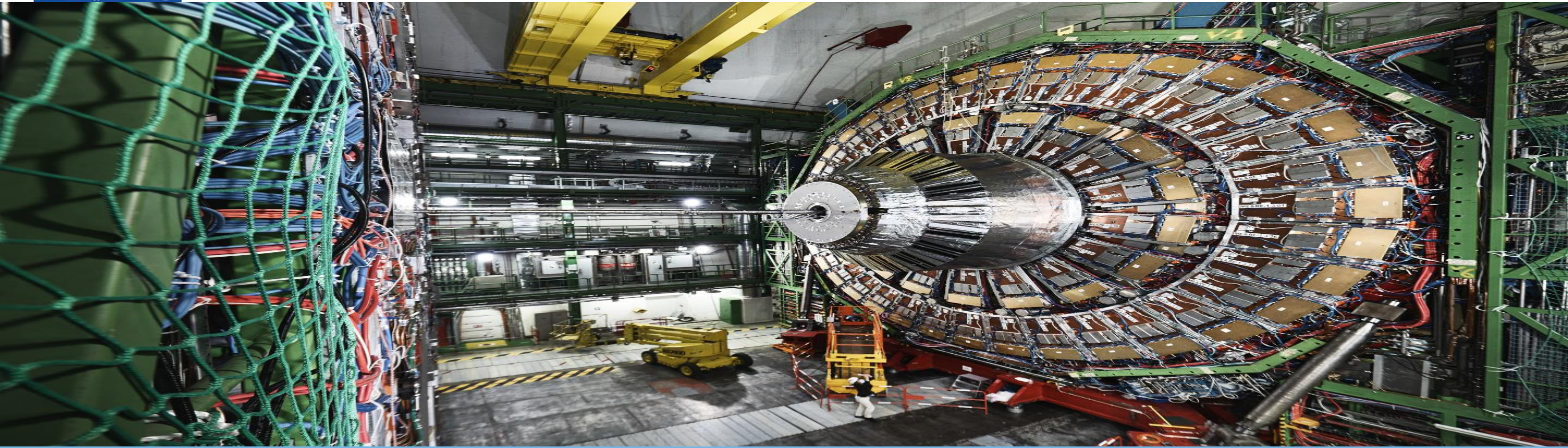


JRA10:CryPTA
Cryogenic Polarized Target Applications

Hartmut Dutz
Physikalisches Institut Universität Bonn

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

JRA10:CryPTA
Cryogenic Polarized Target Applications

Cooperation of four partners

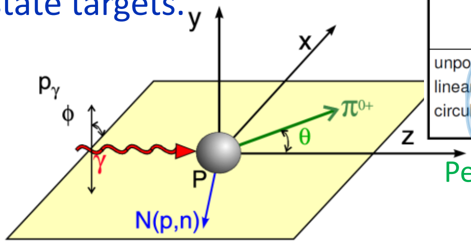
Organization legal name	Short name	Activity leaders
Ruder Boskovic Institute	RBI	M. Korolija
Ruhr-Universität Bochum	RUB	G. Reicherz
Rheinische Friedrich-Wilhelms-Universität Bonn	UBO	H. Dutz
Johannes Gutenberg Universität Mainz	UMainz	A. Thomas

Research Objectives

The final goal of CryPTA is to develop groundbreaking s.c. magnet structures and low temperature detector techniques for new and innovative polarization experiments using polarized targets in 4π-detection systems for hadron physics experiments in Europe

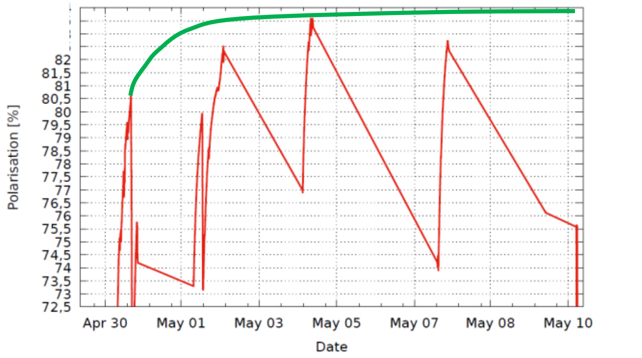
JRA10:CryPTA
Cryogenic Polarized Target Applications

