FC μCC Update

Caius Howcroft

➢ Recap of background rejection cuts
➢ Introduce some new cuts
➢ Using Veto shield
➢ Some Data
➢ High stats MC for better estimate of background
MC BG Rejection Recap.

- Base Cuts:
  - Pass Fully contained digit filter.
  - Single track events
  - Pass the fitter cut.
  - Must be 6/7 track like planes (>80% charge in track tpos+-1 strip).
  - Always label upper end as Vertex.
    - Apply TraceZ>0.5 m, for this end.
    - Do a polynomial fit to last 3 planes in each view. Recalc trace.
    - Look for Overshoot, back track off and recalculate trace.
    - If near Varc Edge open trace cut out to 1.0 M.
    - Check for over shoots back off and recalculate TraceZ
  - Examine 2M cosmics (0.4 KTYrs)

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Remaining events

• Increased MC stats from 1->2M

• Remaining background is in 3 main classes:
  • Turn over events.
  • Dmx errors
  • Steep scattering muons.
“Turn Over” events
Turn Over events (II)

- Look at RMS of hits from track in 1st N planes.
DMX Errors in Vtx plane
DMX Cut

- Remove Vtx plane and refit over last 3 planes in each view.
Steep muons

- Muons travel down one plane deposit a huge amount of PE’s in one plane.
Steep Muons

Max PE in first 3 planes vs RMS in that plane

Q/PE

Q weighted RMS /m

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Summary:
- BG 38+/-11 events/KTYr, unoscillated signal (23.0 events/KTYr)
- Only have 12 MC BG events left (out of 2M)
- Efficiency of truly fully contained events (events where all the muon/Vtx show hits are within the fiducial volume).
Using The Shield

- Previously
  - pointed track back to shield, correlated hits had $\Delta x < 1\text{m}$. Looked in pretrigger window for dead pmts.
  - 99% background rejection from shield but 20% signal rejection.

- However,
  - With signal:background ratio ~1:1, no longer need 99% background rejection.
  - Want something robust against reco errors.

- Some Methods:
  - Double ended hits
  - Total Q in shield
  - Number of hits etc......
• Look for nice straight muon tracks.

• Straight line fit, use upper end as vertex. project back to shield. DO NOT USE SR.

• Background is dominated by events with low dcosz, only select steep events. |dcosz|<0.3, and apply a 5 plane veto.
MC Shield

- Take several seconds of singles run
- Overlay 5000 200 ns windows on each MC atmos event. (50K events)
- Count number of times each event is vetoed.
ShieldPlanks

- Shield strips are ganged together in groups of 8 (or 4) with same multiplexing pattern on both sides. NO Demuxing possible.

- 8 strips form a 33cm (~1 foot) plank.

- Use CandShieldPlankModule to build “CandStrips” for shield
  - Timing corrections, not T0.
  - ADC->PE Calibration using 1PE peak results.
  - Convenient interface to single and double ended strips.
  - Not in CVS, help?
Timing

- Take Vtx time as Q weighted time in vtx plane.
- Apply all T calibrations and fibre length corrections to detector hits.
- Apply fibre length corrections to the shield (have to use the mean length).

\[ T_{vtx} - T_{shield}, \text{ All Shield Digits} \]

<table>
<thead>
<tr>
<th>North</th>
<th>Entries</th>
<th>25779</th>
<th>Mean</th>
<th>17.45</th>
<th>RMS</th>
<th>31.39</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \chi^2 )/ndf</td>
<td>996 / 267</td>
<td>Constant</td>
<td>352.3 ± 3.6</td>
<td>Mean</td>
<td>19.09 ± 0.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>South</th>
<th>Entries</th>
<th>25283</th>
<th>Mean</th>
<th>13.76</th>
<th>RMS</th>
<th>30.95</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \chi^2 )/ndf</td>
<td>986.9 / 372</td>
<td>Constant</td>
<td>373.3 ± 3.7</td>
<td>Mean</td>
<td>14.56 ± 0.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plank</th>
<th>Entries</th>
<th>37811</th>
<th>Mean</th>
<th>14.03</th>
<th>RMS</th>
<th>19.36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \chi^2 )/ndf</td>
<td>2113 / 388</td>
<td>Constant</td>
<td>597.7 ± 5.6</td>
<td>Mean</td>
<td>14.46 ± 0.10</td>
</tr>
</tbody>
</table>

No T0 Corrections
Jeremy noticed that the residual of the early hits in the shield show a large peak at 0.
Detector Prehits

- Look for same effect in the detector.
Shield BG rejection

- Want veto method which is robust against reco errors.
- Apply a loose cut in total charge in shield above SM.

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<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Cosmic Muon</td>
<td>8.6 ± 0.3%</td>
</tr>
<tr>
<td>Signal</td>
<td>0.67 ± 0.1%</td>
</tr>
</tbody>
</table>

Worse Case!
Using Vtx Z position

- Know Vtx Z position to within +- 1 plane and muons are steep
  - Only look in section above Vtx.
  - Correct for attenuation in WLS fibre.
- Apply a 5 PE cut to the corrected charge.

