Field Emissions and Dark Current Simulations

MICE CM36 - IIT

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June 18, 2013

Using FES (Field Emissions Simulation) V1.2

Field Emissions and X-Rays

- Very high field gradients induce electron quantum tunnelling accross metal surface.
- Local imperfections magnify electric field $\longrightarrow$ greater electron current.
- Fowler and Nordheim described this:

$$j(E) = \frac{A\beta^2 E^2}{\phi} e^{-B\frac{\phi^{3/2}}{\beta E}} \tag{1}$$

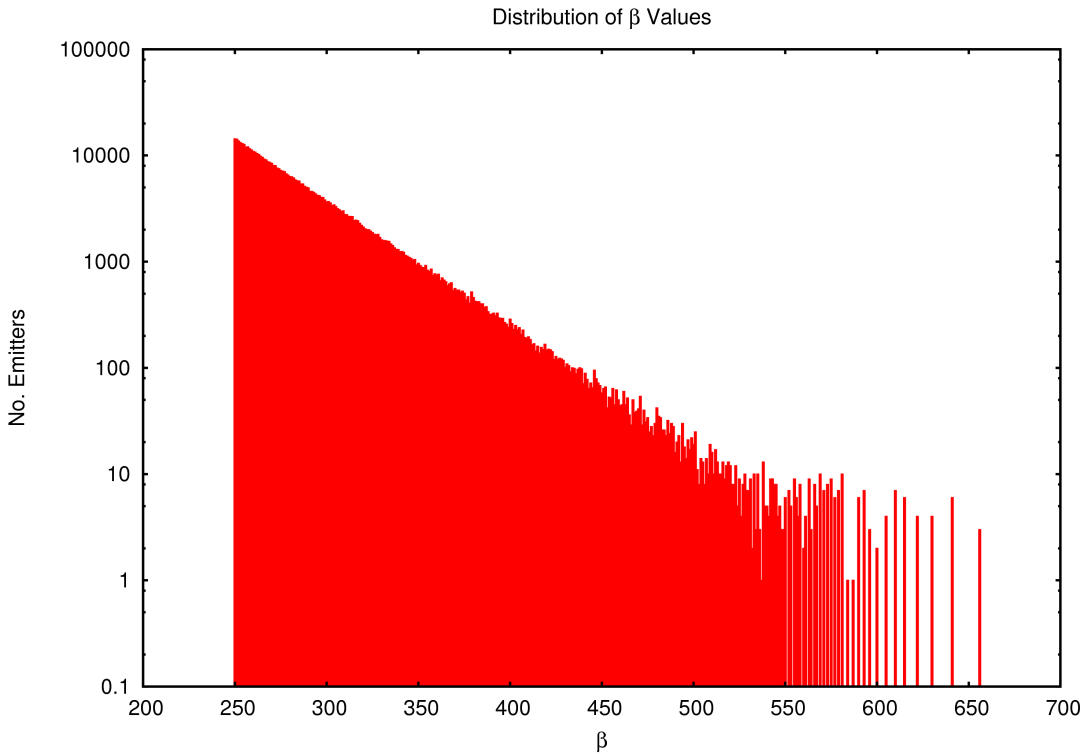
- Field emitted electrons will enevitably hit something:
  Trackers, people, cavities...

Assumptions

- Cavity Geometry
  - Ideal pillbox shaped cavities
  - No Be windows
  - Emitters on found on flat faces of cavity
- Field Simulation
  - Perfect field simulation (TM010 Mode)
  - No edge effects at cavity iris
  - Solenoid Fields not currently supported
- Particles
  - Produced at rest
  - Space charge negligible
  - Emitters have identicle area
  - No integrated X-Ray simulation
  - No dE/dx simulated

The Code

Very rough estimate for emitter distributions used (Moretti et al). More data needed to improve emitter distribution.



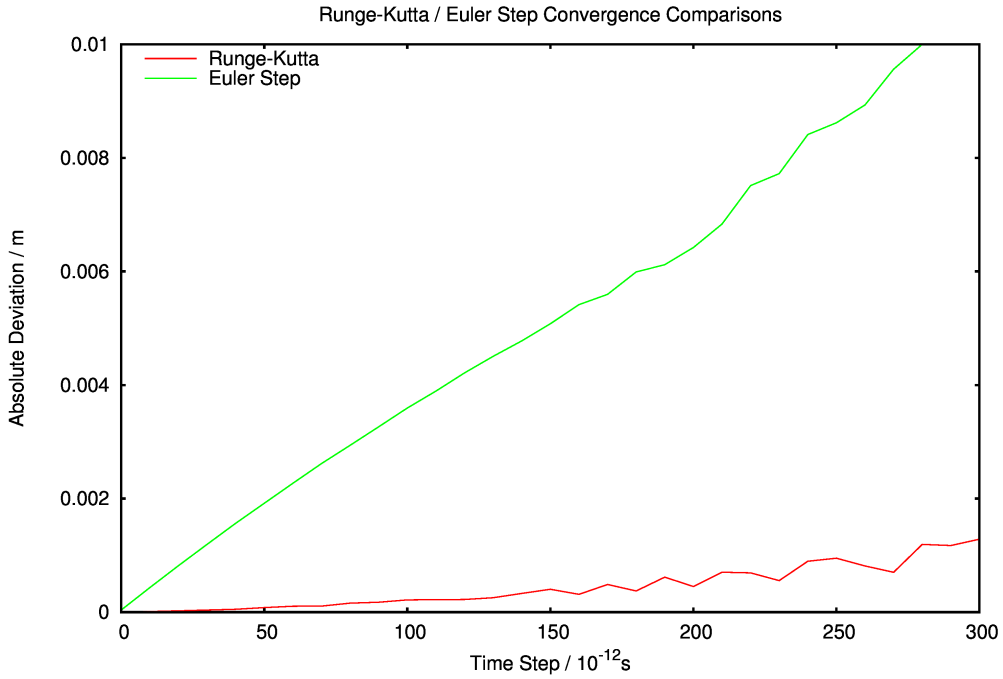
Distribution of β for emitters

$\beta < 250$ neglected. Emitter Current negligible.

The Code

XML File used to allow runtime varying of all simulation parameters.

Convergence of Runge-Kutta & Euler Step methods studied.

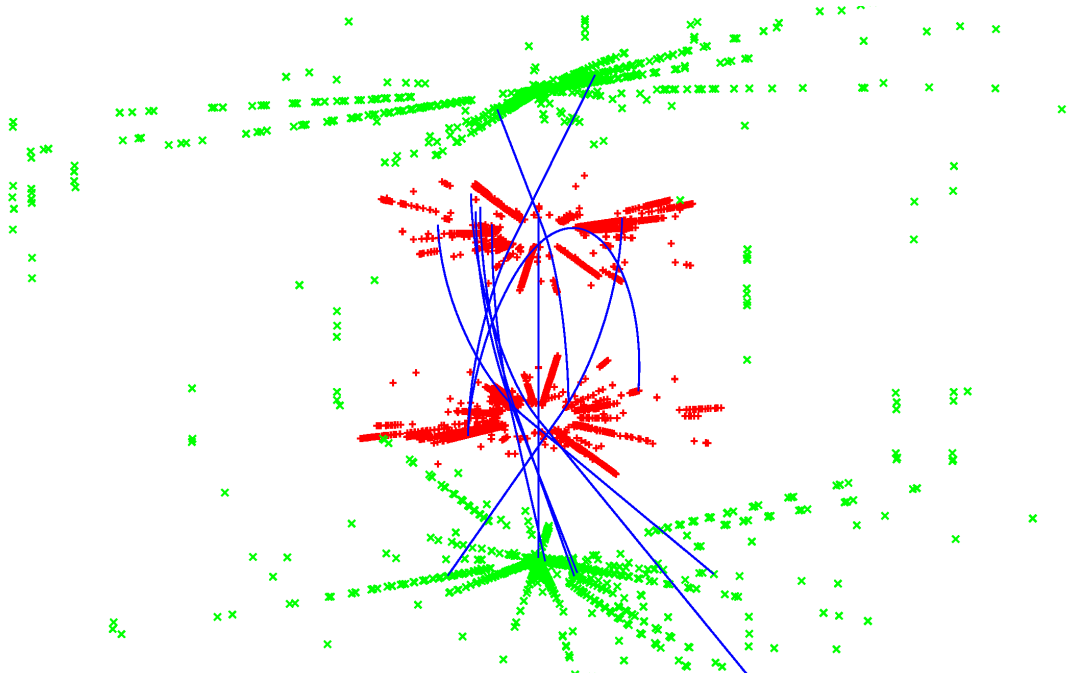


Radial deviation of particle-cavity interaction point with respect to step size.

Geometry

Simple cavity design used for testing. NOT a MICE Cavity!

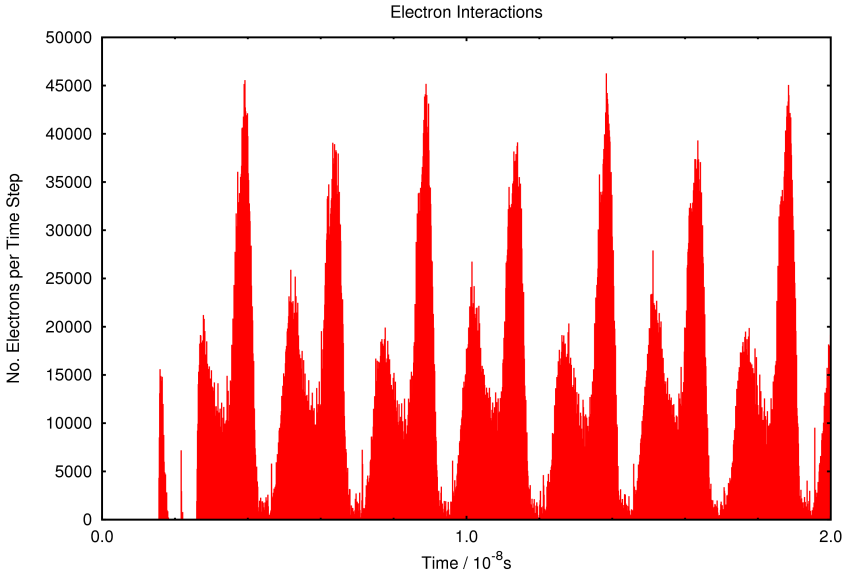
Radius	0.5m
Length	0.4m
Iris Radius	5cm
Mode	TM010
Frequency	201.25 MHz
Gradient	8.0MV/m

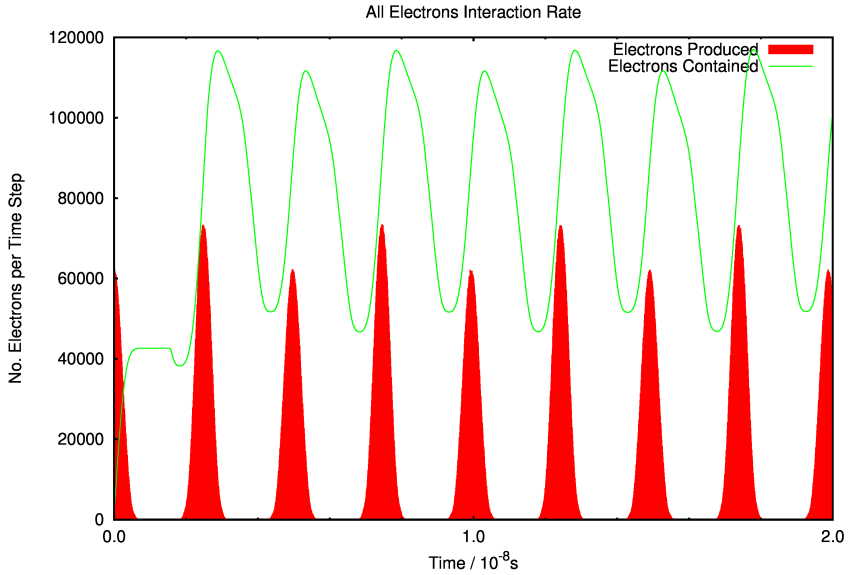


RED: Electron-Cavity Interaction Points
GREEN: Electrons Leaving the Simulation Volume
BLUE: Example Electron Tracks

Rates and Currents

Time dependendent results. Interaction and production rates as a function of time.



