Comparison of beam profiles between data and MC

SPS : BT-1885, BT-1902, BT-1922

PS : BT-1460, BT-1485

1 - Criteria of comparison

1.1 - Position and “dimensions” of the beam

1.2 - Incidence angle of the beam

1.3 - Variables quantifying proximity to edge in Cal

1.4 - Shower shape in calorimeter

2 - Custom MC simulations to match with experimental beam profile … ongoing work …

Important remark

The only cuts applied to the data are :

1 - CalEnergyRaw > 10 MeV (No-empty events)

2 - TkrNumTracks > 0.5 (events with at least 1 track)

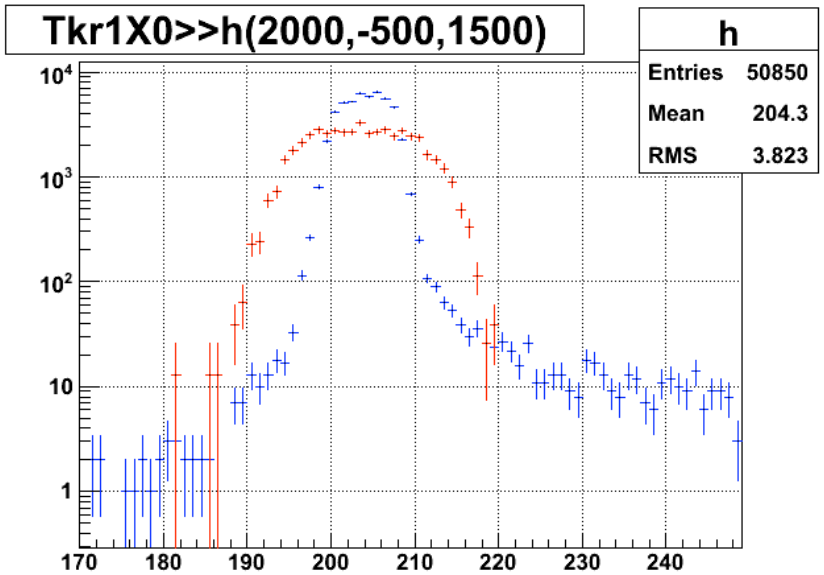
These are very simple cuts which are expected to be fulfilled by all the electrons (>20 GeV) entering in the calibration unit.

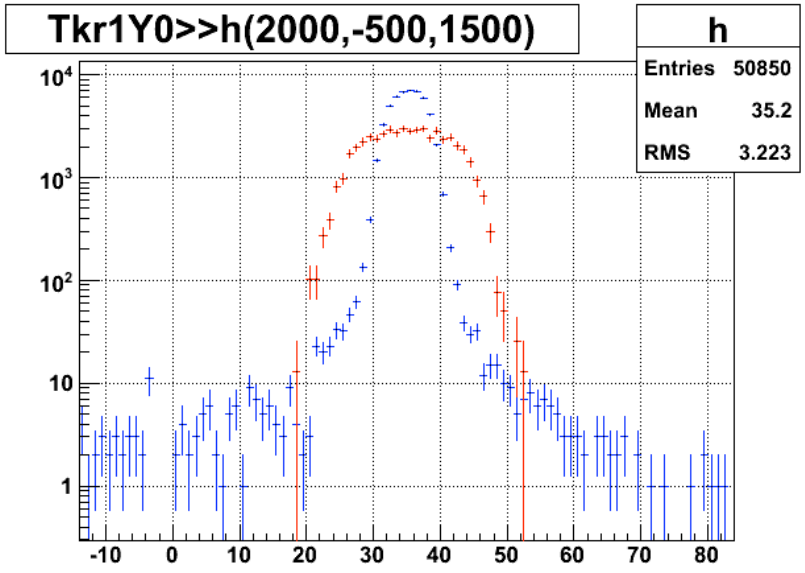
More sophisticated cuts (e.j. removing events crossing cracks, removing MIPs…) which might improve the agreement data-mc are NOT applied. These additional cuts must be applied with care, since they might also bias the comparison if not carefully done

BT-1885, which matches with data run 700001911

E = 196 GeV , 0 deg **MC in red**; **Data in blue**

Run 1911



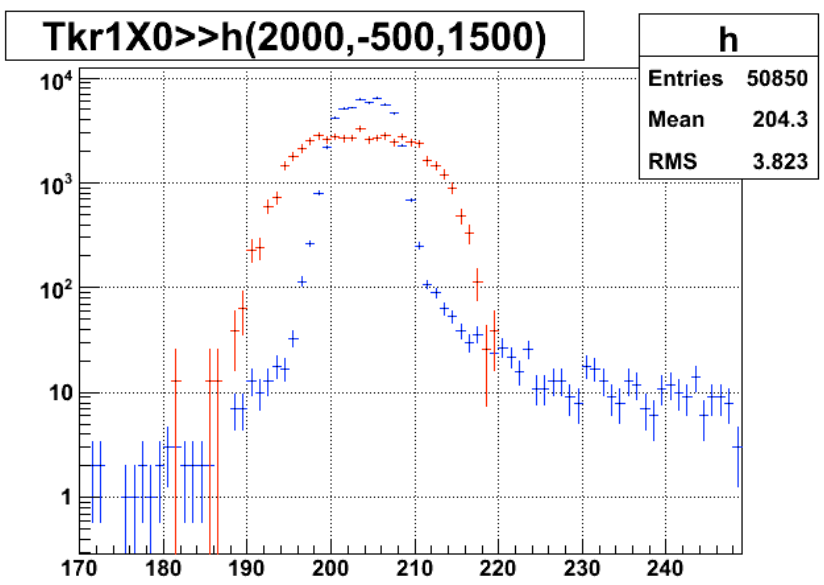


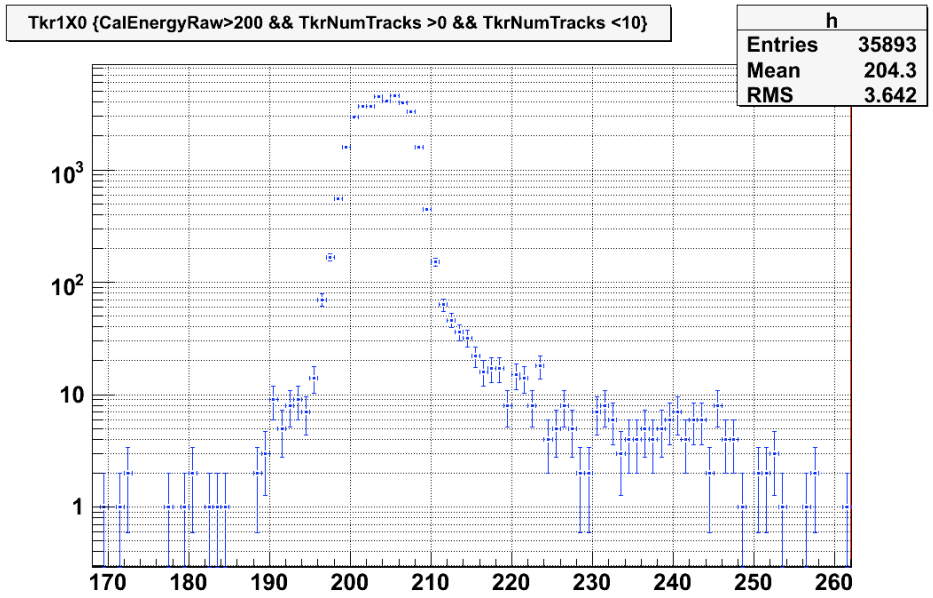
Beam impact point is at the RIGHT position, but MC beam is about 2.5 wider

BT-1885, which matches with data run 700001911

E = 196 GeV , 0 deg **MC in red**; **Data in blue**

Run 1911 **Stronger filter cuts**



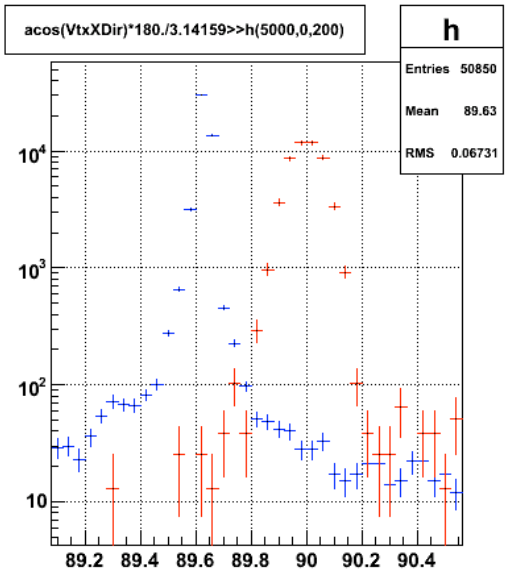


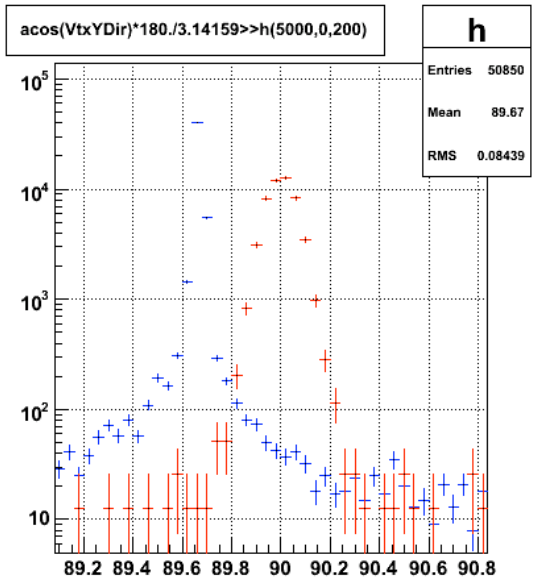
Stronger filter cuts improve somewhat the tails of the distribution. It is not something I worry at the moment…

