Standard Model Handles and Candles WG (session 1)

Conveners:
Experiment: Craig Buttar, Jorgen d'Hondt, Markus Wobisch
Theory: Michael Kramer, Gavin Salam

This talk: the 'jets' sub-group

1. Background + motivation
2. Status / plans

Physics at TeV Colliders workshop
Les Houches, 12 June 2007

Jets: what for?

If all you need to do is a rough job (e.g. discover huge 1 TeV Z' peak), then you needn't worry about how you define your jets.

Any jet algorithm will pick them out for you

Where details of jet finding matter

- Extracting precise masses and couplings

  You need control over what you're measuring

- Extricating complex signals from background

  You need maximal information about each event

- Comparing to NLO, NNLO

  They may only make sense / converge well with proper jet algs.

- Comparing between experiments

  Compare like with like

Jets: what for?

If all you need to do is a rough job (e.g. discover huge 1 TeV Z' peak), then you needn't worry about how you define your jets.

Any jet algorithm will pick them out for you

Where details of jet finding matter

- Extracting precise masses and couplings

  You need control over what you're measuring

- Extricating complex signals from background

  You need maximal information about each event

- Comparing to NLO, NNLO

  They may only make sense / converge well with proper jet algs.

- Comparing between experiments — Compare like with like

LHC is not LEP

"I don't understand what all the fuss is about — why don't they [Tevatron] just use the k_t algorithm?"

by an ex-director of a large French particle-physics lab

LEP

- $M_{BSM} \sim 1$ TeV
- $M_{EW} \sim 100$ GeV
- $p_{t,\text{pileup}} \sim 25 - 50$ GeV/unit rap.
- $p_{t,\text{UE}} \sim 2.5 - 5$ GeV/unit rap.
- $p_{t,\text{hadr.}} \sim 0.5$ GeV/unit rap.

Multitude of scales → must understand how they interact with your jet algorithm

LHC is not LEP or Tevatron

"I don't understand what all the fuss is about — why don't they [Tevatron] just use the k_t algorithm?"

by an ex-director of a large French particle-physics lab

Tevatron

- $M_{BSM} \sim 1$ TeV
- $M_{EW} \sim 100$ GeV
- $p_{t,\text{pileup}} \sim 25 - 50$ GeV/unit rap.
- $p_{t,\text{UE}} \sim 2.5 - 5$ GeV/unit rap.
- $p_{t,\text{hadr.}} \sim 0.5 - 1$ GeV/unit rap.

Multitude of scales → must understand how they interact with your jet algorithm

LHC is not LEP or Tevatron

"I don't understand what all the fuss is about — why don't they [Tevatron] just use the k_t algorithm?"

by an ex-director of a large French particle-physics lab

LHC

- $M_{BSM} \sim 1$ TeV
- $M_{EW} \sim 100$ GeV
- $p_{t,\text{pileup}} \sim 25 - 50$ GeV/unit rap.
- $p_{t,\text{UE}} \sim 5 - 10$ GeV/unit rap.
- $p_{t,\text{hadr.}} \sim 0.5 - 1$ GeV/unit rap.

Multitude of scales → must understand how they interact with your jet algorithm

LHC is not LEP or Tevatron

"I don't understand what all the fuss is about — why don't they [Tevatron] just use the k_t algorithm?"

by an ex-director of a large French particle-physics lab

LHC

- $M_{BSM} \sim 1$ TeV
- $M_{EW} \sim 100$ GeV
- $p_{t,\text{pileup}} \sim 25 - 50$ GeV/unit rap.
- $p_{t,\text{UE}} \sim 5 - 10$ GeV/unit rap.
- $p_{t,\text{hadr.}} \sim 0.5 - 1$ GeV/unit rap.

Multitude of scales → must understand how they interact with your jet algorithm

Is debate just k_t v. cone?

- Choice is not restricted to k_t and "cone". A contender for a good all round jet-alg. is *Cambridge/Aachen* algorithm.

