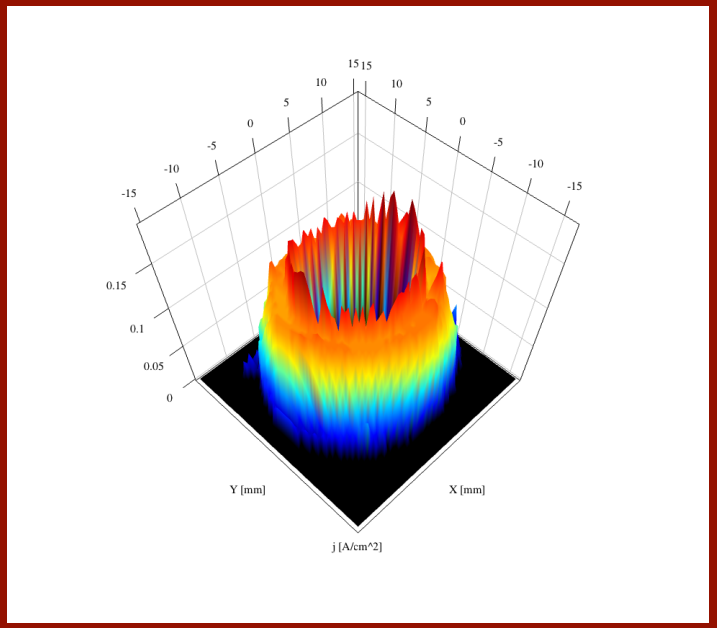
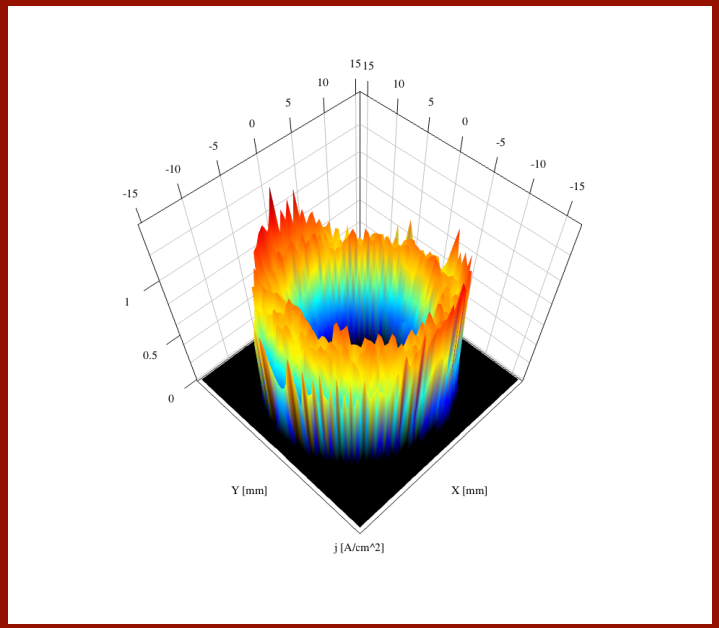
Electron Hollow Gun Collimation Performance & Simulations

Topics:

- What has been done?
  - Perveance Measurements
  - Profile Measurements
  - Electric Field Measurements
  - Polar Decomposition
  - WARP Commencement
  - Transmission
- To be done & Deadlines?
  - WARP @ CERN
  - Implementation

Vince Moens, 11.04.2013





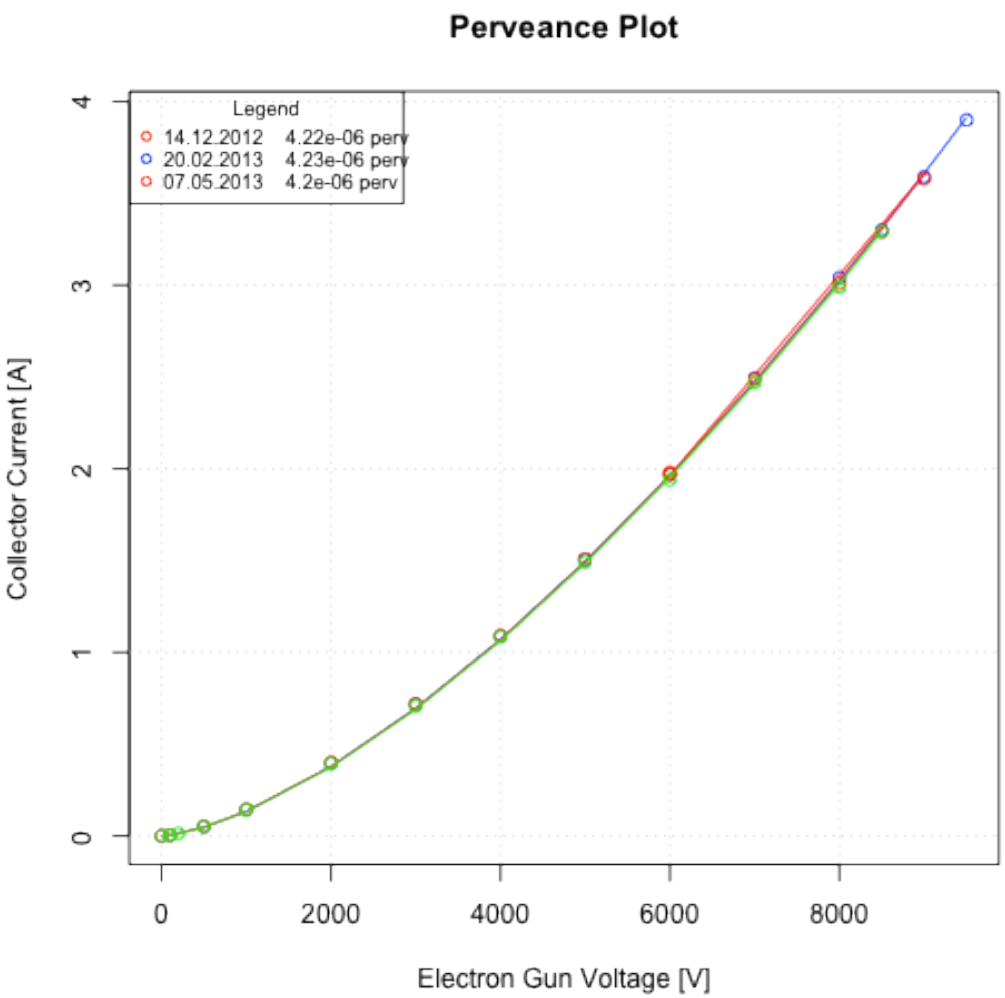
What has been done?

- Perveance
- Profile Measurements
- Field measurements
- Polar Decomposition
- Transmission

Yield
- Time Comparisons -

- Yield: Transmission & Perveance
- Aim: Space-Charge Limited Regime
- Child-Langmuir Law
- Perv ≈ 4.2e-6 perv

