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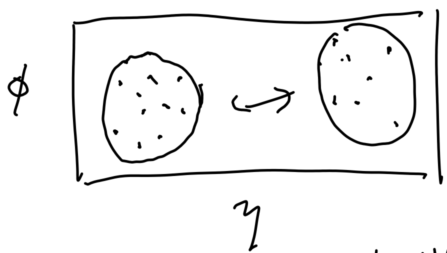
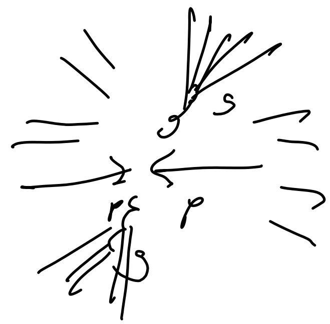
Lecture 12

Jet Clustering Algorithms





- need is a algorithm that clusters particles into "jets"
- # jets is not fixed

→ jets are not fundamental

a good jet cl. algo. should produce jets that are approx or typically aligned w/ underlying partons but can never be perfect

useful & empirically valid way of organizing events

form of dim. reduction

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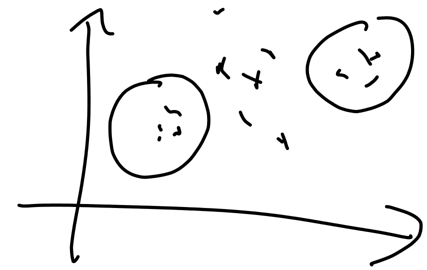
(Tevatron)



- Early jet clustering algos based on simple cones
    - problems w/ overlap
    - not robust against soft emission
    - slow or complicated
    - one modern cone algo: "SISCONE"

- Modern jet clustering are sequential recombination type
    - try to cluster ptcls mimicking QCD parton shower
    - allow for fast unclustering/reclustering → jet substructure
    - robust against soft crap

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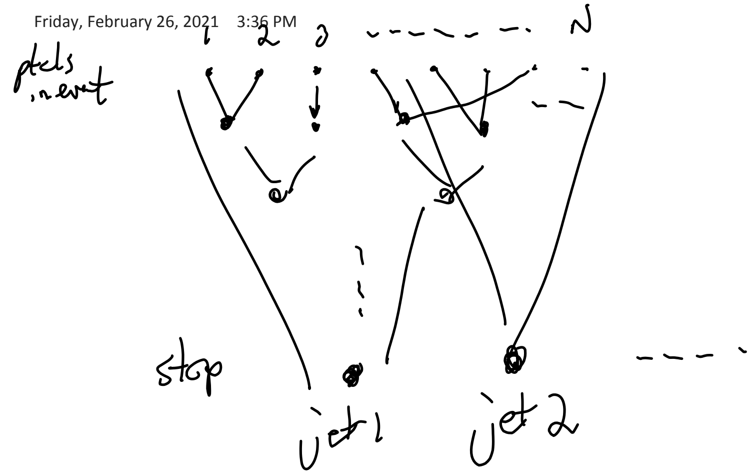

idea is to iterate on list of ptcls

some distance measure d_{ij} btw ptcl i & j

- if d_{ij} < threshold, combine $i+j \to k$ "pseudojet"
- repeat until d_{ij} > threshold $\forall j$
  → call i a jet.

depends on a size parameter, jet radius R.

"generalized k_T algo."

$$d_{ij} = \min(p_{Ti}^{2p}, p_{Tj}^{2p})\, \Delta R_{ij}^2$$

p, R are params of the algo.

$$d_{iB} = p_{Ti}^{2p} R^2$$ "beam distance"

1. if $\min\{d_{ij}, d_{iB}\}$ ($\forall i,j$) is a d_{ij}, combine $i,j \to k = i+j$.
2. if " " is a d_{iB}, call i a jet & remove from list.
3. Repeat until no pseudojets are left. → "inclusive mode"

$d_{iB} < d_{ij}$ $\forall j$ ($\Delta R_{ij} > R$)

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$p = 1$ "k_T algorithm" $d_{ij} = \min(p_{T_i}^2, p_{T_j}^2)\,\Delta R_{ij}^2$

- softest ptcls clustered first!

