Status of JRA10:CryPTA
Task 1 PT UBO

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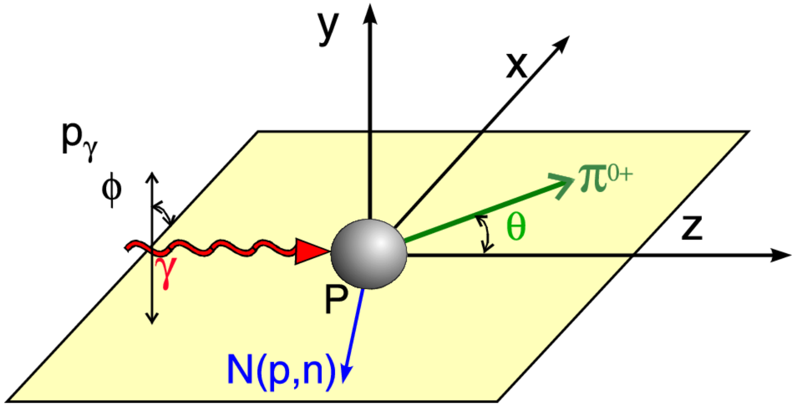
Motivation

Structure mapping @ ELSA and MAMI

→ Double polarization experiments
→ Modell independent partial wave analysis
→ Complete experiment



$$\frac{d\sigma}{d\Omega}(\Theta,\phi) = \frac{d\sigma}{d\Omega}(\Theta)\cdot\Big[1 - p_\gamma^{lin}\Sigma(\Theta)\cos(2\phi)$$
$$+ p_t^x\cdot\left(-p_\gamma^{lin}H(\Theta)\sin(2\phi) + p_\gamma^{circ}F(\Theta)\right)$$
$$- p_t^y\cdot\left(+p_\gamma^{lin}P(\Theta)\cos(2\phi) - T(\Theta)\right)$$
$$- p_t^z\cdot\left(-p_\gamma^{lin}G(\Theta)\sin(2\phi) + p_\gamma^{circ}E(\Theta)\right)\Big]$$

Photon		Target		
		x	y	z
unpolarized	σ	0	T	0
linear	(-Σ)	H	(-P)	(-G)
circularly	0	F	0	(-E)

Collaborative target group: Dubna/Mainz/Bochum/Bonn (2015 – 2022)
'Mainz/Dubna frozen spin target' + internal 'holding' coil(s)

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Motivation

Run-time polarized target (cold cryostat)

2017 (long. polarization) ~ 800h

→ max. pol: p_+ = 63 %, (butanol, TEMPO)

→ Relaxation time: $\tau \sim$ 1300h (@ 0.4 T, I ~ 10^8/s)

→ $\bar{P} \sim$ 56 %

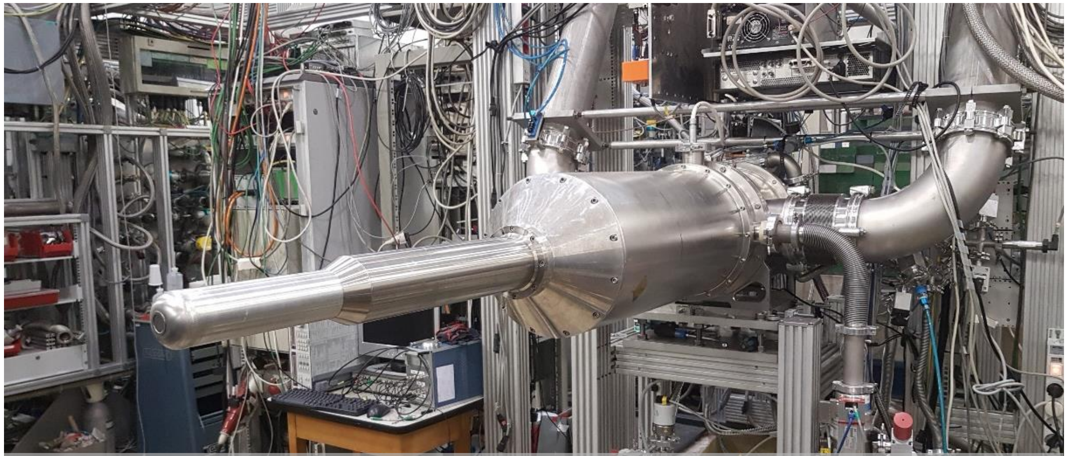
2018 (transv. polarization) ~ 1000h

→ max. pol: p_+ = 83 %, p_- = 87 % (butanol, porphyrexide)

→ Relaxation time: $\tau \sim$ 500 h (@ 0.4 T, I ~ 10^8/s)

