The Bi-Event Subtraction Technique (BEST) for Hadron Colliders

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arXiv:1104.2508
Outline

1. Combinatoric Background at Colliders
   - Standard Model @ Large Hadron Collider
   - Beyond SM @ LHC Example: SUSY

2. Bi-Event Subtraction Technique
   - BEST Explained
   - BEST does $t\bar{t}$
   - BEST does SUSY

3. Conclusions
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Standard Model of Particle Physics

Standard Model (SM) Particles

- Explains matter and interactions on our planet.
- Higgs yet to be found.
- Mostly understood. ⇒ Room for improvement!
- Beyond SM needed for dark matter, dark energy, inflation...

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**Standard Model (SM) Particles**

<table>
<thead>
<tr>
<th>(u_L)</th>
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<th>(e_L)</th>
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<th>(\nu_e)</th>
<th>(\nu_{eL})</th>
<th>(\nu_{eR})</th>
<th>(\mu_L)</th>
<th>(\mu_R)</th>
<th>(\tau_L)</th>
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</tr>
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<tr>
<td>(d_L)</td>
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<td>(W^+)</td>
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| (u)_{L} | u_{R} | (e)_{L} | e_{R} |
| (d)_{L} | d_{R} | (\nu_{e})_{L} | \nu_{e} |
| (c)_{L} | c_{R} | (\mu)_{L} | \mu_{R} |
| (s)_{L} | s_{R} | (\tau)_{L} | \tau_{R} |
| (t)_{L} | t_{R} | (\nu_{\tau})_{L} | h^{0} |
| (b)_{L} | b_{R} | (W^{+}) | Z^{0} |

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<tr>
<td>(c)</td>
<td>c_R</td>
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<tr>
<td>(s)</td>
<td>s_R</td>
<td>\nu_\mu</td>
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<tr>
<td>(t)</td>
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<td>\tau_L</td>
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<td>(b)</td>
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**Standard Model @ Large Hadron Collider**

**Beyond SM @ LHC Example: SUSY**
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Large Hadron Collider

Hadron Colliders
- Standard Model
- Beyond the Standard Model
  - ex. Supersymmetry

$\ell, W^+, W^-, t, \bar{t}, b, \bar{b}$

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BEST 4/10
Large Hadron Collider

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\[ q \rightarrow W^+ \rightarrow t \rightarrow b \]

\[ q \rightarrow W^- \rightarrow t \rightarrow \bar{b} \]

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$q \leftrightarrow W^- \leftrightarrow \ell \rightarrow \nu$

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SUSY at the LHC Dilemma...
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\[ \tilde{q} \rightarrow j_1, q, \tilde{\chi}^0_2 \]
\[ \tilde{\tau}^\pm_1, \tau^\pm \]
\[ E_T \]

\[ p \rightarrow \tilde{g} \rightarrow j_3, q, \tilde{\chi}^\pm_1 \]
\[ \tilde{\chi}^0_1 \rightarrow W^+ \rightarrow j_4, q, j_5 \]
Bi-Event Subtraction Technique (BEST)

Event \#n

j

(W)

j

j
Bi-Event Subtraction Technique (BEST)

Event \#n

\[
\begin{pmatrix}
\text{(W)} \\
n_j
\end{pmatrix} \\
m_{jj}^{\text{same}}
\]

\[
\begin{pmatrix}
\text{j} \\
n_j
\end{pmatrix}
\]
Bi-Event Subtraction Technique (BEST)

Event \#n-1

Event \#n

\[ j \]

\[ j \]

\[ j \]

\[ j \]

\[ j \]

\[ j \]

\[ j \]

\[ (W) \]

\[ m_{jj}^{\text{same}} \]

\[ m_{jj}^{\text{bi}} \]
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Event #n-1

\[ j \]

\[ j \]

\[ j \]

\[ m_{jj}^{bi} \]

\[ j \]

Event #n

\( \{ j \} \)

\[ (W) \]

\( m_{jj}^{same} \)

\[ j \]

\[ j \]

\[ j \]
What BEST Looks Like...
What BEST Looks Like...

![Graph 1](counts_same)

![Graph 2](counts_bi)

**m_{jj}^{\text{same}} (GeV)**

**Counts / 5 GeV**

**m_{jj}^{\text{bi}} (GeV)**

**Counts / 5 GeV**

**Normalization**
What BEST Looks Like...

- \( m_{jj}^{\text{same}} \) (GeV)
- \( m_{jj}^{\text{bi}} \) (GeV)
- \( m_{jj}^{\text{BEST}} \) (GeV)
**t Reconstruction with BEST**

Even with backgrounds, BEST triumphs.

- 7 TeV collision energy @ LHC, 2 fb⁻¹.
- ALPGEN - $t\bar{t}$ signal and $W$+jets background
- PYTHIA - shower
- PGS - detector

$$m_W = 81.11 \pm 0.32 \text{ GeV}$$

$$m_t = 170.5 \pm 1.5 \text{ GeV}$$
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Endpoint Techniques with BEST

Even with backgrounds on top of SUSY, BEST triumphs.

- 14 TeV collision energy @ LHC, 100 fb$^{-1}$.
- nuSUGRA: $m_0 = 360$ GeV, $m_{1/2} = 500$ GeV, $\tan \beta = 40$, $A_0 = 0$, and $m_H = 732$ GeV.
- SM: $\bar{t}t$, $W+$Jets, and $Z+$Jets.
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$\text{Counts / } 5 \text{ GeV}$

$\text{Counts / } 50 \text{ GeV}$

$m_{jj}^{\text{same}}$, $m_{jj}^{\text{bi}}$, $m_{jj}^{\text{BEST}}$

$m_{jj}$ (GeV)

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The Power of BEST

- Removes combinatoric background of jets.
- Useful without charge or flavor.
- Can help to uncover nearly invisible signals.
- Useful for any hadron collision experiment.

arXiv:1104.2508
Also see:

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Backup Slide: Huge $W$ finding plot for SUSY.
Sideband Subtraction

\[ N_{SB} = \frac{\int_{m_{jj}^{\text{band}}} f(m_{jj}) \, dm_{jj}}{\int_{m_{jj}^{\text{sideband}}} m_{jj} \, dm_{jj}} \Rightarrow m_{jj}^{\text{Sub}} = m_{jj}^{\text{W band}} - N m_{jj}^{\text{sideband}} \]
Backup Slide: Sideband Subtraction

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Backup Slide: Sideband Subtraction

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