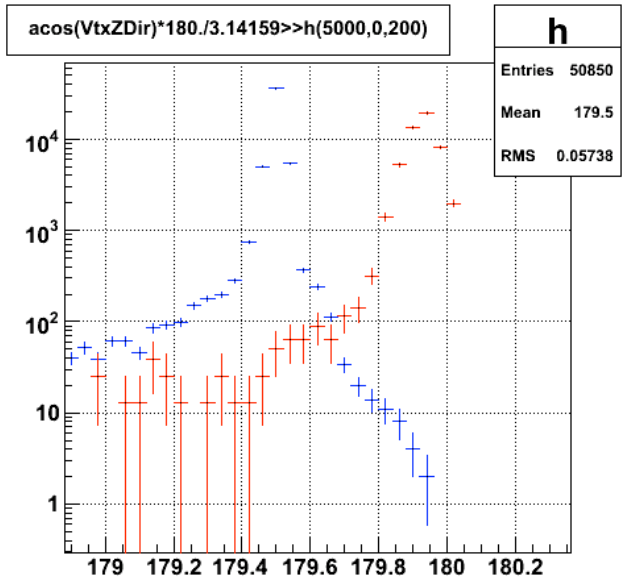
BT-1885, which matches with data run 700001911

E = 196 GeV , 0 deg **MC in red**; **Data in blue**

Run 1911







Small difference in incoming angle (0.5 degrees)

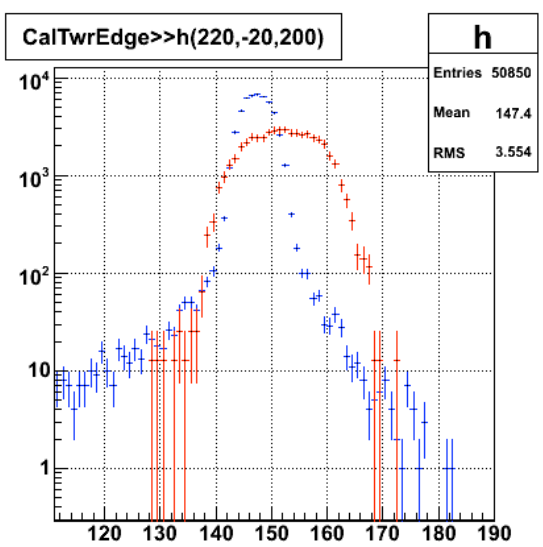
Should we worry about it ?

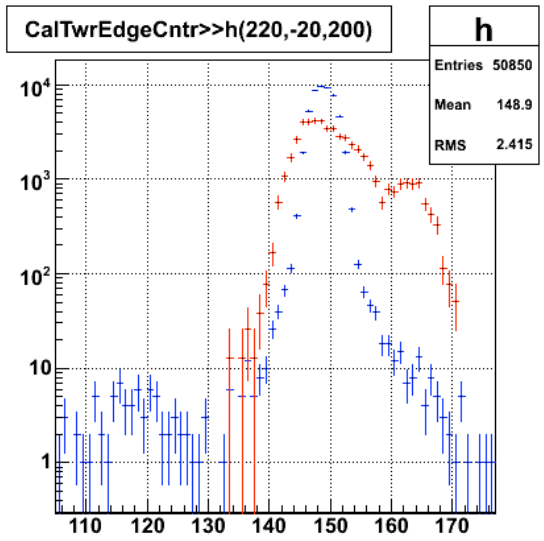
Distance top tracker to top calorimeter = 653 mm

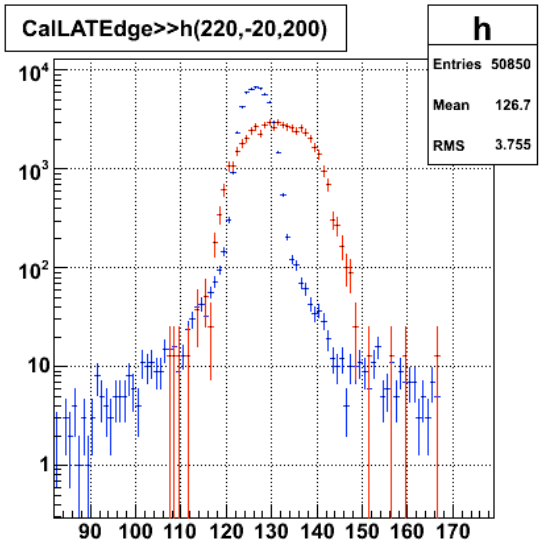
Displacement at top calorimeter = tan(0.4)*653. = **6 mm**

BT-1885, which matches with data run 700001911

E = 196 GeV , 0 deg **MC in red**; **Data in blue**





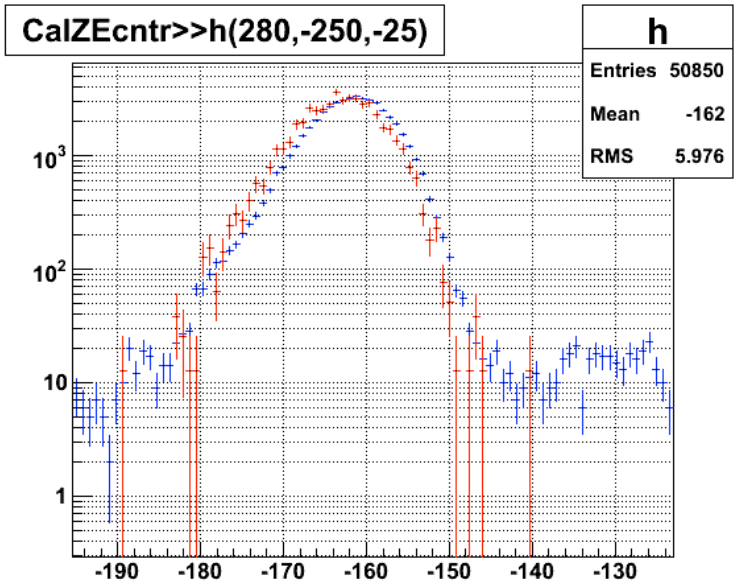


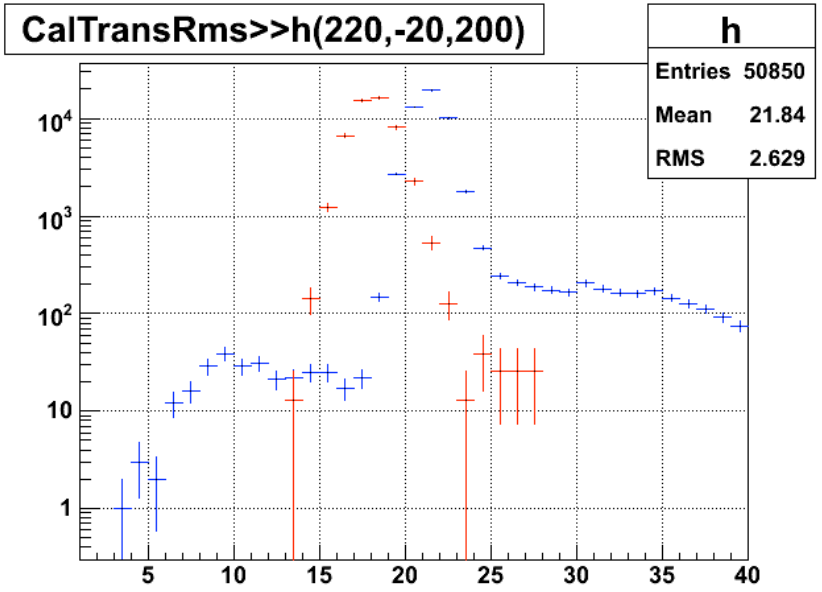
Difference in variables quantifying the distance of the location of energy deposition with respect to the tower edge. **This is due to the beam profile differences: beam width and incidence angle**

In case the beam was close to the tower edge, the energy reconstruction would be significantly affected

BT-1885, which matches with data run 700001911

E = 196 GeV , 0 deg **MC in red**; **Data in blue**





Vertical location of center of gravity is slightly different. This is NOT due to beam profile differences. Perhaps due to differences GEANT 3- GEANT 4

Transverse dimension per single shower is larger in Data.

However, the beam profile is larger for MC. Beam profile has no impact in shower RMS

Quantification of beam profile using macro described in Beam test meeting in Paris (Nov 2006)

https://confluence.slac.stanford.edu/display/BeamTest/Beamtest+workshop4+agenda

```
   Beam characteristics for RUN NUMBER  1911
**********************************************************************

Beam incoming direction (cosinus directors):
       Tkr1ZDir =    -0.9999619853
       Tkr1XDir =   0.006467330596
       Tkr1YDir =   0.005833762689

Beam impact point on Calorimeter input (CalZ =  -47 mm):
      PosXAtCalZ (mm) =      208.2381711
      PosYAtCalZ (mm) =      38.99697954

Beam width (Sigma) estimated from projected beam width (X,Y)
on the first hit height, and incoming beam direction:

Beam Width (Sigma) in X direction (mm) = 3.077448185
Beam Width (Sigma)  in Y direction (mm) = 2.760020121
```

