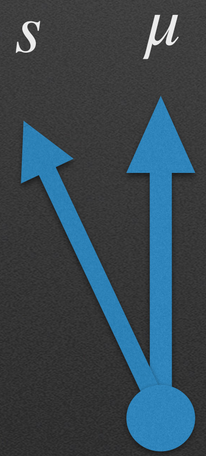
# Combined PDFs

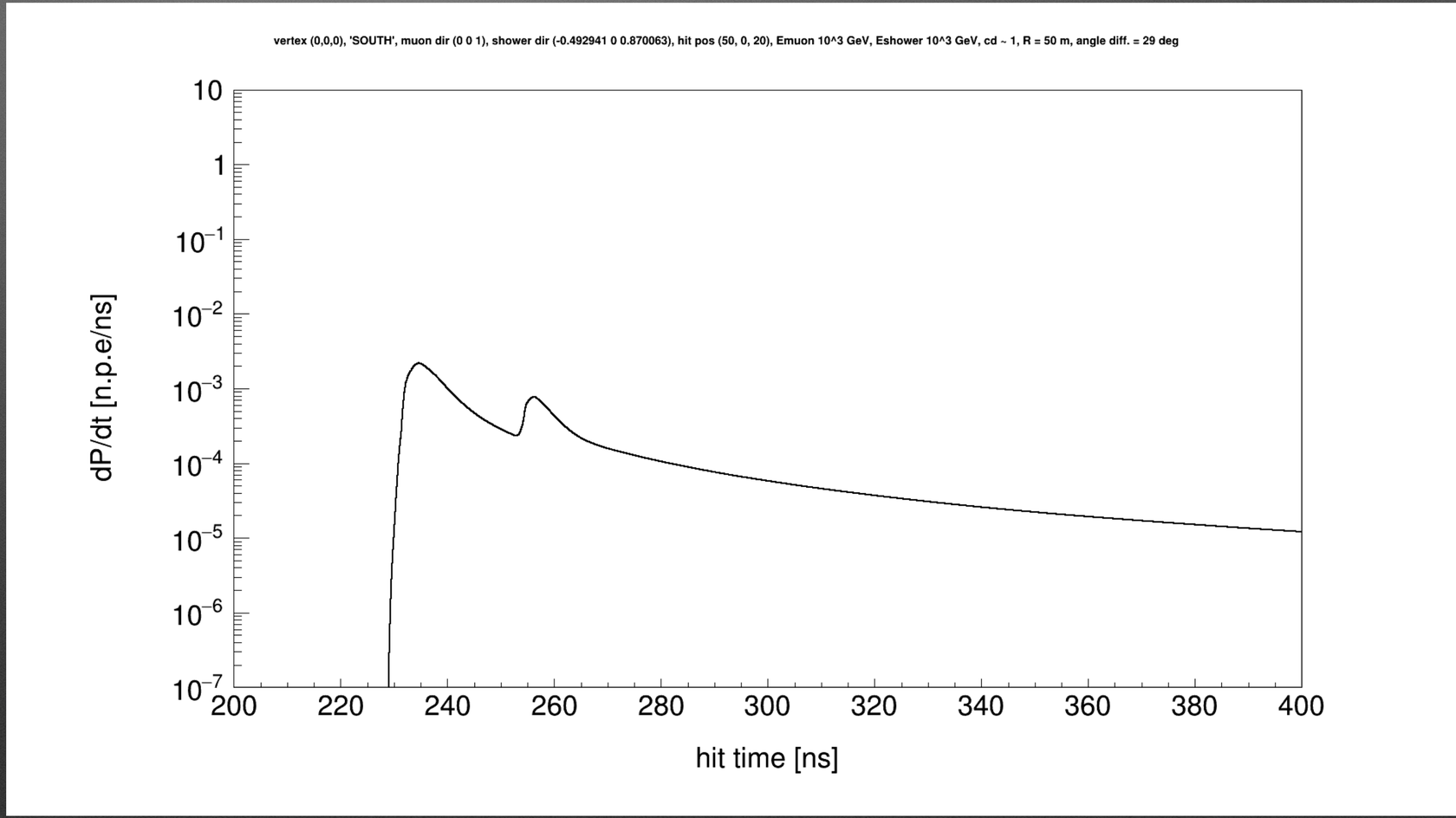
- Likelihood: will begin with first hit probability
- $P_{\text{first hit}} = f \cdot \dfrac{e^{-v}}{1 - e^{-V}}$
- $f$ rate of photoelectrons, $v$ cumulative number of p.e.'s up to that time, $V$ total number of p.e.'s

# Combined PDFs

- So for one example..

‘SOUTH’



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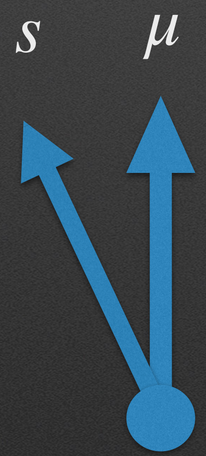


