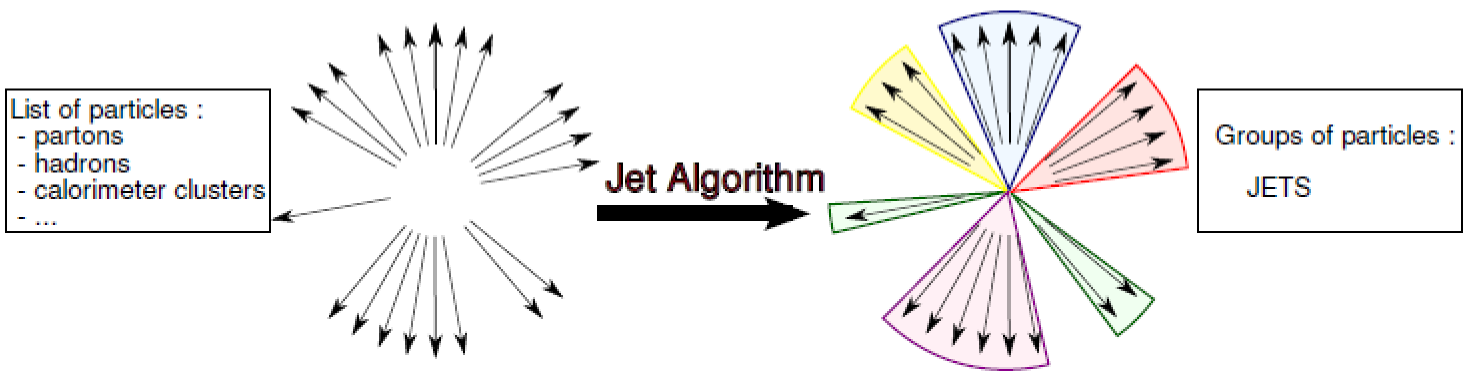
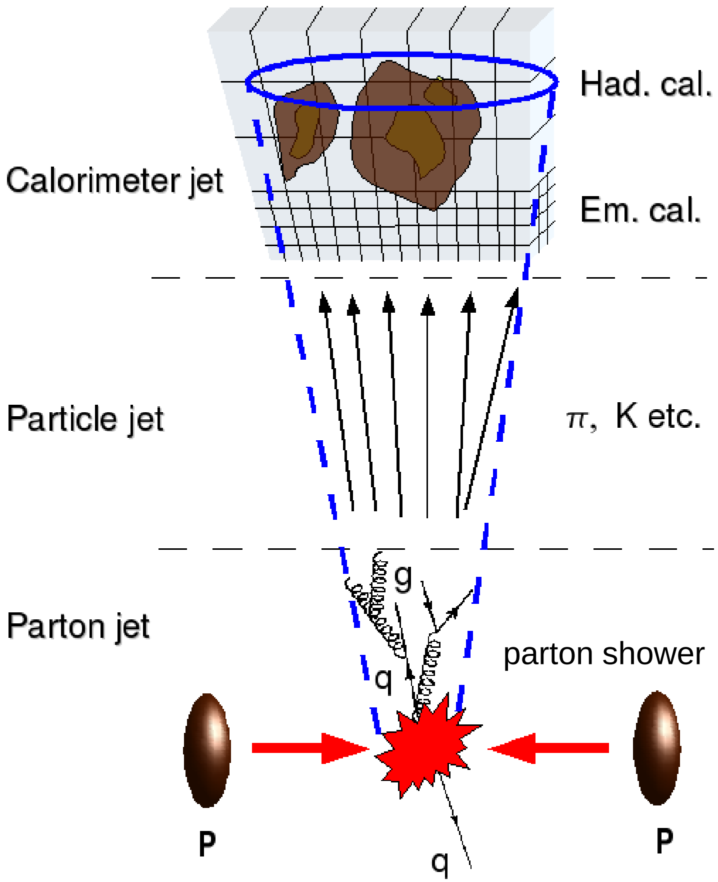
Jet algoritms

Pavel Weber



Evolution of the partonic system



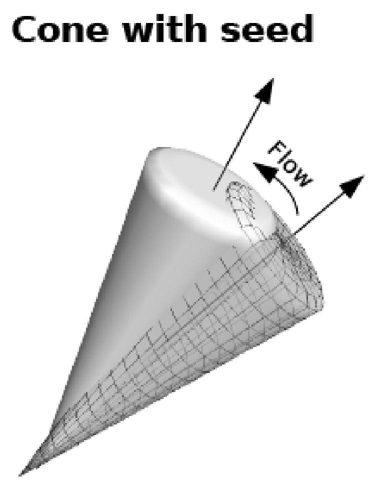
Definition of the jet
- Different, depends on the **algorithm**
- Observation level

Calorimeter jet
- Reconstructed jet after applying jet algorithms
- Uncertainties: Detector properties (non linear response, dead regions noise etc),pile-up

Particle jet
- Particle jets are reconstructed applying jet algorithm to stable particles
- Physics: UE, out-of-cone, pile-up

Parton jet
- Energy of initial parton

ATLAS Cone algorithm



Cone size: $R \leq \sqrt{\Delta\eta^2 + \Delta\phi^2}$

Reconstruction procedure:
– Find a cone based on seed
– Calculate the centroid (recombination)
– Redraw cone around the new centre
– Recalculate centroid
– Find stable cone
– Apply split-merge algorithm to separate jets, depending on energy fraction fin overlapping region

Recombination scheme:
E-Scheme or 4-vector recombination

$$p^J = (E^J, p^J) = \sum_{i \subset J} (E^i, p_x^i, p_y^i, p_z^i)$$

$$p_T^J = \sqrt{(p_x^J)^2 + (p_y^J)^2}$$

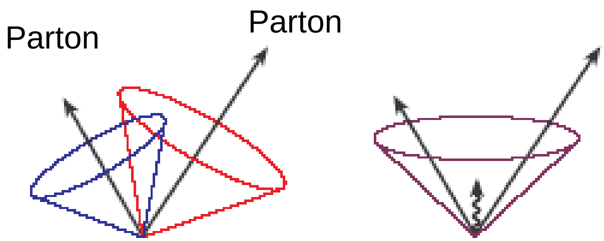
$$y^J = \frac{1}{2} \ln \frac{E^J + p_z^J}{E^J - p_z^J}, \varphi = \tan^{-1} \frac{p_y^J}{p_x^J}$$

F = 50-75%
- Energy in overlap > F ->merge
- else split

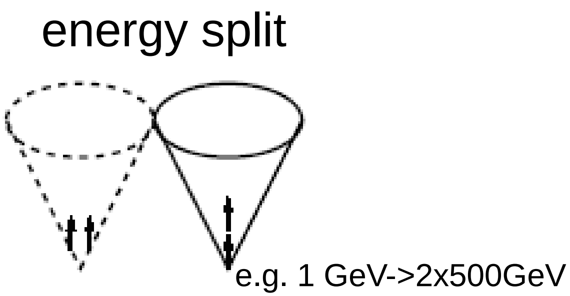
Theoretical and experimental requirements for jet algorithm

- Experimental:
  - Detector technology independence
  - "Easy" to calibrate
  - High reconstruction efficiency
  - Efficient use of computing resources
- Theoretical:
  - Infrared safety
  - Collinear safety
  - Easy to compare with theory

