



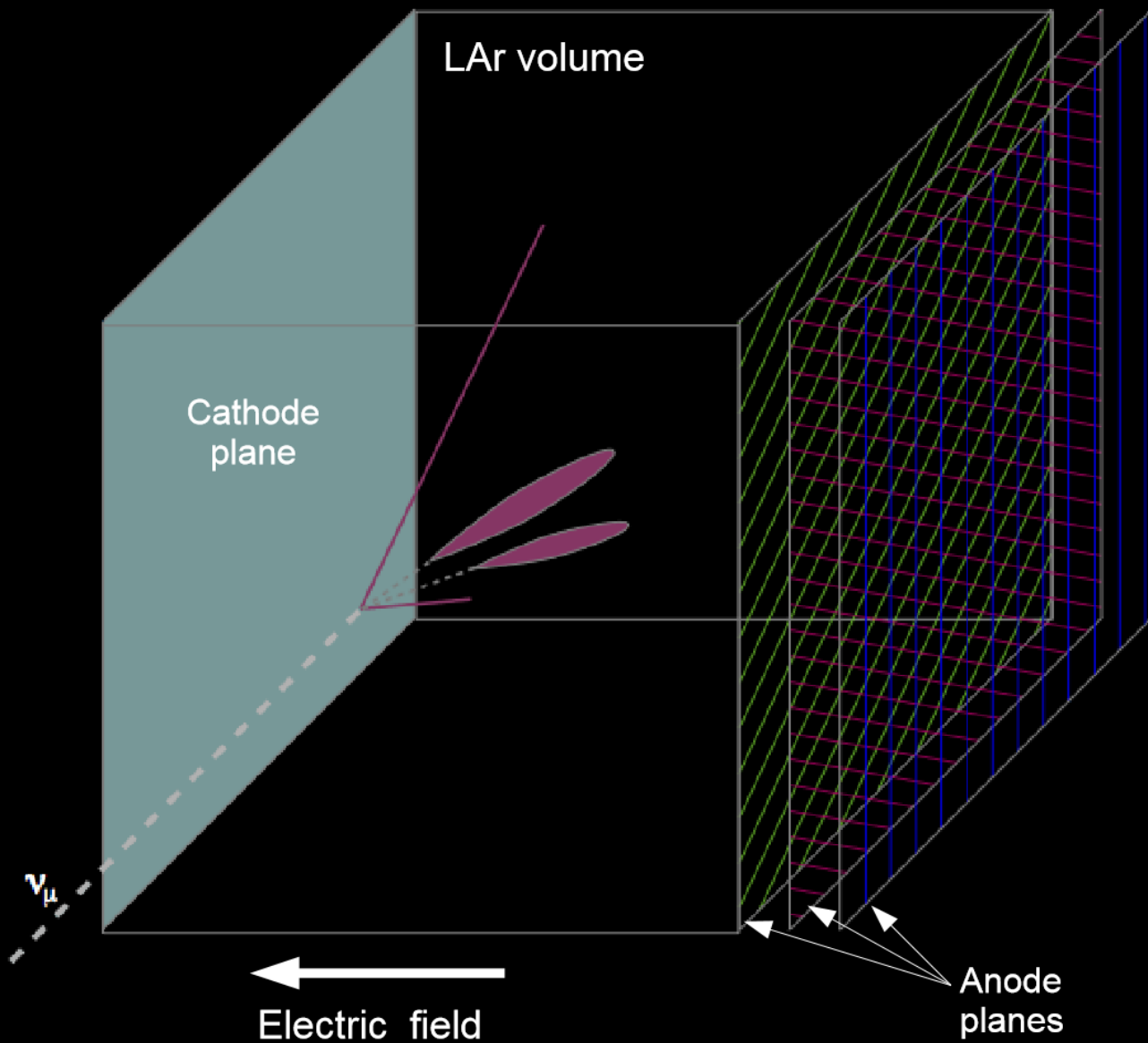
LArTPC detector basics, ProtoDUNE, DUNE goals

Dorota Stefan (CERN/NCBJ)

