Edepillim: A New Muon Energy Reconstruction Method for Large Scale Neutrino Detectors

Sally Robertson[2,3], Gary Hill[1]

[1] University of Adelaide [2]University of California Berkeley

[3]Lawrence Berkeley National Laboratory

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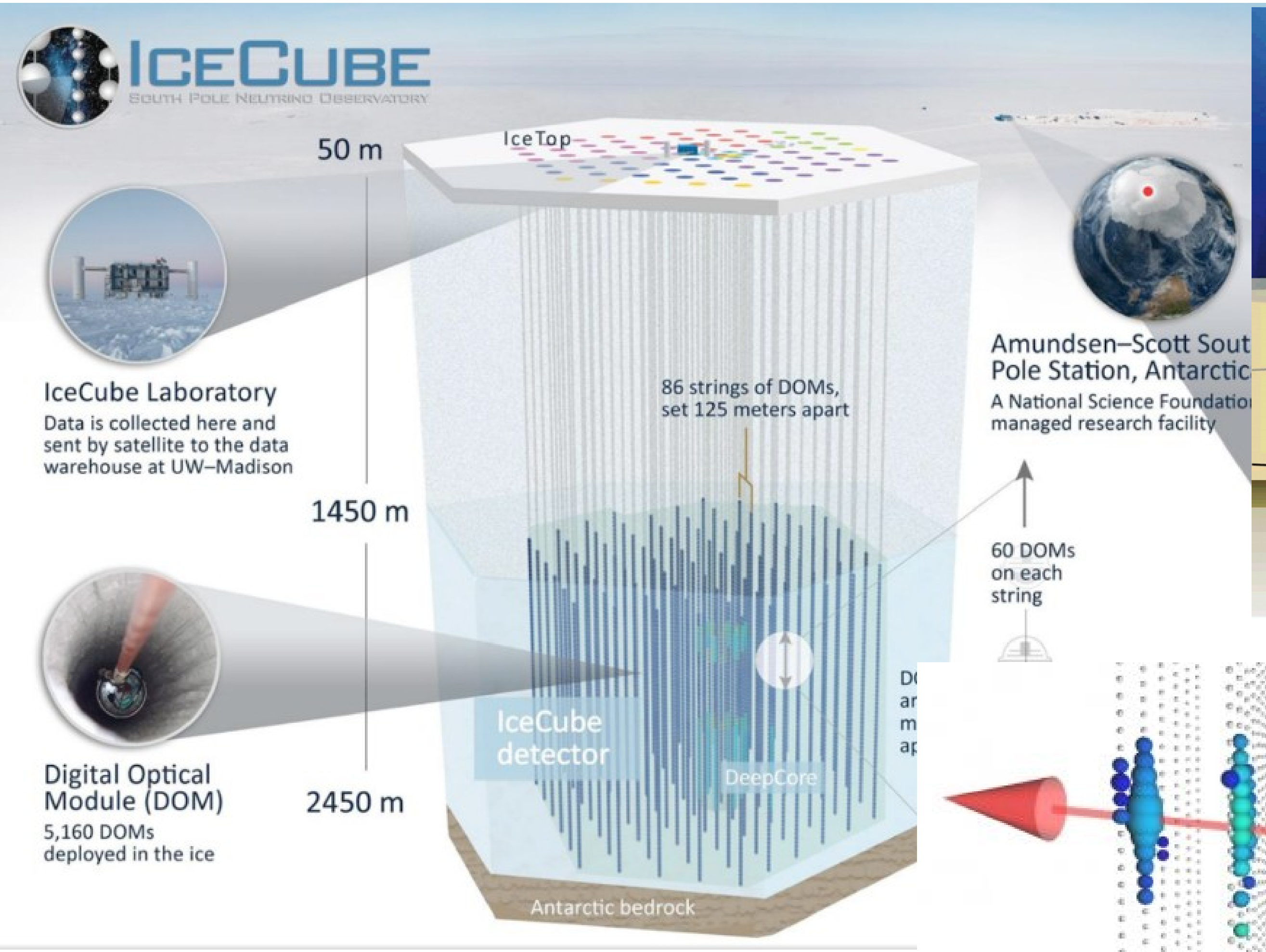
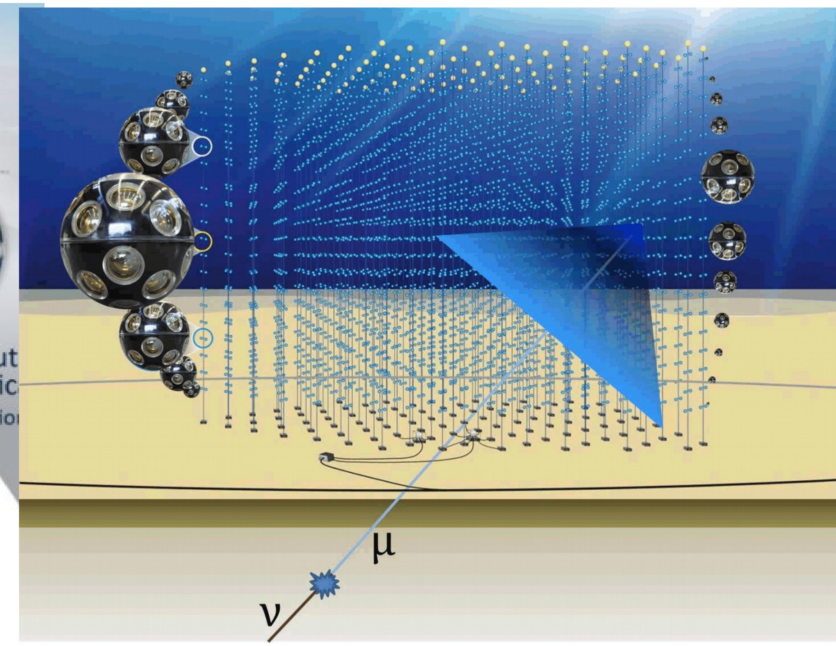
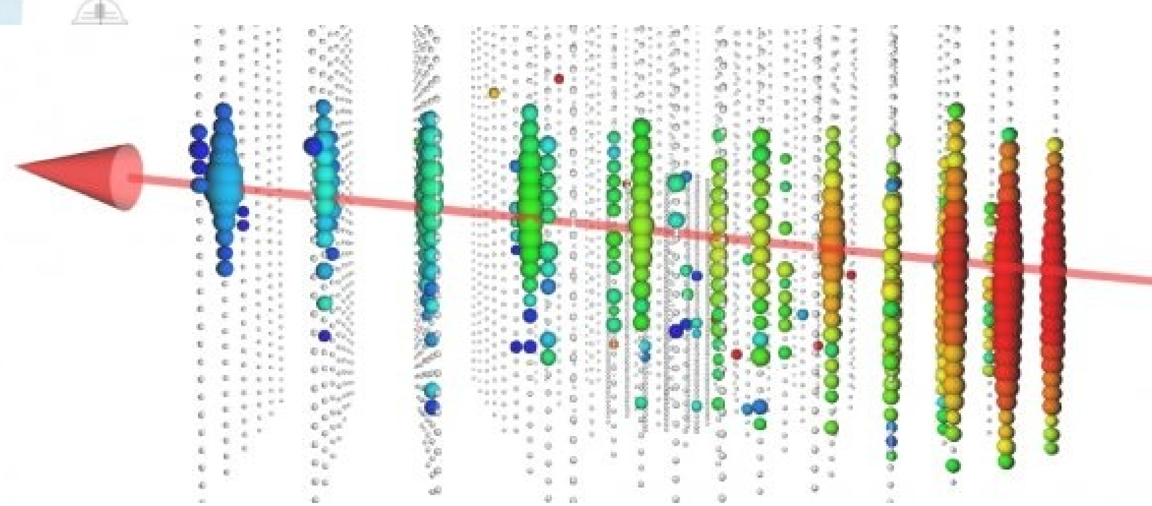
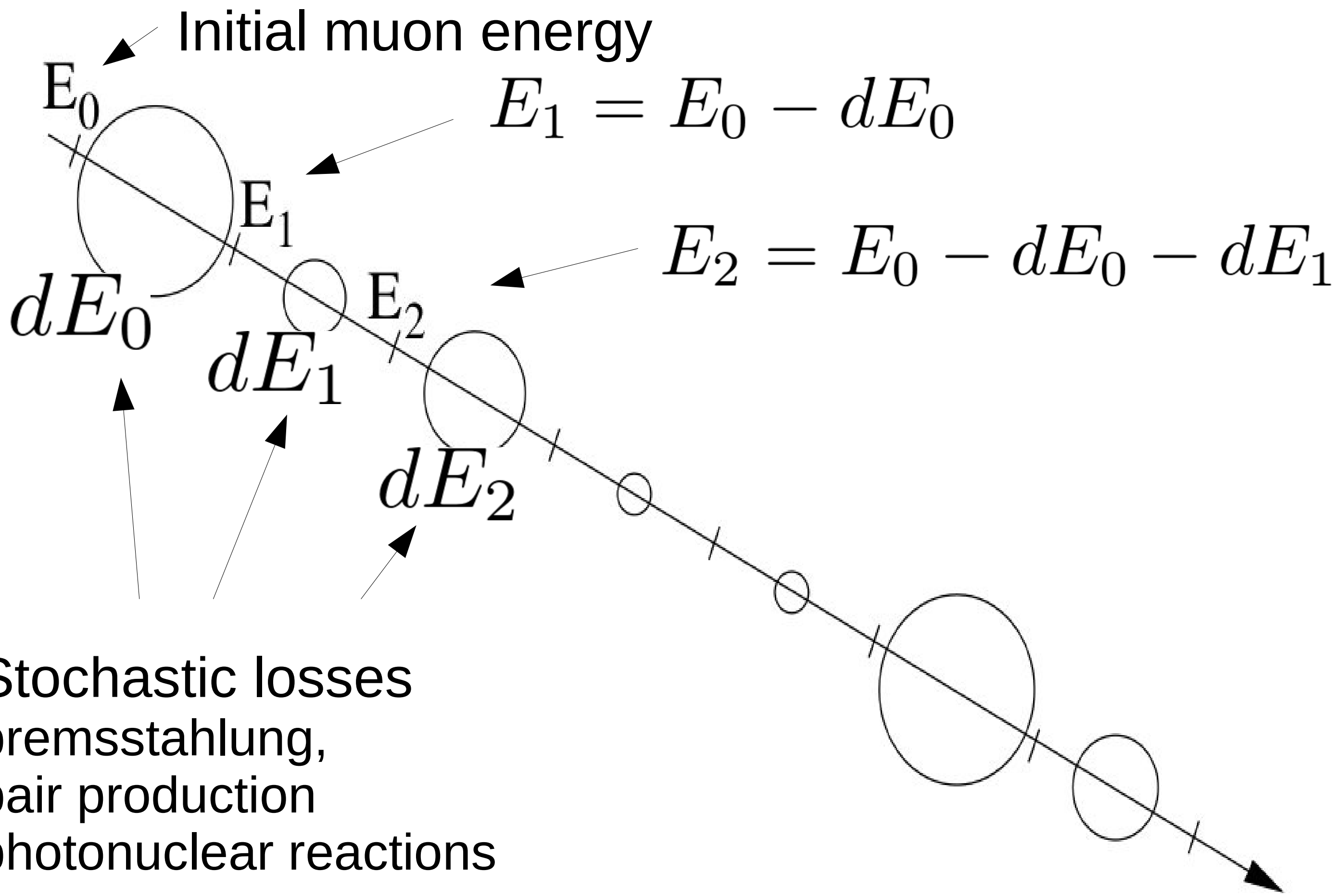
Large Scale Neutrino Detectors







