O modelo LArQL para a descrição da produção de luz e carga em argônio líquido

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Overview

- Theoretical background and motivation
- Preliminary evaluation and potentialities
- Conclusions/perspectives

LArQL

Motivations, Goals and Limits

- Improvement on the description for Scintillation Light emission in LAr inside LArG4/LArSoft
  - ✦ Data analysis results sensitive to some non yet adequately simulated effects of light from recombination
- Unitary model for Ionization Charge AND Scintillation Light in LAr as function of deposited energy density (dE/dx) and electric field (ξ)
  - ✦ Cover the range of interest for LArTPC for Neutrino Experiments:

$2\ \text{MeV/cm} < dE/dx < 40\ \text{MeV/cm}, \qquad 0 \leftarrow 0.25\ \text{kV/cm} < \xi < 0.5\ \text{kV/cm} \rightarrow 0.75$

LArQL

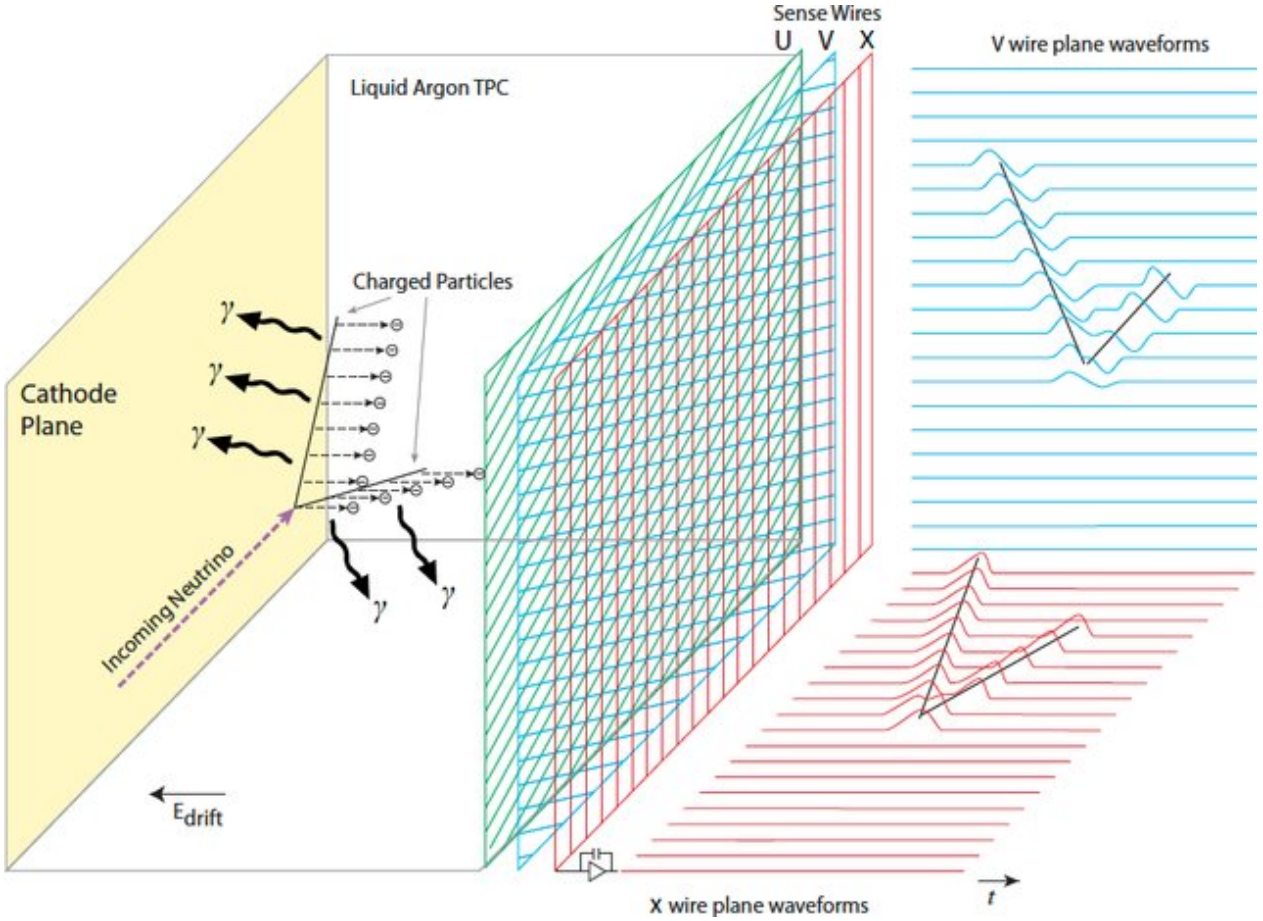
Theoretical/Phenomenological foundations:

- Free ionization charge and scintillation light anticorrelated/complementary at a given (dE/dx, ξ) pair: Charge - Light Master Equation

