Cryogenic gas cell at SHIPTRAP

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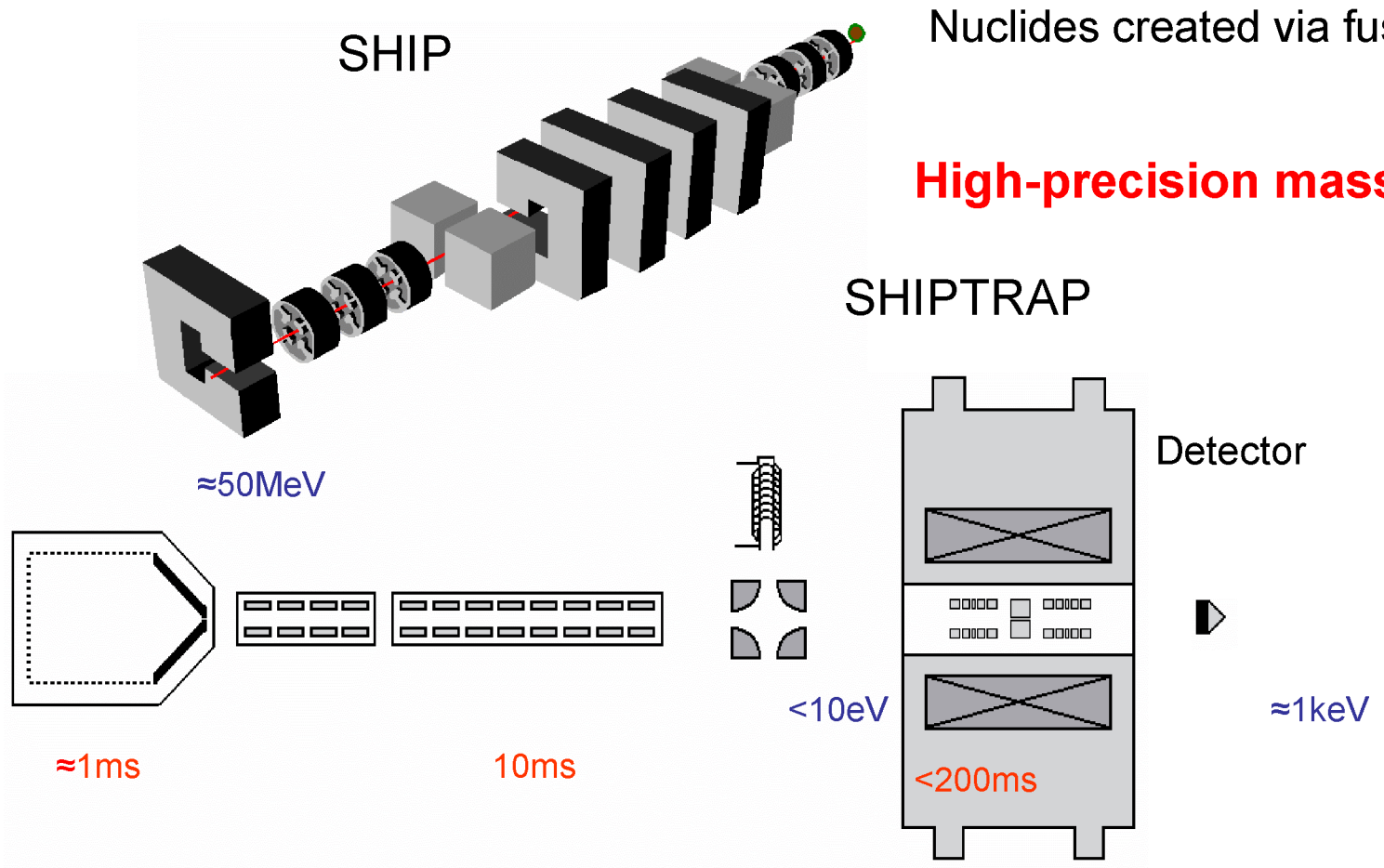
E. Minaya Ramirez, L. Schweikhard and P. Thirolf

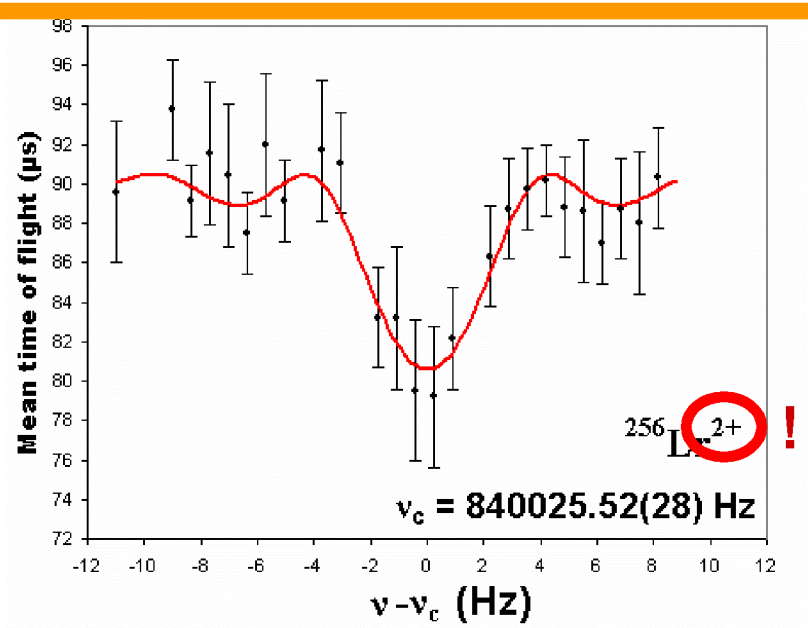
Experimental Setup



Nuclides created via fusion-evaporation

High-precision mass measurements

Mass Measurements at SHIPTRAP

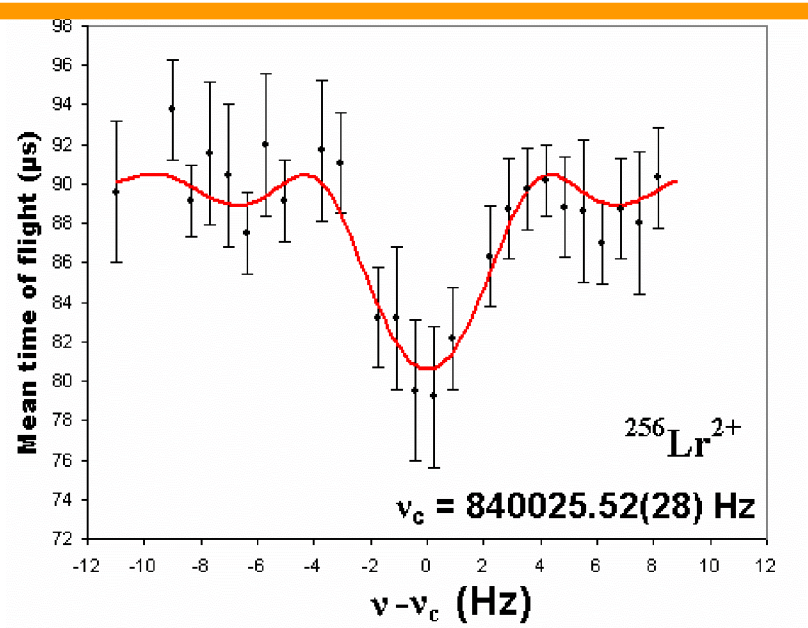


Lowest production cross section :
$^{256}Lr^{2+}$ (60 nb)
4 days for one resonance (48 ions)

