Jet Energy Calibration and Lund Jet Plane studies

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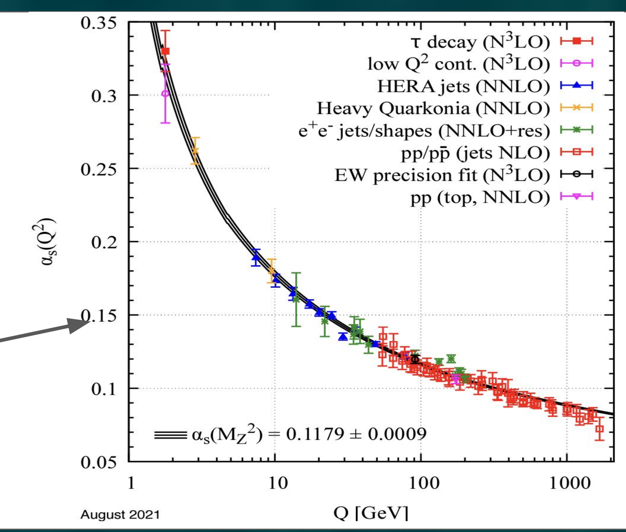
- Goal: study how the strong coupling constant α_s varies with energy using jets and their substructure
- Due to detector effects in jet reconstruction, the implementation of a Jet Energy Scale Calibration procedure is necessary.
- The Lund Jet Plane representation of jet substructure effectively disentangles perturbative and nonperturbative effects within jets.



α_s evaluations using different processes, along with a global fit at Z-pole

Jet Energy Scale (JES) Calibration at ATLAS

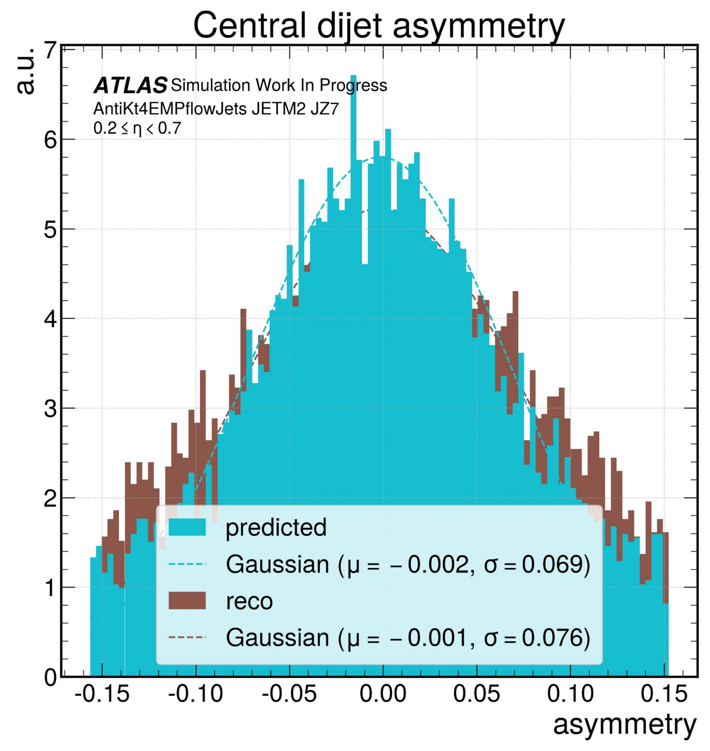
1. **Reconstructed Jets** — Jet finding applied to tracking- and/or calorimeter-based inputs.
2. **p_T-density based pileup corrections** — Applied as a function of event pile-up p_T density and jet area.
3. **Residual pileup correction** — Removes residual pile-up dependence, as a function of μ and N_{PV}.
4. **Absolute MC based corrections** — Corrects jet 4-momentum to the particle-level energy scale. Both the energy and direction are calibrated.
5. **Global Sequential calibration** — Reduces flavour dependence and energy leakage effects using calorimeter, track, and muon-segment variables.
6. **Residual in situ calibration** — A residual calibration is applied ***only to data*** to correct for data/MC differences.

