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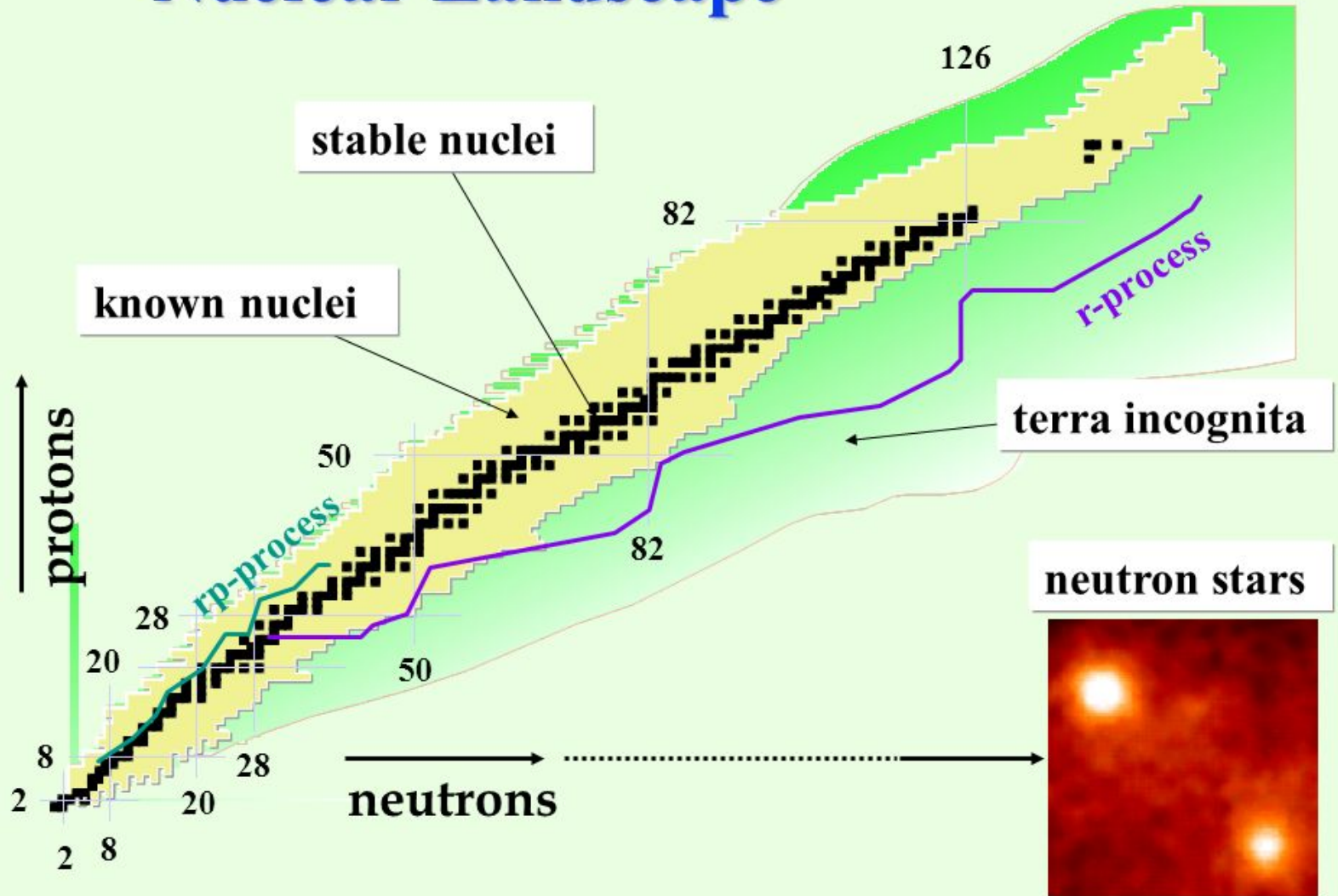


Charting Terra Incognita – MLLTRAP

- I. The project
- II. MLLTRAP status
- III. In-trap spectroscopy

The project

Nuclear Landscape



I. The project

- S3
- LINO
- POLAREX
- MLLTRAP

II. MLLTRAP status

- Progress on the line
- On-going/future work

III. In-trap spectroscopy

- Optimization
- Simulations
- Lifetime measurement
- On-going/future work

Conclusion

The project – S3

I. The project

- S3

- LINO

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II. MLLTRAP status

- Progress on the line

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III. In-trap spectroscopy

- Optimization

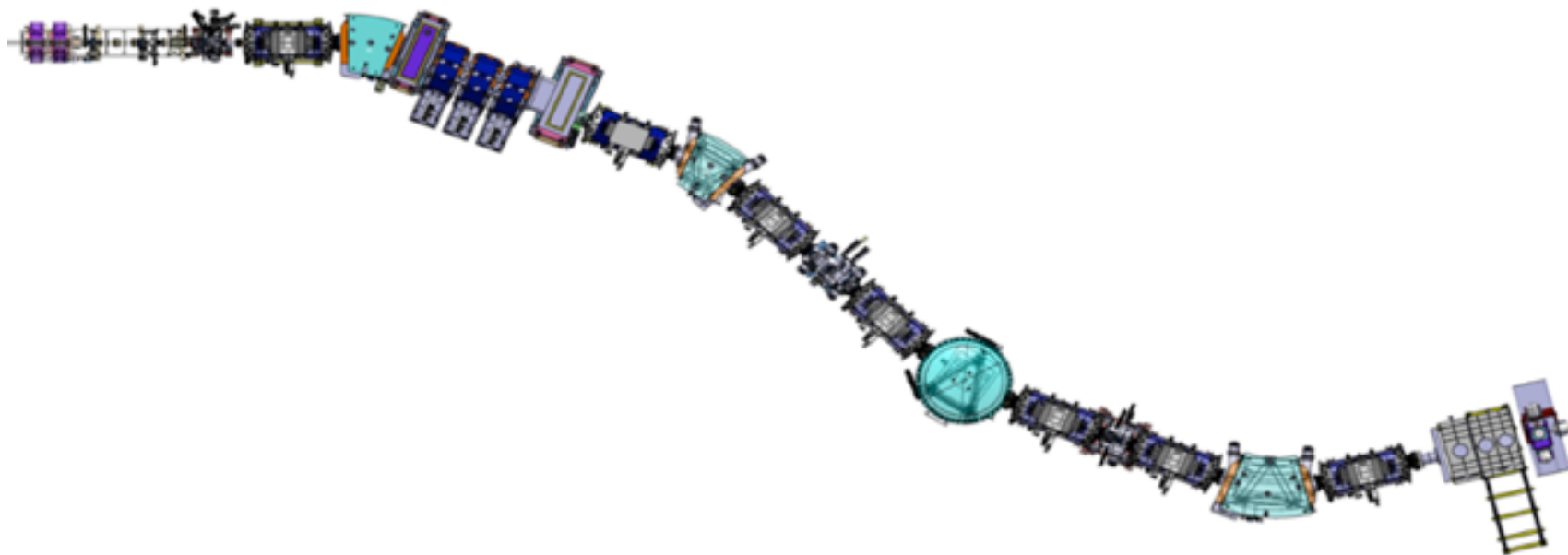
- Simulations

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- On-going/future work

Conclusion

Super Separator Spectrometer (S3) at SPIRAL2



The project – S3

I. The project

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II. MLLTRAP status

- Progress on the line

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III. In-trap spectroscopy

- Optimization

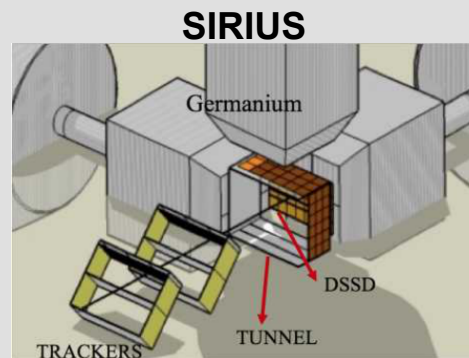
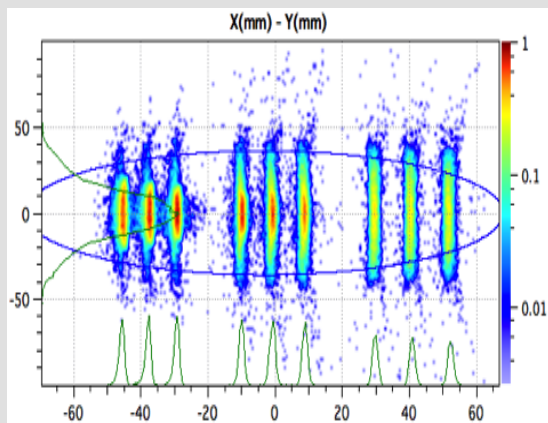
- Simulations

- Lifetime measurement

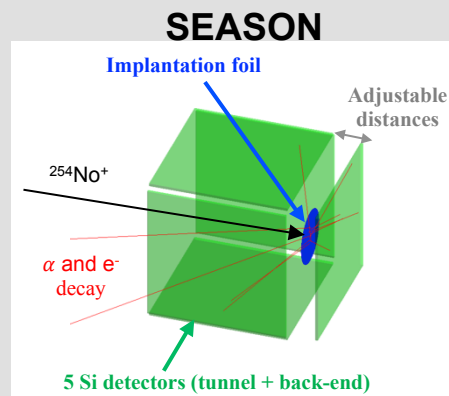
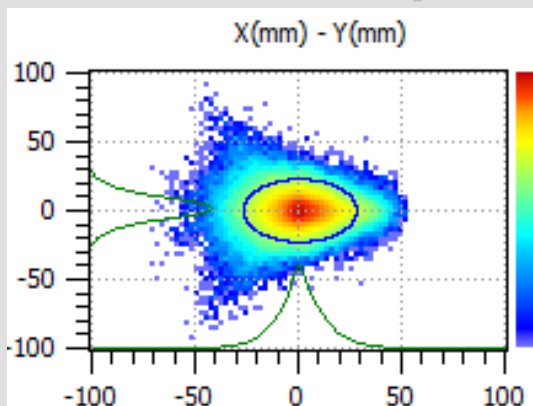
- On-going/future work

Conclusion

Maximum resolution



Maximum efficiency



Courtesy of T. Goigoux

The project – S3

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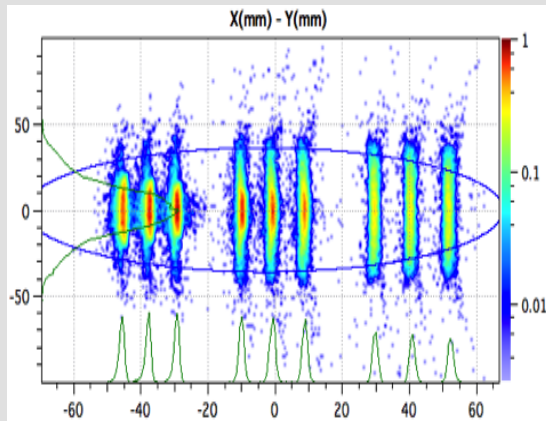
- Simulations

- Lifetime measurement

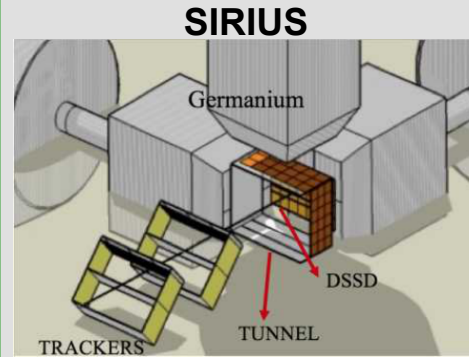
- On-going/future work

Conclusion

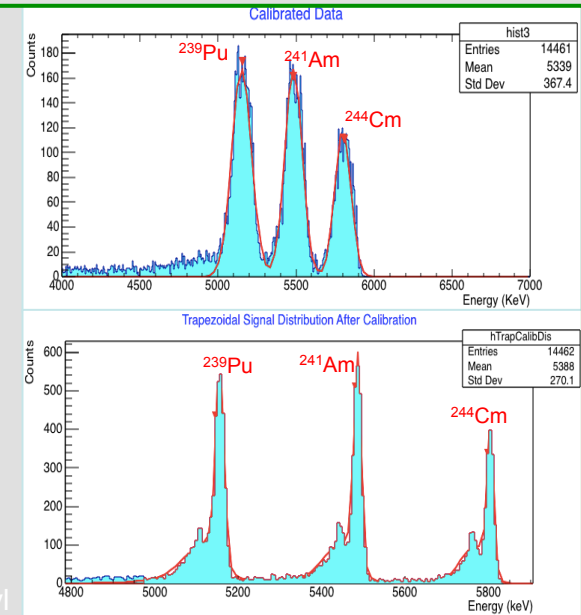
Maximum resolution



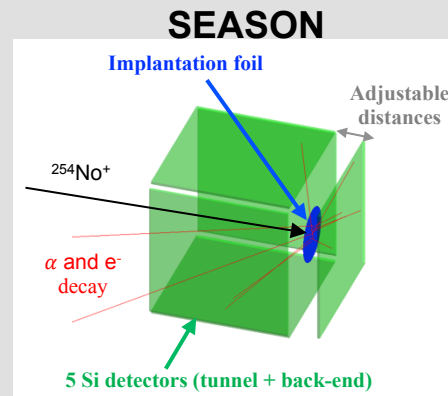
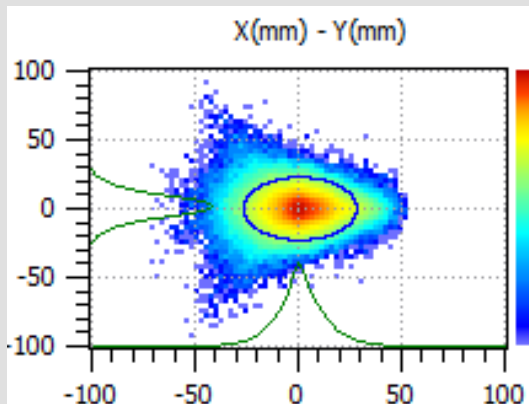
Electronic design



