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A CW radiofrequency ion source for production of negative hydrogen ion beams for cyclotrons

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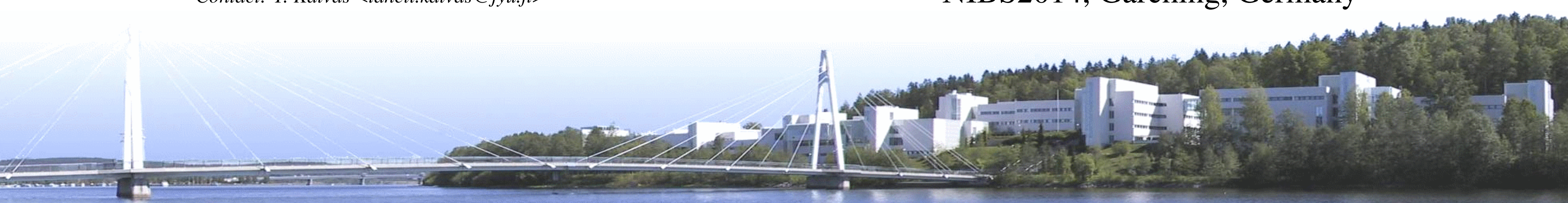

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Radiofrequency ion source RADIS

Presentation outline

- Introduction to the project
- Source and test stand
- Results
- Plans for future

Ion source for the MCC30/15 cyclotron

Background

As a part the compensation of the former Soviet Union debt to Finland, the *D.V. Efremov Scientific Research Institute of Electrophysical Apparatus* manufactured and installed the MCC30/15 cyclotron at Jyväskylä.

The device produces 18–30 MeV H^+ (200 μA) and 9–15 MeV D^+ (60 μA) from negative ions with high-efficiency stripping extraction.

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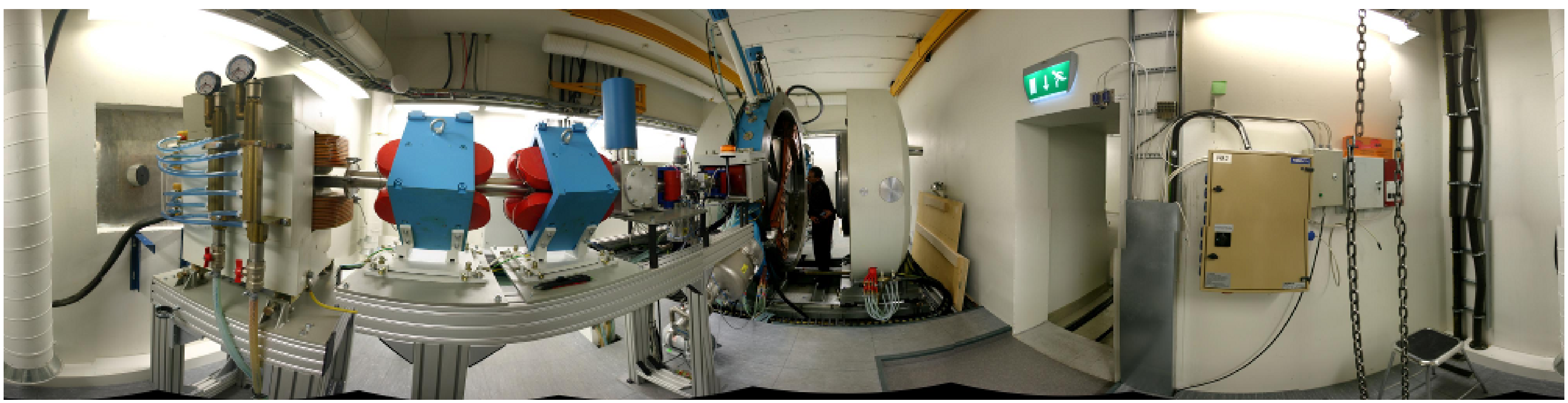
Photograph © Ari Lehtiö 2009

- Cyclotron was delivered in August 2009
- Accepted for use in April 2010
- Beams are used for medical isotope production and nuclear physics

Problem with ion source

The ion source delivered with the cyclotron is a conventional filament- driven multicusp source for H^- and D^- production.

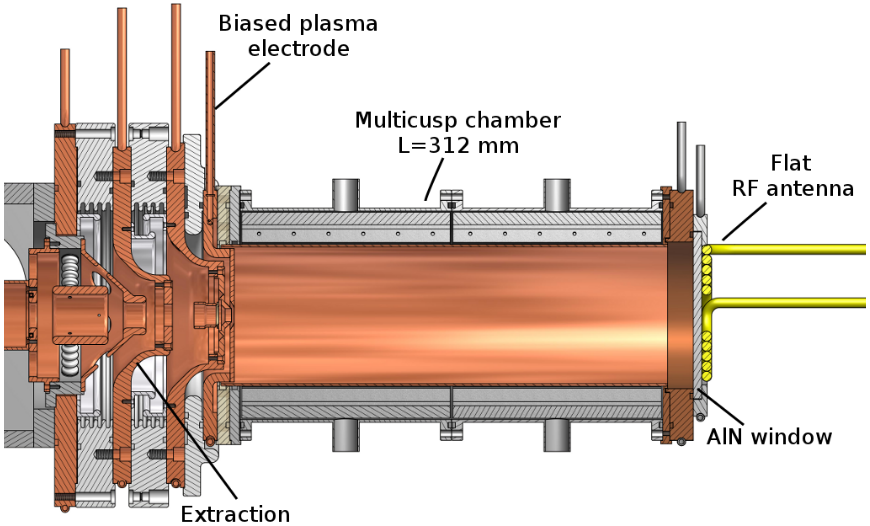
- Problem: The filament lifetime with 1 mA output is about $\sim$ 130 h.
- Filament renewal is slow because the cyclotron vault cooldown after accelerator use can take up to 12 hours.
- Users require up to 350 h and longer experiments.
- A long-lifetime ion source is needed to replace the filament ion source



Radiofrequency ion source for H^- production

The RADIS project was started in 2011.

- Experiments were made on existing TRIUMF multicusp chamber and extraction with flat spiral RF antenna.



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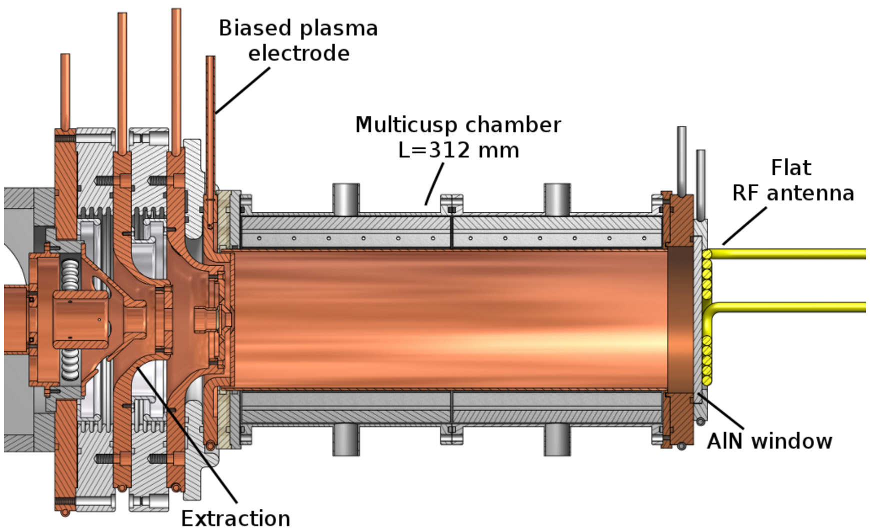

- Achieved 210 µA of H^- and 21 mA of e^- with 1500 W RF input power.
- Based on the experience with the test source, a new plasma multicusp plasma chamber, extraction and test stand were built.