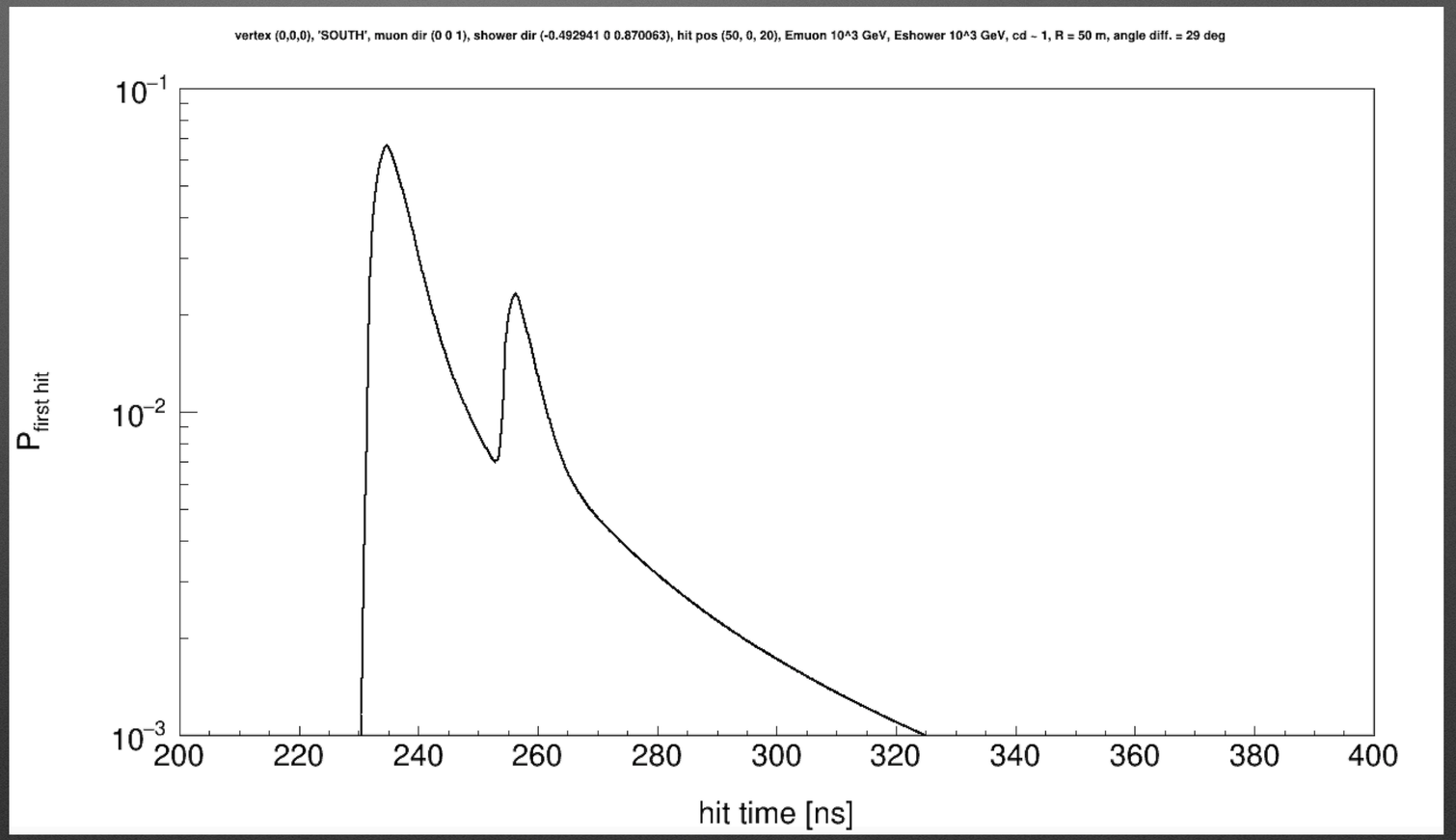

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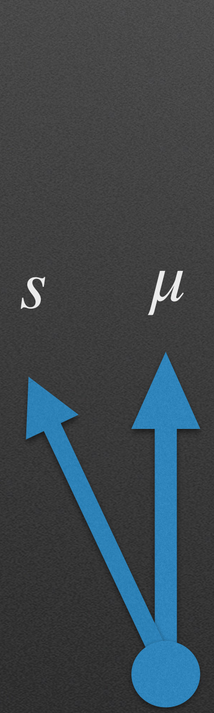