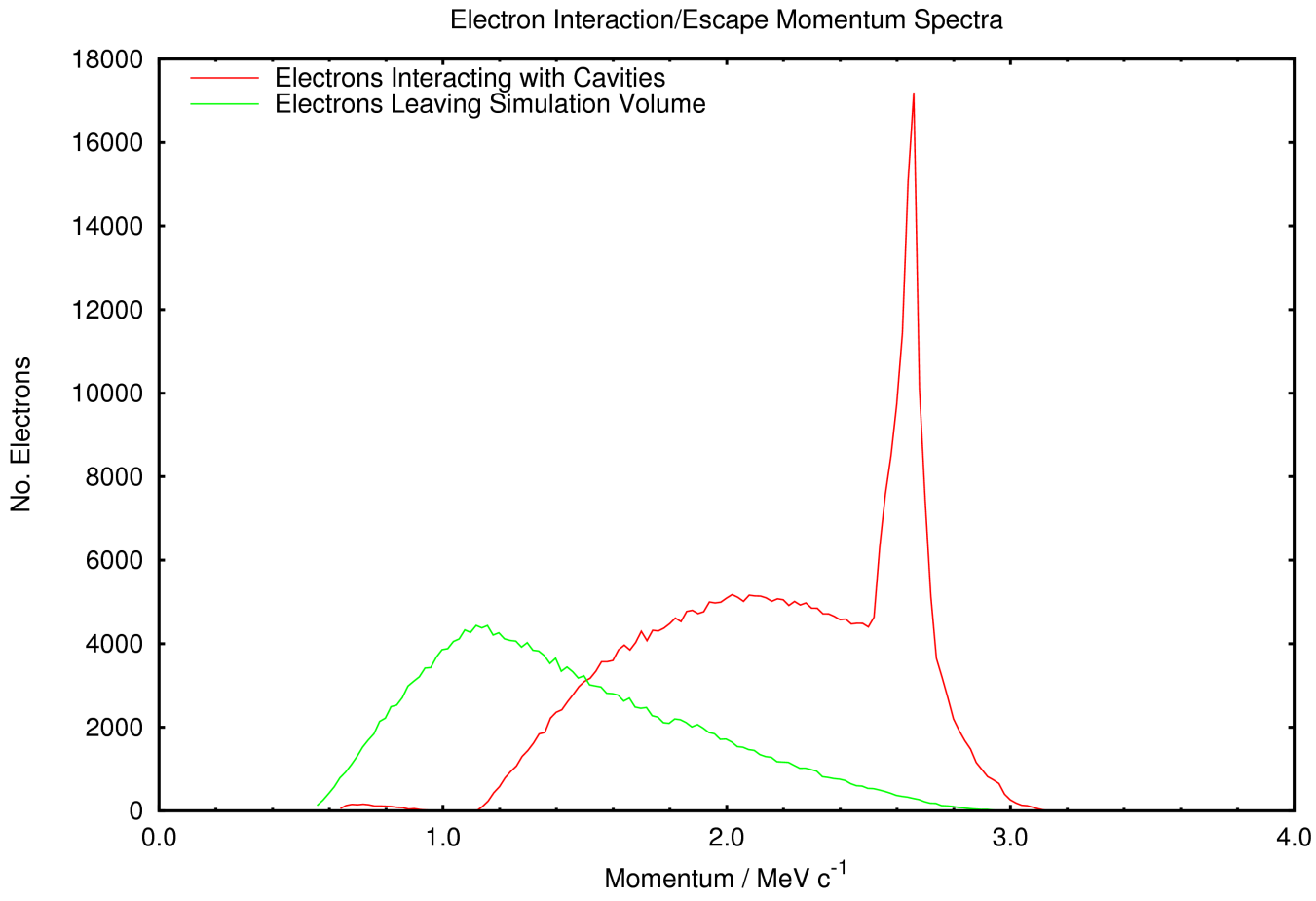


No. Electron-Cavity Interactions per Time Step

RED: No. Electrons Produced per Time Step

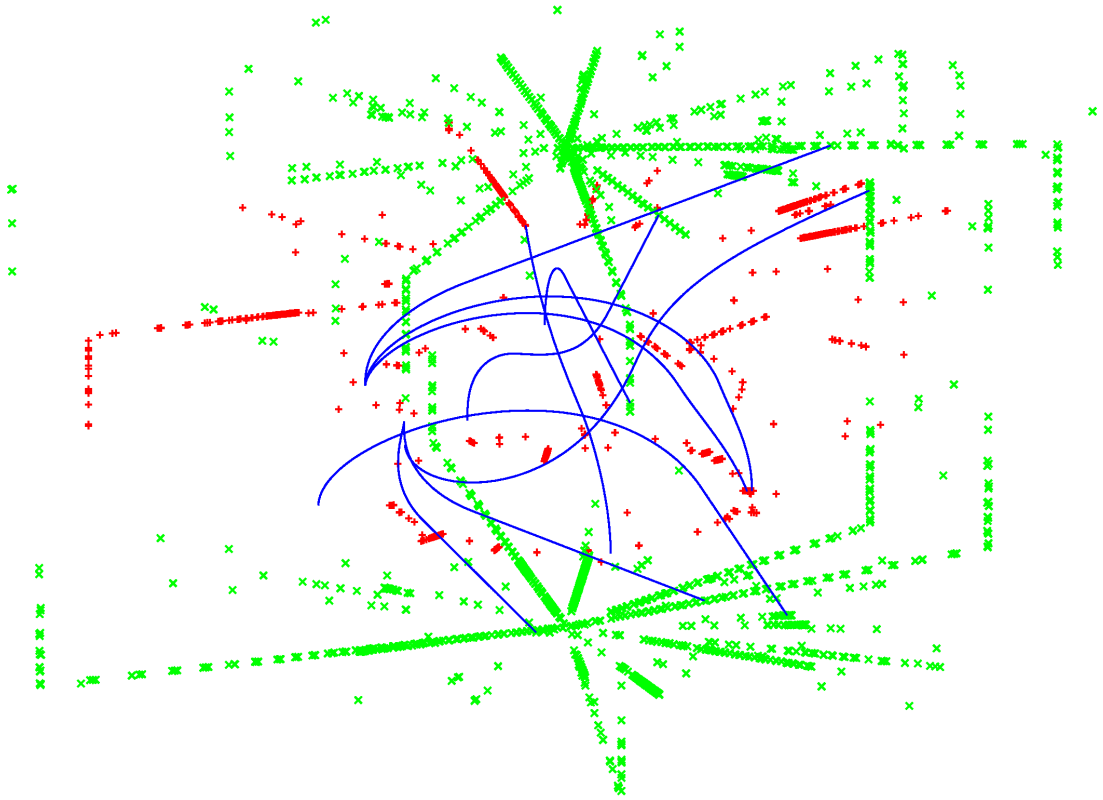
GREEN: No. Electrons Contianed with the Simulation

Spectra



RED: Electron-Cavity Interaction Momenta
GREEN: Electrons Leaving Simulation Momenta

