THE UNIVERSITY OF IOWA

MIP RECONSTRUCTION TECHNIQUES

AND

MINIMUM SPANNING TREE CLUSTERING

(TOWARDS PFA)

presented by Wolfgang Mader
(for M. Charles, W. Mader, U. Mallik, and N. Meyer)

2005 INTERNATIONAL LINEAR COLLIDER WORKSHOP
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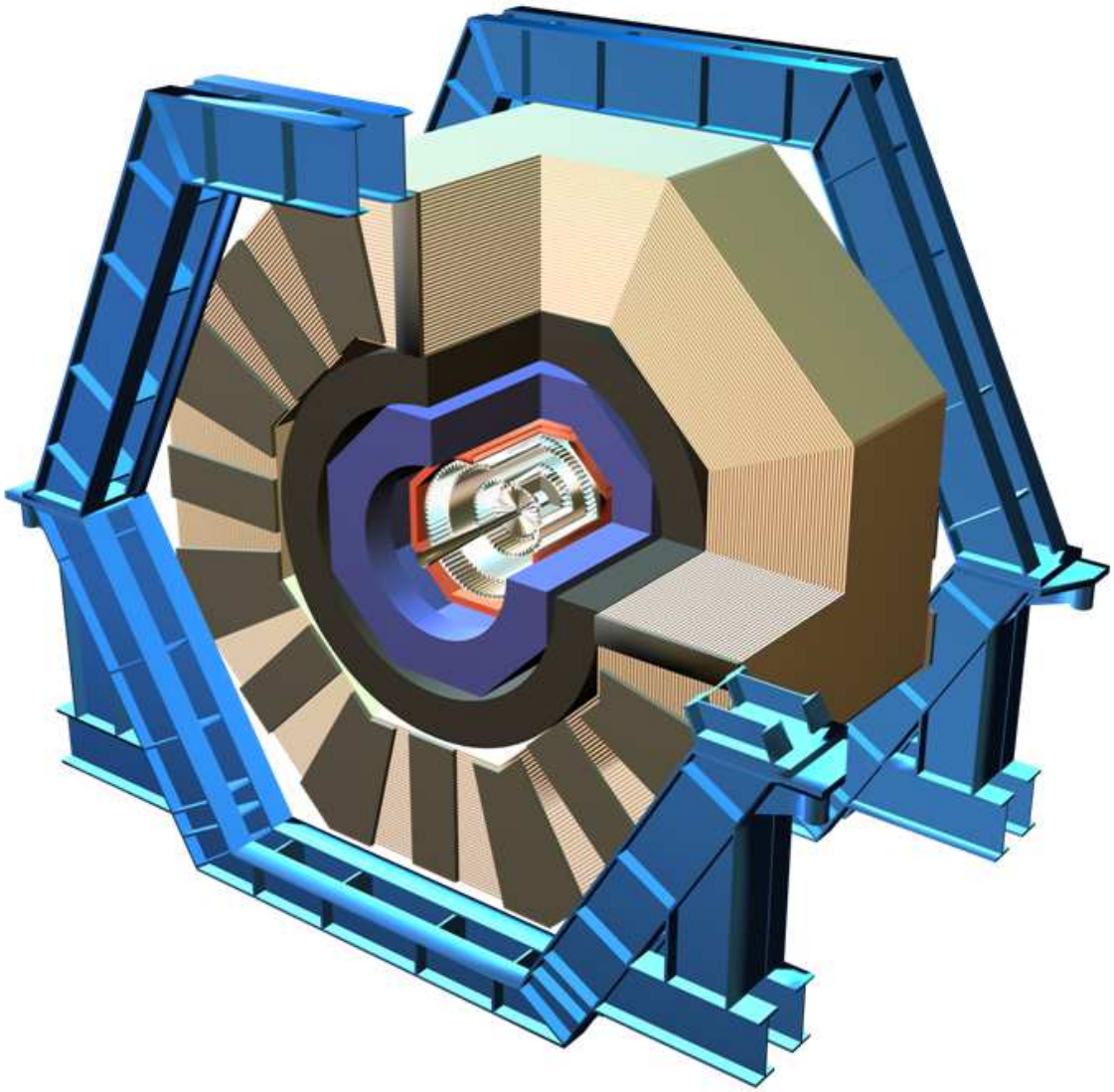


Electromagnetic Calorimeter (EMCal)

- **30 Layers,** ~ 125 **cm** $<$ **R** $<\sim 140$ **cm**
- **W(0.25cm)/Si(0.04cm)**
  ~ 20 **E.M. Interaction Length (**X_0**)**
  ~ 0.8 **Had. Interaction Lengths (**λ_I**)**
- **Cell Size:** $\sim 5\mathrm{mm} \times \sim 5\mathrm{mm}$

Hadronic Calorimeter (HCal)

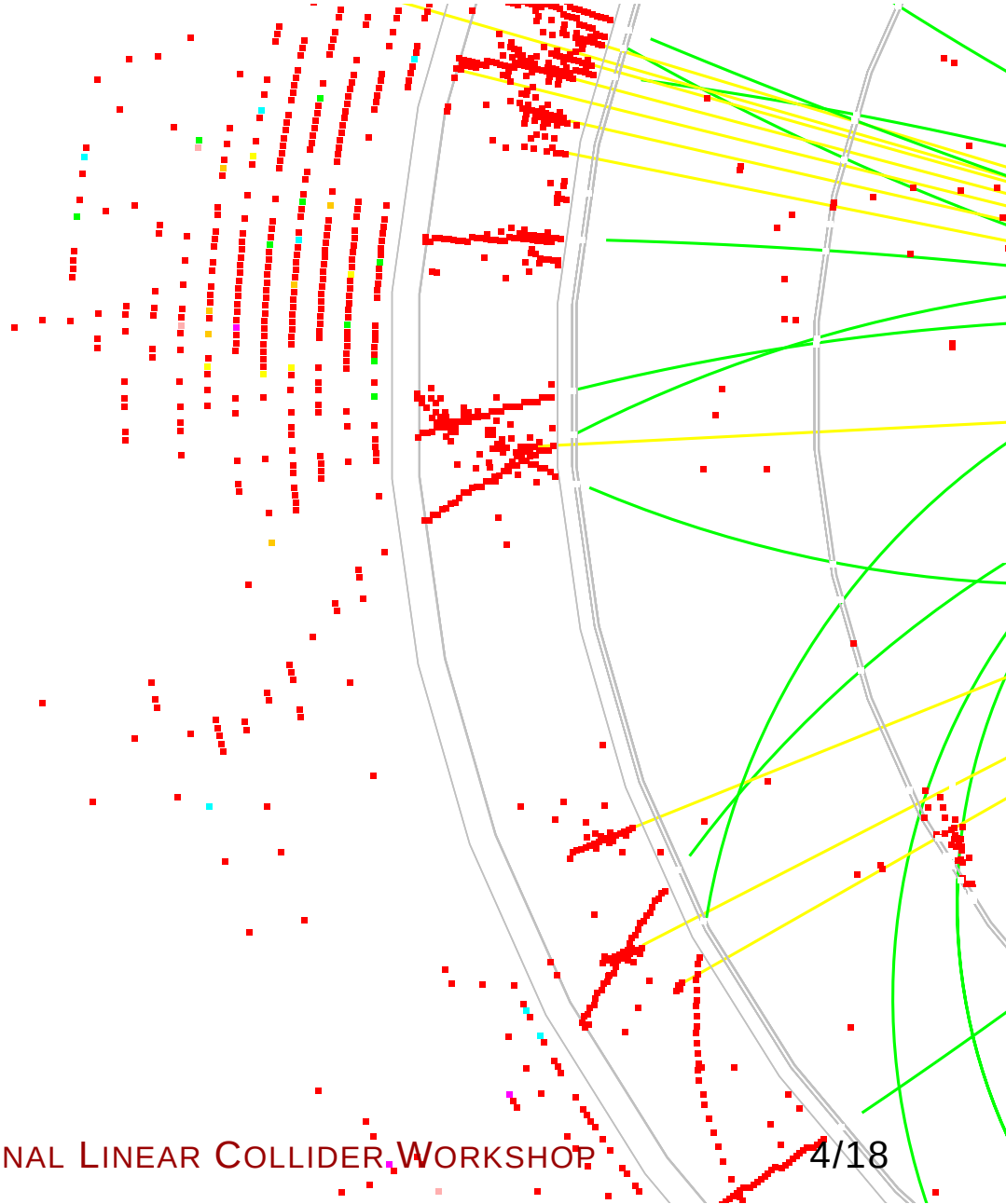
- **34 Layers,** ~ 145 **cm** $<$ **R** < 250 **cm**
- **SS(20 cm)/Scin(1.0 cm)**
- $40\mathrm{X}_0, 4\lambda_\mathrm{I}$
- **Cell Size:** $\sim 1\mathrm{cm} \times 1\mathrm{cm}$

MIP-Reconstruction Techniques

MIP Reconstruction

Benefits

- **Particle Identification**
- **Shower Identification (em/charged-hadr./neutral-hadr.)**
- **Seeds for Shower Reconstruction**
- **Tracking for long-lived Neutrals (e.g. $\mathrm{K}_{\mathrm{S}}^{0}$)**



