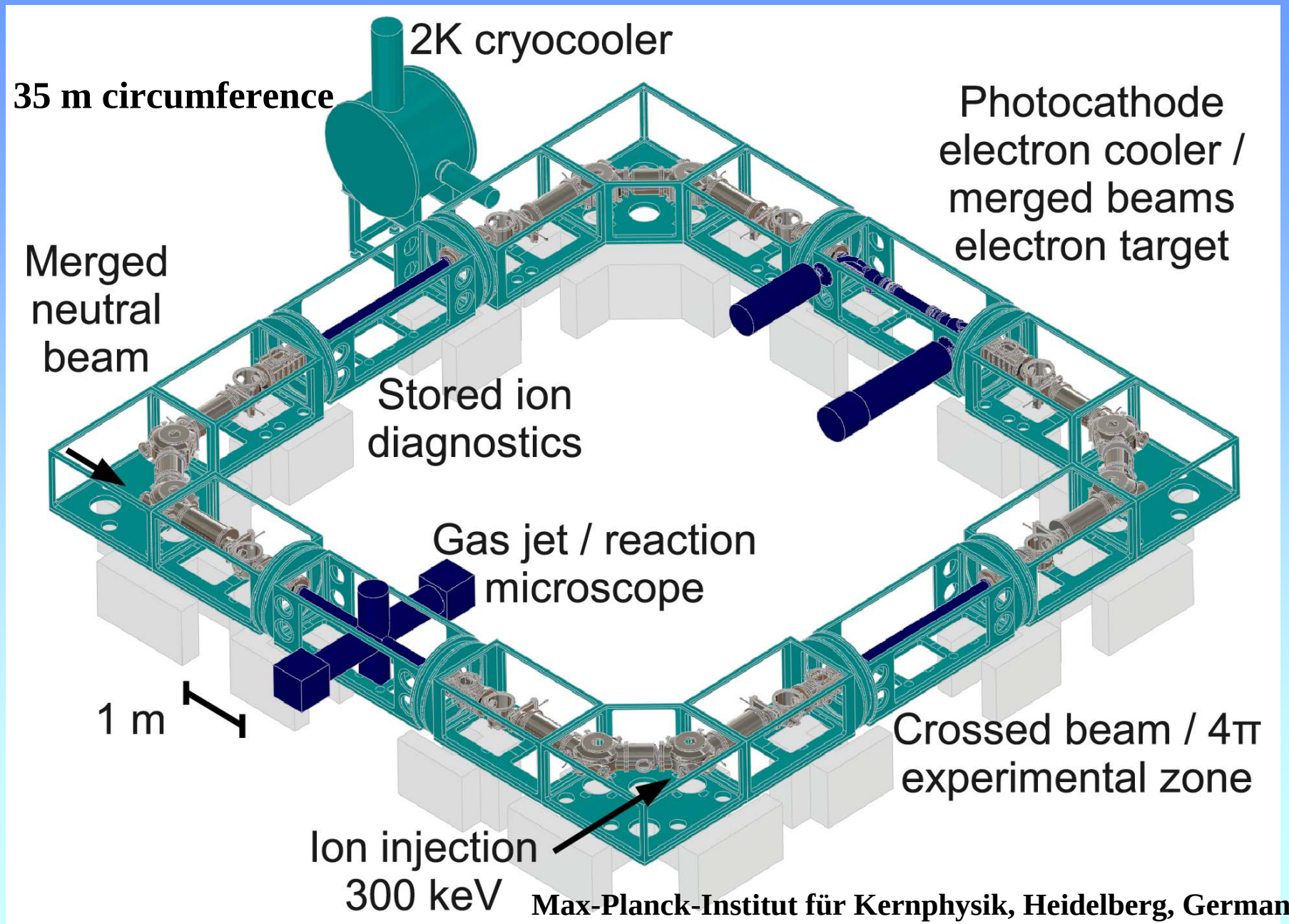
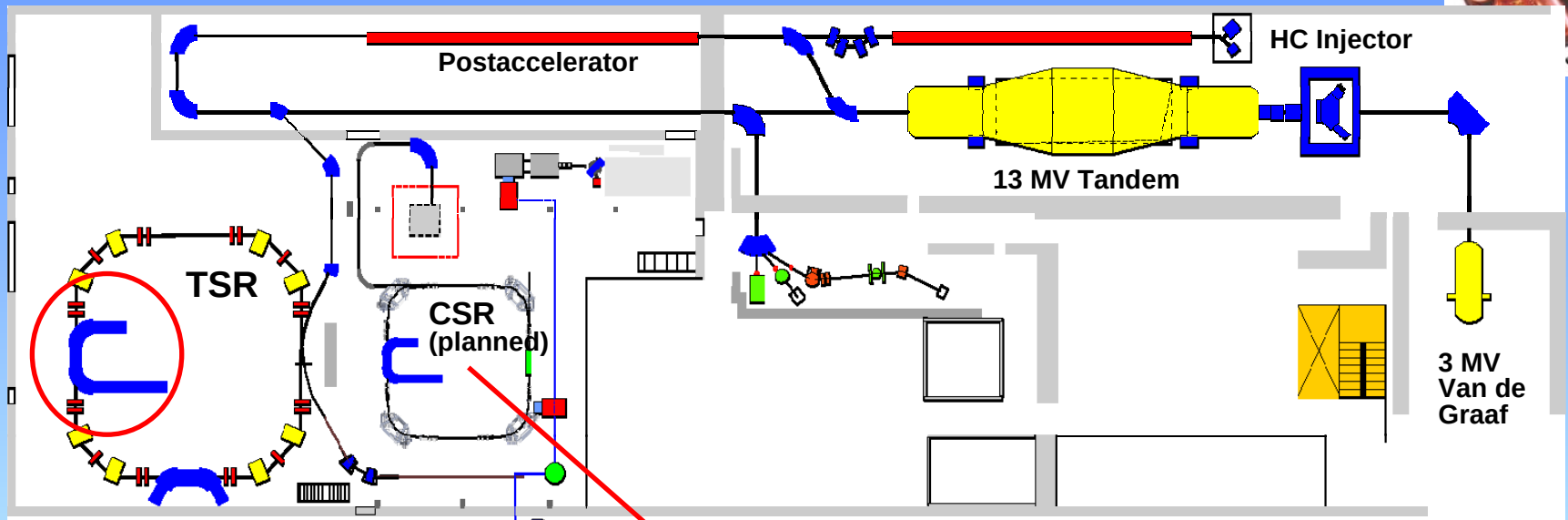
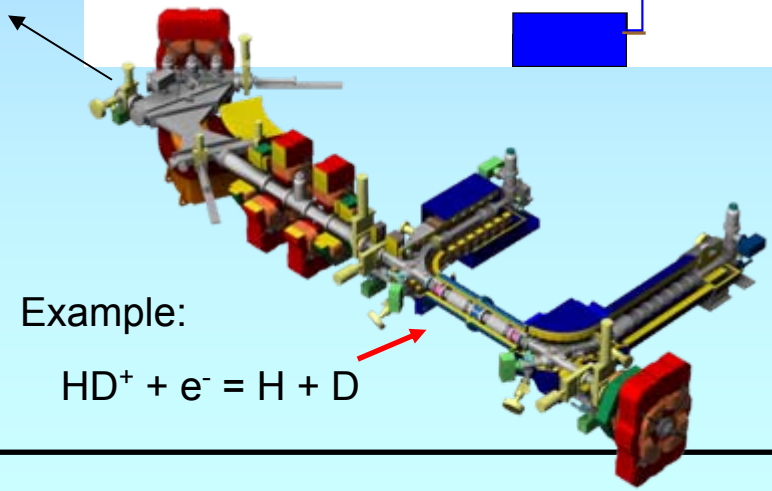
Status of the Cryogenic Storage Ring (CSR)



The CSR Project at MPI-K

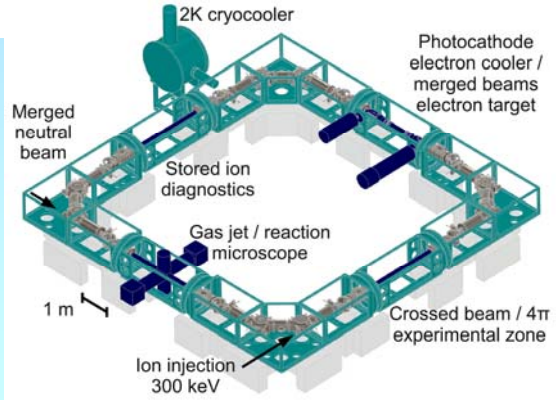


H D neutral



Example:

$HD^+ + e^- = H + D$



Ring at 2-10 K ?

⇒ **XUHV**
⇒ **τ ~ 1000s**
⇒ **υ = 0**
J = 0

Electrostatic ?

⇒ **Heavy molecules**

Requirements for the CSR

- **Beam energy variable between 20 keV and 300 keV (*q),**
- **Very large mass range up to bio molecules**

⇒ CSR should be electrostatic

- **Long life time, molecules in ground state**

⇒ Vacuum at low temperatures: $1*10^{-13}$ mbar (RT equivalent)

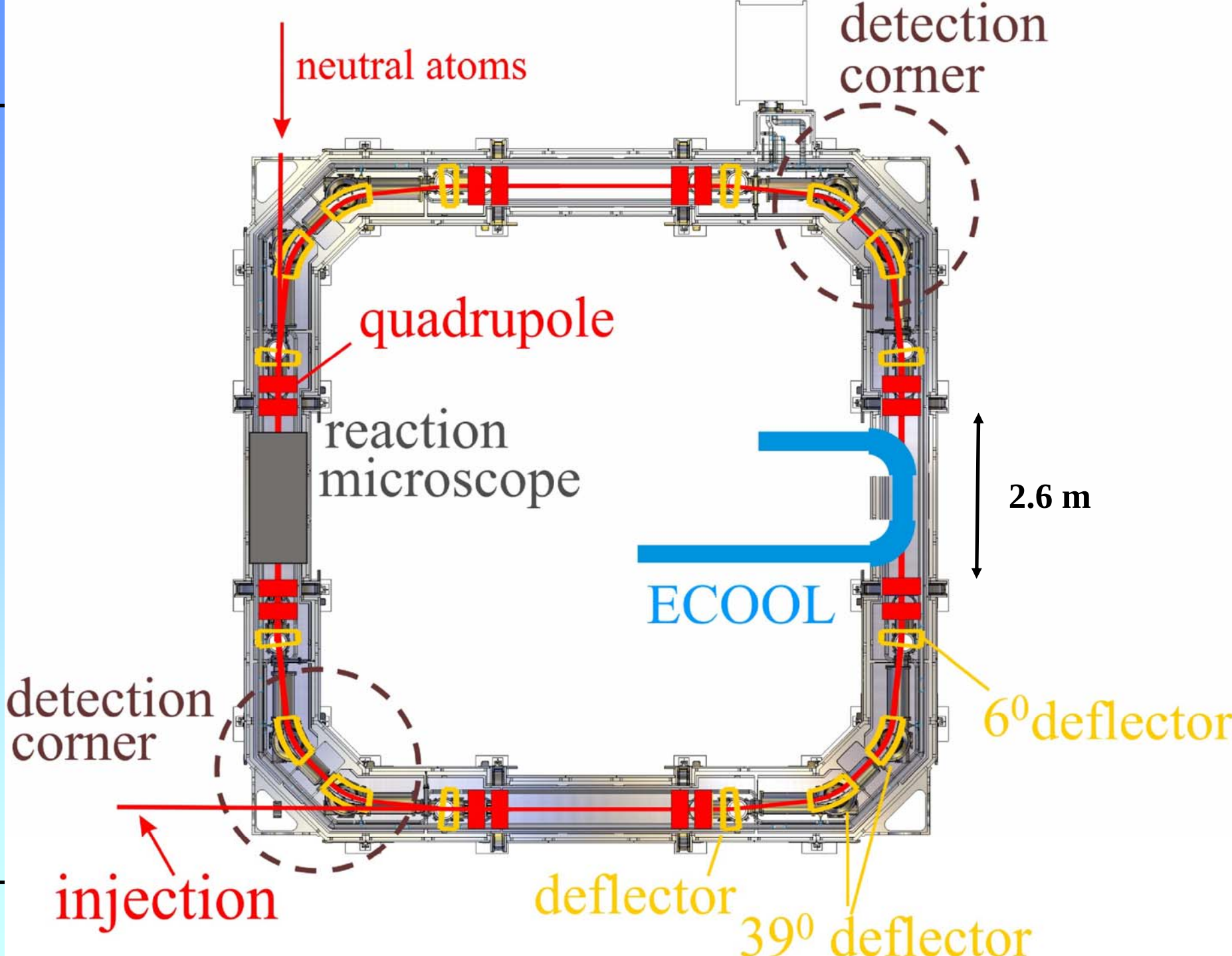
⇒ CSR must be cryogenic (10 K),
For H_2 2 K must be available at a determined number of positions

