Midpoint jet discussion

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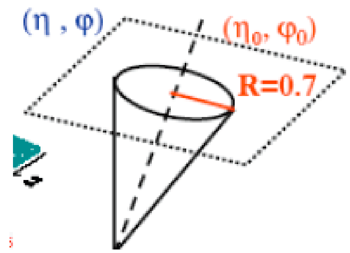
Midpoint cone algorithm

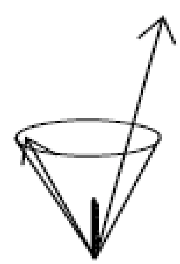
- Generate p_T ordered list of towers (or particles/partons)
- Find proto-jets around seed towers (typically 1 GeV) with p_T>threshold (typically 100 MeV)
  - include tower k in cone if



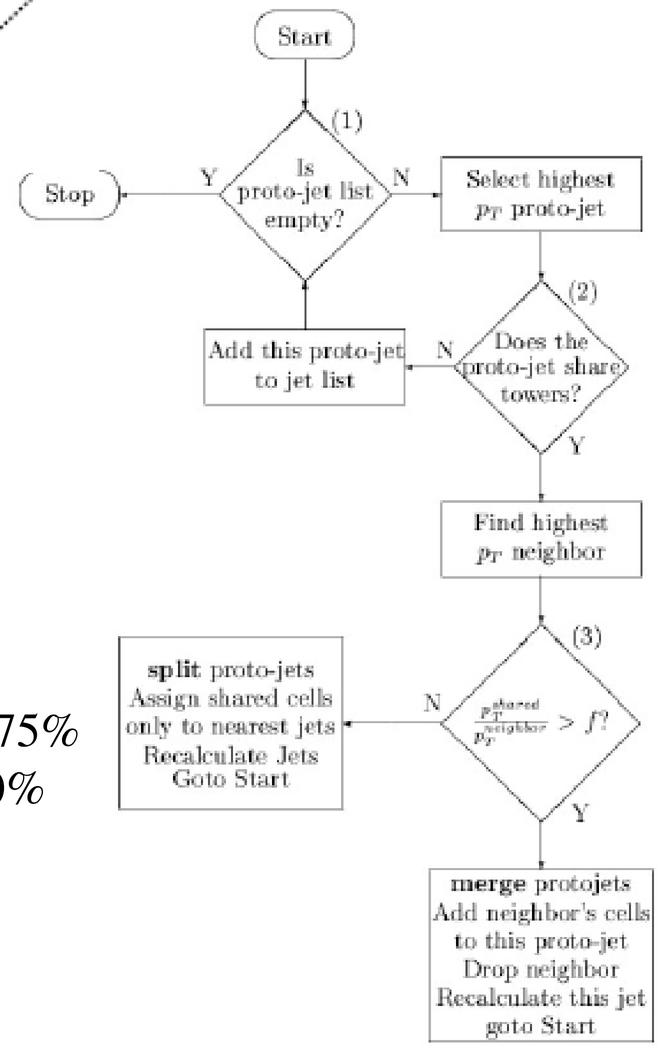
$$k \subset C \text{ iff } \sqrt{(y_k - y_C)^2 + (\phi_k - \phi_C)^2} \leq R_{cone},$$

$$p_C = (E_C, \vec{p}_C) = \sum_{k \subset C} (E_k, \vec{p_k}), \quad \bar{y}_C \equiv \frac{1}{2} \ln \frac{E_C + p_{z,C}}{E_C - p_{z,C}}, \quad \bar{\phi}_C \equiv \tan^{-1} \frac{p_{y,C}}{p_{x,C}}$$

  - iterate if $(y_C,\phi_C) = (y_C,\phi_C)$
  - NB: use of seeds creates IR-sensitivity
- **Generate midpoint list from proto-jets**
  - using midpoints as seed positions reduces IR-sensitivity
- Find proto-jets around midpoints
- Go to splitting/merging stage
  - real jets have spatial extent and can overlap; have to decide whether to merge the jets or to split them
- Calculate kinematics (p_T,y,ϕ) from final stable cones

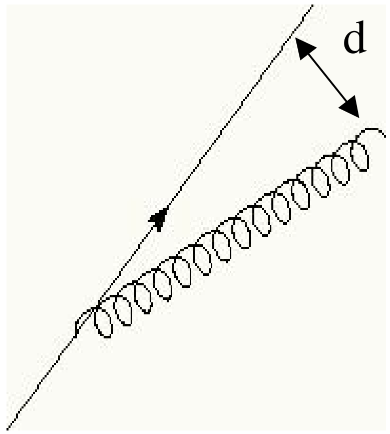


CDF uses f=75%
D0 uses f=50%



Jet algorithms at NLO

- Remember at LO, 1 parton = 1 jet
- At NLO, there can be two partons in a jet and life becomes more interesting
- Let's set the p_T of the second parton = z that of the first parton and let them be separated by a distance d (=ΔR)
- Then in regions I and II (on the left), the two partons will be within R_{cone} of the jet centroid and so will be contained in the same jet
  - ~10% of the jet cross section is in Region II; this will decrease as the jet p_T increases (and α_s decreases)
  - at NLO the k_T algorithm corresponds to Region I (for D=R); thus at parton level, the cone algorithm is always larger than the k_T algorithm



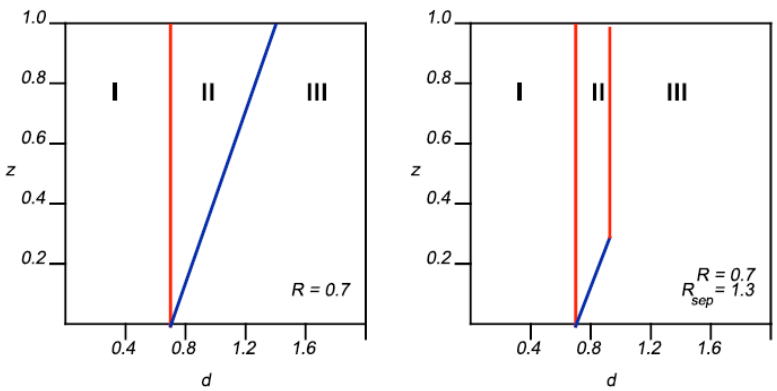


Figure 22. The parameter space (d,Z) for which two partons will be merged into a single jet.

Jets at NLO continued

- Construct what is called a Snowmass potential

shown in Figure 50, where the towers unclustered into any jet are shaded black. A simple way of understanding these dark towers begins by defining a "Snowmass potential" in terms of the 2-dimensional vector $\vec{r} = (y, \phi)$ via

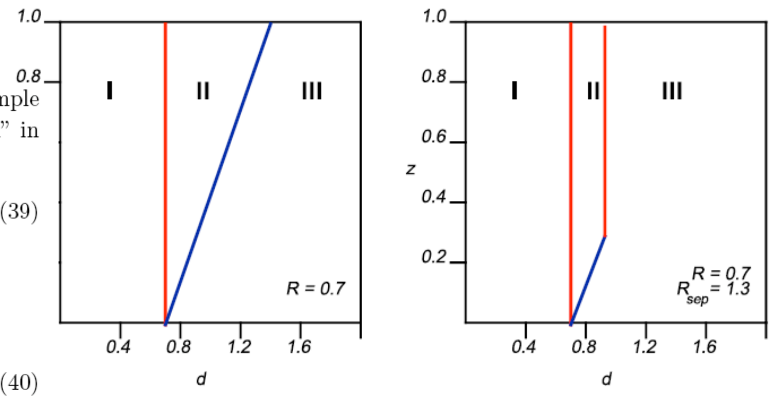
$$V(\vec{r}) = -\frac{1}{2}\sum_j p_{T,j}\left(R_{cone}^2 - (\vec{r_j} - \vec{r})^2\right)\Theta\left(R_{cone}^2 - (\vec{r_j} - \vec{r})^2\right) . \qquad (39)$$

The flow is then driven by the "force" $\vec{F}(\vec{r}) = -\vec{\nabla}V(\vec{r})$ which is thus given by,

$$\begin{aligned}\vec{F}(\vec{r}) &= \sum_j p_{T,j}(\vec{r_j} - \vec{r})\,\Theta\left(R_{cone}^2 - (\vec{r_j} - \vec{r})^2\right) \\ &= \left(\vec{r}_{C(\vec{r})} - \vec{r}\right)\sum_{j\subset C(r)} p_{T,j}, \qquad (40)\end{aligned}$$

where $\vec{r}_{C(\vec{r})} = \left(\bar{y}_{C(\vec{r})}, \bar{\phi}_{C(\vec{r})}\right)$ and the sum runs over $j \subset C(\vec{r})$ such that $\sqrt{(y_j - y)^2 + (\phi_j - \phi)^2} \leq R_{cone}$. As desired, this force pushes the cone to the stable cone position.

