Universität Siegen

universität innsbruck

Portable trap development and first tests

Speaker: Giovanni Cerchiari

16-19th December 2024

AEgIS collaboration meeting

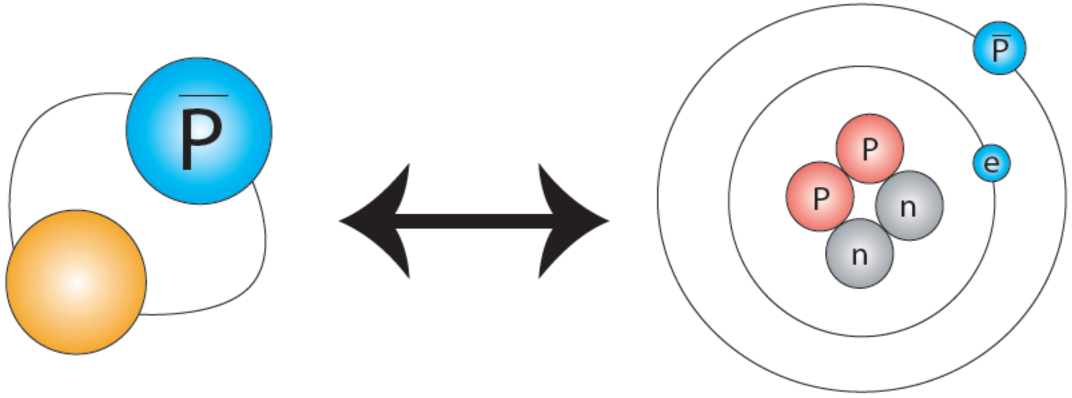
THE ANTIMATTER EXPERIMENT

Gravity | Interferometry | Spectroscopy

AEgIS

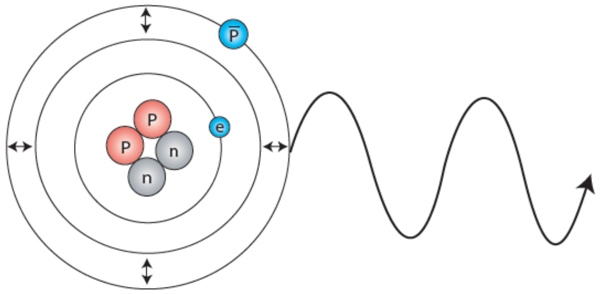
CERN

Antiprotonic atoms

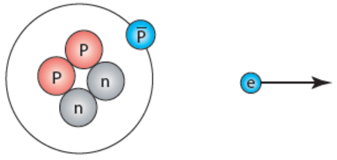


Life of a $\bar{p}$-atom (~ 10 µs)

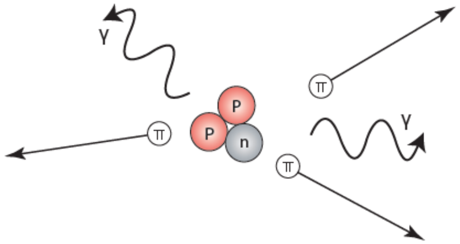
1) The $\bar{p}$ in a Rydberg state (n > 35) decays to lower atomic states by emitting radiation



2) The $\bar{p}$ expells all the electrons from the atom via a series of Auger decays

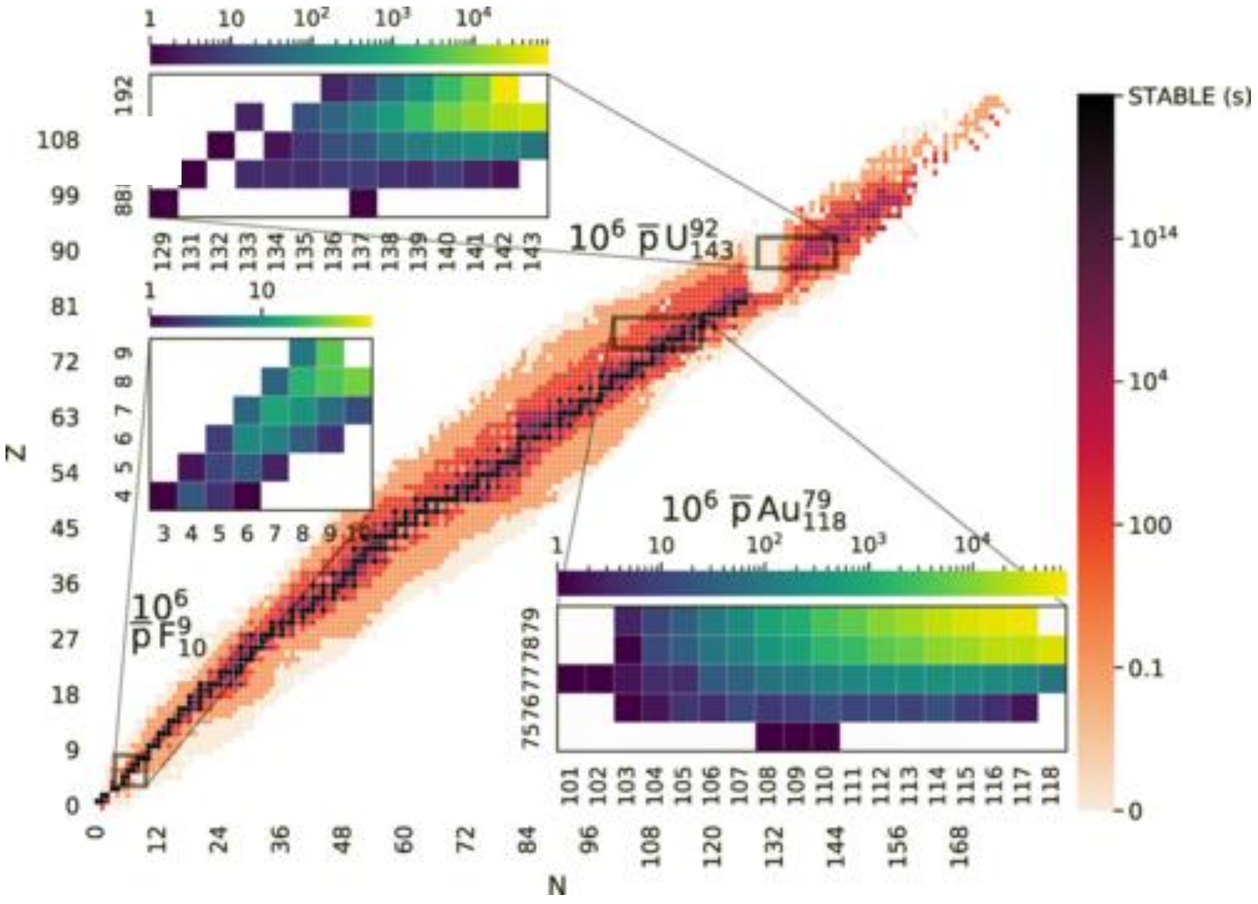


3) The $\bar{p}$ annihilates with a proton or a neutron in the nucleus



Can we do alchemy with the annihilation?

Nuclear reaction



Annihilation products are highly charged.

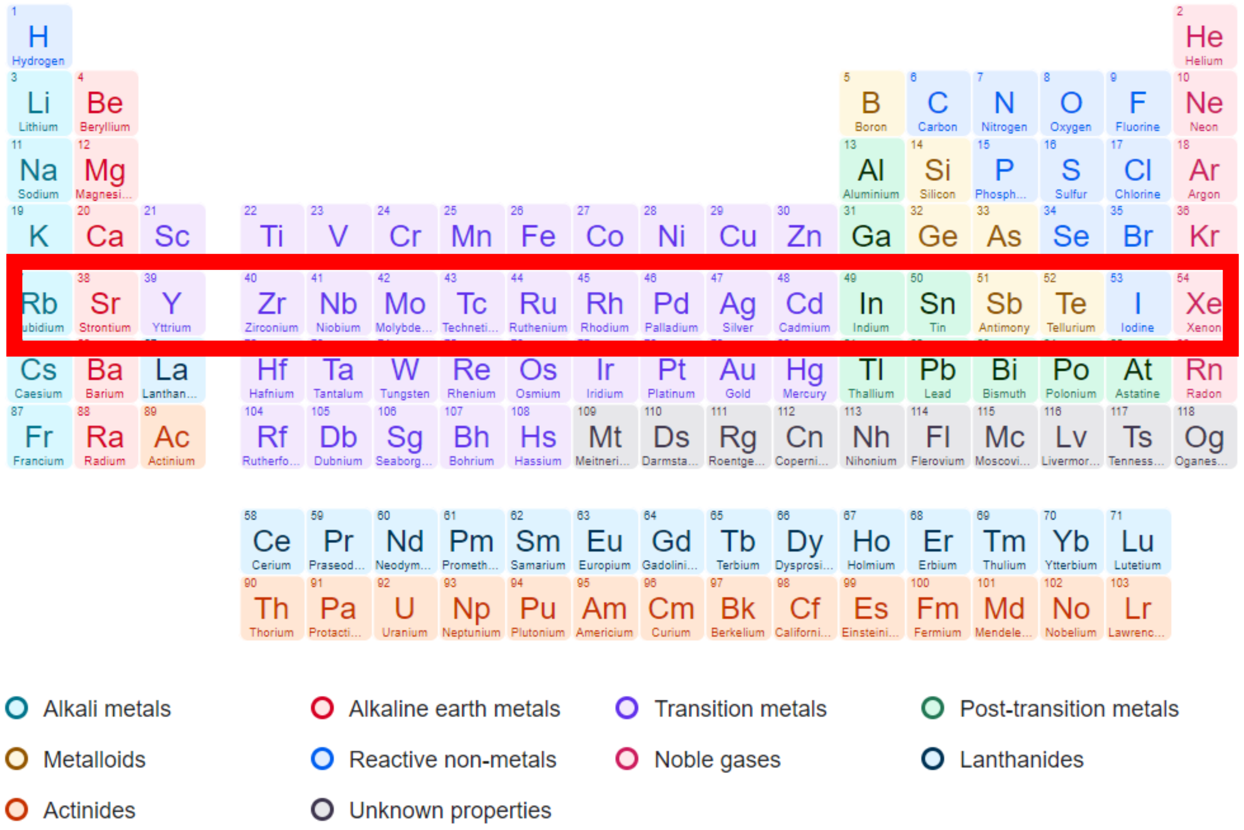
↳ Highly sensitive to EM fields

↳ can be trapped

G. Kornakov, G. Cerchiari, et al., Phys. Rev. C **107**, 034314 (2023)

Hyperfine splitting in HCI

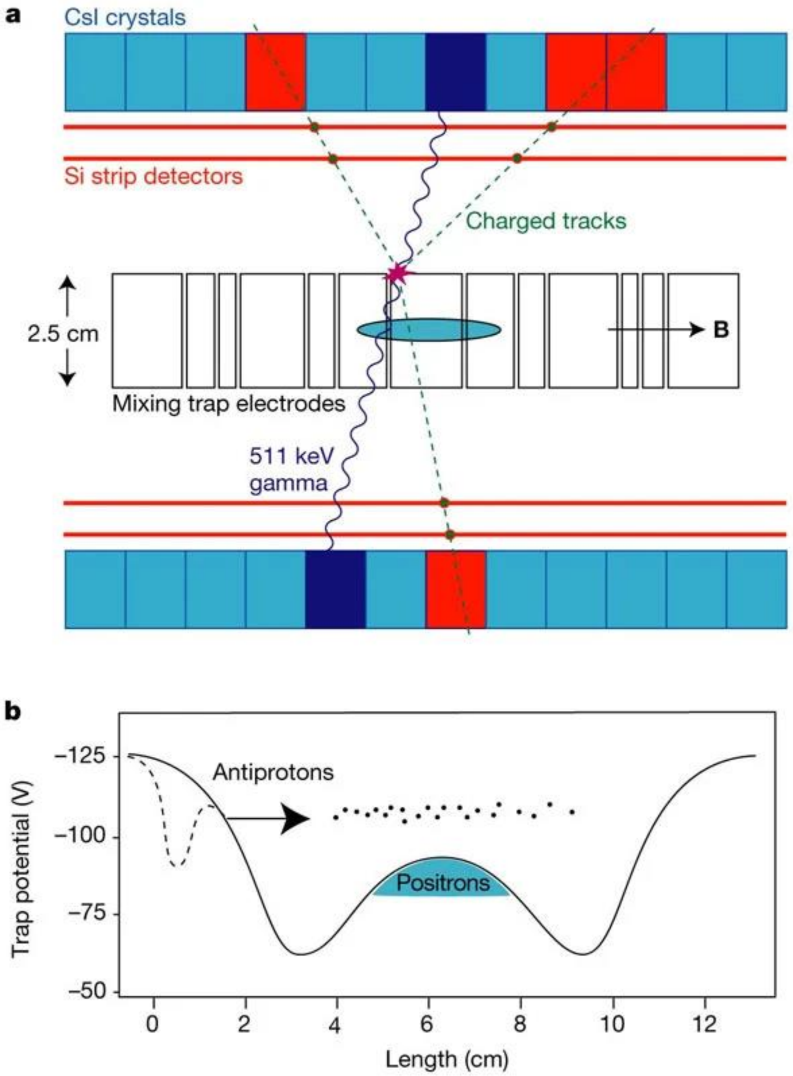
- Elements between Kr and Xe
- IR wavelength < 2 µm
- Lifetime >30 min
  - Isomers
  - Synthetic nuclei