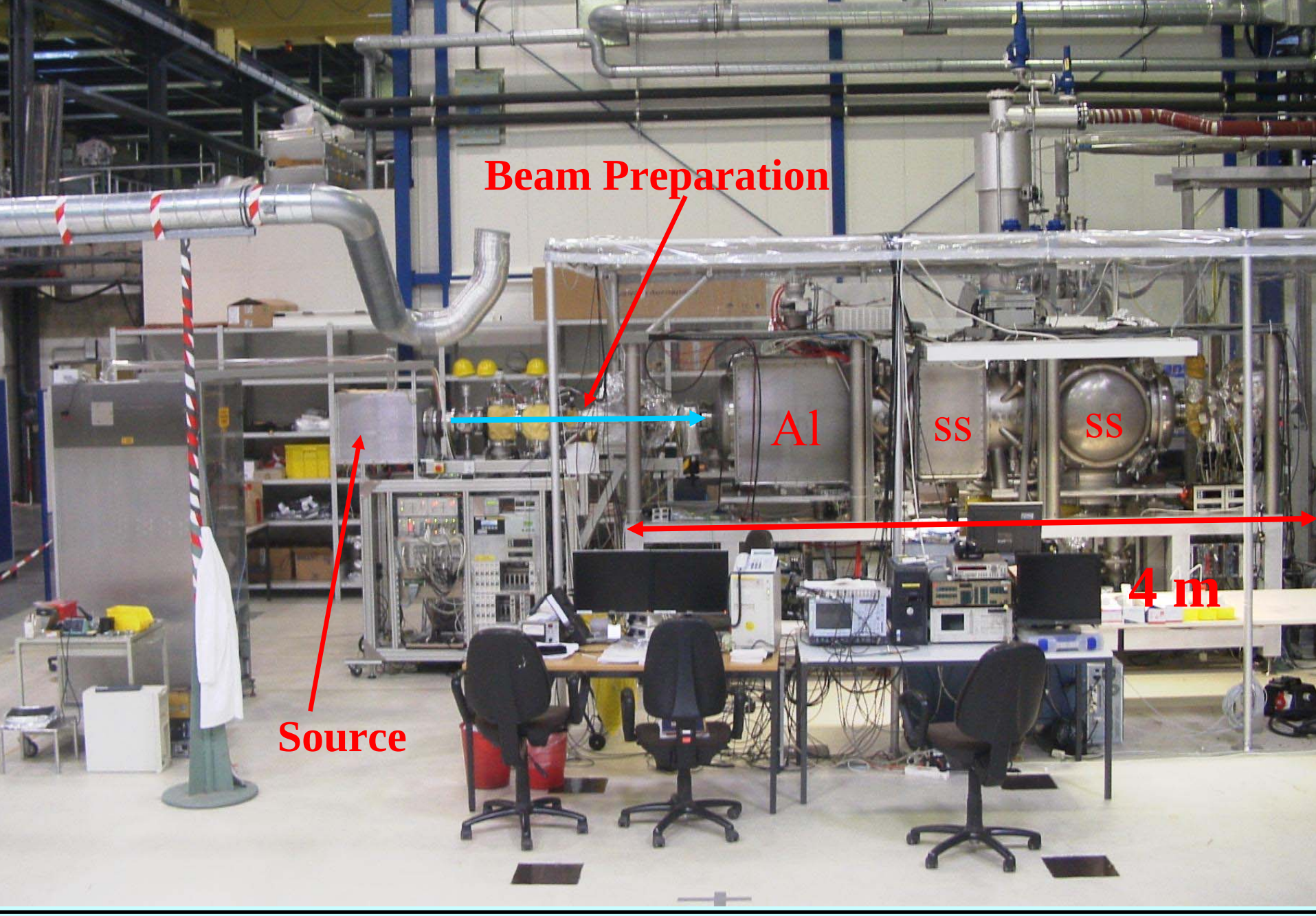
- **Operation temperatures between 10 and 300 K**

⇒ Usage of a Helium refrigerator delivering 2 K Helium

- **Vacuum at room temperature: $1*10^{-11}$ mbar**

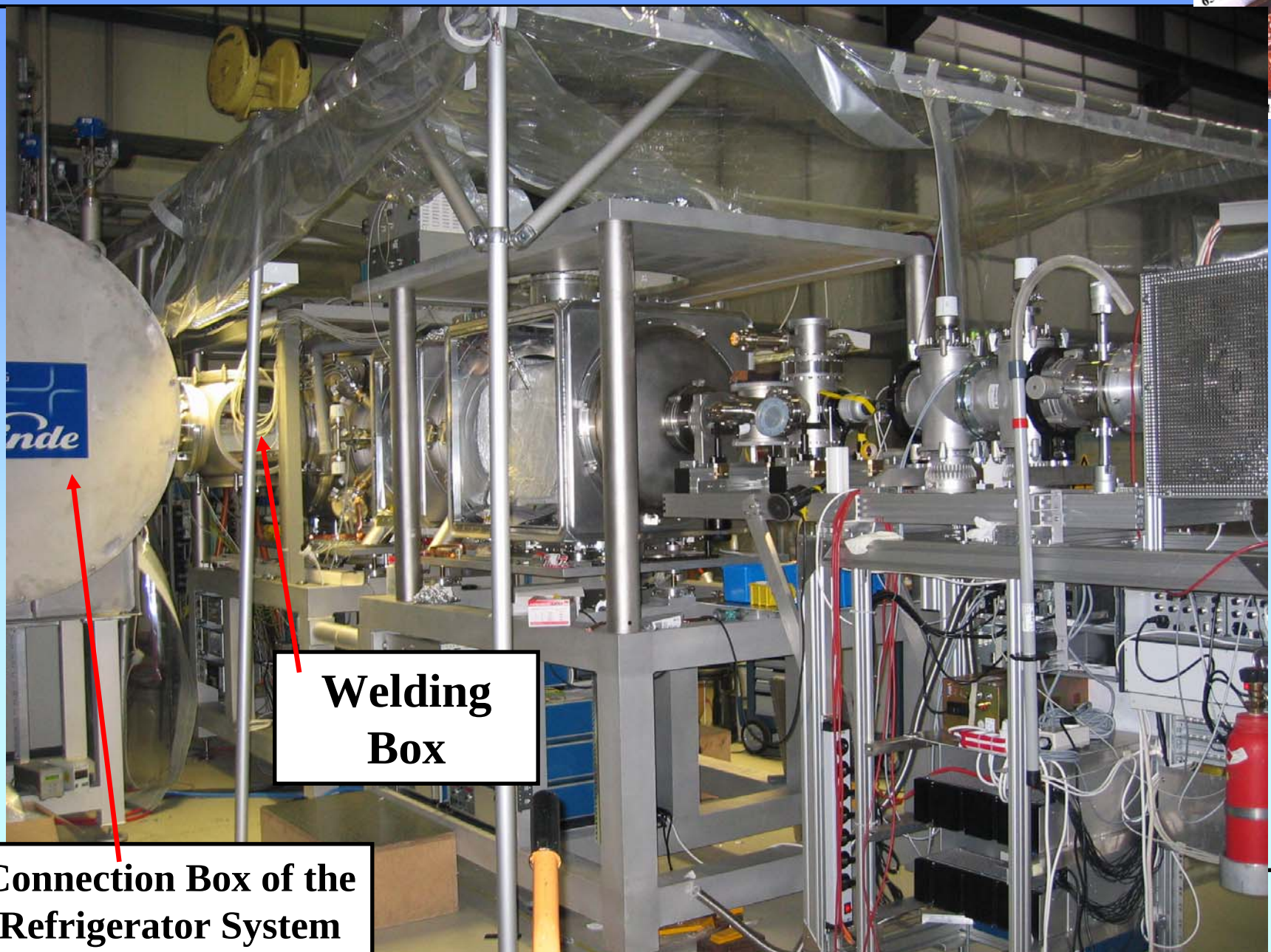
⇒ The ring must be baked up to 600 K


neutral atoms
detection corner
quadrupole
reaction microscope
2.6 m
ECOOL
detection corner
6⁰deflector
injection
deflector
39⁰ deflector