Two Cavity Geometry



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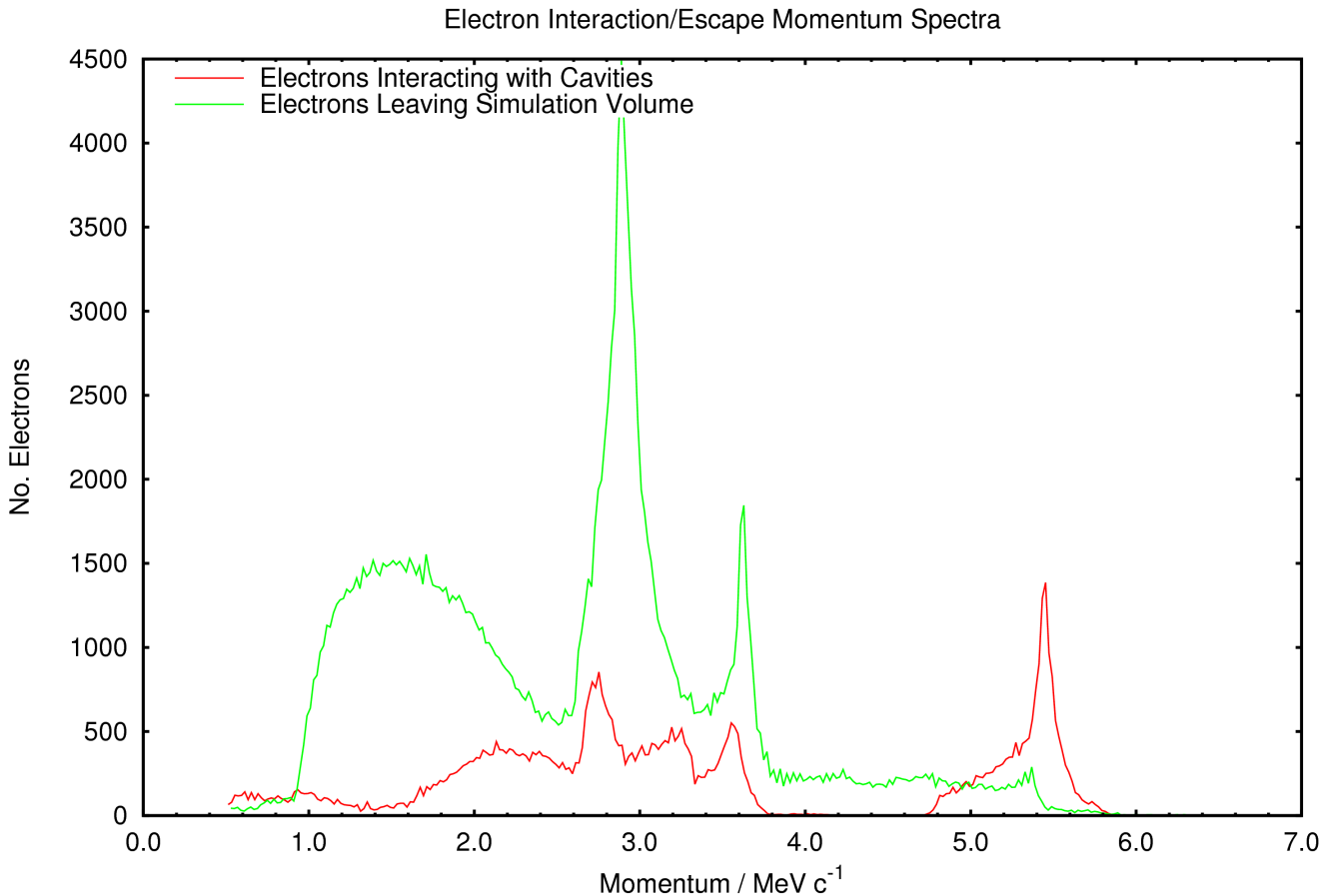
