Progress in Recognition of Energy deposition of charged particle in ECAL

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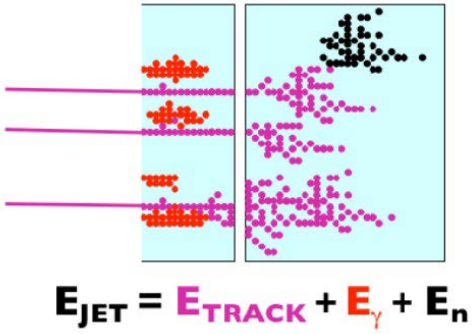
Introduction

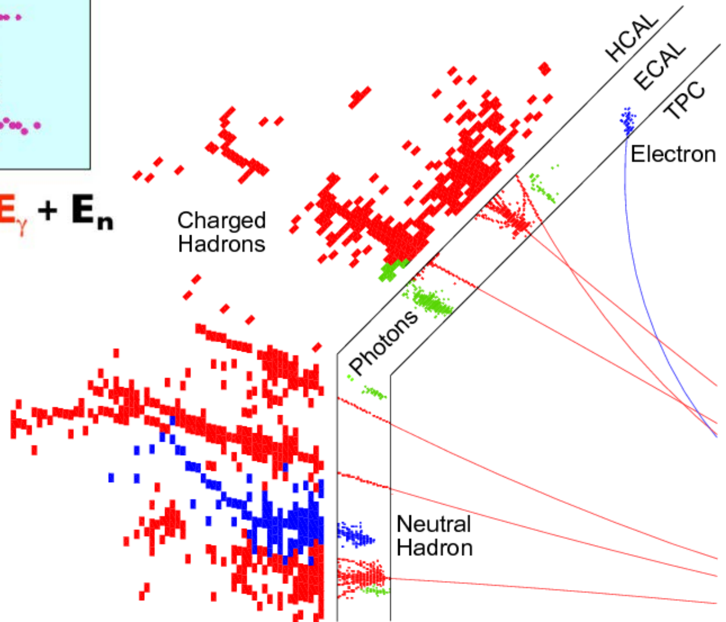
- CEPC, a high precision H/Z factory
  - Heavy bosons separation and precise Higgs measurements require excellent jet energy resolution 3~4%.
  - Fine γ/π^0 reconstruction for flavor physics.

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) = 2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E = 3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E = \frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

- Particle flow Approach
  - Identification of energy deposits from each individual particle.
  - $\sigma_{jet} = \sqrt{\sigma^2_{Track} + \sigma^2_{EM} + \sigma^2_{Had} + \sigma^2_{Confusion}}$

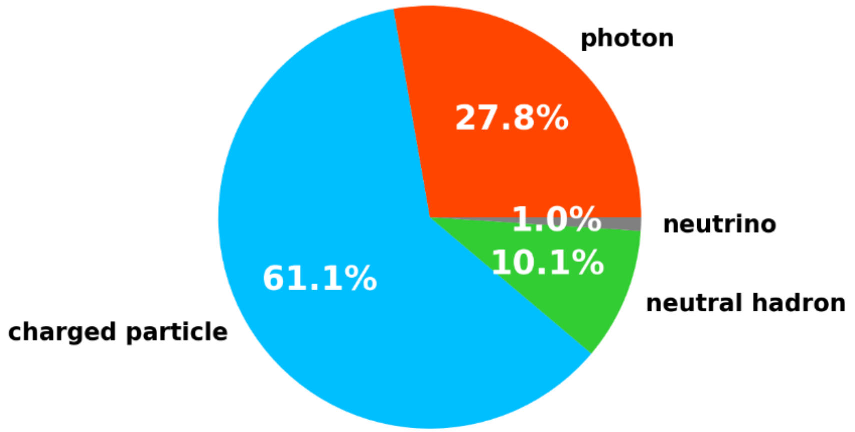
e.g. part of charged hadron shower misidentified as a separate neutral cluster, the energy is double-counted



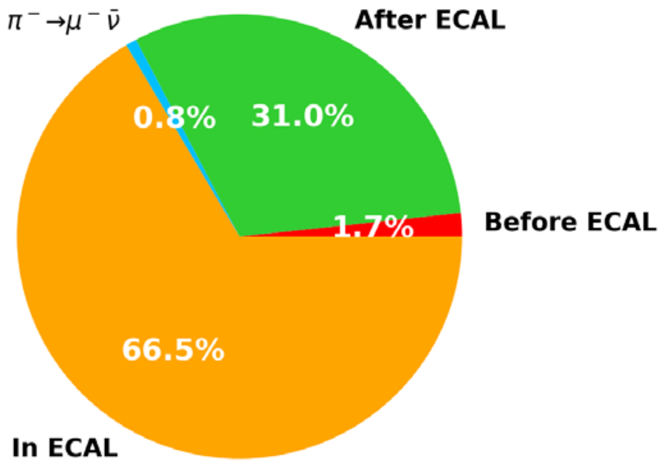


Energy of charged particle deposit in ECAL

- ~60% of the jet energy is carried by charged particle
- ~2/3 of charged hadrons shower in ECAL



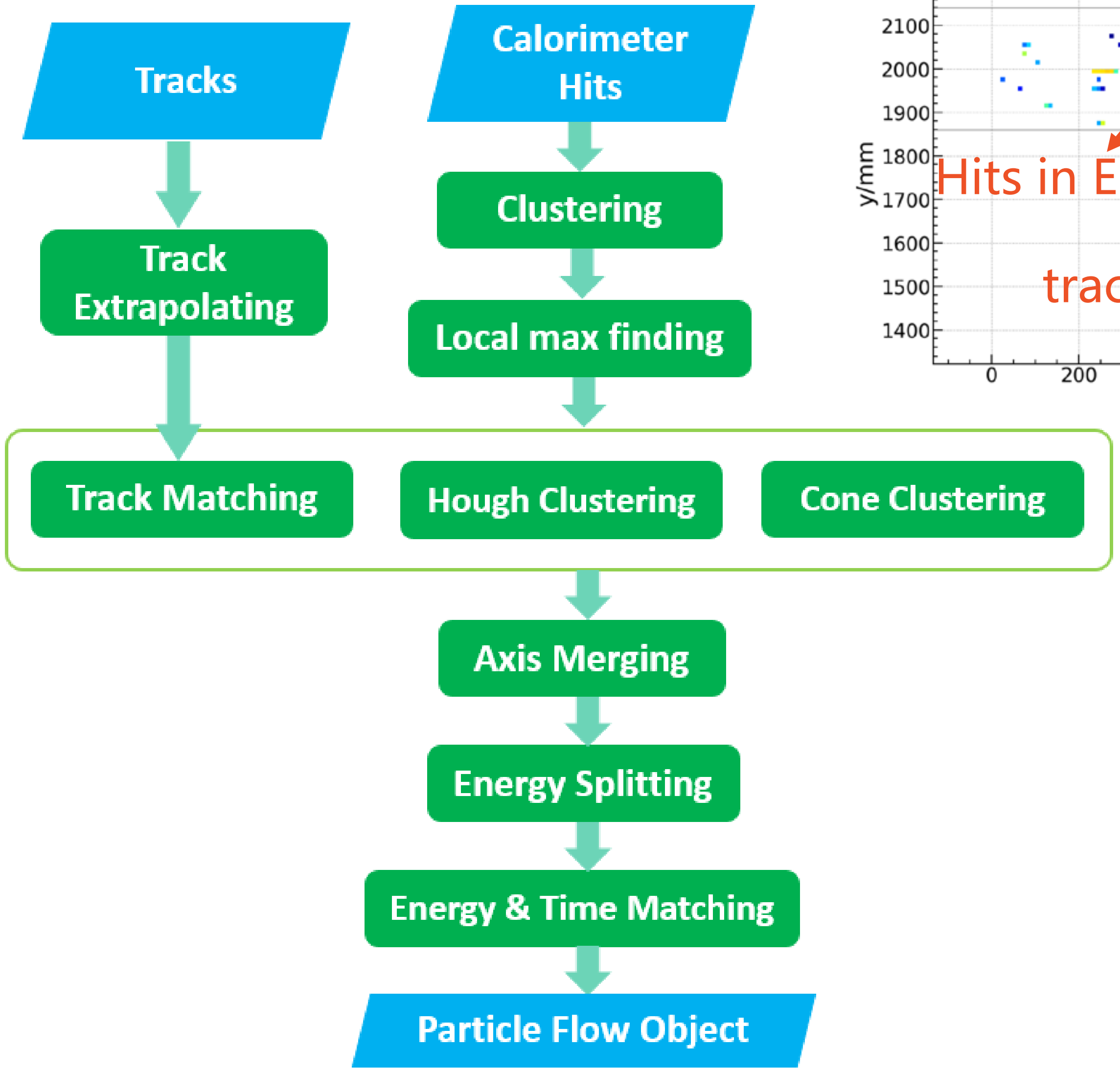
Energy proportion of different particles in jet

