Reconstruction and energy estimation for tracks

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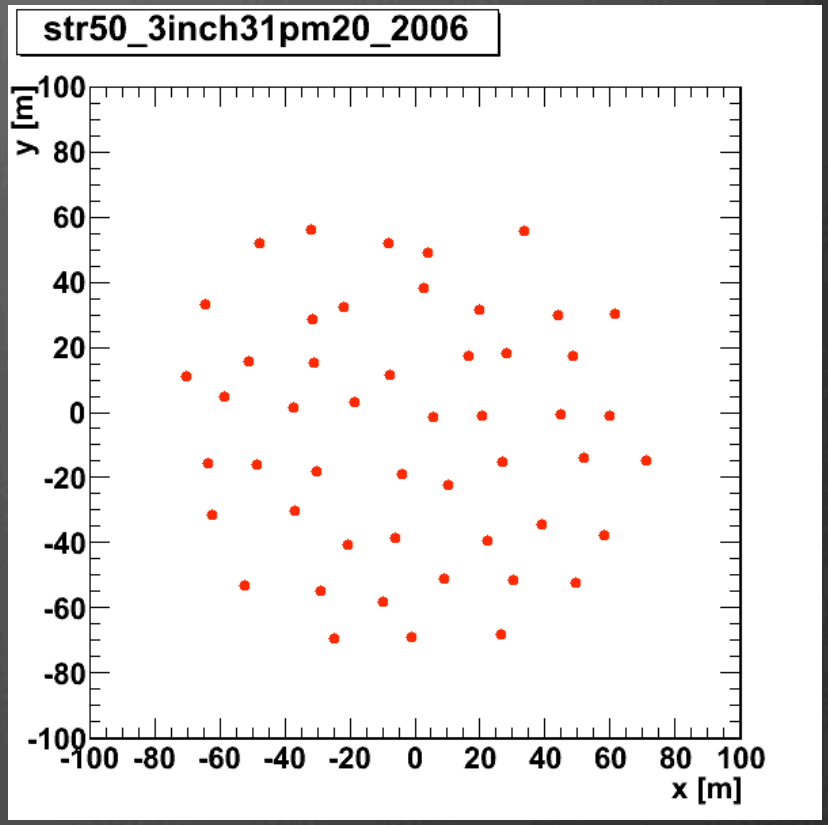
Detector layout

- ✓ 50 Strings
- ✓ OM=31 3”PMTs
- ✓ 20 OM in each string
- ✓ 6 m vertical distance between OM
- ✓ 20 m average distance between strings

Instrumented volume = 1.75 Mt

RECONSTRUCTION OF MUON NEUTRINOS OPTIMISED FOR THIS PARTICULAR LAYOUT



Hit selection

All hits are analyzed to look for the following patterns:

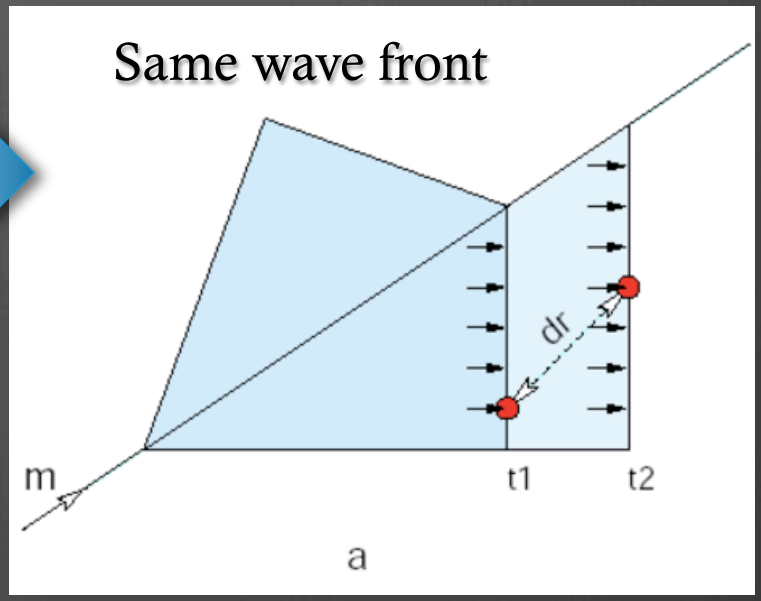
- L1: simple coincidence between 2 PMTs on the same OM in a time window $\Delta t = \pm 5$ ns
- T00: coincidence between two simple hits on adjacent OMs on the same line in $\Delta t = \pm(5\text{ ns} + \Delta d/v)$
- T0: like T00 but between an L1 hit and a simple hit
- T1: like T00 but between 2 L1 hits
- N0: coincidence between an L1 hit and a simple hit on nearby strings in $\Delta t = \pm(5\text{ ns} + \Delta d/v)$
- N1: like N0 but between 2 L1 hits
- L2: multiple (>2) coincidence between PMTs on the same OM in $\Delta t = \pm 5$ ns

Each type of coincidence gives a "score" (L1<T00<T0<T1<N0<N1<L2) to the correspondent hit → Only hit with coincidence more complex than L1 (score>L1) are used during the reconstruction

Causality filter

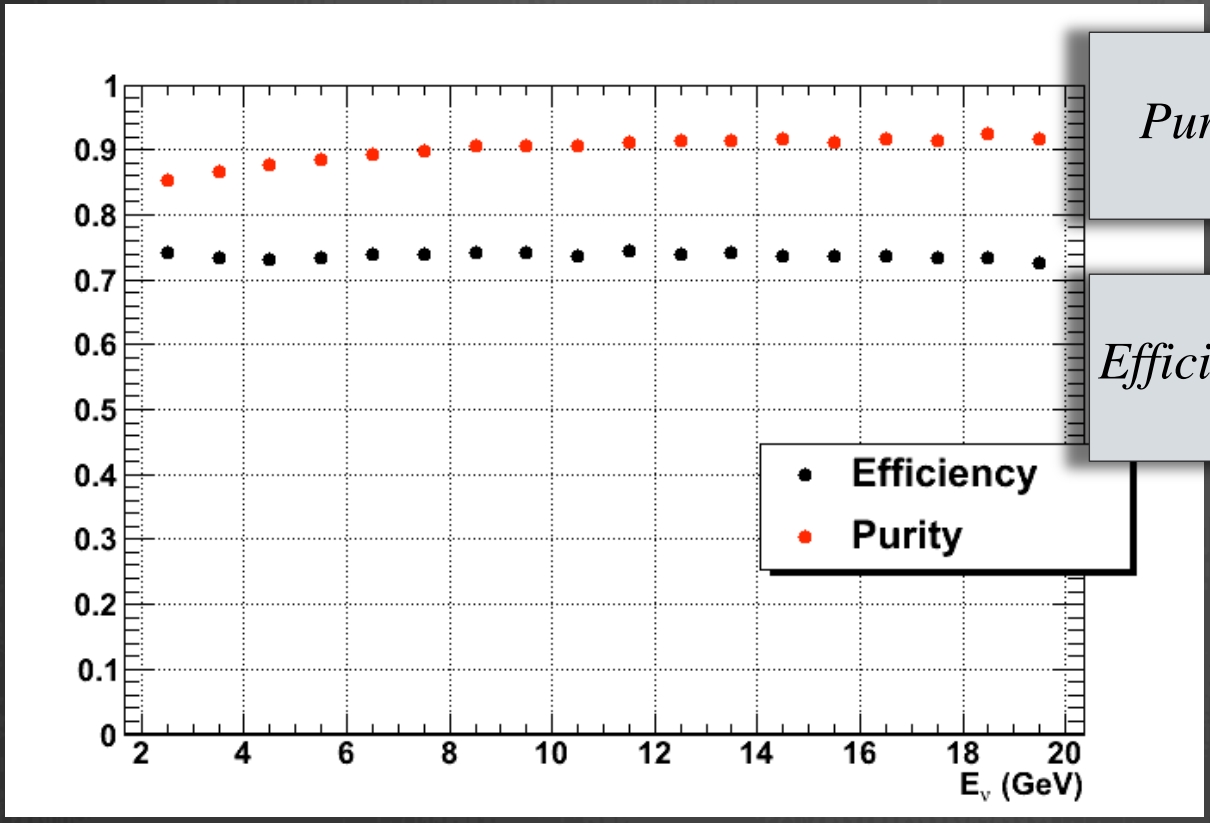
Further selection requiring that each hit fulfills the causality filter condition w. r. t. to a reference hit chosen as the hit with the highest score

