Simulation of the CERN GTS-LHC ECRIS extraction system

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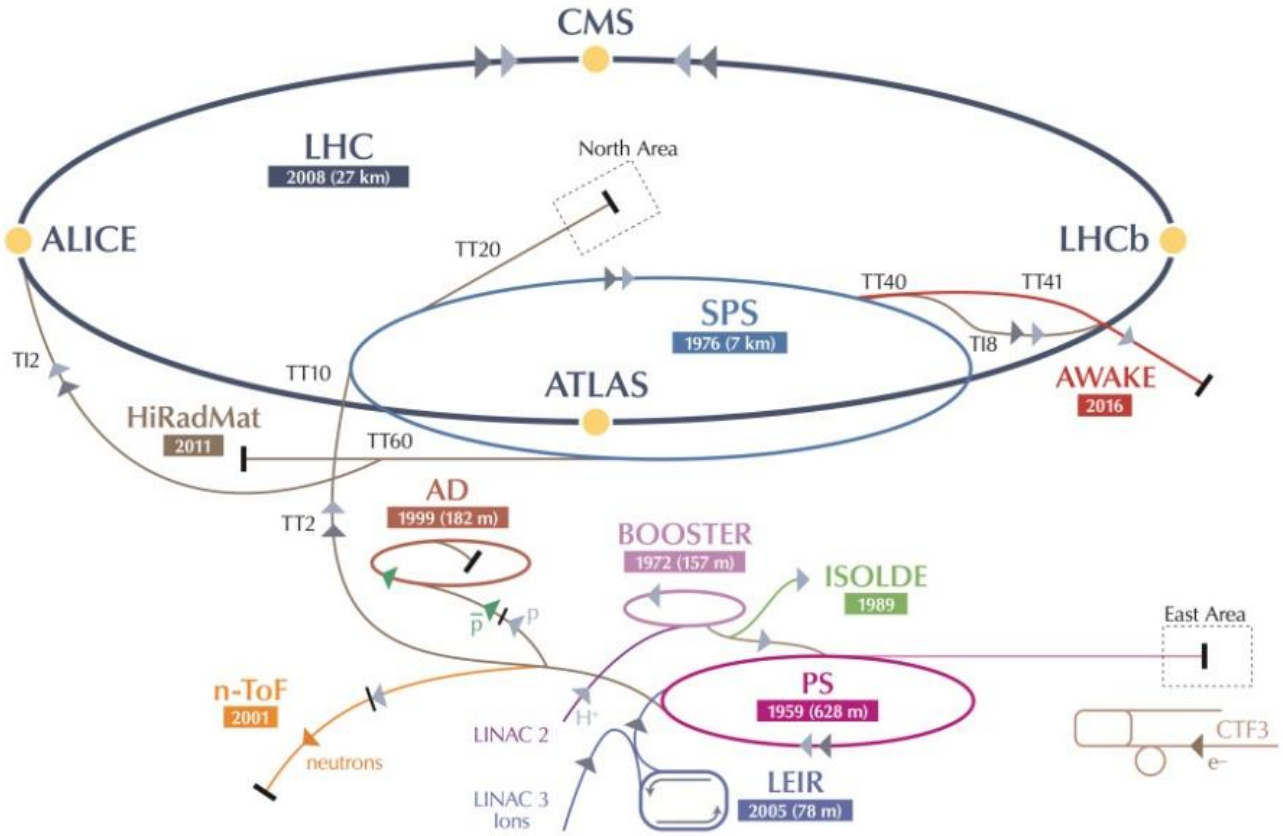
CERN's Accelerator Complex



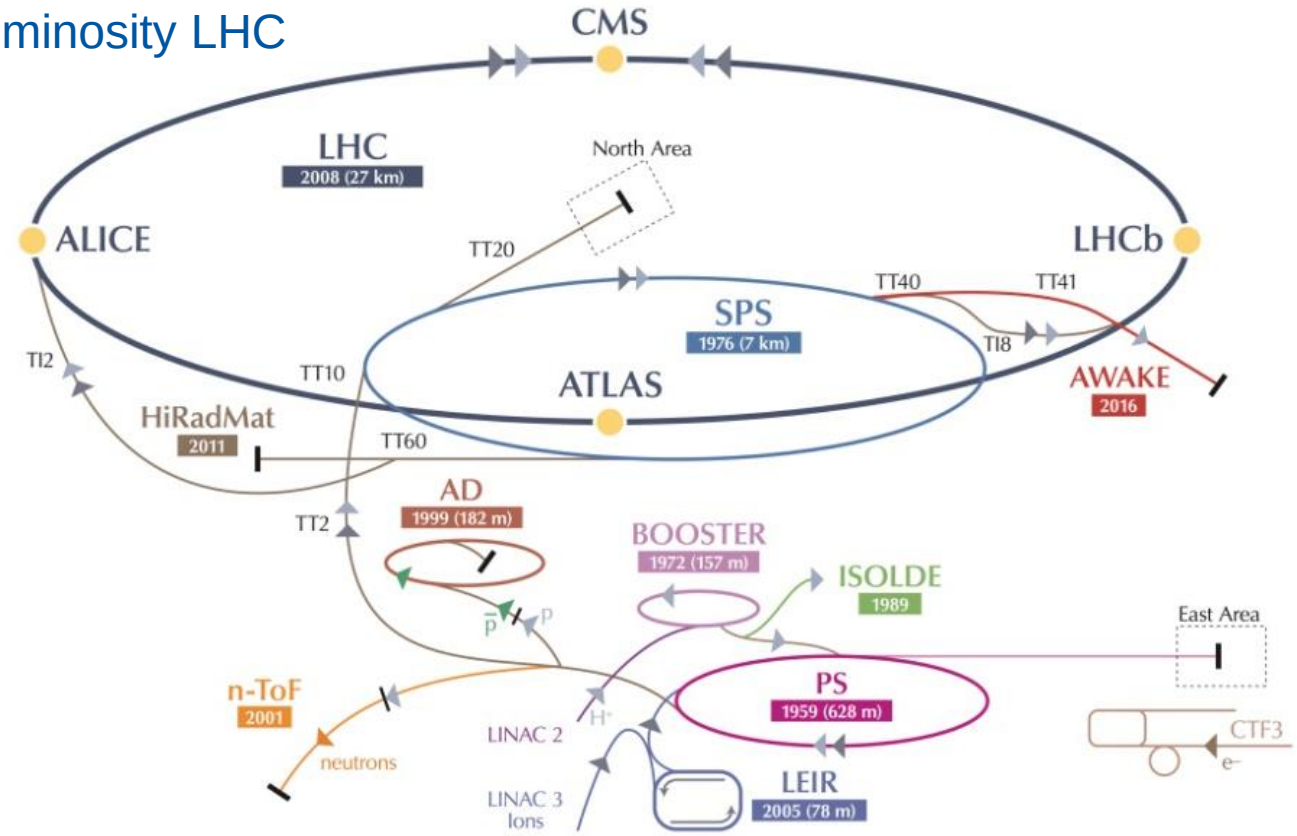
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility AWAKE Advanced WAKefield Experiment ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight HiRadMat High-Radiation to Materials

CERN's Accelerator Complex

High Luminosity LHC



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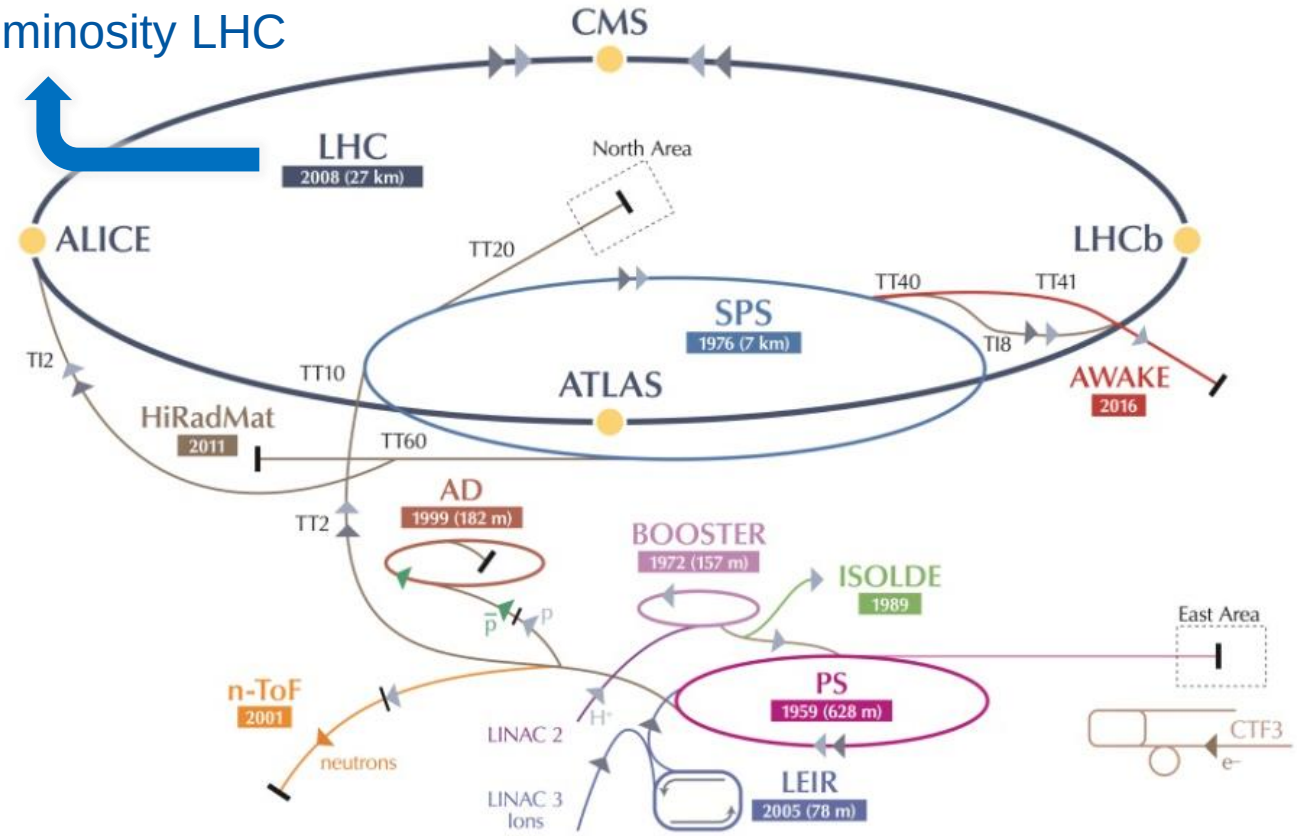

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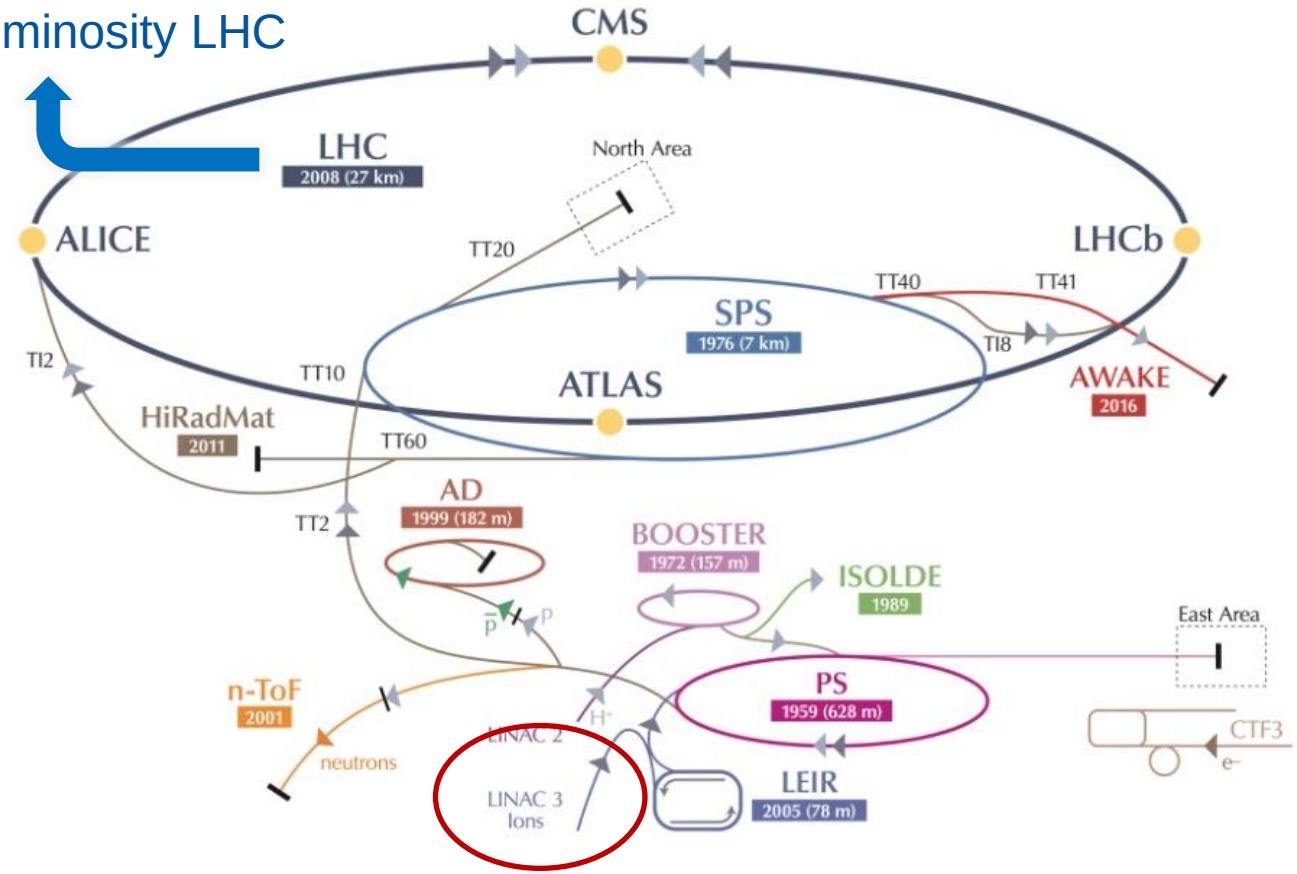

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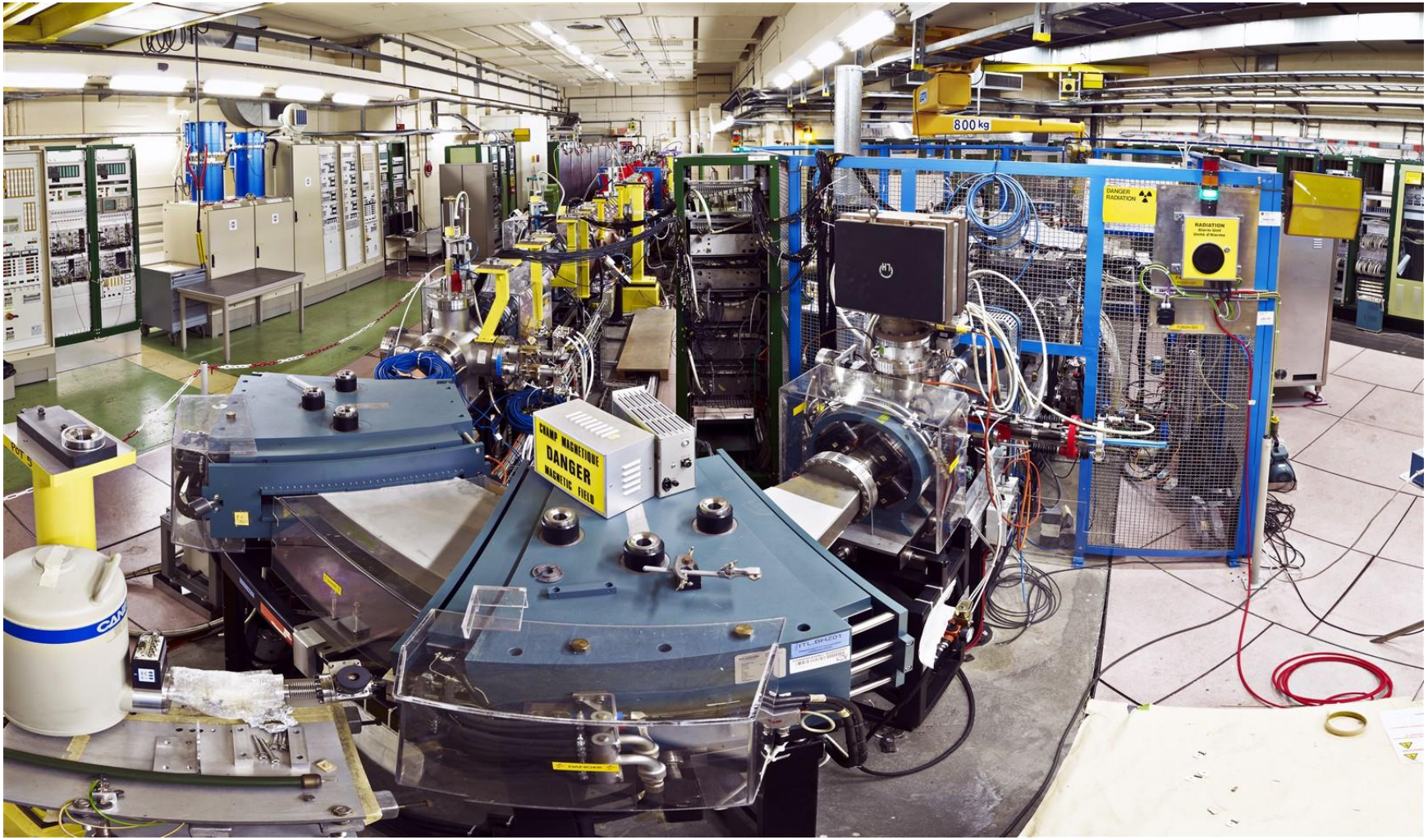
Heavy ion injector Linac3



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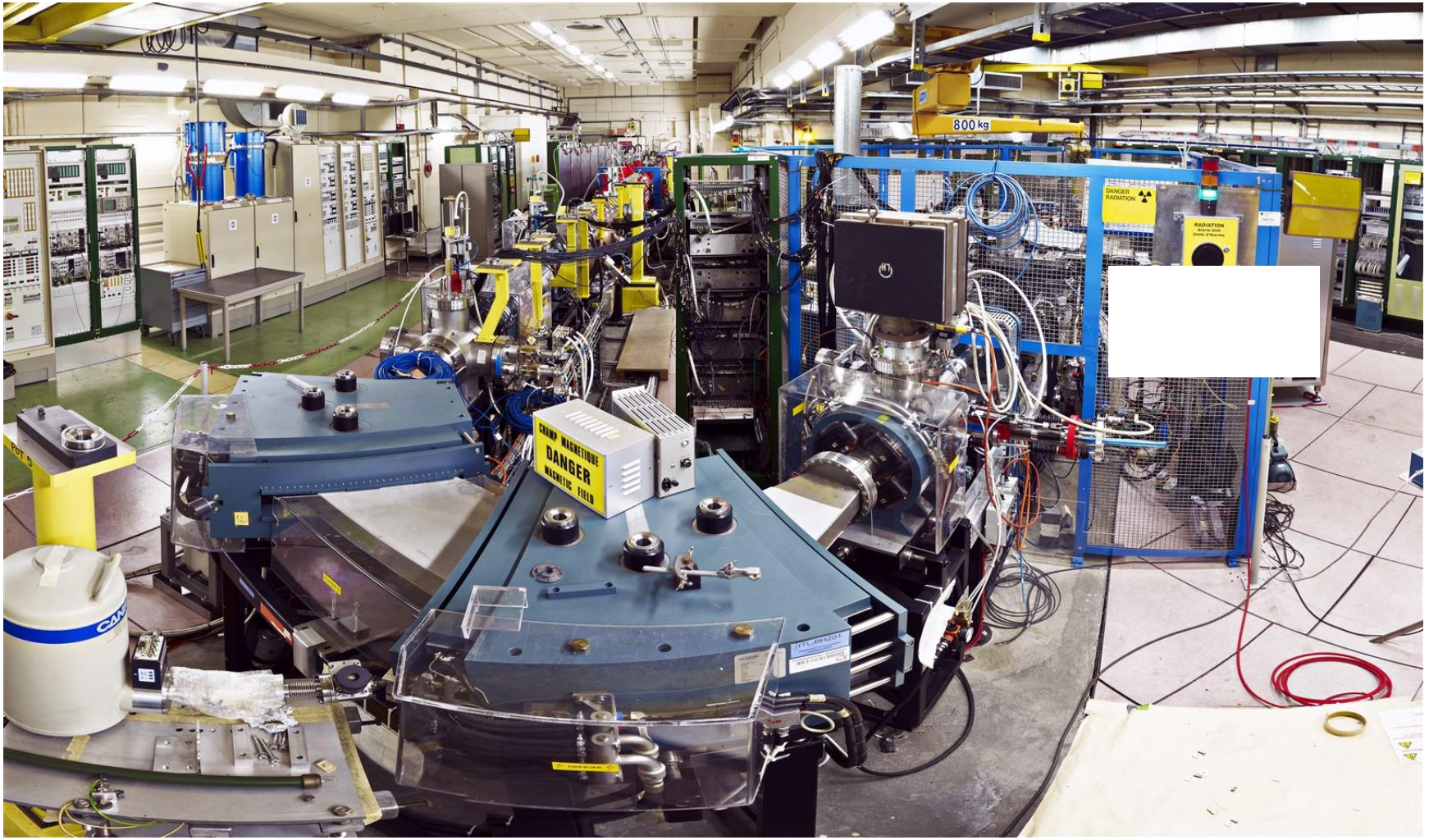

