BooNE MC status, Jan. 6 2016

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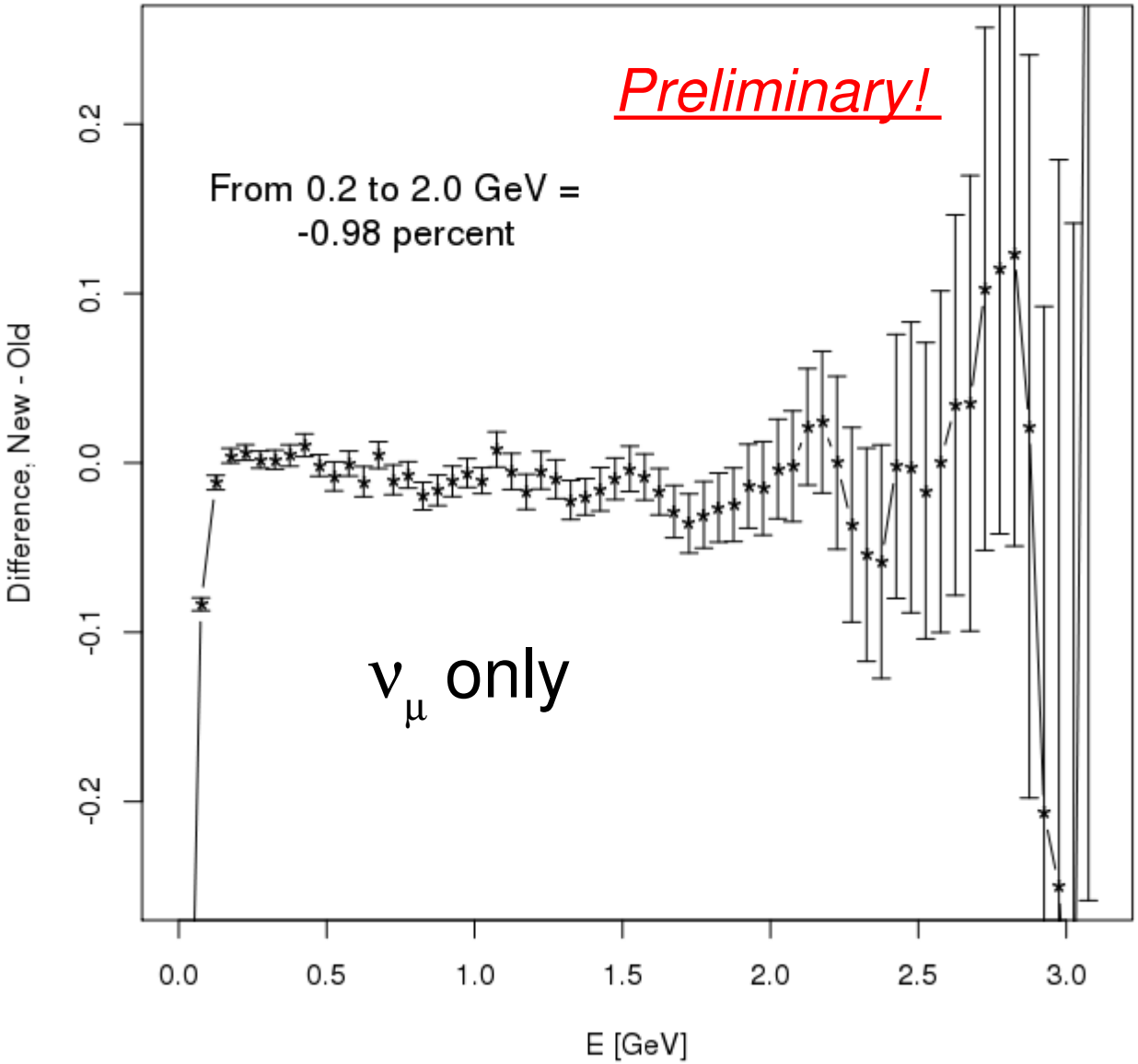
With help from Elena Gramellini and Zarko Pavlovic

Outline/summary

- What changed in the past few month, status of the ν_μ spectrum from π decay.
  - "Good" news: Now with ~ 10% across the relevant energy range.
- Details: (including "back-tracking".... "being more systematics"....)
  - Thin/Thick target comparison.
  - New checks on geometry & Magnetic fields
    - For further details, see

      https://cdcvs.fnal.gov/redmine/projects/booster-neutrino-beamline/wiki
- Further studies on pi-Carbon quasi-elastic scattering..
- Outlook: What's next?
  - More validation of the existing V4.9 version of G4BooNE.. (done by a MicroBooNE proponent, please ..)
  - Improvments to geometry + new Horn, when blue print available.
  - Move to G4 10.02.

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

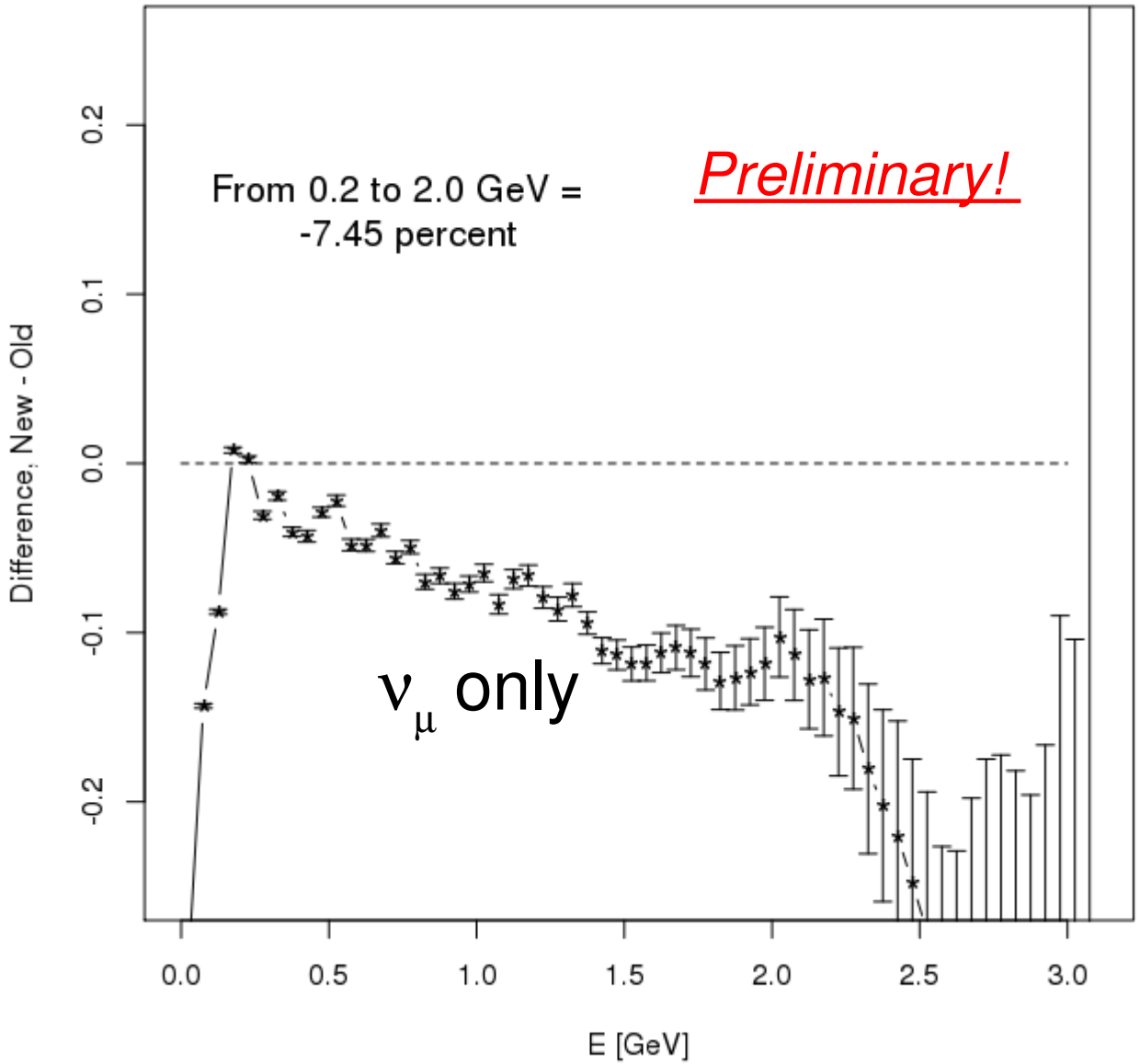


Obtained by (I) running the old BooNE program on a dedicated workstation running SL5, with Geant4 4.8, CERNLIB, (Hbook, etc..).. The genuine code.. (almost!)