Edepillim



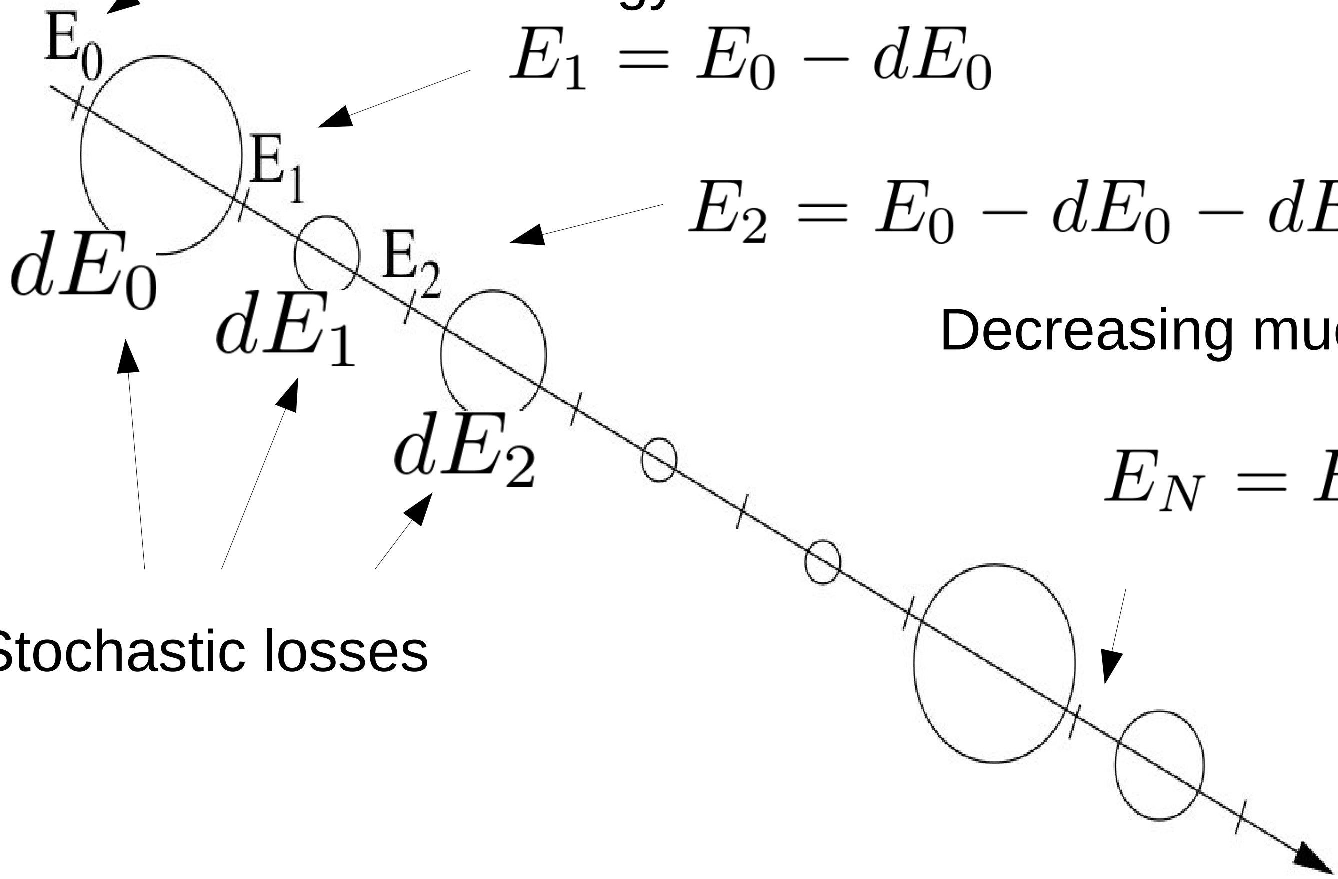
Stochastic losses
bremsstahlung,
pair production
photonuclear reactions

Edepillim

Initial muon energy

$$E_1 = E_0 - dE_0$$

$$E_2 = E_0 - dE_0 - dE_1$$



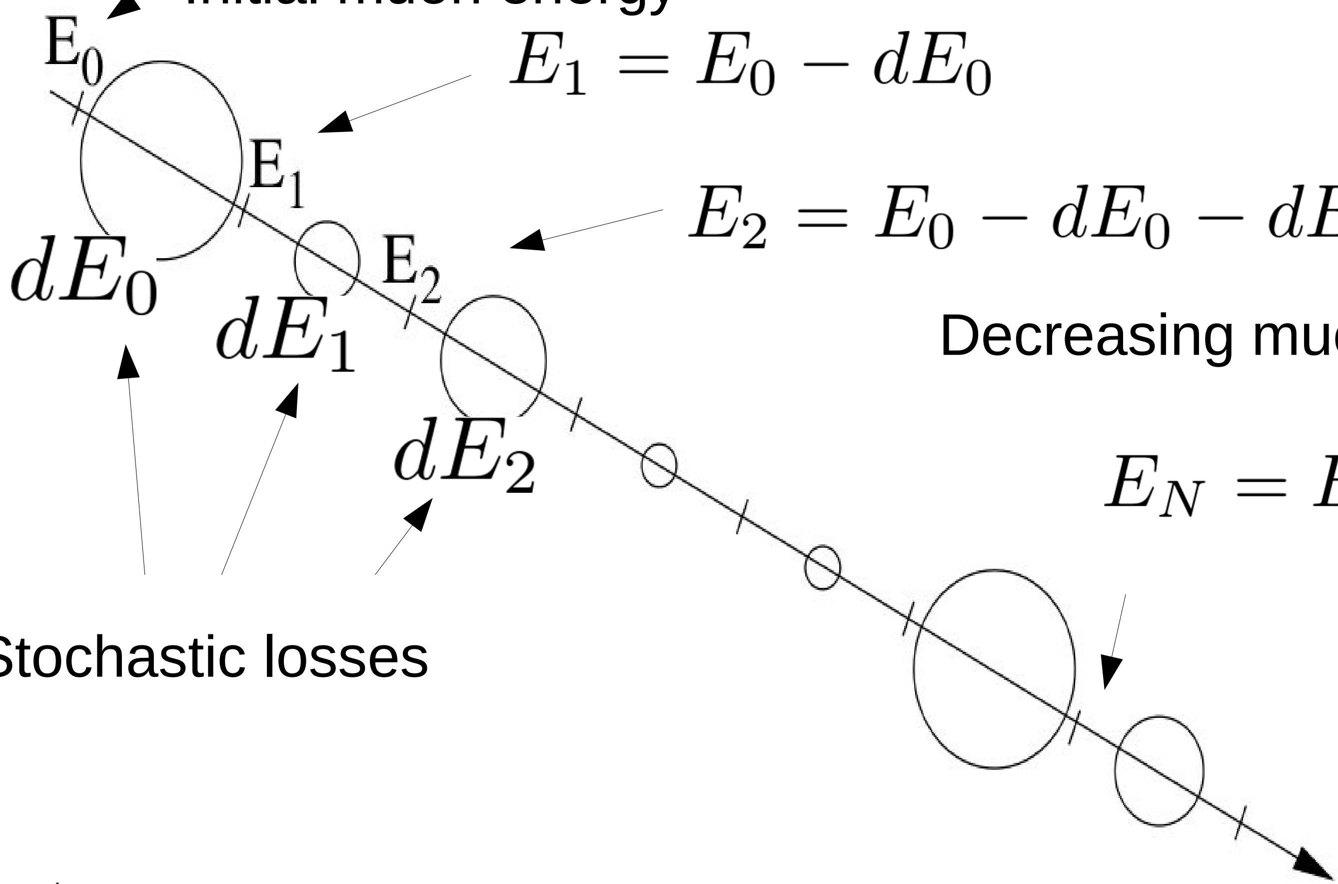
Decreasing muon energy along track

$$E_N = E_0 - \sum_{i=0}^{N-1} dE_i$$

Stochastic losses

Edepillim

Initial muon energy



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Decreasing muon energy along track

$$E_N = E_0 - \sum_{i=0}^{N-1} dE_i$$

Stochastic losses

$$p(d\vec{E}; E_0) = p(dE_0; E_0)p(dE_1; E_1)...p(dE_N; E_N)$$

$$p(d\vec{E}; E_0) = p(dE_0; E_0) \prod_{j=1}^{N} p(dE_j; E_0 - \sum_{i=0}^{j-1} dE_i)$$