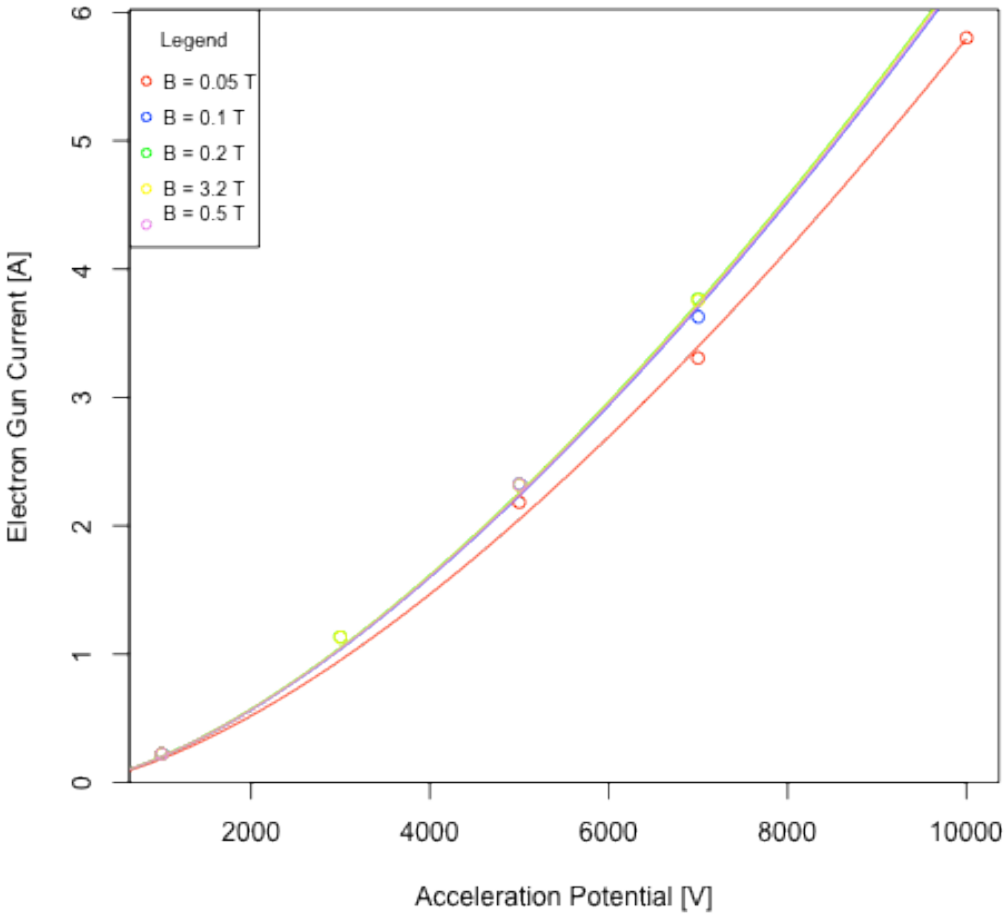
$$I = P \times V^{\frac{3}{2}}$$



Yield
- SAM Simulations -

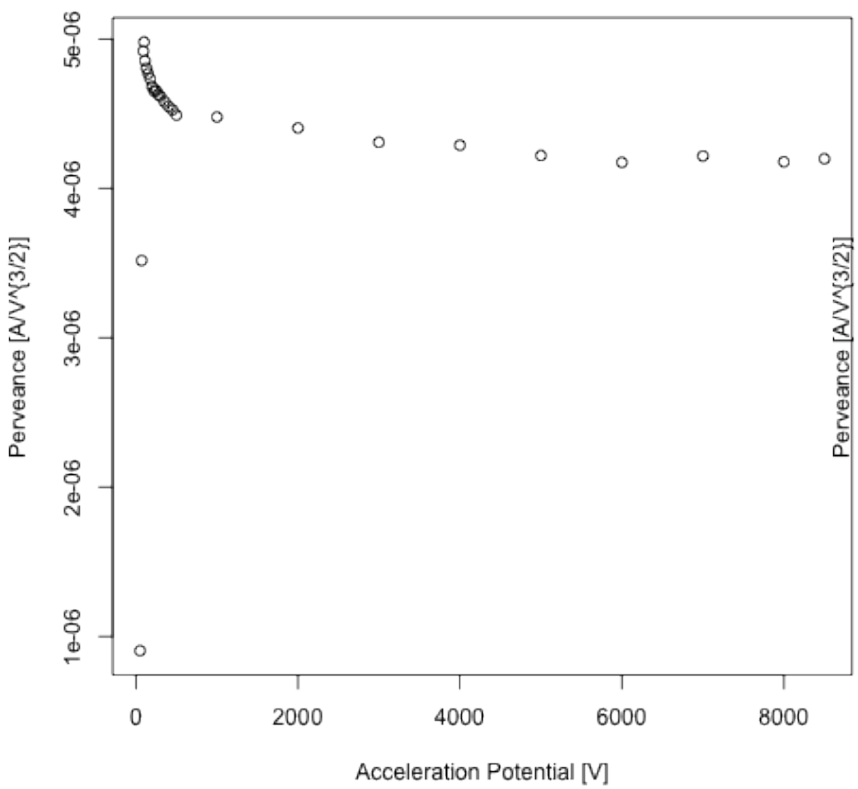
- SAM: 6e-6 perv
- Check SAM using WARP

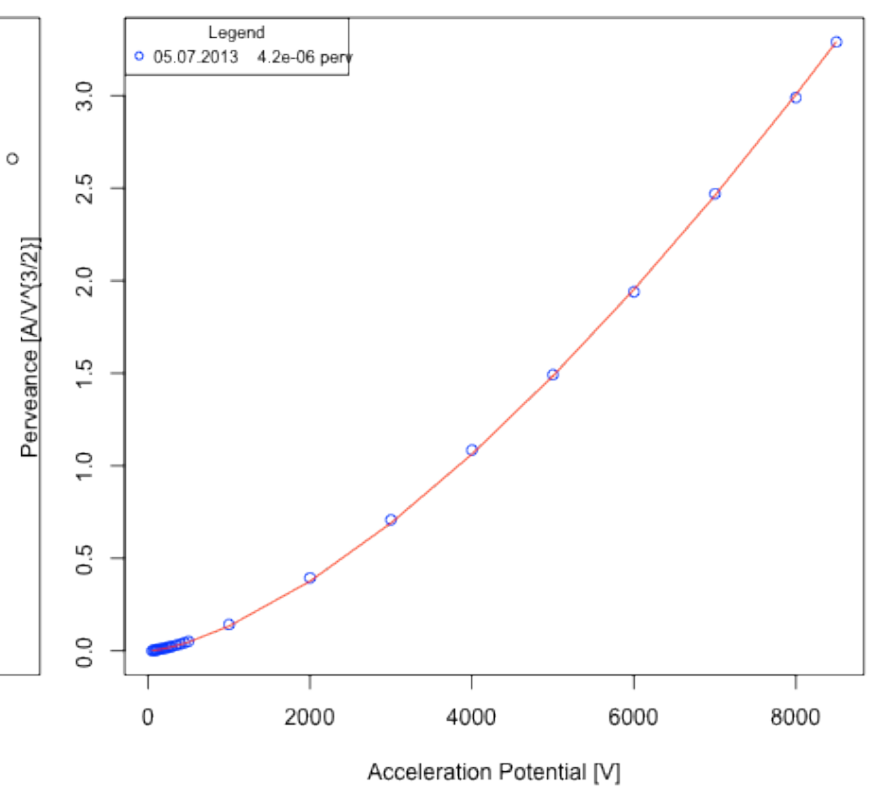
$$I = P \times V^{\frac{3}{2}}$$



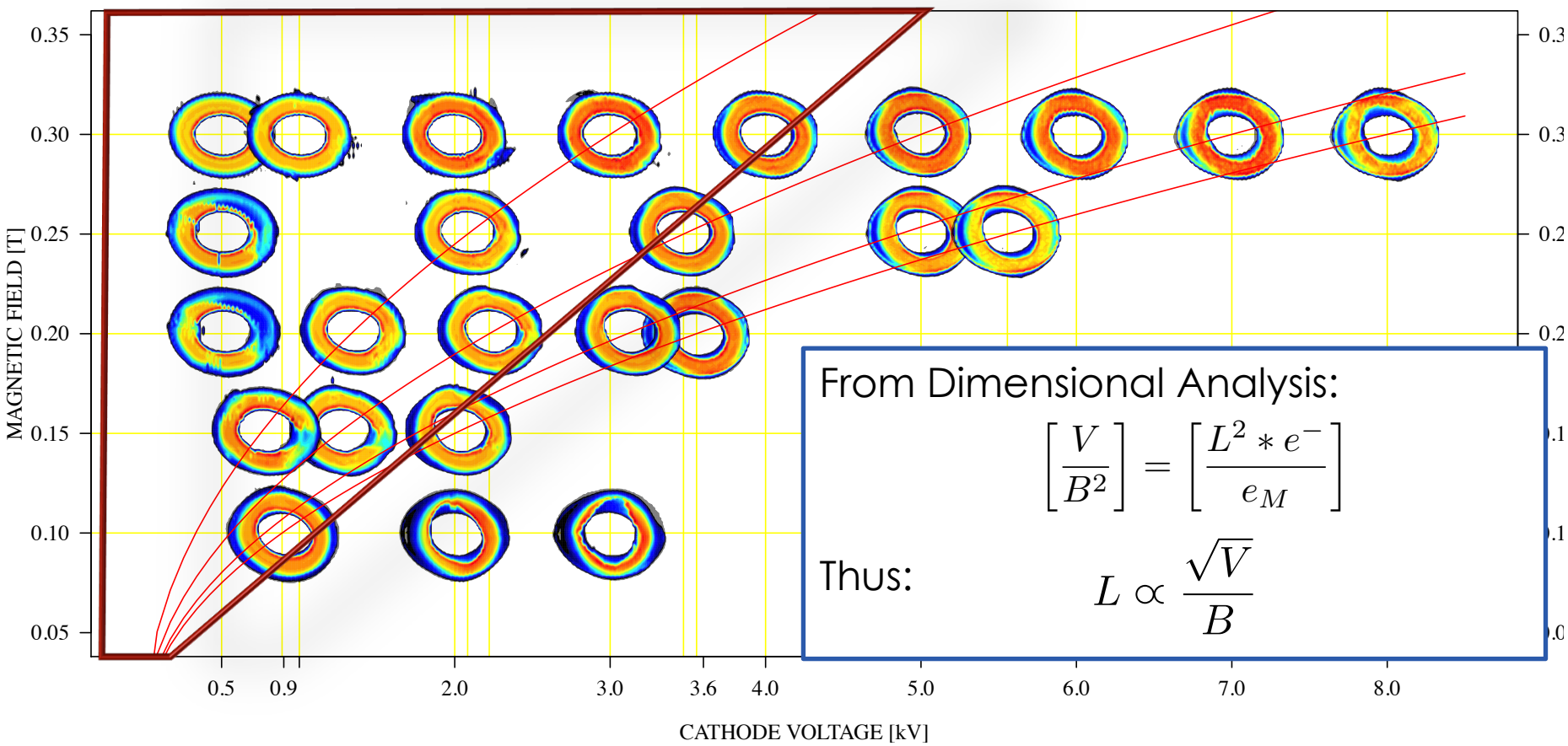
Yield
- Detailed Measurements -

Generalized Perveance & Neutralization to be calculated





Profiles
- Measured Profiles -



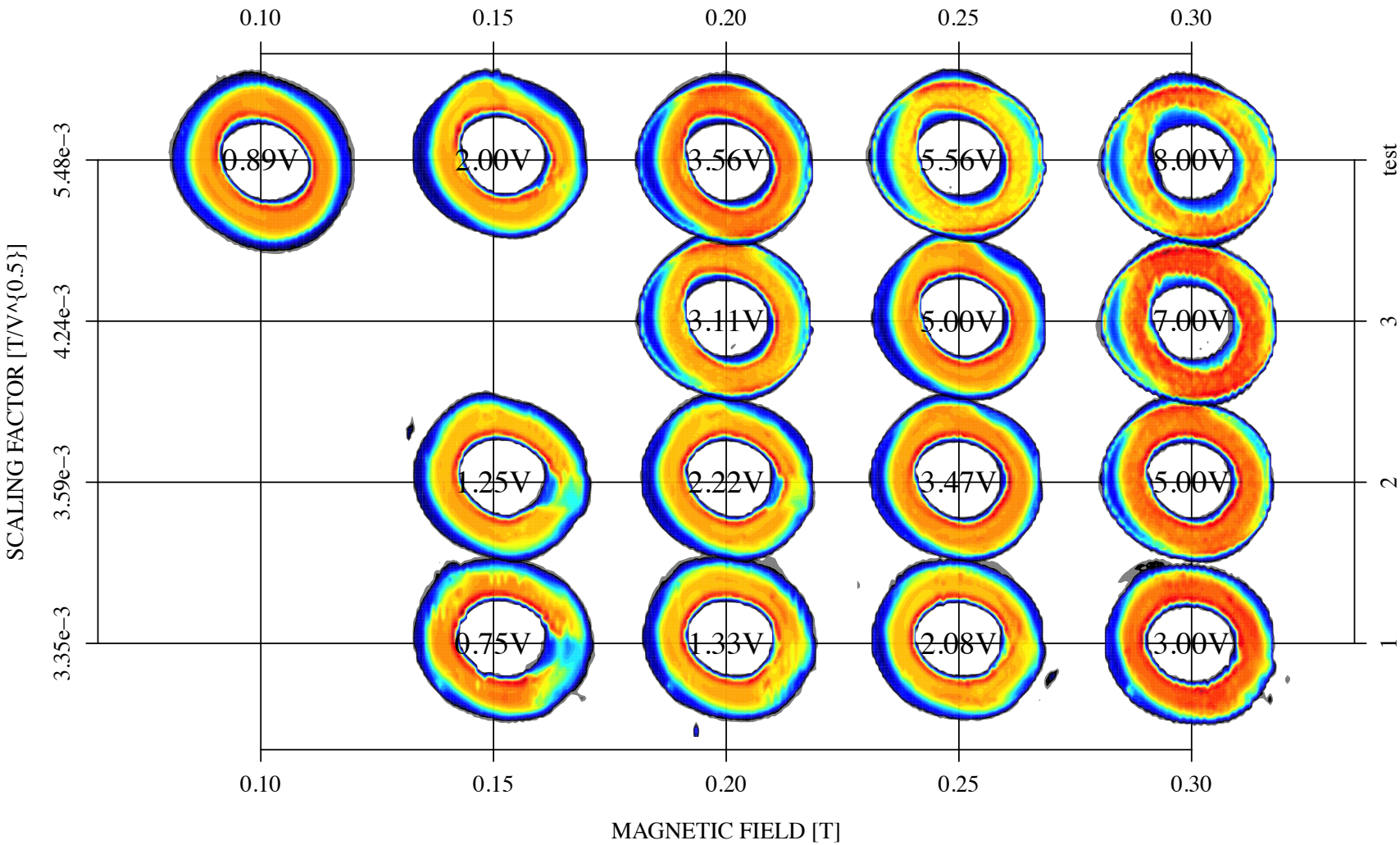
From Dimensional Analysis:

$$\left[\frac{V}{B^2}\right] = \left[\frac{L^2 * e^-}{e_M}\right]$$

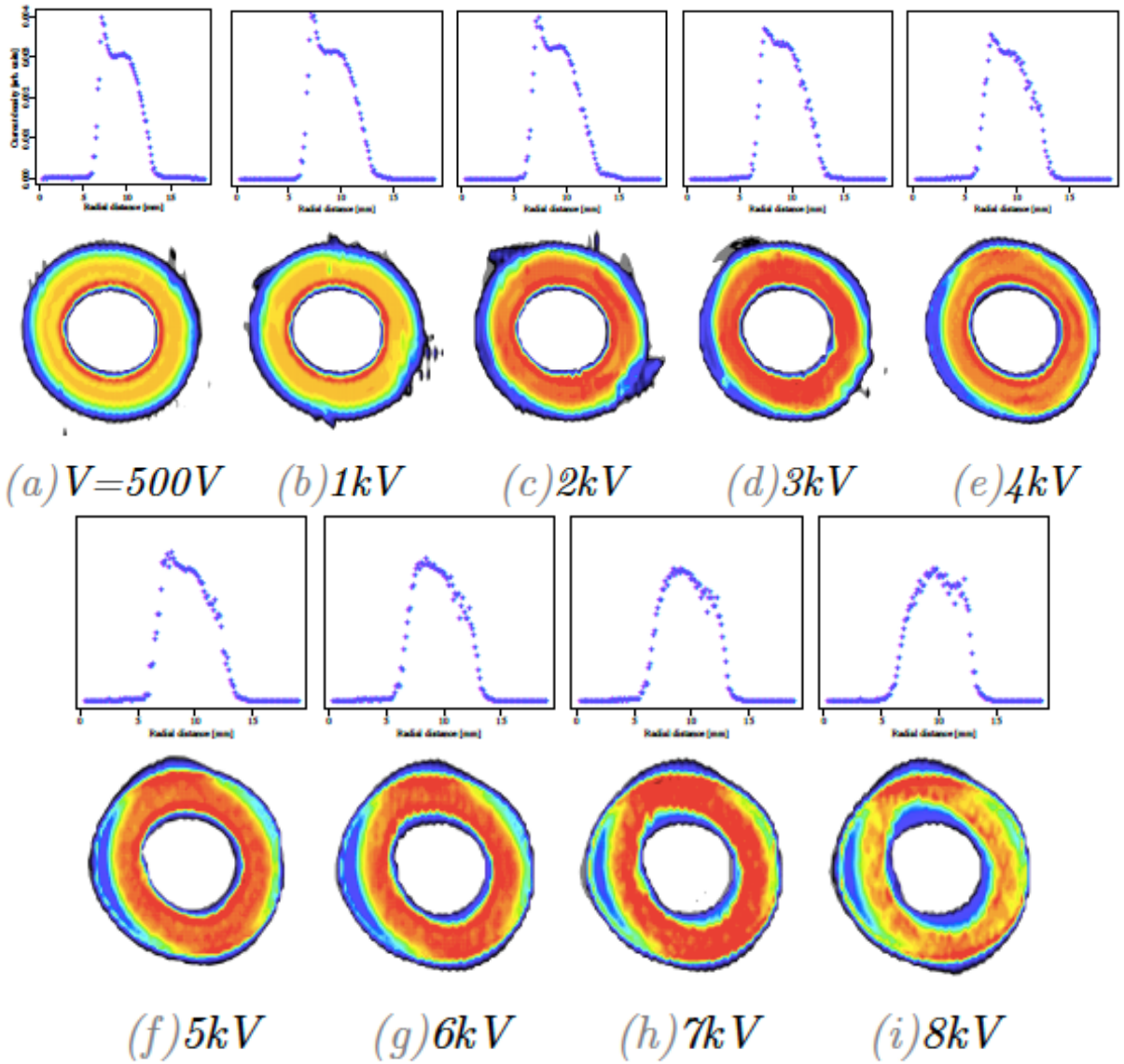
Thus:

$$L \propto \frac{\sqrt{V}}{B}$$

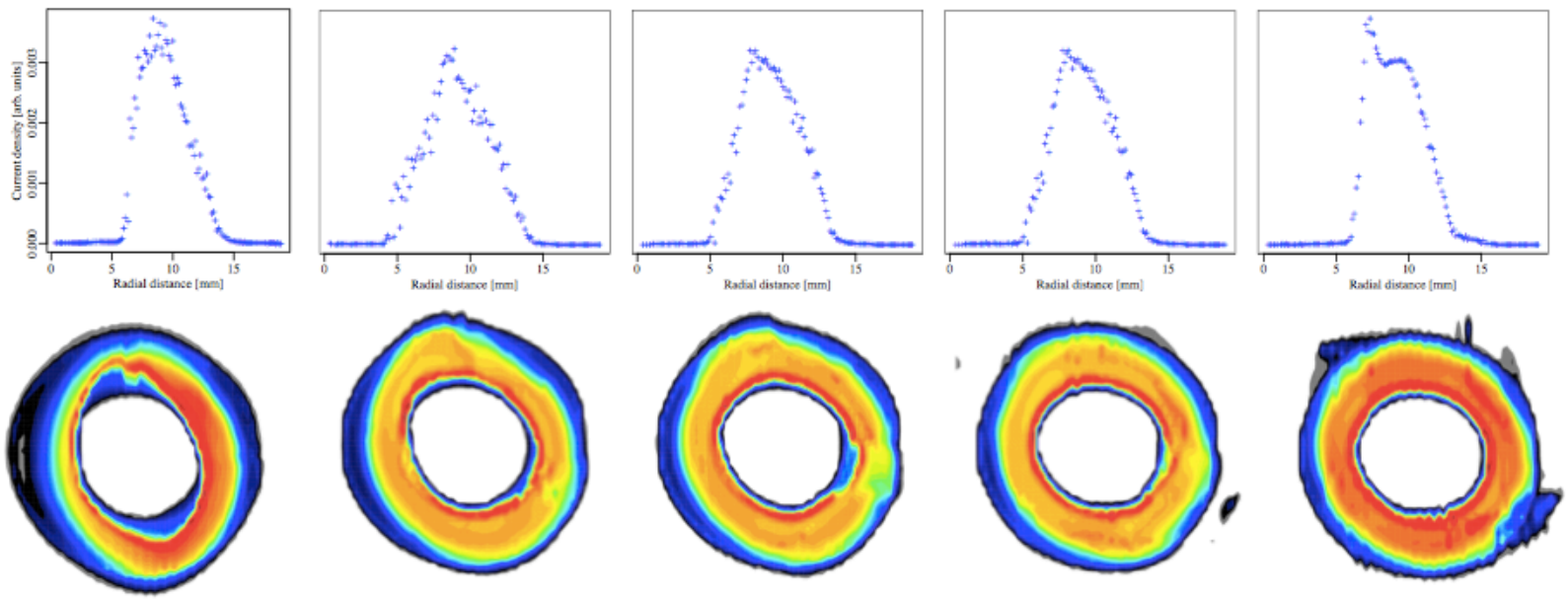
Profiles
- Scaling-



Electron Gun Characterization
- Change with Voltage -

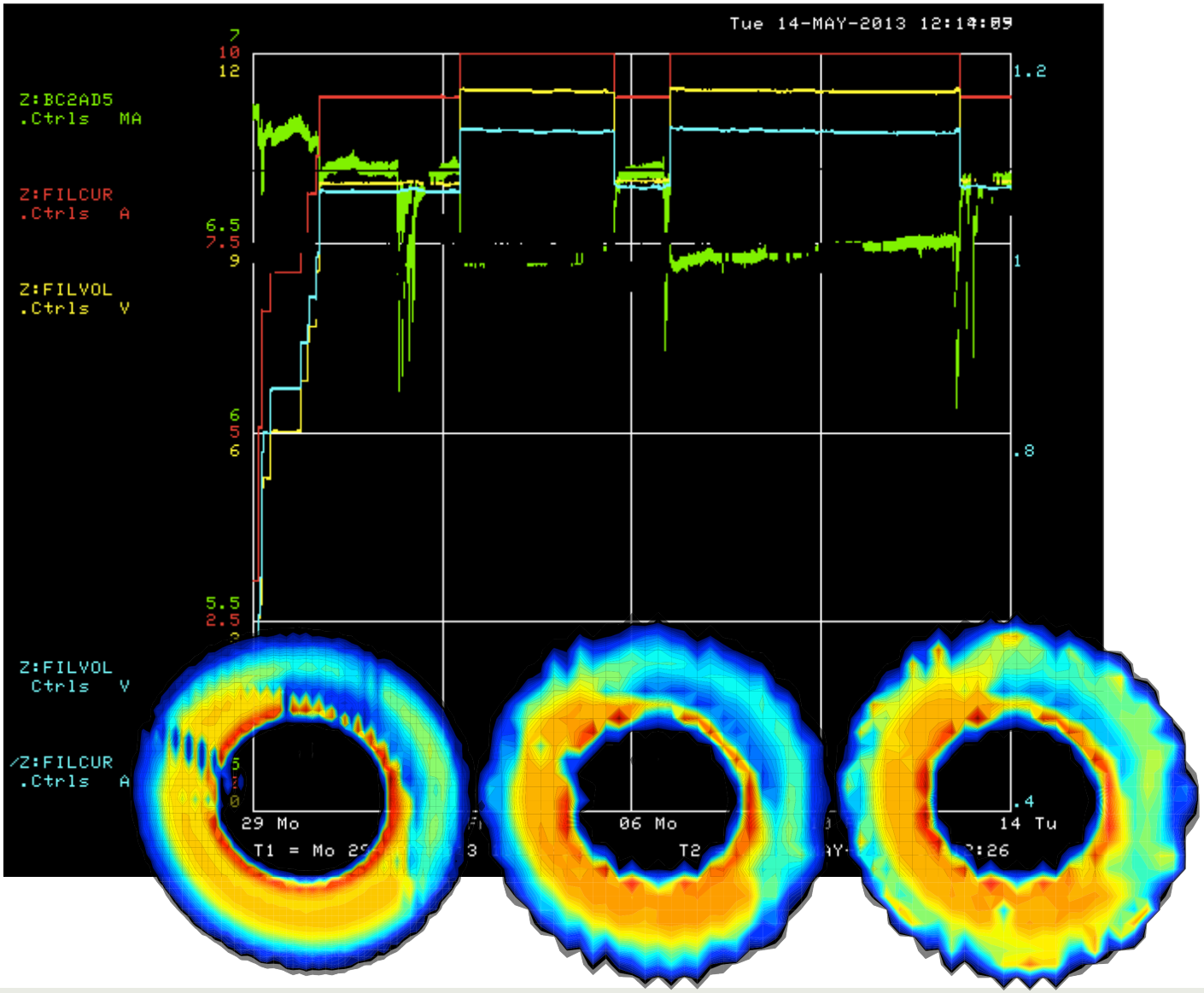


Electron Gun Characterization
- Change with Field-



$(a) B=0.1T$ $V=2kV$ $(b) B=0.15T$ $V=2kV$ $(c) B=0.2T$ $V=2.2kV$ $(d) B=0.25T$ $V=2.1kV$ $(e) B=0.3T$ $V=2kV$

