PSI Center for Accelerator Science and Engineering

The HiMB Project at PSI

High Intensity Muon Beam: Magnets in a high radiation environment

A. L. Gabard

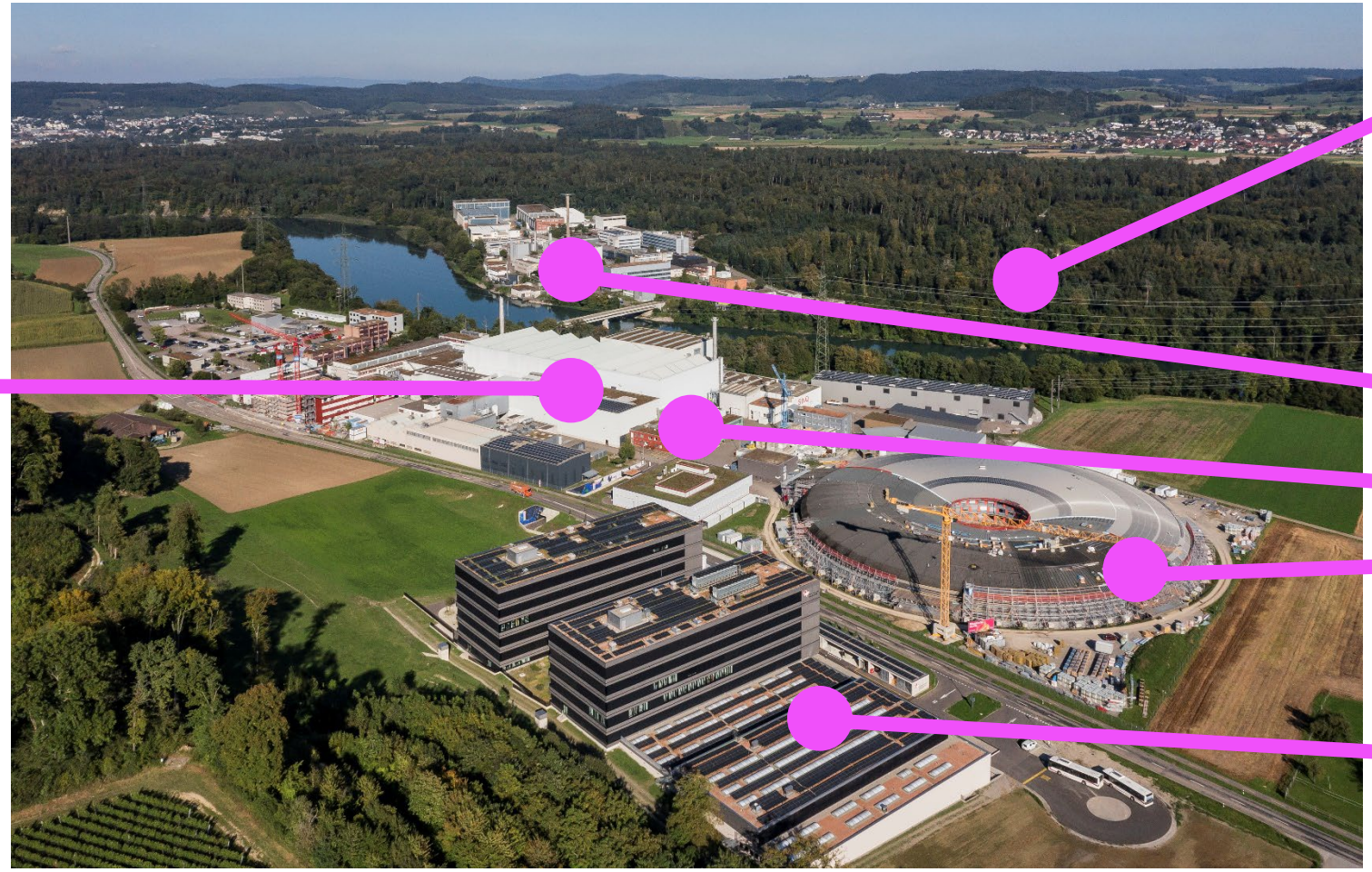
RADSUM, 15 January 2025

Contents

PSI: The Paul Scherrer Institute

PSI

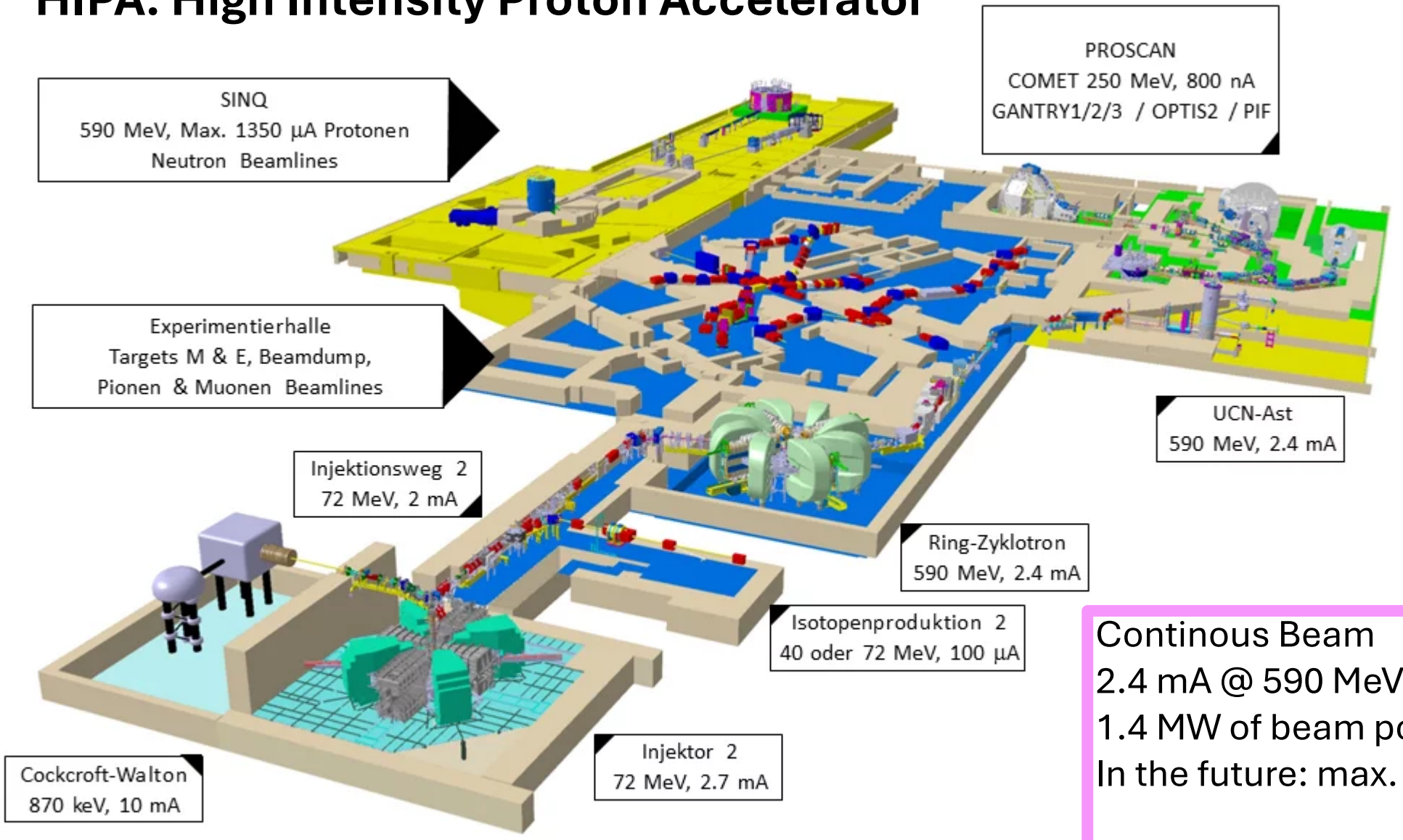
Biggest research institute in Switzerland ☺



2100 employees- member of the ETH domain

- R&D on: Matter and Materials, Energy, Environment, Human Health, Accelerator Technologies & Instruments
- Education and technology transfer

