Positron Source Modelling using Geant4

Recent Activities at DESY Zeuthen

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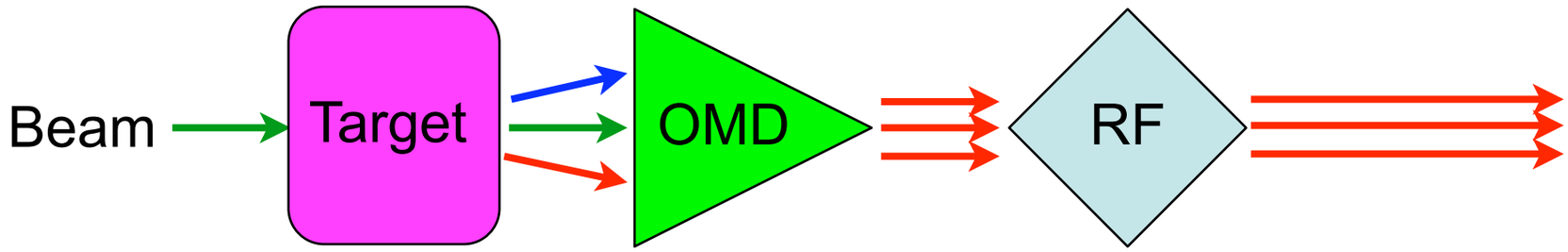
Outline

- Introduction
  - PPS Overview
  - Geant4 Overview
- PPS-Sim
  - Features
  - Results
- Live Demo
  - Example Run
- Outlook
  - Possible next Steps

Introduction

Polarised Positron Source (for the ILC)

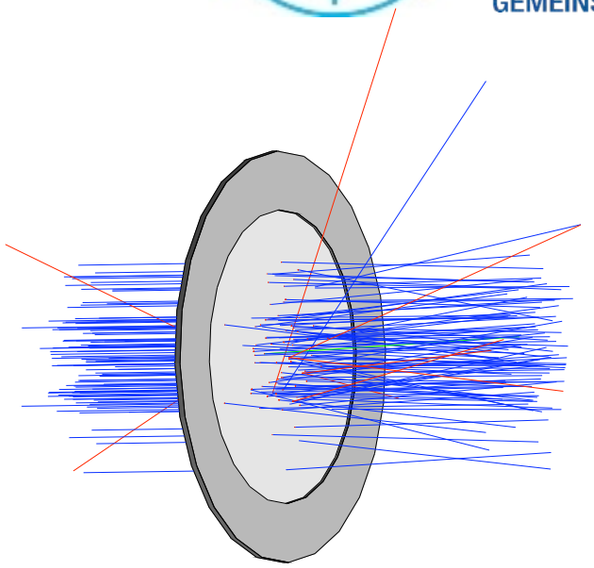


- Primary beam
  - Photons from Undulator / Compton
  - Electrons (conventional source)
- Target
  - Ti wheel, Liquid Lead
- Positron Capture Optics (OMD)
  - AMD, QWT, Li-Lens
- Acceleration of Positron in RF Cavities
  - Solenoid field

Introduction

Geant4 Toolkit

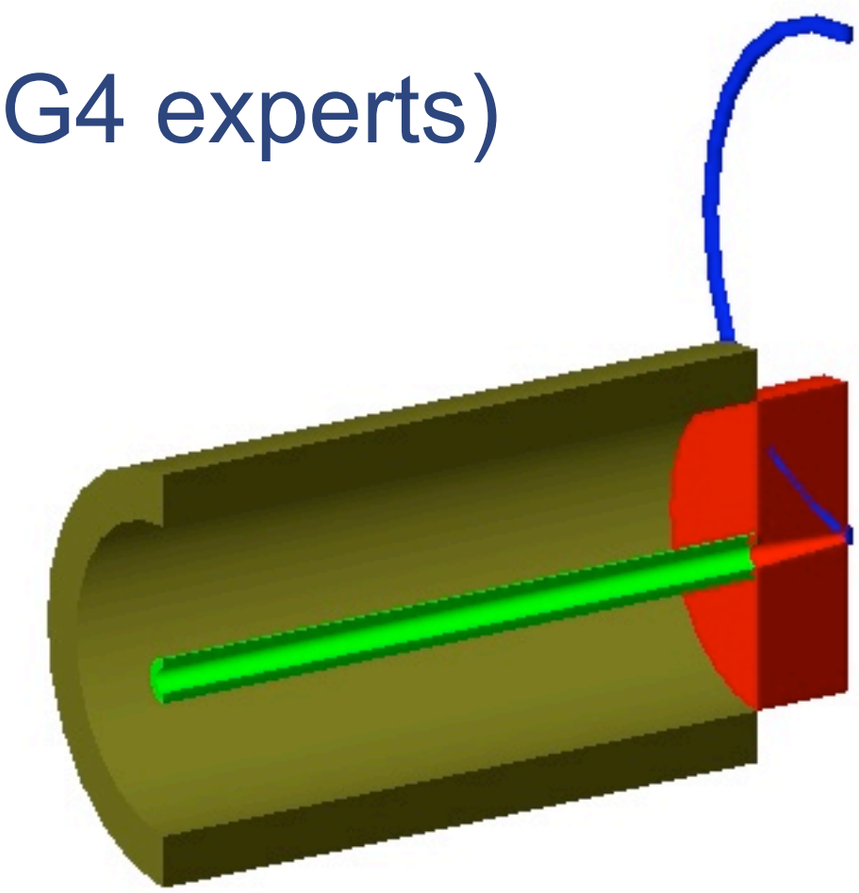
"a toolkit for the simulation
of the passage of particles through matter"



- Features include
  - powerful geometry package
  - electromagnetic and hadronic shower simulation
  - polarisation transfer in physics processes
  - particle and spin tracking in electromagnetic fields
  - visualisation (geometry, particles, energy deposition,...)
  - GUI (XM, Qt,...)
  - ...

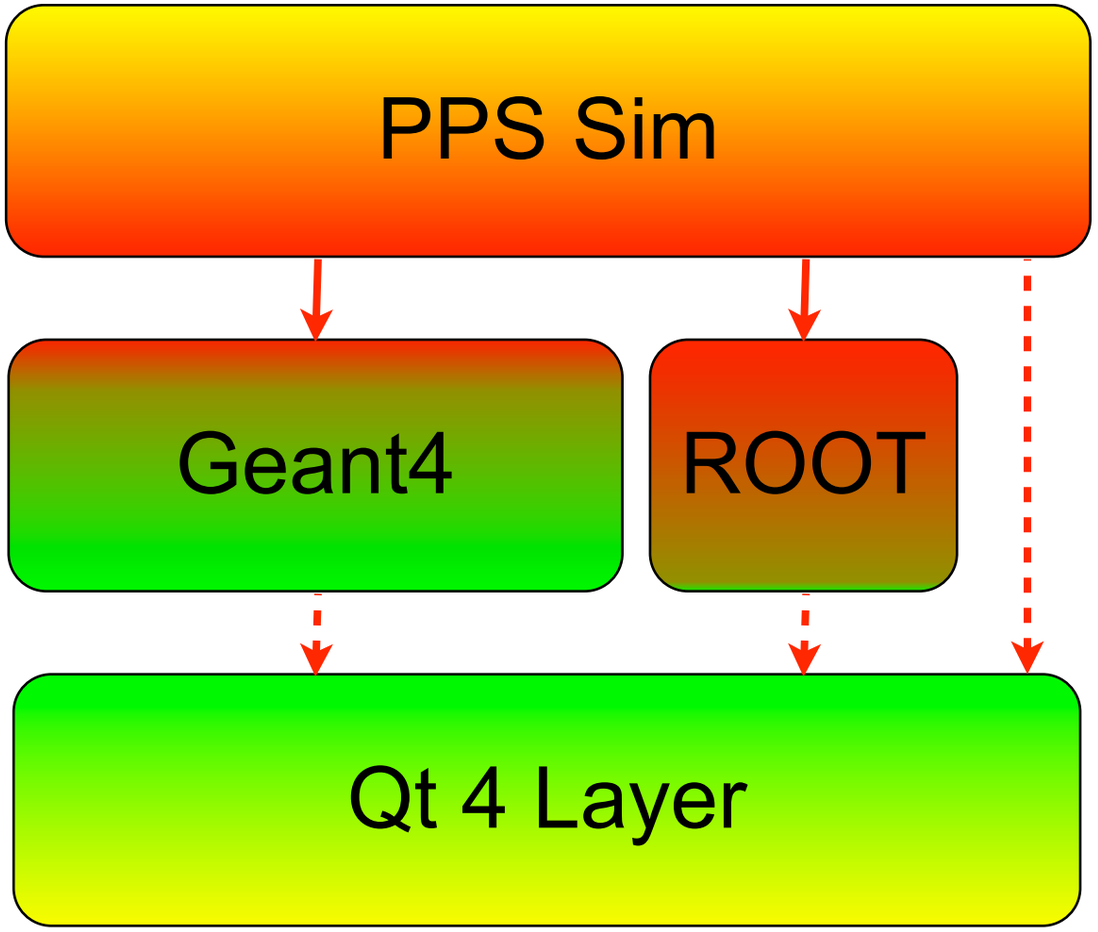
PPS-Sim

- Idea: use Geant4 for modelling of PPS
  - start from positron production (target)
  - end after first accelerator structure
  - simplified geometry
- aim: easy usage (also for non-G4 experts)
  - graphical user interface (GUI)
  - visualisation
  - internal analysis
- allow for batch mode running
  - high statistics runs
  - configure via macro commands
  - post analysis



PPS-Sim

- Layout
  - use Geant4 for:
    geometry, physics, UI
  - use ROOT for:
    data analysis,
    persistency



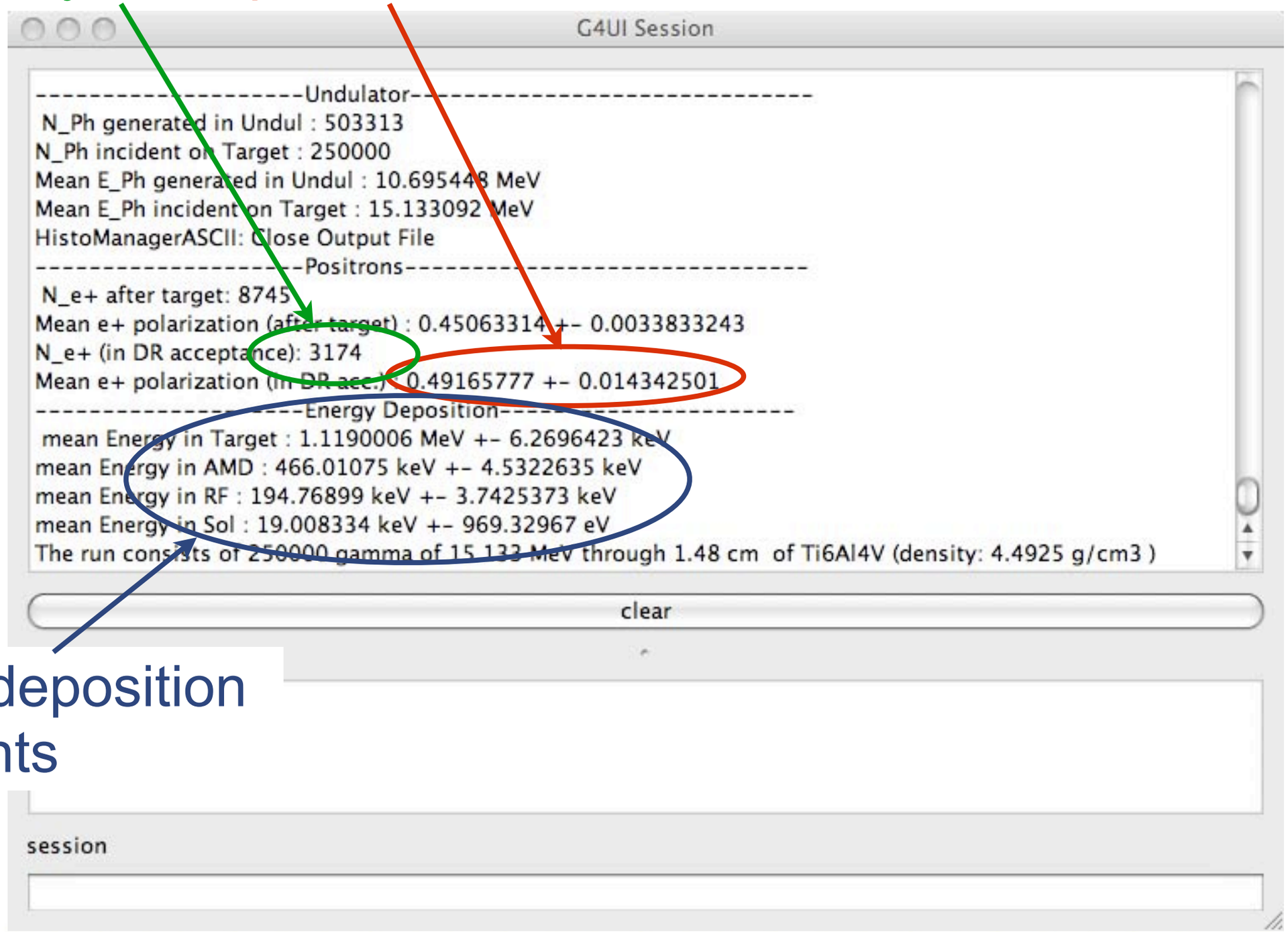
- Prerequisites
  - Geant4 9.2
    (incl. Qt4 binding)
  - ROOT 5.22
    (incl. Qt4 binding)
  - Qt 4.2 or above
    (4.4.x recommended)

PPS-Sim

- Input:
  - Beam, Target & OMD (free configurable)
- Output:
  - positron yield & polarisation (incl. DR acceptance)
  - beam properties (width, emittance, energy, ...)
  - total energy deposition in components
  - ...
- User interface:
  - GUI allows for setting of simulation parameter
  - visualisation of geometry & tracks
  - semi-automatic parameter scans (e.g. RF phase)
  - output as .root, .eps, ...

