Simulations, design and commissioning of the debuncher prototype for the EMILIE project

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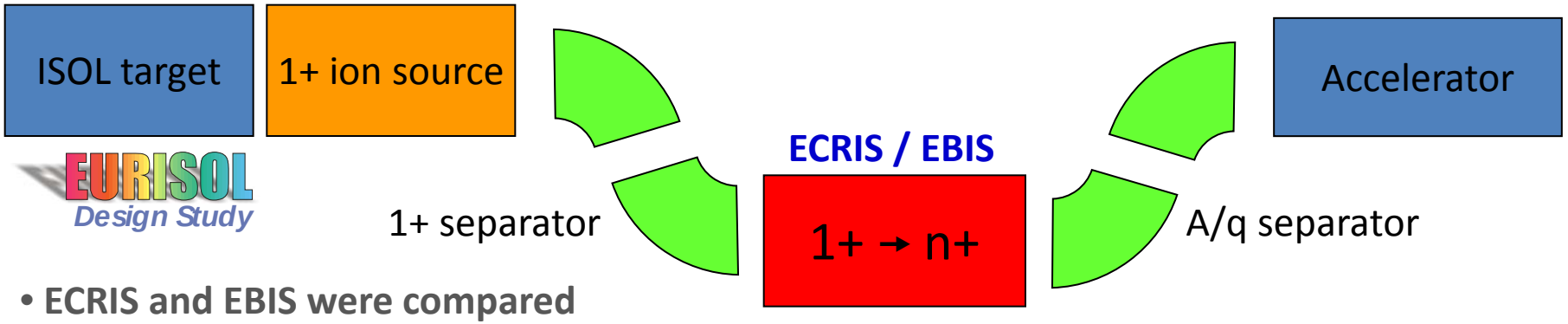
Evaluation of charge breeding options for EURISOL (FP6)

- Matching the A/q acceptance of the post-accelerator
- Higher charge states = more compact post-accelerator and / or higher energies



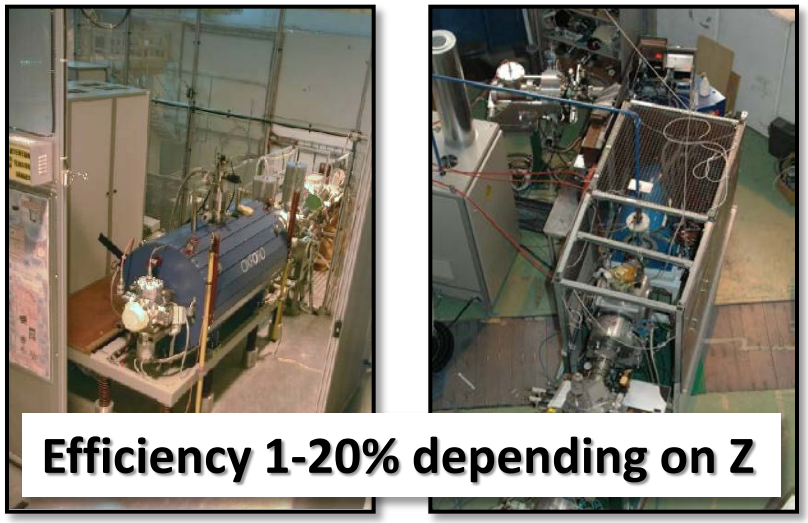
- ECRIS and EBIS were compared
- Advantages and drawbacks were identified

REX-EBIS

Operational at
REX-ISOLDE

$^{136}Sn \sim 10^5$ ions/s

EBIS pros
- Higher charge states
- Higher purity



Phoenix ECRIS

Test stand at
LPSC and ISOLDE

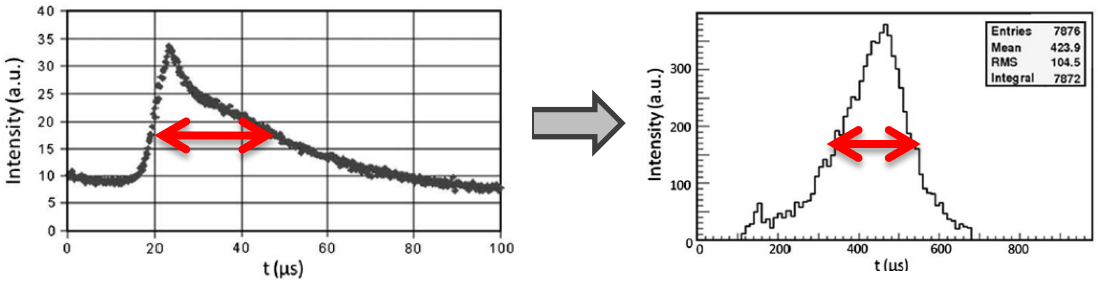
$^{132}Sn > 10^{13}$ ions/s

ECRIS pros
- No space charge limit
- CW device

P. Delahaye, O. Kester, C. Barton, T. Lamy, M. Marie-Jeanne, F. Wenander, Eur. Phys. J. A 46 (2010) 421

Extraction from EBIS charge breeders and EMILIE WP2

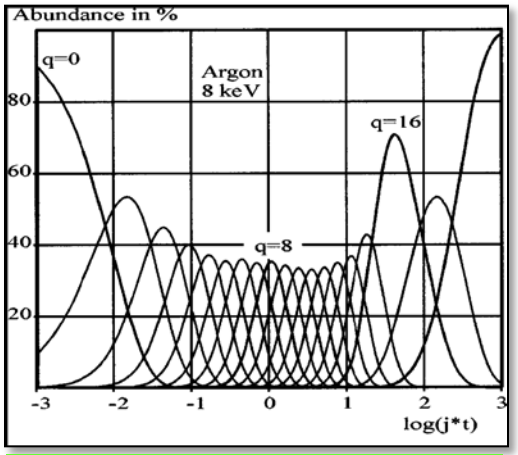
Extraction modes from REXEBIS



FWHM ~30 μs

FWHM ~400 μs

D. Voulot et al., Nucl. Instr. Meth. Phys. Res. B 266 (2008) 4103–4107



400 μs in every 40-400ms!

EBIS challenges

For mid-term ISOL facilities time structure is the prime issue before space charge limitations

⇨ **Large dead times, pile-ups and fake coincidence problems**

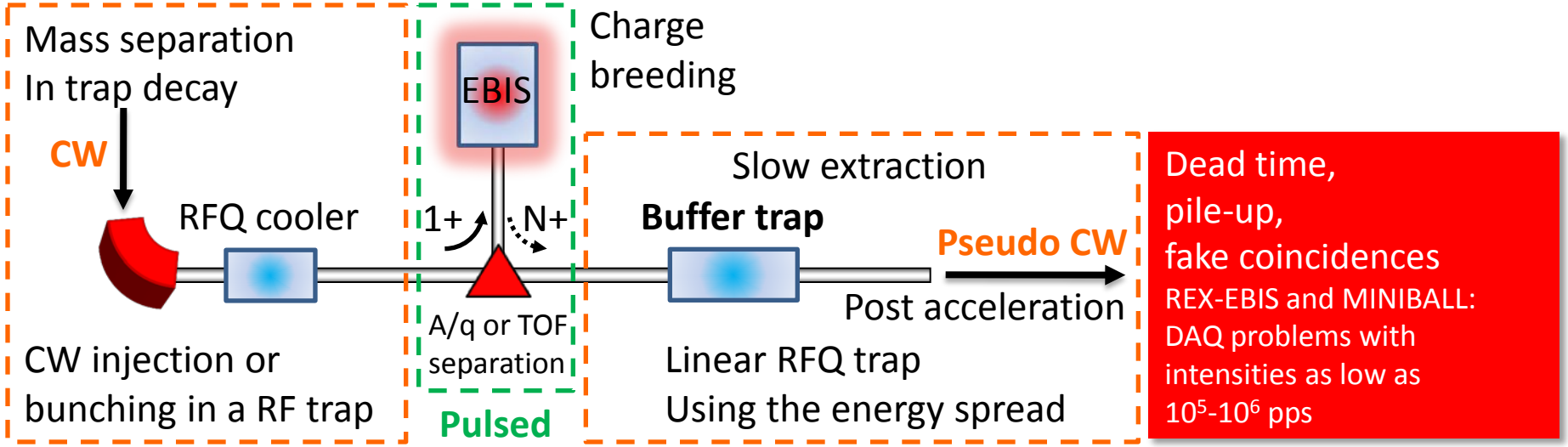
REX-EBIS and MINIBALL: data acquisition problems with intensities as low as 10^5-10^6 pps

EMILIE debuncher project (WP2)

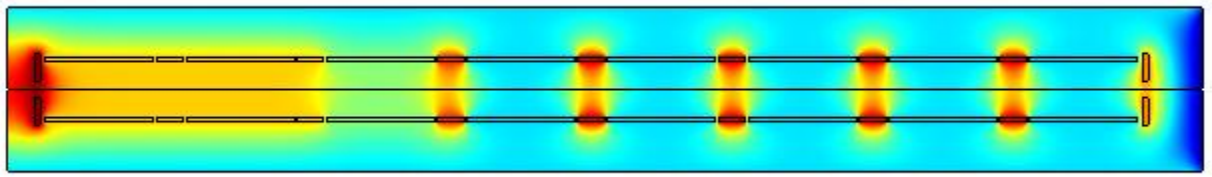
Transformation of pulsed EBIS *n+* beams into continuous wave (CW) beams for operation at higher beam intensities

- **Simulations and main characteristics**
- **Mechanical design and electronics**
- **Prototype building and testing**
- **Commissioning experiments**

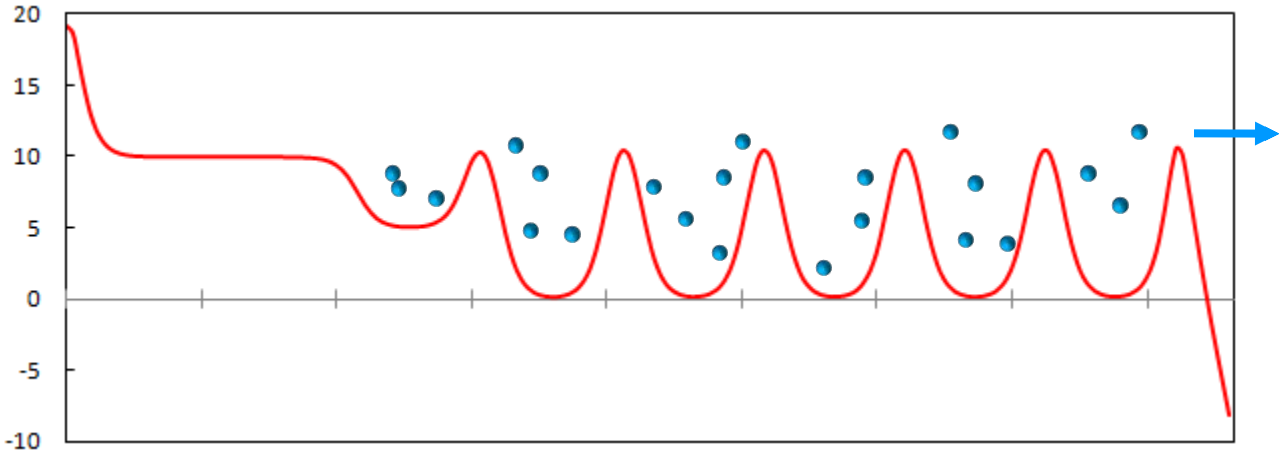
Ion beam debuncher – operation principles



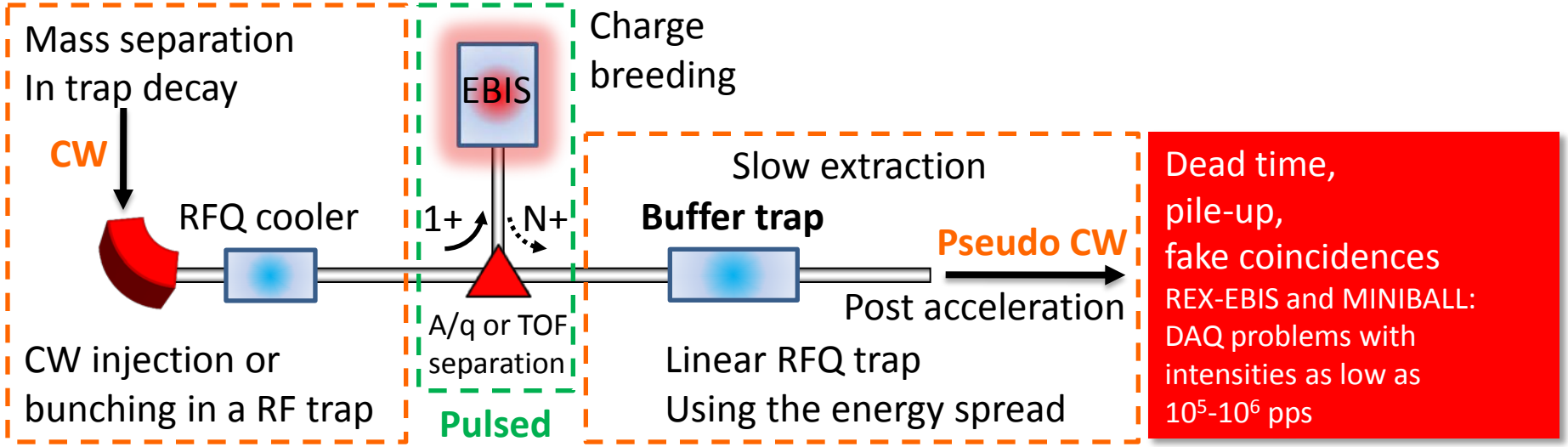
No buffer gas, UHV design



DC for axial + RF for radial trapping



Ion beam debuncher – operation principles



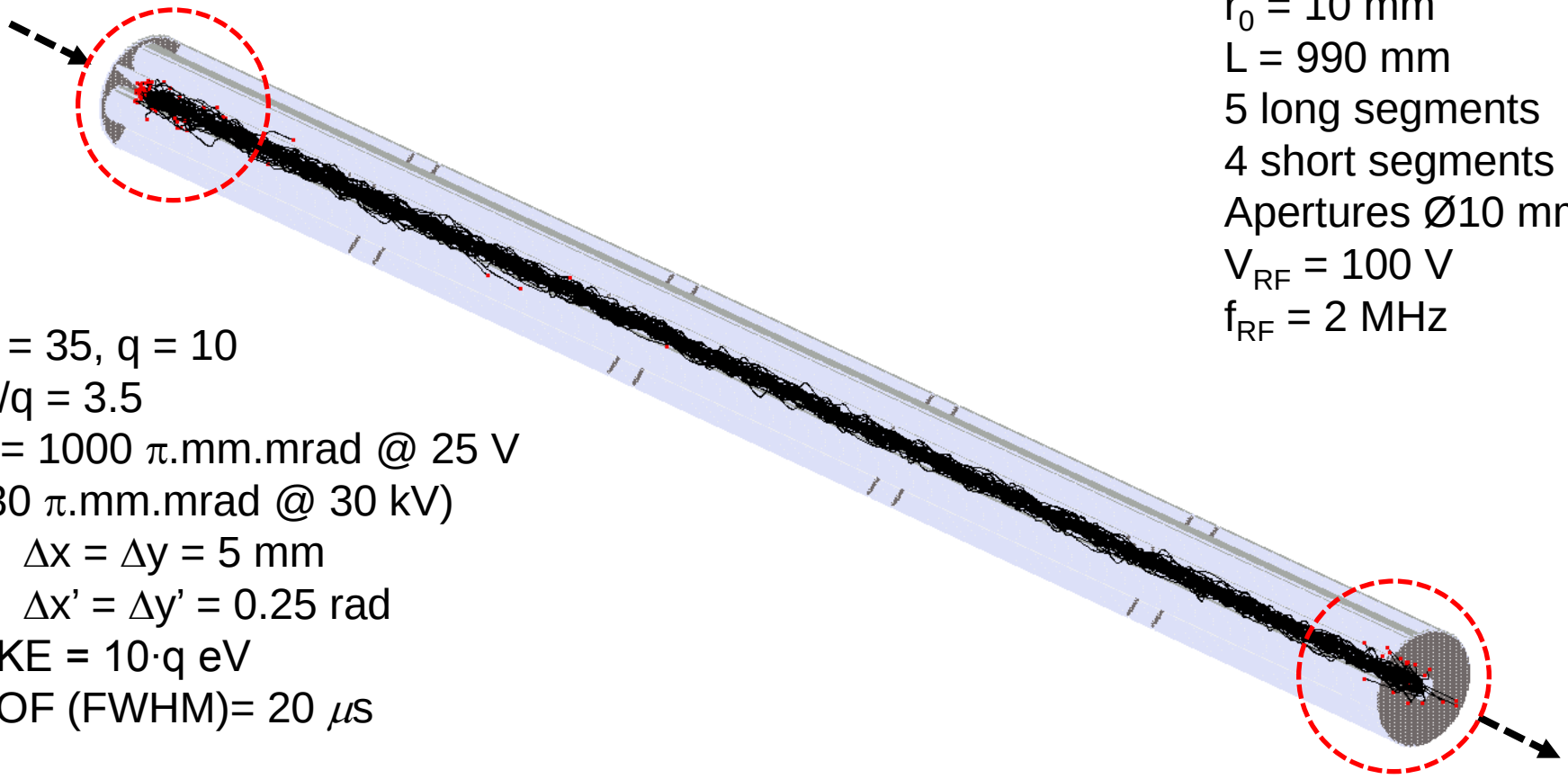
DC for axial + RF for radial trapping

- CW beams using

1) Injection in a long trapping area (flight time = injection pulse duration)
2) Segmentation for forming “drawers” by raising barrier potentials
3) E-spread for slow extraction of the bunches from the buffer trap one after the other

Segmentation allows for a lot of flexibility
Many DC programs to be investigated and compared for a “perfect CW”

Results from preliminary simulations

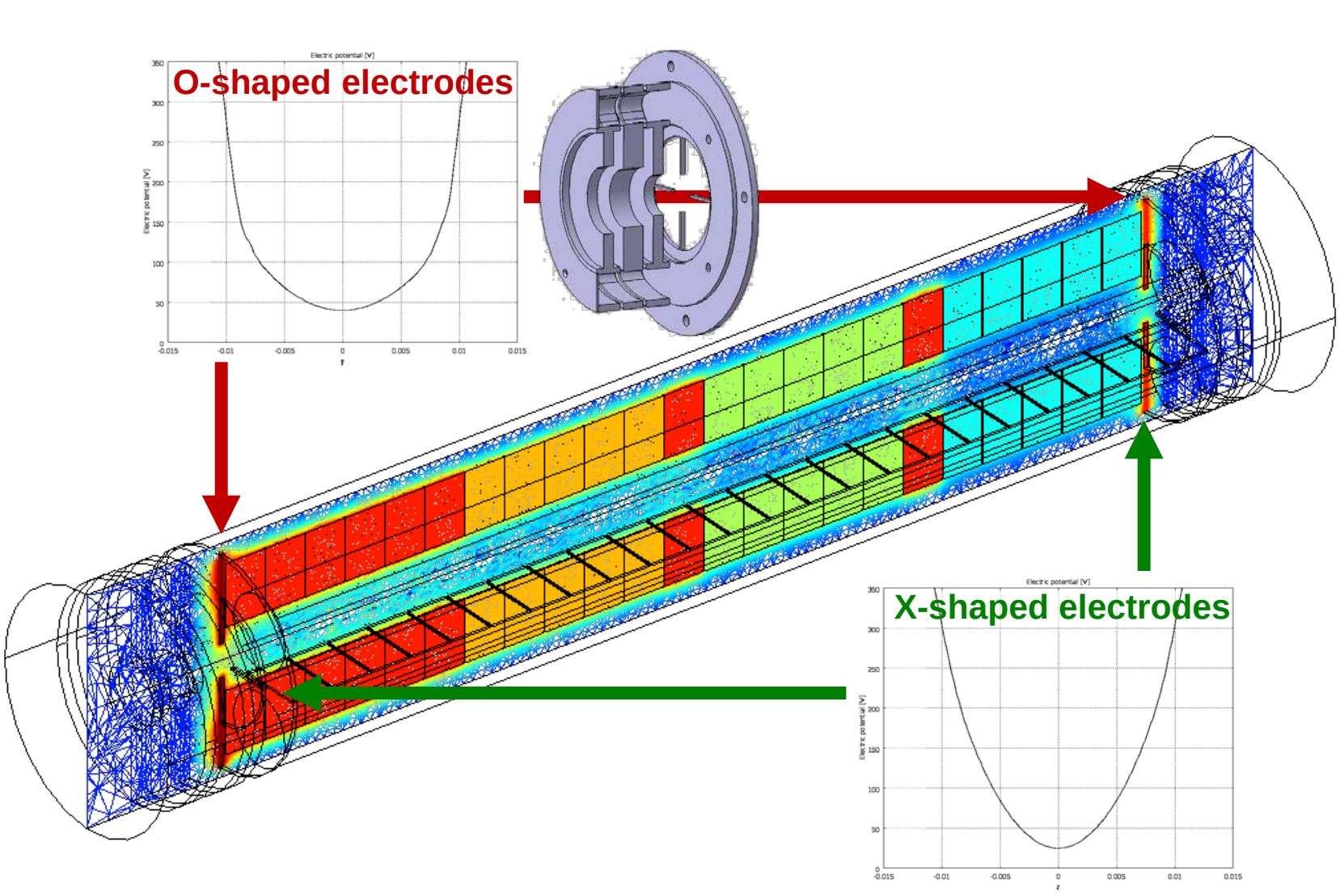


r_0 = 10 mm
L = 990 mm
5 long segments
4 short segments
Apertures Ø10 mm
V_{RF} = 100 V
f_{RF} = 2 MHz

A = 35, q = 10
A/q = 3.5
ε = 1000 π.mm.mrad @ 25 V
(30 π.mm.mrad @ 30 kV)
$\Delta x = \Delta y$ = 5 mm
$\Delta x' = \Delta y'$ = 0.25 rad
ΔKE = 10·q eV
TOF (FWHM)= 20 μs

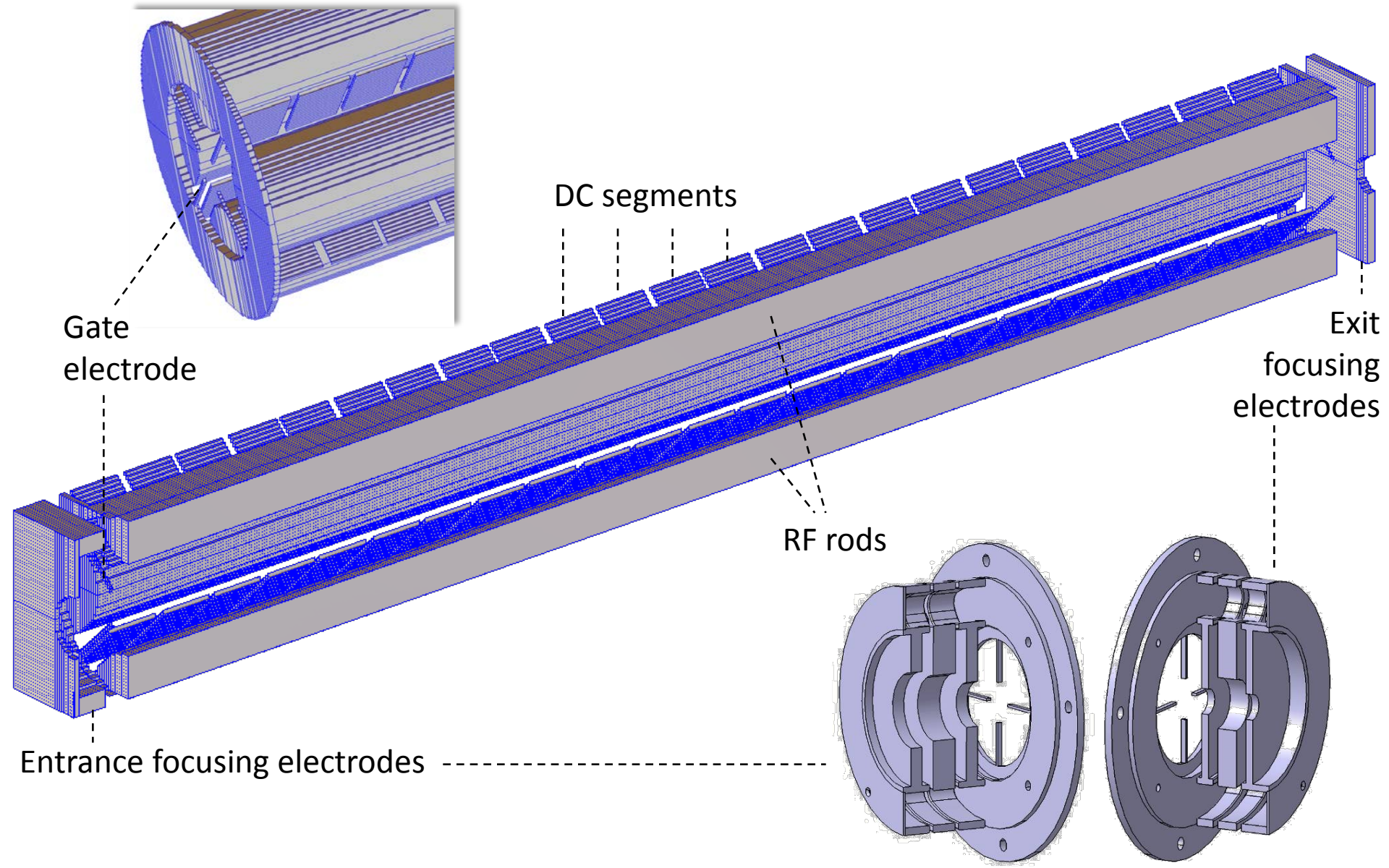
→ Good knowledge of TOF and KE distributions desired

Simulations and main characteristics

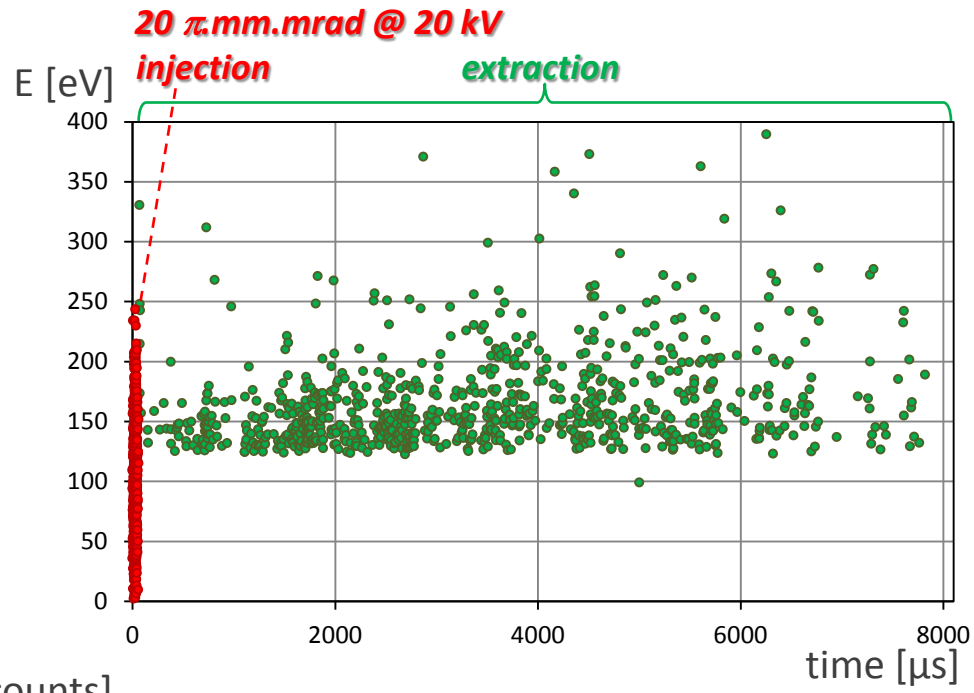


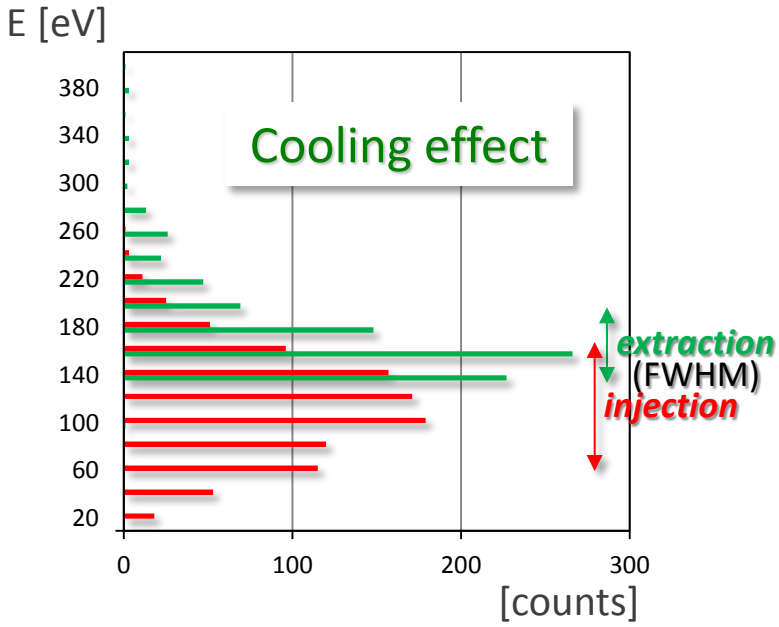
- Calculation of the potentials inside the trap volume
- Comparison of two designs of the gate electrodes

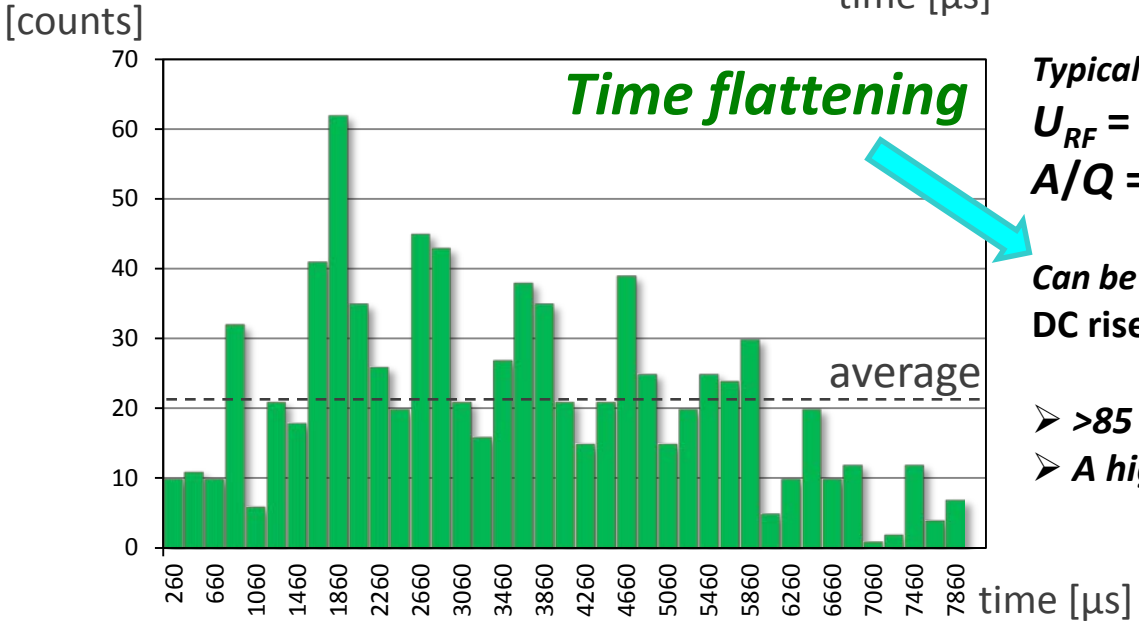
Simulations and main characteristics



Simulations with SIMION – results







Typical settings:

U_{RF} = 400 V, f_{RF} = 4 MHz, T_{cycle} = 8000 µs,
A/Q = 3.5, ΔE = 10.Q eV , ΔTOF = 50 µs.

Can be flattened further by

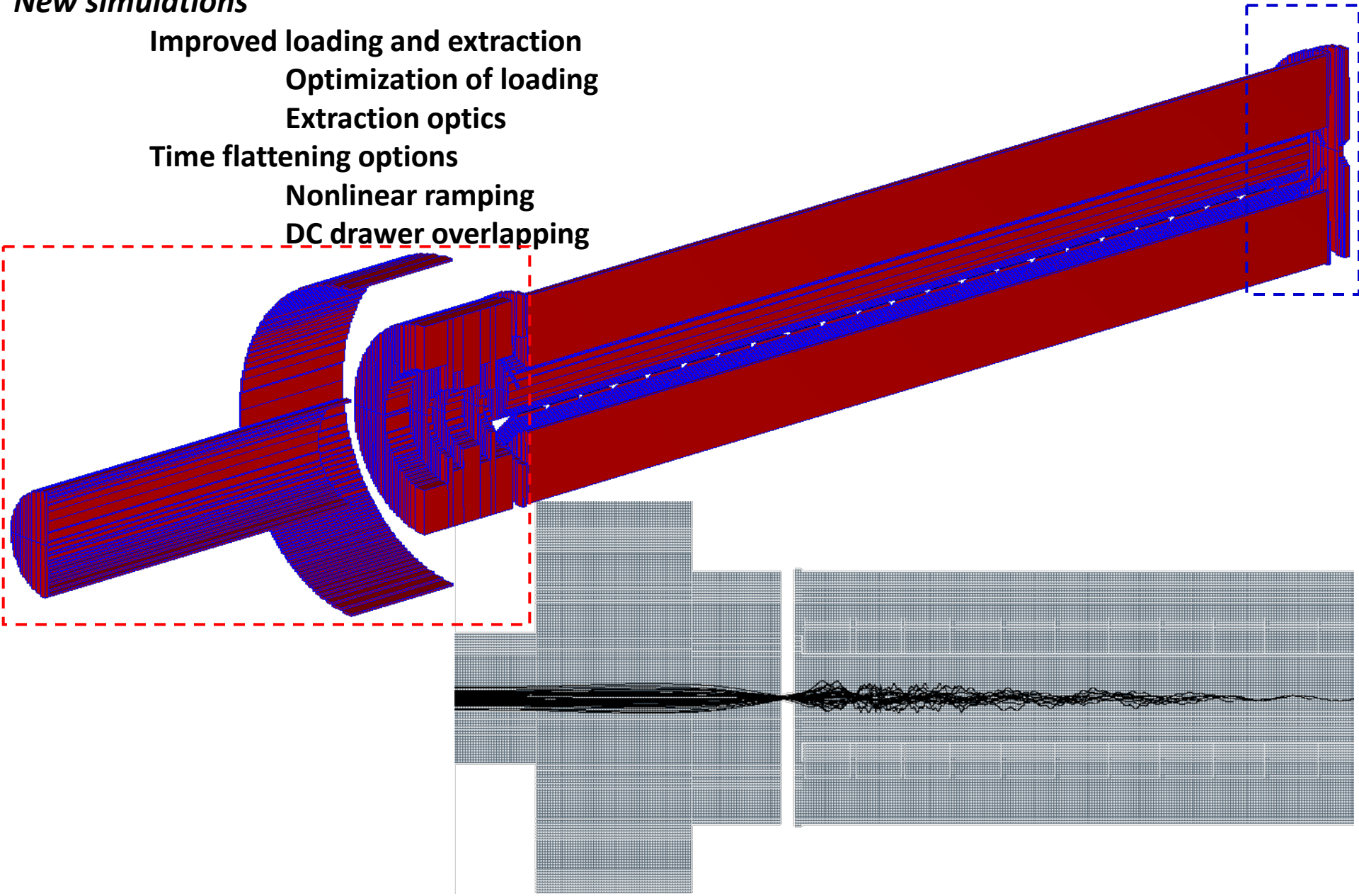
DC rise time, overlapping, number/size of drawers

- ***>85 % transmission for a 45 cm long debuncher***
- ***A higher energy spread would require***
  - ***→ longer debuncher***
  - ***→ stronger confinement***

More simulations with SIMION – results 2013

New simulations

- Improved loading and extraction
  - Optimization of loading
  - Extraction optics
- Time flattening options
  - Nonlinear ramping
  - DC drawer overlapping



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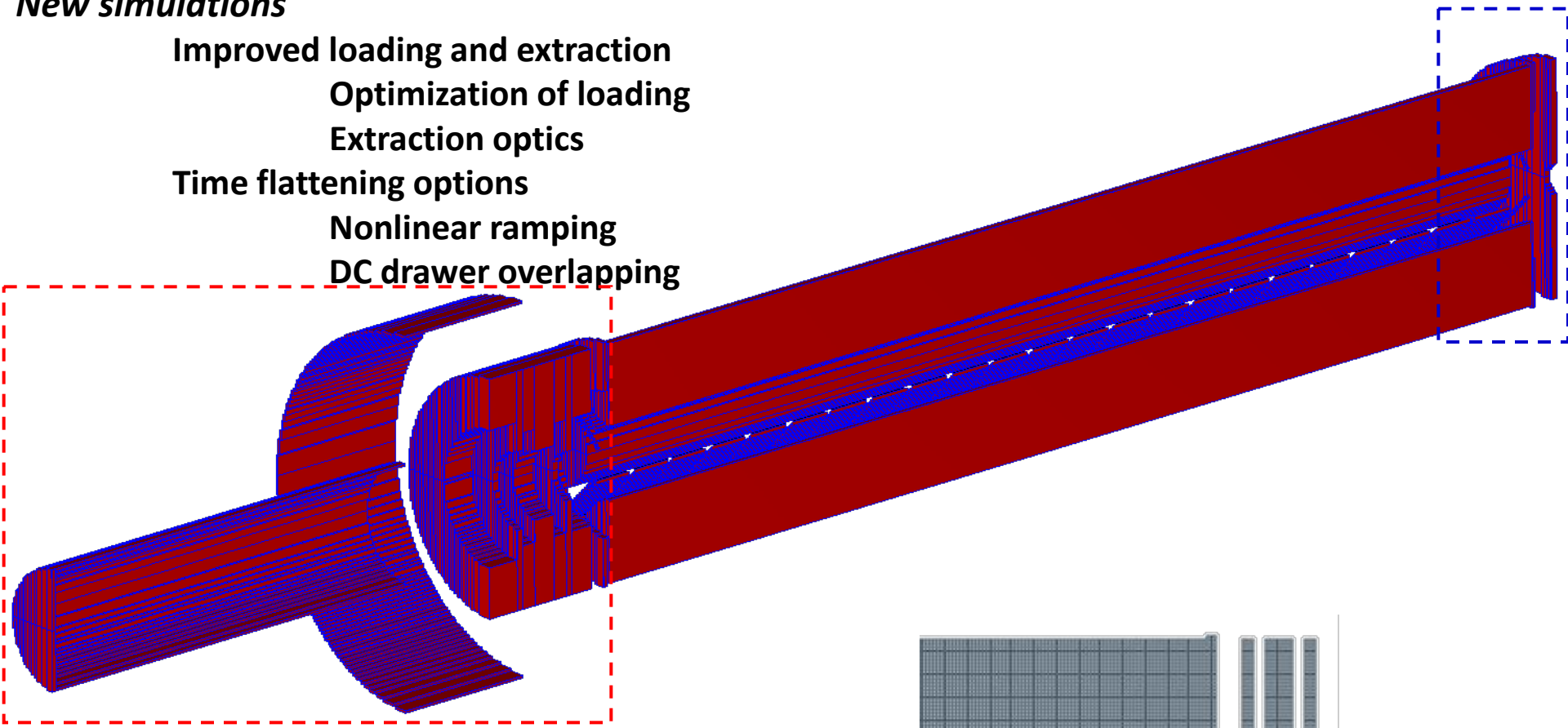

