DEEP UNDERGROUND NEUTRINO EXPERIMENT

The University Of Sheffield.

Incorporating a new muon generator - MUSUN

Karl Warburton with guidance from Tingjun Yang and Vitaly Kudryavtsev

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What is the generator?

- Code designed to propagate muons deep underground to calculate backgrounds.
- Widely used in experiments such as LZ and also previous background studies for LBNE.
- Loads in some pre-made library files containing depth and flux information.
- It then uses random number generators to ‘decide’ what θ, ϕ, depth and positions to use on an event by event basis.
- Can generate muons on either surface of sphere or parallelepiped, through assigning a fcl parameter — explained in MUSUN.fcl.

Acknowledgements

- Original MUSUN code written in fortran by Vitaly Kudryavstev (Sheffield)
- Conversion from Fortran to C, Kareem Kazkaz (LLNL) and David Woodward (Sheffield)
- Notable contributions to surface map profiling, Chao Zhang (USD) and Jeff de Jong (Oxford)
- Default slant depths and surface profile work, Martin Richardson (Sheffield)
- Incorporation into LArSoft, Karl Warburton (Sheffield)

Status of generator

- Fully functioning in LArSoft.
- I have generated 10M muons to compare to a 10M muon sample produced by Vitaly and they are broadly consistent, so little to no further work required.

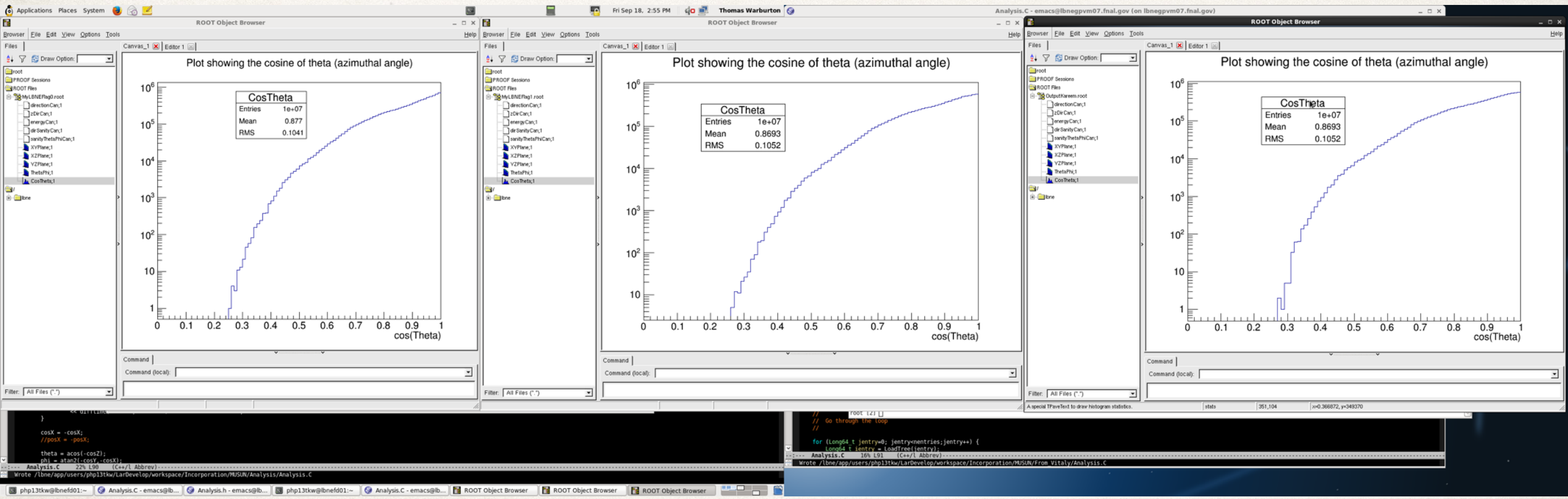
What I am asking for

- Code is currently residing in feature branch in larsim (up to date with develop)
  - feature/php13tkw_GaisserParam
    - https://cdcvs.fnal.gov/redmine/projects/larsim/repository?utf8=✓&rev=feature%2Fphp13tkw_GaisserParam
- Libraries which it loads are currently in;
  - /lbne/data/users/warburton/MUSUN/
- I want to merge feature branch to develop and include 3 files to a new library path, as was done for the Gaisser parameterisation module a few months ago.