- The minima of the potential function indicates the positions of the stable cone solutions
  - the derivative of the potential function is the force that shows the direction of flow of the iterated cone
- The midpoint solution contains both partons



igure 22. The parameter space (d,Z) for which two partons will be merged into a ngle jet.

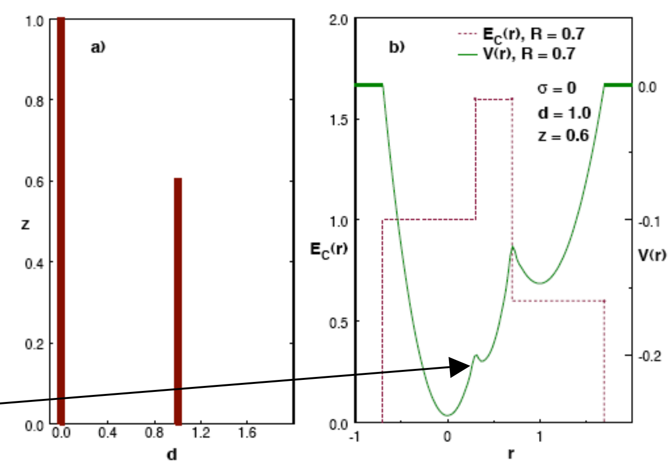


Figure 51. A schematic depiction of a specific parton configuration and the results of applying the midpoint cone jet clustering algorithm. The potential discussed in the text and the resulting energy in the jet are plotted.

Jets in real life

- Thus, jets don't consist of 1 fermi partons but have a spatial distribution
- Can approximate this as a Gaussian smearing of the spatial distribution of the parton energy
  - the effective sigma ranges between around 0.1 and 0.3 depending on the parton type (quark or gluon) and on the parton p_T
- Note that because of the effects of smearing that
  - the midpoint solution is (**almost always**) lost
    - thus region II is effectively truncated to the area shown on the right
  - the solution corresponding to the lower energy parton can also be lost
    - resulting in dark towers

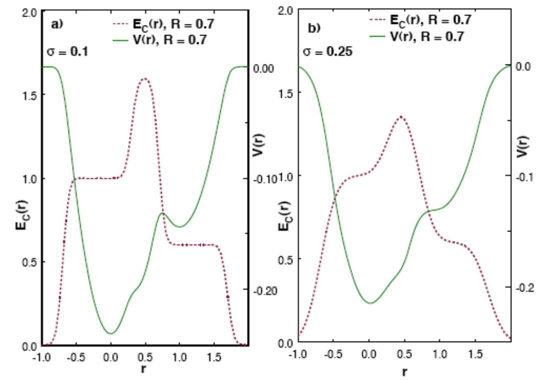


Figure 52. A schematic depiction of the effects of smearing on the midpoint cone jet clustering algorithm

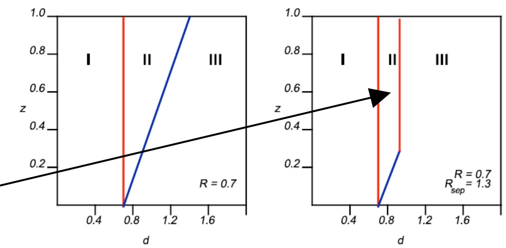


Figure 22. The parameter space (d,Z) for which two partons will be merged into a single jet.

