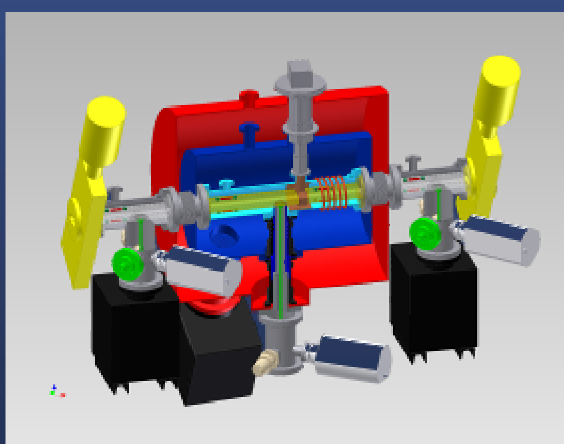
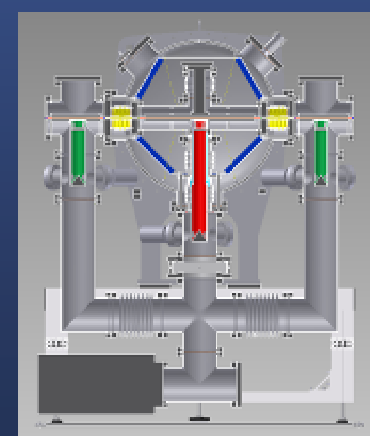
COLDDIAG: a cold vacuum chamber for diagnostics

Stefan Gerstl

Institute for Synchrotron Radiation, ISS, Campus Nord, Karsluhe Intitute of Technology





In collaboration with…

T. Baumbach, S. Casalbuoni, A. W. Grau, M. Hagelstein, D. Saez de Jauregui,
Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany,

C. Boffo, G. Sikler, *BNG, Würzburg, Germany,*

V. Baglin, *CERN, Geneva, Switzerland,*

M. P. Cox, J. C. Schouten, *Diamond, Oxfordshire, England,*

R. Cimino, M. Commisso, B. Spataro, *INFN/LNF, Frascati, Italy,*

A. Mostacci, Rome University 'La Sapienza', Rome, Italy,

E. J. Wallén, *MAX-lab, Lund, Sweden,*

R. Weigel, *Max-Planck Institute for Metal Research, Stuttgart, Germany,*

J. Clarke, D. Scott, *STFC/DL/ASTeC, Daresbury, Warrington, Cheshire, England,*

T. W. Bradshaw, *STFC/RAL, Chilton, Didcot, Oxon, England*

R. M. Jones, I. R. R. Shinton, *University Manchester, Manchester, England*

Outline:

- Motivation
- Possible Beam Heat Load Sources
- Cryogenics and Vacuum Design
- Instrumentation
- Planned Measurements
- Summary

Motivation

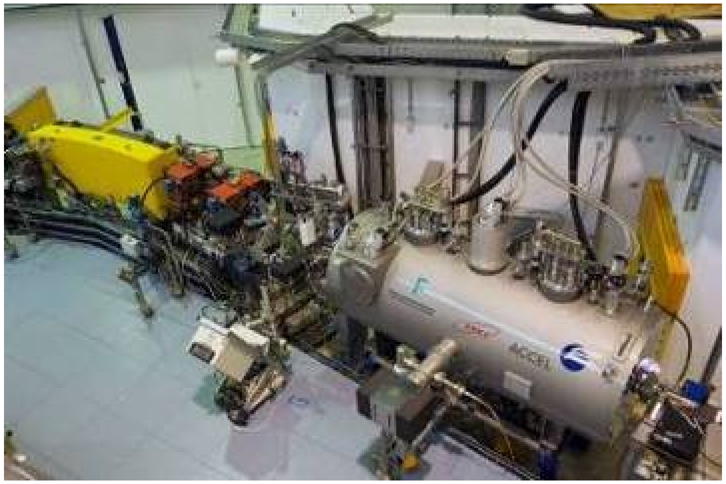
- Since 2005 superconducting Undulator SCU14 installed at ANKA

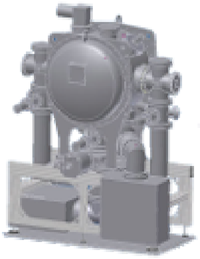
→ Higher beam heat load then expected

→ Reduced max. current/field

- Known heat intake of the beam

→ Crucial for cryogenic design of superconducting insertion devices





Cold vacuum chamber to measure the beam heat load is needed!

The diagnostics will include measurements of the **heat load**, the **pressure**, the **gas composition**, and the **electron flux of the electrons bombarding the wall**.

Possible Beam Heat Load Sources

Synchrotron Radiation

From upstream bending magnet:

$$P_{\mathrm{Synchrotron}} \propto I \cdot f(geometry, energy)$$

$I =$ stored average beam current

Resistive Wall Heating

Image currents on the cold surface:

$$P_{\mathrm{Resistive\ wall}} \propto I^2 \cdot f(geometry, filling\ \ pattern, bunch\ length)$$

RF-effects

$$P_{\mathrm{RF}} \propto I^2 \cdot f(geometry, filling\ \ pattern, bunch\ length)$$

e⁻ and/or ion bombardement

$$P_{\mathrm{e}^-, ion} \propto \Delta W \cdot \dot{N}$$

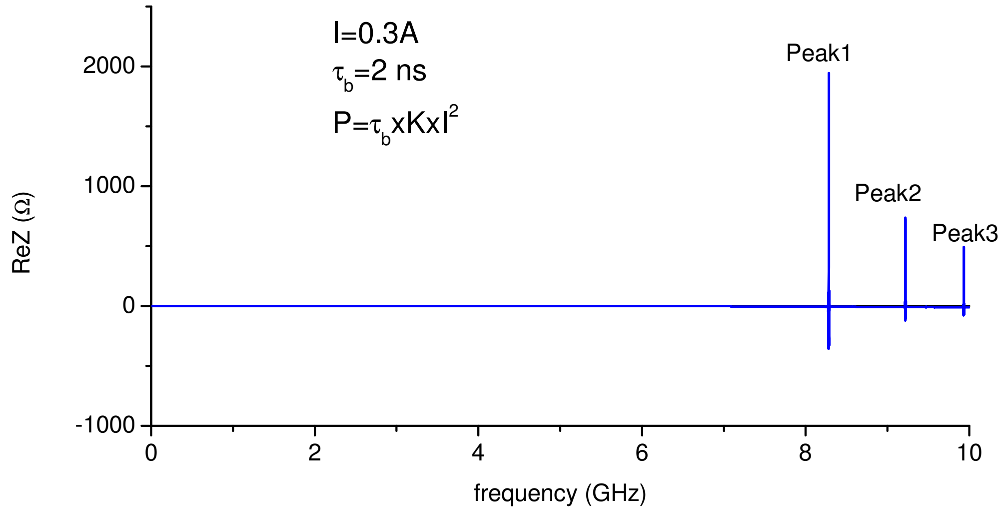
$\Delta W =$ energy increase of one electron due to the kick by a bunch

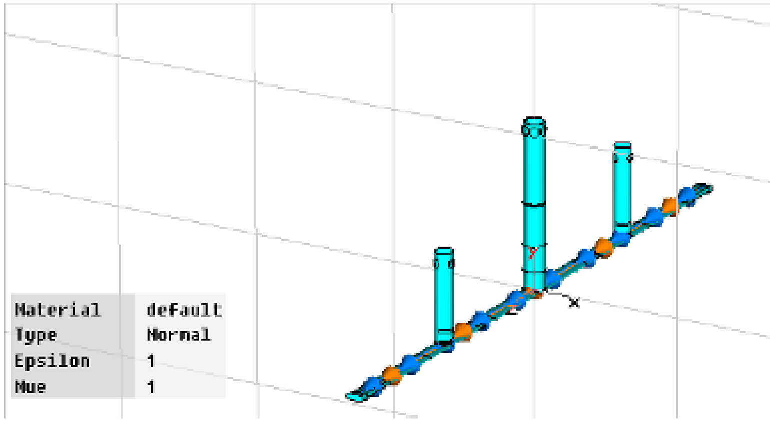
$\dot{N} =$ electrons hitting the wall per sec

E. Wallèn, G. LeBlanc, Cryogenics 44, 879 (2004)
S. Casalbuoni. et al., Phys. Rev. ST Accel. Beams 10, 093202 (2007)

Calculated Beam Heat Load due to RF effects

--	Cu@300K	Cu@4K; RRR=70
Peak	P (W)	P (W)
1	0.32852	0.00469
2	0.10762	0.00154
3	0.0735	0.00105





CST particle studio calculations from
I. Shinton (University of Manchester)

Cryogenics and Vacuum Design

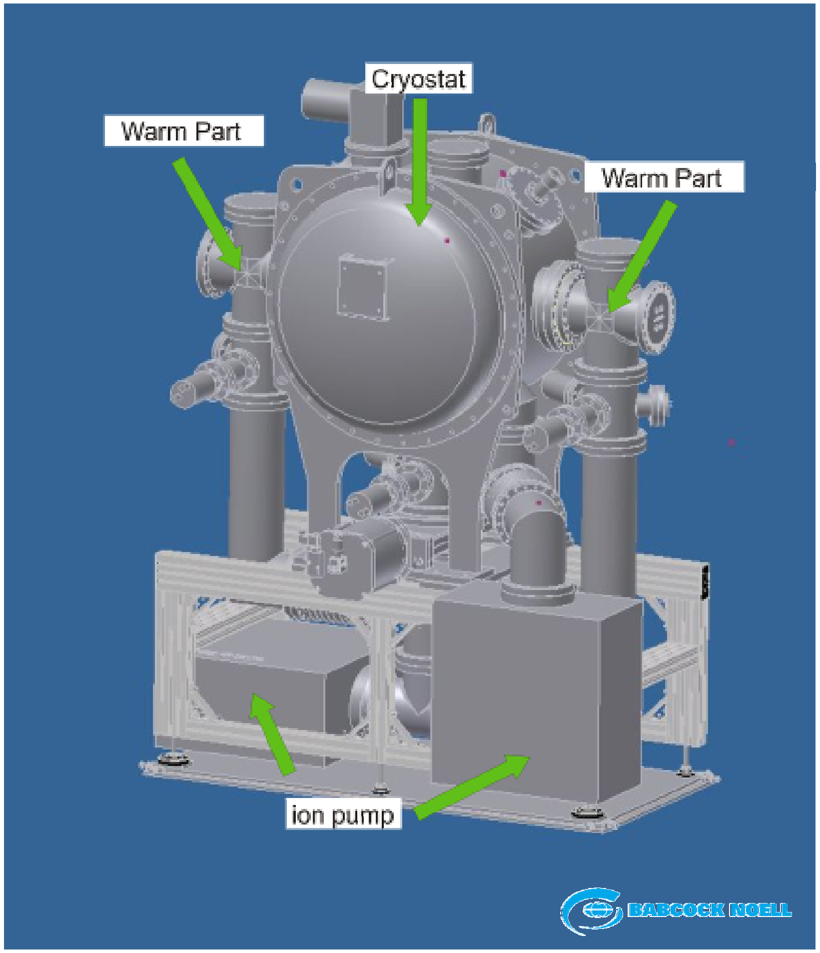
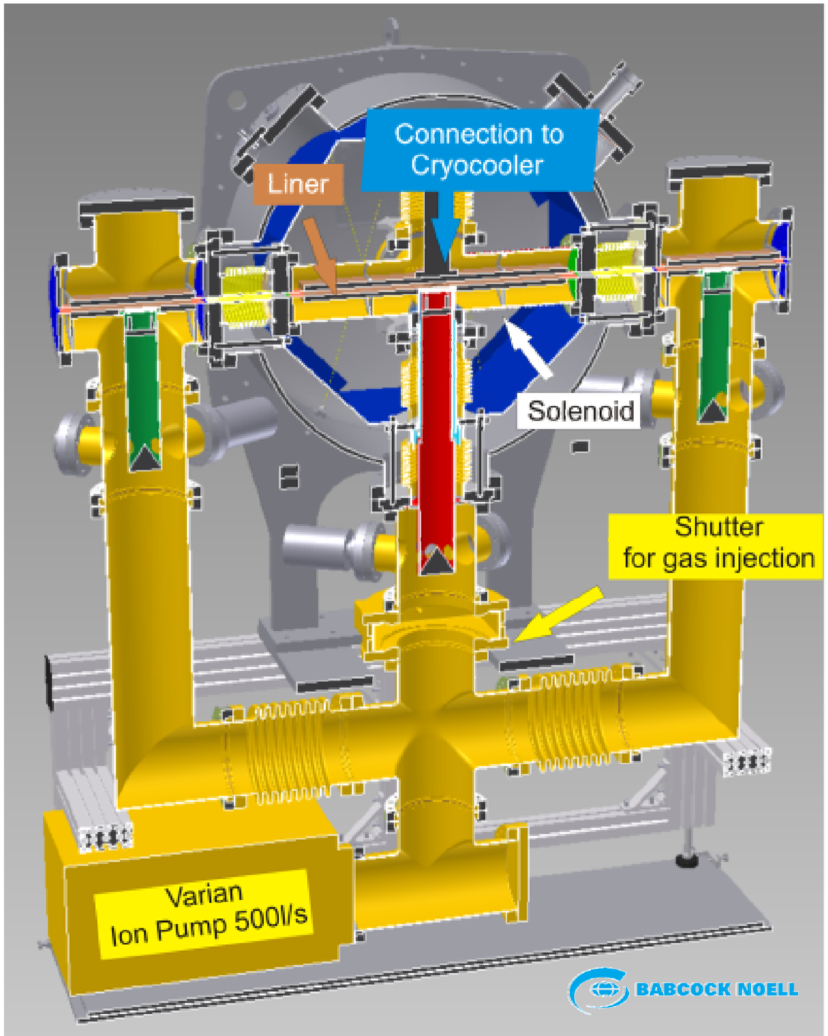