Work of T. Kallunkathariyl



Maximum efficiency



Courtesy of T. Goigoux

The project – S3

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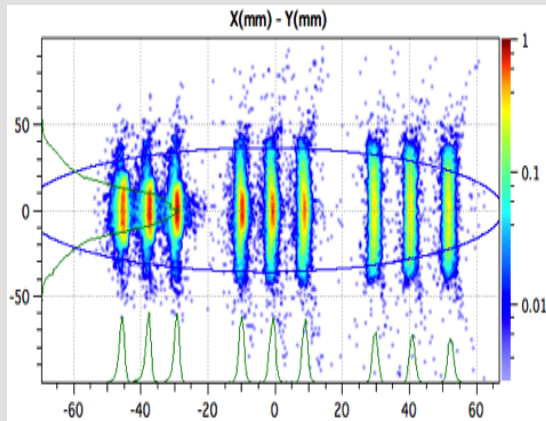
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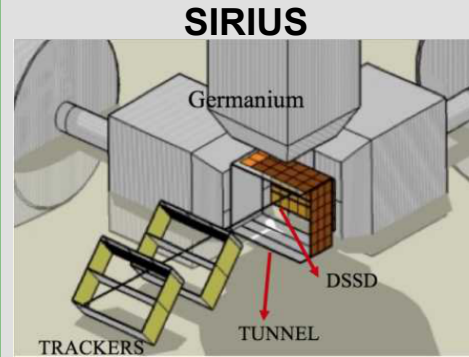
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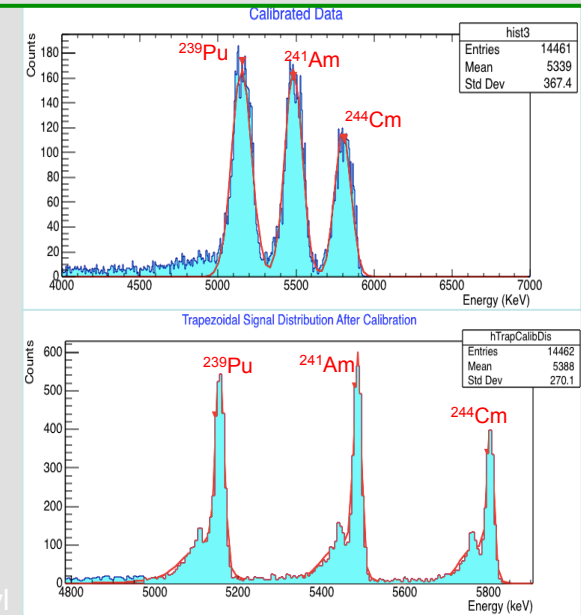
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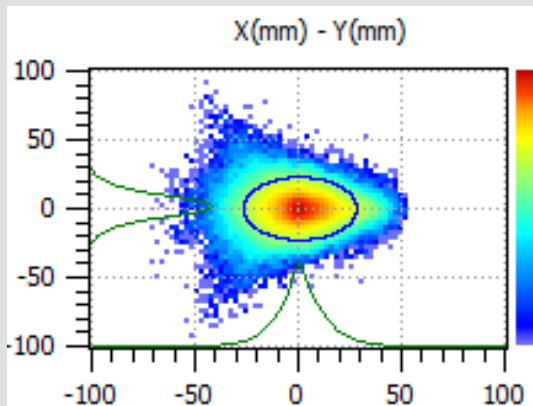
Electronic design



Work of T. Kallunkathariyl

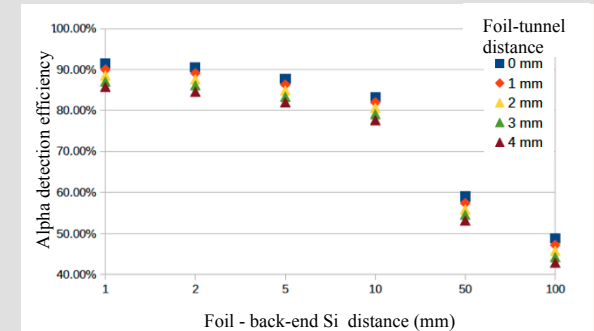
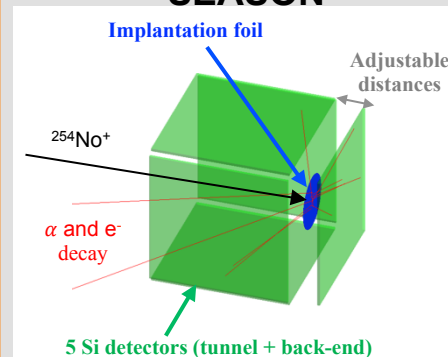


Maximum efficiency



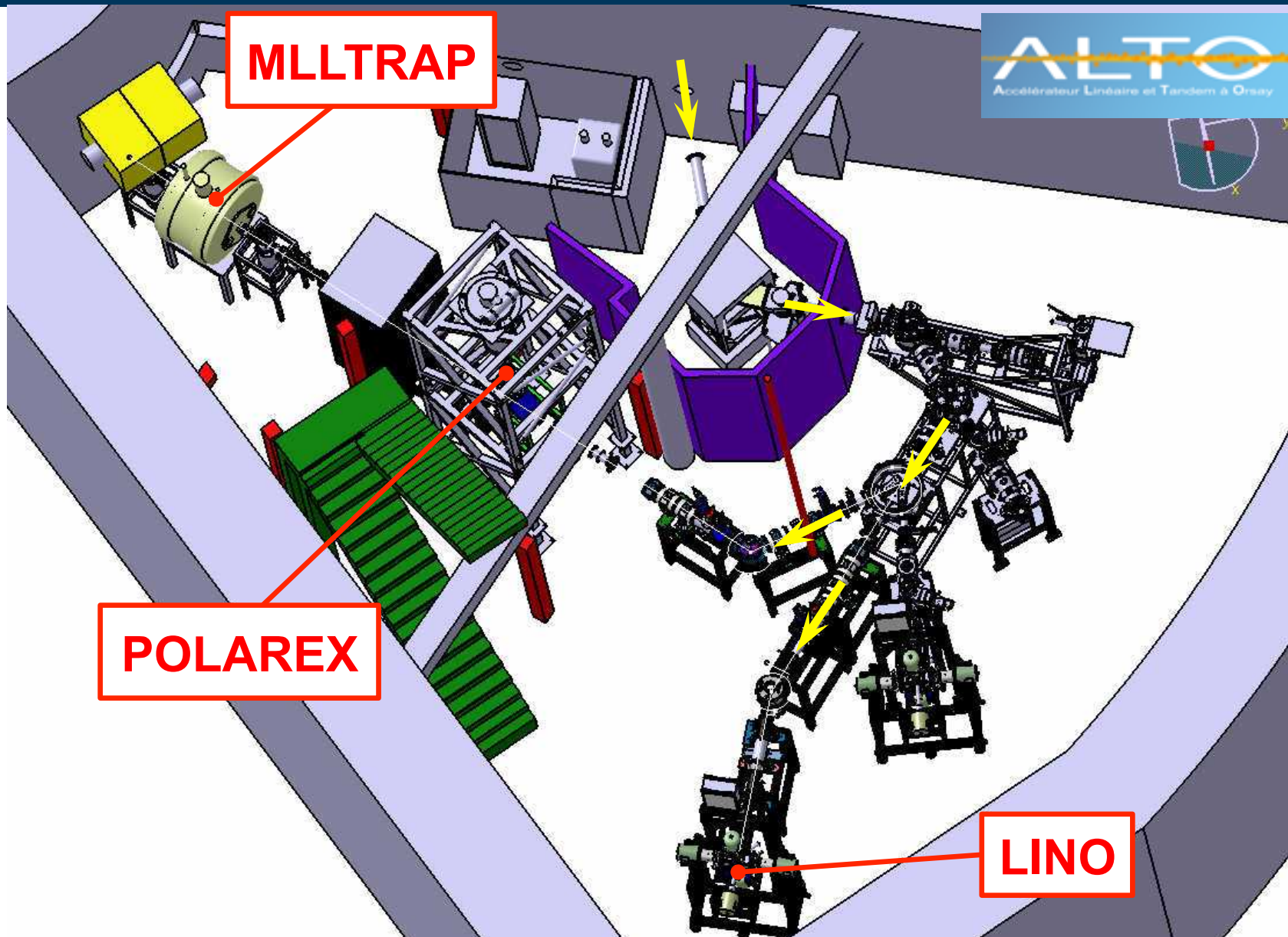
Detector design (ongoing)

SEASON



Courtesy of T. Goigoux

The project – ALTO



I. The project

- S3
- LINO
- POLAREX
- MLLTRAP

II. MLLTRAP status

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III. In-trap spectroscopy

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Conclusion

The project – LINO

I. The project

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- LINO

- POLAREX

- MLLTRAP

II. MLLTRAP status

- Progress on the line

- On-going/future work

III. In-trap spectroscopy

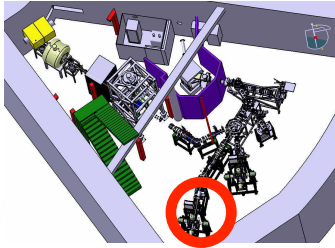
- Optimization

- Simulations

- Lifetime measurement

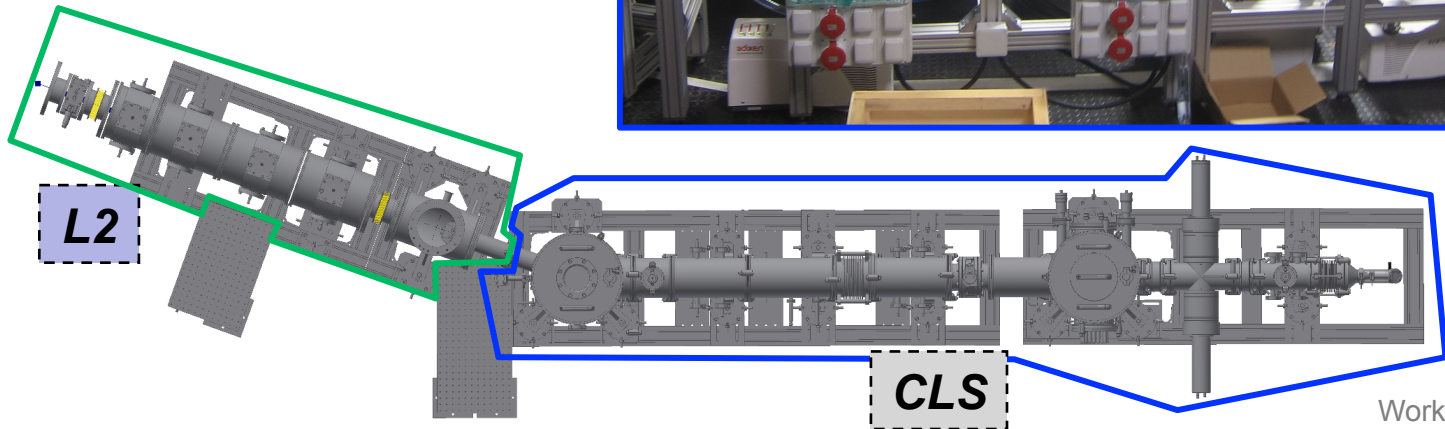
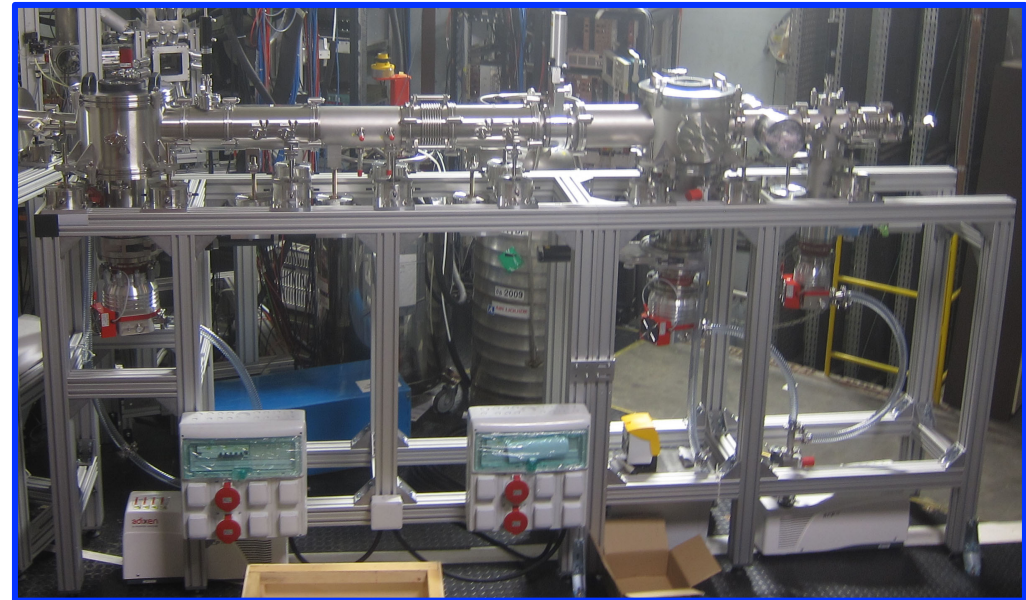
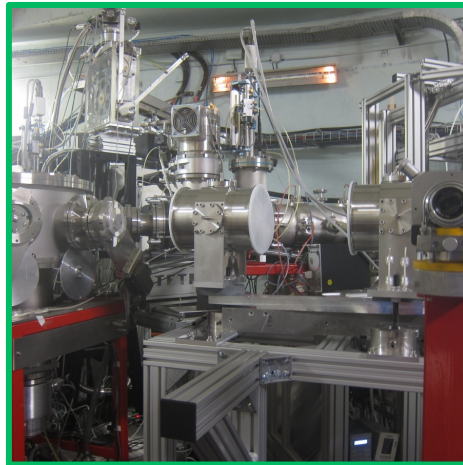
- On-going/future work

Conclusion



LINO = Laser Induced Nuclear Orientation

- Collinear laser and ion beam
- Fluorescence detectors

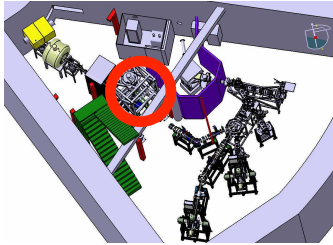


Work of D. Yordanov

The project – POLAREX

I. The project

- S3
- LINO
- POLAREX
- MLLTRAP



POLAREX = POLARization of EXotic nuclei with On-Line Nuclear Orientation

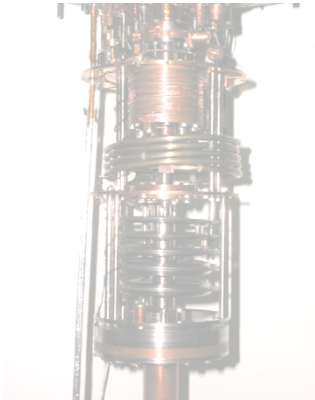
- Low temperature (7 mK)
- High magnetic field (10-100 T)
- 4 Ge detectors