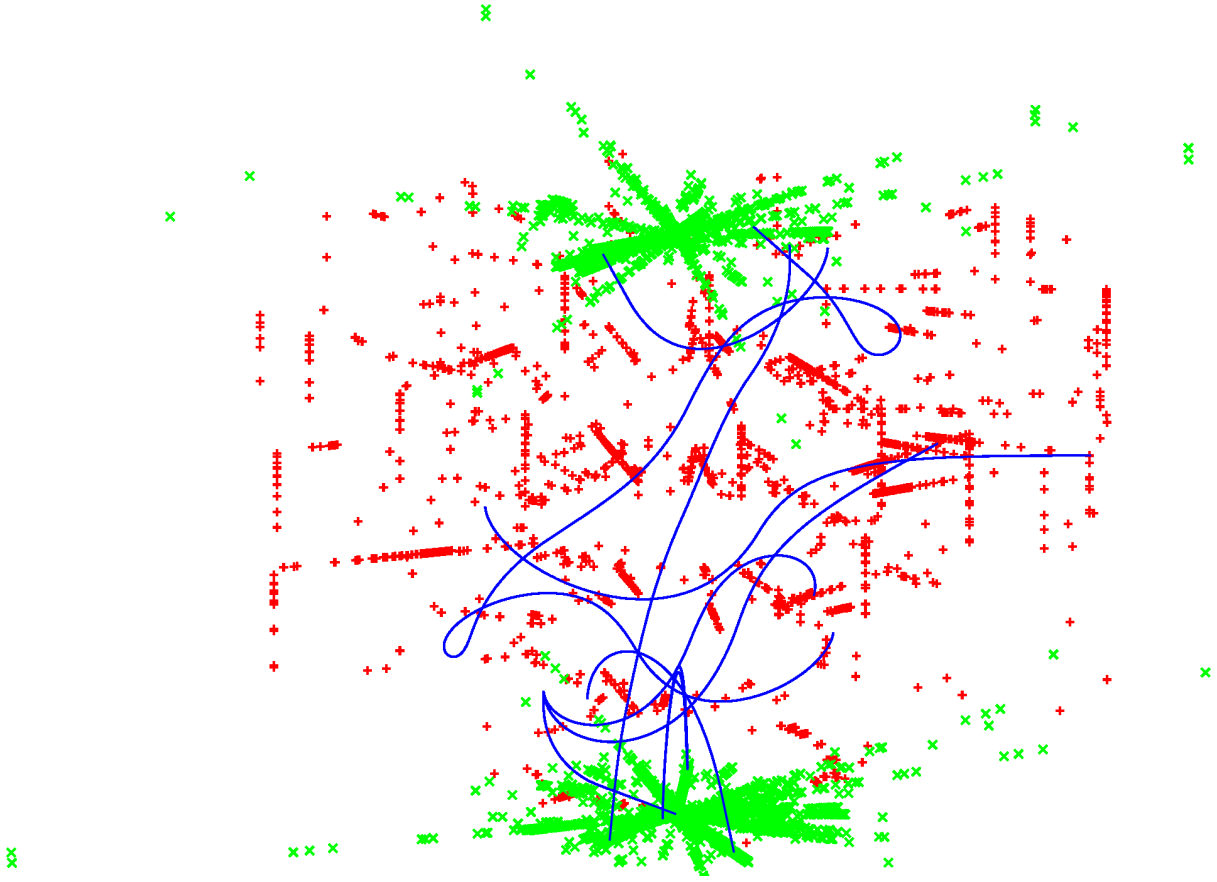
Two Cavity Spectra

More cavities introduces more features to the spectra. There a more faces to hit!



