FUTURE CIRCULAR COLLIDER

NIELS BOHR INSTITUTE
UNIVERSITY OF COPENHAGEN

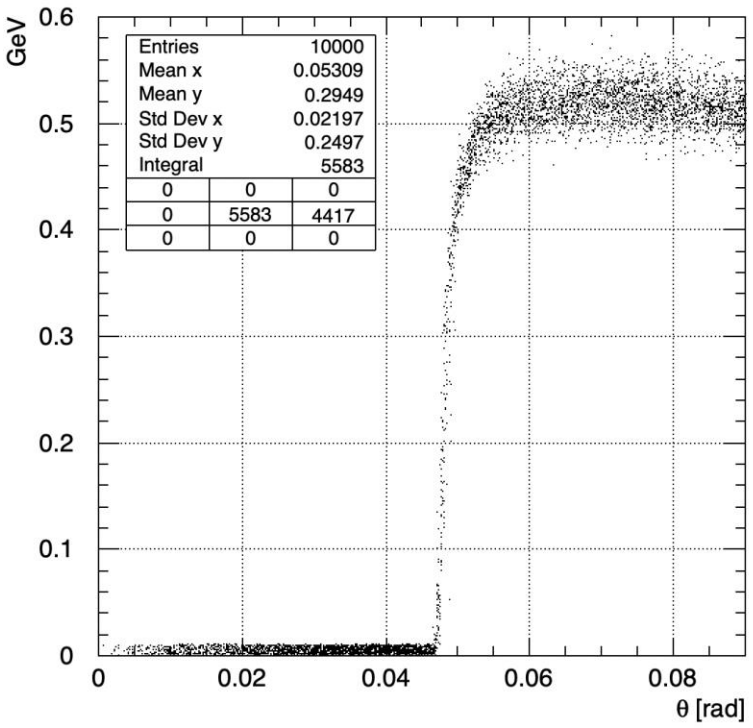
Background signal from Incoherent Pairs in LumiCal

