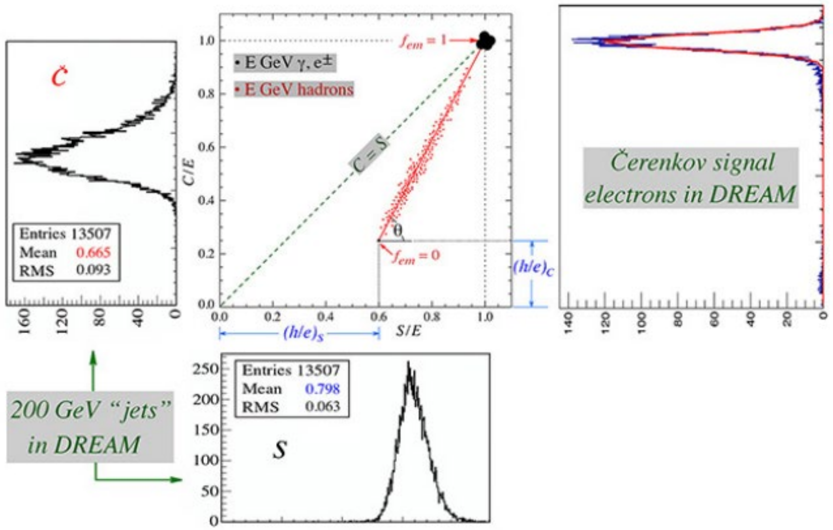
Correlations between scintillation and Cherenkov light

Plot from classic paper https://arxiv.org/abs/1712.05494



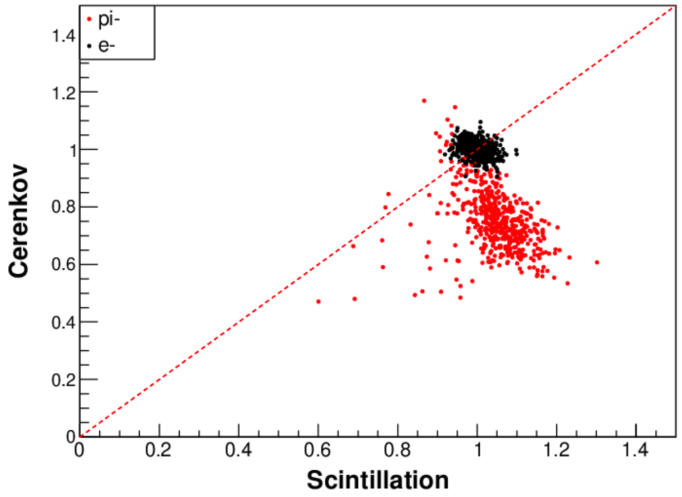
Gives out canonical equations

$$S/E = (h/e)_S + f_{\mathrm{em}}\left[1 - (h/e)_S\right]$$
$$C/E = (h/e)_C + f_{\mathrm{em}}\left[1 - (h/e)_C\right]$$

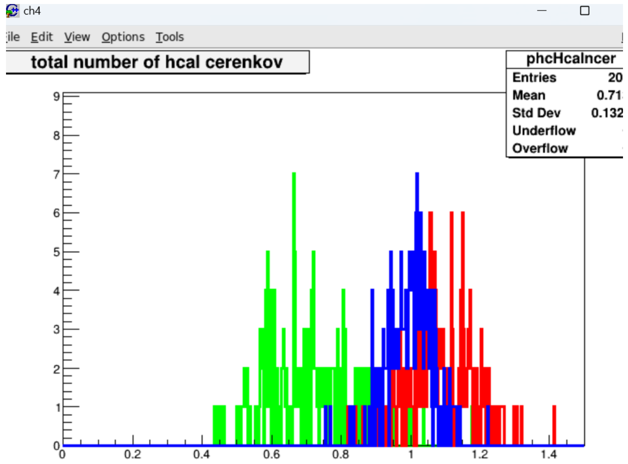
$$\cot\theta = \frac{1 - (h/e)_S}{1 - (h/e)_C} = \chi$$

$$E = \frac{S - \chi C}{1 - \chi}$$

Sara noted an unusual pattern in the Cherenkov versus scintillation light for our fiber calorimeter



Although the dual readout correction works



Green Cherenkov
Red scintillation
Blue dual readout

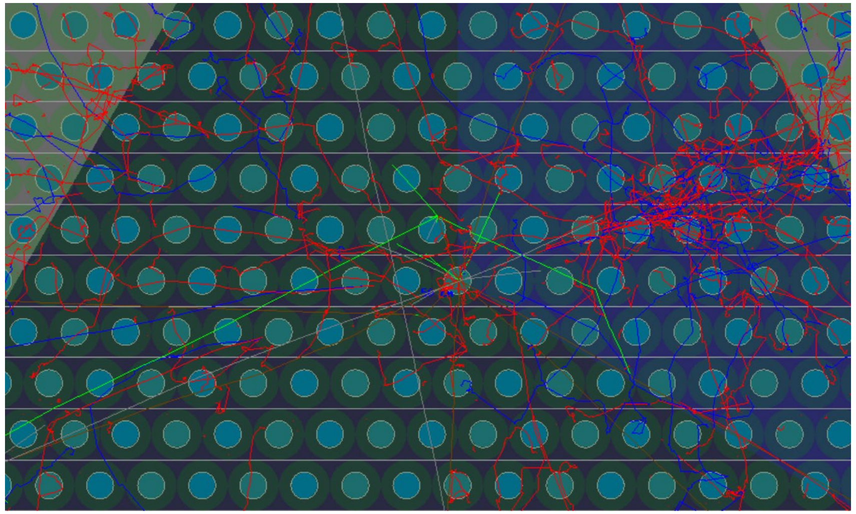
```
<!-- constants for dual readout spagetti fiber hcal calorimeter in SCEPCAL -->
<!-- these are radii (or half widths) -->
    <constant name="DRFiberAbswidthSCE" value="1.0*mm"/>  <!-- should be 1.0 mm -->
    <constant name="DRFiberFibwidthSCE" value=".5025*mm"/>  <!-- should be 0.5025 mm -->
    <constant name="holeoverSCE" value="0.025*mm"/>
    <constant name="gapSCE" value="0.0001*mm"/>
    <constant name="DRFiberlengthSCE" value="210*cm"/>   <!-- should be 210 cm -->
    <constant name="DRFiberNsizeSCE" value="250"/>        <!-- should be 250 -->
```

```
<comment>Hadronic Calorimeter</comment>


<!-- here z_length is the absorber length, thickness is length of an end side
z1 is the photodetector length gap is the distance between modules, and dz is how far the fiber sticks out of the absorber.  Nsize
is the number of cells to make
zmin is where the dtector goes
 -->

<dimensions numsides="DRFiberNsizeSCE" thickness="DRFiberAbswidthSCE" z_length="DRFiberlengthSCE" gap="gapSCE"  zmin="2*killthick+e
dgeoffset+DRcrystallength1+DRcrystallength2+DRcrystalgapl+EcalHcalgap" z1="killthick"/>
<!-- <dimensions numsides="DRFiberNsize" thickness="DRFiberAbswidth" z_length="DRFiberlength" gap="0.1*mm" dz="0.0*mm" zmin="0." z1
="5*mm"/> -->


<!-- not in core and hole rmind is not used -->
      <structure>
        <core1 name="core1" rmax="DRFiberFibwidthSCE" rmin="0.0" material="DR_Polystyrene" vis="ScintVis" sensitive="yes"/>
        <core2 name="core2" rmax="DRFiberFibwidthSCE" rmin="0.0" material="DR_Quartz" vis="CerenVis" sensitive="yes"/>
        <hole name="hole" rmax="(DRFiberFibwidthSCE+holeoverSCE)" rmin="0.0" material="Air" vis="holeVis" sensitive="yes"/>
        <absorb material="Brass" vis="AbsVis" sensitive="yes"/>
        <phdet1 name="phdet1" rmax="DRFiberFibwidthSCE" rmin="0.0" material="killMedia2" vis="phdetVis" sensitive="yes"/>
        <phdet2 name="phdet2" rmax="DRFiberFibwidthSCE" rmin="0.0" material="killMedia3" vis="phdetVis" sensitive="yes"/>
      </structure>
    </detector>
  </detectors>
```