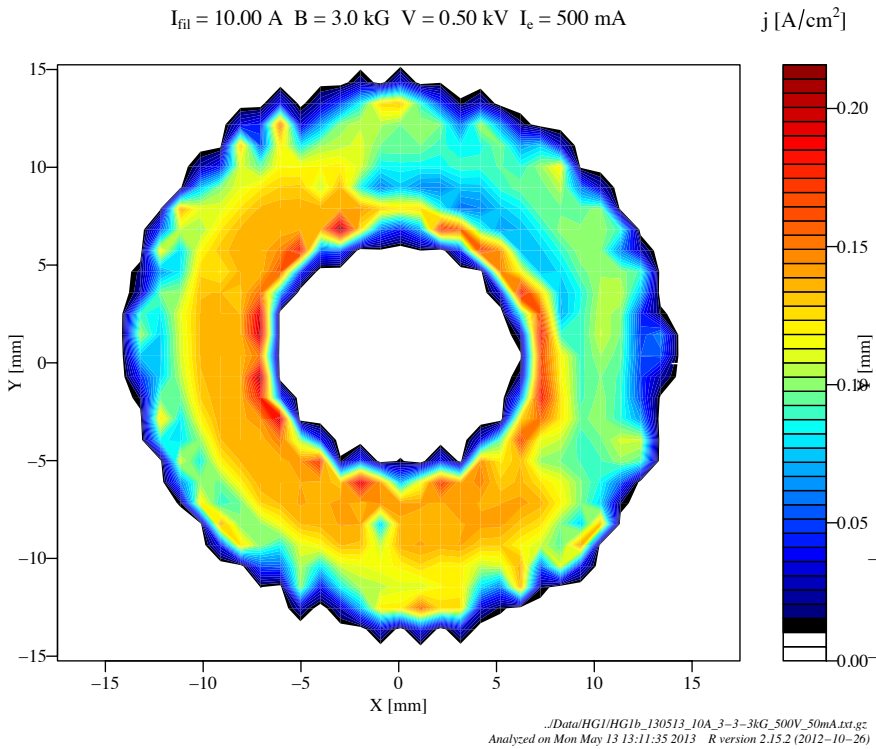
Electron Gun Characterization
- Conditioning -

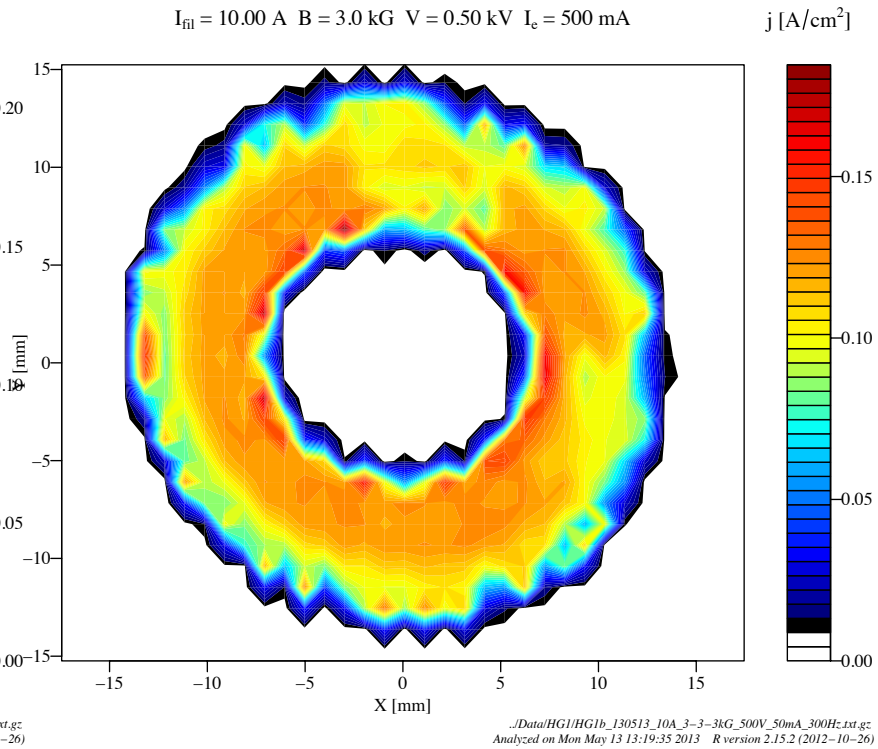


Electron Gun Characterization
- Dependence on Repetition Rate -

Left measurement taken at 1 kHz and right at 300 Hz

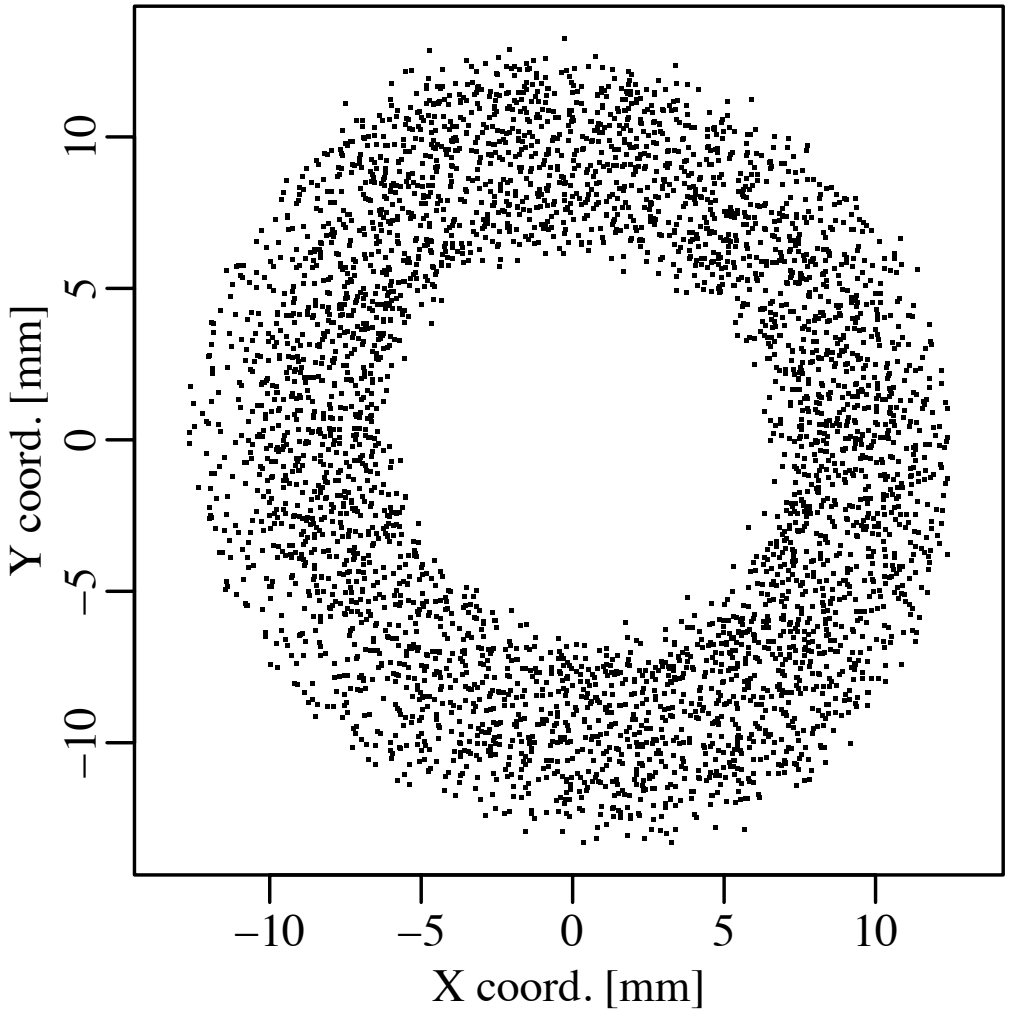
Both measurements at B=0.3T and V = 500 V



