Simulations of Various RFAs for Future Designs

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ILCDR08 Workshop

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Goals

- To understand the characteristics of the various RFA designs.
  - In particular the APS design.
- Understand why the signal is so small in the Main Injector (MI)
  - The numbers will serve as parameters for a possible new RFA design for the MI and its associated electronics. Do we use a current amplifier or an MCP?
- To glean from the experience of RFA designers at this workshop
  - Can we measure the electron cloud energy distribution to better than say 10%?

Software Tool

- We will use SIMION for all the RFA simulations
  - Optimisation of physical parameters of the RFA.
  - Calculation of the attenuation factor for different slot geometries.
  - Calculation of the attenuation factor of the mesh used for grids.

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RFAs compared

- High precision RFA
  - “High-resolution retarding field analyzer”, S.D. Johnson et al, J. Vac. Sci, Technol. B 21 (1), Jan/Feb 2003.
- Bessel Box design from ANL
  - R.A. Rosenberg et al, “Design and Implementation of Simple Electron Detectors for Accelerator Diagnostics”, PAC2001.
- APS design (standard)
  - R.A. Rosenberg
- New proposed design

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Simulation Parameters

- The grid is always set to -100V.
- The electrons at the entrance of the RFA fills the hole uniformly and has a uniform angular distribution of $\pm 10^{\circ}$ in both azimuth and elevation.
  - The entrance hole is 1” (25.4mm) in diameter in all the simulations EXCEPT for the APS RFA where it is 0.75” in diameter.
- Electrons which make it to the end of the RFA are counted
  - 1000 electrons are used per KE step.

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High Precision RFA

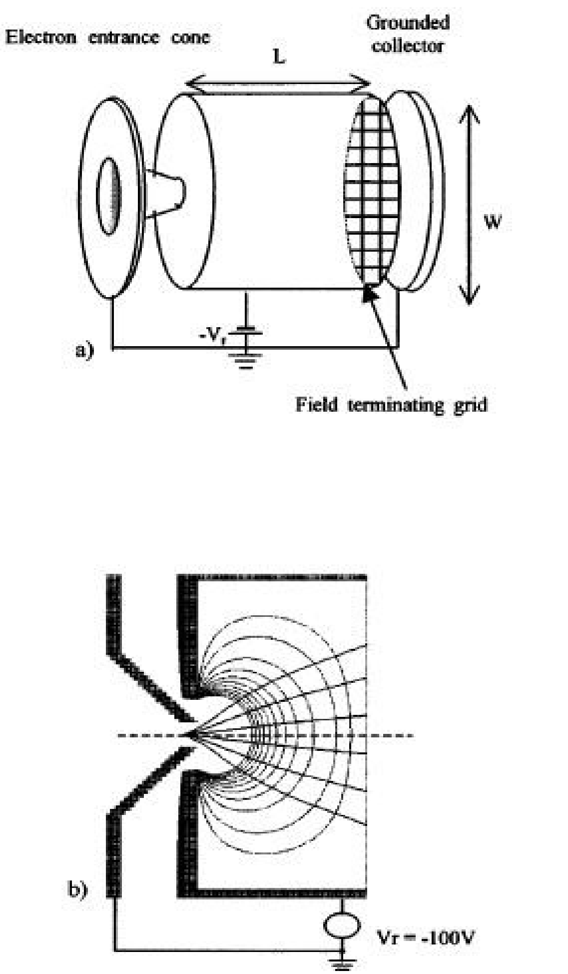
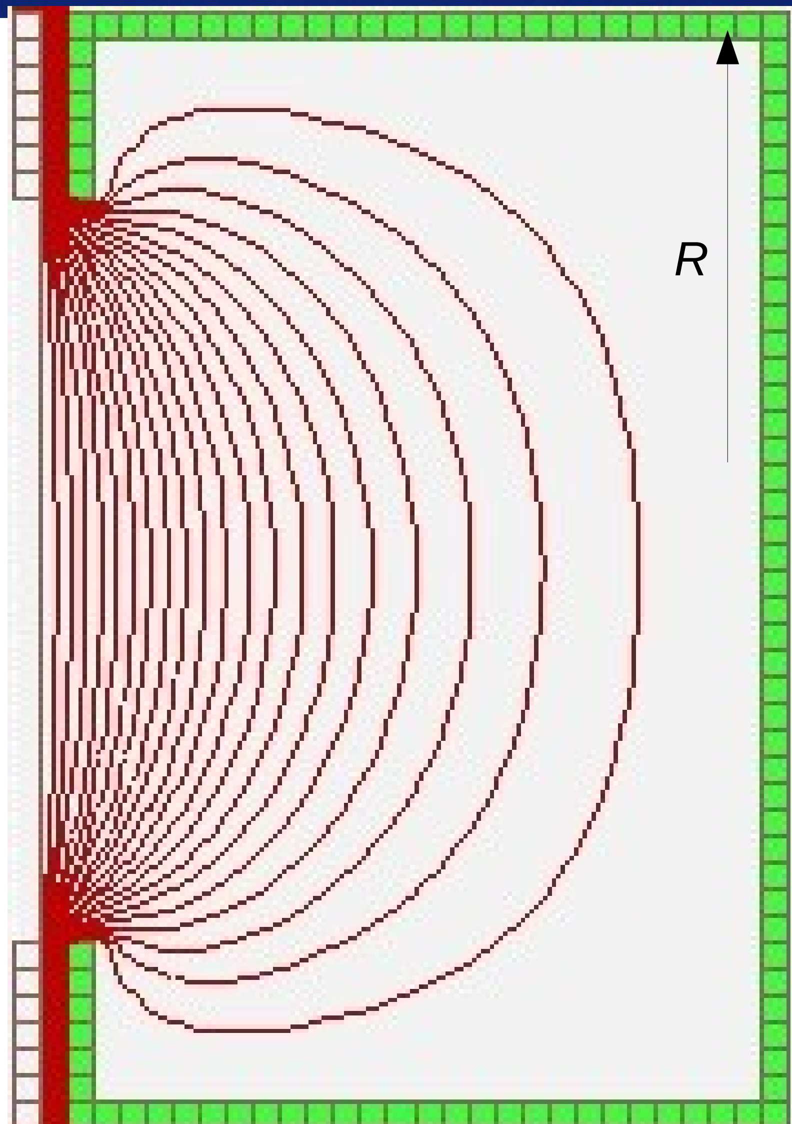
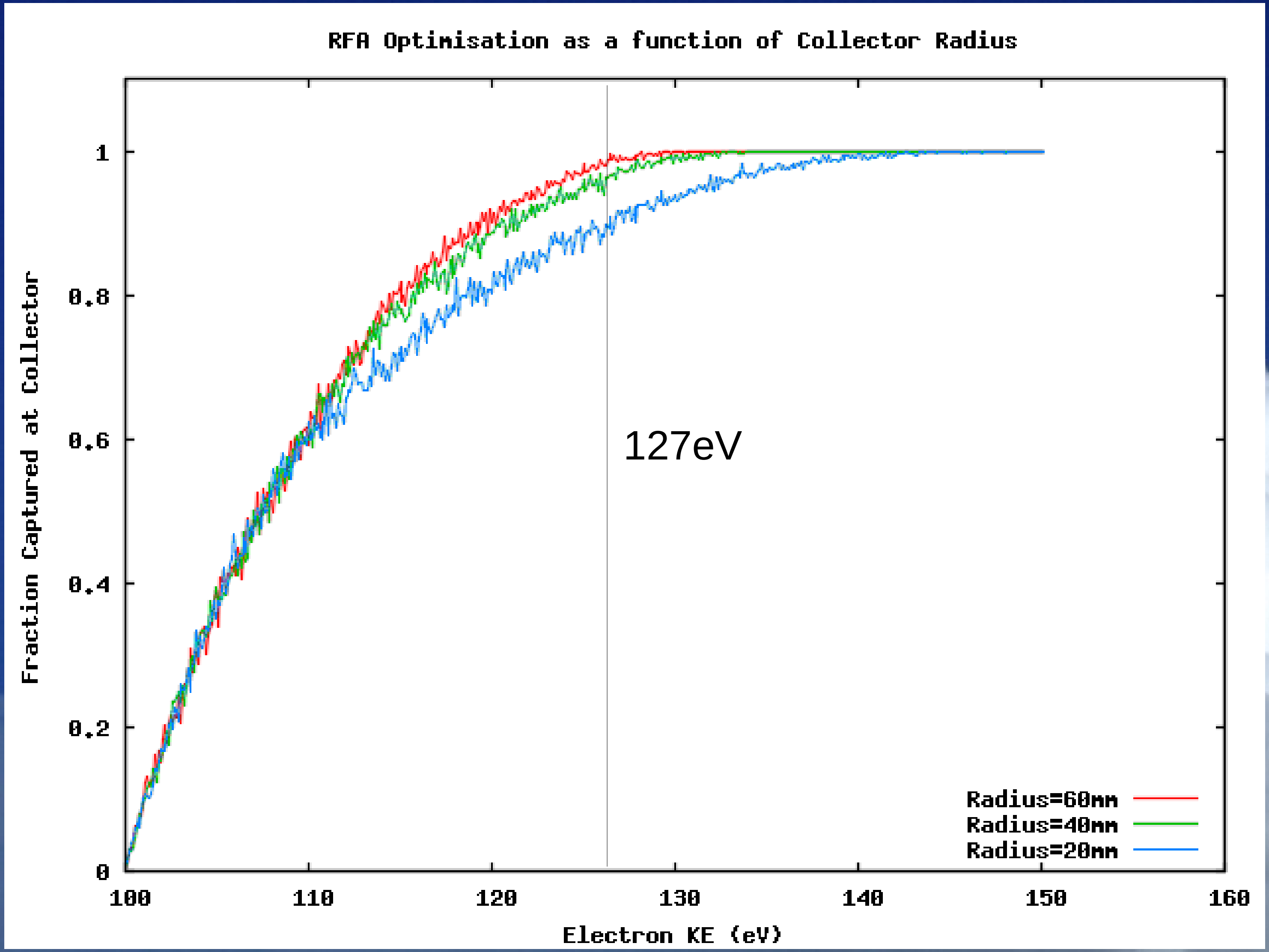