$$|\Delta t| - \frac{\Delta r}{c/n} < 20ns$$



Hit selection performance

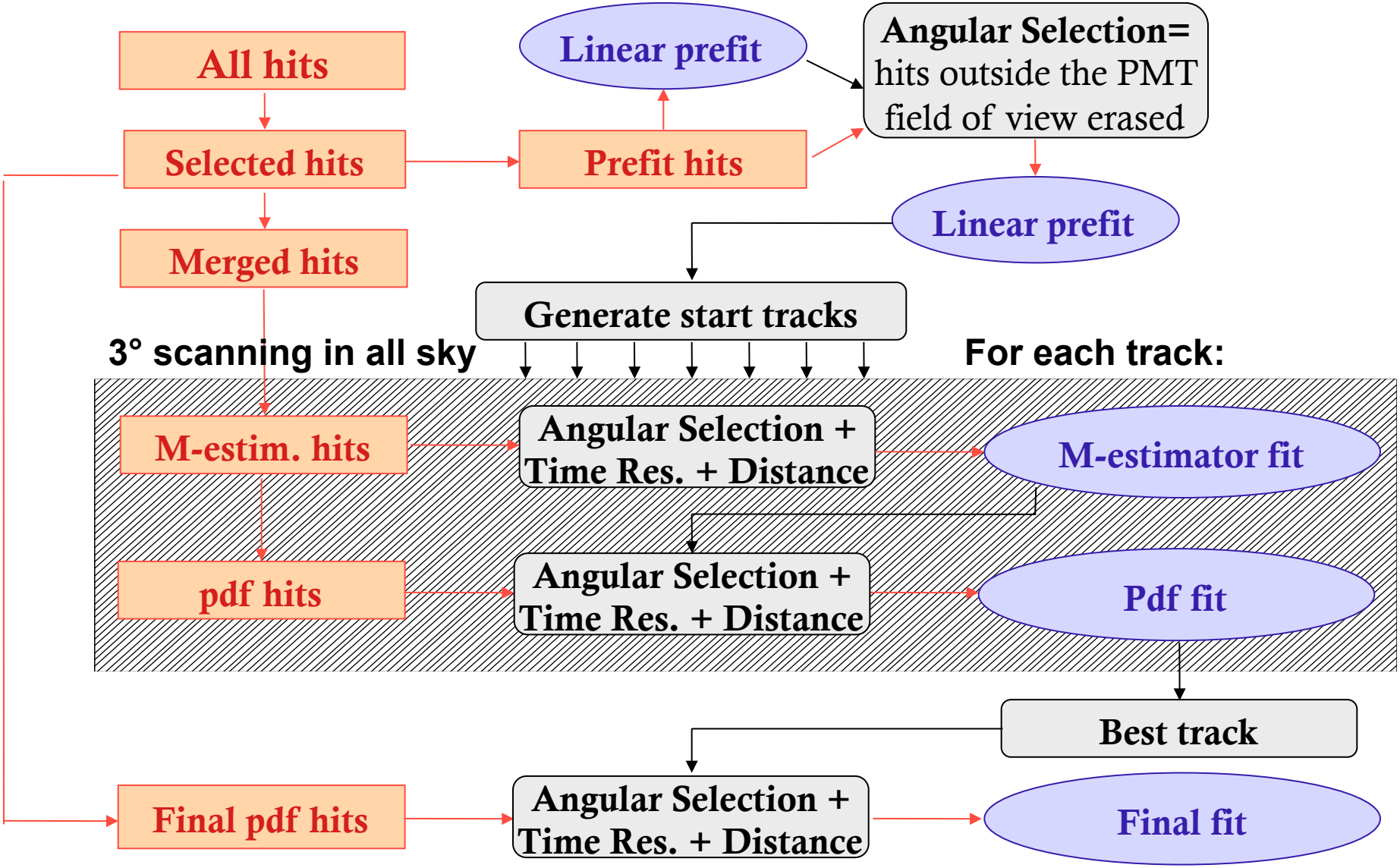
- Nhit_selected = total number of hits with score>L1 that fulfill the causality filter
- Nhit_selected_signal = subset of Nhit_selected obtained considering hit that are also true signal hits
- Nhit_signal = total number of true signal hits



$$Purity = \frac{Nhit\_selected\_signal}{Nhit\_selected}$$

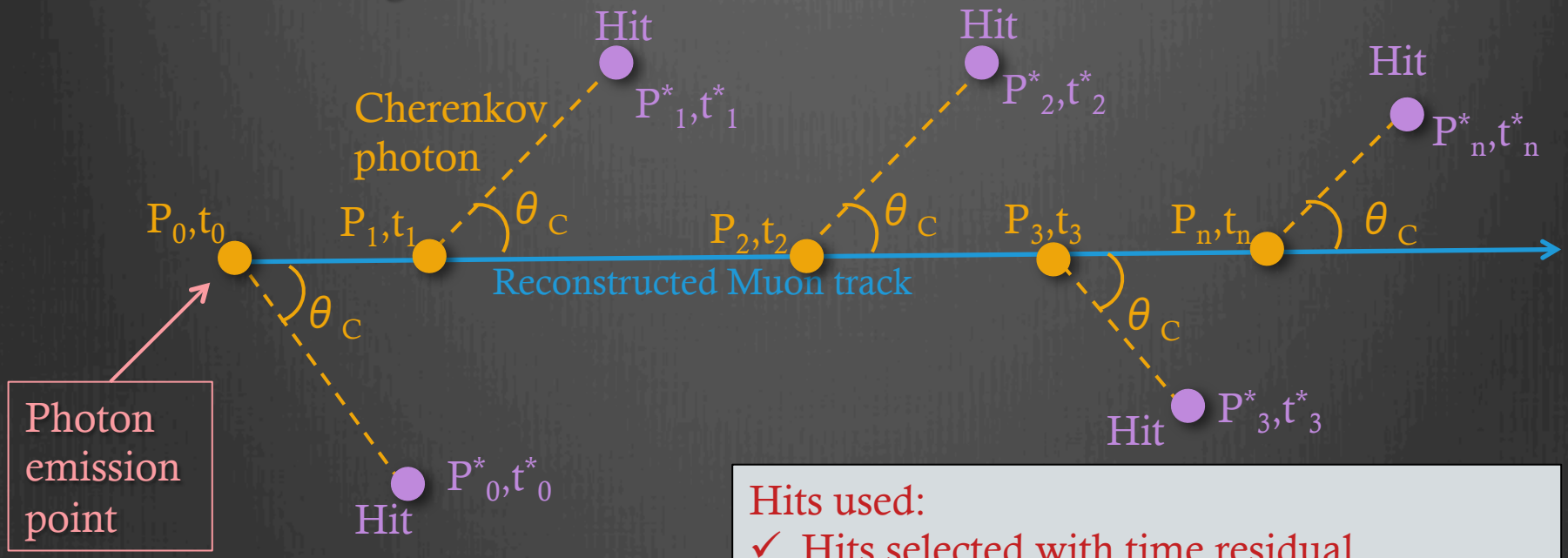
$$Efficiency = \frac{Nhit\_selected\_signal}{Nhit\_signal}$$