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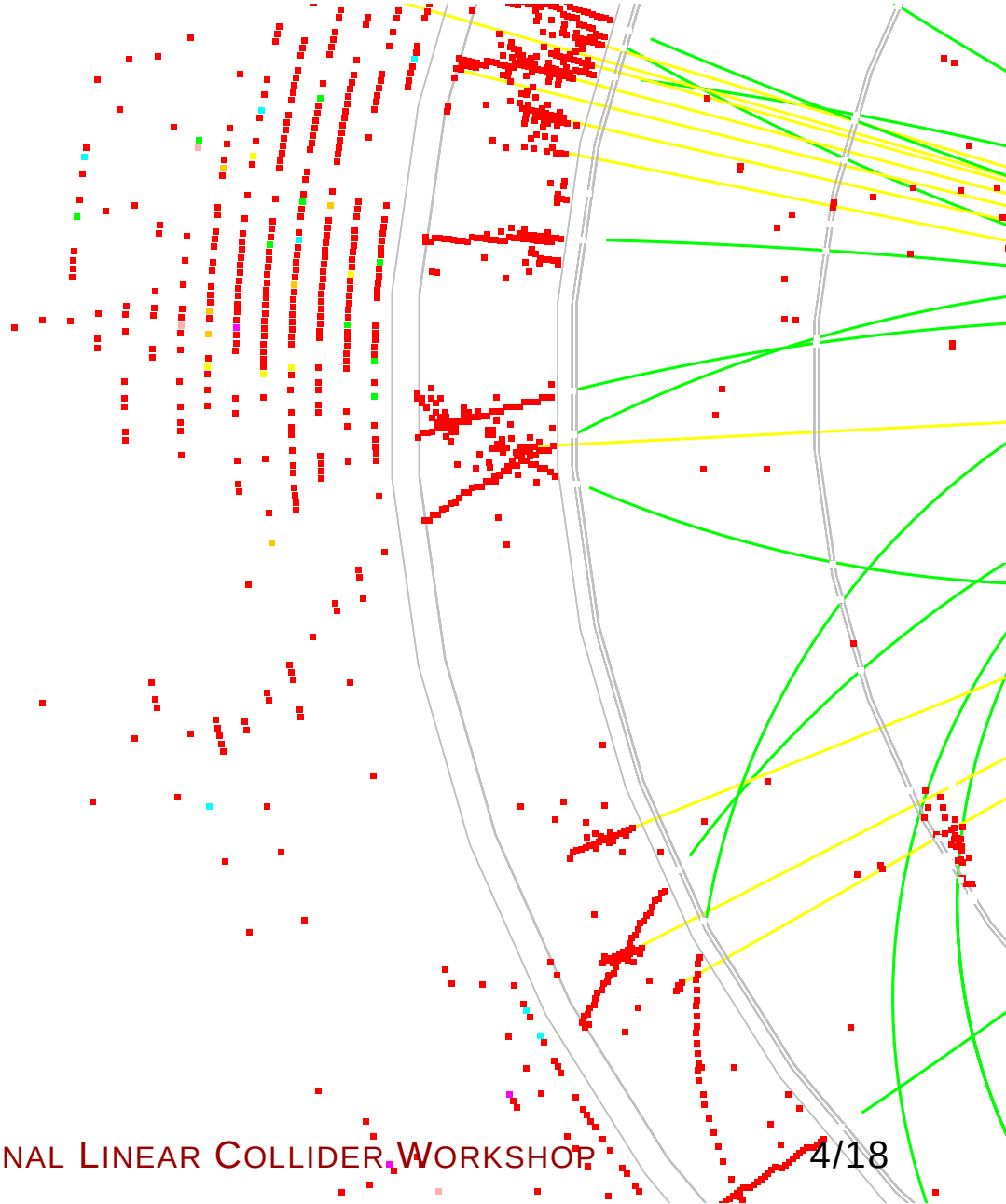
Implementation

1. **Inside-out MIP-Tracking**
2. **Outside-in MIP-Tracking**
3. **χ^2 MIP-Segment Matching**



MIP-Identification

Selection of MIP-Seeds

- **At least 1 Isolated Hit in Layers 0/1 (3x3 Matrix of Cells)**
- **Energy Deposit Consistent with MIP**
- **At least 3 Hits in Layers 0-3**

MIP-Reconstruction

- **Isolated Hits found**
- **Second Hit allowed (δ-Rays)**
- **Gap of One Layer**

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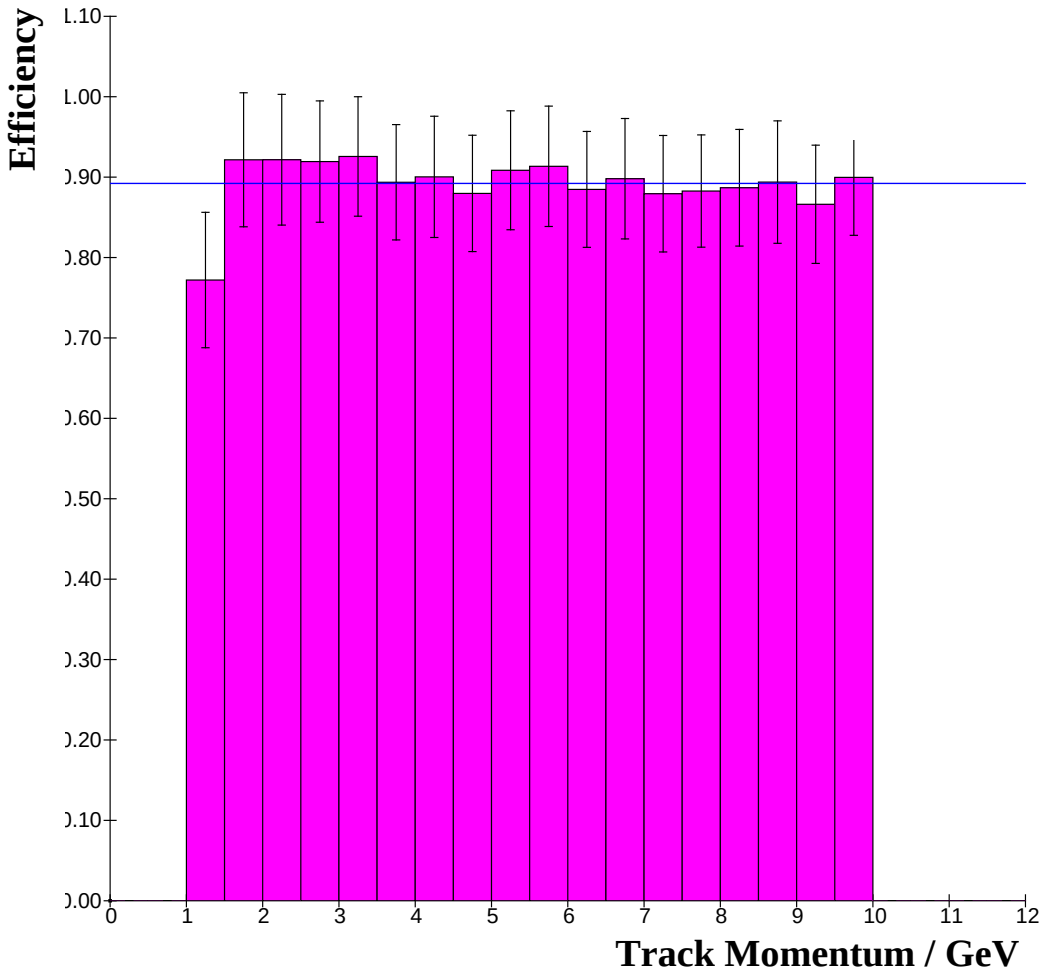
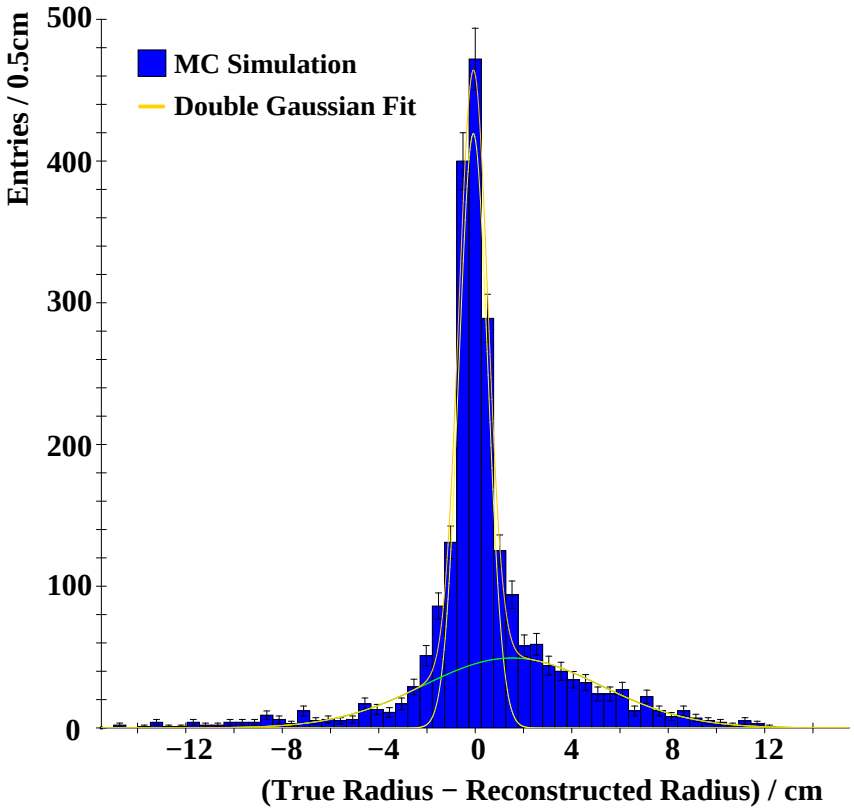
Efficiency (Single π Samples)

