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Simulation of H^- ion source extraction systems for the Spallation Neutron Source with IBSimu

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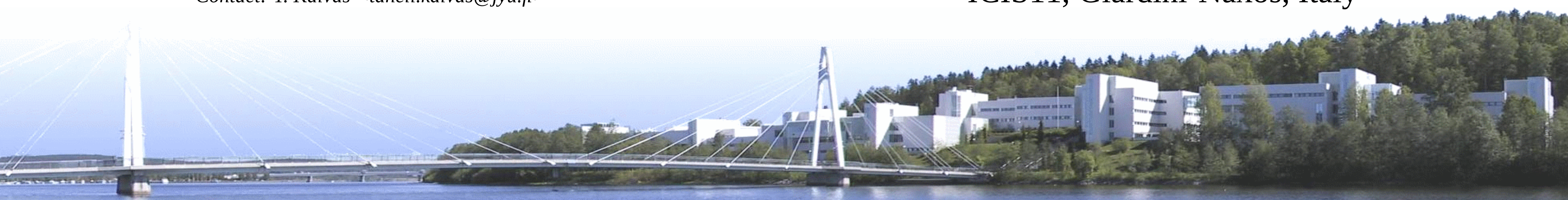


Presentation outline

- Introduction to IBSimu
- SNS baseline extraction
- Proposed high-current extraction
- Magnetic LEBT for SNS

Ion Beam Simulator

IBSimu is an ion optical code package made especially for the needs of ion source extraction design. The code can model

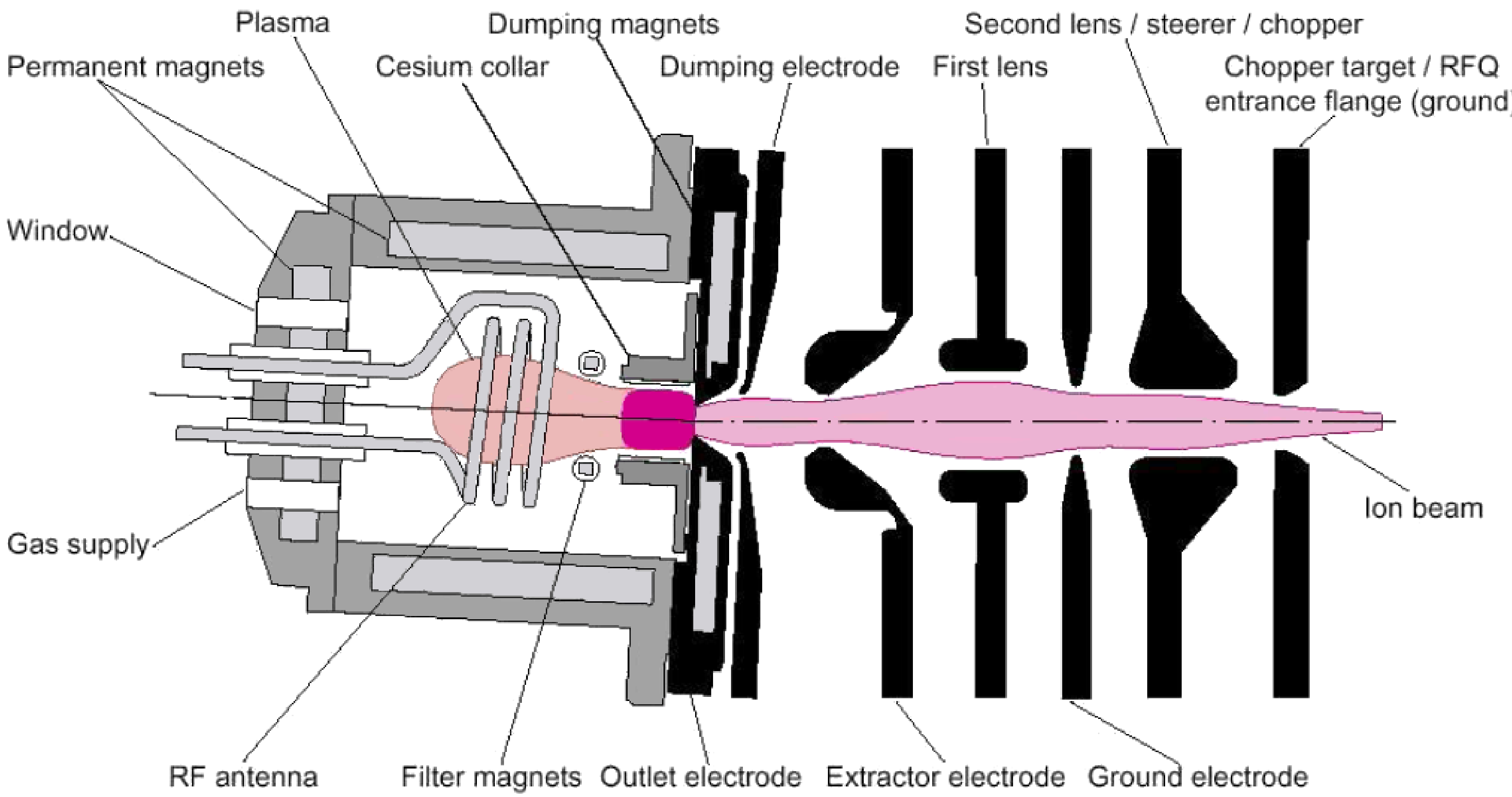
- Systems of electrostatic and magnetic lenses
- High space charge beams (low energy)
- Positive and negative multispecies 3D plasma extraction

The code is made in C++ and is released* freely under GNU Public Licence.

- Highly versatile and customizable.
- Can be used for batch processing and automatic tuning of parameters.

**) http://ibsimu.sourceforge.net/*

SNS Ion Source Baseline Extraction



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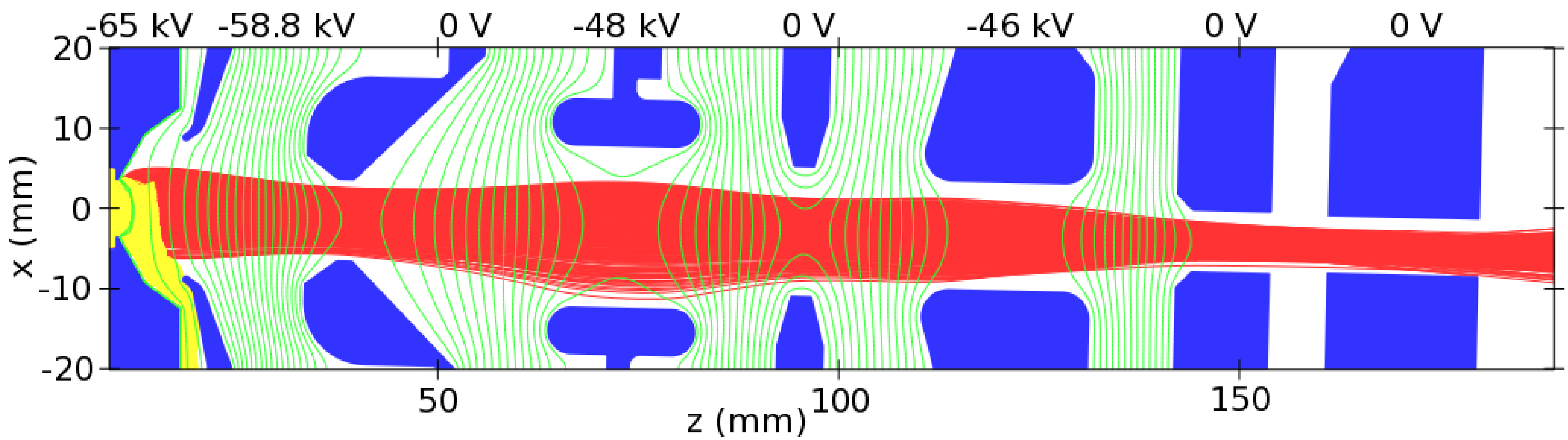
Plasma parameters

Previously, the same plasma parameters were used as in other published simulation work. Fine tuning was now made made to match results to experimental emittance data.

- Transverse temperature of e^- and H^- $T_t = 2.0$ eV
- Plasma potential $U_P = 15$ V
- Emitted electron to ion ratio $I_{e^-}/I_{H^-} = 10$
- Thermal positive ion to negative ion ratio $\rho_{X^+}/\rho_{H^-} = 0.5$
- Initial energy of particles $E_0 = 2.0$ eV

