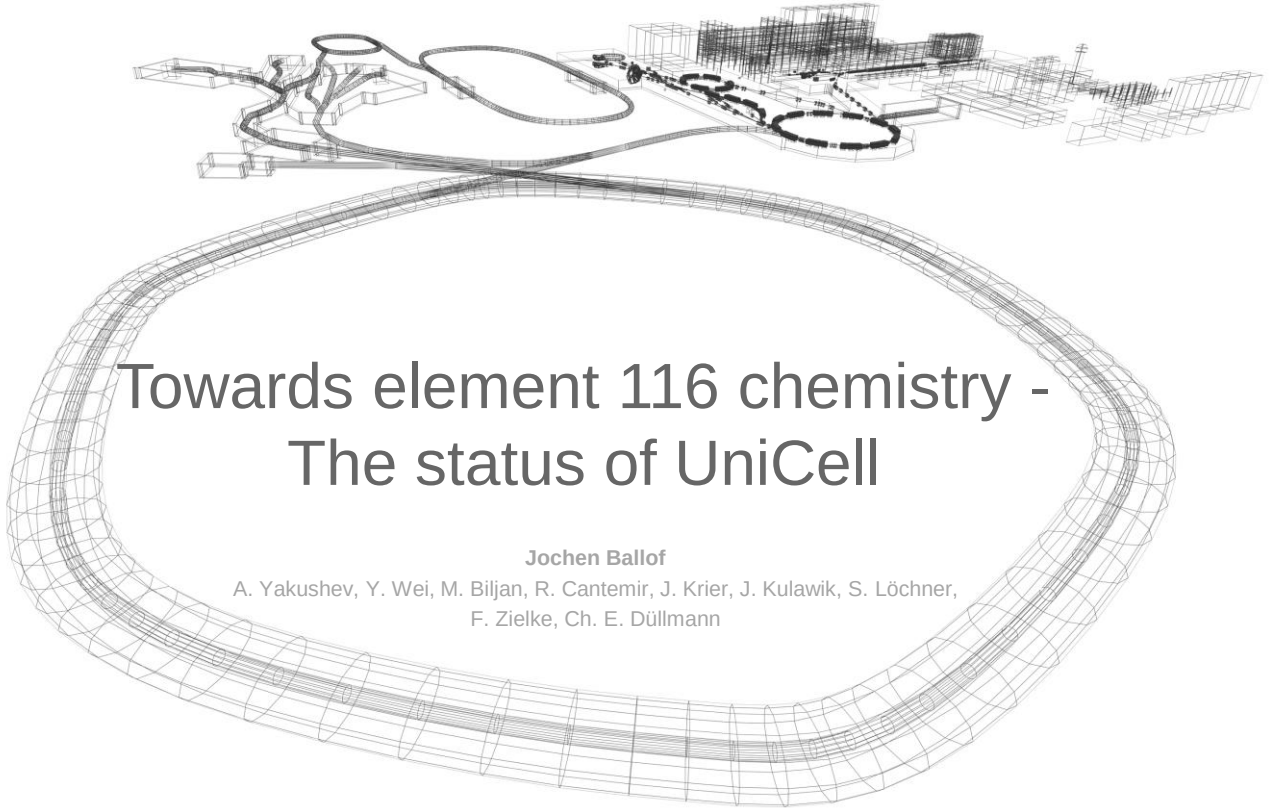
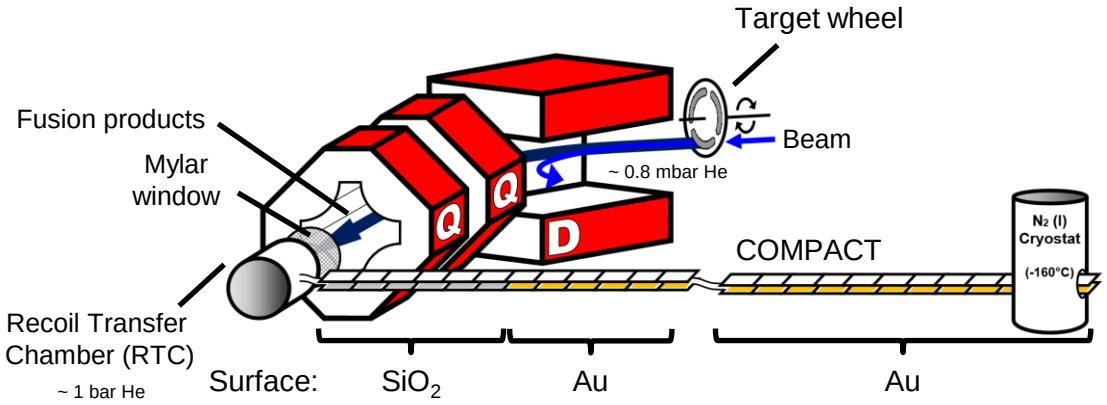


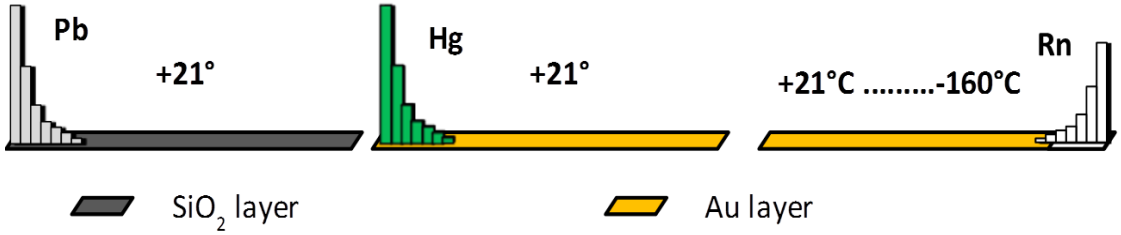
# Towards element 116 chemistry - The status of UniCell

**Jochen Ballof**

A. Yakushev, Y. Wei, M. Biljan, R. Cantemir, J. Krier, J. Kulawik, S. Löchner, F. Zielke, Ch. E. Düllmann

# SHE chemistry experiments



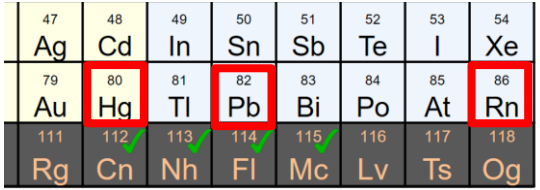




Typical gas-phase chemistry experiment:

- Probing interaction strength / „inertness“
- Adsorption time per encounter

$$\tau = \tau_0 \cdot \exp\left(-\frac{\Delta H_{ads}}{R \cdot T}\right)$$

- Comparison to homologues



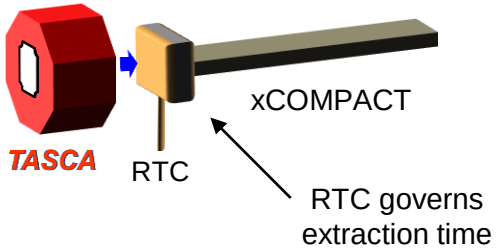

J. Ballof
Diploma Thesis 2014

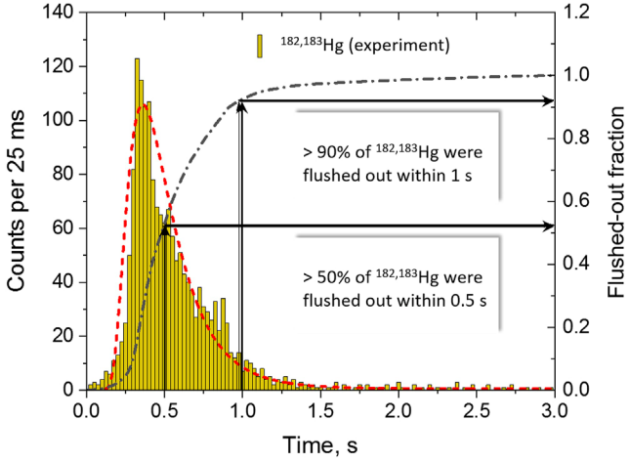
Yakushev *et al*, Inorganic Chemistry 53 (2014) 1624

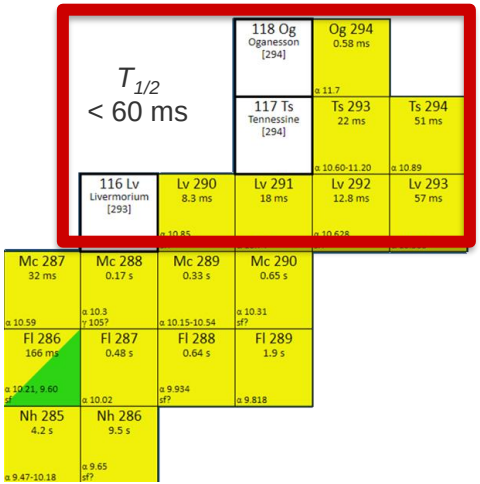
L. Lens *et al*.
Radiochim. Acta 106 (2018) 949

# Towards chemistry studies of $_{116}$Lv and $_{117}$Ts

- All known $_{116}$Lv and $_{117}$Ts isotopes have half-lives below 60 ms
- Current MiniCOMPACT + RTC setup needs ca. 500 ms extraction time

