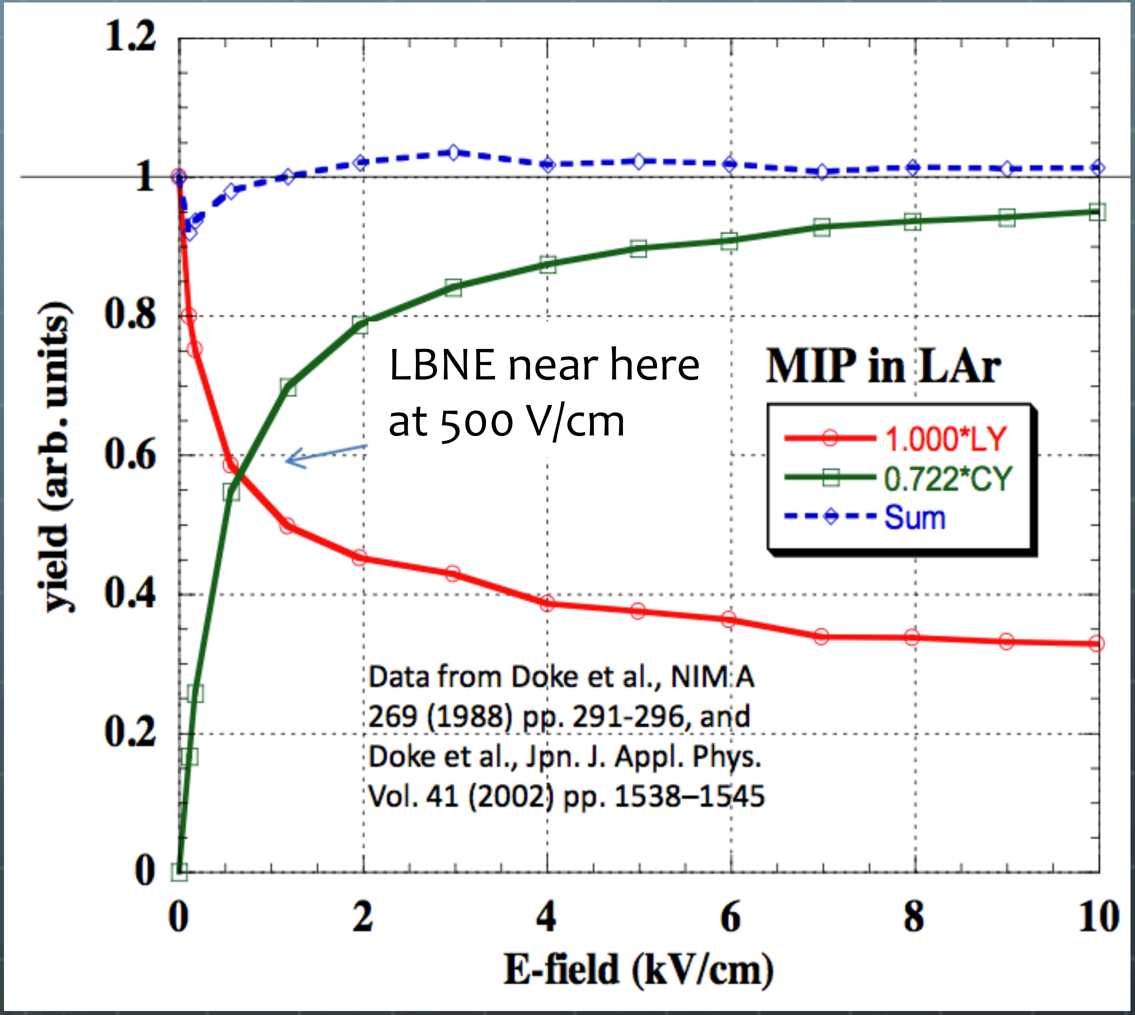
Combined-Scale Energy Reconstruction

Matthew Szydagis, UC Davis

Reminder: Motivation



- Anti-correlation of light (LY) and charge (CY) yields demonstrated by re-analysis of old LAr data
- Was confirmed by DarkSide (dark matter LAr TPC)
- Given excitation plus electron recombination, nearly half of deposited energy goes into scintillation light

