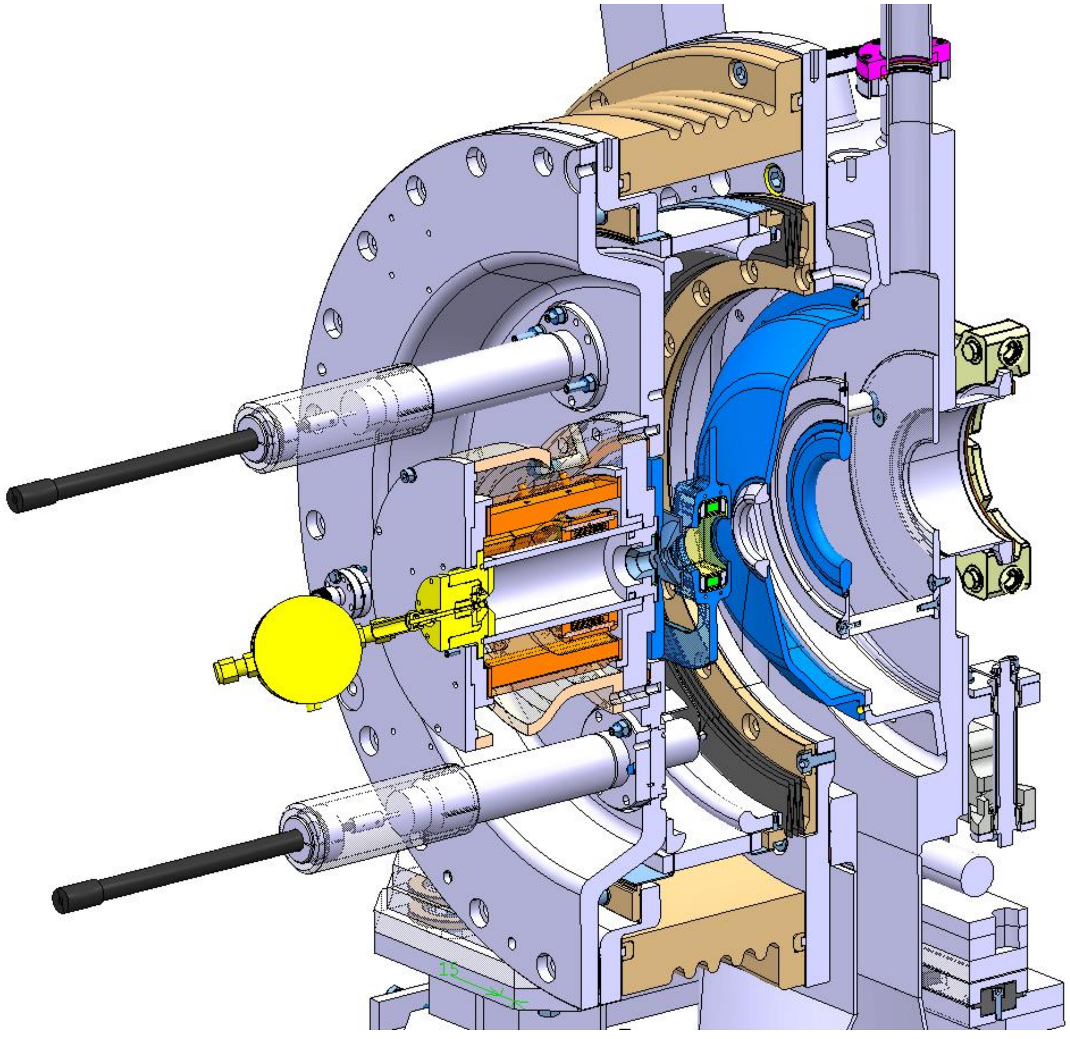
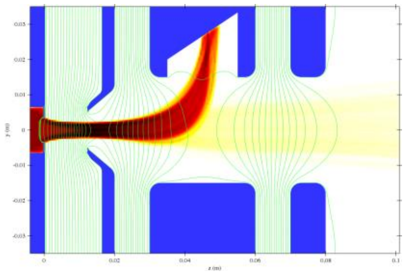
Linac4 ion source review
Beam optics simulations and measurements



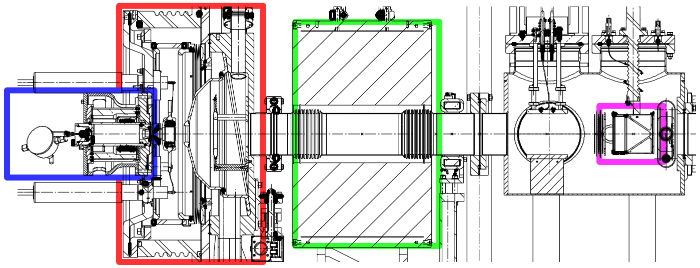
Øystein Midttun
European Organization for Nuclear Research
University of Oslo

14.11.2013

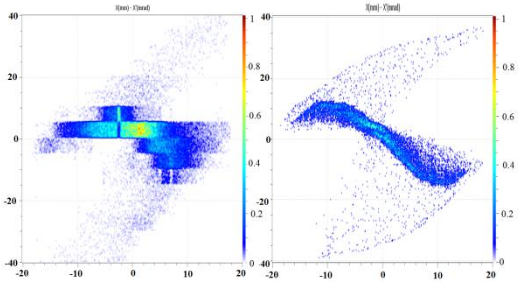
This presentations compares H^- beam simulations and measurements, and proposes improvements



Ion beam extraction system



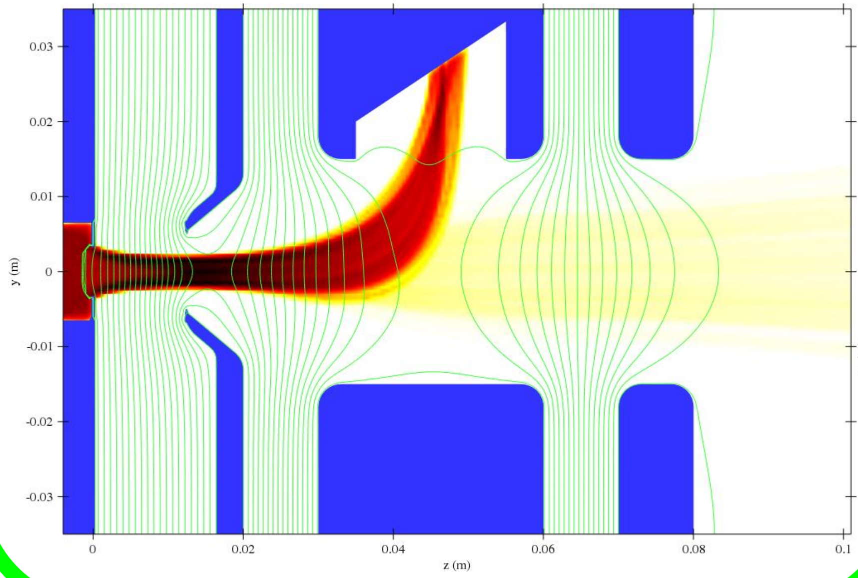
Benchmarking of simulations



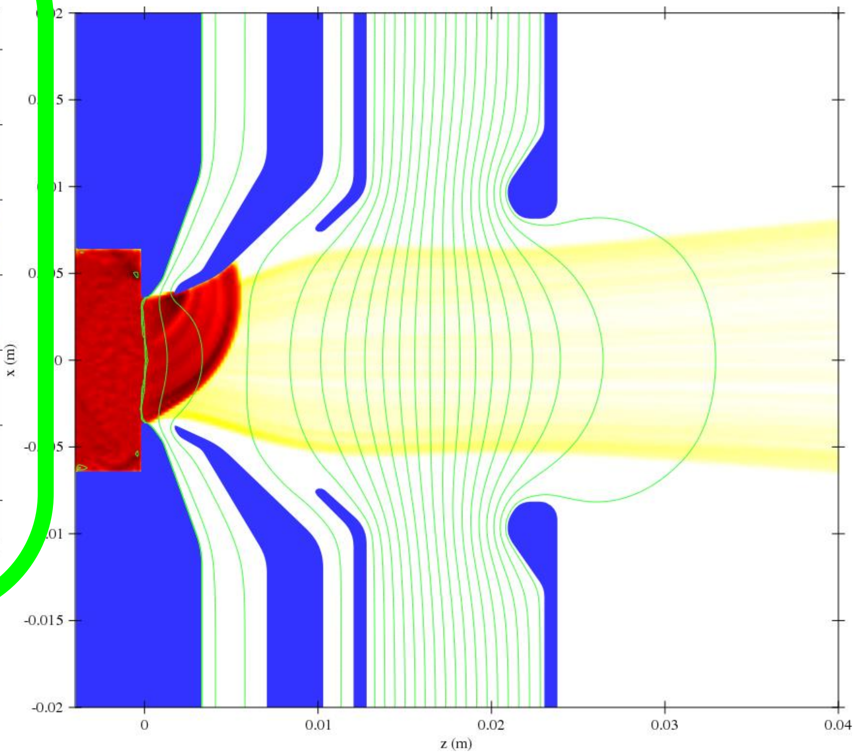
Emittance improvements

Two extraction systems were compared with emphasis on low electron power density and low H^- beam divergence

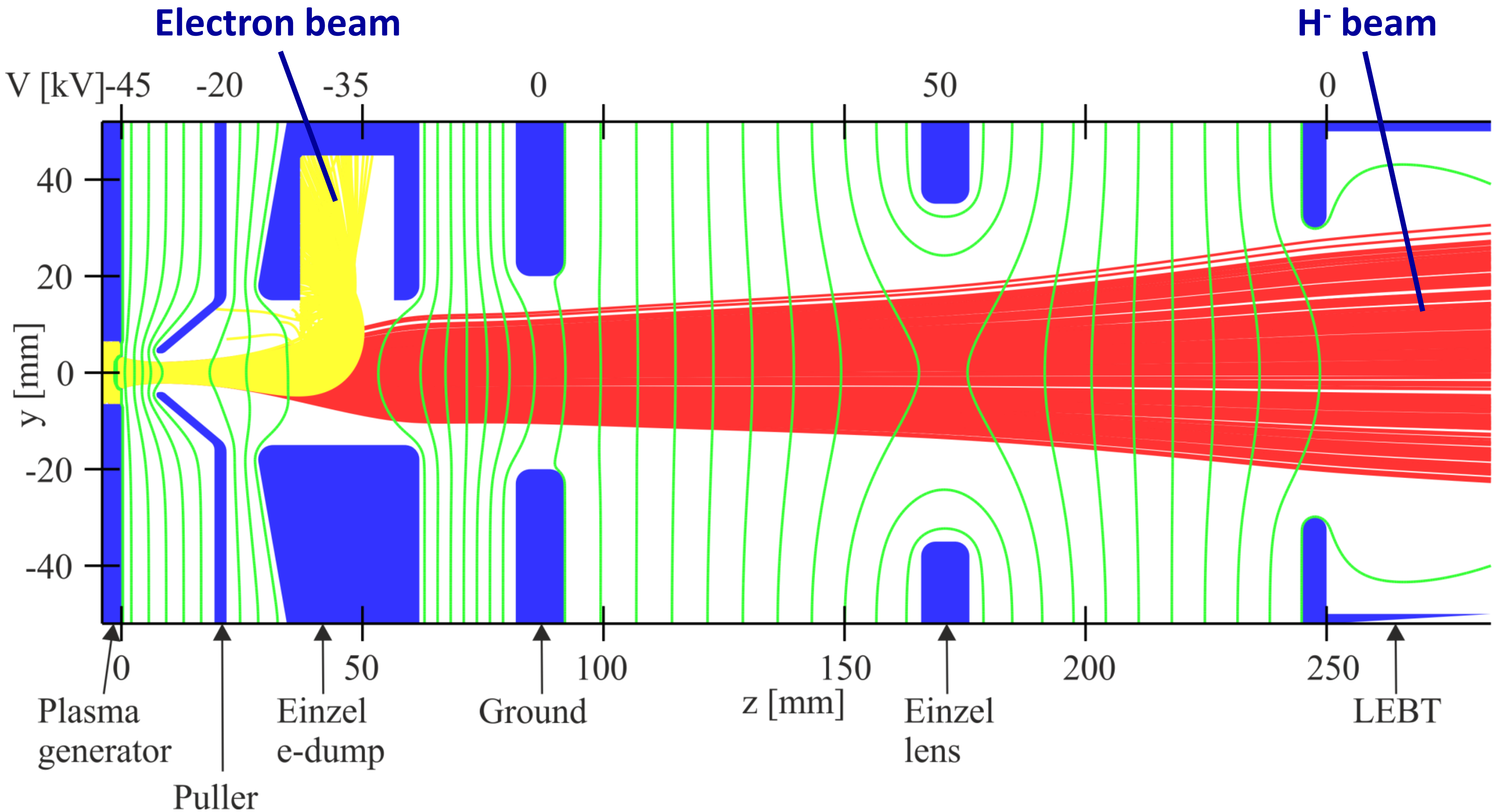
1. e^- dump in magnetized Einzel lens



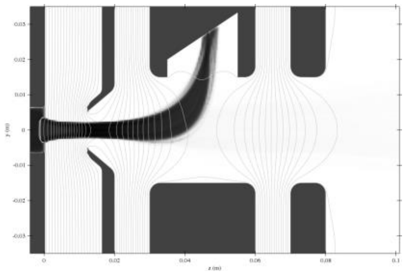
2. e^- dump in intermediate electrode



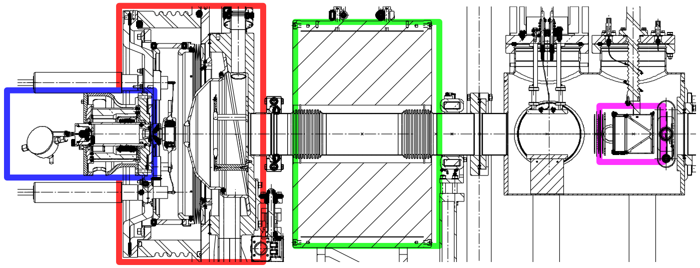
The new extraction system uses a magnetized Einzel lens to dump co-extracted electrons