→ $\bar{P} \sim$ 78 %

Relaxation time without beam: 1800 h



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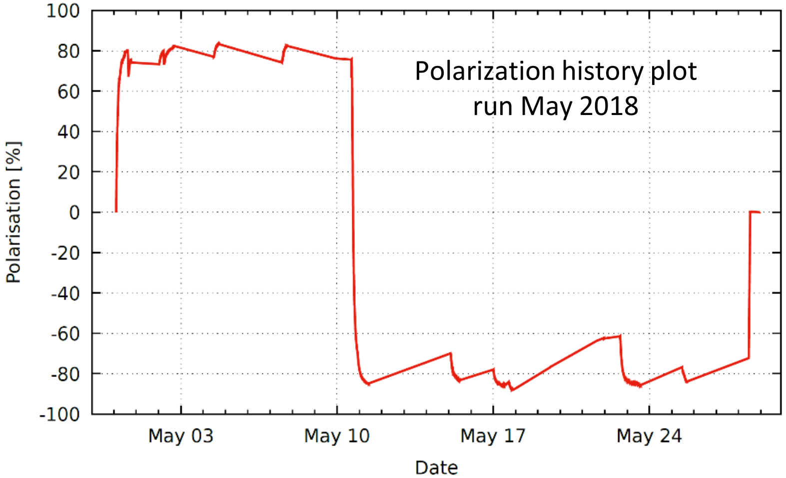

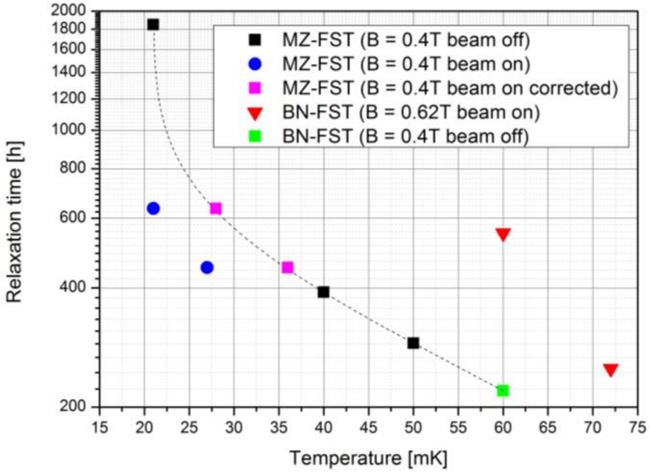

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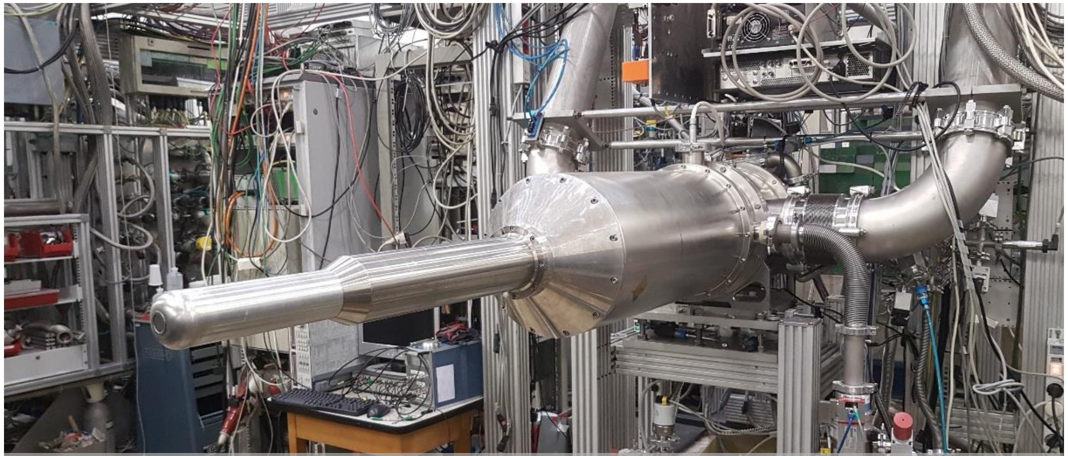

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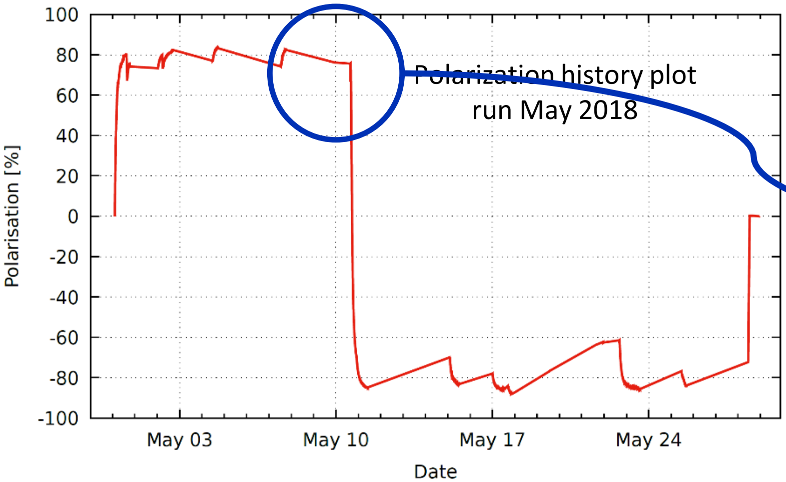