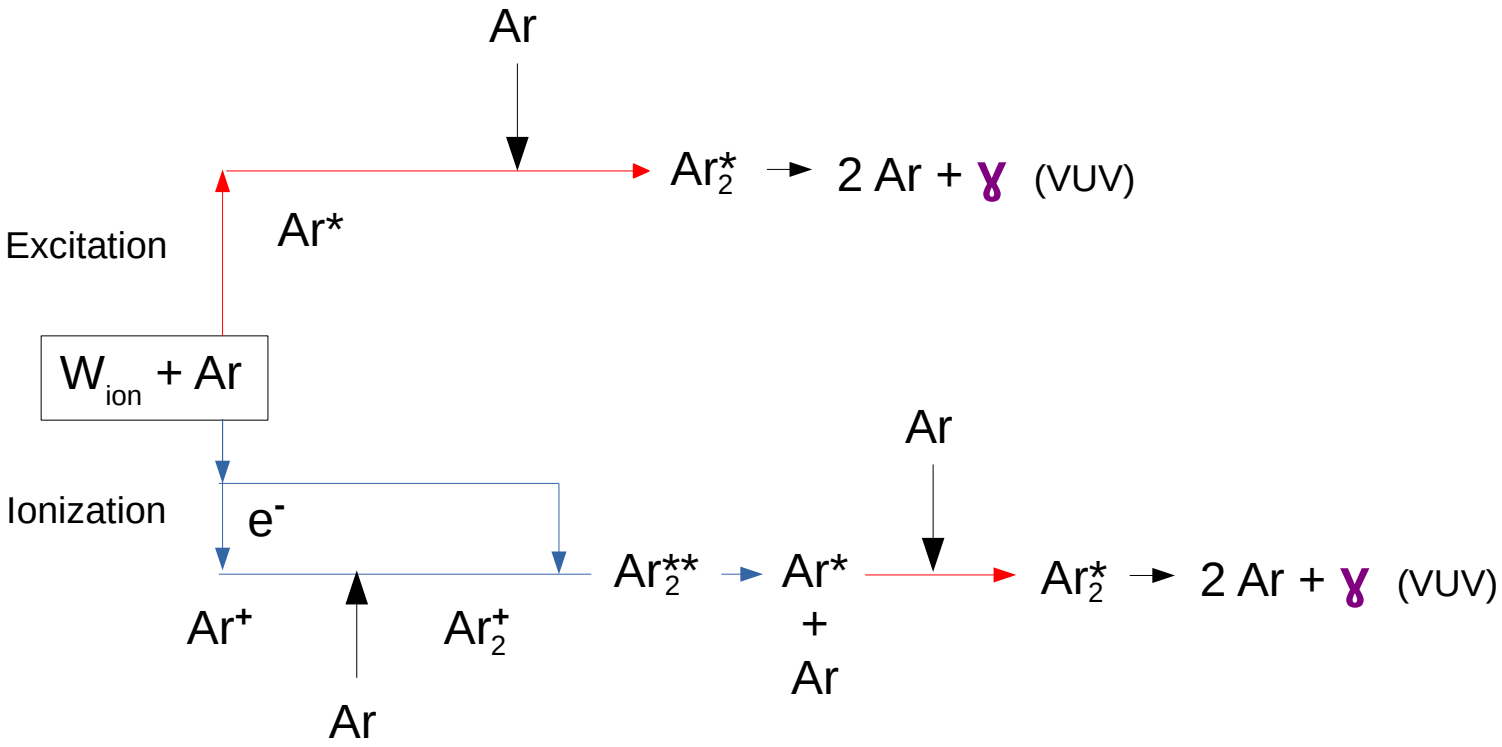
- Observed reduction of scintillation light in the low dE/dx region at $\xi = 0$ attributed to “escaping electrons”.

- T. Doke, Fundamental properties of liquid Argon, Krypton and Xenon as Radiation detector media, Portugal Phys. 12 (1981), 9.
- S. Kubota, A. Nakamoto, T. Takahashi, T. Hamada, E. Shibamura, M. Miyajima, K. Masuda and T. Doke, “ Phys. Rev. B 17 (1978) 2762.
- T. Doke, H. J. Crawford, A. Hitachi, J. Kikuchi, P. J. Lindstrom, K. Masuda, E. Shibamura and T. Takahashi: Nucl. Instrum. & Methods A 269 (1988) 291
- T. Doke, A. Hitachi, J. Kikuchi, K. Masuda, H. Okada and E. Shibamura, Absolute Scintillation Yields in Liquid Argon and Xenon for Various Particles, Jpn. J. Appl. Phys. 41 (2002) 1538

LArTPC


Sense Wires
U V X
Liquid Argon TPC
V wire plane waveforms
Charged Particles
Cathode Plane
Incoming Neutrino
E drift
X wire plane waveforms
t

