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4D shower simulation and digitization

M. Ramilli

CALICE collaboration Meeting
Matsumoto, 05/03/2012

Overview

- Motivation: the Fall Test-beam experiment
- Timestamping: implementation of the ASIC logic in digitization
- Results of the simulations
- Outlook

The Fall 2012 Test Beam Experiment

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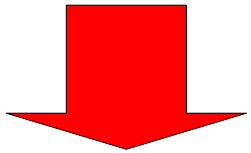
Event:
• planned CALICE test beam in fall 2012 at CERN SPS
• (minimum) 1 layer of AHCAL technological prototype (4 HBUs) to be mounted downstream the DHCAL

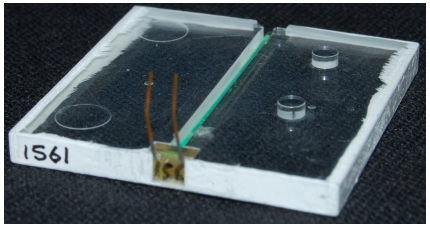
Physics goal of the Test Beam Experiment:
•Electronic test of the multi-HBU readout in the beam
•Study of time development of hadronic showers (extended T3B study with one complete layer)



simulations have been performed to prepare the physics case

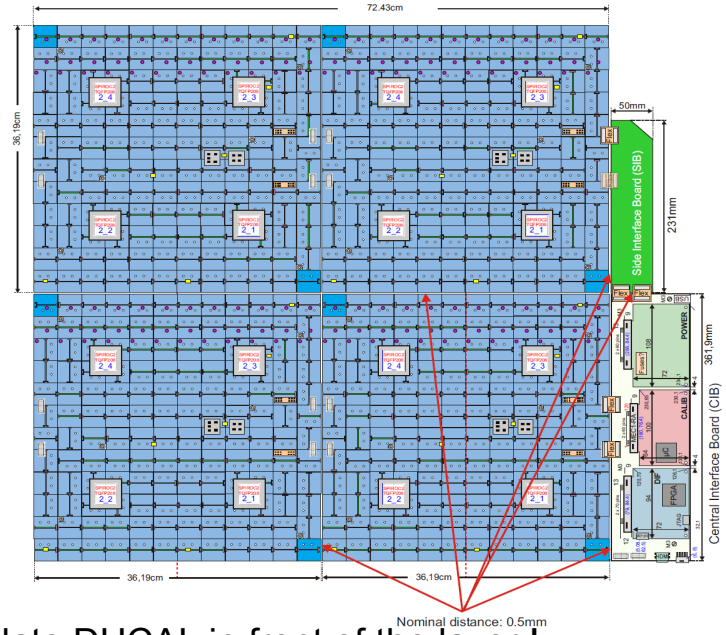
The Simulation

The layer:
- 4 HBUs each one equipped with 144 tiles with 3 cm side
- each tile is 3 mm thick



New Mokka driver had been developed by Shaojun Lu (TBhcal4d)
some calorimeter parameter can be modified from steering file:

parameter	value	steerable?
Cell border	30 mm	yes
N of cells x, y	30	yes
Integration time	500 ns	yes
Absorber	Tungsten	no
Cell thickness	3 mm	no
N of layers	38	yes



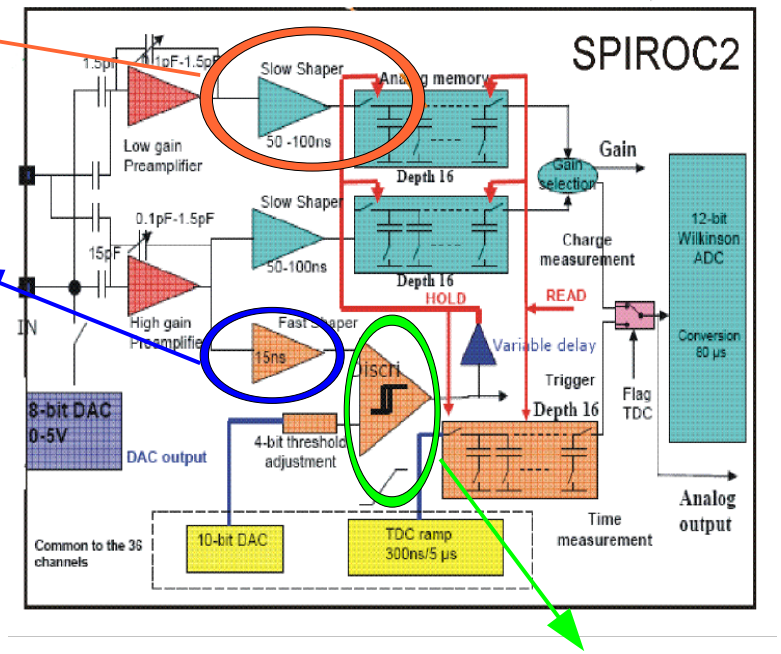
to simulate DHCAL in front of the layer !

- 50 GeV muons – 10000 events with QGSP_BERT and QGSP_BERT_HP
- 10 GeV pions – 100000 events with QGSP_BERT and QGSP_BERT_HP

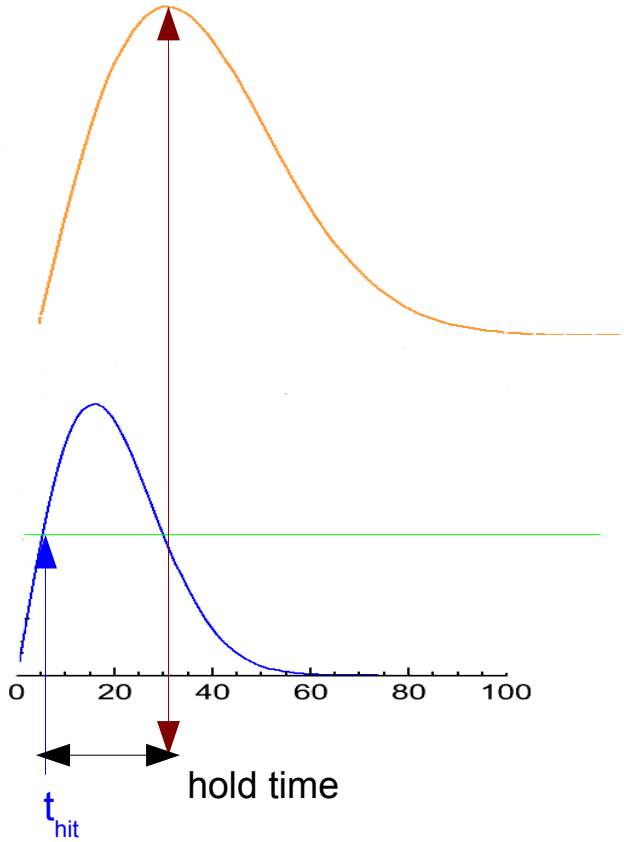
Timestamping: the ASIC

Slow shaper

Fast shaper



Threshold discriminator



Hit signal splitted:

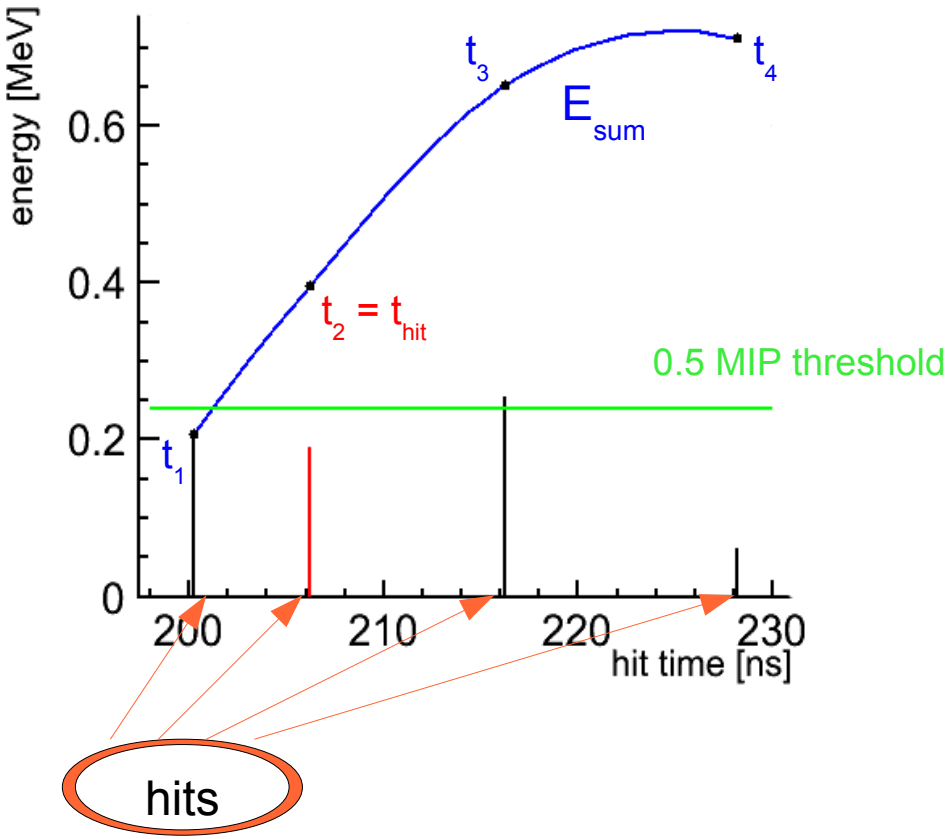
- A fast shaper (~ 25 ns shaping time) feeds a threshold discriminator;
- A slow shaper (~ 50 ns) feeds the analog memory;

Whenever fast signal amplitude passes the threshold:
- Time information is stored (of threshold passing);
- Amplitude of slow signal at hold time is stored;

(Thanks to Mark for the useful discussions)

Timestamping: digitization

For each cell several hits characterized by:
•A time value
•A deposited energy value



To simulate ASIC behavior, for each Cell:

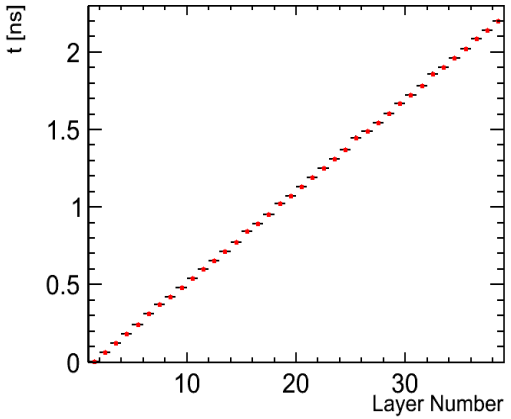
1a) hits are temporally ordered
1b) hit energy is added until $t_i = t_1 + 25$ ns
1c) $t_{hit} = t_i$ first hit passing threshold

2) E_{sum} = sum of E_i until $t < t_{hit} + t_{hold}$ $t_{hold} \sim 50$ ns

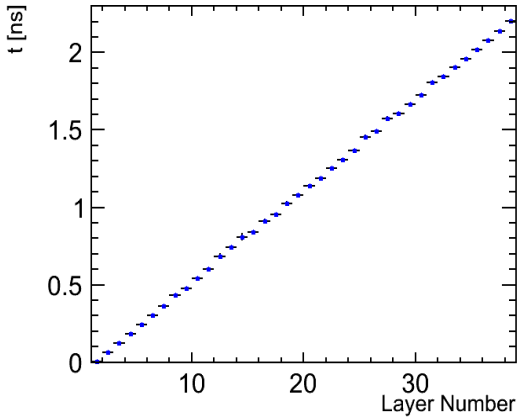
No ASIC noise or time jitter had been considered yet ...

Muon Runs

50 GeV muon QGSP_BERT_HP

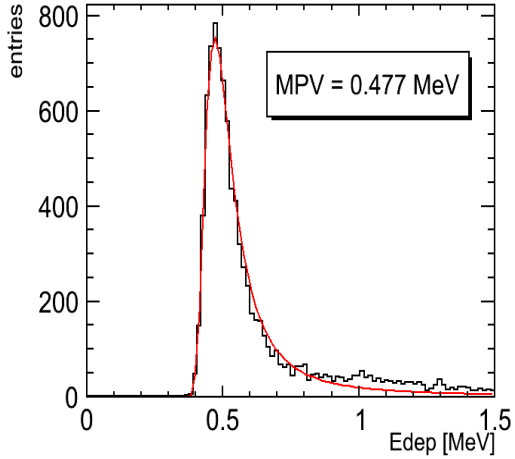


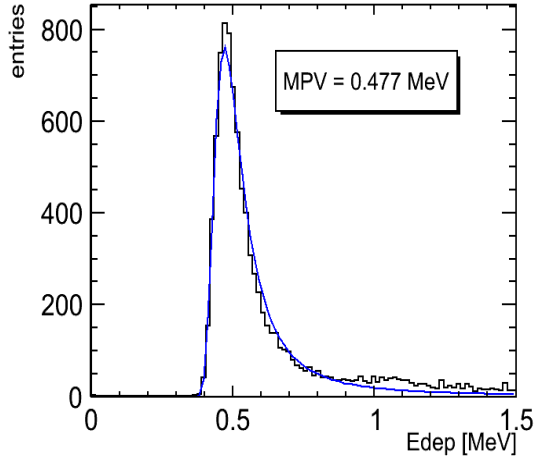
50 GeV muon QGSP_BERT



Time Of Flight correction:
0.06 ns/layer

Energy deposited in one cell:





MIP value cross-check:
MIP_{3mm} = 477 keV = 3/5 MIP_{5mm}

Pions: Hits time Distribution

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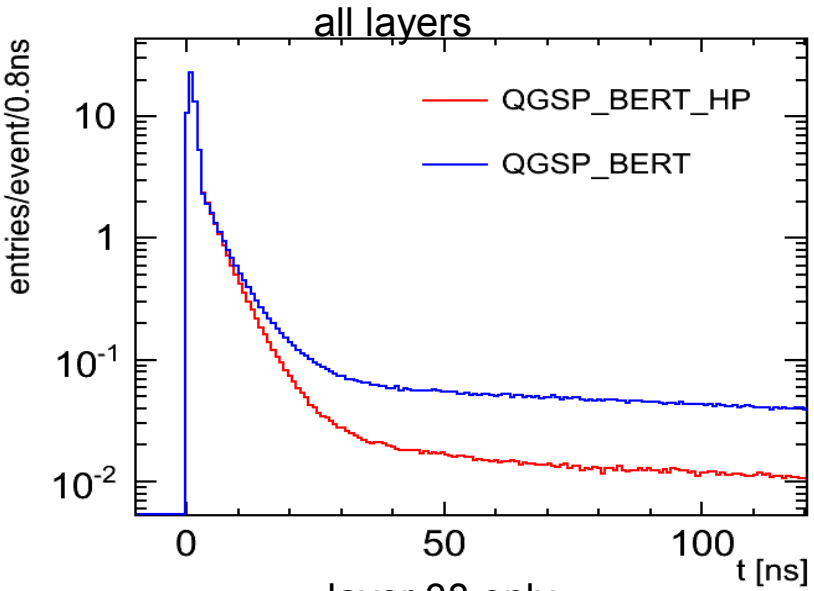
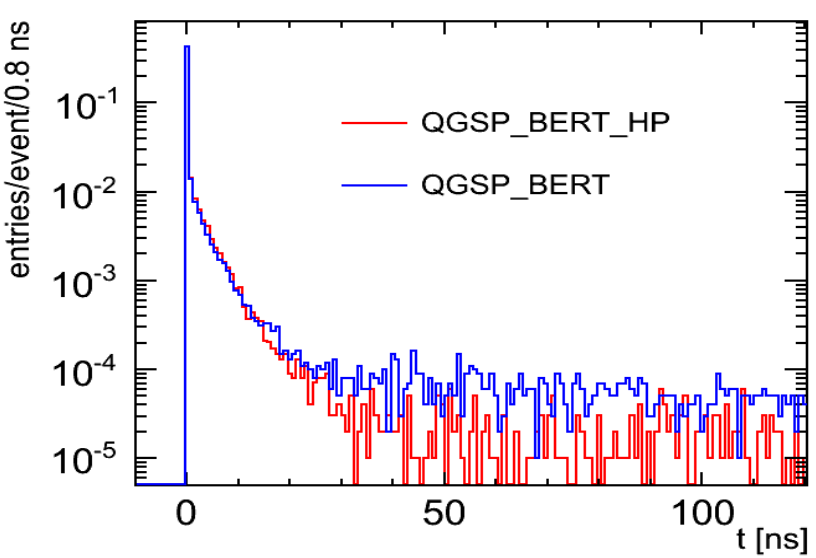
10 GeV pions hit time distribution:

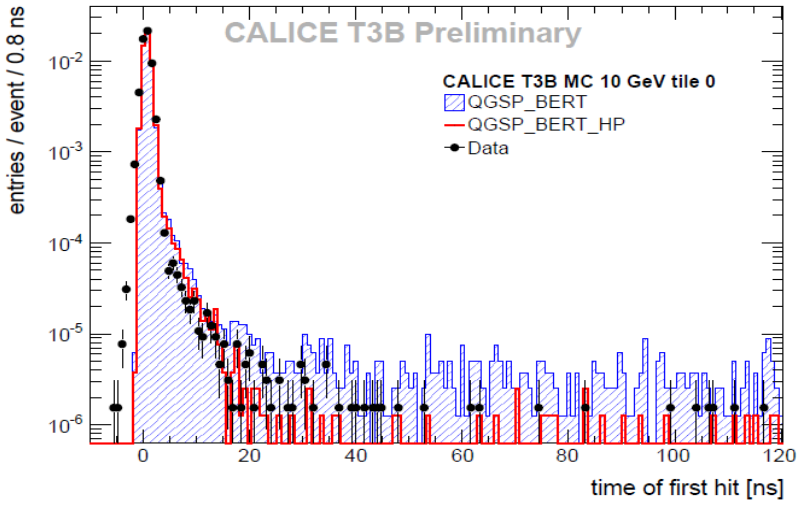


Physics lists predict different time behavior:
HP physics List has less late events over threshold

Less evident when restricting only to layer 38



T3B simulations and data



Mean Layer Dependance

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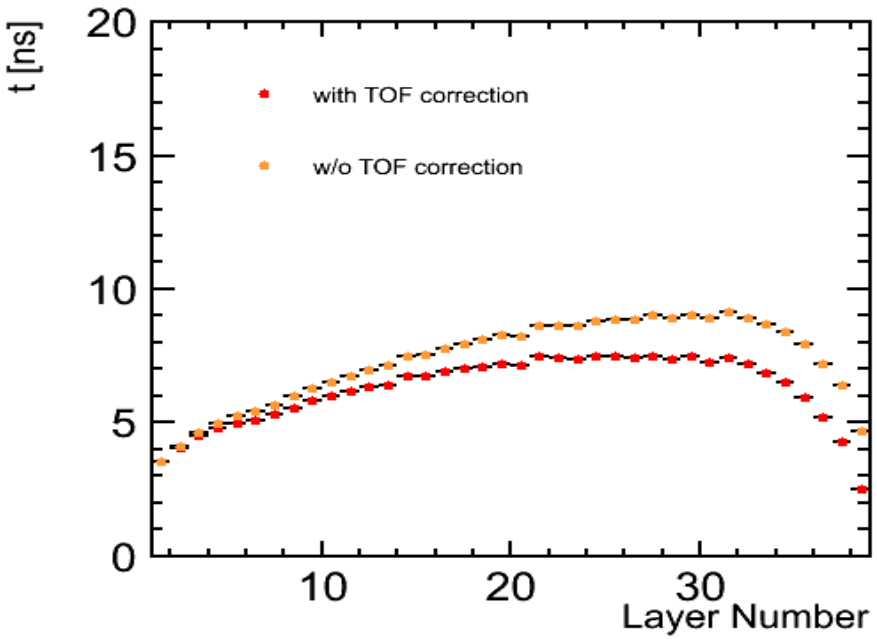
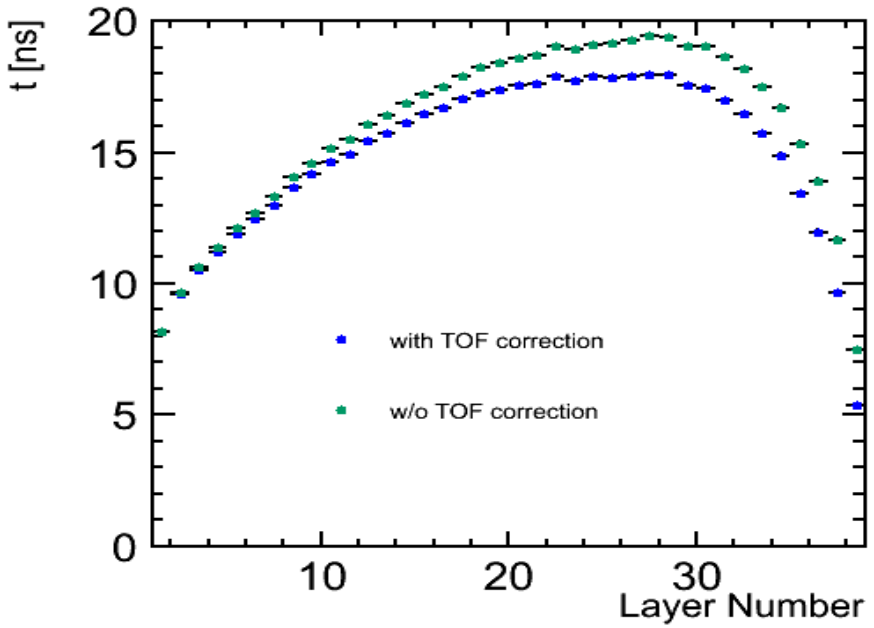
Mean hit time per layer:

10 GeV pions QGSP_BERT_HP



10 GeV pions QGSP_BERT

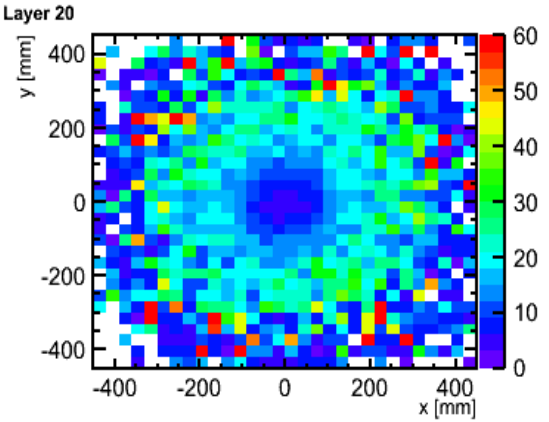


•Late shower component more present between layers 5 and 30;
•HP physics list predicts an overall faster shower development;

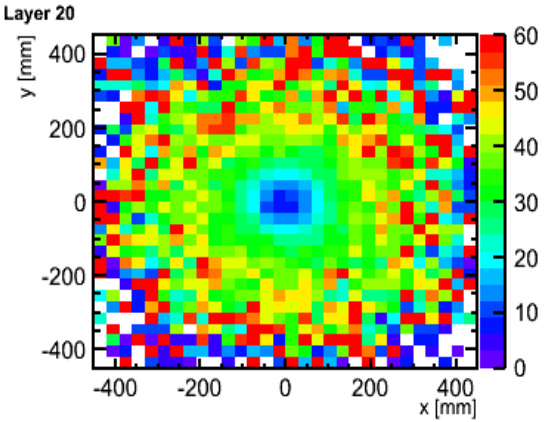
Single-Layer Time Distribution

Average hit time distribution as function of the hit position:
(timescale in ns indicated by palette colors)

10 GeV pion QGSP_BERT_HP

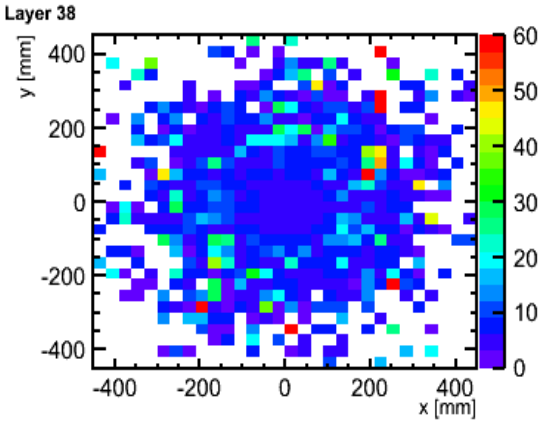


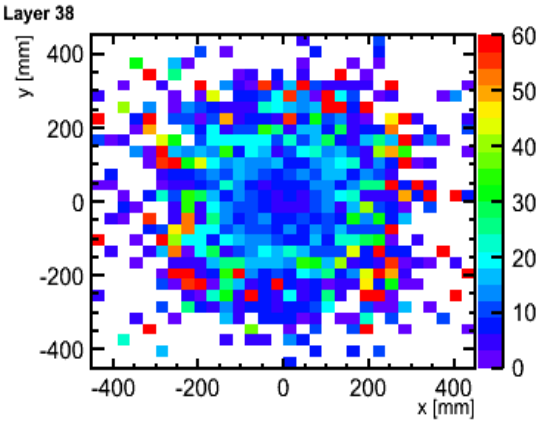
10 GeV pion QGSP_BERT



On average later hits are found:

- at larger radii
- in inner layers
- for non-HP physics list





Single-Layer Time Distribution

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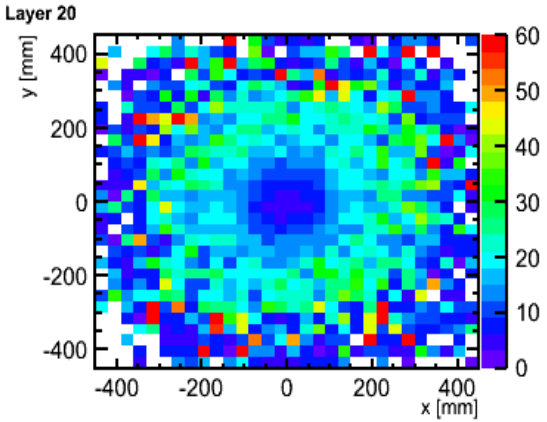
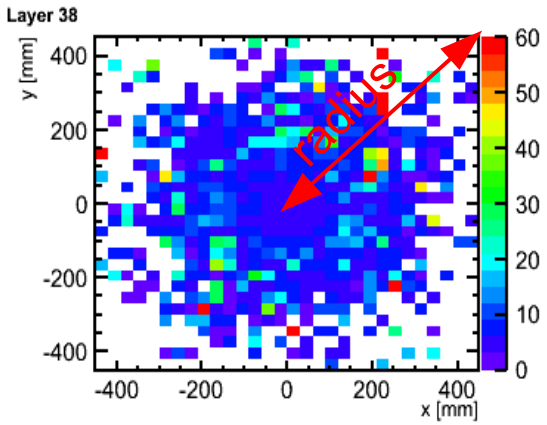
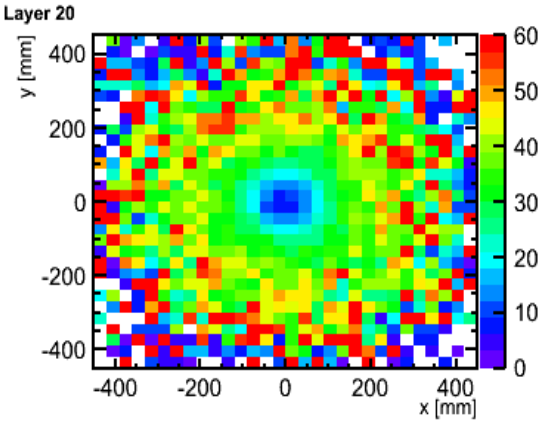
Average hit time distribution as function of the hit position:
(timescale in ns indicated by palette colors)