FIG. 1. (a) Schematic diagram of the standard HiRes RFA and (b) simulation results indicating the equipotential surfaces of the retarding field along with three 100 eV electron trajectories with entrance angles of ±5°, ±15°, and ±25°.



Cone has been removed.
Length has been optimised separately to 30mm.
Radius of RFA optimised for HPF characteristics.

Optimising Radius of RFA



Very poor HPF characteristics. See later designs.

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Bessel Box RFA

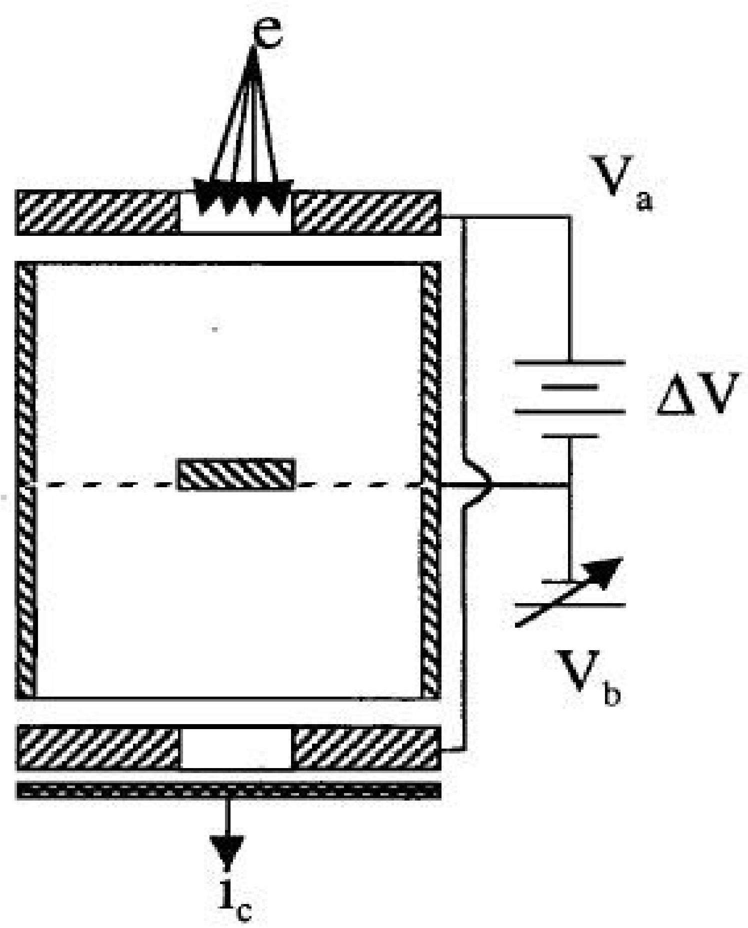
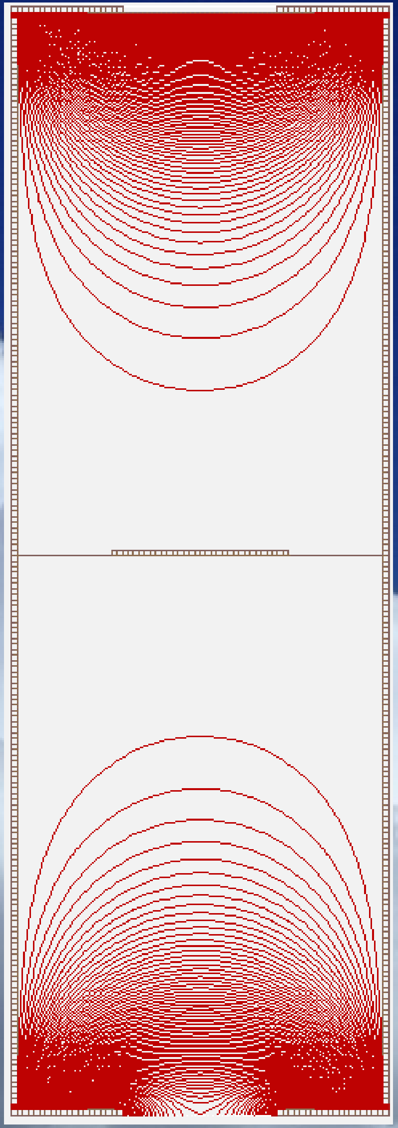


Figure 2: Schematic diagram of the Bessel Box analyzer. (Symbols are described in text.)