  Recombine closest pair with min ΔR_{ij}; repeat until all $DeltaR_{ij} > R$

  Simple; fast; extendable; combines strengths of k_t and "cone"

- *"The cone"* does not exist: there are $\gtrsim 5$ different cones (UA1, Iterative, JetClu, MidPoint, SISCone)

  They're all rather different

  Only SISCone is infrared and collinear safe

- k_t can be used in a range of ways

  Inclusive, exclusive, subjets, ...

- *Different algorithms have complementary strengths and weaknesses.* Choose the right one for the occasion — or use several and gain robustness.

  We should understand quantitative features of the algs.

  And use the information to help do a better job

Is debate just k_t v. cone?

- Choice is not restricted to k_t and "cone". A contender for a good all round jet-alg. is *Cambridge/Aachen* algorithm.

  Recombine closest pair with min ΔR_{ij}; repeat until all $DeltaR_{ij} > R$

  Simple; fast; extendable; combines strengths of k_t and "cone"

- *"The cone"* does not exist: there are $\gtrsim 5$ different cones (UA1, Iterative, JetClu, MidPoint, SISCone)

  They're all rather different

  Only SISCone is infrared and collinear safe

- k_t can be used in a range of ways

  Inclusive, exclusive, subjets, ...

- *Different algorithms have complementary strengths and weaknesses.* Choose the right one for the occasion — or use several and gain robustness.

  We should understand quantitative features of the algs.

  And use the information to help do a better job

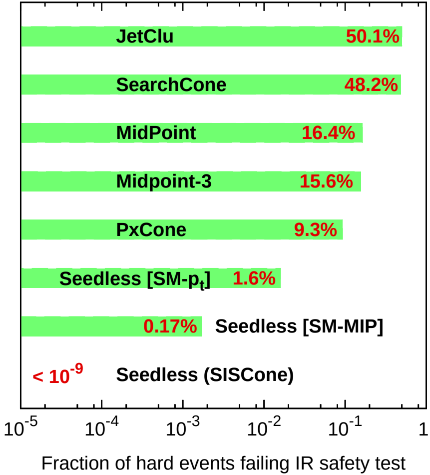
Is debate just k_t v. cone?

- Choice is not restricted to k_t and "cone". A contender for a good all round jet-alg. is *Cambridge/Aachen* algorithm.
  Recombine closest pair with min ΔR_{ij}; repeat until all $DeltaR_{ij} > R$
  Simple; fast; extendable; combines strengths of k_t and "cone"
- *"The cone"* does not exist: there are $\gtrsim$ 5 different cones (UA1, Iterative, JetClu, MidPoint, SISCone) They're all rather different
  Only SISCone is infrared and collinear safe
- k_t can be used in a range of ways Inclusive, exclusive, subjets, ...
- *Different algorithms have complementary strengths and weaknesses.* Choose the right one for the occasion — or use several and gain robustness. We should understand quantitative features of the algs.
  And use the information to help do a better job

Is debate just k_t v. cone?

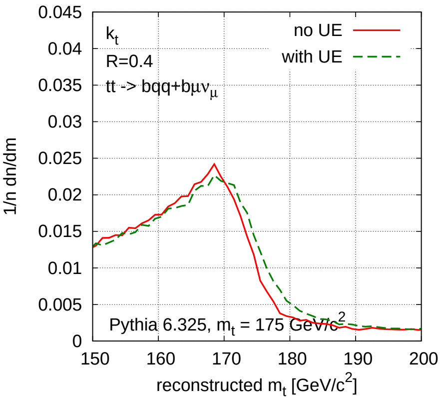
- Choice is not restricted to k_t and "cone". A contender for a good all round jet-alg. is *Cambridge/Aachen* algorithm.
  Recombine closest pair with min ΔR_{ij}; repeat until all $DeltaR_{ij} > R$
  Simple; fast; extendable; combines strengths of k_t and "cone"
- *"The cone"* does not exist: there are $\gtrsim 5$ different cones (UA1, Iterative, JetClu, MidPoint, SISCone) They're all rather different
  Only SISCone is infrared and collinear safe
- k_t can be used in a range of ways Inclusive, exclusive, subjets, ...
- *Different algorithms have complementary strengths and weaknesses.* Choose the right one for the occasion — or use several and gain robustness. We should understand quantitative features of the algs.
  And use the information to help do a better job