Element	$T_{1/2}$ (g.s.)	σ (nb)	Counts / h
^{252}No	2.44(4) s	400	3
^{253}No	1.62(15) min	1800	15
^{254}No	51(10) s	2000	17
^{255}No	3.1(2) min	140	1
^{255}Lr	30(4) s	300	3
^{256}Lr	28(3) s	60	0.5

E. Minaya Ramirez et al., Science 337, 1207 (2012)

Mass Measurements at SHIPTRAP



Lowest production cross section :
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Next Step:

Element	$T_{1/2}$ (g.s.)	σ (nb)	Counts / h
^{256}Lr	28(3) s	60	0.5
^{257}Rf	**4.4(3) s**	**15**	**0.1**
…			

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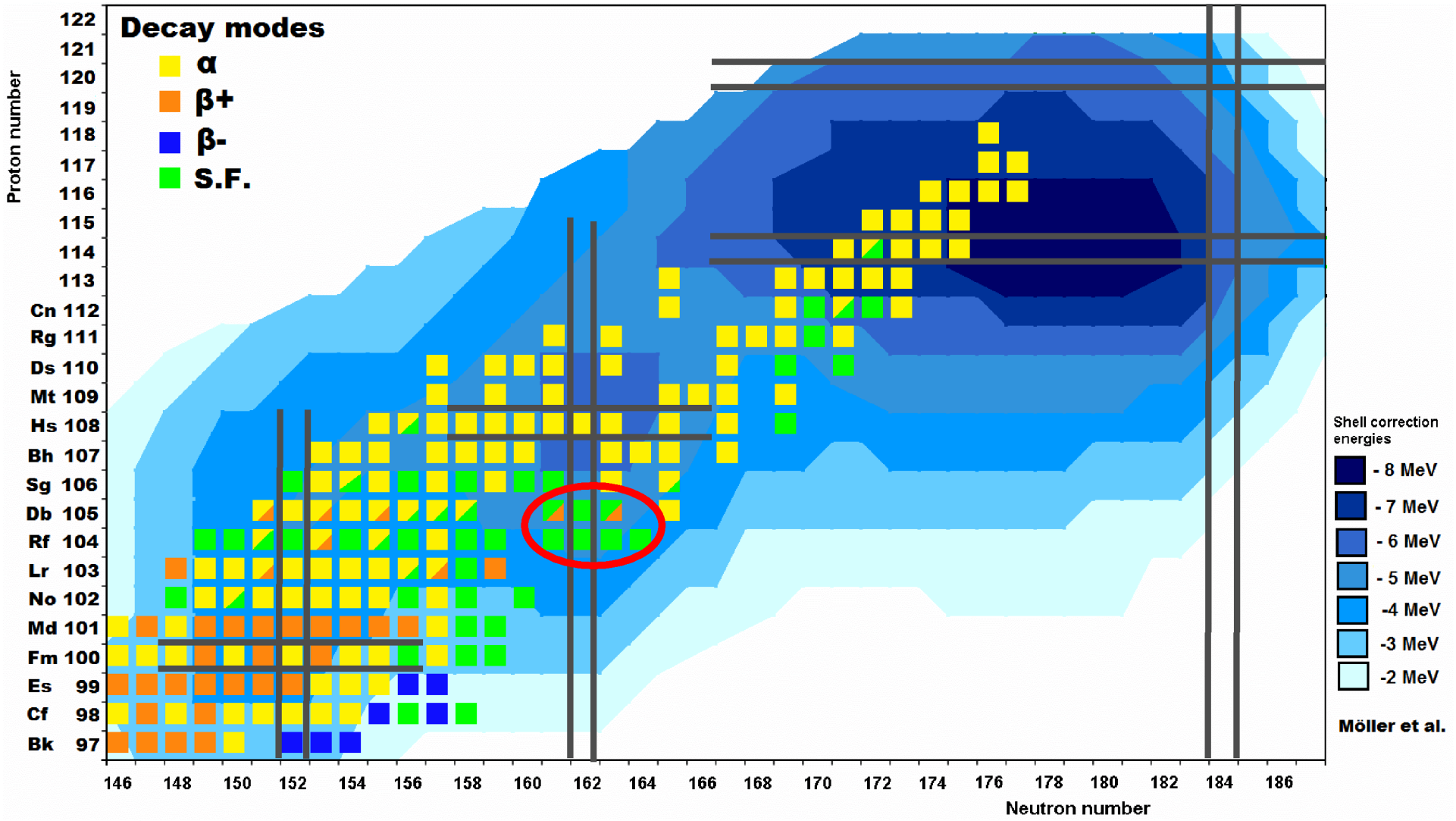
Mass measurements at SHIPTRAP



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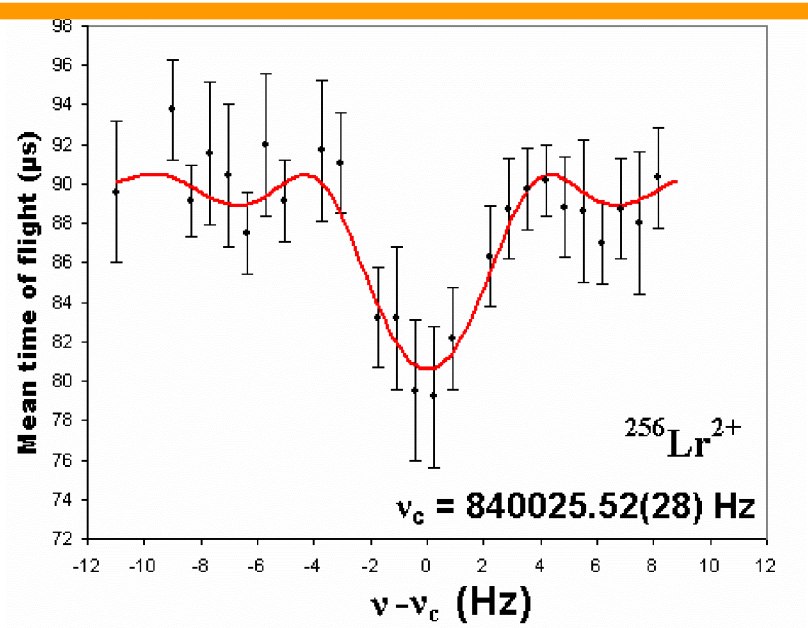

