APEX ^{8}B energy resolution, continued

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APEX biwkly mtg

My past presentation at the March 2024 FNAL collab mtg

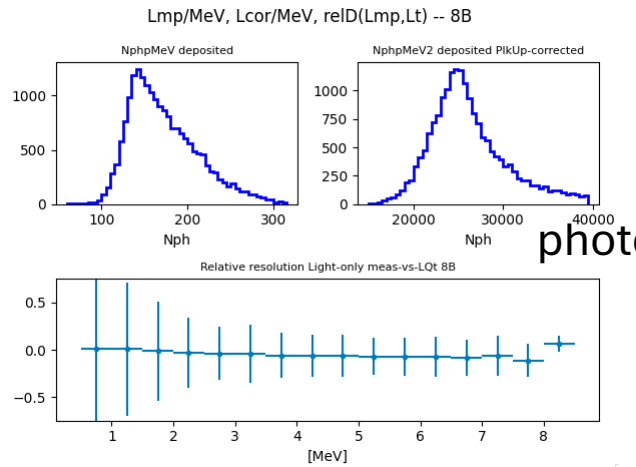
- Rushed and heavy on details
- And right before the afternoon coffee break

- But to remind, I showed ^{8}B νs deposited Marley energy spectra in my standalone simulation (that shares a geometry with Franciole).
  - Overlaid with cryostat neutrons and cavern neutrons
  - The latter dominate
  - We should insist on water/poly shielding outside the cryostat!

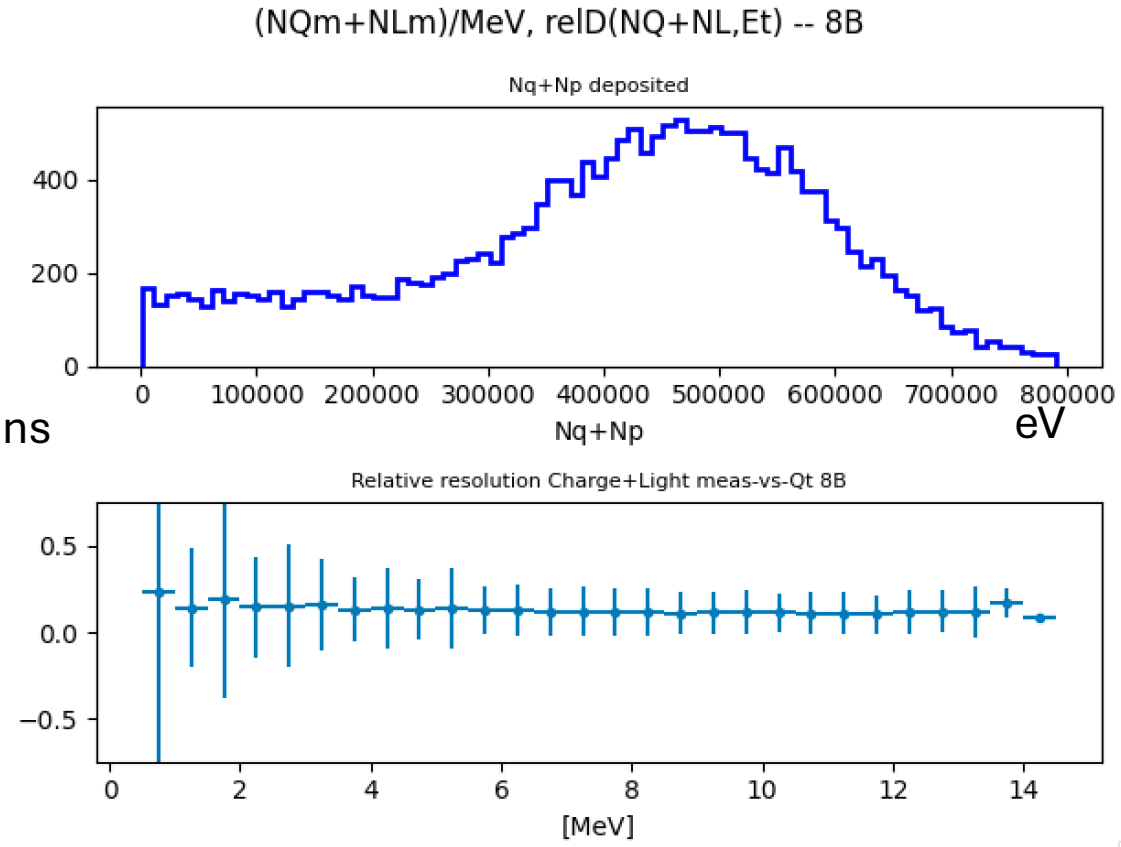
- But for this presentation today I'm just going to discuss energy resolution at and below ~8 MeV
- The big differences from what Wei, et al, are doing is that my error bars are correlated *and* the LY map contributes non-negligible uncertainty. More on this later.