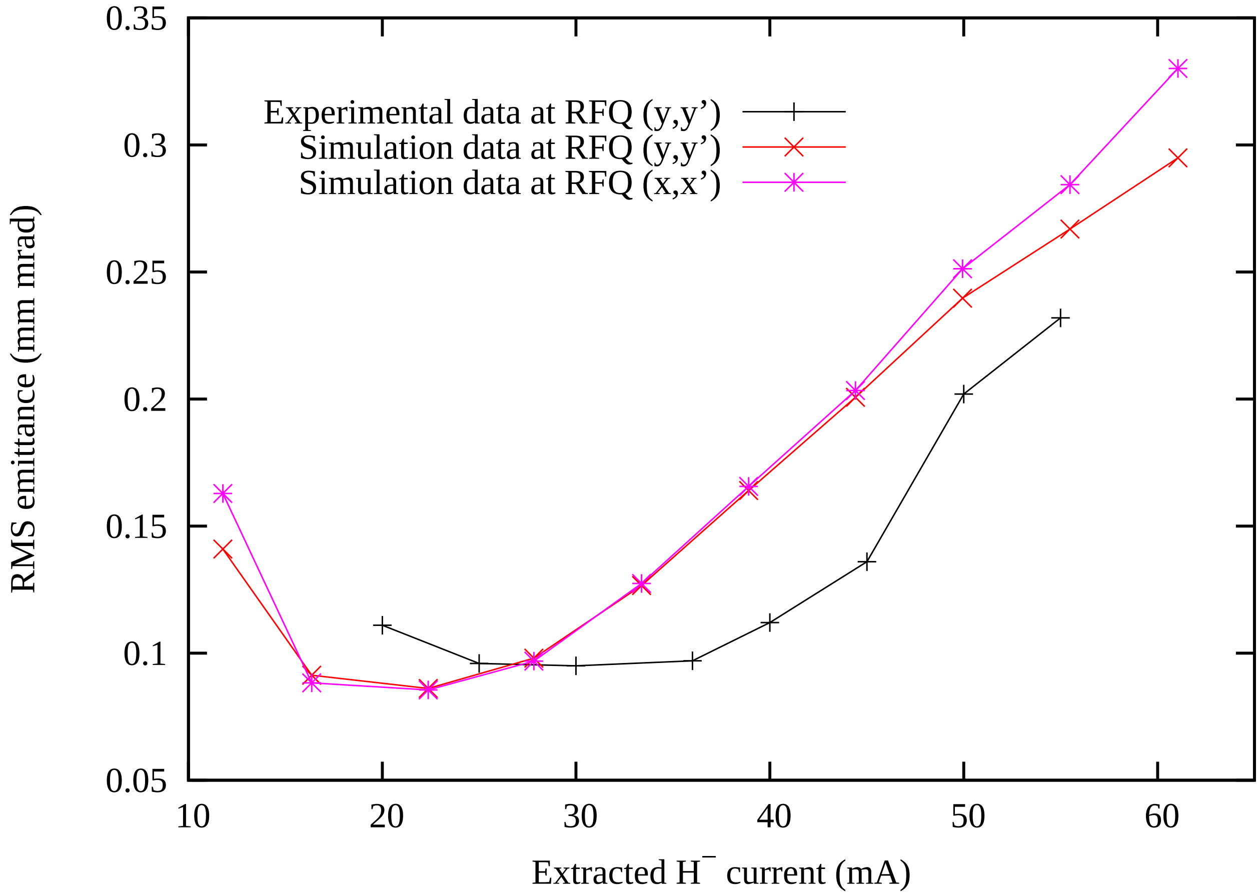
Angle and Offset

A parametric scan was done to find an optimum delivering beam centered and straight in the RFQ in IBSimu:



Optimum at 1.4° (24.4 mrad) source angle and 0.8 mm offset. These parameters were as a reference point in simulations.

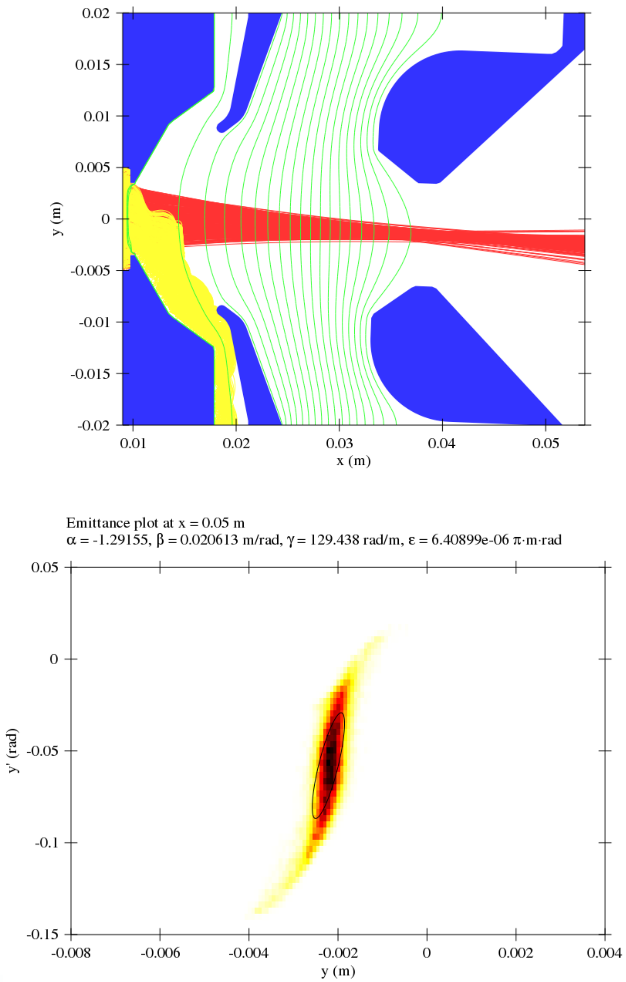
Emittance results



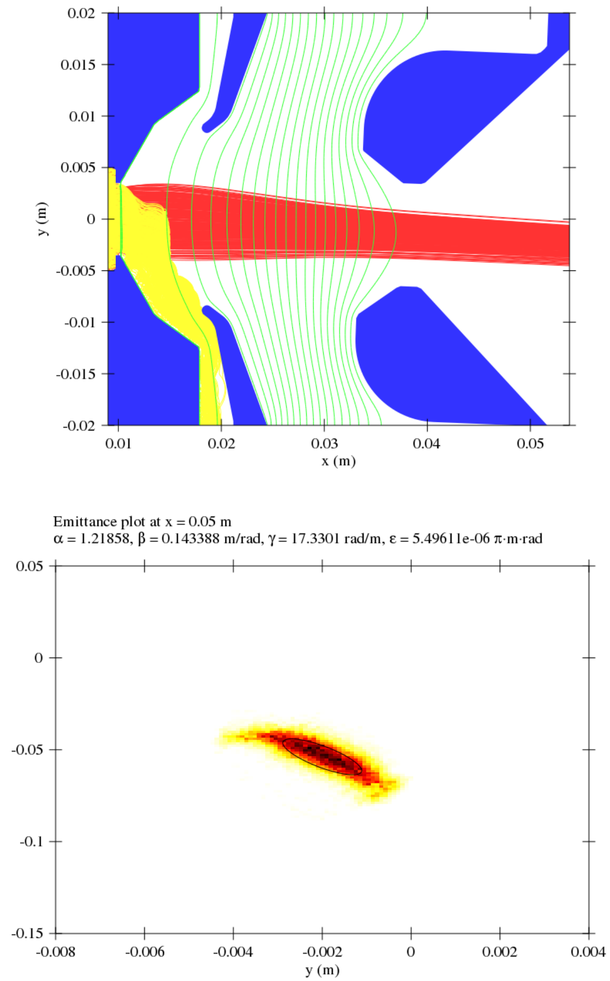
Experimental emittance data: B. X. Han, RSI 81 02B721 (2010)