Data

MC

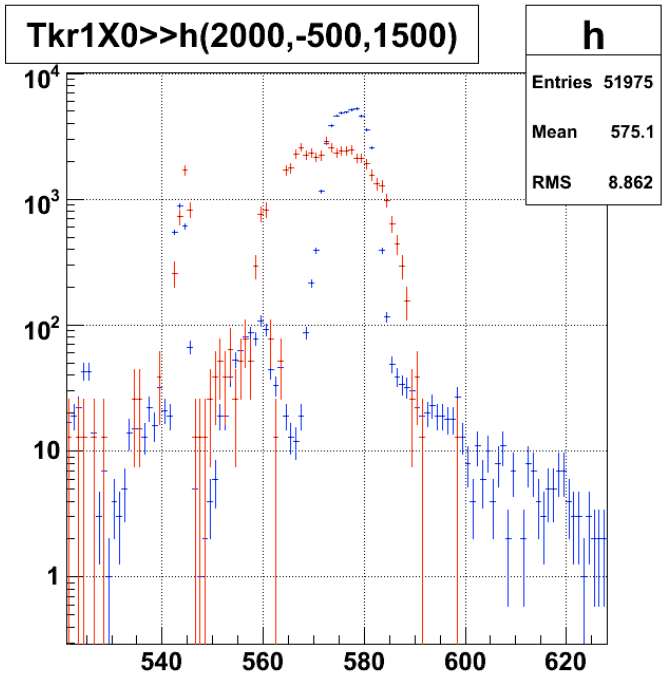
```
   Beam characteristics for RUN NUMBER  1885
**********************************************************************

Beam incoming direction (cosinus directors):
       Tkr1ZDir =    -0.9999991404
       Tkr1XDir =  1.599206763e-05
       Tkr1YDir = -1.427429201e-05

Beam impact point on Calorimeter input (CalZ =  -47 mm):
      PosXAtCalZ (mm) =      203.7701246
      PosYAtCalZ (mm) =      35.45494865

Beam width (Sigma) estimated from projected beam width (X,Y)
on the first hit height, and incoming beam direction:

Beam Width (Sigma) in X direction (mm) = 6.939793841
Beam Width (Sigma)  in Y direction (mm) = 6.972287596
```

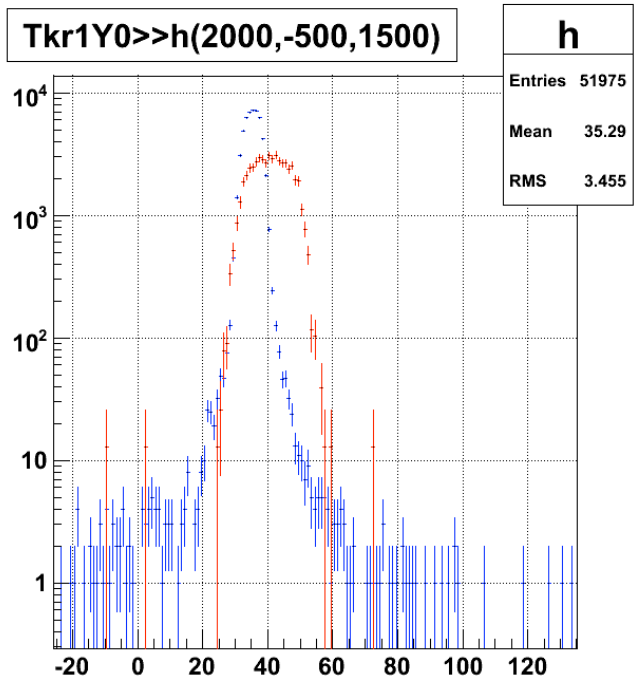
The beam profile is significantly different

BT-1902, which matches with data run 700001902

E = 196 GeV , 30 deg **MC in red**; **Data in blue**

Run 1902

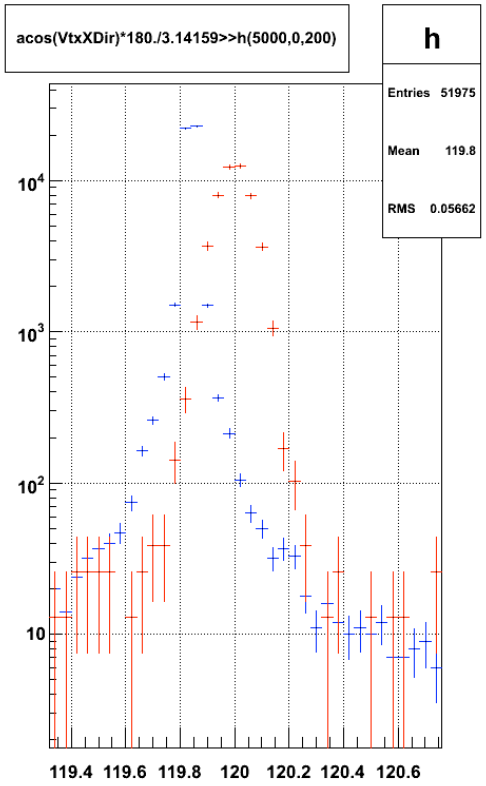


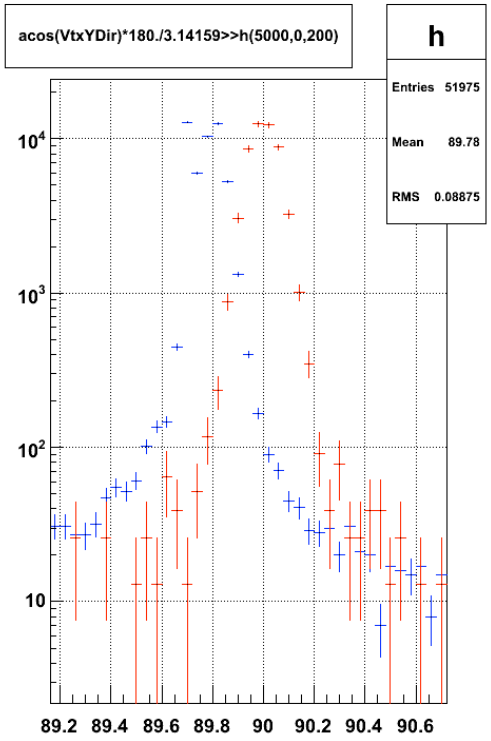


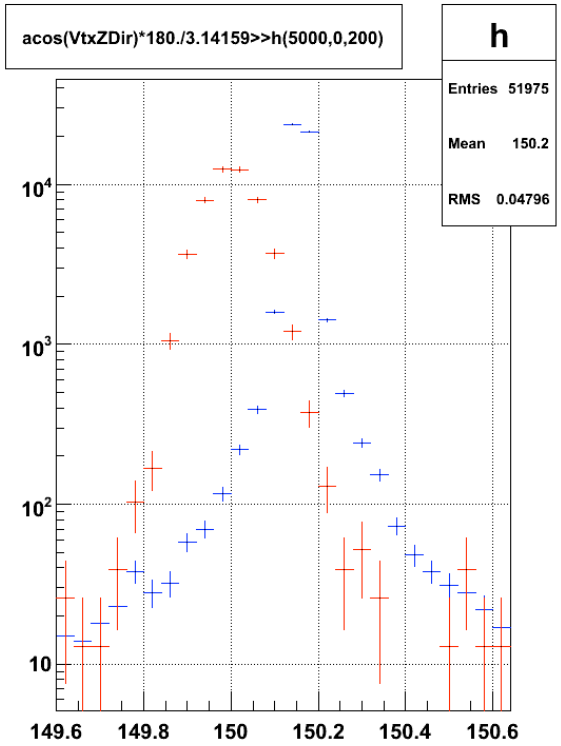
Beam impact point is shifted by ~5 mm, and MC beam is about ~2 wider

BT-1902, which matches with data run 700001902

E = 196 GeV , 30 deg **MC in red**; **Data in blue**







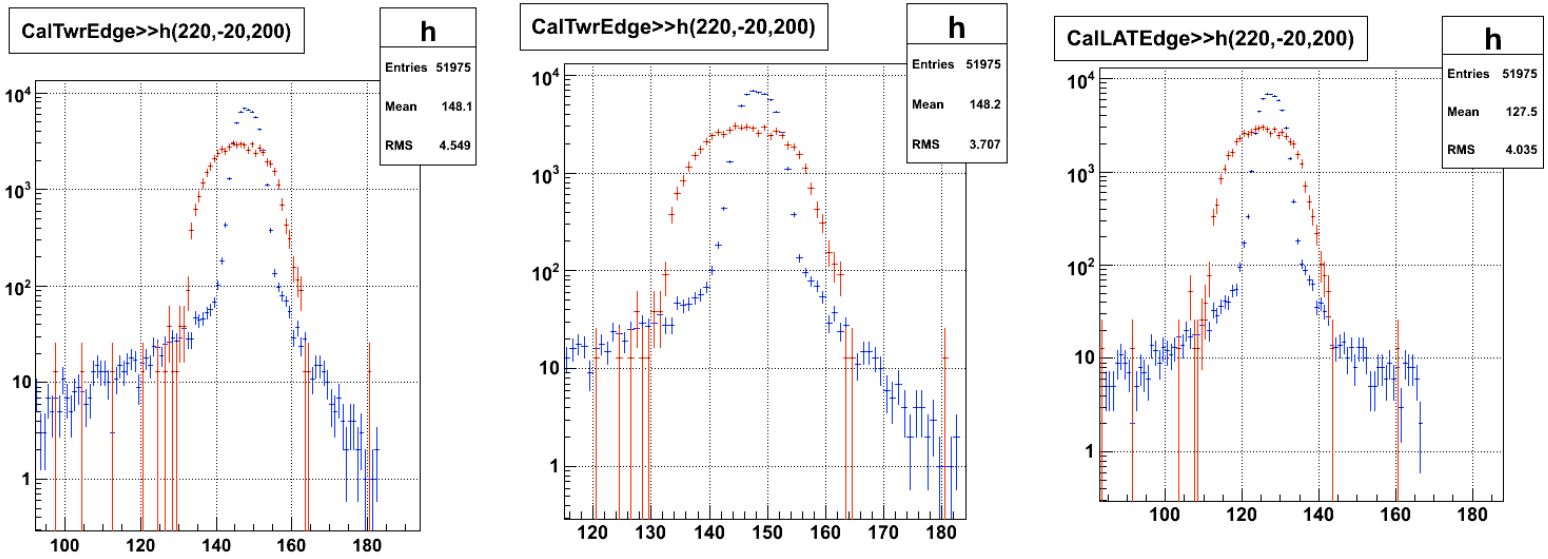
Tiny difference in incoming angle (0.2 degrees)