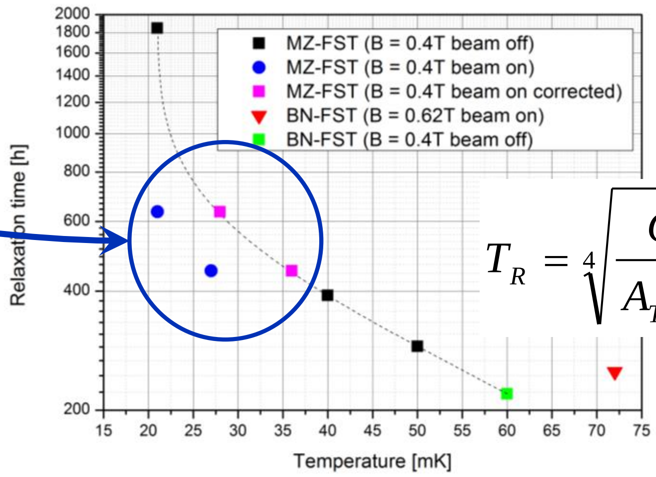

$$T_R = \sqrt[4]{\frac{\dot{Q}_v}{A_T \cdot \alpha} + T_{Bad}^4}$$

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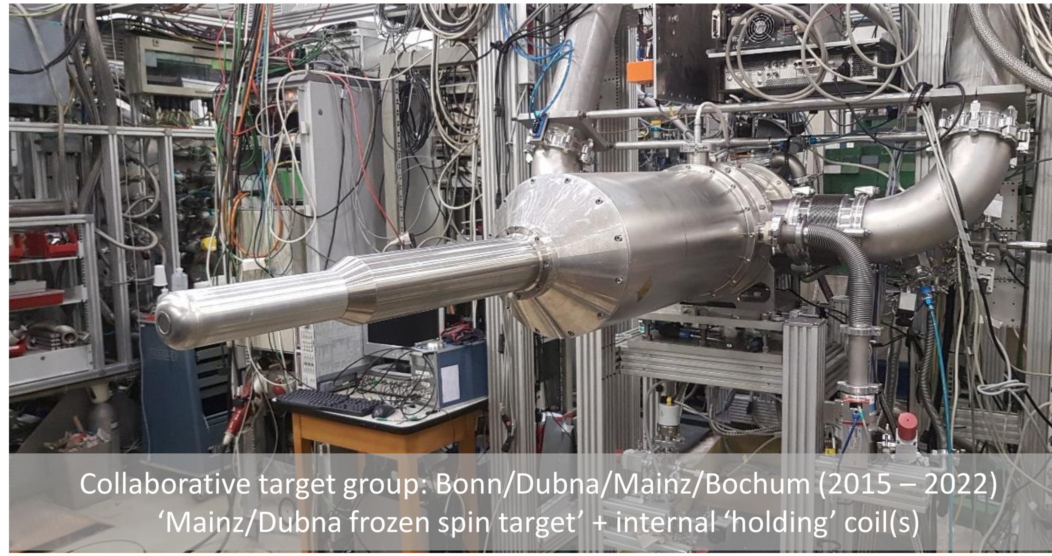
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'Mainz/Dubna frozen spin target' + internal 'holding' coil(s)

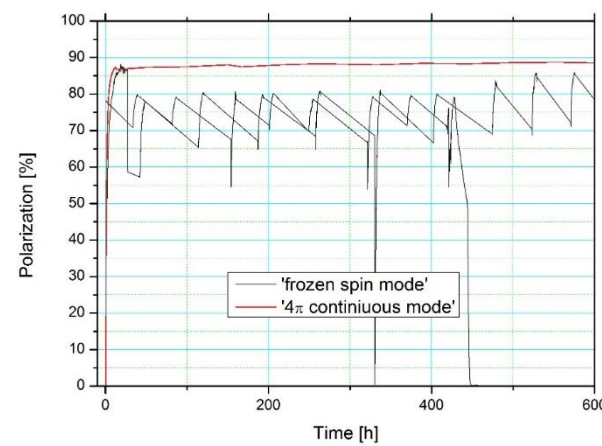
FSTechnique Limitations :

- Large acceptance target system requires dedicated railway system
- Beam time efficiency $\mathcal{F} \leq 0.8$
- $FoM = n_T \, f^2 \, \bar{P}^2$ (relaxation τ)
- $\mathcal{L} = I \, n_T \; (I \leq 10^8/s)$

Combine advantages of the frozen spin technique with the advantages of a continuous polarization:

'4π continuous mode target'

replace the holding coil by an internal polarizing magnet!



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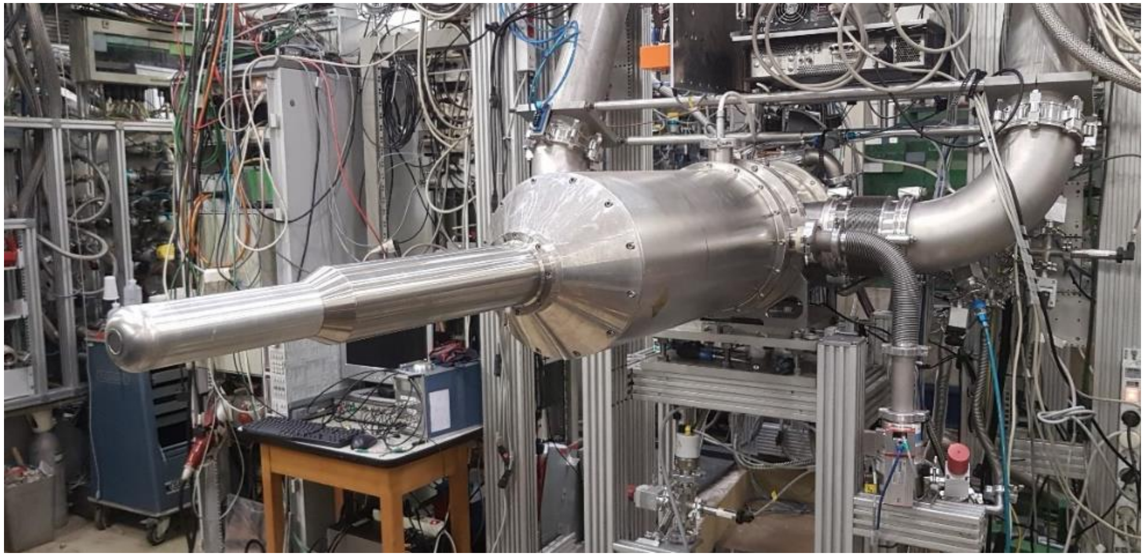
Horizontal dilution refrigerator with int. high field pol. magnets