MidPoint cone → IR unsafe



Last meaningful order	
Process	MidPoint alg.
Inclusive jets	NLO
W/Z + 1 jet	NLO
3 jets	LO
W/Z + 2 jets	LO
jet masses in $2j + X$	**none**

Robustness example



Game: measure top mass to 1 GeV

example for Tevatron

$m_t = 175$ GeV

- Small R: lose 6 GeV to PT radiation and hadronisation, UE and pileup irrelevant

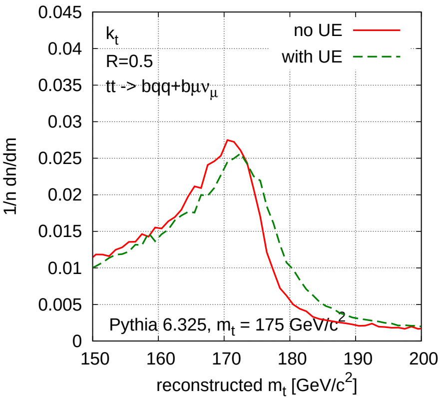
- Large R: hadronisation and PT radiation leave mass at ~ 175 GeV, UE adds $2-4$ GeV.

Is the final top mass (after W, jet-energy-scale and Monte Carlo unfolding) independent of R used to measure jets?

Powerful cross-check of systematic effects

cf. Seymour & Tevlin '06

Robustness example



Game: measure top mass to 1 GeV

example for Tevatron

$m_t = 175$ GeV

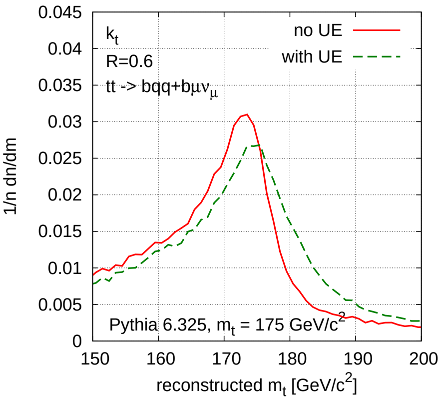
- Small R: lose 6 GeV to PT radiation and hadronisation, UE and pileup irrelevant
- Large R: hadronisation and PT radiation leave mass at ~ 175 GeV, UE adds $2-4$ GeV.

Is the final top mass (after W, jet-energy-scale and Monte Carlo unfolding) independent of R used to measure jets?

Powerful cross-check of systematic effects

cf. Seymour & Tevlin '06

Robustness example



<u>Game: measure top mass to 1 GeV</u>

example for Tevatron

$m_t = 175$ GeV

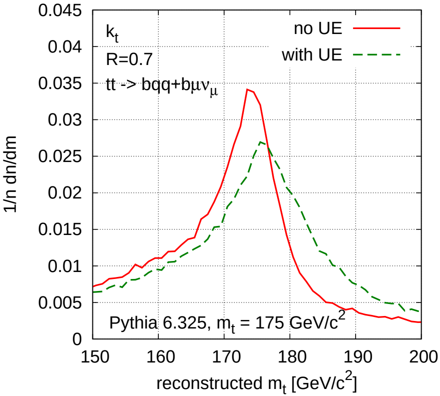
- Small R: lose 6 GeV to PT radiation and hadronisation, UE and pileup irrelevant
- Large R: hadronisation and PT radiation leave mass at ~ 175 GeV, UE adds $2-4$ GeV.

Is the final top mass (after W jet-energy-scale and Monte Carlo unfolding) independent of R used to measure jets?

Powerful cross-check of systematic effects

cf. Seymour & Tevlin '06

Robustness example



Game: measure top mass to 1 GeV

example for Tevatron

$m_t = 175$ GeV

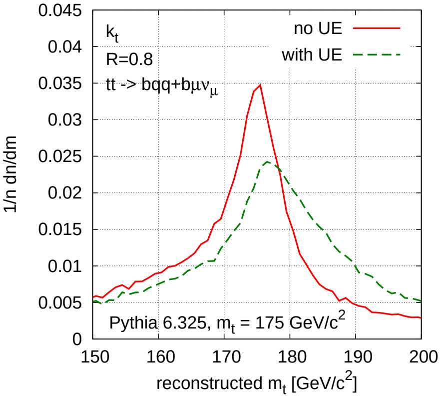
- Small R: lose 6 GeV to PT radiation and hadronisation, UE and pileup irrelevant
- Large R: hadronisation and PT radiation leave mass at ~ 175 GeV, UE adds $2-4$ GeV.

Is the final top mass (after W jet-energy-scale and Monte Carlo unfolding) independent of R used to measure jets?

Powerful cross-check of systematic effects

cf. Seymour & Tevlin '06

Robustness example



<u>Game: measure top mass to 1 GeV</u>

example for Tevatron

$m_t = 175$ GeV

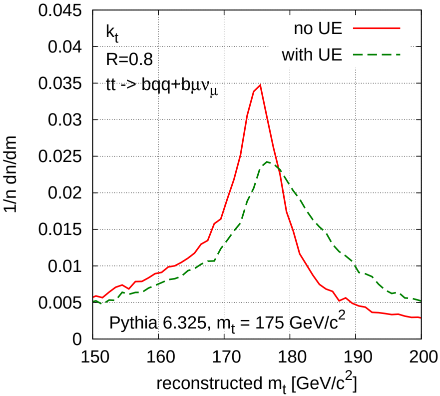
- Small R: lose 6 GeV to PT radiation and hadronisation, UE and pileup irrelevant
- Large R: hadronisation and PT radiation leave mass at ~ 175 GeV, UE adds $2 - 4$ GeV.

Is the final top mass (after W jet-energy-scale and Monte Carlo unfolding) independent of R used to measure jets?

Powerful cross-check of systematic effects

cf. Seymour & Tevlin '06

Robustness example



<u>Game: measure top mass to 1 GeV</u>

example for Tevatron

$m_t = 175$ GeV

- Small R: lose 6 GeV to PT radiation and hadronisation, UE and pileup irrelevant
- Large R: hadronisation and PT radiation leave mass at ~ 175 GeV, UE adds $2 - 4$ GeV.

Is the final top mass (after W jet-energy-scale and Monte Carlo unfolding) independent of R used to measure jets?

Powerful cross-check of systematic effects

cf. Seymour & Tevlin '06

Jets are not just about kinematics

Heavy-flavour

- *b*-jets: using a good theoretical definition can reduce NLO uncertainties from $40-60$ to $10-20\%$. Banfi, GPS & Zanderighi

  But can it be measured?

Quark–gluon discrimination

- Various tools developed at LEP and HERA
- Could they not be used (e.g. in searches) at LHC

  Many signals: quark jets; backgrounds: gluon jets
- Can techniques be improved?

STATUS AND PLANS

Tools at our disposal

Let's stick to infrared and collinear safe tools

We start to have a choice of jet algorithms for hadron-colliders:

- k_t
- Cambridge/Aachen
- SISCone — IR safe, exact stable cone alg.
- anti-k_t — sequential recombination that behaves like a cone
  Cacciari, GPS & Soyez, prelim.

Whole sets of jet algs. in one package: *FastJet*, *SpartyJet*

Benchmarking

What not to do:

- Take a Pythia parton
- let it shower, hadronize, ...
- compare the resulting jet with the parton

No good because a parton is not a physical object beyond LO

What you might do

- Take a W (e.g. in top decay)
- let it decay, shower, hadronize, ...
- compare the mass reconstructed from the two jets

Better — W is almost a physical object.

Understanding our tools

What's R (jet radius) dependence of

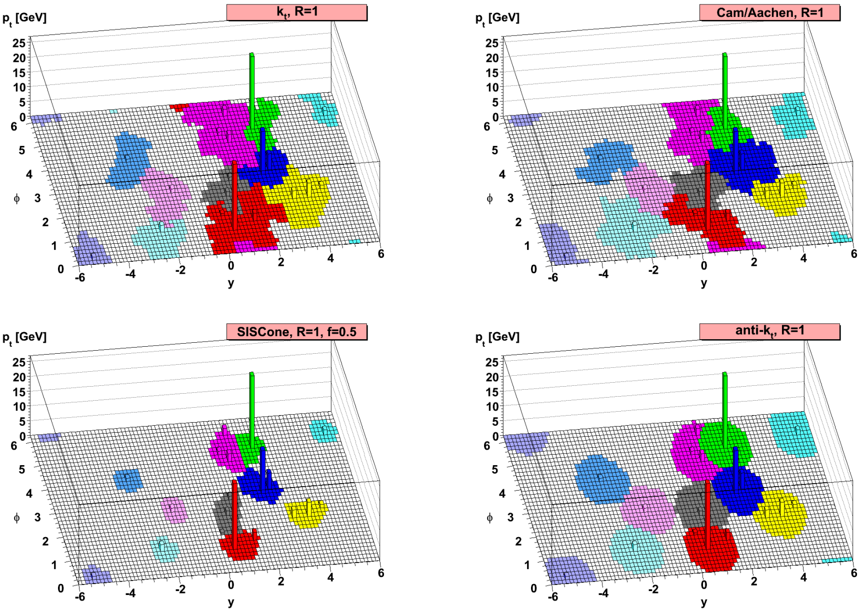
- Perturbative effects $\alpha_s p_t \ln R$
- Hadronisation effects $-\Lambda/R$
- Underlying event and pileup events $-\Lambda R^2$

Cacciari, Dasgupta, Magnea & GPS, prelim.

How, why and by how much do various algorithms differ

- Concept of jet areas — related to UE and pileup contamination, amenable to analytical calculation Cacciari, GPS & Soyez prelim.

Jet areas – visualised

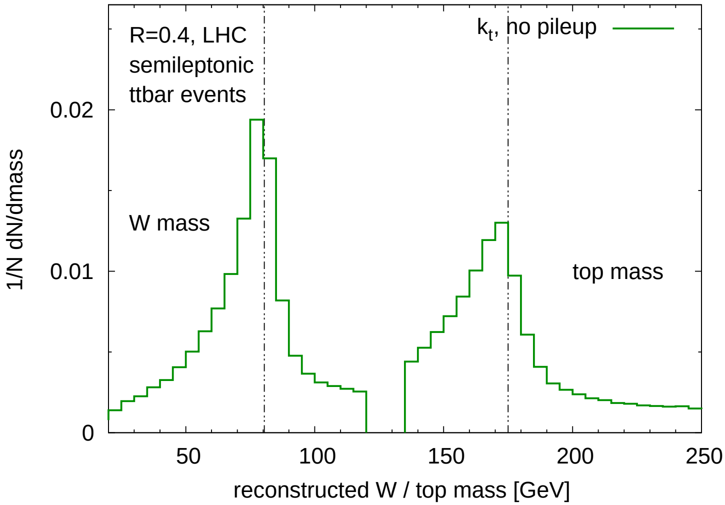


High-lumi

What do you do when pileup adds $25 - 50$ GeV/unit rapidity?

- Corrections based on $\#$ of primary vertices
- Corrections based on direct measure of pileup momentum-density
- Applied before jet-finding (calorimeter-level) or after (jet-by-jet)?
- How do detector effects (magnetic fields) modify pileup distribution?
- Do we subtract just PU, PU+UE?

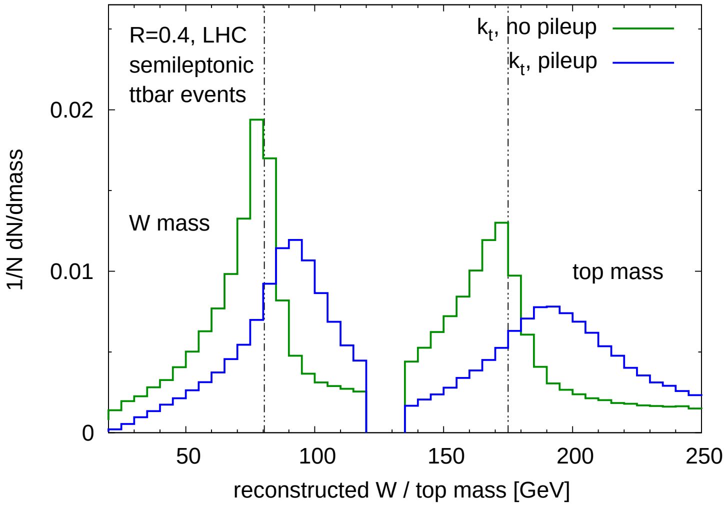
High-lumi



Example of jet-area based pileup subtraction [Cacciari & GPS, prelim.]

Will it work in a real experimental context?

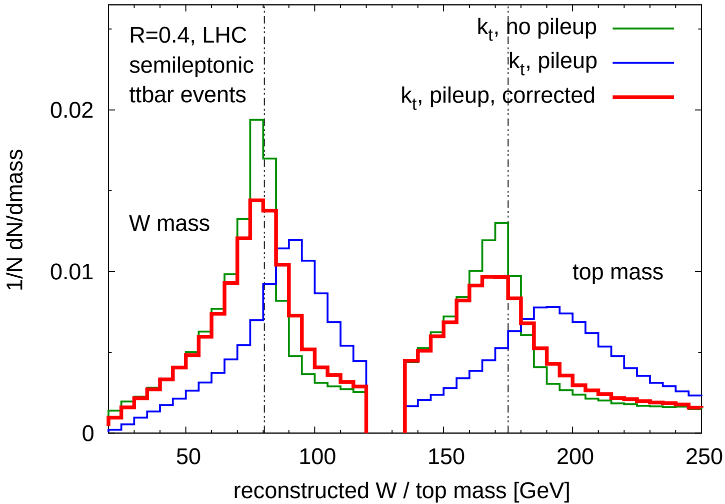
High-lumi



Example of jet-area based pileup subtraction [Cacciari & GPS, prelim.]

Will it work in a real experimental context?

High-lumi



Example of jet-area based pileup subtraction [Cacciari & GPS, prelim.]

Will it work in a real experimental context?

Advanced reconstruction techniques

Multi-scale, multi-jet final states have scope to benefit significantly from well-designed jet analyses.

Can we

- Get some benchmark BSM reconstruction tasks?
- Design "pre-packaged" strategies for boosted top/W/H?

E.g. subjet analyses with k_t algorithm
Butterworth Ellis & Raklev '06

- Check to what extent they survive detector effects?

Summary: broad goals for jets sub-group

- Get understanding of basic behaviour of jet algorithms in a range of contexts (top, BSM, with/without pileup)

  Standard “benchmark” event sets might be useful?

- Make sure the understanding applies to realistic LHC operation (range of luminosities, etc.)
- Use the information
  - to help guide hi-tech applications of jet algs. (certain searches, precision mass & coupling measurements)
  - recommend a ‘manageable’ set of jet-finding options for LHC

    Enough to retain flexibility, while staying simple

    But leave door open to future developments