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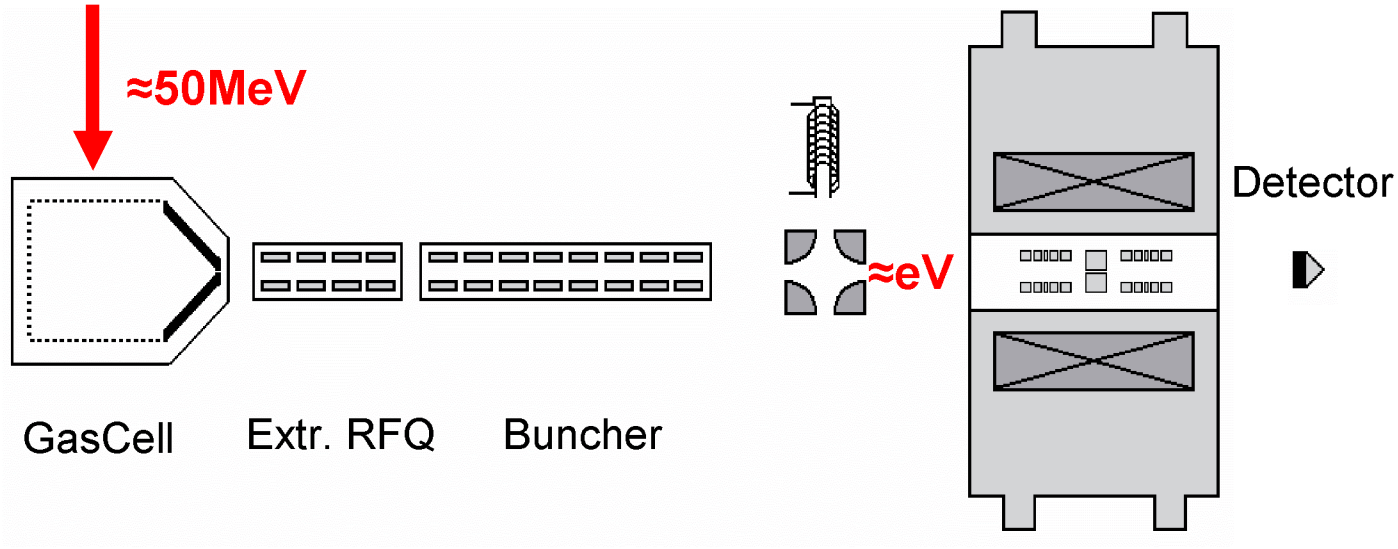
→ Problems: experimental difficulties (e.g. longterm stability of magnetic field-strength) , poor statistics and not enough beamtime

→ **Increase in sensitivty (PI-ICR, FT-ICR) and efficiency of SHIPTRAP setup**

E. Minaya Ramirez et al., Science 337, 1207 (2012)

Experimental Setup

Reaction products from SHIP



Overall efficiency approximately ≈ 2%

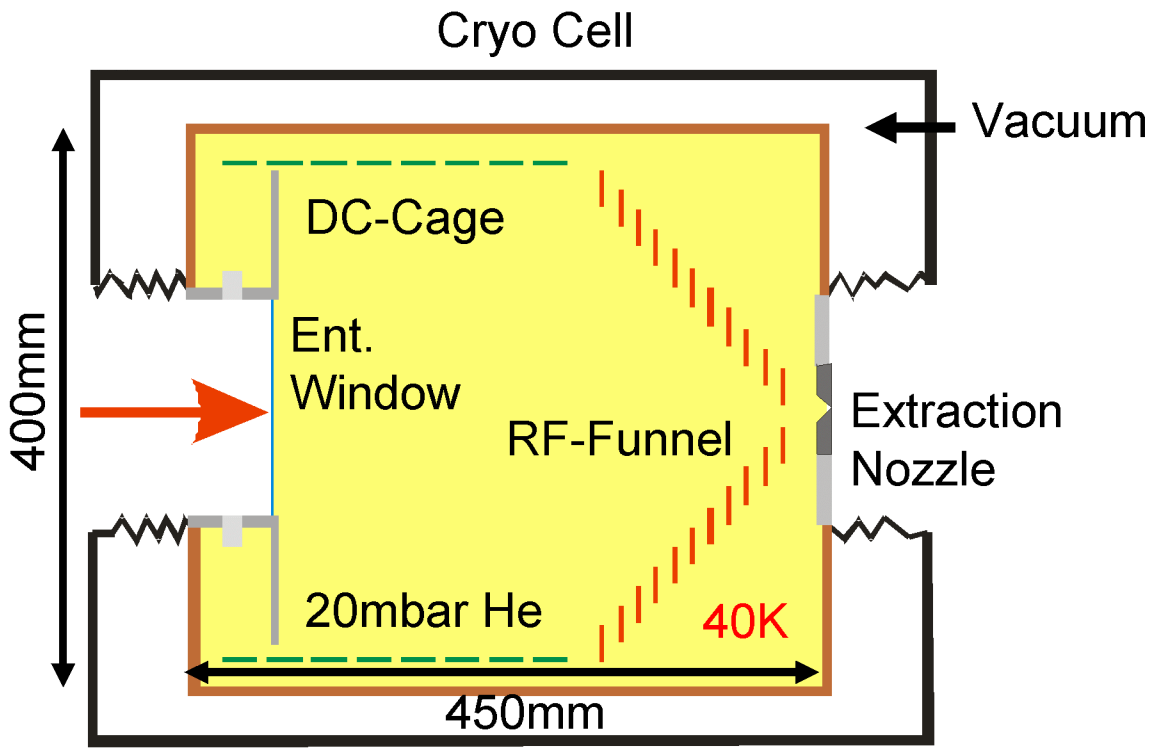
7T Solenoid
with Tandem-Penning Trap

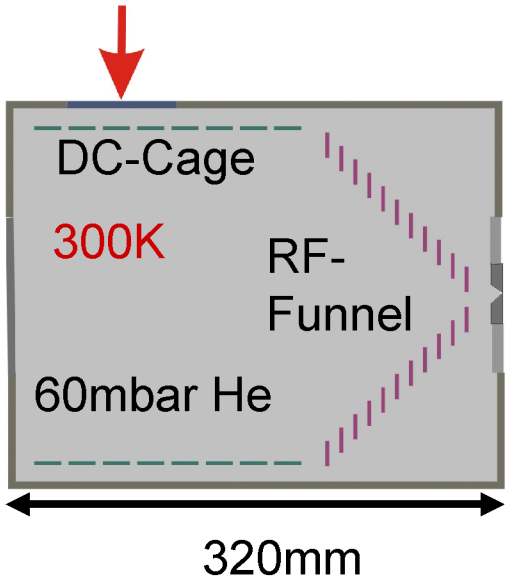
Bottleneck : gas stopping cell (stopping+extraction efficiency ≈ 10%)[1]
(stopping efficiency ≈ 40%)