Results

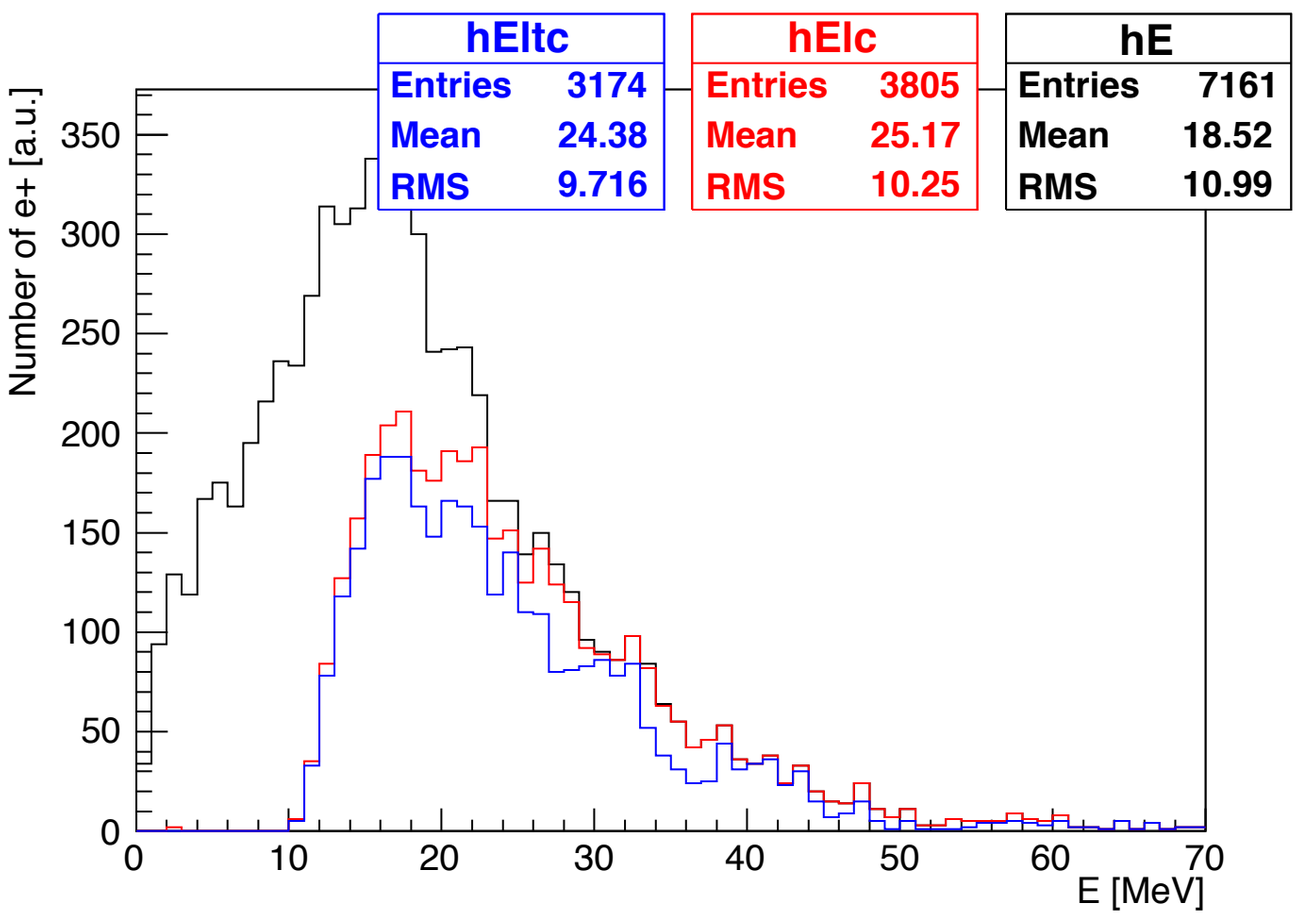
- positron yield & polarisation

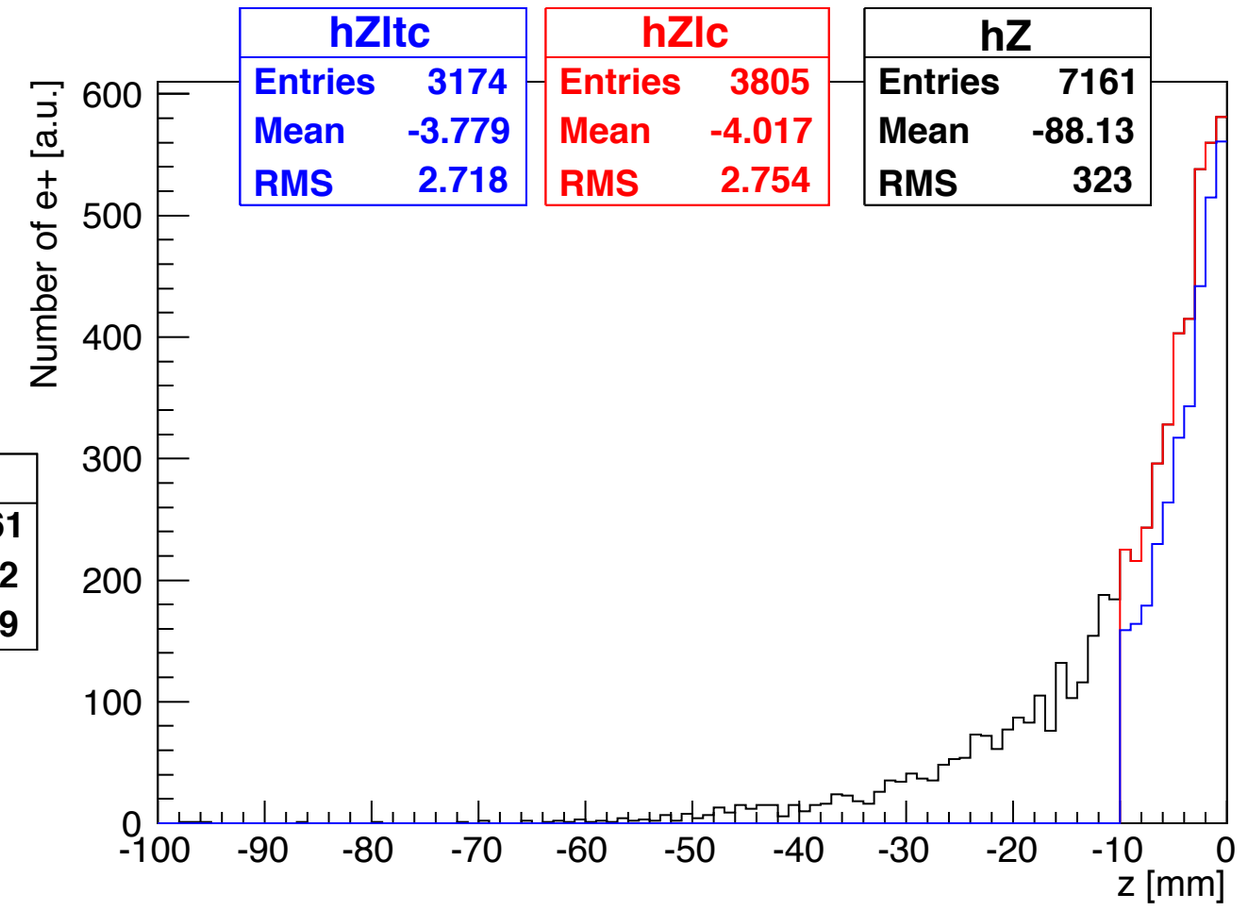