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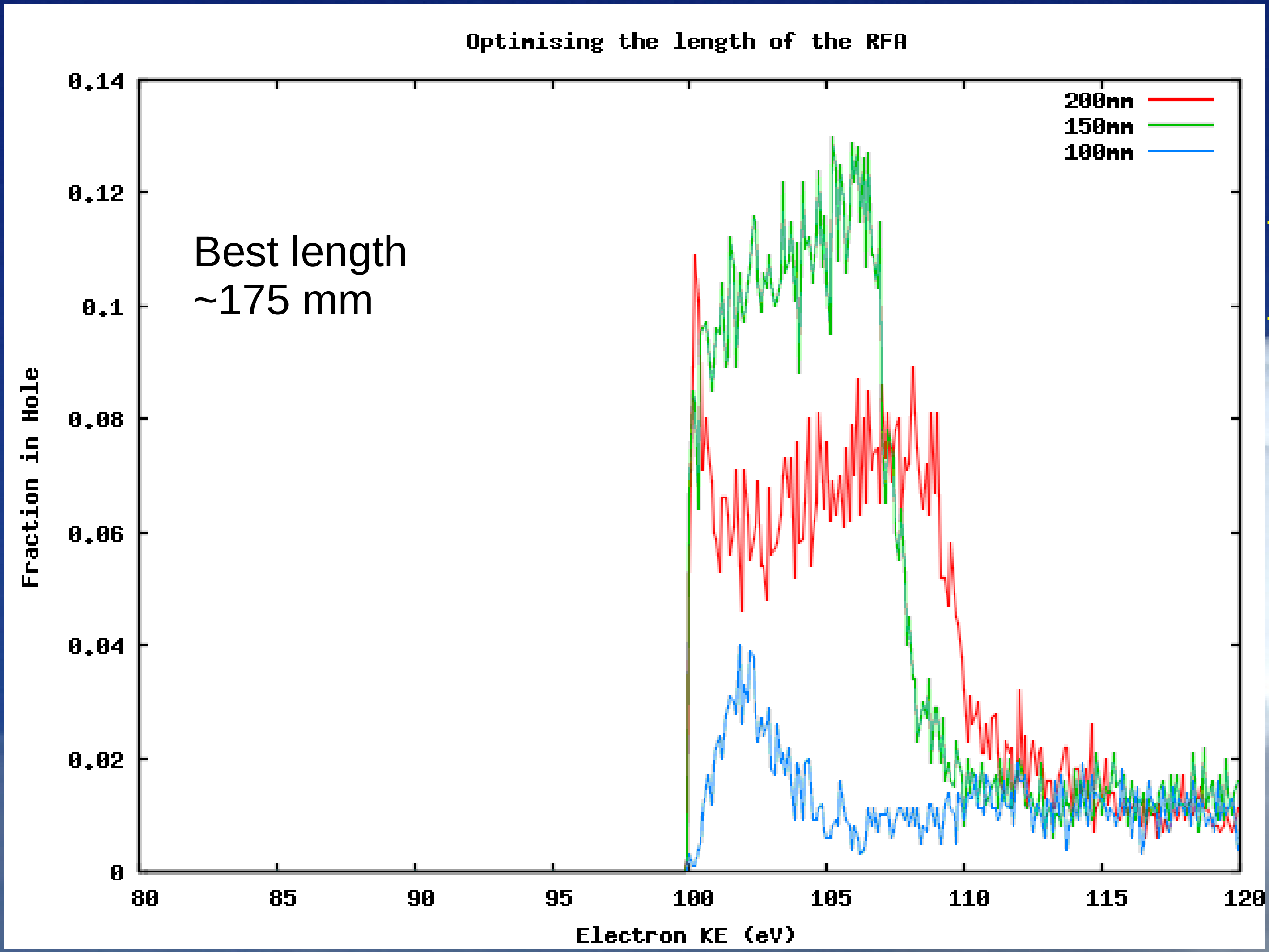
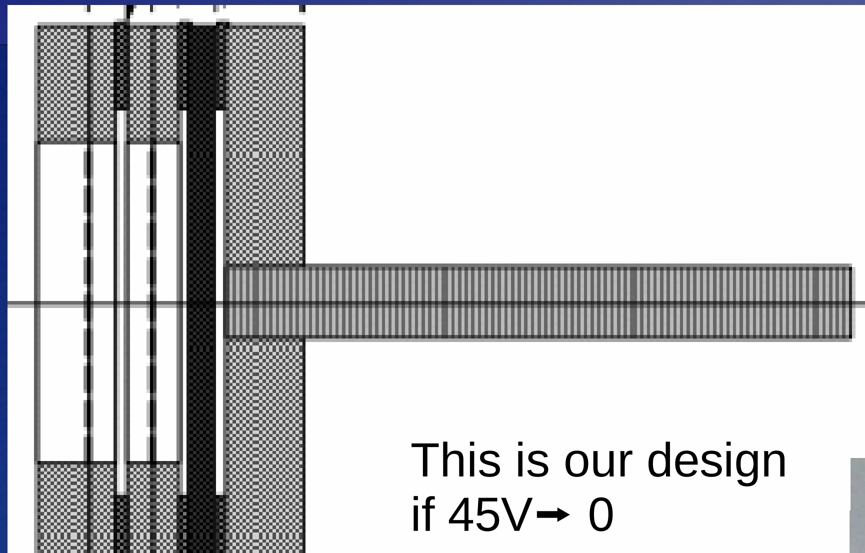
Optimising the Length of the RFA



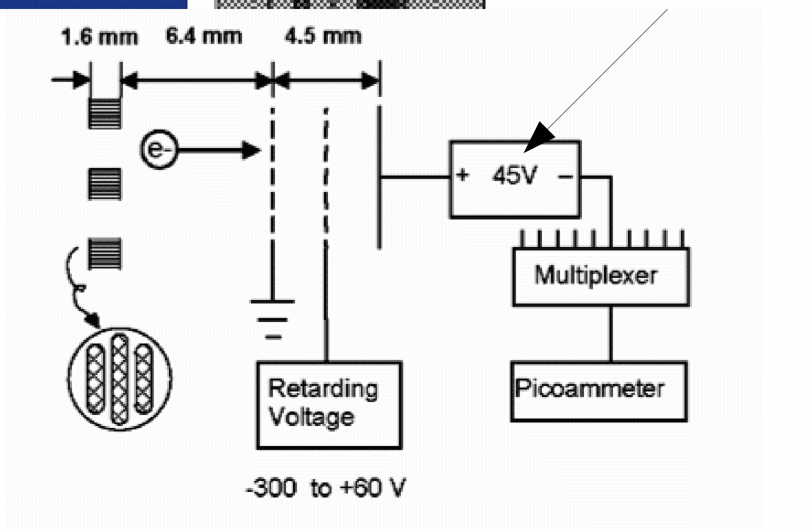
Poor capture efficiency. Behaviour is that of a BPF. BPF design is unnecessary because grid voltage needs to be stepped for a scan and postprocessing needs to be done anyway.