Photo and CAD models courtesy of

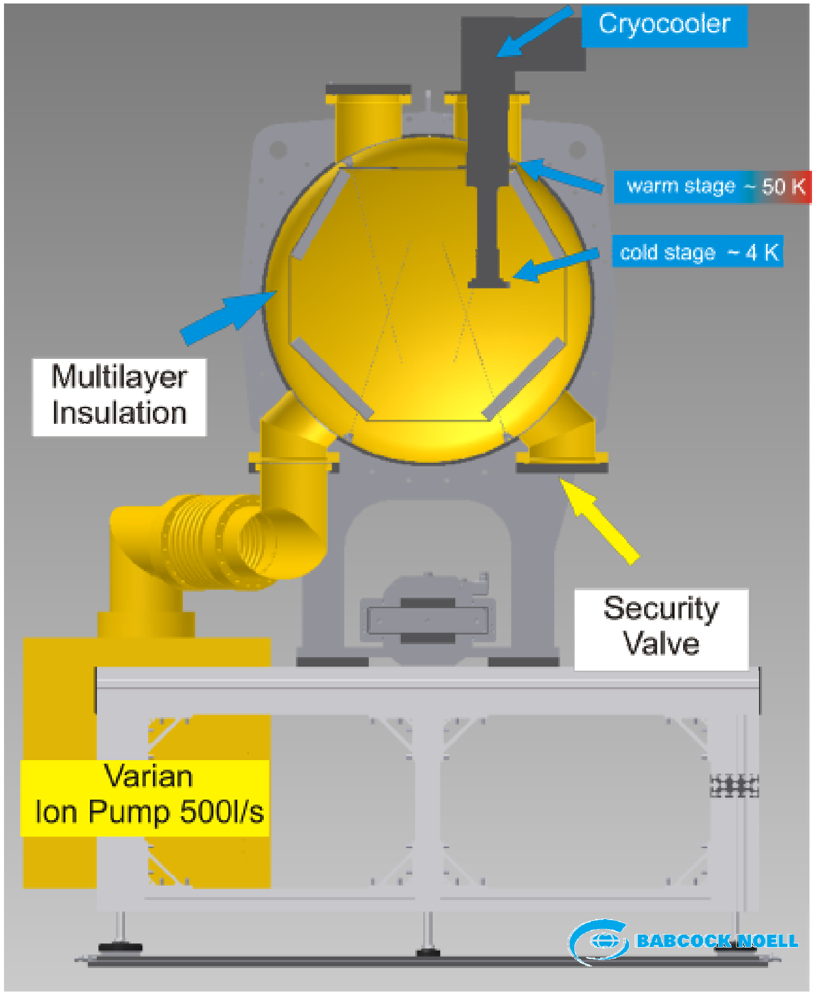
Babcock Noell GmbH

Cryogenics and Vacuum Design



- UHV vacuum:
  - Beam pipe, Liner
  - Pressure gauges
  - Temperature sensors
  - Mass Spectrometer
  - Calibration heaters

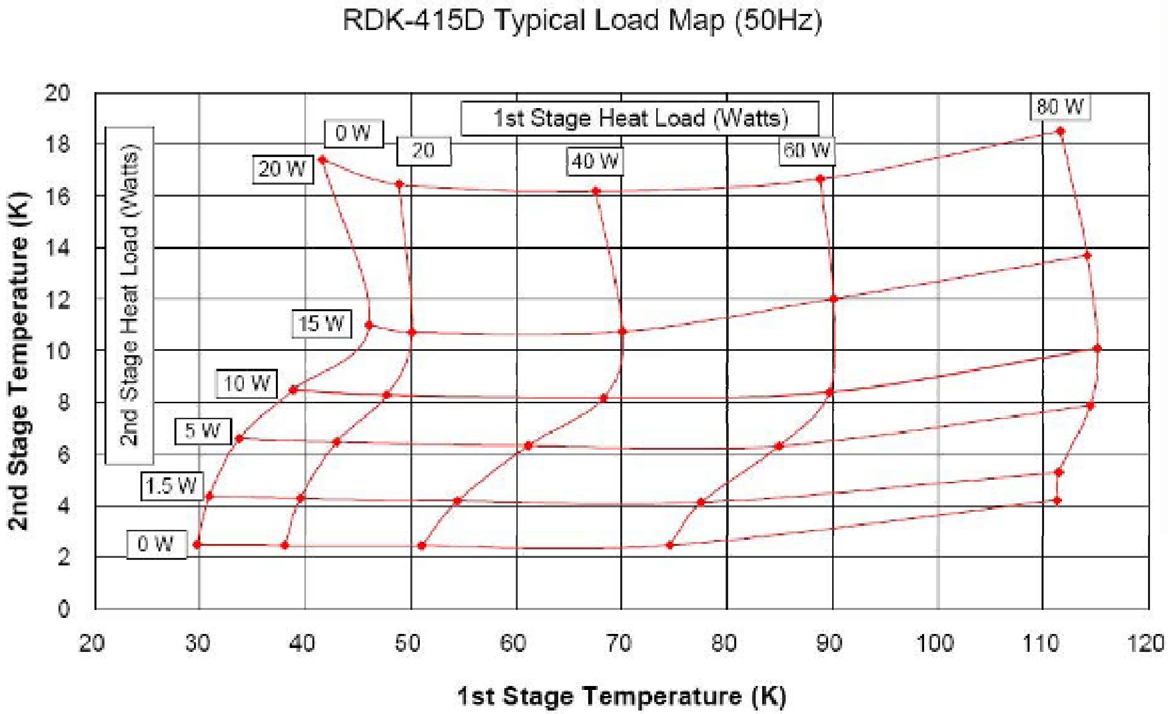
Cryogenics and Vacuum Design

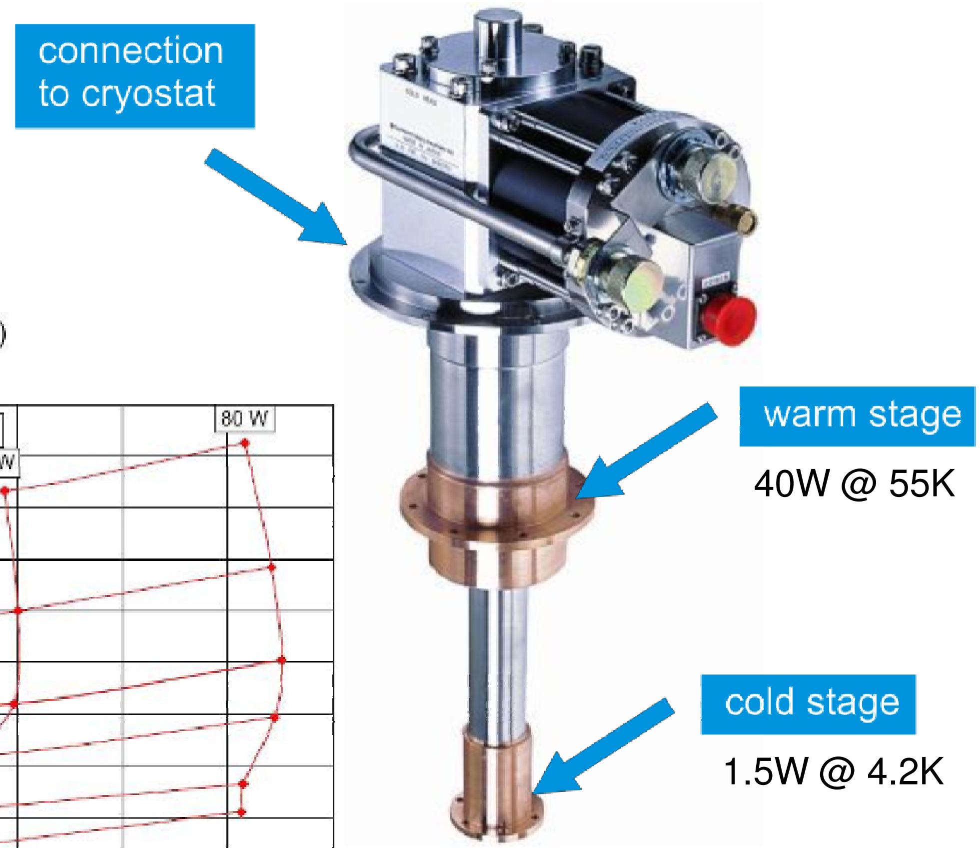


- Isolation vacuum:
  - Multilayer Insulation
  - Solenoid
  - Heater at the Cryocooler cold stage

