Progress report on Laser Resonance Chromatography (LRC)

Elisa Romero Romero, M. Block, E. Kim, S. Raeder, E. Rickert, J. Schneider, P. Sikora, M. Laatiaoui

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HIM HELMHOLTZ Helmholtz-Institut Mainz

erc European Research Council

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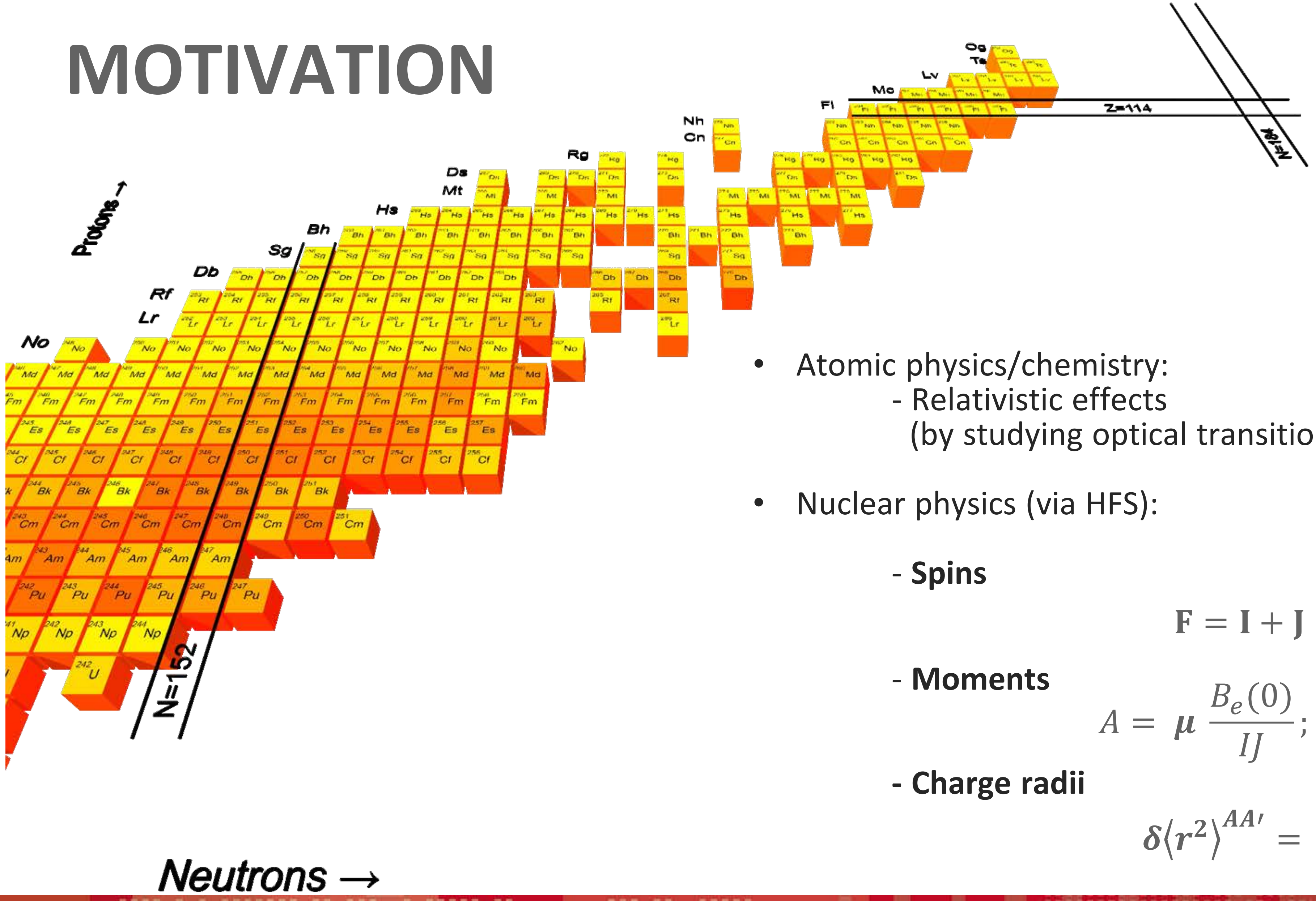
MOTIVATION



- Atomic physics/chemistry:
  - Relativistic effects
    (by studying optical transitions & ionization potentials)

- Nuclear physics (via HFS):

  - **Spins**

$$\mathbf{F} = \mathbf{I} + \mathbf{J}$$

  - **Moments**

$$A = \boldsymbol{\mu} \frac{B_e(0)}{IJ}; \qquad B = e\boldsymbol{Q_s} \left\langle \frac{\delta^2 V}{\delta z^2} \right\rangle$$

  - **Charge radii**

$$\boldsymbol{\delta \langle r^2 \rangle^{AA'}} = \left(\Delta\nu^{AA'} - \frac{A - A'}{AA'} M \right) \frac{1}{F}$$

REQUIREMENTS FOR TECHNIQUES

Speed

Fast detection between the production and the start of the measurement

Selectivity

Good separation between the specific element over the background

Sensitivity

Needs to overcome single atom production

Efficiency

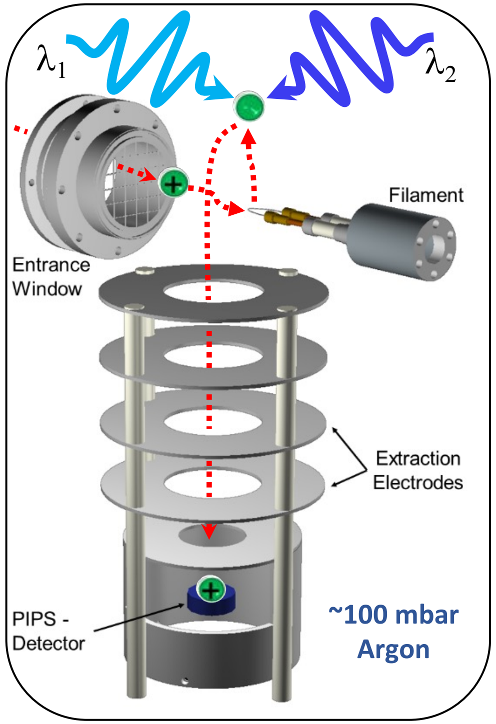
Continuously operating system without cycle losses

Detection

Suitable for nuclear decay signature, event-by-event recording of the data.