Furthermore, this is with an ideal grid. Efficiency will be reduced by 20% with non-ideal grid.

APS Design



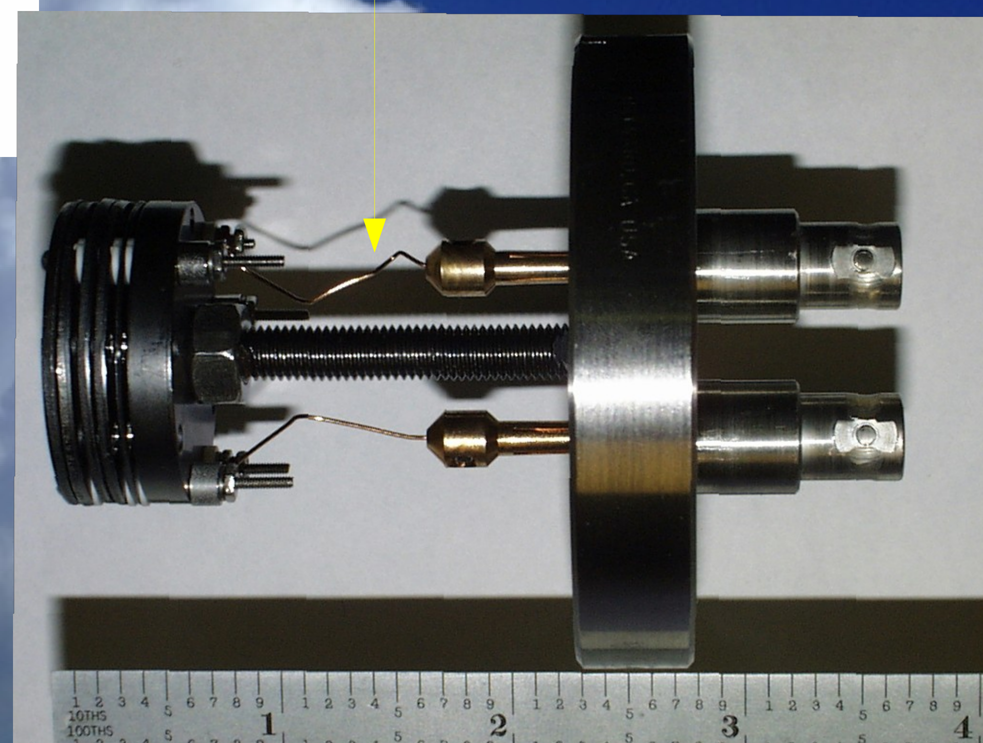
This is our design if 45V➡ 0



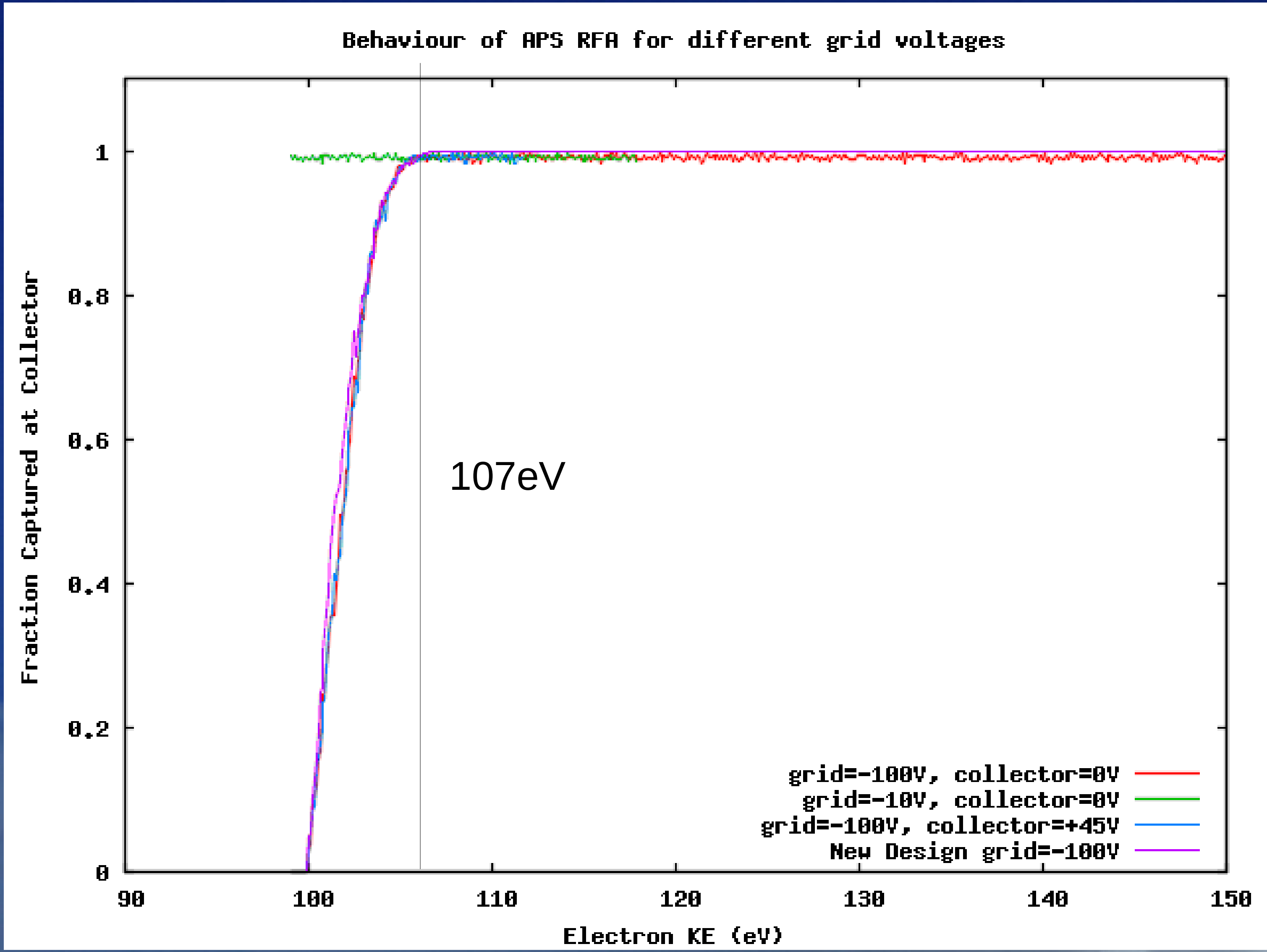
Detail showing RFA installation behind vacuum penetration slots cut into APS chamber wall. Total slot area ~ 1 cm^2. (K. Harkay)

Note: Hole is 0.75” in diameter.

Clearly NOT 50Ω



HPF characteristics of APS RFA



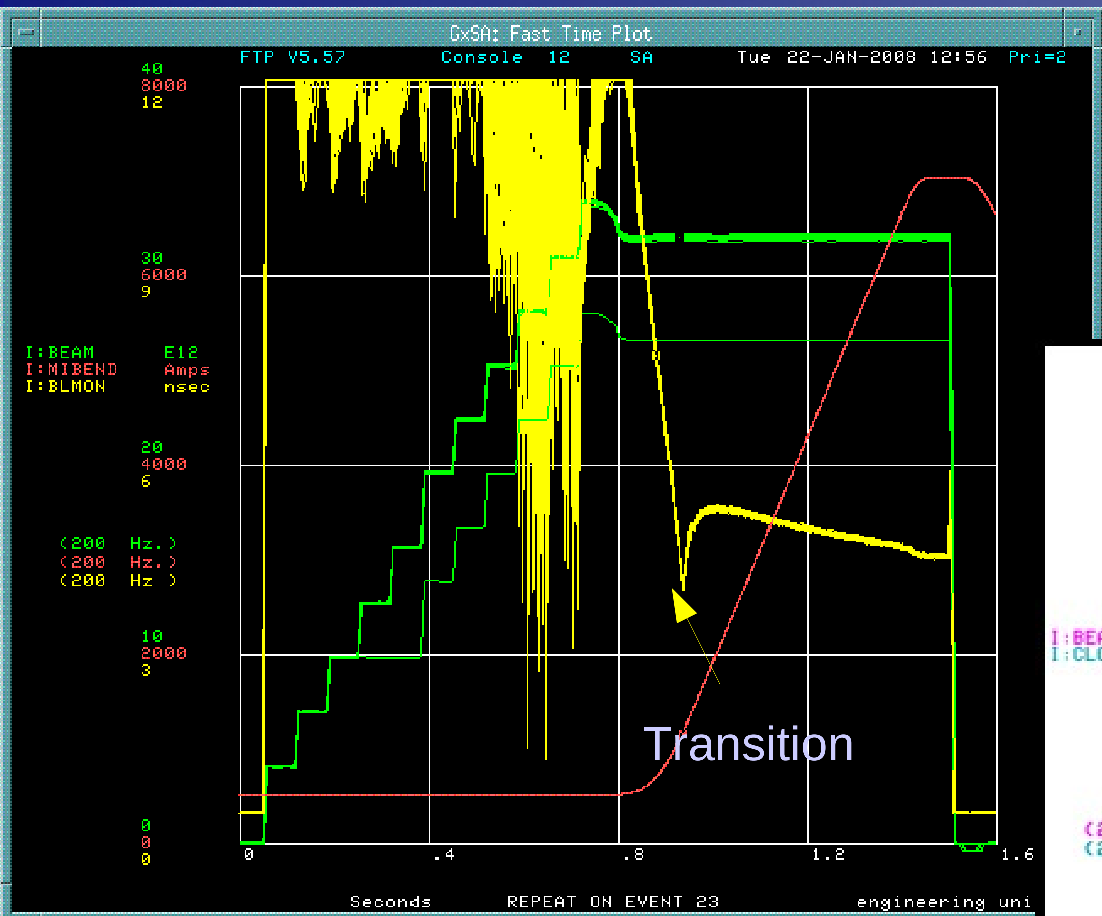
Our design is a miniscule efficiency improvement. This probably comes from the larger dimensions of our design.

Having the collector at +45 V is rather irrelevant. Only PD's count! The PD between -100 and 0 is 100.

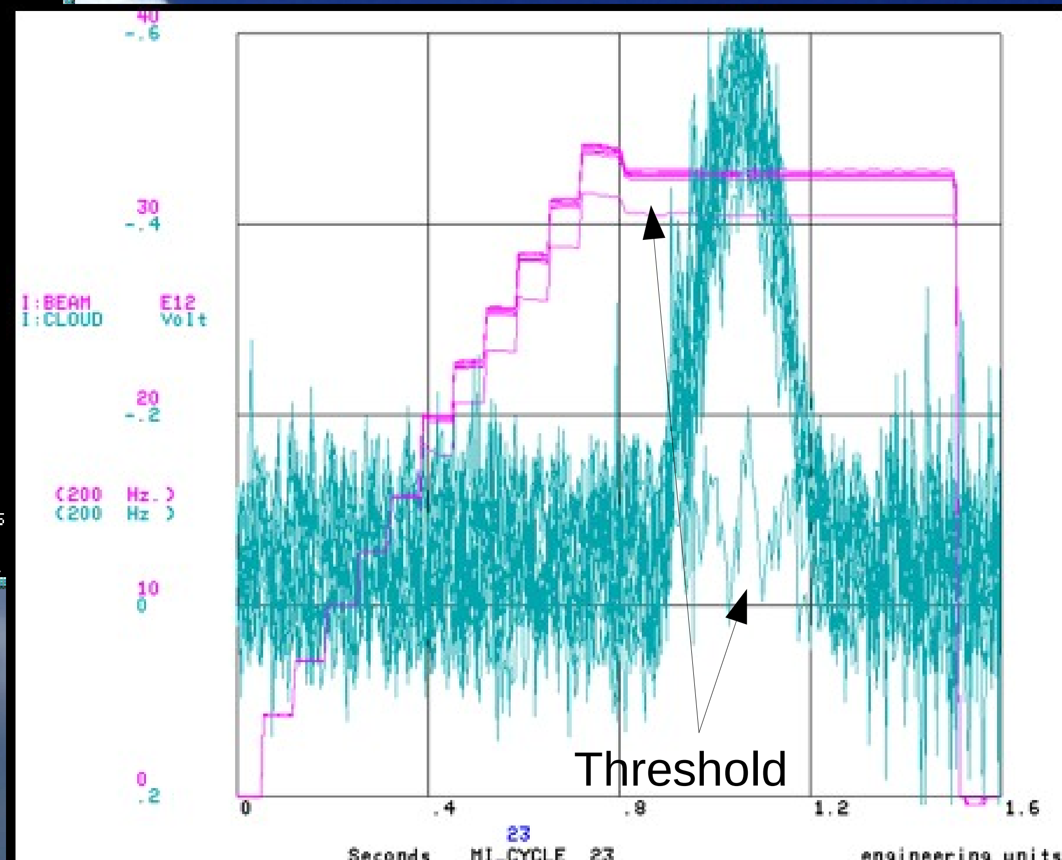
APS RFA Performance in MI

- Note that the APS RFA has poor S/N in the MI
  - We do NOT connect the RFA as designed:
    - Signal measured at grid, held at a few volts
    - Very small signal on collector.
    - Simulations show that ALL the electrons should end up on the collector but we do not observe this
      - Are the slots or grid attenuating the electron signal?