The triangle is just GEANT's origin marker

How can we understand this?

First let's note that this is gendet=3. so we are looking at energies deposted into each type of fiber.
We are not actually looking at generated light. (for gendet=1, we are looking at generated light)
Let's also note that that the lines of code relevant are:

DualTestBeam / compact / Resolution.C

Code Blame Executable File · 2063 lines (1509 loc) · 71.2 KB

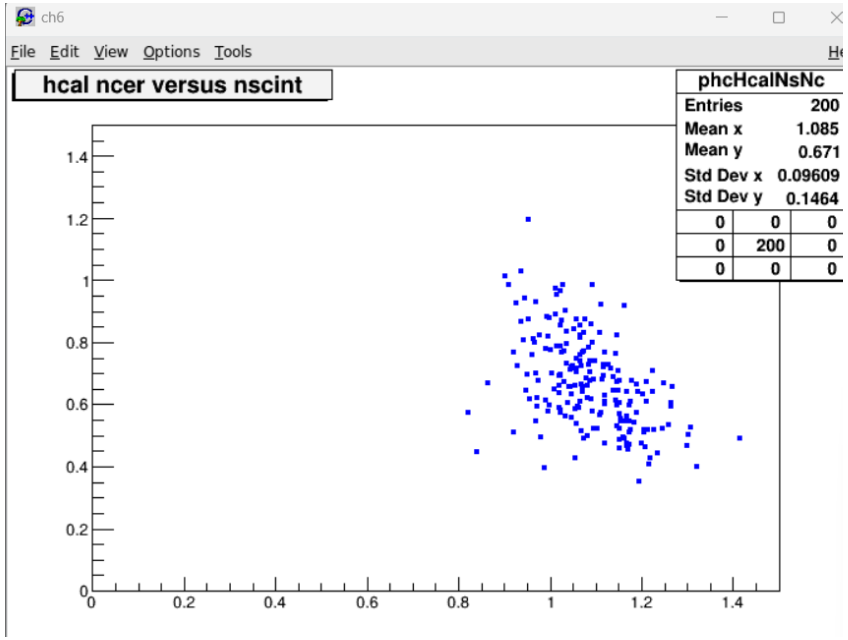
```
          if(iphdet==1) {  // take light that hits photodetectors
            meanscinHcal+=ahcalhit->nscintillator;
          }
          if(iphdet==2) {  // take light that hits photodetectors
            meancerHcal+=ahcalhit->ncerenkov;
          }
        }
        else if(gendet==3||gendet==4) {
          if(idet==6) {
          if(ifiber==1) {
            meanscinHcal+=ahcalhit->energyDeposit;
          }
          if(ifiber==2) {
            if(gendet==3) meancerHcal+=ahcalhit->edeprelativistic;
            if(gendet==4) meancerHcal+=ahcalhit->energyDeposit;
          }
          for(size_t j=0;j<zxzz.size(); j++) {
            if((zxzz.at(j)).time<timecut) ehcaltimecut+=(zxzz.at(j)).deposit;
          }
          }
        }
```

We can see that for gendet=3, the scintillating fibers (ifiber1) count the whole energy while the quartz fibers (ifiber2) count only the relativistic energy.

There is a "debug" mode gendet=4 which uses the full energy for each fiber.

So can we rephrase the problem this way: this a different way: the bigger the total energy in the fibers, the smaller the relativistic energy

