Energy Correlators for Jet Analysis

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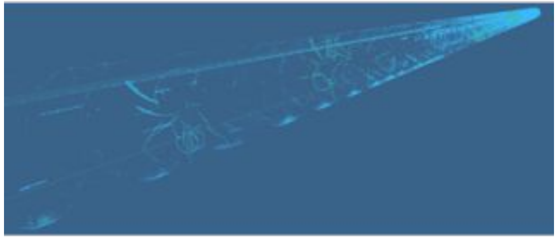


Introduction to the n-point projected energy correlator

$$\mathcal{E}(\vec{n}) = \lim_{r\to\infty} \int_0^\infty dt\ r^2 n^i T_{0i}(t, r\vec{n})\,, \qquad (1)$$

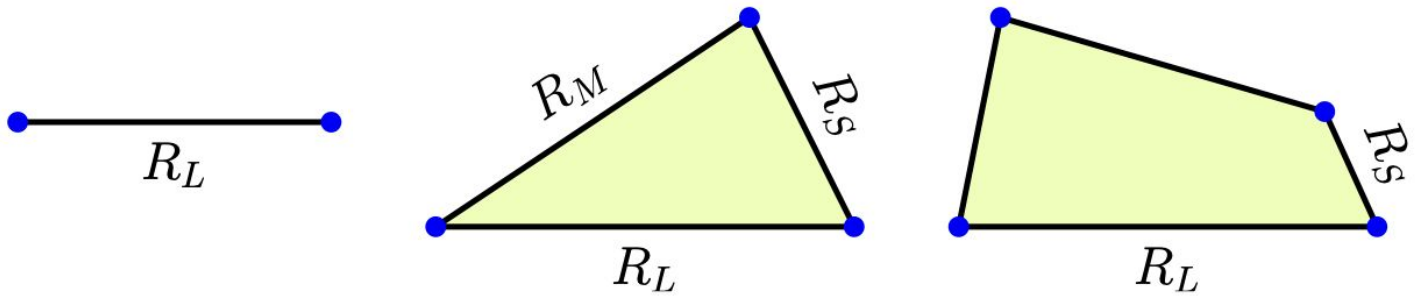
(Komiske, Moult, Thaler, Zhu, 2023)

$$\text{ENC}(R_L) = \left(\prod_{k=1}^{N} \int d\Omega_{\vec{n}_k}\right) \delta(R_L - \Delta\hat{R}_L) \cdot \frac{1}{(E_{\text{jet}})^N} \langle \mathcal{E}(\vec{n}_1)\mathcal{E}(\vec{n}_2)\ldots\mathcal{E}(\vec{n}_N)\rangle\,, \qquad (2)$$

$$ENC(R_L) = \sum_{i_1,\ldots,i_k}^{i_N} \int dR_L \frac{p_T^{i_1}, p_T^{i_2} \ldots p_T^{i_N}}{p_{T,jet}^N} \delta(R_L - \Delta\hat{R_L})$$

Introduction to the n-point projected energy correlator

N=2 and N=3:



(Komiske, Moult, Thaler, Zhu, 2023)

Looking ahead:

- another way to probe α_s
- in the regions where perturbative theory is reliable:

$$\frac{E3C(R_L)}{EEC(R_L)} \sim \alpha_s + \mathcal{O}(\alpha_s^2) + \ldots$$

- a new way to measure a fundamental constant from jet observables

Introduction to the n-point projected energy correlator

IRC safety

1. Collinear and infrared (soft gluon) emissions are physically unresolvable

$$N \equiv \text{number of jet constituents}$$

$$z_{leading} \equiv \frac{p_{T,\,leading}}{\sum_{i \in jet} p_{T,i}}$$

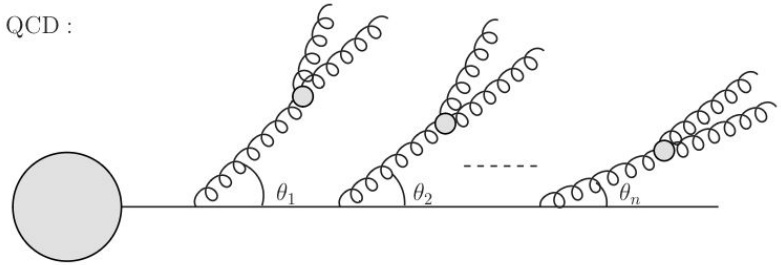
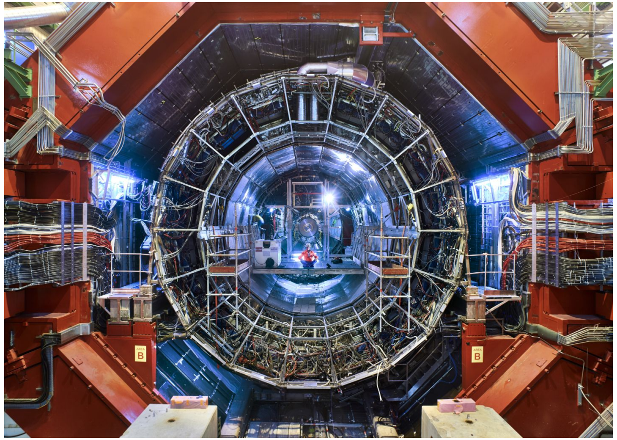


Image Credits: Luizoni and Marzani, 2015.



The pest of dimensionality

1. The standard n-point energy correlator function (ECF):

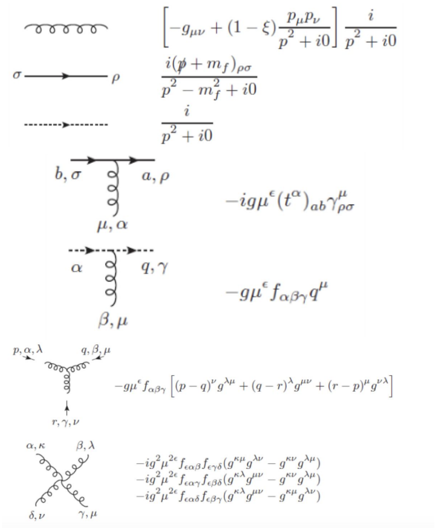
$$e_n^{(\beta)} = \sum_{i_1 < i_2 < \cdots < i_n} \left(\prod_{a=1}^{n} p_{T,i_a} \right) \prod_{1 \leq a < b \leq n} R_{i_a i_b}^{\beta}$$

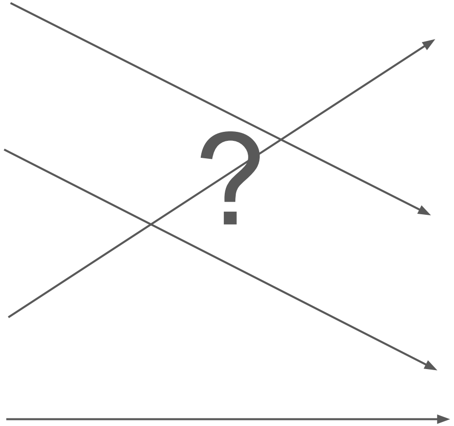
2. one dimensional only for the n=2 case. At n=3 need to compare three unique values for R -> 3-axes needed for visualization. At n=4, would need a 6 dimensional plot!
3. generated data also get sparser, which can complicate analysis: the curse of dimensionality

Methods

Jet Matching

1. A key complication in detector studies
2. A theorist's definition of jets involves perturbative QCD calculations including all particles
3. Detectors measure the tracks of charged particles, but neutral particles can only be seen by calorimeters -> jets are constructed using charged particles
4. Also have to account for detector effects: hadronization, pileup, noise, etc.