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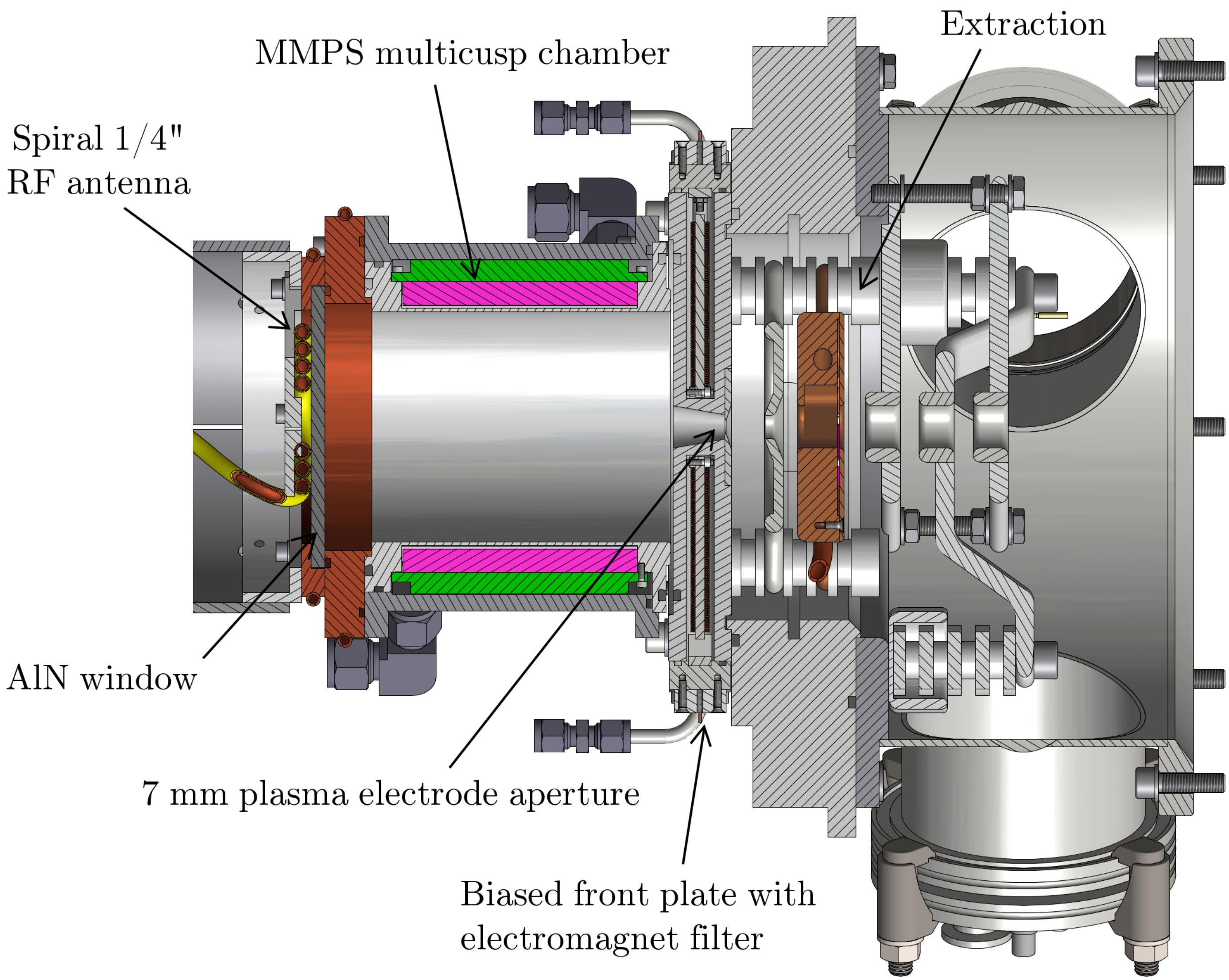
The ion source



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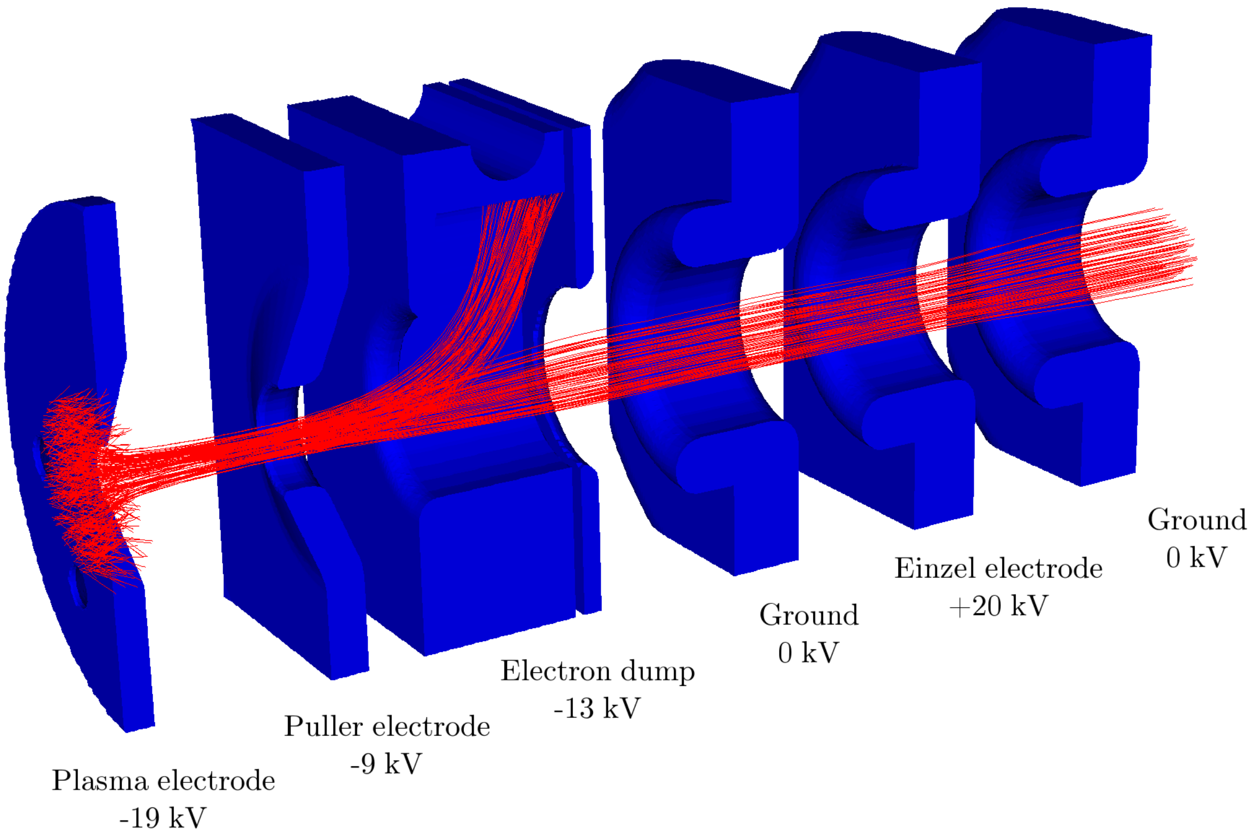
The extraction system

Extraction designed with IBSimu for 1 mA H^-, up to 100 mA e^-.



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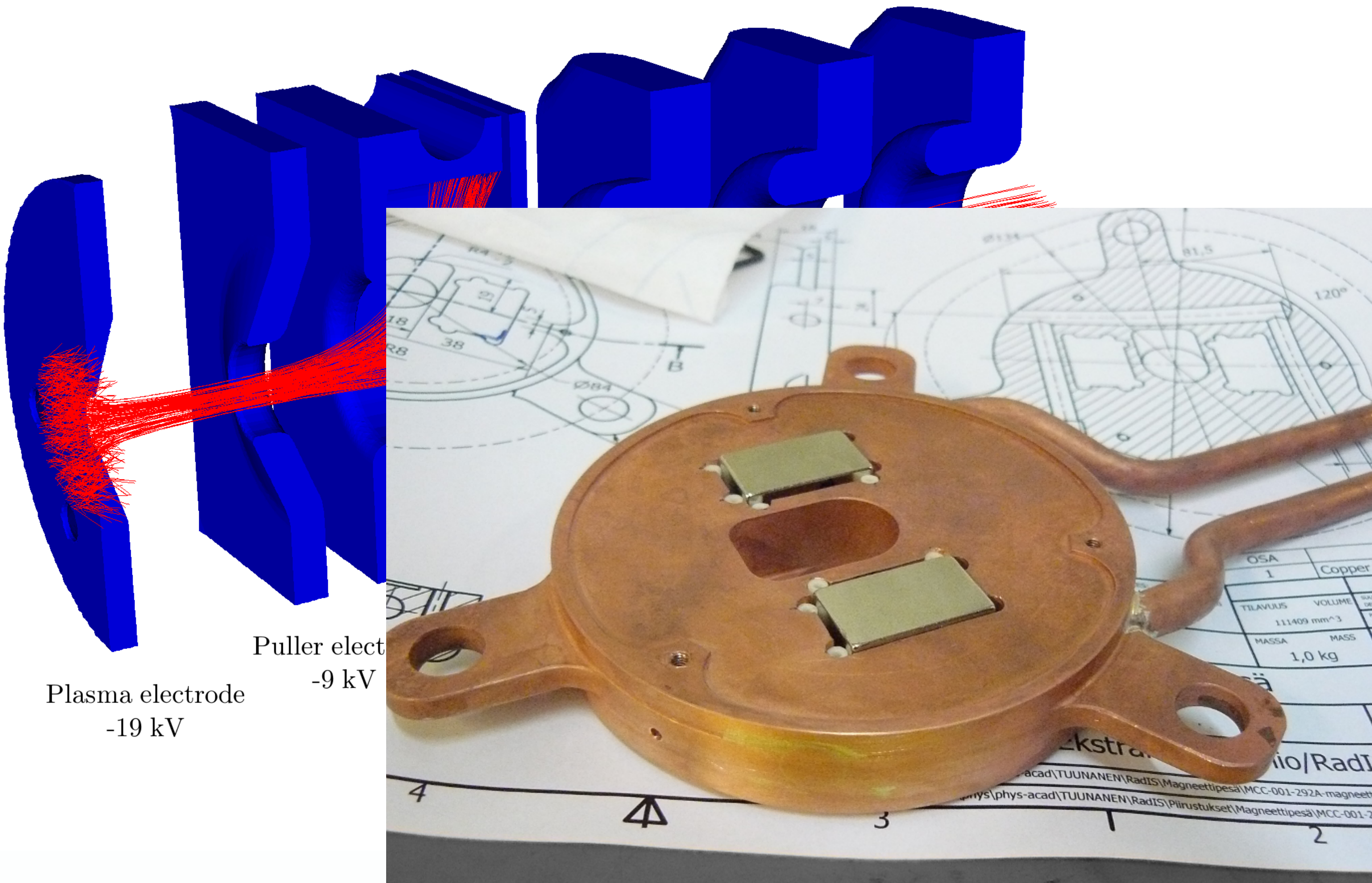