Backup slides

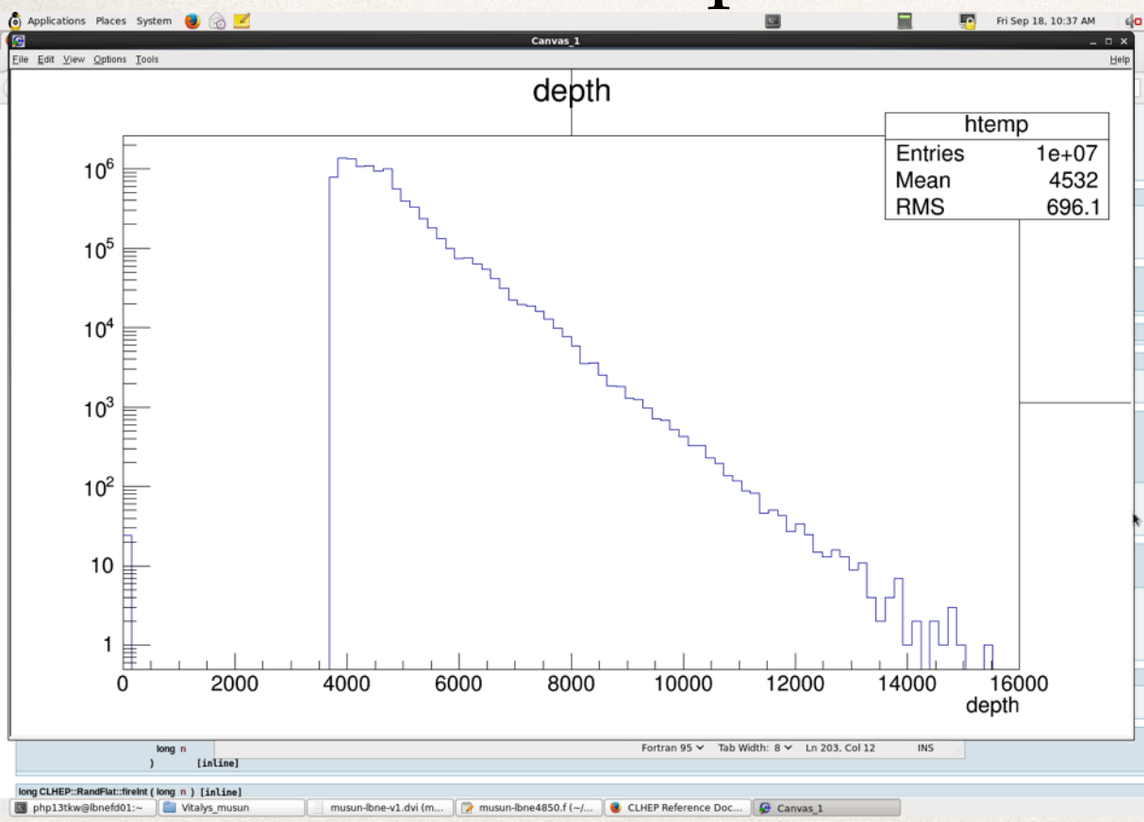
Comparisons between muons generated in LArSoft and using Vitaly's code

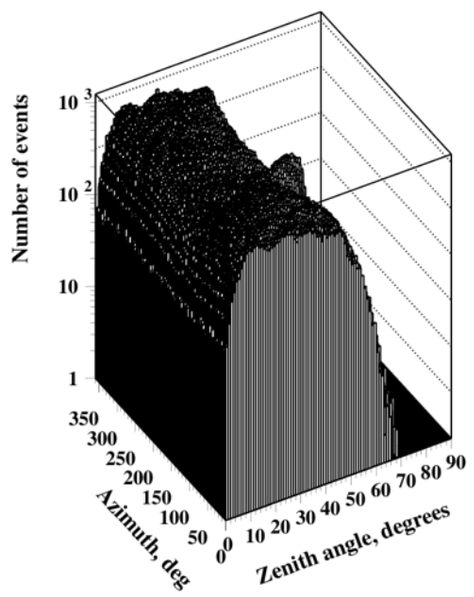
Cos (θ)


ROOT Object Browser
Plot showing the cosine of theta (azimuthal angle)
CosTheta
Entries 1e+07
Mean 0.877
RMS 0.1041
cos(Theta)
ROOT Object Browser
Plot showing the cosine of theta (azimuthal angle)
CosTheta
Entries 1e+07
Mean 0.8693
RMS 0.1052
cos(Theta)
ROOT Object Browser
Plot showing the cosine of theta (azimuthal angle)
CosTheta
Entries 1e+07
Mean 0.8693
RMS 0.1052
cos(Theta)
Wrote /lbne/app/users/php13tkw/LarDevelop/workspace/Incorporation/MUSUN/Analysis/Analysis.C
Wrote /lbne/app/users/php13tkw/LarDevelop/workspace/Incorporation/MUSUN/From Vitaly/Analysis.C

Depth

- Need to look at why Vitaly has a cut off at 12 km w.e which I don't get when using LArSoft….
- Mean slant depth is consistent though!





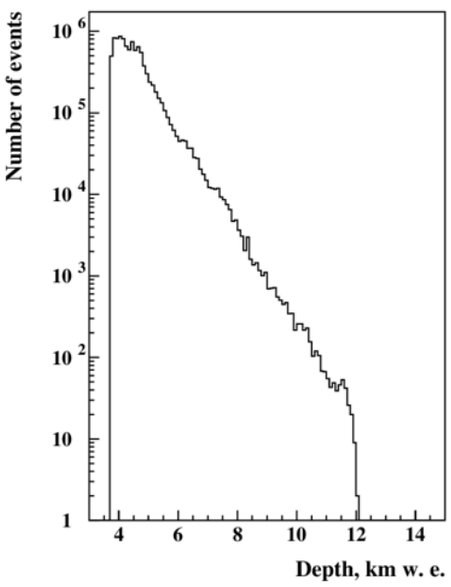
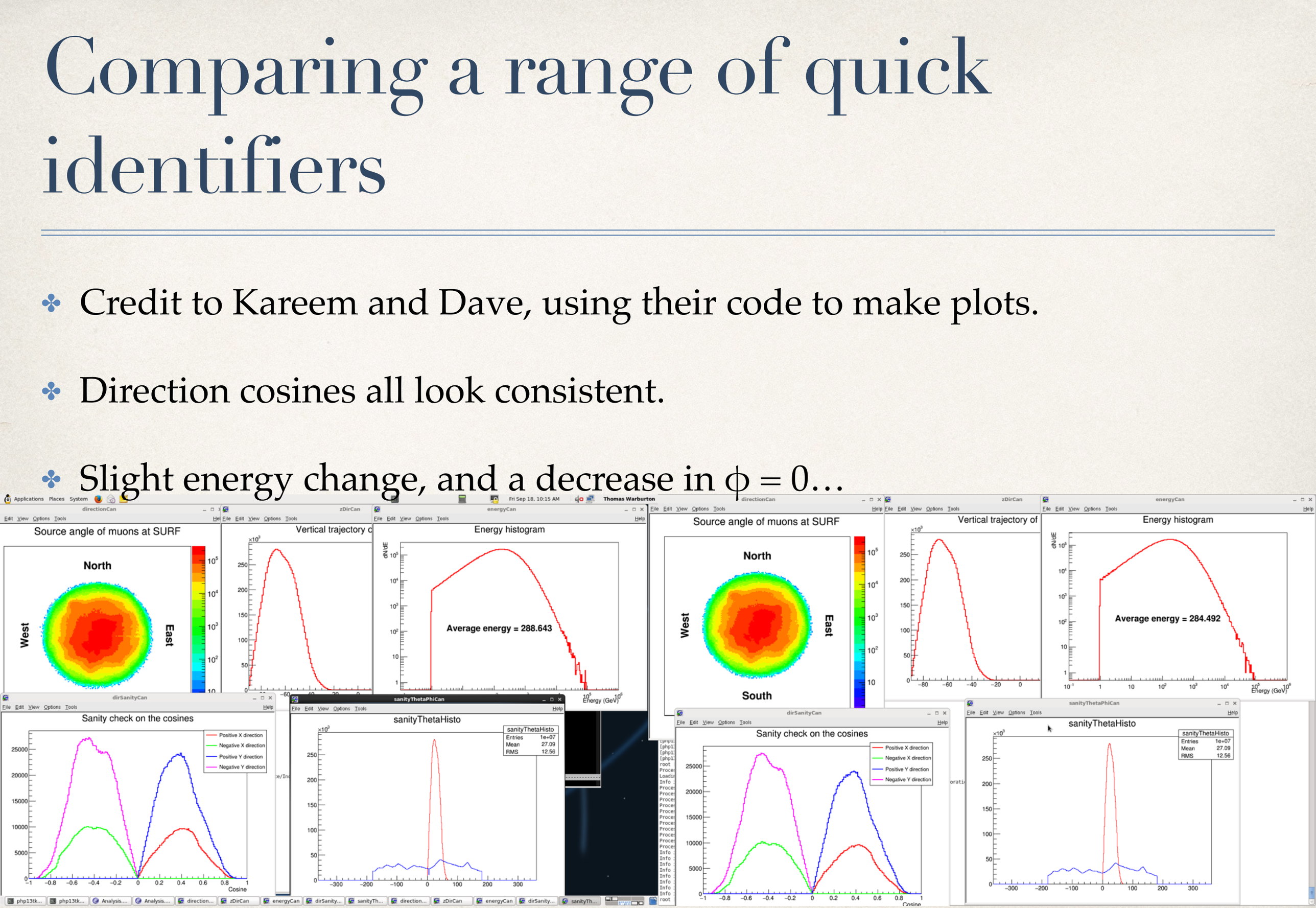


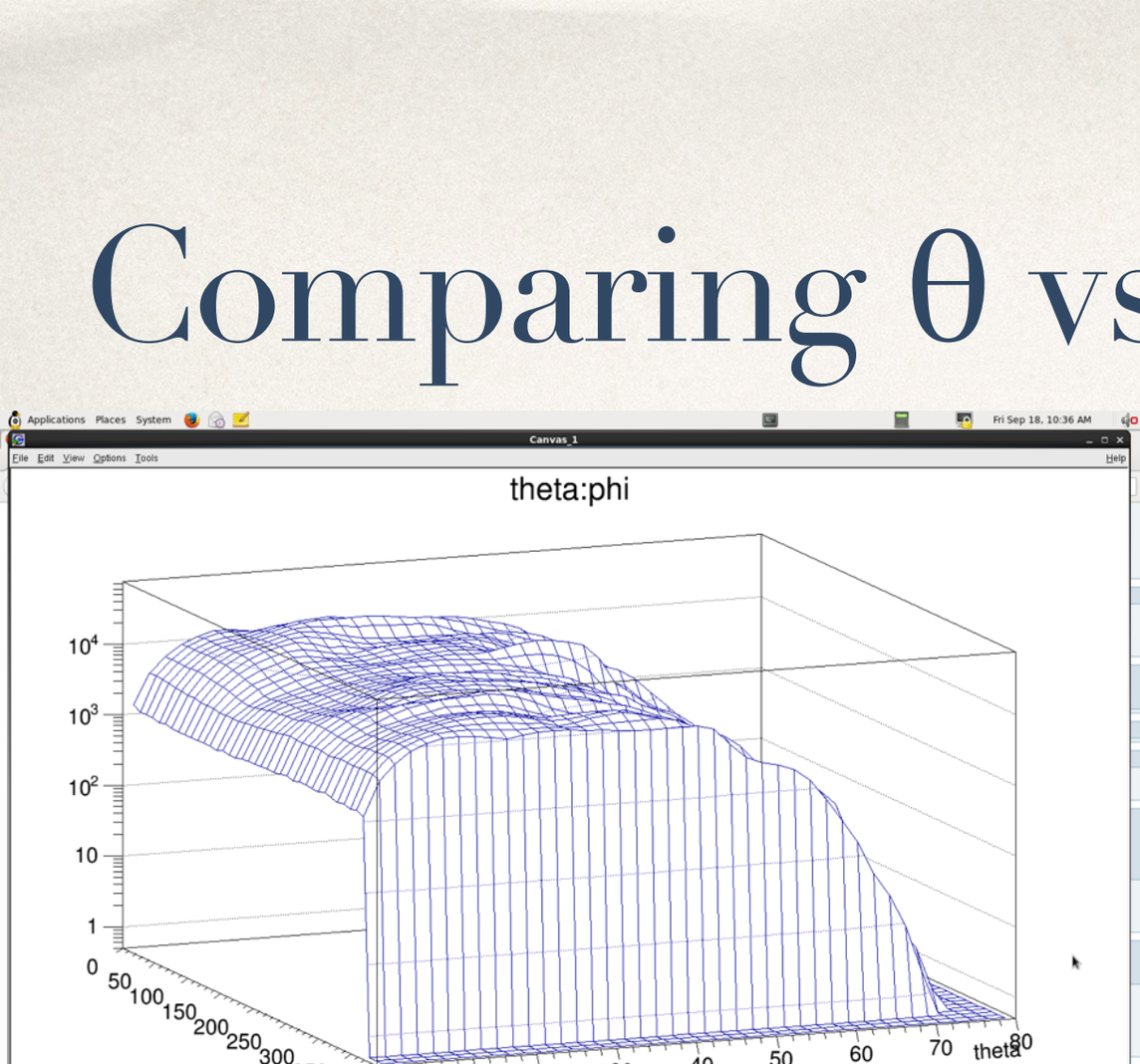
Figure 3: 2D angular distribution of muons at SURF (potential far detector location) as

