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Collinear laser spectroscopy at the IGISOL: upgrades and new opportunities

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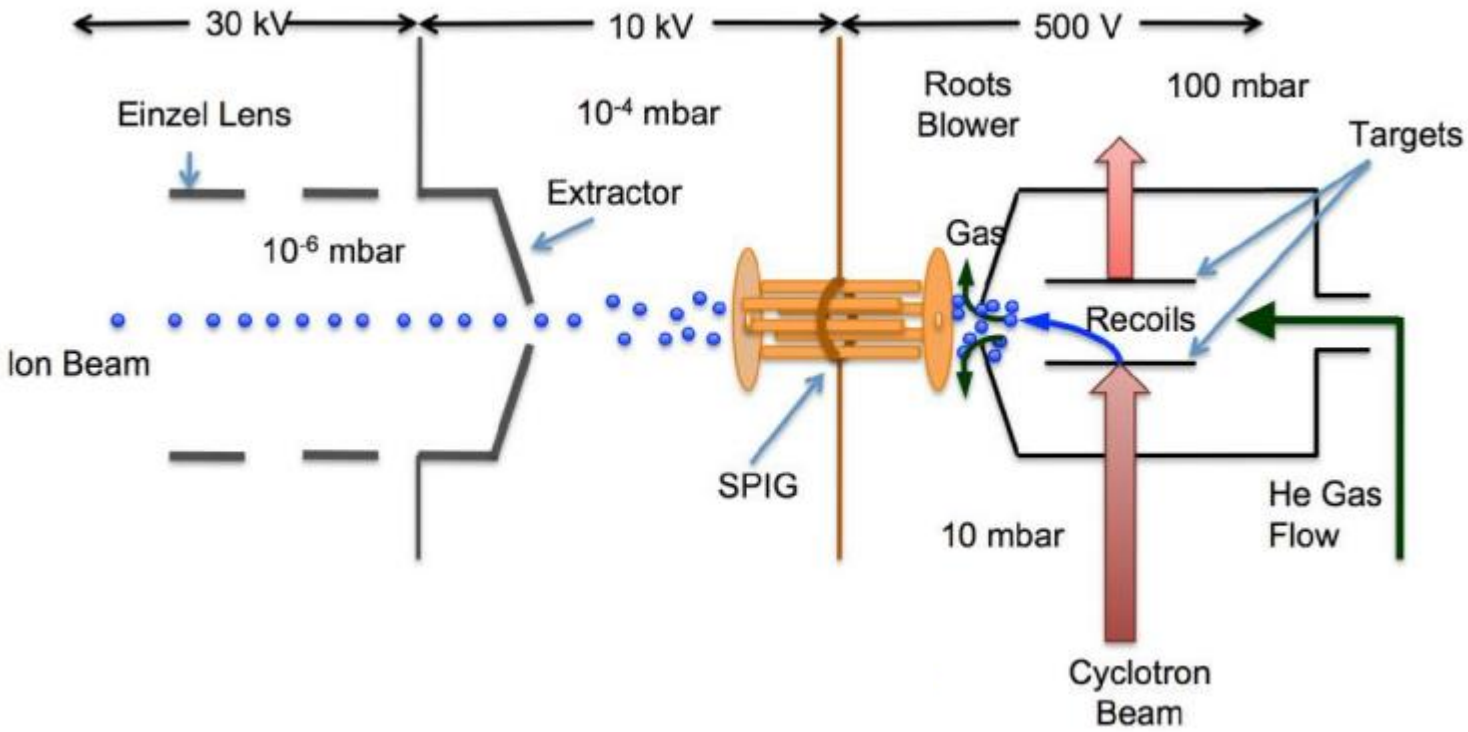
Outline

- The IGISOL laboratory
- Collinear laser spectroscopy at the IGISOL
  - Upgrades to the laser line
  - Upgrades to the cooler-buncher
- Conclusion and outlook

The IGISOL laboratory

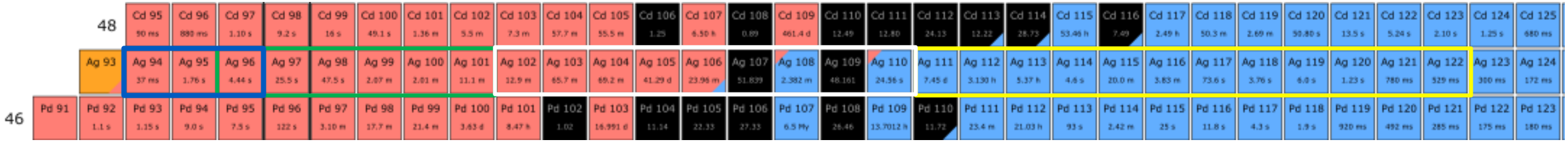
The IGISOL facility

- Cyclotron beam hits thin target
- Recoils stopped in He buffer gas
- Supersonic jet guides into an ion guide
- Universal: refractory ions are possible



The IGISOL facility

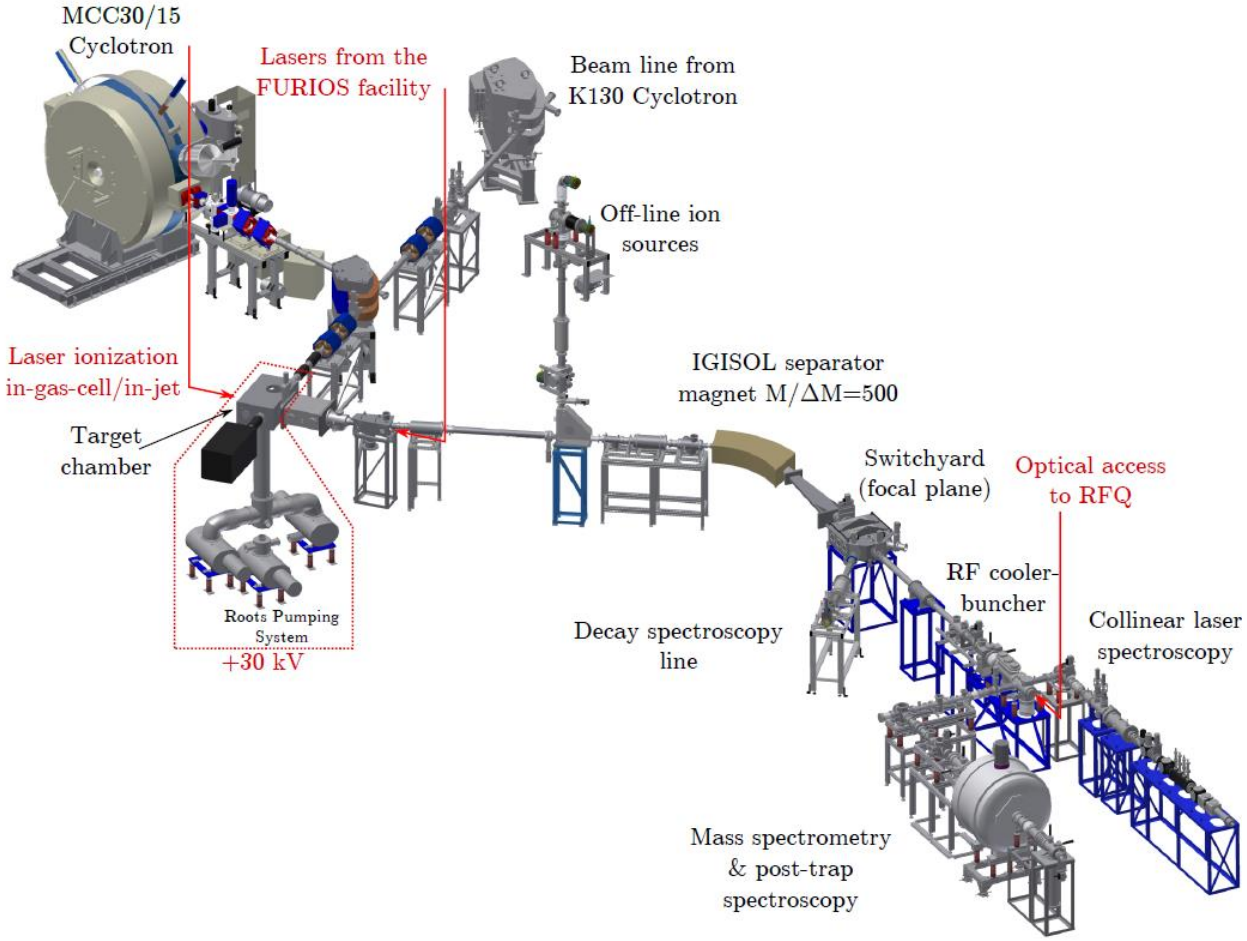
- Cyclotron can produce a variety of beams, so many target-beam combinations possible



- Example for Ag:
  - ^{nat}Pd(p, xn)Ag ~ $^{100\text{-}110}$Ag
  - p,d-induced fission ~ $^{111\text{-}122}$Ag
- Yields too low for collinear spectroscopy right now:
  - ^{nat}Mo, ^{92}Mo(^{14}N,2pxn)Ag ~ $^{97\text{-}103}$Ag
  - ^{58}Ni(^{40}Ca,pxn)Ag ~ $^{96\text{-}94?}$Ag (few per second?)

