PTOLEMY kick-off meeting LNGS, December 11th, 2017

The PTOLEMY experiment
Analysis and MC simulation

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PTOLEMY
simulation and analysis tools

The PTOLEMY experiment aim at the detection of few electrons having energies of fraction of eV above those of the β decay endpoint

Extremely high accuracy is needed in:

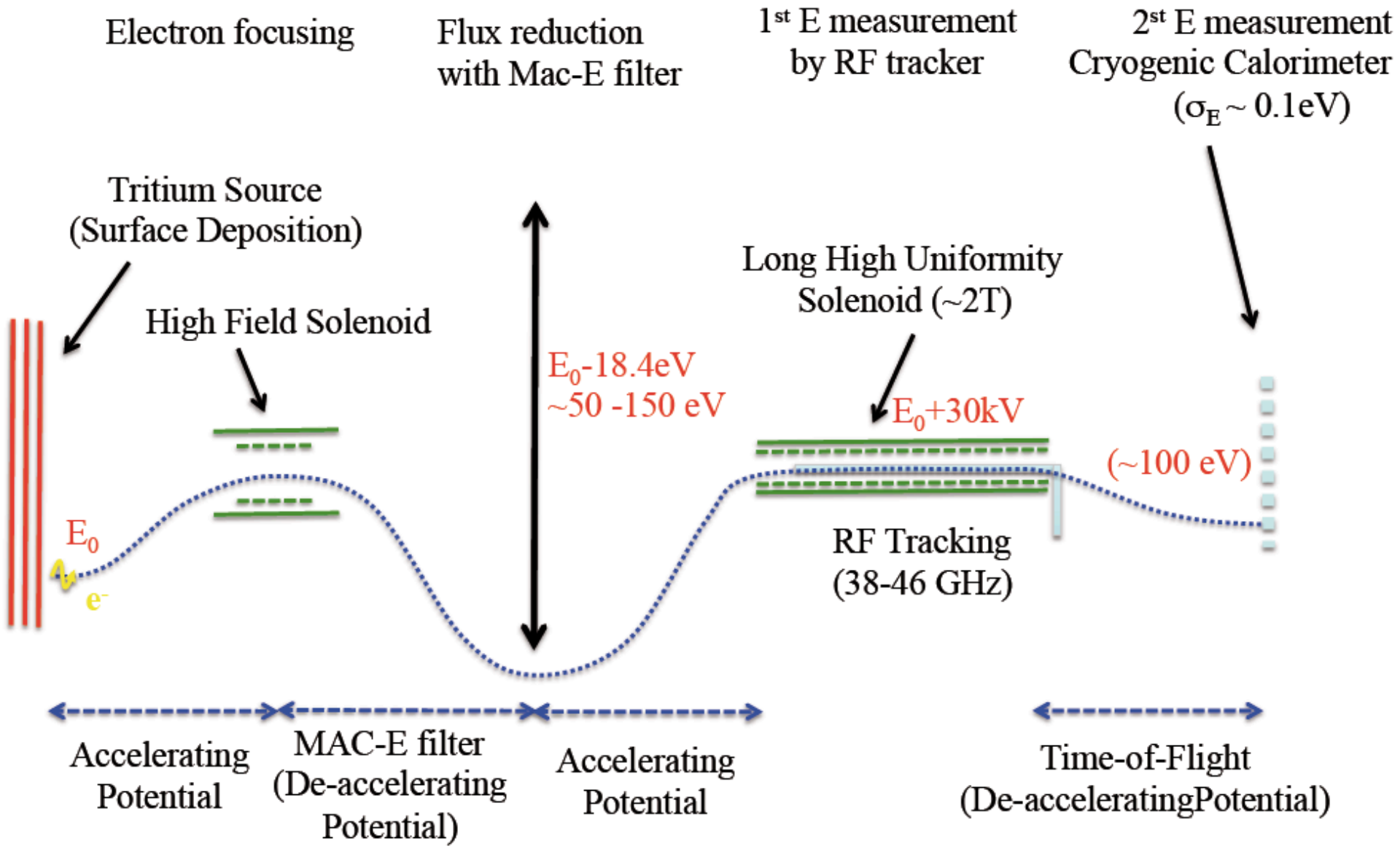
- designing the filter (E×B or E•B)
- studying systematic effects that could spoil the precision on E_e

Work toward the setup of:

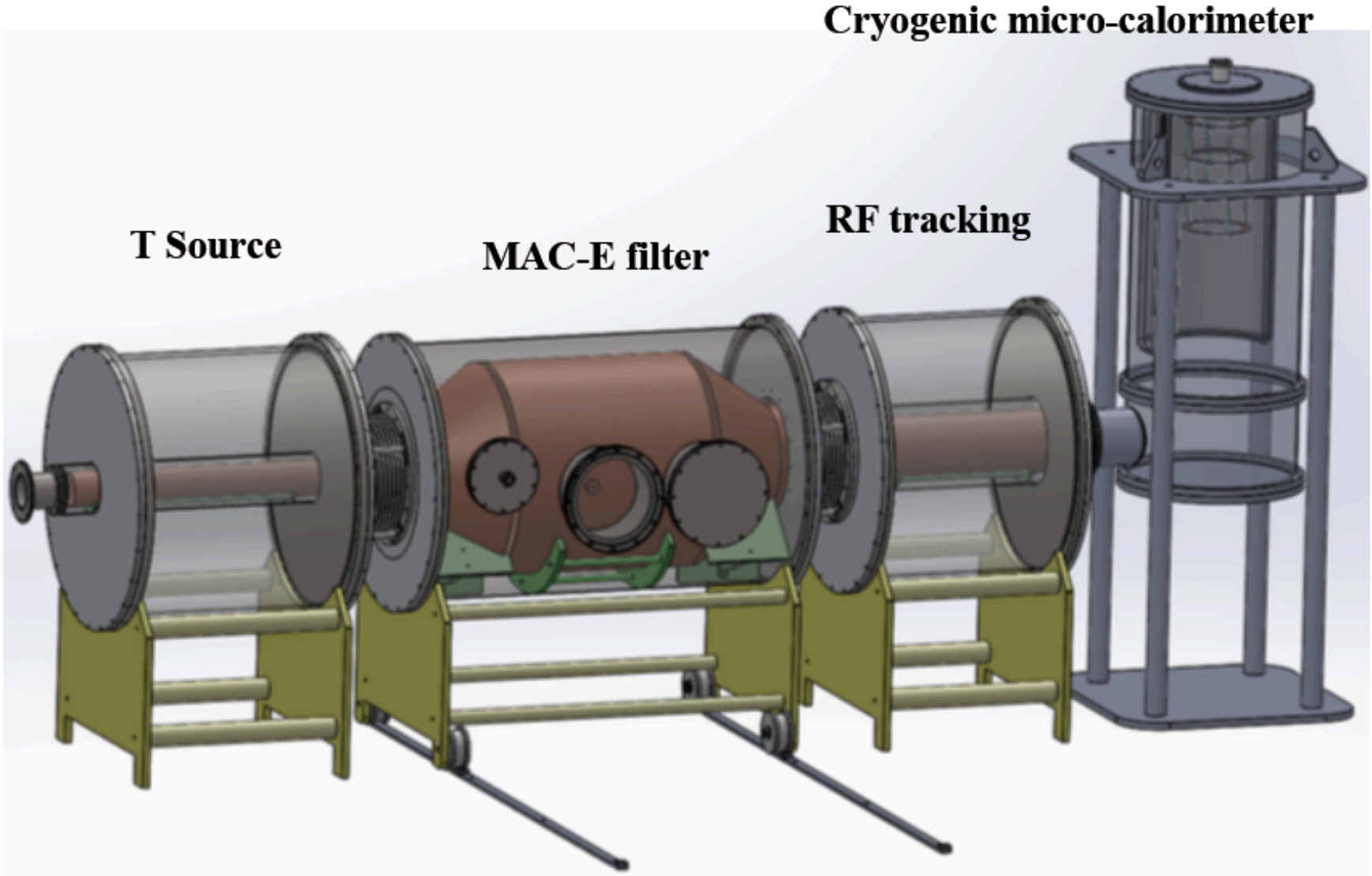
- COMSOL (commercial, FEM and “multiphysics”)
- GEANT4 (CERN, particle physics oriented)
- Kassiopeia (custom, courtesy of Katrin colleagues)

Analysis is performed using Root (whenever is possible)

