Aashowerfit

High energy cascade reconstruction

Introduction

- Track reconstruction exclusively from timing information
- Direction of shower from amplitude information
  (and soon using time info, Jordan)

Aashowerfit algorithm has two steps

1. Position fit (x,y,z,t)
2. Direction and energy fit (θ, ϕ, E)

Vertex fit

Hit selection

- Hits merging: hits within 350 ns on a pmt are merged with time of first hit

  When there is more photons hitting a PMT: first hit gives most information

  What if the first hit is background?

- Select coincidences: two merged hits in a single DOM within 20 ns

  Gets rid of background

Vertex fit

Fitter

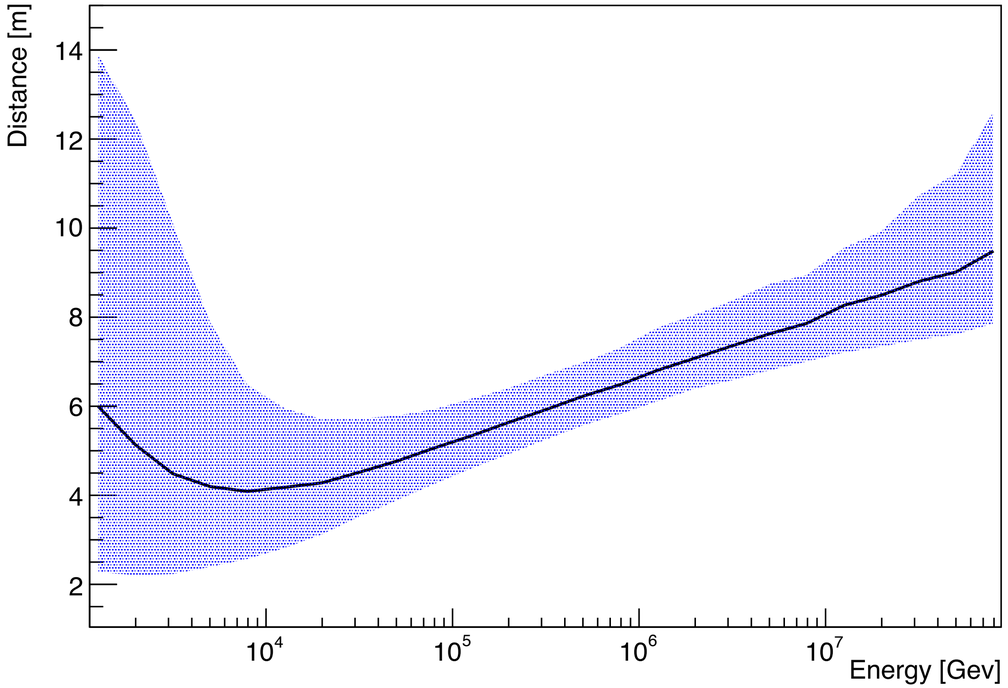
M-estimate minimisation of hit time residuals: $M = \sum_{hits} \sqrt{1 + r_i^2}$