Should we worry about it ? Probably no…

BT-1902, which matches with data run 700001902

E = 196 GeV , 30 deg **MC in red**; **Data in blue**

Run 1902



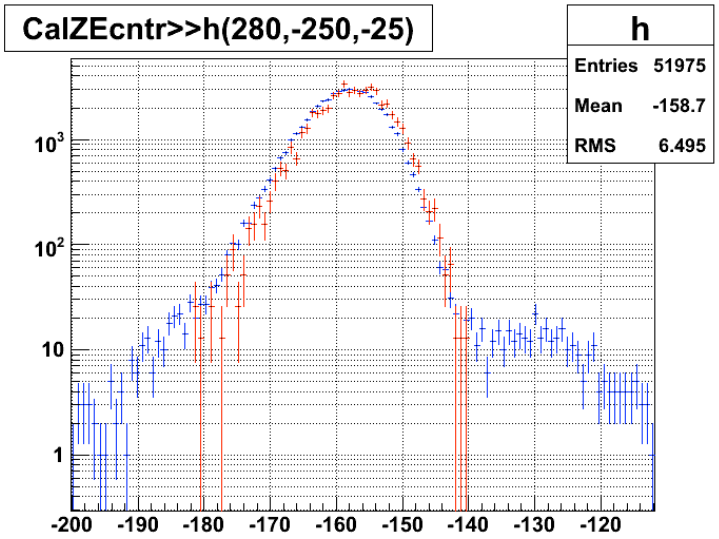
Difference in variables quantifying the distance of the location of energy deposition with respect to the tower edge. This is due to the beam profile differences

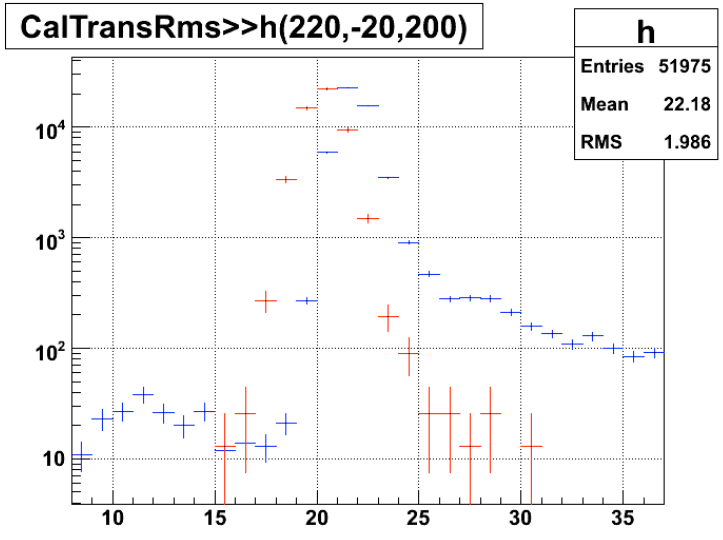
In case the beam was close to the tower edge, the energy reconstruction would be significantly affected

BT-1902, which matches with data run 700001902

E = 196 GeV , 30 deg **MC in red**; **Data in blue**

Run 1902





Vertical location of center of gravity is slightly different.

Difference has opposite sign to the one observed for 0 degree incidence angle (BT-1885). Guau !

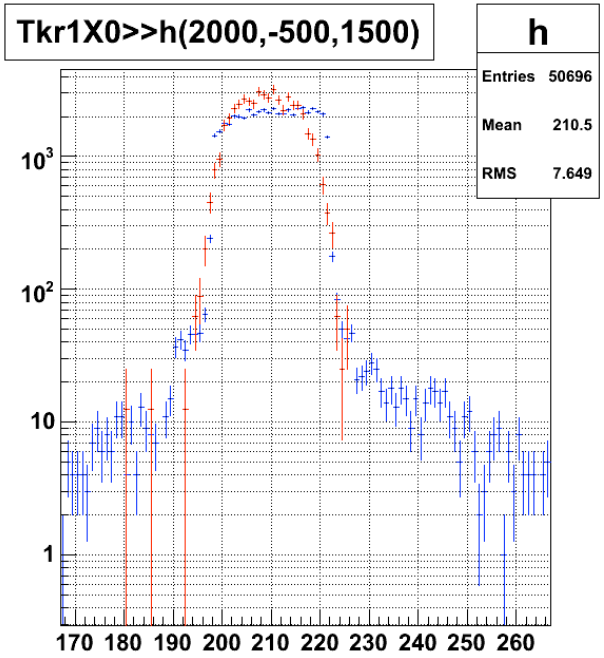
Transverse dimension per single shower is larger in Data.

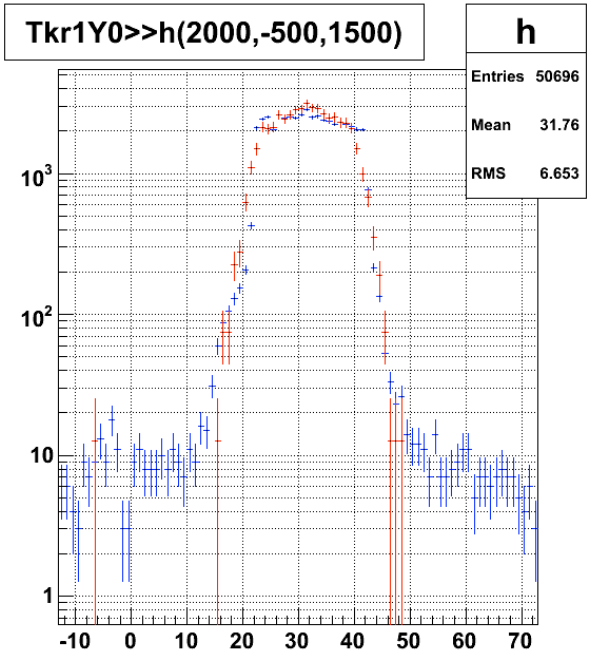
However, the beam profile is larger for MC. Beam profile has no impact in shower RMS

BT-1922, which matches with data run 700001922

E = 282 GeV , 0 deg **MC in red**; **Data in blue**

Run 1922



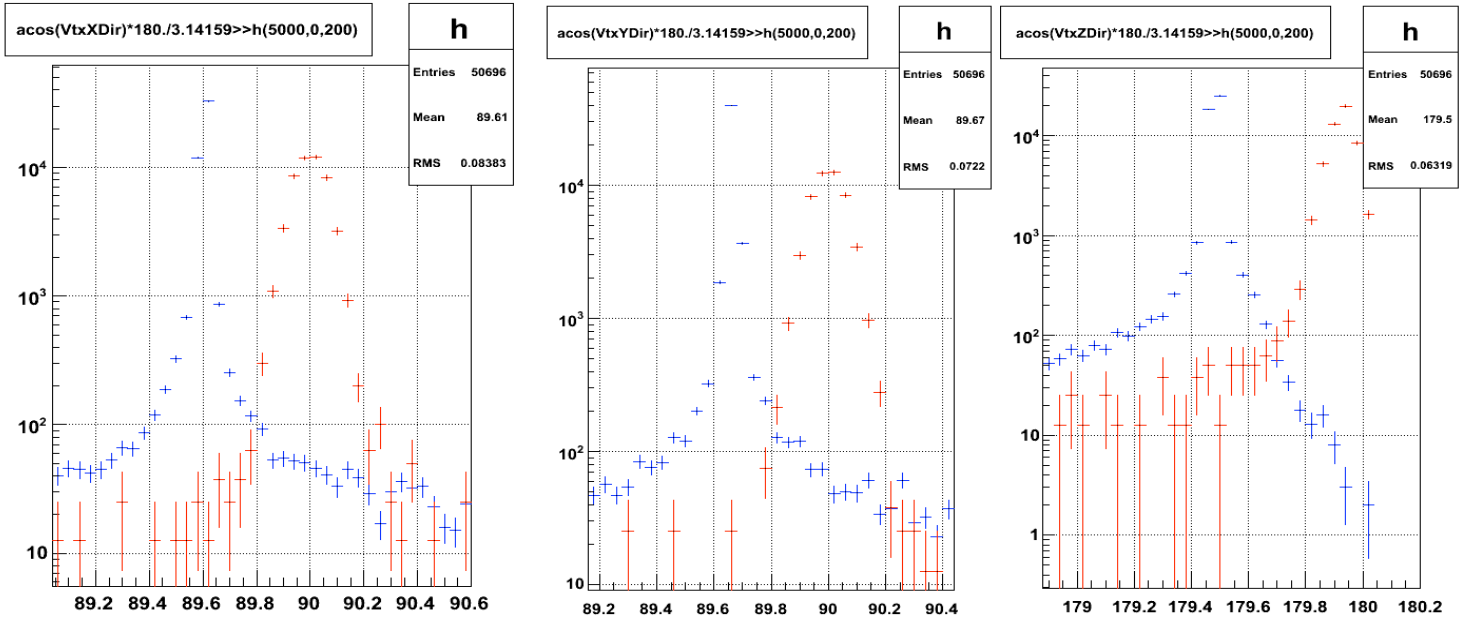


Very good agreement data-mc !!