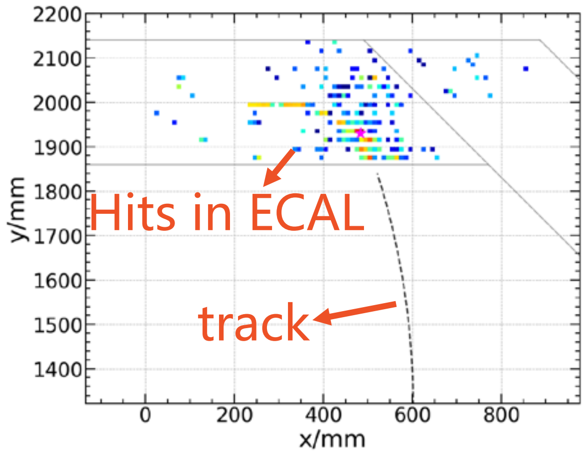


Location where π^- shower or decay occurs

- Important to recognize energy deposits of charged particles in ECAL to get the best $\sigma_{confusion}$

Overview of Reconstruction Algorithm in ECAL





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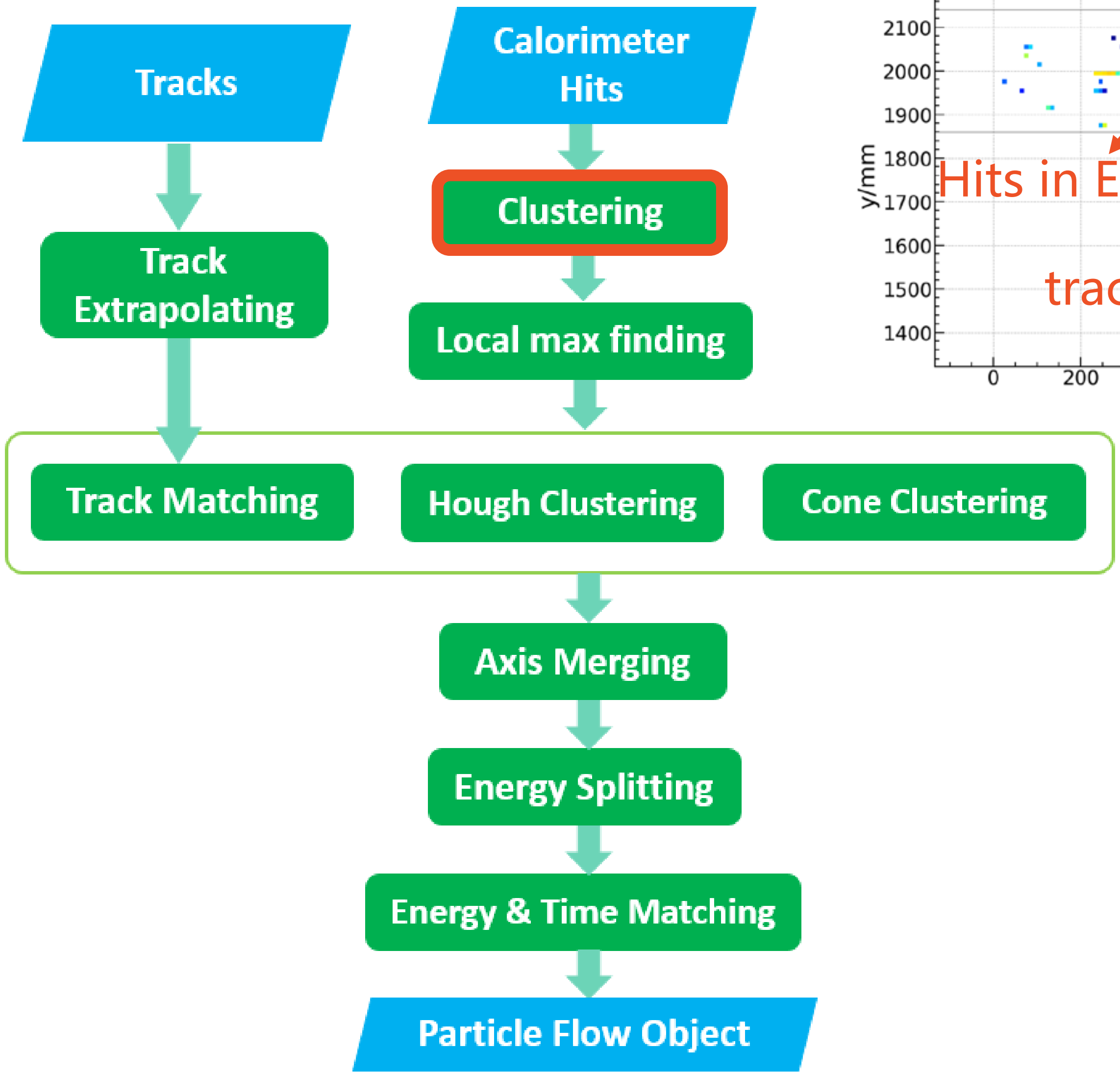