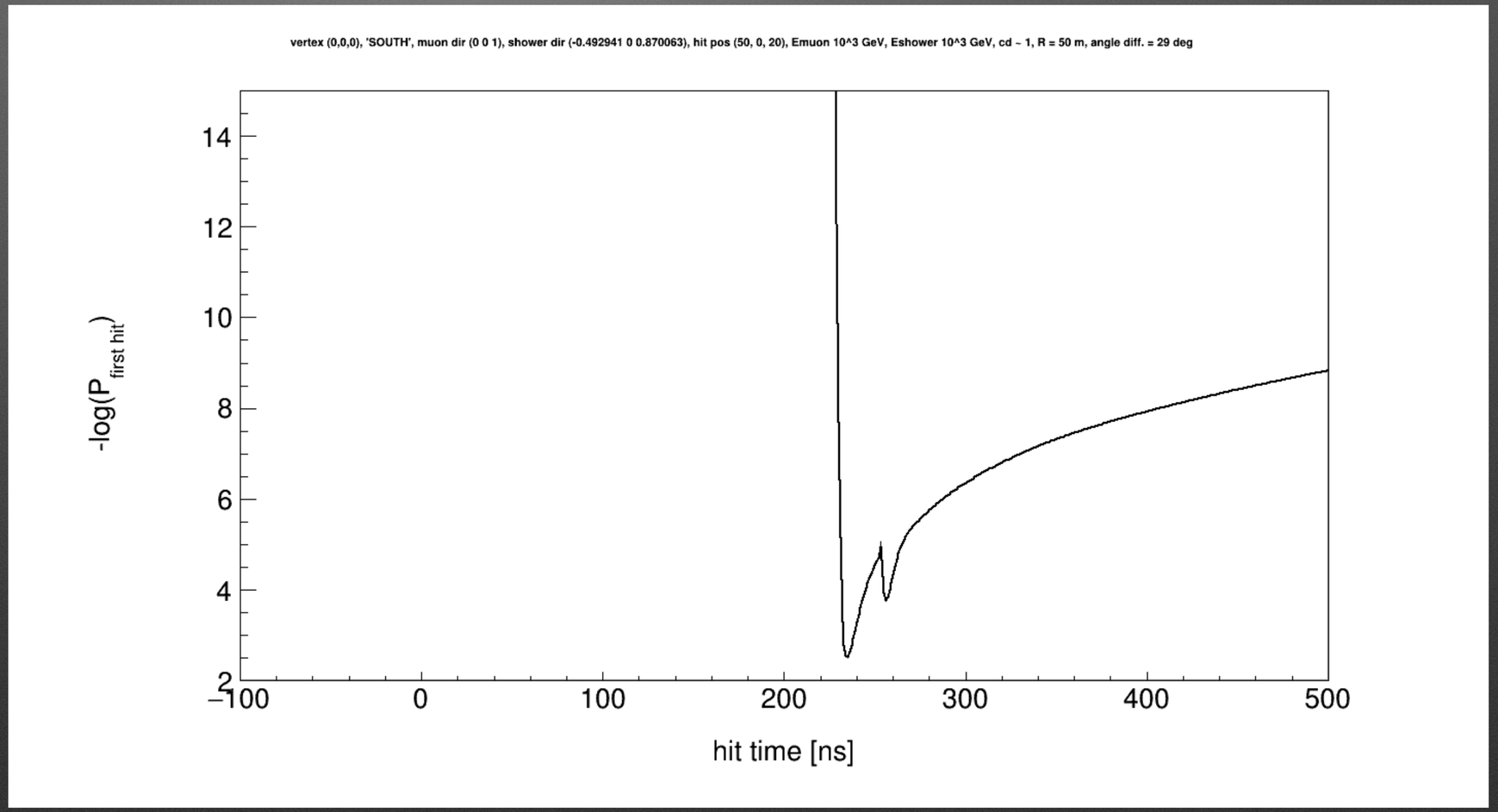

# Combined PDFs

- An edge case..

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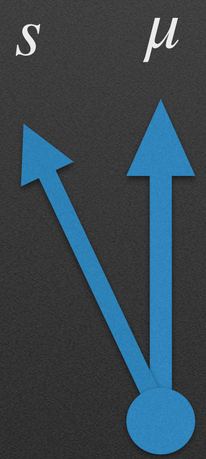