We refer to E_0 as observable

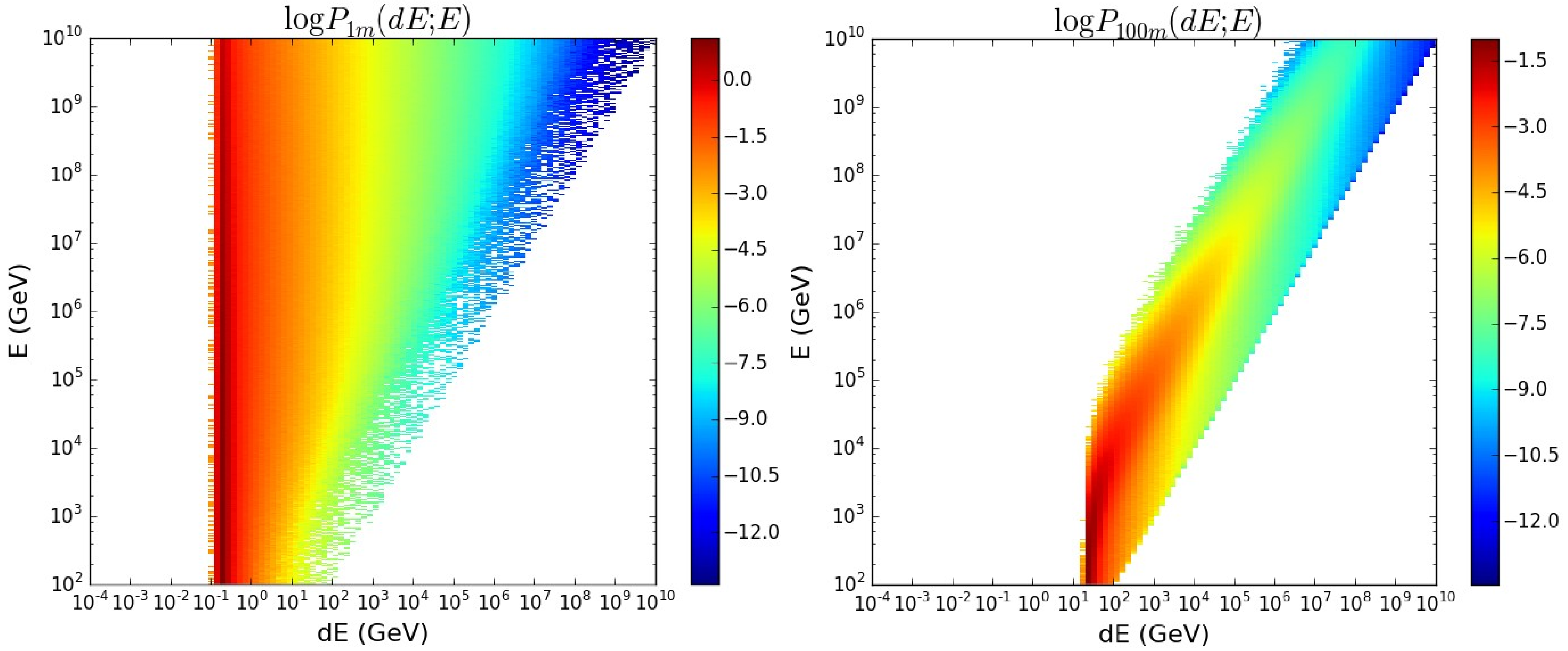
Probability is the product of the probabilities of the energy loss given muon energy.

Probability Distribution Function

PROPOSAL - **Pr**opagator with **o**ptimal **p**recision and **o**ptimized **s**peed for **a**ll **l**eptons

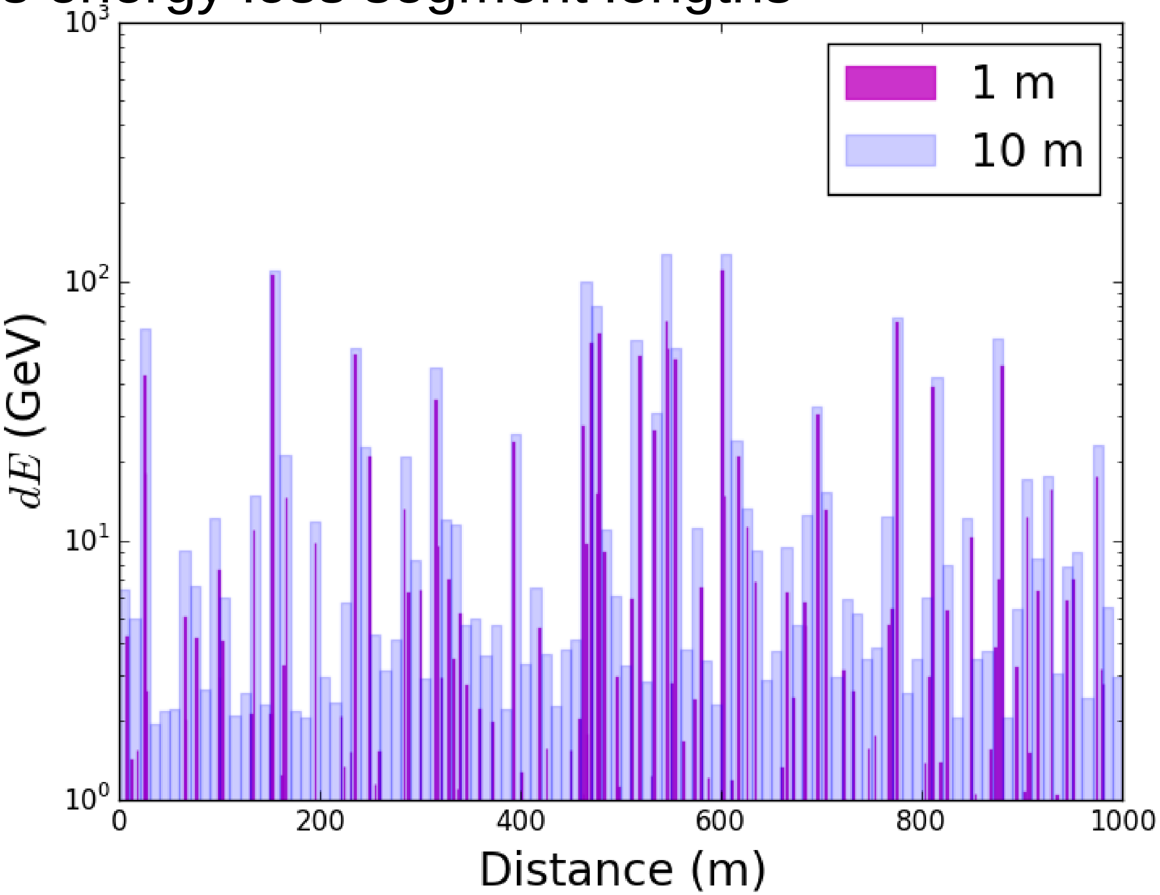
A tool for propagation of charged leptons, in this case muons

PDFs are built using PROPOSAL, simulating a muon energy E over a track length collecting the continuous and stochastic losses.



Muon Energy Loss Segment Length

In large scale neutrino detectors, accurate energy loss pattern reconstruction can be limited depending on the medium and the detector. To show the performance of Edepillim under different detector conditions the individual energy loss patterns of the simulated events were combined to make various energy loss segment lengths



