BooNE MC status, Feb 19 2016

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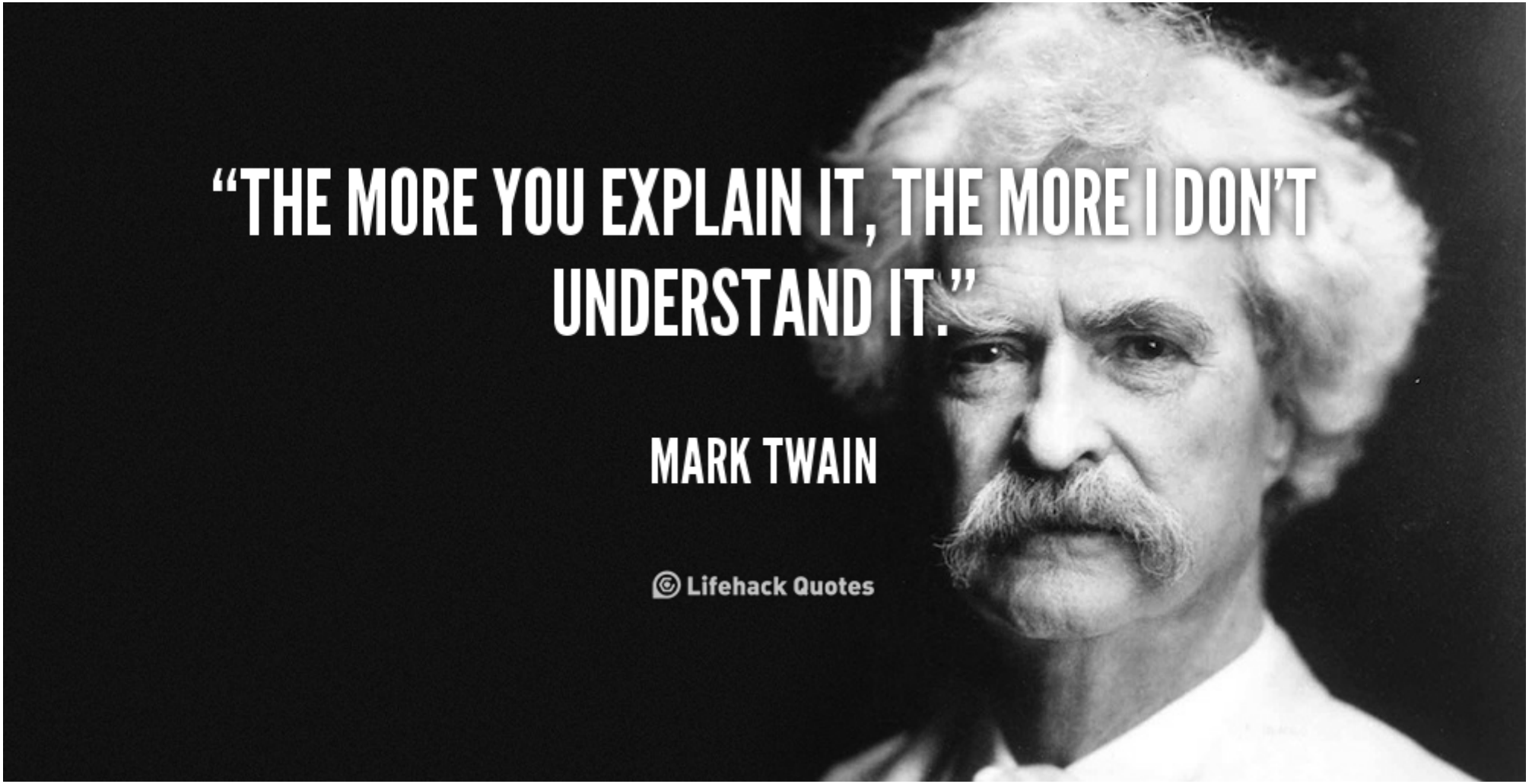
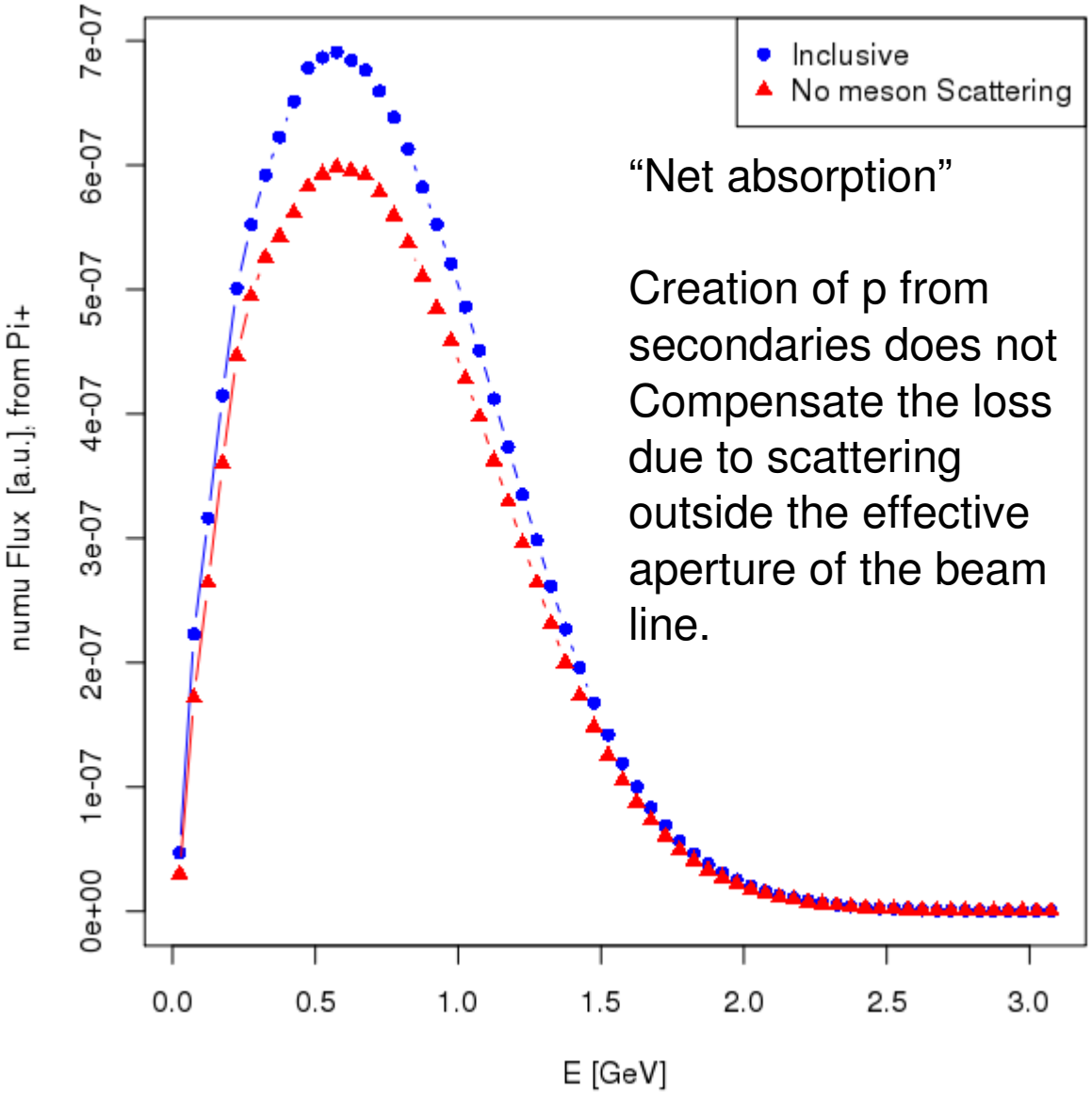
With help from Zarko Pavlovic


"THE MORE YOU EXPLAIN IT, THE MORE I DON'T UNDERSTAND IT."
MARK TWAIN
Lifehack Quotes

The issue to be resolved..

- At the last meeting, it was suggested to go back to a much cleaner configuration, where one has a non-trivial geometry, with materials, where all hadronic interaction (expect primary proton on Be) are some how removed. If so, the two codes must give the same neutrino flux, as our thesis that most (if not all) the differences between the two code comes from the differences in pion scattering, that occurring anywhere downstream of the primary interaction.
- One way to accomplish this, in the G4 Stepping Action, is to flag any track that undergoes a process that is know to be non-hadronic, such multiple scattering, ionization, or simple transportation (encountering volume boundary). Such are allowed to proceed to the next step. Otherwise, the track stops.
- Note: in doing we also kill the secondary hadrons, that could produce a few more neutrinos.
- This neutrino flux is predicted to be smaller than the “default cuts” one..



"Net absorption"

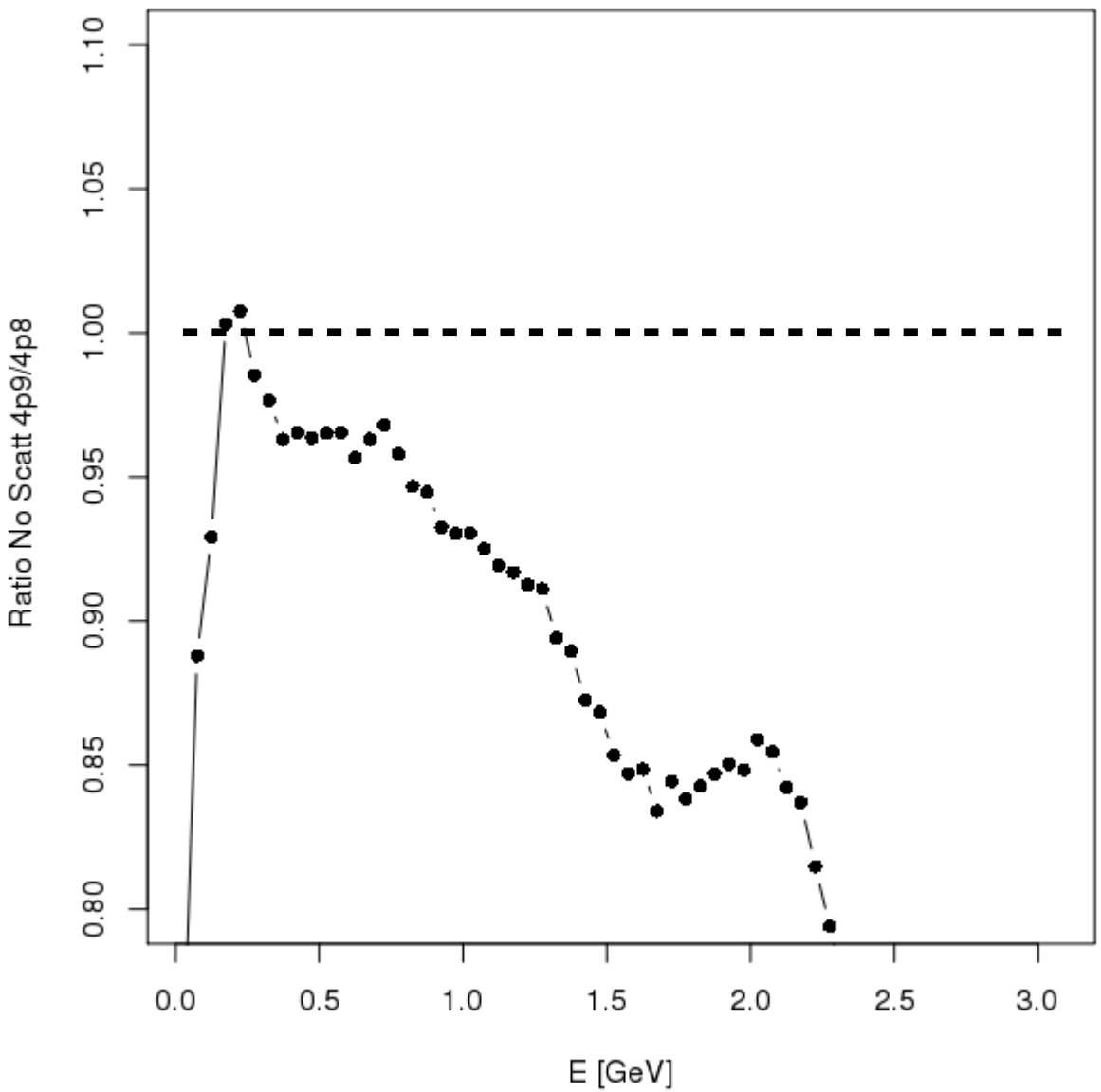
Creation of p from secondaries does not Compensate the loss due to scattering outside the effective aperture of the beam line.

This the neutrino flux from $\pi^+ \rightarrow \mu^+ \nu_\mu$ obtained with G4, v4p9

"Inclusive" means we include all pions, whatever their ancestry might be.

"No scattering" means that, if the parent of the pion is not the primary proton, we exclude the Neutrino. This was first implemented in the Dk2Nu post-G4 processing.

We now implement this algorithm in the BooNEG4Beam itself, such that the implementation can be "back-ported" to v4p8, without modification of BooNEBeamNT code.



This the ratio of the "No Scattering" neutrino fluxes, $\pi \rightarrow \mu\ \nu_\mu$ only, V4p9/v4p8

This is with the full geometry.

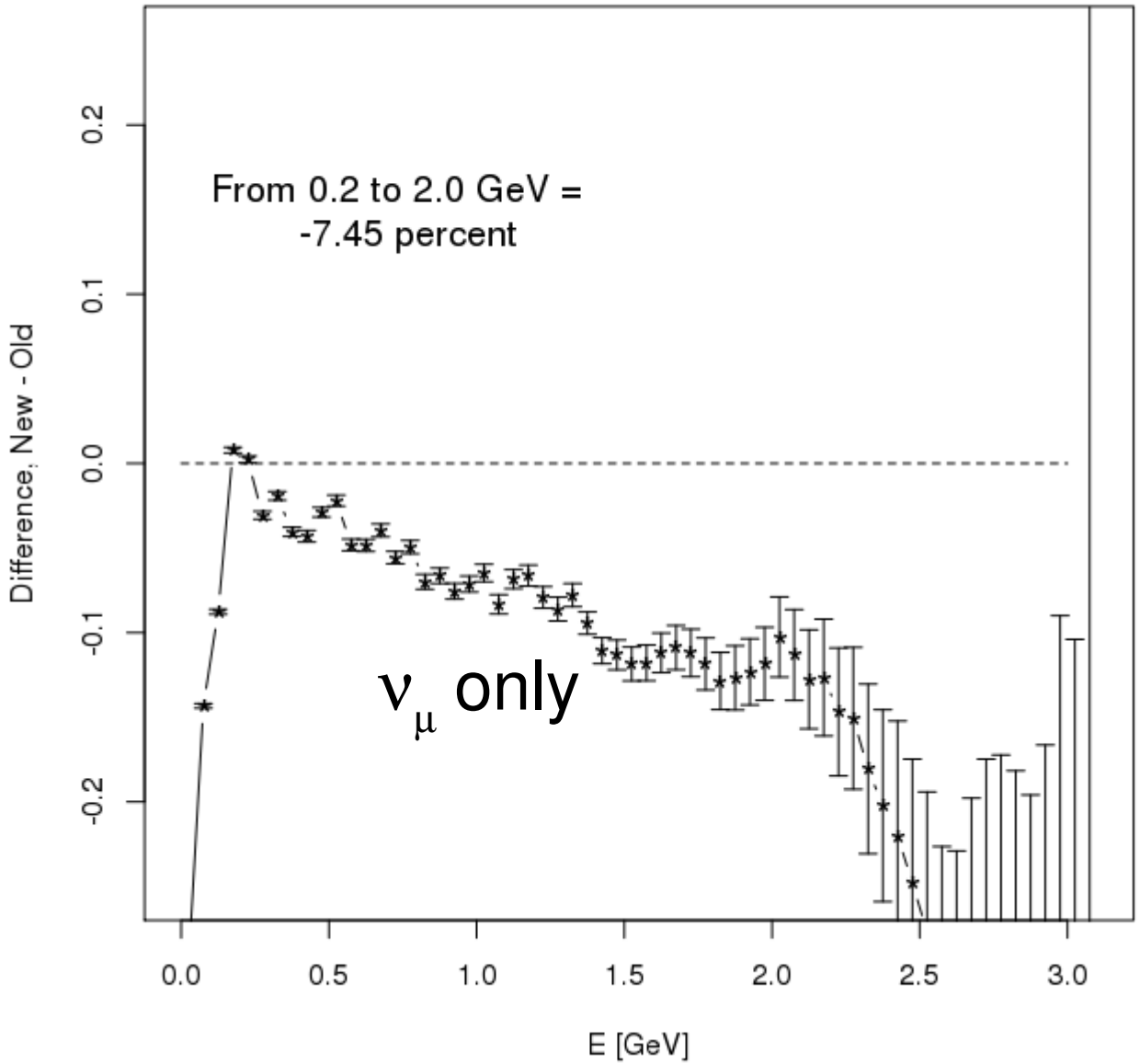
Inclusively, we have ~ 8% difference (see next slide)

Not what we predicted, 2 weeks ago..

(I had reservation about that prediction, but was not expecting such a large effect either...)

O.K., this is worth investigating.

Benchmark ν_μ flux, Thick target, V4.8 vs 4.9



In the previous plot, we had only one slug of Beryllium. In addition, no material in the horn, collimator, air... Same geometry, same magnetic field, just no interaction downstream of that 1rst Be slug.

For this plot, we now restore the full geometry.

In both versions,G4 v4.8.1 and v4.9.6

Shown on Jan 6 2016..
No change in the BooNEG4Beam code since then !..

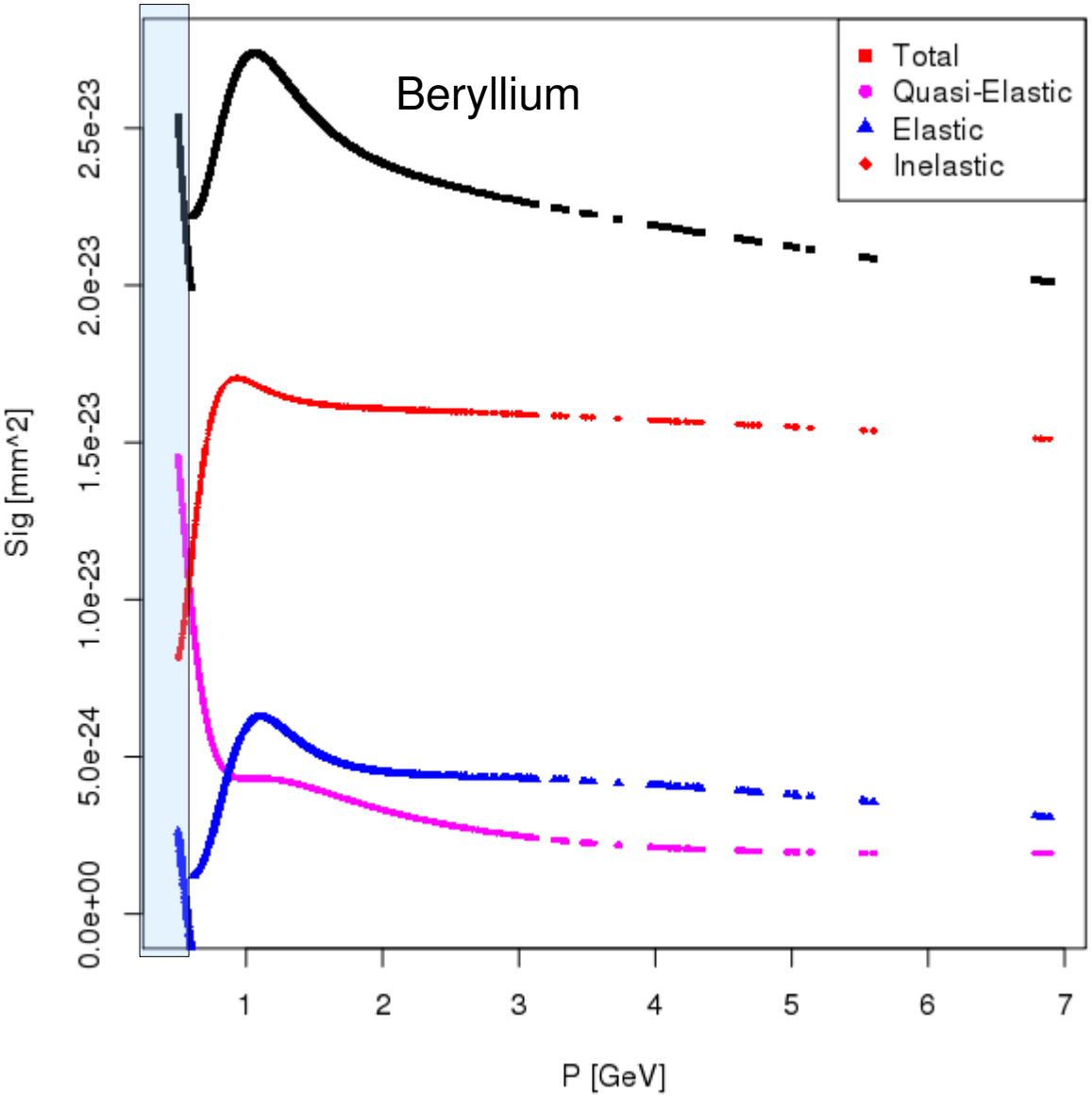
Investigating the “No Pion Scattering ratio, v4p8/v4p9”

- Compare the two codes. On average, if, (and only if),
  - The 6D momentum phase space for the p-> Be π^+ + X are identical
  - The mean free path for all hadronic processing processes are identical, for all tracking medium, over the entire momentum range
  - The average track length in a given tracking medium are identical
- Then, this ratio should be 1 (within statistics).
- Reviewing the above conditions..
  - 6D phase space of pions: Checked, HARP model implemented consistently in both versions.
  - The other two assumptions are a bit more tricky....

On Mean free paths..

- If all hadronic total X-sections are identical, then, the hadronic mean free paths should be identical
  - Should be true for π^+ on Beryllium and Aluminium, since BooNEG4Beam “overwrites” (overloads, in C++ terminology) the native G4 cross sections. This, for pion momenta between 0.5 and 11 GeV
  - This overload is applied only to “Elastic” and “Inelastic” processes.
  - MiniBooNE proponents added a third process, “Quasi-Elastic”. This is strictly a “User” process. (own cross-section, own model).
  - No “simple-minded” double counting occurs. Note that the “Elastic” cross sections is obtained by subtracting the Inelastic & Quasielastic from the total cross-section.
- However, all this does not apply to scattering in steel (collimator, tunnel walls..) !..

Checking the BooNE p scattering X-sections.



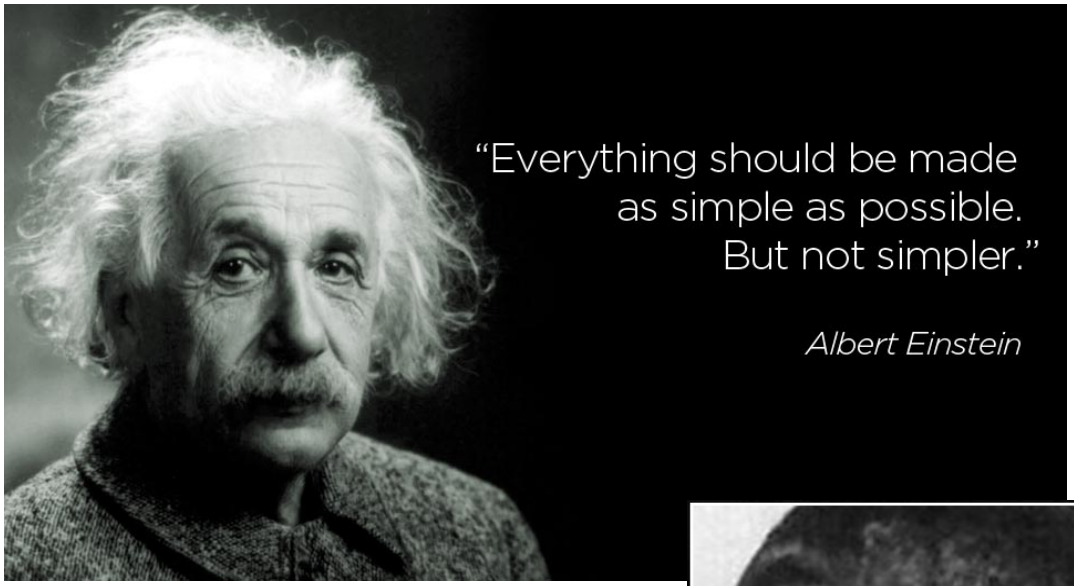
This is a graphical rendering of BooNEHadronCrossSections Class.

They are not used below 0.5 GeV. The code reverts back to the native G4 values.

This class gives identical results under BooNEG4Beam v4p8 and v4p9.

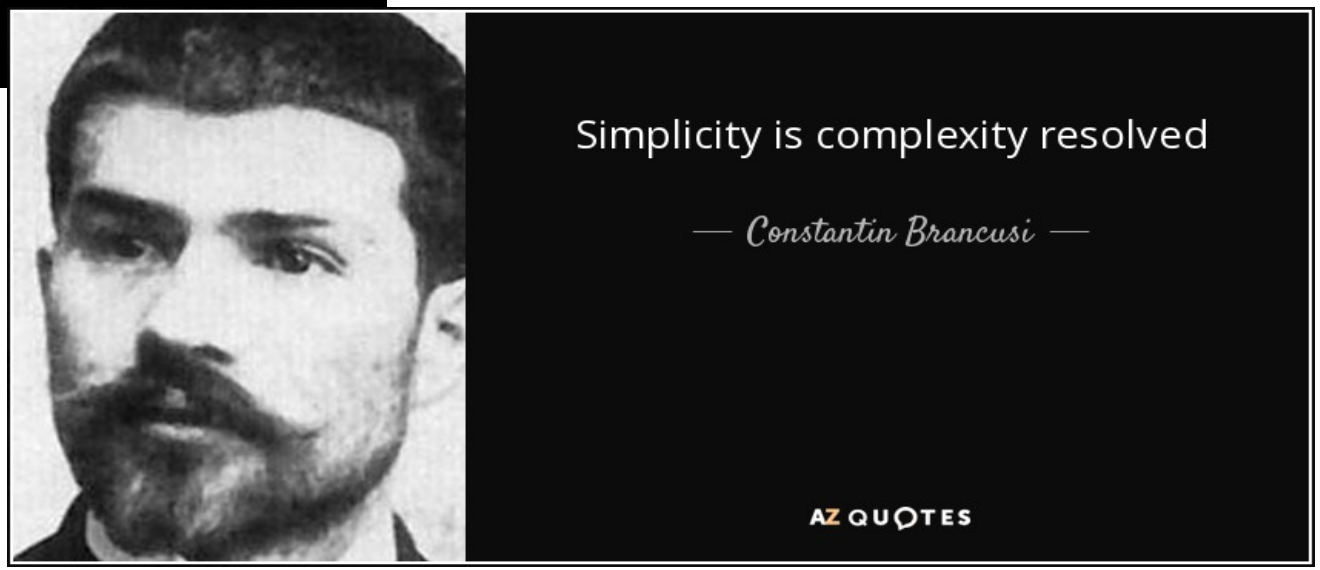
Simplify! Let us go back to the simple configuration of one Be Slug, and measure the p+ scattering rate (a simple counting experiment), and look at the neutrino flux ratio (v4p9/v4p8) when scattered pions are removed .

Preposterous comments..

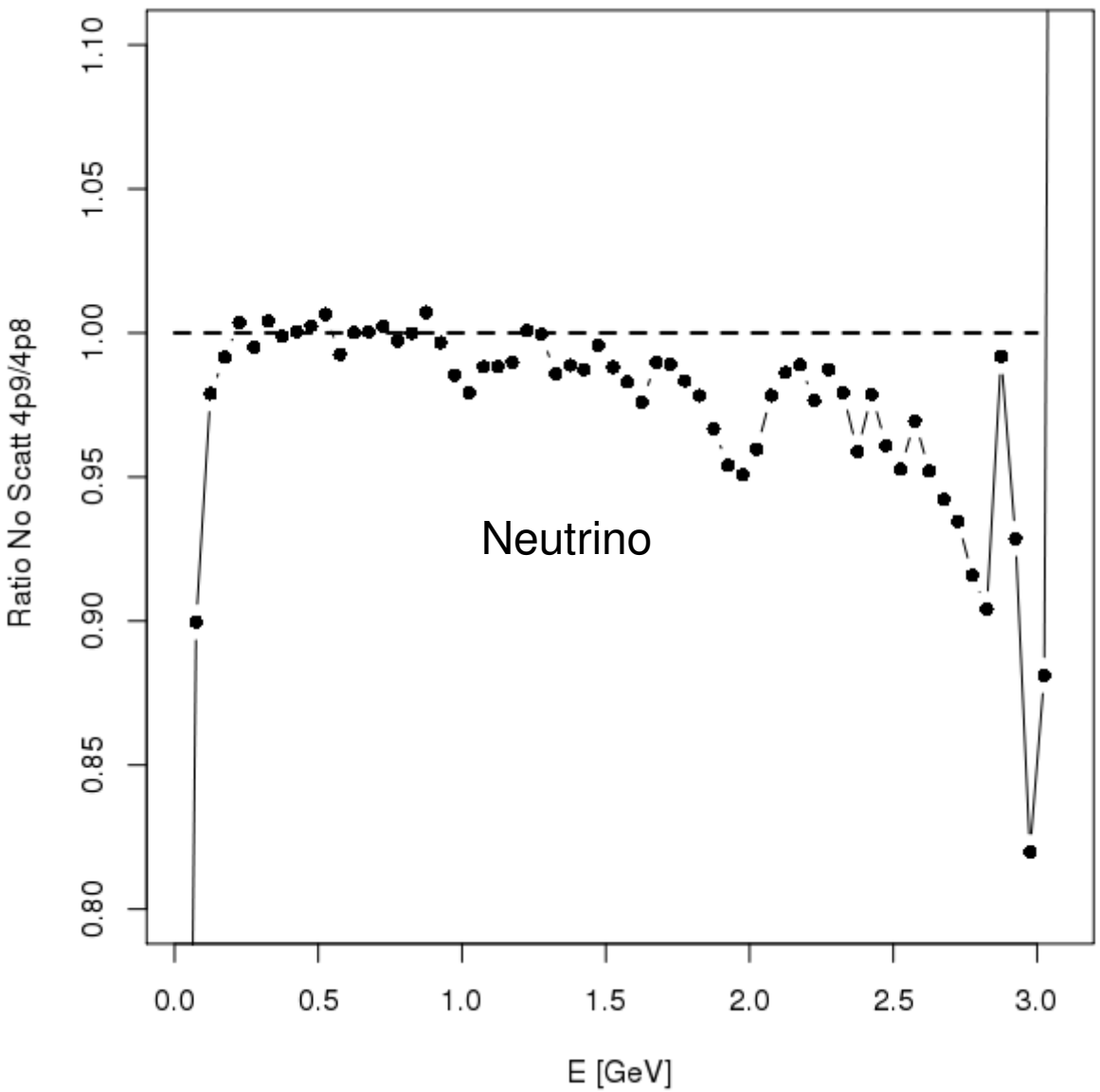


(Who am I for daring to quote such giants..)

(*Given that I am in serious trouble on this project, I should not waste time snickering around, but hey, I have to admit, boredom is taking on..*)



The ν_μ flux with one slug, all scattered hadrons are removed. ..



We still do have a problem, well above 0.5 GeV !

Of course at ~0.25 GeV, the calculation becomes very sensitive to the value of the (large!) QE X-scattering, as the native hadronic X-sections changed

I don't have an explanation for this effect!...

Scattering rate measurement, one slug geometry.

Hadronic Processes	All P	P > 0.5
Elastic	0.955 +- 0.012	0.990 +- 0.016
Quasi Elastic	1.001 +- 0.015	0.994 +- 0.017
Inelastic	0.971 +- 0.009	0.959 +- 0.015

Shown here are the ratios, v4p9/v4p8, of the scattering scattering rate occurring in the short Be target (100.2 mm)

Uncertainties are statistical only.

Within the allowed momentum range, same scattering rate in both code. Except for the PionPlusInelastic Channel. (2.7 sigma)

Tedious to measure with such a thin target !...

Scattering rate measurement, Full geometry.

Hadronic Processes	All P	P > 0.5
Elastic, Beryllium	0.930 +- 0.014	0.992 +- 0.019
Elastic, Aluminium	0.942 +- 0.007	0.992 +- 0.010
Inelastic, Beryllium	0.952 +- 0.010	0.956 +- 0.018
Inelastic, Aluminium	0.931 +- 0.008	0.955 +- 0.024

Shown here are the ratios, v4p9/v4p8, of the scattering scattering rate occurring in the long Be target (100.2 mm)

Uncertainties are statistical only.

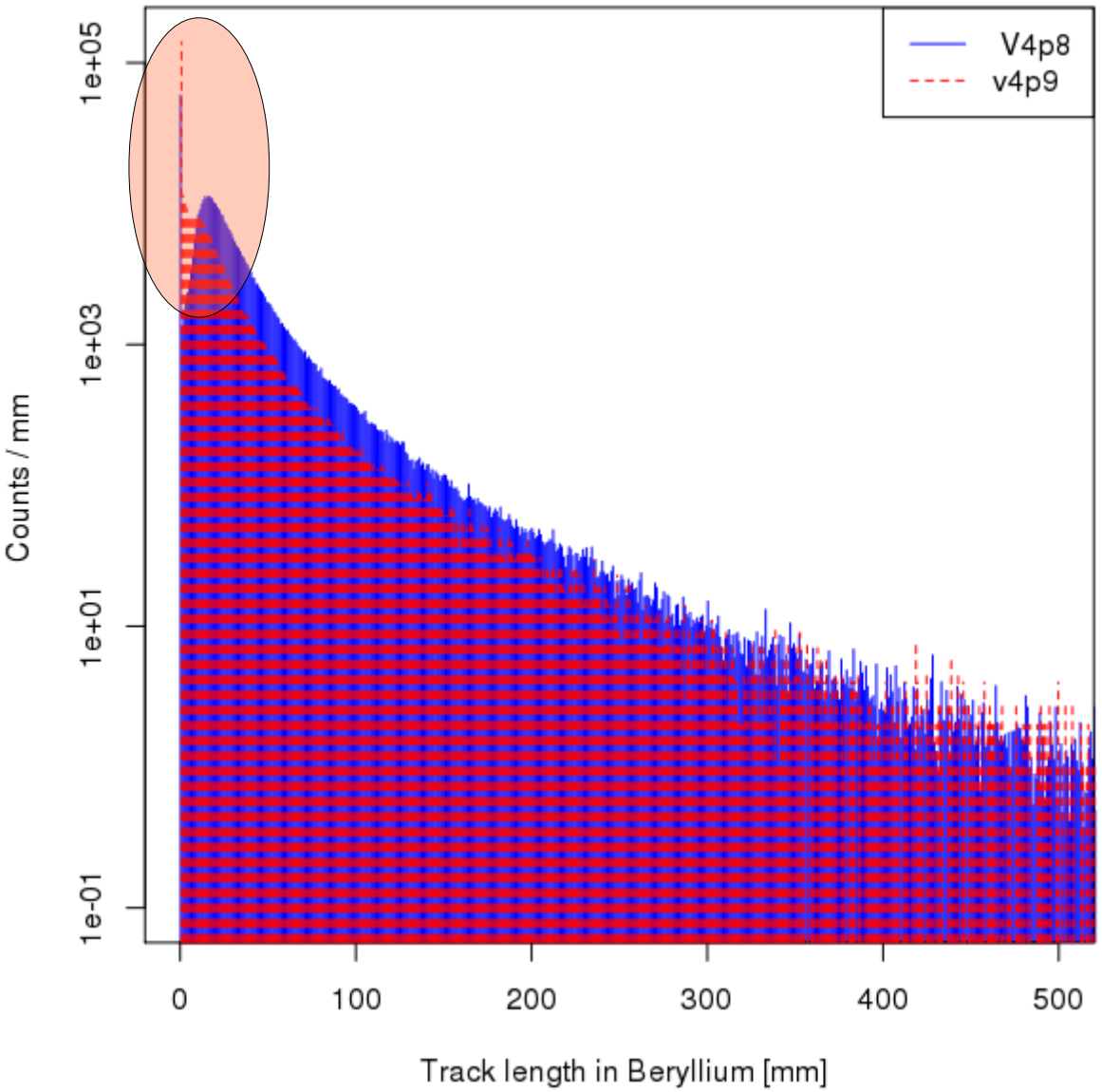
Again, we seem to have a problem with the meanfree path associated to the inelastic channel.

Momentum cuts applied consistently for each channel?

More basic: are the mean track length in a given medium consistent, v4p8, v4p9

Note: scattering rate on steel is 20% different, v4p8 vs v4p9, because different X-sections.

Verification of the path length in a given material



More confusion!..
I tried to check the integrated path length in a given tracking medium. That is, a given material. This can, in principle, can be done by summing up the step length, G4Track by G4Track, if the starting point of the step is in the medium.

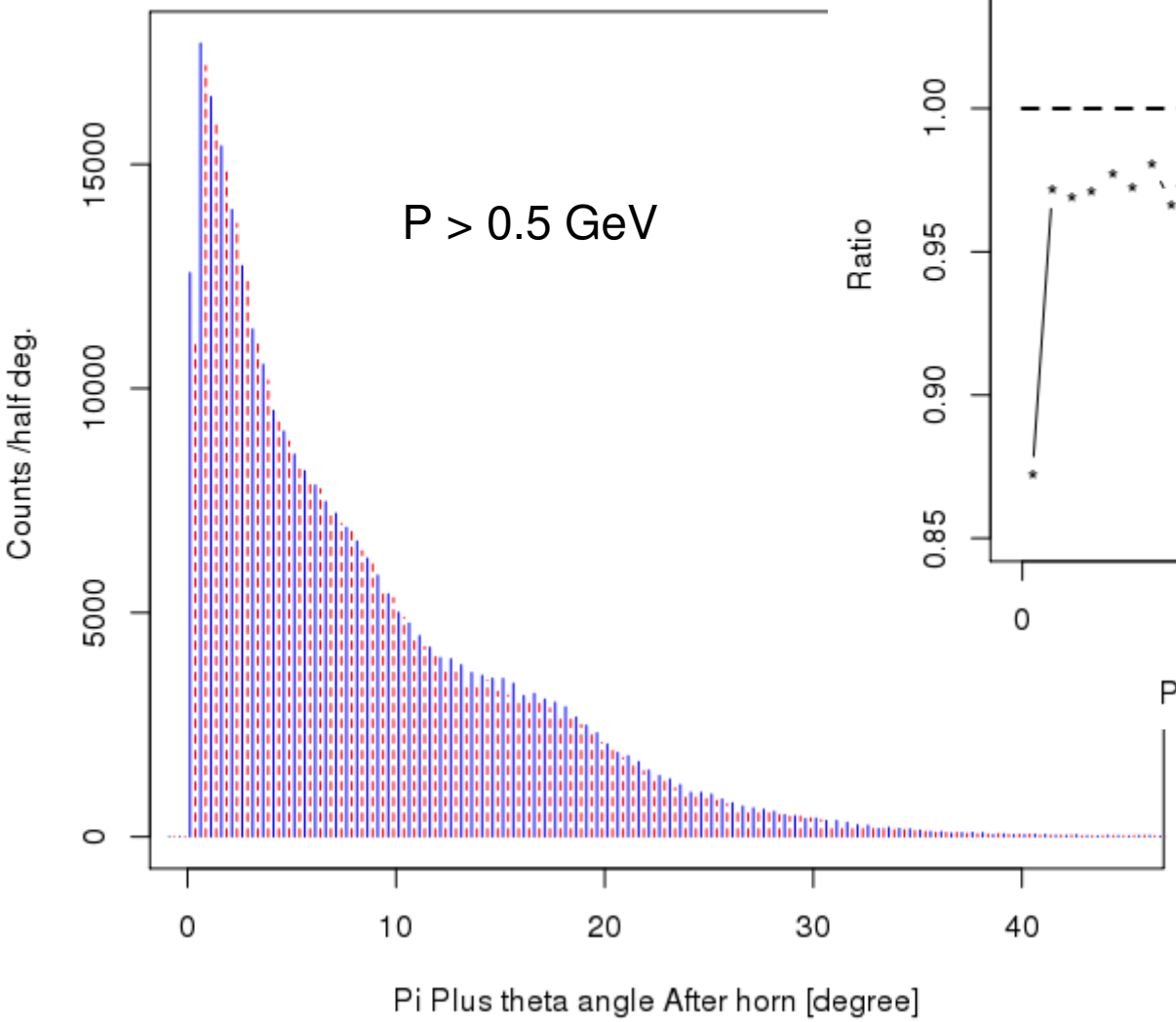
What do we do for the end point? In this plot, no further selection.. This definition could G4 version dependent!..

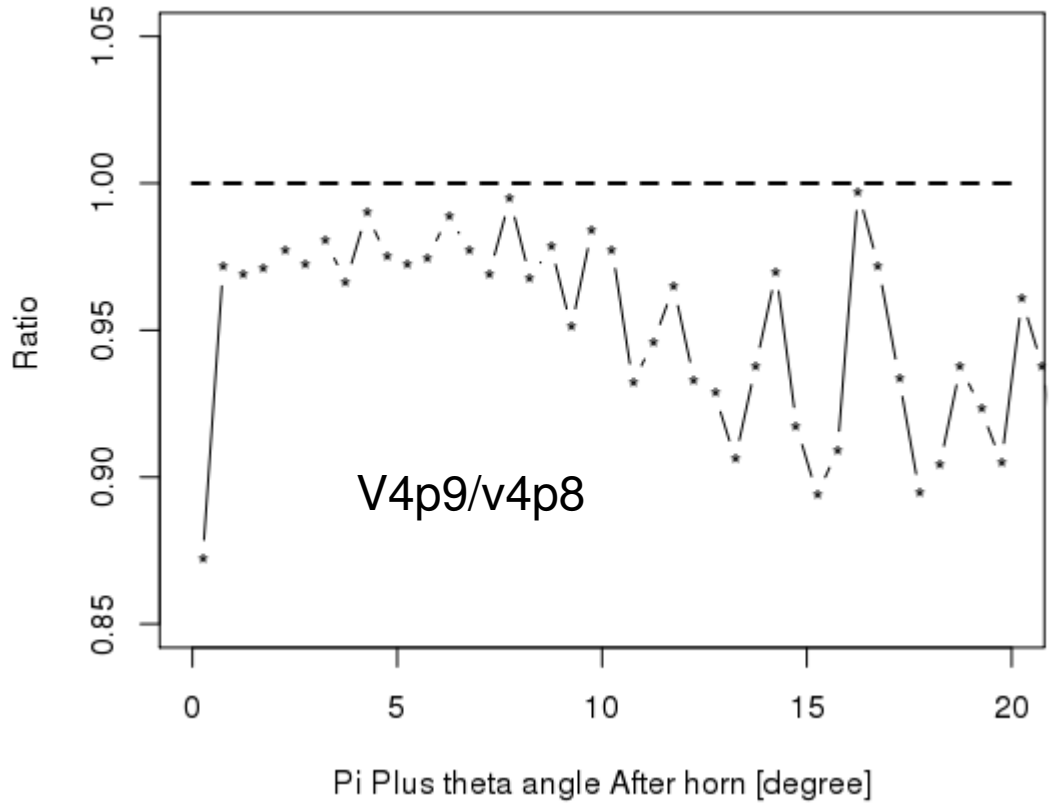
At short distances, (few (~ 1 step!) obvious differences...

However, evidently, both versions Compute the correct mean free path.

Angular (polar angle, θ) distribution after horn.

