MUON ANGULAR DISTRIBUTIONS

RESULTS FROM THE MEGA-MINI DETECTOR OPERATING AT DAB

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INTRODUCTION

- This is meant be to a rather brief but dense talk focusing on the muon angular distribution analysis with mega-mini.
  - An appetizer showing the capabilities of our detector

- More details on the mega-mini detector can be found in Doc-DB-2651 and -2761 and the ORC documents of Doc-DB-3003.

- The results included in this presentation are based on an 8 h “baseline” run sequence taken at DAB.
  - Results on the absolute muon flux reported in Doc-DB-3007

- Here, the extraction of the zenith and azimuthal muon angle distributions will be presented.
Mega-mini is equipped with four bilayer modules

- Two modules in both X and Y directions separated in Z
  - These features allow some muon tracking capabilities ...

x bi-layers

y bi-layers
A crossing muon activates eight bars of the detector. This leaves us with the knowledge of 8 coordinates in X and Y. All the Z coordinates are, of course, known.
The scintillator bars have dimensions of $20 \times 5 \times 1 \text{ cm}$

- *This means that the pointing resolution is not going to be great!*
- Reject events with more than 8 hits:
- The scintillator bars have dimensions of $20 \times 5 \times 1$ cm
  - *This means that the pointing resolution is not going to be great!*
- Reject events with more than 8 hits:

![x bi-layers](image1)

![y bi-layers](image2)
The scintillator bars have dimensions of $20 \times 5 \times 1$ cm

- This means that the pointing resolution is not going to be great!

Reject events with more than 8 hits

- Hold only those events with exactly 8 hits
- Four pairs of $(X_i, Z_i)$ and $(Y_i, Z_i)$

**RECONSTRUCTION ALGORITHM**

- Approximate muon tracks with 3-D straight lines
- Track parameterization: $\vec{R}(Z; X_{in}, Y_{in}, X_{out}, Y_{out})$
- Minimization of a common “two-fold” $\chi^2$

$$\chi^2 = \sum_{i=0-3}^{x \text{ hits}} \frac{(X_i - P_x(Z_i; X_{in}, Y_{in}, X_{out}, Y_{out}))^2}{2.5^2 + (\tan \theta \cos \phi \cdot 0.5)^2} + \sum_{i=0-3}^{y \text{ hits}} \frac{(Y_i - P_y(Z_i; X_{in}, Y_{in}, X_{out}, Y_{out}))^2}{2.5^2 + (\tan \theta \sin \phi \cdot 0.5)^2}$$

Best fit returns: $X_{in}, Y_{in}, X_{out}, Y_{out}$
We have develop a rather simplistic Monte-Carlo to propagate muons through our detector.

- It seems to be more than adequate since a detailed Geant4 MC is outside of the scope of this study
- Difficult to validate/tune a more complicated MC
- Most of the detector features stem just from geometry

- A C++/ROOT code implementing the mega-mini geometry
  - 3-D cells in the exact orientation
  - Calculate the X – Y hits when a cell is crossed by a track

- Then we can reconstruct the muon track using previous ideas
  - Both TRUE and RECO. information at hand
GENERATED EVENTS

x bi-layers

y bi-layers

Solid line: MC true info
Dashed line: Reconstructed track
GENERATED EVENTS

x bi-layers

y bi-layers

Solid line : MC true info
Dashed line : Reconstructed track
EFFECTIVE AREA

Zenith angle distribution

Monte-Carlo

\[ \cos^2\theta \]
Azimuthal angle distribution

- Initial PDF
- Simulated data
- After the geometry

Monte-Carlo Flat
- Pointing resolution is poor but,
- ... still better than nothing!
Vertical and near-vertical tracks are badly reconstructed in $\phi$, with:
- Small “trace” in the detector
- Ambiguity in $\phi$ when $\theta \approx 0^\circ$
- A software cut of $\theta > 35^\circ$ is required to improve the resolution
After a $\theta_{\text{RECO}} > 35^\circ$ cut the resolution improves significantly

Still not excellent though ...
- Azimuthal distribution is driven by the big width of the strips, 5 cm
Results from a “baseline” run taken at VT

- Five bins of $15^\circ$ in $\theta$ and bins of $10^\circ$ in $\phi$
- Geometry and reconstruction “smear” things out but,
- **Data and MC are in excellent agreement!**
■ Systematical error distributed evenly on all bins ...
■ Distributions at DAB look good
  ▪ Close like these on surface; small differences due to the 3 floor overburden in the one side
The mega-mini tracking algorithms are in a very good shape!

The analysis of those baseline data taken at DAB show the capabilities of mega-mini extracting both muon rate and angular distributions.

In the meantime, and in another universe ... many data sets have been taken at LArTF (ground floor, pit)

Our main priority is to finalize and complete the analysis of these runs
This will serve several purposes:

- Give us the rate and angular distributions of muons in LArTF (in two different positions in LArTF)
- Know the absolute ratio of the rate on the surface and pit
- Use this data to validate CRY (talk given on previous SG meeting)

In case of disagreement with CRY many paths can be taken:

- Contact the guys from LLNL; wait for an updated version
- Investigate whether there is a problem with the muon transport code or the proper implementation of the detector surroundings
- Try another cosmic ray shower software
THANK YOU

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Muon zenith angle distribution
Muon azimuthal angle distribution

φ in deg
Reco - True azimuthal angle distribution

Entries 4211696
Mean -1.354
RMS 45.26

$\phi_{\text{reco}} - \phi_{\text{true}}$ in deg
AFTER THE THETA CUT

Bias in the azimuthal angle

$\phi_{\text{reco}} - \phi_{\text{true}}$ vs $\theta$ angle in deg