What we see

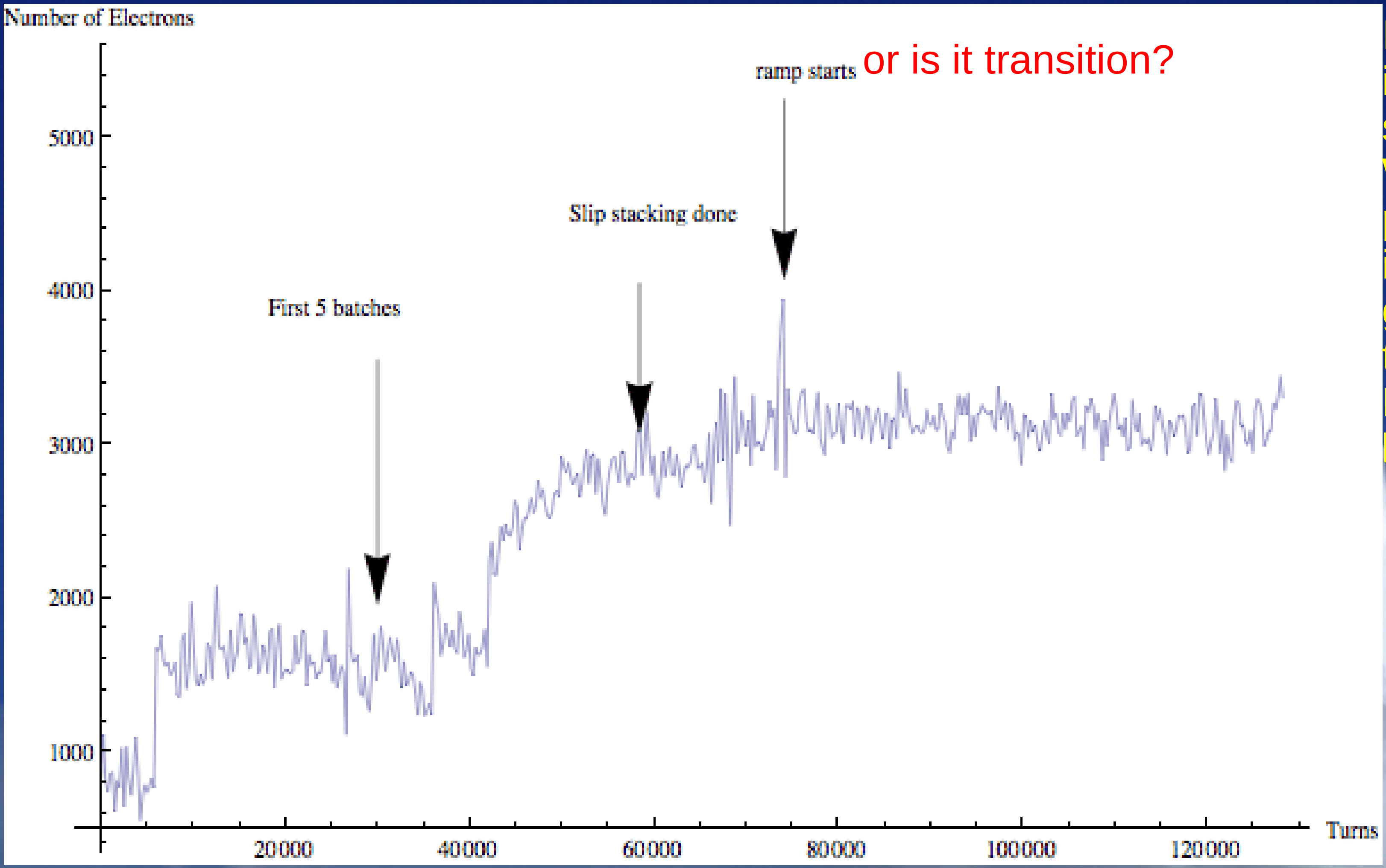


Signal is **VERY** noisy



Is transition where we really see lots of action? Looks like after transtion.
Also not at flattop!

Compared with IPM (which uses MCP)



IPM is still looking at ions despite having sweep field off.
We have reverse polarity data but ... instrumentation guys not giving us the file format.
Eyeballing data looks good!

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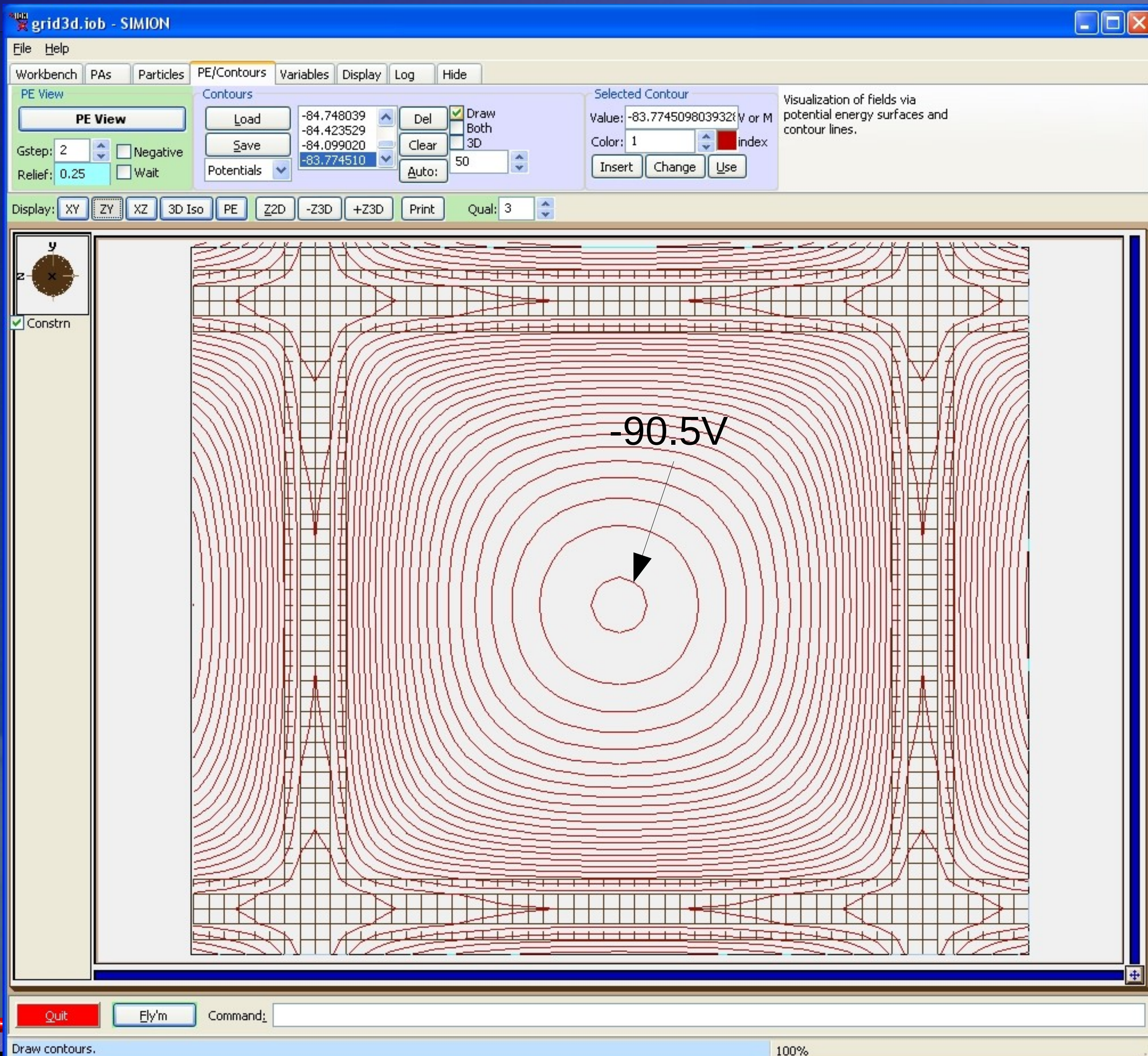
Effect of Mesh

