A facility for testing bulk superconducting MgB_2 cylinder

for the production of holding magnetic fields for polarized targets and nuclear fusion fuels

Giuseppe Ciullo

INFN-Ferrara & University of Ferrara

Interest on Bulk Superconducting material :

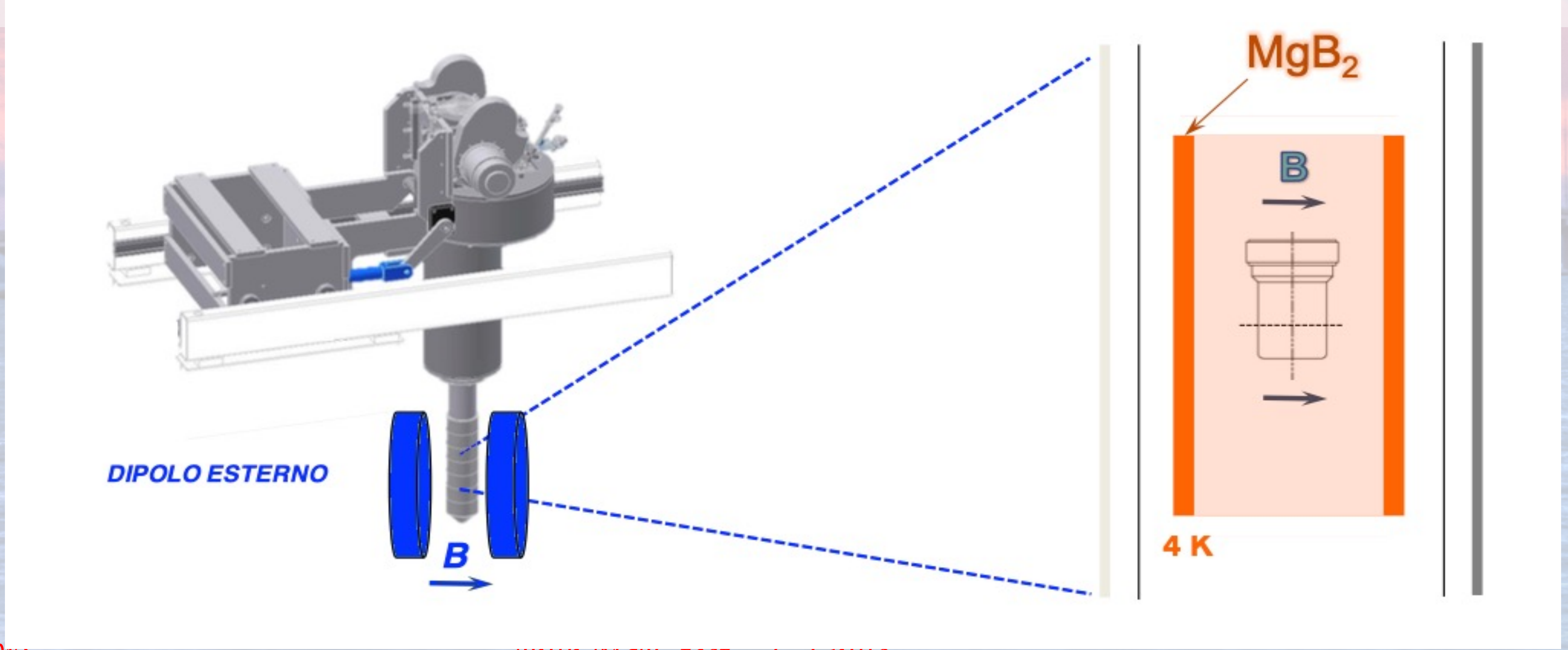
in polarized nuclear targets a magnetic holding field is required, nuclear targets might feel detector fields, influencing the polarization axis.

We are interested in fundamental studies on the orientation between projectiles and targets: indipendent fields and shielding of the surrounding fields are required.

We are around the interaction point, then we look for low thickness of material, low Z, reducing, or avoiding, material for powering, transportability from the preparation laboratory to the experimental site.

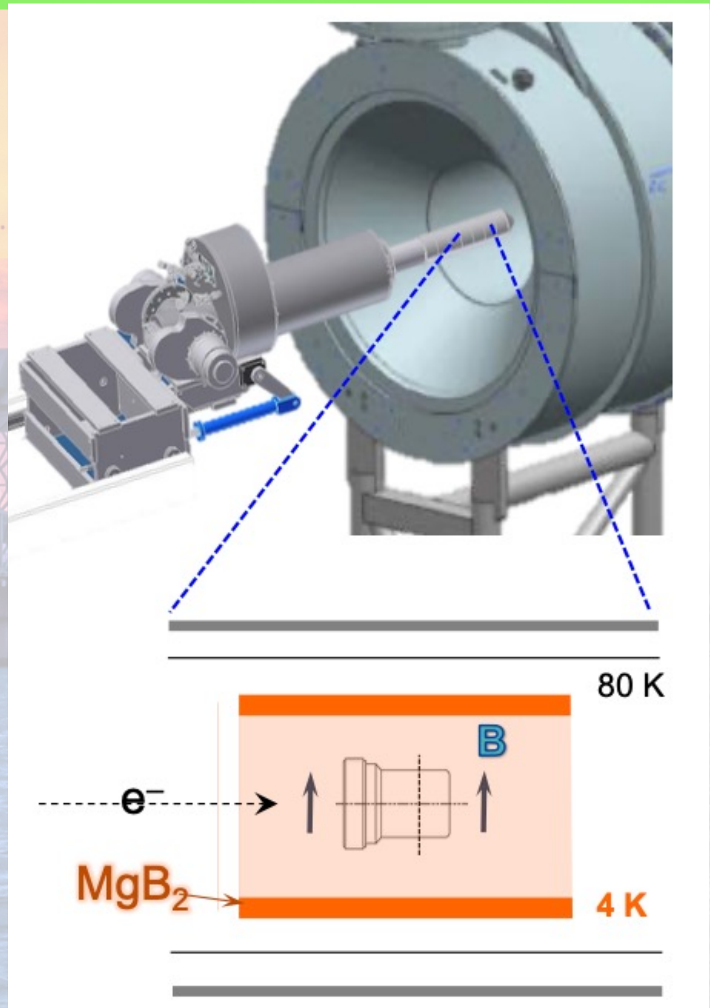
Outline of the idea for
nuclear polarized target CLAS12-type

- *Choose a MgB_2 S.C. cylinder surrounding the target.*
- *Set an outer transverse field.*
- *Cool down the S.C. Cylinder in the IBC (In Beam Cryostat) at 4 K*
- *Ramp down the outer magnetic field.*
- *The perfect diamagnetism of the S.C. MgB_2 generates self supercurrents, which mantain the seen field inside the cylinder.*

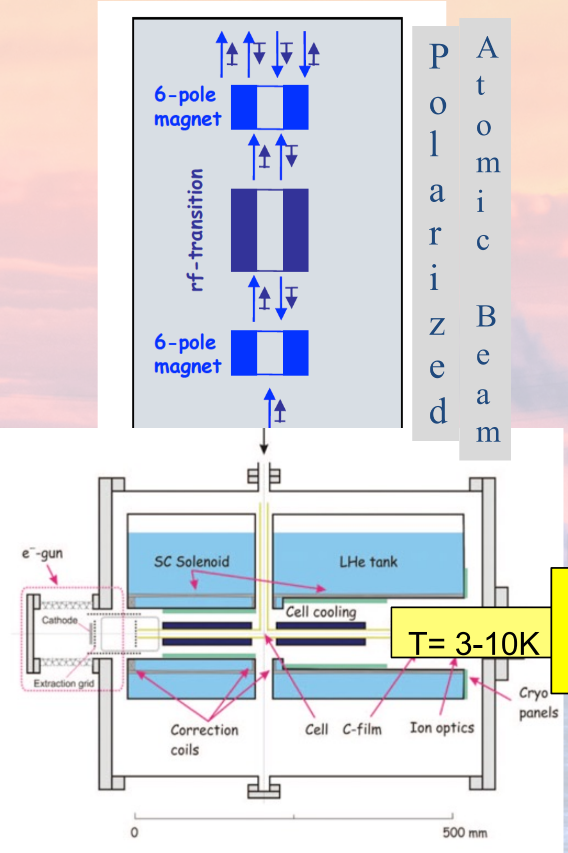


Moving to experimental or test sites

- IBC (In Beam Cryostat) can be moved and inserted in CLAS-12.
- In case of increasing of CLAS-12 field: supplementary self supercurrents in the MgB_2 will mantain the transverse field.
- Everything without any power supply and corrent leads, or coils, in the surrounding.

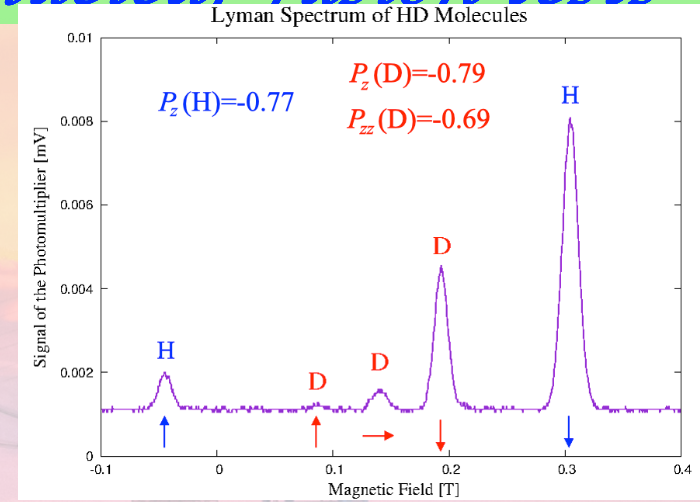


Outline of the Idea for
Polarized Fuel for nuclear fusion tests



Cold Head

Recombinig Polarized Atoms in hyperpol. molecules



Cold Head with an MgB_2 cylinder providing a holding field, in this case it will parasitically mantain the solenoidal field of the recombination chamber. The cylinder hosts inside substrate for condensation and it will be useful for transportation for fusion studies and tests.

... our starting point for faisibility study is a magnetic field of 1 T.

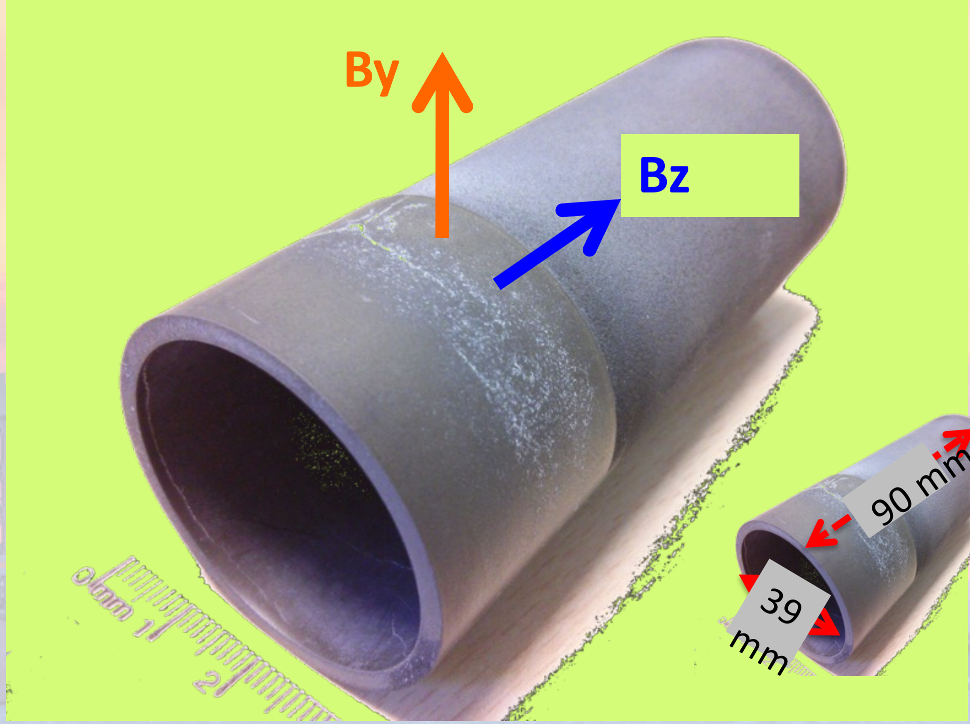
The compact «self» magnet

Cylinder

MgB_2

Shielding longitudinal fields

Mantaining transverse fields.



M. Statera et al. (2015). IEEE Tr Appl. S:C., vol. 115(3): 1 - DOI: 10.1109/TASC.2015.2388855

Available Waste Material Machinable (G. Giunchi)
diameter 39 mm - length 90 mm
thickness ~1 mm

Advantages

No Power feeding
No Copper and Coils
Auto tuning
Semplicity
Low cost of production
few mm of thickness
External Magnet

Production of MgB_2

➢ *Discovered 2001 (J.Nagamatsu [1] Nature 410(2001) 63).*

Different techinques of production:

- *Japanese scientists: high pressure sintering – HIP (Hot Isostatic Pressing)[1] or UHP (Uniaxial Hot Pressing).*
- *American Scientists: Mg vapor sintering of B fibers [2]*
- *Italian Scientists: Mg Reactive Liquid Infiltration [3]*

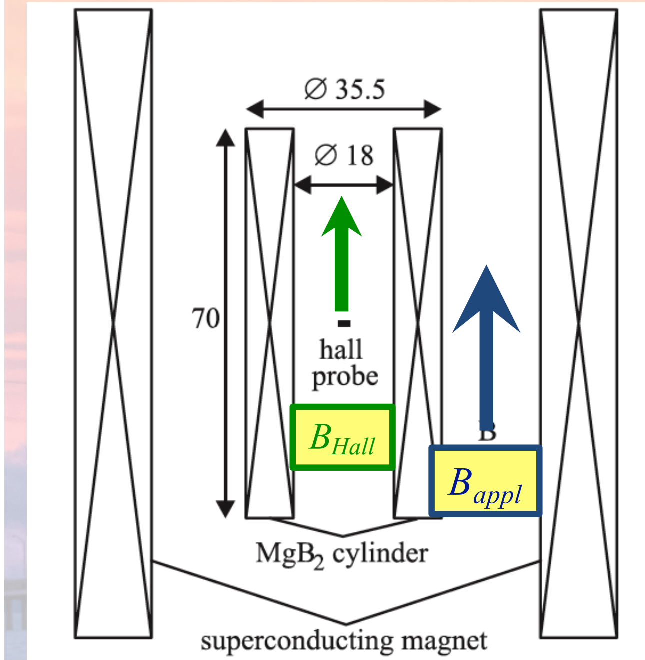
(Italian Patent Edison Spa pat., G. Giunchi, S.Ceresara 2001)

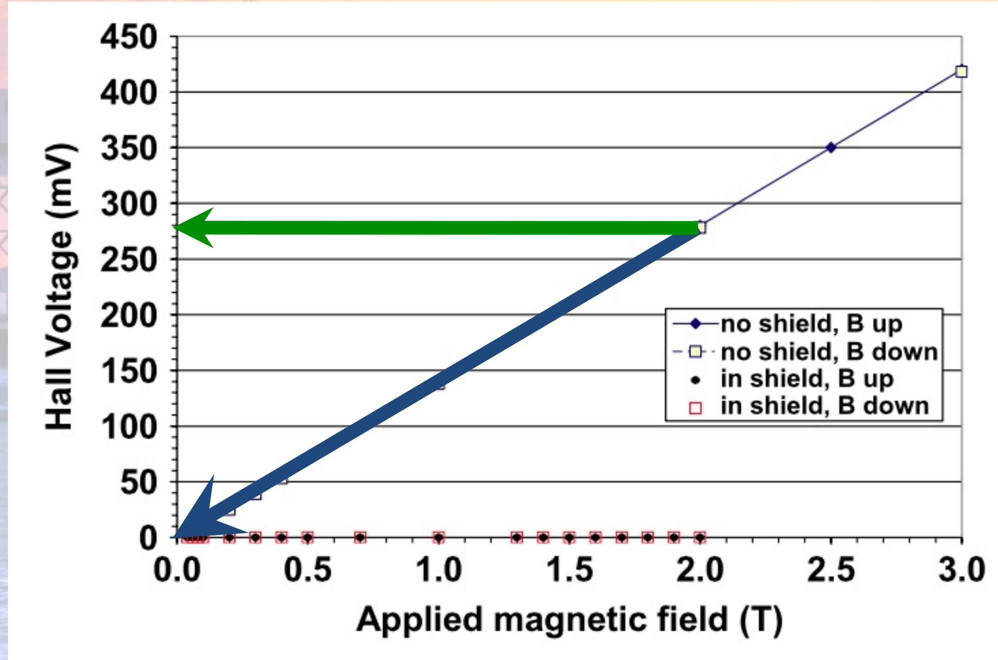
[1] J.Nagamatsu et al. Nature **410** (2001) 63.
[2] P.C. Canfield et al. PRL 86 (2001) 2423].
[3] G. Giunchi et al. Int. J.Mod.Physics B 17 (2003) 453.

Available Waste Material Machinable
(G. Giunchi)
diameter 39 mm - length 90 mm
thickness ~1 mm

Field Cooling - Field Trapping

Field Cooling (FC), early cooling with applied field of 2 T, lowering down the applied field B_{appl} , B_{hall} measures the self field.



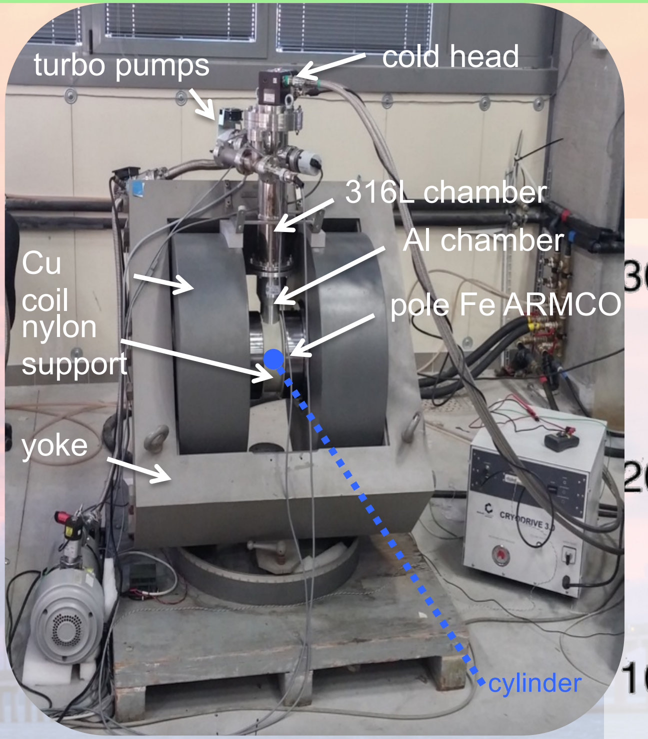


P100 MgB_2 L = 70 mm
R_{ext}=17.75 mm, R_{int}=9 mm

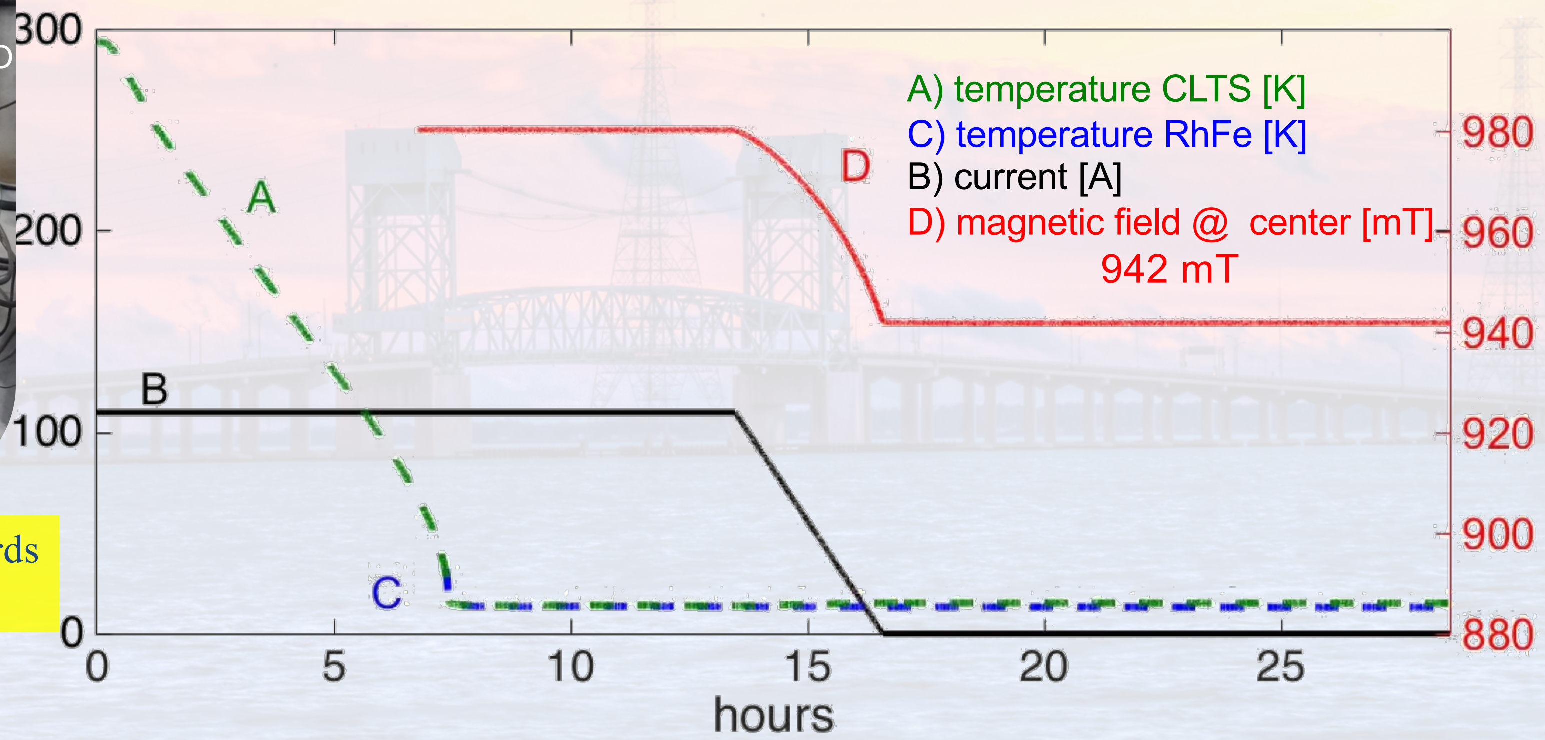
J. J. Rabbers et al. "Magnetic shielding capability of MgB2 cylinders" Supercond. Sci. Technol. Vol. **23**, 2010

Field Trapping (Field Cooling)

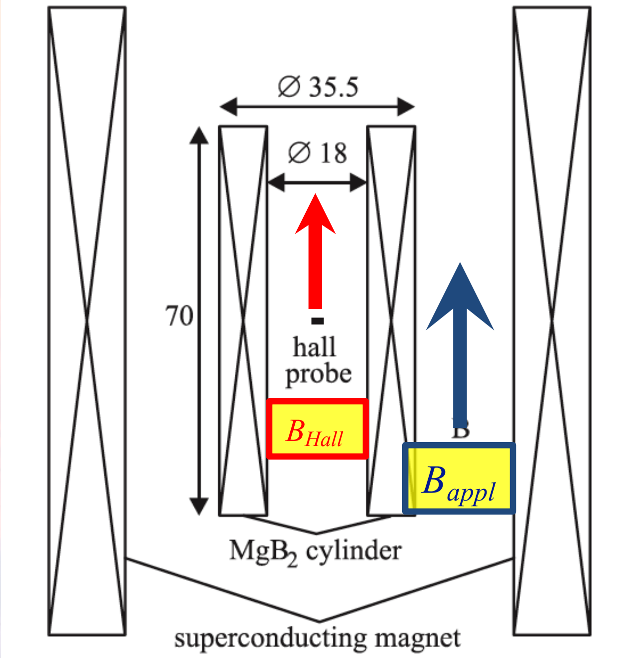
7.5 hours to cool down from RT to 13 K
Field trapping after more than 12 h (thermal homogeneity?)
Low Temperature 13 K
Ramp down of the current feeding the magnet: : 0.25 A/4 s (0.06 A/s)