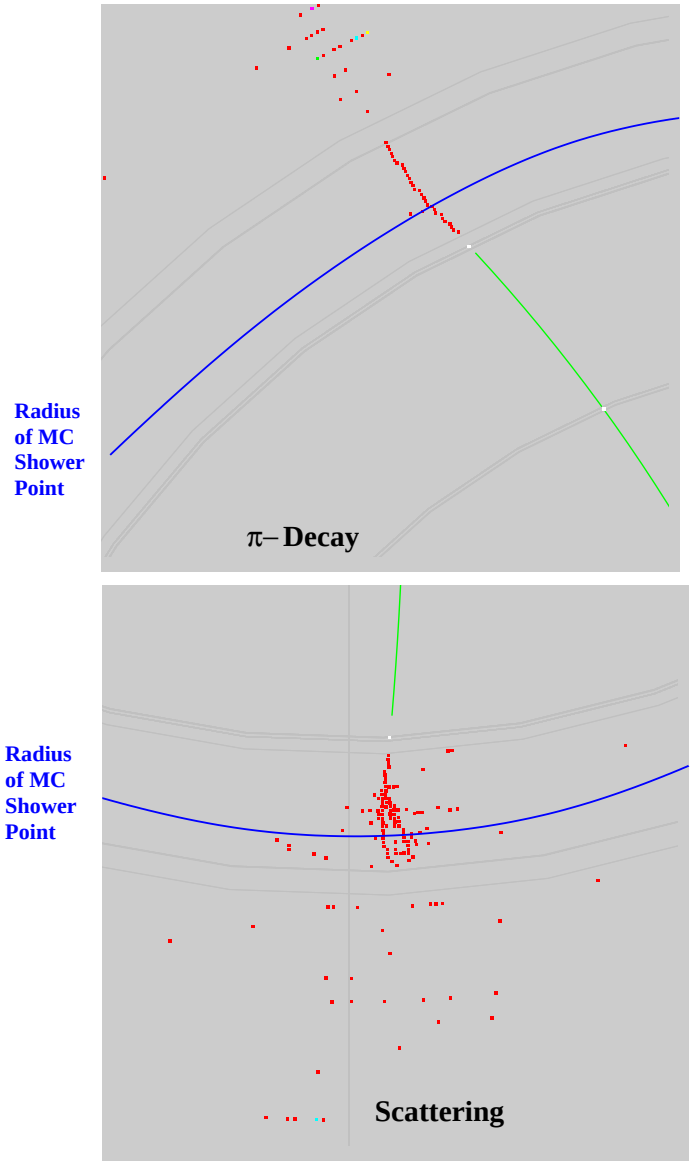
- **High Efficiency**
- **Efficiency independent of Momentum**



Reconstructing the Showering Point

- **Used Later as Seed in Clustering**
- **Double Gaussian Fit**
- **Resolution** $\sim 0.6\,\mathrm{cm}$ **(**± 1 **Layer)**



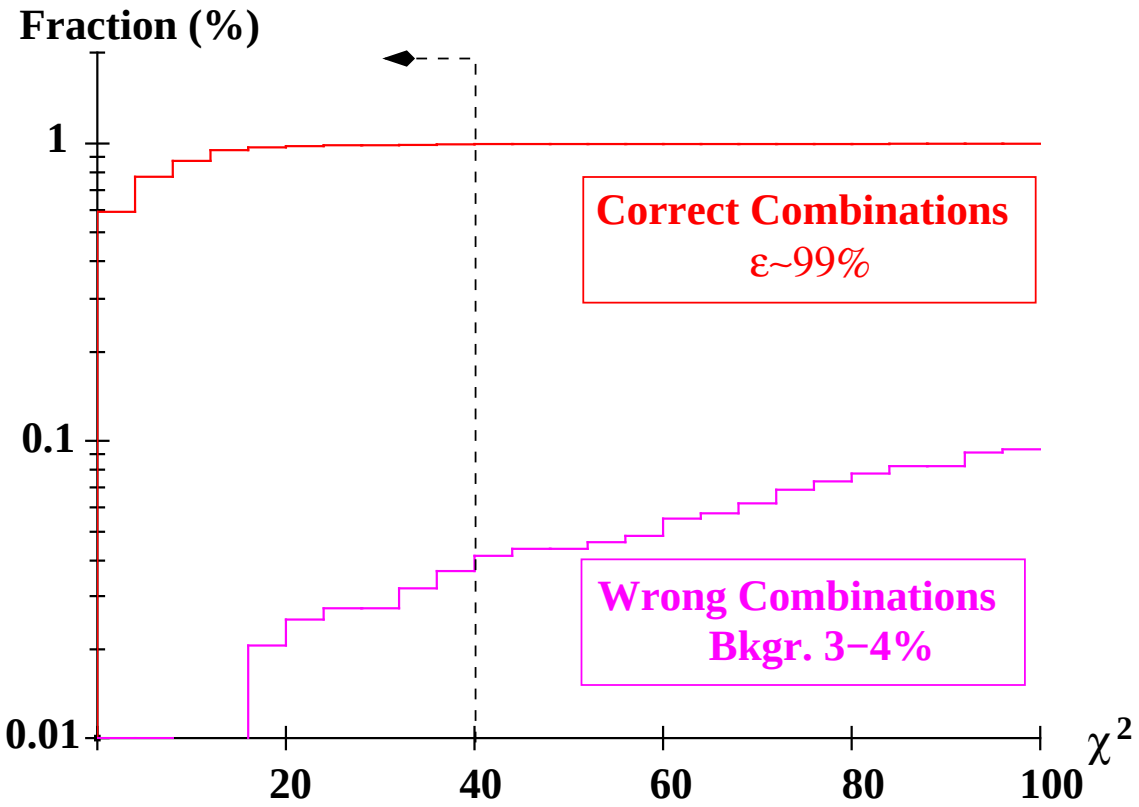


Combine Segments that lie 'nearby' in Parameter Space

- Get Track Parameters for each MIP-Segment
  - $\mathbf{v}_i(\kappa,\ \phi_0,\ d_0,\ \tan\lambda,\ z_0)$: **Parameter Vector for MIP-Segment** i
  - $\mathbf{m}_i$: **Covariance Matrix for MIP-Segment** i
- Define χ^2 Criteria

$$\chi^2 = \sum_i (\mathbf{v}_i - \mathbf{v}_0) \cdot \mathbf{m}_i^{-1} (\mathbf{v}_i - \mathbf{v}_0)^{\mathrm{T}}$$

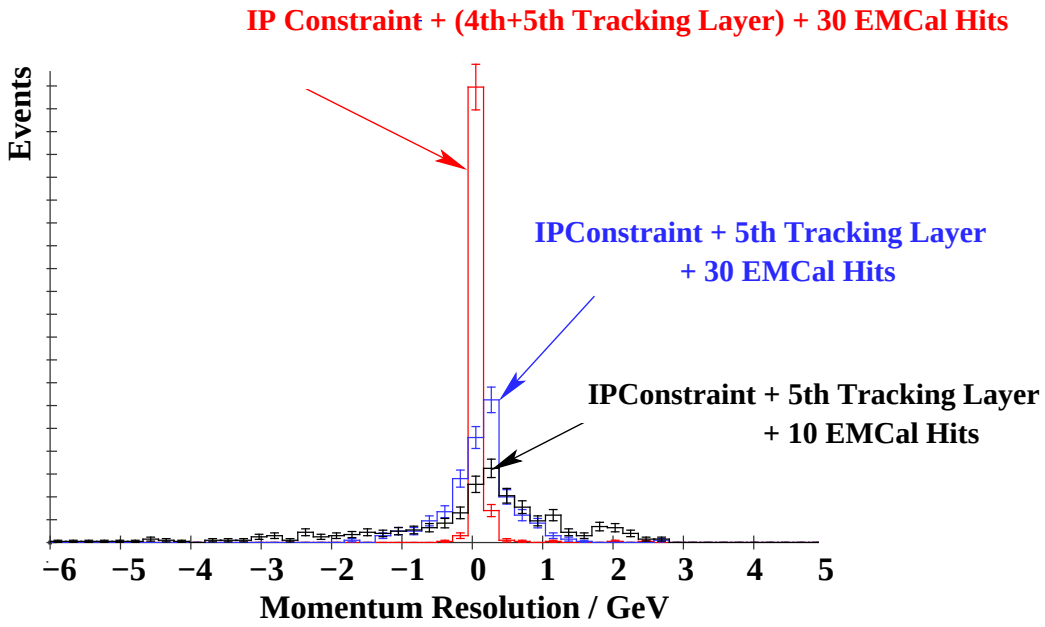
  - $\mathbf{v}_0$: **Solution for MIP-Track Parameters Giving Minimal** χ^2



Extrapolation to Tracking Layers

Algorithm

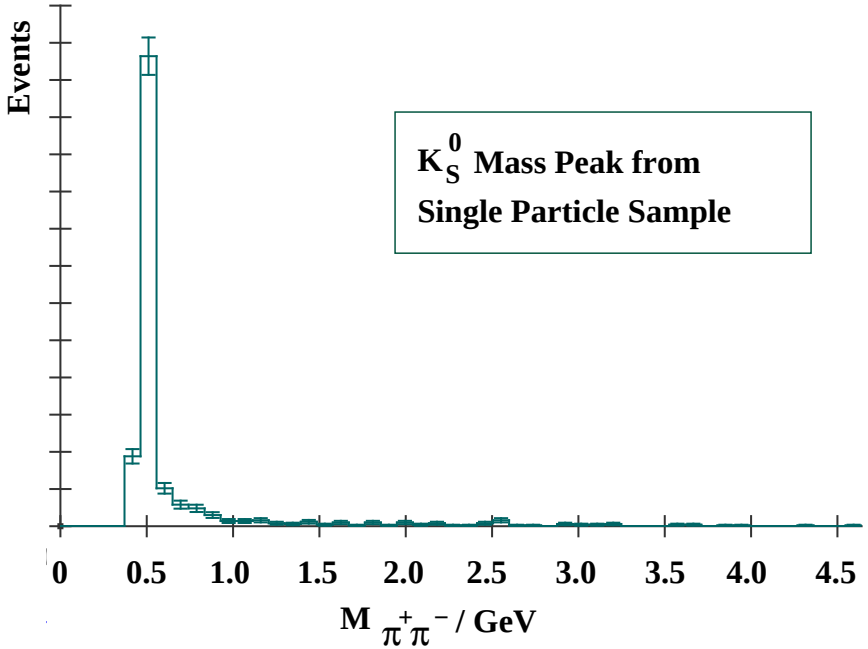
1. **Identify & Fit MIP-Track in EMCal**
2. **Extrapolate to Central Tracking System**
   - 1^{st} *EMCal Layer* @ $\sim 127cm$
   - *Last Tracking Layer* @ $\sim 125cm$
3. **Pick up Hits & Refit**



K^0_S Reconstruction

Algorithm

1. **Reconstruction of MIPs in EMCal**
2. **Extrapolate to 4^{th} & 5^{th} Tracking Layer and Refit MIP-Track**
3. **Fit Pair of MIP Tracks to Common Vertex**



MINIMUM SPANNING TREE CLUSTERING

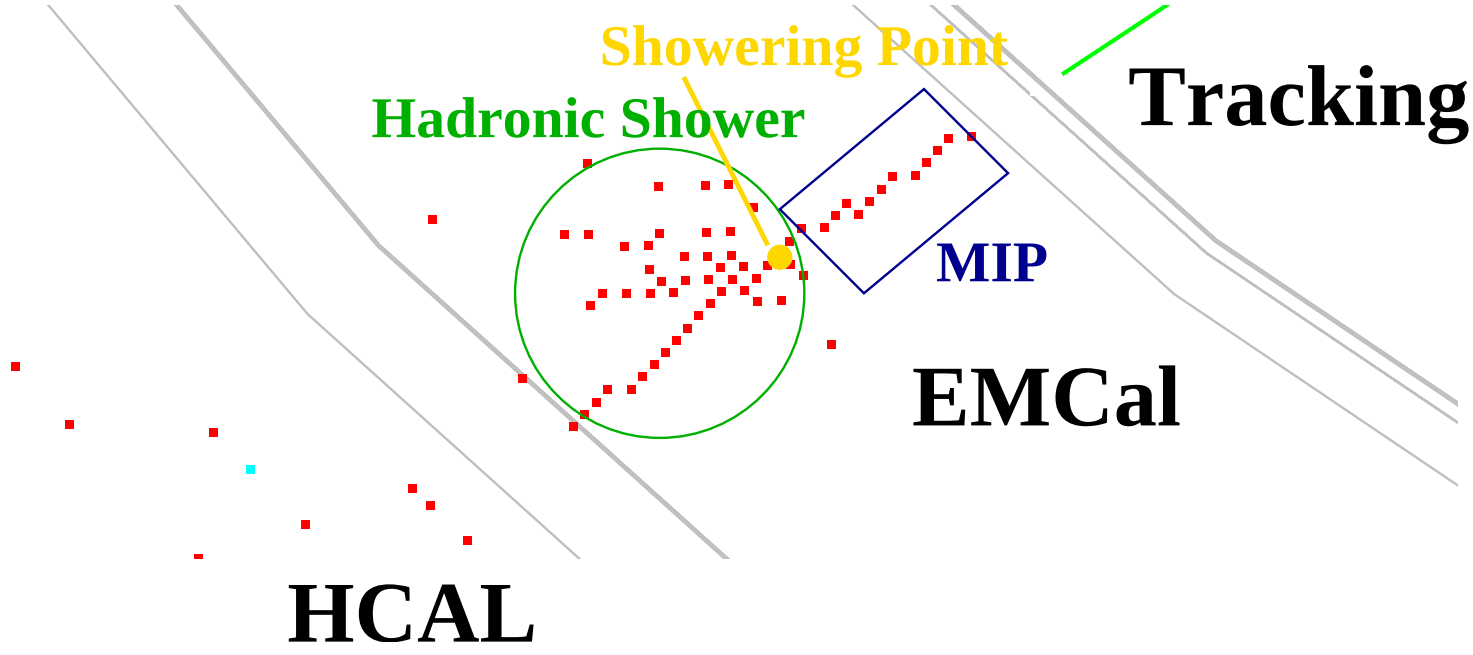
(for Details: See Talk at SLAC Simulation Meeting, 16./17. March)

Algorithm:

- Searches in a ($3 \times 3 \times 3$)-Cell Environment for Hits
- If Found, Add to ‘Selected Hit’...
- ... else Next Hit is Seed for New Cluster

Single Pion Event:

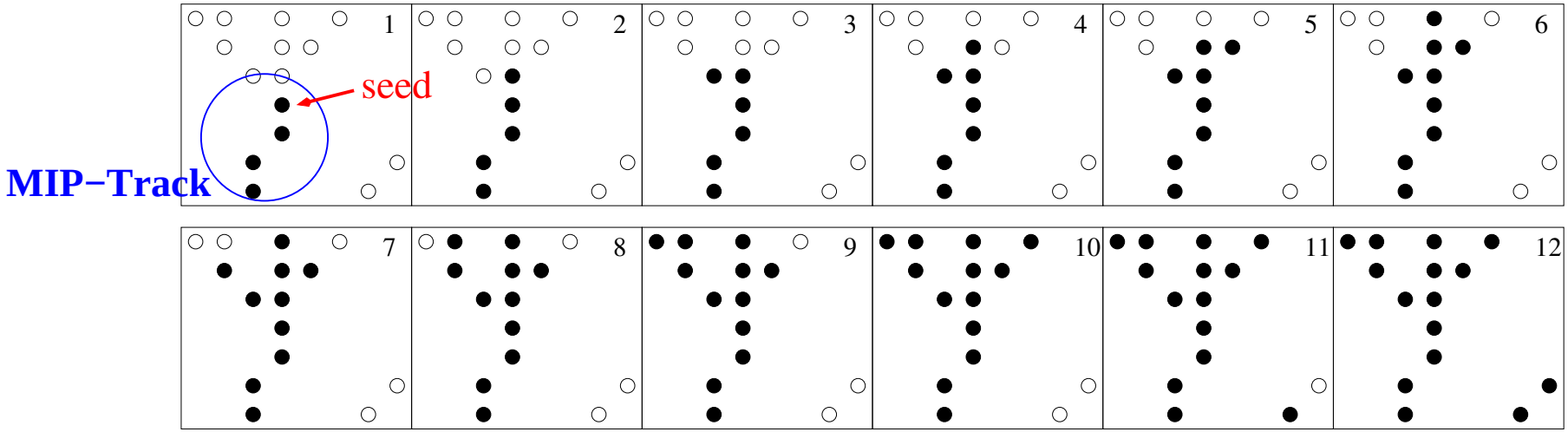
- 21 Cluster Reconstructed in EMCal



Minimum Spanning Tree Algorithm (MST)

Algorithm:

1. Start from Seed Point
   - **Showering Point from MIP Reconstruction**
   - **Hit from Last Tracking Layer**
2. Find Hit with Minimum Distance D_{min} to any 'Selected Hit'
3. Add Hit to 'Selected Hits'
4. If more Hits present **and** $D_{\mathrm{min}} < D_{\mathrm{Threshold}}$ Continue with (2)



MINIMUM SPANNING TREE ALGORITHM (MST)

Implementation:

- For Testing Purposes: Only Hits Associated with Hadronic Showers (EMCal and HCal)
- Recursive Algorithm using 'Adjoining Array' Approach
- Independent of Calorimeter Configuration
- Flexible Metrics
  - **Proximity (Geometrical Distance)**
  - **Energy Density**
  - **...**

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Analysis Strategy:

1. Define Cluster Cores which Should ...
   ... Resemble 'Real Particles'
   ... Contains Bulk of the Energy
   ... Be Dominated by Energy Contribution from One Particle

Tuning Parameters:

- Threshold
  Maximum Allowed 'Distance' between any Hit already Assigned to the Cluster Core and Closest Hit not yet Assigned
- Minimum #Hits Required for Cluster Core

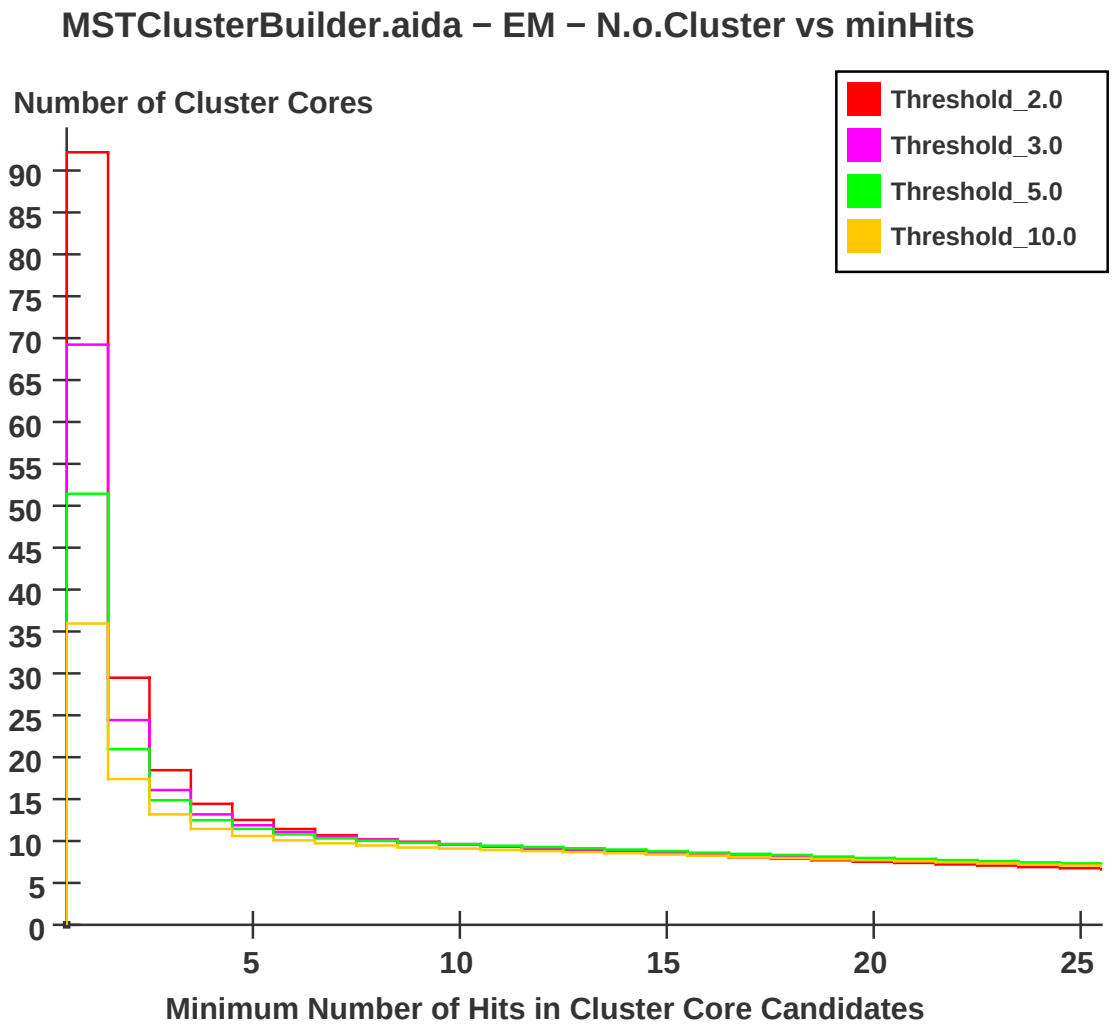
EMCal Hits

(Barrel Region)

Tuning of the MST Algorithm on Z^0 Events (EMCal)

Criteria:

- Number of Cluster Cores
- Fraction of EMCal Energy
- 'Energy Purity' of Cluster Cores
- Number of Cluster Cores Per MC Particle



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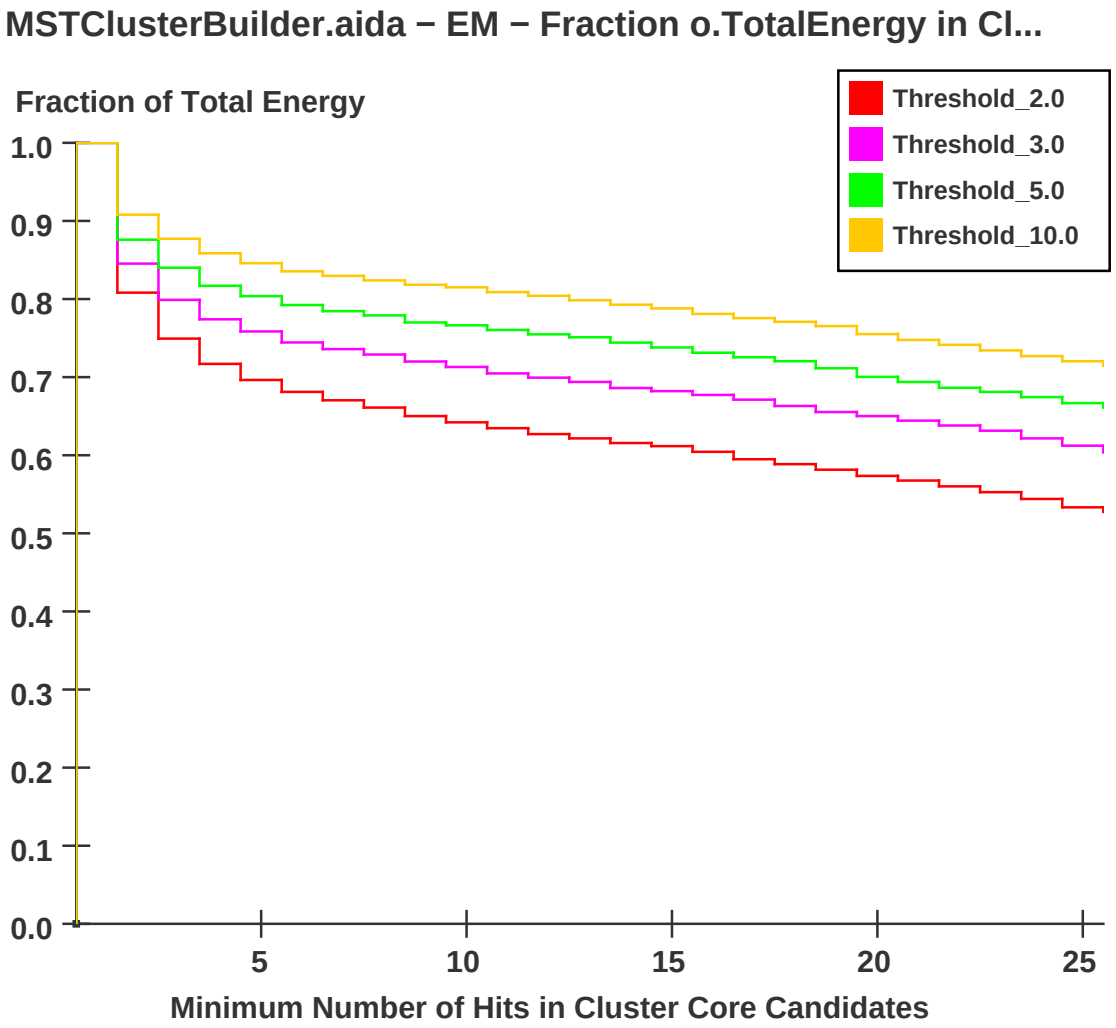

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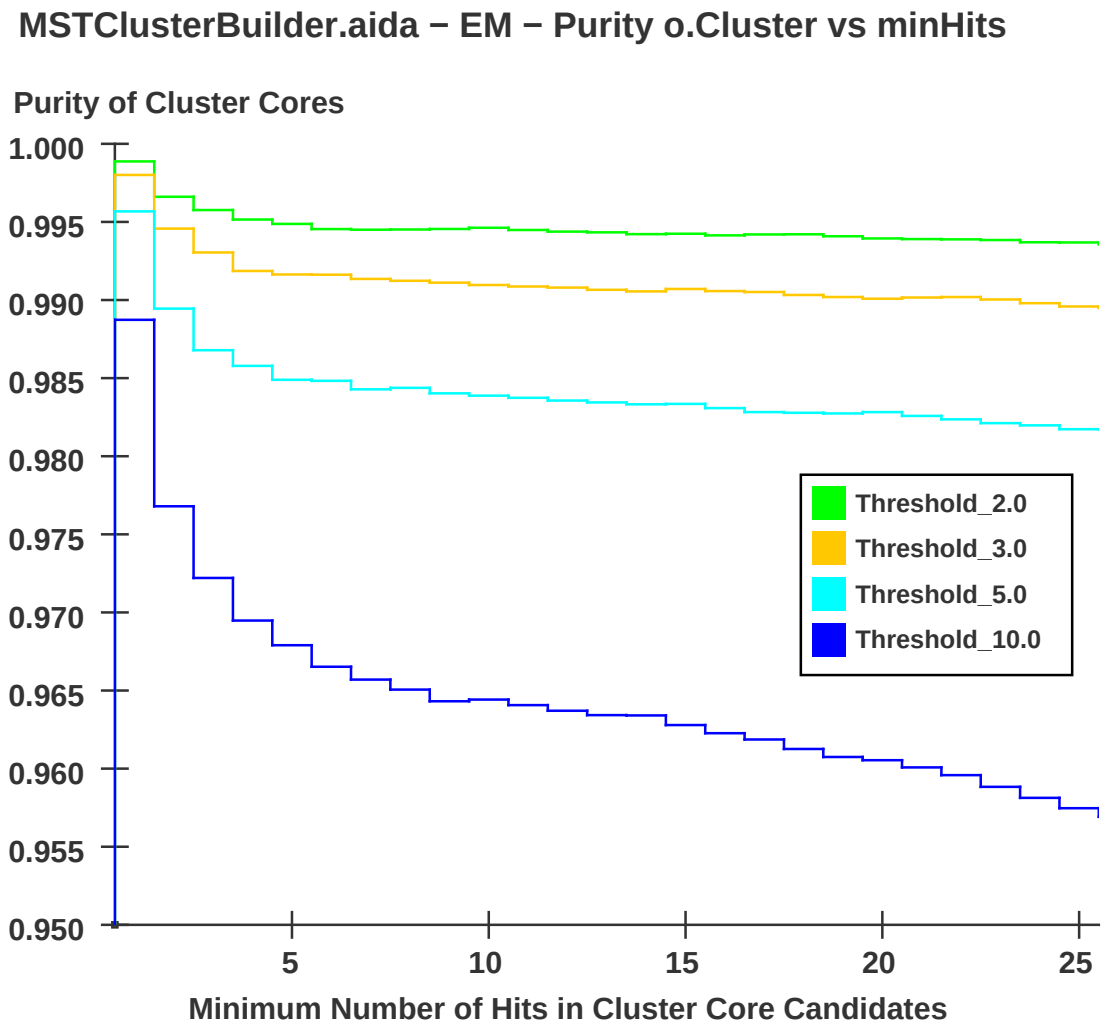

