RF source, volume and caesiated extraction simulations (e-dump)

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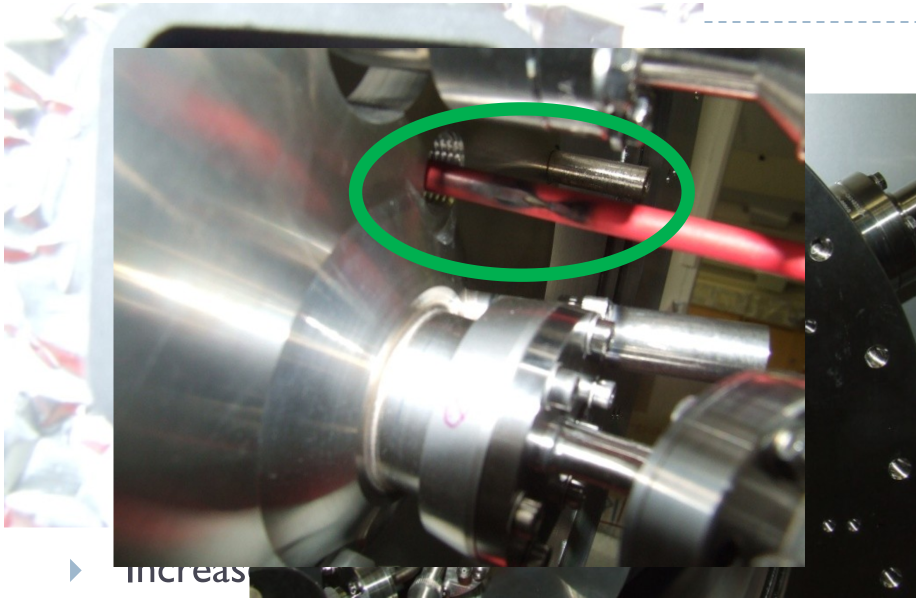
Linac4 Ion Source Review 07.06.2011

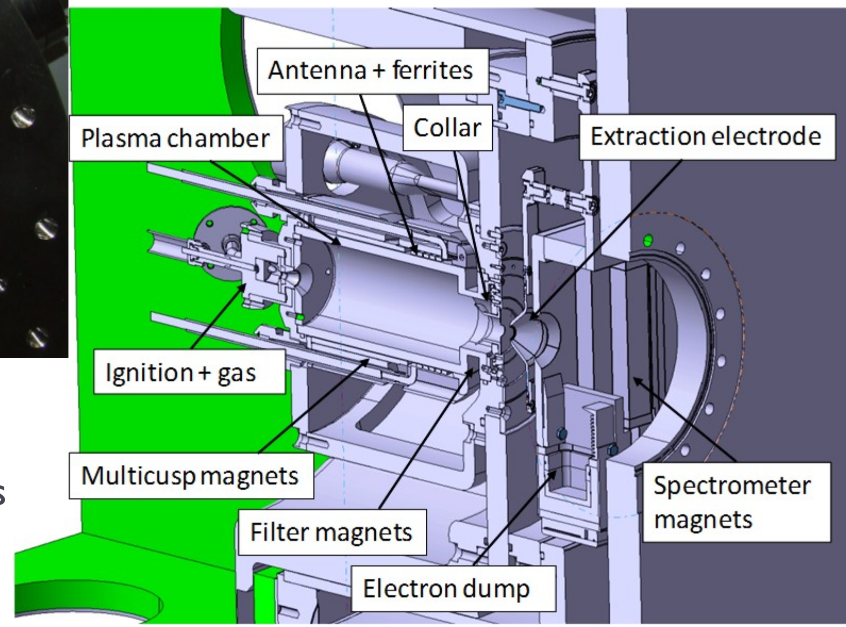
Summary

- Linac4 H^- volume source
- H^- 35 keV commissioning results
- H^- 35 keV simulations
- Comparison of H^- emittance measurements and simulations at 35 keV
- Vaporization of electron dump
- Volume source, two upgrade proposals for 45 kV extraction
  - Concept 1: Electron dumping at low energy in Einzel lens
  - Concept 2: Electron dumping on intermediate electrode
- Deliverables, manpower, milestones

Linac4 H^- volume source



- Increas
- Following issues occurred from these modifications
  - High voltage breakdowns across insulators
  - Vaporization of the electron dump
  - Sparking in the antenna
- We understand that we did not understand the system very well



H^- 35 keV commissioning results

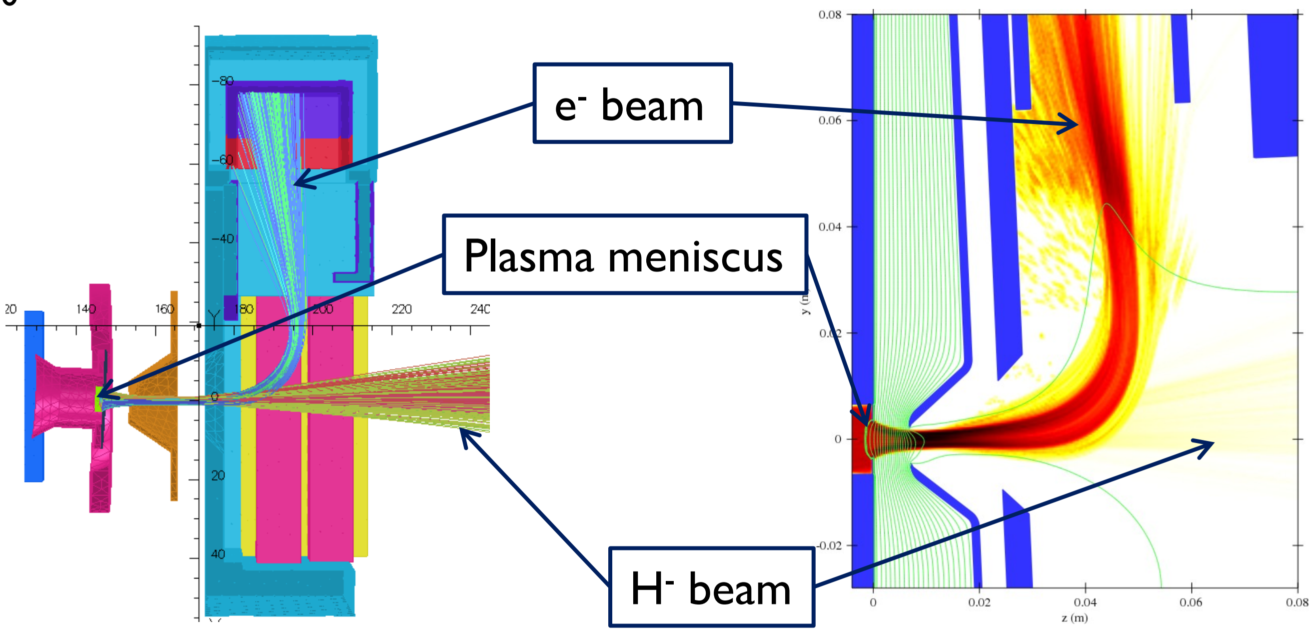
Parameter	Linac4 design parameters	Measured parameters
Energy [keV]	45	35
H^- current [mA]	80	23
Pulse length [ms]	0.4	0.5
Repetition rate [Hz]	2	0.8
Duty factor [%]	0.08	0.04
RF power [kW]	100	20-60
Emittance [mm mrad]	0.25	0.26

- Stable beam pulse short term
- High voltage breakdowns:15 per 24 hours, average over 12 days

