Status of track reconstruction with ACTS in FCCSW

Julia Hrdinka (TU Wien)

On behalf of the ACTS & FCCSW Team

Motivation

The right tools at the right time…

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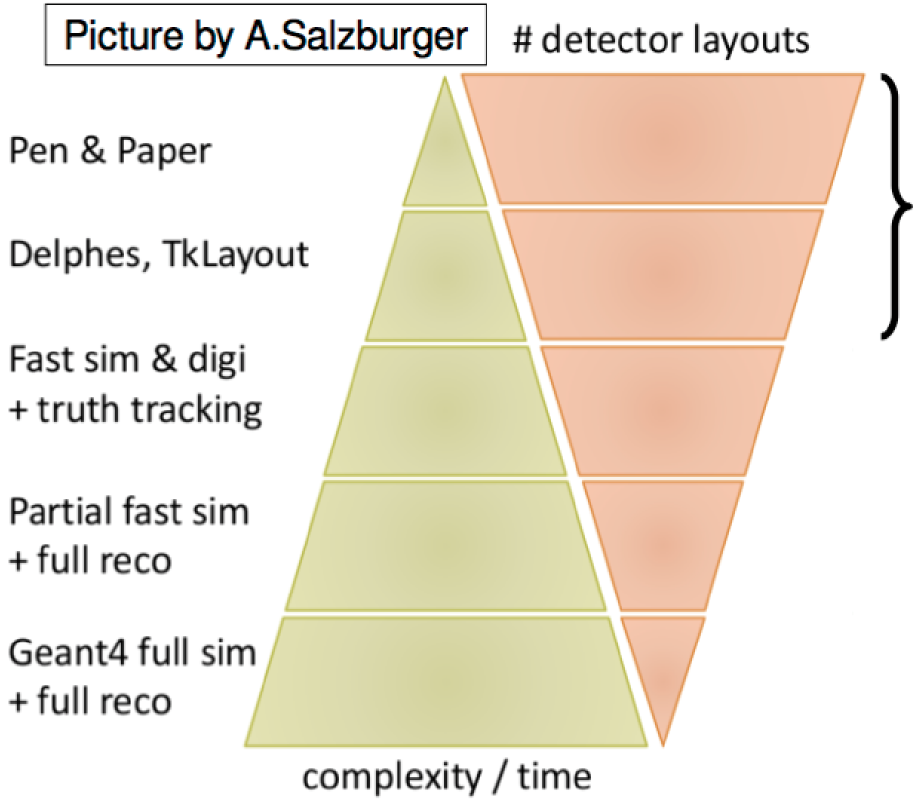

The tracker layout mainly optimized by applying:

- Approx. analytical approach: **tkLayout** (CMS)
- Numerical approach: **Mathematica**
- + using B field maps & Fluka simulated fluence map

=>See Talk Z.Drasal from the morning

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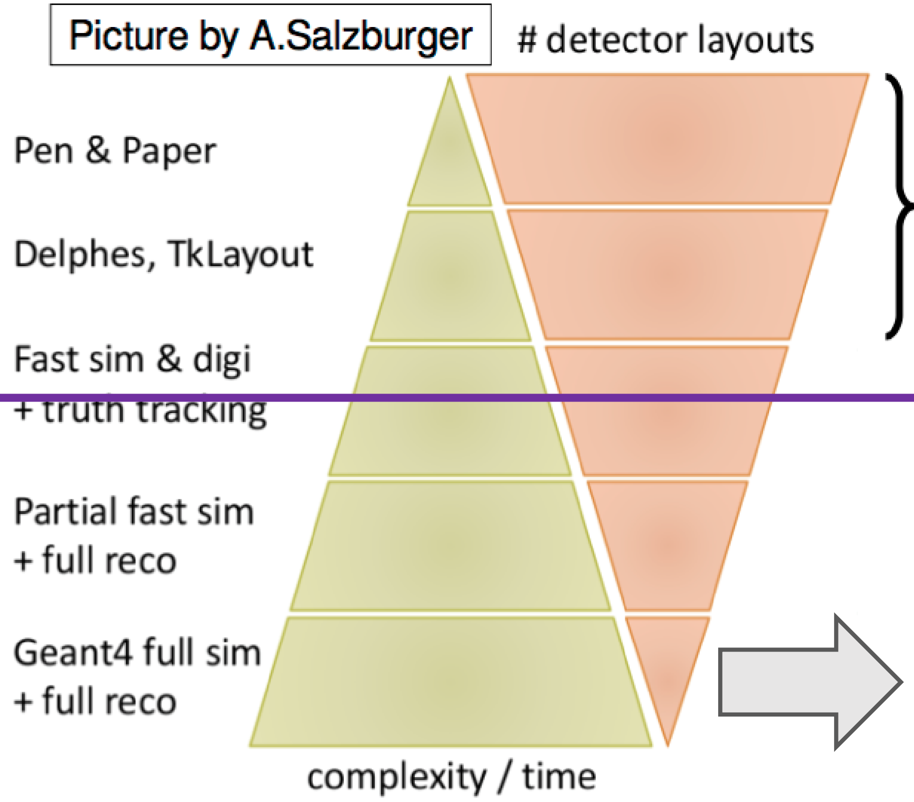

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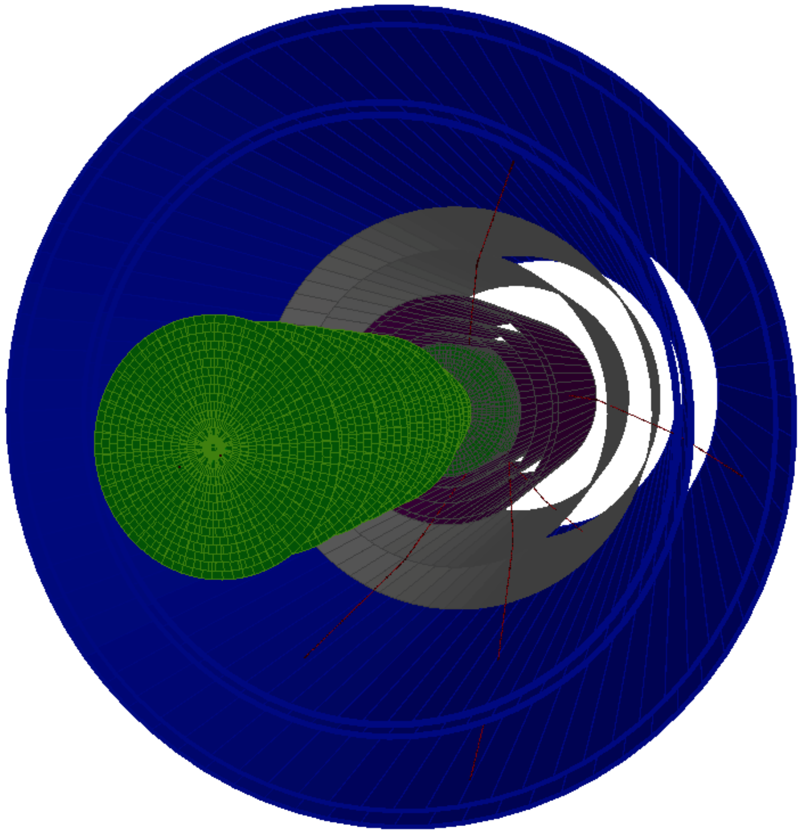
Long term strategy:

- Needs full geometry + material support
- Magnetic field description
- Full simulation
- Digitization
- Reconstruction

⇒ Detailed detector performance studies

Detector setup in tracking package ACTS

- **Full DD4hep geometry**
- **Automatically translated into tracking geometry**
  - Inner detector
  - Barrel of current **Muon System** implementation
    (DD4hep description from K. Terashi)
    => also chamber geometry can be supported
  - Barrels of **Calorimeter material**
  - Next step: implement end caps



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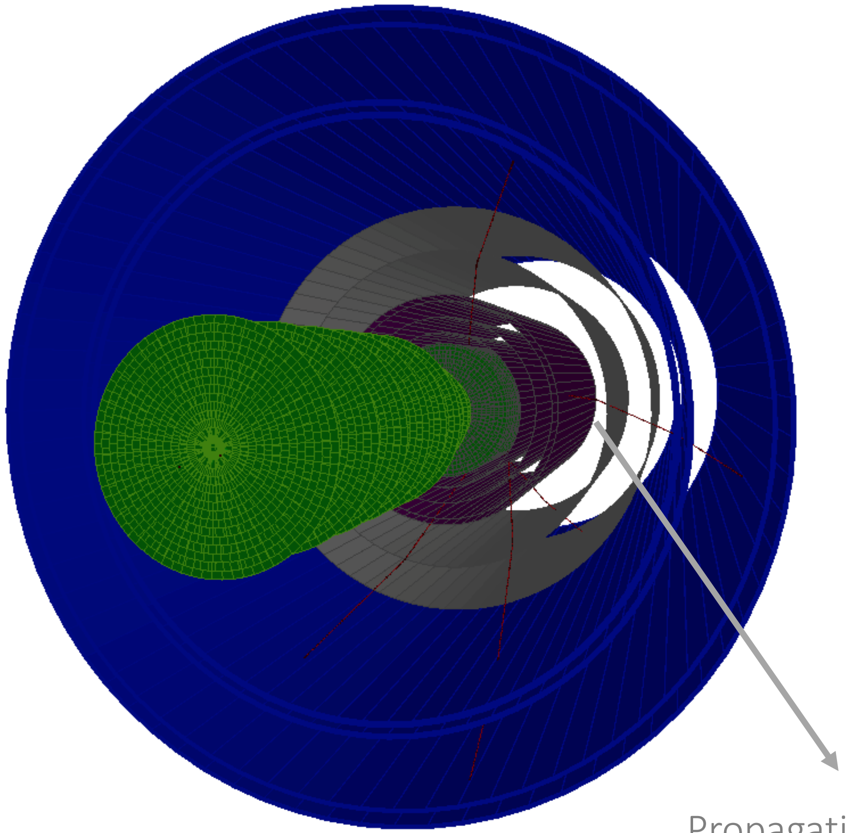
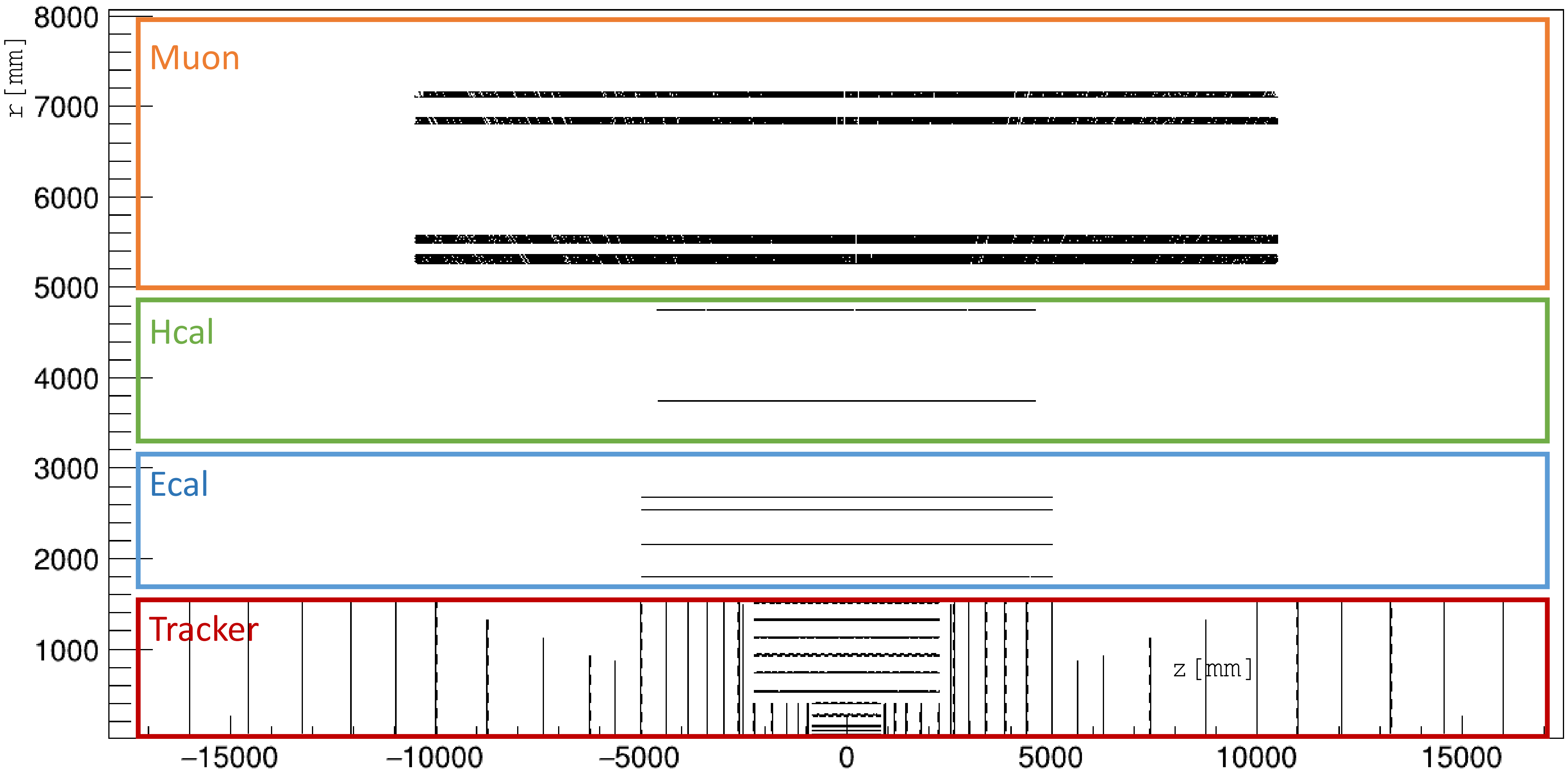