Task 1 **CryPTA:SuperconductingMagnet** for permanent DNP in polarized solid state targets.
Polarization experiments @ ELSA and MAMI (i.e. baryon spectroscopy)
→ Modell independent partial wave analysis, complete experiment



Photon polarization		Target polarization			Recoil nucleon polarization			Target and recoil polarizations			
		X	Y	Z(beam)	X'	Y'	Z'	X' X	X' Z	Z' X	Z' Z
unpolarized	σ	-	T	-	-	P	-	$T_{x'}$	$L_{x'}$	$T_{z'}$	$L_{z'}$
linear	-Σ	H	(-P)	-G	$O_{x'}$	(-T)	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(L_{x'})$	$(-T_{x'})$
circular	-	F	-	-E	$C_{x'}$	-	$C_{z'}$	-	-	-	-

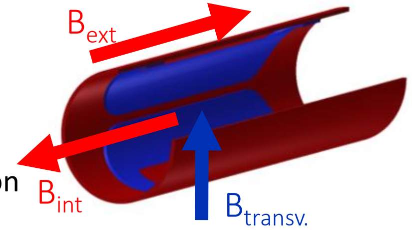
Permanent high dyn. Polarization @ data taking



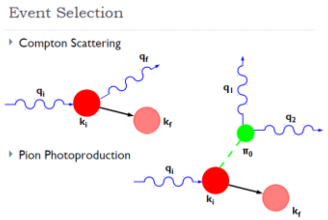
Task 2 **CryPTA:SuperconductingShield** for passive shielding of the PANDA spec. field for transv. polarization

High temperature ScM for passive or active magnetic field shielding for polarization experiments with internal pol. targets @ PANDA.

Imaginary part of time like FF single spin target asymmetry → transverse polarization



Task 3 **CryPTA:ActivePolarizedTarget** materials to detect the recoil proton in-situ, inside the polarized target @ MAMI: Measurements of the Proton Spin-Polarizabilities with Double-Polarized Compton Scattering



Main problems:
- Low energetic recoil protons do not escape from the target and do not reach the detector.
- Events are produced on the background nuclei (Carbon, coherent, incoherent, k~13%).

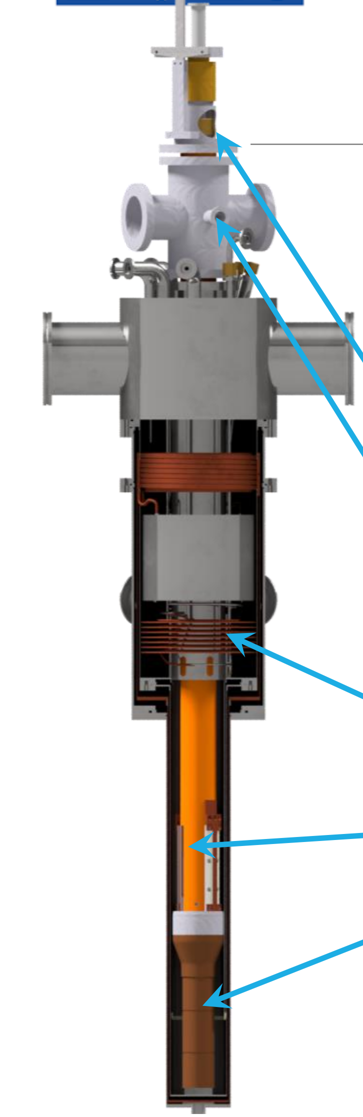
→ detect the recoil proton in-situ, inside a highly polarized target material