List of candidates (preliminary)

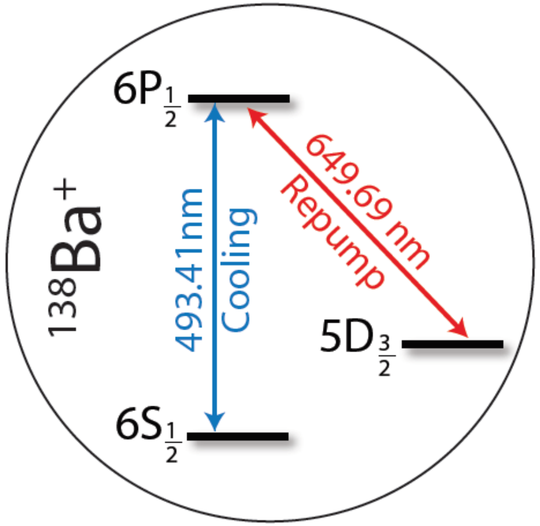
Product	Isomeric state (keV)	Reagent	Natural aboundance (%)	Isotope yield (%)	λ_a (µm)	λ_{GRASP} (µm)	Lifetime (ms)
^{87}Y	381	^{90}Zr	51.45	8.6	2.551	2.544	358.8
		^{89}Y	100	8.9			
^{90}Y	682	^{91}Zr	11.22	1.9	3.121	3.119	637.1
		^{92}Zr	17.15	7.1			
^{92}Nb	135	^{93}Nb	100	9	1.962	1.953	183,7
		^{94}Mo	9.2	5.2			
^{101}Rh	157	^{102}Pd	1	6	1.831	1.814	132,5
		^{103}Rh	100	8.5			
		^{104}Pd	11.14	6.6			
^{102}Rh	141	^{104}Pd	11.14	6.6	2.537	2.513	343,7
		^{103}Rh	100	7.9			
		^{105}Pd	22.33	NP			
^{114}In	190	^{115}In	95.72	6.86	1.620	1.613	93,7
		^{116}Sb	14.54	NP			
^{118}Sb	250	^{121}Sb	57.21	5.2	2.897	2.920	540,7
^{120}Sb	0+x	^{121}Sb	57.21	5.2	2.872	2.599	381,4
		^{122}Te	2.55	3.9			

Co-trapping with positive ions



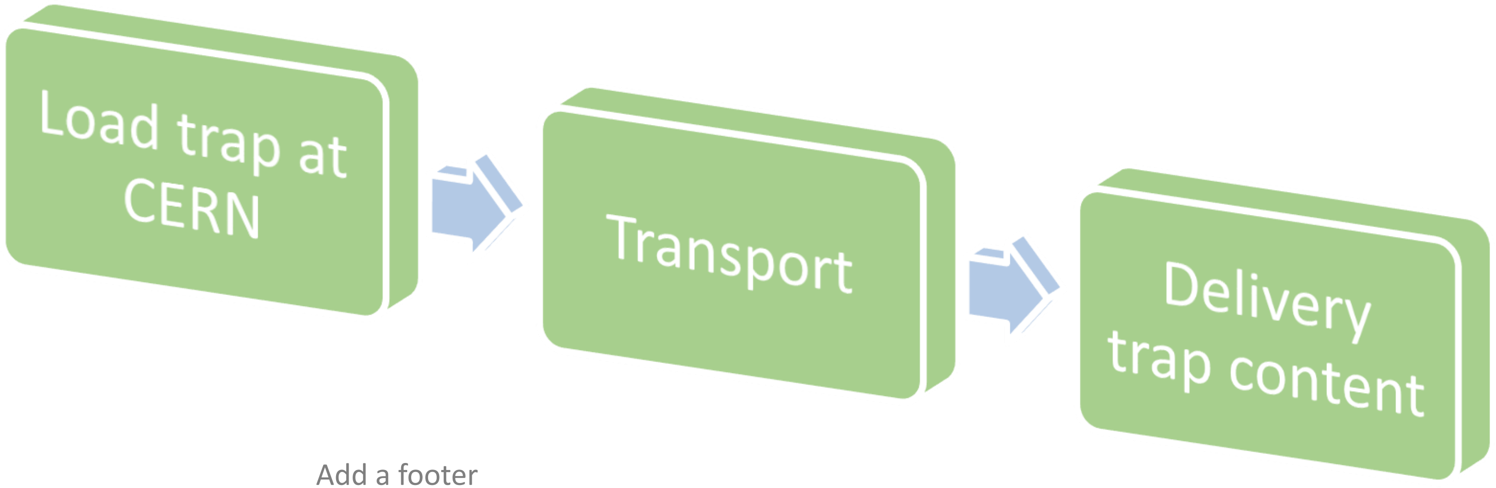
M. Amoretti, et al., Nature **419**, 456 (2002)

- Scheme is used for $\overline{\mathrm{H}}$ synthesis
- Currently limited by e^+ temperature
- Substitute e^+ with laser cooled ions
- The nuclear fragments can be cooled sympathetically



Antiproton transport

- Proven. Antiprotons can live indefinitely in an ion trap.
- Innovation. Ion trap that can function while being transported.



Goal we set for 2024

- Store antiprotons in a room-temperature ion-trap
- Trap antiprotons in a Paul trap
- Transport antiprotons in a room-temperature Penning trap
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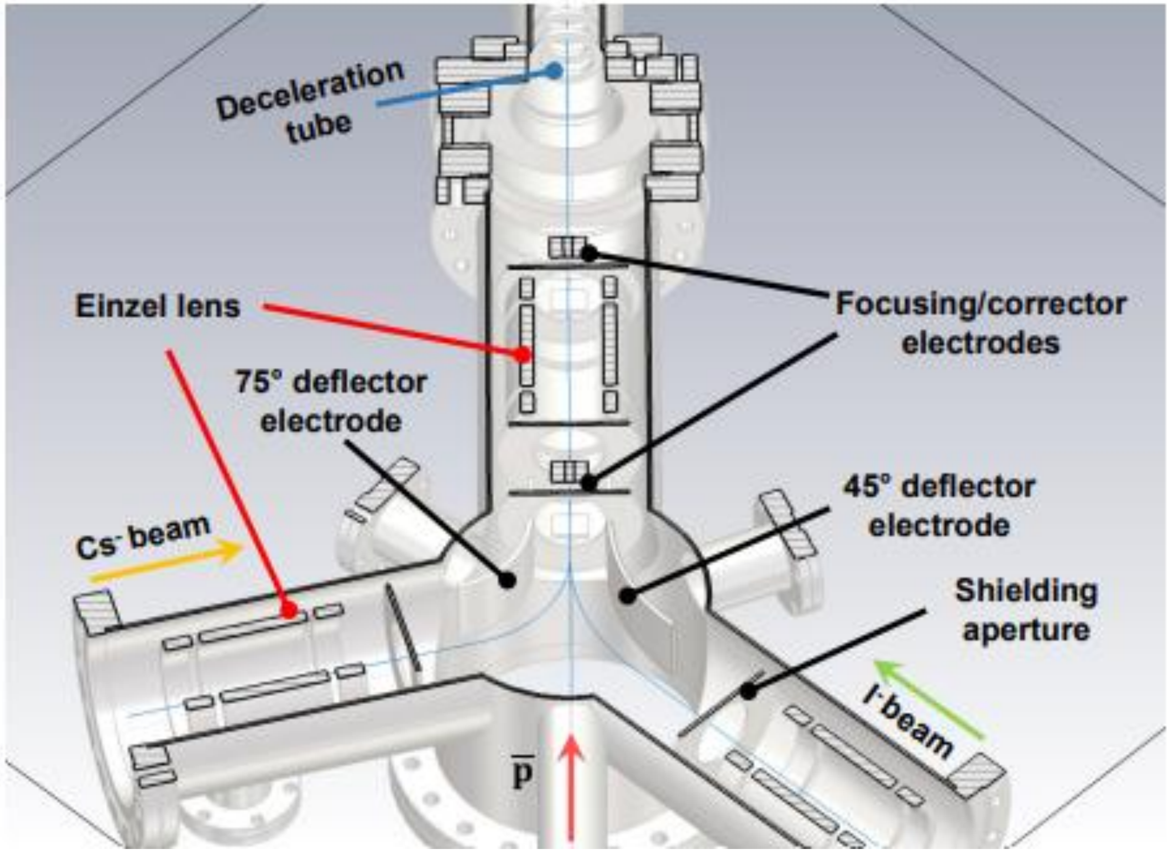
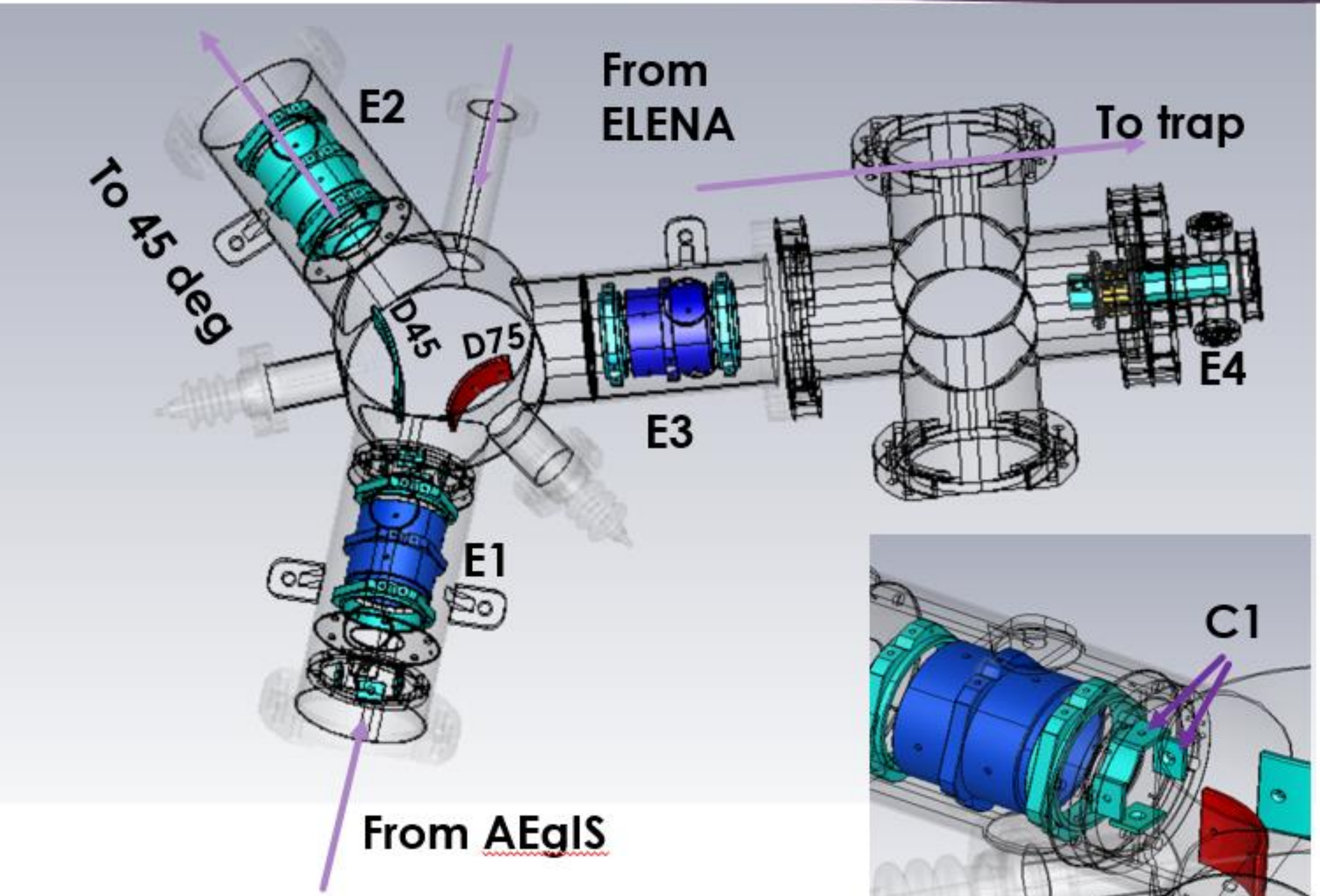
The beamline @75 deg



- Converting injection into ejection
- Docking a portable device

Electrodes overview

Slide from: Volodymyr Rodin

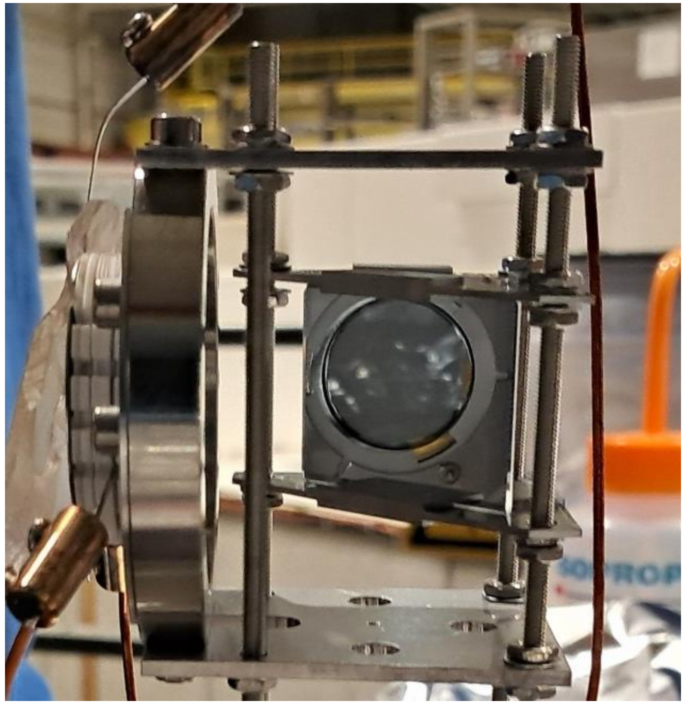


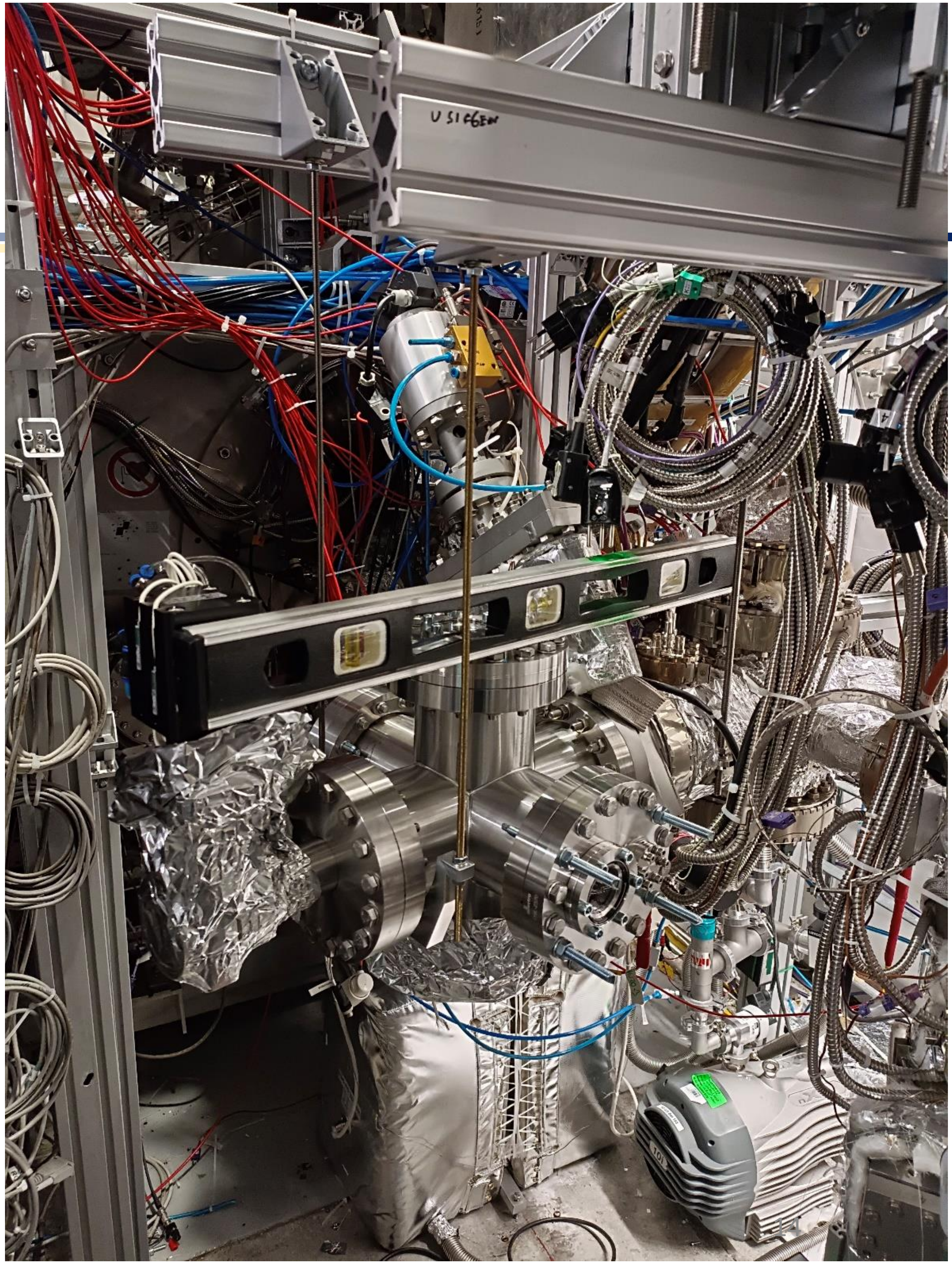
- Einzel lenses marked - **En**
- Main bending electrodes – **Ddeg**
- Corrector **C1** after **E1** main for 5T mag. field compensation

Main	sides	middle
E1	0 V	-1500 V
D75	-	5500 V
E3	-400 V	-2000 V
E4	0 V	2000 kV
D45	-	floating
E2	floating	floating
Corrector	**vertical**	**horizonta**
C1	~Δ200 V	~Δ100 V

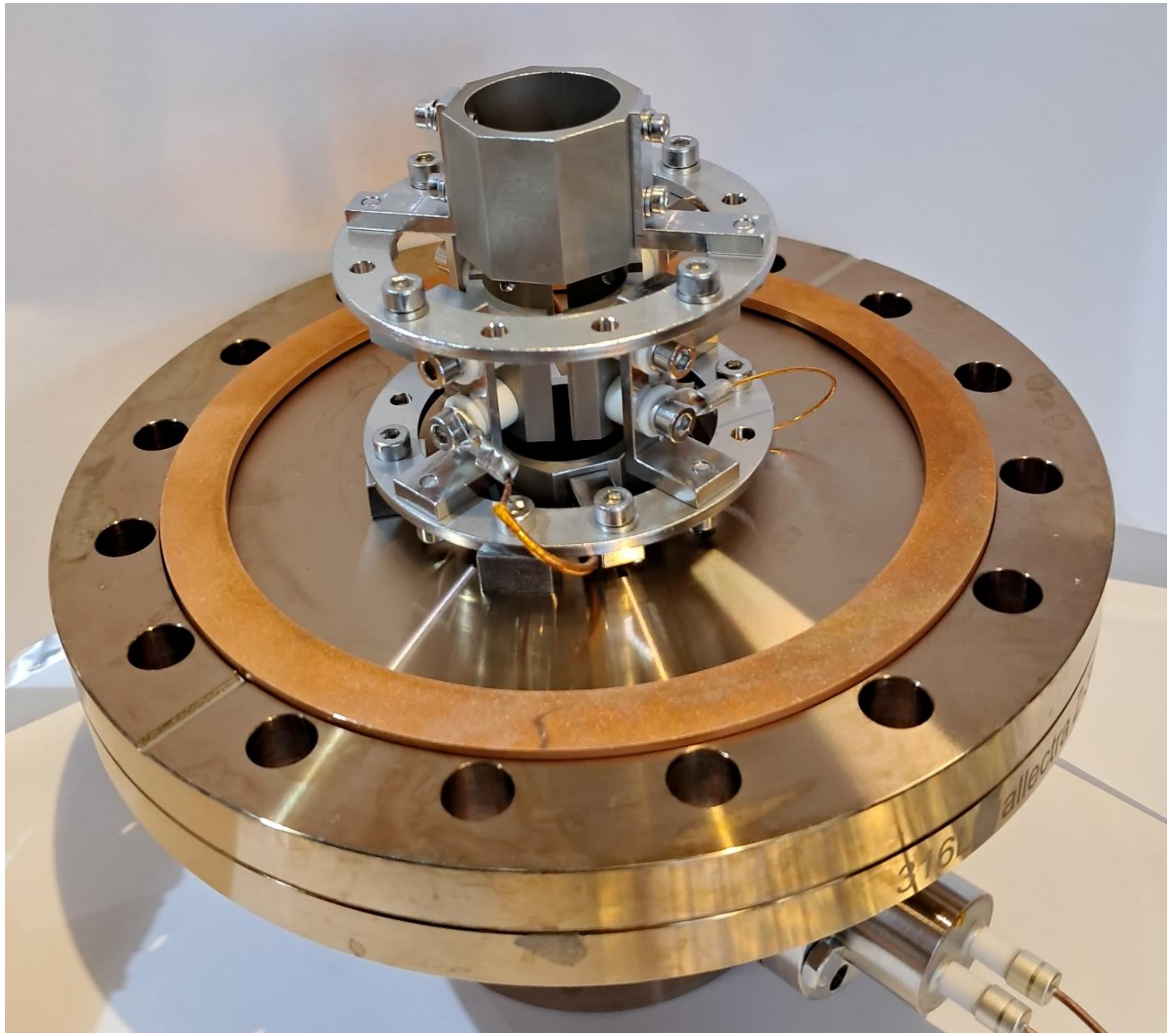
A cross

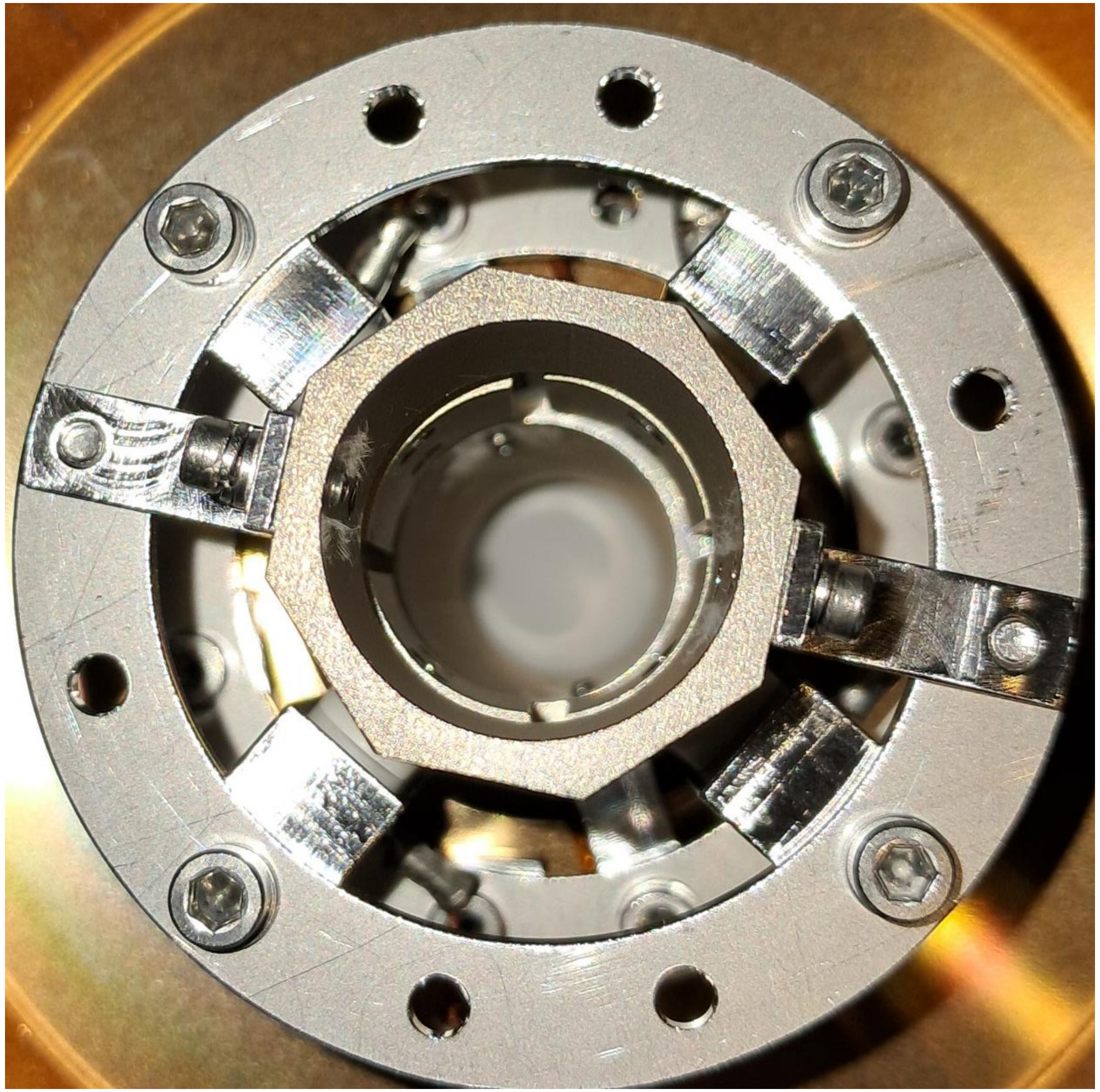
- Access to the 45 port
- Independent pumping
- Beam detection



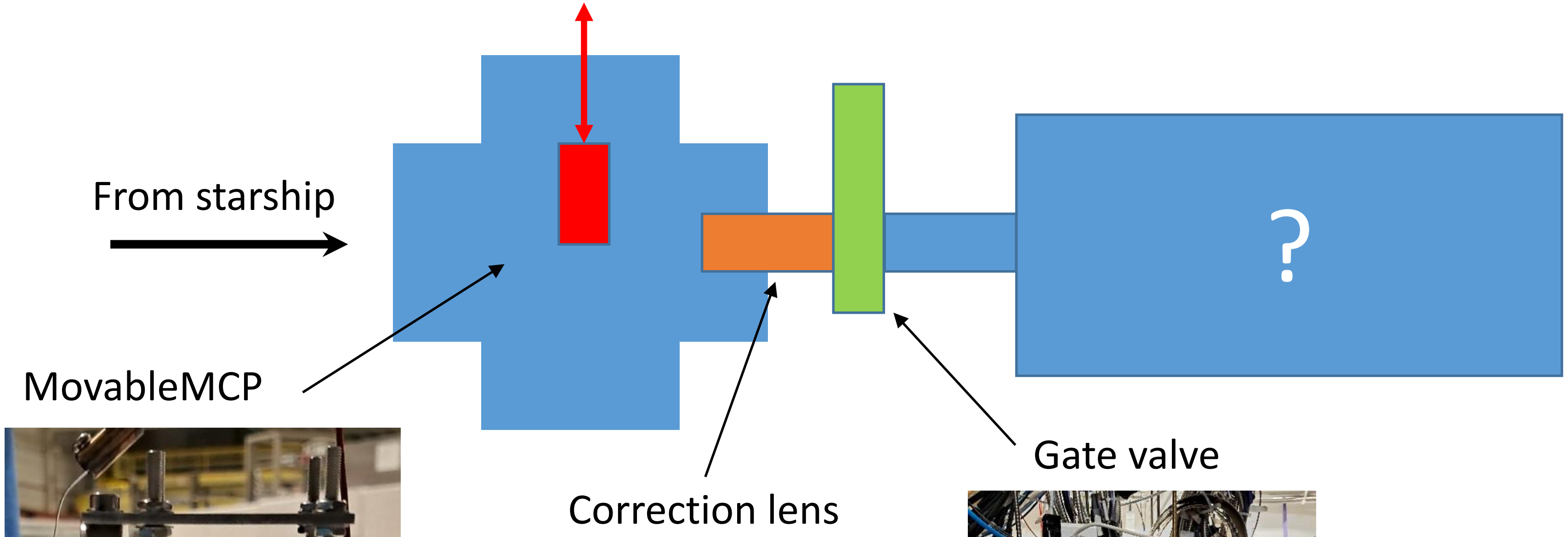


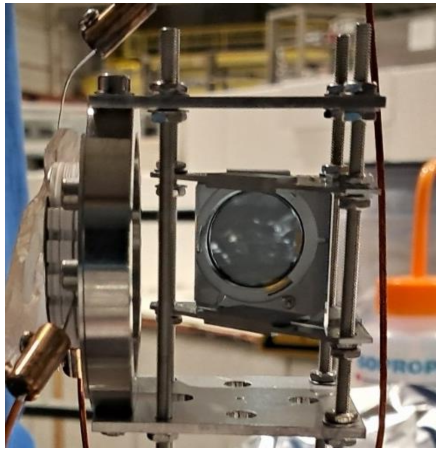
The beamline @75 deg

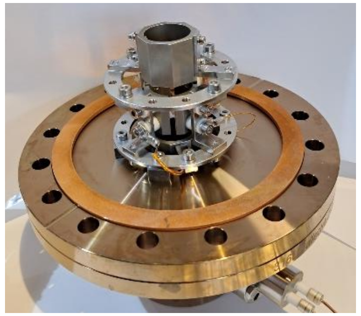


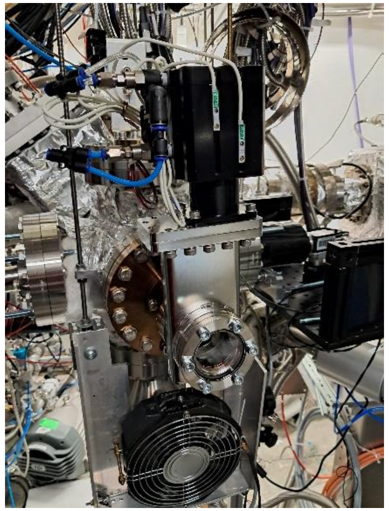


Docking setup





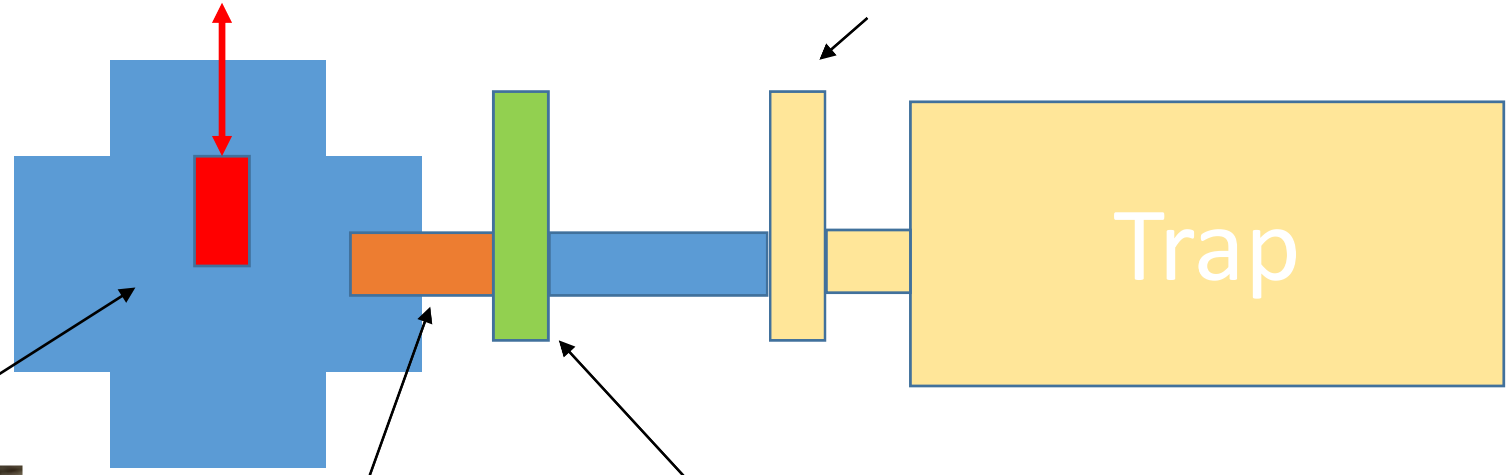




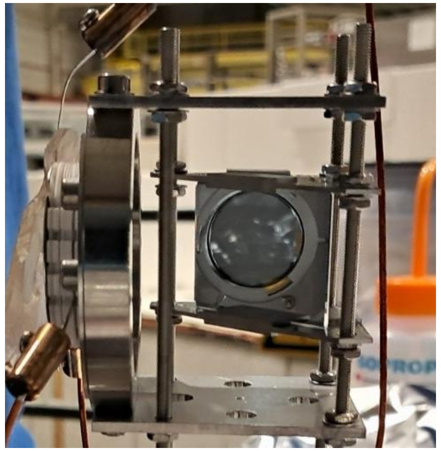
Docking setup

valve

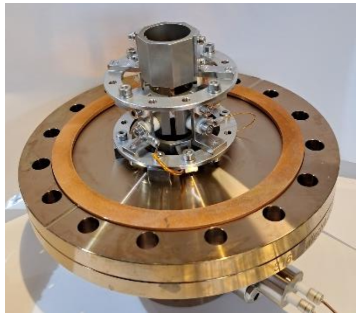
From starship



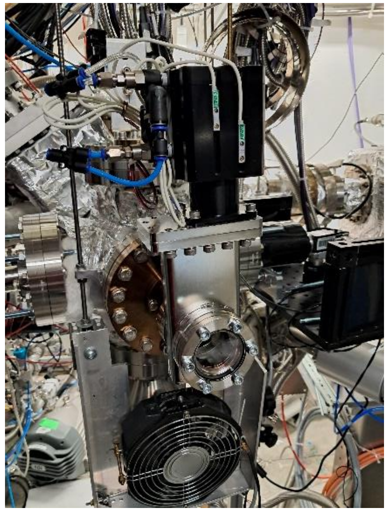
MovableMCP



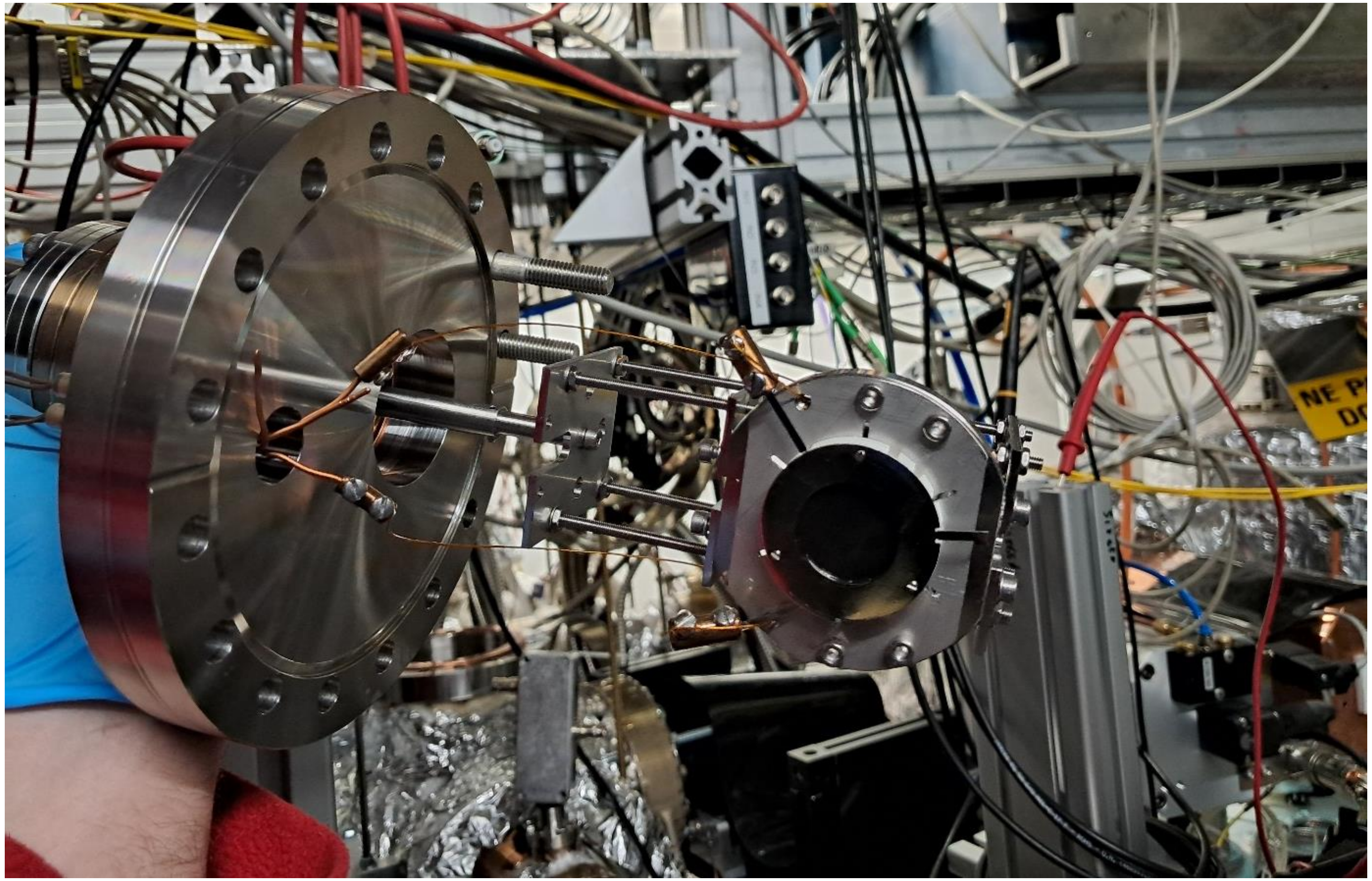
Correction lens

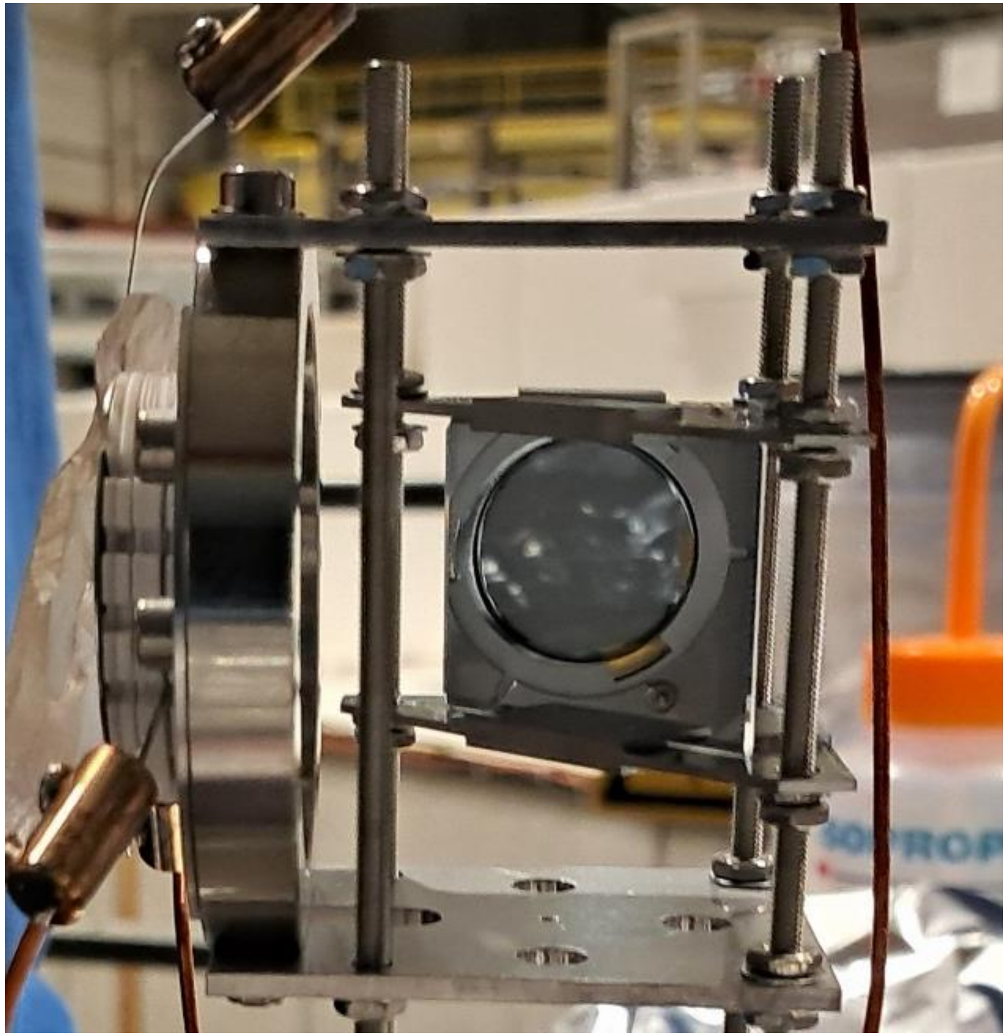


Gate valve

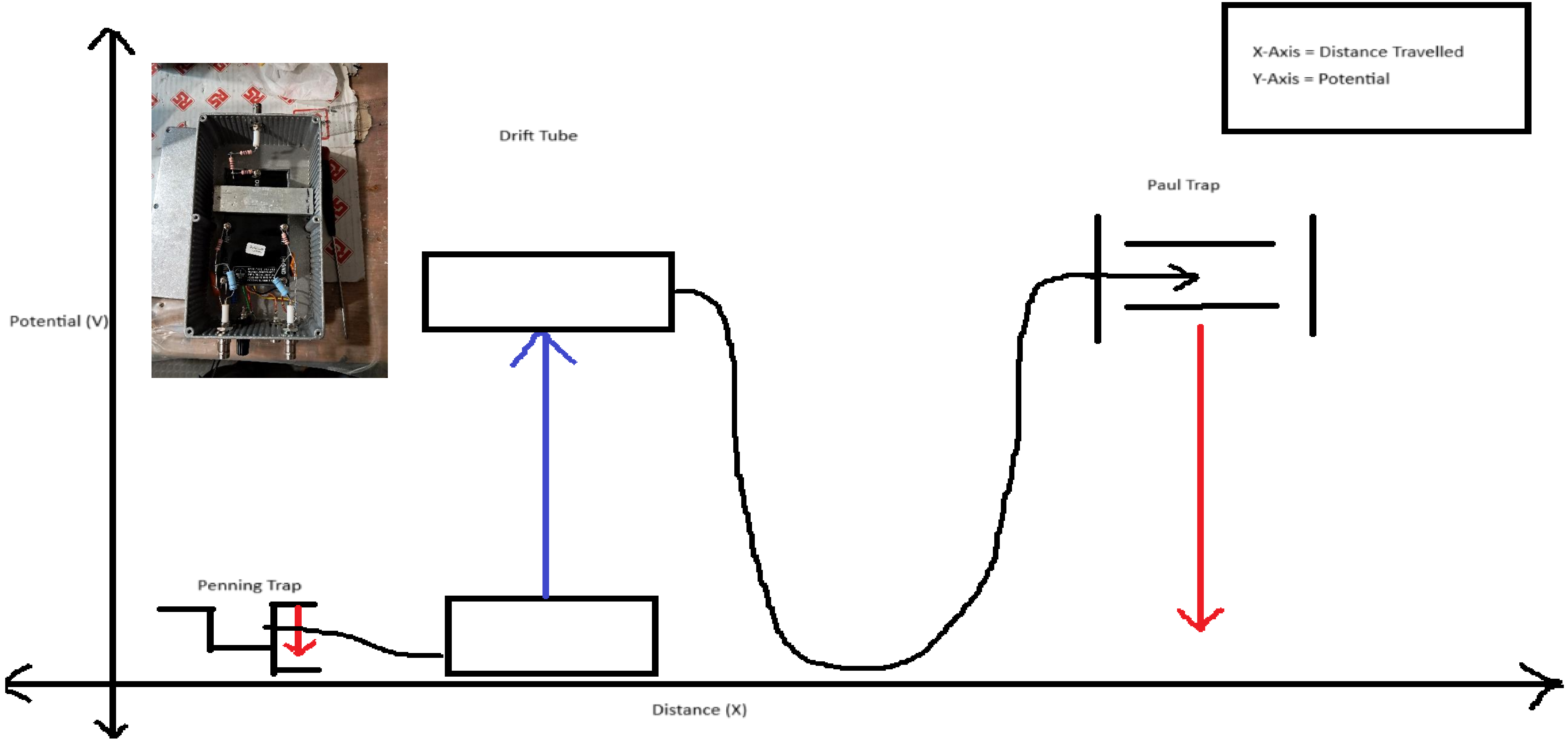


Detection MCP

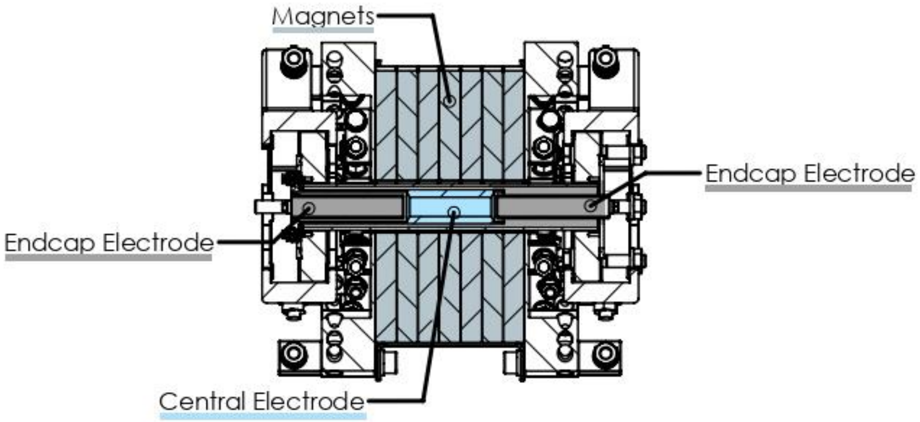


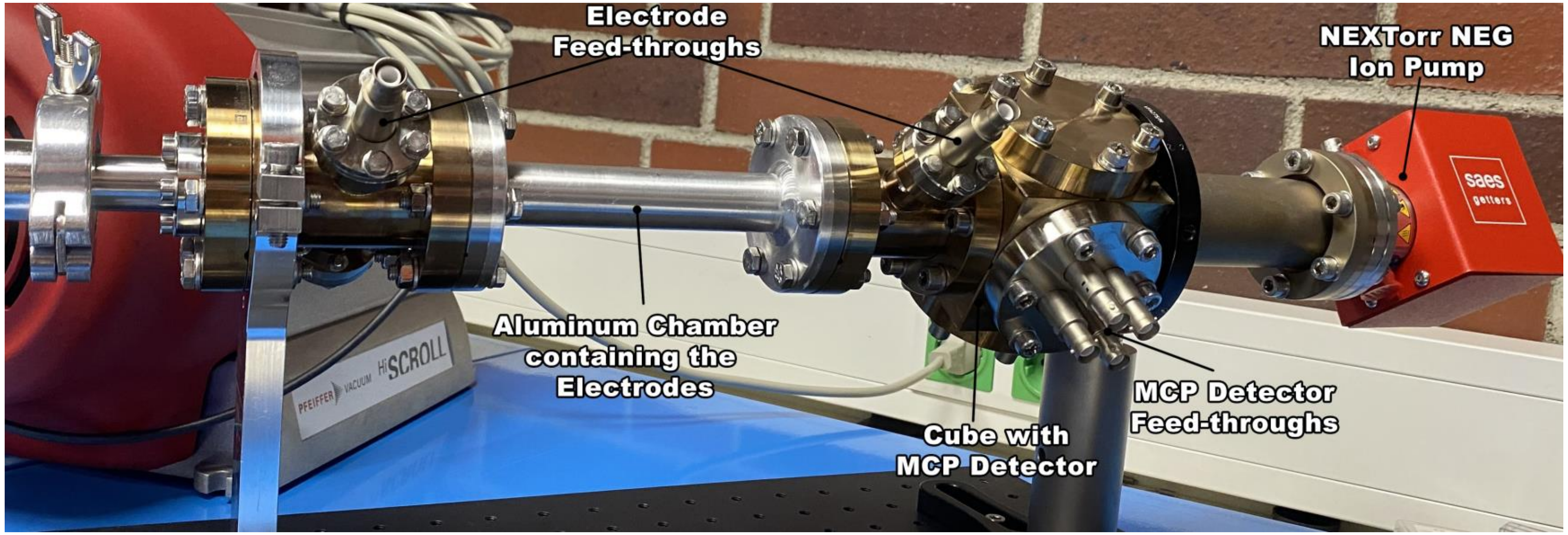


Extraction strategy



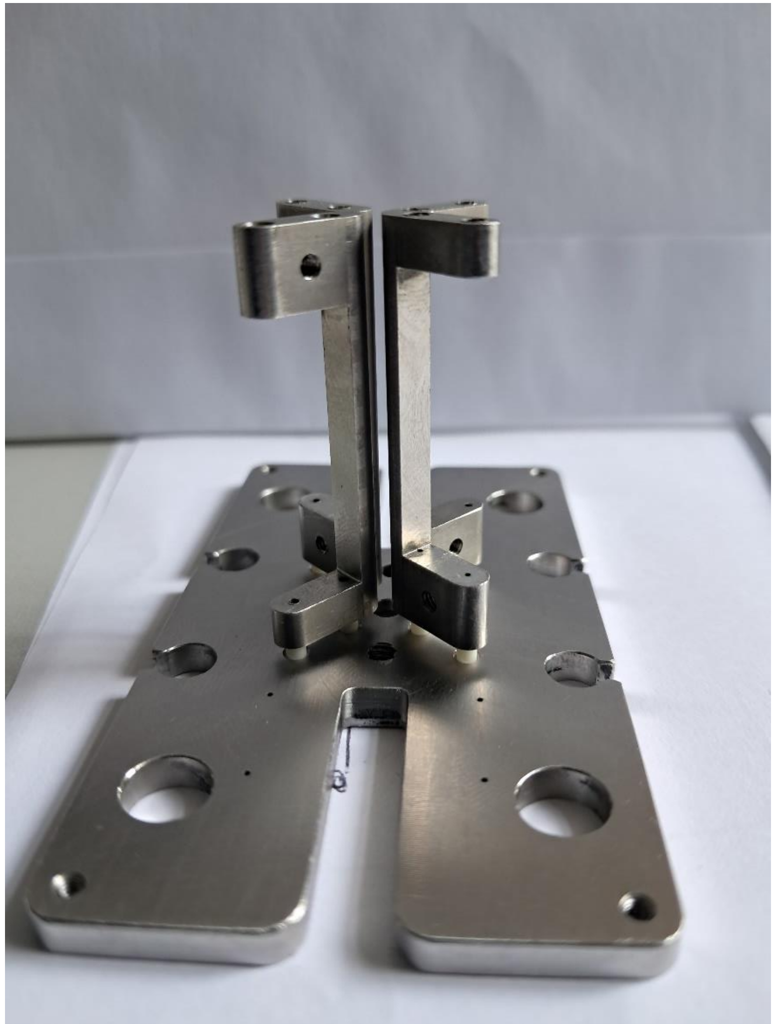
Penning trap

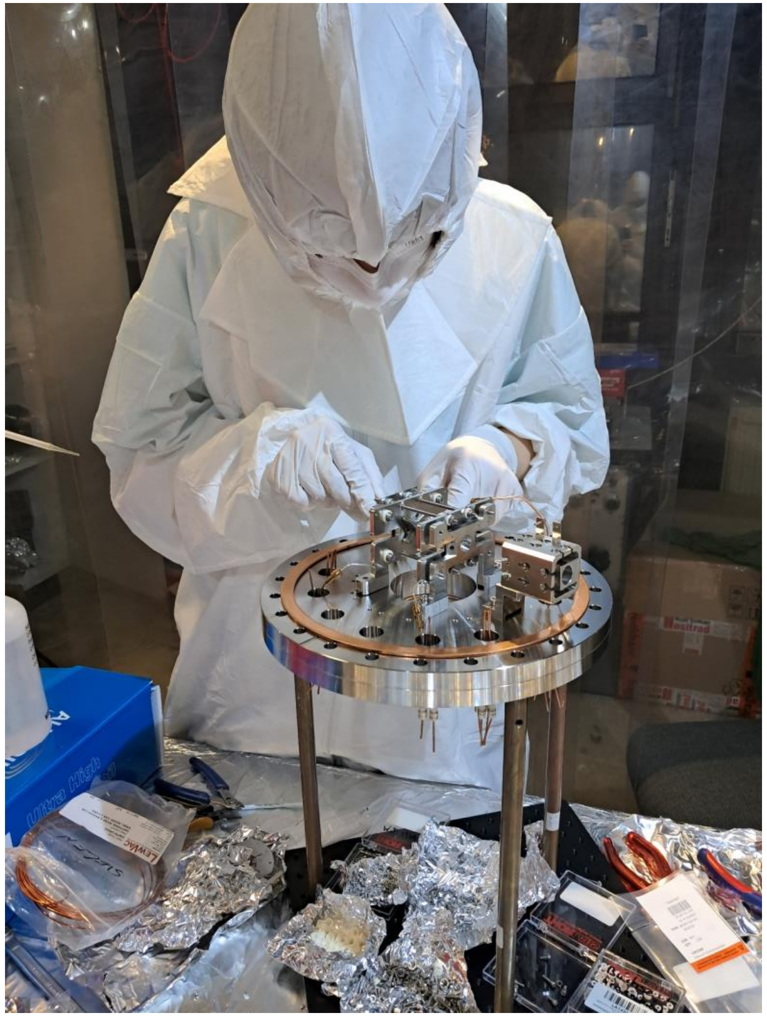




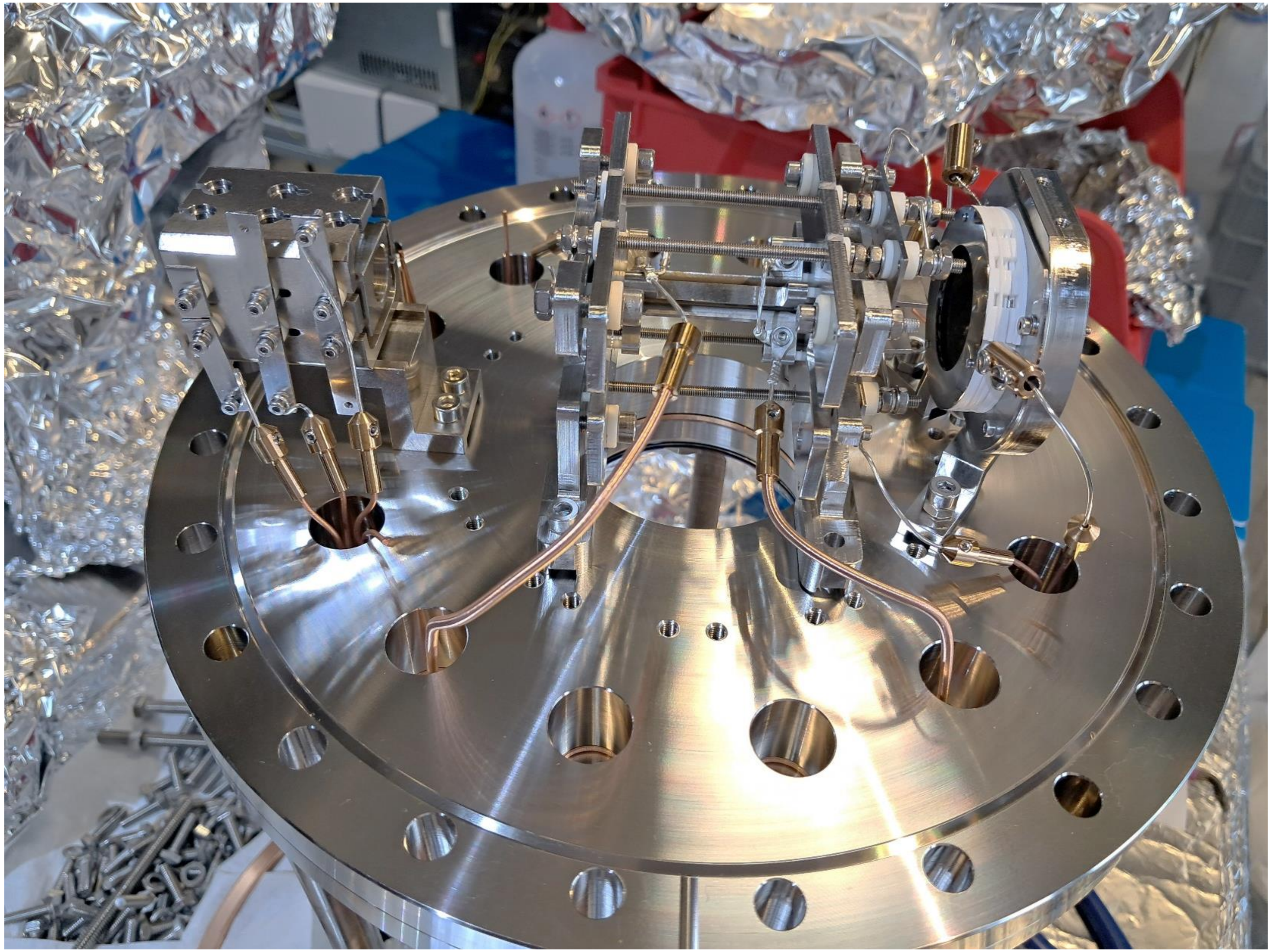
Magnets

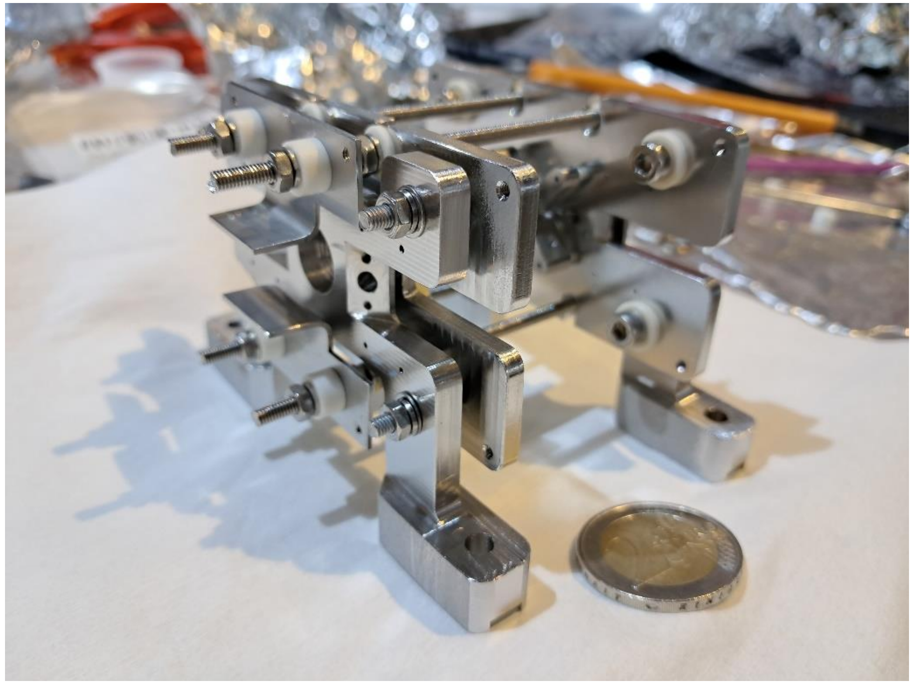
Paul trap



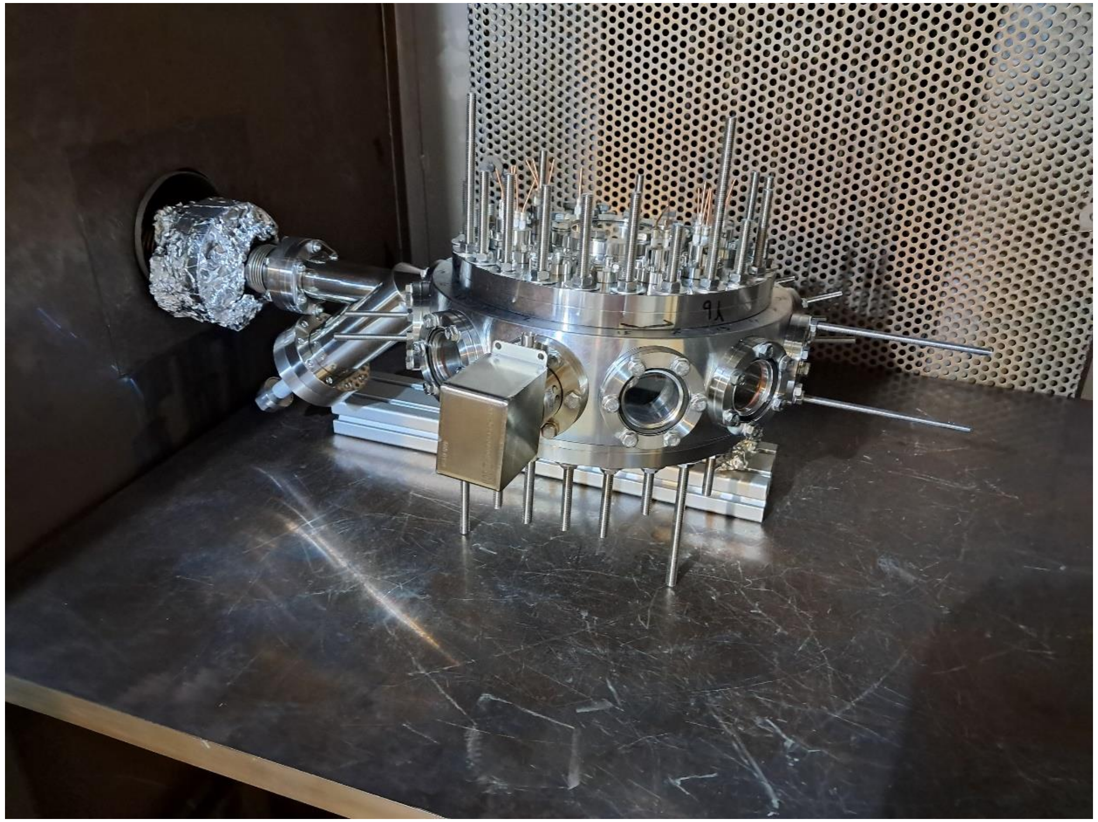


Receiver – Paul trap

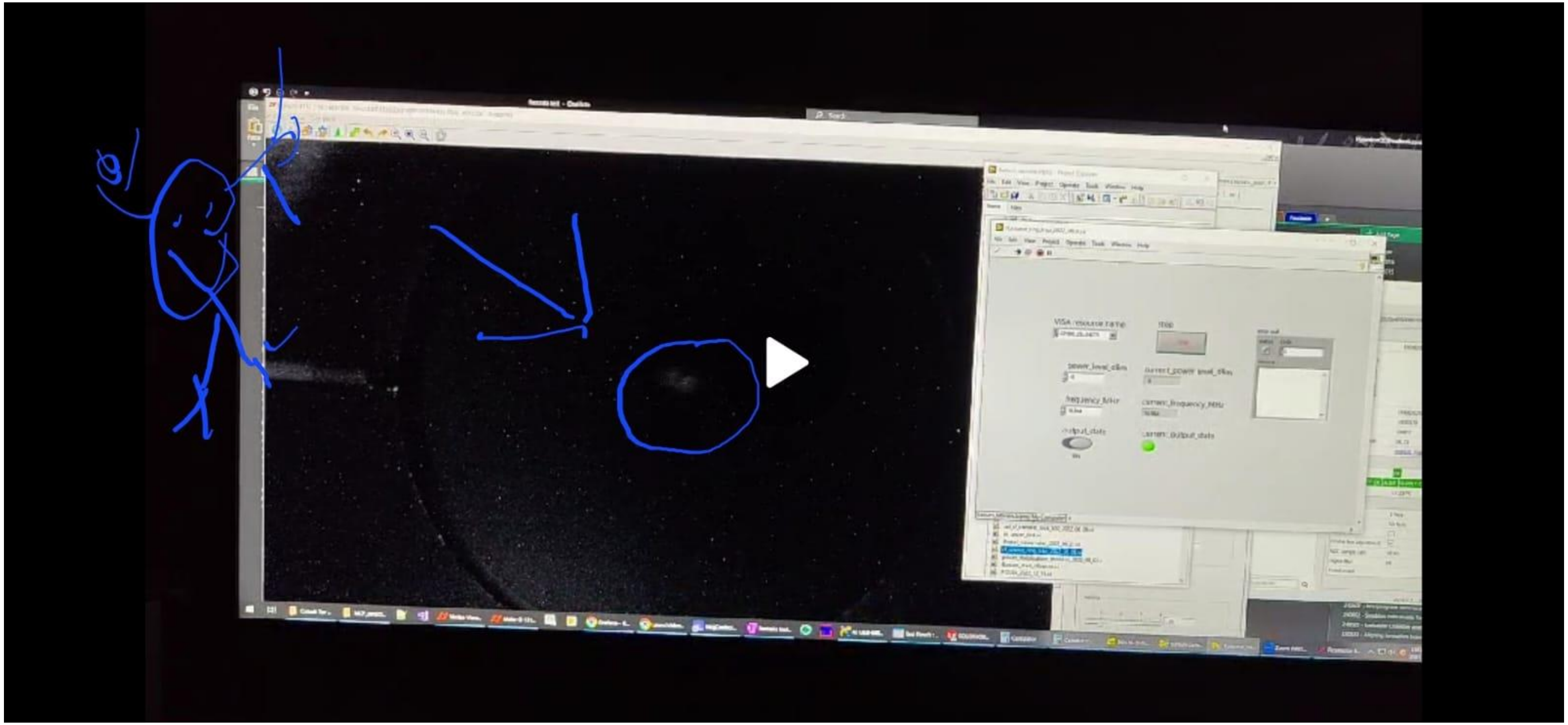




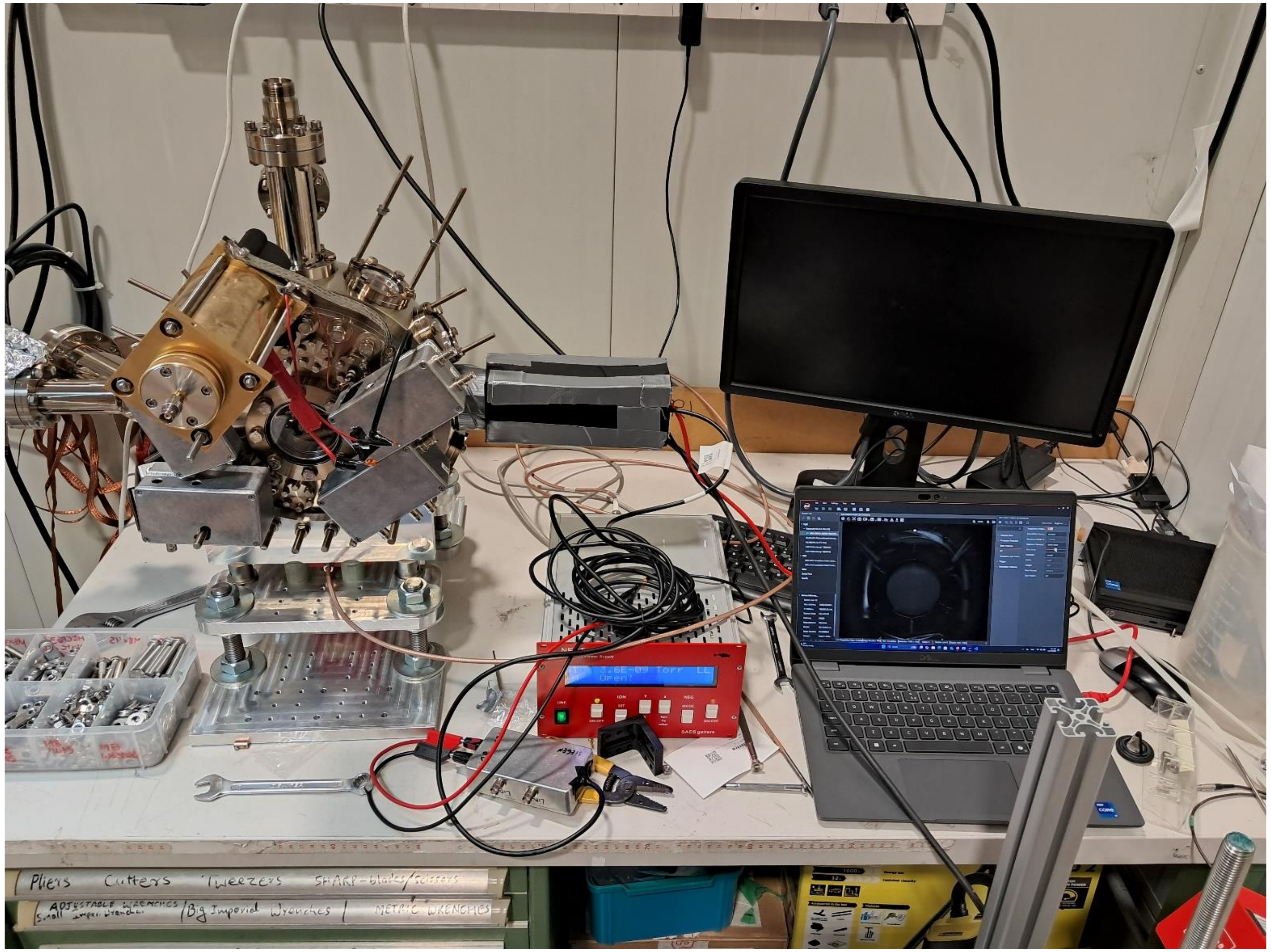
Baking – 240 deg – 1 week

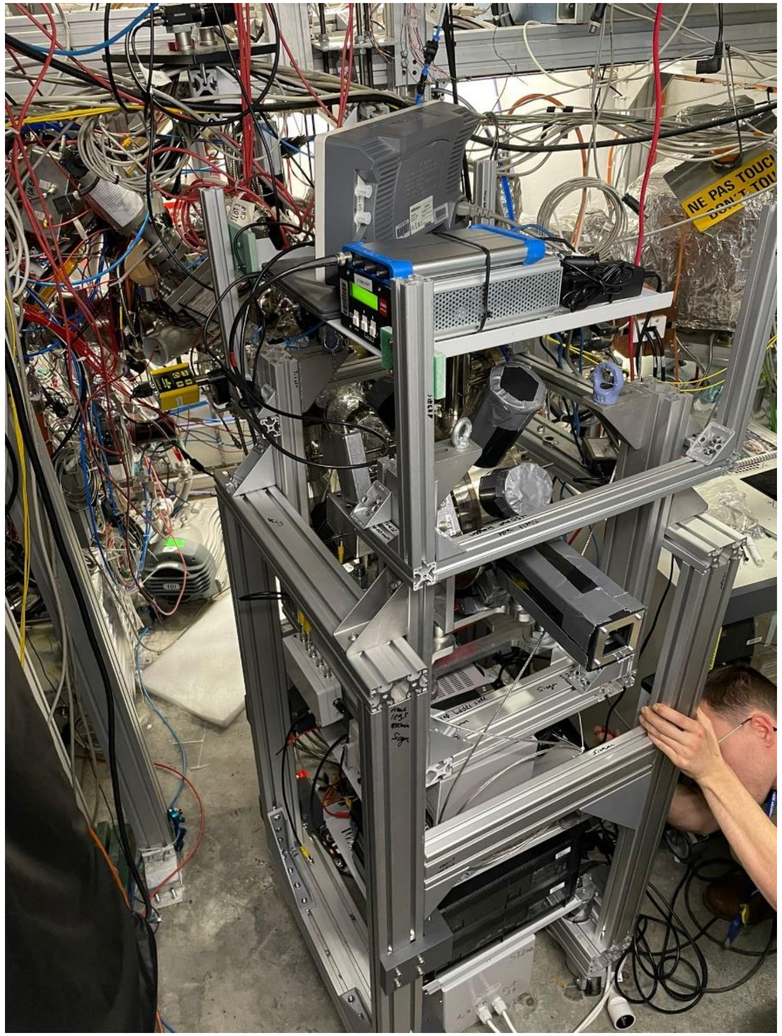


Test



Assembly up to the beamline





Paul trap stability diagram

J. Phys. B: At. Mol. Opt. Phys. **52** (2019) 155003 G Cerchiari *et al*

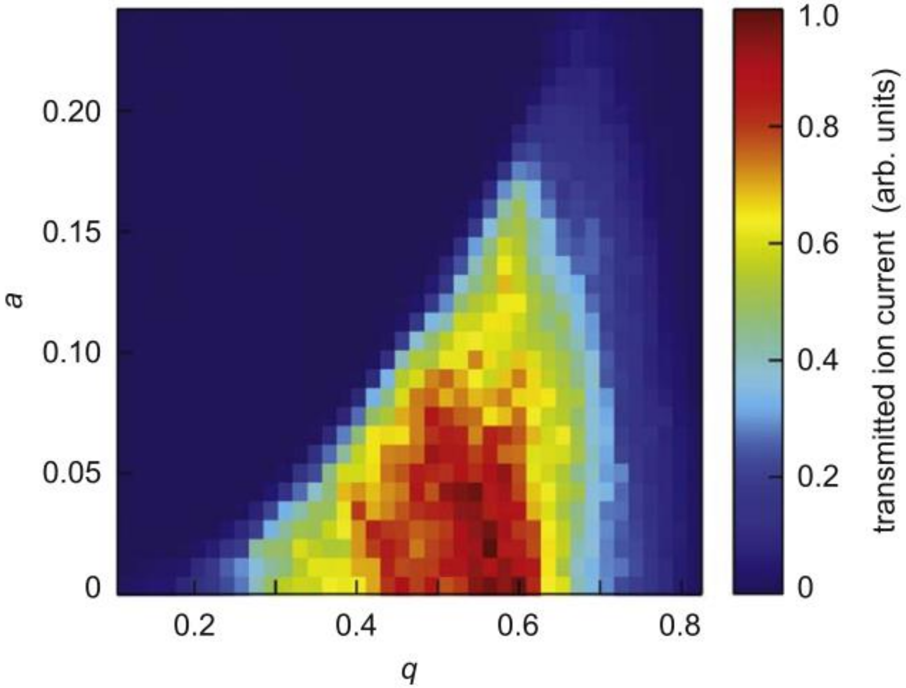


Figure 5. Stability region of radial RF confinement in transmission mode. The plot shows the O^- current transmitted without axial trapping potential as a function of the Mathieu parameters q and a.

