

Low-Energy Physics in LArTPCs (LEPLAr): A Snowmass Whitepaper

The LEPLAr Interest Group

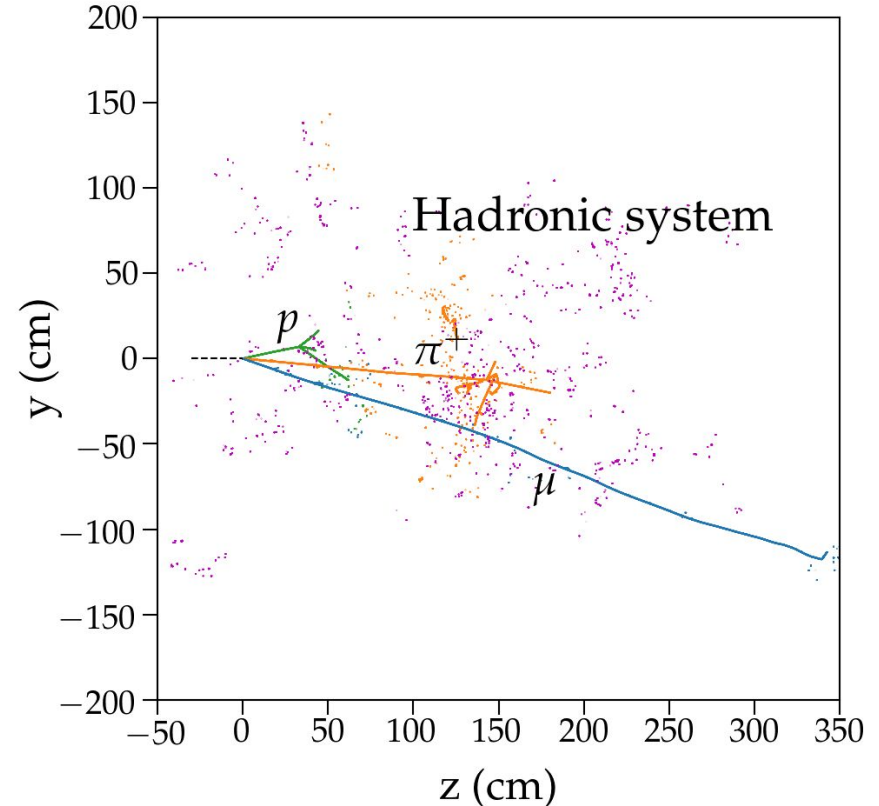
What is LEPLAr? What do we mean?

- Large LArTPCs have so far done an amazing job building physics results out of bright light flashes, tracks, and showers!



What is LEPLAr? What do we mean?

- As a field, we have focused less on considering neutrino LArTPCs at low-energy / low-length scales
- In LArTPCs, there are mm-scale, MeV- and sub-MeV scale light/charge features that we can see, and that hold physics!
- LEPLAr refers to these low-energy signatures: what physics do they hold, how do we simulate them and reconstruct them, and how do we build detectors to make sure we can see them?





November 30th - December 3rd 2020
<https://indico.fnal.gov/event/XXXXX/>

LEPLAr

workshop on Low Energy Physics in Liquid Argon

Organizers:

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J. Reichenbacher
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T. Yang
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Workshop was
DUNE-oriented
but had also
non-DUNE
participation