Reconstruction scheme



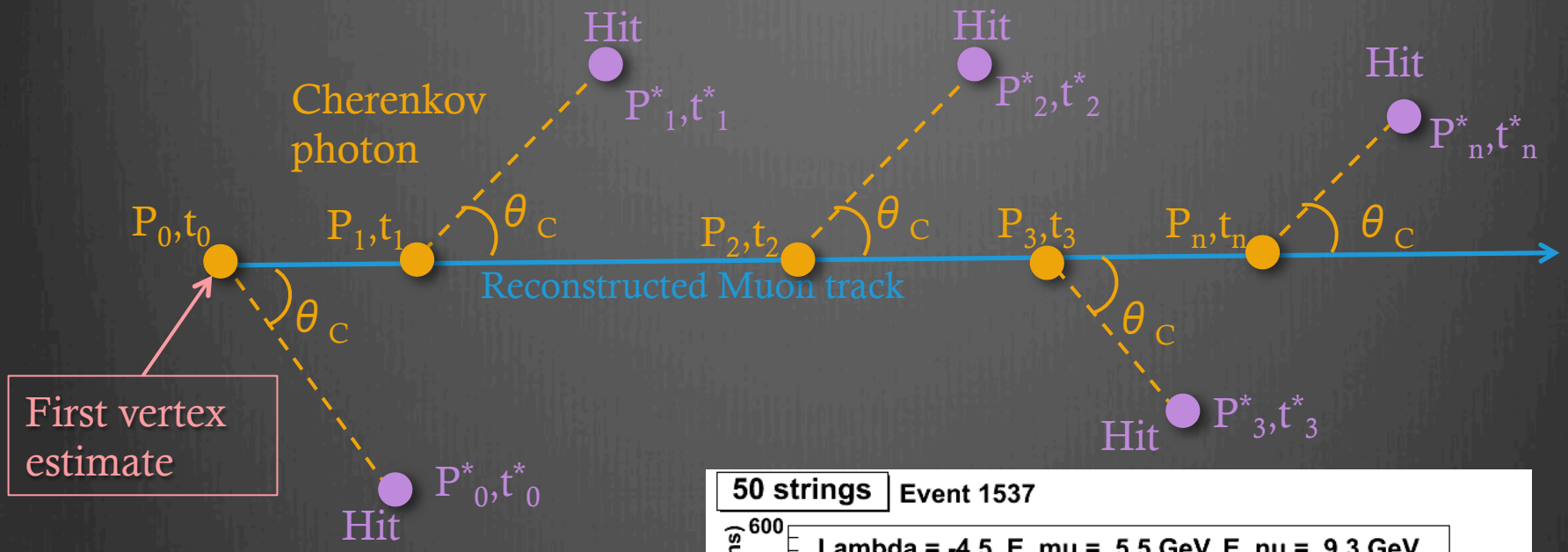
Muon Track length estimate

- From the position P^*_i and the time t^*_i of each hit, the photon emission point P_i and the emission time t_i can be calculated
- The distance between the first point P_0 and the last point P_n is an estimate of the muon track length



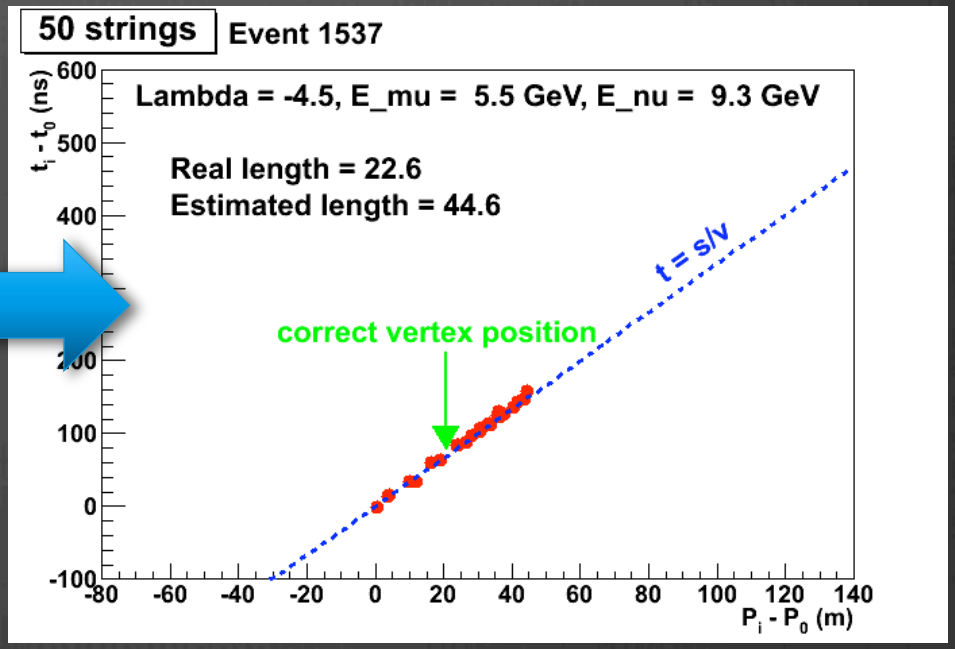
Hits used:
- ✓ Hits selected with time residual $-10\text{ns} < \Delta t_{res} < 10\text{ns}$
- ✓ High density of points P_i along the track required (1Point/2meter)

Muon Track length estimate



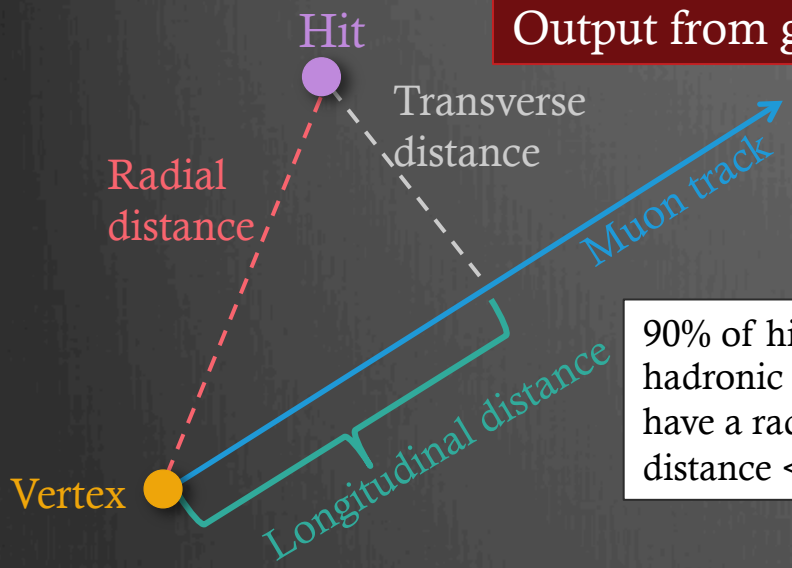
Track length often overestimated because of hits from hadronic shower

