The Data:
A set of 10K 500GeV $e^+e^-\rightarrow BB\_bar$ with the CM_energy of the B going as low as 2 GeV and produced at NIU.

Examples

The Algorithm:

The Muon Identification Efficiency:

Contamination

Conclusion:
Examples

Typical B-Bbar events follow to clarify further the choice of the Algorithm.
Example (1)
Two characteristic Muons with 31 layers each and 1 hit/Layer most of the time.
Example (2)
Two Typical Pions, one of them has 10 Layers with hits and 3 to 4 hits/Layer in more than 3 layers.
Example (3)
A Muons and a Pion “disguised” in muon and passing having 1 hit/Layer in 31 layers.
Example (4)
Two Muons one of them with hits in 12 Layers, 2 hits/Layer in more than ½ the layers.
Example (5)
Two Muons with both many two hits/layer.
B-Bbar- 2 “Typical” Muons
Mu-(30.7GeV) –Mu+(8.7GeV)
Each One with Hits in 31 Layers in MuDet
B-Bbar- 2 “Typical” Pions
1\Pi(15\text{GeV})-1\pi(11.4\text{GeV})
15 \text{ GeV} - 3 \text{ Layers } \geq 3 \text{ hits, 11.4 GeV No Track Fit}
B-Bbar-2 “Candidates” Muons
1Mu(5GeV), 1Pi(4.3GeV)
Each With 1Hit/Layer-31Layers
B-Bbar to 2 “Candidates” Mu(8GeV) -Mu(4GeV)
Mu(4GeV) With 12 Layers
(7*2hits/Layer+1*3hits/Layer)
B-Bbar- 2Mu "Candidates"
1Mu(13.4 GeV)-8 Layers-8*2hits/Layer
1Mu(6.25 GeV)-28 Layers-10*2hits/Layer
B-Bbar- A Muon “Candidate” Which Is A Pi(12 GeV) 1Hit/Layer-31 Layers
The SD Muon Detector

**MuCal:**

Outer_Radius 660.5cm  
Inner_Radius 348.5cm  
---------  
312 cm

**The Unit:**

Fe 5cm  
Gap 1.5cm RPC/gap  
48 Layers  
80cm Fe=16 planes  

#Inter. Length(λ)  |  SD(EM+HAD)= 3.9 λ(Si+W)
Prior to MuDet  |

SD Magnetic Field = 5 Tesla
The Muon Detection

The Muons Candidates Have been defined by :

- Extrapolating a reconstructed Track to the Calorimeters
- A set of hits in HDCal within a number of \((\phi, \theta)\) bins from the track – (bin size \(\pi/600\)).
- At least 16 hits in MUCal within momentum dependent \((\phi, \theta)\) bins from the track \(\Delta\Phi_{\text{bins}}(\text{Tk-HDCal}) = \text{Max}(2*20/P , 2)\) and \(\Delta\theta_{\text{bins}}(\text{Tk-HDCal}) = \text{Max}((20/p)+1 , 2)\) - (bin size \(\pi/150\)).


- The Momentum dependant cut has allowed to expand the low energy end from 4 GeV/c down to 3 GeV/c. It also improves the detection efficiency energy for Muons below 6 GeV/c. For the same task, the EMCal information has been included to the package.

Remark: We are looking only in the Barrel Detector.
The Hadron suppression:
- Hadrons tend to produce multi-hits/Layer, the Muons 1hit/Layer and at most two. We require at least 8 layers for 16 hits and a cut in the Number of layers of multiplicity \( \geq 3 \) hits/Layer, allow to get rid of more than 50% of hadrons without affecting the muons.

Remarks:
- The End-Caps have been accounted for by a cut in 0.95 \( \Theta < \Phi \leq 2.2 \) rd

- The Compton Scattering and the dE/dx have been studied extensively and it has been shown to be included in the smearing in angles of the order of one bin in the MUCal and EMcal and 2 bins in the HDCal and it is covered by our \( \Theta \) and \( \Phi \) cuts. (see http://home.fnal.gov/~caroline - multi_scat.pdf)
The Data

The BB_bar have been generated at NIU using Pandora-Pythia

**PANDORA** is a parton-level Event generator which includes:
- Bremssthalung
- Initial States Radiations
- Full treatment of Polarization effects

Events produced by Pandora are processed by **PYTHIA** used to
- Simulate gluon showering
- Fragmentation of final state quarks
- **TAUOLA** is used to decay Tau-leptons

There are **NO RADIATIVE CORRECTIONS** included
The Detection

The Muon Momentum Distribution and Detection efficiency:

The Muon detection efficiency is given next in the Barrel alone.

It has been extracted from the Momentum distribution which follows.

- A cut at 2.96 GeV for the generated Muons takes care of those Muons which does not reach the Muon Detector. An overall mean Detection Efficiency for Muons \( \geq 3 \text{ GeV/c} \) of \( 81.8\pm4.4\% \).
- At 3 GeV/c the Detection efficiency is \( 28.57\%\pm8.75\% \) versus \( 23.11\%\pm0.75\% \) for singles.
- At high momenta the detection is easy as shown in the figures, one deals with well penetrating Muons.
Muons Detection Efficiency As a Function of the Muon Momentum (GeV/c)

- In Blue: the Detection Efficiency for Muons from 10000 B-Bbar Events.
- In Red: the Muon Detection efficiency from samples of 5000 single Muons each using the same Algorithm.
Distributions of Momentum of Produced Versus Detected Muons

In the 2 following slides are represented:

• The Momentum Distribution overlay of produced and detected Muon Momenta above with a cut at 2.5 GeV. For B-Bbar events the low momenta bin up to 5 GeV are more populated.

• The $P_T$ of produced and detected Muons overlayed distributions shows the effect of the low momentum detection inefficiency on the detected Muons
P-Distribution of Muons Generated versus Detected in the Barrel from 10000 B-Bbar

**P(GeV/c)** - 1 GeV/bin

Left figure overlay

- Generated in yellow
- Detected in green

The figure to the right is used as reference to check overlaps
Muon -Pt Distribution

- Generated in Red
- Detected in Magenta
Muons Produced From Direct B and B_bar

• Next is represented the Muon detection efficiency from direct B and B_bar

• Following is a lepton Universality check in the electron and muon channel.
One gets 845 Electrons for 850 Muons produced in Barrel+End-Caps as shown in the overlay of their Theta distributions.
Muon Detection Efficiency from Direct B’s and Bbar’s

The Muon Detection Efficiency as a function of the Momentum is shown also for a sub-sample from Direct B and Bbar’s and is ~100% as well.
Barrel End-Cap Electron & Muon Theta Comparison - From Direct B and Bbar

About the same number of Electrons and Muons were directly produced.
Hadrons Contamination

The Hadron contamination with their P distribution

In the next figure is reported the Momentum distribution for the Generated and Detected Pions and Muons in 10K B-Bbar events.

• There are ~70 times more Pions produced than Muons in the B-Bbar Events.
• One get a **Pion Rejection of ~300 to 1** from a sample of 10000 B-Bbar.
• The Contamination for 940 particles passing the algorithm is
  P Contamination: 19.9% ± 1.6%
  K Contamination: 9.04% ± 1.02%
  Proton - : 2.66% ± 0.54%
P-Distribution of Mu&Pi Generated versus Detected from 10000 B-Bbar

- Generated Pions in Yellow
- Generated Muons in light blue
- Detected Muons in navy blue
- Pions Detected as Muons in Red.

The Pion Rejection is shown to be ~300 to 1
Hadron Contamination- From 5000 B-Bbar

**PMC (Mu-Detected)**
- entries: 332.00
- mean: 19.666
- rms: 20.391
- min: 3.1591
- max: 110.93

**PMC (Pions-Detected)**
- entries: 89.000
- mean: 11.731
- rms: 11.017
- min: 2.1105
- max: 58.890

**PMC (Kaons-Detected)**
- entries: 39.000
- mean: 19.395
- rms: 13.288
- min: 2.7979
- max: 52.382

**PMC (Protons-Detected)**
- entries: 8.0000
- mean: 9.2894
- rms: 6.6848
- min: 2.6548
- max: 25.183
Wrong Particle Wrong Association-From 5000 B- Bbar events

In Blue: Non Muons passing the Algorithm, 136 tracks
In Red: Those non-Muons with a Hit in the 1st layer of MuCal with a Muon Monte-Carlo ID, 94/136 = ~70% of them

<table>
<thead>
<tr>
<th>pdgid</th>
<th>wrong particle by trackID</th>
<th>wrong association non-mu trackID</th>
<th>MuHit 1st layer</th>
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<tbody>
<tr>
<td></td>
<td>entries: 136.00</td>
<td>entries: 94.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mean: 361.05</td>
<td>mean: 350.14</td>
<td></td>
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<tr>
<td></td>
<td>rms: 406.37</td>
<td>rms: 483.44</td>
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<tr>
<td></td>
<td>min: 211.00</td>
<td>min: 211.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>max: 2212.0</td>
<td>max: 2212.0</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

- The conclusions reached in this preliminary analysis of the B-Bbar One gets an overall detection efficiency of 81.8+/4.4 % of Muons in B-Bbar.
  The detection efficiency of 3 GeV muons 28.57+/-8.75% . At high energy the detection efficiency is ~100% as shown in the figure, we are limited by statistics.
  The Mu detection efficiency is compatible with the single at the same Momentum.
- The Pi Rejection is 300 to 1

The Lower energy range might benefit further from Information in HDCal and EMCal.
Backup Transparencies
Muons and Electrons Generated in Barrel+End-Cap in 10 K B-Bbar
Muon Status Code – Produced Mu versus Detected Mu

All the Mu considered Final stdHEP Status = 1
Single Muons - Distribution of Hits/Layer in Hadron Calorimeter -

- C.Milistene-5GeV Muons-HD Hits per Layer with hit (Real Muon)
  - Minimum hits: 3.0000
  - Maximum hits: 3.0000

- C.Milistene-10GeV Muons-HD Hits per Layer with hit (Real Muon)
  - Minimum hits: 1.0000
  - Maximum hits: 3.0000

- C.Milistene-20GeV Muons-HD Hits per Layer with hit (Real Muon)
  - Minimum hits: 1.0000
  - Maximum hits: 3.0000

- C.Milistene-50GeV Muons-HD Hits per Layer with hit (Real Muon)
  - Minimum hits: 1.0000
  - Maximum hits: 3.0000
Single Pions - Distribution of Hits/Layer in Hadron Calorimeter