(ii) running on lbnegpvm0x, Slf6, Geant4 v4.9.6, same BooNE physics model.. (Except for the elastic & quasi-elastic pi-Nucleus scattering model)

Shown here is the relative difference between the two spectra, New vs Old.

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

Better agreement than ~3 months ago.. What changed? (i.e.,... now come the details)

First, removed the cut on the minimum energy of 50 MeV for the neutrino to appear in the output (Dk2nu) ntuple. However, parent particle at rest are rejected. Impacts the low energy (E < 500 MeV) region

Second, the spectrum is now obtained using the T2K “re-decay + fiducial” cut to estimate the flux at the MiniBoone detector, instead of the “Boosted Lorentz solid angle” method used by NuMI. This is a minor change, provided the detector location is smeared upon, the NuMI method gives same results.

Thirdly, in the New (G4 v4.9.6) version, ran with the same model for the skin depth (B field in the inner conductor) then in Old (v4.8.1) (It was implemented all along in New, but Zarko and I miss-communicated on what we should be running..)

These are the only change made in the last 6 months.

From Preliminary to “a bit more robust”

Independent review of the calculation...

By a proponent of MicroBooNE

On going : Elena Gramellini, Zarko Pavlovic

More early-bird users are most welcomed..

Review: Towards a “more systematic approach.”

Hum... Back ~9 months ago (March 16 2015), I was not aware I was working on a version of the BooNE code that has already been modified (by Elena G. with help from Julia Y.), such that it runs under a new version of the compiler and Geant4. Without a code management system.... This made the comparison between the code I was running and the official MiniBoone code (running fmb0x machines) suspicious..

==> had to backtrack and understand the bug fixes made prior to March 16. Established a new Fermi RedMine sub-project, starting with the same version as on fmb02. Also, re-booted an old Auger workstation (augera3) still running slf5, re-install Geant48, HBOOK, etc, such that my work does not interfere with program activity on fmb02. Compare and check benchmark fluxes, fmb02 and augera3, O.K.,

Understand what the bug fix was, (exceeded array boundary access, read), with Elena informal logs, and convinced that the old MiniBoone flux were correct, the illegal access were innocuous , under the compiler they used...

Fixed that bug (a second time!) and moving on..

Documented various studies on the wiki site...

Prior to march 16 2015

Most of the effort went into porting the BooNE Hadronic Physics Models from Geant4 v4.8 to v4.9

The intialization phase for these models needed to be re-organized, and the (some of it private!) interface between the G4 physics list and the internal methods to simulate a given interaction have been changed, G4 v4.8 to v4.9 And did changed again, v4.9 to v4.10 And are likely to change again.

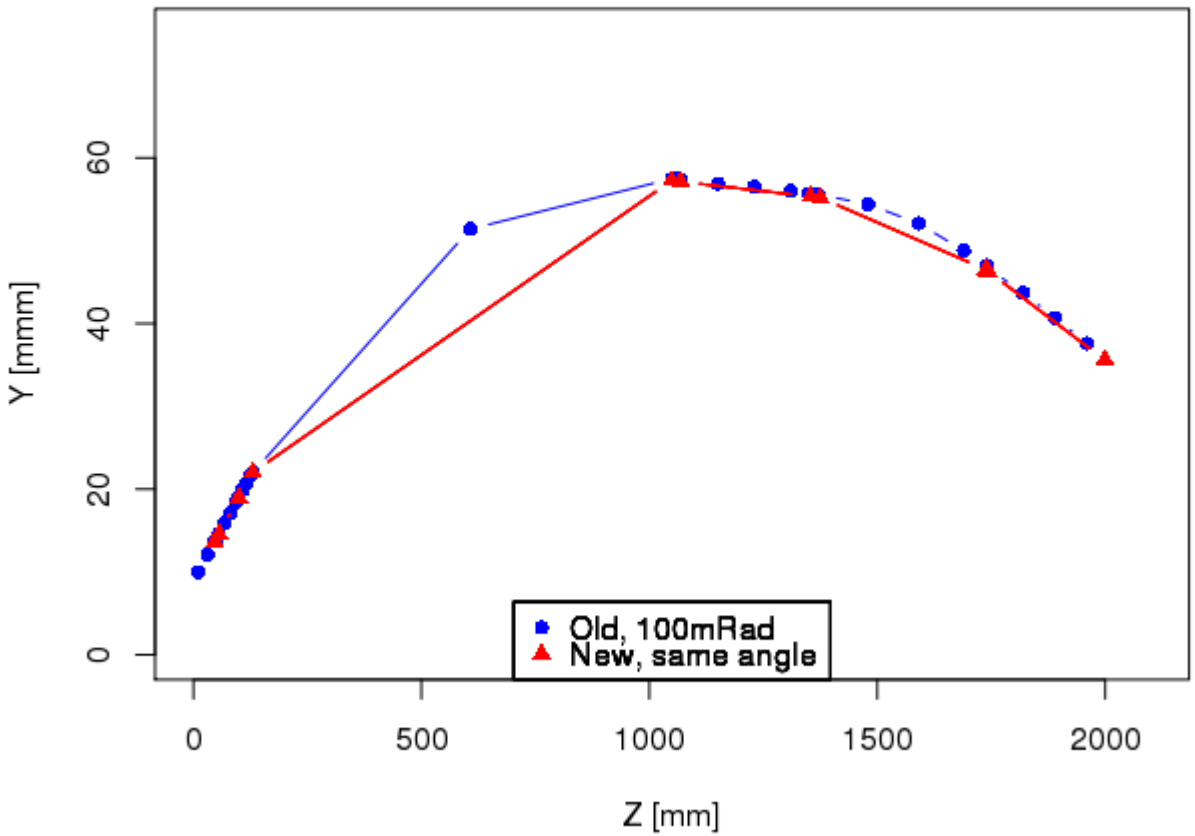
This allowed us to allow the user to run with a default (BooNE) tune without having to keep all the settings (hundreds of a parameter values) in his G4 input macro. (a good thing from a maintenance perspective)

To validate this transfer, tests were made using debugging statements in these methods, and direct comparison of kinematic variables for pions, kaons coming out of the target were done.

Studies done in the last 6 months: Outline

- Check the propagation of muons through the magnetic fields + mult. scatt.
- More comparison the pion yields, New/Old, at target, after horn, after collimator and in the decay pipe.
- This, with one slug, no material downstream of target, and full geometry.
- Trace down the changes in pion-nucleus scattering processes, Geant4, v4.8.1 vs v4.9.6. These are sufficient to explain the differences New/Old
- Studied the p- on Carbon scattering in multiple versions of Geant4, and compared to recent data (KEK) – Not used to tweak G4, 4.8.2, probably not G4.9.6, and not MiniBooNE.
- Studied & cross-check the T2K “re-decay” vs “Lorentz boosted solid angle/NuMi (implemented in Dk2Nu) calculation.

Checking the Magnetic field..



Agreed on a Horn current setting, New vs Old

Verify values for the magnetic fields at specific locations. O.K., New vs Old.

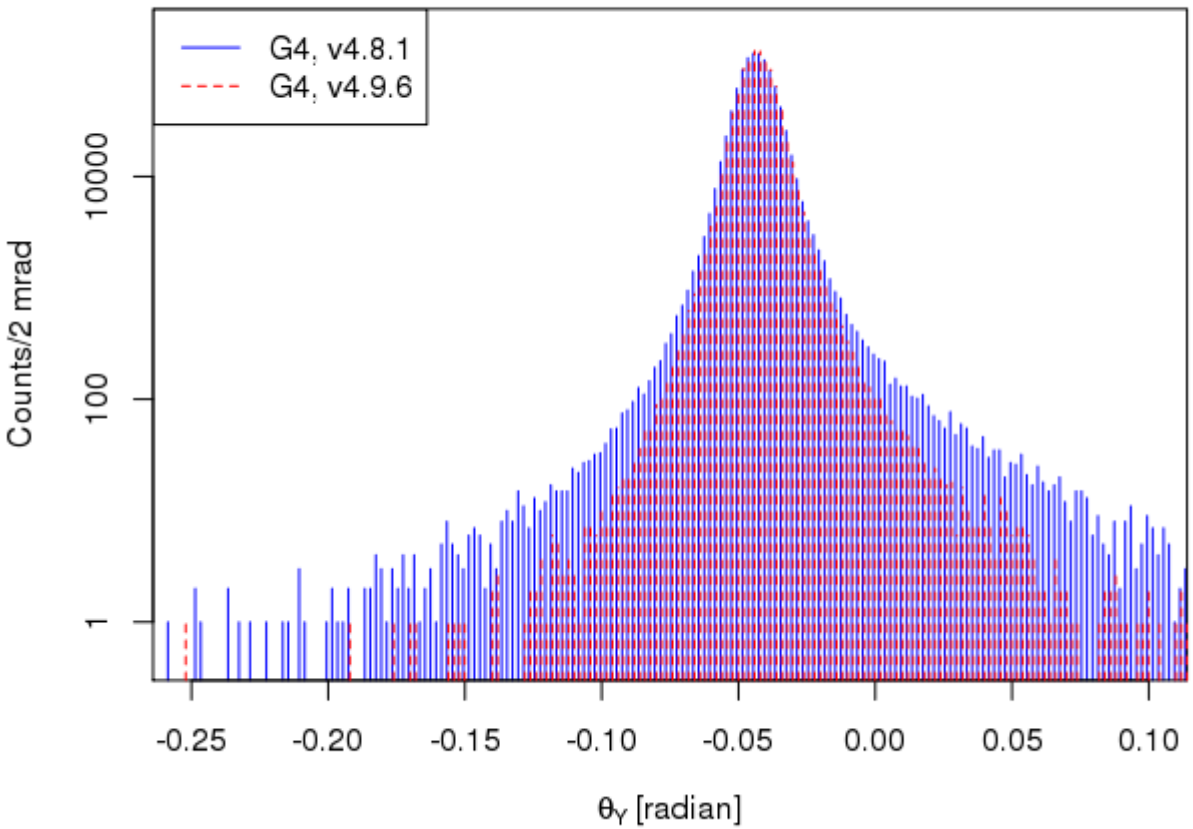
Ran muons.. From the beginning of the target. Record position set by the G4 algorithm, for a few traks.

Unfortunately, the multiple scattering interfered ==>

Take material away.

See result on the left.

Checking the multiple scattering, in a typical horn



Changed as well, New vs Old.!

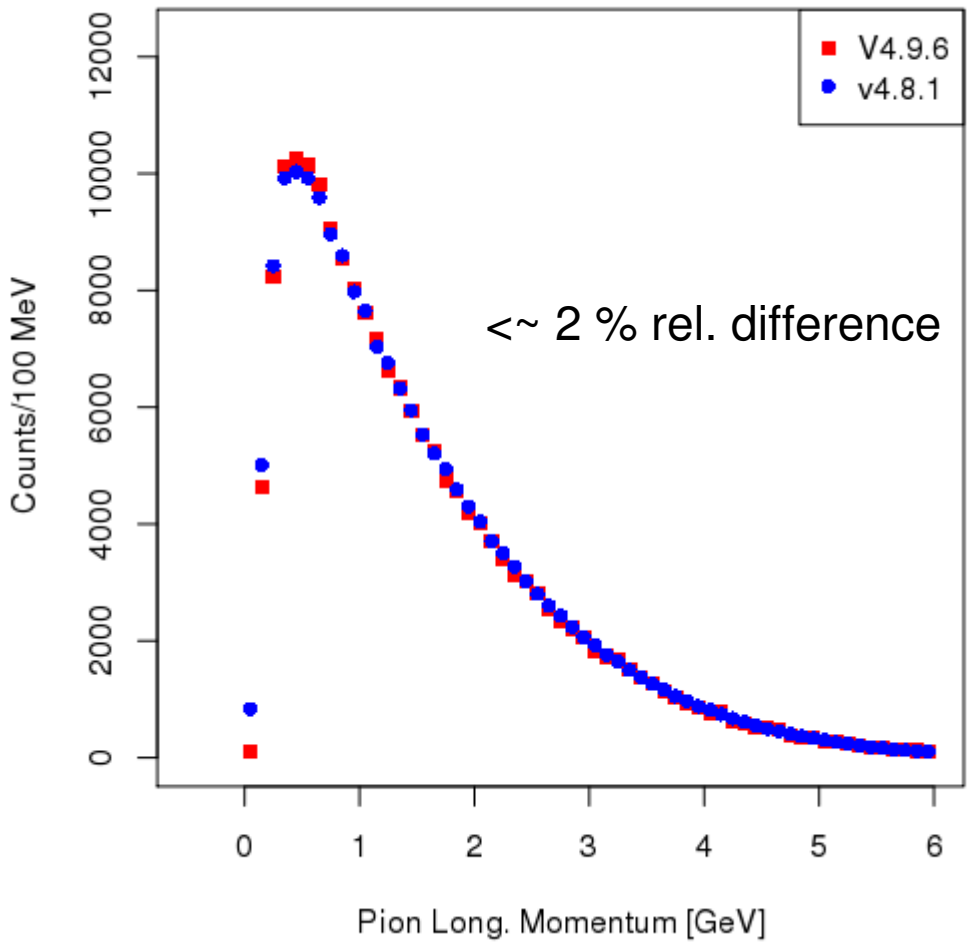
But not significantly.

Took a recent horn, 1.8 m. long, from Zarko's BNB upgrade studies. (details not important here..), implemented in a stand-alone BNB simple G4 sims (twice, one in G4 v4.8.1, one in G4 v4.96

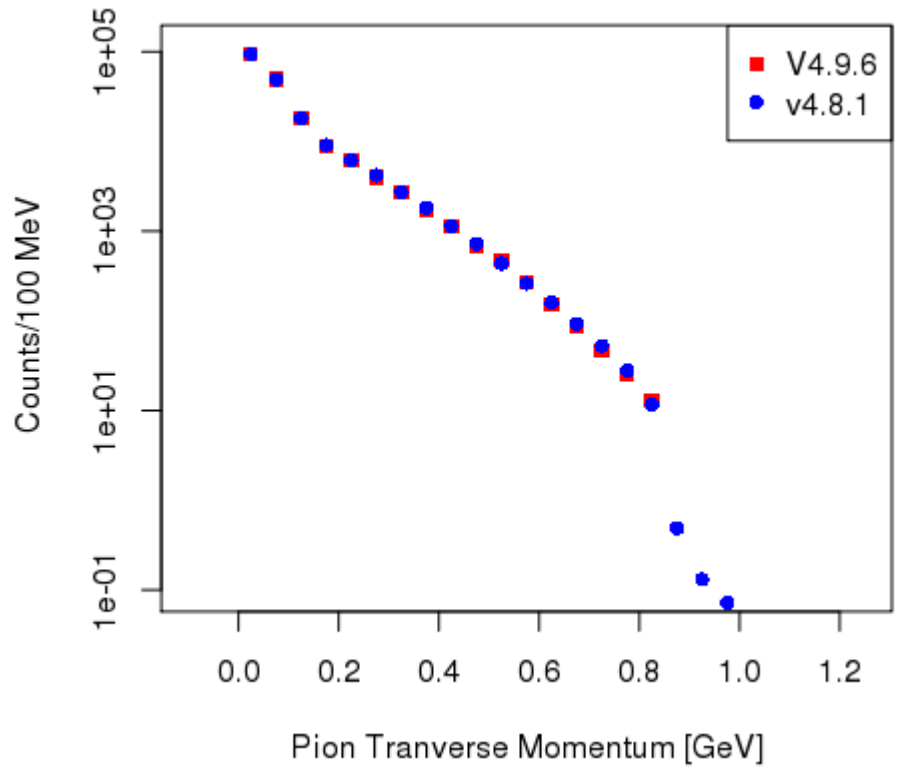
Ran muons, (positive, forward Horn current), 2 GeV, 100 mRad, from target location, let it be deflected and scatter in the Horn material + air.

Record positions and angle at Z = 2 m. Tails are a bit different.

Pion Yields, after the collimator (Z= 2 m.) , thin target.