BT-1922, which matches with data run 700001922

E = 282 GeV , 0 deg **MC in red**; **Data in blue**

Run 1922



Small difference in incoming angle (0.4 degrees)

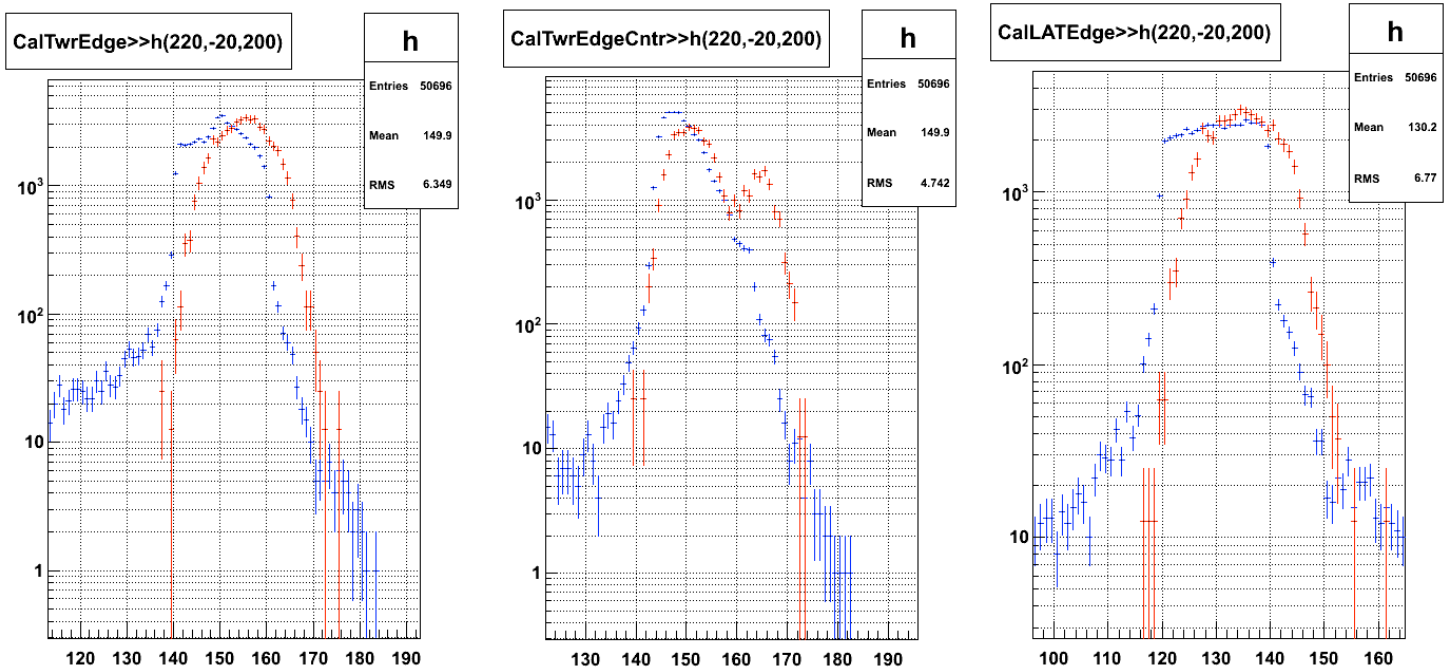
Should we worry about it ?

Distance top tracker to top calorimeter = 653 mm

Displacement at top calorimeter = tan(0.4)*653. = **5 mm**

BT-1922, which matches with data run 700001922

E = 282 GeV , 0 deg **MC in red**; **Data in blue**

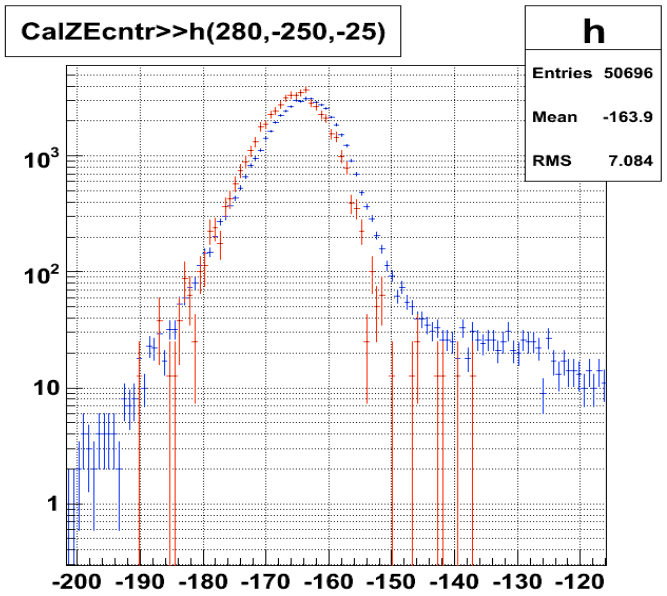


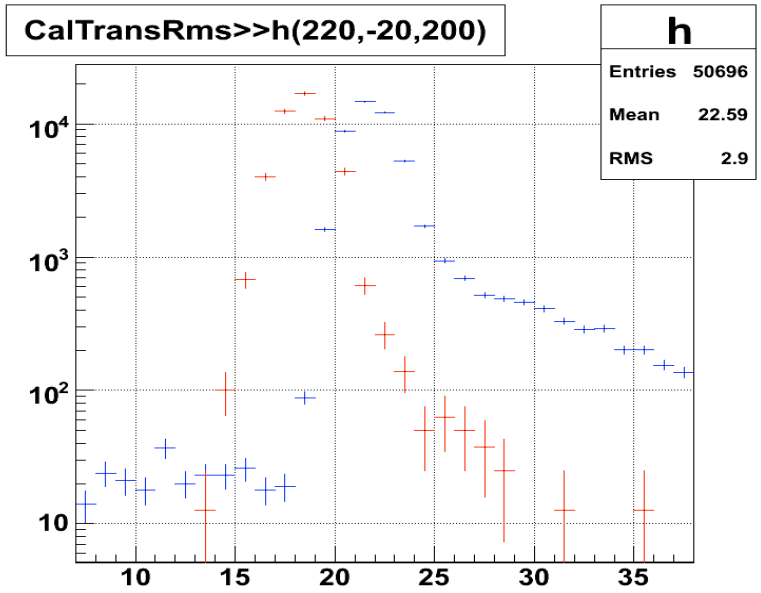
Small shift in variables quantifying the distance of the location of energy deposition with respect to the tower edge. Note that this time the beam profile is correct. **This shift is produced by the difference in incoming angle.**

What is the origin of the second bump in CalTwrEdgeCntr?

BT-1922, which matches with data run 700001922

E = 282 GeV , 0 deg **MC in red**; **Data in blue**





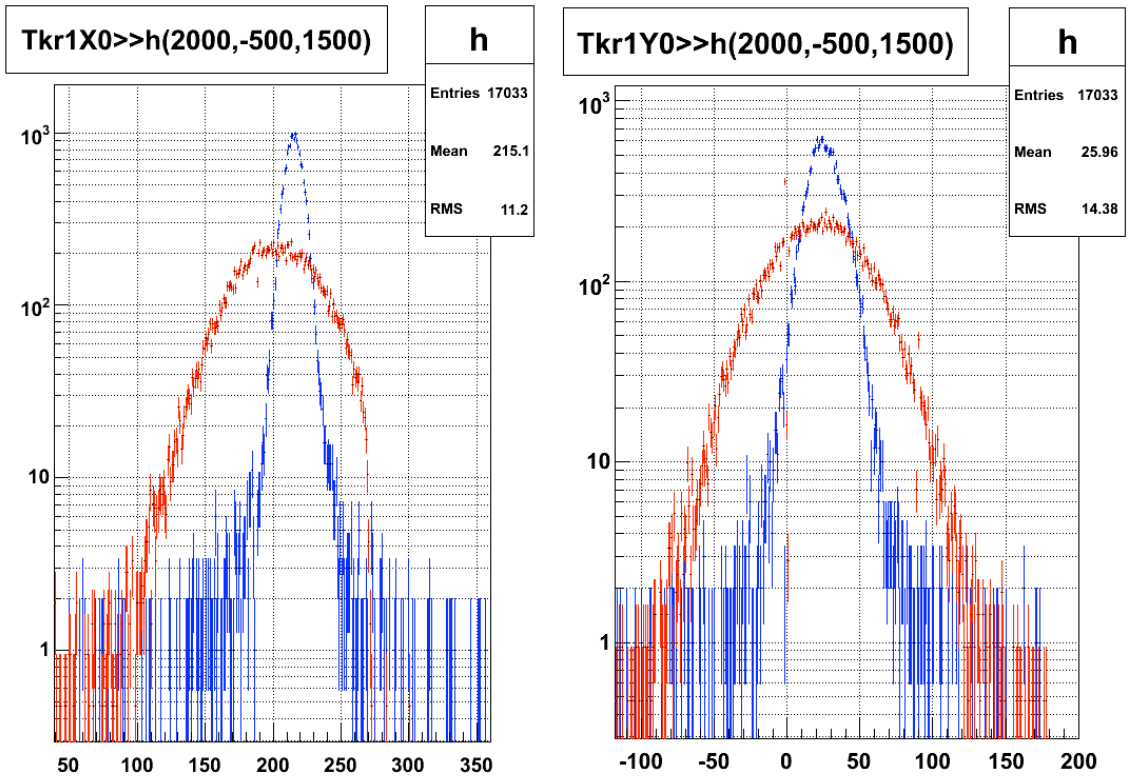
Vertical location of center of gravity is slightly different. This is NOT due to beam profile differences. Perhaps due to differences GEANT 3- GEANT 4

Transverse dimension per single shower is larger in Data.

