A few updates in one set of slides

Goals for collaboration meeting two months away

Update on Delta++ production in deuterium and hydrogen

For collaboration meeting

Jaesung says nusystematics is ready for new dials

We will ask for a plenary and one or two parallel sessions

Sketch for a plenary (possibly Jaesung):
Nusystematics is now open for contributions
Reminder of who the customers are
Works in LarSoft and standalone and our CAFS & technical stuff
Examples of distributions across this universe of customers
One should be this 3D distribution with two muons and Ehad
Description of dials that are contributed and being tested
Short summary of ones that are still in development

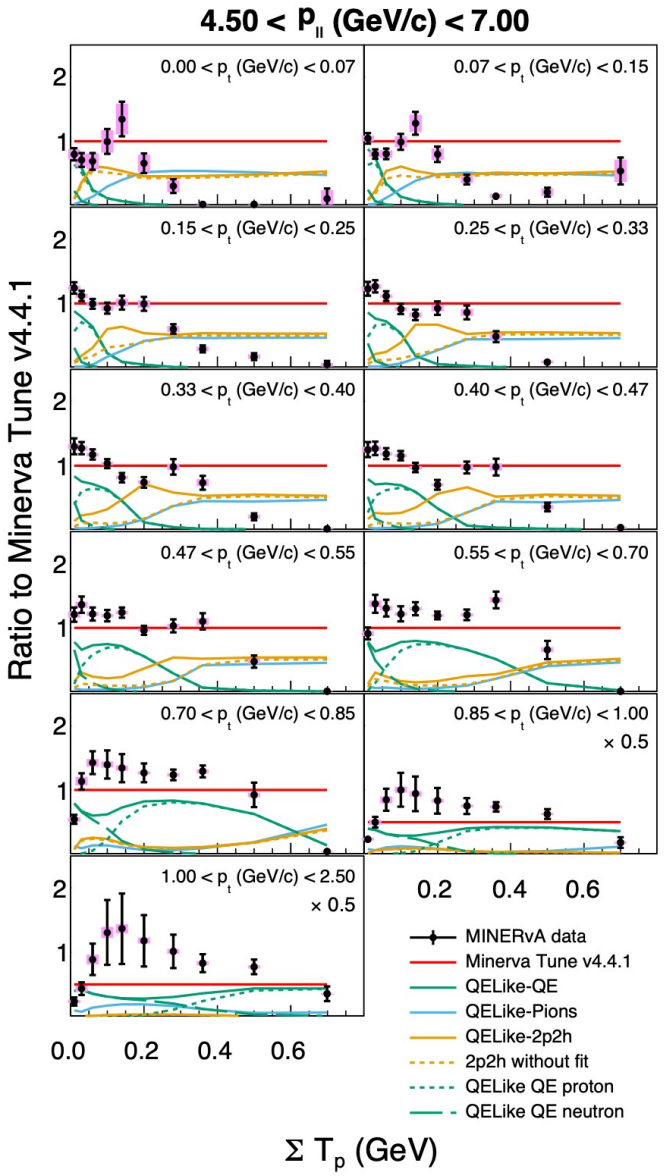
Example of 3D distribution

We proposed this is where at least NDLAr constraints will happen

Started to code up a GENIE truth version of one, not done in time.

Every dial we implement should be tested against it by us
and tested in the truth and/or reco spaces where it operates

When we do this, we should save information that can be
used later as documentation for our customers
because they are not experts at the knobs
but they are going to be looking at these distributions



Example of 3D distribution spec

MINERvA's hadron energy scale are 40 MeV
Which get larger at high hadron energies

Our GENIE truth (validation) should be 10 MeV
NDLAr might choose 20 MeV not sure

Pt bins are around 80 MeV/c at low pt
Our truth distributions might be 20 MeV/c

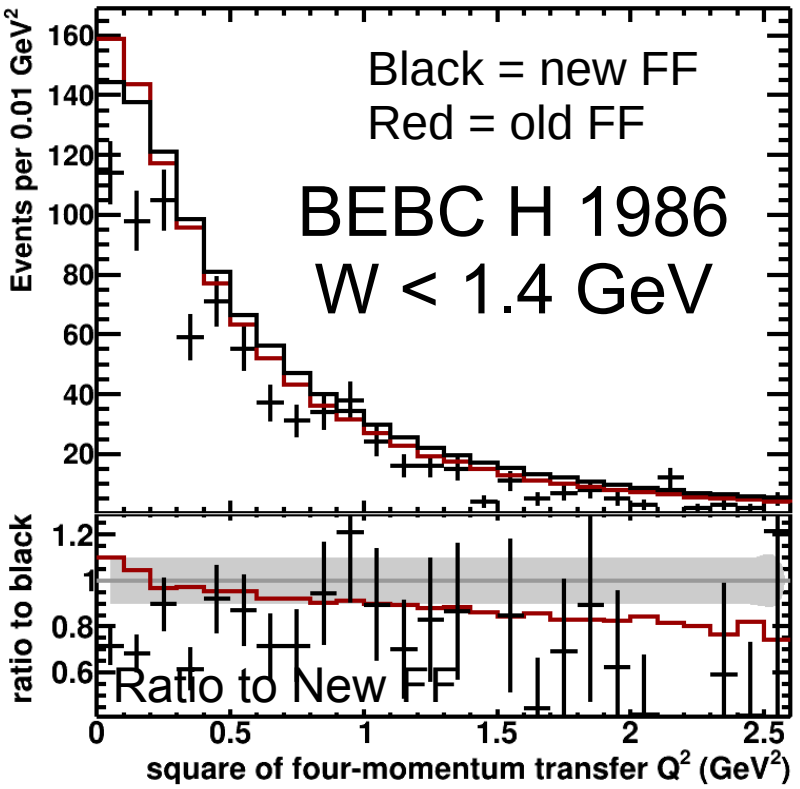
P|| bins are 2.5 GeV at NuMI/MINERvA peak
We should aim for 0.5 MeV at our lower Enu

Basically 4x smaller in every dimension

Comments? Can folks meet those goals?

Delta++ in GENIE vs deuterium Update
Now with hydrogen data!

Delta++ in GENIE3 update: now with hydrogen



BEBC has both H and D data
flux peaks ~ 30 GeV, long tail
813 events (goes out to Q2 = 3.5)

No deuterium effects
No neutrons in final state

Even more than MINERvA,
only W2 structure function matters

Led to some interesting realizations

P. Allen et al. Nucl.Phys.B 264 (1986) p.221

What are the goals of this analysis?