most physical
jets are most sensitive to soft radiation

- soft ptcls could be widely separated yet have small d_{ij}

$\rightarrow$ non circular jets
and not very compact

not practical
re: calibration

$p = 0$ "Cambridge-Aachen alg." $d_{ij} = \Delta R_{ij}^2$

pure geometrical
clustering based on angles

$p = -1$ "anti-k_T alg." $d_{ij} = \min\left(\frac{1}{p_{T_i}^2}, \frac{1}{p_{T_j}^2}\right)\Delta R_{ij}^2$

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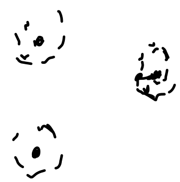
anti k_T : hardest ptcls "seed" jets



↳ jet grows by absorbing neighbors

↓

tends to produce circular jets robust against soft radiation

↓

most commonly used jet algo. @ LHC.

$R = 0.4$ or 0.5 most commonly used for QCD jets

(larger $R \sim 1$ used for "fat jets" eg. boosted top tagging)

$$R \sim \frac{2m}{p_T}$$

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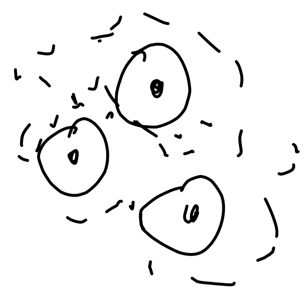
have to specify # jets

- exclusive jet algo. (N)

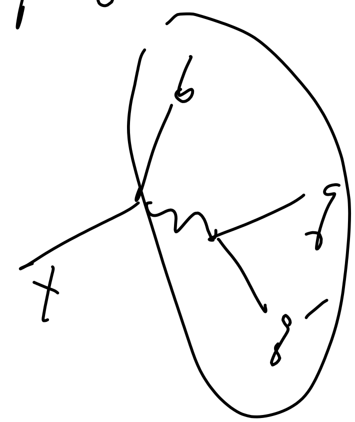
1. if min(distances) is d_{ij}, $i+j \to k$ as before
2. if min(---) is d_{iB} remove i completely. (not a jet)

stop when N pseudojets are left ⟶ these are the exclusive jets.

only makes sense for $p \geq 0$ since then cleans out softest ptcls



application to jet substructure ⟶ recluster a jet into subjets



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N-subjettiness

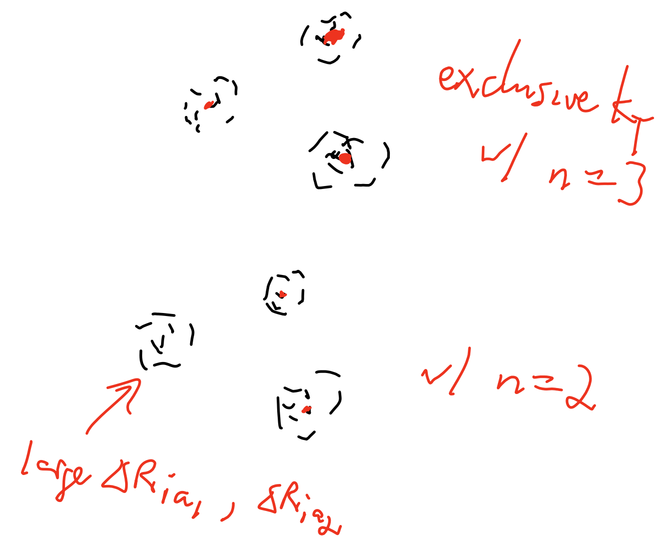
Measure of how many prongs in a jet

$$\tau_N = \sum_{i \in \text{jet}} p_{T,i} \min(\Delta R_{i a_1}, \ldots \Delta R_{i a_N})$$

"N-jettinesss"

$a_1, \ldots a_N$: "subjet axes"
e.g. from exclusive k_T.

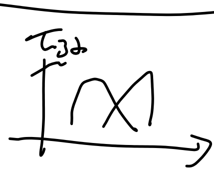
if a jet has N prongs
expect $\tau_n \begin{cases} \text{large for } n < N \\ \text{small for } n \geq N \end{cases}$



N-subjettiness

$$\tau_{N,N-1} = \frac{\tau_N}{\tau_{N-1}}$$

expect small if exactly N prongs
$\mathcal{O}(1)$ otherwise.



QCD: