Miteinander forschen
Wirtschaft stärken
Perspektiven schaffen

ILK DRESDEN

Exzellenz ab null Kelvin



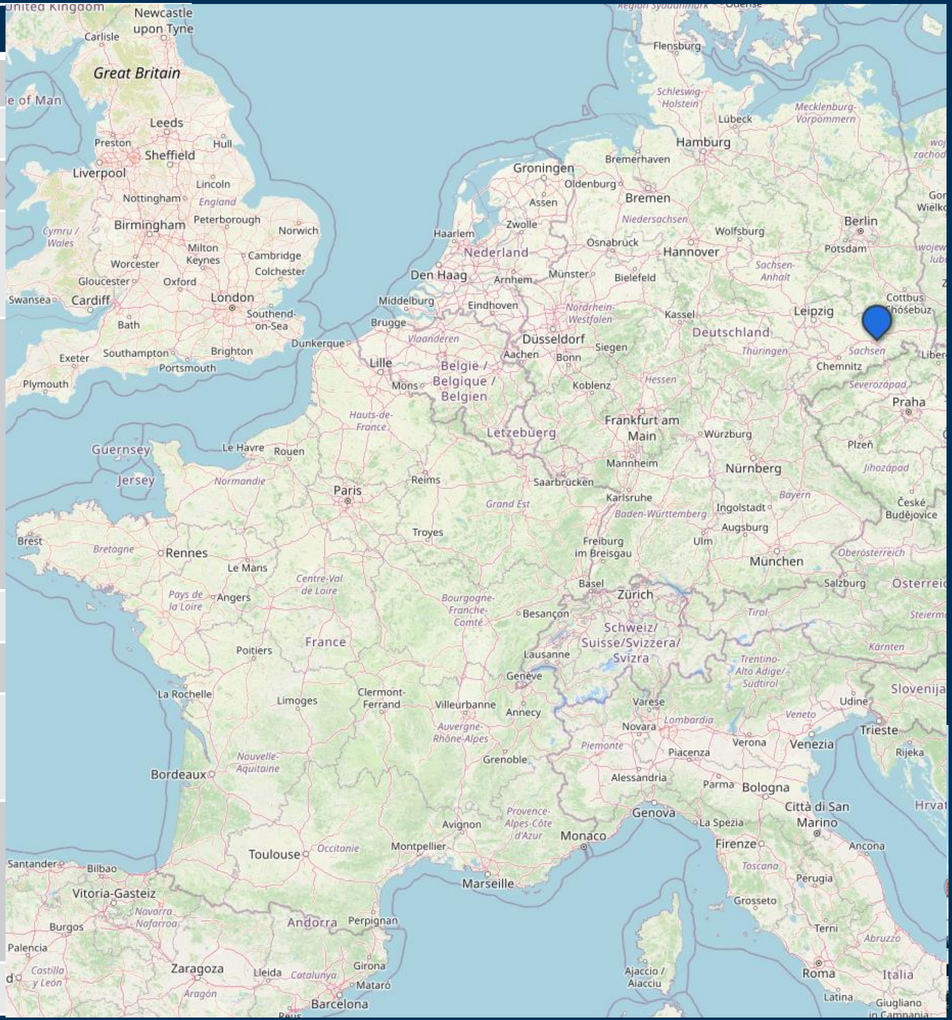

ILK Dresden
I.FAST Workshop

16.04.2024

Dr. U. Zerweck-Trogisch, Dr. A. Kade

ILK - THE INSTITUTE

KEYFACTS	DESCRIPTION
NAME:	Institut für Luft- und Kältetechnik gemeinnützige Gesellschaft mbH
LOCATION:	Bertolt-Brecht-Allee 20; 01309 Dresden
LEGAL STATUS:	Non-profit limited liability company
KIND OF BUSINESS:	Research organization
FIELDS OF ACTIVITY:	Cryogenics and low-temperature physics; Refrigeration and heat pump technology; Ventilation and air-conditioning technology; Applied materials technology; Applied energy technology
FOUNDED:	1964
EMPLOYEES:	> 150; High level of education
ANNUAL TURNOVER:	> € 15 million
INFRASTRUCTURE: (EXTRACT)	3,000m² of experimental space, 25 physical-chemical laboratories, as well as state-of-the-art equipment and facilities
CERTIFICATES	ISO 9001:2015; DIN EN 17025:2018



Services and products

Main Department of Cryogenics and Low Temperature Physics:

- Special equipment, devices and parts for accelarators
  - Heater and controller
  - Temperature sensors & calibration
  - Terminals / Interceptions
  - Measurement electronics
  - Quench detection and protection systems
- Cryostats / Anticryostats (non-metallic)
- Material testing
- Customized special cryogenics and cooling devices
- Cryogenic gas separation units (colliders, semiconductor facilities, etc.)

Presentation

Dry cooling with cryocoolers for magnets and insertion devices

Cryo-collimator for SIS18, GSI

SIS18: synchroton to accelerate low-charge heavy ion beams

Injection accelerator for the future SIS100

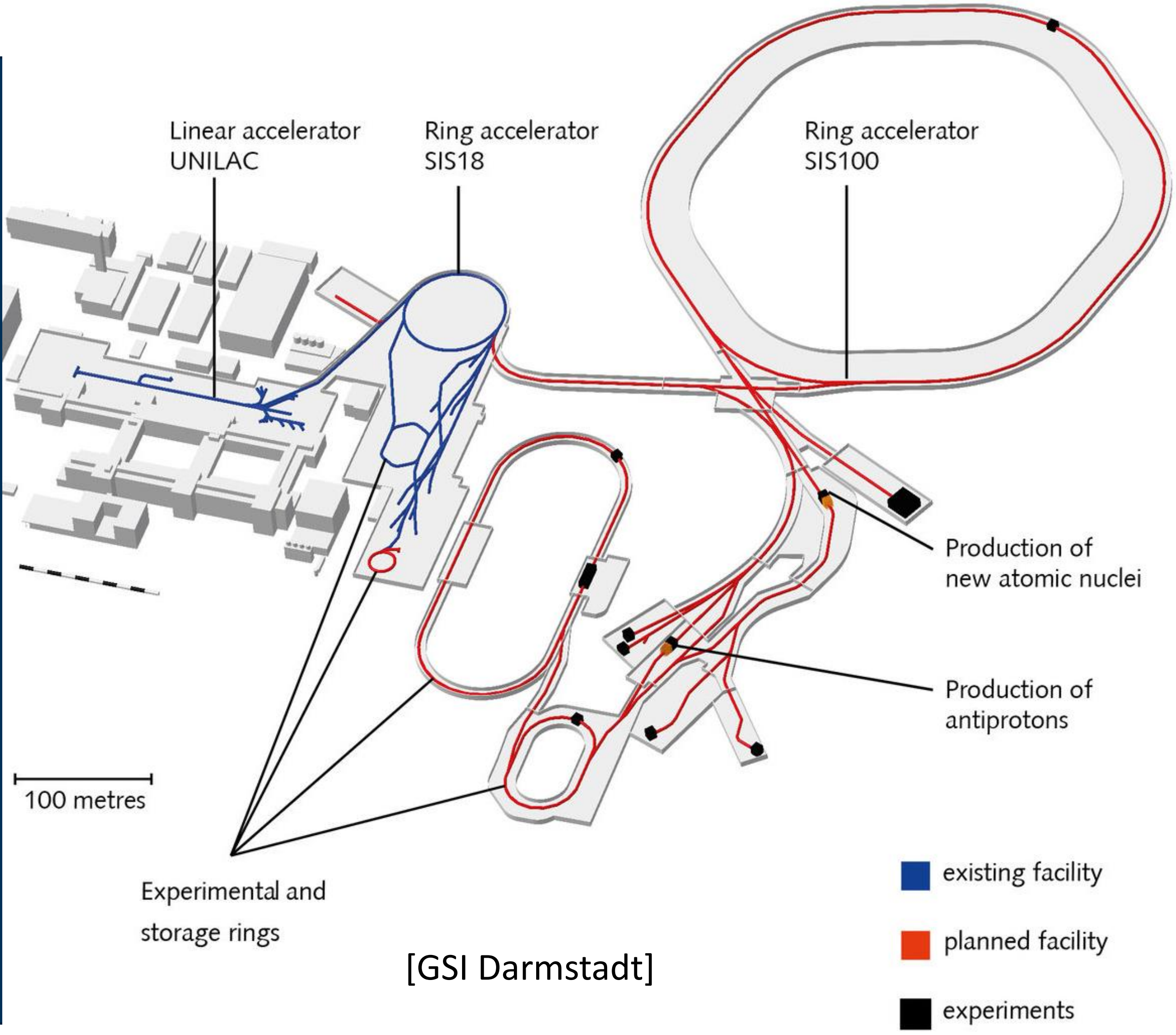
Extremely low, static residual gas pressure required: XHV

Heavy residual gas components: high effective cross section

→ partial pressure of heavy residual gas components must be minimal: e.g. argon

→ leads to recharging of heavy ion beam

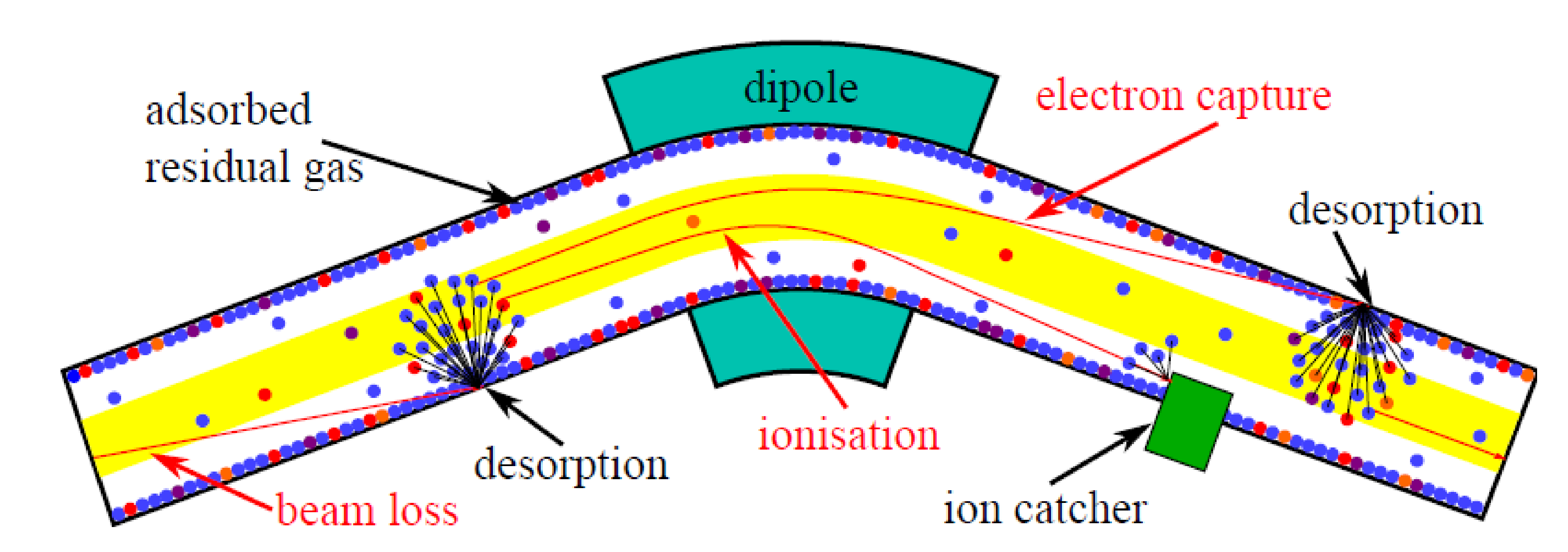
→ beam loss



[GSI Darmstadt]

Cryo-collimator for SIS

CRYOGENIC SURFACES IN A ROOM TEMPERATURE SIS18 ION CATCHER



Principle of ionization loss and dynamic vacuum
[L.H.J. Bozyk, S. Aumüller, P.J. Spiller, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany]

Cryo-collimator

Deviated ions hit collimator
(before they reach beam pipe wall)

Plume of desorbed residual gas forms

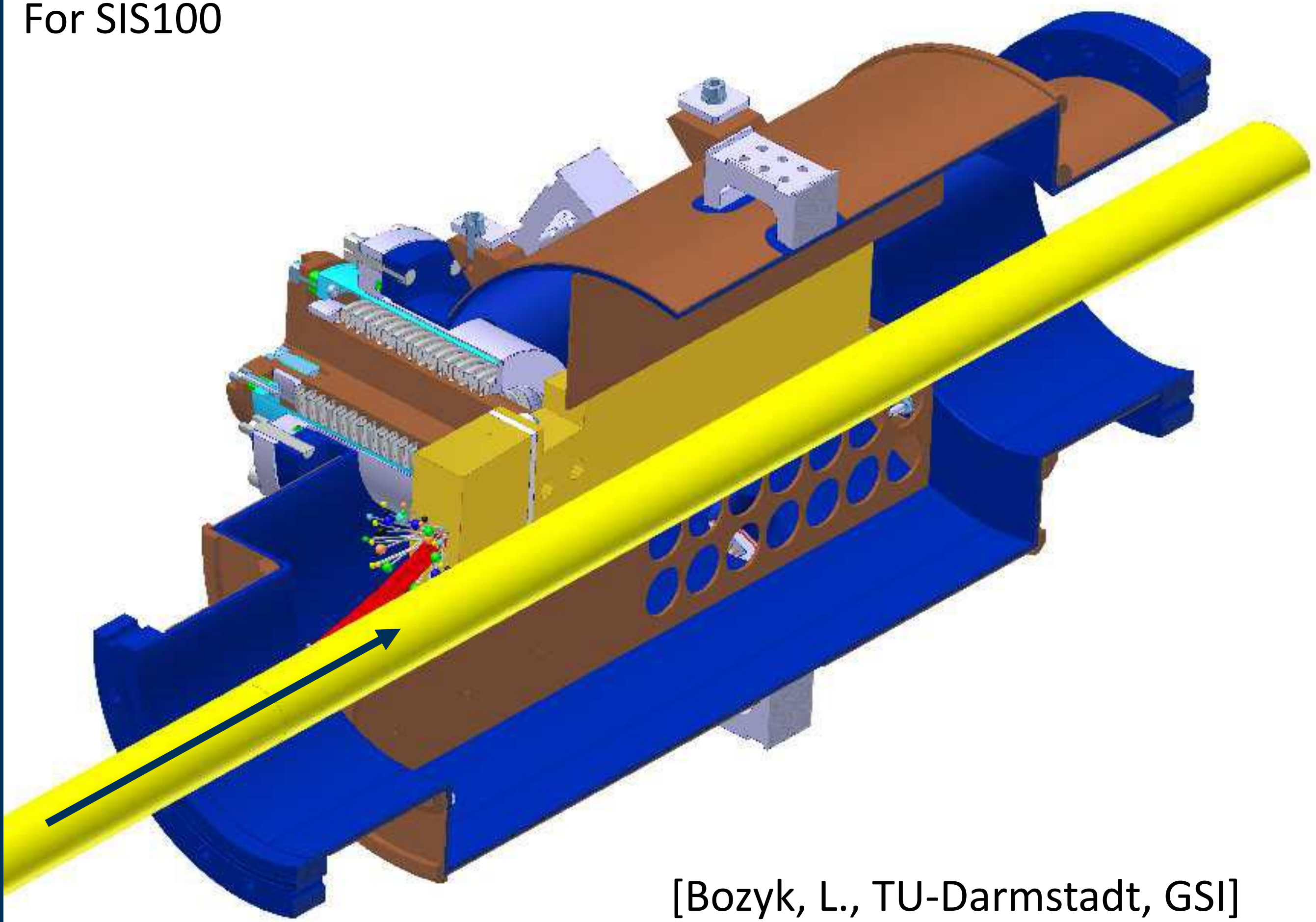
Task: Catch as much as possible!

How to catch?

Very cold surfaces, very close!

SIS18: normal conductive dipoles, no LHe

For SIS100



[Bozyk, L., TU-Darmstadt, GSI]

