Top mass reconstruction at the LHC

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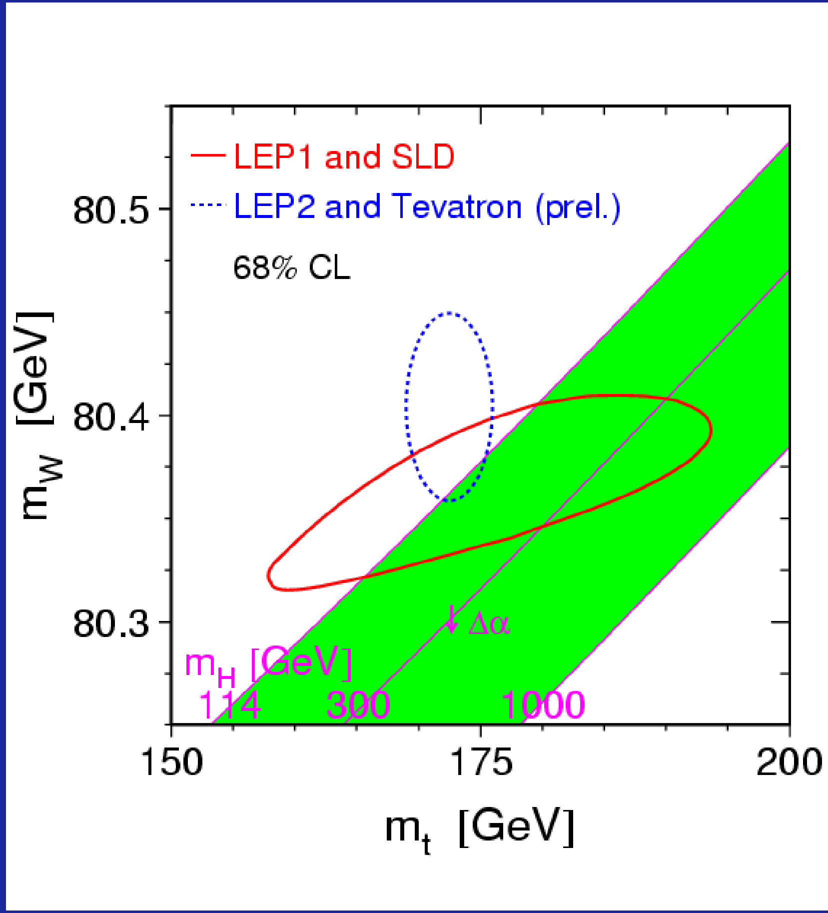
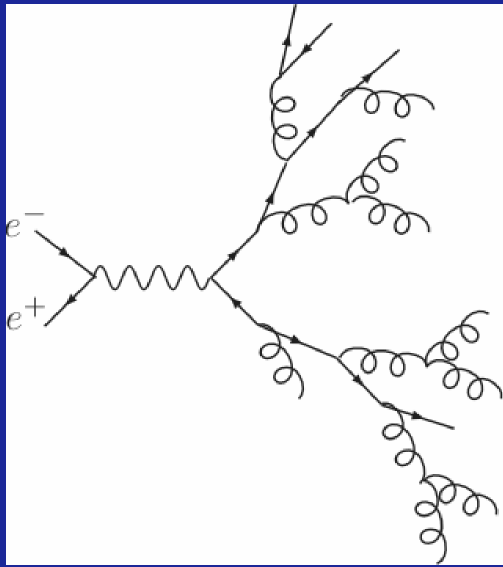
Motivation - Why the top mass?

- Measure properties of a quark (very short lifetime)
- Constrain the mass of the SM Higgs
- Also many BSMs - expect new physics to couple strongly to top
- Good playground to test QCD and SM



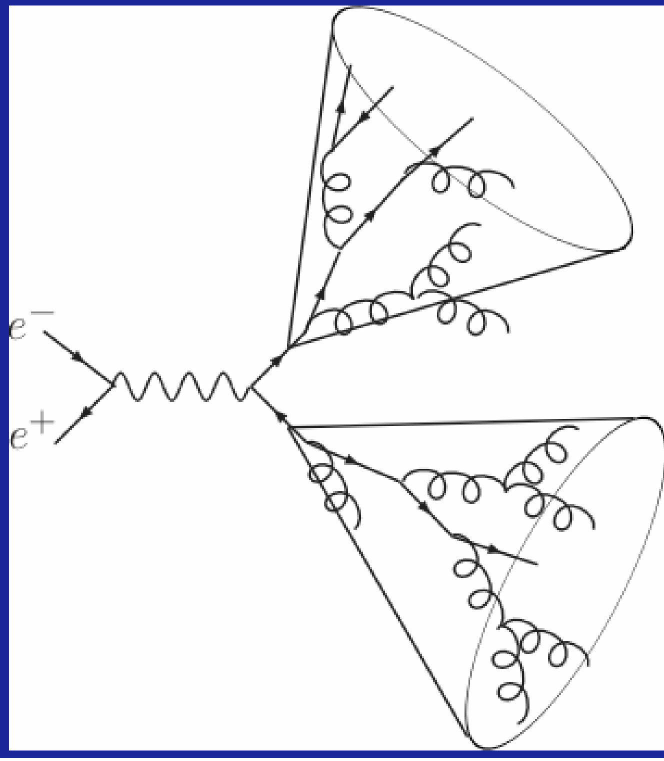
Jet Algorithms

- QCD - confinement (only colour singlets propagate over macroscopic distances)
- No unique method of assigning (colourless) hadrons to (coloured) partons
- Require a ‘sensible’ definition of a Jet - two of the main types of algorithm are:
  - Cone Algorithms
  - Cluster Algorithms