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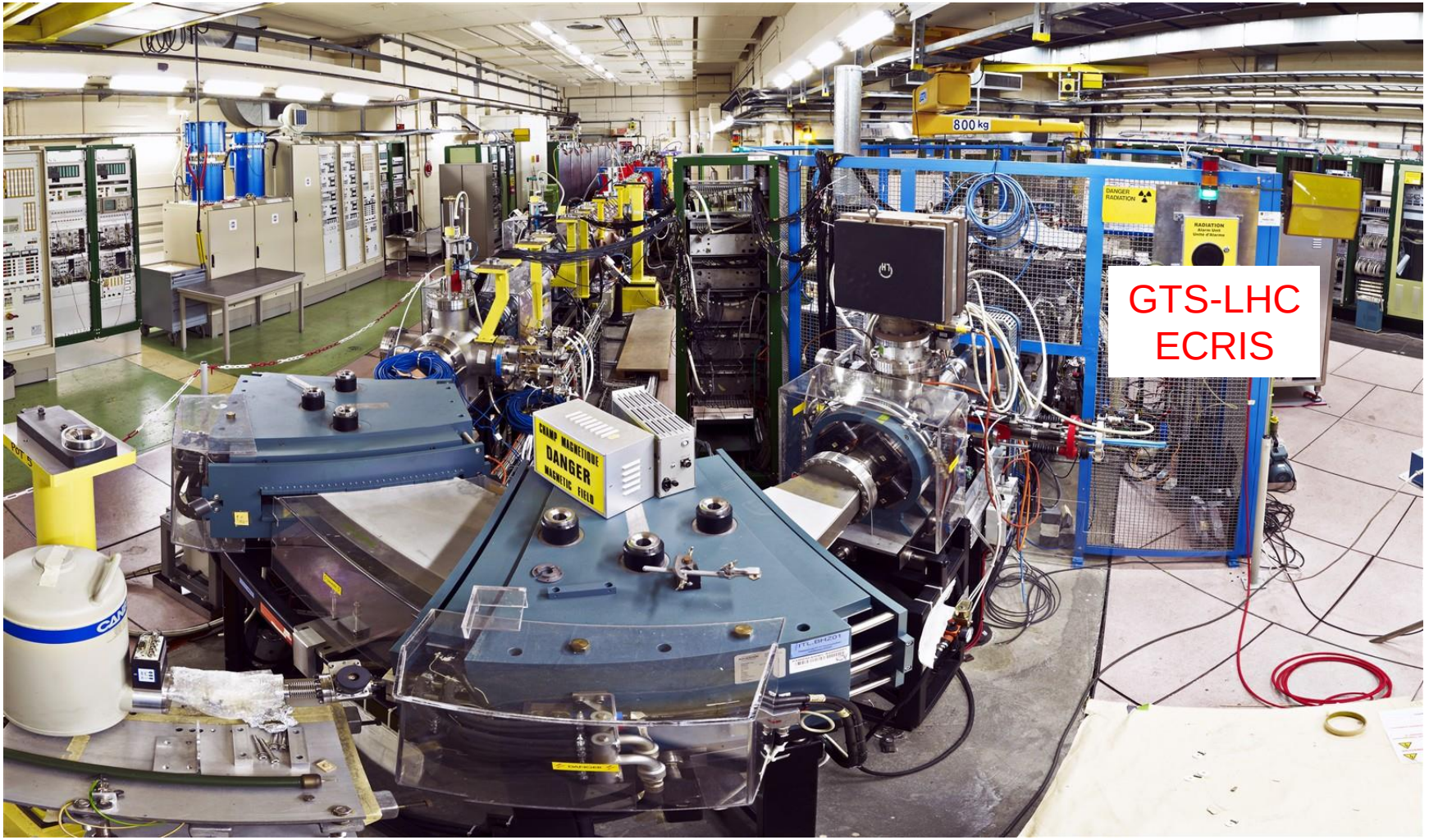

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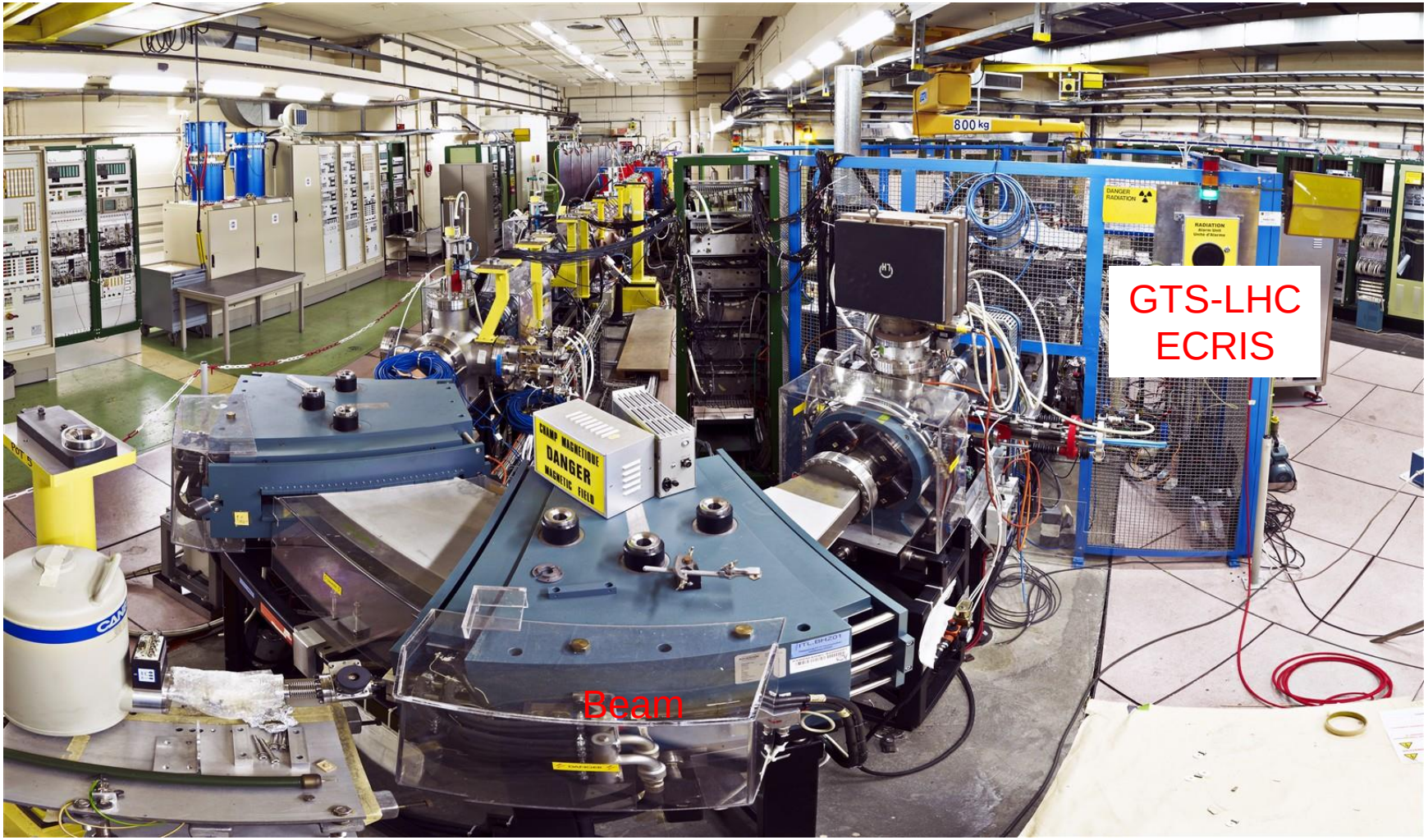

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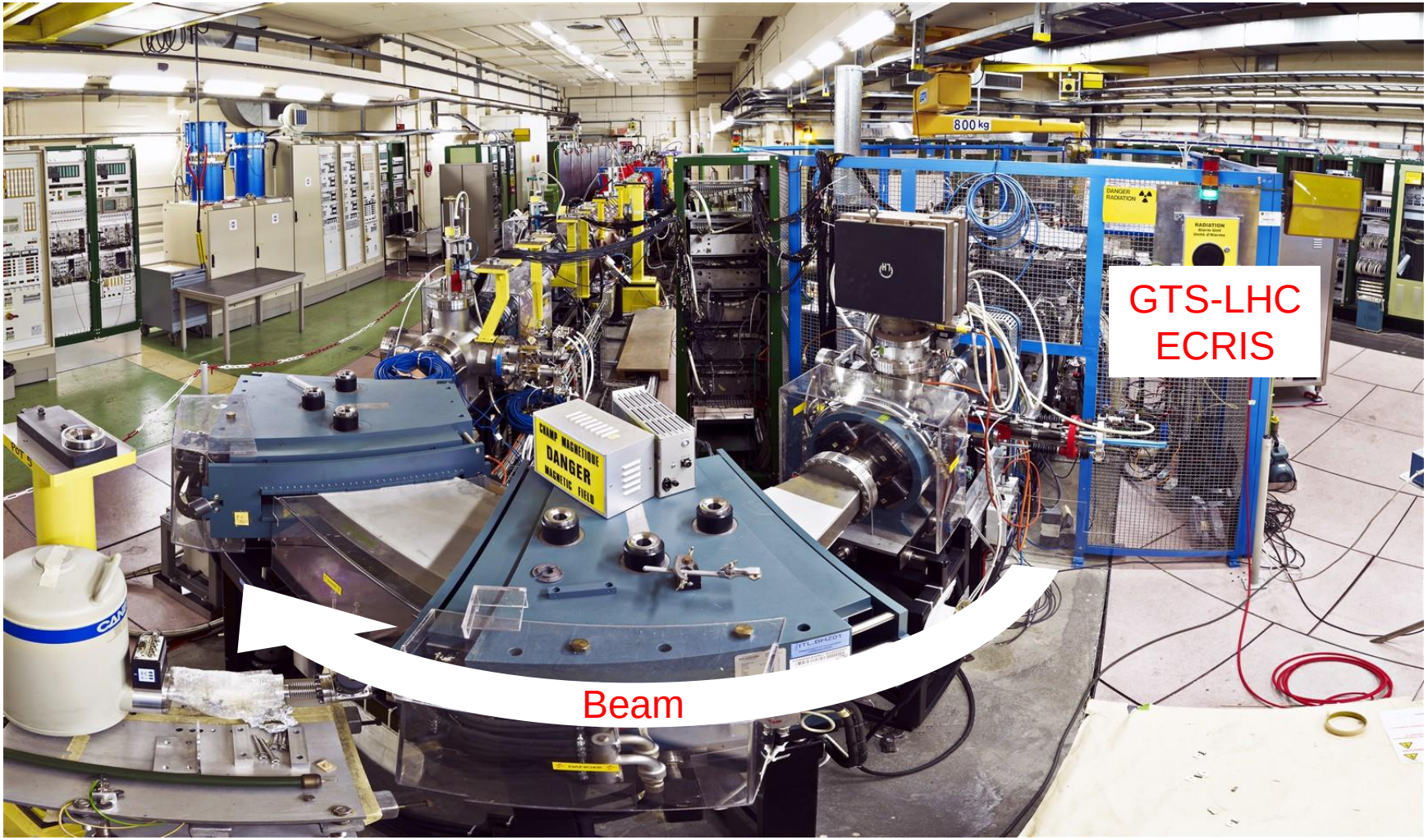

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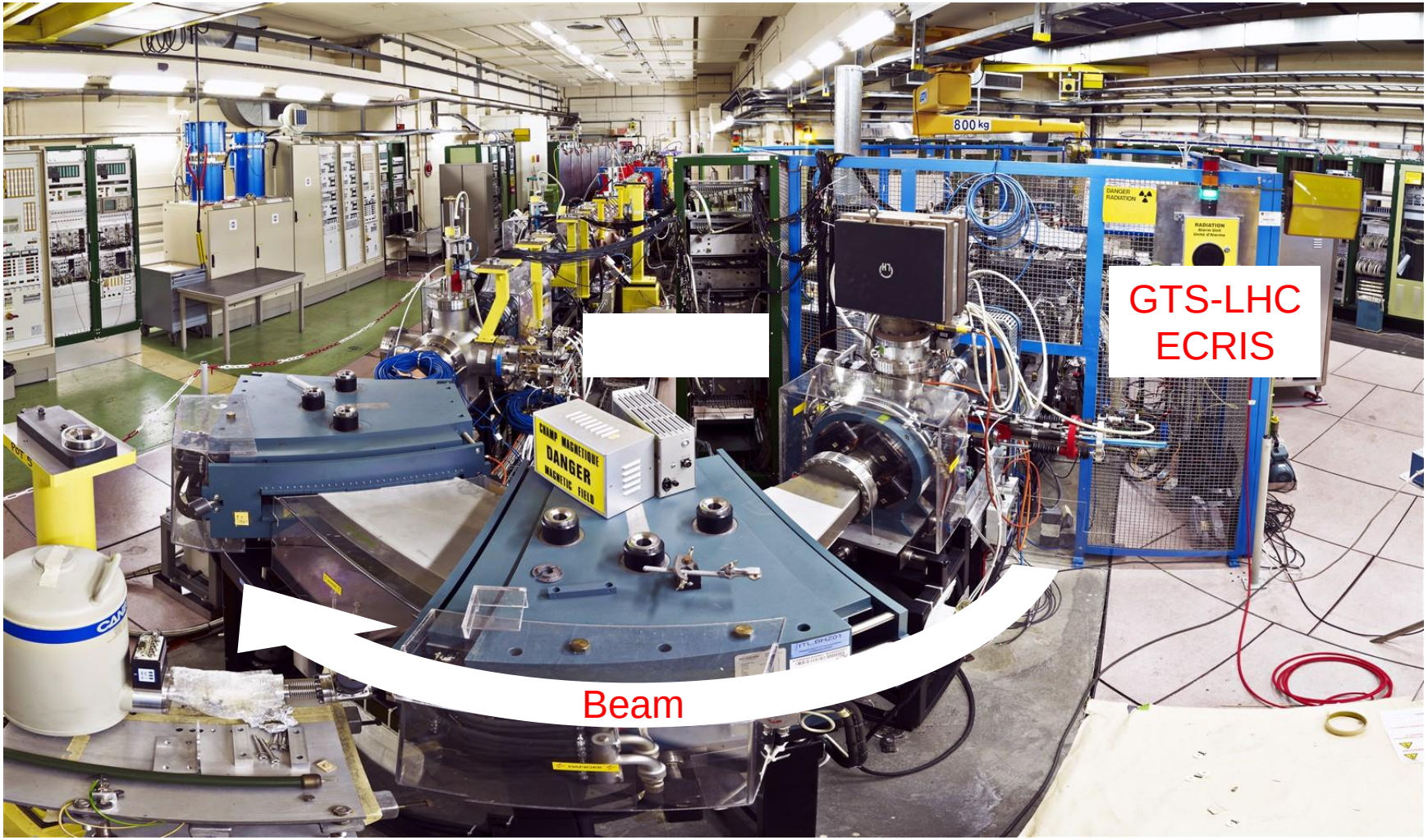

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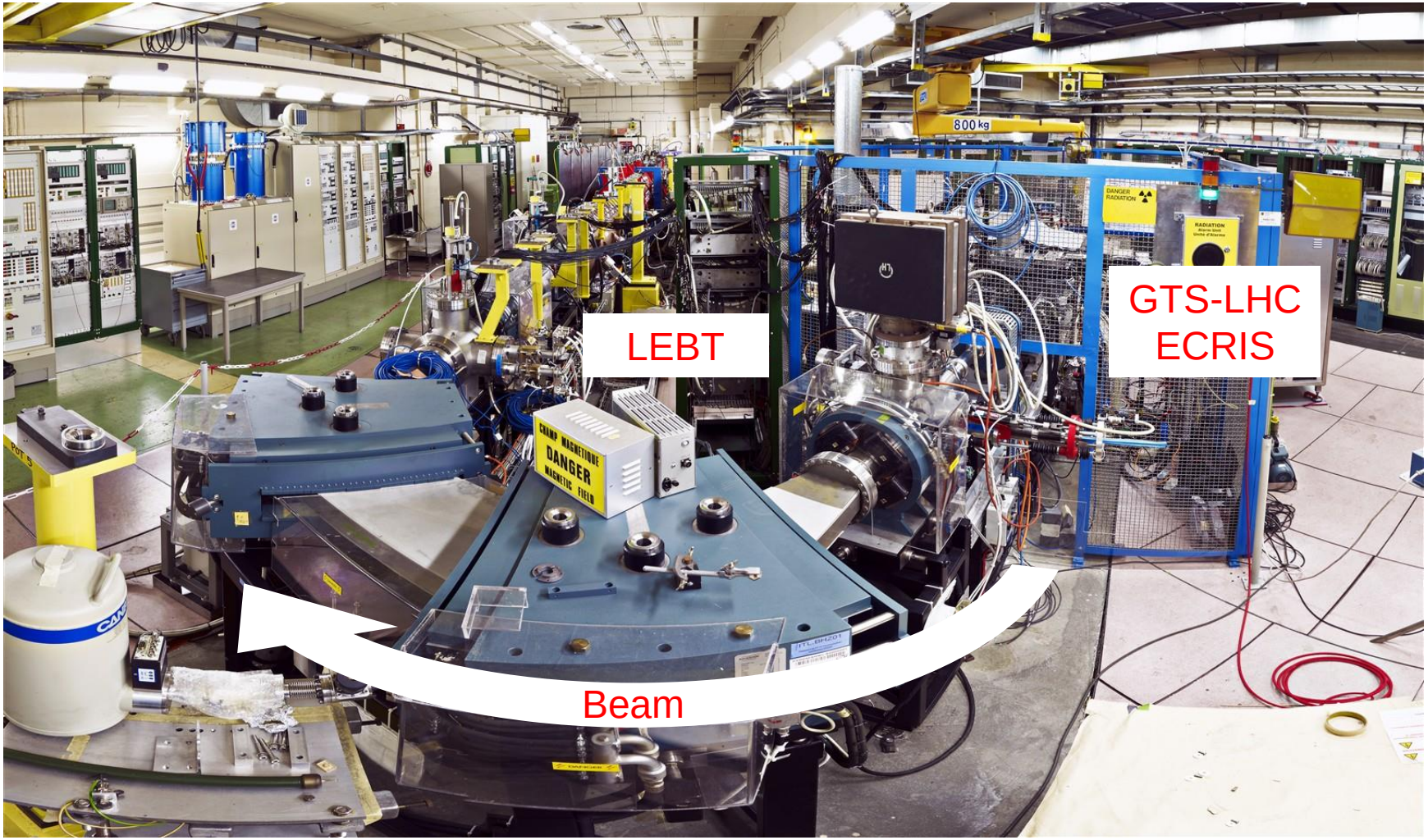

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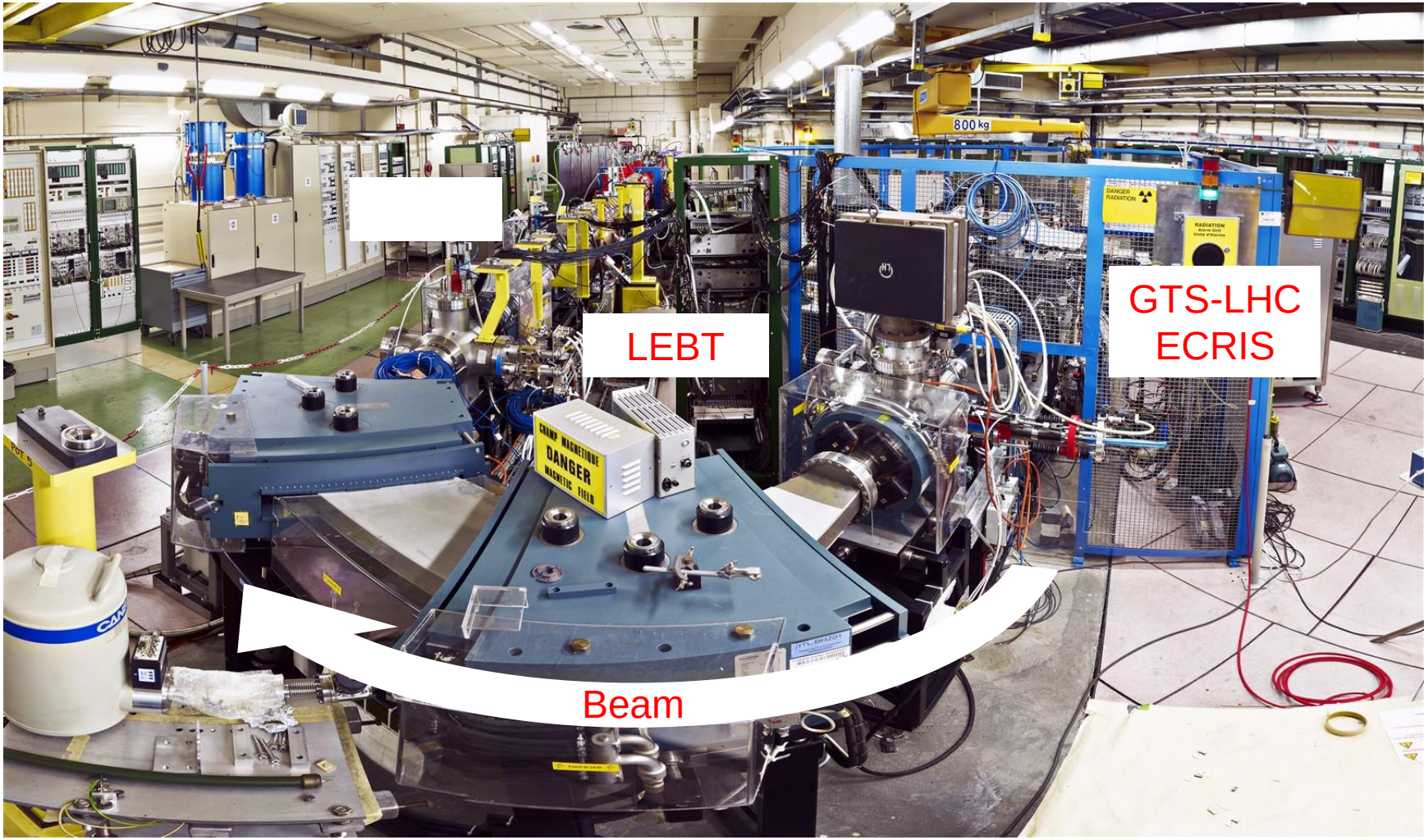

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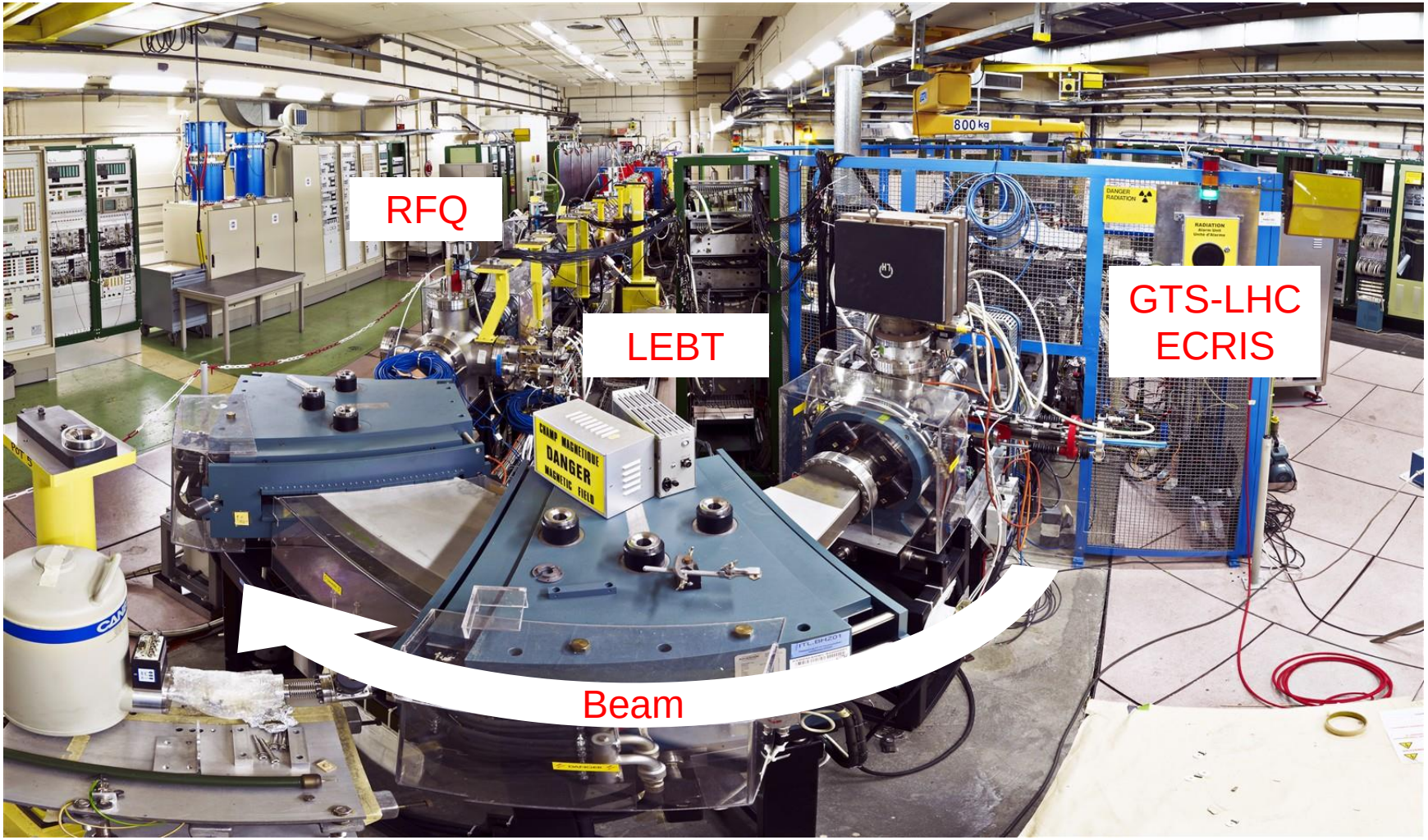

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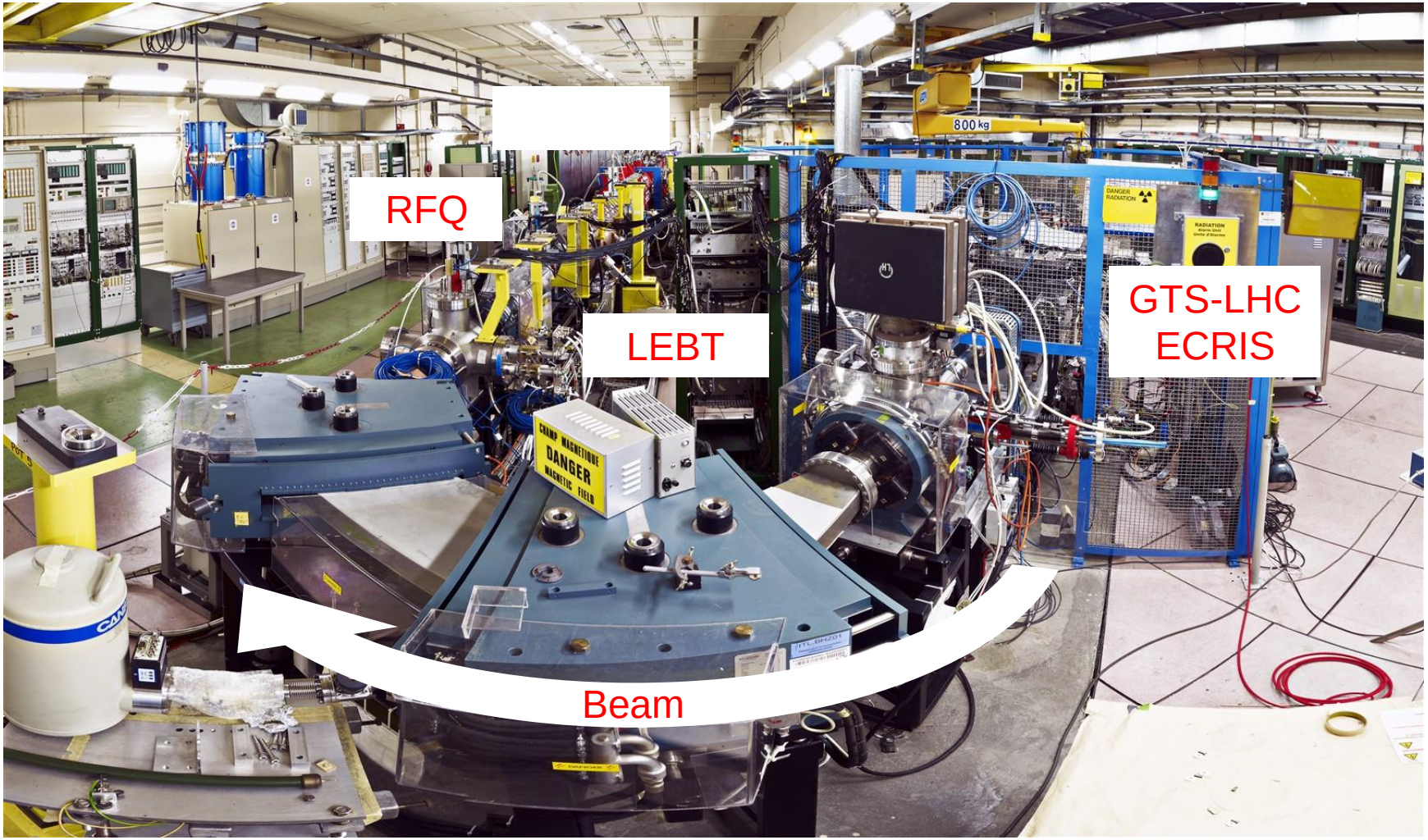

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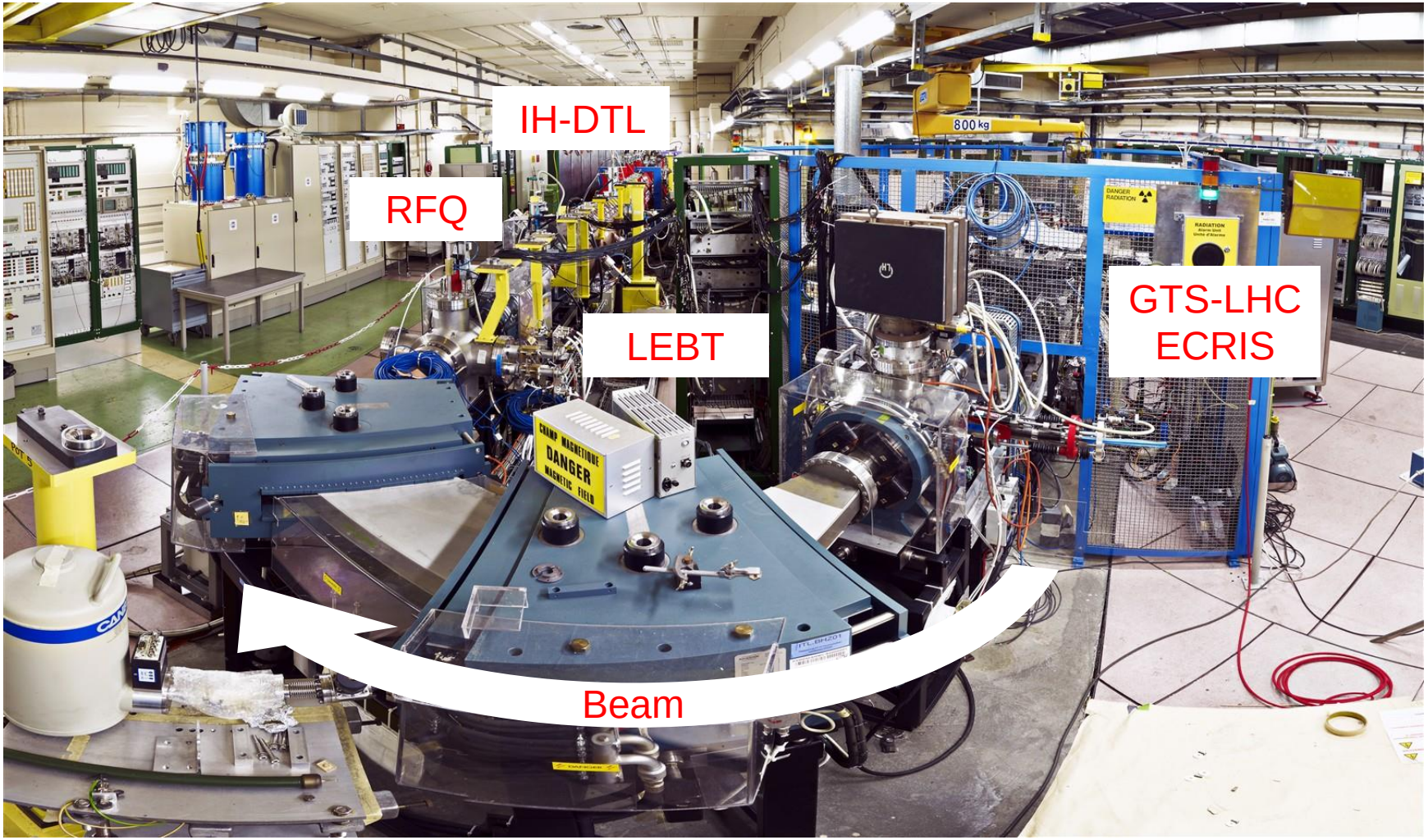

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- Linac3 performance improvement requested
  - Performance limitations not fully understood
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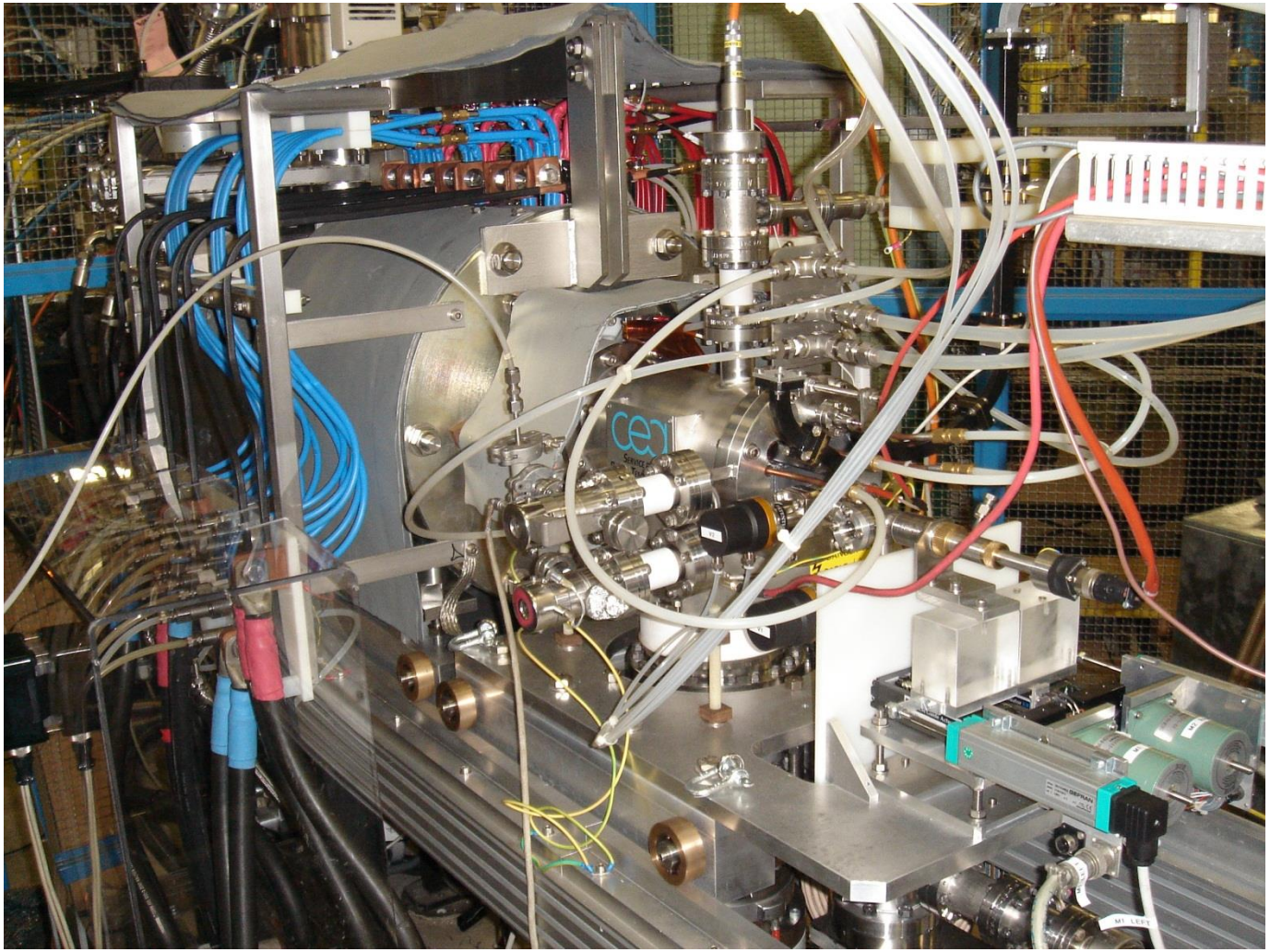
GTS-LHC ECRIS



GTS-LHC ECRIS

- 14.5 GHz 2nd generation RT ECRIS
- Based on the Grenoble Test Source (GTS) built by CEA, Grenoble
- Primarily for Pb beam production
- Operated in afterglow mode
  - (10 Hz / 50% duty cycle)

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- Challenging and complex plasma conditions
- Added complication: extraction during afterglow
- IBSimu chosen for extraction simulations
  - Good results from previous ECRIS studies
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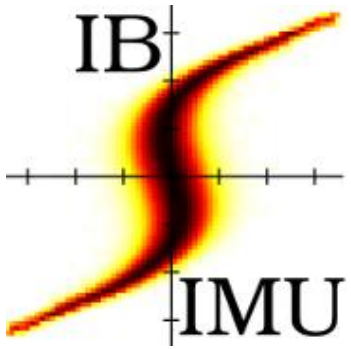

Simulation settings, assumptions

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- 3D model of extraction geometry
- 3D magnetic field calculated with Opera (solenoids and hexapole)
- Measured CSD during afterglow
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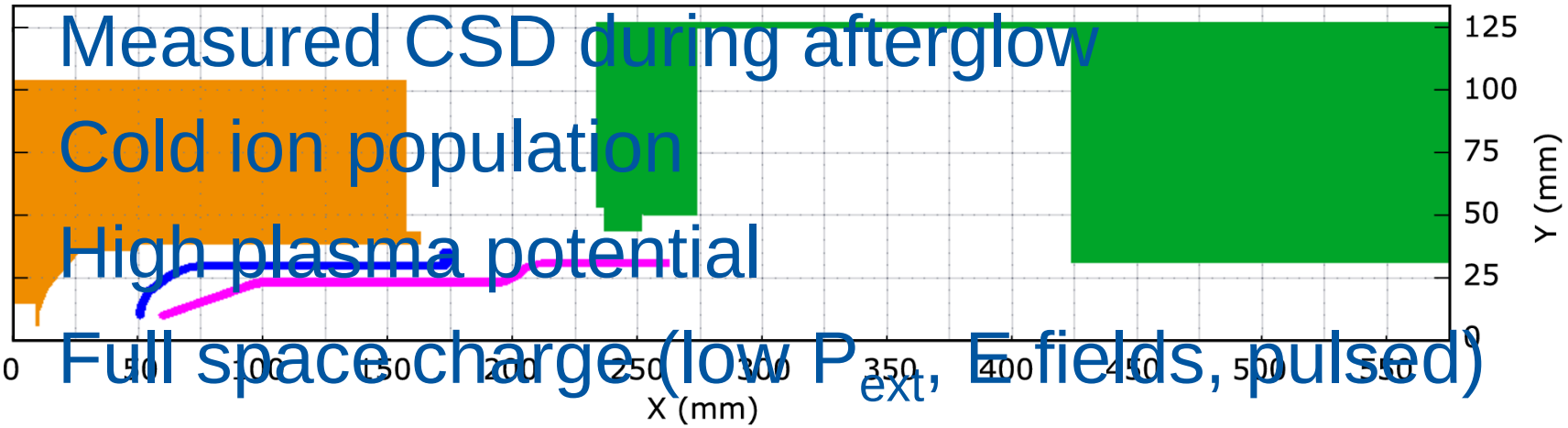

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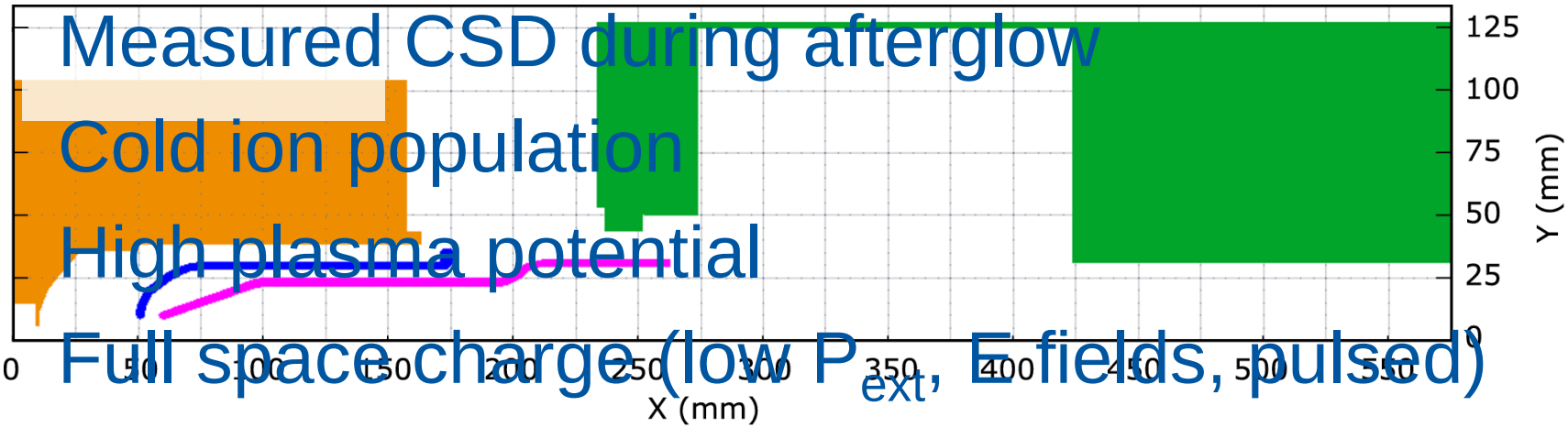

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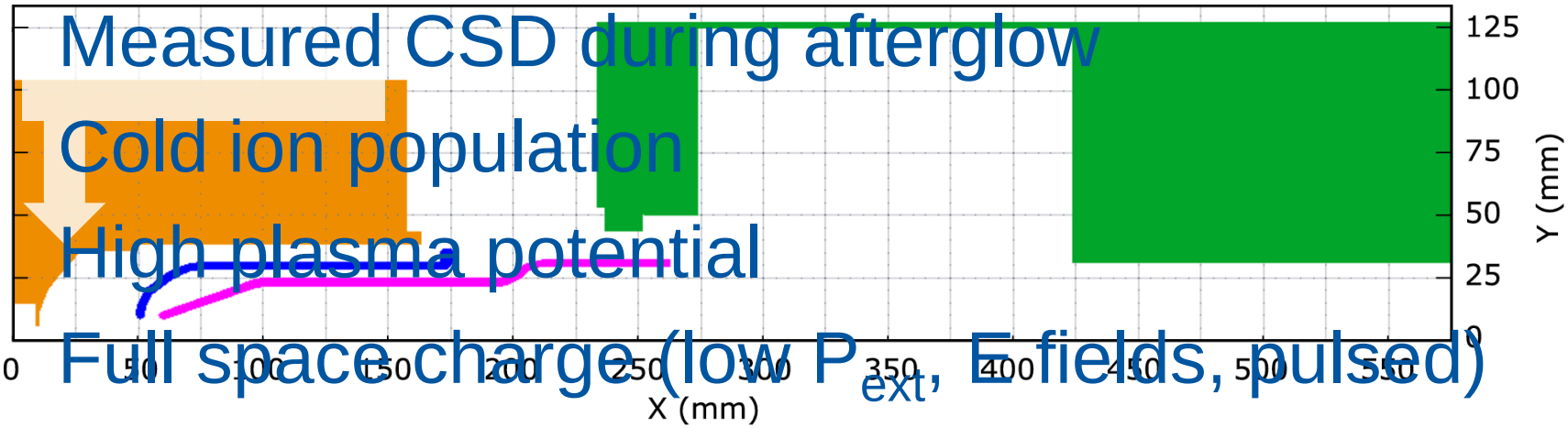