H^- 35 keV simulations

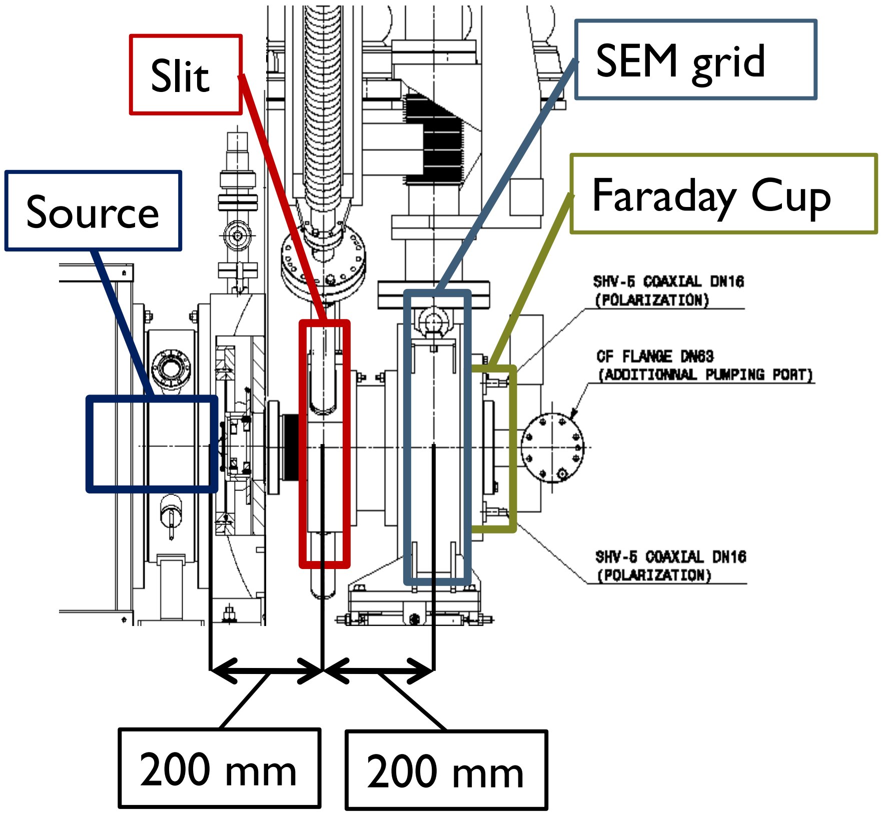
- Vector Fields Opera SCALA/TOSCA
- 3D Electromagnetic simulation
- Used to optimize the dumping of the electrons
- No simulation of particle extraction from a plasma.
- Particles are extracted from a conductor. Shape of plasma meniscus is shaped/guessed to get a convergent solution
- I_{H-} = 36 mA
- e/H = 50

- IBSimu
- 3D simulation of particle extraction from a plasma
- Modular software. This case:
  - Geometry imported as a DXF-file
  - Magnetic field imported from Opera
- I_{H-} = 36 mA
- e/H = 50