A different vertex estimate is needed

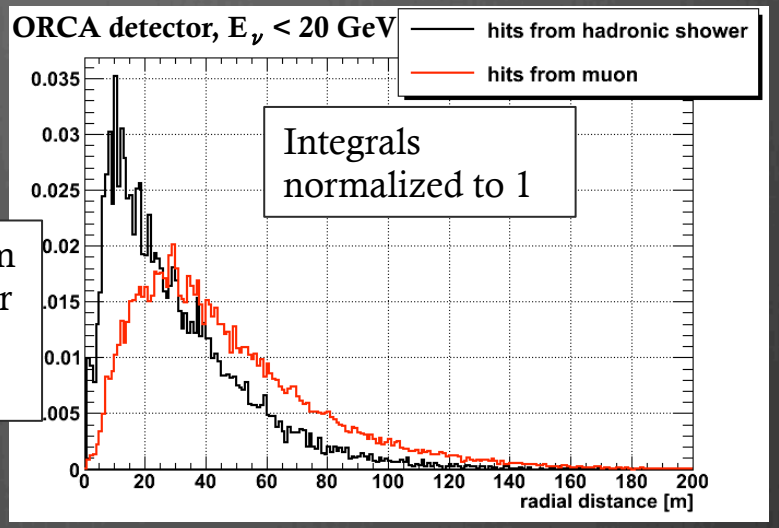


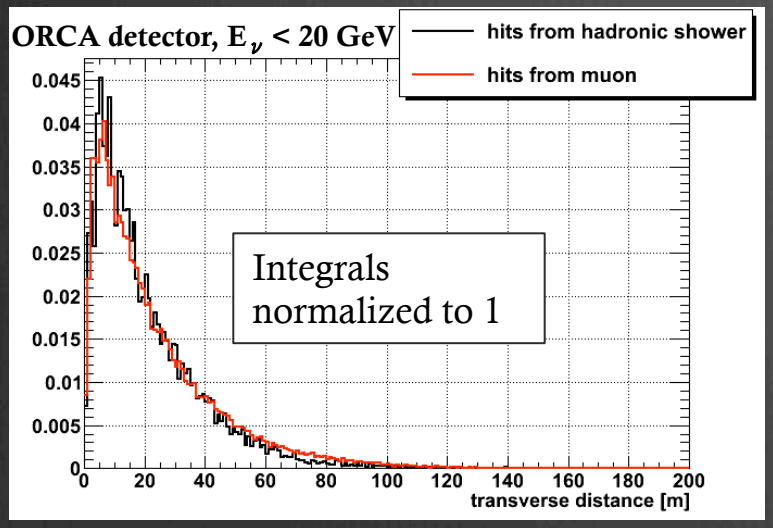
Hadronic shower analysis: can hits from hadronic shower be identified?

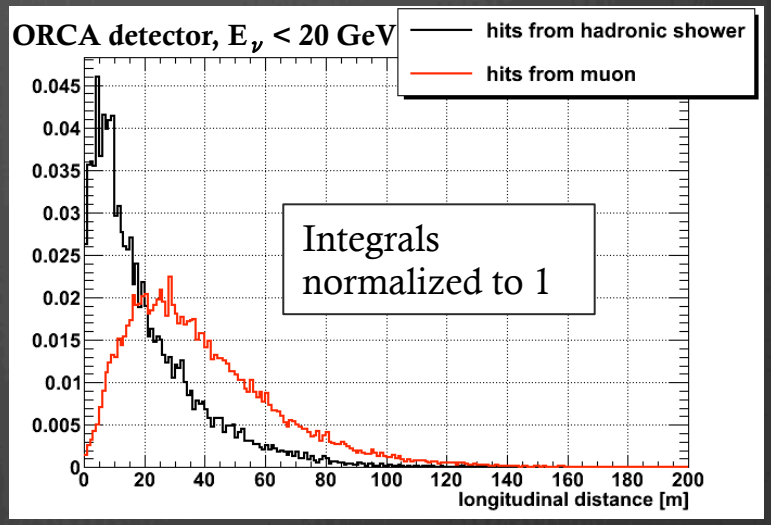
Output from geasim ➔ no ^{40}K background



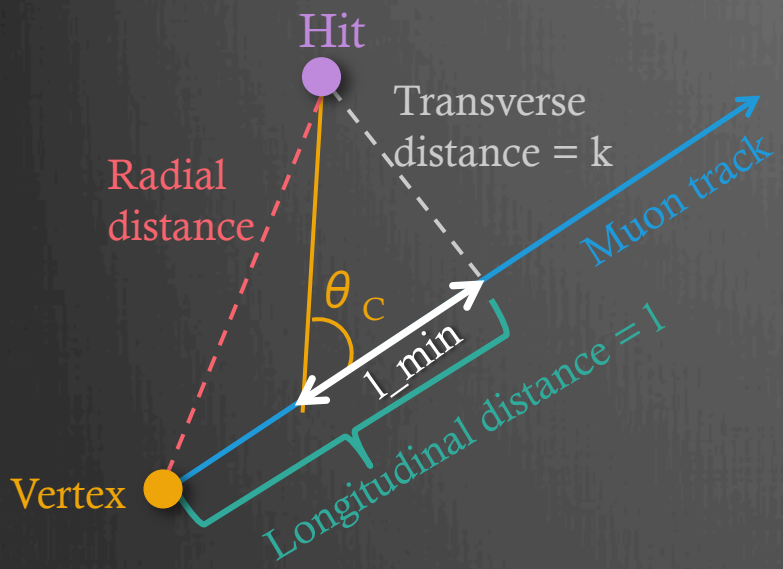
90% of hits from hadronic shower have a radial distance <60m