Plasma meniscus asymmetry

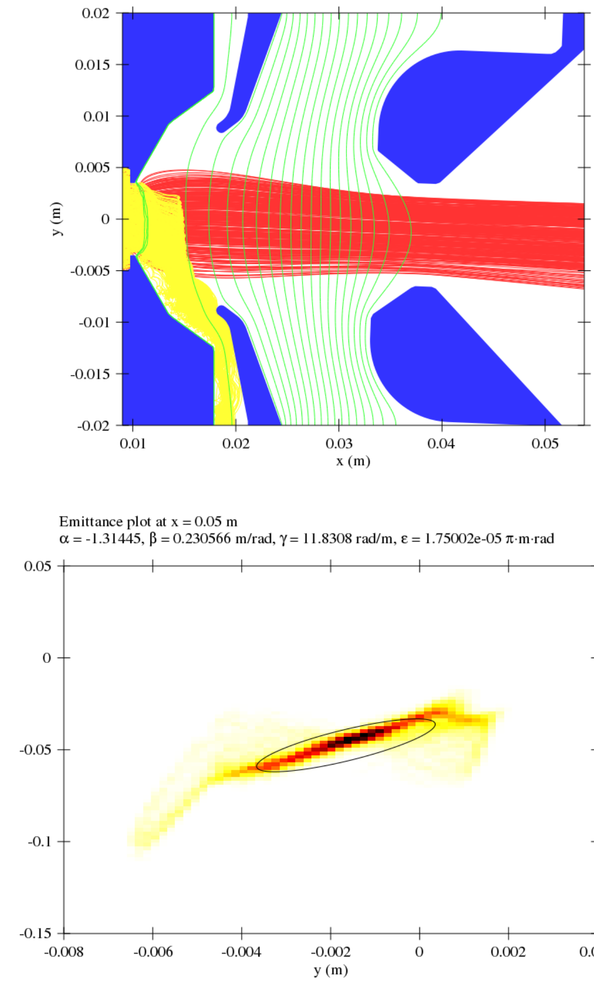
15 mA

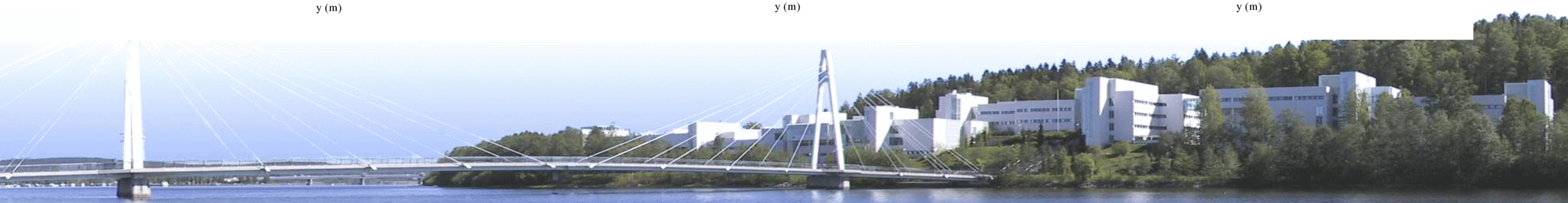


25 mA



50 mA





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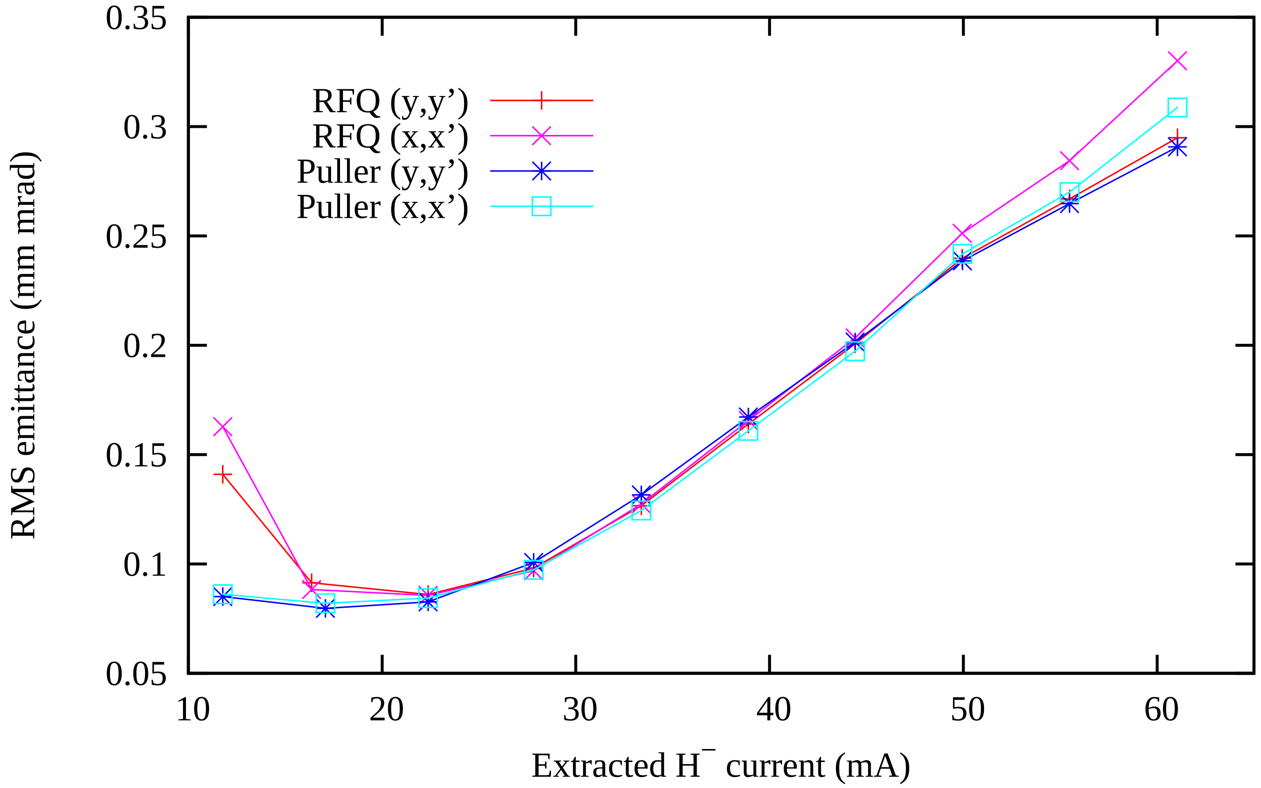
Emittance after puller vs. at RFQ



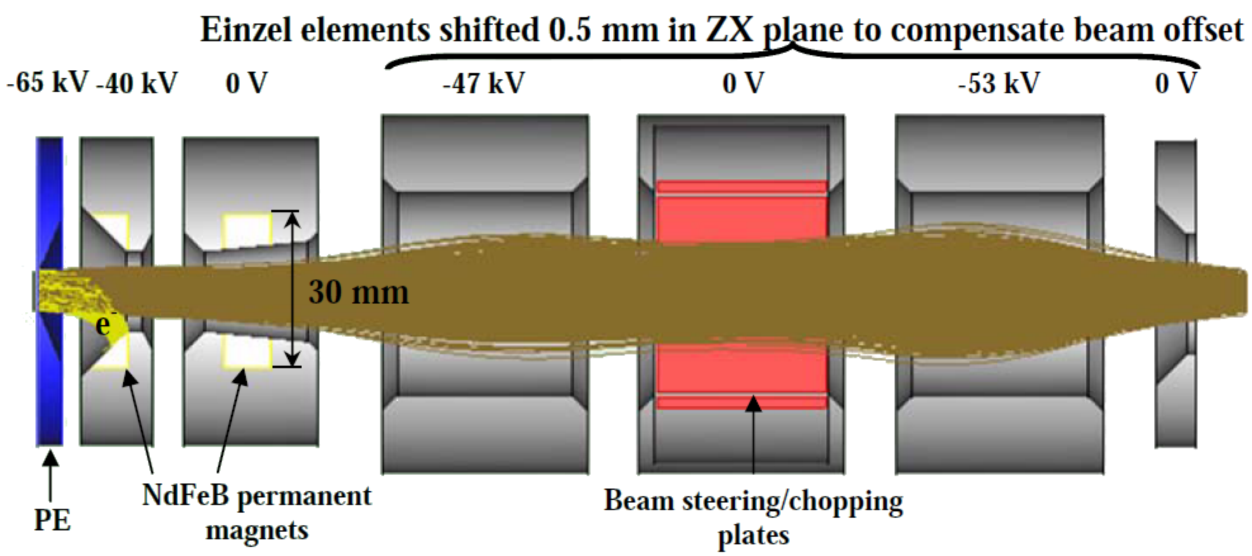
Linac beam of ∼60 mA will likely be required by a future power upgrade.

- Beam is approaching the acceptance limit of the RFQ near these current levels.

Front-end upgrade

Idea: Do electron dumping downstream at higher, intermediate energy

- Enables use of high E-field, low B-field, flat meniscus extraction leading to low emittance. *R. Keller, S. K. Hahto, PNNIB-06*



- RFQ injection done by magnetic LEBT, which is under development at SNS. Simpler extraction is sufficient.
- Preliminary design made at Oak Ridge using PbGuns and Lorentz, IBSimu was used to refine the system and analyze it with greater detail.