GENIE3 resonances are untethered to (almost-)free nucleon data

Current form factor model (code, formulae) almost undocumented

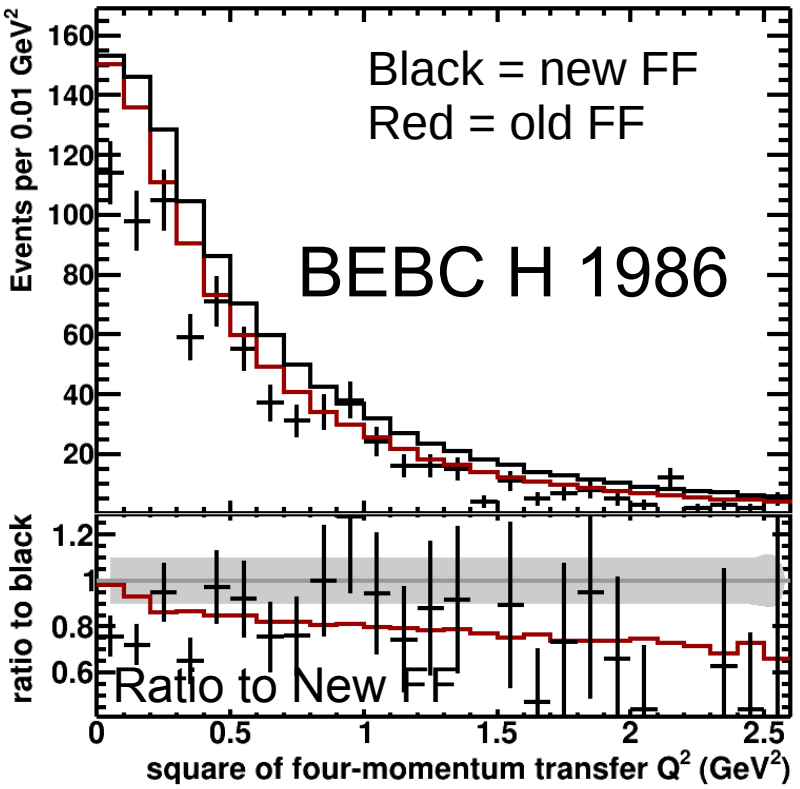
Have learned comparisons to bubble chamber data are challenging

Reassess a reasonable form factor uncertainty

Evaluate the resulting energy dependence from form factors

Create nuclear effect modifications separate from form factors

BEBC 1986 data μ- p π+ analysis strategy

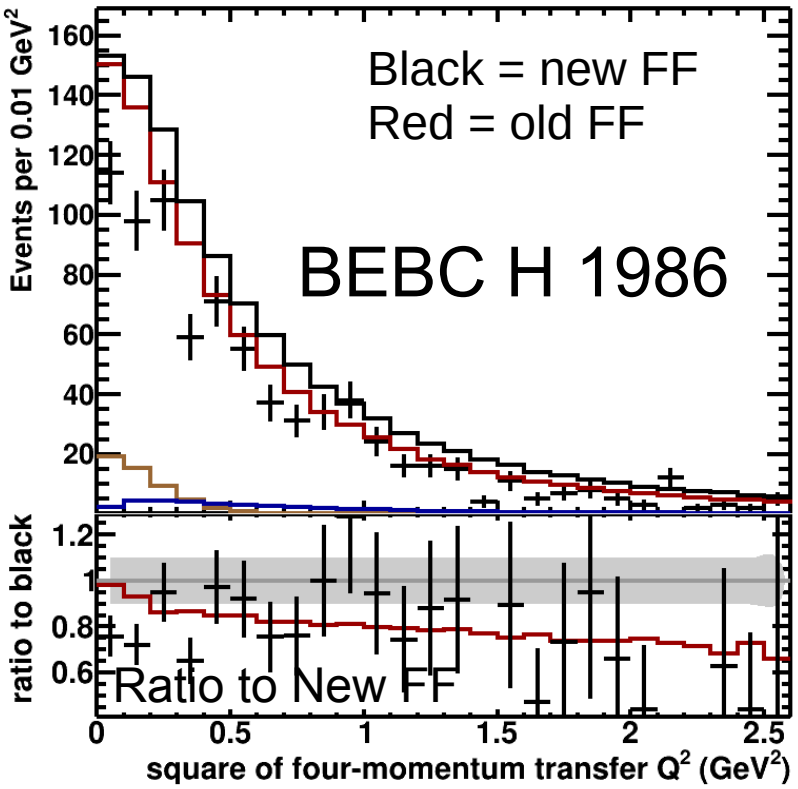


Published σ(E) for W<2.0 & W>2.0
Based on 1027 events
GENIE predicts the same
Flux-weight integrate ratio Data/GENIE

Apply ratio to GENIE Q2 event rate Integral. Same events ! NOT! Oops.
Event rate for W < 1.4, <2.0, > 2.0
Assume for now ratio same for W<2.0 and W<1.4 probably ok

For ANL & BNL, used Nuisance to do this integral norm.
Doing this by hand the long way.

GENIE predicts ~10% diffractive, ~3% nonres=DIS



Those will affect our understanding of the resonance form factors.

Diffractive pi+ production on H?
like Rein Sehgal coherent pion
but for hydrogen nuclei, not D, C, Al
scales with size of nucleus

Where is the diffractive model from?
Rein 1986, based on BEBC 1986 data

n.b. Rein Sehgal also have a NC coherent single photon production model that possibly nobody uses but we should probably start

What do we know about the Rein diffractive model?

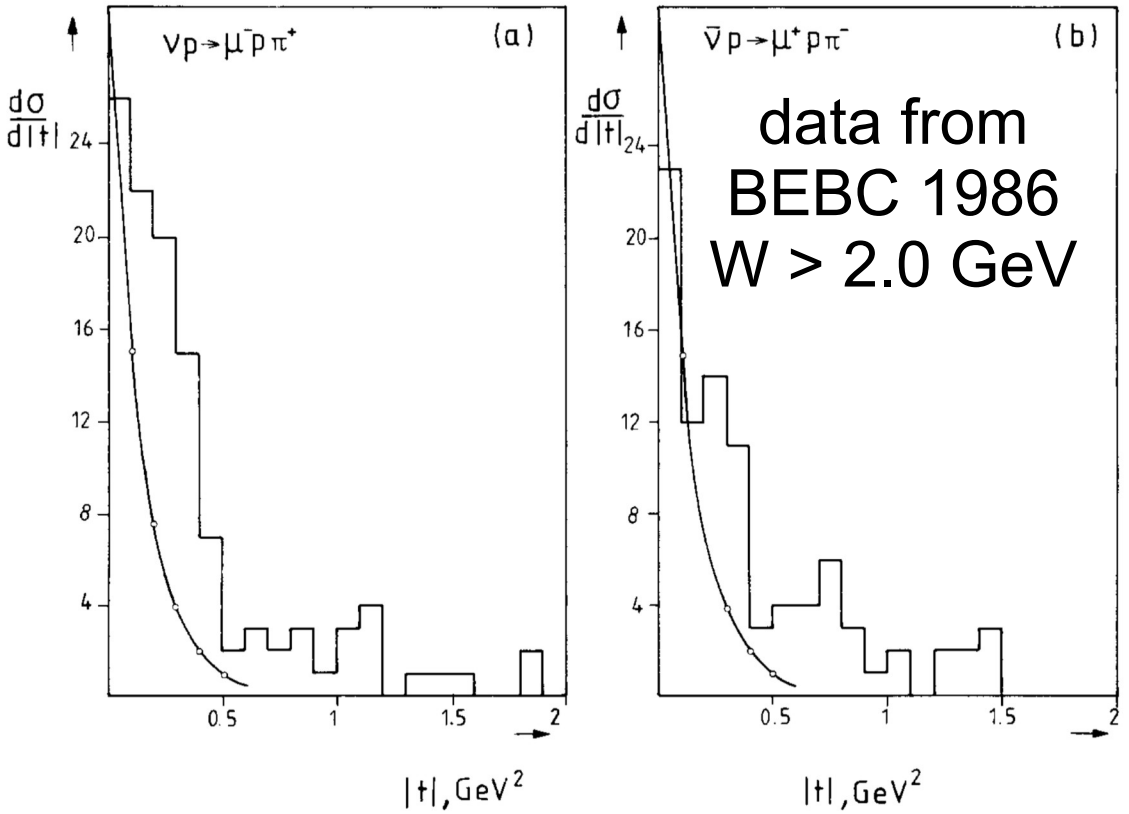


Fig. 7. t-distributions compared with data (from ref. [8]) (a) for neutrino reaction (b) for antineutrino reaction; $W > 2$ GeV, $b = 7$ GeV $^{-2}$, $m_A = 1.1$ GeV/c^2.

Complicated what Rein did
And what GENIE did.

Rein's model (and GENIE)
Integrates to this distribution
And 9.4 ± 1.4 10e-40 cm2

But (arbitrary normalized)
model is lower t than data
is about 1/3 of the total.

GENIE is about 1/3 too
not sure why

Model D. Rein Nucl.Phys.B 278 (1986) p.61
Data P. Allen Nucl.Phys.B 264 (1986) p.221

What else do we know about this model in GENIE?

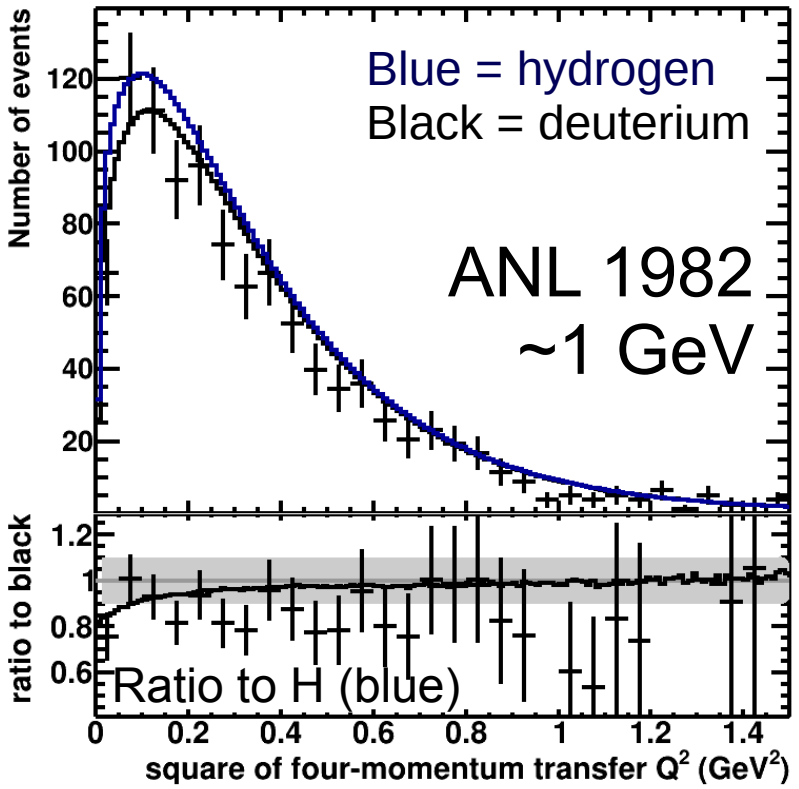
Development version in GENIE 2.6.8
Official version in GENIE 2.12.0 but not on by default
It is on by default in GENIE3 since sometime, including AR23

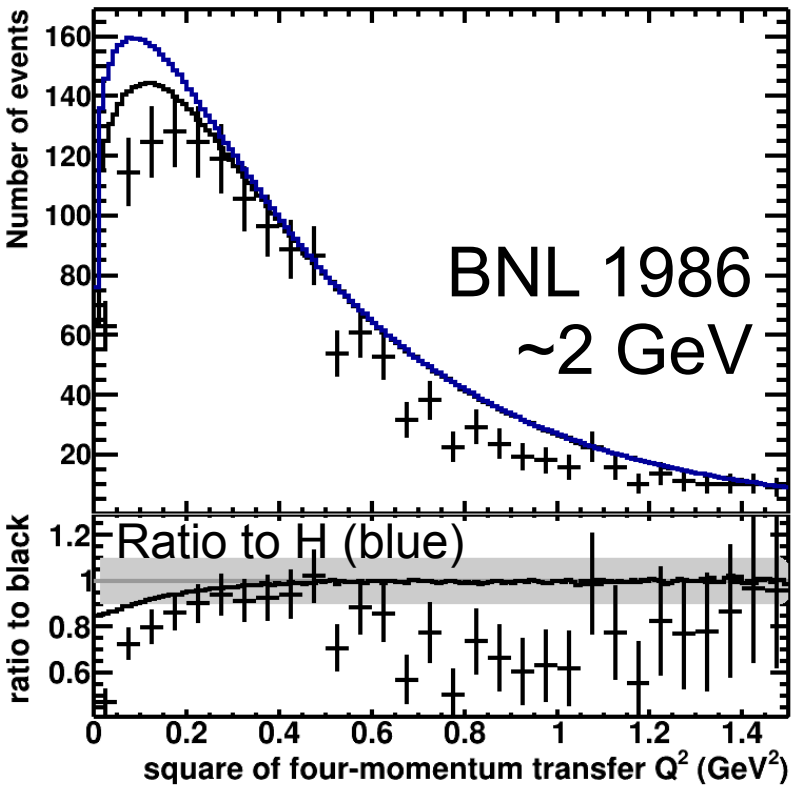
MINERvA has this turned on for our 2.12.10 based analyses
Observed the NC process Wolcott et al. PRL 117 (2016) 111801
by its absence from nue in GENIE versions before GENIE 2.12

In most CH, CH2, H2O coherent data papers mentioned as background or signal. Unknown (?) to ANL+BNL pre 1983

GENIE implements about 1/3 Rein, but maybe by accident.