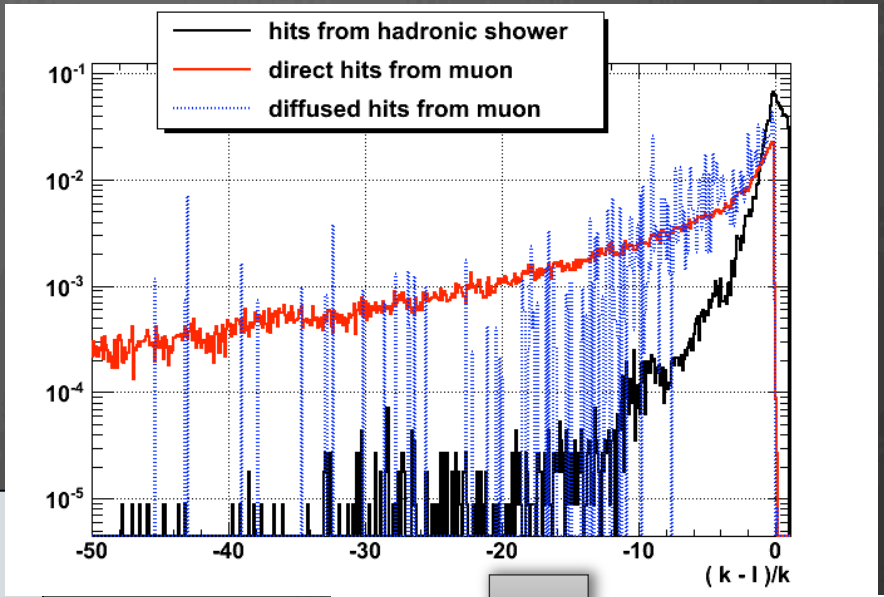




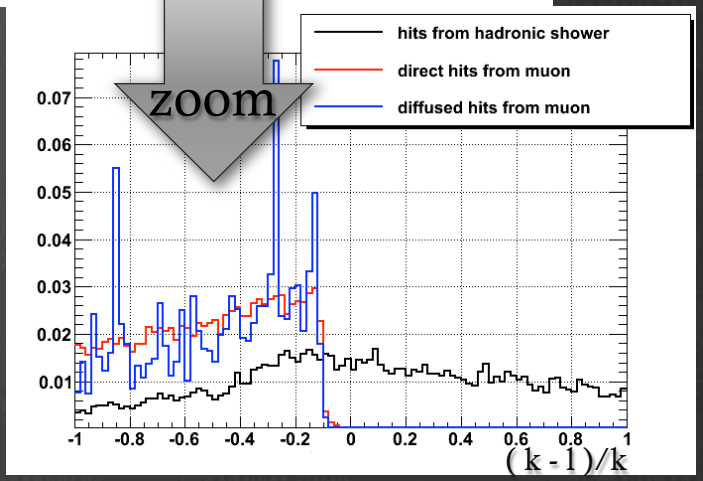
Hadronic shower analysis: can hits from hadronic shower can identified?



Output from geasim ➔ no ^{40}K background



zoom



For hits from muon track the minimum value of the lingitudinal distance is given by
l_min =k*cotan(θ_C) ≈ 1.11*k ➔ minimum of (k-l)/k≈-0.1

Muon track hits: (k-l)/k < -0.1

Shower hits: (k-l)/k > -2

Hadronic shower analysis: hits from hadronic shower can be identified?

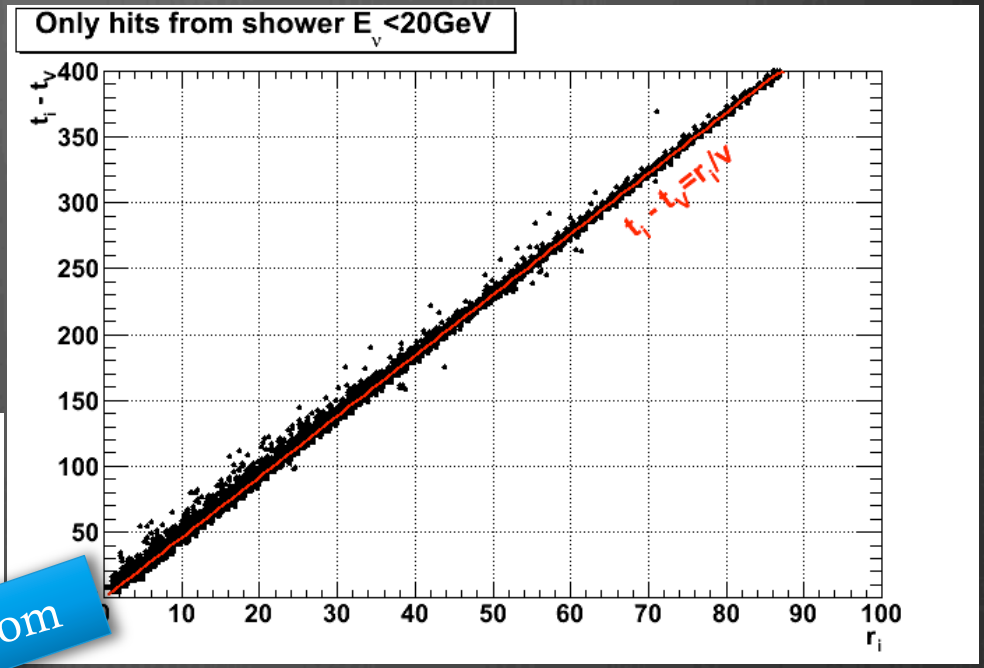
Output from geasim ➔ no ^{40}K background

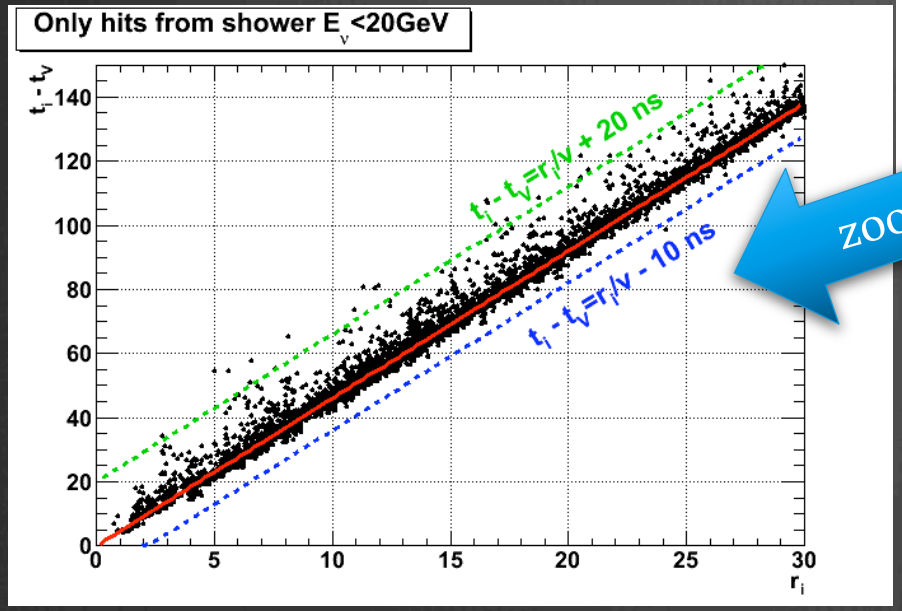
Assuming the evolution of the shower as a spherical wave, each hit time should be:

$t_i = t_{vertex} + r_i/v$

Radial distance hit-vertex

light speed in water





zoom

Defining a "time residual" as

Δt = recorded – expected time

$= t_i - (t_V + r_i/v)$,

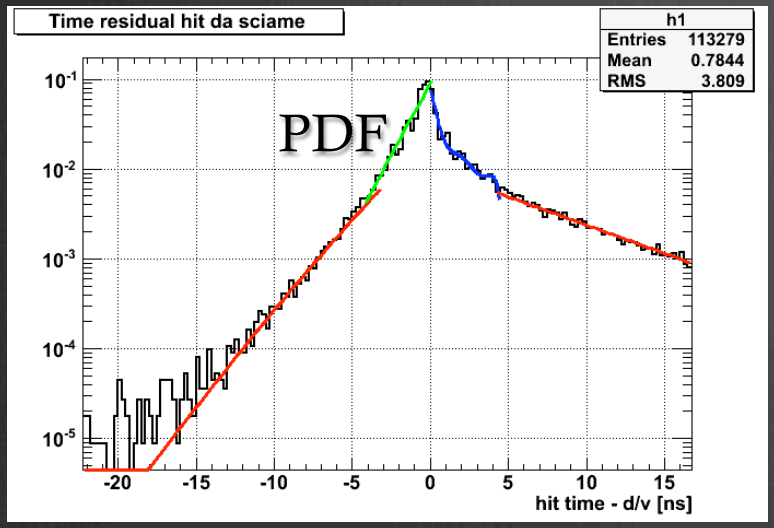
99% of hits from shower have

$-10ns < \Delta t < 20ns$

Vertex estimate

Interaction vertex estimate through the following steps:

1) First vertex estimate from the first photon emission points on the reconstructed muon track
2) Hits from the hadronic shower identified through cuts on time residual, on the distance from the first vertex estimate and on (k-l)/k
3) Second vertex estimate from a maximum likelihood fit applied to the selected hit using a PDF ➔ PDF from the time residual distribution obtained by the MC truth assuming the shower as a spherical wave:



Δt = recorded – expected time = $t_i - (t_V + r_i/v)$

Vertex time

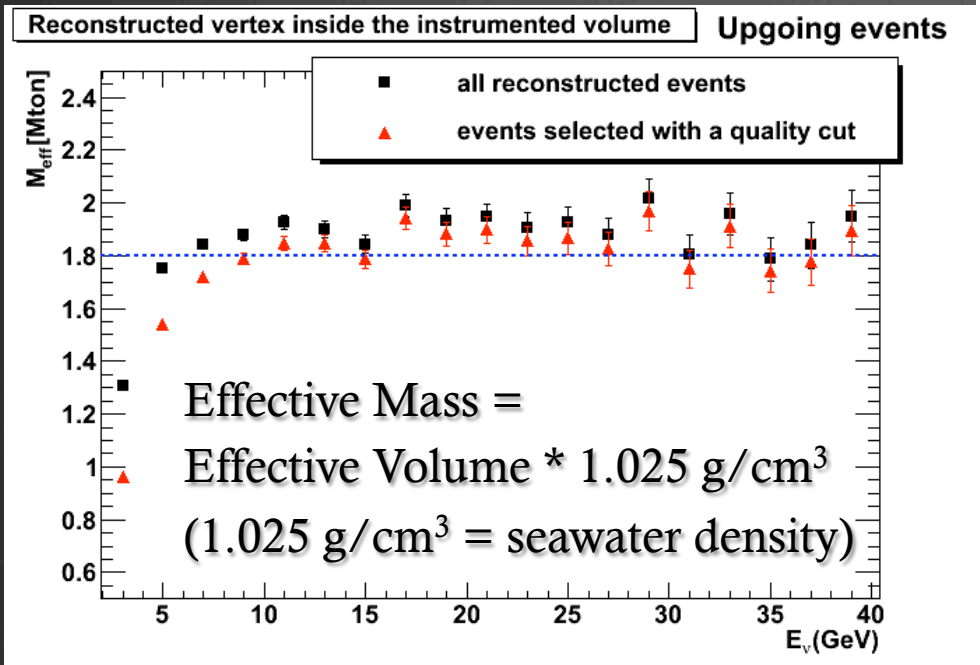
Radial distance hit-vertex

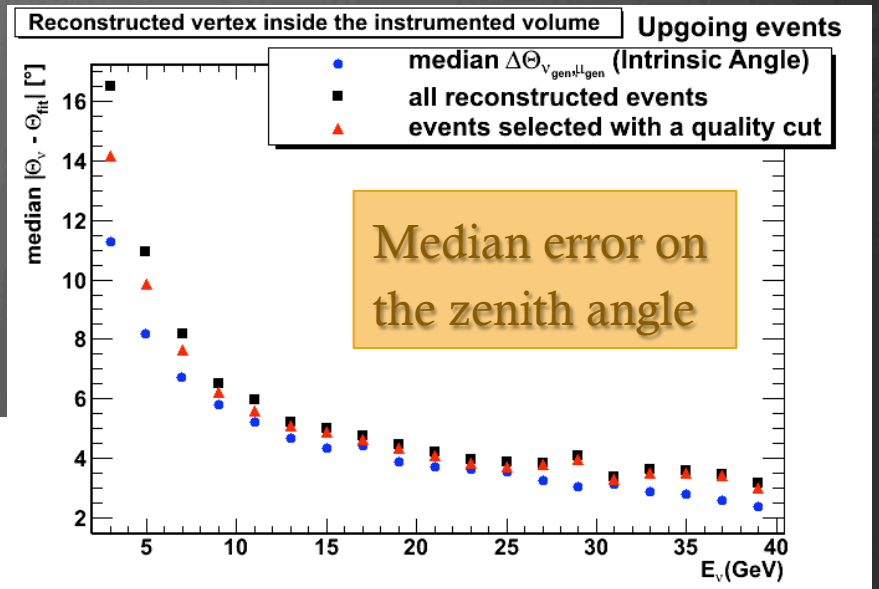
Light speed in water

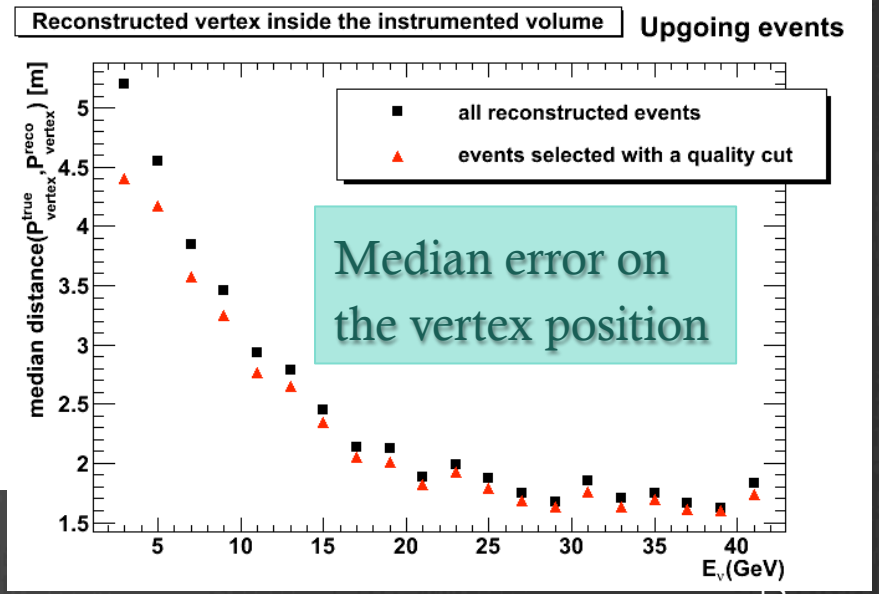
4) Final vertex estimate chosen between the first and the second according the likelihood value of the fit

Results

Only events reconstructed as upgoing and with the reconstructed vertex inside the instrumented volume