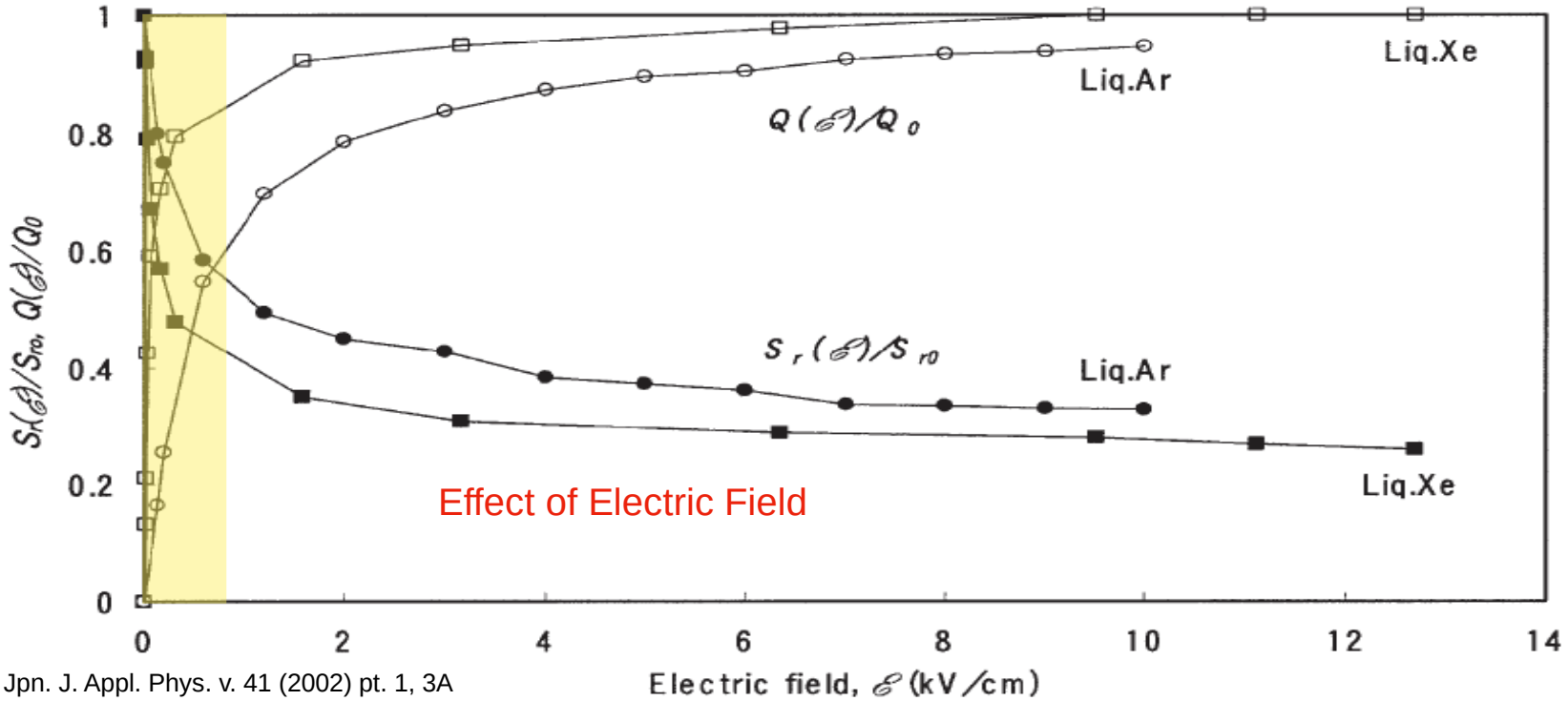
Scintillation light production



Charge – light master equation

$$QY\left(dE/dx,\xi\right)+LY\left(dE/dx,\xi\right)=N_i+N_{ex}$$

Free Charge Yield: [e/MeV] Light Yield: [ph/MeV]



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Effect of deposited energy density

Light reduction at ξ=0 and low dE/dx due to electrons escaping recombination

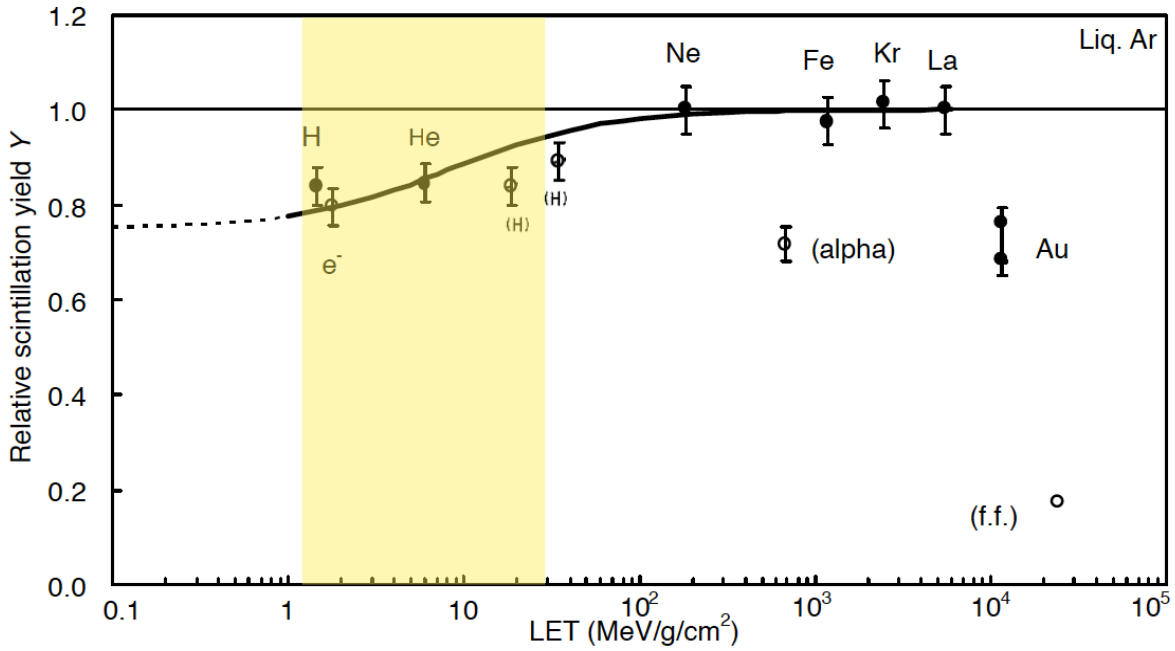
N_0: # of escaping electrons per energy unit

$$\eta_0 = \frac{N_i - N_0 + N_{ex}}{N_i + N_{ex}}$$

Fractions of interest:

$1-\eta_0$: missing photons

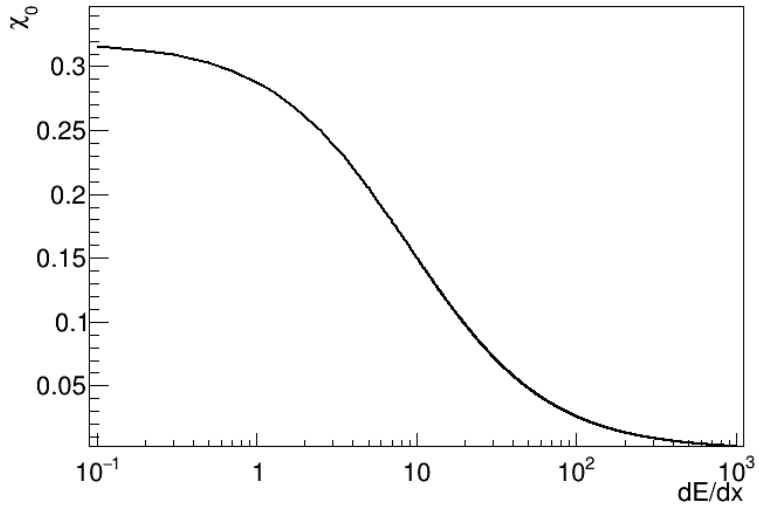
$\chi_0 = \frac{N_0}{N_i}$: escaping electrons



LArQL: QY vs LY relationship at ξ = 0 kV/cm

3 experimental parameters

- $N_i = 1/W_{ion}$: ionizations per energy unit
- N_{ex}/N_i: excitations/ionizations
- χ_0(dE/dx)



Light yield obtained from free charge yield

$$LY = N_i - QY + N_{ex} = LY_{rec} + LY_{ex},$$ as e^-_{rec} = ph.$_{from\ rec}$

LArQL: QY vs LY relationship at ξ = 0 kV/cm

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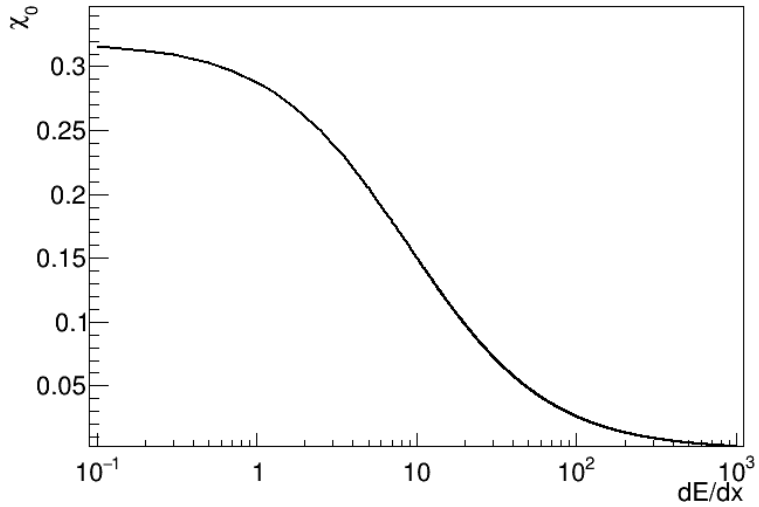


$$\chi_0\left(dE/dx\right) \neq dQ/dE_{birks/box} = 0$$

In friction with charge models

LArQL

Modifies Birks charge model correcting for escaping and additional electrons at lower ξ range

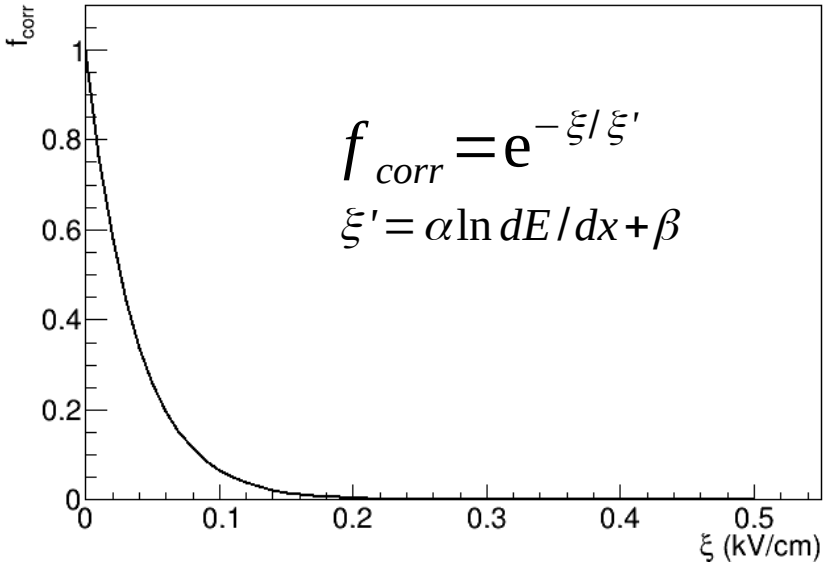
1- At ξ = 0, escaping electrons taken into account

2- Just above ξ = 0 adds field extracted electrons

3- At higher, escaping $e^- \rightarrow 0$ and Birks recovered

$$\chi_0 \rightarrow \chi = \chi_0 (dE/dx) f_{corr}(\xi, dE/dx)$$

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



LArQL

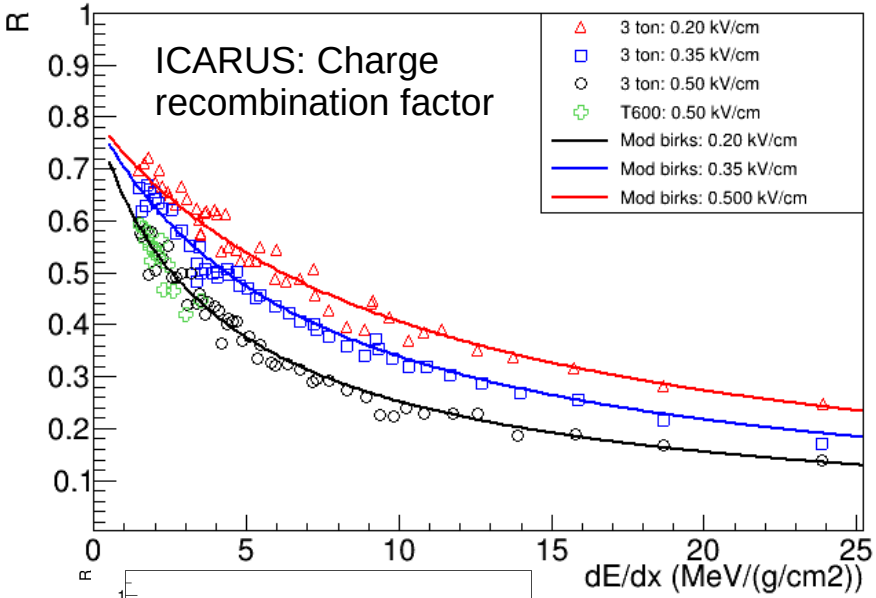
Modifies Birks charge model correcting for escaping and additional electrons at lower ξ range

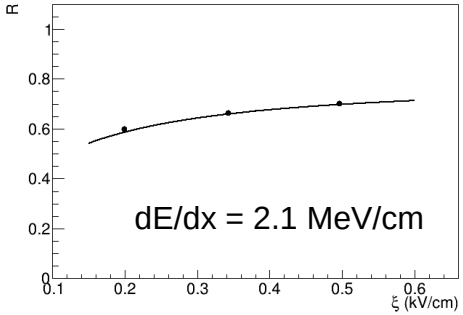
$$\chi_0 \rightarrow \chi = \chi_0 (dE/dx) f_{corr}(\xi, dE/dx)$$

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

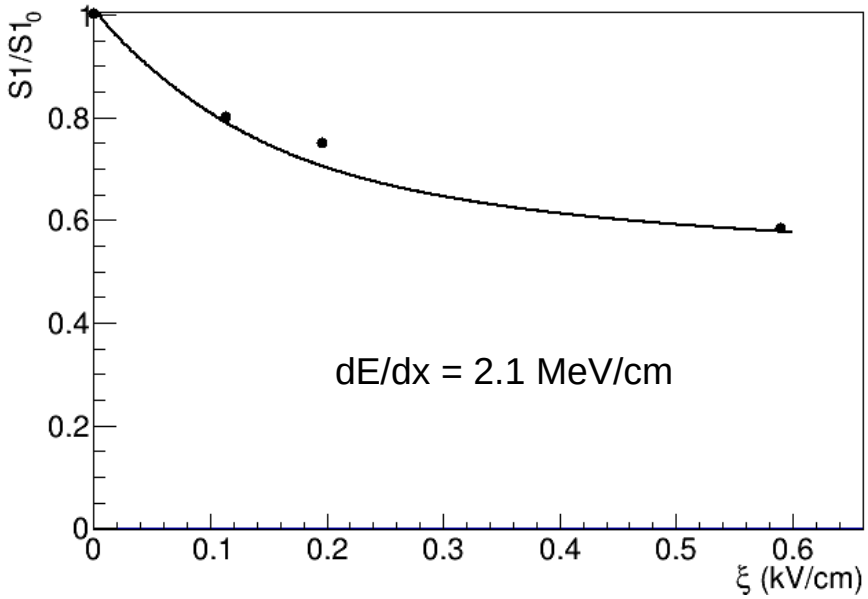
$$dQ/dx = \left(\frac{A_B}{1 + \frac{k_B}{\xi \rho_{LAr}} \frac{dE}{dx}} + \chi_0 (dE/dx) f_{corr}(\xi, dE/dx) \right) \frac{1}{W_{ion}} \frac{dE}{dx}$$

Charge and light data





NIMA 523 (2004) 275–286



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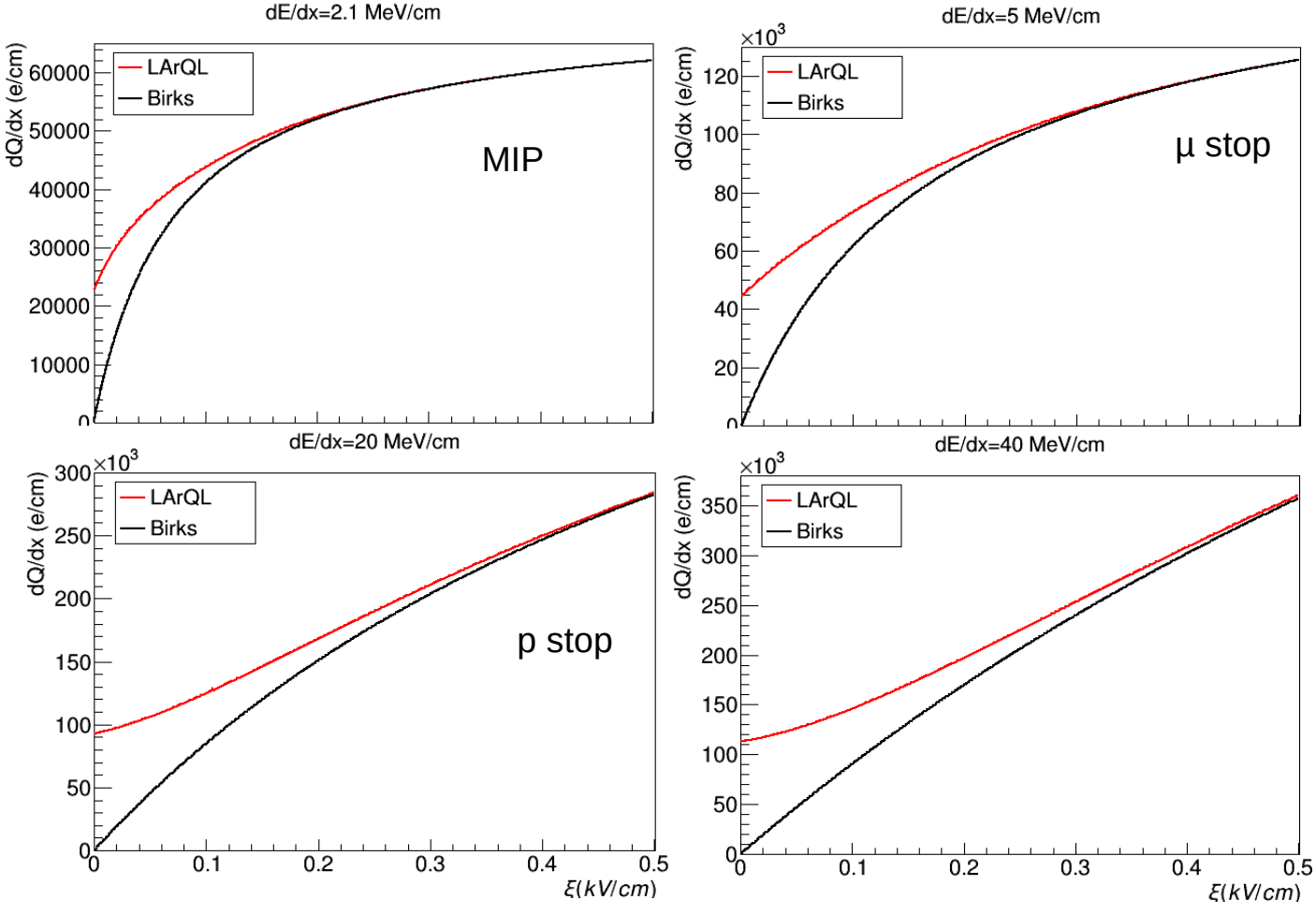
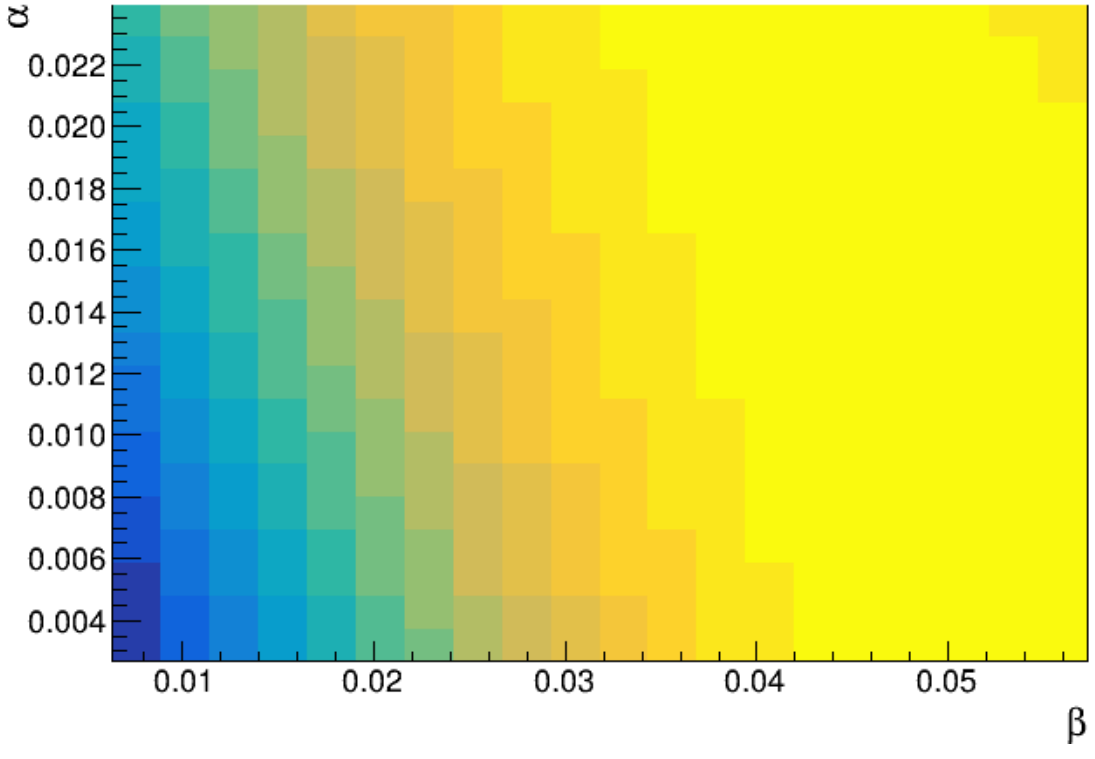
Predictions on charge sector differ from Birks only for heavily ionizing particles at lower ξ

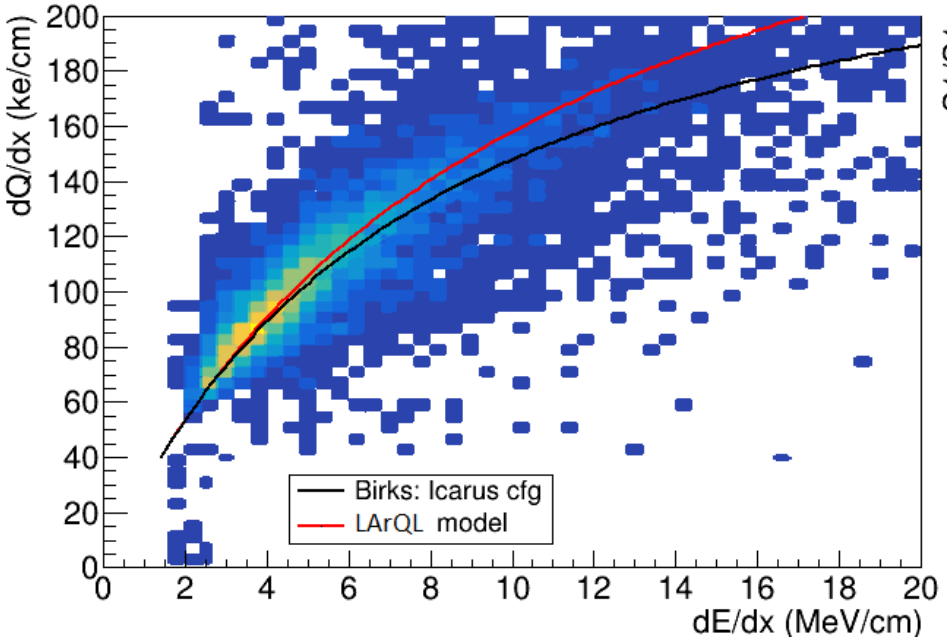


Combined fit procedure: early exercise

- Previous data + ARIS ($S1/S1_0$)
- Minimize model-data point residuals
- Only f_{corr} parameters varied
- Birks and χ_0 parameters fixed

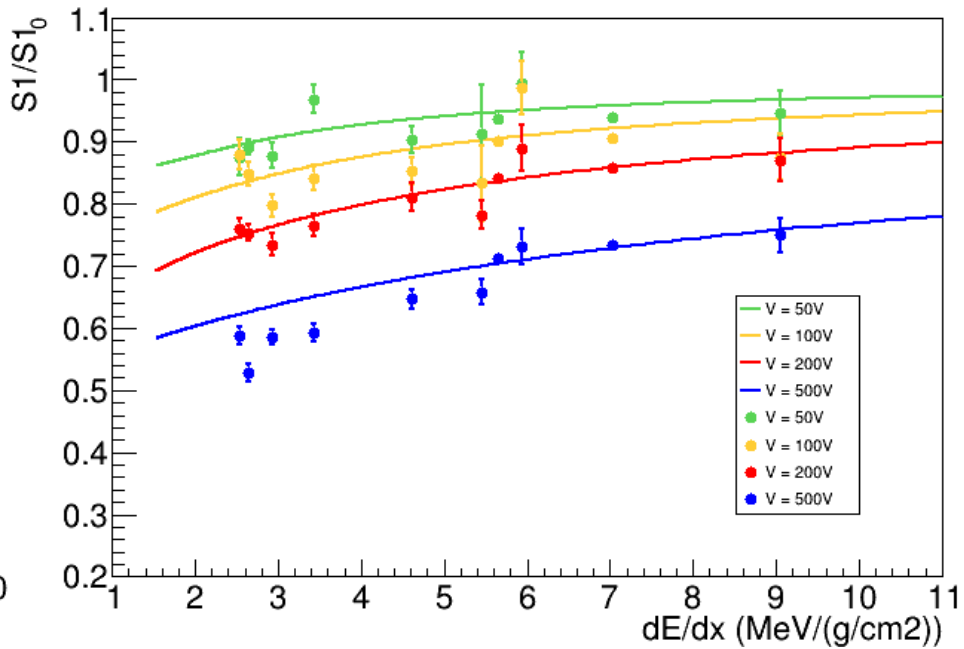


LArQL model vs data comparison



Microboone charge data @ 270 V/cm

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



ARIS experiment data

P. Agnes et al., Phys. Rev. D97 (2018) 112005

Conclusions

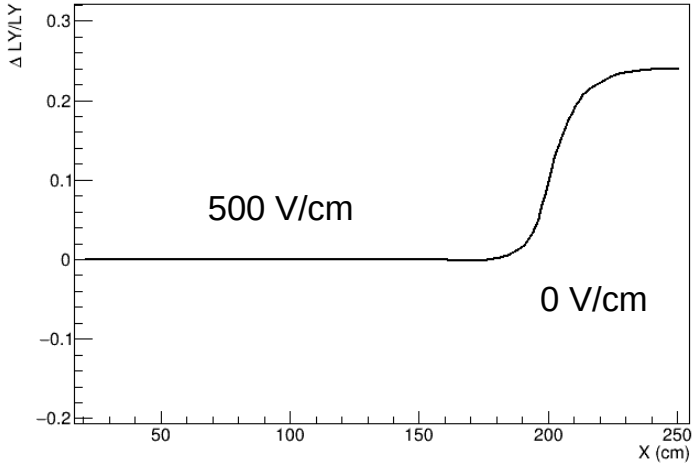
- A novel model for constrained free charge and scintillation light in LAr
- Satisfactory description at dE/dx and field ranges
- Improvements via data sets compilation and “global” fit
  - model perfecting possible if needed
- LArSoft implementation already available

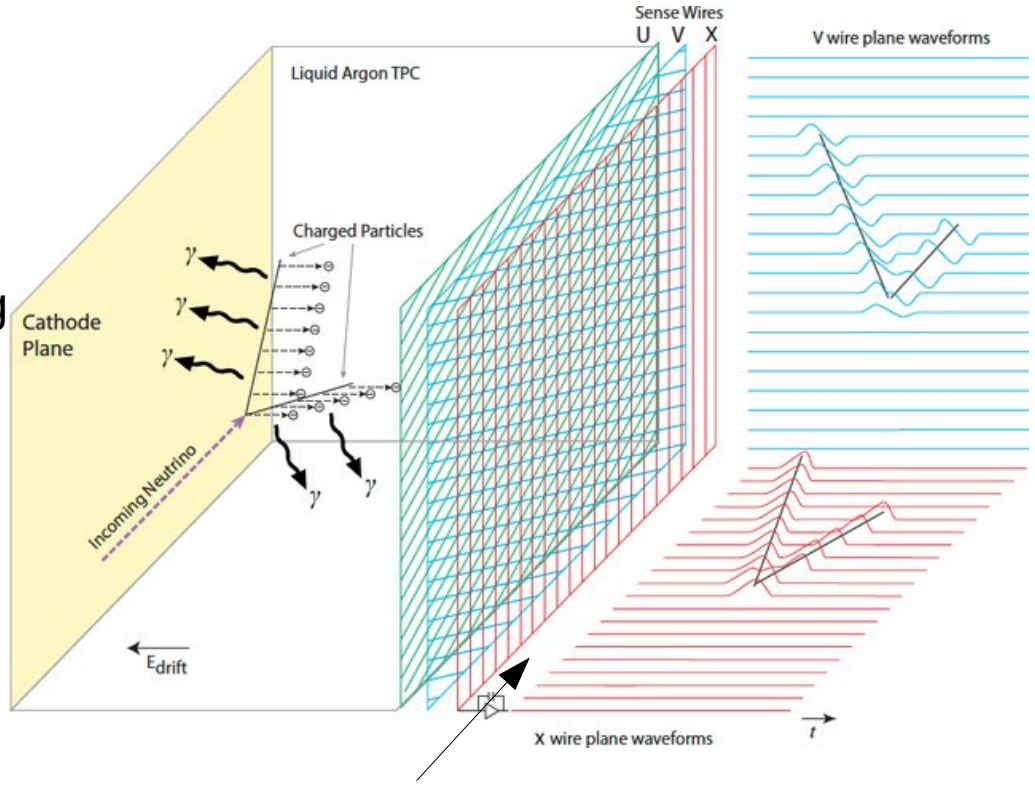
Conclusions

- LArSoft implementation already available...

  and used in SBND, DUNE

- Position of scintillation positioning





Scintillation detectors