Poster credit: David Caratelli
Photo: Steve Krave

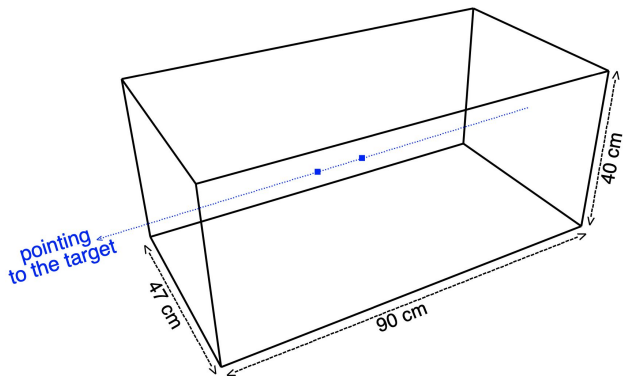
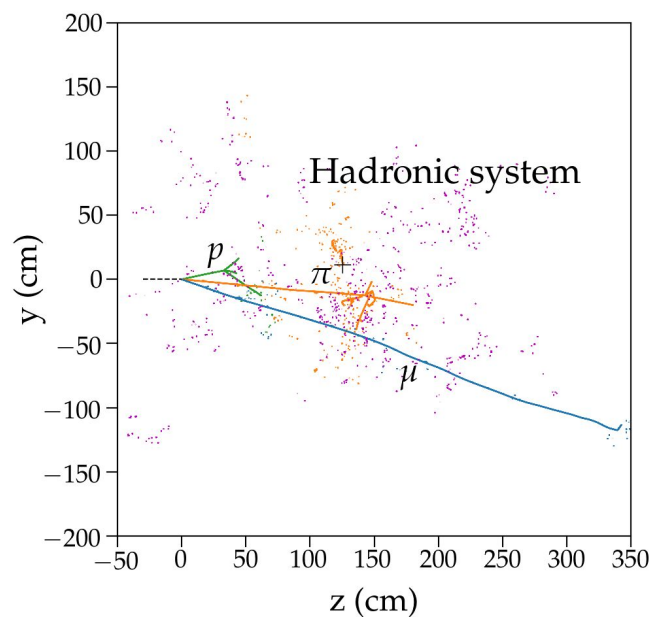
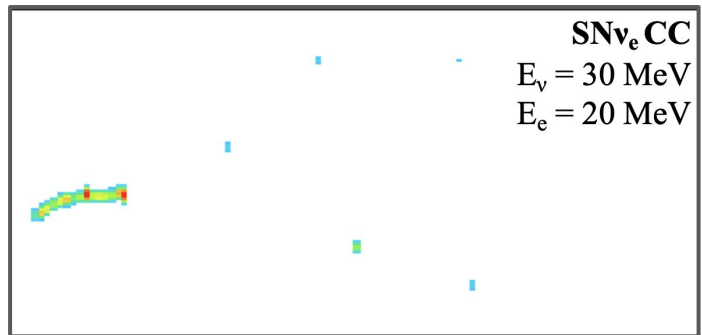
Purpose: **coordinate DUNE LE activity** spread
over multiple working groups

Organization

- Whitepaper is based around the LEPLAr, held virtually in December 2020:
<https://indico.fnal.gov/event/46641/>
- Section 1: Introduction
- Section 2: Physics Enabled by LEPLAr Signals
- Section 3: Modelling Required for LEPLAr Signals
- Section 4: Relevant Detector Features and R&D
- Section 5: Reconstructing LEPLAr Signals
- Section 6: Triggering and Computing Considerations
- Section 7: Connections and Summary of Needs

Section 2: Physics Enabled

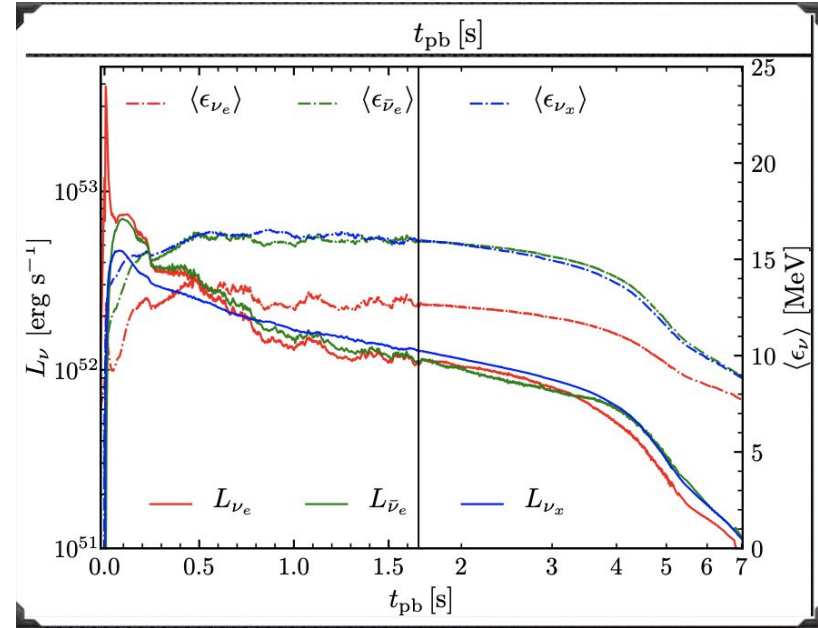
- Neutrino Oscillation Physics:
 - For a GeV+ LBNF neutrino beam, lots of energy will go towards the hadronic system; much of this will be blips.
- BSM Physics:
 - Some BSM physics only exhibits itself as blips (mCP, upscatters)
 - Blips can enable PID, which aids BSM (π/μ ; sign separation)
- Supernova and Solar Neutrinos, of course:
 - 1-50 MeV-scale neutrinos largely make MeV-scale signatures