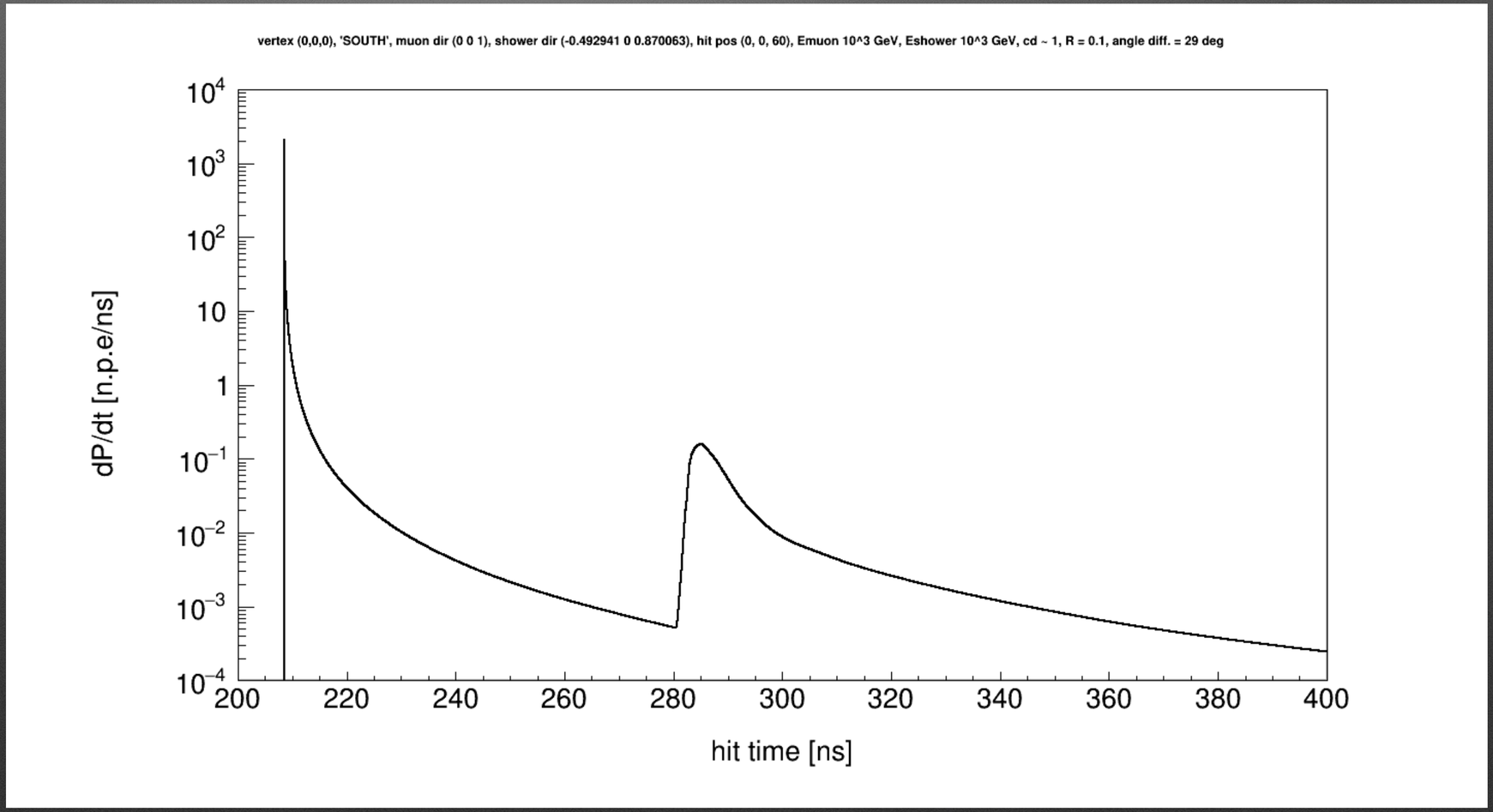

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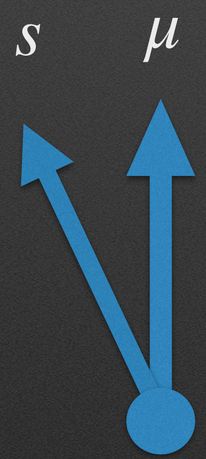