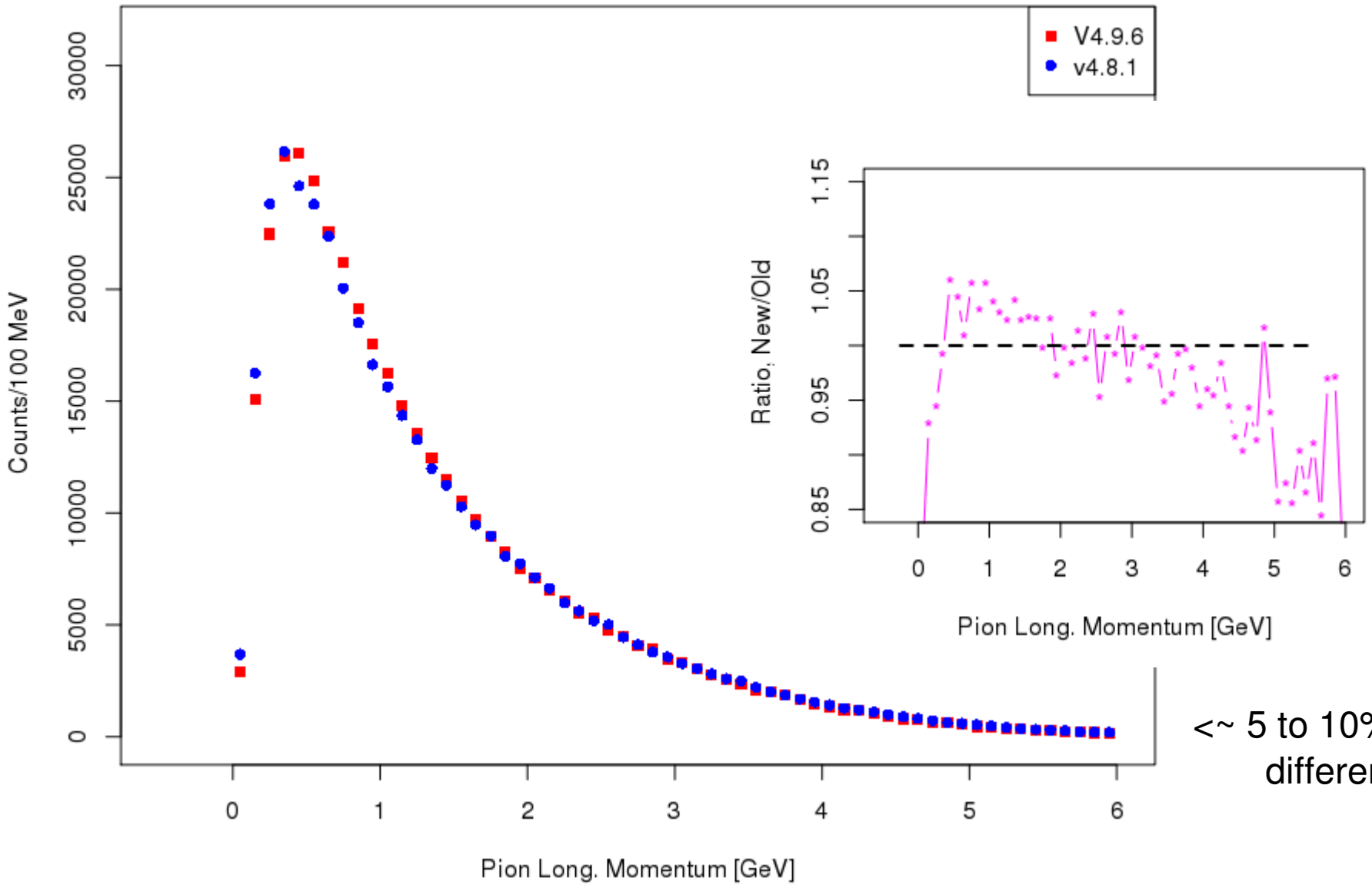


The only material in the simulation is the first, ~ 4 inch long, Beryllium slug. We compare the pion production yield (based, in both cases, on the HARP data, MiniBooNE fit).



Pion Yields, after the collimator, thick target.

This time around, full geometry.



<~ 5 to 10% difference

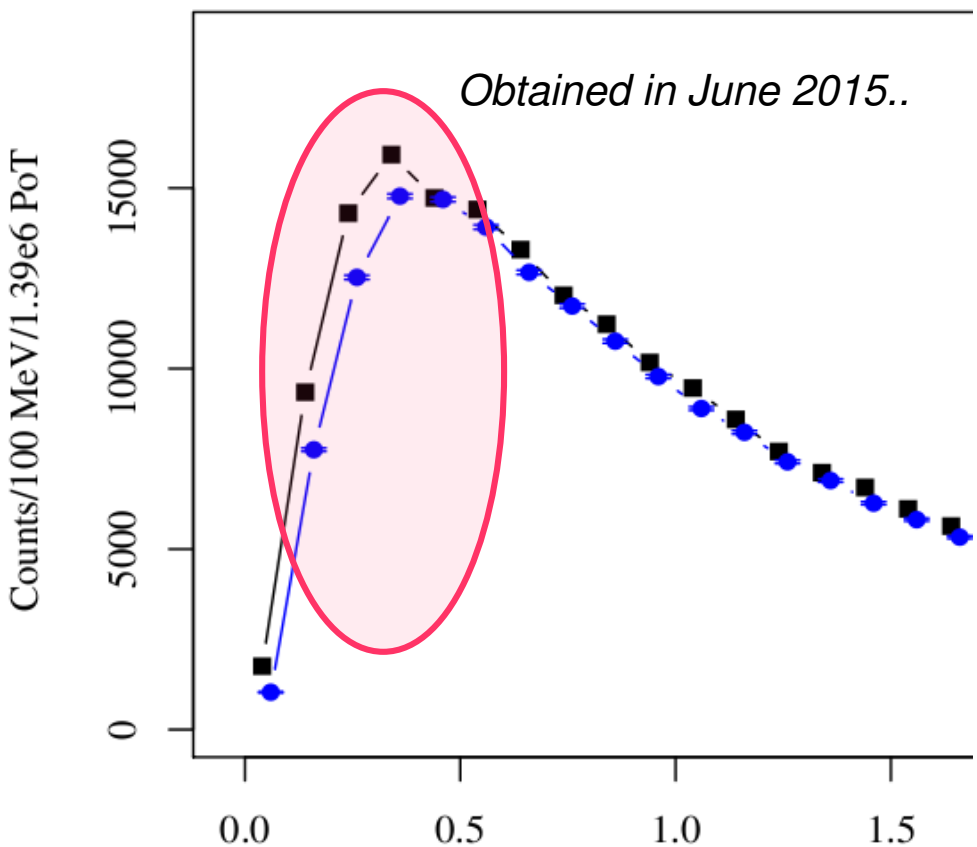
Not a new thing, observed before..

See talk given to the MicroBooNE beam's group, Oct. 7 2015.

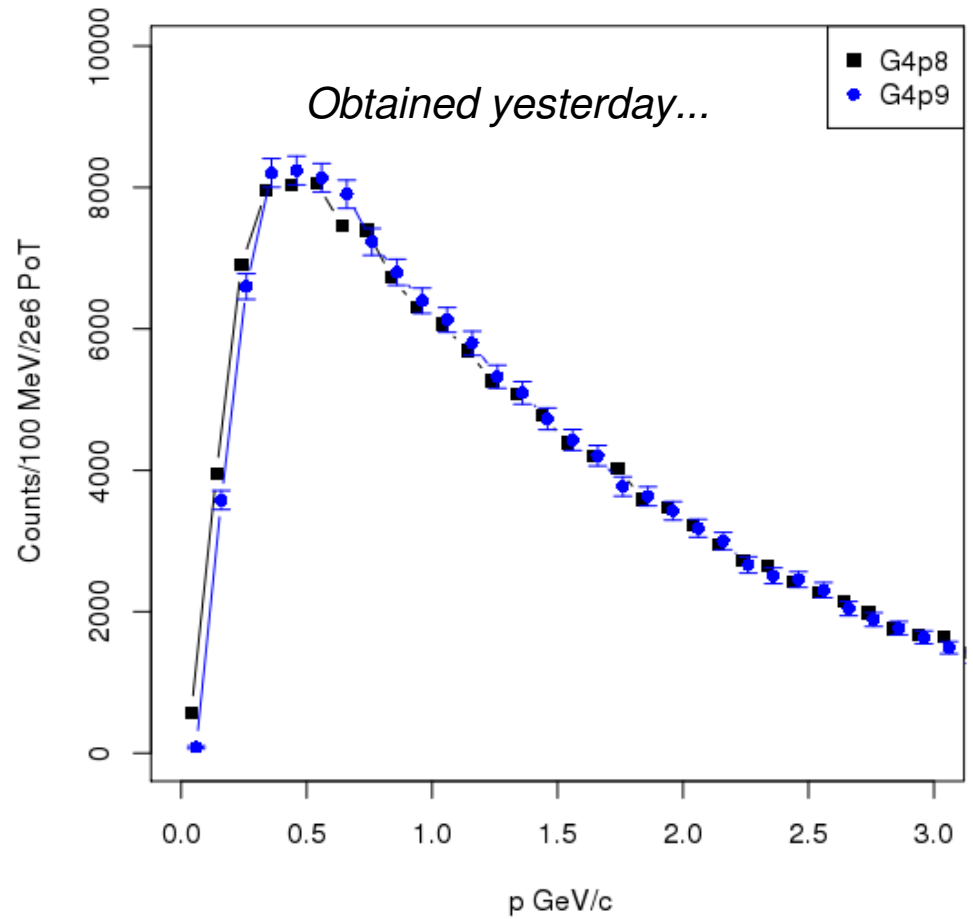
Note: the Skin depth mode was different between Old and New.. This has been corrected.

Momentum spectra of π^+ observed after the collimator..

