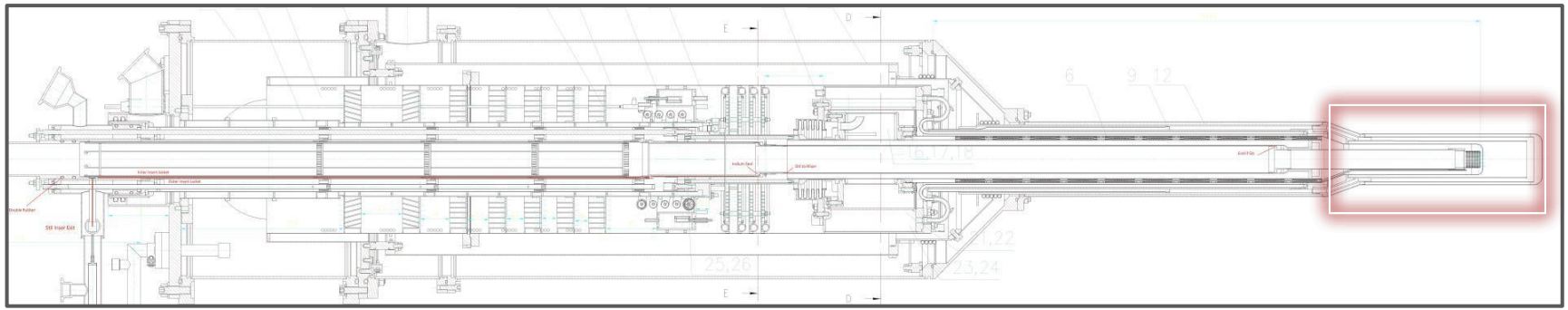


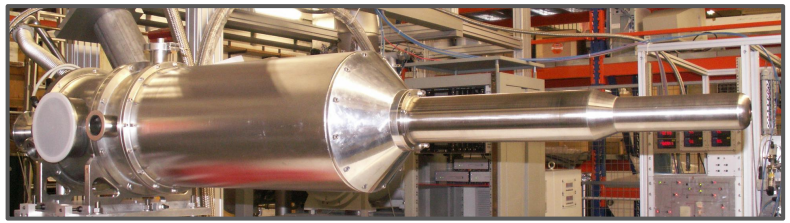


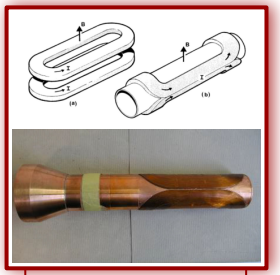


287 hr
17 days
73% Polarization

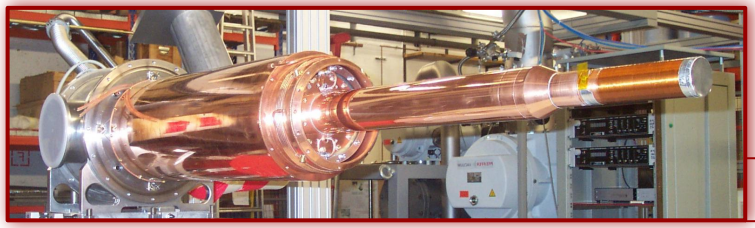
Holding Coils







Transverse



Longitudinal

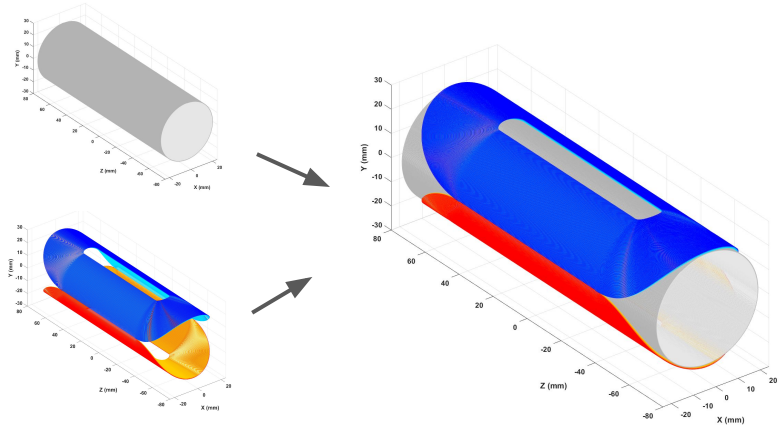
Operates at < 1.5 K

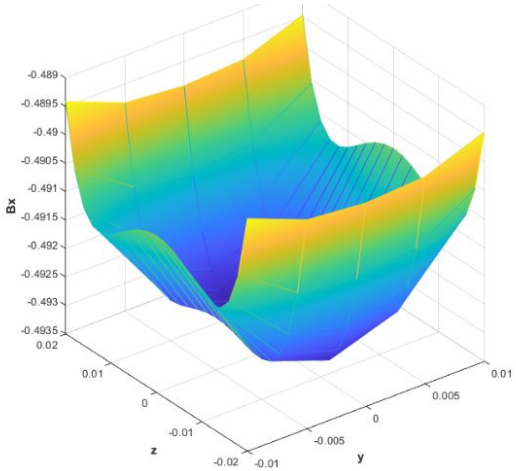
Longitudinal Coil:
4 layers, 2400 turns, 0.6 T

Transverse Coil:
4 layers, 845 turns, 0.45 T (@35A)

Approx. 1 week to transition between coils

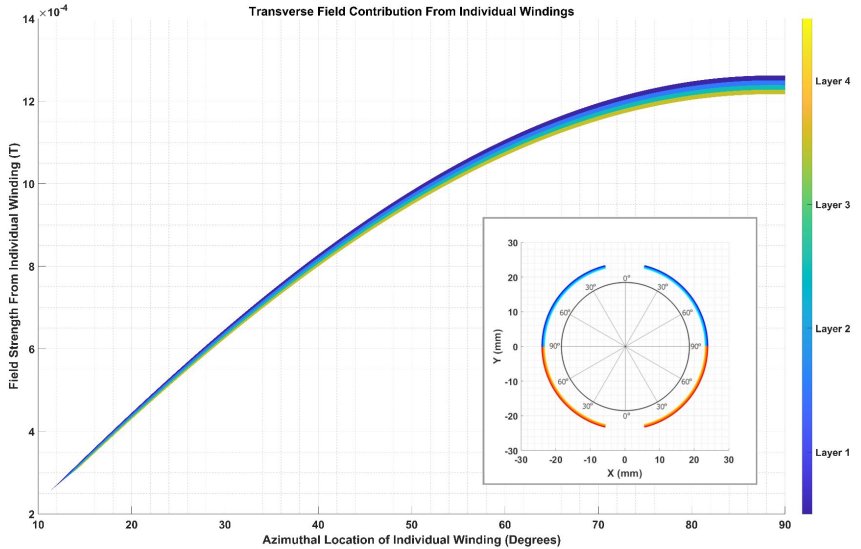
Combined Holding Coil





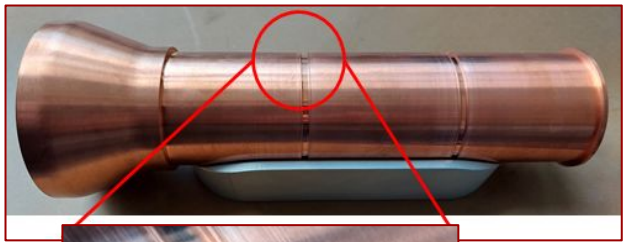
Combined holding coil allows for quick and easy transition between longitudinal and transverse polarization directions.

