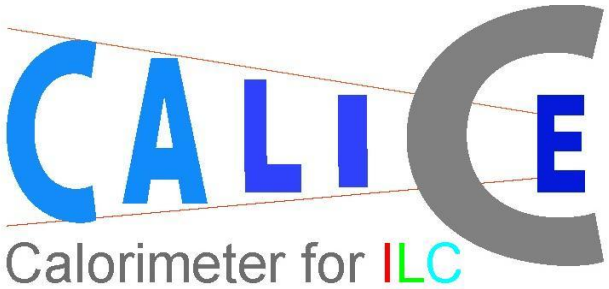


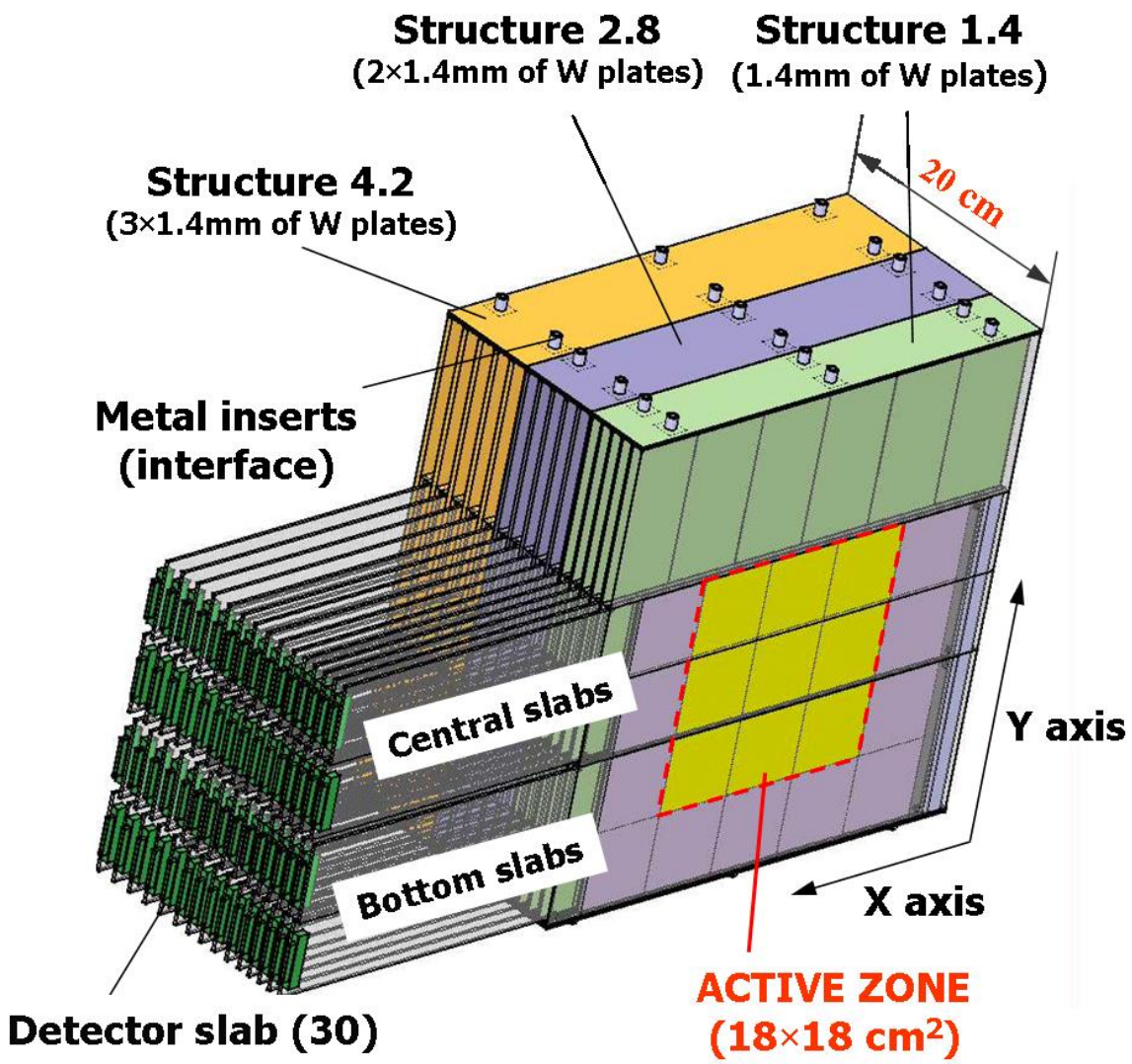
Detailed shower reconstruction in the SiW ECAL

Michele Faucci Giannelli

Outline

- The SiW ECAL
- Description of the new package
- Performance on MC
- MC-DATA comparison
  - 2-10 GeV pions at FNAL
  - 6 GeV electron at CERN
- Outlook

The SiW ECAL



Absorber material: Tungsten

Active material: Silicon wafers

1x1 cm^2 cells

6x6 cells in a wafer
3x3 wafers in a layer

30 layers of Tungsten:
- 10 x 1.4 mm (0.4 X_0)
- 10 x 2.8 mm (0.8 X_0)
- 10 x 4.2 mm (1.2 X_0)
  - ~24 X_0 total
  - ~1 λ_{int} total

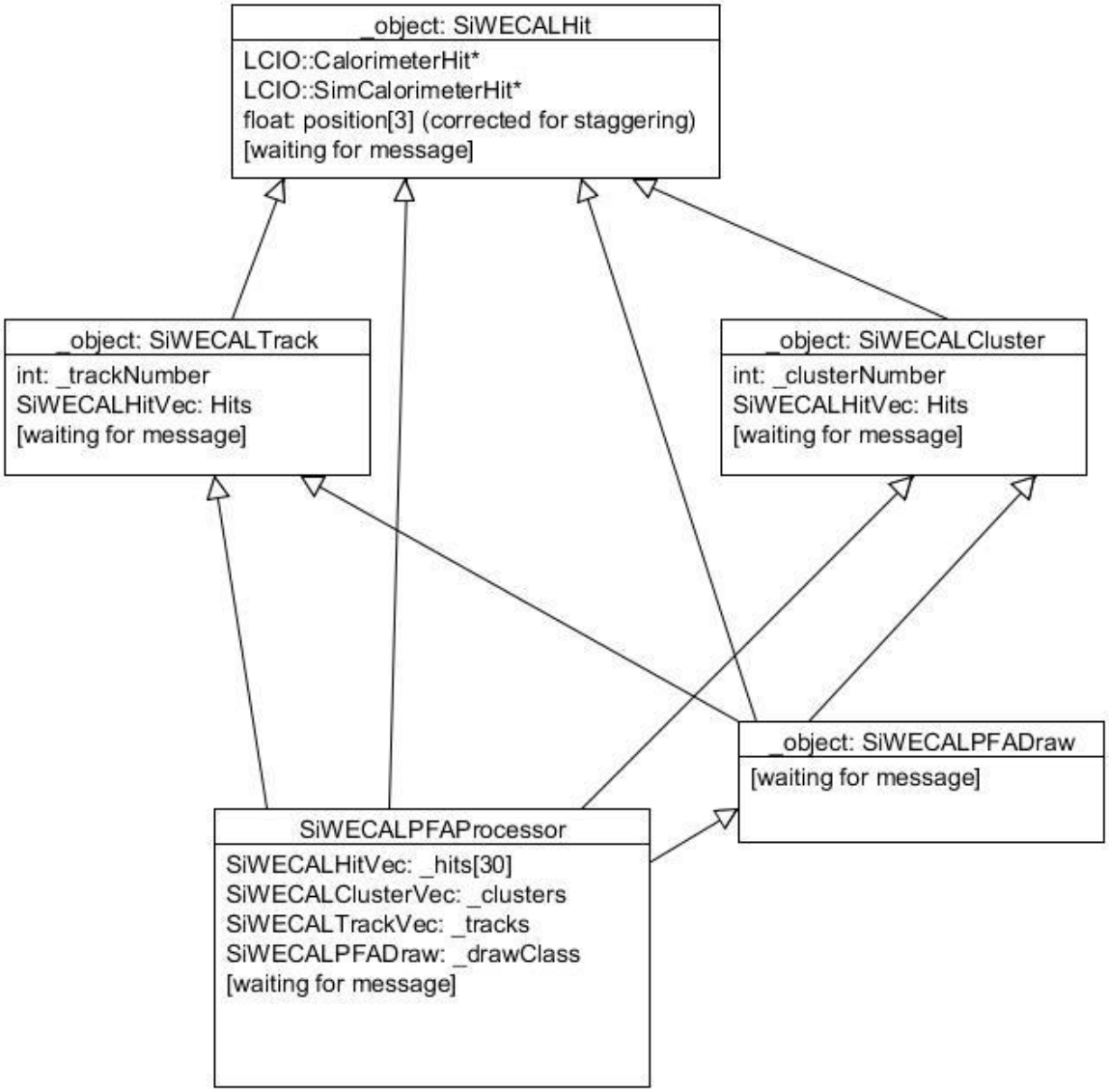
Layers staggered along X

9720 channels

The reconstruction package

- This is a completely new package working within the CALICE software framework
- It consist of:
  - a reconstruction/analysis processor
  - An event selection processor
  - 4 Classes:
    - Hit
    - Track
    - Cluster
    - Helper draw class (no histo defined in the reconstruction processor)

Package


_object: SiWECALHit
LCIO::CalorimeterHit*
LCIO::SimCalorimeterHit*
float: position[3] (corrected for staggering)
[waiting for message]
_object: SiWECALTrack
int: _trackNumber
SiWECALHitVec: Hits
[waiting for message]
_object: SiWECALCluster
int: _clusterNumber
SiWECALHitVec: Hits
[waiting for message]
_object: SiWECALPFADraw
[waiting for message]
SiWECALPFAProcessor
SiWECALHitVec: _hits[30]
SiWECALClusterVec: _clusters
SiWECALTrackVec: _tracks
SiWECALPFADraw: _drawClass
[waiting for message]

Reconstruction Algorithm

- Initialisation
  - 0.6 MIP threshold for all hits
- Track Seed
- Iteration over layers
- Finalisation of tracks
- Track-track intersection
- Track-cluster intersection
- Classification of the event
  - Interaction layer used as figure of merit

Seed tracks

- The first layer with a hit start a track which is defined as primary track
  - The criteria is valid for any type of detector and can be used in an extended PFA reconstruction to the full detector
  - Limitation: if first layer is missed by primary track but there is noise, the primary track is not defined.
    - Thanks to the small noise this is a very secondary effect which I have never observed

Iteration at each layer

- Track grow
- Cluster grow
- Merge clusters
- Remove overlaying tracks
- Remove short tracks
- Start new tracks

Track Grow

- All tracks are compared with all hits, those compatible (dist < 16mm in both directions and max 2 layer from last hit in track) are added to the track
- If 2 hits with an energy sum smaller than 50 MIPs or 3 hits with an energy smaller than 15 MIPs are compatible, two or three tracks are created
- If 4 hits (or 2/3 and energy > 50/15) are found, then the track is stopped and a cluster is started from the last hit of the track

Cluster

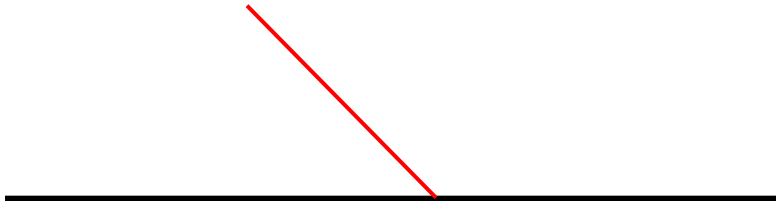
- All hits compatible with the cluster are added to the cluster
- Compatibility is defined as: ±25 mm and ±2 layer from any hit in the cluster and an energy of at least 3 MIPs
  - i.e.: if 4 hits caused the start of the cluster but only one is above 3 MIPs than only that hit is added
- All cluster sharing at least 1 hit are merged in one cluster