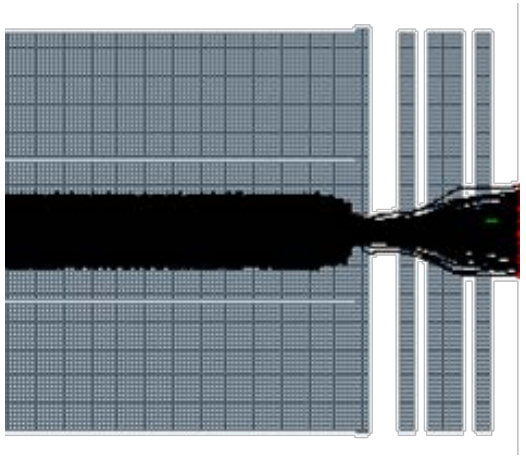

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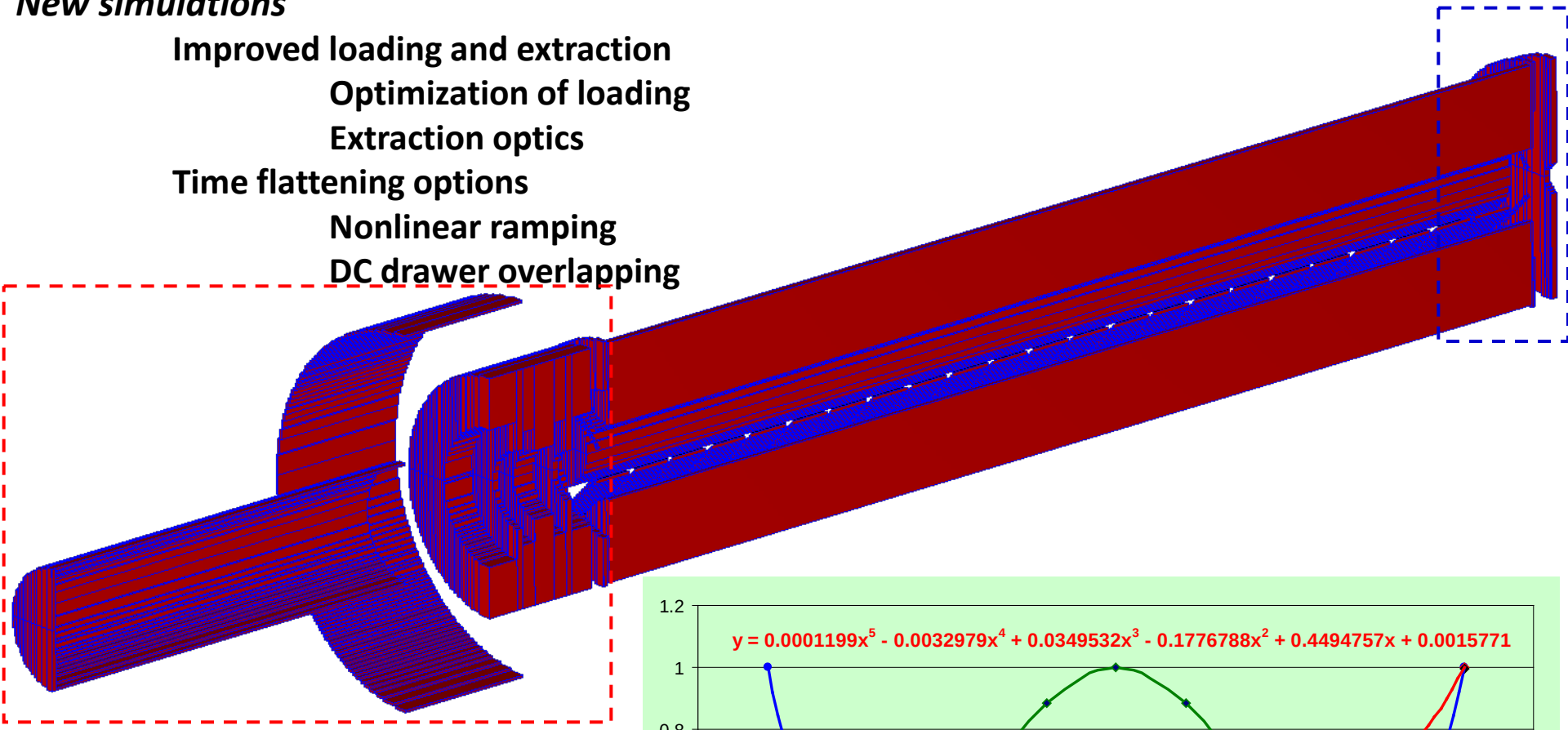
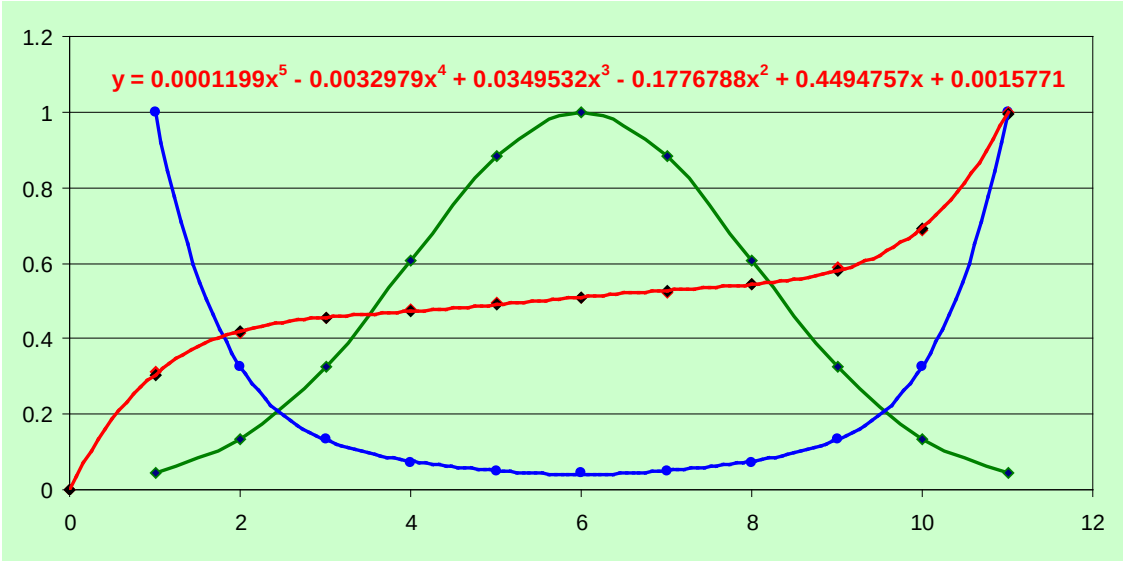
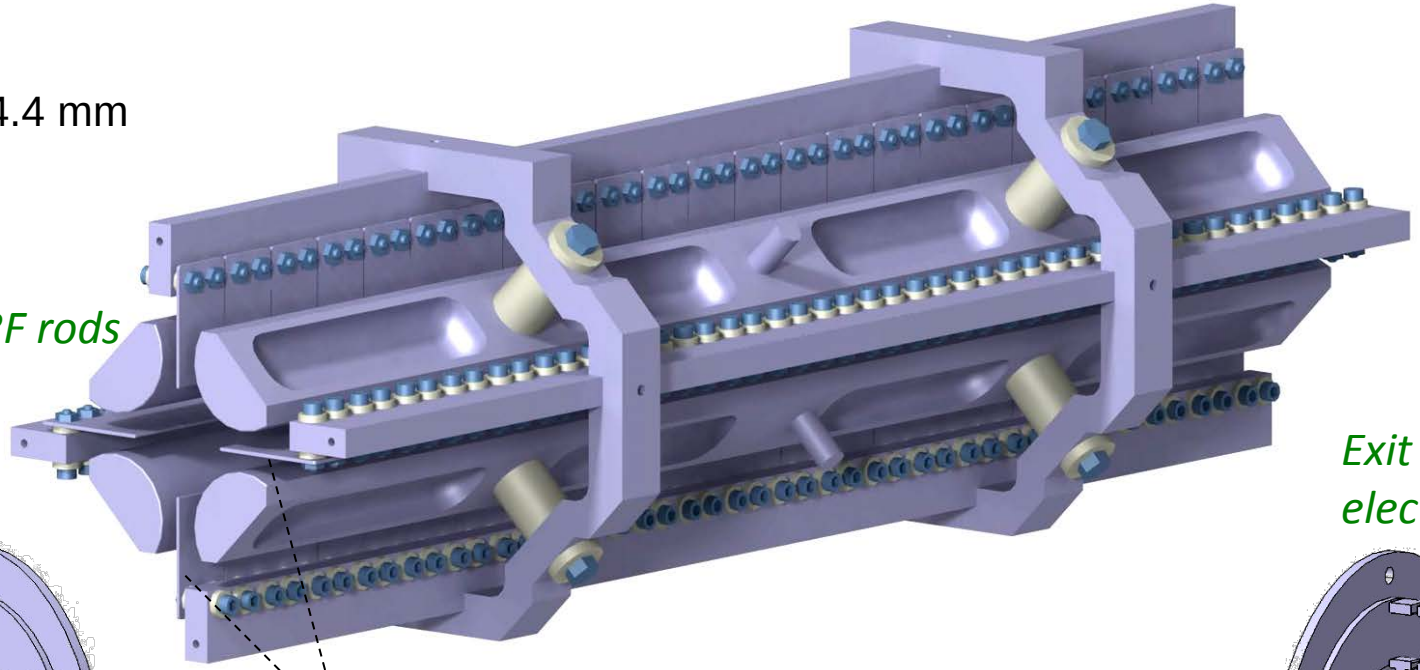