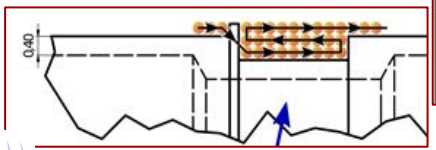
Saddle: 3 layers (0.4 T, 0.63 mm)
Solenoid: 2 layers (0.4 T, 0.45 mm)

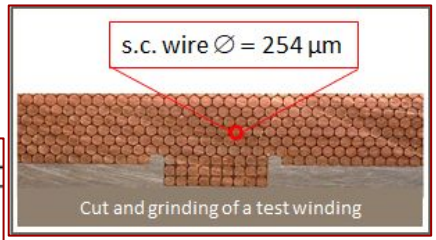


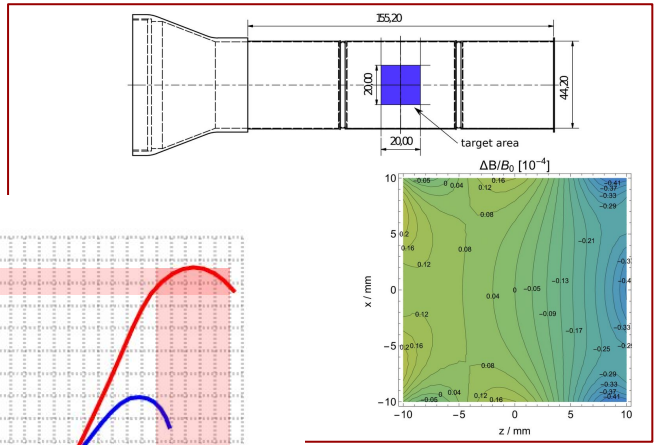
An internal polarizing magnet would remove the need for cycling data taking

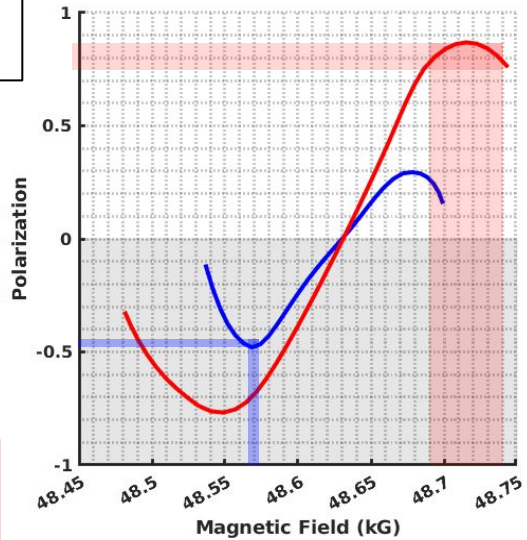
Requires extreme efficiency and uniformity





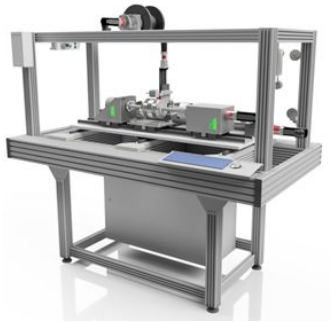






Proton: $\Delta B/B = 10^{-4}$

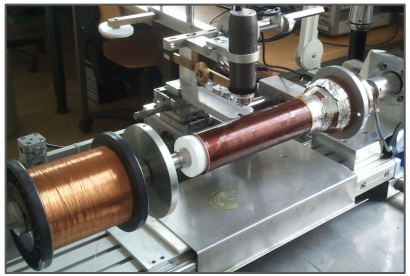
Deuteron: $\Delta B/B = 10^{-3}$

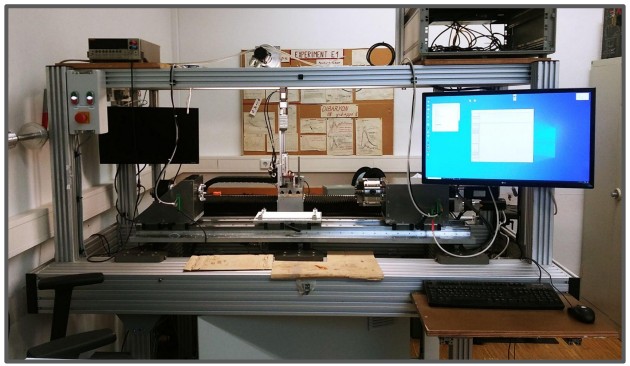


We have successfully recommissioned the Mainz-Dubna-Bonn polarized target.

Already acquired 34 days of data on both protons and deuterons.

Actively developing the next generation of polarized targets for the future.





Thank You