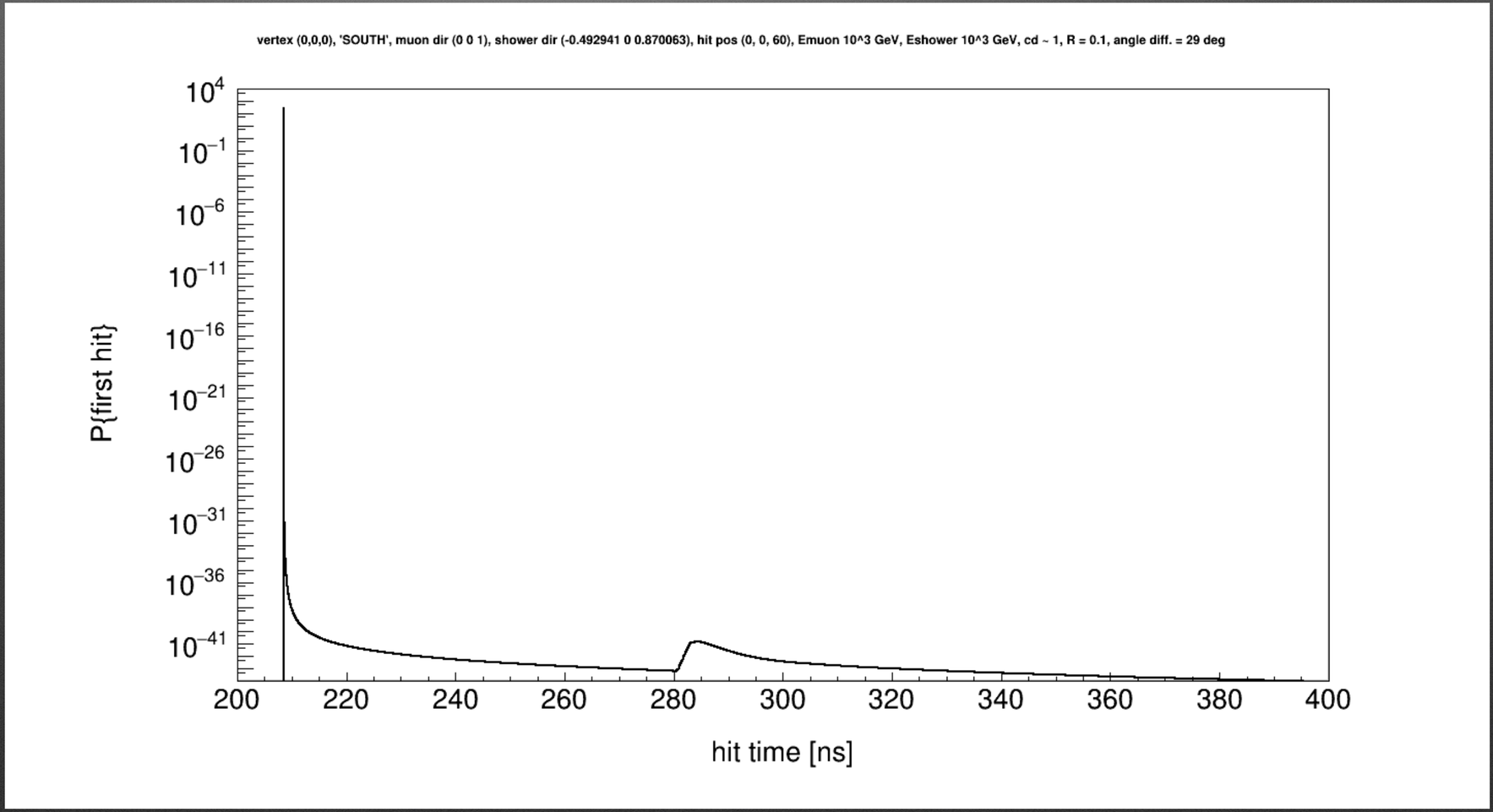

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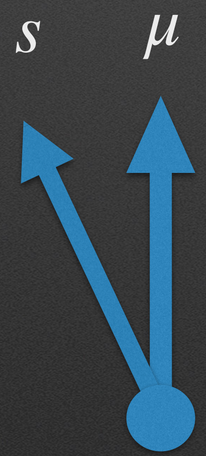
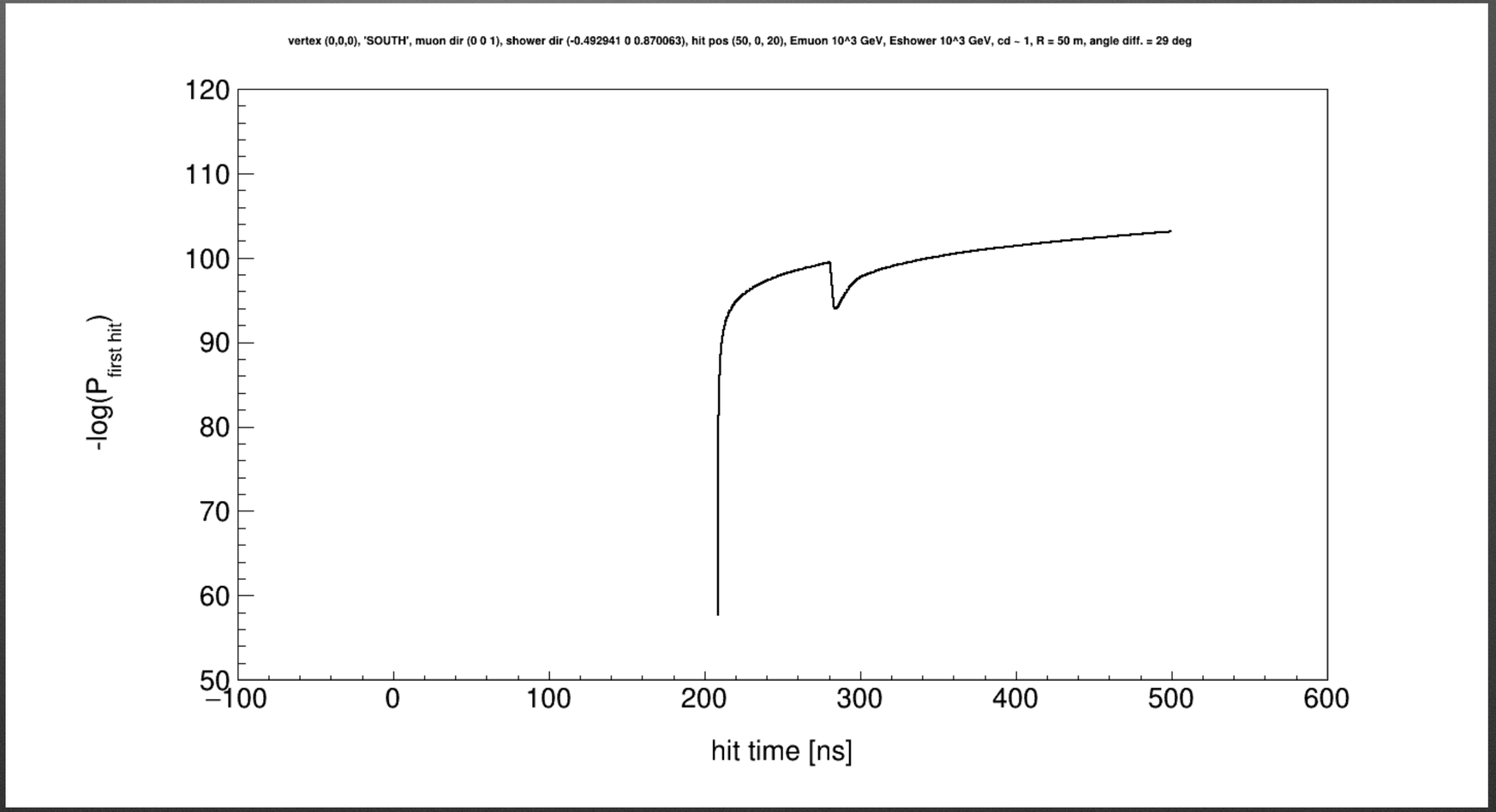


- Move from a hit-based likelihood study to event-based likelihood
- Deviate true model parameters from likelihood minimum
- Choose a clean sample of events to test likelihood on..

- Choose a set of events from a triggered data file: well-understood, clean events.
- Store the DAQ events & MC truth info in parallel.
- Choose clean samples with cuts: e.g.

  - vertex is inside detector volume
  - number of PMTs hit, e.g. 10
  - number of muons per event, e.g. 1 minimum
  - track length cut, e.g. 50 m track - strict one only for muons

- Cuts can be optimised as we go along

- Script to loop through input events, calculate first hit likelihood and no-hit likelihood for those events
- Within this script: call function which takes (daq event, mc event)
- fill event vertex model of vertex with track + shower with true parameters: vertex position, Emu, Esh, muon dir, shower dir
- At the moment, using “hadronic cascade” particles for my shower - average direction and total energy of a hadronic cascade
- For all the first hits, calculate likelihood assuming track+shower model

$$-log\mathscr{L} = \sum_{hits} log\left(n(t) \cdot \frac{e^{-N(t)}}{1 - e^{-N_{total}}}\right) + \sum_{non-hit\ PMTS} log\left(e^{-N_{total}}\right)$$