Assembly and measurements mainly by: M. Lange, M. Froese, S. Menk

Prototype and Refrigerator



Linear Electrostatic Ion Trap

Injected ion beam

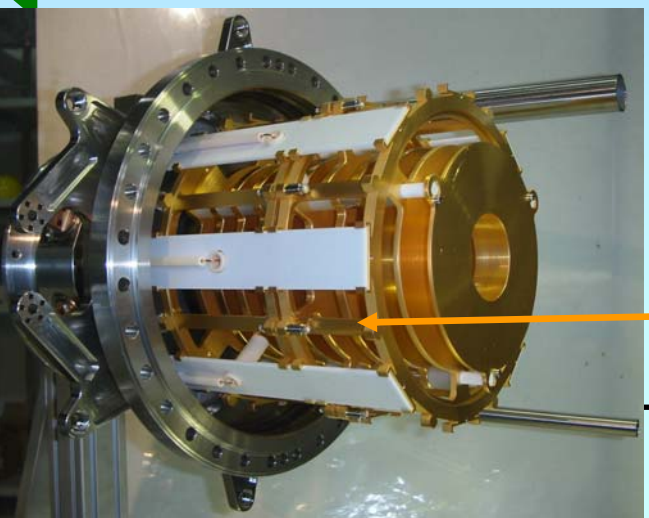
Middle chamber

~1 m

~3 m

Electrostatic ion trap

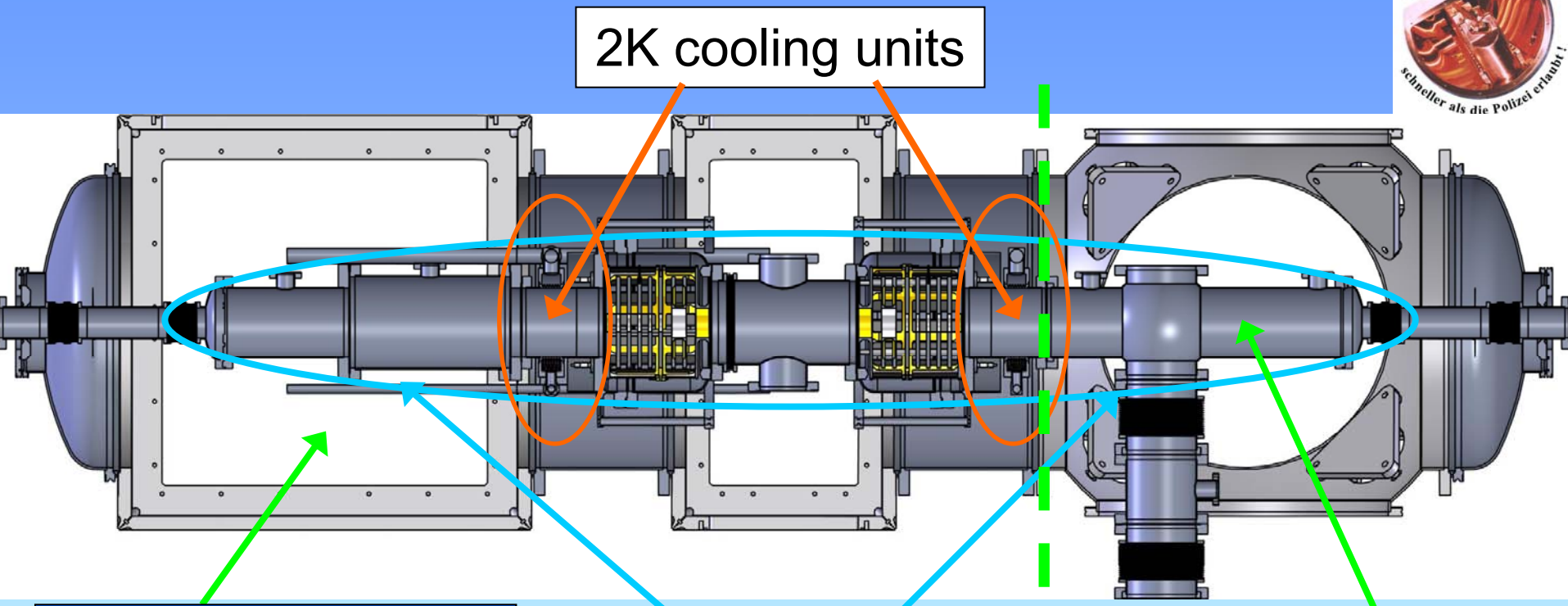
Pumping



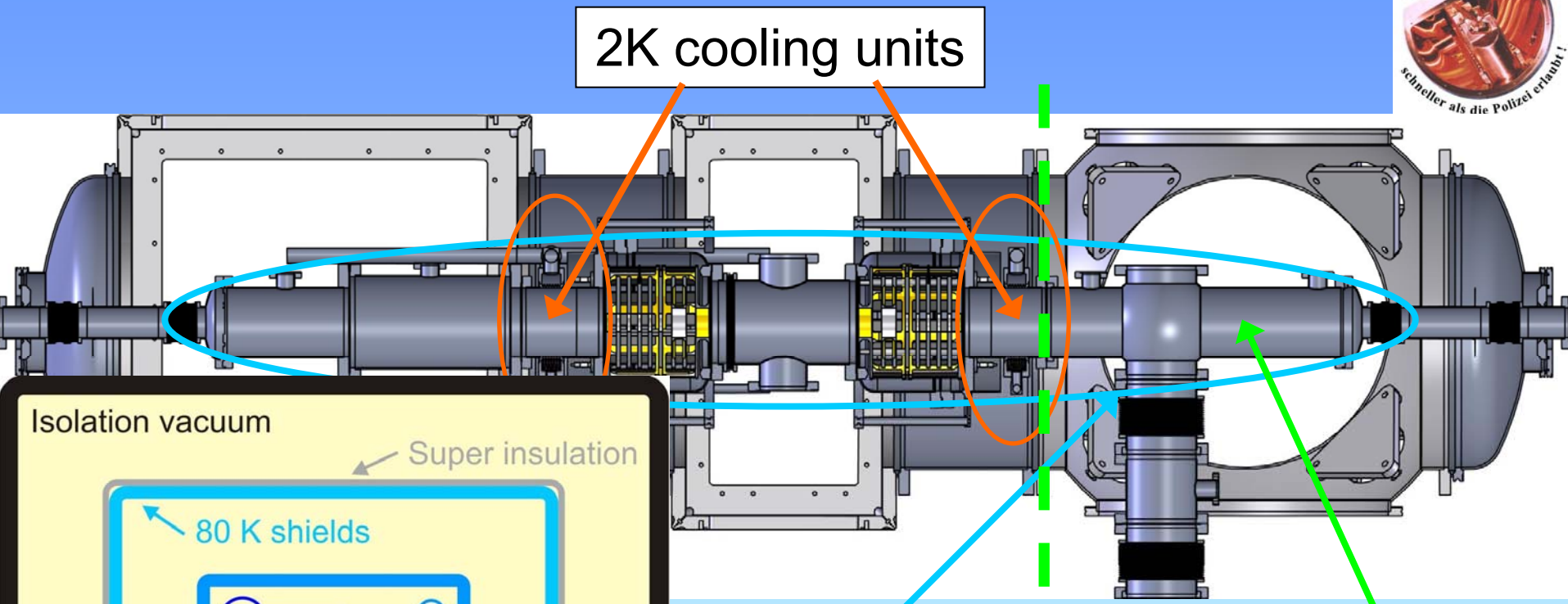
Gold plated electrodes

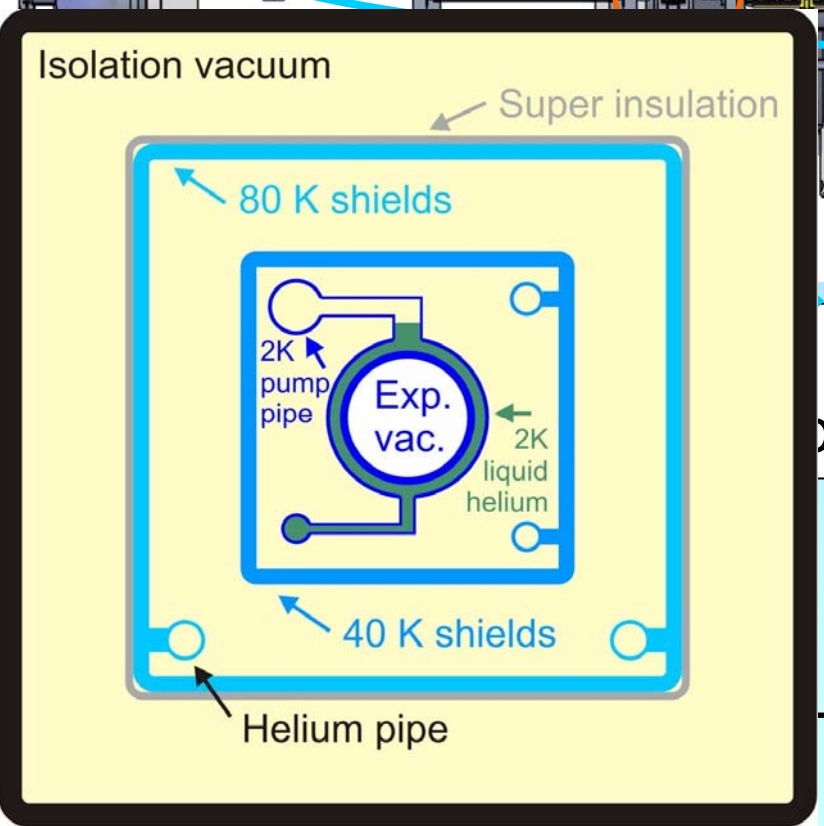
Robert von Hahn for the CSR-Team

Cooling techniques and thermal shielding

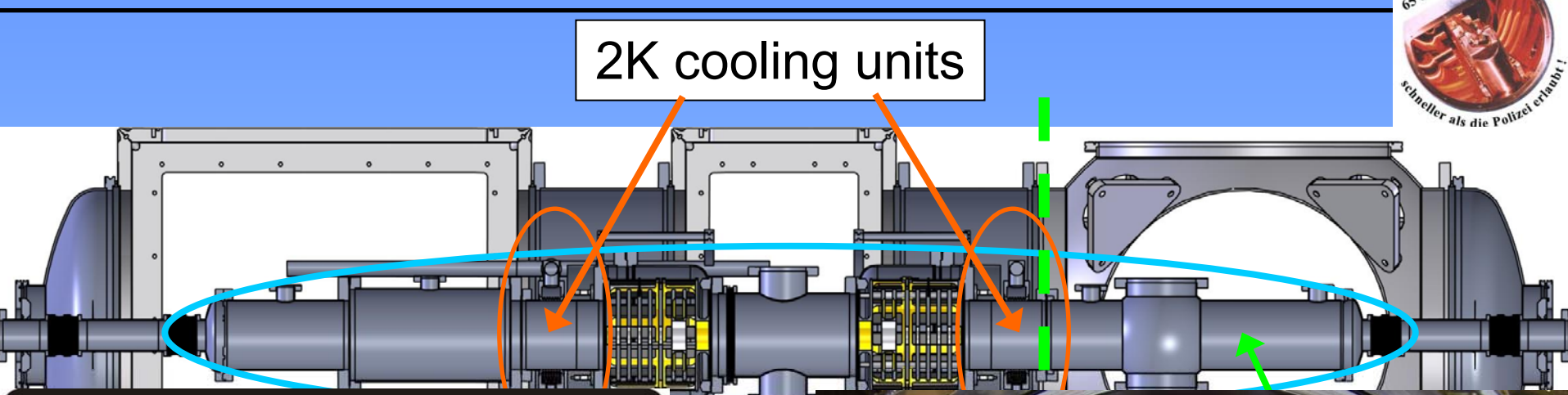


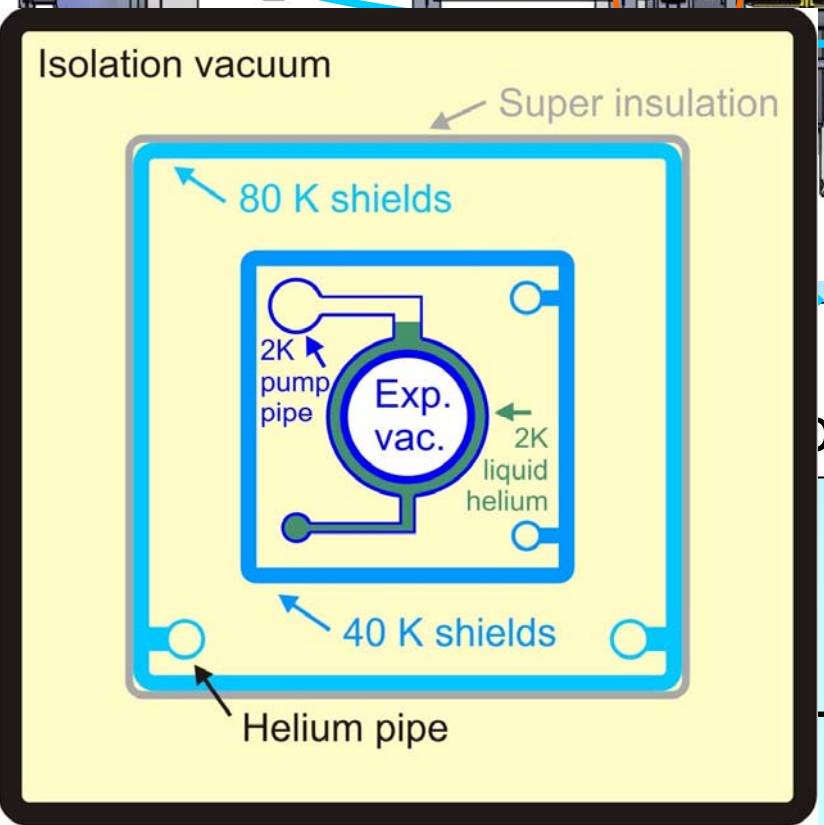
Cooling techniques and thermal shielding