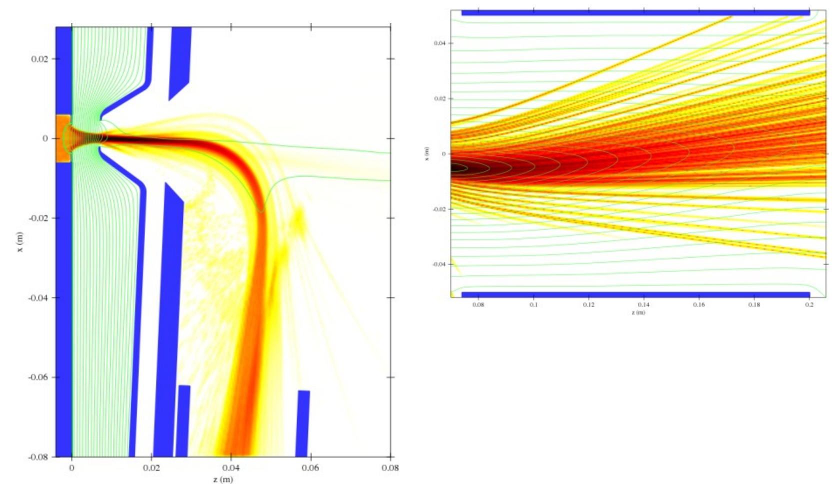


Comparison of H^- emittance measurements and simulations at 35 keV

Measurement setup



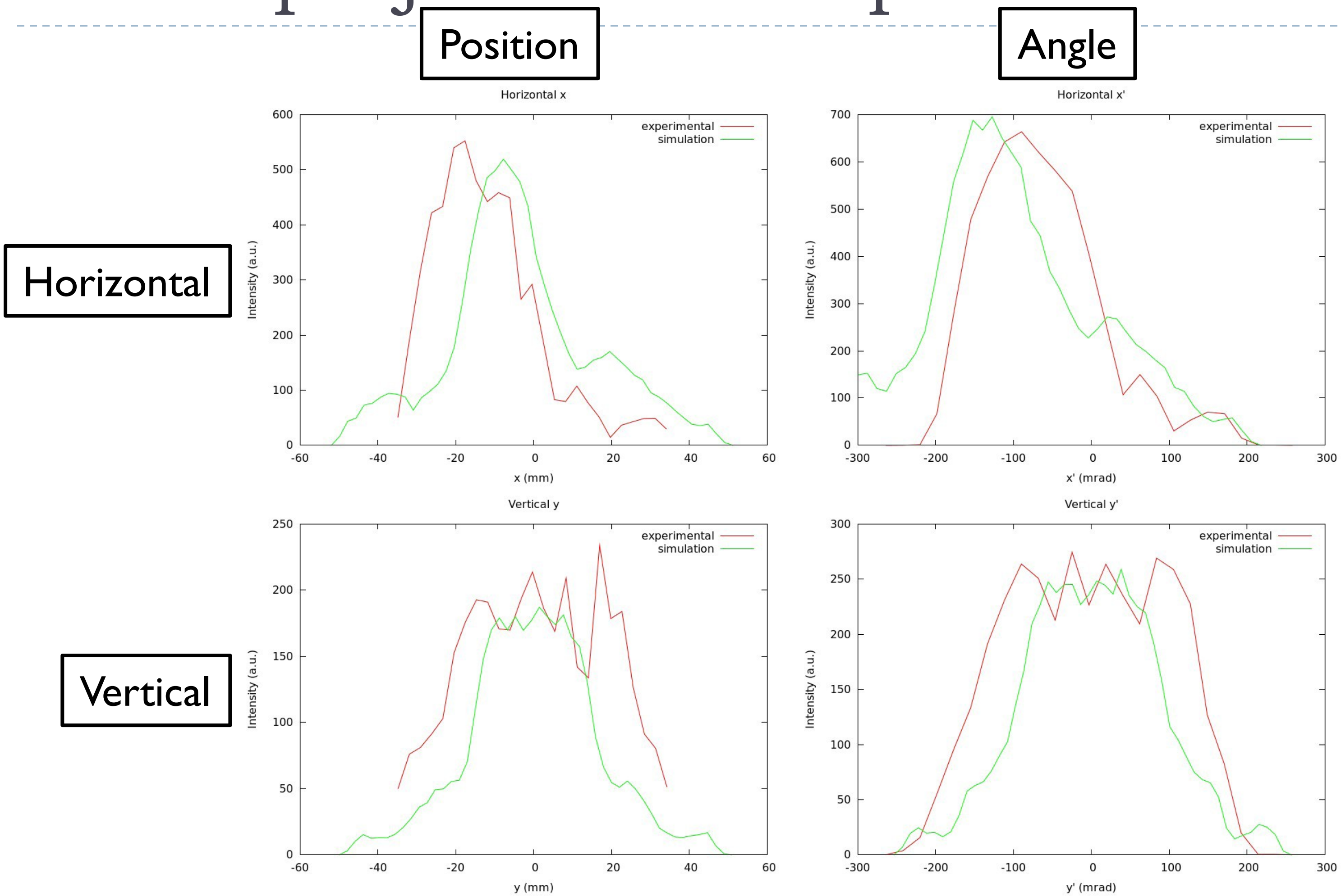
Simulation



1st part: Plasma extraction and electron dumping

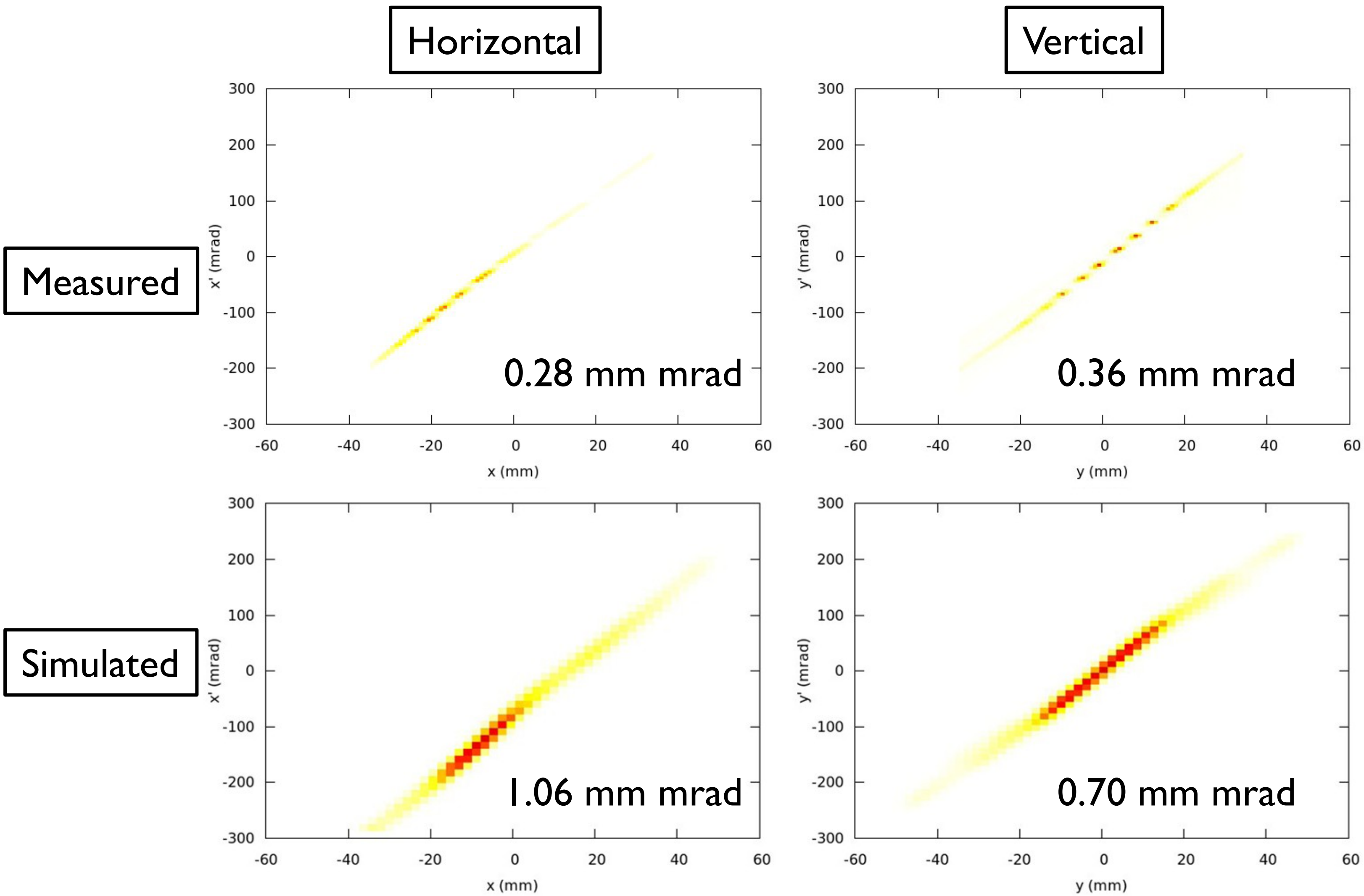
2nd part: Drift through beam pipe to the slit

Beam projections comparison



- Comparison of measured (red) and simulated (green) beam projections
- Beam projections corresponding well between measurements and simulations

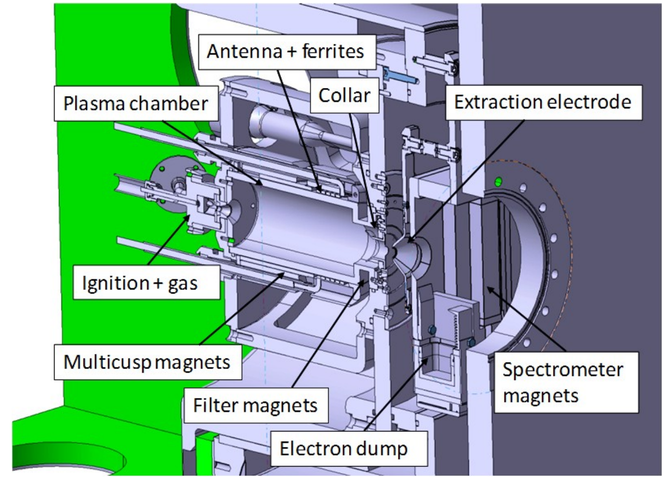
Emittance measurements and simulations at 35 keV (10% filtered)

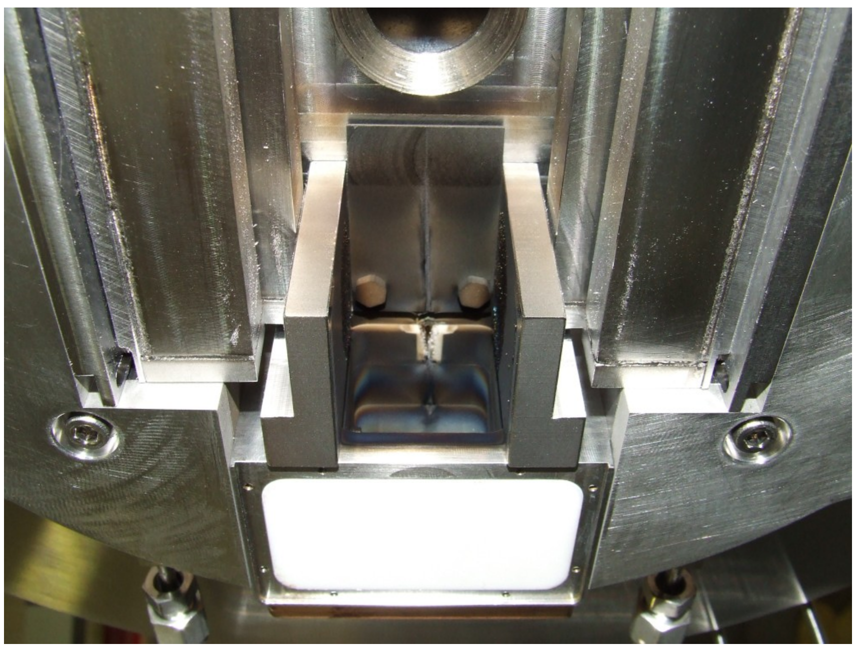


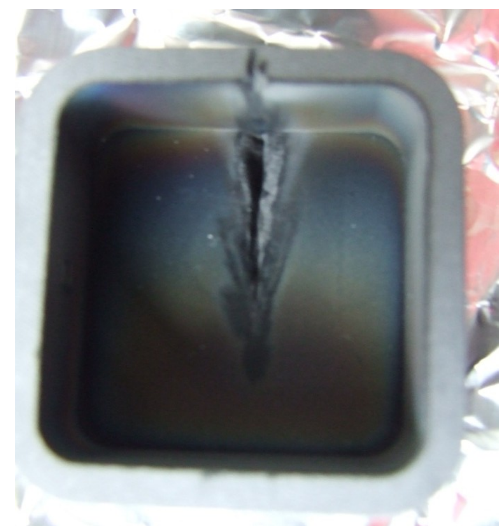
Differences due to binning size of plots, can be corrected
It is difficult to make emittance comparisons when the shape is a thin line

Vaporization of electron dump at 35 keV

Permanent B-field in the electron dump gives the electron beam a different curving radius for different energies. The beam is sweeping the surface when ramping up the beam energy from 0-35 keV for high voltage conditioning



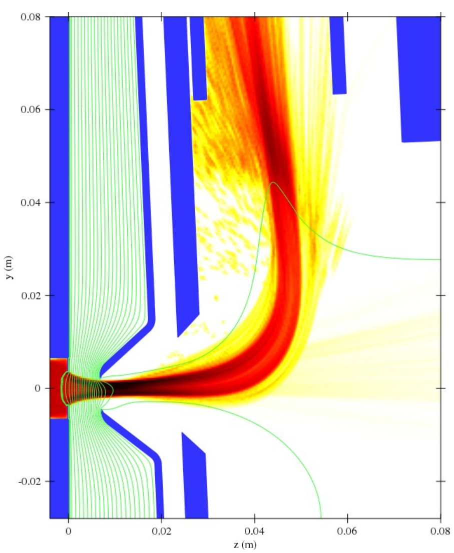




Carbon dump after 35 keV operation

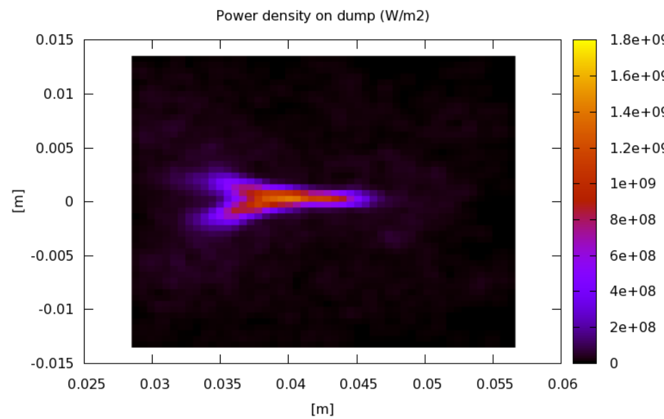
IBSimu power density plots of electron dump