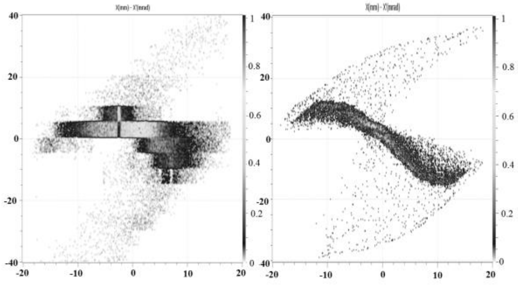
The electrons are dumped with an energy of 10 keV, and spread over a large surface to reduce the power density



Ion beam extraction system

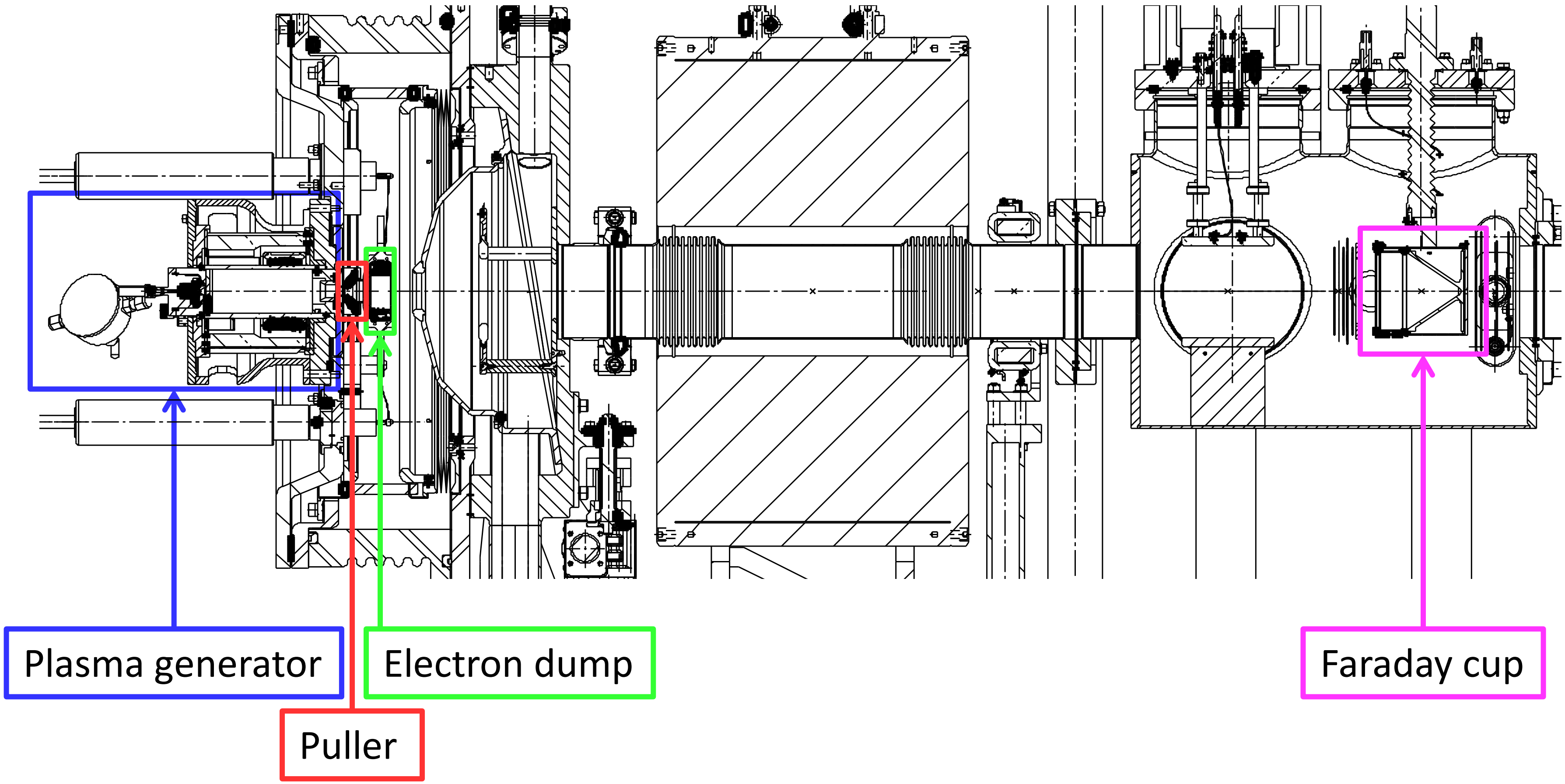


Benchmarking of simulations

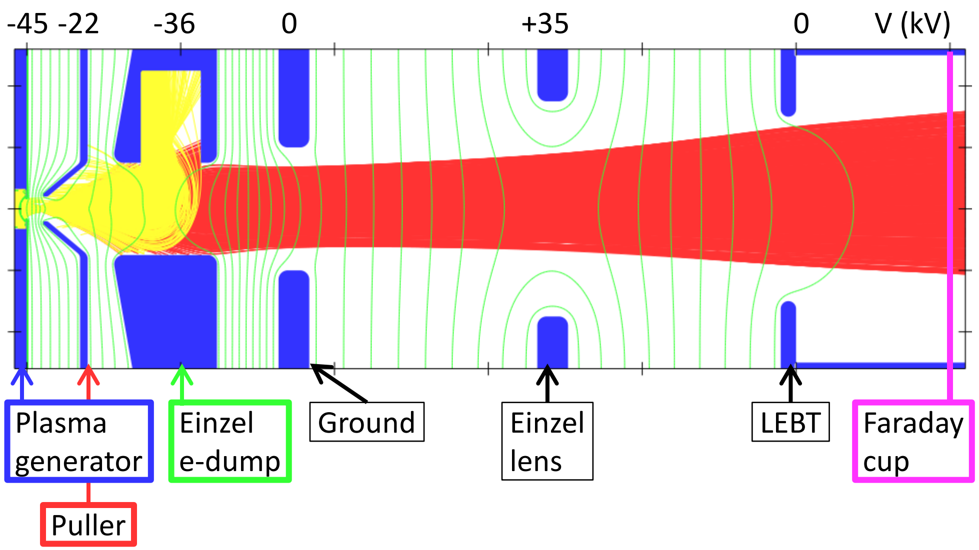


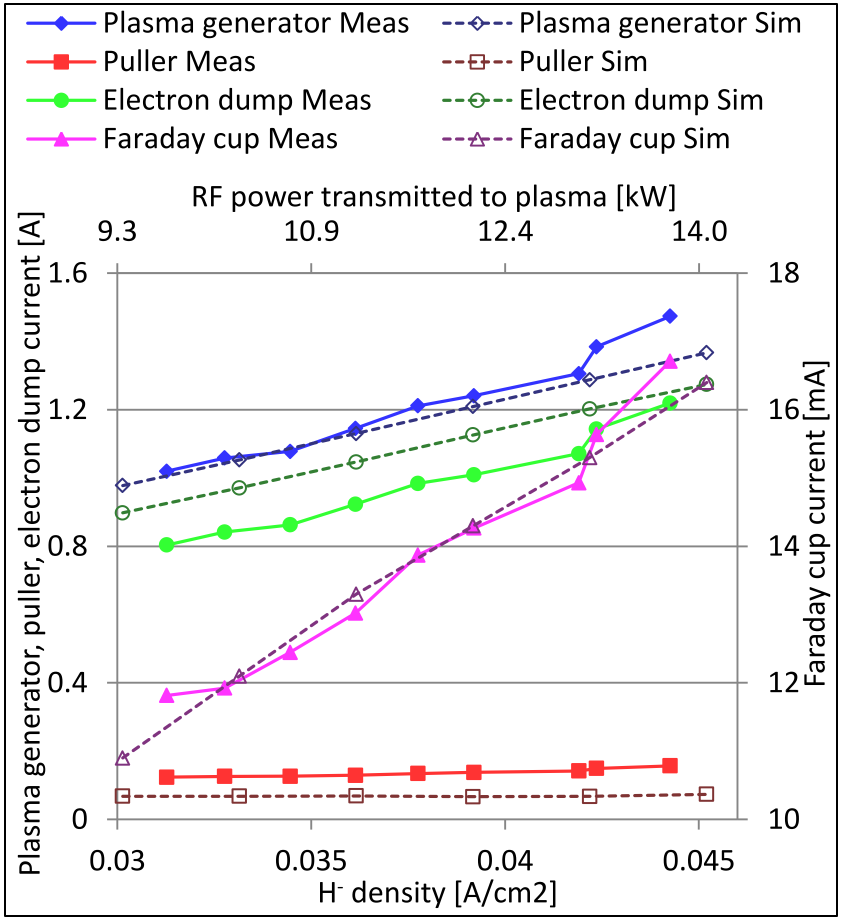
Emittance improvements

The comparison to simulations has been made by using the currents measured on four electrodes



RF-power changes the H^- density in the plasma, thus the extracted beam current

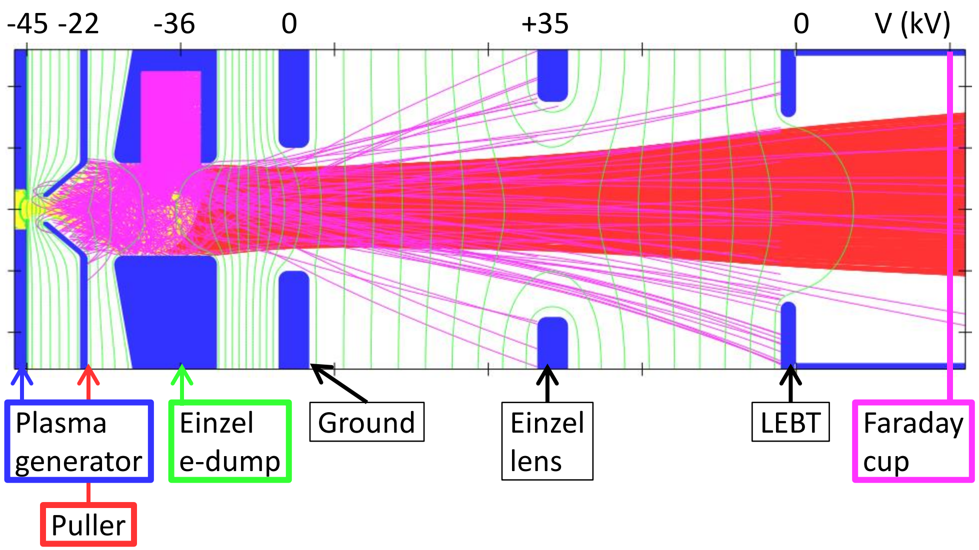


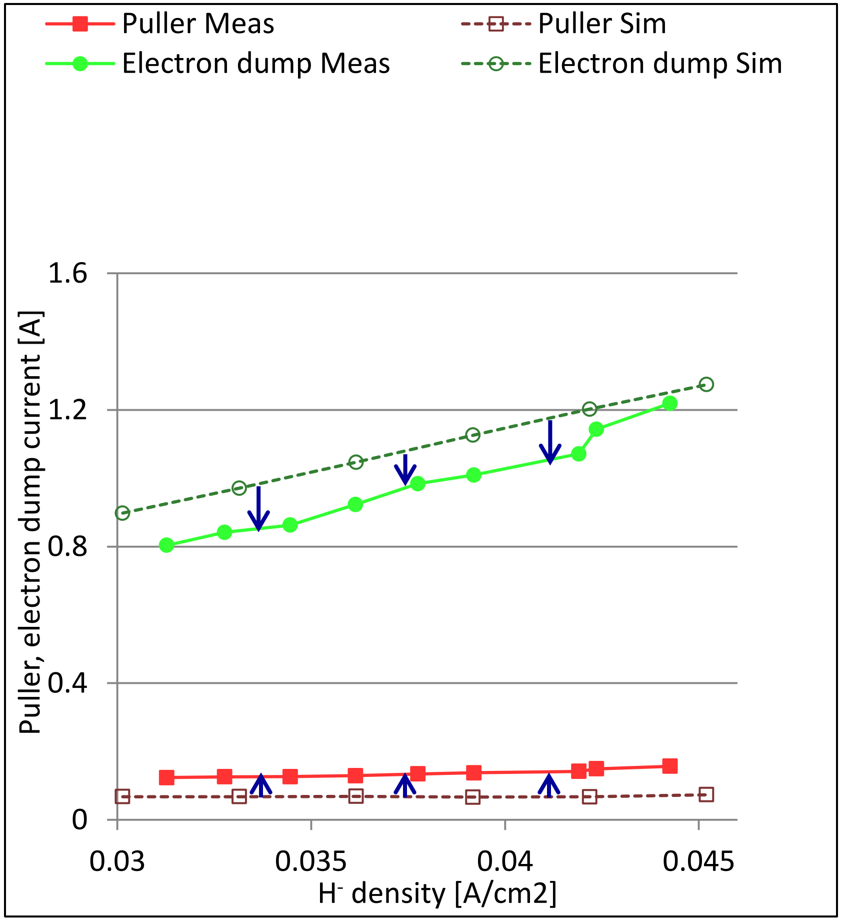


Linear scaling between

- **RF-power (measurement)**
- **H^- density (simulation)**

The simulations of the puller and electron dump current do not correspond to the measured values