RED: Electron-Cavity Interaction Momenta
GREEN: Electrons Leaving Simulation Momenta

Four Cavity Geometry



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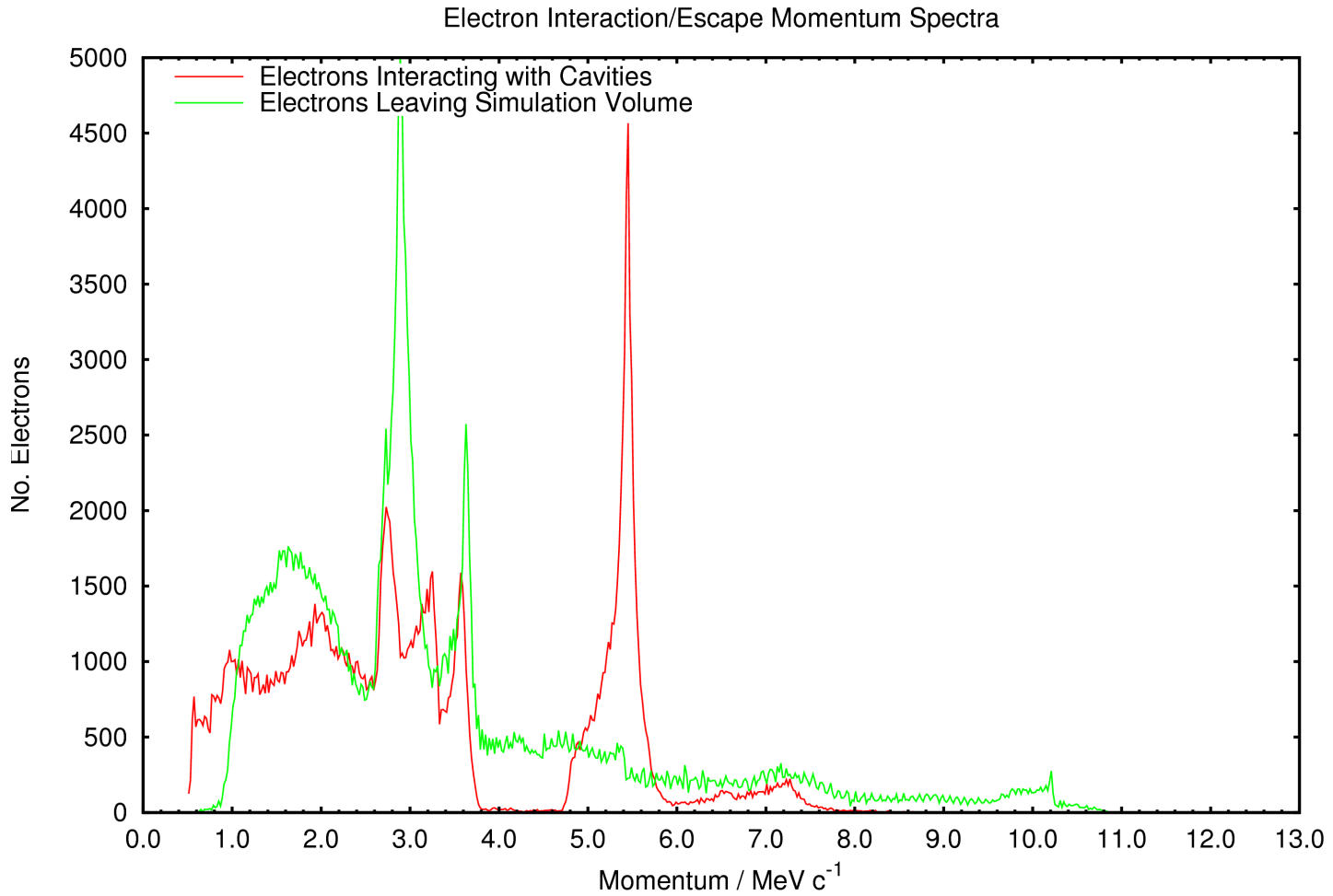
Four Cavity Spectra