8th FCC Physcis Workshop
Jan 14, 2025

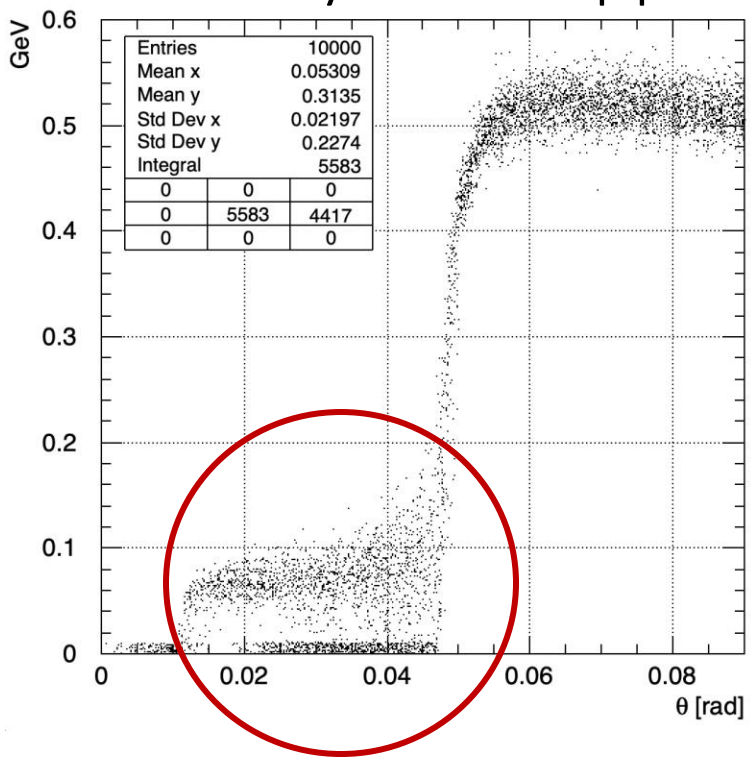
Mogens Dam
Niels Bohr Institute

Start with a check on Beam pipe

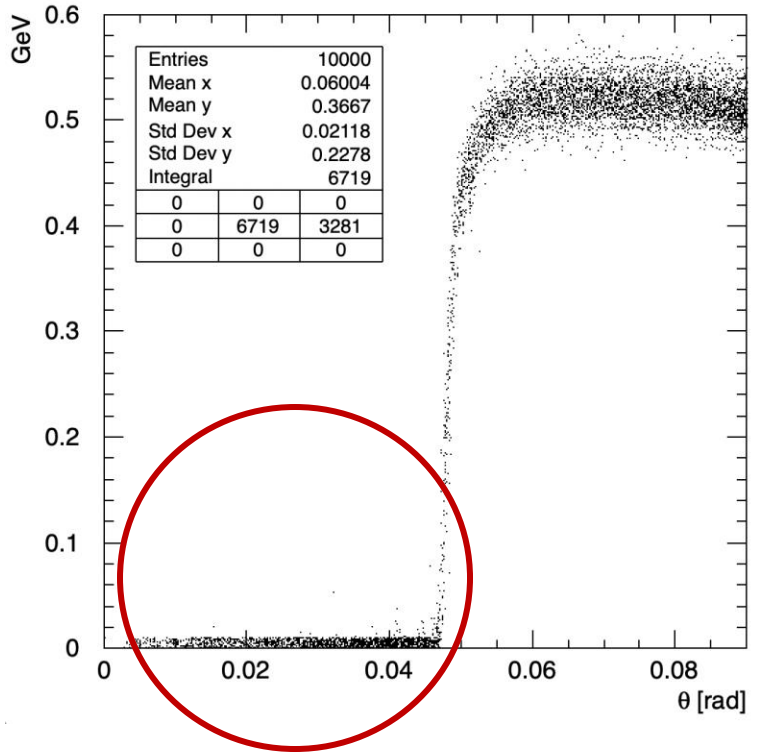
No beam pipe



Annecy CAD beam pipe

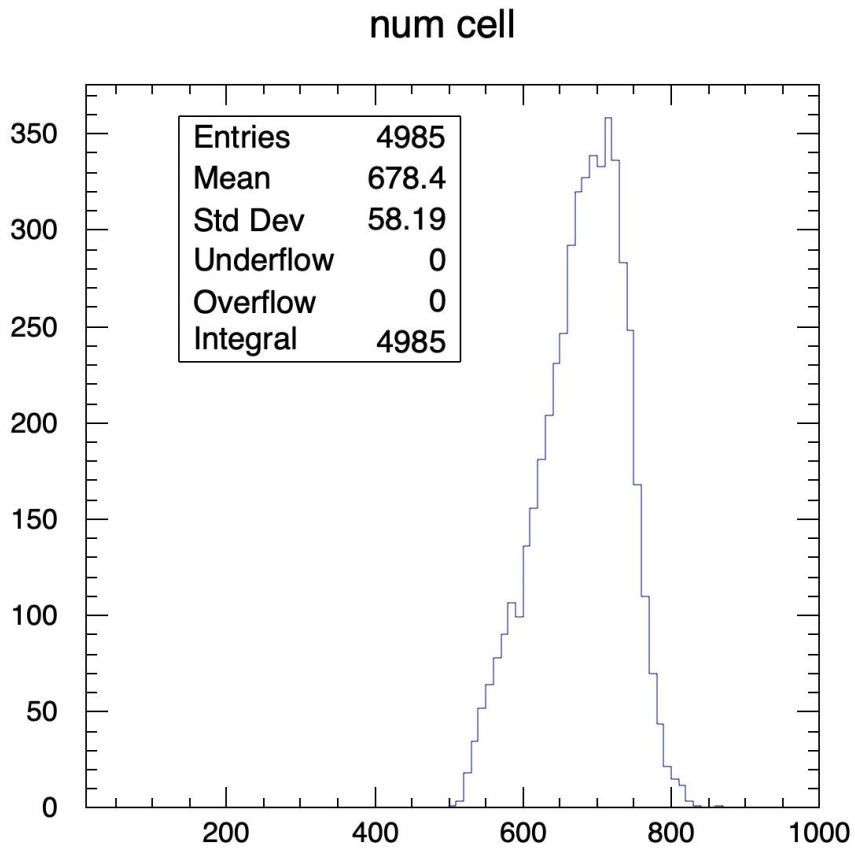


New CAD beam pipe

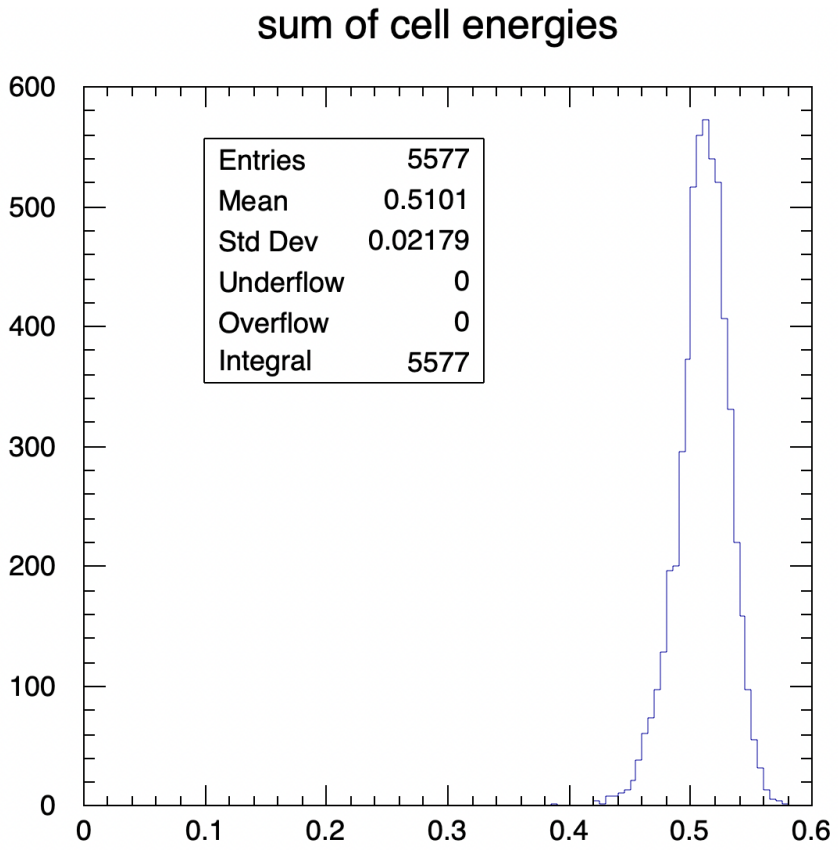


New beam pipe is major improvement compared to previous Cu manifold

LumiCal response to 45.6 GeV electrons



Average: 680



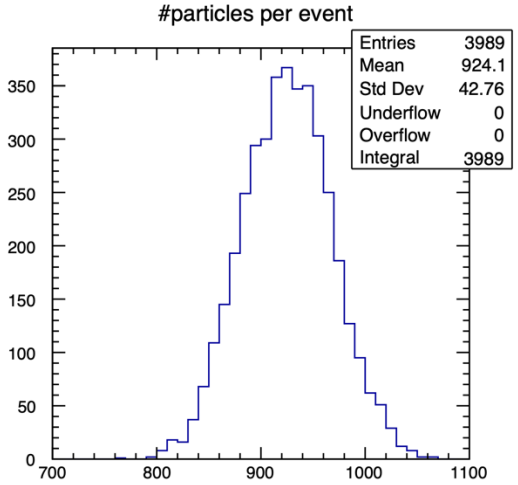
Average: 510 MeV

Sampling fraction: 0.510/45.6 = 1.1%

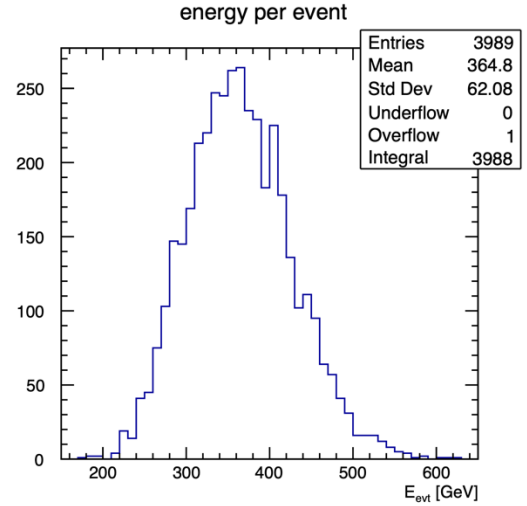
IPC particles at E_{beam} = 45.6 GeV

3989 events GP generated by Andrea Ciarma

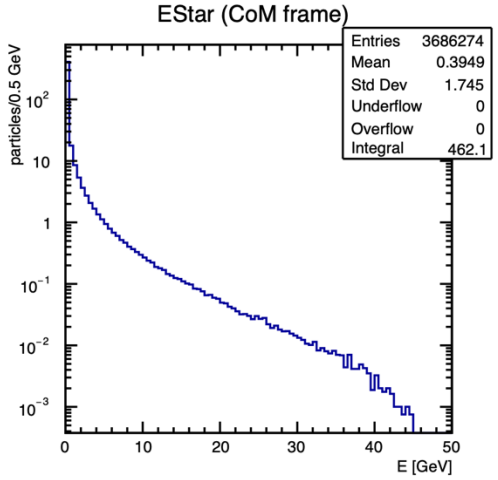
No minimum momentum cut-off on electrons



924 particles per BX

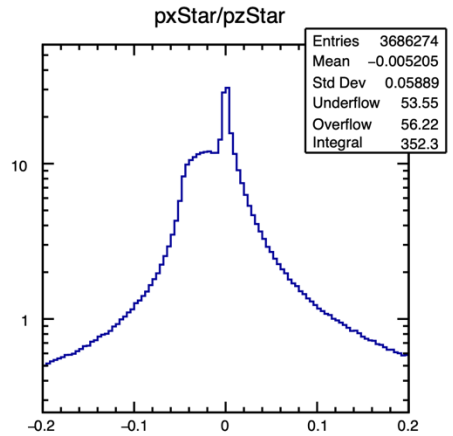
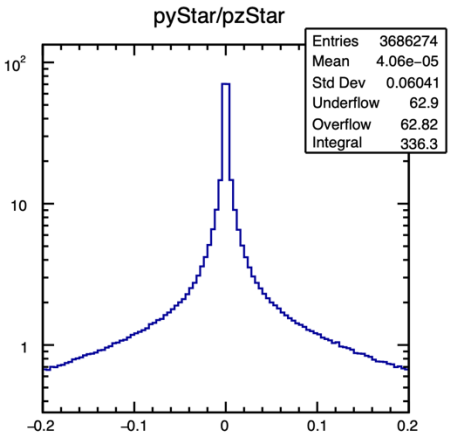
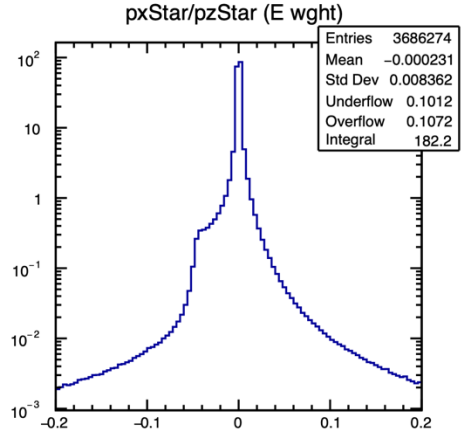
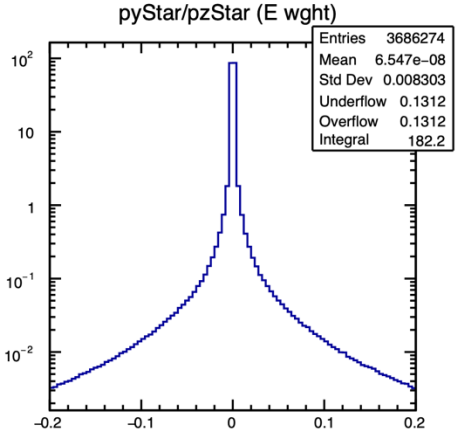


365 GeV per BX



Average particle energy: 395 MeV

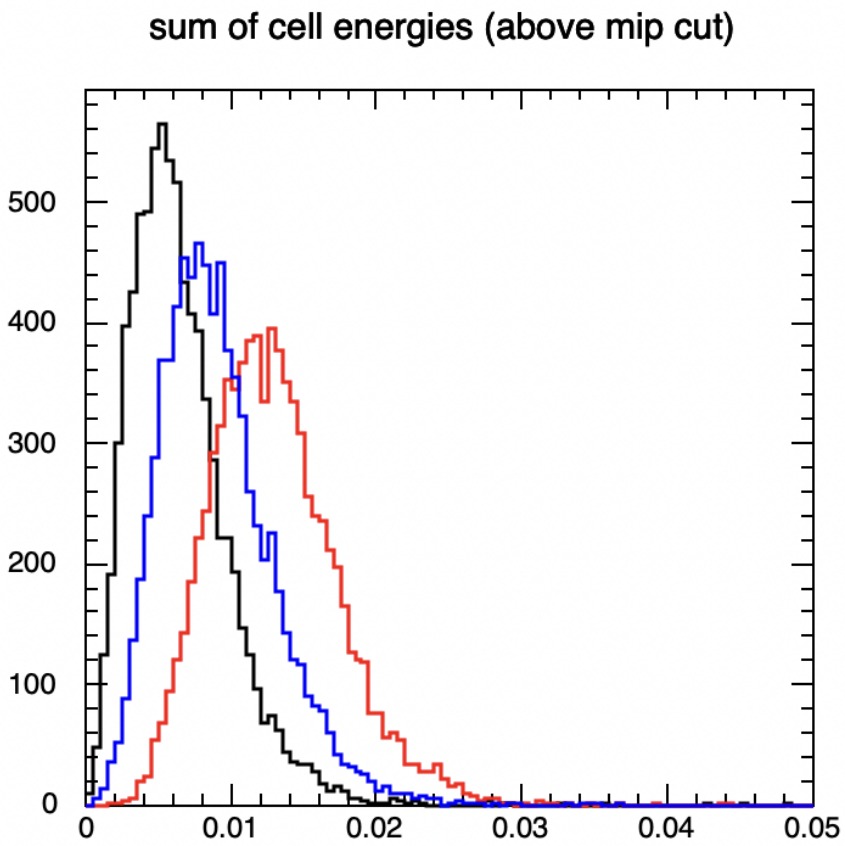
CMS Frame = LumiCal System

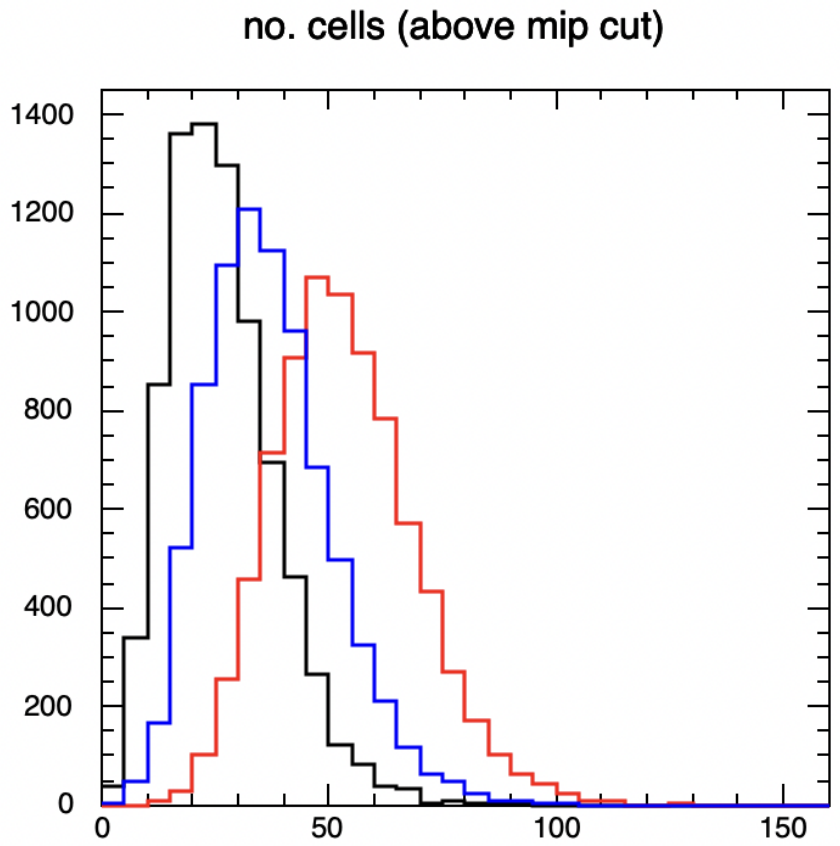
	px/pz	py/pz
Per particle		
Energy weighted		

