Cosmic Scintillator Simulation

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Cosmic ray muons

Ideal for alignment:

- High momentum - ~3 GeV, so almost straight
- Little scattering or energy loss
- Go through different parts of the detector

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Somewhat unpleasant:

- Low rate: A few Hz for the size of Mu3e
- Strong directional dependence: Mostly from above
- Almost straight - can cause numerical problems in track reconstruction if one is not careful
(should be ok in Mu3e software after Uli's thesis)

Simulating cosmic ray muons in Mu3e

- Use the same Geant4 based simulation as for all Mu3e simulations
- Note that simulated geometry does not have any detail outside the magnet inner bore
- Magnet is modelled as a massive iron cylinder
- Area (roof!) is not modelled

- Concurrent beam and cosmic simulation is currently not implemented (but straightforward)

Cosmic ray generator

- Based on Biallas & Hebekker, arxiv:0907.5514 (CMS cosmic generator)
- Parametrisation of the cosmic ray zenith angle and energy spectrum in terms of polynomials
- See Mu3ePrimaryGeneratorAction, lines 145ff for implementation (partly inversion method, partly accept/reject)

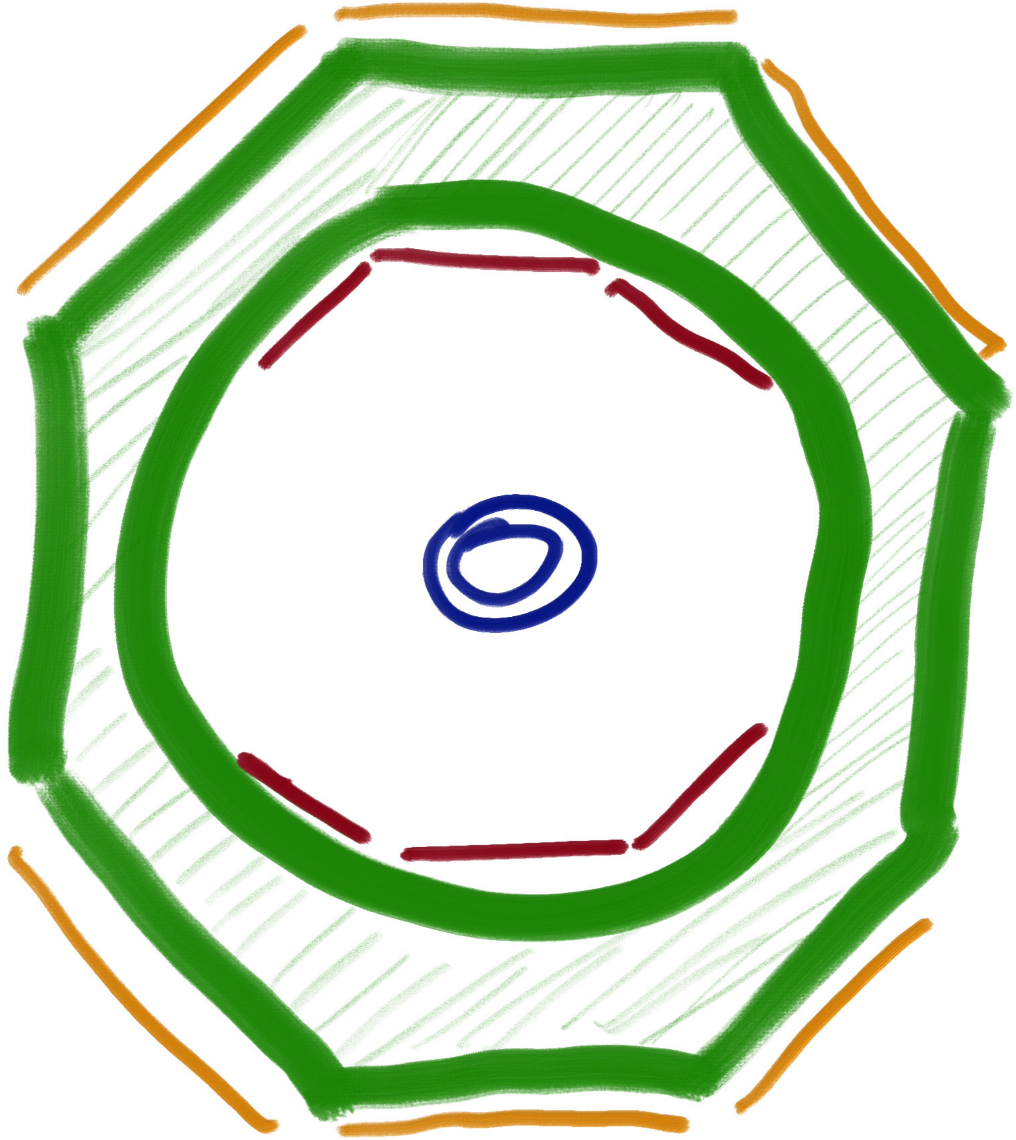
Cosmic ray generator (II)