New horizontal dilution refrigerator is under construction by the JINR Dubna group, first 1K (^{4}He-mode) tests have been successfully performed end of 2020. Launch in dilution mode end of the year

New internal magnets have to be adapted to the new refrigerator



Collaborative target group: Dubna/Mainz/Bochum/Bonn (2015 – 202X)
'Dubna horizontal dilution refrigerator' + internal 'polarizing magnet'

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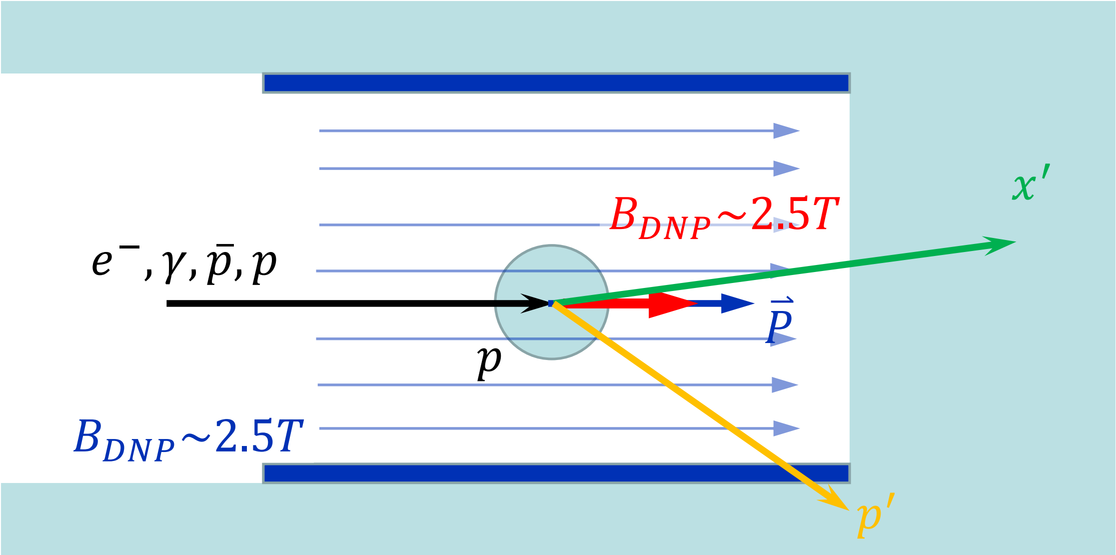
Research Objectives Task1: high field thin s.c. magnets

Polarized solid state target (DNP @ 0.2 – 0.3 K) (horizontal dilution refrigerator)
→ high mag. longitudinal field for DNP (B_{DNP} ~ 2.5 T)



4π – continuous mode target (what do we gain?):

- → good angular acceptance (~ 4π)
- → high luminosity L ~ $10^{33}/cm^2s^{-1}$ (N ≈ 10^{10}/s) [N < 10^8/s]
- → high mean polarization (P_p ~ 90%, P_d ~ 85%) [P_P ~ 75 %]
- → good beam time efficiency

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Research Objectives Task1: high field thin s.c. magnets

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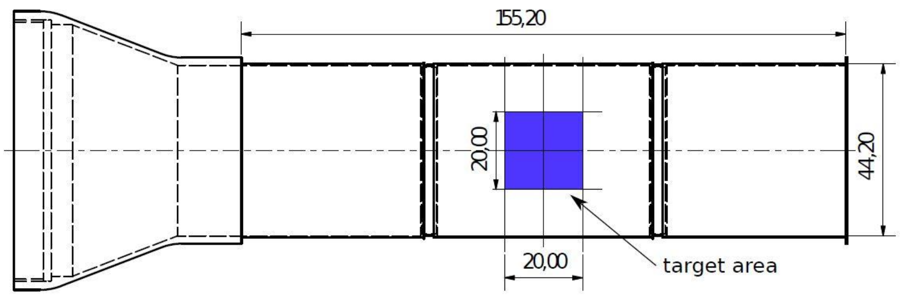
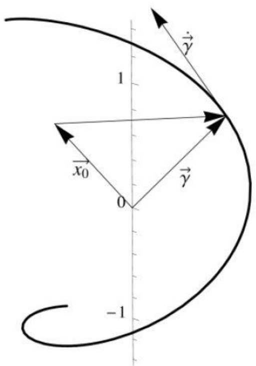
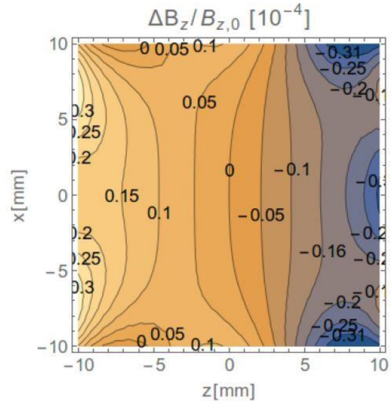
Internal polarisation magnet - Field calculation