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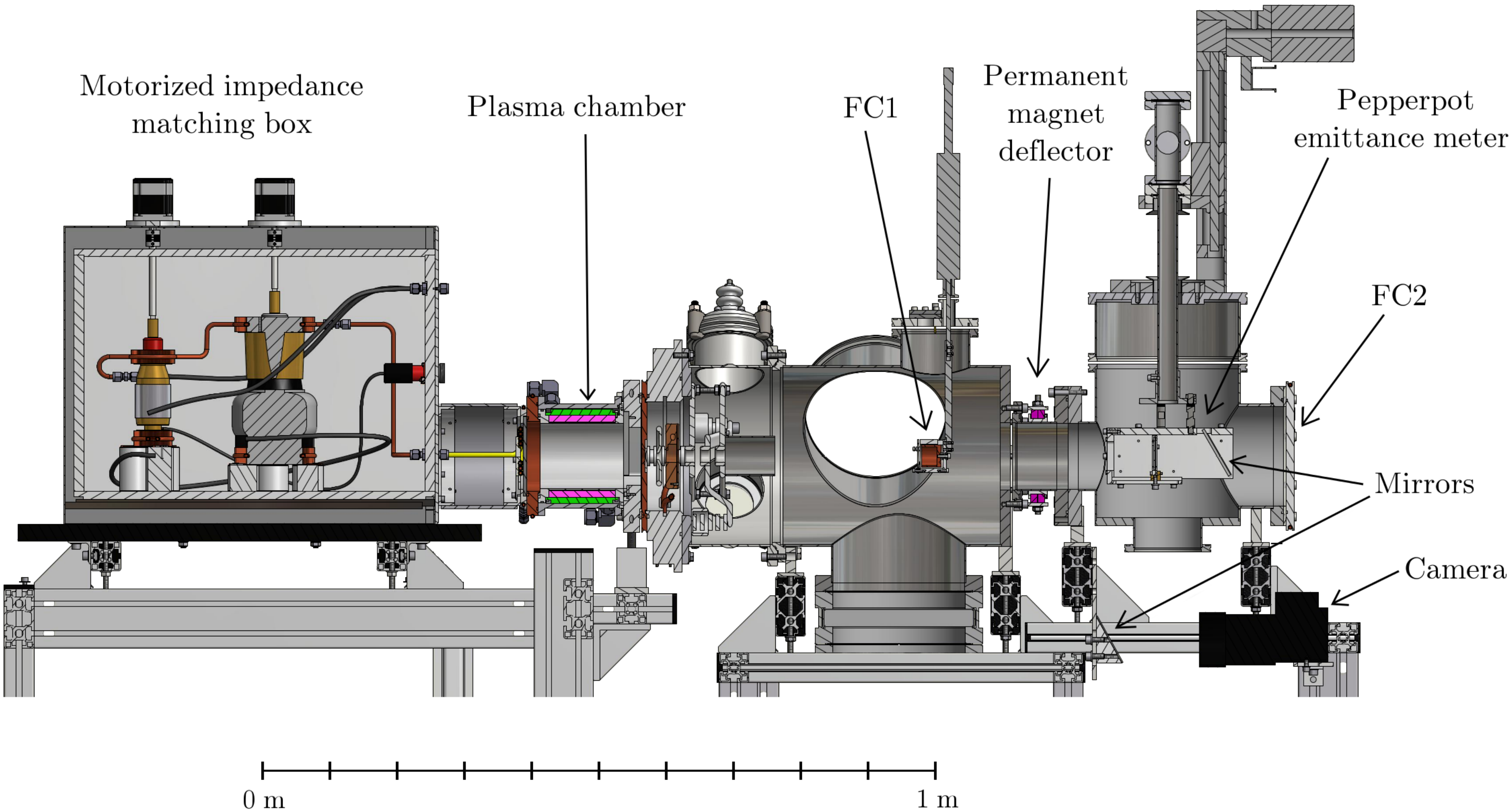
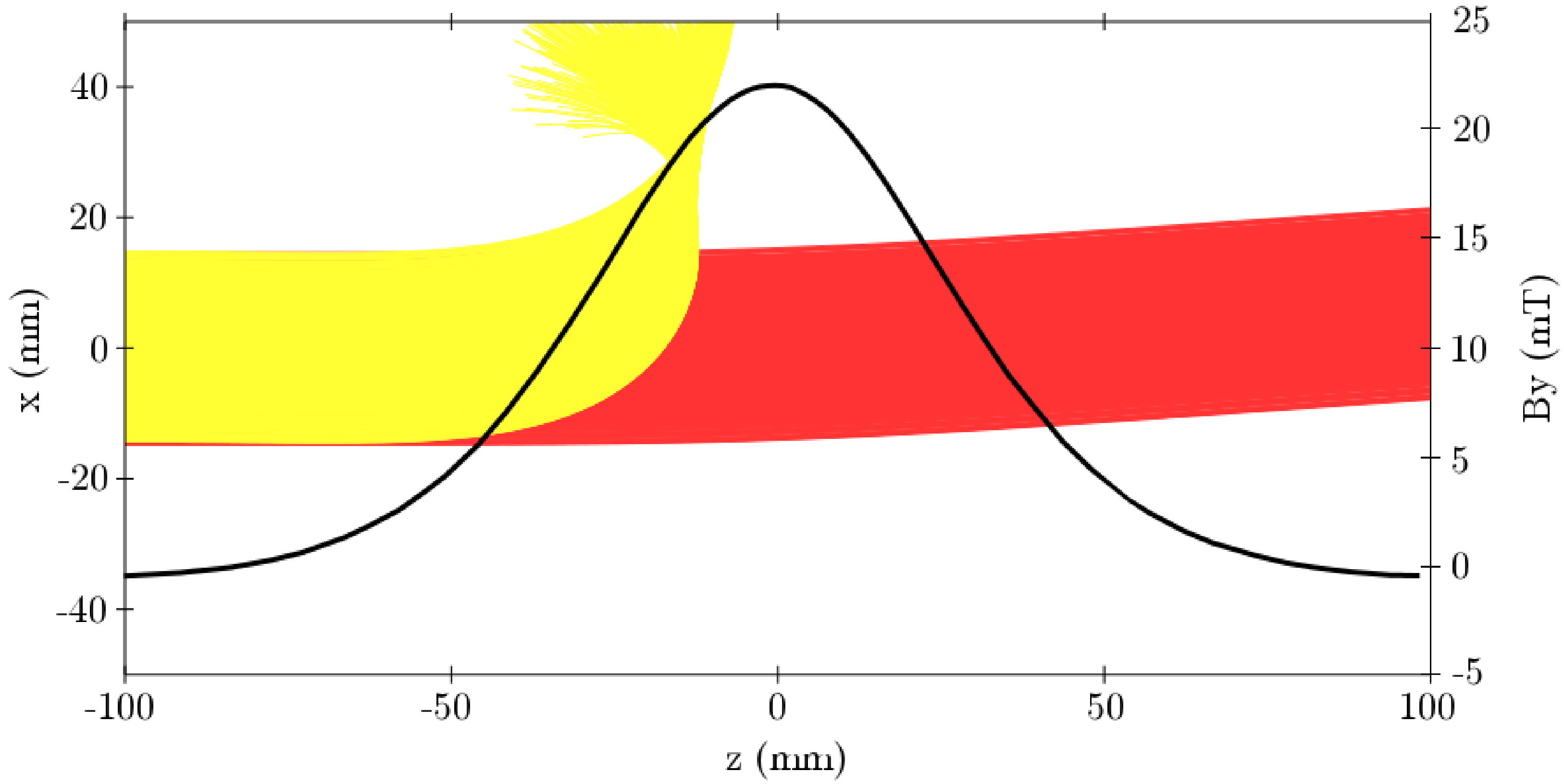
The test stand

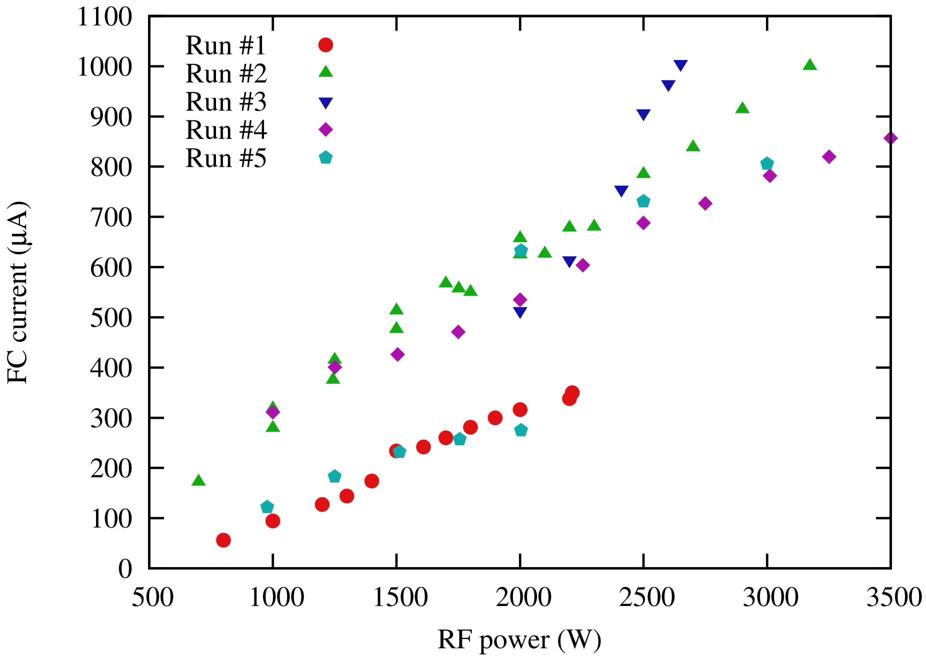


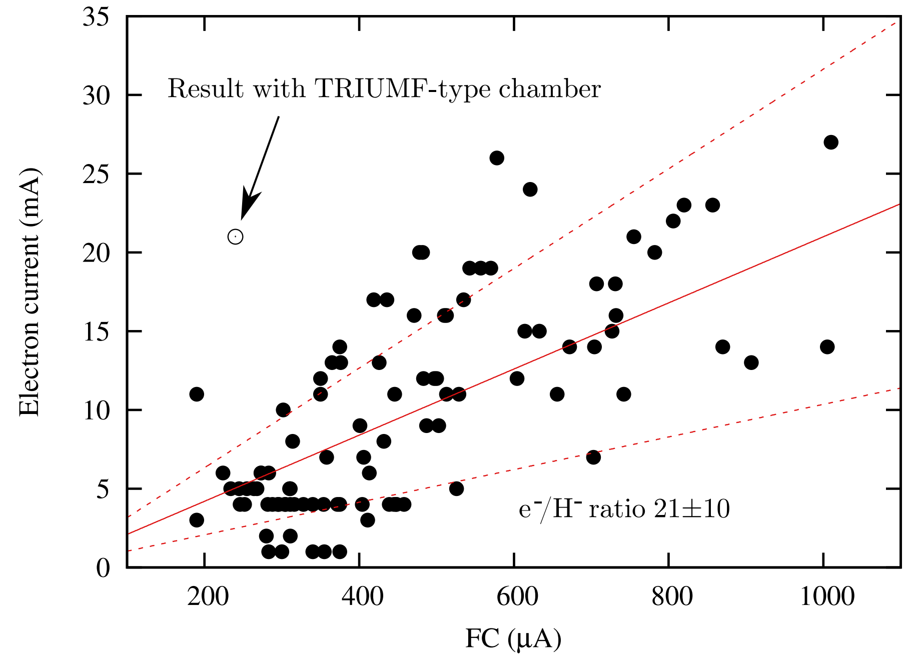
Permanent magnet deflector

Any remaining electrons are blocked by deflector



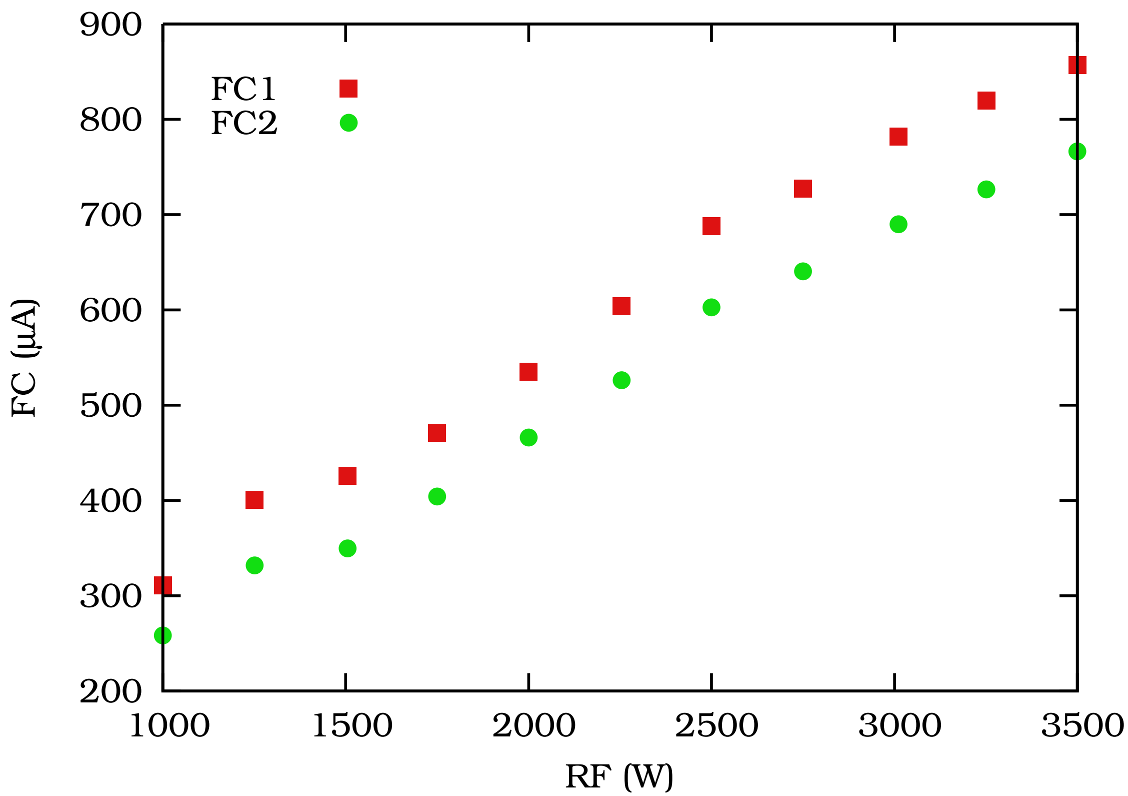
Measured H^- and e^- currents



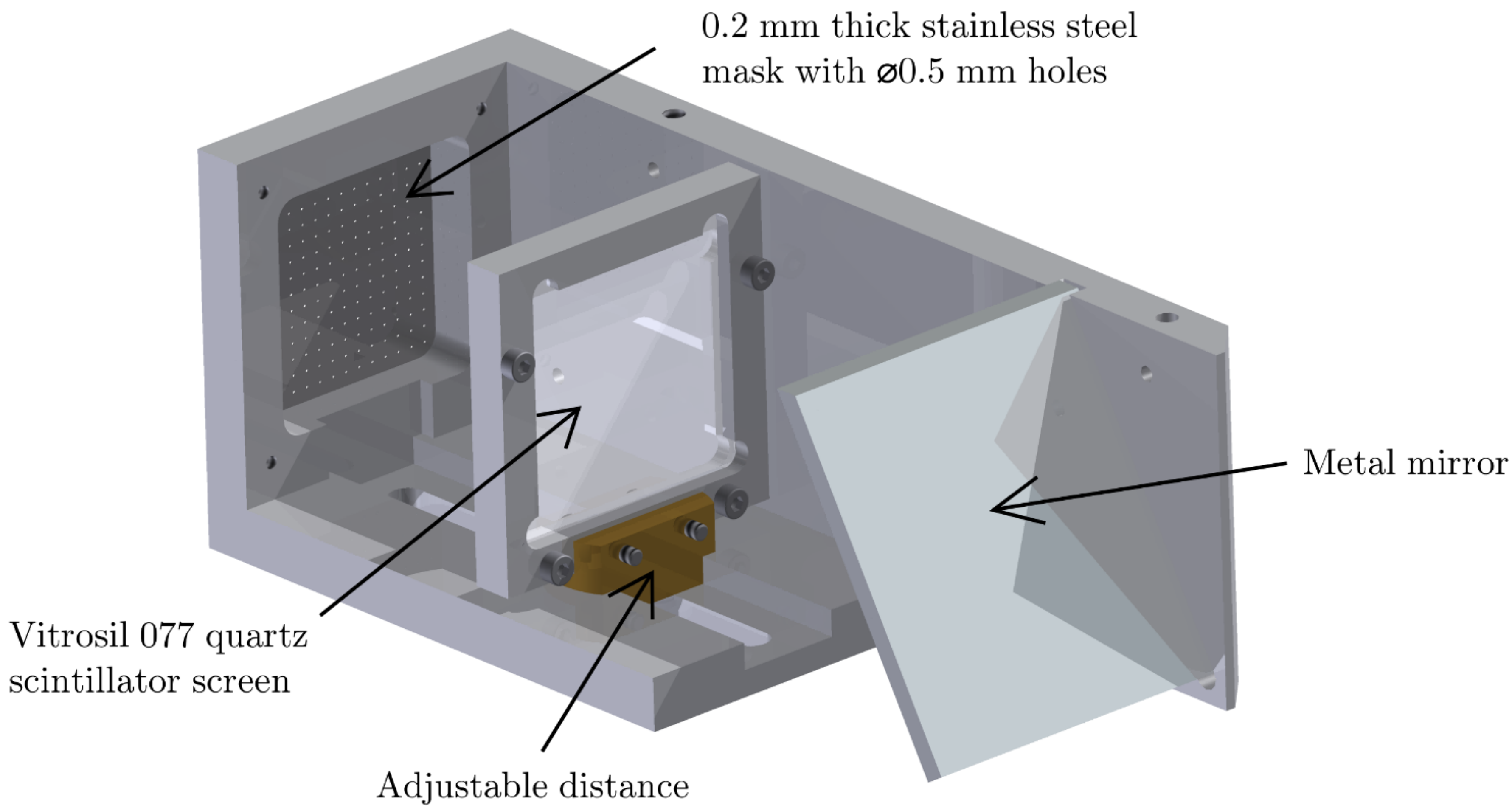


Measured H^- current

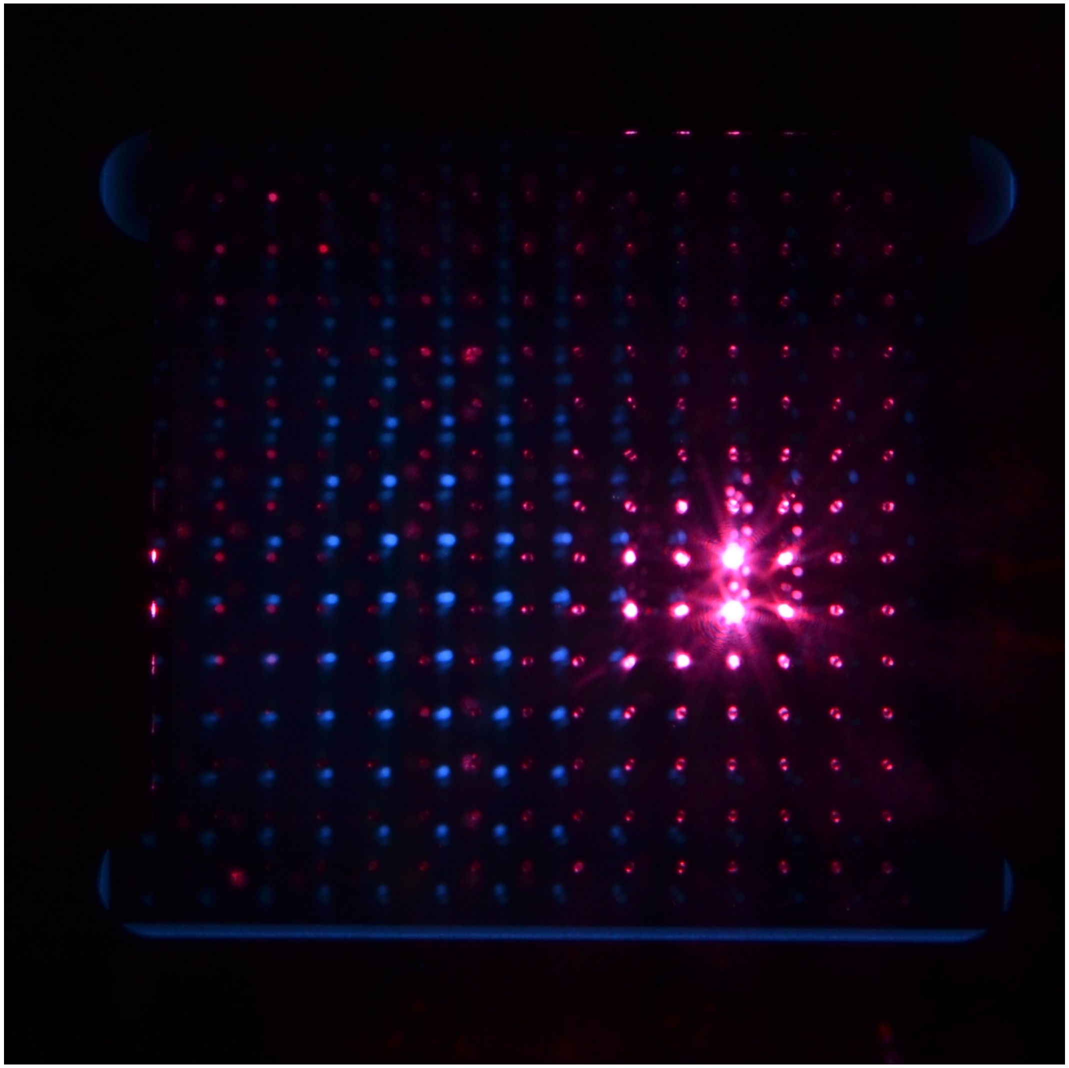
H^- content of FC1 signal > 90 %, verified with PM deflector before FC2



Pepperpot device



Pepperpot images



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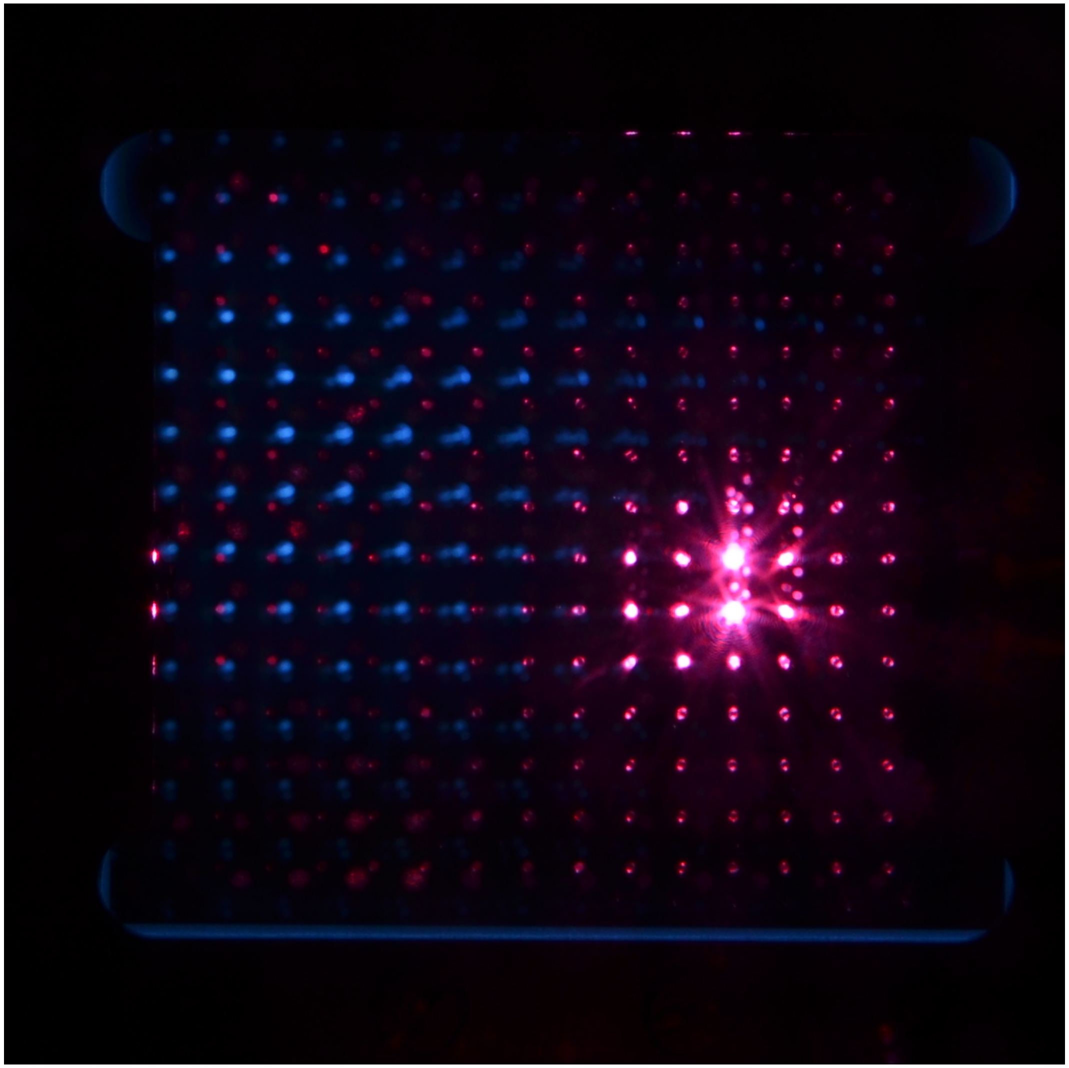