100 g T source + MAC-E filter + RF tagging + sub-eV resolution μ-cal



The PTOLEMY prototype

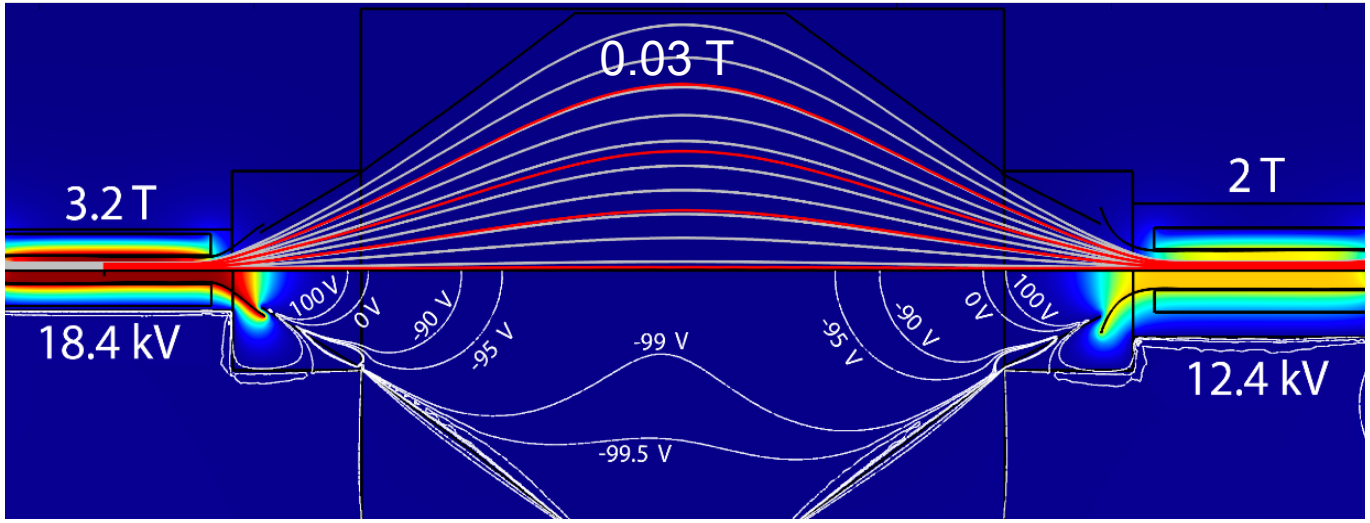


MAC-E filter

Low magnetic gradient adiabatically transforms cyclotron trajectories into longitudinal motion

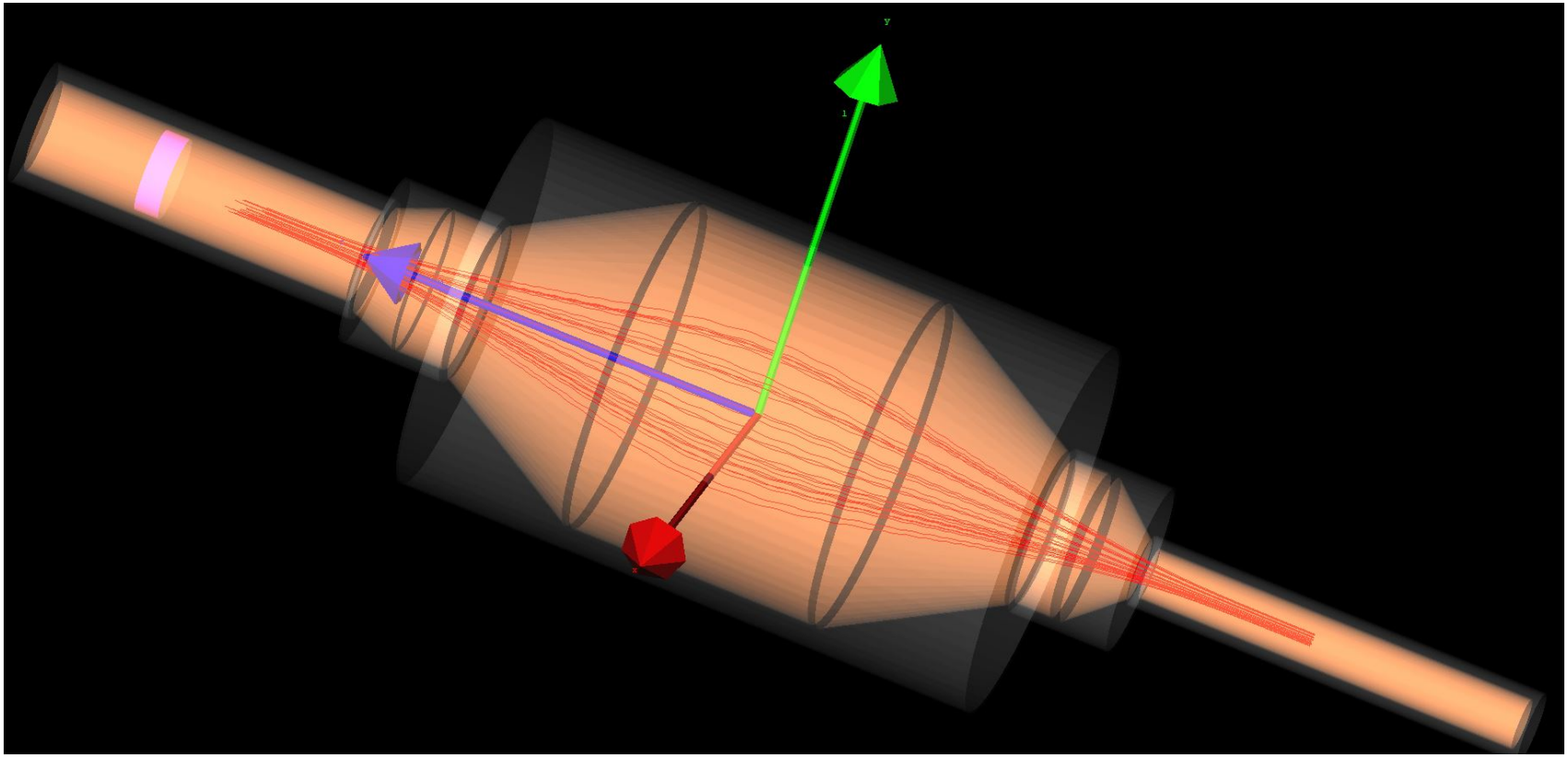
$$\mu = \frac{E_\perp}{B} \qquad \frac{\Delta E}{E} = \frac{B_{\min}}{B_{\max}}$$