Very strongly forward peaked (along outgoing beam)

- In particular, energy

Response to IPC (45.6 GeV)





- Red: No mag field
- Black: 2T field
- Blue: 2T + anti field

For full field (blue):

Avg. = 9.0 MeV

1.7% of 510 MeV (45.6 GeV electrons)

Avg. = 36 cells

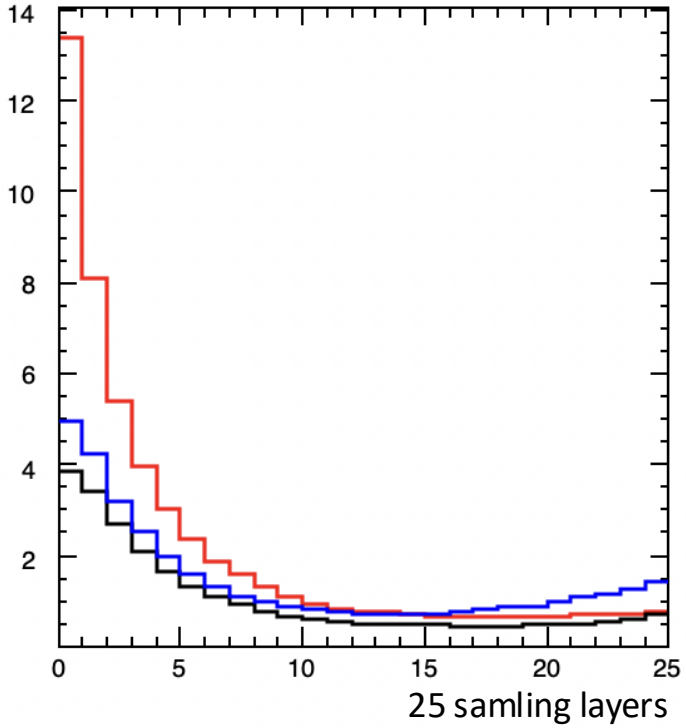
5.3% of 680 (45.6 GeV electrons)

IPC - Distribution of hit cells (45.6 GeV)

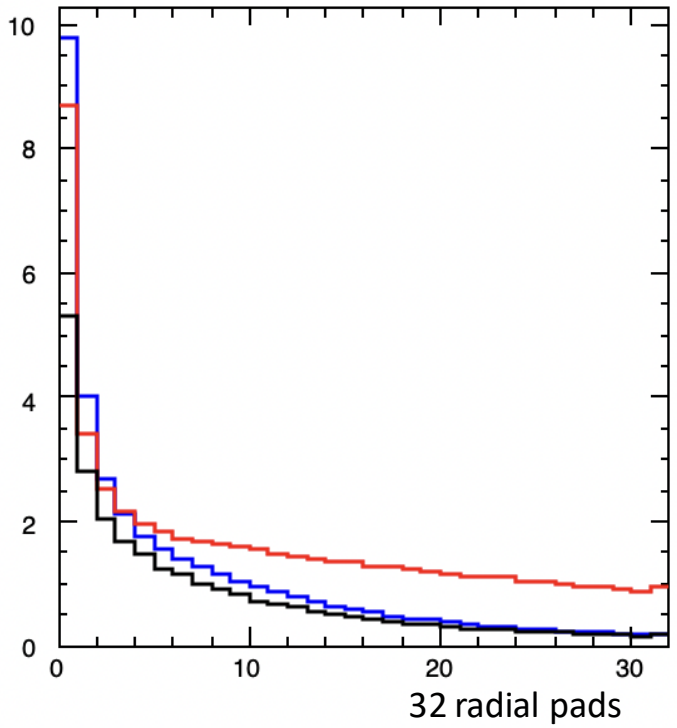
y-axes: #cells hit per event per LumiCal

- Red: No mag field
- Black: 2T field
- Blue: 2T + anti field

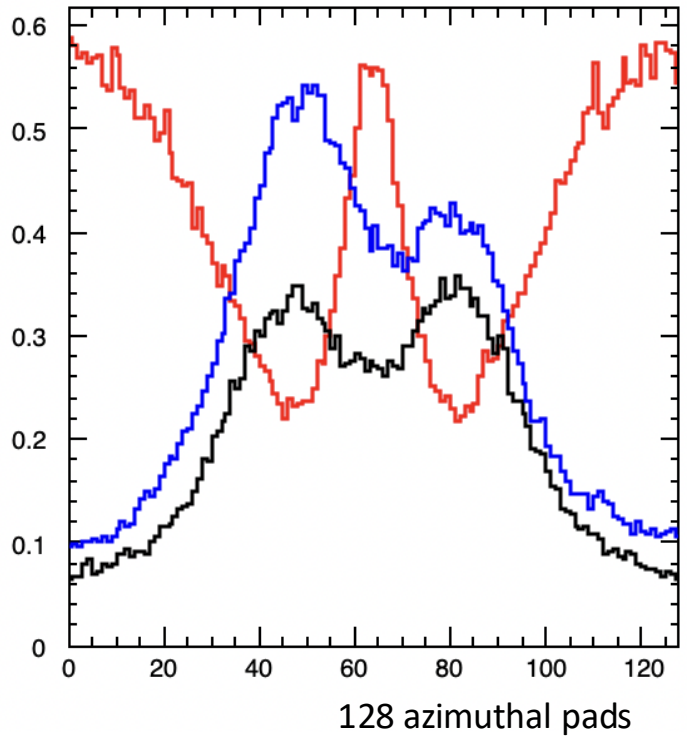
cell: layer



cell: radial sector



cell: phi sector



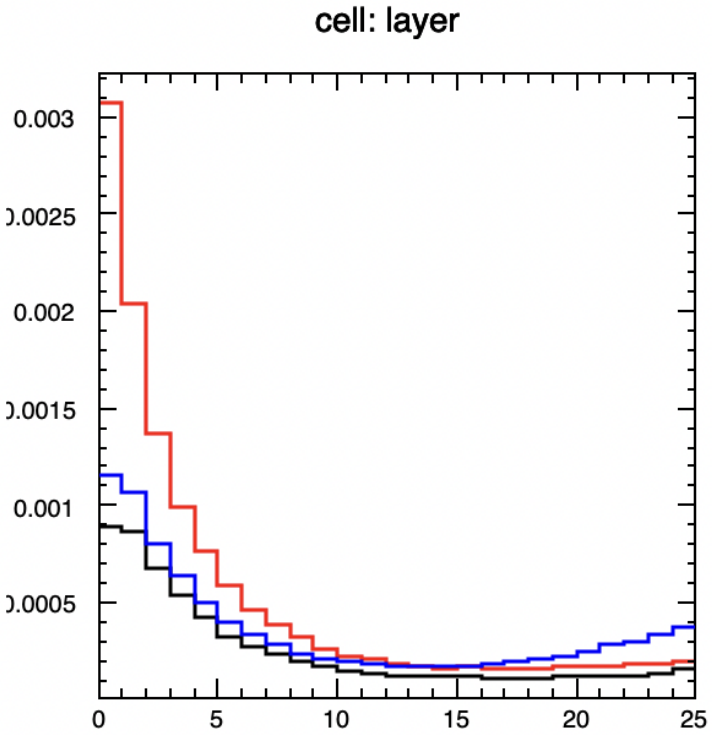
- Many particels hitting front face – also at larger radii
- Suppression in particular of particles hitting face
- Higher overall, but in particular at rear of LumiCal
  -> Divergence in radial coordinate of field

Complicated …

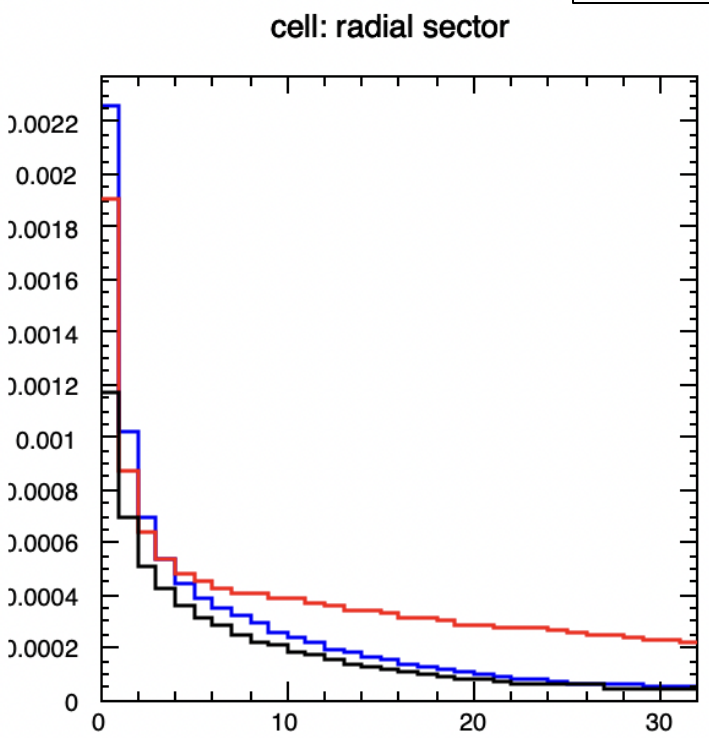
IPC - Distribution of deposited energy (45.6 GeV)