Her’s is gendet=3, but this persists for gendet=1



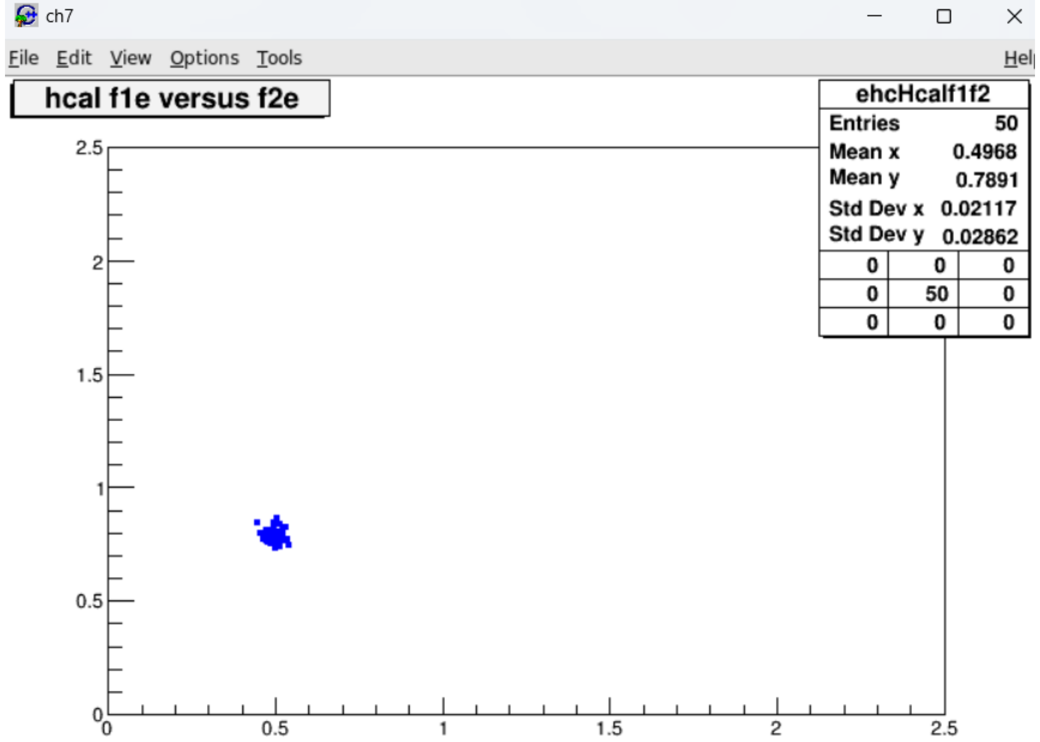
Fiber eneries. This code is the full energy

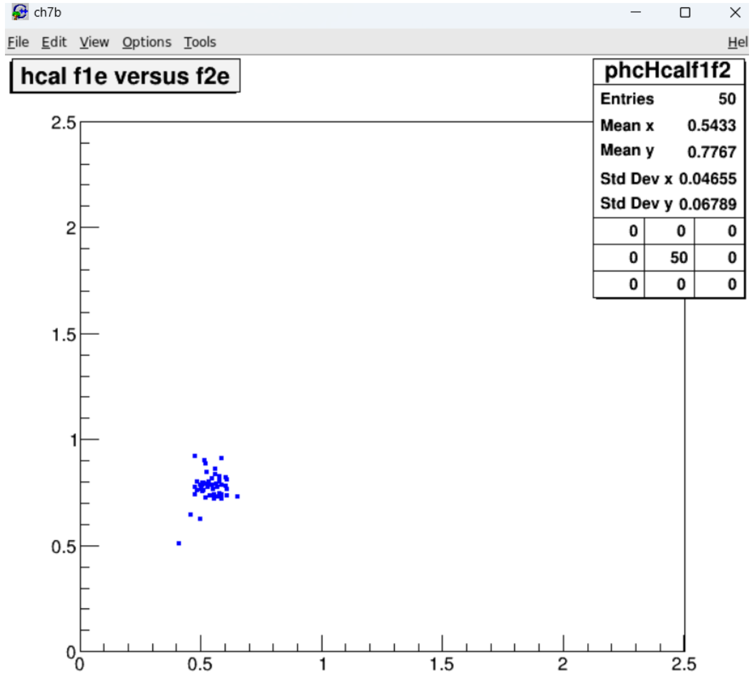
```
}

if(ifiber==1) {eesumfiber1+=ah;}
if(ifiber==2) {eesumfiber2+=ah;}
if(iabs==1) {eesumabs+=ah;}
if(iphdet>1) {eesumPDh+=ah;}
//std::cout<<"   "<<ihitchan<<" " <<idet<<"
```

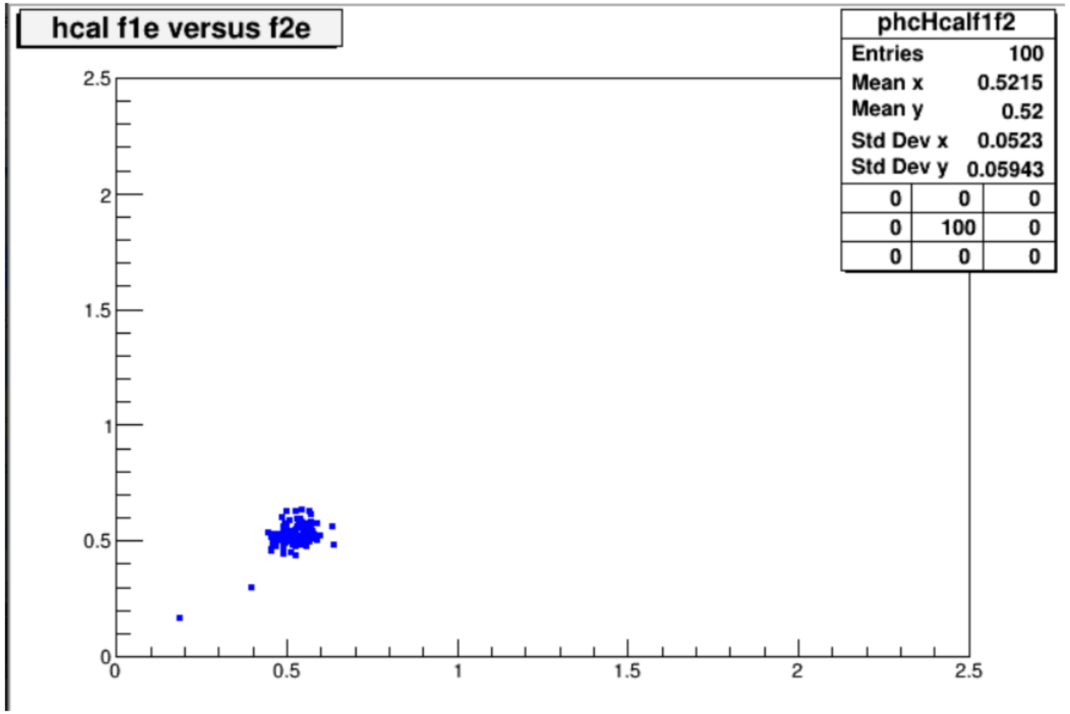
Fiber 2 is the quartz. Higher energy deposit in quartz than in scintillation. Since the diameters are the same, this is just due to the difference in material.

```
ehcHcalf1f2->Fill(eesumfiber1/1000.,eesumfiber2/1000.);
```