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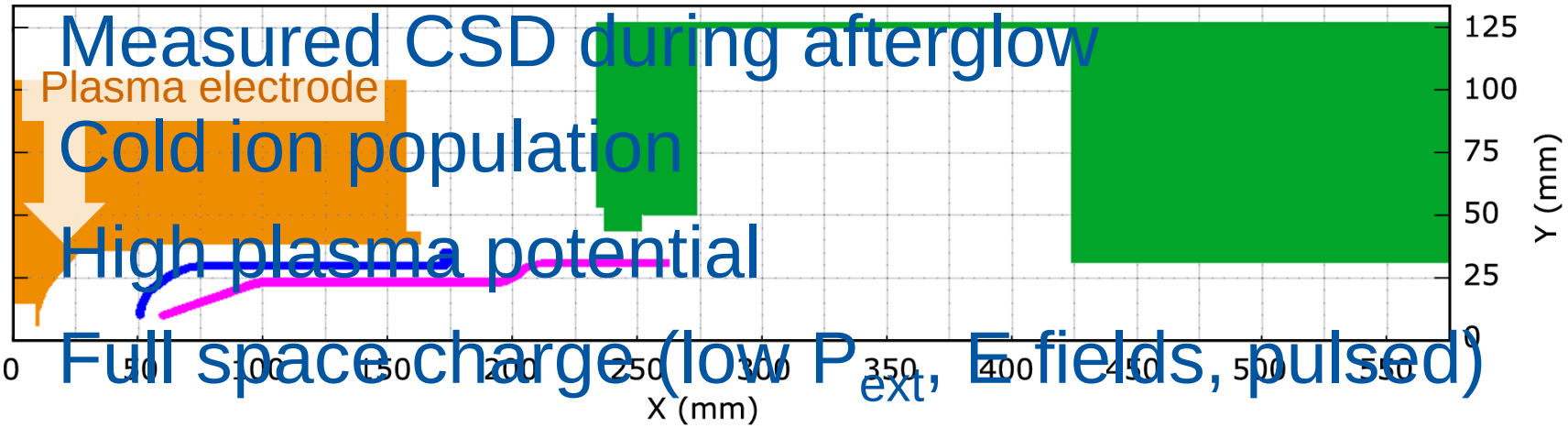

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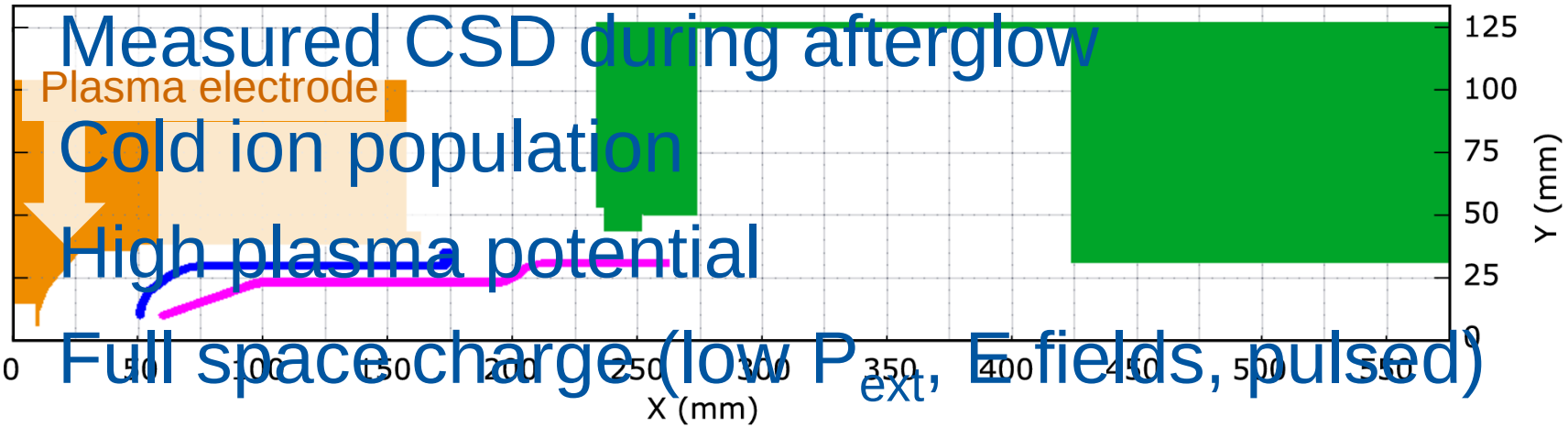

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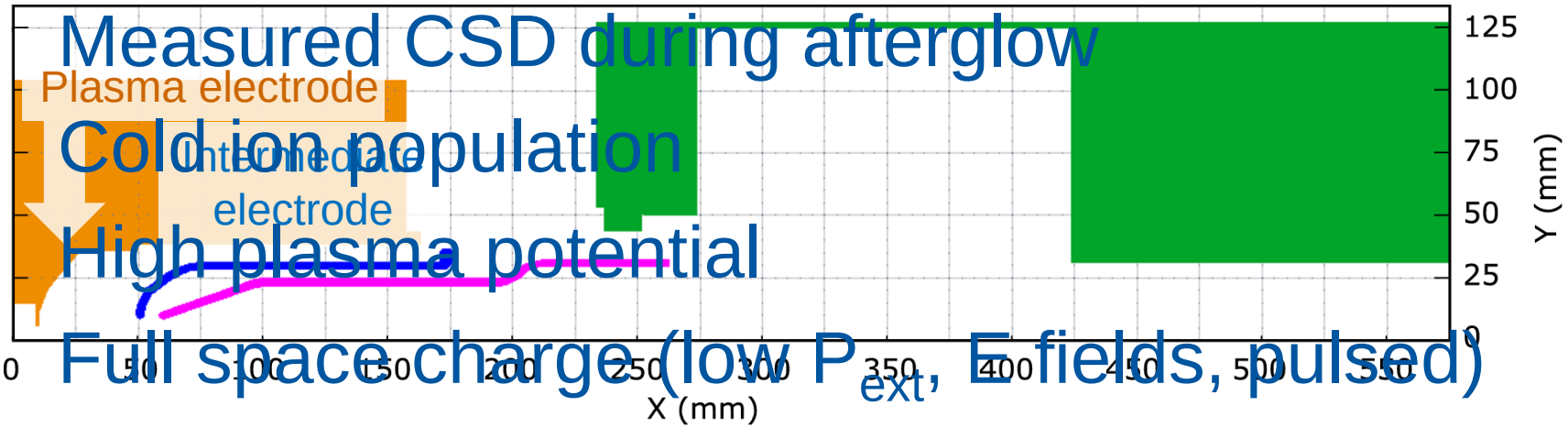

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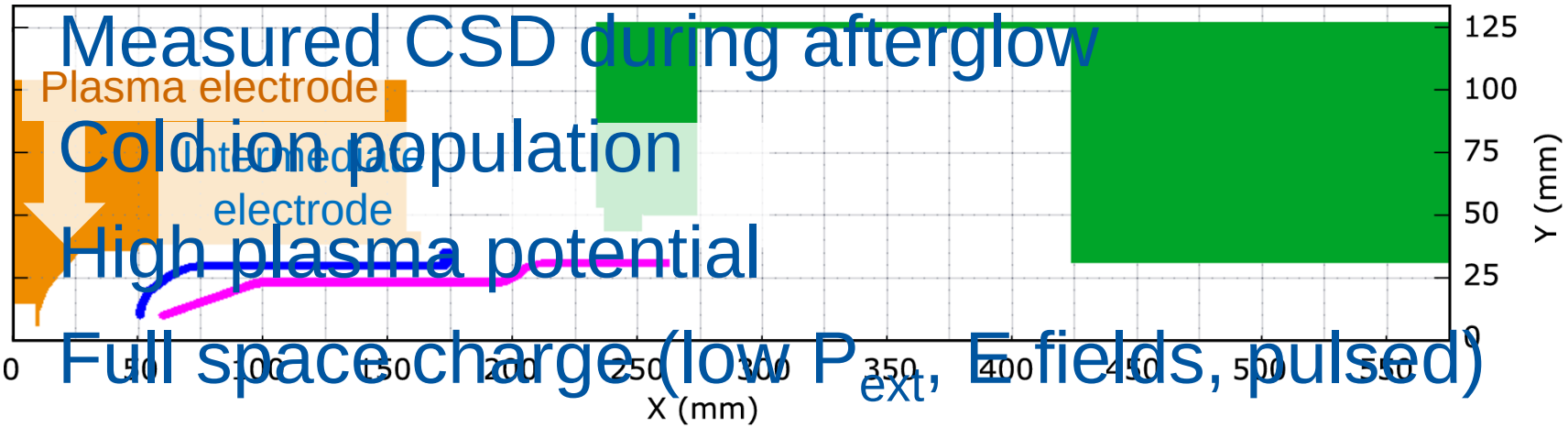

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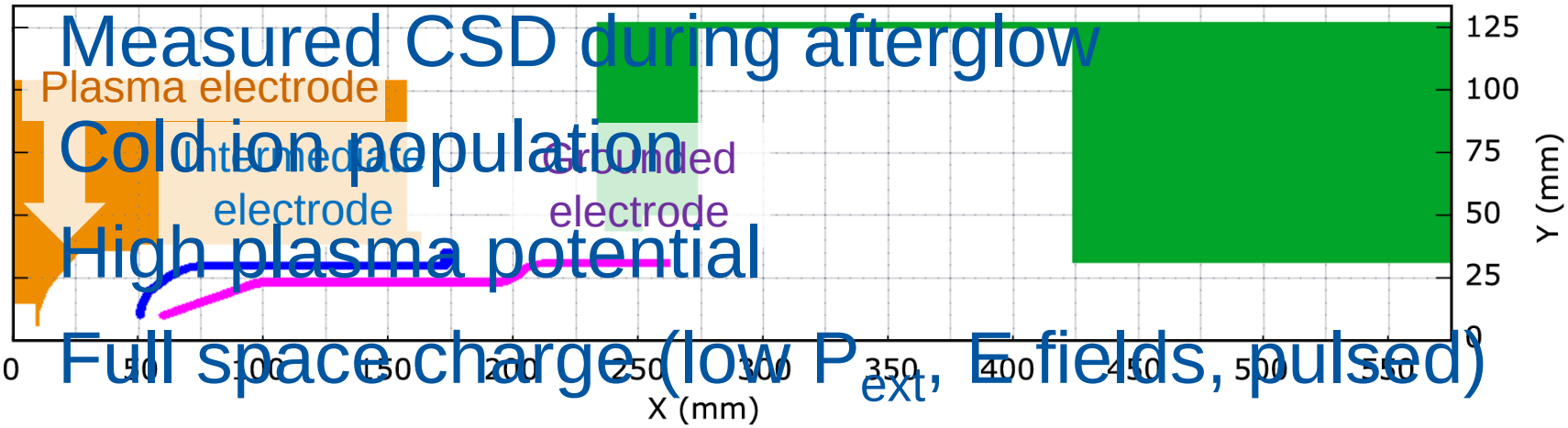

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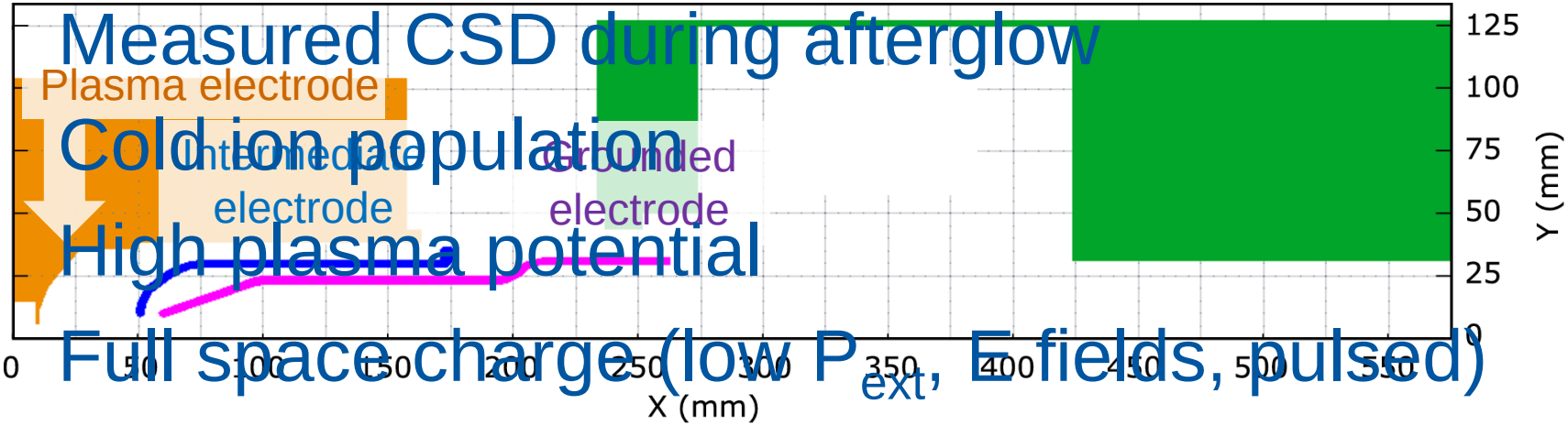

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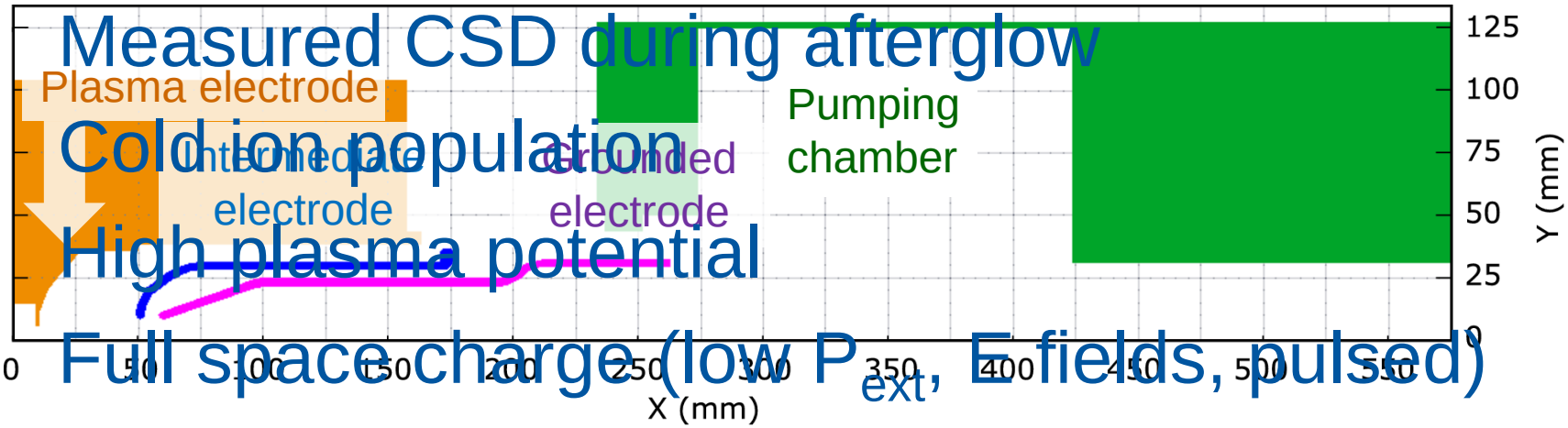

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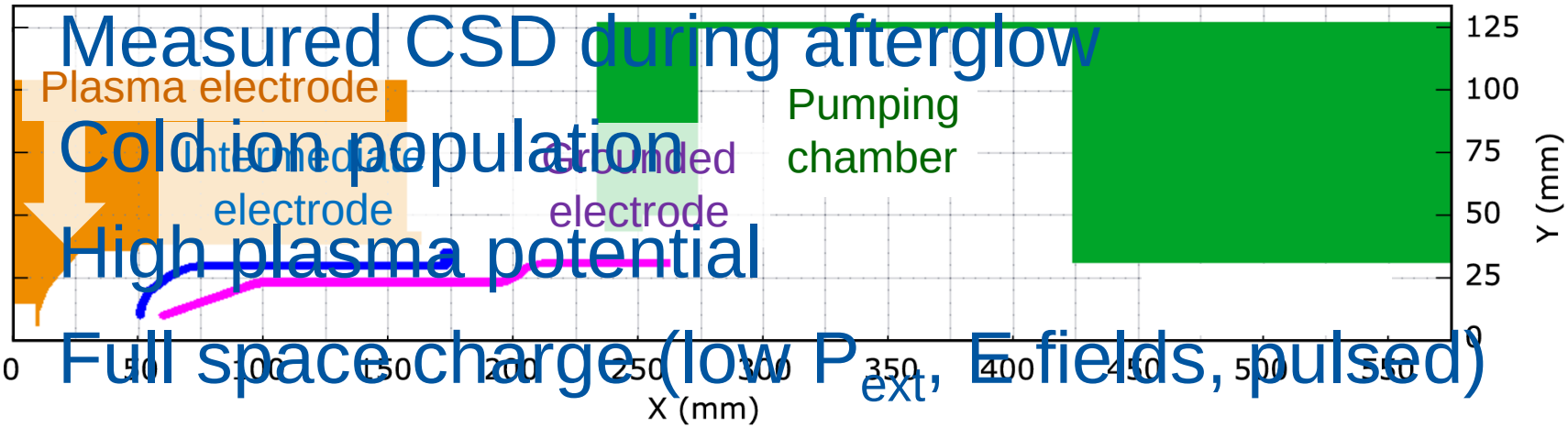

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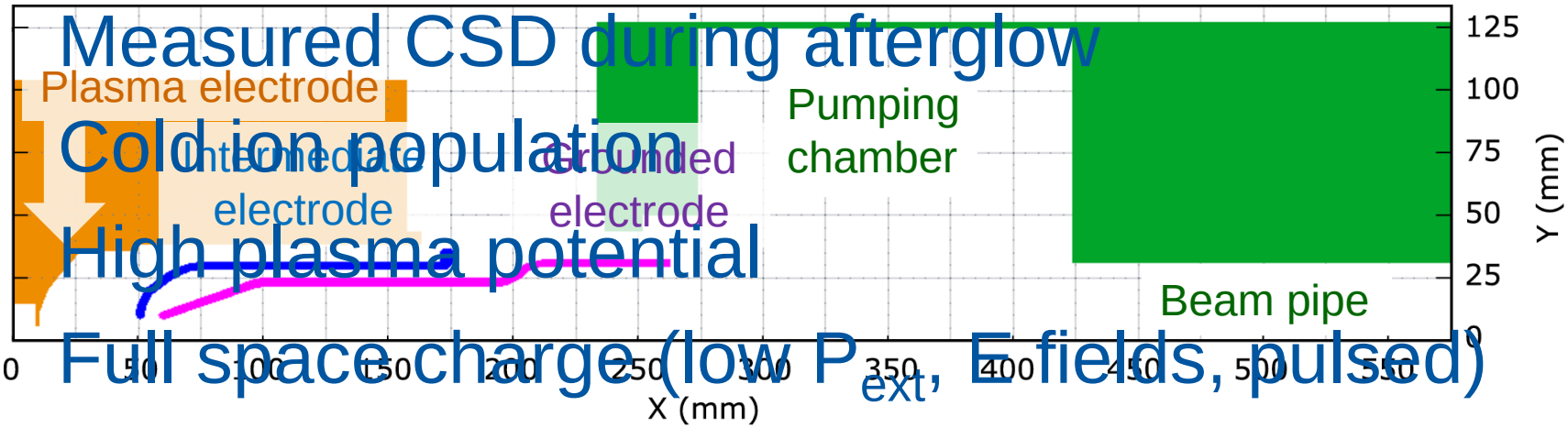

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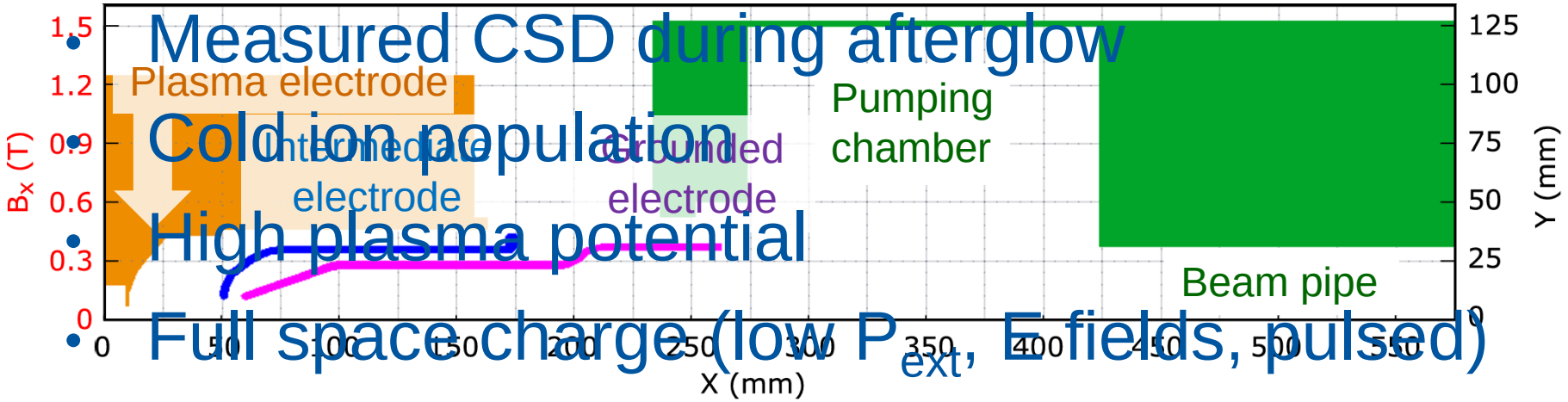