Canonical examples



infrared sensitivity

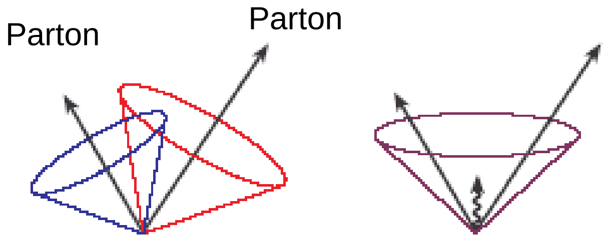


collinear sensitivity

- Seedless Algorithm resolve the infrared sensitivity, but rather slow
  - Seedless Infrared-Safe Cone – SISCone implemented in ATLAS

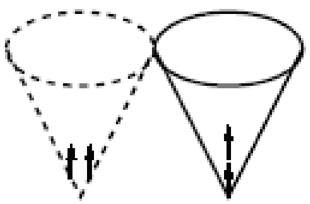
Cone Algorithm problems

Canonical examples



infrared sensitivity

energy split



collinear sensitivity

- Seedless Algorithm resolve the infrared sensitivity, but rather slow
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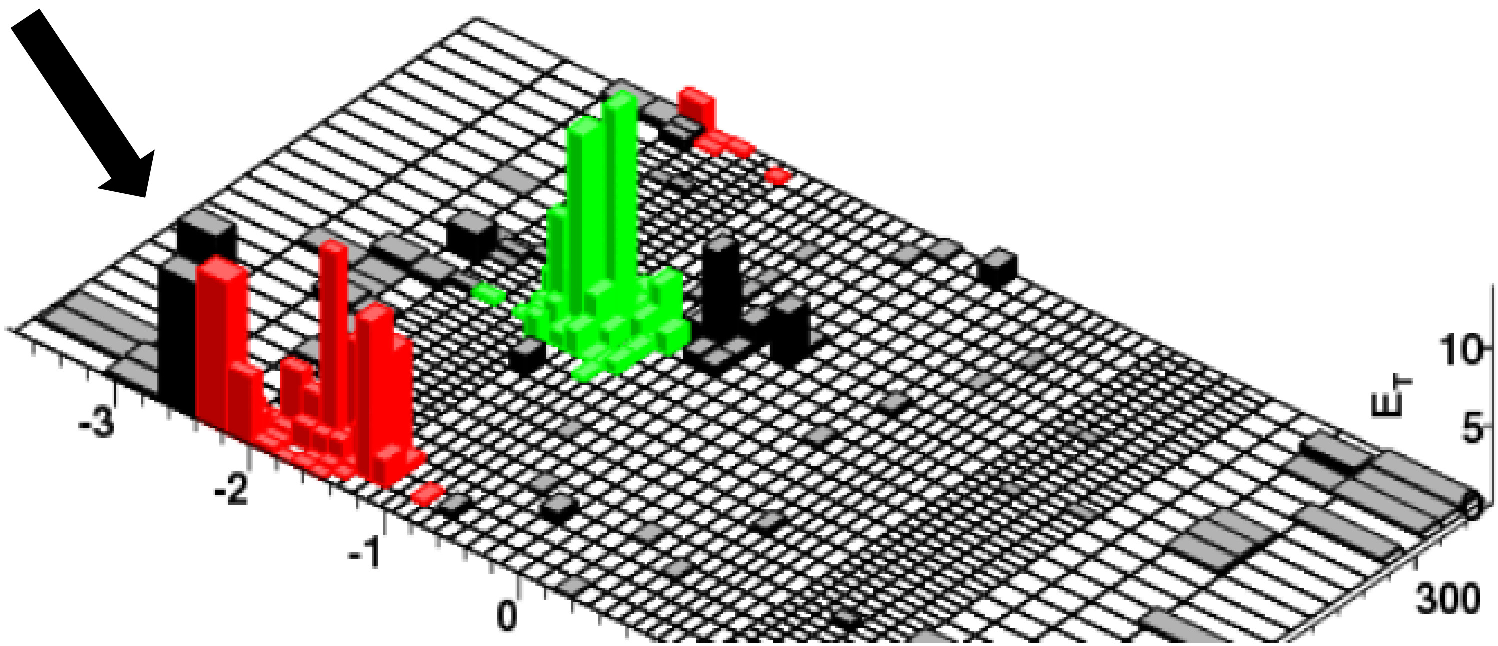
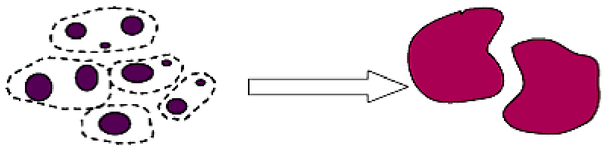
Dark Tower

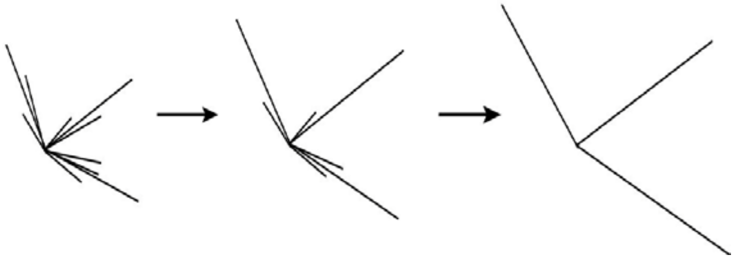
Cone Algorithm problems

- Dark towers found in ATLAS when using the Cone algorithm
- These are energetic clusters which are outside any jet in event