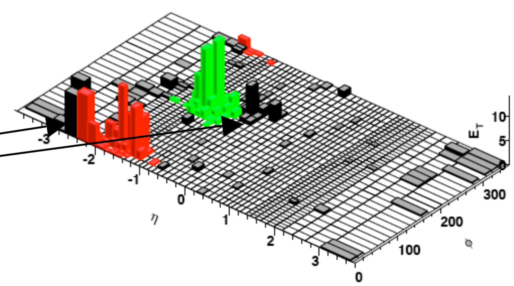
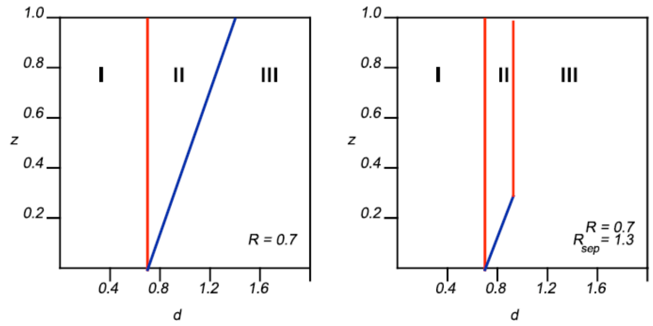


Figure 50. An example of a Monte Carlo inclusive jet event where the midpoint algorithm has left substantial energy unclustered.

Jets in real life

- In NLO theory, can mimic the impact of the truncation of Region II by including a parameter called R_{sep}
  - only merge two partons if they are within R_{sep}*R_{cone} of each other
    - R_{sep}~1.3
  - ~4-5% effect on the theory cross section; effect is smaller with the use of p_T rather than E_T (see extra slides)
  - really upsets the theorists (but there are also disadvantages)
- Dark tower effect is also on order of few (<5)% effect on the (experimental) cross section



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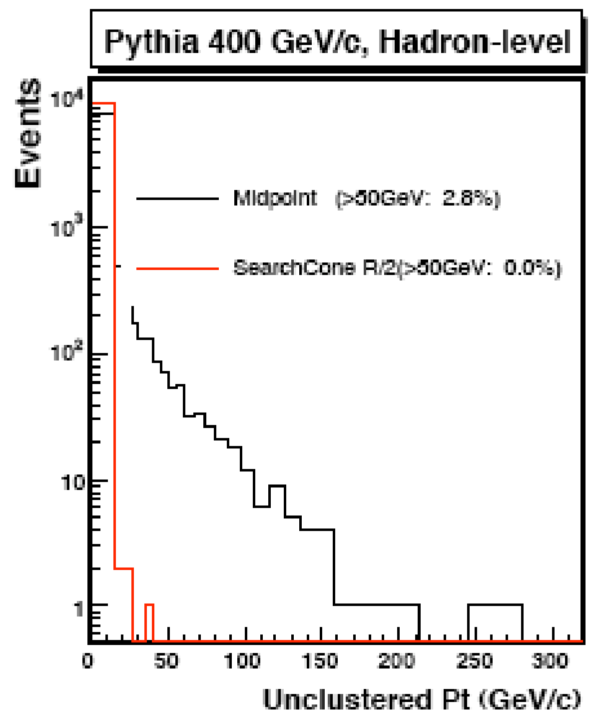
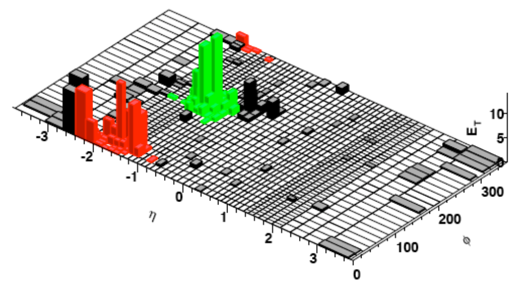


Jets in real life

- Search cone solution
  - use smaller initial search cone (R/2) so that influence of far-away energy not important
  - solution corresponding to smaller parton survives (but not midpoint solution)
  - but some undesireable IR sensitivity effects (~1%), plus larger UE subtraction



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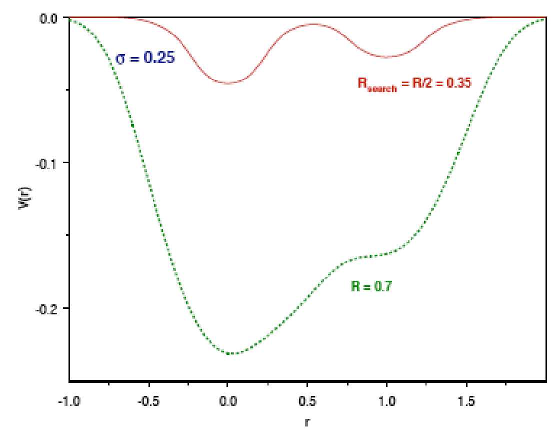
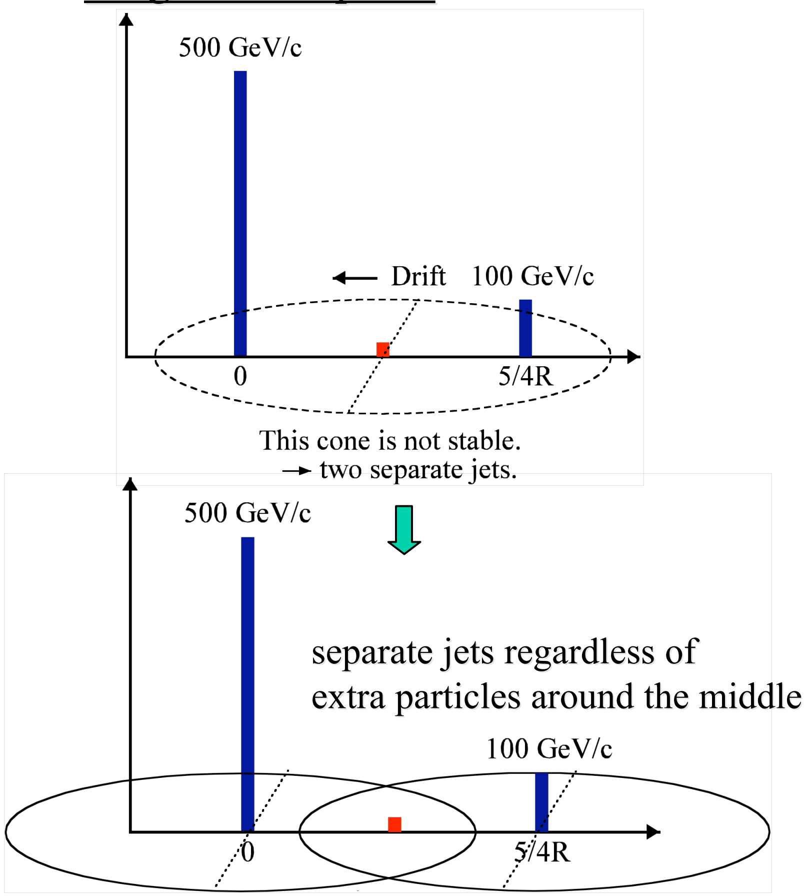


Figure 20. A schematic depiction of the effects of smearing on the midpoint cone jet clustering algorithm and the result of using a smaller initial search cone.

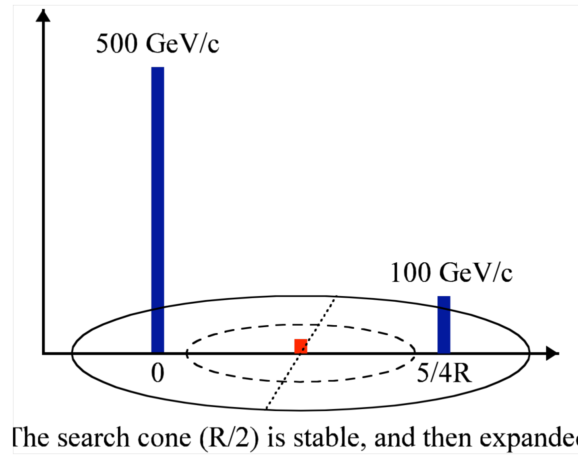
IR sensitivity of the search cone algorithm

It was pointed out by M. Wobisch, G. Salam et al. that the fixed Midpoint (search cone) algorithm is IR-sensitive at NNLO.

Original Midpoint



Fixed Midpoint (search cone)



The clustering depends on extra soft particles between the original two partons.
_ IR-sensitivity at NNLO.

What is the numerical size of this effect?

IR sensitivity of the search cone algorithm

Two well-separated partons [region (c) in the upper plot] which will NOT be merged with the original Midpoint algorithm may get merged [region (d) in the lower plot] with the search cone algorithm.

The region (c/d):

$$R_{cone} < d < 2R_{cone}$$

$$z = p_T^{parton2} / p_T^{parton1} < (d - R_{cone}) / R_{cone}$$

When a soft particle at the middle is away from the original 2 partons by more than $R_s = R_{cone}/2$, the search cone from the soft particle can be stable.

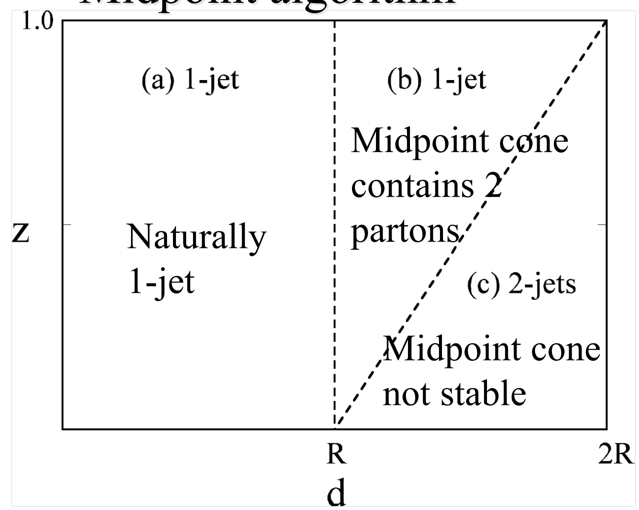
$$R_s = R_{cone}/2 < d_{extra} < R_{cone} \qquad \text{(from parton 1)}$$

$$R_s = R_{cone}/2 < d - d_{extra} < R_{cone} \qquad \text{(from parton 2)}$$

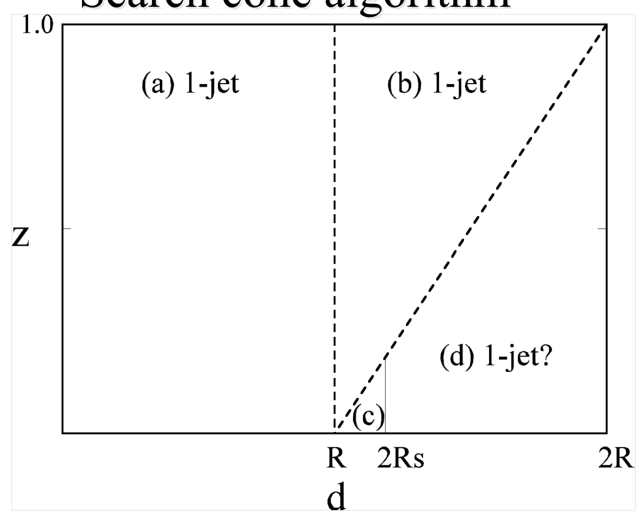
When it's expanded to radius R_{cone}, it will form a jet containing the two original partons.

When such a search cone is prohibited, how does the cross section change?