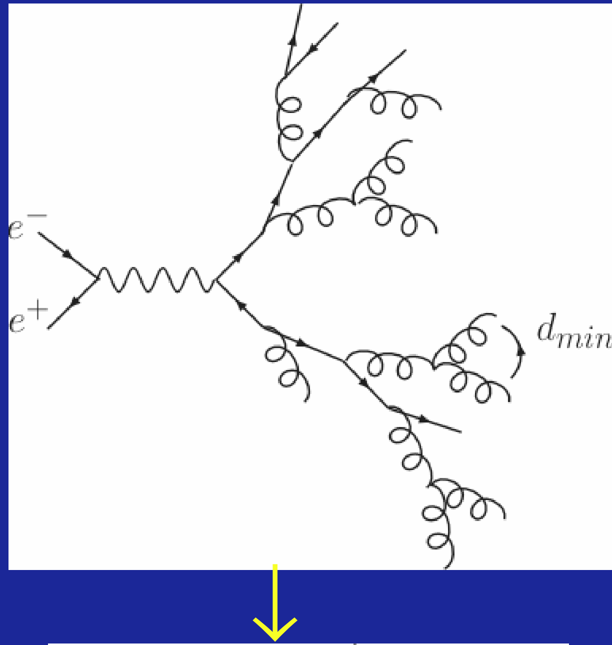
PxCone

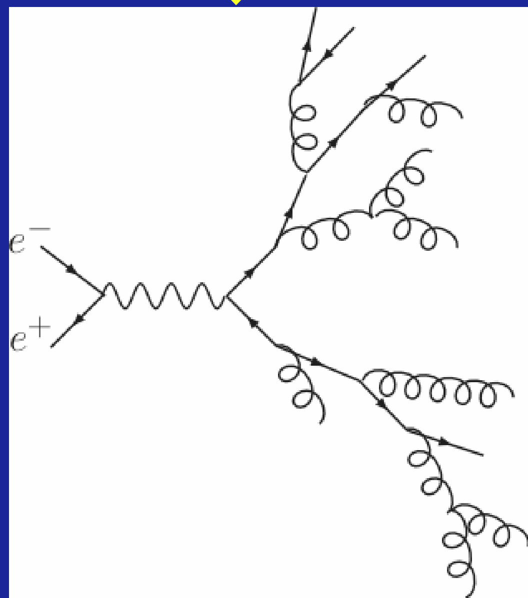
- Draw a cone around every object
- Combine all objects inside the cone
- If this new object points in a different direction, draw a new cone around the combined object and repeat steps 1-2
- When you've done this, draw a cone around the mid-point between each pair of jets (IR safety)
- Deal with overlaps - objects don't contribute to more than 1 jet



KtJet

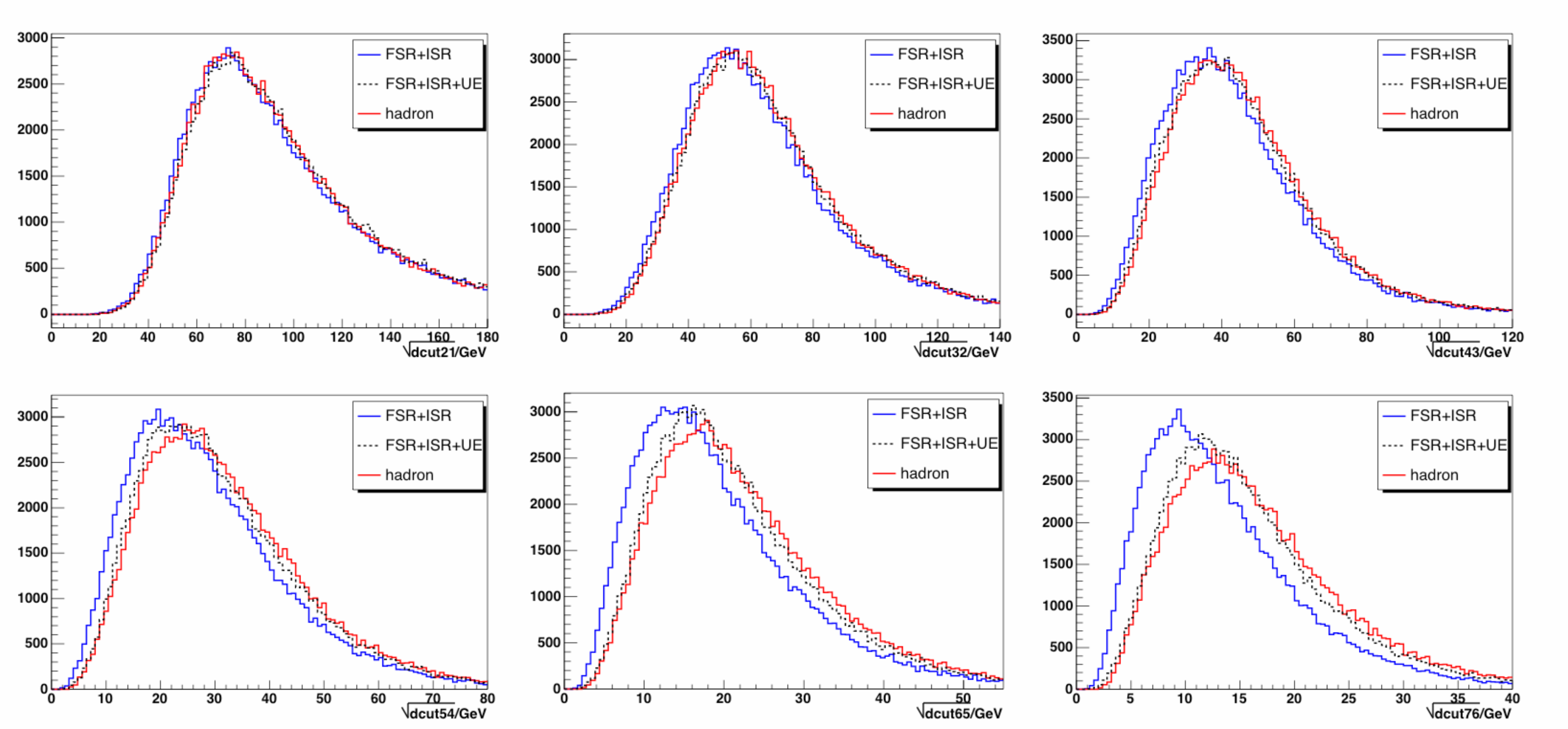
- For each object, j, compute the closeness parameter, d_{jB}, and for each pair of objects, i and j, compute the closeness parameter, d_{ij} (IR safety)
- Find the smallest member of the set $\{d_{jB}, d_{ij}\}$. If this is a d_{jB}, then remove it from the list; if it is a d_{ij}, then combine the two objects i and j in some way (eg 4-momentum addition)
- Repeat steps 1-2 until some stopping criteria is fulfilled (eg a specific jet multiplicity)





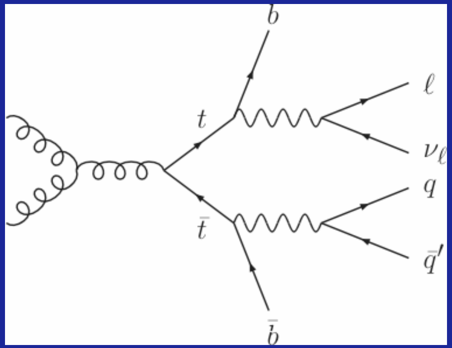
Factorization of the Underlying Event

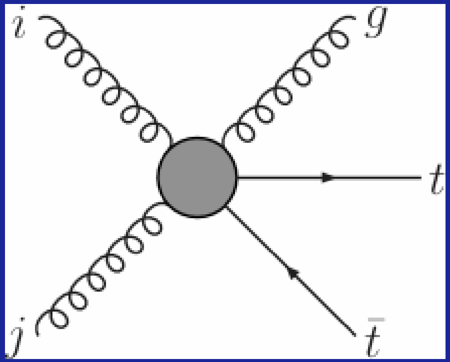
- Run over different levels of MC truth:
  - Blue parton from hard scatter
  - Black (dash) all partons - including those from UE
  - Red stable hadrons

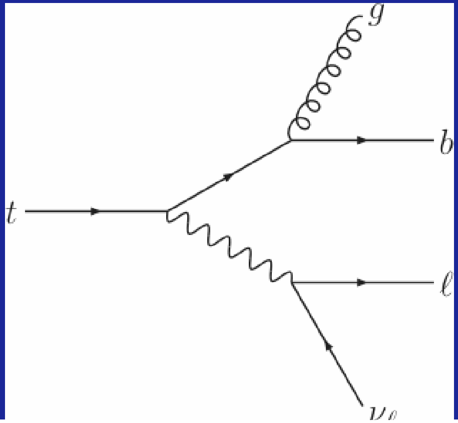


How do I run KtJet?

- In the SM tops decay almost exclusively to Wb
- Define signal process to as inclusive tt production, with one of the W bosons decaying leptonically, the other hadronically
- At LO one would expect 4 hard well isolated jets, one charged lepton and missing transverse energy $\Rightarrow$ cluster to 4 jets
- Also expect some events with 5 jets hard jets - this prescription will not always work



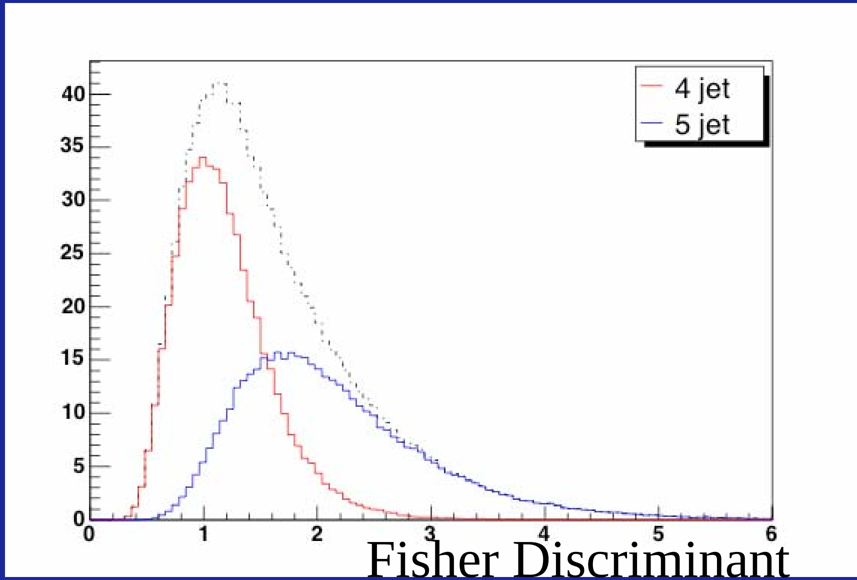




Fisher Discriminant

- Linear combination of the (perturbative) merging scales:

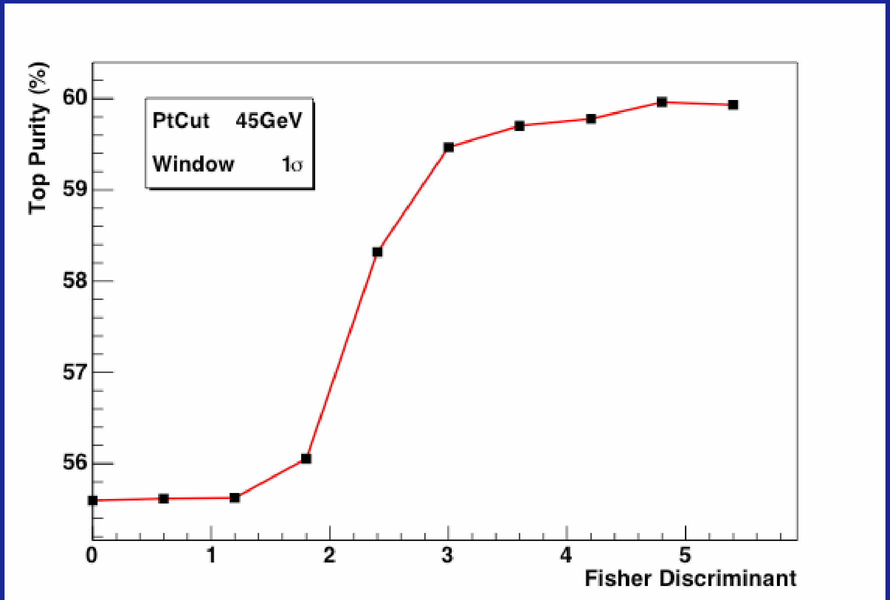
$$F = 0.010\frac{d_{21}^{1/2}}{70} + 0.083\frac{d_{32}^{1/2}}{50} + 0.151\frac{d_{43}^{1/2}}{32} + 0.319\frac{d_{54}^{1/2}}{18} + 0.251\frac{d_{65}^{1/2}}{12} + 0.194\frac{d_{76}^{1/2}}{8}$$

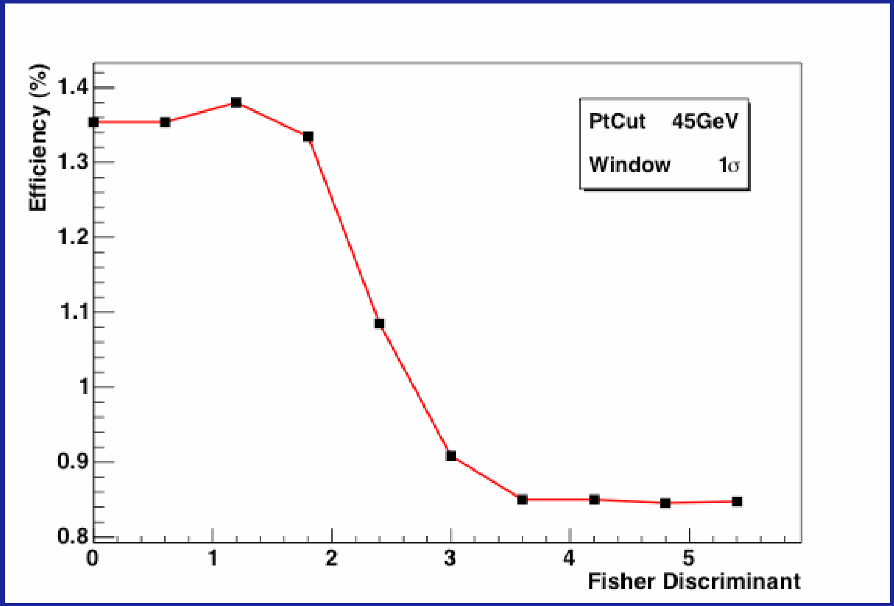


Analysis

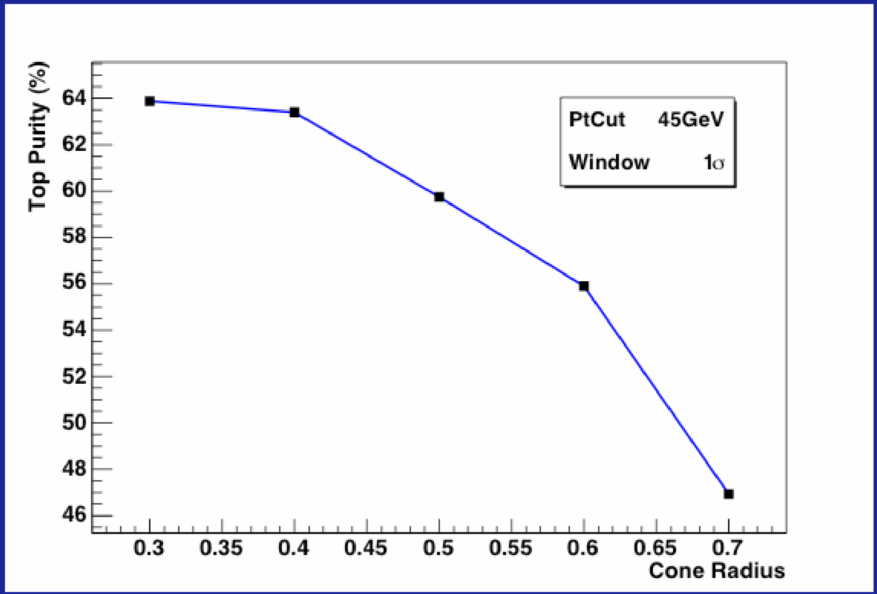
- Selection Cuts:
  - >20GeV missing E_T
  - 1 lepton with E_T>20GeV, $|\eta|<2.5$
  - At least 4 jets with E_T>45GeV (exactly 2 b-jets)
- W mass constraint
- Top reconstruction

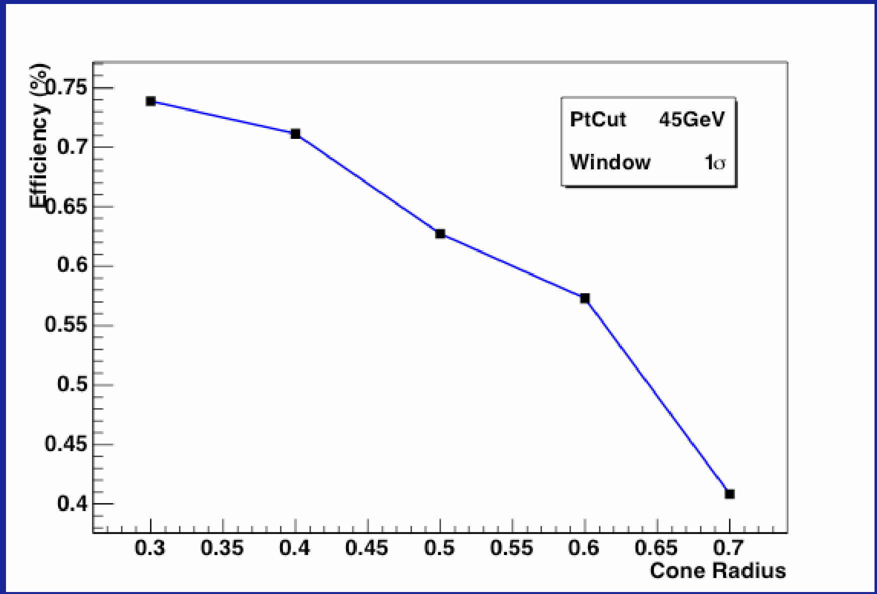
KtJet (purity/efficiency)





PxCone (purity/efficiency)

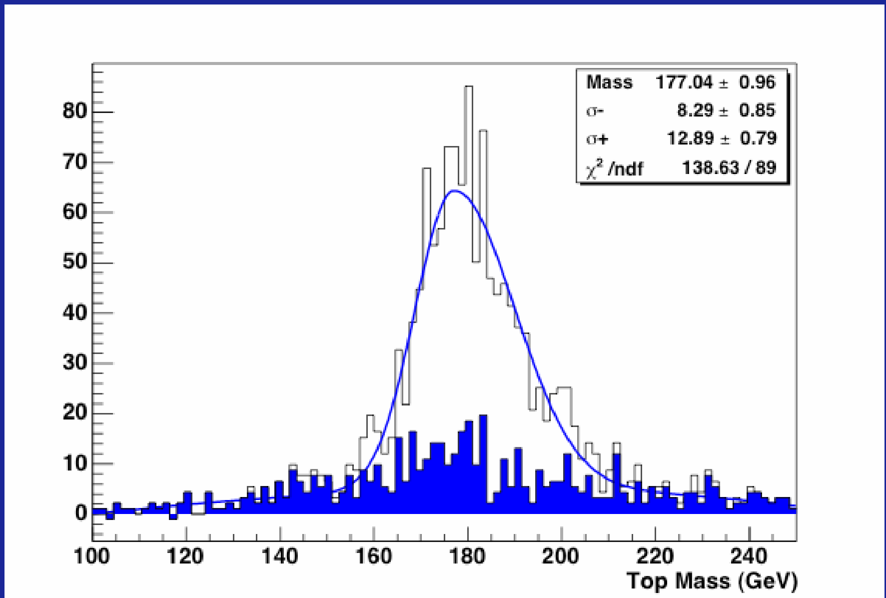




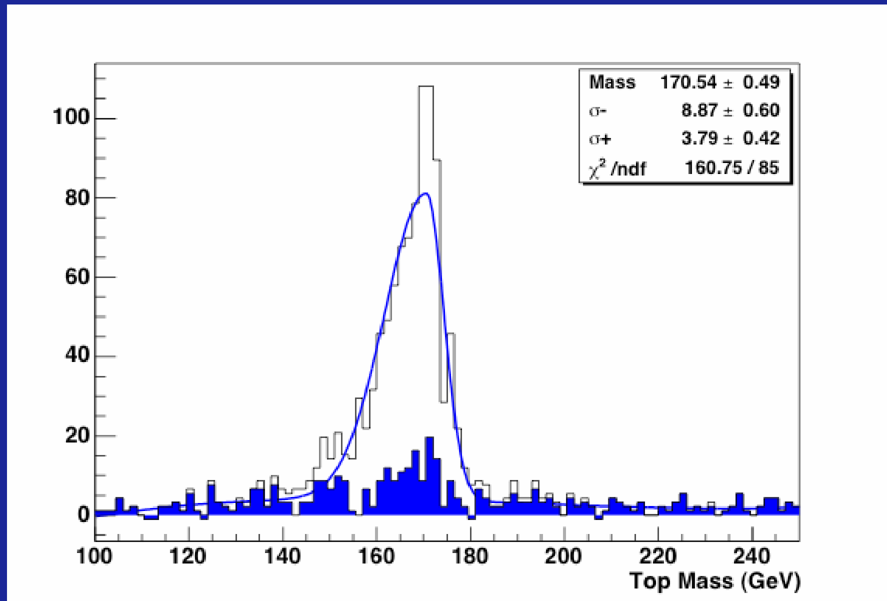
Reconstructed top mass

Generated top mass 175GeV (MC@NLO)

KtJet (Fisher cut=5.4)



PxCone (R=0.4)



Systematic Errors

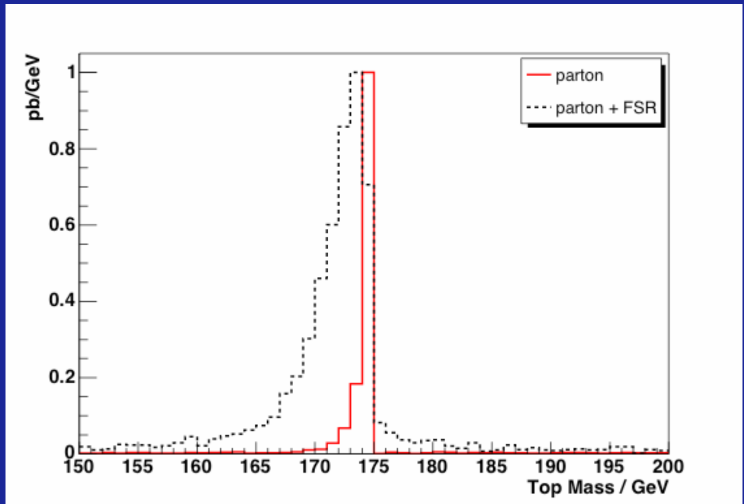
Physics:

- Initial and Final State Radiation (ISR/FSR)
- Underlying Event
- b-quark fragmentation
- Parton distribution functions (pdfs)

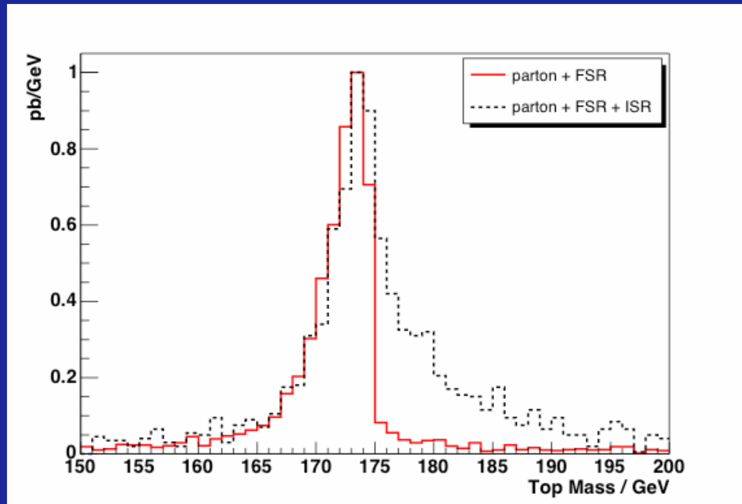
Detector:

- The Jet Energy Scale (JES)

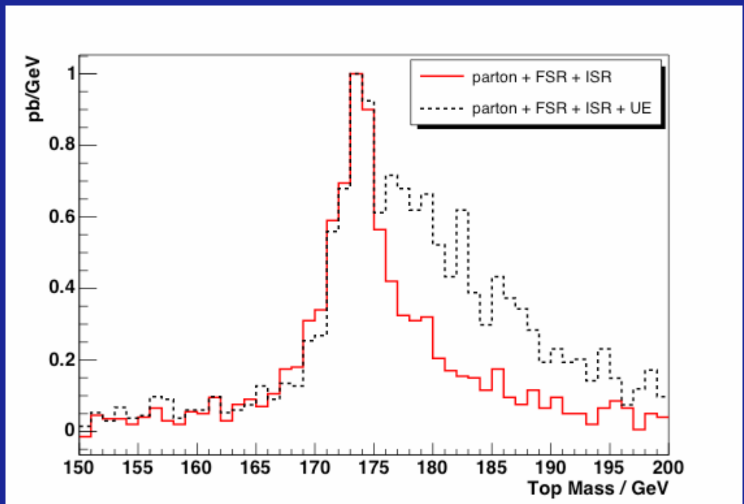
KtJet



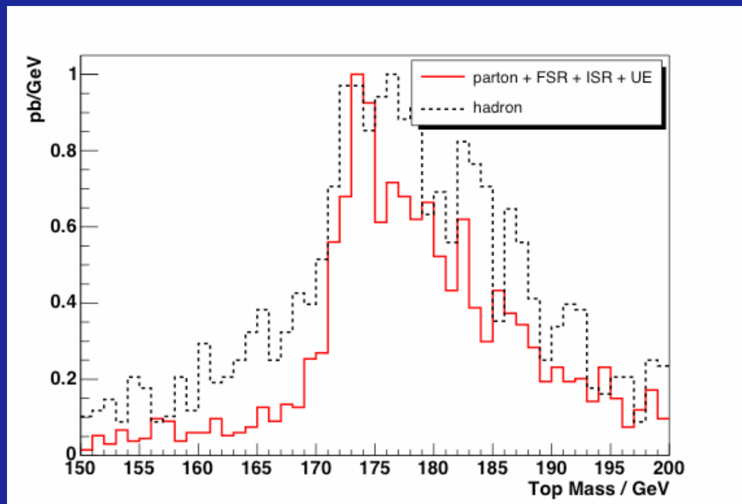
pb/GeV
Top Mass / GeV
parton
parton + FSR