IN-GAS-CELL LASER IONIZATION RESONANCE SPECTROSCOPY

RADRIS
Radiation-Detected Resonance Ionization Spectroscopy



M. Laatiaoui et al., Nature **538** (2016) 495

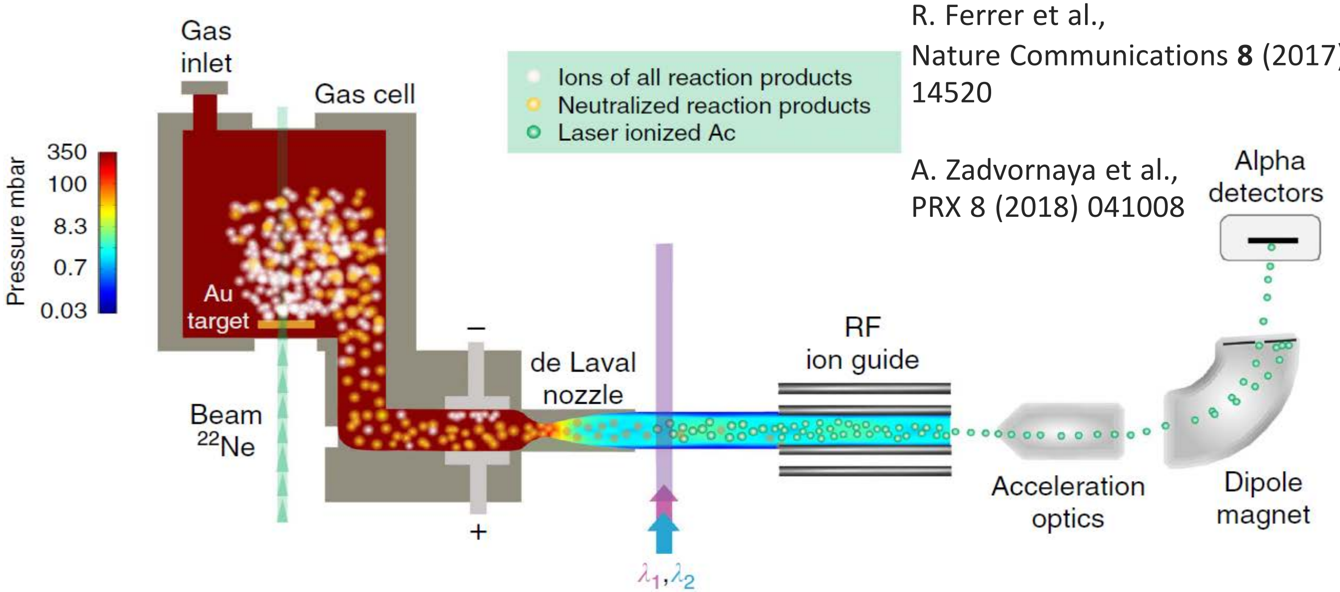
P. Chhetri et al., PRL **120** (2018) 263003

S. Raeder et al., PRL **120** (2018) 232503

M. Block et al., Prog. Part. Nucl. Phys. DOI:10.1016/j.ppnp.2020.103834

T. Kieck talk from Tuesday

In-jet Laser Spectroscopy



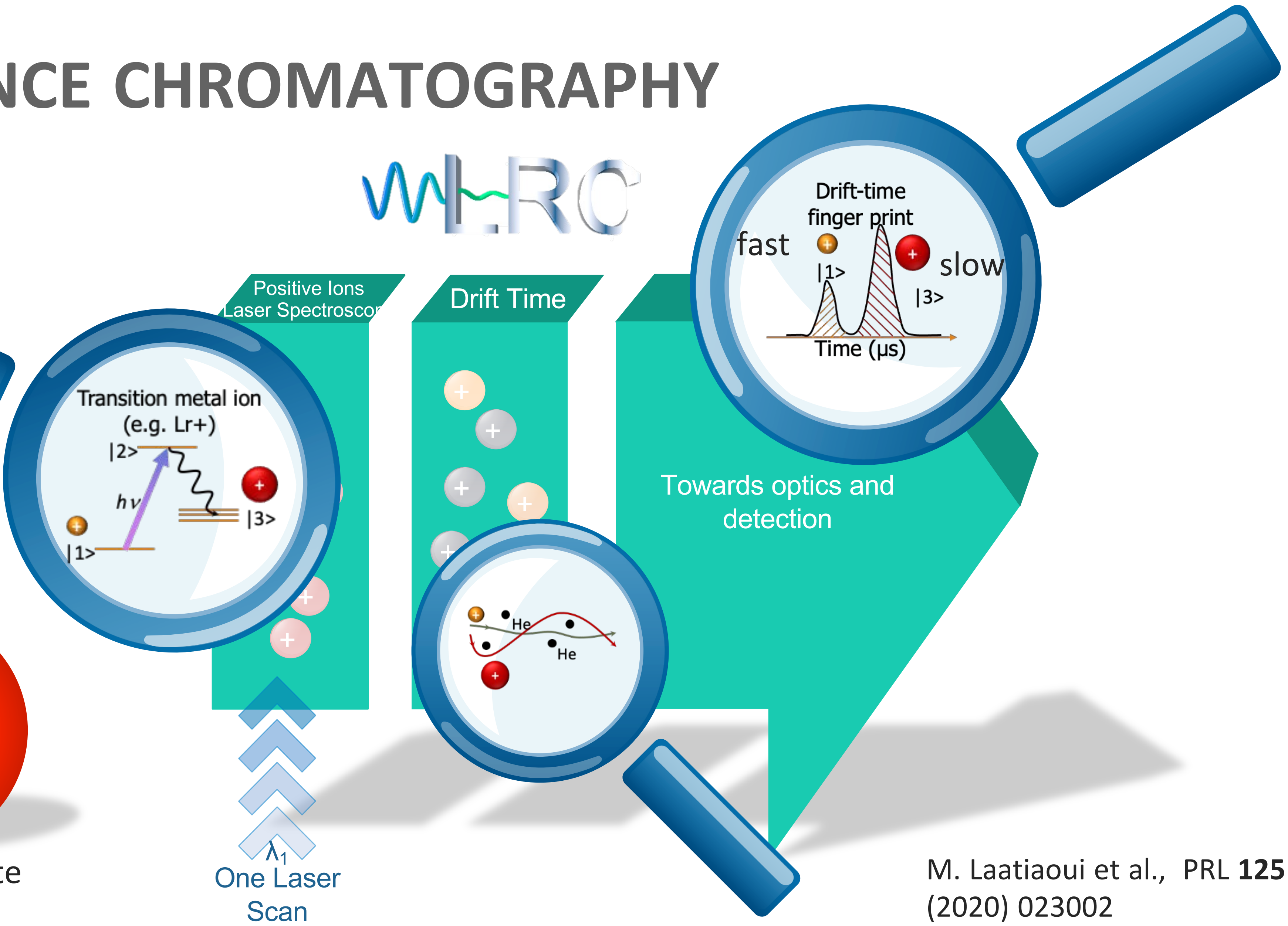
R. Ferrer et al., Nature Communications **8** (2017) 14520