- Buckbee-Mears the usual supplier of fine copper meshes is OUT OF BUSINESS! (Sold to International Electron Devices, no website)
  - We don't have the exact data of MC-7 used in the APS RFA but according to the assembly drawing it is 25 lines/inch.

Effect of Mesh (Zoomed in)



Mesh is at -100V but centre of holes are NOT at -100V which means particles < 100eV can get through.

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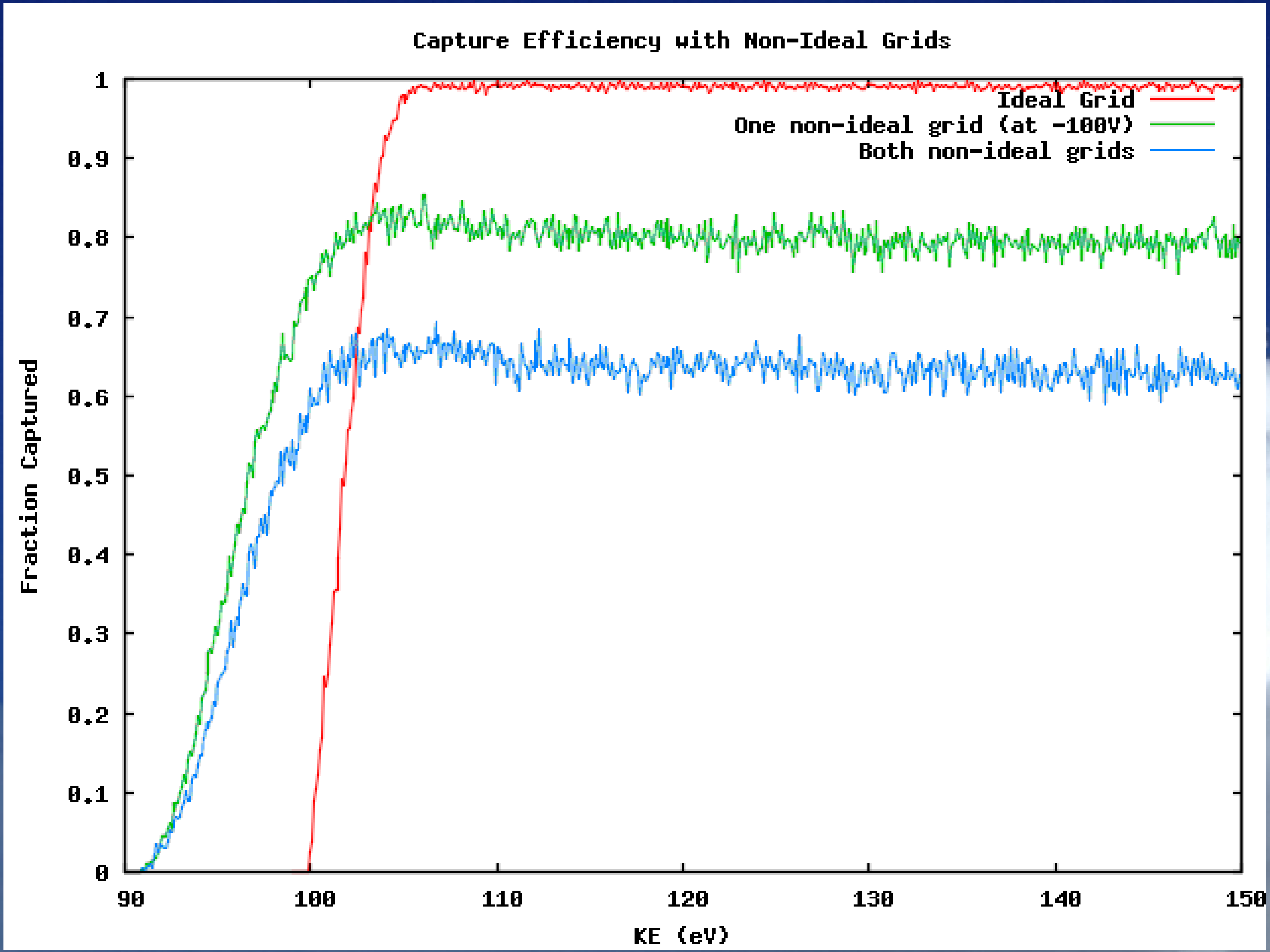
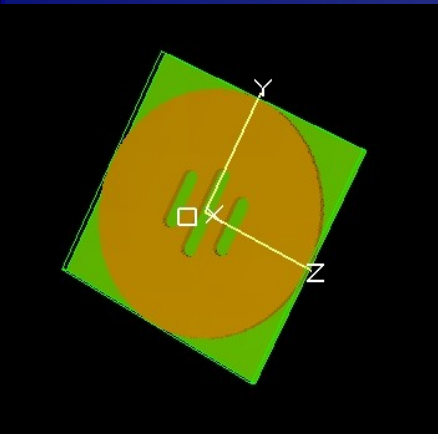
Effect of Non-Ideal Grids on APS Design



Effect of grid is to lower the rise point of HPF. Make the slope much less steep.

Effect of Slots



Calculating the slot area, these 3 slots basically allow 55% of particles to get through. SIMION simulations show that this is indeed the case.

Other geometries like honey combed holes must have area MUCH larger than these 3 slots, or else it is rather pointless. There MUST be a path for the image current to flow.

Therefore, with 2 grids and the slots, the capture efficiency is only 30% !!!!