The IGISOL facility

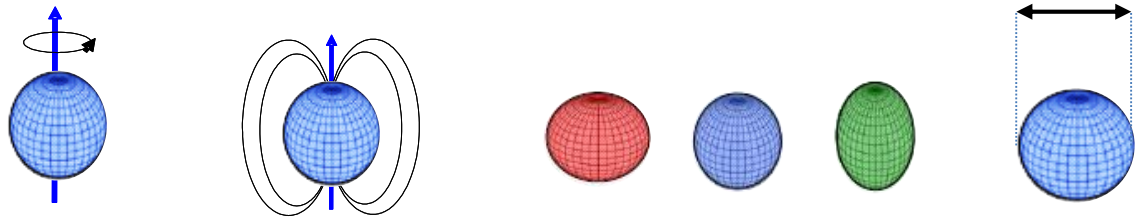
- Two cyclotrons (one dedicated to IGISOL)
- Dipole separator magnet
- Beamlines:
  - Line for temporary installations
  - Magneto-optical trap
  - JYFLTRAP: MR-TOF, penning traps
  - Collinear laser spectroscopy beamline



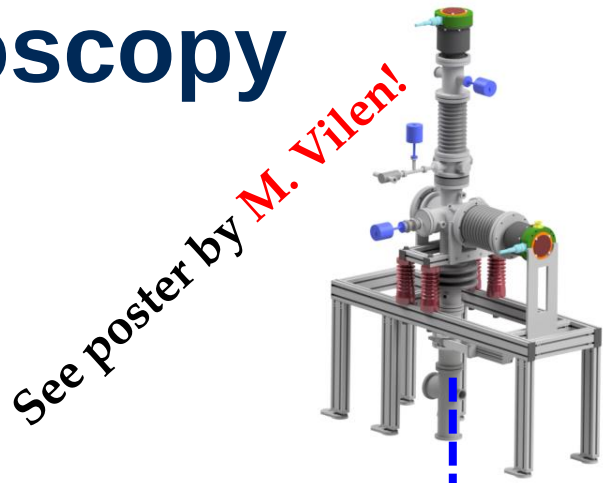
Collinear laser spectroscopy at the IGISOL

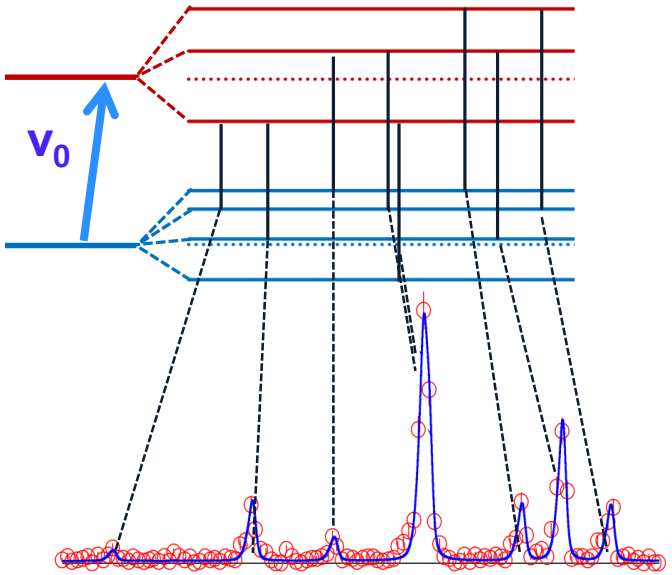
Collinear laser spectroscopy

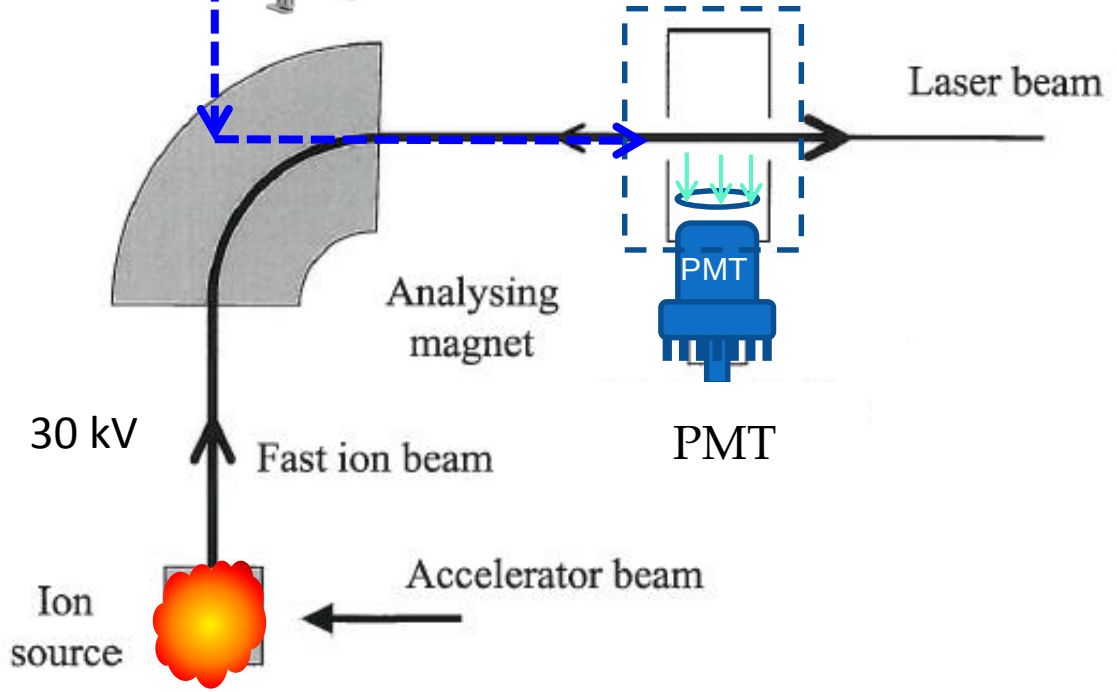
- Hyperfine interaction: nuclear and atomic properties
- Model-independent extraction of



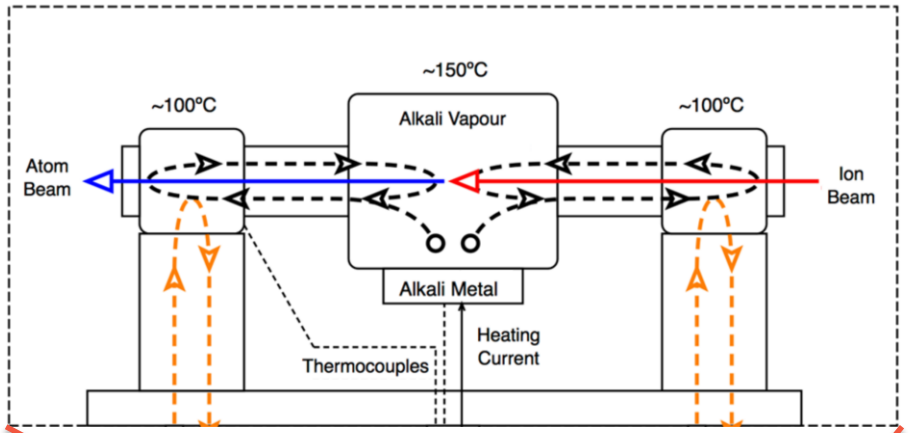
See poster by M. Vilen!



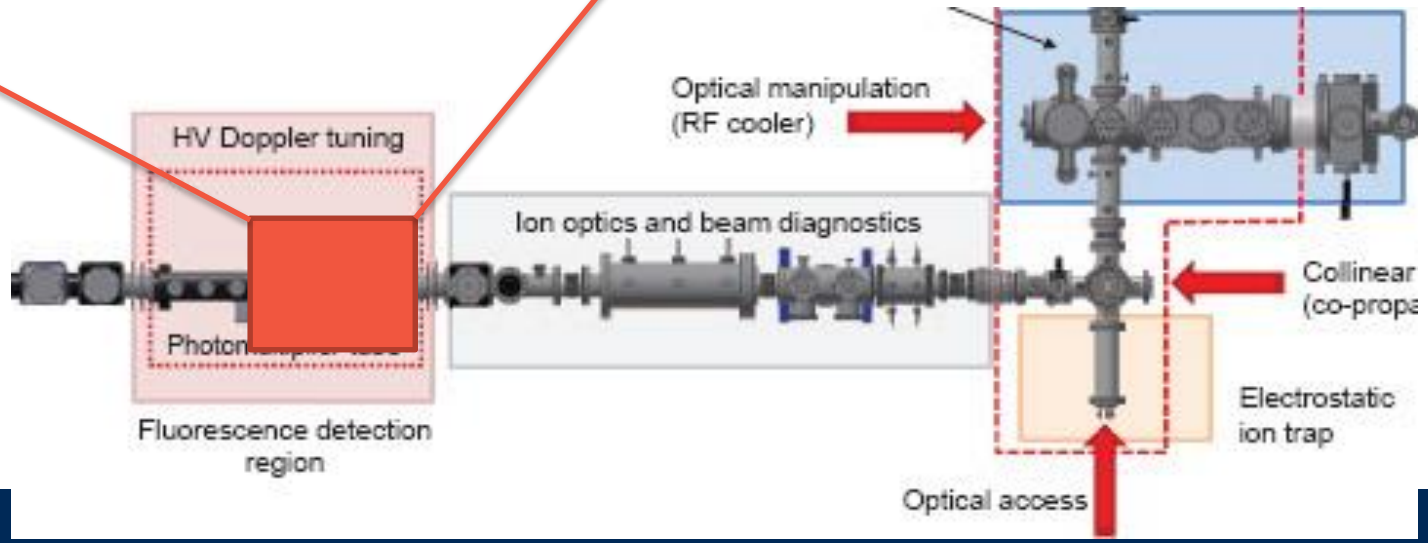




Upgrades for the collinear laser programme



- Many elements do not have convenient optical lines in their ionic form
- Charge exchange:
  $X^+ + K/Na/\ldots \Rightarrow X + K^+/Na^+/\ldots$

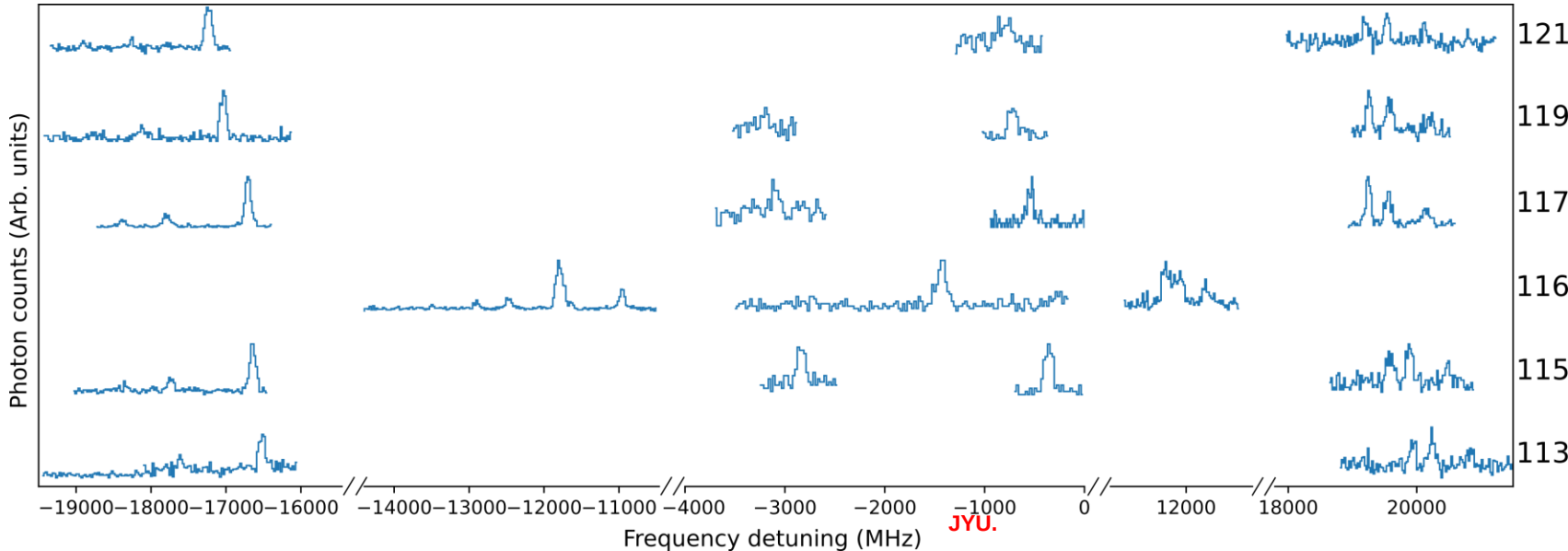


Big thanks to W. Nörtershäuser and J. Krämer for (help with) the TRIGA charge exchange cell!

