Track Engine Study
A topological Muon Trigger

by Matthias Danninger
Overview

➢ Example of targeted events → so far untriggered and lost
➢ Short introduction of Track Engine and available parameters
➢ Different investigated binning definitions for track direction
➢ Investigated first applications:
  → FPGA 2-D optimisation → hardware ready to test
  → 6-D study
➢ Summary of results
➢ Important next steps

People Involved:
Ideas: D.Nygren, P.-O.Hulth, C.Bohm
Simulations: G.Wikström, S.Euler, M.Danninger
Hardware: C.Robson, C.Wernhoff, H.Kavianipour
Event 1:

LC (6)

161 GeV (ν)
Event 1:

LC (6)

161 GeV (ν)
Event 2:
LC (7)
174 GeV (ν)
Event 3:

LC (7)

118 GeV (ν)
Track Engine

➢ All DOM-Hits are sorted in time
➢ Exploit topological features of straight line trajectories within DOM-array
➢ **Focus for now**: Horizontal low-E muon tracks
➢ Possible future TE-extensions: Monopoles, Cascades
Forming Pairs

➢ Form all DOM pairs within 5μs time window (physics-physics) ↔ (noise-physics) ↔ (noise-noise)
➢ Intra-string pairs are excluded → false peaks
➢ **First DOM-pair-selection:**
➢ Only accepted if pair is within physics region of speed c [ 0.3c , 1.0c ]
➢ Distance d between pairs required to d < d_{max}
➢ All parameters for each DOM pair are stored in large lookup-tables (26625600 entries)
Track Engine Parameters

**TE-1:** FPGA board to find peak in 2-dimensional space \((\vartheta, \phi)\)

**TE-2:** TE-algorithm searches for peak of DOM-pairs in 6-dimensional space, spanned by 6 “independent” parameters \((\vartheta, \phi, \tau, r, \omega, \phi)\)

\[(x, \vartheta, \phi)\] and \(\tau = (t^1 + t^2)/2 + x/c\)

Point of closest approach

IceCubeCenter
Binning

➢ From binning with variable size
➢ “Simple” binning with 'constant' size

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Simple Binning

- 344 equal sized bins
- Binning used in TE-1
- Each DOM-Pair is assigned unique bin-ID
- Problem of events with bin overlap
“Soccer-Ball” Binning

➢ Solving bin-overlap problem **TE-2**

➢ 1\textsuperscript{st} lookup table: (482) bin-ID+2 closest neighbour bin-IDs

➢ 2\textsuperscript{nd} lookup table: (960) form bin triplets for each DOM-Pair with the assigned direction of CM-triplet

➢ **Trigger:** each new entry in bin (time sorted) forces triplet of 3 closest bins to be read out and reported
FPGA-2D Implementation (TE-1)

Investigated first parameter optimization for 2-dimensional FPGA version:

- Speed interval: \([0.3c, 1.0c]\), \([0.3c, 1.05c]\), \([0.3c, 1.1c]\)
- Time Window size: 3.5, 4.0, 4.5, 5.0, 5.5, 6.0 (in \(\mu s\))
- Dom-Pair-Distance: 250, 300, 350, 400, 450, 500 (in m)
FPGA-2D Implementation (TE-1)

**Noise-only** represents the same simulated events with physics ($\nu_\mu$) removed

Noise-trigger rate is estimated by ($N_{\text{triggered-noise}}/\Sigma \text{tevent}$)

Selected parameters for **TE-1**:
- TW 5µs
- 400 m for d
- 4 min. Pairs in bin
- LC 3

Improvement trigger rate ($\nu_\mu$):
- $E < 1000$ GeV (1.4)
- $E < 100$ GeV (1.6)
- Low Noise 11.2 Hz
6D Implementation (TE-2)

Selected parameters for **TE-2**: TW 5μs, d<400m

![Diagram showing trigger conditions for 6D implementation.](image)

- **Bin 6D > 7**
- **Bin 6D ≥ 2**
- **Bin 6D ≤ 7**
- **LC > 5**
- **3 ≤ LC ≤ 5 (d_{LC,av} ≤ 350m & \{(θ,φ) or (ω,φ) > 3)\}**
6D Results (TE-2)

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6D Results (TE-2)

Improvement trigger rate ($\nu\mu$):

- $E < 1000$ GeV ($\sim 2$)
- $E < 100$ GeV ($\sim 4$)
- Low Noise 34.2 Hz
- $\mu-$Rate increase 12.7 %
- Horizontal tracks favoured
- Acceptable first guess
Comparison

G. Wikström initial study (internal report)
**TE-2 for WIMP signal (50, 100 GeV)**

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Important next steps (Simulation)

- How to use these triggered events
- Events with very low or 0 LC → select physics
- How well can we reconstruct these events (fraction)
- Noise Filtering
- Contribution at final analysis level
- Identify coincident μ events
- Final tuning of parameters/settings
- Extension to other topologies (Cascade, Monopole)

Working-group specific

- TrackEngine Tag of DOMs in peak
- Use TE as 1st guess and try LLH
- Indistinguishable events
- WIMPs (pointing accuracy)

Ip (ω, φ)
High-E Muon Bundles (not coincident)
Important next steps (Hardware)

- FPGA remotely configurable (changes → upgrades)
- identical trigger system in Stockholm for algorithm development
- TE-2 development in progress aim at working design during spring
Important next steps (Hardware)

String hubs → Sort engine → FPGA CPU system → FPGA TE processor

➢ String hub software must be adapted for TE communication other units operational

TE-1 milestones:

➢ Adapting string hub to TE now – mid October
➢ Integrating String hub and TE at SPTS mid – October
➢ Integrating trigger server parts in Stockholm until end October
➢ Tests of Trigger server November
➢ Full system test at SPTS December
End

Thank You