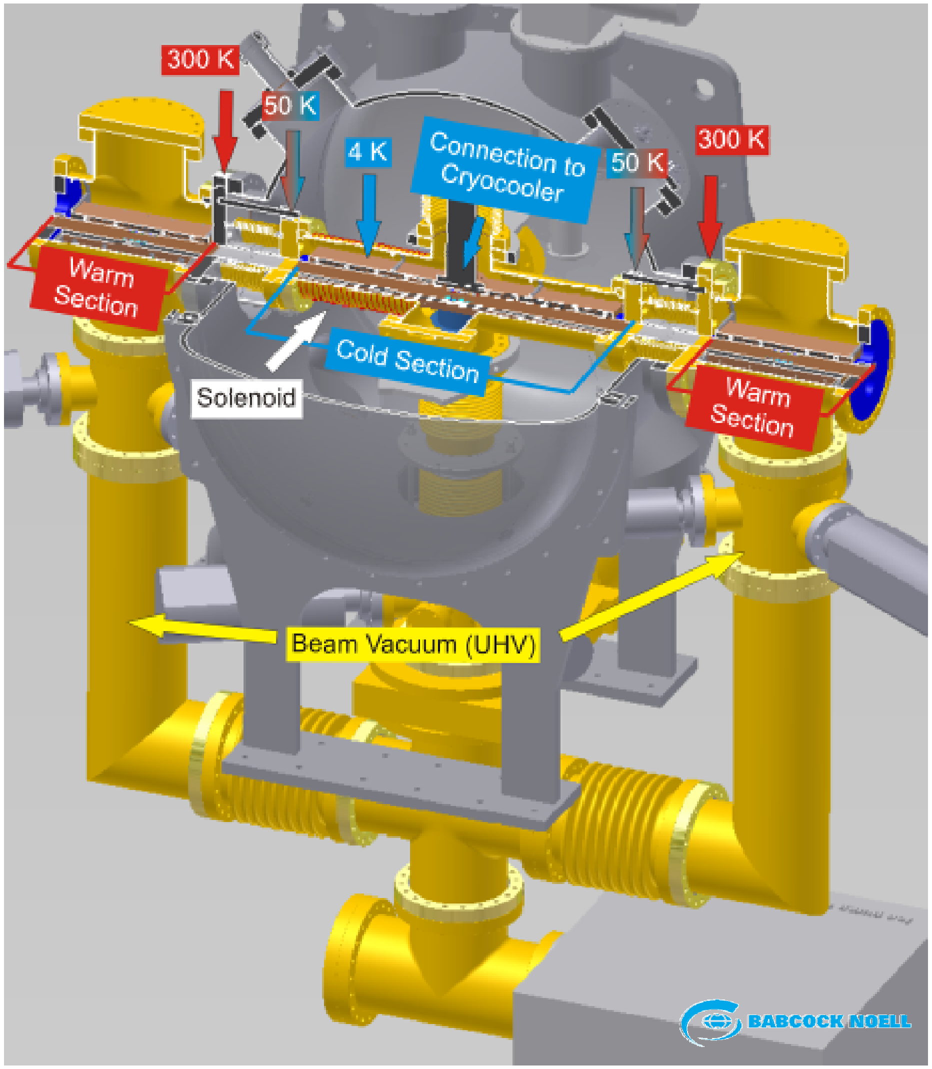
Cryogenics and Vacuum Design

- Cryogen-free system
- 1 x Sumitomo RDK-415D cryocooler





Cryogenics and Vacuum Design

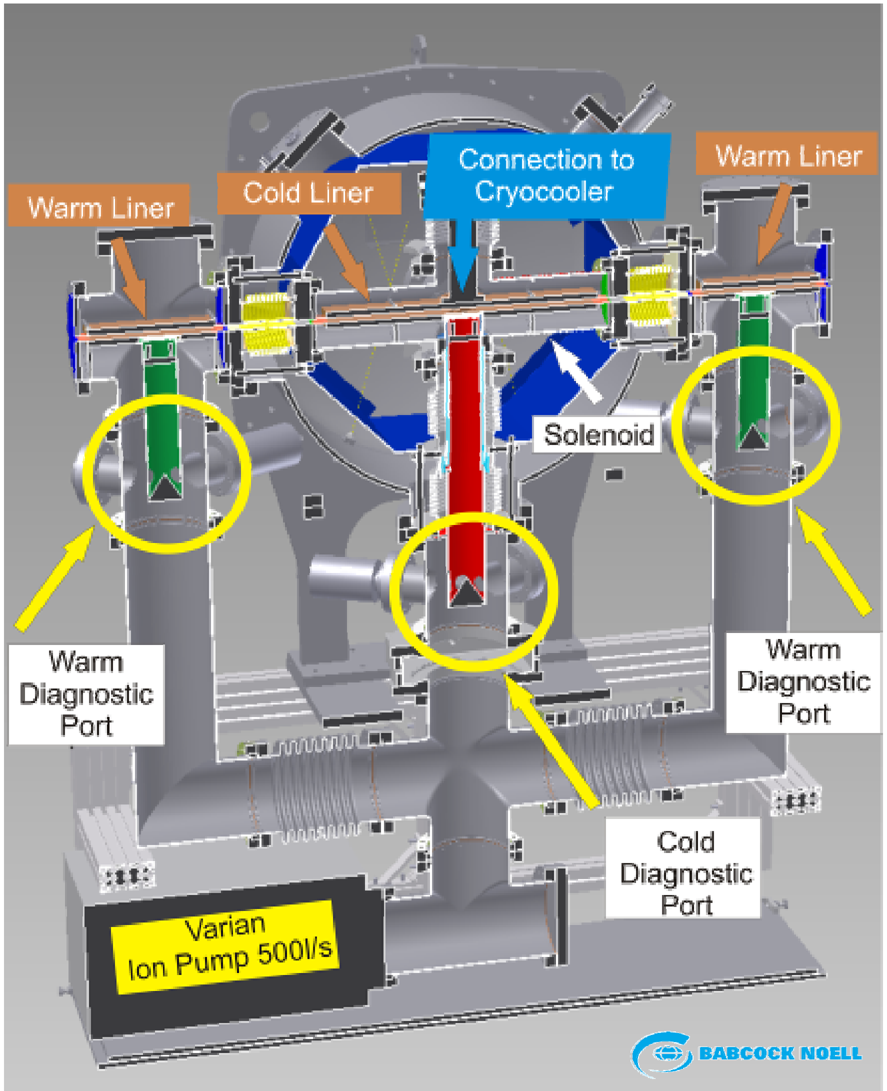


- Cold liner section
  between two warm sections
  → to compare beam heat load
- High purity copper liner
  → homogeneous temperature profile
- 30µm copper plating
  → to simulate liner of SCUs at ANKA
- Gaps and steps <10µm in the cold section
  → to minimize contribution of the RF effects to the beam heat load

Cryogenics and Vacuum Design – Thermal Budget

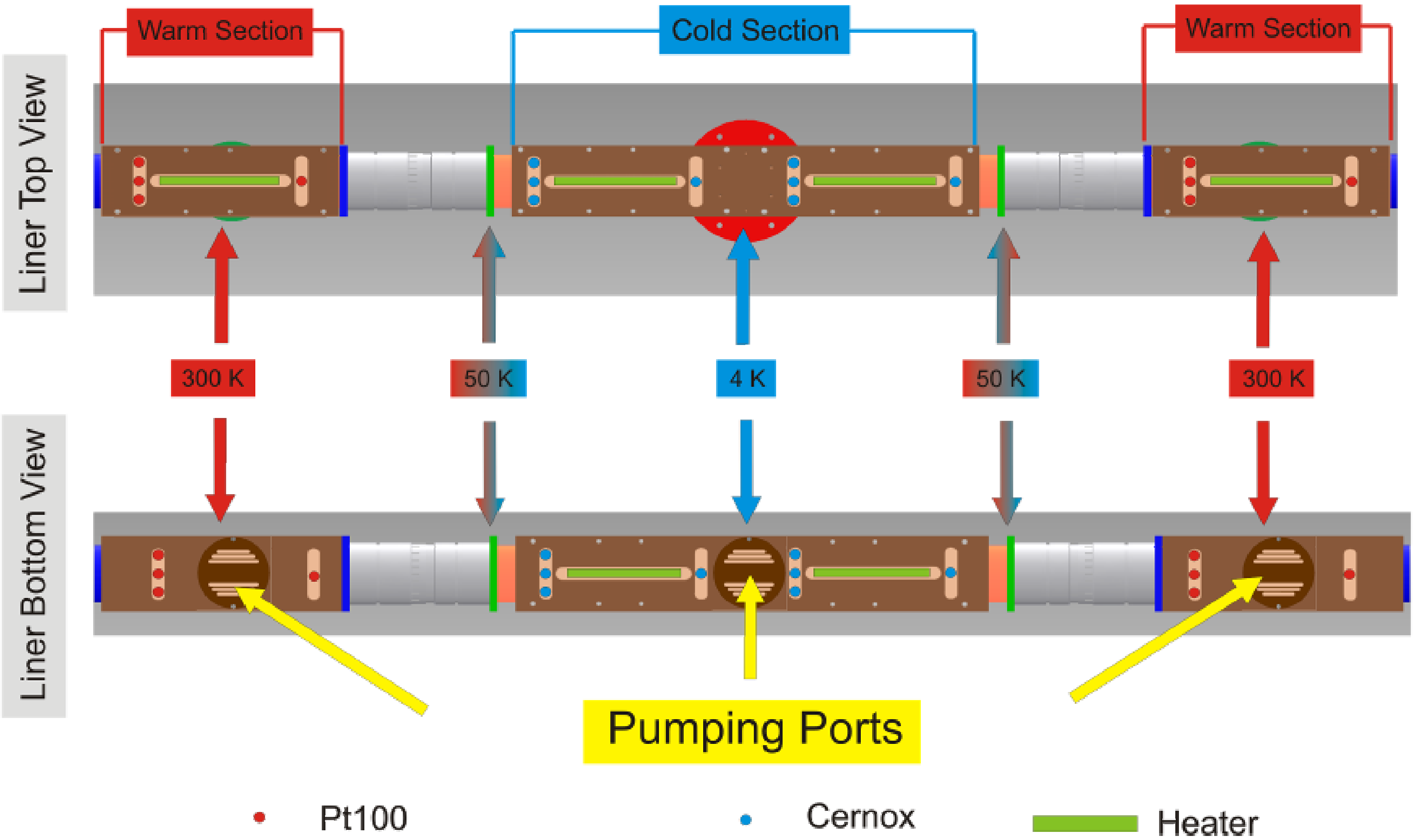
	Cold Mass (worst case)	Cold Mass (with thermal contact conduction)	Thermal Shield
Radiation [W]	0.2	0.2	12
Conductance [W]	5.6	1.2	36
Sum [W]	**5.8**	**1.4**	**48**
Cooling Power	6 W @ ~ 7 K	1.5 W @4.2 K	50W @ 60 K

Instrumentation:



- **Cryocooler Cold Stage:**
  - Main Heater
- **Liner:**
  - Temperature sensors
  - Heaters for calibration
- **All Pumping Ports:**
  - Residual Gas Analyzer
  - Penning Pressure Gauge
  - Retarding Field Analyzer
- **Cold Pumping Port:**
  - Additional Extractor Gauge
  - Valve for Gas injection

Instrumentation - Temperature Sensors mounting Positions:



Instrumentation – Pressure Gauges and Residual gas analysers

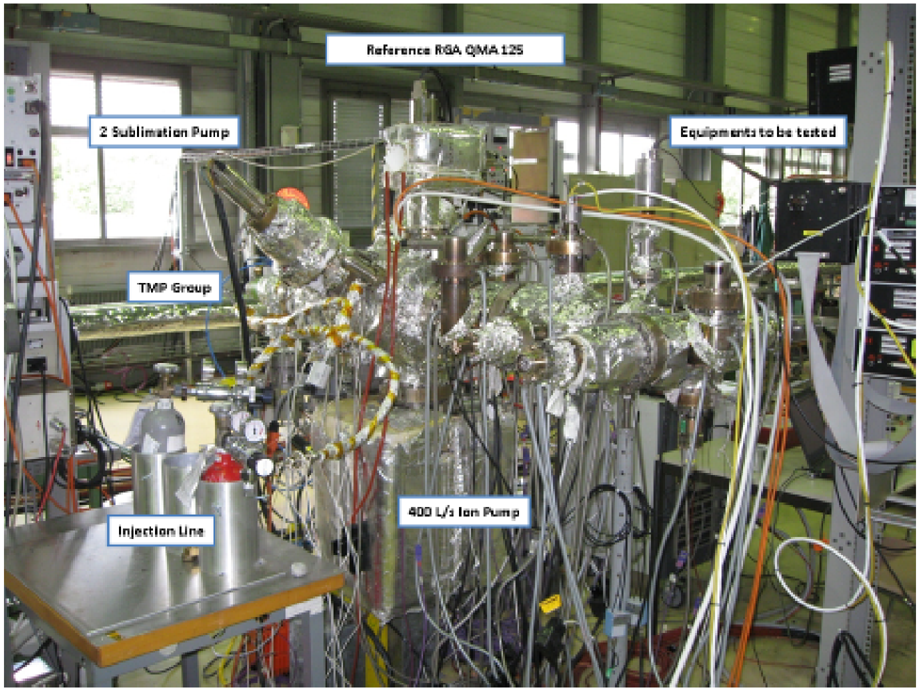
- MKS Penning Gauge: lowest pressure reading ~ 1×10^{-10} mbar
- Leybold Extractorgauge: lowest pressure reading ~ 1×10^{-12} mbar

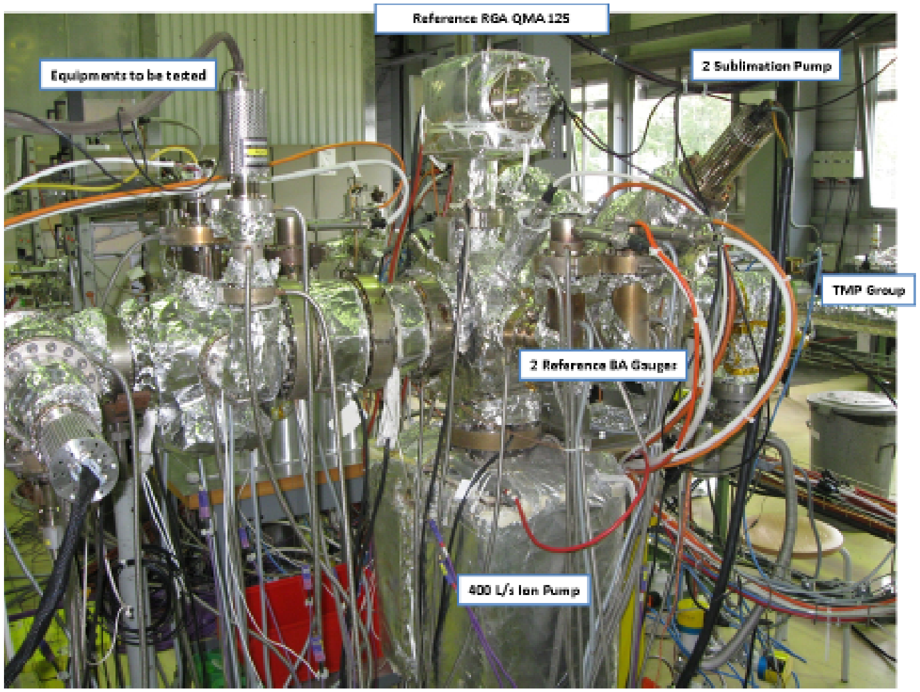
- MKS Satellite LM61
- Farady cup
- 300 amu triple filter

Parts are provided by STFC

Instrumentation - Calibration of Diagnostics from STFC:

Calibration Setup at CERN



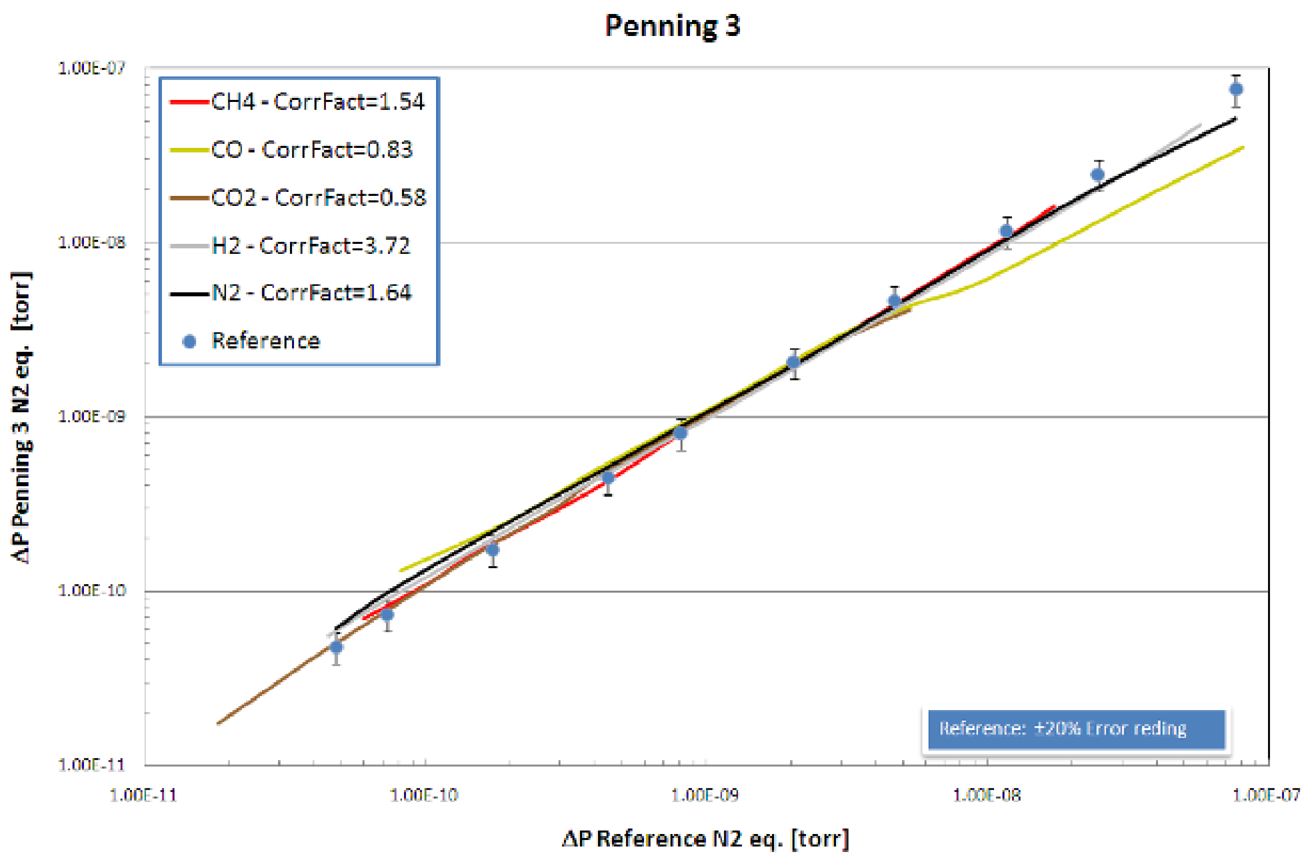


Many thanks to:

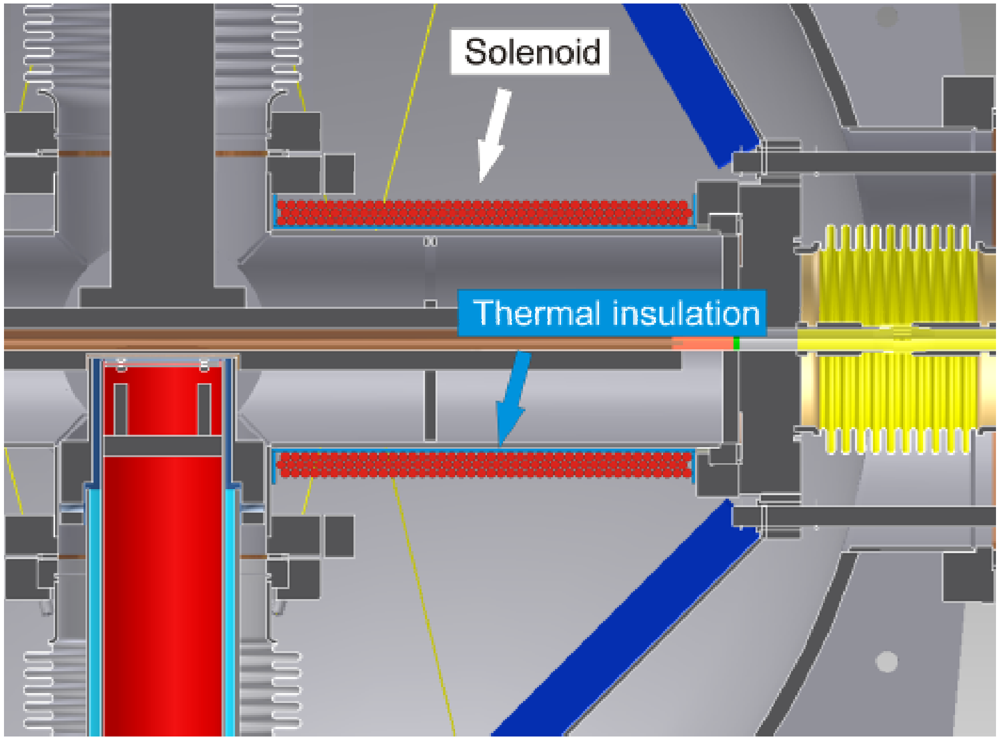
Vincent Baglin, Giuseppe Bregliozzi,

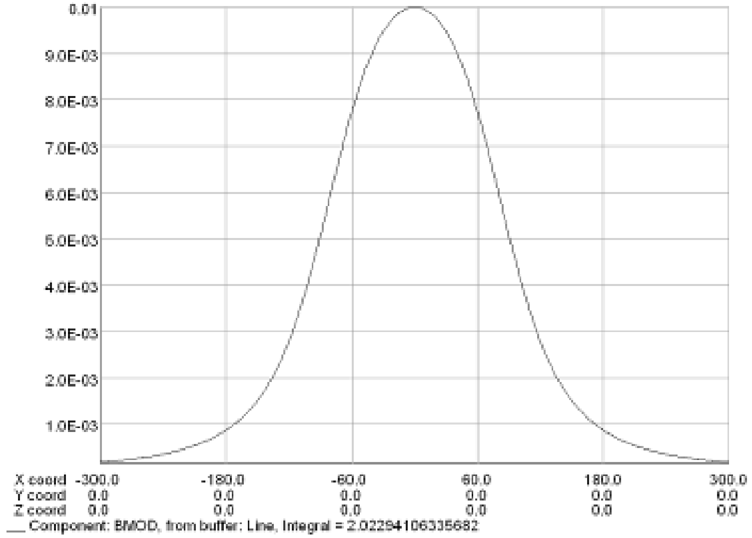
Julien Finelle, …

Instrumentation - Calibration of Diagnostics from STFC:



Instrumentation - Solenoid

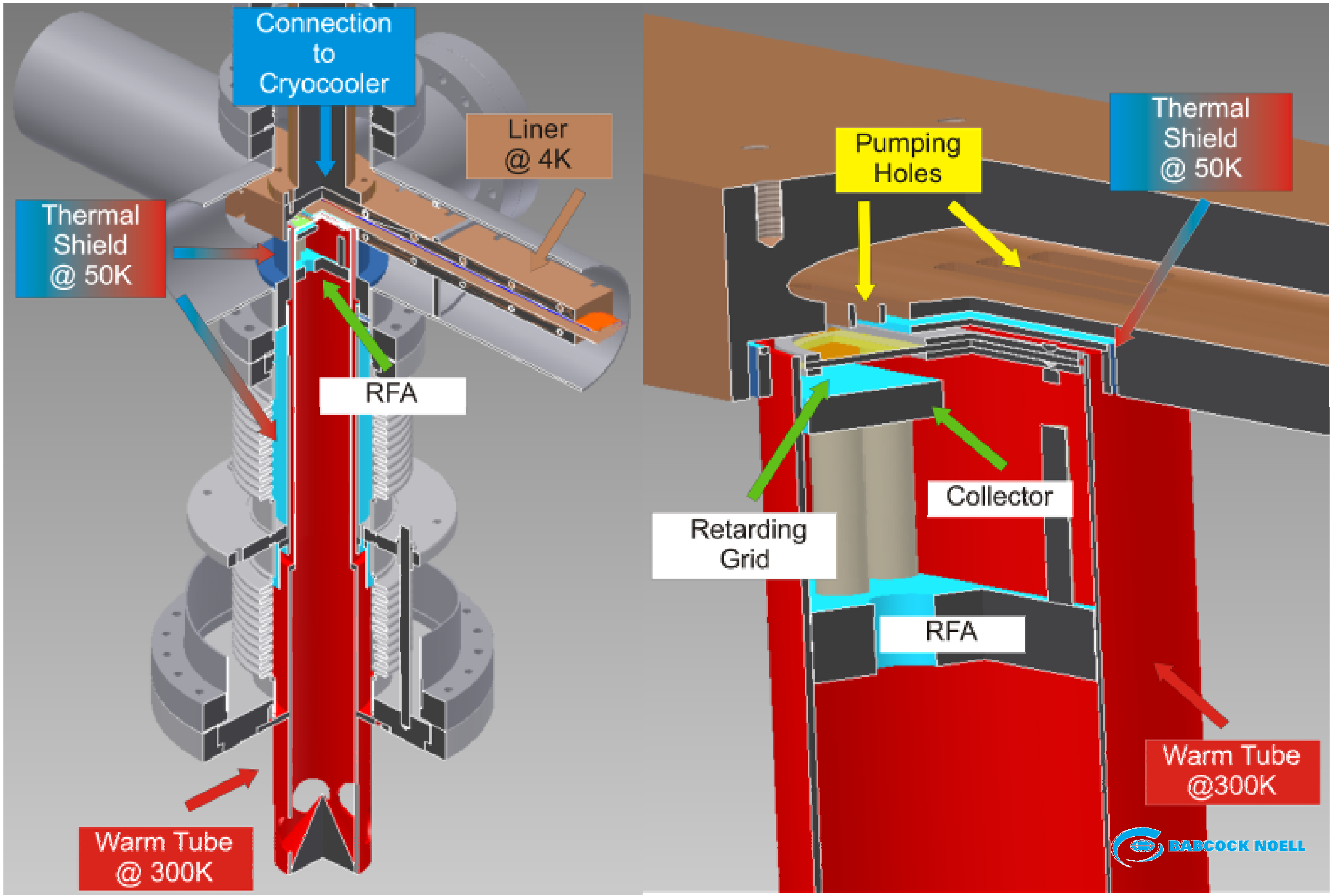




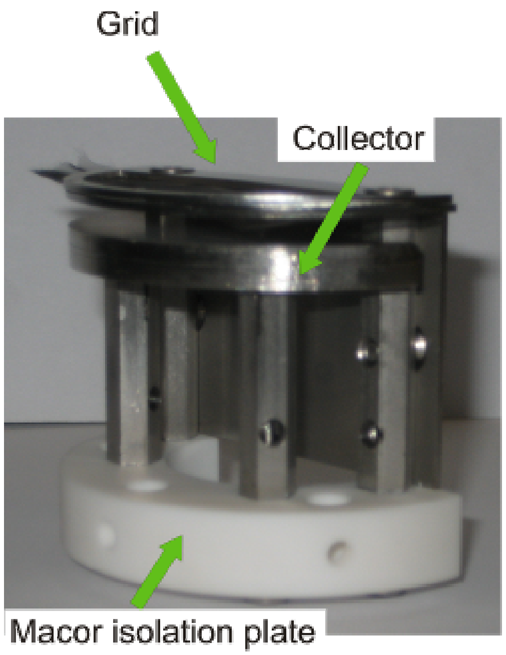
- Maximum magnetic field is limited by the heat intake of the solonoid:

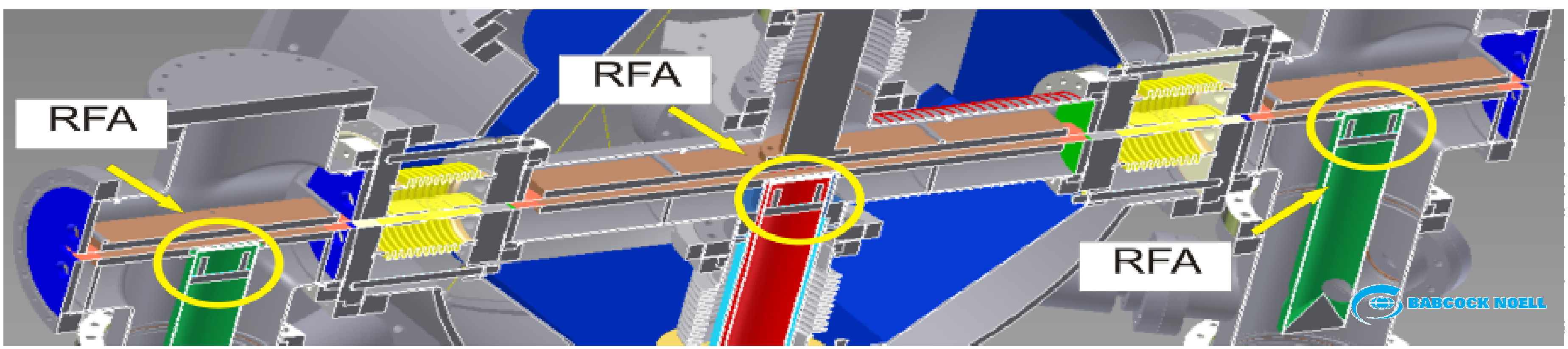
-> 5 mT - 10mT

Instrumentation - Warm Diagnostic Port

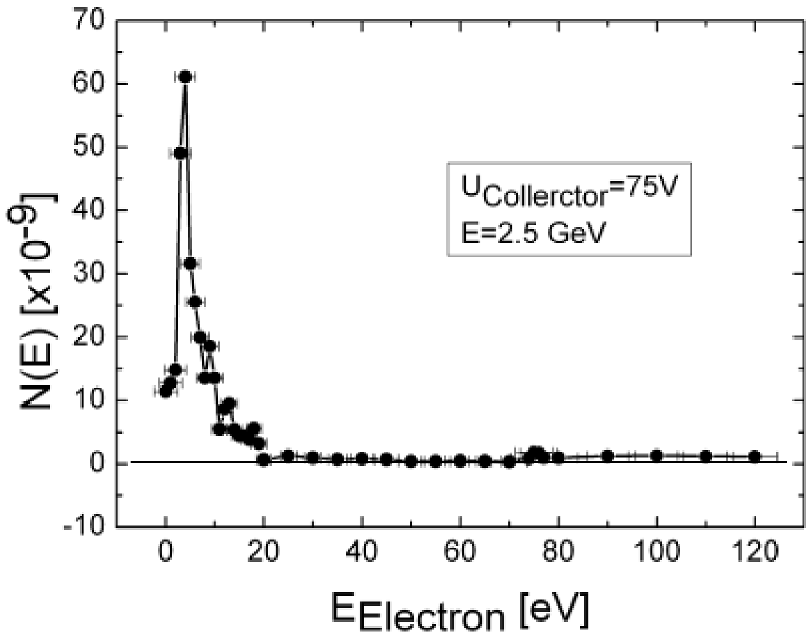


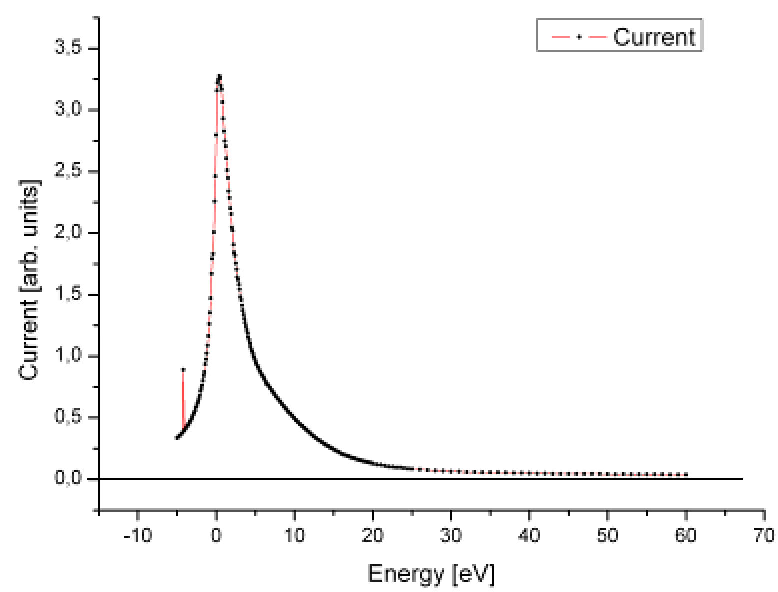
Instrumentation - Retarding Field Analyzer





Retarding Field Analyser – Measurements at ANKA



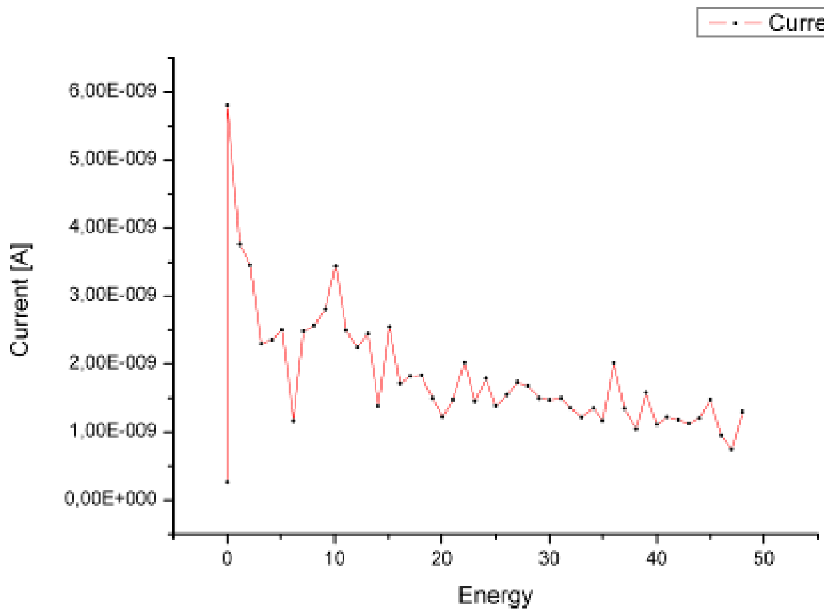


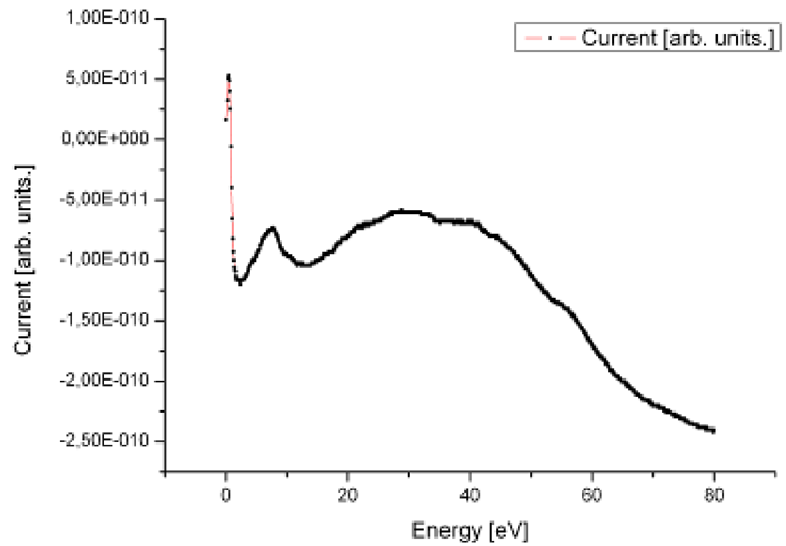
- Without Lock-in Amplifier
- With Lock-in Amplifier