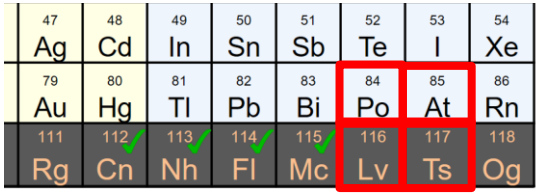


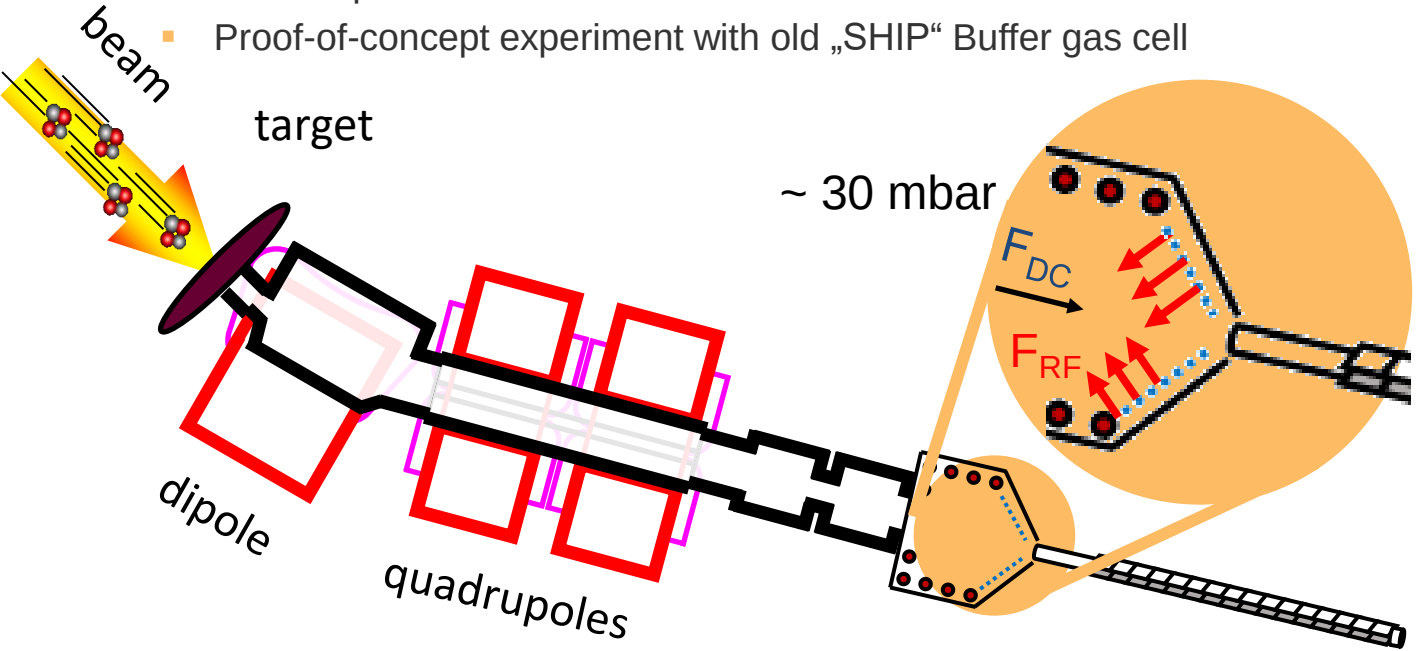

## Prerequisites for Lv or Ts studies

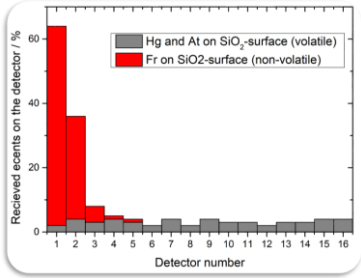
1) Development of a gas-stopping cell with shorter extraction time
2) Studies with homologues Po and At



# Towards faster extraction – Stopping Cell

- Replaceing RTC by existing Buffer-gas cell with ion funnel
- DC field accelerates ion -> faster extraction
- RF field prevents wall encounters
- Proof-of-concept experiment with old „SHIP“ Buffer gas cell



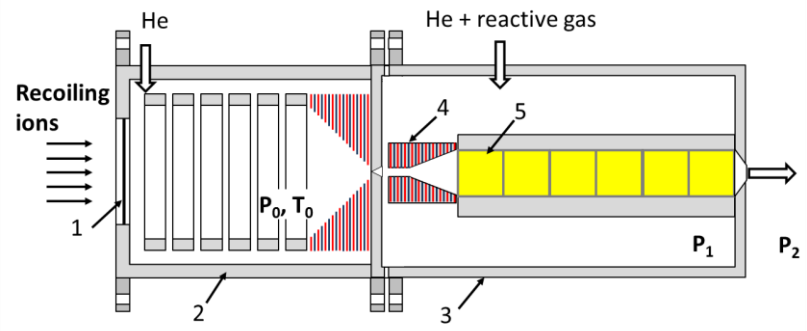

$\varepsilon_{extr}$ (Fr) = 24%

≈ 50 ms extraction time

S. Götz *et al.*, NIM A 165090 (2021)
S. Götz *et al.*, NIM B 27 (2021)

# Towards faster extraction – UniCell

## UniCell: High-density and faster extraction



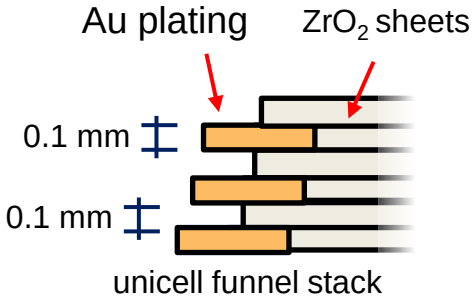

- Faster extraction by higher DC field
- Requires stronger RF repelling force
- High stopping efficiency at 1 bar

| Simulation SIMION / VARJET | |
|---|---|
| Extraction time | ~ 2 ms |
| Pressure | ~ 1 bar |
| Efficiency | ~ 100% |