A. Zadvornaya et al., PRX 8 (2018) 041008

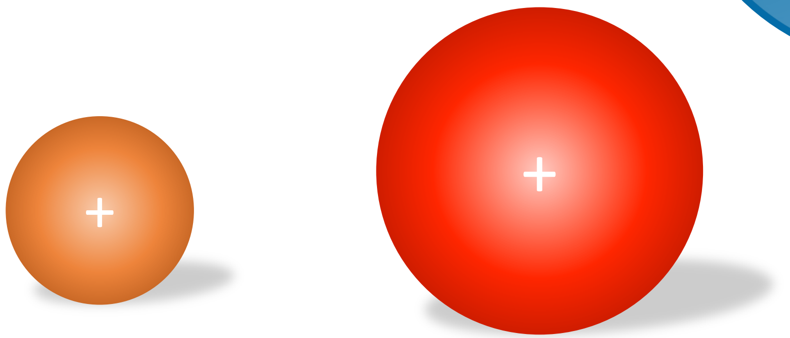
Towards SHE challenges:

- **desorption** of **neutral** atoms
- fast **neutralization** of stopped ions

LASER RESONANCE CHROMATOGRAPHY CONCEPT



Change in size



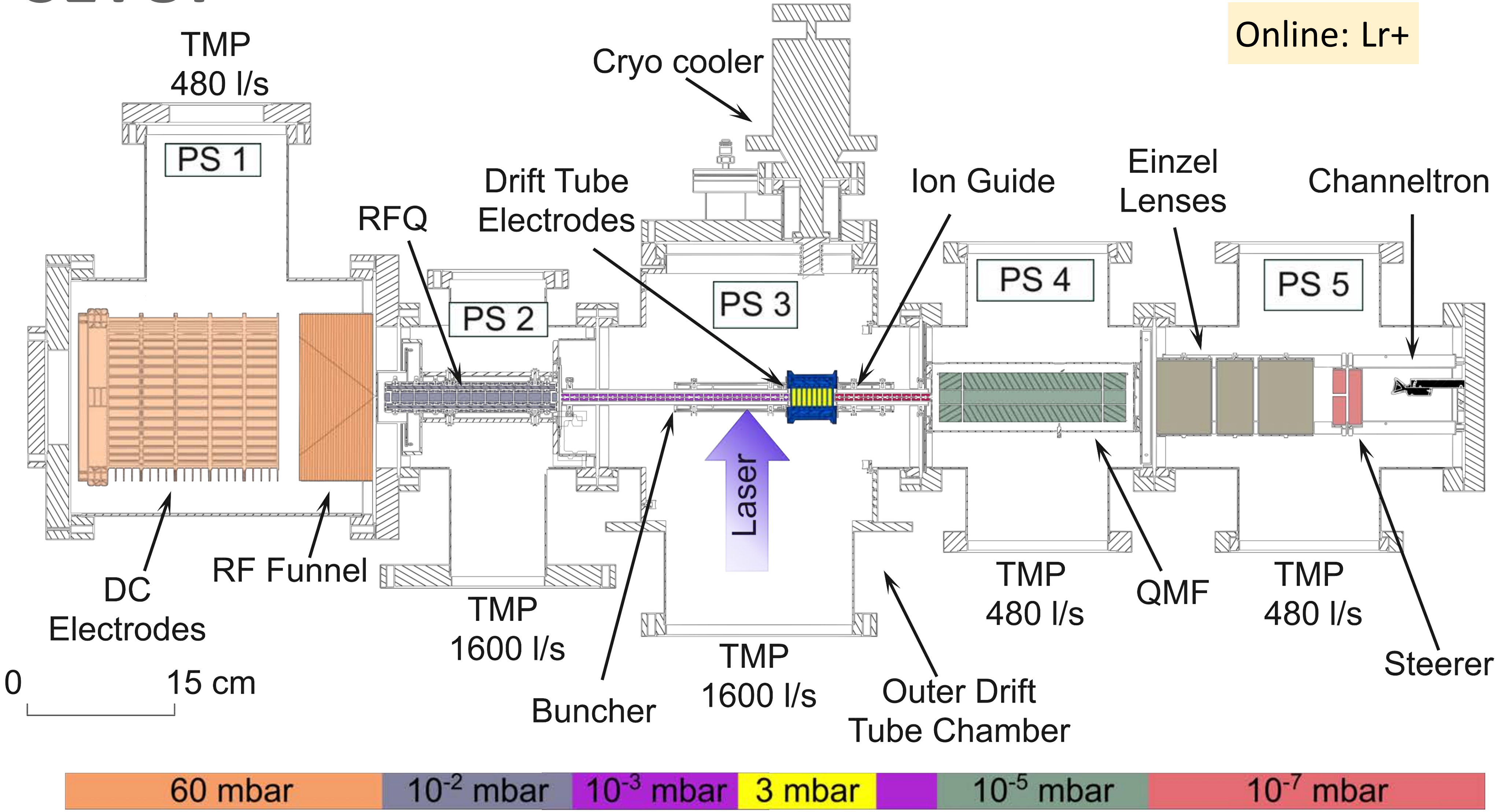
Ground state   Metastable state