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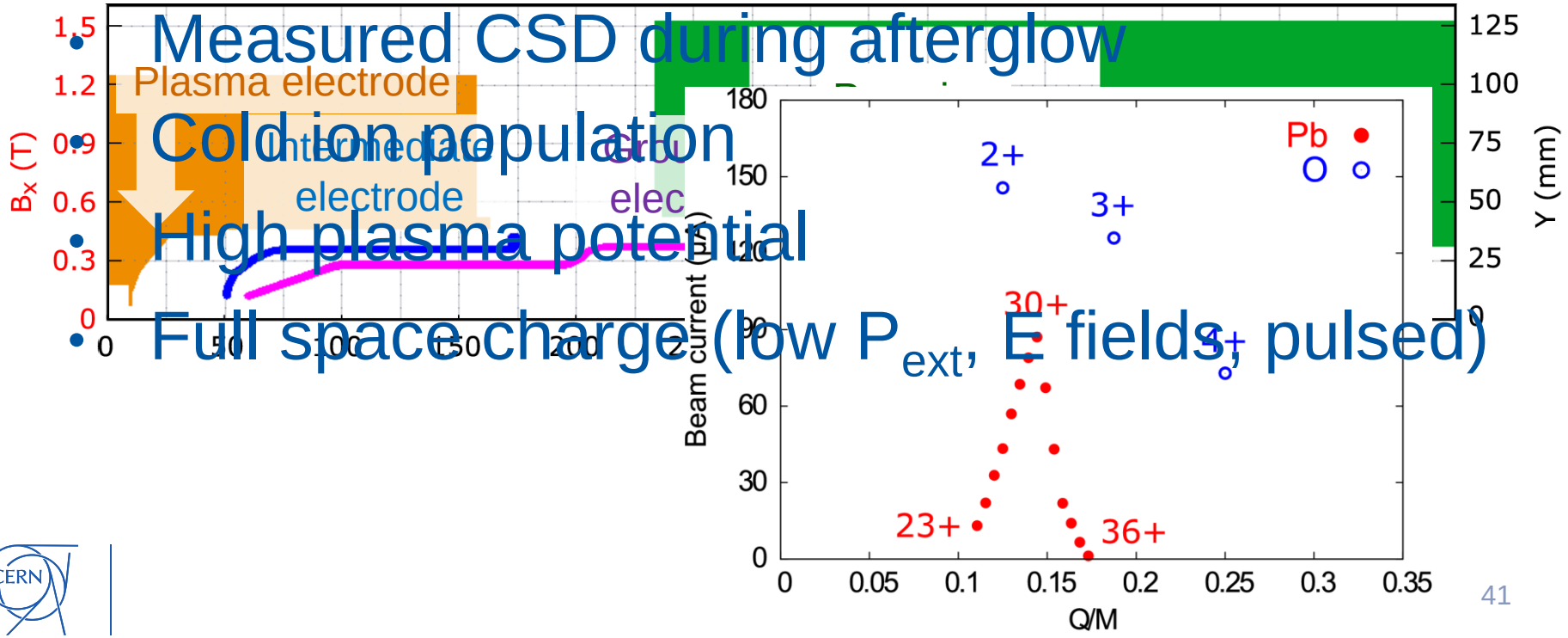

Three studied cases

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1. Tuned for $^{208}Pb^{29+}$
   - Current operational settings
   - Model goal – but no beam available until 2015
2. Tuned for $^{208}Pb^{27+}$
   - Old operational settings
   - Existing experimental data – basis for 29+ case
3. Tuned for $^{40}Ar^{11+}$
   - Will be delivered for physics experiments in 2015
   - Currently available for experiments

Extracted beams, all ion species

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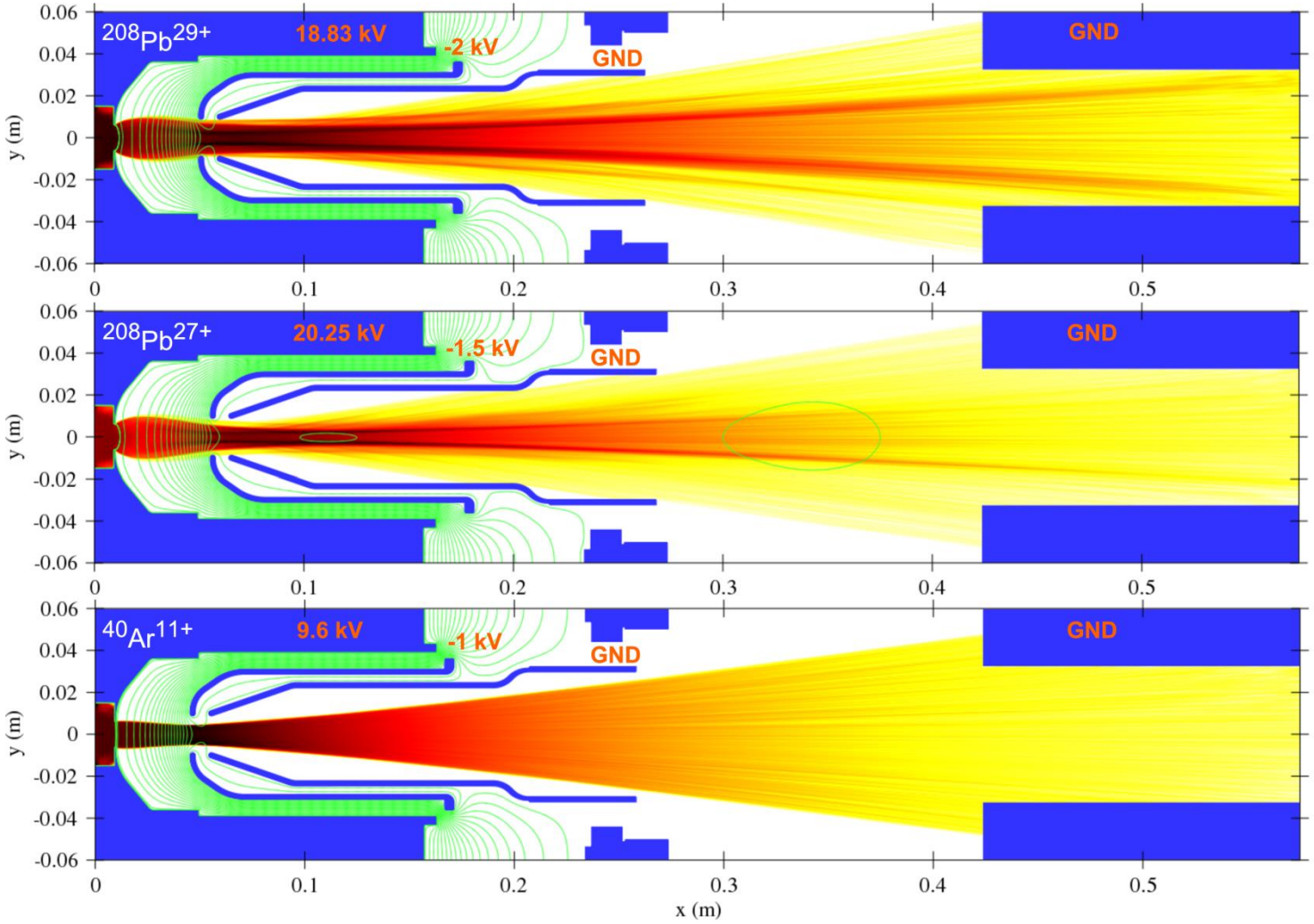

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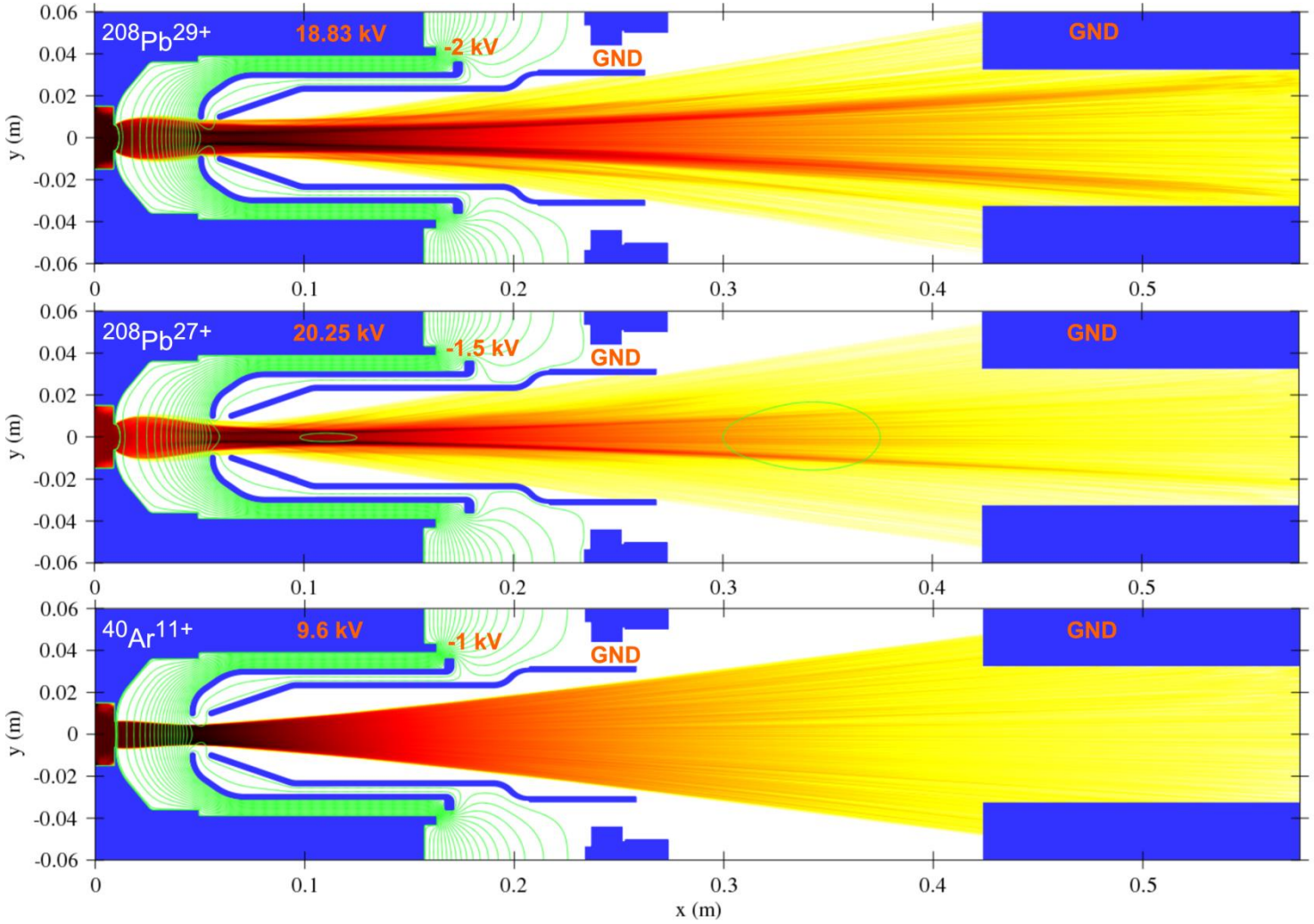

$^{40}Ar^{11+}$

1.6 mA

35 mm gap

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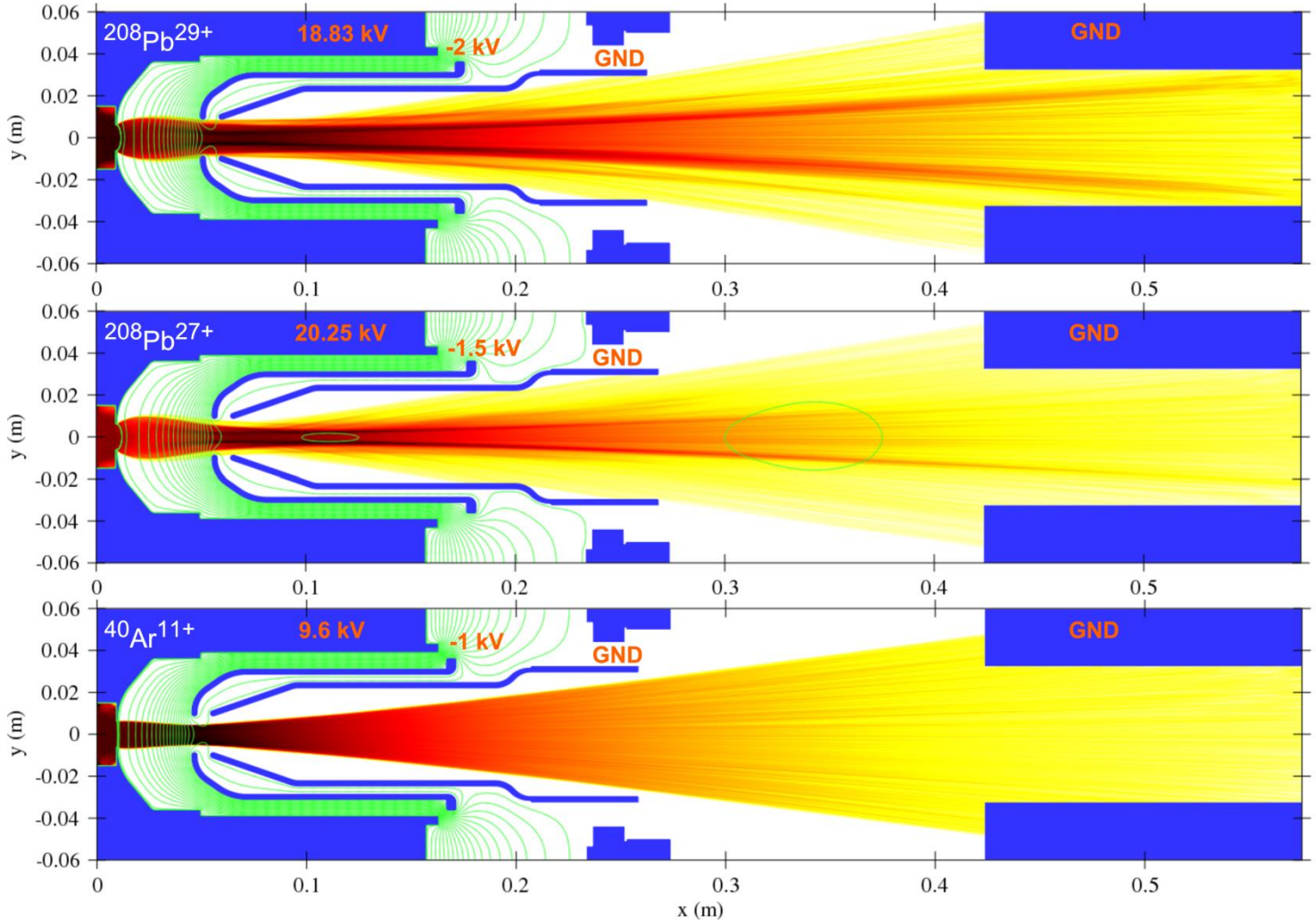

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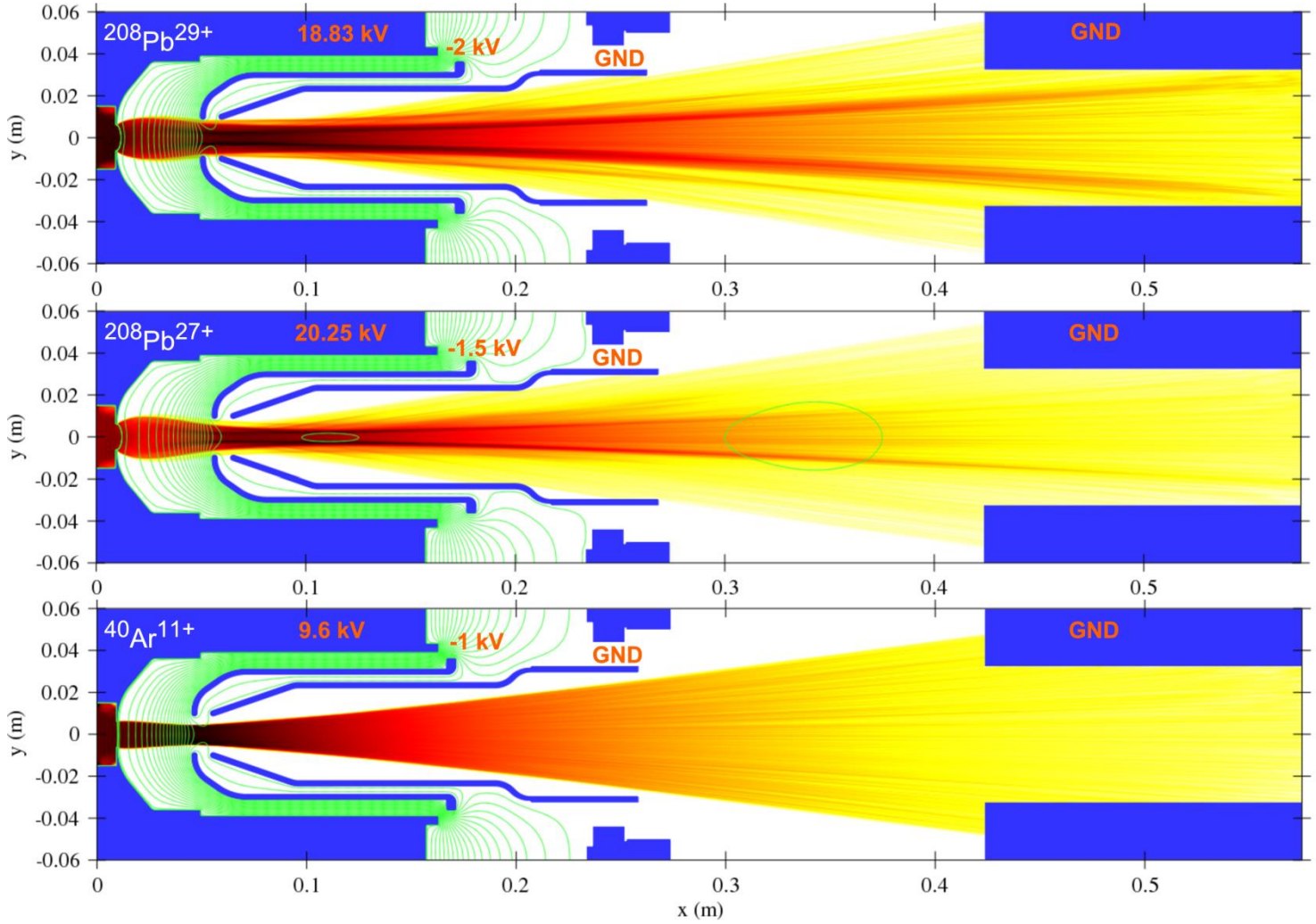

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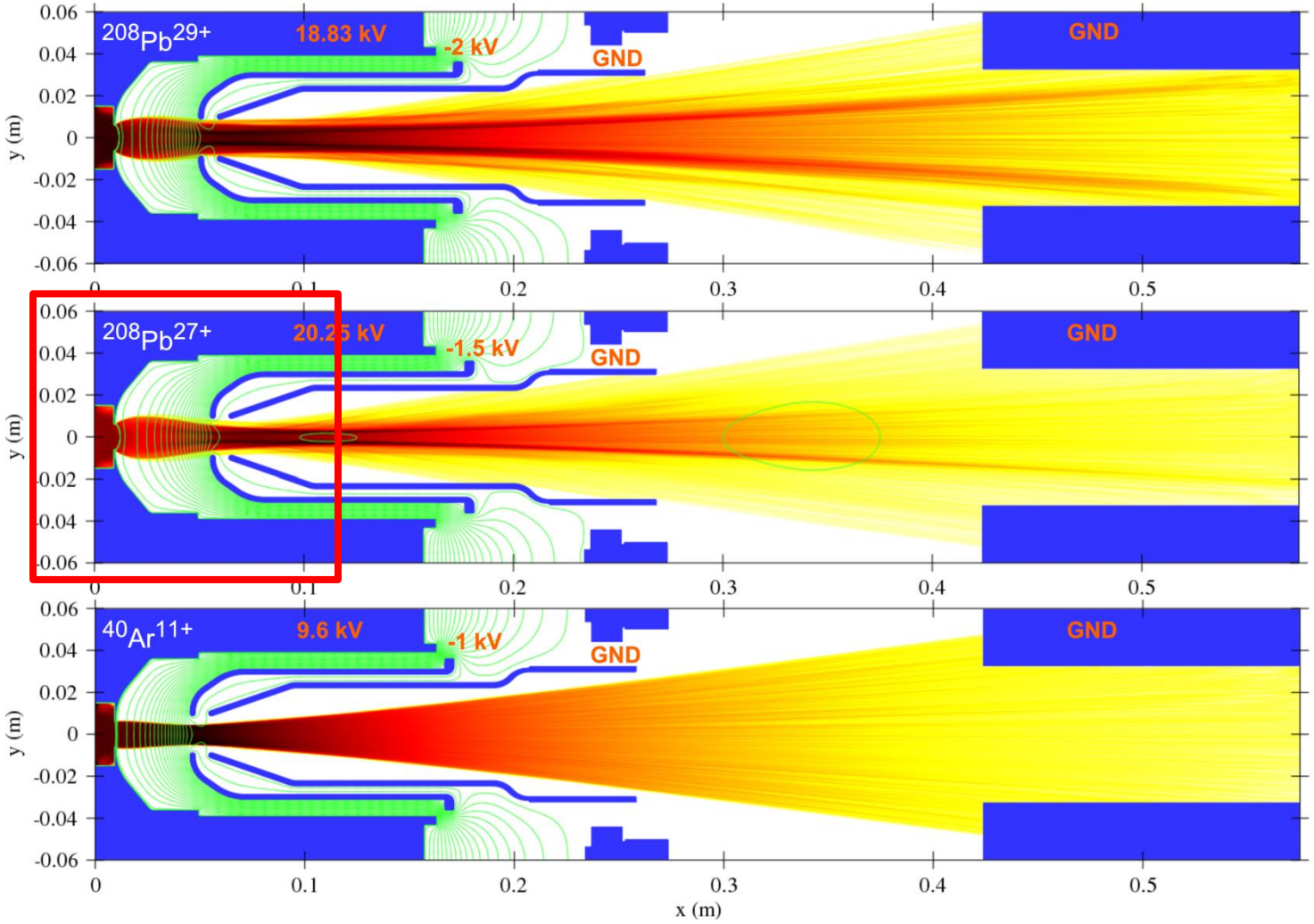