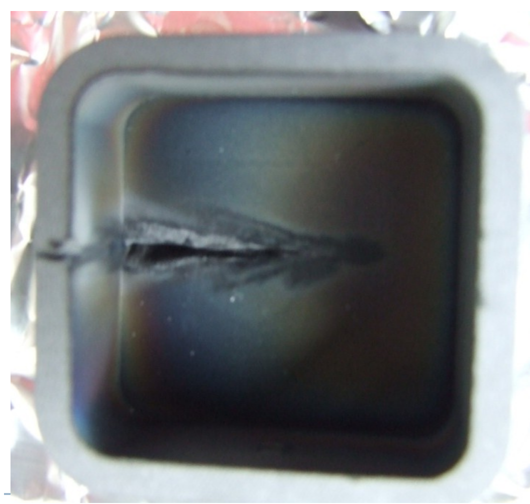
Thermal simulations show that pulsed power densities above 1 kW/mm^2 (for 500 μs pulses) will vaporize the dump surface



e^- beam 35 keV, 1.5 A, 500 μs

Max power density 1.8 kW/mm^2

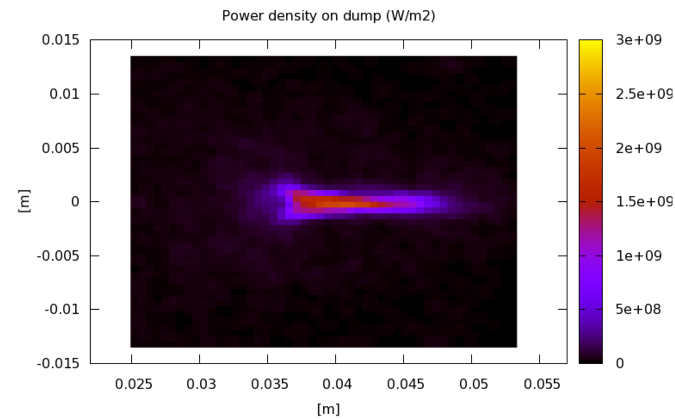


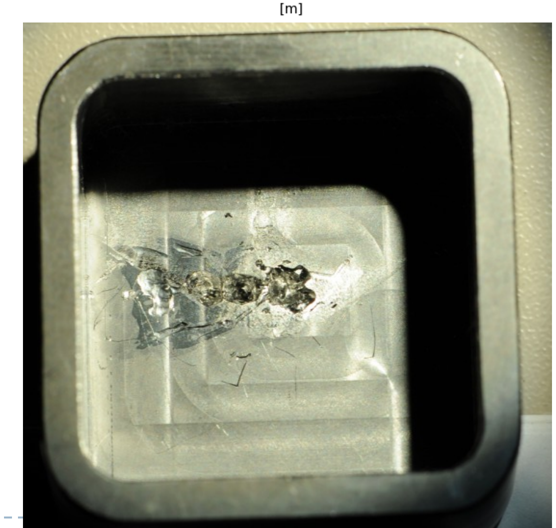


26 mm

e^- beam 45 keV, 1.5 A, 100 μs

Max power density 3.0 kW/mm^2





26 mm

Volume source, two upgrade proposals for 45 kV extraction

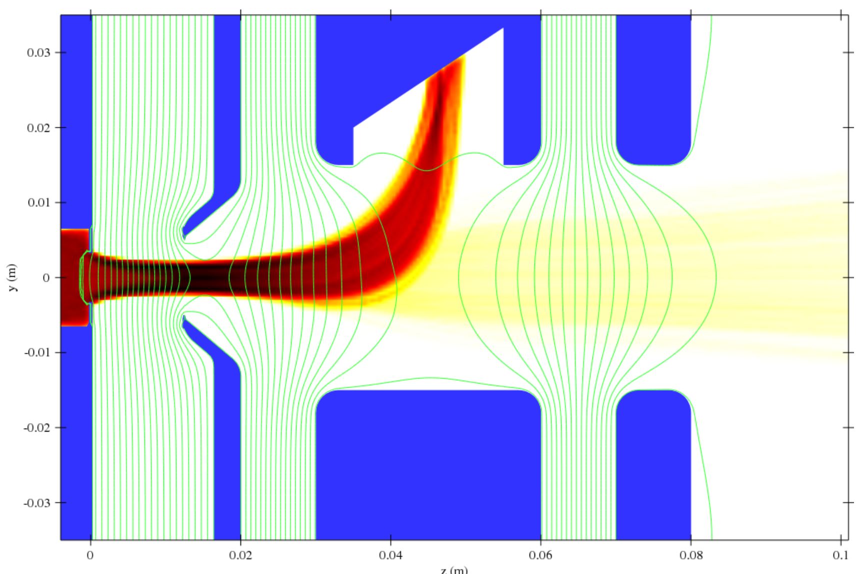
A new concept should :

• Reduce electron power density by lowering electron dumping energy and spread electron dumping surface

• Have a less divergent beam at the entry of the LEBT

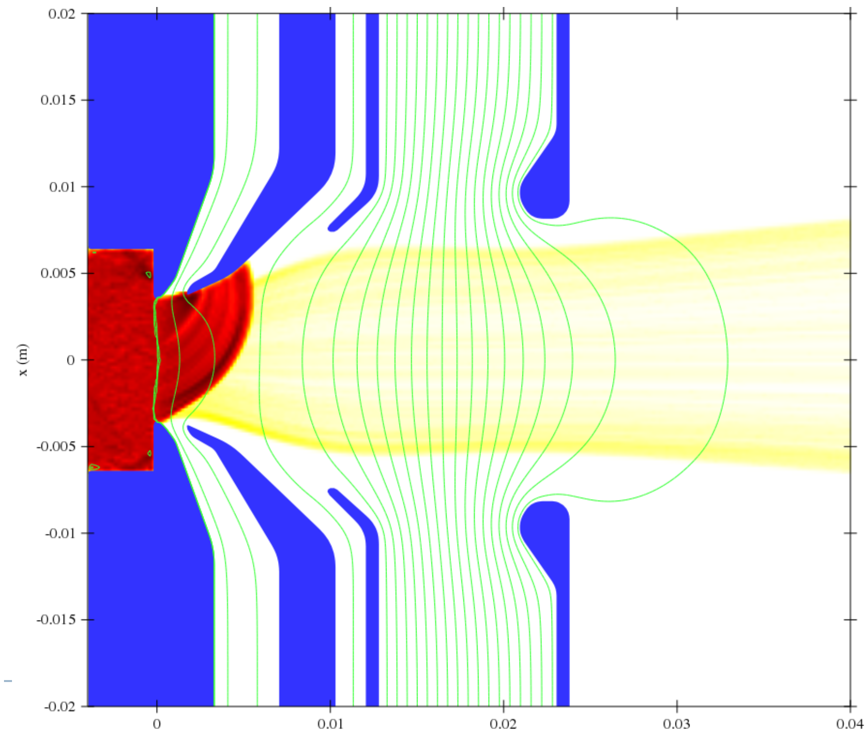
(Electrode potentials are given in kilovolts relative to ground)