y-axes: deposited energy [GeV] per event per LumiCal

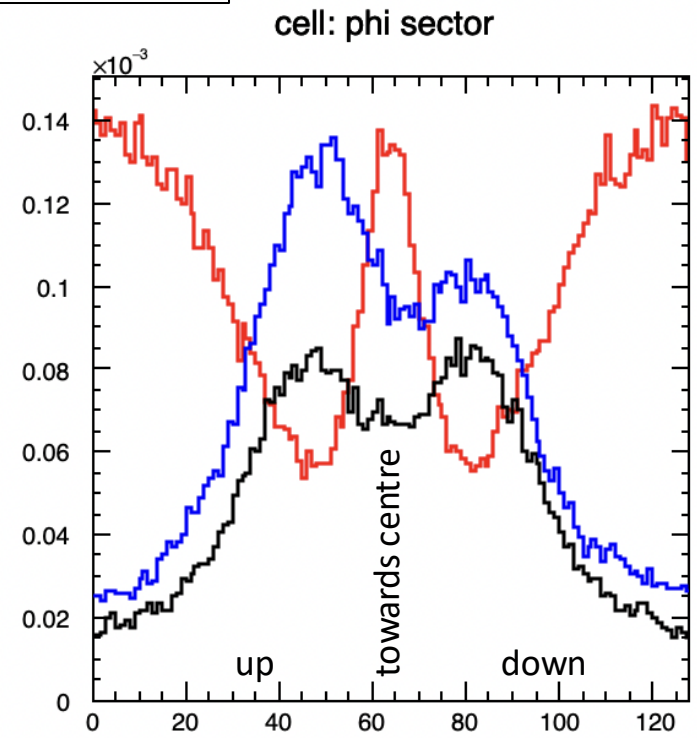
- Red: No mag field
- Black: 2T field
- Blue: 2T + anti field