Propagating tracks through entire geometry + BField

Detector description inside ACTS

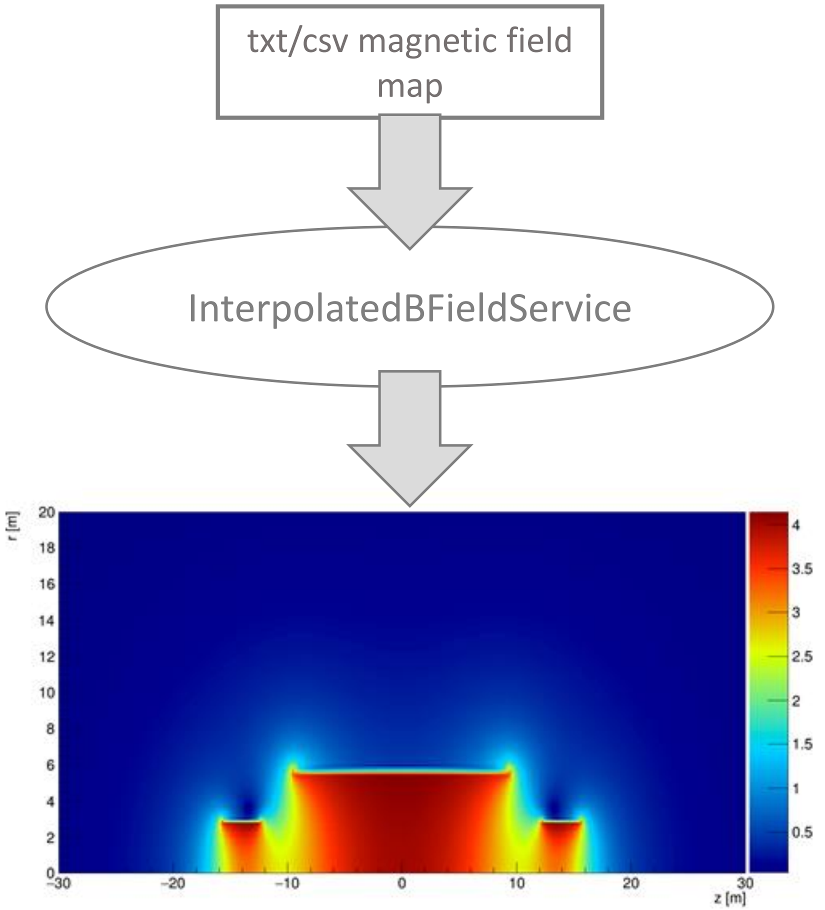
Sensitive and material hits seen by fast simulation



Magnetic field implementation in FCCSW

Magnetic field service

- Allows non uniform magnetic field
- Internally uses ACTS magnetic field implementation
- Can read field map from root/csv file
- Linearly interpolates field value within grid cell
- Field cache only gets updated when entering new cell
- Full simulation support in Geant4 (geant4 wrapper)
- Standalone tests implemented
- Tests inside full simulation ongoing



=>Written out during interpolation inside FCCSW

⇒ Open PR – will be merged after FCC week

⇒ Allows to study both magentic field options in detail

Status in FCCSW

Simulation → Digitization → Seeding → Track Reconstruction

Simulation
- Full Simulation (Geant4)
- Fast Simulation (Geant4,Delphes)
- Fast Simulation (ACTS)

Digitization

Analogue/ Digital Clustering

Seeding
- ATLAS Seeding (ACTS release 0.06)
- Trick Track (see V. Volkl)
- ACTS seeding prototype (untested)

Track Reconstruction
- Track following (expected by summer)
- Track fitting (currently being validated)

Working
Currently in progress
Not started

Digitization inside FCCSW using ACTS

Digitization inside FCCSW using ACTS

Close to realistic detector response

- Translate hit into measurement

Depends on technologies used for specific detector

- Use purely geometric approach
- Flexible
  - Mimic analogue/digital readout
  - Can take lorentz angle into account
- Can use either full or fast simulation hits as input
- Uses the granularities of FCChh reference design v3.03

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⇒ Allows to test digital/analogue readout
⇒ Allows to study readout of detector
⇒ First studies using digitzation in second part of talk

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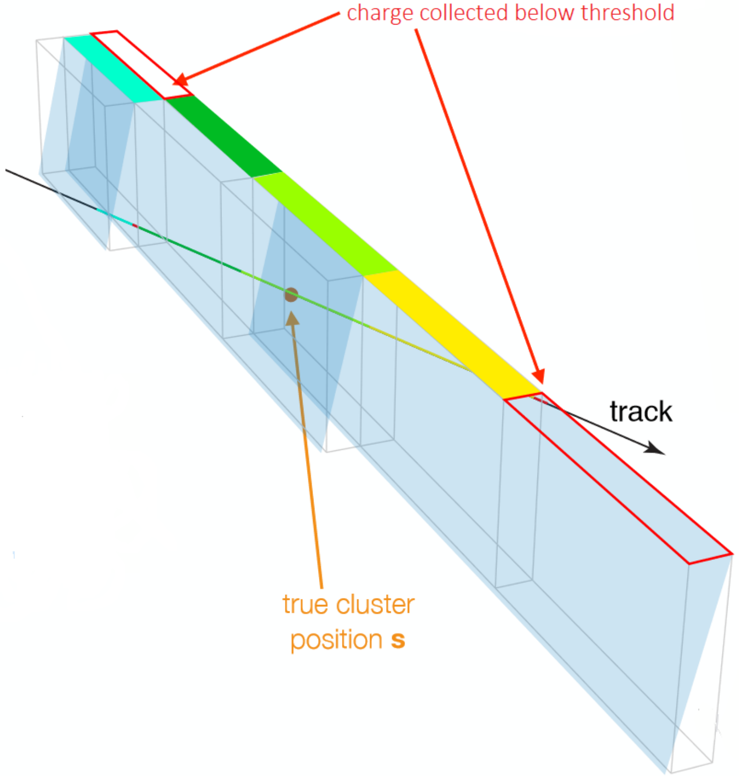

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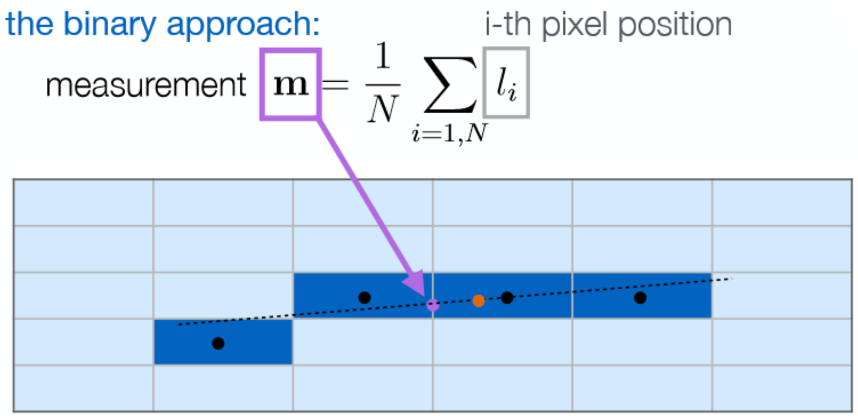
Digitization – creating measurements

- Determines cells hit by particle
- Create clusters from neighbouring cells using **connected component analysis** (boost)
  - Labels connected cells which will be merged into one cluster
  - Allows single clusters from multiple particles



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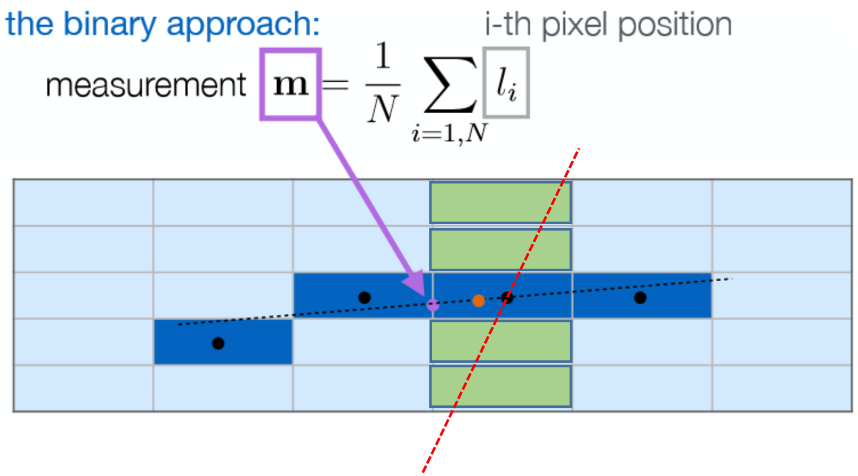

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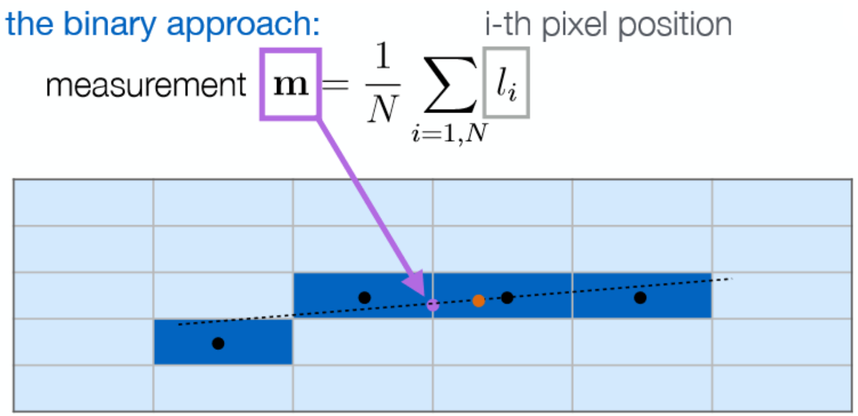

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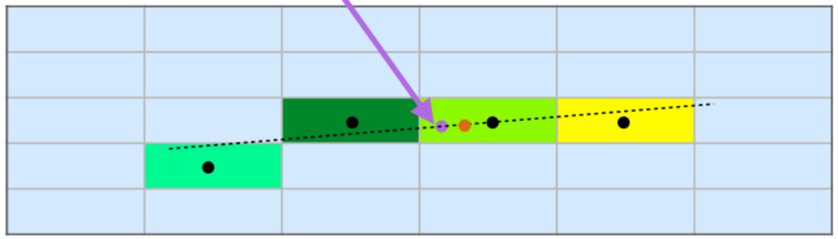
the charge-weighted approach :

$$\mathbf{m} = \frac{1}{\sum_{i=1,N} q_i} \sum_{i=1,N} q_i l_i$$

charge collected in cell i



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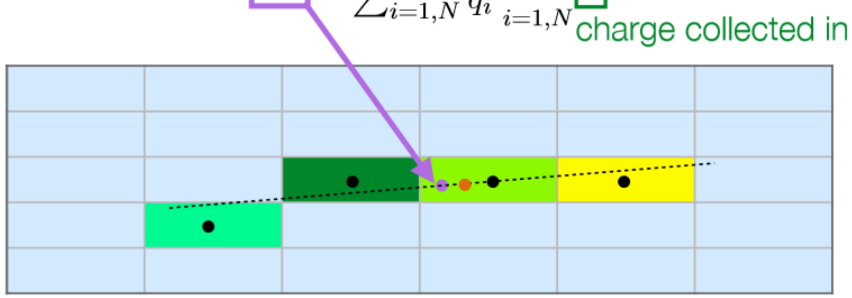


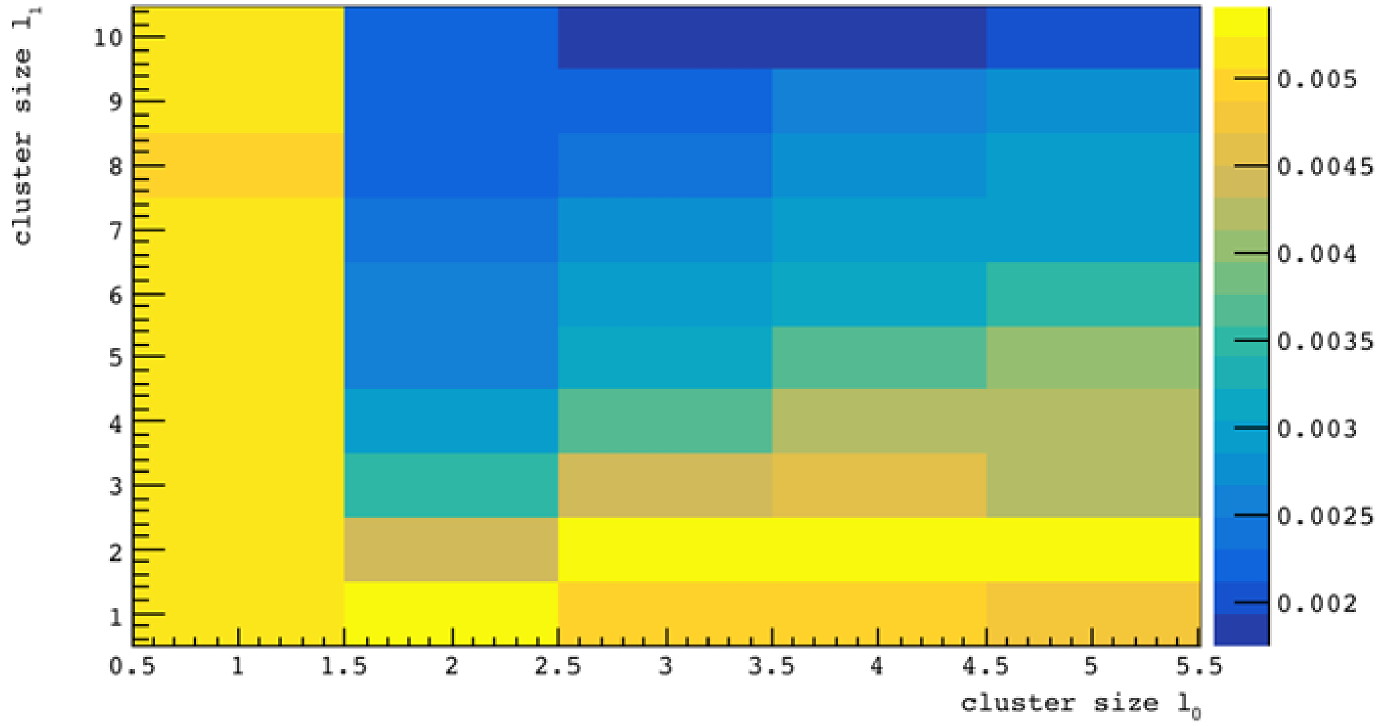
Resolution depends on:
- readout granularity
- Incident angle (i.e. cluster shape)

