

Study of the Underlying Event

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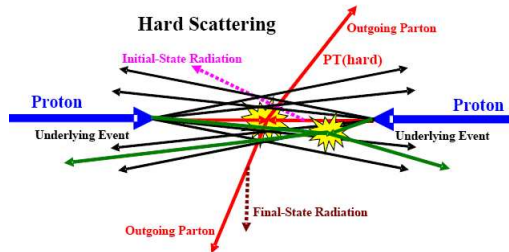
LMU Munich, LS Schaile

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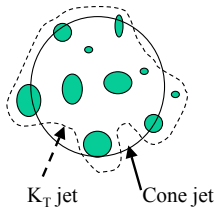
Goal: Determine the contribution of the Underlying Event and finally subtract it from the signal

⇒ hard part of the interactions (without Underlying Event)



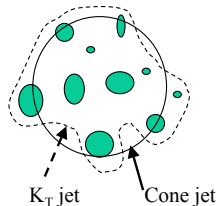
k_T -Jet algorithm

Different ways to identify particles as part of a jet



k_T -Jet algorithm

Different ways to identify particles as part of a jet



Exclusive k_T -Jet algorithm

- d_{Cut} : cut-off parameter for jet-merging
(we used: $d_{Cut} = 400 \text{ GeV}^2 \Leftrightarrow p_{T,min} \approx 20 \text{ GeV}$)
- jet-size and -shape are dynamic $\rightarrow$ no overlapping jets

Our concept

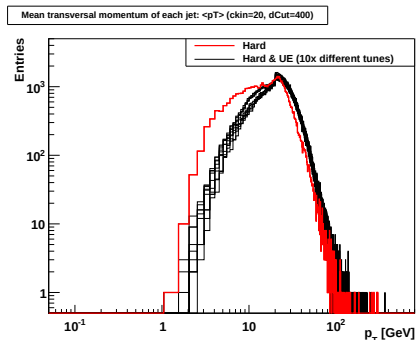
Taking the Underlying Event
into account:

- One additional jet per event (on the average)
- Transverse momentum of jets increases by approx. 10 GeV

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Approximation of the Underlying Event with low- p_T jet

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Basic idea:

Approximation of the Underlying Event with low- p_T jet

low- p_T jet:

- Jet with lowest p_T in an event
- If there are only 2 jets per event $\rightarrow$ force 3rd jet

Realization

$$\text{Data} \hat{=} (\text{Hard} + \text{UE})_{\text{simulation}}$$

Approach: $\text{Hard} = w \cdot \text{Data} = w \cdot (\text{Hard} + \text{UE})$

Assumption: $w = \frac{(\text{Data}) - (\text{low-}p_T)}{(\text{Data})}$

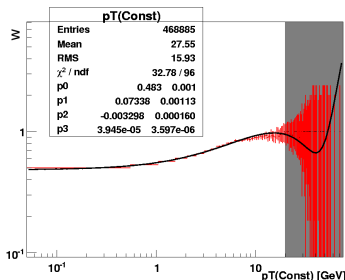


With the idea: Underlying Event $\approx$ low- p_T jet

Realization

With the idea: Underlying Event $\approx$ low- p_T jet

- Usage of function w for correcting single events separately
- Large statistical errors around 20 GeV
 $\Leftrightarrow$ Apply weight w for $p_T < 20$ GeV ($w \approx 1$ for $p_T > 20$ GeV)



Realization

- With $w = \frac{(Data)-(low-p_T)}{(Data)}$:

Data corrected for Underlying Event $\Rightarrow$ **Hard process**

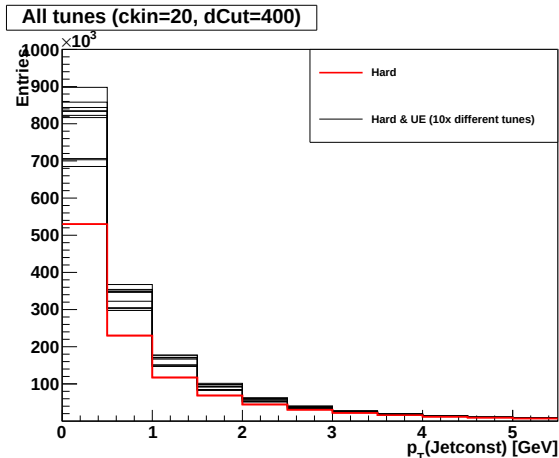
Used tunes

Tune	Published	
AMBT1 (first of ATLAS: 7 TeV)	May 2010	} New tunes
ATLAS MC09	2009	
ATLAS MC09c	2009	
Perugia K	May 2010	
Perugia10	May 2010	
Perugia 0	Feb 2009	
Pro-Q20	Feb 2009	
Tune A (CDF Tune)	Oct 2002	} Old Tunes (often used in publications)
Tune DW (CDF Tune)	April 2006	
Multiple parton interaction (mpi)		
New model of mpi	~2005	

Implementation

- Event generator: Pythia 6.4.23
- Simulations:
 - Hard scattering
 - Hard scattering + Underlying Event

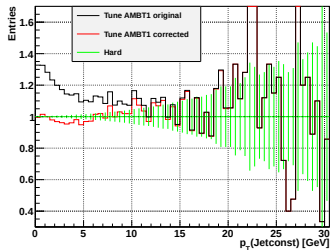
p_T constituents of Hard & Hard+UE



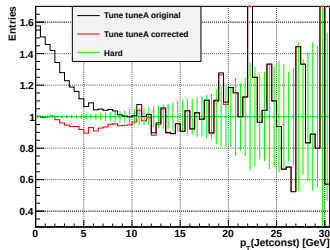
$d\text{Cut} = 400 \text{ GeV}^2$, $\underline{c_{\text{kin}}} = 20 \text{ GeV}$ and **scaled** low- p_T jet

Normed with Hard (**scaled** low- p_T jet):

scalefactor diff, ckin20: AMBT1



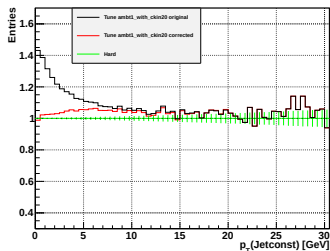
scalefactor diff, ckin20: tuneA



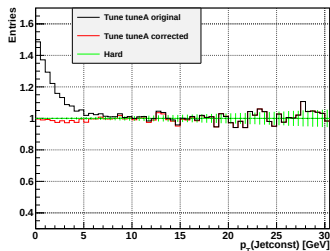
$d\text{Cut} = 400 \text{ GeV}^2$, $c_{\text{kin}} = 100 \text{ GeV}$ and **scaled** low- p_T jet

Low- p_T jets from $c_{\text{kin}} = 20 \text{ GeV}$

scalefactor diff, ckin100: ambt1_with_ckin20



scalefactor diff, ckin100: tuneA

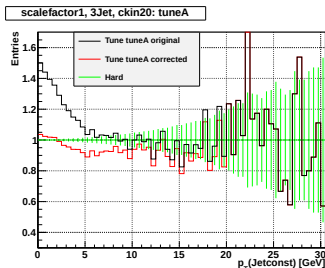
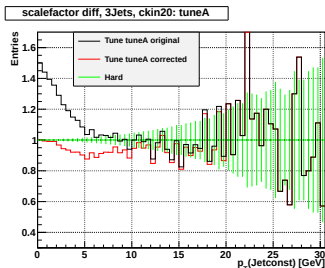


Comparison: Scaled & Unscaled tunes

Scaled



Unscaled



There seems to be no reason to scale low- p_T jets

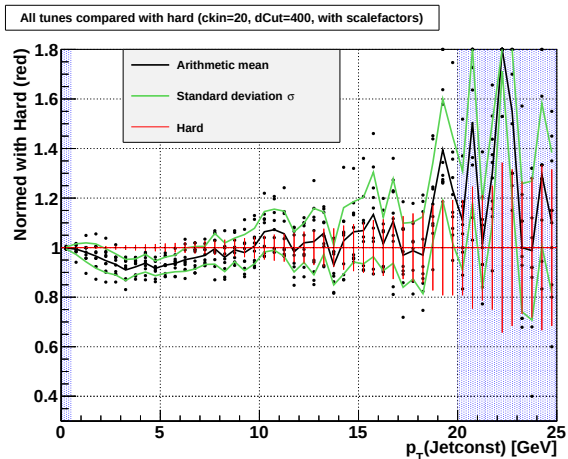
First Idea:

- Reason for scaling: Adjust the different cross sections
- But: No reference point for scaling factor

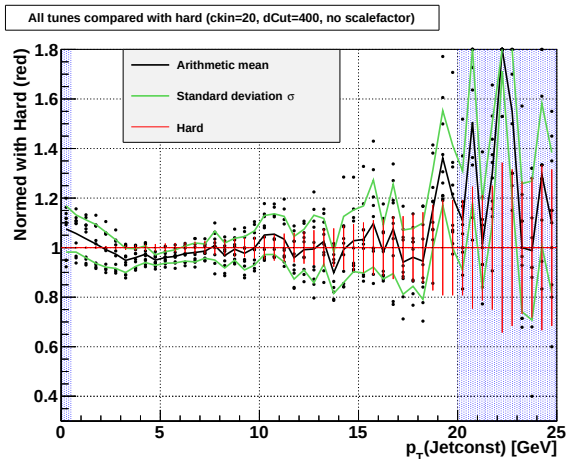
All tunes

Statistical Analysis: All tunes compared with Hard

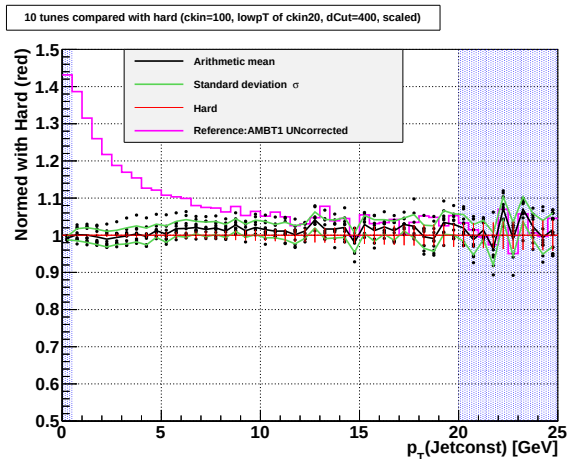
All 10 tunes (scaled): $c_{kin} = 20$ GeV



All 10 tunes (**unscaled**): $\text{ckin} = 20 \text{ GeV}$



All 10 tunes (scaled): $c_{kin} = 100$ GeV



Summary

- Underlying Event correction by low- p_T jet yields Hard process within range of statistical uncertainty

⇒ Confirmation: Underlying Event $\approx$ low- p_T jet

- In the important region $2 \text{ GeV} < p_T < 15 \text{ GeV}$:
The New Method approximates the Underlying Event with an error of at most 10 %.

BACKUP

Realization

- $\text{Data} \hat{=} (\text{Hard} + \text{UE})_{\text{simulation}}$
- **Assumption:**
 - $\text{Hard} = w \cdot \text{Data} = w \cdot (\text{Hard} + \text{UE})$
 - $w = \frac{(\text{Data}) - (\text{low-}p_T)}{(\text{Data})}$, weights each particle with $p_T < 20\text{GeV}$

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- **Assumption:**
 - $\text{Hard} = w \cdot \text{Data} = w \cdot (\text{Hard} + \text{UE})$
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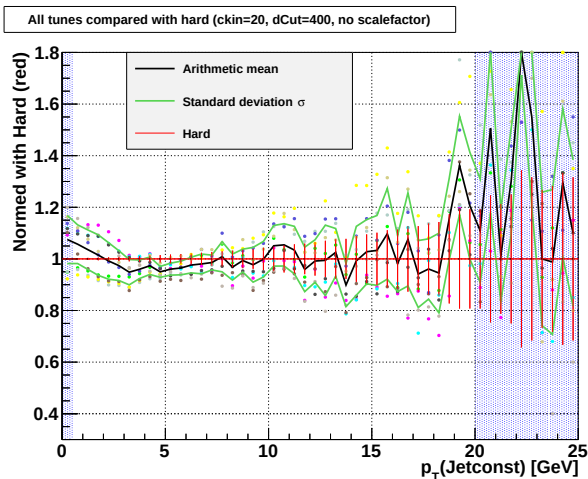
- Justification:

$$\begin{aligned}
 \text{Hard} &\stackrel{?}{=} w \cdot \text{Data} \\
 &= w \cdot (\text{Hard} + \text{UE}) \\
 &= \frac{(\text{Hard} + \text{UE}) - (\text{low-}p_T)}{(\text{Hard} + \text{UE})} \cdot (\text{Hard} + \text{UE}) \\
 &= (\text{Hard} + \text{UE}) - (\text{low-}p_T) \\
 &= \text{Hard}
 \end{aligned}$$



- with the idea: Underlying Event $\approx$ low- p_T jet

All 10 tunes (**unscaled, colored**): $\text{ckin} = 20 \text{ GeV}$



AMBT1

Atlas MC09c

Atlas MC09

DW

MPI

New: MPI

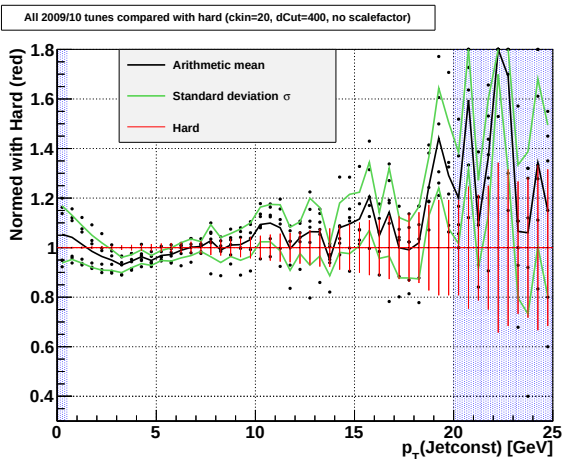
Perugia 10

Perugia k

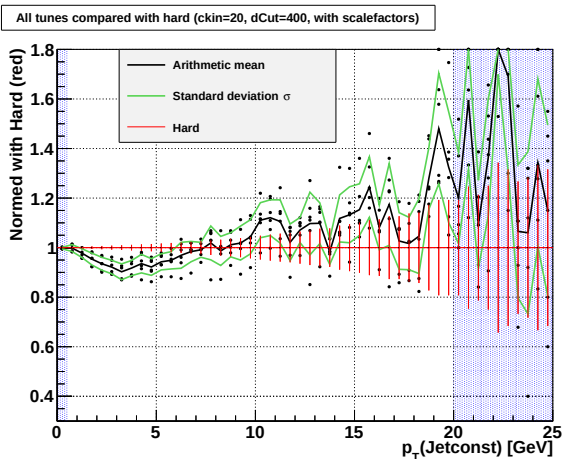
Pro-q2o

tuneA

New 2009/10 tunes (unscaled): $\text{ckin} = 20 \text{ GeV}$



New 2009/10 tunes (scaled): $\text{ckin} = 20 \text{ GeV}$



Implementation parameters

Six major parameters:

- 1 cm-energy: $\sqrt{s} = 7 \text{ TeV}$
- 2 Number of collisions (20.000)
- 3 Only keep particular particles (final-state particles)
- 4 Different tunes
- 5 dCut-value (400 GeV^2) and alternatively fixed 3-jet events
- 6 ckin-value ($\hat{=}$ lowest p_T in hard $2 \rightarrow 2$ scattering):
20 GeV, 50 GeV, 100 GeV