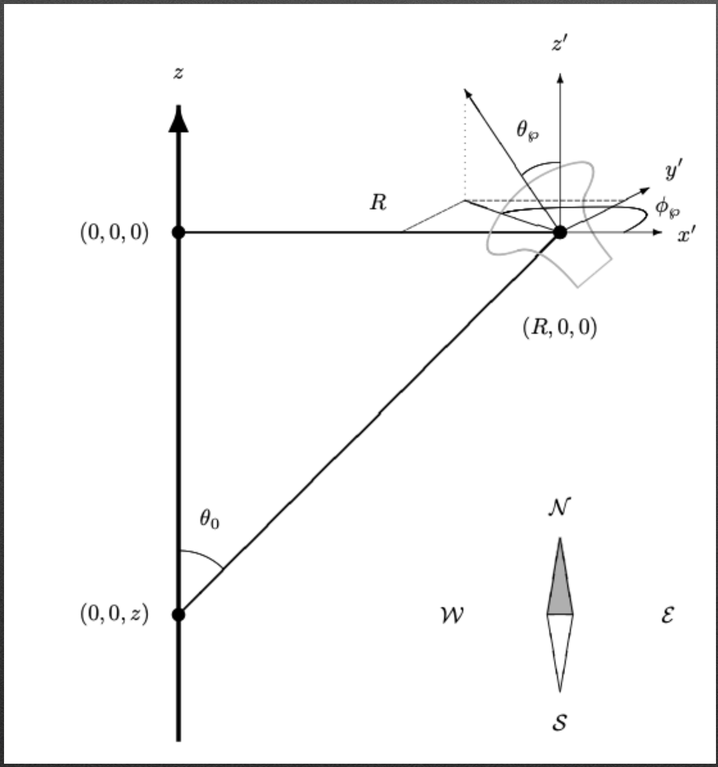
Prob_first hit

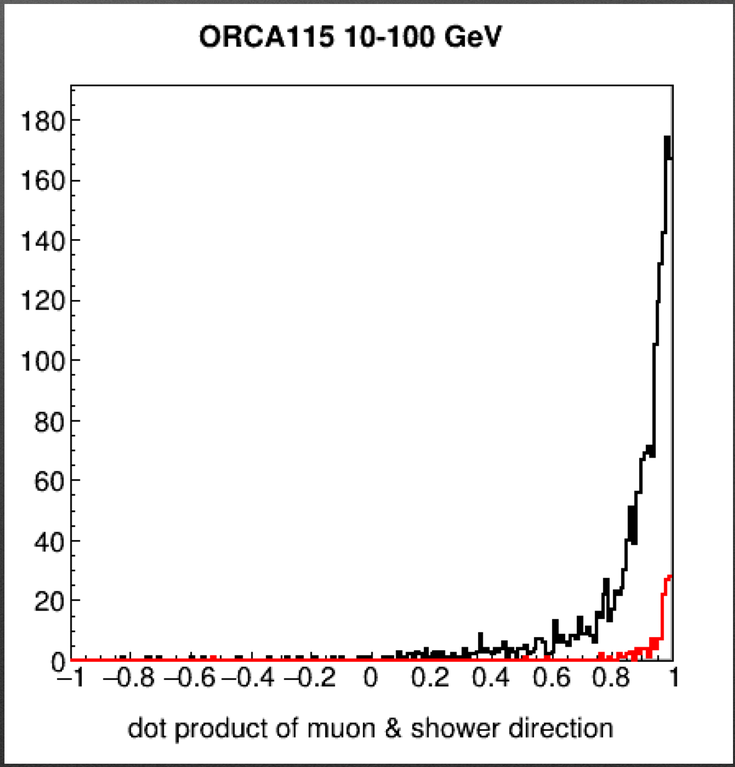
Prob_no hit

- Initially, testing on a trigger-level file (ORCA 115, 10-100 GeV) mcv5.0.gsg_muon-CC_10-100GeV.km3sim.jte.100.root - only first hits

- Operating in JPP framework. One needs to rotate the hits to be in the direction of the muon or shower - PDFs are evaluated assuming muon/shower in *z*-direction with PMT position in the *x*-*z* plane.

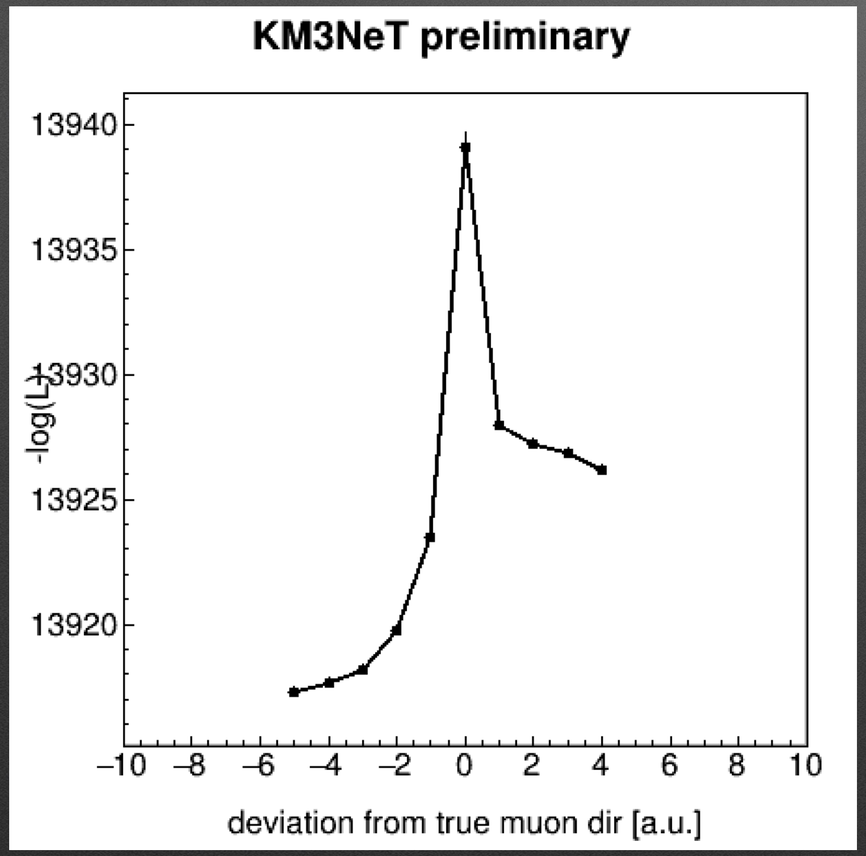
- For this, I assume the muon and shower components are co-linear..currently rotating according to muon direction.