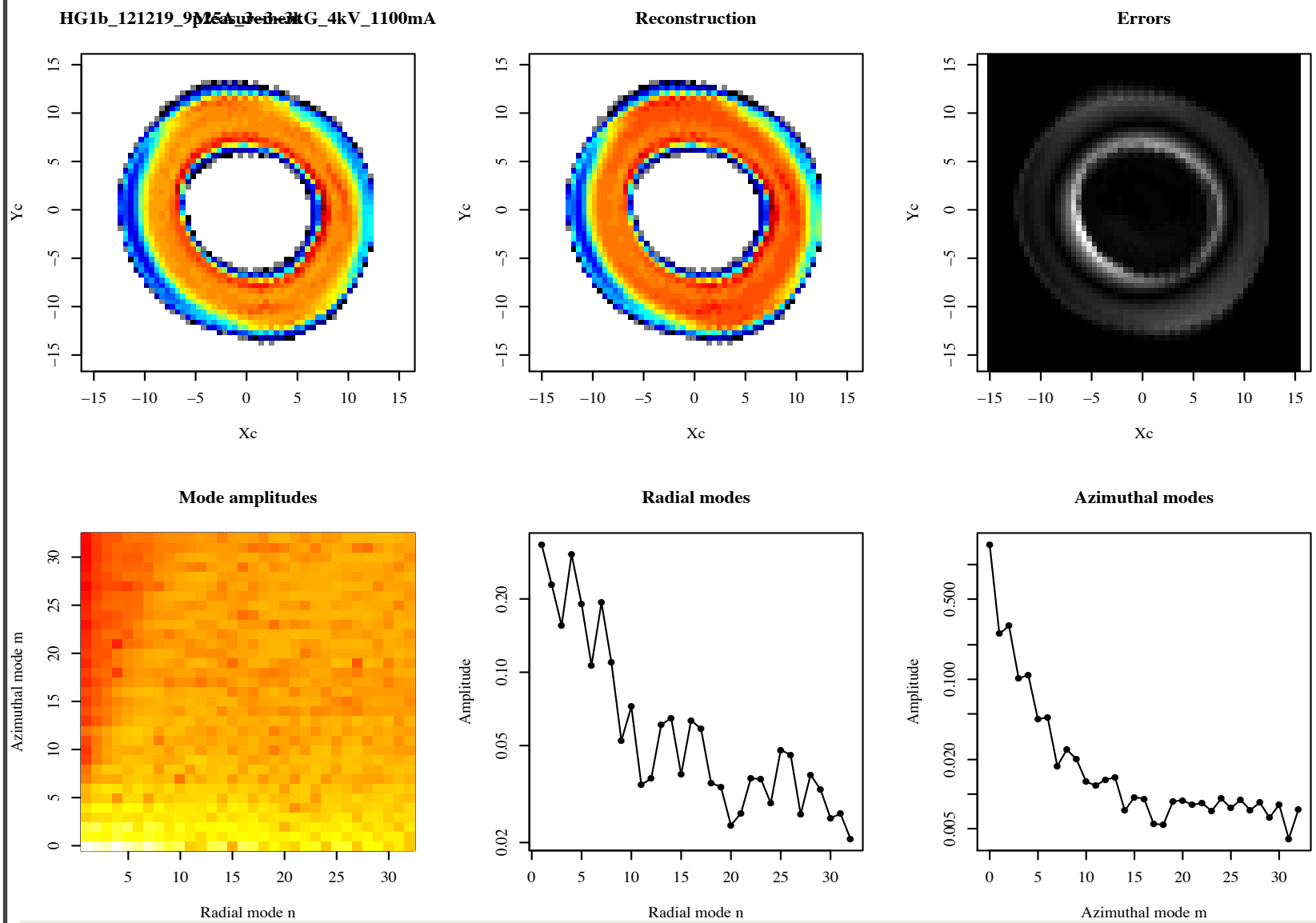


Electron Gun Characterization
- Particle Density Profiles-

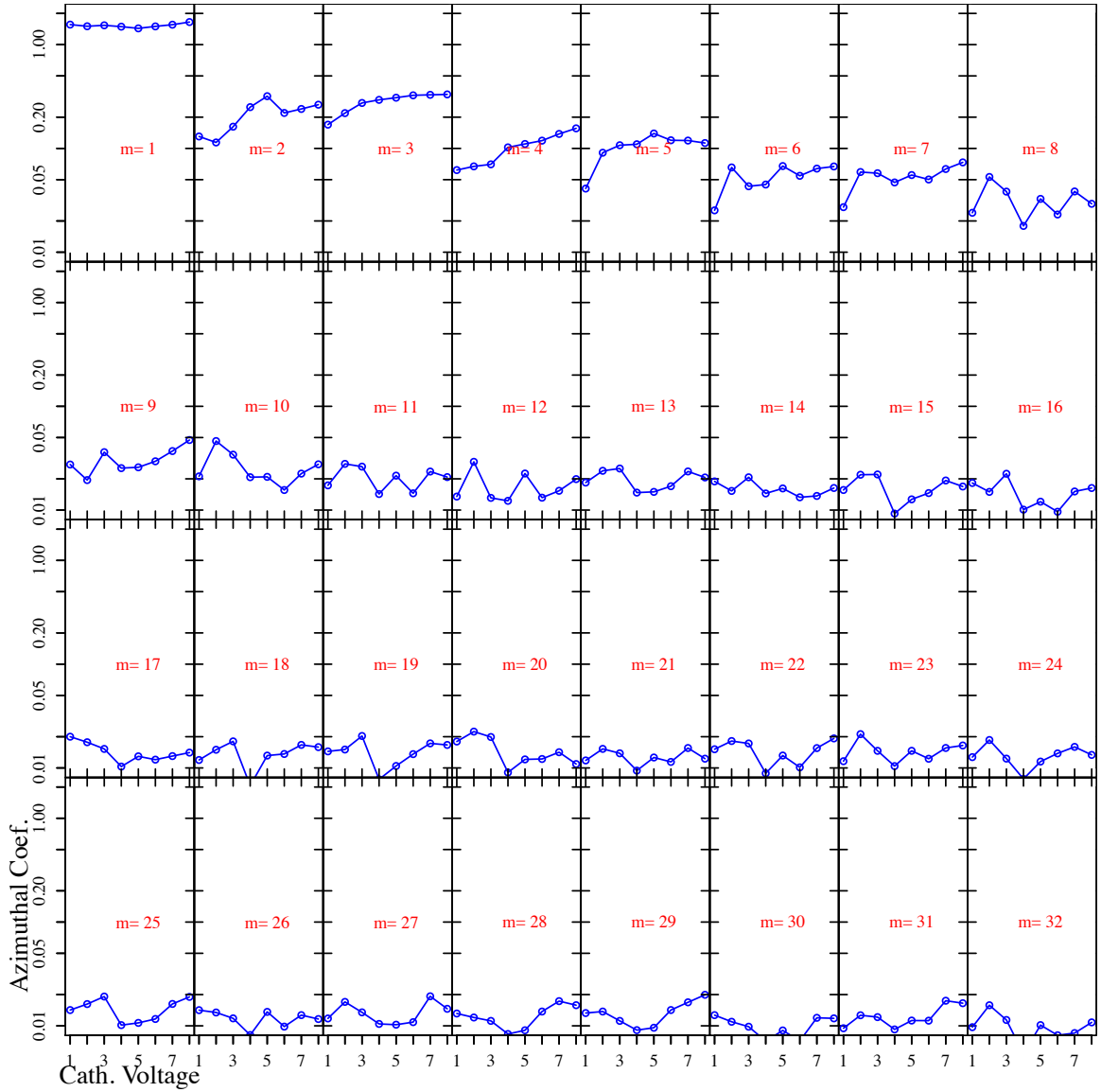
- Radial profile of current density
- Representative of cathode shape (25.4mm/13.2mm)
- Appears fairly uniform & symmetric



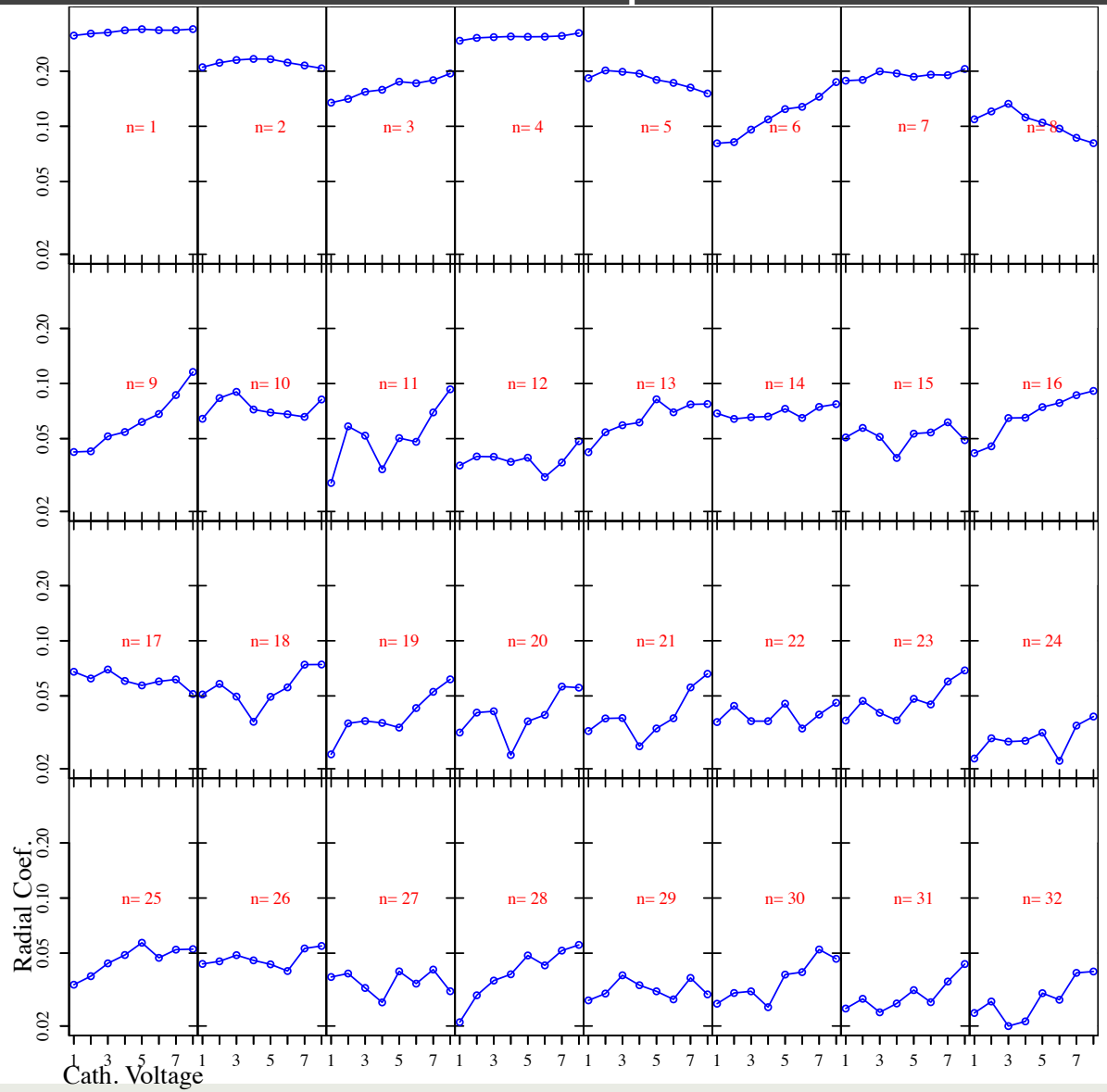
Electron Gun Characterization
- Polar Decomposition -



Electron Gun Characterization
- Azimuthal Components -

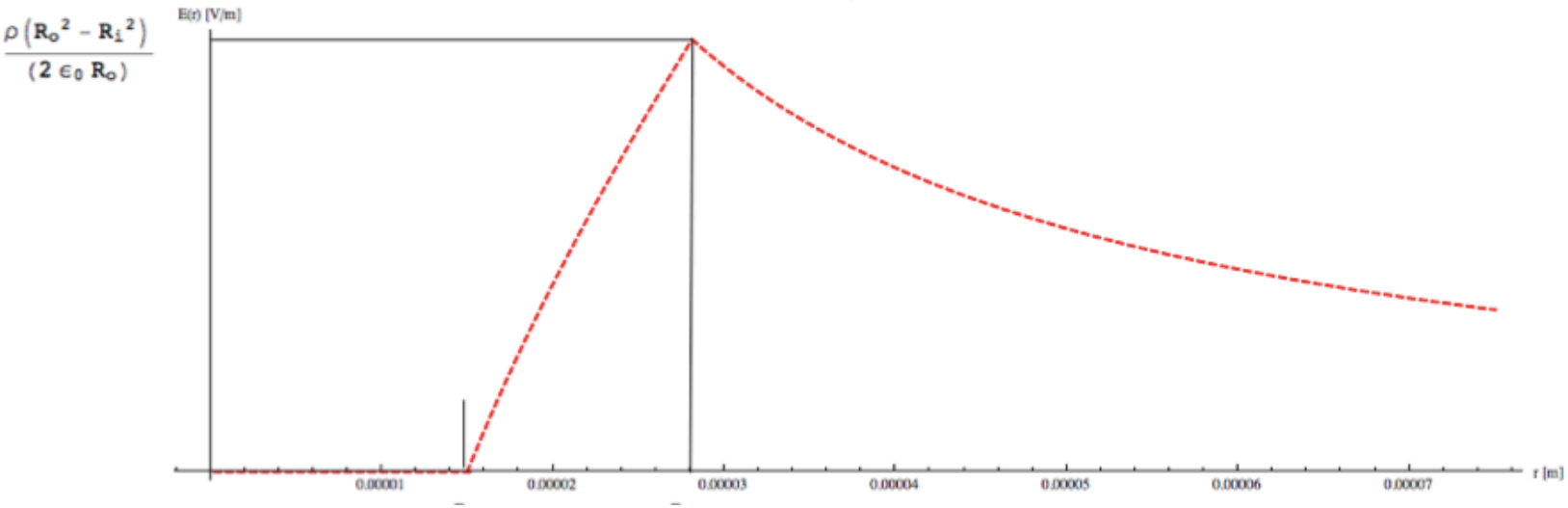


Electron Gun Characterization
- Radial Components -



Electron Gun Characterization
- Electric Field & Potential -

Field.png



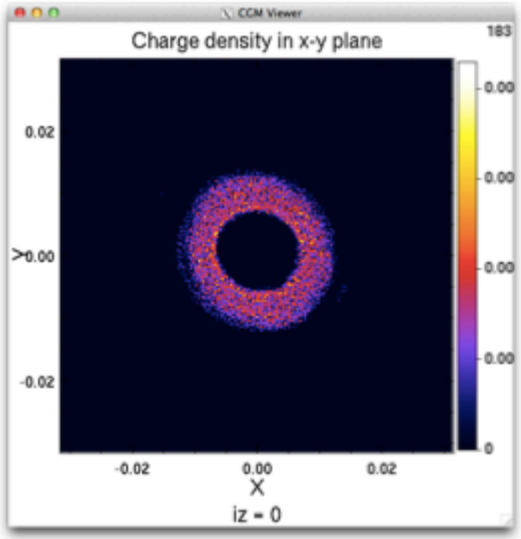
$$\oiint_{\partial\Omega} E \cdot \mathrm{d}S = \frac{Q_{\mathrm{encl},\Omega}}{\varepsilon_0}$$