Select physics highlights I

DUNE's ability to measure SNB ν_e 's gives it unique physics reach.

SuperK/HyperK will have more SNB neutrino interactions. However, oscillation effects may not be visible in the nuebar channel, because the starting spectra are very similar.



3D simulation from
Bollig *et al*, ApJ 2021

Select physics highlights II

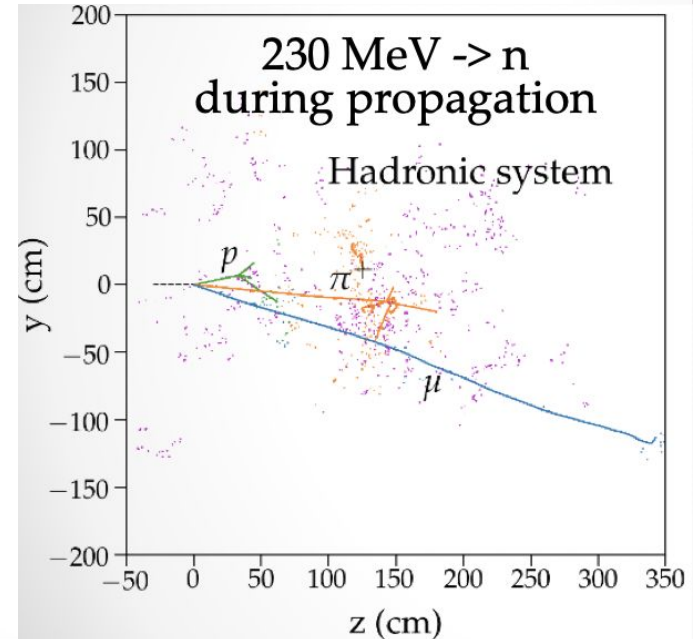
In GeV events, there are both primary and secondary neutrons and a lot of their energy goes into a spray of small charges.

- Recovering their charges can improve energy resolution by ~25%

Friedland, Li
2018

170 MeV \rightarrow n
at the primary vertex

GENIE+FLUKA: 4 GeV ν_μ in Argon



Select physics highlights III

- BSM in LAr: Blips are a valuable handle!