HIPA: High Intensity Proton Accelerator

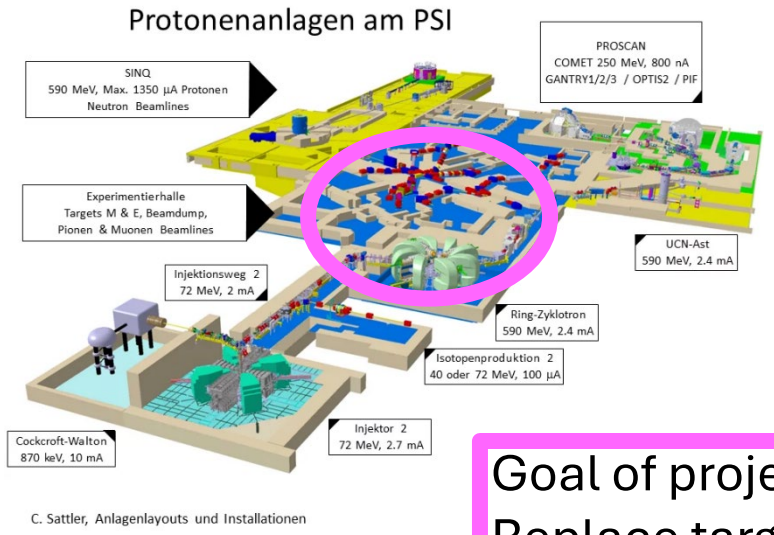


C. Sattler, Anlagenlayouts und Installationen

Continous Beam
2.4 mA @ 590 MeV
1.4 MW of beam power
In the future: max. 3 mA

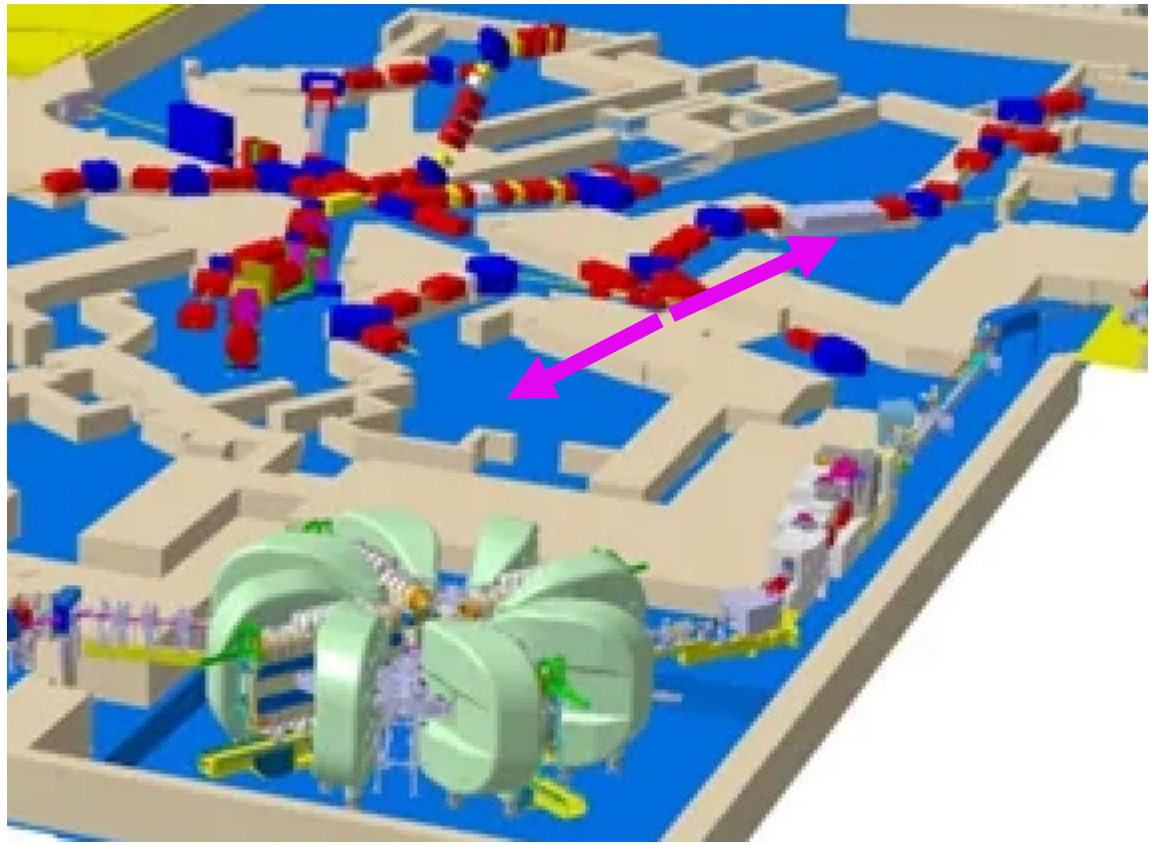
Magnet consumption: 2.6 MW
HIPA annual consumption: 40 GWh

The HiMB project: High Intensity Muon Beam



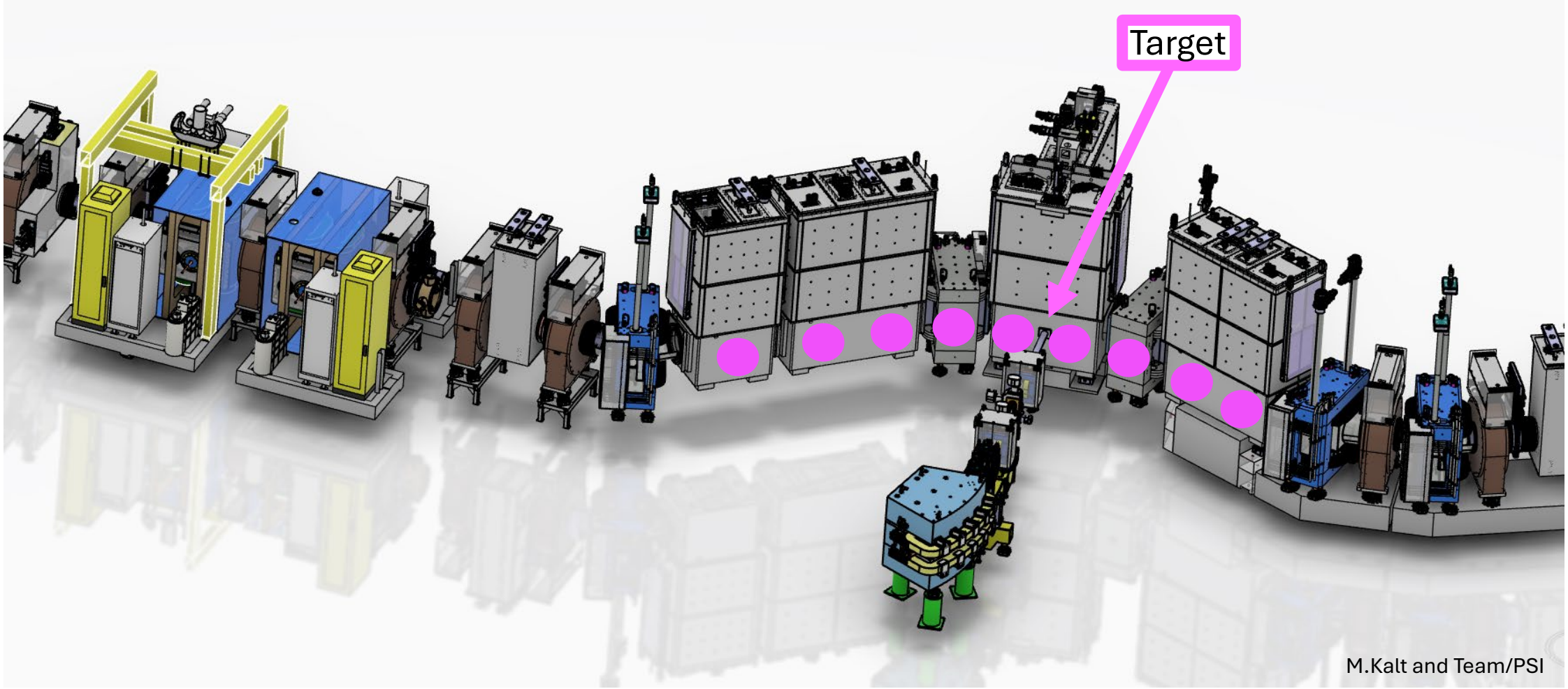
Goal of project HiMB: Replace target «M» with new design and build new beamlines

Power increase from 120 kW to 650 kW



« Magnet Design for the High-Intensity Muon Beams Project /HIMB) at PSI's Accelerator Complex HIPA», R.Riccioli et al., IEEE Transactions on Applied Superconductivity. 2024; 34(5): 4004305 (5 pp.).

New Target Region



- seven radiation hard solenoids in vacuum
- two radiation hard dipoles

● radiation hard magnets

Radiation load along beamline MuH2

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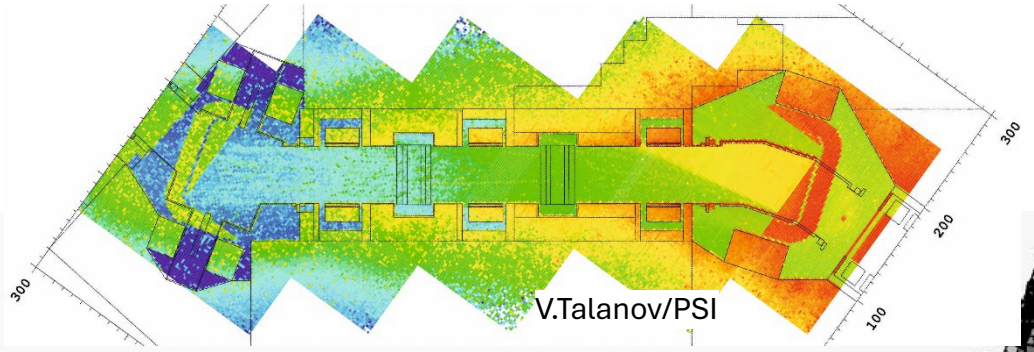

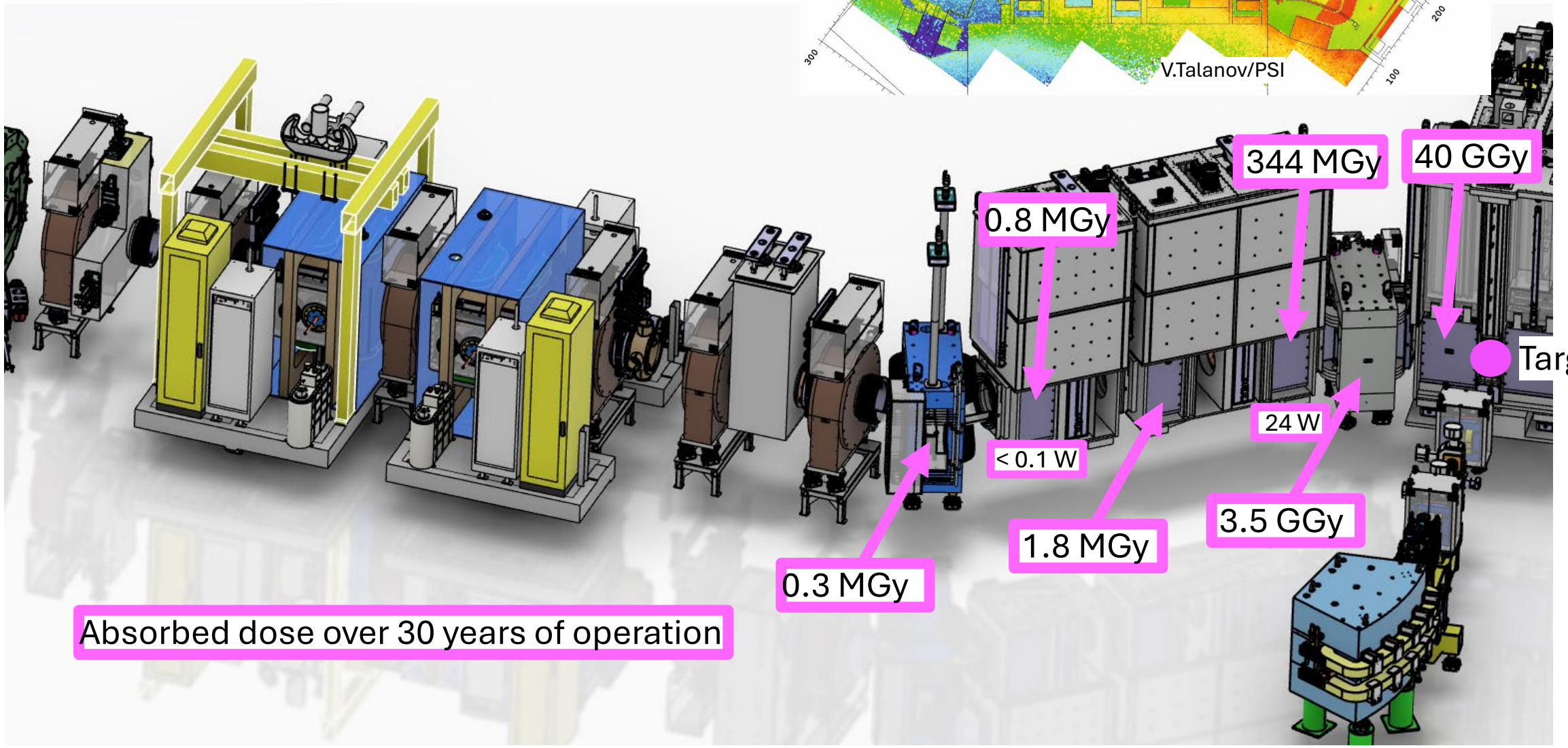

Mineral Insulated Conductors (MIC) for radiation hard magnets

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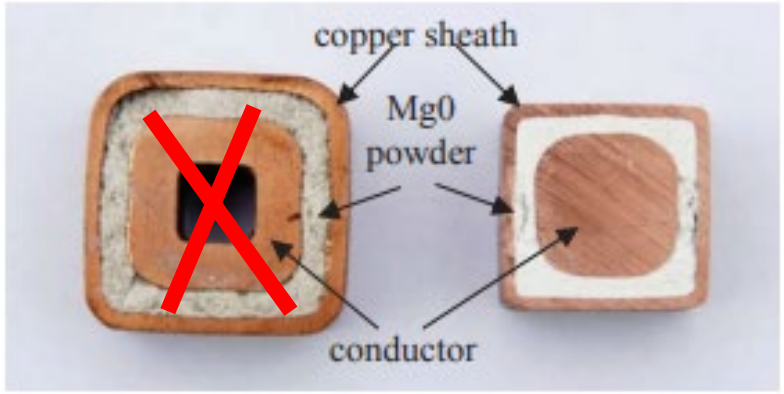
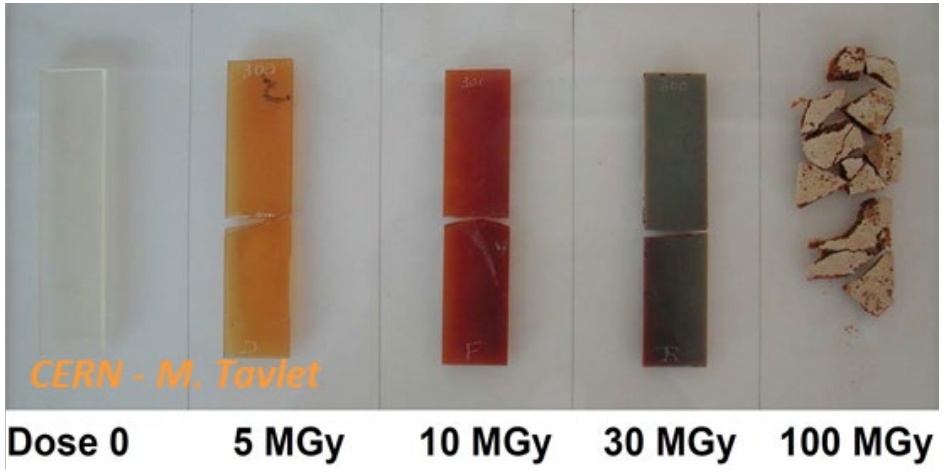
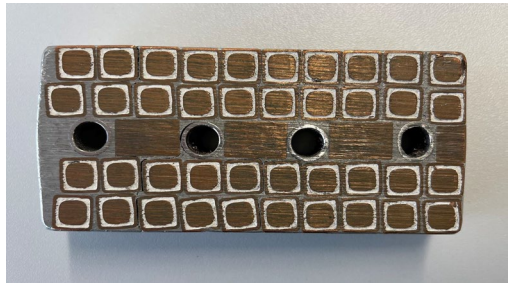
- Avoid organic materials
- Metals, ceramics only
- Indirect cooling only



Radiation damage on Epoxy





MIC: Copper + MgO

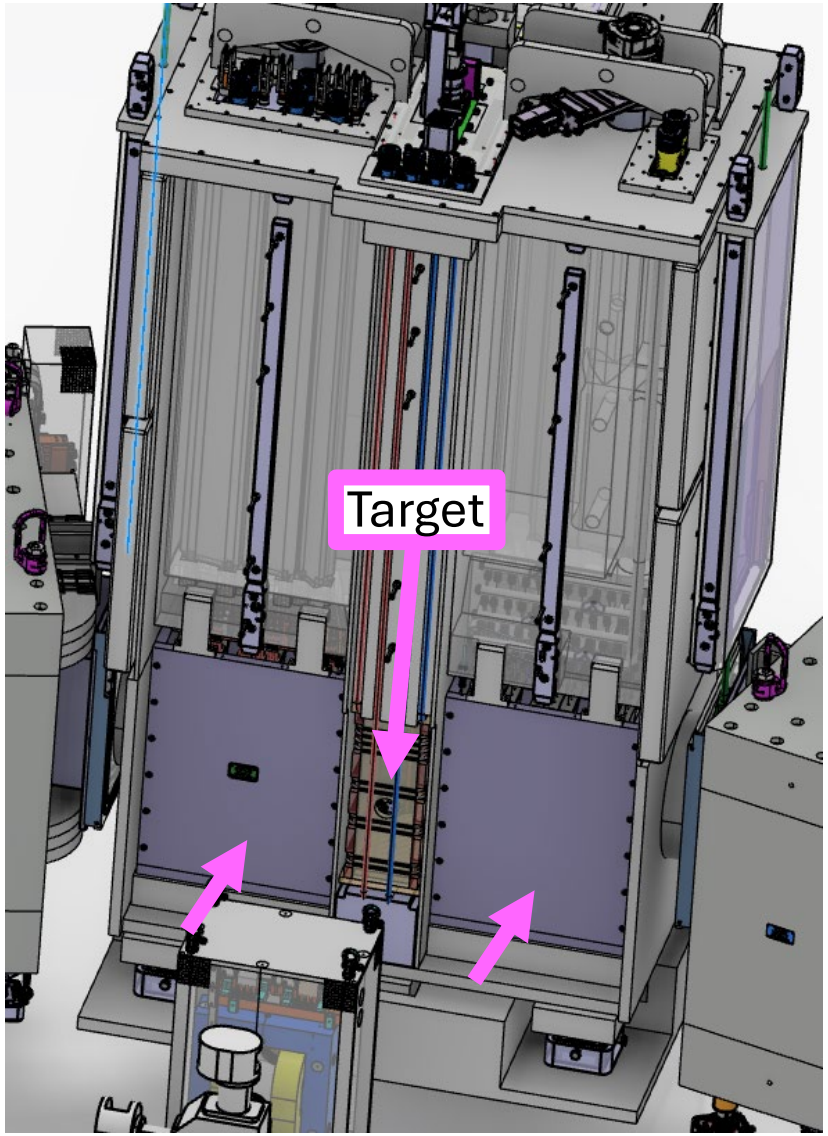
- Inorganic
- Hygroscopic
- Fragile
- Prone to short-to-ground