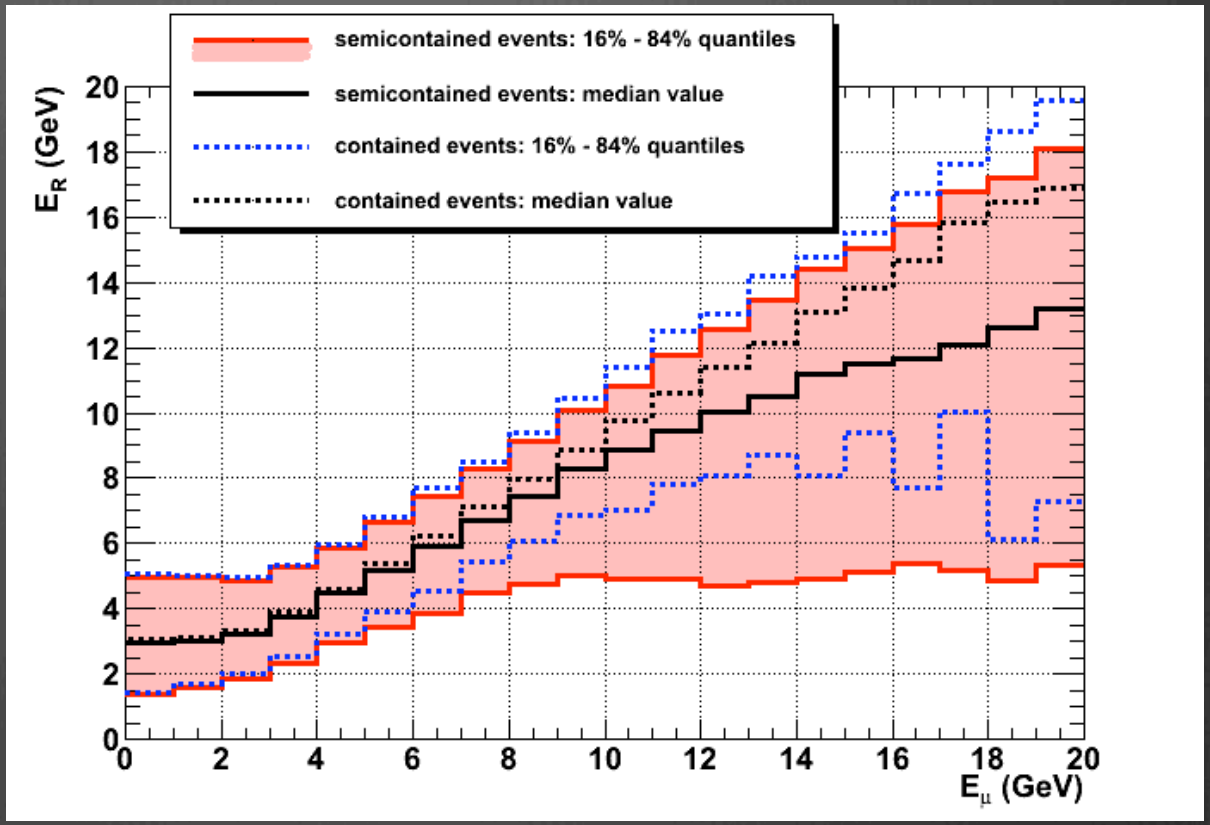




Muon energy estimate

Only events reconstructed as upgoing and with the reconstructed vertex inside the instrumented volume

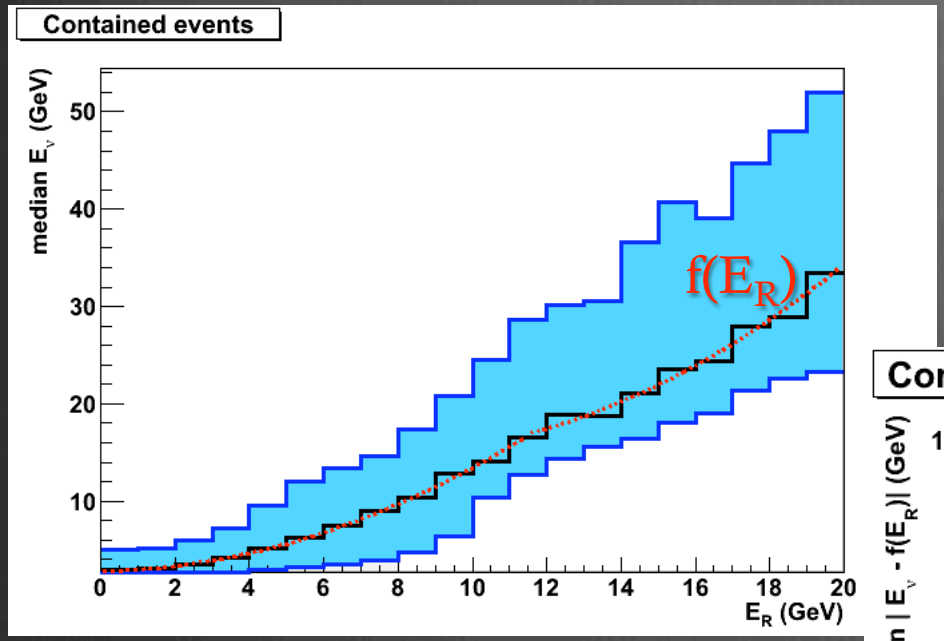
Reconstructed muon energy as a function of the real muon energy. The red band is the 1-sigma range (16% to 84% quantiles) the black line is the median per muon energy bin.

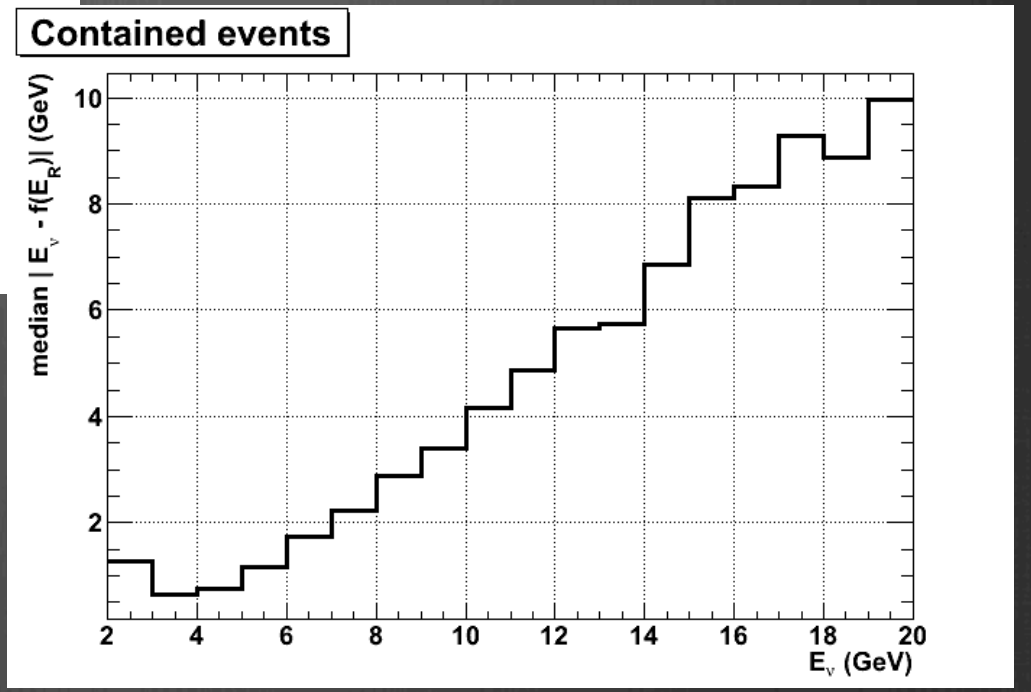


Semi-Contained events: muon reconstructed vertex inside the instrumented volume

Contained events: events that have the estimated ending point closer to the detector centre than the estimated vertex →condition to be improved…