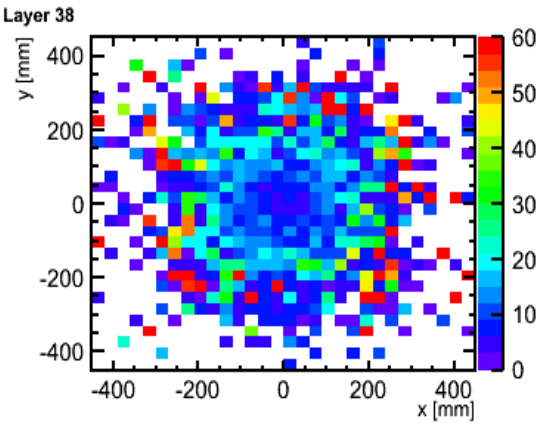
10 GeV pion QGSP_BERT_HP





10 GeV pion QGSP_BERT





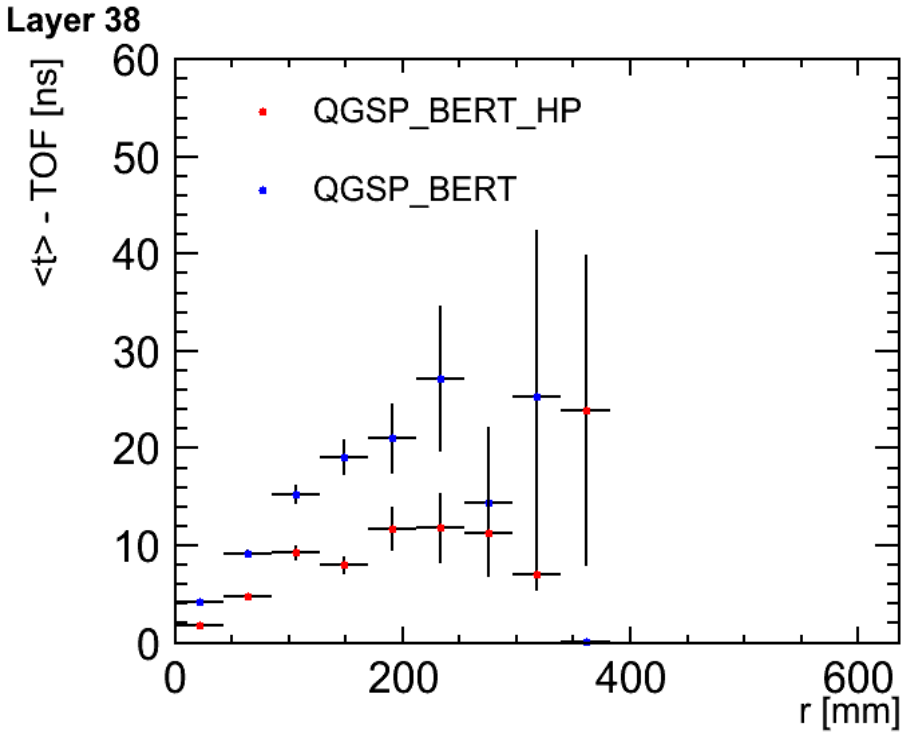
On average later hits are found:

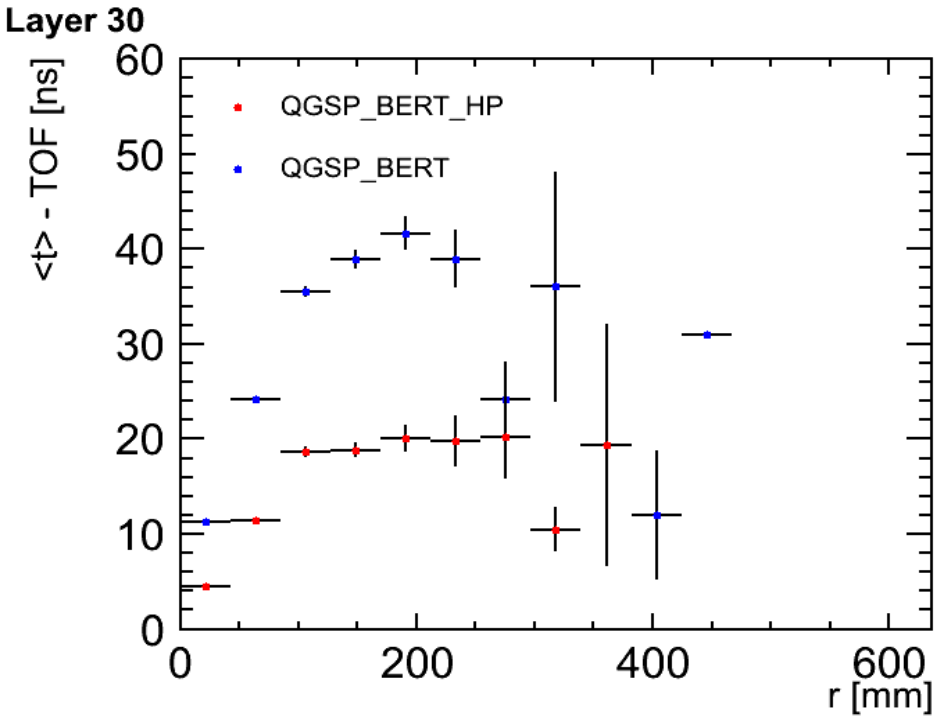
- at larger radii
- in inner layers
- for non-HP physics list

need quantify radial dependence of hit time!

Radial Timing profiles ...

- Assigning hit position to the cell center
- Correcting for the Time Of Flight



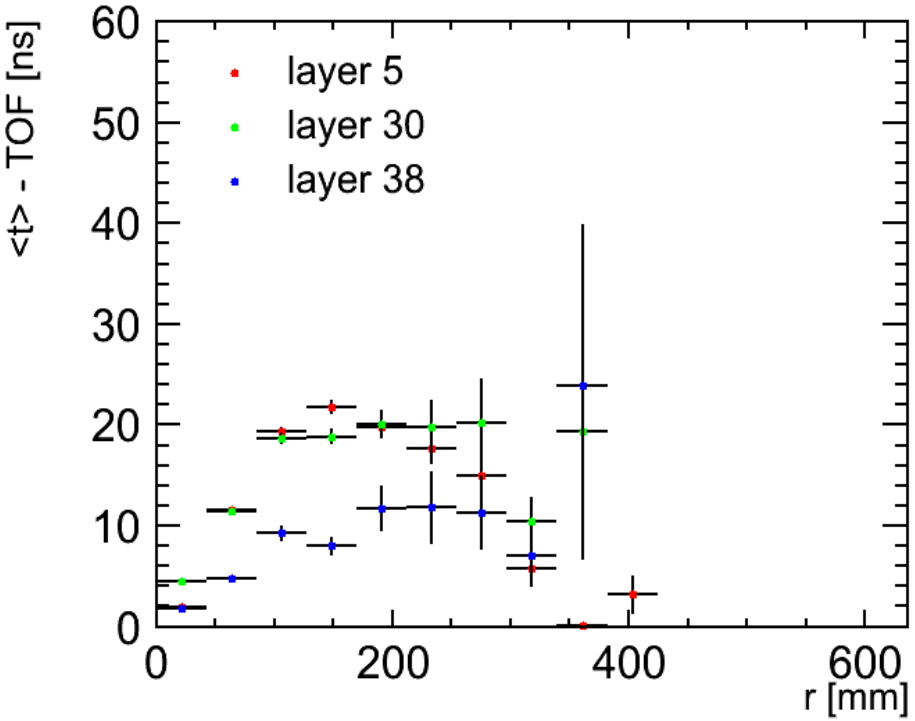


r < 300 mm distinguishable behavior:
- separation greater than statistical error (with 100000 events)
- separation greater than expected time resolution (~ 1 ns)