LArTPC: Liquid Argon Time Projection Chamber

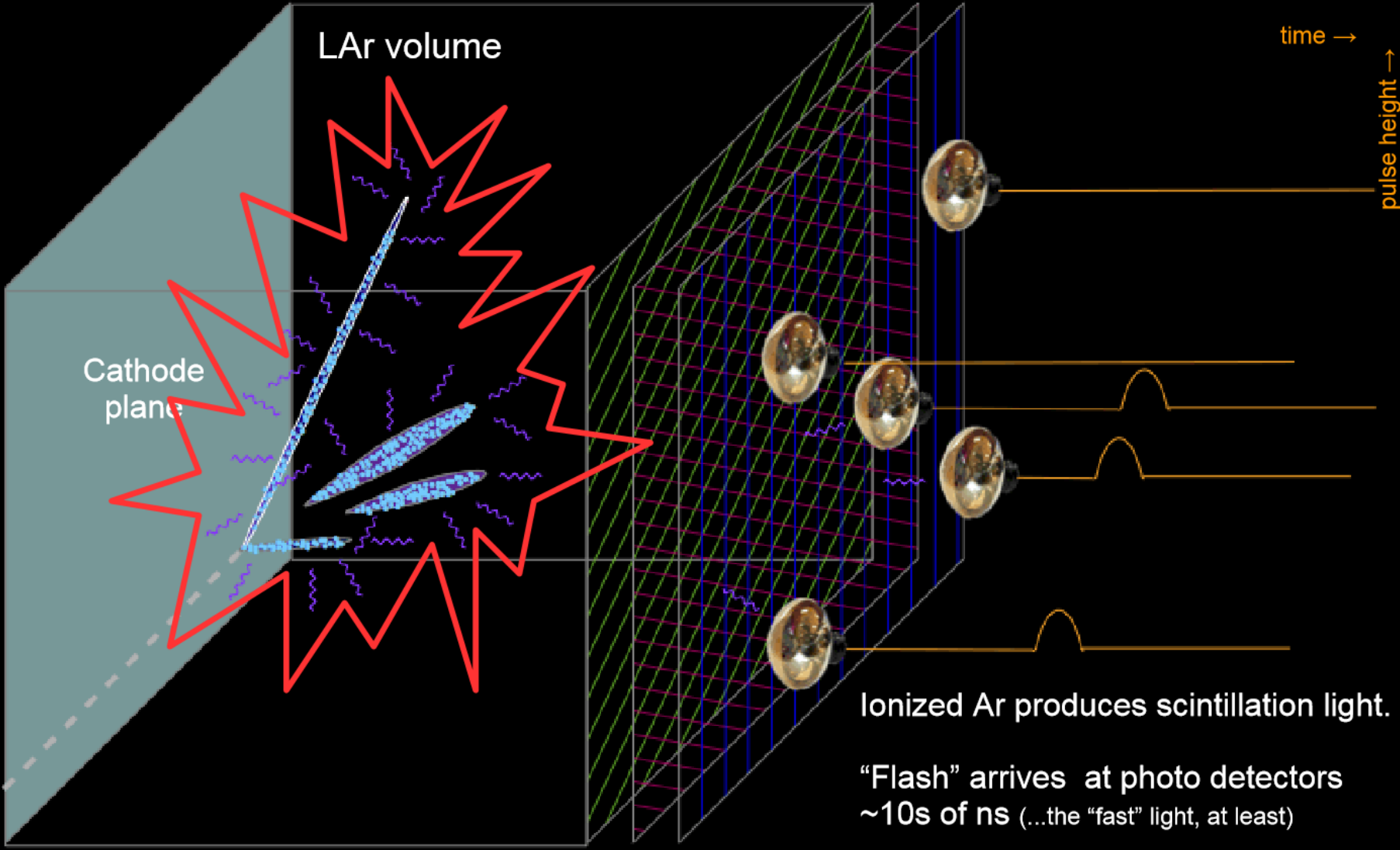
- Liquid argon is denser than water or oil → more neutrino collisions per unit volume.
- It acts as both a target and detector for neutrinos.
- Both tracking and calorimeter at the same time.
- Argon is transparent to own light.
- Ability to record charge particles, neutrino vertex.
- Relatively small radiation length for shower containment.

