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Development of H^- Ion Source for JYFL Pelletron Accelerator

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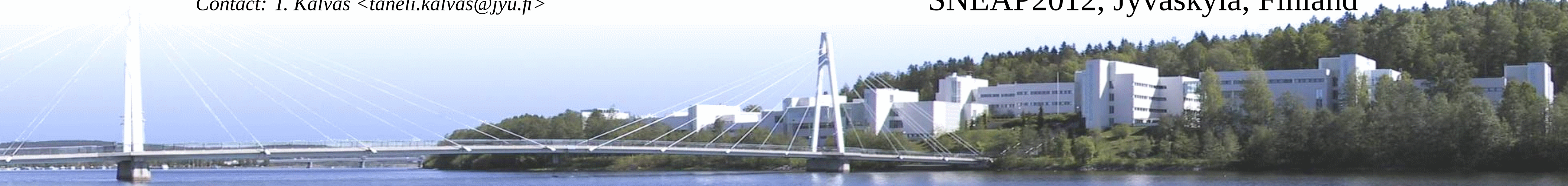

Presentation outline

- Short introduction to JYFL Accelerator Laboratory
- Background to ion source development
- Design of filament-driven H^- ion source
- Measurements
- Future plans for ion source development

JYFL: Personel of 190, including 85 Ph.D. students

Main research areas:

- Nuclear and accelerator based physics:
- Material physics
- High-energy physics

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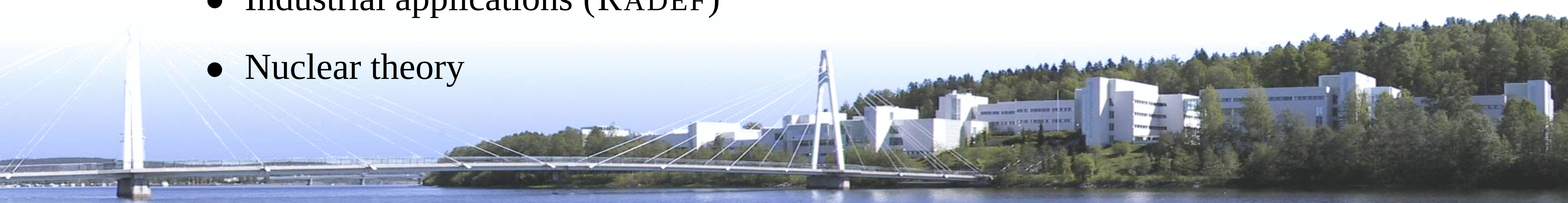
In Accelerator Laboratory:

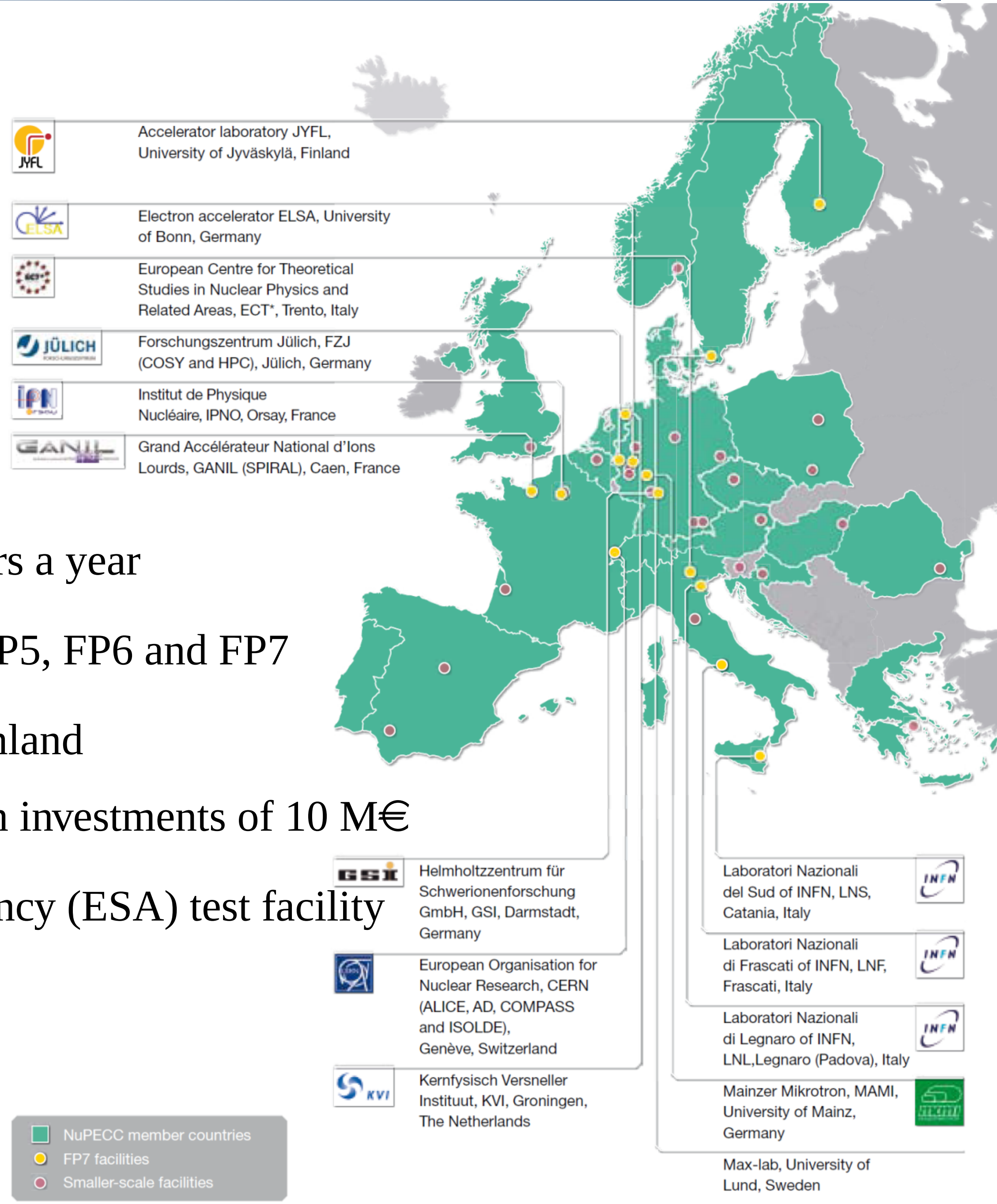
- Accelerator technology
- Rare isotope beam science (IGISOL)
- Nuclear structure at the limits (RITU, MARA, JUROGAM)
- Nuclear reactions
- Accelerator based material physics (PELLETRON)
- Industrial applications (RADEF)
- Nuclear theory



One of the leading stable-ion beam facilities

NuPECC Long Range plan 2010

- Accelerator Laboratory is an integral part of the Department of Physics
- K130: over 6000 beam time hours a year
- EU Access Laboratory in FP4, FP5, FP6 and FP7
- International infrastructure in Finland
  - over 200 users a year, foreign investments of 10 M€
- Accredited European Space Agency (ESA) test facility