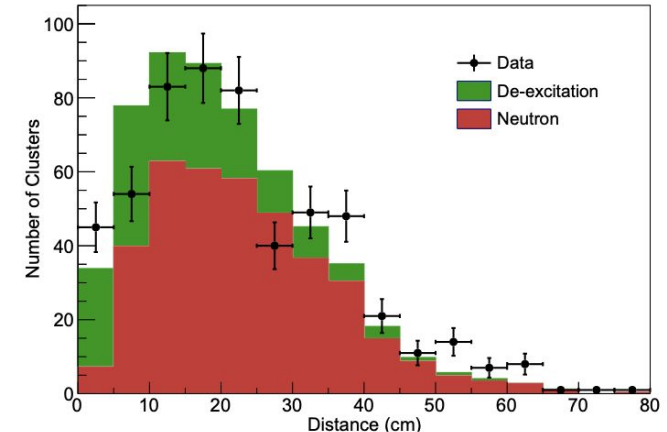
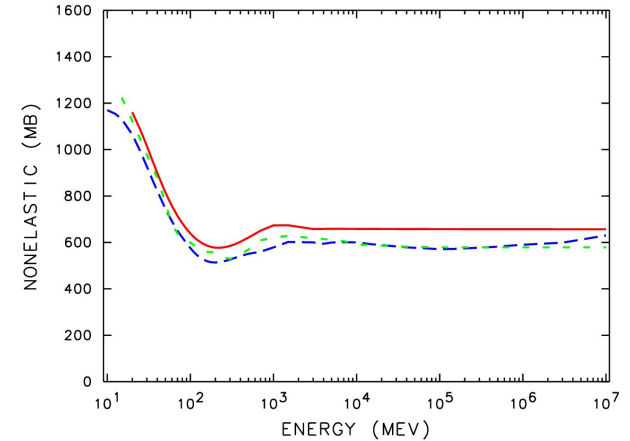
From P. Machado's FNAL
PAC talk yesterday

[illegible]

Section 3: Modelling LEPLAr

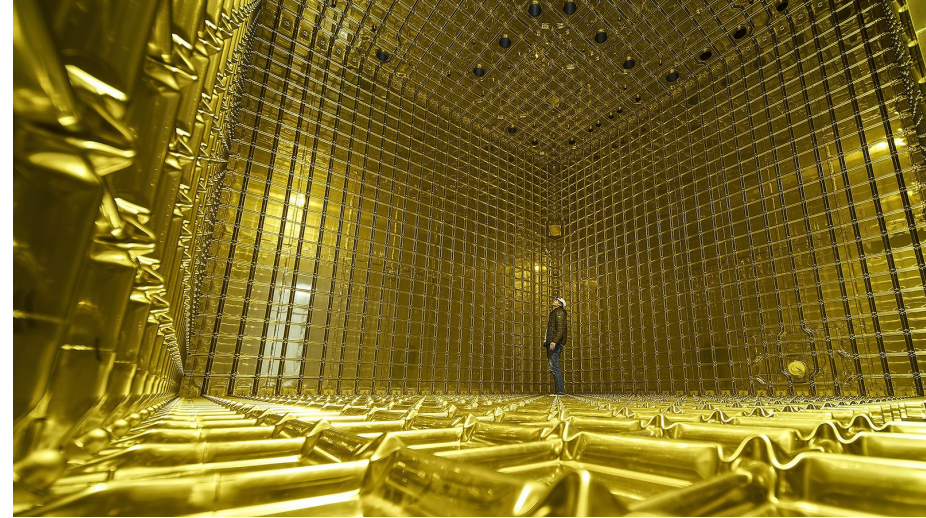
- What kind of neutrons and gammas do neutrino interactions make?
- What kind of neutrons and gammas do hadron inelastic interactions make, and how often do these interactions happen?
- How many blips do low-energy and high-energy neutrons make?
- Do we have software that does all of this modelling correctly?

NEUTRONS ON A = 40 Z = 18
EVAL: BLACK CIRCLE FLUKA: BLUE LONG DASH
NASA: RED SOLID DGM-OM: BLACK SQUARE
B&P: GREEN DOT-DASH W&A: MAGENTA DASH