pb/GeV
Top Mass / GeV
parton + FSR
parton + FSR + ISR

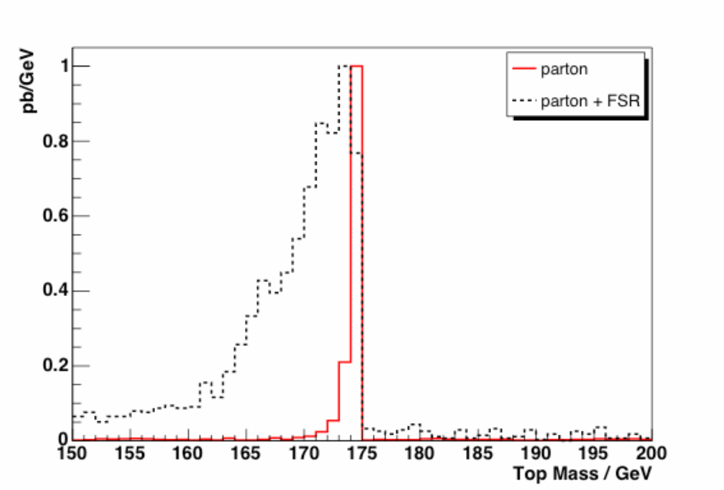


pb/GeV
Top Mass / GeV
parton + FSR + ISR
parton + FSR + ISR + UE

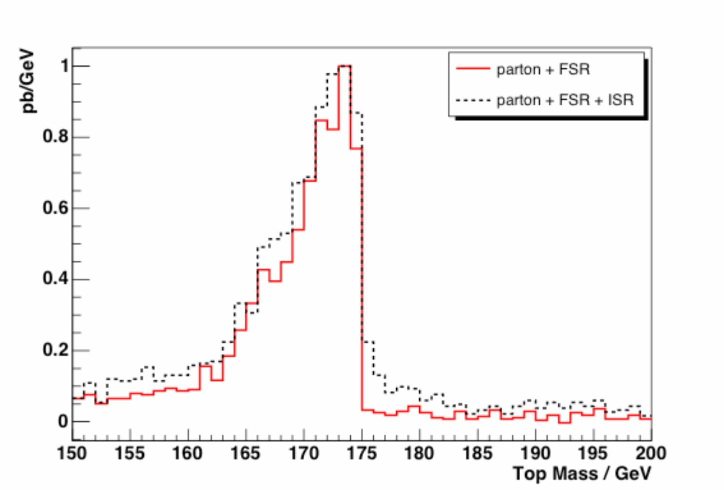


pb/GeV
Top Mass / GeV
parton + FSR + ISR + UE
hadron

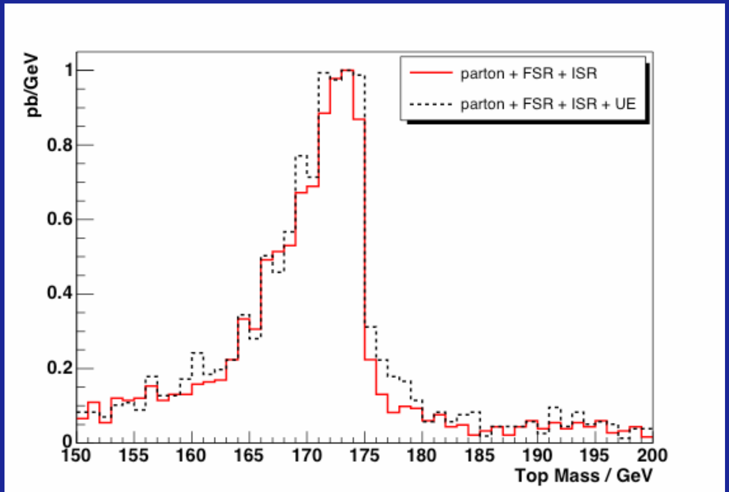
PxCone



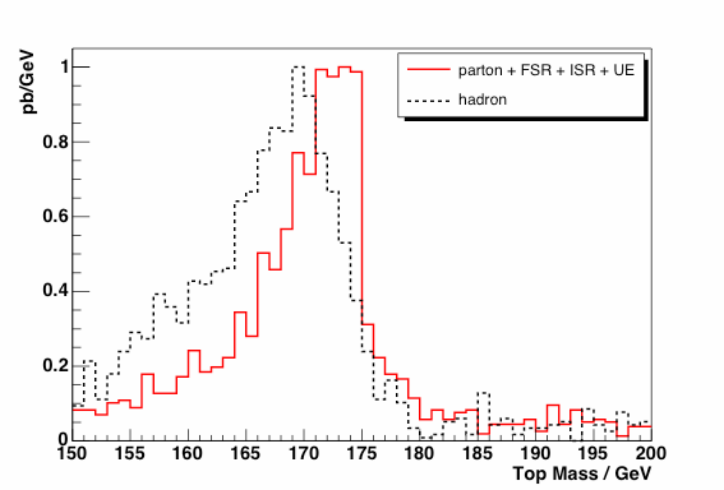
pb/GeV
parton
parton + FSR
Top Mass / GeV



pb/GeV
parton + FSR
parton + FSR + ISR
Top Mass / GeV



pb/GeV
parton + FSR + ISR
parton + FSR + ISR + UE
Top Mass / GeV



pb/GeV
parton + FSR + ISR + UE
hadron
Top Mass / GeV

Summary

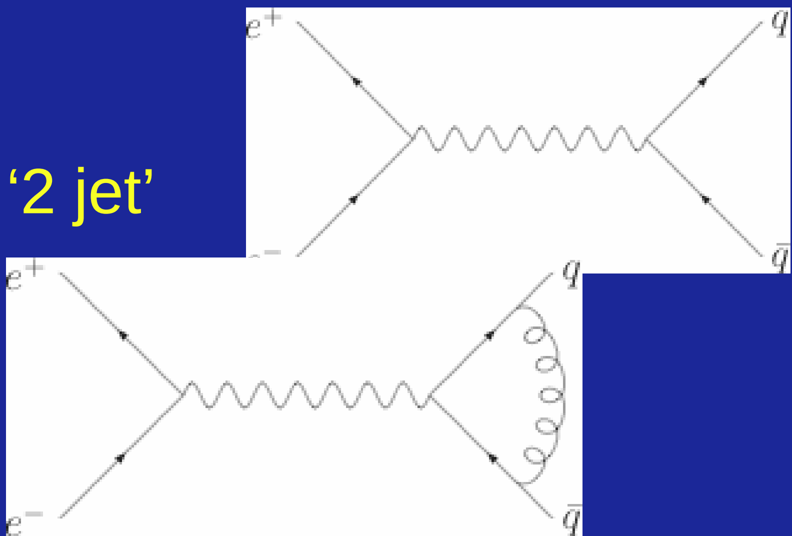
- Compared the two algorithms
  - Similar purities & efficiencies
  - Better mass resoultion with PxCone
- Optimised both algorithms
  - Considered different Jet Multiplicities (Fisher cut) - not much advantage
  - Optimal Cone Radius 0.4
- At indication that the dominant sources of systematic errors are different for the two algorithms - could be interesting with data!