G18_02a (RFG+hA) with new (default) form factors



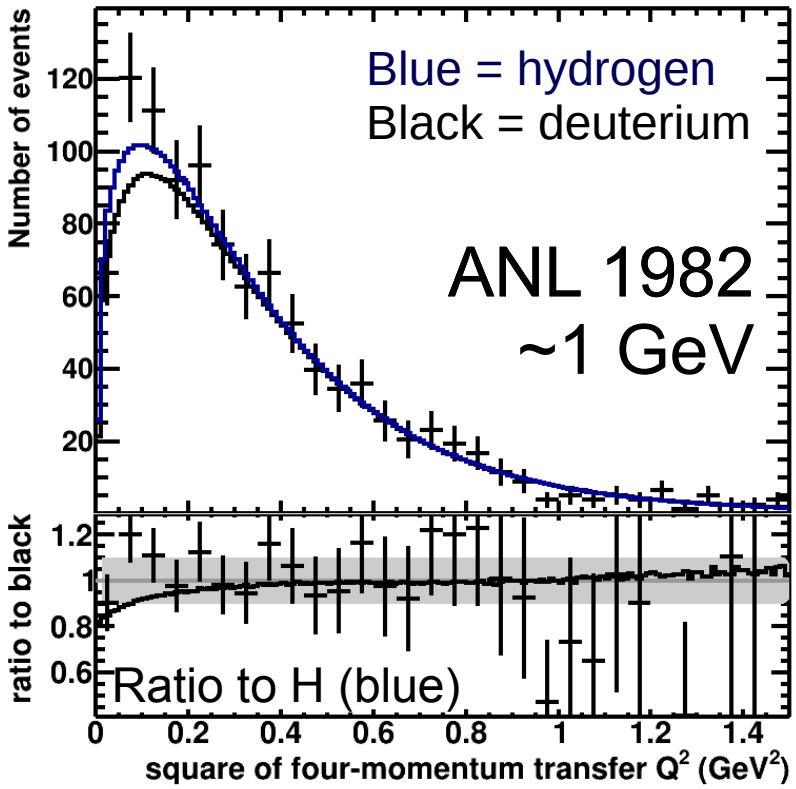


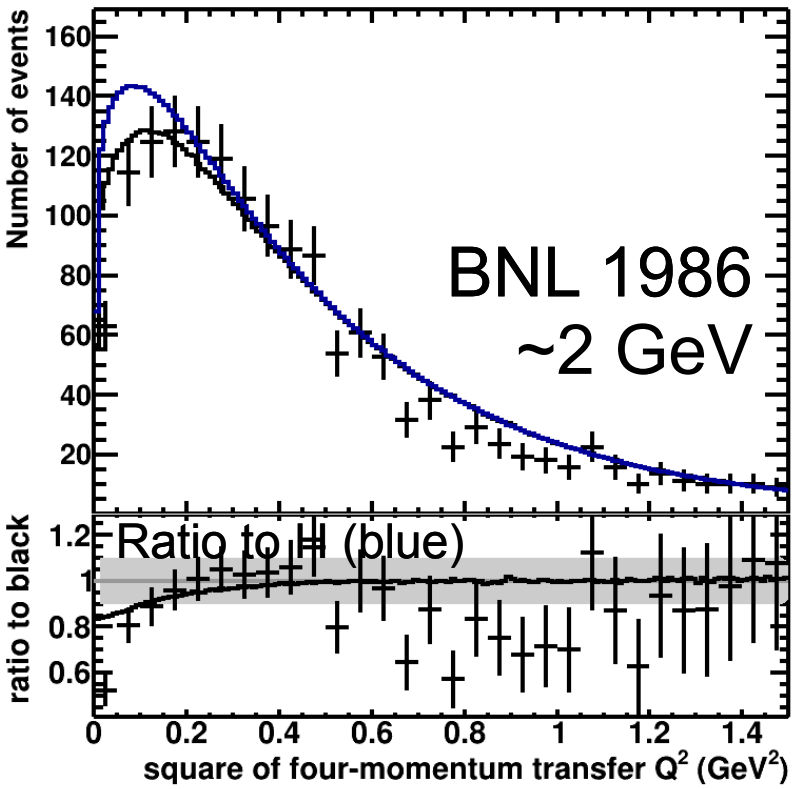
Showed this last time. Similar discrepancy to BEBC despite energy.

Hay! Blue has Diffractive but Black does NOT have coherent. Should it?

Naive test, true W(~~p~~d pi) > 2.0 . Need to test assuming reco proton

G18_02a (RFG+hA) with old Rein Sehgal Form Factors





This prediction is a lot lower. Hard to tell by eye, but the shape is different.
MA=1.12 fit this model to these data, before the Callum+Phil modification.
and according to people not literally using GENIE (Naumov et al.)

Next steps for BEBC data

Revisit things that were done rough the first time.

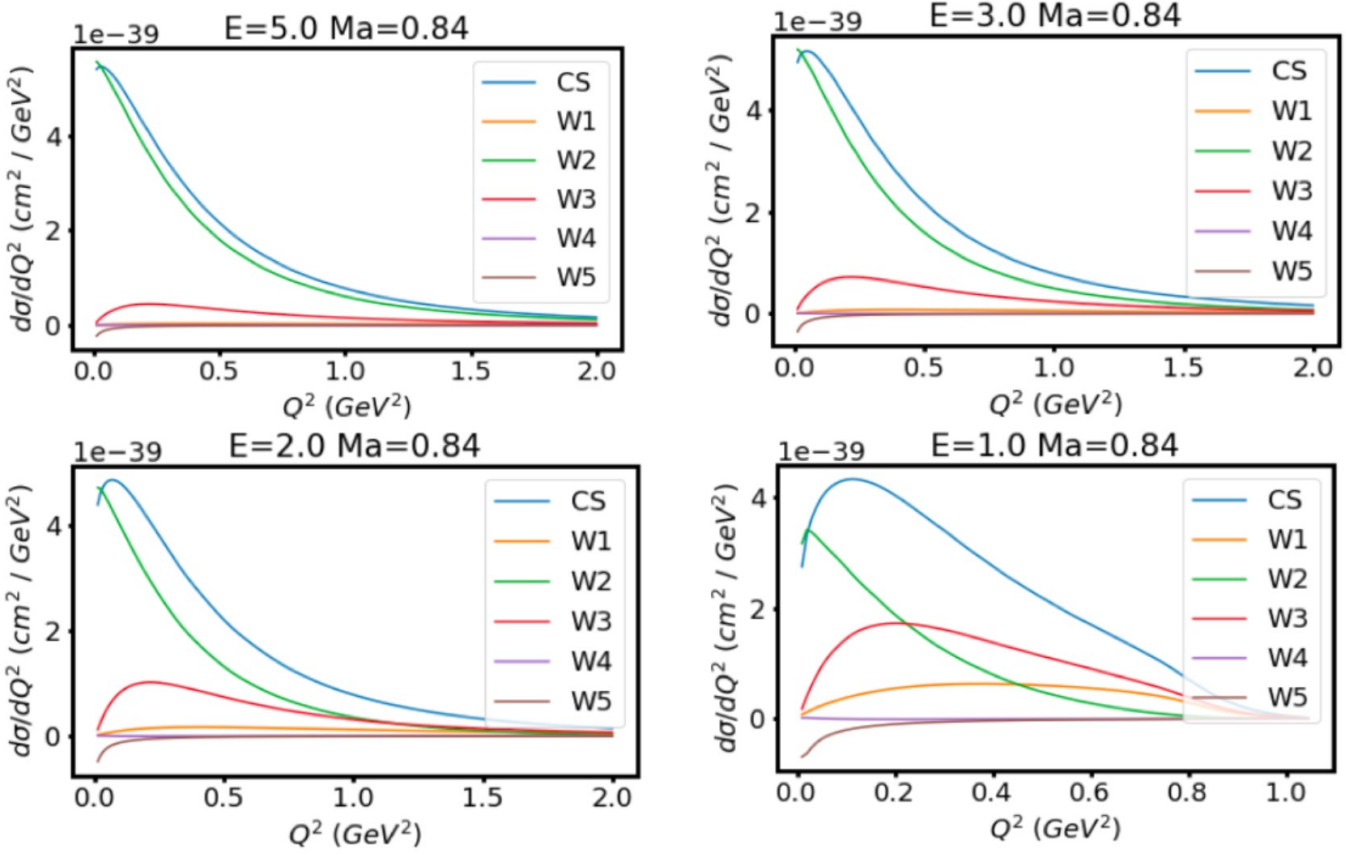
Maybe try the anti-neutrino mu p pi- process on hydrogen