Cluster errors (residuals to truth position) => realistic resolution estimate

Measurement resolutions I

Output of single particle simulation as input to error parameterization

- first estimate cluster sizes per layer,
  e.g. innermost Pixel layer with l_0 x l_1 = 25 µm x 50 µm pixelization



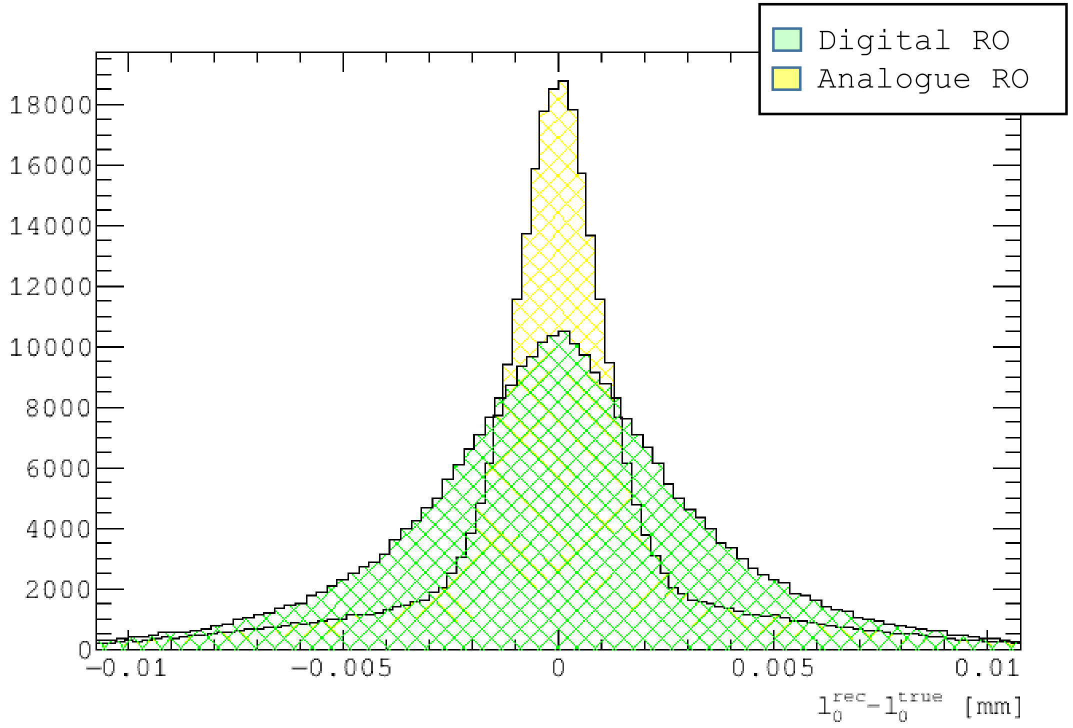
- Resolutions for different cluster sizes
- Obtained with fast track simulation using tracking geometry

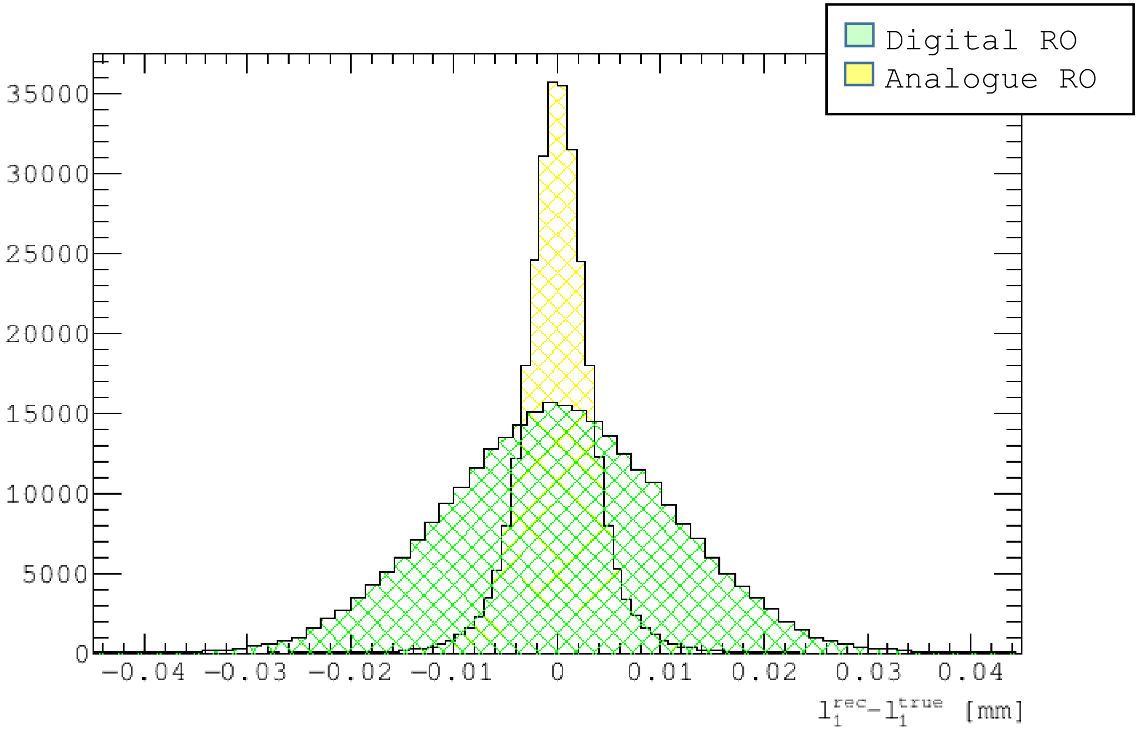
Measurement resolutions II

Output of single particle simulation as input to error parameterisation

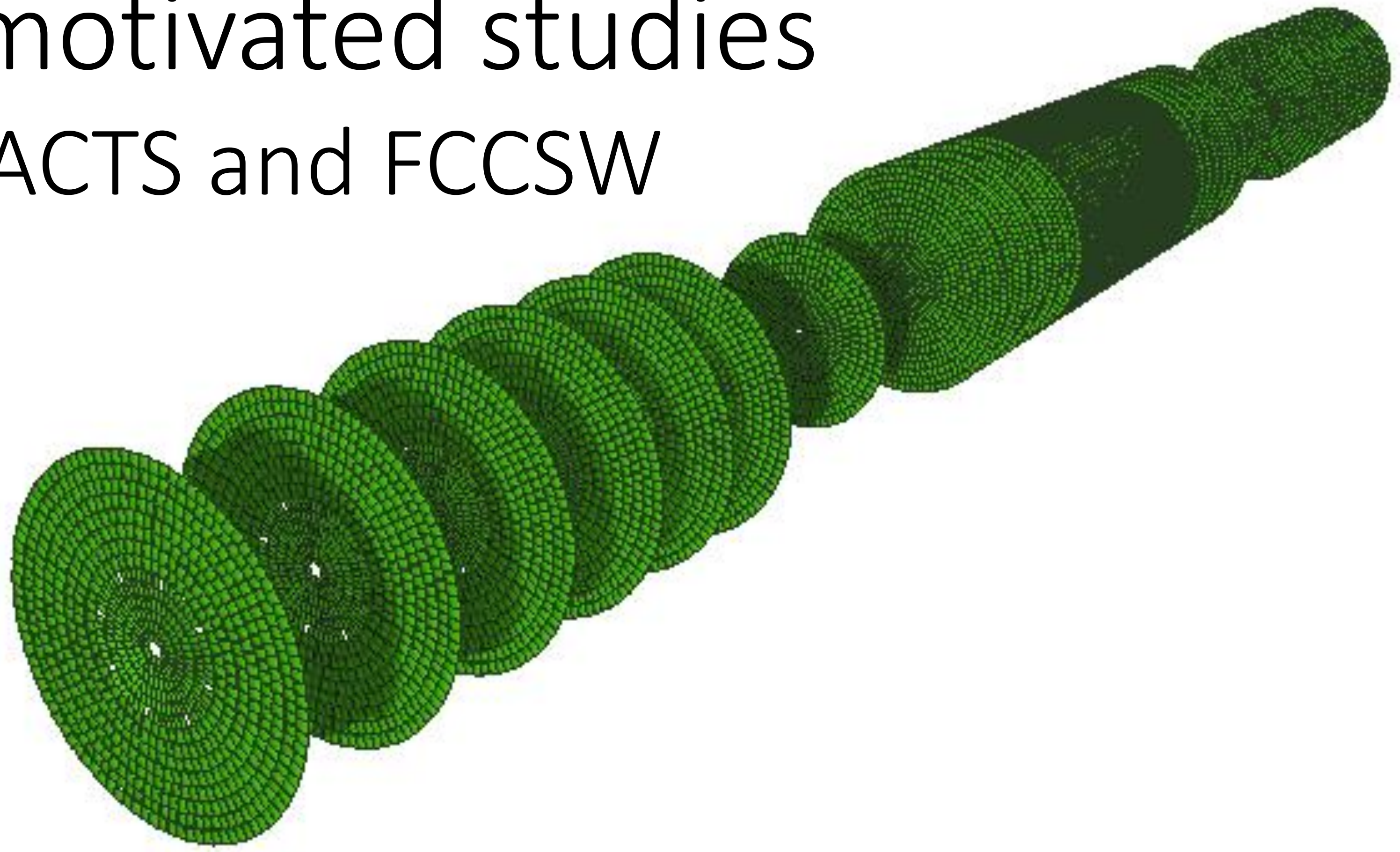
- ➢ second, create resolution plots for different cluster sizes

  e.g. innermost Pixel layer with l_0 x l_1 = 25 µm x 50 µm pixelization





Physics motivated studies
using ACTS and FCCSW



Pattern Recognition

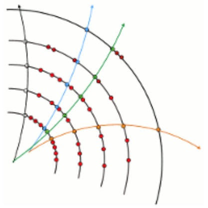
Two main challenges for the detector @ 100 TeV collider

- Pile up of 1000
  - How big is the channel occupancy?
  - Can we do pattern recognition at such harsh environment?

⇒ Studied with full simulation

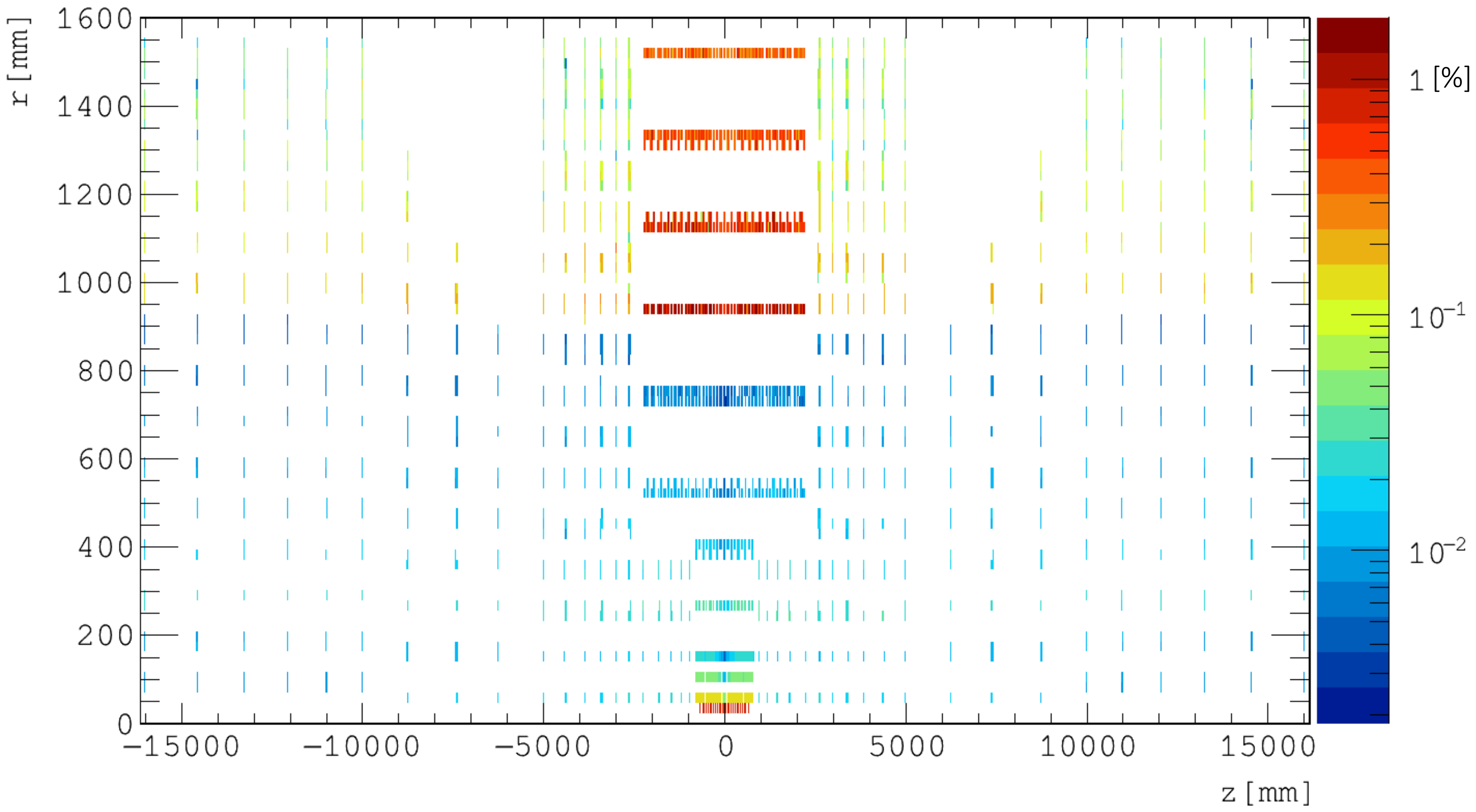
⇒ First application of digitization

- Colliminated Jets
  - Can we resolve two close by tracks?
  - On top of 1000PU



Channel Occupancy I

Full simulation, 1000 Pile up Event, minBias, const BField, **primaries only**



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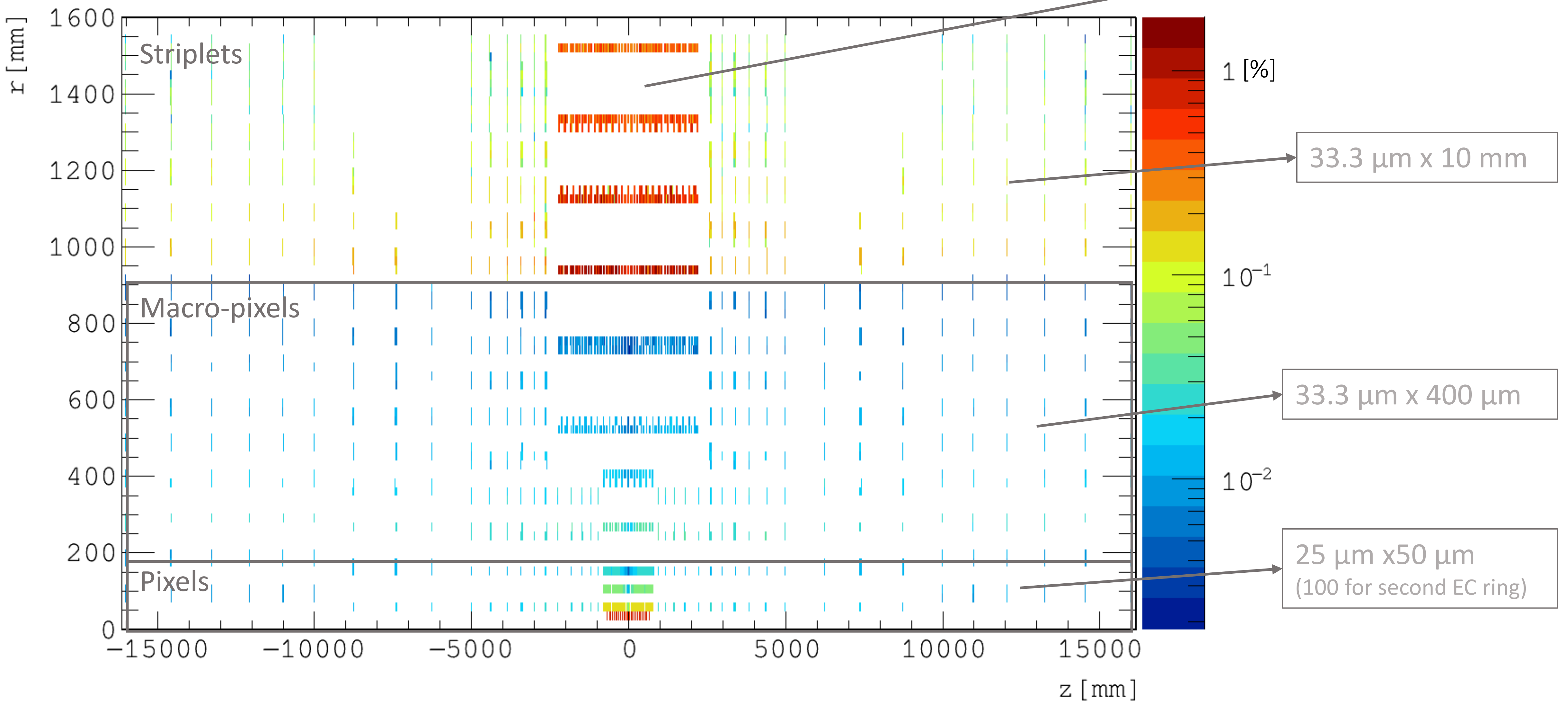
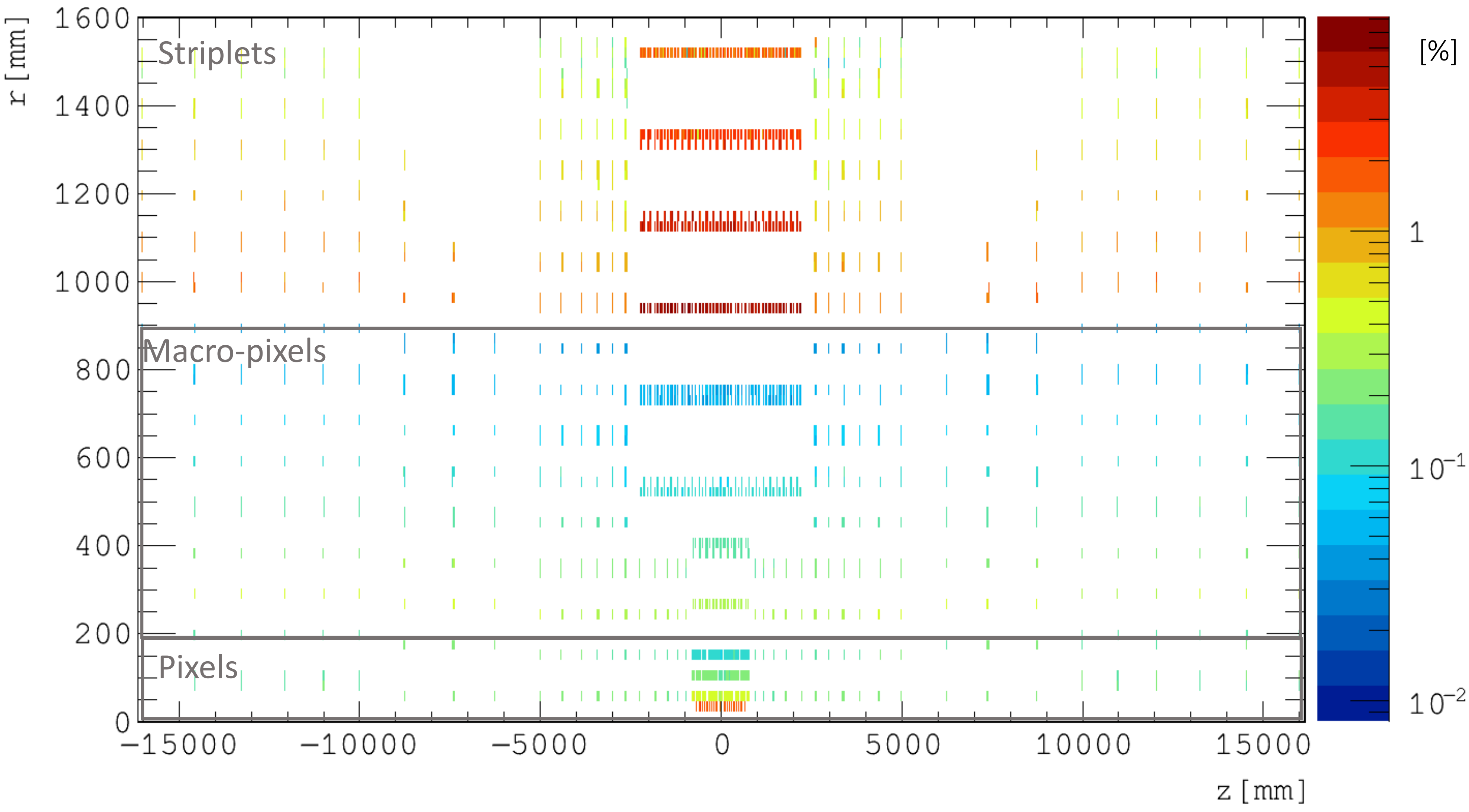


Channel Occupancy II

Full simulation, 1000 Pile up Event, minBias, const BField, **secondaries included**



All particles are digitized apart from:

- Pixels < 1000eh pairs
- Strips < 6500eh pairs

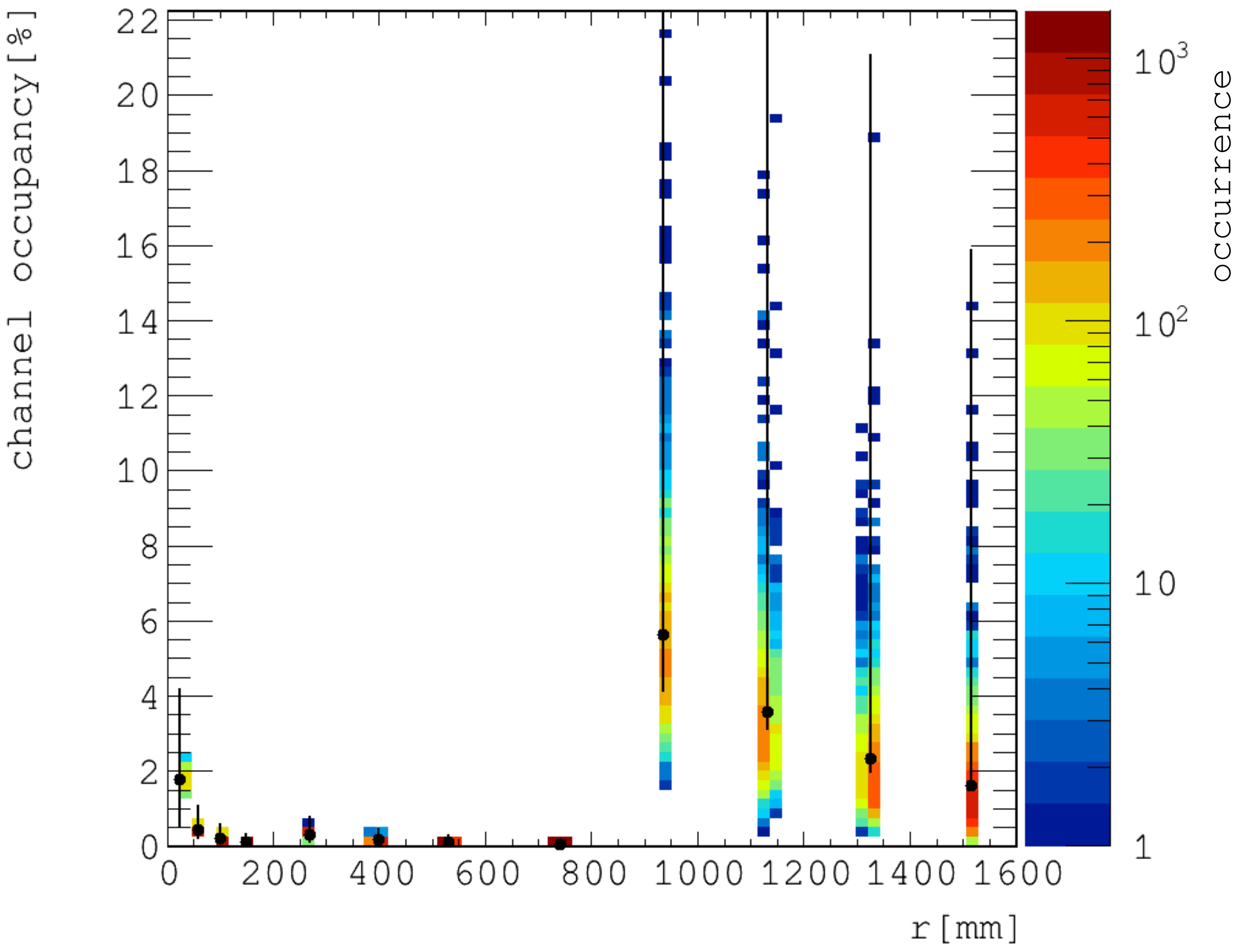
High rates may be compensated for tilted layout

Different striplet lengths:

- Barrel: 1.75mm (50mm)
- EC: 1.75mm (10mm)

Channel Occupancy - barrel layers

Full simulation, 1000 Pile up, minBias, **secondaries included**

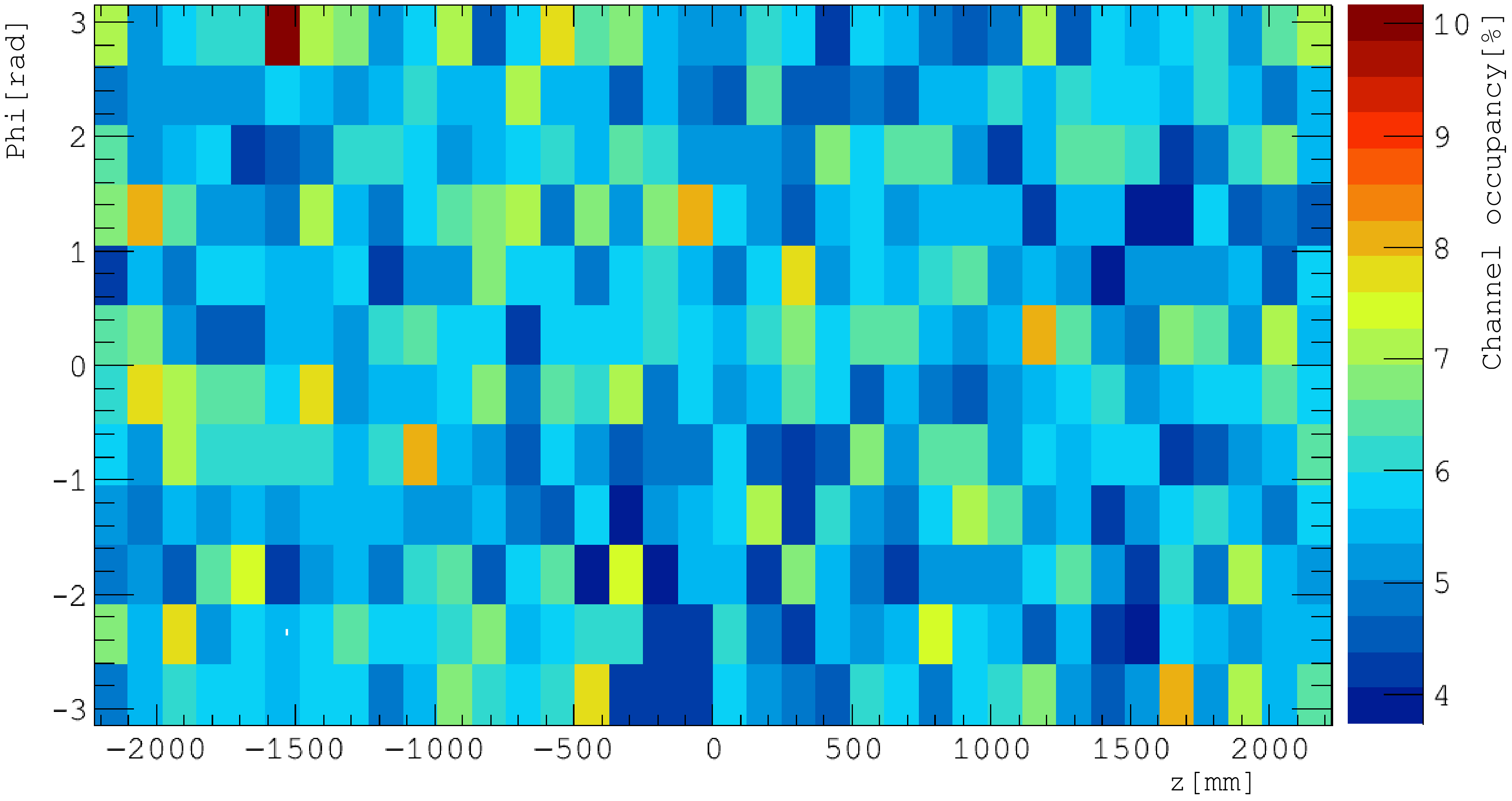


Barrel Layer	All particles (mean±σ)	Prim. Only (mean±σ)	Calculation(*) (max)
1	1.79 ± 0.23	0.73 ± 0.10	0.45
2	0.43 ± 0.07	0.13 ± 0.03	0.11
3	0.20 ± 0.03	0.05 ± 0.01	0.05
4	0.11 ± 0.02	0.02 ± 0.01	0.02
5	0.30 ± 0.04	0.03 ± 0.01	0.08
6	0.16 ± 0.03	0.02 ± 0.00	0.04
7	0.10 ± 0.02	0.01 ± 0.00	0.02
8	0.05 ± 0.01	0.01 ± 0.00	0.01
9	5.6 ± 1.95	1.09 ± 0.82	0.75
10	3.57 ± 1.62	0.69 ± 0.61	0.43
11	2.32 ± 1.27	0.46 ± 0.44	0.27
12	1.61 ± 1.04	0.37 ± 0.47	0.21

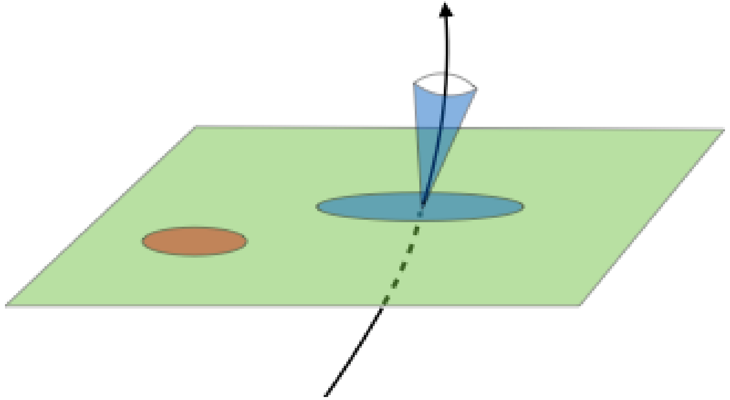
⇒ Discrepancies seen to calculations
⇒ Need to understand why

(*)Calculated by Z.Drasal using Fluka rates (see)

Channel occupancy – layer with highest mean



Difficulty of pattern recognition



Propagate error ellipse through detector (with material)

- ➢ Use measurements obtained from primaries only
- ➢ Calculate if measurement is disturbed by other measurement in 95% if error ellipse for one layer
- ➢ Accumulate over all layers

⇒ Obtain probability for backround contamination along one track

⇒ Material induced confusion big enough to surpress you to 0 efficiency

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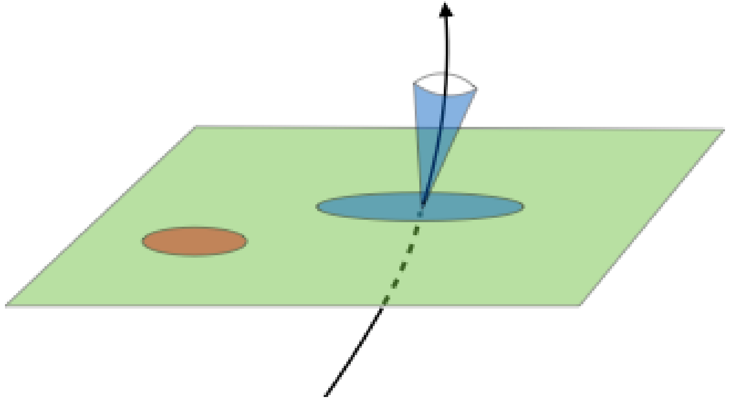

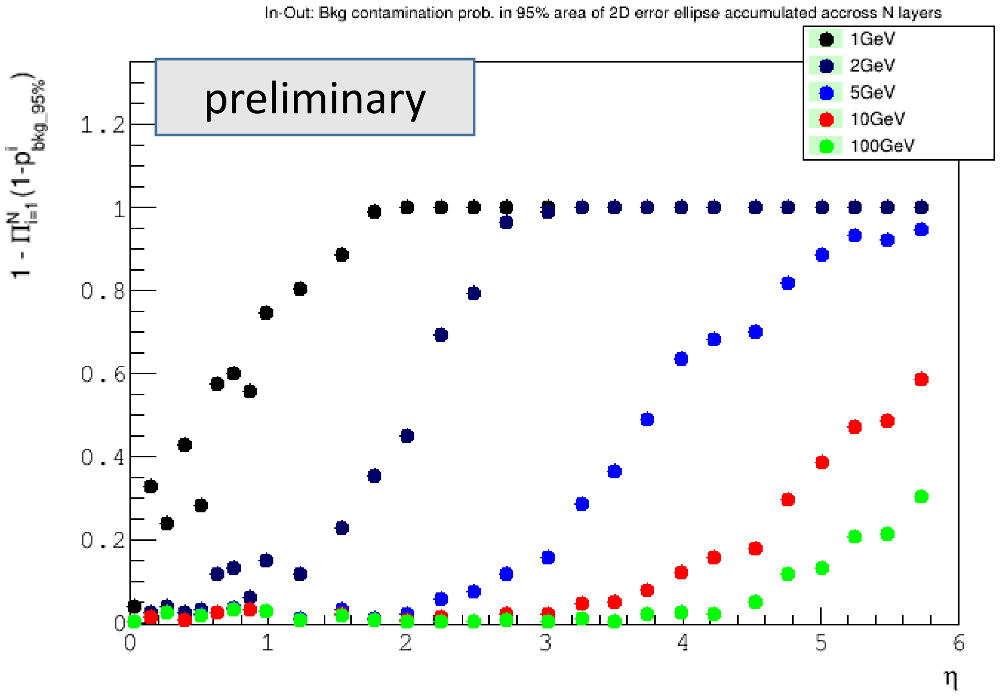

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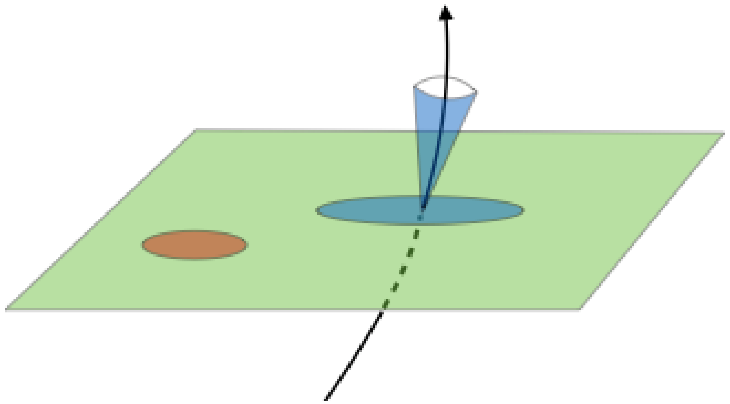

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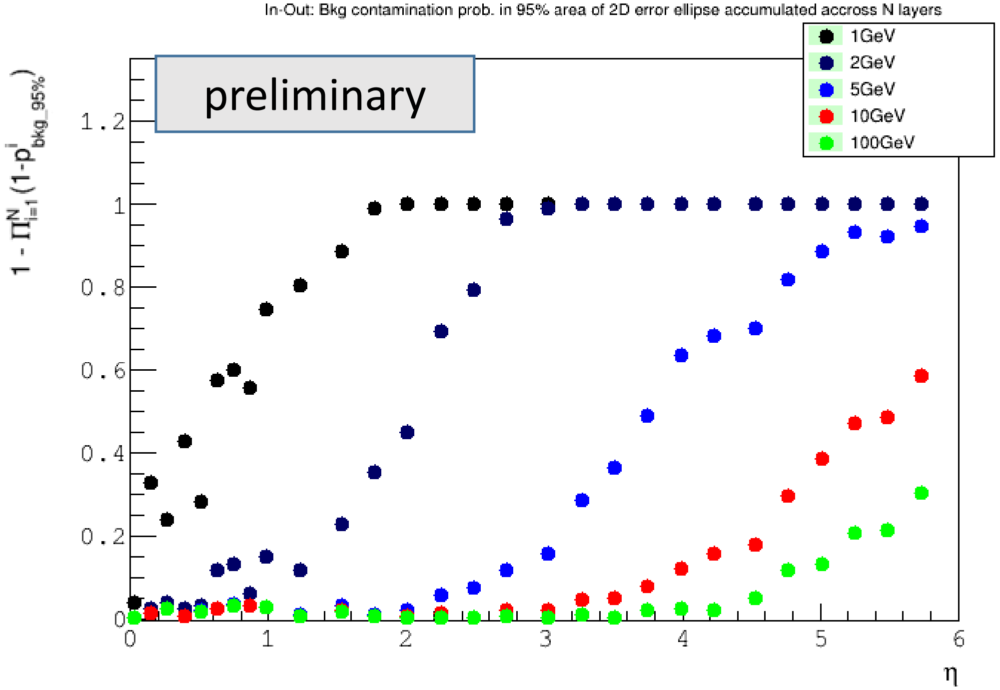
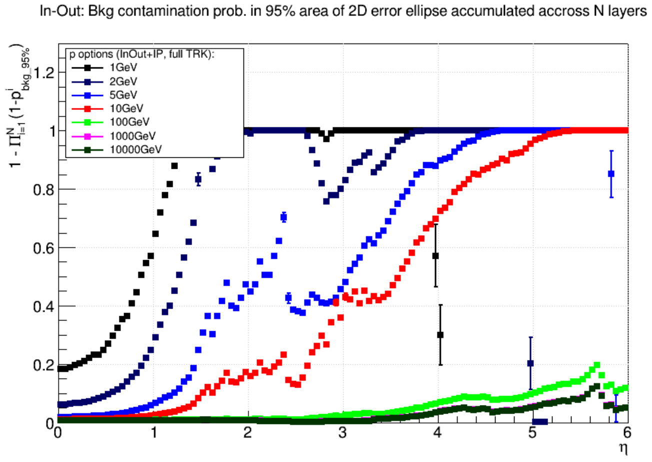


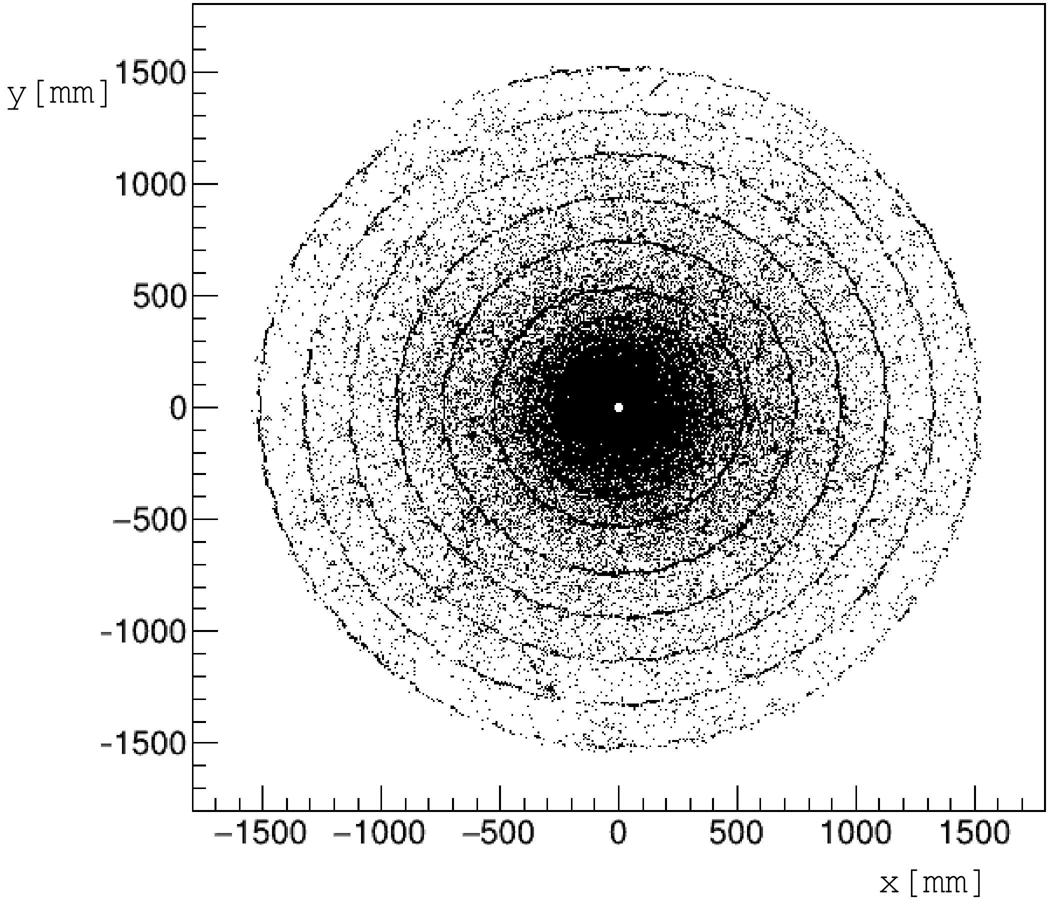
⇒ Need to redo with Kalman filter

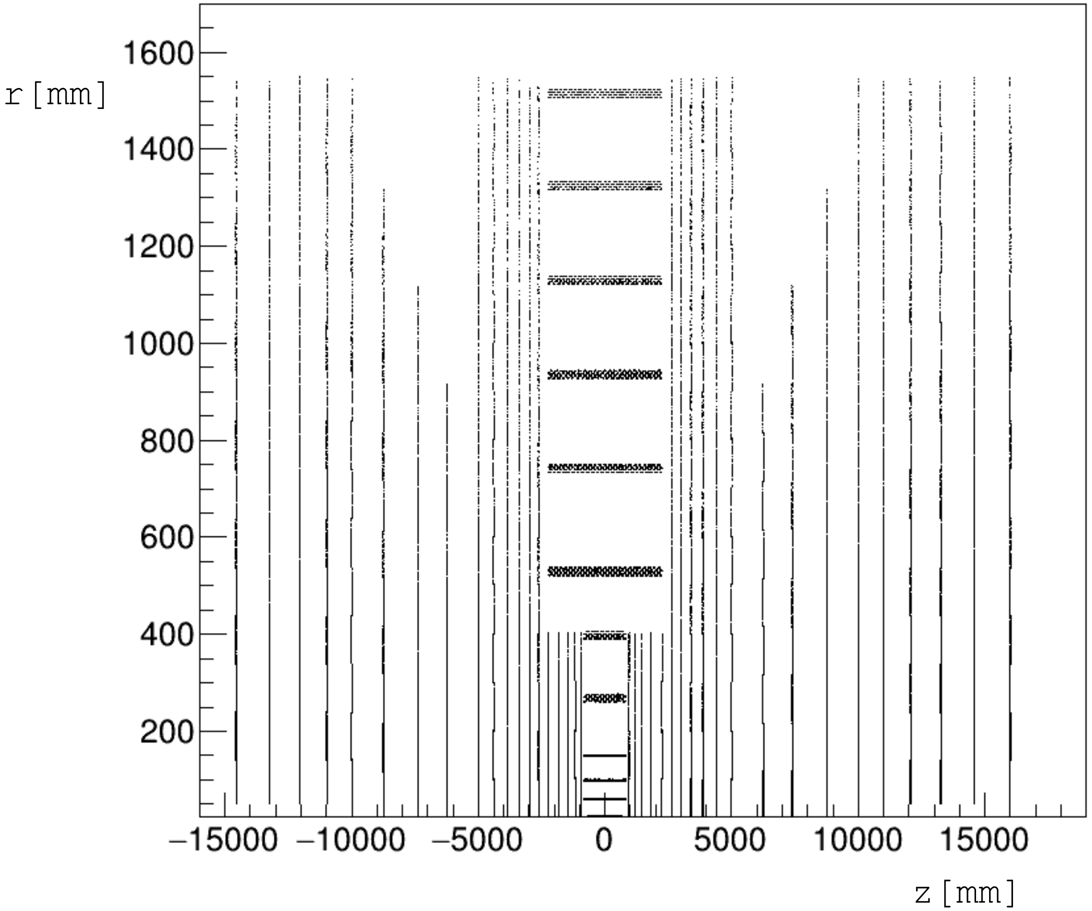
⇒ Finally want to compare with results obtained with analytical approach + FLUKA simulation by Z.Drasal



Sensitive hits 1 TeV bjets – 1 Event

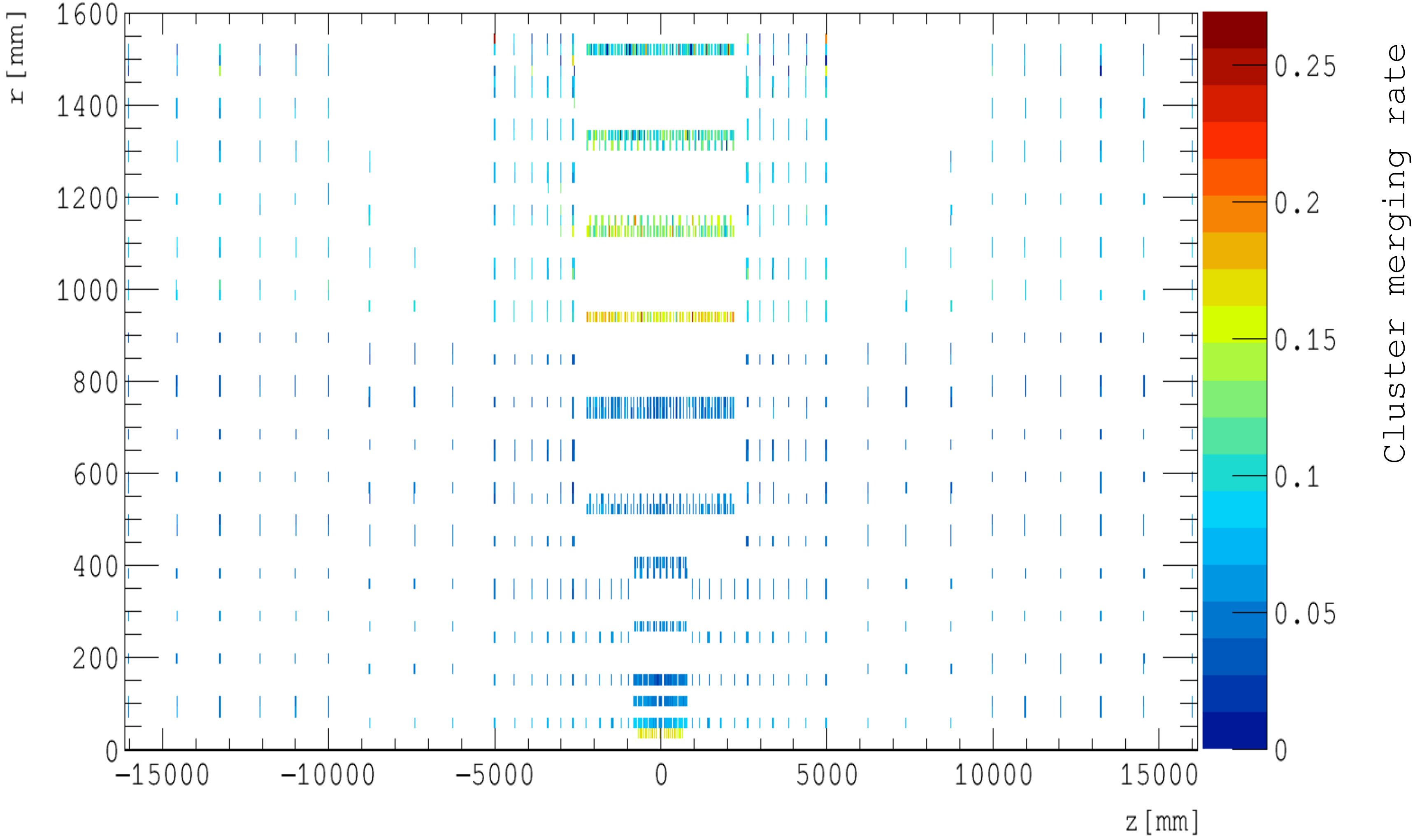
Full simulation, secondaries included, no pile up, const Bfield





Merged Cluster Rate

Full simulation, 1000 Pile up minBias + 1TeV bjets, **secondaries included**



Merged cluster rate:

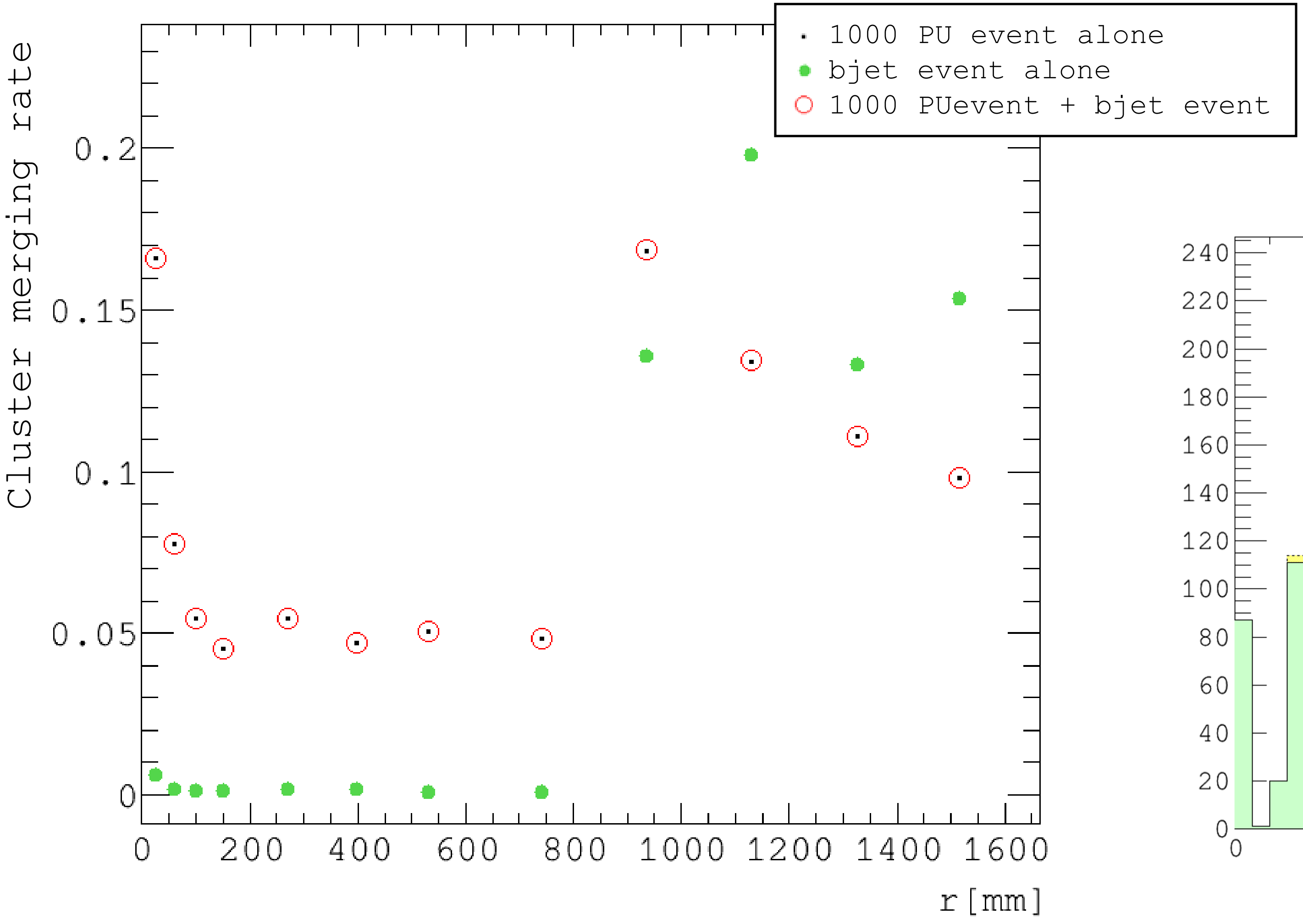
$$merged\ clusters(1)\ /clusters(2)$$

Per module

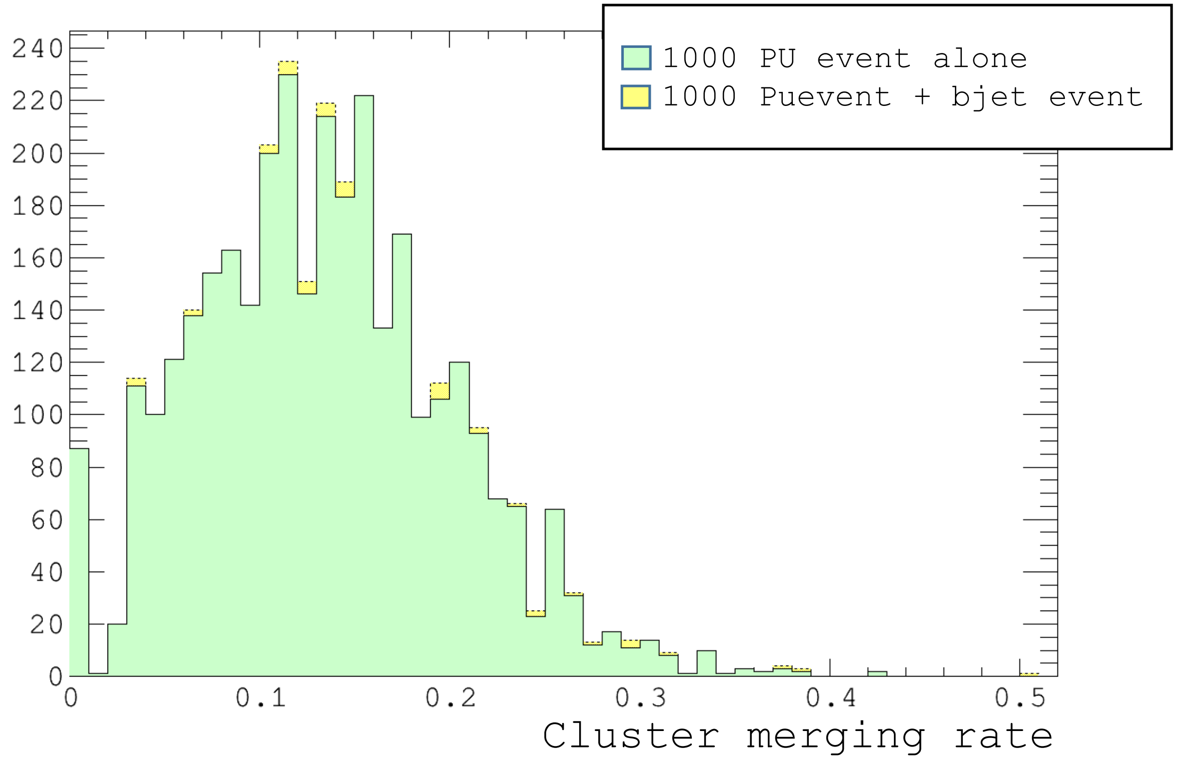
(1) Number of clusters containing more than one particle

(2) clusters

Merged Cluster Rate

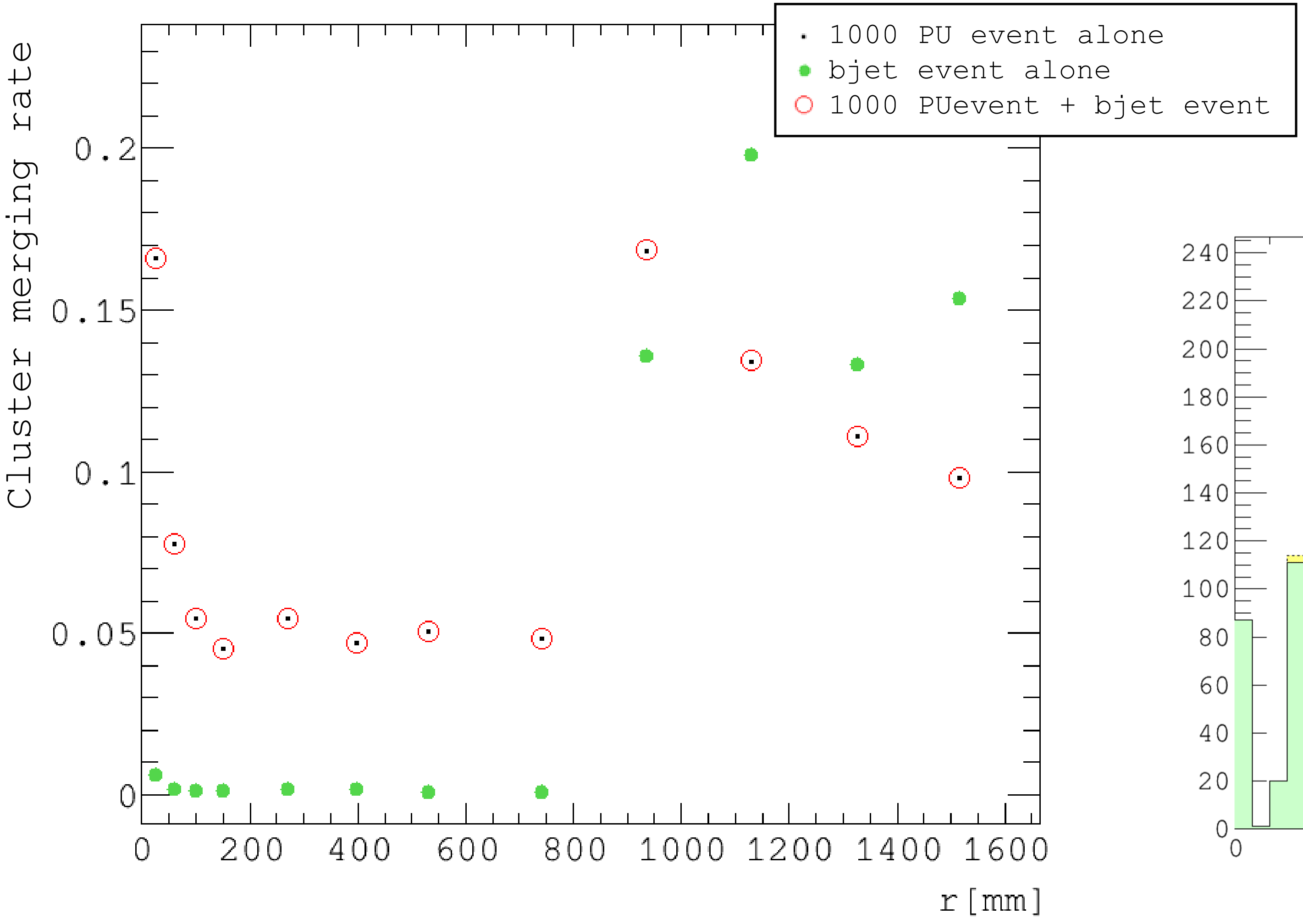


Cluster merging rate Layer 10



Merged Cluster Rate

⇒ Pile up is dominant
⇒ Bjet event on top adds up less than 1% of merged clusters



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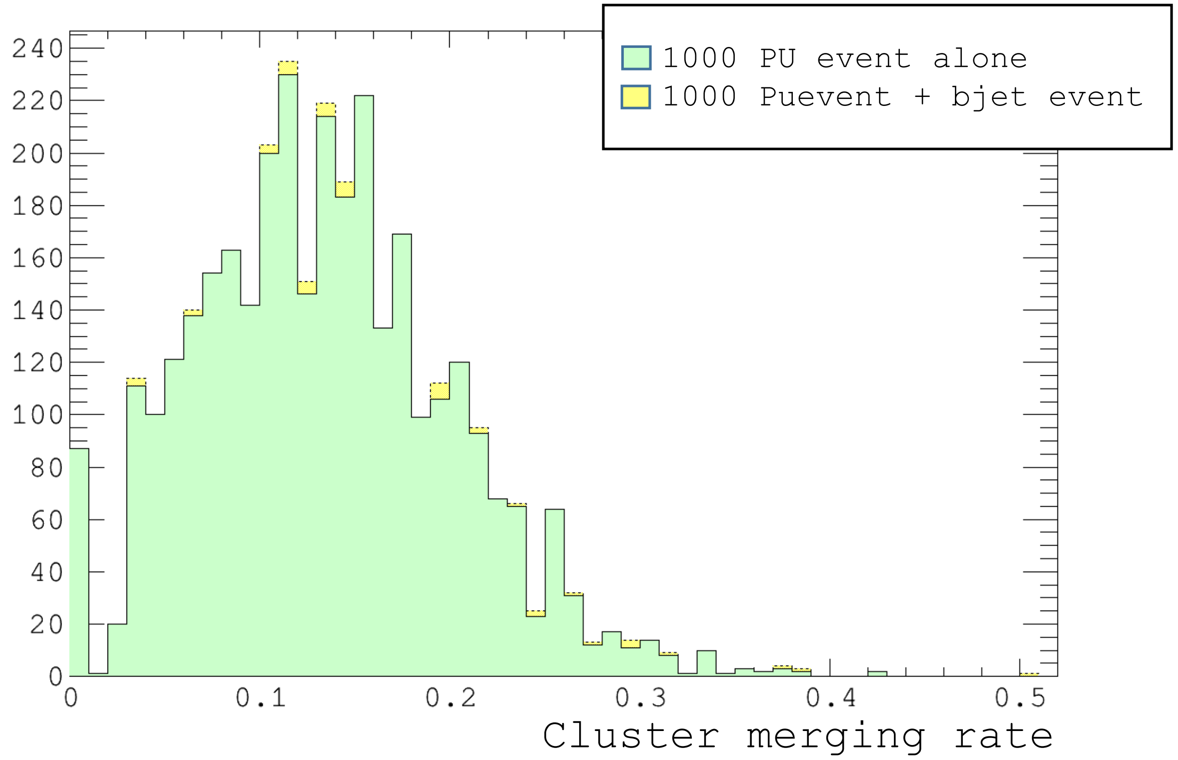
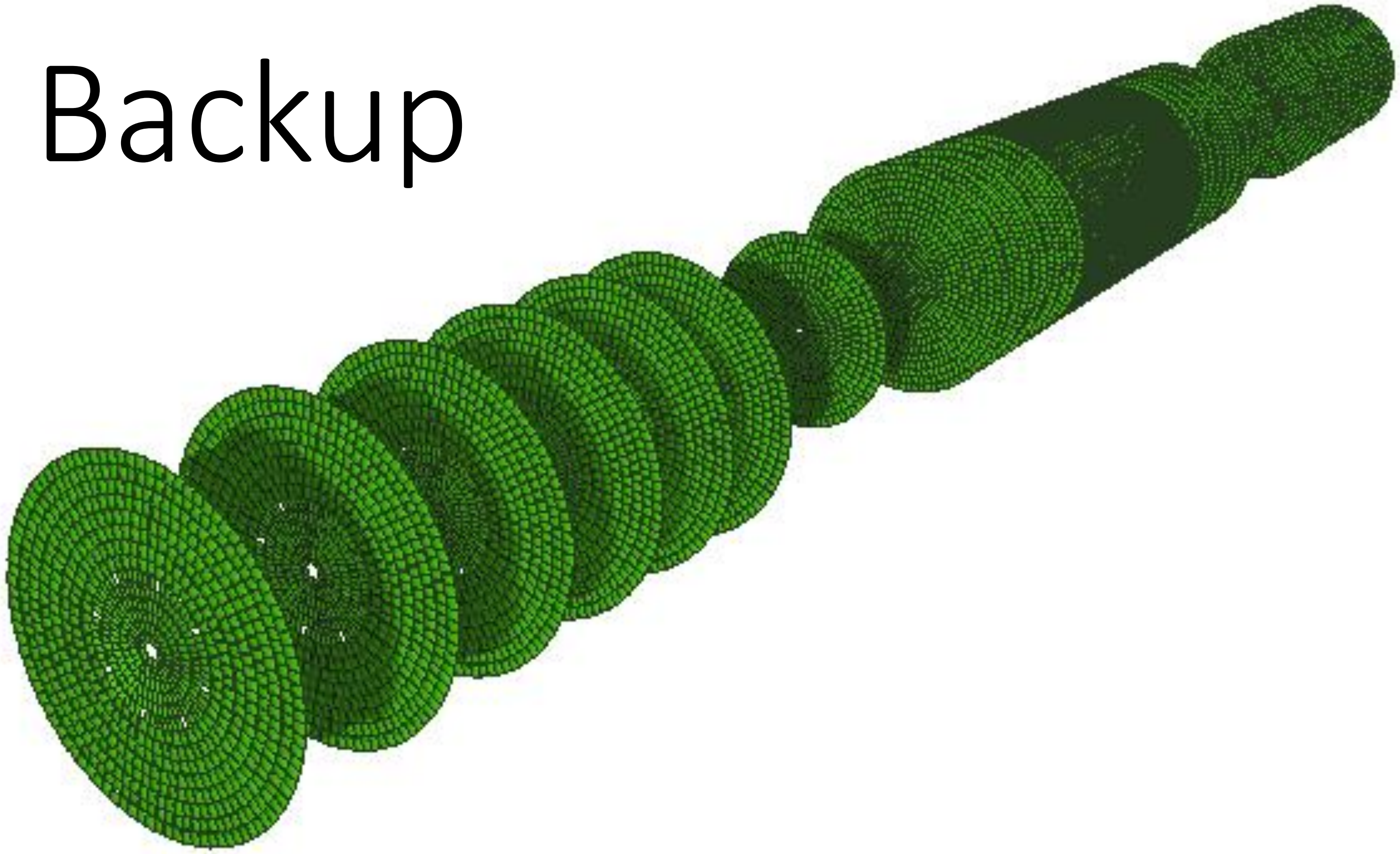


Conclusion & Outlook

- First studies could be done using FCCSW full simulation & ACTS
- Continue integration & testing in FCCSW
- Integrate fast track simulation & track fitting into FCCSW
- Build track segments with trick track (see V. Volkl) and fit with ACTS
- Continue studies with further details and statistics for CDR
- Find reason for high occupancy rates
- Study double track resolution from generated jets using Jet algorithm