- total energy deposition in components

Results

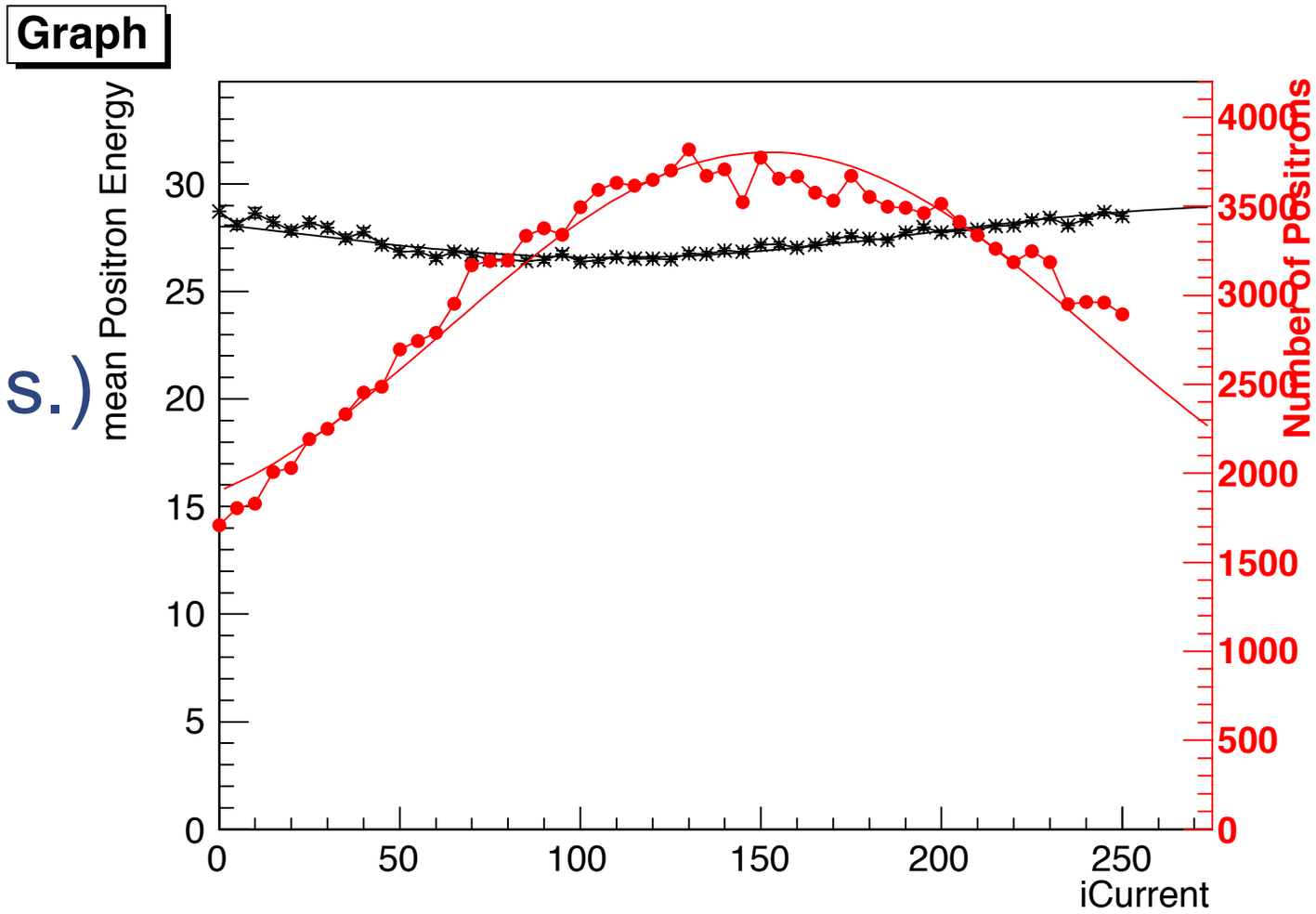
- Energy distribution
- Phase space