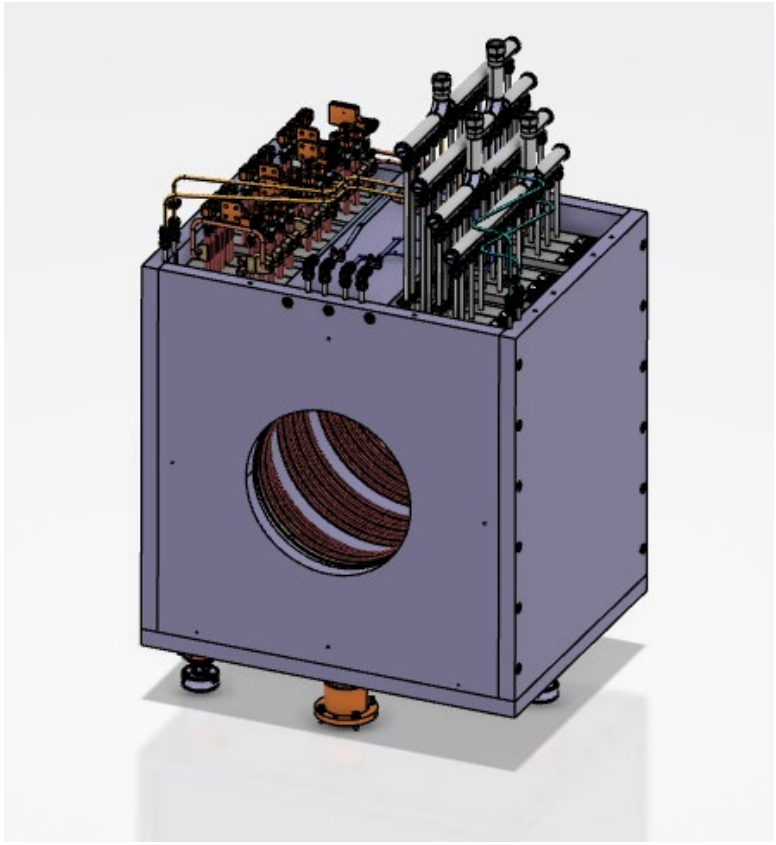
Copper corrosion

Copper oxide obstructs cooling channels

« Radiation hard magnets at the Paul Scherrer Institute », A. Gabard et al., Proceedings of IPAC2012

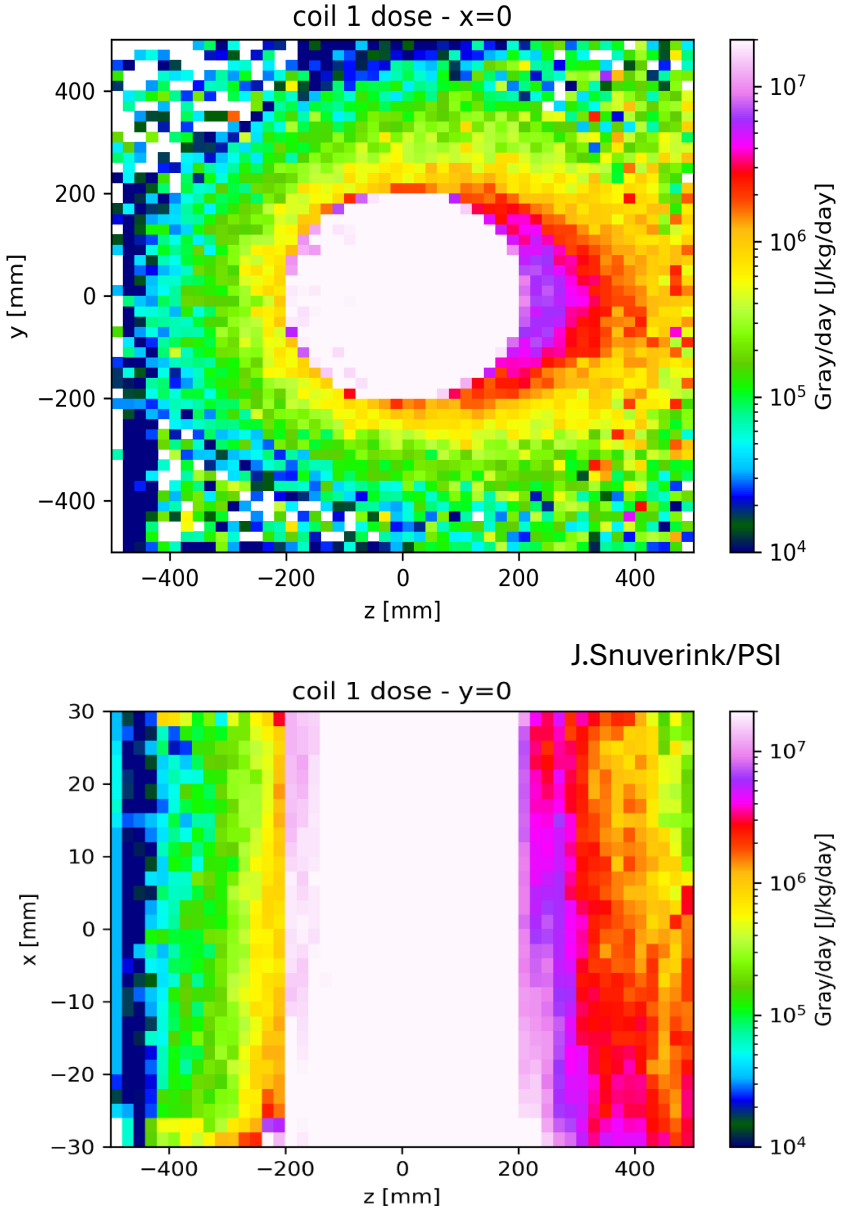
Capture Solenoids

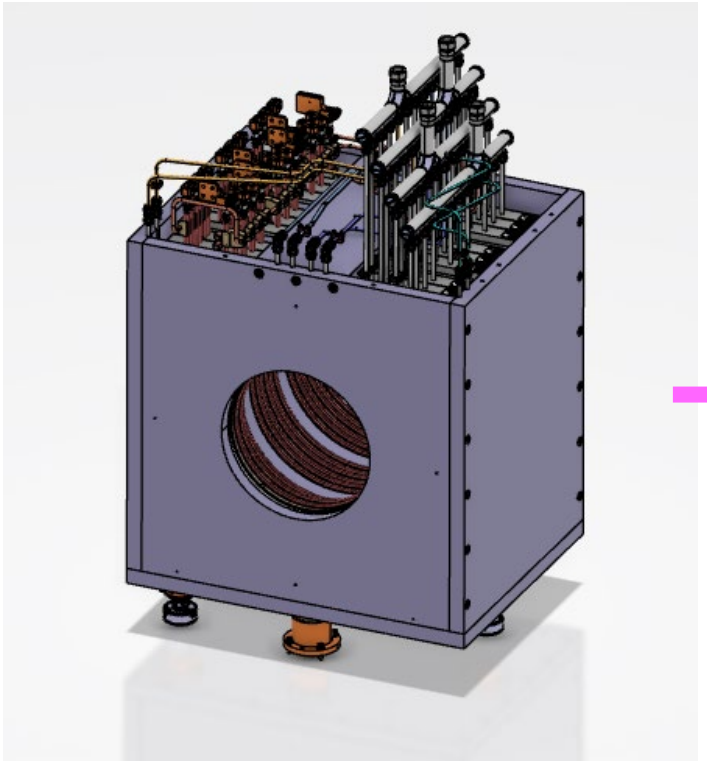


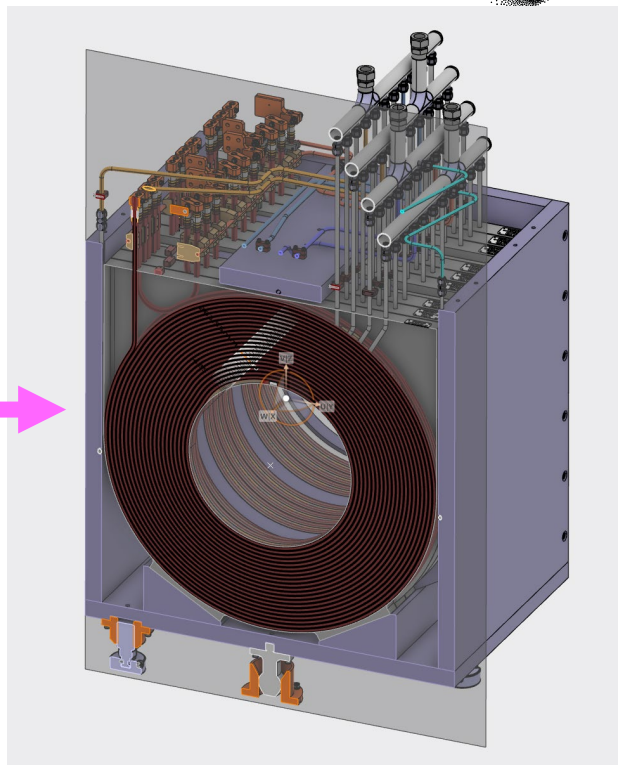


Max. current 650A
Three coil packages
First coil at 250 mm from target
Power consumption in operation 250 kW