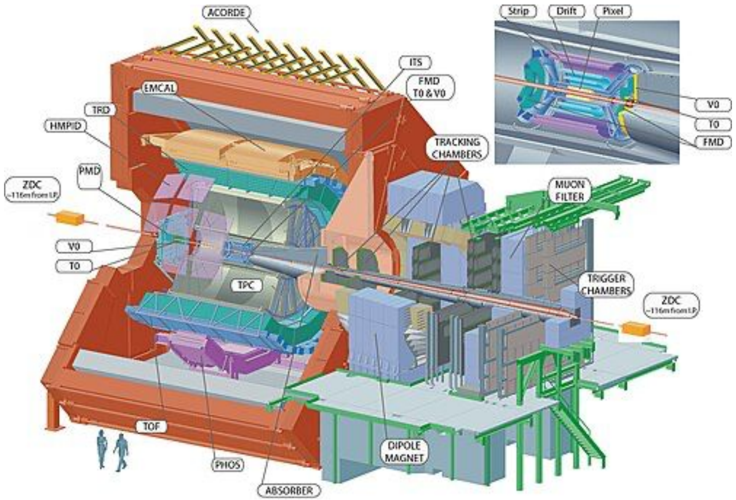


Image Credits: ALICE collaboration

Methods

Simulation pipeline

FastJet

PYTHIA event generation

Full jet

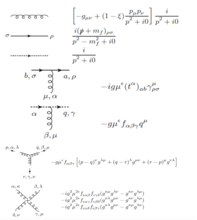
Charged Jet (from charged particles)