1. e$^-$ dump in Einzel lens



-45 0 - 35 0

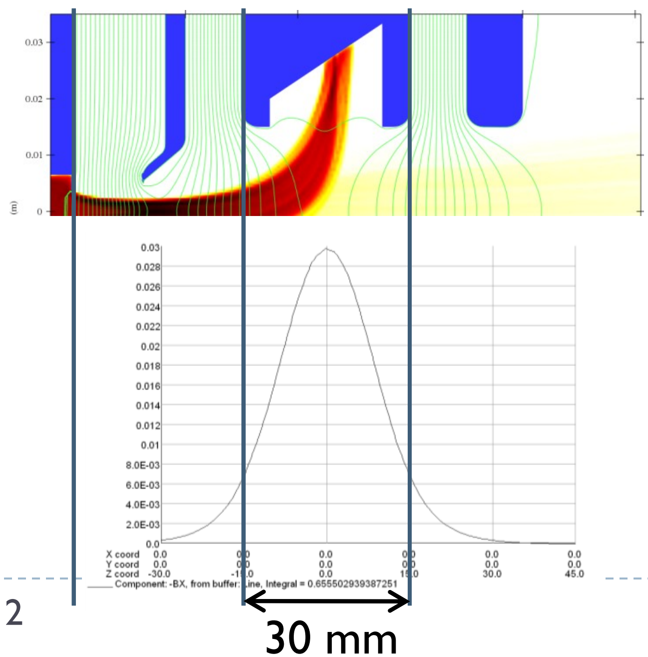
2. e$^-$ dump in intermediate electrode



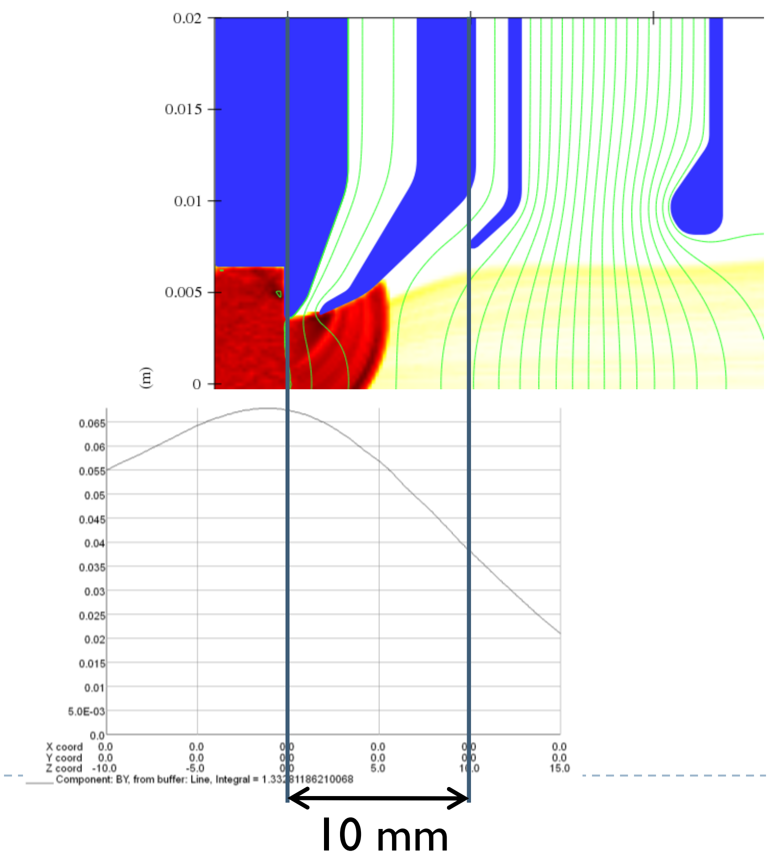
-45 - 40 -39 0

Electron dumping B-field

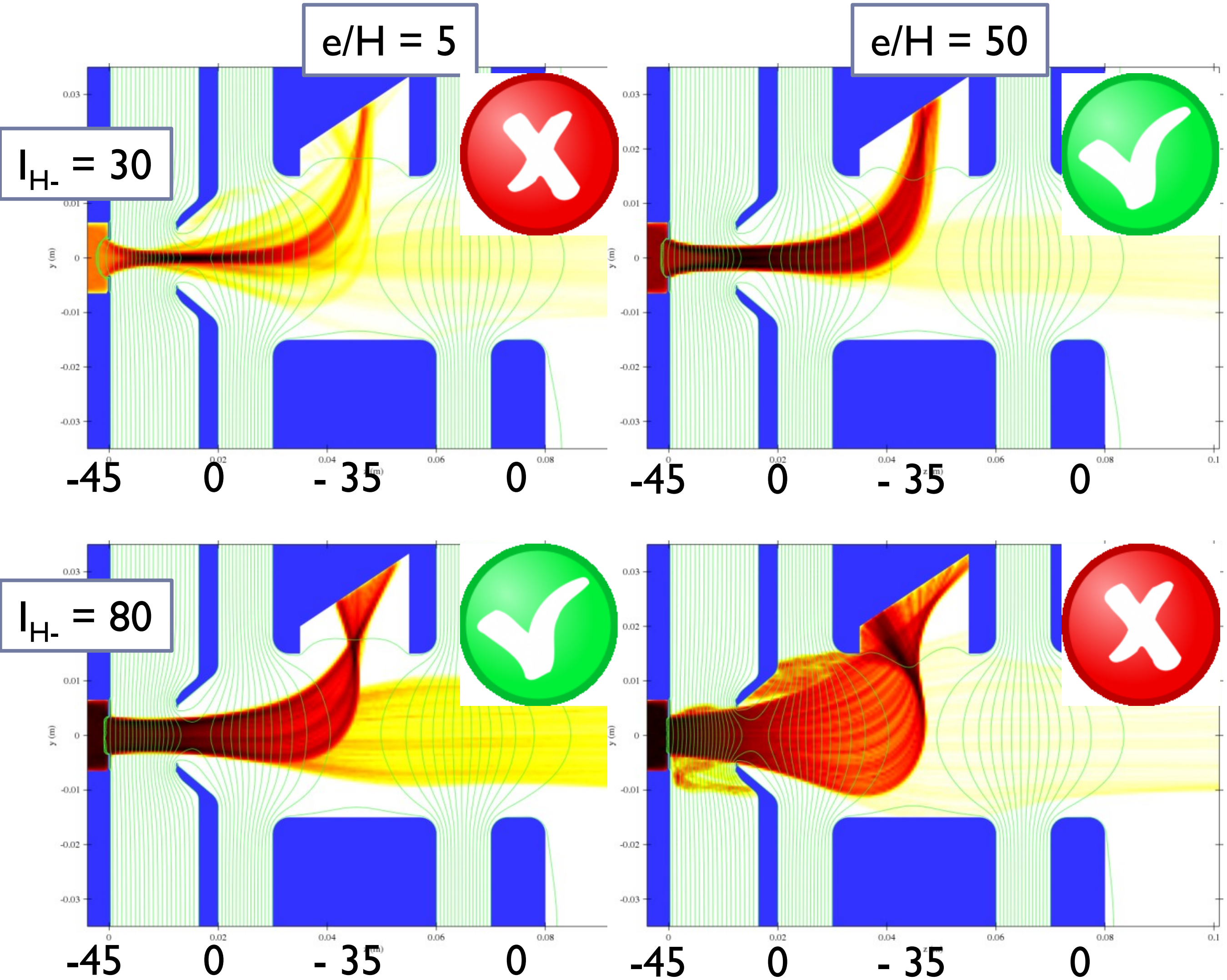
- B-field simulation from Vector Fields Opera
- Two permanent magnets inside Einzel lens creating a dipole field of ~ 30 mT (peak)
- Magnetic shielding on both sides of Einzel lens and in the electron dump



- Six permanent magnets in Halbach-type dipole configuration
- Magnets are located in the collar
- Maximum field ~ 65 mT