<table>
<thead>
<tr>
<th>Cosmic Muon</th>
<th>3.6 ± 0.2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>1.6 ± 0.4%</td>
</tr>
</tbody>
</table>
Using a loose Pointing Cut

- Sum attenuation corrected Q within $\theta < 45$
  
- 3 sigma for multiple scattering.

- Prob of single hard scatter $< 10^{-5}$.

- Limited by geometry of planks.

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<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Cosmic Muon</td>
<td>$4.2 \pm 0.2%$</td>
</tr>
<tr>
<td>Signal</td>
<td>$0.8 \pm 0.3%$</td>
</tr>
</tbody>
</table>
## Combining Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Value (± Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmic Muon</td>
<td>2.3 ± 0.2%</td>
</tr>
<tr>
<td>Signal</td>
<td>2.1 ± 0.1%</td>
</tr>
</tbody>
</table>

- Applying to previous cuts: 2±1% background before oscillations
- Some work needs to be done to investigate signal rejection from upwards going PC events.
Real Data

• 1.1 KTY of data from 01 Aug - 03 Nov.

• Trigger == 4,

• >0.5 PE/S in all shield PMTs

• Do a quick pass removing through going muons, writeout CandShieldPlank, CandDigits, CandStrips.

  • FC reduced Dataset is available from the cambridge website: http://www.hep.phy.cam.ac.uk/~howcroft/atmos/data/. 22K events.

• Apply cuts and shield requirements.

• Look at some real events!
BG MC Normalisation

- Use 10 hrs of FarDet data.
- Do a simple straight line fit to through going muons, nPlanes>10.
- 100k MC events = 32.9 Hrs.
## Cut Summary: Data

<table>
<thead>
<tr>
<th>Cut</th>
<th>MC Background</th>
<th>Data /1,1 KTY</th>
<th>MC excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>DigitContainment</td>
<td>29334+/-301+/-3000</td>
<td>22170</td>
<td>32%</td>
</tr>
<tr>
<td>Single track &gt;=8 planes</td>
<td>9748+/-173+/-975</td>
<td>5945</td>
<td>63%</td>
</tr>
<tr>
<td>Track contained</td>
<td>5457+/-130+/-546</td>
<td>3483</td>
<td>57%</td>
</tr>
<tr>
<td>Trace&lt;0.5</td>
<td>1063+/-57+/-100</td>
<td>862</td>
<td>23%</td>
</tr>
<tr>
<td>Track like planes</td>
<td>641+/-45+/-64</td>
<td>436</td>
<td>49%</td>
</tr>
<tr>
<td>FitQ/VarcTrace</td>
<td>591+/-42+/-62</td>
<td>417</td>
<td>45%</td>
</tr>
<tr>
<td>Vtx Refit</td>
<td>285+/-30+/-29</td>
<td>224</td>
<td>27%</td>
</tr>
<tr>
<td>Max Q plane/RMS</td>
<td>81+/-16+/-8</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Singles end hits in vtx plane</td>
<td>65+/-14+/-7</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>int RMS over 1st 4 planes</td>
<td>40+/-11+/-4</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Shield</td>
<td>0.8+/-0.22</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>
Events!

20998/6938

- Red: Section 1
- Green: Section 2
- Blue: Section 3
- Yellow: Section 4

In time Planks

Out of time Planks
Events (II)...

20629/31711

20818/65032

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Events(III)...

21162/2737

21386/1778

Section 1
Section 2
Section 3
Section 4
Events (IV)...

20131/33435

Section 1
Section 2
Section 3
Section 4

20147/26192

Section 1
Section 2
Section 3
Section 4
Events V

21406/18579

Section 1
Section 2
Section 3
Section 4

21283/39583

Section 1
Section 2
Section 3
Section 4
Events VI

18581/63807

18866/62010

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Events VII

18537/70101

- Red: Section 1
- Green: Section 2
- Blue: Section 3
- Yellow: Section 4

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Remaining Issues.

- Coil hole.
  - 2 events sneak in through coil hole. Coil wasn’t been well simulated until recently.

- Plex problem in Section 4 west wing.
  - increased shield inefficiency in this region.

- reduced double ended singles rates (2Khz in section 1 ->0.8 KHz section 4)
High Stats studies.

- Over Xmas period Pat generated 2M cosmic muons.
- I haven't yet finished processing them all but:
  - Processed 8.9 M
  - Ran them through AtNuReco and SR as of 18th Dec 2003.
  - SR BG has increased by factor 100.
  - But AtNuReco (with a little retuning) gives 13±3 bg events per KTYr for 20 Signal events.
Summary

• Have a reasonably stable set of cuts.

• Shield efficiency of ~2% is good enough
  • Signal shield inefficiency <3%
  • some remaining issues not simulated in my signal shield mc, PC events contaminating the FC same.

• Have 1.1 KTYrs Data (with a lot more since Nov), with ~12 REAL neutrino events

• Things we still need.
  • Verification of MC. What do we need to show to be able to defend results?
  • Data Quality: how do I know if part of the detector is dead? Crate 15 timing? Almost totally unaddressed. CandMorgue, Ben’s Data Quality...?
  • A stable reco chain.

• Request for help:
  • 2 independent analyses would be great.