II. MLLTRAP status

- Progress on the line
- On-going/future work

III. In-trap spectroscopy

- Optimization
- Simulations
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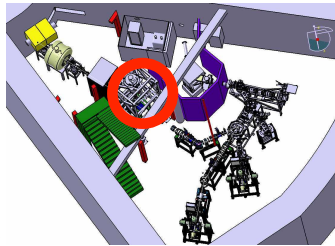
Conclusion

Courtesy of C. Gaulard

The project – POLAREX

I. The project

- S3
- LINO
- POLAREX



POLAREX = POLARization of EXotic nuclei with On-Line Nuclear Orientation

- Low temperature (7 mK)
- High magnetic field (10-100 T)
- 4 Ge detectors

Funding ANR

+ CNRS IN2P3 Les deux infinis

(installed)

Tube cryo

Cage de faraday

Iris

Steerer

Quadrupole triplet

Deflecteur 90° (Objet de la demande)

Funding P2IO Physique des 2 Infinis et des Origines

(ordered and partially delivered)

Funding île de France SESAME

(Order beginning 2019)

ALTO Beam

MLLTRAP

Funding ERM (delivered)

UNIVERSITÉ PARIS SUD

université PARIS-SACLAY

II. MLLTRAP status

- Progress on the line
- On-going/future work



III. In-trap spectroscopy

- Optimization
- Simulations
- Lifetime measurement
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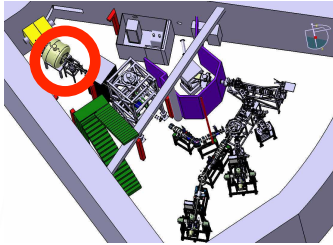
Conclusion

Courtesy of C. Gaulard

The project – MLLTRAP

I. The project

- S3
- LINO
- POLAREX
- MLLTRAP



MLLTRAP = Penning trap received from Maier-Leibnitz Laboratory

- 7T Magnet superconducting magnet
- 2 double trap assemblies

II. MLLTRAP status

- Progress on the line
- On-going/future work

III. In-trap spectroscopy

- Optimization
- Simulations
- Lifetime measurement
- On-going/future work

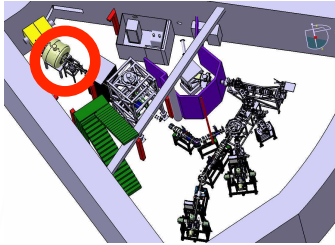
Conclusion

Courtesy of E. Minaya Ramirez

The project – MLLTRAP

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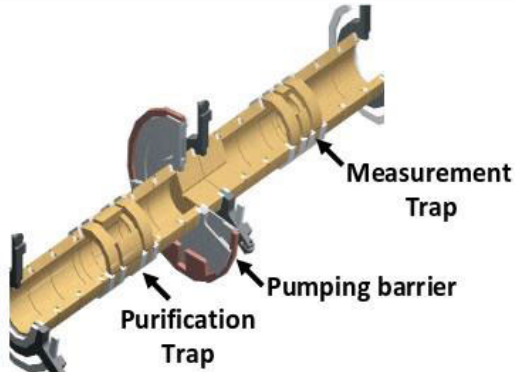
- Progress on the line
- On-going/future work

III. In-trap spectroscopy

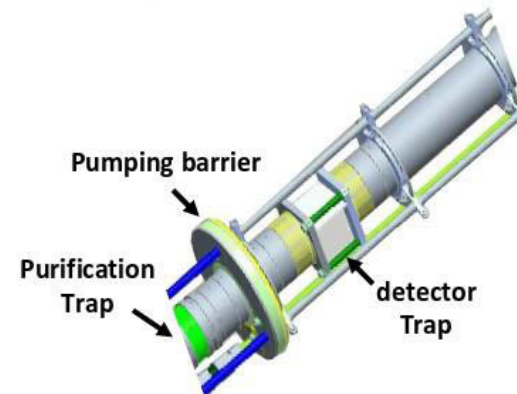
- Optimization
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Conclusion

High-precision mass measurements ("M")



In-trap decay spectroscopy ("S")

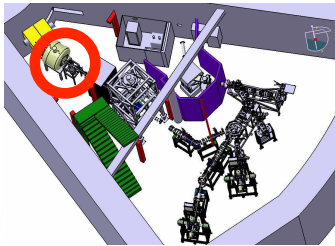


Courtesy of E. Minaya Ramirez

The project – MLLTRAP

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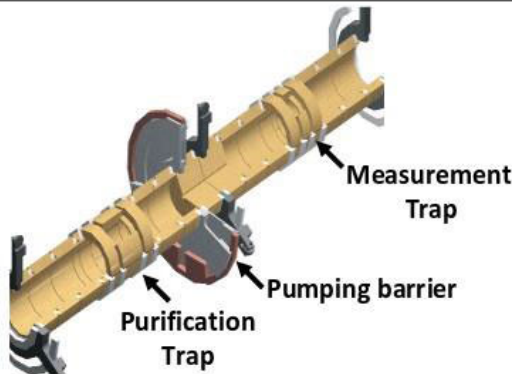
- Progress on the line
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III. In-trap spectroscopy

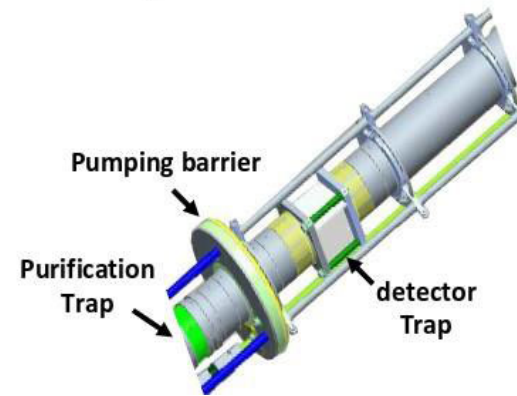
- Optimization
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Conclusion

High-precision mass measurements ("M")



In-trap decay spectroscopy ("S")



First trap: mass selective cooling/centering

Second trap: mass measurement

Measure $\nu \propto m$ $\frac{\delta m}{m} \propto T^{-1}$

Second trap: decay spectroscopy

Mass-less decay

Separation α/e^-

Courtesy of E. Minaya Ramirez

MLLTRAP Status – Progress on the line

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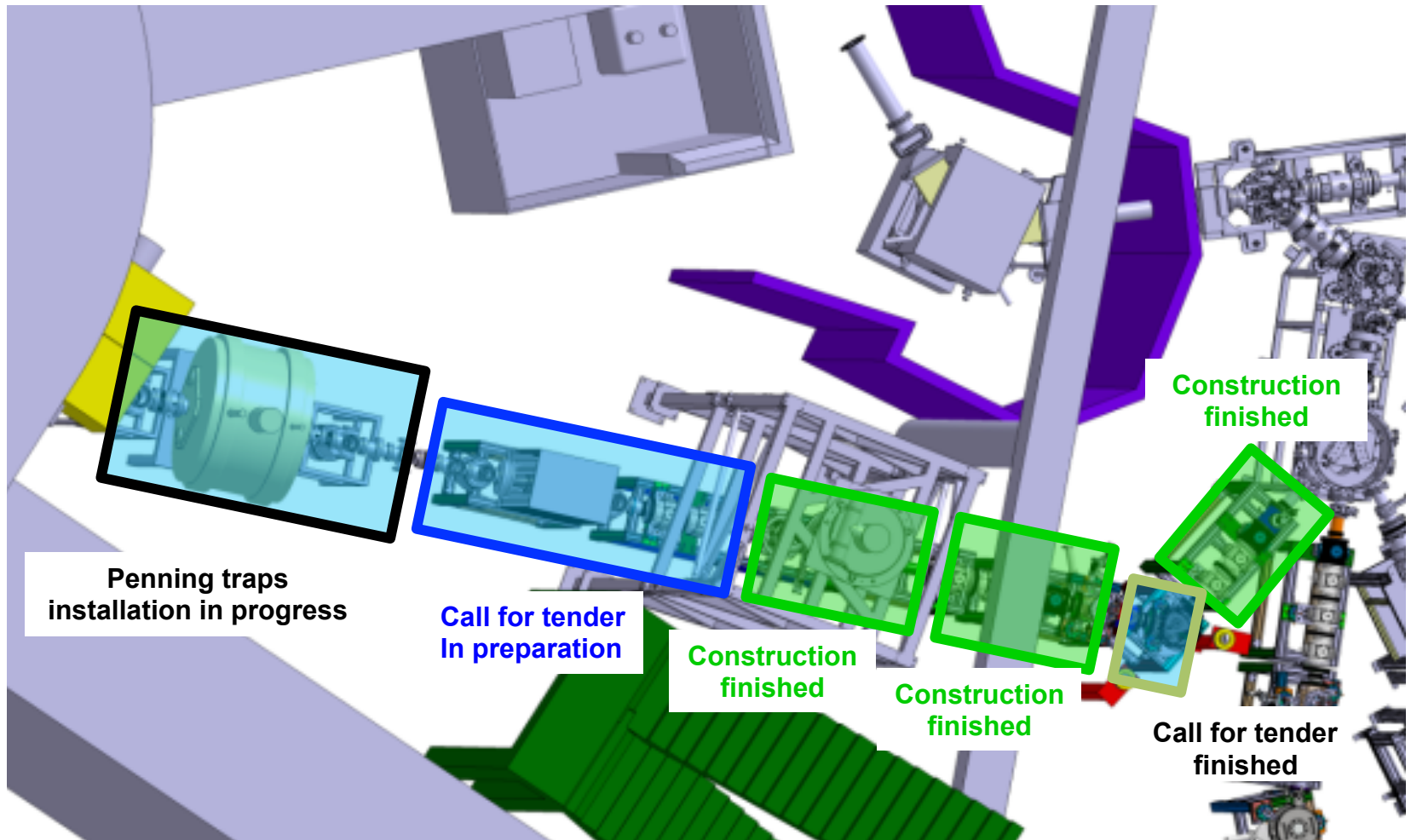
II. MLLTRAP status

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III. In-trap spectroscopy

- Optimization
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- On-going/future work