→ **Setup of a second generation gas stopping cell with a higher efficiency**

[1] J. B. Neumayr et al., Nucl. Instr. And Meth. B 244 (2006) 489

CryoCell Setup



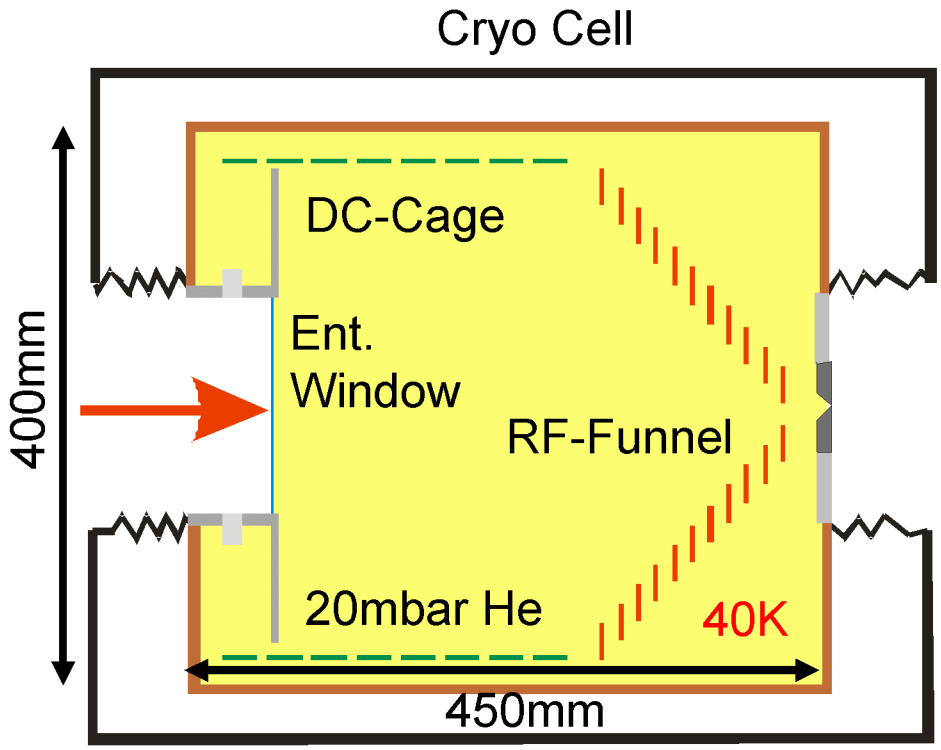


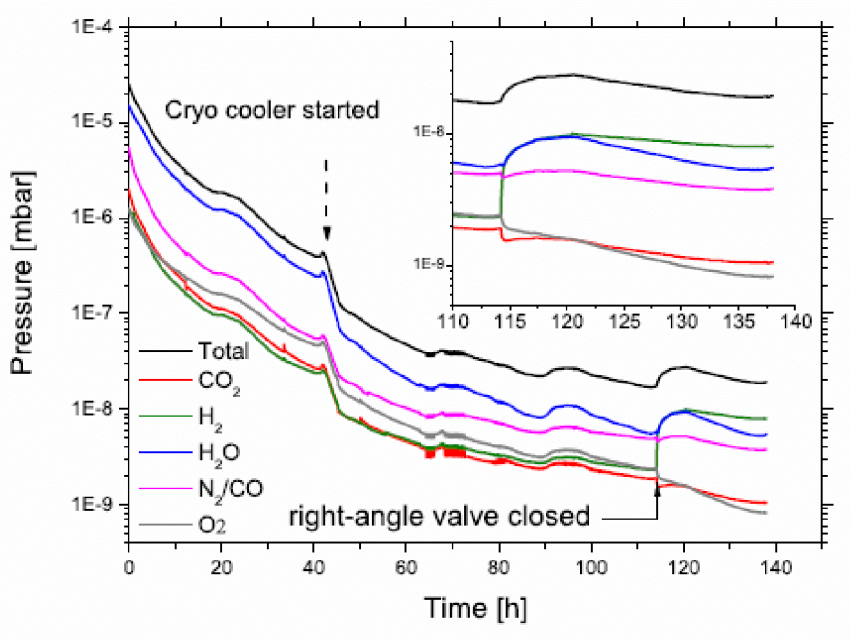
Advantages compared to 1st generation gas cell:

- Larger stopping volume
- Coaxial injection of reaction products

Isotope	E_{kin}/MeV	Ti Window / µm	Δ_{Stop} / mm	ε_{GC}^{Stop} /%	ε_{CC}^{Stop} /%
^{87}Tc	70	2.3	78	45.3	89.6
^{147}Ho	95	7.1	101	62.2	90.7
^{205}Rn	50	4.5	103	44.4	91.6

CryoCell Setup





Advantages compared to 1st generation gas cell:

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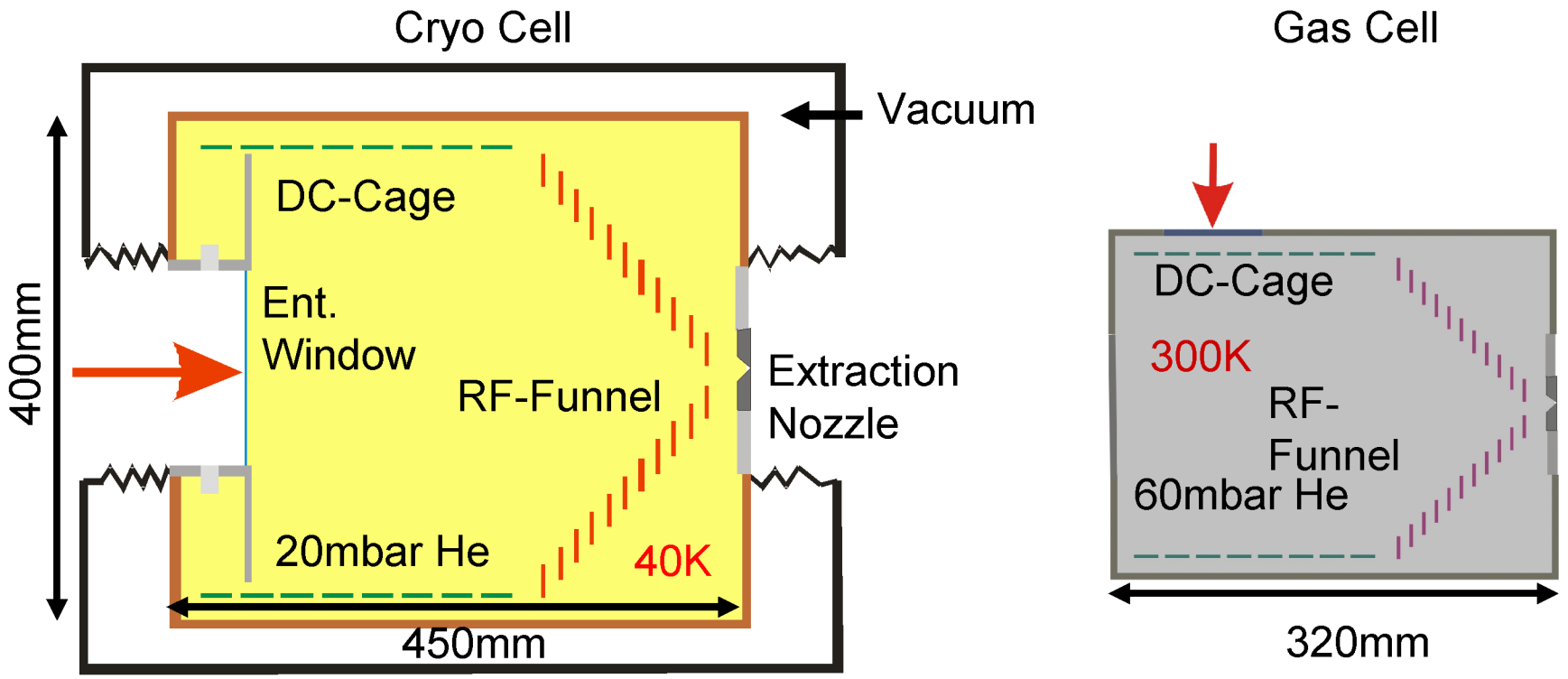
- Coaxial injection of reaction products
- Higher cleanliness