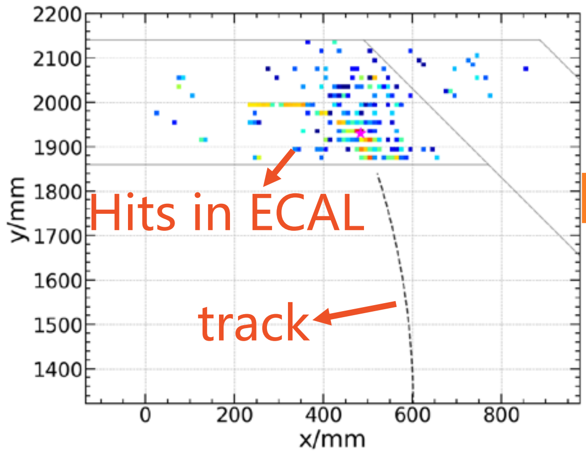

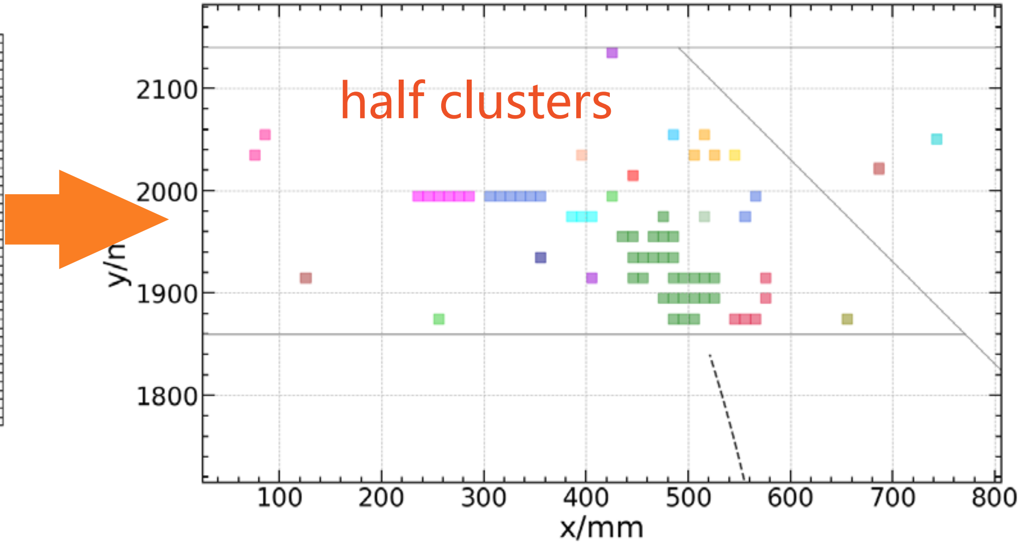

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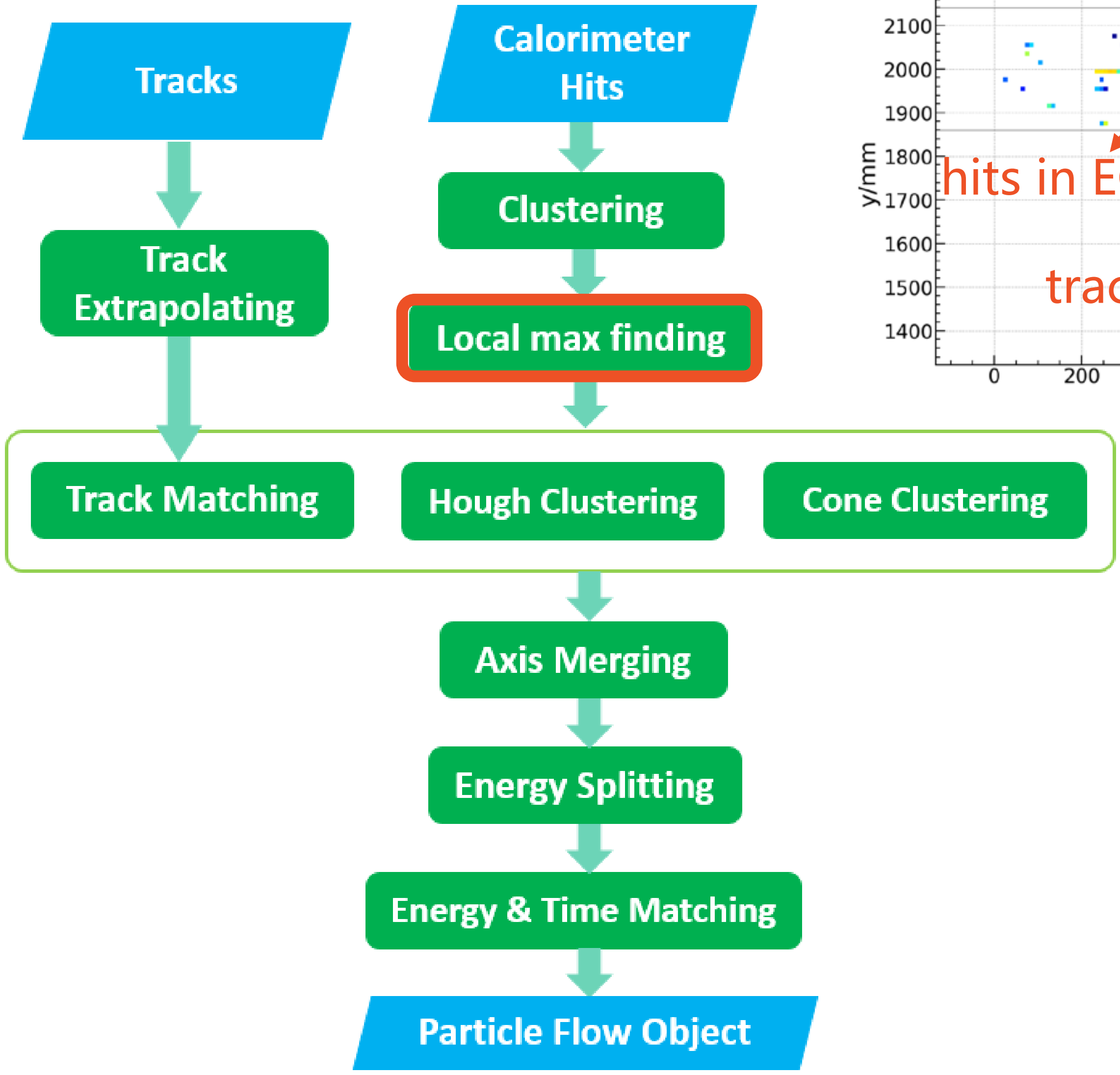