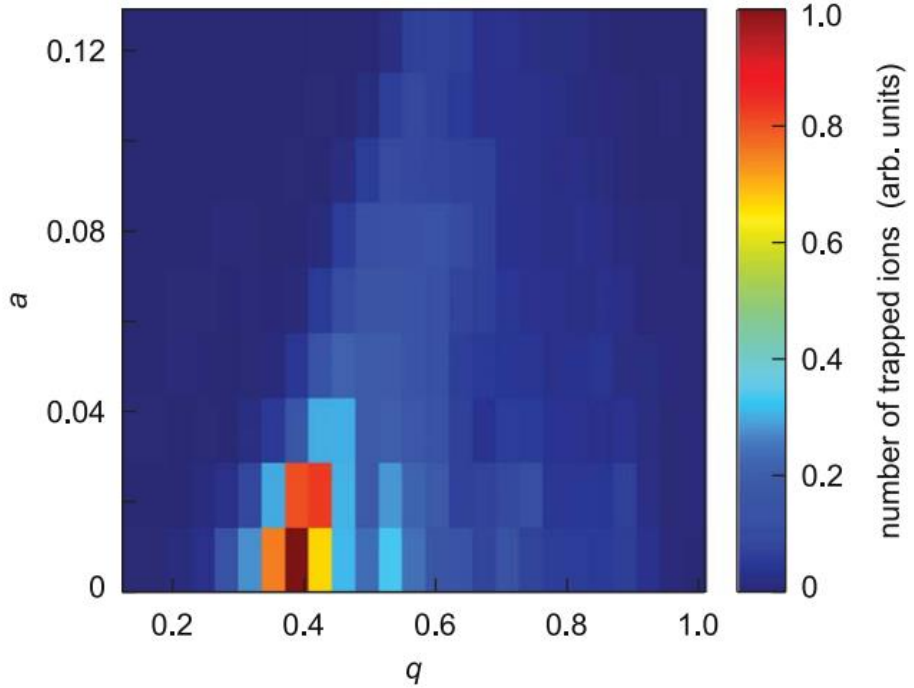
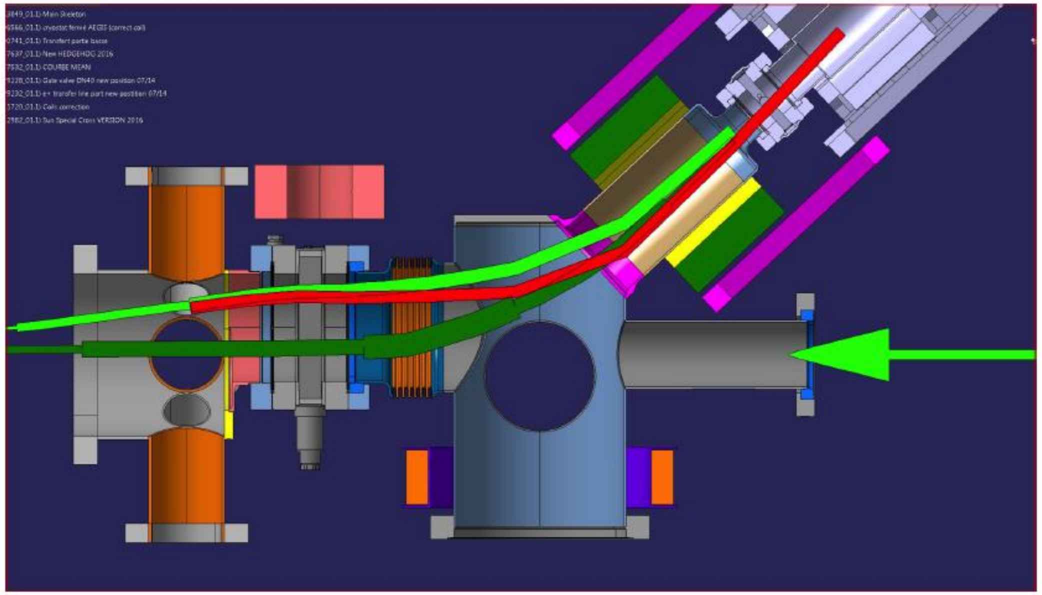
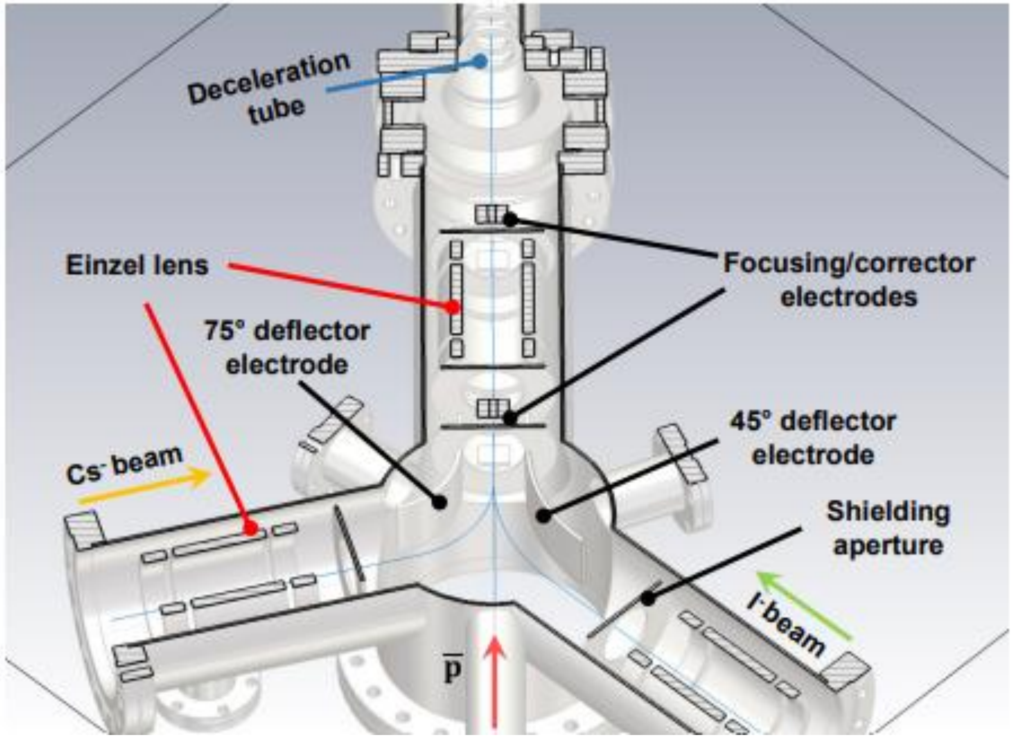


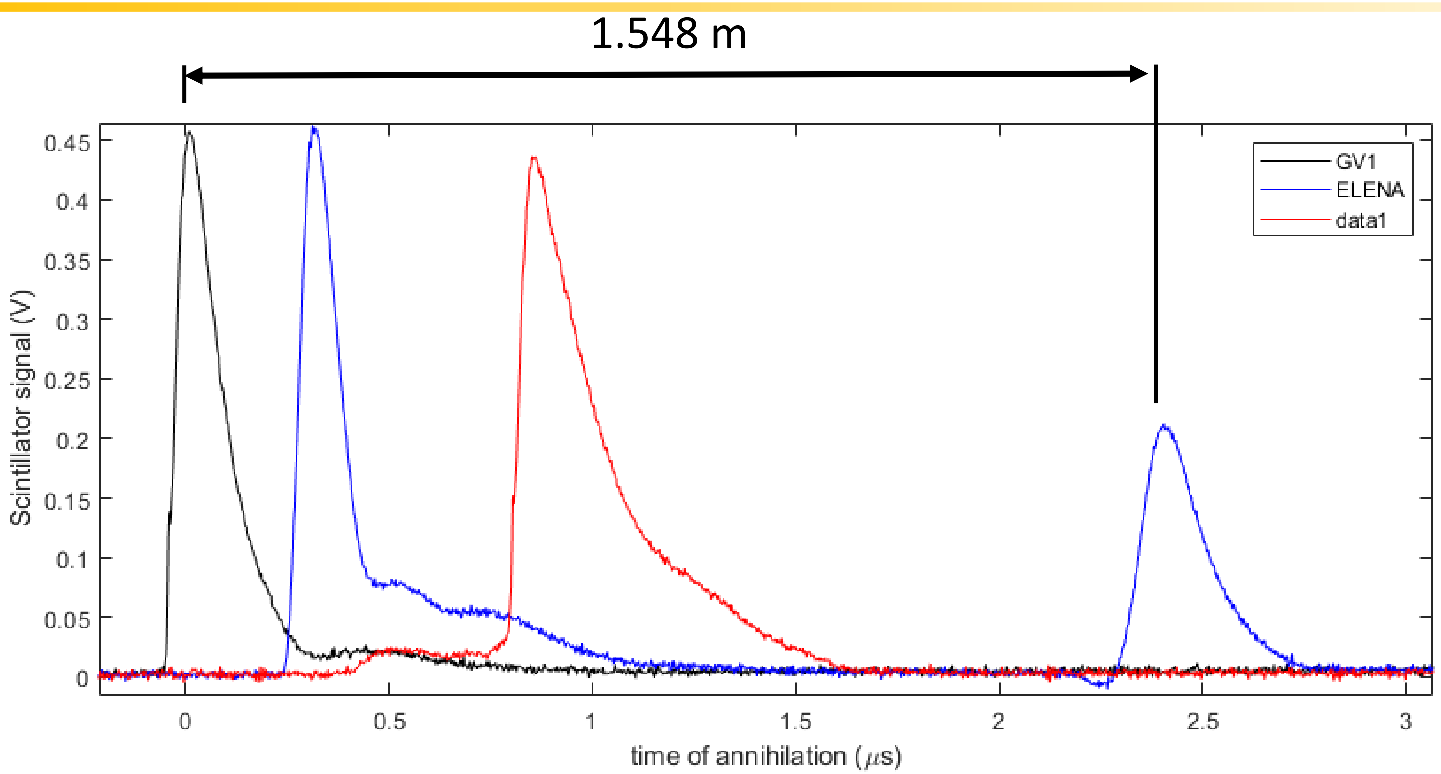
Figure 6. Stability region of radial RF confinement in trapping mode. The plot shows the number of trapped O^- ions as a function of the Mathieu parameters q and a.

In between?




Deceleration tube
Einzel lens
Focusing/corrector electrodes
75° deflector electrode
45° deflector electrode
Cs- beam
Shielding aperture
I- beam
p̄

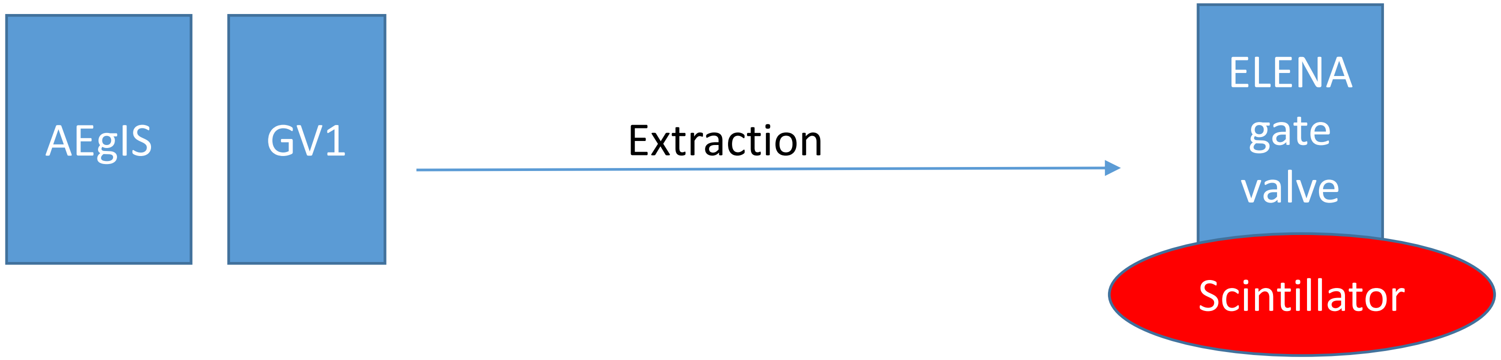
Extraction of cold antiprotons



To **1st gate valve**
- Catch and e-cooling of pbars
- Pulse on the drift-tube

From **1st gate valve** to **ELENA**
- Current on the bottom coil of the PS transfer line

From **ELENA** to **Bending region (data1)**
- Antiprotons plasma compression $\phi \approx 1\ \mathrm{cm} \ \rightarrow 1\ \mathrm{mm}$



Parameters of extraction
- Drift-tube voltage 2900 V
- Drift-tube delay pulse 6.5 us
- Resulting acceleration 2000 V

Aims for 2025

- **Extraction of antiprotons**

- *Store antiprotons in a room-temperature ion-trap*
- *Trap antiprotons in a Paul trap*
- *Transport antiprotons in a room-temperature Penning trap*
- *Transport antiprotons in a room-temperature Paul trap*

- Co-trapping of antiprotons with Ba^+
- Annihilation of antiprotons with Ba^+

Imminent tasks for 2025

- **Extraction of antiprotons**
- **Integrating with AEgIS, removing obstacles**

- Store ions in a room-temperature ion-trap
- Trapping and laser cool ions
- Transport ions
- Make the trap suitable for crane transport
- Fix detection of the antiprotons in the portable trap

Great to work with you ☺