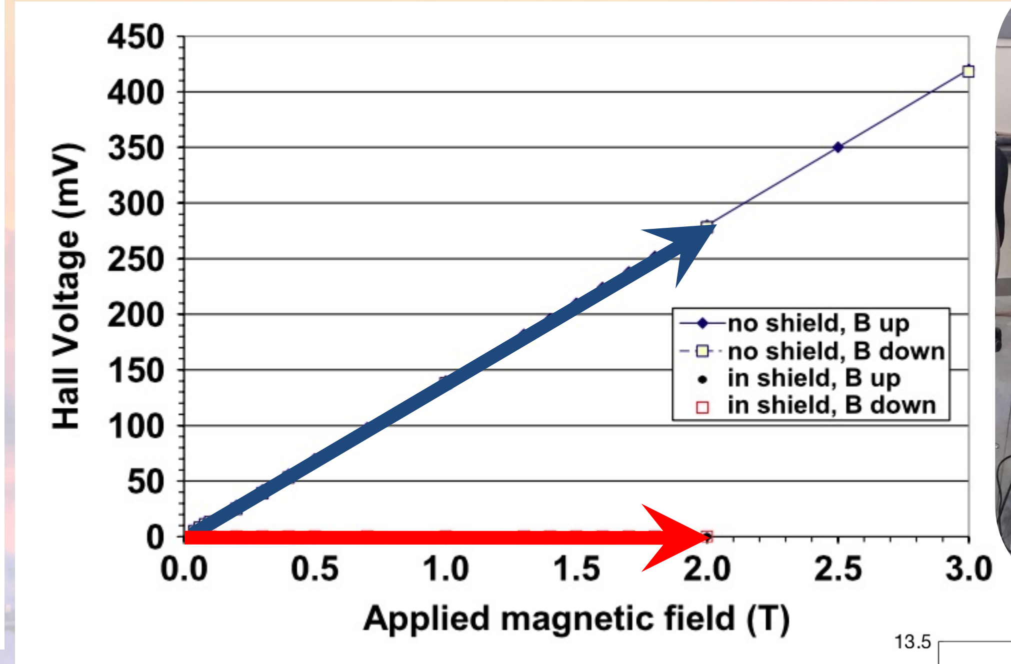


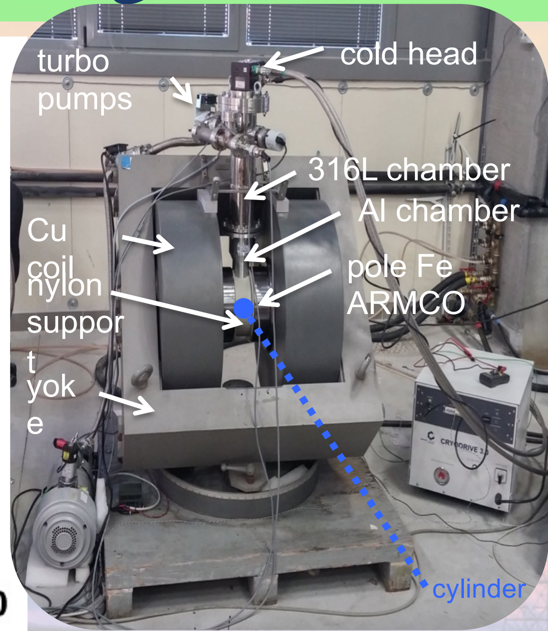
Feasibility studies with oxford-Edwards cold head 6/30

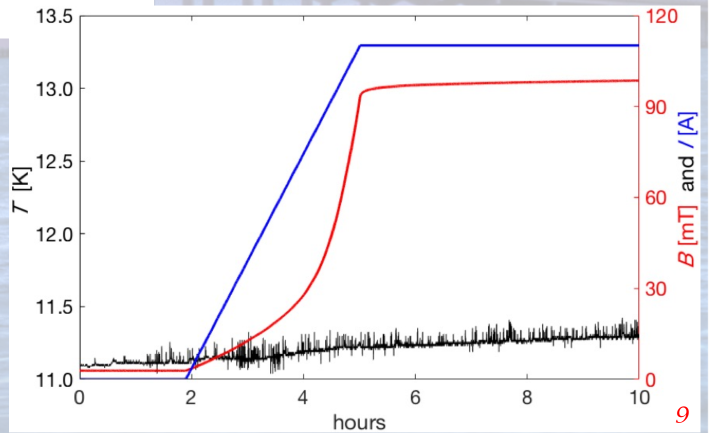


Zero Field Cooling or shielding









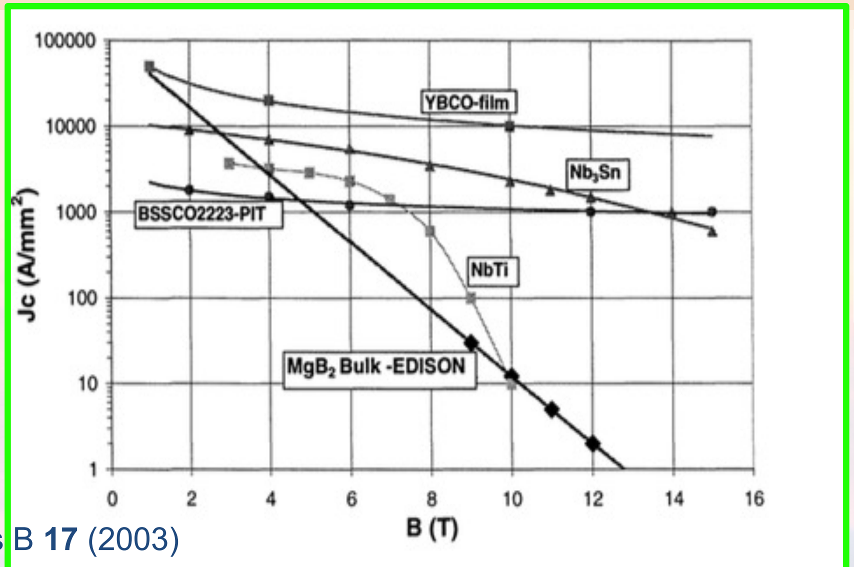
Zero Field Cooling (ZFC)

early cooling without external field, increasing up the applied field, B_{appl}, B_{Hall} provides the penetrated fields.

J. J. Rabbers et al. Supercond. Sci. Technol. **23** (2010) 125003.

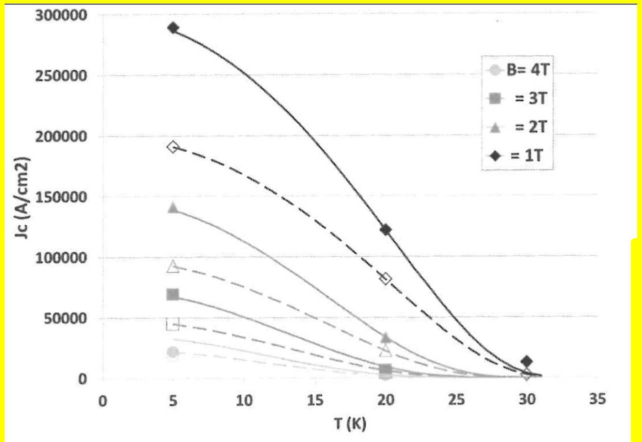
MgB_2

- Low Z
  Cheapper than LTS and HTS
  Machinable: spark erosion and diamond tools



For the condition of
HD-ice at 4 K
Current density
$J_c \geq 10\,000$ A mm^{-2}
(extrapolated)

G. Giunchi Internationl Journal of modern Physics B **17** (2003)



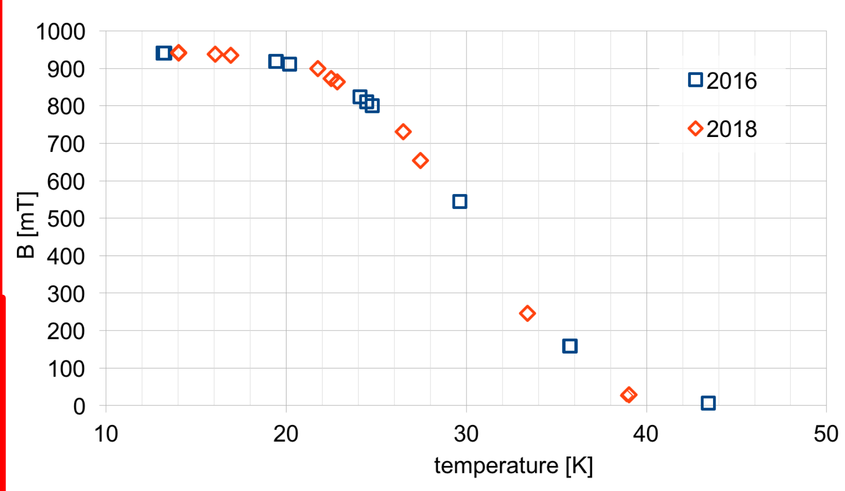
To be conservative we assumed
for our preliminary studies
$J_c \geq 1\,000$ A mm^{-2}

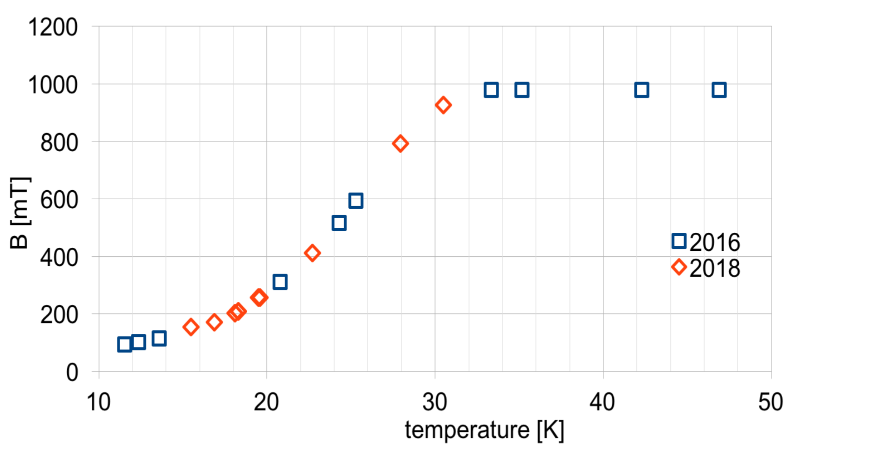
J_c experimental data for
SG (Small Grain size) continuous
and LG (Large Grain size) dashed line

T Characterization in the feasibility study

Trapping Field (Field Cooling)

Evidence of T_c = 39.5 K
Good Performance @ T < 20 K
Good Reproducibility

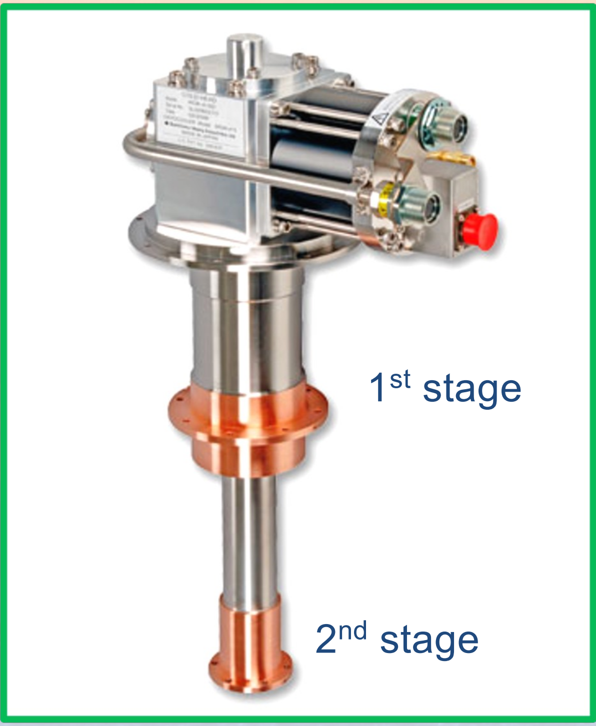




More sensitive to T
Good performance at lower T
Reproducibility after many thermal cycles, quenches or flux jumps, opening of system and change of thermal insulation materials
(2016 vs 2018)

Shielding
Zero Field Cooling

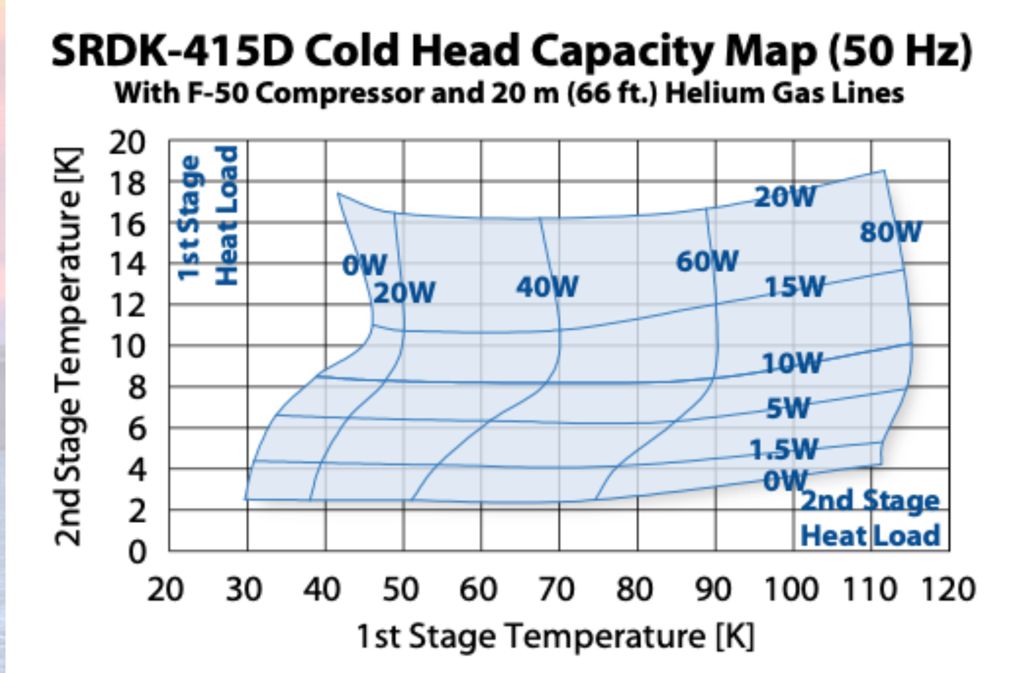
New cold head (on loan from FZJ –R. Engels)



RDK-415D Sumitomo (SHI Cryogenics Group):

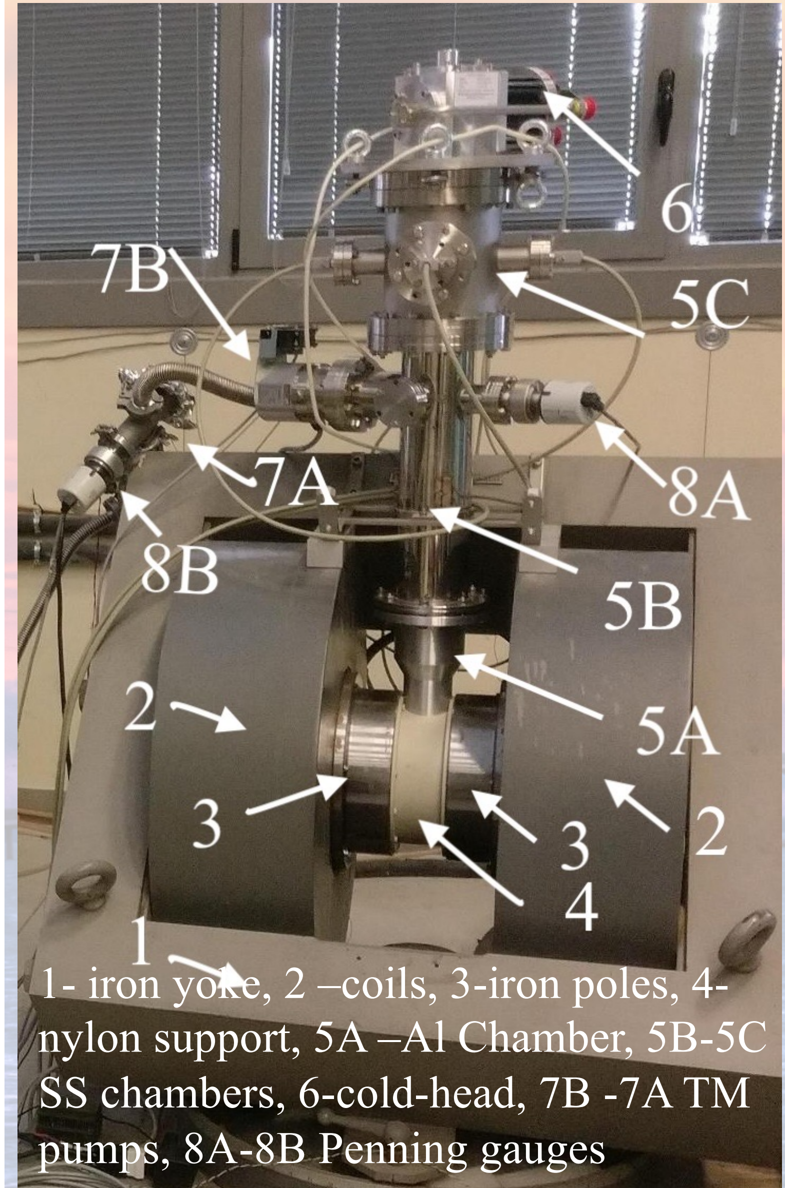
1st stage 35 W @ 50 K ,2nd stage 1.5 W @ 4.2 K

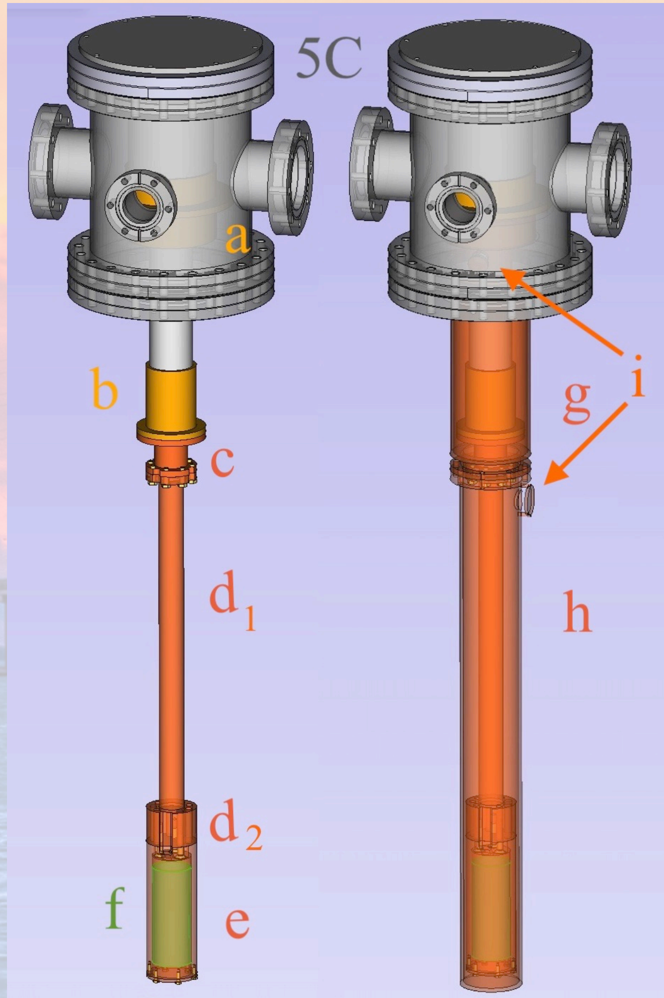
(previous: 30 W @ 77 K, 6 W @ 10 K) .

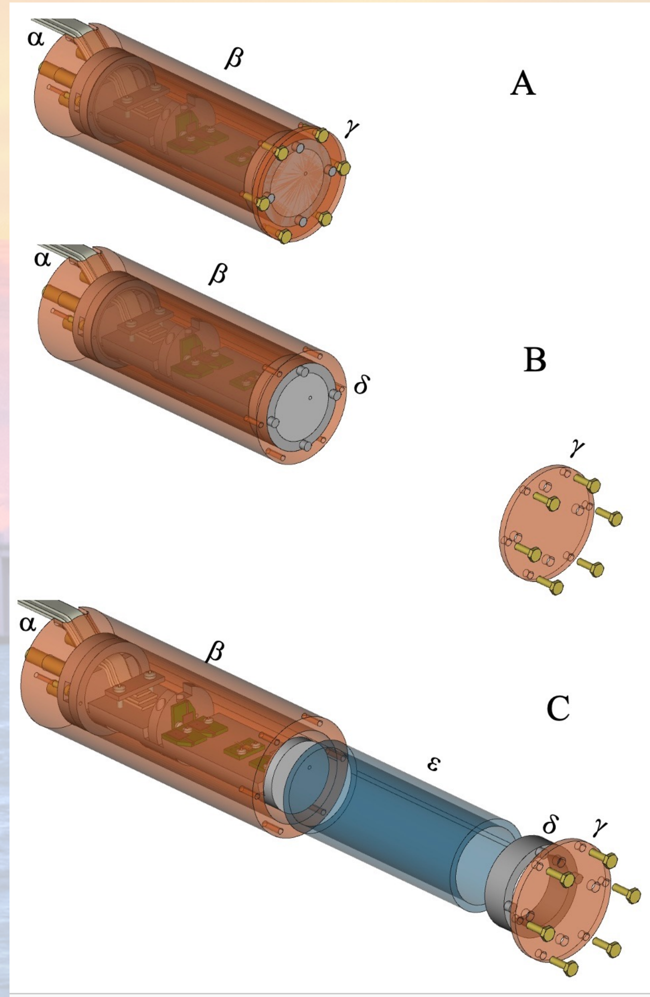


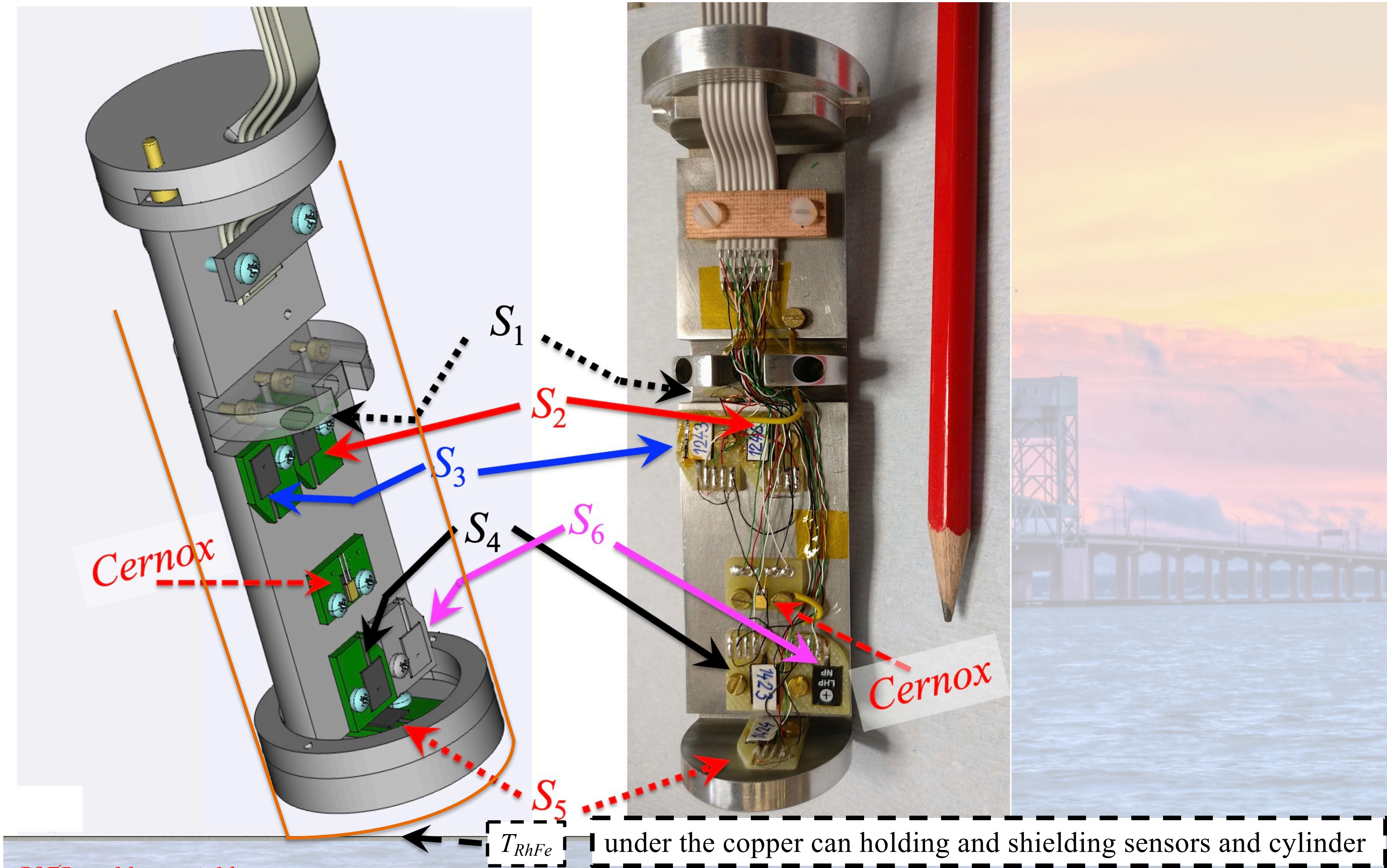
Better thermal stability and lower themperature