Cryo-collimator for SIS18

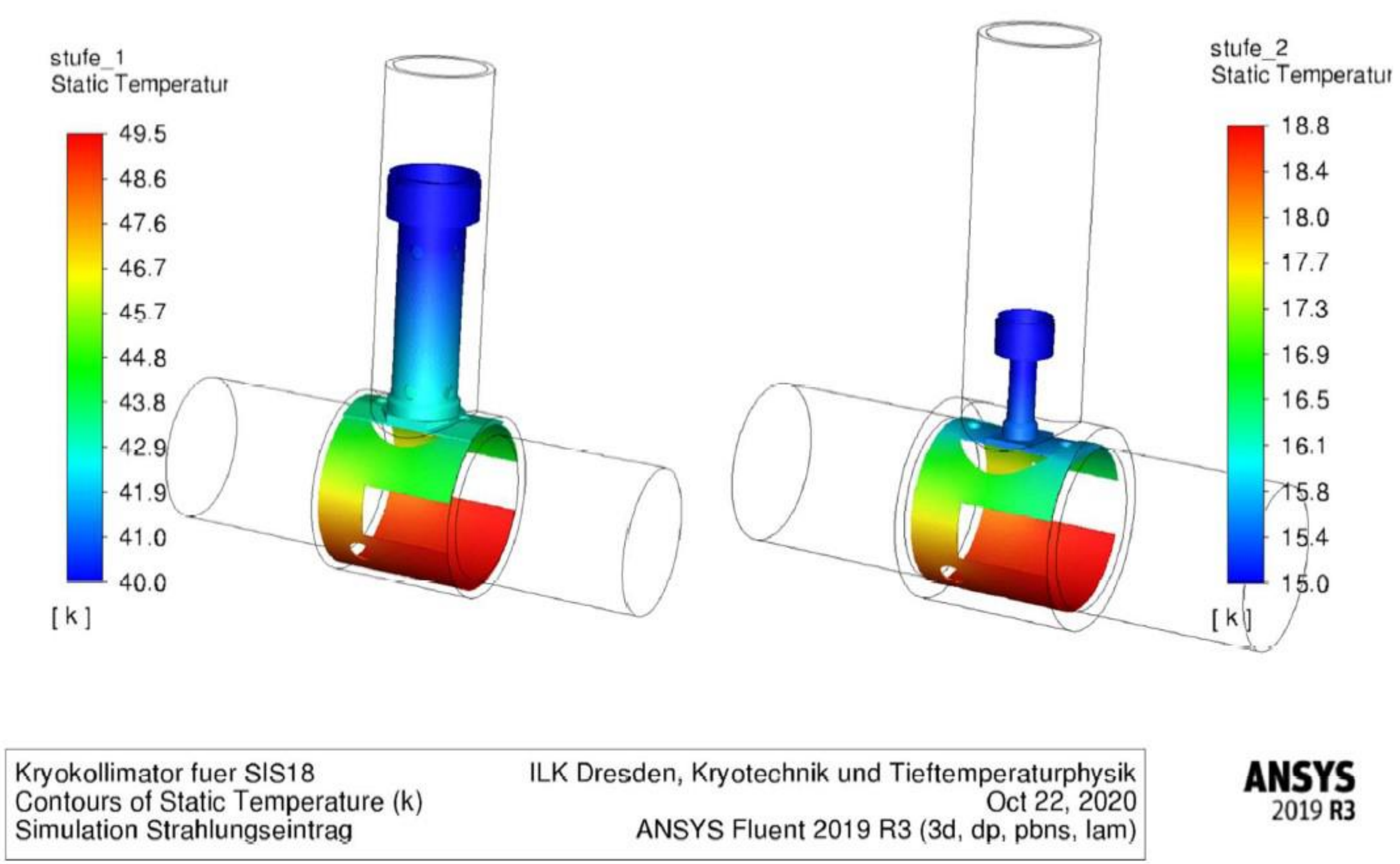
Two-stage cryocooler

Surround the collimator with cold surfaces

The more, the better, but mountability

Thermal radiation shielding

Temperatur distribution simulation



Cryo-collimator for SIS18

Two-stage cryocooler: < 10 K

Tube-in-tube design for
radiation shield and adsorption shield

Goal: Adsorption shield < 20 K at warmest spot
→ good thermal **coupling** of cryocooler

XHV: bakeout 250 °C possible

→ thermal **decoupling** of cryocooler essential

Cryo-collimator for SIS18

Two-stage cryocooler: < 10 K

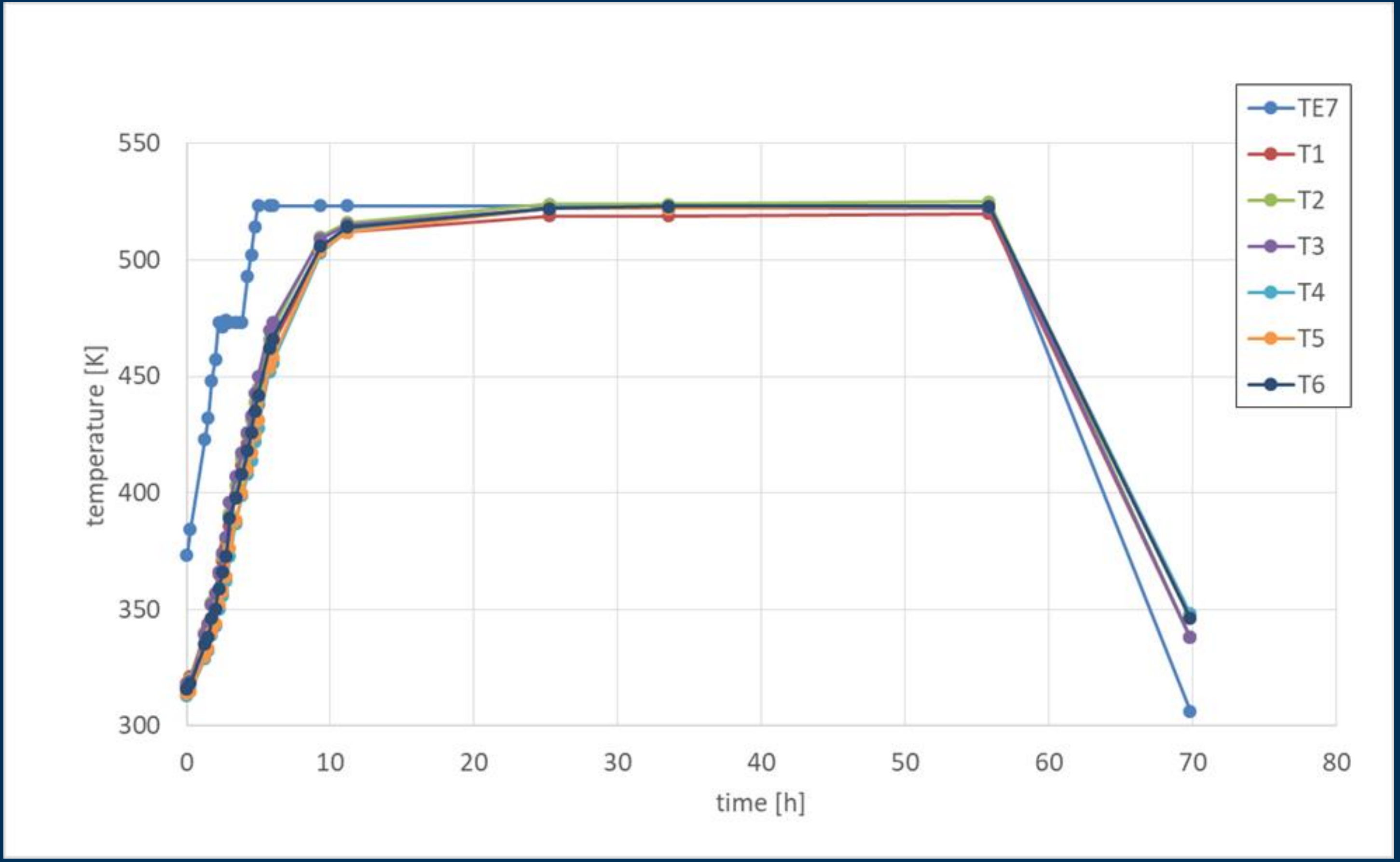
Tube-in-tube design for
radiation shield and adsorption shield