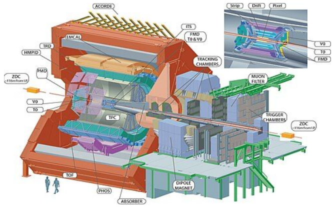
Charged Jet reconstructed

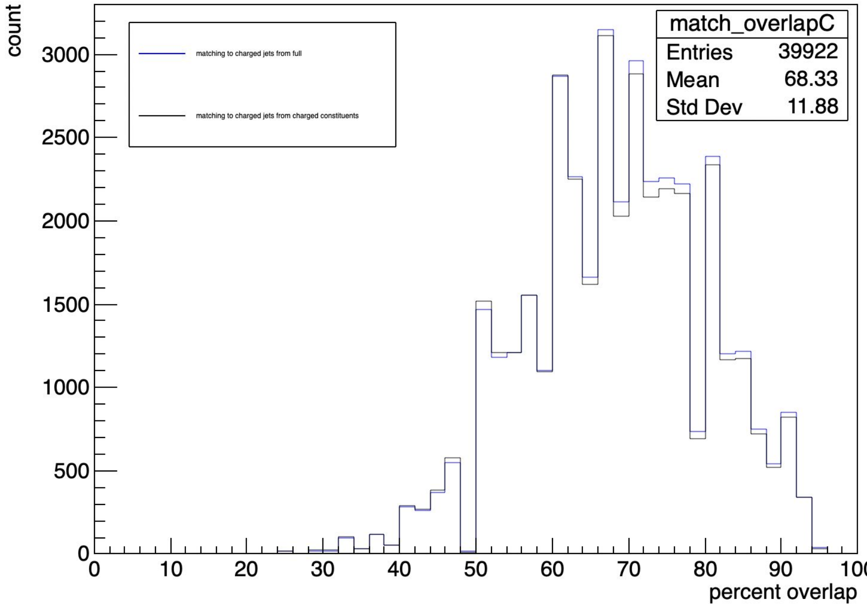
Analysis: matching, correlators, …

Methods

Jet Matching: an iterative process

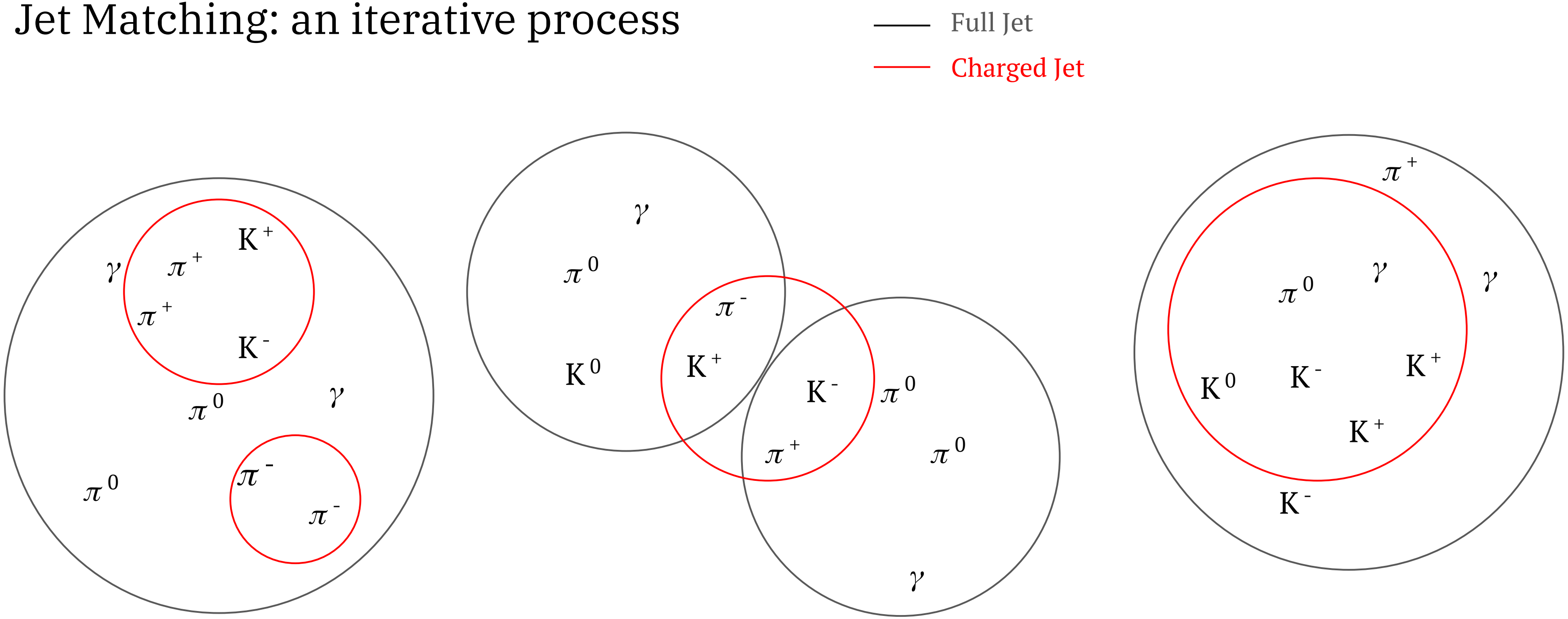






Methods

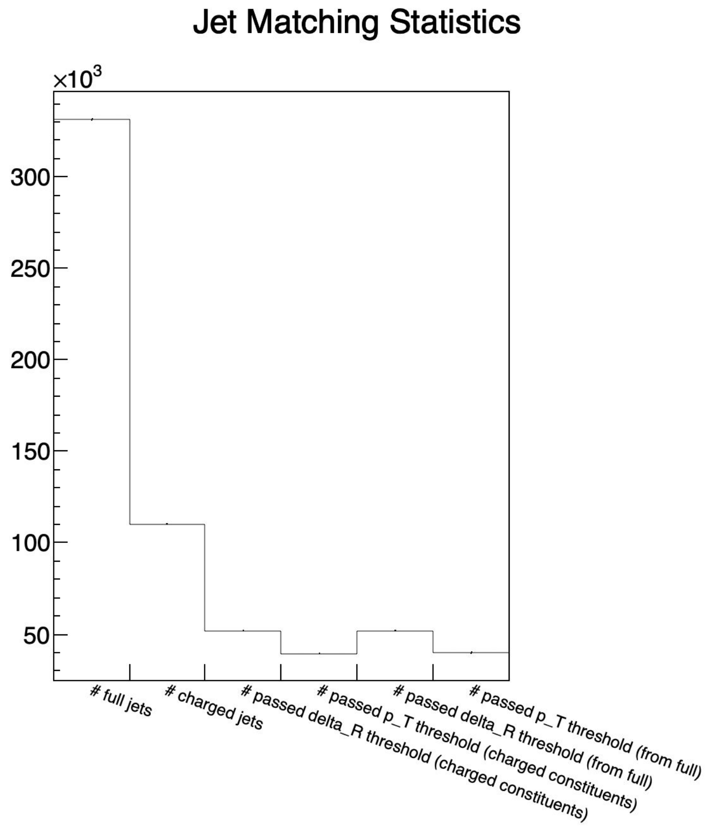
Jet Matching: an iterative process



1. Cut first based on difference in jet axis (R<0.1)
2. Further cut based on minimum constituent pT fraction of charged jet compared to full (pTcharged/pTFull > 0.8)

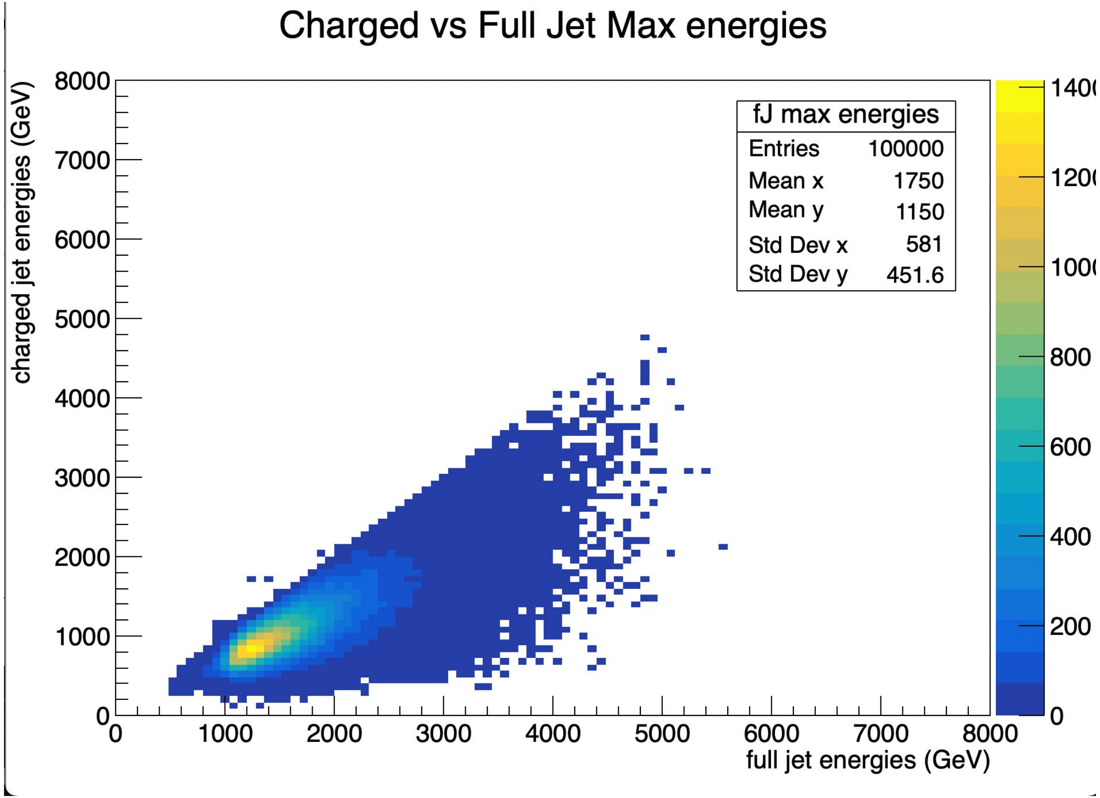
Methods

Jet Matching: an iterative process



Methods

Jet Matching: an iterative process



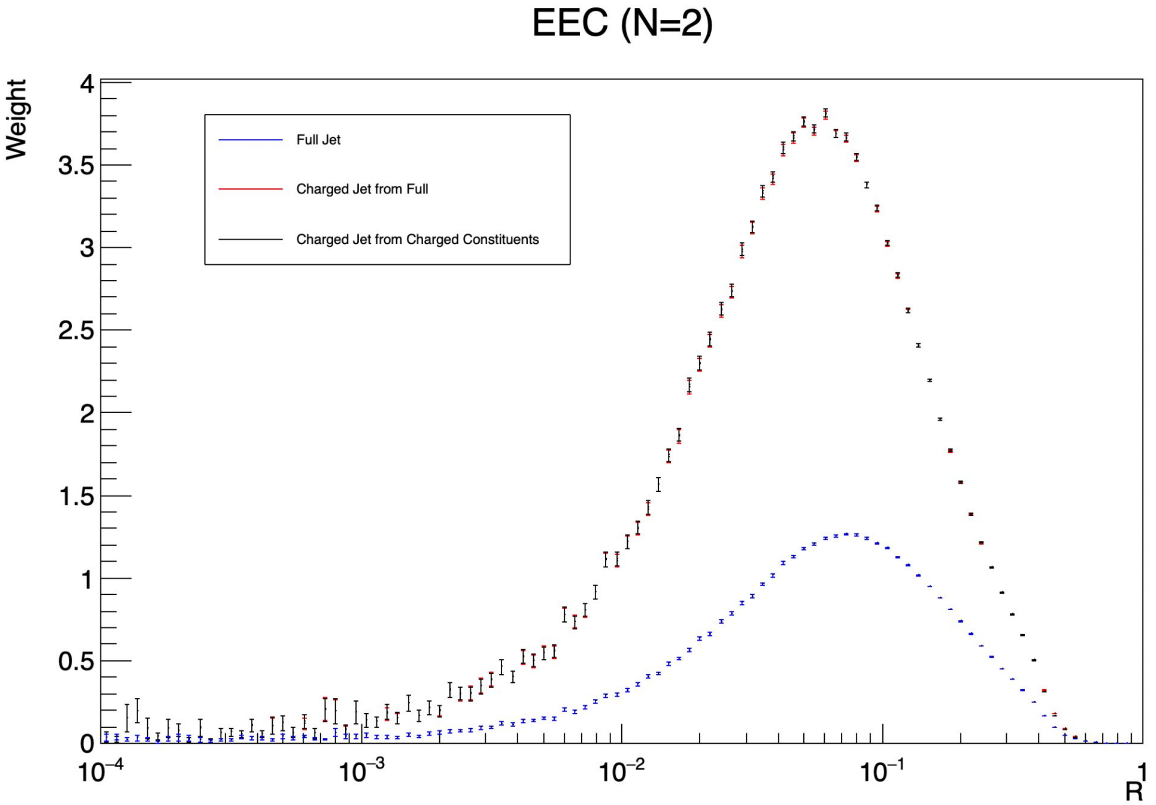
Results

Energy correlators from Pythia

$$\sqrt{s} = 13.0\,TeV$$

$$R = 0.4,\ \eta_{jet} < 0.5$$

$$p_{T,track} > 1\,GeV/c$$



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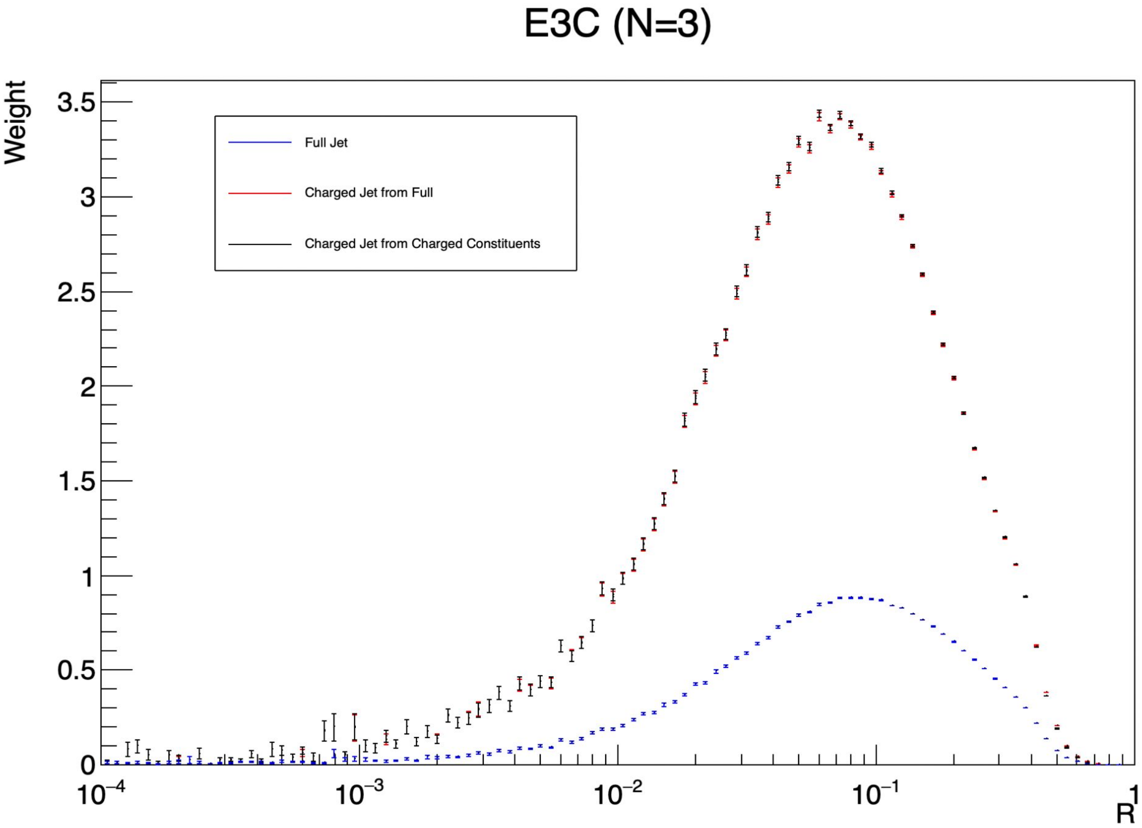

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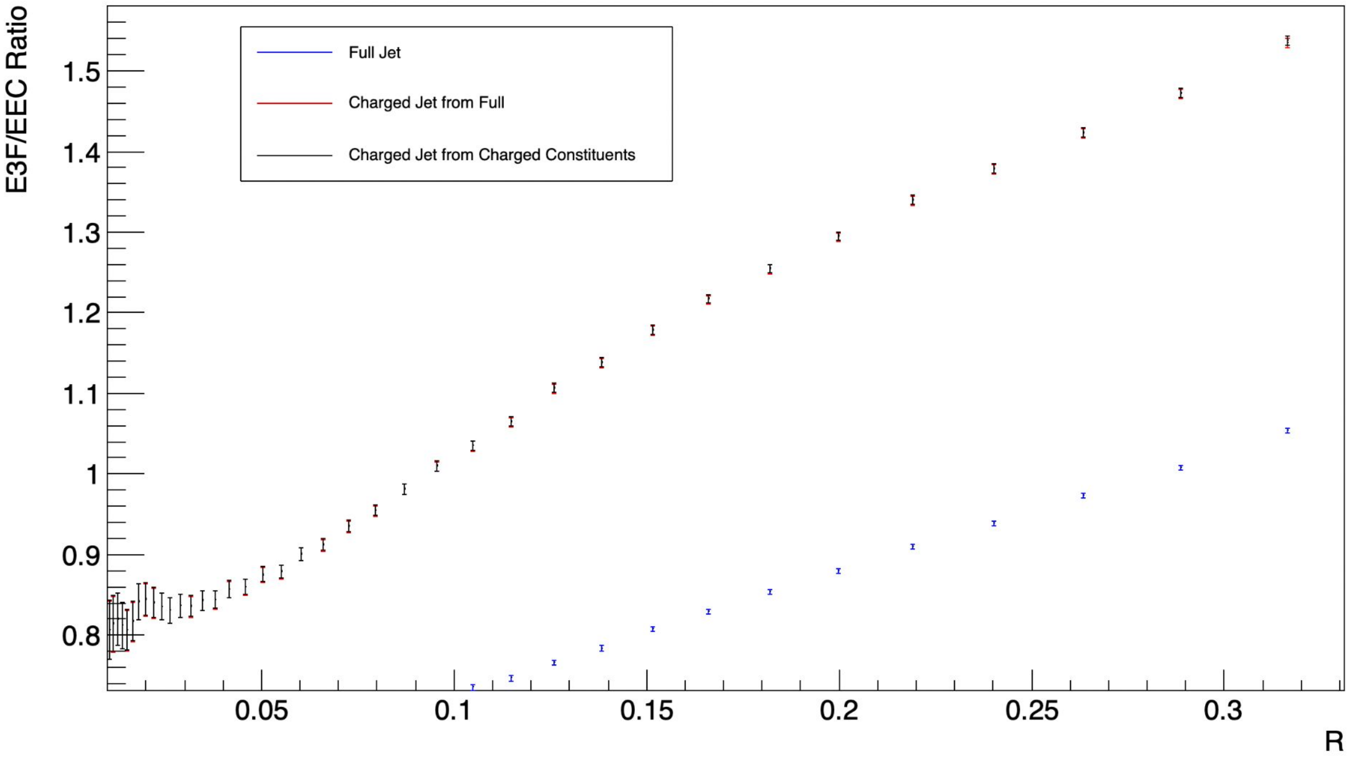

Discussion

Future directions

- n-point energy correlators (n>3)
- extracting α_s
- tuning jet matching
- beyond pp collisions