Tools for Calculations in Microdosimetry and Radiobiology

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Introduction

Microdosimetry

- *Lineal energy = energy imparted over mean chord length:*

$$y = \frac{\varepsilon_s}{\bar{l}}$$

(mean chord length calculated assuming uniform irradiation condition)

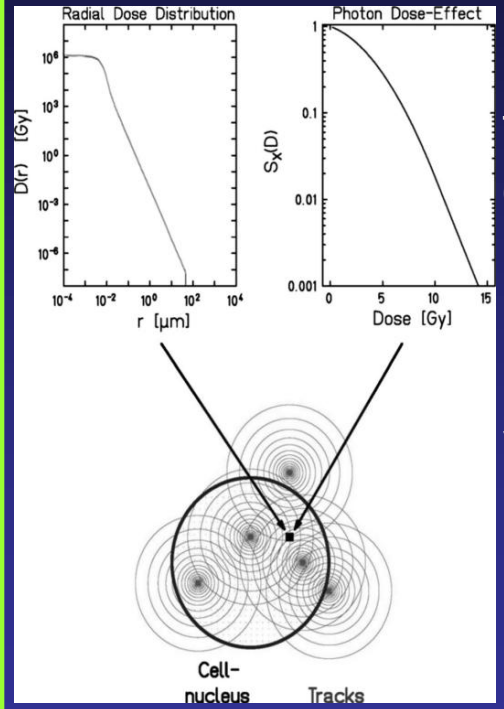
- *Frequency mean (yF) and dose mean (yD) lineal energy:*

$$\bar{y}_f = \int_0^\infty y f(y) \mathrm{d}y$$

$$\bar{y}_d = \int_0^\infty y d(y) \mathrm{d}y = \frac{1}{\bar{y}_f} \int_0^\infty y^2 f(y) \mathrm{d}y$$

Radiobiology

(Equivalent Dose = Dose × RBE)



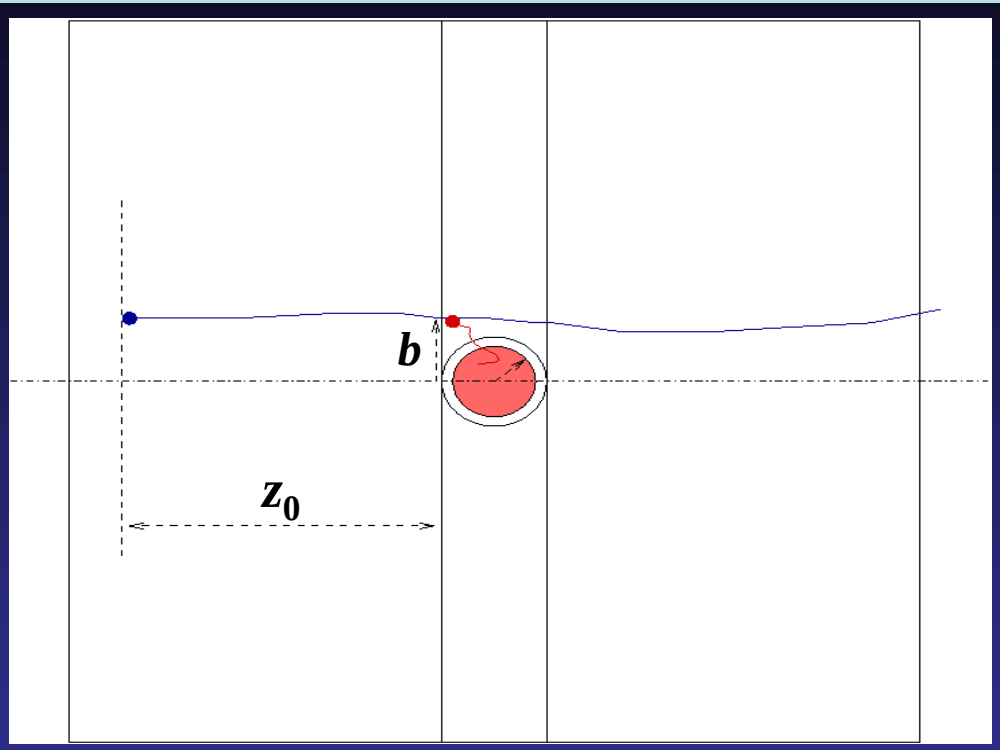
Elsässer and Scholz, Rad. Res. 167 (2007)

Track structure calculations (e.g. radial dose) are of interest for radiobiology models such as LEM.