Radiation load on Capture Solenoid





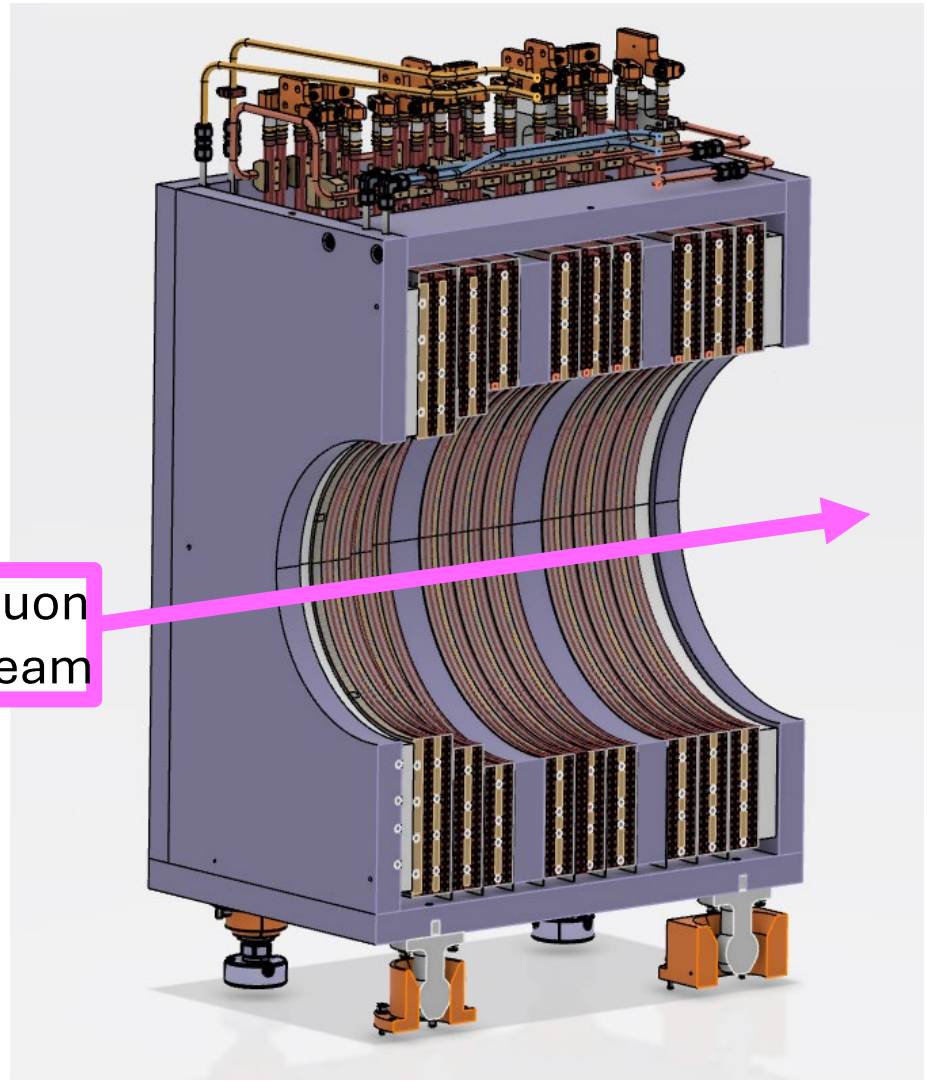


Hotspot: 10 MGy per day at 3 mA operation

Typical max. radiation load for Epoxy = 10 MGy

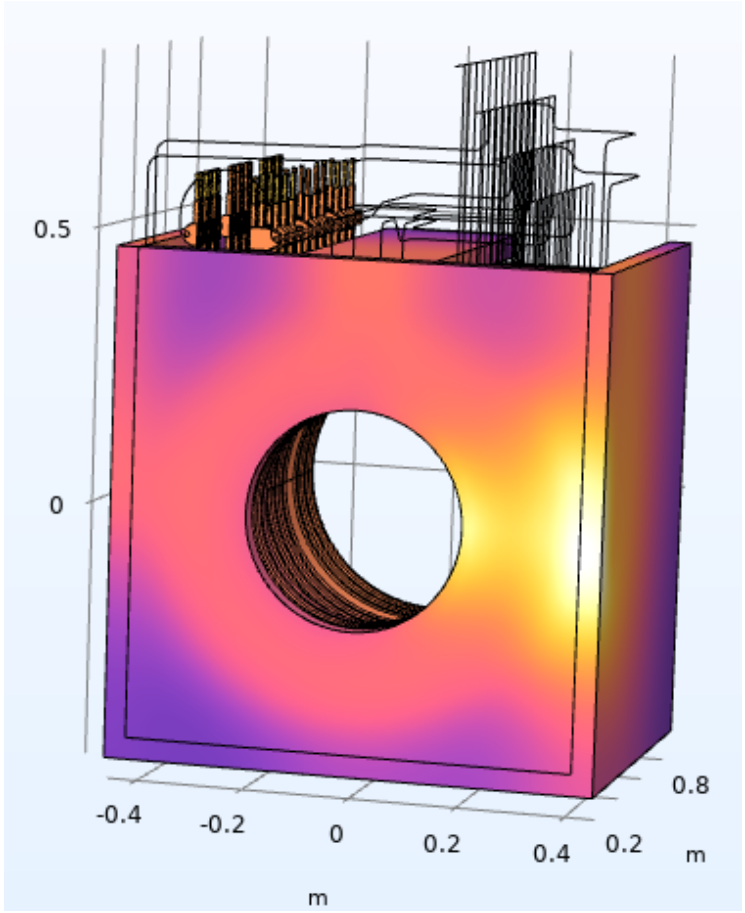
→ Conventional magnet definitely not possible

Heat load on capture solenoid



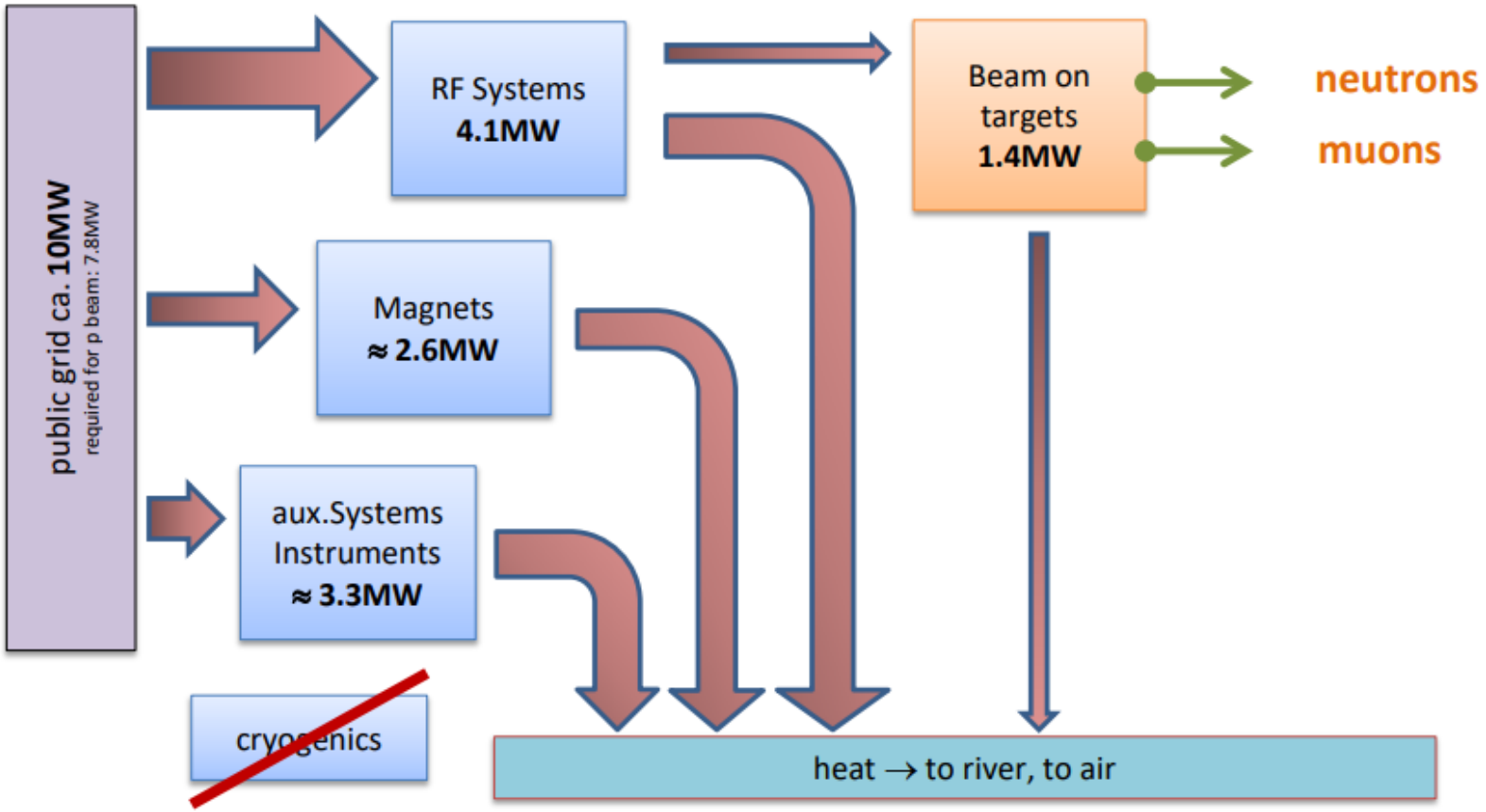
Mirror plate	3.00 kW
1st coil	1.82 kW
2nd coil	0.49 kW
3rd coil	0.25 kW
1st ARMCO plate	0.31 kW
4th coil	0.24 kW
5th coil	0.20 kW
6th coil	0.16 kW
2nd ARMCO plate	0.12 kW
7th coil	0.10 kW
8th coil	0.08 kW
9th coil	0.07 kW
Total:	6.84 kW