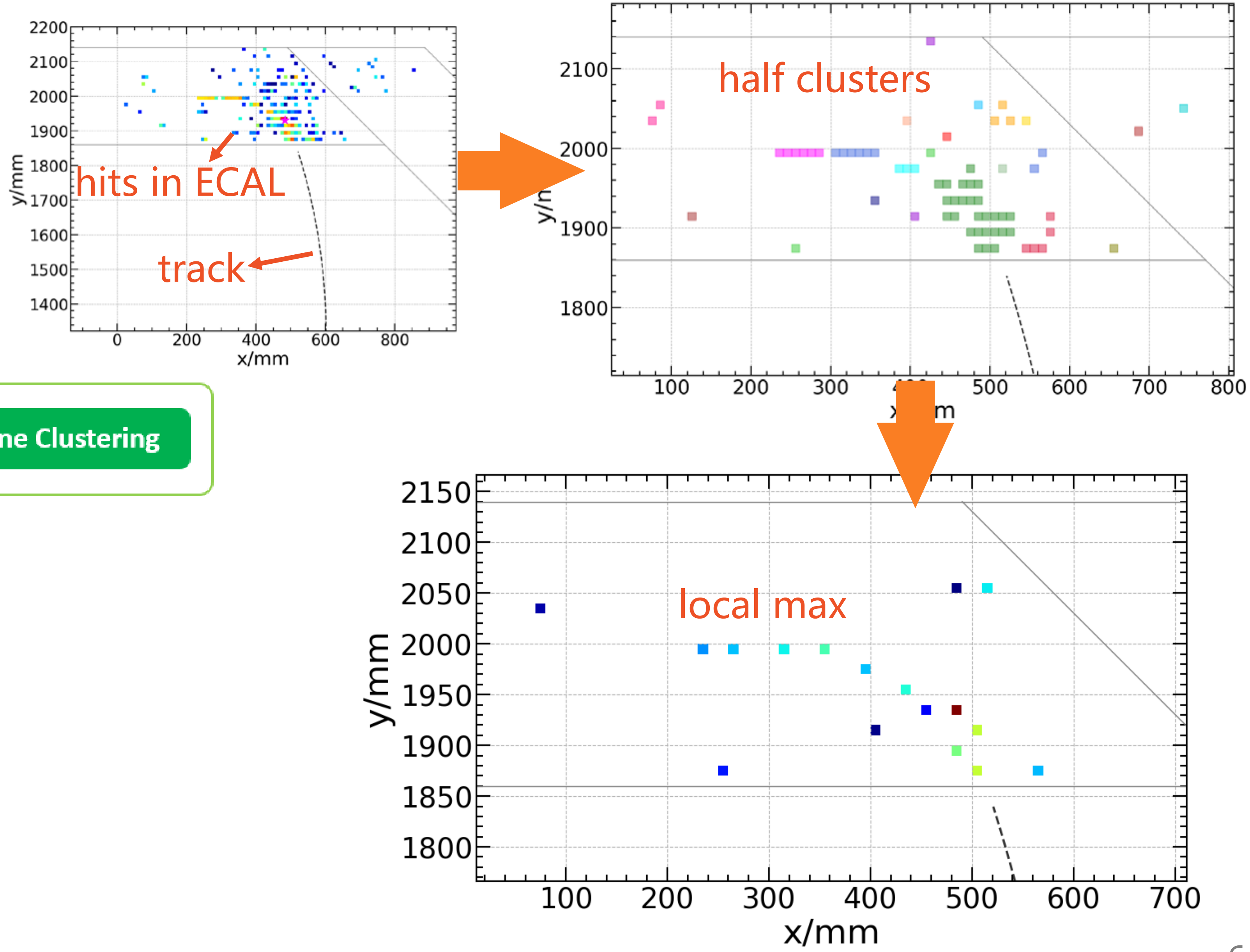

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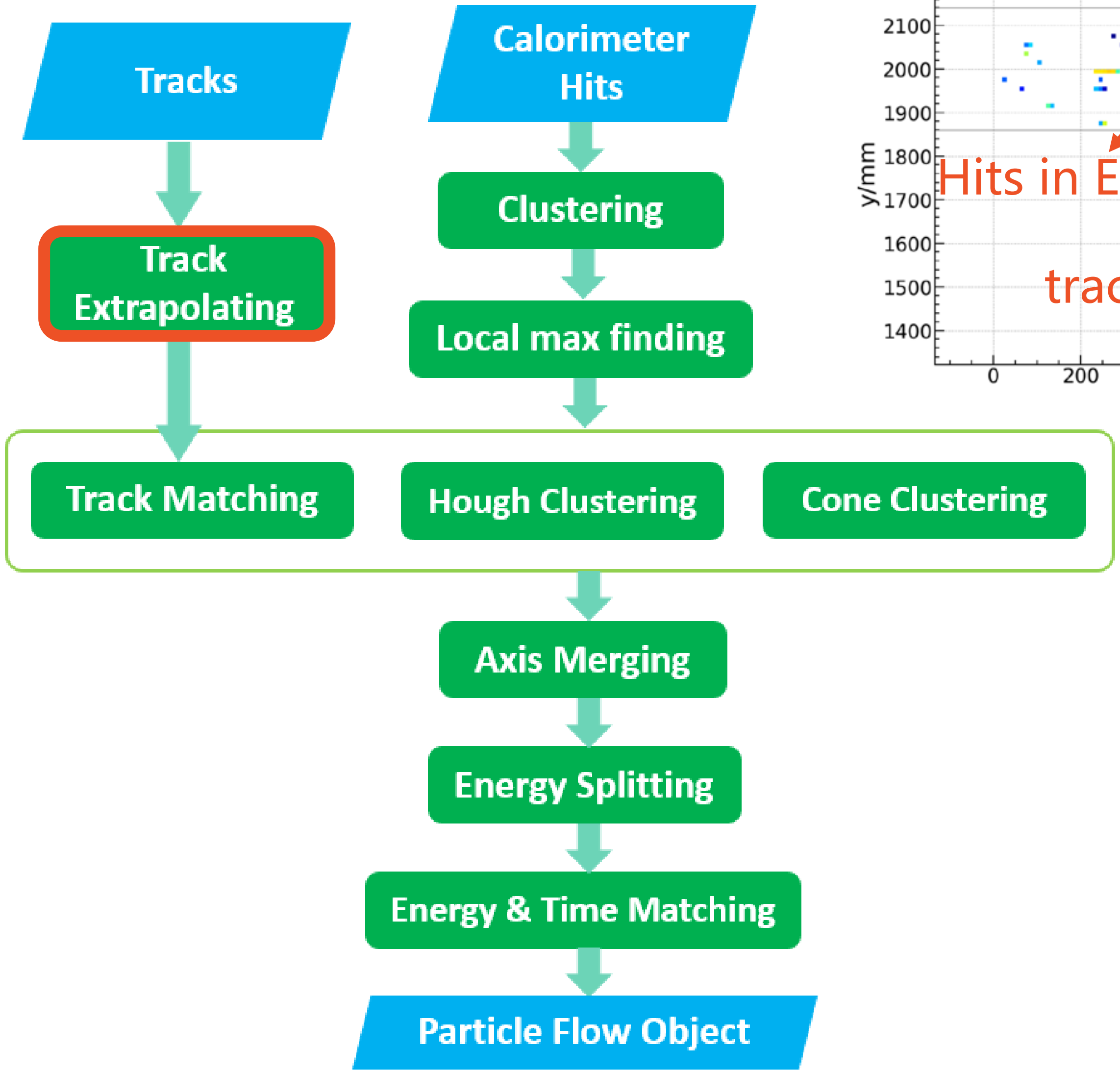