Jet calibration with data-based ML (3 – 6)

- **Goal:** optimise jet energy resolution (JER) with machine learning (ML) using experimental data
- Introduce asymmetry-based loss: Treat one reco jet as a 'well calibrated' object and compute the asymmetry $\mathcal{A}$ of the two jets and its standard deviation $\sigma_{\mathcal{A}}$
- Implement a ML model combining asymmetry- and truth-based terms:

$$\mathcal{A}_1 = \frac{p_{T_1}^{pred} - p_{T_2}^{reco}}{p_T^{avg}}, \text{ with } p_T^{avg} = \frac{p_{T_1}^{pred} + p_{T_2}^{reco}}{2}$$

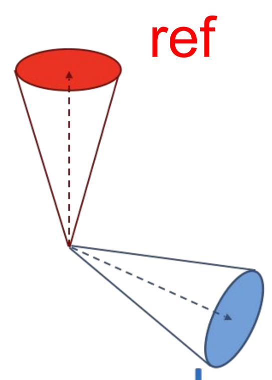
$$loss(\theta) = f_a \cdot (\sigma_{\mathcal{A}_1(\theta)} + \sigma_{\mathcal{A}_2(\theta)}) + f_t \cdot MSE(p_T(\theta), p_T^{true}), \quad f_a, f_t \in \mathbb{R}^+ \quad \text{with} \quad \mathcal{A}_2 = \frac{p_{T_1}^{reco} - p_{T_2}^{pred}}{p_T^{avg}}, \text{ with } p_T^{avg} = \frac{p_{T_1}^{reco} + p_{T_2}^{pred}}{2}$$



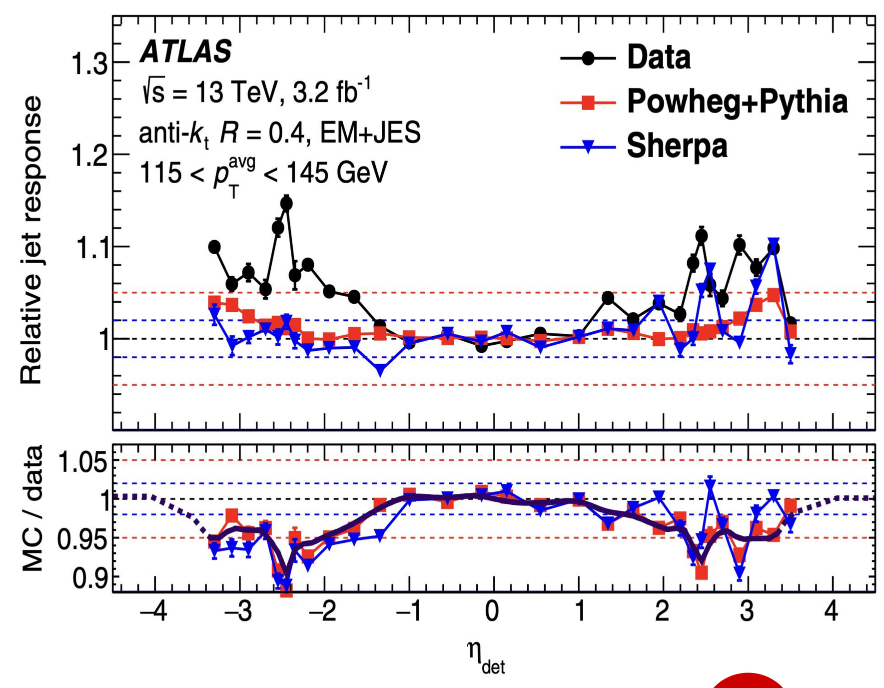
η-intercalibration (6)

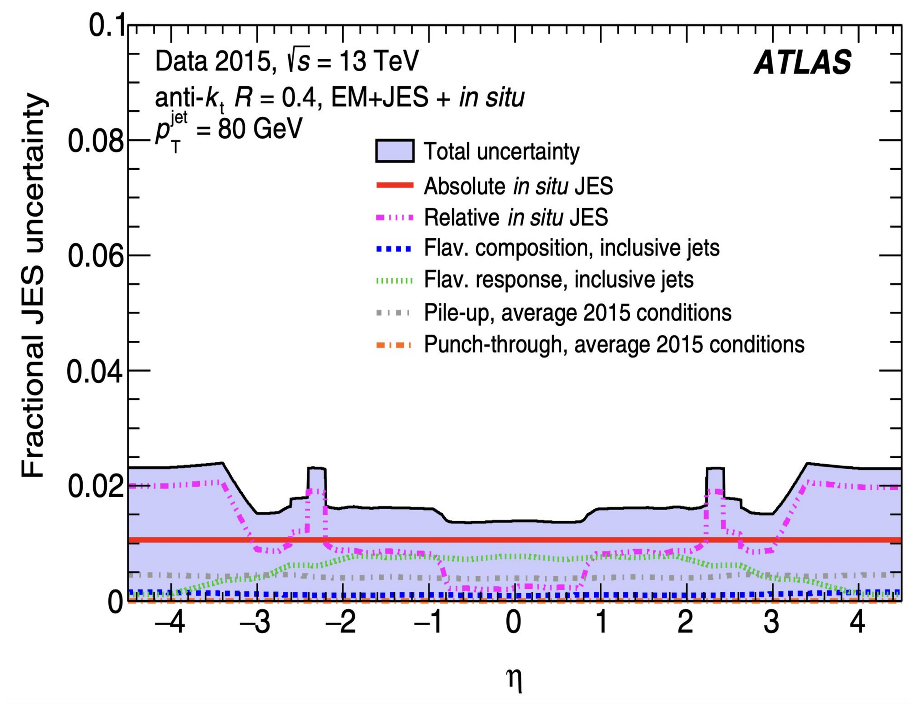
- Using p_T balance in *in situ* dijet events to achieve homogeneity of the calibration in η
- Deriving calibration factors in bins of p_T, η:

$$\mathscr{C} = \left[\frac{(p_T^{probe})_{reco}}{p_T^{ref}}\right]_{data} \Bigg/ \left[\frac{(p_T^{probe})_{reco}}{p_T^{ref}}\right]_{MC}$$



- Work on making the method more robust and enhancing the statistics by recovering data that was discarded
- Improved treatment of statistical uncertainties





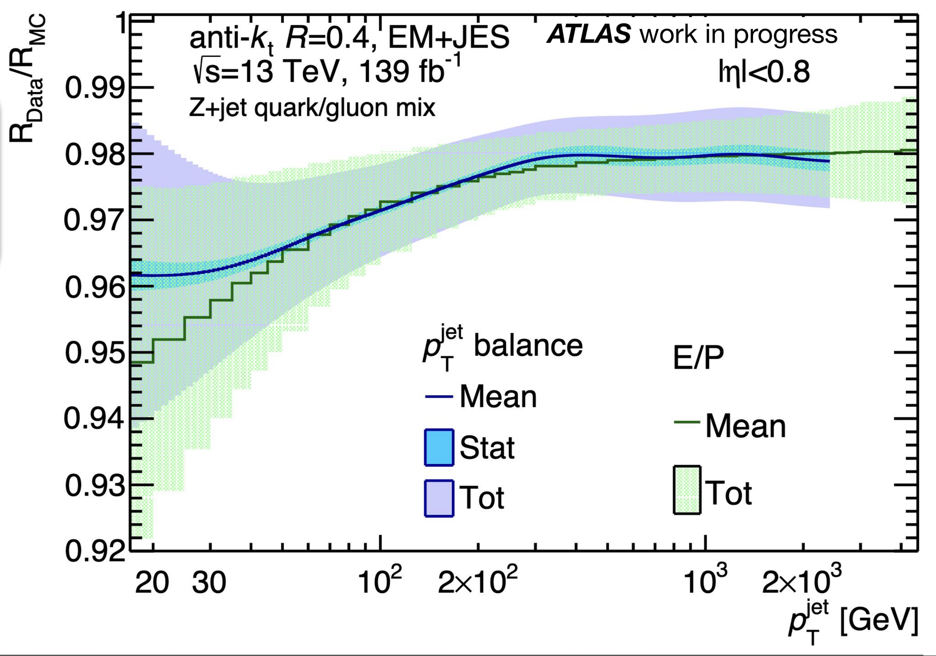
JES calibration based on E/p single particle measurements (6)

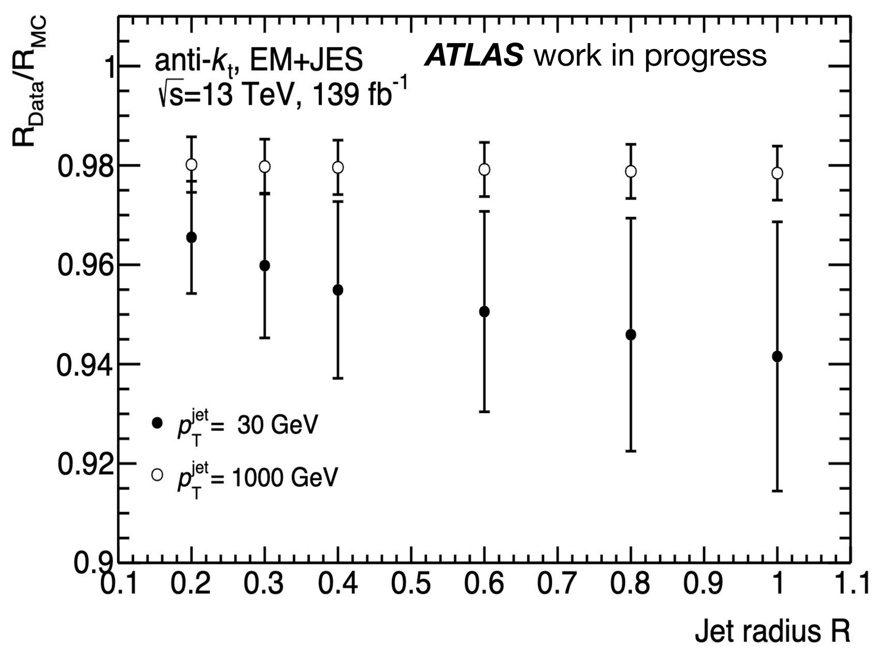
- Input: calorimeter response corrections for single particles from isolated track P and calorimeter energy deposition E
- Aim: Derive JES using jet constituents level information

Truth matched EM jets → EM jets associated cluster of cells → True energy deposition (Hits) inside cells → Corrections from E/p inputs following truth particle properties → Corrected/Smeared deposited energy matched with truth particles

$$f(p_T) = \text{Poisson}(f_{Data/MC}(p_T), \Delta f_{Data/MC}(p_T))$$

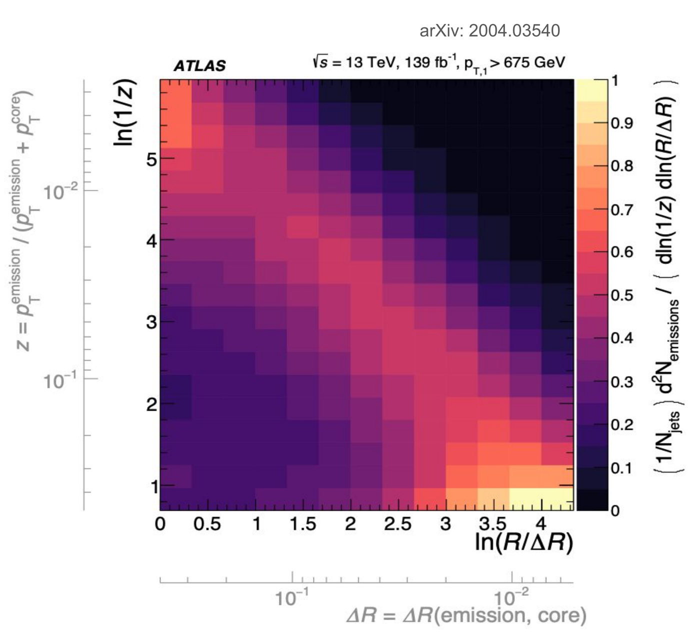
- Good agreement with *in situ* p_T balance method
- Reduced JES uncertainty to < 1% for jets with p_T > 200 GeV
- Method can be used for various jet collections

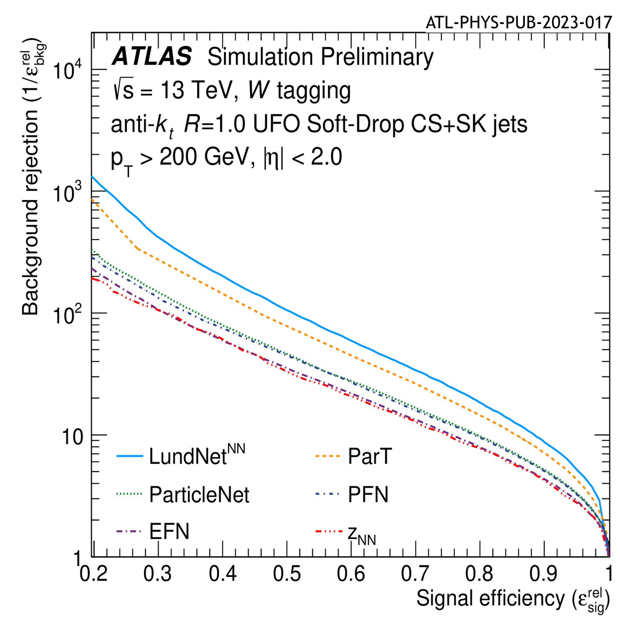


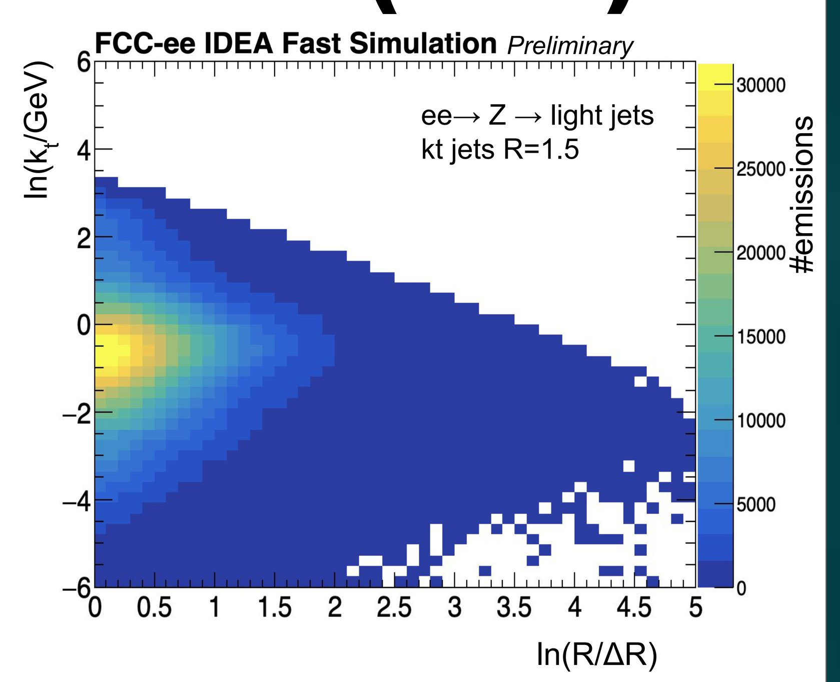


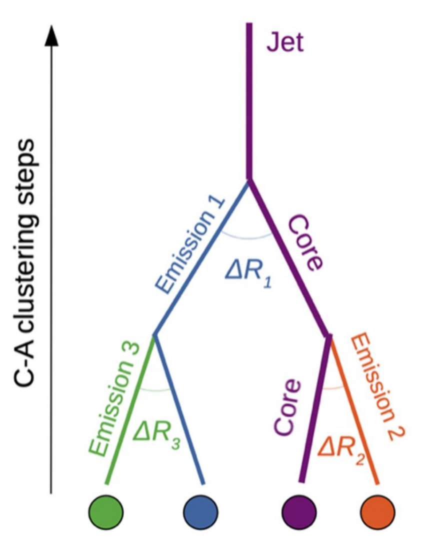
Jet substructure representation using Lund Jet Plane (LJP)

- LJP works as handle to separate perturbative and non-perturbative effects related to QCD jet formation in a 2D representation

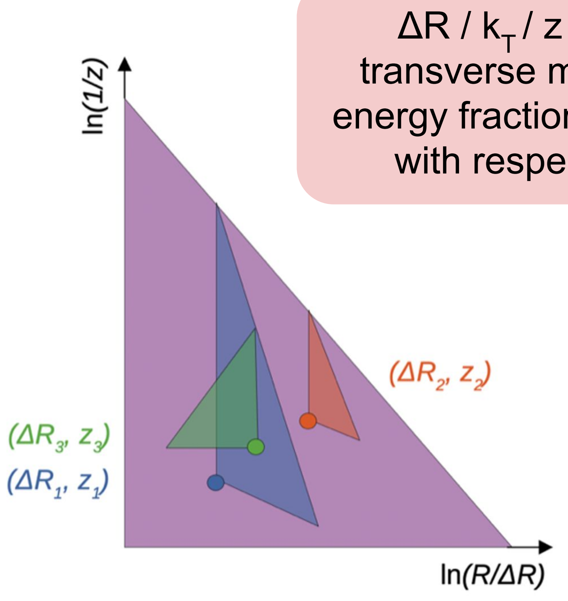








ΔR / k_T / z = angle / transverse momentum / energy fraction of emission with respect to core



- Study the jet substructure using angle and energy of emissions in jets
- Develop the tagging methods to identify W boson jets from QCD jet
- Also perform projections to study the jet substructure at FCC-ee

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