- For each cosmic, the intersection with the horizontal plane (y=0) is diced as a flat distribution over z = -1 m to z = 1 m and x = -20 cm to x= 20 cm
- From this point, the particle is moved back 1 m opposite its momentum direction (straight line approximation) and released for Geant4 simulation

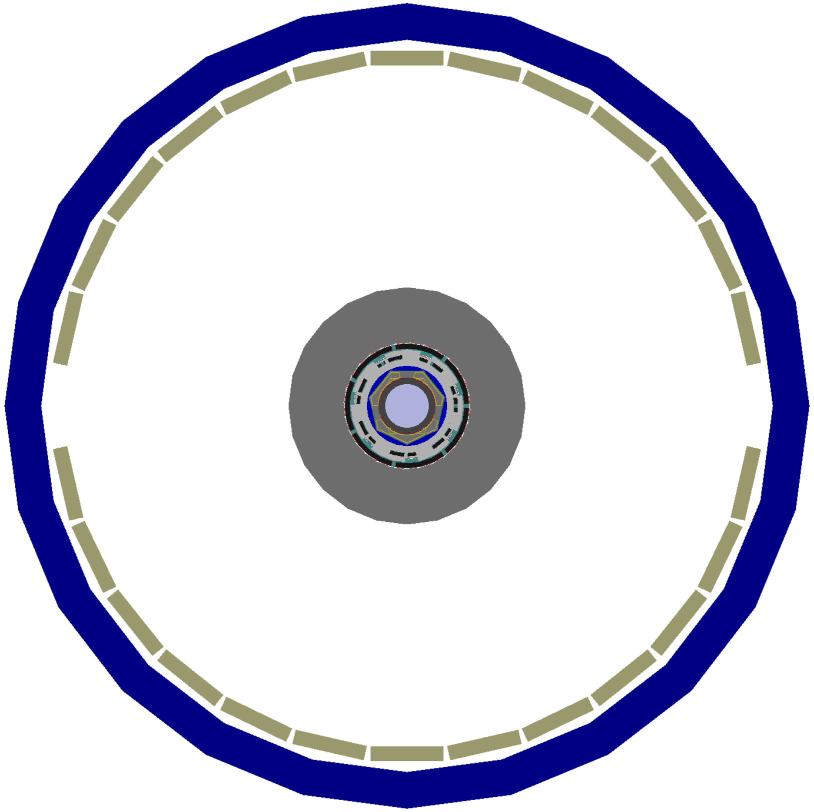
Cosmic trigger

- Scintillator coincidences above/below the detector
- Inside or outside the magnet?
- The usual questions: Mechanics, Cabling, Power etc…