Upgrades for the collinear laser programme

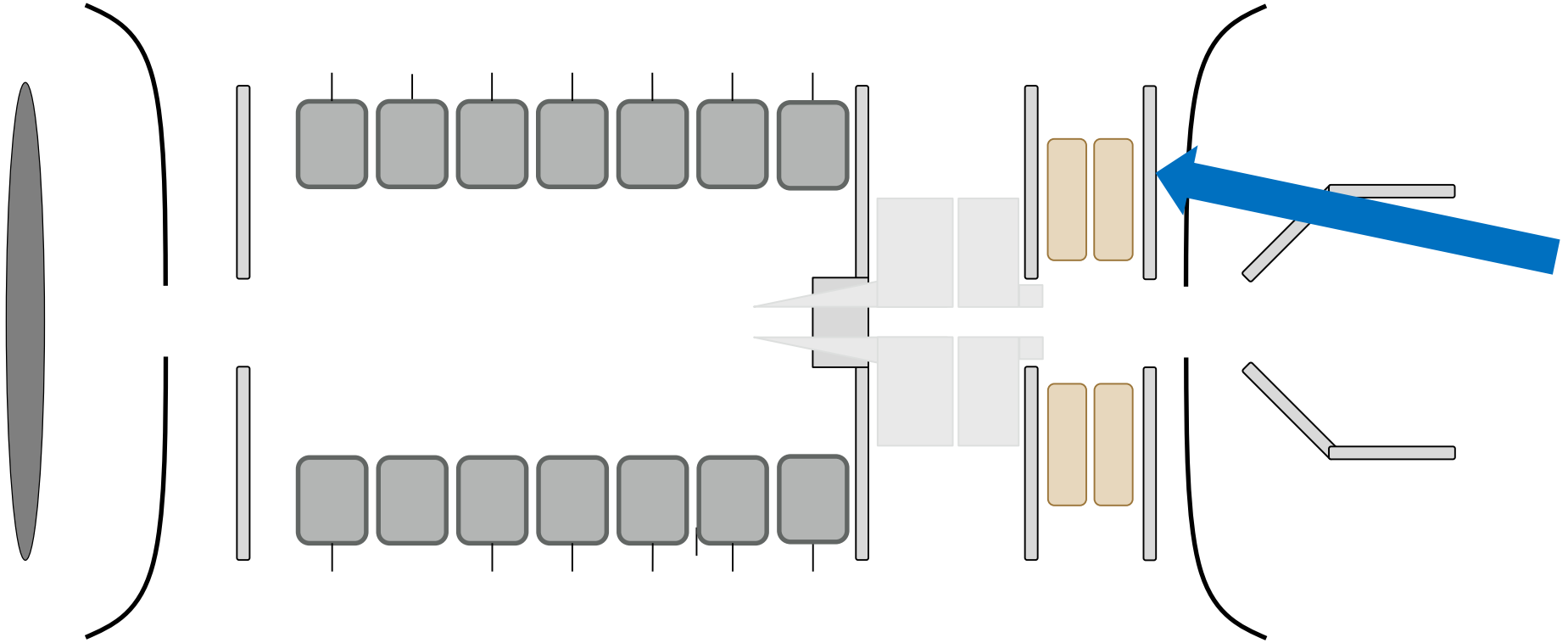
- Commissioning experiment: laser spectroscopy of silver
- First experiment July 2018: $^{113\text{-}121}$Ag
  - Dipole, quadrupole moments, changes in charge radii and spins

More runs planned, goal is $^{102\text{-}123}$Ag



Upgrades for the collinear laser programme

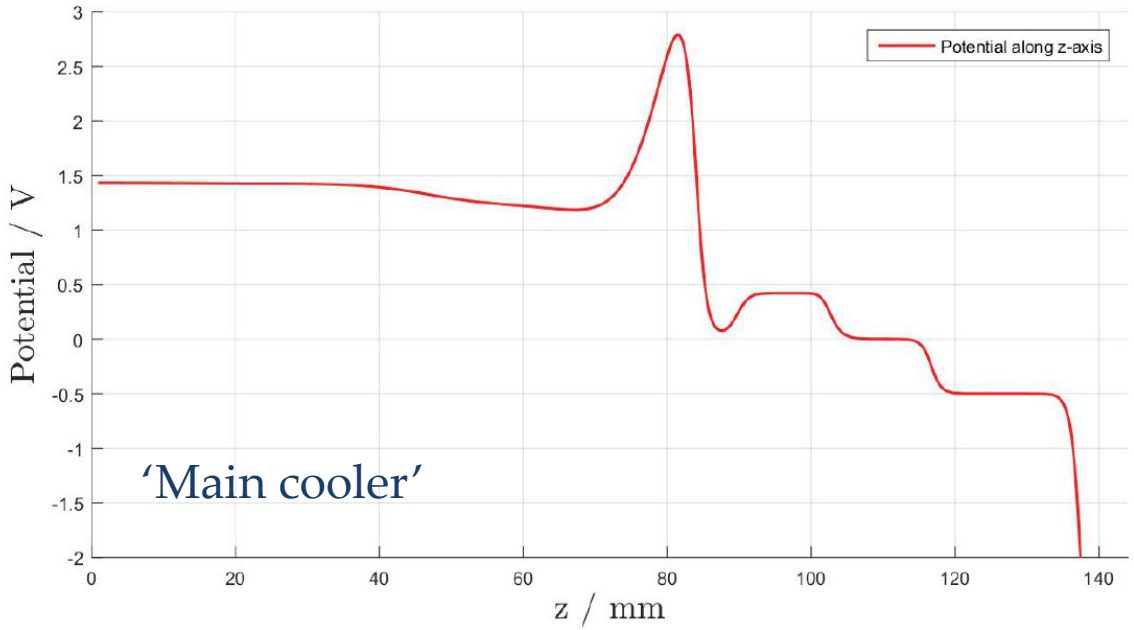
Cooler-buncher upgrades: reduce bunch width