K_T Algorithm

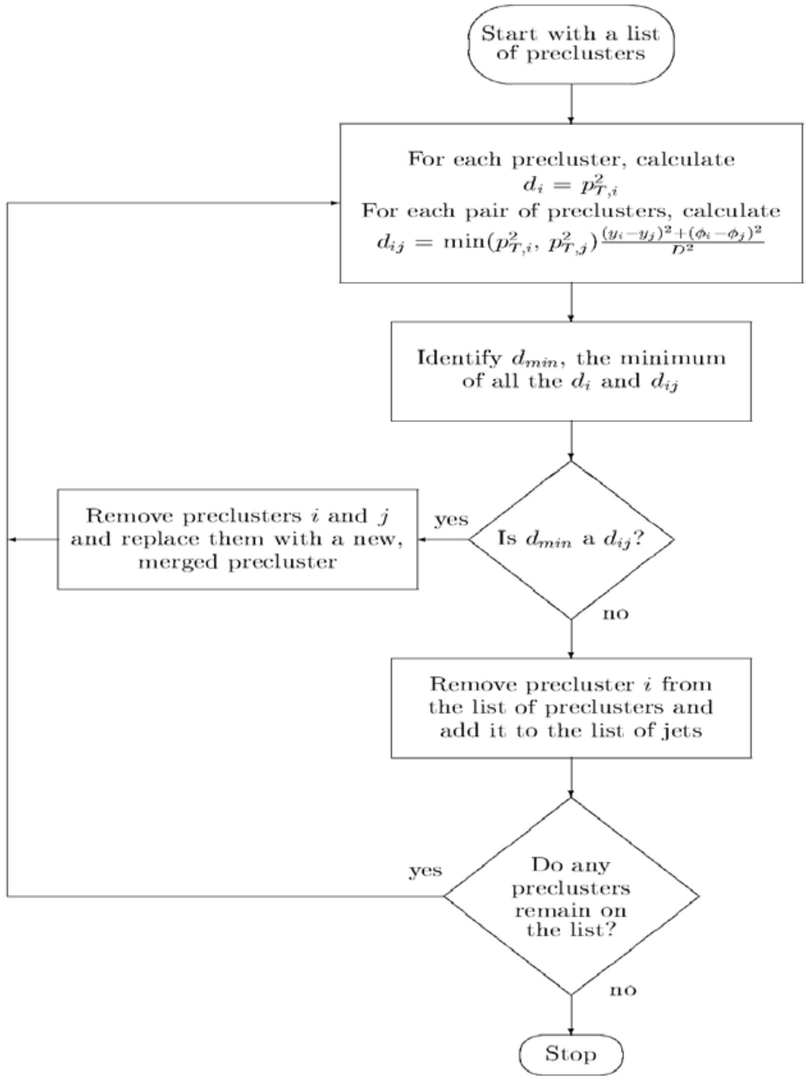


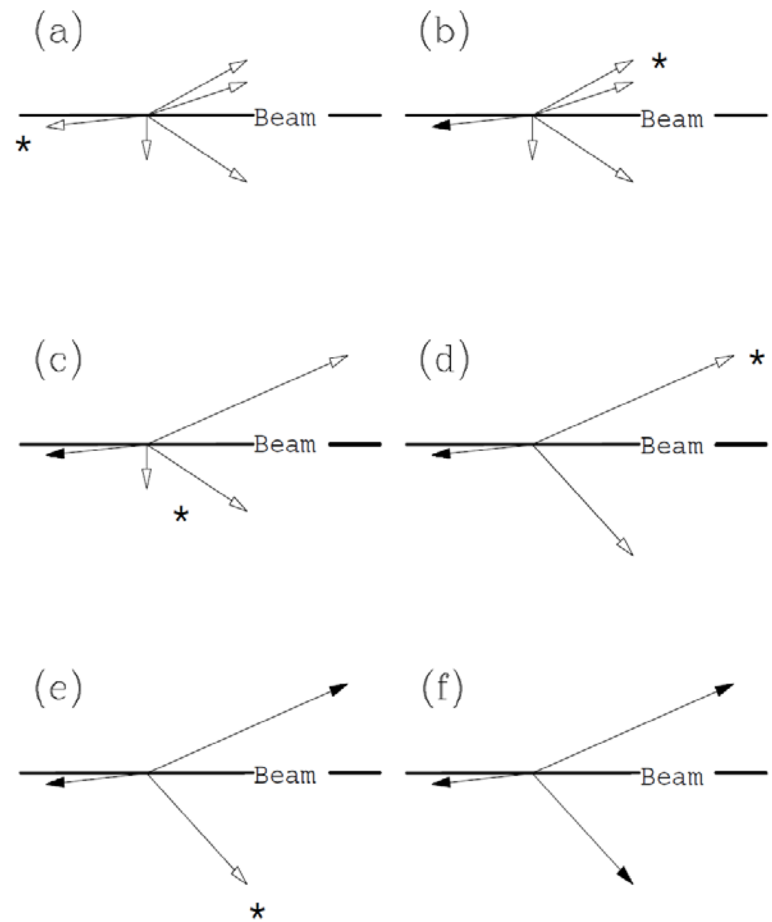


successive recombination of pairs of
clusters in an iterative procedure in order of increasing relative P_T

- No seed needed
- Infrared and collinear safe
- No overlapping problem, no spit/merge
- Complex boundaries
- Pile-up problems

K_T Algorithm





Empty arrows – preclusters

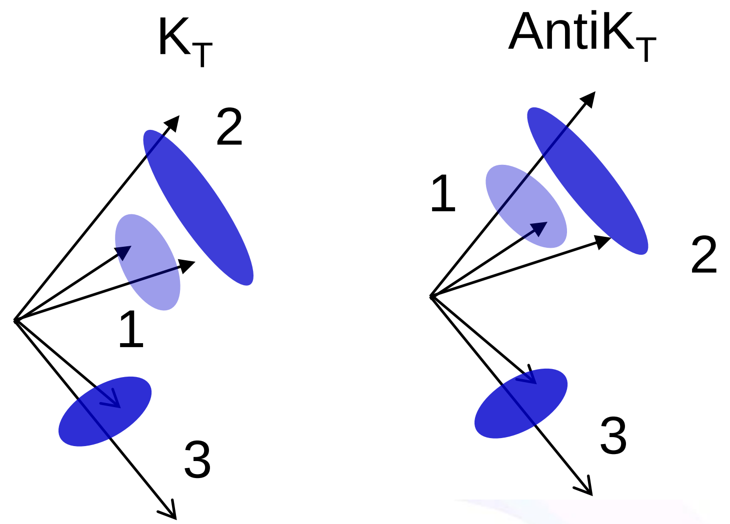
Filled arrows – final jets

K_T Algorithm

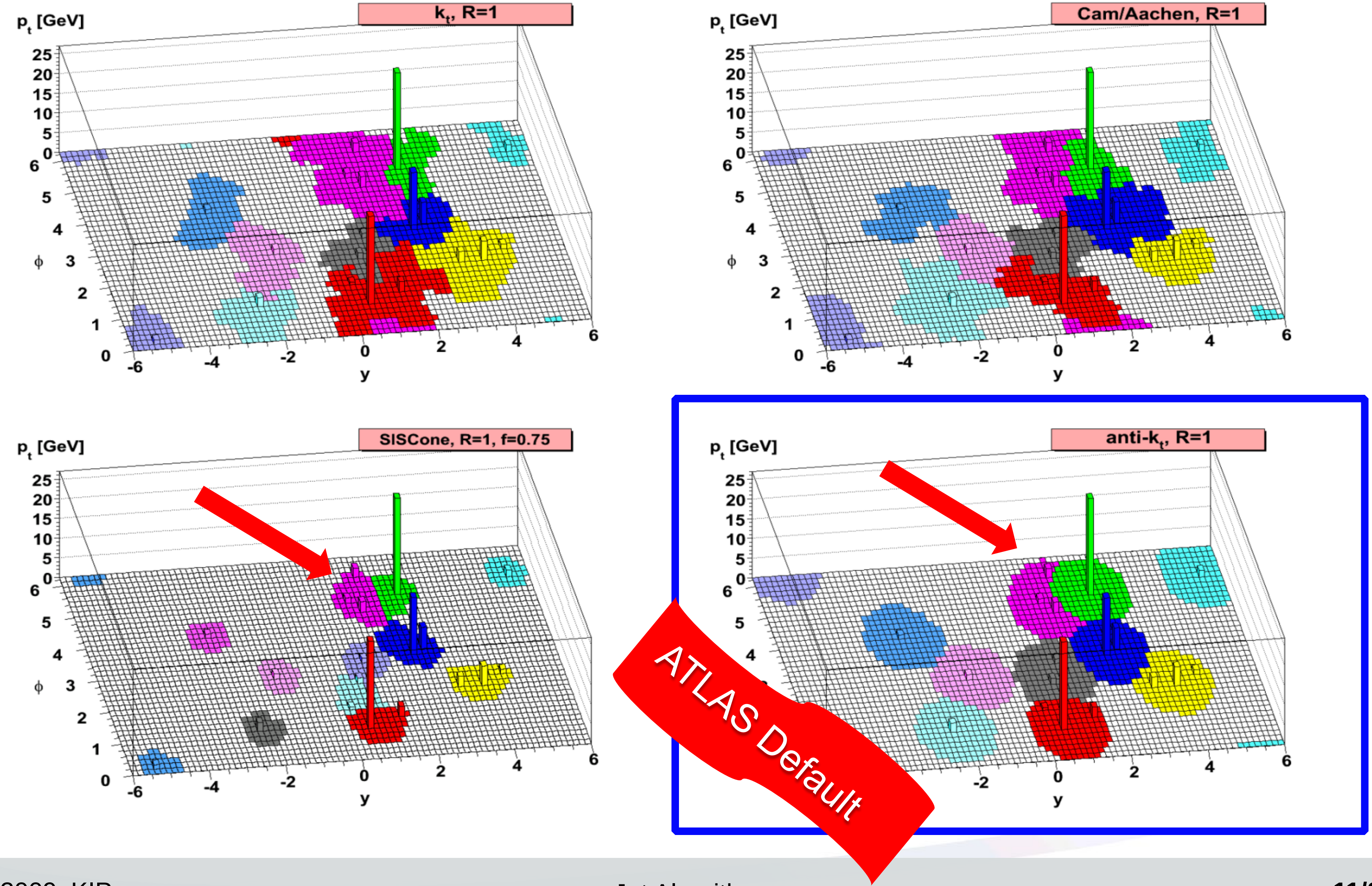
- Similar to the K_T, but:
  - Recombination starts from hardest objects
  - Soft particles tend to cluster with hard ones long before they cluster among themselves
  - Regular boundary shape
    - Shape of the jet is unaffected by soft radiation