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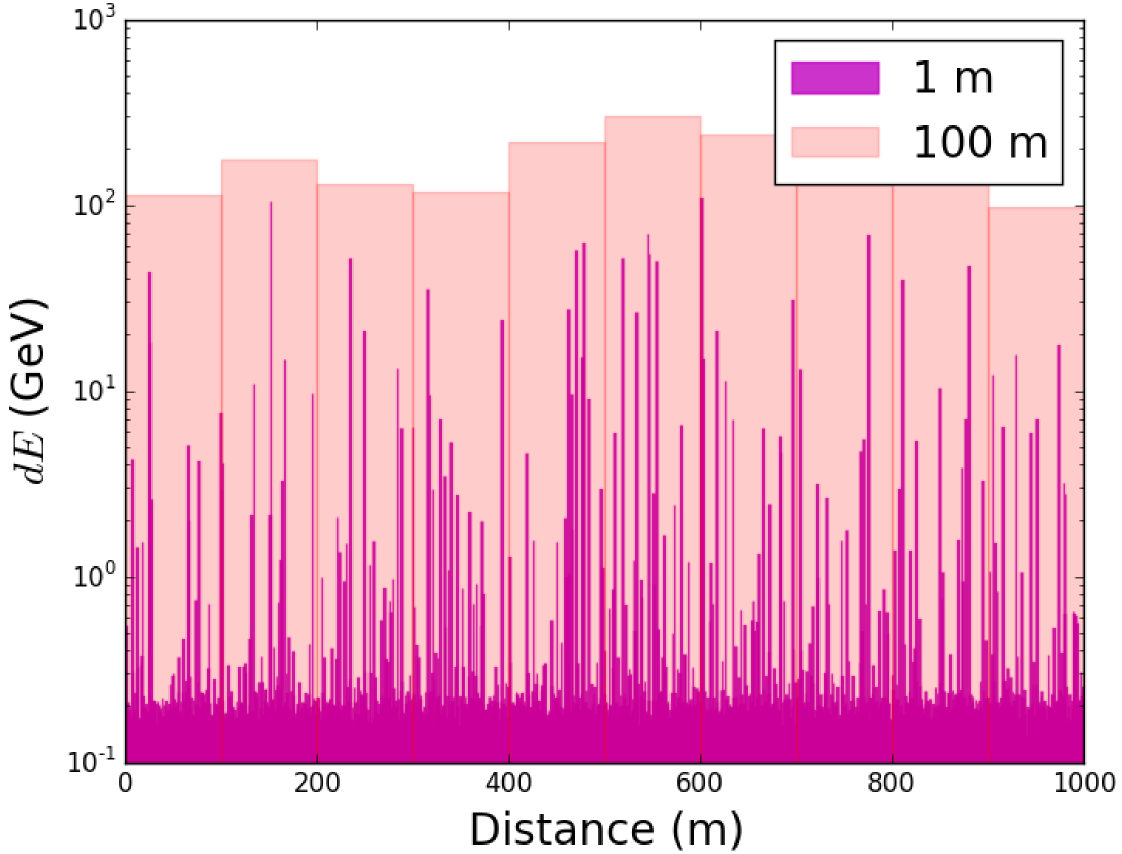
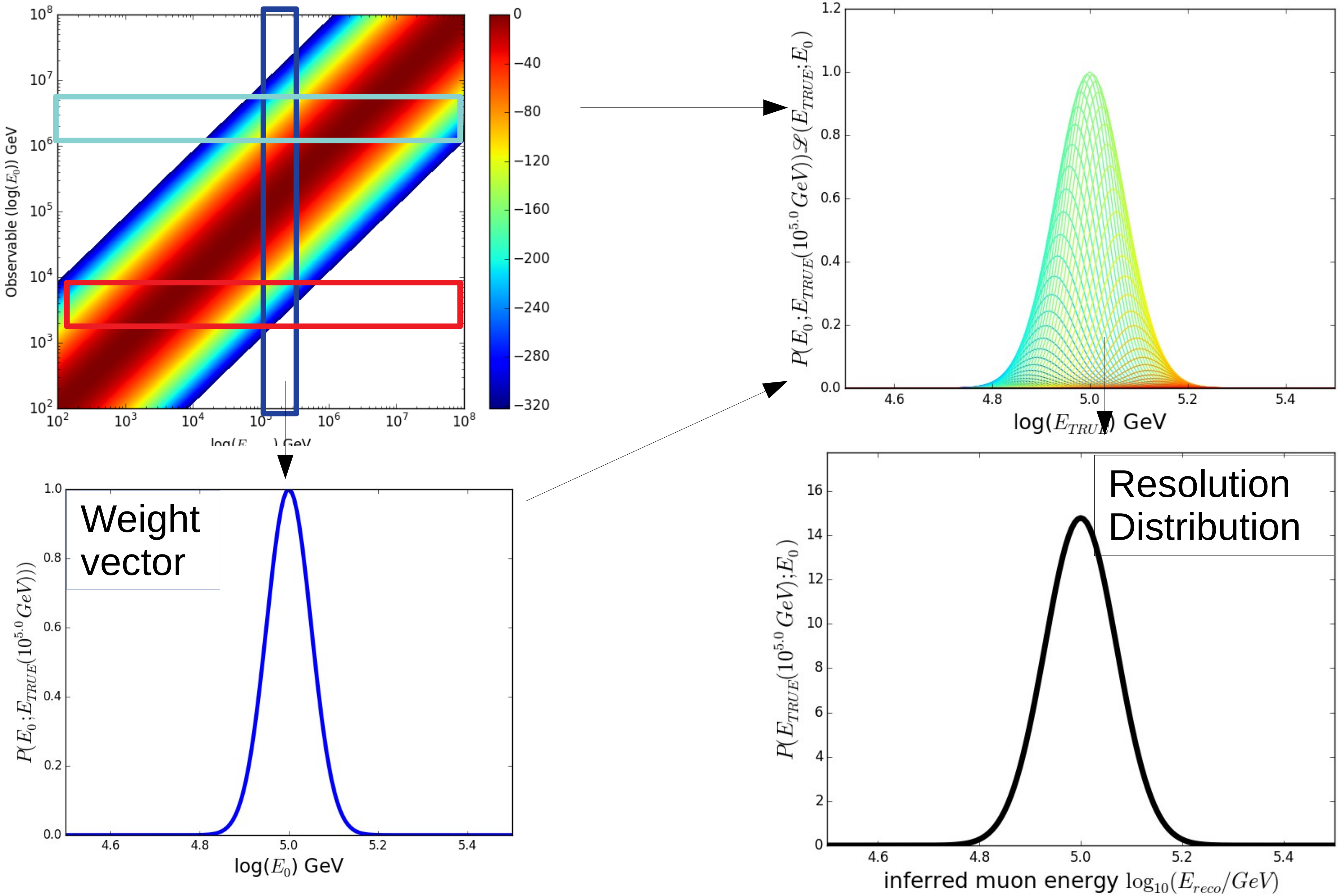