Operation of single-phase LAr TPC



*Slides from Erica Snider,
<https://indico.fnal.gov/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=12889>*

Operation of single-phase LAr TPC



v_d

Cathode plane

LAr volume

time →

pulse height →

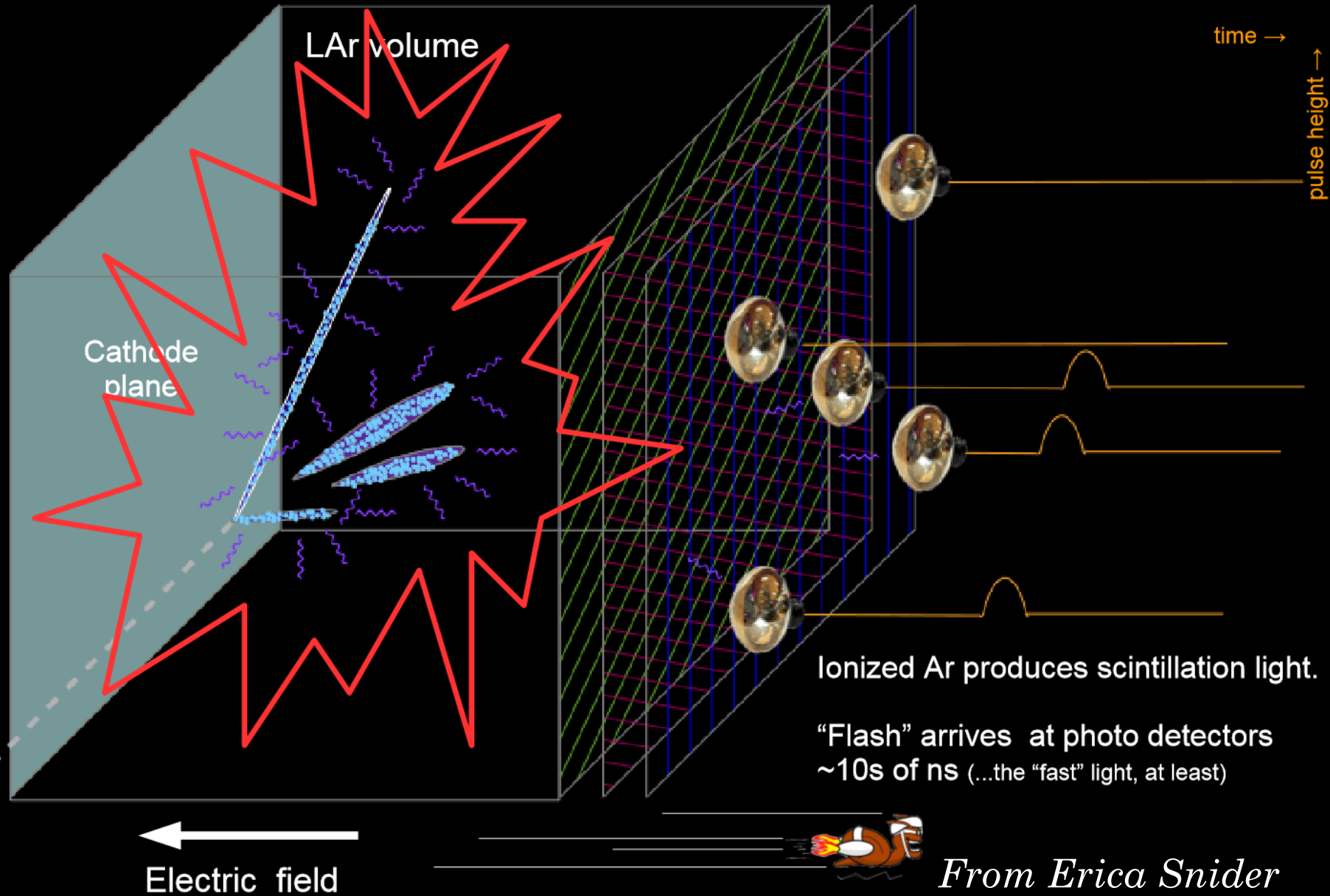
Ionized Ar produces scintillation light.