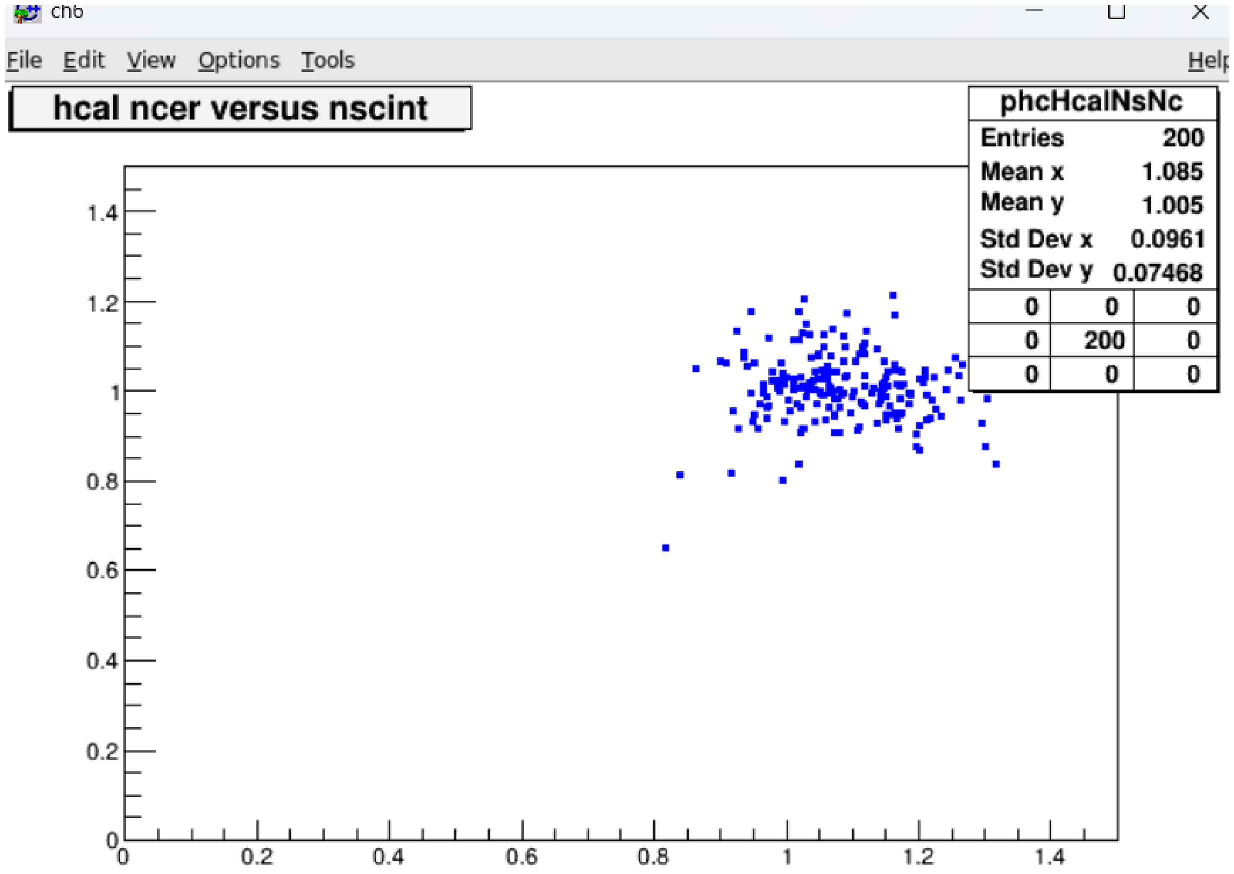


Same plots with quartz replaced with non-scintillating polystyrene



Energy deposit now the same

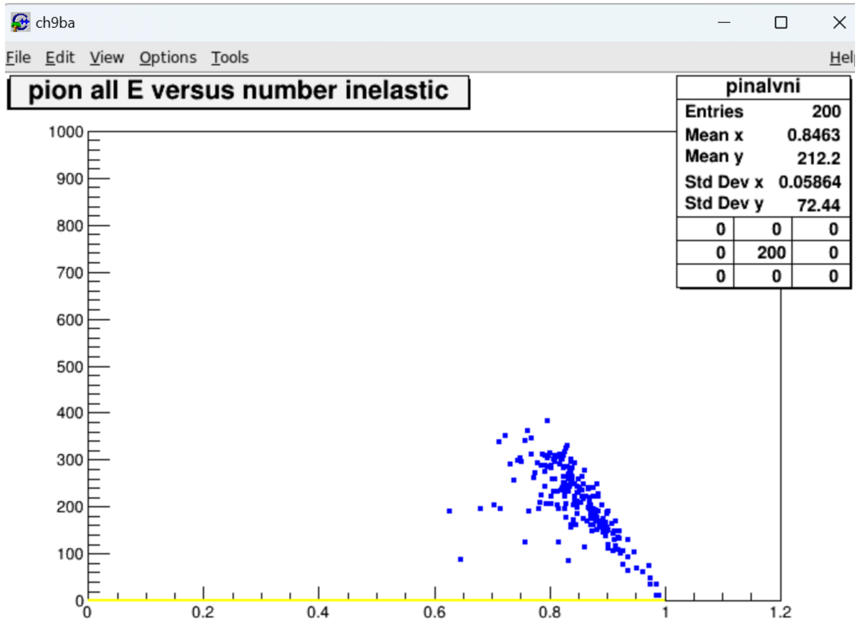
For gendet=4, we see a different behavior.



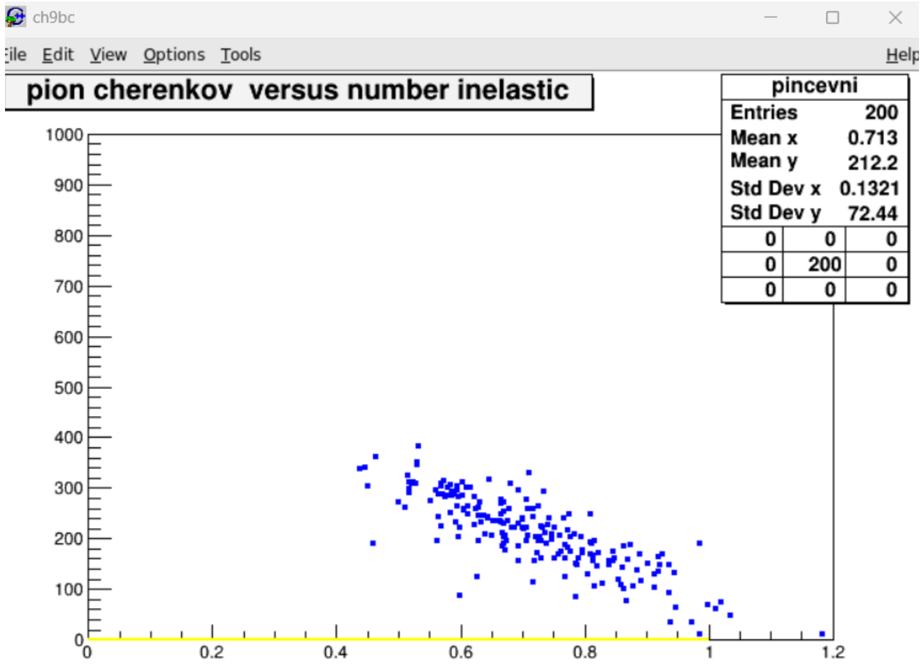
We see the resolution in the Cherenkov is narrow than in the scintillation. This is consistent with the larger energy deposit.