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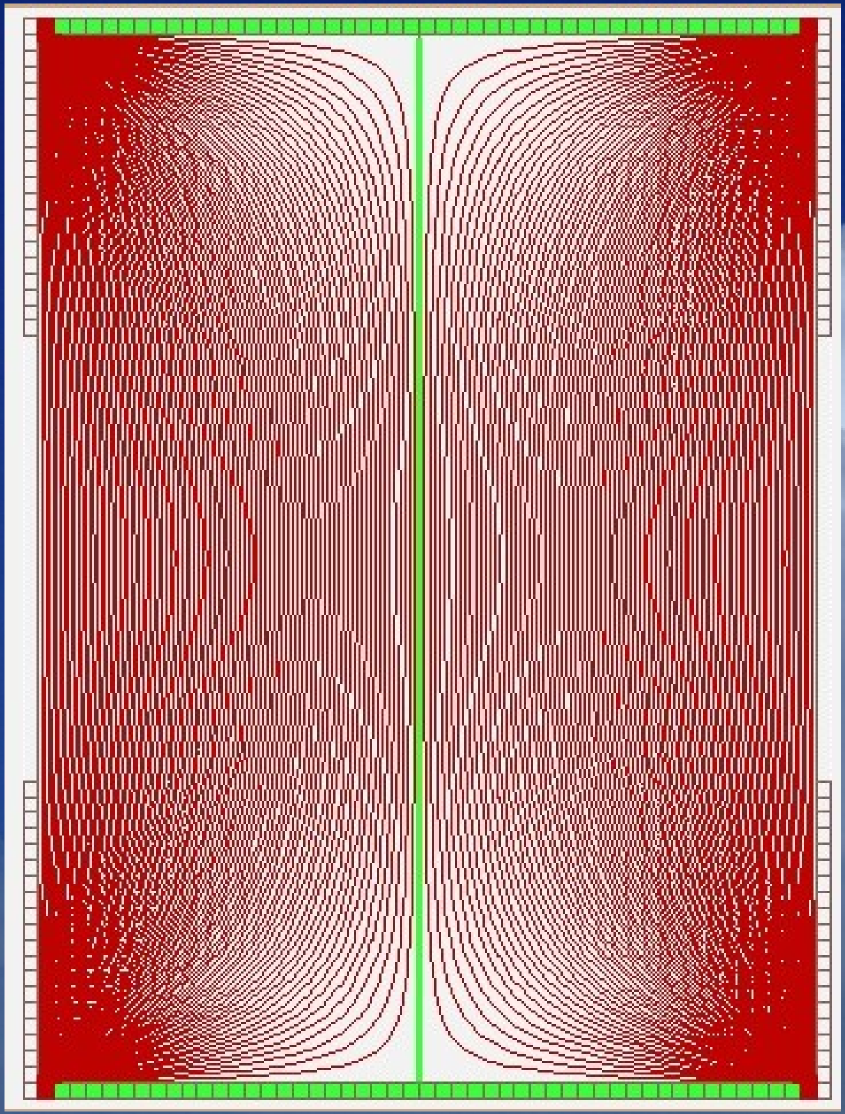
Proposed Design



Similar to Bessel box except stop is removed. (Green is held at -100V)
Radius is 34mm.
1 mesh instead of 2.
Hole is larger. 1” instead of 0.75”.
Diameter is 7cm. Length is 5 cm.

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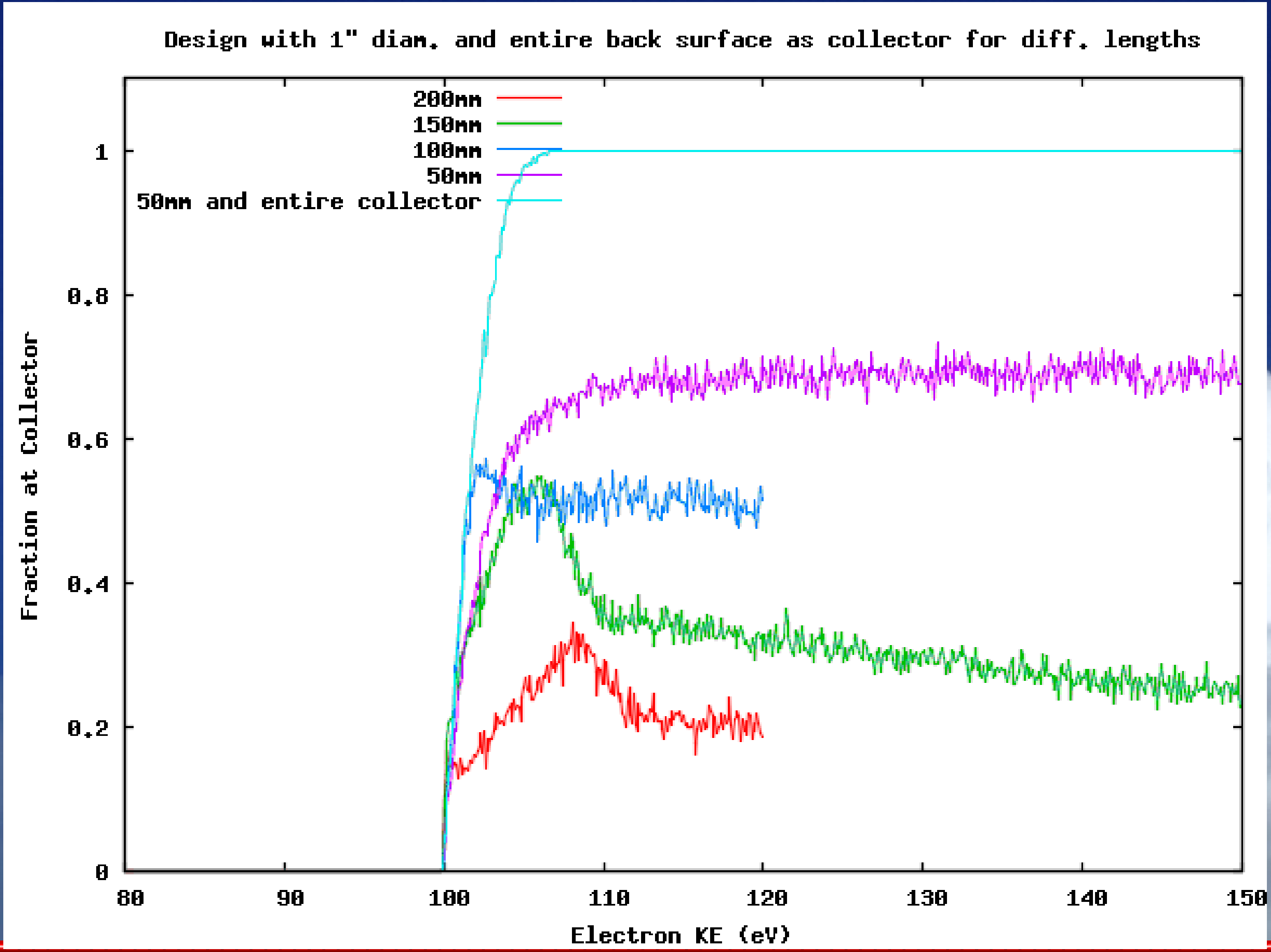
Proposed Design Length Optimised



Very nice HPF behaviour. About 7eV at roll off when entire collector is used. Nice 100% efficiency. Diameter is always 7cm, hole is 1" diameter.

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Questions

- Should we match the collector plate to 50Ω?
- Do we need to have a distance between the slots and the first grid like in the APS design?
- Mu metal shielding?
- What are the good hole geometries which reduce electric fields from passing bunches? Area, area, area!!
- Is using an EMT or MCP a good idea?
  - Immunity to electric fields from bunch
  - High gain
    - Calibration?
  - Cannot be left on continuously.
  - Is signal dependent on KE of electrons?