Full beamline (G4p8/G4p9, fmb02 vs lbnegpvm03)



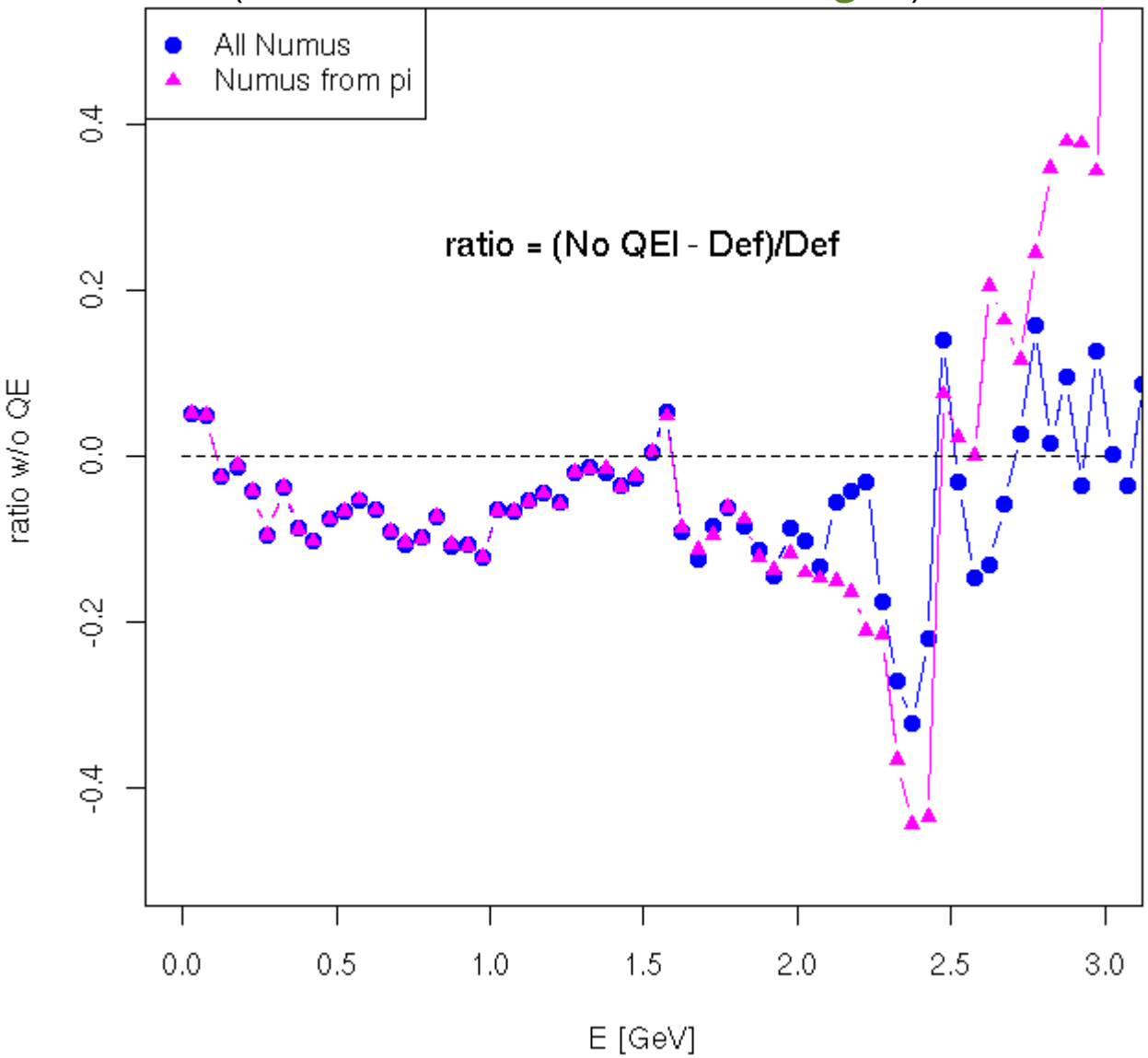
4" Beryllium, everything else vacuum. (G4p8/G4p9, augera3 vs lbnegpvm03)



With a thin target, using the HARP production model, consistently, G4p8, G4p9, good agreement on the pion momentum distribution.. Disagreement with the full system. It has been verified that this is not due to the a difference in tertiary yield.

What is the impact on the ν_μ energy spectrum of simply turning off the BooNE pion QE scat.?

(***Also shown in Oct 7 meeting...***)



Using G4p8, on SLF5, (with gcc 4.8.1)

Quasi Elastic "G4particleChange" set to identity.. ==> No quasi elastic.

Using the full beamline (default 50 m geometry.)

Significant impact...

Note: In BooNE MC, BooNE model, quasi elastic only implement for pion, kaon, nucleons on Al and Berylium.

Pions grazing the inner surface of the Iron collimator are not affected By this change.

We also saw commensurate difference in the pion flux in the decay pipe, and other locations, except at the production point, where the MiniBoone pion production model (class BooNEpBeInteraction, etc..) runs identically v4.8.1, v4.9.6.)

We also verified that the pion lifetime is the same in both G4 version (minute difference, irrelevant..)

However, one established difference is the G4 internal pion-Nucleus scattering (elastic & quasi-elastic) model. While BooNE uses it's total cross-section fits to set the probability for the process, (but not for all materials in the SBN beamline) the internal scattering model is ultimately the one(s) from G4.

That G4 code changed, v4.8 and v4.9. Worse, in v4.9, some such interaction models were deemed “deprecated”, and indeed are no longer in v4.10.x

How well does these new G4 models compare to new data?

For instance, consider (relatively) recent pi- scattering data on carbon:

PHYSICAL REVIEW C, VOLUME 64, 034608

Quasielastic π^--nucleus scattering at 950 MeV/c

Y. Fujii,[1,*] O. Hashimoto,[1] T. Nakagawa,[1] Y. Sato,[1] T. Takahashi,[1] J. T. Brack,[2] C. J. Gelderloos,[2] M. V. Keilman,[2] R. J. Peterson,[2] M. Itoh,[3] H. Sakaguchi,[3] H. Takeda,[3] K. Aoki,[4] H. Hotchi,[4] H. Noumi,[4] Y. Ohta,[4] H. Outa,[4] M. Sekimoto,[4] M. Youn,[4] S. Ajimura,[5] T. Kishimoto,[5] H. Bhang,[6] H. Park,[6] and R. Sawafta[7]

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(Received 14 May 1999; revised manuscript received 31 May 2000; published 22 August 2001)

Quasielastic scattering cross sections have been measured with a 950 MeV/c π^- beam on targets of ^{2}H, ^{6}Li, C, Ca, Zr, and ^{208}Pb, over a range of three-momentum transfers from 350 through 650 MeV/c. Results for carbon are compared to a finite-nucleus continuum random-phase approximation calculation including distortions. The pion spectra at our lowest range of momentum transfers show less scalar/isoscalar correlation than predicted.

DOI: 10.1103/PhysRevC.64.034608 PACS number(s): 25.80.Ls

Got help from Hans Wenzel, SCD/G4 group, who contacted the lead author (Y. Fujii), got his phd thesis, and data tables.

(http://lambda.phys.tohoku.ac.jp/~db/human_resource/thesis/1989_B_1_D_1.ps)

Hans plans to include this set of data and corresponding G4 results in his G4 Hadronic validation web site.
(http://g4devel.fnal.gov:8080/G4WebAppNG/)