Neutrino energy resolution





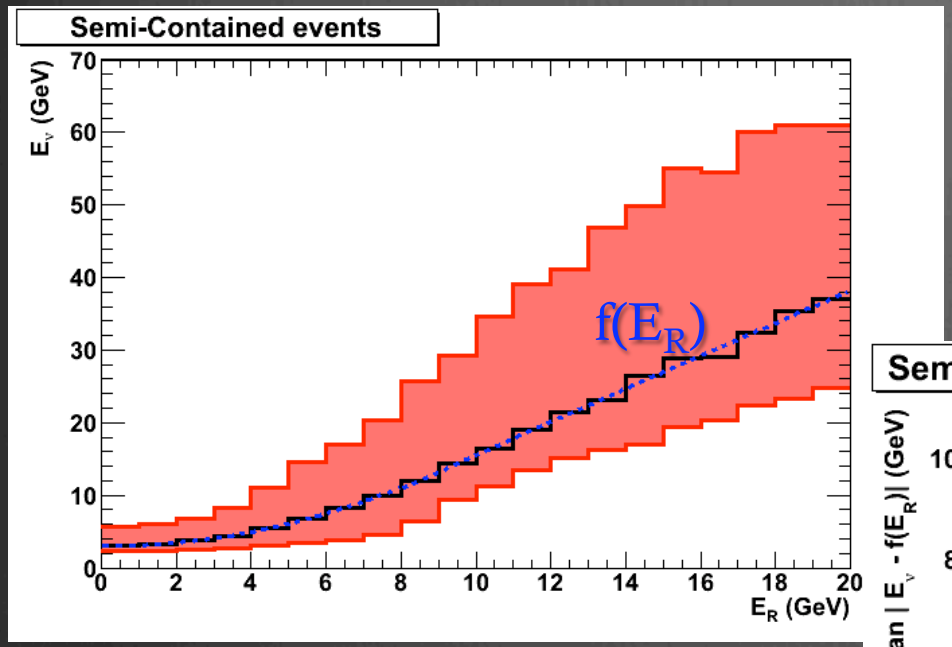
Contained events: events that have the estimated ending point closer to the detector centre than the estimated vertex →condition to be improved…

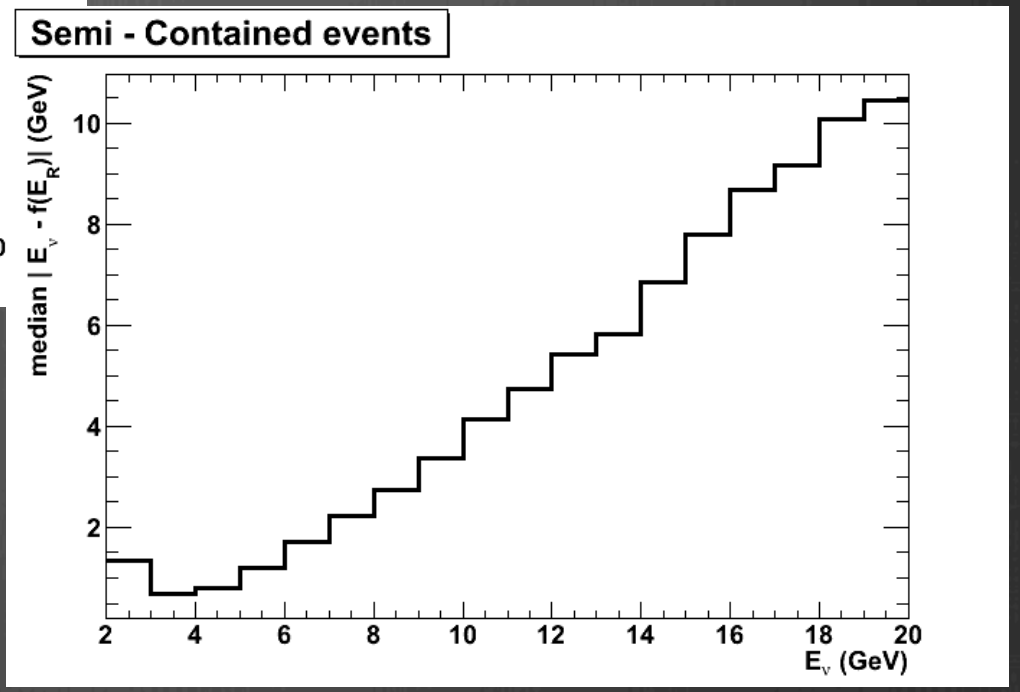
To do list

- Muon track length/energy estimate needs a study on containment conditions
- Estimate of the shower energy has to be done (there is no clear relation between the total number hits from the shower and the shower energy)

Thank you for your attention!

Neutrino energy resolution



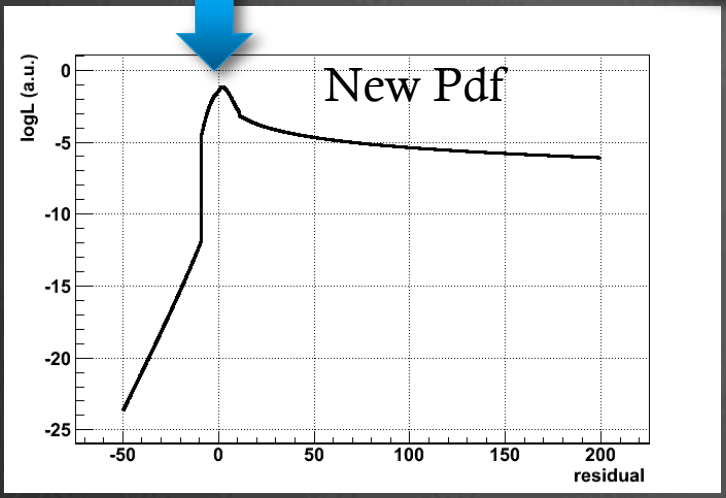


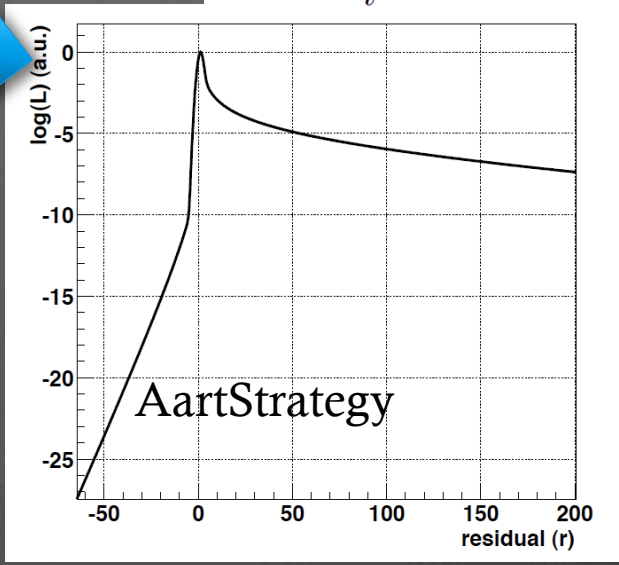
Semi-Contained events: muon reconstructed vertex inside the instrumented volume

Fit

- For each track:
  - M-estimator fit ➔ same as Aartstrategy
  - PDF fit

$$G = \sum_i -2\sqrt{1 + r_i^2/2}$$





- A best track is chosen according to the higher value of Q=Nhit – Chi2/(Nhit-5)
- Final fit ➔ same as Aartstrategy
- Each fit use the result of the previous procedure as a starting point and are used only hits selected with the "angular selection" and with limits on the time residual and on the orthogonal distance from the reference track. Hits with the highest score are always added.