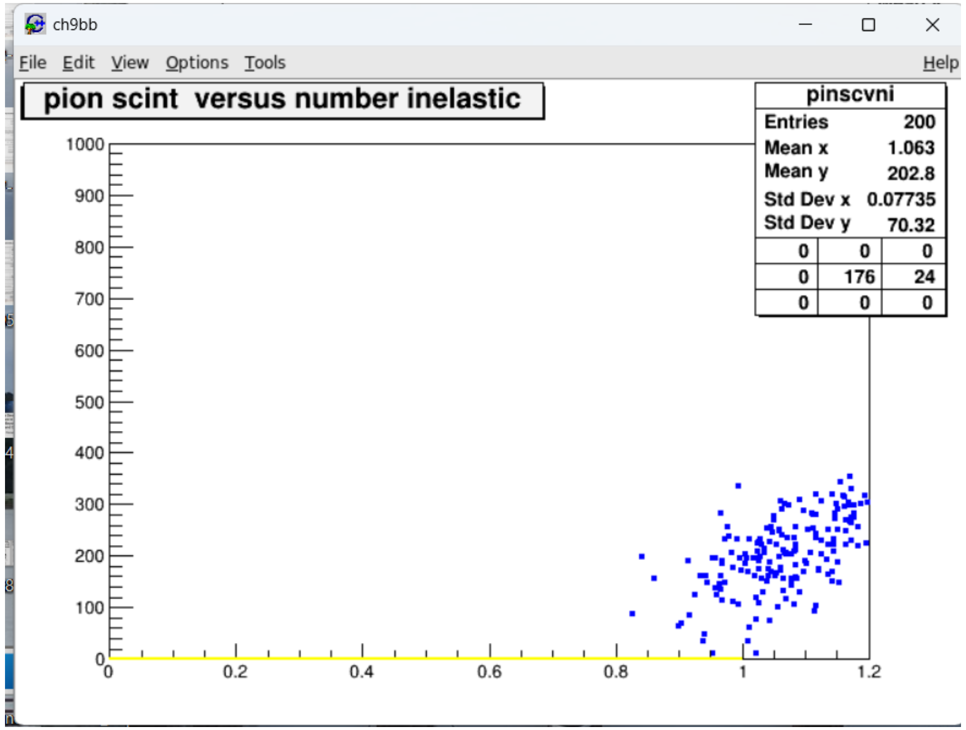
We also see no correlation between the fibers.

This constrains possible causes. It cannot be just the shower happened near one type of fiber so it was enhanced and the nearby decreased.



Here we see the behavior of the total calorimeter energy deposit, deposit in scint, deposit in quartz versus the number of inelastic collisions in the pion shower. Here we see we have better containment of the shower when the number of inelastic collisions is low. We see little correlation between the relativistic energy and the number of collsions. We see a positive correlation between the scintillation energy and the number of collsions





A compensating calorimeter is one where the loss in energy due to nuclear binding energy is “compensated” by a boosted response to neutrons (as these are made when nuclei break up)

This works best for hydrogen-based materials (like polystyrene).

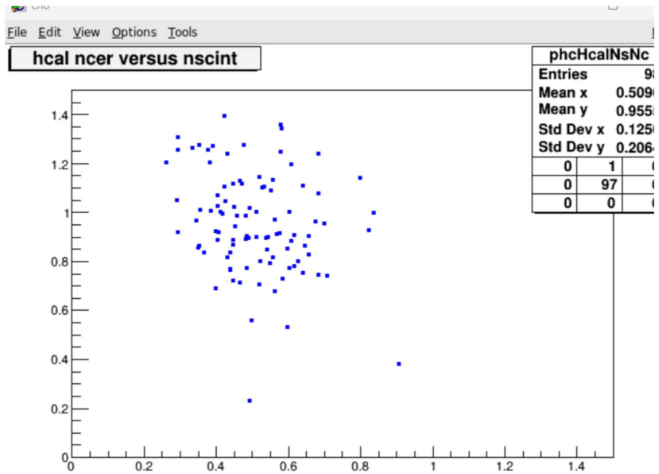
If you get perfect balance, the response does not depend on the EM (relativitistic) fraction of the shower

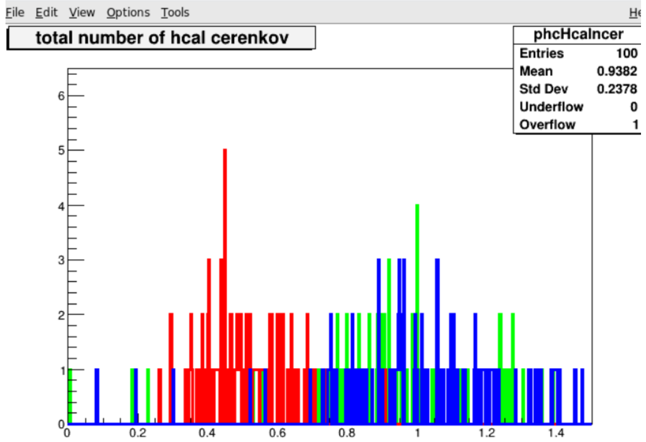
This seems to happen, though, when the sampling fraction is low. So what you gain in resolution due to removing variation in f, you lose in resolution due to the low sampling fraction