Maybe try the 1990 BEBC WA25 deuterium paper

Clear up where coherent deuteron events land

Describe what the FSI process is doing

Energy dependence and form factors



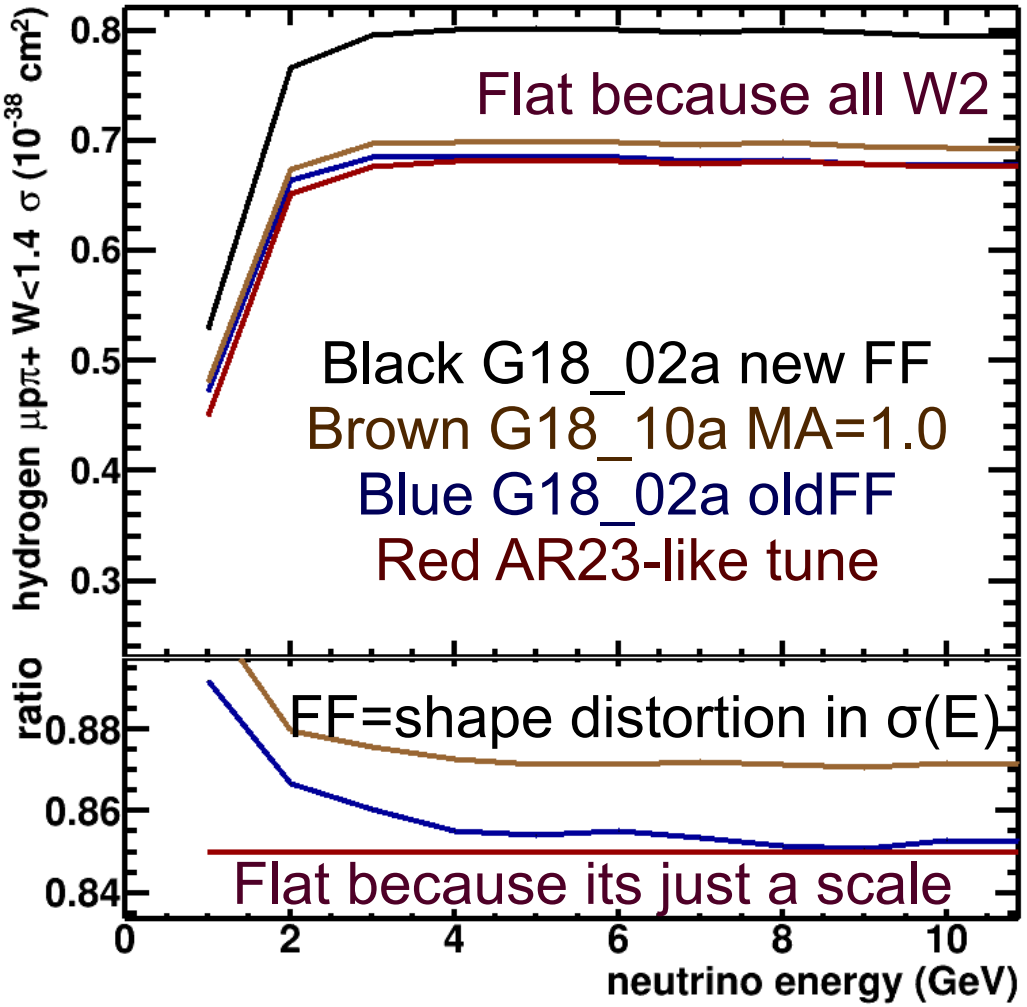
Structure functions get multiplied by factors of 1/E^2 and 1/E and 1

Form factors are inside structure fun

Kinematic boundary
High Q2 reach
Decreases at low E

Ishmam Mahbub MS thesis Duluth 2021
Model by Lalakulich and Paschos 2005

W<1.4 Energy dependence and form factors, first look



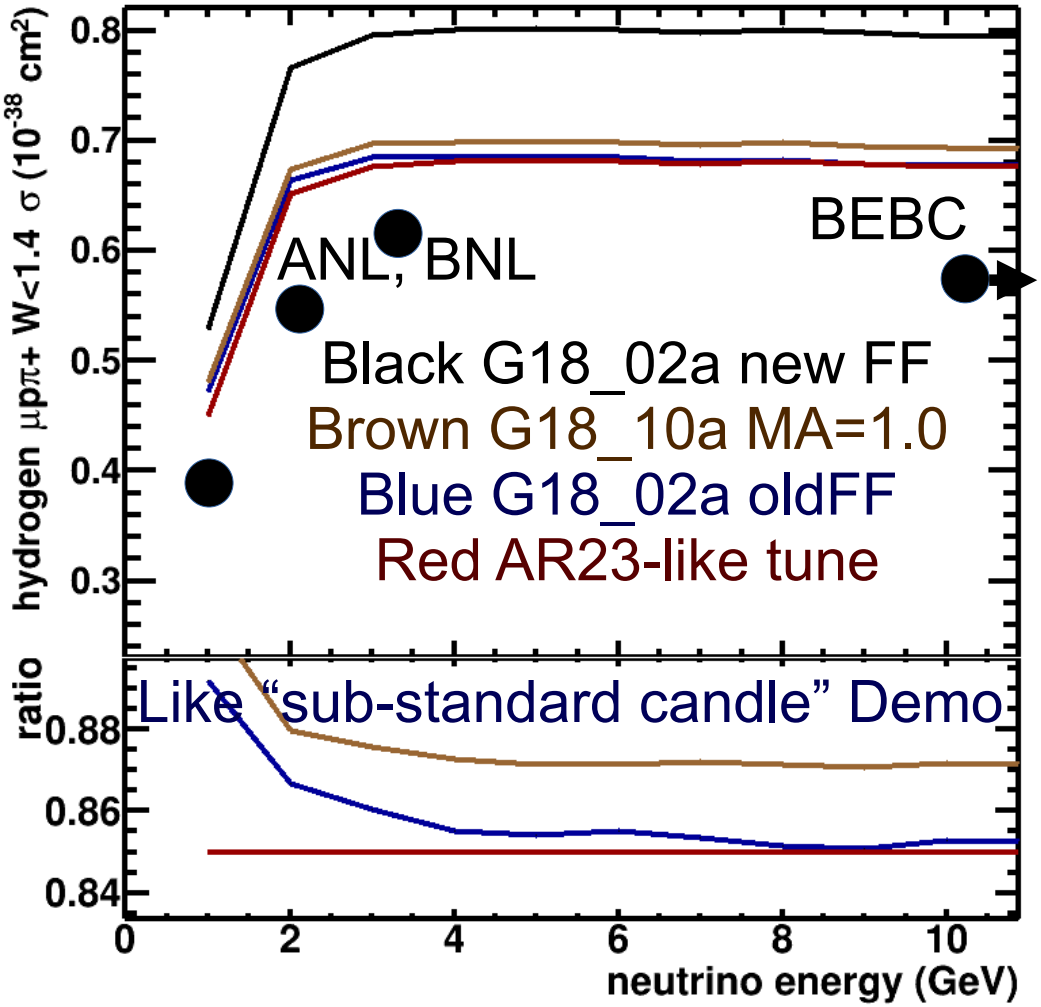
Black is GENIE no tune RFG
new form factors, same MV, MA
MA is not retuned to data

Blue is original R-S form factors
Same MV and MA orig. Kuzmin tune
Similar to untuned MINERvA sim

Brown G18_02a "tune" MA = 1.00

Red is approximation to AR23
With Julia Tena Vidal's tune
Approximate: scale RES 0.85
(really mostly scale, little MA)

Energy dependence and form factors, commentary



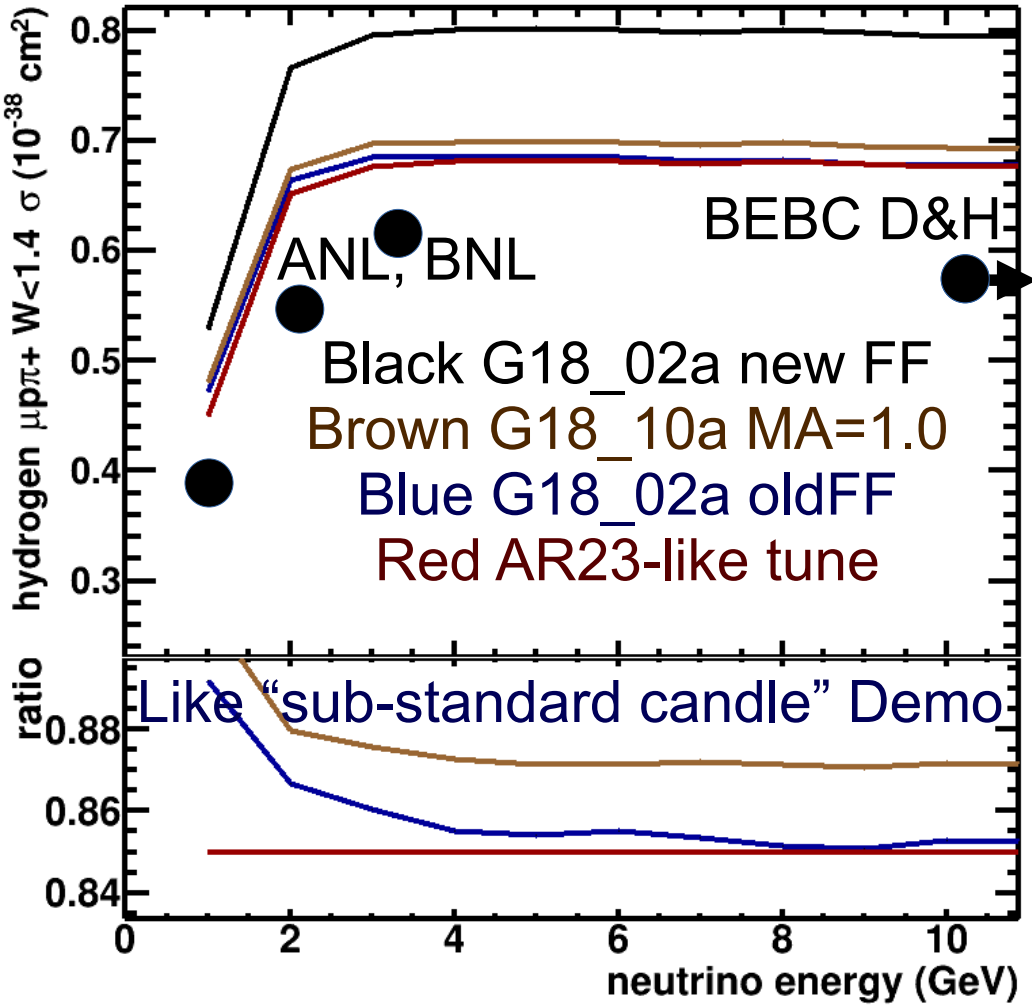
The two lower lines would better describe bubble chamber data

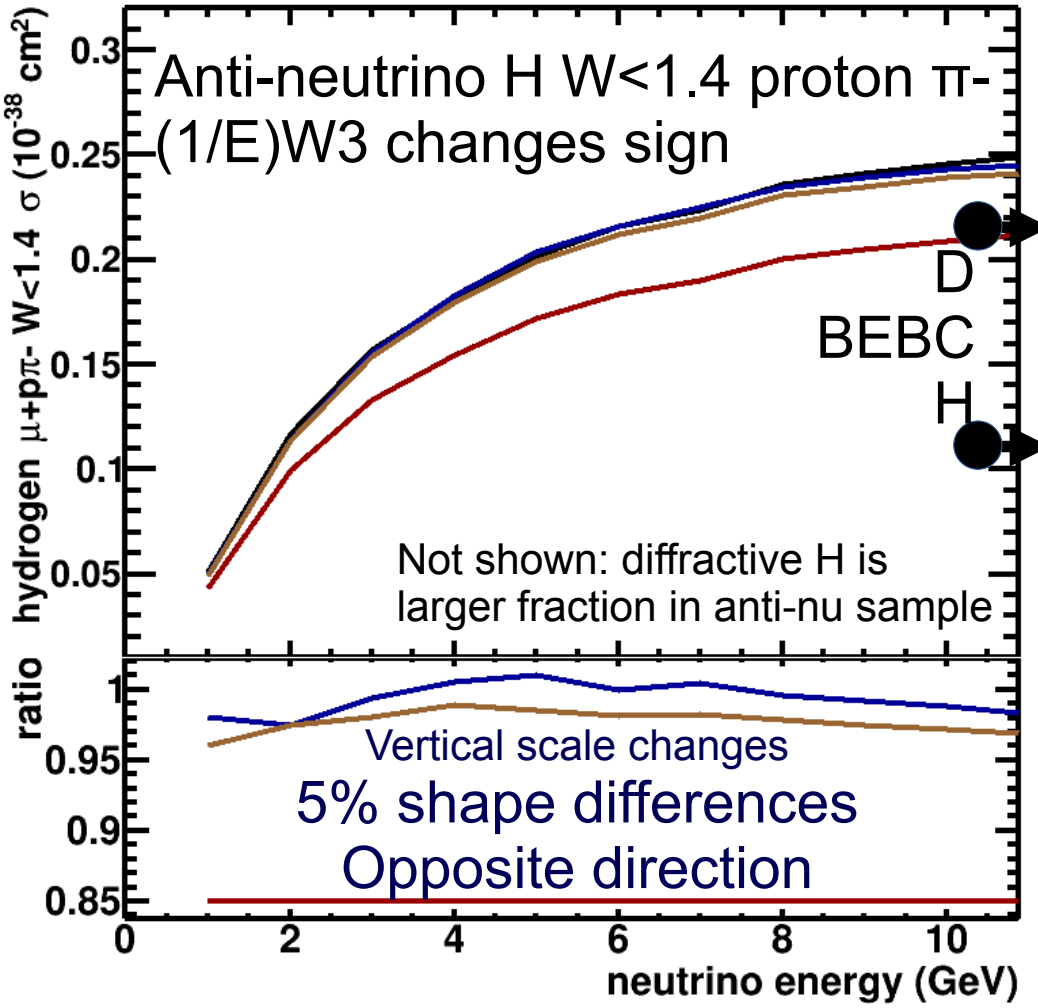
Upper plot shape is complicated
Form factors (Ishmam's plot)
Kinematic Q2 limit at low E
Coherent & Diffractive

For some reason black better for MiniBooNE & MINERvA

What NIUWG uses needs to capture these effects

Nu and Anti-nu similar 5% shape, opposite direction





Next steps for analysis

Jarek Nowak will be at Fermilab next week
He implemented the Lalakulich and Graczyk Sobczyk form factors

Our goal is a paper tentatively titled
That what GENIE does for pions with W < 1.4 GeV
Had a different four letter word in mind at first

Documents both physics inputs and observable effects
plots I'm showing are candidates for publication

Deliver uncertainties to nusystematics

Conclusion, things are moving rapidly

Technical detail I've not fully resolved yet.