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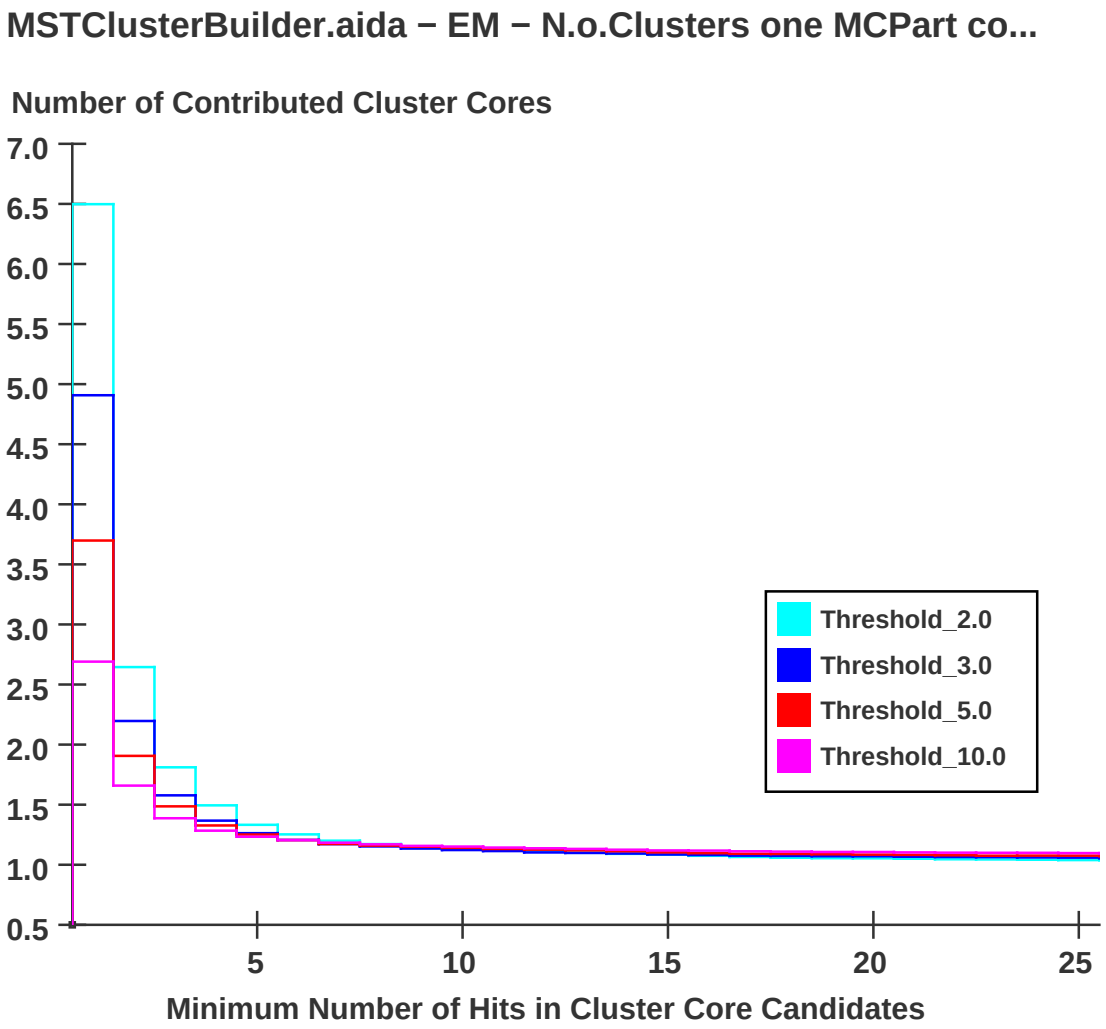

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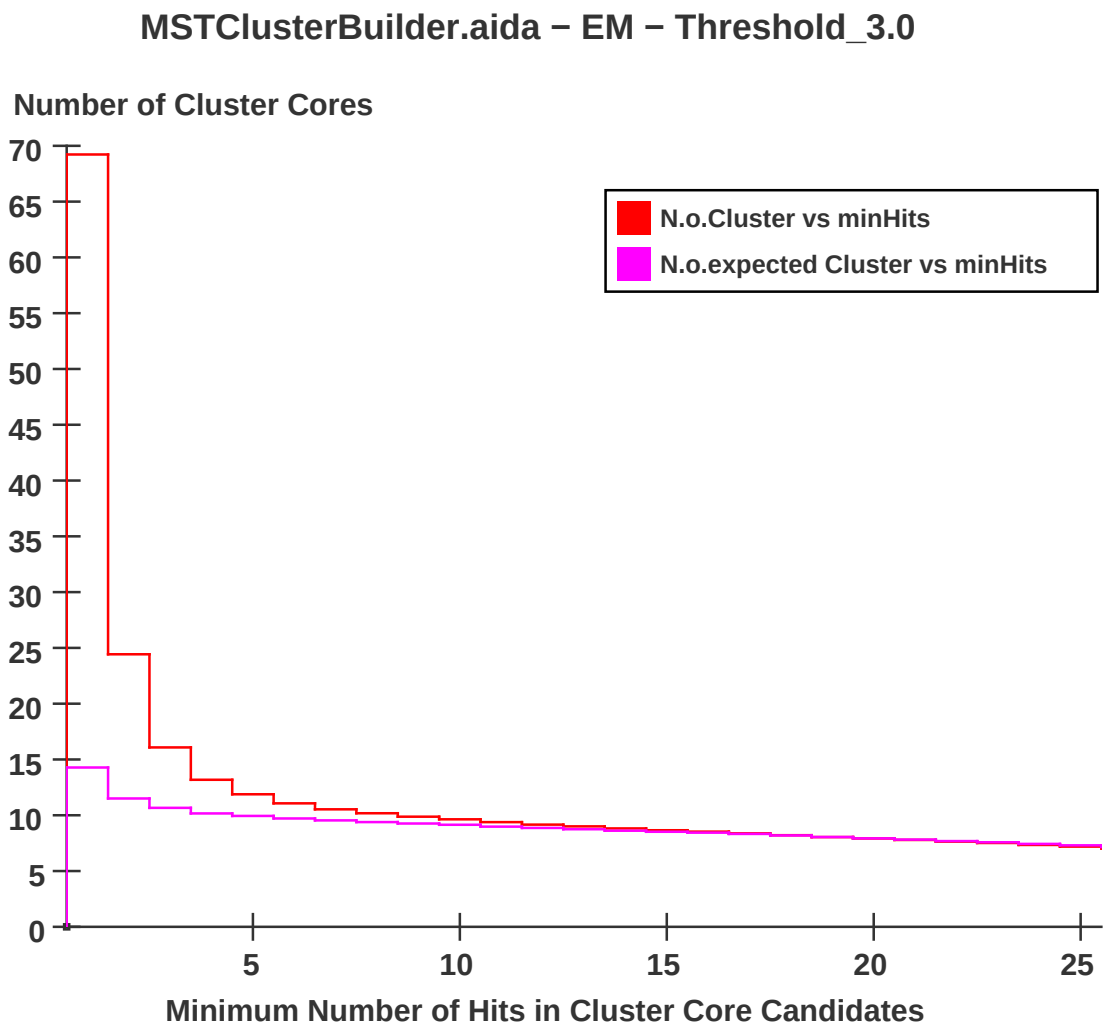

Working Point (EMCal):

- Threshold: 3cm
- Min. Number of Hits in Core: 5

HCal Hits

(Barrel Region)

Tuning of the MST Algorithm on Z^0 Events (HCal)