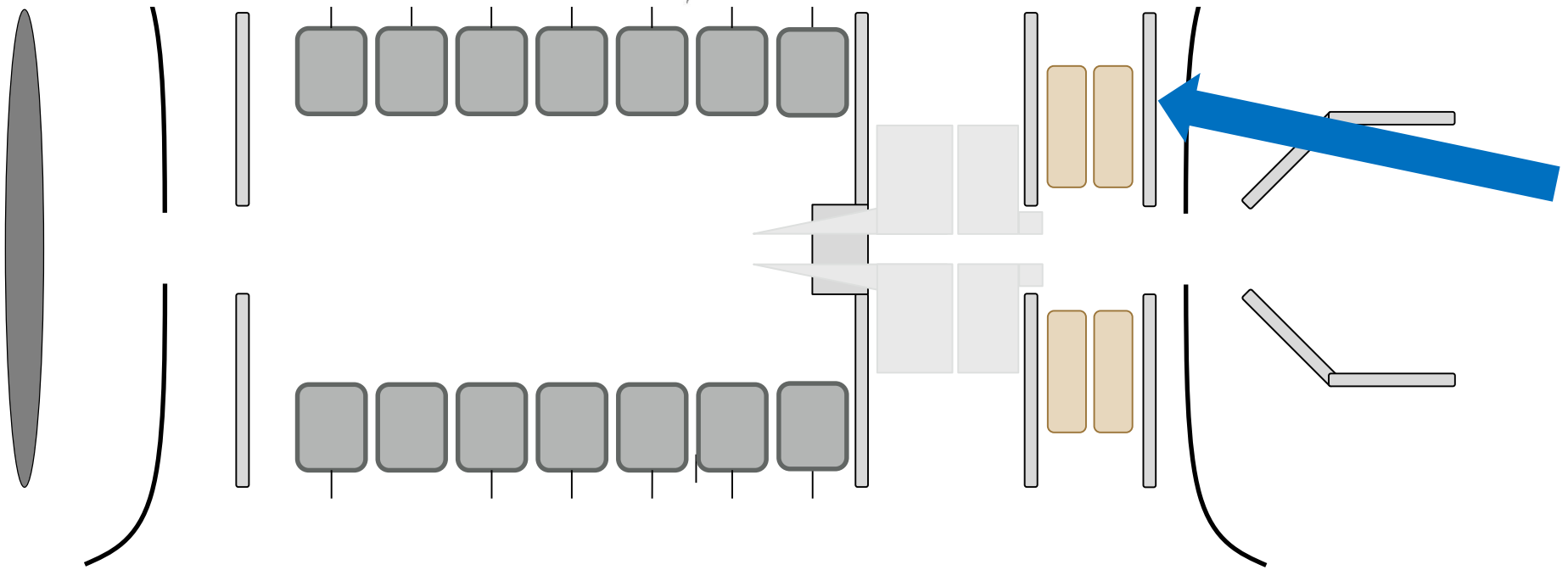


Addition of new, small bunching region with push-pull DC plates

U r programme

(unch width





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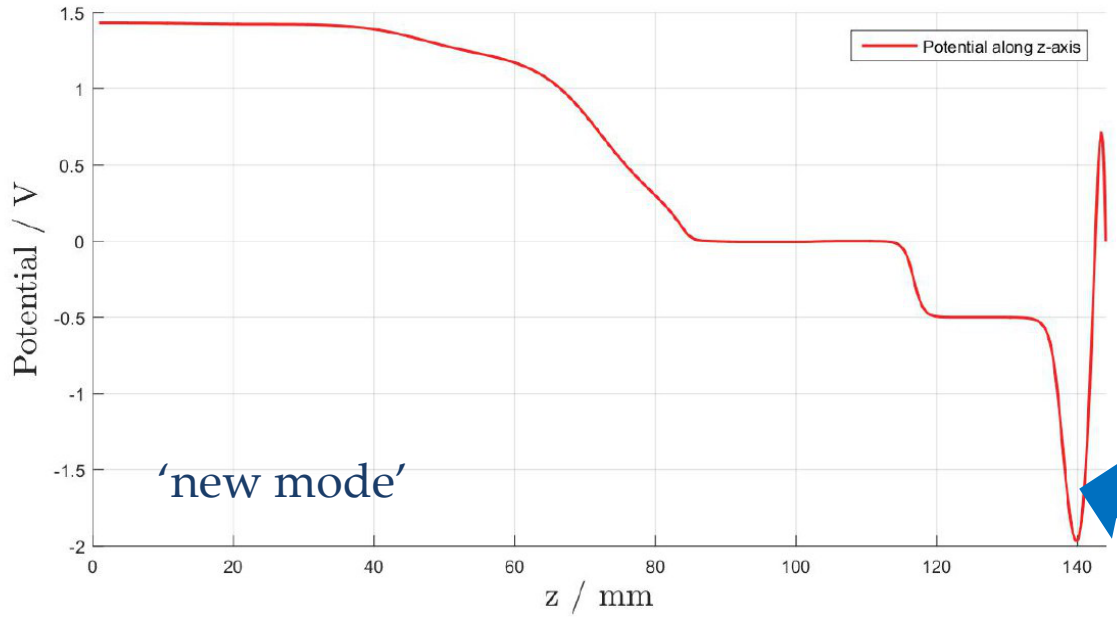
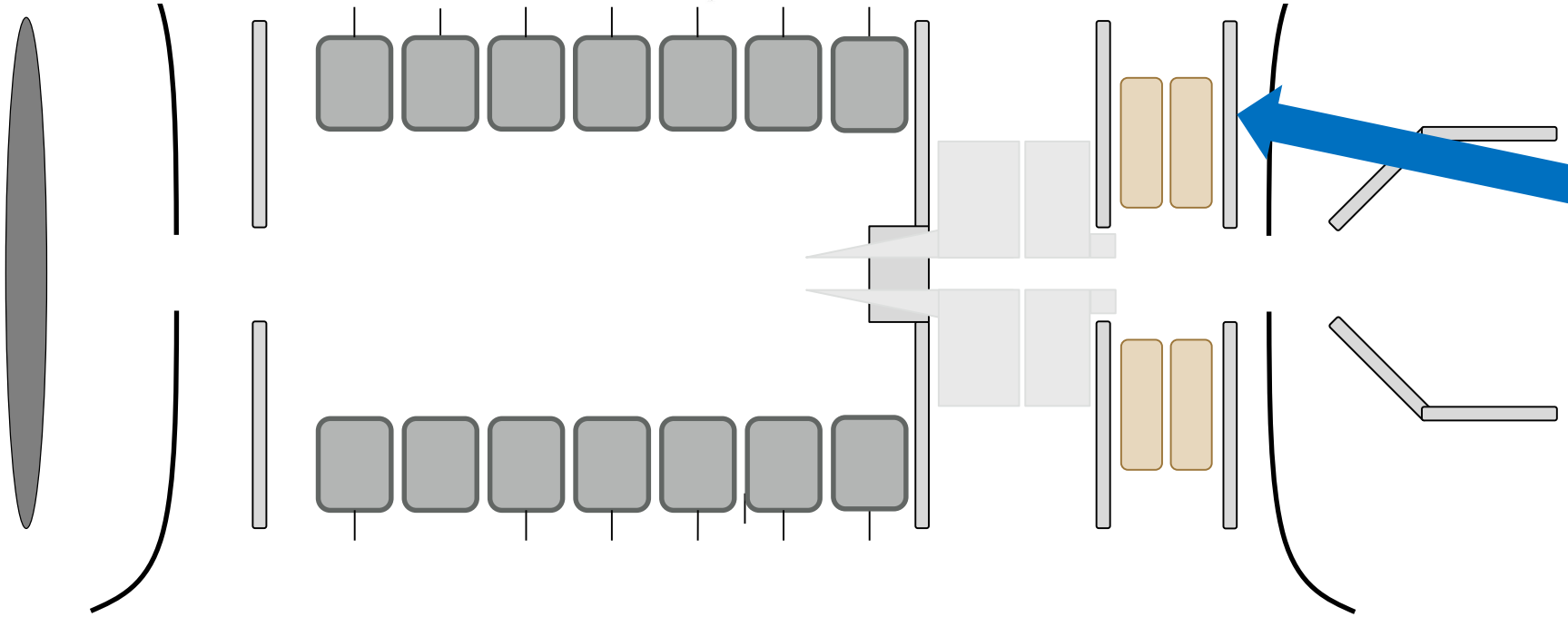
ɔunch width



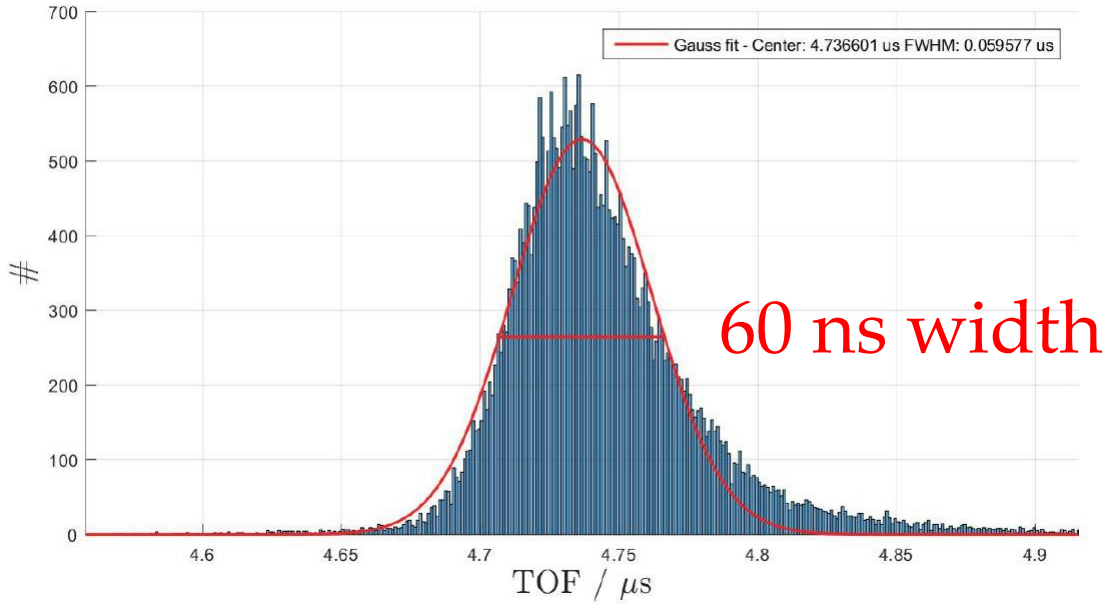


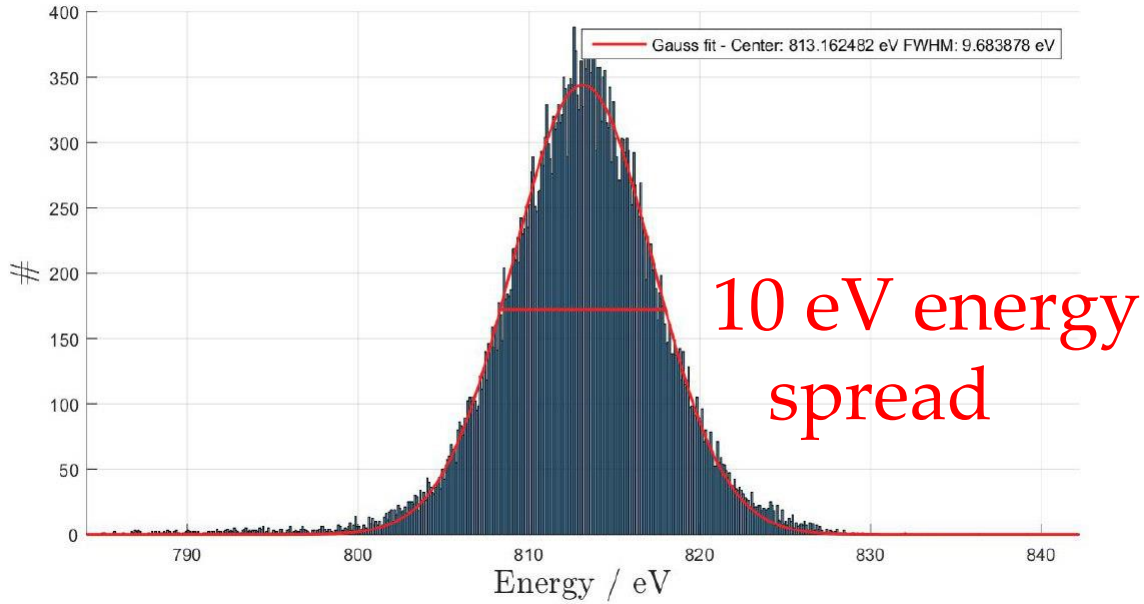
New trapping region

Addition of new, small bunching region with push-pull DC plates

Upgrades for the collinear laser programme

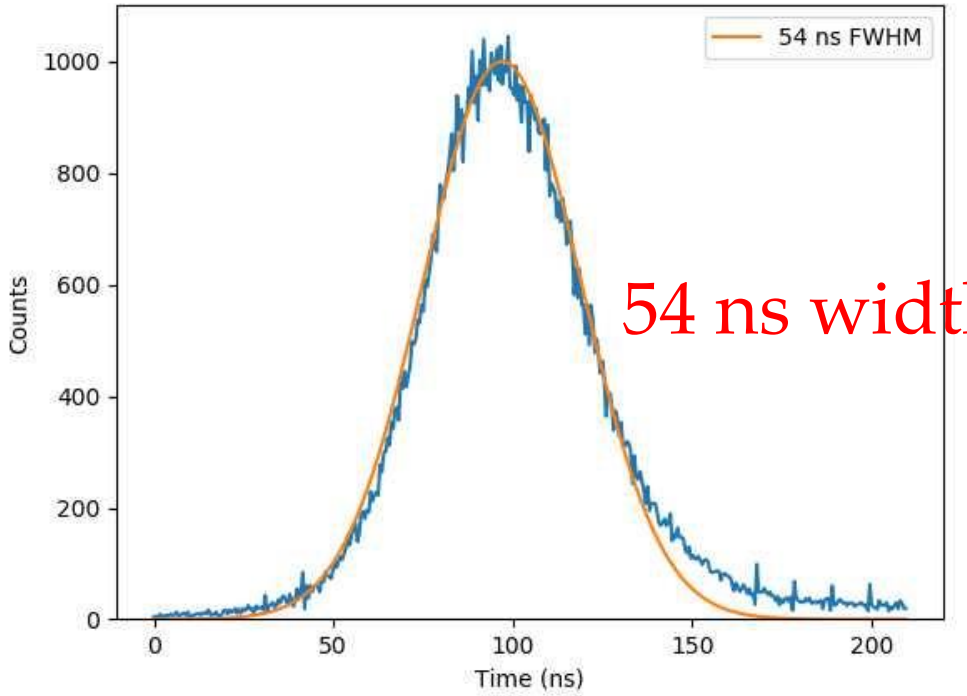
- Simulated time and energy spread:





First commissioning results

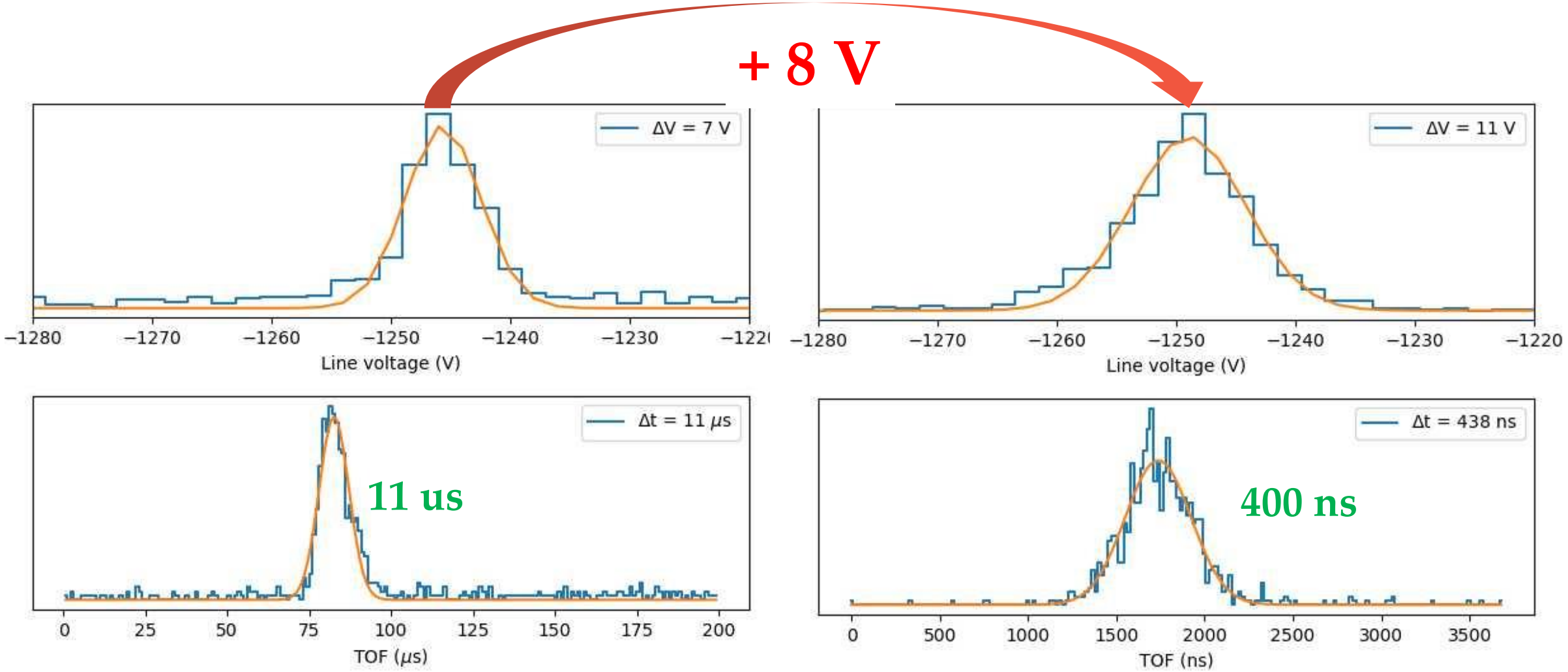
- Experimentally:



54 ns width

Energy spread?

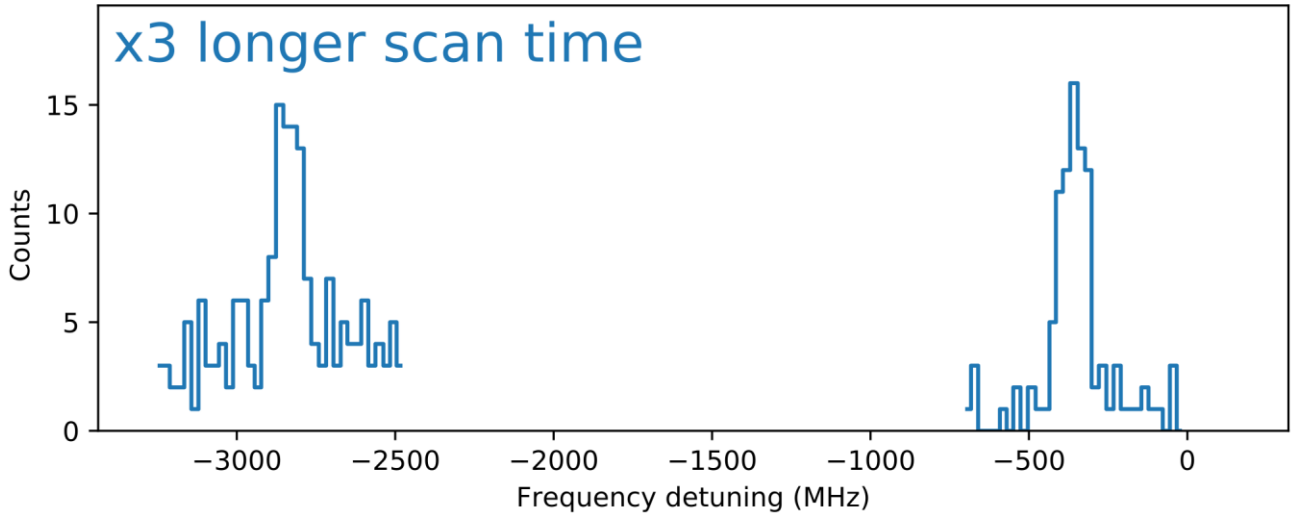
First commissioning results

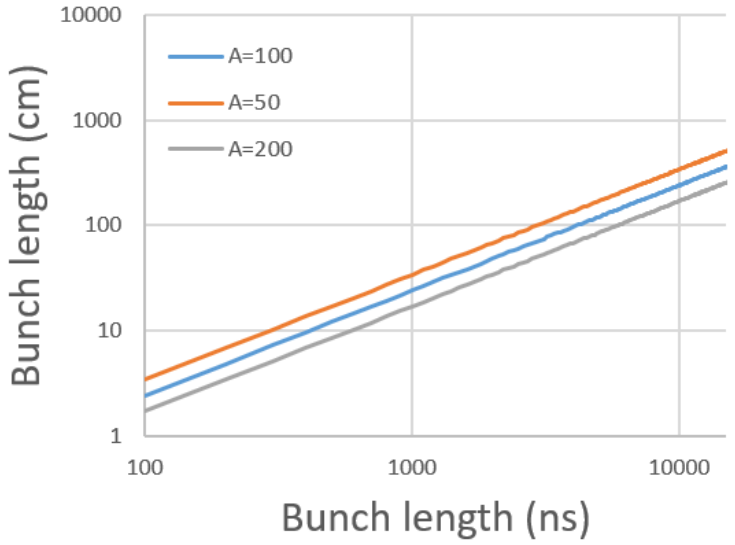


Upgrades for the collinear laser programme

Implications for laser programme

- Suppression of laser-related background by factor 150!
- Shorter bunches => fast switching of laser beam to reduce optical pumping e.g. A. Voss et al., Phys. Rev. C **91**, 044307

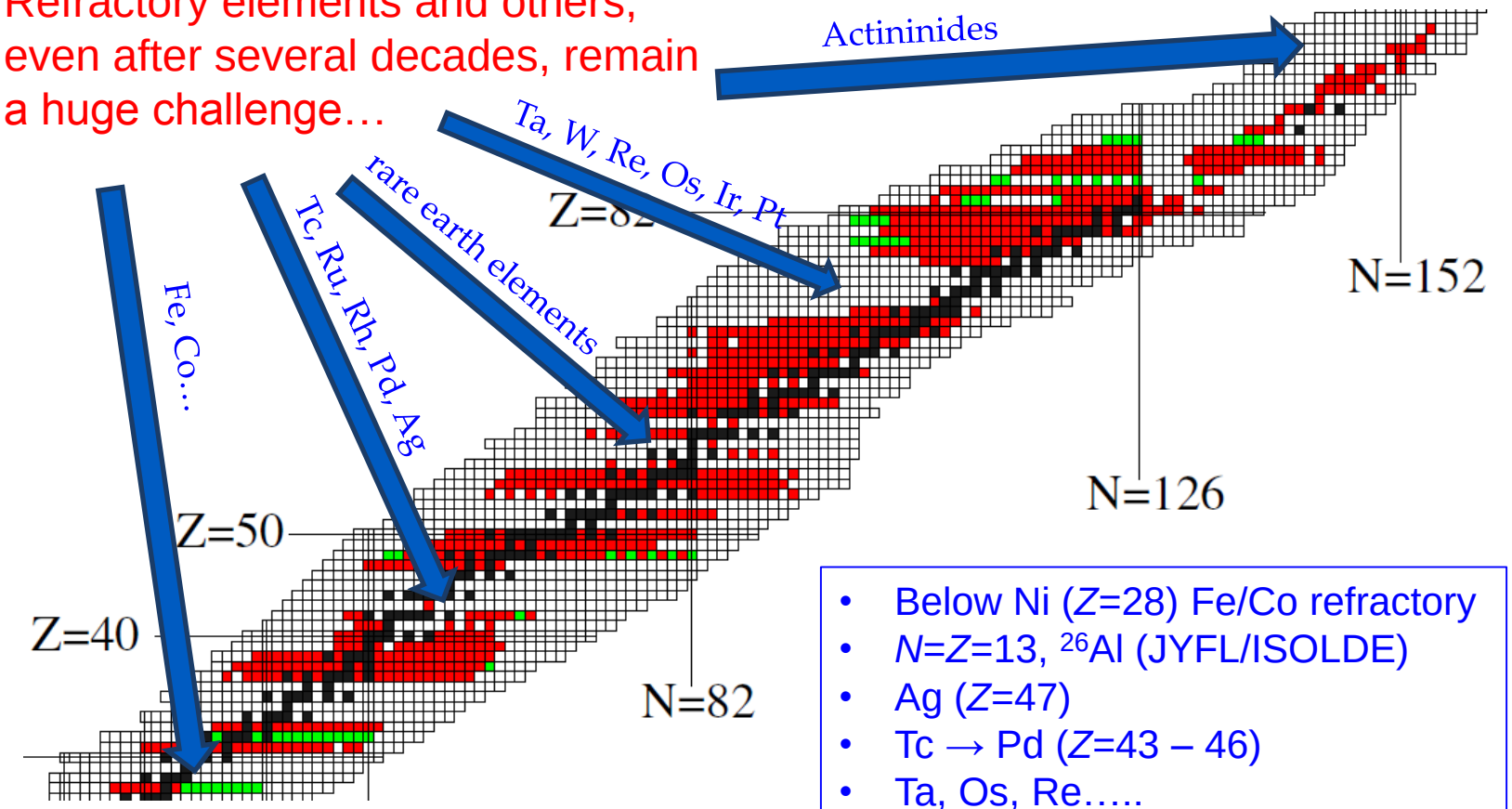




Future perspectives

New opportunities

Refractory elements and others, even after several decades, remain a huge challenge…