JRA10:CryPTA
Cryogenic Polarized Target Applications

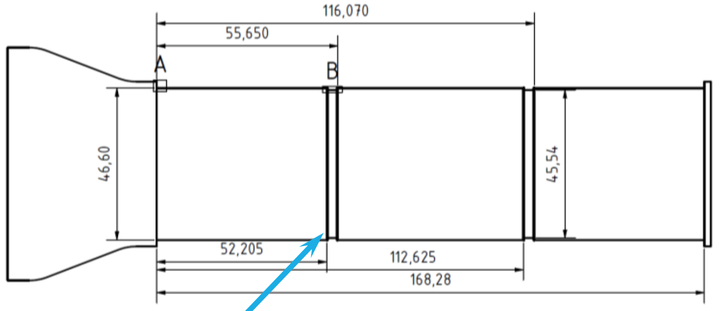
TASKS/Subtasks	Year 1				Year 2				
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
1. Development of low mass superconducting high field magnets									
1.1 High precision winding machine for thin superconducting wires			1						
1.2 Manufacture and test of a small size low mass polarizing solenoid with high homogeneity									
1.3 Design manufacture and cold test of a prototype low mass, combined field superconducting magnet system									2
1.4 Magnet field design studies for a low mass large sc. tracking solenoid									
2. Development of low mass superconducting passive shielding									
2.1 Magnet field calculations for PANDA low mass superconducting passive shielding									3
2.2 Design and Manufacture of prototype HTSC shields and test at cryogenic temperatures									
3. Detection of recoil particles in active polarized targets at cryogenic temperatures									
3.1 Design studies for polarized, scintillating target material									
3.2 Prototypes of a scintillating target stacks with electronic readout									4
3.3 Prototype of a new cryogenic insert with active target material									

JRA10:CryPTA:Task 1

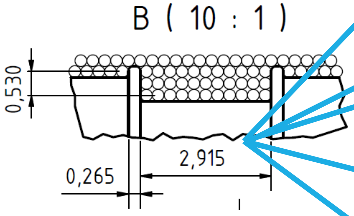
1.2 Manufacture and test of a small size low mass polarizing solenoid with high homogeneity



- → Small superconducting magnet designed and build for DNP (2.5 T) in a dilution refrigerator will be wound soon on the new winding machine.
  - → N=5116, 8 Layers, 2.5T @ 68.6A/1K, thickness 2.4 mm



- → New ^4He evaporation refrigerator as simple 1K test facility for superconducting magnets is under construction
  - → Fits into the external high field DNP-magnet (B_{max} = 6.5T)
  - → Field measurement (mapping) by pulsed-, cw-NMR, Hall-probe
  - → Equipped for DNP (50 – 140 GHz)
  - → Variable temperature range (1K – 70K)
  - → Flexible and open access via insert tube
  - → Large low temperature volume for magnet tests (500 mm x ∅75 mm, 2.2l)

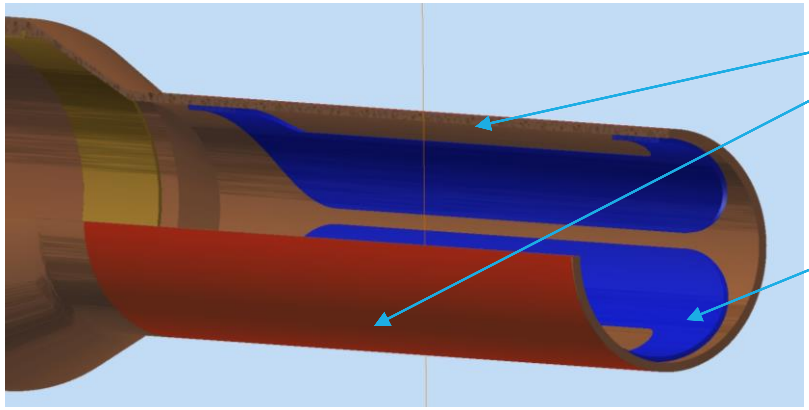


- → New magnet has to be tested under nominal conditions (1K).
- → 1K test facility will be available first half next year