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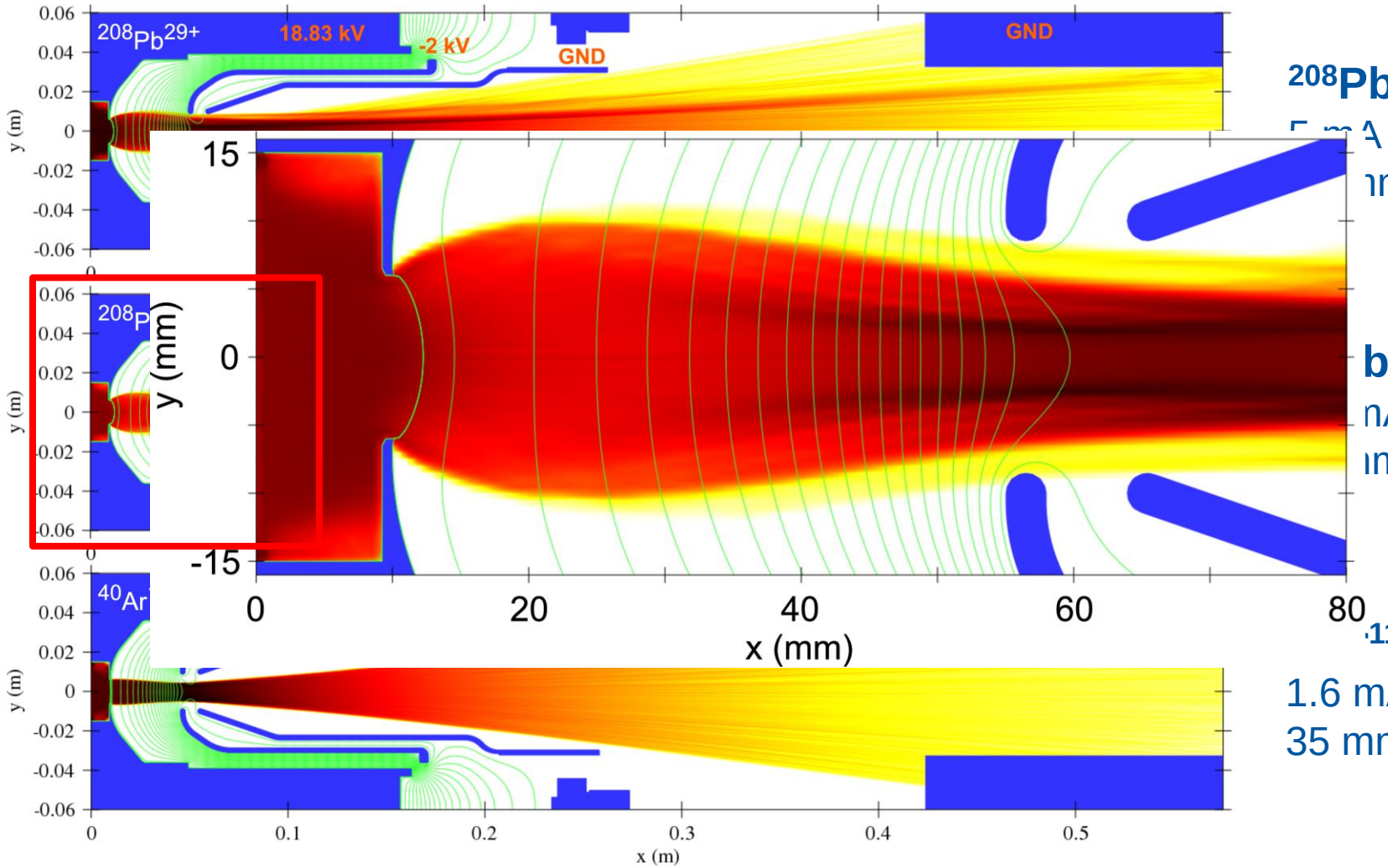

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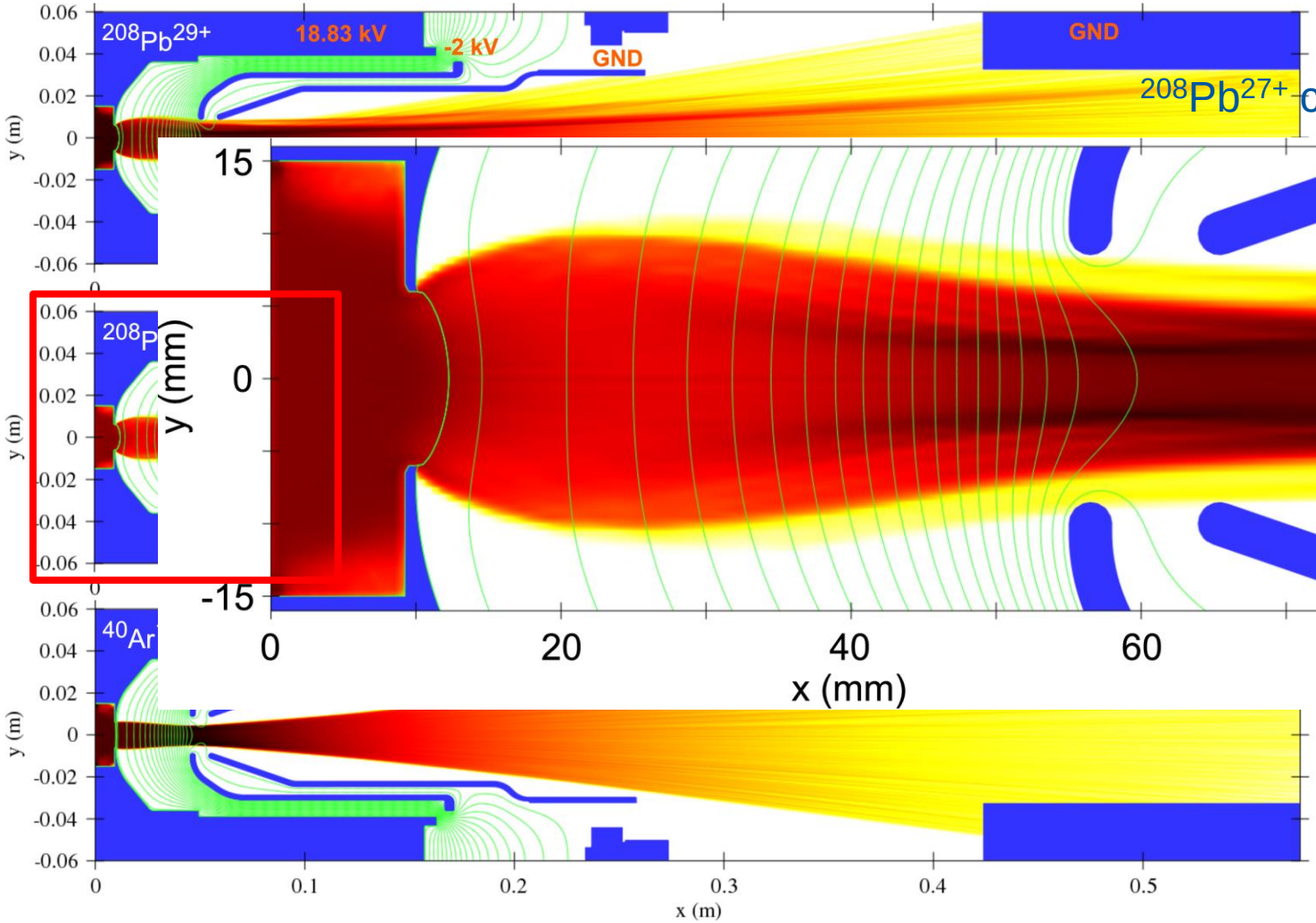

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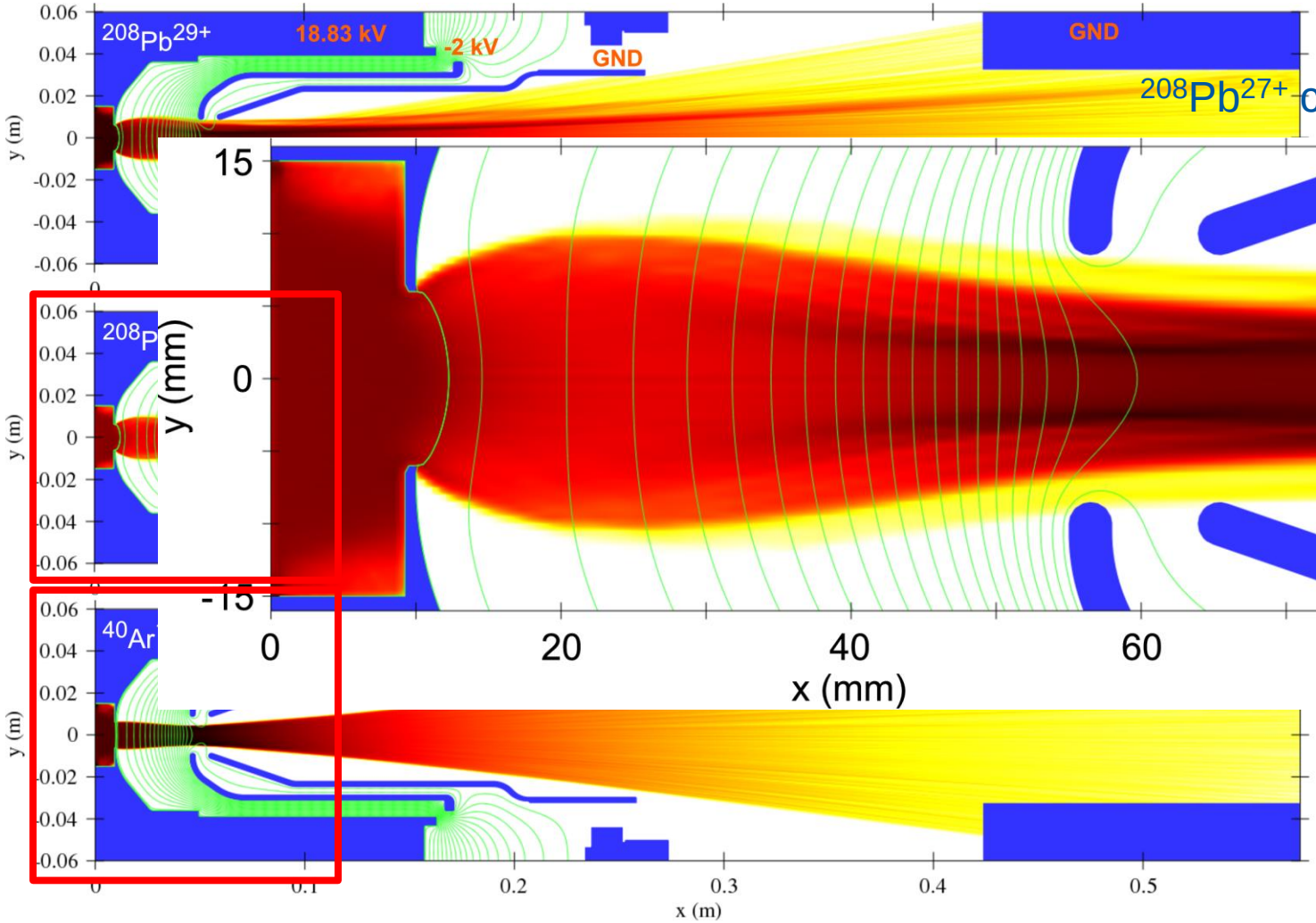

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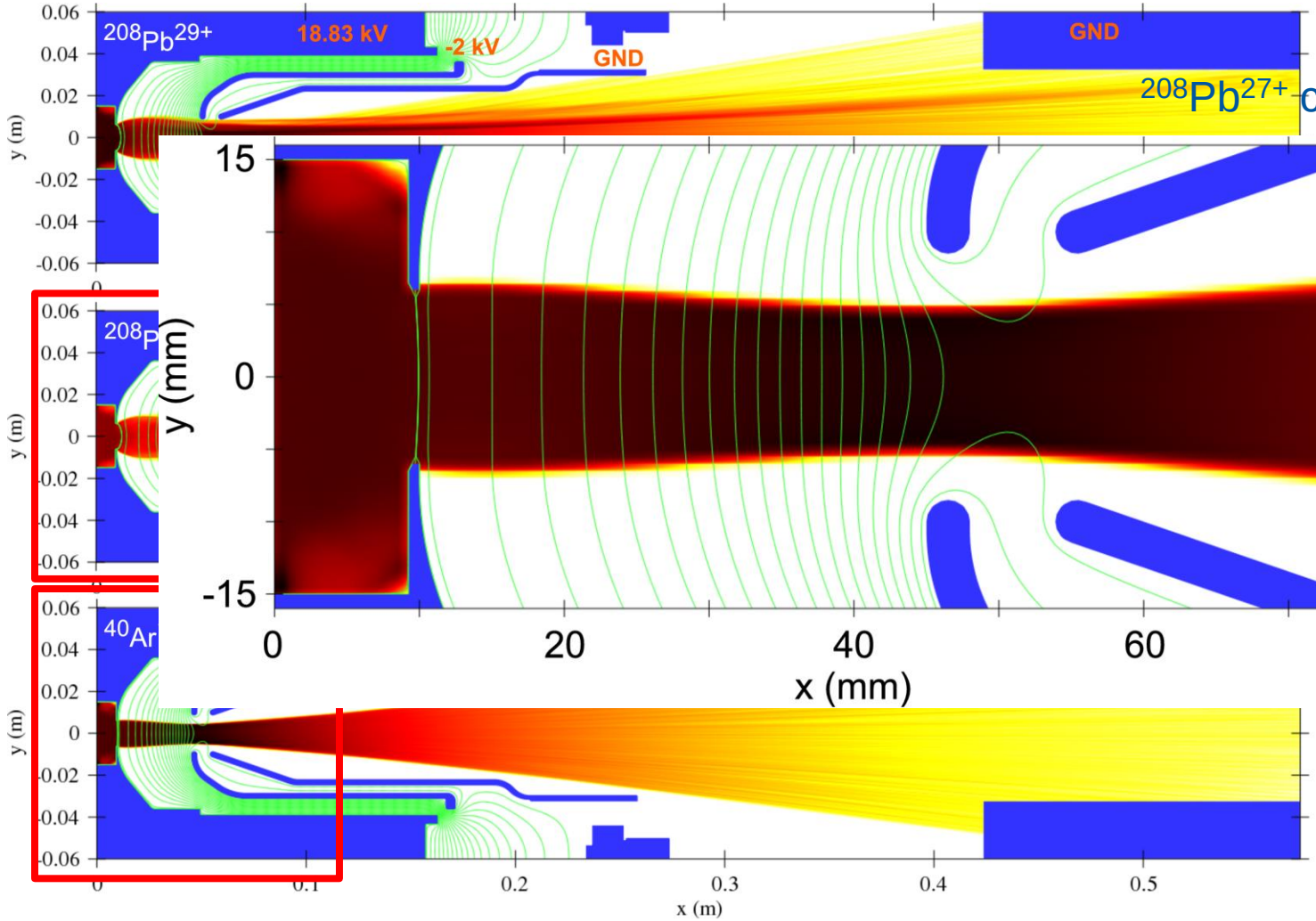

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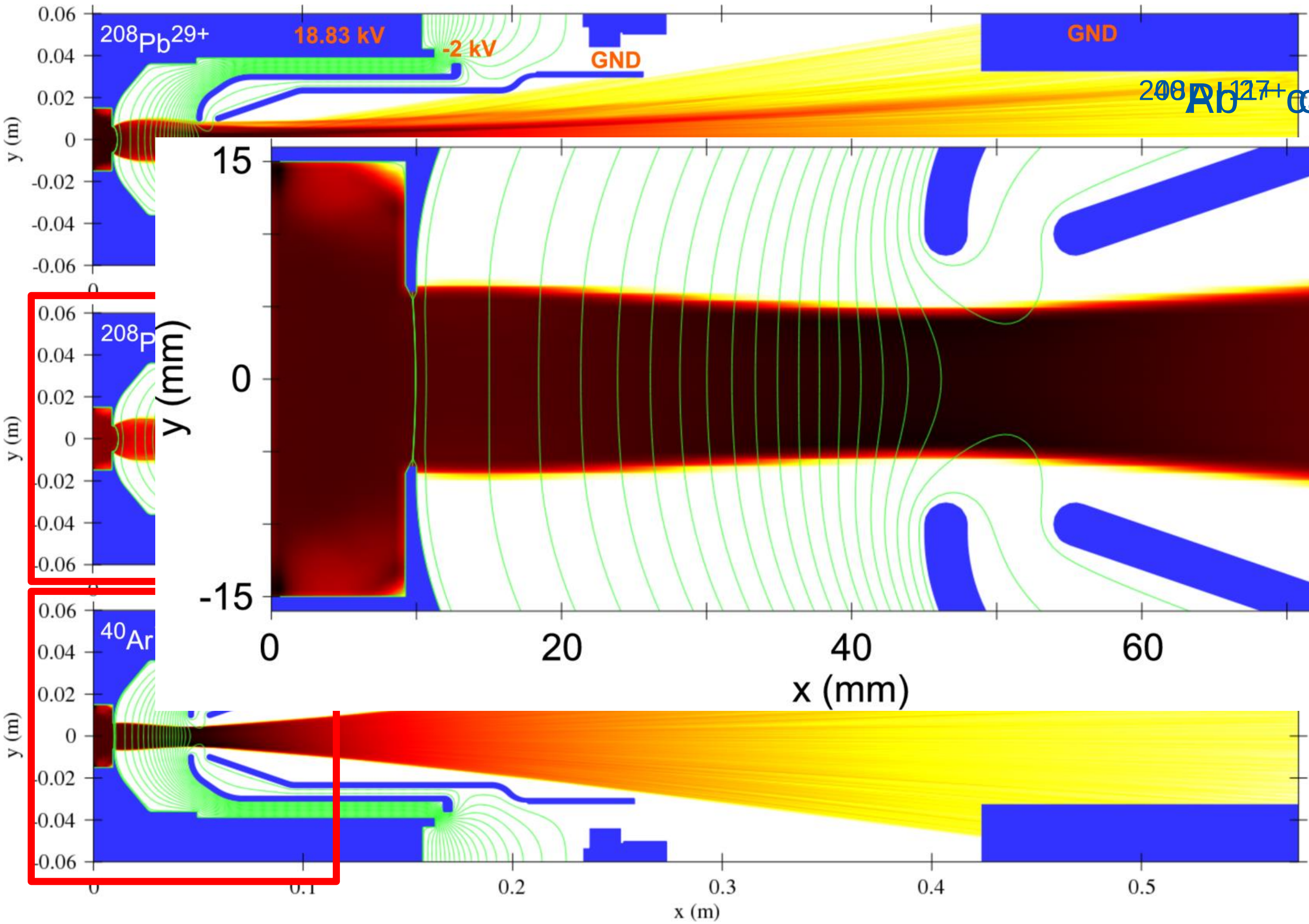

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m gap

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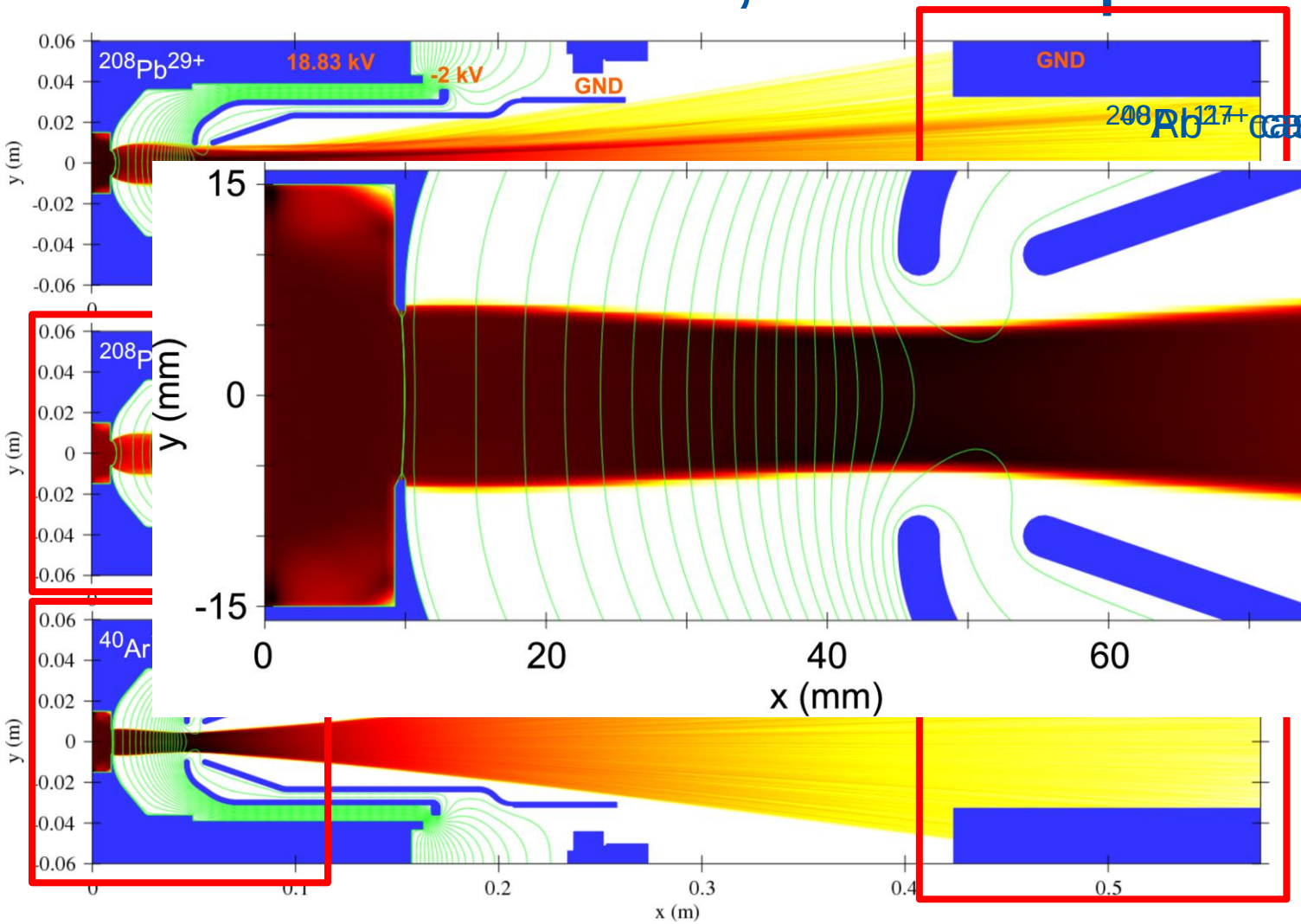
35 mm gap