The BEBC H paper doesn't give a clean accounting of Acceptance corrections going into their cross section.

So I can't apply them to the Q2 event rate plot easily

ON the other hand, the only acceptance correction that Made me worry with deuterium was the neutron spectator There would be a GENIE model dependence with it But it is not an issue with H.

My scaling strategy might still be sound. Hope so.

Comment

The behavior of old vs new FF in BEBC
Matches the middle plot next slide
The GENIE predictions for Ar40 at 3 GeV

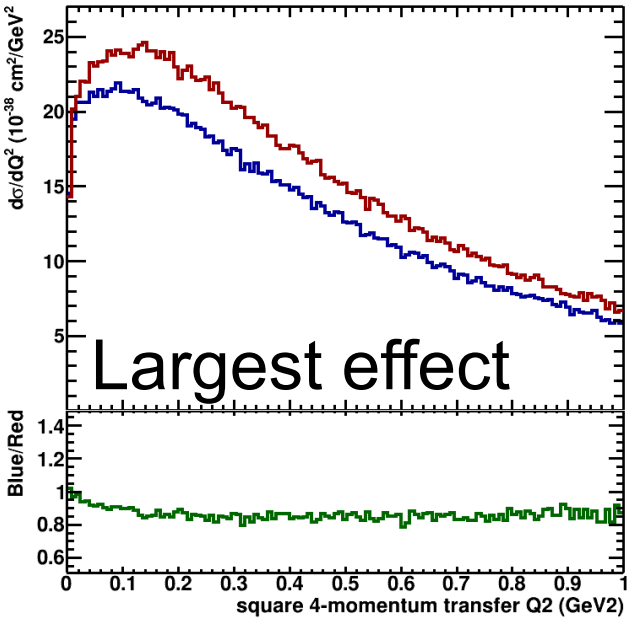
The old FF are universally lower than new FF
In the ANL and BNL comparisons.

Possible but unexpected.

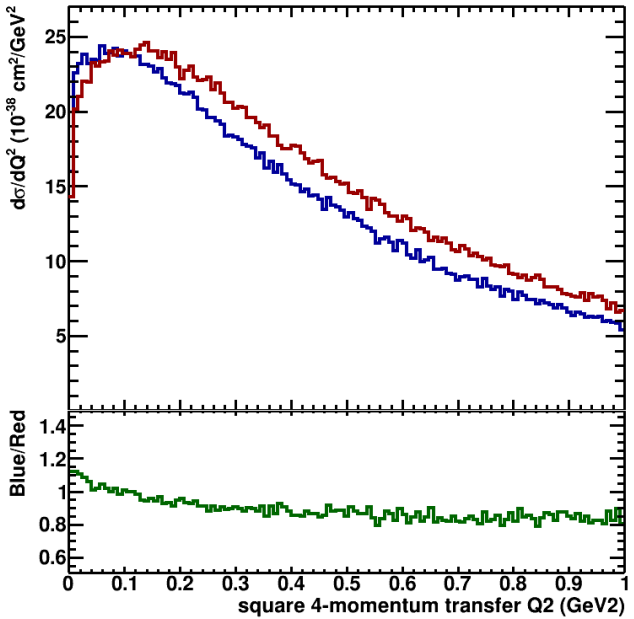
However, my workflow for the ANL & BNL
uses Nuisance for a step
Whereas I did that step myself for BEBC
Need to try ANL & BNL the BEBC way and check.

Bode Applegate follows Ben Utt's work

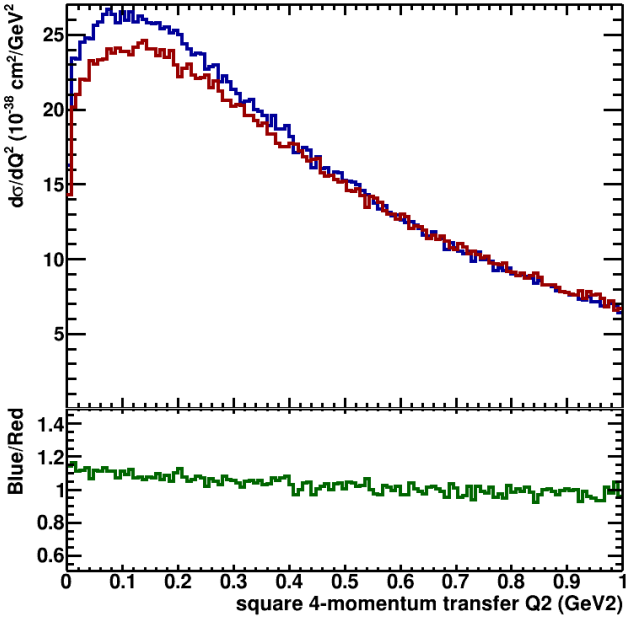
Red: default GENIE3 newFF Argon Δ++ 3 GeV no FS selection



Old Vector FF
But same MV



Old Axial & Vector
but same MA, MV



Old Axial FF
But same MA

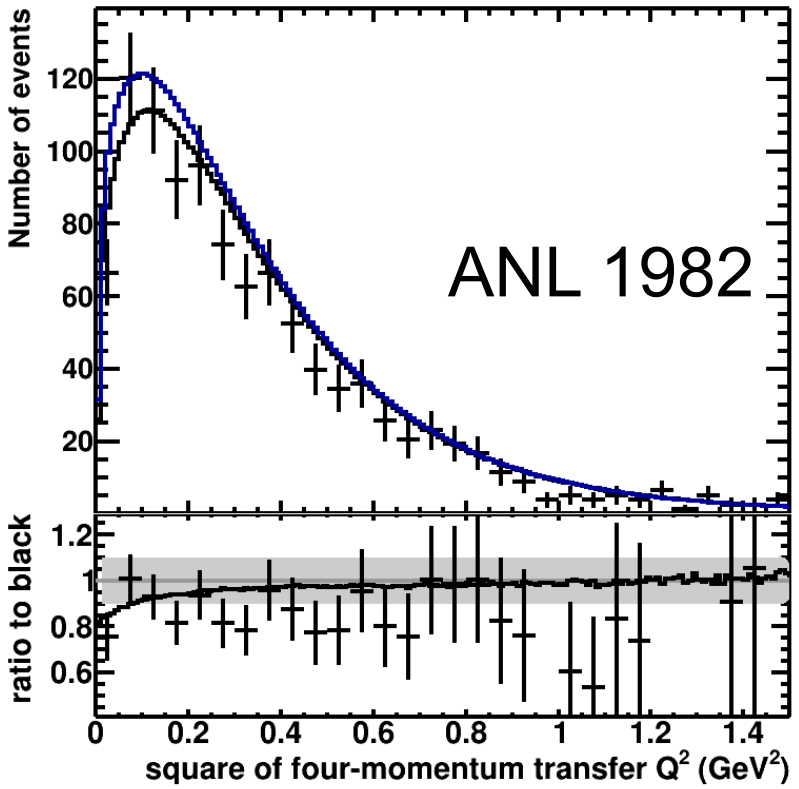
Old = just BS dipole, backed out Graczyk & Sobczyk, Lalakulich