- Below Ni (Z=28) Fe/Co refractory
- N=Z=13, ^{26}Al (JYFL/ISOLDE)
- Ag (Z=47)
- Tc → Pd (Z=43 – 46)
- Ta, Os, Re…..
- Actinides (Pu, Th, U….)

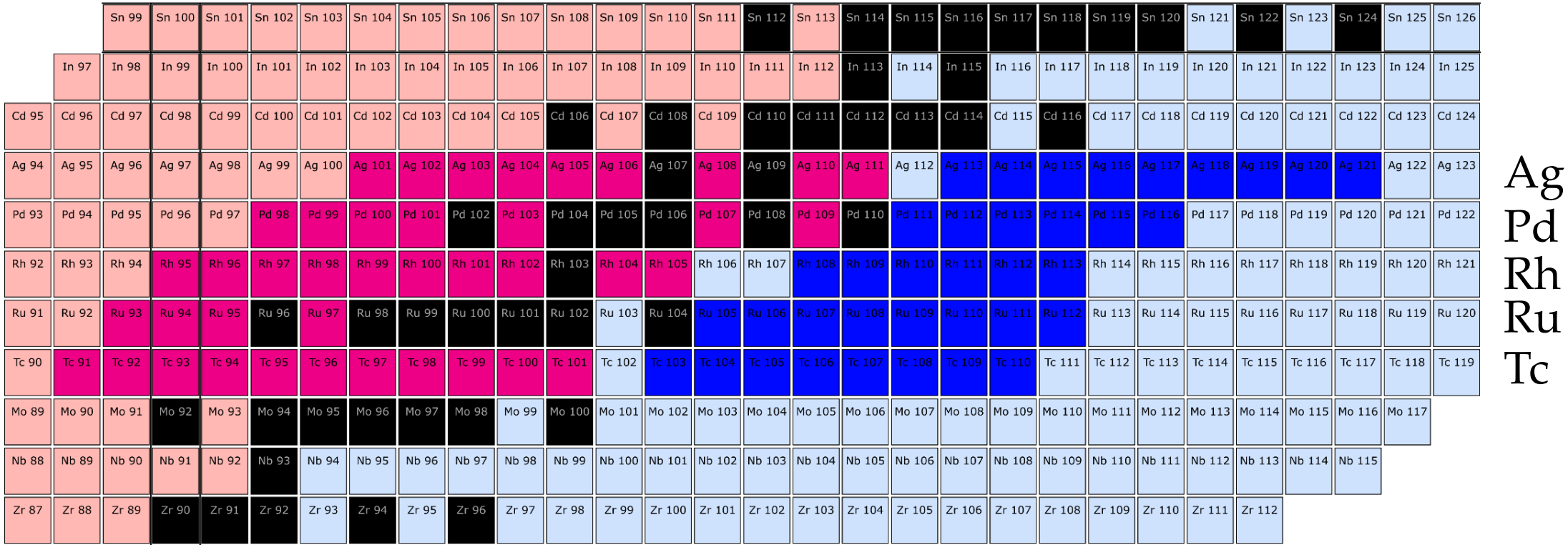
- Sensitivity improvements are needed!
  - Cooler upgrade: incremental improvements
- Flexibility is key!
  - Charge exchange changes the rules of the game for the IGISOL
  - Optical manipulation in-cooler
  - etc…

New opportunities

Example: elements below Sn simplified/enabled by CEC

Light-ion fusion evaporation

p-induced fission



New opportunities

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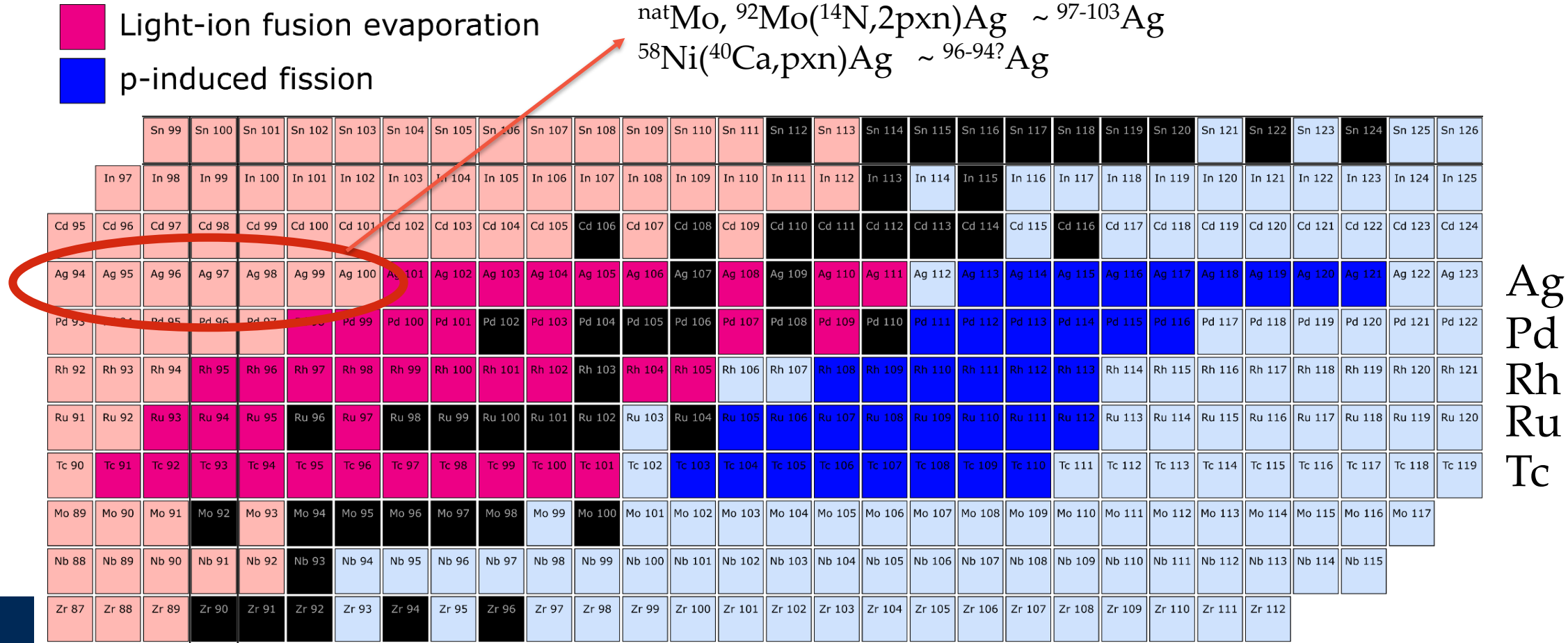
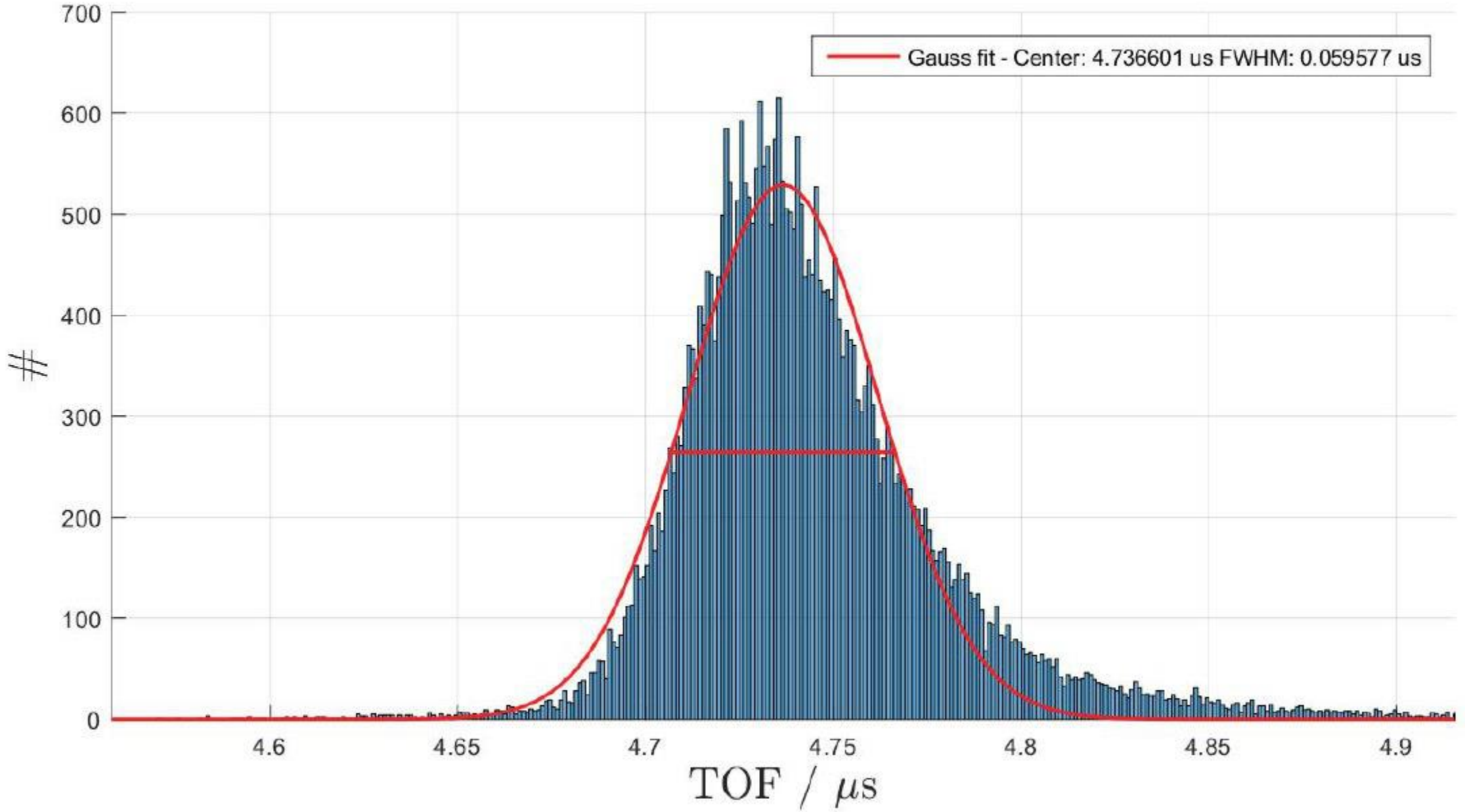