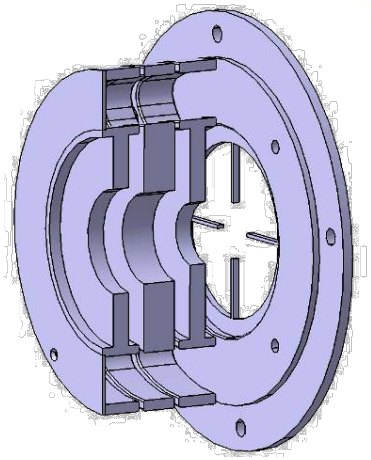


Design, manufacturing, and assembly

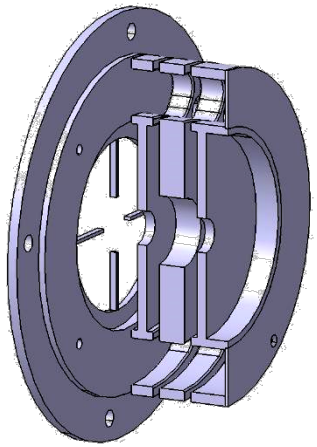
R_0 = 15 mm
RF rods Ø34.4 mm



Entrance electrodes



Exit electrodes



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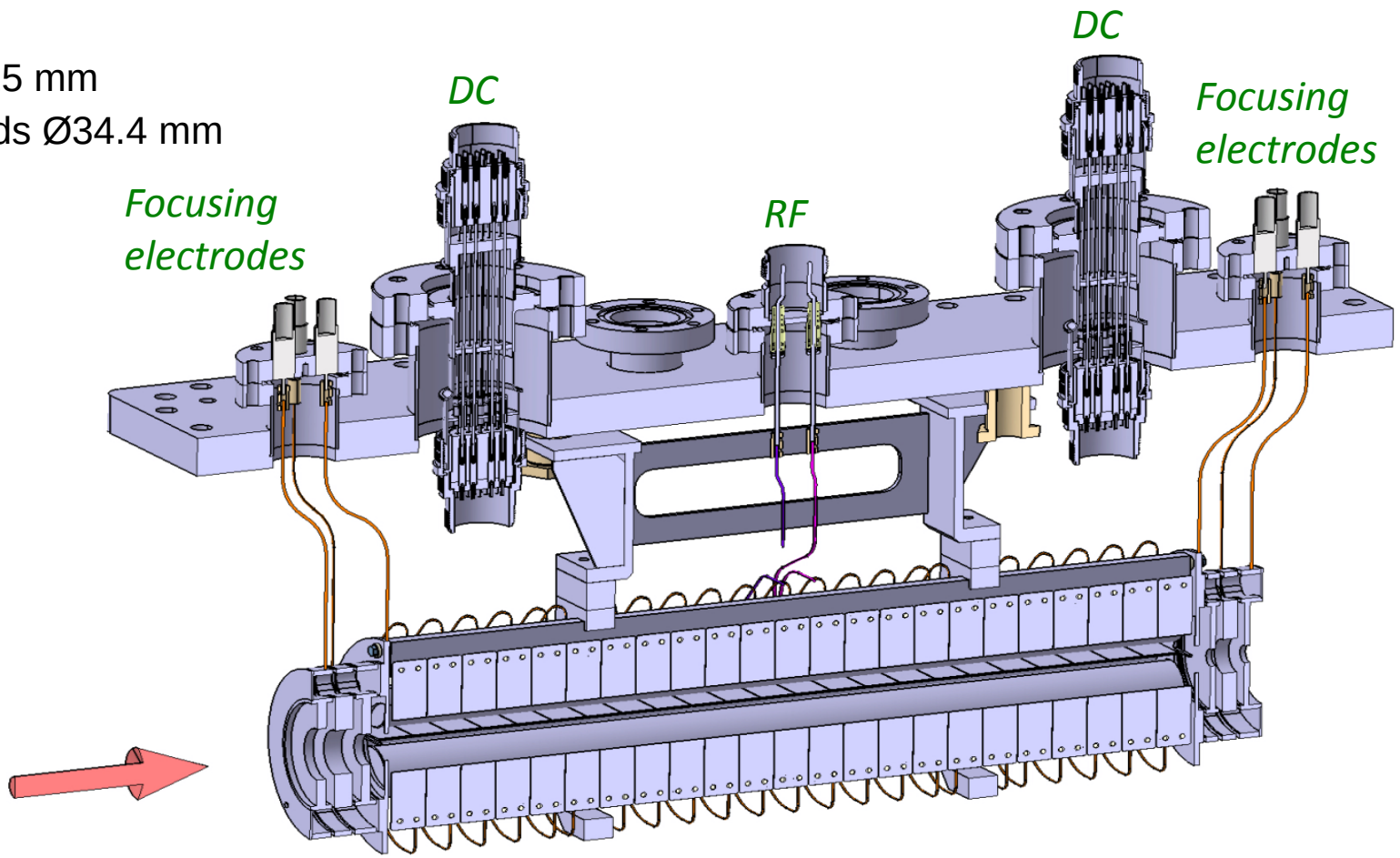
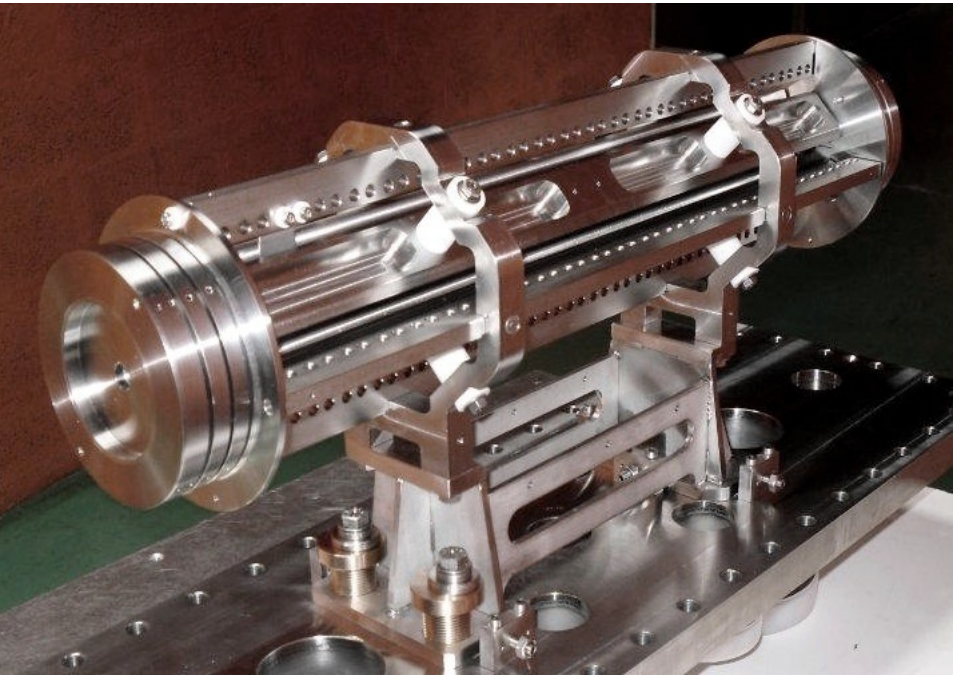
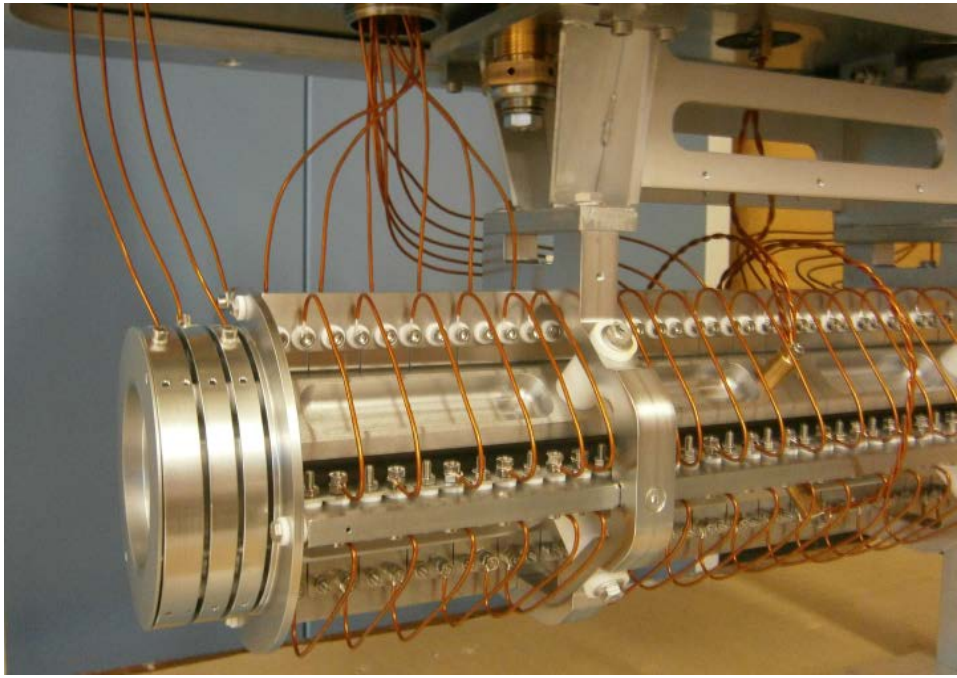


Design, manufacturing, and assembly

Trap structure was built and assembled at LPC Caen already in 2012

Electronics: RF generator, AWGs, RF and DC amplifiers (details by J.-F. Cam)





Tests at SHIRaC2, LPC Caen in 2015 with singly charged ions

Tests at GANIL after 2016 with ECRIS n+ chopped beams (?)

Other sites (?)

Design, manufacturing, and assembly

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Electronics: RF generator, AWGs, RF and DC amplifiers (details by J.-F. Cam)

2 x 4 chn Arbstudio AWG

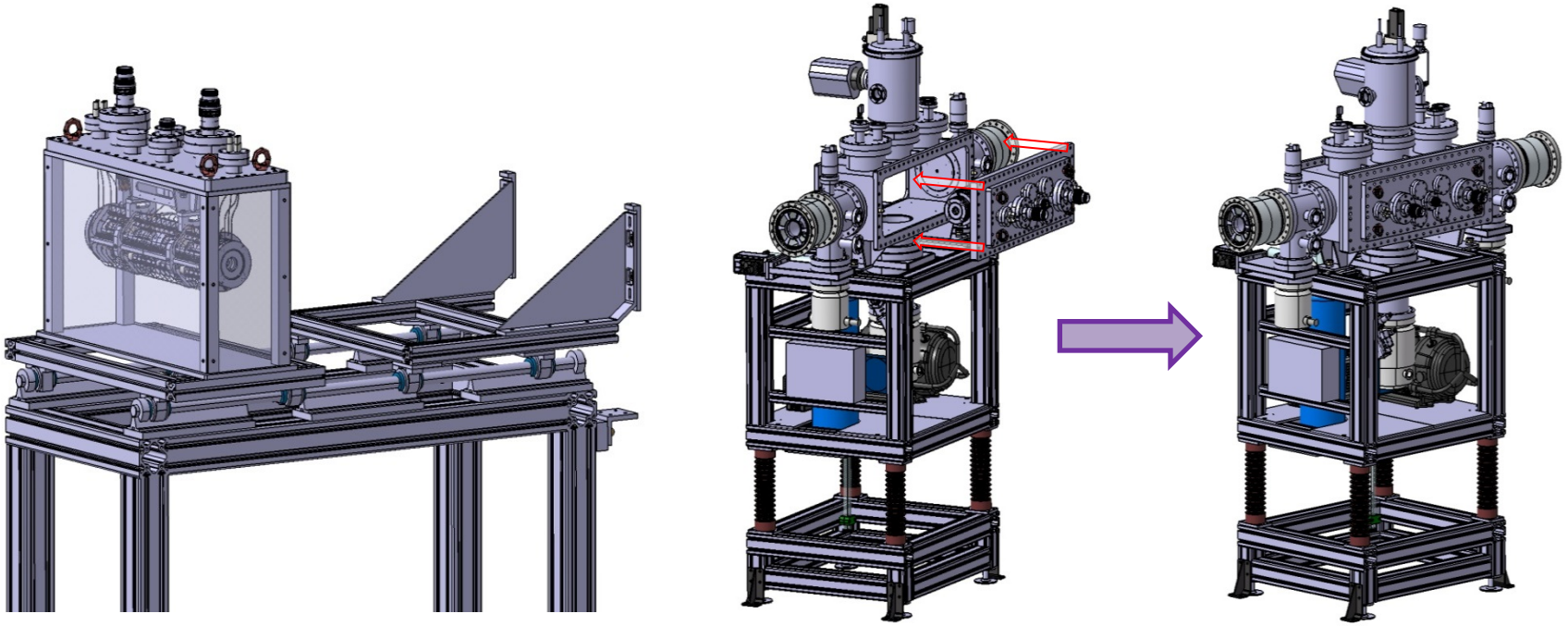
8 channel DC amplifier

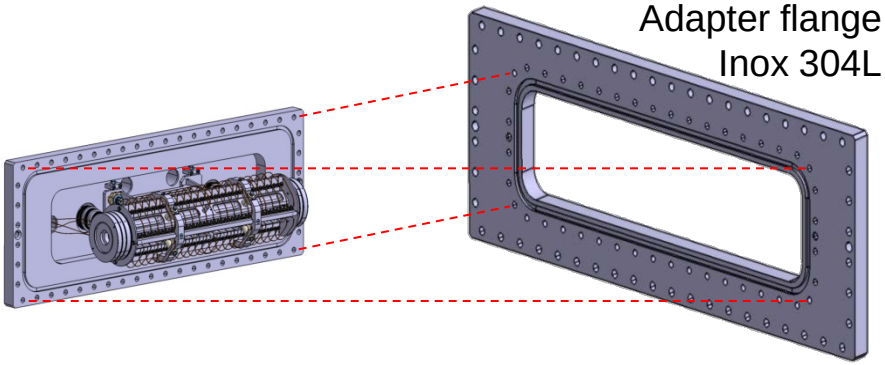
Tests at SHIRaC2, LPC Caen in 2015 with singly charged ions

Tests at GANIL after 2016 with ECRIS n+ chopped beams (?)

Other sites (?)