Usual feature which does not depend on beam profile

PS runs BT-1460, which matches with data run 700001460

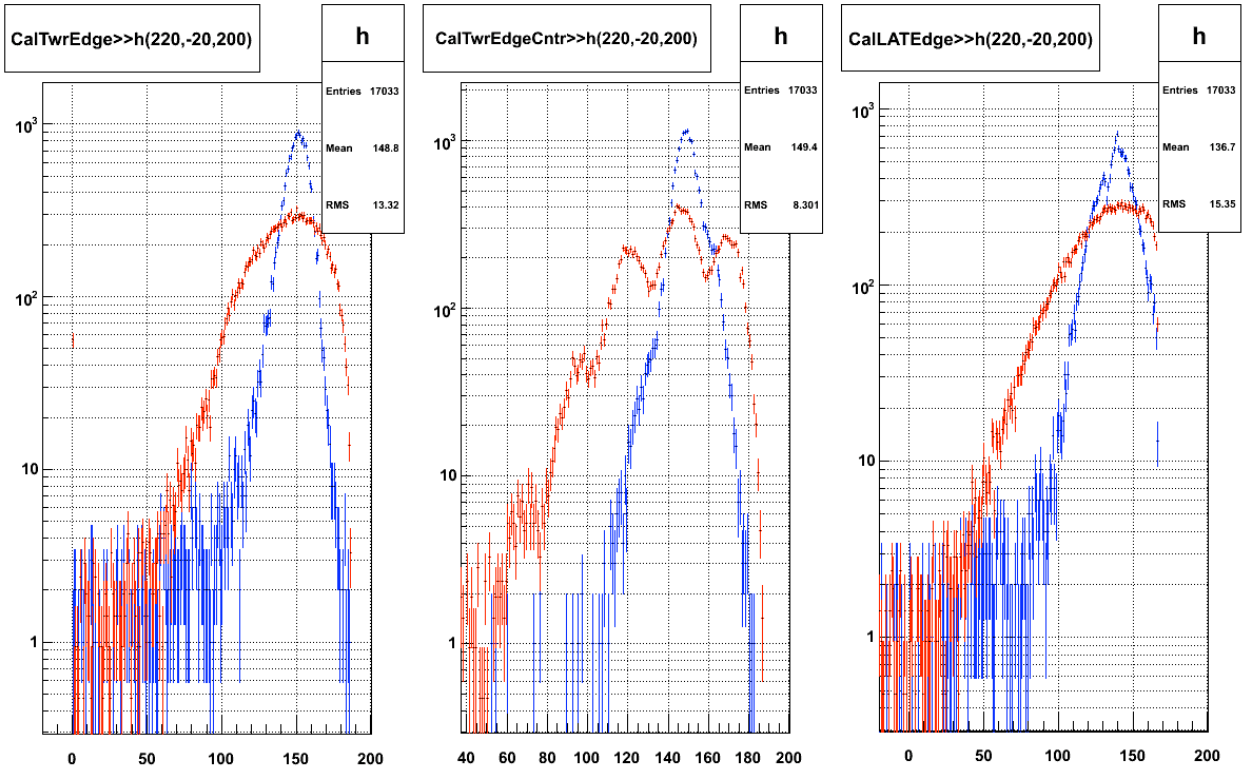
E = 5 GeV , 0 deg **MC in red**; **Data in blue**



Beam impact point is shifted by ~5-10 mm, and MC beam is about ~2 wider

PS runs BT-1460, which matches with data run 700001460

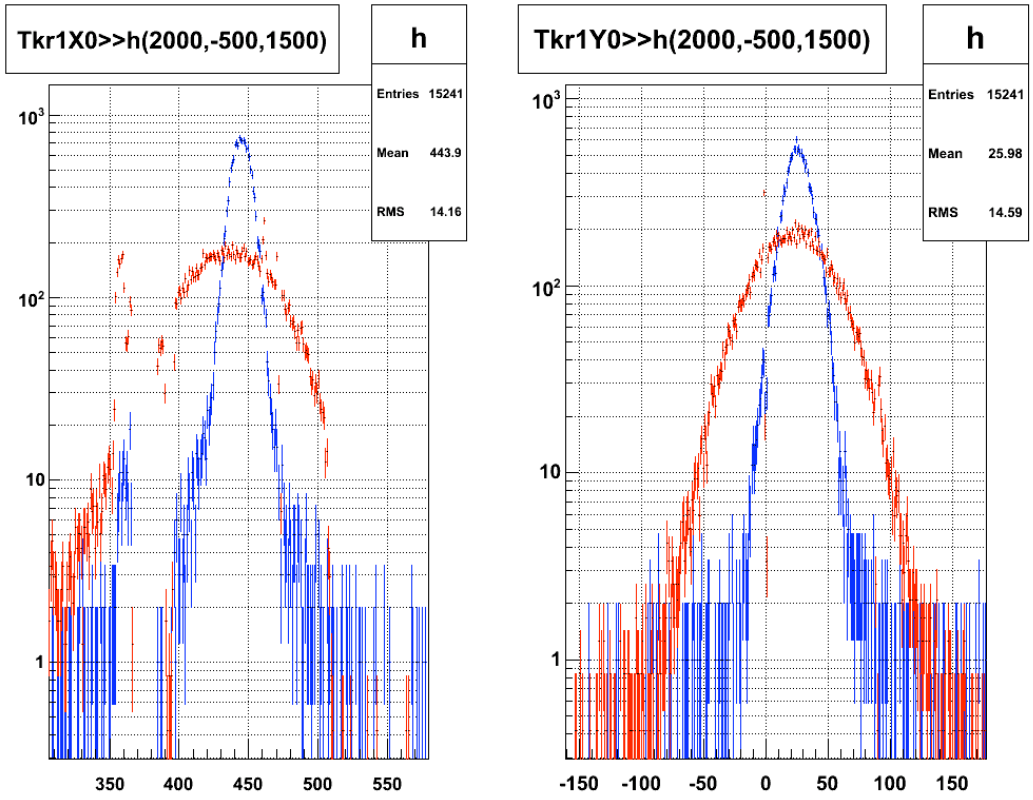
E = 5 GeV , 0 deg **MC in red**; **Data in blue**



Difference in variables quantifying the distance of the location of energy deposition with respect to the tower edge. This is due to the beam profile differences

PS runs BT-1485, which matches with data run 700001485

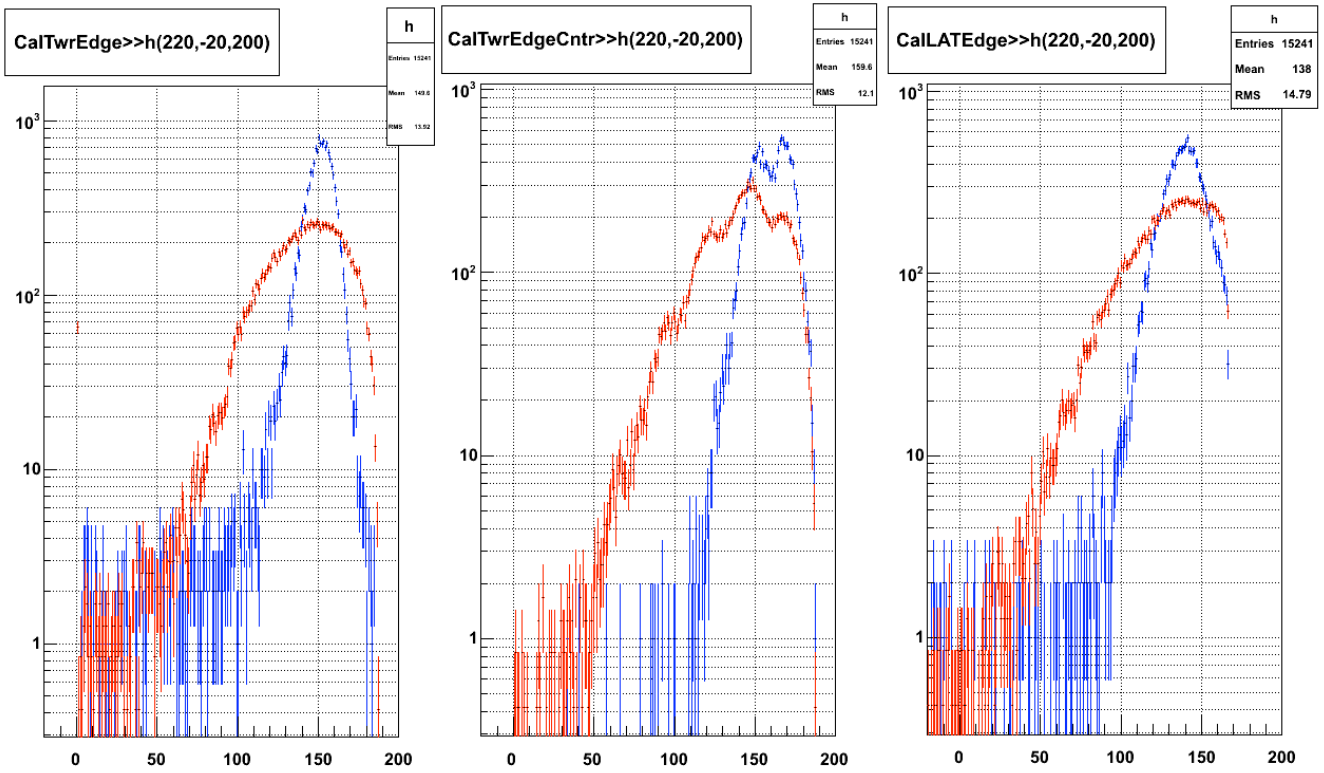
E = 5 GeV , 20 deg **MC in red**; **Data in blue**



Beam impact point is shifted by ~5-10 mm, and MC beam is about ~2-3 wider

PS runs BT-1485, which matches with data run 700001485

E = 5 GeV , 20 deg **MC in red**; **Data in blue**



Difference in variables quantifying the distance of the location of energy deposition with respect to the tower edge. This is due to the beam profile differences

Significant differences Data-MC found in beam profile from both SPS and PS runs

In order to get proper evaluation of the performance of the CU (PSF, energy reconstruction…) we need to have a MC beam profile which describes reasonably well the experimental beam profile

The beam profile can be easily (in general) estimated from the data. In Beamtest meeting in Paris, I showed a very rough and quick estimation for all runs (PS and SPS).