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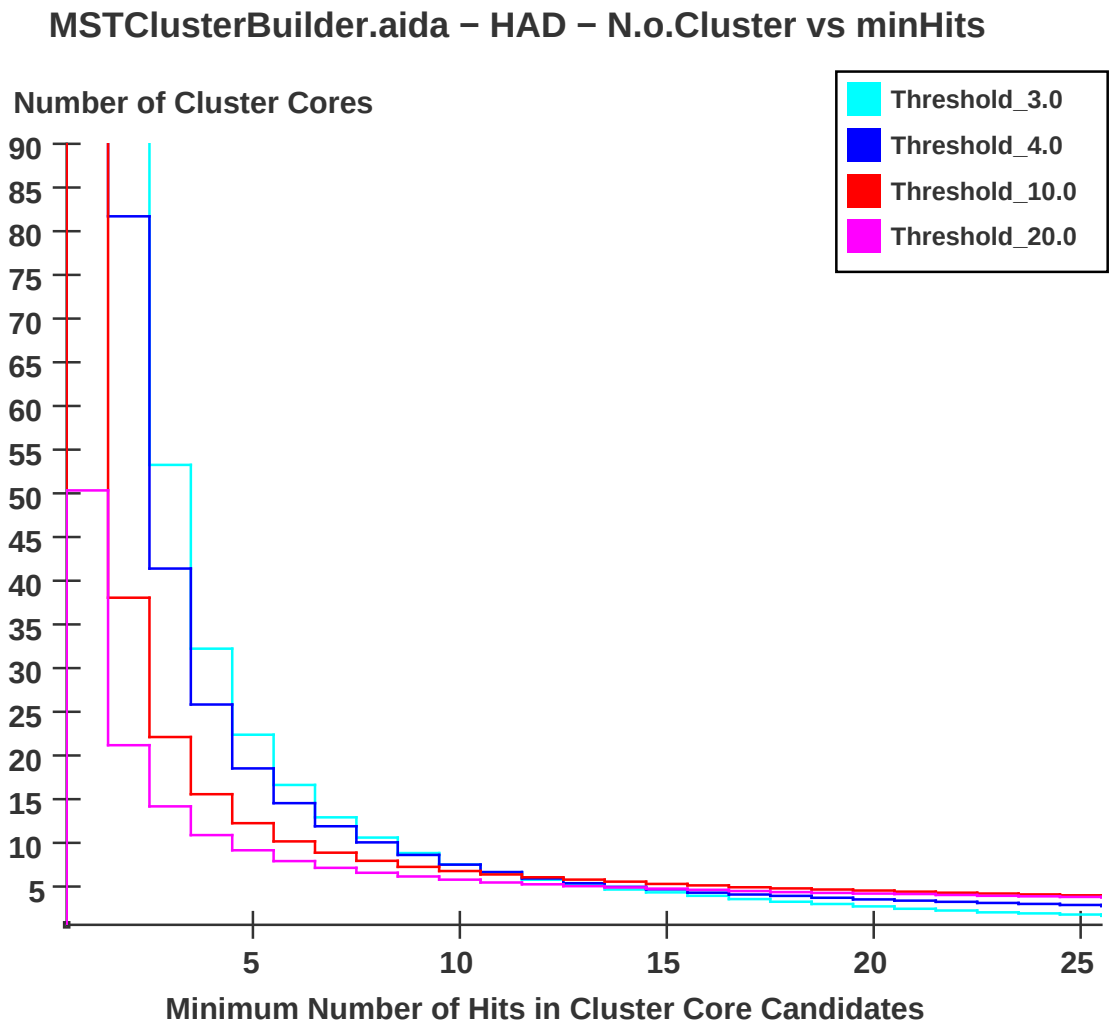

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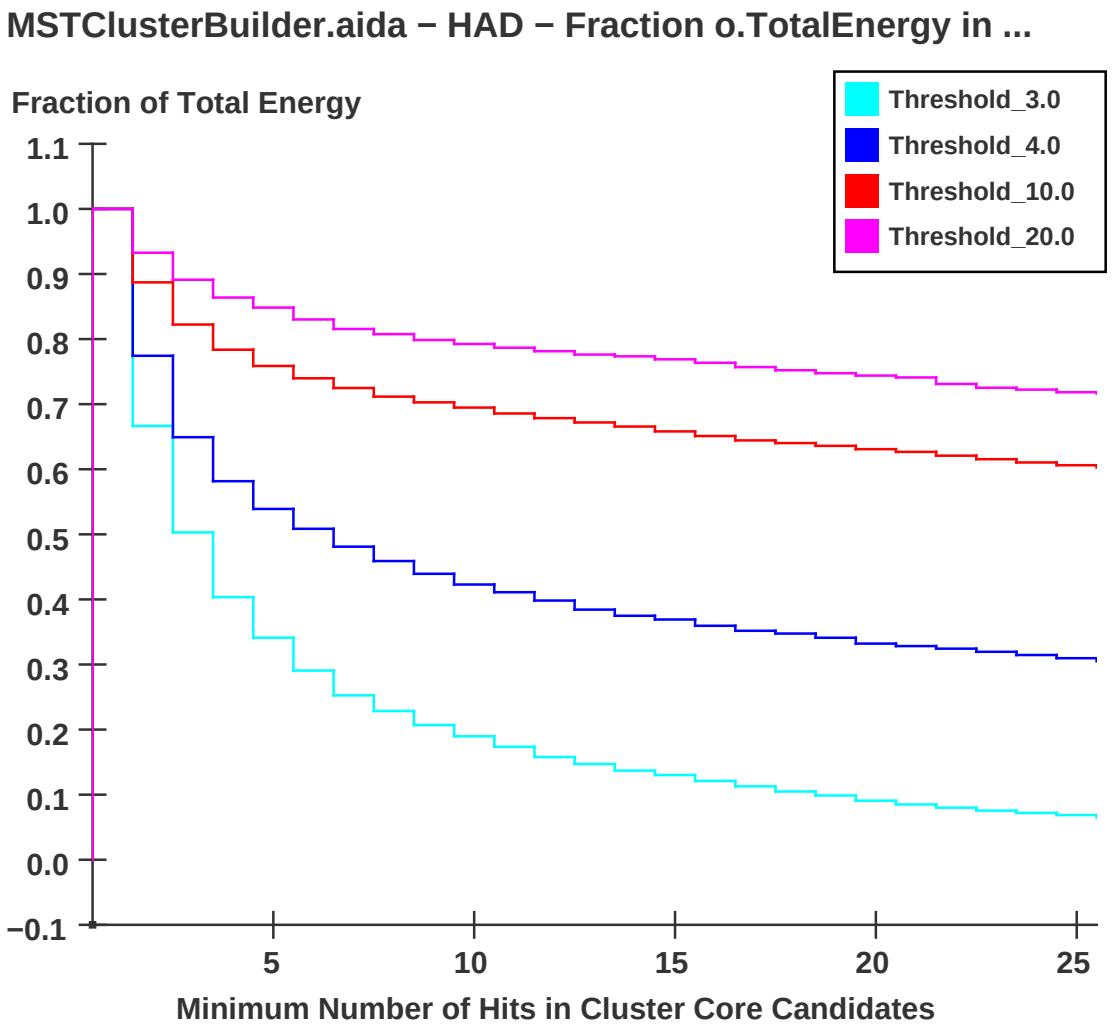

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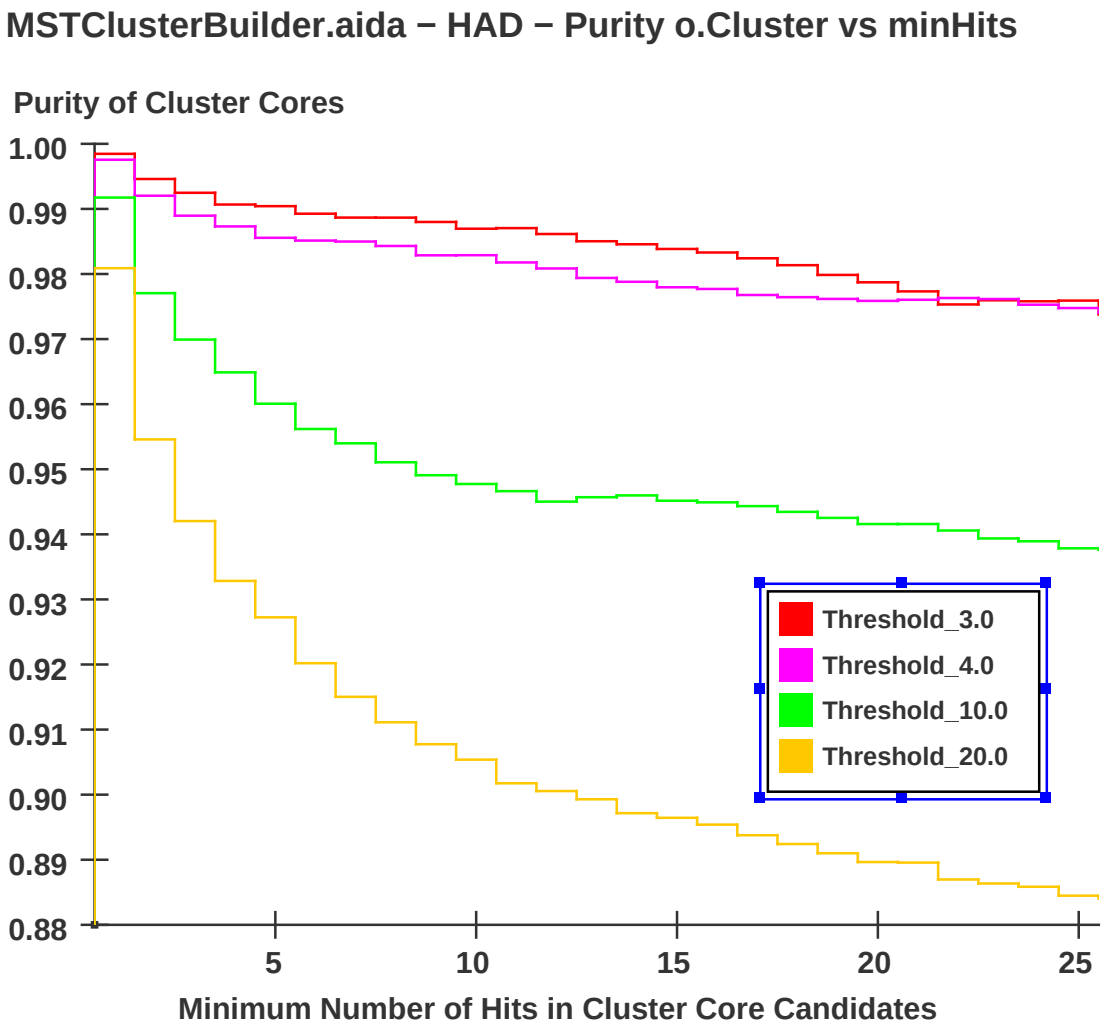