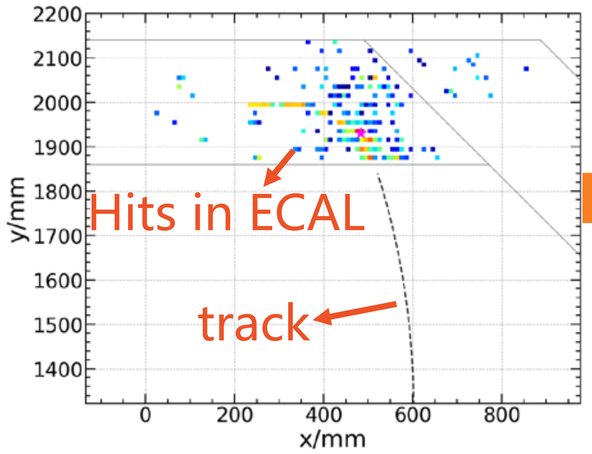

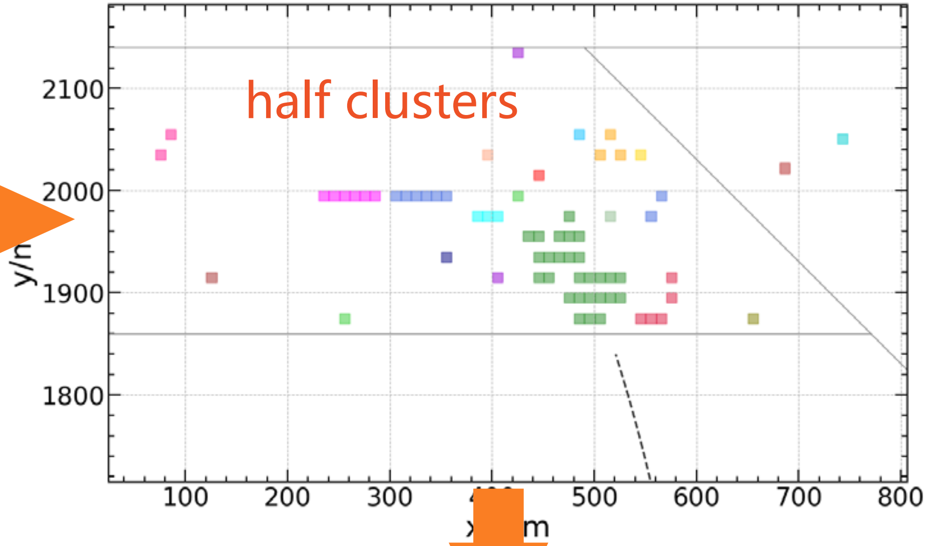

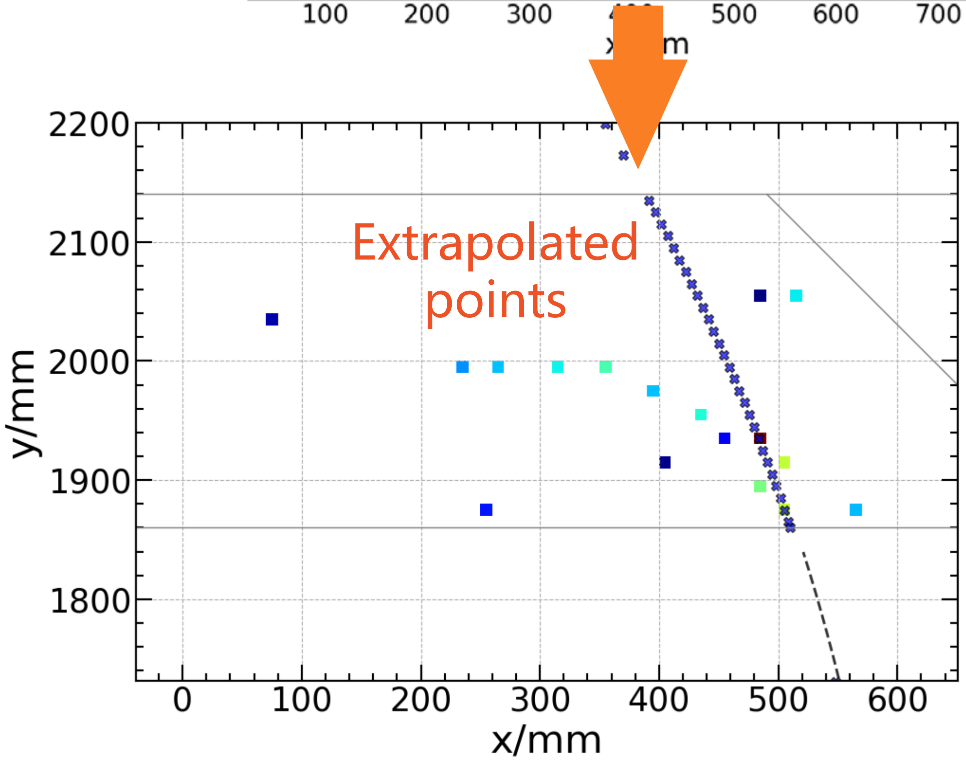

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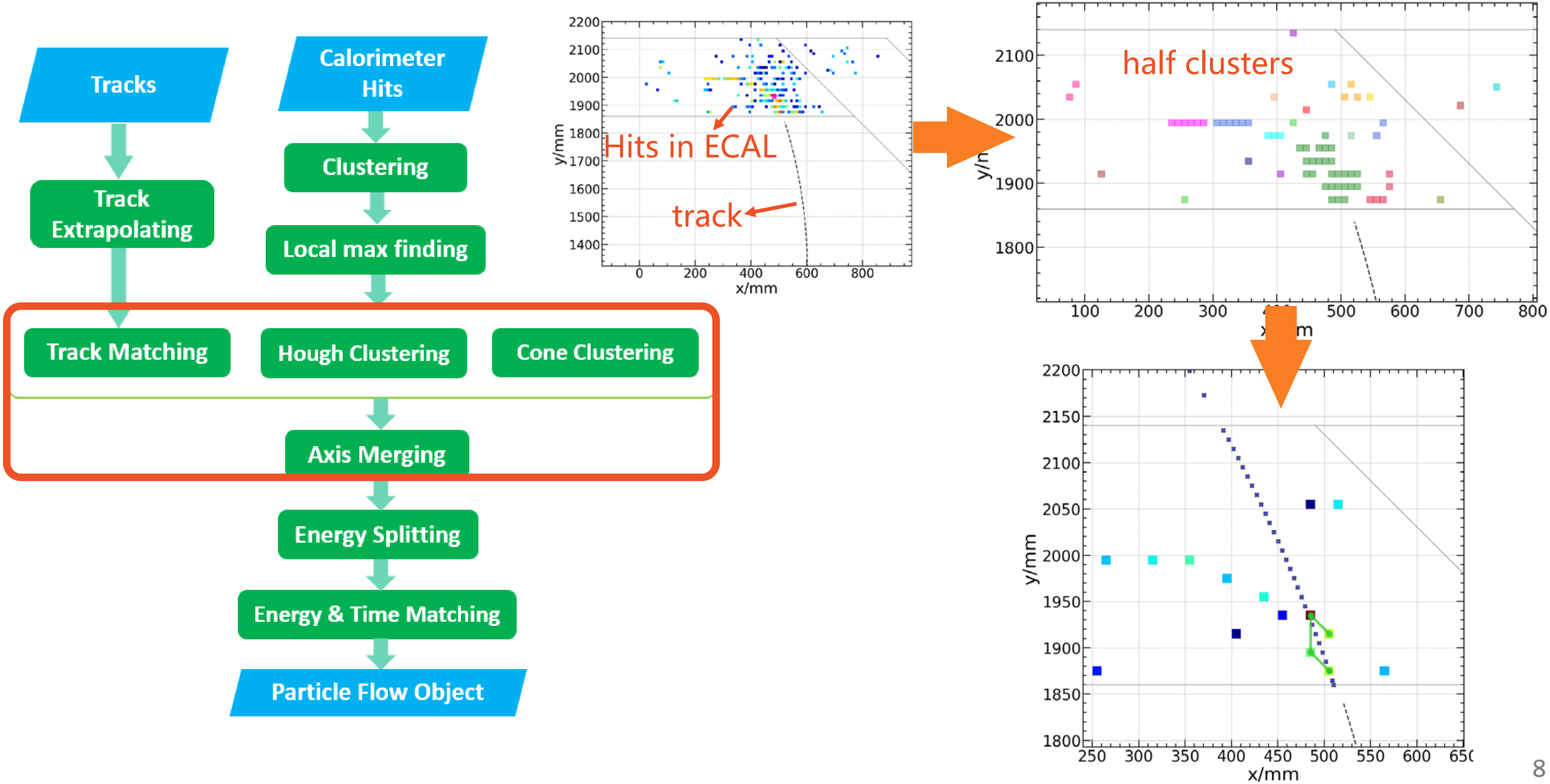
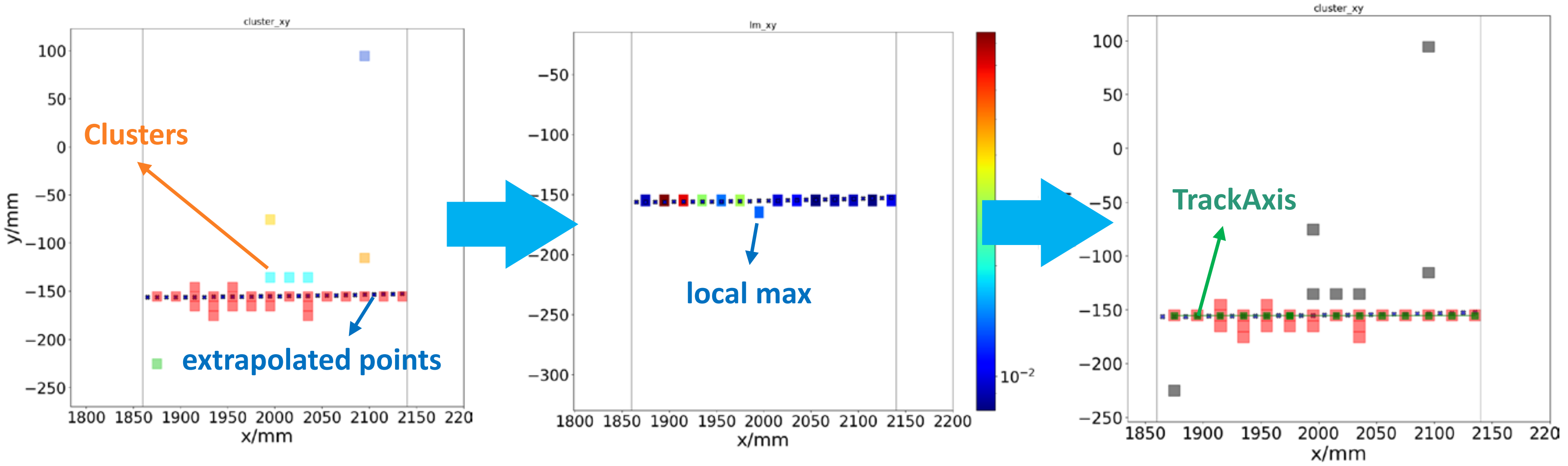
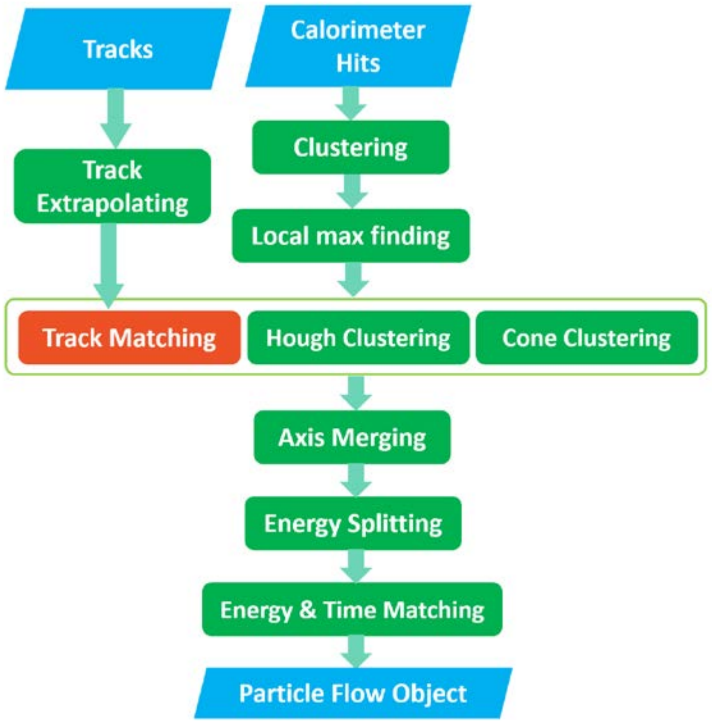


