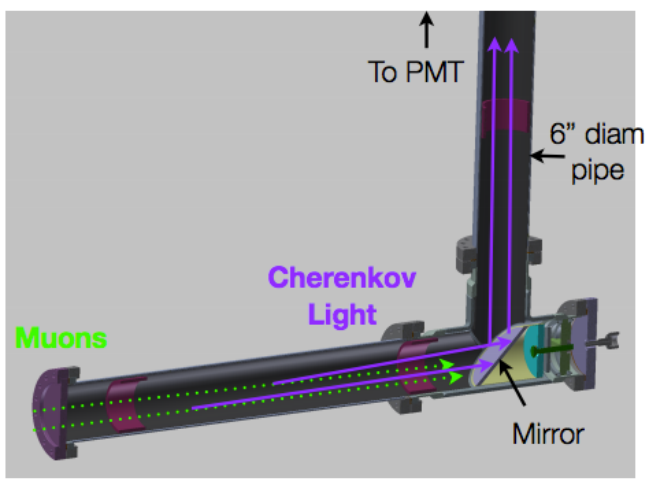
Gas Cherenkov Muon Monitor Update for Numi-X

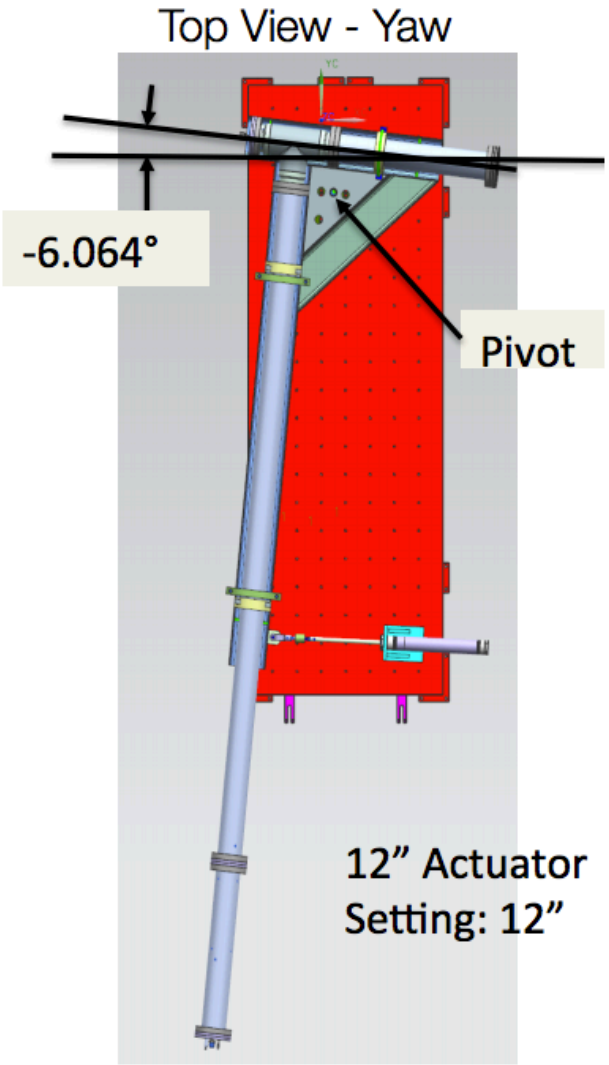
Peter Madigan
University of Colorado Boulder
8.28.2015

The prototype gas Cherenkov detector

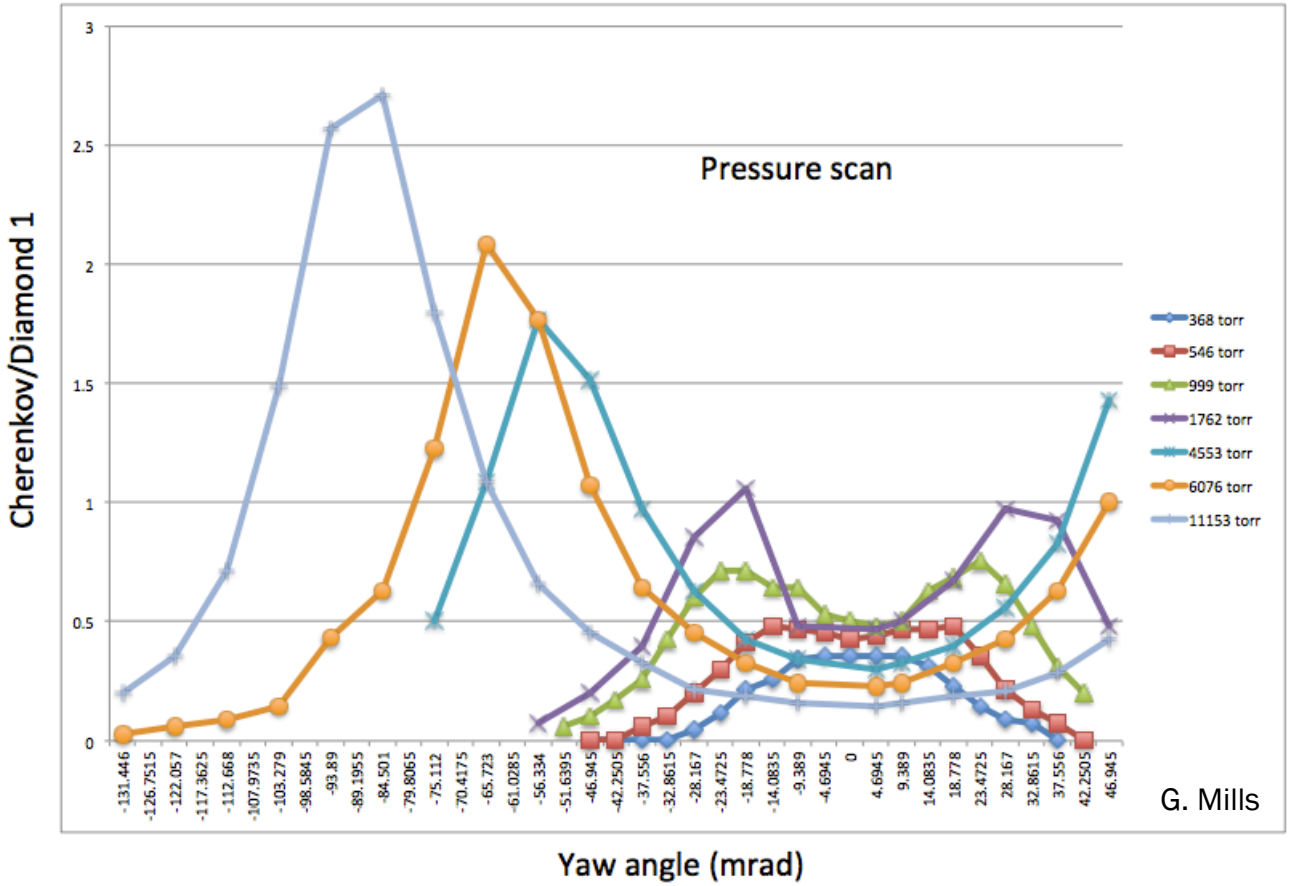
- A short radiating chamber filled with argon gas attached to longer chamber, housing a PMT ~5m away from the beam
- A pressure system can remotely change the density of argon in the chamber
- A set of actuators allows two degrees of rotational freedom (pitch and yaw)

One currently installed in alcove 2 and there are plans to install another in alcove 1 in the near future



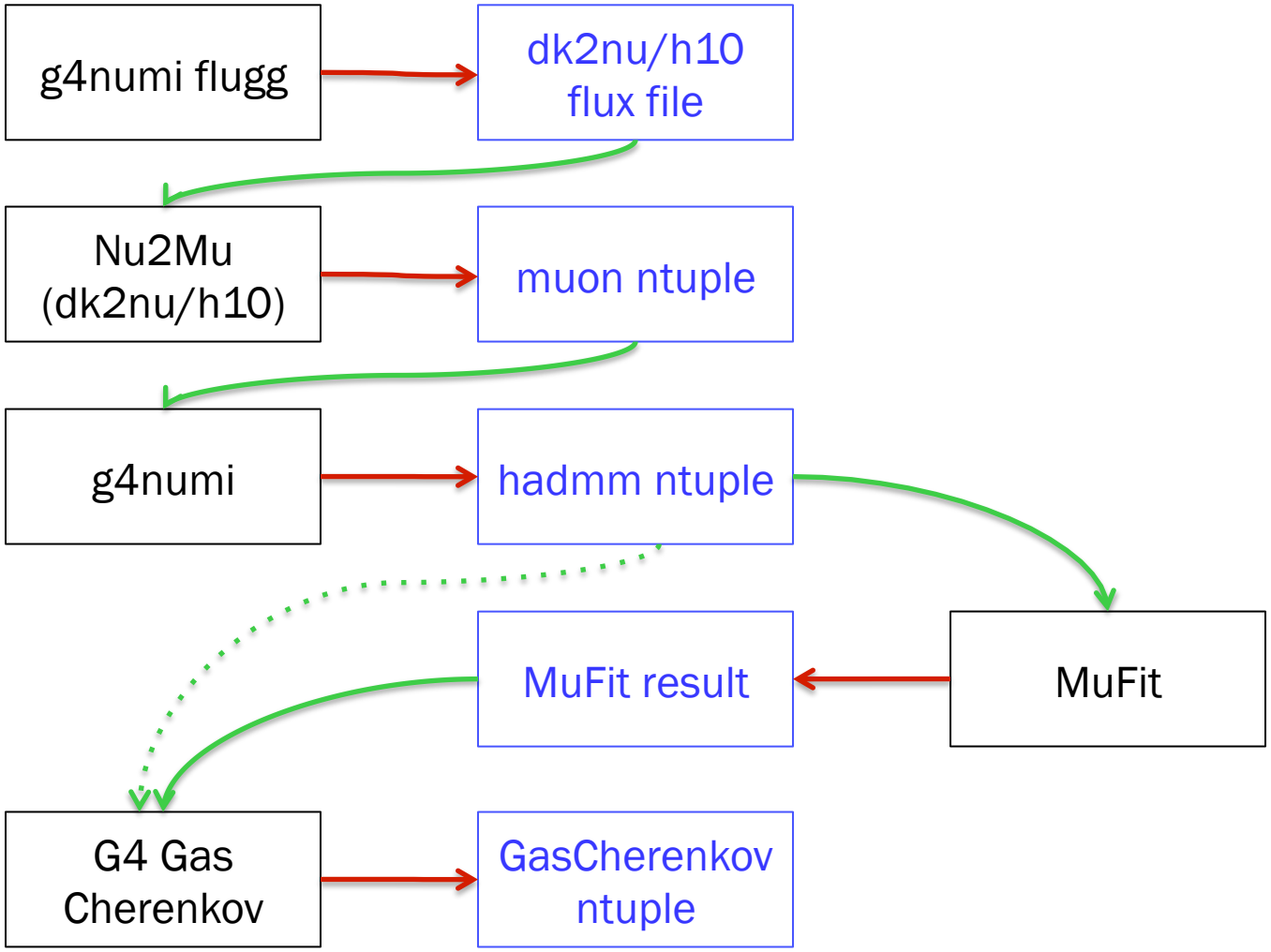


Results from prototype gas Cherenkov detector



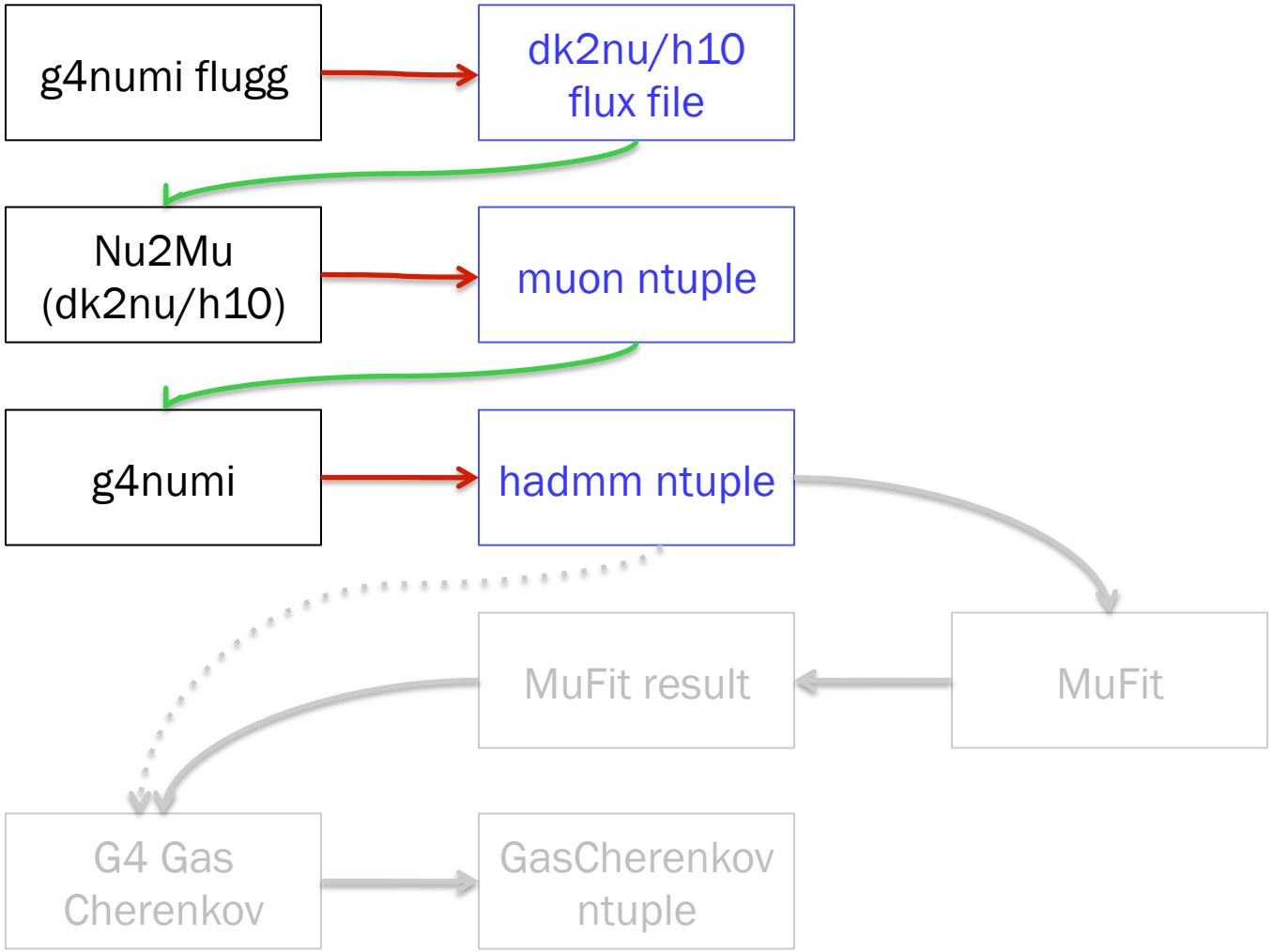
Lots of information contained in these plots – the heights and widths of these angular scans can be related to the kinematics of the muon beam

Simulating the gas Cherenkov response



Simulating the gas Cherenkov response

Producing realistic alcove fluxes:



Previously...

I presented my attempts to use the old simulation chain (including muonRW) to simulate the muon fluxes in the muon alcoves.

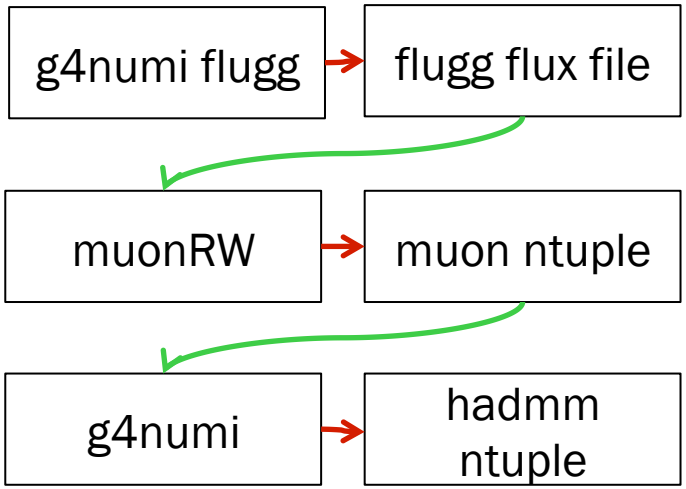
The changes and preliminary results from these efforts can be found in numix-docdb:113.

As a summary:

G4numi flugg produces neutrino flux files

MuonRW redecays muon parents and creates an "efficient" muon list projected to the end of the decay pipe

G4numi can then be run in "muon" mode to produce alcove 1-3 muon fluxes



Previously...

However, the muon fluxes produced by muonRW did not agree with corresponding fluxes produced by g4numi using a simple verification process.

The current status of the issues of muonRW was discussed in a numi-x meeting in August (slides are included #15-29).

As a summary:

To verify muonRW, I

- Used the “default” g4numi settings to simulate a decay chain p -> pi -> mu
- Used g4numi to output muon alcove and neutrino ntuples
- Ran muonRW with the neutrino output
- Reran g4numi with the muonRW output, producing another muon alcove ntuple
- Compared the two muon alcove ntuples

Previously…

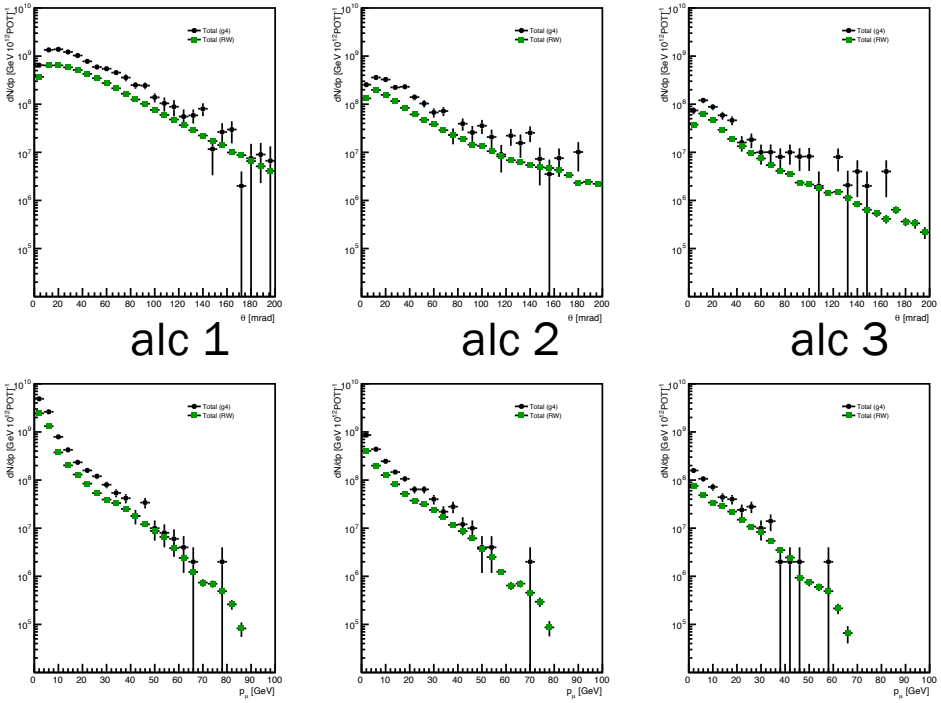
However, the muon fluxes produced by muonRW did not agree with corresponding fluxes produced by g4numi using a simple verification process.

The current status of the issues of muonRW was discussed in a numi-x meeting in August (slides are included #14-28).

As a summary:

Revealing a factor of ~2 difference between muonRW and g4numi:

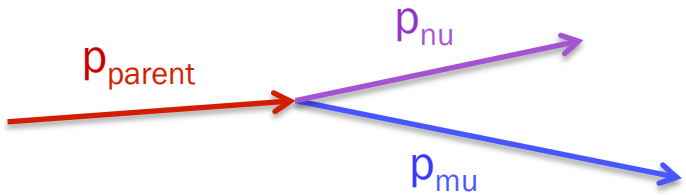
After attempts to track down the specific issue, I've had to move on. However, Alysia is going to take over this task using a stand-alone geant4 simulation.



Moving on to produce a realistic muon flux

$$\pi^{\pm} \rightarrow \mu^{\pm} + \overset{(-)}{\nu}_{\mu}$$

$$K^{\pm} \rightarrow \mu^{\pm} + \overset{(-)}{\nu}_{\mu}$$

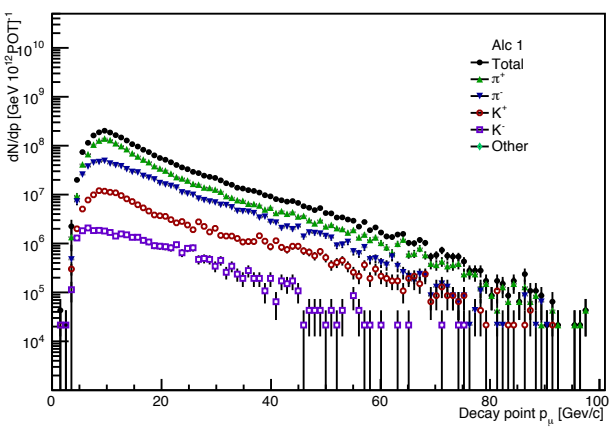


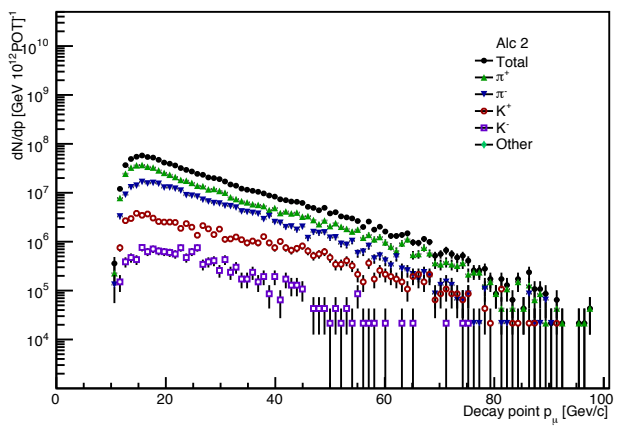
$p_{mu} = p_{parent} - p_{nu}$

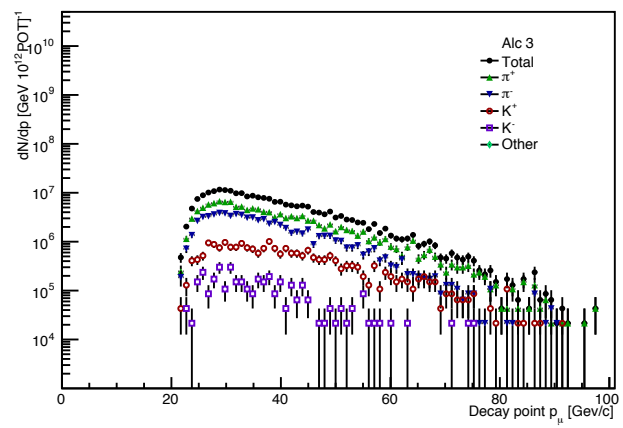
$r_{mu} = r_{decay}$

I've created a simple work-around to make progress towards estimating the muon flux in the alcoves that uses parent and neutrino information in the flux files to produce an unweighted muon list.

I also made some minor changes in my personal version of g4numi to allow this muon list to be generated at any z location.

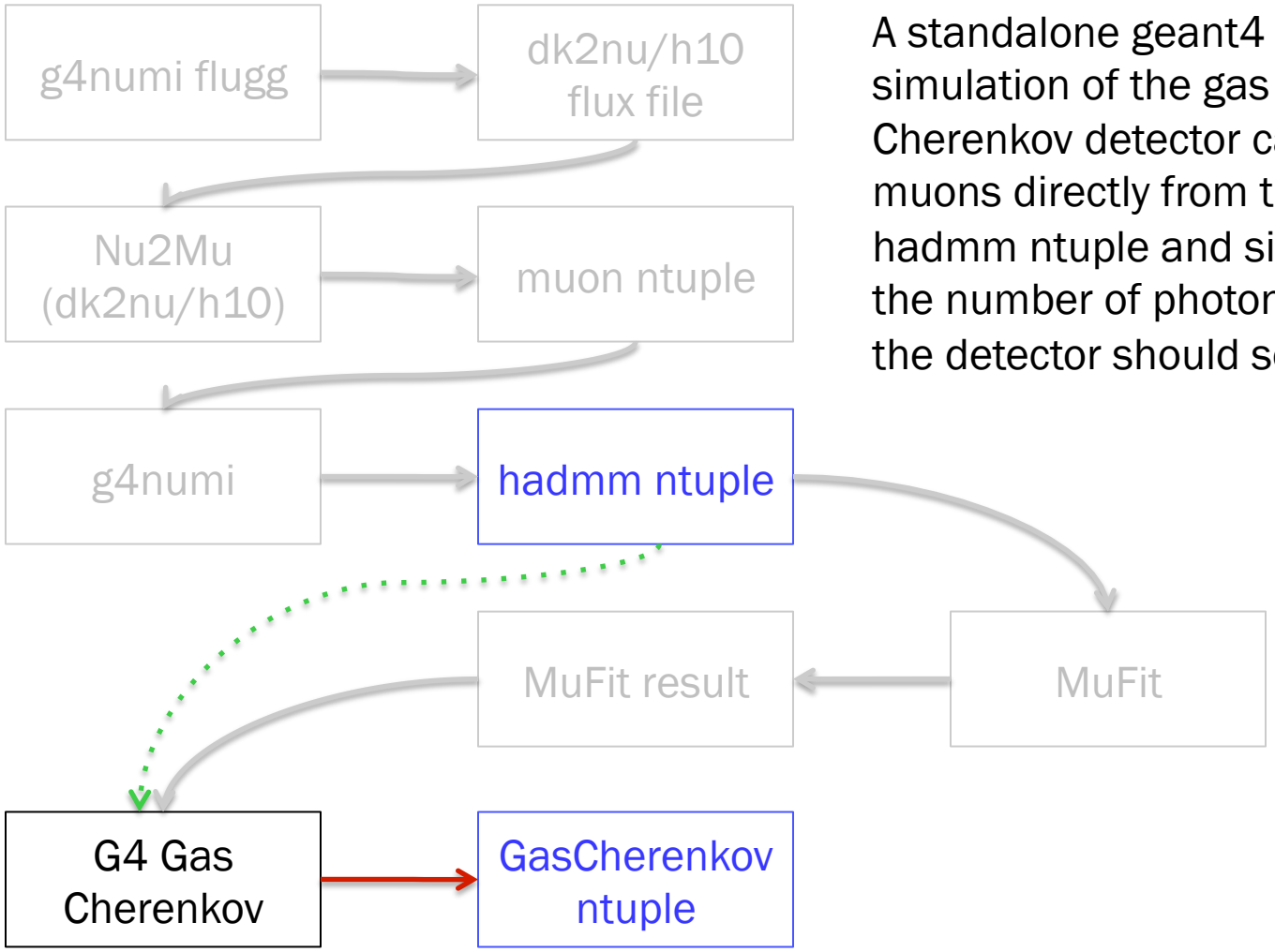






Simulating gas Cherenkov response

Part 2:



A standalone geant4 simulation of the gas Cherenkov detector can grab muons directly from the hadmm ntuple and simulate the number of photons that the detector should see.

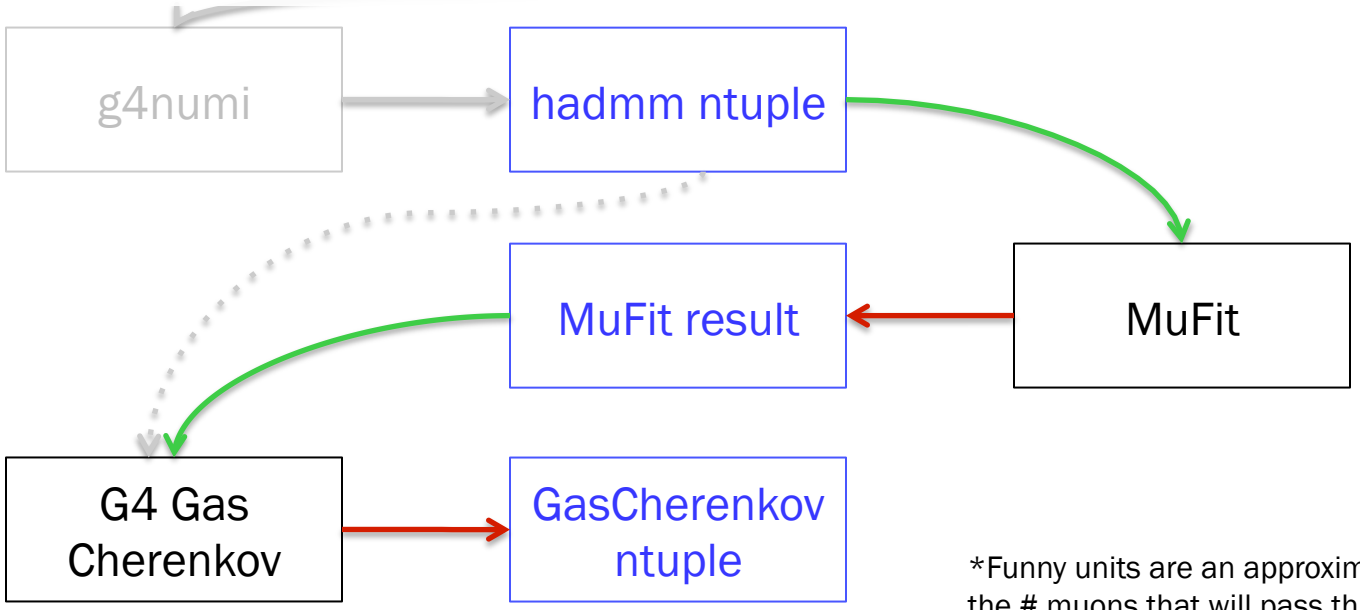
Simulating gas Cherenkov response

Part 2:

However, the hadmm ntuple has relatively limited statistics:

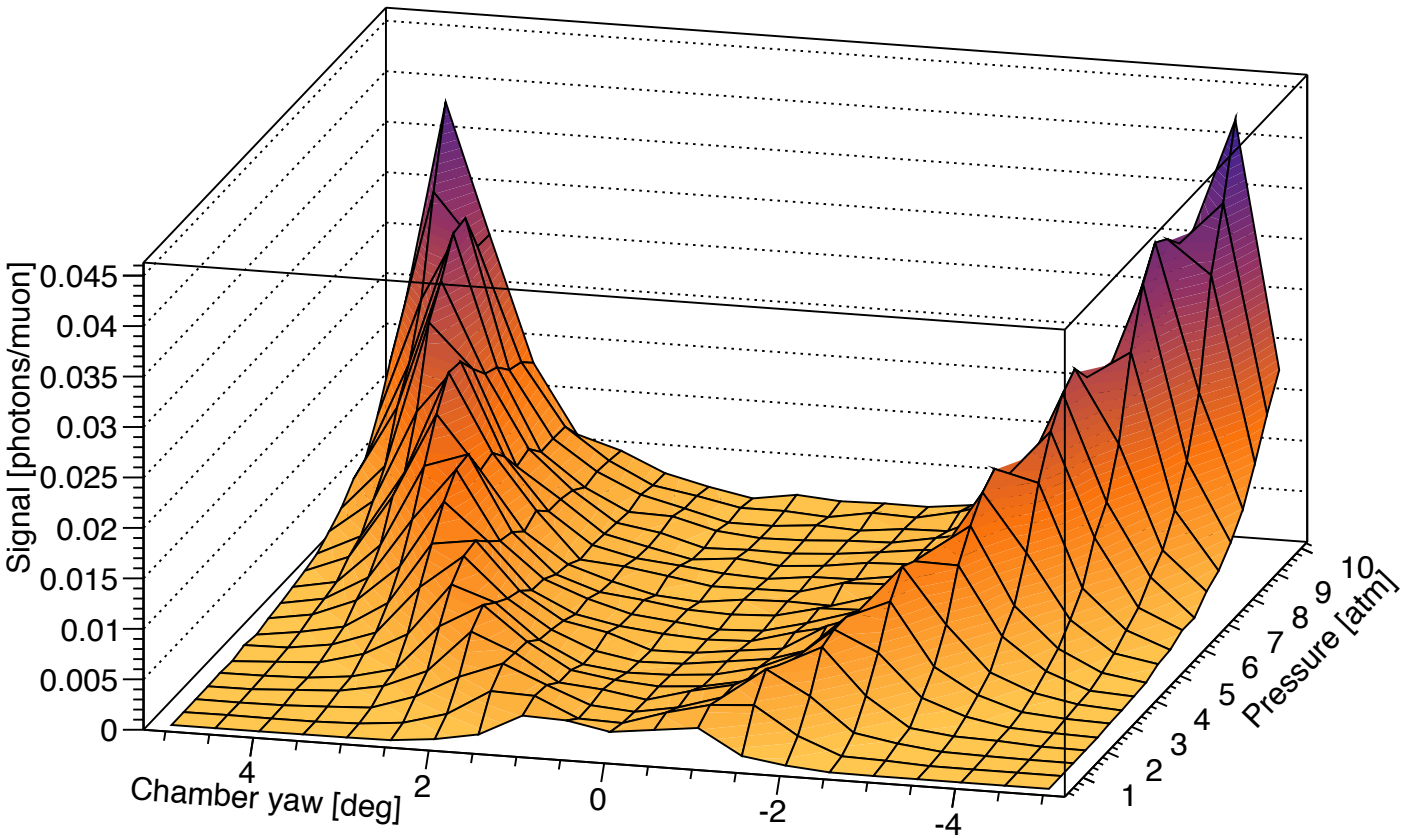
- mn000z200i: mu/100cm^2 5·10^{5}POT* ~ 2.5 (alc. 2)
- mn000z000i: mu/100cm^2 5·10^{5}POT ~ 0.75 (alc. 2)

So, I've also attempted to parameterize muon p v. theta in the alcove with a fitting routine (MuFit), which can also be fed into the Gas Cherenkov Monte Carlo.



*Funny units are an approximation of the # muons that will pass through the Cherenkov detector for a single flux file.

Simulated response



Agrees qualitatively well with the “caldera” plots produced by the installed detector.

Extracting a muon flux from the caldera plots

The photon yield from a specific pressure and angle of the Cherenkov detector can be expressed as

$$Y(P,\Theta) = \sum_{E,\theta} N_\mu(E,\theta) \cdot \epsilon(E,\theta,P,\Theta)$$

P = chamber pressure
Theta = chamber angle
N_{mu} = # of muons @ *E*, *theta*
E = Kinetic energy
theta = muon angle relative to beam center
epsilon = avg # photon/muon

So, by simulating these "efficiencies" we should be able to fit the muon E v. theta distribution to the photon yield of the detector at different pressures and angles.

Additional Slides

MuonRW issues/results

Peter Madigan
University of Colorado Boulder
8.10.2015

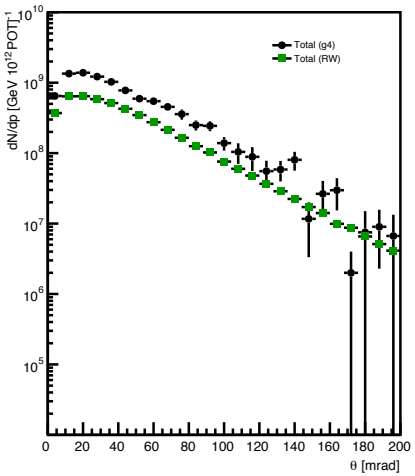
The problem with MuonRW

After producing the initial muon alcove data that I showed at the last numix meeting, we wanted to check and see if the MuonRW weighted distributions were consistent with unweighted geant4 distributions. So, I

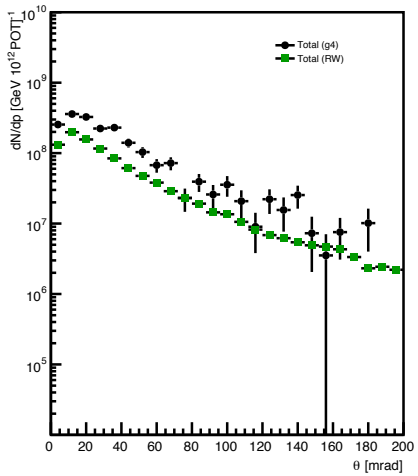
- Used the “default” g4numi settings to simulate a decay chain p -> pi -> mu

  (The input cards for g4numi don’t necessarily match any current beam configuration, but do provide a way to compare geant4 to MuonRW)
- Got g4numi to output both “hadmm” and “nudata” ntuples
- Changed variable names in MuonRW to accept the nudata format
- Ran MuonRW with the nudata input
- Ran g4numi with the MuonRW output, producing another “hadmm” ntuple
- Compared the original hadmm ntuple with the MuonRW-produced hadmm ntuple

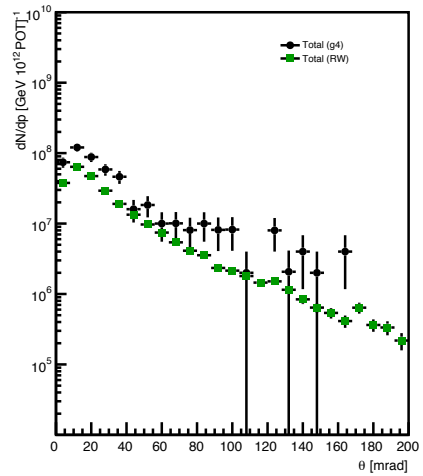
The problem with MuonRW



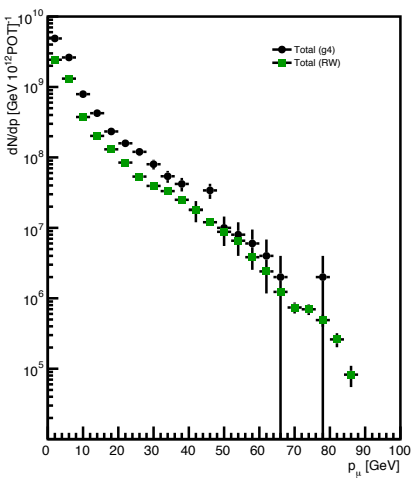
alc 1

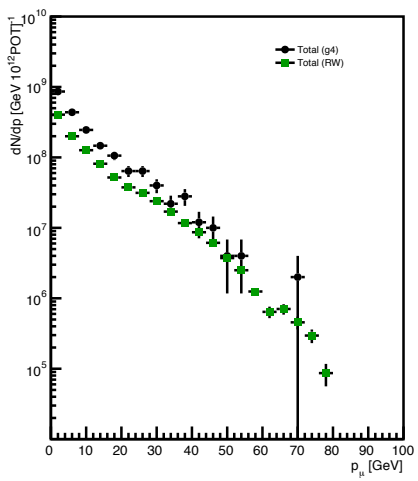


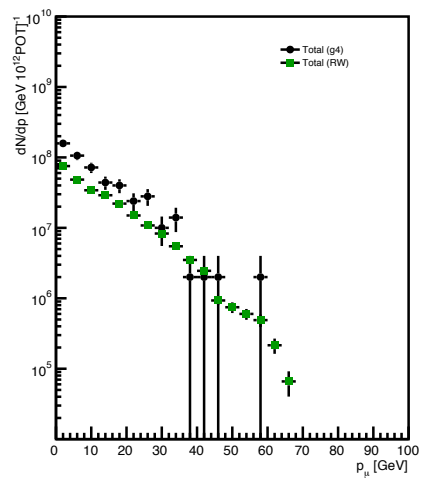
alc 2



alc 3







Attempts to isolate the issue

- Vacuum v. He decay pipe
- Pion beam
  - perfectly focused
  - some spread/divergence
- Exit statements
- Geant4 standalone

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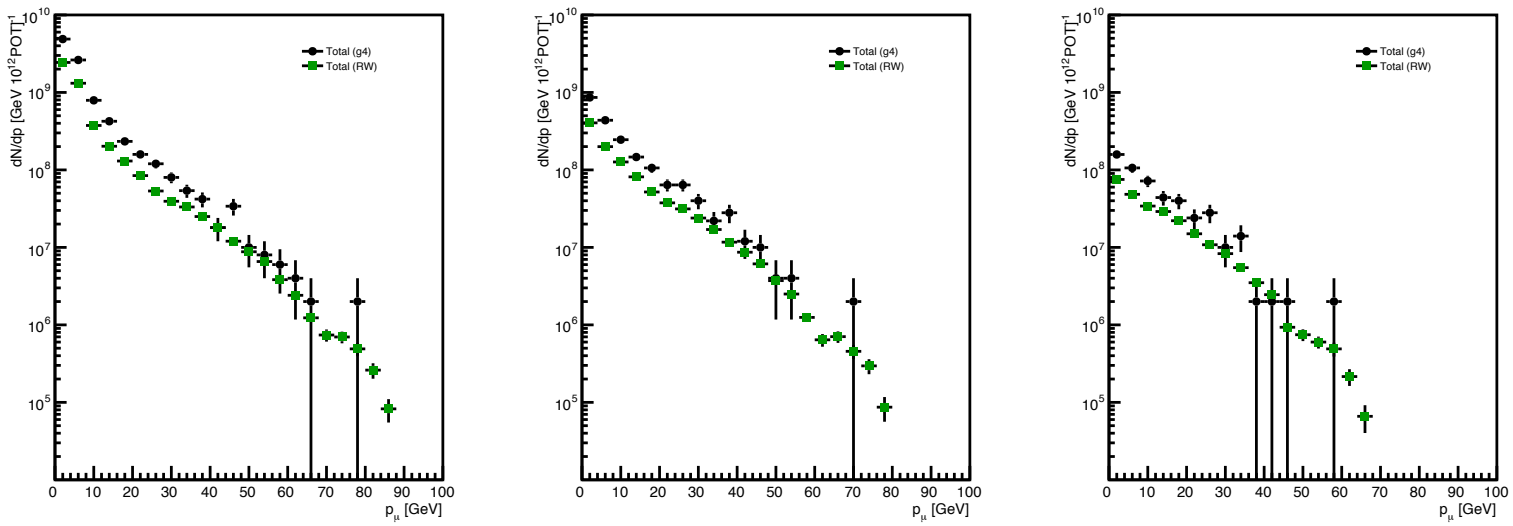
Helium decay pipe:



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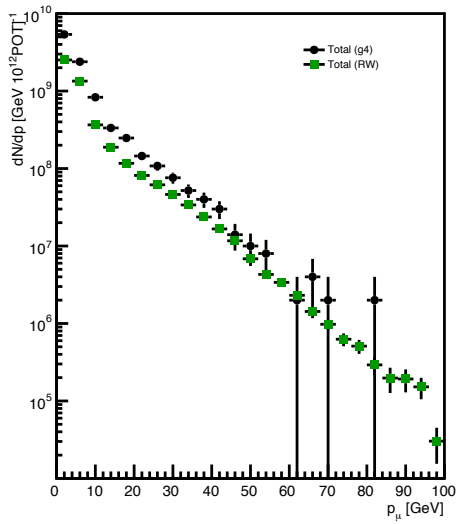
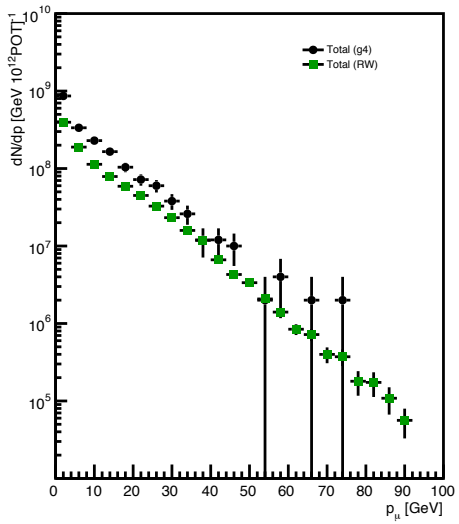
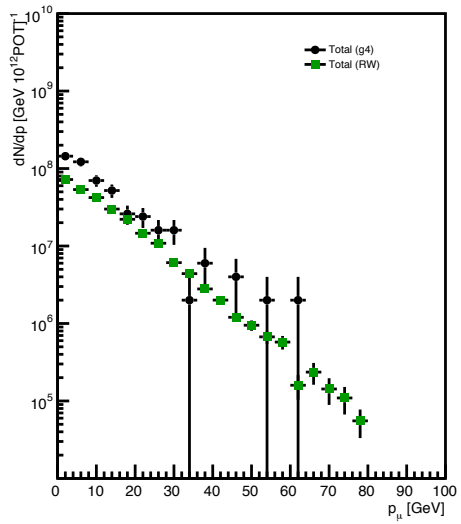
Vacuum decay pipe:







Attempts to isolate the issue

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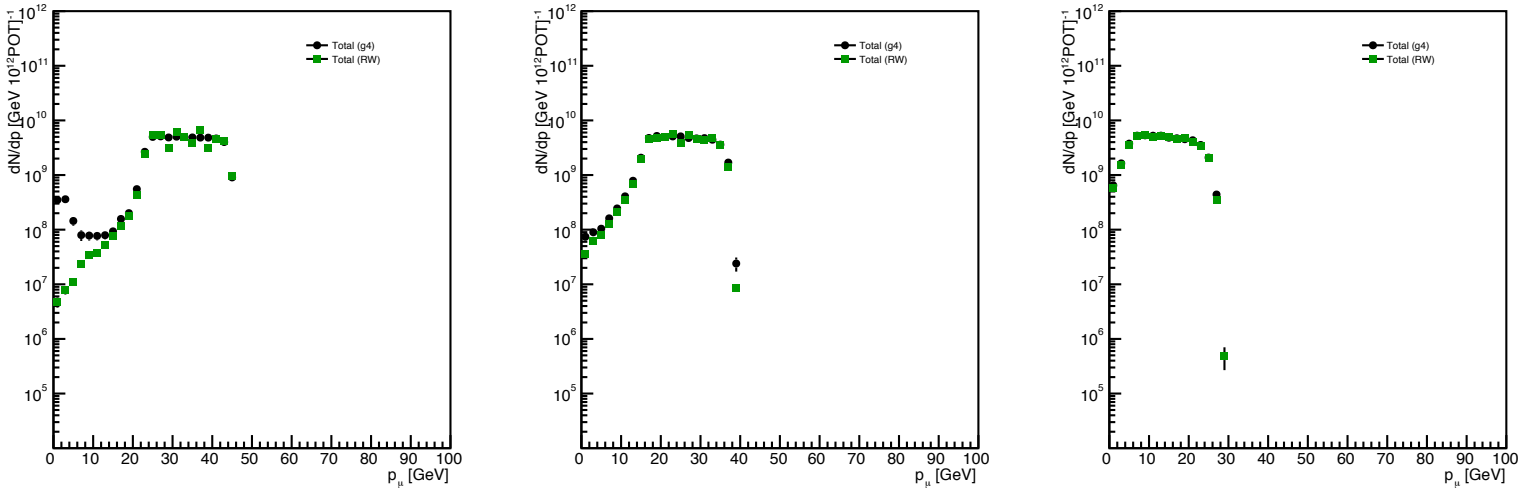
Perfect pion beam (50GeV @ 150m before EODP):



Attempts to isolate the issue

- ~~Vacuum v. He decay pipe~~
- Pion beam
  - ~~perfectly focused~~ (?)
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- Exit statements
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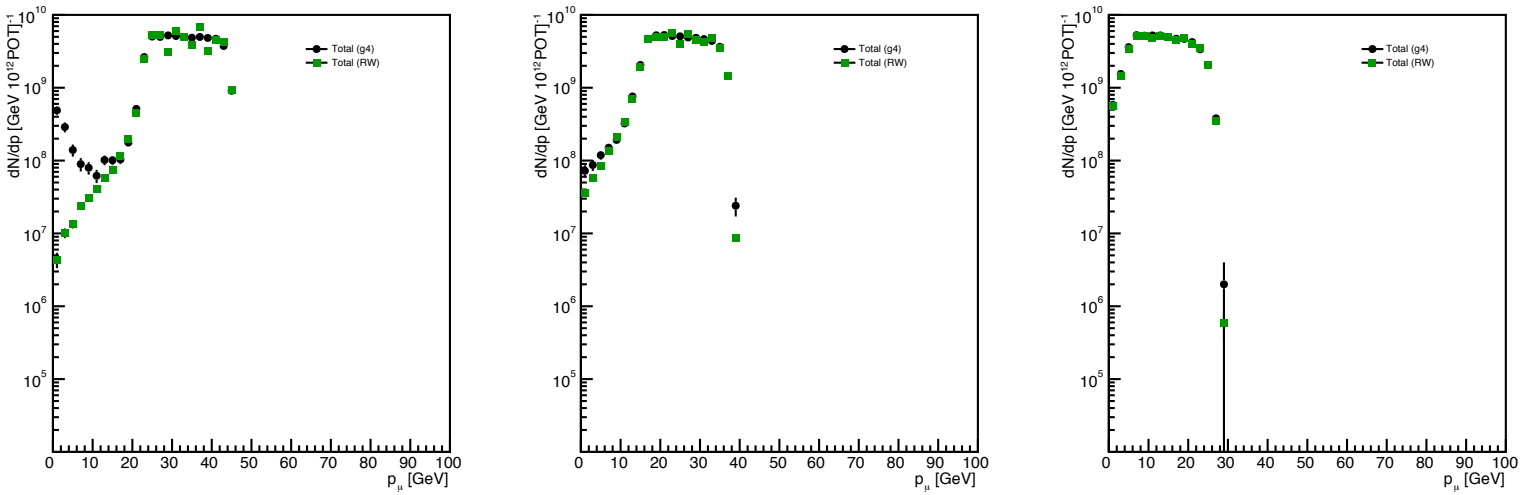
Perfect pion beam (50GeV w/50cm uniform spread @ 150m before EODP):