Biot-Savart-Law:

$$\vec{B}(\vec{x_0}) = \frac{\mu_0}{4\pi} I \int \frac{(\vec{\gamma}(t) - \vec{x_0}) \times \frac{\dot{\vec{\gamma}}(t)}{|\dot{\vec{\gamma}}(t)|}}{|(\vec{\gamma}(t) - \vec{x_0})|^3} \mathrm{d}t$$





Loop parametrization:

$$\vec{\gamma} = (r\cos(t), r\sin(t), n \cdot d)$$

r: radius of each loop

$n \cdot d$: loop position

d: effective distance between 2 wires

DNP requires $\Delta B/B \leq 10^{-4}$

Internal magnet developments for polarized targets 7/14

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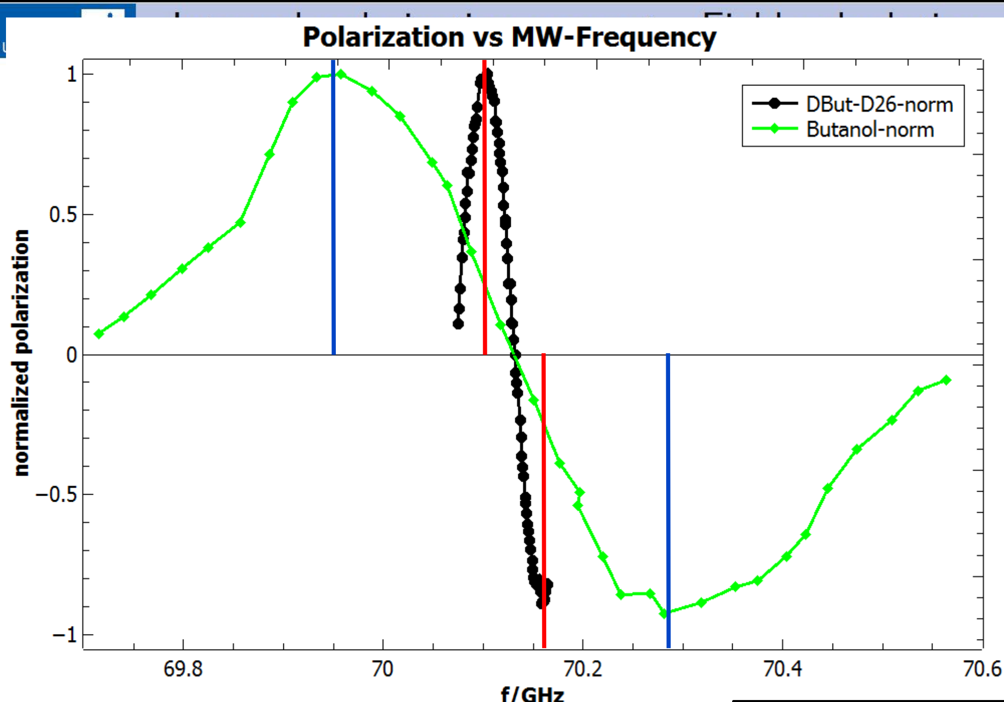

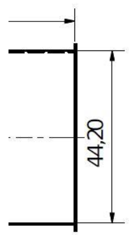

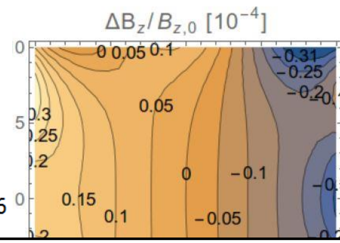

$$\vec{\gamma} = (r\cos(t), r\sin(t), n \cdot d)$$

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DNP requires $\Delta B/B \leq 10^{-4}$

High precision winding technique to guarantee 'orthozyclic winding'