JRA10:CryPTA:Task 1

1.3 Design, manufacture and cold test of a prototype low mass combined field superconducting magnet system

Combined longitudinal and transverse holding coil for the new dilution refrigerator for a variable polarization direction in plane (Milestone MS64)



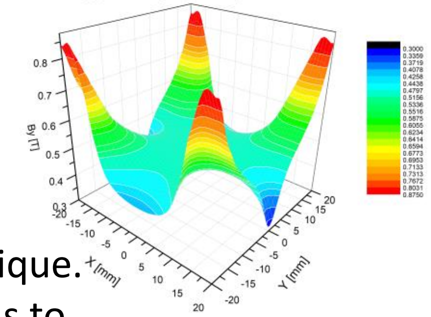
Cu-support (cooling)

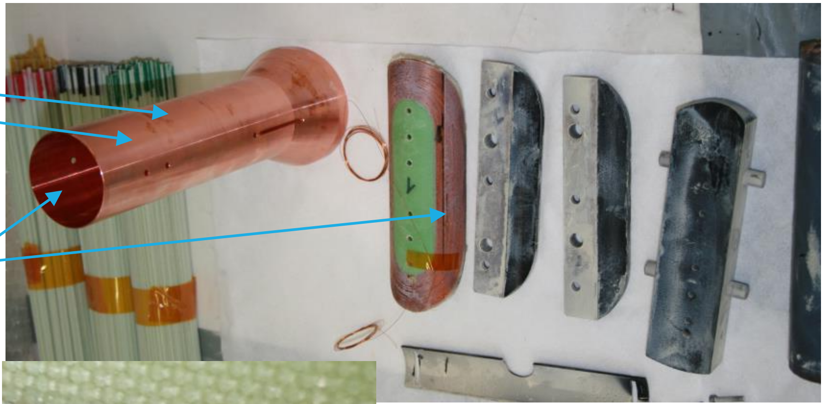
Longitudinal field: solenoid (outside)

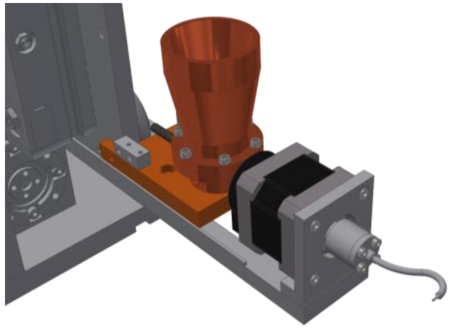
- → 4 layers á N590
- → I_{max} ~ 32 A
- → B_{max} ~ 0.52 T

Transverse field: race track like dipole (inside)