The “difficulty” is in the proper selection of the parameters to be put in the configuration files for the simualtion . Those parameters are NOT the measured beam profile

We need a kind of a map or “conversion table”

G4config.mac

```
# Macro file for 2006 sps electron runs
# Sets some default verbose
/control/verbose 2
/run/initialize
/run/verbose 2

/Cern/random/run 0
/Cern/random/event 1
##################################################
#END OF GLOBAL CONFIG FILE
#Following lines should be written by the script
##################################################


#Automatically written by JOcreator on Fri Dec 15 17:45:39 2006
#Using Analysis report is True
#/Cern/detector/trigger 2
#/Cern/detector/field 0
/Cern/gun/ydiv 1.000000 mrad
/Cern/gun/zdiv 1.000000 mrad
/Cern/gun/edispersion 1.000000
/Cern/gun/ywidth 1.000000 cm
/Cern/gun/zwidth 1.000000 cm
/gun/particle e-
/Cern/gun/pos -5000. 0 0 cm
/Cern/detector/cherenkovpressure 0.800000
/Cern/gun/energy 196.120000 GeV
/run/beamOn 100
```

The beam widens along the beam axis; In G4Config file width is 1.0 cm, while in the CU it is 7.0 cm

MC

```
   Beam characteristics for RUN NUMBER  1885
****************************************************************

Beam incoming direction (cosinus directors):
       Tkr1ZDir =    -0.9999991404
       Tkr1XDir =  1.599206763e-05
       Tkr1YDir = -1.427429201e-05

Beam impact point on Calorimeter input (CalZ =  -47 mm):
      PosXAtCalZ (mm) =      203.7701246
      PosYAtCalZ (mm) =      35.45494865

Beam width (Sigma) estimated from projected beam width (X,Y)
on the first hit height, and incoming beam direction:

Beam Width (Sigma) in X direction (mm) = 6.939793841
Beam Width (Sigma)  in Y direction (mm) = 6.972287596
```

In SPS we mostly did not use the Cherenkov counters. Should not we set the Cherenkov pressure to zero

Any clever idea of how to get "easily" that conversion ??

For the time being, I used BRUT FORCE to get this table (for only one configuration run BT-1885; E = 196 GeV)

I produced MC runs with beam widths spanning from 0.1 to 1.0 cm in steps of 0.1 cm

Then I evaluated the beam profile for each of this runs with macro described in Paris Beam test meeting

Remark: In order to be "quick" with simulation (avoid problems of using farm splitting simulation into pieces) I simulated 2000 events (instead of 10000 events). For this purpose that is enough statistics

```
   Beam characteristics for RUN NUMBER  1911
*****************************************************************

Beam incoming direction (cosinus directors):
       Tkr1ZDir =    -0.9999619853
       Tkr1XDir =   0.006467330596
       Tkr1YDir =   0.005833762689

Beam impact point on Calorimeter input (CalZ =  -47 mm):
      PosXAtCalZ (mm) =      208.2381711
      PosYAtCalZ (mm) =      38.99697954

Beam width (Sigma) estimated from projected beam width (X,Y)
on the first hit height, and incoming beam direction:

Beam Width (Sigma) in X direction (mm) = 3.077448185
Beam Width (Sigma)  in Y direction (mm) = 2.760020121
```

Data

Note that these quantites will probalby depend on the beam settings (energy, cherenkov pressure…)

```
          width = 0.1 cm
Beam Width (Sigma) in X direction (mm) = 2.604220671
Beam Width (Sigma)  in Y direction (mm) = 2.645699246

          width = 0.2 cm
Beam Width (Sigma) in X direction (mm) = 3.047110913
Beam Width (Sigma)  in Y direction (mm) = 3.125083241

          width = 0.3 cm
Beam Width (Sigma) in X direction (mm) = 3.713497883
Beam Width (Sigma)  in Y direction (mm) = 3.770104313

          width = 0.4 cm
Beam Width (Sigma) in X direction (mm) = 4.462590084
Beam Width (Sigma)  in Y direction (mm) = 4.61967358

          width = 0.5 cm
Beam Width (Sigma) in X direction (mm) = 5.30335311
Beam Width (Sigma)  in Y direction (mm) = 5.192112611
```

```
          width = 0.6 cm
Beam Width (Sigma) in X direction (mm) = 5.943862973
Beam Width (Sigma)  in Y direction (mm) = 5.885670486

          width = 0.7 cm
Beam Width (Sigma) in X direction (mm) = 6.282669848
Beam Width (Sigma)  in Y direction (mm) = 6.182292587

          width = 0.8 cm
Beam Width (Sigma) in X direction (mm) = 6.477504101
Beam Width (Sigma)  in Y direction (mm) = 6.3345287

          width = 0.9 cm
Beam Width (Sigma) in X direction (mm) = 6.748320178
Beam Width (Sigma)  in Y direction (mm) = 6.97075119

          width = 1.0 cm
Beam Width (Sigma) in X direction (mm) = 6.792431346
Beam Width (Sigma)  in Y direction (mm) = 6.868319627
```

```
   Beam characteristics for RUN NUMBER  1911
*****************************************************************

Beam incoming direction (cosinus directors):
       Tkr1ZDir =    -0.9999619853
       Tkr1XDir =   0.006467330596
       Tkr1YDir =   0.005833762689

Beam impact point on Calorimeter input (CalZ =  -47 mm):
      PosXAtCalZ (mm) =      208.2381711
      PosYAtCalZ (mm) =      38.99697954

Beam width (Sigma) estimated from projected beam width (X,Y)
on the first hit height, and incoming beam direction:

Beam Width (Sigma) in X direction (mm) = 3.077448185
Beam Width (Sigma)  in Y direction (mm) = 2.760020121
```

Data

Reasonably good agreement in all the quantities … "By construction" …

MC, width = 0.2 cm in G4

Note however that incidence angle is slightly different:

Tkr1XYDir ~ 0.006

650 mm * 0.006 ~ 4 mm

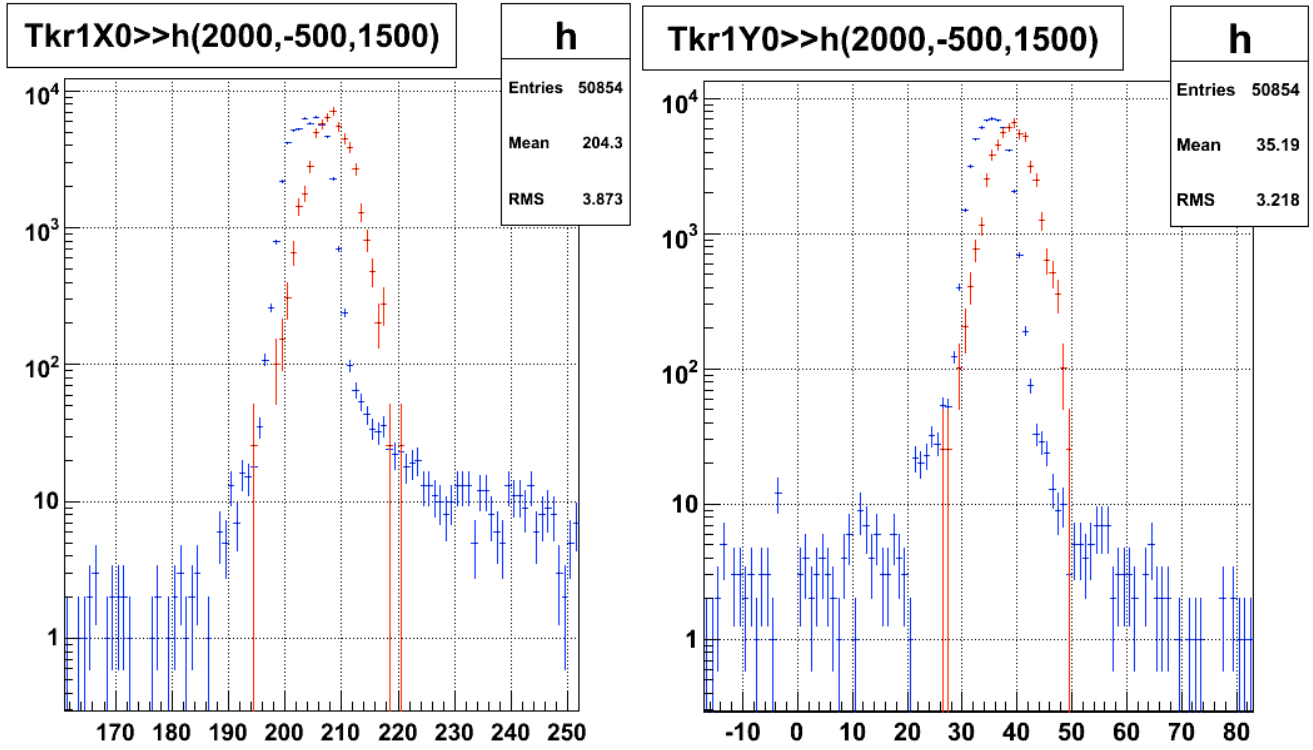
Displacement of 4 mm between top tracker and top Cal

```
   Beam characteristics for RUN NUMBER  1885_W2
*****************************************************************

Beam incoming direction (cosinus directors):
       Tkr1ZDir =    -0.9999991056
       Tkr1XDir =  2.398175769e-06
       Tkr1YDir =  1.961470475e-06

Beam impact point on Calorimeter input (CalZ =  -47 mm):
      PosXAtCalZ (mm) =      208.1451144
      PosYAtCalZ (mm) =      38.96320978

Beam width (Sigma) estimated from projected beam width (X,Y)
on the first hit height, and incoming beam direction:

Beam Width (Sigma) in X direction (mm) = 3.047110913
Beam Width (Sigma)  in Y direction (mm) = 3.125083241
```

I only saw one angle in jobOptions:
BeamTransform.table_rotation (I guess this is in X dir)