Conclusion



Funding



Courtesy of E. Minaya Ramirez

MLLTRAP Status – On-going/future work

I. The project

- S3
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- POLAREX
- MLLTRAP

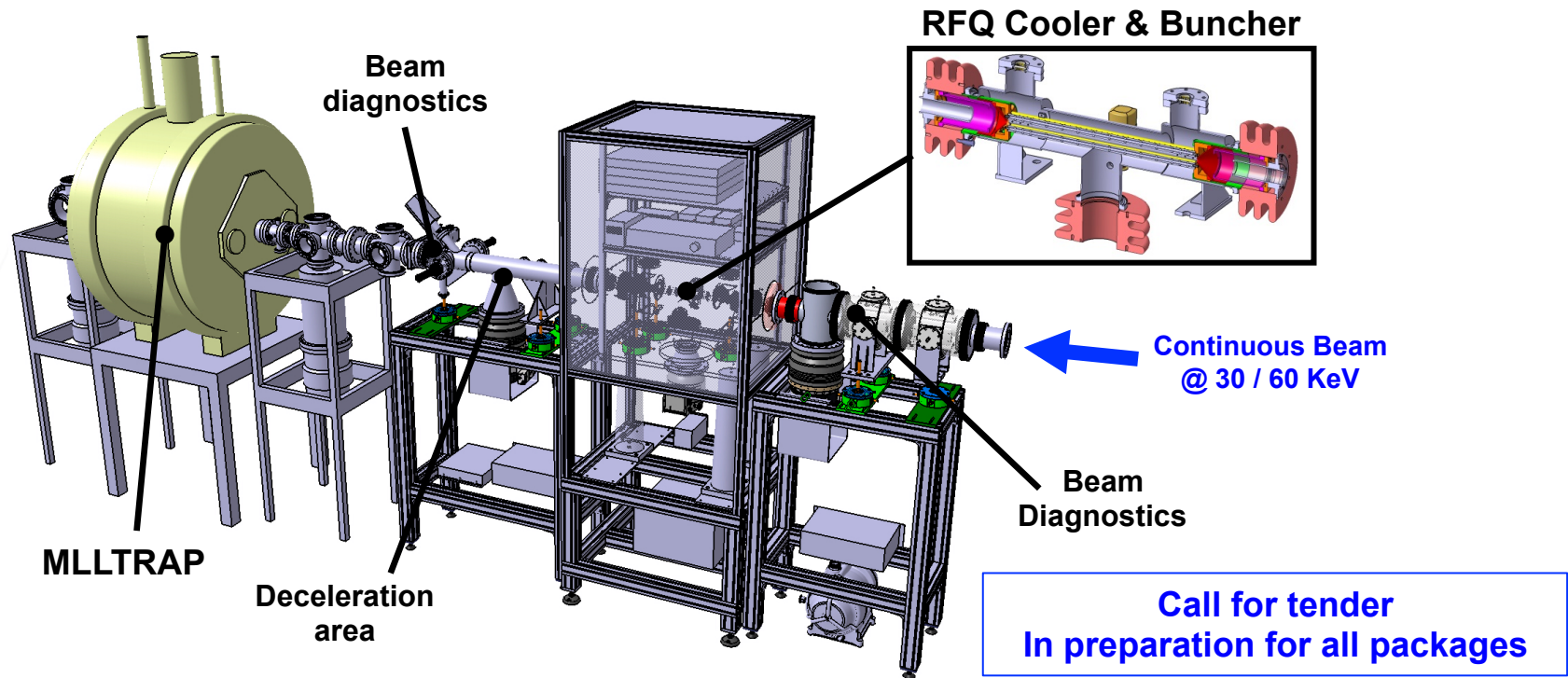
II. MLLTRAP status

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Conclusion



Courtesy of E. Minaya Ramirez

MLLTRAP Status – On-going/future work

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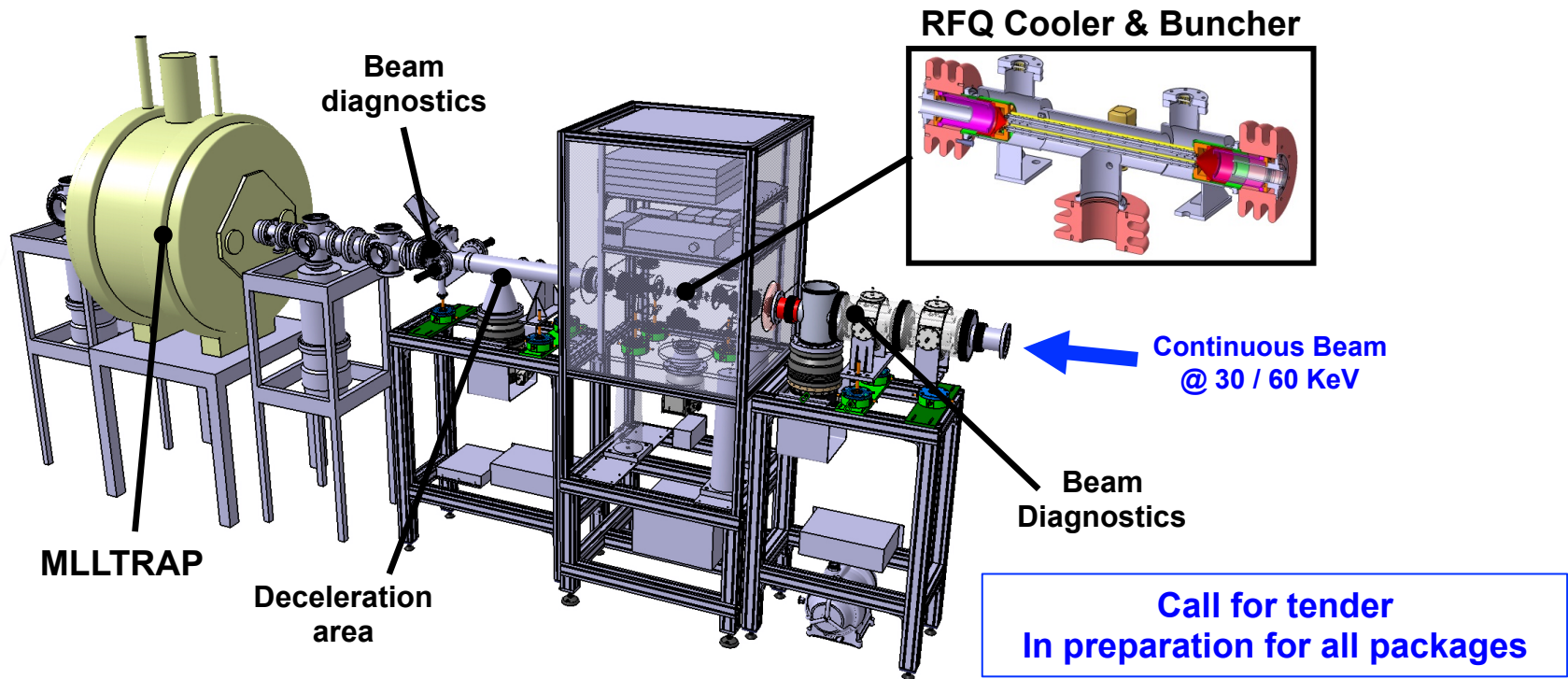
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Conclusion

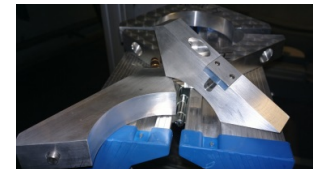


- R&D project with



for real time tracking of the magnet's field variation.

➔ Modifications of the vacuum tube support



Courtesy of E. Minaya Ramirez

MLLTRAP Status – On-going/future work

I. The project

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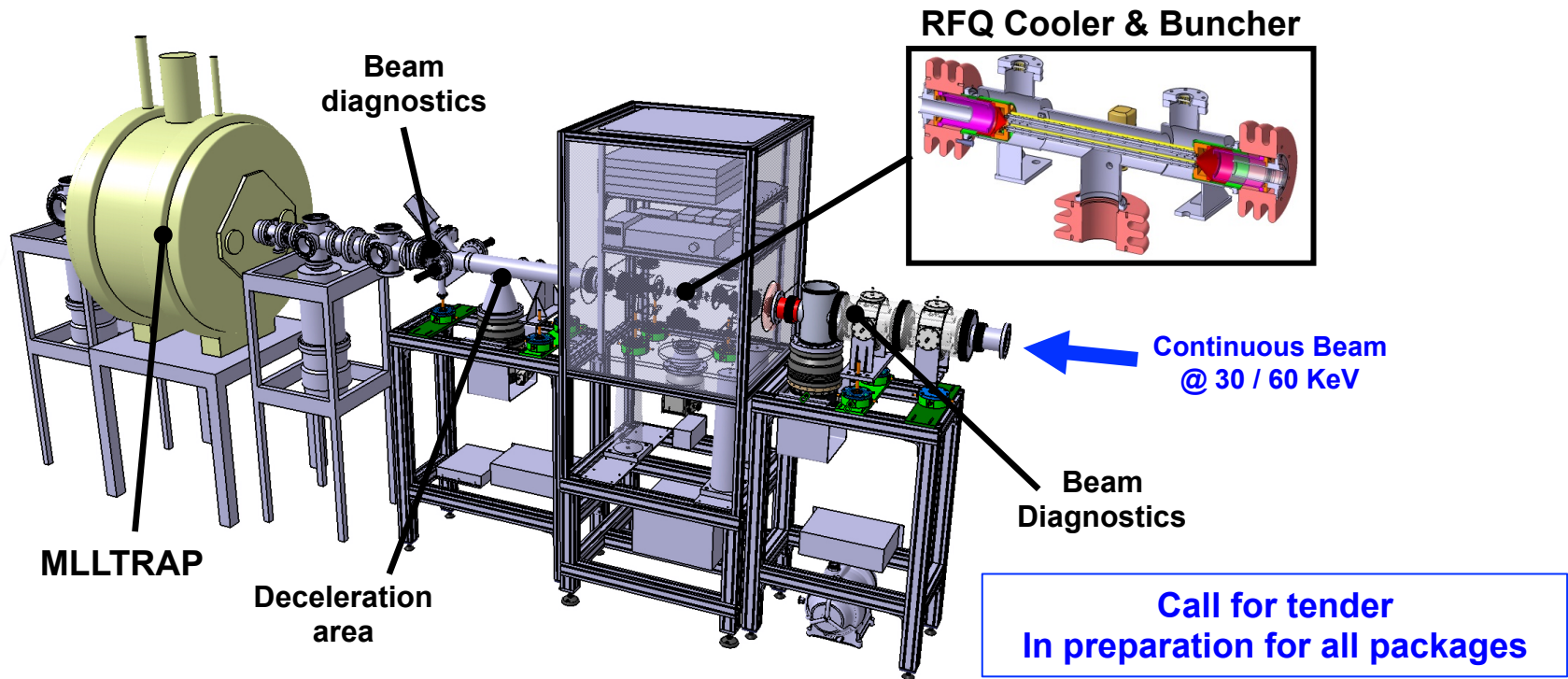
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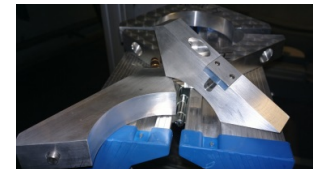


- R&D project with



for real time tracking of the magnet's field variation.

➔ Modifications of the vacuum tube support



- Alignment of the vacuum tube in progress.



Courtesy of E. Minaya Ramirez

In-trap spectroscopy

I. The project

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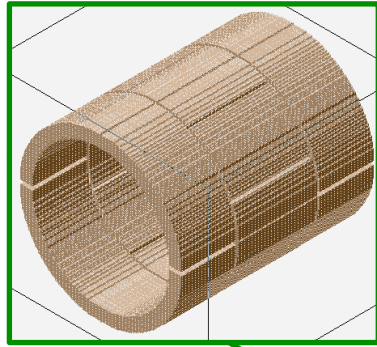
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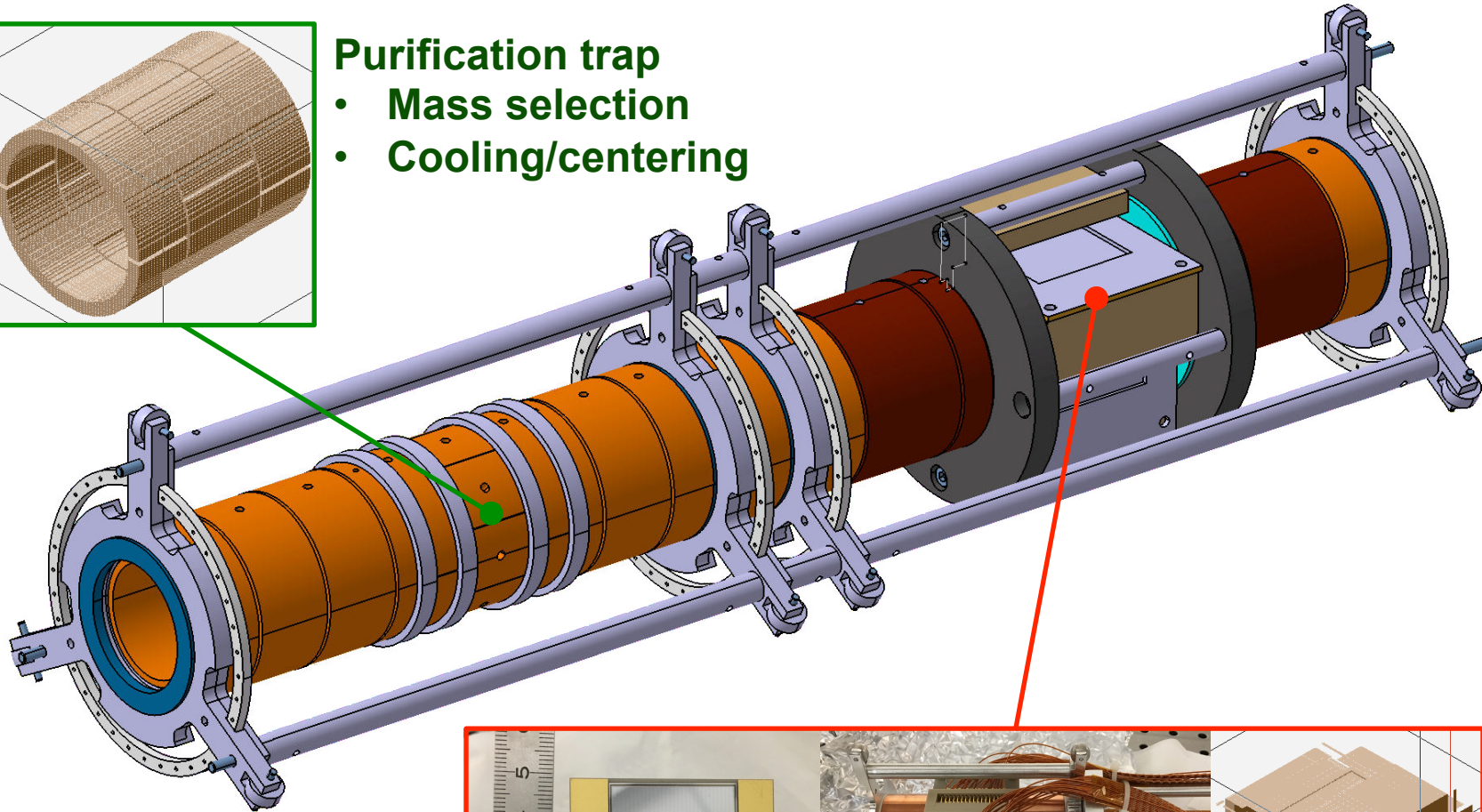
- Optimization
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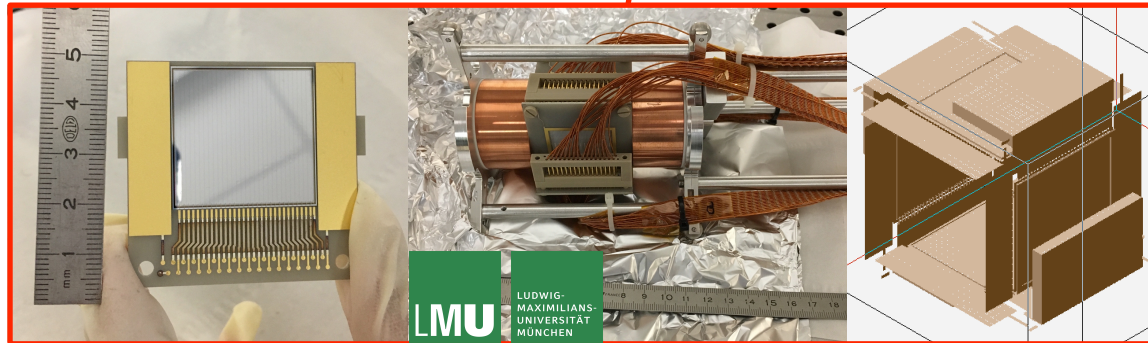
Purification trap

- Mass selection
- Cooling/centering



Spectroscopy trap

- α -spectroscopy
- $T_{1/2}$ measurement
- Mass measurement



In-trap spectroscopy – Optimization

I. The project

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- LINO
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II. MLLTRAP status

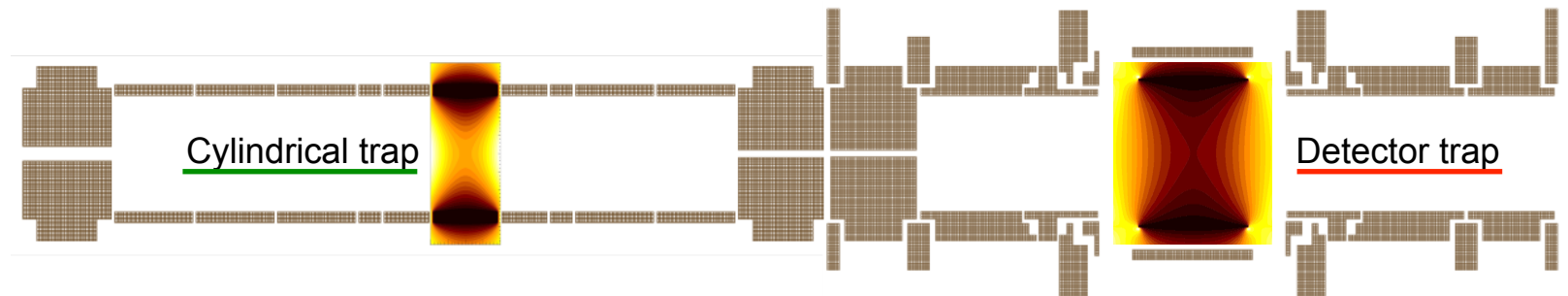
- Progress on the line
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III. In-trap spectroscopy

- Optimization
- Simulations
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Conclusion