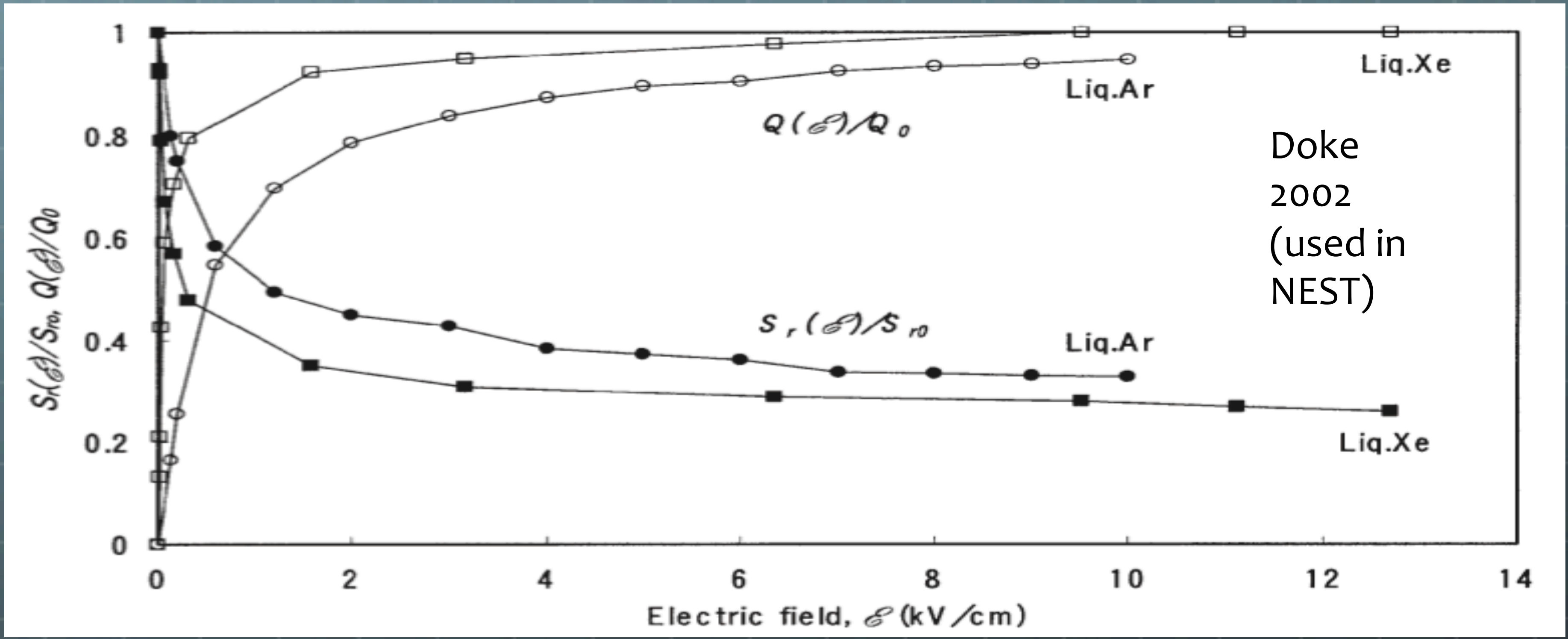
Formulation

- E [MeV] = [(LY_c / g1) + (CY_c / g2)] * 19.5e-6 MeV
- LY_c is the primary scintillation light yield, as measured in PE, either an average or corrected to a fixed reference point within detector (such as the center)
- g1 is the product of the geometric light collection efficiency (due to reflectivity, absorption, scattering) times the QE of the SiPMs; units of [PE/photon]
- CY_c is the charge yield, or Q, as measured in electrons, corrected for the finite electron absorption length caused by electronegative impurities
- g2 “corrects” for wire efficiency, radius, pitch, etc.; units of [measured electrons / original electrons]

Practical Example

- Take a 5 GeV electron
- "Optimistic" g1 of 2e-5 raw, from Norm (based on value of 0.5 PE/MeV for a MIP at 500 V/cm)
- Mean LY = (24,000 photons/MeV) * (5,000 MeV) * (2e-5 PE/photon) = 2400 PE
- Mean CY = (27,000 electrons/MeV) * (5,000 MeV) * ?
- Typically, then E=[(2400/2e-5)+1.35e8]*19.5e-6 MeV ~ 5,000 MeV
- Charge conversion "Birks' correction" to dE/dx no longer needed: combined energy scale absorbs the effect of recombination