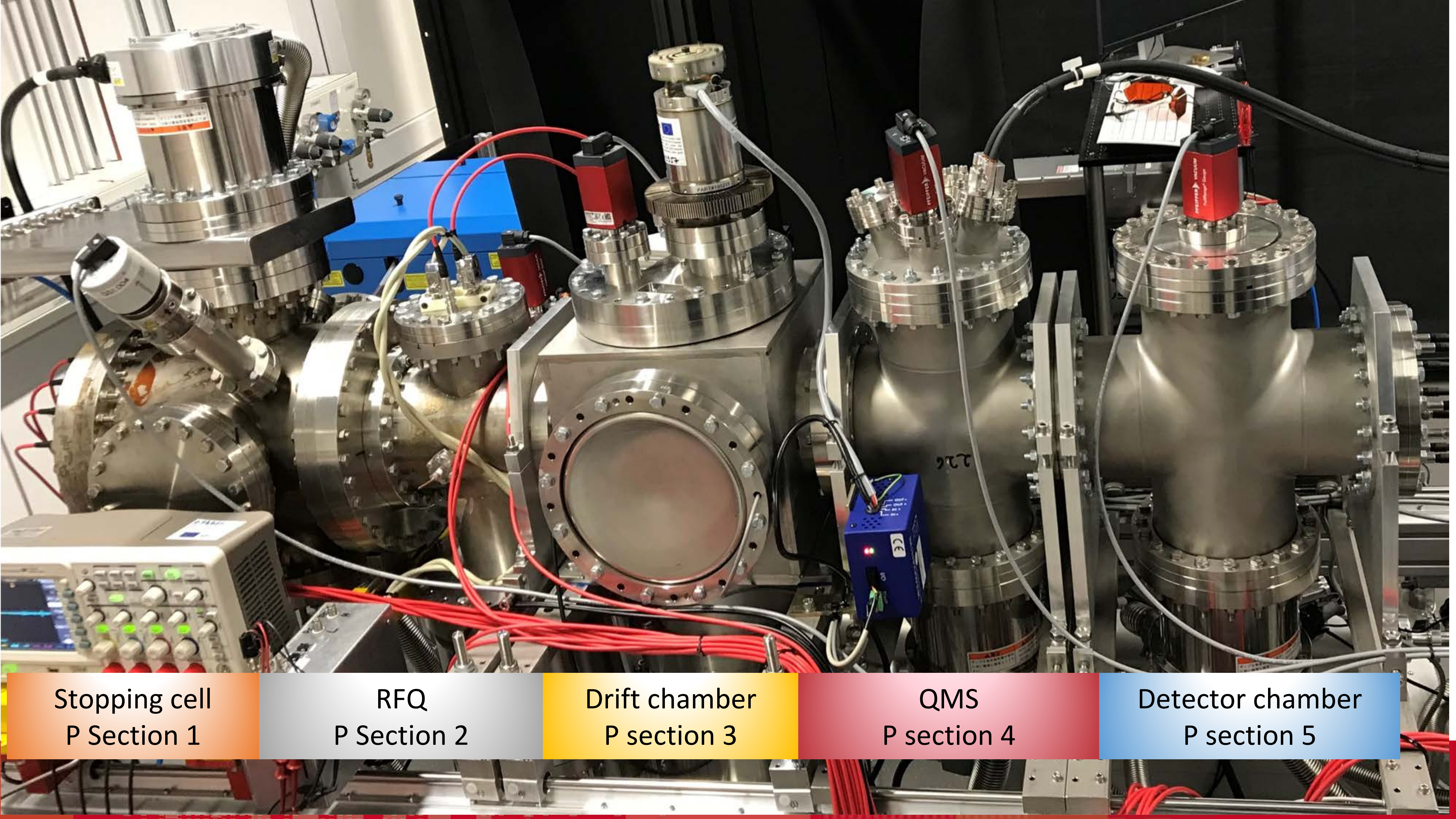
$v_d \propto 1/R$

M. Laatiaoui et al., PRL **125** (2020) 023002

LRC SETUP

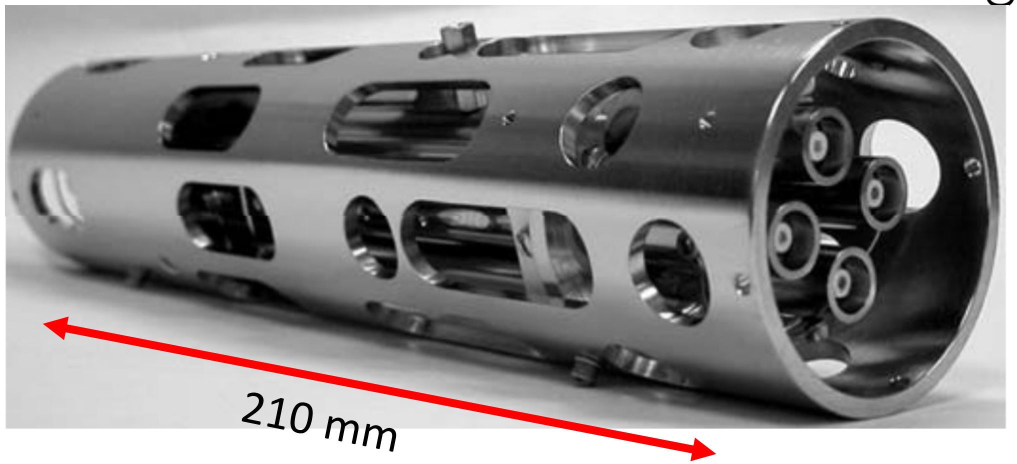
Online: Lr+

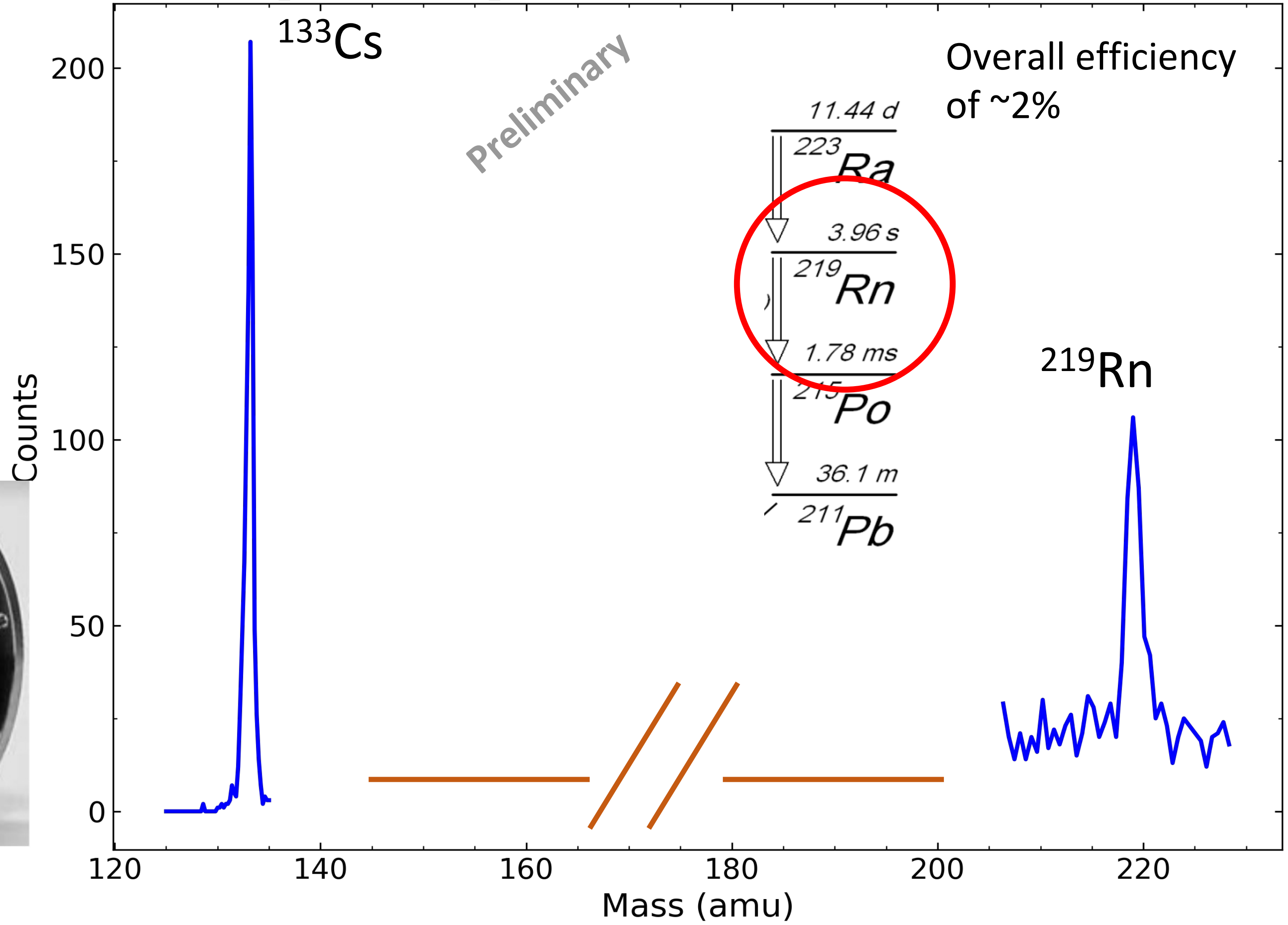



Stopping cell
P Section 1
RFQ
P Section 2
Drift chamber
P section 3
QMS
P section 4
Detector chamber
P section 5

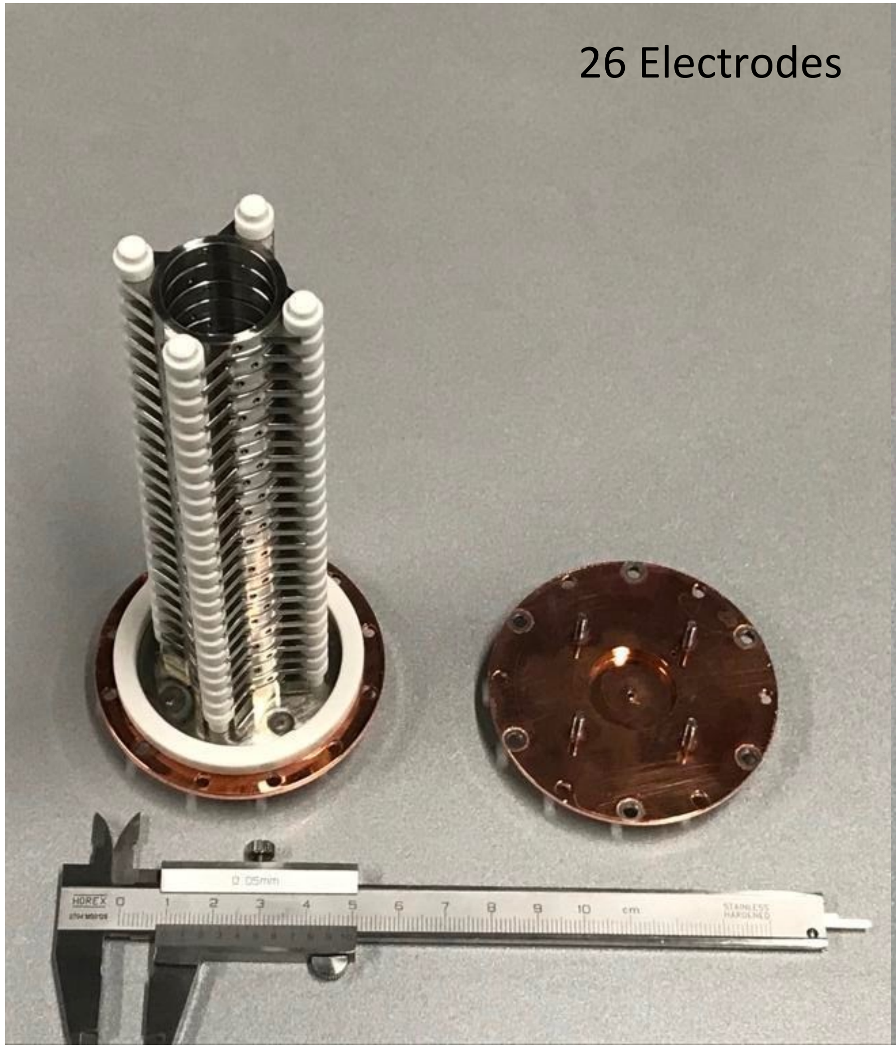
QUADRUPOLE MAS FILTER (QMF) CALIBRATION

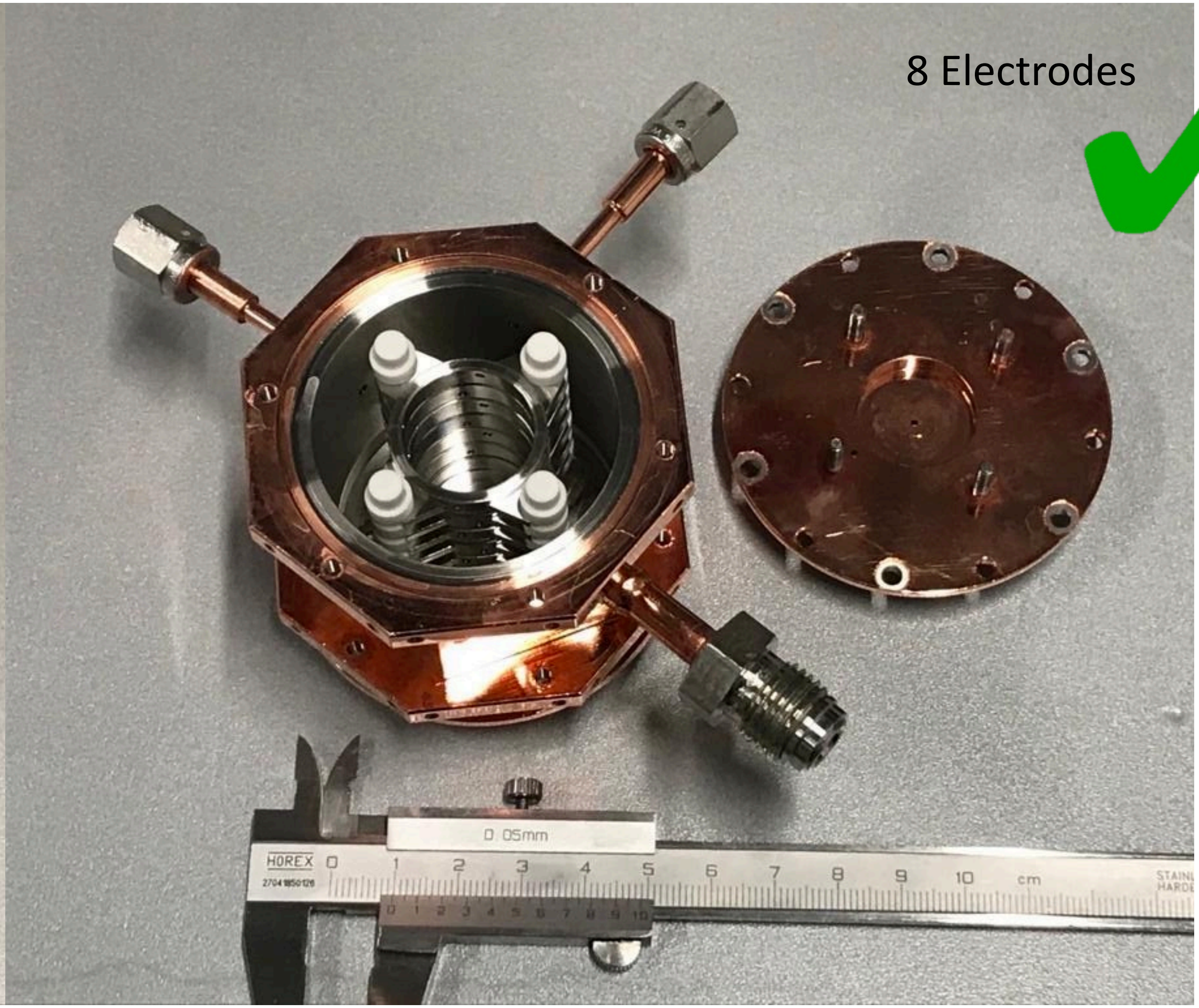
Extrel QMF
- 19 mm diameter rods
- Operating freq 1.2 MHz
- Mass range 1-500 amu





DRIFT TUBE



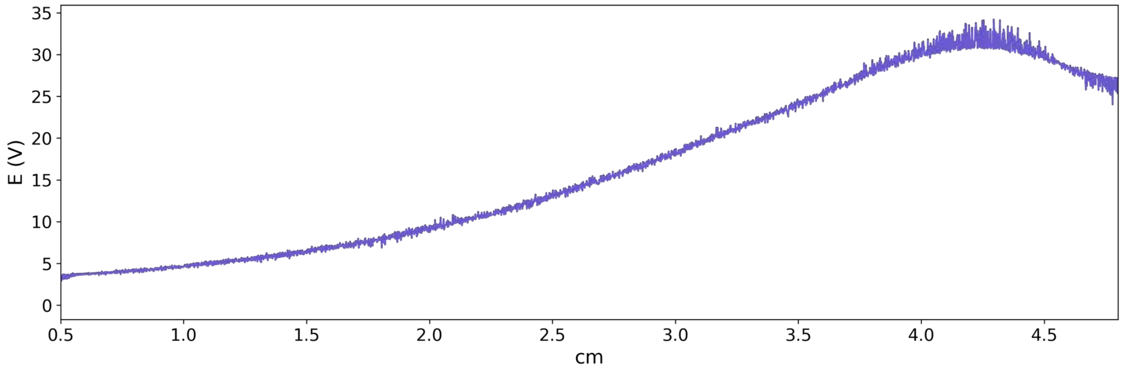


DRIFT TUBE SIMION SIMULATIONS ON ^{45}SC+

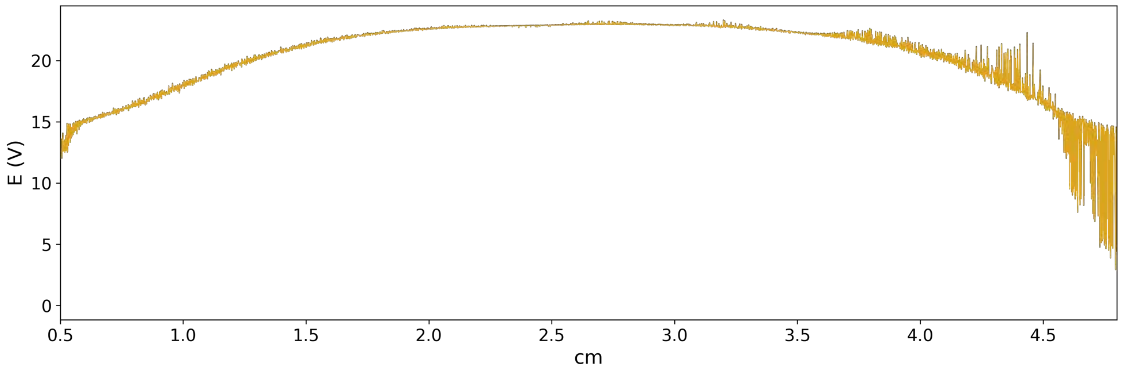
- Viscous damping model
  - Velocity affected by a drag force
- Stastitical Diffusion Simulation (SDS) model
  - Viscous damping model and monte carlo calculations for a random jumps
- Simulation parameters:
  - 10000 ions
  - 1 mm orifice entrance and exit to optimize resolution
  - Sc as test case (isoelectronic to Lu+ and Lr+)
  - Ion mobility values K_0: M. J. Manard and P. R. Kemper, Int. J. MassSpectrom. 407, 69 (2016)

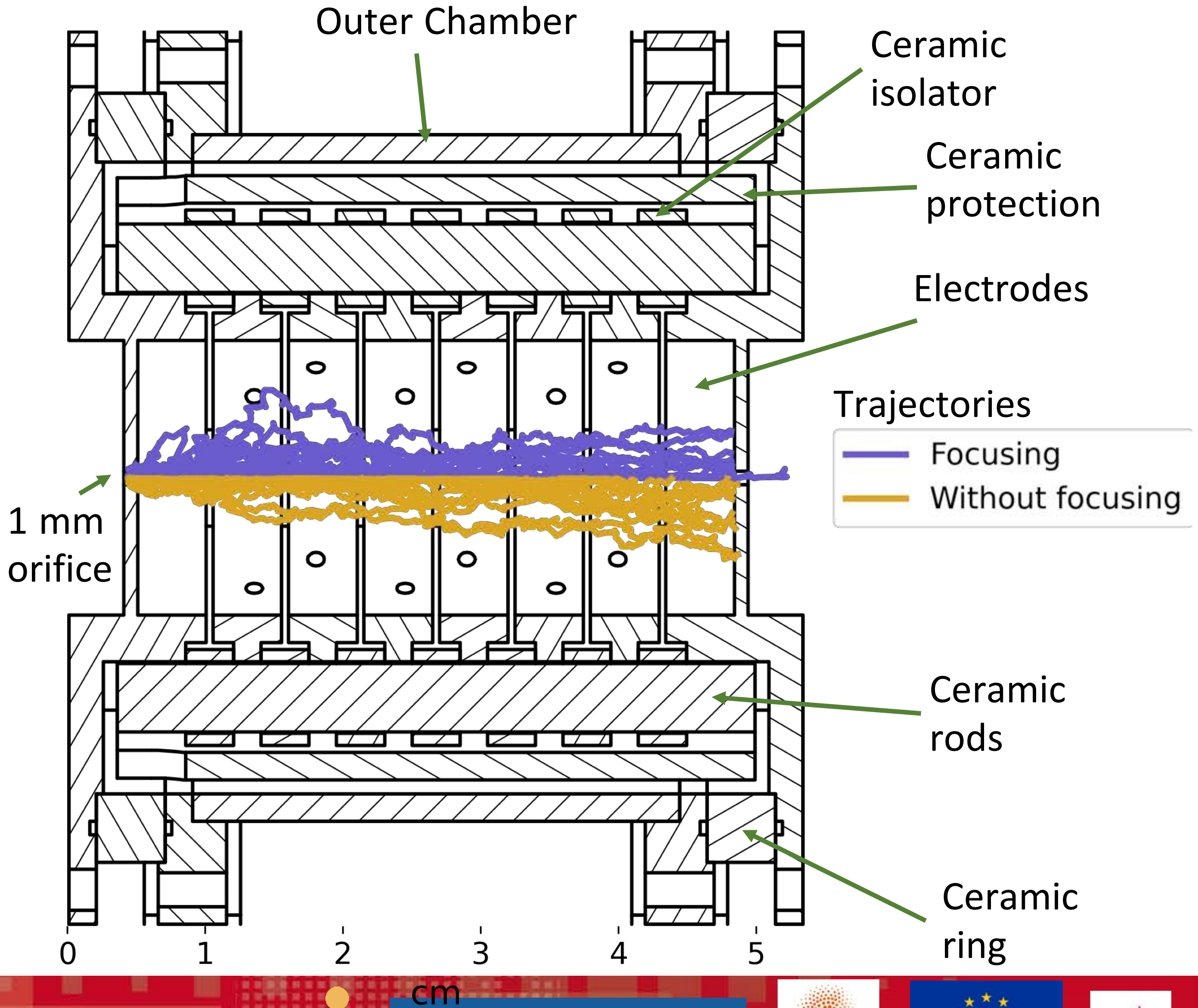
SIMION SDS – VOLTAGE OPTIMIZATION

Focusing - Increasing Gradient



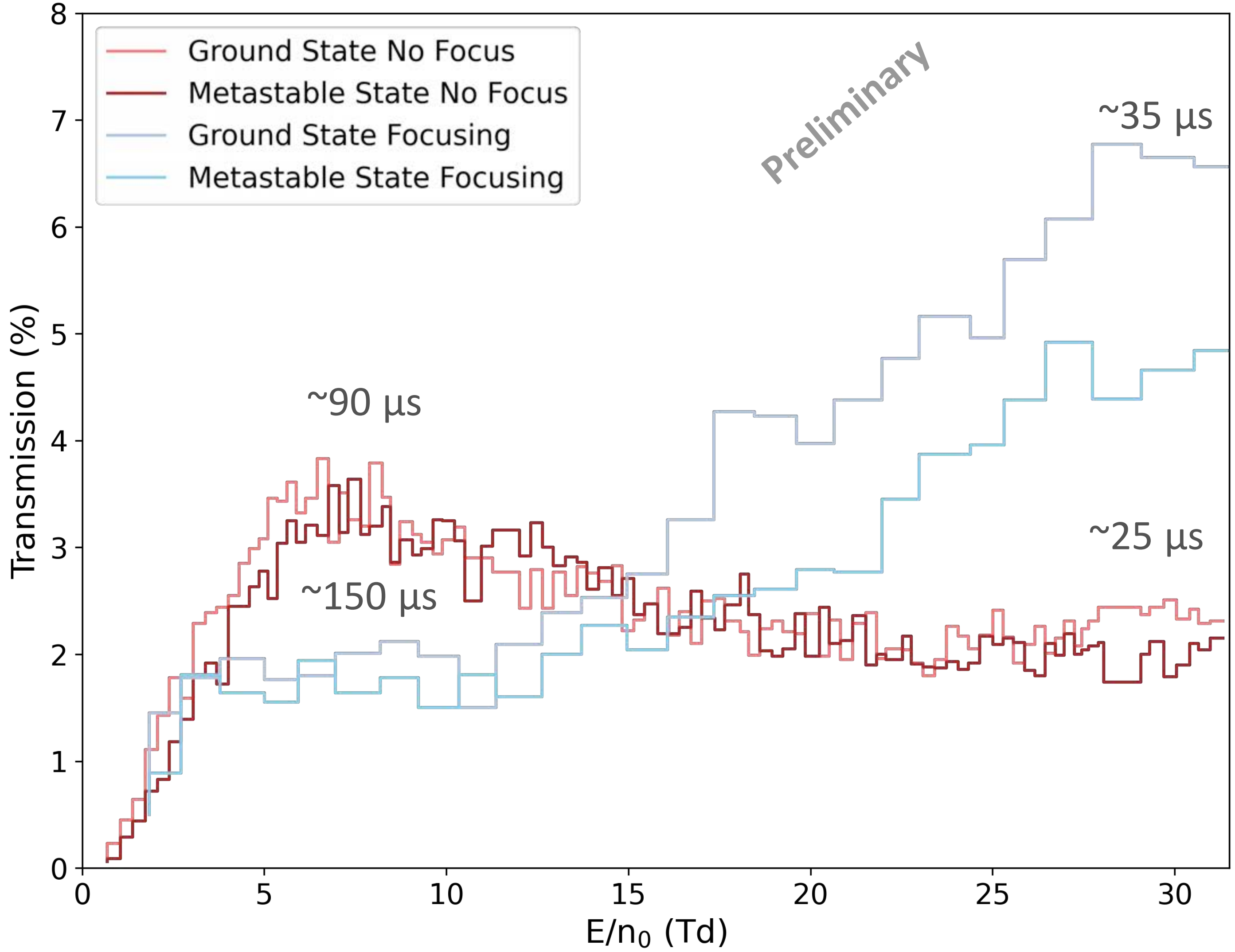
Without focusing - Constant Gradient



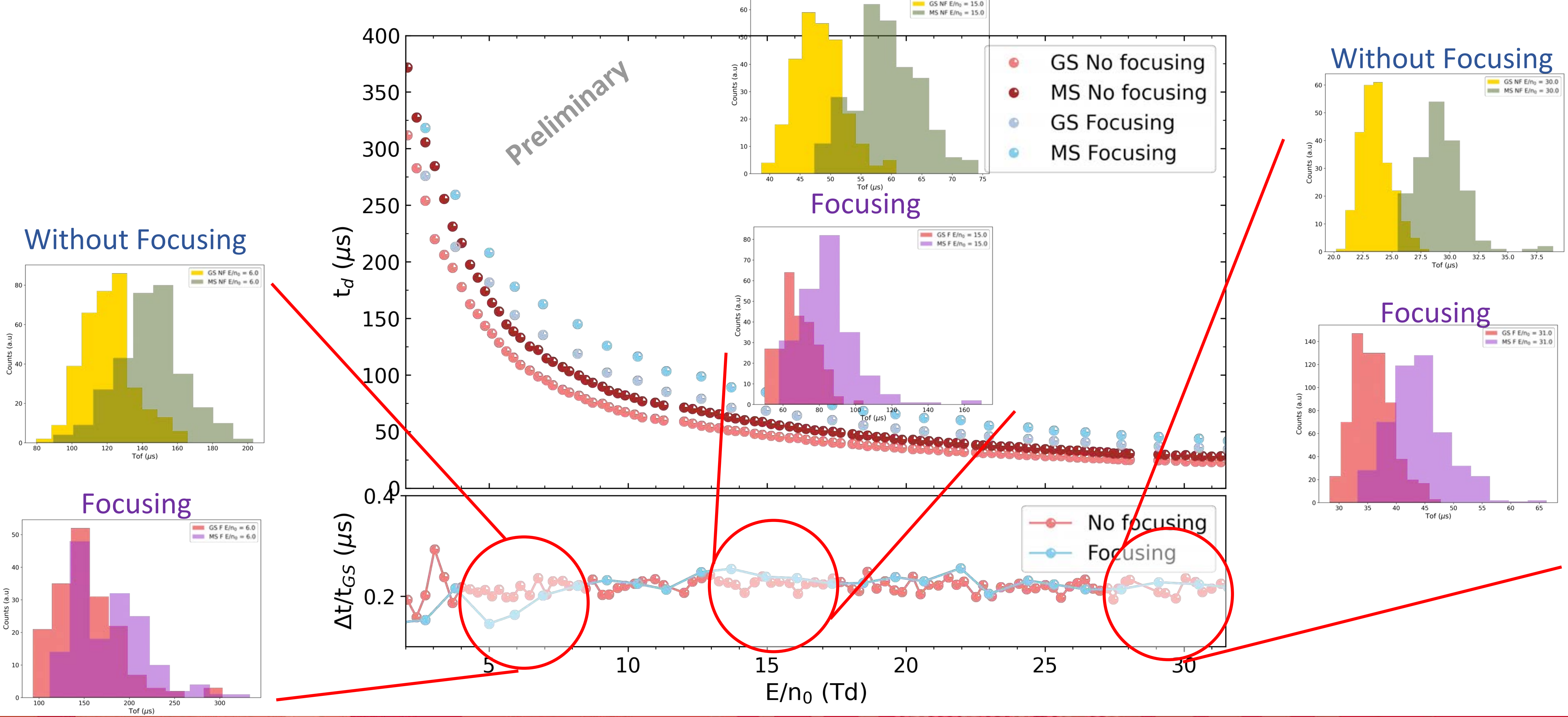


TRANSMISSION COMPARISON

- Less quenching
  - ➢ low E fields
- High transmission efficiency
  - ➢ high E fields
- Larger drift time
  - ➢ low E Fields
- High resolution
  - ➢ high E fields



DRIFT TIME DIFFERENCES



SUMMARY

- LRC provides a novel way of laser spectroscopy of ions without the need of neutralization and using only one laser
- Experimental setup is on site
- Calibration and optimization of QMS is finished
- Drift tube ready to be implemented
- SIMION simulations on the drift tube with Sc helped to understand voltages, drift times, and transmission of ions
- Next:
    - Simulations with the complete setup
    - Installation of drift tube and measurements on Sc+

LRC TEAM

THANK YOU

LRC Team

Mustapha Laatiaoui
Elisa Romero Romero
Eunkang Kim

Collaborators

M. Block
S. Raeder
E. Rickert
J. Schneider
P. Sikora

https://www.lrc-project.eu/

LRC_Mainz