CryoCell Setup

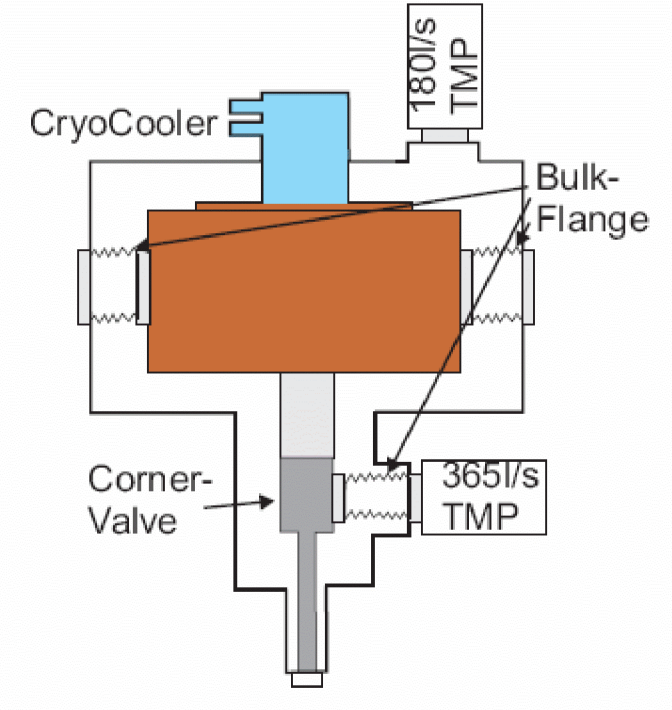


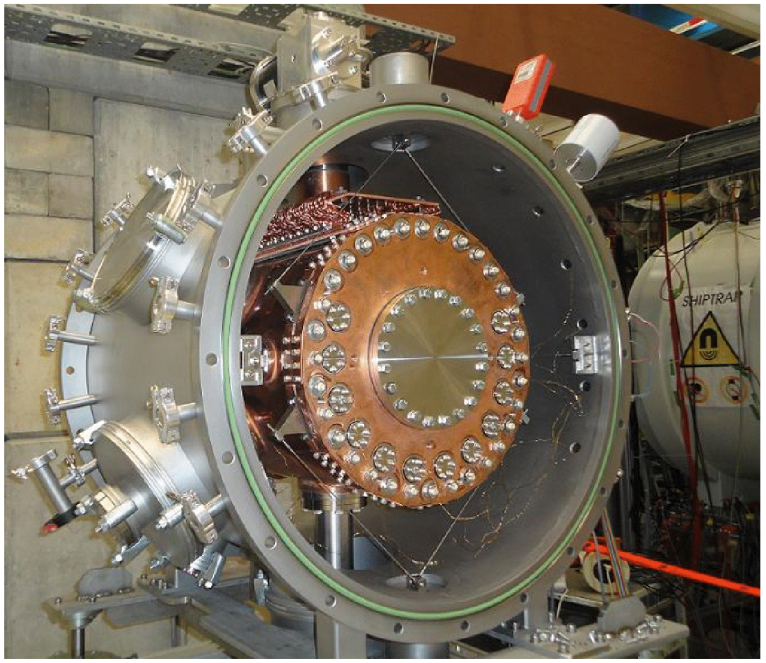
Advantages compared to 1st generation gas cell:

- Larger stopping volume
- Coaxial injection of reaction products
- Higher cleanliness
- Larger gas density at a lower absolute pressure

→ **Efficiency Boost by at least a factor of five**

CryoCell Setup

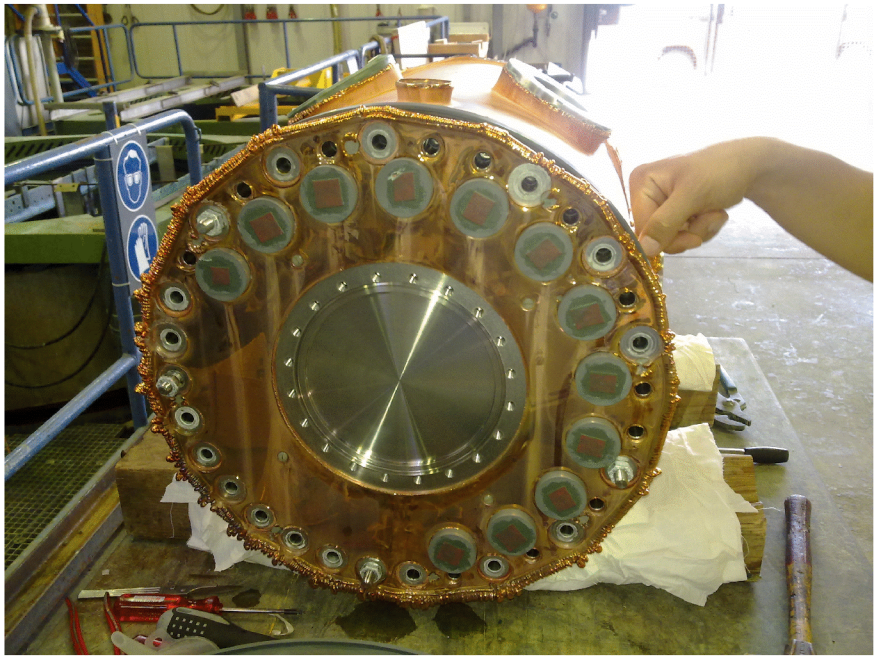


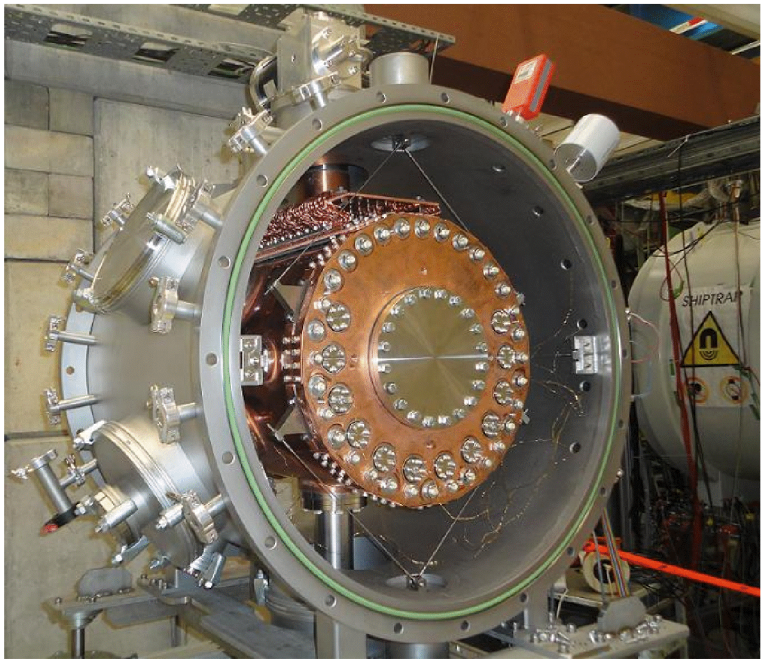


Outer chamber: - 500mm in diameter and a length of 650mm
- evacuated by a 180l/s TMP to 10^{-6}mbar

Inner chamber: - copper plated with a 2mm layer
- cooled with 20K single-stage cryo cooler (100W at 77K)
- fixed with 12 “Inconel X-750“ rods of 1.6mm thickness to outer chamber
- wrapped in multilayer insulation foil

CryoCell Setup





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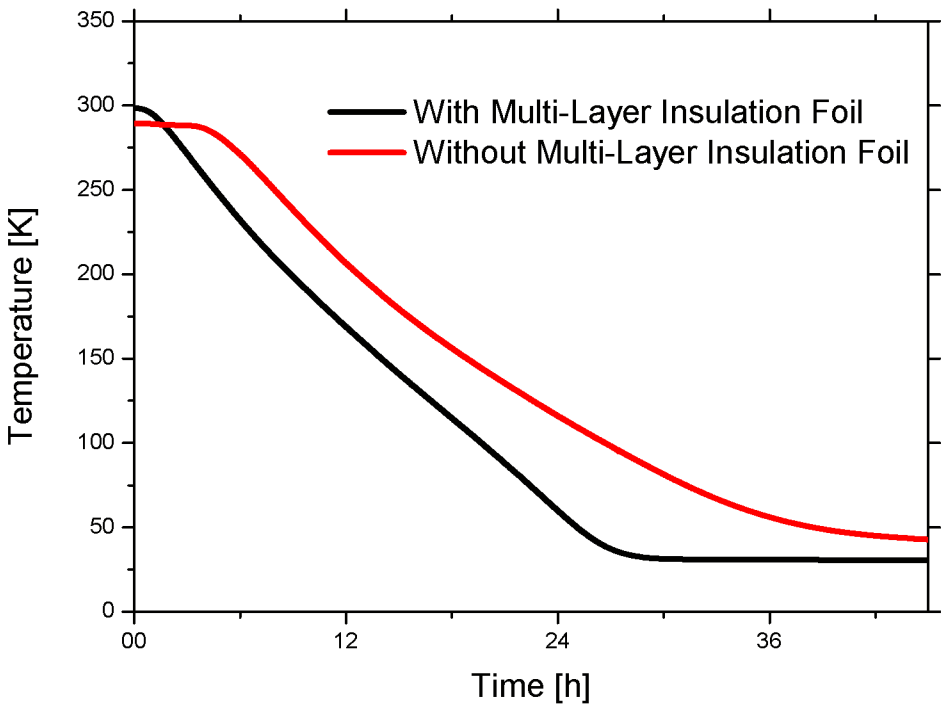