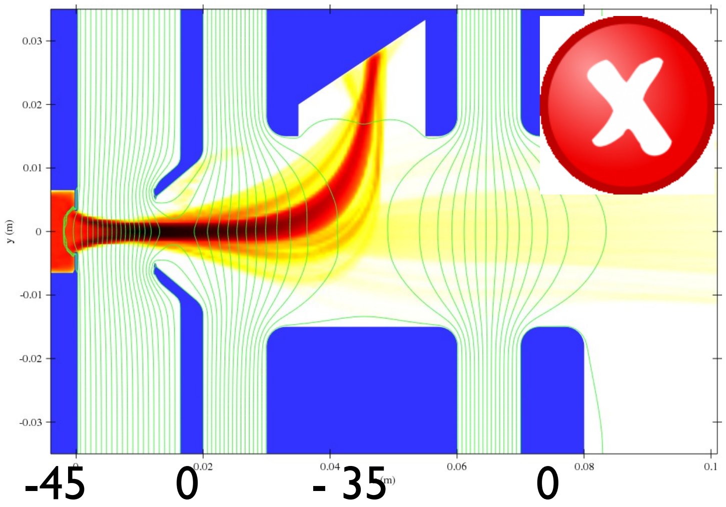


Concept 1: Beam optics depending on current and e/H ratio

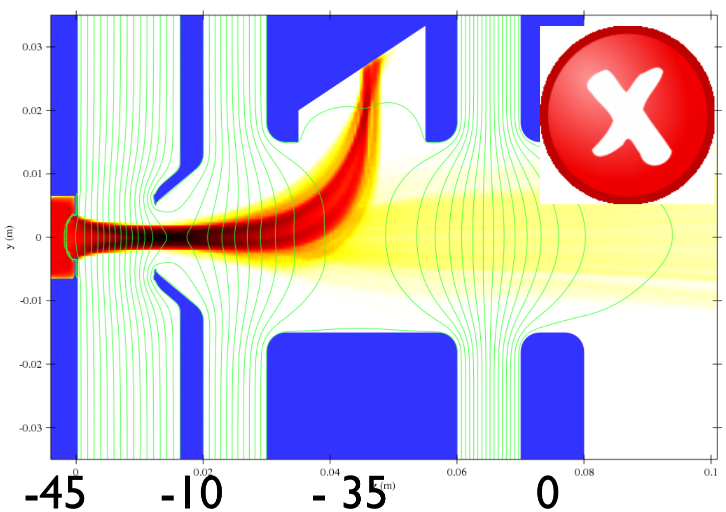


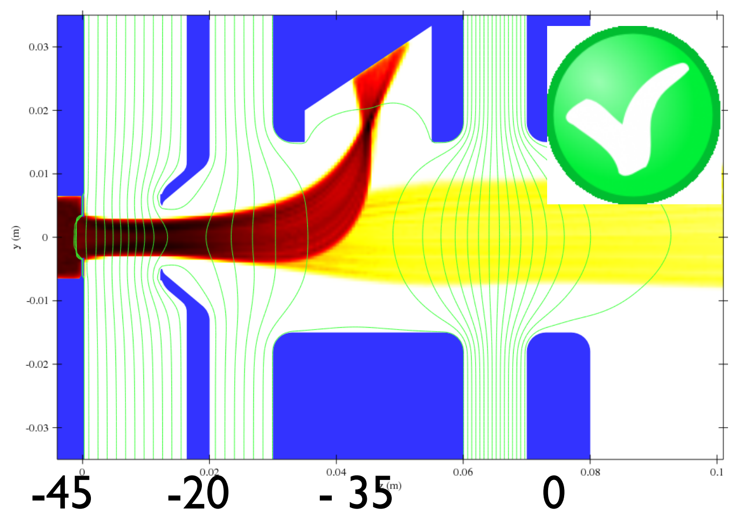
- Low current, low e/H ratio (I_{H-} = 30, e/H = 5)
  - Plasma meniscus pushed back
  - Over-focused beam
  - Beam is divergent with a halo
- High current, high e/H ratio (I_{H-} = 80, e/H = 50)
  - Beam is exploding
  - High space charge is pushing electrons back into the extraction region
- We need different settings for different current extractions
- There exists a solution for the different cases

Concept 1: Use puller voltage to optimize beam optics



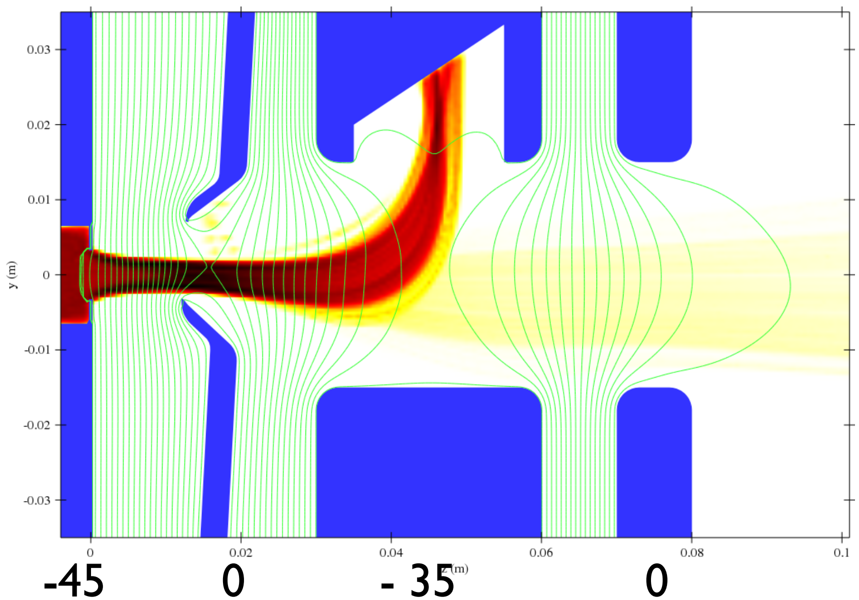
- Simulation with
  - I_{H-} = 30 mA
  - e/H = 15
- Changing puller voltage to optimize beam optics
  - 0, -10, -20 kV
- No mechanics needed
- Allows operational adjustment



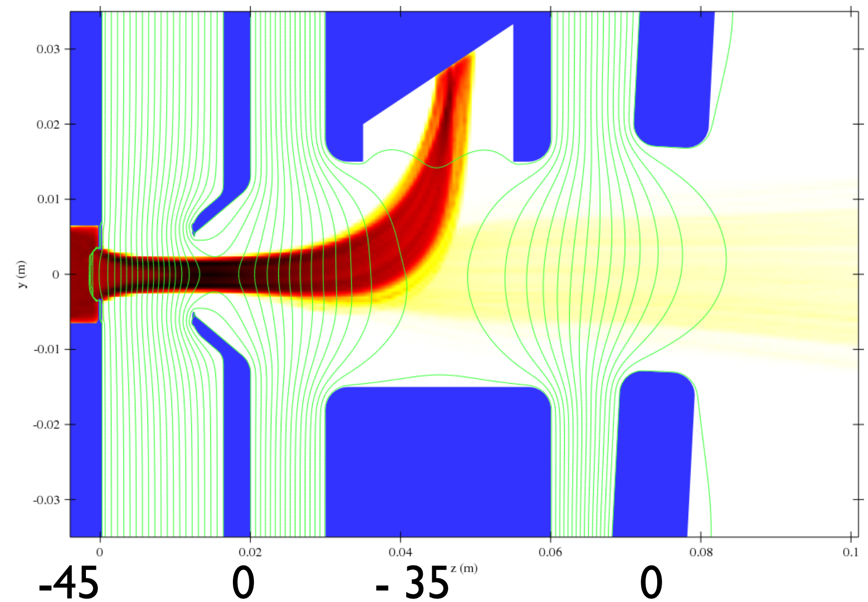


Concept 1: Correction beam position and angle by tilting and moving electrodes

- Horizontal tilt and offset of either puller electrode or ground electrode
- I_{H-} = 30 mA
- e/H = 50
- Possibility of optimizing beam position and angle



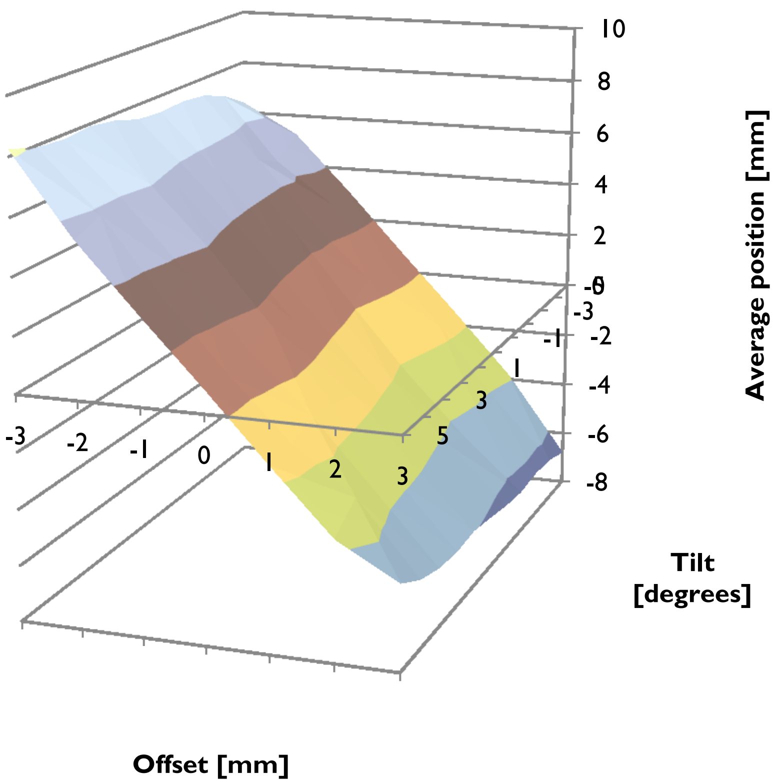
Puller tilt (3°) and offset (2 mm)