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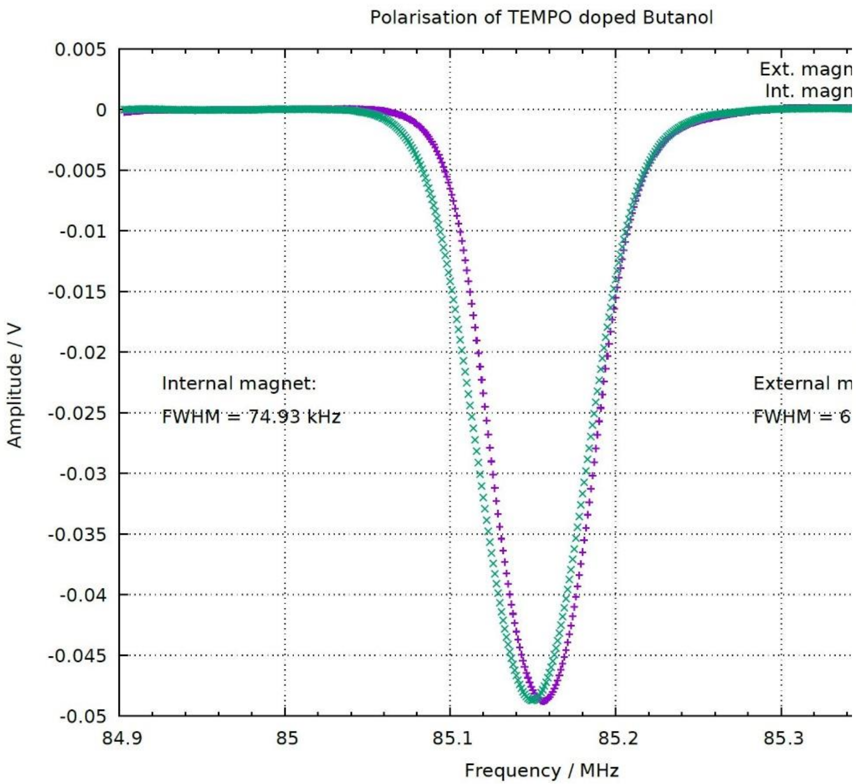
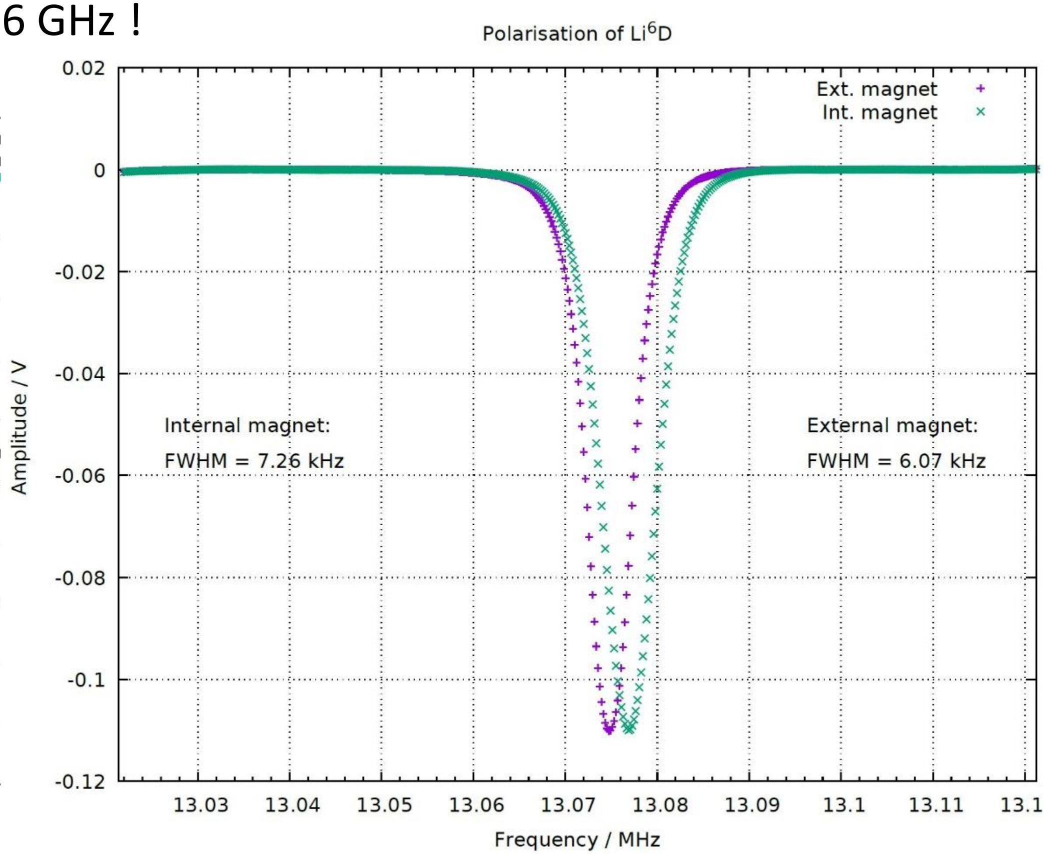
Research Objectives Task1: high field thin s.c. magnets

First DNP-signals in the **new internal thin s.c. polarizing magnet**

T_P = 1K!, B_P = 2 Tesla, $F_{\mu w}$ = 56 GHz !