$R \leq R_o$ $\qquad E = 0$

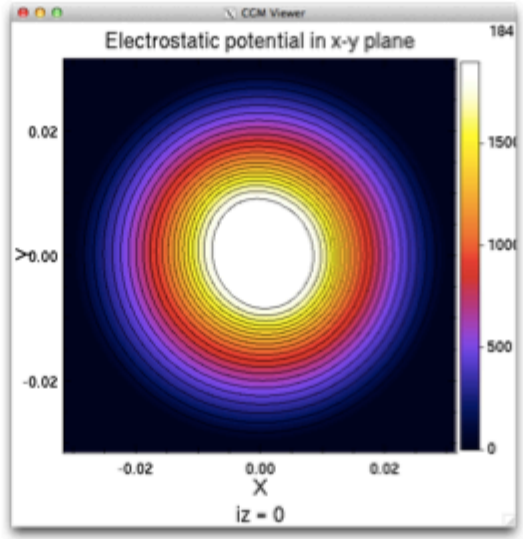
$R_i \geq R \leq R_o$ $\qquad E = \frac{\rho(R^2 - R_i^2)}{2\varepsilon_0 R}$

$R_o \geq R$ $\qquad E = \frac{\rho(R_o^2 - R_i^2)}{2\varepsilon_0 R}$

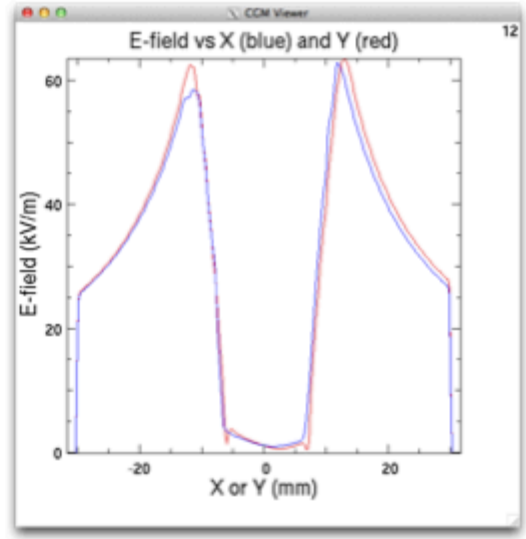
Electron Gun Characterization
- Electric Field & Potential -



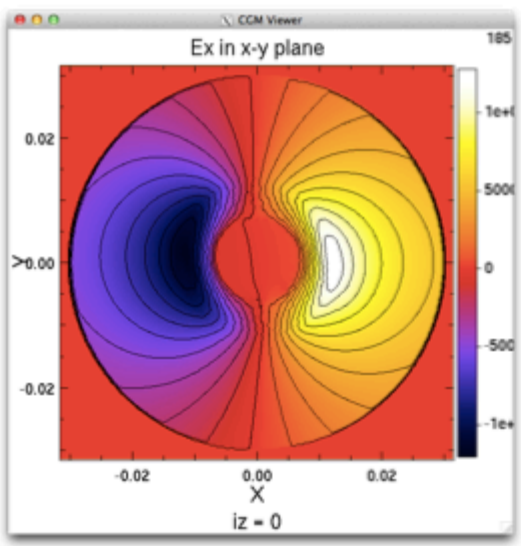
(a) *Charge Density*

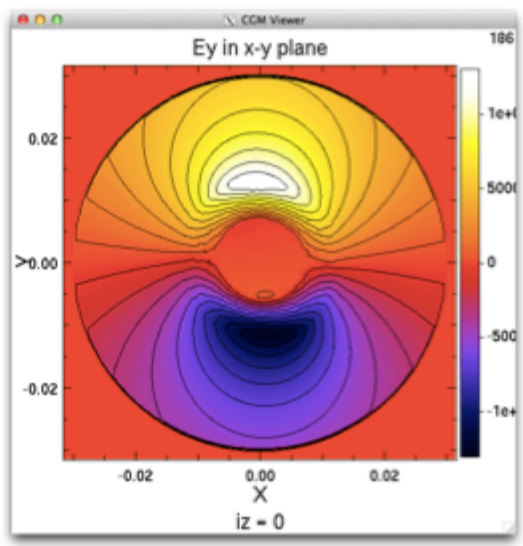


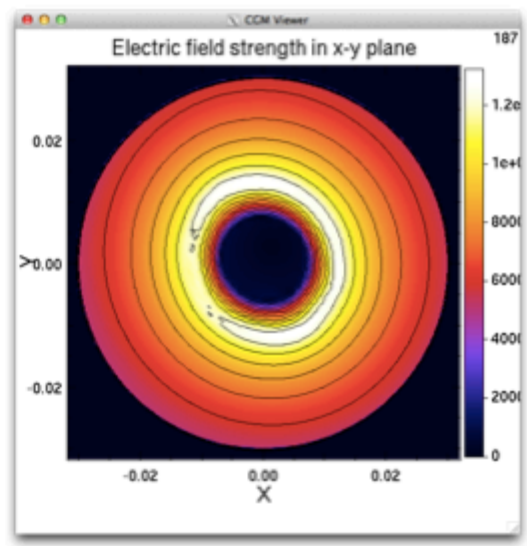
(b) *Electric Potential*



(c) *Charge Density*







Electron Gun Characterization
- Emittance Growth -

$$p_r = qEt$$

$$\vartheta = \frac{\gamma m_0 q E_r L}{E_0^2 - m_0^2}$$

$$\varepsilon = \gamma x_n^2 + \alpha x_n x_n' + \beta x_n'^2$$

$$\Delta\varepsilon = \beta\vartheta^2 = \beta\left(\frac{E_0 q E_r L}{(E_0^2 - m_0^2)}\right)^2$$

$$\varepsilon_{RMS} = \frac{\sigma_x^2}{\beta} \qquad \varepsilon_N = \varepsilon_{RMS} \times \gamma\beta_c$$

$$\sigma_x = \sqrt{\varepsilon_{RMS}\beta} = \sqrt{\frac{\varepsilon_N \beta}{\gamma\beta_c}} = 4.69 \times 10^{-4}\ m$$

Electron Gun Characterization
- Emittance Growth-

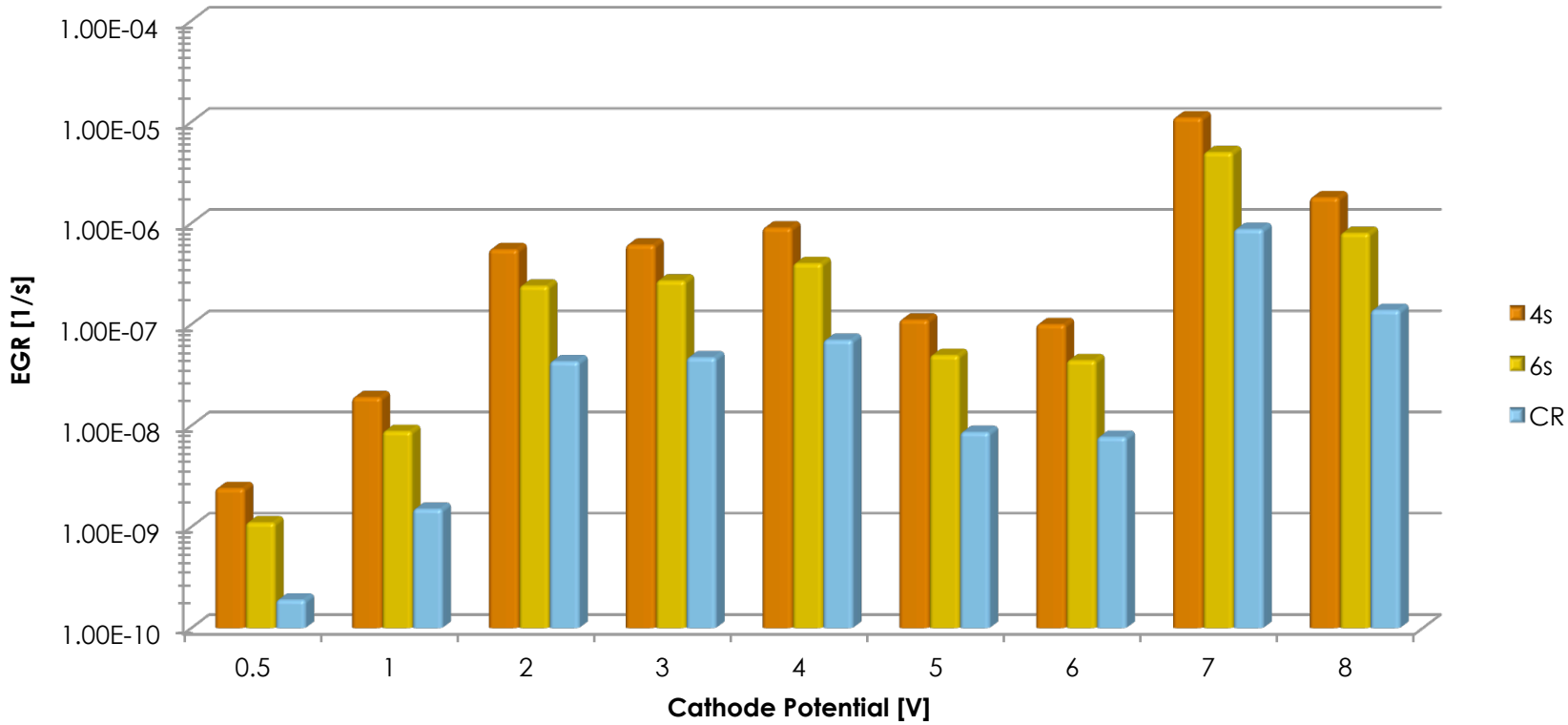


TABLE VI. Initial emittances (wire scan, synch-light, average), emittance growth rates (EGR) γ, and diffusion slopes D'.