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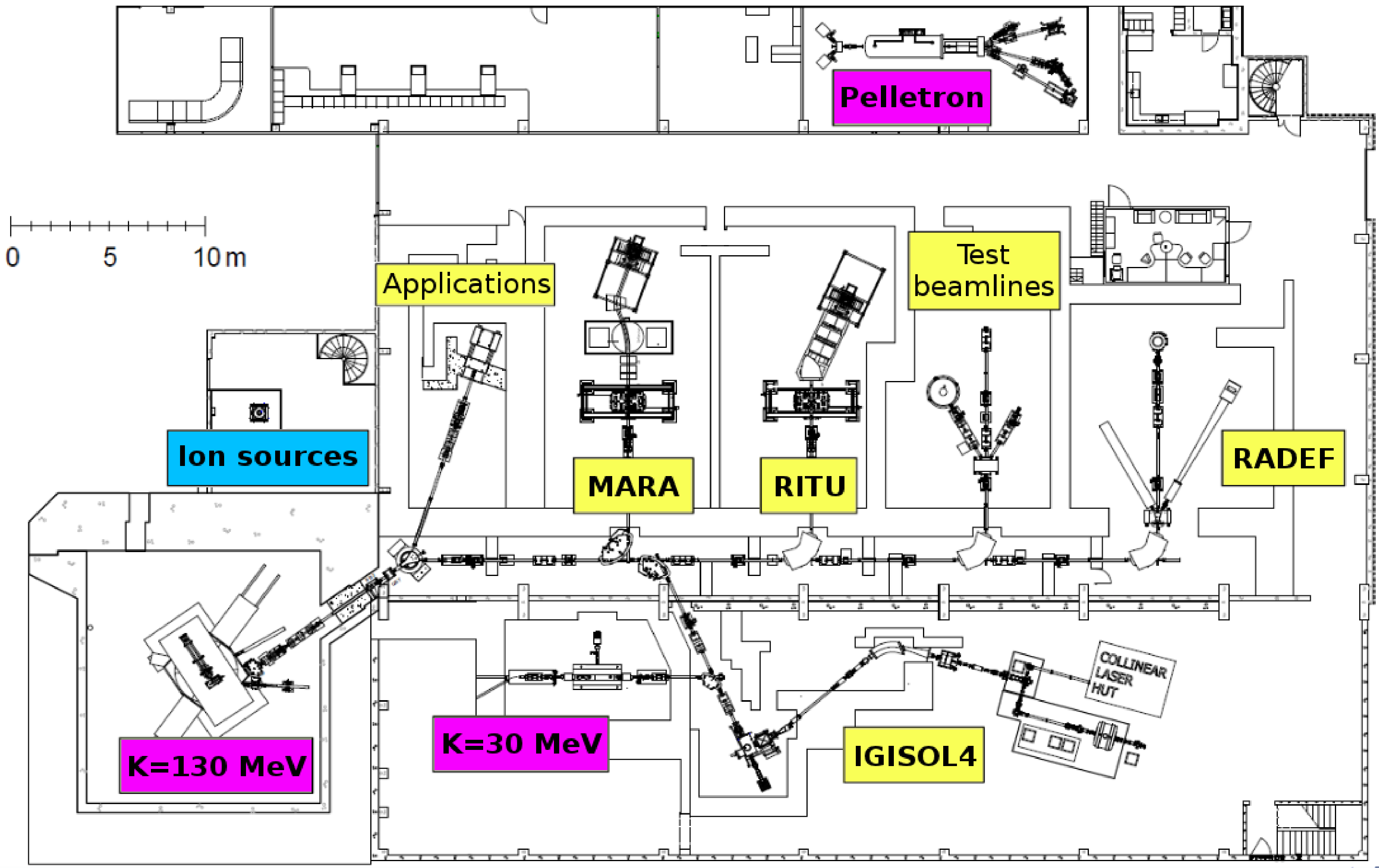
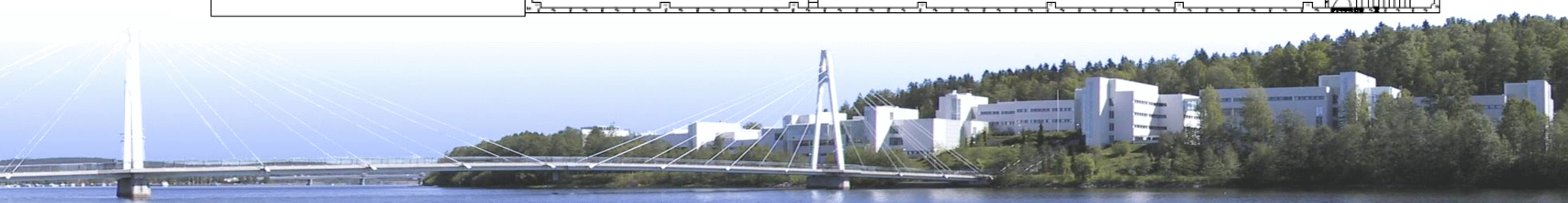
Accelerator Laboratory layout



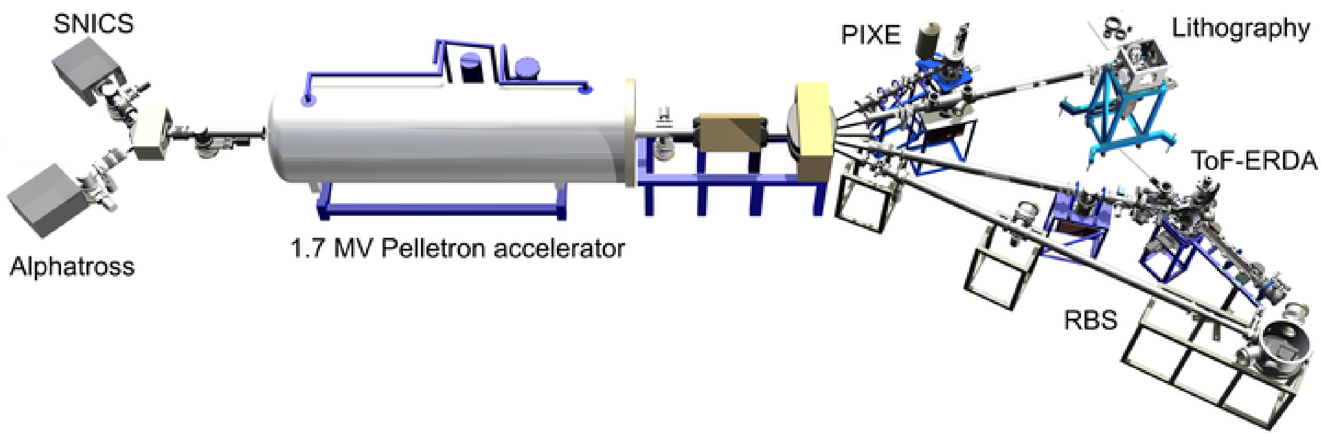


H^- ion source for Pelletron

Motivation

The JYFL 1.7 MV Pelletron accelerator is primarily used for ion beam analysis and ion beam lithography

More about the Pelletron facility after the coffee in a talk by M. Laitinen.



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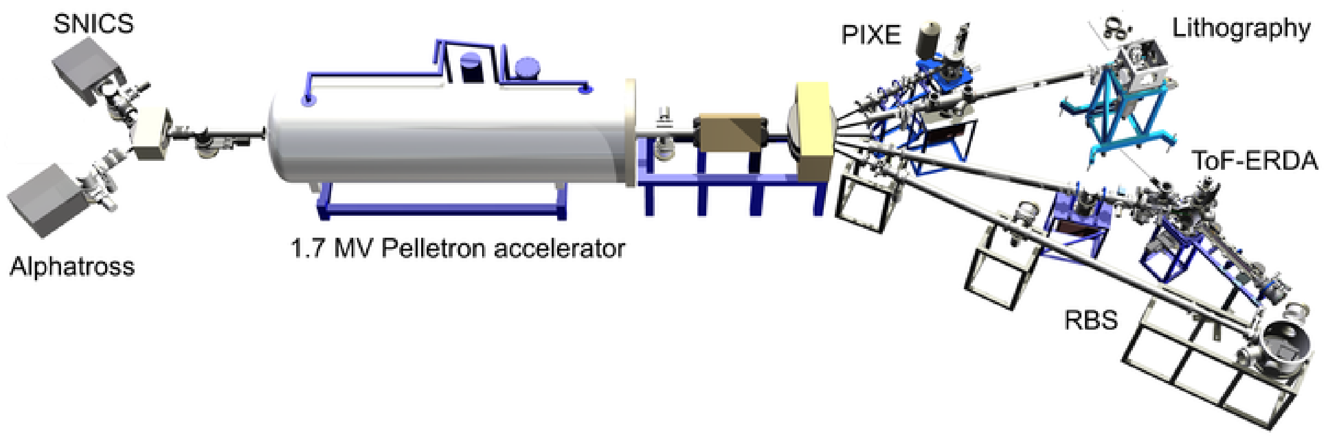

The applications would benefit from high brightness proton beams, that the existing Alphatross and SNICS ion sources couldn't produce.

Production of H^- with existing ion sources

Alphatross RF source

- Produces typically up to 250 nA of H^-, too low intensity
- Unconvenient to change between He and H, different size Ta channel needed

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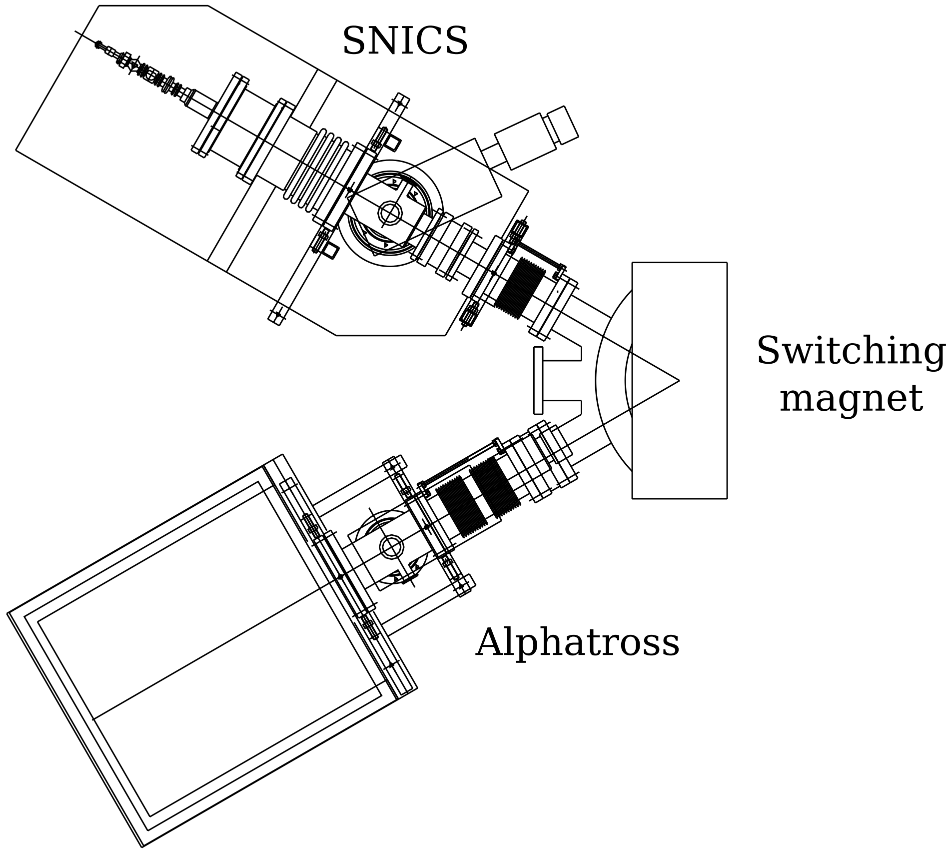
It would be convenient to have a dedicated H^- ion source.