“Flash” arrives at photo detectors
~10s of ns (...the “fast” light, at least)

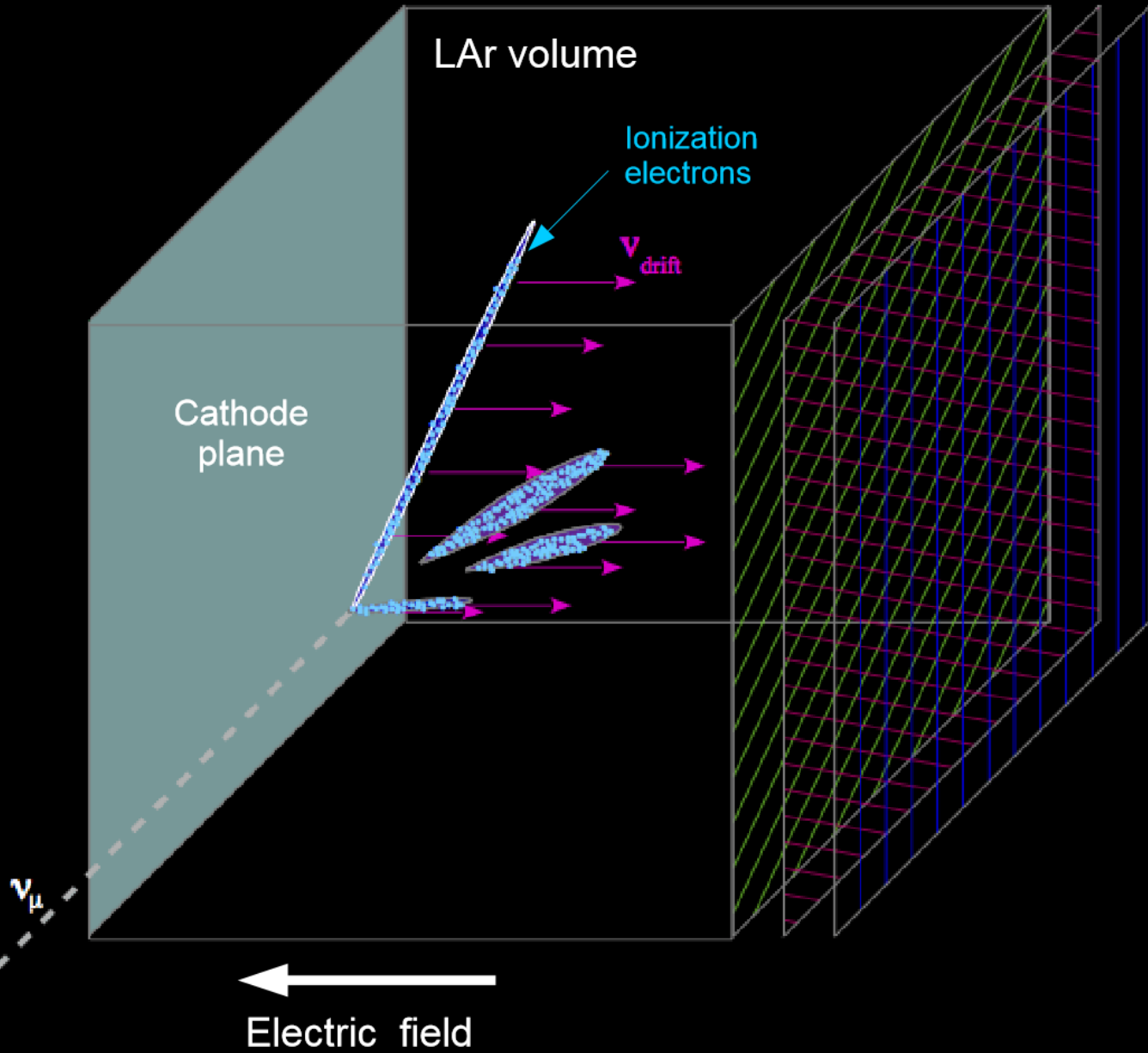
← Electric field

From Erica Snider

Operation of single-phase LAr TPC



Operation of single-phase LAr TPC