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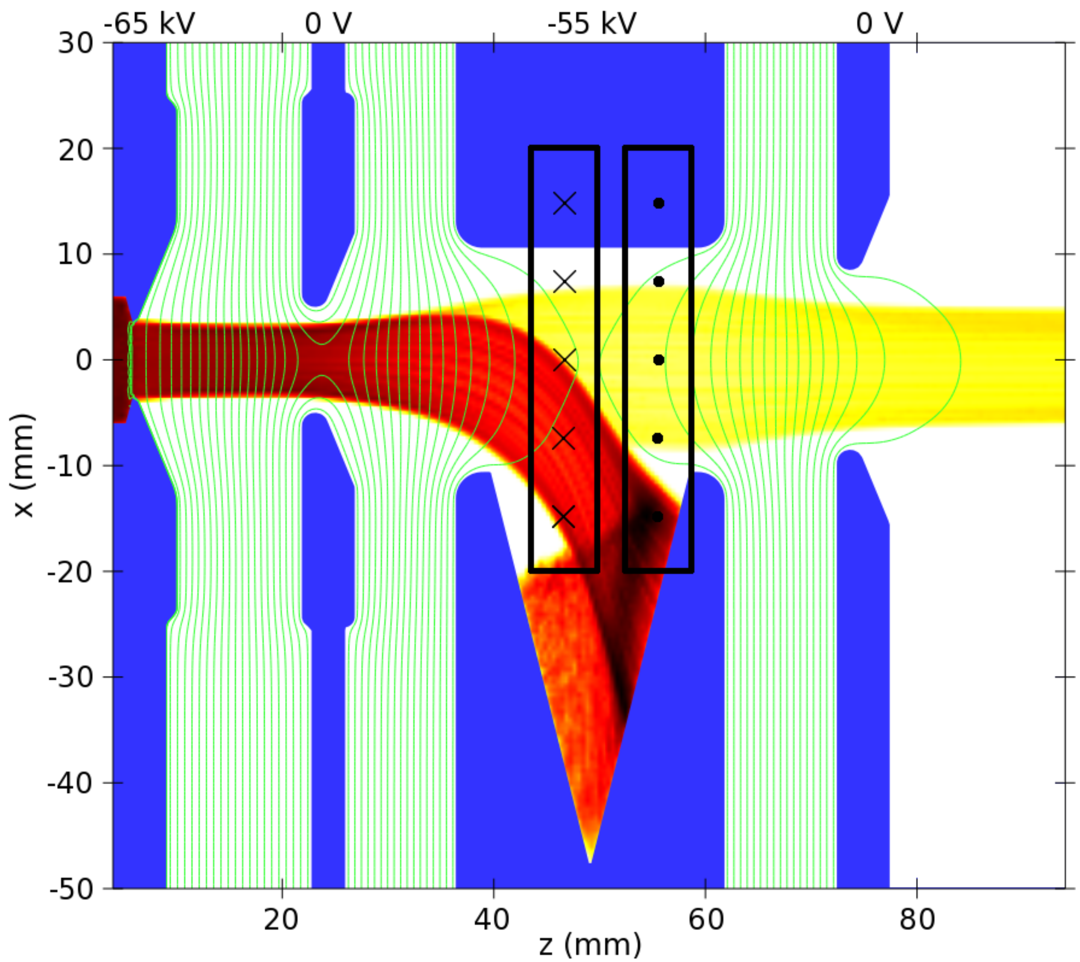
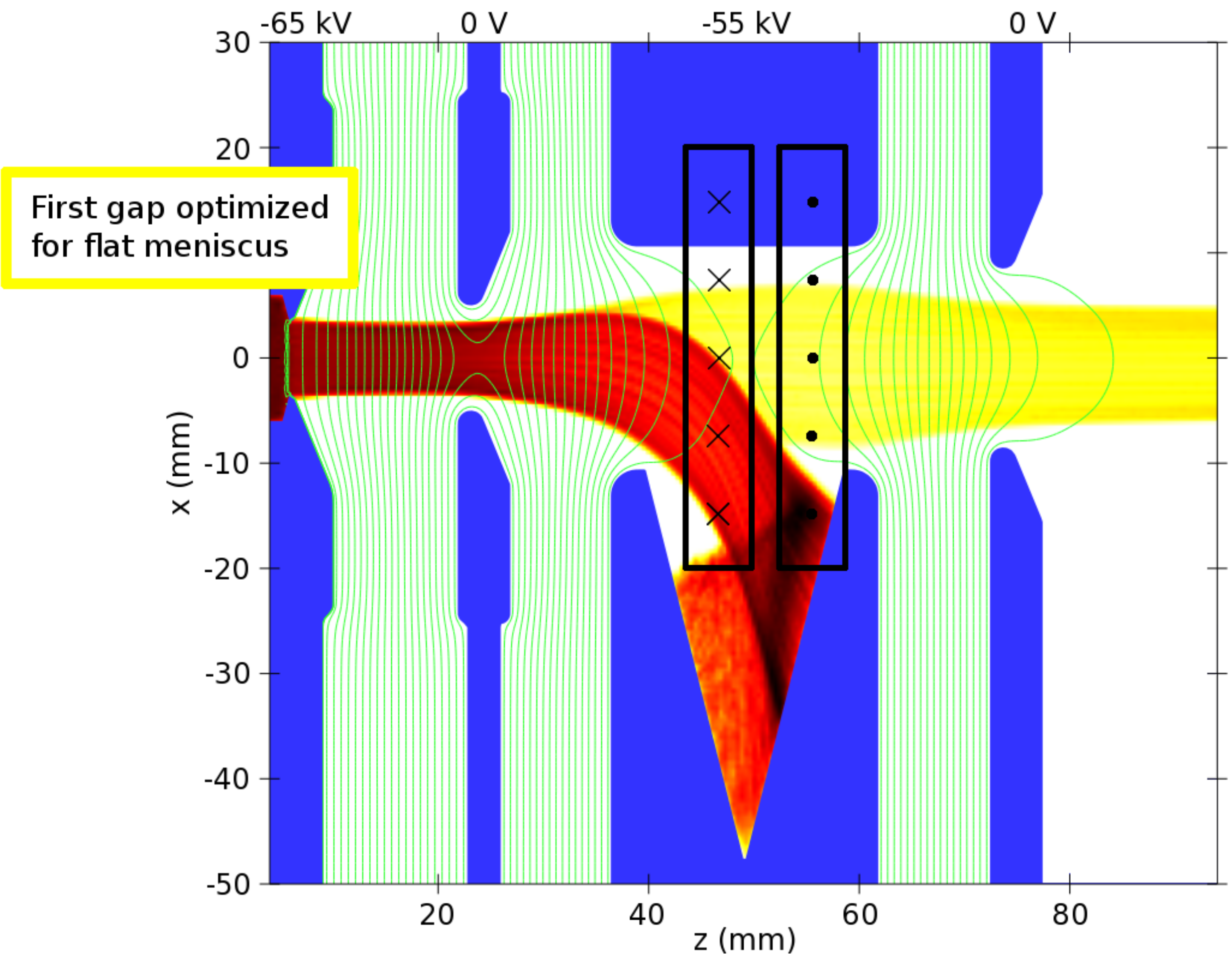
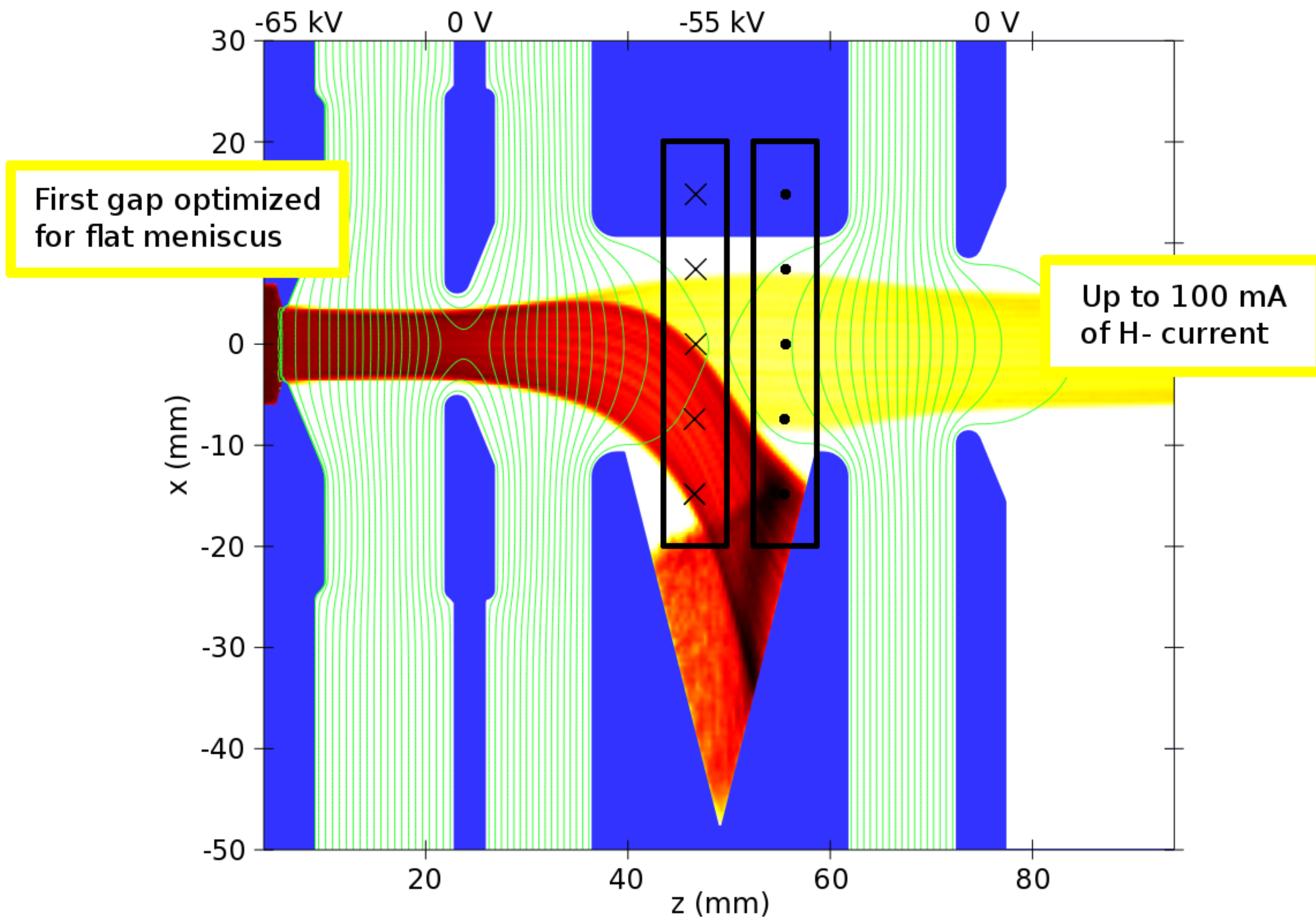
Proposed design



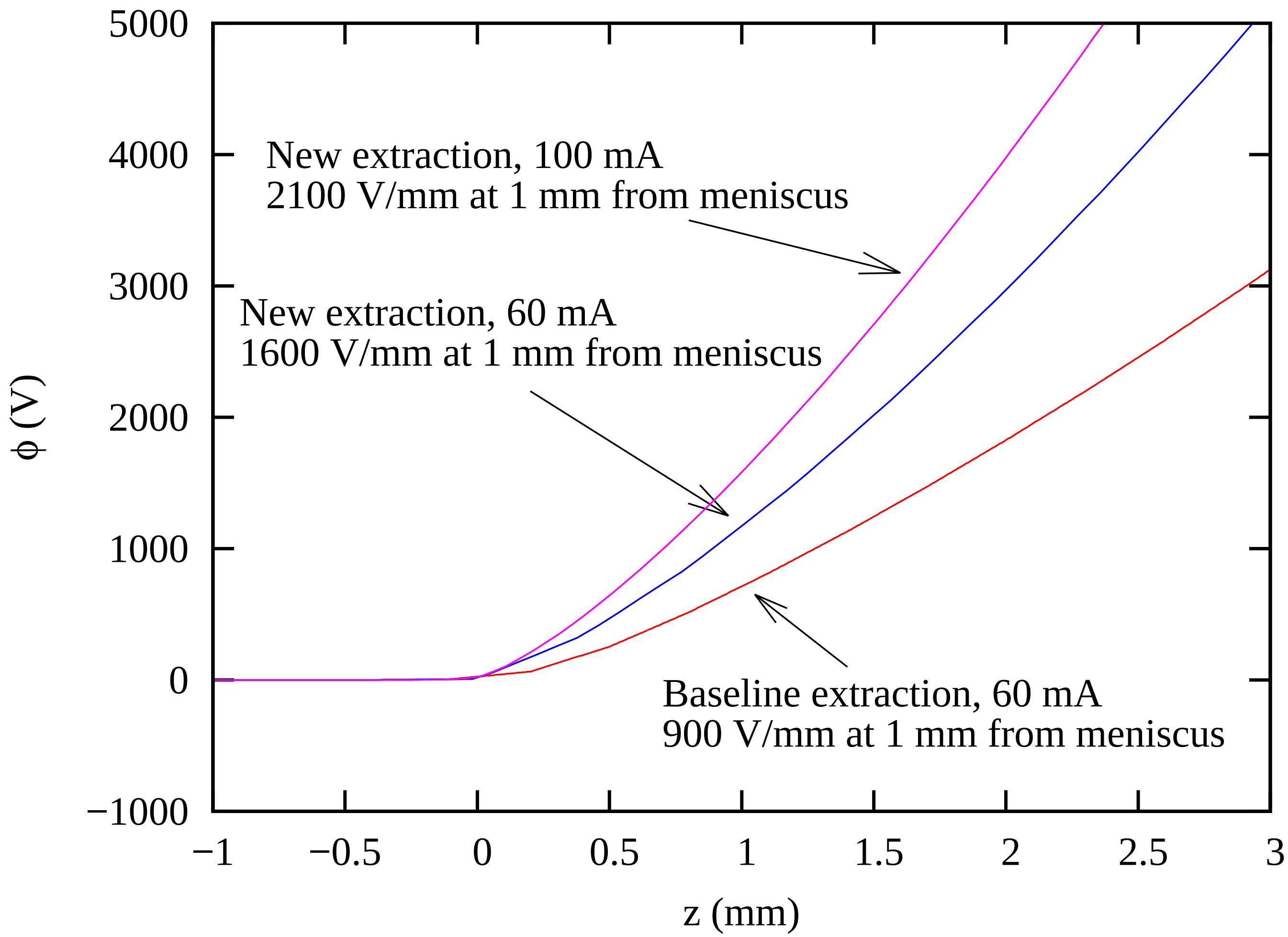
Proposed design



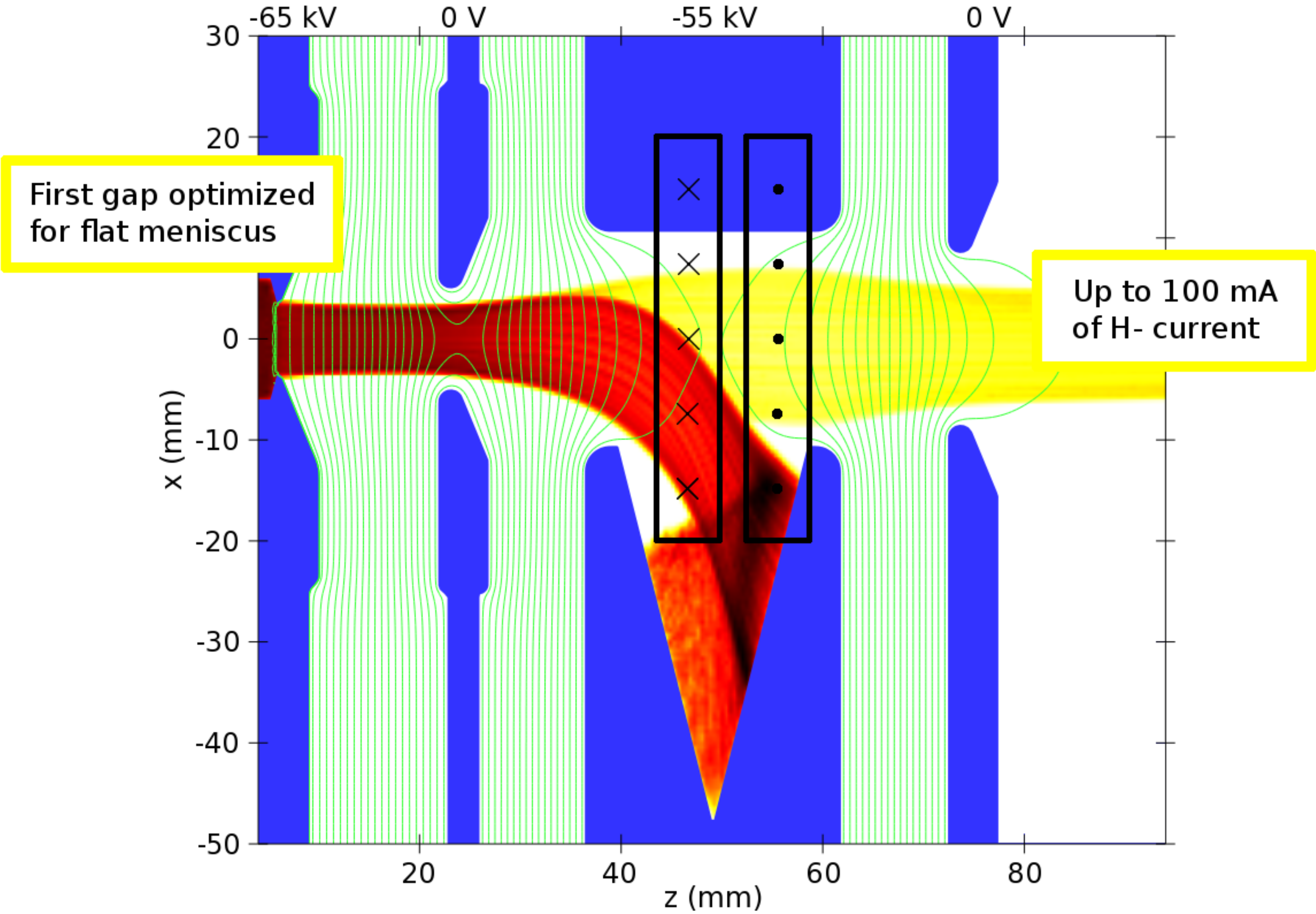
Proposed design



Extraction field



Proposed design



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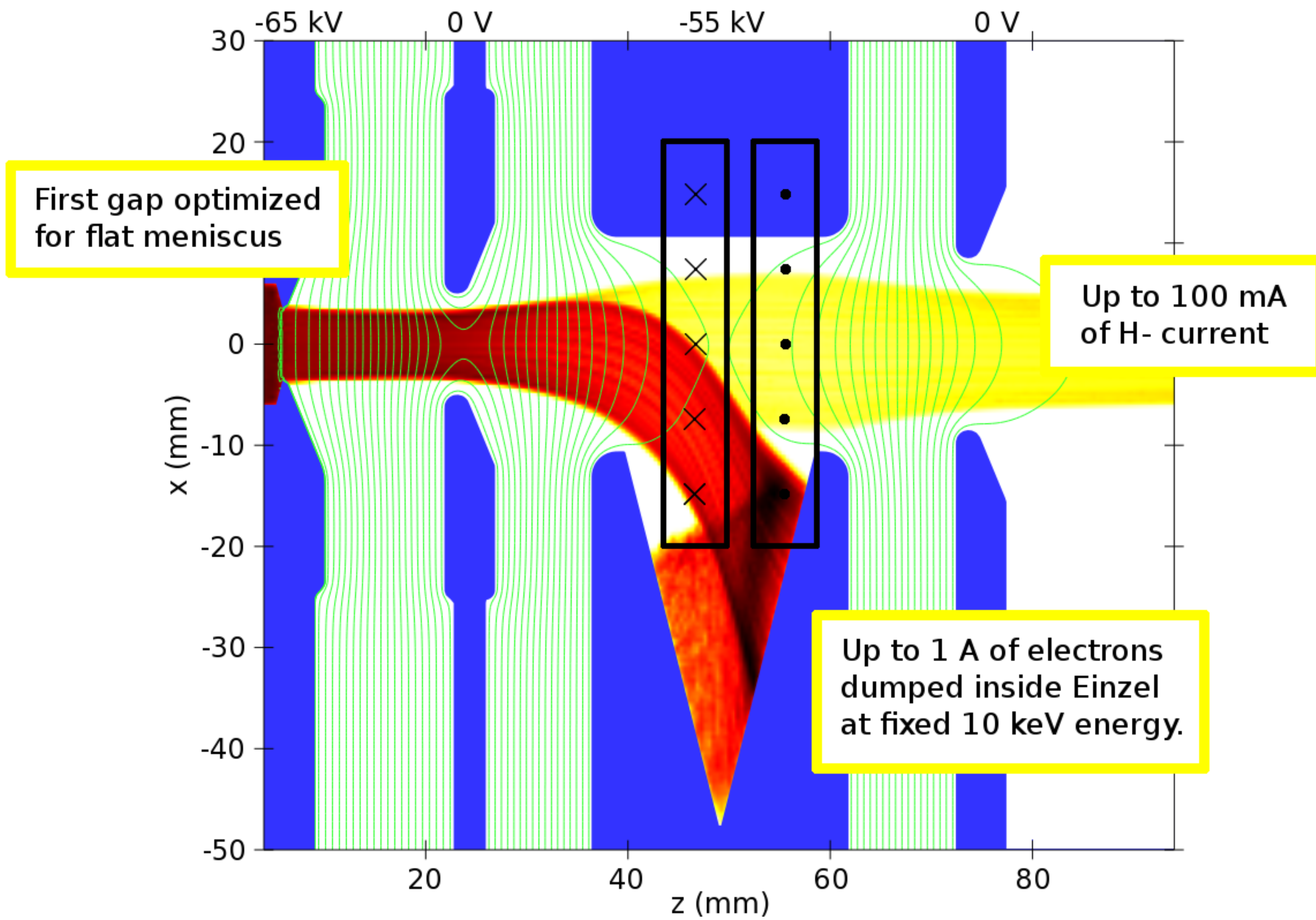
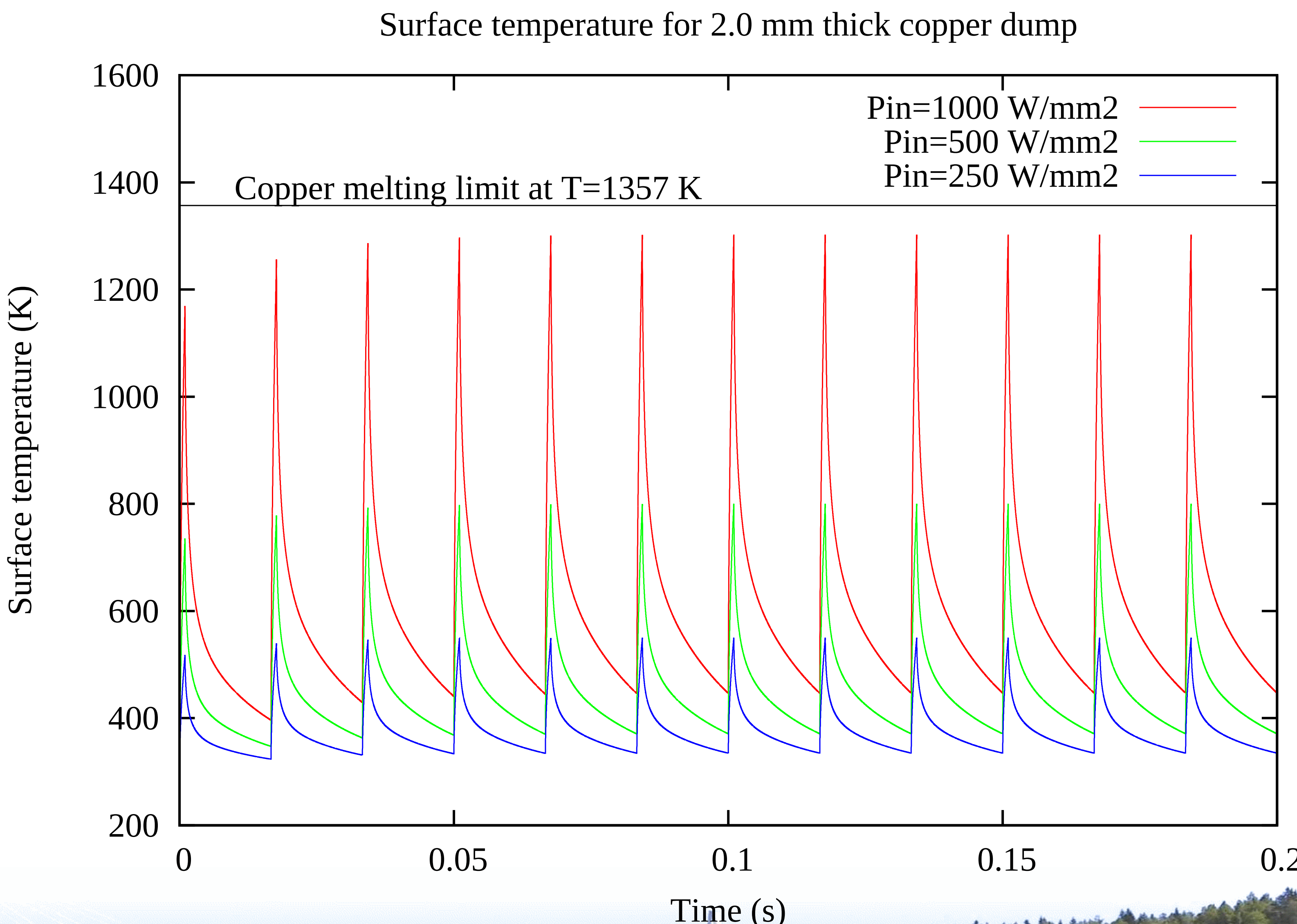
Proposed design



Thermal considerations



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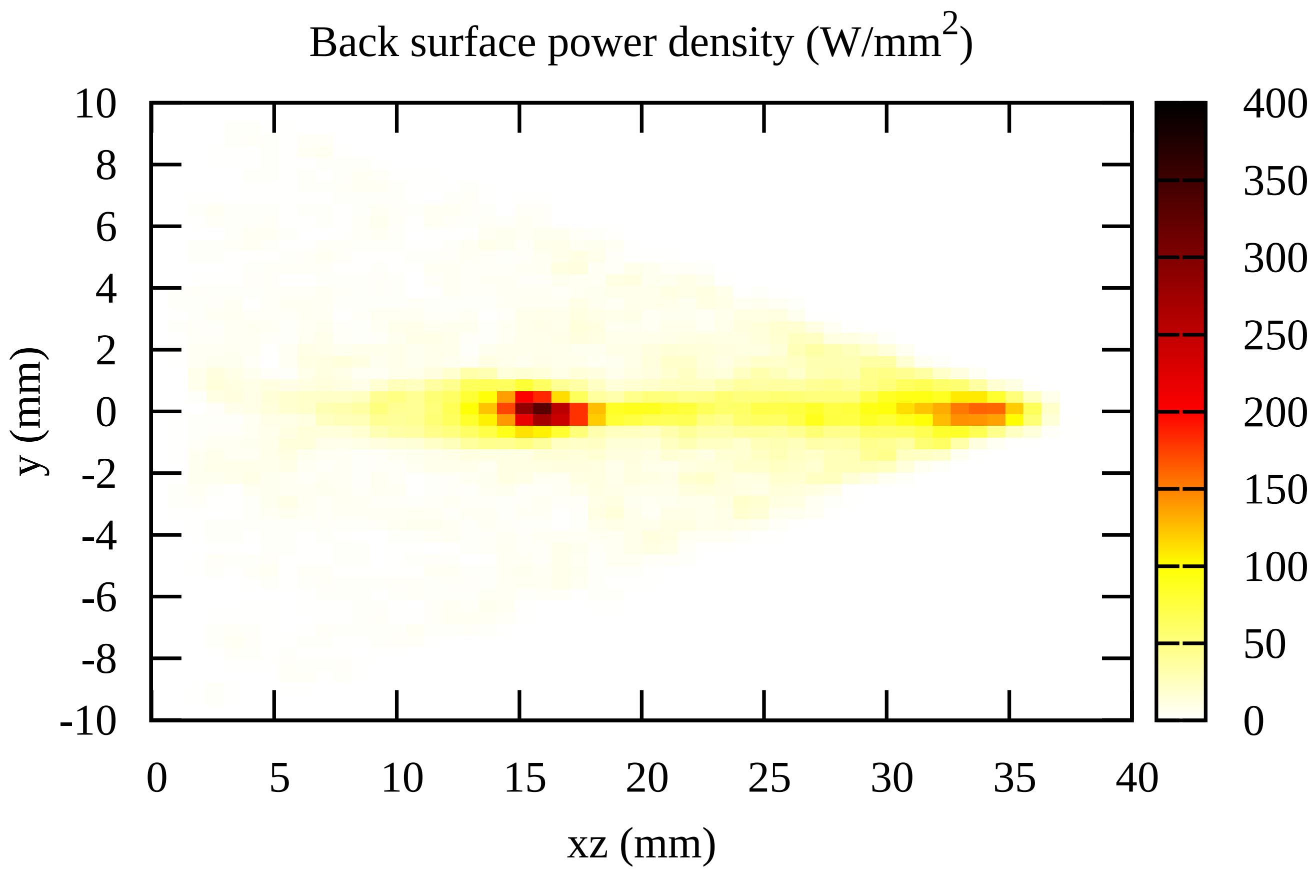
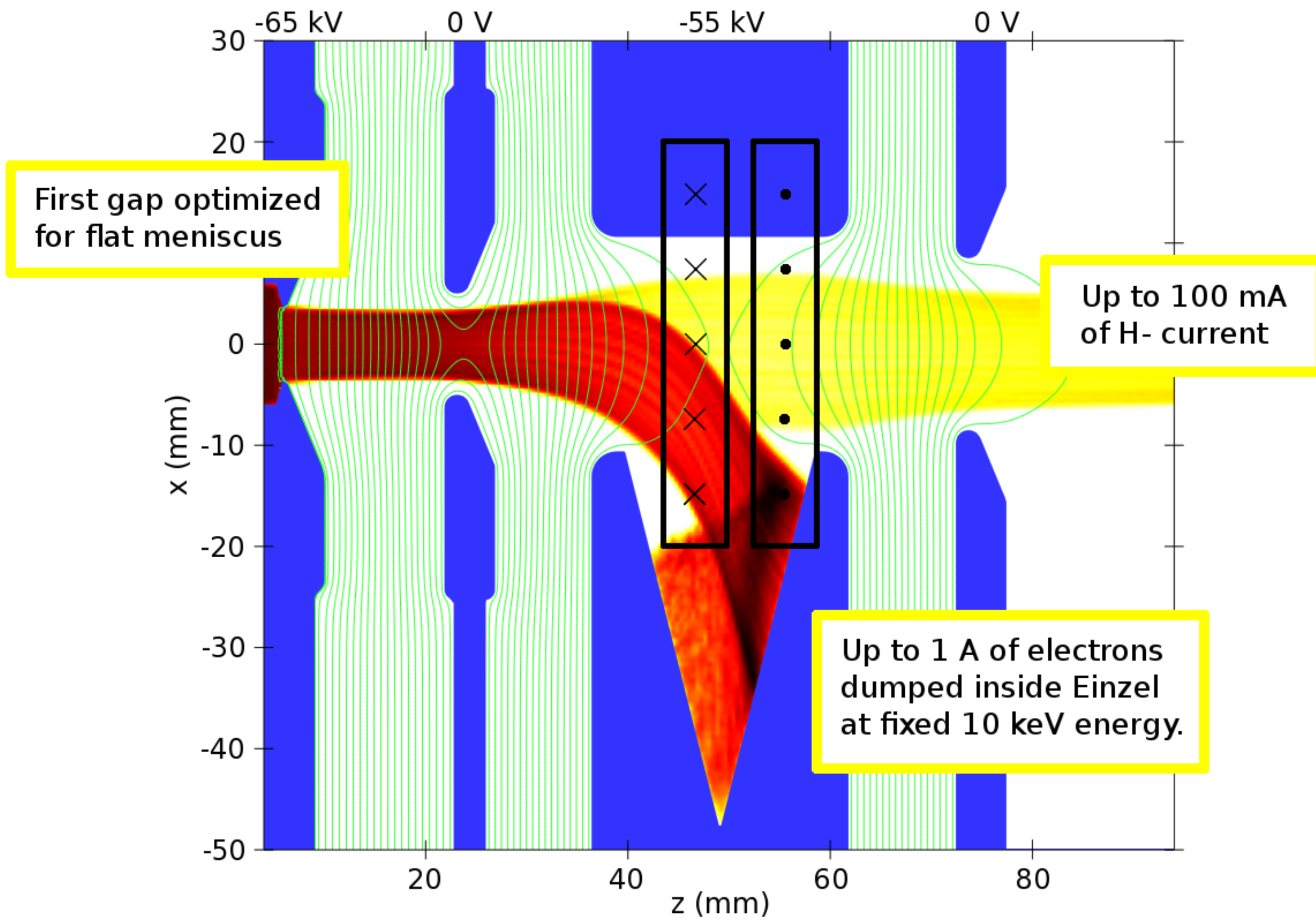
Power density on dump

Assuming 100 mA of H^- and e^- to H^- ratio of 10



Proposed design



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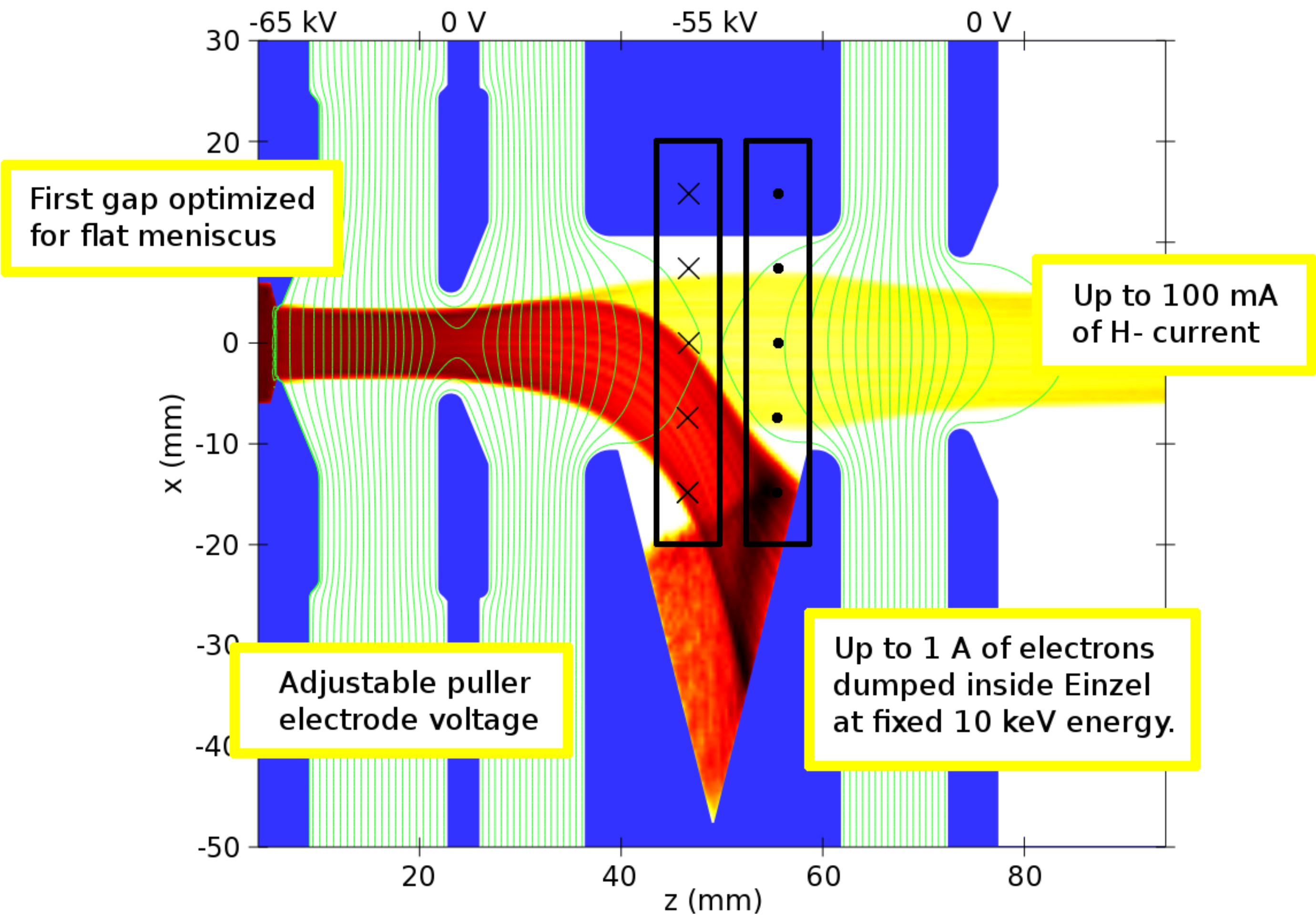
Proposed design