Try changing the diameter of the absorber

```
<!-- constants for dual readout spagetti fiber hcal calorimeter in SCEPCAL -->
<!-- these are radii (or half widths) -->
    <constant name="DRFiberAbswidthSCE" value="2.0*mm"/>  <!-- should be 1.0 mm -->
    <constant name="DRFiberFibwidthSCE" value=".5025*mm"/>  <!-- should be 0.5025 mm -->
    <constant name="holeoverSCE" value="0.025*mm"/>
    <constant name="gapSCE" value="0.0001*mm"/>
    <constant name="DRFiberlengthSCE" value="210*cm"/>   <!-- should be 210 cm -->
    <constant name="DRFiberNsizeSCE" value="360"/>        <!-- should be 250 -->
```

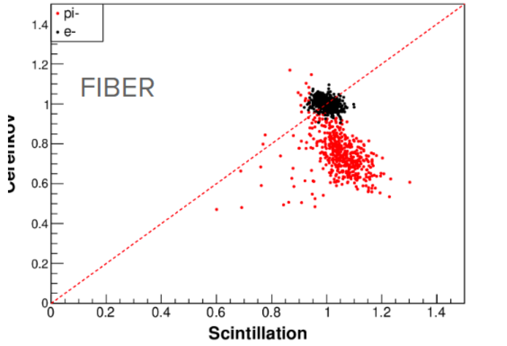
```
<!-- constants for dual readout spagetti fiber hcal calorimeter in SCEPCAL -->
<!-- these are radii (or half widths) -->
    <constant name="DRFiberAbswidthSCE" value="0.75*mm"/>  <!-- should be 1.0 mm -->
    <constant name="DRFiberFibwidthSCE" value=".5025*mm"/>  <!-- should be 0.5025 mm -->
    <constant name="holeoverSCE" value="0.025*mm"/>
    <constant name="gapSCE" value="0.0001*mm"/>
    <constant name="DRFiberlengthSCE" value="210*cm"/>   <!-- should be 210 cm -->
    <constant name="DRFiberNsizeSCE" value="360"/>        <!-- should be 250 -->
```

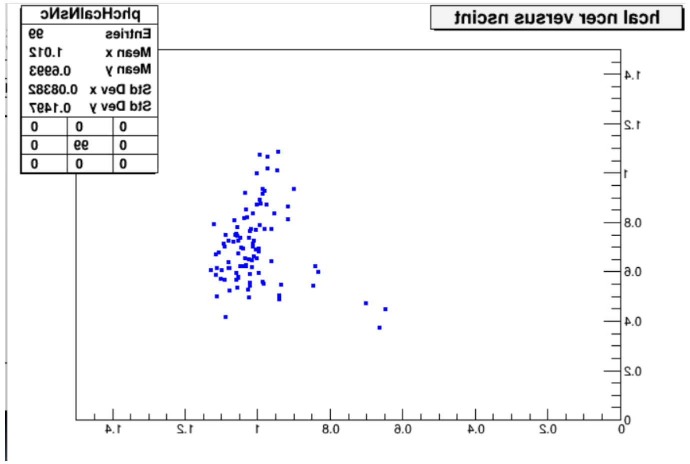


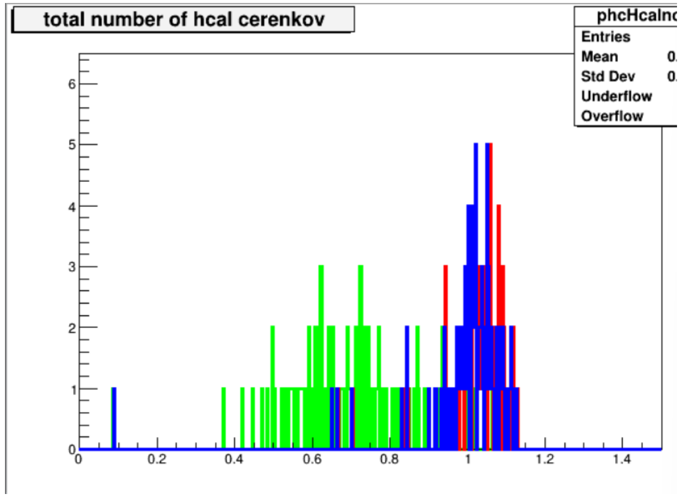


Maybe the large diameter one looks a little more normal, but still not really what we expect