Neutrino interacts with Ar nucleus

Charged secondaries ionize the Ar

Electrons drift in the electric field toward anode wires

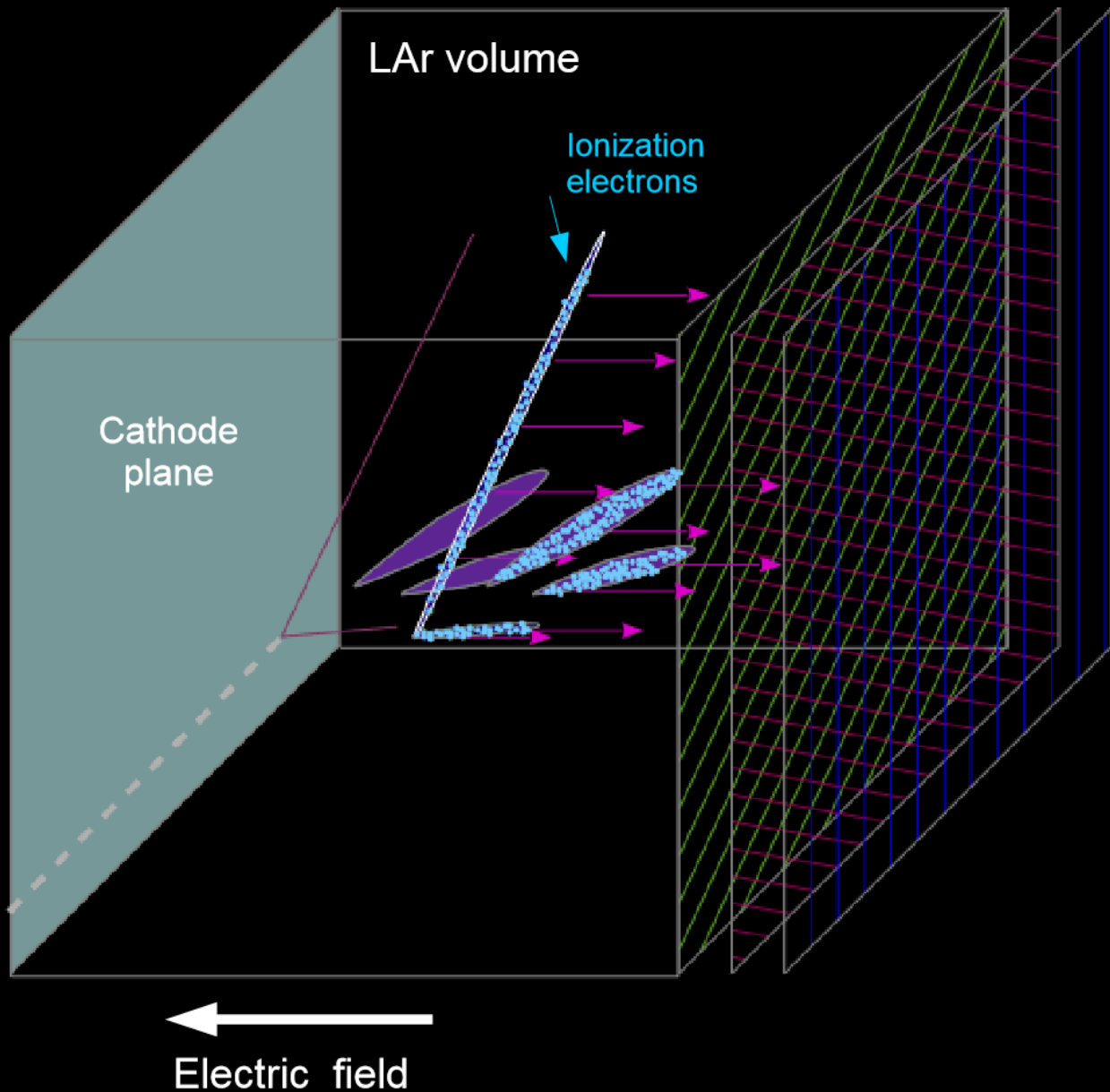
$$v_{drift} \approx 1 - \text{few mm}/\mu\text{s}$$



Max drift time ~ ms!!