Remove tracks

- All tracks with at least 3 hits are ordered by type (primary track, track originate by primary, other) and by $\chi 2$
- Starting from first track, the energy of all hits is reduced by 1 MIPs for every
- All following tracks are evaluated with the new hit energy, all hits below 0.6 MIP are not considered
- If ((2*hitabovethreshold-1)<=hitsnumber) track is killed
  - i.e.: only 3 hits above threshold out of 5 kill the track

Final part of iteration

- Kill all tracks with only two hits and with the last hit more than 2 layers before actual layer
- Kill all tracks completely contained in a cluster
- Start new track from all hits with an energy larger than 4 MIPs (maybe first layer of a track exiting a cluster)
- Start a new track from all hits not in a track (back scattered)



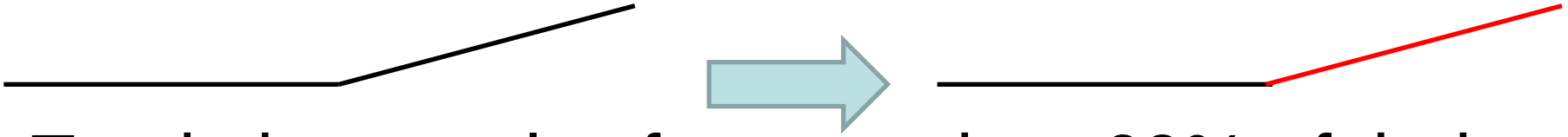
Finalise Cluster

- All hits around every clusters are added to the cluster if they are not in a cluster or in a track
- Cluster are merged if they share at least one hit

Finalize tracks

- Only tracks with at least 3 hits are kept
- Track with large gaps are joined

- Track with kinks are splint



- Track that overlay for more than 60% of their hits with other tracks (after ordering) are removed
- Clusters with less than 10 MIPs are removed
- Hits not in cluster or track are *isolate*

Intersections

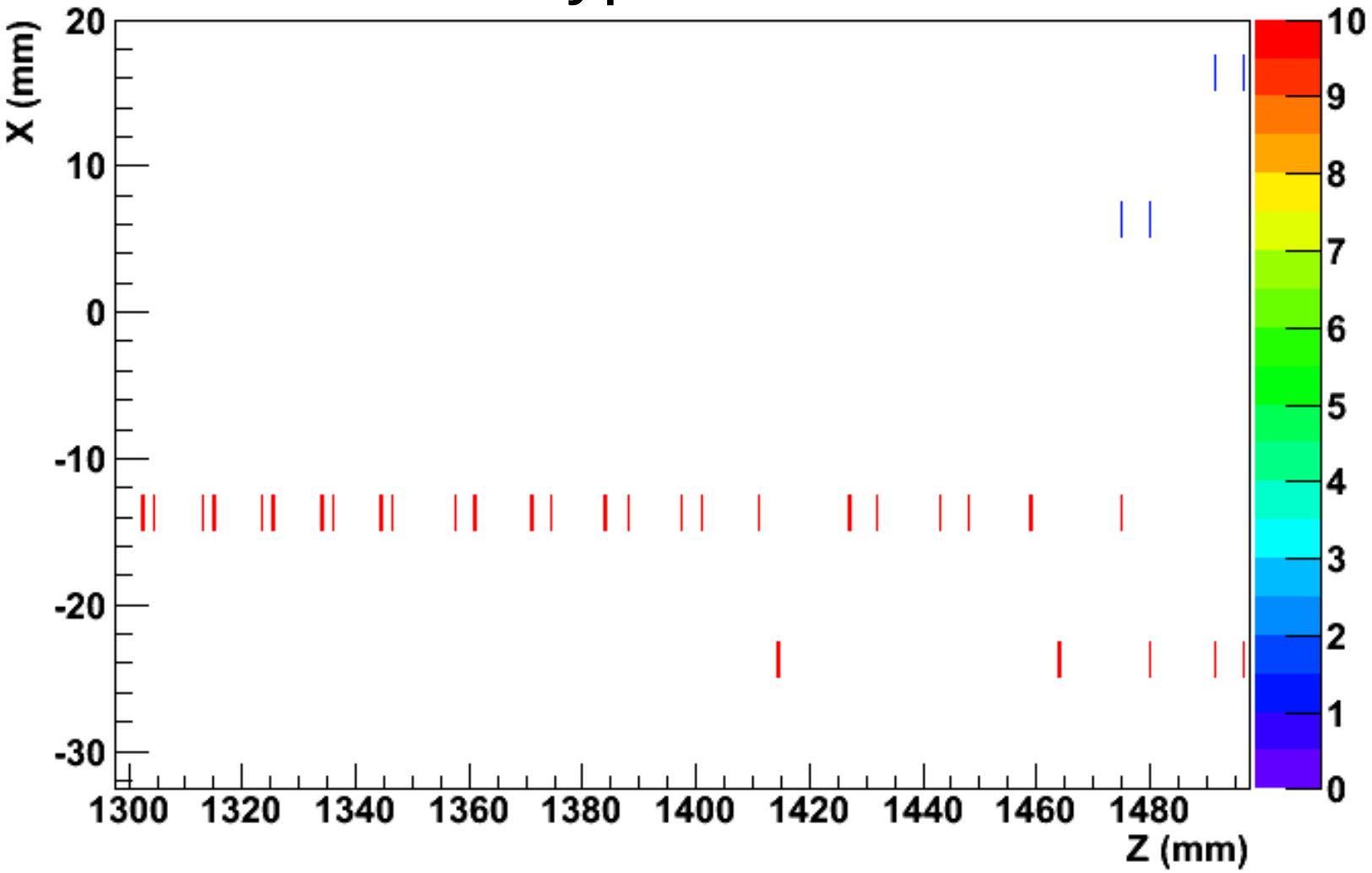
- Only 4 layers && 4 hits tracks are considered
- Only 30 MIPs && 6 hits cluster are considered
- Track – track intersections are found and final links between primary and fromPrimary type of track is defined.
- Track – cluster intersection define cluster fromPrimary and delta ray
  - If a track pass through a cluster without deviation, the cluster is a delta ray
- Tracks are defined backscattered if the intersection is one of the last 2 hits.

Classification

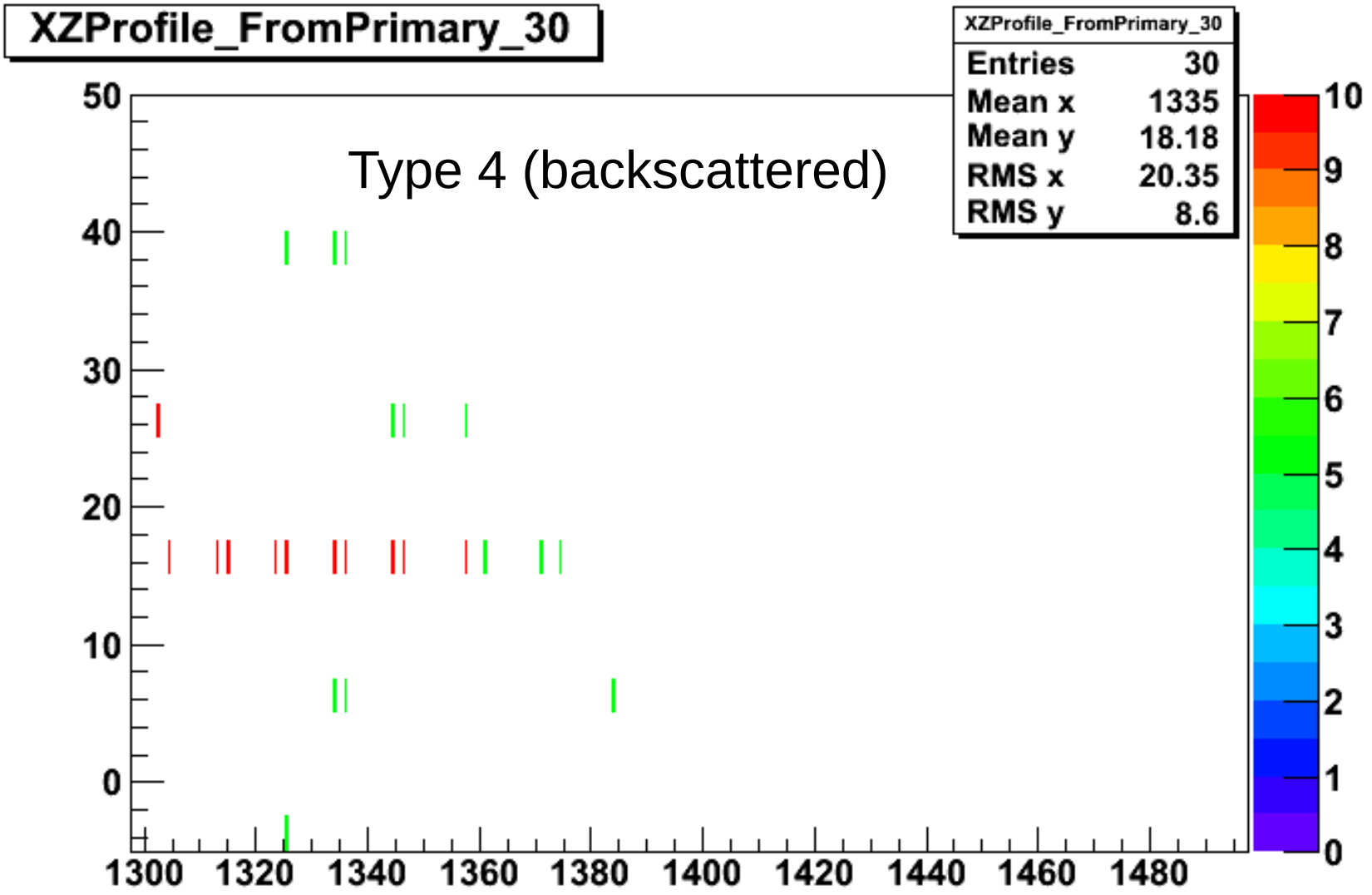
- Type 0: nothing reconstructed (noise + backscattered + strait in hole)
- 1 primary + tracks
  - Type 1: nothing
  - Type 2: 1 non connected track
  - Type 3: backscattered, no cluster
  - Type 4: backscattered + cluster
  - Type 5: large angle track (w, w/o cluster)
  - Type 6: small angle track (correction applied)

Example

Type 2

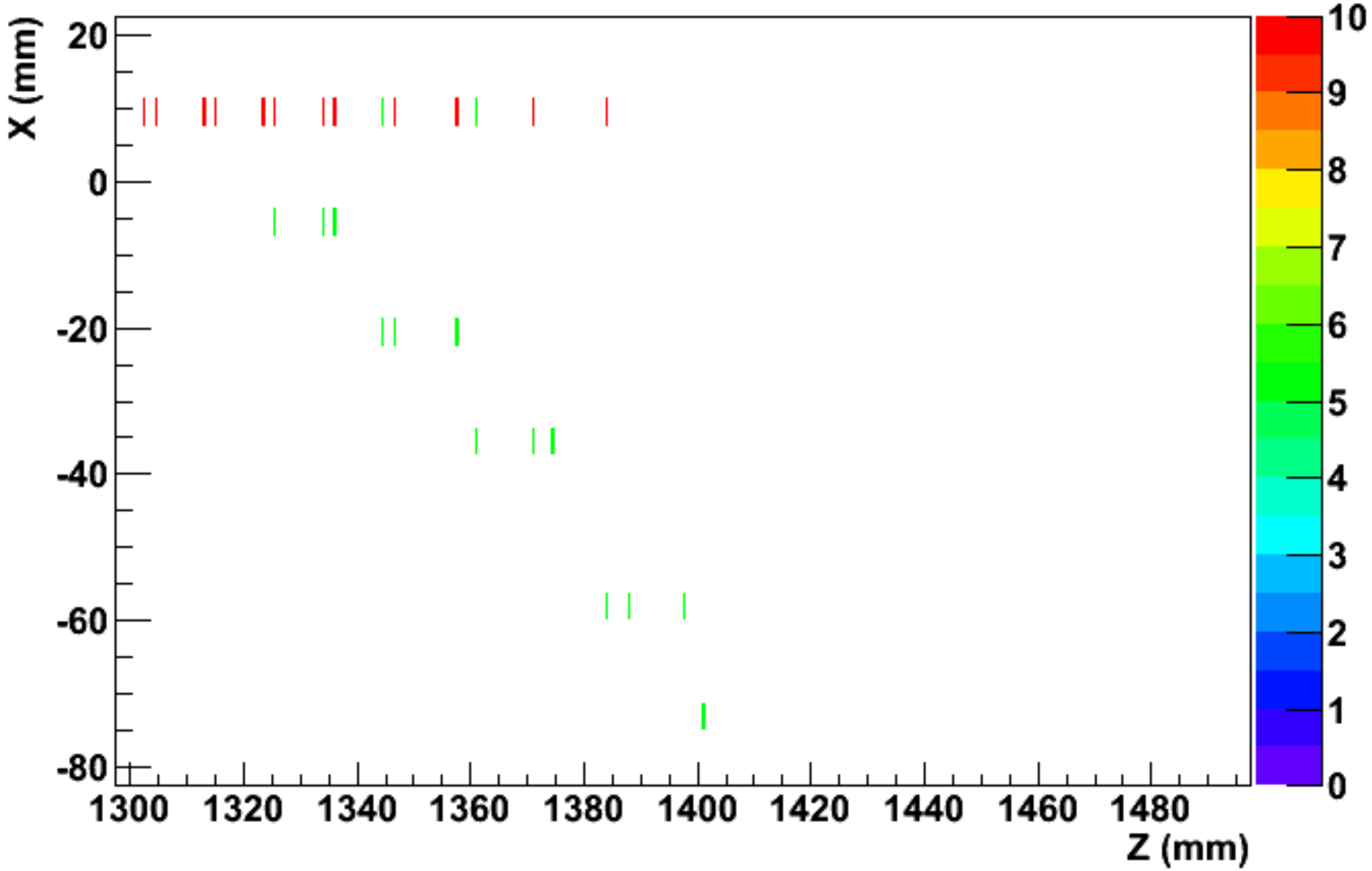


Example


XZProfile_FromPrimary_30
XZProfile_FromPrimary_30
Entries 30
Mean x 1335
Mean y 18.18
RMS x 20.35
RMS y 8.6
Type 4 (backscattered)
50
40
30
20
10
0
1300
1320
1340
1360
1380
1400
1420
1440
1460
1480
10
9
8
7
6
5
4
3
2
1
0

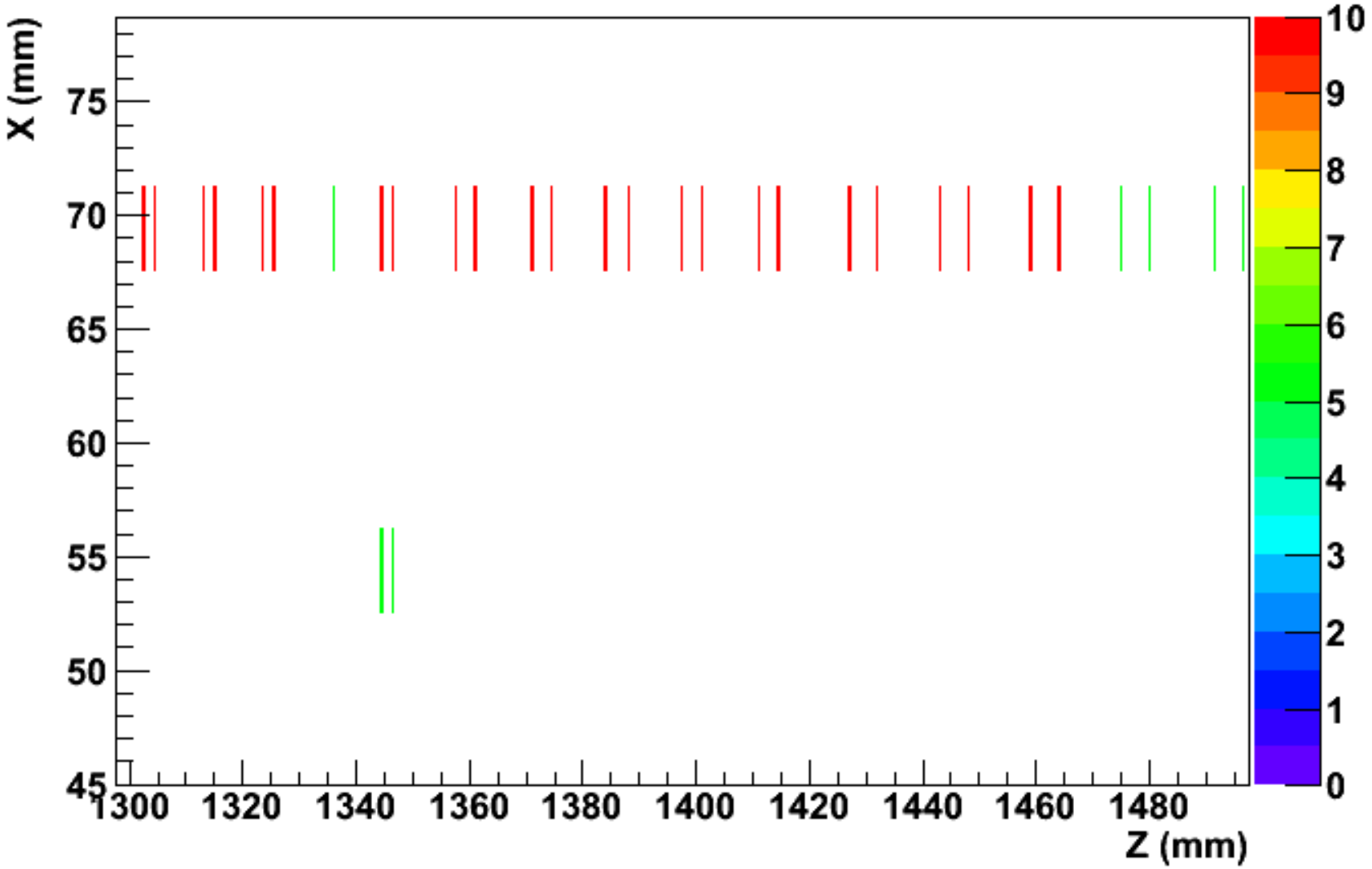
Example

Type 5 (large angle track)



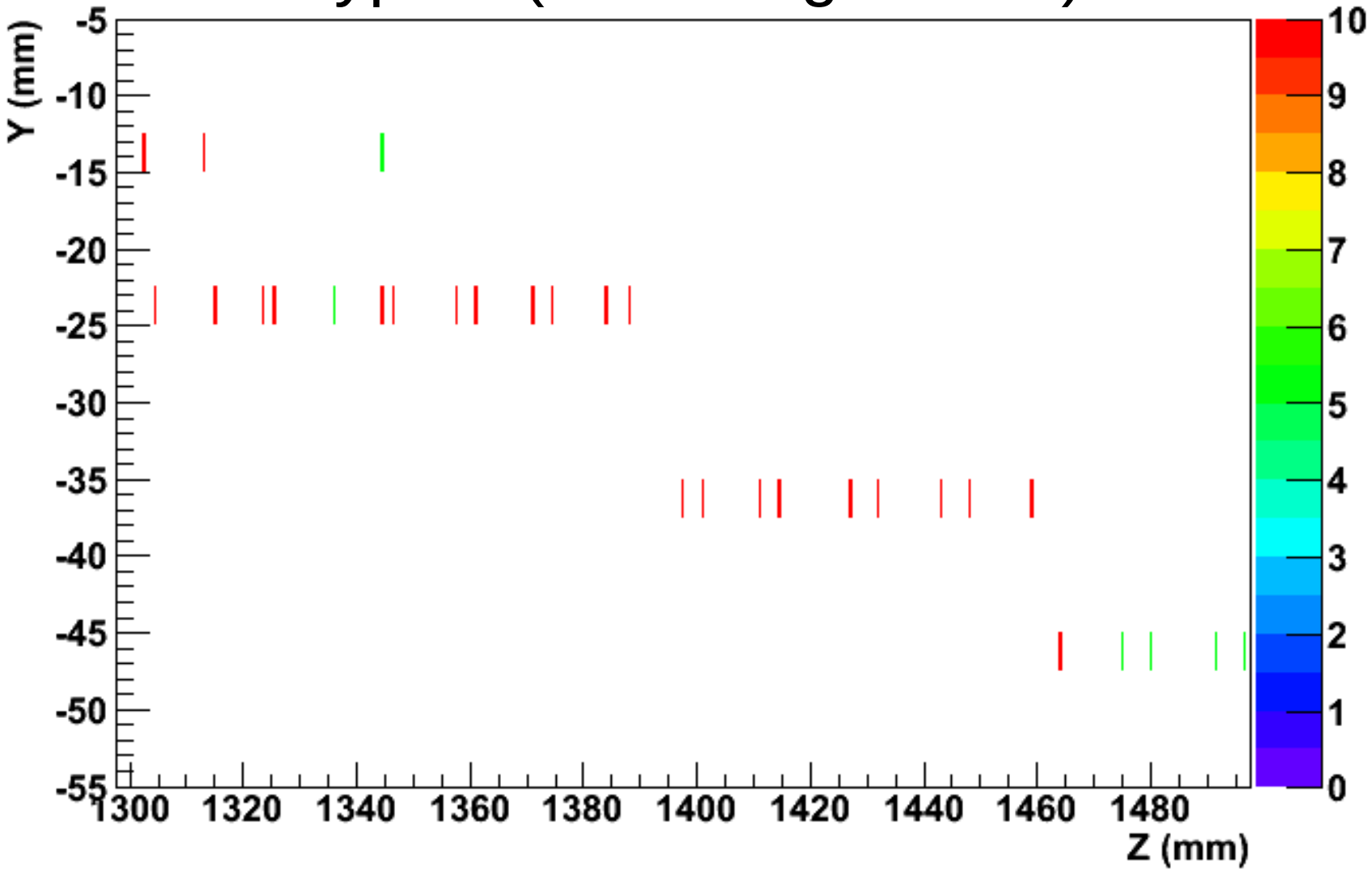
Example

Type 5 (small angle track)



Example

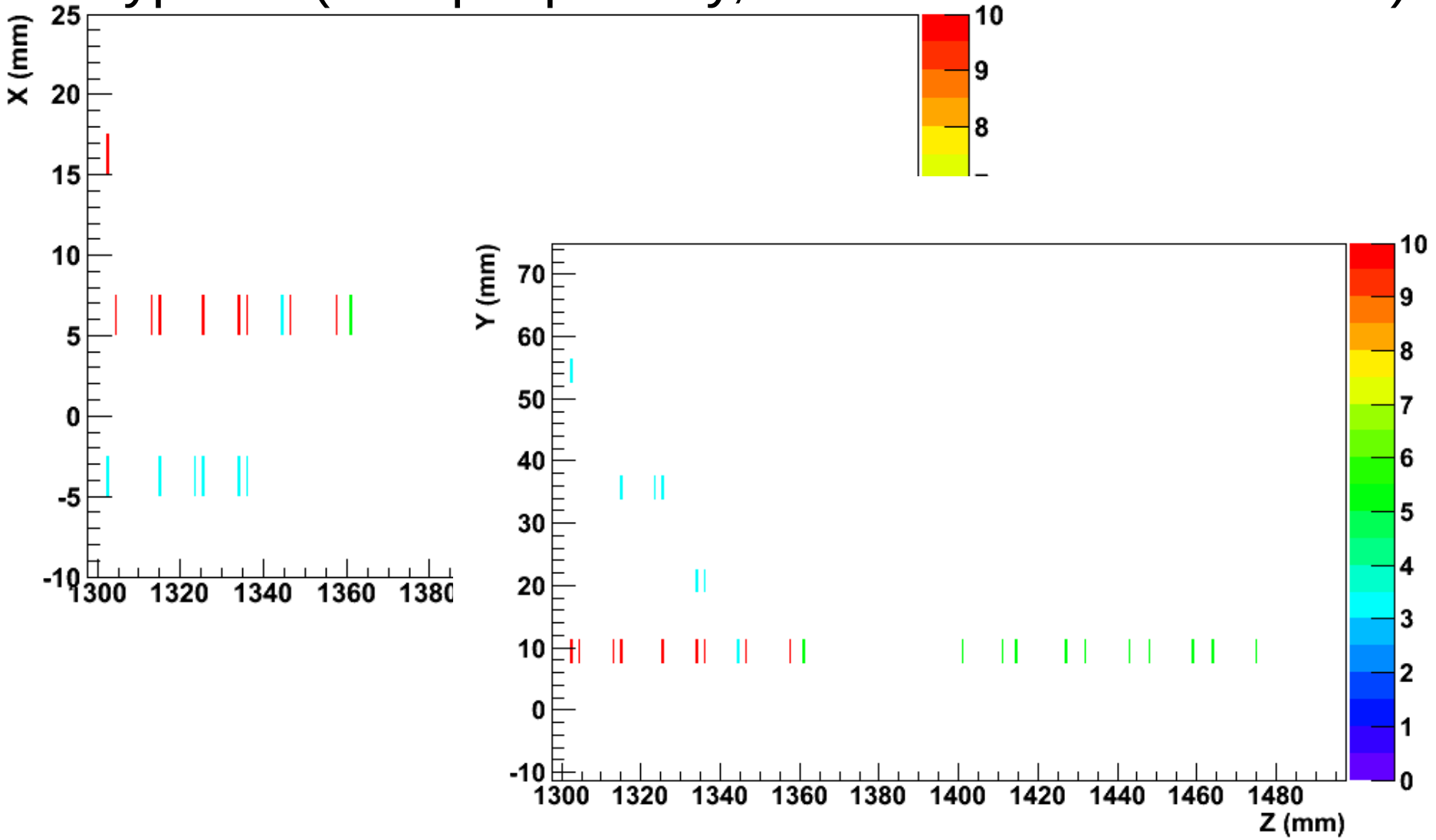
Type 5 (small angle track)



- 1 primary + 1 cluster
  - Type 7: primary deep in cluster
  - Type 8: all other
- 1 primary + multi tracks/clusters
  - Type 9:
- 0 primary, clusters or tracks
  - Type 11: cluster only
  - Type 14: anything else
- 2 primary:
  - Type 15: backscattered recovered
  - Type 16: not recovered (usually early cluster)

Example

Type 15 (multiple primary, recovered backscattered)

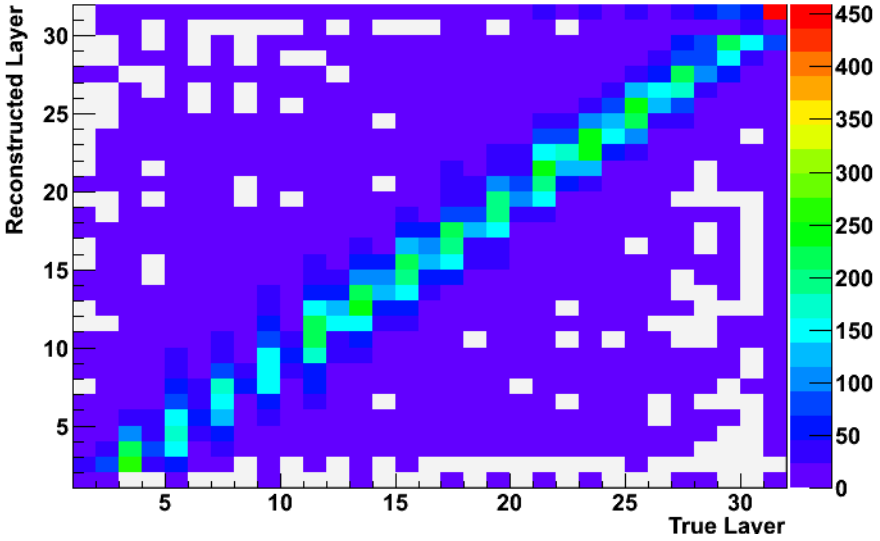


Performance on MC

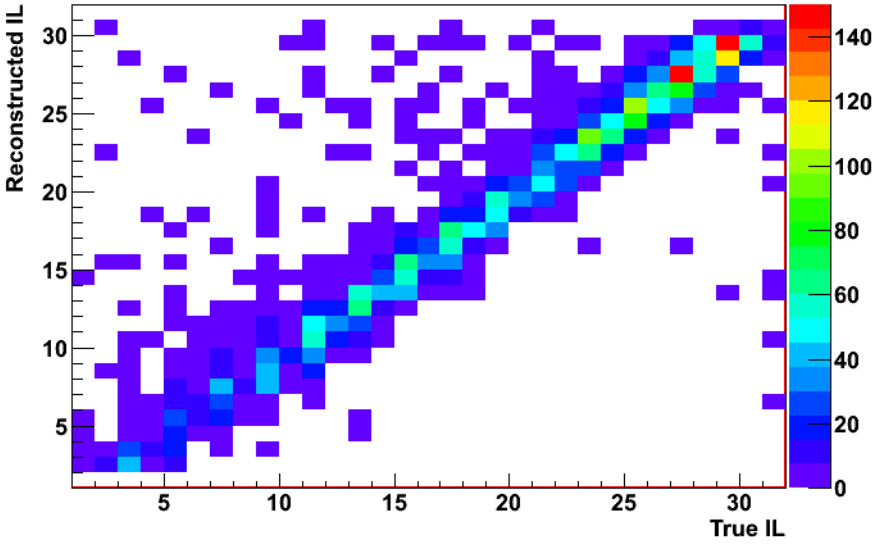
- Interaction layer used as benchmark to optimise the reconstruction
- Separation between low energy deposit (<40 MIPS) and significant interaction
- Every type has different contributions
  - And problems
- The reconstruction is completely energy independent
  - Hence compromises has to be taken to have good performance at all energy
    - Cut on small cluster improves high but kill low energies

Some plots

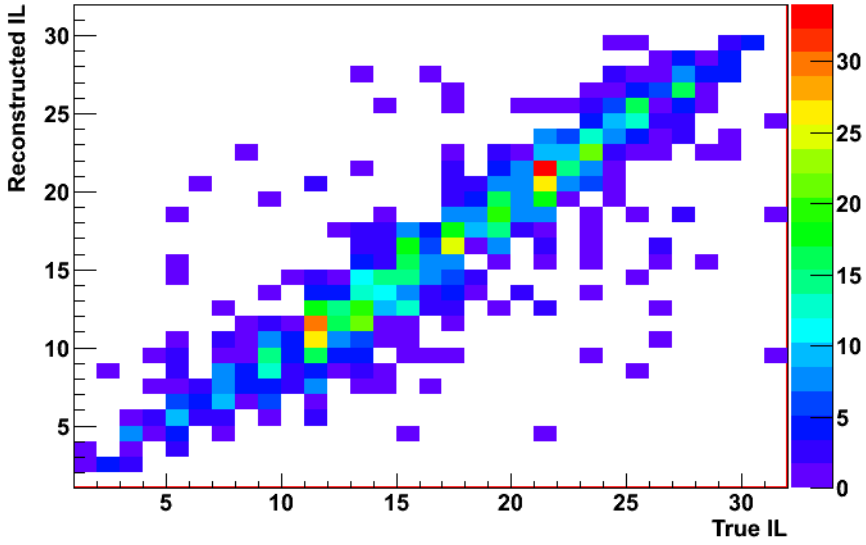
All



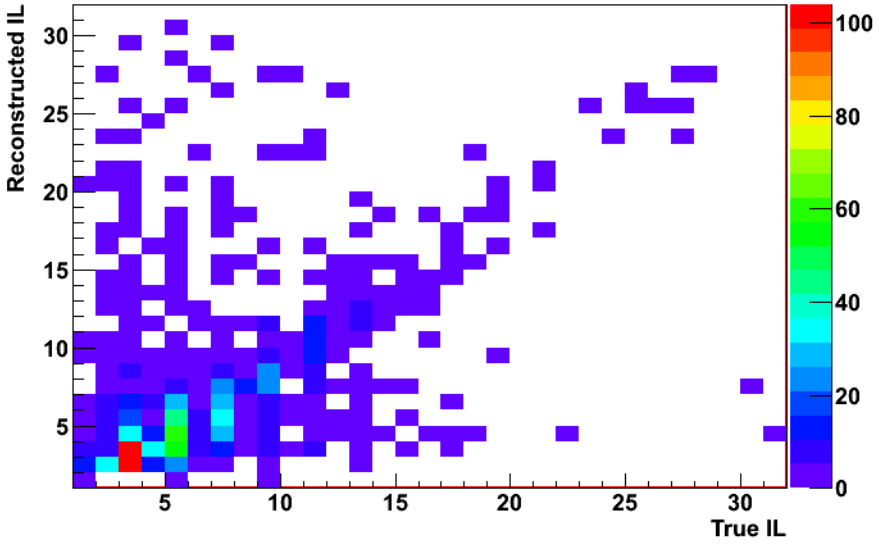
Type 8



Type 4



Typ16



Efficiency

Energy	High	Low	All	PD
2	0,621	0,662	0,65	0,67
4	0,678	0,766	0,72	0,73
6	0,767	0,882	0,81	0,76
8	0,758	0,909	0,81	0,78
10	0,755	0,920	0,81	0,84

Overall efficiency very similar to Philippe

Type 2: maybe secondary track is actually from primary, small number of events

Type 6: small angle tracks, still need to improve correction (see next slide)

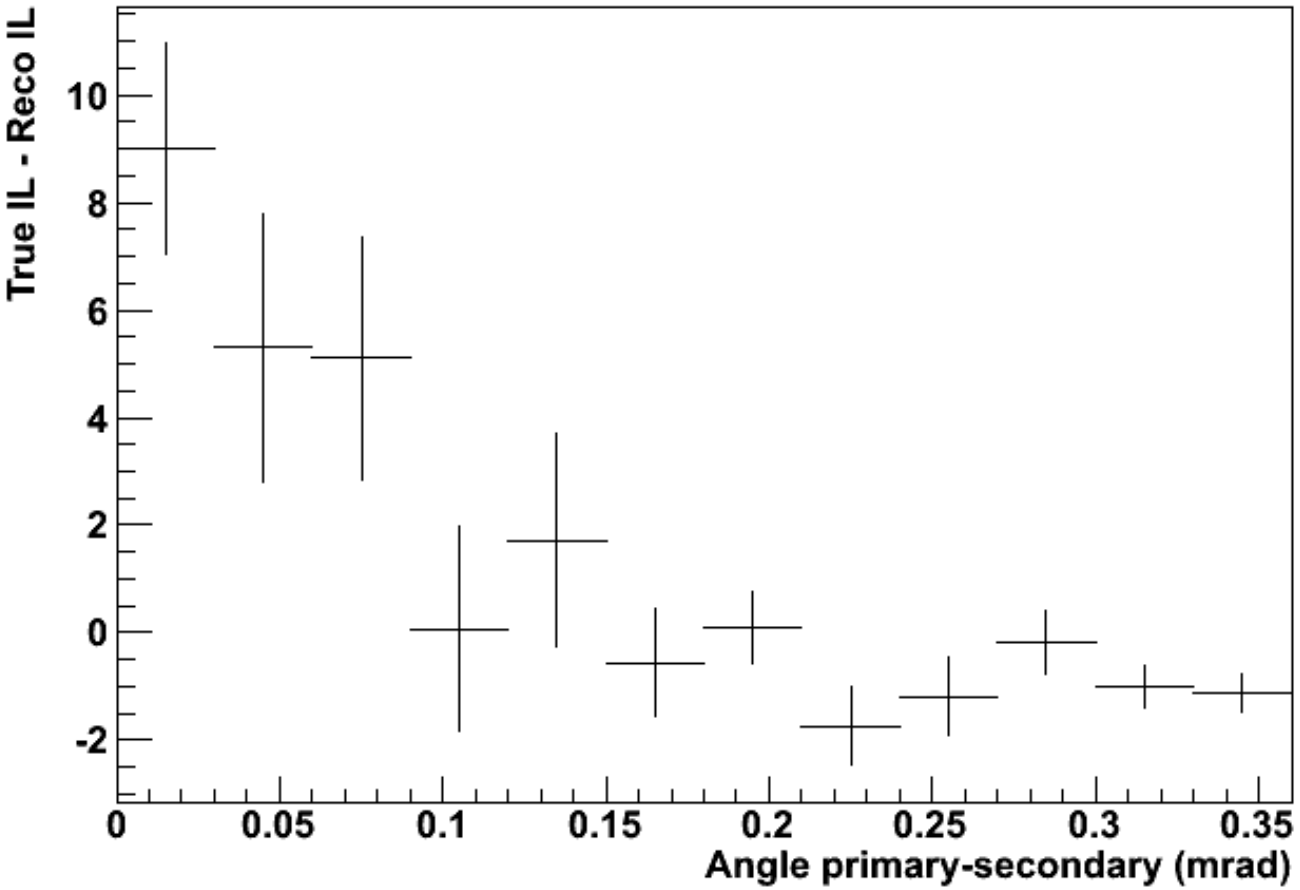
Type 3: backscattered not perfect (but small sigma and # events)