Extracted beams, all ion species



$^{208}Pb^{29+}$

mm gap

$^{208}Pb^{27+}$

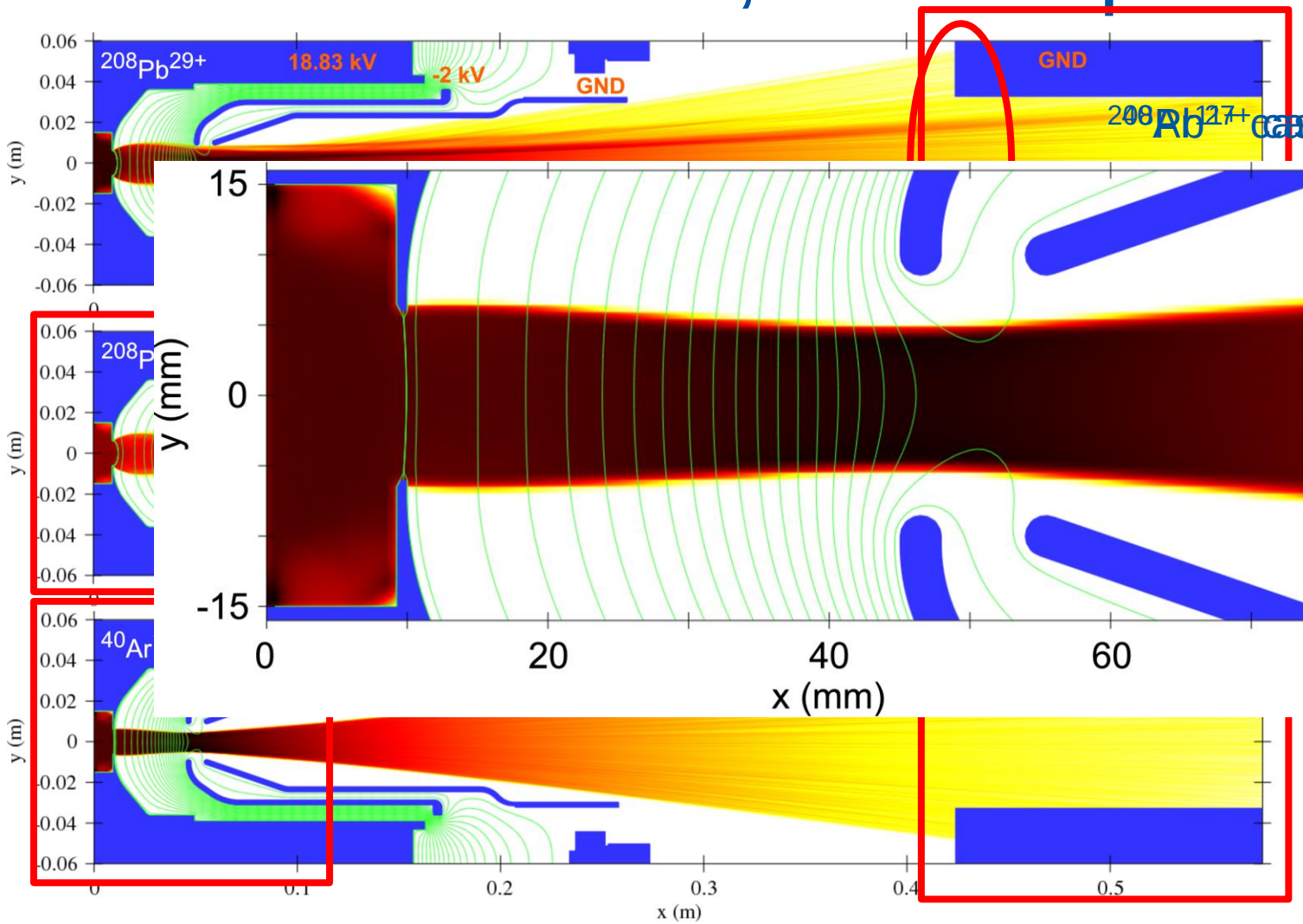
mA

mm gap

$^{11+}$

1.6 mA
35 mm gap

Extracted beams, all ion species

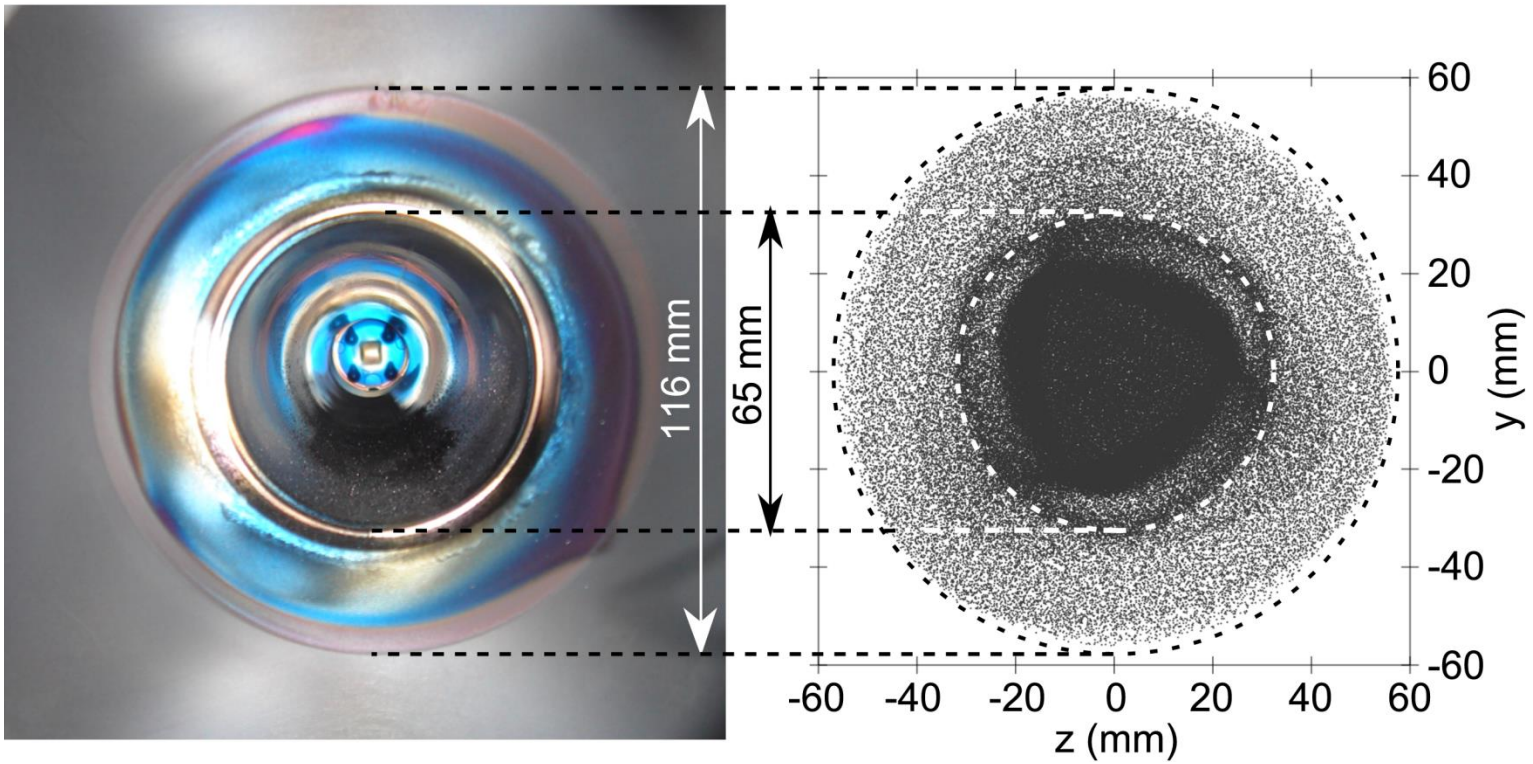


$^{208}Pb^{29+}$

$^{208}Pb^{27+}$

$^{40}Ar^{11+}$
1.6 mA
35 mm gap

Collimation matches observations



Profiles exhibit typical ECRIS features

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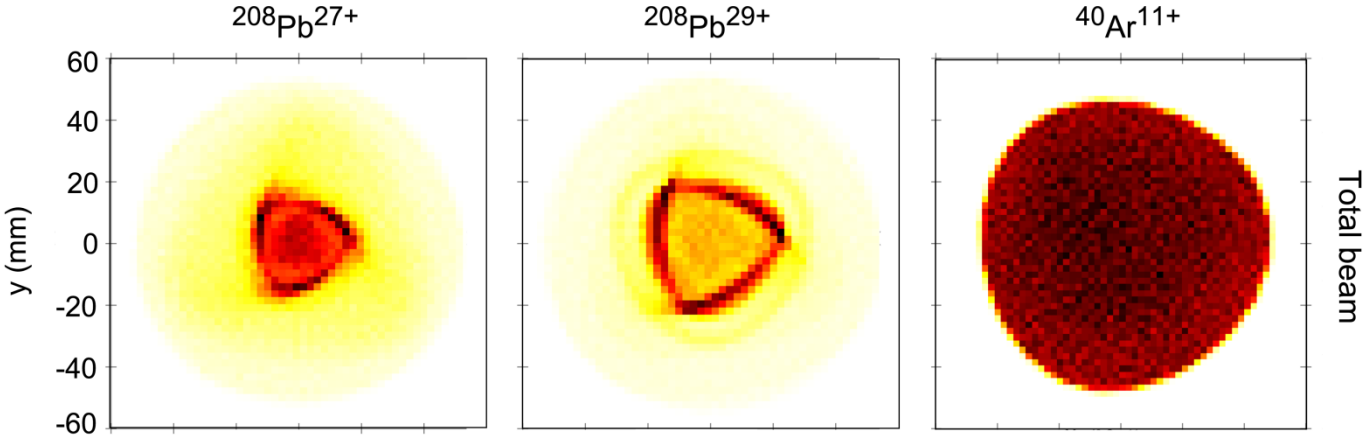


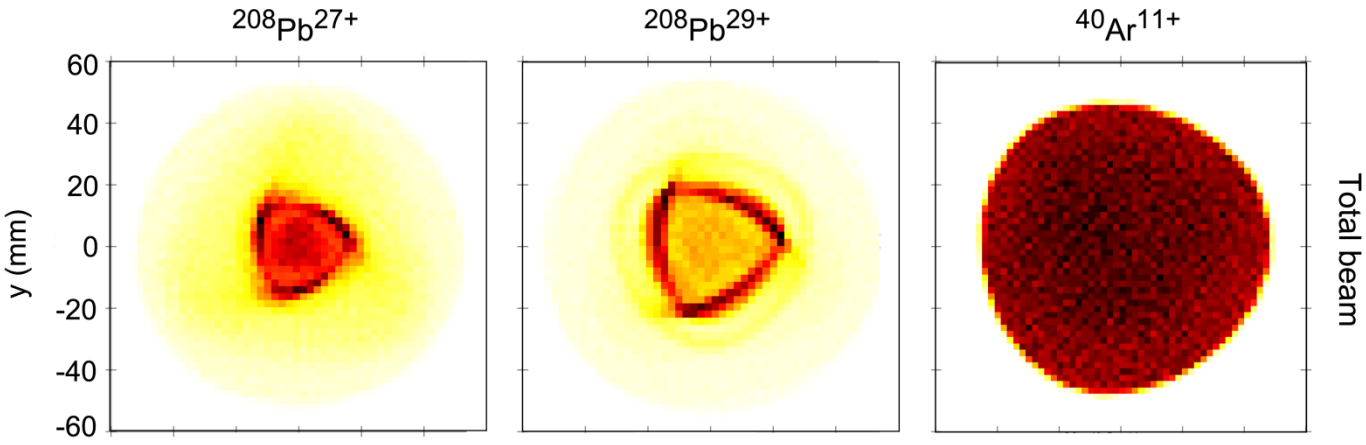
Profiles exhibit typical ECRIS features

Beams before collimation

Triangular shapes
Hollowness
Over-focusing

Ar case more uniform

Not imposed, produced self-consistently



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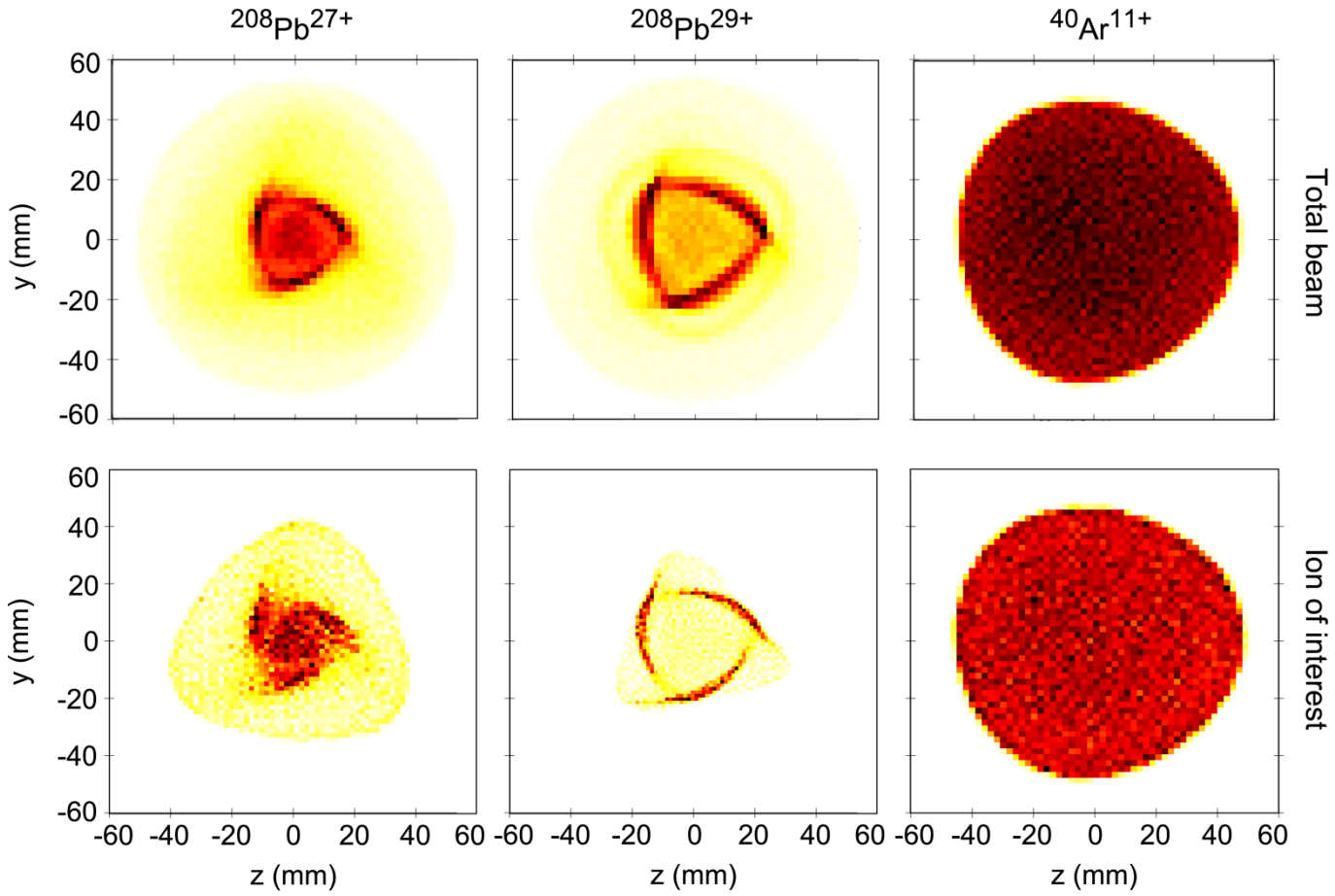
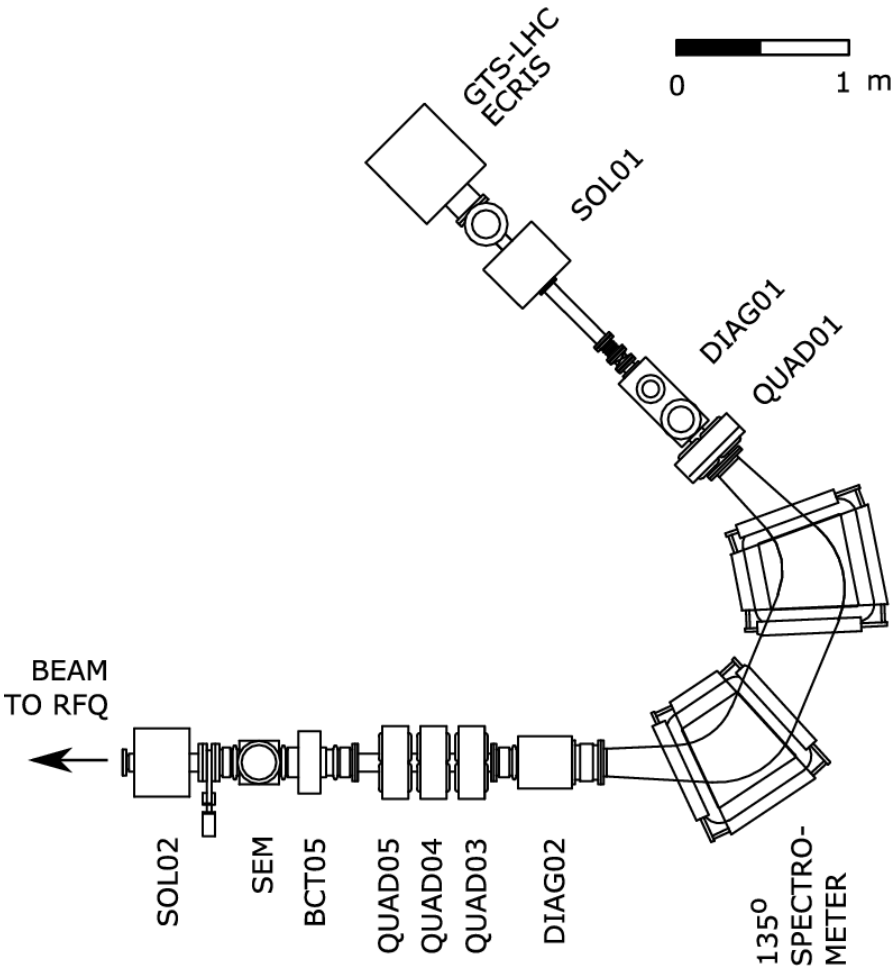


Extracted beams with LEBT model

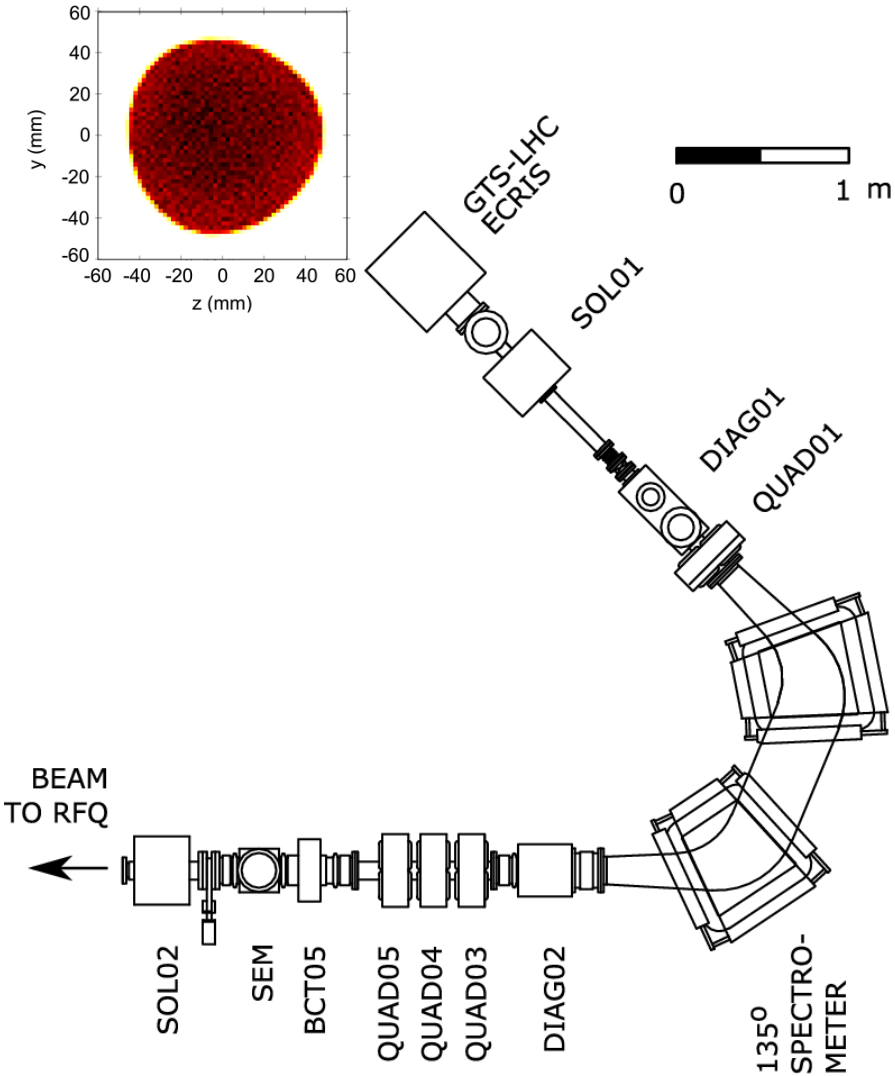
Extracted beams with LEBT model

- 3D simulation with multiparticle tracking code PATH
- Constructed with measured properties of the beam line elements
- Realistic aperture model
- Simulations with operational LEBT settings
- LEBT model still under development
  - Limited diagnostics
  - Preliminary results

