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
Motivation

The right tools at the right time...

Long term strategy:
- Needs full geometry + material support
- Magnetic field description
- Full simulation
- Digitization
- Reconstruction

⇒ Detailed detector performance studies

=>See Talk Z.Drasal from the morning
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
Detector setup in tracking package ACTS

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Propagating tracks through entire geometry + BField
Detector description inside ACTS

Sensitive and material hits seen by fast simulation

Detector description inside ACTS

- **Tracker**
- **Ecal**
- **Hcal**
- **Muon**
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

⇒ Open PR – will be merged after FCC week
⇒ Allows to study both magnetic field options in detail

=> Written out during interpolation inside FCCSW
Status in FCCSW

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

Simulation

- Analogue/Digital Clustering

Digitization

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

Seeding

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

Track Reconstruction

Working
- Currently in progress
- Not started

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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
Close to realistic detector response
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⇒ Allows to test digital/analogue readout
⇒ Allows to study readout of detector
⇒ First studies using digitization in second part of talk
Digitization inside FCCSW using ACTS

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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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![Diagram of the binary approach](image)
Digitization – creating measurements

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- Create clusters from neighbouring cells using *connected component analysis* (boost)
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\[
\text{the binary approach: } \quad m = \frac{1}{N} \sum_{i=1,N}^{} l_i
\]
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the charge-weighted approach:

\[ \mathbf{m} = \frac{1}{\sum_{i=1,N} q_i} \sum_{i=1,N} q_i \mathbf{e}_i \]

charge collected in cell i

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Digitization – creating measurements

- Determines cells hit by particle
- Create clusters from neighbouring cells using **connected component analysis** (boost)
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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 $l_0 \times l_1 = 25 \, \mu m \times 50 \, \mu m$ 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 $l_0 \times l_1 = 25 \, \mu m \times 50 \, \mu m$ 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

➢ Collimated 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**
Channel Occupancy I

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

- **Striplets**
- **Macro-pixels**
- **Pixels**

**Channel Occupancy**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Pixels</th>
<th>Macro-pixels</th>
<th>Striplets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full simulation</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>1000 Pile up Event</td>
<td>minBias</td>
<td>const BField</td>
<td>primaries only</td>
</tr>
</tbody>
</table>

- **33.3 μm x 50 mm**
- **33.3 μm x 10 mm**
- **33.3 μm x 400 μm**
- **25 μm x50 μm**

*(100 for second EC ring)*
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**

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

⇒ 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 background contamination along one track
  ⇒ Material induced confusion big enough to suppress you to 0 efficiency
Difficulty of pattern recognition

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

⇒ 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, \textit{secondaries included}

- Merged cluster rate: \textit{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

Cluster merging rate

1000 PU event alone
bjet event alone
1000 PU event + bjet event

Cluster merging rate Layer 10

Cluster merging rate

1000 PU event alone
1000 PU event + bjet event

Cluster merging rate
Merged Cluster Rate

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

Cluster merging rate Layer 10

![Cluster merging rate graph](image-url)
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
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

![Graph 1: Hits vs r (mm)]

![Graph 2: Hits vs r (mm)]
Cluster merging rate Layer 10

1000 PU Minbias

1000 PU Minbias + bjets