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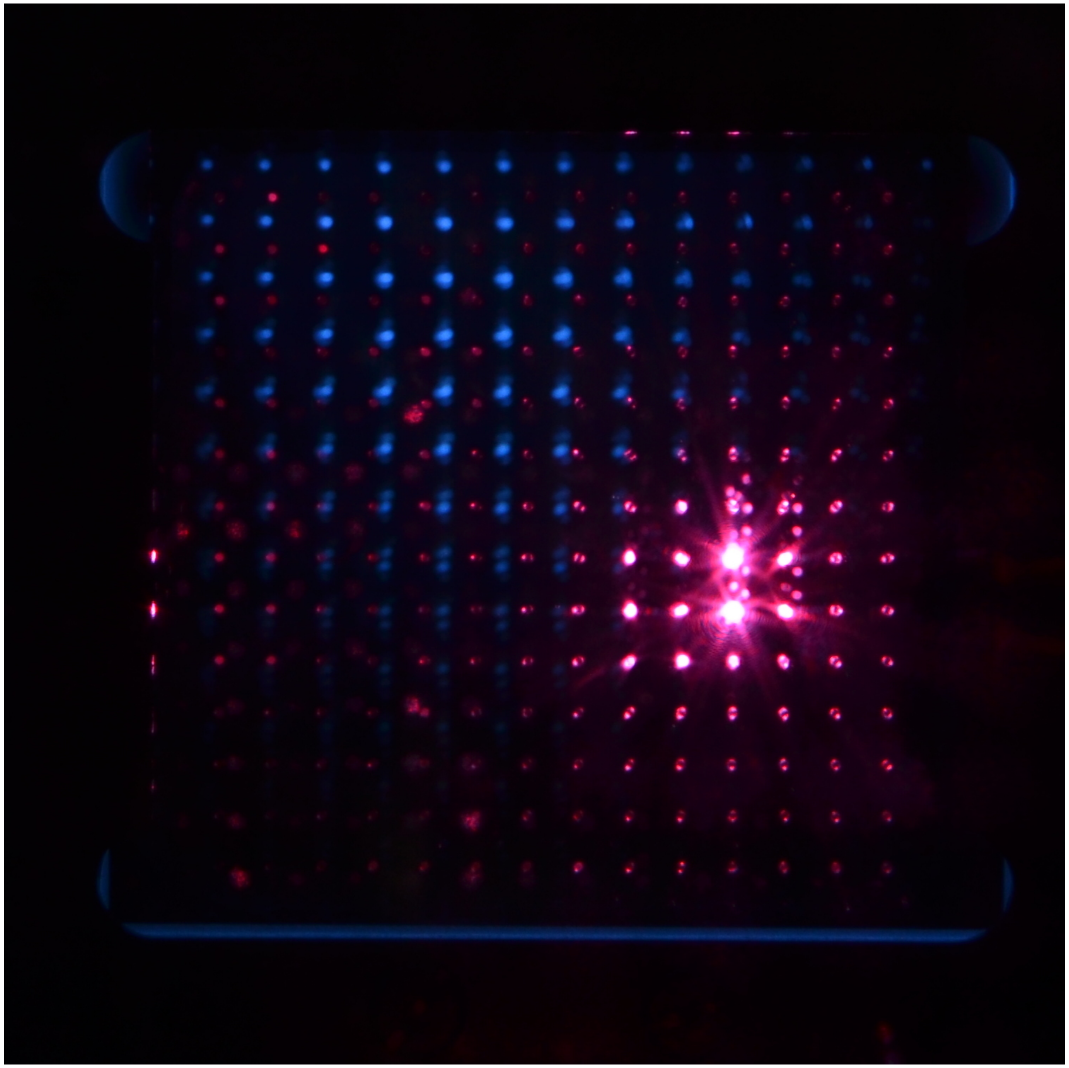

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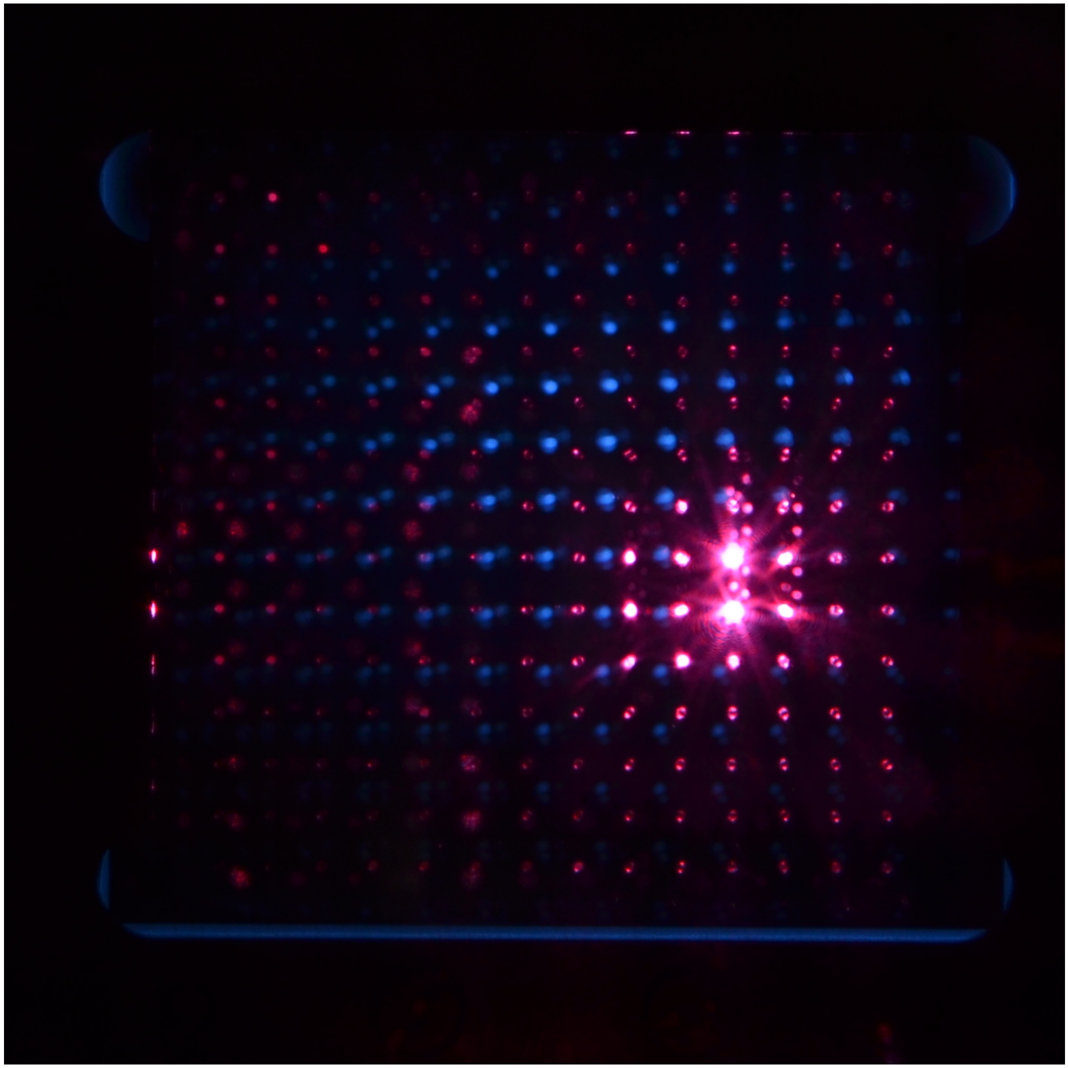
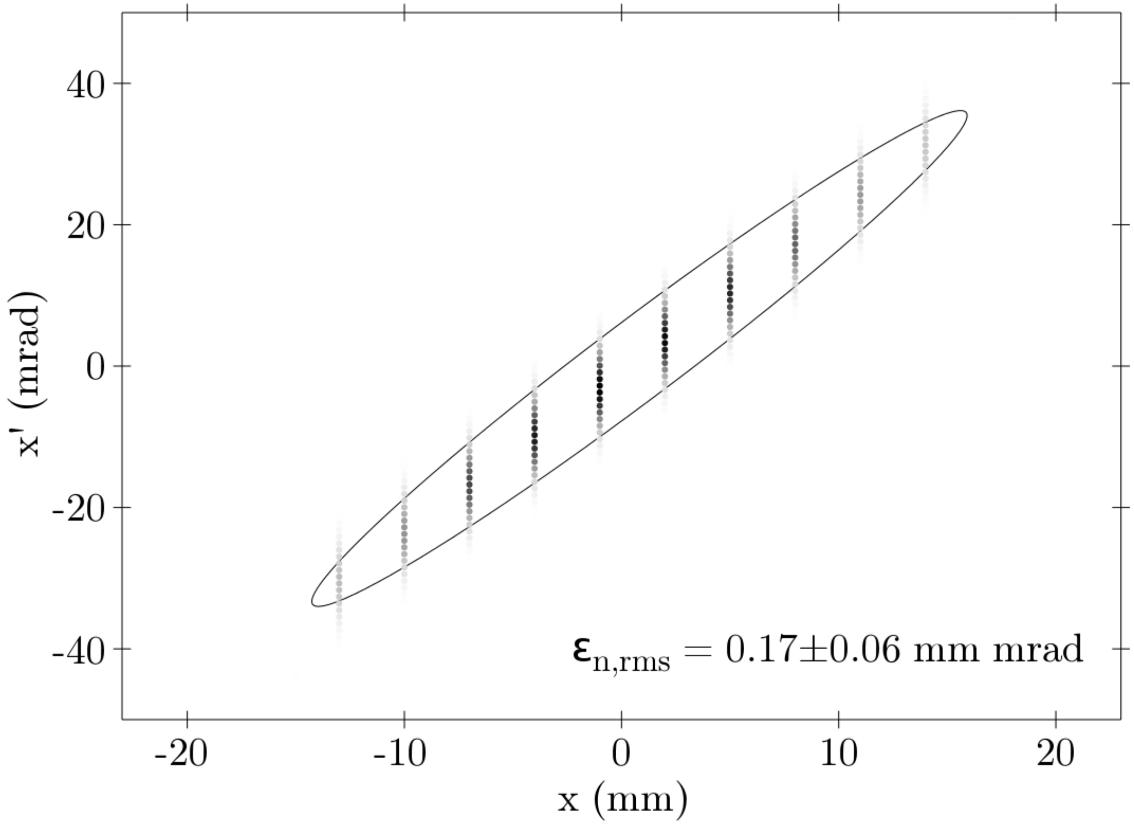