EMILIE debuncher at SHIRaC2 test bench

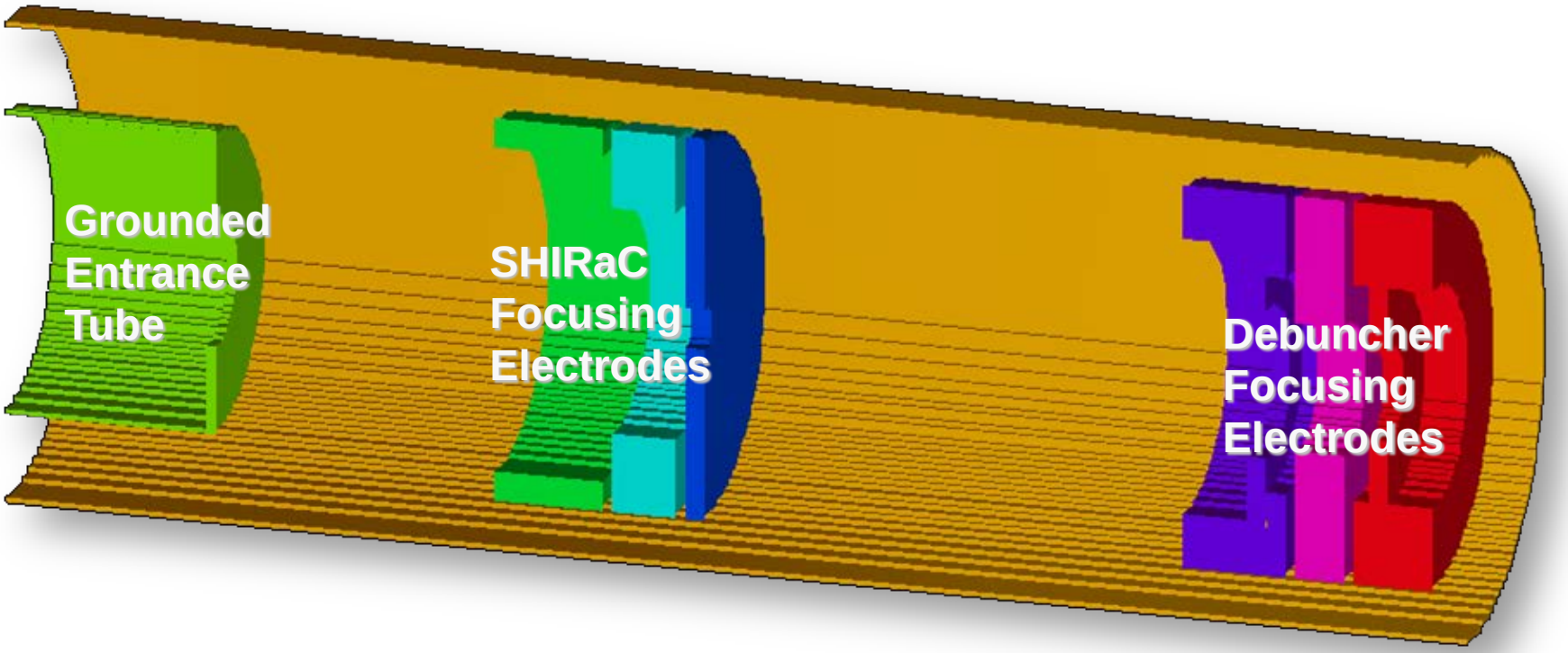




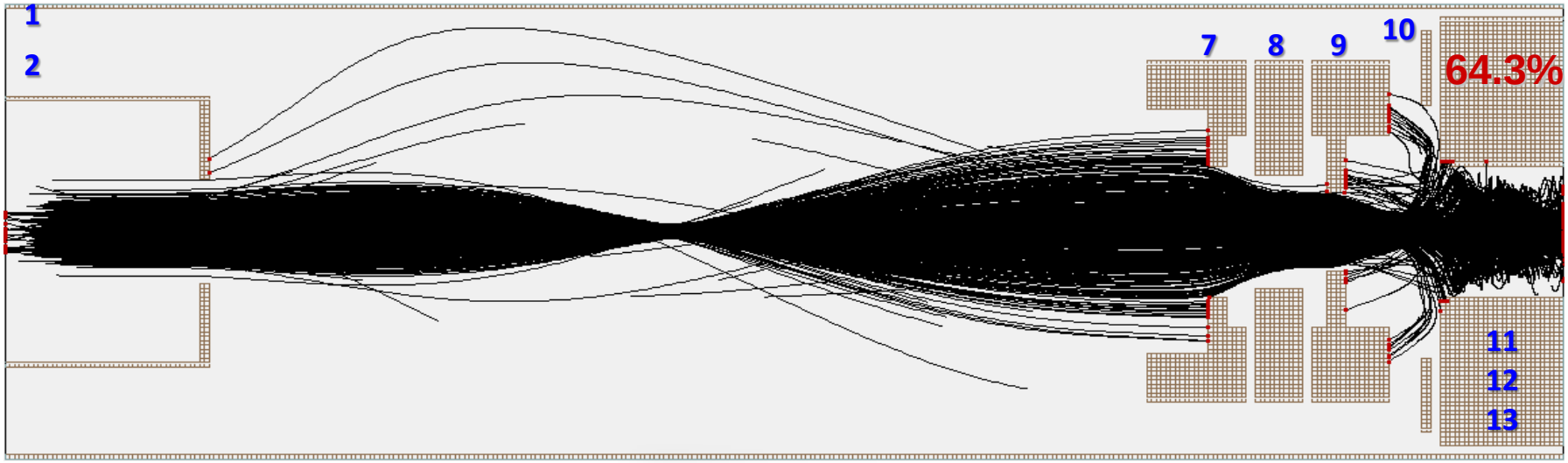
EMILIE debuncher smaller than SHIRaC2 RFQ
⇨ fits into chamber

Shorter length compared to RFQ
⇨beam optics adjustments necessary
⇨injection and extraction simulations

Ion injection into the debuncher at SHIRaC2

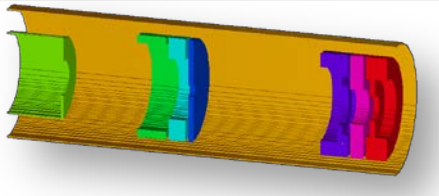


Ion injection into the debuncher at SHIRaC2



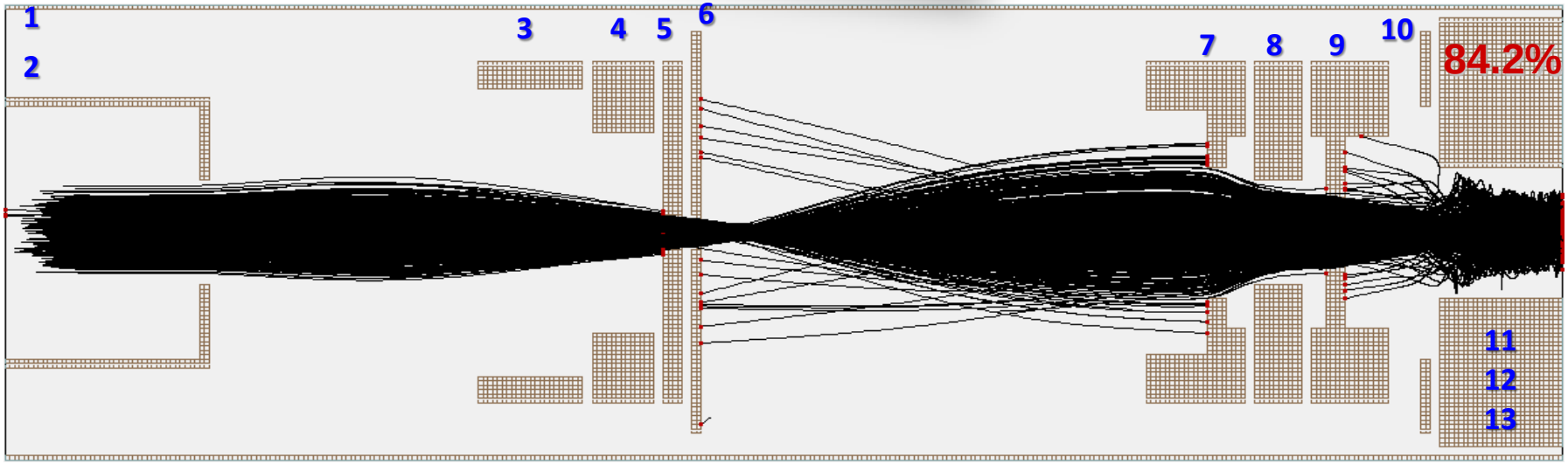
1: 4900 V (HV enclosure)
2: grounded tube

3: 4400 V
4: 4600 V
5: 4800 V
6: 4900 V (HV)

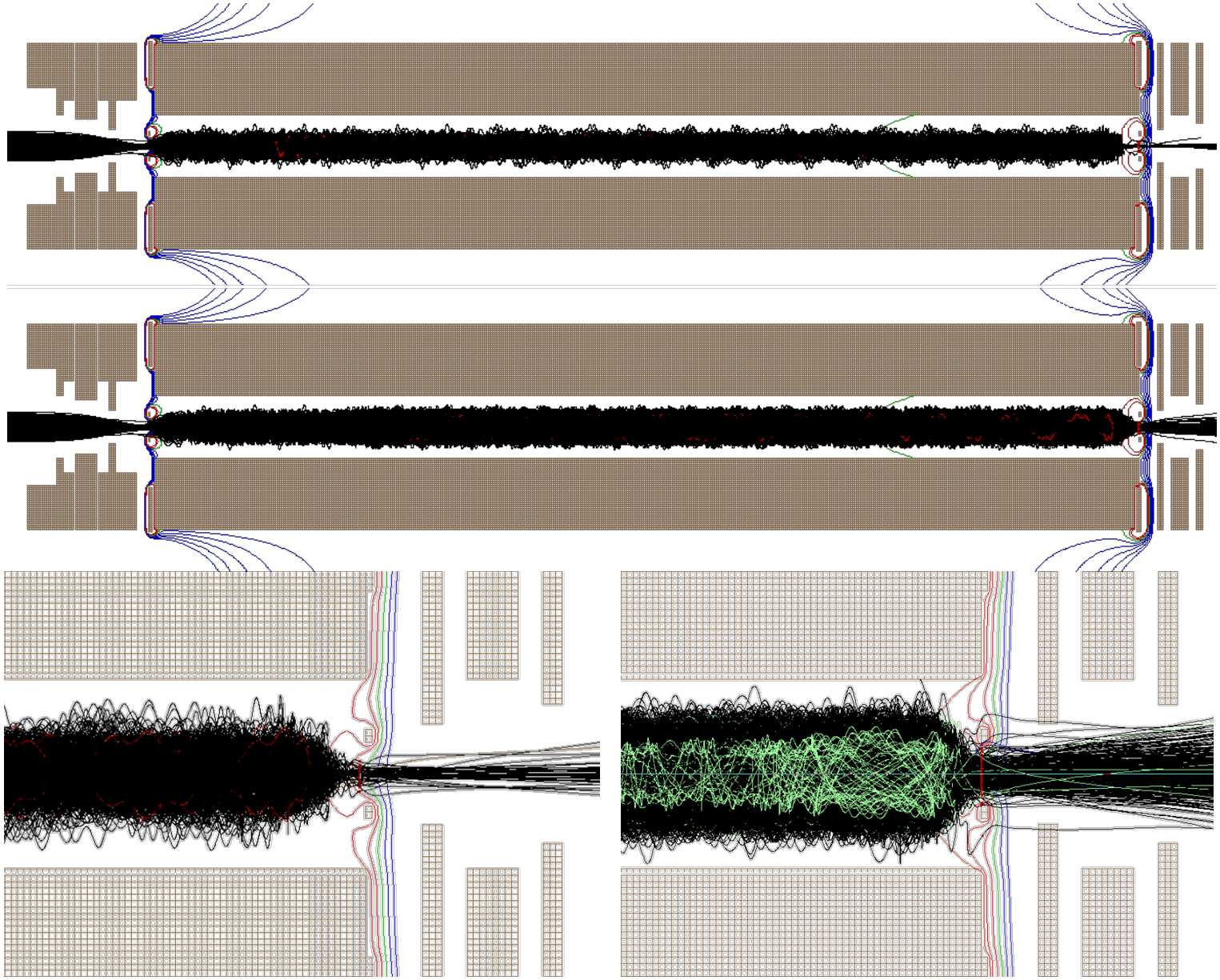


7: 4600 V
8: 2700 V
9: 4400 V

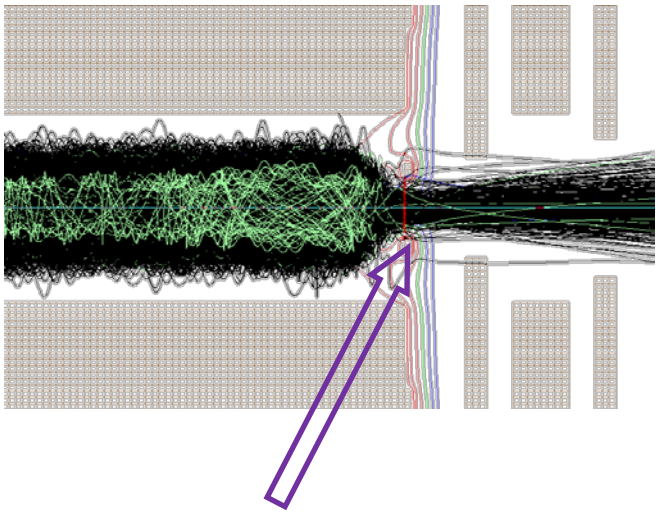
10: 4980 V (X)
11: RF+4980 V
12: -RF+4980 V
13: 4980 V (DC)



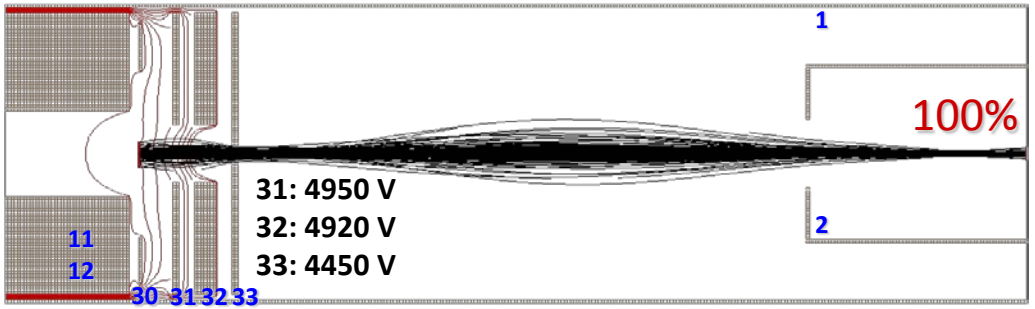
CW beam formation and time variation



Ion extraction from the debuncher at SHIRaC2

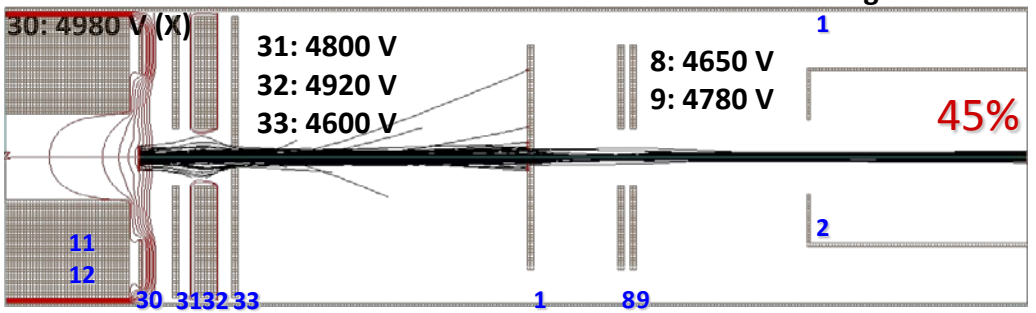


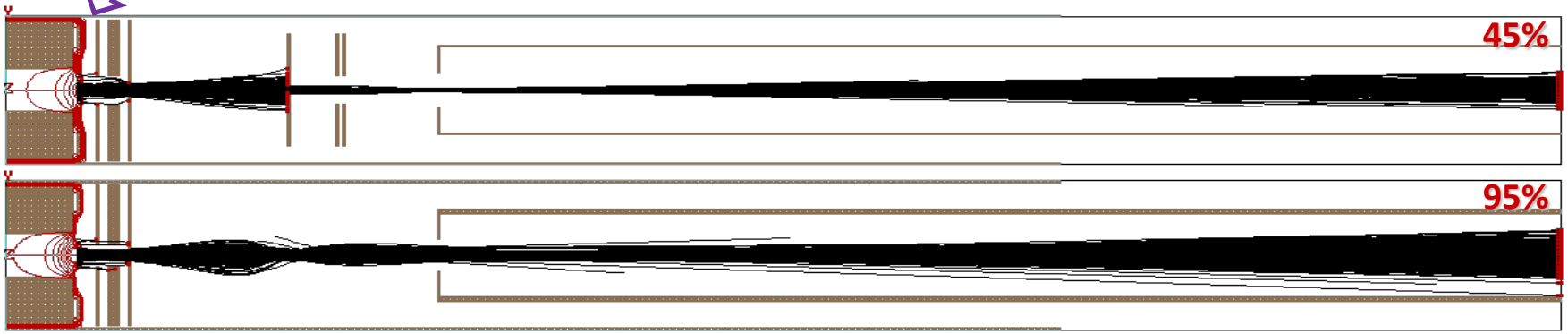
Saved ion distribution



11: RF+4980 V
12: -RF+4980 V
30: 4980 V (X)