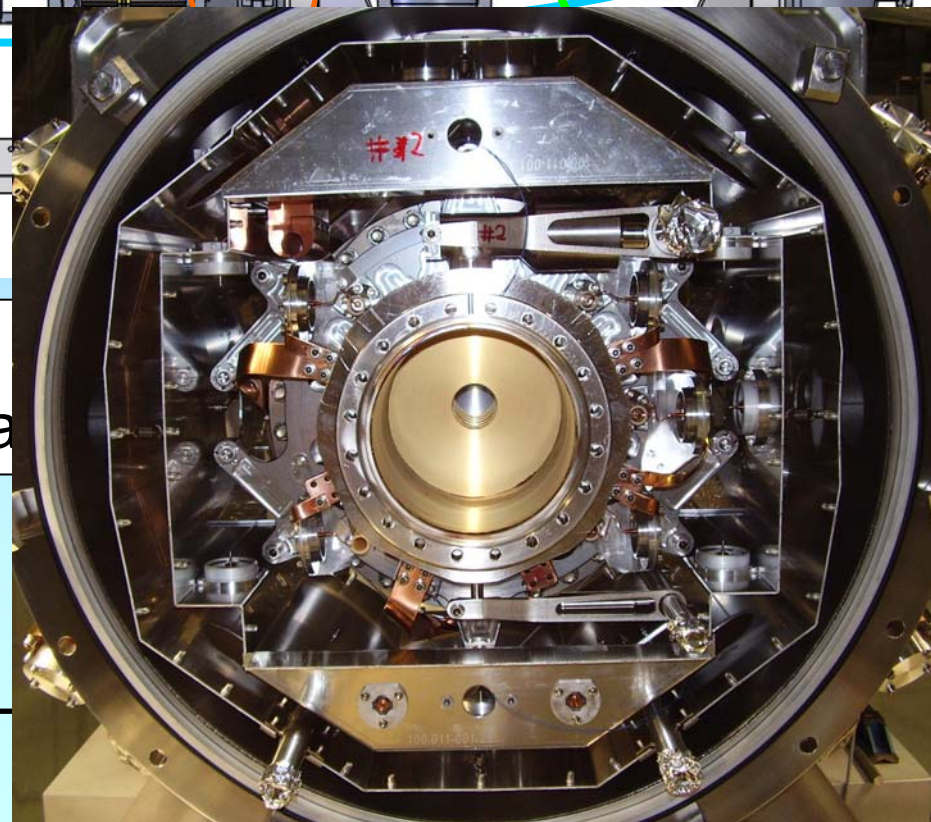


Cooling techniques and thermal shielding

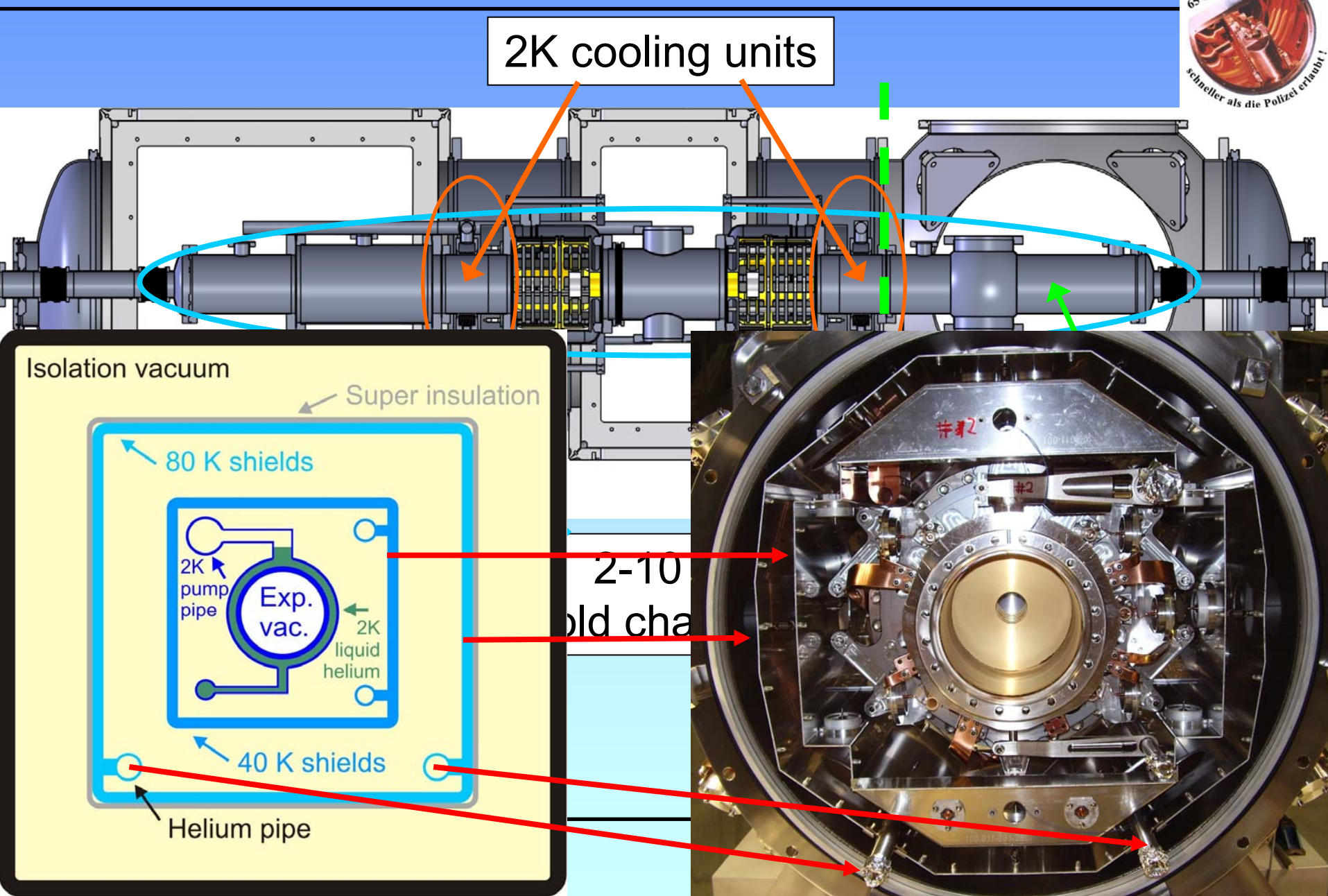




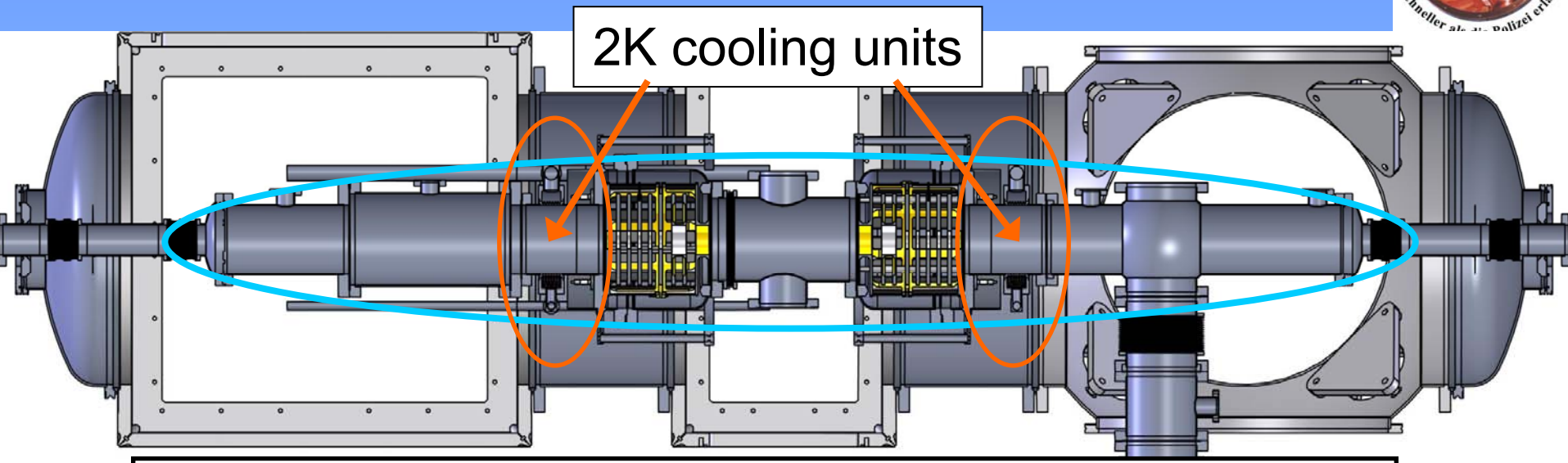
2-10
old cha

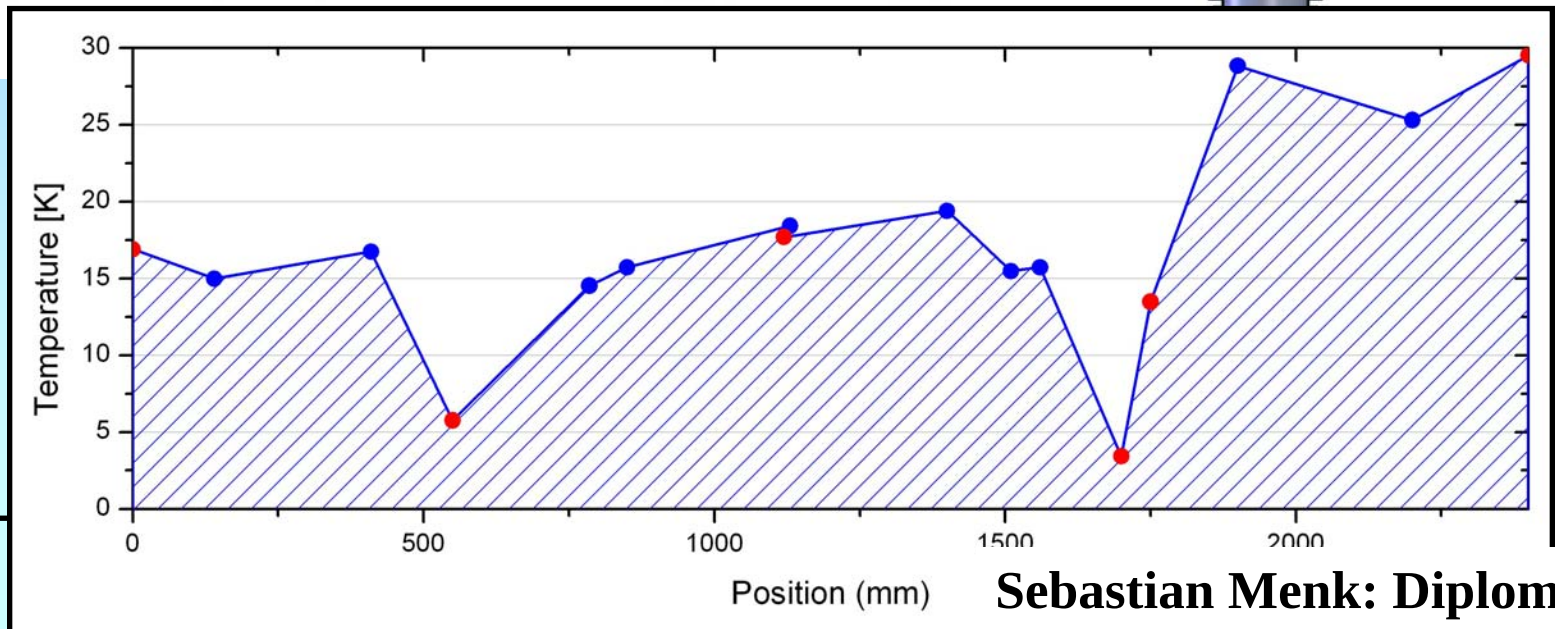


Cooling techniques and thermal shielding



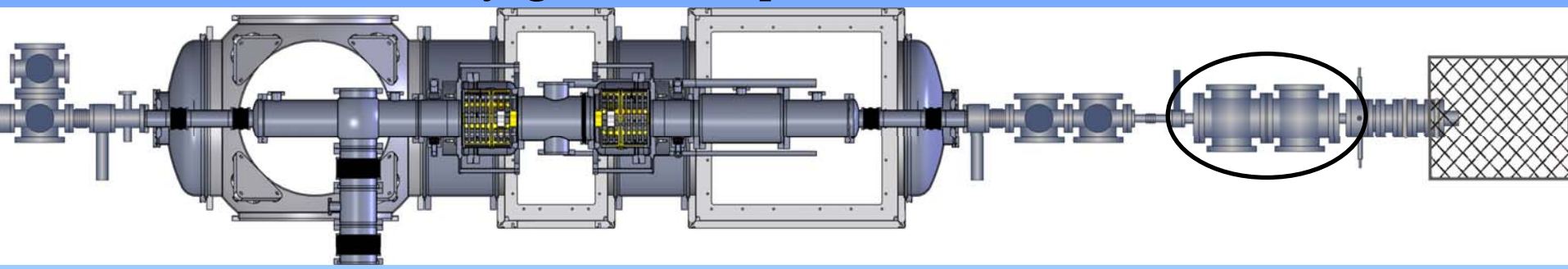
Measured cryogenic temperatures at cool downs





Sebastian Menk: Diploma Thesis

Ion production and beam preparation

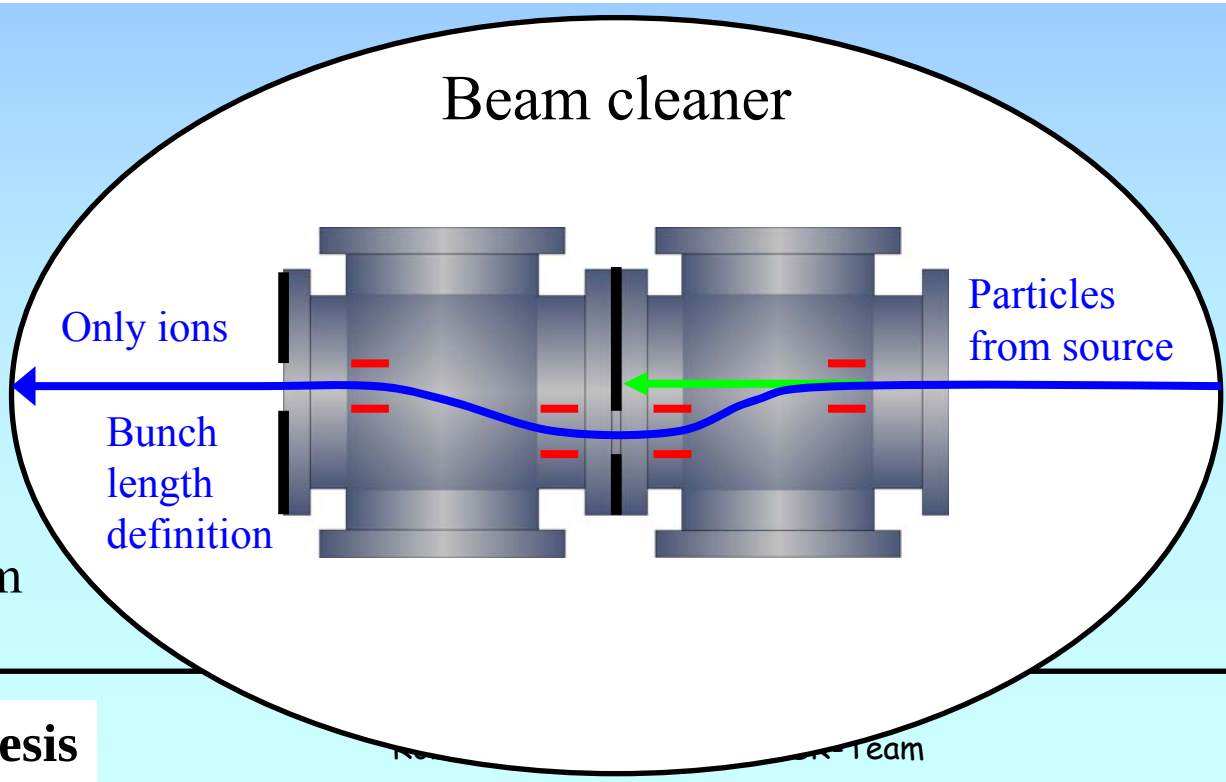


Penning source:

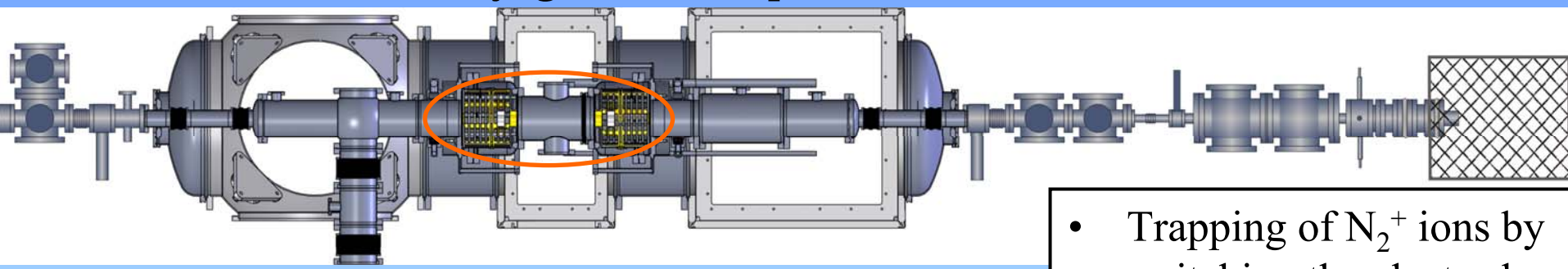
- Produces N_2^+ ions with energies of 2-10 keV