L only, Q only and Q+L resolutions for ^{8}B Edep

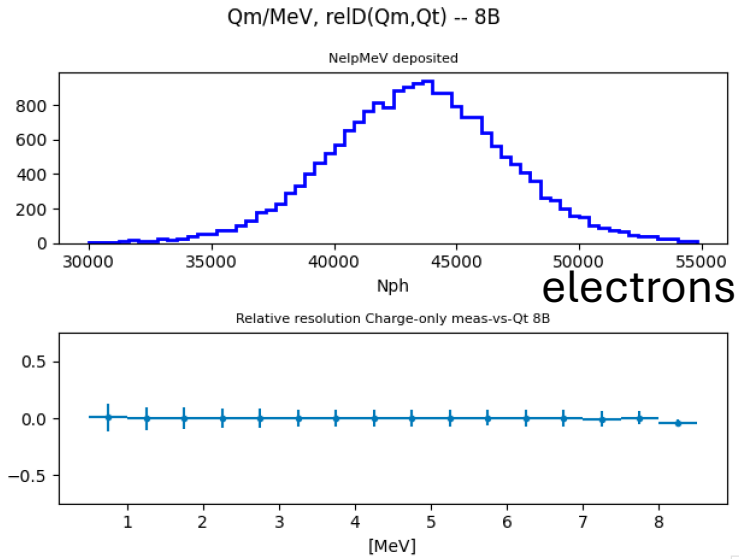
Spatial photon responses applied.