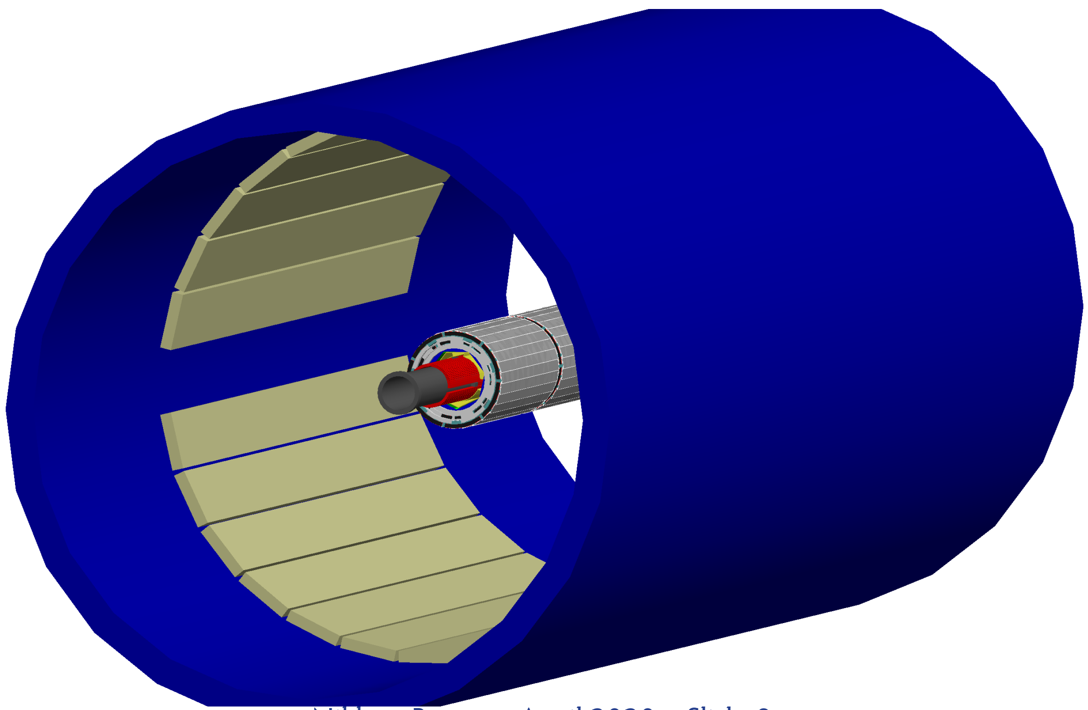
- Studied here: Option inside the magnet



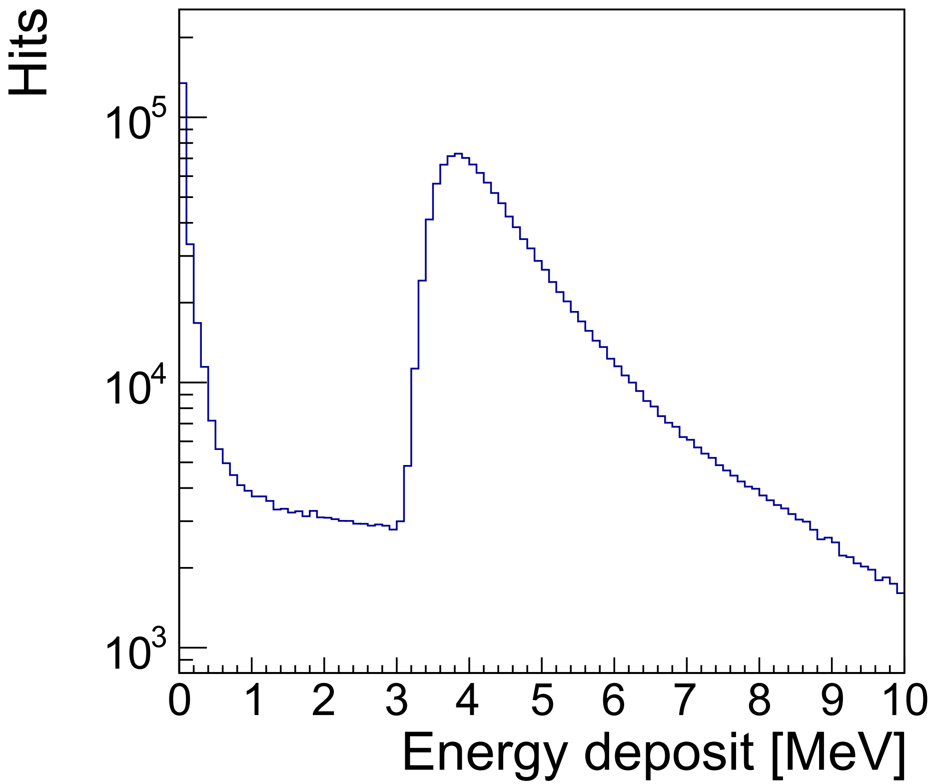
Geometry



- 28-fold geometry, horizontal missing (rails)
- 2 x 10 x 150 cm scintillator slabs
- Polystyrol as material (for interactions)
- Scintillation/light transport not simulated