Optimization goals: enhance cooling efficiency, enable mass measurement



In-trap spectroscopy – Optimization

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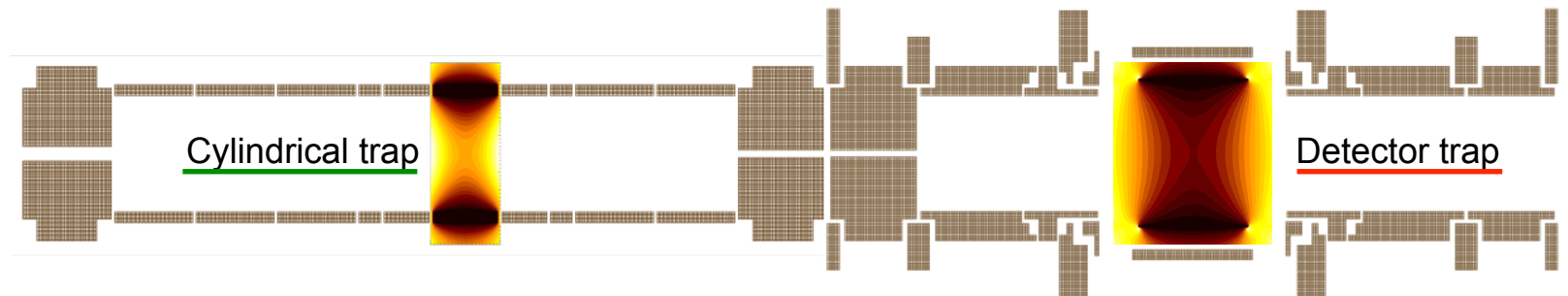
III. In-trap spectroscopy

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- Simulations
- Lifetime measurement
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Conclusion

Optimization goals: enhance cooling efficiency, enable mass measurement

Optimize $V(x, y, z)$ so that: $V(x, y, z) - V(0, 0, 0) \approx \frac{V_0(2z^2 - x^2 - y^2)}{2d^2}$ | Perfect trap



In-trap spectroscopy – Optimization

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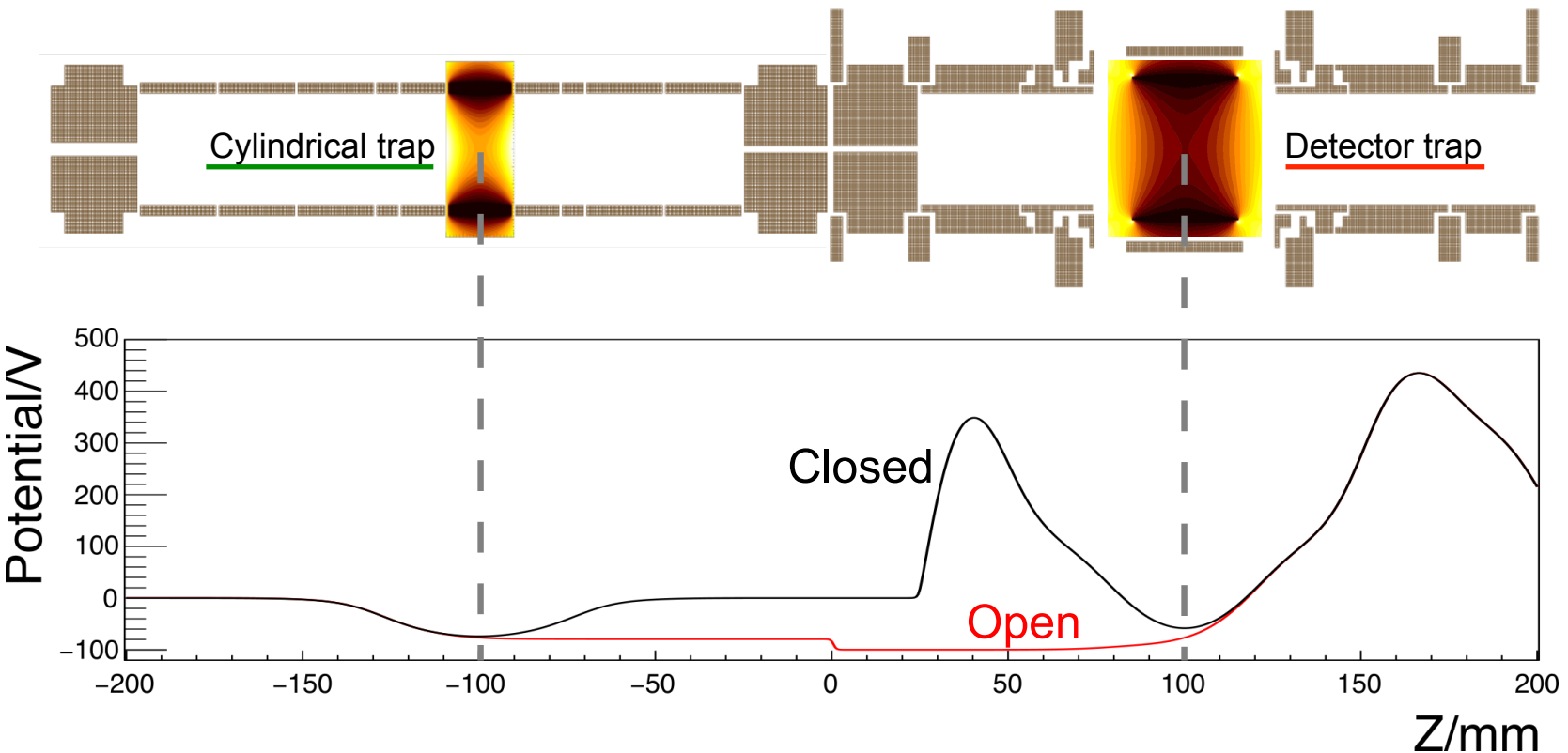
III. In-trap spectroscopy

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Optimization goals: enhance cooling efficiency, enable mass measurement

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In-trap spectroscopy – Simulations

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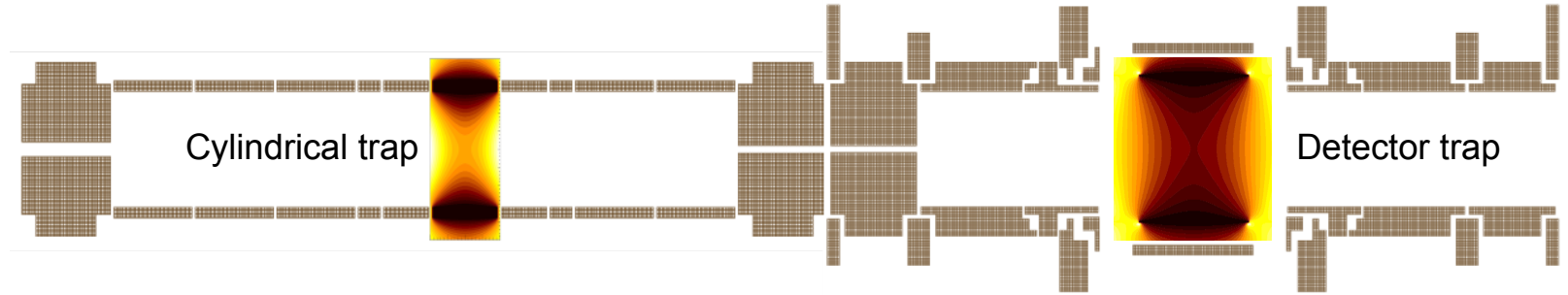
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III. In-trap spectroscopy

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- Simulations

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Conclusion



Realistic simulation of a 100 ions bunch in both trap

In-trap spectroscopy – Simulations

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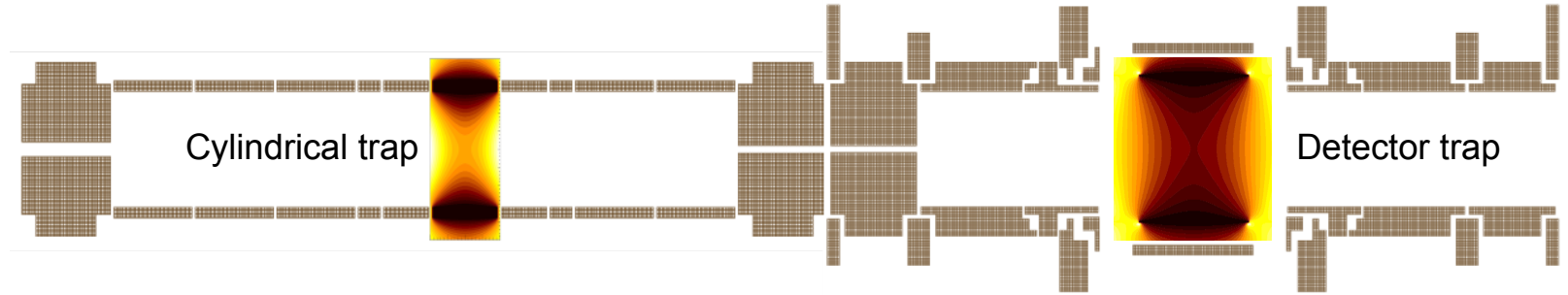
- Progress on the line
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III. In-trap spectroscopy

- Optimization
- Simulations

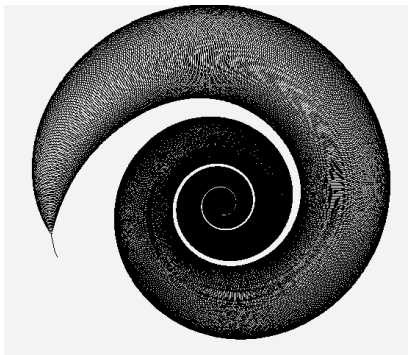
- Lifetime measurement
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Conclusion



Realistic simulation of a 100 ions bunch in both trap

For: Cooling and centering



In-trap spectroscopy – Simulations

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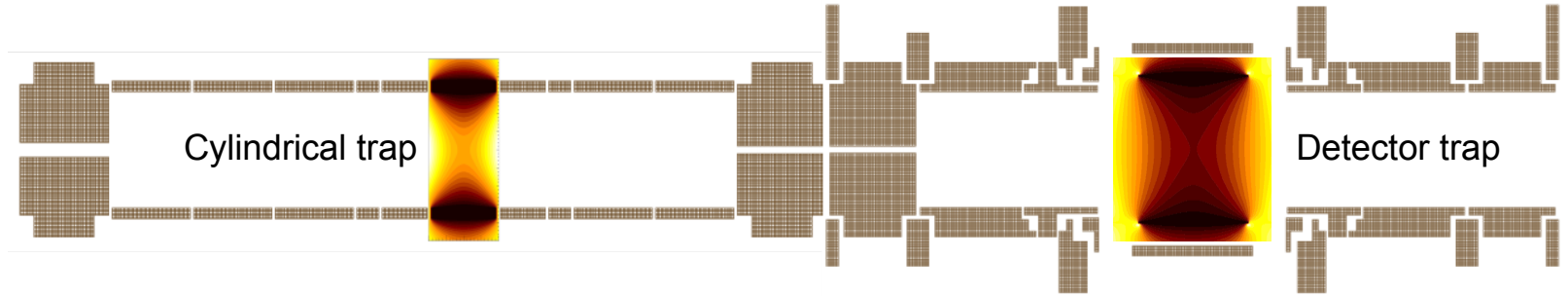
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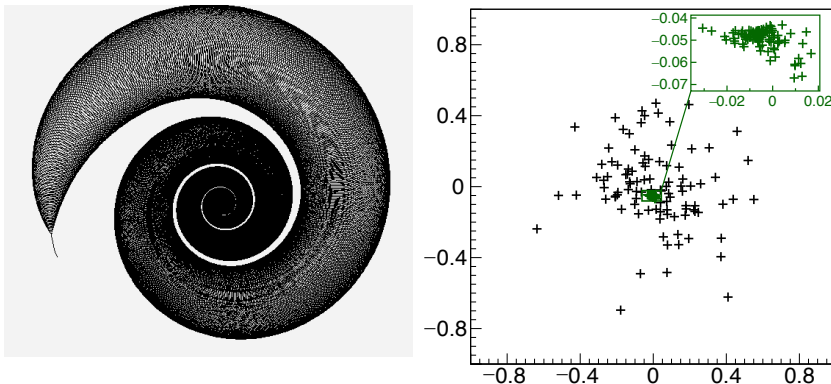
Conclusion



Realistic simulation of a 100 ions bunch in both trap

For: Cooling and centering

Result: Bunch size reduced by ~ 30



In-trap spectroscopy – Simulations

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II. MLLTRAP status

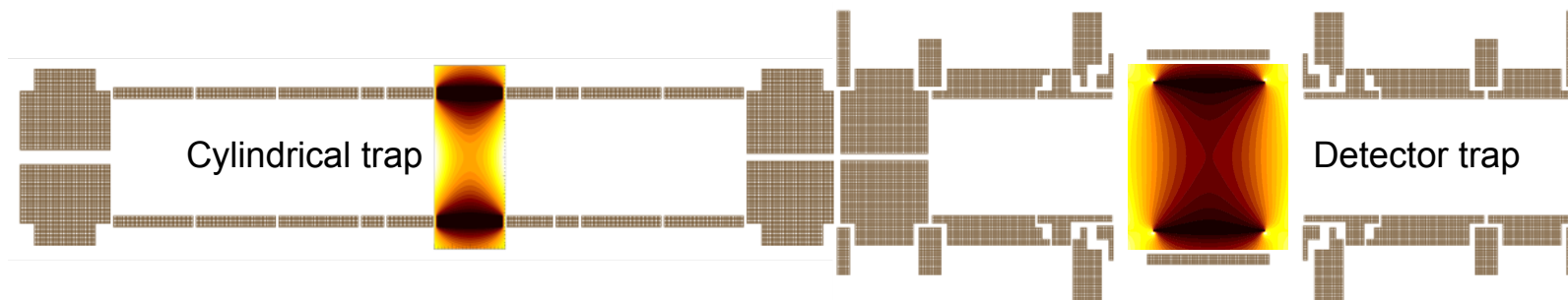
- Progress on the line
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III. In-trap spectroscopy

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Conclusion

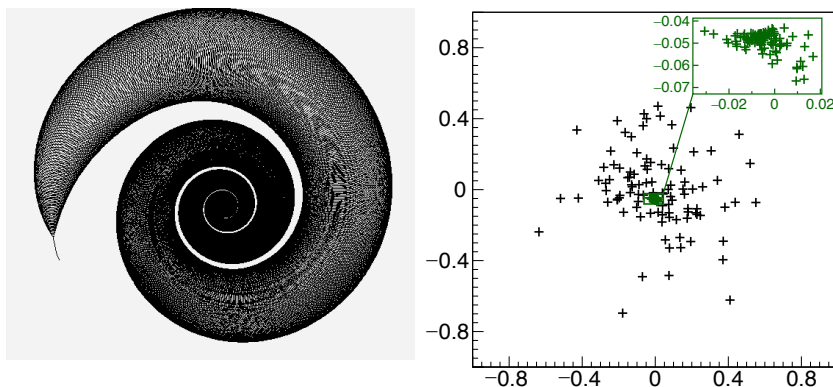


Realistic simulation of a 100 ions bunch in both trap

For: Cooling and centering

Result: Bunch size reduced by ~ 30

For: Mass measurement in the spectroscopic trap



In-trap spectroscopy – Simulations

I. The project

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- MLLTRAP

II. MLLTRAP status

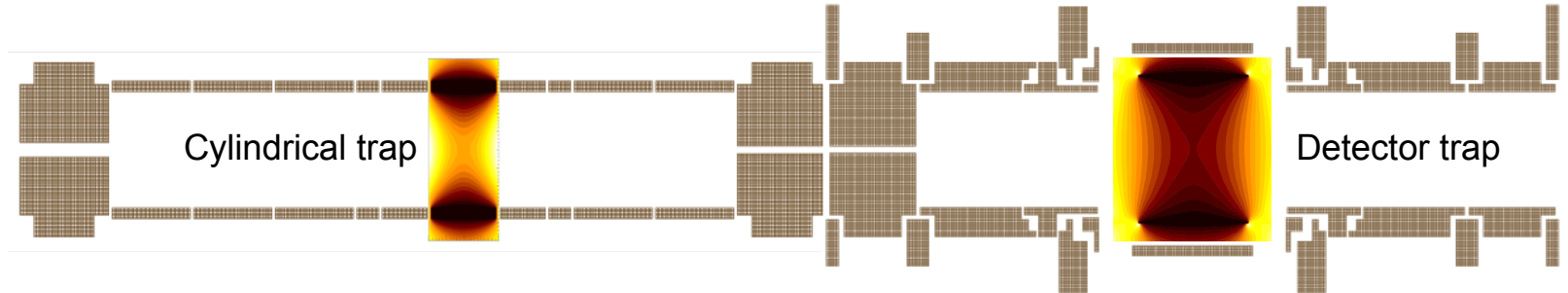
- Progress on the line
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III. In-trap spectroscopy

- Optimization
- Simulations

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Conclusion



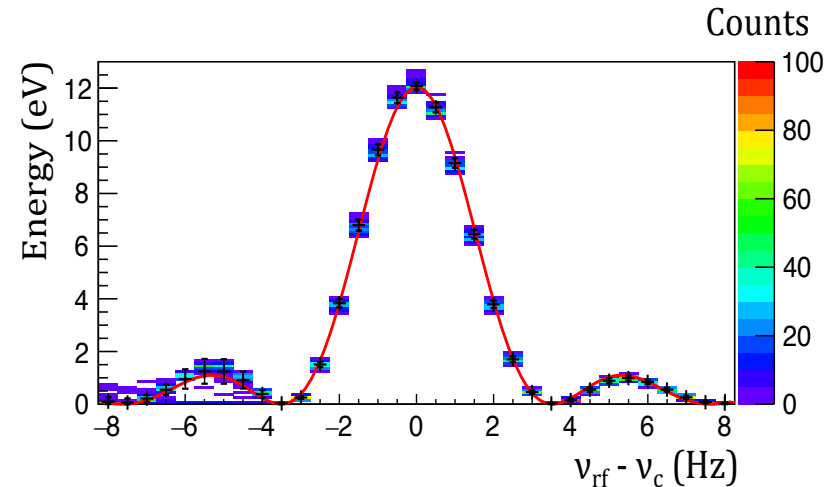
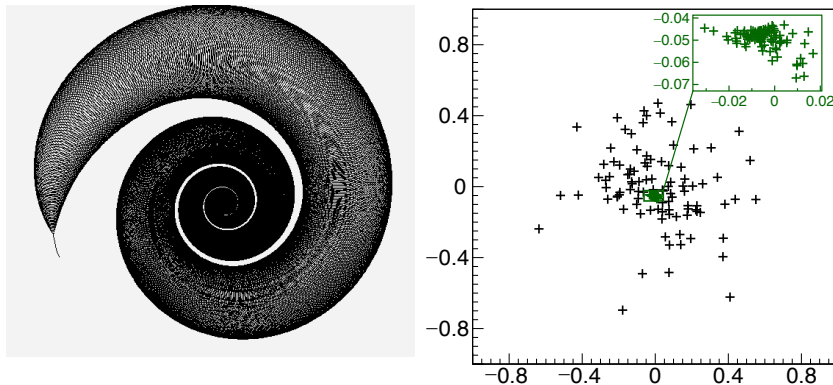
Realistic simulation of a 100 ions bunch in both trap

For: Cooling and centering

Result: Bunch size reduced by ~ 30

For: Mass measurement in the spectroscopic trap

Result: mass uncertainty = $2.3 \cdot 10^{-8}$!



In-trap spectroscopy – Lifetime measurement

I. The project

- S3
- LINO
- POLAREX
- MLLTRAP

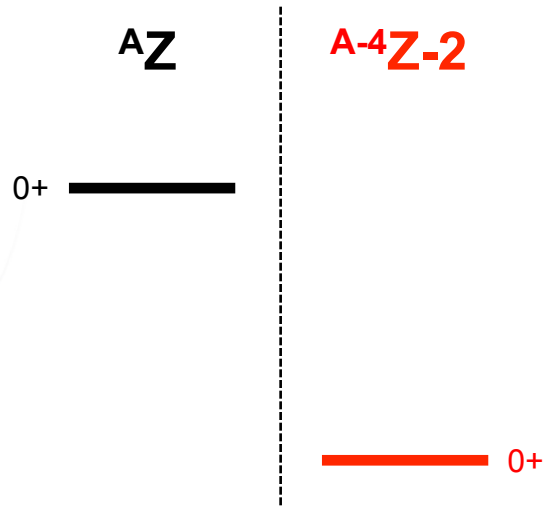
II. MLLTRAP status

- Progress on the line
- On-going/future work

III. In-trap spectroscopy

- Optimization
- Simulations
- Lifetime measurement
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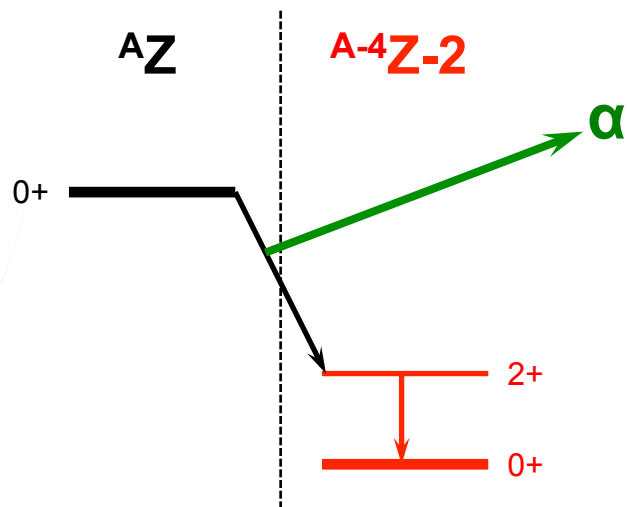
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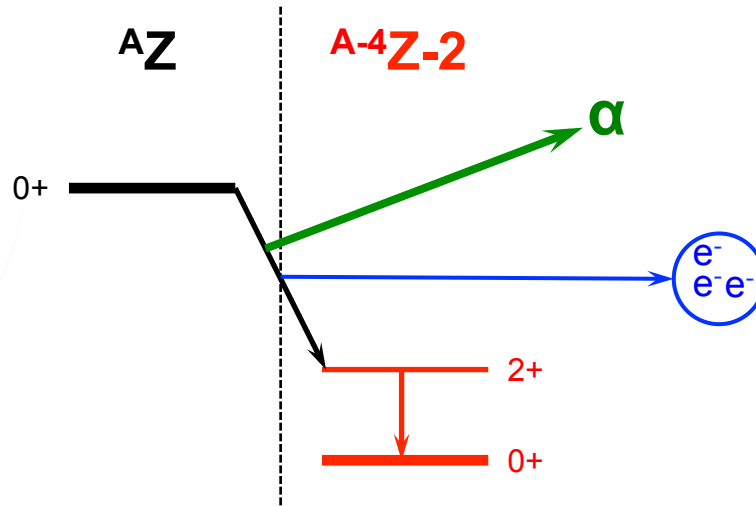
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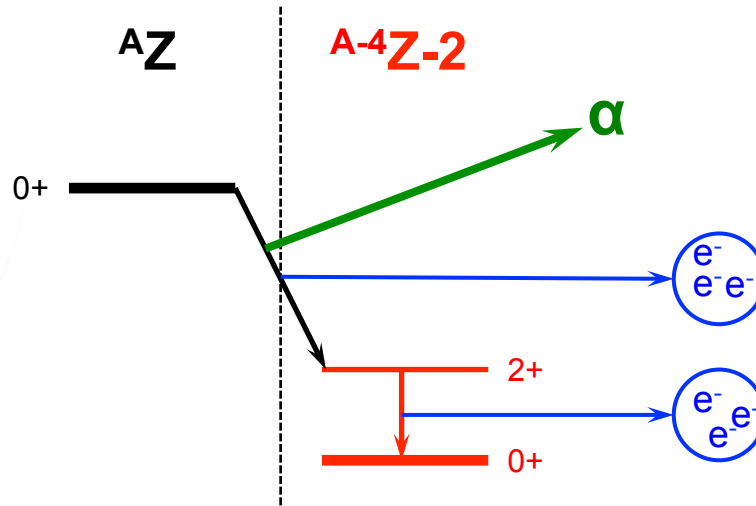
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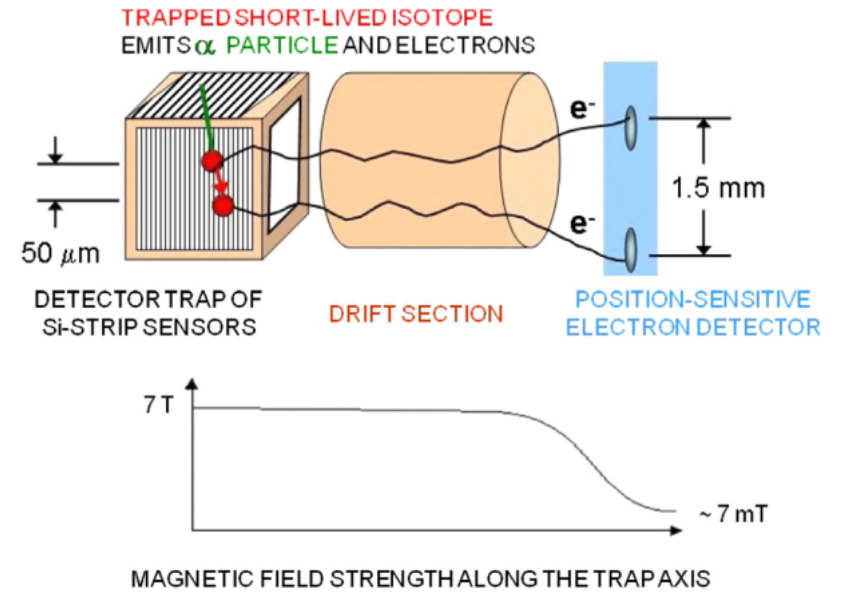
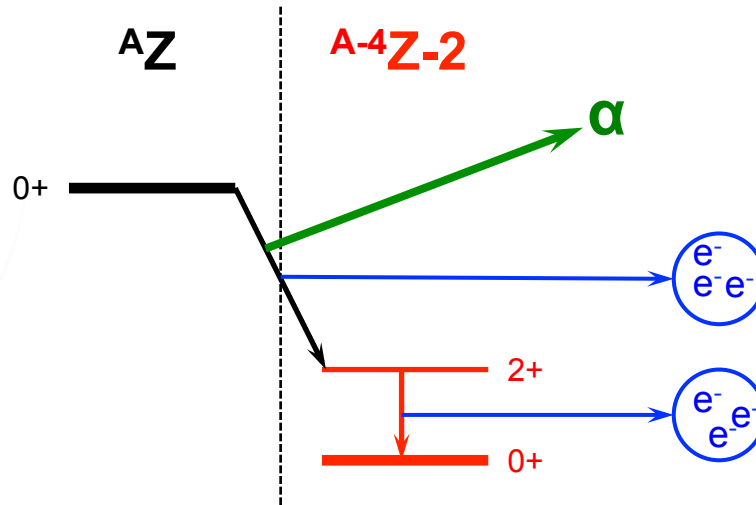
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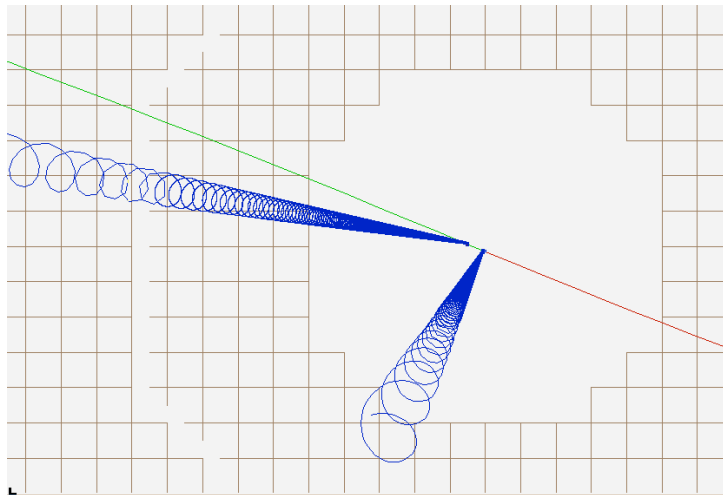
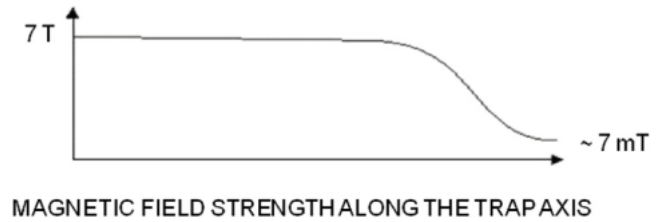
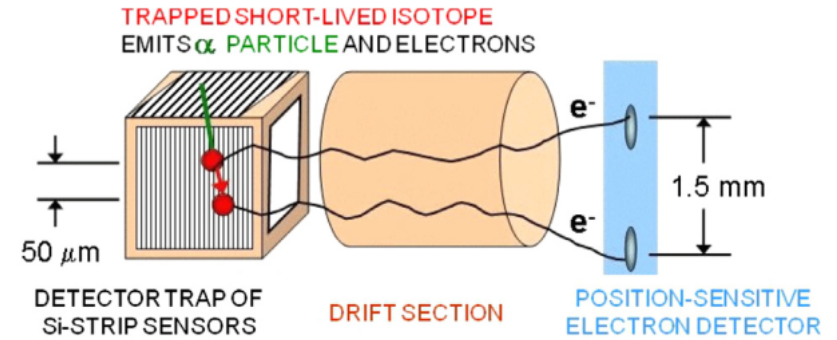
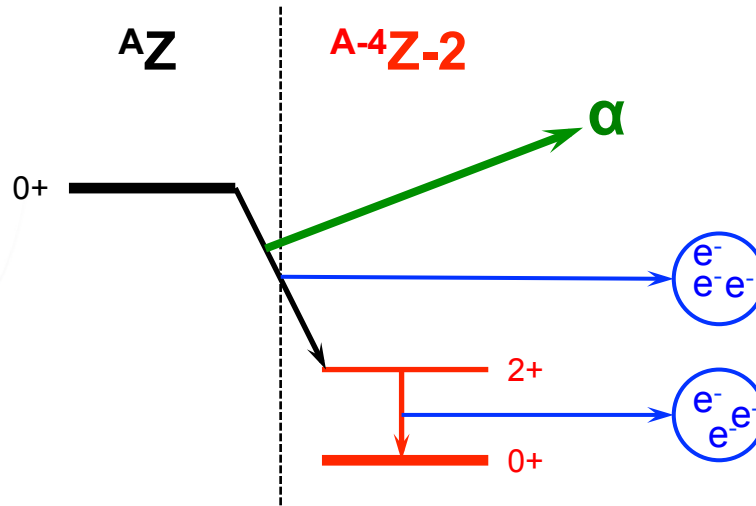
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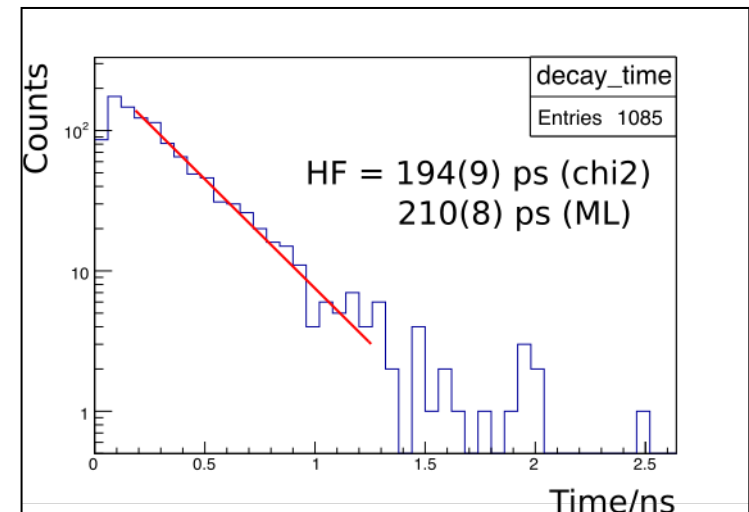
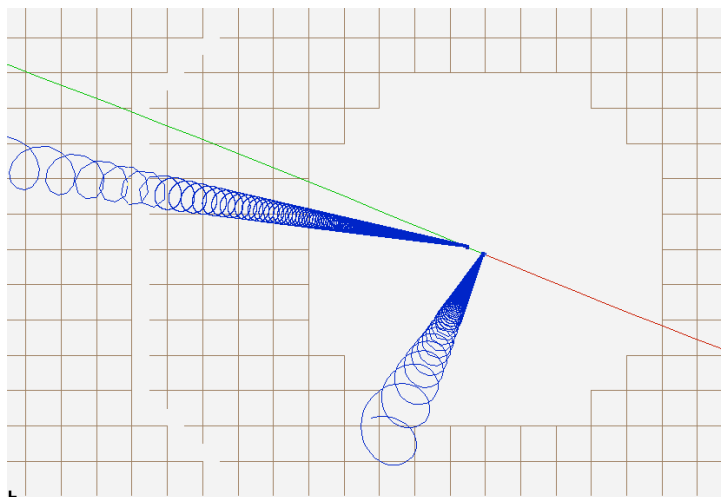
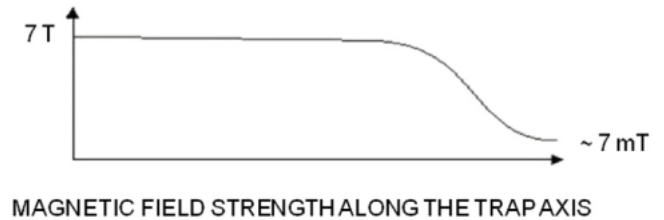
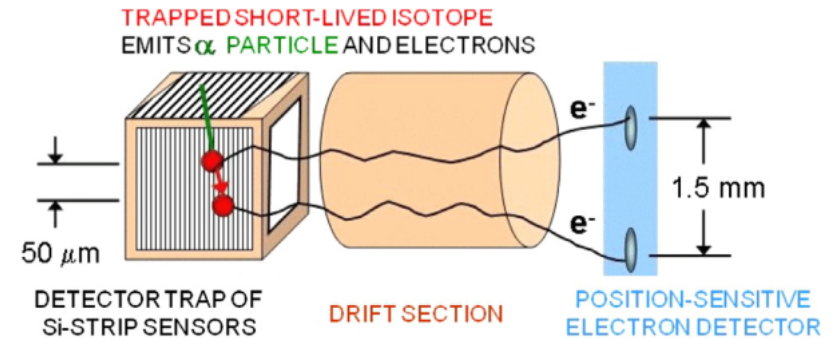
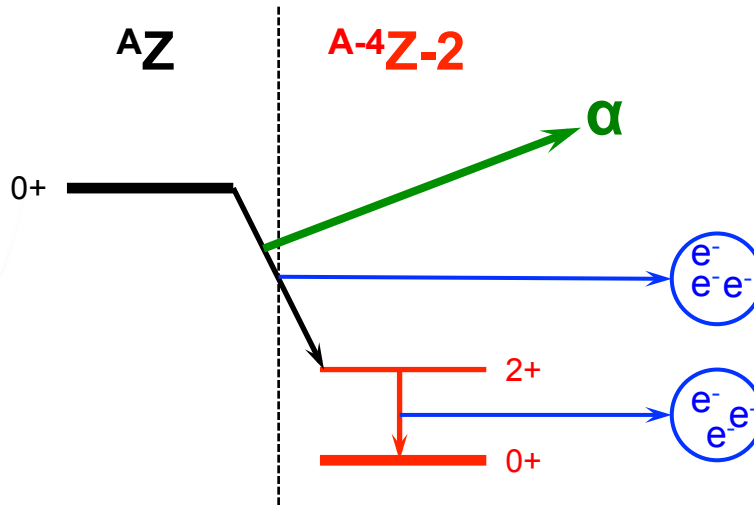
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III. In-trap spectroscopy