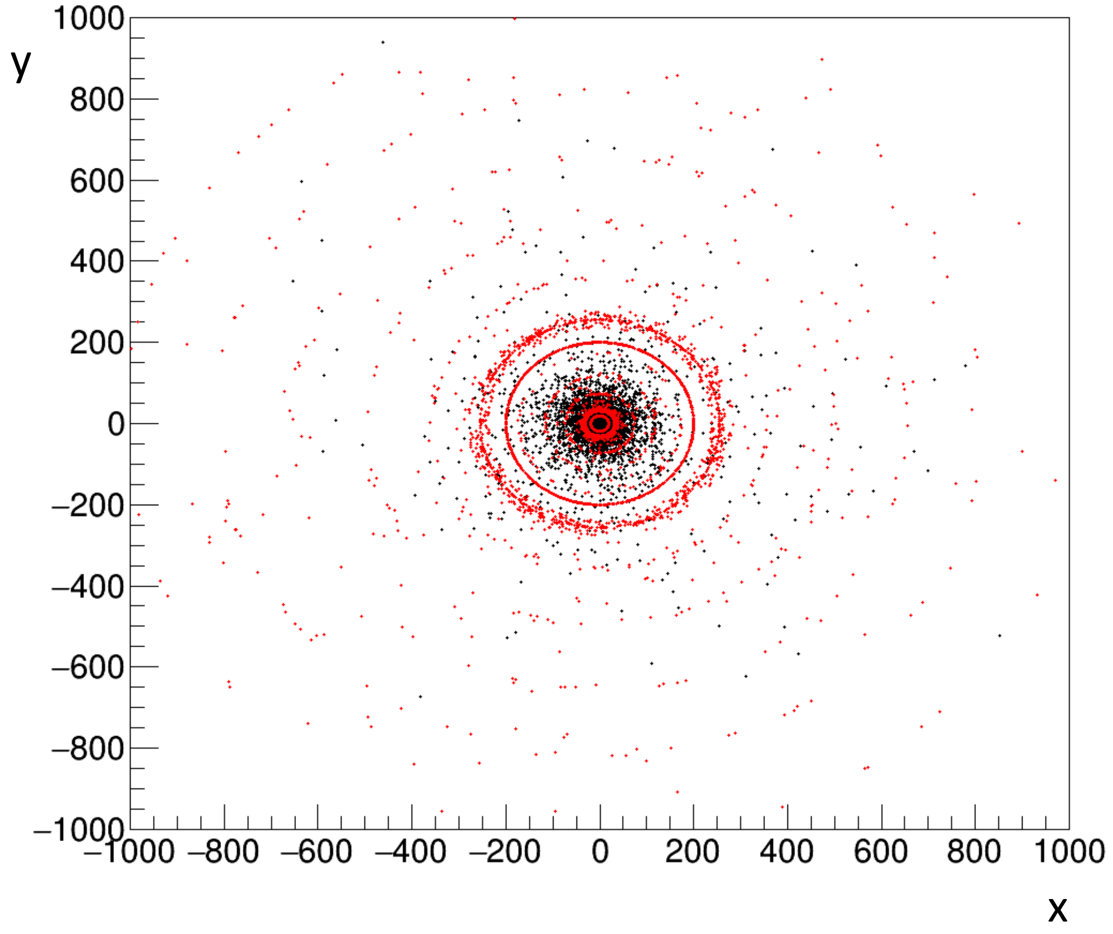
Backup



Fast simulation update

Parametric hadronic interactions switched on

- hadronic interaction vertices
- stable particle vertices Pythia8

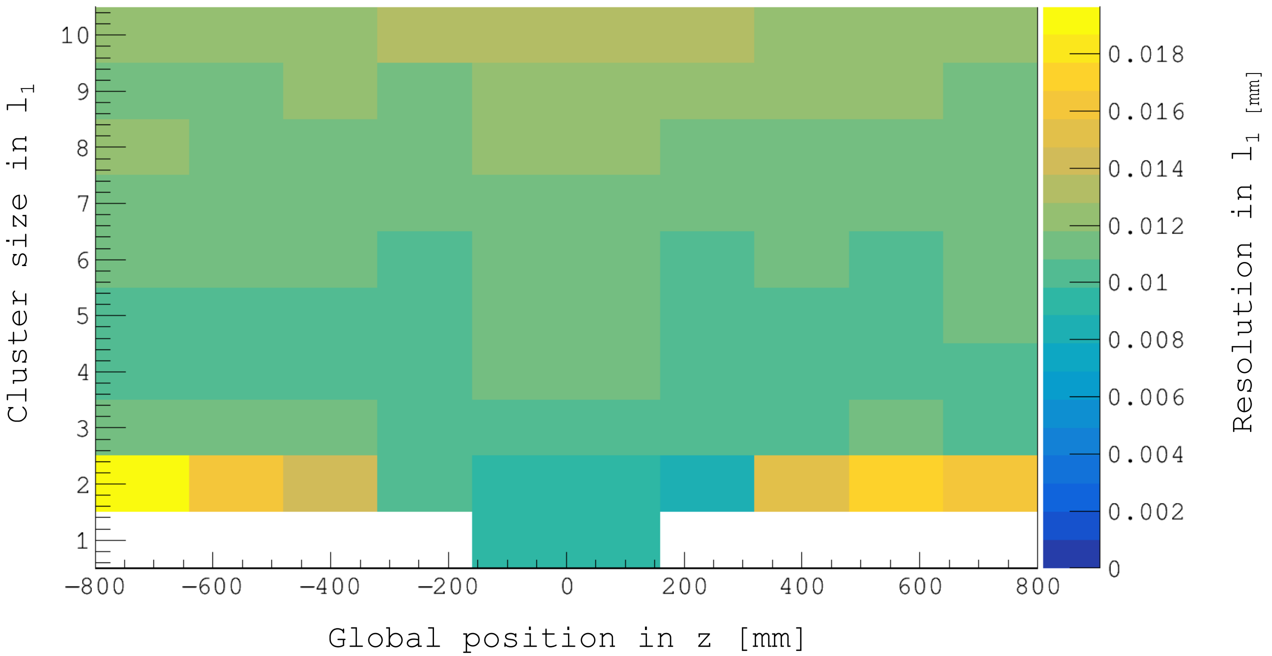


Cluster/error parameterisation

Output of single particle simulation as input to error parameterisation

- second, create layer resolution maps, innermost Pixel layer

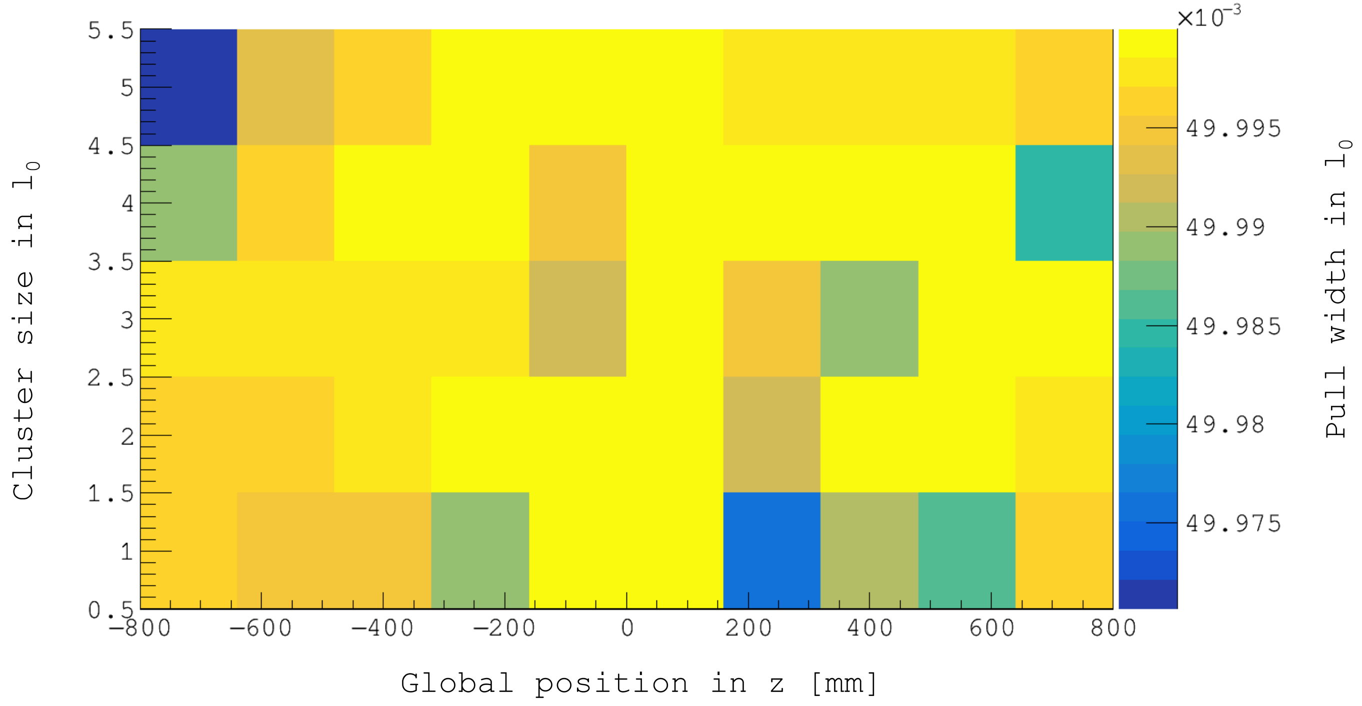
summary:



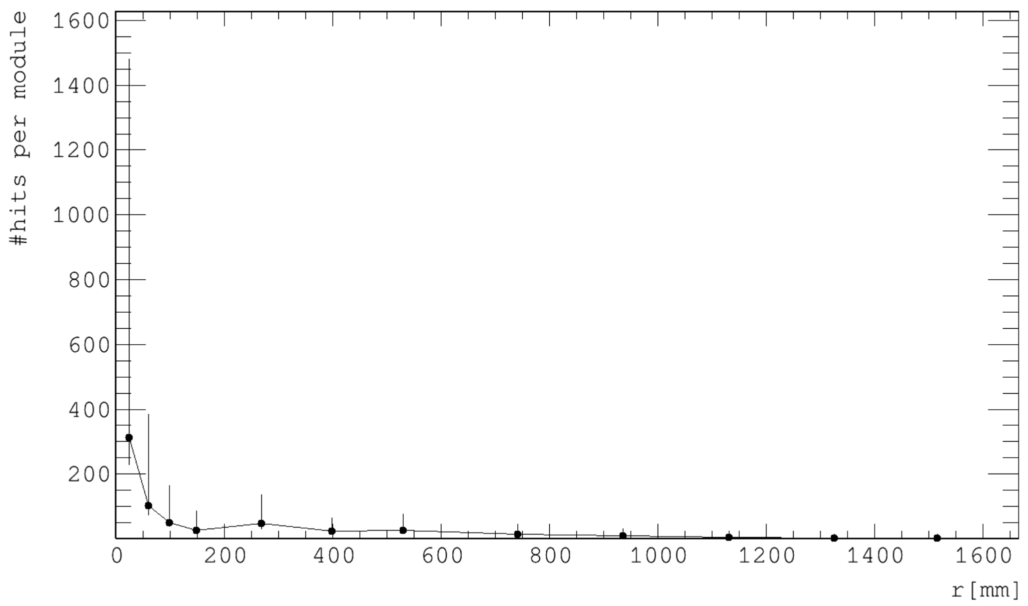
Cluster/error parameterisation

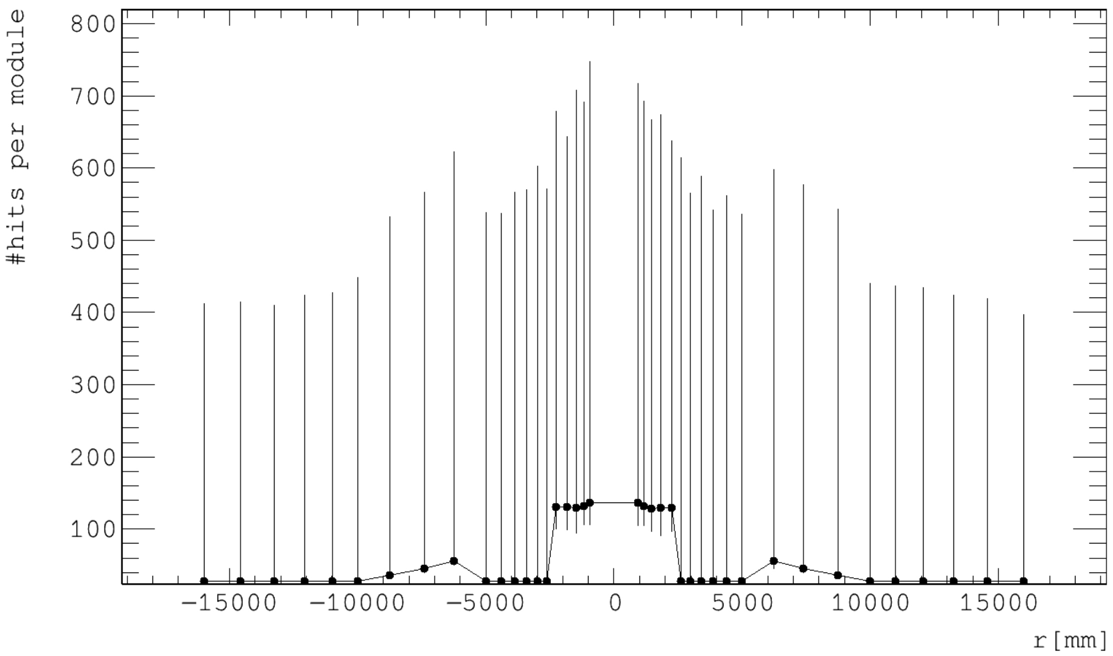
Use as input for ACTS clusterisation

- auto-created root files read back into ACTS to fill cluster error
- check pull distributions



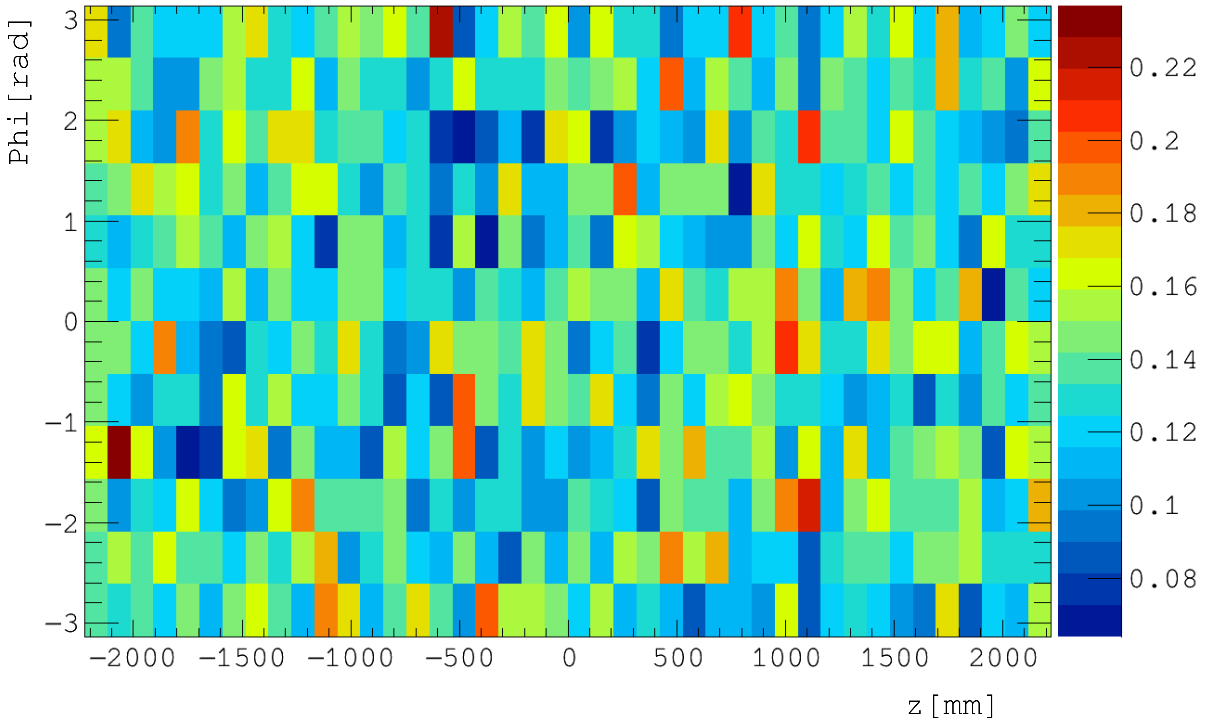
Hits from different particles per Module





Cluster merging rate Layer 10

1000 PU Minbias



1000 PU Minbias + bjets