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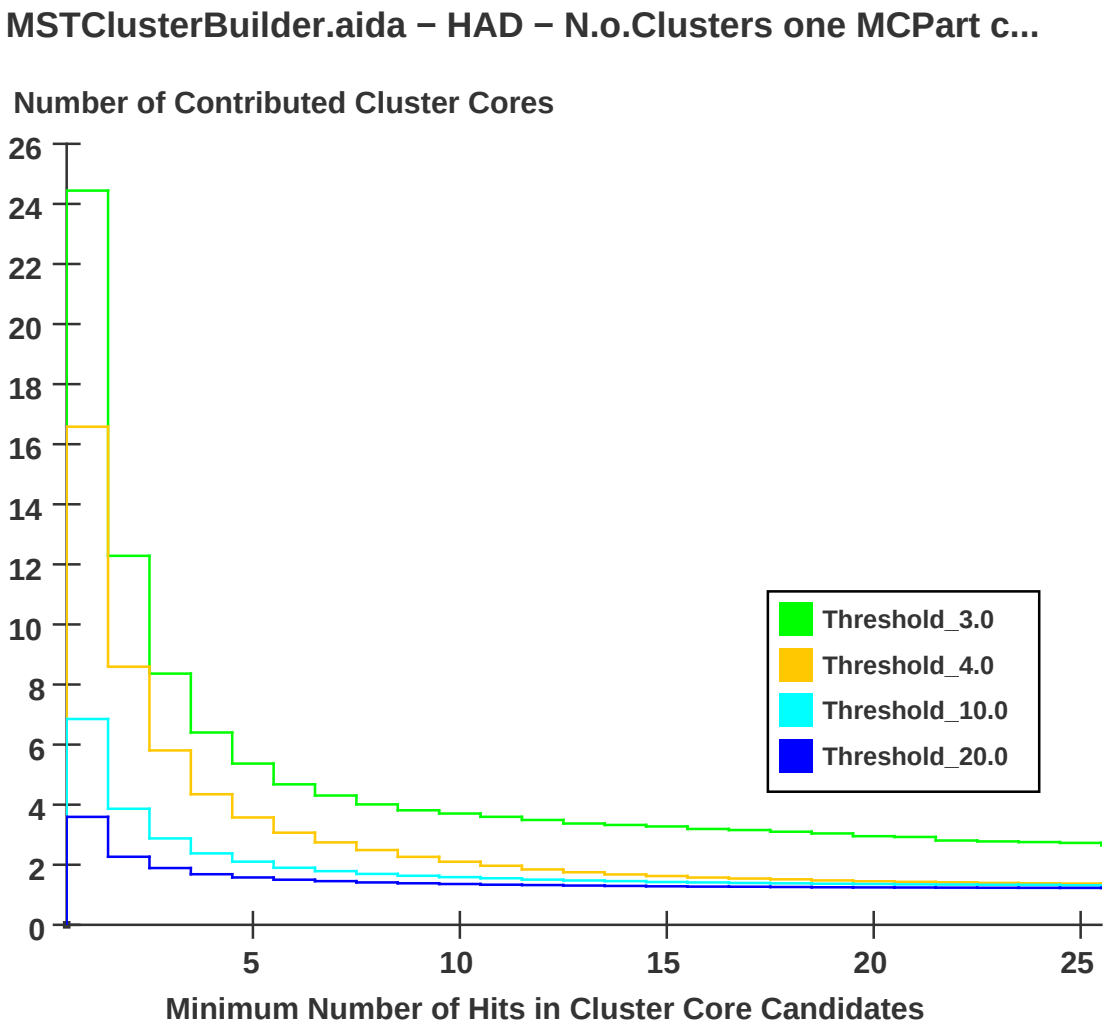

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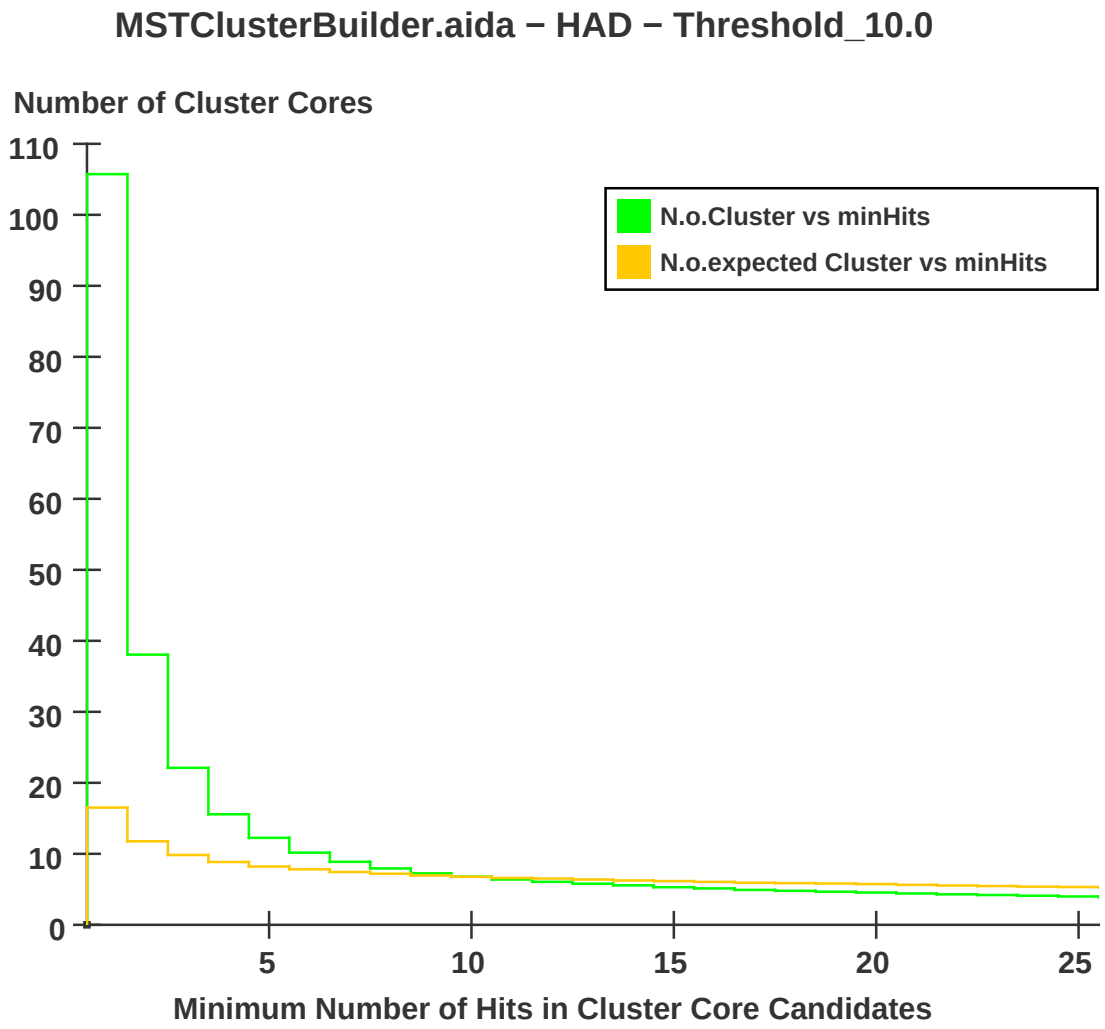


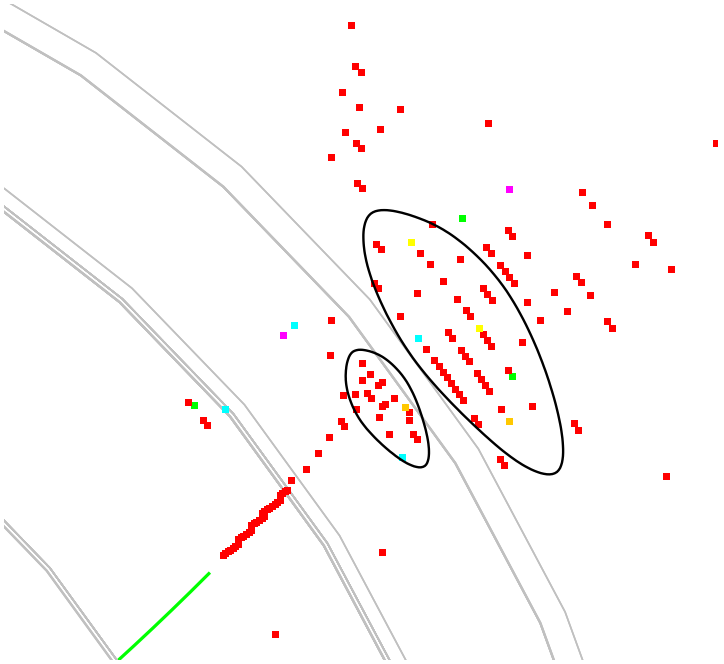
Working Point (HCal):

- Threshold: 10cm
- Min. Number of Hits in Core: 8

Next: Matching of EMCal and HCal Clusters (towards PFA)

Ideas Currently Pursued

1. **Extension of MIP Segments with Helix Fit through EMCal Clusters and HCal Clusters**
2. **Connect and Extend Energy Centroid in each EMCal Layer**
3. **...**



Conclusion

MIP Reconstruction

- **MIP Reconstruction Algorithm**
- **Reconstruction of Showering Point**
- **Extrapolation to Last Tracking Layers**
- $\mathrm{K}_{\mathrm{S}}^{0}$ **Reconstruction Algorithm**

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Minimum Spanning Tree Clustering

- **Very Flexible Alternative to SimpleClusterBuilder**
- **Recursive Algorithm using 'Adjoining Array' Approach**
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- **No Pre-Selection of Hits**
- **Flexible Metrics**

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Submit Both Packages to CVS