MicroCavity

- **Geometry**

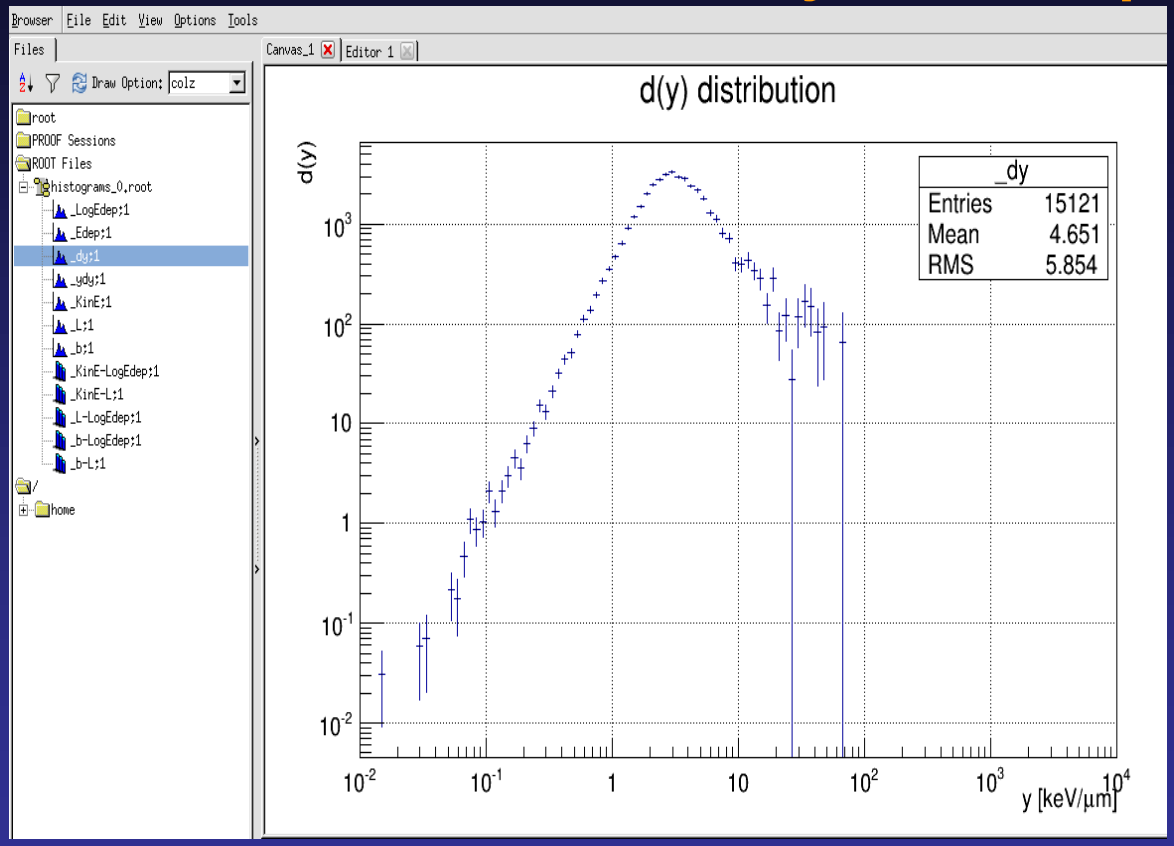
```
############################
### SETUP CONFIGURATION ###
############################
/mygeom/worldSide      325.    um
/mygeom/wallR           05.01 um
/mygeom/wallMaterial    G4_WATER
/mygeom/cavityR         05.00 um
/mygeom/cavityMaterial G4_WATER
/mygeom/addCavitySDLV     Cavity
```



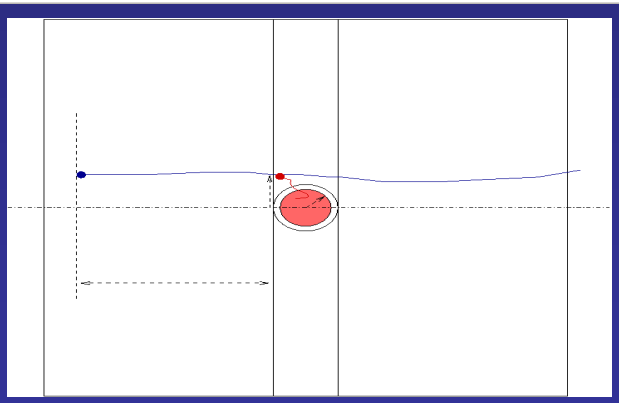
- **Scoring & Stepping Action**
  - SD/HIT for energy deposition and track length calculation within cavity.
  - Kinetic energy and impact parameter of primary registered when entering the slab.