Development of Track-Matching Algorithm

- Match track and clusters(energy deposits) of charged particle

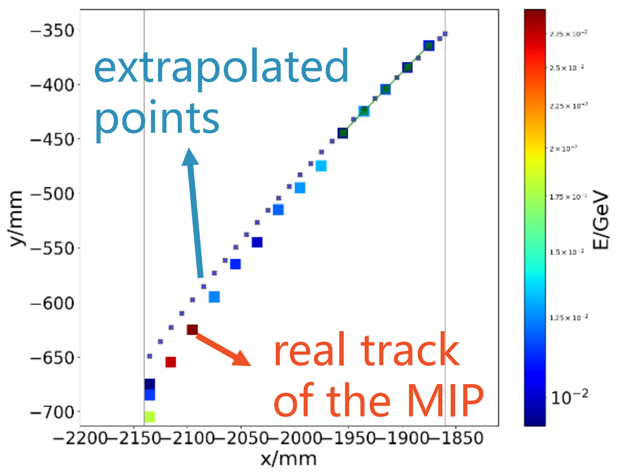


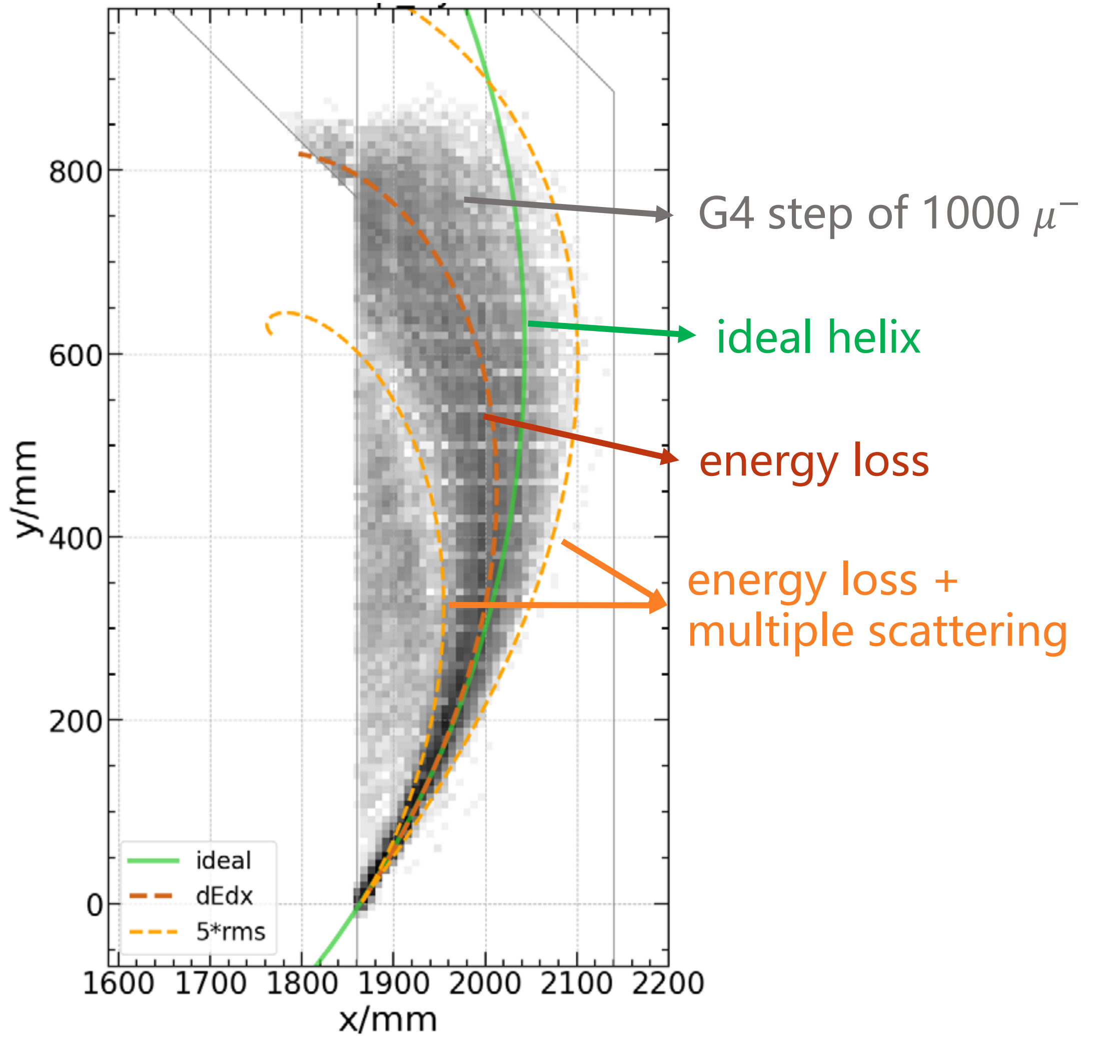


- Works well for particles with high p_T ($\sim$2GeV)

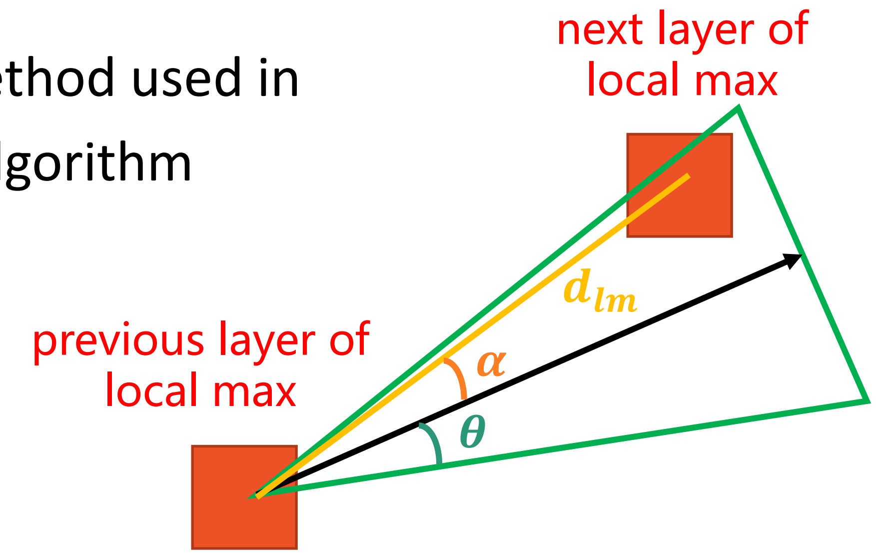
Development of Track Matching Algorithm

- For particle with low p_T, the real track deviates from ideal helix due to energy loss and multiple scattering



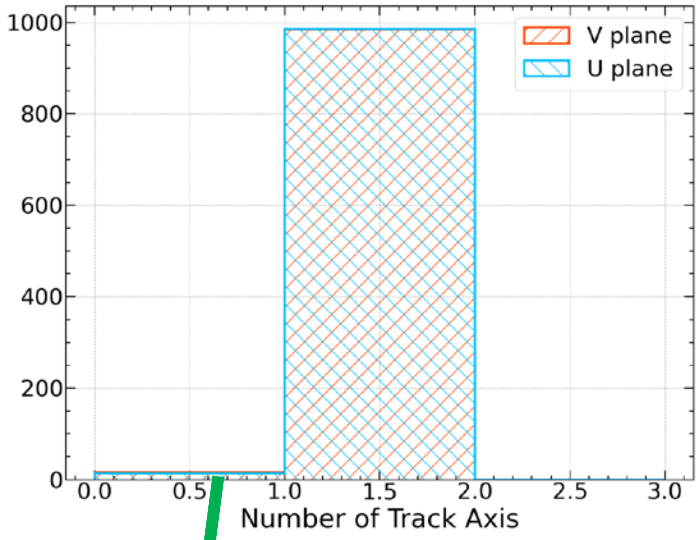


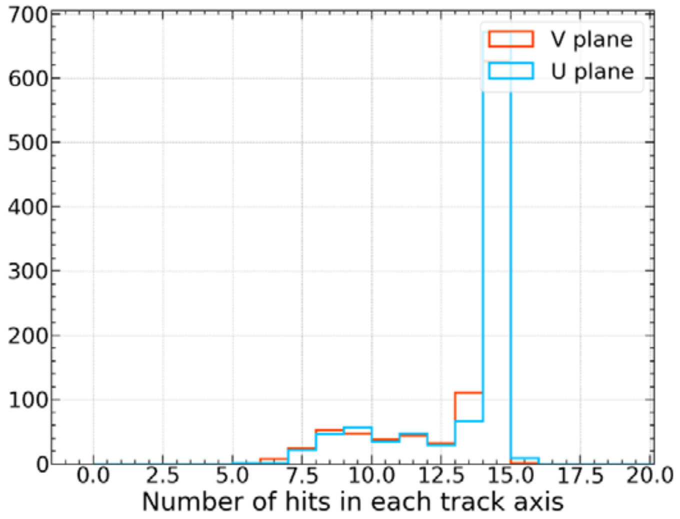
- A cone-based method used in track-matching algorithm