- → 2 x N525
- → I_{max} ~ 30 A
- → B_{max} ~ 0.50 T





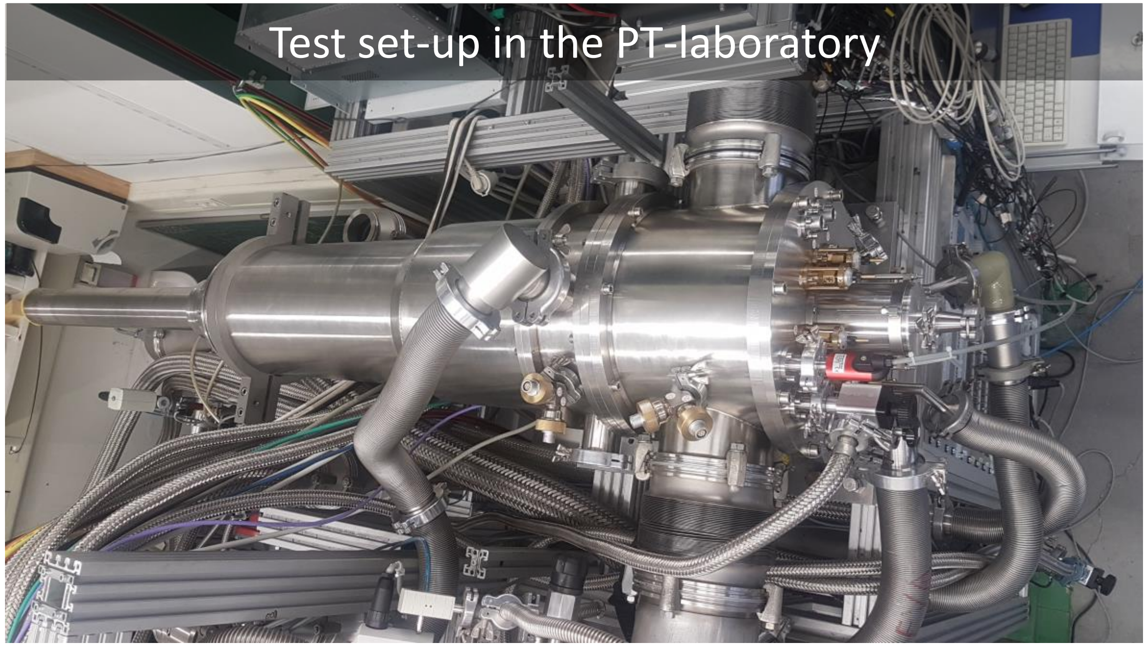


- → Precision wet winding of a solenoid is a well established technique.
- → Wet winding of race tracks with thin superconducting wires has to be improved to guaranty high performance at minimum thickness
- → Problem: inhomogeneous glue distribution within the coil package
- → New wire feeding device is under construction

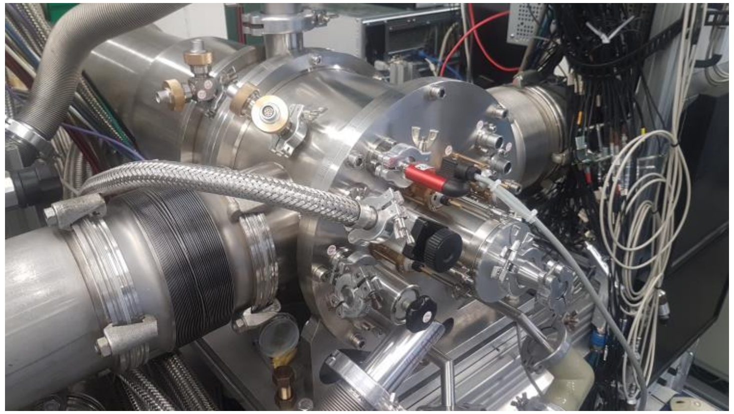
JRA10:CryPTA:Task 1

1.3 Design, manufacture and cold test of a prototype low mass combined field superconducting magnet system

New horizontal dilution refrigerator for polarization experiments with Crystal Barrel detector @ ELSA
Build by cryogenic department of JINR (Dubna)



Central beam line
Target insert for fast and easy target exchange
Designed for various magnet configurations
→ T_{min} < 30 mK , TDNP ~ 250 mK
→ I_{max} ~ 40 A