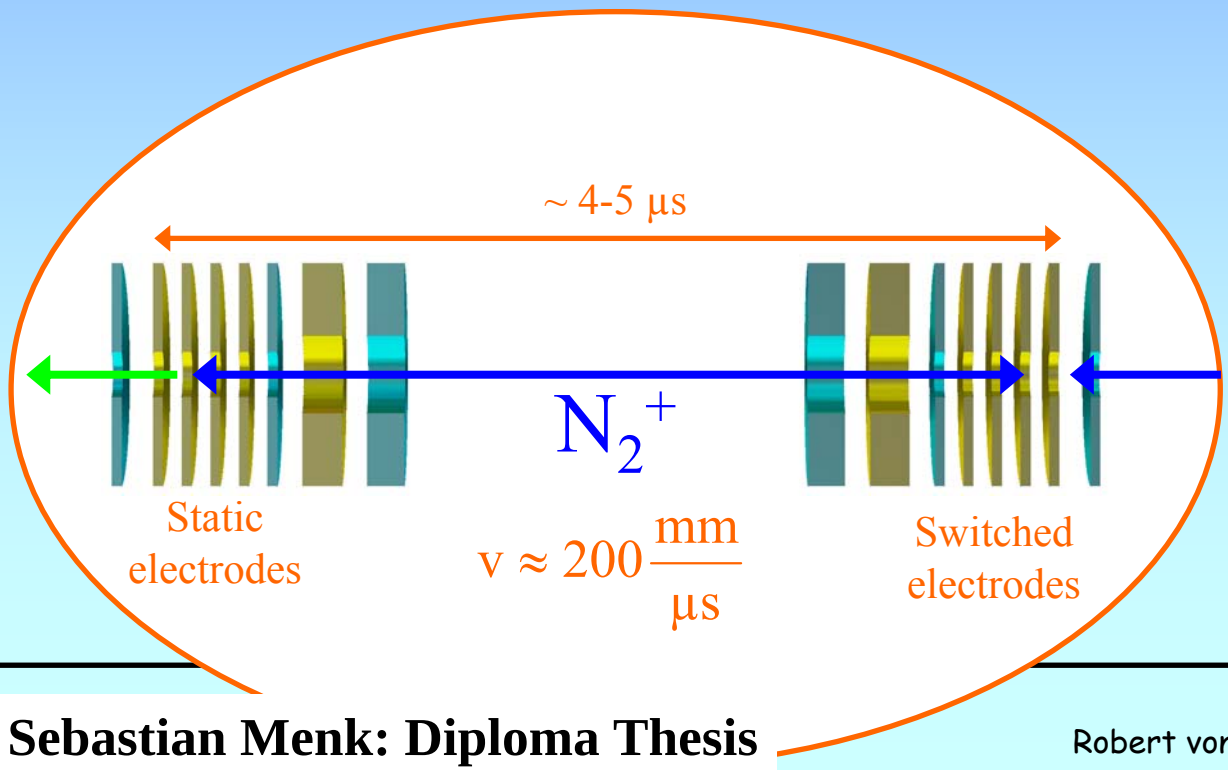
Beam cleaner:

- Pulsed injection with switched deflection plates
- Differential pumping and filtering out of neutral beam



Ion Trapping





- Trapping of N_2^+ ions by switching the electrodes
- After ~400 ns electrode voltage at 95%
- Neutralisation by electron capture of the restgas (mainly H_2 at 2K)
- Using lifetime τ to estimate the pressure

$$\frac{1}{\tau} = n \cdot \sigma \cdot \langle v \rangle \propto p$$

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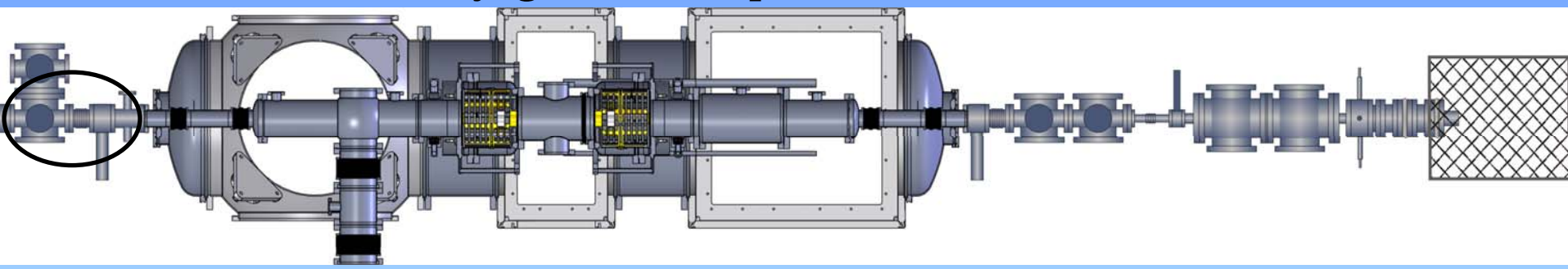
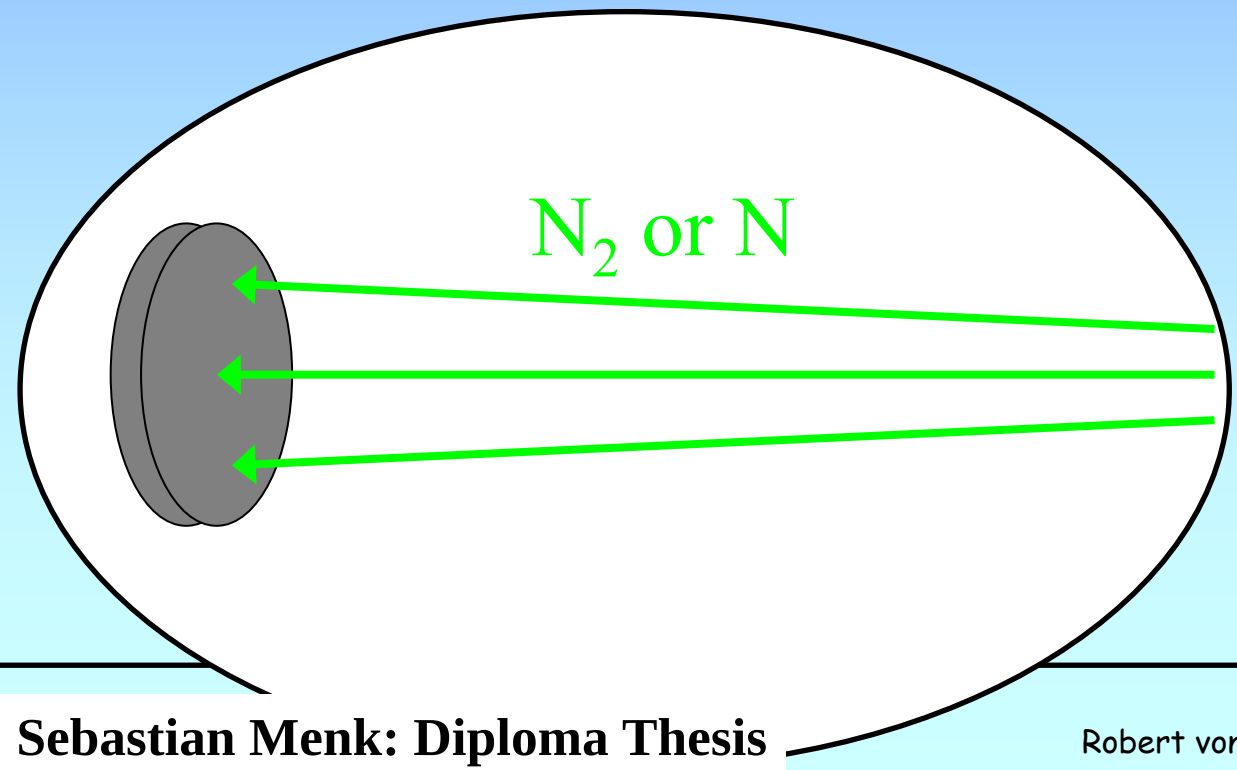
Robert von Hahn for the CSR-Team

Detection and Counting of Neutral Fragments





- Counting of neutral fragments on a chevron MCP
- MCP angular acceptance
  ~ ±8 mrad
- MCP position acceptance
  ~ ±20 mm

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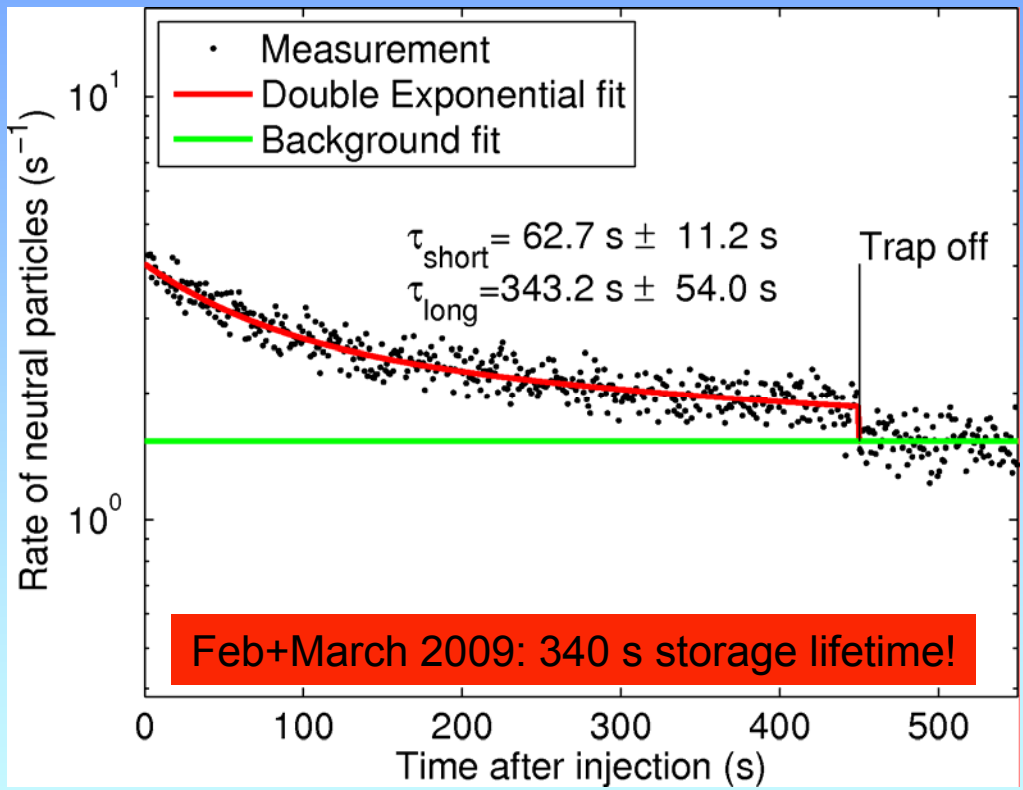
Storage Lifetime

2008: First storage of ions in CTF under cryogenic conditions

However: lifetime limited to 24 s – much shorter than expected

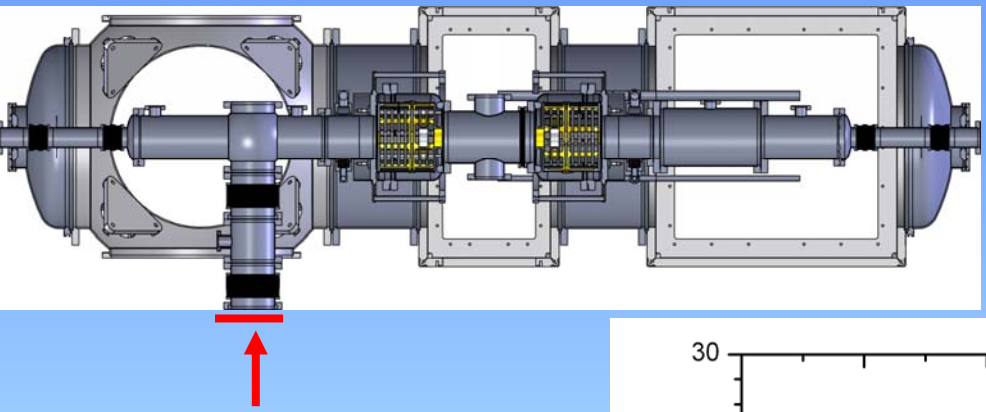
Improvements in 2009:

- Reduced ripple on trap voltages (fast HV switches)
- Cryogenic chamber baked for better vacuum at RT
- Improved differential pumping after ion source
- Improved shielding against infrared radiation at trap entrance+exit

