Overview of the CSR

35 m circumference

Merged neutral beam

2K cryocooler

Photocathode electron cooler / merged beams electron target

Stored ion diagnostics

Gas jet / reaction microscope

Crossed beam / $4\pi$ experimental zone

Ion injection 300 keV

Max-Planck-Institut für Kernphysik, Heidelberg, Germany
The CSR Project at MPI-K

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

Example:

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

Ring at 2-10 K?
⇒ XUHV
⇒ $\tau \sim 1000$ s
⇒ $\nu = 0$
⇒ $J = 0$

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: $1 \times 10^{-13}$ 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: $1 \times 10^{-11}$ mbar
  ⇒ The ring must be baked up to 600 K
Assembly and measurements mainly by: M. Lange, M. Froese, S. Menk
Prototype and Refrigerator

Connection Box of the Refrigerator System

Welding Box
Linear Electrostatic Ion Trap

Injected ion beam

Middle chamber

Electrostatic ion trap

Gold plated electrodes

Pumping

~3 m

~1 m

Robert von Hahn for the CSR-Team
Cooling techniques and thermal shielding

2K cooling units

Isolation vacuum

Super insulation

80 K shields

2K pump pipe

2K liquid helium

40 K shields

Helium pipe

Experimental vacuum

10^{-6} \text{ mbar}

10^{-13} \text{ mbar}

2-10 \text{ K}

Cold chamber
Measured cryogenic temperatures at cool downs

2K cooling units

Sebastian Menk: Diploma Thesis
Ion Trapping & Detection

Counting of neutral fragments on a chevron MCP

Detection  Cryogenic ion trap  Beam cleaner

- Trapping of $\text{N}_2^+$ ions by switching the electrodes
- After $\sim$400 ns electrode voltage at 95%
- Neutralisation by electron capture of the restgas (mainly $\text{H}_2$ at 2K)

Sebastian Menk: Diploma Thesis  Robert von Hahn for the CSR-Team
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).
Model: 2 loss mechanisms:
- residual gas collisions (proportional to pressure)
- ion evaporation from trap acceptance volume (constant)

Total rate from particle loss:
\[ \frac{dN}{dt} = k \ N(t) \]
\[ k = k_c + k_s + k_{ev} \]

Neutral particle rate:
\[ R_0 = \frac{1}{2} \alpha \varepsilon n N_0 \]
Cryostat chambers

2 linear & 1 rectangular chamber /corner
4 middle section chambers
2 bellows/linear section
Schema of the support system

- Targets to determine the beam axis (50µm)
- Supports for 39° deflectors
- Mechanical anchoring due to 10 t horizontal force
- Connection Box
- Cold Box
Support concrete blocks

- Nonmagnetic reinforcement
- Accuracy (locally) 0.5 mm
- Almost no shrinkage
- Anchored through 50 cm concrete floor
- Weight about 2.8 t
Stainless steel supports (0.1 mm accuracy)

- Rectangular corner chamber
- Linear corner chamber
- 39° deflectors
- Quadrupole
- Linear middle chamber
- 60° deflector
- Anchoring
Cryostat chambers

- Stainless steel frame & aluminum plates
- Plates perform the stability
- Thickness of bottom plate 80 mm
- Thickness of other plates 60 mm

Movable connection
39° deflector chamber

Stainless steel chamber

- Fulfilles pressure directive
- Welded with filler
- Material 316L
- Copper layer for temperature levelling
- Equiped with nonmagnetic heater wires
CCC installation in CSR

Collaboration to develop a Squid based cryogenic current comparator CCC to determine currents down to around 10 nA pulsed and DC between Uni Jena, GSI and MPI
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
- Determined pressure to $8\times10^{-14}$ mbar

- Moved trap for further experiments
- Proceeded with ordering and started assembly of CSR
CTF/CSR Team


Thank you for your attention!