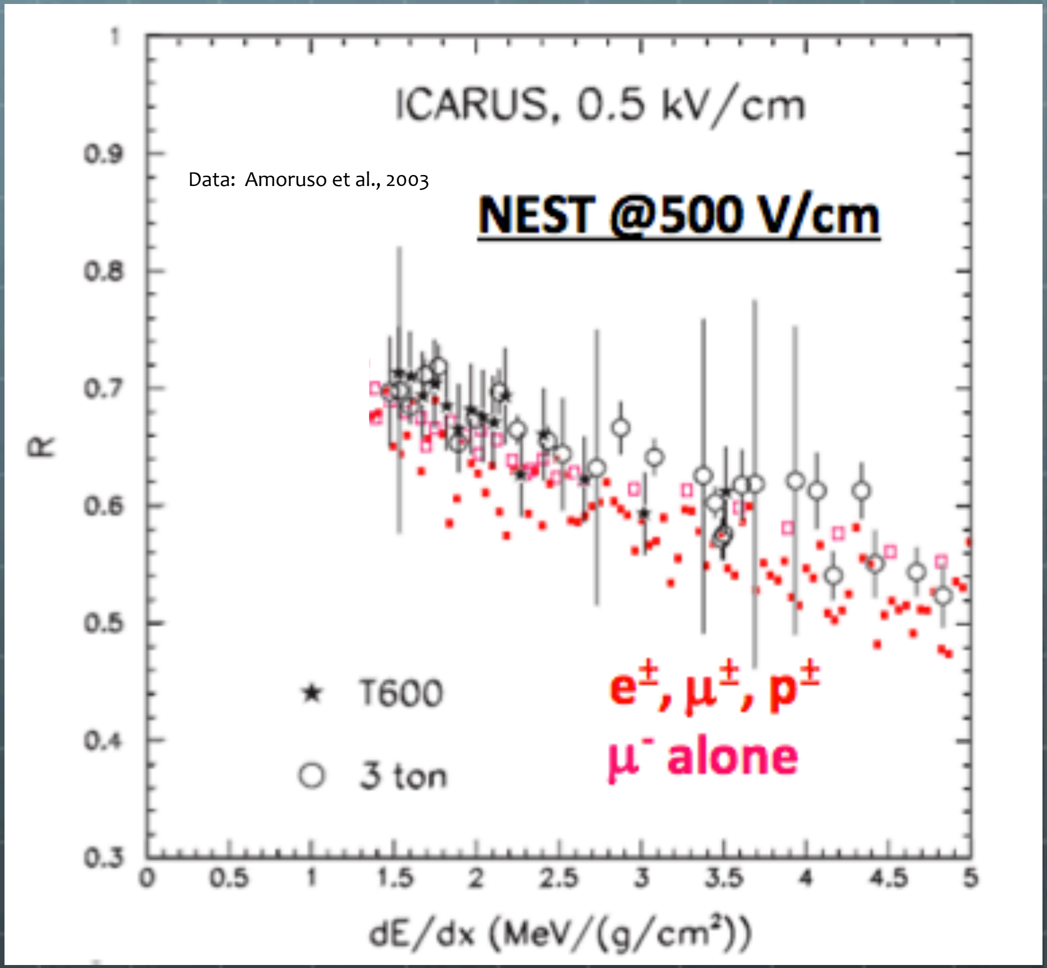
A Recipe for Yields



Doke 2002 (used in NEST)

- 0-field MIP yield measured, well-known: 41,000 photons/MeV (also Doke: 1987, 1989); from above get ~24,000 @500 V/cm
- Charge is just 1/19.5 eV (total yield, all quanta) minus light yield

ICARUS CY "hides" LY



- R = (1 – r) (the escape probability, or 1 minus the recombination probability) = Q/Q_0 where $Q_0 = E/23.6$ eV, and 23.6 eV derivable from (1+exciton/ion ratio)*W = (1.21)*19.5