In conclusion

- The collinear programme has been upgraded
  - Charge exchange cell
  - Beamline modernisation
- Our cooler-buncher is undergoing major improvements
  - Improved bunch width
- A large physics programme on refractory isotopes lies ahead - Fe-Ni (Z=26-28), Tc-Pd (Z=43-46) and W-Os (Z=74-76)


Gauss fit - Center: 4.736601 us FWHM: 0.059577 us
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600
500
400
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#
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4.65
4.7
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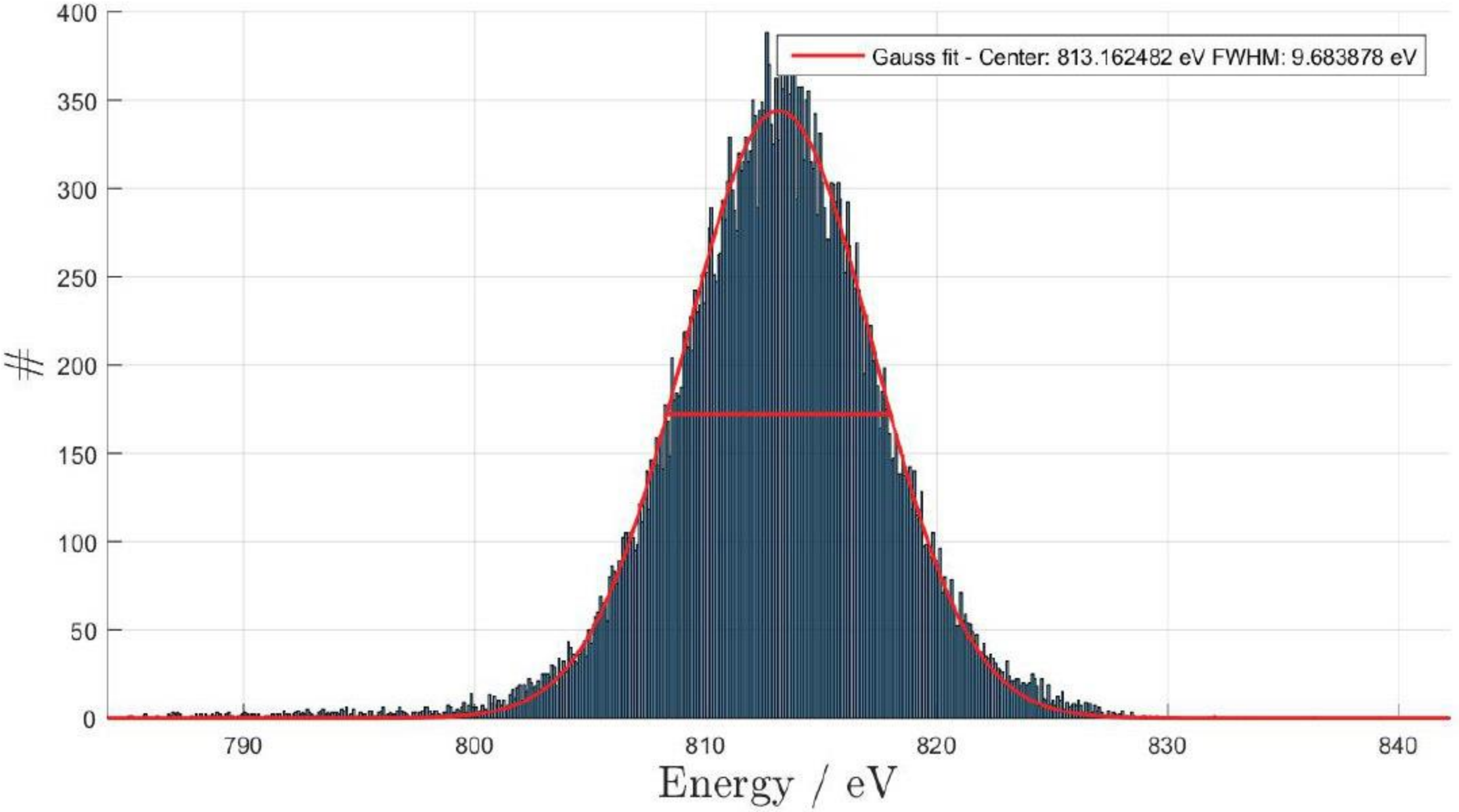
4.8
4.85
4.9
TOF / μs


Gauss fit - Center: 813.162482 eV FWHM: 9.683878 eV
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350
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250
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150
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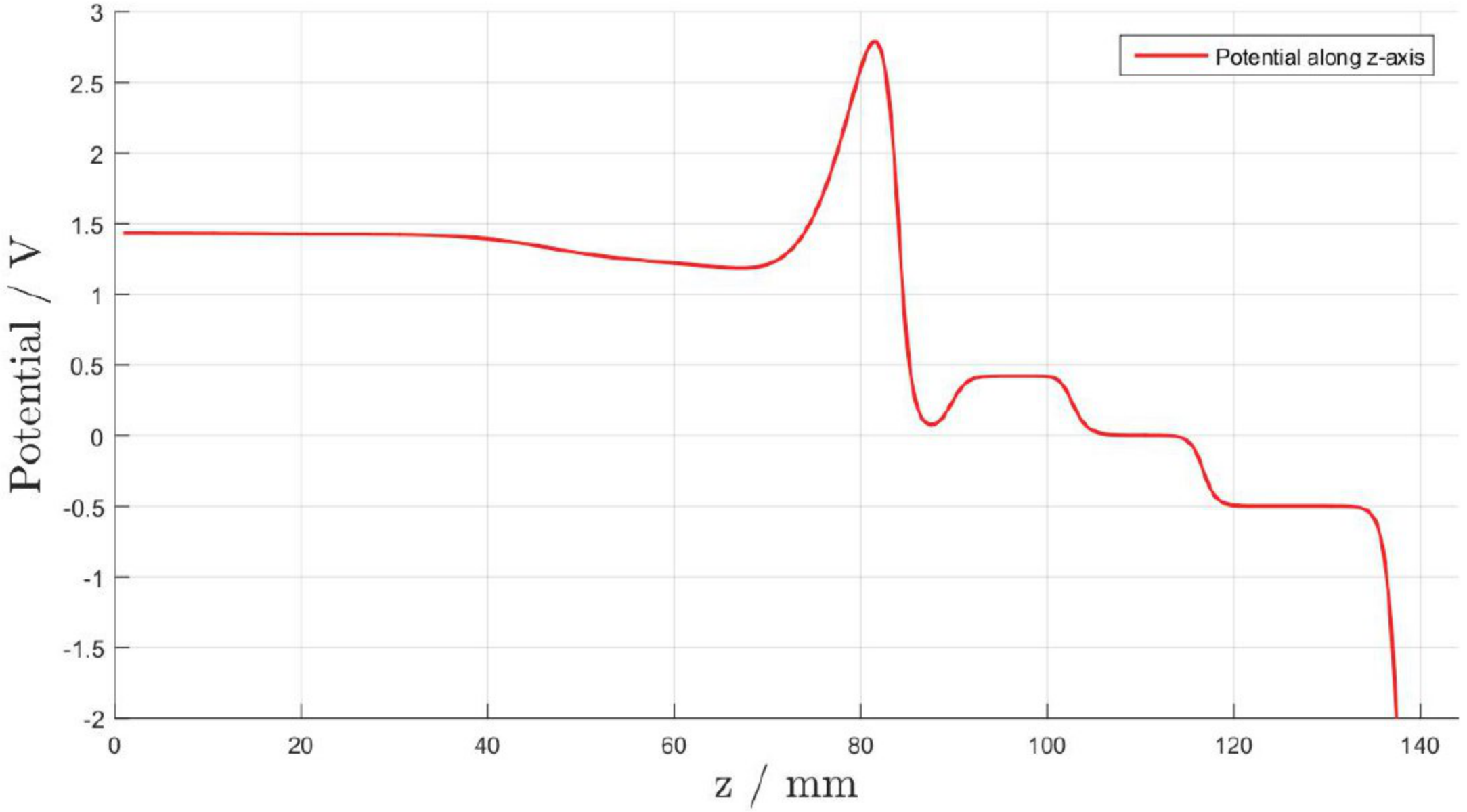
50
0
#
790
800
810
820
830
840
Energy / eV