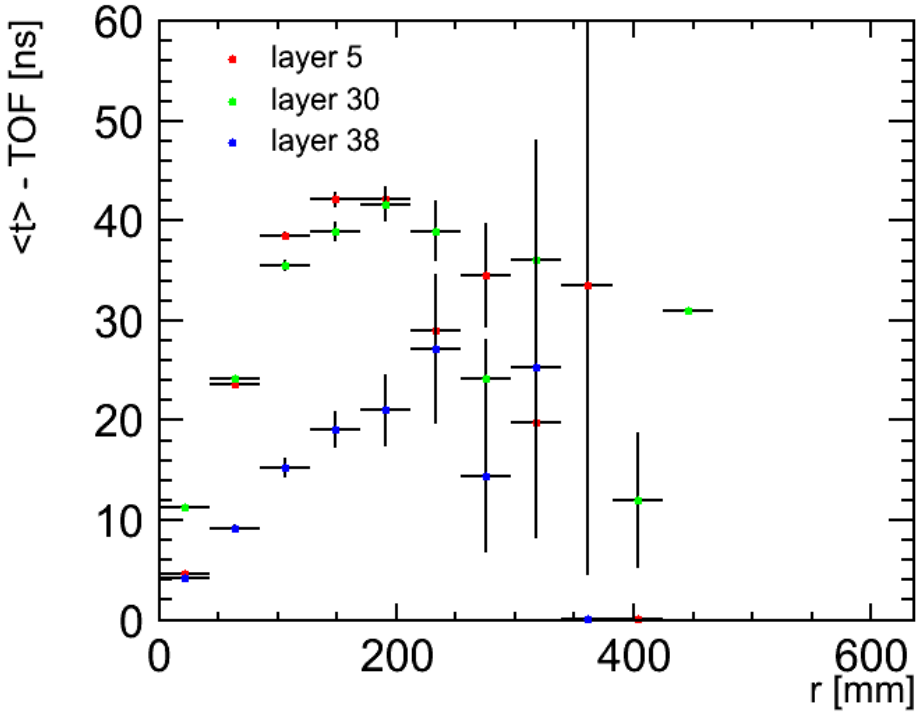
More statistics and better separation

... at different layers

10 GeV pions QGSP_BERT_HP



10 GeV pions QGSP_BERT



For inner layers:
statistical errors are lower (due to more hits)
better separation between physics lists

Mean values per layer

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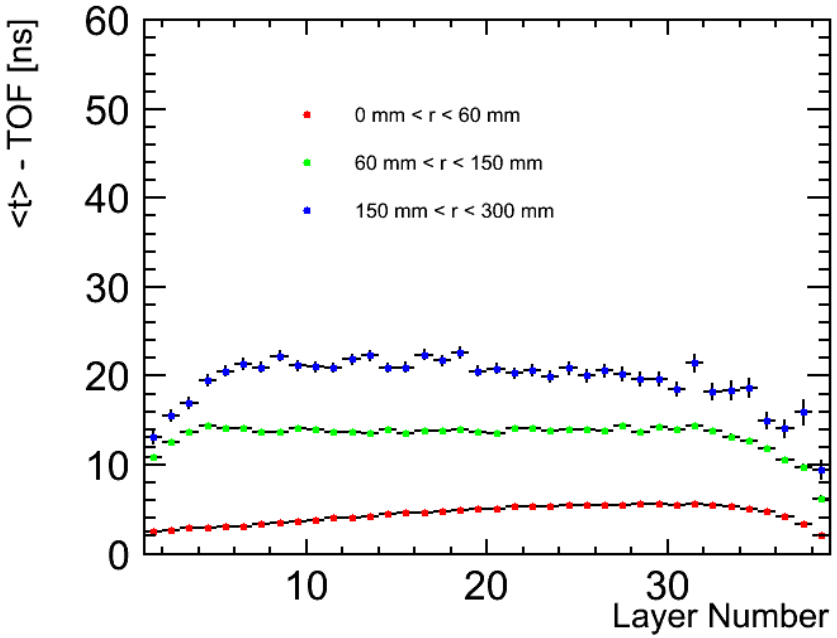
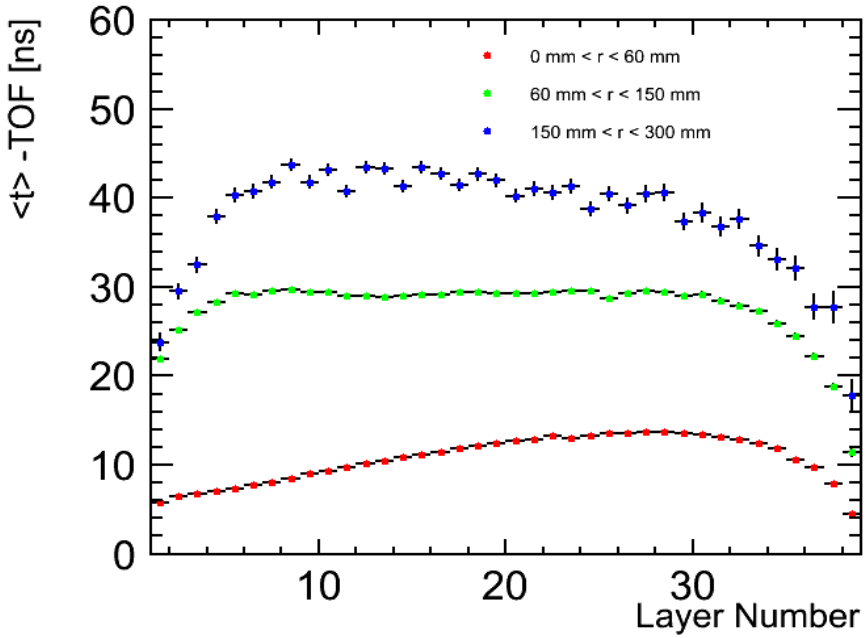
Each layer divided in 4 radial bins:
- 0 mm – 60 mm
- 60 mm – 150 mm
- 150 mm – 300 mm
- more than 300 mm → too few events ...

10 GeV pions QGSP_BERT_HP



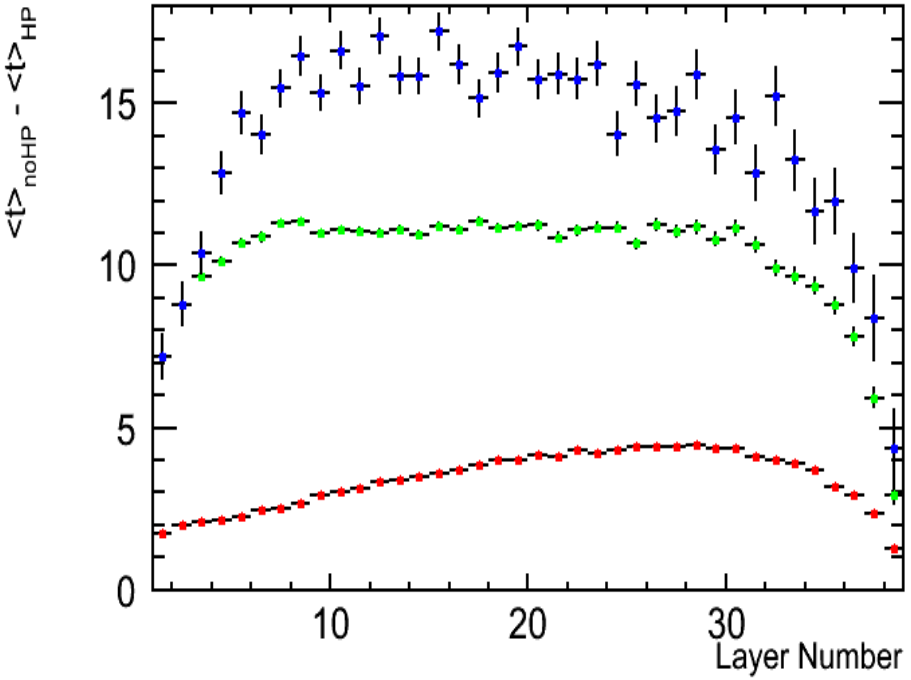
10 GeV pions QGSP_BERT



Late hits are more found:
- at increasing radius
- between layer ~ 5 and layer ~ 30

Difference between physics lists

For each radial bin difference between physics list predictions is computated



@ 10 GeV
Best position for study around layer 30

difference > 1 ns in every layer

(1 ns is the expected ASIC resolution)

Layer 38:
Suffers from low statistics (larger uncertainties)
Difference between PL is closer to ASIC resolution

Summary & Outlook

Thanks to:
•Shaojun Lu for the geometry driver implementation;
•Mark Terwort for discussions about electronics;

- First AHCAL Timestamping Mokka simulations;
- New Mokka Geometry TBhcal4d driver written
- Digitization algorithm simulating the ASIC behavior (in progress);
- Simulations predict capability of distinguishing between physics lists;

In future:

•Introduce noise an jitter effects;

•Simulate 50 layers calorimeter;

•Study dependence from threshold;

•Study dependence from particle type and energy;

•Compare with data!

Backup Slides

The Mokka output

To access time information detailedShowerMode had been used

all the sub-hit structure of the SimCalorimeterHit is made explicit:
➔each Hit is composed by many sub-hits
➔position, time,deposited energy of each sub-hit is stored

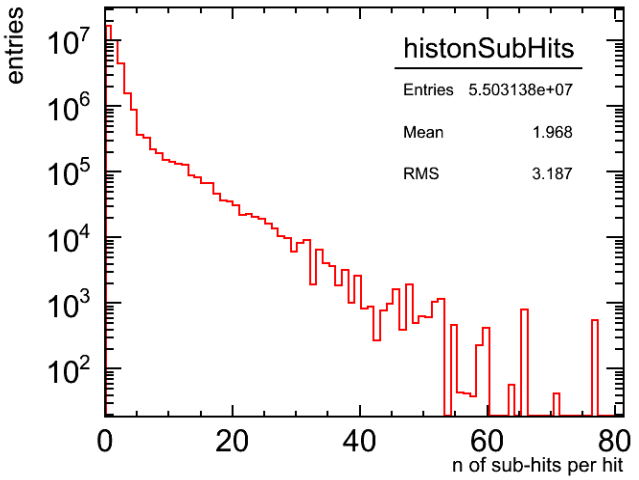
```
===== hcalSD is for AHCAL=====
 collection name : hcalSD
 parameters:

--------------- print out of SimCalorimeterHit collection ---------------

  flag:  0x90000400
 parameter CellIDEncoding [string]: K:8,J:8,I:8,
  -> LCIO::CHBIT_LONG   : 1
     LCIO::CHBIT_BARREL : 0
     LCIO::CHBIT_ID1    : 0
     LCIO::CHBIT_STEP   : 1

 [   id   ] |cellId0 |cellId1 |  energy  |        position (x,y,z)          | nMCParticles
            -> MC contribution: prim. PDG |  energy  |   time   | sec. PDG | stepPosition (x,y,z)
------------|--------|--------|----------|---------------------------------|-------------
 [000000f0] |00540401|00000000|+8.695e-05|+3.850e+02, -4.150e+02, +1.558e+03|          +2
        id-fields: (K:1,J:4,I:84)
           ->                          -211|+3.330e-05|+2.429e+02|+2212| (+0.000e+00, +0.000e+00, +0.000e+00)
           ->                          -211|+5.365e-05|+2.428e+02|+2212| (+0.000e+00, +0.000e+00, +0.000e+00)
 [000000f1] |000d1501|00000000|+1.305e-04|-3.250e+02, -2.450e+02, +1.558e+03|          +1
        id-fields: (K:1,J:21,I:13)
           ->                          -211|+1.305e-04|+2.189e+02|+11| (+0.000e+00, +0.000e+00, +0.000e+00)
 [000000f2] |002a1d01|00000000|+2.357e-06|-3.500e+01, -1.650e+02, +1.558e+03|          +1
        id-fields: (K:1,J:29,I:42)
           ->                          -211|+2.357e-06|+2.571e+02|+1000060120| (+0.000e+00, +0.000e+00, +0.000e+00)
 [000000f3] |00292201|00000000|+2.429e-04|-4.500e+01, -1.150e+02, +1.558e+03|          +3
        id-fields: (K:1,J:34,I:41)
           ->                          -211|+6.199e-05|+2.149e+02|+11| (+0.000e+00, +0.000e+00, +0.000e+00)
           ->                          -211|+1.046e-04|+2.149e+02|+11| (+0.000e+00, +0.000e+00, +0.000e+00)
           ->                          -211|+7.625e-05|+2.149e+02|+11| (+0.000e+00, +0.000e+00, +0.000e+00)

[... ...]
```



Comparison with 100 GeV

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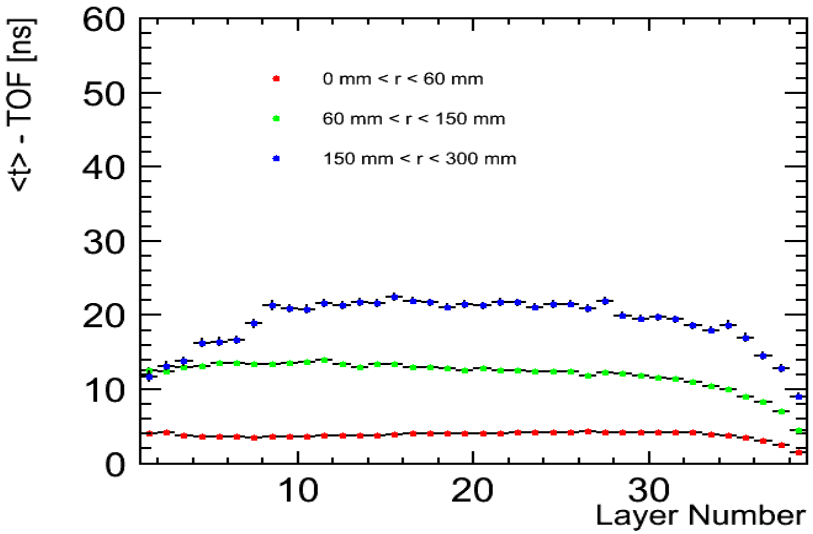
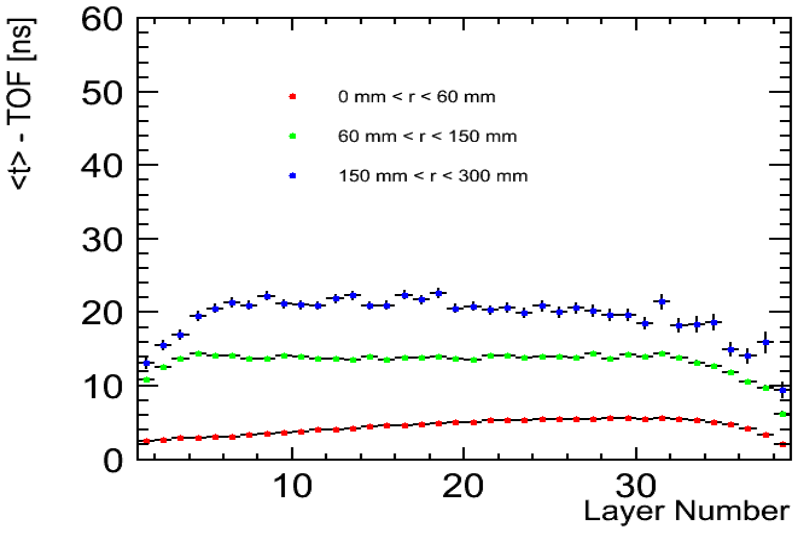
100 GeV pions

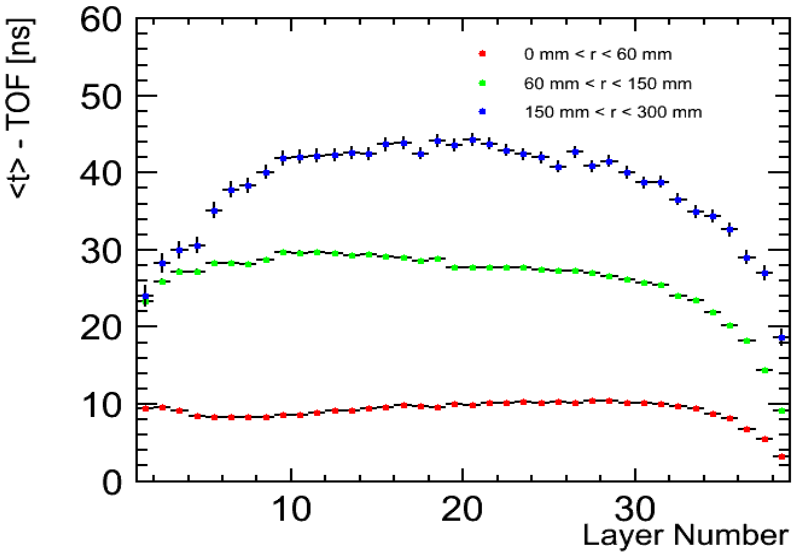
10 GeV pions

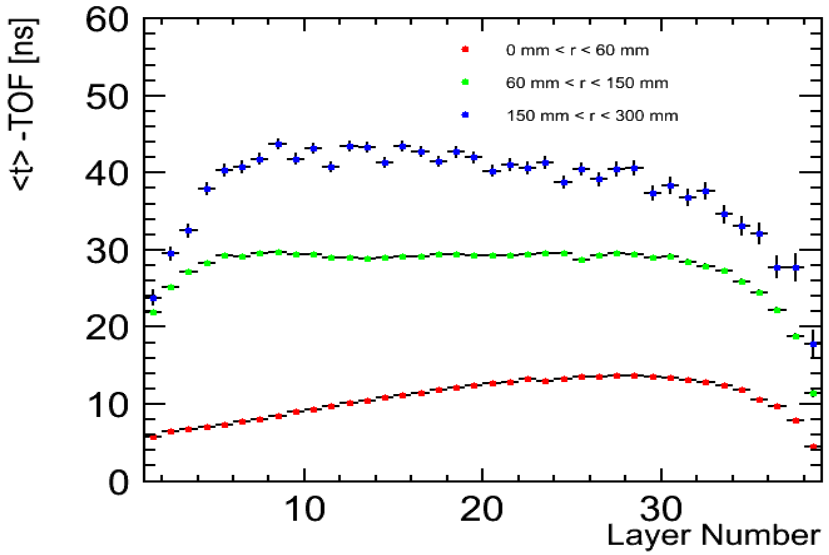
QGSP_BERT_HP





QGSP_BERT





Difference between physics lists: comparison

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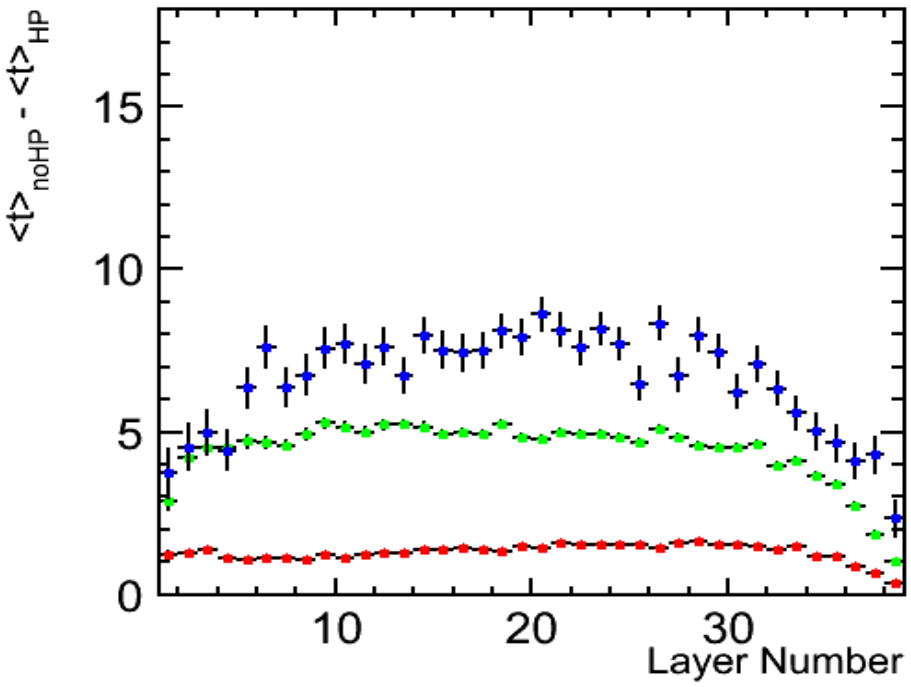
Comparison with a 100 GeV pion (10000 events):

100 GeV pion



10 GeV pion