limited by discharge-voltage ~200 $V_{pp}$

$$F_{RF} \propto \frac{1}{p^2}\frac{V_{rf}^2}{d^3}$$

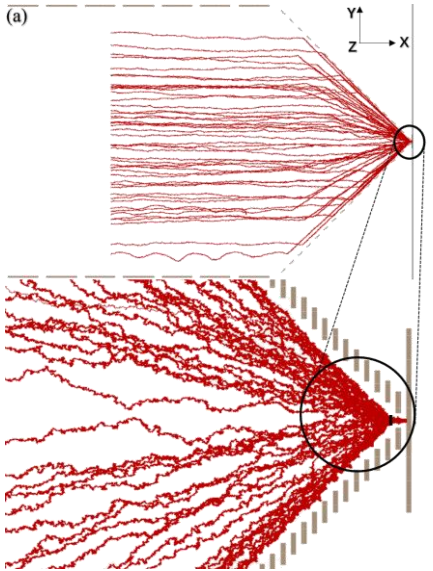
pressure electrode spacing

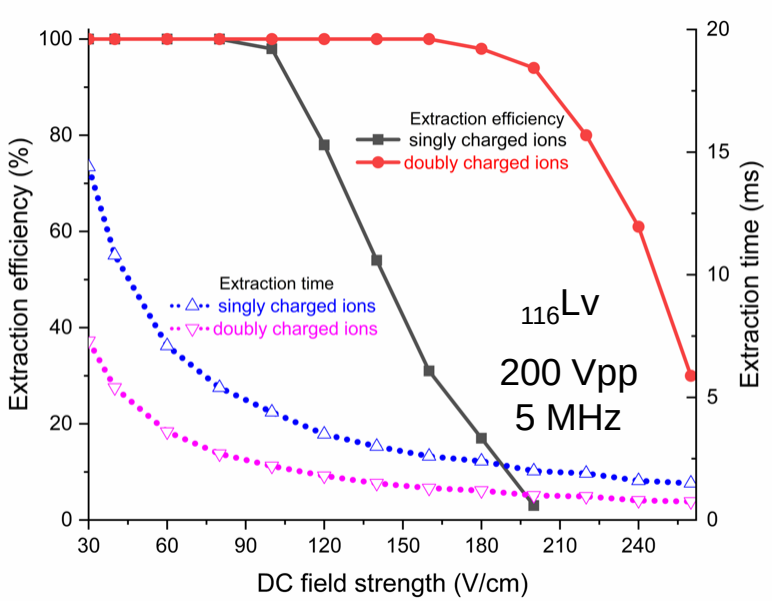



V. Varentsov, A. Yakushev, NIM A 940 (2019) 206

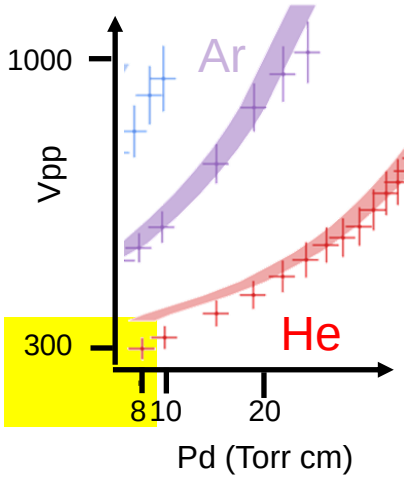
# UniCell-Simulations

- UniCell: ion trajectory simulations in SIMION
- SDS collission model (1 bar He)
- no directed gas flow




RF electrical breakdown
13 MHz, 0.13 mm gap

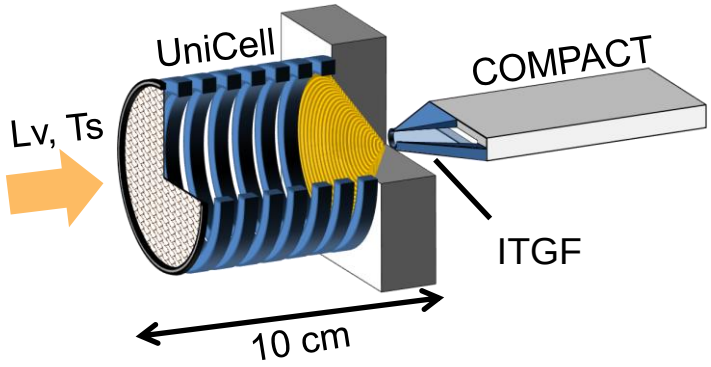



Woodruff et al, JINST P04022 (2020)

Yeqiang Wei et al, accepted for publication in NST (2025)

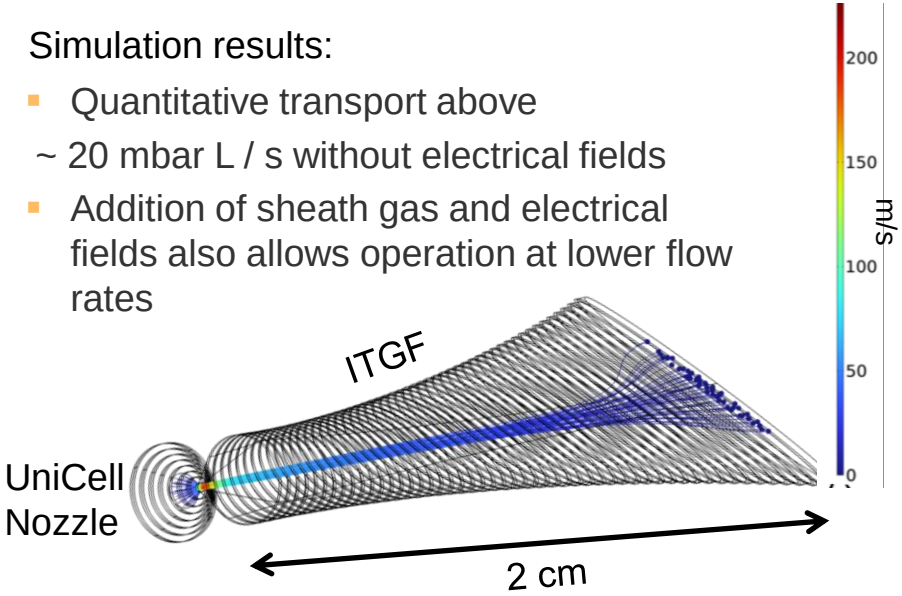
# ITGF Simulations

- Ion Transfer by Gas Flow device
- Interface between Unicell and COMPACT detector




Simulation results:

- Quantitative transport above
  ~ 20 mbar L / s without electrical fields
- Addition of sheath gas and electrical fields also allows operation at lower flow rates




- Gas-flow needs to be taken into account
- COMSOL-simulation of gas-flow (CFD) and ion transport (particle tracing)

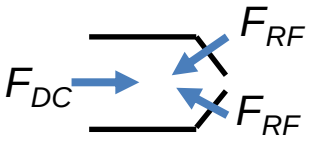
$$F = F_{\mathrm{el}} + F_{\mathrm{drag}} + F_{\mathrm{Brown}}$$

electric — viscous dampening — molecular diffusion

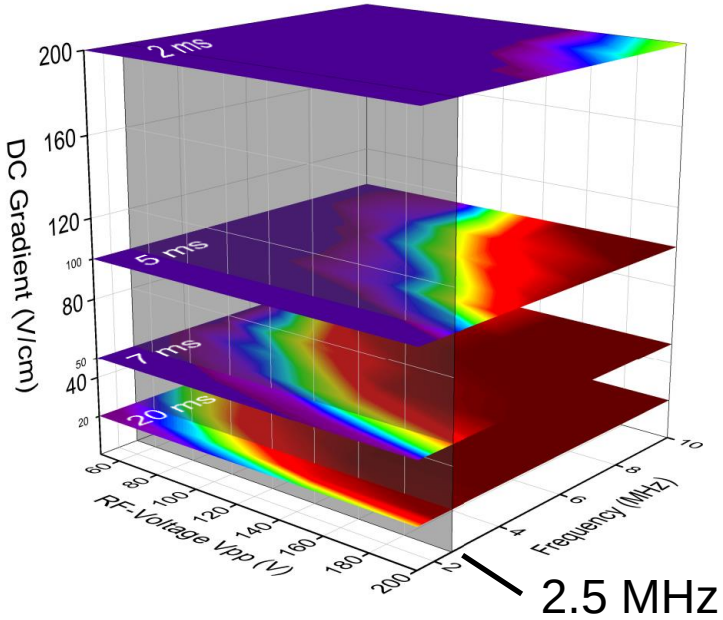
Yeqiang Wei et al, accepted for publication in NST (2025)