25 samling layers

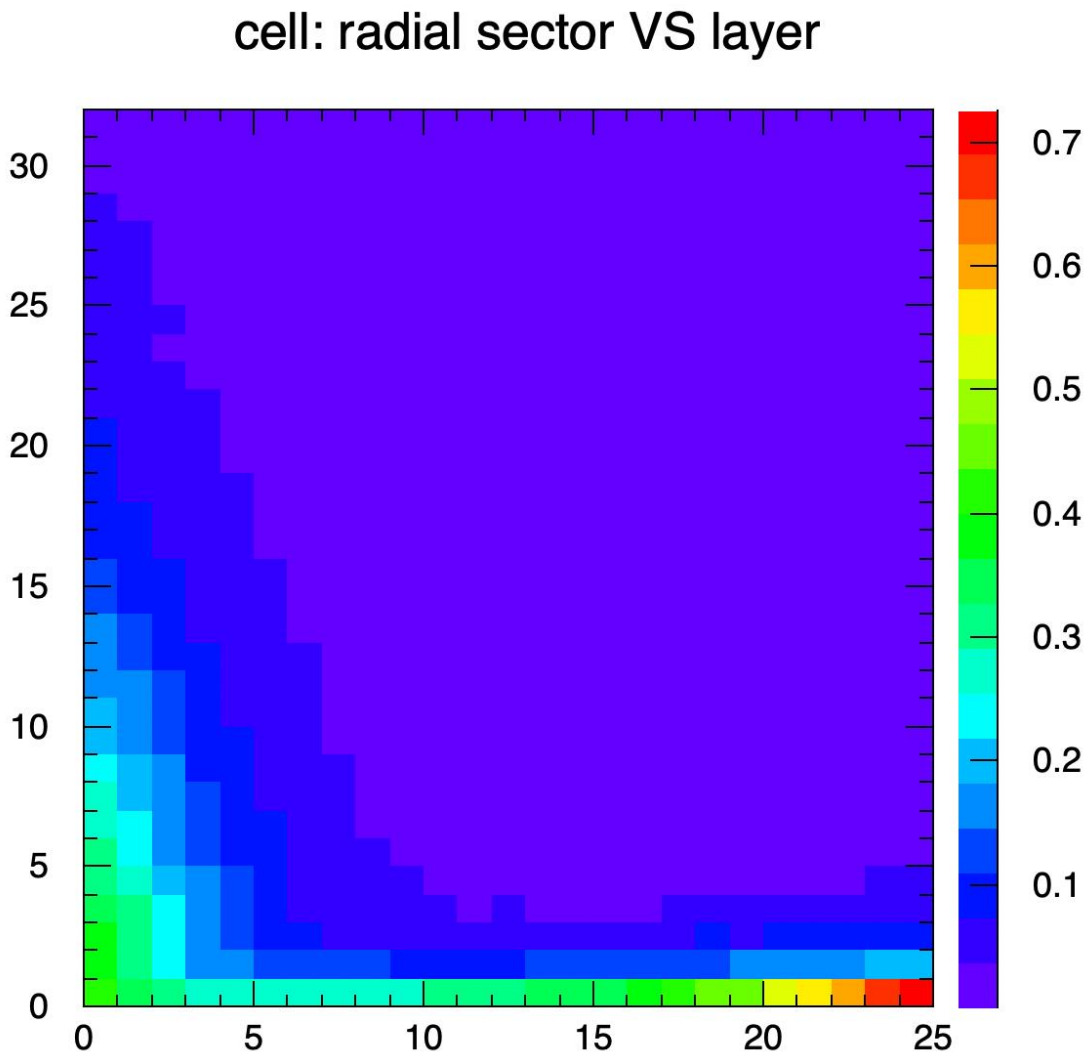


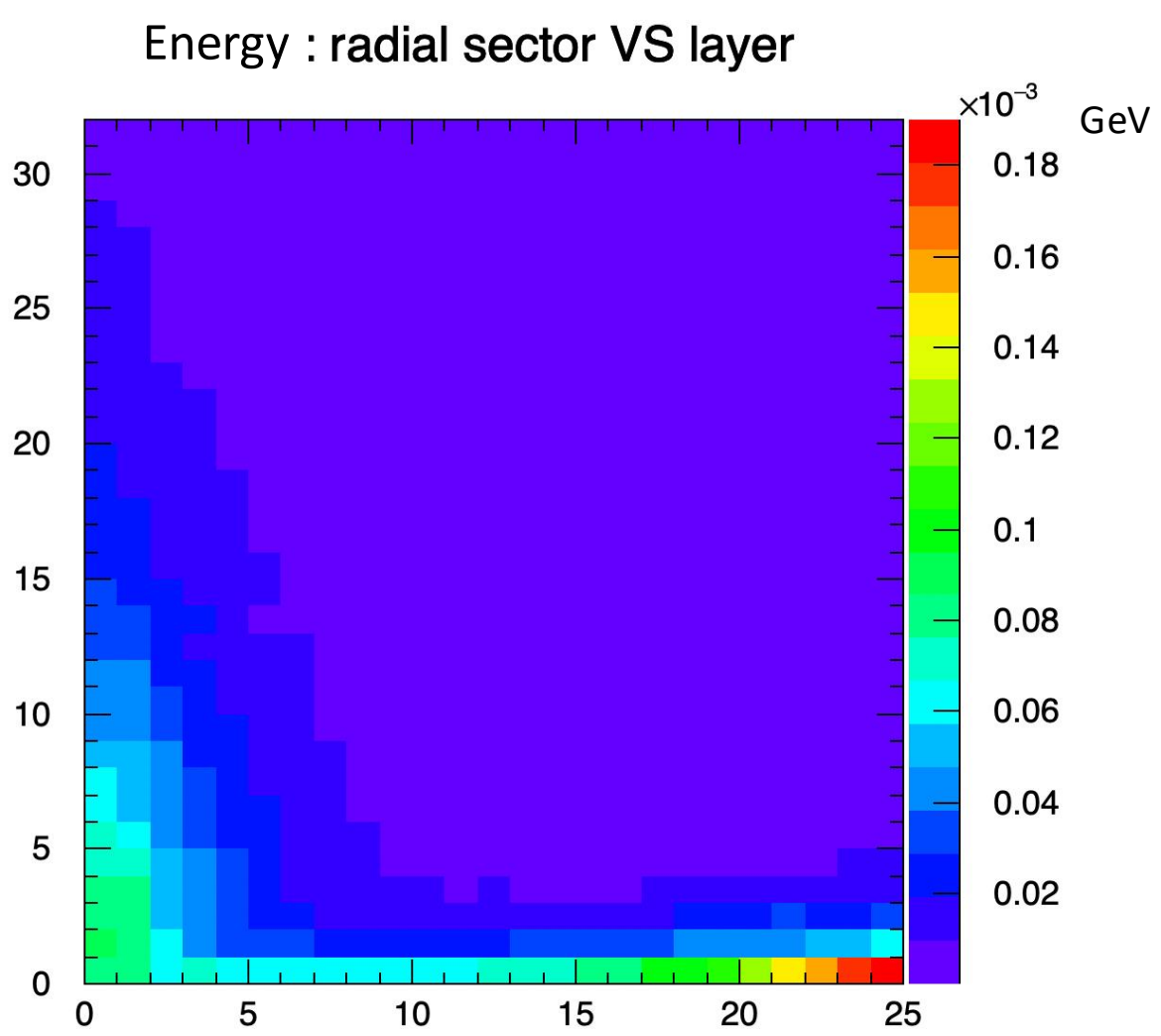
32 radial pads



128 azimuthal pads

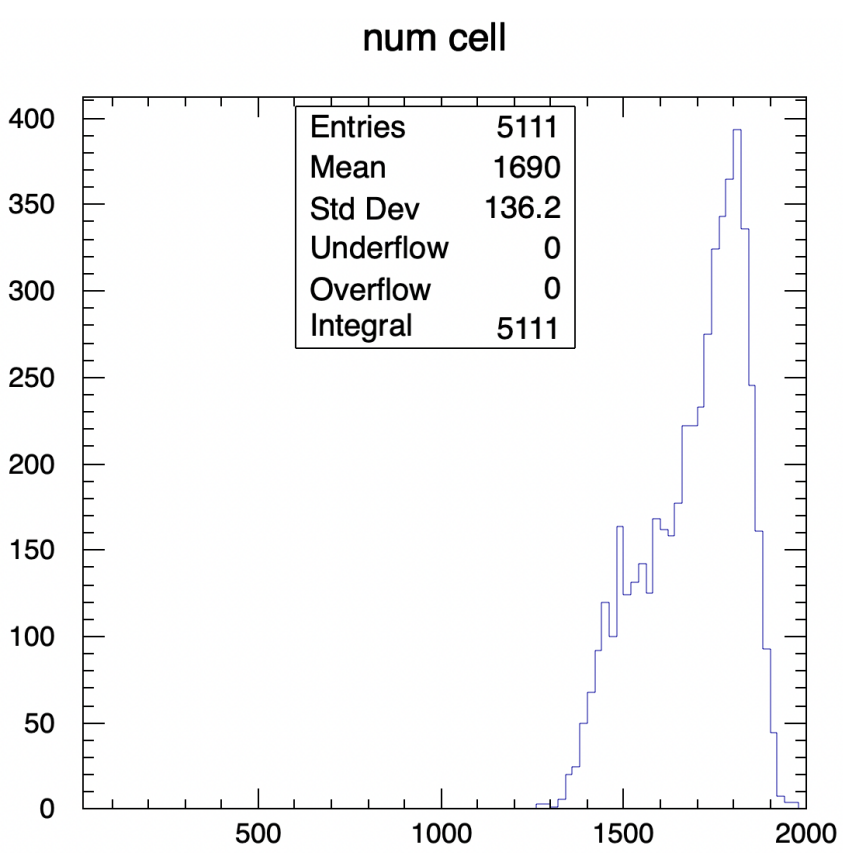
IPC - Distribution of hit cells and energy (45.6 GeV)