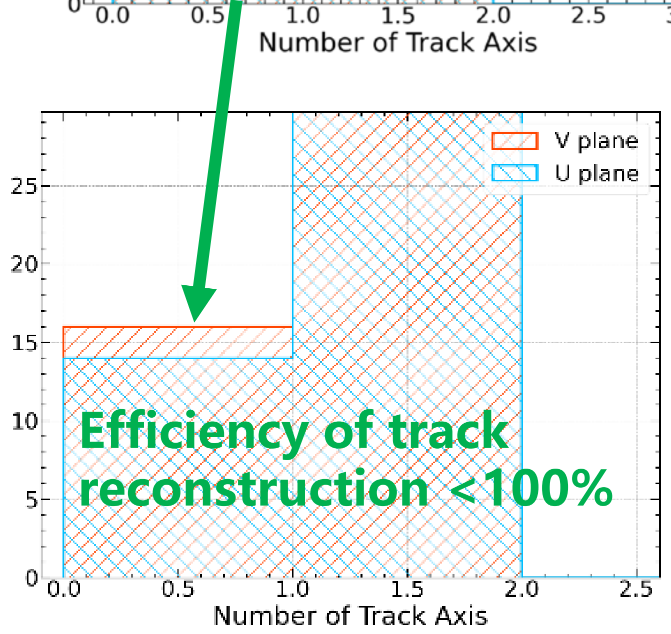


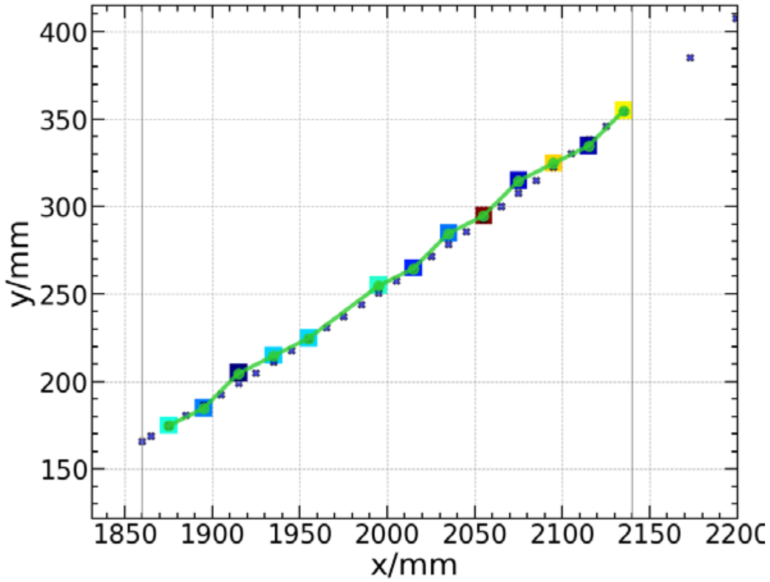
Performance of Track-Matching Algorithm

- $\mu^{-}, E = 2GeV, \theta = 50°\sim130°, \phi = 0°\sim360°,$ 1000 events



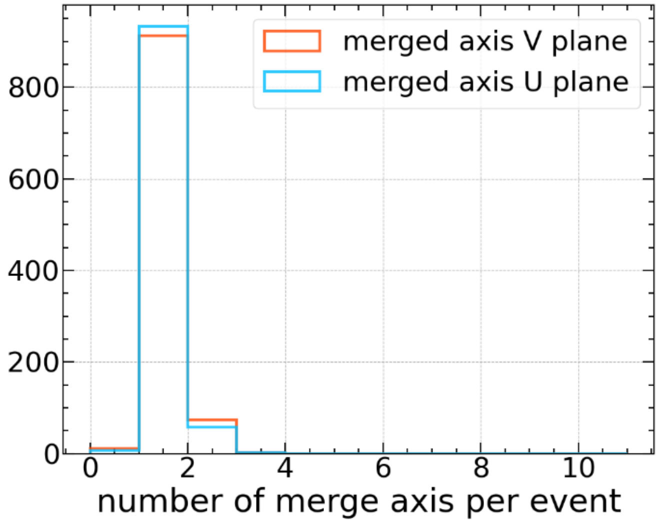


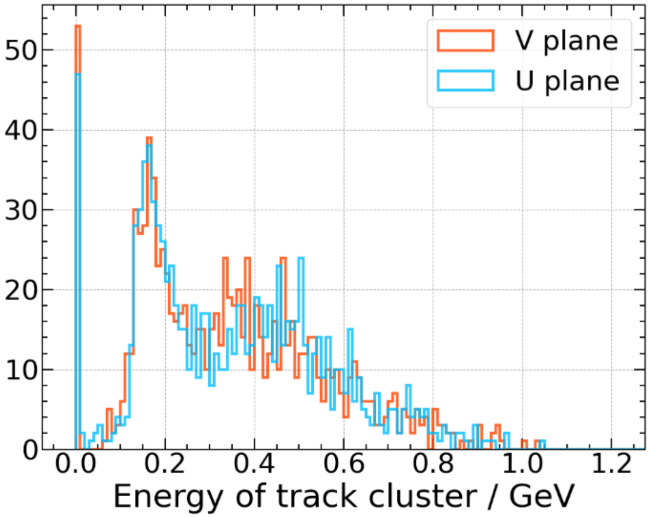


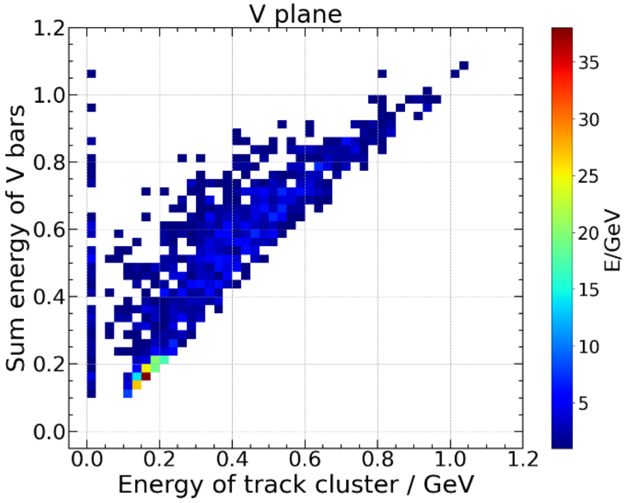


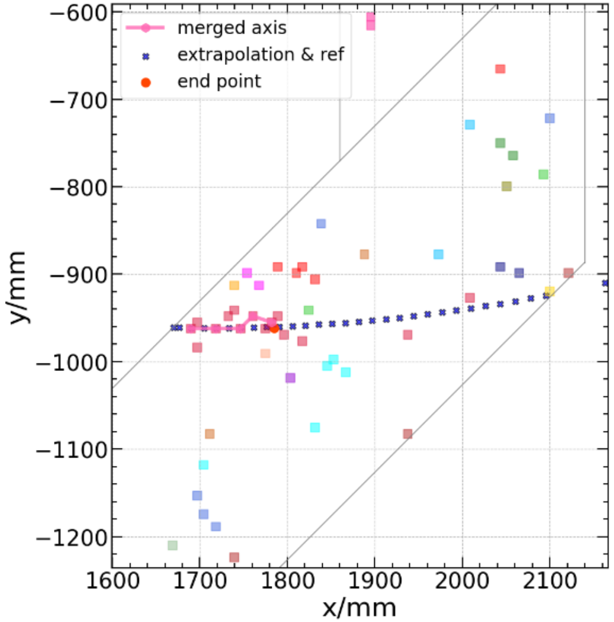
Overview of Reconstruction Algorithm in ECAL

➢ $\pi^{-}, E = 2GeV, \theta = 50°\sim130°, \phi = 0°\sim360°$









Hadronic shower may be gathered into multiple clusters. Only one is matched with track.

The other clusters may be regarded as neutral clusters. This part of energy will contributes to $\sigma_{confusion}$

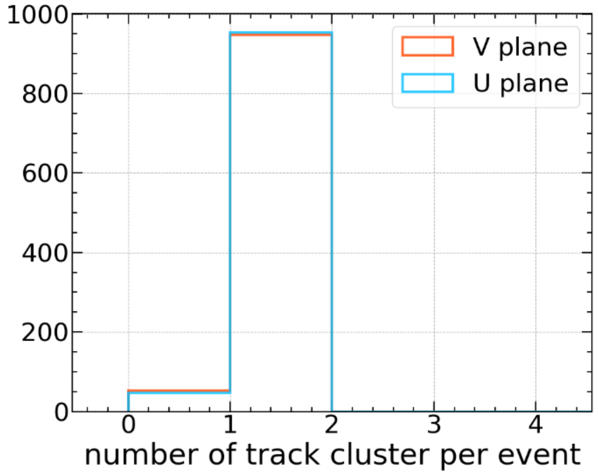
summary

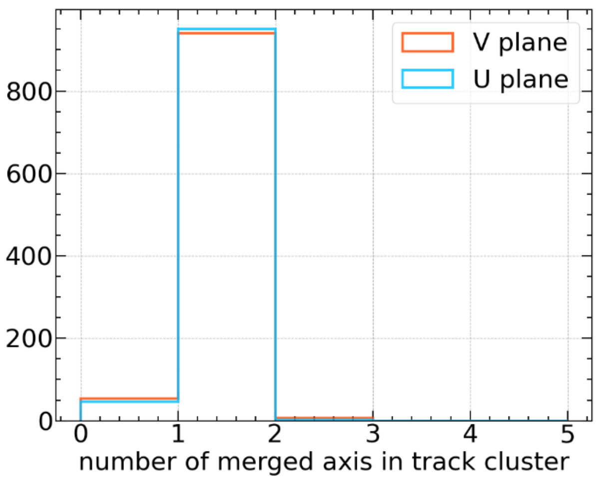
- Track-matching algorithm is developed
  - For charged particles with high p_T, match extrapolated points and local max directly
  - Due to the effect of energy loss and multiple scattering, cone-based method used for charged particles with low p_T

- Performance of MIP and hadronic shower are shown
  - Matching efficiency ~100%
  - Hadronic shower may be gathered into multiple clusters. Only one is matched with track.

backup

- backup



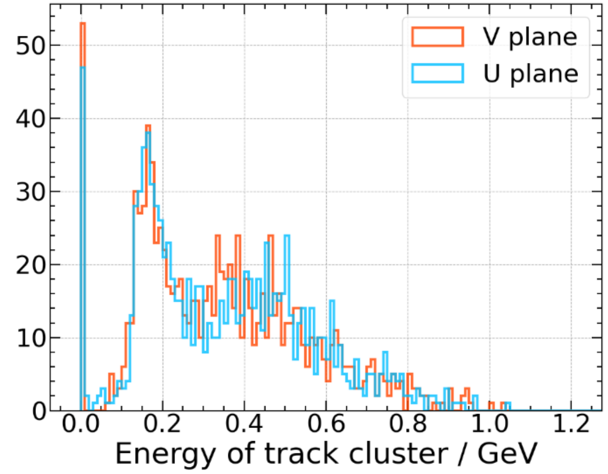


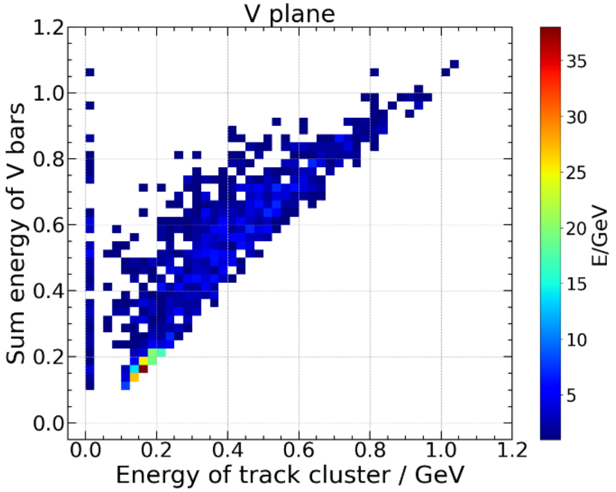
$$\begin{bmatrix} C_r \\ P_r \\ N_r \end{bmatrix} = \begin{bmatrix} \varepsilon_{C\to C} & f_{P\to C} & f_{N\to C} \\ f_{C\to P} & \varepsilon_{P\to P} & f_{N\to P} \\ f_{C\to N} & f_{P\to N} & \varepsilon_{N\to N} \end{bmatrix} \begin{bmatrix} C_t \\ P_t \\ N_t \end{bmatrix}$$