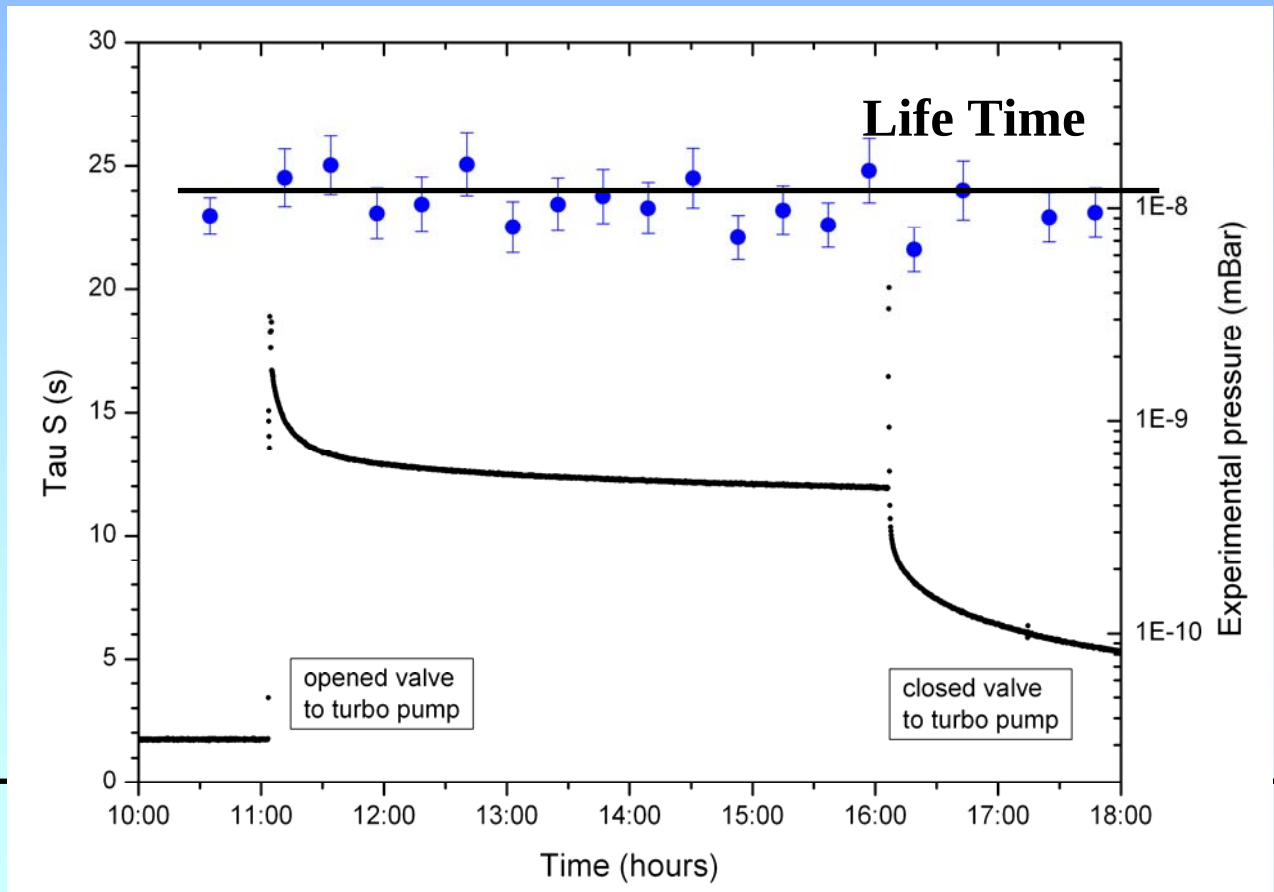


With collision cross-sections from the literature, the new lifetime would translate to a residual gas density of 44000 cm^{-3} or $1.6*10^{-12}$ mbar (at Room Temperature).

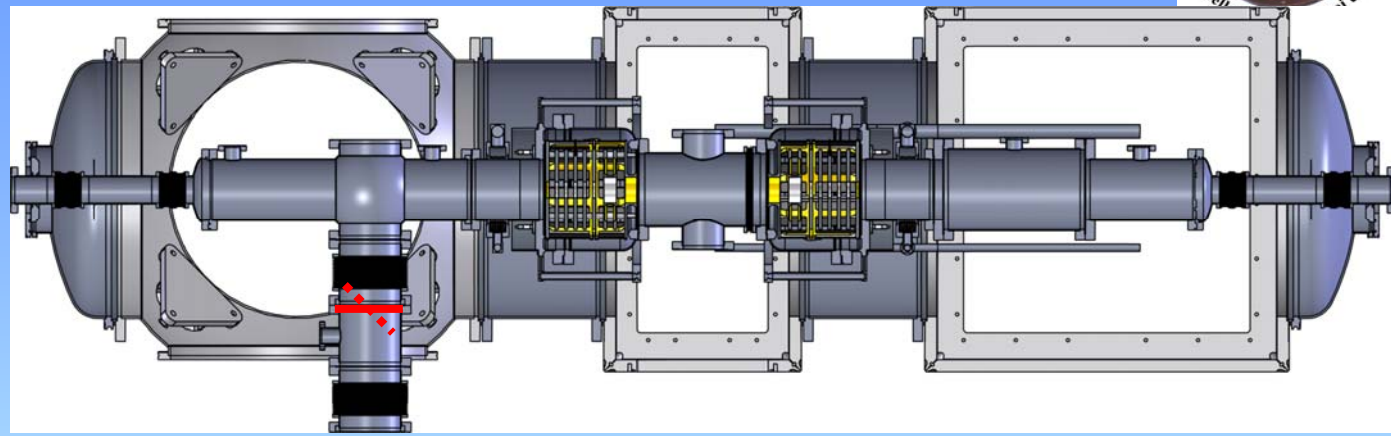
Worsening the pressure by opening the valve to turbo pump

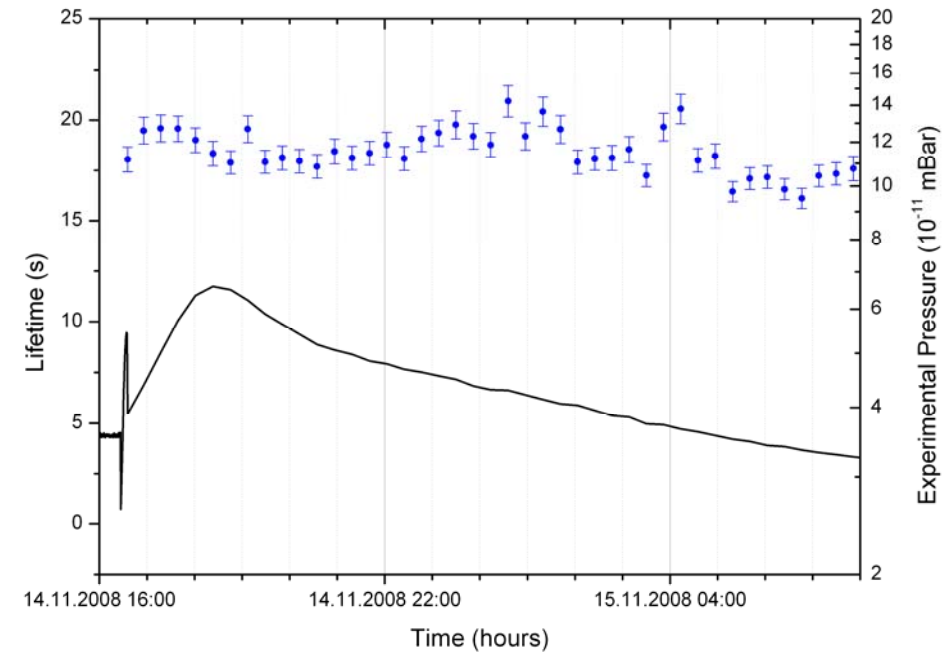


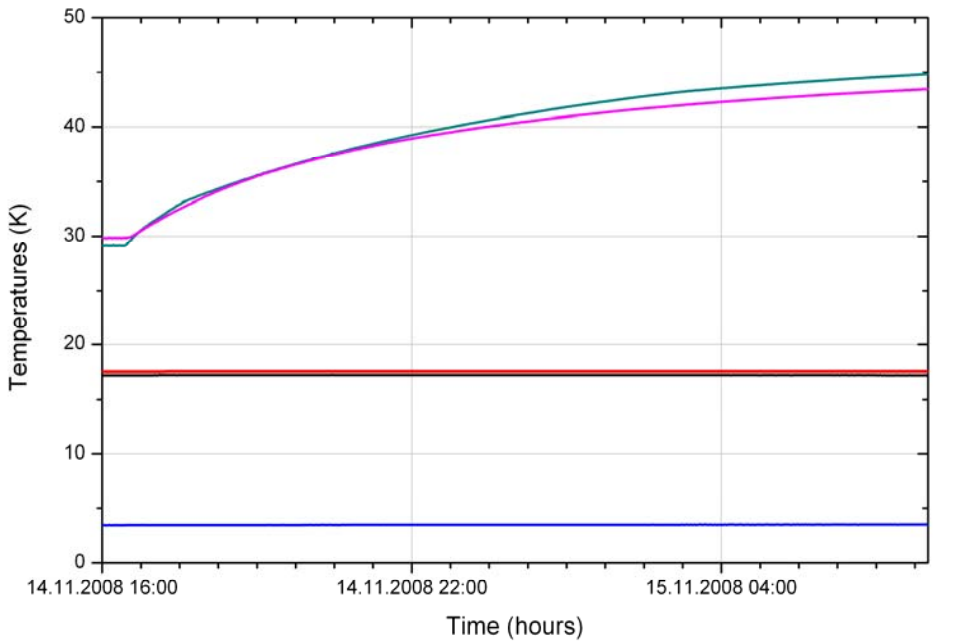
Turbo pump



Worsening the pressure by opening the radiation flap







Trap Vacuum

Cryogenic pumping of hydrogen at 1.8 K: Expect vacuum of few 10^{-13} mbar (RT equiv.)

Most likely particle loss from trap not dominated by residual gas collisions

- Model: 2 loss mechanisms:
  - residual gas collisions (proportional to pressure)
  - ion evaporation from trap acceptance volume (constant)
- 2 beam decay constants:

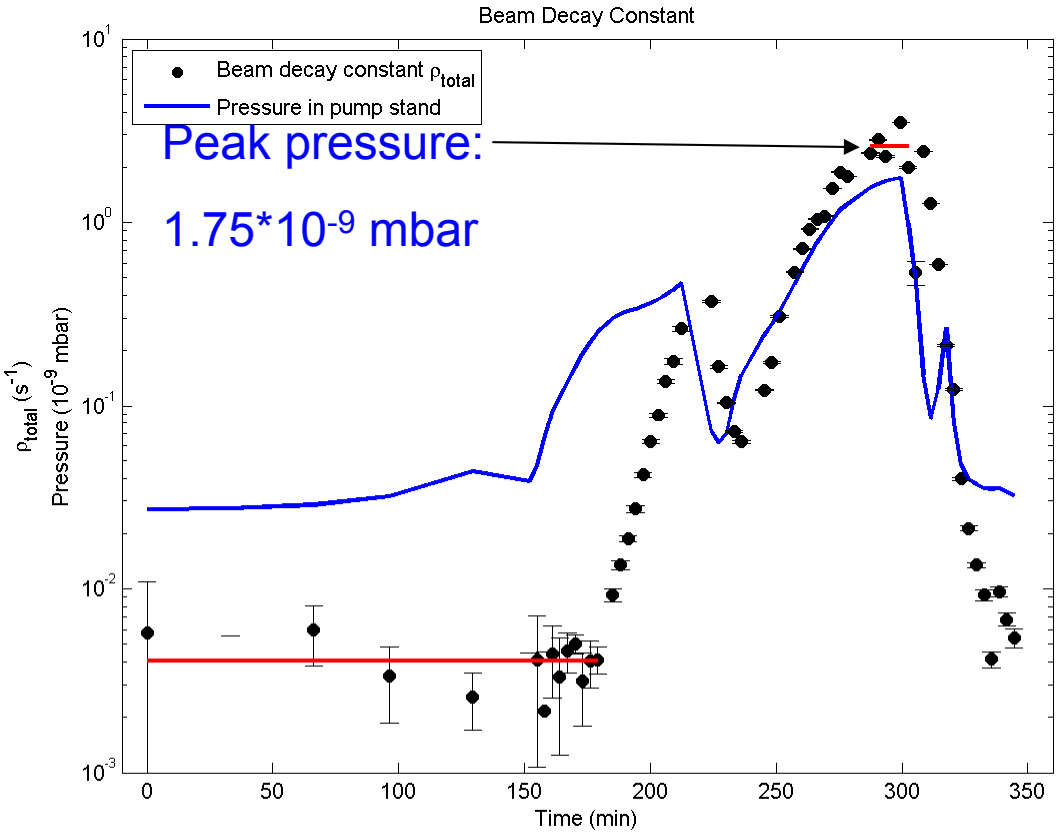
$$\rho = \rho_{gas} + \rho_{ev} \Rightarrow f_{gas} = \frac{\rho_{gas}}{\rho_{total}}$$