Upgraded system @ FE

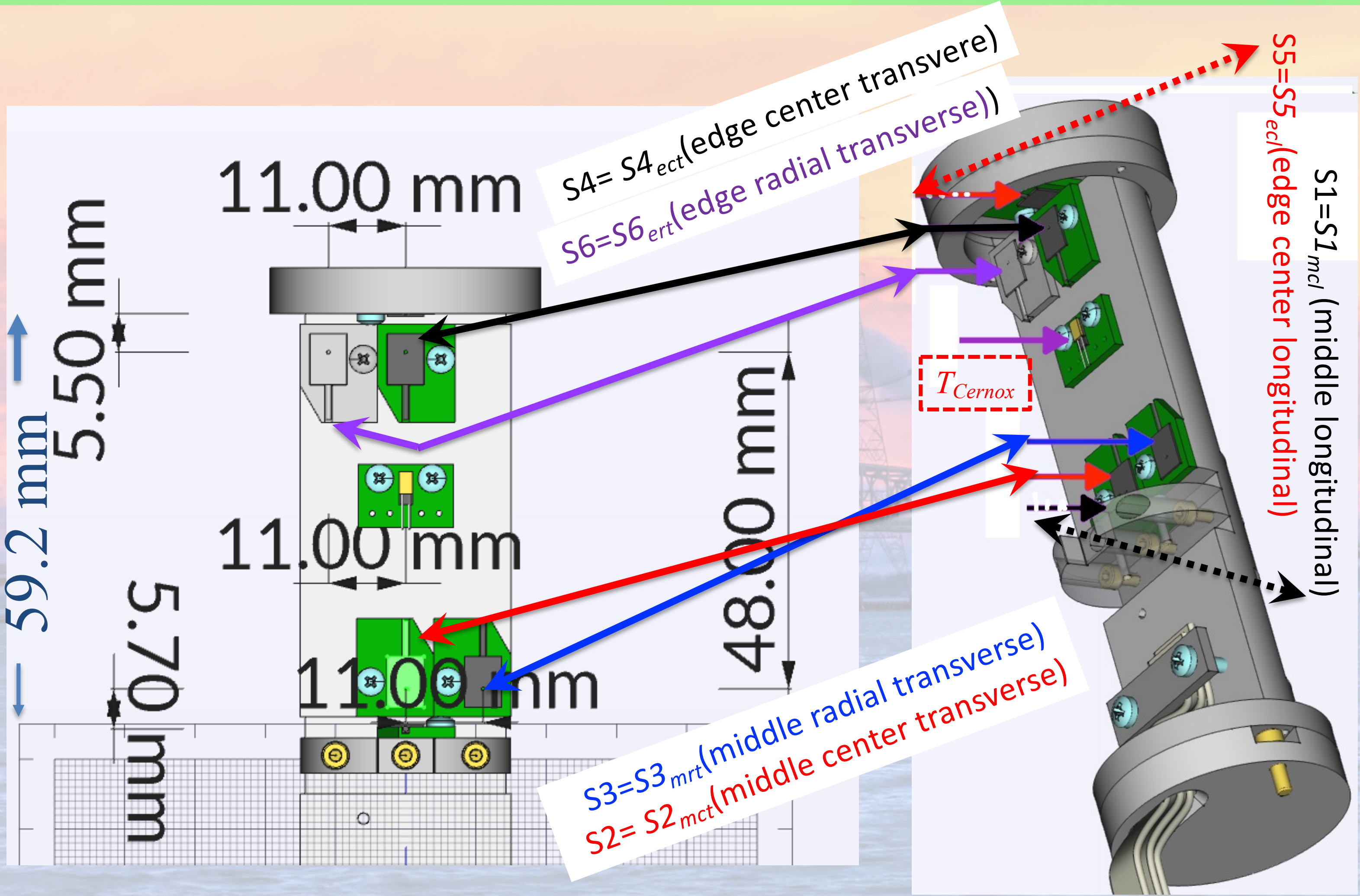






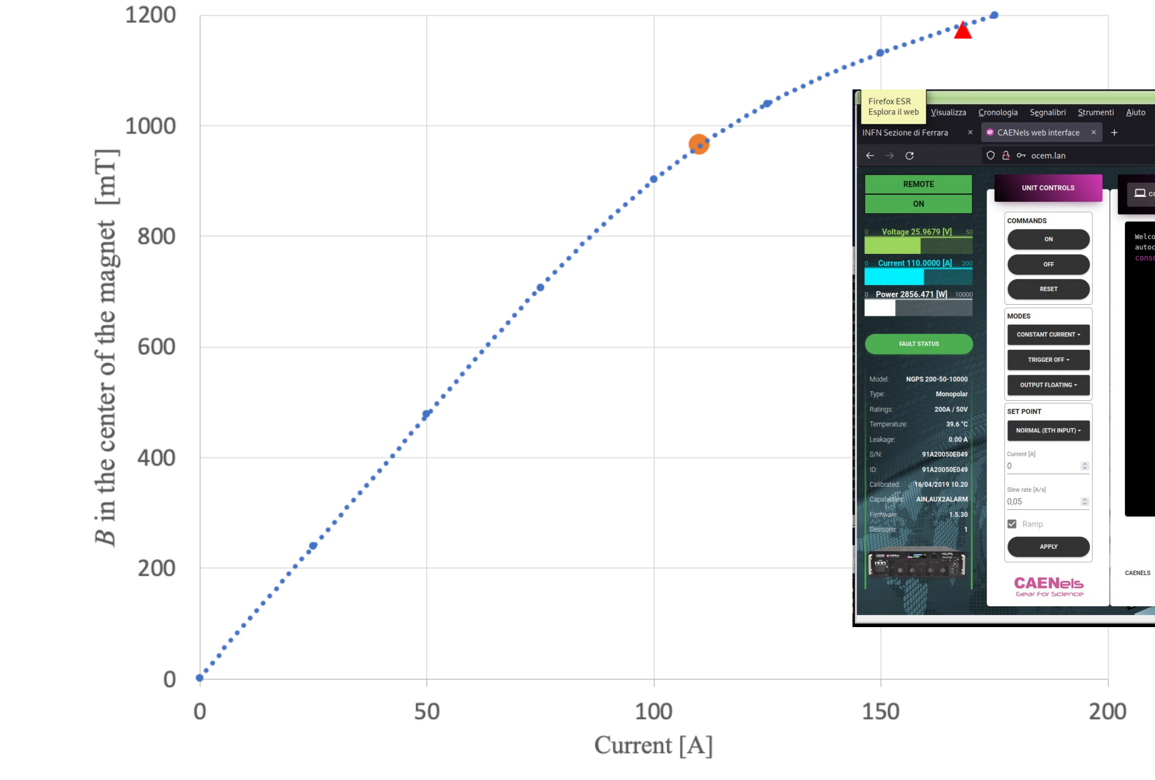

S1
S2
S3
S4
S6
S5
Cernox
Cernox
1243
1245
1423
LHP NP
T_RhFe
under the copper can holding and shielding sensors and cylinder

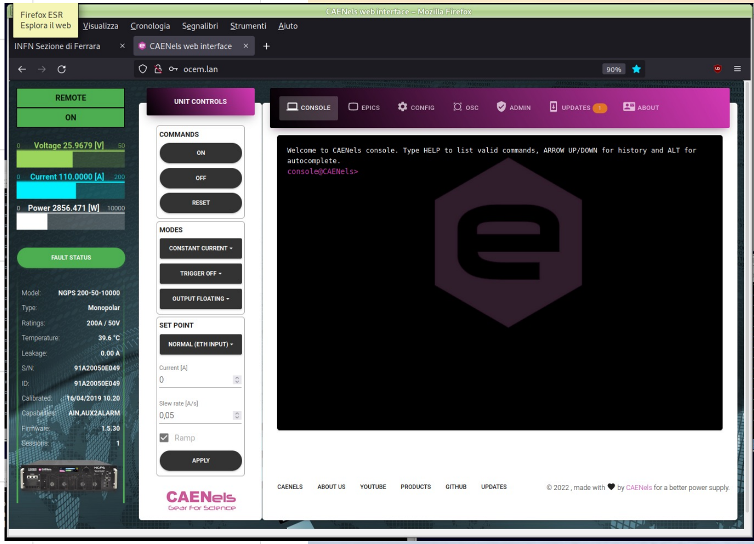
Locations of the transv. and long. Hall probes



New power supply and transv. magnetic fiedl

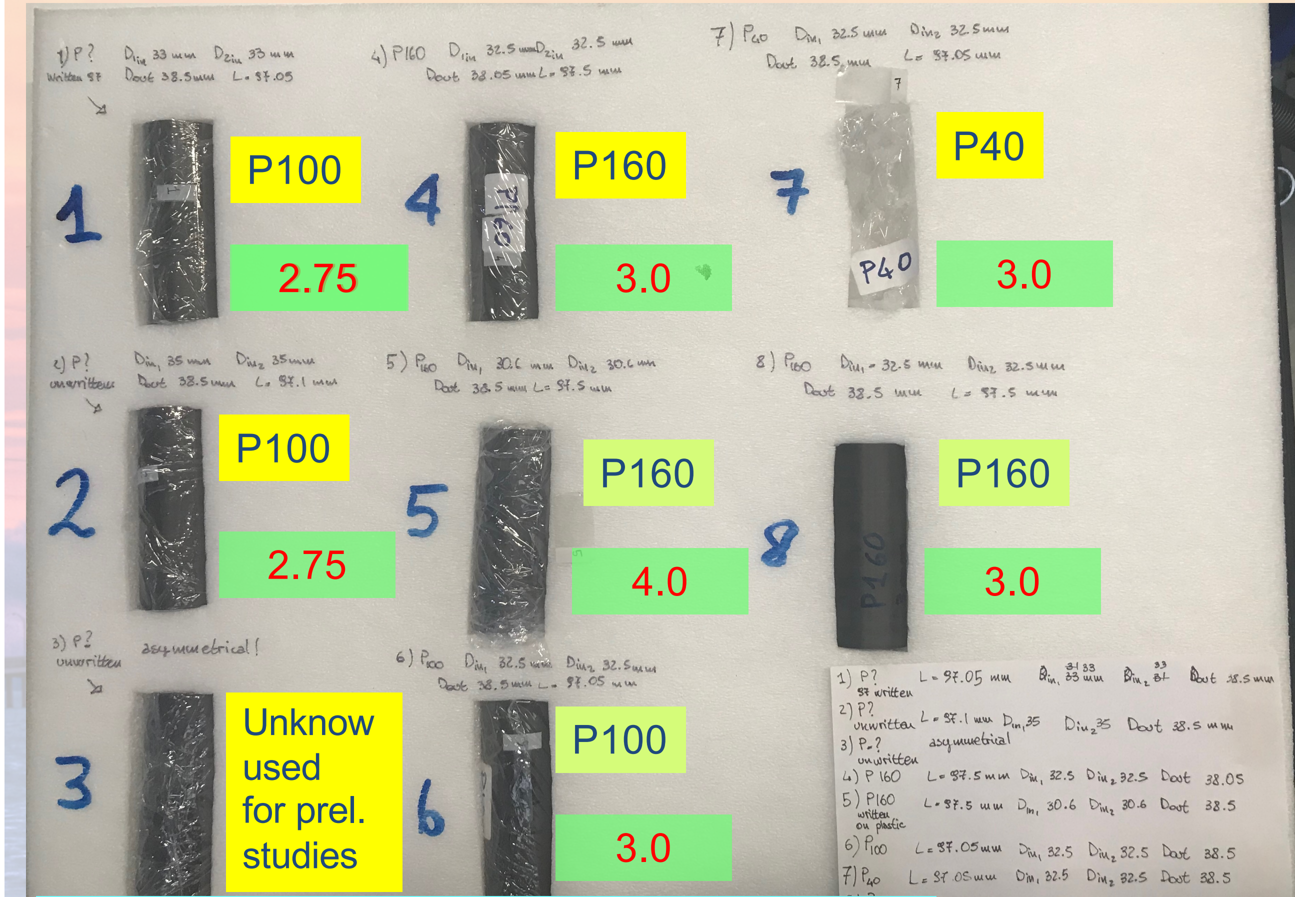
Preliminary tests with 110 A (980 mT), now max current allowed on the coil 168 A (1 200 mT)..





OCEM-CAEN - NGPS 200 A- 50 V
high stability power supply

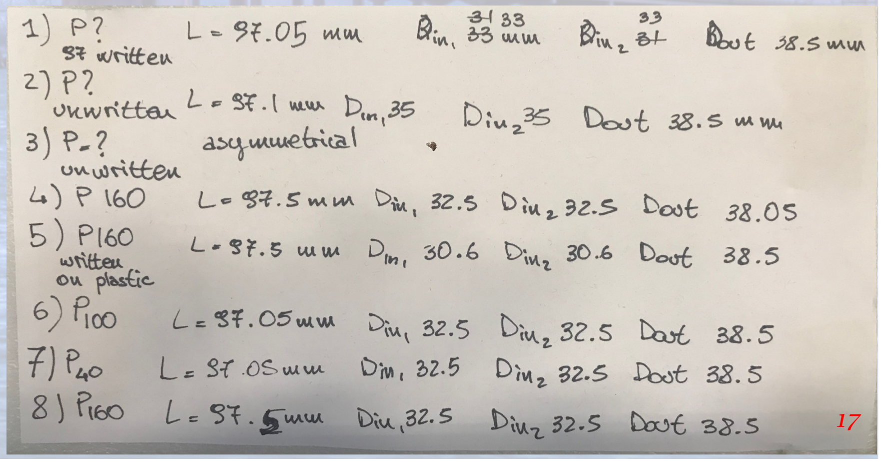
MgB_2 cylinders



Different Boron (99.5 % pure) precursor grain size (μm) from Boron chip (mm) mechanically grounded and sieved to less than (P)nnn μm.

thickness in mm

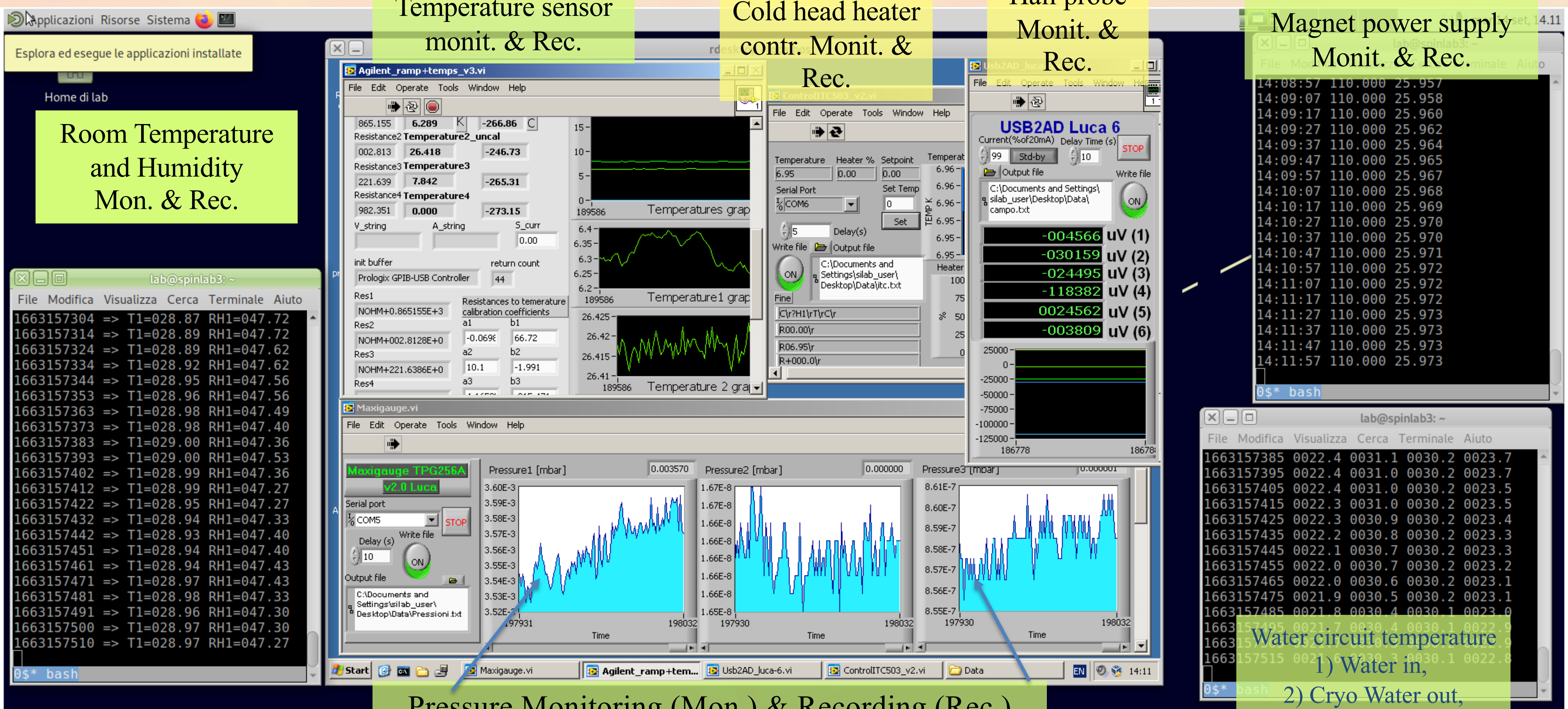
Length 97.05 – 97.5 mm



1) P? 97 written L = 97.05 mm D_{in_1} 33 mm D_{in_2} 33 Dout 38.5 mm
2) P? unwritten L = 97.1 mm D_{in_1} 35 D_{in_2} 35 Dout 38.5 mm
3) P-? unwritten asymmetrical
4) P 160 L = 97.5 mm D_{in_1} 32.5 D_{in_2} 32.5 Dout 38.05
5) P160 written on plastic L = 97.5 mm D_{in_1} 30.6 D_{in_2} 30.6 Dout 38.5
6) P_{100} L = 97.05 mm D_{in_1} 32.5 D_{in_2} 32.5 Dout 38.5
7) P_{40} L = 97.05 mm D_{in_1} 32.5 D_{in_2} 32.5 Dout 38.5
8) P_{160} L = 97.5 mm D_{in_1} 32.5 D_{in_2} 32.5 Dout 38.5

Smaller the grain size higher transport characteristics, but less thermal stability at lower *T* and lower *B*.
Connectivity P100 ~ 61 %, P40 ~89 %, PAM~73 %

Control, monitoring and DAQ



Temperature sensor monit. & Rec.

Cold head heater contr. Monit. & Rec.

Hall probe Monit. & Rec.

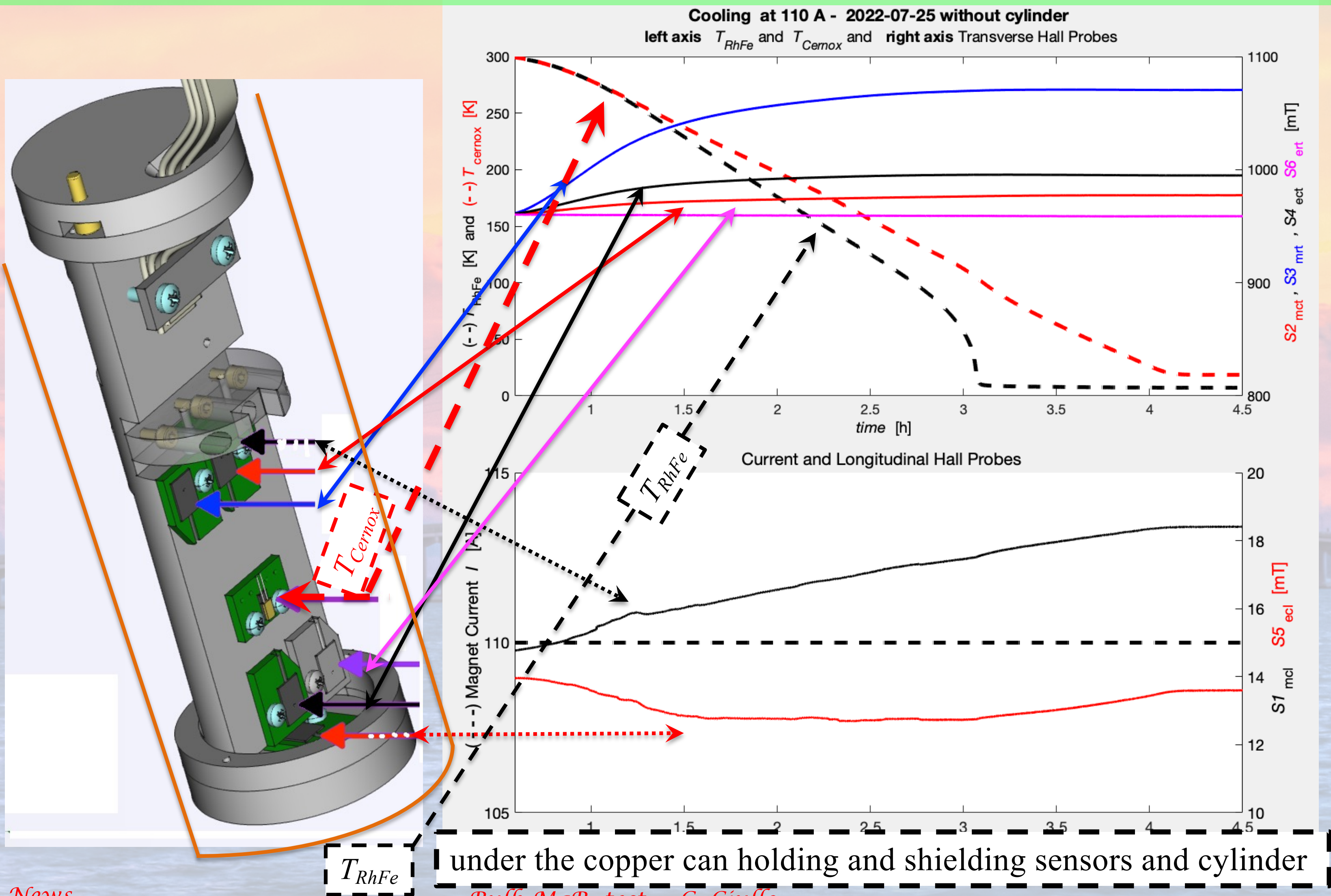
Magnet power supply Monit. & Rec.

Room Temperature and Humidity Mon. & Rec.