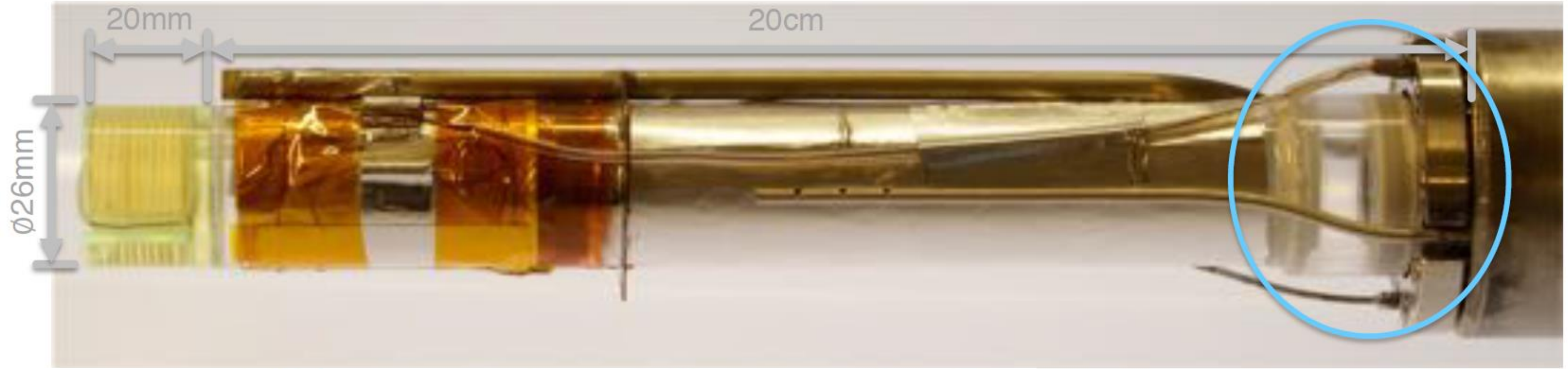


→ Delivered fall 2020, assembled and first 1K tests this summer, commissioning in spring 2022
→ First polarization experiment @ ELSA planned for fall 2022 using the combined sc.coil configuration
→ Foreseen for pol. experiments using active polarized target technology

JRA10:CryPTA:Task 3

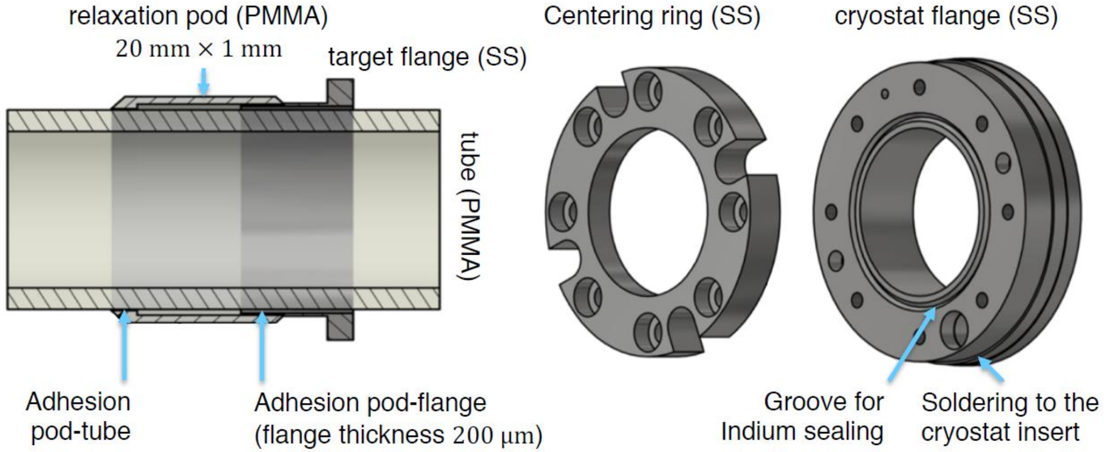
3.1 Design studies for polarized, scintillating target material

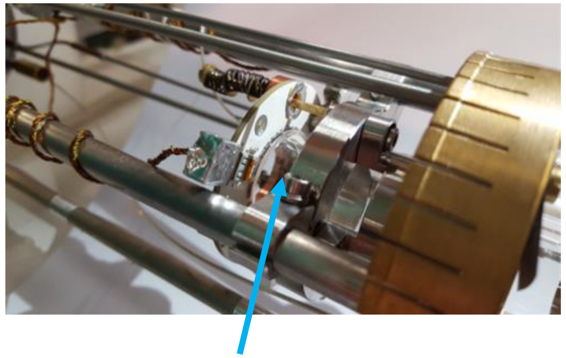
New ideas for a readout with optical fibers have been investigated and further developed in the framework of the finished PhD work of M.Biroth.
He has been engaged using EU funding in the period 4-9/2021 to proceed the conception of the system.



1st problem of the prototype:

The transverse integral thermal expansion of PMMA and stainless steel (SS) differs by a factor of six. This has to be compensated by a relaxation pod, which takes the stress from the tube-flange connection.