Full geometry

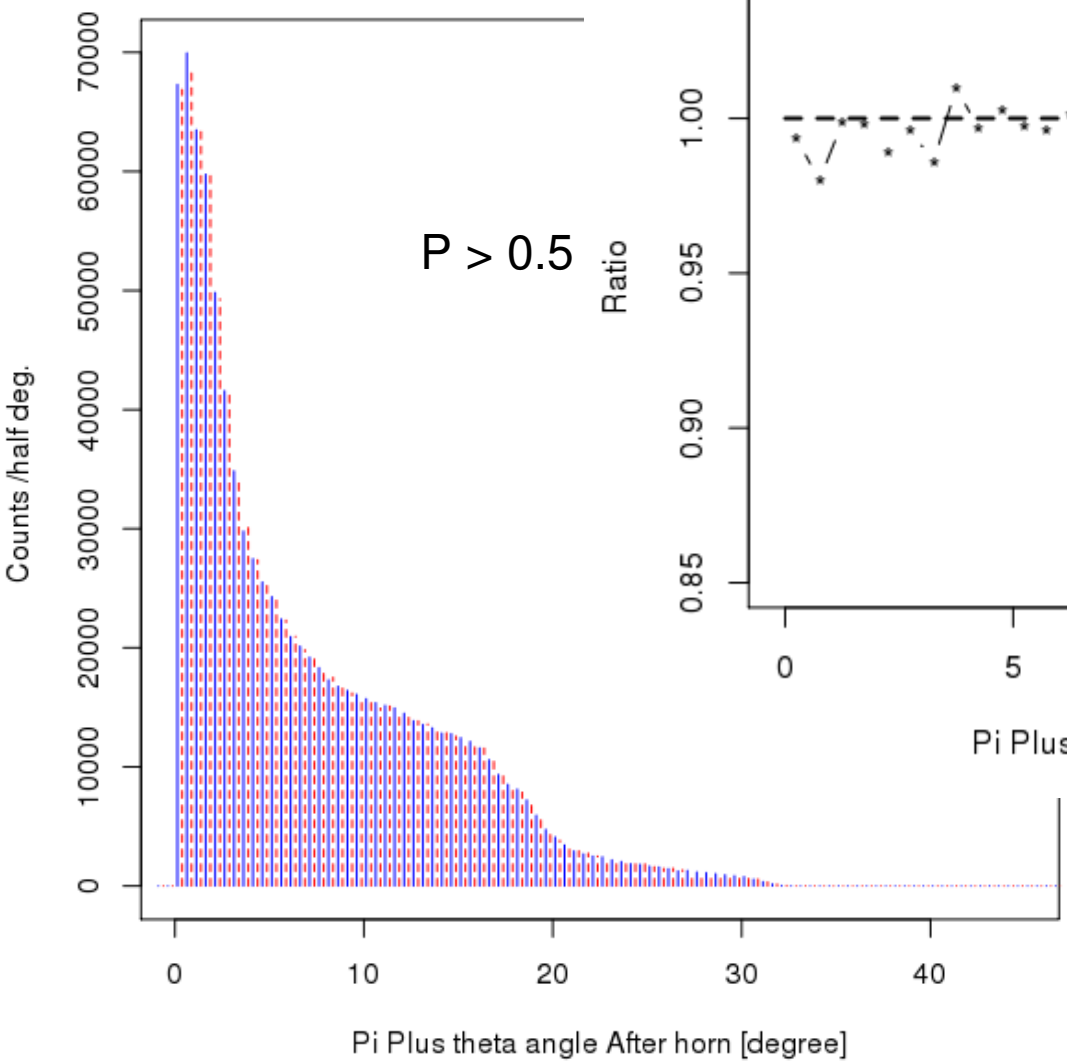




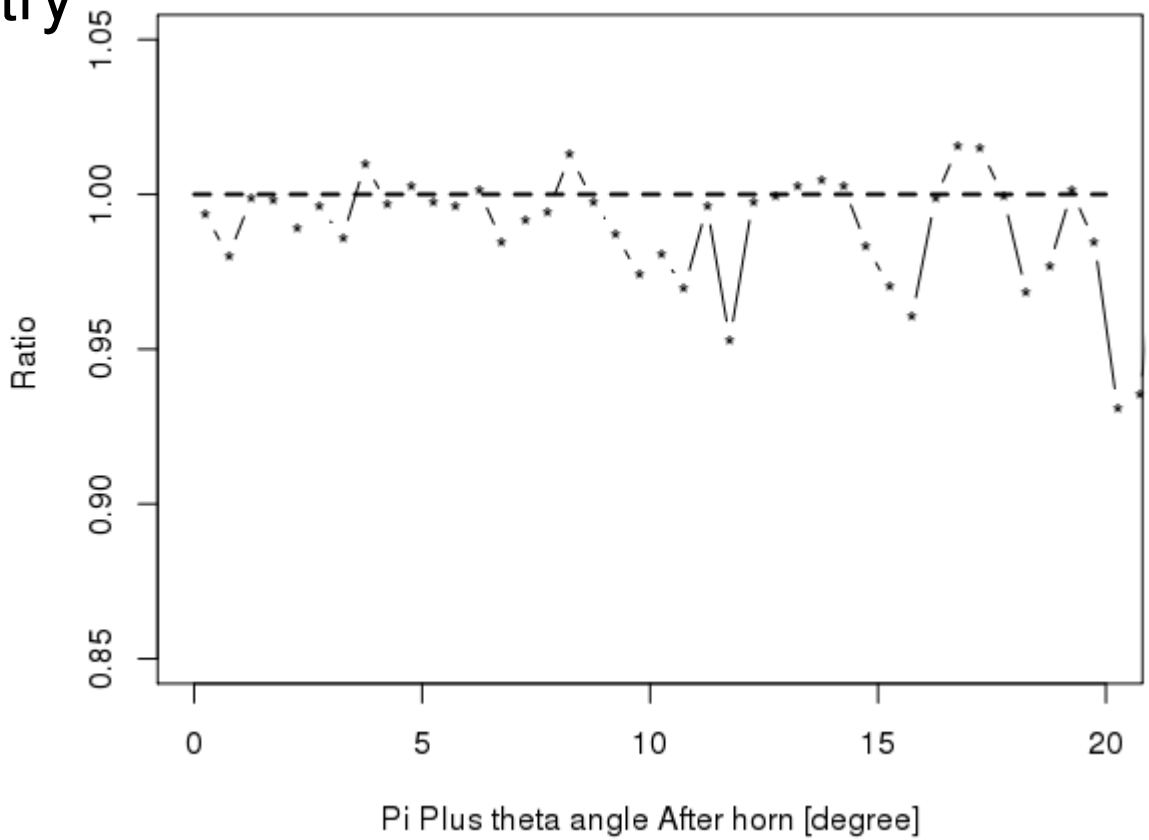
A small deficit, due some difference In the inelastic mean freepath. Also, difference at small angle, most likey due to small diff in multiple scattering code

Angular (polar angle, θ) distribution after horn.

One Slug Geometry



P > 0.5



If thin target, discrepancy vanishes. This point to “cumulative” errors for thick target (and tracking through material in the horn).

Status... (guidance welcome)

One more case we would like to run: Full target, Horn Aluminum, but no other material, rejecting hadronic scattering. Expect less differences in neutrino fluxes than the full geometry..

We are bogged down in “few % details” ... For instance, should we try to track down the ~ 4% in mean free path for the inelastic Cross section rate in Be and Al? This most likely due to further selection on whether or not the process occurs... Or slightly inaccurate calculation of relative probabilities among multiple processes..

Likely outcome: retracing deficiencies in Geant4 v4p8 (now ~12 years old)

Note: our goal should be Geant4 4.10, with update pion scattering models..