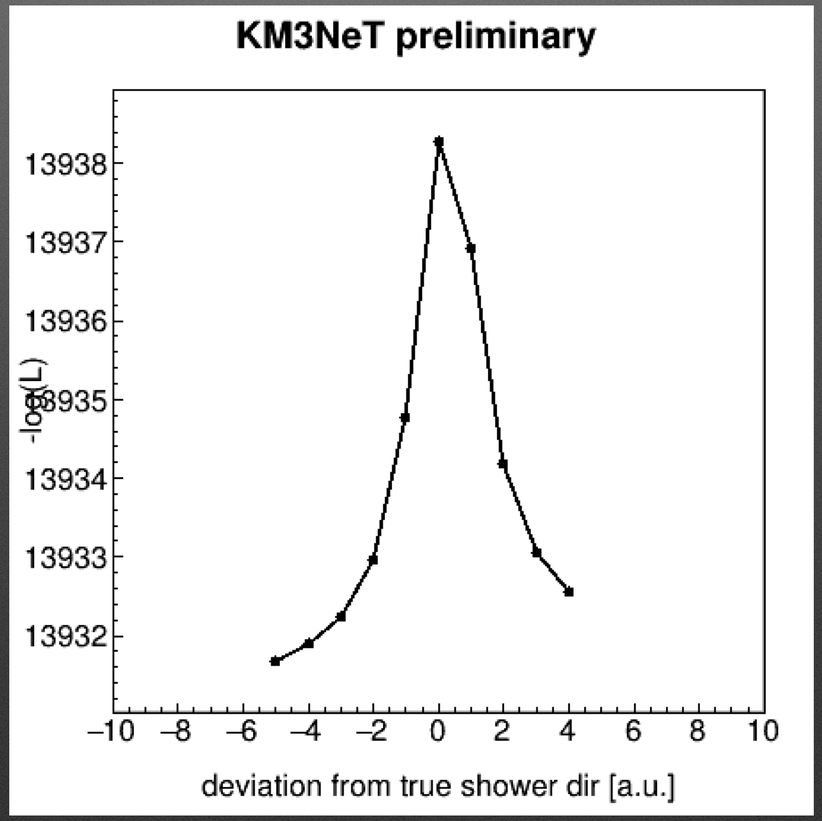


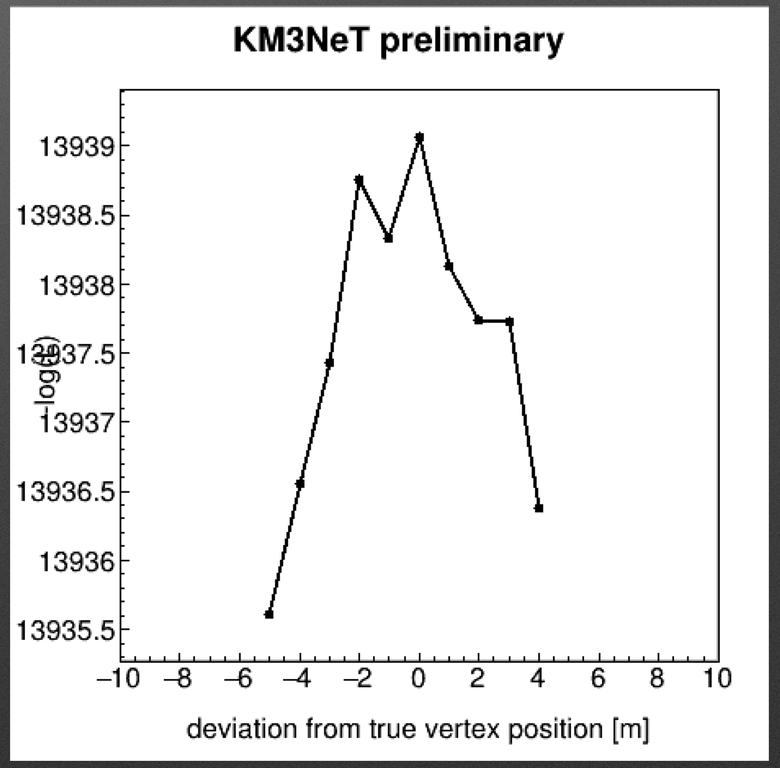



- Have included background
- Testing the likelihood for different deviations from the true value