$$N_{ph} = N_{ex} + rN_i$$
$$N_e = N_i(1-r)$$

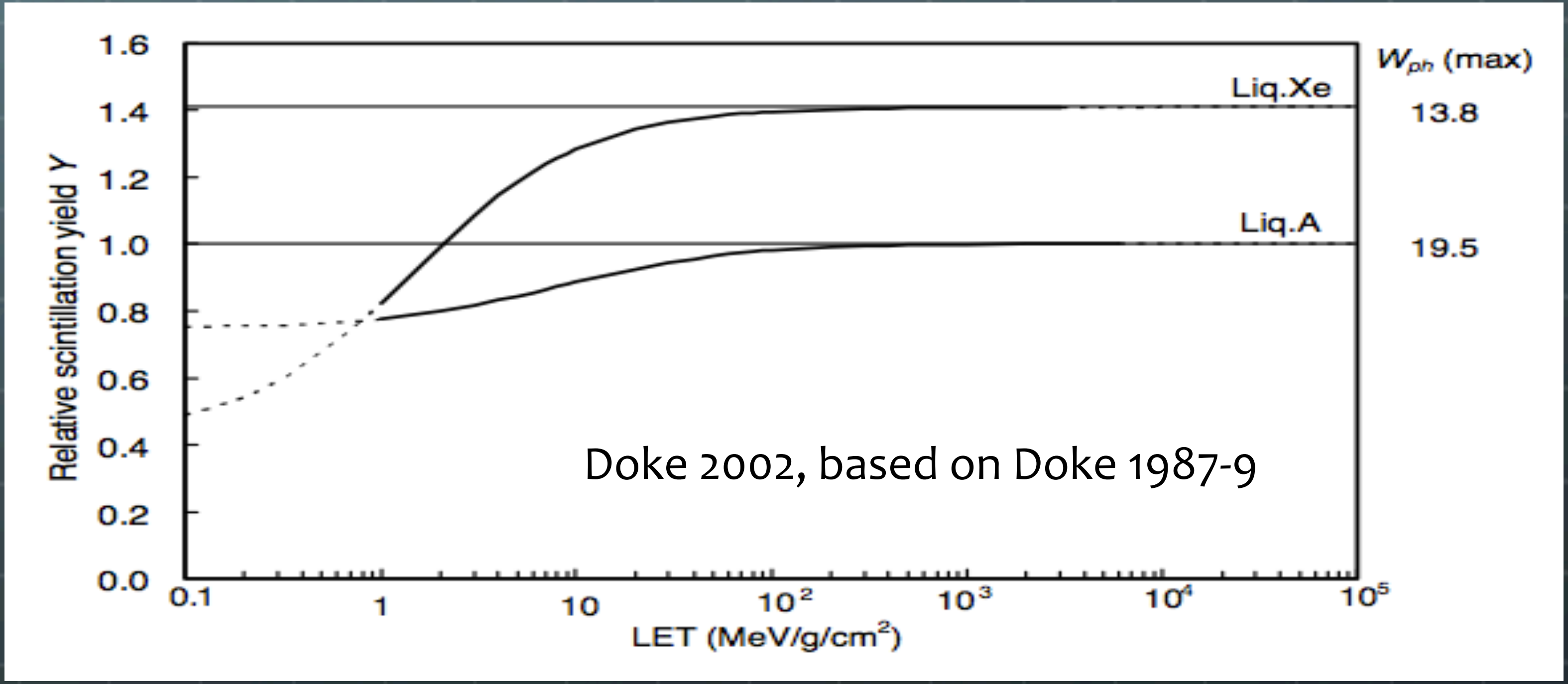
- r known, N_{ex}/N_i known (0.21), $N_{ex}+N_i$ known (1/19.5 eV); can solve

Mutual Consistency

- Consistency check: Q can be written as $R*Q_0$, which is "recombination factor" times "infinite field" yield
- $R*Q_0/E$ = 0.66/(23.6e-6 MeV) = 28,000 e- / MeV
- 1/19.5e-6 - 0.66/23.6e-6 = 23,000 photons / MeV (~Doke, despite very different energy regime, as dE/dx same)
- Why can't always have sqrt(E) vs. E energy resolution using charge alone? Because missing part of the energy (in light), in a dE/dx (and field) dependent fashion!
- dL/dx prop. to dE/dx, not just dQ/dx in liquid argon

Where Does W Come From?

- Isn't W=19.5 eV only the scintillation work function? (W_{ph}?)
- NO: actual represents the *TOTAL* yield (light + charge), i.e., the complete recombination case (extreme dE/dx), analogous to 23.6 eV representing none (N_{ex}/N_i plays role)



Another Cross-check

- Instead of using combined energy reconstruction, can also create an equation analogous to one at right w/ Q
- E (GeV) = (LY_c / g1) * W_{ph}*1.21 / (1.21 – R)
- g1 is just like 'C,' which is like my g2. Reconstructing original number of scintillation photons from efficiency

$$E_i(GeV) = \frac{CW}{R} e^{\frac{t-t_0}{\tau_e}} Q_i$$

K. Woods

- C: calibration factor
- W: Argon ionization energy
- R: recombination factor (electron-Ar^- combination)
- $t - t_0$: drift time
- τ_e: electron lifetime (parameterizes electron tendency to attach to impurities in LAr)
- Q_i: hit area (i indexes hits of an event)

Can't exactly do analogous LY lifetime correction, because photons do not travel along straight lines nor are they governed by one exponential m.f.p.

Conclusion

- Just like with some argon dark matter detectors (but opposite problem here): only one channel used for the energy reconstruction traditionally
- Even with poor light collection, no reason not to use photons as part of the calorimetry
- Goal: everyone tries it, this week even. Great for supernova burst neutrinos, great for 35t, etc.