Custom BT-1885, which matches with data run 700001911

E = 196 GeV , 0 deg **MC in red**; **Data in blue**

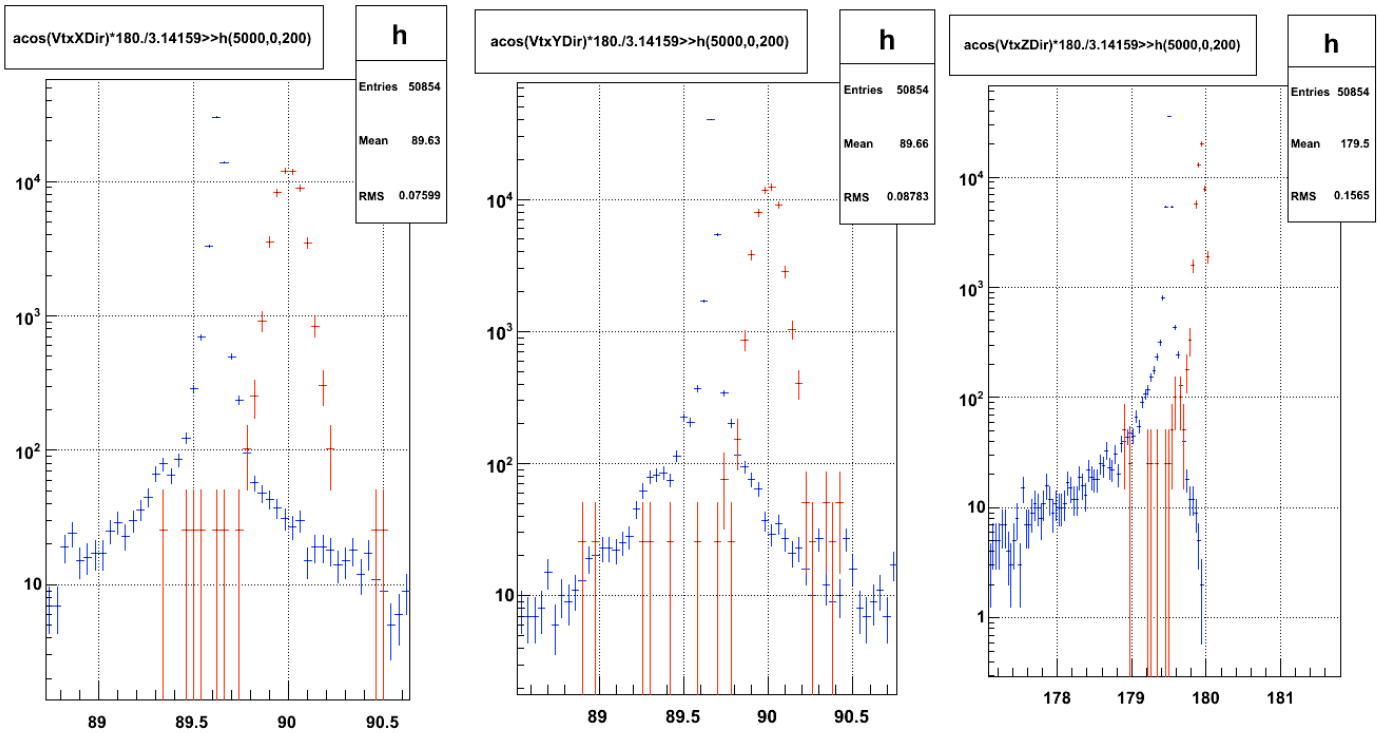


Beam profile is reasonably similar: OK …

There is a displacement of ~ 5mm in position of impact point; this is due to the beam incidence angle

Custom BT-1885, which matches with data run 700001911

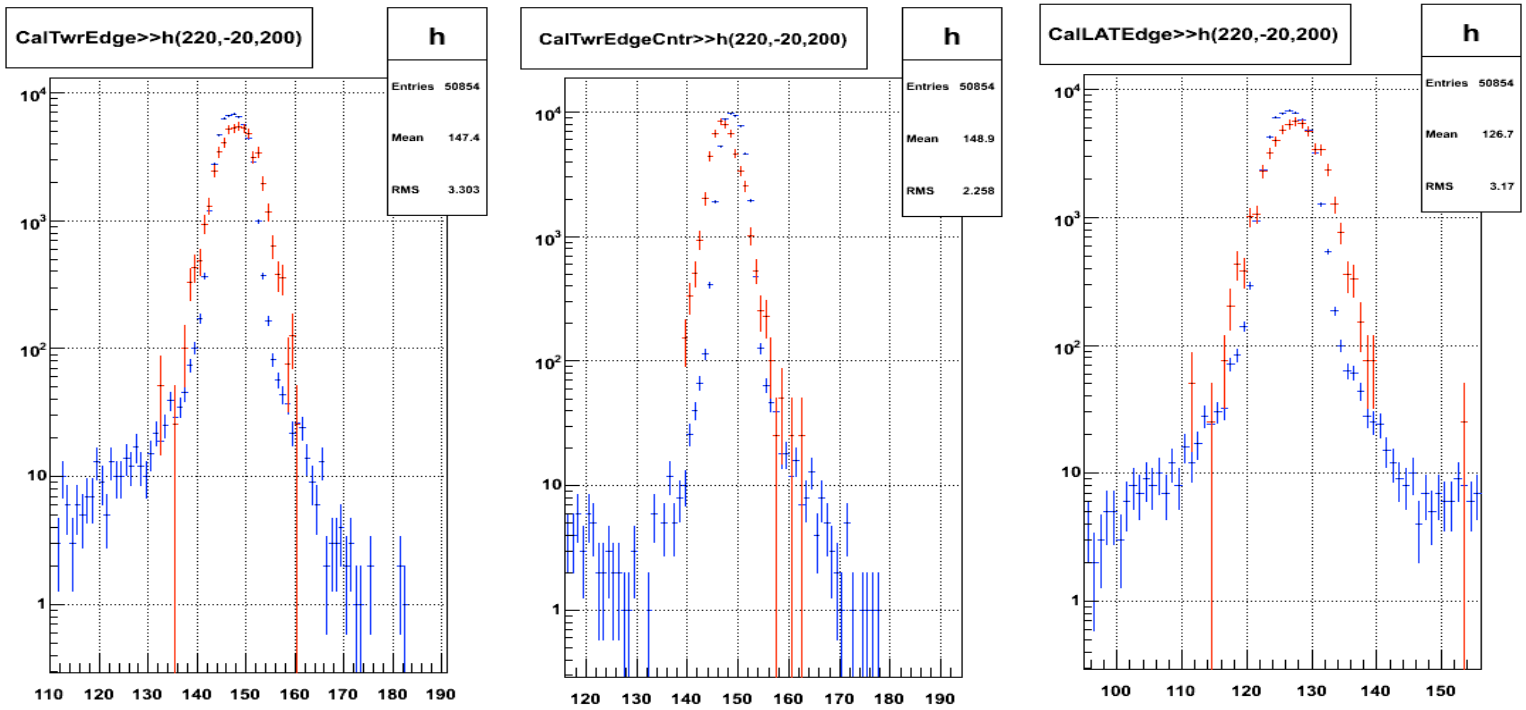
E = 196 GeV , 0 deg **MC in red**; **Data in blue**



Difference of ~0.4 degrees reported in table

Custom BT-1885, which matches with data run 700001911

E = 196 GeV , 0 deg **MC in red**; **Data in blue**

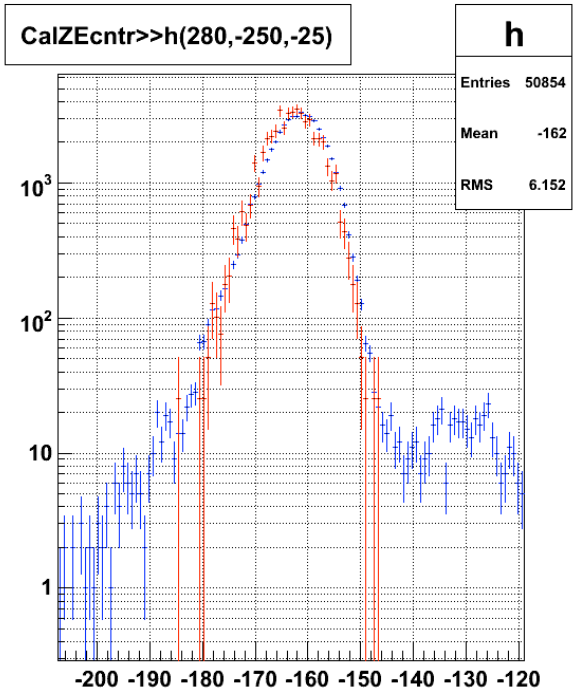


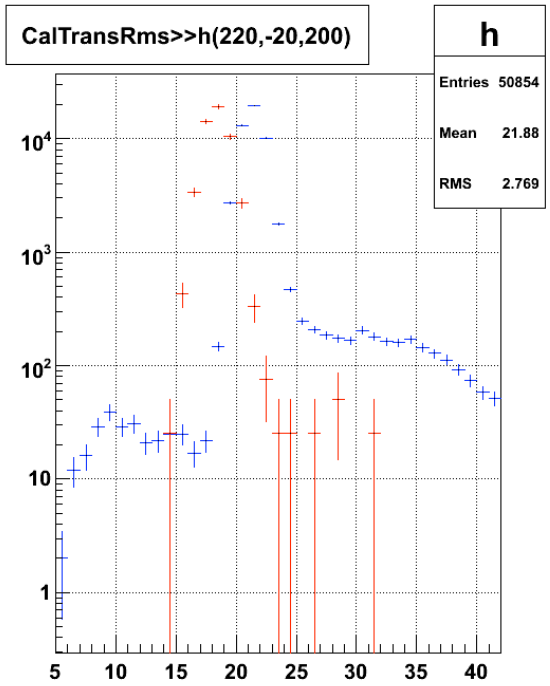
Rather good agreement in the calorimeter quantities used to testimate the missing energy

Note that the in the CAL there is no shift in impact point (by construction), the shift (due to incidence angle) is in tracker

Custom BT-1885, which matches with data run 700001911

E = 196 GeV , 0 deg **MC in red**; **Data in blue**





In these variables, the improvement in the beam profile does not have a significant impact. Expected.

Conclusions

The beam profile of the current MC simulation does not describe properly the beam profile in the experimental data runs

Before looking into details of the agreement data-mc (e.j using Random Forest) one needs first to get a reasonably good agreement in the beam profiles

Beam profile can easily (automatically) be estimated from the data. The “difficult” part is to find the proper values for the Config files. Work ongoing…