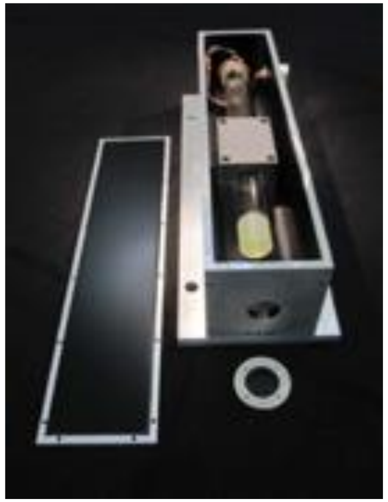


2nd problem of the prototype:

The longitudinal thermal expansion of ~1% of the 1.5 m PMMA tube
has to be compensated at the detector board holder by springs.

JRA10:CryPTA:Task 3

3.2 Prototypes of a scintillating target stack with electronic readout



Prototypes for an readout with optical fibres have been investigated.

Advantages:

- Better light coupling and transport.
- A semi active design using Butanol with better dilution factor becomes possible. D-Butanol is another option.
- Thermal expansion can be partially compensated.

Flange and tube (SS)

Scintillating head with fiber readout

Butanol container (PTFE)

→ the preparation of an improved target insert with optical fiber readout is on the way

JRA10:CryPTA
Deliverables and milestones

List of Milestones in the reporting period

Milestone number	Milestone name	Lead beneficiary	Delivery month from Annex I	Delivered (yes/no)	Actual delivery month	Comments
MS64	Design concept of a low mass, combined field superconducting magnet system	10 – UBO	27	yes	29	A detailed description of the milestone will be available on: https://www.polarisiertes-target.physik.uni-bonn.de/startseite/strong-2020/status-und-eckpunktberichte
MS65	Magnet field calculations for PANDA low mass superconducting passive shielding	10 – UBO	27	yes	27	
MS66	Manufacture of prototype active targets for in beam tests	10 – UBO	27	yes	27	

No Deliverables in the reporting period

→ CryPTA annual meeting 2021, June 24th : https://www.polarisiertes-target.physik.uni-bonn.de/startseite/strong-2020/status-und-eckpunktberichte/statusberichte/crypta-jahrestreffen-2021