MicroCavity

Analysis & Output



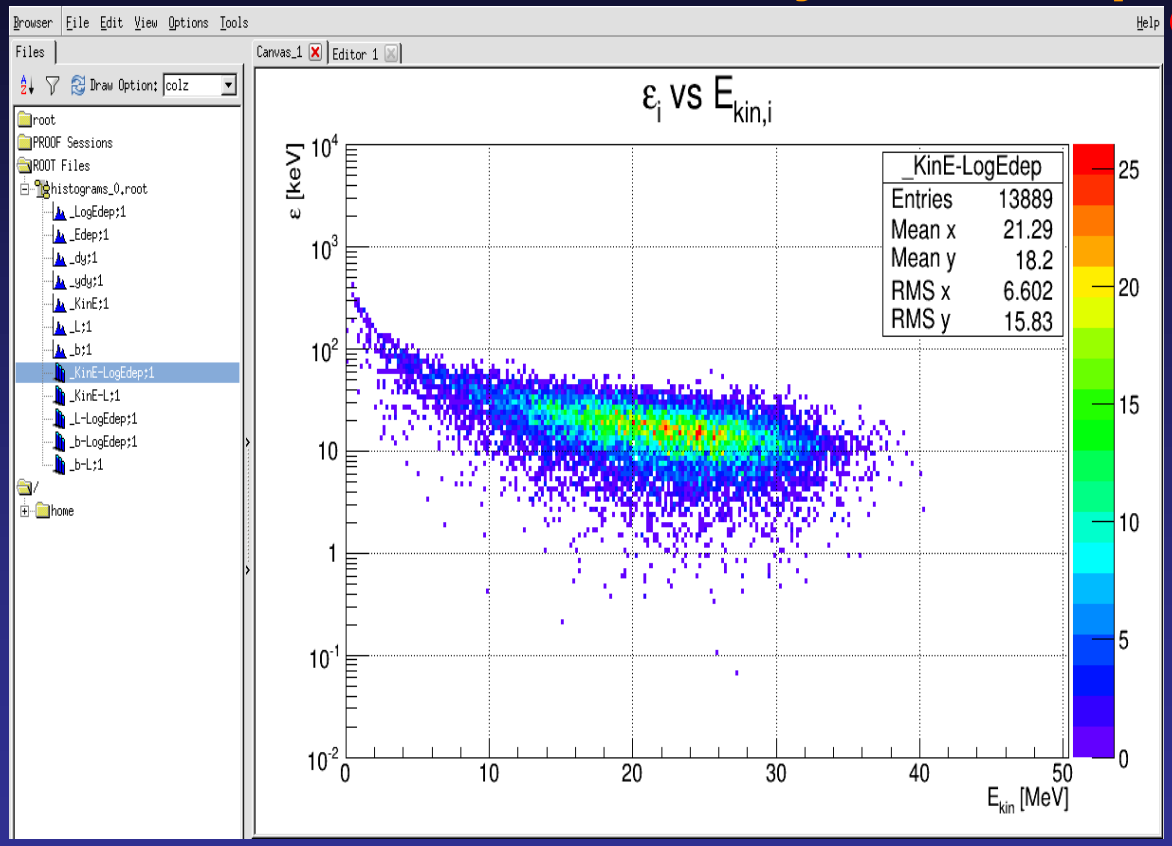

```
# CavityR [um] = 5
# ------------------------------
# nEvt (number of events)
1e+08
#
# nEdep (events with E_i > 0)
120572
#
# nTracks (primaries passing through the cavity)
110704
#
# Edep [keV]
2080085
#
# Edep [keV^2]
65172549
#
# AccumL [um]
742761.43
#
```



Analysis singleton constructed using DetectorConstruction class – Dealing with geometry parameters automatically

MicroCavity

Analysis & Output

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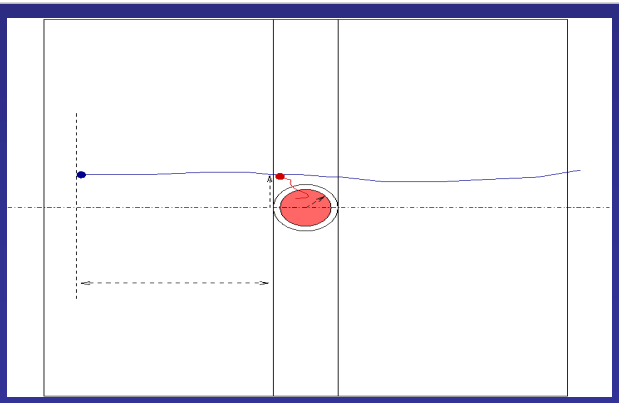
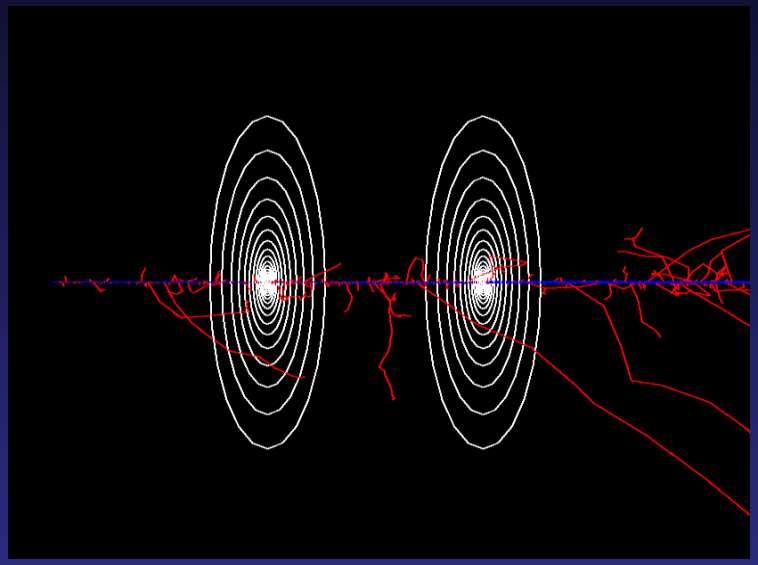


Beam set up so that electronic equilibrium conditions are fulfilled

Radial Dose Calculation (Track Structure)

Geometry

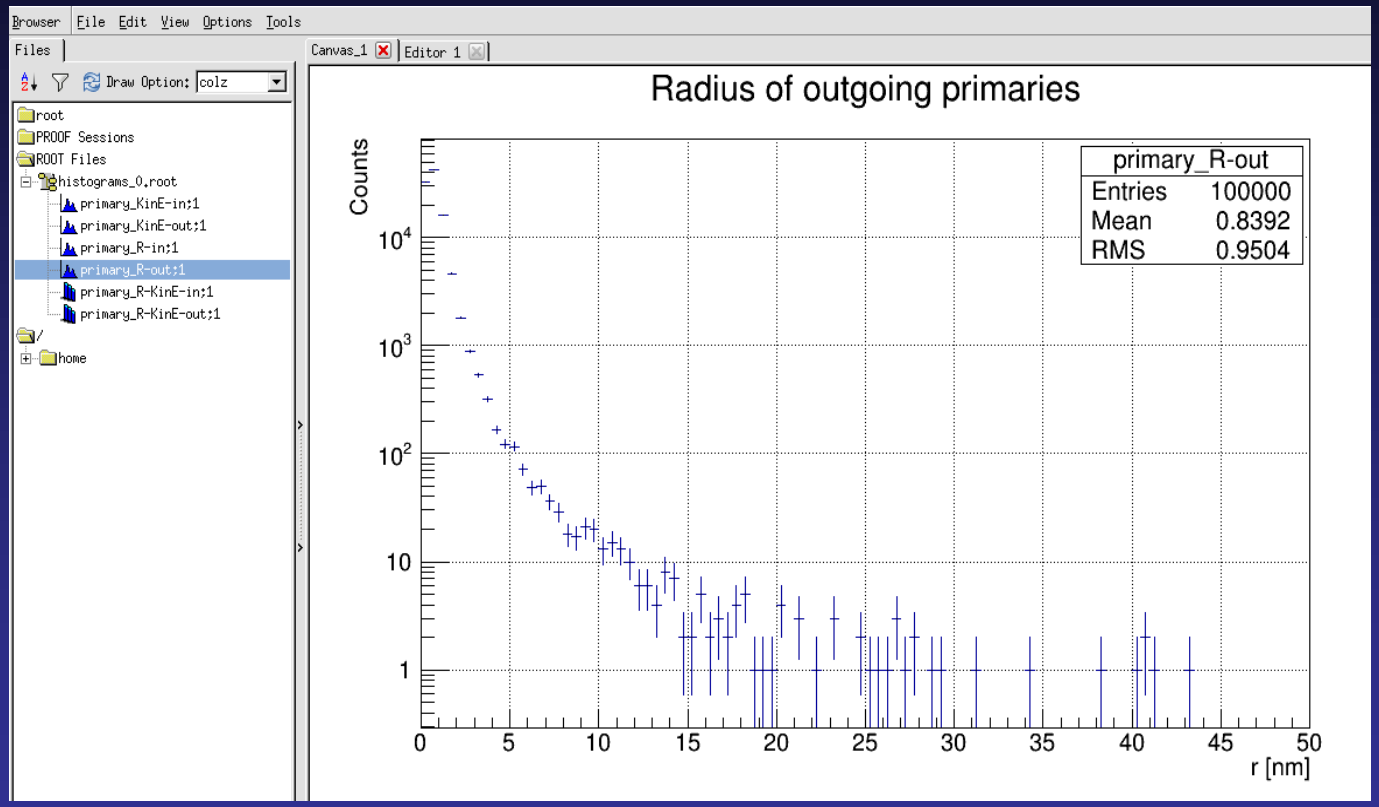


```
############################
### SETUP CONFIGURATION ###
############################
/mygeom/worldR          100.0 um
/mygeom/worldMaterial   G4_WATER
/mygeom/tallyMinR         1.0 nm
/mygeom/tallyMaxR         1.0 um
/mygeom/nBinsPerDecade    5
/mygeom/tallyZ           10.0 um
/mygeom/tallyMaterial   G4_WATER

/mygeom/addSensitiveLVs   Tally
```

- Geometry designed for logarithmic scale representations.
- Pencil beam produced along cylinder axis.
- Electronic equilibrium condition is considered.
- Lateral scattering of primaries not biased.
- Not actually new (e.g. works by F. A. Cucinotta), but in my opinion an useful example.

Radial Dose Calculation (Track Structure)

Analysis (verification purpose)

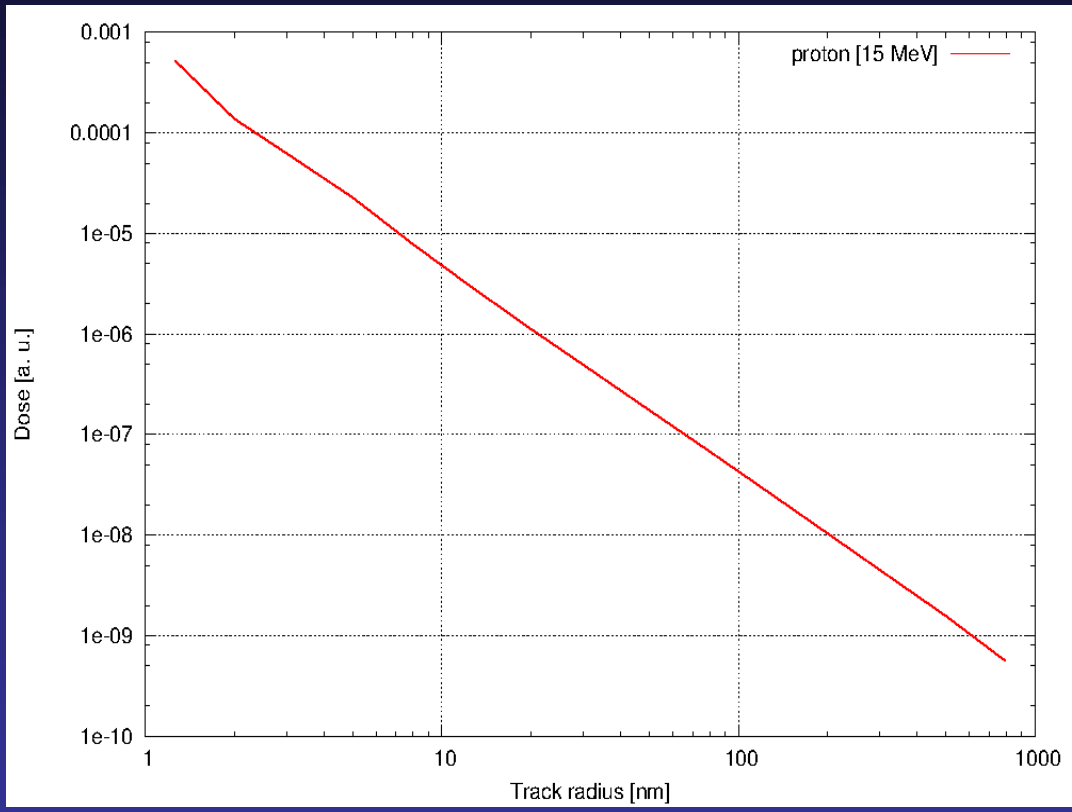


It registers the distance-to-axis and kinetic energy distributions at the entrance and exit of the scoring cylinder

Radial Dose Calculation (Track Structure)

Output

```
# nEvt = 100000
# nMaps = 16
# Tally Material Name = G4_WATER
# TallyZ[um] = 1
# ------------------------------------------------------------
# mapID copyID      SumW         SumW2       MinR[nm]    MaxR[nm]
     0      0   0.008280482  7.628597e-10            0           1
     1      1  0.0005239912  1.013284e-11            1     1.58489
     2      2  0.0001381418  6.840177e-13      1.58489     2.51189
     3      3  5.620823e-05  7.528868e-14      2.51189     3.98107
     4      4  2.270878e-05   1.16177e-14      3.98107     6.30957
     5      5  7.921124e-06   1.80433e-15      6.30957          10
     6      6   2.93595e-06  3.263278e-16           10     15.8489
     7      7  1.123094e-06  6.408431e-17      15.8489     25.1189
     8      8  4.426141e-07  1.331835e-17      25.1189     39.8107
     9      9  1.745027e-07  2.771291e-18      39.8107     63.0957
    10     10  6.893632e-08  5.703558e-19      63.0957         100
    11     11  2.687665e-08  1.129605e-19          100     158.489
    12     12  1.043164e-08  2.198453e-20      158.489     251.189
    13     13  4.025791e-09  4.321643e-21      251.189     398.107
    14     14  1.564305e-09  8.454298e-22      398.107     630.957
    15     15  5.604409e-10  1.459878e-22      630.957        1000
```



Other General Tools

Extended Primary Generator Class

```
#########################################################
### BEAM PROPERTIES (must be after Initialization) ###
#########################################################
/beam/particle proton
#/beam/ion 6 12 0
/beam/energy/histoUnit MeV
/beam/energy/ROOThistoFileName ../../../LETdVerifHistos_0
/beam/energy/ROOThistoName Peak_KinE
/beam/source 610
#/beam/energy/mean       20.0 MeV
#/beam/energy/sigma       2.4 MeV
/beam/position/X0        0.0 um
/beam/position/Y0        0.0 um
/beam/position/Z0     -150.0 um
/beam/position/radius 0150.0 um
#/beam/position/sigma     0.5 mm
```

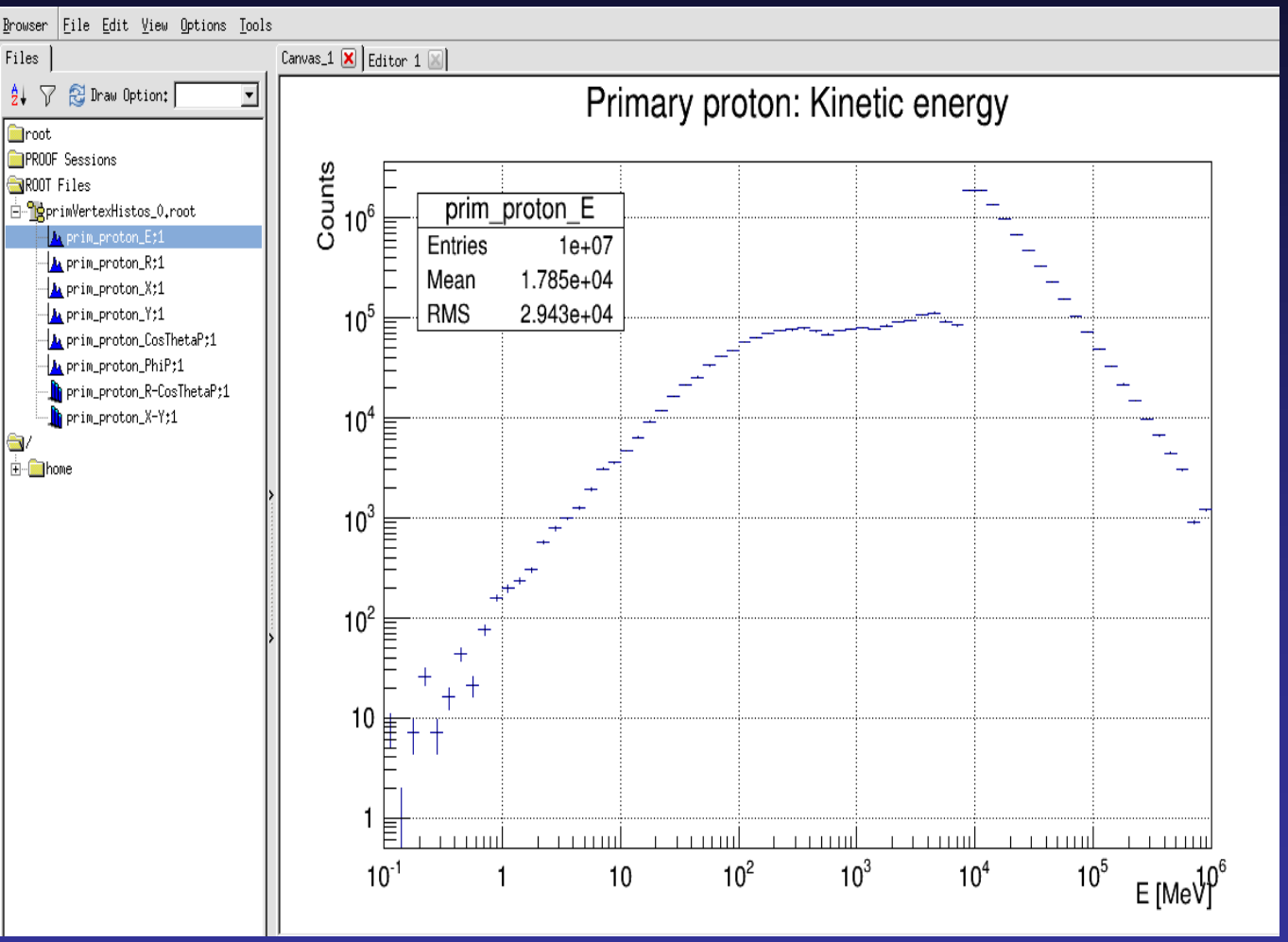
Includes capabilities such as creating primaries from histograms (either ASCII or ROOT format) and from IAEAphsp* files

* Cortés-Giraldo et al. IJRB 88:200-207 (2012)

```
Command /beam/source
Guidance :
Set the type of radiation source based on a
3-digit number:
 - 1st digit (hundreds): Energy Distribution.
    0 = mono or gaussian.
    3 = Histogram in ASCII file.
    6 = Using a ROOT histogram.
 - 2nd digit (tens): Position Distribution.
    0 = point or 2D Gaussian distribution.
    1 = uniform circular/elliptical distribution.
    2 = plane/rectangular surface.
 - 3rd digit (units): Angular Distribution.
    0 = fixed direction or 2D Gaussian aperture.
 Examples:
 - Default value = 000
 - IAEAphsp file = 999

Parameter : choice
 Parameter type  : i
 Omittable       : False

Idle> ls /beam/
Command directory path : /beam/


Guidance :
Set parameters of the beam.

 Sub-directories :
   /beam/energy/   Set kinetic energy parameters of the beam.
   /beam/position/   Position commands of the beam.
   /beam/momentum/   Momentum direction commands of the beam.
 Commands :
   source * Set the type of radiation source based on a
   IAEAphsp * Use a phase-space file as primary generator
   particle * Type of primary particle
   ion * Set an ion as beam particle.
Idle>
```

Other General Tools

Primary Vertex Verifier



Singleton class, similar to the Analysis singleton already presented.

Its goal is to help the user to discover potential bugs within his/her concrete Primary Generator Action class.

Thanks for your attention...
... and enjoy your stay in Seville!