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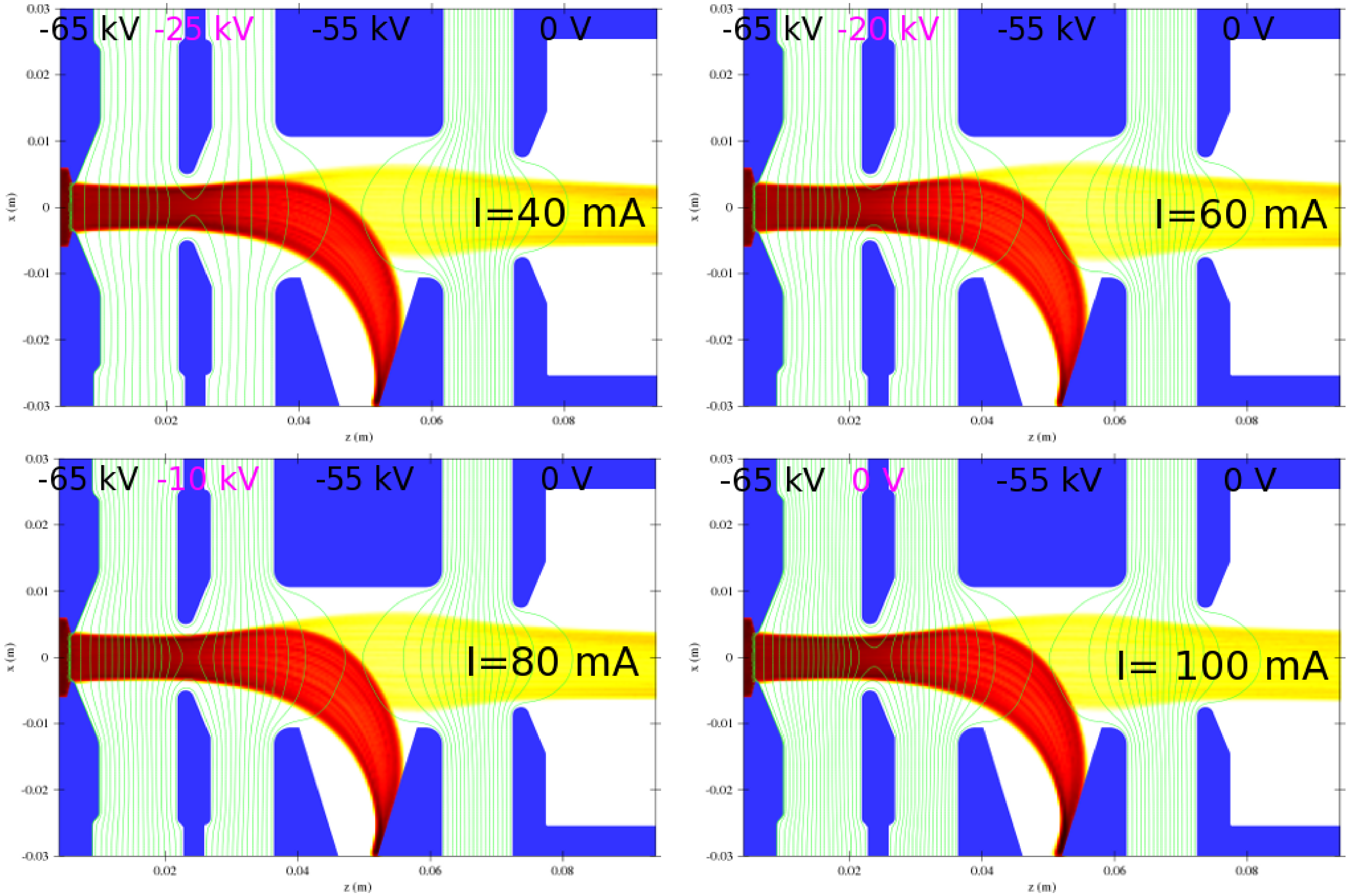
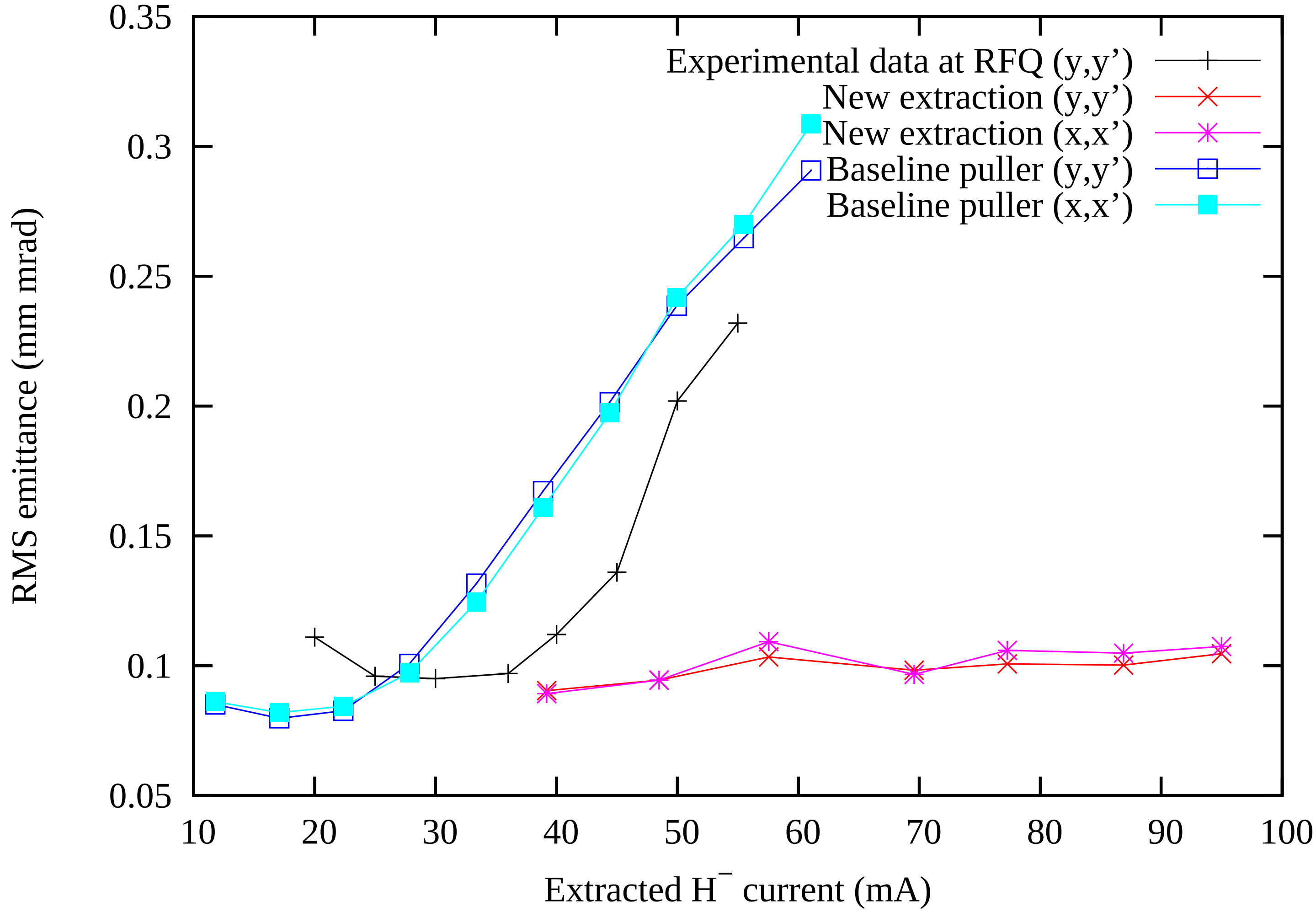
Puller voltage adjust