J.Snuverink/PSI



R.Riccioli/PSI

Energy consumption of the HIPA accelerator



M.Seidel/PSI

10 MW * 4000 hrs = 40 GWh

Current price per MWh for PSI: CHF 150

Operational cost: CHF 6 M

→ CHF 1.6 M for magnet powering

Potential savings: CHF 500k-1 M per year

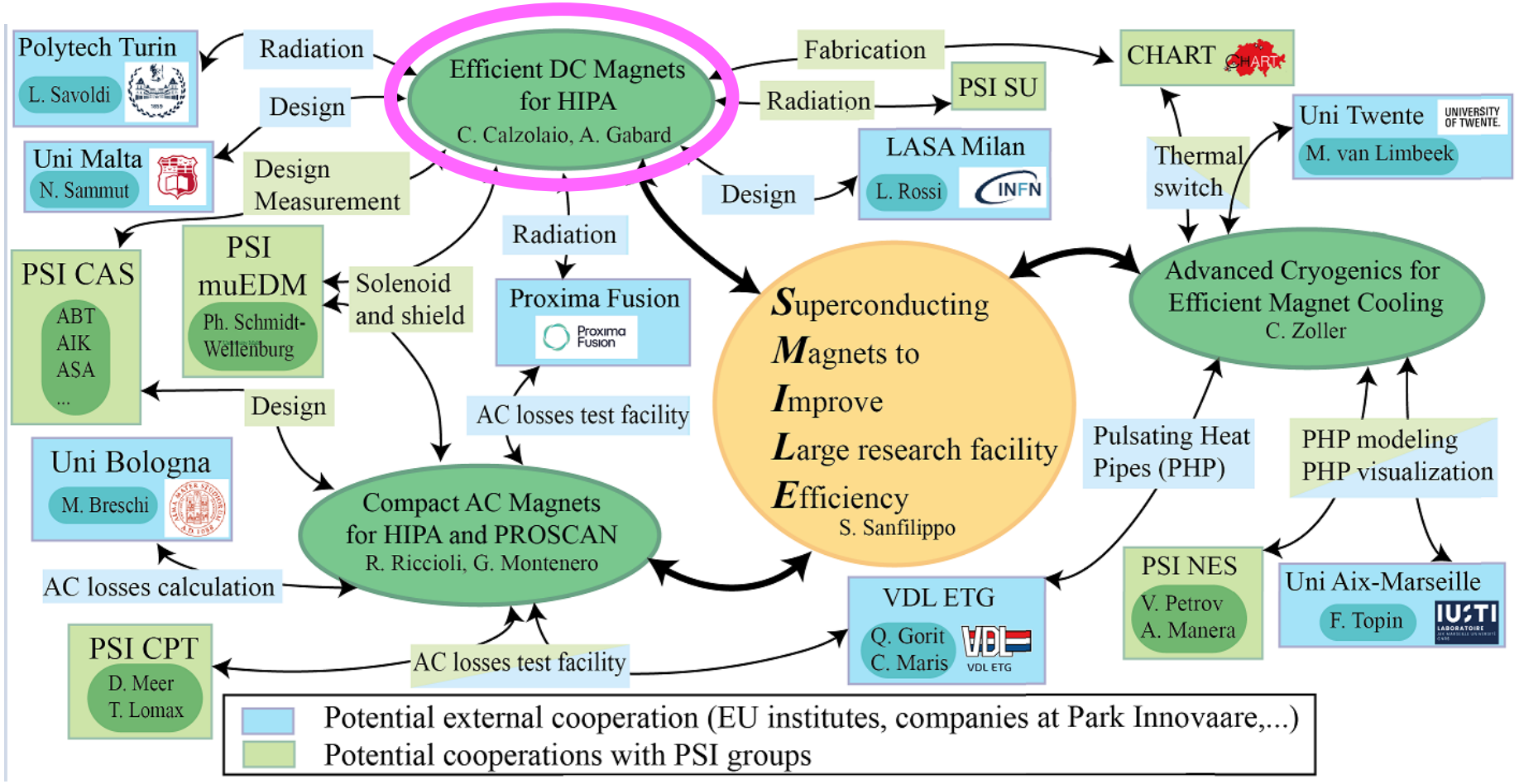
Current plan: operation until 2058

Magnet consumption: 26% of total consumption

HiMB power increase:
2.6 MW → 3.1 MW (20%)

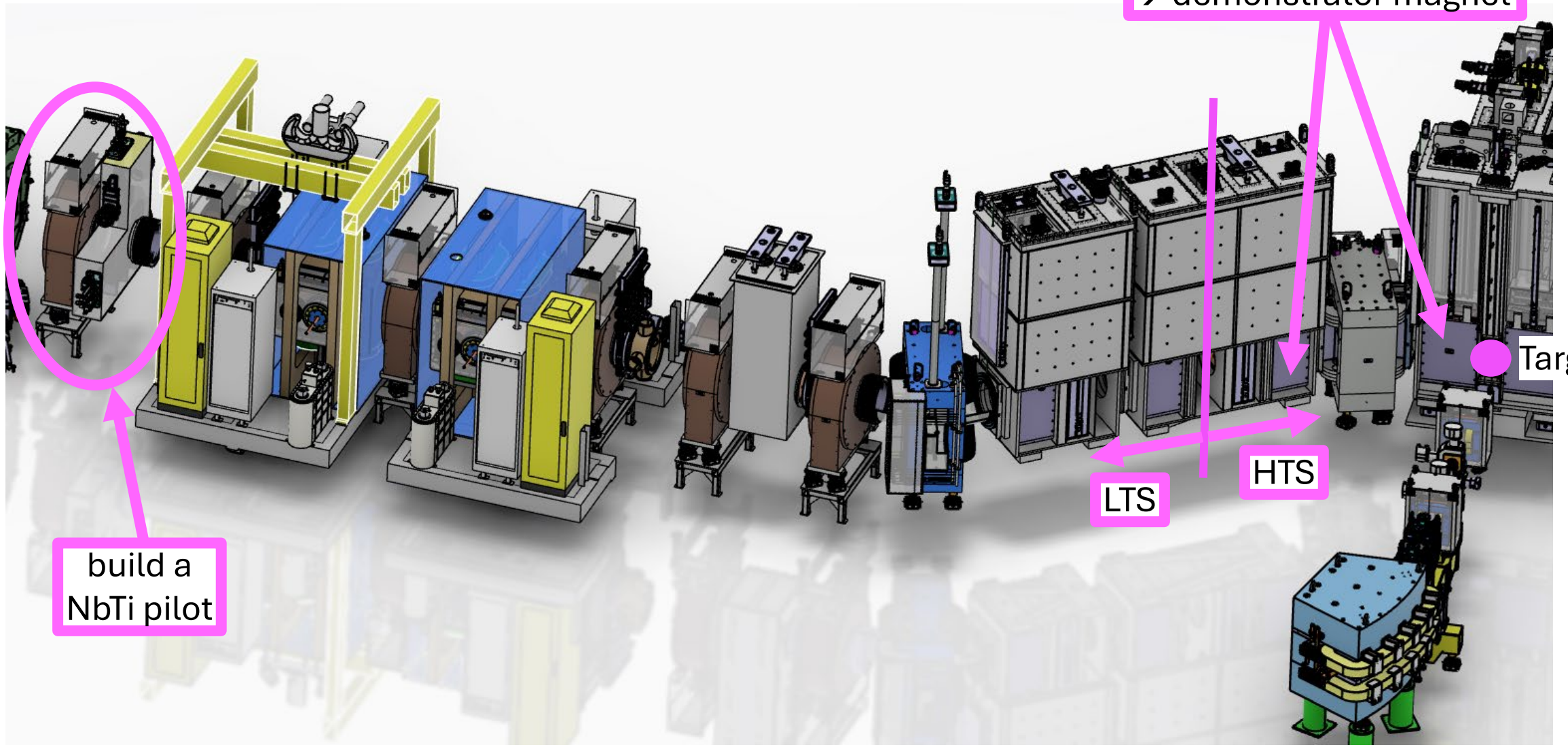
SMILE: mid-term initiative (min. 4 years)