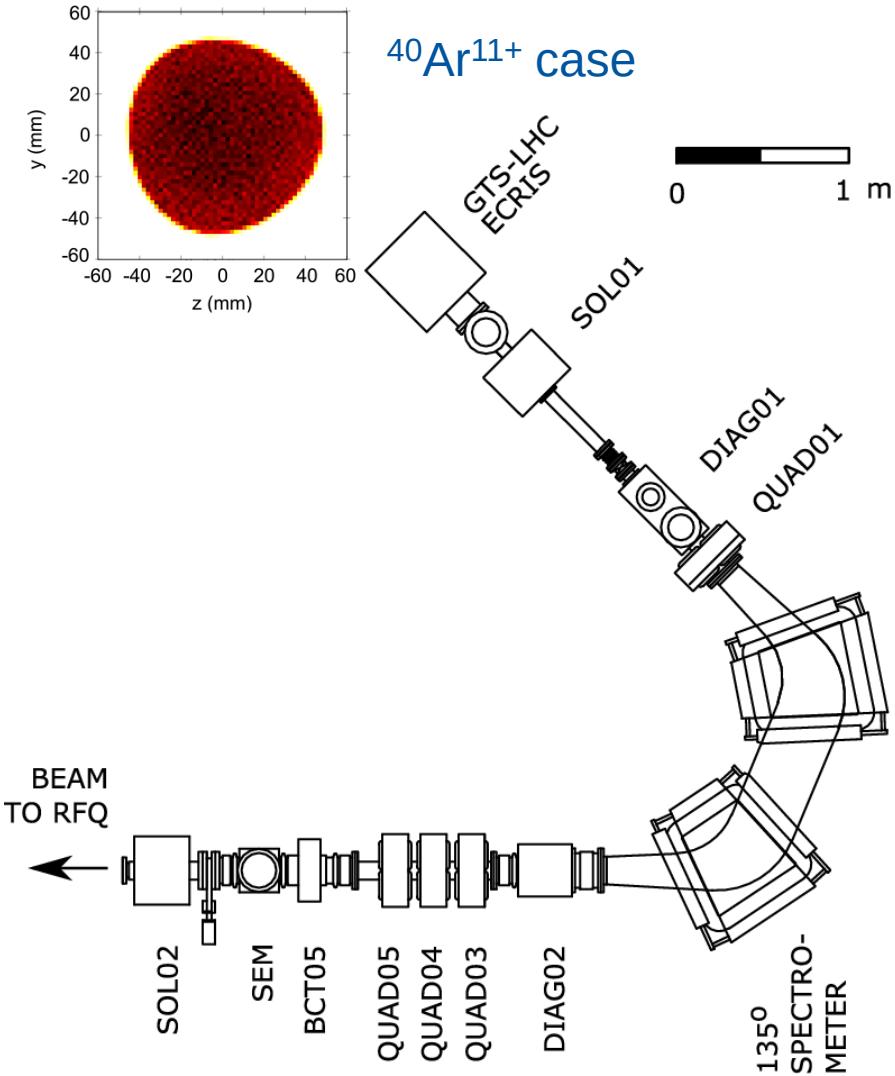
LEBT simulation



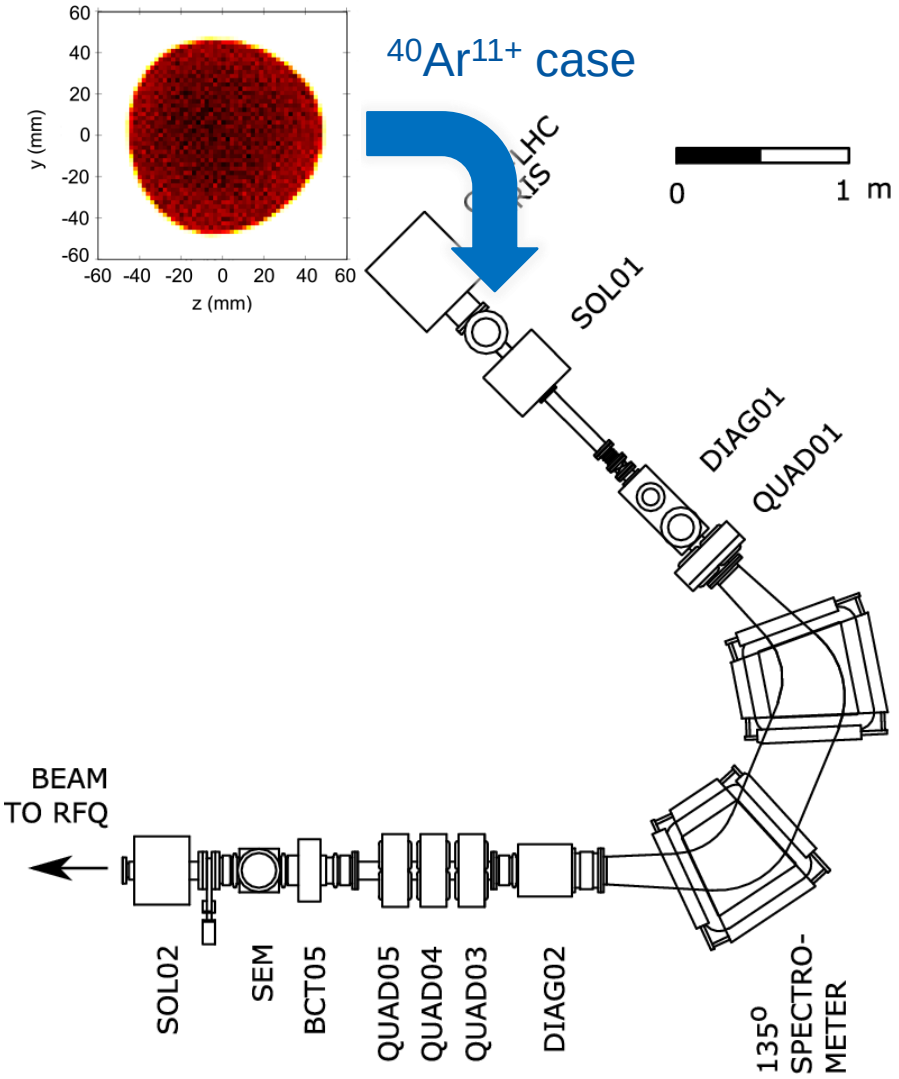
LEBT simulation



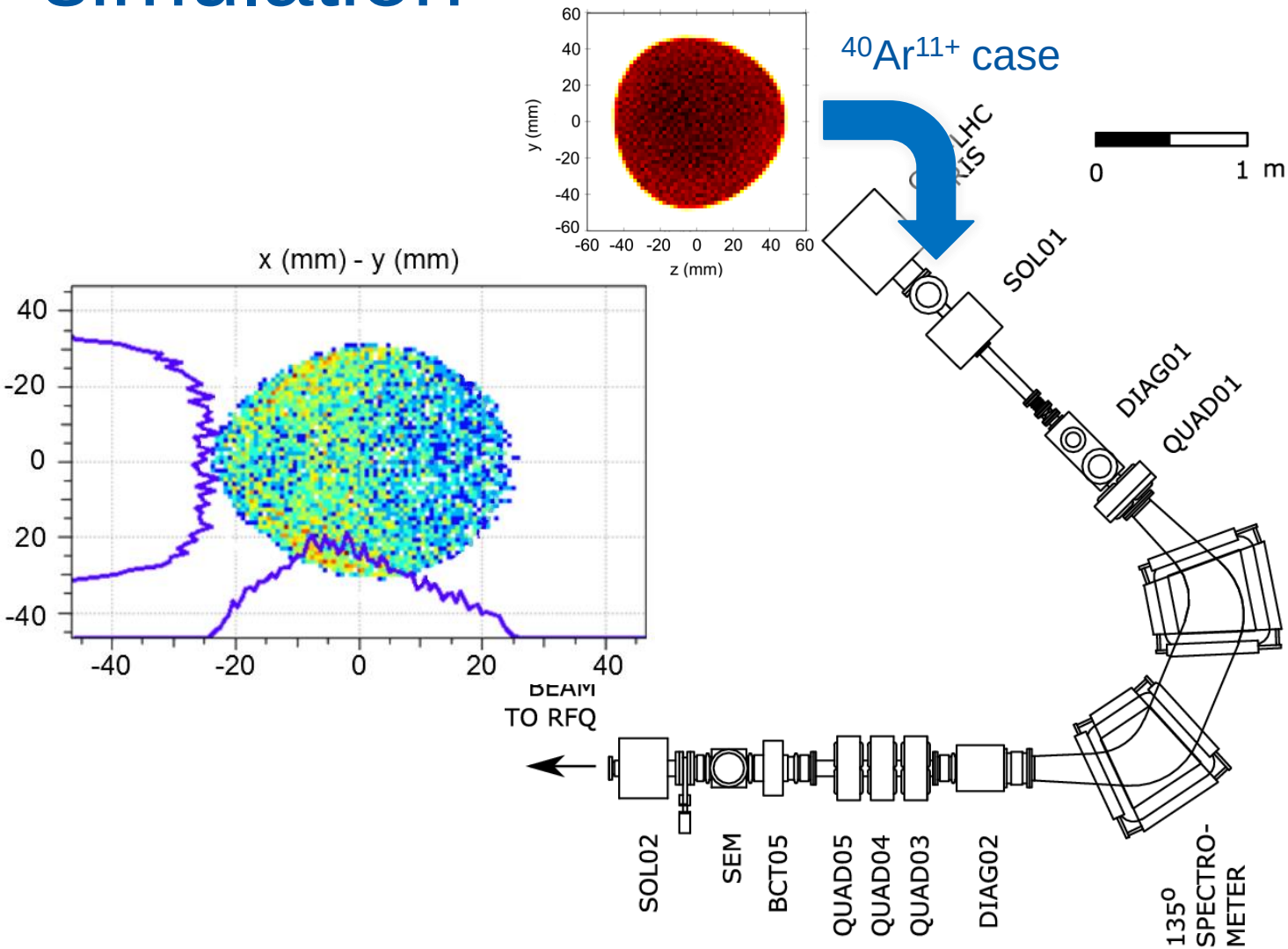
LEBT simulation



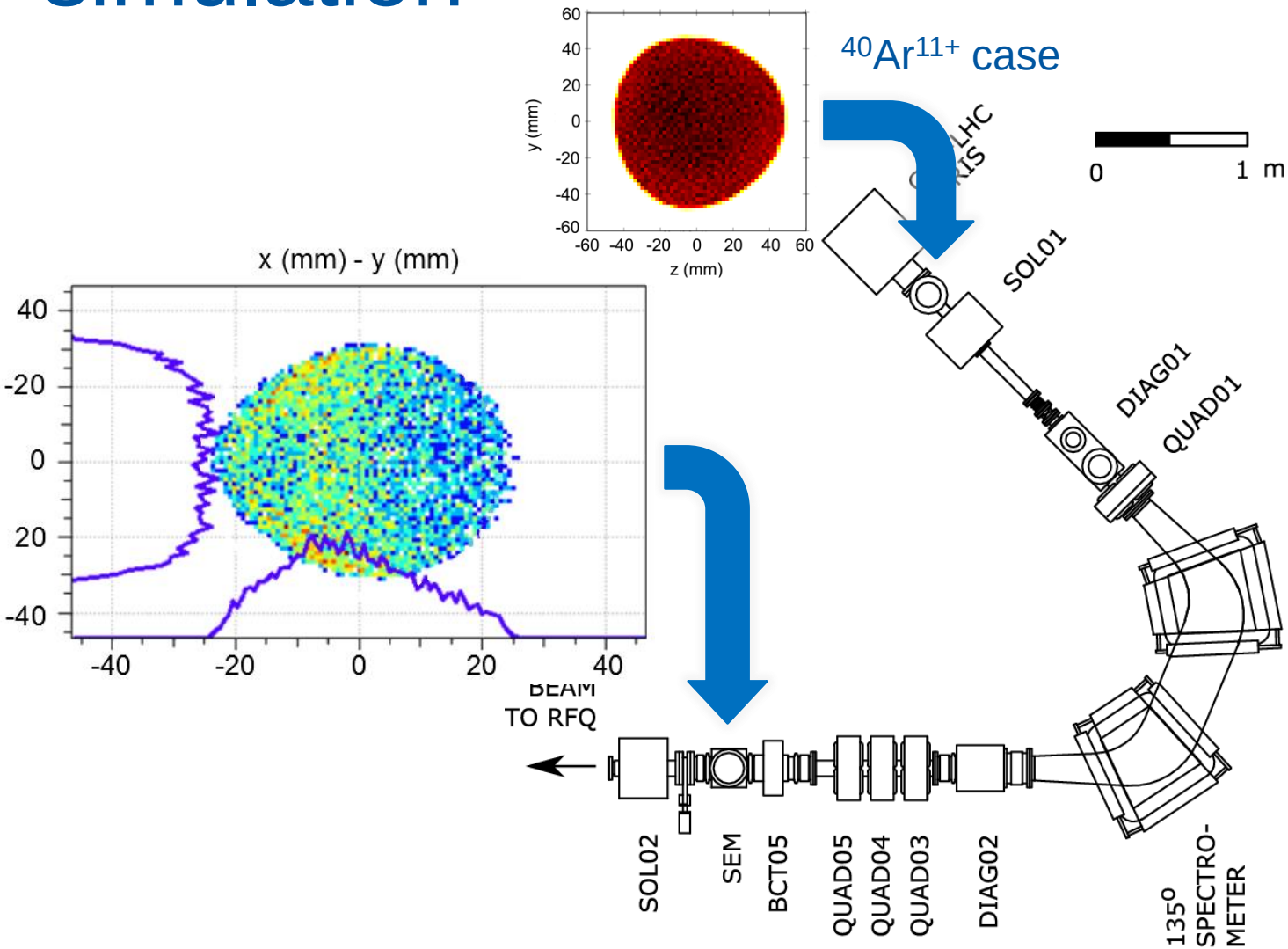
LEBT simulation



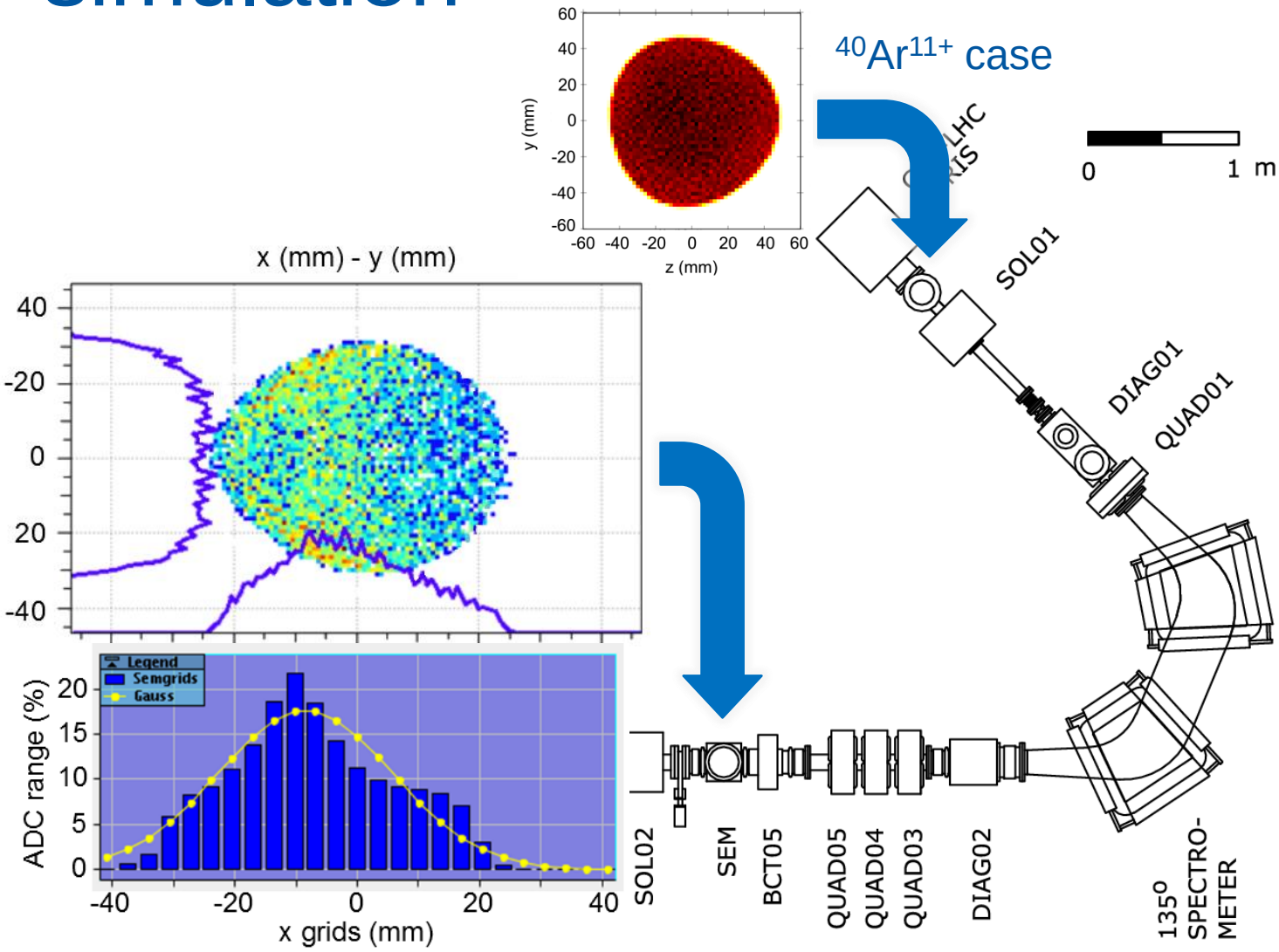
LEBT simulation



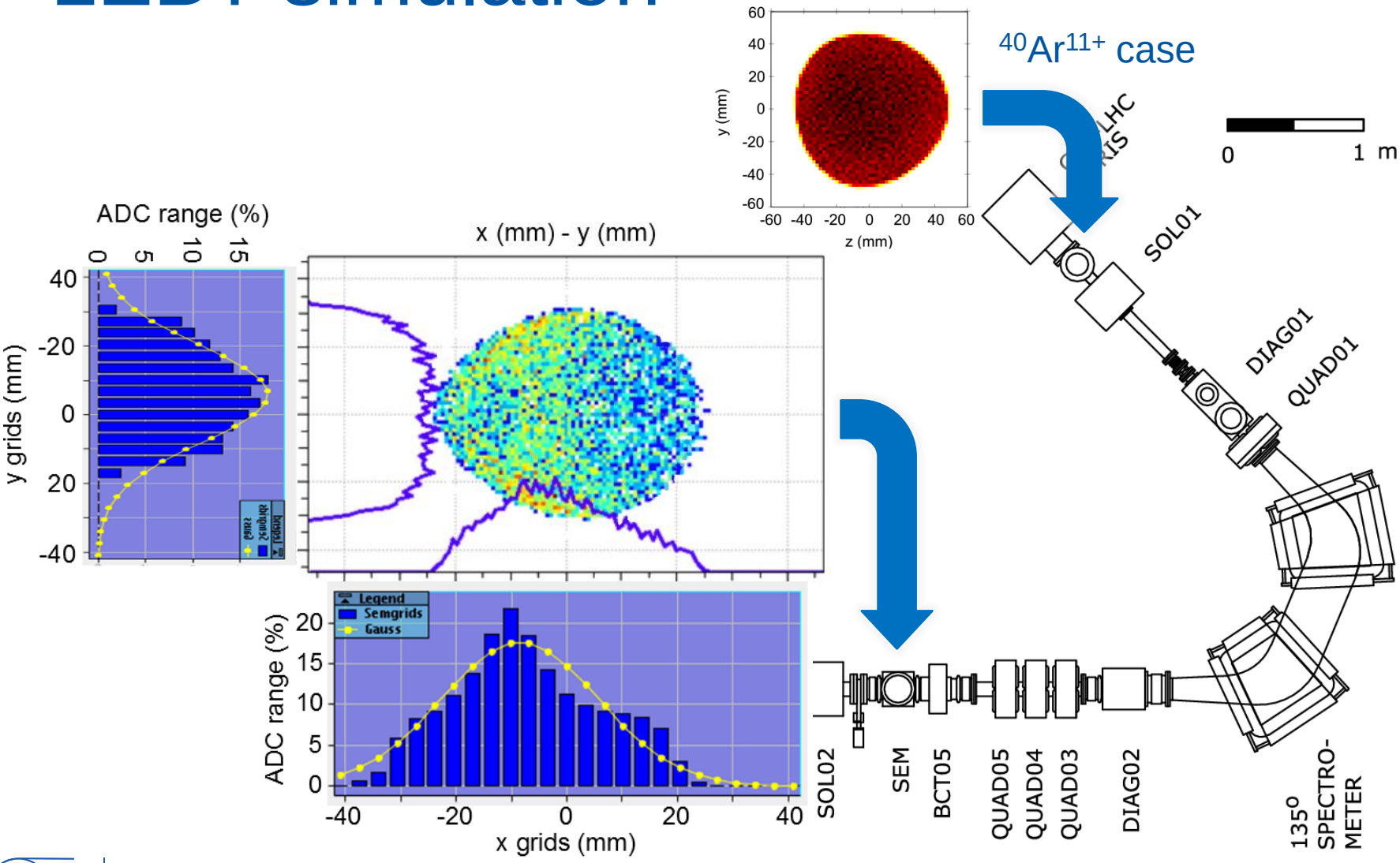
LEBT simulation



LEBT simulation



LEBT simulation



LEBT simulation

$^{208}Pb^{27+}$ after spectrometer

	Profile X (mm)	Profile Y (mm)	Emitt. (x,x') (mm mrad)	Emitt. (y,y') (mm mrad)
$^{208}Pb^{27+}$ simulated	9	11	30	28
$^{208}Pb^{27+}$ measured	7	7	39 ± 4	29.9 ± 0.4

Note: rms values

Summary

Summary

- Extraction simulations indicate potential for extraction system improvement
  - Additional einzel lens
  - Extraction system redesign
  - Pumping chamber / beam line redesign
  - …
- New initial beams yield relatively good match with measured beam properties in LEBT

Outlook

Outlook

- More beam diagnostics to improve the model
  - Pepperpot emittance meter from Pantechnik
- Extension of the model along Linac3
- Identify factors limiting performance
- Plan and execute improvements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