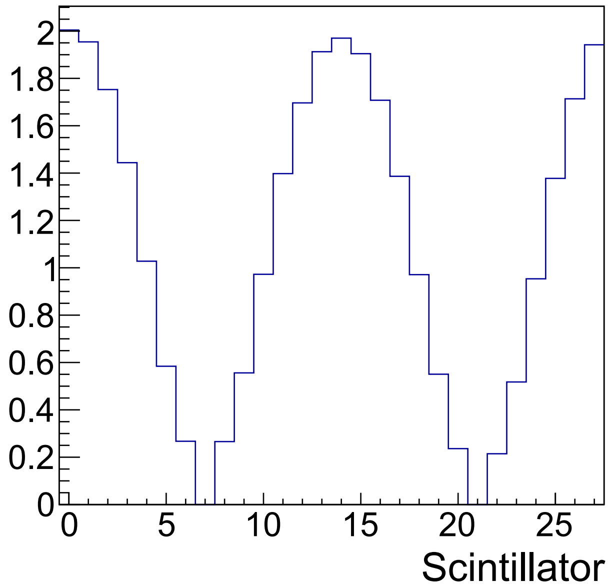


Cosmic simulation

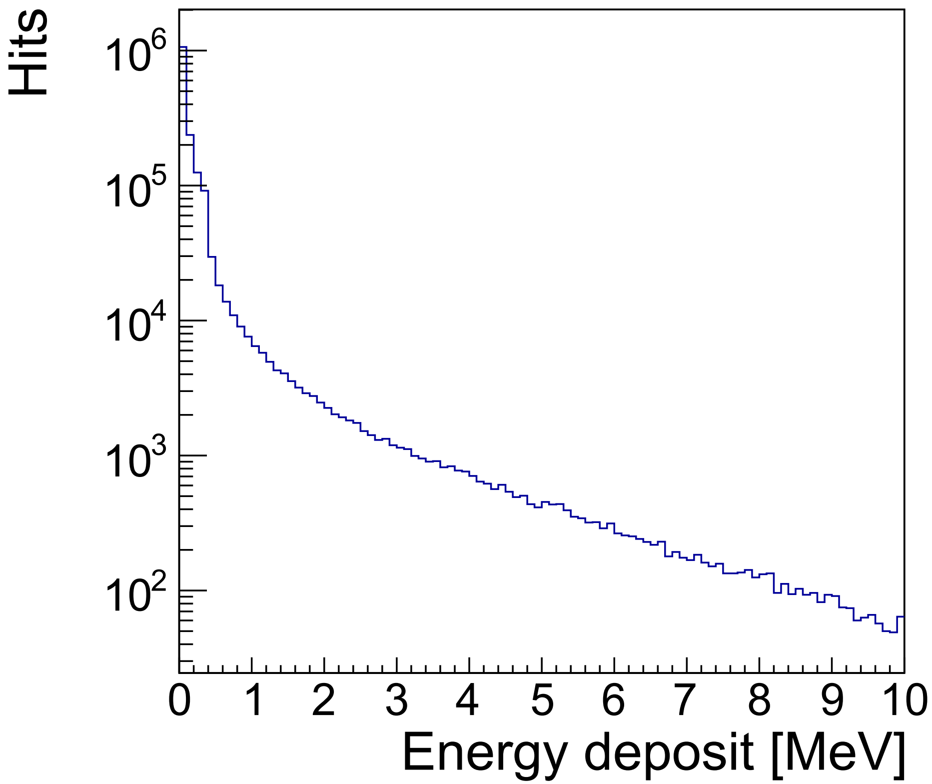


Simulate cosmic muons with realistic zenith angle and energy distribution, no azimuth dependence, restrict to those passing detector

- Landau peak at ~4 MeV
- Mostly vertical
- Rate not simulated, should be O(10 Hz)
- ~3 ns flight time