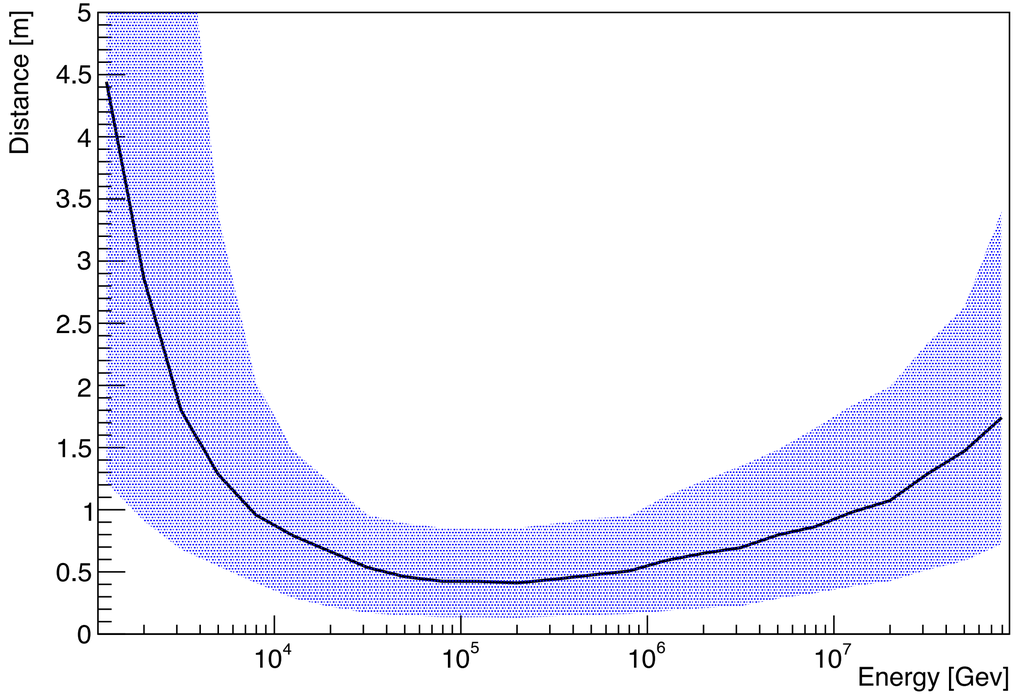
Hit time residual: $r_i = t_i - t_0 - \frac{d}{v_{light}}$

- Tolerant for background hits
- Finds global minimum without accurate starting point
- Fits the shower maximum

Vertex fit

Contained events performance





- Reaches 40 cm at 100 PeV

Direction and energy fit

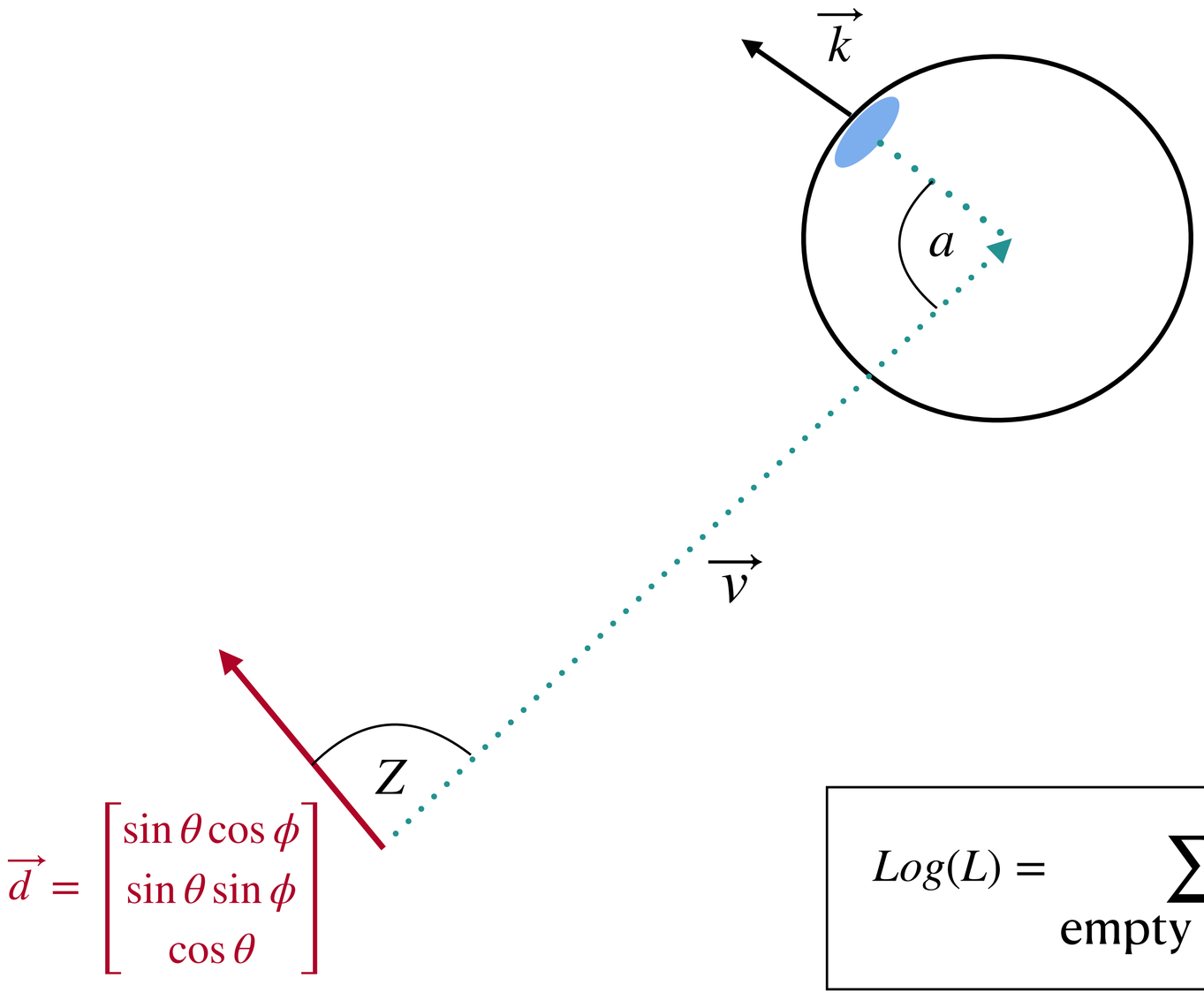
Hit counting using ToT is difficult:

- No direct translation ToT -> photons

Unless in single photon regime:

- Hit PMTs scales linearly with light intensity

Hit counting (hit/nohit) Simplifies PDF to 3 dimensions
PDF obtained from MC



$$\vec{d} = \begin{bmatrix} \sin\theta\cos\phi \\ \sin\theta\sin\phi \\ \cos\theta \end{bmatrix}$$

PDF: $\mu_{sig}(r, z, a)$

Mean detected photons from PeV shower

$$r = |\vec{v}|$$

Distance from DOM to shower

$$z = \vec{d} \cdot \frac{\vec{v}}{r}$$

Peaks at: $z = cos(\theta_c)$

$$a = \vec{k} \cdot \frac{\vec{v}}{r}$$

Head on: $a = -1$

Add background:

$$\mu = \mu_{sig} + R_{bg}T$$

$$P_0 = \exp(-\mu)$$

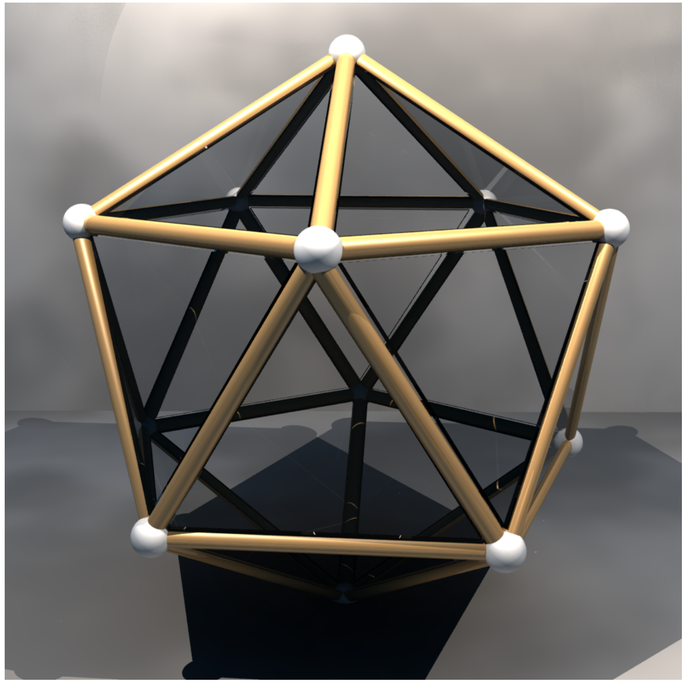
Poisson probability for no hit

$$Log(L) = \sum_{\text{empty PMTs}} Log(P_0) + \sum_{\text{hit PMTs}} Log(1 - P_0)$$

Direction and energy fit

Hit selection

- Hits selected with residuals [-100, 900] ns from vertex fit result



Fit minimises -Log(Likelihood) :

- 12 starting directions fitted
- Starting energy = 500 TeV
- Track with highest likelihood placed at the front

Optimisations

- Vertex position is fixed in direction fit —> precompute distance and angle photon with PMT
  Every PMT gets a 1D likelihood: Z only changes

