Reconstructing Track-CaloClusters (TCCs)

**Topoclusters**

Topoclusters are very large, with a typical width of roughly 0.1 in both $\phi$ and $\eta$. This holds as a function of both $\eta$ and $p_T$.

**Tracks**

The track position is known very precisely, and the uncertainty on its extrapolation to the calorimeter is two orders of magnitude smaller than the width of a cluster at high $p_T$.

**Em Clusters**

Tracks can resolve structure within clusters.

**Matching to clusters**

Matching tracks to clusters smaller than the width of a cluster at high $p_T$. To do this, a track-cluster matching must be performed. This proceeds in two steps:

1. Attempt match with $d\phi < \Delta \phi_{\text{cluster}}$ (width)
2. Match if $(d\eta)^2 < (\Delta \eta^2 + \Delta \phi_{\text{cluster}})^2$

**In case of track-cluster-multi-matches,** create one TCC object per hard-scatter PV track, and share the energy based on $p_T$, ratios:

$\text{TCC}_\text{charged} = (p_T^t, \eta^t, \phi^t, m^t = 0)$

$\text{TCC}_\text{neutral} = (p_T^c, \eta^c, \phi^c, m^c = 0)$

$\text{TCC}_\text{combined} = (p_T^t, \eta^t, \phi^t, m^t, m^c = 0)$

$\text{TCC}_\text{combined mult-matches} = (p_T^t, \eta^t, \phi^t, m^t, m^c = 0)$

Matching fractions:

Charged: unmatched tracks from the PV0

Neutral: clusters not matched to any PV track

Combined: PV0 track matched to cluster(s)

Reconstructing jets from TCCs:

Jet reconstruction

Follow standard ATLAS jet reconstruction:

- Anti-$k_T$ algorithm with $R = 1.0$.
- Trimmed with $R_{\text{cut}} = 0.2$ and $f_{\text{cut}} = 5\%$

Inputs to jet building:

Consider jets built from three types of inputs:

1. LC topoclusters (normal ATLAS approach)
2. All TCCs (charged, neutral, combined)
3. Only combined TCCs

**Jet substructure performance for W/Z boson tagging using TCCs**

Topoclusters use combined mass ($m_{\text{comb}}$), a linear combination of calorimeter ($m_{\text{calo}}$) and track-assisted ($m_{\text{TA}}$) masses:

- $m_{\text{comb}}$ works well at low $p_T$, $m_{\text{calo}}$ at high $p_T$.
- $m_{\text{TA}}$ ignores local charge/neutral variations.

**Tracks**

2. Most powerful for $W/Z$-tag, after mass

$D_2 = \text{ECF}3 \times (\text{ECF}1)^2 / \text{ECF2}^2$

However, $D_2$ precision depends on detector granularity, thus TCC is hugely beneficial.

**Correcting for jet mass resolution**

$\frac{1}{\sigma^2_{\text{true}}} = \frac{1}{\sigma^2_{\text{reco}}} = \frac{1}{\sigma^2_{\text{true}}}$

$\frac{1}{\sigma^2_{\text{reco}}} = \frac{1}{\sigma^2_{\text{true}}}$

$\sigma_{\text{comb}} = \sqrt{\sigma_{\text{true}}^2 + \sigma_{\text{reco}}^2}$

$\sigma_{\text{true}} = \sqrt{\frac{1}{\sigma^2_{\text{true}}} - \frac{1}{\sigma^2_{\text{reco}}}}$

$\sigma_{\text{reco}} = \sqrt{\frac{1}{\sigma^2_{\text{true}}} - \frac{1}{\sigma^2_{\text{reco}}}}$

$\sigma_{\text{true}} = \sqrt{\frac{1}{\sigma^2_{\text{true}}} - \frac{1}{\sigma^2_{\text{reco}}}}$

$\sigma_{\text{reco}} = \sqrt{\frac{1}{\sigma^2_{\text{true}}} - \frac{1}{\sigma^2_{\text{reco}}}}$

**Mass response**

$\frac{m_{\text{true}}}{m_{\text{true}}} = \frac{m_{\text{true}}}{m_{\text{true}}} = \frac{m_{\text{true}}}{m_{\text{true}}} = \frac{m_{\text{true}}}{m_{\text{true}}}$

$\sigma_{\text{true}} = \sqrt{\frac{1}{\sigma^2_{\text{true}}} - \frac{1}{\sigma^2_{\text{reco}}}}$

$\sigma_{\text{reco}} = \sqrt{\frac{1}{\sigma^2_{\text{true}}} - \frac{1}{\sigma^2_{\text{reco}}}}$

All results from ATL-PHYS-PUB-2017-015