Free Ionization Charge and Scintillation Light in LAr:

AntiCorrelated-Complementary at any dE/dx and any EF

through the *Charge - Light Master Equation* *(T. Doke, Fundamental properties of liquid Argon…)*

in LArTPC for Neutrino Experiments $\frac{dQ}{dx}$ primary "observable"

for $(e\ \mu, \pi, K, p)$-ptcl. Tracks emerging from ν-Interactions

range of interest for **LArTPC for Neutrino Experiments**:

$$EF = 0 \ \leftarrow \ 250\frac{V}{cm} \ \leq EF \ \leq \ 500\frac{V}{cm} \ \rightarrow \ 750\frac{V}{cm}$$

$$(e\ \mu, \pi, K, p \text{ at min. stopping pwr}) \ \ 2\ \frac{MeV}{cm} \ \leq \ \frac{dE}{dx} \ \leq \ 40\ \frac{MeV}{cm}\ (\text{p} - \text{stop}) \ \rightarrow 100\ \frac{MeV}{cm}\ (\text{p} - \text{blip})$$

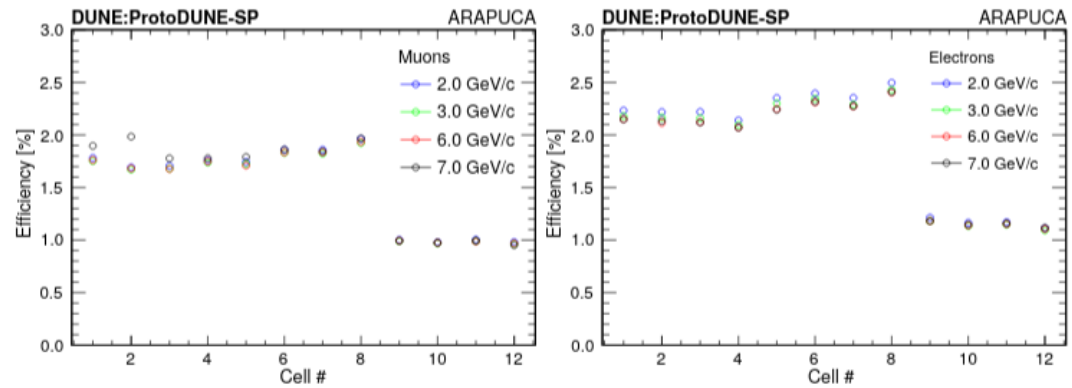
TPC wire pitch (0.5 cm) = min dx set the limit from track into "blips"

TPC CE S/N (≥ 40) set the detectable E threshold for blips

$100\ \text{keV} \leq e \leq 1\ \text{MeV}$, or $1.5\ \text{MeV} \leq p \leq 20\ \text{MeV}$

Charge+Light Model example: LArQL

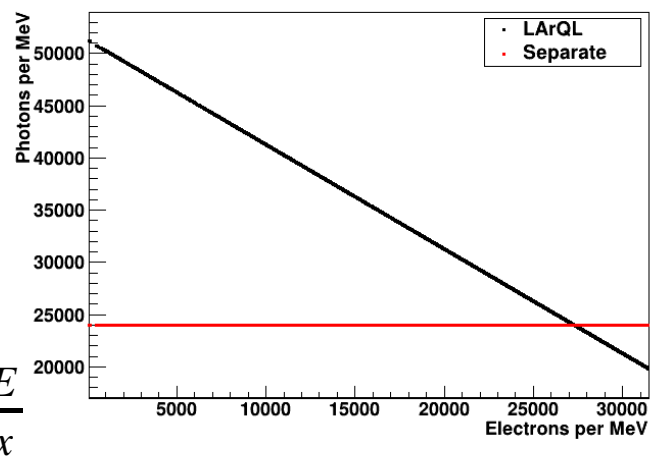
- Modifies Birks(or Box) charge model correcting for escaping and additional electrons at lower $\mathscr{E}$ range
- Motivation: ProtoDUNE PDS data analysis results sensitive to some non yet adequately simulated effects of light from recombination
- Theoretical foundations: observed reduction of scintillation light in the low dE/dx region at $\mathscr{E}$ = 0 attributed to “escaping electrons”.



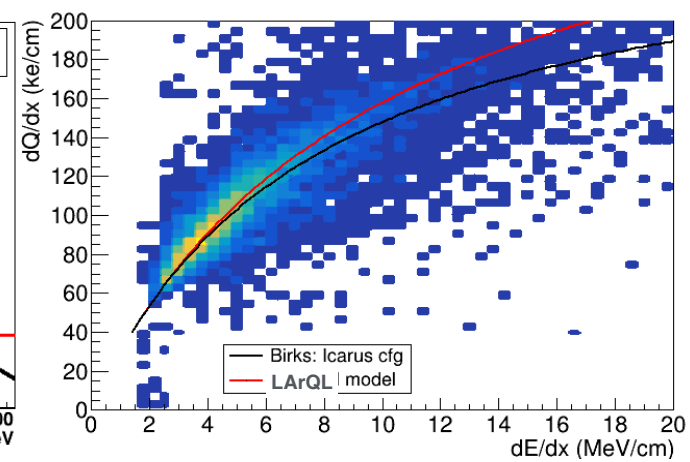
$$dQ/dE_{birks} \rightarrow dQ/dE_{birks} + \chi,$$

$$\chi = \chi_0(dE/dx) f_{corr}(\mathscr{E}, dE/dx)$$

$$dQ/dx = \left(\frac{A_B}{1 + \frac{k_B}{\mathscr{E}\rho_{LAr}} \frac{dE}{dx}} + \chi \right) \frac{1}{W_{ion}} \frac{dE}{dx}$$



Protodune $\mathscr{E}$= 486 V/cm



C. Adams et al. JINST 15 P03022 (2020)