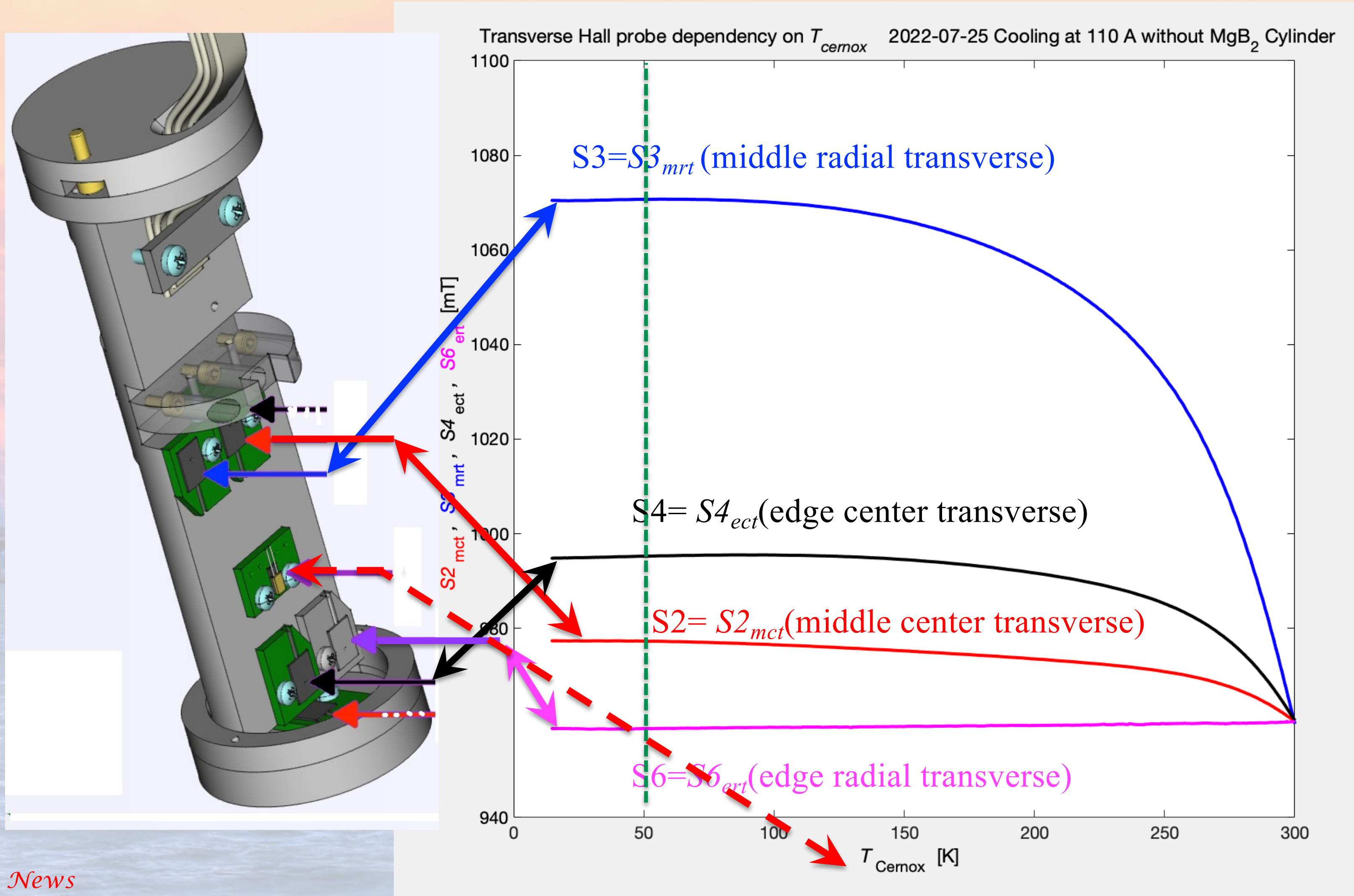
Pressure Monitoring (Mon.) & Recording (Rec.)
($P_{pv} \sim 10^{-2}$ mbar, $P_{bp} \sim 10^{-6}$ mbar, $P_{ch} \sim 10^{-8}$ mbar)

Water circuit temperature
1) Water in,
2) Cryo Water out,
3) magnet body,
4) magnet water out.
Mon. & Rec.

Cooling down W.O. cylinder less than 3.5 (4.5) h against > 7.5 h (blind)

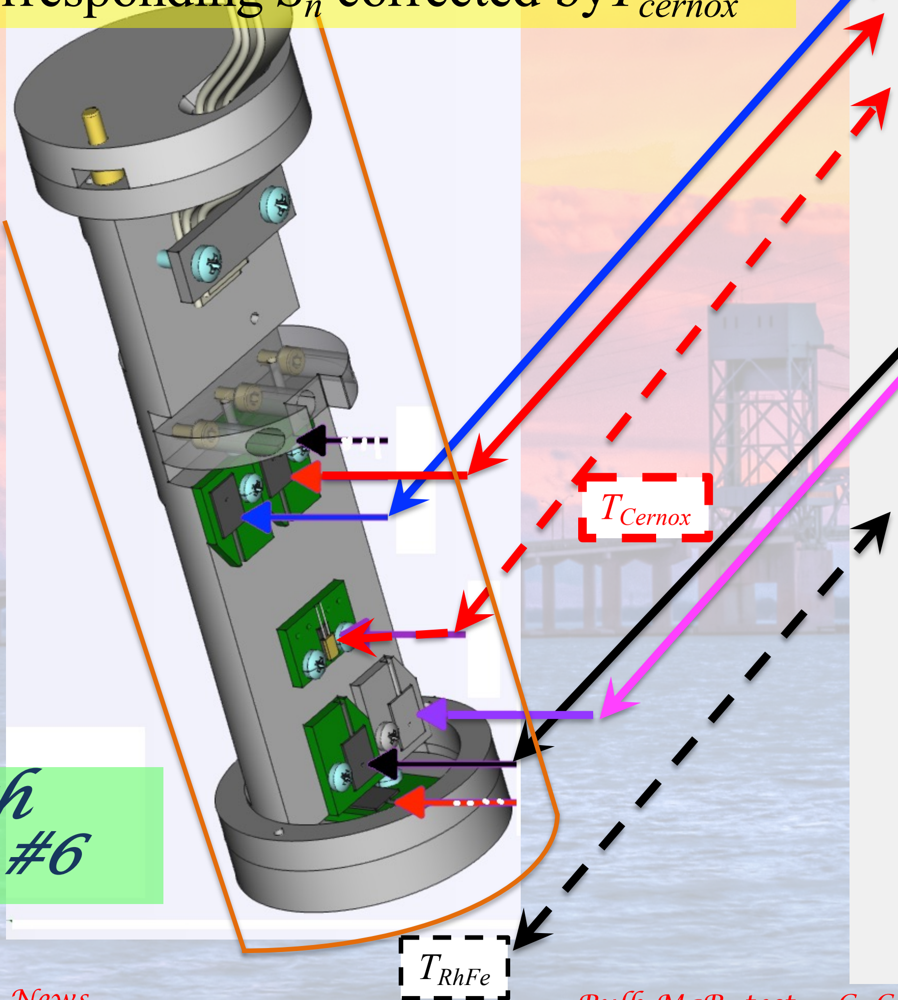


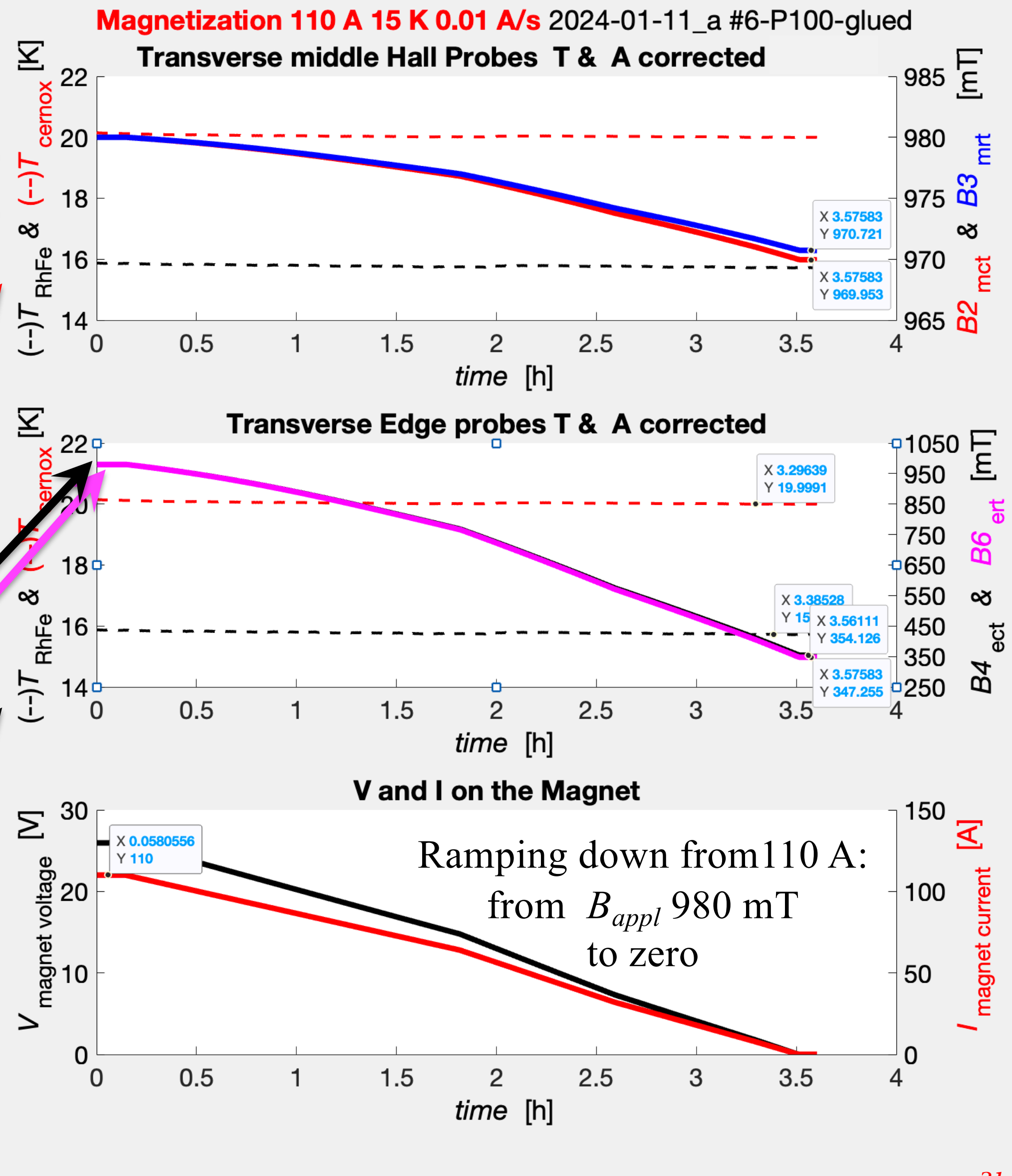
Temperature dependency of Hall probe



Field Cooling-Magnetization

B_n is the corresponding S_n corrected by T_{cernox}



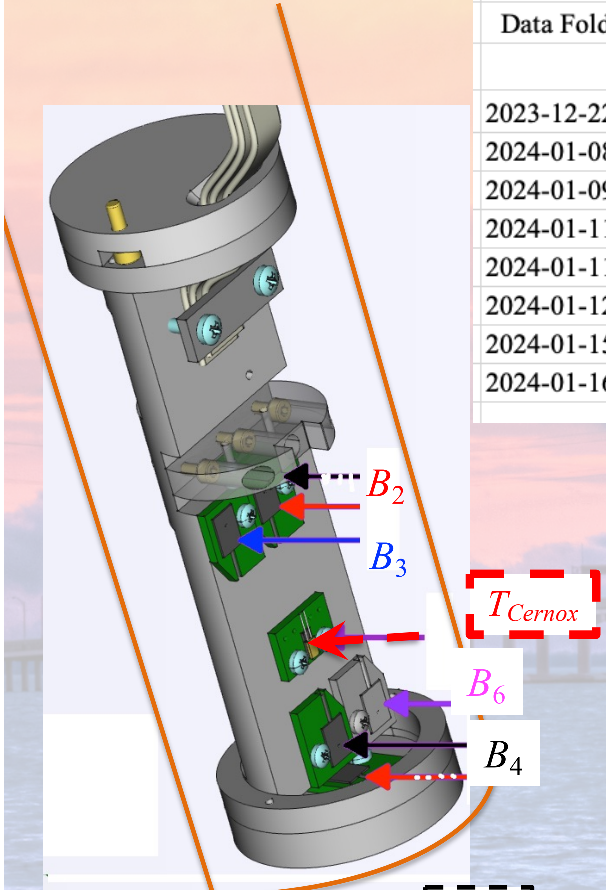


with
P100 #6

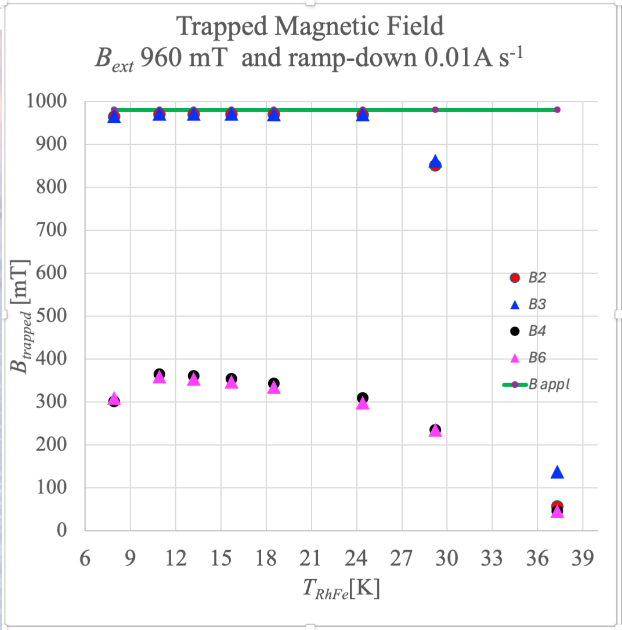
Trapped field vs Heating power (i.e. T)

48 mm

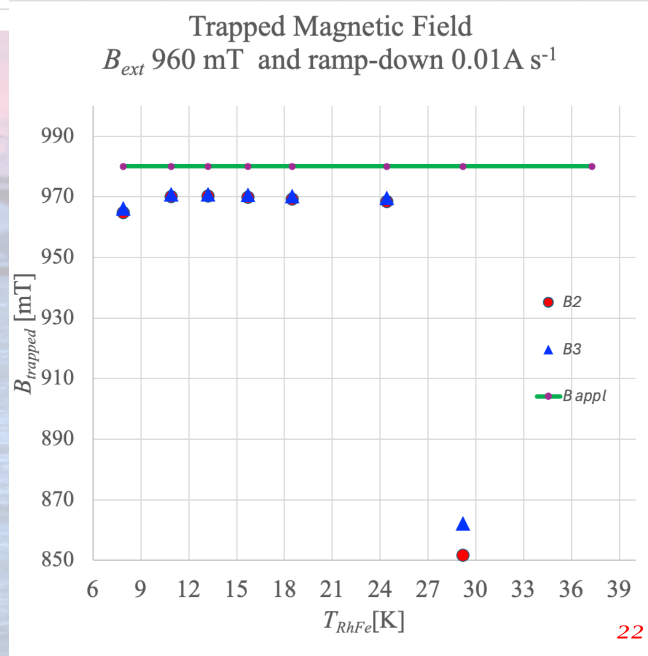
Data Folder	Label	I_{max} [A]	Ramp down [A s^{-1}]	B_{appl} [mT]	B_2 [mT]	B_3 [mT]	ΔB_{23} [mT]	B_4 [mT]	B6 [mT]	ΔB_{46} [mT]	ΔB_{23} [mT]	T_{RhFe} [K]	T_{Cernox} [K]
2023-12-22_d	off	110	0,01	980,00	964,80	966,10	1,30	300,80	308,50	7,70	-664,00	7,9	15,7
2024-01-08_c	11 K	110	0,01	980,00	970,10	970,80	0,70	364,70	358,80	-5,90	-605,40	10,9	17,1
2024-01-09_a	13 K	110	0,01	980,00	970,20	970,90	0,70	360,20	353,80	-6,40	-610,00	13,2	18,4
2024-01-11_a	15 K	110	0,01	980,00	969,95	970,72	0,77	354,12	347,26	-6,86	-615,83	15,7	20,0
2024-01-11_b	17 K	110	0,01	980,00	969,30	970,20	0,90	343,10	335,20	-7,90	-626,20	18,5	21,8
2024-01-12_b	19 K	110	0,01	980,00	968,50	969,70	1,20	308,80	298,70	-10,10	-659,70	24,4	26,2
2024-01-15_b	20 K	110	0,01	980,00	851,60	862,20	10,60	235,10	234,20	-0,90	-616,50	29,2	30,0
2024-01-16_b	21 K	110	0.01	980.00	57.00	137.20	80,20	45,00	45.80	0.80	-12.00	37.3	37.4



P100 #6



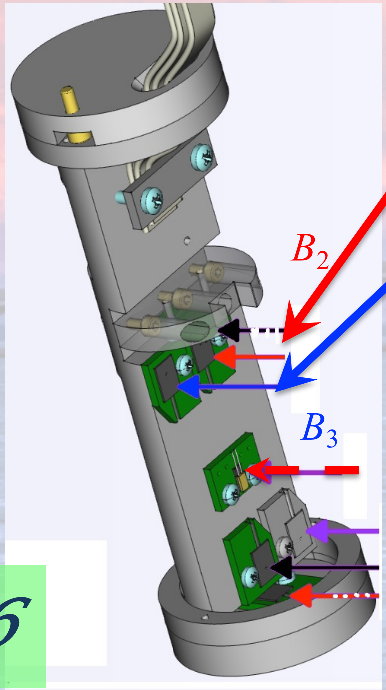
11 mm



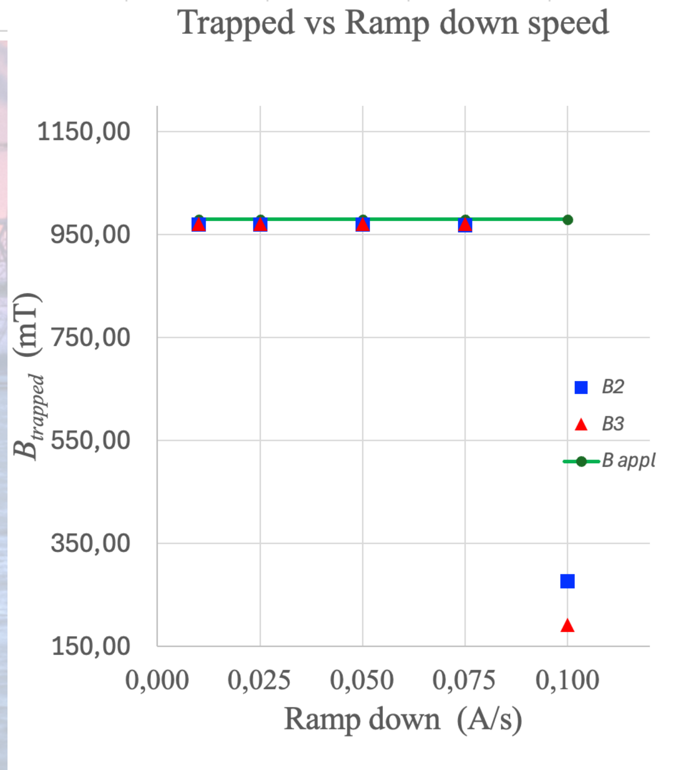
Trapped Field vs Ramp down speed

48 mm

Data Folder	Label	I_{max}	Ramp down	B_{appl}	B_2	B_3	ΔB_{23}	B_4	$B6$	ΔB_{46}	ΔB_{23}	T_{RhFe}	T_{Cernox}
		[A]	[A s^{-1}]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[K]	[K]
2024-01-11_a	15 K	110	0,01	980,00	969,80	970,70	0,90	354,00	346,80	-7,20	-615,80	15,6	20,0
2024-02-22_b	15 K	110	0,025	980,00	969,80	970,70	0,90	345,90	344,30	-1,60	-623,90	15,6	20,0
2024-07-16_h	15 K	110	0,05	980,00	969,84	970,69	0,85	345,91	343,96	-1,95	-623,93	15,6	20,0
2024-07-17_f	15 K	110	0,075	980,00	969,00	970,70	1,70	346,33	344,41	-1,92	-622,67	15,6	20,0
2024-07-16_f	16 K	110	0,1	980,00	277,02	192,20	-84,82	89,70	122,34	32,64	-187,32	15,6	20,0



11 mm

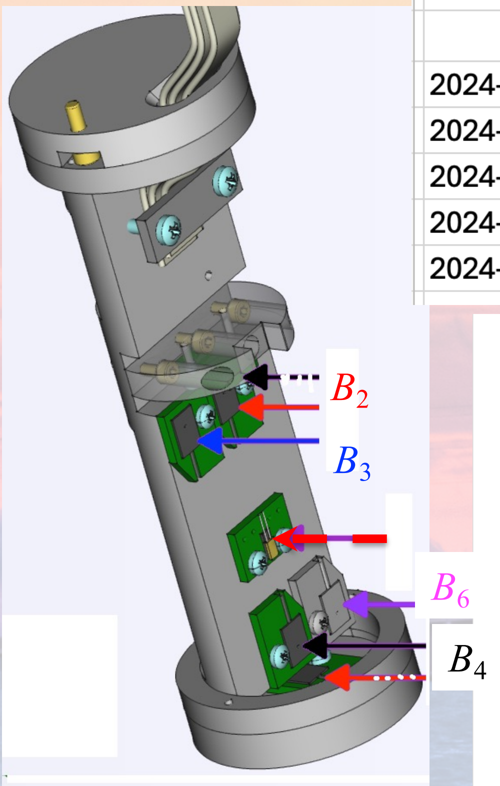


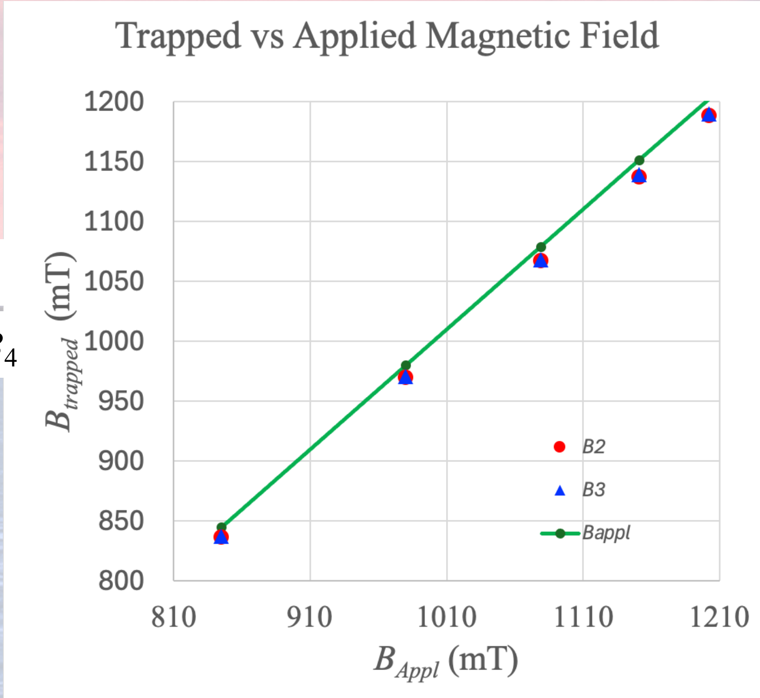
P100 #6

Trapped field vs B_{appl}

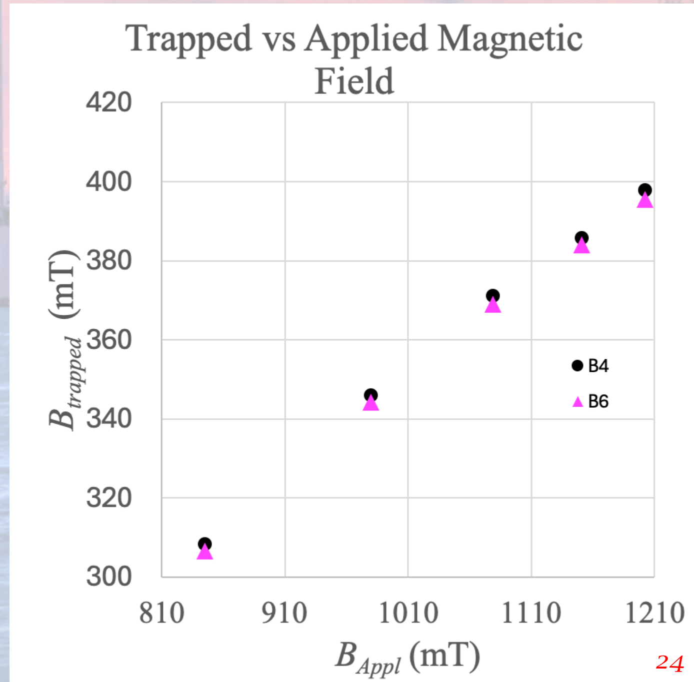
48 mm

Data Folder	Label	I_{max}	Ramp down	B_{appl}	B_2	B_3	ΔB_{23}	B_4	B6	ΔB_{46}	ΔB_{24}	T_{RhFe}	T_{Cernox}
		[A]	[A s^{-1}]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[K]	[K]
2024-07-10_b	15 K	90	0,025	844,90	836,6	837,33	0,71	308,40	306,51	-1,89	-528,22	15,7	19,9
2024-02-22_b	15 K	110	0,025	980,00	969,8	970,7	0,9	345,90	344,30	-1,6	-623,9	15,6	20,0
2024-07-09_b	15 K	130	0,025	1078,96	1067	1068,21	0,94	371,10	369,04	-2,06	-696,17	15,6	20,0
2024-05-24_3	15 K	150	0,025	1150,9	1137	1138,98	1,61	385,70	384,05	-1,65	-751,67	15,6	20,0
2024-07-08_b	15 k	168	0,025	1202,3	1188	1189,39	1,07	397,82	395,44	-2,38	-790,5	15,6	20,0



