b-JETS AT LHCb

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LHCb is an LHC experiment dedicated to $CP$ measurements and $B$ rare decays.

Nominal luminosity $2 \times 10^{32}\text{cm}^{-2}\text{s}^{-1}$

About $10^{12}$ $bb$ pairs per year, one nominal LHCb year (2$fb^{-1}$)
LHCb overview

LHCb is an LHC experiment dedicated to \( \overline{C}P \) measurements and B rare decays

Requirements for measurements in B hadrons system are:
good particle identification, excellent tracking and vertexing
LHCb is an LHC experiment dedicated to $\mathcal{CP}$ measurements and B rare decays

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Vertexing:
Expected primary vertex resolution
~10μm transverse plane and
~60μm in the longitudinal one

Expected Impact parameter resolution $\sigma_{IP}=14\mu m+35\mu m/p_T$
As a textbook case we use SM Higgs decaying to $b\bar{b}$ with $m_H=120\text{GeV}$ in association with $e$ or $\mu$ from $W$ or $Z$.

Comparison of Cone algorithm with seed and $Kt$ shows similar results in terms of di-jet mass resolution for this study. In the following $Kt$ is used.

**Optimal $R$ value is 0.7<$R<$0.9**
b-Jets at LHCb– Hera-LHC workshop, May 27th, 2008 – Victor Coco

**b-JETS RECONSTRUCTION AND IDENTIFICATION**

**Detector acceptance study at generator level**

- Pseudorapidity of b-quarks coming from H(120GeV) (high pt lepton in the acceptance)
  - 15mrad
  - 300mrad

Outside LHCb acceptance

- 4% of 4π str

- Acceptance losses disturb the partonic picture of the event

- Dijet mass resolution is affected

- Real jet axis

Acceptance losses disturb the partonic picture of the event

Dijet mass resolution is affected

**Graphs**

- Pseudorapidity of b-quarks coming from H(120GeV) (high pt lepton in the acceptance)

- Dijet mass with geometrical acceptance cut (GeV/c²)

- Dijet mass without acceptance cut (GeV/c²)
b-Jets reconstruction and identification

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b-JETS RECONSTRUCTION AND IDENTIFICATION
LHCb strategy for jet reconstruction

- Reconstruction
  - Matching tracks and electromagnetic clusters
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LHCb strategy for jet reconstruction

- Reconstruction
  - Matching tracks and electromagnetic clusters
    - Charged
      - Use track information
    - Neutrals
      - Use calorimetric information
  - 4-momenta
**b-JETS RECONSTRUCTION AND IDENTIFICATION**

**LHCb STRATEGY FOR JET RECONSTRUCTION**

![Diagram](image-url)

- **Reconstruction**
  - Matching tracks and electromagnetic clusters
    - Charged
      - Use track information
    - Neutrals
      - Use calorimetric information

- **B-seed finding**
  - Cone algorithm with B-seed
  - 2 B-seed from "2 tracks" secondary vertex

- **2 jets/event created**

- **SRA**
  - Kt jet algorithm
  - B-jet tagging

- **b-jets**

*For R=0.7 ~15 jets/event reconstructed ¼ of them have pt>5GeV/c with mean number of particles: 13

Ideally 2 jets/event

* *SRA: sequential recombination algorithm*
Only the jets that are well inside the acceptance and known to be b-jets are considered here.

Absolute corrections are determined as a function of $p_T$ and $\eta$.

Non-linearity < 5% in energy.

LHCb allow reconstruction of b-jet in the range $2 < \eta < 4$.

Mass pick is displaced 120$\rightarrow$$103\text{GeV}$, mainly because of neutral hadron and neutrino losses.

Improvement expected by adding HCAL information.
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**b-JETS RECONSTRUCTION AND IDENTIFICATION**

**b JETS IDENTIFICATION IN FULL SIMULATION**

Jet is defined as b jet if it has:

- \( pT > 5 \text{GeV} \), 4 tracks and 2% of charged energy (primary cut)
- \( |\text{NNSel}| > 0.2 \)

NNSel is a neural net trained to discriminate b jets from lights and c jets. Made from variables:

- Number of particles in jet
- Number of tracks with \( \sigma_{IP} > 4 \)
- Percentage of energy of from tracks with \( \sigma_{IP} > 4 \)
- Percentage of energy of from charged particles
- Percentage of energy in a cone of \( R = 0.4 \) around the jet axis
- Jet area and pt flux

And two weight defined as:

\[
b_{\Delta_{lll},b\rightarrow\text{light}} = \sum_{\text{constituents}} \ln \left( \frac{p\text{d}f_{b}(\chi_{IP}^{2}, IP, PT)}{p\text{d}f_{\text{light}}(\chi_{IP}^{2}, IP, PT)} \right)
\]

And

\[
b_{\Delta_{lll},b\rightarrow c} = \sum_{\text{constituents}} \ln \left( \frac{p\text{d}f_{b}(\chi_{IP}^{2}, IP, PT)}{p\text{d}f_{c}(\chi_{IP}^{2}, IP, PT)} \right)
\]