Goals: Sustainable energy management for the infrastructure of PSI, with more efficient and improved performance of magnets



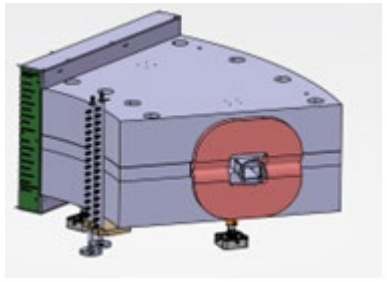
Three work packages : DC and AC superconducting magnets
Advanced cryogenics (Pulsating Heat Pipes)

Next steps

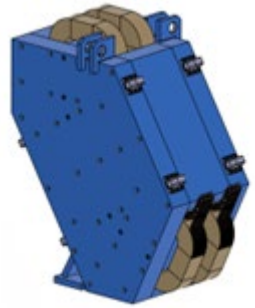

investigate HTS use
→ demonstrator magnet
Target
LTS
HTS
build a
NbTi pilot

Long term goal: replace resistive magnets in HIPA

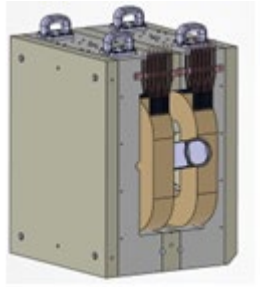
~280 copper coil resistive magnets
~70 magnets with Mineral Insulated Cables (MIC) (highly radiative environment)



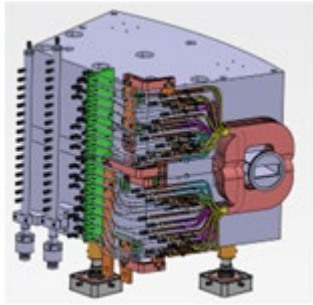
AHC: 128 kW



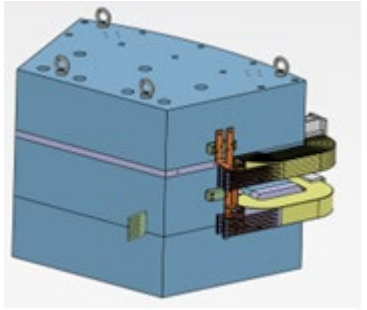
AHO: 145 kW



AHM: 67 kW

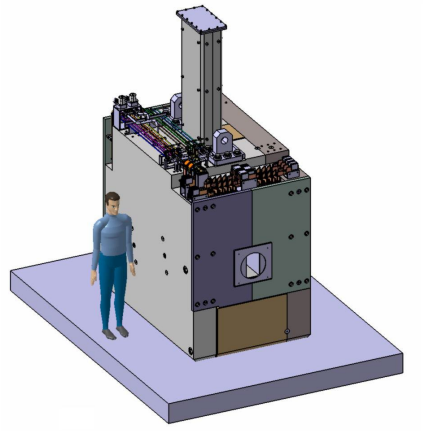


AHB: 189 kW



AHD: 74 kW

AHL: 61 kW



Radiation hard (MIC coils)

Total Power: ~700 kW

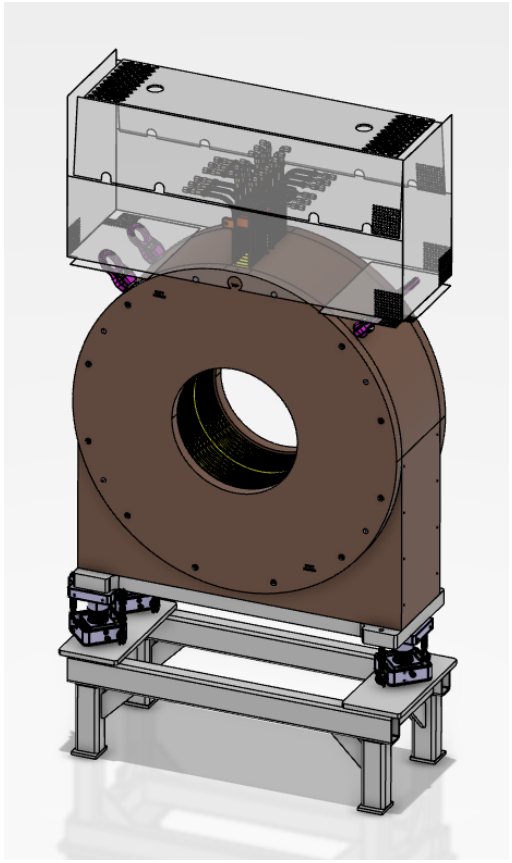
Conclusion

- The HiMB project promises exciting new experiments but increases energy consumption
- There is a lot of potential for energy savings over the whole accelerator
- Radiation is an important topic and influences the choice of technology
- The SMILE initiative was launched to adress these topics

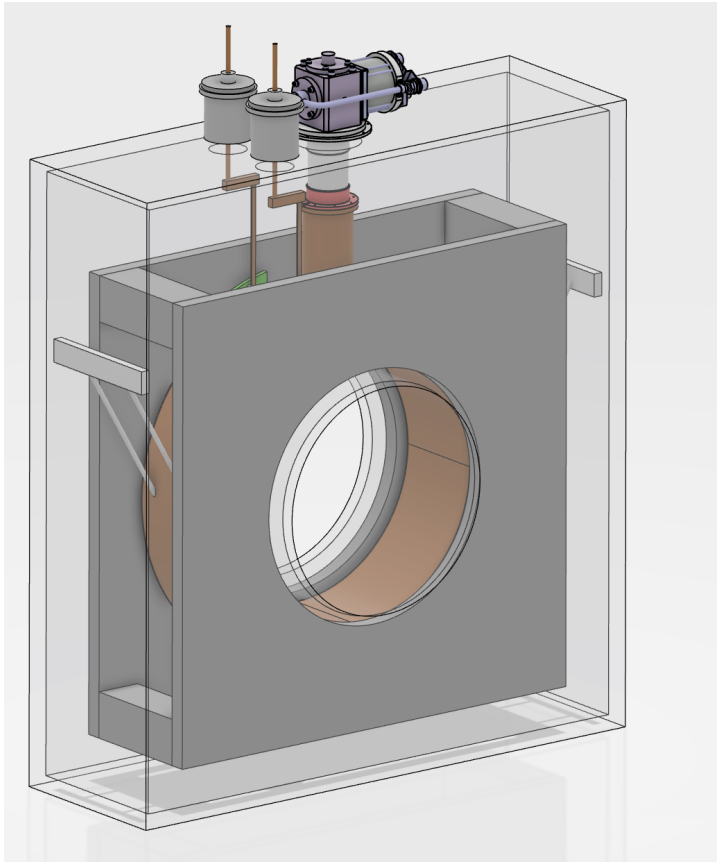
- Complementary presentation: Ciro Calzolaio, Friday at 2 pm

Thank you

LTS Solution: Pilot

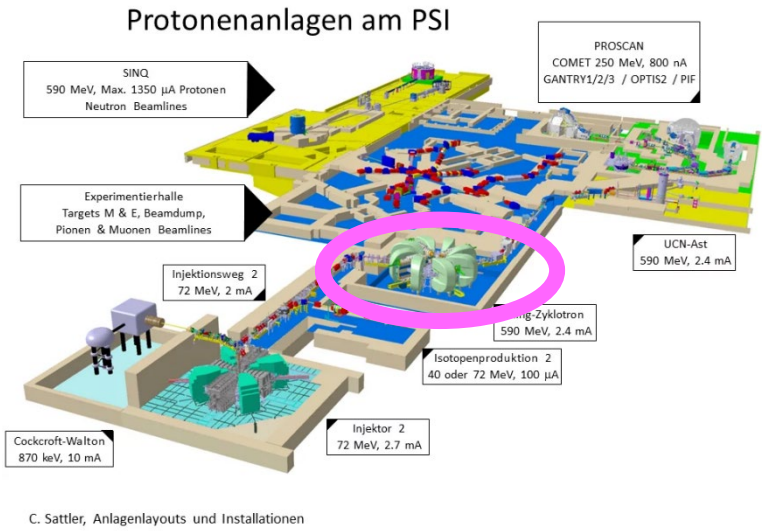


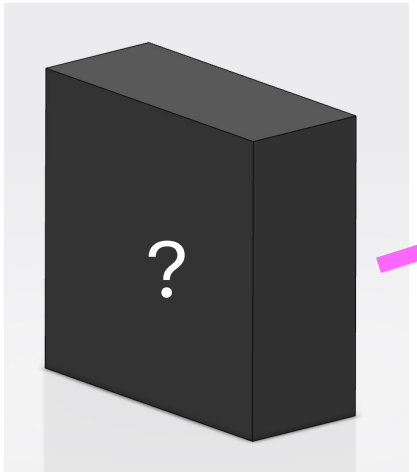
Max. field 0.55 T
Power at max. field 65 kW