	Emittance [μm]						EGR [1/s]		Diffusion [μm/s]	
Plane	ϵ_{ws}	$\delta\epsilon_{ws}$	ϵ_{sl}	$\delta\epsilon_{ws}$	ϵ	$\delta\epsilon$	γ	$\delta\gamma$	D'	$\delta D'$
B1 H	1.92	1.3×10^{-2}	2.15	9.6×10^{-3}	2.03	0.07	5.23×10^{-5}	1.50×10^{-5}	2.49×10^{-8}	7.4×10^{-9}
B1 V	1.36	2.0×10^{-3}	1.29	4.7×10^{-3}	1.33	0.02	1.70×10^{-5}	1.00×10^{-5}	5.27×10^{-9}	3.2×10^{-9}
B2 H	1.69	6.6×10^{-3}	2.43	1.3×10^{-2}	2.06	0.21	5.37×10^{-5}	1.90×10^{-5}	2.60×10^{-8}	9.6×10^{-9}
B2 V	1.73	4.6×10^{-2}	1.98	1.2×10^{-2}	1.85	0.09	1.10×10^{-5}	1.70×10^{-5}	4.79×10^{-9}	7.2×10^{-9}

Electron Gun Characterization
- Transmission -

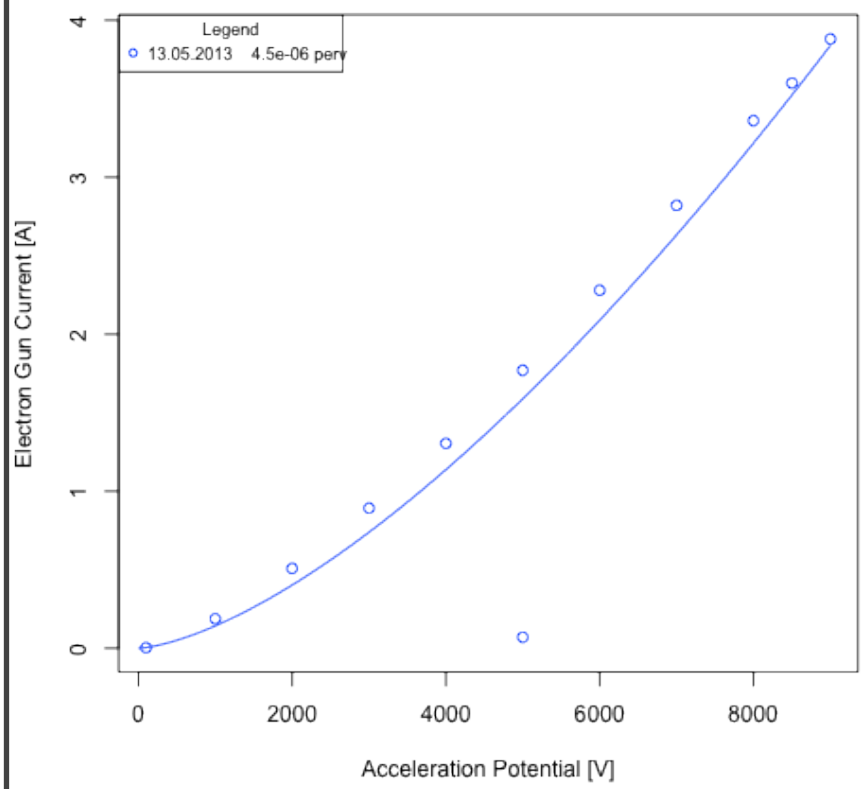
Main Solenoid at 3 kG

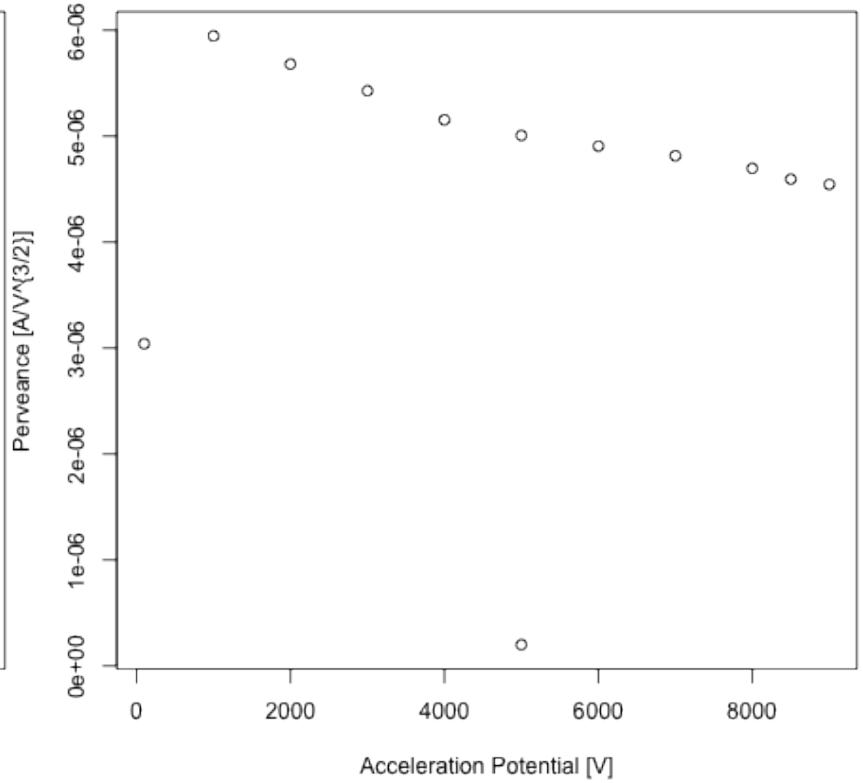
Average of Transmission B:Collector [V]	B:Gun [V] 0.5	1	2	3
0.5	55%	53%		
1	64%	64%		
1.5		75%		
2	83%	85%	71%	
2.5		92%		
3		97%		71%
3.5		98%		

Actual Perveance: 4.2e-6/0.72 = 5.91e-6 ≈ SAM Perveance

Electron Gun Characterization
- Transmission -

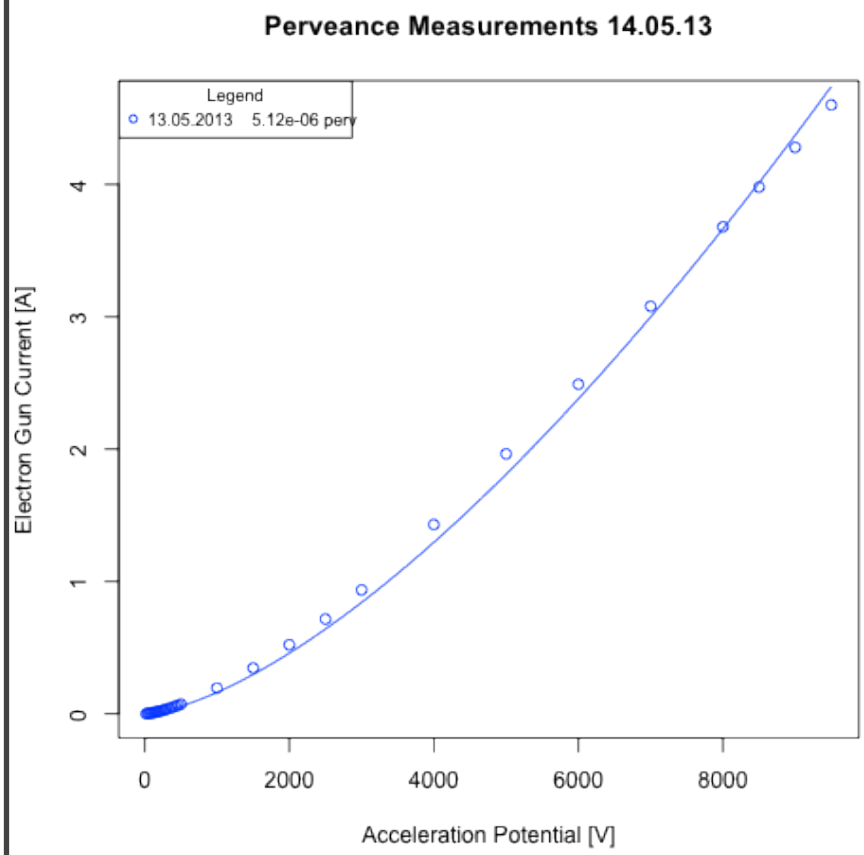
Deviation from space charge limited region at 1-3-3.5 kG

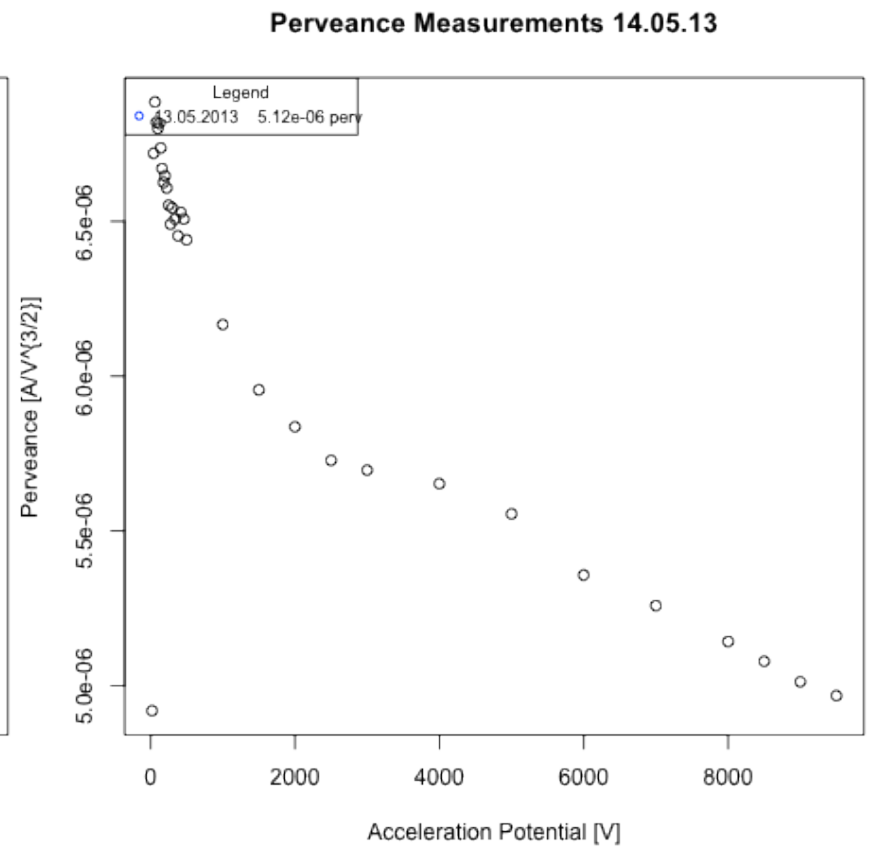




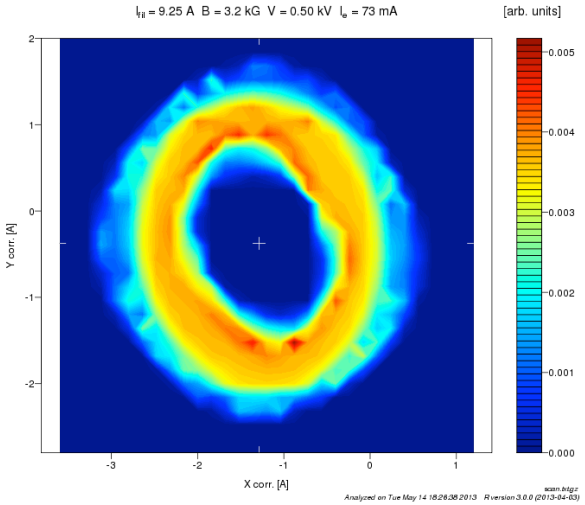
Electron Gun Characterization - 0.8-3.2-0.8 -

