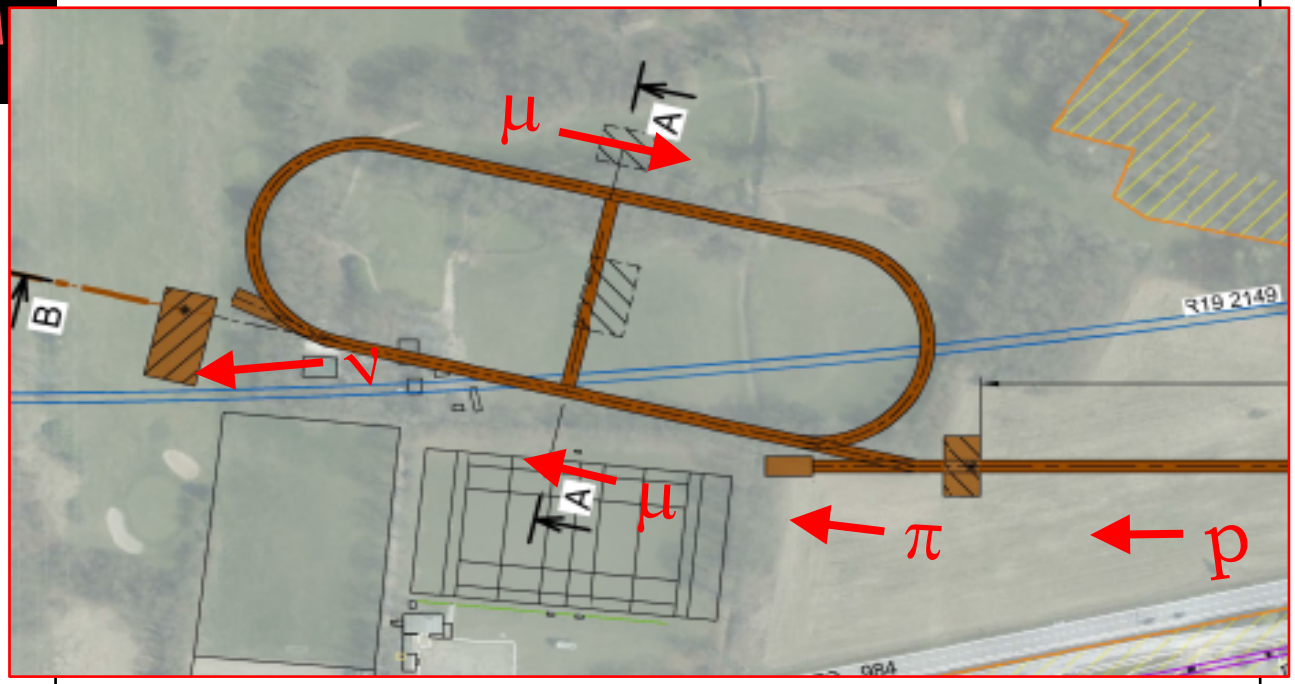
Neutrino fluxes from νSTORM

Paul Kyberd

Problem



Protons on target produce π

Some π captured & transferred to ring

π in the ring decay and produce μ

Some μ captured and circle the ring

μ decay - some ν interact in detector

Losses are such that end to end simulation is unfeasible.

Multiple Simulations

π Production	***Fluka/Mars***
π capture & transfer	***BDSim/G4Beamline***
π decay produces μ	nuSim
μ Orbit	***BDSim/G4Beamline***
ν Production	nuSim
ν Interaction	**GENIE/Geant4**

Four complex simulations

Two simple ones

π decay to μ – simple:two body; single channel

μ decay to ν – simple: three body, formula; single channel (effectively)

All need linking together

nuSim

We have designed a framework, which can:

take the parameterised pion production distributions and use accelerator design software to create a pion distribution.

decay those pions into muons

use accelerator design software to create a captured muon distribution.

decay those muons into neutrinos

Propagate the neutrinos to the detector

the resulting “flux file” seed GENIE
The Genie output to design the detector GEANT4 and to determine physics reach

Current Status

Pion production: from NuMI data

Pion distribution from target nuSTORM performance. Detailed modelling being done

Muon production distribution from **nuSIM**

Muon ring capture from “Racetrack FFAG muon decay ring for nuSTORM with triplet focussing” arXiv:1806.02172v2 [physics.acc-ph]

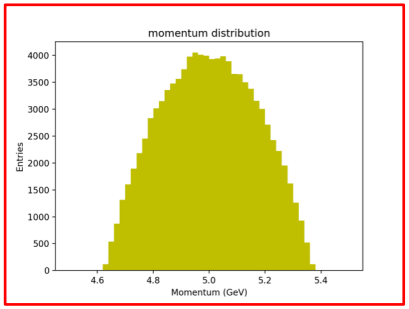
Neutrino production distribution and propagation to the detector plane from **nuSIM**

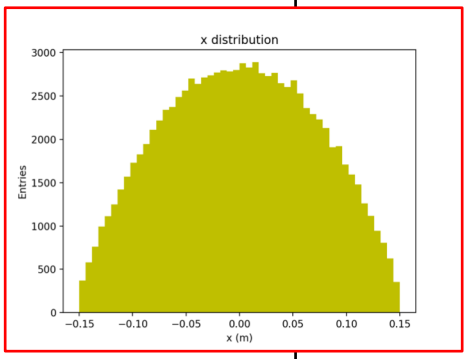
π Production efficiency

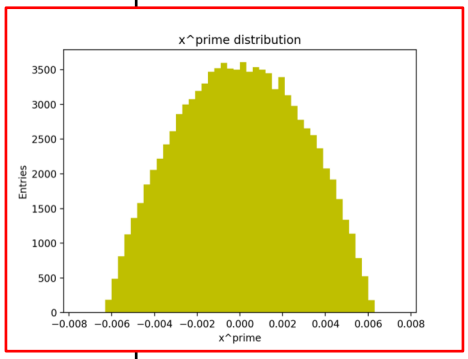
The number of (useful) pions is around 0.1 per proton over the required energy range.

We have are starting studies specific for this incarnation of nuSTORM.

Pion Beam Parameters

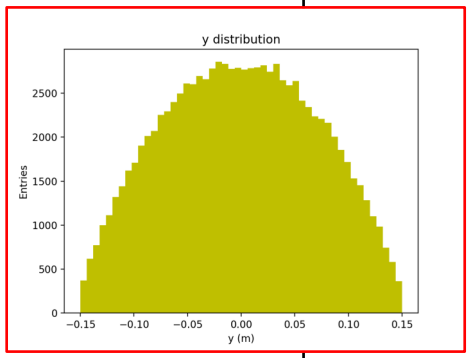


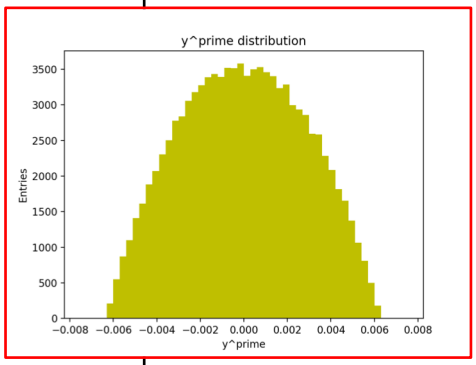


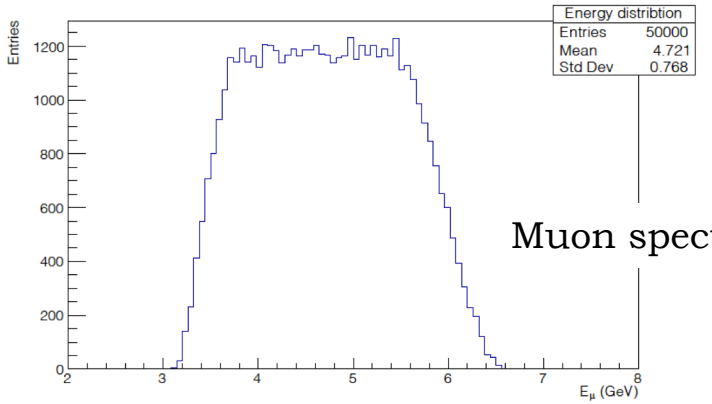


Detailed simulation of the pion transfer line are underway.

This parameterisation corresponds to the outline design specifications.







Muon spectrum at production

ν fluxes from νSTORM
Paul Kyberd

Captured muons

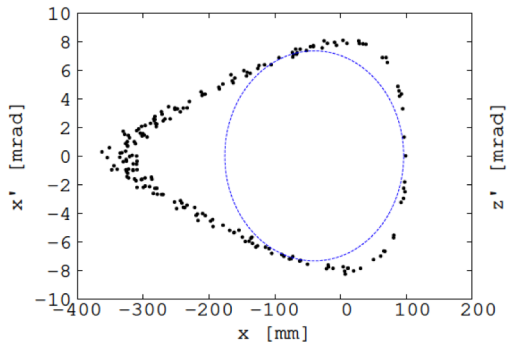


Figure 6: Stable motion in the horizontal Poincare map for maximum initial amplitude over 100 turns for p_0 in JBT. The ellipse shows a 1 mm.rad unnormalized emittance.

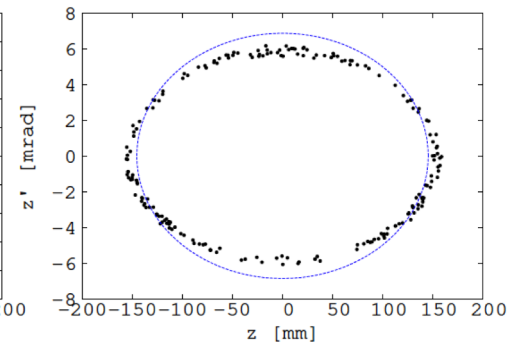
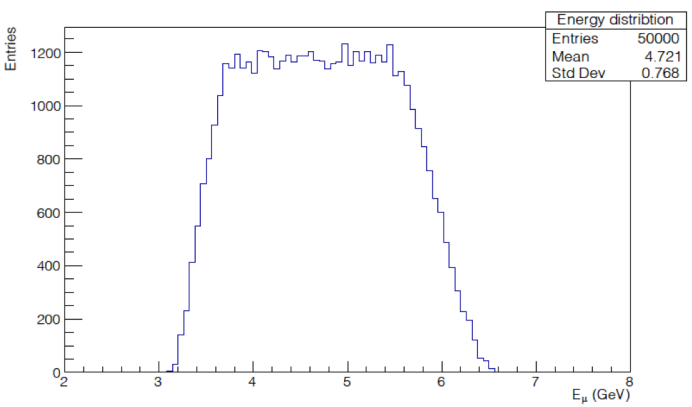
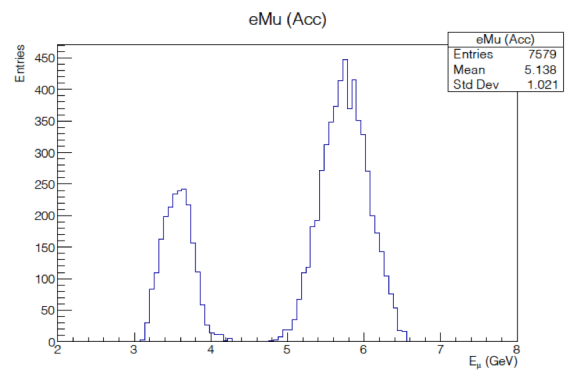


Figure 7: Stable motion in the vertical Poincare map for maximum initial amplitude over 100 turns for p_0 in JBT. The ellipse shows a 1 mm.rad unnormalized emittance.

Using the plots from "Racetrack FFAG muon decay ring for nuSTORM with triplet focussing"

arXiv:1806.02172v2 [physics.acc-ph]





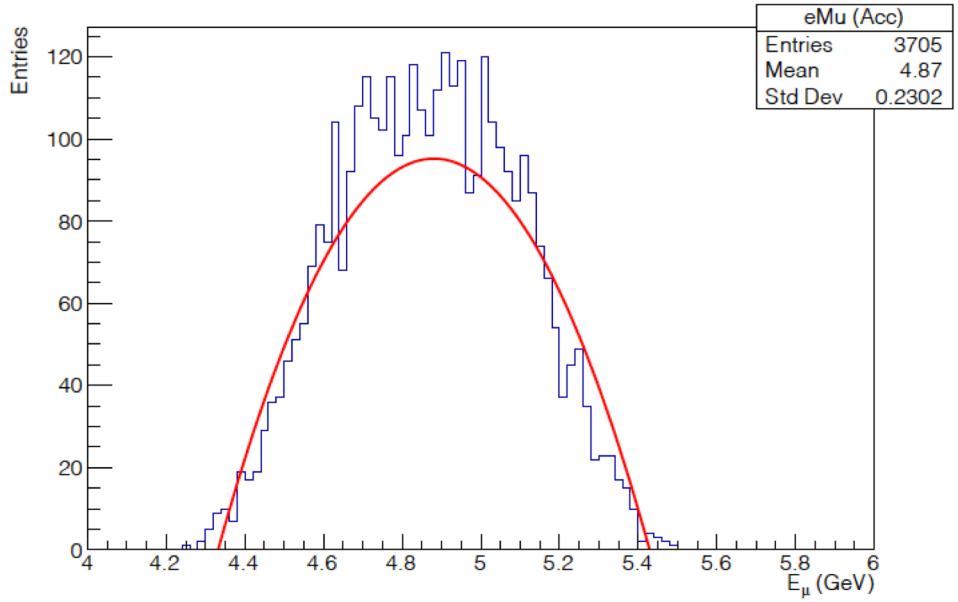
(a) Energy spectrum

Muon spectrum in acceptance

Captured muons

The ring will be tuned to accept the forward going muons.

This gives a spectrum like this



Red line is a parabolic fit.

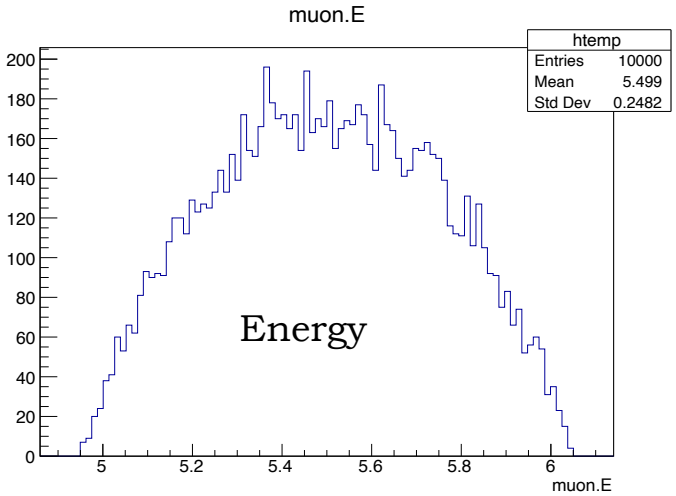
μ Production efficiency

Mean pion Energy	Efficiency
1.5	0.4%
2	0.6%
3	1.2%
4	2.5%
5	5.1%
6	5.4%

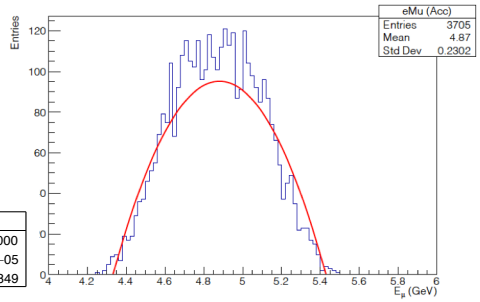
Muons into the ring acceptance
"Beaming" increases acceptance with energy.

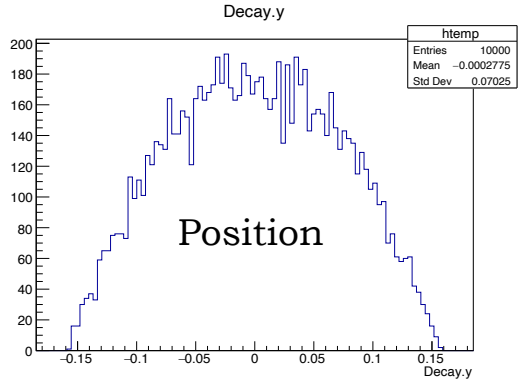
ν production

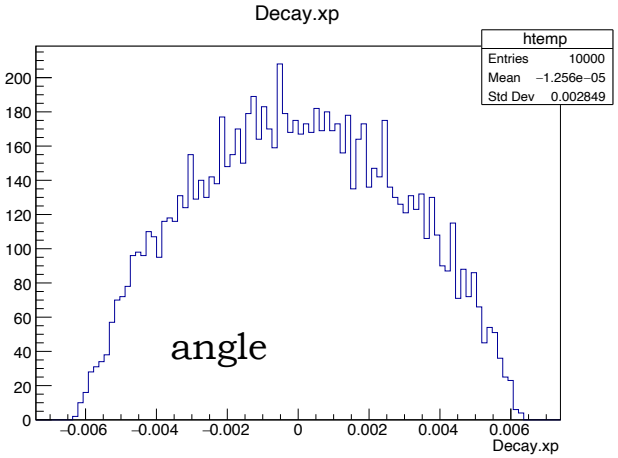
We use a parameterised spectrum for the muons in the ring. A parabolic energy spectrum and a position and angle distributions derived from the target ring specifications.



Its shape agrees with the simulation of the pion decay







ν to detector acceptance

Mean muon Energy	Efficiency
1	4.0%
2	8.2%
3	11.7%
4	14.5%
5	17.2%
5.5	18.5%

Propagate the neutrinos decays from those muons travelling round the nuSTORM ring to a “detector”

Less Energy dependence
Still favours higher Energies

Flux files

Total efficiency is around 0.03%

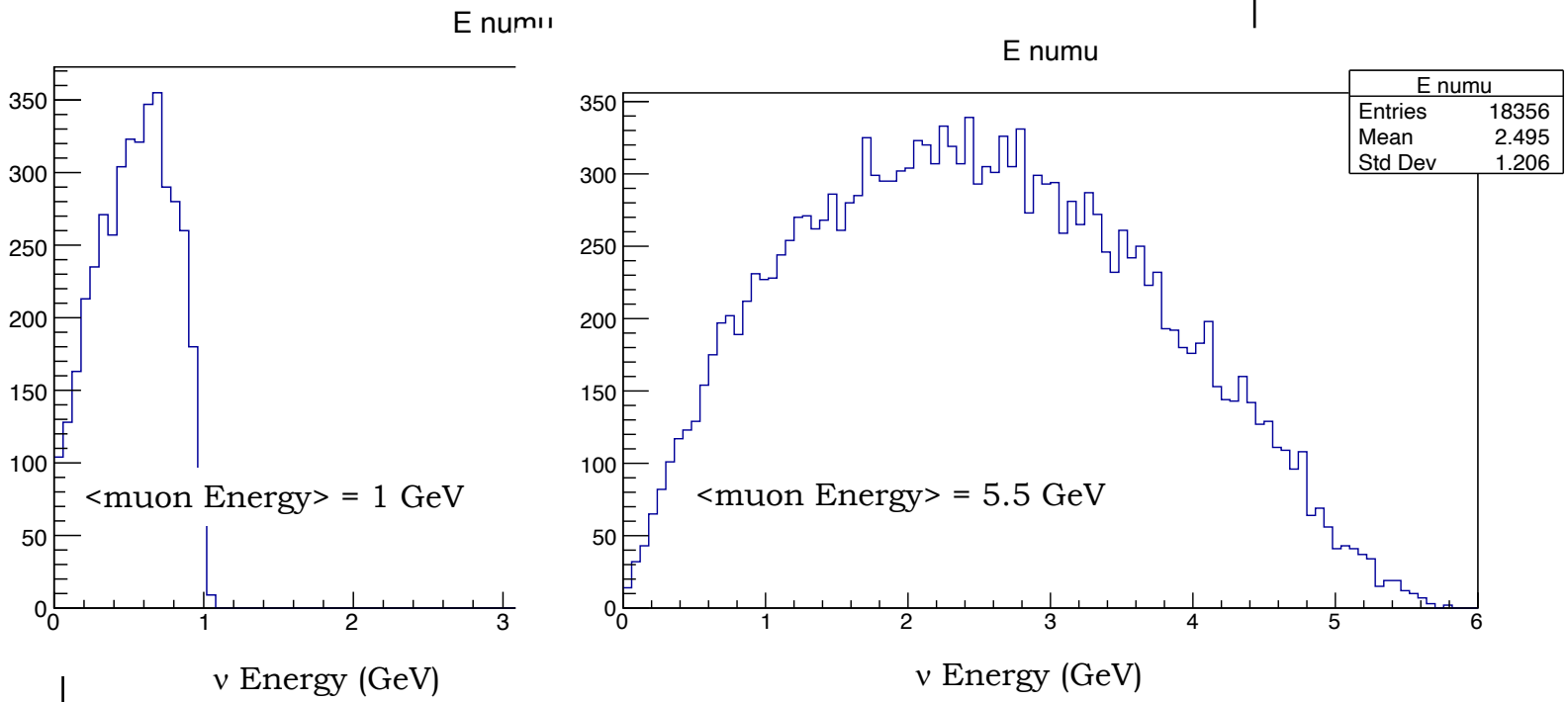
The result of all this is a set of flux files, which correspond the the position, angle and energy of the neutrinos which hit the front face of a “detector plane.”

The plane is located 50m downstream of the end of the production straight, with (0,0) on the axis of the production straight.

Work has started on using those files to generate neutrino interactions using GENIE and looking at final state kinematic distributions to determine detector parameters.

ν "rates"

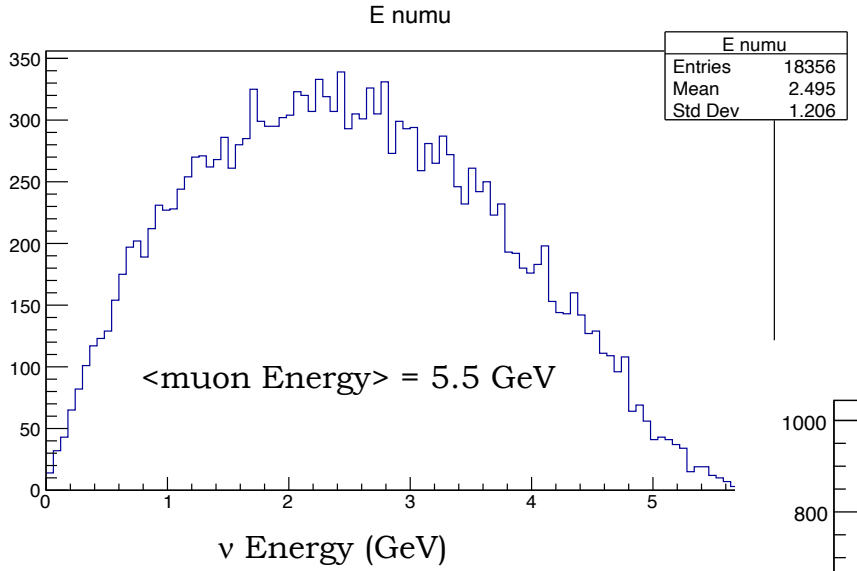
If we define a detector 5 by 5 around the (0,0) point we can look at the neutrino fluxes as a function of Energy.



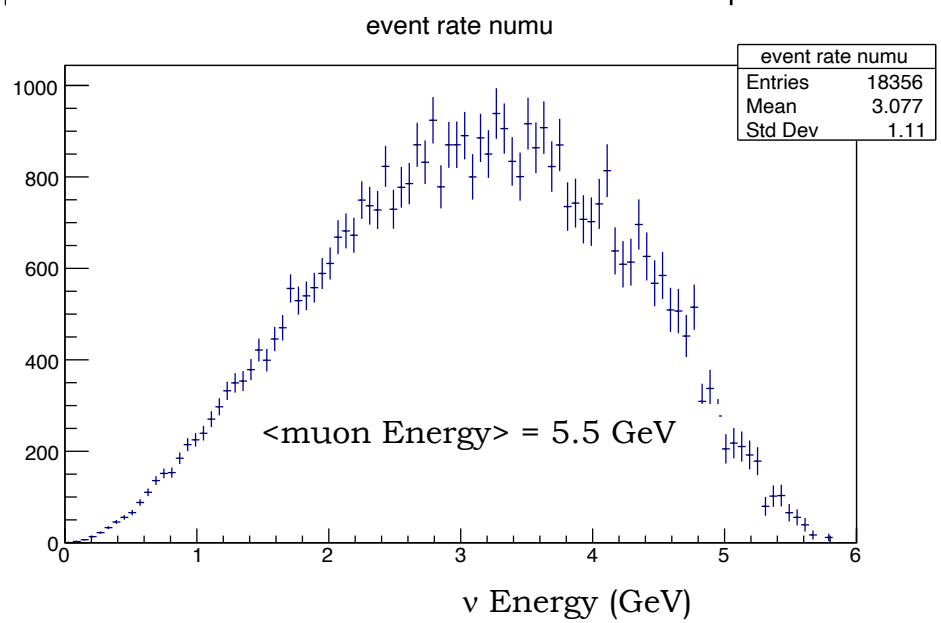
The two plots assume the same number of circulating muons.
Higher Energy give more muons per proton
What is the best way to get 0.5 GeV ν's?

ν interaction "rates"

Number of interactions per incident ν varies with ν energy.



Distribution of ν energies



Relative event rate : weighting flux with ν energy

ν fluxes from νSTORM
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Summary

π Production Fluka/Mars

planning

π capture & transfer BDSim/G4Beamline

1st iteration nearing completion

π decay produces μ

complete

μ Orbit BDSim/G4Beamline

In progress

ν Production

complete

ν Interaction GENIE/Geant4

Preliminary distributions

Wiki and datasets

There is a wiki, which contains information on the status of the project

nustorm.org

And the datasets are also available at

data.nustorm.org

<Energy> muon GeV	Events
1	250k
2	250k
3	250k
4	250k
5	250k
5.5	250k

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Please acknowledge the source