Goal: Adsorption shield < 20 K at warmest spot
→ good thermal **coupling** of cryocooler

XHV: bakeout 250 °C possible

→ thermal **decoupling** of cryocooler essential

XHV reached!



Cryo-collimator for SIS18

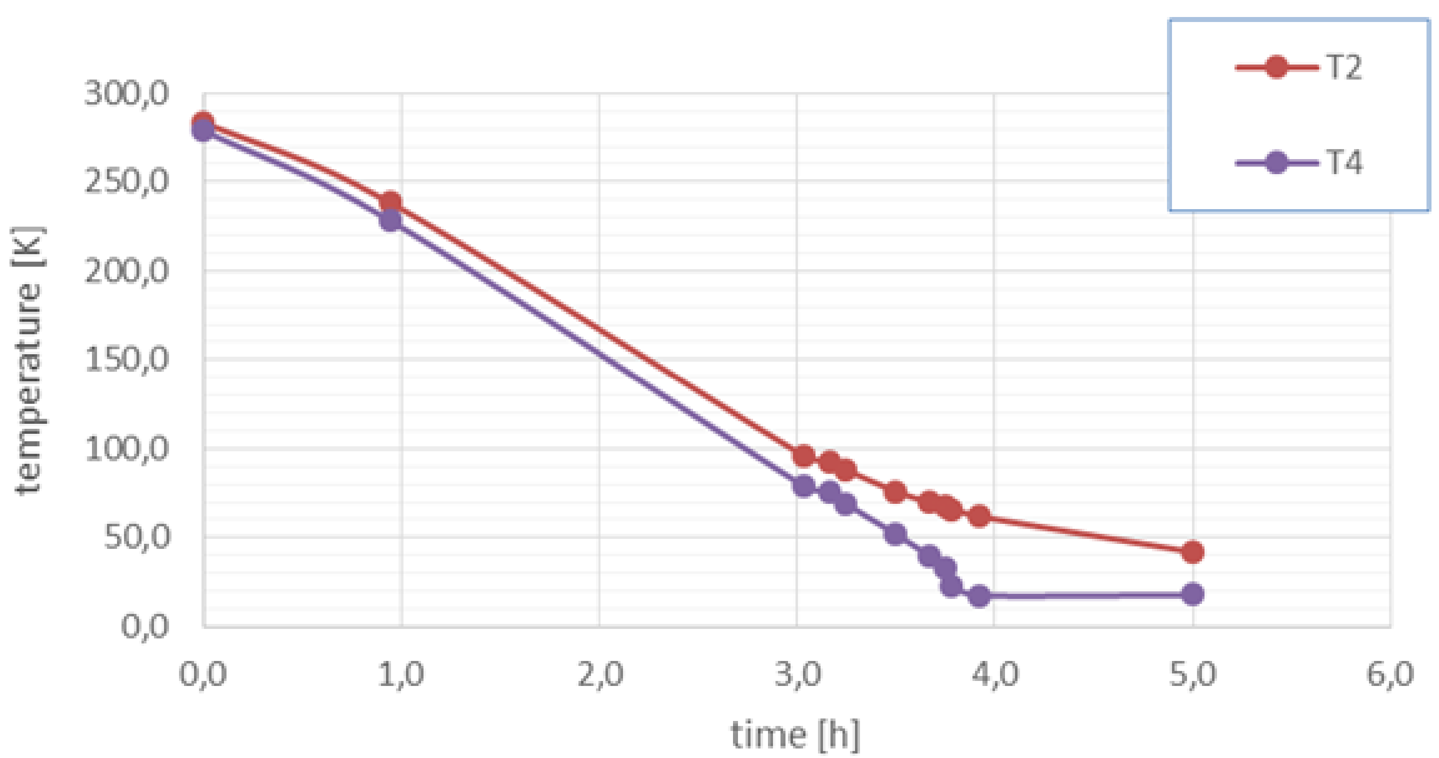
Two-stage cryocooler: < 10 K

Tube-in-tube design for
radiation shield and adsorption shield

Goal: Adsorption shield < 20 K at warmest spot
→ good thermal **coupling** of cryocooler
15 K reached as warmest spot

XHV: bakeout 250 °C possible

→ thermal **decoupling** of cryocooler essential
XHV reached!