Type 14: no primary, no cluster, maybe missed due to noise? Small # events

Type	2 GeV	8 GeV
1	0,55	0,76
2	0,29	0,24
3	0,65	0,55
4	0,70	0,80
5	0,74	0,73
6	0,19	0,10
7	0,75	0,87
8	0,83	0,91
9	0,37	0,49
11	0,56	0,79
14	0,41	0,36
15	0,63	0,66
16	0,50	0,70

Type 9: small angle + cluster

Type 6 problem



Correct reconstructed intersection for very small angles between primary and secondary tracks

MC-Data comparison

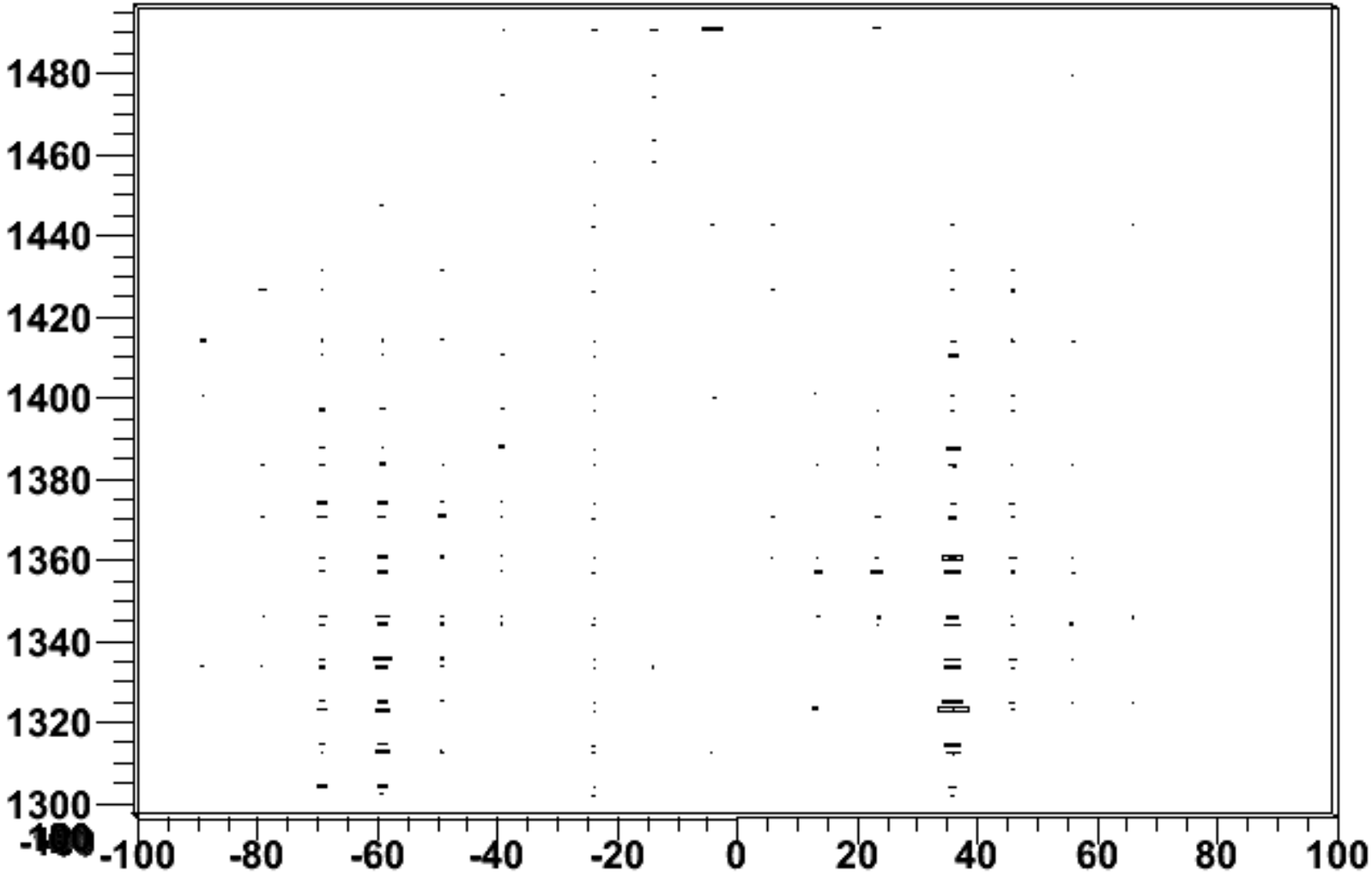
- Samples:
  - 2, 4, 6, 8 and 10 GeV runs from FNAL
  - FTFP_BERT for MC comparison
- Both data and MC have been reconstructed/digitised with the latest version available
- Same selection and detailed reconstruction for both samples
- More list asap (need more disk space)

Problem in data

- Photon contamination
  - Small radius (<15 mm)
  - Long clusters (>15 layers)
  - But (cluster energy/total energy != 1)
- Problem concentrate on types with cluster
  - Comparison done with track types
  - 10 GeV runs do not have electrons