RFA tested also by R. Cimino and M. Commisso in Frascati

Retarding Field Analyser

- Spectrum of a 0.2mm diameter tungsten filament

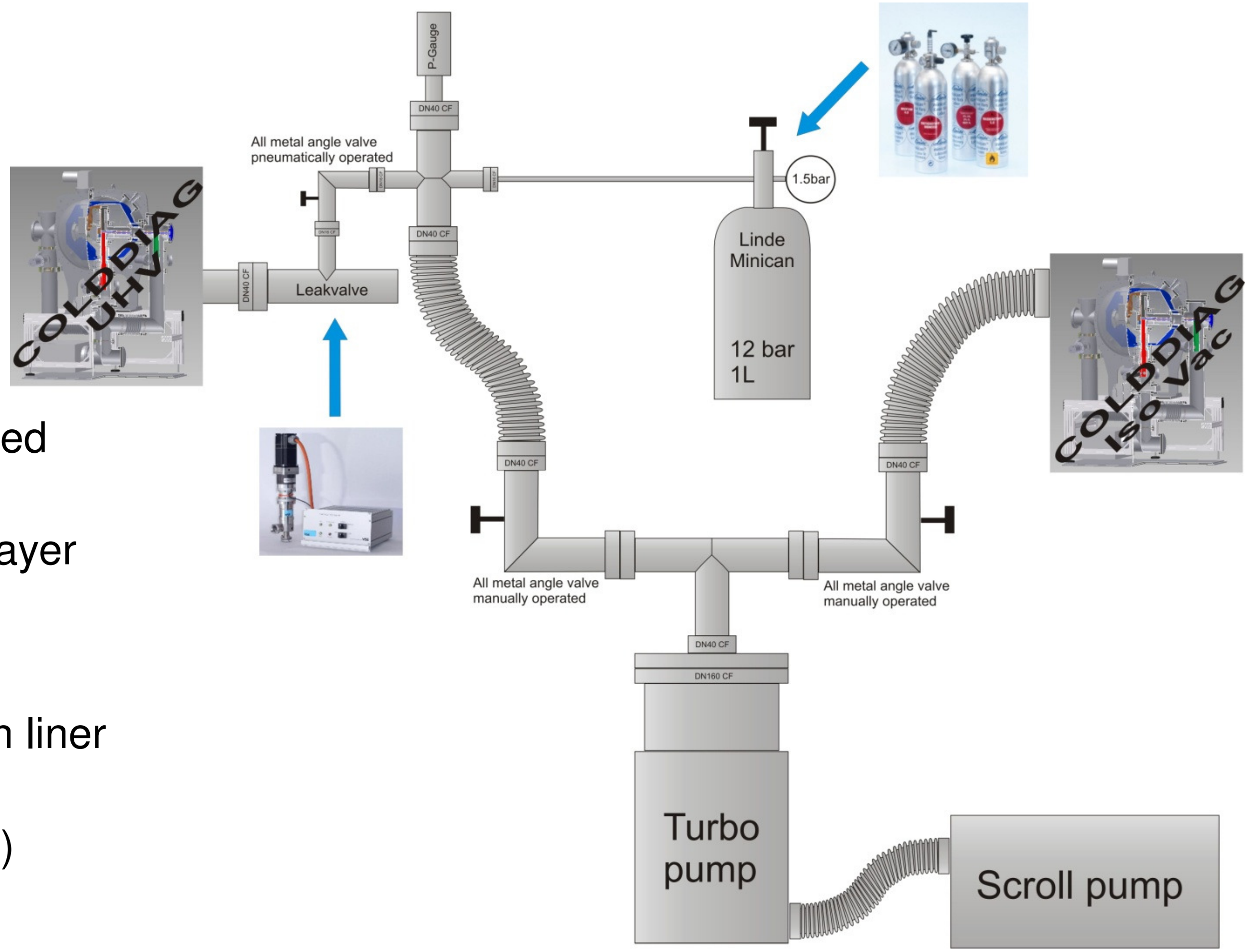




- Without Lock-in Amplifier
- With Lock-in Amplifier

Instrumentation - Gas Injection procedure:

- Warm up of the cold liner to 150 K
  → to “clean”
- Start gas injection (H_2, CO, CO_2, CH_4)
- Adjust leak rate to needed partial pressure for deposition of ~ 1 Monolayer
- Start cool down
- Stop gas injection, when liner starts to cryopump (fast pressure decrease)
- Cool down to 4 K



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Planned Measurements:

Monitoring of the temperature, electron flux, gas composition and pressure in parasitic mode and in machine physics time with different:

- Average beam current from 0 to 300mA

→ Influence of resistive wall heating and synchrotron radiation

- Bunch length at fixed average beam current

→ Influence of resistive wall heating

- Filling pattern

→ Relevance of the electron cloud as heating mechanism

- Beam Position

→ Simulation of different gaps and influence of synchrotron radiation

- Injected Gases

→ Influence of the cryosorbed gas layer

Summary:

- A cold vacuum chamber for diagnostics to measure the beam heat load in an accelerator is currently under construction

- The instrumentation will allow to monitor the
  - Pressure
  - Gas composition
  - Electron flux onto the beam tube
  - Temperature / Beam Heat Load

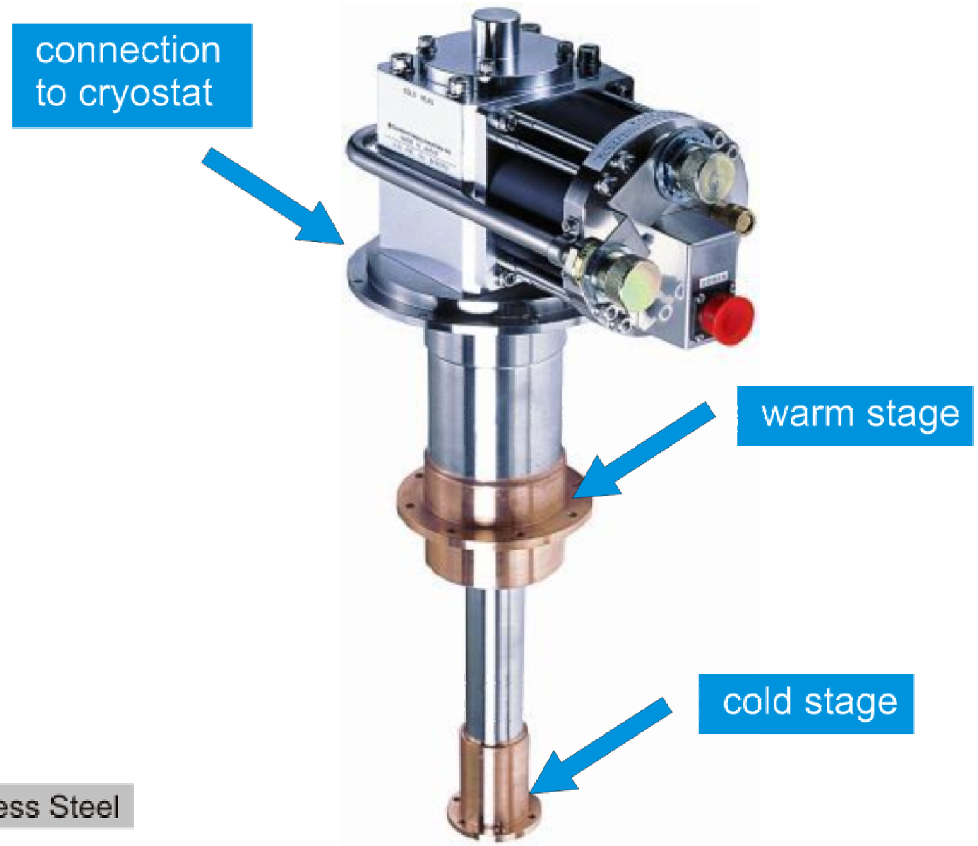
- A first installation at the Diamond Light Source is planned for June 2011

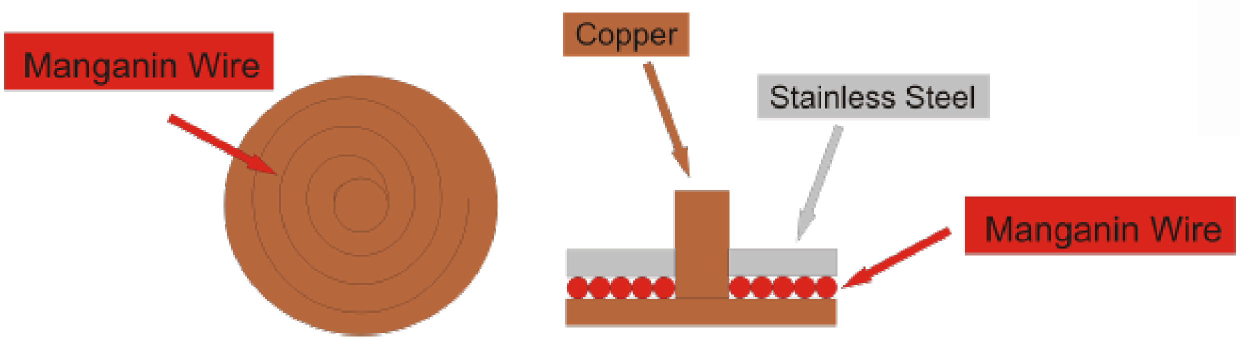
Thank you

for your attention!