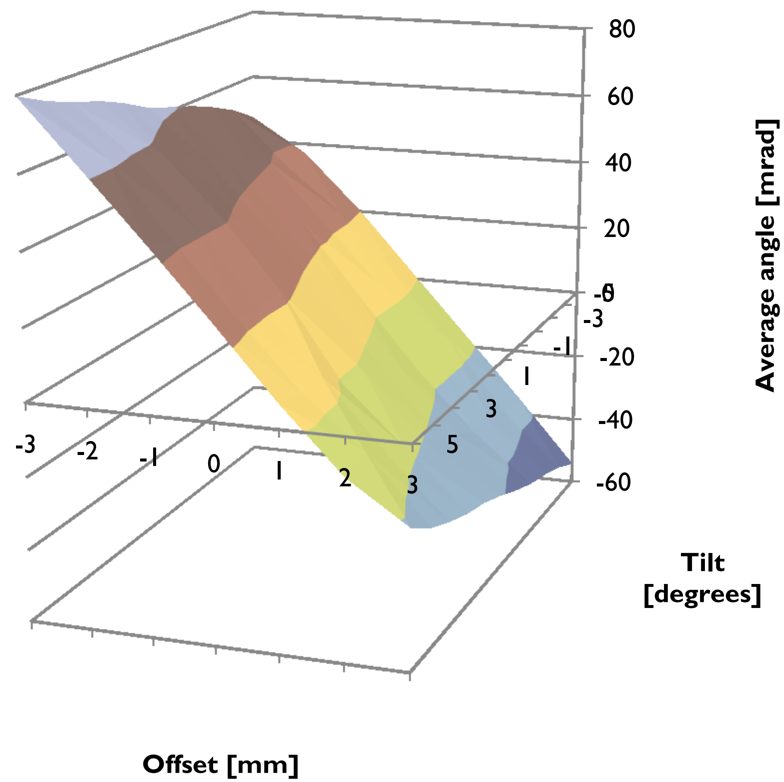
Ground tilt (3°) and offset (2 mm)