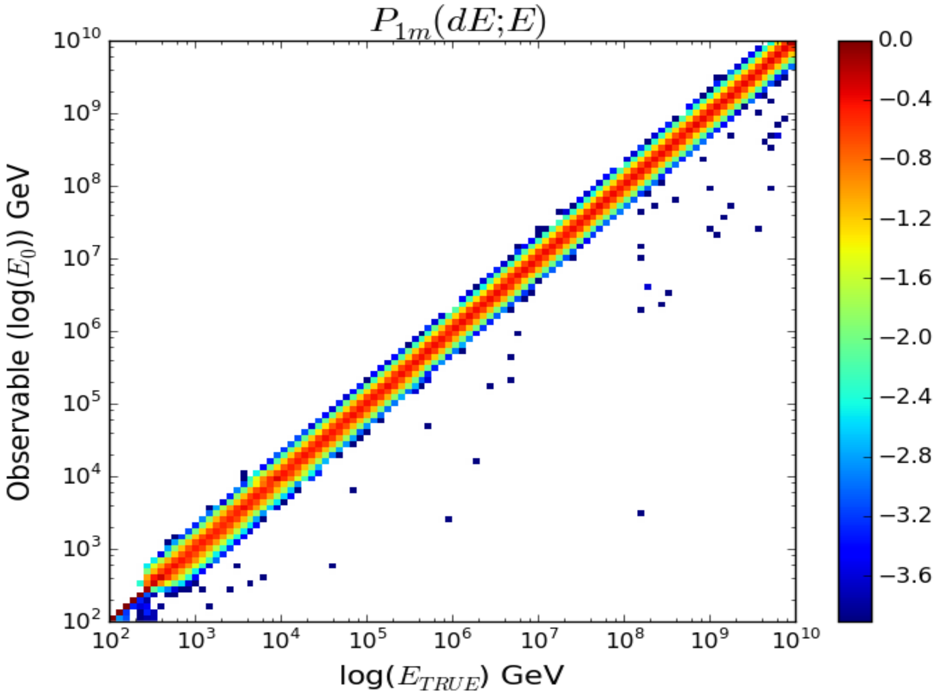
Reconstruction Distribution Using Average Likelihood Function

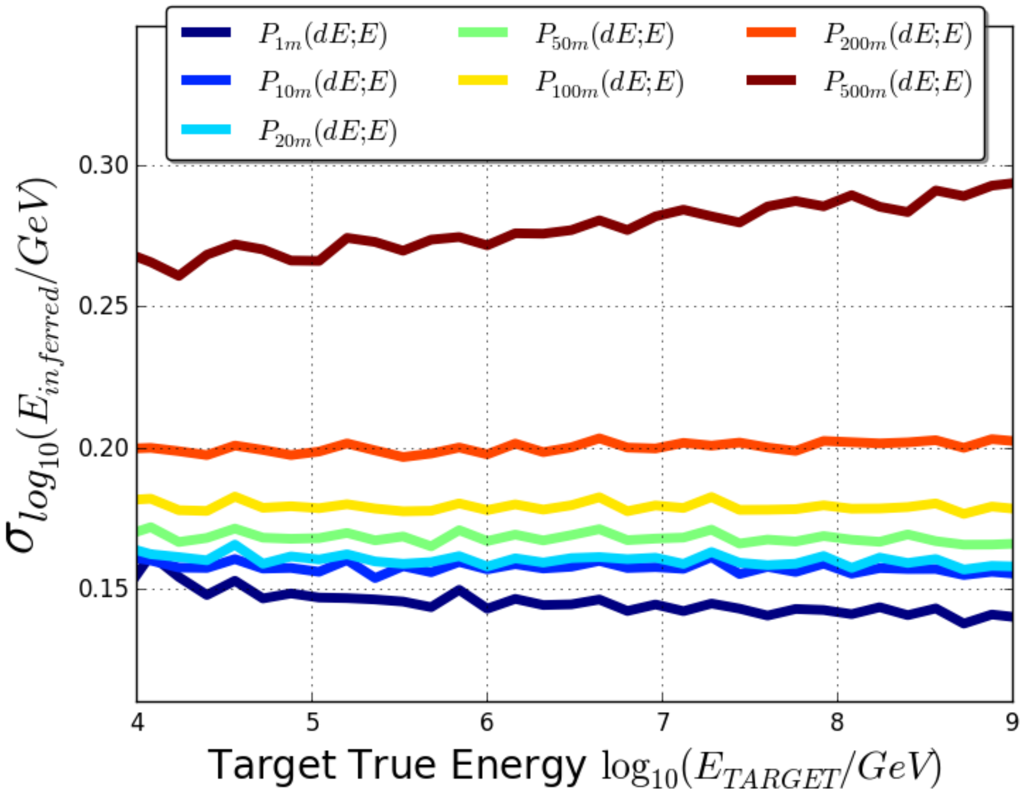
$$P(E_{TARGET}; E_0) = \sum_{i=0}^{N} P(E_0(i); E_{TARGET})\mathscr{L}(E_{TRUE}; E_0(i));$$



Edepillim Performance on Segment Length

Using a PROPOSAL simulation of muon energy loss along a 1000m track, with varying energy loss bin sizes.
using the true losses, larger bin sizes has the effect of worsening the resolution, as detail in the energy loss pattern is lost.