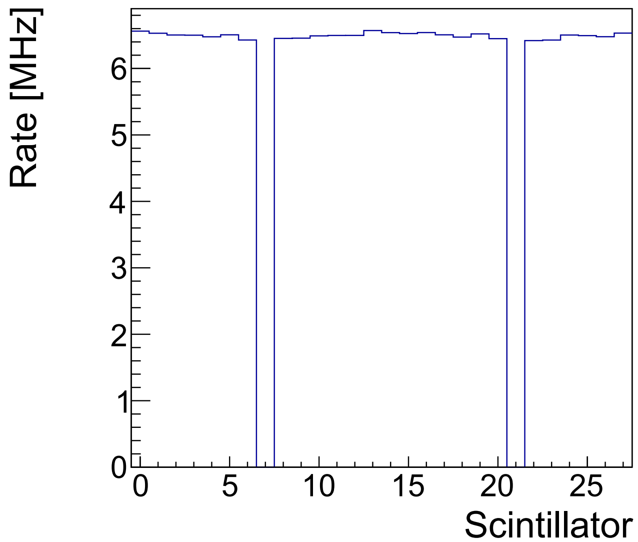


Muon decay simulation

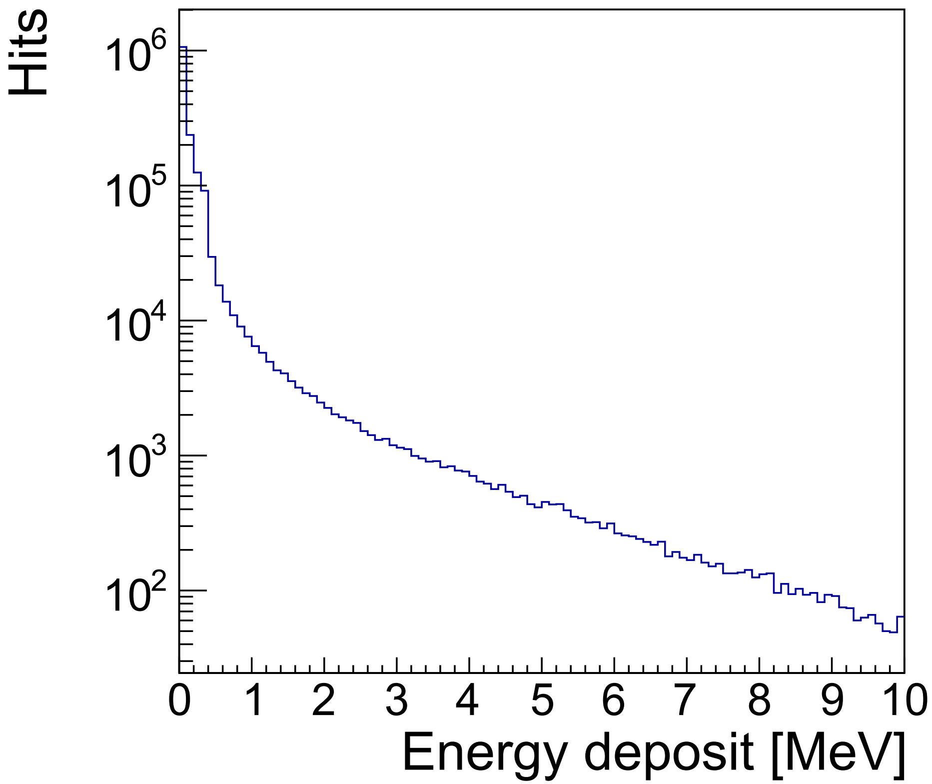


Run at 10^8 stops on target, muons started at z = - 1 m (might under-estimate upstream beam background)

- Mostly very low energy deposits
- Rate above simulation threshold: > 6 MHz/scintillator