Concept 1: Puller tilt and offset influence on beam position and angle

Average position of beam

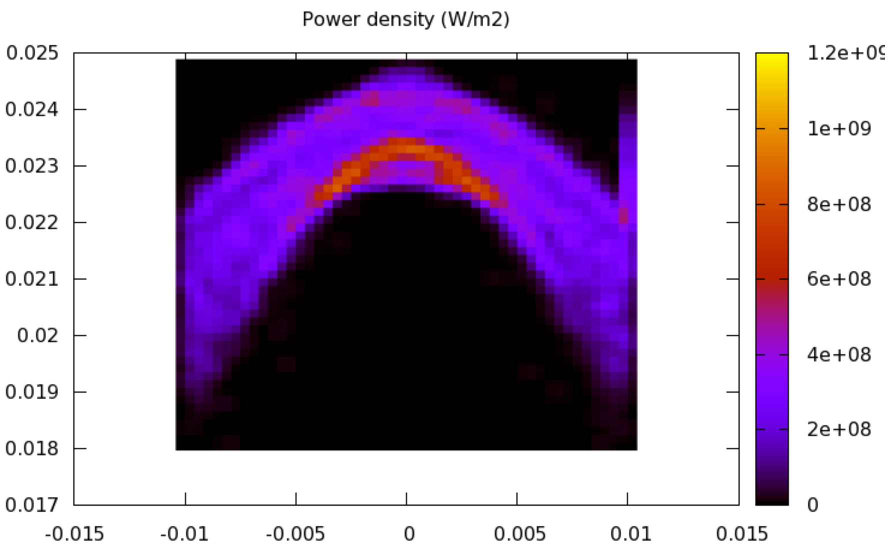


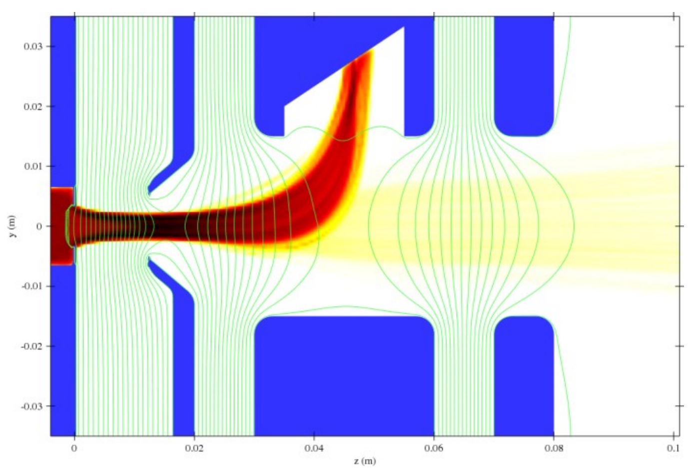
Average angle of beam



Gives the possibility of correcting beam position and angle

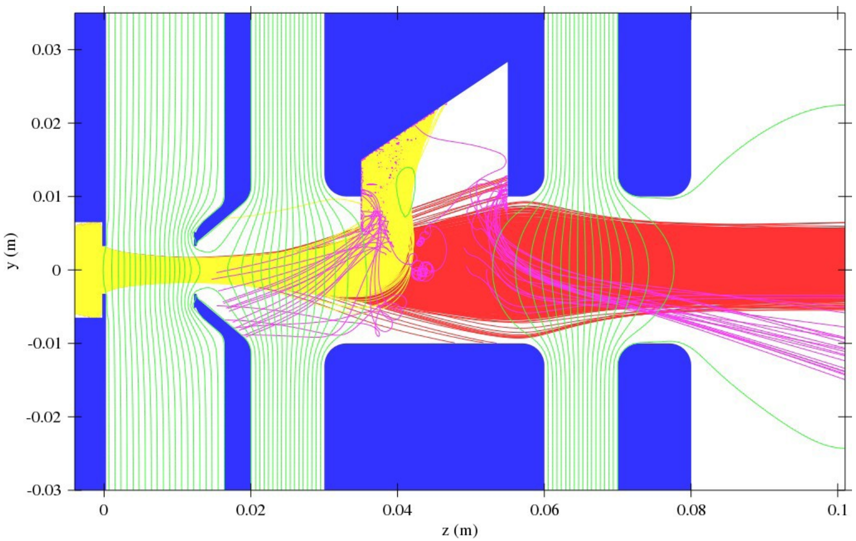
Concept 1: Electron dump power density





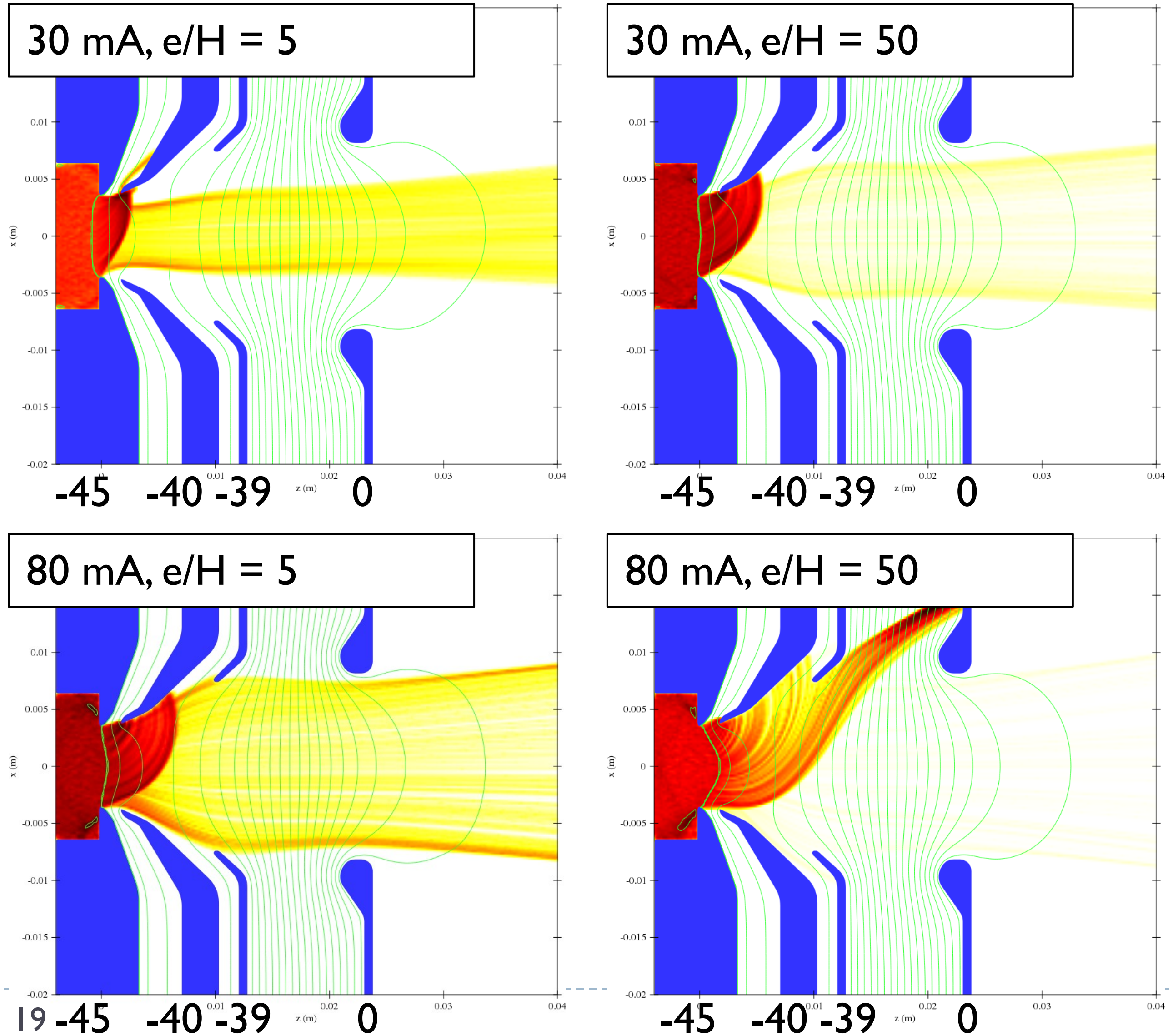
- Power density plot for the case
  - I_{H-} 30 mA
  - e/H 50
- Max power density is 1.2 kW/mm^2
- Reduced from the Linac4 case (3.0 kW/mm^2) due to the lower electron energy
- Dump needs to be optimized for spreading the beam on the surface
- Thermal time behaviour needs to be studied further

Concept 1: Secondary electron emission



- Example of secondary electron emission in IBSimu (non ideal case)
  - Yellow: Electrons
  - Red: Negative hydrogen
  - Purple: Secondary electrons
- Electrons are escaping due to
  - Electron beam hitting the side wall of the dump
  - Part of H^- beam touching inside the dump
- The secondary electrons created in the bottom of the dump do not escape due to the high space charge region from the electron beam

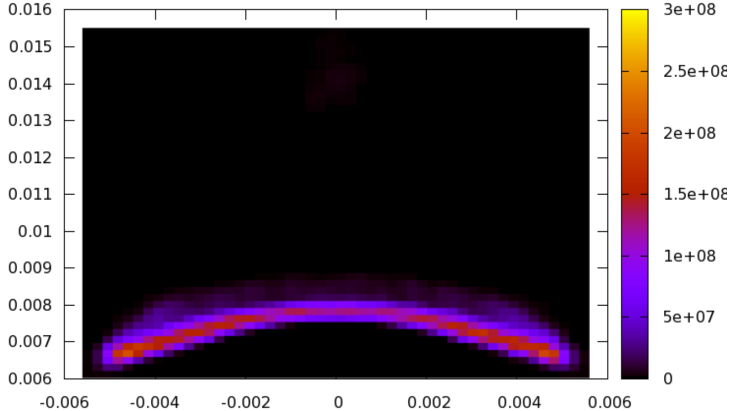
Concept 2: Beam optics depending on current and e/H ratio



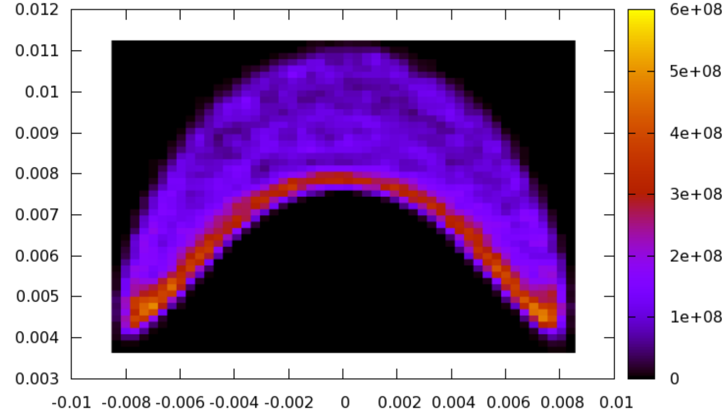
- For higher currents the e/H ratio has to be low
- Study of secondary electron emission in progress

Concept 2: Electron dump power density

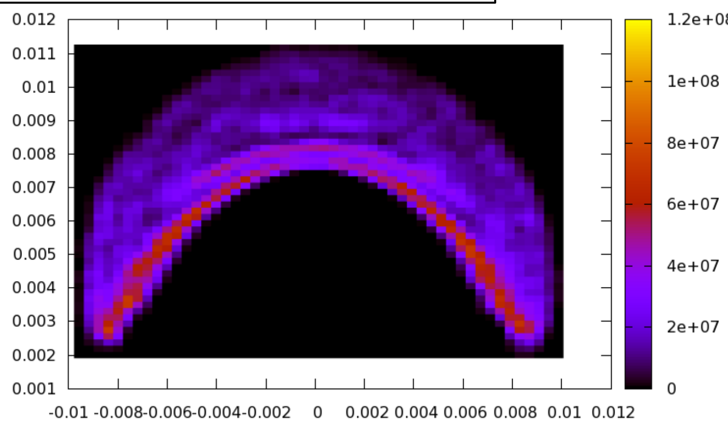
30 mA, e/H = 5



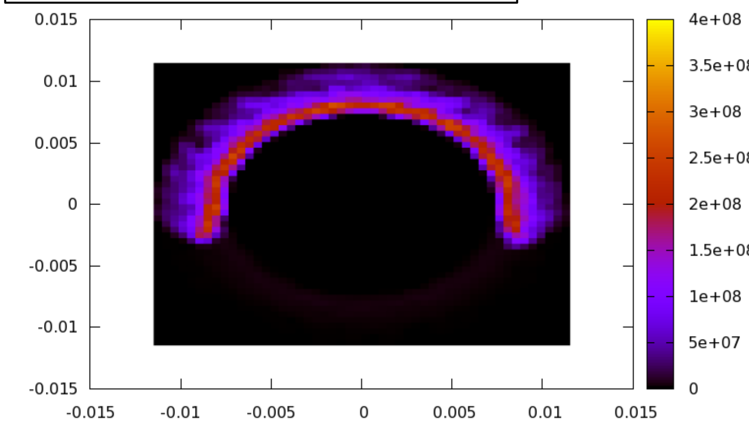
30 mA, e/H = 50



80 mA, e/H = 5



80 mA, e/H = 50



In all cases, we stay below the surface vaporization limit

Summary

- The Linac4 ion source commissioning results show that the beam extraction has to be modified for 45 keV operation
- A study of two different concepts has started
- Concept 1 – Electron dumping in Einzel lens
  - Results in lower electron power density
  - Works for different current densities without modifying geometry
  - Improved beam divergence
  - Beam can be corrected by electrode tilting
- Concept 2 – Electron dumping on intermediate electrode
  - Results in lower electron power density
  - Works for different current densities
  - Improved beam divergence
- Comparison of the two schemes still ongoing
- We have the necessary tools to simulate dump power densities and to optimize H^- beam extraction and electron dumping

Deliverables, manpower, milestones

- Deliverables
  - Simulation of extraction system with IBSimu
- Manpower
  - 2 FTE for IBSimu simulations and measurements
- Milestones
  - Finished simulations for chosen extraction system concept by September 2011 (in parallel with source and extraction integration)
  - Start measurements by end of 2012
  - Design of caesiated source extraction ready by end of 2012
  - Measurements with caesiated source extraction system by end of 2013