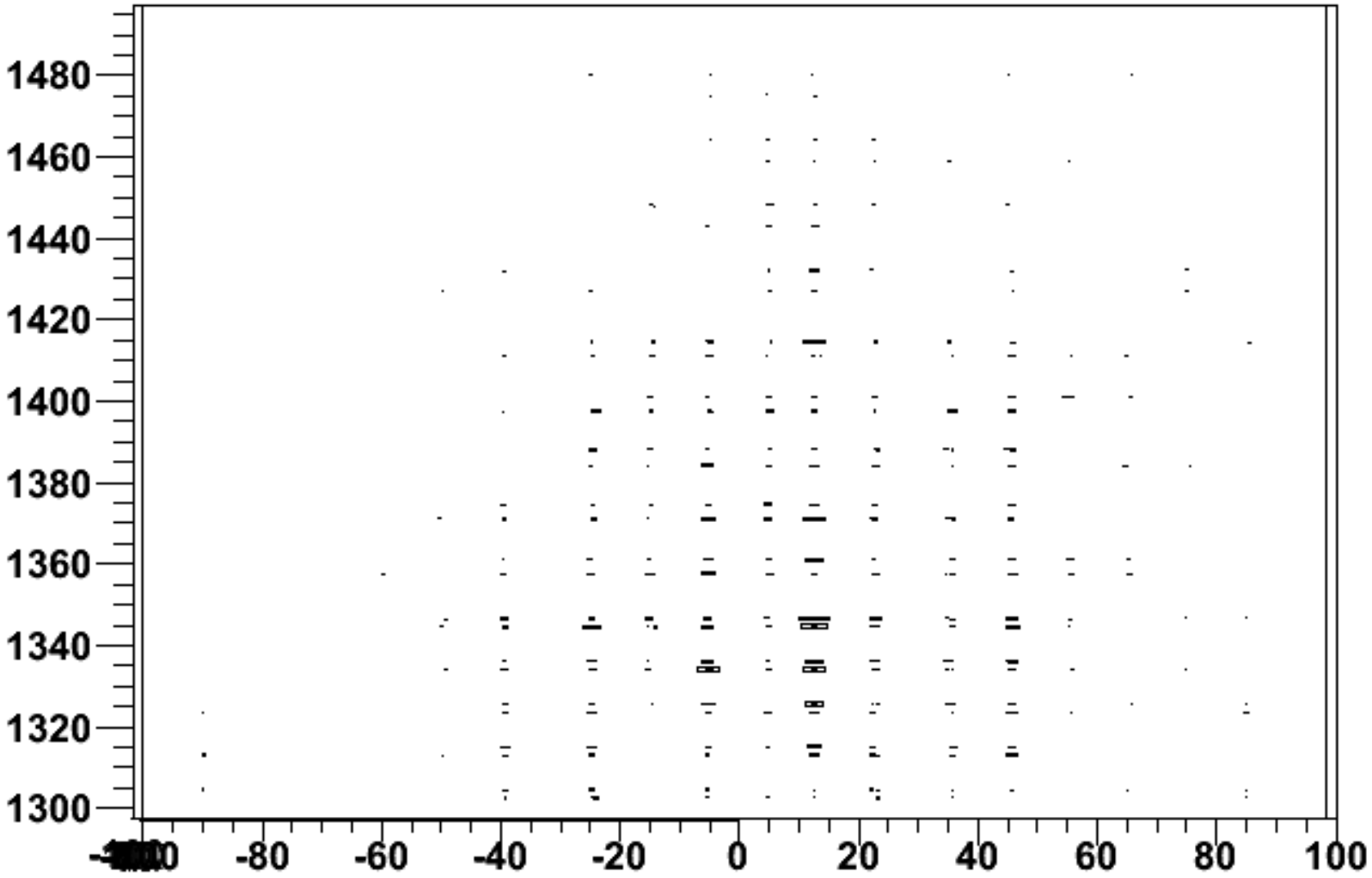
Photon contamination

Clear separation



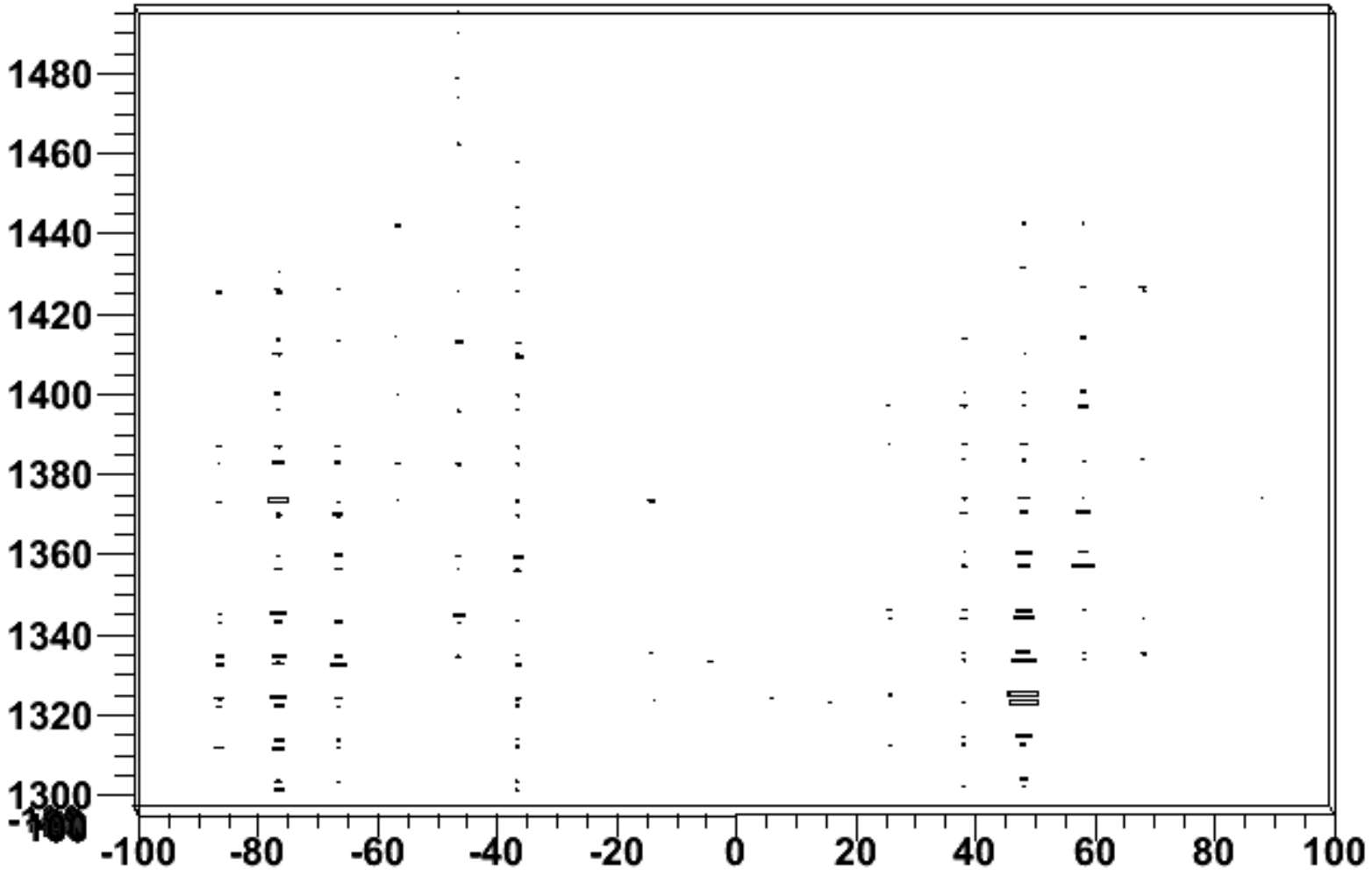
Photon contamination

No separation!