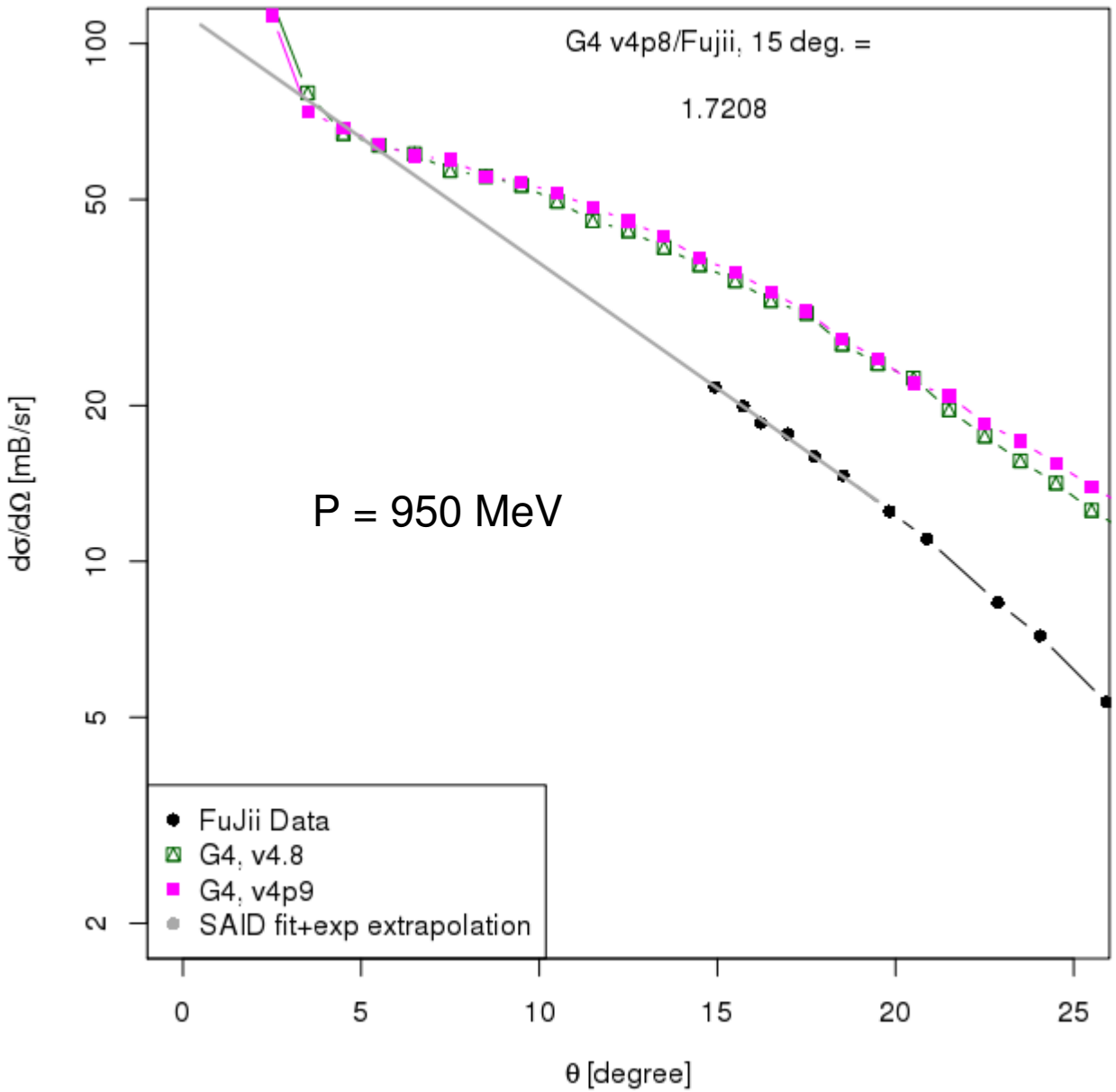
Compare it to G4. Since v4.8 is no longer supported, Hans is only interested in documenting v4.10.. But we (Elena, myself) can work on the v4.8 vs v4.9 versions.

First, simple $d\sigma/d\theta$ on Hydrogen, at 950 MeV, compared to SAID fits

Motivation?

a. We need to study this “effective absorption” of meson due to scattering, in order to improve the accuracy of beam flux calculation (see the recent work done by Minerva)

b. I got curious on how much work is involved in doing these benchmark, and/or improving the G4 package..

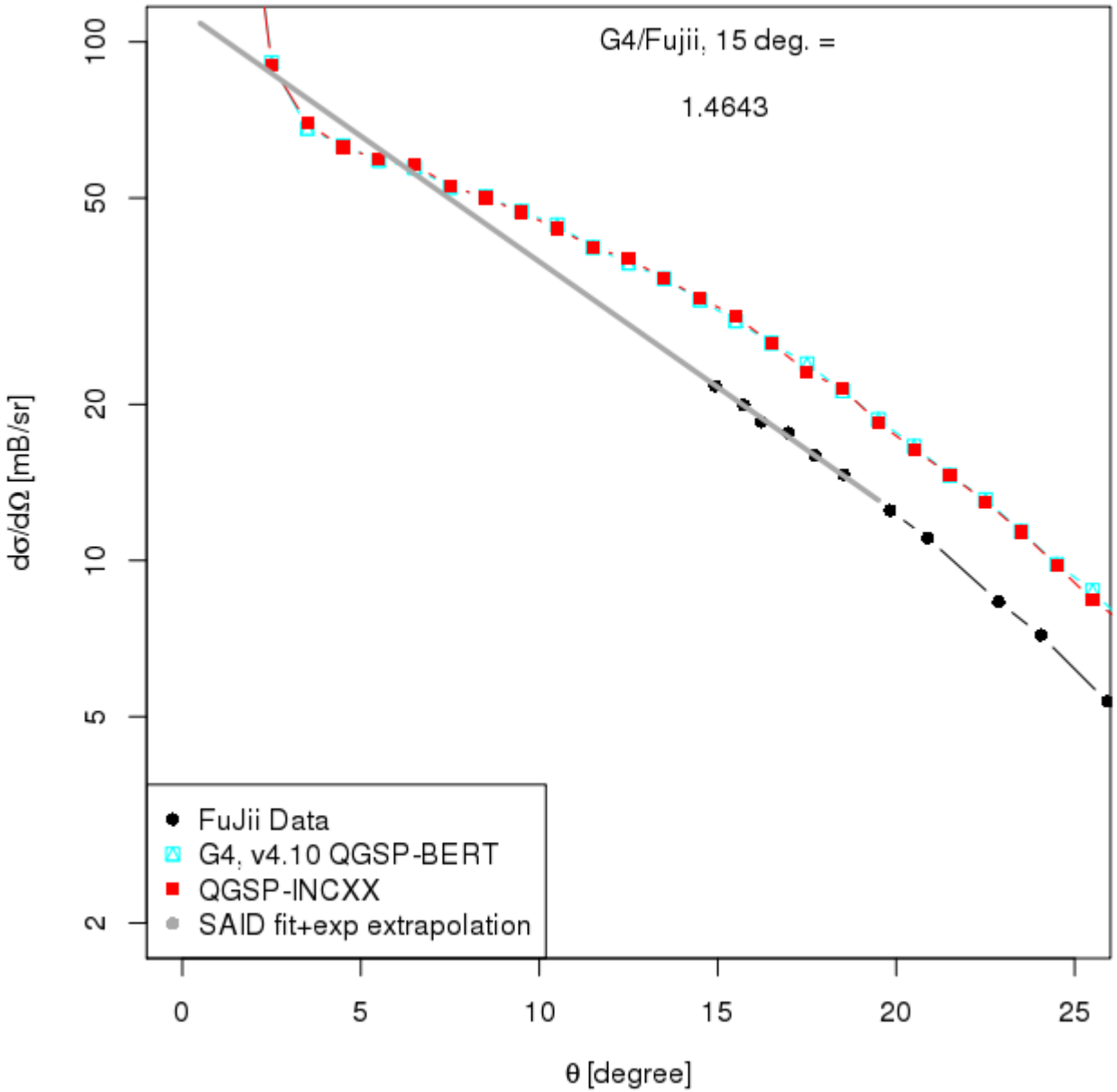


Wrote a small standalone G4 application that simply "measures" the differential cross-section(s) for a thin target, with a perfect detector.

Easily portable across G4 versions (No private, custom, Physics lists or hadron scattering..)

On Hydrogen, ignoring the second kinematic variable, the pion energy loss in the lab frame, not much difference.

Good fit at a few degree (ignoring multiple scattering below ~ 3 degree). Worse at higher angle.



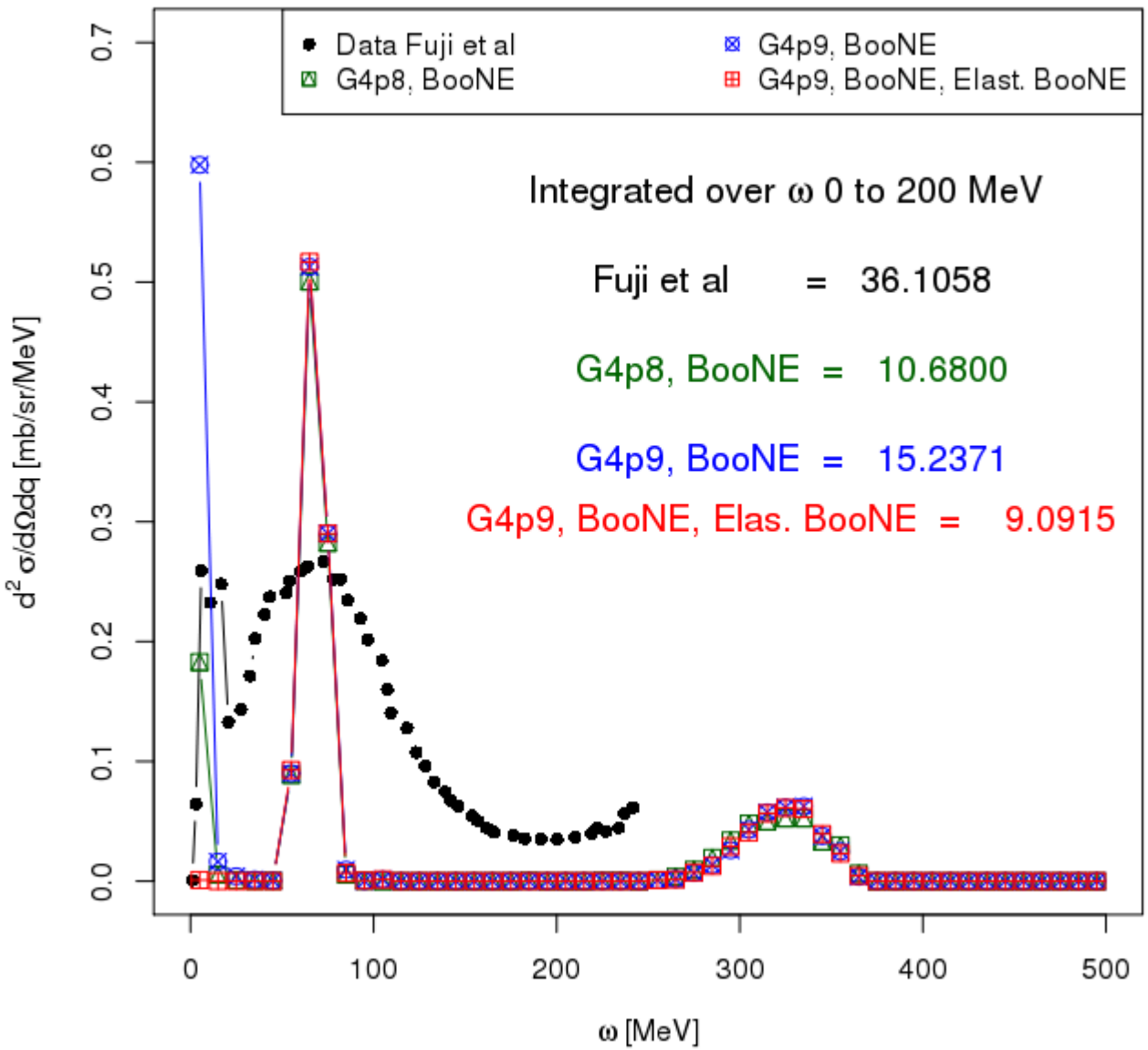
Better agreement in the more recent versions