H^- ion source development for Pelletron

Motivation



We have the space, experience, know-how and workshop at JYFL for designing, engineering and building a filament driven volume production H^- ion source. Also by making it in-house, the costs could be kept low.

H^- ion source for Pelletron

So we started a development project for the Pelletron Light Ion Source, PELLIS.

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Pellis (finnish), Bellis Perennis, English Daisy

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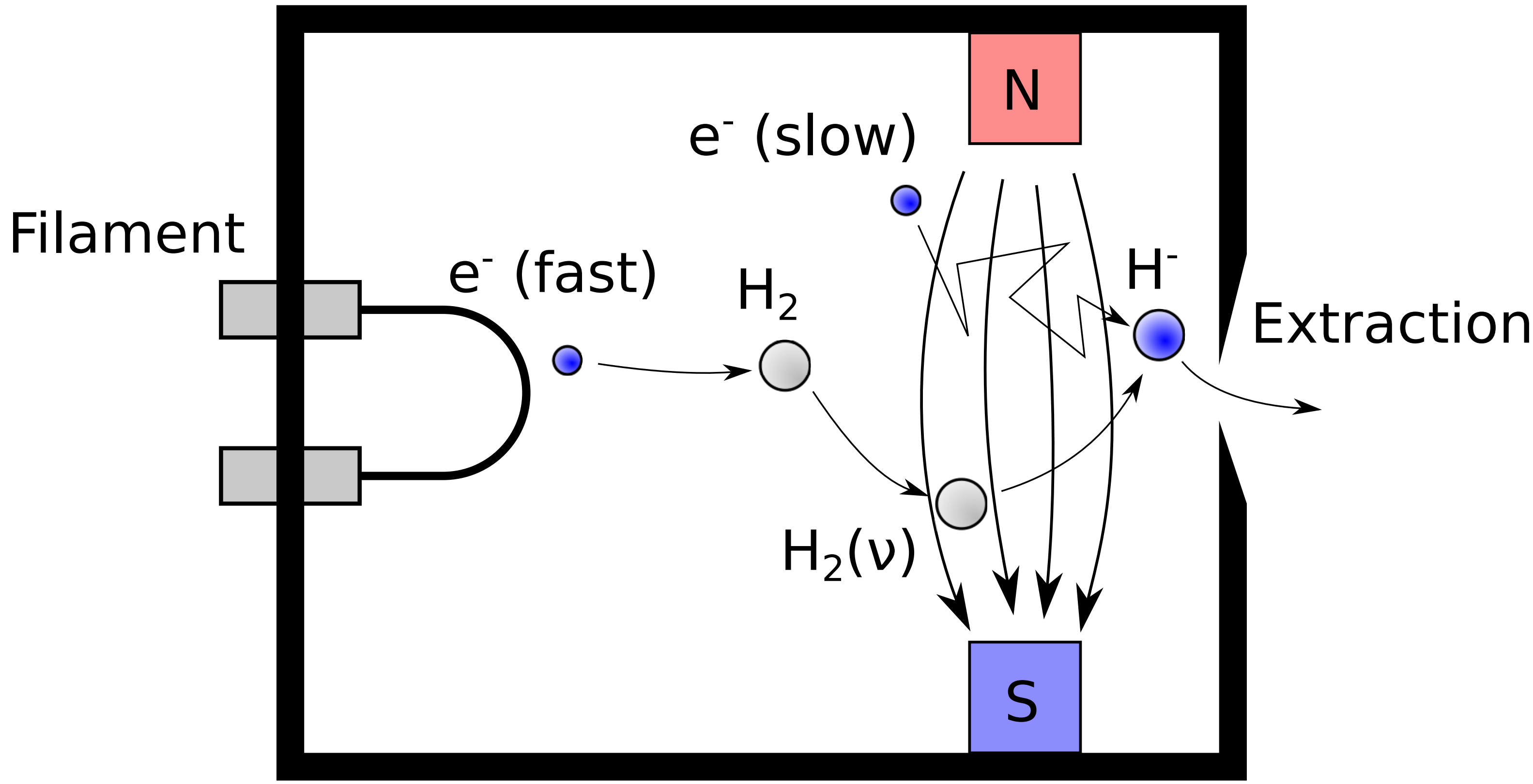
Volume source operation principle



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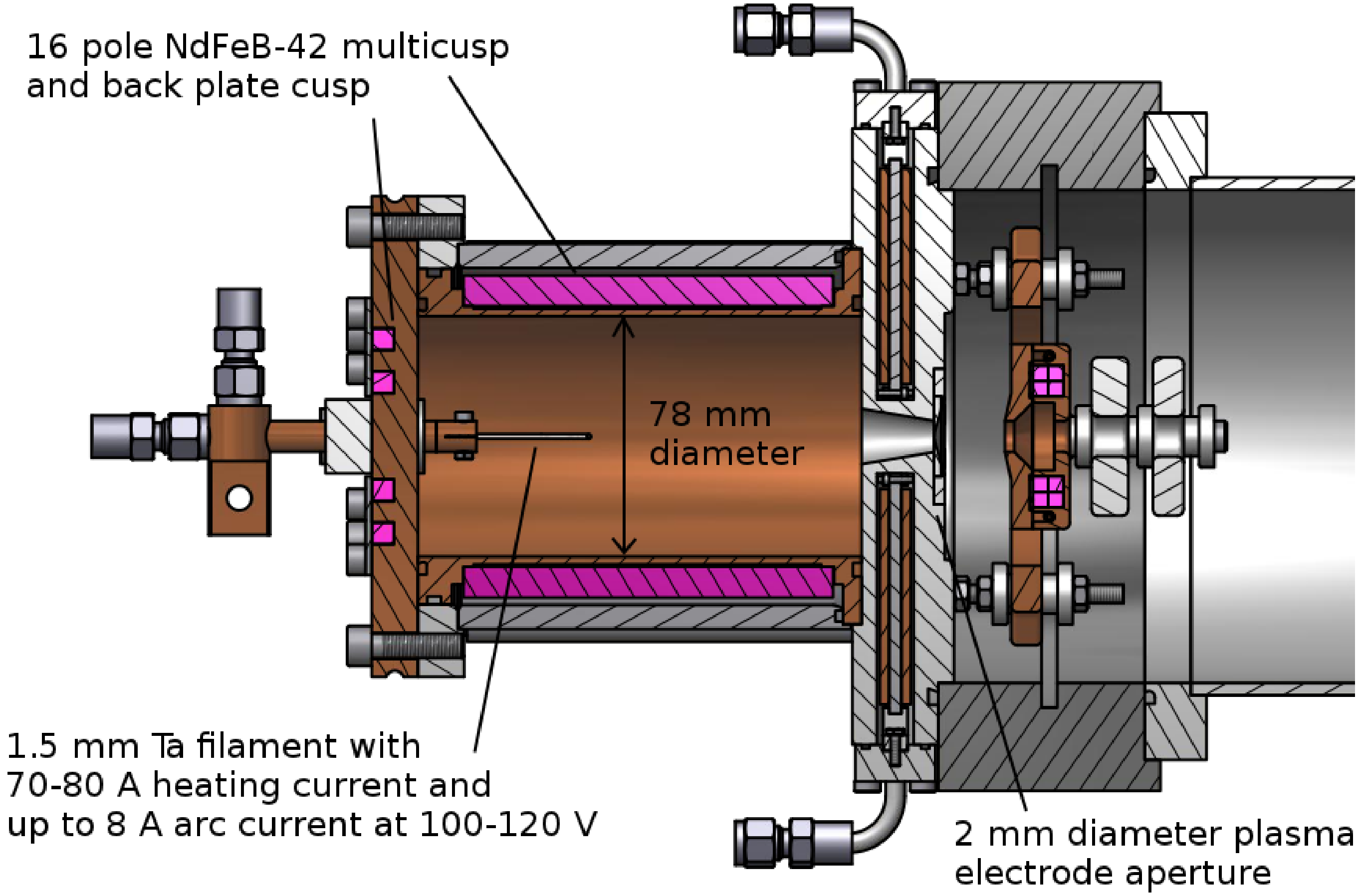
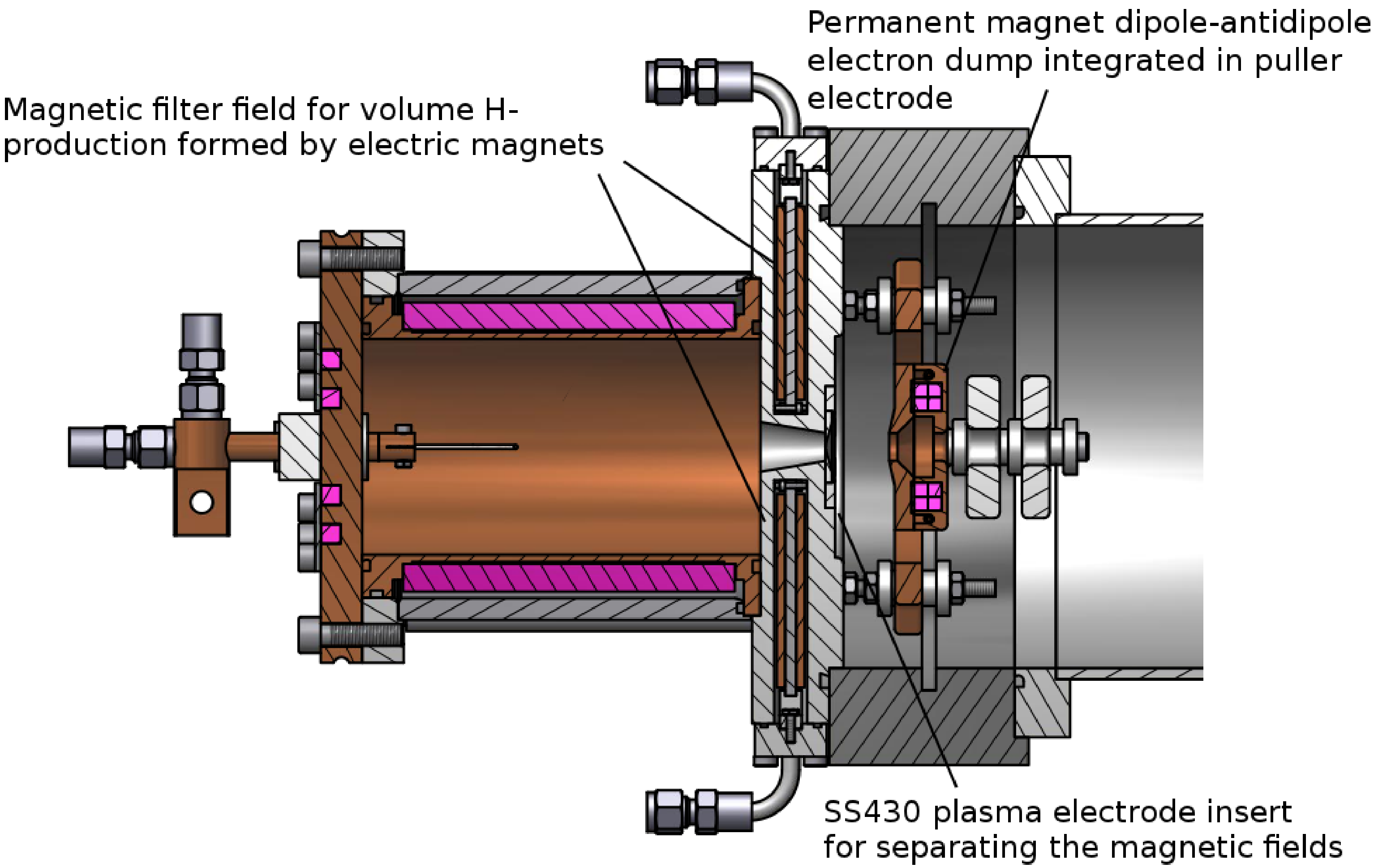
PELLIS design