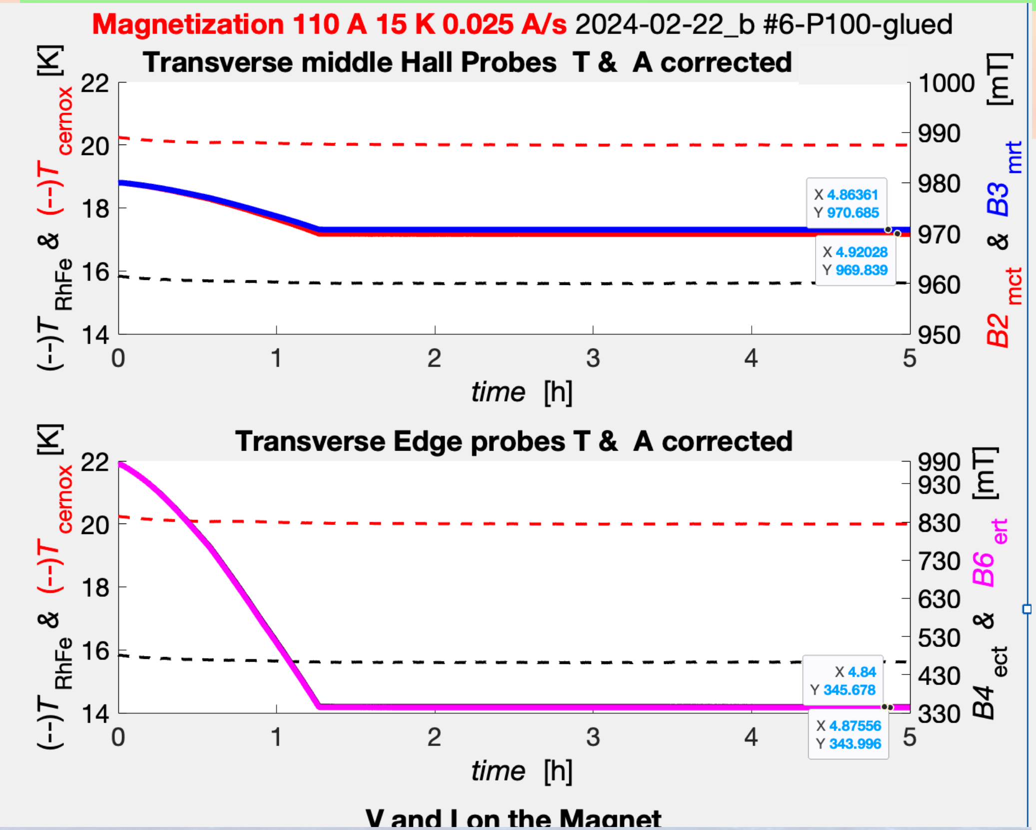


11 mm

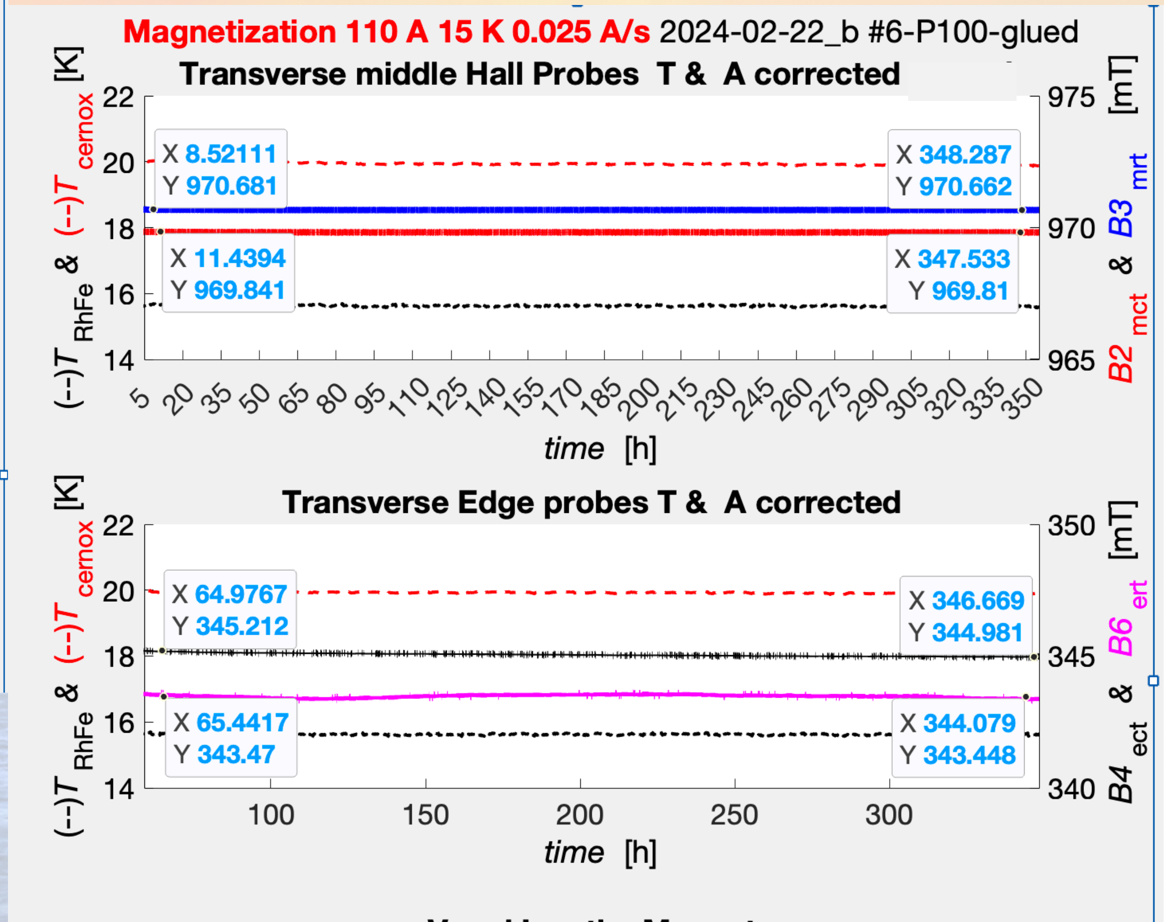


P100 #6

How long the fields can stay an how stable is?

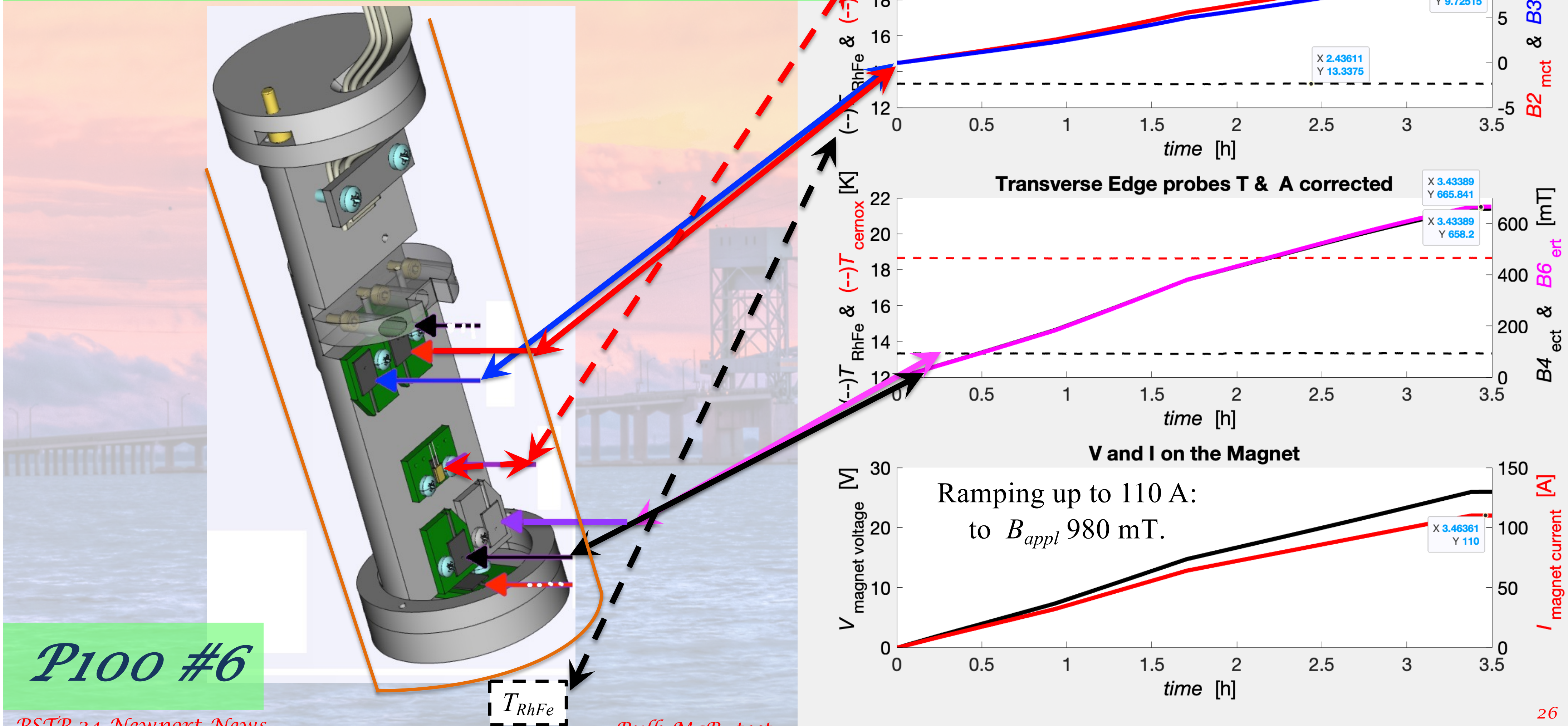


$\Delta B \sim 0.02$ mT in 15 days



P100 #6

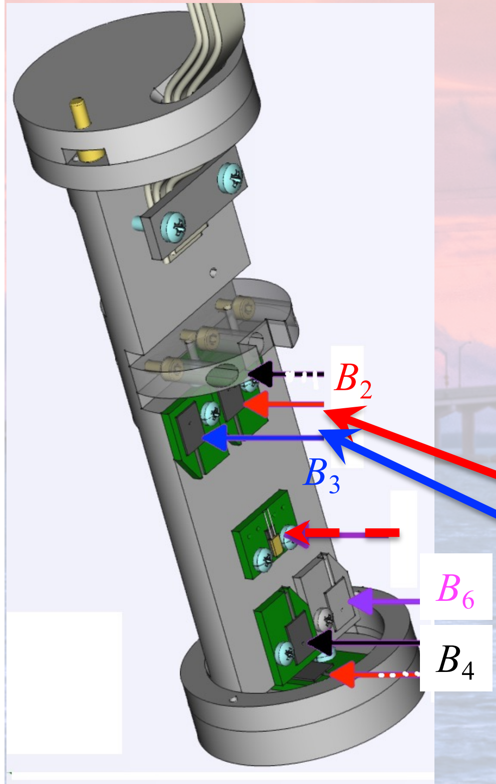
Zero Field Cooling (ZFC) Shielding

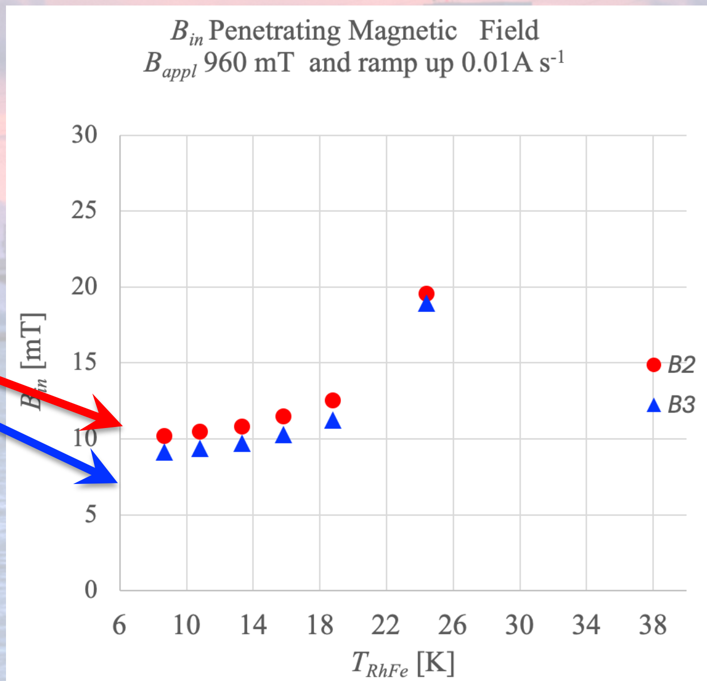


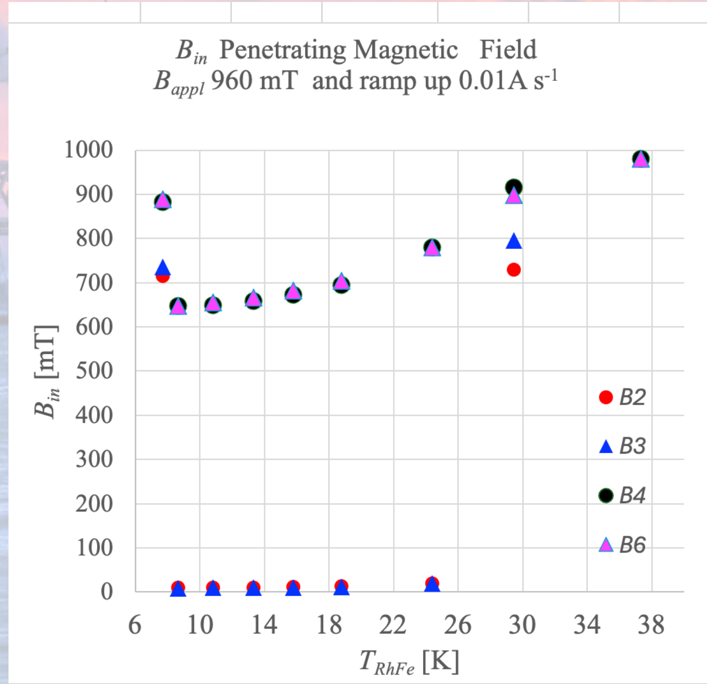
P100 #6

Shielding vs Heater power (Temperature)

Data Folder	Label	I_{max}	Ramp up	B_{appl}	B_2	B_3	ΔB_{23}	B_4	$B6$	ΔB_{46}	ΔB_{24}	T_{RhFe}	T_{Cernox}
		[A]	[A s^{-1}]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[K]	[K]
2023-12-27_d	off	110	0,01	980,00	715,64	735,33	19,7	882,74	889,34	6,60	167,1	7,7	15,7
2023-12-28_b	9 K	110	0,01	980,00	10,20	9,15	-1,1	647,95	647,86	-0,09	637,8	8,7	16,1
2023-12-28_d	11 K	110	0,01	980,00	10,48	9,40	-1,1	649,48	656,12	6,64	639,0	10,8	17,1
2024_01_22_b	13K	110	0,01	980,00	10,84	9,73	-1,1	658,20	665,84	7,64	647,4	13,3	18,7
2024-01-22_d	15 K	110	0,01	980,00	11,48	10,30	-1,2	673,14	681,77	8,63	661,7	15,8	20,1
2024_01_24_c	17 K	110	0,01	980,00	12,56	11,26	-1,3	695,35	704,83	9,48	682,8	18,8	22,0
2024_01_23_d	19 K	110	0,01	980,00	19,54	18,96	-0,6	780,31	780,55	0,24	760,8	24,4	26,2
2024-01-24_e	20 K	110	0,01	980,00	728,82	796,23	67,4	916,20	897,55	-18,65	187,4	29,5	30,2
2024_01_25_b	21 K	110	0,01	980,00	980,00	980,00	0,0	980,00	980,00	0,00	0,0	37,3	37,4

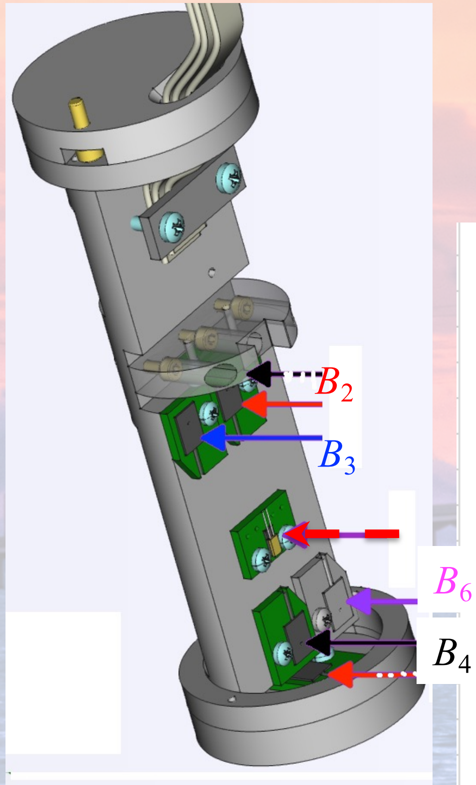


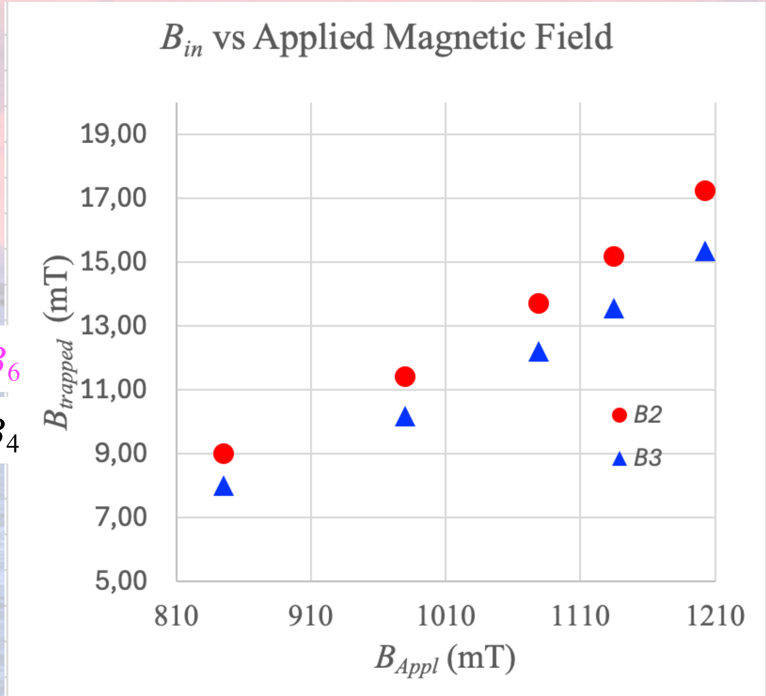


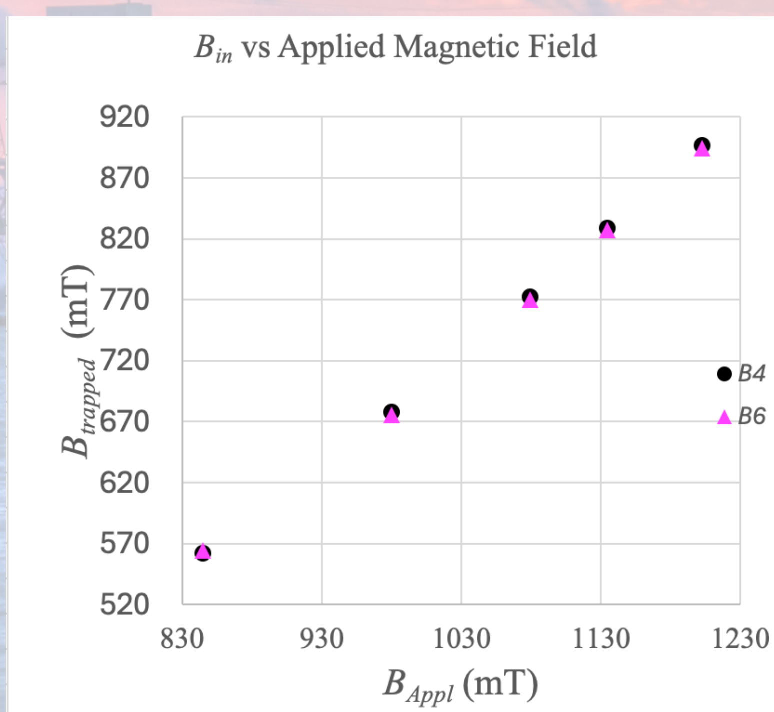


Shielding vs B_{appl}

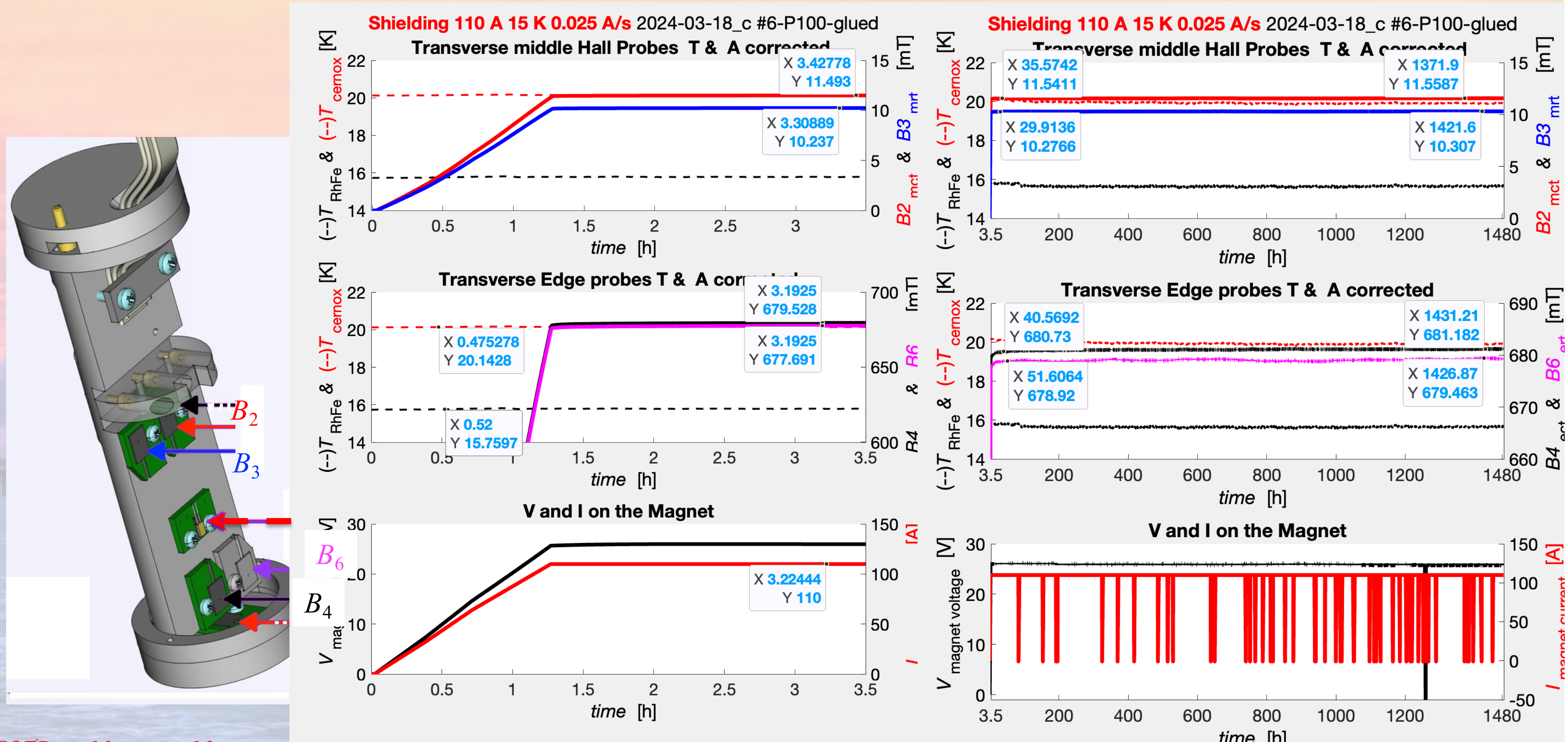
Data Folder	Label	I_{max}	Ramp up	B_{appl}	B_2	B_3	ΔB_{23}	B_4	$B6$	ΔB_{46}	ΔB_{24}	T_{RhFe}	T_{Cernox}
		[A]	[A s^{-1}]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[mT]	[K]	[K]
2024-07-10	15 K	90	0,025	844,90	8,99	8,01	-0,981	562,00	564,00	2,00	553,01	15,7	20,0
2024-02-01	15 K	110	0,025	980,00	11,42	10,18	-1,24	677,49	675,50	-1,99	666,07	15,7	20,1
2024-07-09	15 K	130	0,025	1078,96	13,70	12,21	-1,49	772,05	770,25	-1,80	758,35	15,7	20,0
2024-07-12	15 K	145	0,025	1134,74	15,19	13,55	-1,64	828,82	827,21	-1,61	813,63	15,8	20,0
2024-07-11	15 k	168	0,025	1202,27	17,23	15,36	-1,87	896,42	893,97	-2,45	879,19	15,8	20,1