- Neutral particle rate:

$$R(t) = \underbrace{const \cdot I_{ion} f_{gas} \rho}_{= R_0} \exp(-t\rho)$$

- Cut off supply of 1.8 K liquid helium to CTF
- Over several hours, CTF warms up and gas desorbs from walls
  →Variation of pressure in CTF
- Monitor neutral particle rate and the reading from an ionization pressure gauge (room temp.)
- Determine decay constant $\rho=1/\tau$ and amplitude R_0 of exponentially decreasing count rate on MCP
- Integrate over few injections only, to gain time resolution

Trap Vacuum



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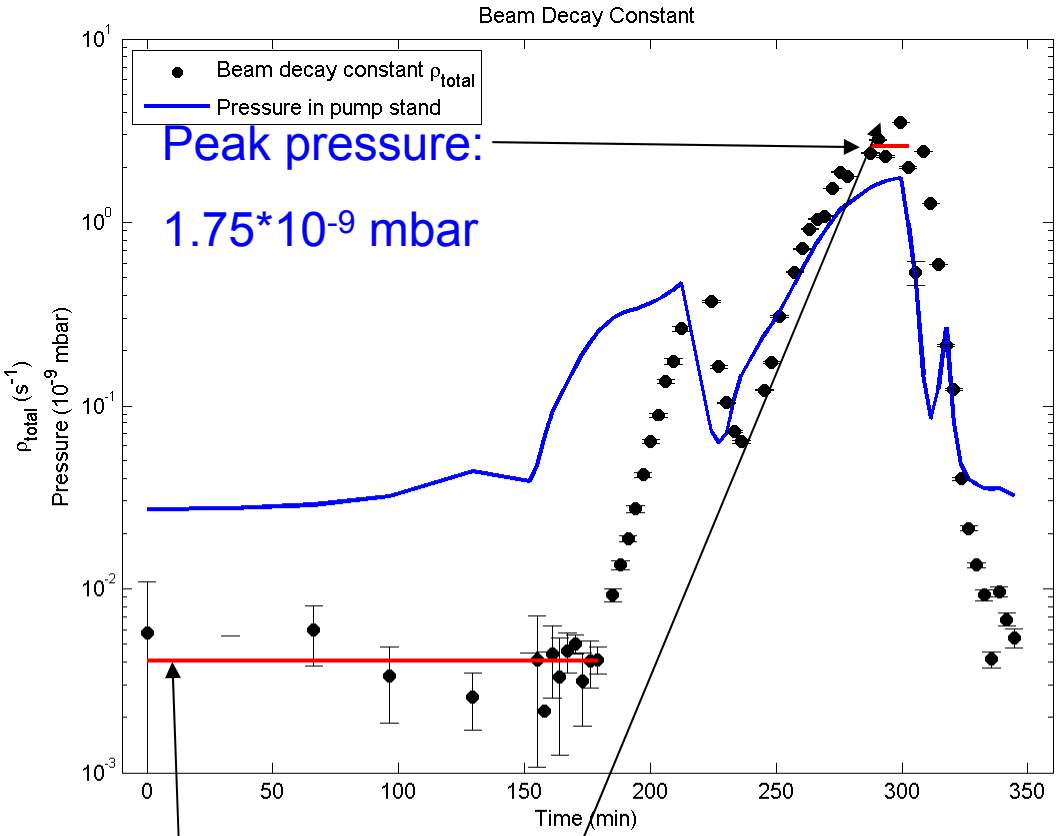
Trap Vacuum



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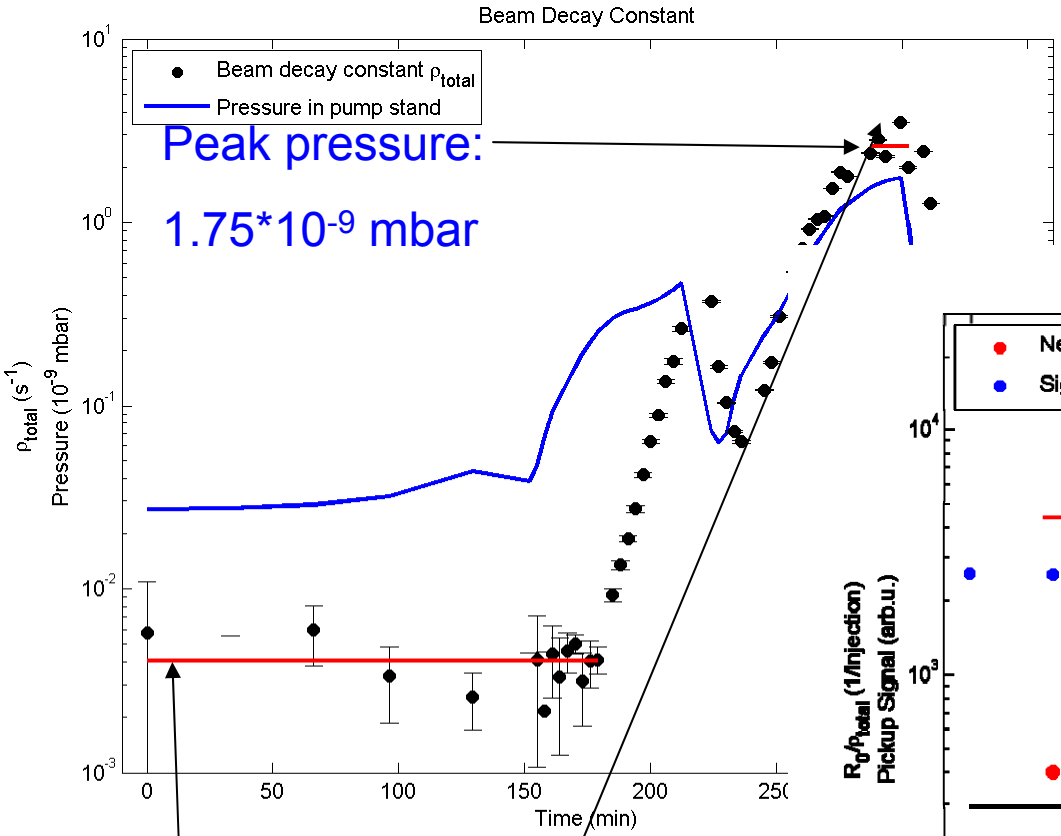
Trap Vacuum

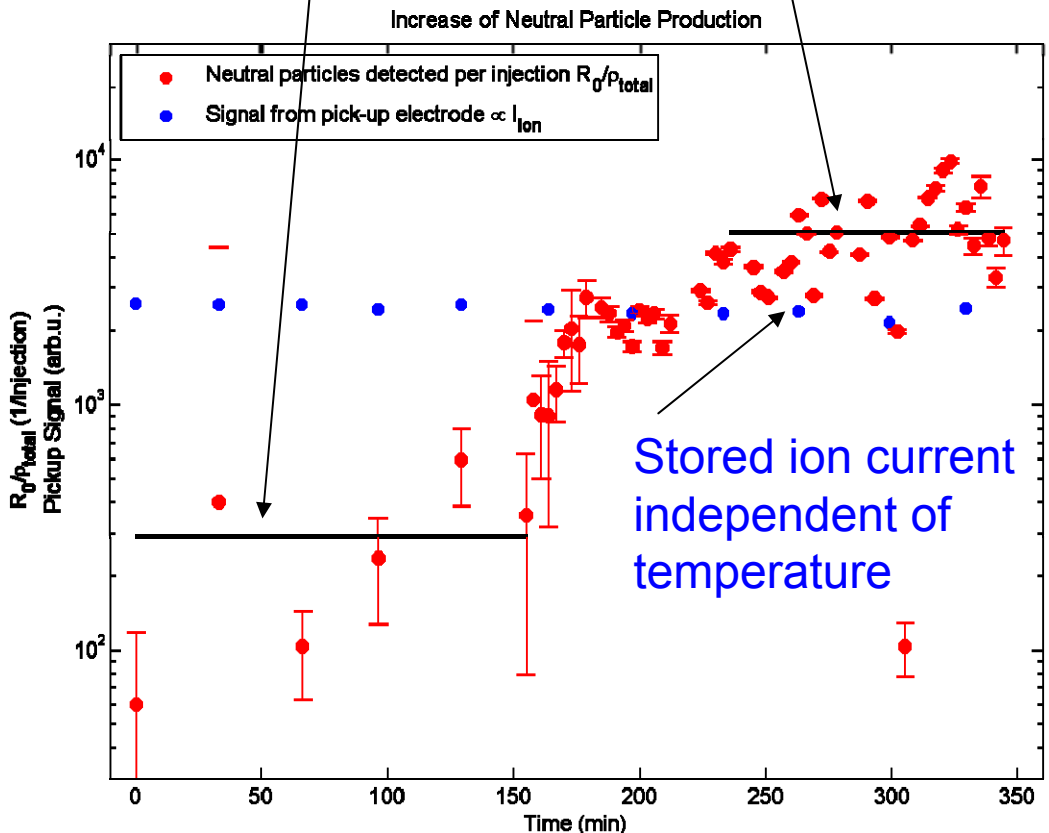
Total number of particles per injection

$$\frac{R_{0,initial}}{\rho_{initial}} = 291 \qquad \frac{R_{0,peak}}{\rho_{peak}} = 5040$$

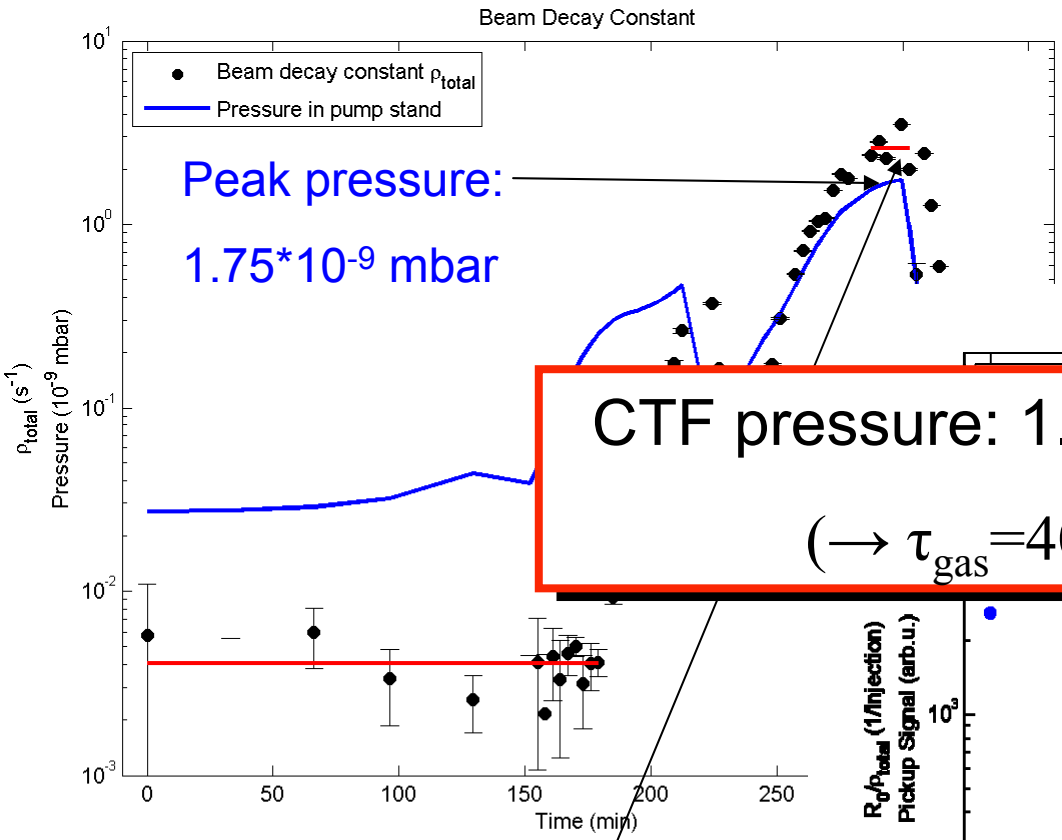


$$\rho_{initial} = 0.004\,\mathrm{s}^{-1}$$

$$\rho_{peak} = 2.6\,\mathrm{s}^{-1}$$



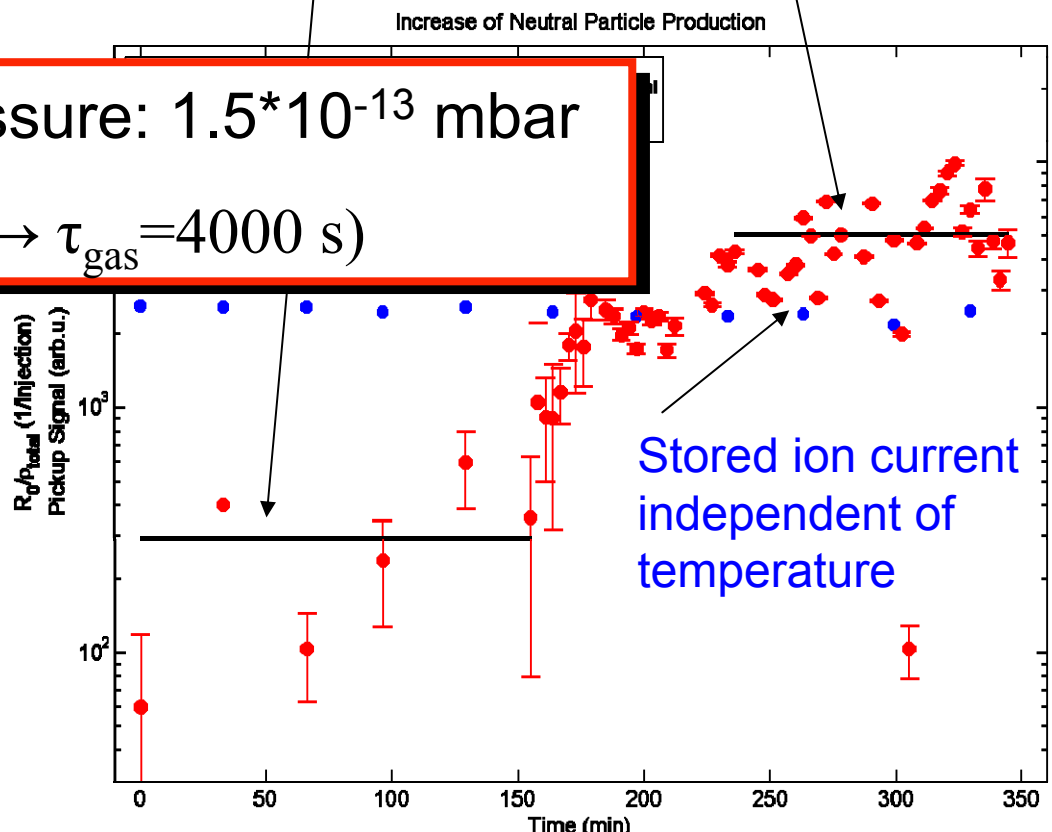
Trap Vacuum



$$\frac{R_{0,initial}}{\rho_{initial}} = 291 \qquad \frac{R_{0,peak}}{\rho_{peak}} = 5040$$