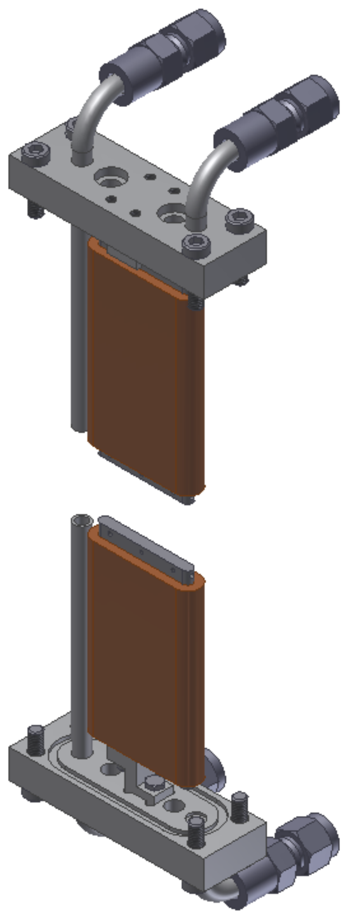


PELLIS design



PELLIS magnetic filter

- Electric magnets with 3×70 rounds of $\varnothing 0.95$ mm copper winding each
- Magnet placed within the ion source front plate immersed in cooling water



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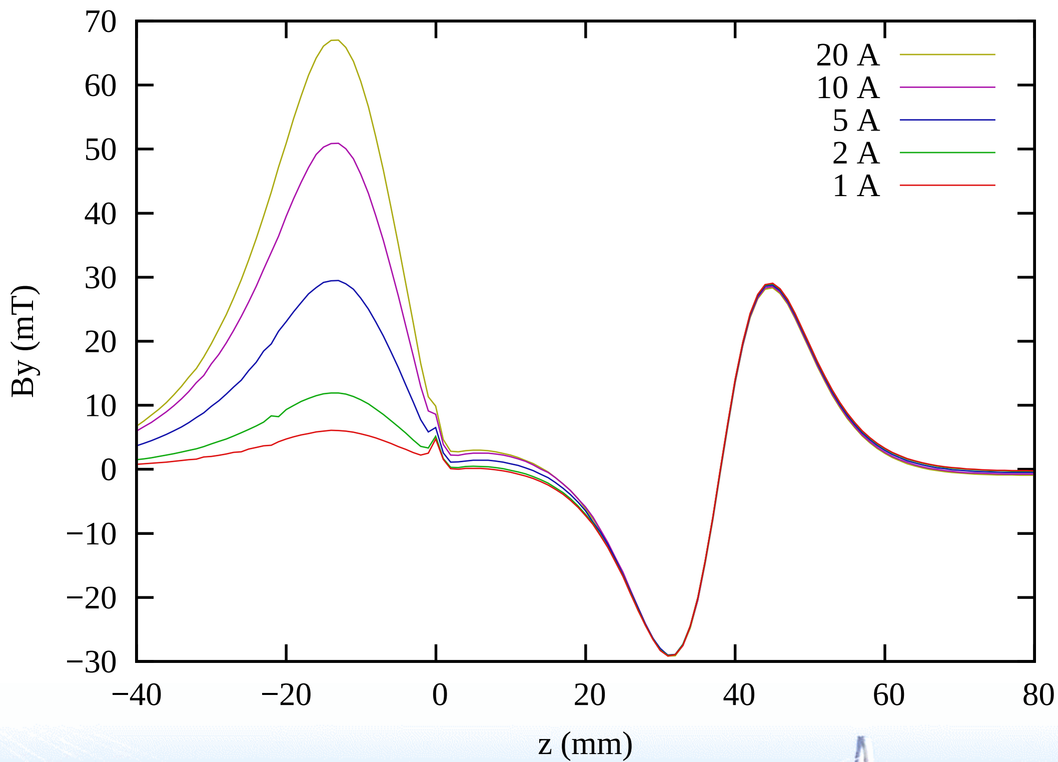
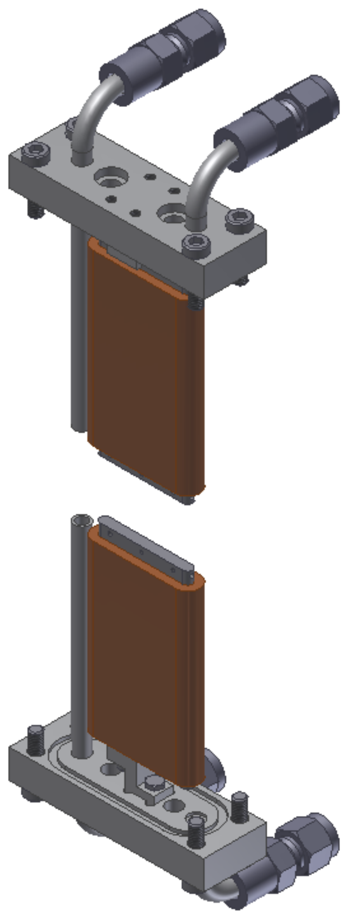
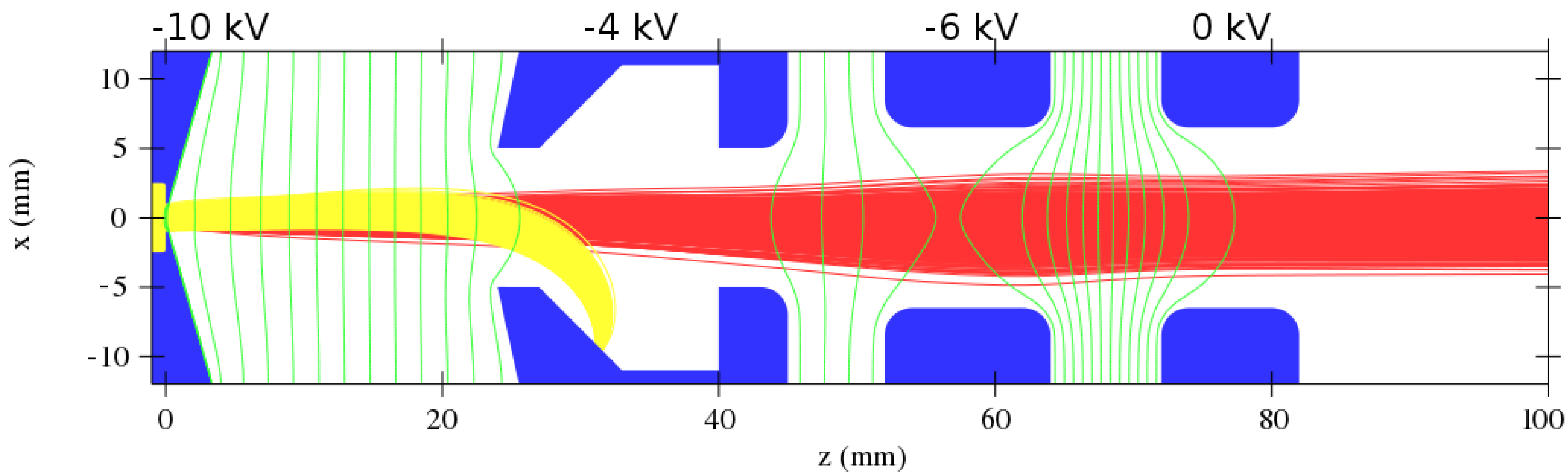




PELLIS extraction simulations

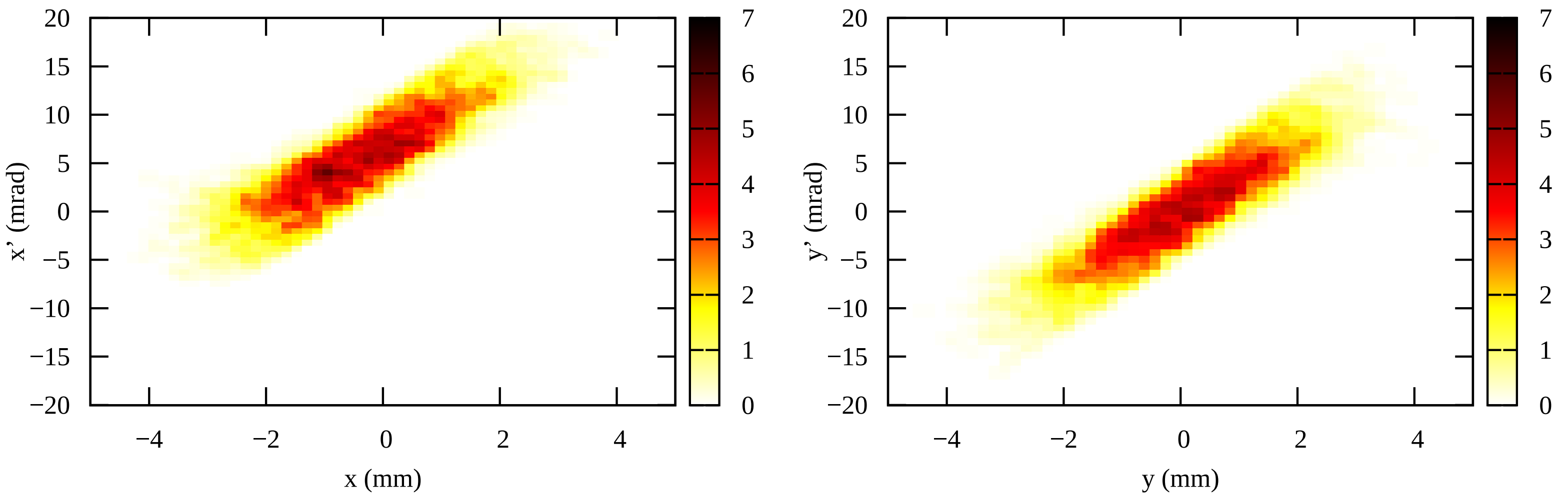
The plasma extraction and low energy beam transport were designed with IBSIMU code.



Nominal beam parameters used in simulations were 100 μA H^- and 3.5 mA e^- with $T_i = 1.0$ eV (upper limit).

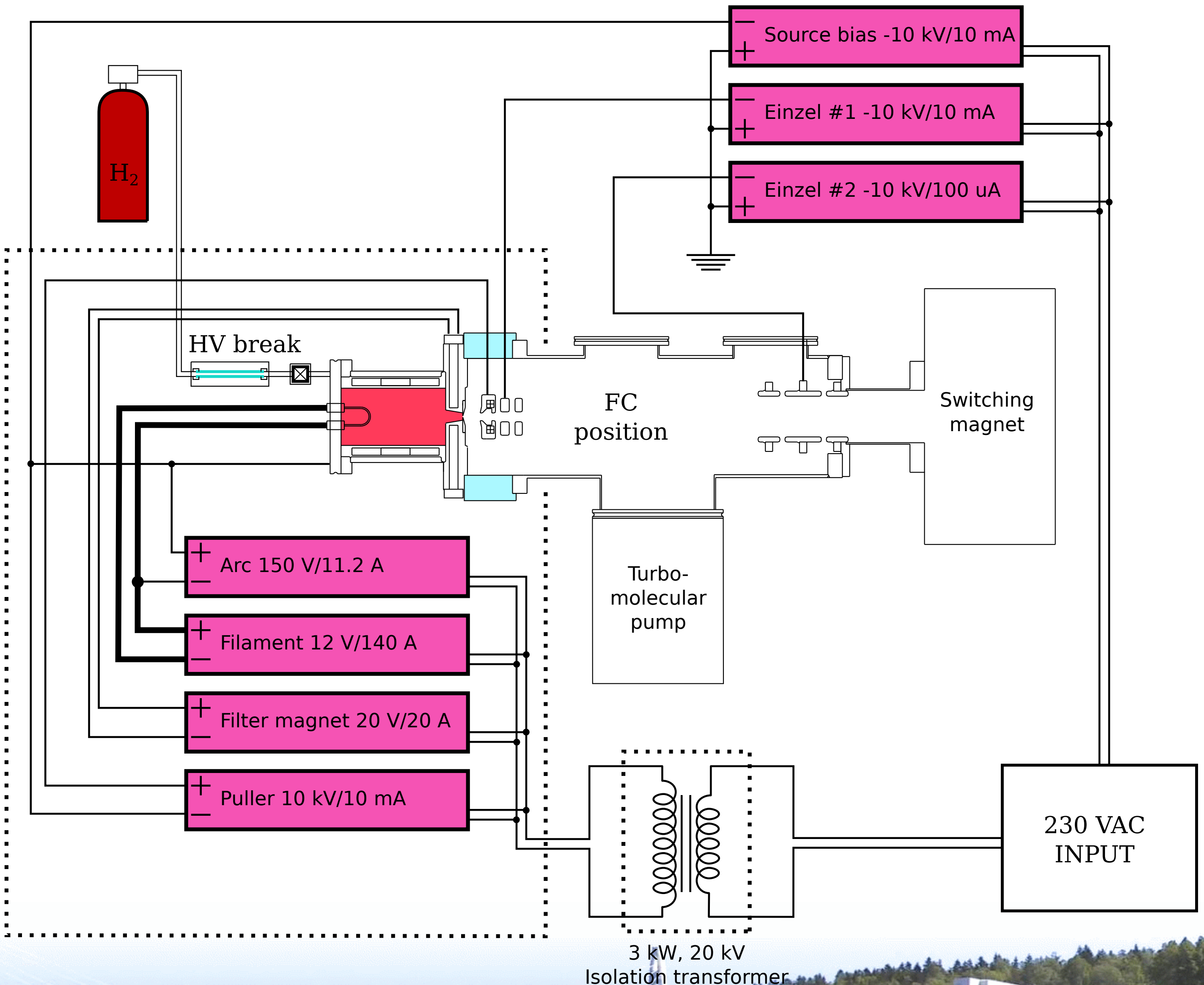
PELLIS extraction simulations

The beam rms emittance from the source/extraction according to the simulations was between 0.017 and 0.020 mm mrad depending on the input parameters.



Beam exits the extraction with a 5 mrad angle. Can be corrected by electrostatic deflectors and/or dipole magnet of the injection beam line.

PELLIS schematic



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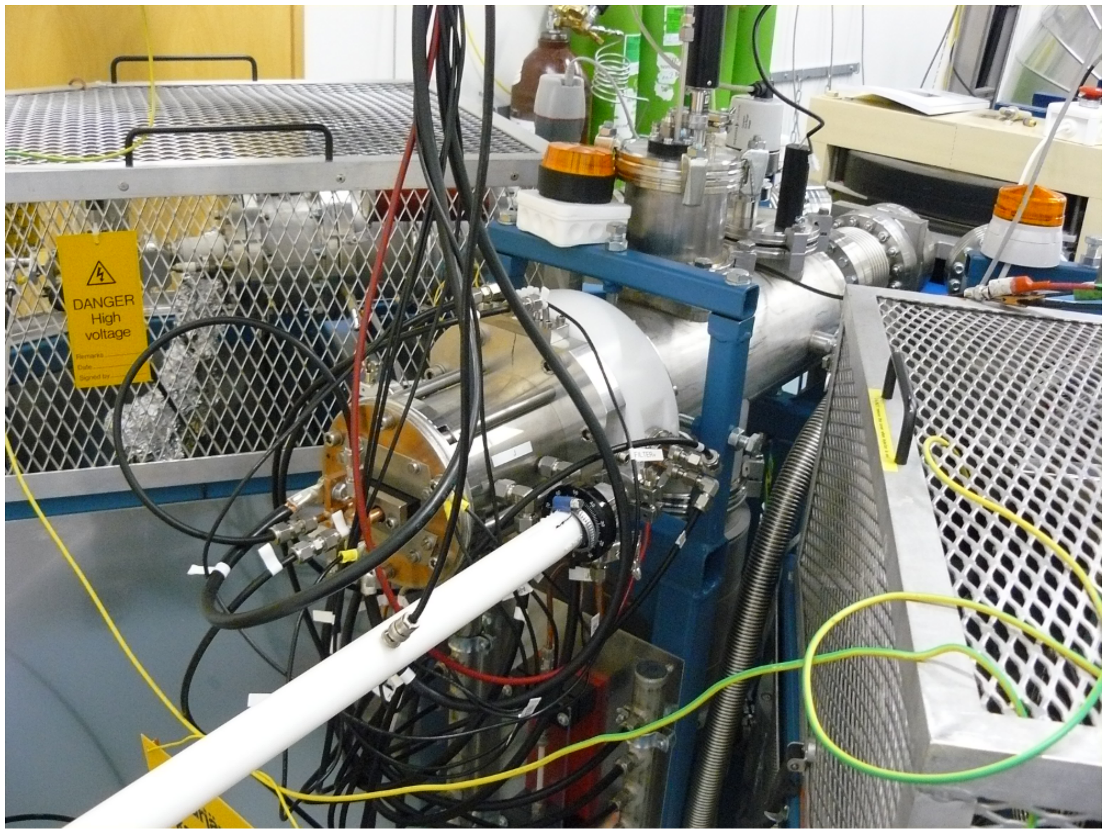
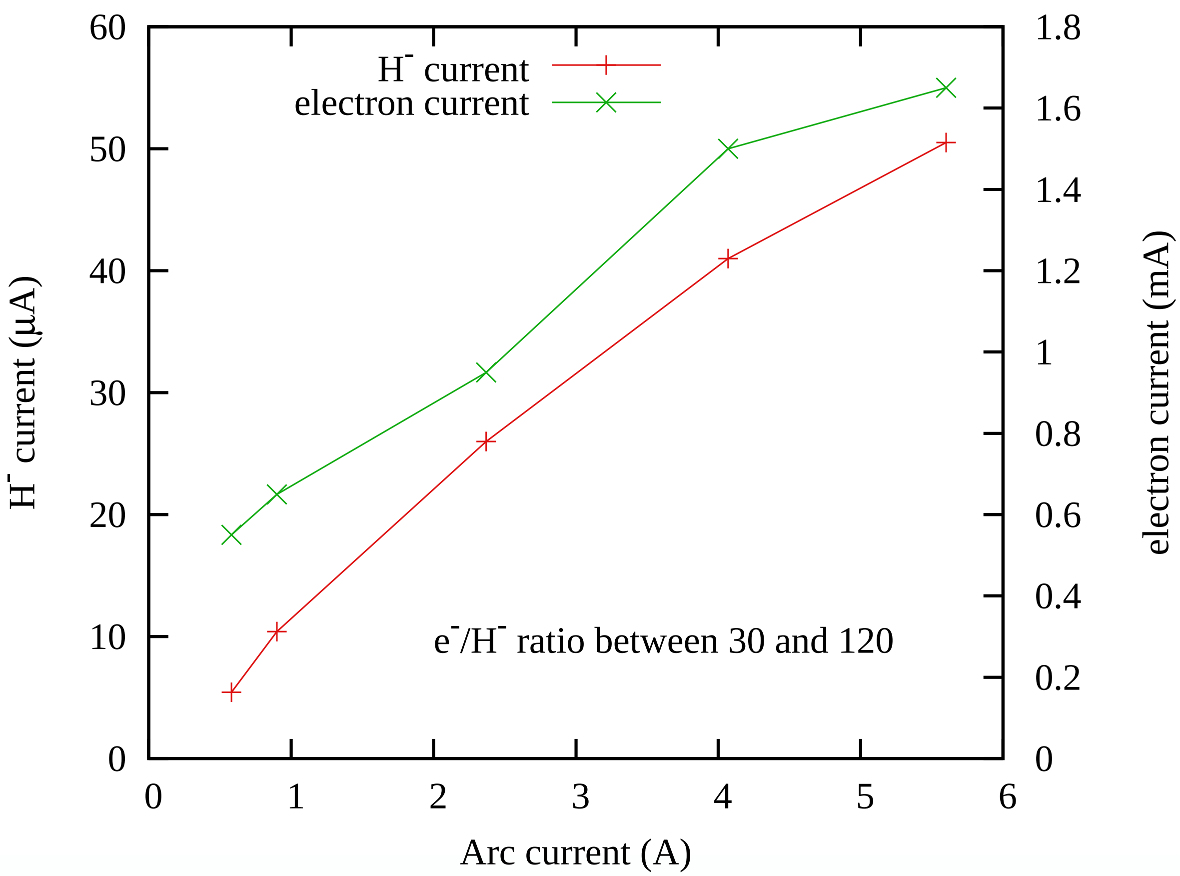
PELLIS installed

The ion source was installed in February 2012 and characterized with current and emittance measurements



PELLIS performance

The H^- current to the first FC and electron current to electron dump with 0.5 Pa gas pressure and filter magnet current for maximal H^- current.



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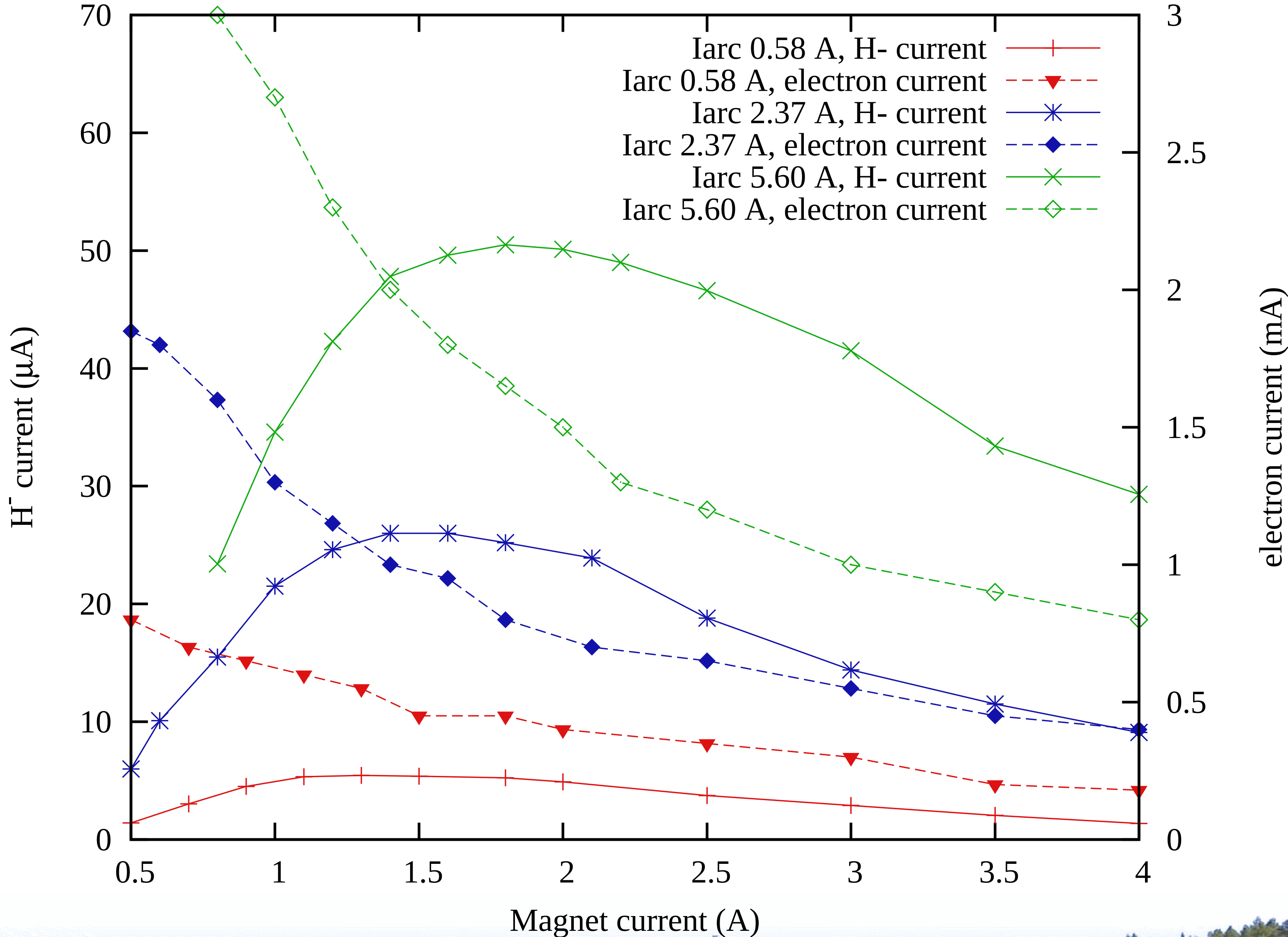
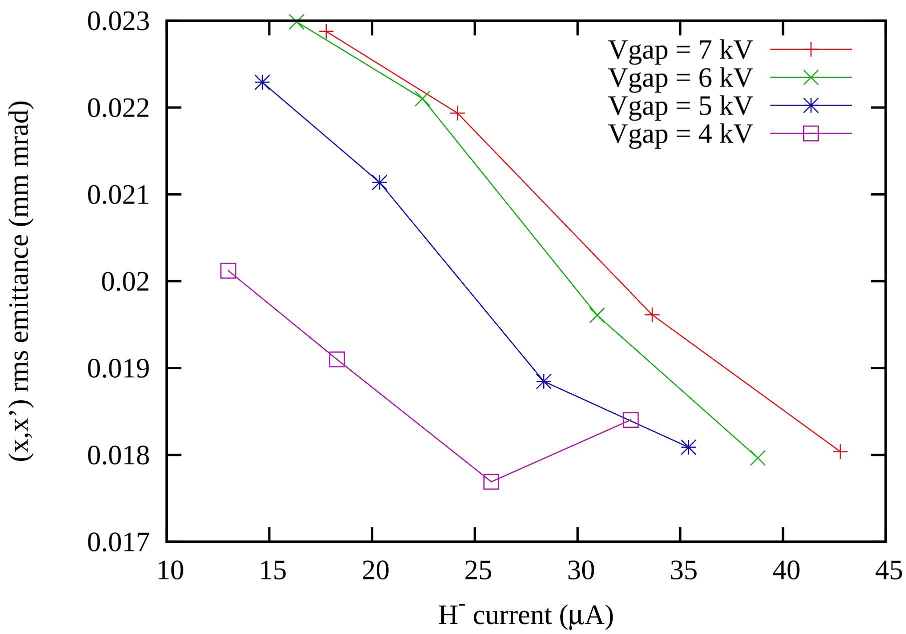
PELLIS performance



PELLIS emittance

Emittances were measured with Allison-scanner at 169 mm from plasma electrode. Data was filtered with thresholding to contain 95 % of beam



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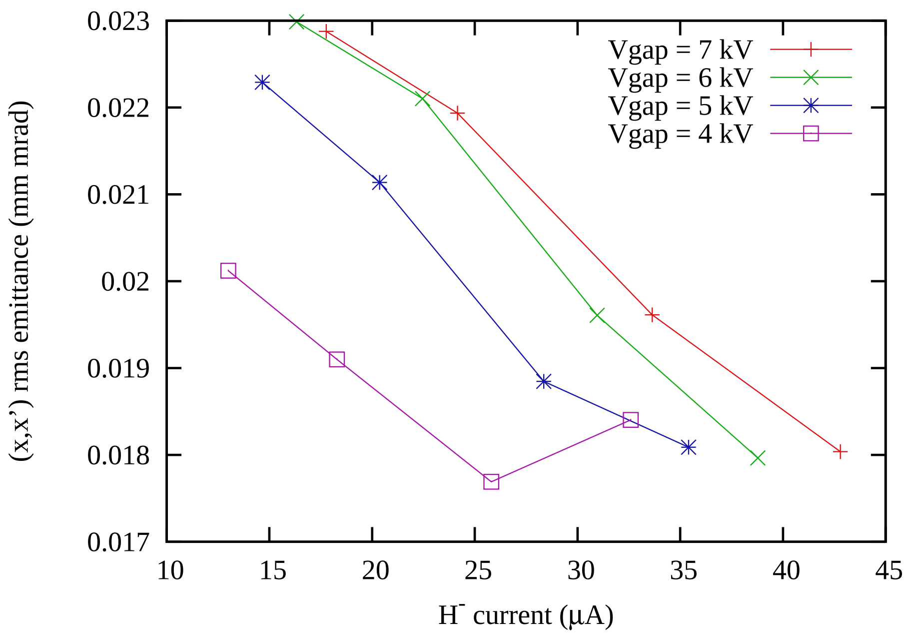
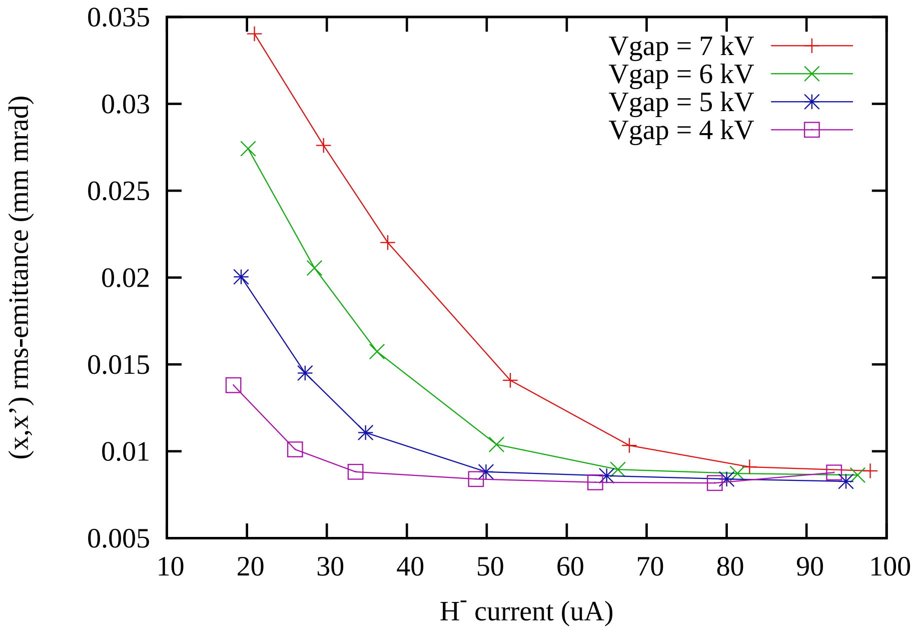


Extraction was designed for 100 μA current. Puller-plasma gap should be **increased** and/or plasma electrode aperture made **smaller** to reach optimum at typical current levels.

Expected emittance behaviour

It is known that there is an optimal operation point at certain current.



The minimum emittance value and location of optimum depends on plasma parameters, which are difficult to estimate ⇒ optimum has to be searched experimentally. Extraction is on threaded rods!

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Beam through the accelerator

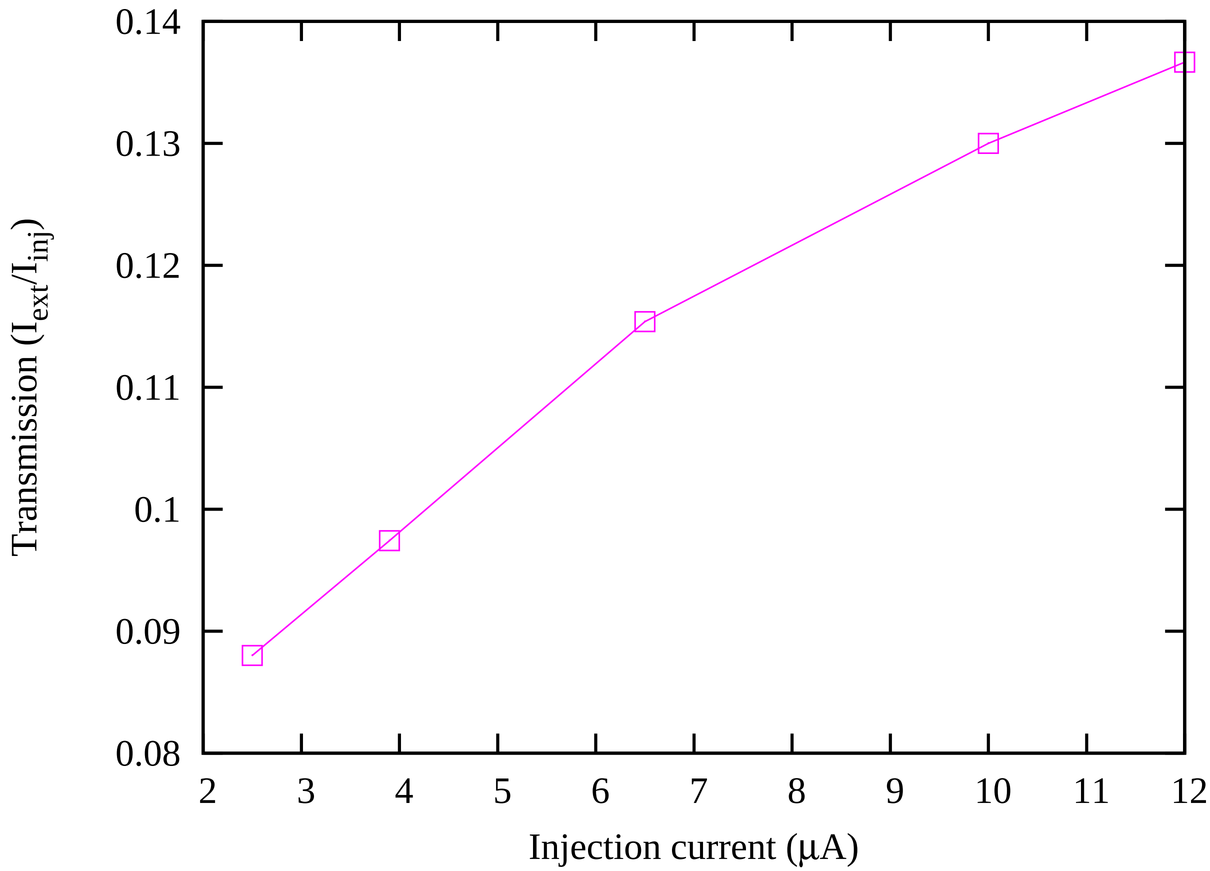
Beam through the accelerator

Applied Kilovolts MS0.2MZZ065 6 channel ± 200 V power supply was acquired for driving the deflector plates in the injection.

- Provides ~ 10 % increase in accelerated beams from other ion sources
- ~ 50 % increase from PELLIS.

Beam through the accelerator

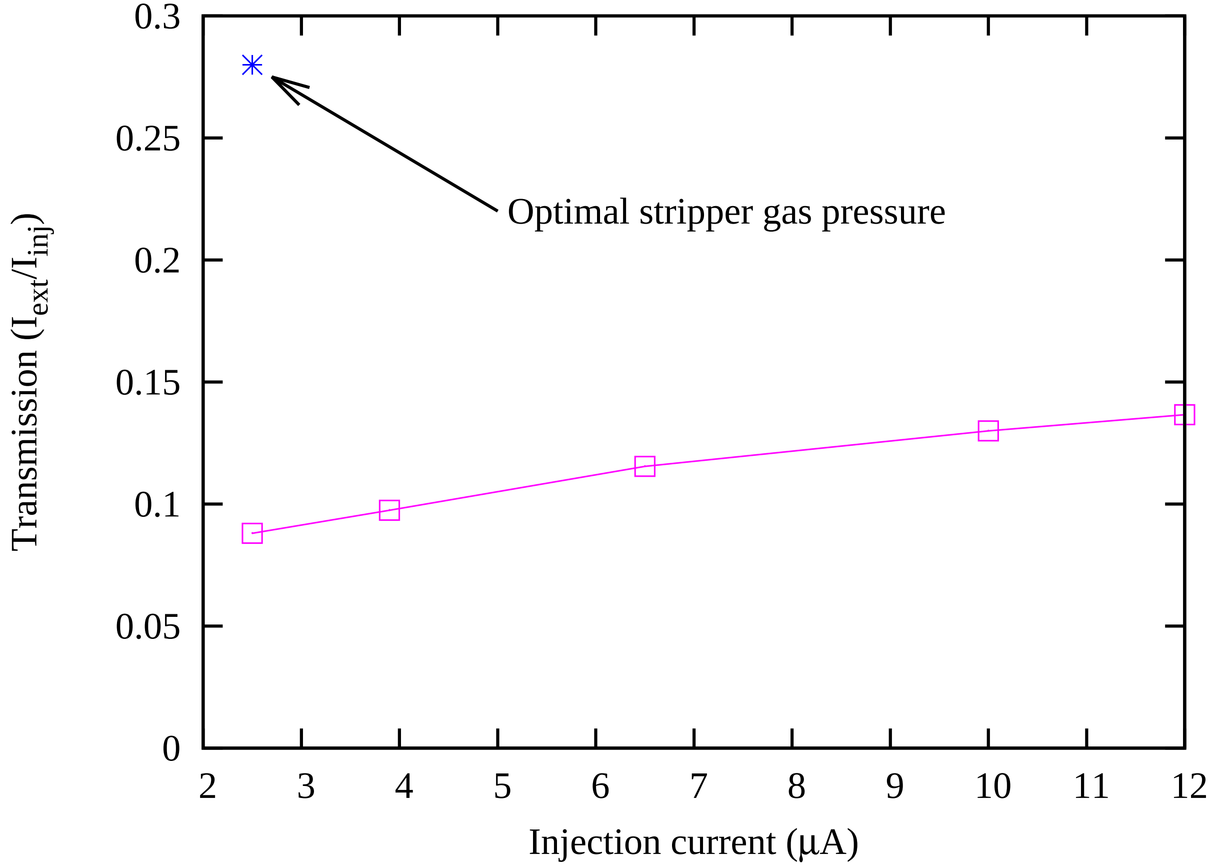
Transmission measurement at 1 MV



1.7 μA highest accelerated H^+ produced so far.

Beam through the accelerator

Transmission measurement at 1 MV



Dependence on stripper gas pressure dominates transmission

Cost of ion source

Cost of ion source

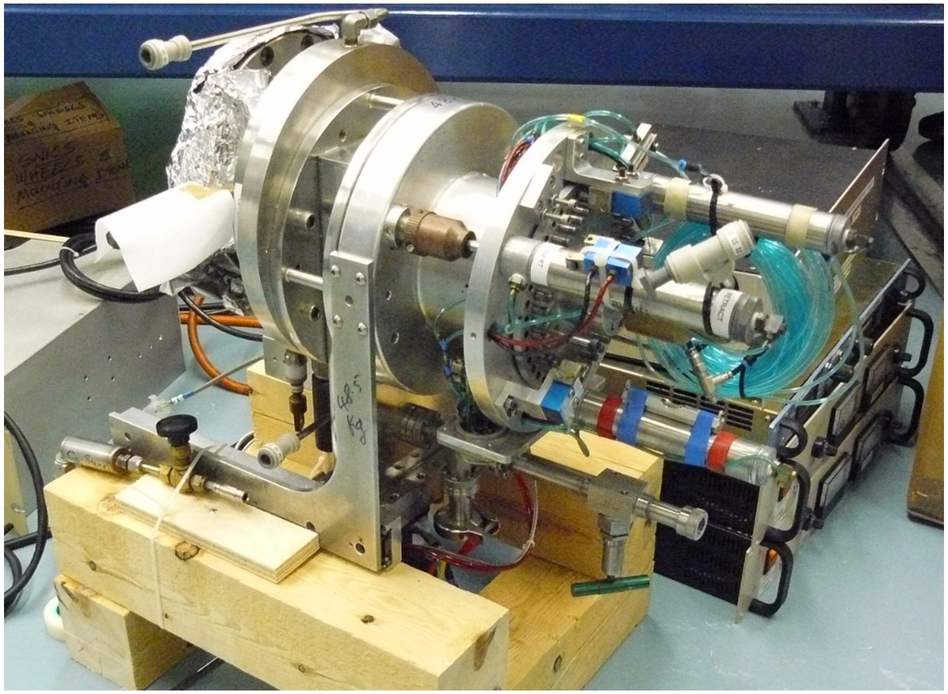
Item	Price
Filament and arc power supplies	4200 €
Filter magnet power supply	1000 €
High voltage power supplies	3700 €
Isolation transformer	1700 €
Magnets	500 €
Gas line, regulator, needle valve, etc.	1200 €
O-rings, water and vacuum fittings, etc.	1200 €
Materials	2500 €
Workshop hours	15000 €
Total	31000 €

Designing, engineering?

Future plans for ion sources

In addition to improving the PELLIS beam brightness with extraction adjustment, two other improvements are underway.

1. Replacement of the existing SNICS ion source with 40 MC-SNICS



Second hand ion source from GNS, New Zealand is ready to be installed.

Future plans for ion sources

2. Improvement of NEC RF-Alphatross performance

Main problems are:

- Production of the He^+ in the RF ion source
- Highly sensitive alignment of the source

He^+ drilling through Tantalum

Future plans for ion sources

Planned improvements:

- Improving the power efficiency of plasma generation with inductive or Helicon-mode RF coupling.
- Change of solenoid magnet and/or magnet power supply for higher B-field.
- Studying He^{+} beam formation, possibly changing to traditional plasma electrode - puller electrode extraction for better control of alignment.

Thank you for your attention!