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Conclusion



In-trap spectroscopy – On-going/future work

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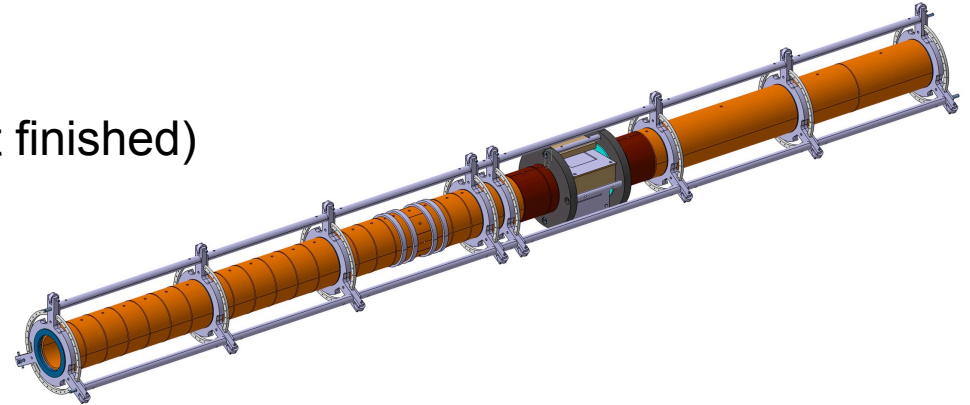
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III. In-trap spectroscopy

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Conclusion

- Mechanical design (almost finished)



In-trap spectroscopy – On-going/future work

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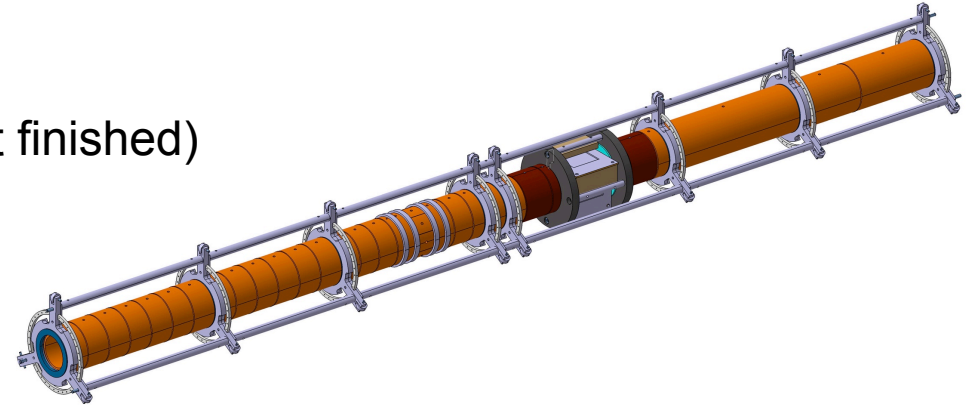
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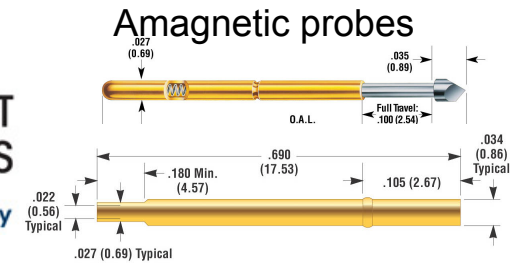
- Optimization
- Simulations
- Lifetime measurement
- On-going/future work

Conclusion

- Mechanical design (almost finished)



- Preparing DSSD test



In-trap spectroscopy – On-going/future work

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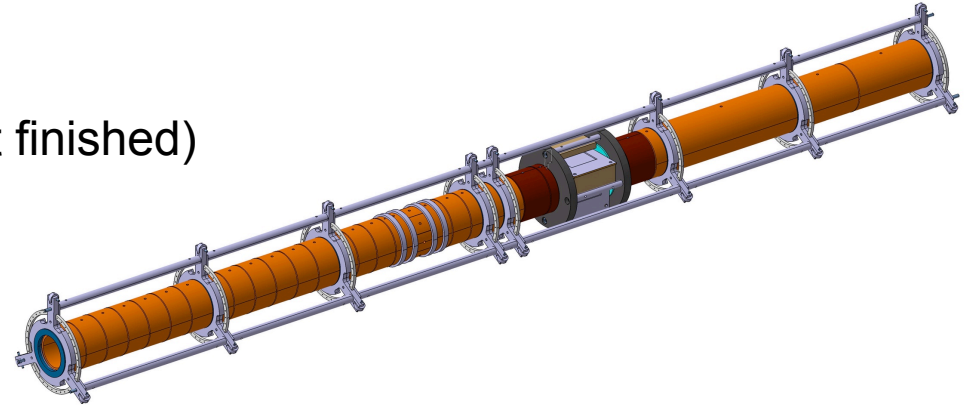
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III. In-trap spectroscopy

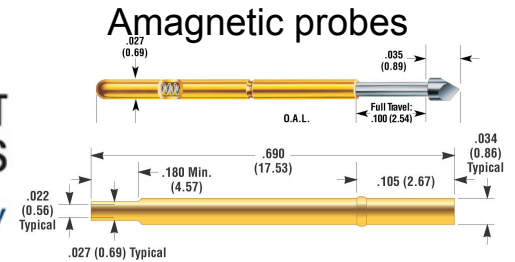
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Conclusion

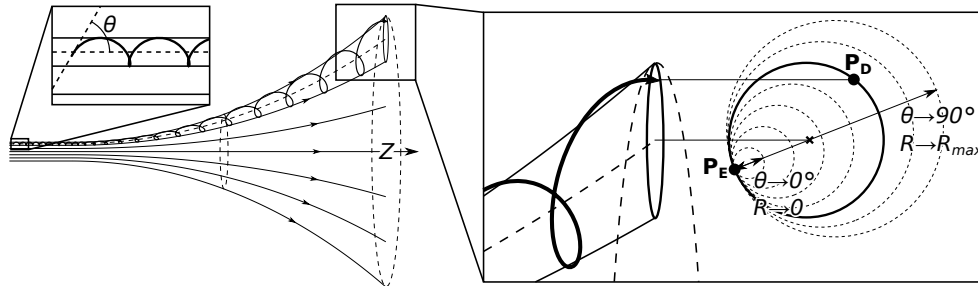
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- Investigating/reducing error on lifetime measurement



In-trap spectroscopy – On-going/future work

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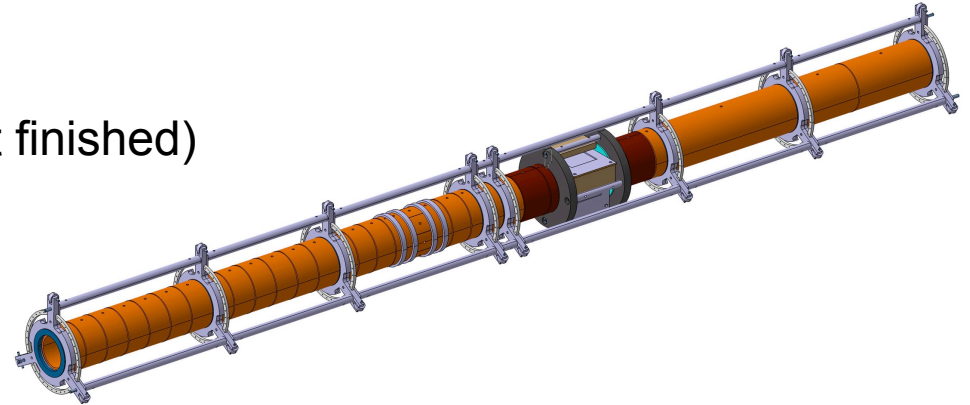
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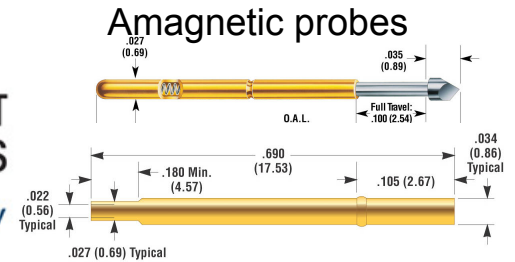
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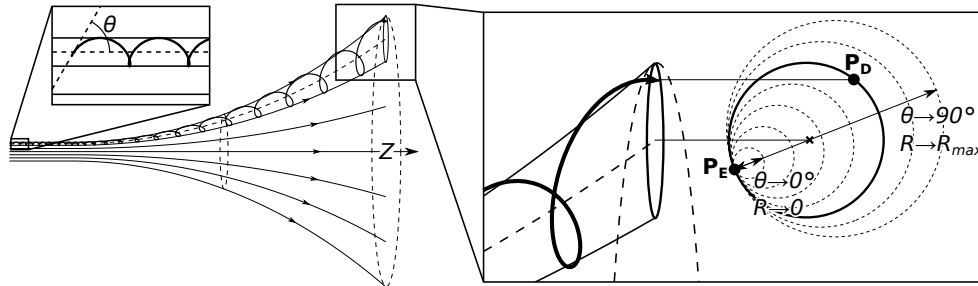
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- Preparing DSSD test



- Investigating/reducing error on lifetime measurement



- Writing article (x2)

Conclusion

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- All Terra incognita projects in the practical phase
- MLLTRAP vacuum system being installed
- Some DSSD tests expected next year.
- Analysis tool development



Conclusion

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Conclusion

THANK YOU FOR YOUR ATTENTION !