Extras

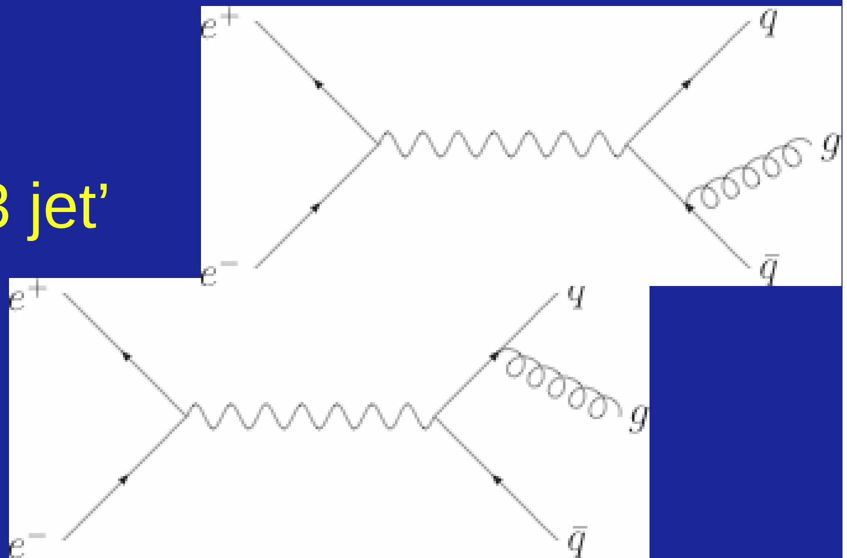
Infrared Safety

- At NLO individual Feynman diagrams contain IR divergences - in any observable, these should cancel (eg the $e^+e^- \rightarrow$jets cross section)
- When we define some observable, eg the 3 jet cross section, we must make sure that if a diagram with a divergence contributes to this, the diagram(s) which cancel it also contribute

‘2 jet’



‘3 jet’



Mid-point Cone

- The IR safety of an Iterating Cone Algorithm is ensured by considering the mid-point of any pair of proto-jets as a seed direction

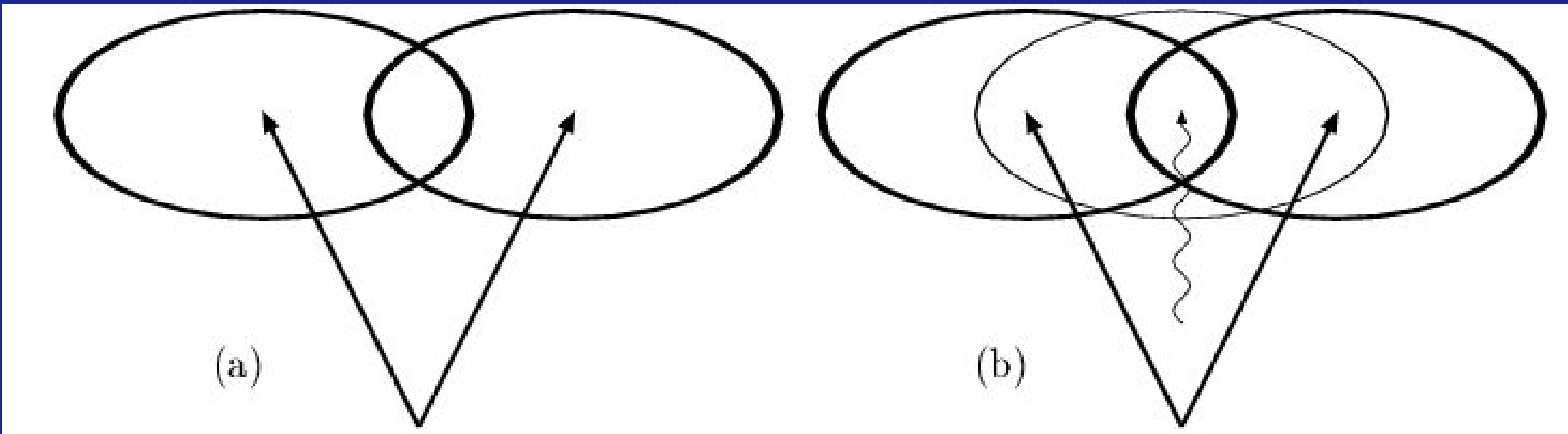


Figure 3: *Illustration of the problem region for the iterative cone algorithm. In (a), there are two hard partons, with overlapping cones. In (b) there is an additional soft parton in the overlap region.*

(Figure courtesy of Mike Seymour)

KtJet (Inclusive Mode)

- For each object, j, compute the closeness parameter, d_{jB}, and for each pair of objects, i and j, compute the closeness parameter, d_{ij}
- Rescale all d_{jB}, by an 'R-parameter' - $d_{jB} \rightarrow R^2 d_{jB}$
- Find the smallest member of the set $\{d_{jB}, d_{ij}\}$. If this is a d_{jB}, then add it to the list of jets; if it is a d_{ij}, then combine the two objects i and j in some way (eg 4-momentum addition)
- Repeat steps 1-3 until all objects have been included in a jet

Jet Multiplicity

- Generated samples of tt+0jet and tt+1jet with ALPGEN
- The merging scales are different in the two cases