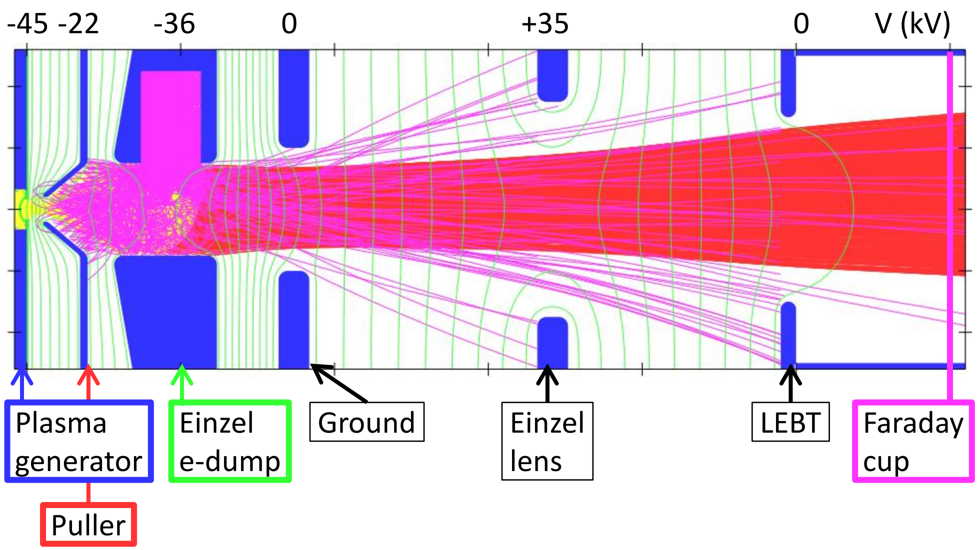




Secondary electrons emitted from the electron dump

- **Reduce the current measured on the electron dump**
- **Increase the current on the puller**

The simulations fit the measurement data when secondary electron emission from the electron dump is considered



Secondary electrons emitted from the electron dump

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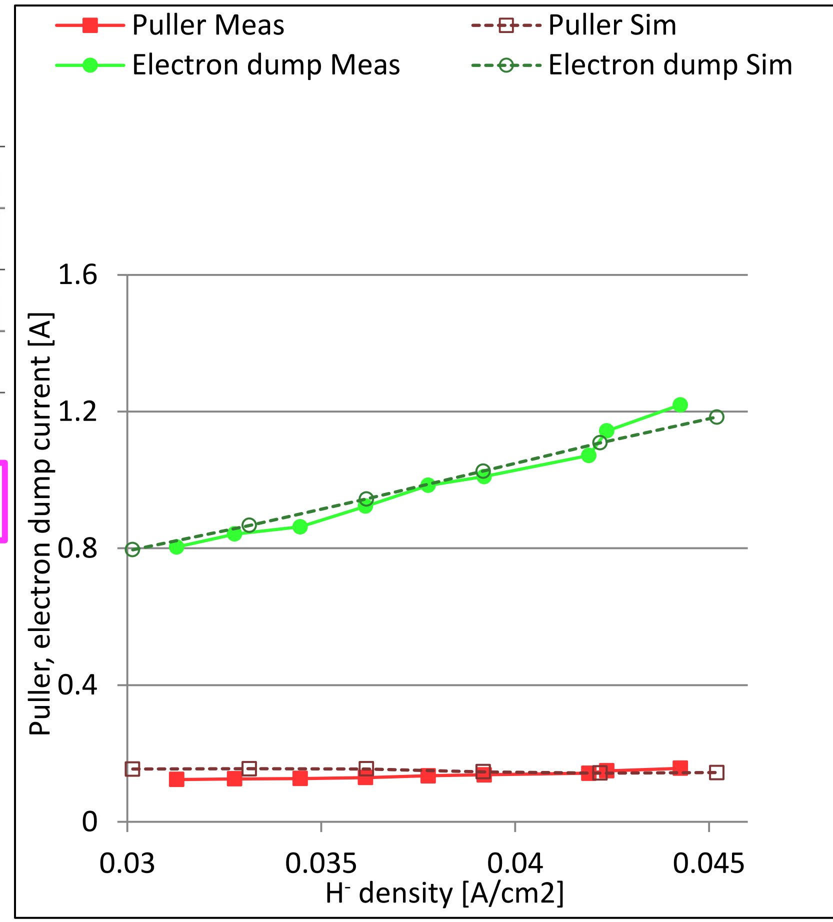
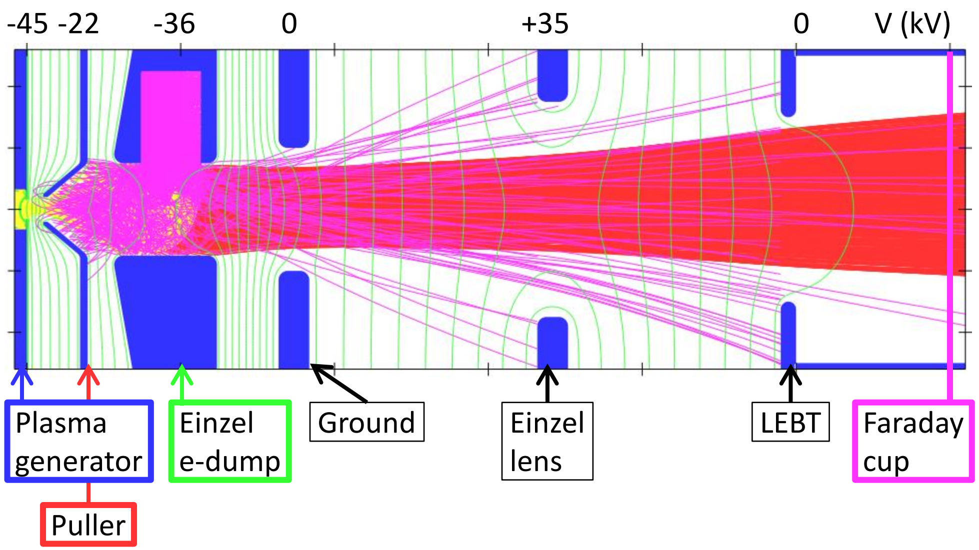
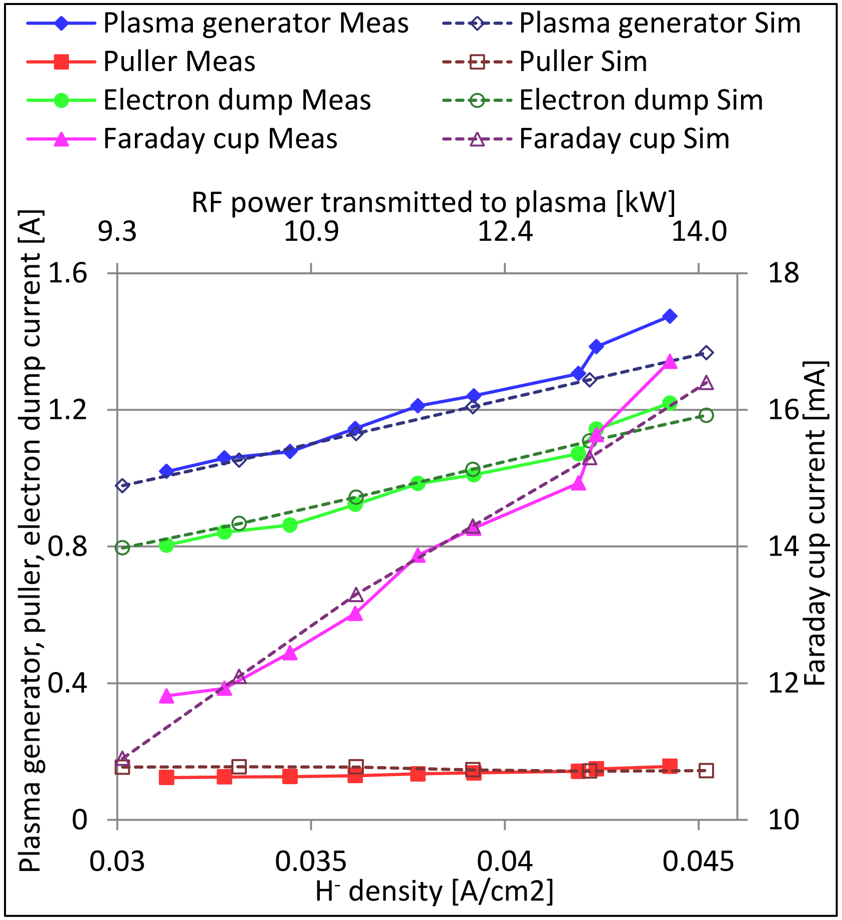


The H⁻ beam extraction has been reproduced for a varying RF-power, with secondary electron emission included in the simulations

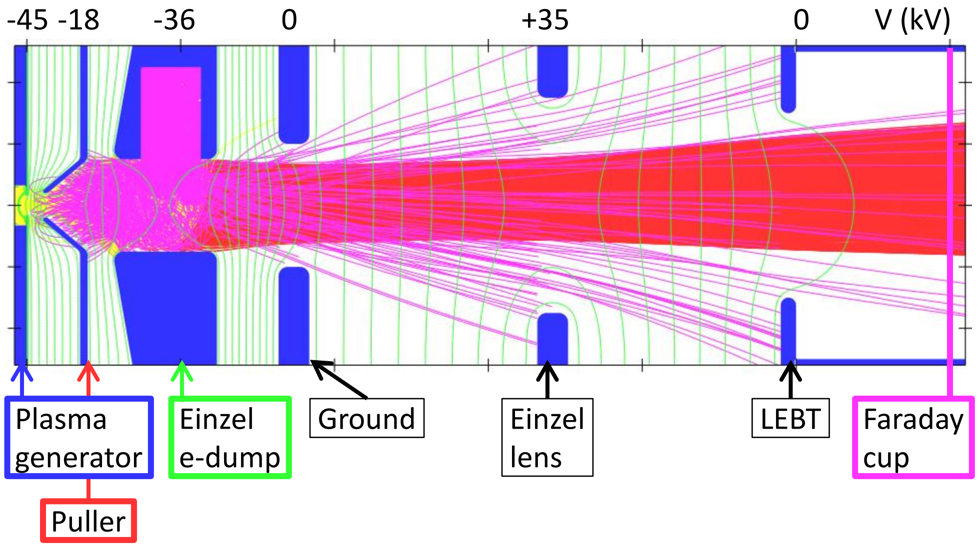


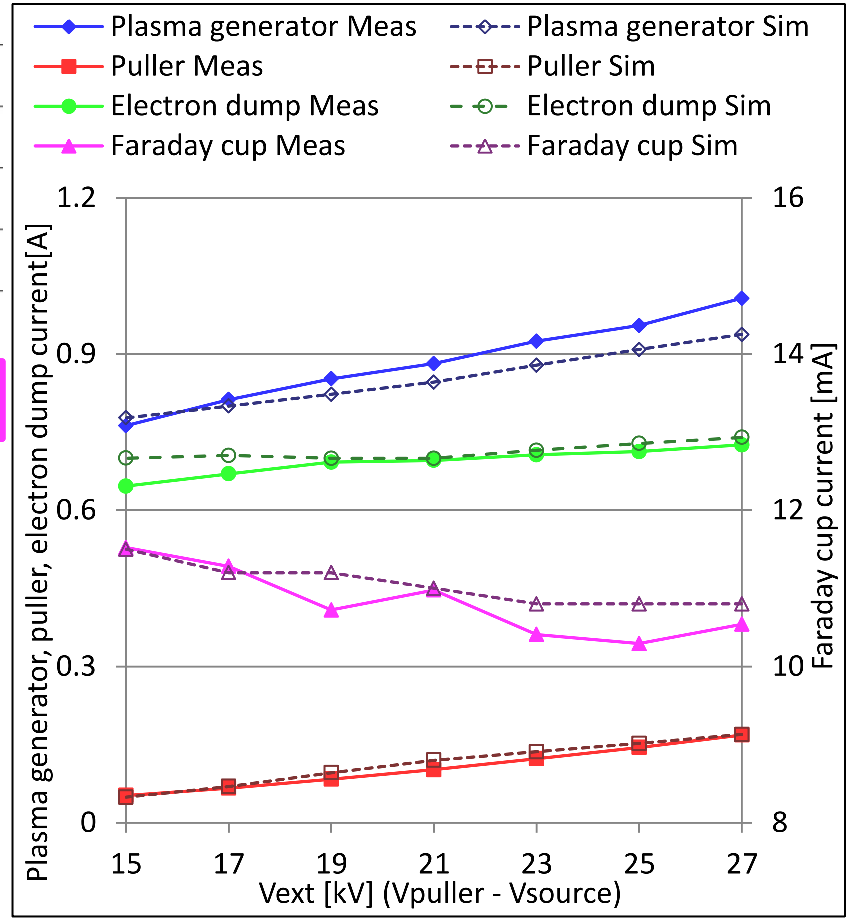


Linear scaling between

- **RF-power (measurement)**
- **H^- density (simulation)**

The puller voltage defines the electric extraction field, and can be used to tune the beam optics