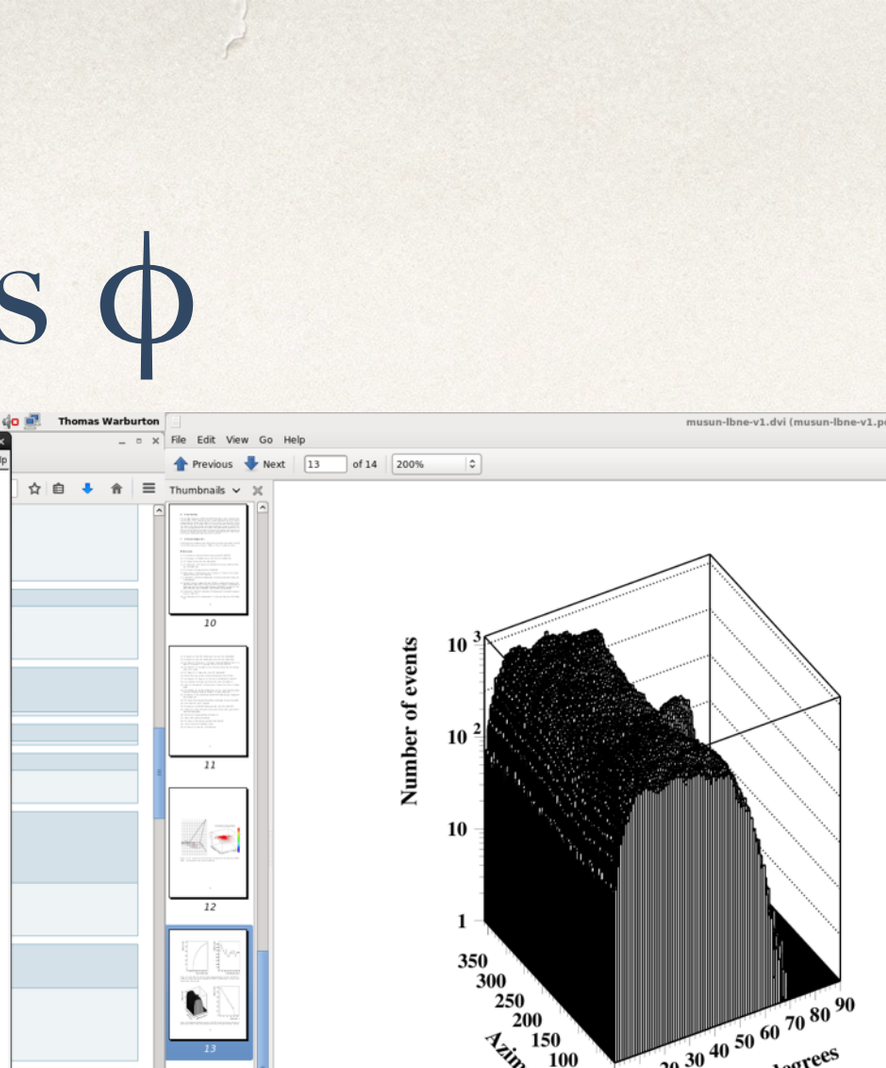
Comparing a range of quick identifiers

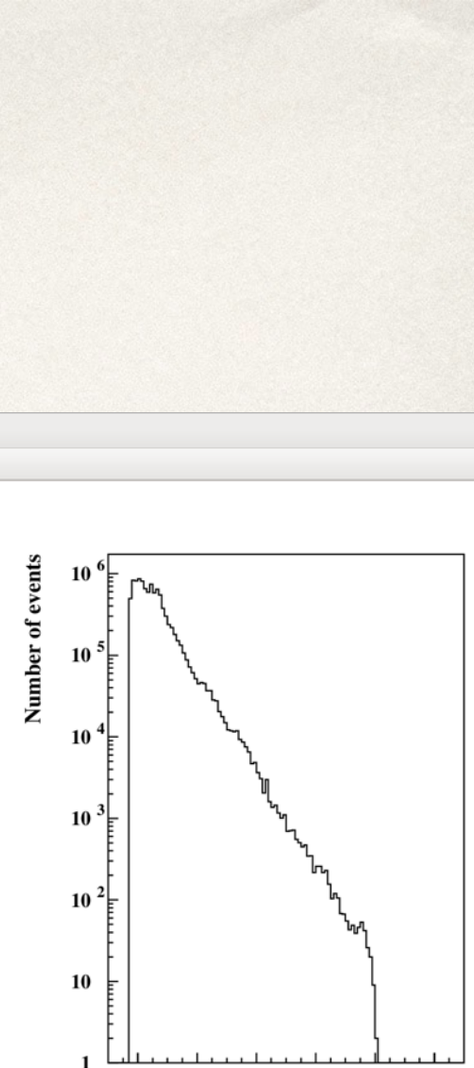
- Credit to Kareem and Dave, using their code to make plots.
- Direction cosines all look consistent.
- Slight energy change, and a decrease in $\phi = 0$…