FiberHCAL scatterplot does not look normal → calibration NEEDED! → WIP

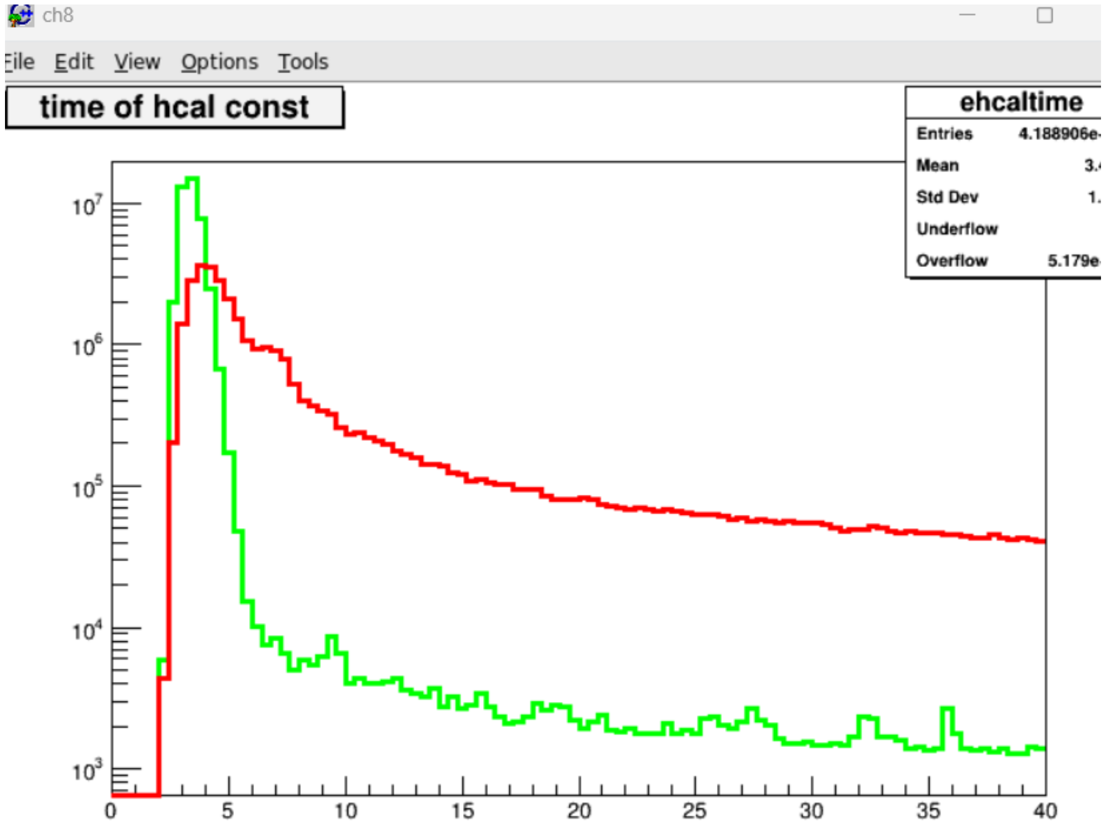






Try changing the integration time to reduce effect of neutrons

Timing distribution of energy deposits

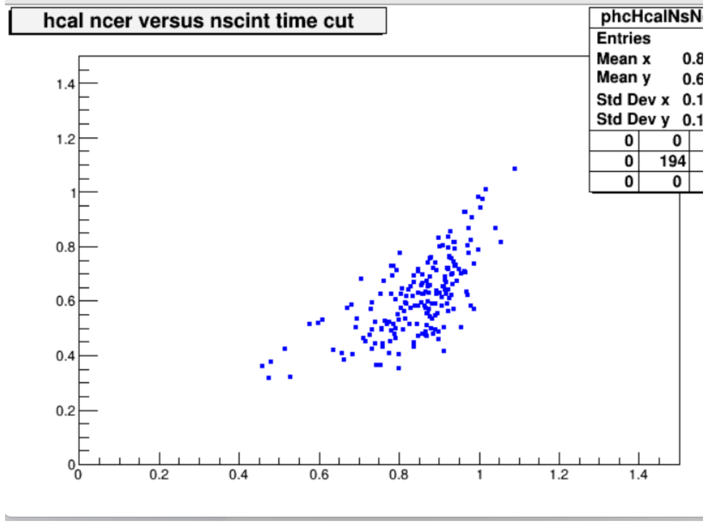


Green electrons
Red pion

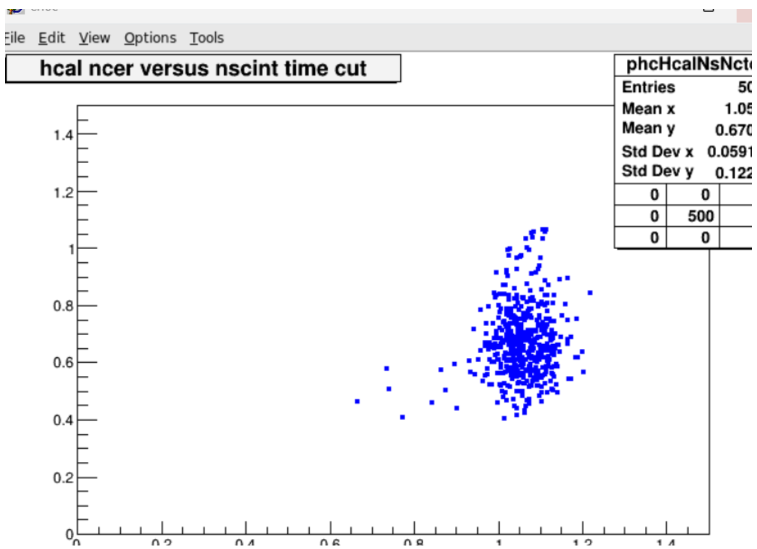
Timing cut of 7 ns

Time cut 400000 (largest time was 16000)

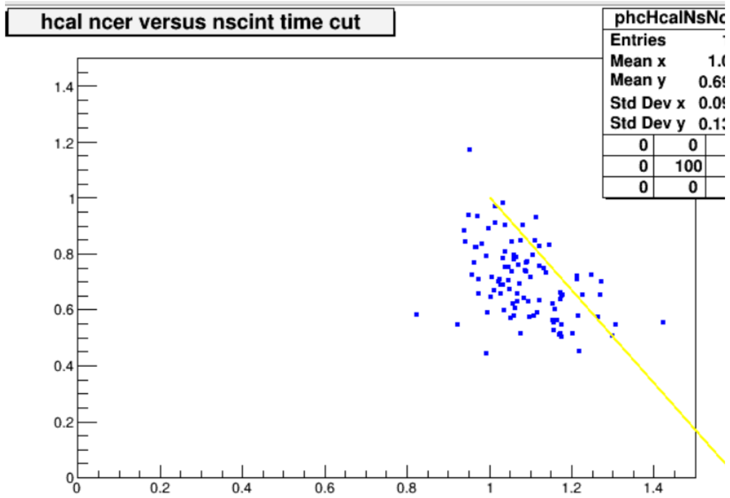
Using total relativistic energy in both polystyrene and quartz fibers

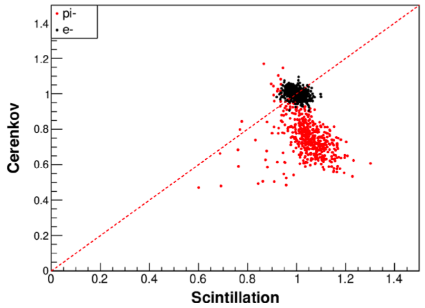


This looks more like it

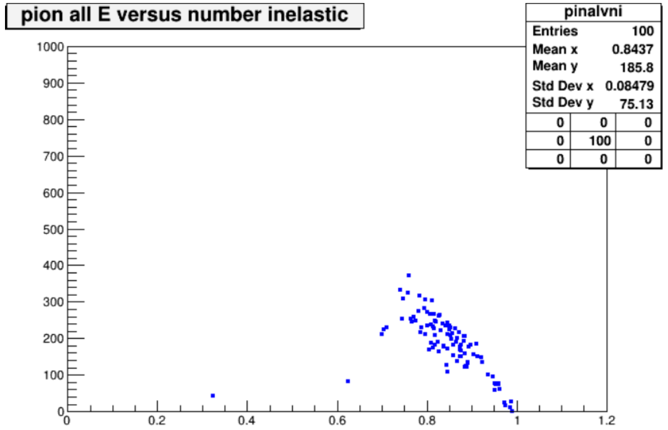


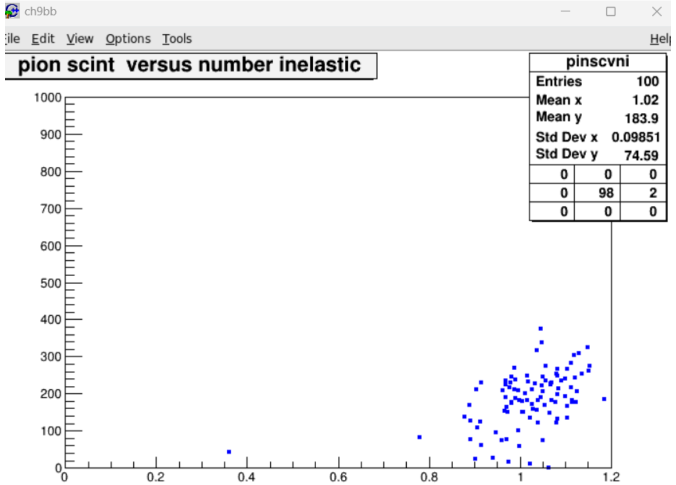
Using total energy only in polystyrene and relativistic in only quartz fibers