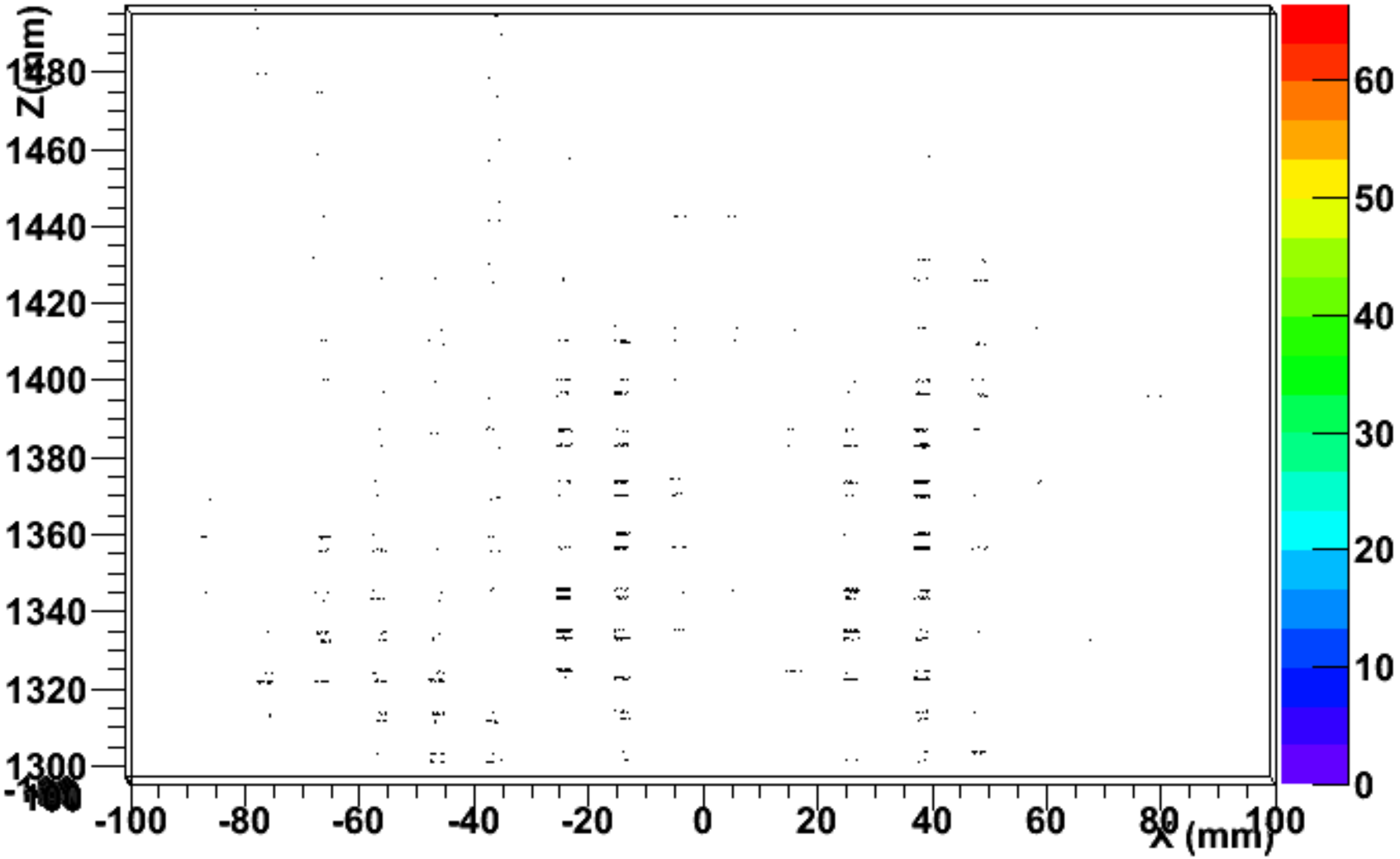
Photon contamination

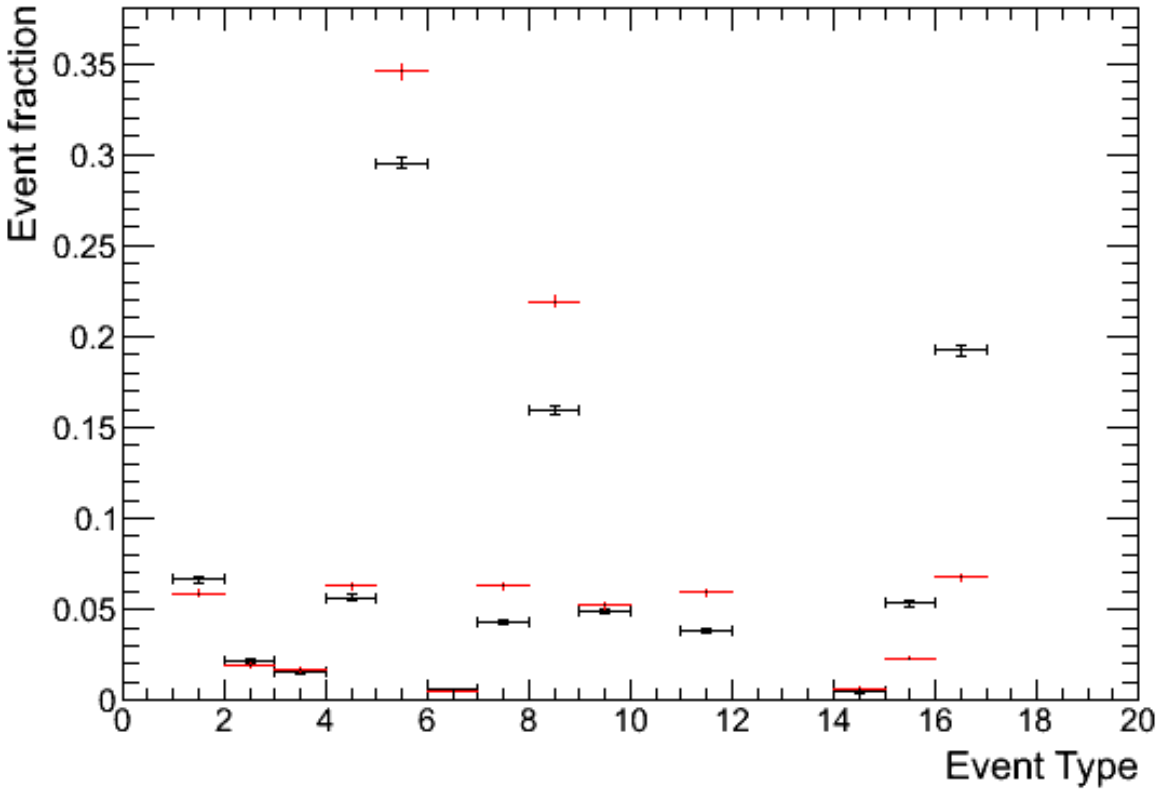
Some confusion



Photon contamination

More confusion

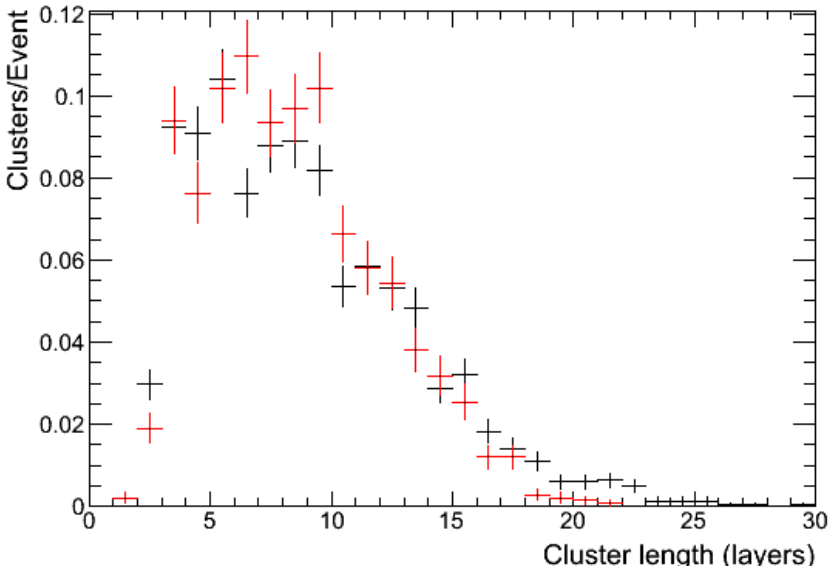




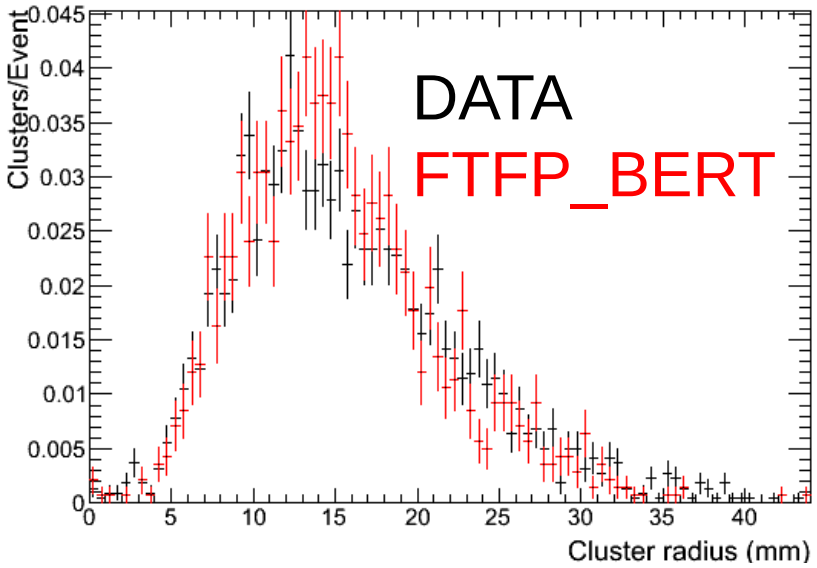
DATA
FTFP_BERT

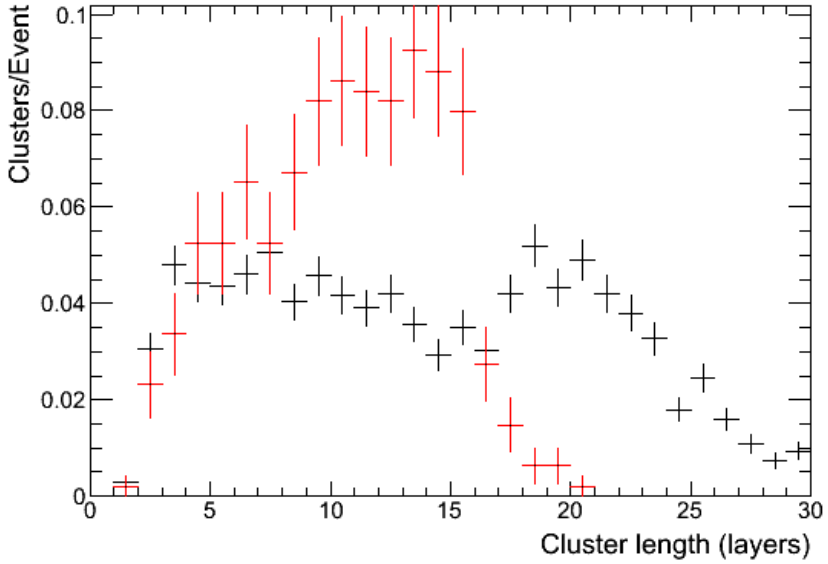
Too many type 16 events in Data than in MC

MC-Data comparison

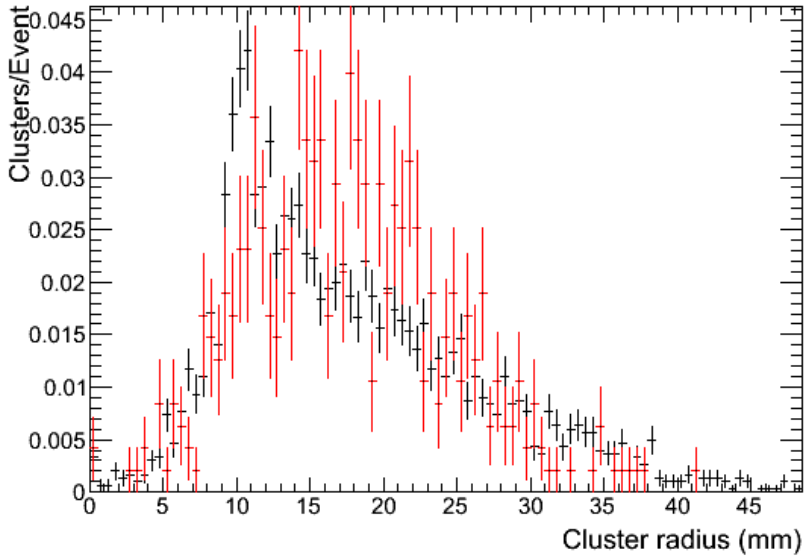


8

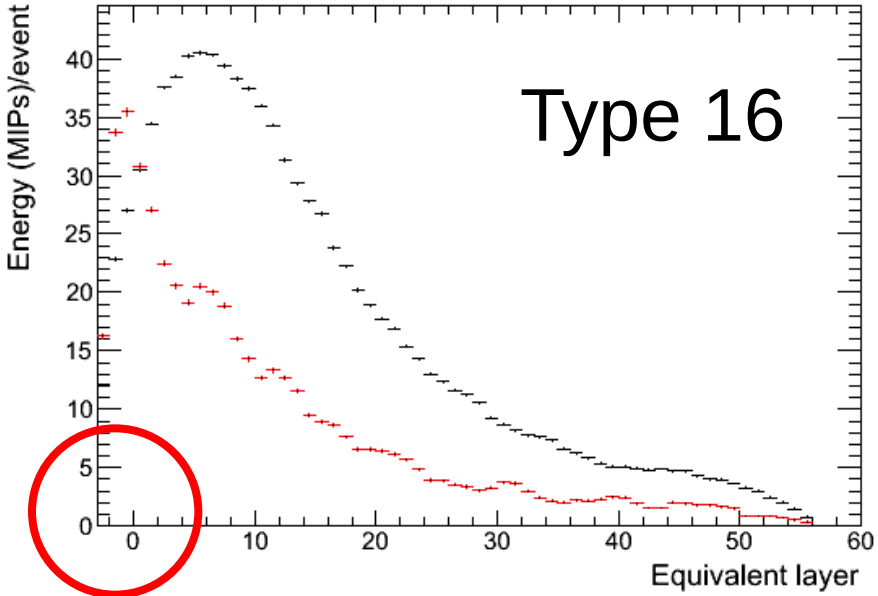




16



MC-Data comparison

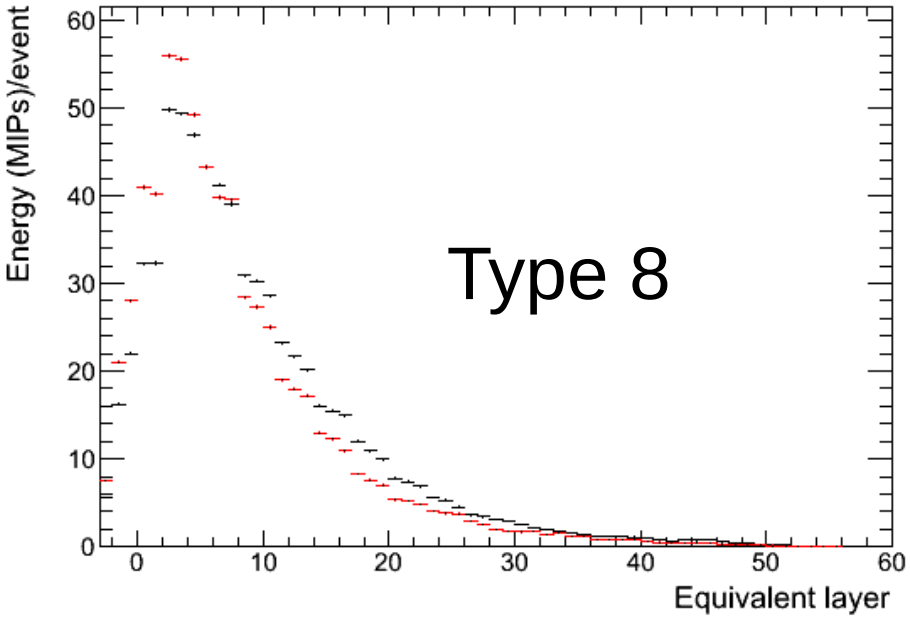


Longitudinal Profile

DATA

FTFP_BERT

Added information of layers before interaction point (not used by David or Philippe)

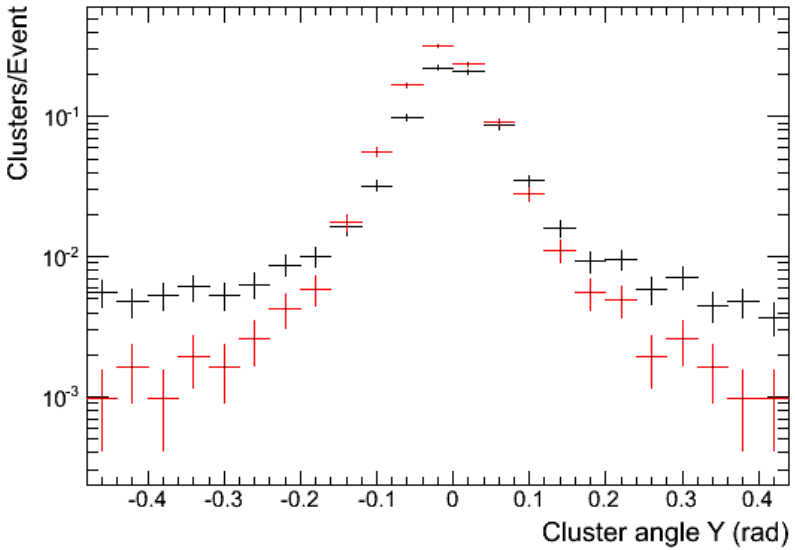


Conclusion

- New detailed reconstruction using the high segmentation is available and almost stable
- Thanks to the definition of tracks and clusters it allows the study of all subcomponents in the shower and the study of variable like # tracks and length
- The program has still some limitations:
  - No orthogonal tracks
  - No proton tracks
  - No multiple events
- First comparison plots available, still need some fine-tuning for specific event type
- Plan to write a note on the reconstruction algorithm
  - Maybe one on pion interaction
  - Electron and ParticleID could be nice topics for a summer student

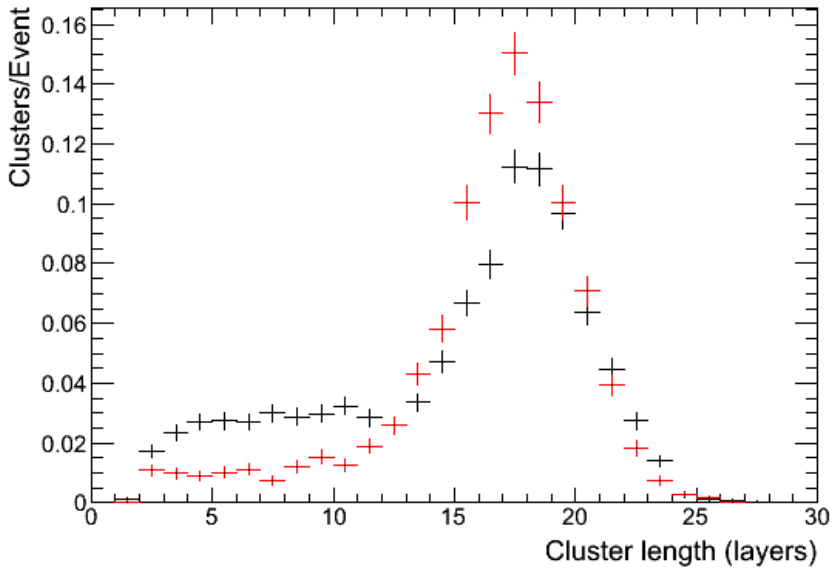
6GeV Electron at CERN

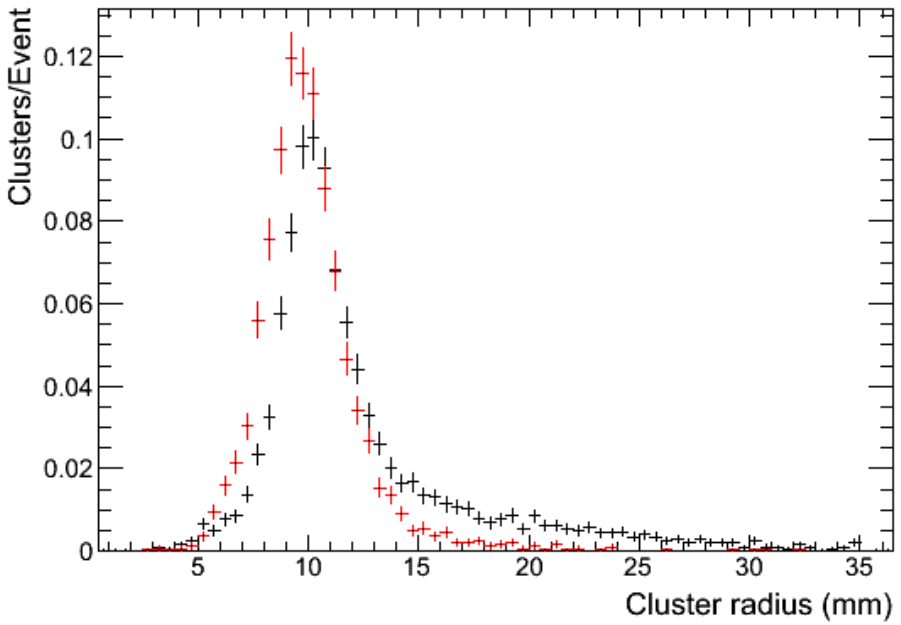
- Samples well known from my previous analysis and 6 GeV is common energy
- Latest reconstruction/digitisation available was used
- Reminder:
  - Poor agreement in profiles and radius between MC and DATA → maybe some types are responsible for the problem and others have good agreement
  - Pre-showering: not studied yet