CTF pressure: $1.5*10^{-13}$ mbar

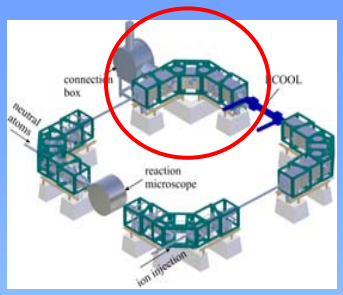
$(\rightarrow \tau_{gas}=4000\ s)$



$$\rho_{initial} = 0.004\ s^{-1}$$

$$\rho_{peak} = 2.6\ s^{-1}$$

CSR Mechanical Layout



Isolation Vacuum Chamber

6^0 Deflector

Isolation Vacuum $p \approx 10^{-6}$ mbar

39^0 Deflector

He Gas

6^0 Deflector

Quadrupole

Liquid He

Inner Vacuum Chamber $p < 10^{-13}$ mbar

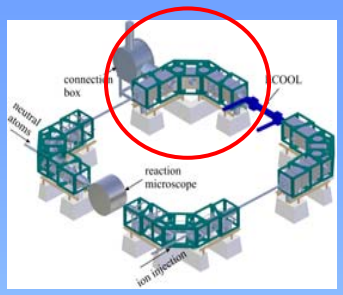
40 K Shield

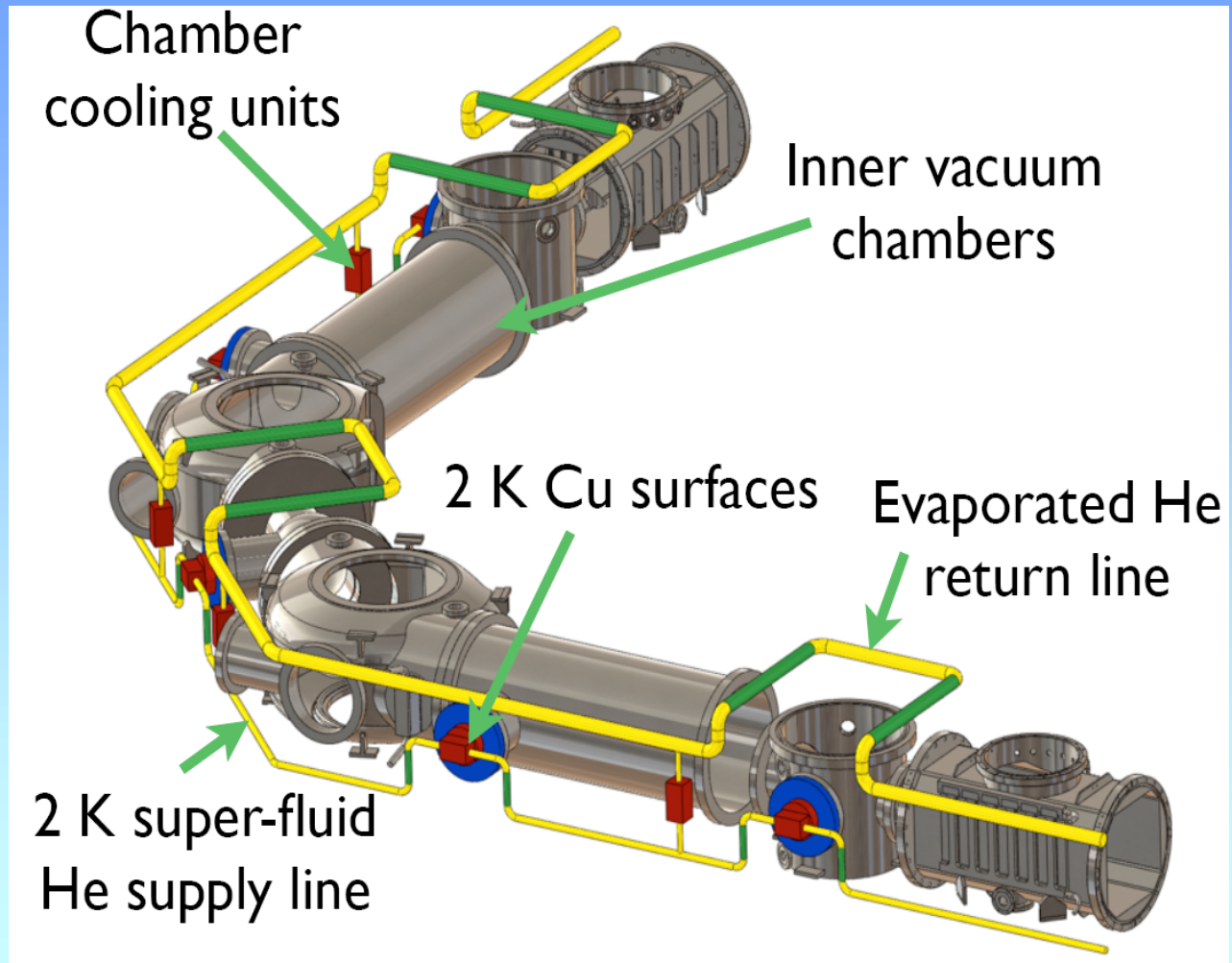
80 K Shield

Concrete Block

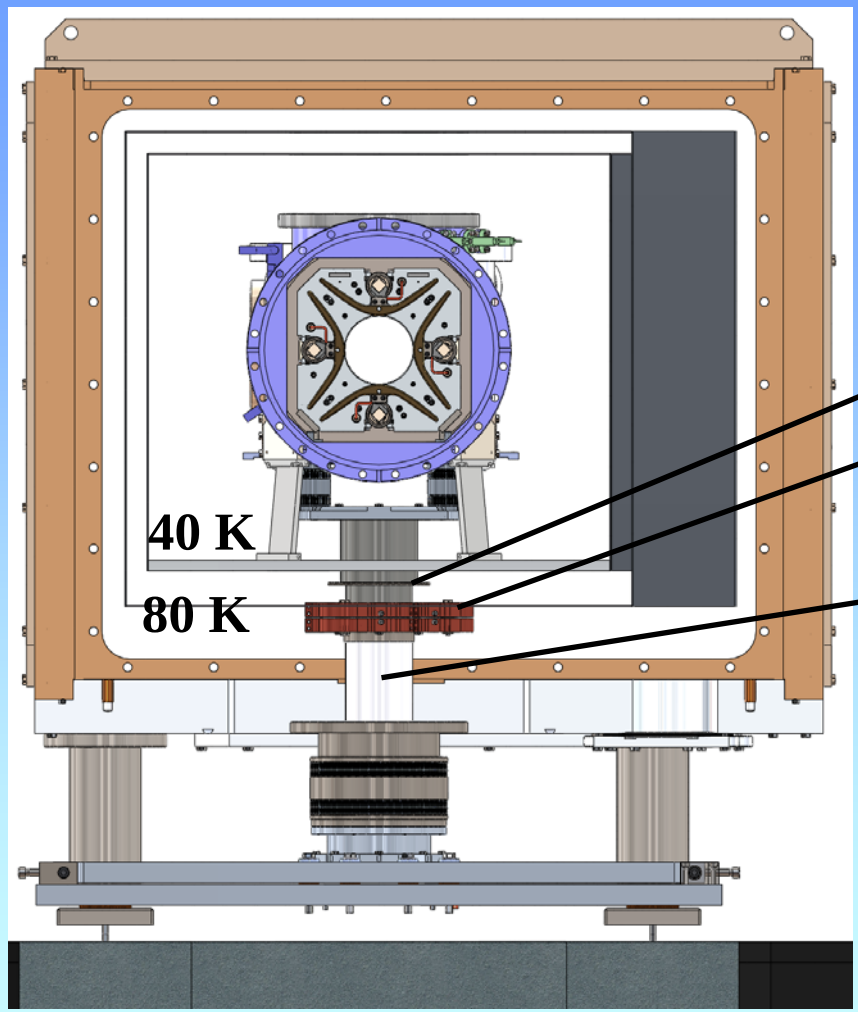
Robert von Hahn for the CSR-Team

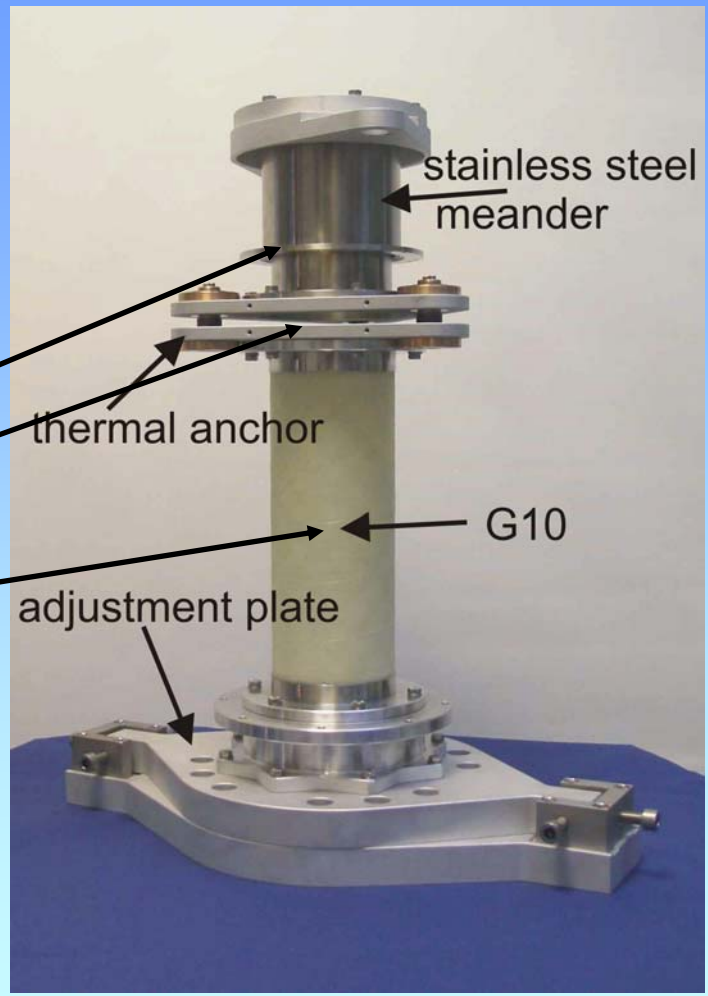
CSR Mechanical Layout





Support Concept





60 cm

Conclusions and Outlook

- First successful operation of the ***cryogenic ion beam trap***
- Achieved ***low temperatures*** of down to 2 Kelvin
- Observed ***linear pressure dependence of the storage life time*** during cool-down
- Determined ***dominant loss processes*** for different pressure conditions
- Pressure tests indicated a limiting ***pressure independent lifetime***
- Modified high-voltage switches with reduced fluctuations
- Lifetime measurements with a BAKED cryogenic ion trap: ***340 s***
- Determined pressure dependent life time of: ***4000 s***

- Move trap for further experiments
- Proceed with ordering and assembly of CSR

CTF/CSR Team

R. Bastert, K. Blaum, F. Fellenberger, M. Froese,
M. Grieser, M. Lange, F. Laux, S. Menk,
D. Orlov, R. Repnow, A. Shornikov, T. Sieber,
R. v. Hahn, A. Wolf

Thank you for your attention!