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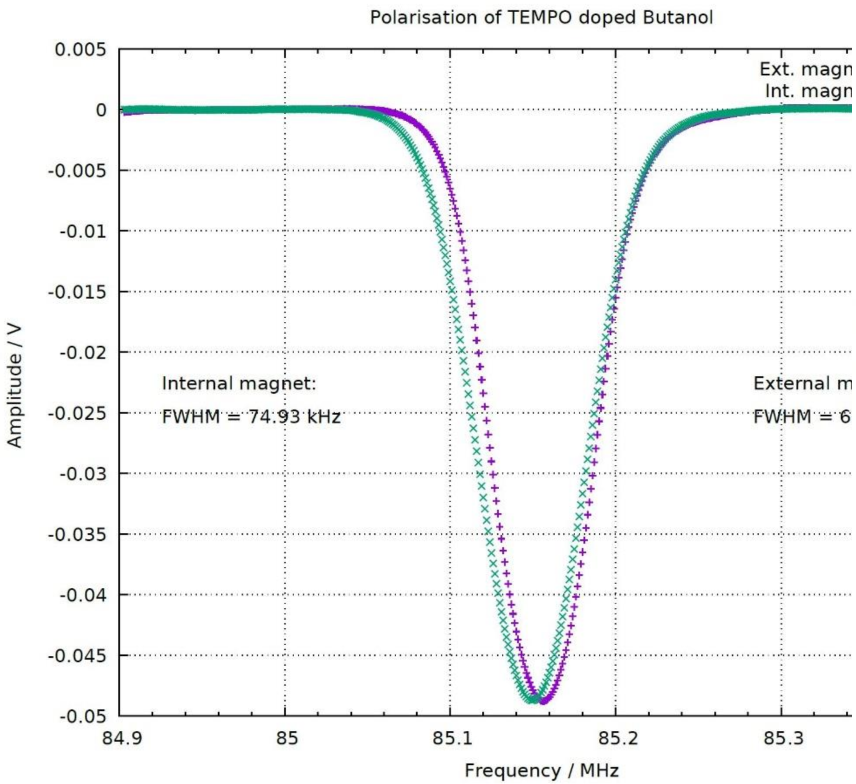