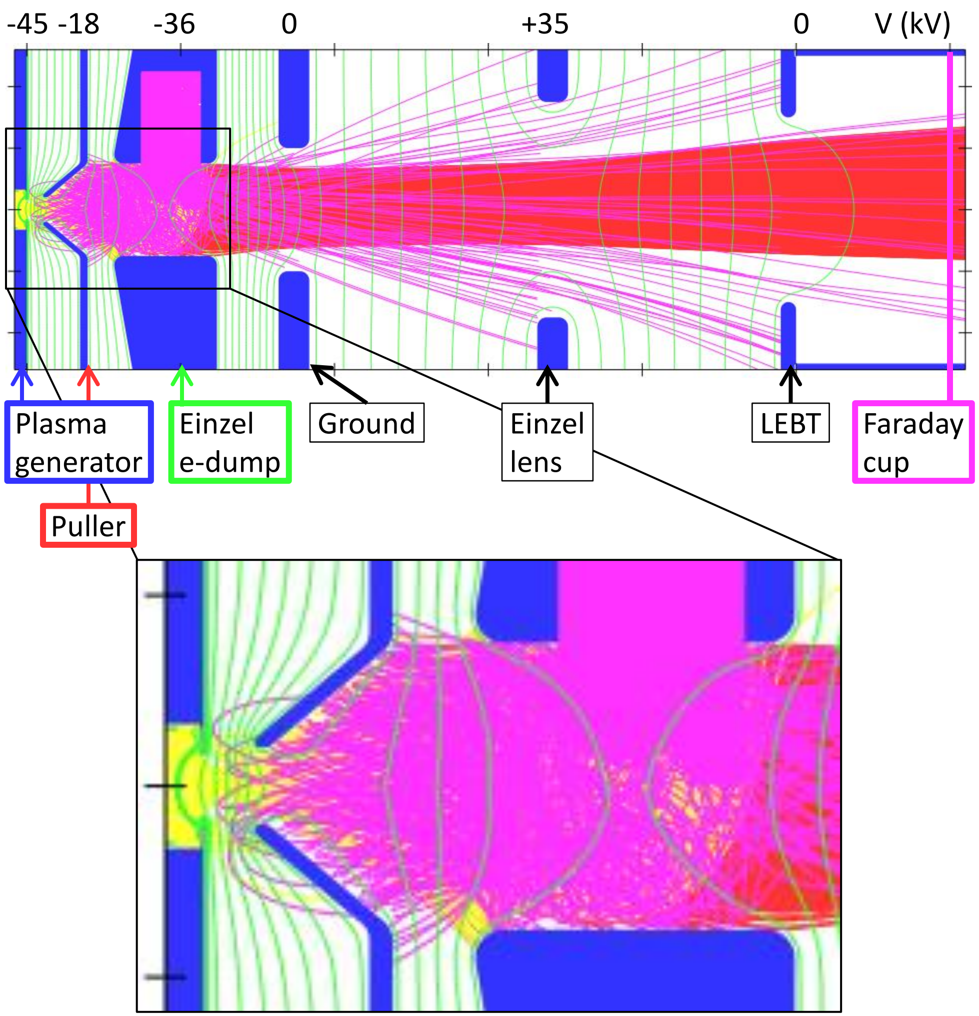
Plasma generator current increases with higher extraction voltage

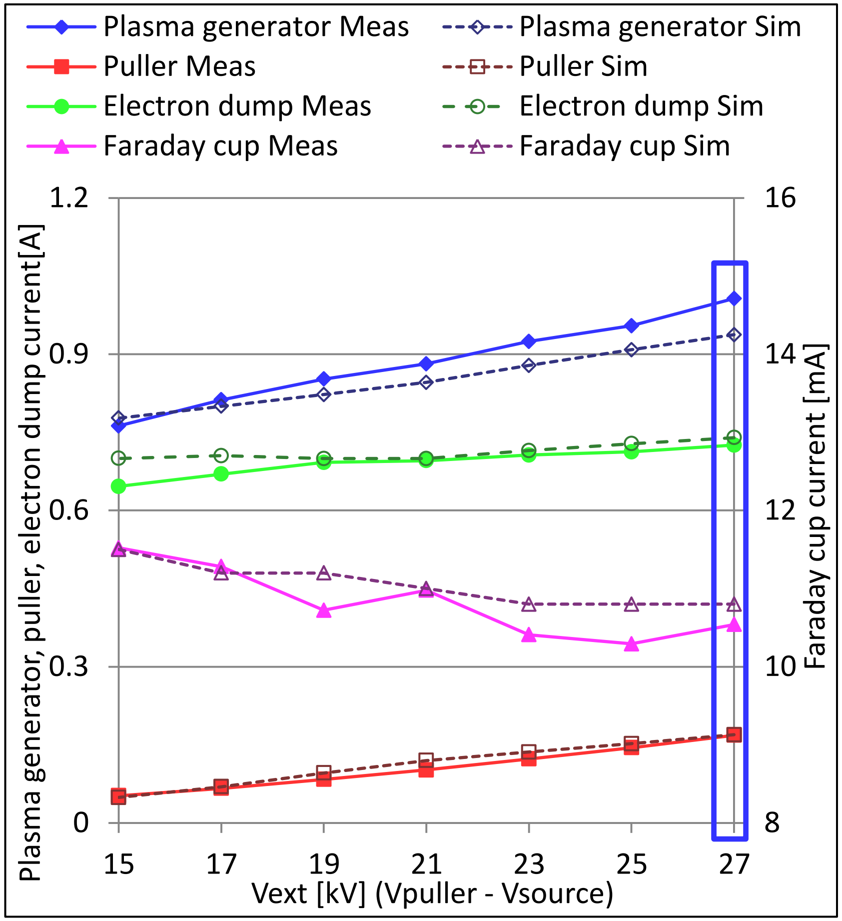
- **Increased plasma meniscus surface**

Measured current increases slightly more than the simulated one

- **Density varies as a function of the depth of the plasma**

The puller voltage defines the electric extraction field, and can be used to tune the beam optics





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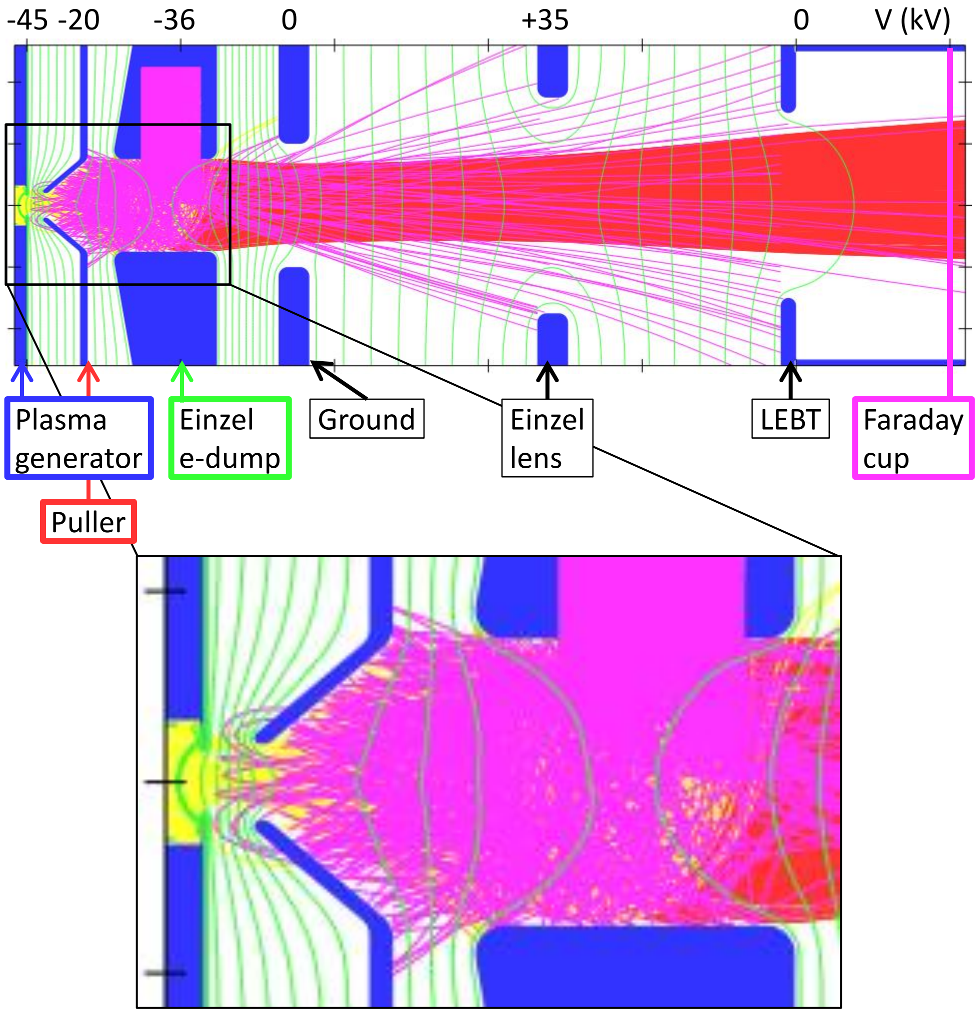

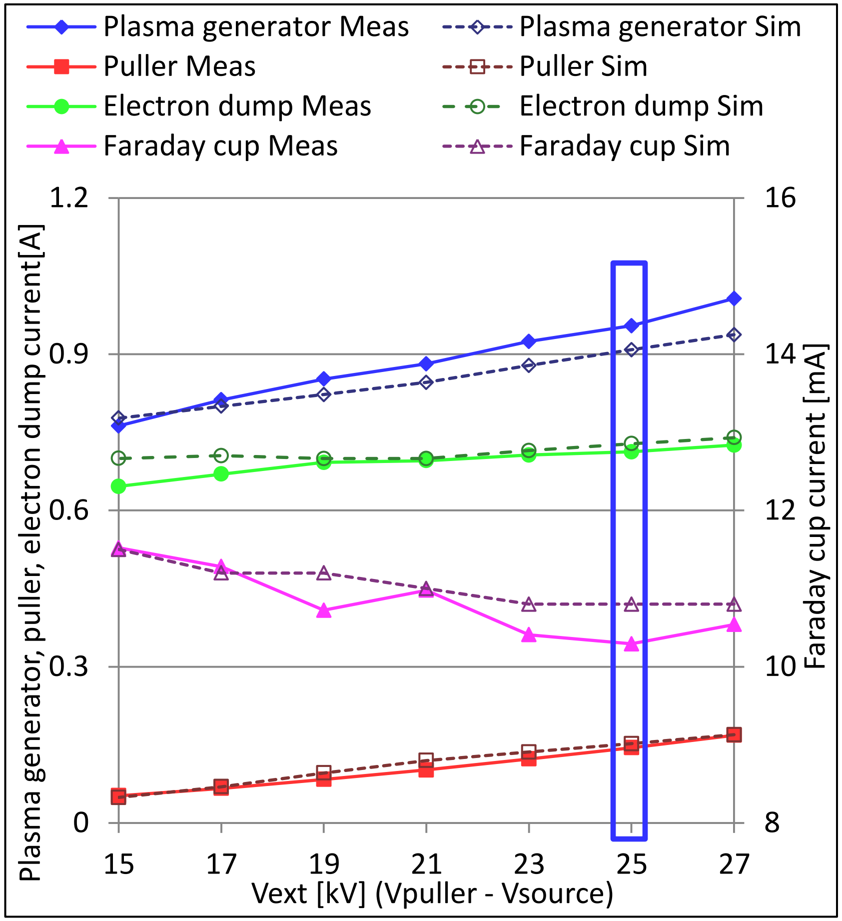

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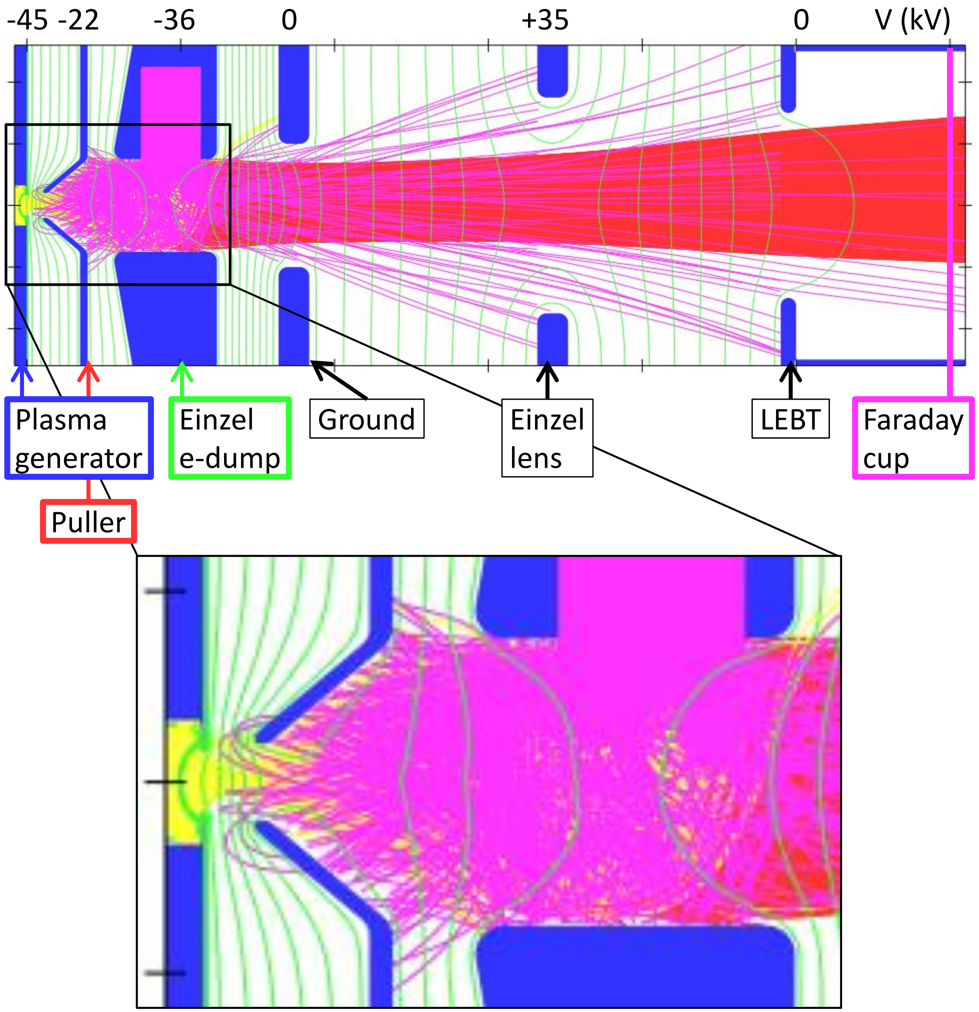

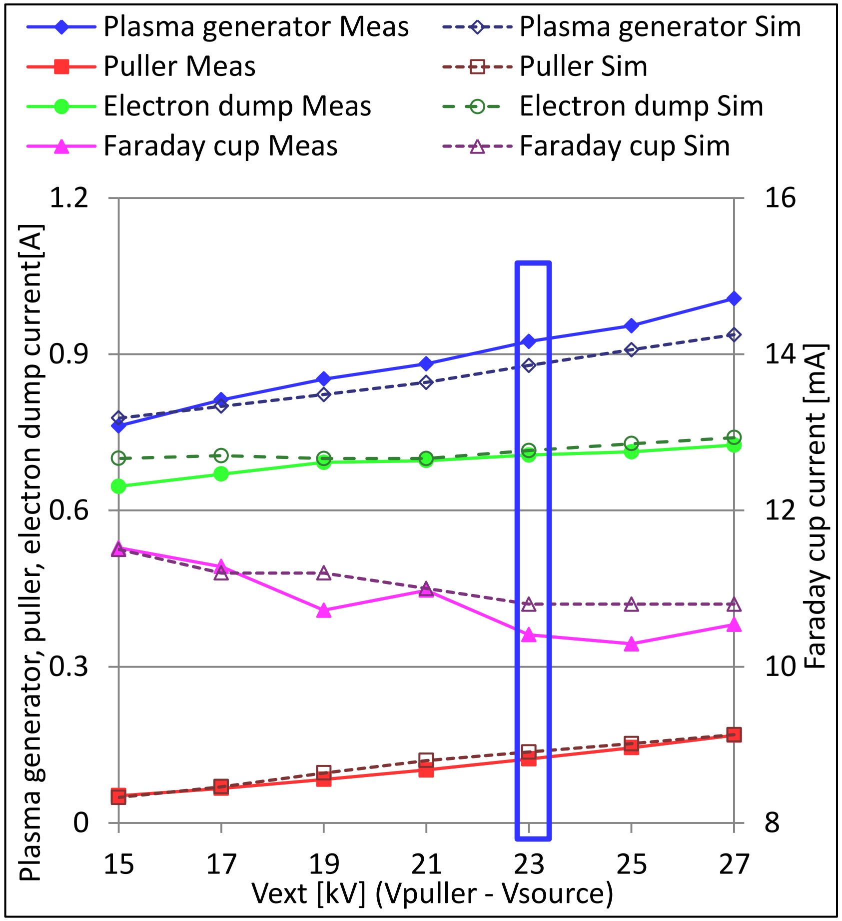

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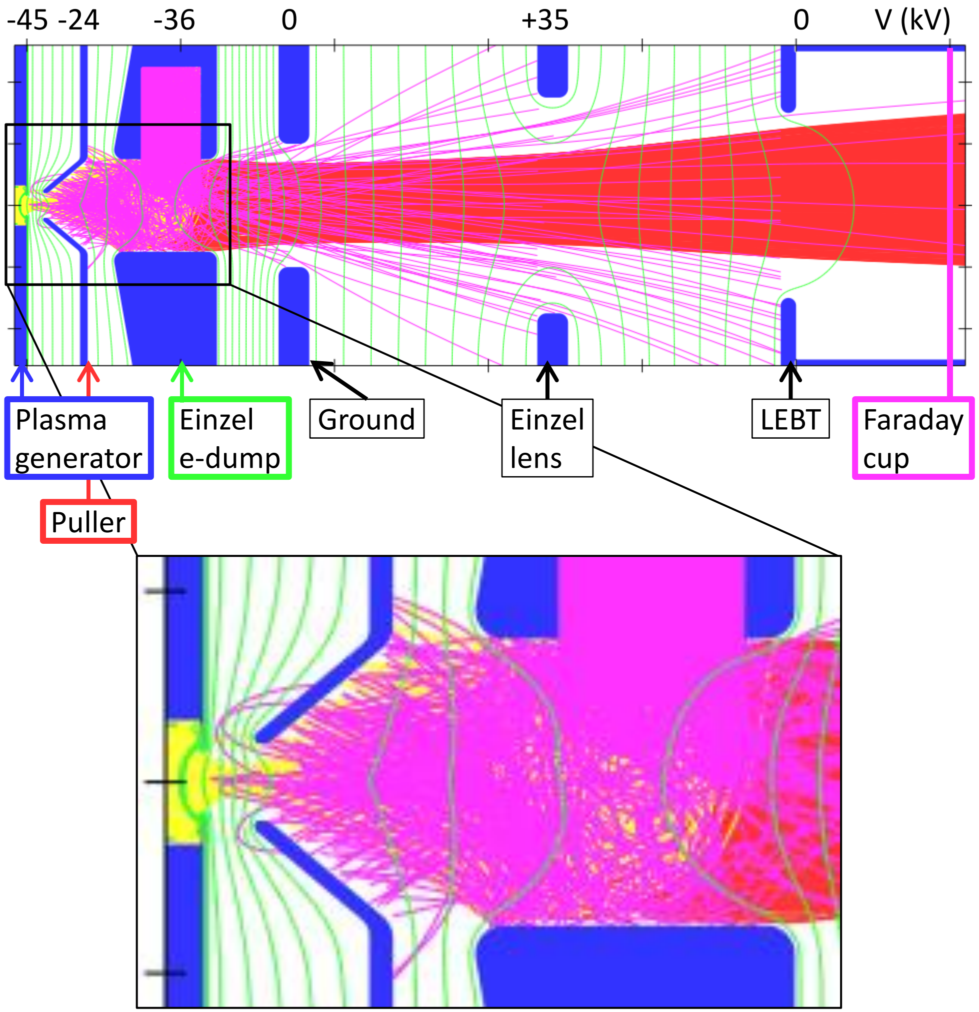

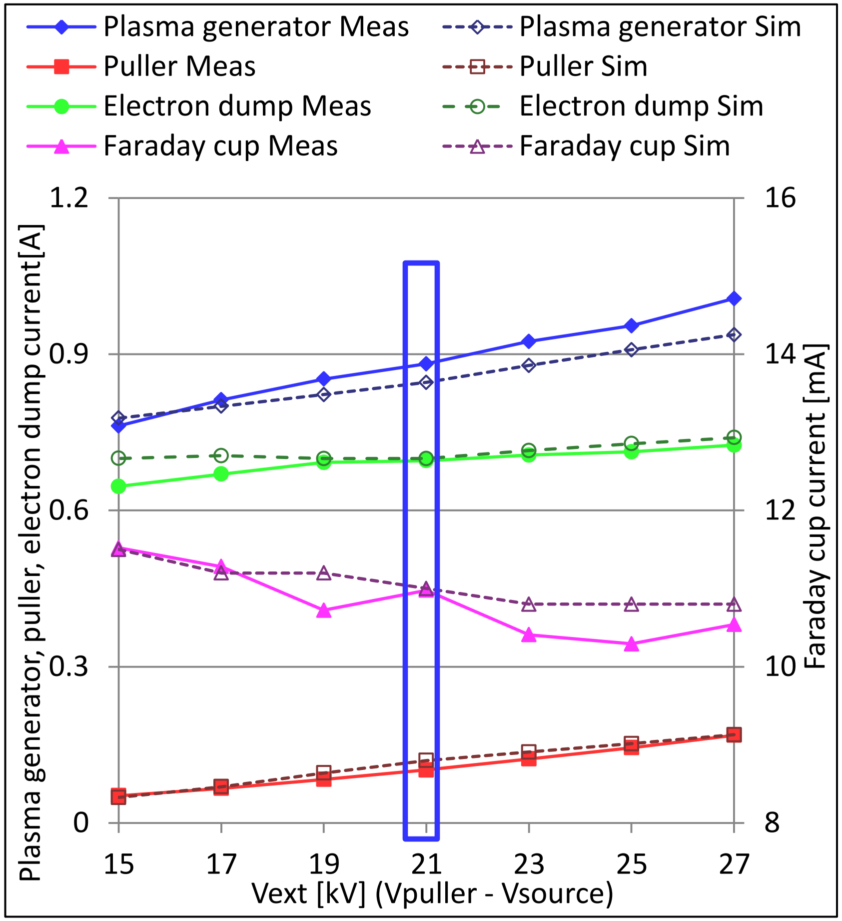

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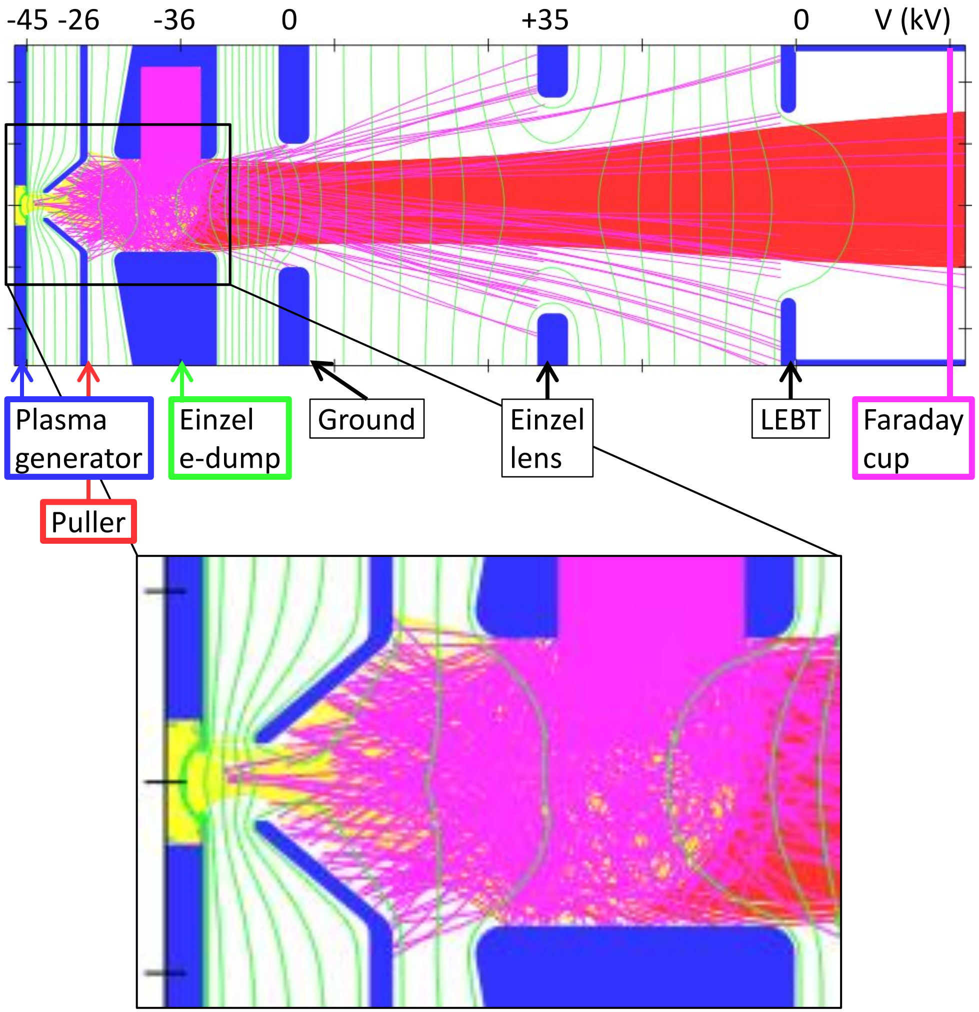

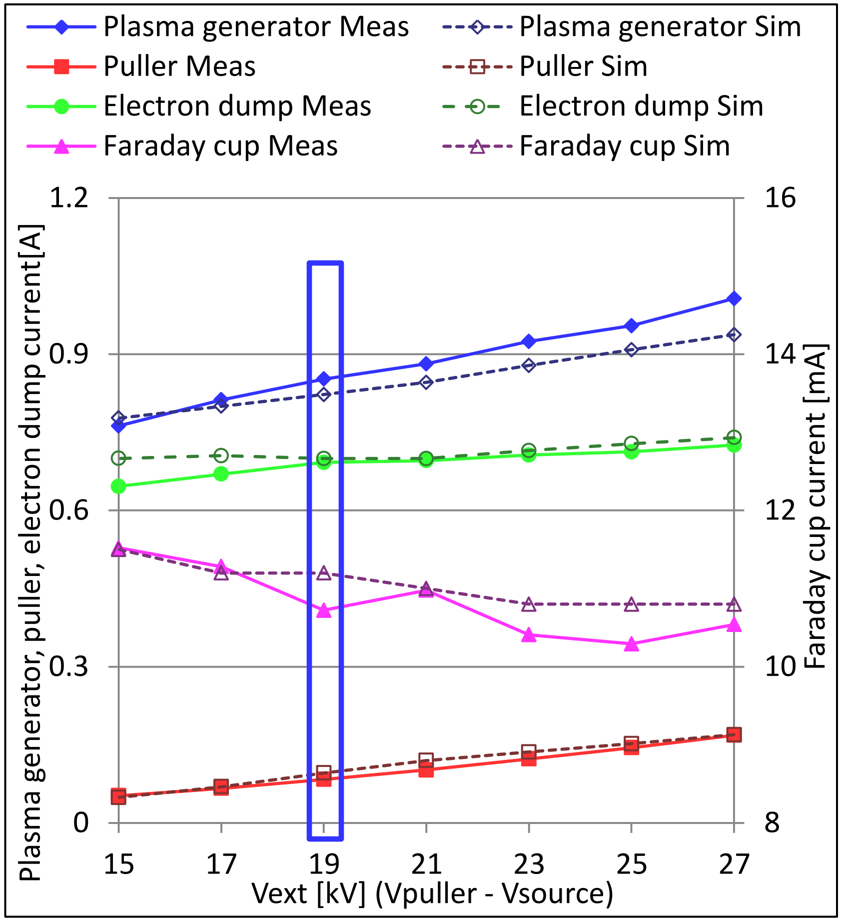

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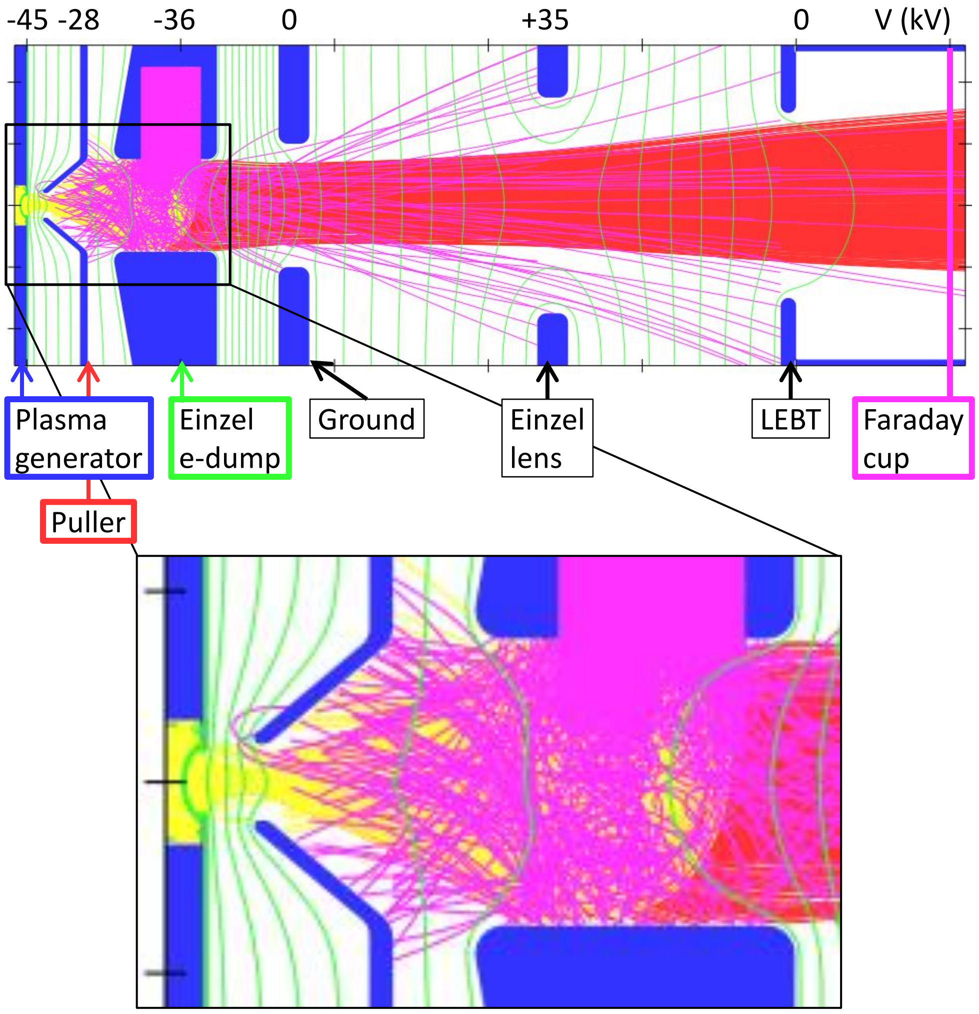

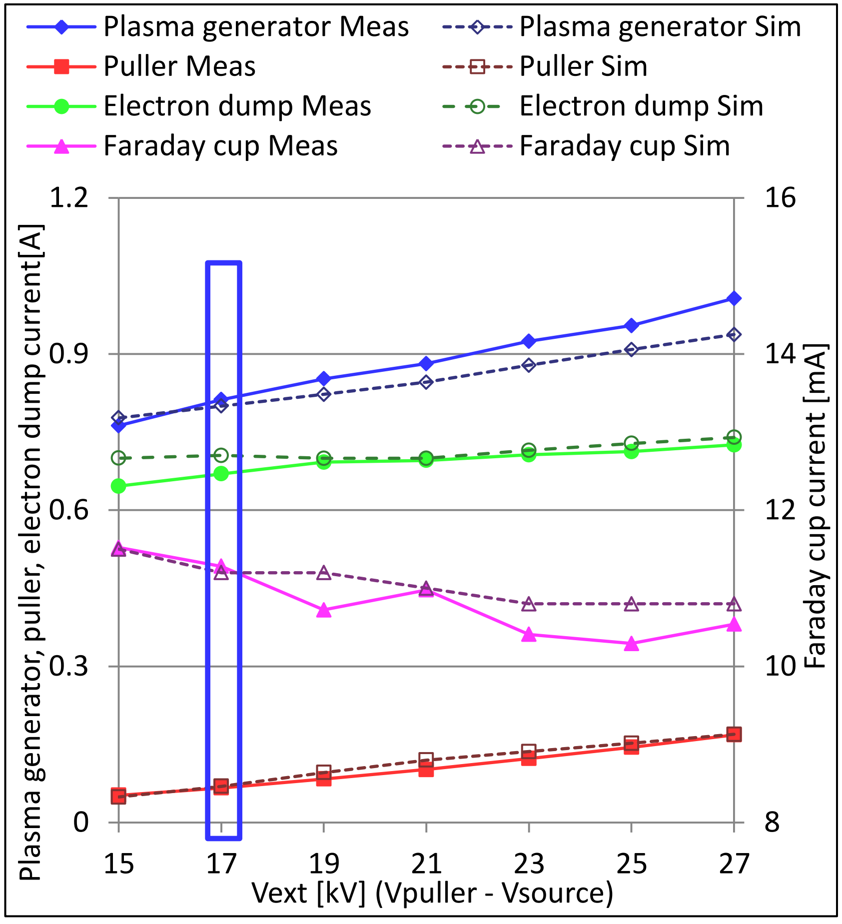

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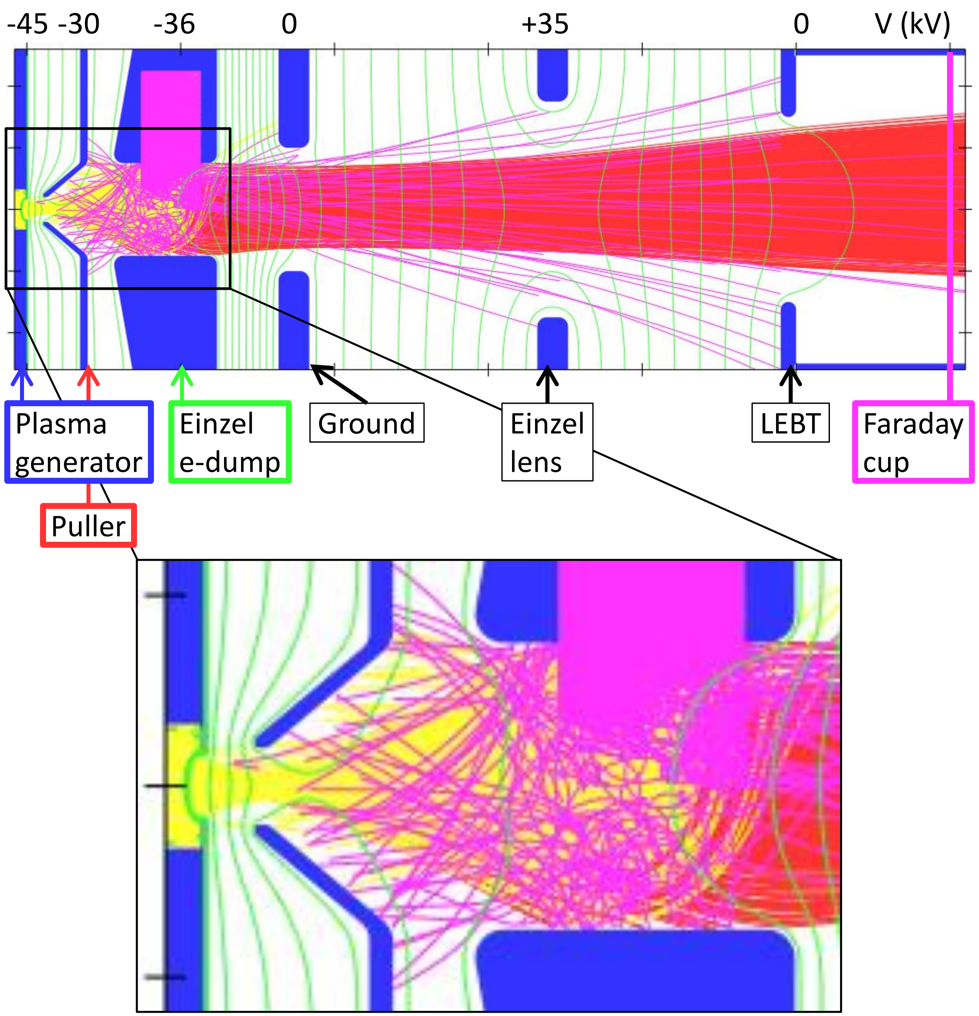
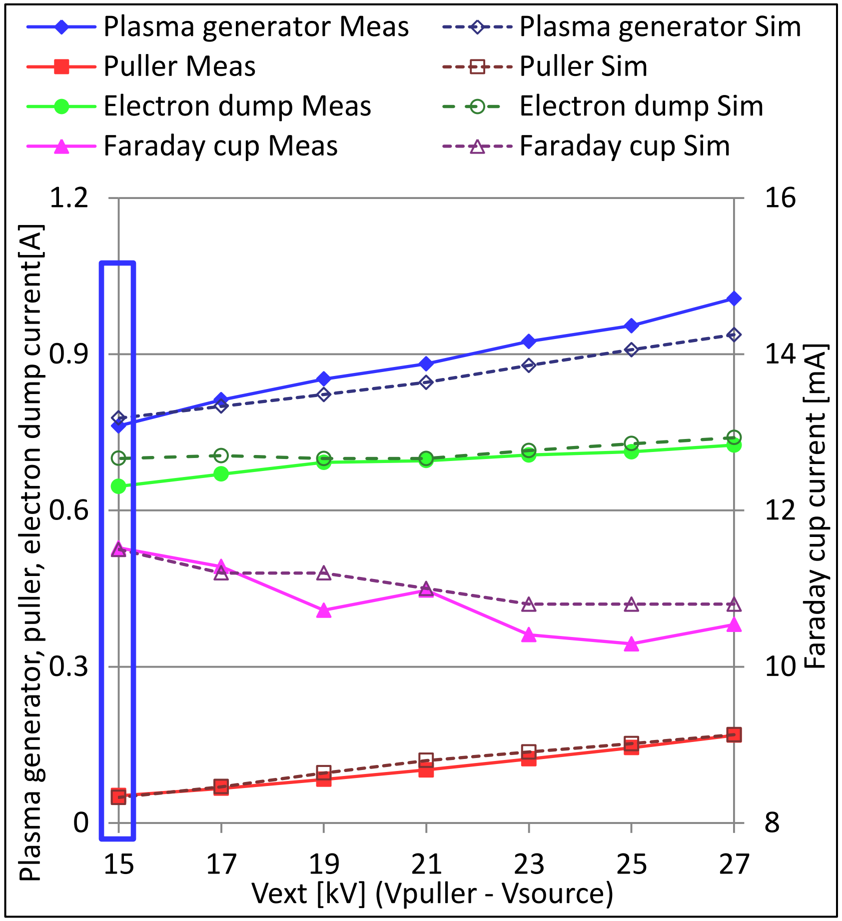
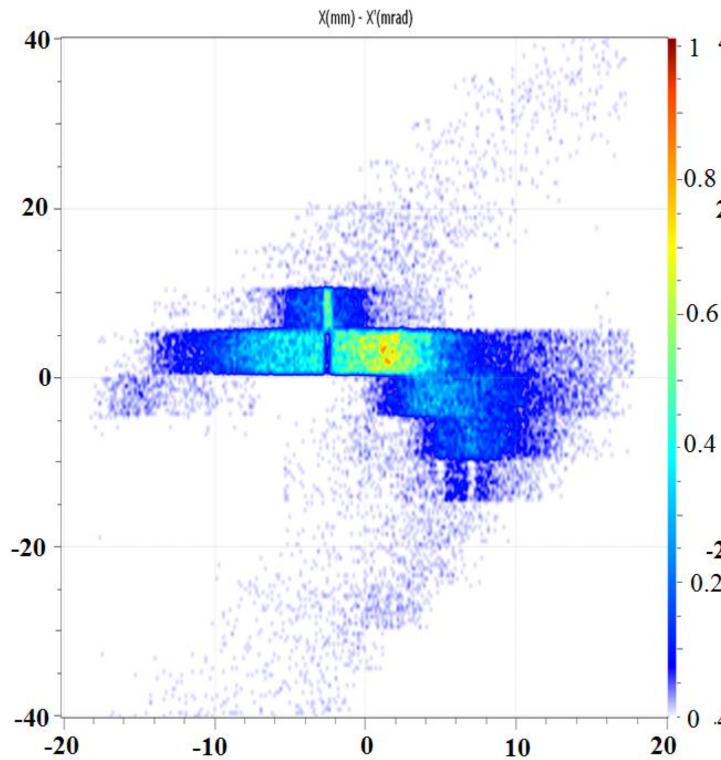




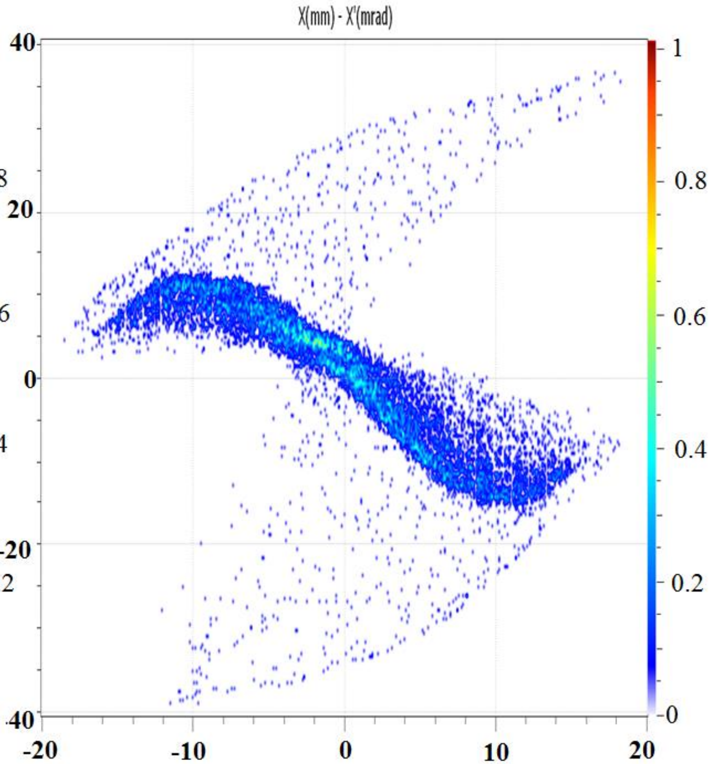
The measured beam emittance is similar to what we expect from simulation

Measurement



$\varepsilon_{NORM,\ 1\ RMS} = 0.5\ \mu m$

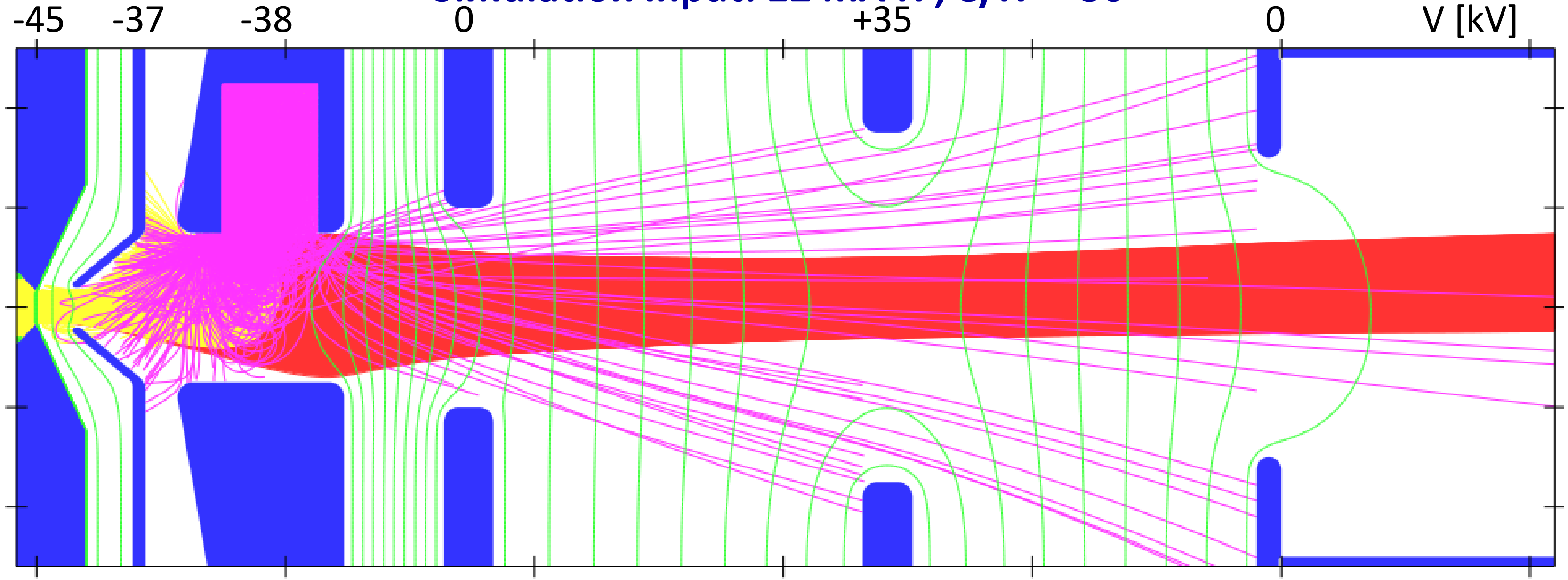
Simulation



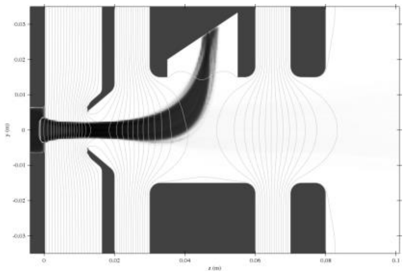
$\varepsilon_{NORM,\ 1\ RMS} = 0.5\ \mu m$

The emittance should be improved since the RFQ acceptance is 0.25 µm

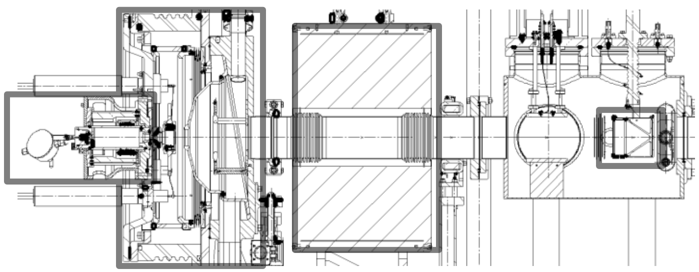
Preliminary comparison of the first measured beam from IS02 (12.11.2013) with a simulation



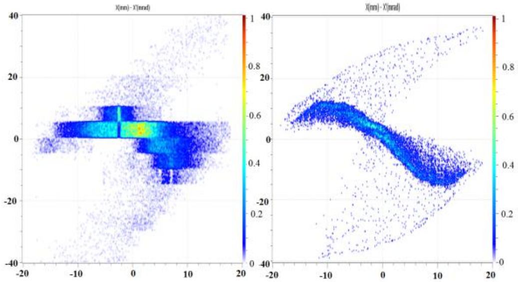
	Source [A]	Puller [A]	E-dump [A]	Faraday cup [mA]	Emittance [µm]
Measurement	0.35	0.15	0.031	13	
Simulation	0.38	0.065	0.030	12	< 0.6



Ion beam extraction system



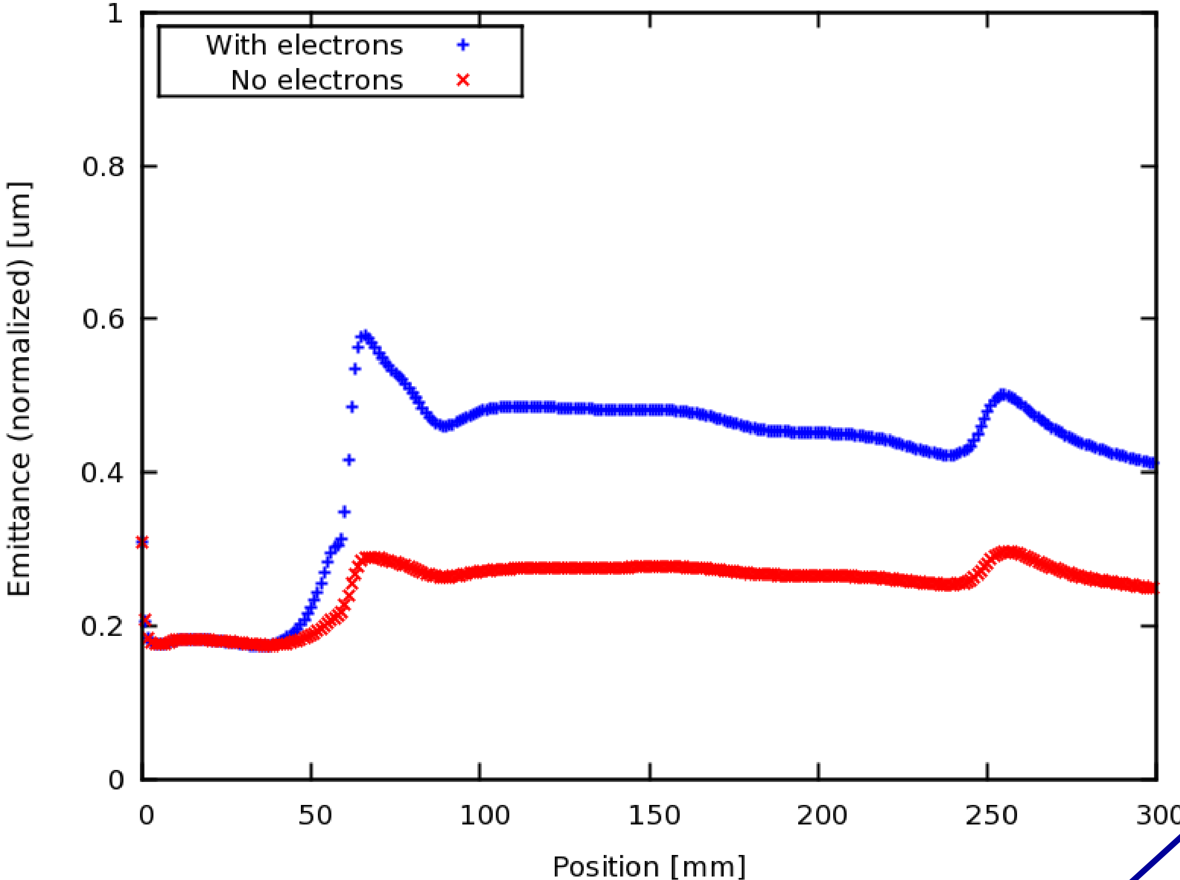
Benchmarking of simulations

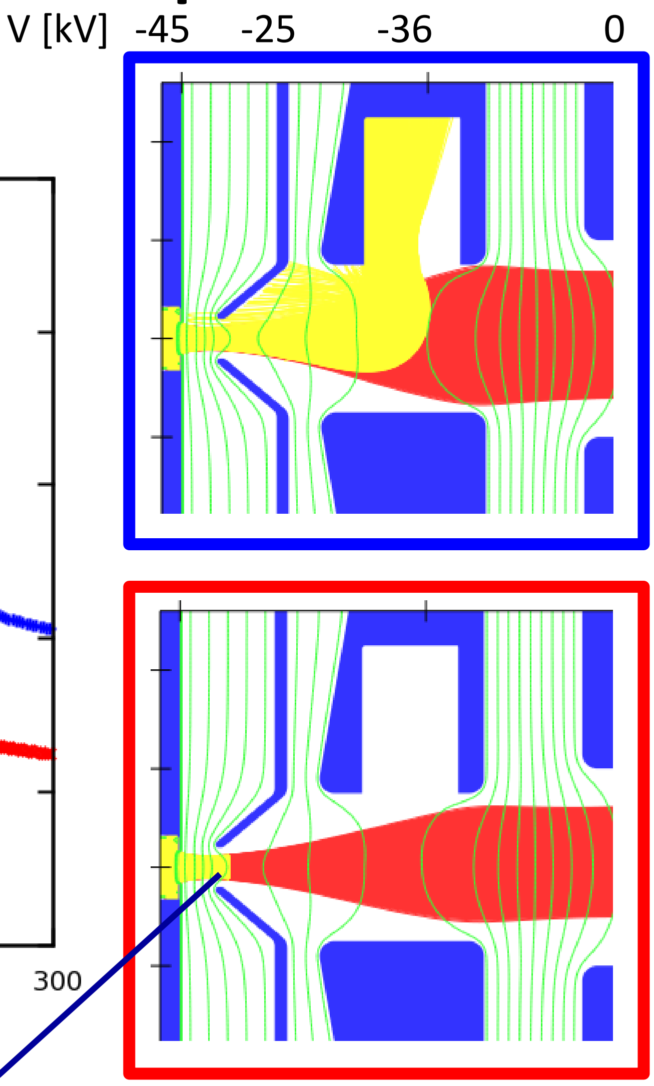


Emittance improvements

Reducing the number of co-extracted electrons, reduces the emittance growth in the electron dump

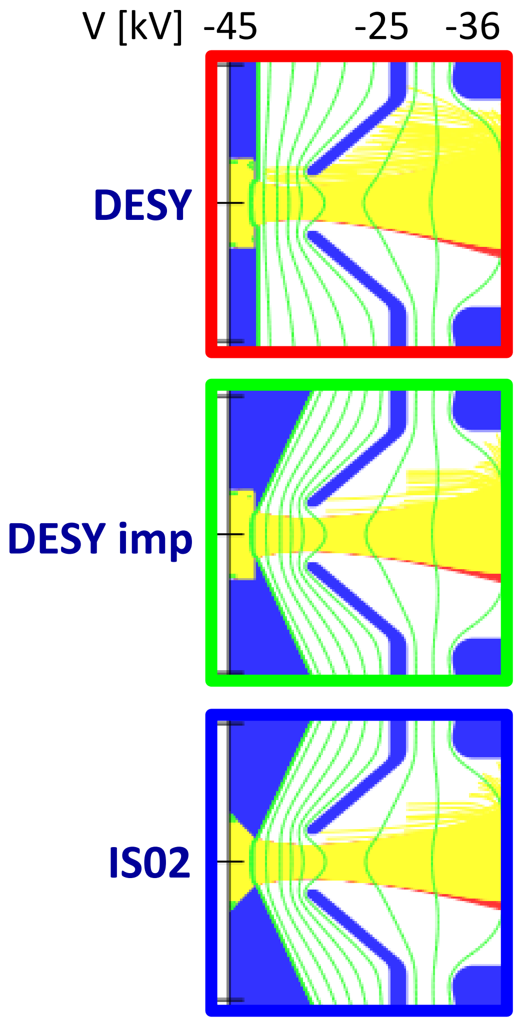
Simulation input: 30 mA H^-, e/H^- = 30



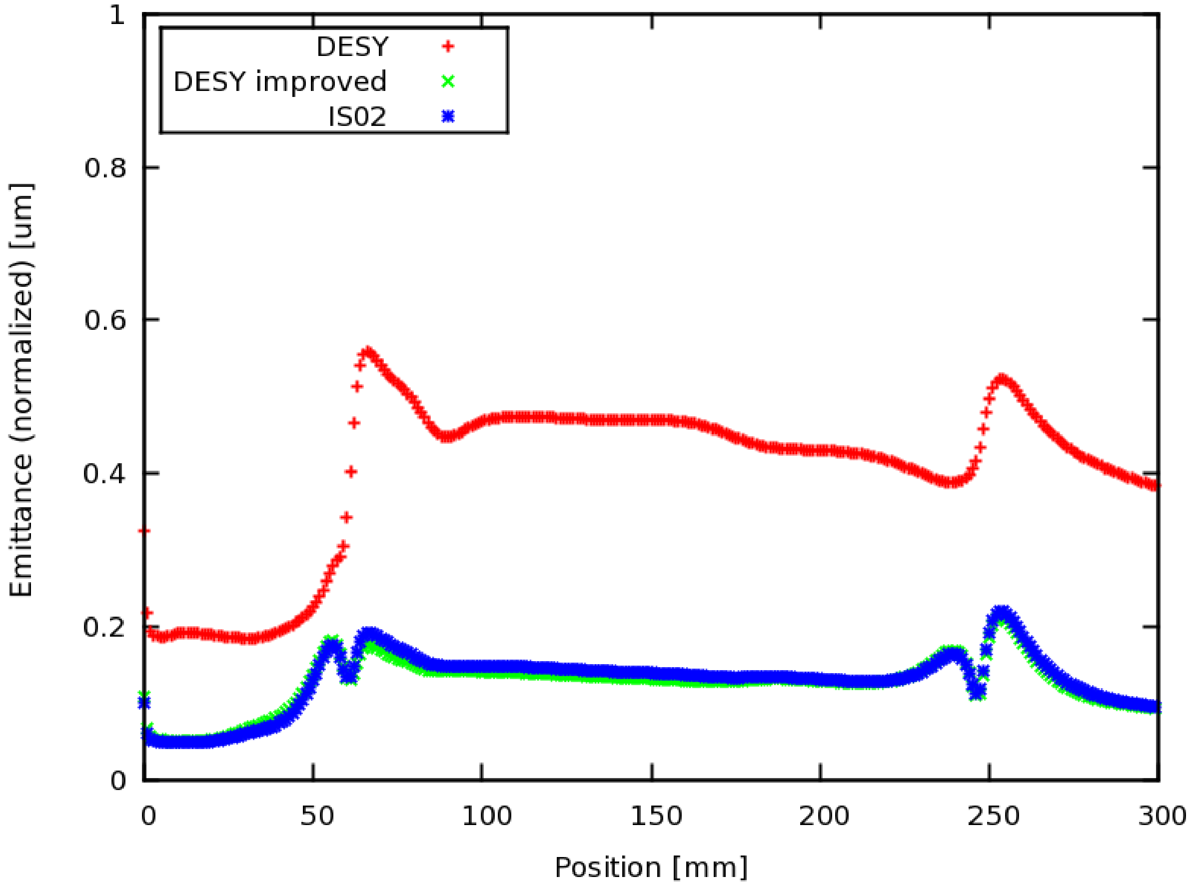


Artificial removing of electrons

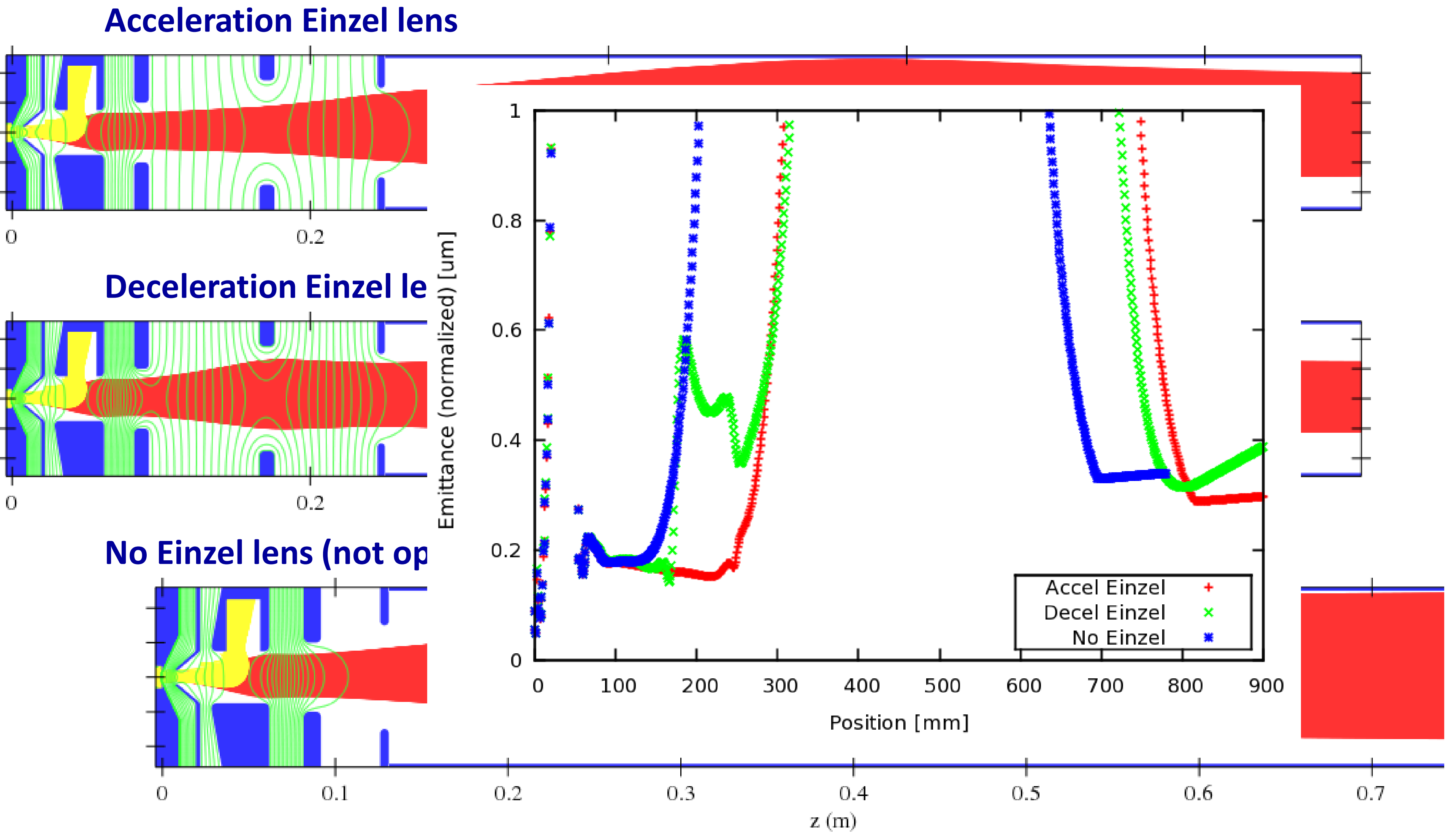
The shape of the plasma electrode improves the emittance



Simulation input: 40 mA H^-, e/H^- = 10



Comparison of different Einzel lens configurations with beam transport through the first solenoid



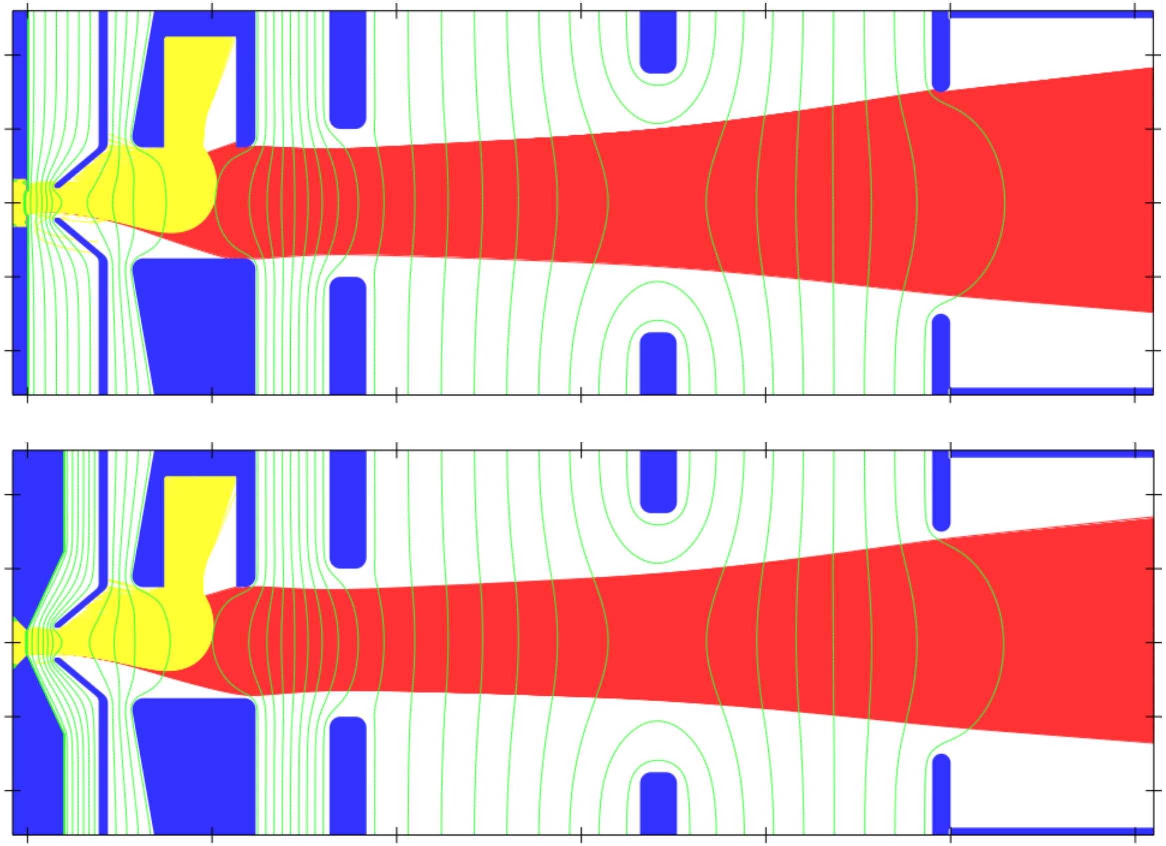
Simulation input: 30 mA H^-, $e/H^- = 30$

With the current extraction system, it is feasible to transport an 80 mA H^- beam

Simulation input: 80 mA H^-, e/H^- = 1

DESY

H^- transmission = 79 %
$\varepsilon_{NORM,\ 1\ RMS}$ = 0.6 µm



IS02

H^- transmission = 99 %
$\varepsilon_{NORM,\ 1\ RMS}$ = 0.6 µm

A redesign should be made to not hit the inside of the electrodes with the H^- beam, and to collect all electrons in the dump

The new extraction system has been commissioned, and verified with simulations

- Stable ion beam extraction with few high voltage breakdowns
- Few resources required for operation
  - 1 expert during start-up
  - 1 expert on call during operation
- Room for improvement of beam current transportation and emittance
- Improving the extraction system (simulations, design, production)
  - Modifying existing: 6-9 months
  - Complete redesign: 9-12 months