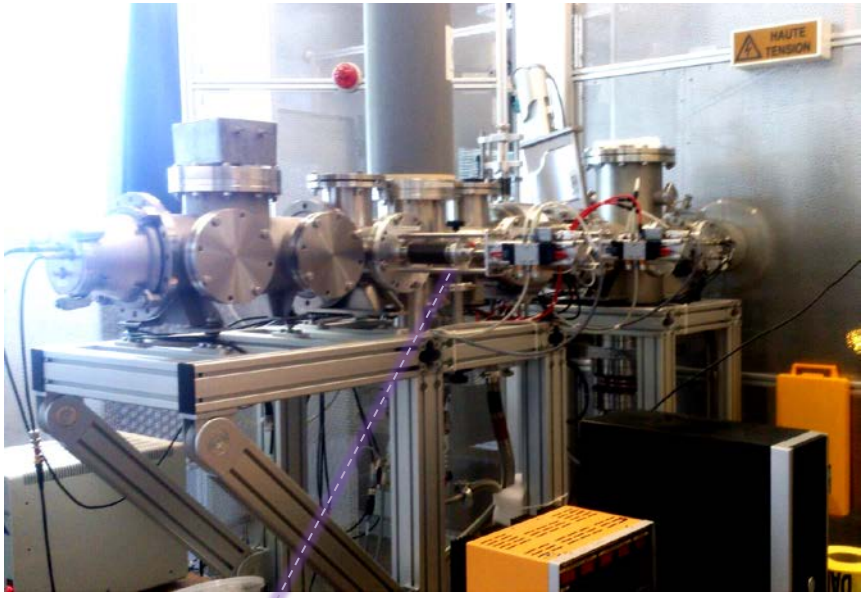
1: 4900 V (HV)
2: ground

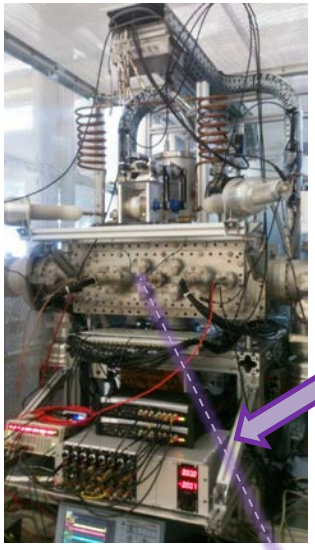


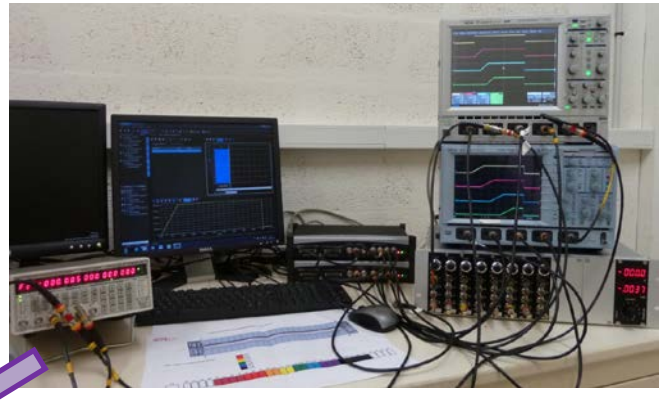


SHIRaC extraction lens electrodes have to be removed for the commissioning tests

Experimental setup at the SHIRaC2 test bench, June 2015







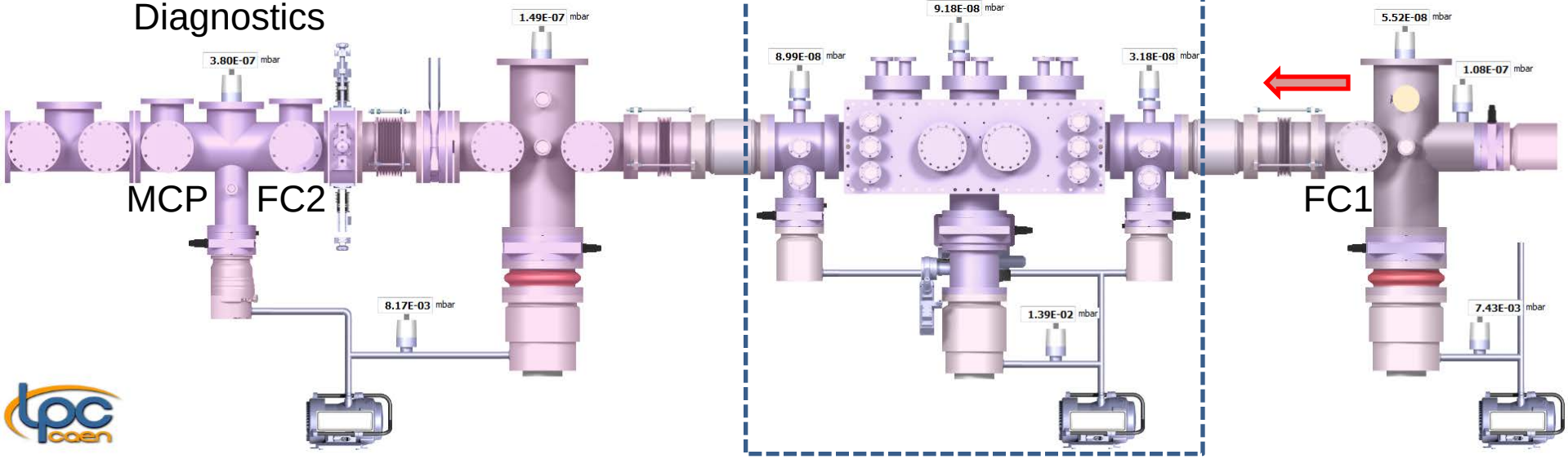
DC generators and amplifiers

HV platform

Debuncher

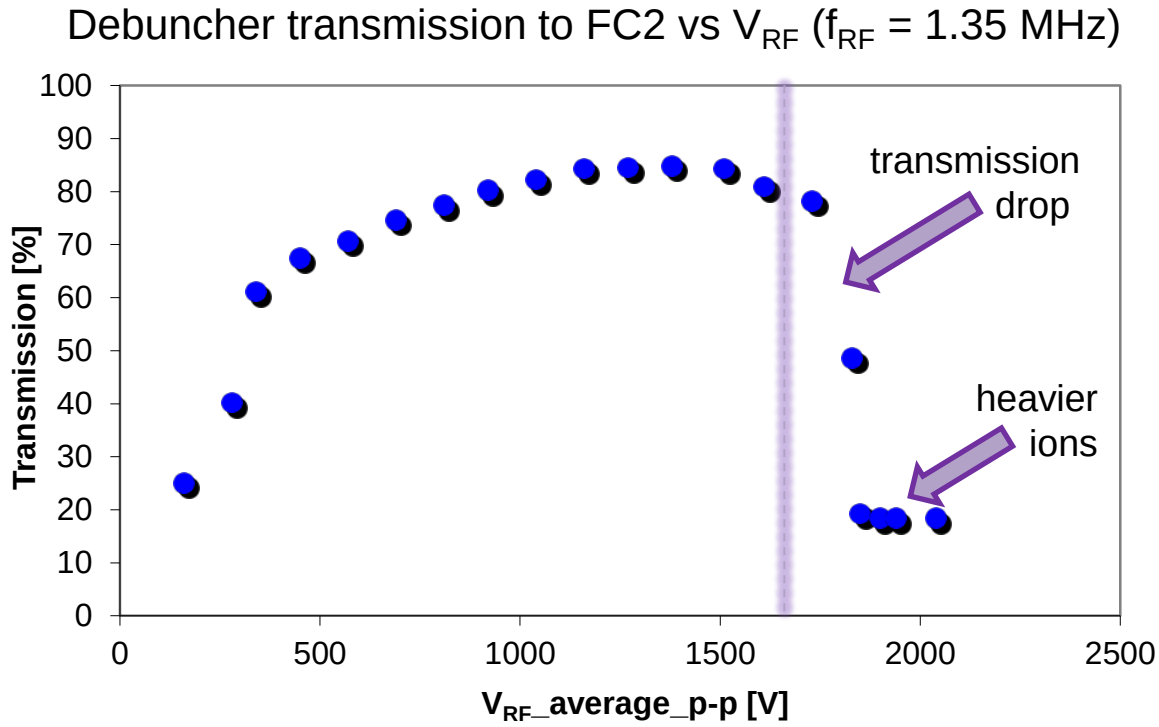
Ion source

Diagnostics



Results from the commissioning tests – June 2015

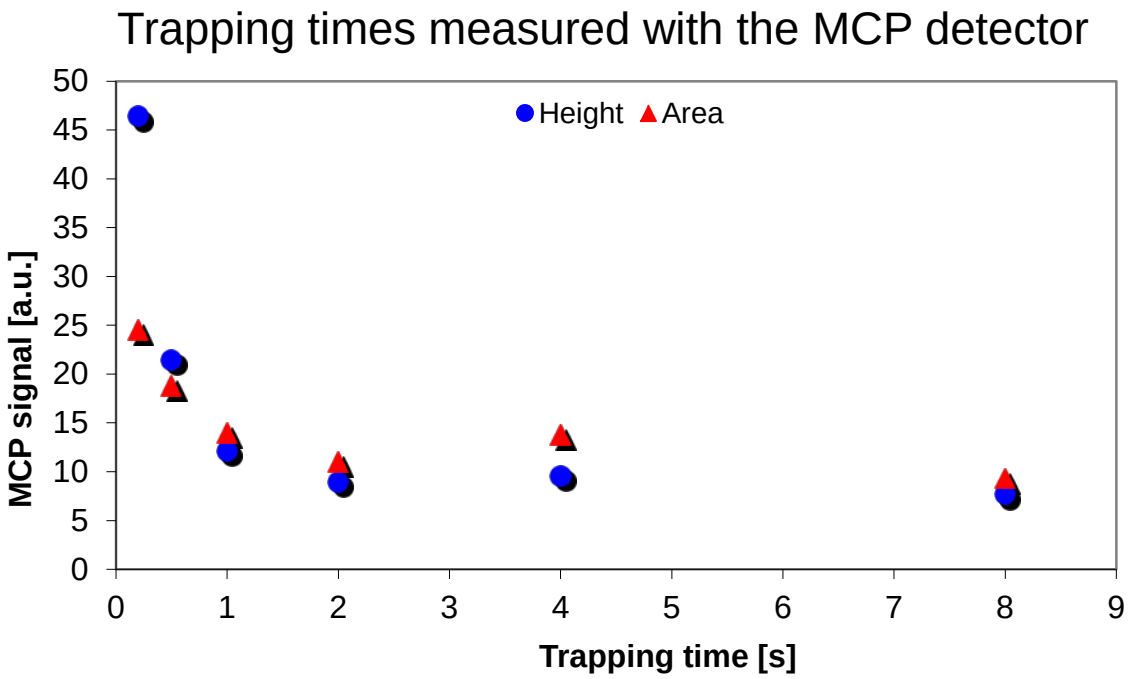
^{7}Li surface ionization source (M/Q = 7)



Sharp decrease of transmission at ~1800 V (Mathieu parameter q = 0.91 for A = 23)
confirms ⇨ $^{23}Na^{1+}$ ions are the largest fraction in the beam

Constant current level at $V_{RF} \geq 1800$ V
confirms ⇨ ~19% of a heavier fraction (probably $^{39}K^{1+}$)