Electric field sets the energy cutoff

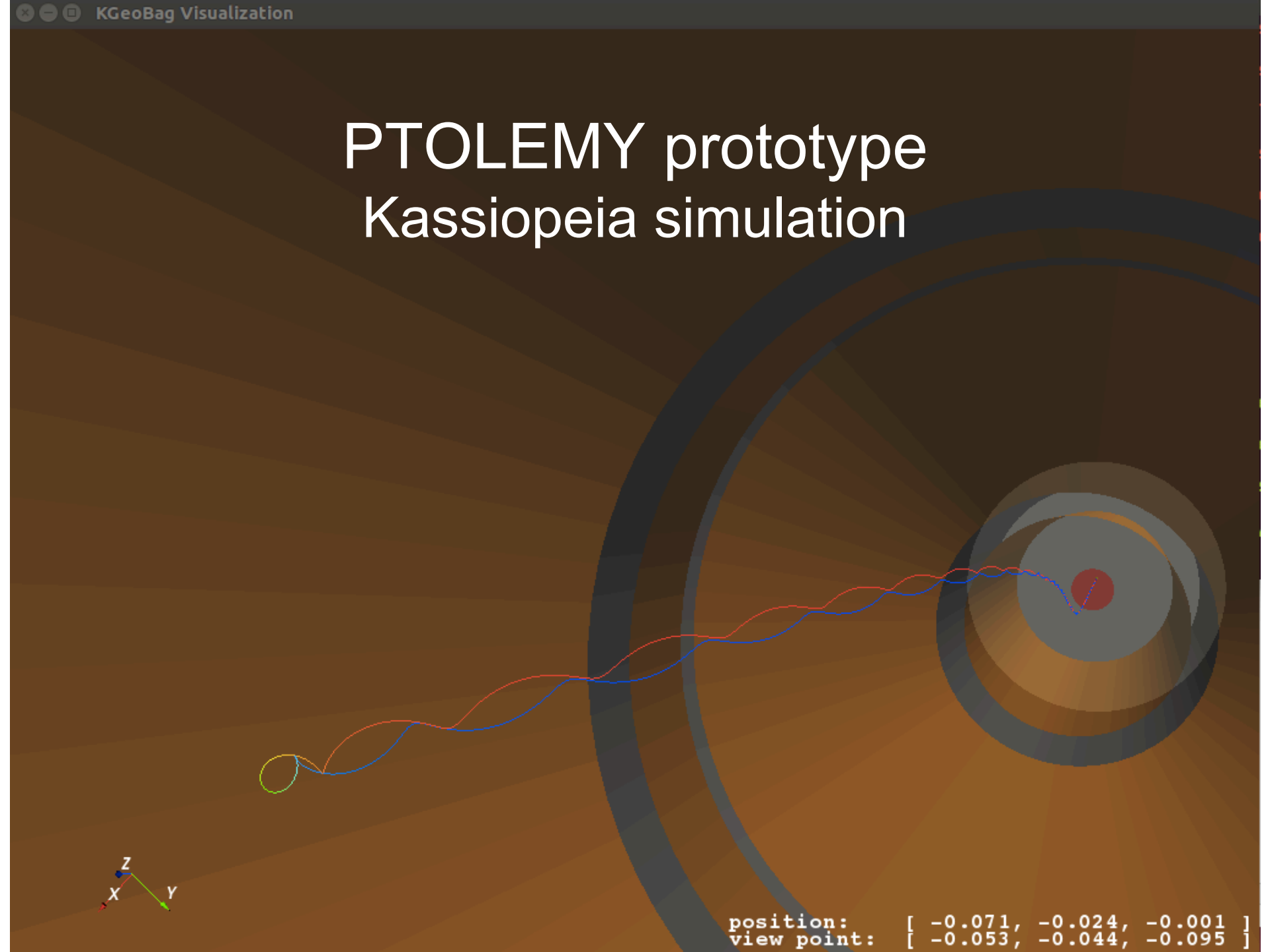


If the threshold is set at ~1eV the event rate reduction is ~ $(\Delta E/Q)^3 = 1.55\ 10^{-13}$
(for comparison, the activity of 1 g of T is of $3.6\ 10^{+14}$ Hz)

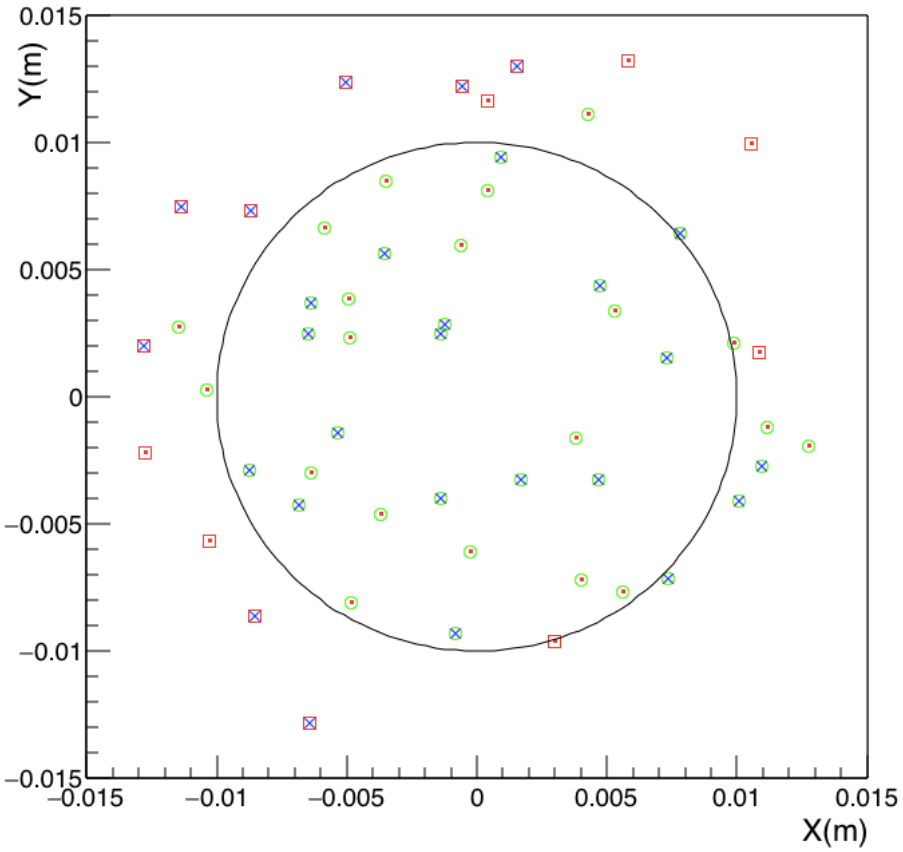
PTOLEMY prototype
GEANT4 simulation



katrin Visualization
PTOLEMY prototype
Kassiopeia simulation
Y
X
Z
position: [-5.414, 2.706, -0.988]
view point: [0.000, 0.000, -0.062]


KGeoBag Visualization
PTOLEMY prototype
Kassiopeia simulation
Z
X
Y
position: [-0.071, -0.024, -0.001]
view point: [-0.053, -0.044, -0.095]

PTOLEMY prototype
Electron transport efficiency vs energy



New E×B filtering design

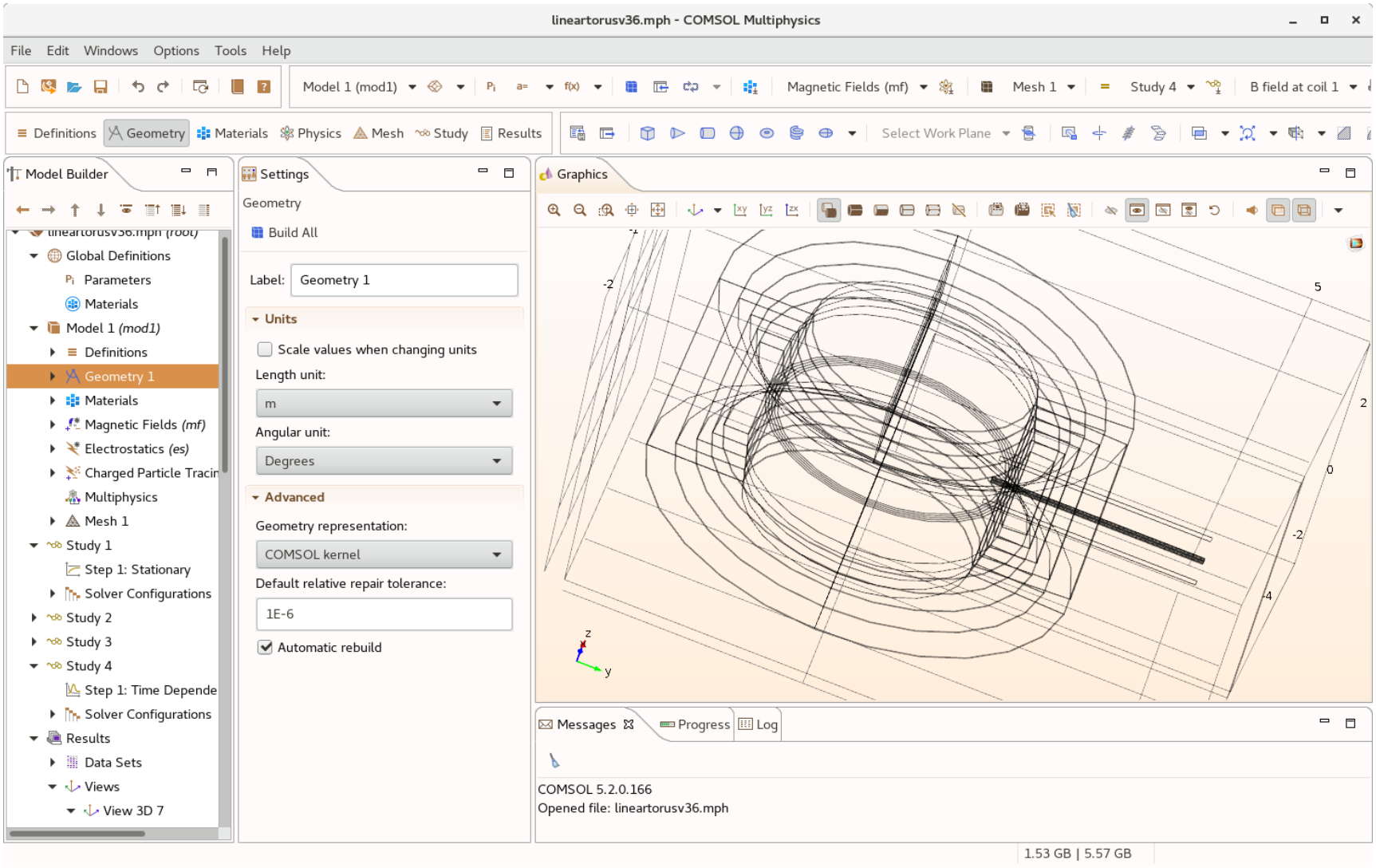
(C.Tully)

In traditional MAC-E filters, as B drops along the longitudinal kinetic energy (KE) of the electron, transverse KE → longitudinal and E•B term trades total KE with potential energy – electrons below filter cut-off bounce (reverse longitudinal momentum) due to E•B

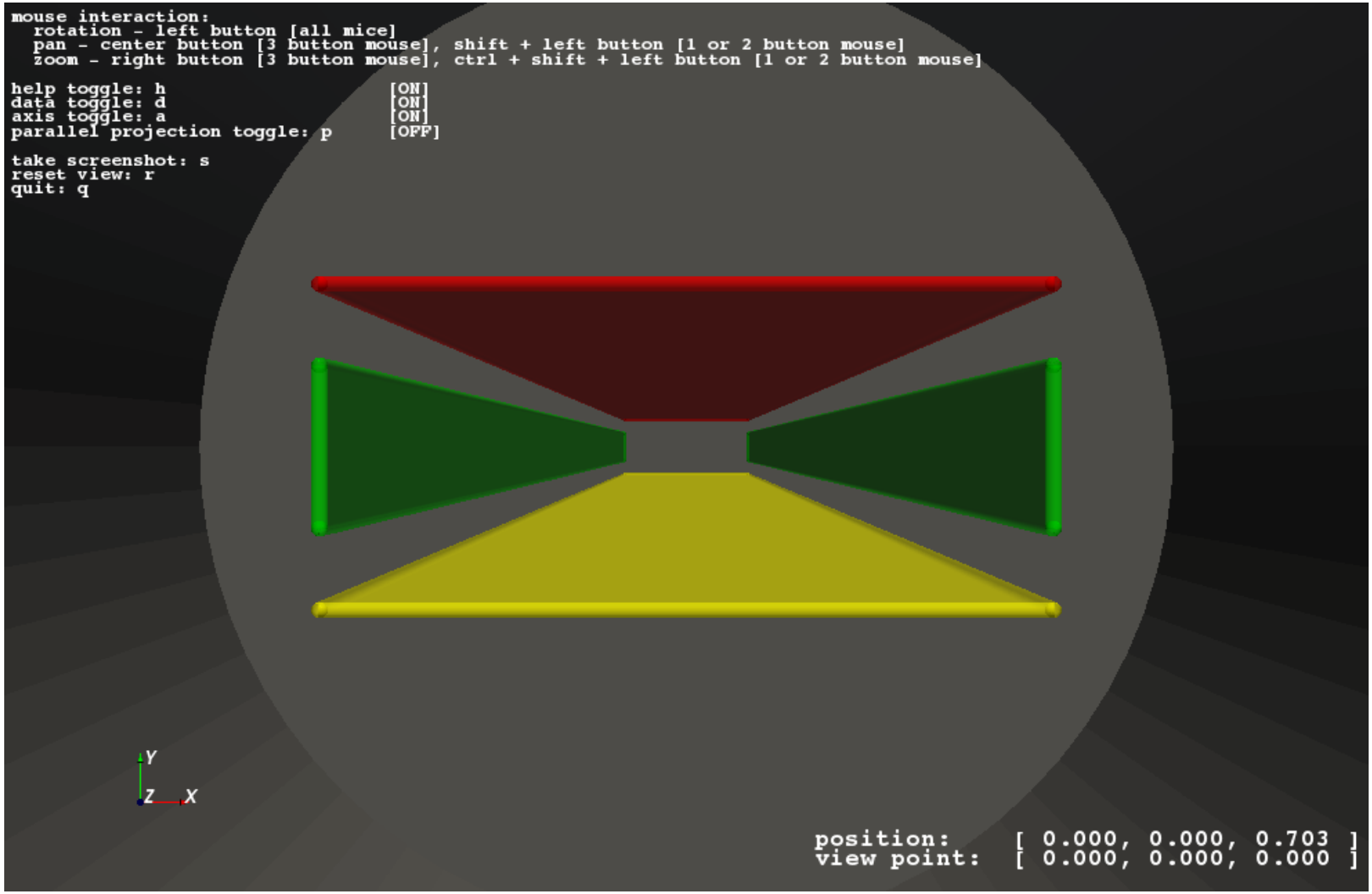
PTOLEMY: electrons enter at a fixed reference voltage into one end of an E•B bottle, as they bounce back and forth, they trade KE for potential energy as they slowly E×B drift vertically in the voltage potential and also drift into lower B field from transverse E×B drift where they exchange transverse KE → longitudinal

Simulation studies shows promising results

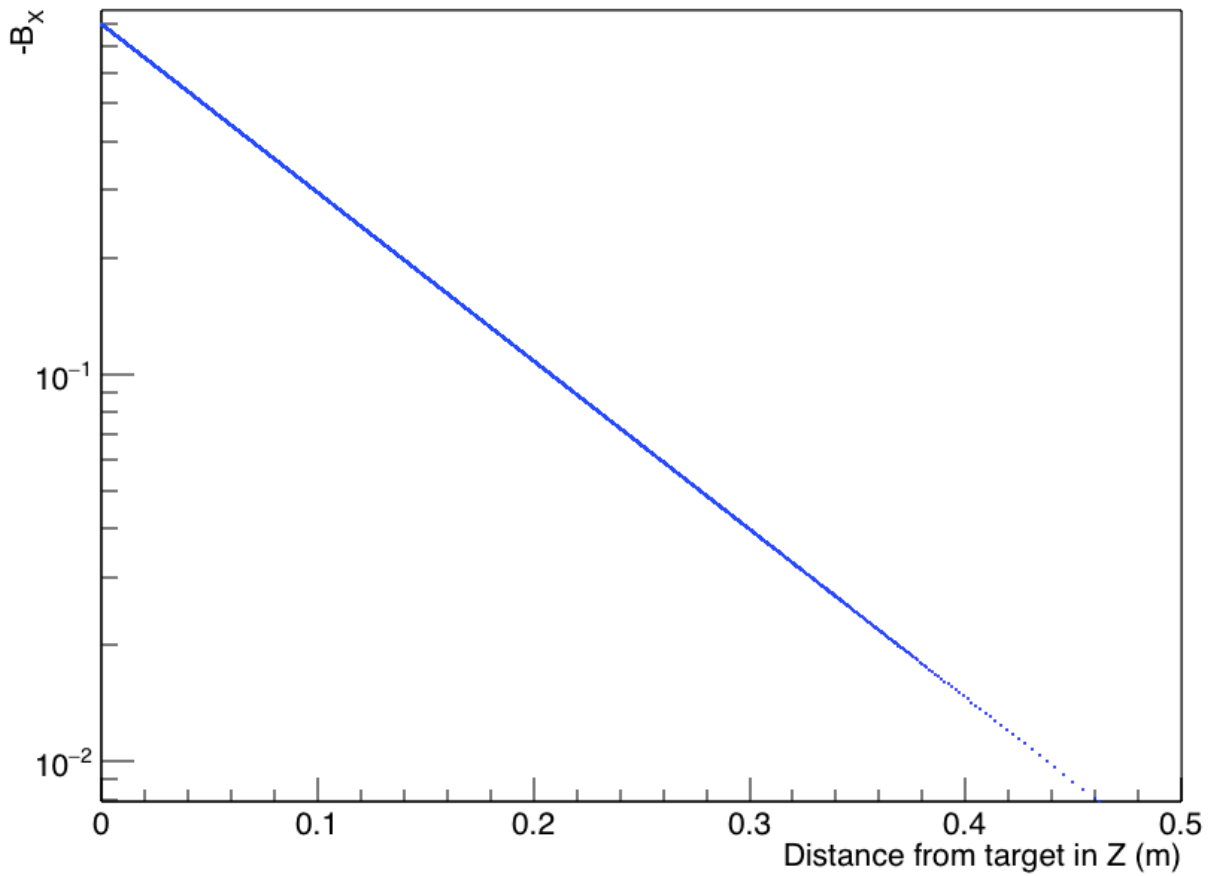
COMSOL 5.2


lineartorusv36.mph - COMSOL Multiphysics
File Edit Windows Options Tools Help
Model 1 (mod1)
Magnetic Fields (mf)
Mesh 1
Study 4
B field at coil 1
Definitions Geometry Materials Physics Mesh Study Results
Select Work Plane
Model Builder
Global Definitions
Parameters
Materials
Model 1 (mod1)
Definitions
Geometry 1
Materials
Magnetic Fields (mf)
Electrostatics (es)
Multiphysics
Mesh 1
Study 1
Step 1: Stationary
Solver Configurations
Study 2
Study 3
Study 4
Step 1: Time Depende
Solver Configurations
Results
Data Sets
Views
View 3D 7
Settings
Geometry
Build All
Label: Geometry 1
Units
Scale values when changing units
Length unit:
m
Angular unit:
Degrees
Advanced
Geometry representation:
COMSOL kernel
Default relative repair tolerance:
1E-6
Automatic rebuild
Graphics
Messages
Progress
Log
COMSOL 5.2.0.166
Opened file: lineartorusv36.mph
1.53 GB | 5.57 GB

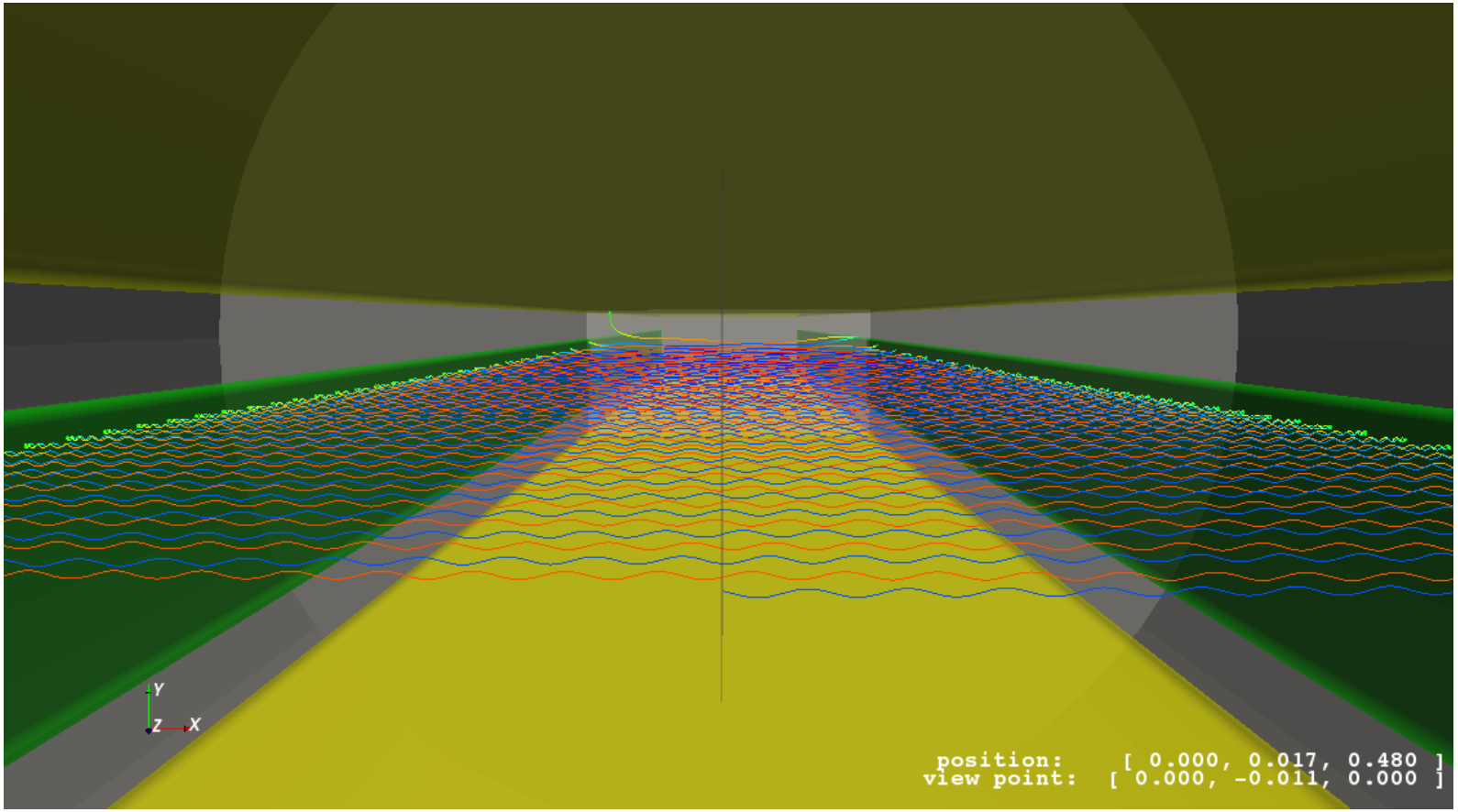
Kassiopeia


mouse interaction:
rotation - left button [all mice]
pan - center button [3 button mouse], shift + left button [1 or 2 button mouse]
zoom - right button [3 button mouse], ctrl + shift + left button [1 or 2 button mouse]
help toggle: h [ON]
data toggle: d [ON]
axis toggle: a [ON]
parallel projection toggle: p [OFF]
take screenshot: s
reset view: r
quit: q
Y
Z
X
position: [0.000, 0.000, 0.703]
view point: [0.000, 0.000, 0.000]

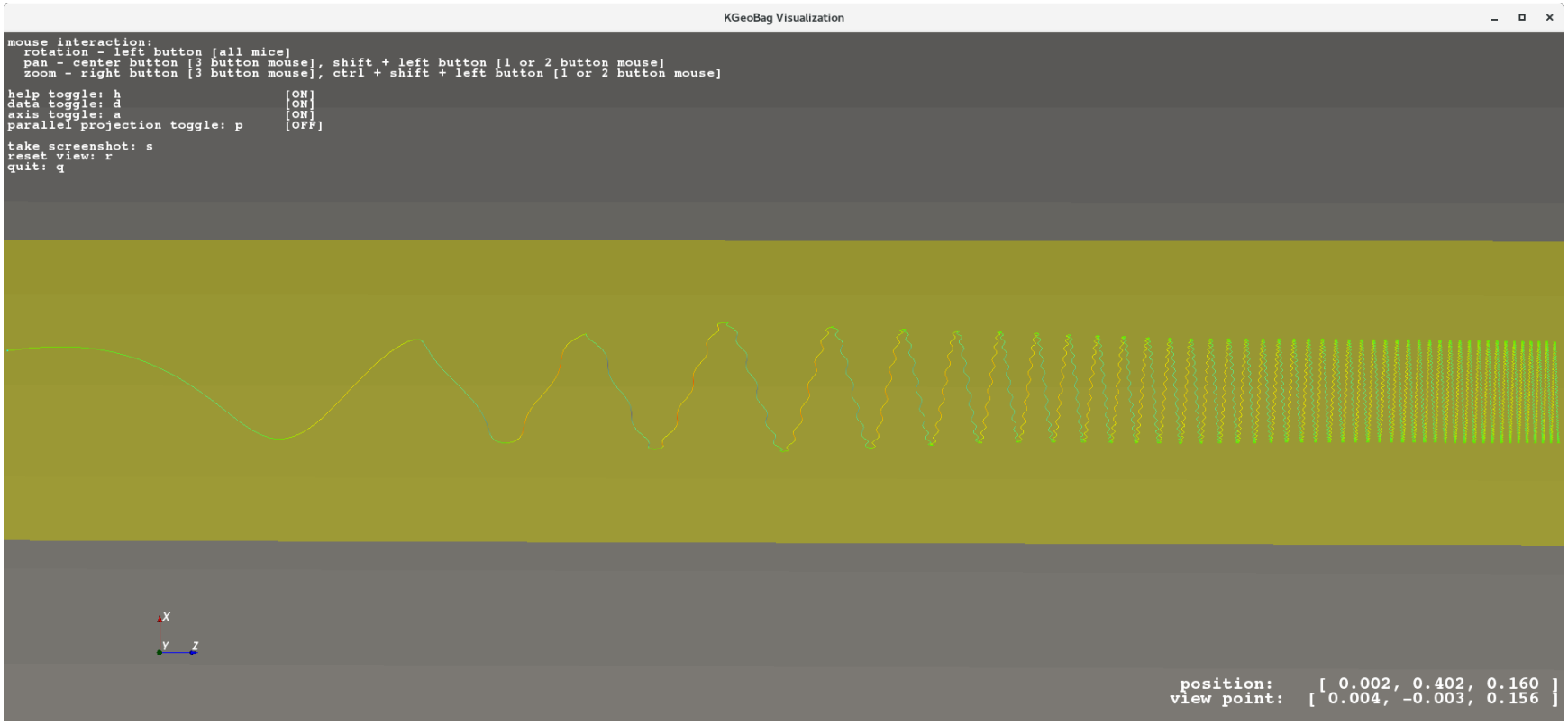
Custom B field setup in Kassiopeia



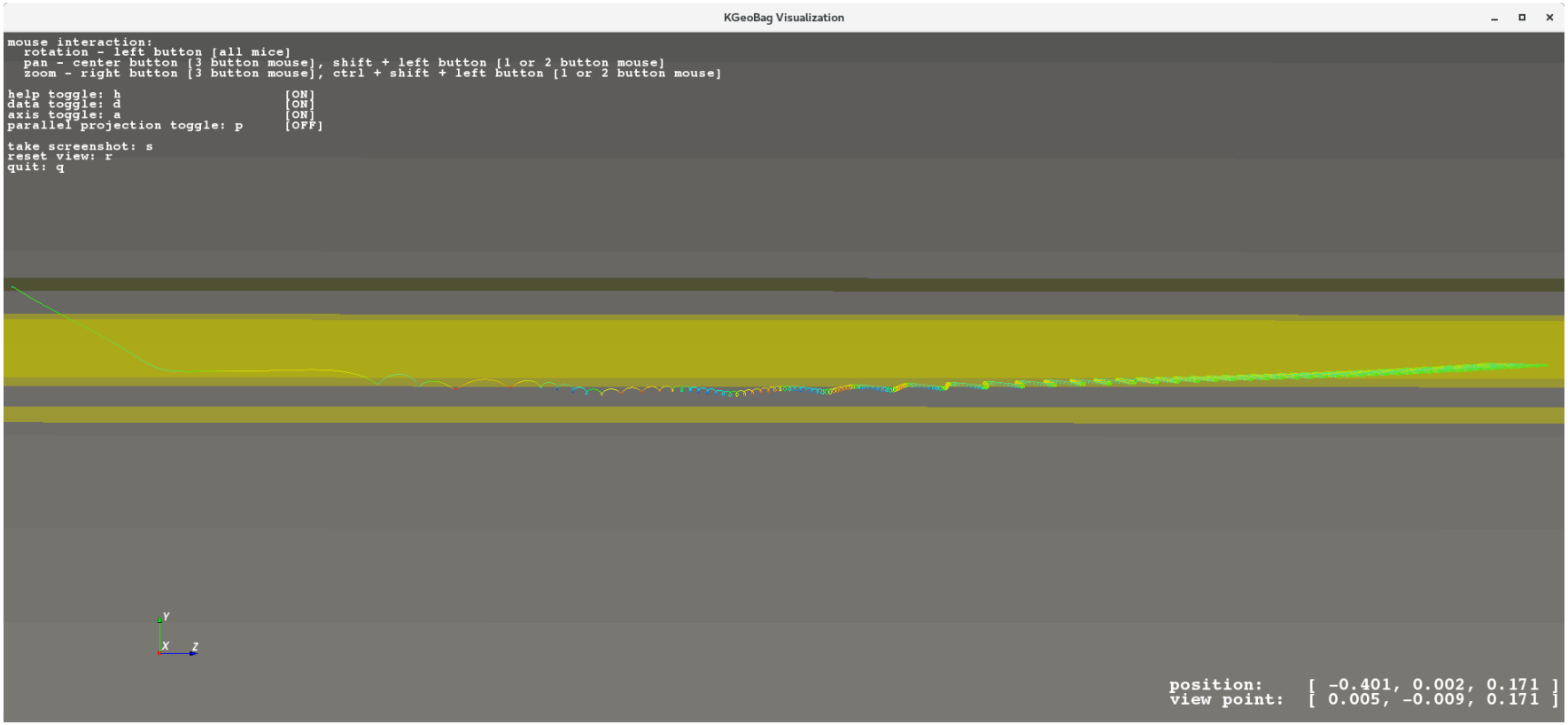
Kassiopeia VTK display



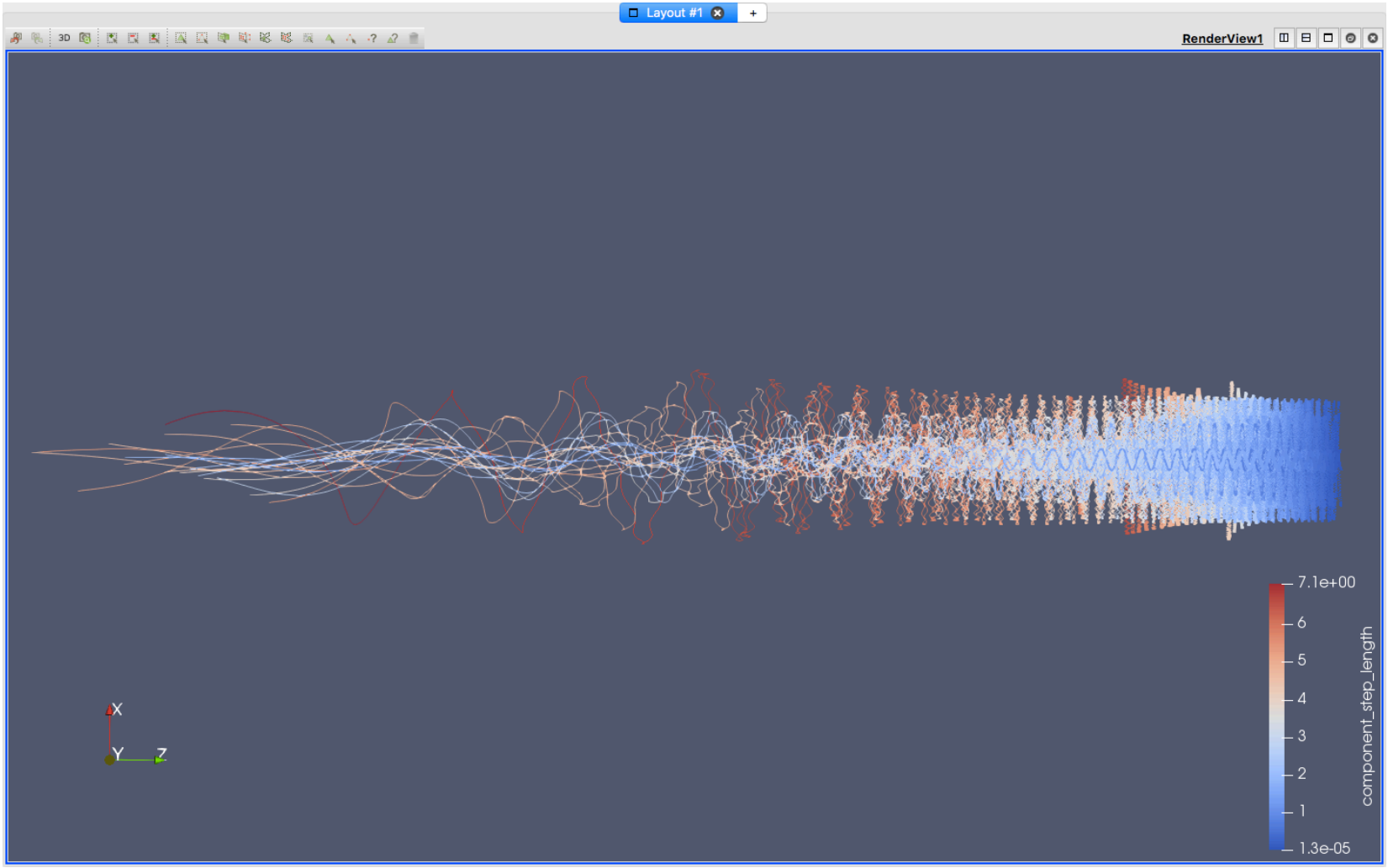
Kassiopeia VTK display



Kassiopeia VTK display



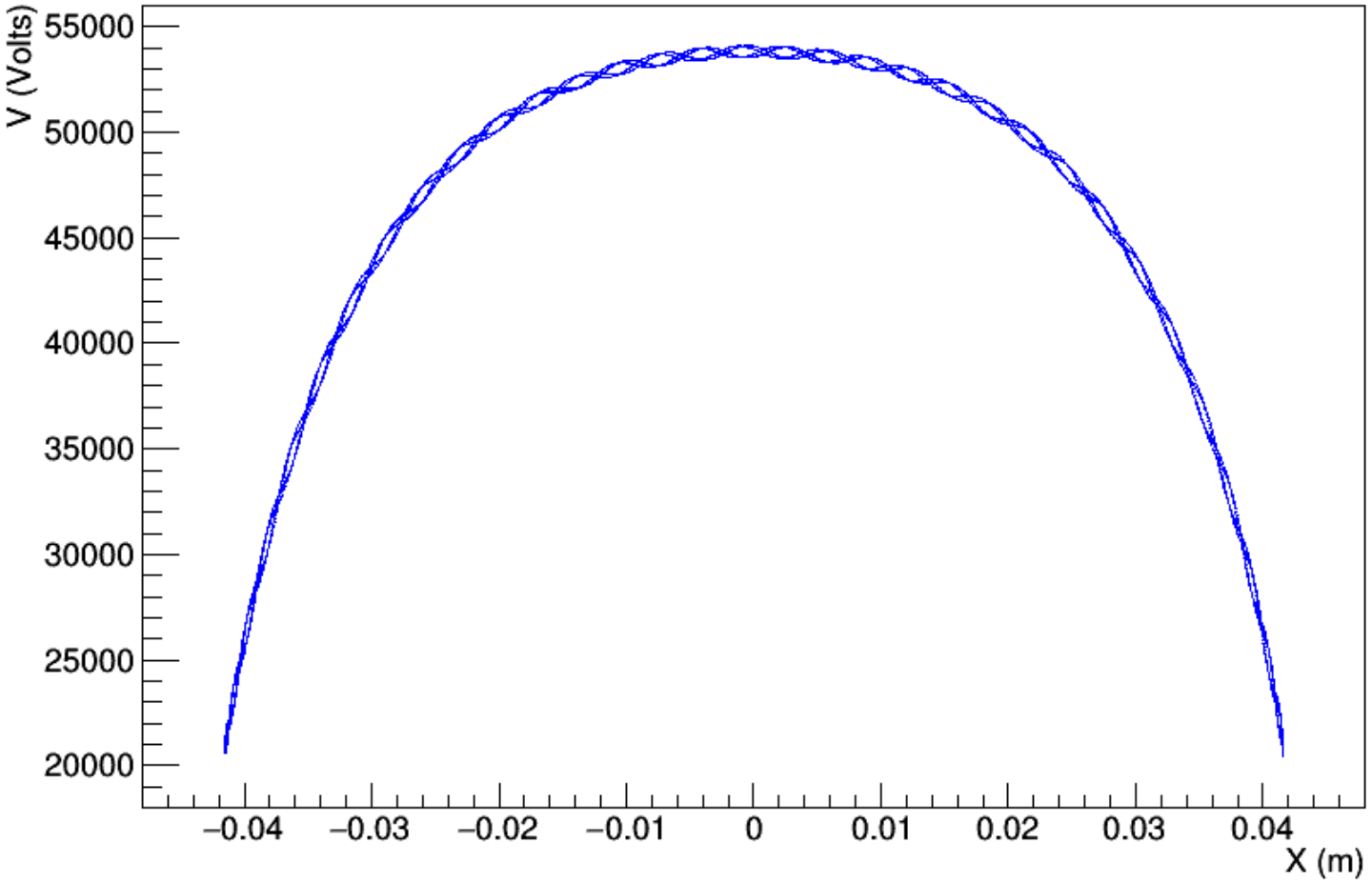
ParaView
analysis on Kassiopeia data



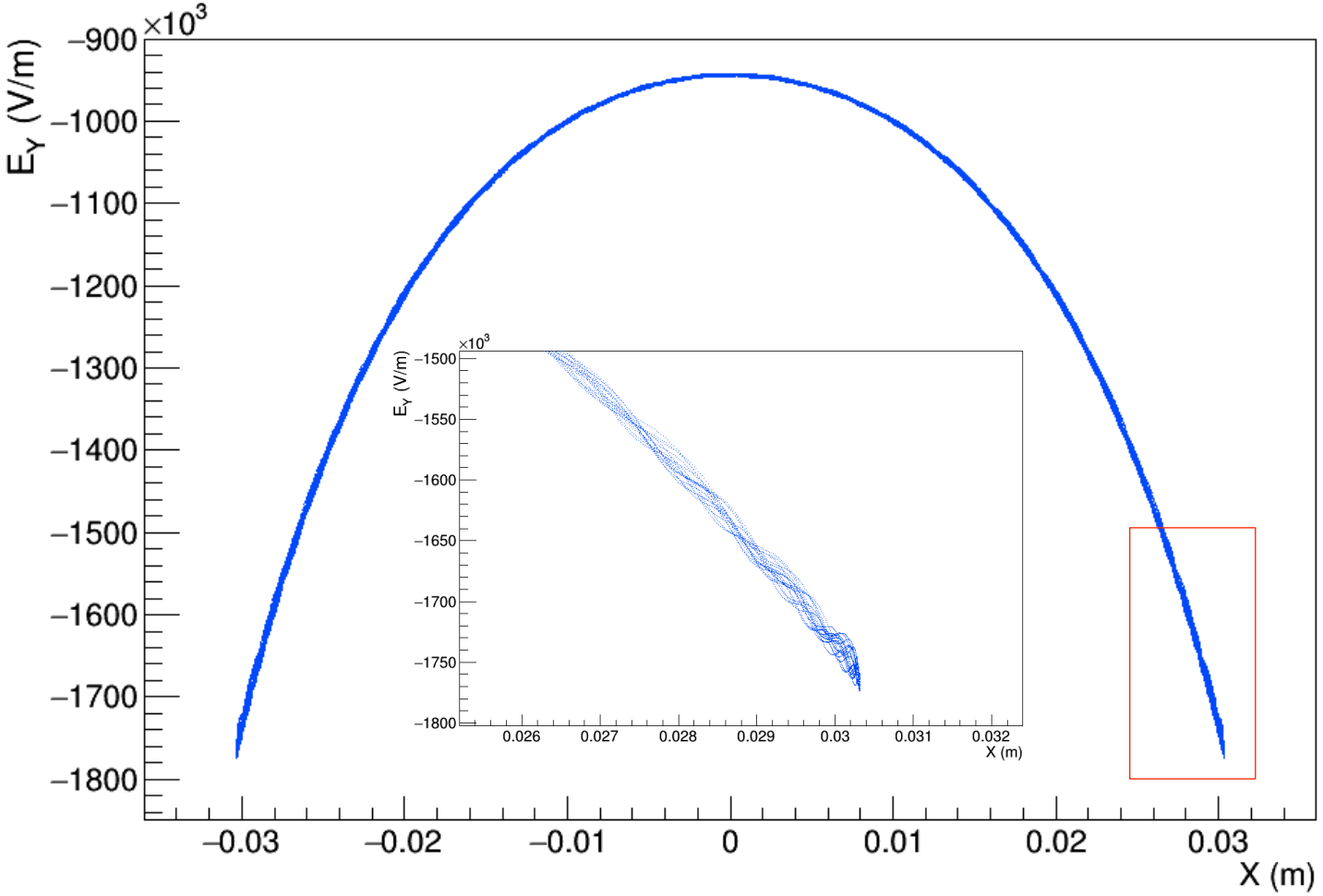
www.paraview.org

Root analysis
of Kassiopeia simulation results

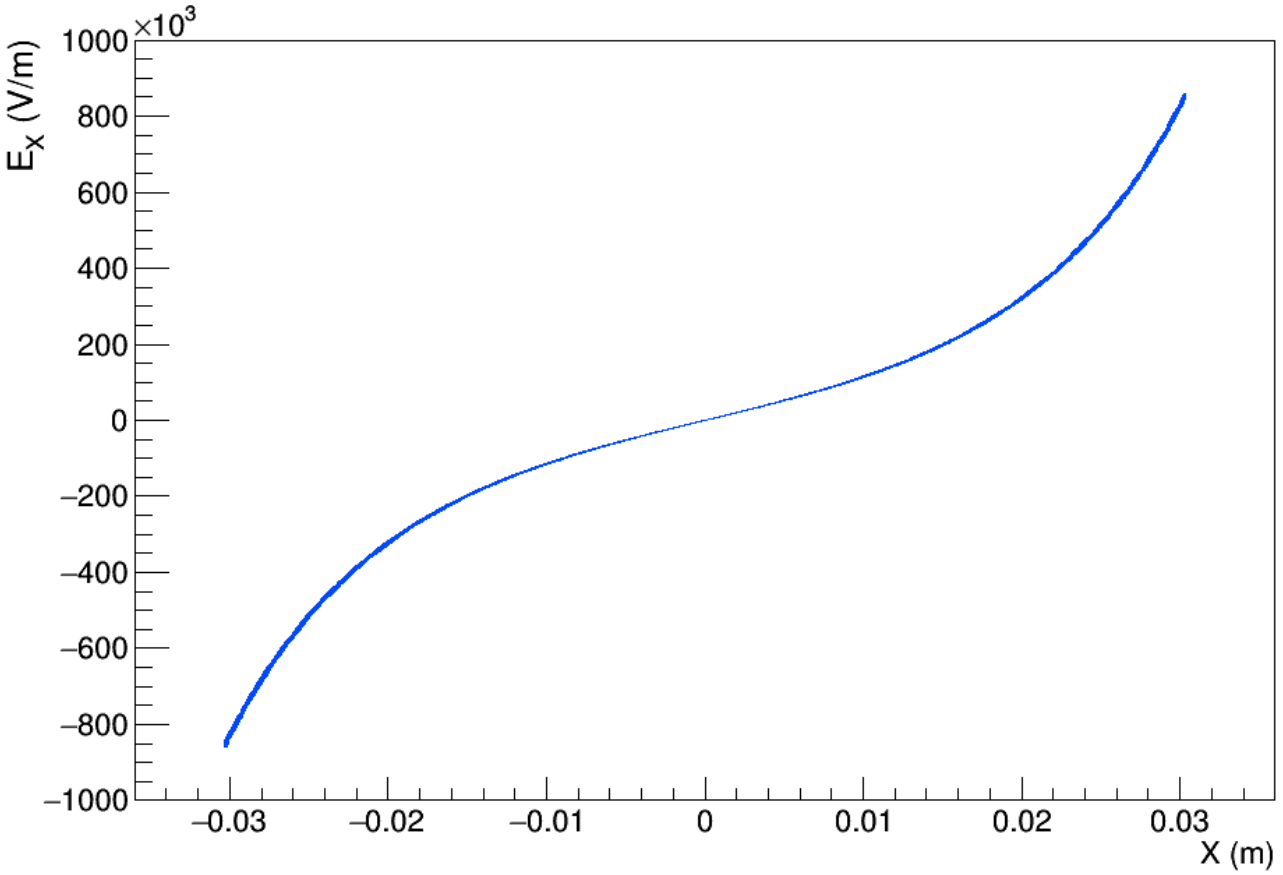
E×B filter
Electric potential



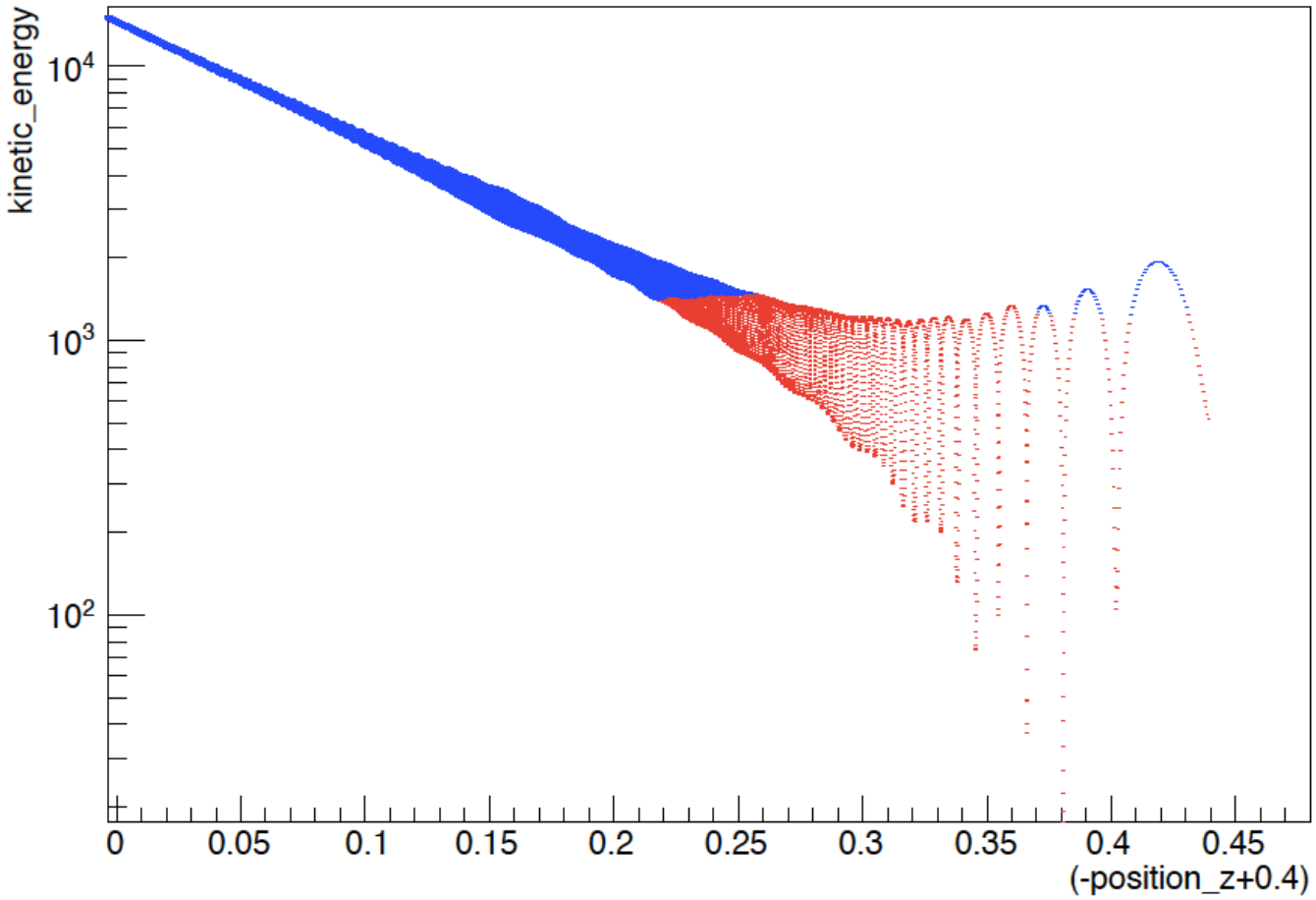
E×B filter
Electric field along Y



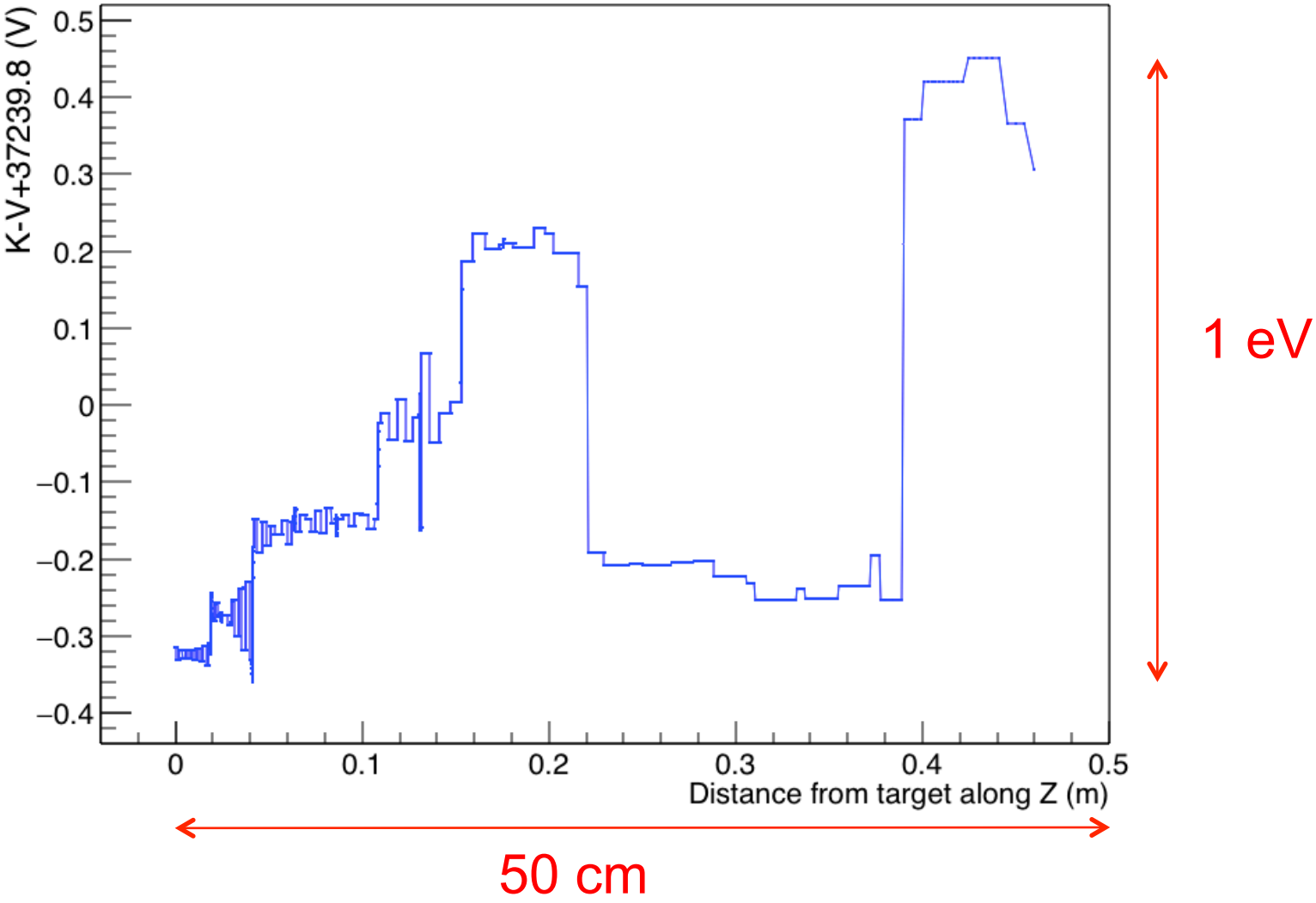
E×B filter
Electric field along X



E×B filter
Kinetic energy along Z



E×B filter
Energy conservation test



Conclusions

A big amount of work is needed in order to properly design the detector

Models and simulations have been partially setup

Many more studies need to be done (e.g. E-gun, RF signal)

Better understanding and tuning of COMSOL/G4/Kassiopeia parameters is needed

New linux machine being setup here at LNGS (all software installed and ready to be used)

Contributions are very welcome !!

Thank you