Emittance

Phase space plot for a 300 μA H^- beam produced with 1 kW of RF power



$\epsilon_{n,rms}$ = 0.19 ± 0.06 mm mrad for a 590 μA H^- beam

Emittance

For higher resolution emittance measurements

- Smaller mask apertures and longer mask to scintillator distance
- Currently divergence resolution $\sigma = 3$ mrad
- Better separation of neutral component

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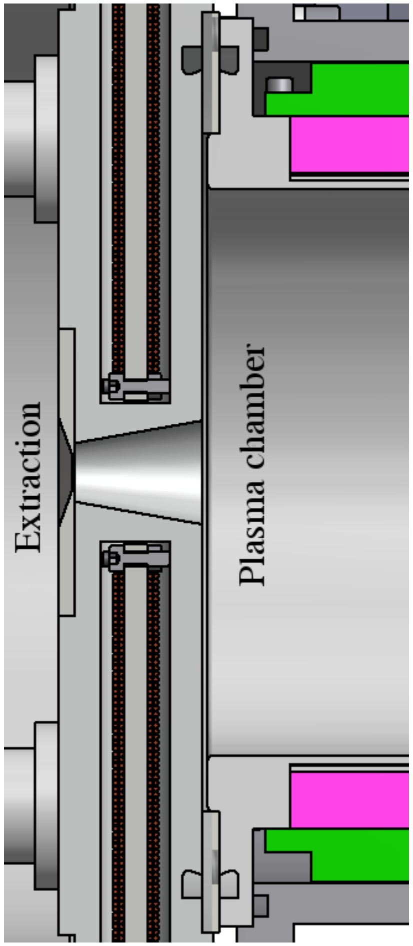
Future

- Emittance as a function of puller voltage and RF power
- Optimization of plasma electrode aperture

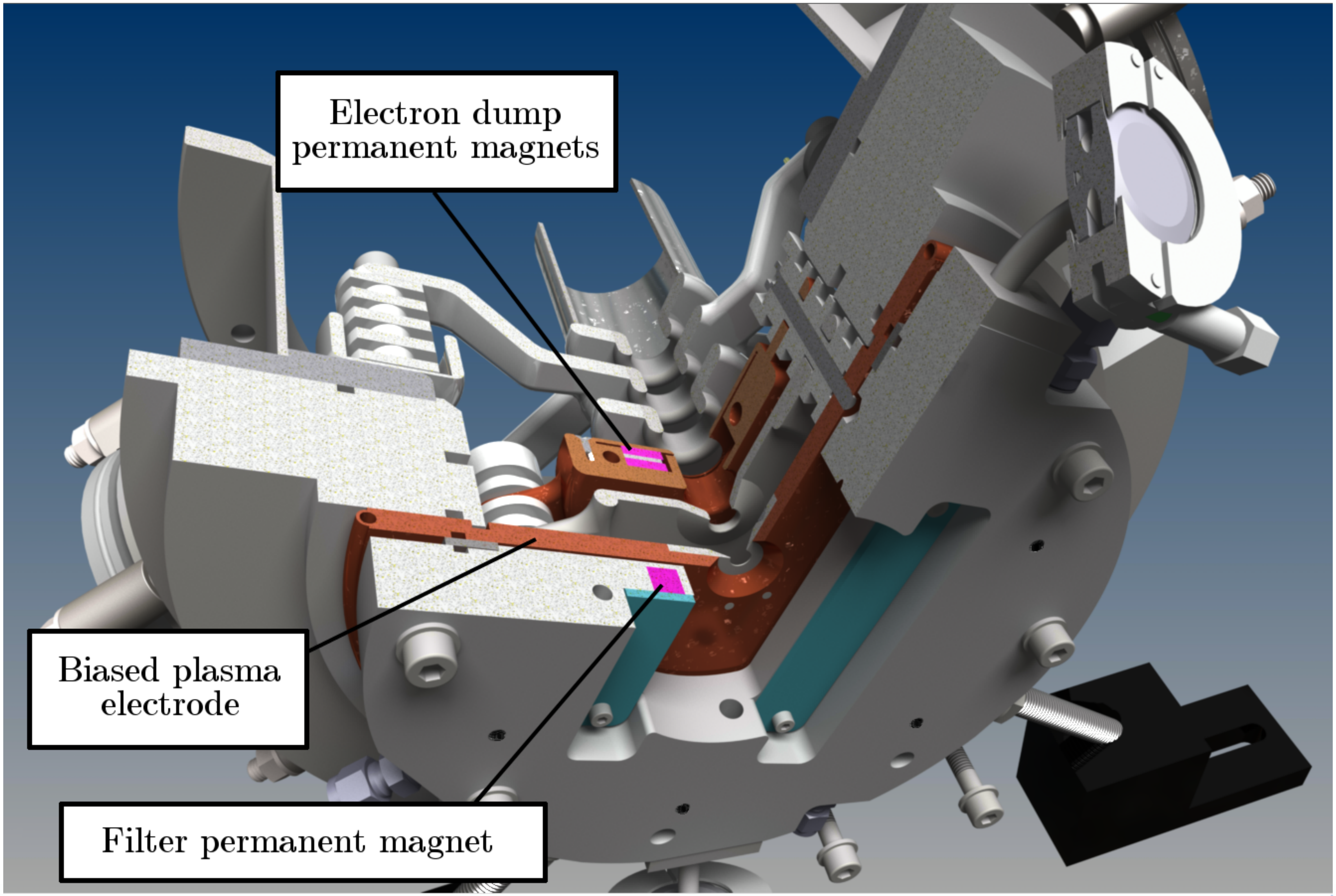
Revision of the front plate

Current front plate / plasma electrode

- 1 mA H^- produced at about 3 kW RF power
- Power efficiency needs to be improved to reach the performance goal persistently.
- Electromagnet front plate has poor confinement and therefore the plasma electrode bias adjusts the whole plasma potential
- Conical channel to the extraction aperture limits the flow of ro-vibrational molecules to the extraction region.

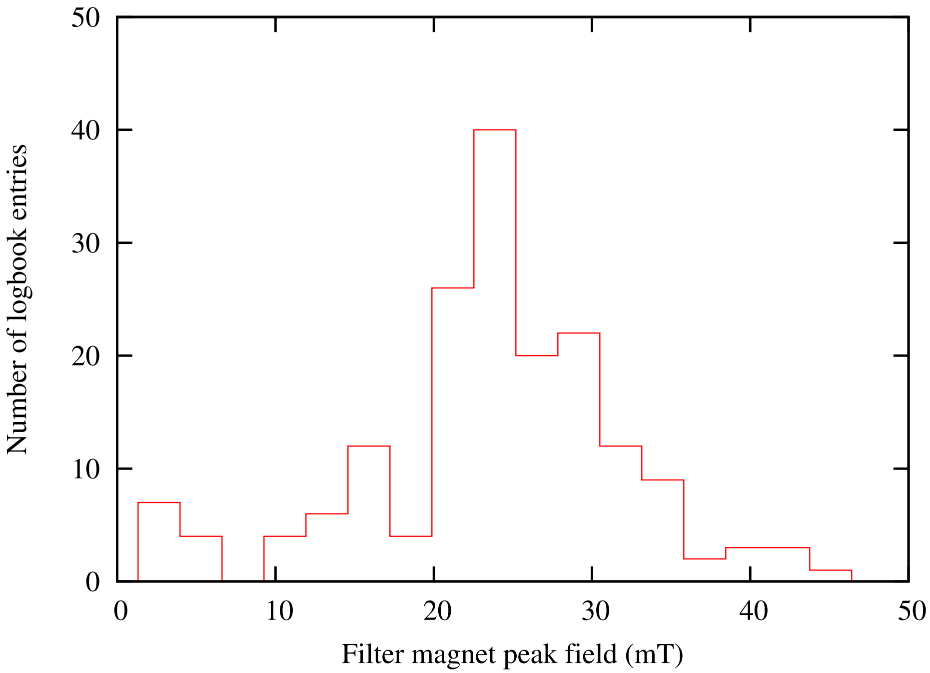


New front plate design



Filter field magnitude

Permanent magnet filter intensity was selected according to most common filter setting (5.5 A) corresponding to 23 mT peak field.