But this is (i) not showing the energy loss distribution and (ii) not on Beryllium or Aluminum.

Analyze the simulated (simple G4) data in more details.. π^- on Carbon, P = 955 mEV/c

Some examples. ..

Awaiting confirmation from Hans W. and/or Elena..



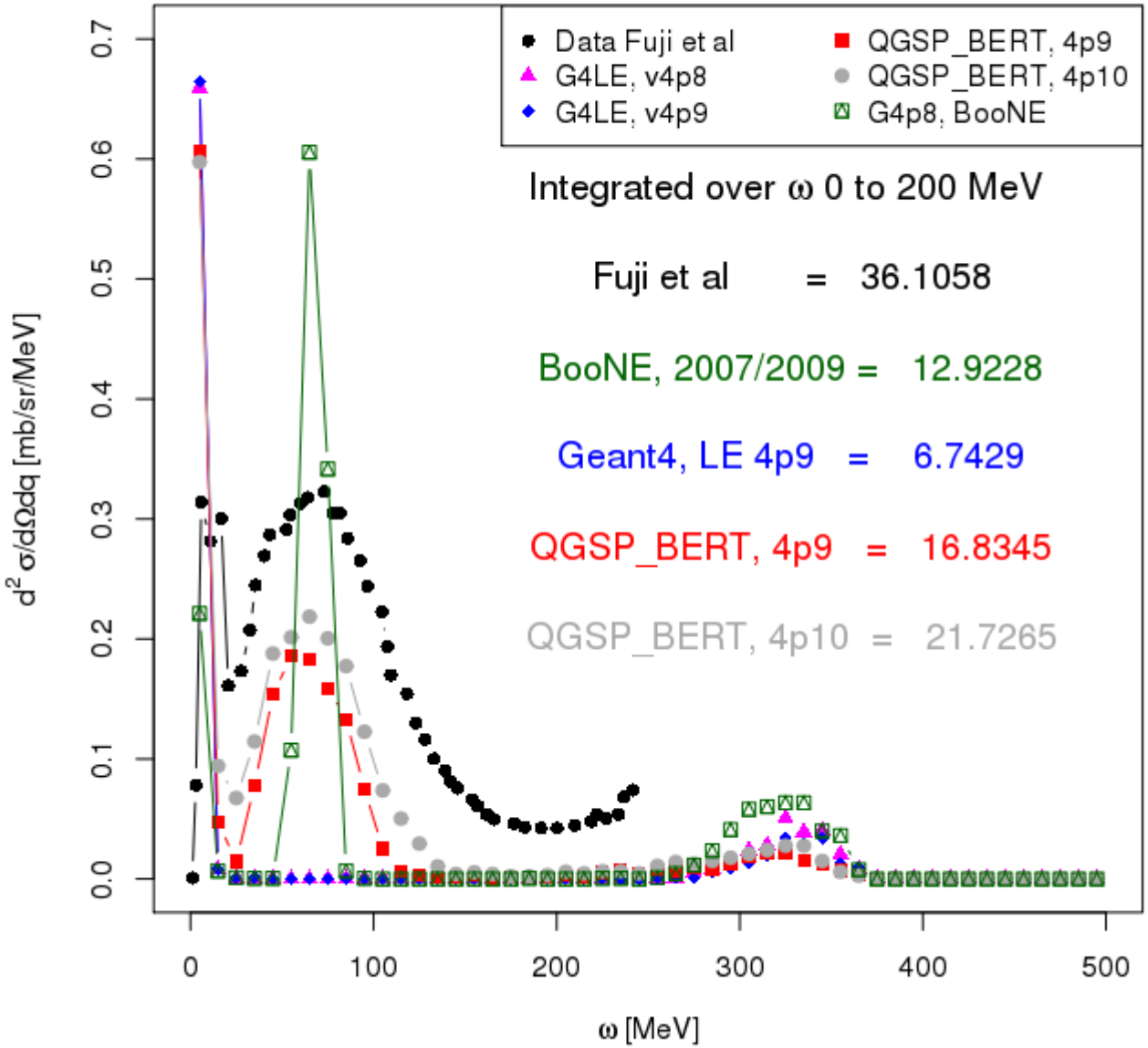
Focus on the Q = 350 MeV (Q is momentum transfer), as it has the largest cross-section among the set of data available to us..

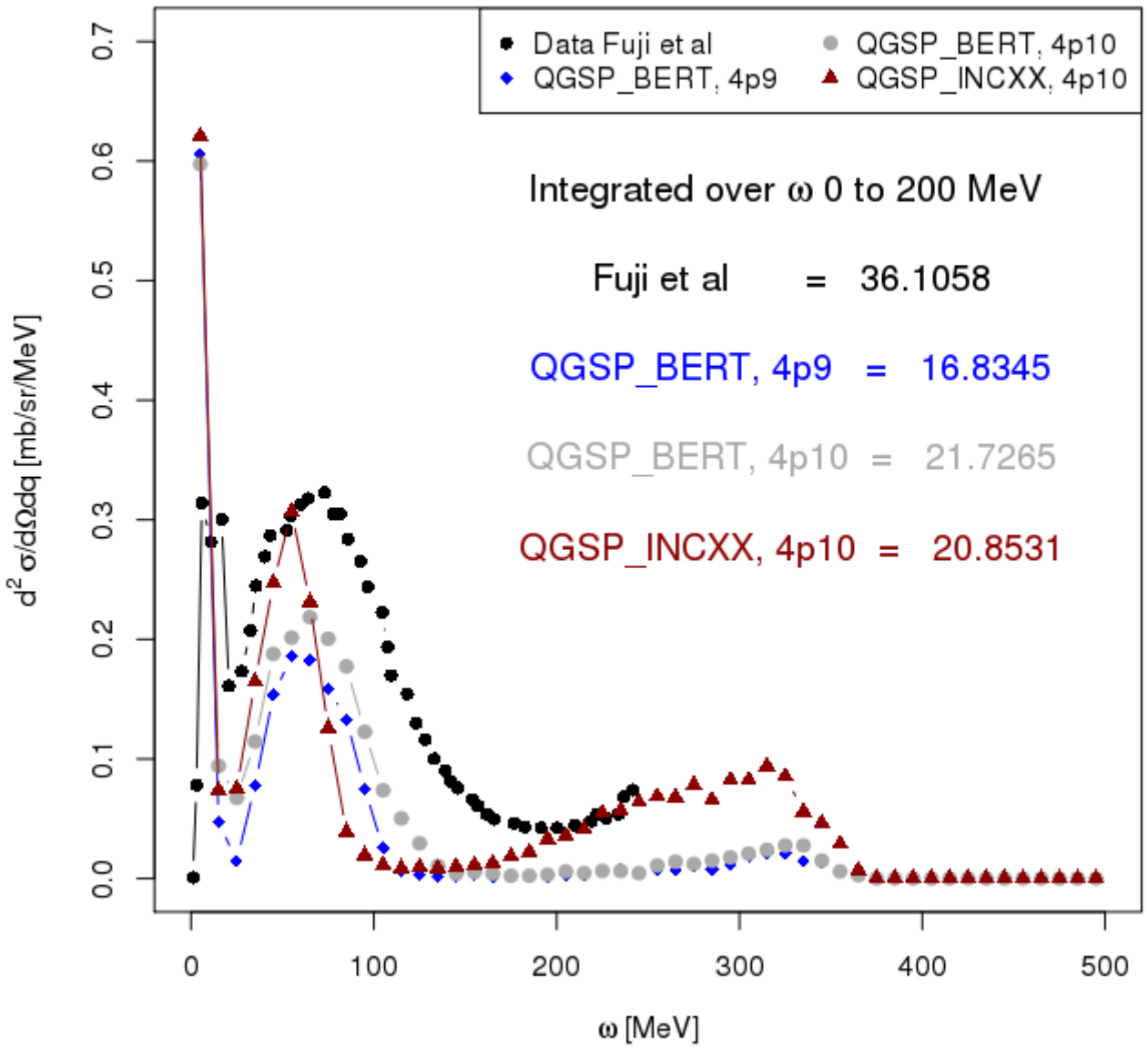
Corresponds to a scattering angle in the lab of about 17 degrees. And a significant energy loss.

Ran the relevant models & G4 version.

Using the total X-section scale factor used in the BooNE (old or New) G4 MC.

More models..


Data Fuji et al
G4LE, v4p8
G4LE, v4p9
QGSP_BERT, 4p9
QGSP_BERT, 4p10
G4p8, BooNE
Integrated over ω 0 to 200 MeV
Fuji et al = 36.1058
BooNE, 2007/2009 = 12.9228
Geant4, LE 4p9 = 6.7429
QGSP_BERT, 4p9 = 16.8345
QGSP_BERT, 4p10 = 21.7265
d² σ/dΩdq [mb/sr/MeV]
ω [MeV]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
100
200
300
400
500



Recent version of G4 are closer

To the data.

Again, to be discussed with the
G4 hadronic experts.

Tedious work!...

Data, models, fit not always easily accessible..

PHYSICAL REVIEW C VOLUME 52, NUMBER 4 OCTOBER 1995

Updated analysis of πN elastic scattering data to 2.1 GeV: The baryon spectrum

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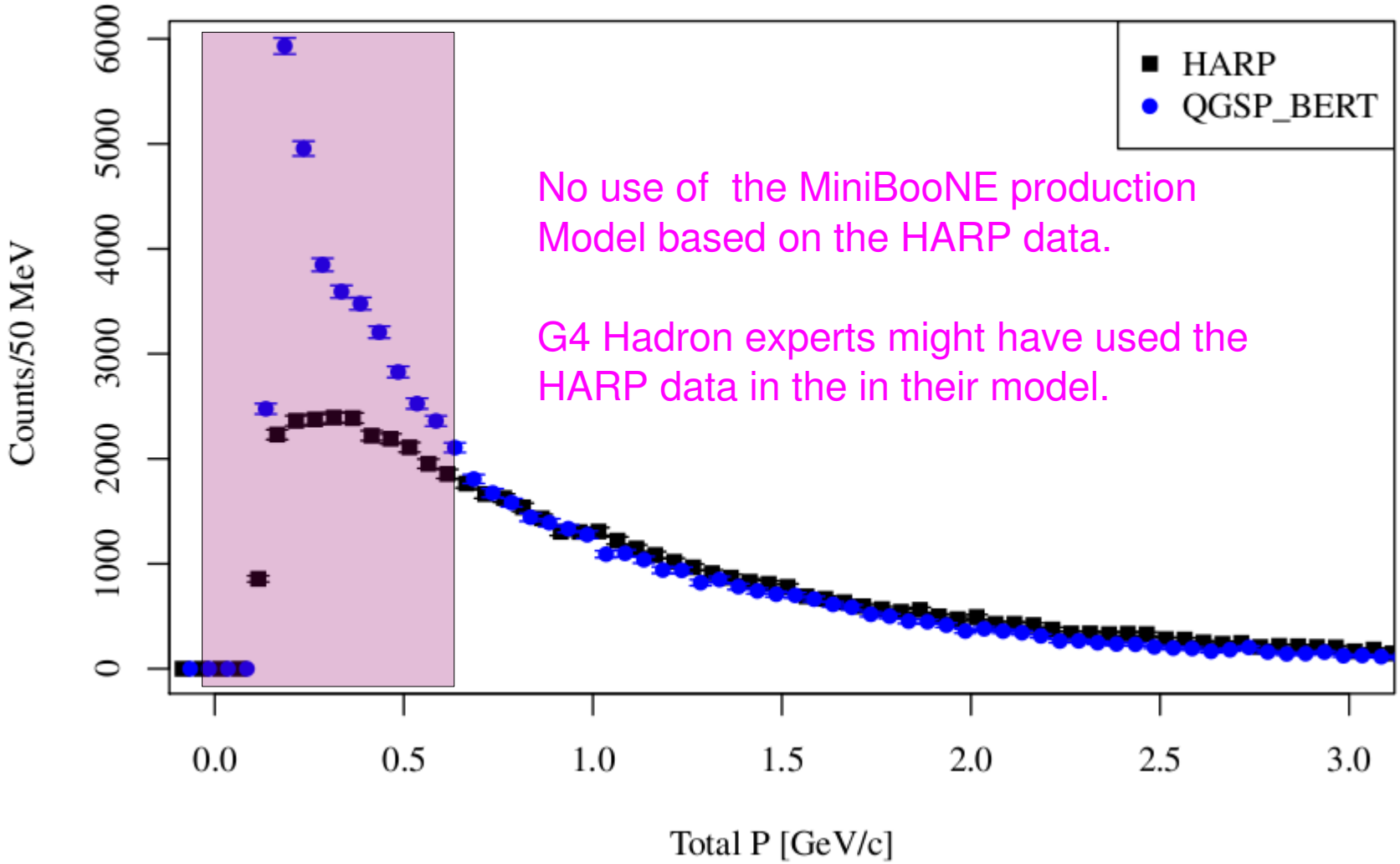
Marcello M. Pavan
University of British Columbia, Vancouver, British Columbia, Canada V6T 2A3
(Received 26 May 1995)

We present the results of energy-dependent and single-energy partial-wave analyses of πN elastic scattering data with laboratory kinetic energies below 2.1 GeV. Resonance structures have been extracted using Breit-Wigner fits, speed plots, and a complex plane mapping of the associated poles and zeros. This is the first set of resonance parameters from a VPI analysis constrained by fixed-t dispersion relations. We have searched our solutions for structures which may have been missed in our previous analyses, finding candidates in the S_{11} and F_{15} partial-wave amplitudes. Our results are compared with those found by the Karlsruhe, Carnegie-Mellon–Berkeley, and Kent State groups.

.....

[34] Those with access to TELNET can run the SAID program with a link to VTINTE.PHYS.VT.EDU (128.173.176.61). The login (password) is PHYSICS (QUANTUM). The user may view the current database and compare our solutions to those of other groups. A WWW server is also available (http://clsaid.phys.vt.edu).

Note: The pion production from 8 GeV on Carbon in G4 has also been retuned, probably based on the HARP data as well... Independent efforts !....



Pion momentum spectrum p-Be, Sanford-Wang param.
Of HARP data, vs QGSP-BERT of G4, v4.9.6

Outlook: What's next?

- More tests.. proposed and studied by MicroBooNE members. If need, be, further corrective actions
- Use the latest S/W parameters obtained by Athula Wickremansinghe (http://inspirehep.net/record/1394639) re-fitting HARP data (thin and Thick targets) No big change expected.
- Improve the Horn geometry ? (Water layer?)
- Adopt a Neutrino Ntuple format in “New” (no Hbook, please..) Suggestion: adopt Dk2nu, but provided a “detector smearing method” to take into effect small change in the effective (boosted) solid angle..
- Study ν_e from m and Kaon decays in G4 v4.9.6 *Distressing fact: very little data on Kaon-Nucleus interactions!.*

Outlook: What's next, Longer term.. (Suggested..)

- Move to G4 v4.10.2 :
  - First, in v4.9.6, deprecated the MiniBooNE Hadronic models. We can easily re-arrange the initialization phase in BooNE such that we can use the G4 physics lists, native (largely already done.. Need exercising..)
  - Second, move to v4.10.x (x=2, for start), and collaborate with G4 Hadronic team on validation of the code. Jointly tune the models if need be.
  - Consider using the “multi-verse” method ***ppfx*** proposed by Minerva to estimate systematics due hadronic re-interaction (“effective absorption probabilities)
  - *Stay current !... with respect to G4 updates. (no longer ~ 9 year hiatus in upgrading the BooNE MC code..)*