# Funnel Transmission $^{298}$Lv in extended parameter space

SIMION simulation of transmission efficiency in wider parameter range

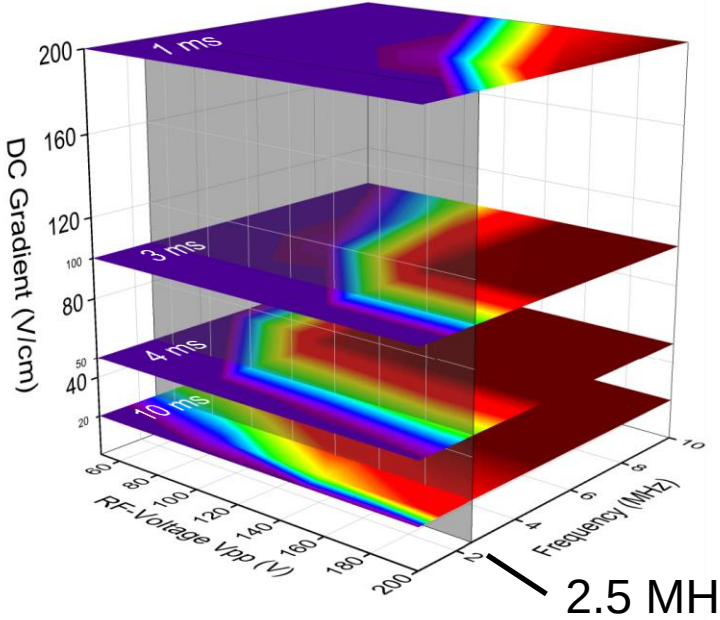



$^{298}$Lv charge 1+

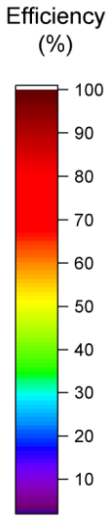



128 simulations, data interpolated

$^{298}$Lv charge 2+ (expected)



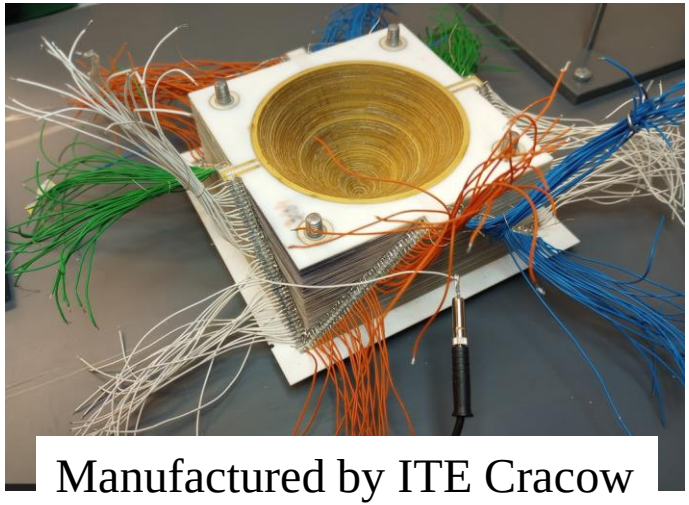

64 simulations, data interpolated




F. Zielke
Summer Student
(2024)

# UniCell – The ion funnel

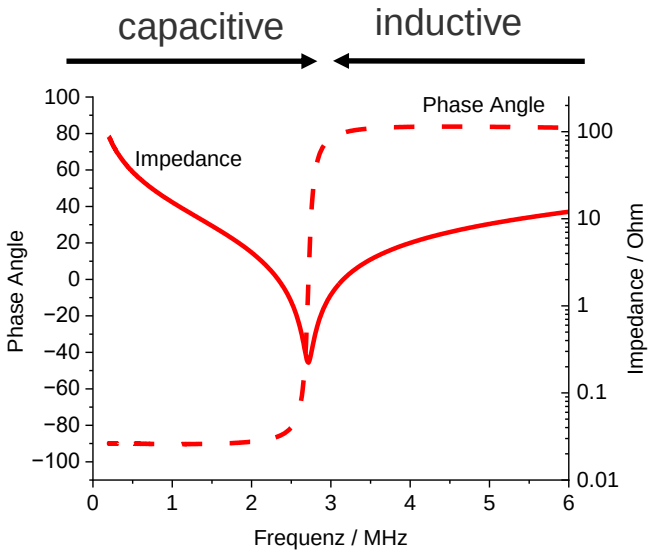
- Funnel made of ca. 350 $ZrO_2$ sheets
- 35 mm height
- Entrance diameter 7 cm



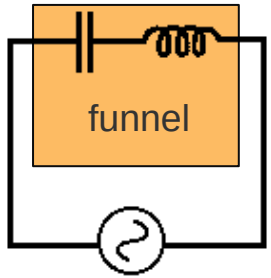
Manufactured by ITE Cracow

## Impedance Analysis

- Self-resonance at 2.7 MHz (electrical short)
- Typically, operation below self-resonant frequency