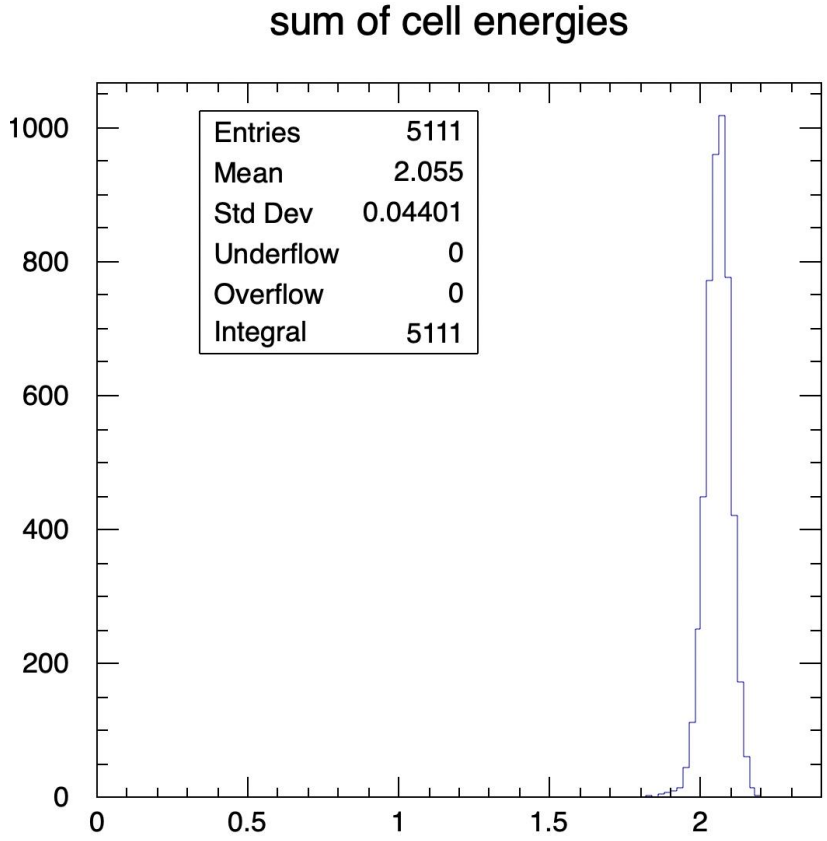


Full B field: 2T + anti solenoid

LumiCal response to 182.5 GeV electrons



Avg.: 1690 cells

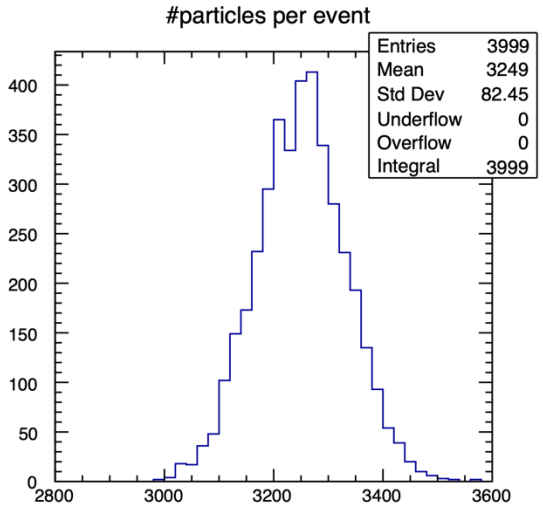


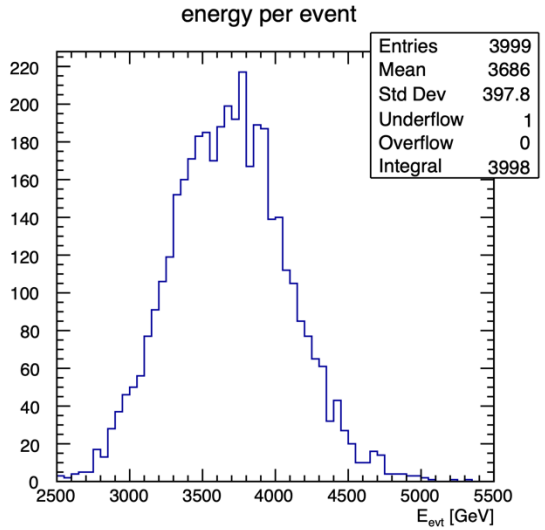
Avg.: 2.06 GeV

Expect: 182.5/45.6 * 0.51 GeV = 2.04 GeV

IPC particles at 182.5 GeV

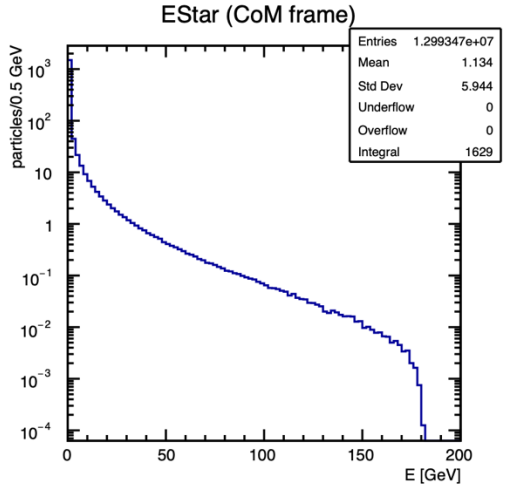
CMS Frame = LumiCal System





3250 particles per BX

3.6 TeV per BX

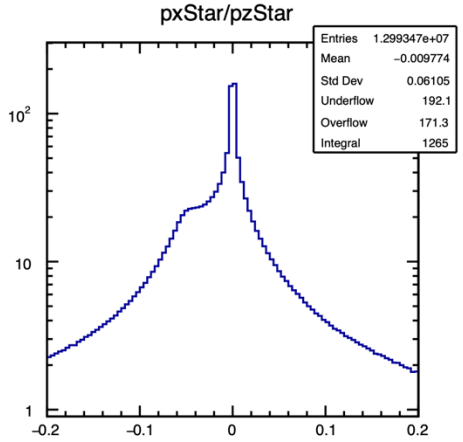


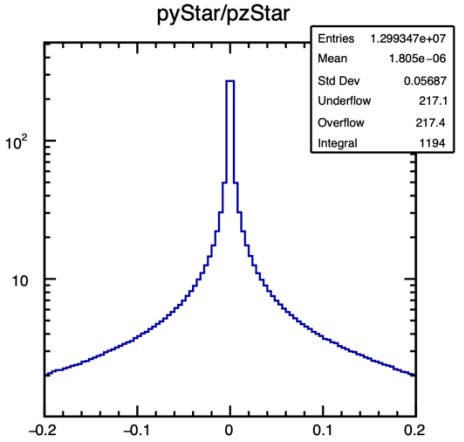
Average particle energy: 1.1 GeV

px/pz

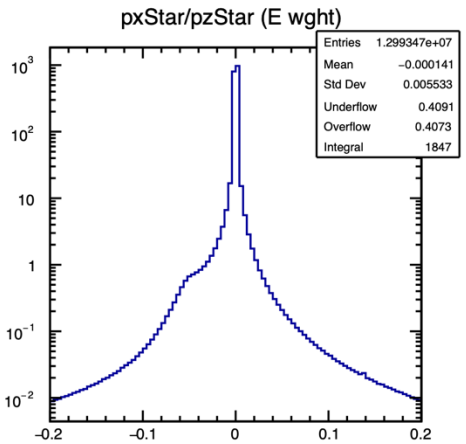
py/pz

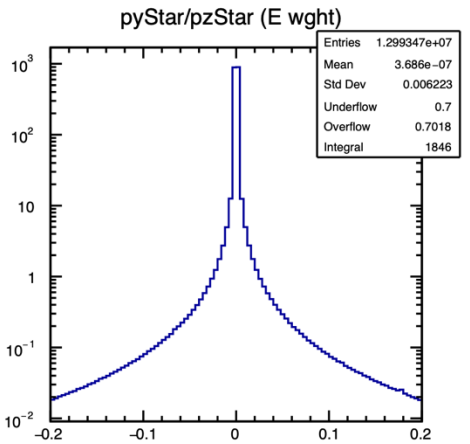
raw



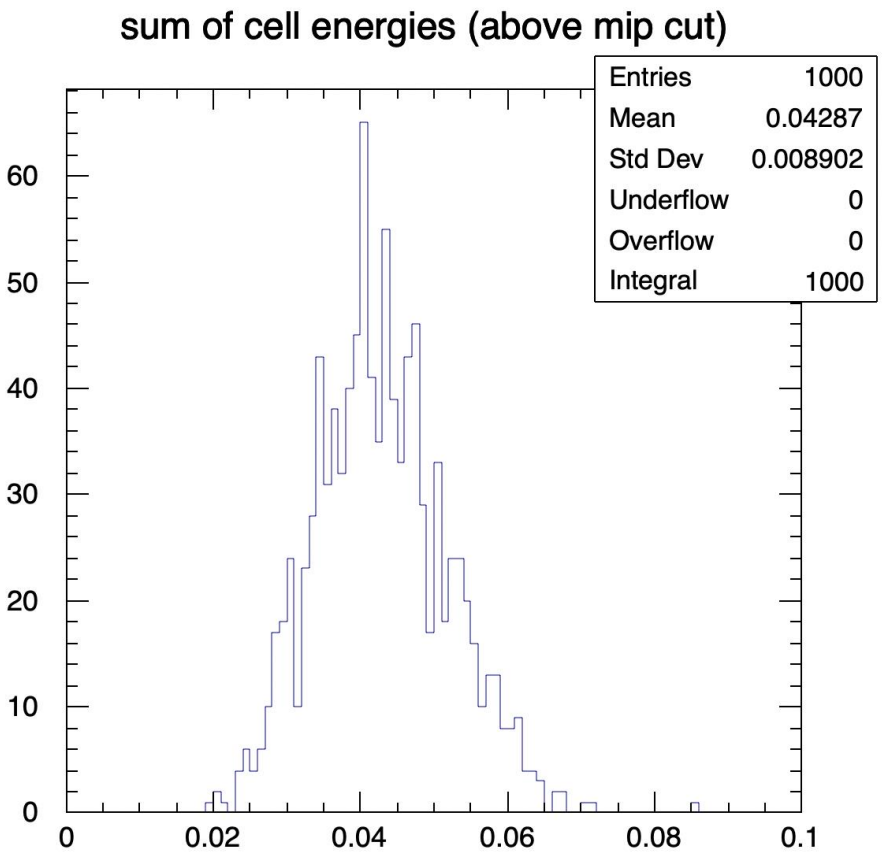


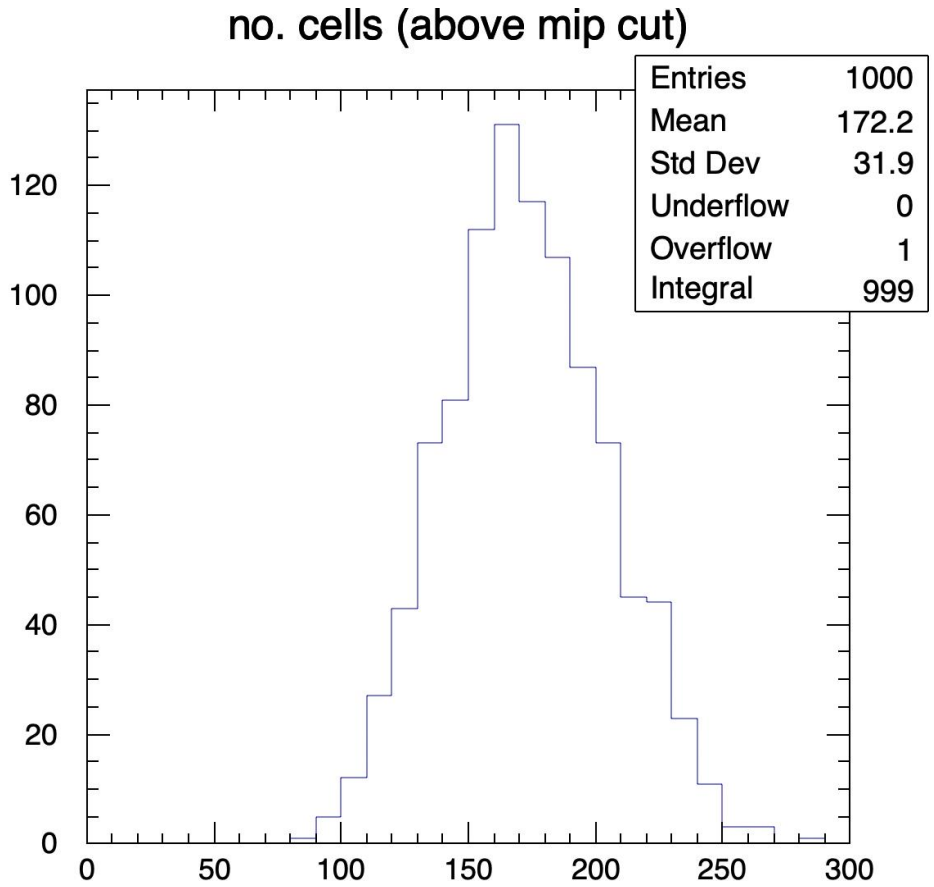
Energy weighted





Response to IPC (182.5 GeV)





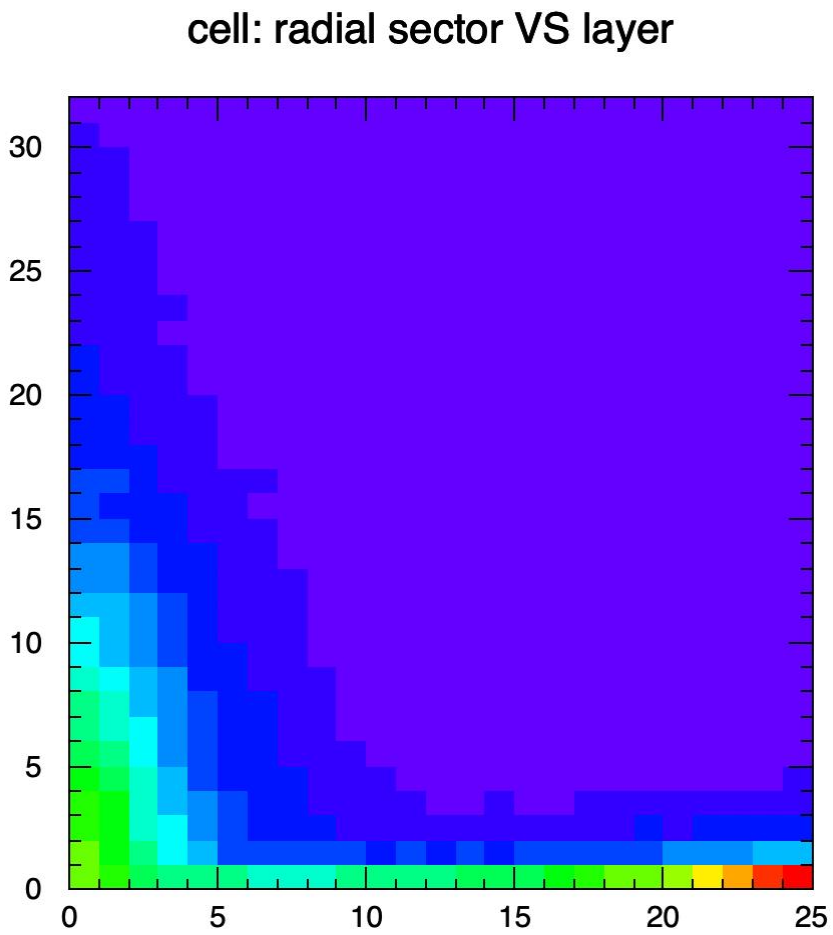
Avg. = 43 MeV

2.1% of 2.06 GeV (182.5 GeV electrons)

Avg. = 172 cells

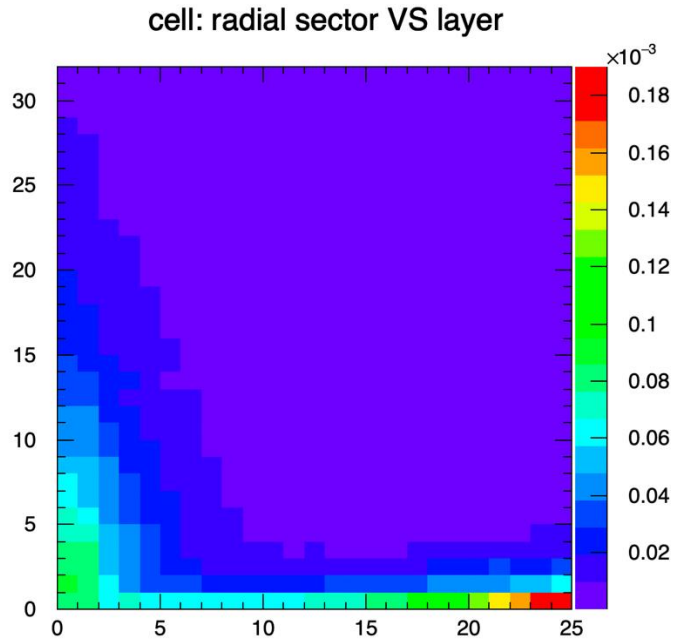
10.2% of 1690 (182.5 GeV electrons)