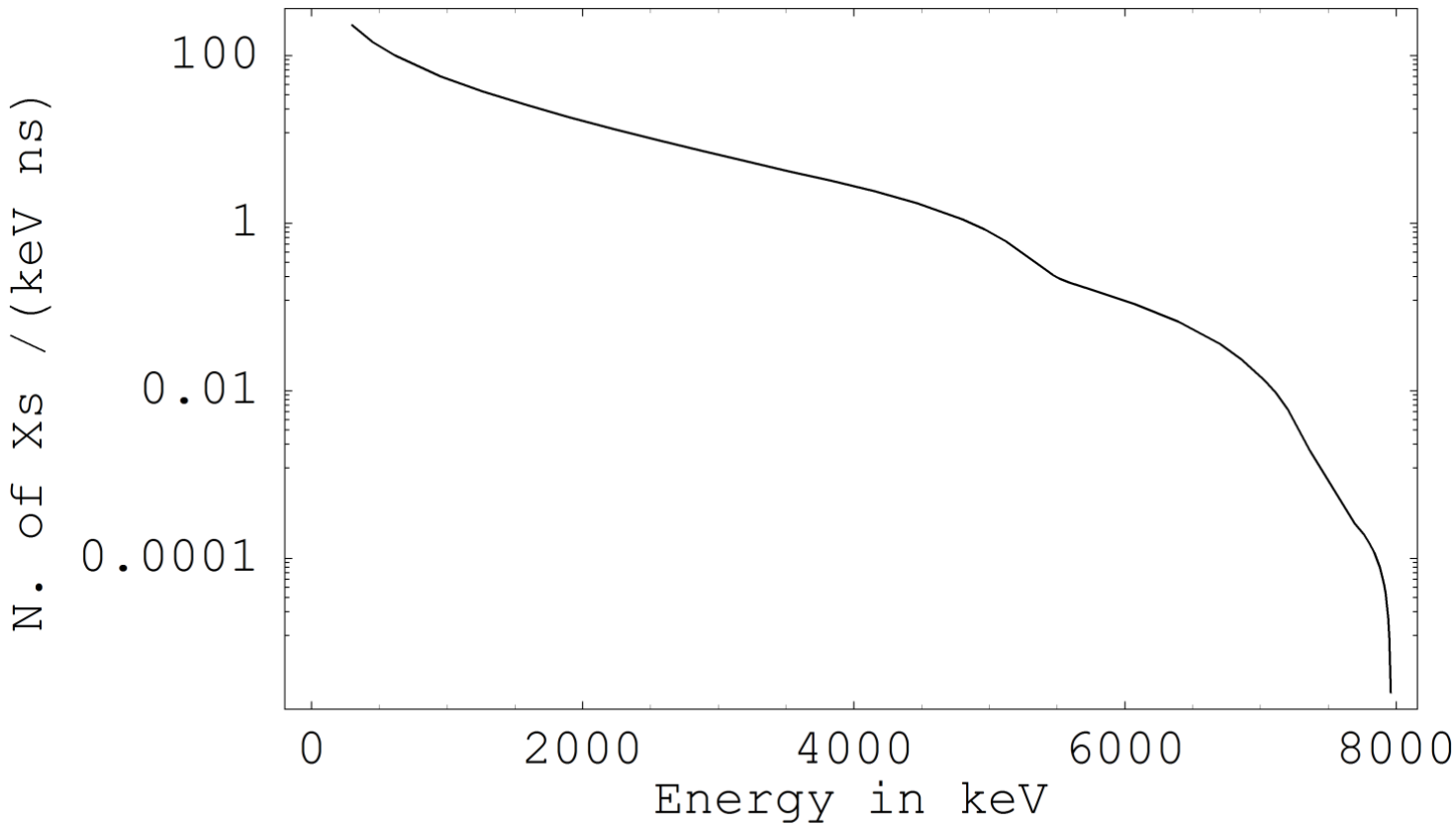
RED: Electron-Cavity Interaction Momenta
GREEN: Electrons Leaving Simulation Momenta

Preliminary X-ray spectrum

- Approximate Kramers formula for thick target was used:

$$\frac{dY}{dk} = \frac{2\times 5\times 10^{-4} Z}{511}\left(\frac{E_{\max} - k}{k}\right)$$ (photons per keV)

- Only interactions with Cu included so far.
- Work in progress to simulate X-ray spectrum in MARS code.



Future Plans

1. Implementation
   - MAUS Monte Carlo Module
   - Stand alone Dark Current Simulation
2. Features
   - Solenoidal Field Simulation
   - dE/dx Approximations
   - Be window simulation
   - Improved analysis
3. Uses
   - Tracker X-Ray Detectors
   - Input to PPE Discussions
   - Cavity Monitoring