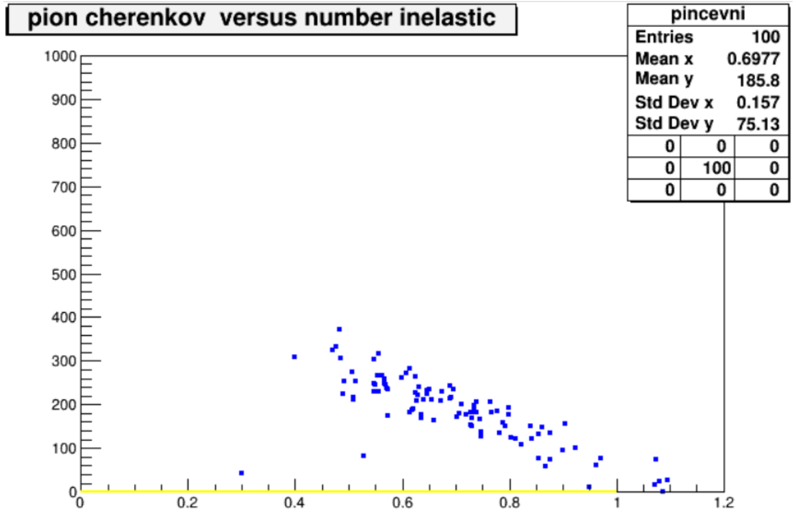




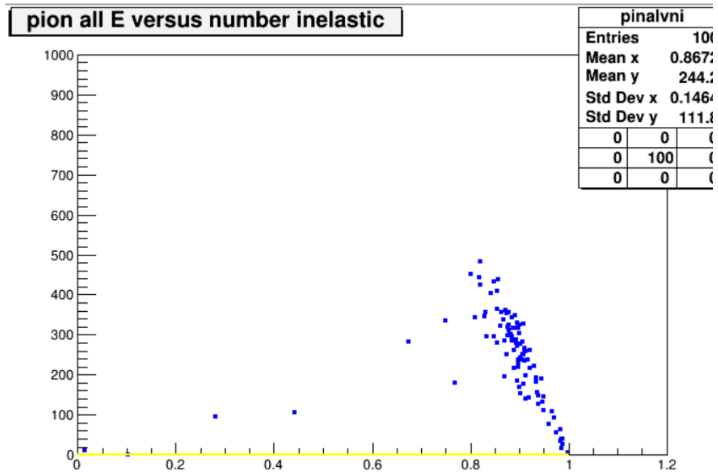
Same plots replacing quartz with non-scintillating polystyrene

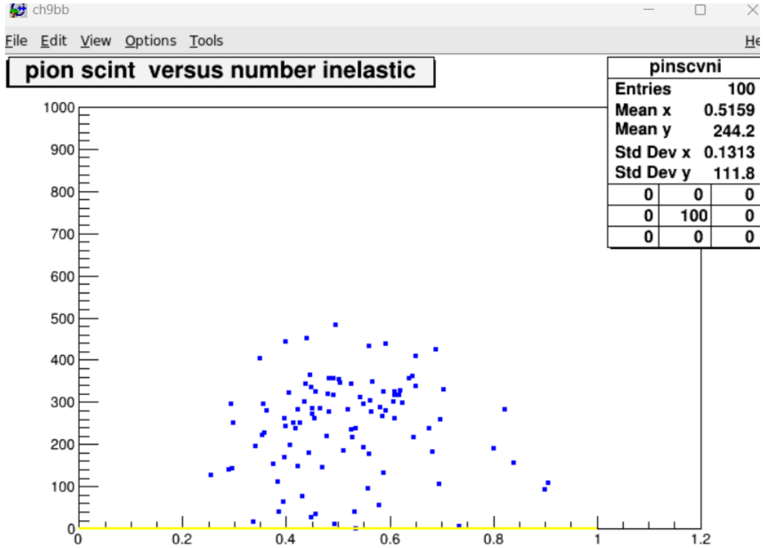


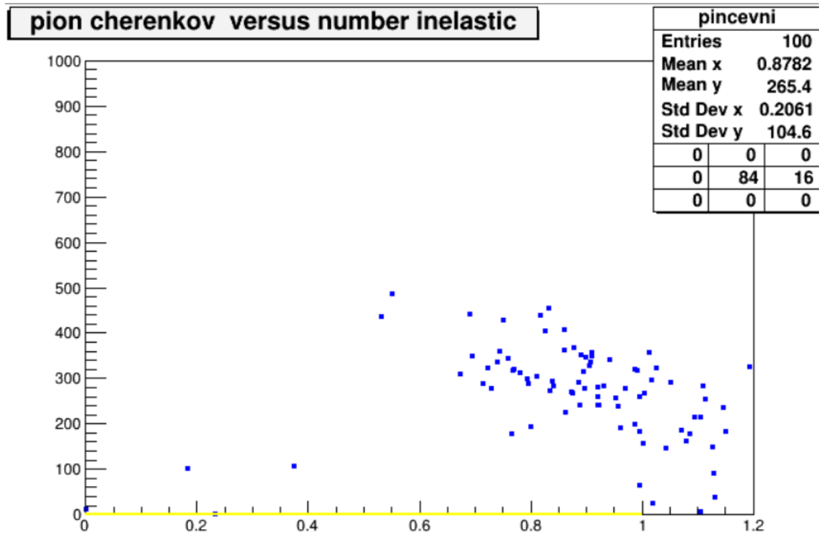




Large annulus absorber







Small annulus absorber