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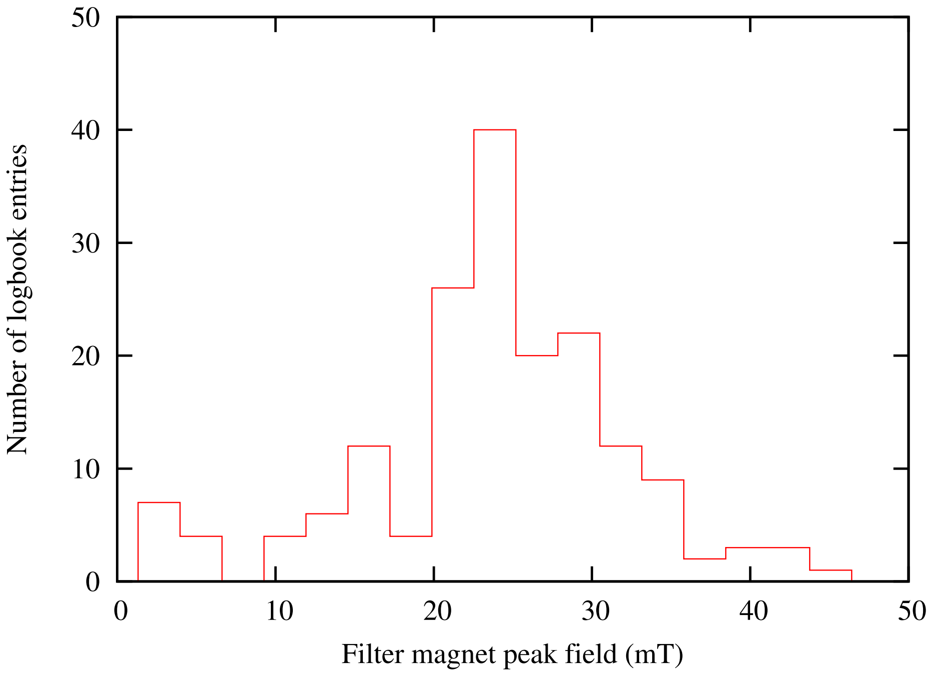

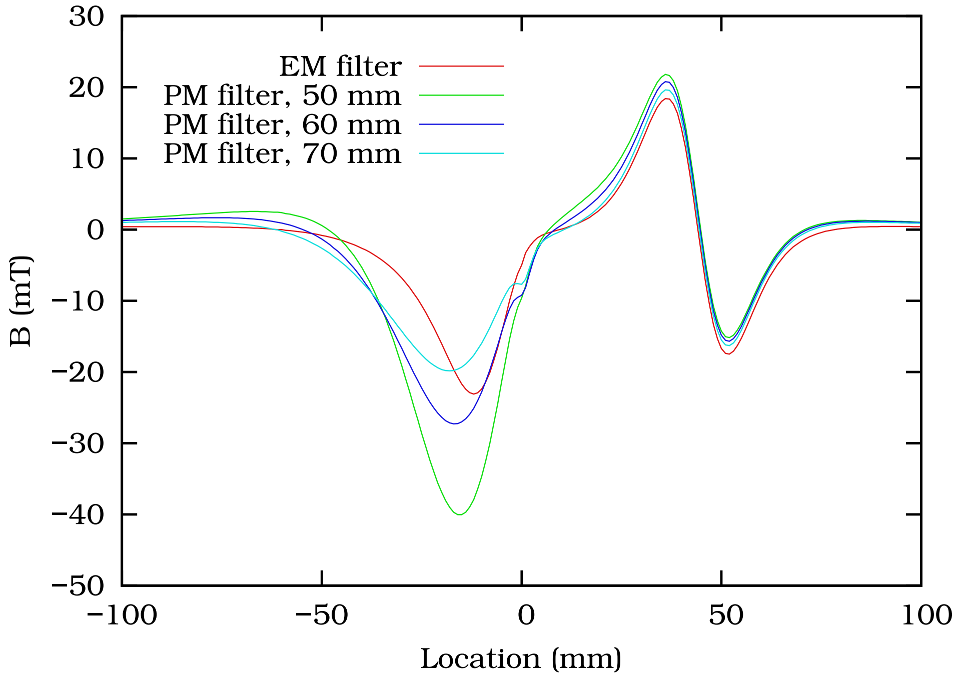

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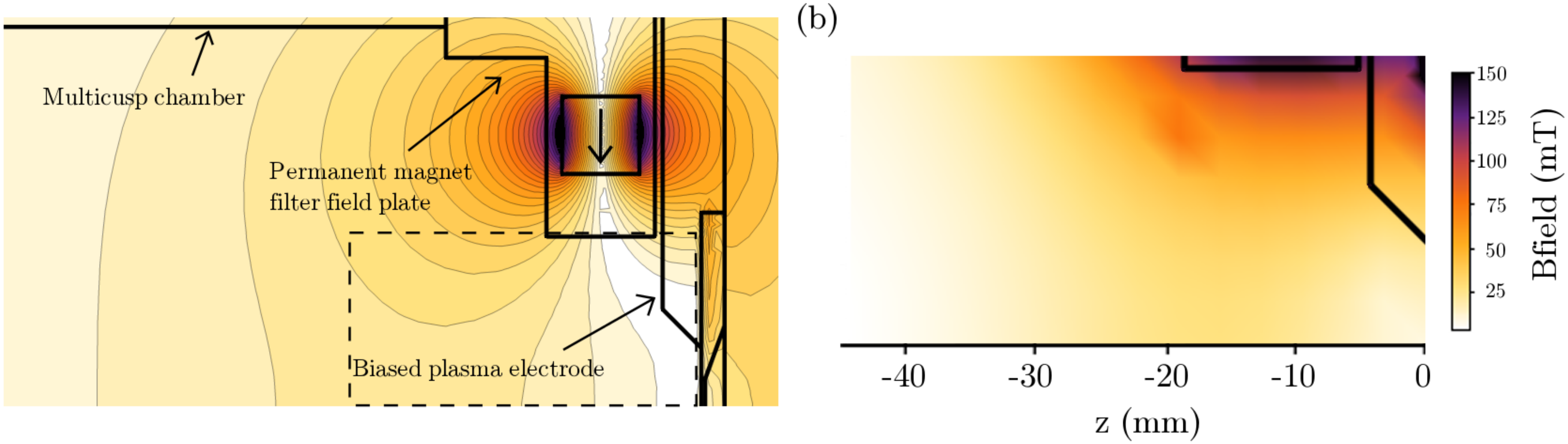
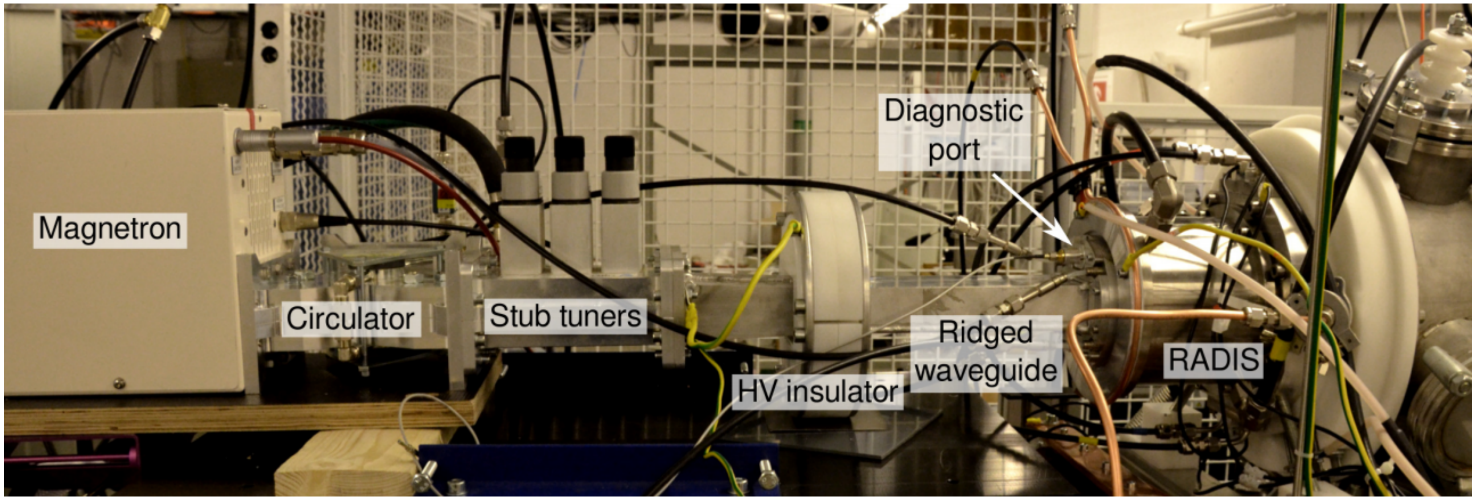
Field topology

(a) (b)



- Provides better plasma confinement at front plate
- Separates the biased plasma electrode from bulk plasma → allows adjustment of local plasma potential to optimize H^- production

Microwave RADIS



	RADIS RF	RADIS 2.45 GHz	LIISA filament	LIISA 2.45 GHz	
H^- beam current	300	170	1500	500	μA
H^- current density	0.78	0.44	1.6	0.53	mA/cm^2
e/H^-	10–30	25–35	2–4	5–15	
Pressure	0.5–1	1	0.45	0.65	Pa
Plasma electrode	7–12	0	1–4	2–15	V
Ignition thresholds					
Pressure	≈4.5	≈4.5	-	0.75	Pa
Power	≈1.0	≈1.5	-	≈1.5	kW

Roadmap

- Improvement of emittance measurement resolution
  → systematic emittance measurements
- Renew the front plate
- Optimization of plasma electrode aperture
  → beam current and emittance
- Durability test of source
- Modification of the injection line at MCC30/15 cyclotron to adapt to the different phase space properties of beam from RADIS source

Course on Ion optics with IBSimu

- August 5–14, 2015
- Part of 25th Jyväskylä Summer School
- More information at code website `http://ibsimu.sourceforge.net/`

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Thank you for your attention!