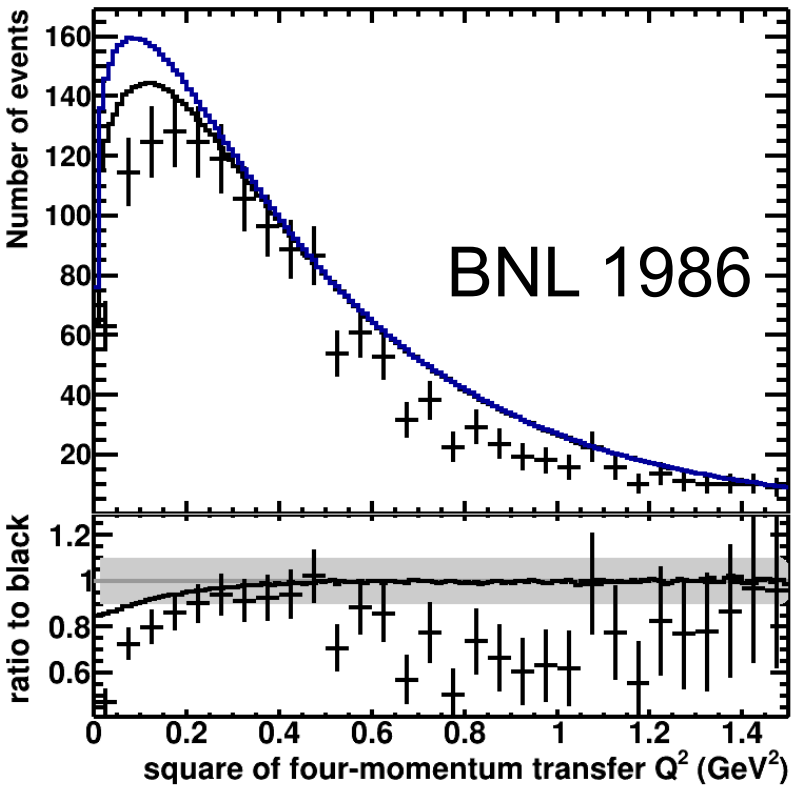
Repeat base slide and flipbook to G18_10a LFG model

First of several comparisons planned
That change the initial state model or FSI

Only deuterium changes in this case.
So its the start of a nuclear-effect “error band” style study.

G18_02a (RFG+hA) with new (default) form factors



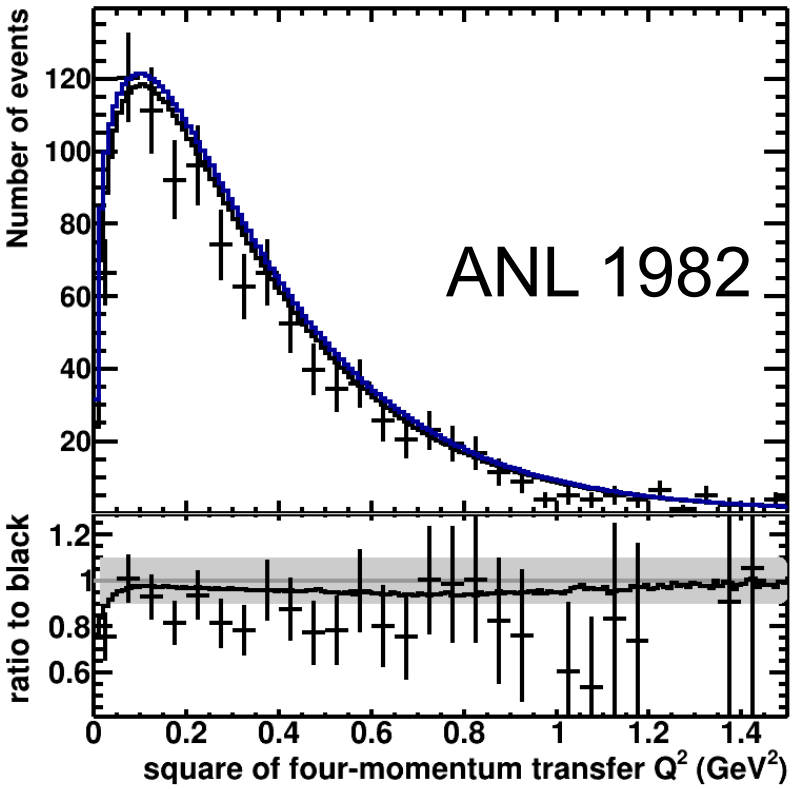


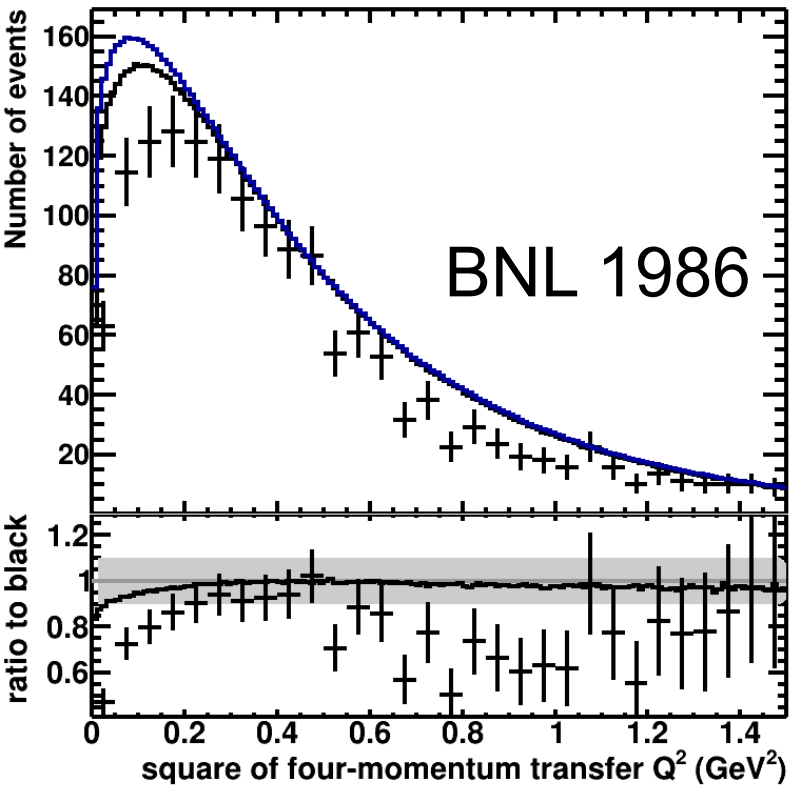
Repeat of earlier slide so I can flipbook.

This is ok, I guess. Its clearly not tuned to these data. Not stupid-bad.

Is there more?

G18_10a (LFG + hA) + same new form factors





Low Q2 behavior changes, and not the same shape either.
High Q2 changes only ~5% hard to see on this scale.