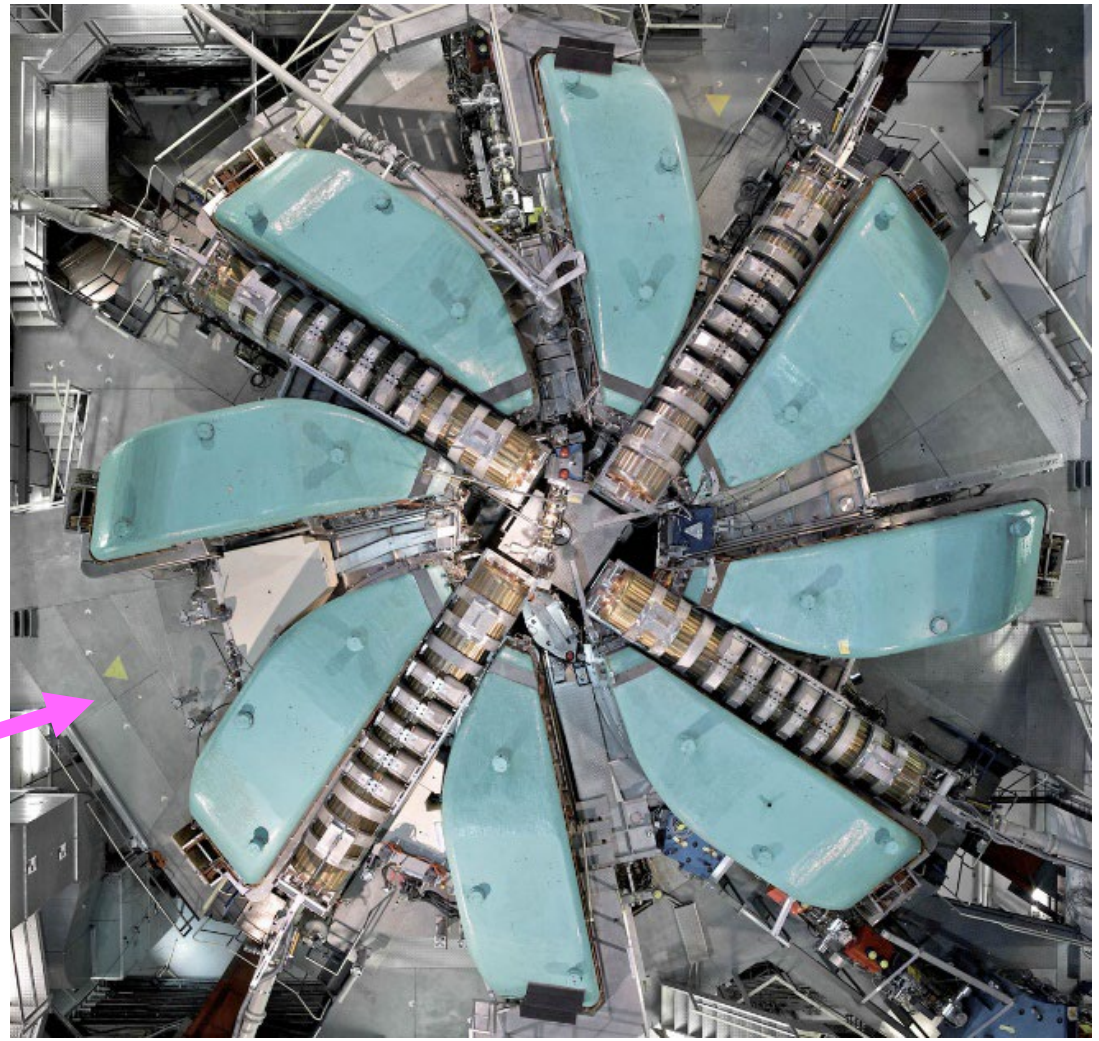


Max. field 1 T
Power at max. field 7.5 kW

HTS Solution: Investigate





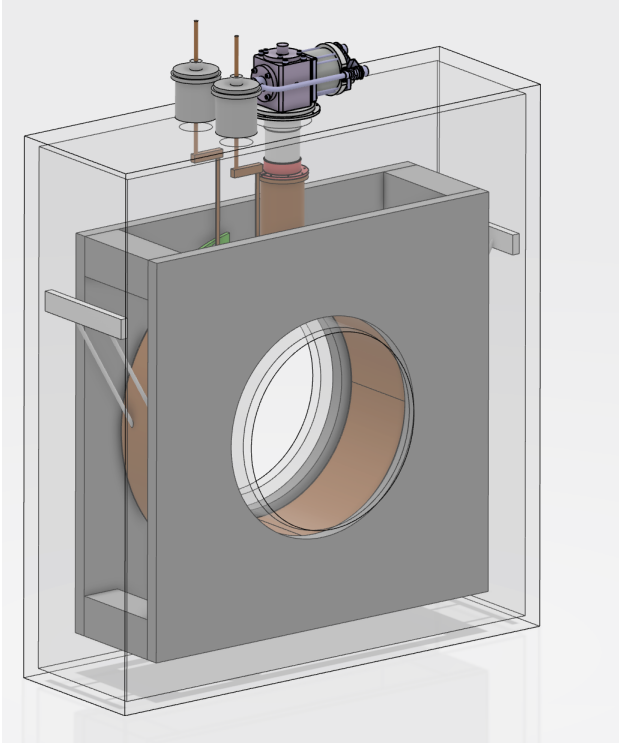


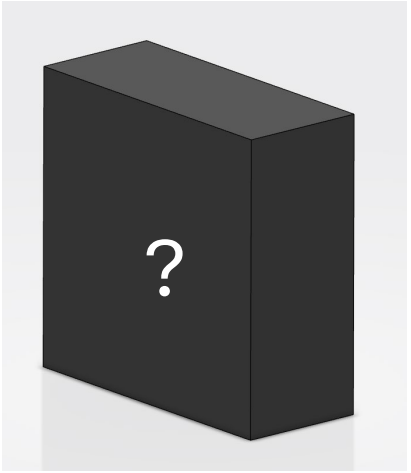
Goal: build a test magnet, place it inside the cyclotron bunker and irradiate it for one operational period (4000 hrs) in 2026

lookout

Presentation of Ciro Calzolaio: **Efficient Magnet Designs and Radiation effects for PSI**

Friday, 2:00 pm

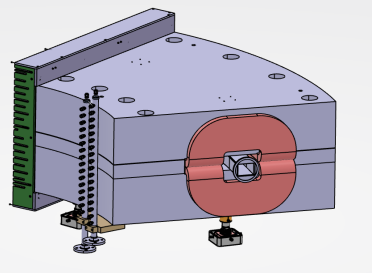




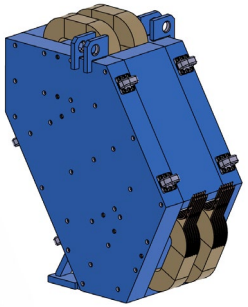
Long term goal: replace resistive magnets in HIPA

~280 copper coil resistive magnets

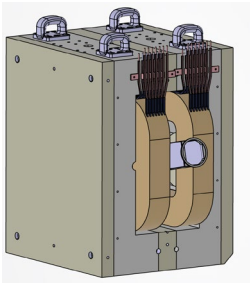
~70 magnets with Mineral Insulated Cables (MIC) (highly radiative environment)



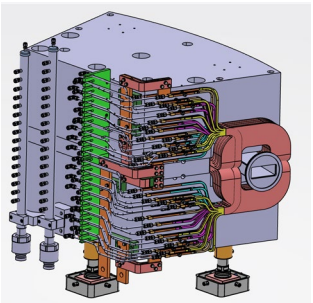
AHC	
Power	128 kW
Field	1.564 T
Integral	2.8 Tm
Size	2x1.5x0.8 m
Weight	12.5 t



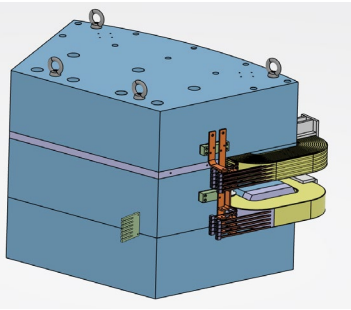
AHO	
Power	145 kW
Field	1.5 T
Integral	4.5 Tm
Size	2.9x2.6x1.5 m
Weight	51 t



AHM, AHN	
Power	67 kW
Field	1.5 T
Integral	3.75 Tm
Size	2x1.5x1.2 m
Weight	22 t

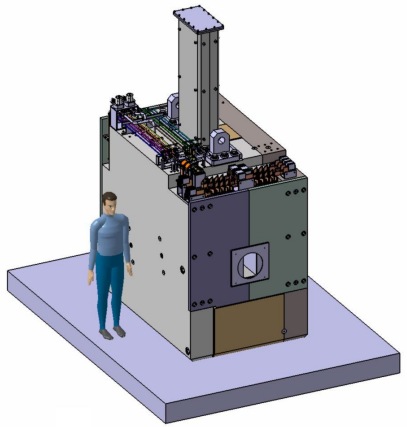


AHB	
Power	189 kW
Field	1.8 T
Integral	2.9 Tm
Size	1x0.7x0.7 m
Weight	4.2 t



AHD1, AHD2	
Power	32 / 74 kW
Field	1.2 / 1.15 T
Integral	2.2 / 2.3 Tm
Size	2x1.2x1.5 m
Weight	19 t

AHL	
Power	61 kW
Field	1.12 T
Integral	2.5 Tm
Size	2.3x2.3x1.5 m
Weight	48 t



Power only, full slide in annex

Radiation hard (MIC coils)