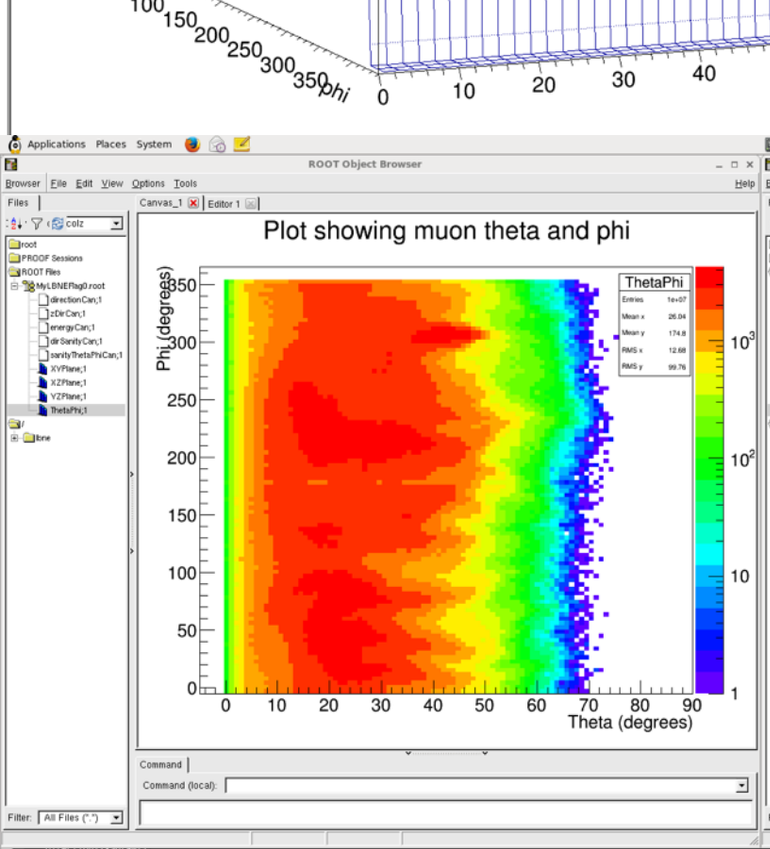


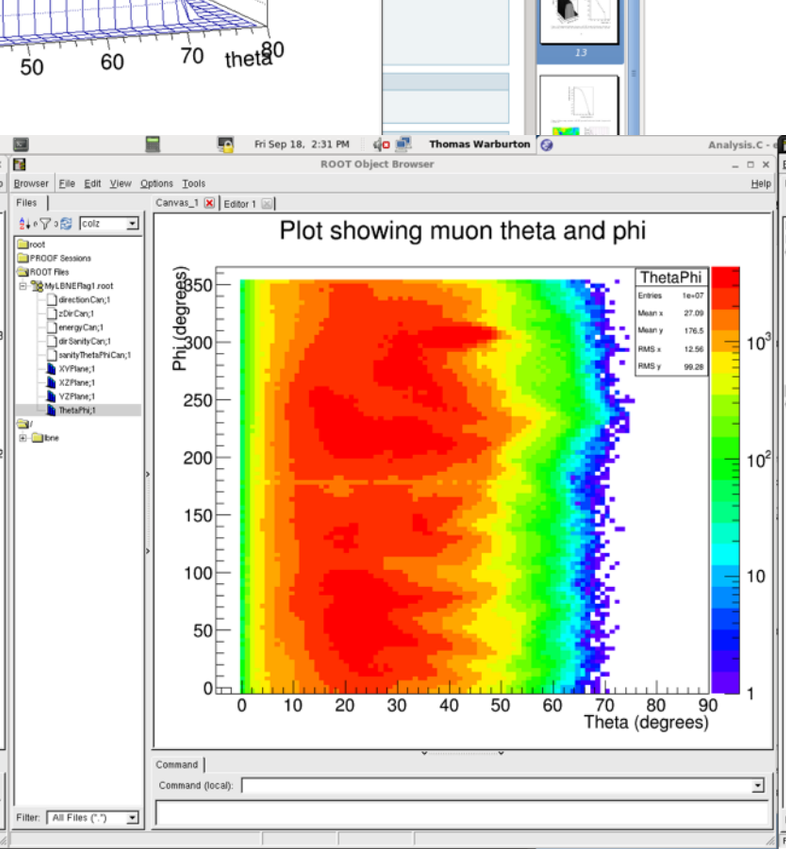
Comparing θ vs ϕ

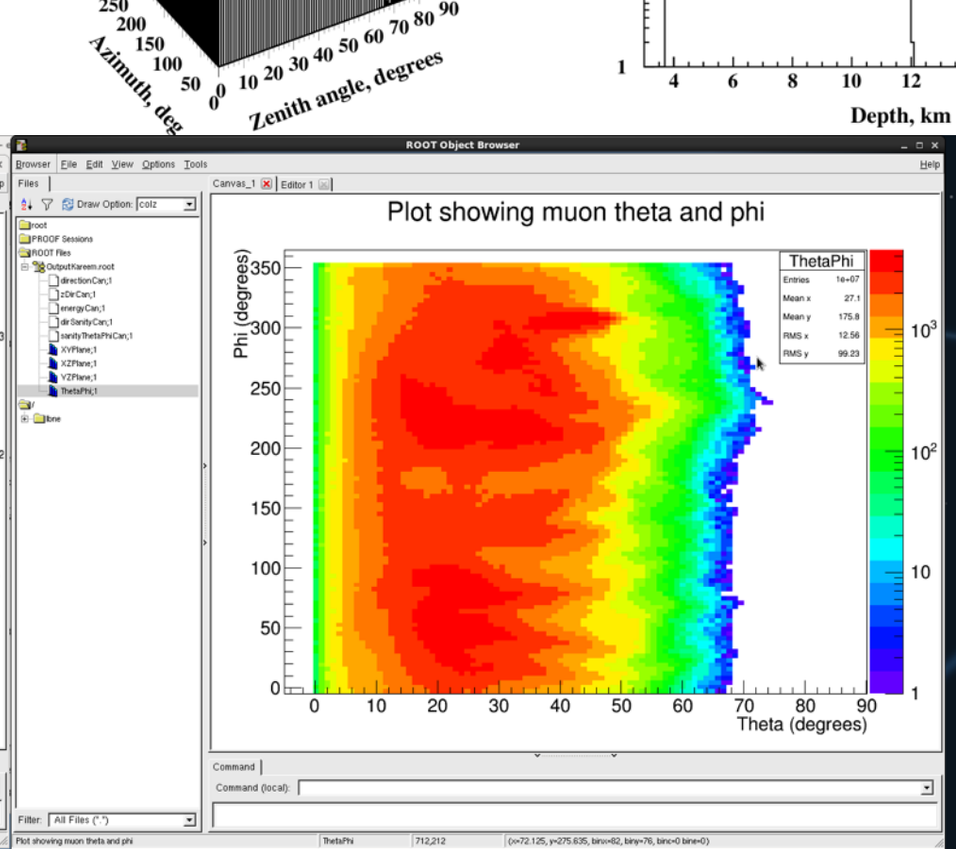




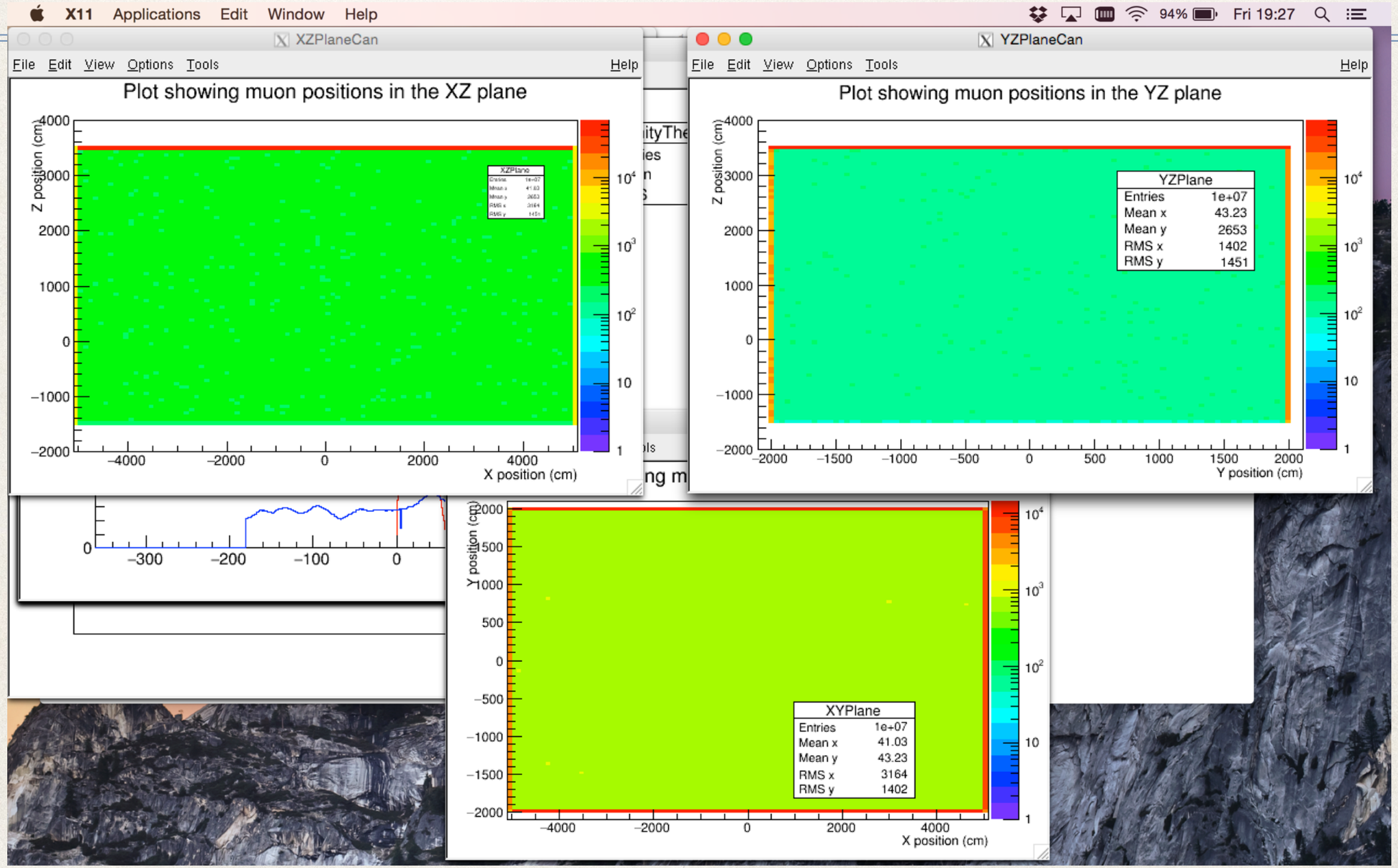








Positions


X11 Applications Edit Window Help
94% Fri 19:27
XZPlaneCan
File Edit View Options Tools Help
Plot showing muon positions in the XZ plane
Z position (cm)
X position (cm)
YZPlaneCan
Plot showing muon positions in the YZ plane
YZPlane
Entries 1e+07
Mean x 43.23
Mean y 2653
RMS x 1402
RMS y 1451
Y position (cm)
XYPlane
Entries 1e+07
Mean x 41.03
Mean y 43.23
RMS x 3164
RMS y 1402