**Taking into account only jets that pass primary cut in some tt events**

- **b-jets selection:** 70%
- Rejection of:
  - b-jets partially in acceptance: 93.5%
  - Non b-jets: 96.5%
  - Composed of:
    - light-jets: 97.5%
    - All c-jets: 95%
    - Hard c-jets: 85%

No explicit vertex reconstruction, and no semi-leptonic B-decays were used

**Still room for improvement (especially for c-jets rejection)**

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b-Jets reconstruction and identification

Influence of acceptance in full simulation

Only the jets that pass the b-jet selection are considered here

With b jet selection, about 50% of the reconstructed di-jet events are selected

In gaussian approximation:

Considering only b-jets well inside acceptance.

Sigma/mean = 21/103 ~ 20%

Considering all selected jets:

Sigma/mean = 23/101 ~ 22%

On which 8% of di-jets contains one jet that is not a b jet well inside the acceptance.
Of course light SM Higgs decaying into $\bar{b}b$ in association with high transverse momentum lepton would be a (very) nice measurement.

But generator level study shows that $\bar{t}t$ background is difficult to remove.

Backgrounds: $\bar{b}b$ inclusive (reduced by high pt isolated lepton)

- $\bar{t}t$, Z+2b, W+2b
- ZZ, ZW

Under study...

The development of a framework for b-jets studies in LHCb open other possibilities

- At LHC start ... measurements of Z production decaying into $\bar{b}b$

- Models beyond SM, involving several b-jets and highly displaced vertices, are studied
  - Hidden Valley Models
  - SUSY models with neutralinos with finite lifetime
Interesting process for LHCb

Hidden Valley

It is a class of phenomenological models which
- appear to be consistent with data and well motivated
- arise in many models
- appear to be consistent with most methods for solving the hierarchy problem

Extend the SM gauge group $G_{SM}$ with non-abelian group $G_v$
High dimension *operators at TeV scale* allow *interactions between SM and new particles*
Some neutral $v$-hadrons can decay into gauge-invariant combinations of SM-particles, *with observable lifetimes* (from zero to infinity)

Matthew J. Strassler & Kathryn M. Zurek
hep-ph/0605193 “Discovering the Higgs through highly-displaced Vertices”

“...Indeed it is possible that the LHCb experiment is ideally suited for detecting and studying such states.”
Interesting process for LHCb

Hidden Valley

Efficiency to reconstruct and associate b-jet to a b-quark

There is potential to reconstruct multi b jets events coming from long life time new particles

Thanks to vertex detector we might be able to reconstruct b jets until lifetime of the order of 50cm
Interesting process for LHCb

Susy Neutralino with finite lifetime

MSSM/MSUGRA with R-parity violation, baryon number violation and non-unified gaugino masses. Light Higgs decays mainly into lightest neutralinos with finite lifetime.

D. Kaplan, L. Carpenter, E.-J. Rhee
hep-ph/0607204 Reduced Fine-Tuning in Supersymmetry with R-parity violation
Proposal for Higgs and Superpartner Searches at the LHCb Experiment

\[ L \propto \frac{1}{\lambda''^2} \]

Baryon number violation coupling constant

\[ \lambda'' = 10^{-3} \]
\[ \lambda'' = 10^{-4} \]
\[ \lambda'' = 10^{-5} \]
\[ \lambda'' = 10^{-6} \]

\[ L \sim 100 \text{ [um]} \]
\[ L \sim 10 \text{ [mm]} \]
\[ L \sim 1 \text{ [m]} \]
\[ L \sim 100 \text{ [m]} \]

Might be detected at LHCb

Aim is to find 4 displaced vertices (2 from \( \chi_0 \) and 2 from B or D daughters) with high number of track

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Interesting process for LHCb
Susy Neutralino with finite lifetime

$m_\chi = 50 \text{ GeV/c}^2 \quad m_{h_0} = 115 \text{ GeV/c}^2 \quad \lambda'' = 10^{-4}$

Generator level study with vertex smearing
Only charged tracks are used

Study is based on topological selection of displaced vertices for $\chi_0$, $B$ and $D$

Displaced vertex are collected two by two to identify a $\chi_0$ decay and then two $\chi_0$ are by events required to build $h_0$

$\sigma_h = 62.7 \text{ pbarn}$

nb of evts = 5000 – 100'000

nb of evts in accept. = 1000 – 25'000

nb of evts after trigger = 800- 20'000

Potential to detect massive displaced vertices with high number of tracks ( > 6)
Tools are developed to *reconstruct b-jets in LHCb*

Reconstruction is effective within $2<\eta<4$

*b-jet identification benefits from high resolution vertexing*

Possibility of detecting *highly displaced vertices* from *new physics* processes

*Beside important B physics measurements*

*LHCb has potential to observe New Physics processes in high rapidity region*