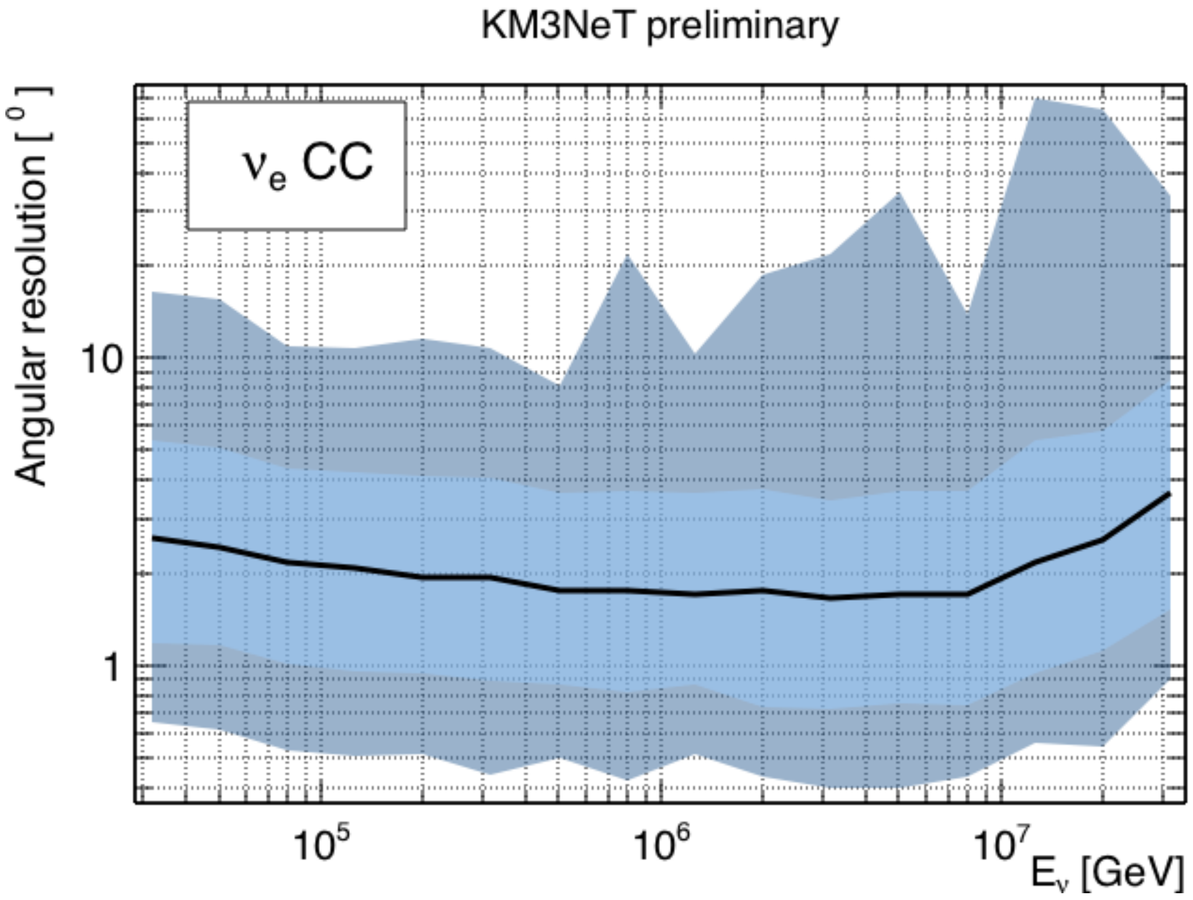
- No hit information tends to be slow
  Aashowerfit selects spherical part of the detector that contains most hits
  Not necessary to loop through the whole detector

- Derivatives of likelihood are calculated to speed up minimisation

Performance

- Gets below 2 degrees above 100 TeV

- Using the Letter of Intent cuts:
  Containment cut
  Likelihood cut



Outlook

- Moving to Jpp PDFs instead of PDFs based on our MC
- Shower elongation not included in aashowerfit
  First try by Jordan showed no improvement
- Timing information not included in aashowerfit
  Work in progress by Jordan