(Now clap your hands)



Spectroscopy Electron Alpha in Silicon bOx couNter (SEASON) for laser ionisation spectroscopy @ LEB S³

Measurement of isotope/isomer shift and hyperfine structure:

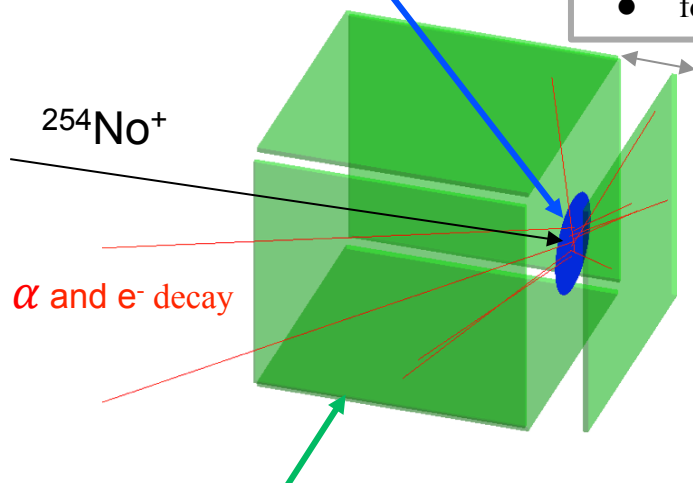
- Atomic observables: charge radii, quadrupole/dipole moment, spins
- Nuclear observables: shape/deformation parameters and single/few particle configurations

Implantation foil

- **C 20 $\mu\text{g}/\text{cm}^2$** (Windmill like)
- Mounted on a scale or **wheel**

Adjustable distances

- For “high counting rate” increase distances between
- foil and tunnel
 - foil and back-end Si



$^{254}\text{No}^+$

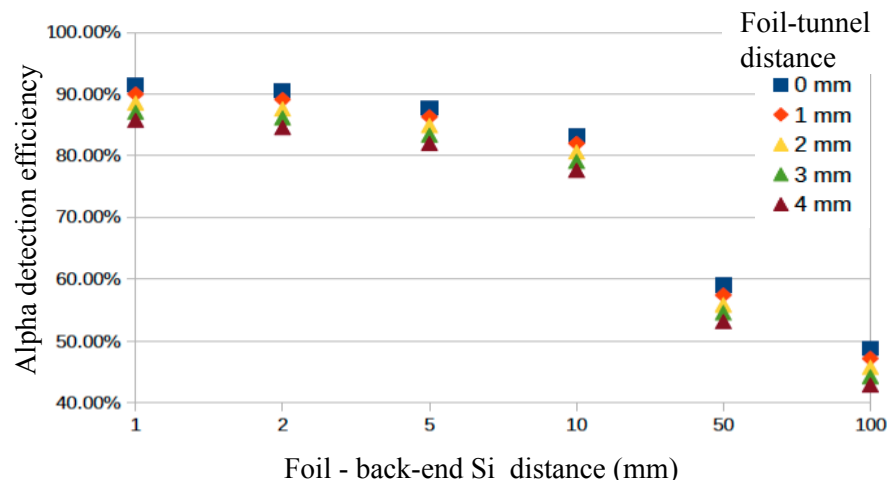
α and e^- decay

5 Si detectors (tunnel + back-end)

- **Cubic configuration** to optimize geometric efficiency
- **1mm thick** to stop electron and α

Monte-Carlo simulations for detection efficiency:

- **Alpha at 8 MeV: 90%** in compact geometry
- **Electrons at 100 keV: 60%** in compact geometry

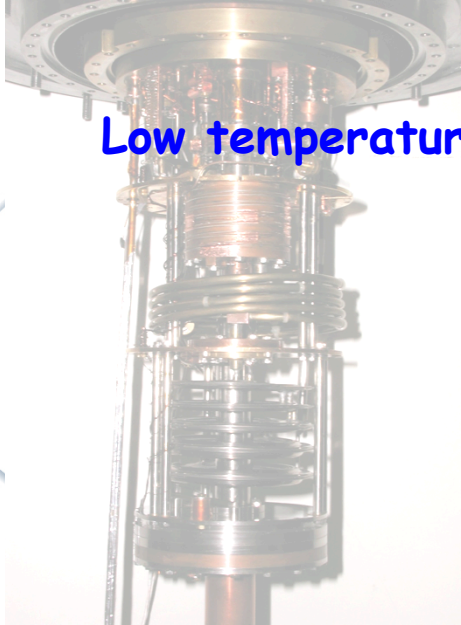


Future work:

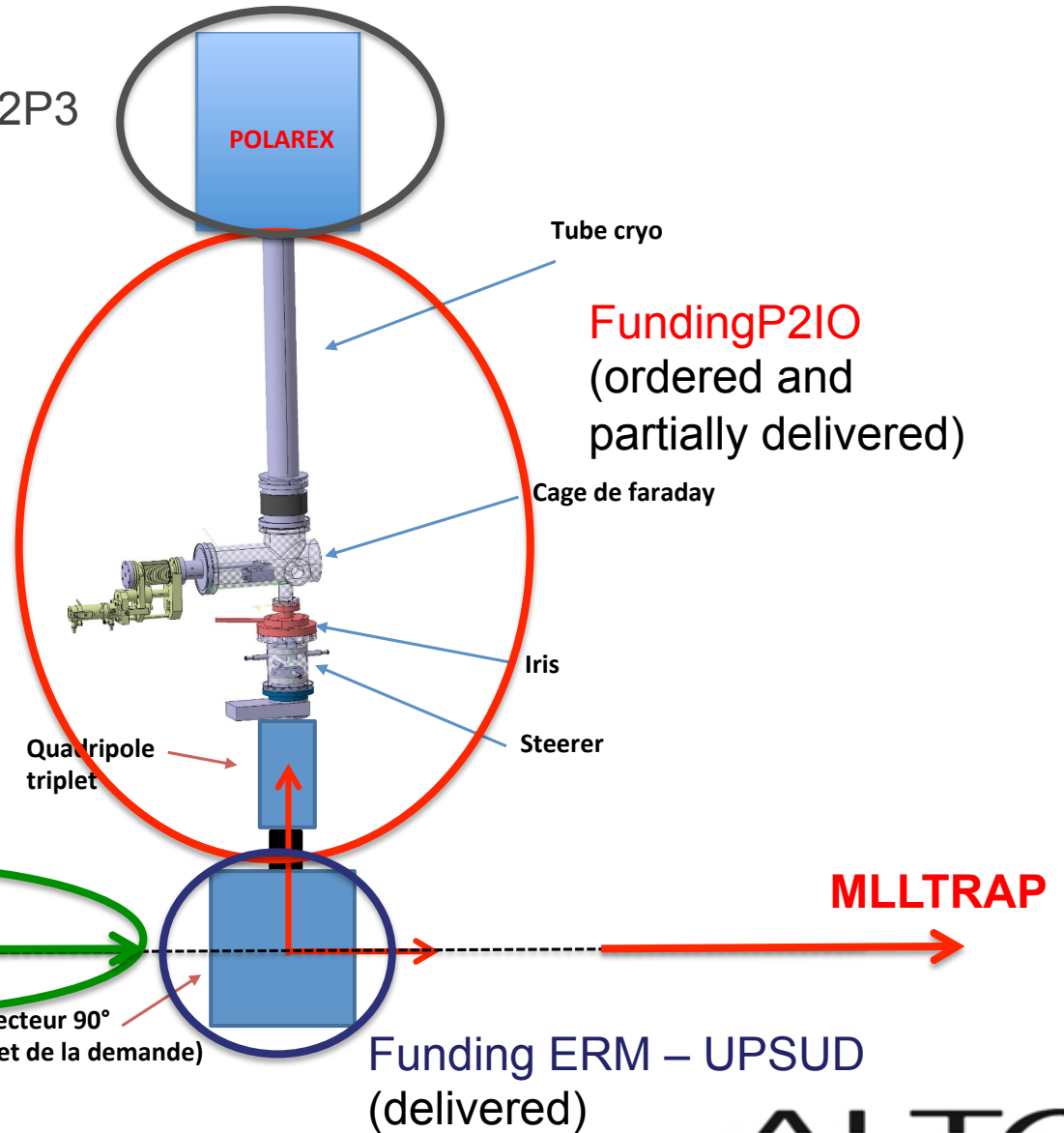
- Evaluation of pile-up of electrons in same pixel (multiple emission)
- Feasibility of simulated design and production

POLAREX : On Line Nuclear Orientation

Low temperature (7 mk) + High magnetic field (10-100 T) + Neutron rich beam



Funding ANR + IN2P3
(installed)

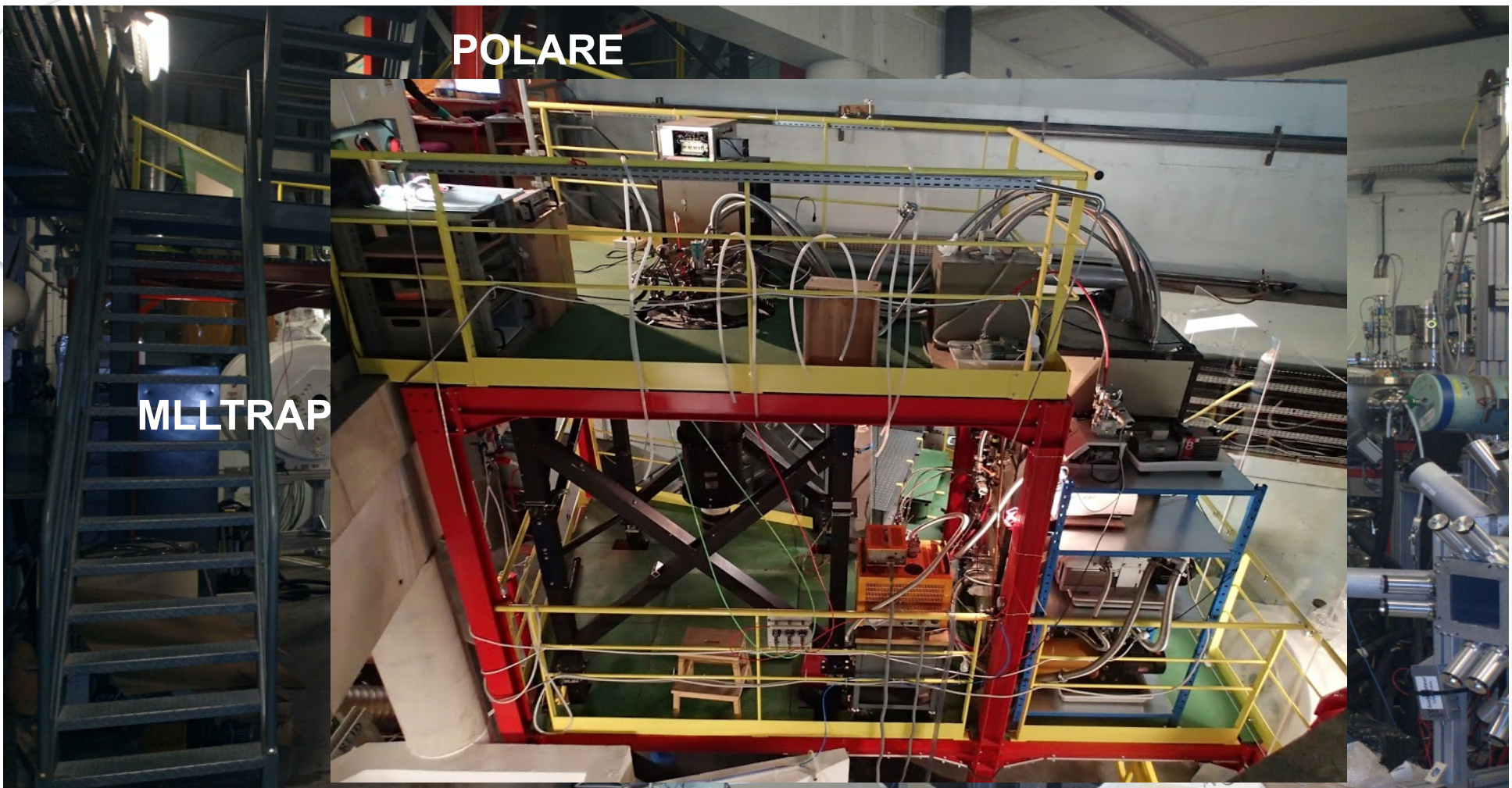


Funding
SESAME – Ile de
France
(Order beginning 2010)

ALTO Beam

MLLTRAP

On-line commissioning end 2019
NIMA 859 (2017)



POLAREX@ALTO