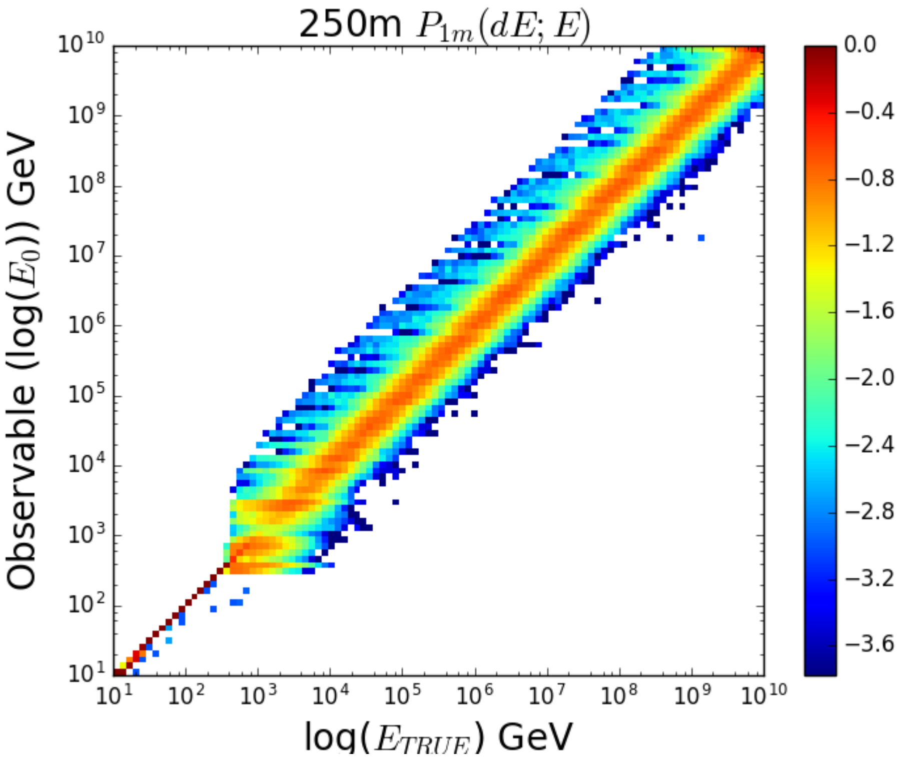


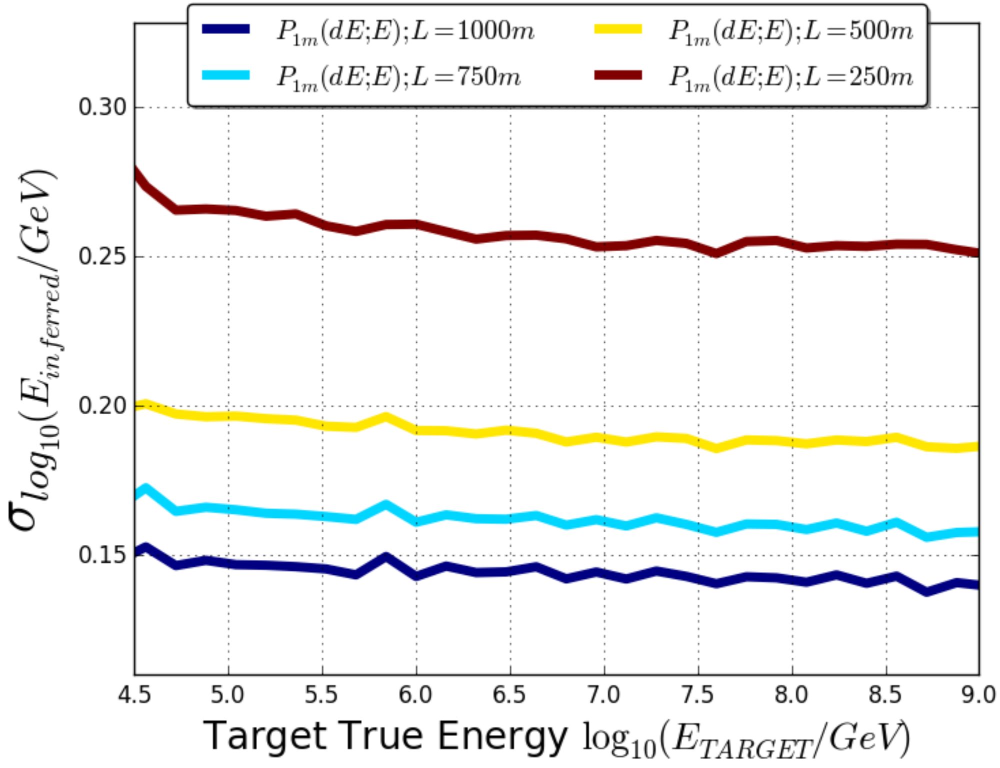


Sally Robertson University of Adelaide - UC Berkeley/LBNL

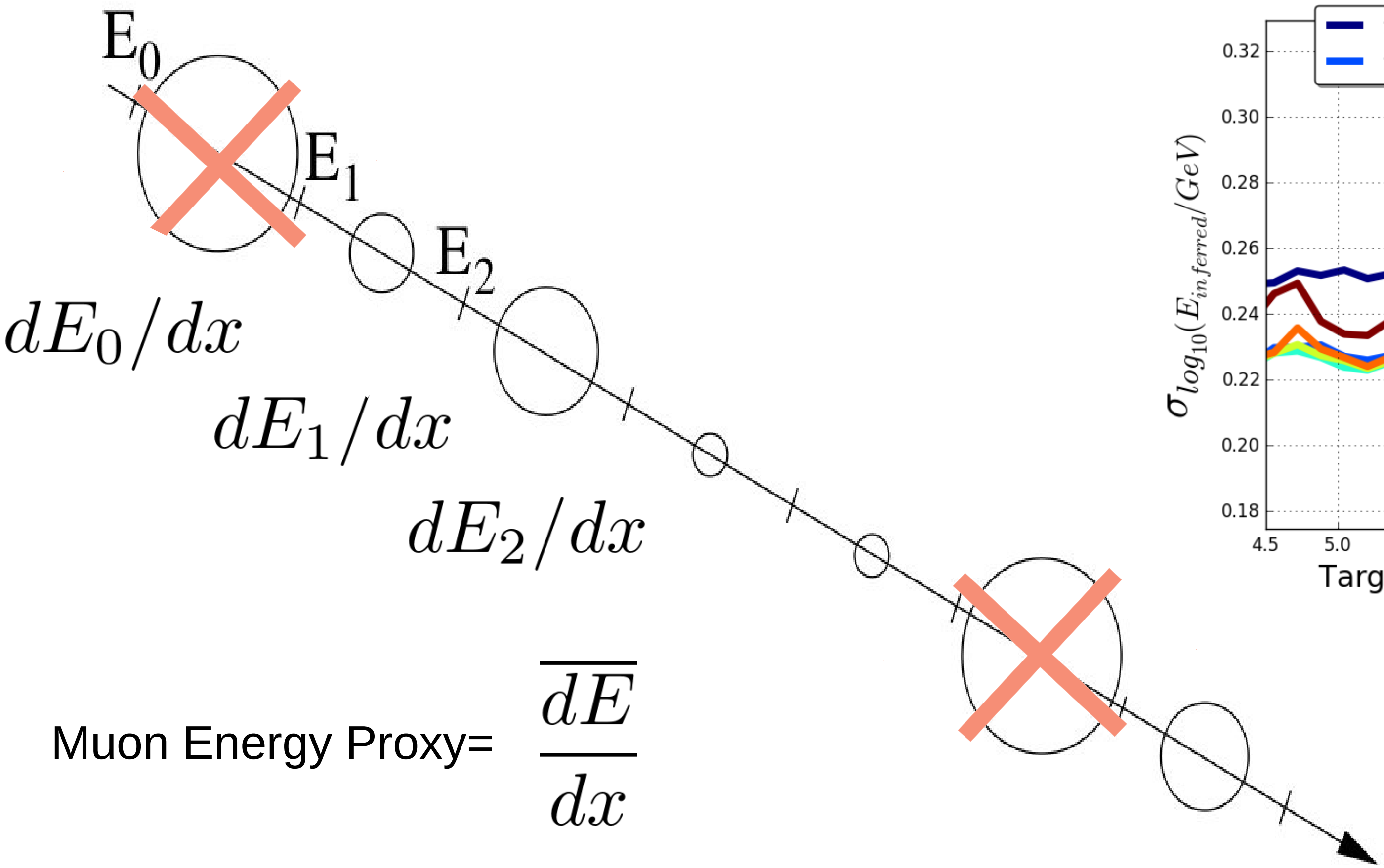
Edepillim Performance on Pattern Path Length

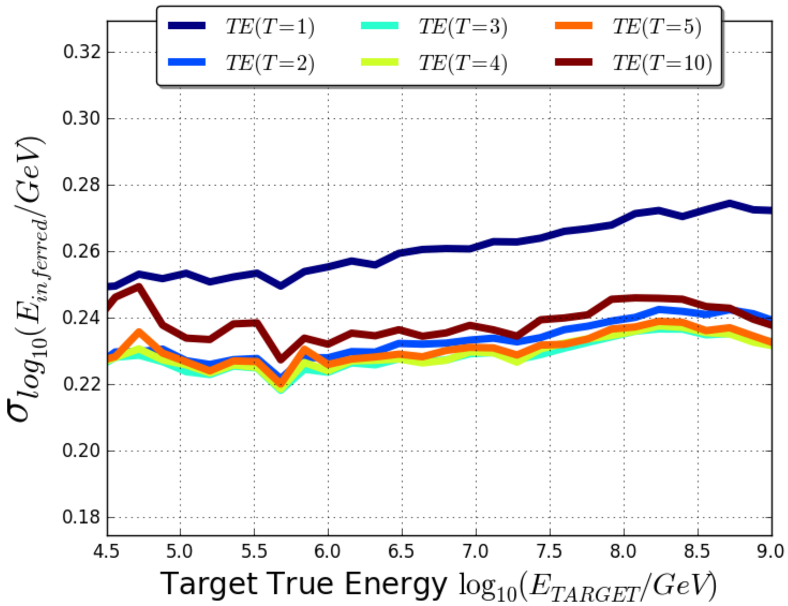
Using the true losses, shortening the track length has the effect of worsening the resolution as there are less energy losses to work with.





Idealised Truncated Mean Energy Loss Rate





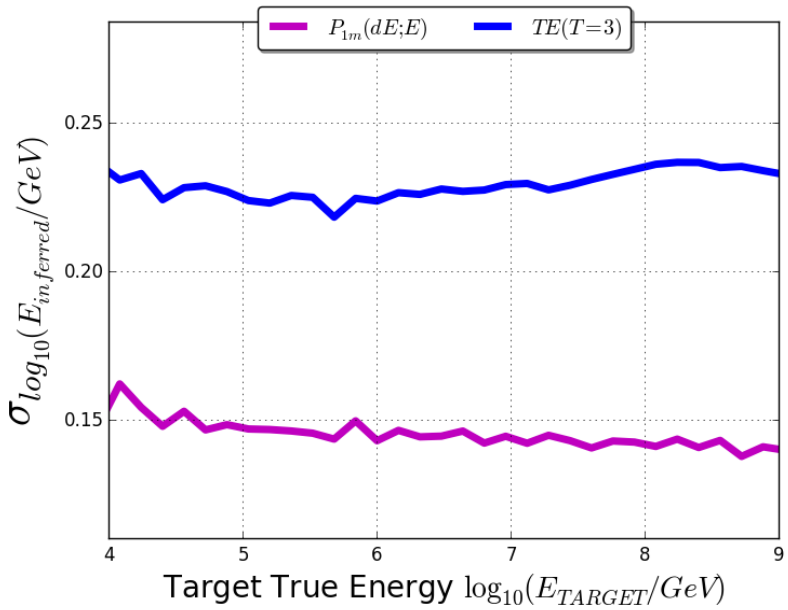
Muon Energy Proxy= $\overline{\frac{dE}{dx}}$

This is a simple version of Truncated Mean Energy Loss Rate[1] using the energy loss pattern. The complete version as used in the IceCube neutrino observatory accounts for detector effects ect.

[1]IceCube Collaboration, R. Abbasi and et al., NIM, 703 (2013) 190 – 198

Comparison to Truncated Mean Energy Loss Rate

- The comparison of an idealised case of the truncated mean energy method (TE) shows the large possible improvement with Edepillim in its best segment length of 1m.
- However detector effects such as energy loss resolution will affect the overall result, worsening the resolution.



Conclusion

- We have developed an new method for reconstruction of muon energy using the stochastic energy loss pattern.
- The new method Edepillim works best for long muon tracks where the energy losses can be well resolved.
- In an idealised case it is the energy reconstruction method with the higher energy resolution

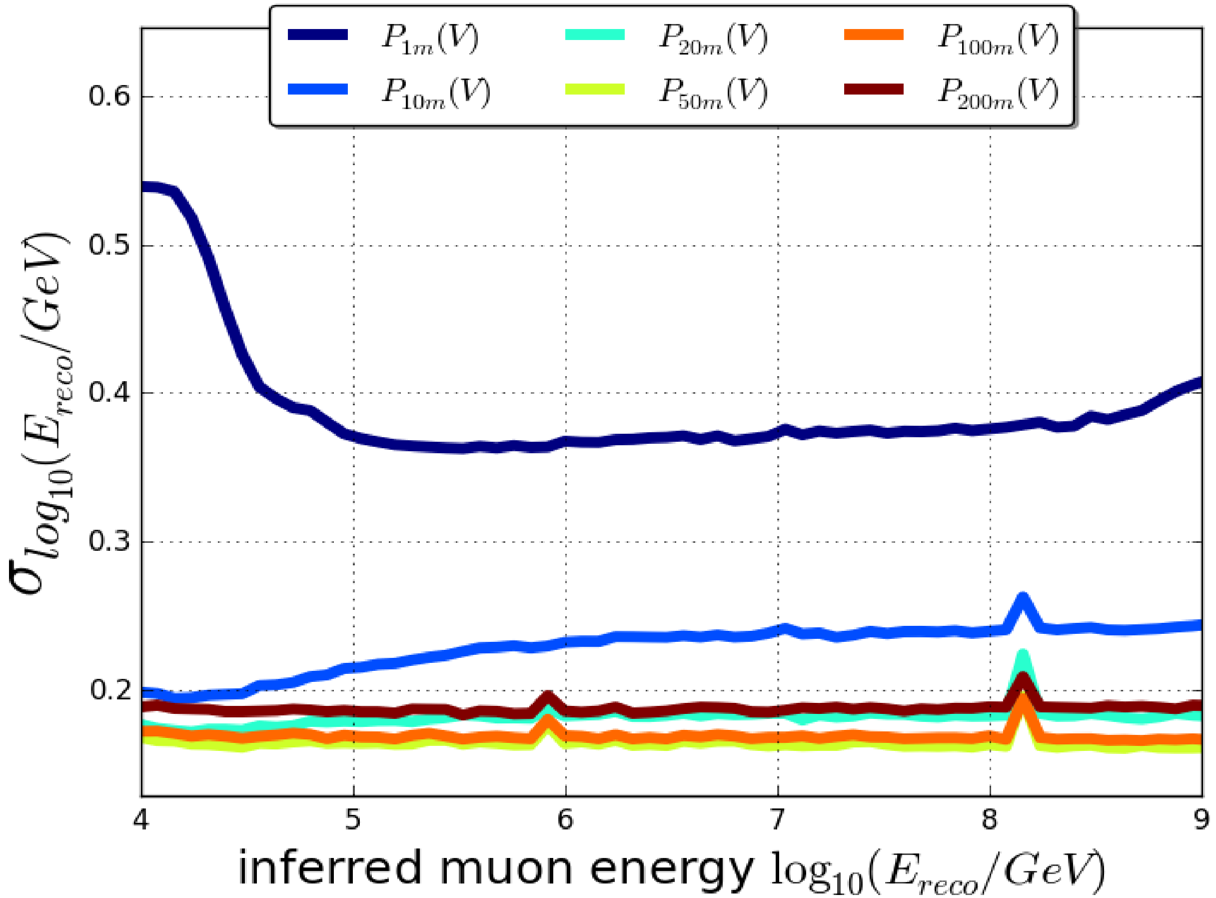
Thank You!

Backup

Alternative Method- PK

In *Petrukhin and Kokoulin,Theory of the Pair Meter for High Energy Muon Measurements,1987* published a similar method (PK).

$$\ln L = \sum ln[VP_x(V)] \qquad V = dE/E$$



Probability Distribution Function- PK

PK uses an average PDF in the likelihood function.
At high bin lengths this accurately describe all energies.
At low bin lengths it does not.