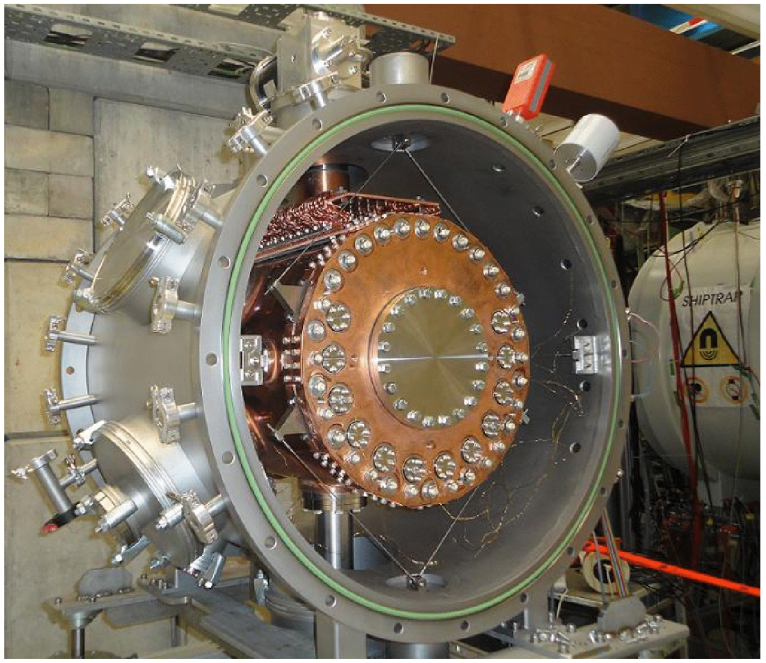

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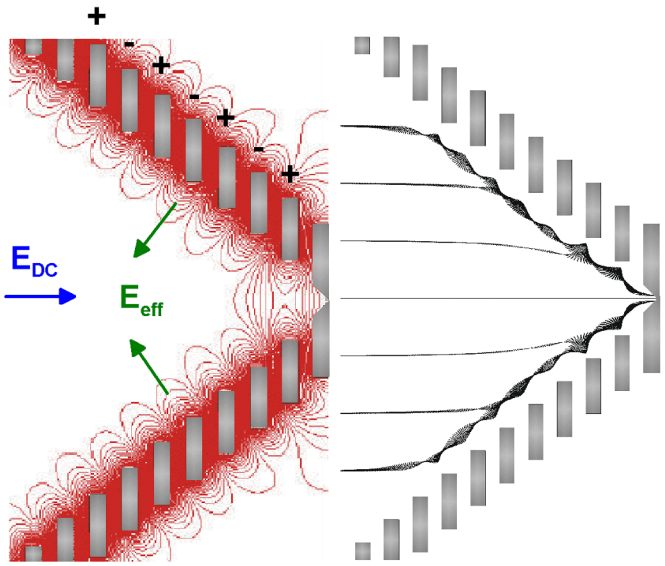
RF-Funnel

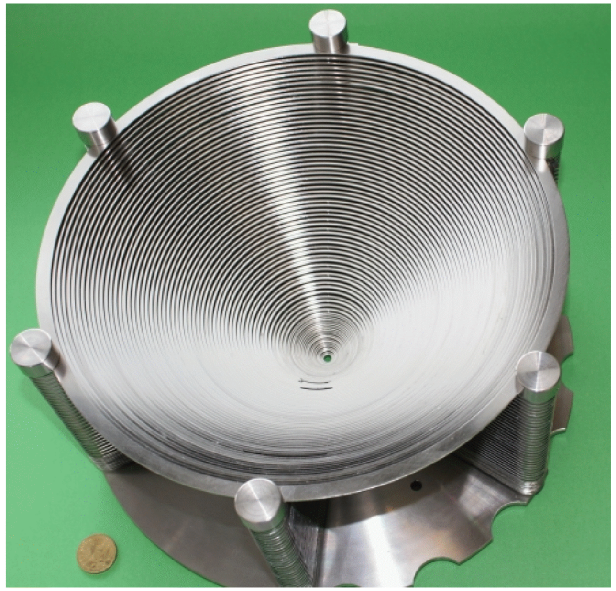
- 76 ring electrodes
- Diameter: from 266mm down to 5mm
- Total capacity of 2.6nF
- 1mm distance between electrodes (0.5mm at last 20 segments)



RF with 180° phase shift between neighboring electrodes superimposed with DC gradient

RF-Test in UHV and 60mbar He at 300K and 20mbar He at 40K:

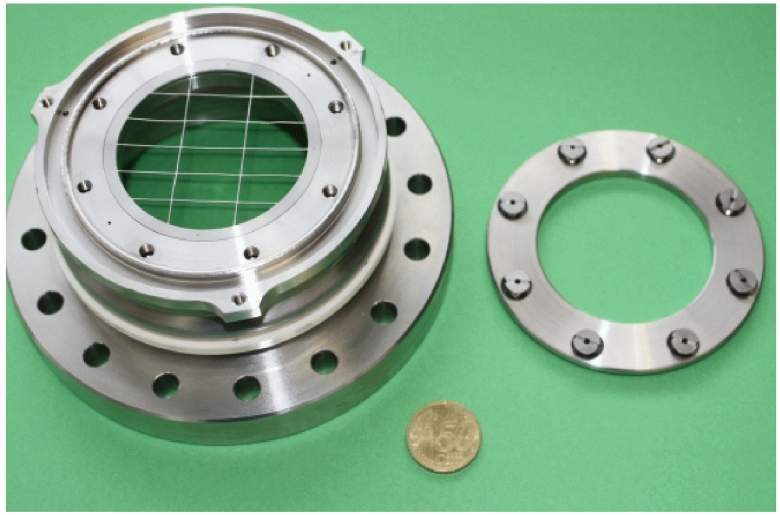
f = 1017kHz
$U_{out,pp}$=320V



DC-Cage and Entrance Window

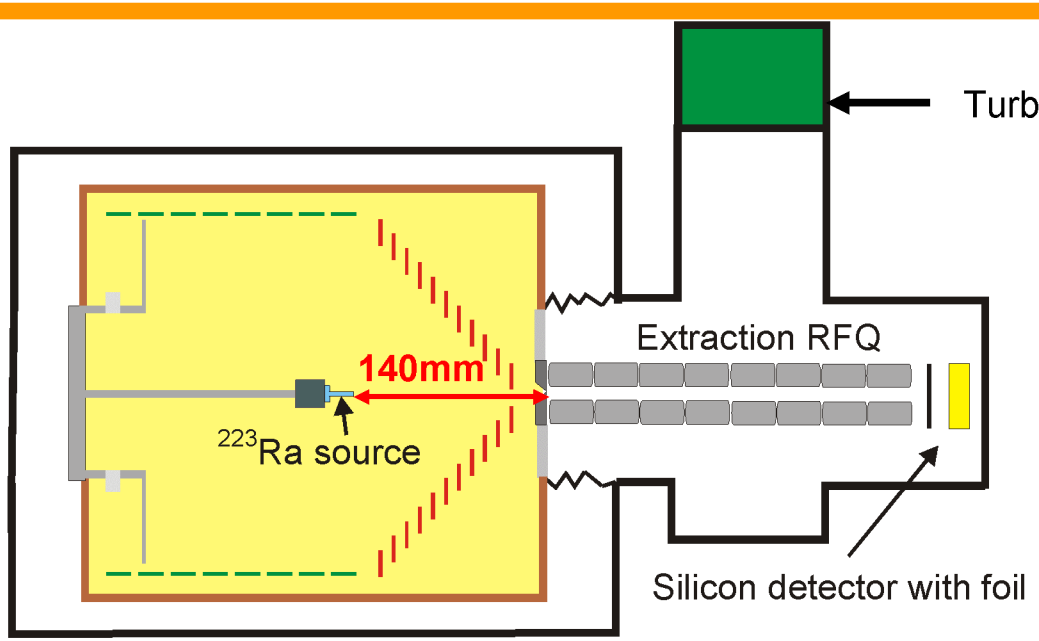
- 8 ring segments with a DC gradient of >10V/cm
- Diameter of 260mm
- Extraction Time ≈ ms

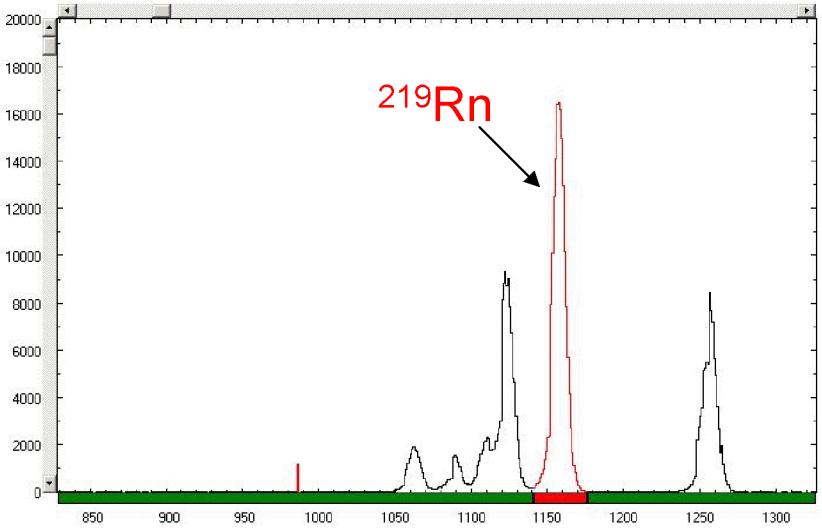
- 90% energy loss of reaction products
- currently 3µm Ti foil + gold sealing
- beam diameter behind SHIP of 60mm
- electrical insulated
  -> increase homogenity of DC potential



Efficiency Measurement

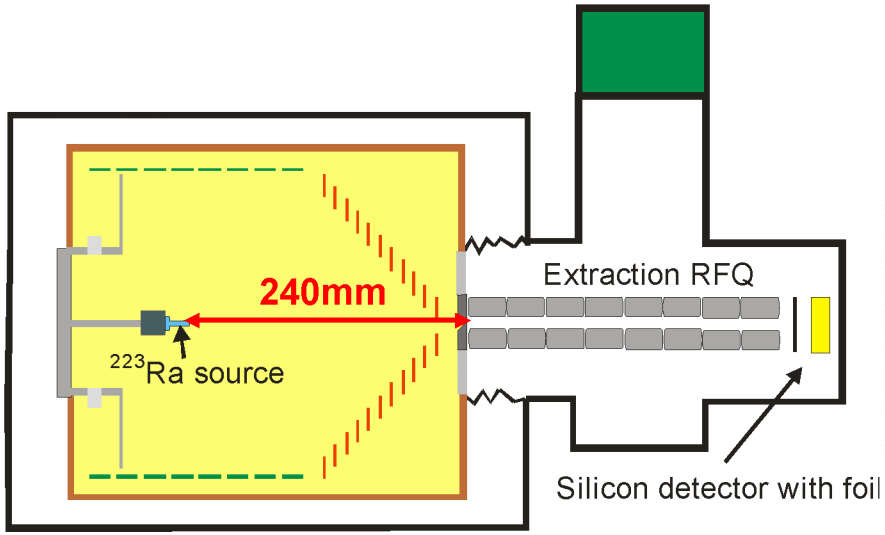
Setup:

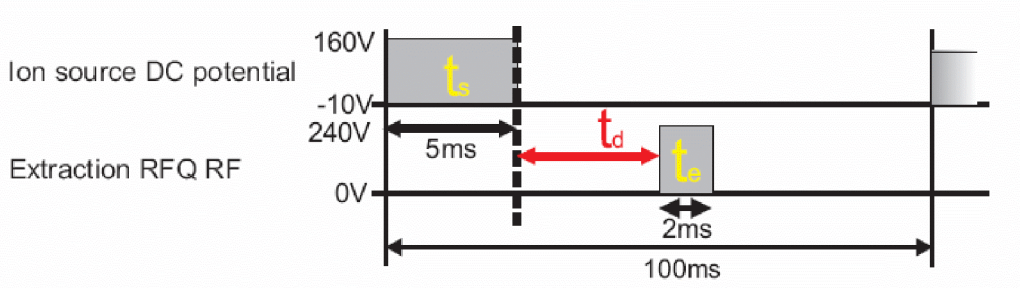




Preliminary Efficiency:
64(3)% at 40K
37(3)% at 300K

Extraction Time Measurement





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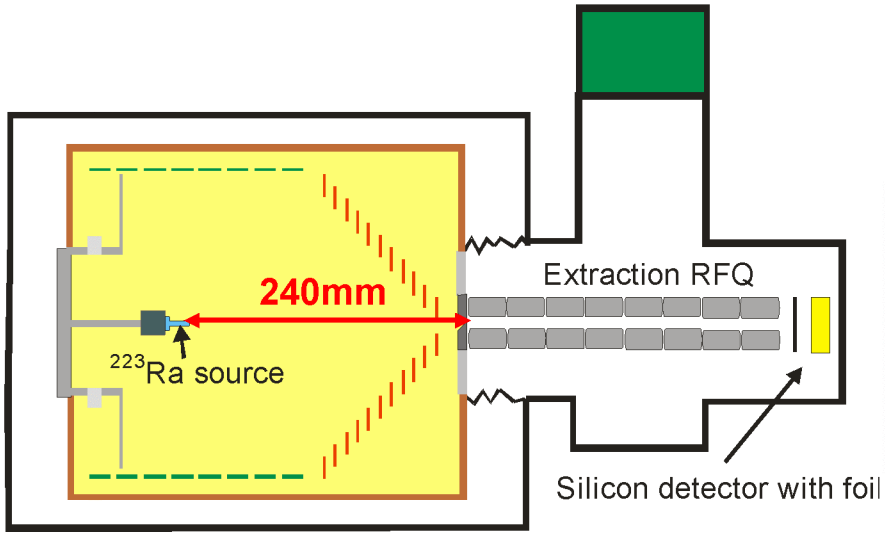
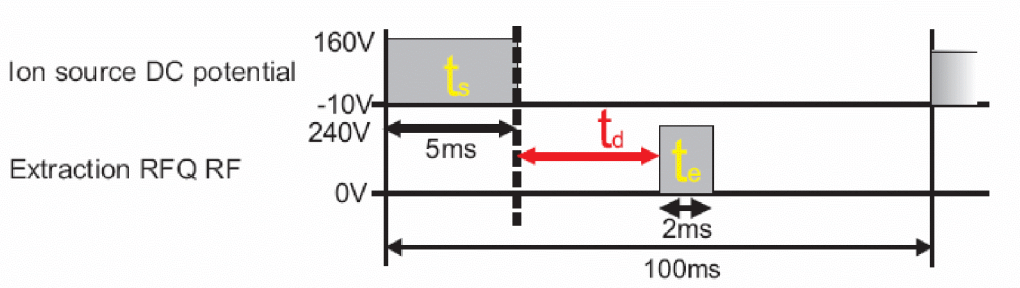