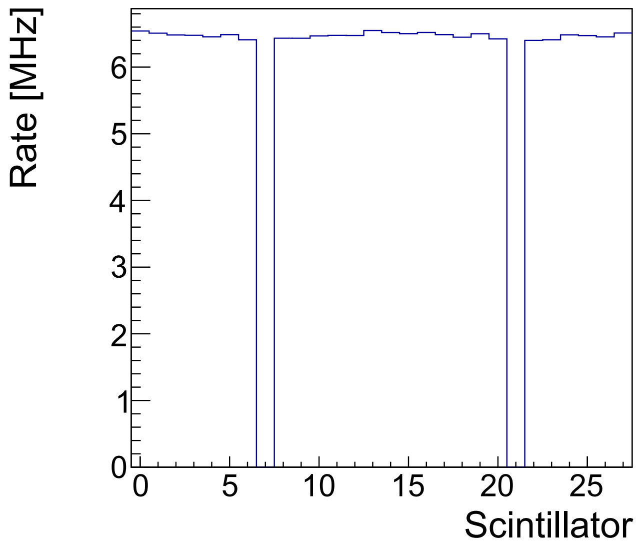


Muon decay simulation

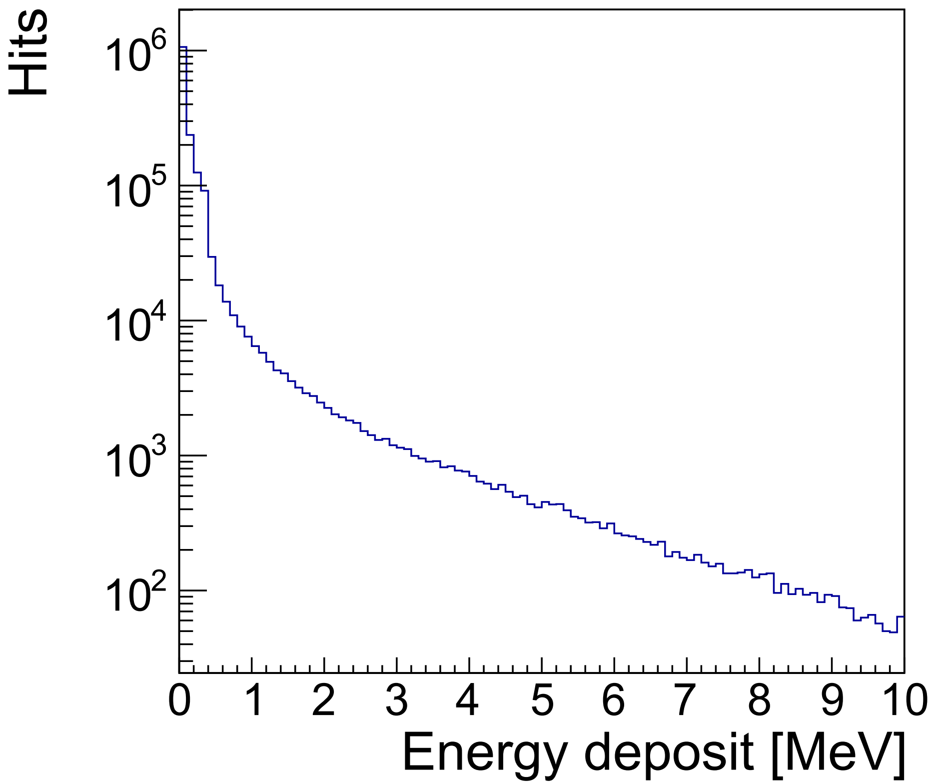


Run at 10^8 stops on target, muons started at z = - 1 m (might under-estimate upstream beam background)

- Mostly very low energy deposits
- Rate above scintillation threshold (100 eV): > 6 MHz/scintillator

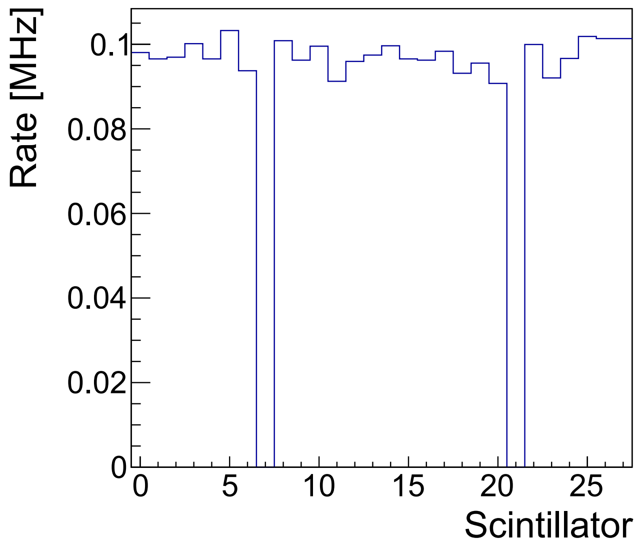


Muon decay simulation



Run at 10^8 stops on target, muons started at z = - 1 m (might under-estimate upstream beam background)

- Mostly very low energy deposits
- Rate above muon threshold (3 MeV): ~ 100 KHz/scintillator



Coincidences

Coincidence rates:

- 2 scintillators with > 3 MeV, 50 ns window: 400 KHz
- as above, excluding neighbour coincidences: 250 KHz
- as above, opposite side (8 slabs): 90 KHz

- 2 scintillators with > 3 MeV, 3 ns window: 40 KHz
- as above, excluding neighbour coincidences: 30 KHz
- as above, opposite side (8 slabs): 10 KHz

Conclusions

- Mu3e simulation implements cosmic muons using simple parametrizations
- Can reduce to O(10 KHz), or a signal/BG of 1/1000
- Bandwidth/reconstruction load after this could probably be handled by an extra farm PC and software reconstruction