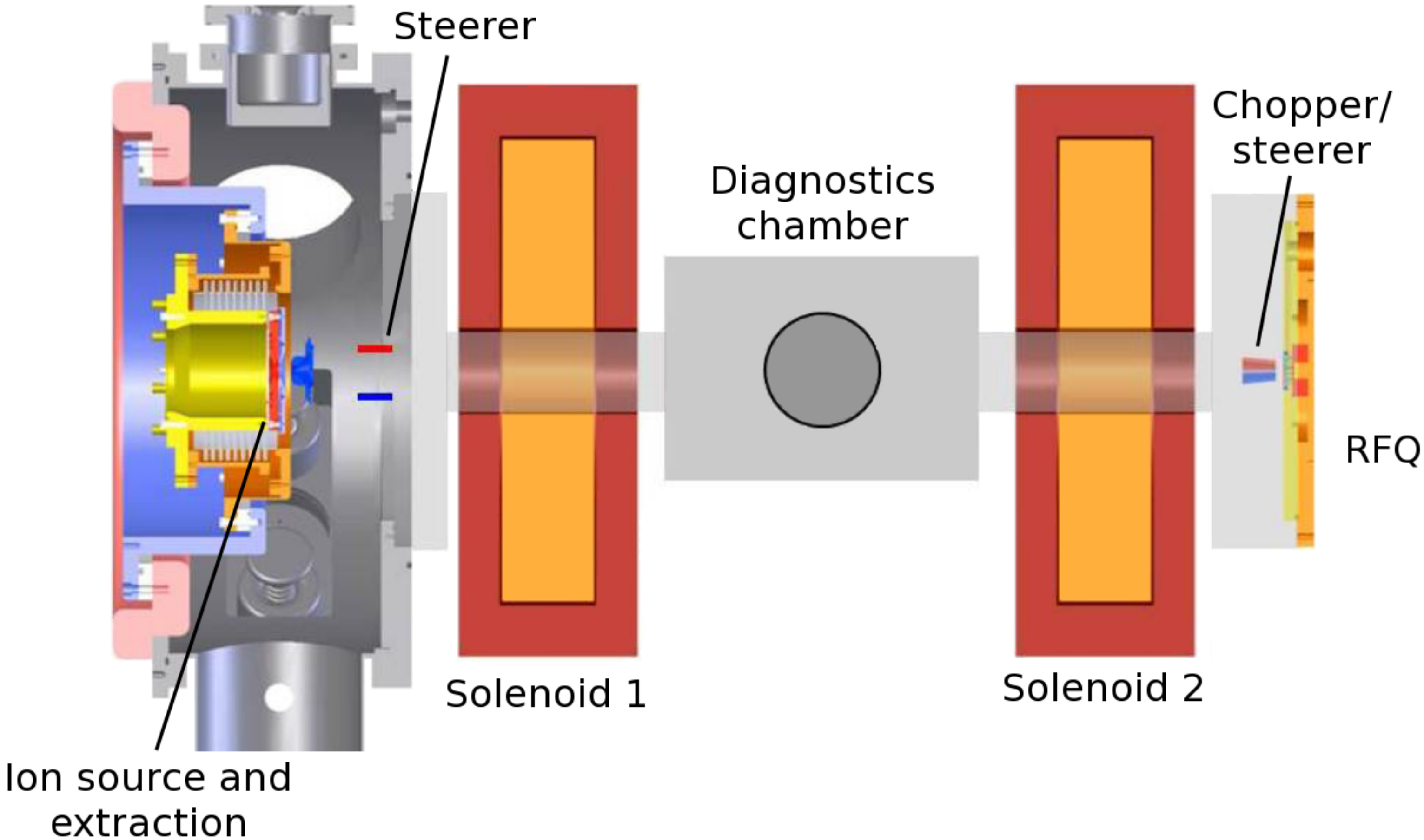


Emittance comparison



Magnetic LEBT

Designed at SNS and is currently at prototype stage

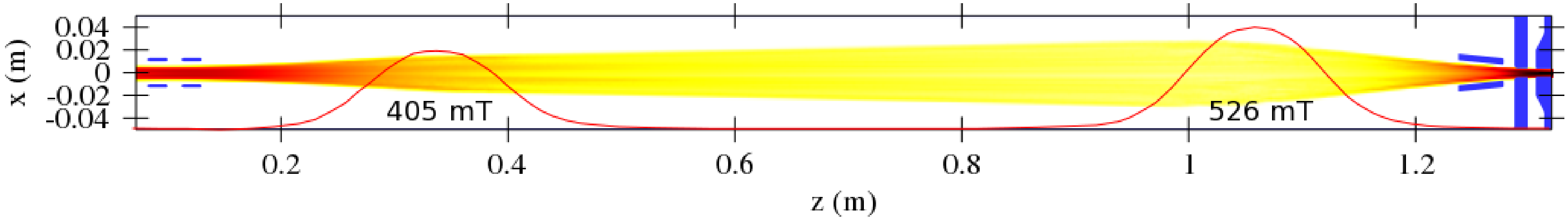


Magnetic LEBT simulations

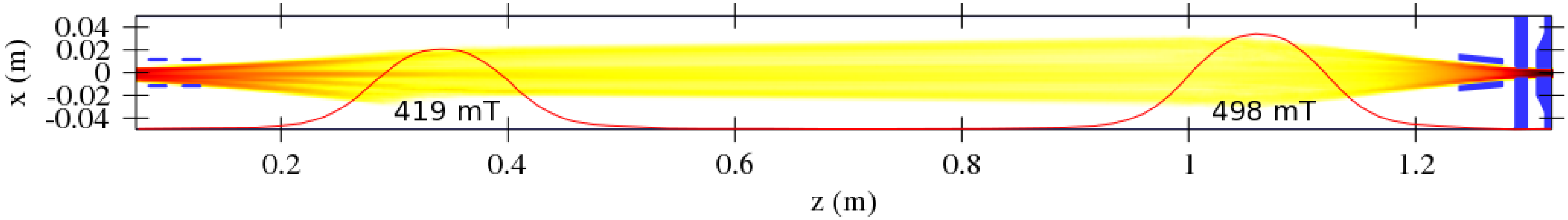
- Magnetic LEBT simulated with IBSimu using particle data from
  1. Baseline extraction up to puller electrode with angle and offset
  2. New extraction
- Particle distributions were centered with a pair of parallel plates.
- Magnetic field data calculated with FEMM.
- High degree of compensation was assumed.
- Solenoid currents were optimized to get Twiss $\alpha = 1.7$ and $\beta = 0.06$ m/rad at RFQ.

Magnetic LEBT simulations

Baseline extraction, 60 mA, 90 % compensation



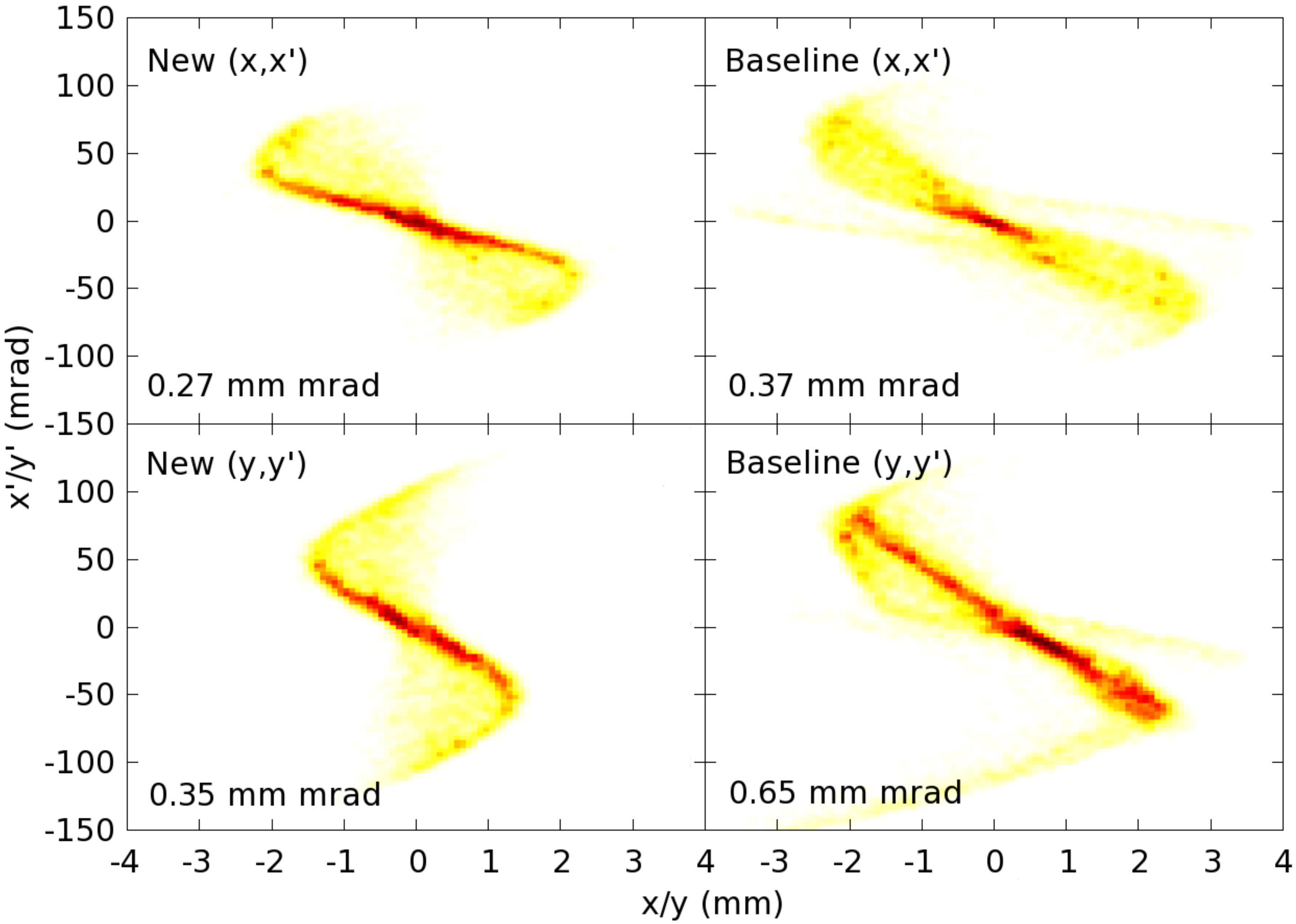
New extraction, 60 mA, 90 % compensation



New extraction:

- 80 mA inside RFQ acceptance with 90 % compensation
- 100 mA inside RFQ acceptance with 95 % compensation
- New extraction is compatible with magnetic LEBT.

Emittance comparison at RFQ



Comparisons of emittance numbers should be done with caution.

Summary

Bottom line: New extraction has more potential than baseline extraction.

- Gives lower emittance beam at currents higher than 40 mA.
- Possibly increases beam intensity from source.
- Work need to be done to increase safety factor of electron dump.
- Hopefully prototype will be soon built.

Thank you for your attention!

Please notice that the 3rd International Symposium on
Negative Ions, Beams and Sources is at Jyväskylä in September 2012.

http://www.nibs2012.jyu.fi/