Underlying Event Studies for LHC Energies

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Outline

0. Motivation

I. Definition for Underlying Event
   - The CDF method
   - SB – a new method for UE studies

II. Test SB method by jets & hadron correlation
   - Underlying Event analysis with jets
   - Hadron correlation with 'set-selections'
   - π, K and p-triggered correlations

III. Summary & Outlook

Refs.: AG Agócs, P Lévai: PoS EPS-HEP 2009 472
AG Agócs, GGB, P Lévai: Proc. for HQ2010
0. Motivation

- What should be more motivative than this...?
I. The Underlying Event
CDF definition of UE

- Developed to subtract the UE as a background.
- There is no dependence contrary to the cone-like shape of jets.
- “The transverse region is perpendicular to the plane of the hard 2->2 scattering and is very sensitive to the UE component of the QCD MC models.”
Generalization of UE

A new method for UE

- Based on surrounding cones, ring-shaped subregions can be defined: Surrounding Belts (SB) of the UE. They grasp the border region between the UE and jets.
- Inner and outer SB, for both near-side and away-side jets.

**AGA & PL: PoS EPS-HEP 2009 472**

UE is defined as everything outside the jet cones. The geometry is more “liquid”, in both $\Phi$ and $\eta$. 

09/30/10 G.G. Barnaföldi, MTA KFKI RMKI
Comparison of CDF & SB UE

- **Common**
  - Similar for back-to-back di-hadron corr.
  - Test areas are fix in both cases.
  - SB is generalization of CDF, so a huge size SB looks CDF-like.
  - Even small statistic is enough to evaluate.

- **Differences**
  - SB can handle 2 -> 3 and good for $n$-jets.
  - Depends on jet cone size (or jet finder alg.).
  - Taking more SBs leads to differential test of UE properties.
  - Requires higher statistic (in SBs).
II. Test SB method by jets and hadron-hadron correlation
Geometrical structure of UE

Proton-proton @ 14 TeV

• Analysis:
  • 100 k PYTHIA 6.4 CSC
  • UA1 jet finder, R=0.7
  • $Q > 100$ GeV/c
  • $P_T < 3$ GeV/c
  • **SB**: $\delta R=0.1$

• Polar plot for charged hadron $p_T$-distribution with:
  • Intermediate multiplicity: $50 < N_{ch} < 60$

$\langle p_T\rangle_{UE} < 1$ GeV/c

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  • $\textbf{SB: } \delta R=0.1$

• Polar plot for charged hadron $p_T$-distribution with:

  • High multiplicity: $80 < N_{\text{ch}} < 90$
UE study with mean-$p_T$ vs. $N_{\text{UE2}}$

Proton-proton @ 14 TeV

- **Jets:**
  - Leading & Away side jets has high-$<p_T>$ & low-$N_{\text{UE}}$

- **Surrounding Belts:**
  - Independent, constant $<p_T> = 1$ GeV/c

- The newly defined UE:
  - $<p_T>$ increasing with larger $N_{\text{UE2}}$
From jets to di-hadron correlation

High-$p_T$ tests:

- Jets: full geometry reconstruction
- Hadron-hadron correlation ($\Phi$ direction)

Jet analysis

\[ + \int d\eta \quad \]
• Assume to have identified jets or 'jet-like' objects at near side and away side.
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• Define the projection of 1st surrounding cone (SC1) minus jet cone ⇒ Result: surrounding belt (SB1) on the near and away side (width: $\delta \Phi$).
Defining Surrounding Belts (SB2)

• Assume to have identified jets or 'jet-like' objects at near side and away side.
• Define the projection of 1\textsuperscript{st} surrounding cone (SC1) minus jet cone $\Rightarrow$ Result: surrounding belt (SB1) on the near and away side (width: $\delta\Phi$).
• Define a 2\textsuperscript{nd} cone (SC2), then subtract SC1 $\Rightarrow$ Result: SB2 on the near and away side (chosen width: $\delta\Phi$).
Physical observables for SBs

SB studies are similar to CDF UE:
- $p_T$ spectra for the SB
- Multiplicity in each SB
- Mean $p_T$ for inner and outer SB
- PID-triggered study

Comparison between SBs can be make also:
- Ratio of SB's $p_T$-spectra
- Jet-side effects, jet enviroment studies, etc.
Technical details of the simulation

The events are generated

- PYTHIA 6.4 ATLAS-CSC tune

For hadron correlation studies we use

- Minimum-bias events, $|\eta| < 0.35$
- $100M$ events @ $\sqrt{s} = 200$ GeV
- $100M$ events @ $\sqrt{s} = 2.36$ TeV
- $45M$ events @ $\sqrt{s} = 7$ TeV
PID-triggered angular correlations @ 7TeV pp

- Trigger in $p_T$ [2 GeV/c ; 4 GeV/c]
- Hadron flavor dependence is seen.
Ratios of $p_T$ spectra $\pi$-triggered $\pi$

- Near side spectra / UE
- Away side spectra / UE
- Near / Away side spectra
Selections for SB with size-vary

- Based on definitions of SB1 & SB2, we defined 3 'sets' testing UE via the new SB method.

| Selection | SB angle | $R_{\text{effective}}$ | Belt width $\delta\Phi_{SB} \& \delta R$ |
|-----------|----------|-------------------------|--------------------------------------|
| CDF-set   | 120°     | 2.3                     | 6° & 0.1                             |
| R-set     | 60°      | 1.3                     | 6° & 0.1                             |
| $\sigma$-set | $\sigma_{\text{near}} = 16°$ | $R_{\text{near}} = 0.75$ | 6° & 0.1 |
|           | $\sigma_{\text{away}} = 19°$ | $R_{\text{away}} = 0.77$ |                                       |
Results on p-triggered SB near /SB away

![Graph showing results on p-triggered SB near /SB away](image)

**Legend:**
- **SB**$_{\text{inner}}$ / SB$_{\text{outer}}$
- **SB**$_{\text{inner}}$ / SB$_{\text{outer}}$ CDF-set
- **SB**$_{\text{inner}}$ / SB$_{\text{outer}}$ R-set
- **SB**$_{\text{inner}}$ / SB$_{\text{outer}}$ σ-set

**Graph Details:**
- **Particles:** $\pi^+$, $\pi^-$, $K^+$, $K^-$, $p$
- **Collisions:** 7 TeV p+p
- **Regions:** Full: INNER (SB1), Empty: OUTER (SB2)

**AGA, GGB, PL.: Proc. for HQ2010**
Comparing p- and π-triggered cases

PID triggered SB near / SB away spectra ratios

- Quantum numbers are conserved (C, I, S, B)
- Strong effect on baryon number, B (and S also)
- HMPID or VHMPID may measure this, using PID
III. Summary & Outlook

- **UE defined by the Surrounding Belt:**
  - Similar like CDF UE, but more physical observables.
  - In case of hadron-hadron correlation in pp SB1 and SB2 are similar.
  - Triggered hadron-hadron correlation, led to test e.g.: baryon/anti-baryon or strangeness balance.

- **Outlook:**
  - More detailed study with jets (different algorithms)
  - Similar analysis on PbPb is ongoing (UE modification)
  - Simulations for using PID detector capabilities
BACKUP SLIDES
An ancient red pottery story

- No, it's not workin'!
- ...wait for a new tune...
- ...go to PYTHIA and tell 'er!
An ancient red pottery story

No, it's not workin'!

...wait for a new tune...

...go to PYTHIA and tell 'er!

You know me... I'm an oracle!

You are not forTUNE teller!
New method in pp collisions at 2.36 TeV:
Angular (\(\Phi\)) and \(p_T\) distributions
Clear back-to-back structure is seen
Particles, hadrons
Bayesian on high \(p_T\)s in given bins