Midpoint algorithm

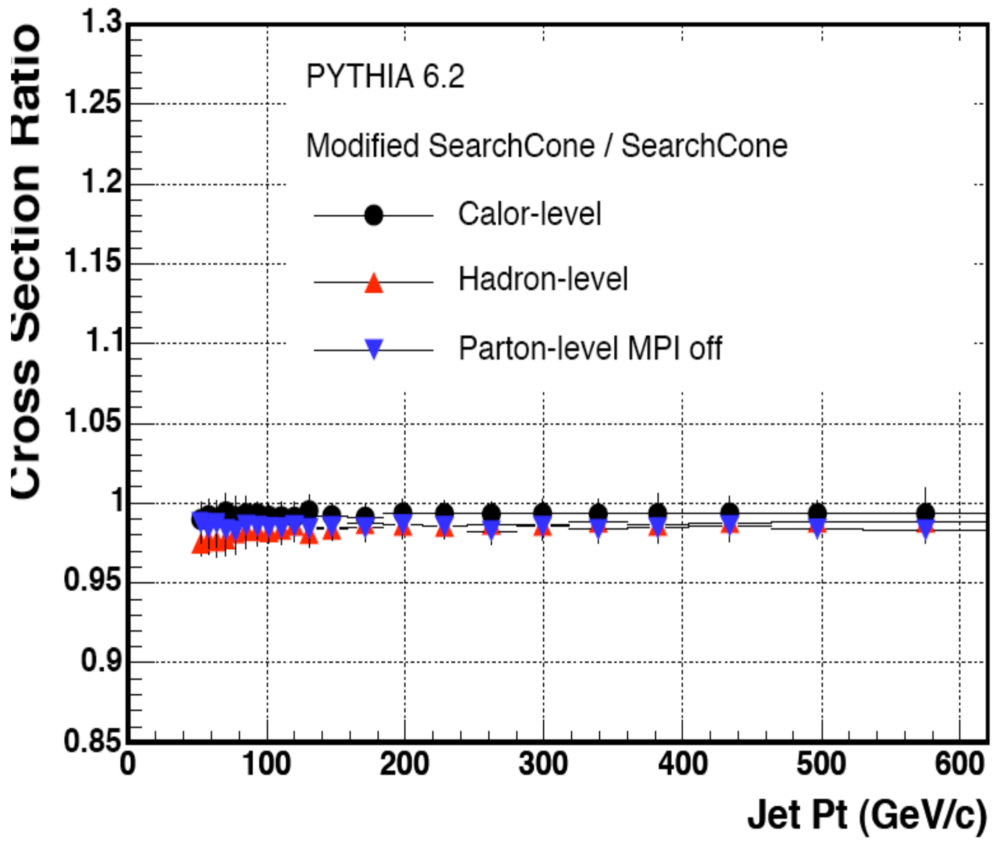


Search cone algorithm



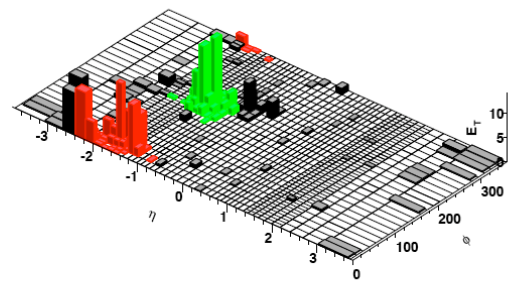
IR sensitivity study with Pythia

- The modified search cone algorithm was made which removes the search cone satisfying the condition of the previous page.
- The modified algorithm changes the cross section in Pythia by only ~1-2% independent of jet Pt. Negligible effect.



Jets in real life

- Search cone solution
  - use smaller initial search cone (R/2) so that influence of far-away energy not important
  - solution corresponding to smaller parton survives (but not midpoint solution)
  - but some undesireable IR sensitivity effects (~1%), plus larger UE subtraction
- **TeV4LHC consensus**
  - run standard midpoint algorithm
  - remove all towers located in jets
  - run 2nd pass of midpoint algorithm, cluster into jets
  - at this point, can either keep 2nd pass jets as additional jets (recommended for now)
    - use appropriate value of R_{sep}
  - or merge in (d,z) plane
  - correct data for effects of seeds (~1%) so comparisons made to seedless theory



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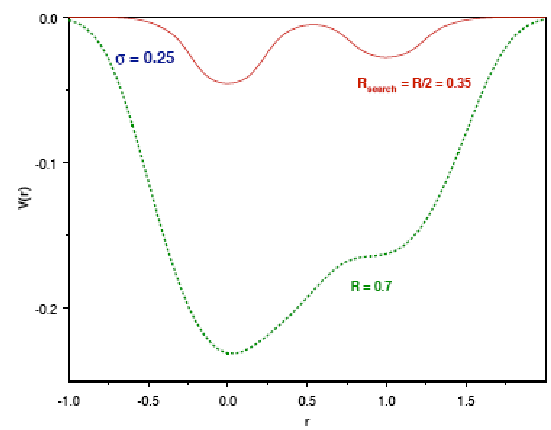

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What do we do with the >fb^{-1} sample?

- Removing the search cone means re-processing all of the jet data
- The net effect will be fairly small (<5%)
  - but can we publish without doing this?
- The original midpoint algorithm uses a split/merge criterion of 50%
  - but we've been using 75%, as in JetClu
  - some evidence that 50% can lead to trouble in active environments
  - I'd prefer to stick with 75%, but am just starting a systematic study of the effect