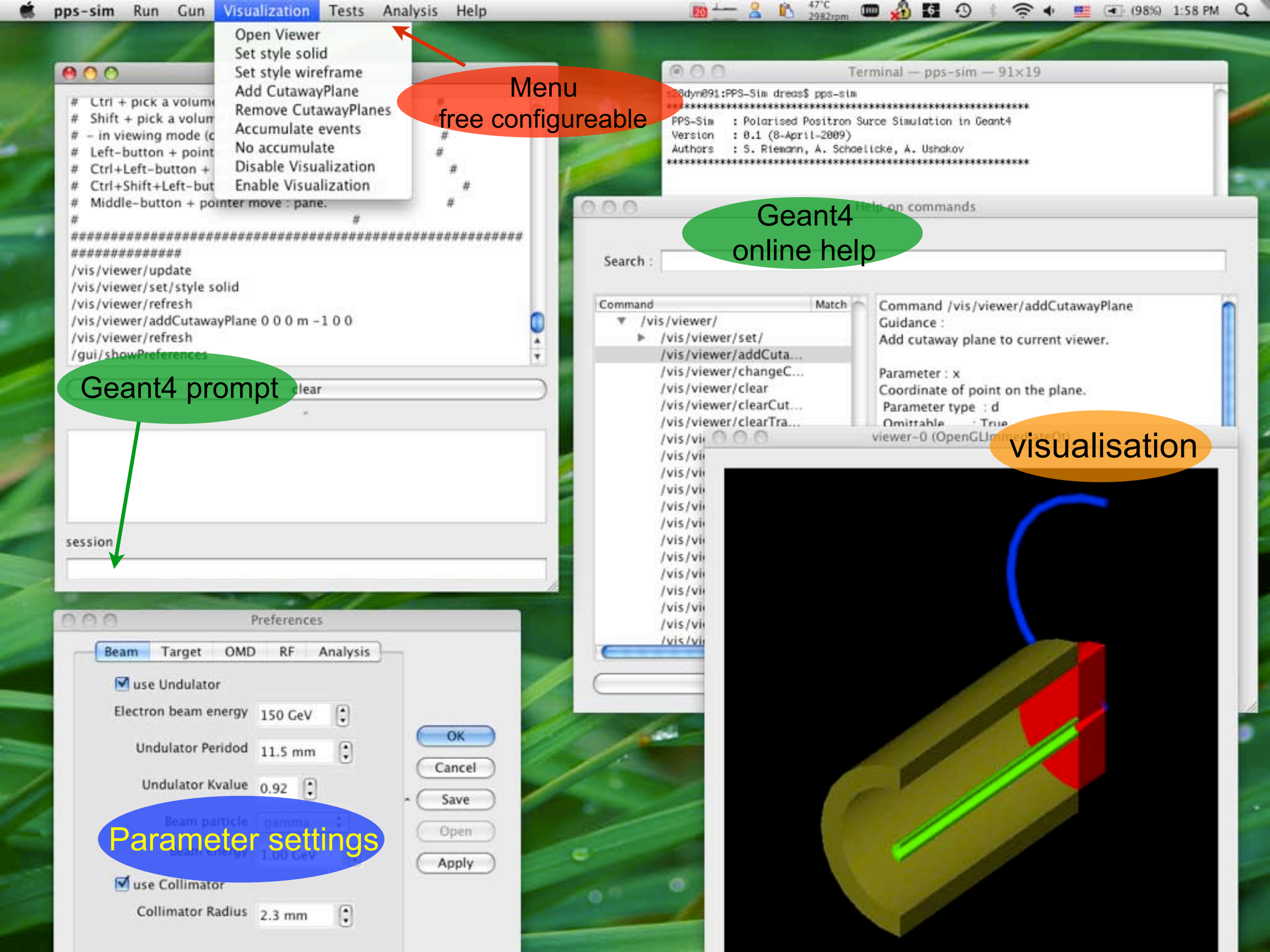


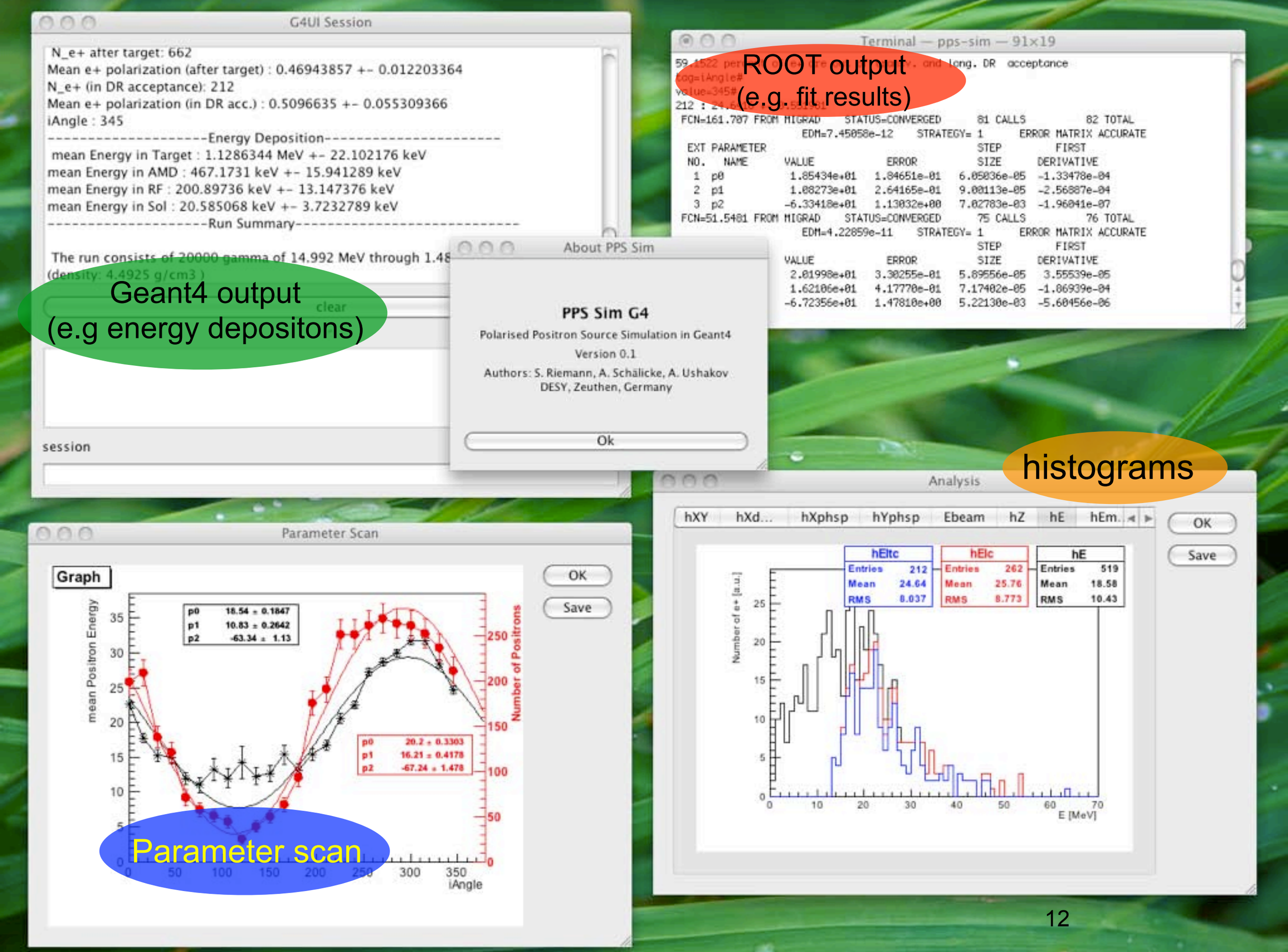


Results

- (almost) arbitrary scans, e.g.
  - RF phase
  - target thickness
  - lens current (liquid Lithium)
  - field strength, OMD length (quarter wave trans.)
  - ....