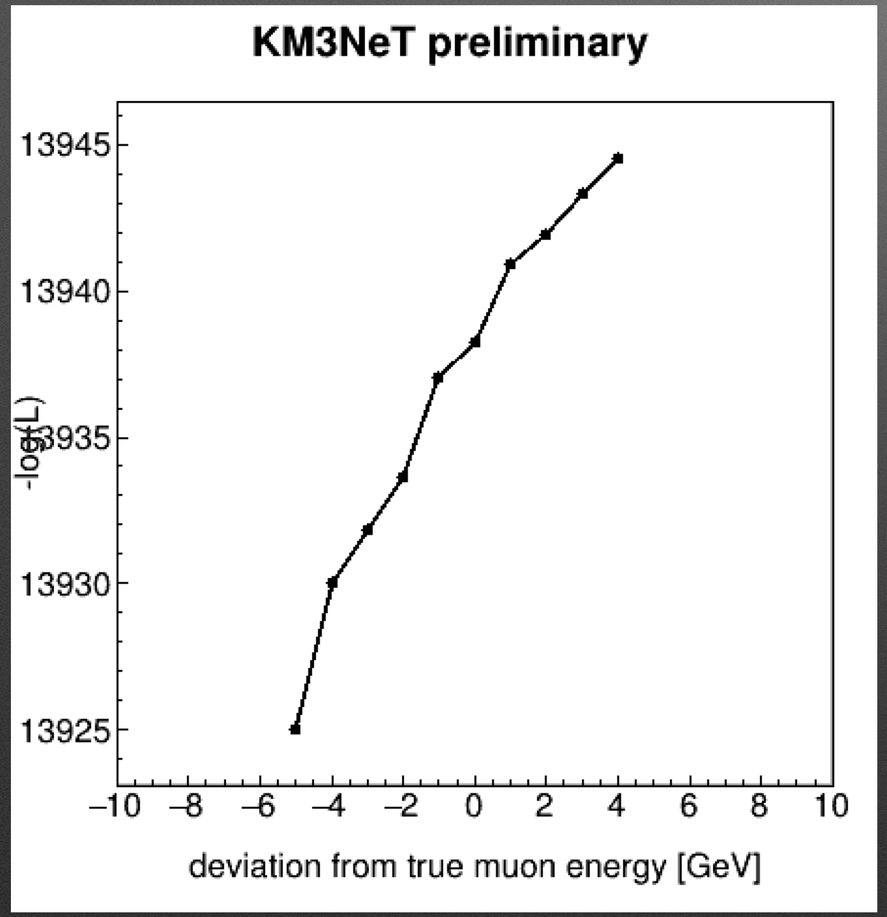
- If this was the likelihood the plots make sense, but they should show the -log l(ikelihood)..

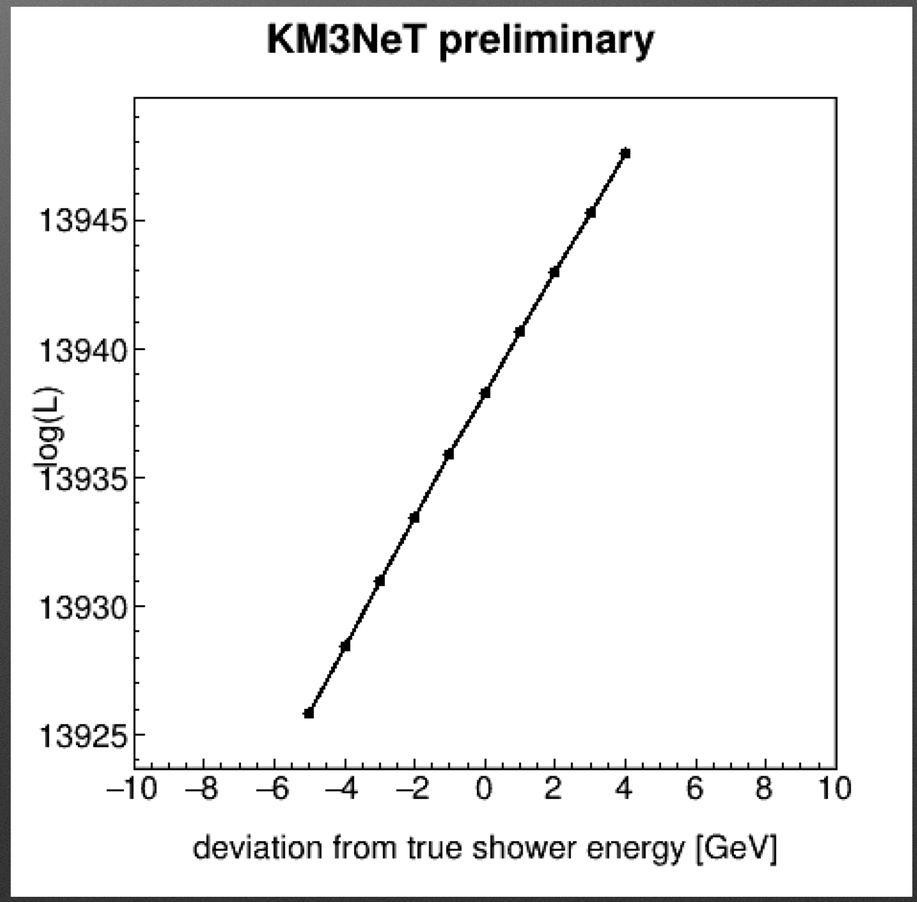


- If this was the likelihood the plots make sense, but they should show the -log (likelihood)..
- Lone first hit likelihood is not sensitive to the energy (makes sense)



- Simply using a getChi2 function for the likelihoods and summing..

```
/**
 * Get probability of first hit.\n
 * The probability is defined at the moment JResultPDF::f and JResultPDF::v have been evaluated
 * and it is normalised to the total interval corresponding to JResultPDF::V.
 *
 * \return                    probability
 */
double getP() const
{
  return exp(-v) * f / (1.0 - exp(-V));
}


/**
 * Get chi2 of first hit.\n
 * The chi2 corresponds to <tt>-log(P)</tt>, where <tt>P</tt> is the probability JResultPDF::f.
 *
 * \return                    chi2
 */
double getChi2() const
{
  return -log(getP());
}
```

So I am missing a minus sign somewhere?? Or very wrong