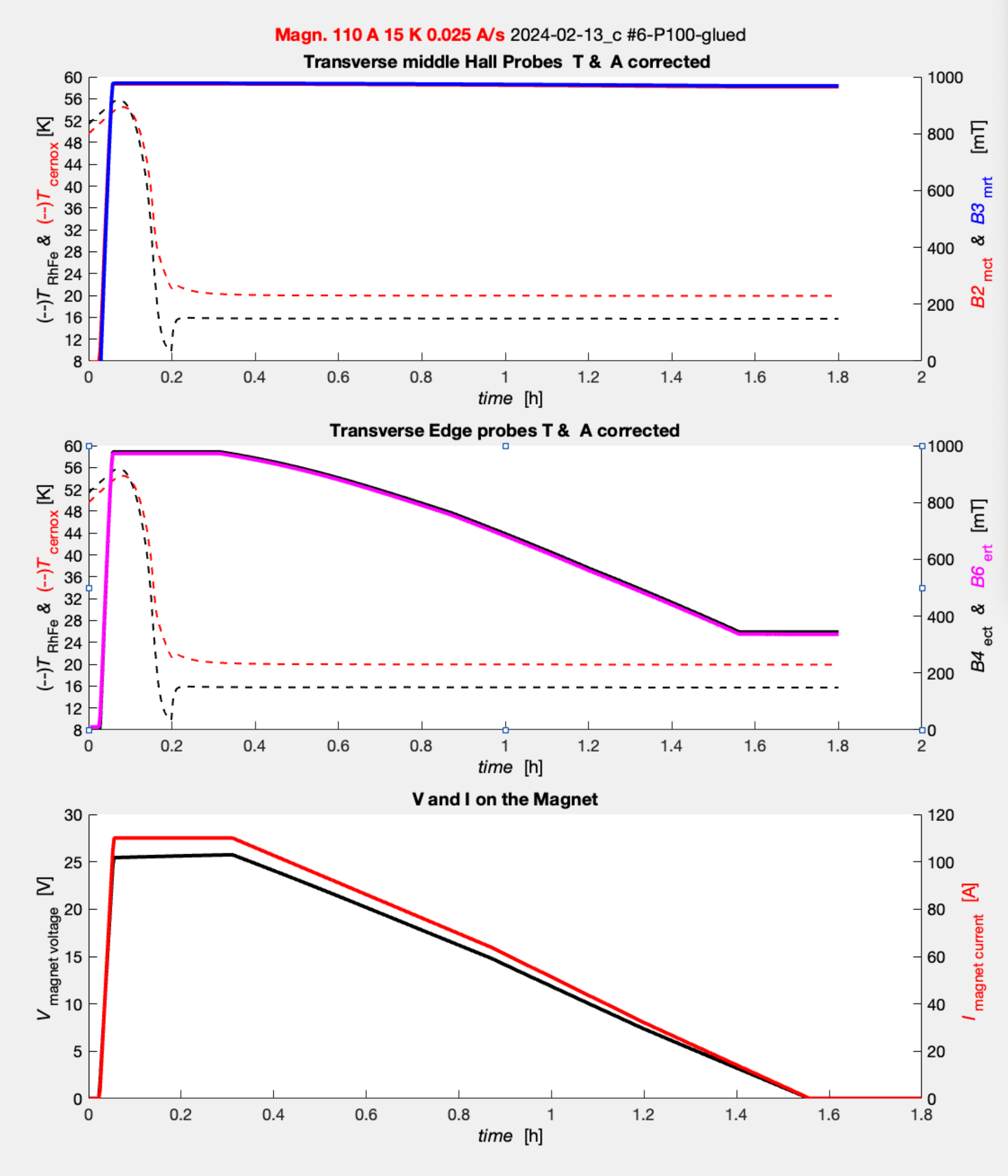






How long works the shield and how stable is it?





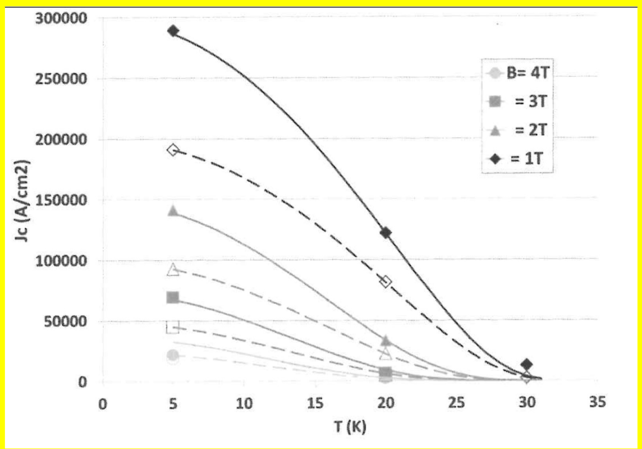
From SC to NC then Back in SC

in 1/2 hour,
we can go from superconducting state to the normal conducting one, and back at the set temperature.

And the other cylinders: P40 #7, P160 #8

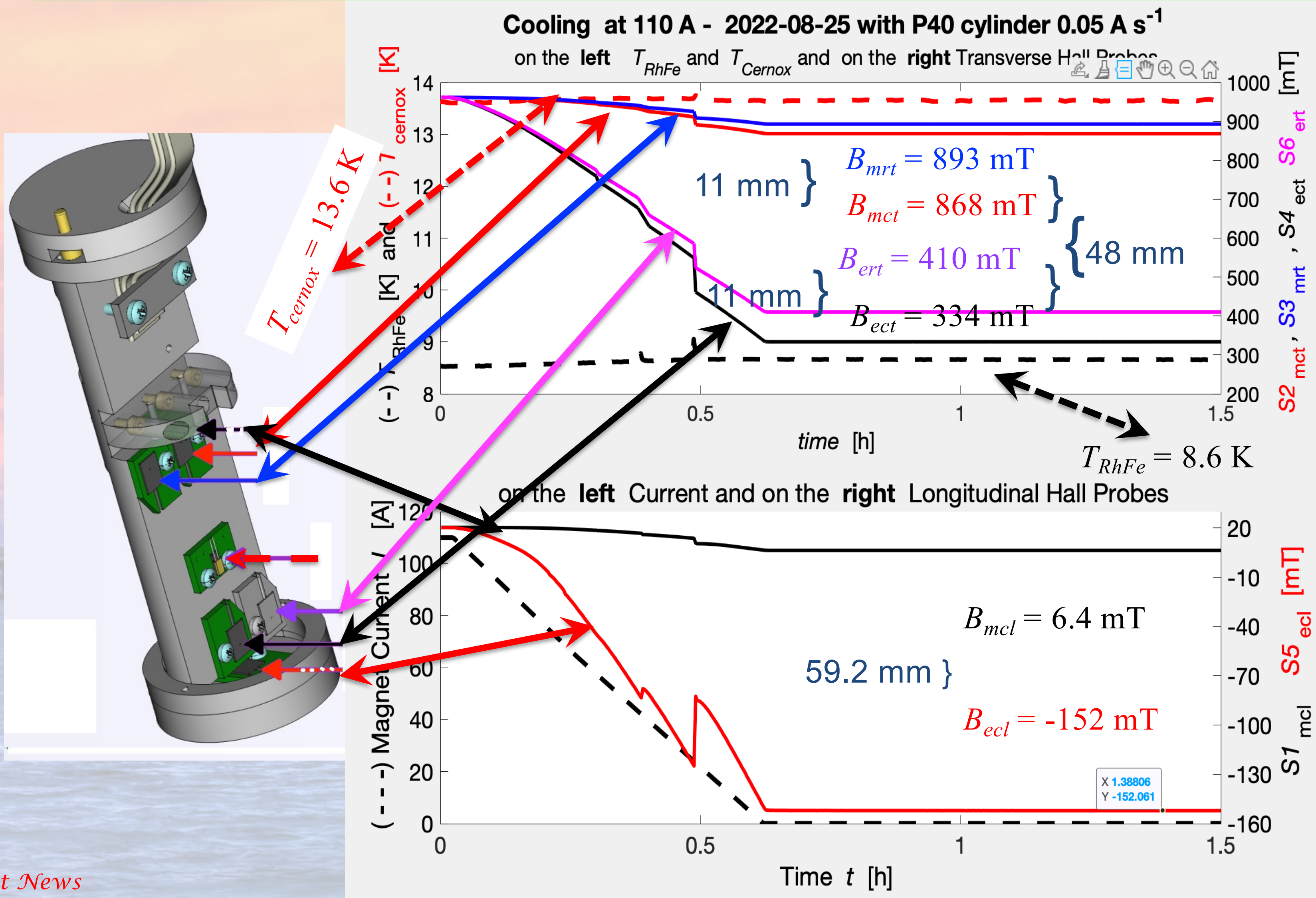
P40 was the first one istalled after the upgrade, but ...

Smaller the grain size higher transport characteristics,
but less thermal stability at lower *T* and lower *B*.
Connectivity P100 ~ 61 %, P40 ~89 %, PAM~73 %

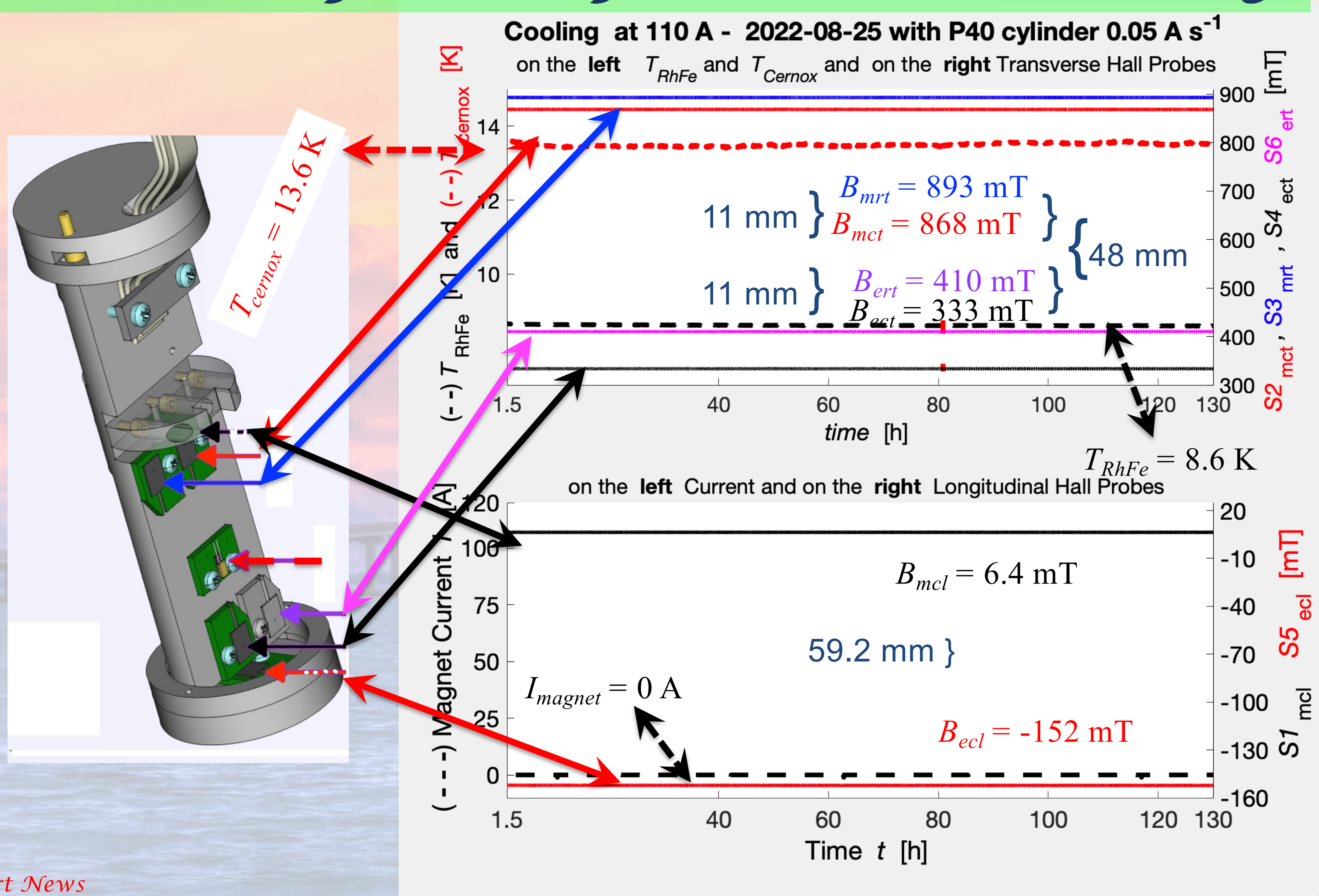


J_c experimental data for
SG (Small Grain size) continuous
and LG (Large Grain size) dashed line

P40 #7 Sample Ramp down 0.05 A/s



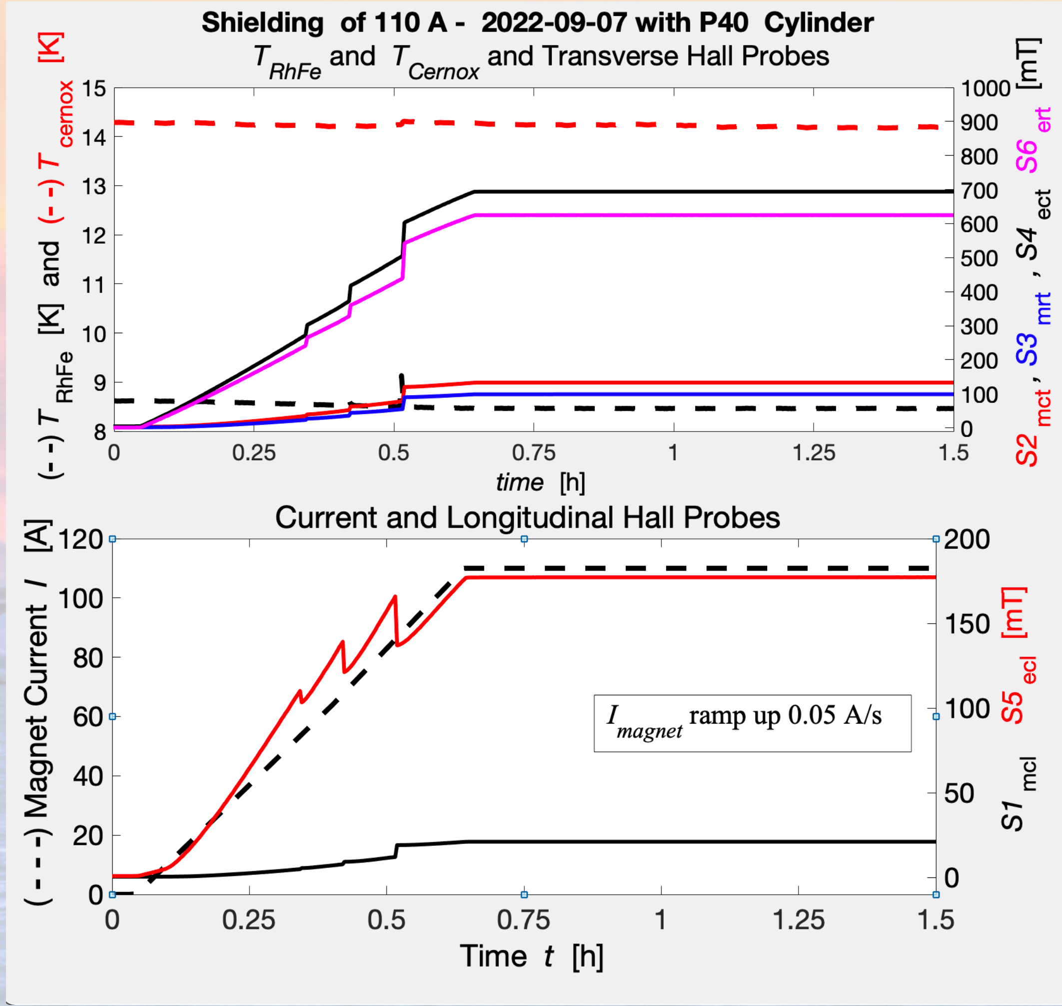
P40 #7 Sample Ramp down 0.05 A/s long

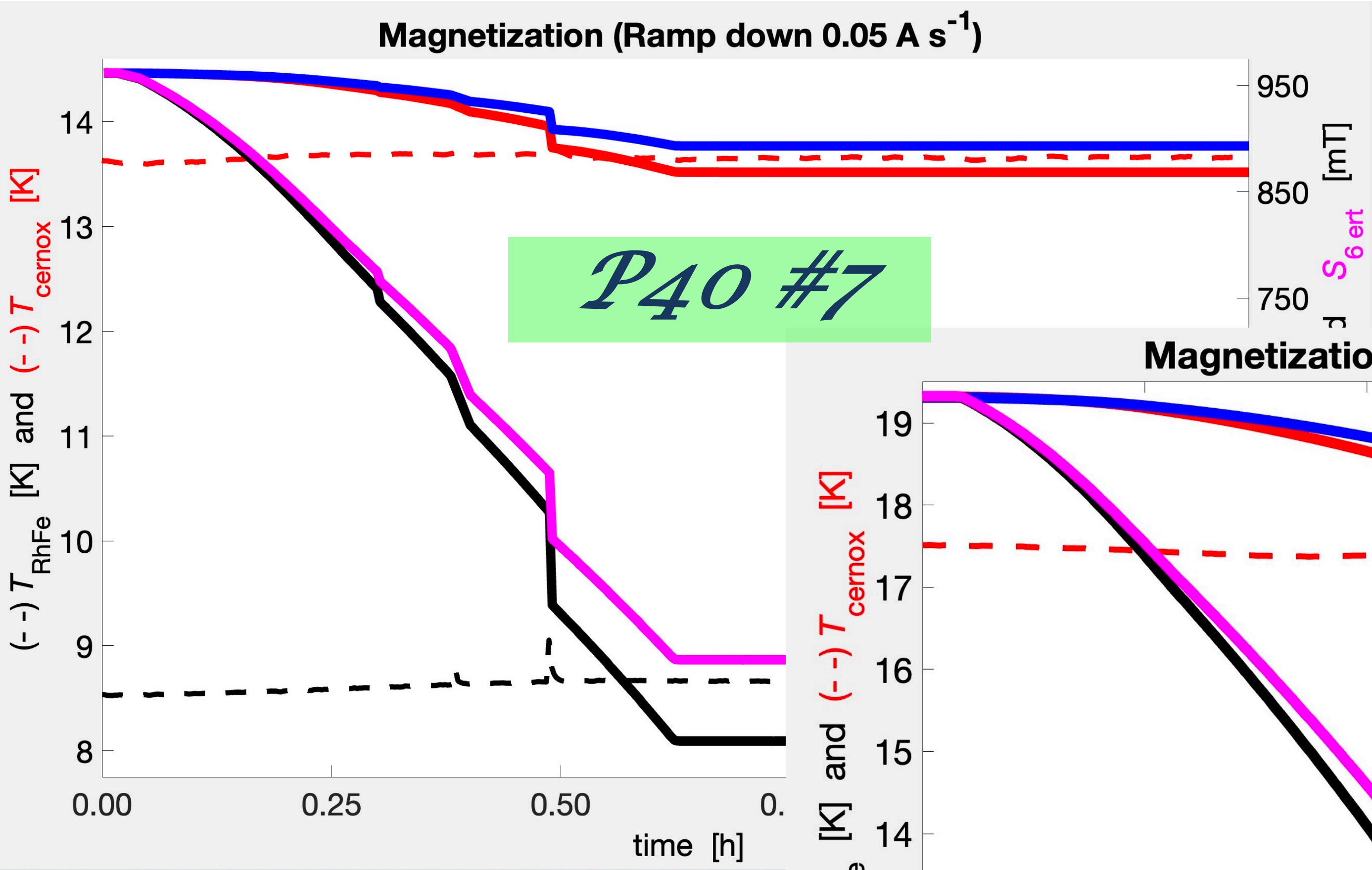


Shielding 110 A ramp up 0.05 A/s

P40 #7

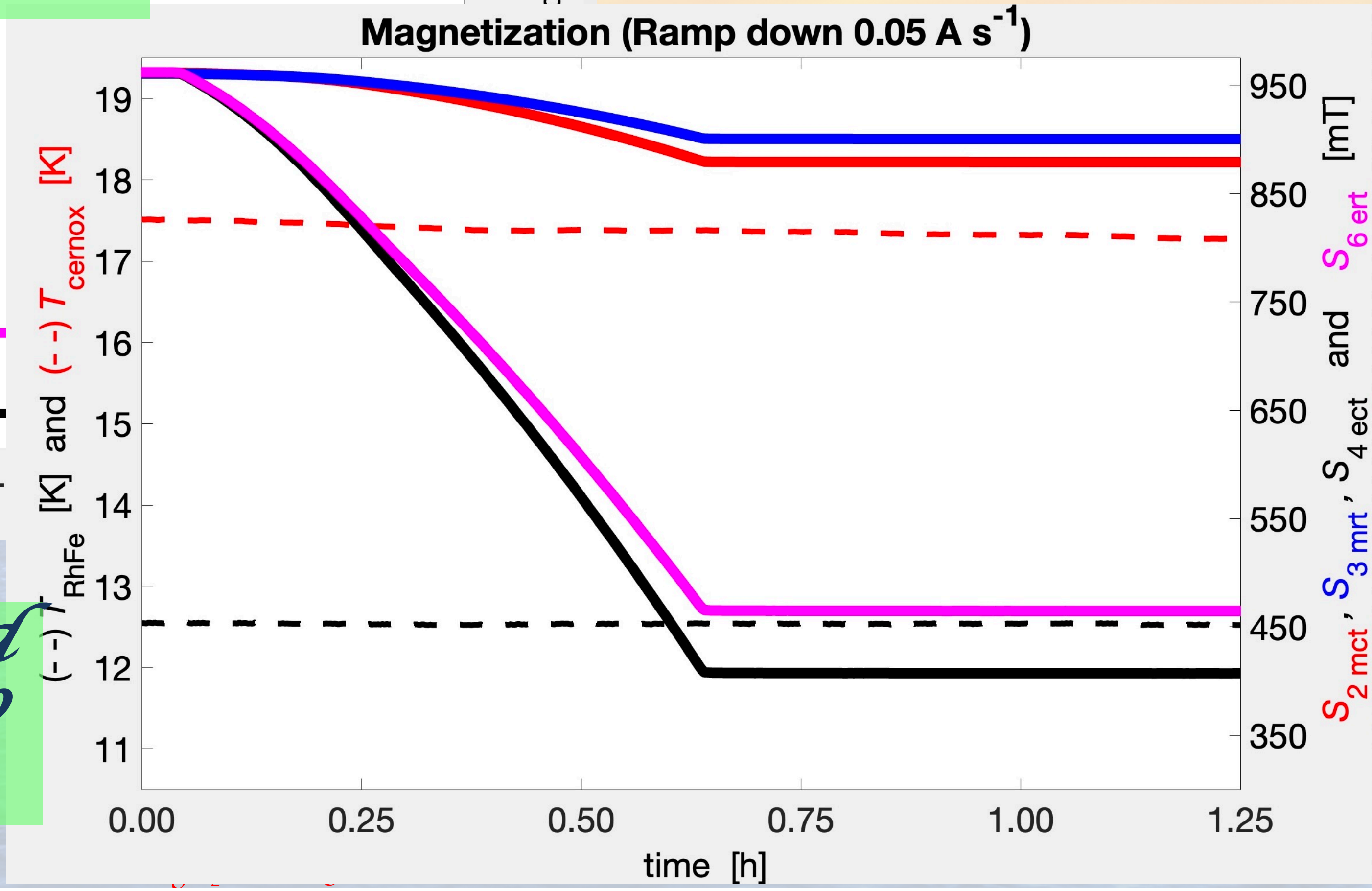
Early
Zero Field Cooling
then after
reaching the lowest
temperature
Ramp up the
external field.





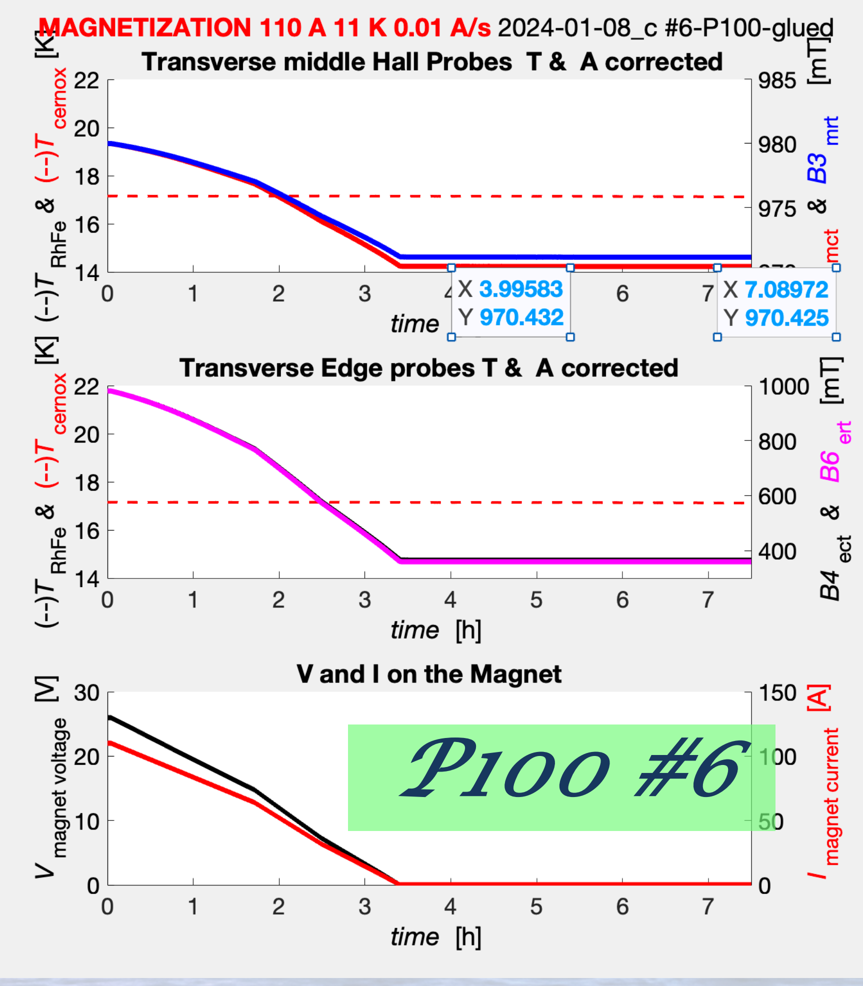
P40 #7

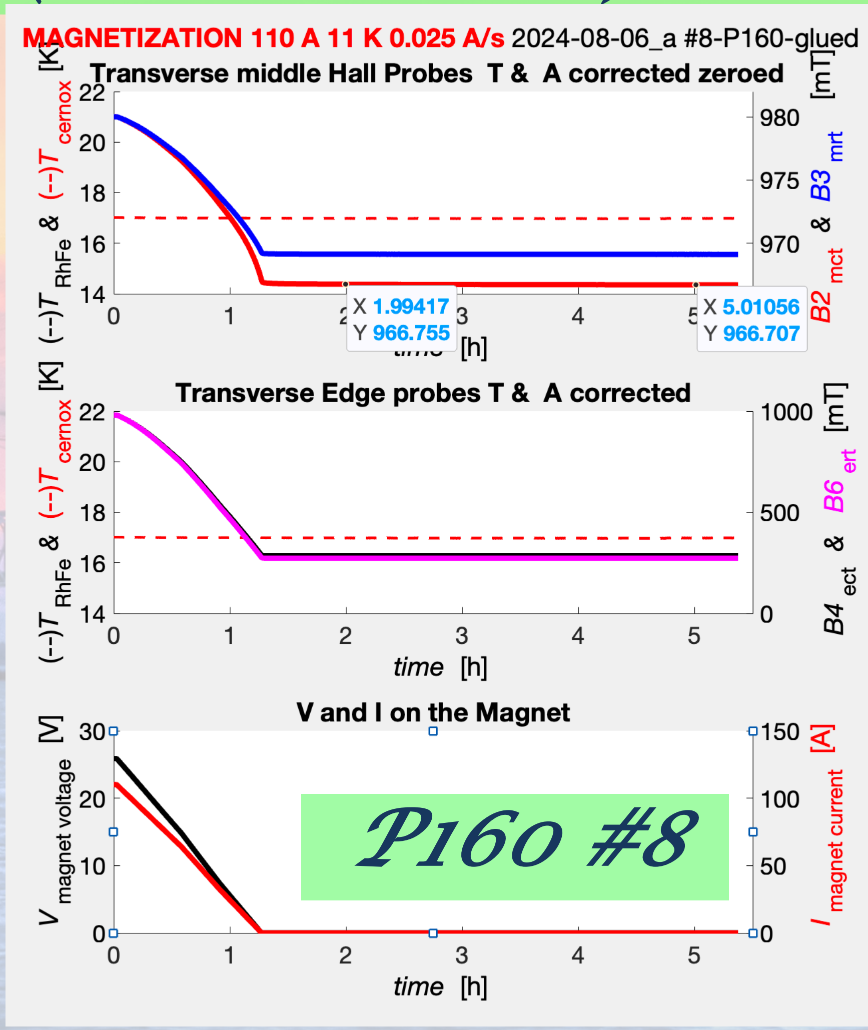
At higher temperature no flux jump



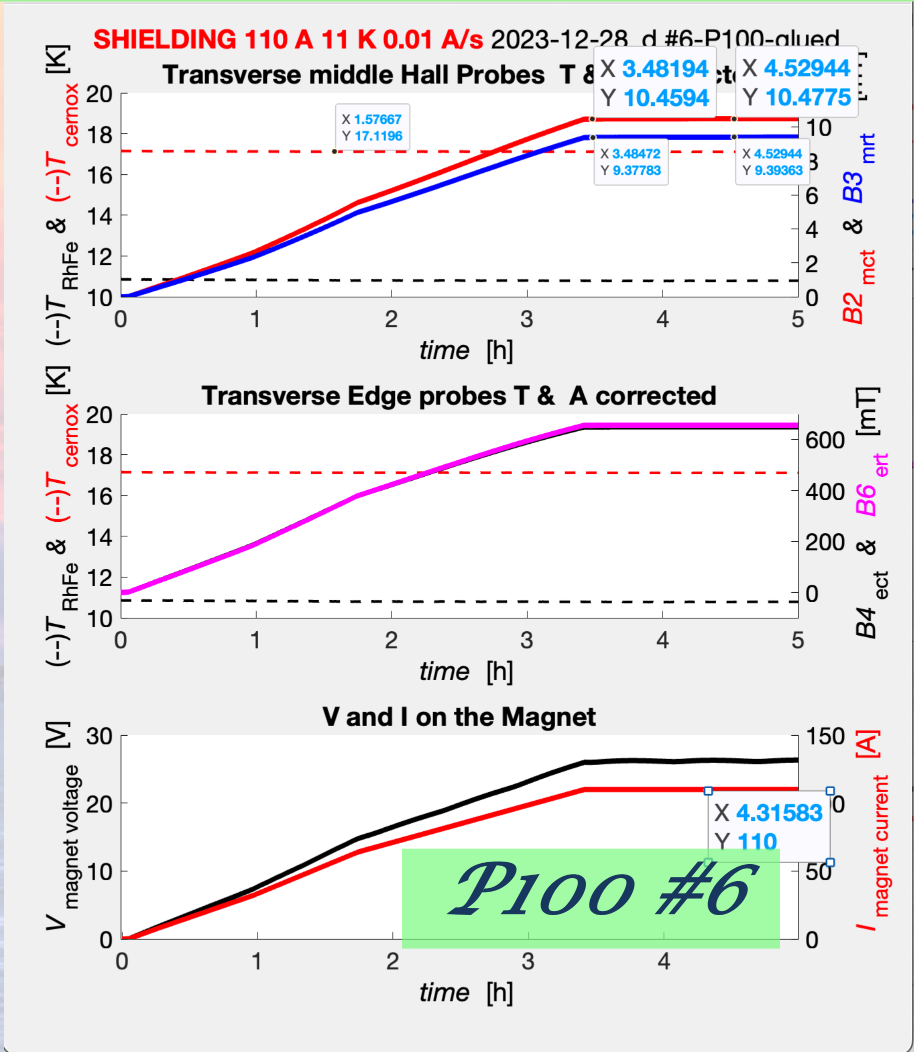
... but lower trapped field with respect to the P100 #6.

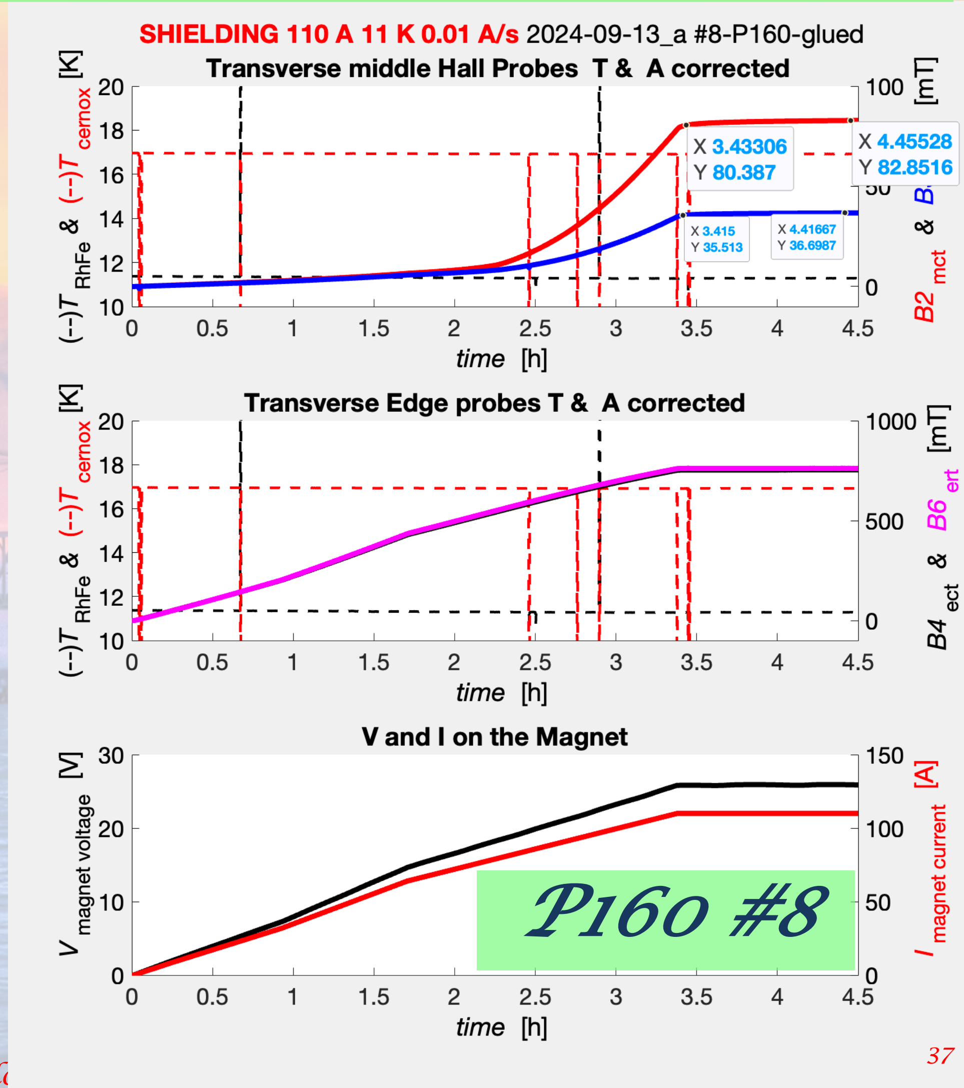
MAGNETIzzAZION: less Trapped field and decreasing speedly (10 times more)





SHIELDING: higher B_{in} and increasing speedly (100 times more)





Conclusions and Plans

- We have in hands the system for testing «global» behavior of real bulk MgB_2 cylinders.

- We can investigate the behavior of the cylinder with different preparation procedure also checking their reproducibility on the nominal label P160, P100, P40 and PAM cylinders.

- We can test the superconducting behavior from the reached low temperature (T_{RhFe} 9 K - T_{cernox} 13 K) to the normal state transition.

FE apparatus at LASA-Milano (or…)

(Laboratorio di Acceleratori e Superconduttività Applicata)

– At LASA is under plan to put in operation a 10 T superconducting solenoid.

- Experimental tests on
  - Trapping of Tranverse field and shielding of longitudinal field (target).
  - Trapping of longitudinal field (fusion), but this is less critical than transverse field-
  - Mapping of field for tranverse self field and external longitudinal field, mapping of longitudinal field.

- Checking theoretical model and tuning of them on data for field generation and shielding.

- Long time stability test for crossed beam in time interval for JLab targets and fusion test.

- Stability under movement in working conditions

I'd like to mention people involved in this work

Ferrara: Barion Luca, Contalbrigo Marco, Lenisa Paolo

Ferrara: SQUID measurements on MgB_2 sample of the production
Spizzo Federico and Del Bianco Lucia

Bari: Tagliente Giuseppe – DAQ

JLab: Lowry Michael, Sandorfi Andrew – HD-Ice and simulations

Milano: Statera Marco

Thanks to the organizers for accepting the contribution
and
to the audience for the attention.


Spare Slides for details

TEsts and measurements on P40 #7

Cilindro#7_P040

Misura	Data		T(ITC)	Heater(ITC) [%]	T(RhFe) [K]	T(Cernox) [K]	inizo [A]	fine [A]	Rampa [A/s]	S2_inizio [mT]	S2_fine [mT]	Delta [mT]	#FJ	Fj_1 [mT]	FJ@ [A]	Note
M	2022-07-28	a	off	0	7.8	12.8	110	0	0.01	947	843	104	4	2	58	
M	2022-08-10	a	-	1.8=>0	7.9=>8.0	13.0	110	0	0.02	947	802	145	4	2	58	
M	2022-08-11	a	-	2=>0	7.9=>8.0	13.0	110	0	0.04	947	846	101	4	2	57	
M	2022-08-22	b	off	0	8.3=>8.5	13.1	110	0	0.1	948	844	104	3	7	44	
M	2022-08-23	b	-	1.1=>0	8.3=>8.5	12.9	90	0	0.05	818	750	68	3	1	45	
M	2022-08-24	b	-	1.3=>0	8.4=>8.5	13.0	70	0	0.05	852	607	245	3	1	27	
M	2022-08-25	b	-	0.9=>0.2	8.4=>8.5	13.0	50	0	0.05	472	447	25	0	-	-	
M	2022-08-25	d	-	1.4=>0	8.4=>8.6	13.0	110	0	0.05	946	853	93	3	2	57	130h
M	2022-09-01	b	off	0	8.4=>8.5	13.9	110	0	0.25	948	826	122	2	10	40	110h
S	2022-09-06	b	off	0	8.5=>8.4	13.9	0	110	0.1	5	127	122	3	6	57	+OtherTests
S	2022-09-07	d	off	0.9=>0.2	8.5=>8.3	13.6	0	110	0.05	2	132	130	3	5	54	280h
S	2022-11-10	b	-	13=>16	9.2=>9.4	14.1=>14.6	0	110	0.05	2	137	135	2	10	64	
M	2022-11-14	b	-	23=>18	10.4=>9.8	15.7=>15.5	110	0	0.05	946	857	89	1	18	30	
S	2022-11-16	b	-	13=>16	9.2=>9.4	15.2=>15.5	0	110	0.05	7	627	620	2	12	65	
S	2022-11-17	a	-	13=>16	9.2=>9.5	15.2=>15.4	0	110	0.05	4	678	674	2	15	68	
M	2022-11-18	b	-	23=>17	10.4=>9.8	15.7=>15.5	110	0	0.05	670	580	90	1	22	8	
S	2022-11-22	a	9K	12.1	9.1	14.7	0	110	0.05	7	137	130	2	11	65	
S	2022-11-23	a	11K	24.1	10.6	15.7	0	110	0.05	3	124	121	1	37	81	
S	2022-11-24	a	13K	35.2	12.2	16.7	0	110	0.05	3	724	721	1	633	96	
M	2022-11-25	b	13K	35.2	12.3	16.7	110	0	0.05	946	864	82	0	-	-	70h
M	2022-11-28	b	11K	24.1	10.7	15.9	110	0	0.05	948	499	449	1	379	8	
M	2022-11-28	c	9K	12.2	9.2	15.6	110	0	0.05	948	862	86	1	12	34	
S	2022-11-29	a	15K	44.8	13.9	17.5	0	110	0.05	7	113	106	0	-	-	
M	2022-11-30	b	15K	44.8	14.0	17.5	110	0	0.05	947	862	85	0	-	-	

glued to Al turret

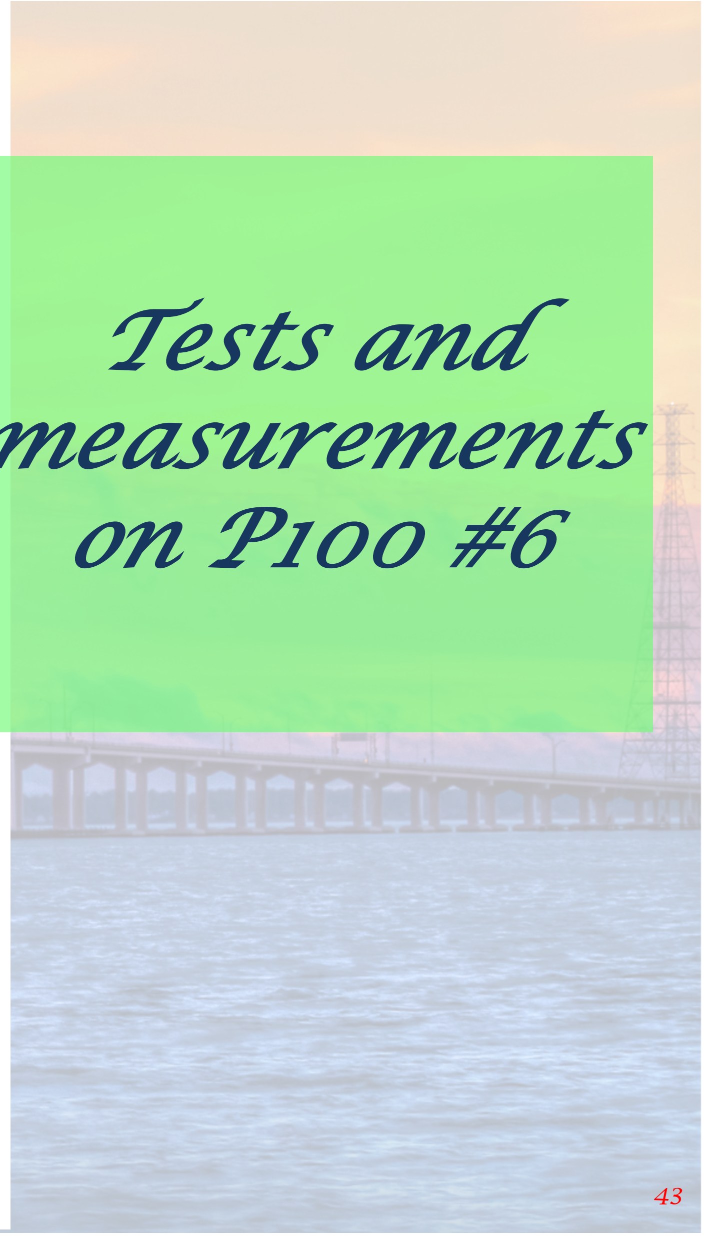
M	2023-12-22	a	off	0	7.7	15.3	110	0	0.01	964	441	523	3	0.3	61
M	2023-12-22	d	off	0	7.7	15.2	110	0	0.01	964	949	15	2	0.2	63
S	2023-12-27	b	off	0	7.8	15.2	0	110	0.01	6	889	883	3	1	51
S	2023-12-27	d	off	0	7.8	15.2	0	110	0.01	3	736	733	1	723	85

Cilindro#6_P100

S	2023-12-28	b	9K	11.9	8.6	15.5	0	110	0.01	4	15	11	0	-	-	
S	2023-12-28	d	11K	23.9	10.7	16.5	0	110	0.01	4	15	11	0	-	-	
M	2024-01-02	f	9K	11.9	8.6	15.6	110	0	0.05	966	937	29	1	20	26	
M	2024-01-02	h	11K	24.1	10.8	16.5	110	0	0.05	966	390	576	1	567	12	
M	2024-01-03	b	11K	23.9	10.7	16.5	110	0	0.05	964	378	586	1	577	11	
M	2024-01-03	f	off	0	7.8	15.2	110	0	0.05	966	950	16	2	0.3	61	
M	2024-01-08	c	11K	24.1	10.8	16.5	110	0	0.01	964	955	9	0	-	-	
M	2024-01-09	a	13K	35.1	13.0	17.8	110	0	0.01	965	955	10	0	-	-	
M	2024-01-11	a	15K	44.8	15.5	19.4	110	0	0.01	964	954	10	0	-	-	
M	2024-01-11	b	17K	53.1	18.2	21.2	110	0	0.01	964	954	10	0	-	-	
M	2024-01-12	b	19K	60.8	23.8	25.4	110	0	0.01	966	953	13	0	-	-	
M	2024-01-15	b	20K	64.6	28.5	29.3	110	0	0.01	964	861	103	0	-	-	
M	2024-01-16	b	21K	68.5	36.6	36.4	110	0	0.01	964	128	836	0	-	-	
S	2024-01-18	a	off	0	8.1	15.4	0	110	0.01	7	742	735	1	727	86	
S	2024-01-22	b	13K	35.1	13.0	18.0	0	110	0.01	5	16	11	0	-	-	
S	2024-01-22	d	15K	44.8	15.4	19.4	0	110	0.01	5	16	11	0	-	-	
S	2024-01-23	b	17K	53.3	18.3	21.4	0	103	0.01	5	16	11	0	-	-	Truncated
S	2024-01-23	d	19K	60.8	23.8	25.5	0	110	0.01	5	24	19	0	-	-	
S	2024-01-24	a	off	0	8.2	15.2	0	110	0.01	5	738	733	1	724	86	
S	2024-01-24	c	17K	53.3	18.2	21.3	0	110	0.01	3	16	13	0	-	-	
S	2024-01-24	e	20K	64.6	28.5	29.3	0	110	0.01	3	733	730	1	672	79	
S	2024-01-25	b	21K	68.6	35.9	35.9	0	110	0.01	3	963	960	0	-	-	
S	2024-01-25	d	20K	64.6	28.3	29.1	0	110	0.01	5	734	729	1	663	79	

Cryostat lift for BES3 measures

M	2024-02-01	a	15K	44.6	15.3	19.4	110	0	0.025	975	965	10	0	-	-	
S	2024-02-01	c	15K	44.6	15.3	19.3	0	110	0.025	6	18	12	0	-	-	
M	2024-02-05	c	15K	44.6	15.5	19.4	110	0	0.05	976	965	11	0	-	-	
S	2024-02-05	e	15K	44.6	15.4	19.4	0	110	0.05	6	855	849	1	838	97	no pre-cool
S	2024-02-06	b	15K	44.6	15.4	19.4	0	110	0.05	5	854	849	1	840	97	yes pre-cool
S	2024-02-06	d	17K	53.1	18.2	21.3	0	110	0.05	4	898	894	1	881	102	
S	2024-02-06	f	19K	60.6	23.7	25.4	0	110	0.05	4	850	846	1	831	94	
S	2024-02-06	h	13K	34.9	13.2	18.0	0	110	0.05	4	788	784	1	774	91	
S	2024-02-08	a	19>11K	60.1-31.4	21.0-12.4	22.7-17.6	0	110	0.05	4	777	773	1	764	88	
M+rS	2024-02-13	a	15K	44.6	15.4	19.3	110	-110	0.025+0.01	976	-427	1403	1	1380	-45	Magnet reverse
M	2024-02-13	c	15K	44.6	15.4	19.3	110	0	0.025	976	966	10	0	-	-	ForPresentation
M	2024-02-22	b	15K	44.6	15.2	19.2	110	0	0.025	976	965	11	0	-	-	Long: 15 gg



Tests and measurements on P100 #6

TEsts and measurements on P100 #6

Cilindro#6_P100

S	2024-03-18	a	15K	44.7	15.3	19.3	0	110	0.025	4	15	11	0	-	-	Long: 61 gg
M	2024-05-24	e	15K	44.8	15.4	19.5	150	0	0.025	1146	1133	13	0	-	-	150A
M	2024-07-08	b	15K	44.8	15.3	19.3	168	0	0.025	1197	1183	14	0	-	-	168A
M	2024-07-09	b	15K	44.8	15.3	19.2	130	0	0.025	1073	1061	12	0	-	-	130A
M	2024-07-10	b	15K	44.8	15.3	19.2	90	0	0.025	843	834	9	0	-	-	90A
M	2024-07-11	a	15K	44.8	17.0	24.0	130	0	inf	1073	1052	21	0	-	-	VeryFast 130A
S	2024-07-11	c	15K	44.8	15.4	19.3	0	168	0.025	3	21	18	0	-	-	130A
S	2024-07-12	a	15K	44.8	15.4	19.3	0	146	0.025	9	20	11	0	-	-	RegFault@146A
S	2024-07-12	c	15K	44.6	15.3	19.3	0	130	0.025	2	16	14	0	-	-	130A
S	2024-07-12	e	15K	44.8	15.3	19.3	0	146	0.025	2	18	16	0	-	-	150A, RegFault @146A
S	2024-07-12	g	15K	44.6	15.3	19.3	0	90	0.025	2	11	9	0	-	-	
M	2024-07-15	c	15K	44.8	15.4	19.4	110	0	1	976	421	555	1	547	5	FastRamp
M	2024-07-15	e	15K	44.8	15.4	19.4	110	0	0.5	975	350	625	1	616	6	FastRamp
M	2024-07-16	b	15K	44.8	15.4	19.3	110	0	0.25	975	324	651	1	642	4	FastRamp
M	2024-07-16	d	15K	44.8	15.4	19.3	100	0	0.5	914	287	627	1	618	0.1	FastRamp,100A
M	2024-07-16	f	15K	44.8	15.4	19.4	110	0	0.1	975	272	703	1	693	1	FastRamp
M	2024-07-16	h	15K	44.8	15.4	19.3	110	0	0.05	975	965	10	0	-	-	
M	2024-07-17	b	15K	44.8	15.4	19.4	90	0	0.5	841	833	8	0	-	-	FastRamp, 90A
M	2024-07-17	d	15K	44.8	15.4	19.4	90	0	1	841	833	8	0	-	-	FastRamp, 90A
M	2024-07-17	f	15K	44.8	15.4	19.3	110	0	0.075	975	965	10	0	-	-	FastRamp
M	2024-07-17	h	15K	44.8	15.4	19.4	90	0	1.25	841	833	8	0	-	-	FastRamp, 90A
M	2024-07-17	l	15K	44.8	15.4	19.4	90	0	1.5	841	367	474	1	467	0.1	FastRamp, 90A
(S)	2024-07-22	a	15K	44.8			0	168	0.025							RegFault@150A
(S)	2024-07-23	a	15K	44.8			0	168	0.025							RegFault@148A

TEsts and measurements on P160 #8

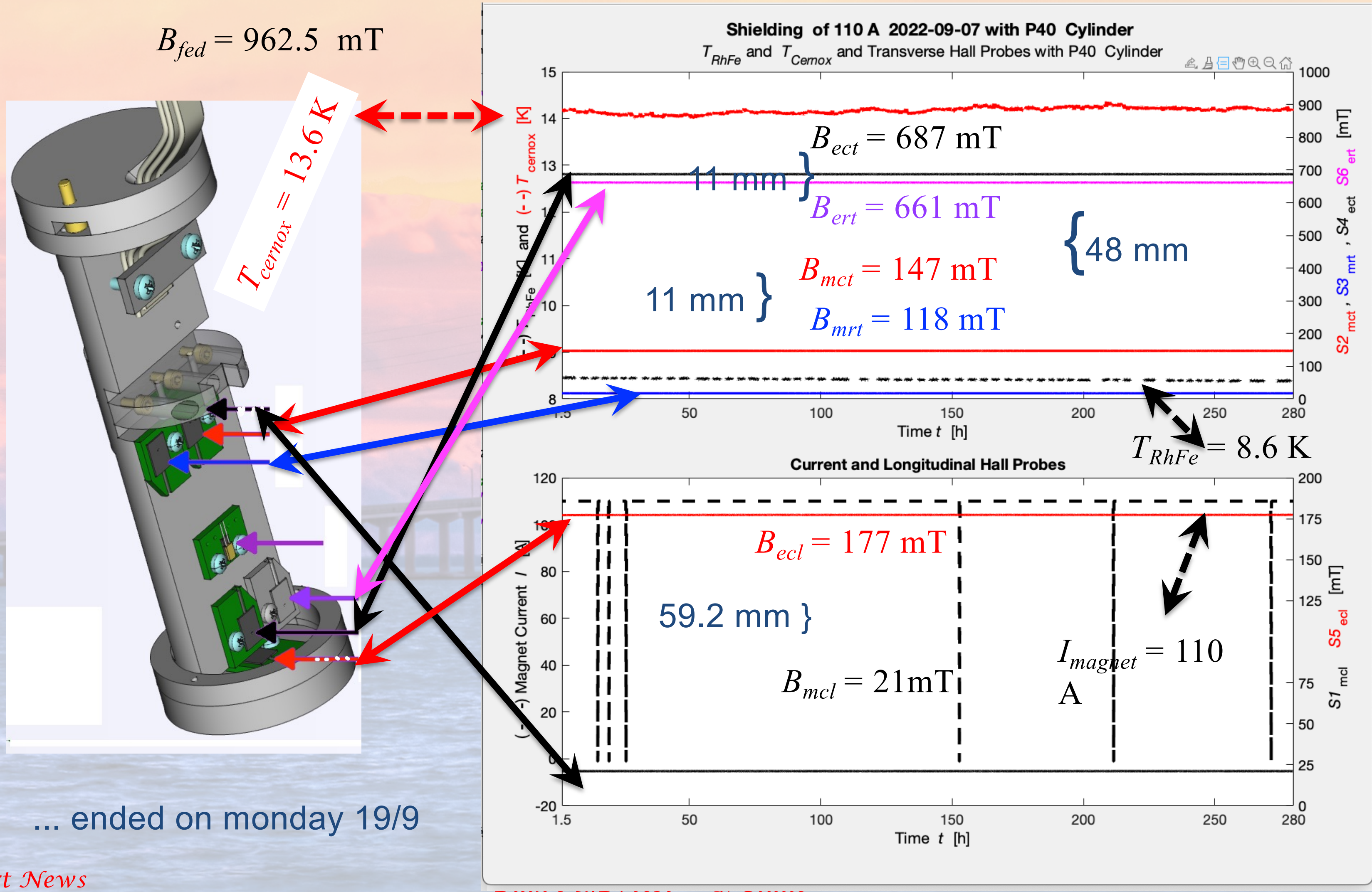
Cilindro#8_P160

S	2024-09-16	b	17K	53.3	18.3	21.1	0	110	0.01	4	325	321	0	-	-	S2 increasing
S	2024-09-17	a	19K	60.8	23.7	25.3	0	110	0.01	4	655	651	0	-	-	S2 increasing

glued to Al turret

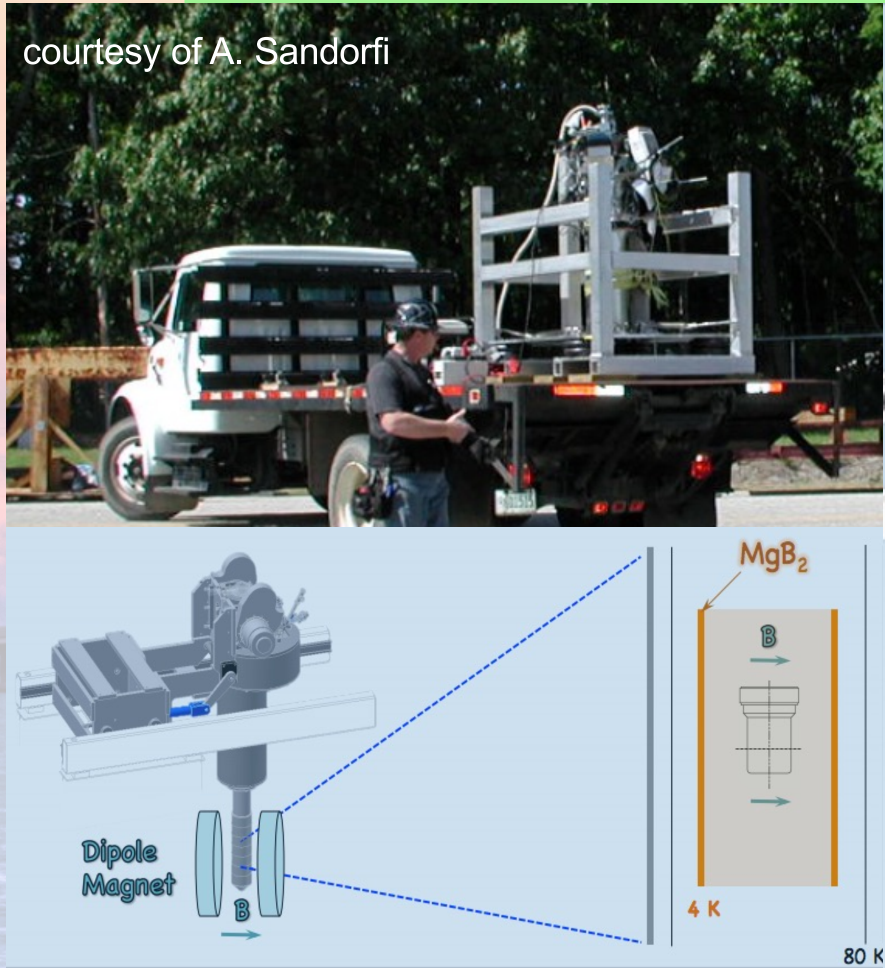
M	2024-08-01	c	off	0	8.6	15.2	110	0	0.025	976	700	276	5	1	57	
M	2024-08-01	d	15K	44.8	15.7	19.4	110	0	0.025	976	948	28	0	-	-	
(S)	2024-08-05	b	15K	44.8			0	150	0.025			0				RegFault@146A
S	2024-08-05	c	15K	44.8	15.6	19.2	0	140	0.025	2	370	370	0	-	-	S2 increasing, RegFaultDelayed
M	2024-08-06	a	11K	24.1	11.3	16.4	110	0	0.025	976	962	14	0	-	-	S2 decreasing
S	2024-08-20	b	15K	44.8	15.3	19.2	0	110	0.025	6	195	189	0	-	-	S2 increasing
M	2024-08-20	c	13K	35.1	13.1	17.6	110	0	0.025	975	957	18	0	-	-	S2 decreasing
(M)	2024-08-20	d	17→off	35.1→off	17.6→14.7	13.1→8.5	0	0	0	957	957	0	0	-	-	LongTail
M	2024-08-21	a	17K	53.3	18.3	21.2	110	0	0.025	976	925	51	0	-	-	S2 decreasing
S	2024-08-22	a	17K	53.3	18.2	21.1	0	110	0.025	7	328	321	0	-	-	S2 increasing
S	2024-09-11	a	off	0	8.4	14.9	0	110	0.01	6	504	498	2	481	71	
S	2024-09-12	a	9K	12.2	9.3	15.3	0	110	0.01	4	856	852	1	814	103	
S	2024-09-13	a	11K	24.1	11.2	16.3	0	110	0.01	4	87	83	0	-	-	S2 increasing
S	2024-09-13	c	13K	34.9	13.0	17.7	0	110	0.01	4	132	128	0	-	-	MagTripAfter,S2increase
S	2024-09-16	a	15K	44.8	15.4	19.1	0	110	0.01	3	199	196	0	-	-	S2 increasing

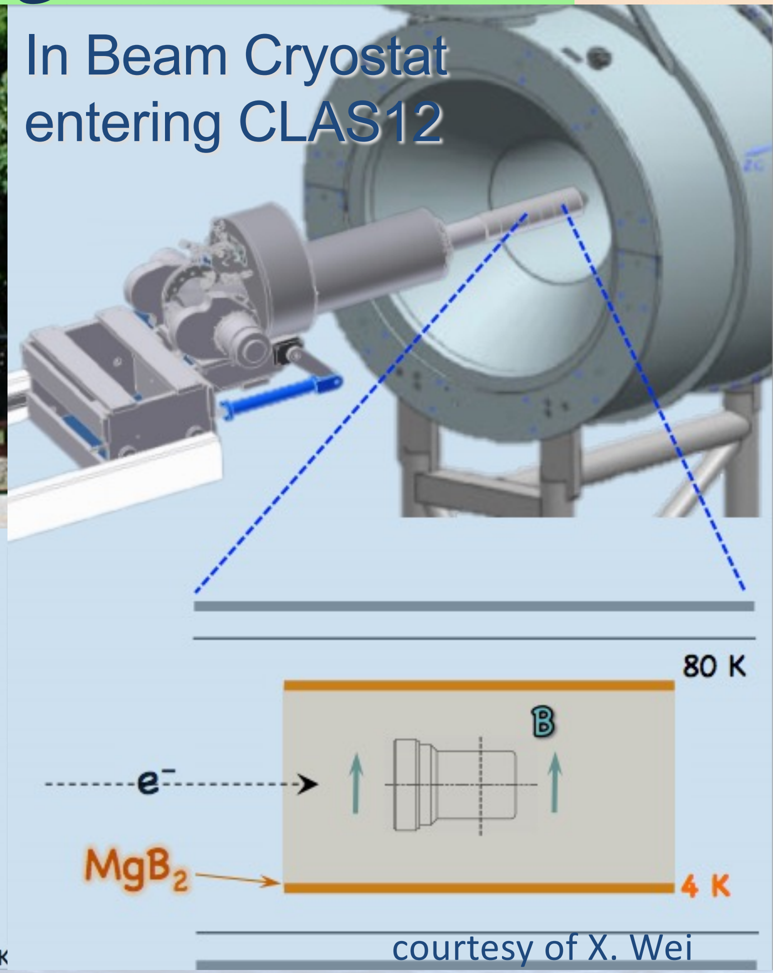
Shielding long term stability 1.5 -280 h.



... ended on monday 19/9

CLAS12 INTEGRATION





Longitudinal polarized target

Longitudinally Polarized Target - Technical Parameters

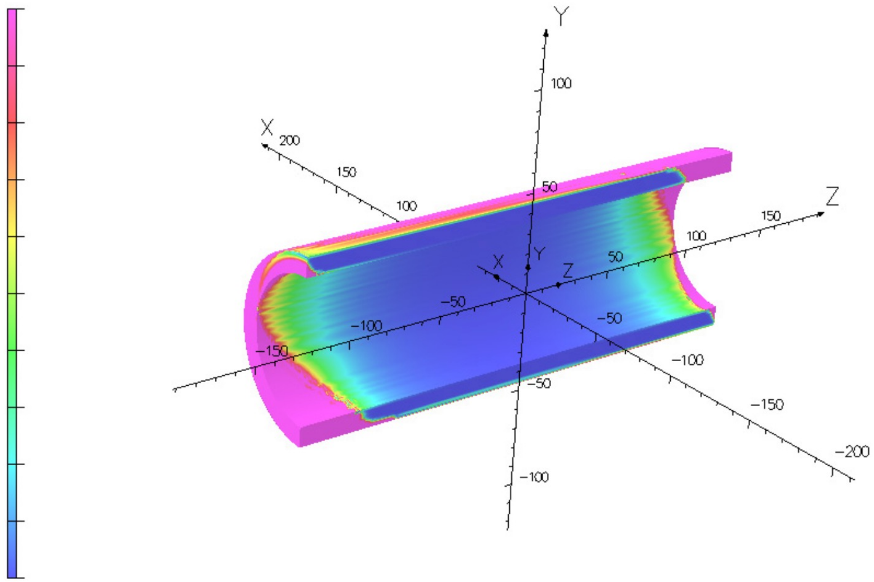
PARAMETER	DESIGN VALUE
Target material	Protons / deuterons (NH_3/ND_3, LiH, LiD)
Sample dimensions	2.5 cm diameter x 4 cm long, 60% filling factor
Polarization method	Dynamic Nuclear Polarization (DNP)
Magnetic field	5.0 Tesla
Temperature	1 Kelvin
Expected Performance	**DESIGN VALUE**
Proton polarization	>90%
Deuteron polarization	>40%
Proton & Neutron Luminosity	1.4×10^{33} cm^{-2} s^{-1} per nA beam current
Maximum Beam Current	30 nA

Our starting point for faisibility study

Transversely Polarized Target – Technical Parameters

Parameter	**Design Value**
Polarizable target material; mass fraction	HD; 80%
Unpolarizable material; mass fraction	Al (as wire); 20%
Target dimensions	2.5 cm ∅ × 2.5 cm long
Polarization method	High-field, Low-temp equilibrium
In-beam holding field B × dL	1.2 tesla × 15 – 25 cm
H polarization	> 60%
H Luminosity	$5\ 10^{33}$ cm^{-2} s^{-1} per 2 nA
In-beam lifetime	≥1 nA-week per target

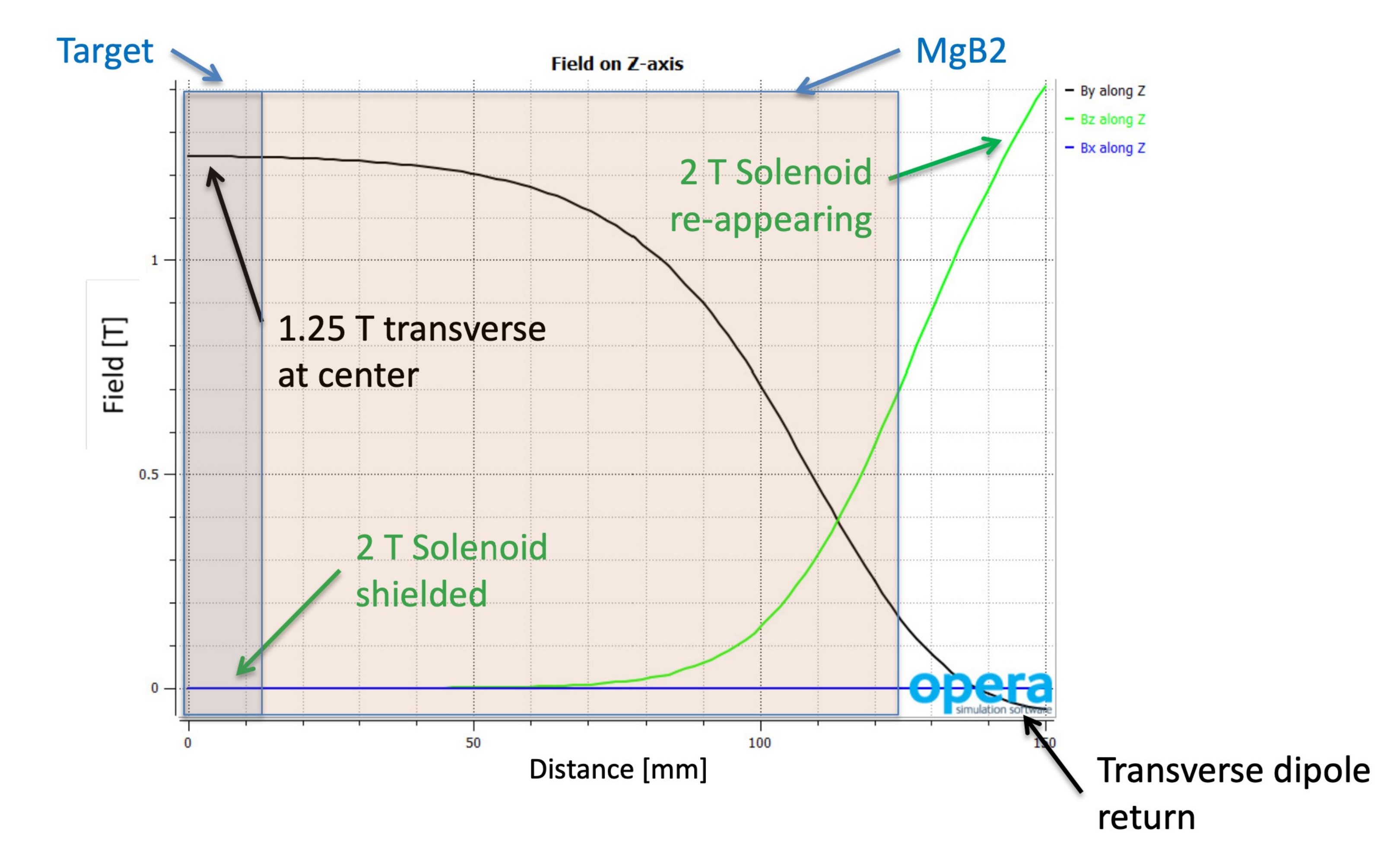
Lowry simulations



MgB2 cylinder:
86 mm Ø
250 mm long
7 mm wall

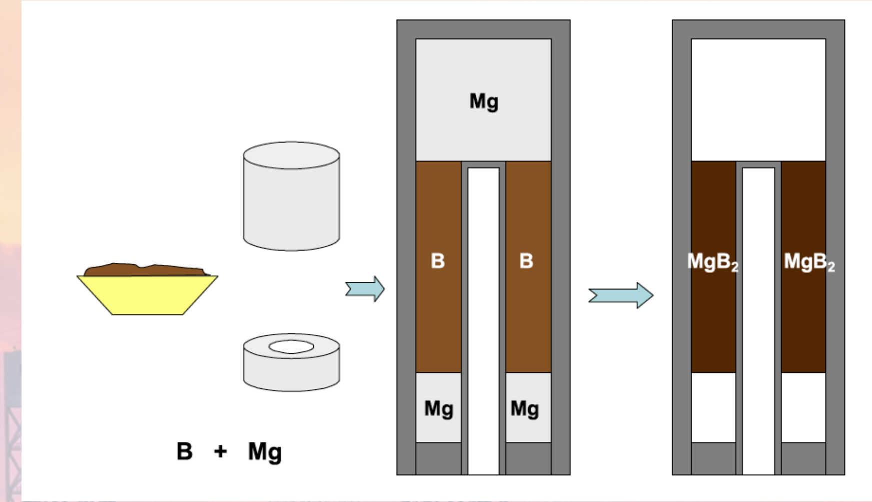
1.25 T transverse magnetization
2.0 T axial shield
5x10-3 uniformity (Y_{20}/Y_{00})
over 20 mm radius sphere

Lowry simulations



Production of MgB_2 by Mg-RLI
(Mg Reactive Liquid Infiltration)

Fill a steel container by B Power and large chunks of MgB_2,
weld the container and perform thermal treatment at about 900-950 ºC in conventional oven for 12-24 h.



Critical temperature
(T_C) 39.5 K
High density 2.4 g/cm^3
High connectivity
Very high superconducting characteristics
High value of critical currents