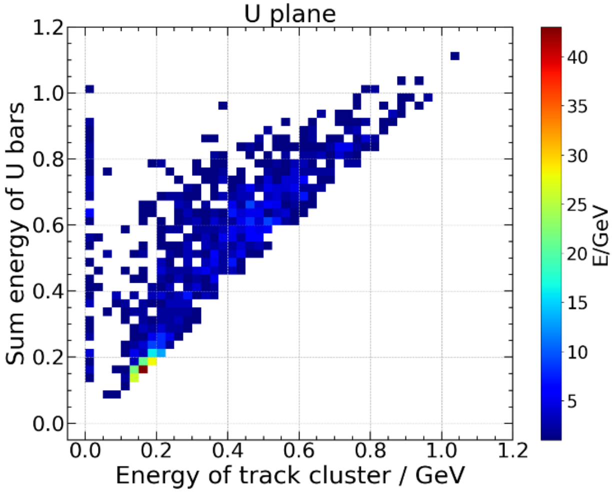
C: charged particle
P: photon
N: neutral hadron
t: truth
r: reconstruction

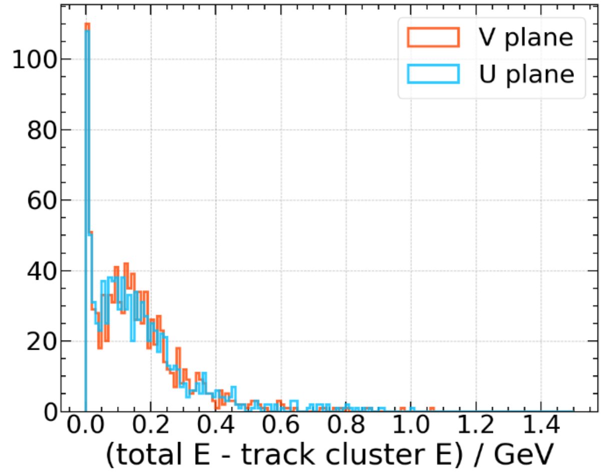
track cluster

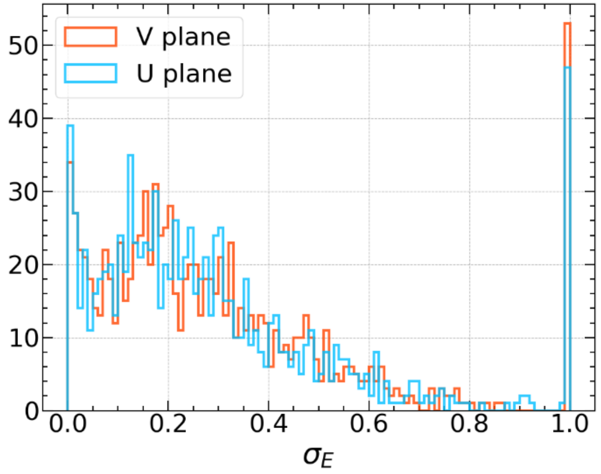
- track cluster：与带电粒子径迹匹配上的 HalfCluster











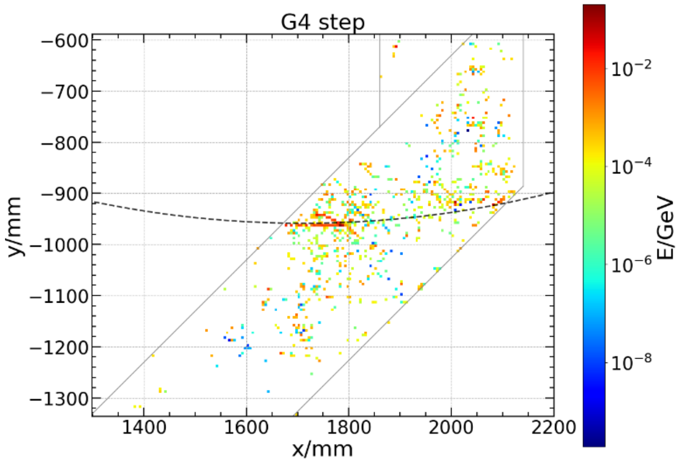
$$\sigma_E = \frac{E_{total} - E_{track\ cluster}}{E_{total}}$$

$$\begin{bmatrix} C_r \\ P_r \\ N_r \end{bmatrix} = \begin{bmatrix} \varepsilon_{C\to C} & f_{P\to C} & f_{N\to C} \\ f_{C\to P} & \varepsilon_{P\to P} & f_{N\to P} \\ f_{C\to N} & f_{P\to N} & \varepsilon_{N\to N} \end{bmatrix} \begin{bmatrix} C_t \\ P_t \\ N_t \end{bmatrix}$$

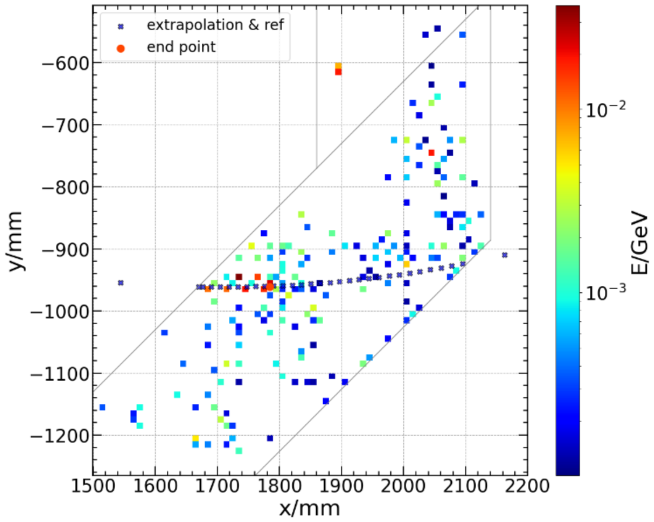
$E_{total} - E_{track\ cluster}$ 这部分能量对应 $f_{C\to P}$与$f_{C\to N}$

带电强子发生簇射时，能量沉积分散，导致会被聚类成多个 HalfCluster, 其中大量的 HalfCluster 没有对应的径迹，将被当做中性簇射。这部分能量是带电强子congfusion项的主要贡献

event display



G4 step



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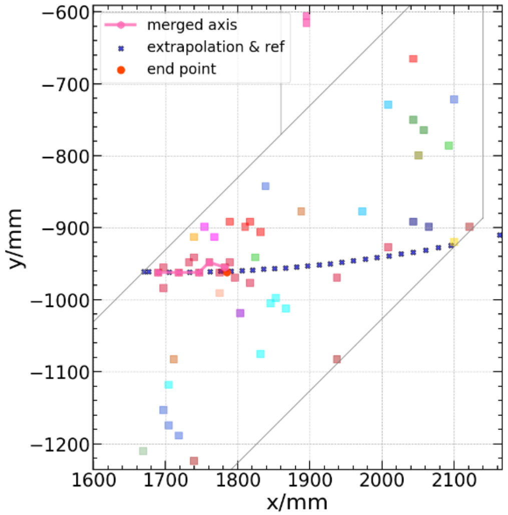
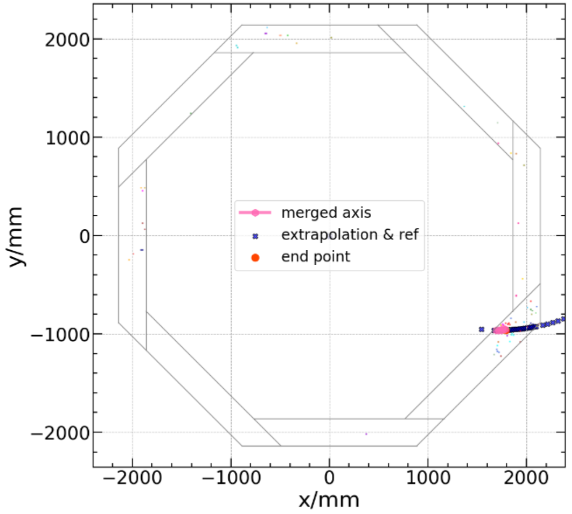


HalfClusters



HalfClusters
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