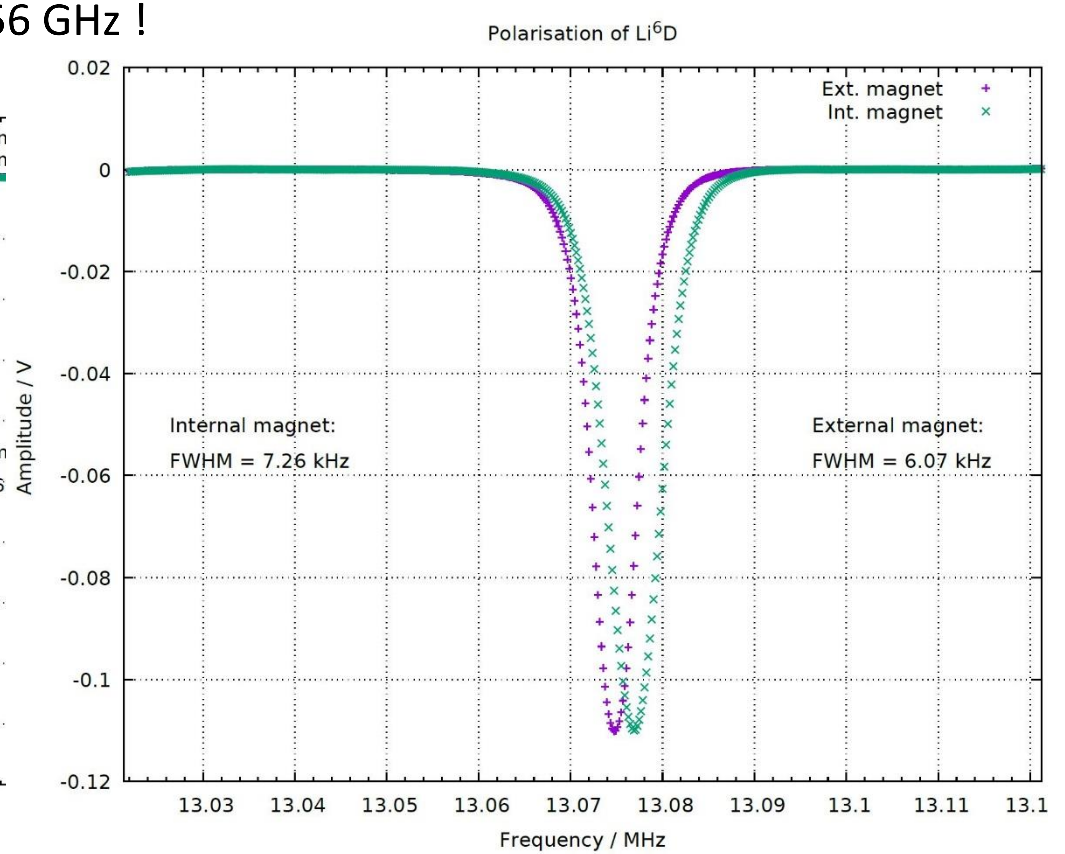

4π-continiuous mode scheme has been proven

Next: 8-layers coil for the new Dubna dilution refrigerator

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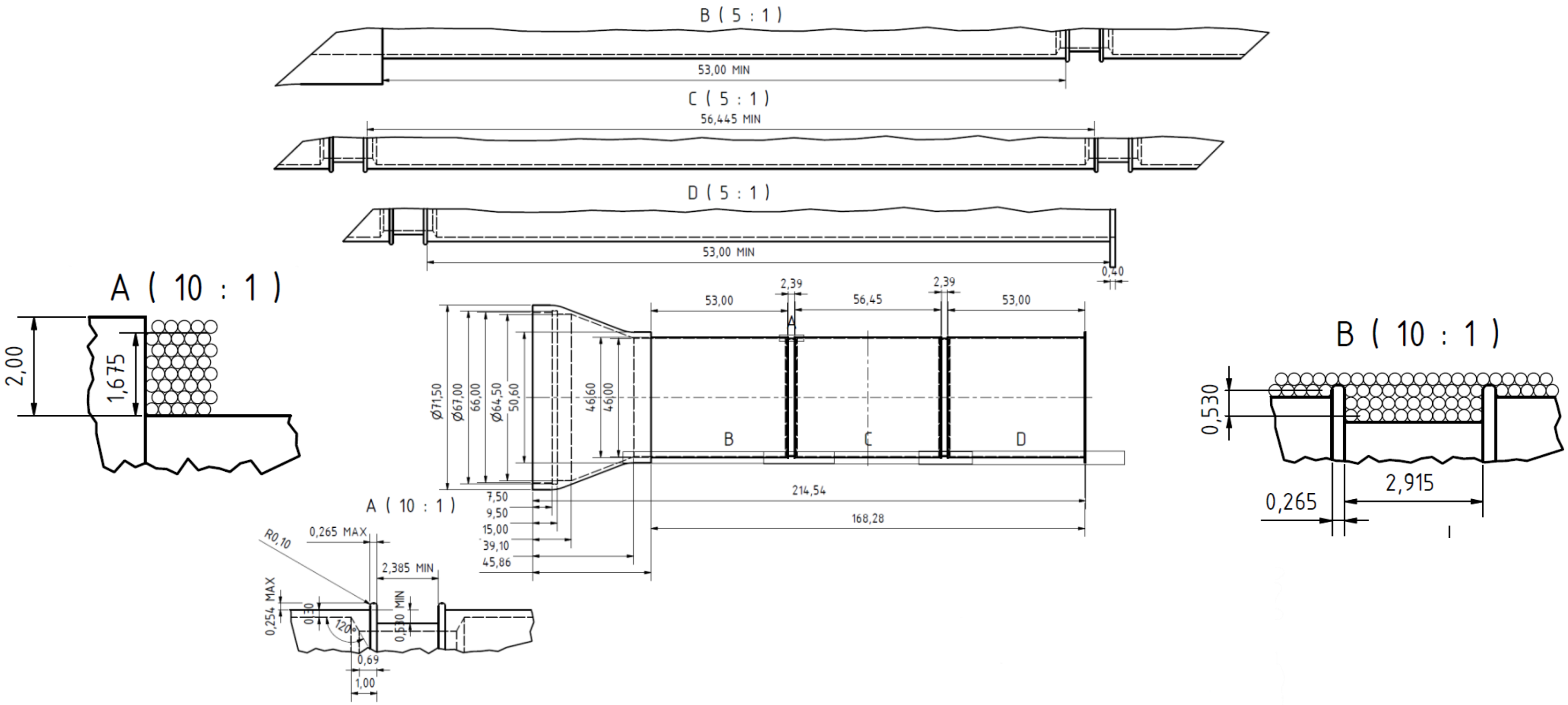
Research Objectives Task1: high field thin s.c. magnets

8 (12)-layers coil for the new Dubna dilution refrigerator is under construction

T_P = 1K!, B_P = 2.5 Tesla @ I_N = 64 A, $F_{\mu w}$ = 70 GHz !



For first double polarization experiments at CB-Detector:

Combined longitudinal and transverse holding coil for the new Dubna dilution refrigerator

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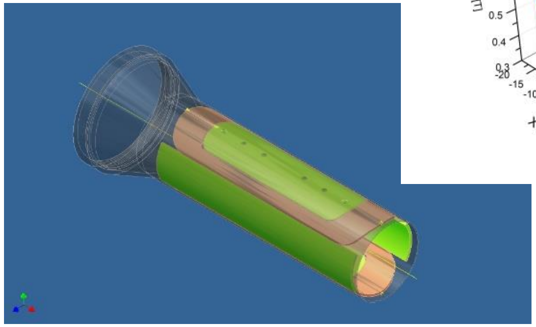
Combined longitudinal and transverse holding coil for the new Dubna dilution refrigerator (Milestone MS64)

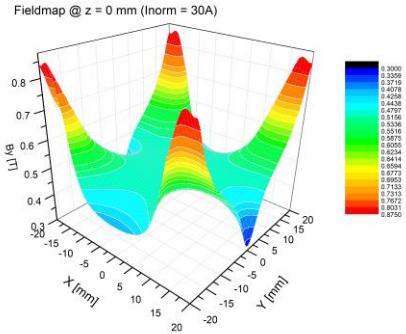
Longitudinal field: solenoid (outside)

- → 4 layers á N590
- → $I_{max} \sim 32$ A
- → $B_{max} \sim 0.52$ T

Transverse field: race track like dipole (inside)

- → 2 x N525
- → $I_{max} \sim 30$ A
- → $B_{max} \sim 0.50$ T





Transverse test coils wound (wet winding process), next: final dipoles

Wet winding of a longitudinal solenoid is a well known technique

For low temperature tests new 1K-test facility is under construction (next talk, Stefan Runkel)

Summary

The final goal is to provide low mass sc. magnets and new target materials for polarized targets operated in a 4π-detection system.

Key technology to improve the polarized target performance:

- increase the luminosity, FoM and availability
- gain to new polarization observables

Scheme has been proven @ 1K, 2 Tesla

With the new refrigerator and the cooperation with
Mainz/Dubna/Bochum PT-groups
we hope to realize the
'4π continuous mode target concept'
for real photon double polarization experiments at ELSA and MAMI
soon