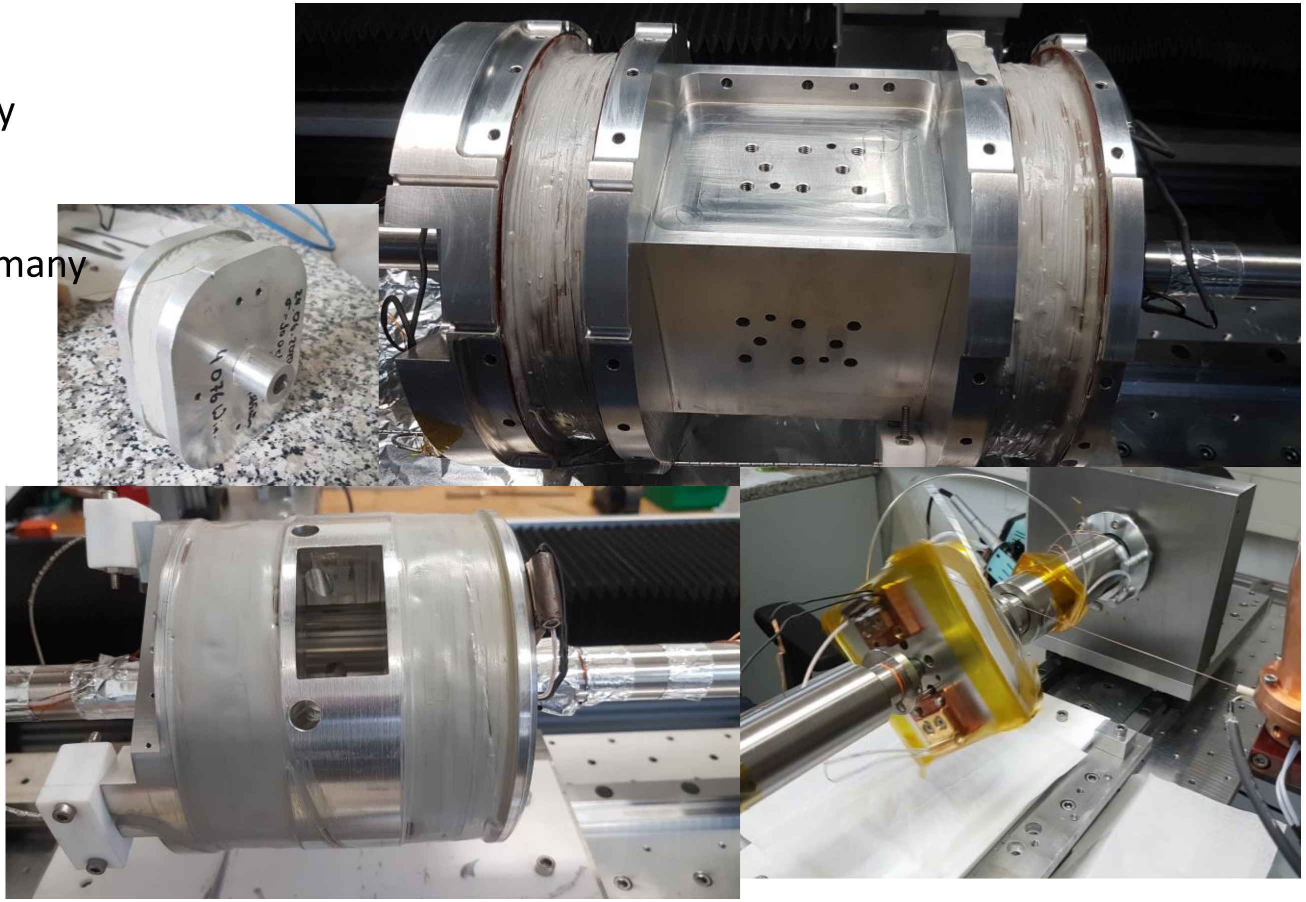
→ CryPTA workshop planed for spring 2022 in Croatia (RBI)

JRA10:CryPTA:Task 1

Outreach / Technology transfer to SME

The design and construction of small sc-magnets using thin sc-wires leads to a new type of sc-magnets for UHV applications

- → Wet winding process of thin sc-wires is the key technology
- → High field, low current, indirect cooled (dry cooling), bakeable and UHV qualified magnet for RTMs
- → Collaborative research program with CryoVac GmbH, Germany funded by BMWi (ZIM)
- → Wet winding of a one component epoxy resin
- → Winding and curing in one process
- → Classical and 3D magnet geometries for UHV-RTMs



Good example for successful technology transfer from a hadron physics project to new commercial products

JRA10:CryPTA
Conclusions / Outlook

Research Objectives

The final goal of CryPTA is to develop groundbreaking s.c. magnet structures and low temperature detector techniques for new and innovative polarization experiments using polarized targets in 4π-detection systems for hadron physics experiments in Europe

Despite the currently unfavorable circumstances: the 3 Tasks are (up to now) on the right track

Task 1: → completing the small size low mass polarizing solenoid with high homogeneity and commissioning of the magnet test refrigerator.
→ preparing a combined magnet for the new dilution refrigerator and the near future (2022) data taking campaign.
Task 2: → Magnet field calculations for PANDA low mass superconducting passive shielding has been successfully completed.
Task 3: → detailed design concepts for low temperature polarized active targets are defined.
→ the preparation of an improved target insert with optical fiber readout is on the way .

But: Corona is affecting more and more the work and progress of JRA10
So: lets hope the best

More information about CryPTA: https://www.polarisiertes-target.physik.uni-bonn.de/startseite/strong-2020/