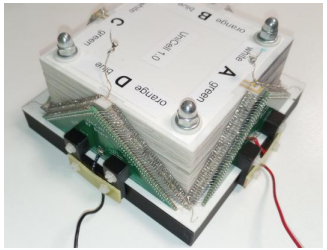


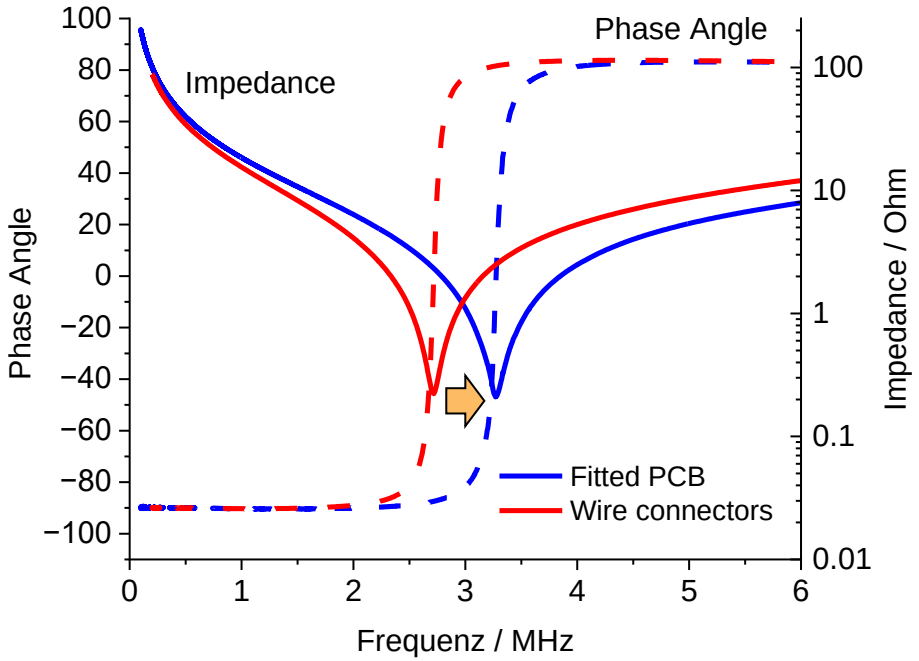

series resonant circuit



# UniCell – RF Interface PCB

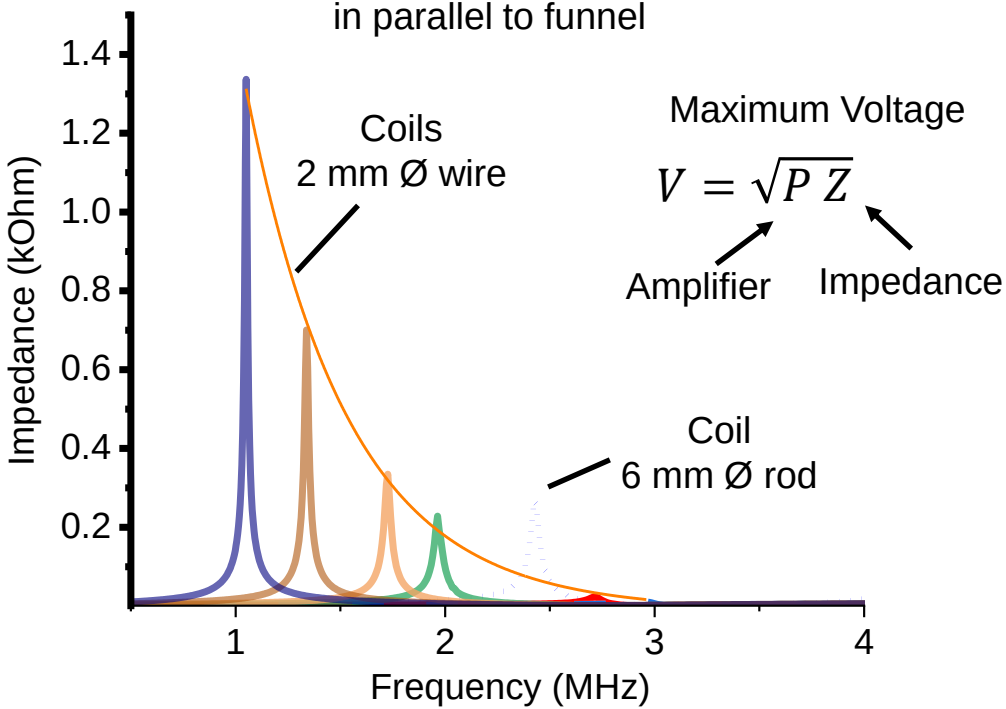
- Wire connectors on each plate replaced by coupling PCB
- RF coupled to funnel plates via 1.5 nF capacitors
- Self-resonant frequency shifted slighty to higher frequency 3.2 MHz



# UniCell – Benchtop testing

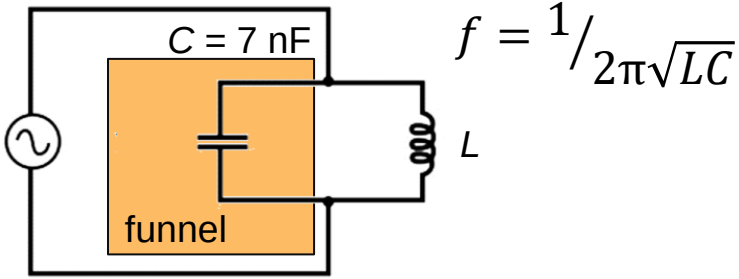
Measured impedance with different coils in parallel to funnel



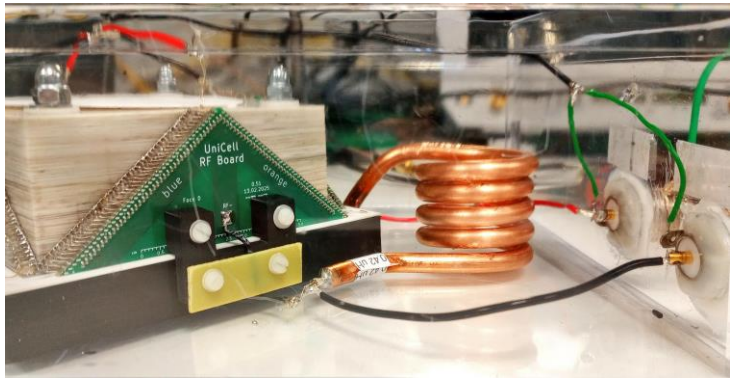

Maximum Voltage

$$V = \sqrt{P\,Z}$$

Amplifier — Impedance

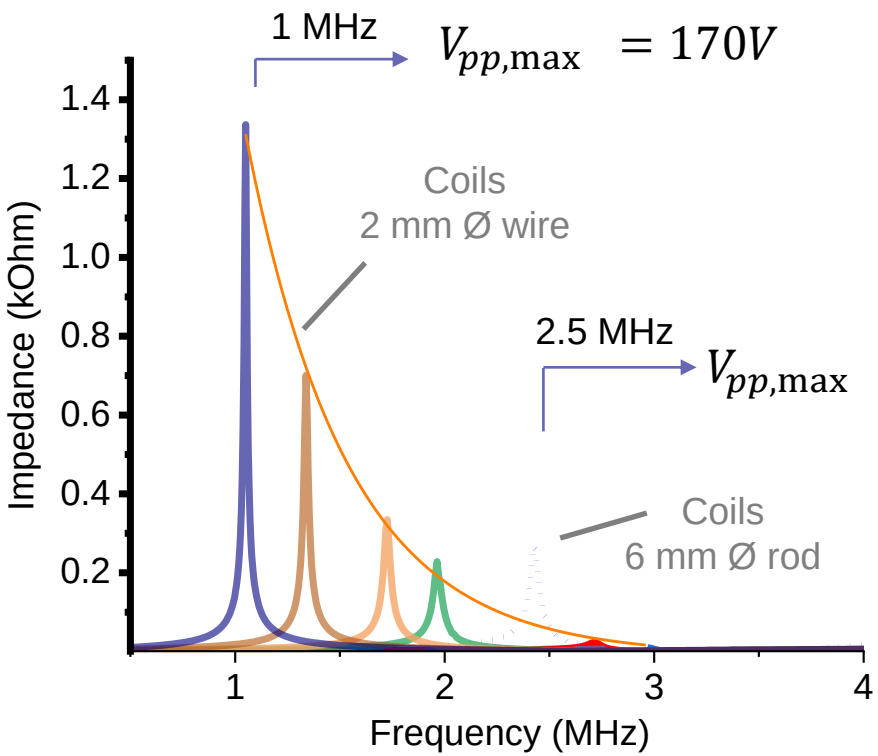


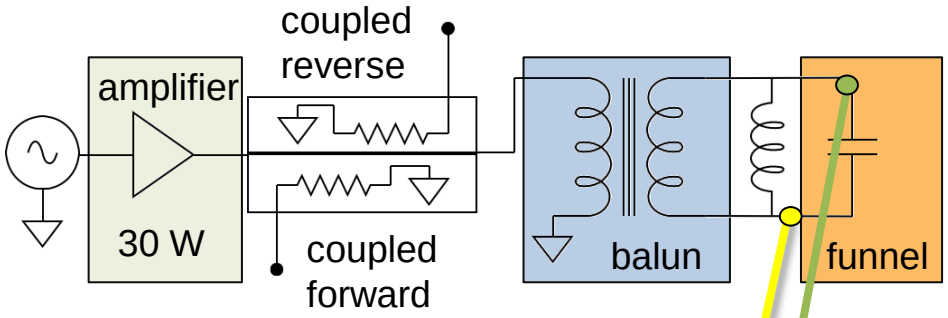

$$f = {}^{1}/_{2\pi\sqrt{LC}}$$

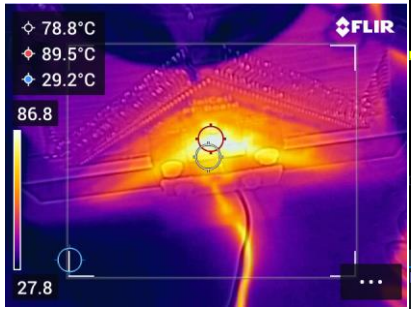


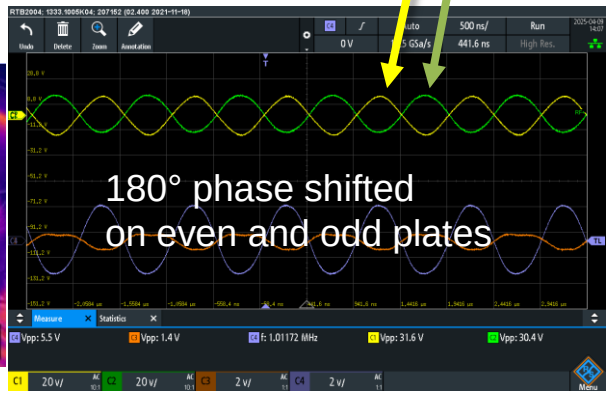

funnel with coil (6 mm Ø)

# UniCell – Benchtop testing - Measured RF Voltages



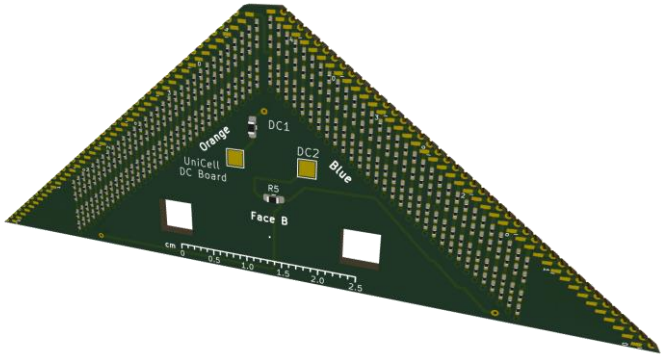



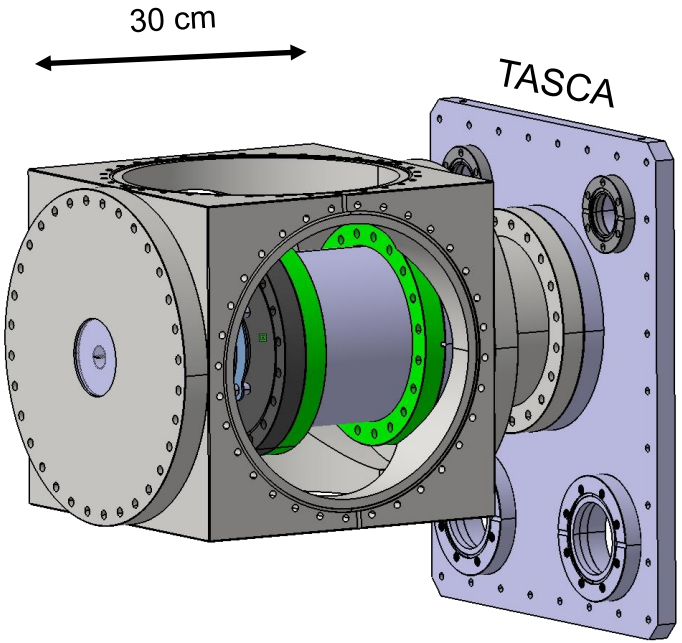
# UniCell – Summary and next steps

## Ongoing

- Design of RF/DC Mixing Board (Y. Wei)

  First prototype in production
- Heat management for RF board
- Mechanical design and fabrication of flanges
- Control system development



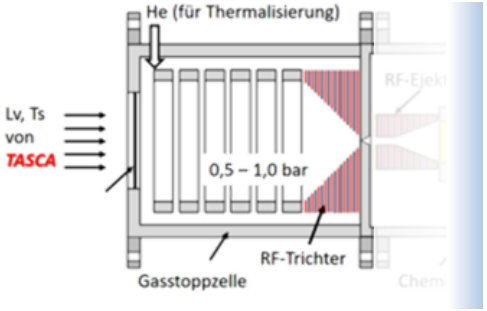



# UniCell – Outlook

Bundesministerium für Bildung und Forschung

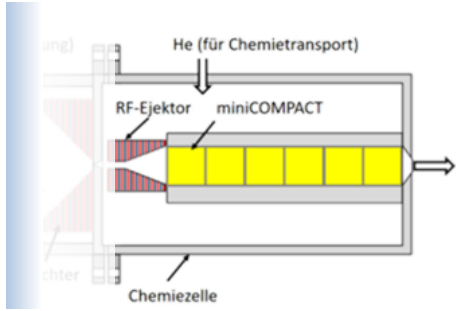
## UniCell

**Uni**versal gas stopping **cell**




## Phase 1

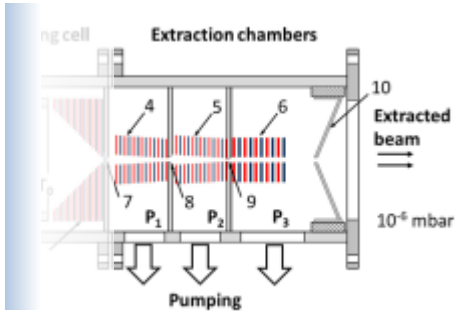
Fast stopping and extraction




## Phase 2

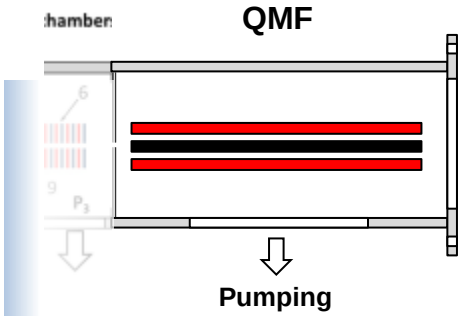
ITFG – Chemistry interface

- Chemistry-experiments at ~ 0.3 – 1 bar
- In-design / under construction now




## Phase 3

Vacuum interface




## Phase 4

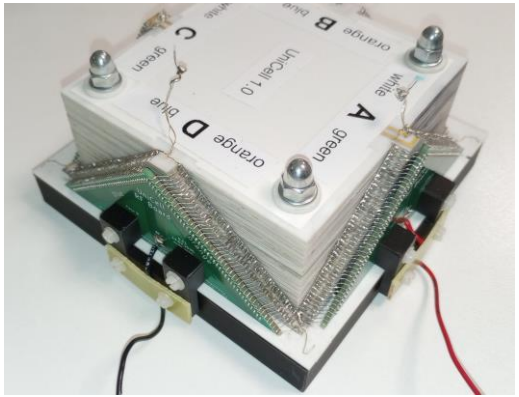
Mass filter

- Experiments in vacuum
- Mass-resolved (m/q) SHE beams

# UniCell – Summary

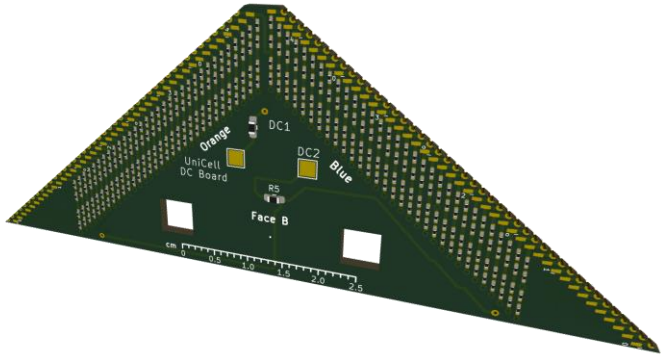
## Status

- Ion funnel with 175 electrodes and 0.1 mm electrode spacing fabricated
- Efficient extraction at 2.5 MHz between 10 and 20 ms expected
- RF-Voltages up to 90 Vpp measured, with improved setup 200 Vpp in reach




## Outlook

- Optimizations to to reach 200 Vpp and integration of DC mixing board
- Finalize mechanical design
- First commissioning in Offline Test



Thank you!