Results from the commissioning tests – June 2015

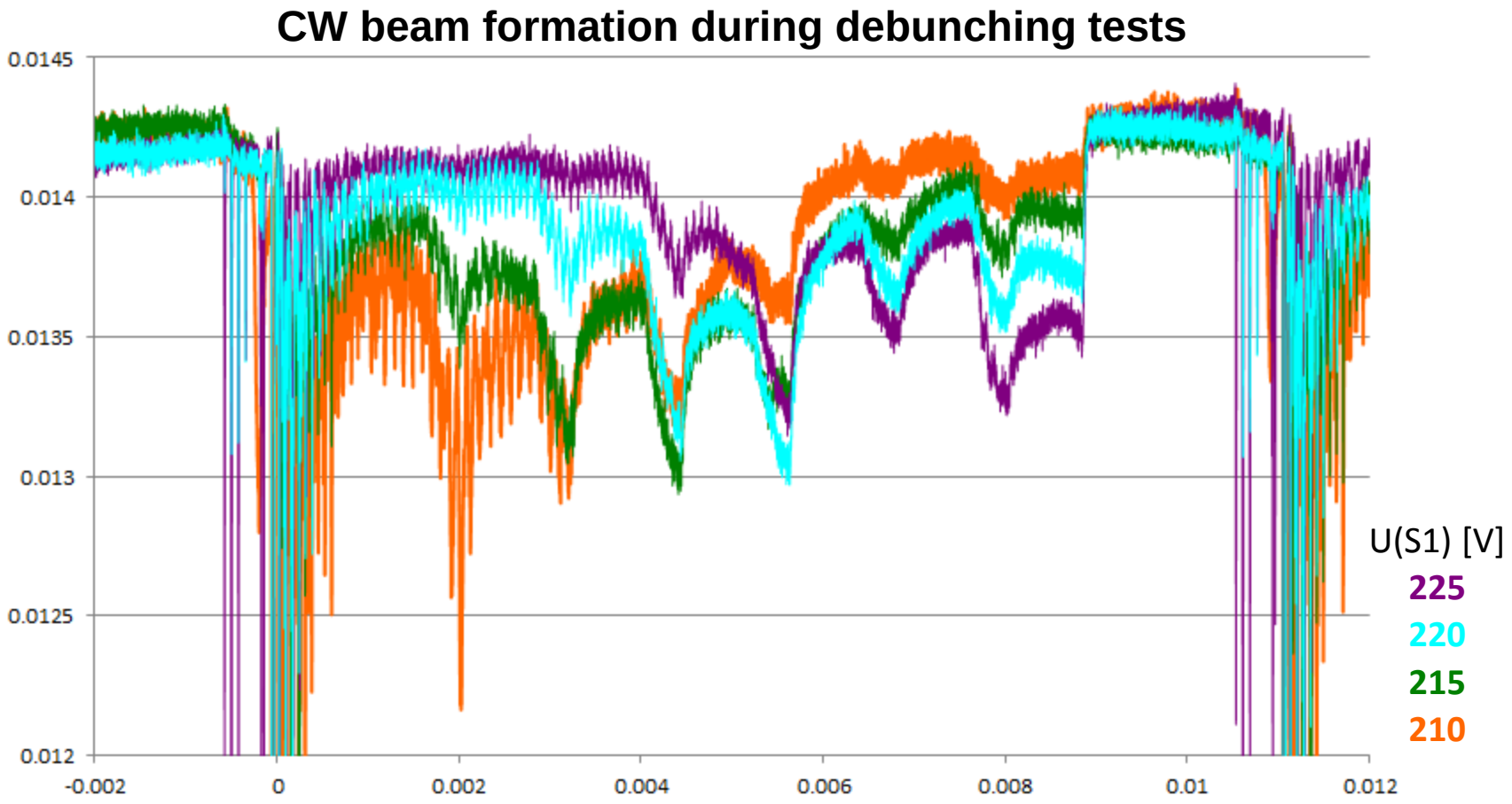


Two components observed

- short (< 1 s)
- long (~ several seconds)

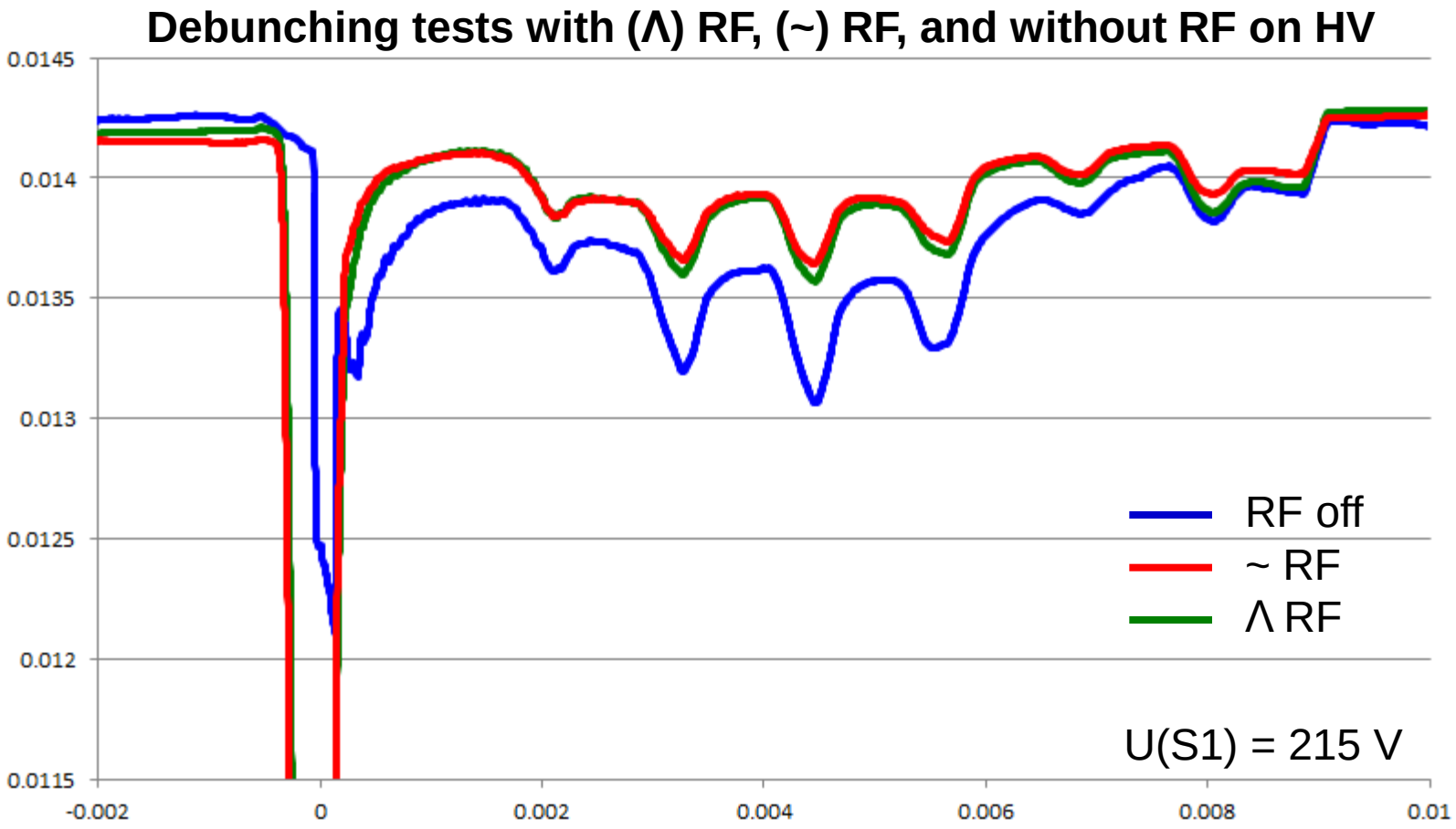
Probably due to multi-component ion beam

Results from the commissioning tests – June 2015



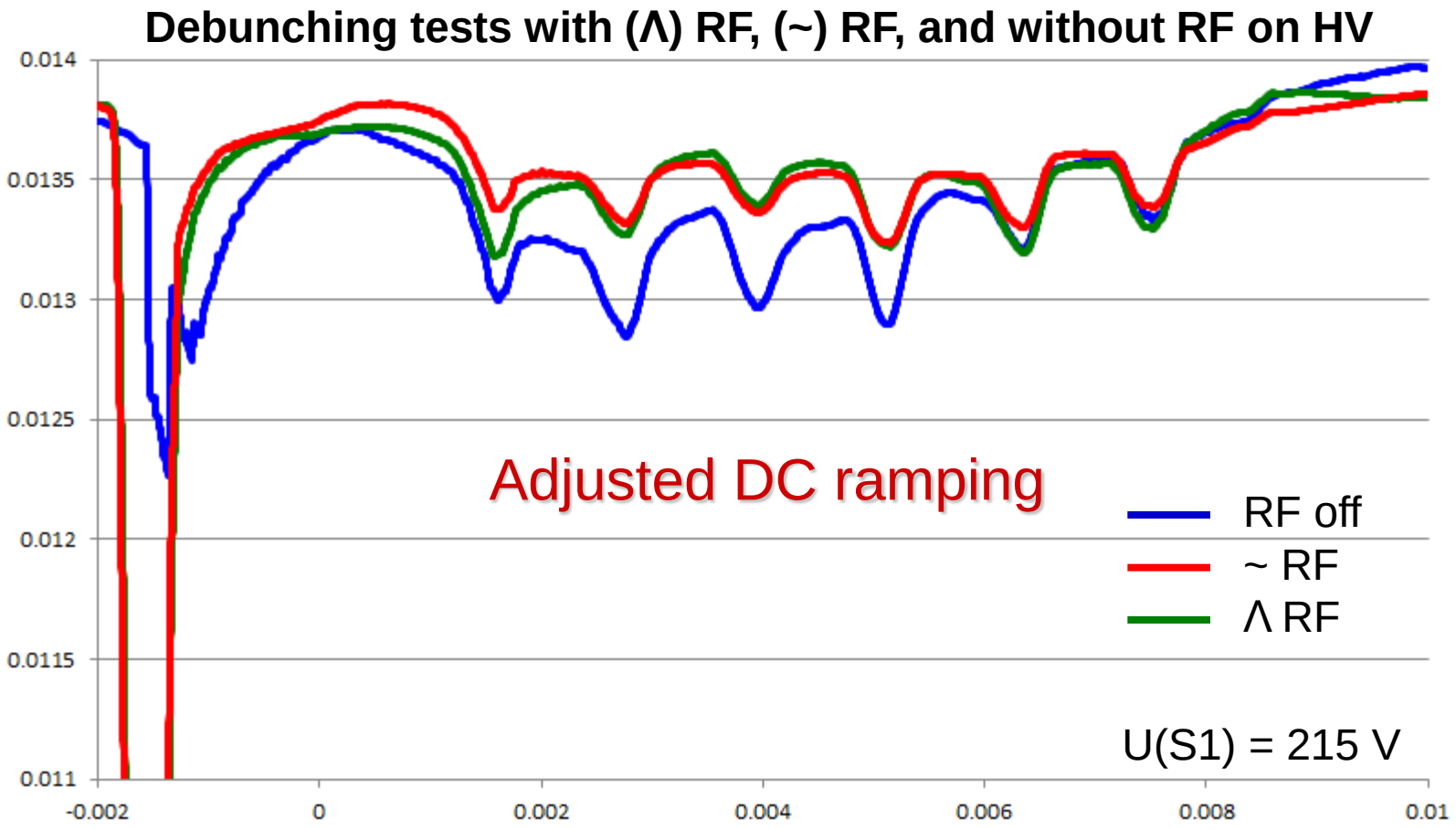
- Master trigger at 90 Hz (11.1 ms) / DC cycle set to 11 ms / delay 2 ms
- Switching on entrance x-shaped electrode (E4: 0 V / +100 V)
- U(S1) = 210 V ÷ 225 V (potential on exit x-shaped electrode)
- Minimal DC ramp amplitude: 25 V (scaling range 0.5 to 1.5 with DC_{ref} = 50 V)

Results from the commissioning tests – June 2015



- With/without RF on HV platform +/- 7 V at 100 kHz (4980 V +/- 7V)
- Master trigger at 90 Hz (11.1 ms) / DC cycle set to 11 ms / delay 1 ms
- Switching on entrance x-shaped electrode (E4: 0 V / +100 V)
- U(S1) = 215 V (potential on exit x-shaped electrode)
- Minimal DC ramp amplitude: 25 V (scaling range 0.5 to 1.5 with DC_{ref} = 50 V)

Results from the commissioning tests – June 2015



- With/without RF on HV platform +/- 7 V at 100 kHz (4980 V +/- 7V)
- Master trigger at 80 Hz (11.1 ms) / DC cycle set to 11 ms / delay 2 ms
- Switching on entrance x-shaped electrode (E4: 0 V / +100 V)
- U(S1) = 215 V (potential on exit x-shaped electrode)
- Minimal DC ramp amplitude: 25 V (scaling range 0.5 to 1.5 with DC_{ref} = 50 V)

Conclusion and future plans

- EMILIE debuncher achievements
  - EBIS debuncher construction (2012)
    - Simulations and design (GANIL, LPC)
    - Building and assembly (LPC)
    - RF and DC electronics (LPC)
  - EBIS debuncher prototype commissioning
    - Tests with singly charged ions at SHIRaC2 in June 2015
- Future plans
    - More tests with real bunches and/or with highly charged ions?