Potential along z-axis
Potential / V
z / mm
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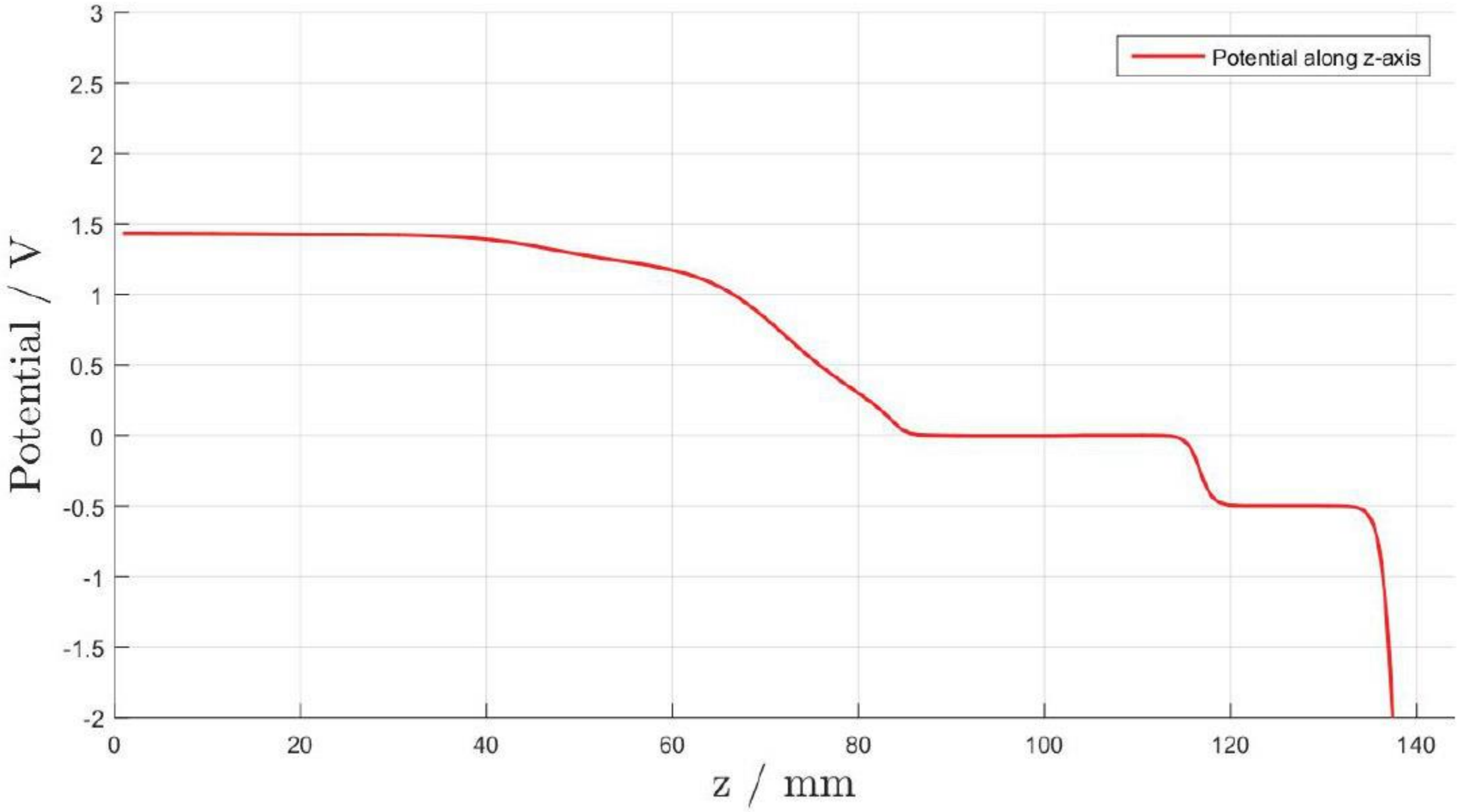
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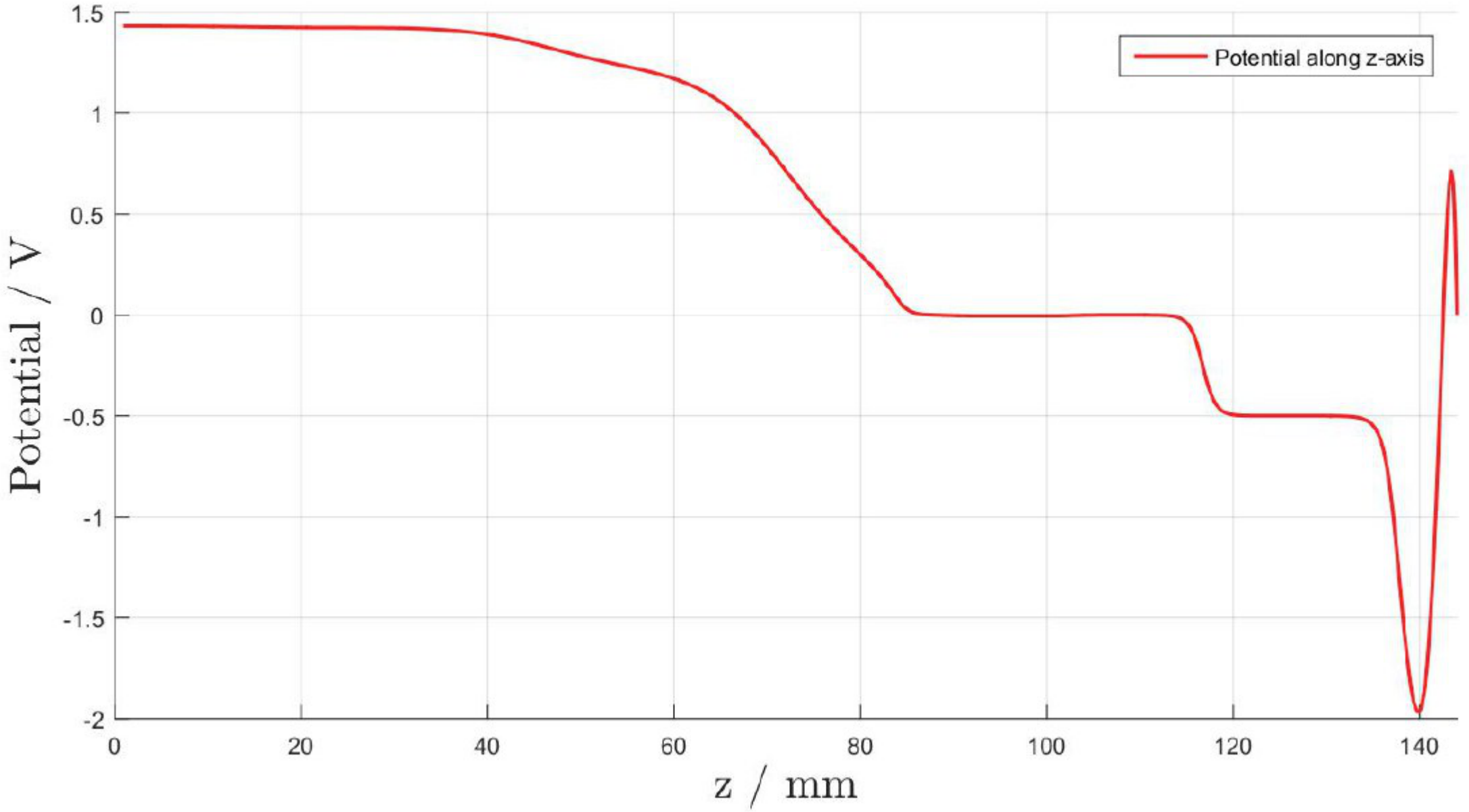
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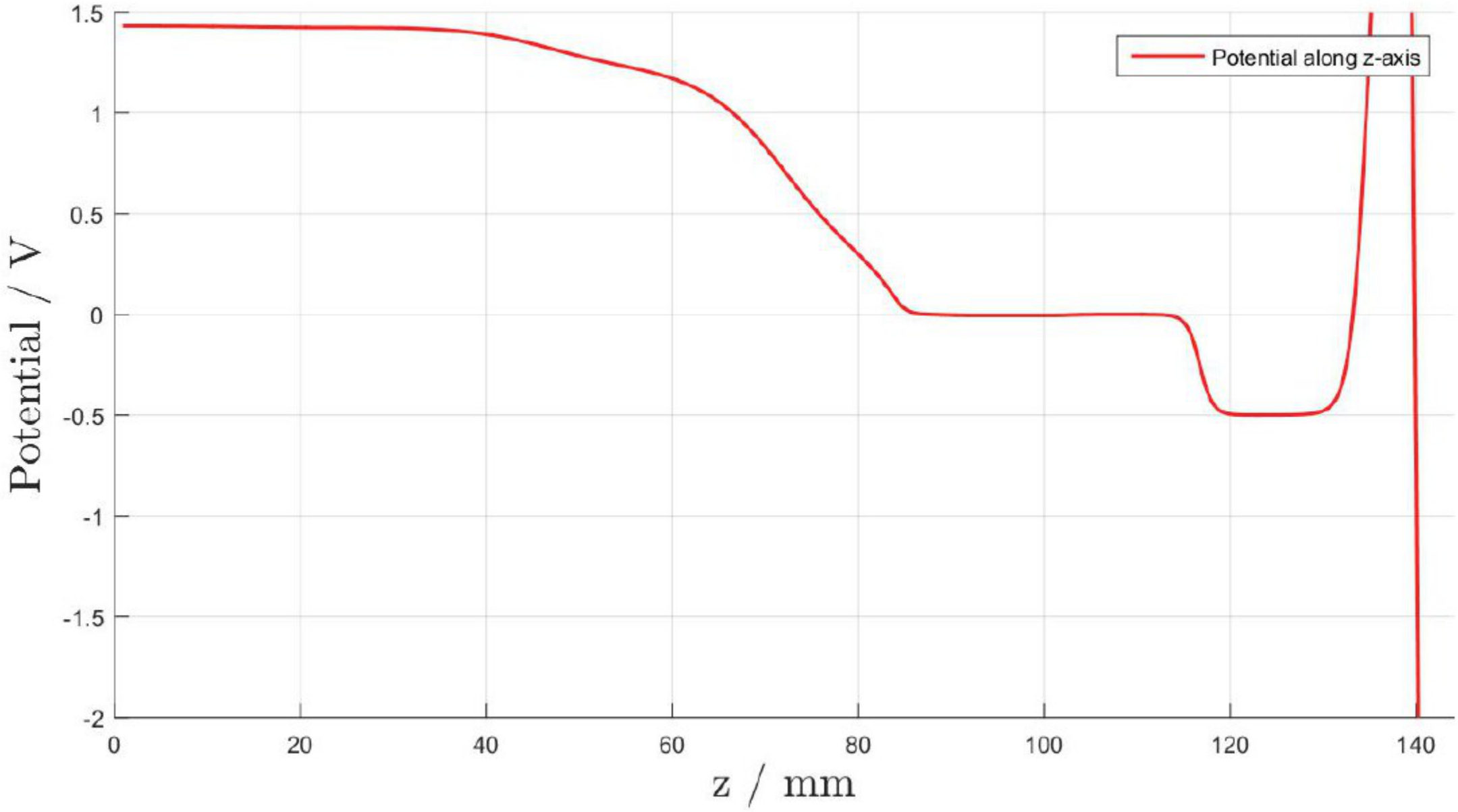
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