Cryo-collimator for SIS18

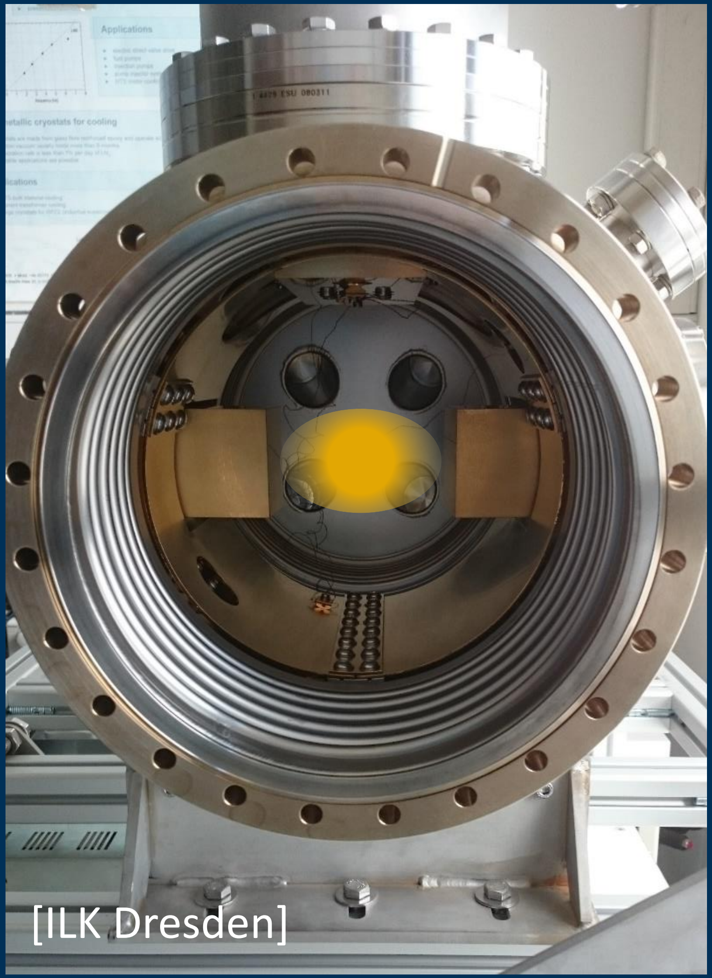
Two-stage cryocooler: < 10 K

Tube-in-tube design for
radiation shield and adsorption shield

Goal: Adsorption shield < 20 K at warmest spot
→ good thermal **coupling** of cryocooler
15 K reached

XHV: bakeout 250 °C possible

→ thermal **decoupling** of cryocooler essential
XHV reached!



Cryocooler vs LHe → efficiency

Cryocooler:

keeping something cold at 4 K

η_{Carnot} = 1.3%

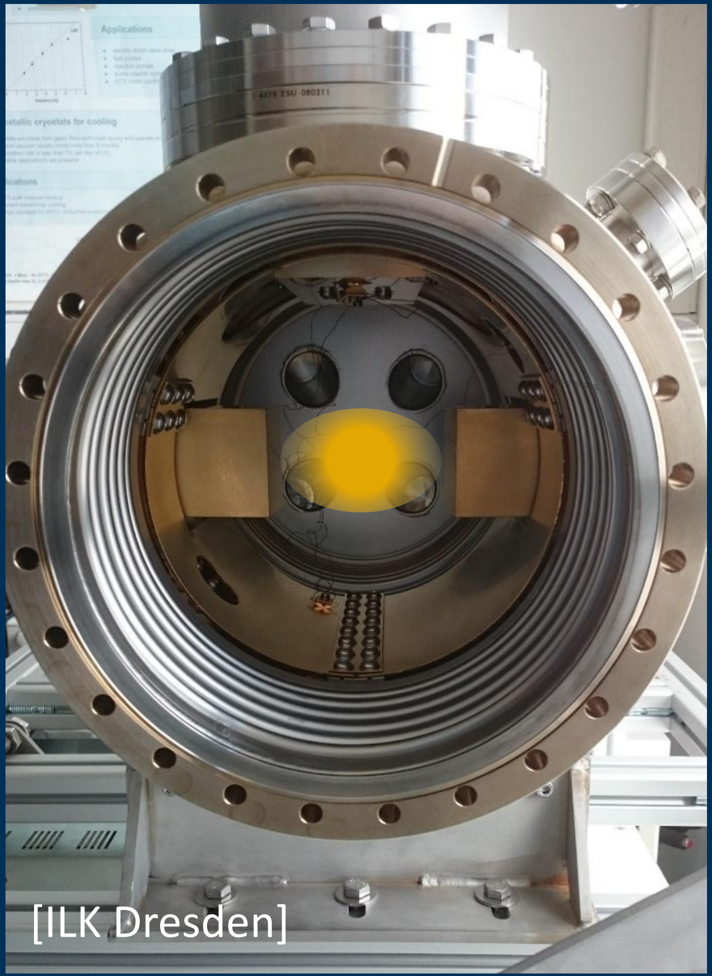
$\%_{Carnot} = \frac{\eta_{Cryocooler}}{\eta_{Carnot}}$

e.g. F-50 compressor with RDE-418D4

8 kW 2W → 0,025%

$\sim 2\%_{Carnot}$

still: dry cooling,
no LHe and GHe handling required


[ILK Dresden]

Cryocooler vs LHe → efficiency

Cryocooler:

keeping something cold at 4 K

η_{Carnot} = 1.3%

$\%_{Carnot} = \frac{\eta_{Cryocooler}}{\eta_{Carnot}}$

e.g. F-50 compressor with RDE-418D4

8 kW 2W → 0,025%

$\sim 2\%_{Carnot}$

still: dry cooling,
no LHe and GHe handling required

[ILK Dresden]

Cryocooler vs LHe: dipoles/quadrupoles

SIS300 @ ILK Dresden

300 Tm magnetic rigidity

6.5 t cold mass → 10 kJ from 5 K to 4 K

ramped 1.5 T … 4.5 T (3 kA … 9 kA)

fast-ramped 1 T/sec (2 kA/s @ 20V)

5 m long → forced flow cooling

[ILK Dresden]

Cryocooler vs LHe: dipoles/quadrupoles

ILK satellite refrigerator unit (SRU)
@ Dubna, Russia

no moving parts inside (standard) → 30 years

3 items delivered and installed in recent years

all NICA magnets tested with SRU since 2016

Cryocooler vs LHe: dipoles/quadrupoles

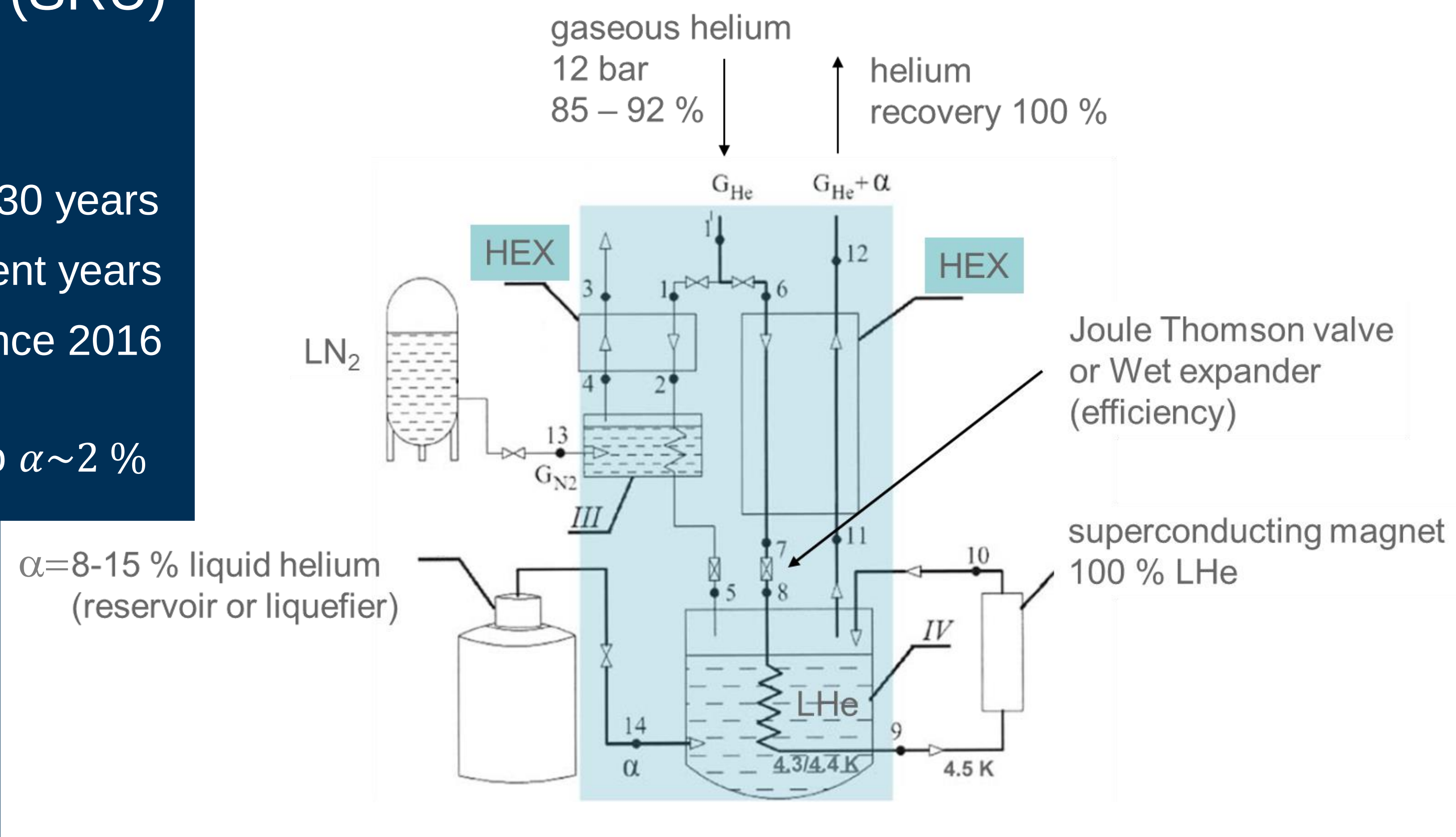
ILK satellite refrigerator unit (SRU) @ Dubna, Russia

no moving parts inside (standard) → 30 years

3 items delivered and installed in recent years

all NICA magnets tested with SRU since 2016

$\alpha\sim10\ \%$ reduced by turboexpander to $\alpha\sim2\ \%$

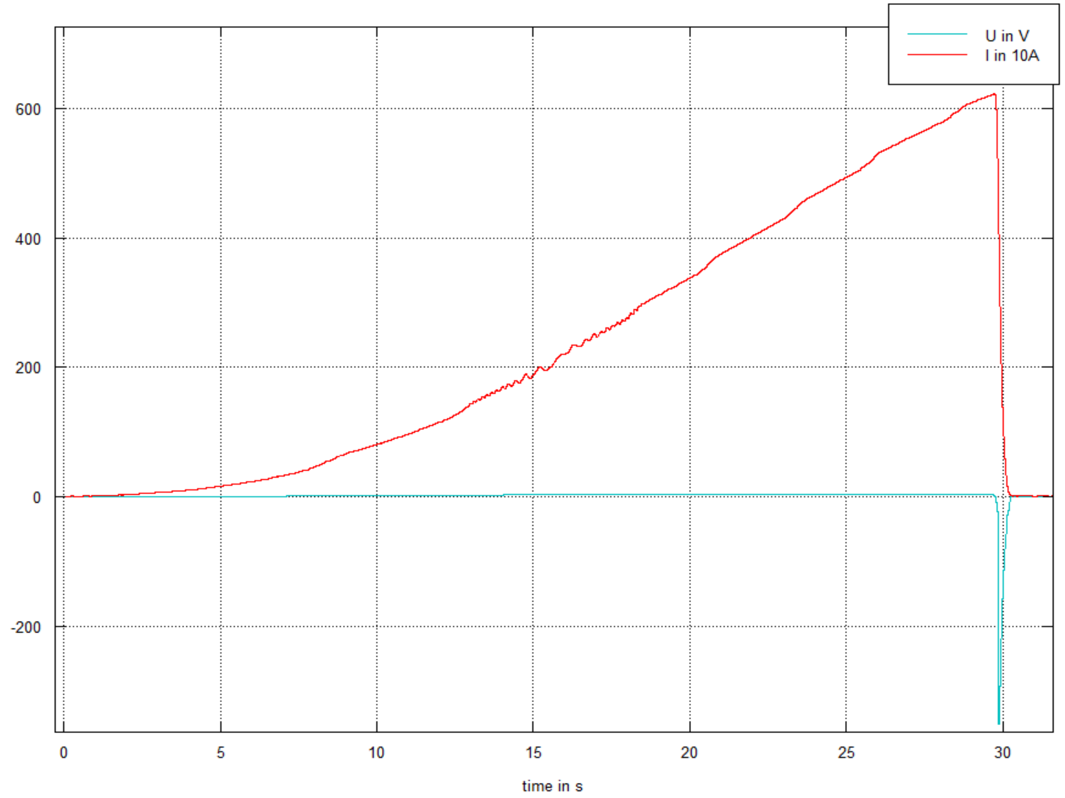


Power Supply for Magnets

output voltage	-24 V … +24 V at the same time!
output current	-14 kA … +14 kA
usage	superconducting magnets
certified	low voltage directive
construction	modular / custom oriented
consists of	14 x 4-quadrant power supply each 1 kA
	17 x power bank modules in 19“ rack, 5.5 MJ
protection	quench detection: digitally set analogue comparator, > 2 mV
	quench protection: 5 ms delay, 90% energy extracted in 0.2 s

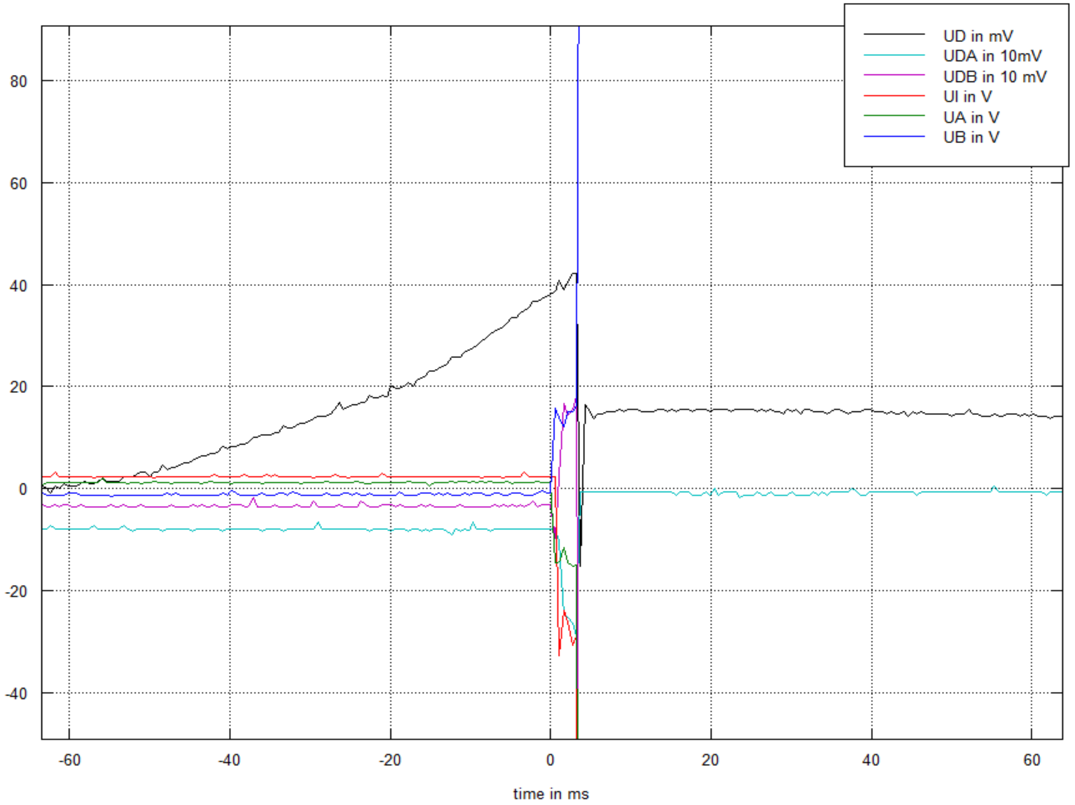
Power Supply for Magnets

output voltage	-24 V … +24 V at the same time!
output current	-14 kA … +14 kA
usage	superconducting magnets
certified	low voltage directive
construction	modular / custom oriented
consists of	14 x 4-quadrant power supply each 1 kA
	17 x power bank modules in 19“ rack, 5.5 MJ
protection	quench detection: digitally set analogue comparator, > 2 mV
	quench protection: 5 ms delay, 90% energy extracted in 0.2 s



Power Supply for Magnets

output voltage	-24 V … +24 V
output current	-14 kA … +14 kA
	at the same time!
usage	superconducting magnets
certified	low voltage directive
construction	modular / custom oriented
consists of	14 x 4-quadrant power supply each 1 kA
	17 x power bank modules in 19“ rack, 5.5 MJ
protection	quench detection: digitally set analogue comparator, > 2 mV
	quench protection: 5 ms delay, 90% energy extracted in 0.2 s



Conclusion

Cryocoolers if

no LHe is available,

no recovery of GHe (unless €€€)

not-too-cold temperatures are needed ($\eta_{Cryocooler@T}$ vs. $\eta_{Liquefier@4K}$)

temperature gradient can be tailored (e.g. actively cooled current leads)

He liquefiers / refrigerators if

large cooling capacity required

forced flow for stretched objects

low vibration

Thank you for your attention – questions?

ILK DRESDEN
Exzellenz ab null Kelvin

Dr. rer. nat. Ulrich Zerweck-Trogisch

Dr. rer. nat. Andreas Kade

Main Department

Cryogenics and Low Temperature Physics

ulrich.zerweck@ilkdresden.de

andreas.kade@ilkdresden.de

Institut für Luft- und Kältetechnik gemeinnützige Gesellschaft mbH

Bertolt-Brecht-Allee 20 | 01309 Dresden | www.ilkdresden.de

Power Supply for Magnets