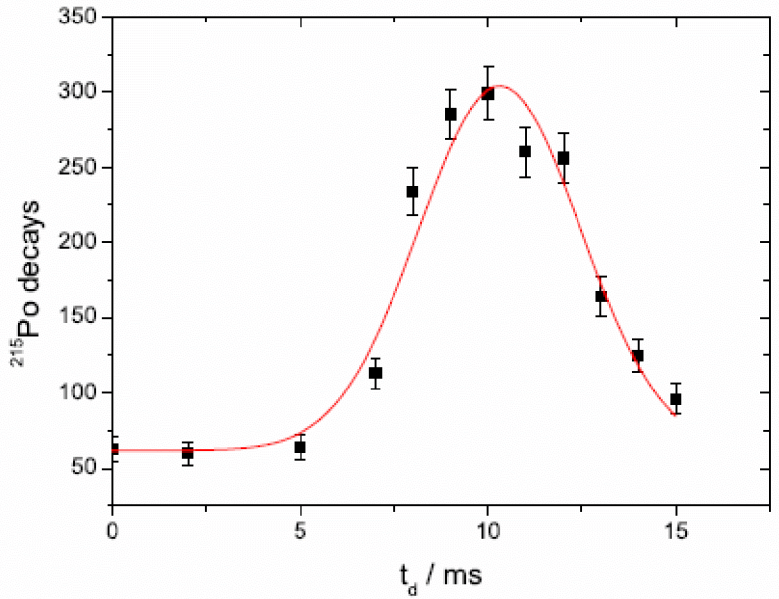


Number of extracted ^{215}Po as a function of time was recorded for t = 200s (2000 cycles)

- T = 300K and p = 56mbar
- Gradients: DC-Cage = 7V/cm
  RF-Funnel = 12.5V/cm
  Extraction RFQ = 0.6V/cm

→ Mean extraction time = 10.3(1)ms

→ **Access to short-lived exotic nuclei**



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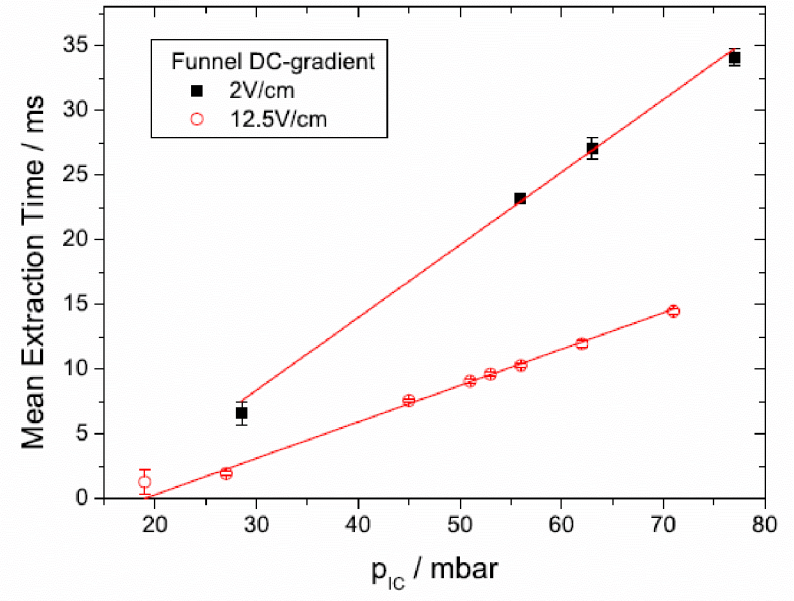
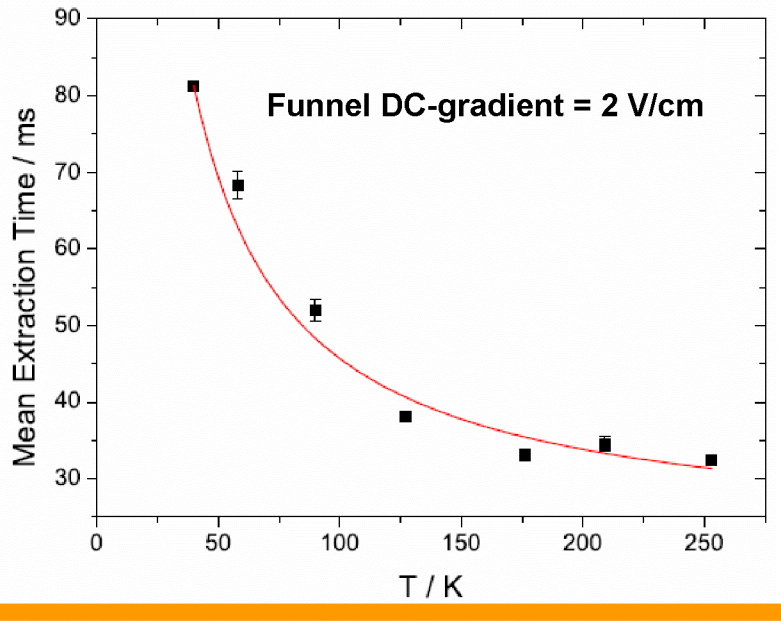


Extraction time as a function of the buffer gas pressure (T=300K):

- Linear correlation between extraction time and buffer gas pressure
- Extraction times lower than 10ms possible

Extraction time as a function of the buffer gas temperature:

- Agreement with ion mobility spectroscopy $t \propto T^{-1}$
- Extraction time decreases to 36ms for Funnel DC gradient of 12.5V/cm for 40K



Outlook and Conclusion

- Offline commissioning phase of CryoCell is finished
- Increased stopping efficiency (≈ 90%) by a factor of two due to improved geometry
- Efficiency almost doubled from 37(3)% to 64(3)% for cryogenic temperatures
- Extraction times of less than 40ms at 40K can be achieved
- Extraction time dependency on DC-gradients, buffer-gas pressures and temperatures according to theory
- Next steps until beam is available, e.g.:
  - Test Funnel performance at larger RF frequencies
  - Determine extraction time and efficiency at different ion source positions
  - Minimize extraction time (increase DC gradients)
- Perform online test

Thank you for your attention

D. Ackermann, K. Blaum, M. Block, C. Droese, M. Dworschak, S. Eliseev, E. Haettner, F. Herfurth, F. P. Heßberger, S. Hofmann, J. Ketter, J. Ketelaer, H.-J. Kluge, M. Laatiaoui, F. Lautenschläger, G. Marx, E. Minaya Ramirez, D. Nesterenko, Yu. Novikov, W. R. Plaß, A. Popeko, D. Rodríguez, C. Scheidenberger, L. Schweikhard, P. Thirolf, C. Weber

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