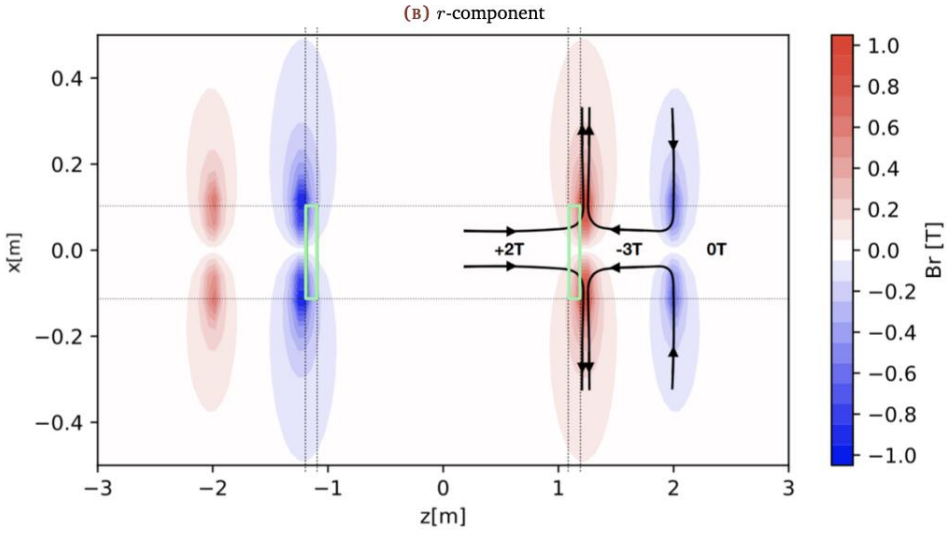
IPC - Distribution of deposited energy (182.5 GeV)



Conclusion on IPC

- Very large amount of energy radiated via incoherent pairs
  - 365 GeV / BX @ 45.6 GeV ; 3.6 TeV / BX @ 182 GeV
- Of that hitting LumiCal
  - 0.8 GeV / BX @ 45.6 GeV ; 4.0 GeV / BX @ 182 GeV
  - 1.7 % of Bhabha shower ; 2.1 % of Bhabha shower
- 2 T detector field helps to focus these events down below LumiCal acceptance
- ”Collision” of 2T field with -3T anti-field creates divergence of particles at rear end of LumiCal
  - Hot spot
- However, probably hot front lower corner is a bigger problem.
  - Possibly need shielding





A few words on Radiative Bhabhas

Helmut Burkhardt

https://indico.cern.ch/event/864680/

Radiative Bhabha or Beam-Beam Bremsstrahlung

large cross section, several hundred millibarn (larger than pp)

~ completely dominating the lifetime with collisions

1st process observed in e+e- collisions, 1963 with AdA @ LAL

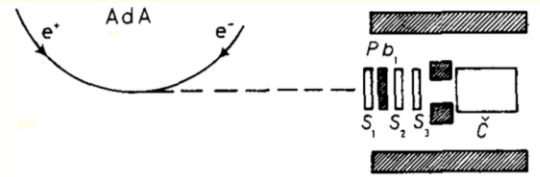
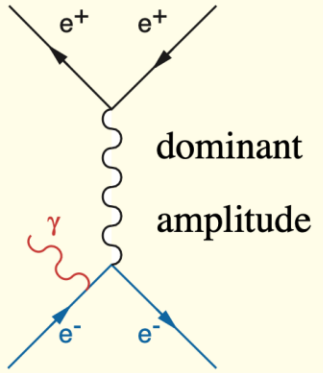


Fig. 3. – Experimental arrangement for the observation of γ-rays from the reactions $e^+ + e^- \to e^+ + e^- + \gamma$ and $e^+ + \text{gas molecule} \to e^+ + \text{gas molecule} + \gamma$.



Fast eventgenerator BBBrem by Ronald Kleiss + H.B. , 1994

based on Matrix element e+e- —> e+e-γ **with mass terms** for scattering angles down to 0

excellent agreement with measurements at LEP

as documented in "Beam Lifetimes at LEP" EPAC94

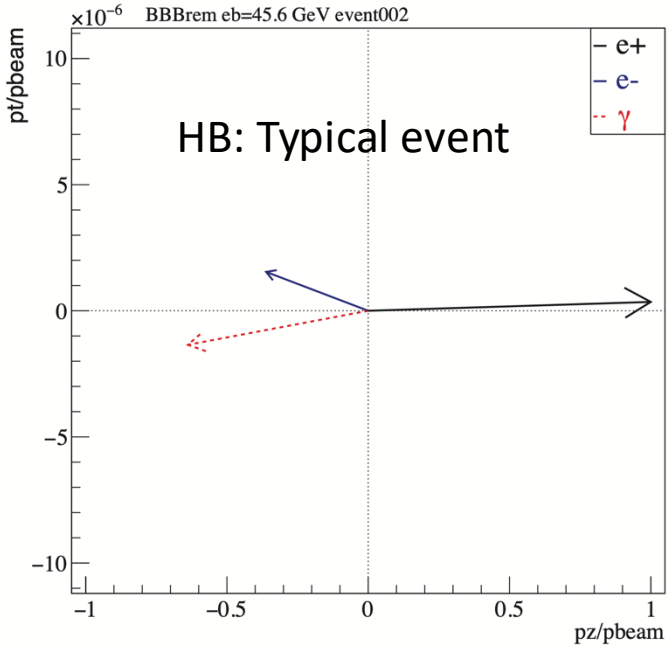
and "Beam Lifetime and Beam Tails in LEP" at e+ e- Factories '99

BBBrem generator:
https://gitlab.cern.ch/hbu/bbbrem

Very easy to setup and run

Running BBBrem

- Running BBBrem
  - Beam energy: E_{beam} = 45.6 GeV
  - Photon energy cut: E_γ / E_{beam} > 0.5
  - t-channel momentum transfer cut off reflecting beam size (36.5 nm): sqrt(-t) > 5.41079e-09 GeV [A.Ciarma]
  - Unweighted events
  - ☞ **σ = 18.3 mbarn** (10^6 times LumiCal cross section)



#---- text and binary output format Columns:

q2_1 q2_2 q2_3 q2_4 p2_1 p2_2 p2_3 p2_4 qk_1 qk_2 qk_3 qk_4

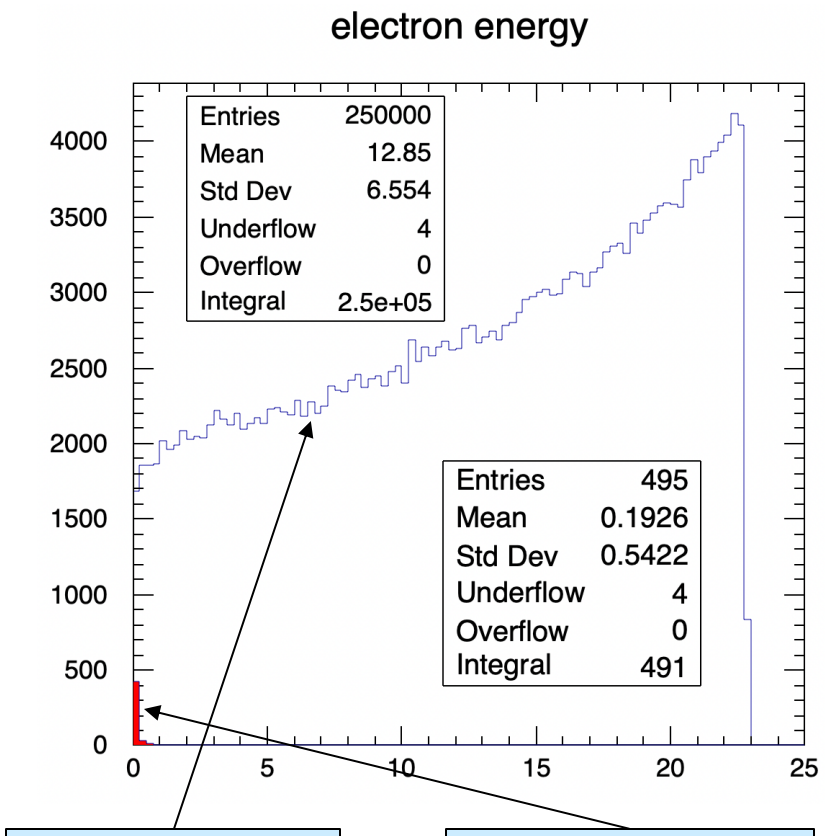
positron electron photon

four-vectors

In BBBrem, electron move towards negative z (?).
I like positive numbers: simply change sign on all z-momenta