Attempts to isolate the issue

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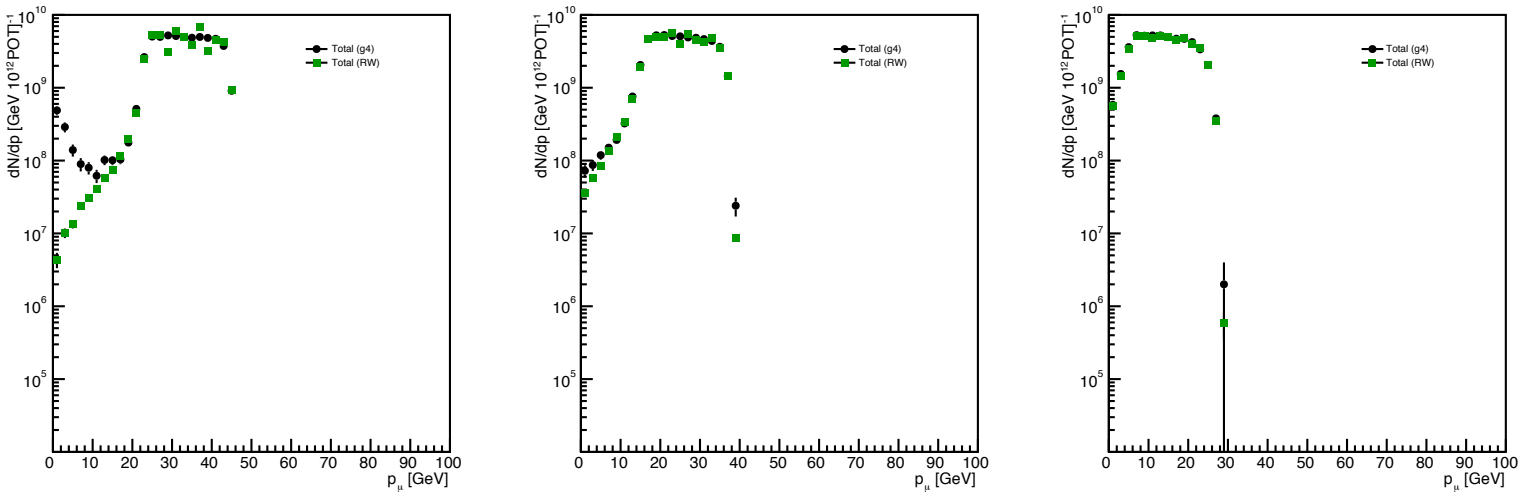
Perfect pion beam (50GeV w/50cm and 10mrad divergence uniform spread @ 150m before EODP):



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- Pion beam (?)
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Exit statements

	Total muon-producing decays	Low-energy parent	Parent-projection overlap	Muon cone overlap
#	131526	2336	1248	92898
fraction	1.0	0.018	0.009	0.706

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- Pion beam (?)
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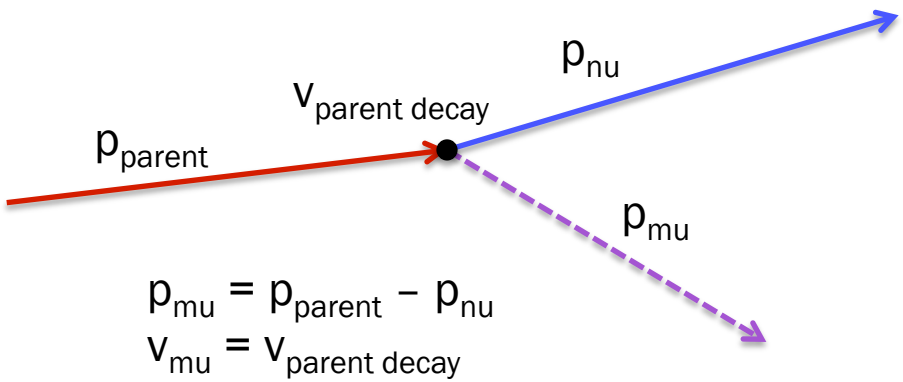
Working around MuonRW

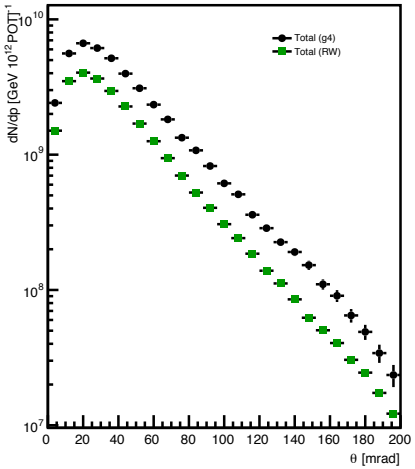
I created a short root program:

Nu2Mu (momentum conservation)

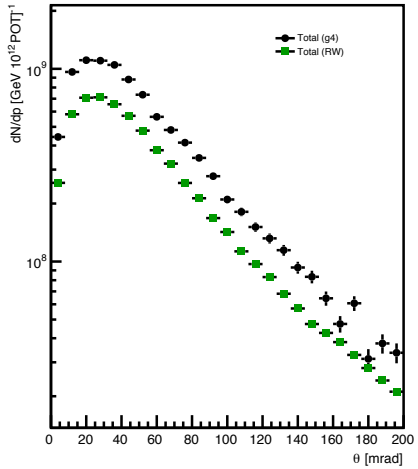


And I made a few edits to my personal version of g4numi so that muons could be generated at a given vertex in “muon” mode.

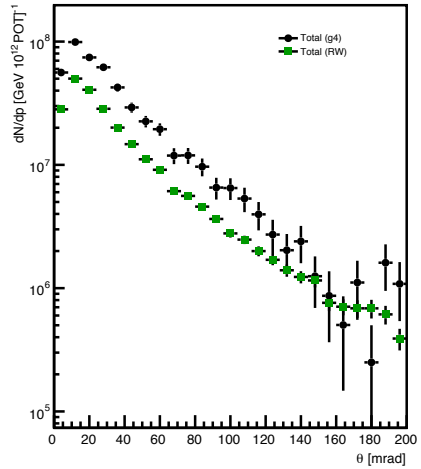
Comparison between MuonRW and the work-around:



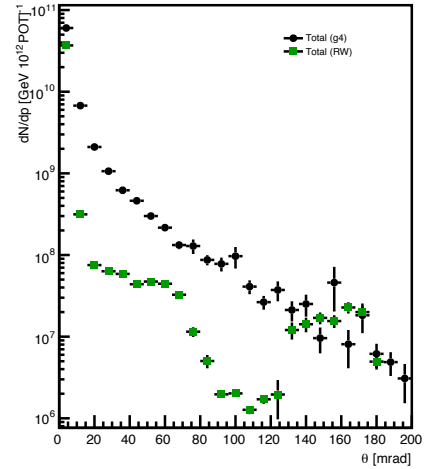
alc 1



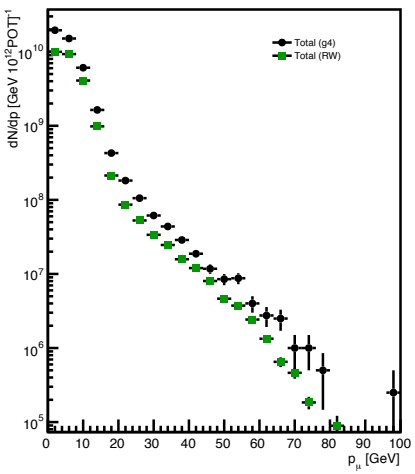
alc 2

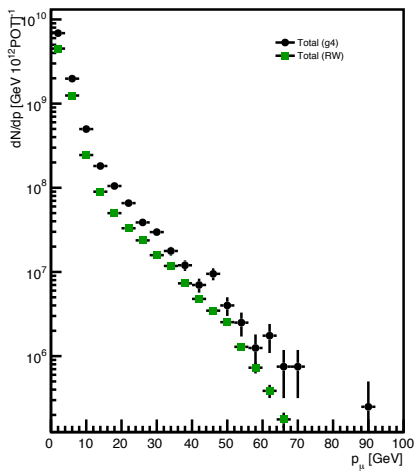


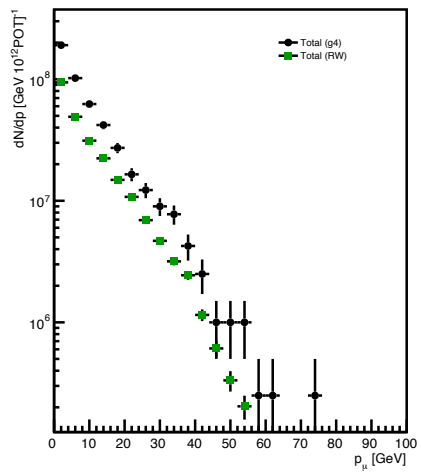
alc 3

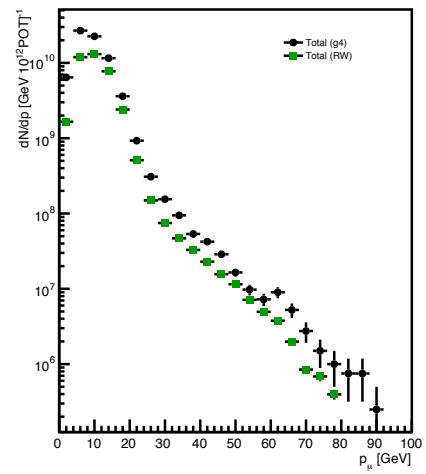


hadmon

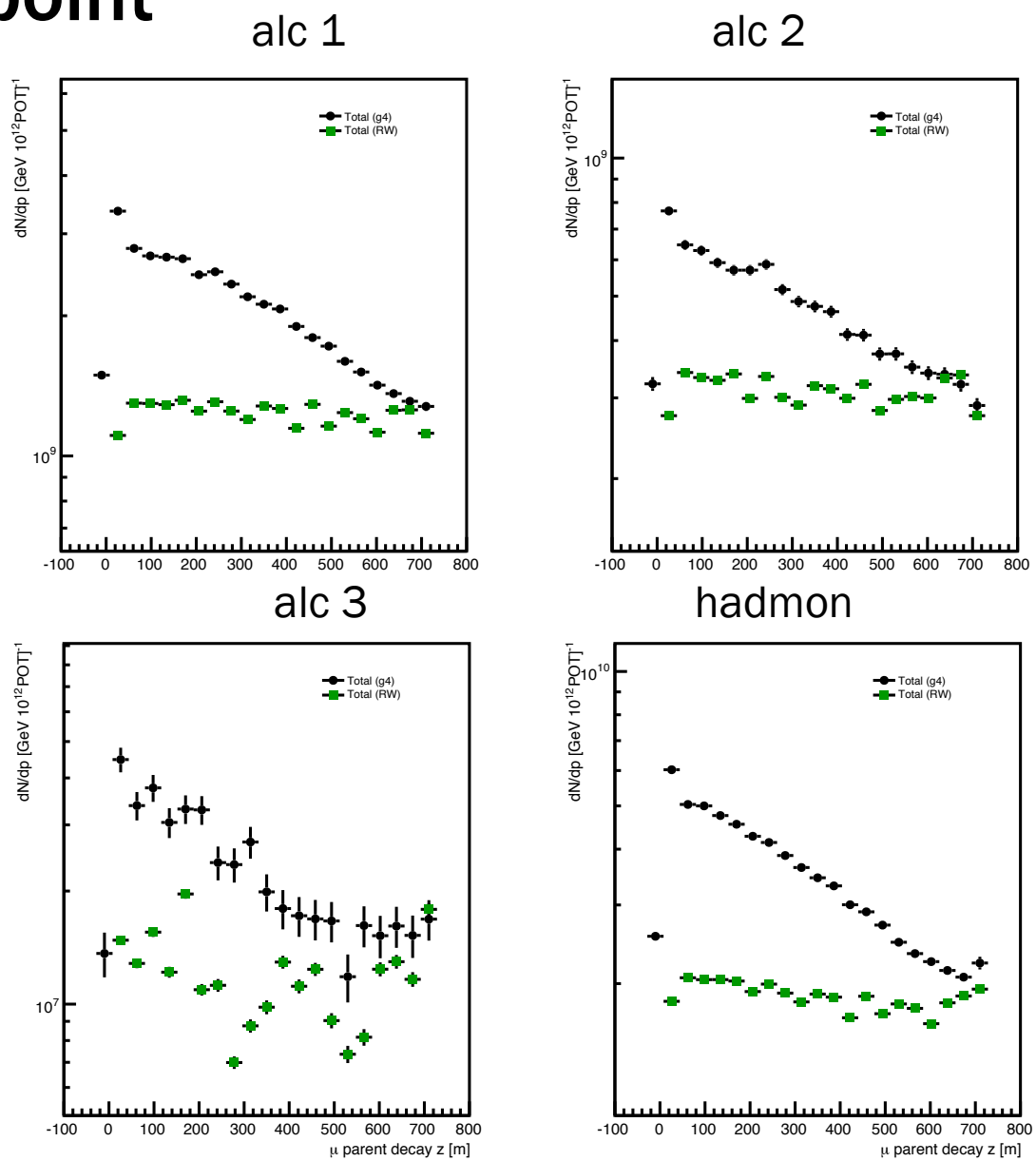




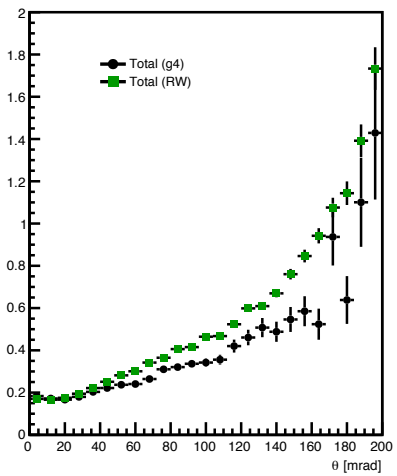




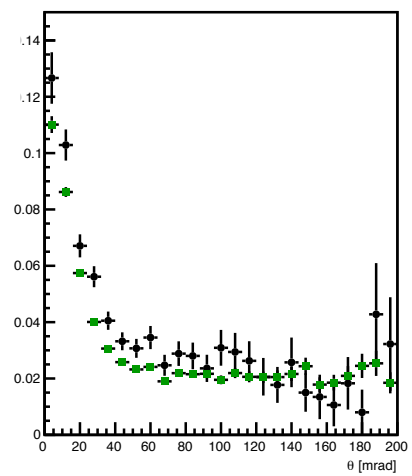
Decay point


alc 1
alc 2
alc 3
hadmon
Total (g4)
Total (RW)
dN/dp [GeV 10^12POT]^-1
μ parent decay z [m]
-100 0 100 200 300 400 500 600 700 800
10^9
10^10
10^7

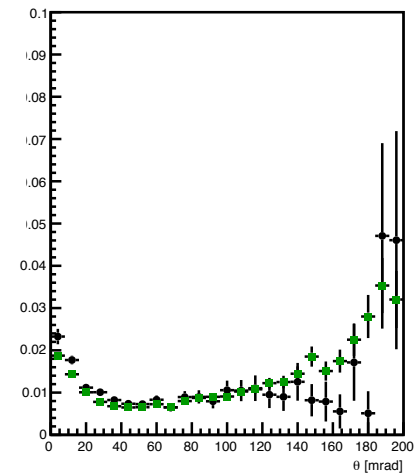
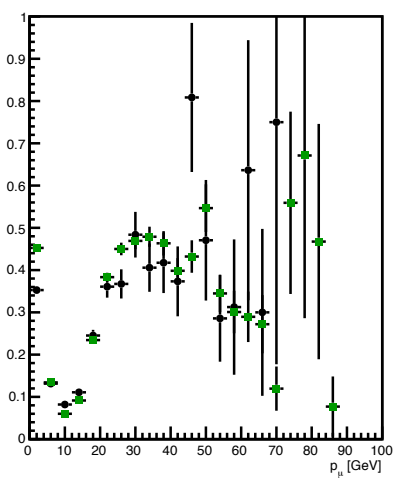
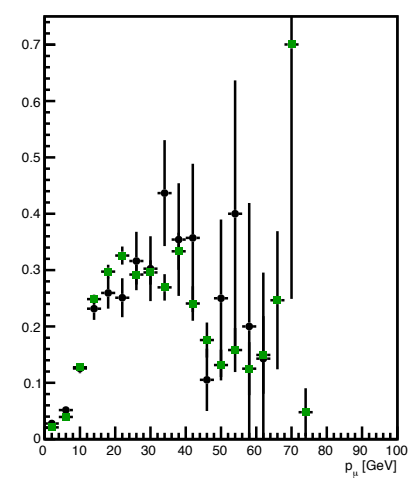
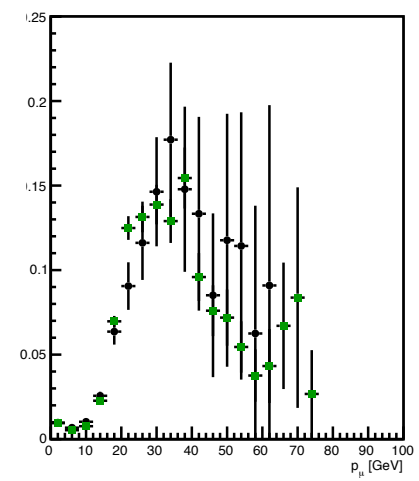
Alcove ratios



alc 2/alc 1



alc 3/alc 2



alc 3/alc 1