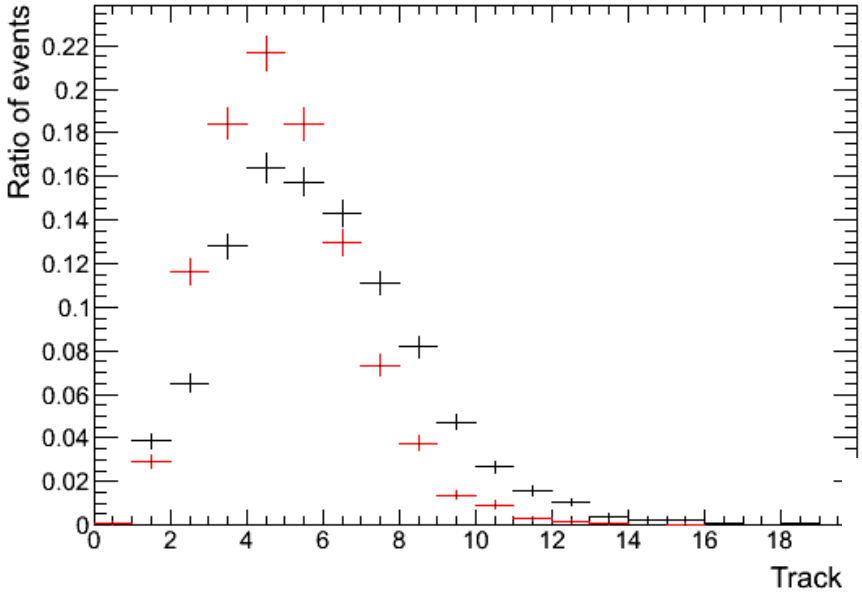


DATA

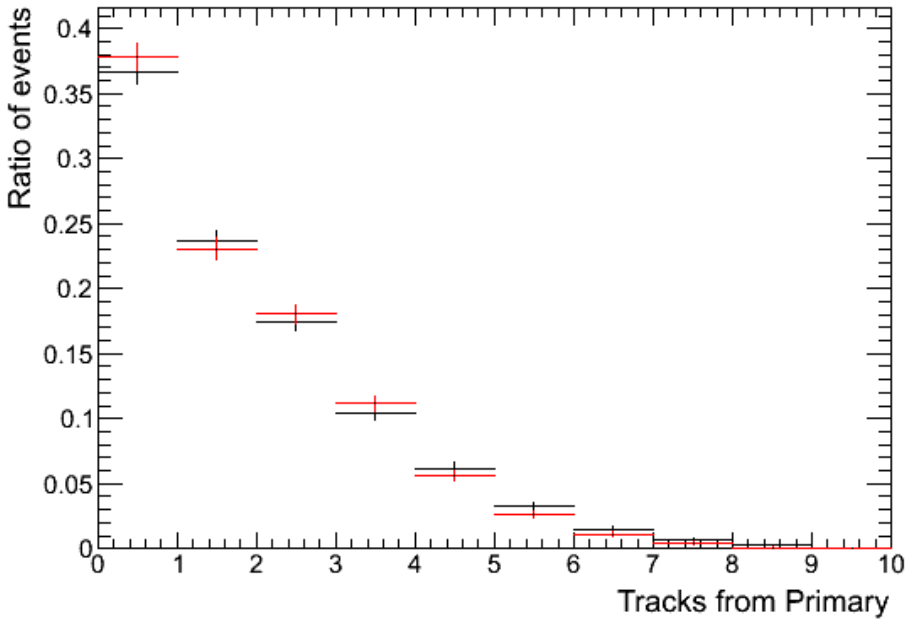
FTFP_BERT

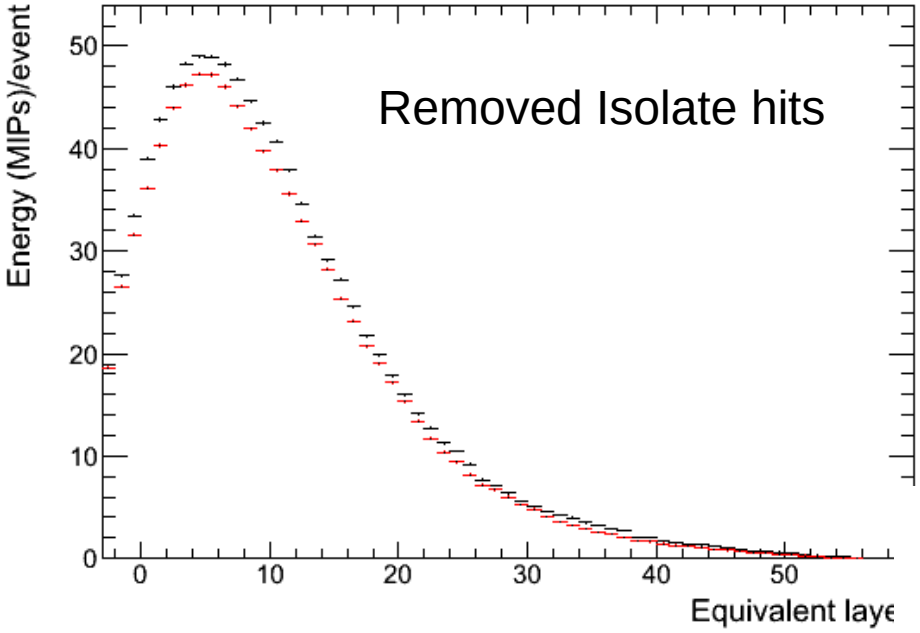






DATA
FTFP_BERT

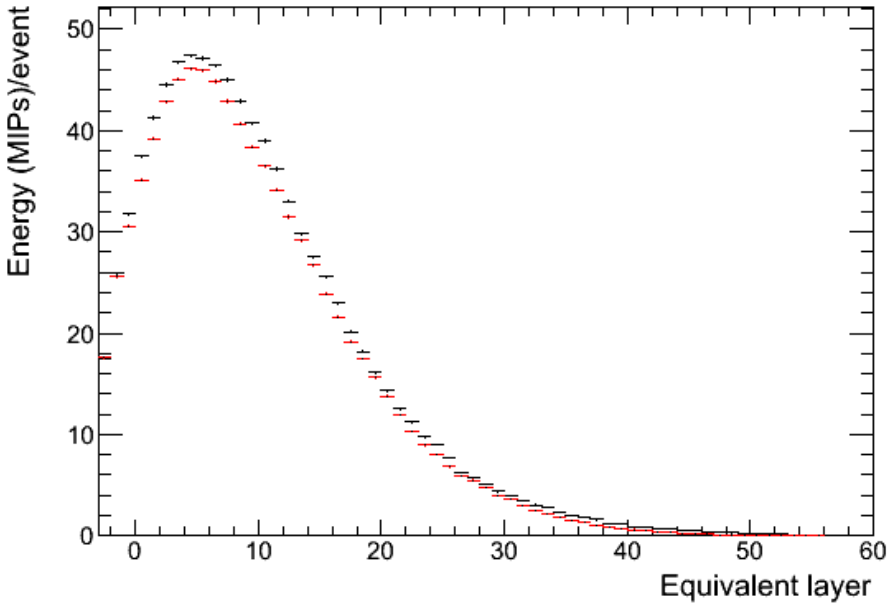


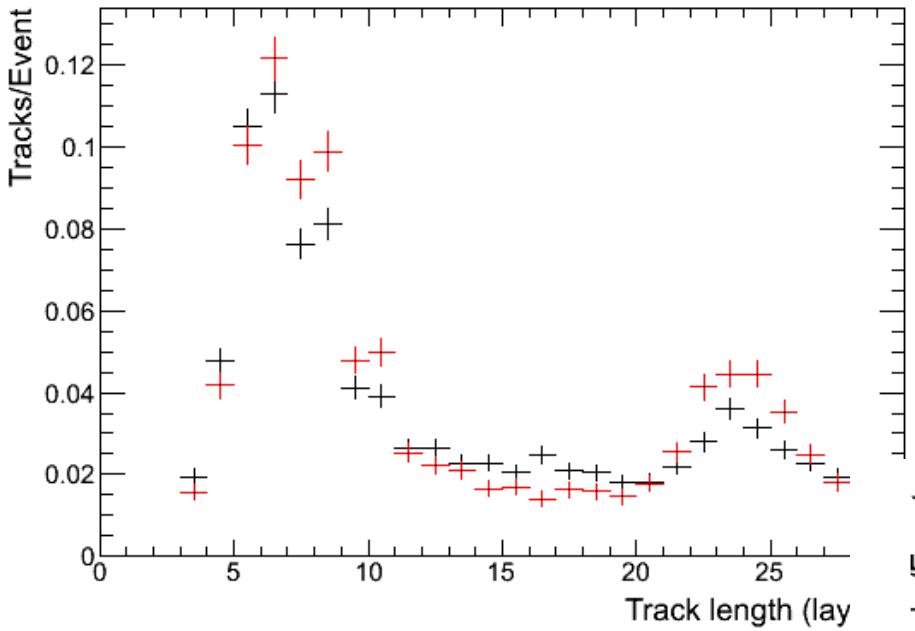


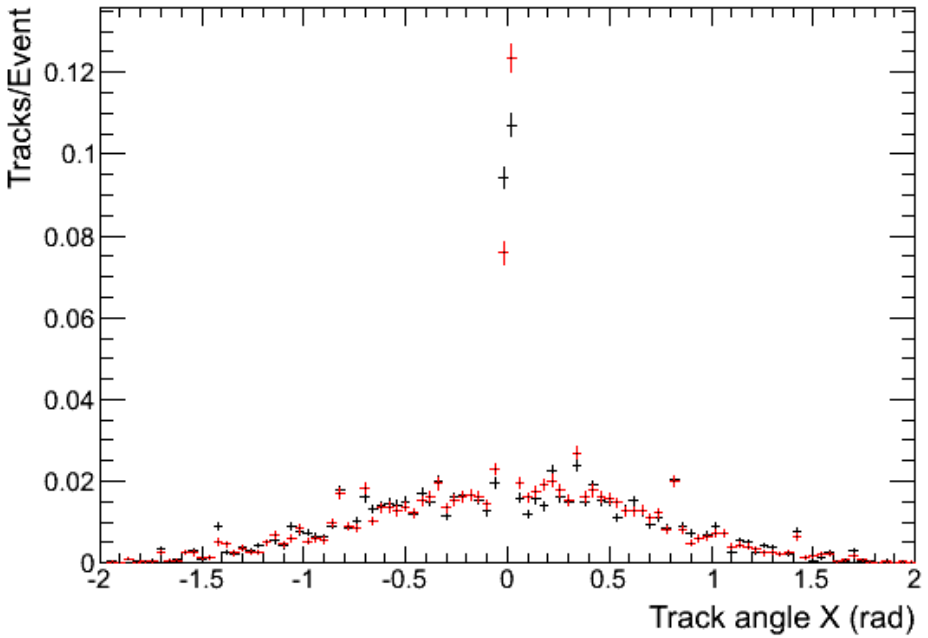
DATA

FTFP_BERT

ALL hits




Tracks/Event
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
Track length (lay


Tracks/Event
0.12
0.1
0.08
0.06
0.04
0.02
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Track angle X (rad)