BBBrem result

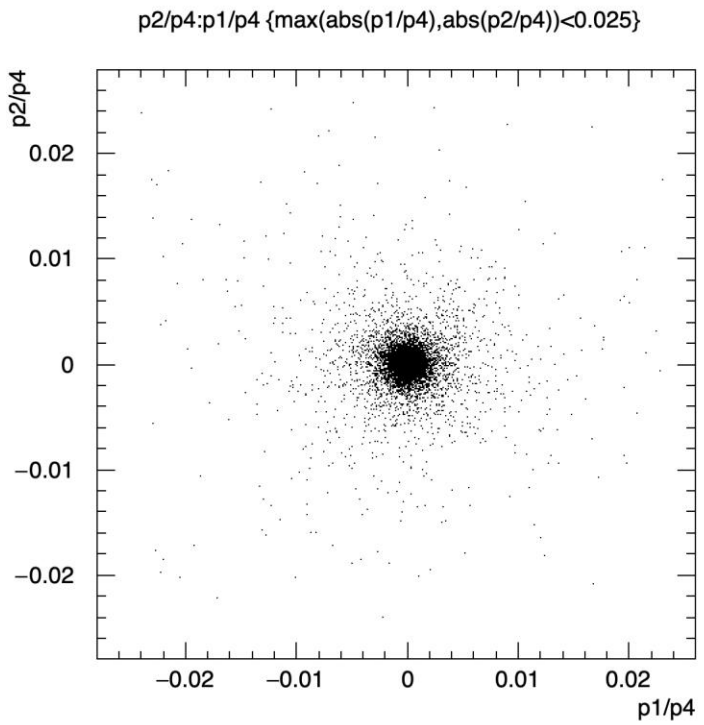
Electron after photon radiation



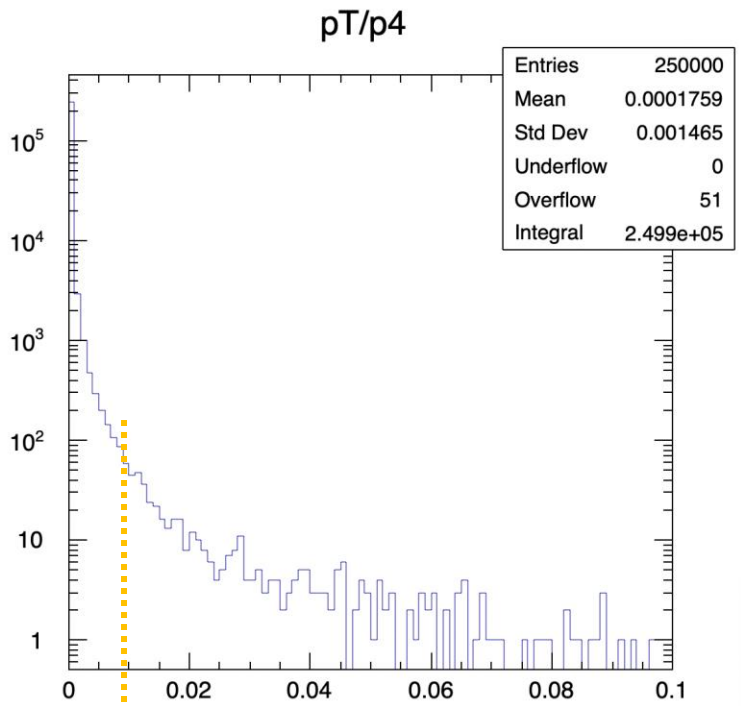
No cuts:
- 676 e^- / BX
- 8.7 TeV / BX

pT/E > 0.01
- 1.3 e^- / BX
- 260 MeV / BX

Leaving beam pipe before 1 m



Angular distribution is symmetric



Leaving beam pipe before 1 m
- 0.2% of e^-
- 0.003% of energy

Running GuineaPig

Program easily available – on lxplus:

$ source /cvmfs/sw.hsf.org/key4hep/setup.sh
$ guinea

Prepare bahbha.ini file

```
event index |
px1 | py1 | pz1 | E1 |
px2 | py2 | pz2 | E2 |
number of photons
```

e^- moving towards positive z

e^+ moving towards negative z

Use accelerator parameters from A. Ciarma

```
$ACCELERATOR:: FCCee_Z_4IP_29may24
{energy=45.6;
particles=21.6;
beta_x=110;
beta_y=0.7;
sigma_z=15600;
dist_z.1=0;
dist_z.2=0;
sigma_x=8775.;
sigma_y=36.5;
offset_x=0.0;
offset_y=0.0;
n_b=1;
f_rep=1;
angle_x=-0.015;
charge_sign=-1;
}
```

Output

The **pairs.dat** file contains the same information as the **pairs0.dat** file, but after tracking (when the particles are "far" from the IP, and have been deflected by the EM field of the bunch they left):

```
event index | E1 | vx1 | vy1 | vz1 | x1 | y1 | z1 |
event index | -E2 | vx2 | vy2 | vz2 | x2 | y2 | z2 |
```

The rows in the **pairs.dat** file are shuffled. They can be sorted using the following shell instruction:

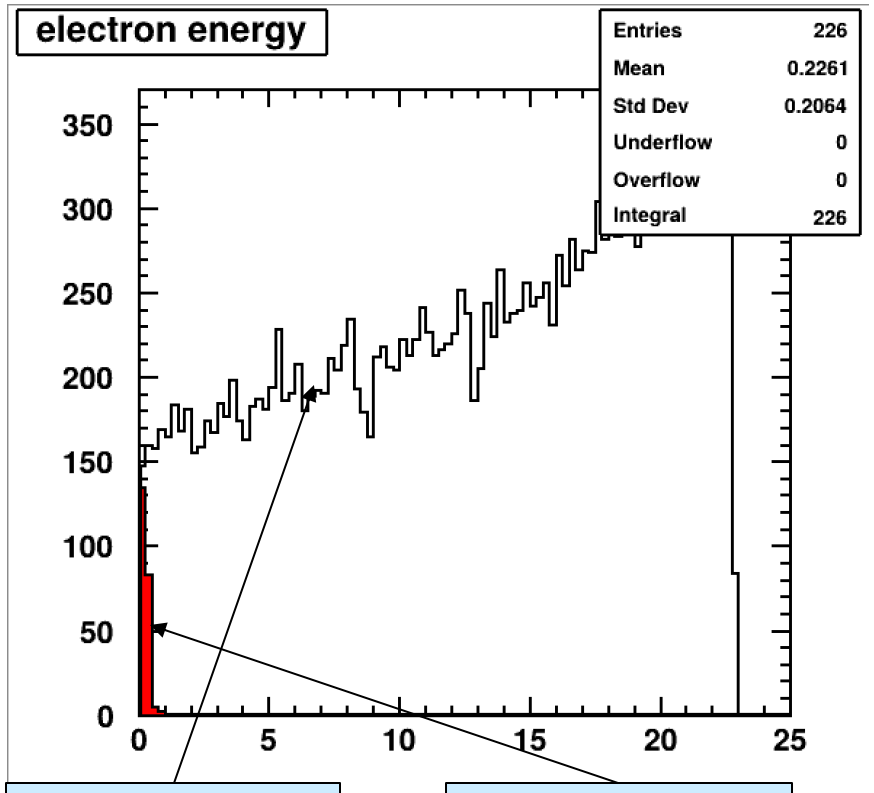
velocities

For some reason GuineaPig gives me 21331 Bhabha events in output

```
1 3.13569 -0.000560813 -7.22316e-05 1 436077 -4550.79 6.22234e+07 -1 0 0
1 -45.6 -6.12452e-05 -6.17759e-05 -1 464130 -3856.85 -6.20907e+07 -1 0 0
2 19.8655 -0.000182926 4.58358e-05 1 457291 2806.47 6.1838e+07 -1 1 1
2 -45.6 -5.90257e-05 -1.65244e-05 -1 458630 -1063.53 -6.18913e+07 -1 1 1
...
```

GuineaPig Result

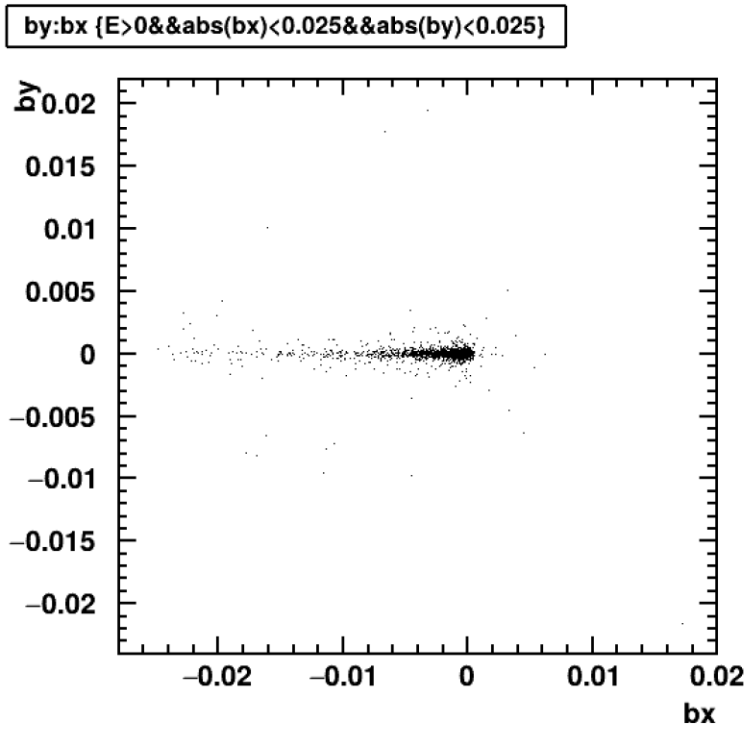
Preliminary – need checks



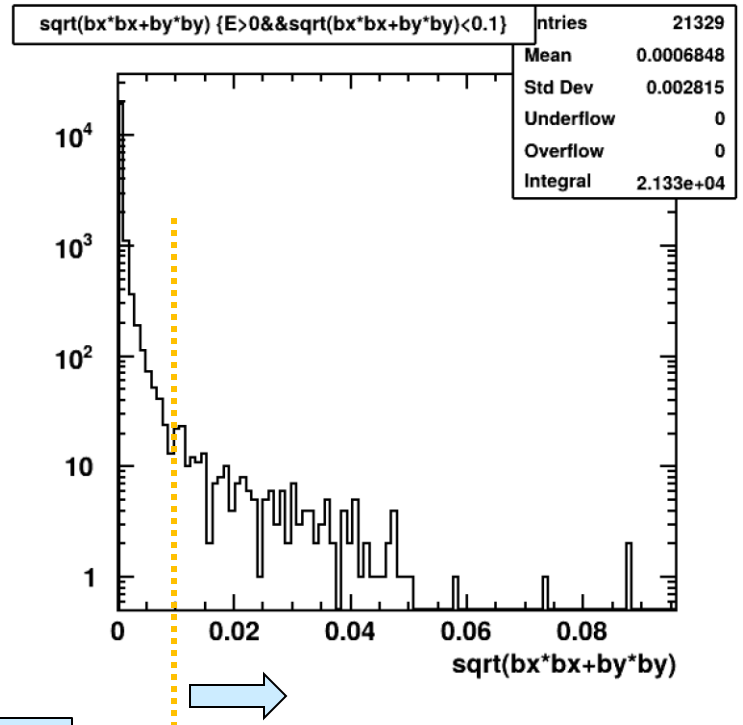
No cuts:
- 676 e^- / BX
- 8.6 TeV / BX

pT/E > 0.01
- 7.2 e^- / BX
- 1.6 GeV / BX

Leaving beam pipe before 1 m



Angular distribution unsymmeric
- Defocussing of electrons by opposing beam
- Mainly for low energy electrons



Leaving beam pipe before 1 m
- 1.1% of e^-
- 0.02% of energy

Run GuineaPig events through FullSim

Very preliminary – need checks

- Out of 21331 “Bhabha events” in 31 bunch Crossings, only 9 leave signal in LumiCal
- A total of 93 cell hits oberved in 31 bunch crossing with a total of 18 MeV deposited in Si
- With a sampling fraction of 1.1% this gives about 60 MeV incoming energy per event
  - About 0.1% of 45.6 GeV for “real” Bhabha event
  - Factor 20 below ICP level