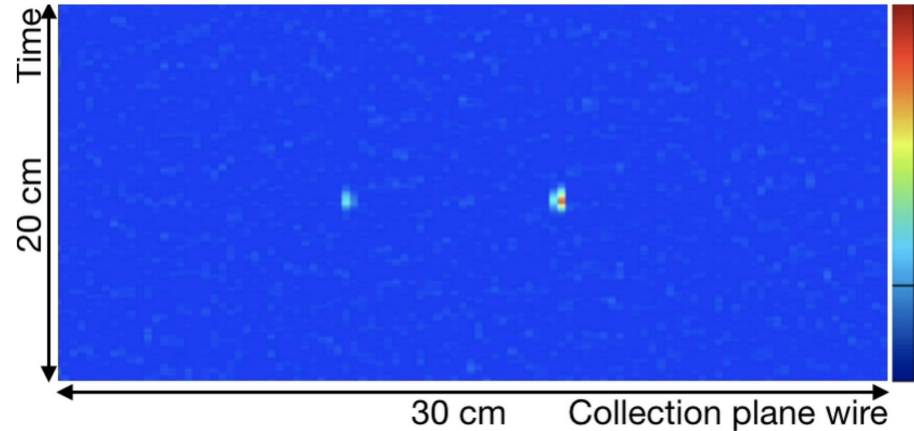
Section 4: Detector Features and R&D

- What do we need to do to make sure our detectors see blips associated with good physics?
 - General requirements
 - Reducing charge collection noise
 - Improving light collection
 - Reducing external bkg (shielding etc)
 - Reducing internal bkg (depletion etc)
 - SP versus DP capabilities
 - Calibrating low energy signals
 - Calibration WITH low energy signals



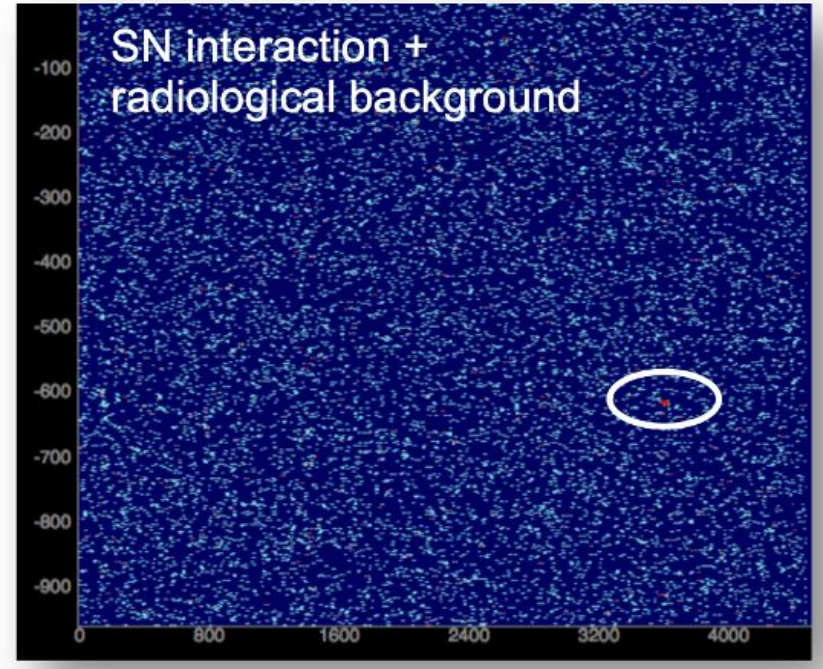
Section 5: Reconstructing LEPLAr signals

- We need to produce a robust reconstruction chain for these kinds of signals
- Low-level processing
 - Hit finding, reco with low S:N
- High-level charge reco
 - 'Blip reconstruction'
- Light-based reconstruction



Section 6: Triggering and Readout Considerations

- How do we pull a blip ‘needle’ out of a DUNE ‘haystack’? We don’t have computing resources to look at every single piece of hay...
 - Solar and supernova ν !
- What are the solutions?
 - Supernova triggering schemes
 - Interesting-TPCs-only readout
 - ‘ROI-only’ triggering/readout
 - ‘Trigger primitives’
 - Fast ML?



G. Karagiorgi

Section 7: Connections and Summary of Needs

- Bulleted list of every ‘recommended item for future measurement/study given in all of the previous sections.’
- Tables relating ‘LEPLAr physics goals’ to ‘Required modelling, detector, reco, and triggering developments/improvements’

Draft will be sent to DUNE APB (December 15)

Low Energy Physics in Liquid Argon

The LEPLAr Workshop Convener Team

2021

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Likely configuration
Will be “limited
authorship” and open to
non-DUNE authors
(TBC)

We can cross-reference
related white papers!