$$d_{ij} = \min\left(\frac{1}{p_{Ti}}, \frac{1}{p_{Tj}}\right)\frac{\Delta_{ij}^2}{D^2}$$

$$d_i = \frac{1}{p_{Ti}}$$

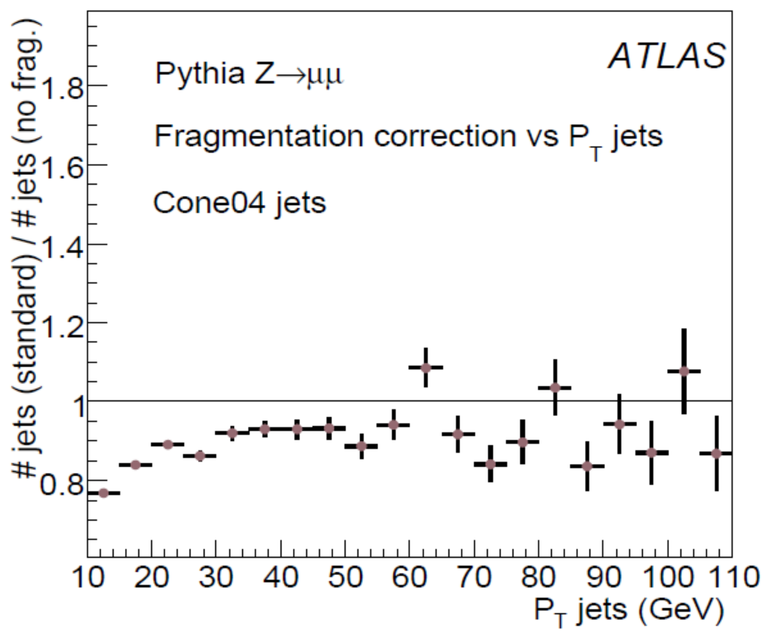


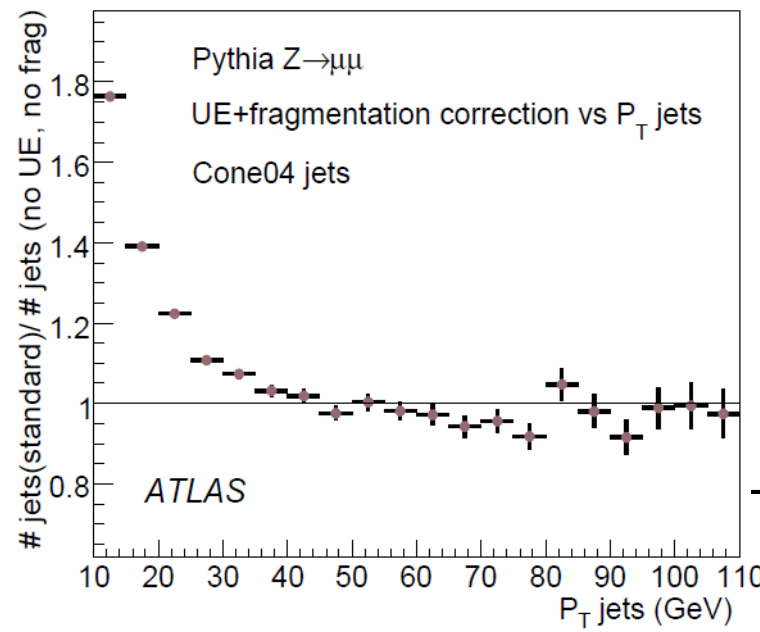
Algorithm Boundaries



Underlying Event, Fragmentation…

- Underlying Event is known not very well
- Predictions for LHC differ by 30% depending on generator
- Always competitive effects of fragmentation, UE, ISR/FSR

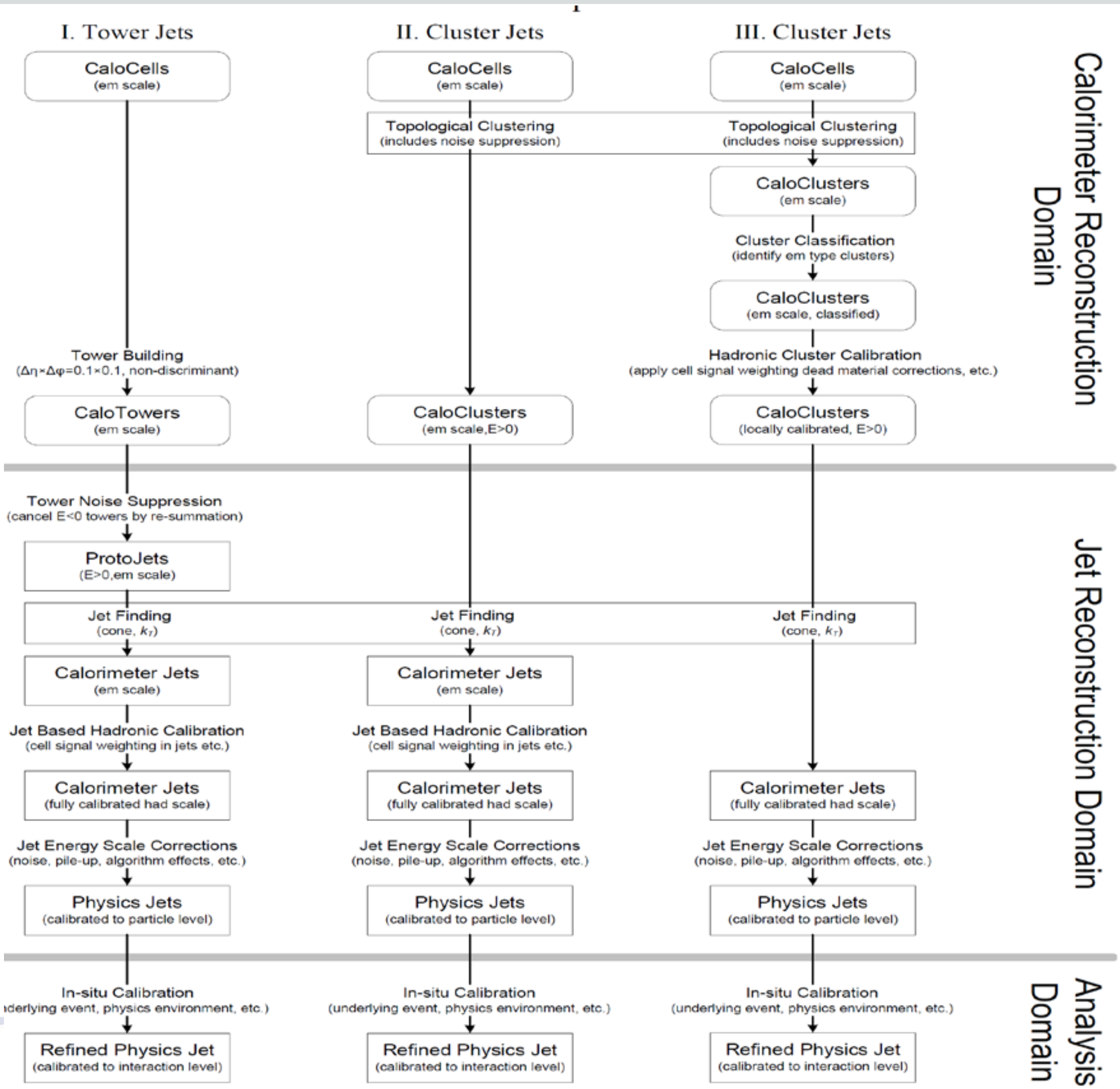




Tricolli

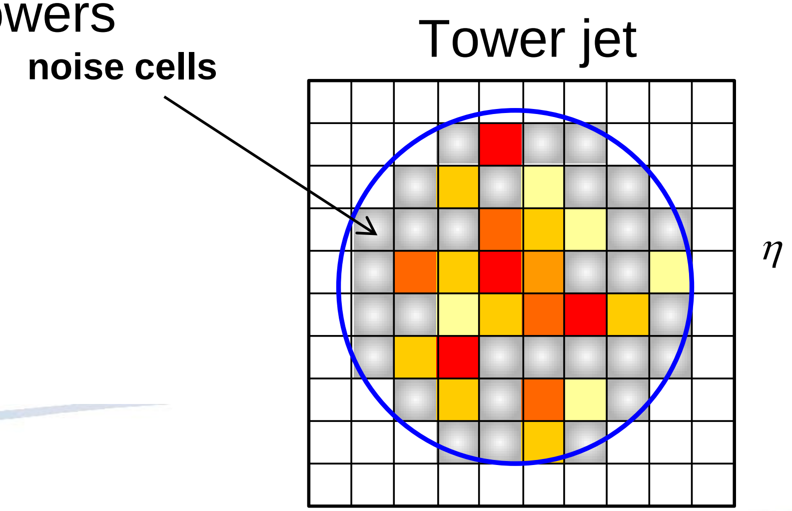
Fragmentation reduces the amount of energy in cone, while UE adds it

Calorimeter Jets Reconstruction



Tower jets

- Tower jets:
  - Input: Calorimeter signal towers – fixed geometry
  - Relatively easy to calibrate
  - Too many non-signal cells included in jet
  - Problematic to use with K_T algorithm
  - Noise tool – cancellation noise neighbor-by-neighbor basis
    - Negative energy towers are cancelled by close-by positive towers



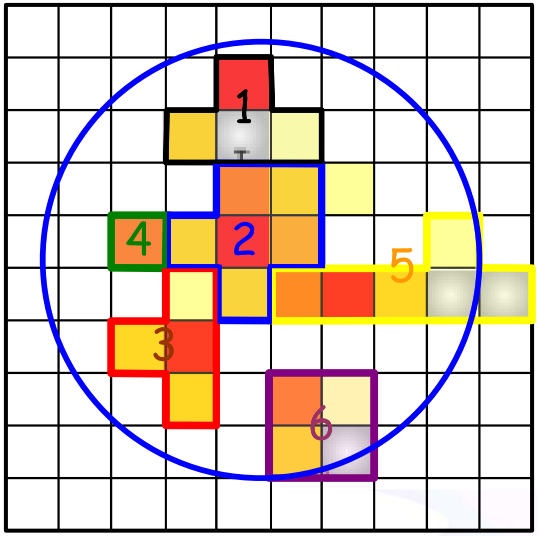
Cluster Jets

- Topocluster jets:
  - Input: “3-d energy blobs”
  - noise suppression
  - Natural approach, but complication in multistep calibration procedure: e/h, dead material, out-of-cluster corrections etc.

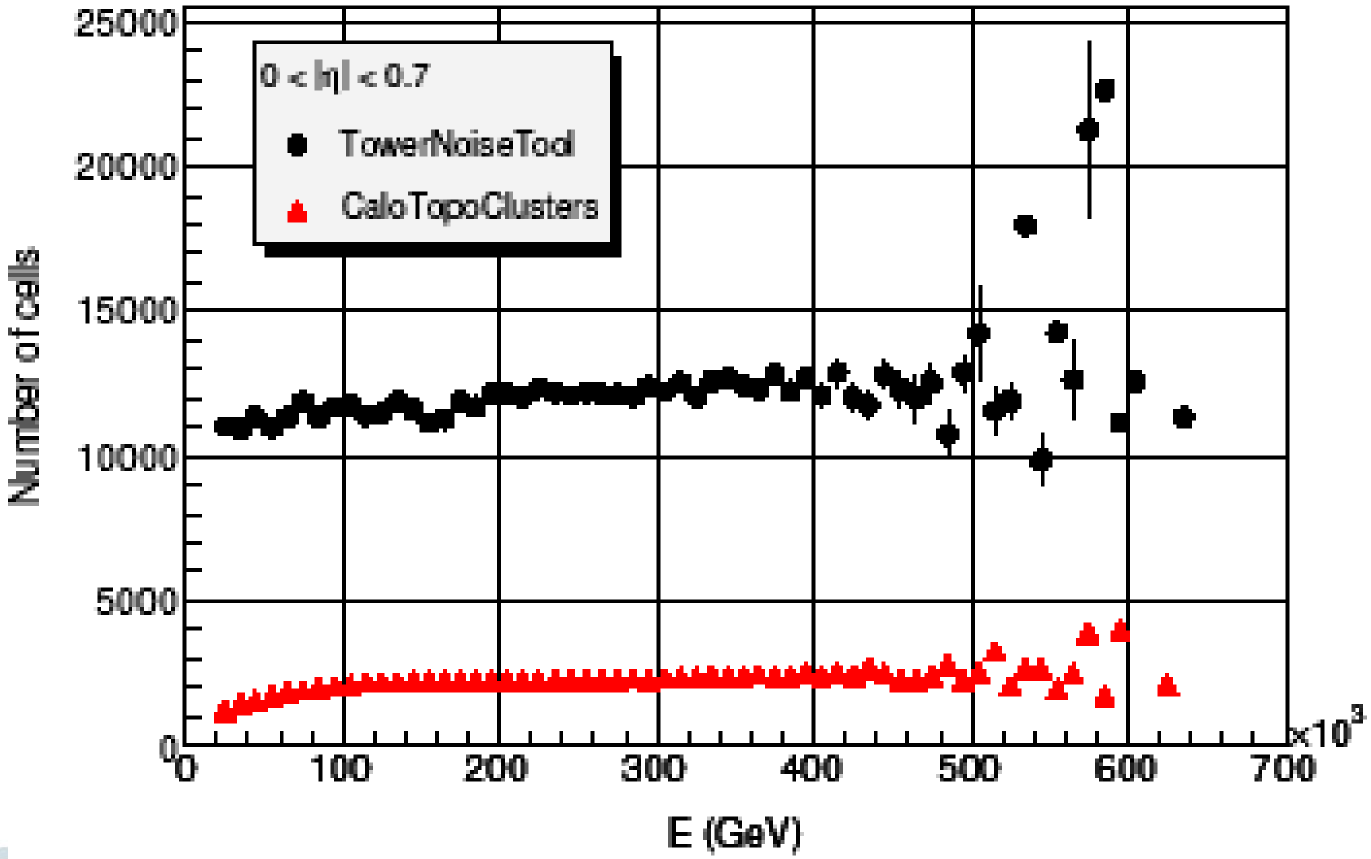
Primary seeds $$\left|\frac{E_{cell}}{\sigma_{cell}^{noise}}\right| > 4$$

Secondary seeds $$\left|\frac{E_{cell}}{\sigma_{cell}^{noise}}\right| > 2$$

Basic threshold $$\left|\frac{E_{cell}}{\sigma_{cell}^{noise}}\right| > 0$$



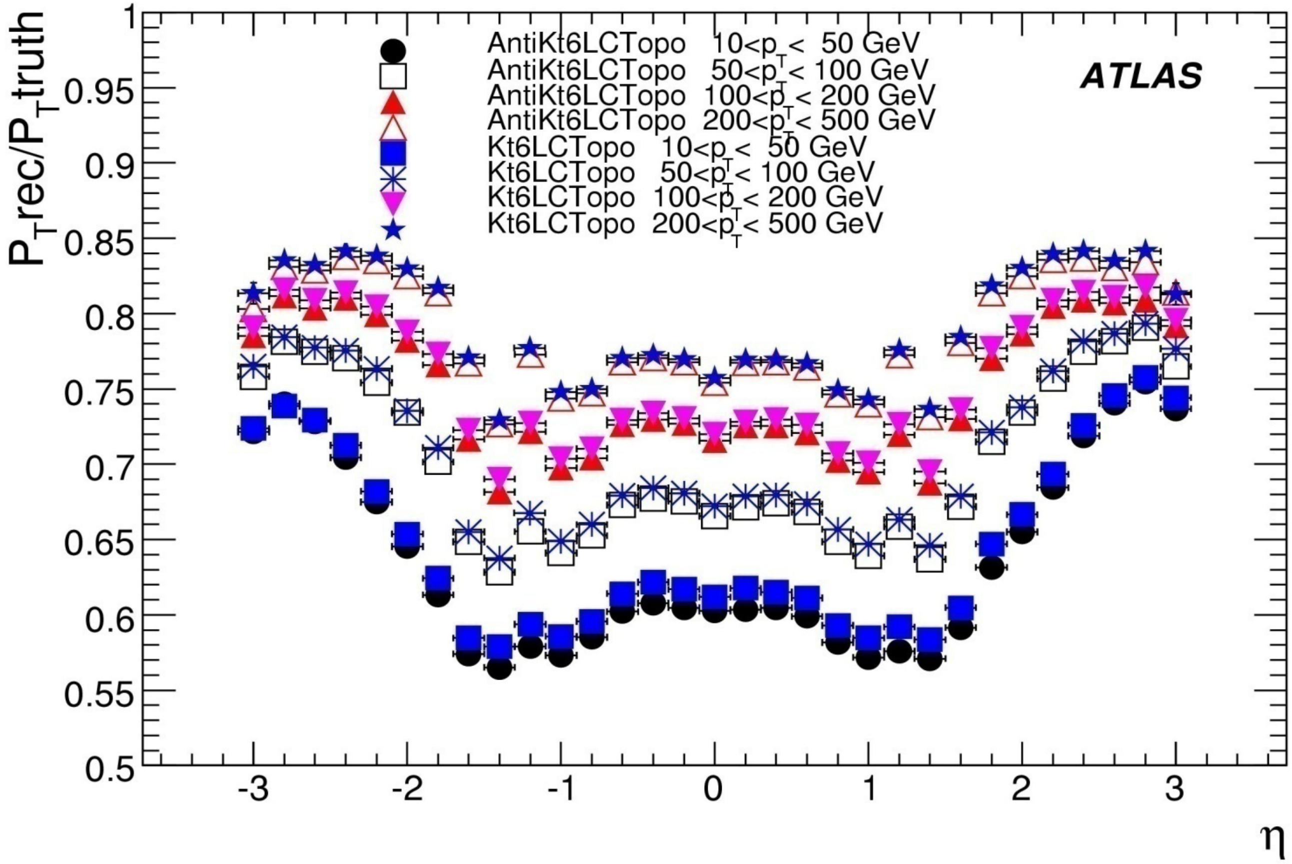
Cluster Jets



Jet Algorithm Peformance

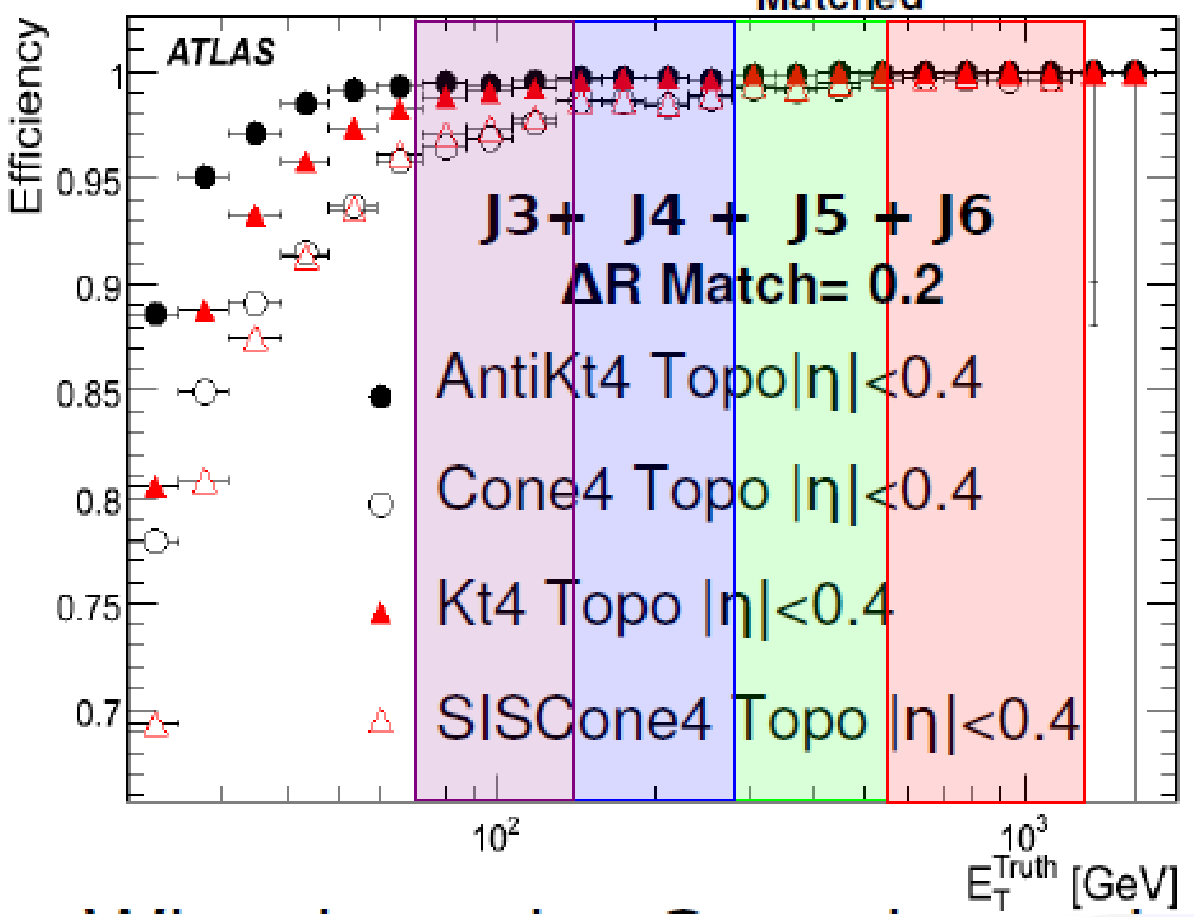
- In MC studies jet at particle level is a reference jet for main quantities:
  - Signal linearity
  - Signal uniformity
  - Energy resolution
  - Reconsturaction efficiency
  - Reconsturction purity

Signal Uniformity at em scale



Reconstruction Efficiency

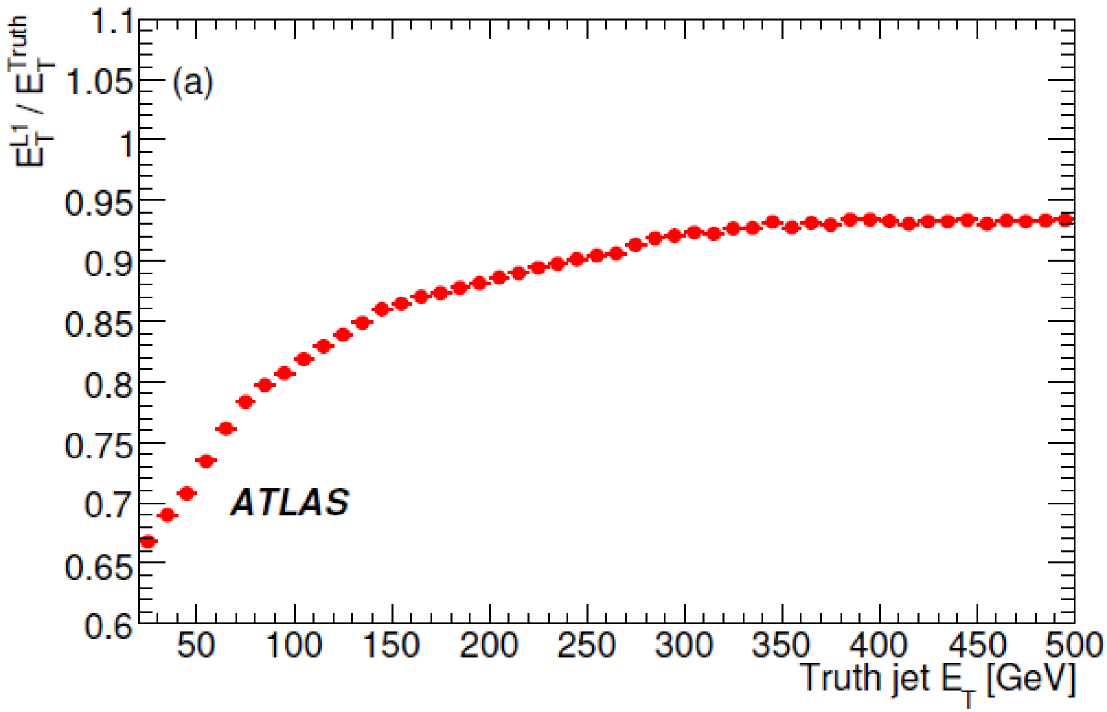
$$\text{Efficiency} = N^{Truth}_{Matched} / N^{Truth}$$

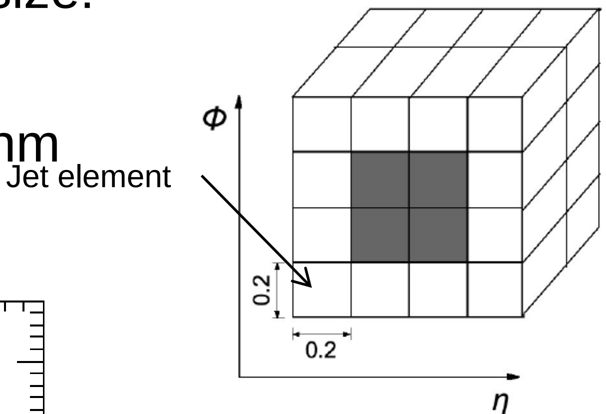


Francavilia

L1 Trigger Jet Performance (linearity)

- Sliding window jet algorithm with different size: 2x2,3x3,4x4
- Jet elelements as a input for L1 Jet Algorithm



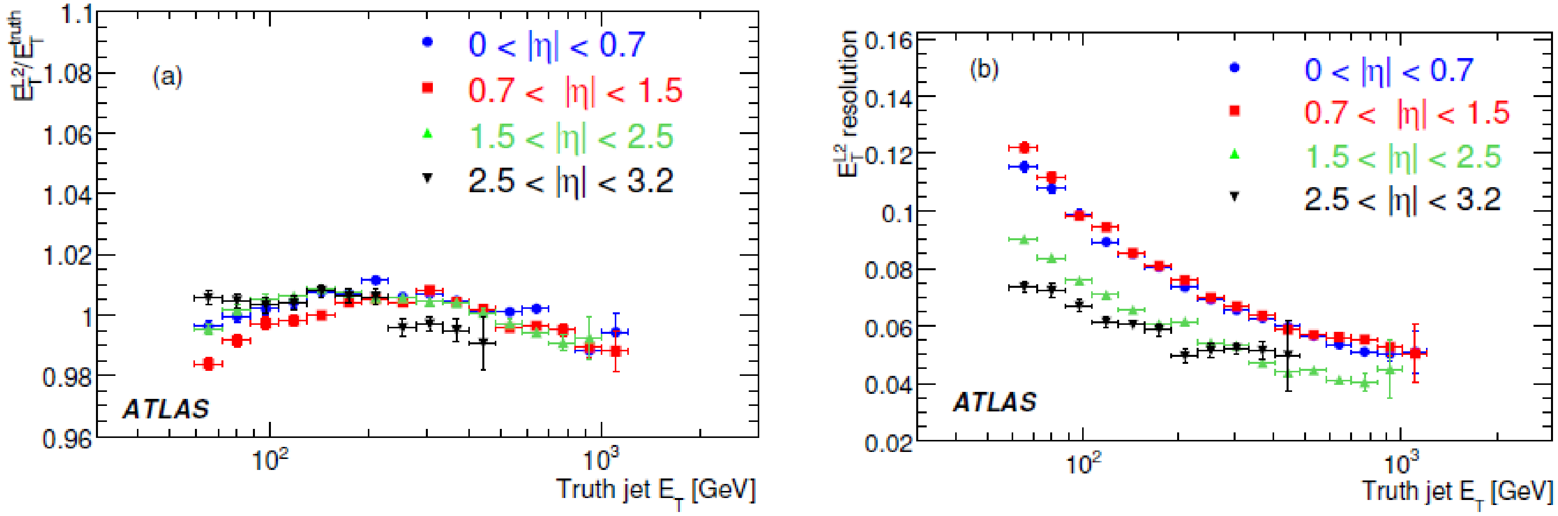


L1 jet algorithm

The L1 jet transverse energy scale as function of truth jet transverse energy

L2 Jet Performance

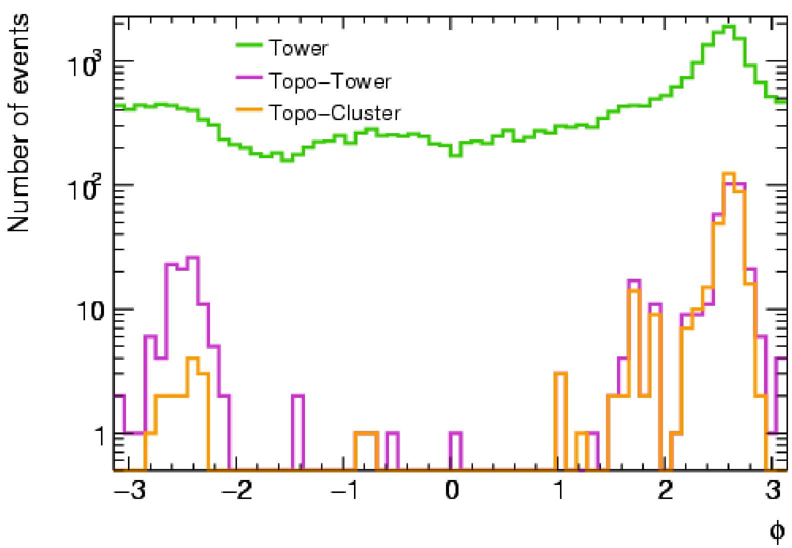
- L2 Jet algorithm is simple iterative cone based on L1 RoI
- Maximum 3 iterations
- Cone R=0.4, window size in etaxphi 1.4x1.4
- Simple hadronic calibration based on layers



➢Jet energy scale and resolution for the L2 jets as a function of the truth jet E_T and pseudorapidity

Algorithm behaviour with random trigger data

- In data taken with random trigger: no jets are expected …
- Noise can create fake jets in random trigger events
  - Coherent noise in PS $2<\varphi<\pi$
  - Noise in Lar: uniform in φ



		Fraction of evts with at least 1 jet (%) (et>7GeV)		
R	Algo	Towers	Topo towers	Topo clusters
0.4	Cone	0.01	0.01	0.04
	SISCone	0.19	0.04	0.05
	Kt	0.08	0.03	0.04
	AntiKt	0.15	0.04	0.04
0.7	Cone	0.03	0.01	0.06
	SISCone	4.11	0.07	0.06
	Kt	3.02	0.07	0.06
	AntiKt	4.14	0.07	0.05

Nicola Macovec

Acknowledgments

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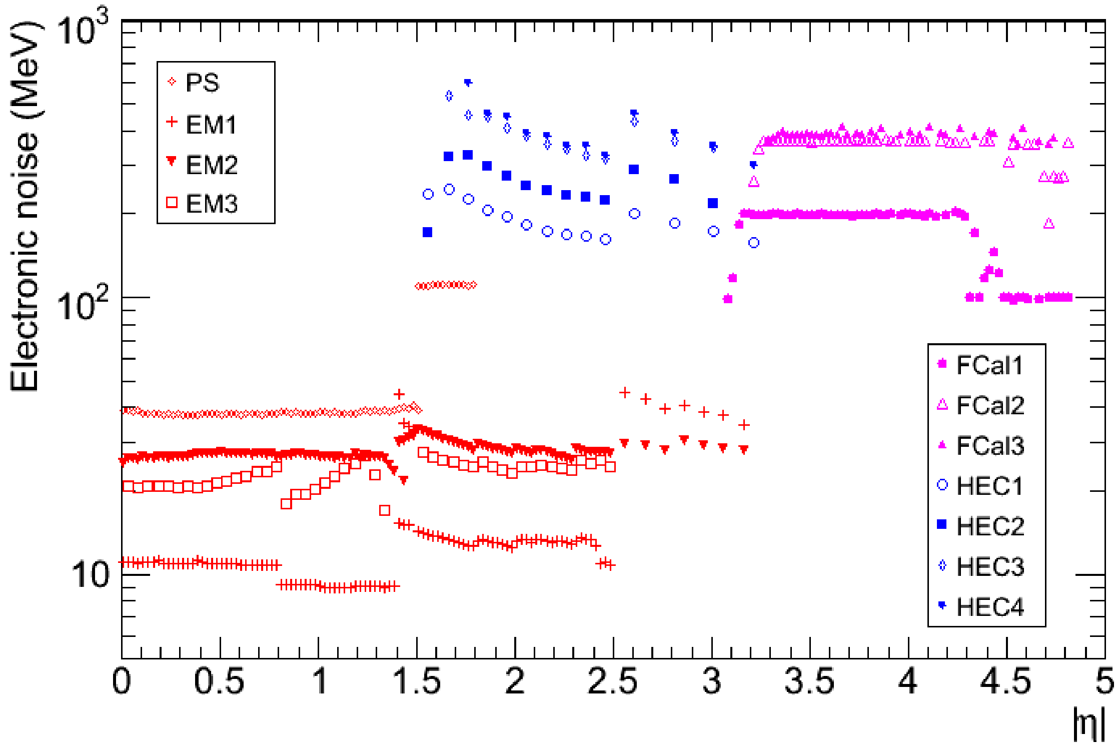
Backup



Electronic noise (MeV)
10^3
10^2
10
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
|η|
PS
EM1
EM2
EM3
FCal1
FCal2
FCal3
HEC1
HEC2
HEC3
HEC4