pps-sim Run Gun Visualization Tests Analysis Help
Open Viewer
Set style solid
Set style wireframe
Add CutawayPlane
Remove CutawayPlanes
Accumulate events
No accumulate
Disable Visualization
Enable Visualization
Menu
free configureable
/vis/viewer/update
/vis/viewer/set/style solid
/vis/viewer/refresh
/vis/viewer/addCutawayPlane 0 0 0 m -1 0 0
/vis/viewer/refresh
/gui/showPreferences
Geant4 prompt
clear
session
Terminal — pps-sim — 91×19
PPS-Sim : Polarised Positron Surce Simulation in Geant4
Version : 0.1 (8-April-2009)
Authors : S. Riemann, A. Schaelicke, A. Ushakov
Help on commands
Geant4
online help
Search :
Command
Match
/vis/viewer/
/vis/viewer/set/
/vis/viewer/addCuta...
/vis/viewer/changeC...
/vis/viewer/clear
/vis/viewer/clearCut...
/vis/viewer/clearTra...
Command /vis/viewer/addCutawayPlane
Guidance :
Add cutaway plane to current viewer.
Parameter : x
Coordinate of point on the plane.
Parameter type : d
viewer-0 (OpenGLImmediateQt)
visualisation
Preferences
Beam
Target
OMD
RF
Analysis
use Undulator
Electron beam energy 150 GeV
Undulator Peridod 11.5 mm
Undulator Kvalue 0.92
Beam particle gamma
Beam energy 1.00 GeV
use Collimator
Collimator Radius 2.3 mm
OK
Cancel
Save
Open
Apply
Parameter settings


G4UI Session
N_e+ after target: 662
Mean e+ polarization (after target) : 0.46943857 +- 0.012203364
N_e+ (in DR acceptance): 212
Mean e+ polarization (in DR acc.) : 0.5096635 +- 0.055309366
iAngle : 345
----------Energy Deposition----------
mean Energy in Target : 1.1286344 MeV +- 22.102176 keV
mean Energy in AMD : 467.1731 keV +- 15.941289 keV
mean Energy in RF : 200.89736 keV +- 13.147376 keV
mean Energy in Sol : 20.585068 keV +- 3.7232789 keV
----------Run Summary----------
The run consists of 20000 gamma of 14.992 MeV through 1.48
(density: 4.4925 g/cm3)
clear
session
Geant4 output
(e.g energy depositons)
About PPS Sim
PPS Sim G4
Polarised Positron Source Simulation in Geant4
Version 0.1
Authors: S. Riemann, A. Schälicke, A. Ushakov
DESY, Zeuthen, Germany
Ok
Terminal — pps-sim — 91×19
ROOT output
(e.g. fit results)
FCN=161.707 FROM MIGRAD STATUS=CONVERGED 81 CALLS 82 TOTAL
EDM=7.45058e-12 STRATEGY= 1 ERROR MATRIX ACCURATE
EXT PARAMETER STEP FIRST
NO. NAME VALUE ERROR SIZE DERIVATIVE
1 p0 1.85434e+01 1.84651e-01 6.05036e-05 -1.33478e-04
2 p1 1.08273e+01 2.64165e-01 9.00113e-05 -2.56887e-04
3 p2 -6.33418e+01 1.13032e+00 7.02783e-03 -1.96041e-07
FCN=51.5481 FROM MIGRAD STATUS=CONVERGED 75 CALLS 76 TOTAL
EDM=4.22859e-11 STRATEGY= 1 ERROR MATRIX ACCURATE
VALUE ERROR SIZE DERIVATIVE
2.01998e+01 3.30255e-01 5.89556e-05 3.55539e-05
1.62106e+01 4.17770e-01 7.17402e-05 -1.06939e-04
-6.72356e+01 1.47810e+00 5.22130e-03 -5.60456e-06
Parameter Scan
Graph
OK
Save
p0 18.54 ± 0.1847
p1 10.83 ± 0.2642
p2 -63.34 ± 1.13
p0 20.2 ± 0.3303
p1 16.21 ± 0.4178
p2 -67.24 ± 1.478
mean Positron Energy
Number of Positrons
iAngle
Parameter scan
Analysis
histograms
hXY hXd... hXphsp hYphsp Ebeam hZ hE hEm...
OK
Save
hEltc Entries 212 Mean 24.64 RMS 8.037
hElc Entries 262 Mean 25.76 RMS 8.773
hE Entries 519 Mean 18.58 RMS 10.43
Number of e+ [a.u.]
E [MeV]

Summary

- PPS-Sim
  - exploitation of the Geant4 toolkit
  - provides Qt GUI for easy usage
  - allows batch runs for high statistics accumulation
  - uses ROOT for data analysis and persistency
- Features
  - e+ production: Undulator, Conventional
  - capture: AMD, QWT, Li-Lens
  - acceleration: RF & solenoid incl. spin tracking
- Available
  - upon request from authors
  - web page in preparation

Outlook

- model improvements
  - extend beyond 1st accelerator section
  - include detailed energy deposition (scoring)
  - add alternative e^+ production mechanism
    (e.g. Compton, CBS)

(help welcome)

- UI improvements
  - simplify physics settings
  - allow speed improvements
    (e.g. no tracking of lost particles)

- other program improvements
  - multi processor (core) support
  - reduce dependencies on Qt