- Better, not yet optimal. Leave SCL regime

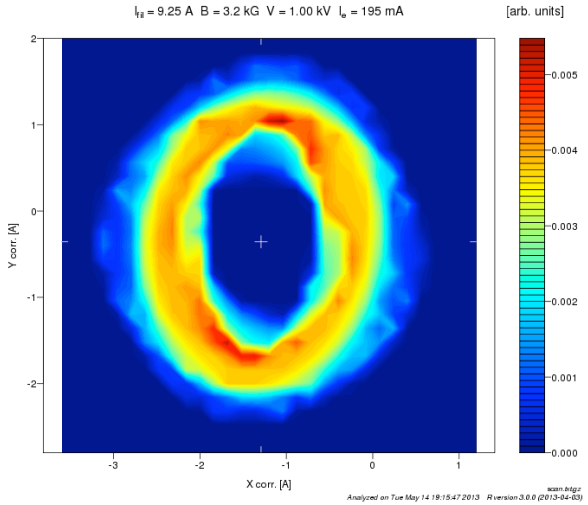




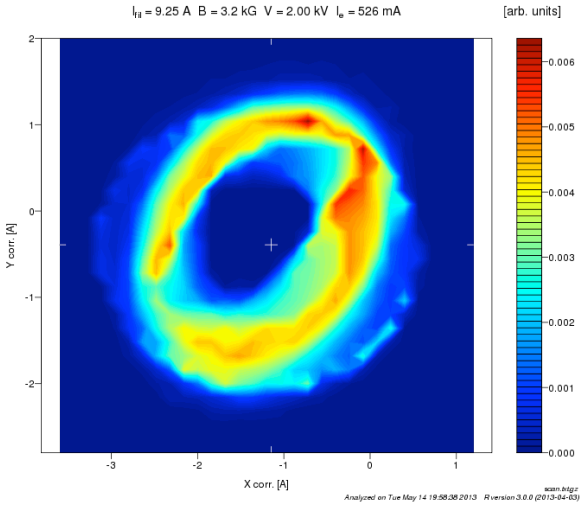
Electron Gun Characterization
- 0.8-3.2-0.8 -



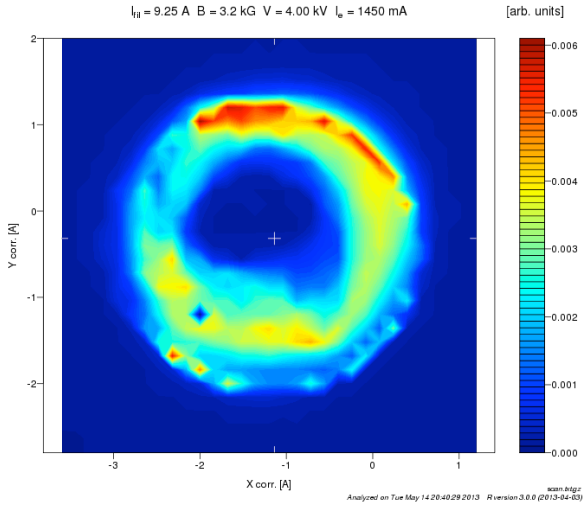
V=500V



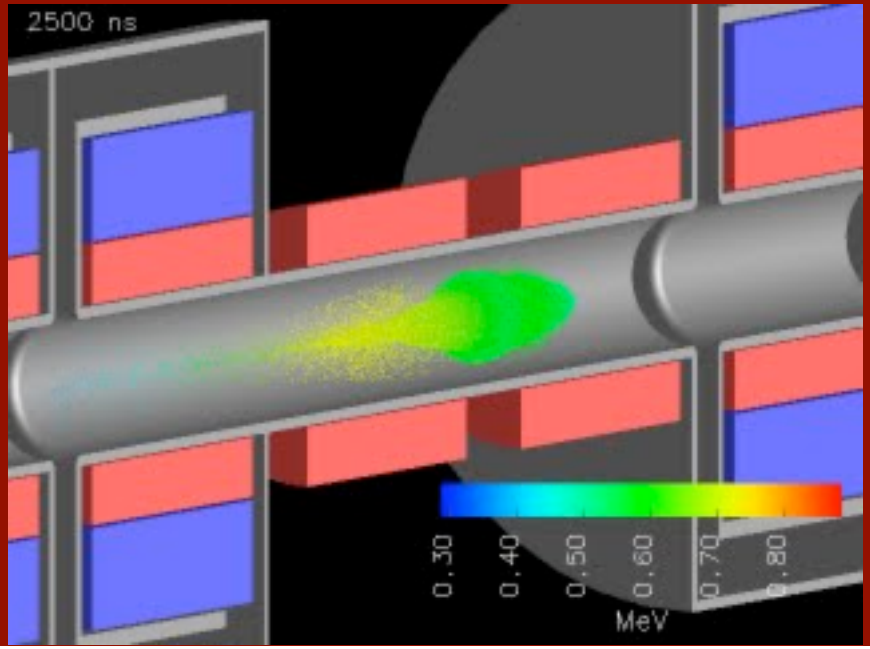
V=1kV



V=2kV



V=4kV



Electron Beam Evolution

- WARP Simulations
- Non-Linear Maps

WARP
- Installation -

- WARP is running on TEV (single mode)
- Parallel mode to come
- Cross-Checking required

Installation of WARP on the TEV cluster

Vince Moens
vince.moens@epfl.ch
Ecole Polytechnique Fédérale de Lausanne (EPFL)

May 14, 2013

1 Introduction

For the purpose of this document, TEV refers tot he Wilson Cluster.

The tarball that accompanies these instructions can be found at: `https://cdcvs.fnal.gov/redmine/documents/619`.

Installing WARP on TEV brings a few complications. These include compatibility issues with the python installed on TEV, compiler issues and super user rights. Instead of finding a solution in which one could bind the python package WARP, which has to be installed locally, into the native python of TEV by creating links and changing a lot of PATHS, we decided to just install a clean version of python in the local directory and use that distribution.

These instructions are for the installation of a non-parallel version of WARP. A parallel version of WARP will be installed later and a new set of isntructions will be drafted.

Unless someone sent you this document, you should have found these instructions in a directory named `INSTRUCTIONS` in a tarball named `WARP_Install`.

2 Installation procedure

Place that tar file in your home directory on TEV. You can use scp to place it there.

```
scp -r WARP_Install.tar.gz username@tev.fnal.gov:/home/username/
```

Open up a terminal and go to your home directory. Once there expand your tarball using:

```
cd
tar -xvf WARP_Install.tar.gz
```

You will now find a directory labeled `WARP_Install` in your home directory. Create a directory where you would want to install Python and WARP. For the purpose of this tutorial we will use the directory `Python` in your home directory.

```
cd
mkdir Python
```

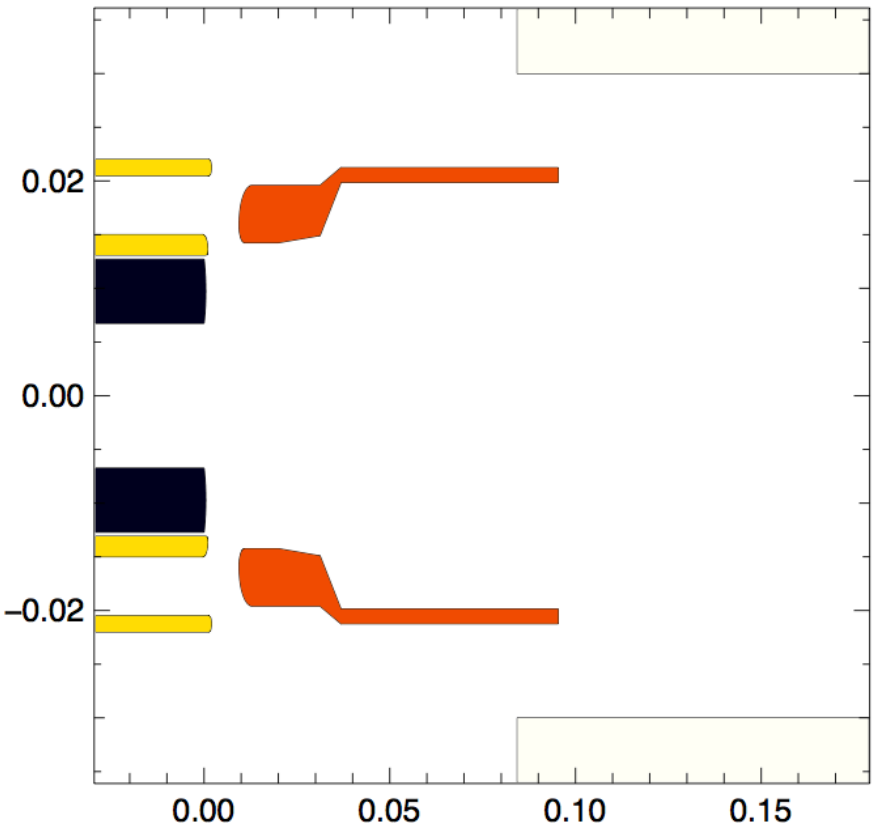
Next we want to make sure that every compilation of a python script from this point is done using the same compilers and your new python installation. There is two methods to do this. The first is the recommended one and automatically loads the new path upon opening a window. In order to do this check for a file named `.bash_profile` in your home directory.

```
cd
ls -lisa
```

If it does not exist, create it by typing:

WARP
- Progress -

- No substantial progress since last meeting
- TEV & Test Bench setups are set up
- Simple WARP test simulation to follow (maybe before I leave)



WARP
- Next Steps -

- Not on halt – commence in Switzerland
- Work mainly with David P. Grote (off-site)
- Simulations
  - Test Bench with injected & simulated particles
  - TEL2 with simulated Particles
    - With & Without Bends -> effect of bends on beam!
    - Analytic calculations to be done as well

Next 3 months!

- Deadline: August 9, 2013
- Defense: Begin September 2013
- In meantime:
  - Intermediate report for Fermilab on Electron Gun Characterization
  - WARP 3D simulations
  - Final Master Thesis for August for Fermilab, CERN and EPFL
- Work:
  - Part-time at CERN/EPFL
- Contact & Collaboration
  - Skype & Email

Questions?

Acknowledgements

- **Giulio Stancari**
  for his role as supervisor and answering all my questions
- **Moses Chung**
  for aid with WARP and plasma physics
- **Alexander Valishev**
  for support during research and technical issues
- **David Grote (LBL)**
  for support with compatibility issues with WARP and TEV
- **Eric Stern**
  for technical support using TEV and installing WARP
- **Valentina Previtali**
  for technical discussions on Hollow Electron Beams