photons



eV

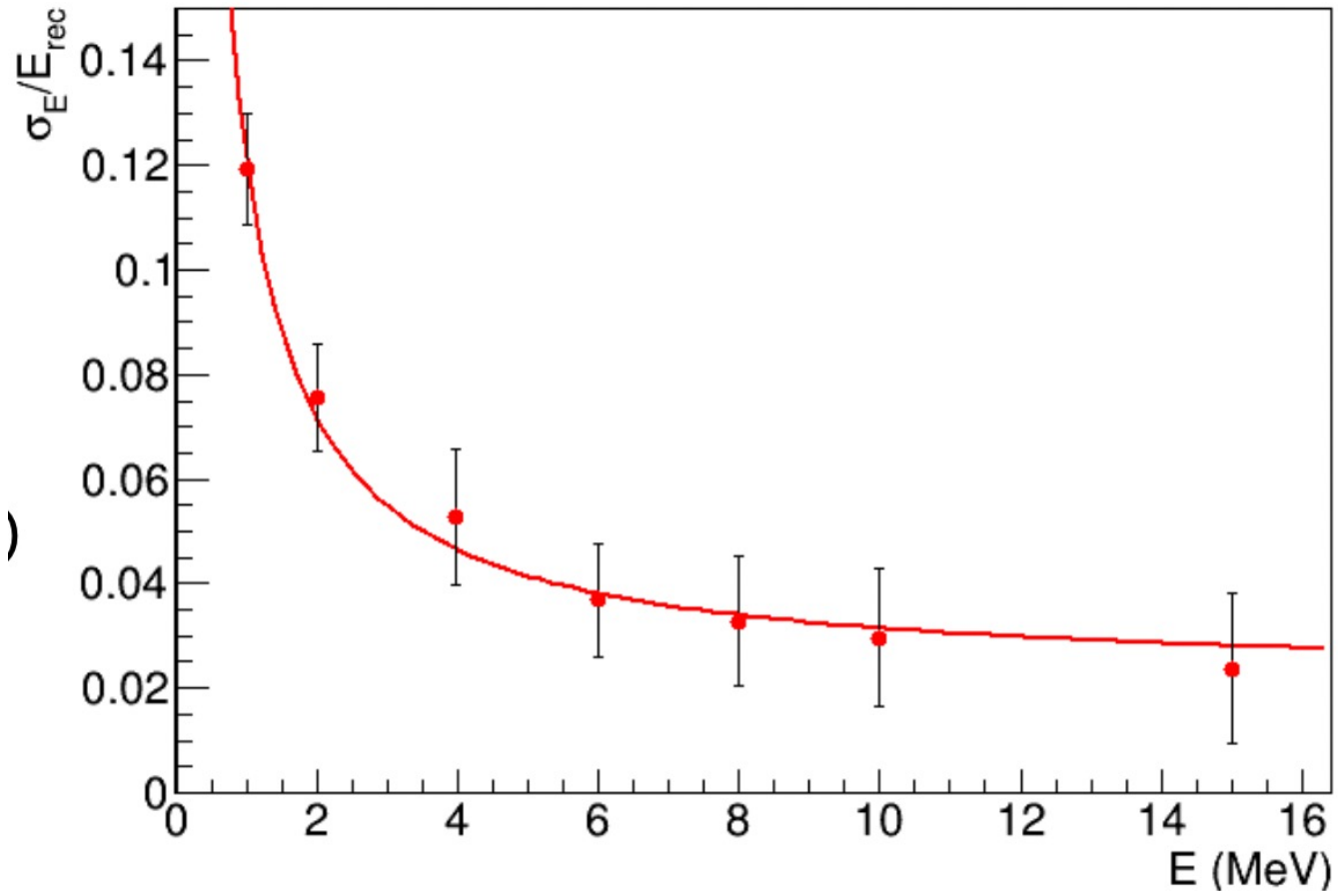


electrons

Franciole's result from point photon sources

At the midplane!

Red line shows stat errors, 1/sqrt(L)



https://indico.fnal.gov/event/63965/contributions/287360/attachments/176521/239905/module3_ly_v5.pdf

Why is my Light resolution worse ?

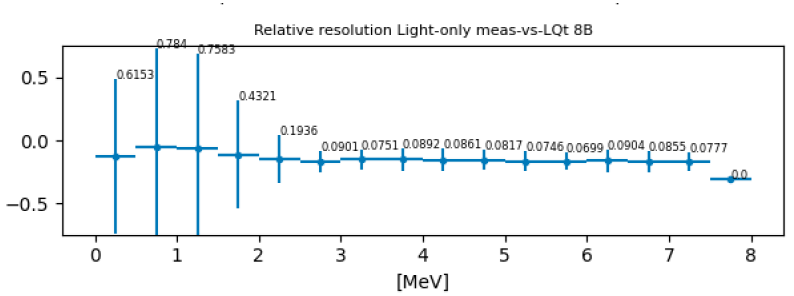
- I get ~15% (slide 3 this presentation) compared to Franciole's 3% at 8 MeV

- I agree that 8 MeV photons give ~200,000 * 0.28 * 0.02 photons, for which ~1/sqrt(1250) is 3%, as shown on prev plot.

- *I correct back using LY map across energy and volume.*

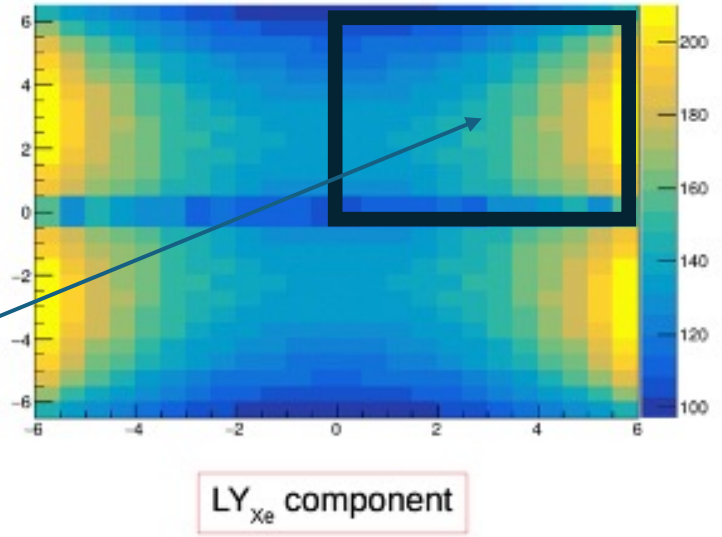
Since the collab meeting, I did 2 simulation checks

- Check the ^{8}B L resolution for events only near the mid-plane
  - This is much better : ~8% at ~8MeV. Expected rms stats error is 1/sqrt(20k*1/3*1/10) = 3%.



- Check optical photons from mono-energetic electrons: emitted, and also hitting the xAs. Also check the ΔR, the variation in recombination event-by-event.
  - I indeed get the expected number of optical photons emitted and hitting xA +/- ~2% in the ensemble of events I ran.
  - This is true of course over the whole LAr volume

Light Yield map from Franciole



We now calculate the LY including the third dimension z,
and exploit the 3-fold symmetry and generate
in only (+x,+y, +z) octant.

Use (0.5 m)^3 voxels => 13k jobs. 125k photons per voxel.
Run on PNNL compute grid.

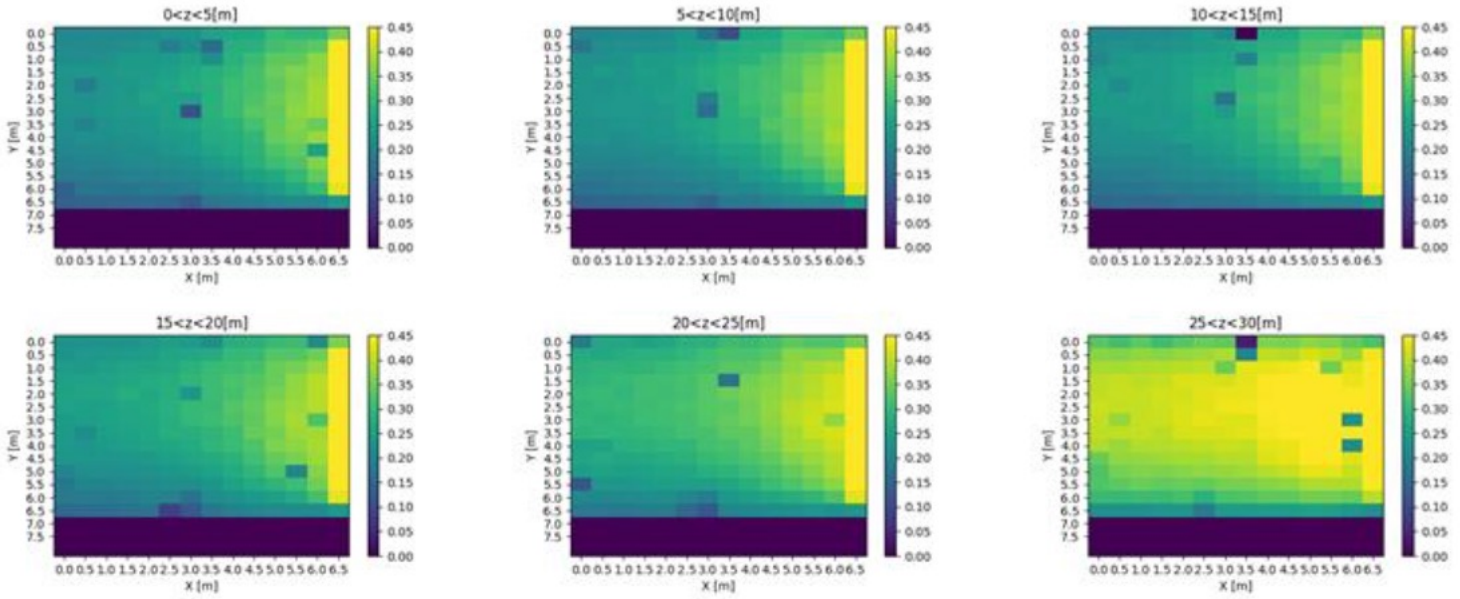
(Remember x is sideways here and y up.)

Thanks to Carlos Moreno at PNNL!

3d Light Yield maps in APEX

We show avgs in 5m slices of z.

This is $N_{hitXA}/N_{launched}$ in the Xe model.



Note increase in yield as we move along z.

The holes are where jobs have failed. Or, in fact, in places where we start photons in the edge material, not LAr.

Systematic Errors

- The light yield varies from 0.15 to 0.40 across the detector, and so to claim the error in E_L is mostly from hit-XA statistics requires to get this yield correction correct to 1%.
  - The previous presenters do not include this systematic yet.
    - I think, because unlike my simulation, they do not track optical photons and count the hit XAs and apply the light map over x,y,z.
  - My experience in even just the mid-plane (slide 6), with smearing the x,y positions is that the error is more like 8% at 8 MeV.
  - I am working on calculating this, but it's hard to see how it's going to be as low as 4% at 8 MeV
    - Which is what's needed to give ~2% at 30 MeV

Errors 2

- In reality, the Q,L errors are correlated.

- Uncorrelated result is $E = 1/2\ (E_Q + E_L)$, from which follows $\Delta E/E = \text{sqrt}\ ((\Delta E_Q^2 + \Delta E_L^2))/2$.
  - ΔE_Q = A/sqrt(E) \circplus B and ΔEL = 1/sqrt(L)+…
  - This assumes there is no stochastic Recombination fluctuation event-to-event. That you know those factors perfectly: R and (1-R).
- In the correlated result we can not average, so we do not get the bonus ½, but we do subtract an extra term.
  - $E = E_Q + E_L$
  - $\Delta E/E = \text{sqrt}\ (\Delta E_Q^2 + \Delta E_L^2 - (\text{A/sqrt(E)} \text{ \circplus } \text{B})*1/L)$

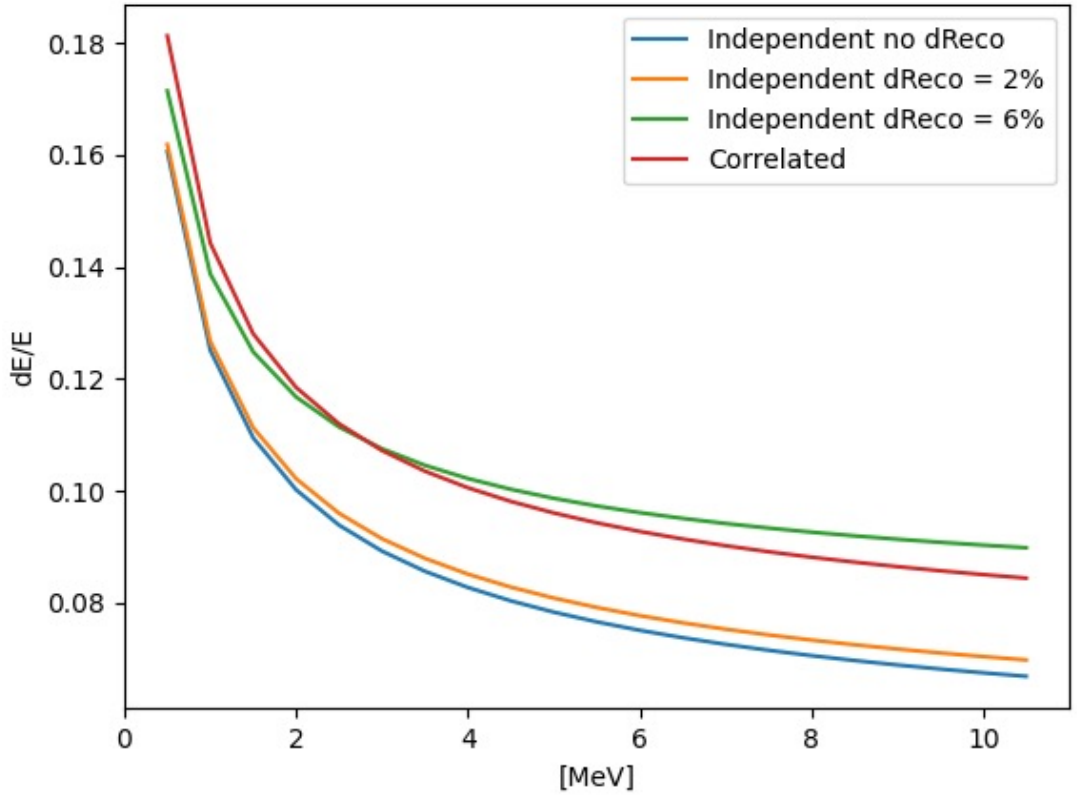
Still keeping LY correction systematic out of it:

Doing this analytically -- no simulations

This is for A=0.12 and B=0.06, which seem conservative charge error parameters for DUNE.

2% is about the ΔR error I see at 8 MeV in G4. I add this ΔR error in quadrature to the uncorrelated error calculation L.

Remember, the correlated calculation is insensitive to ΔR.



If I use smaller Q measurement errors

This is for an optimistic A=0.06 and B=0.03.

That 3.2% error at 10 MeV scales to Wei's 2% from last presentation at 30 MeV, dividing by 1/sqrt(10/30). So, I think this captures effectively what they're doing, with their reco error.

Here the correlated error is also small, and smaller than properly including an error from ΔR.