Instrumentation - Main Heater:

- Inside Isolation vacuum
- Mounted on the cold stage of the cryocooler
- For faster heat up of the liner
- Between 50 W and 100 W
- Operation current ~ 1 A

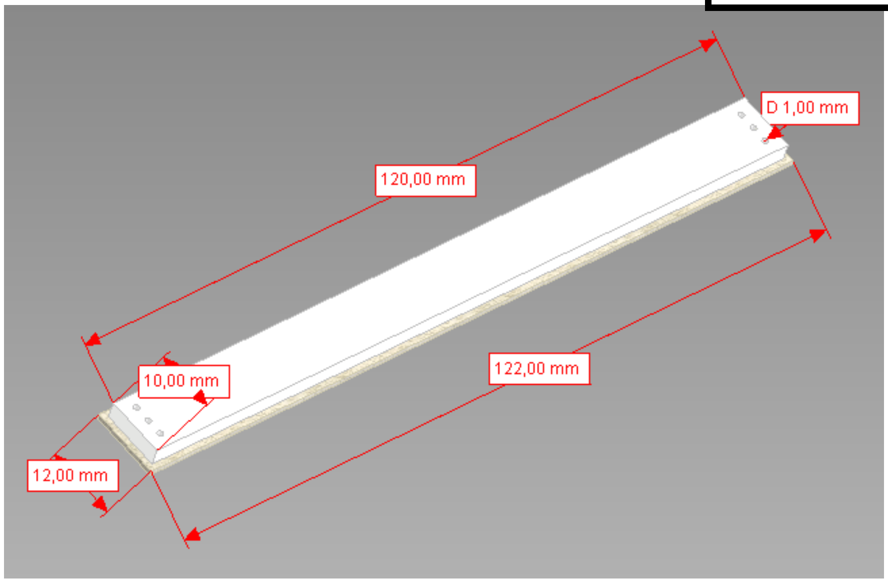




Instrumentation - Heater:

- Sapphire plate:
  - 1mm x 12mm x 122mm
- Macor plate:
  - 3mm x 10mm x 120mm

stainless steel wire diameter [mm]	0.2	0.1
Length [mm]	3 x 120	3 x 120
Resistance [Ω] @ 4K	5.4	21.3
Operating current max. [A]	1.0	0.75
Voltage [V]	5.4	21.3
Dissipated Power [W]	5.4	12



- Cold section:
  - 4 Heater
  - Total Power ~ 21 W – 48 W
- Warm section:
  - 1 Heater
  - Power 5.4 W – 12 W

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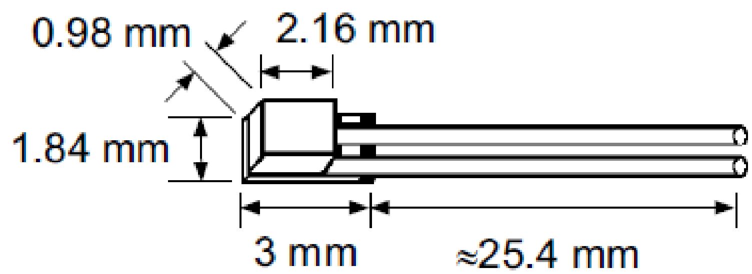
Temperature Sensors

- Cernox 1050-SD:

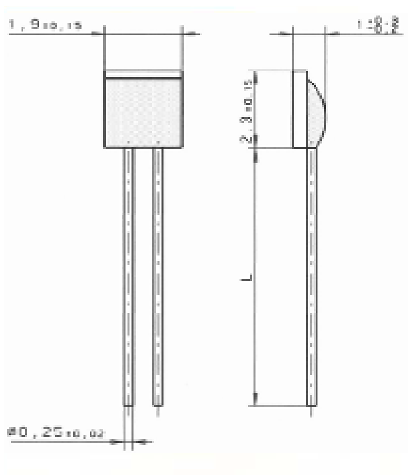


Leads: 32 AWG
(0.2 mm diameter)
Phosphor-Bronze
Sensor Mass: 0.03 gram

- PT100:

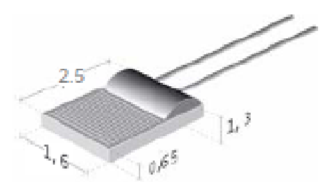
Accuracy +/- 0.005 *|t|

Accuracy +/-0.002*|t|



t=Temp in ℃

Temperaturbereich von -200°C bis +400°C in der DIN 60751 Klasse A
minimale Hysterese
Messwiderstände mit Drahtanschlüssen
Platin/Nickel-Manteldraht 0.2 mm x 10 mm (Ø x L), (lötbar, schweissbar,
Temperaturkoeffizient 3911 ppm/K

Bauform Dimensionen in mm	Nennwiderstand bei 0°C in Ohm	Chip-Abmessung in mm
	50 100	LxB 2.5 x 1.6 LxB 2.5 x 1.6

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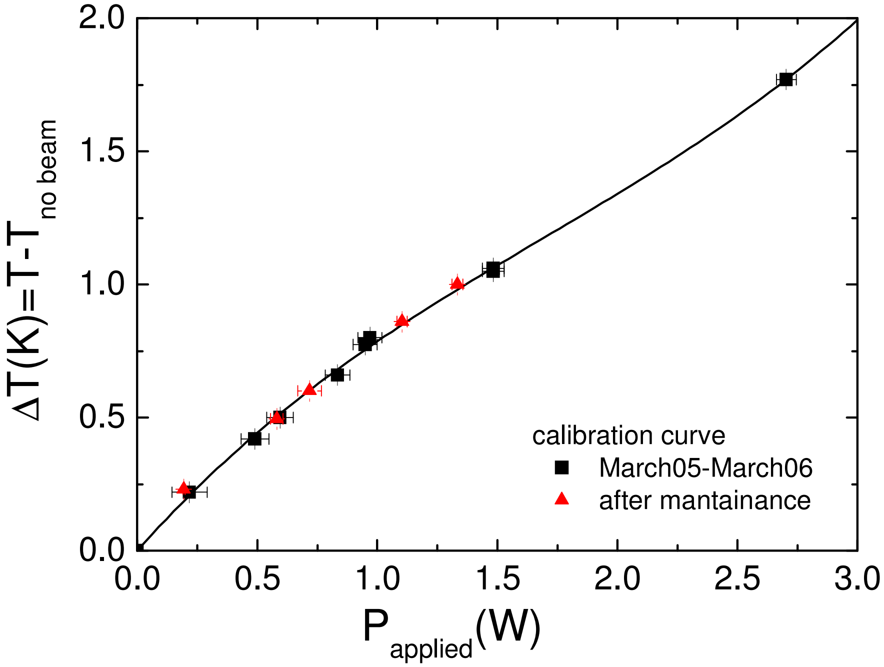
Precision of Beam Heat Load Measurement

From SCU14 minimum beam heat load measurable ~0.05W,
with COLDDIAG can be determined after factory acceptance test



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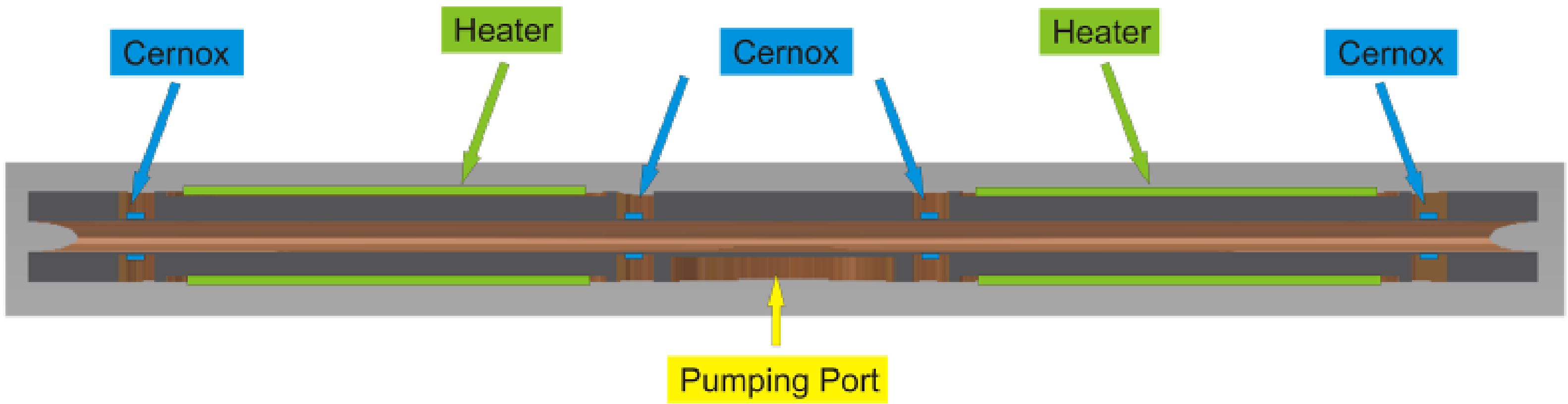
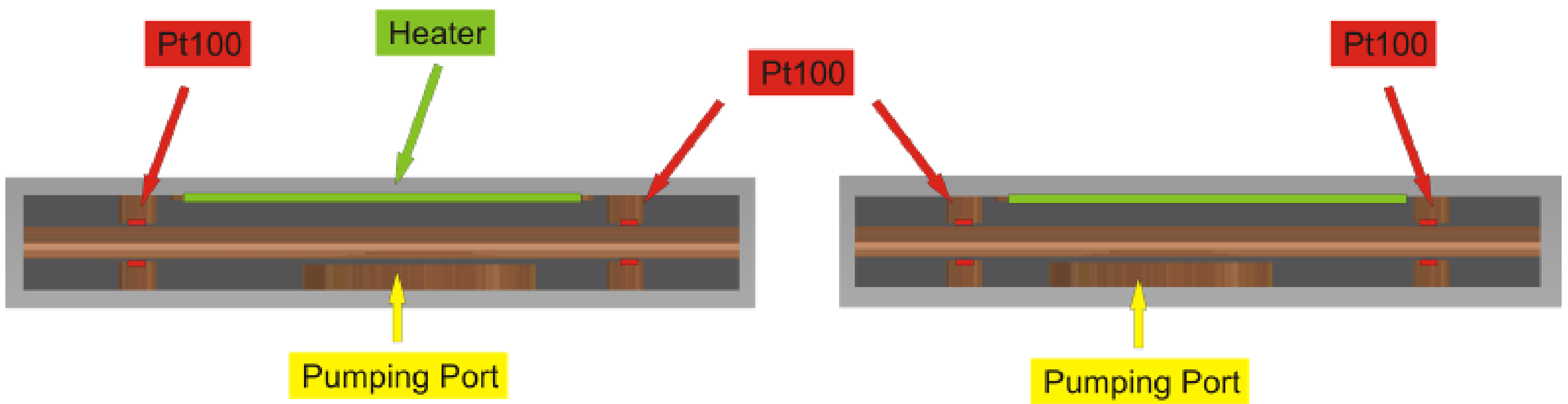
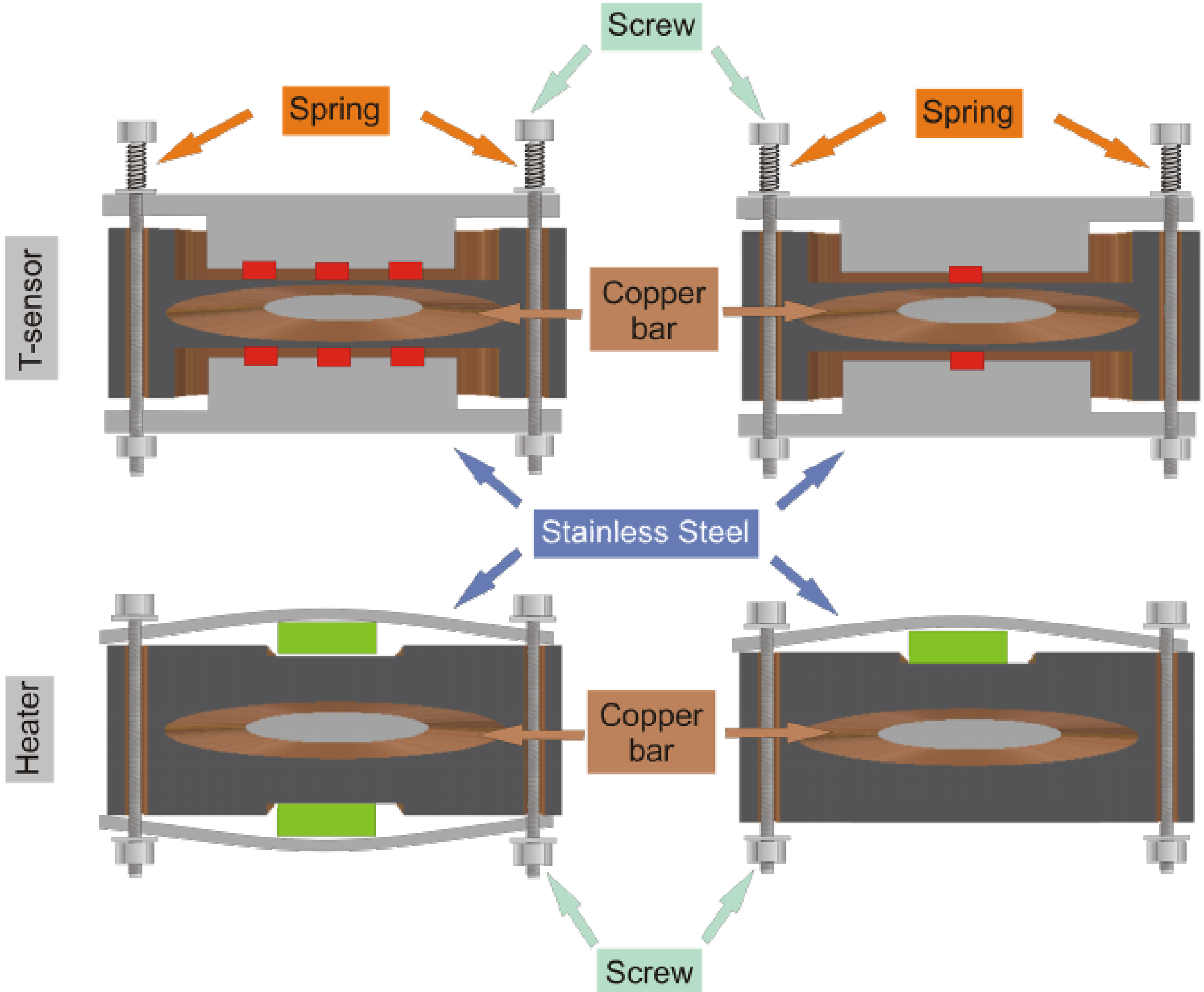
Temperature Sensors mounting Positions:



Cut along beam axis

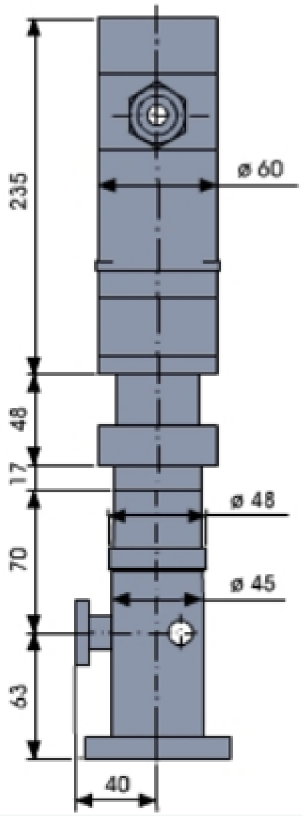


Fixing of the T-sensors:



Gas injection:

Gas dosing valve



Leakvalve CF 35 / 16 rotatable flanges,motor driven

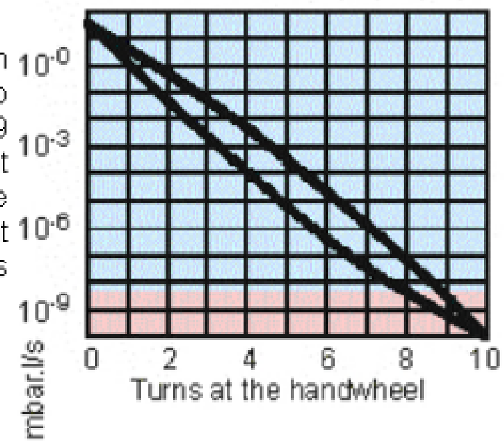
VSE vacuum high precision all metal leakvalve

LEAKDIAGRAM:

In the range of turn 0 - 3 the diaphragm does not touch the valve seat. Due to physical reasons, control between 10 E-9 und 10 E-10 is not possible, if used at room temperature (red range in the diagram). In this case the valve is tight approx at turn 9 to 10. Control in this range is possible if the valve is heated.

Maximum throughput: 60 mbar.l/s

Subject to change



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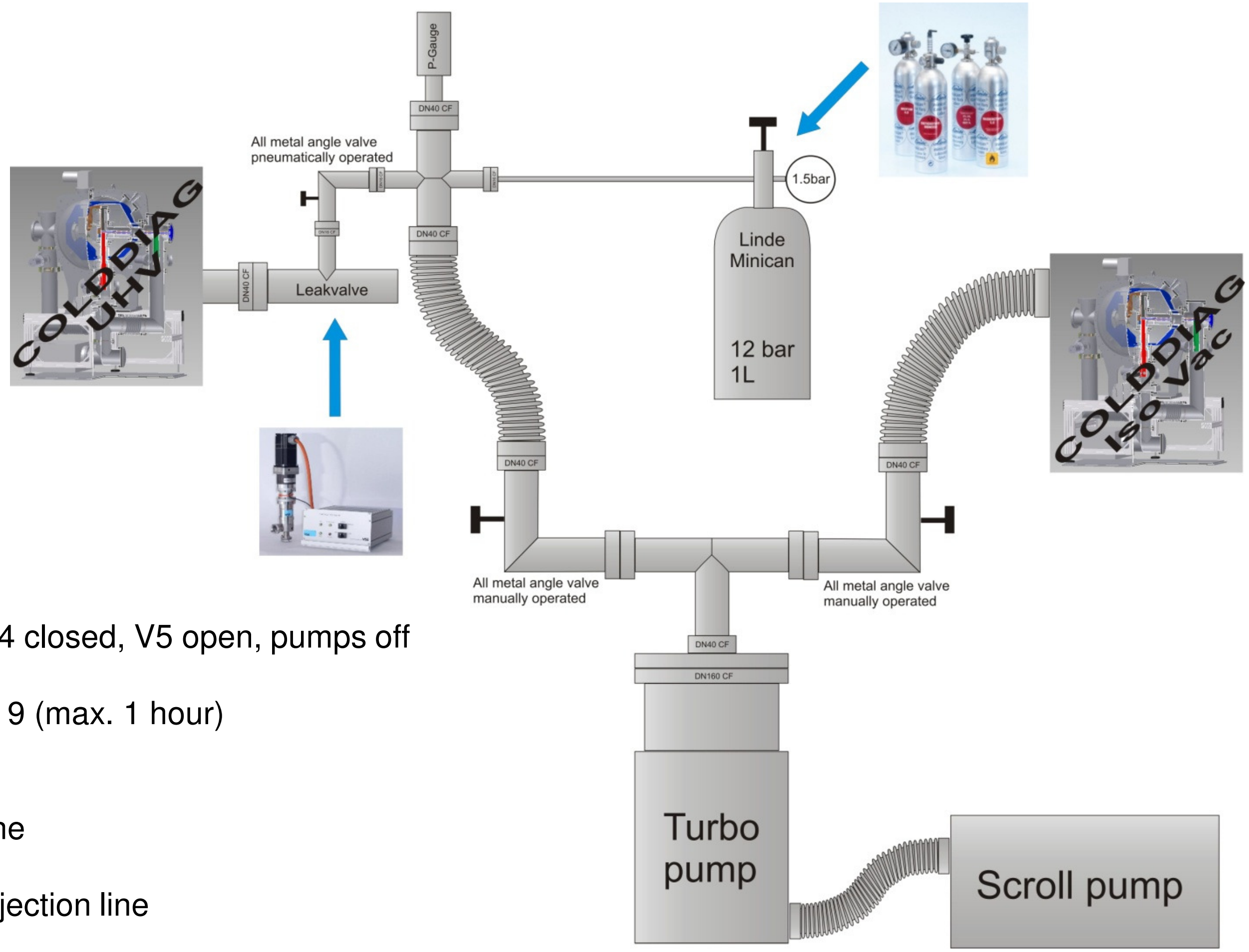
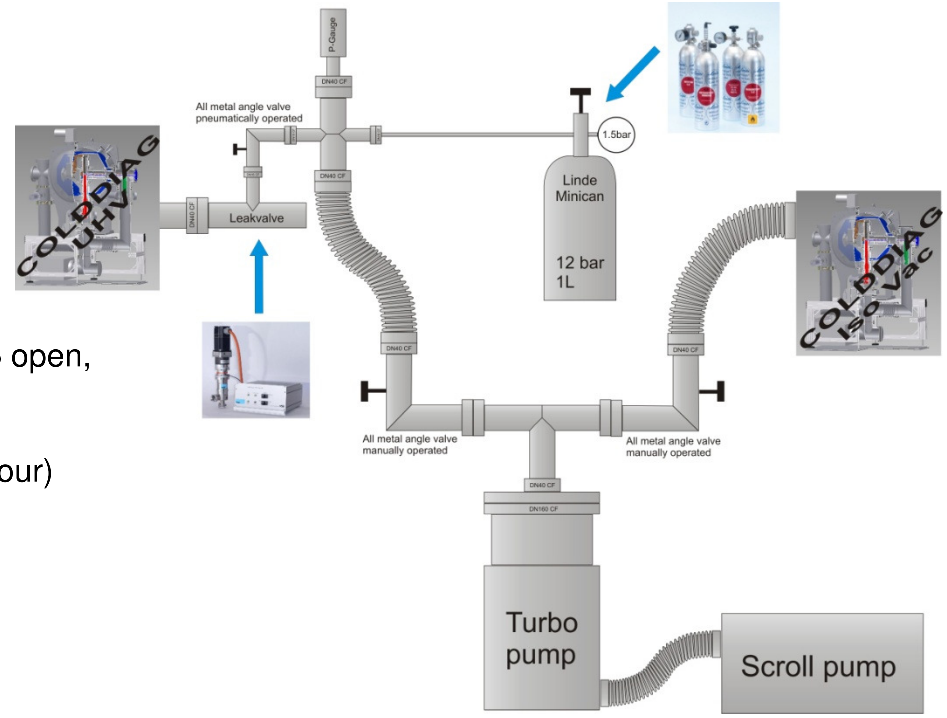
Gas injection:



Change gas bottle:

1. Starting condition: V1, V2, V3, V4 closed, V5 open, pumps off
2. Open V2, check V1
3. Access to tunnel needed till step 9 (max. 1 hour)
4. Close V5, change bottle
5. Switch on pumps
6. Open V3 to evacuate injection line
7. Close V3 / open V5
8. Repeat steps 6 and 7 to clean injection line
9. Close V3, switch off pumps
10. Close V2 remotely

Gas injection:



Flush injection line

(need to be checked if necessary)

1. Starting condition: V1, V2, V3, V4 closed, V5 open, pumps off
2. Open V2, check V1
3. Access to tunnel needed till step 9 (max. 1 hour)
4. Close V5, change bottle
5. Switch on pumps
6. Open V3 to evacuate injection line
7. Close V3 / open V5
8. Repeat steps 6 and 7 to clean injection line
9. Close V3, switch off pumps
10. Close V2 remotely

Inject gas:

1. Starting condition: V1, V2, V3, V4 closed, V5 open, pumps off
2. Open V2
3. Inject gas with remote leak valve V1