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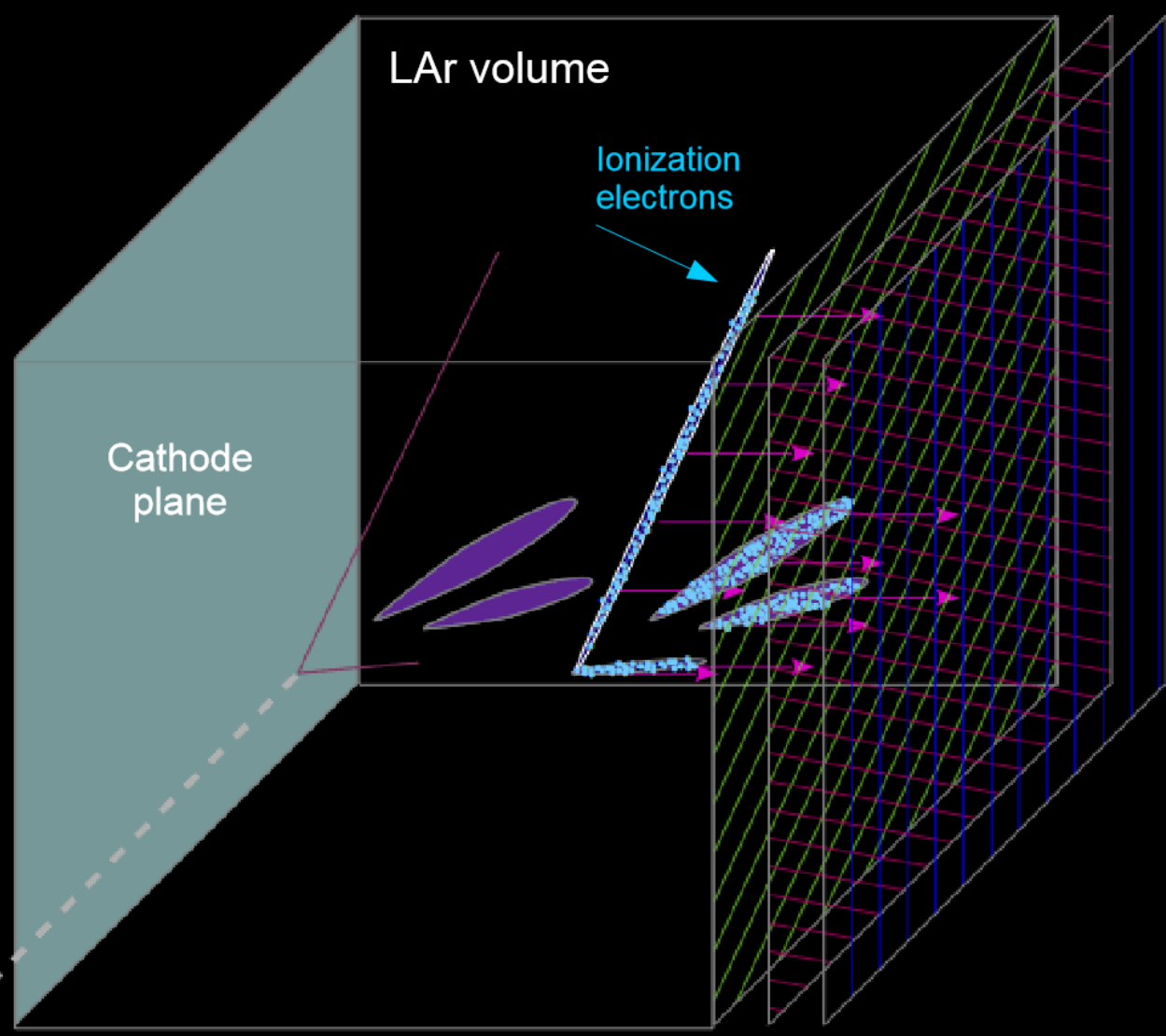
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Max drift time \sim ms!!

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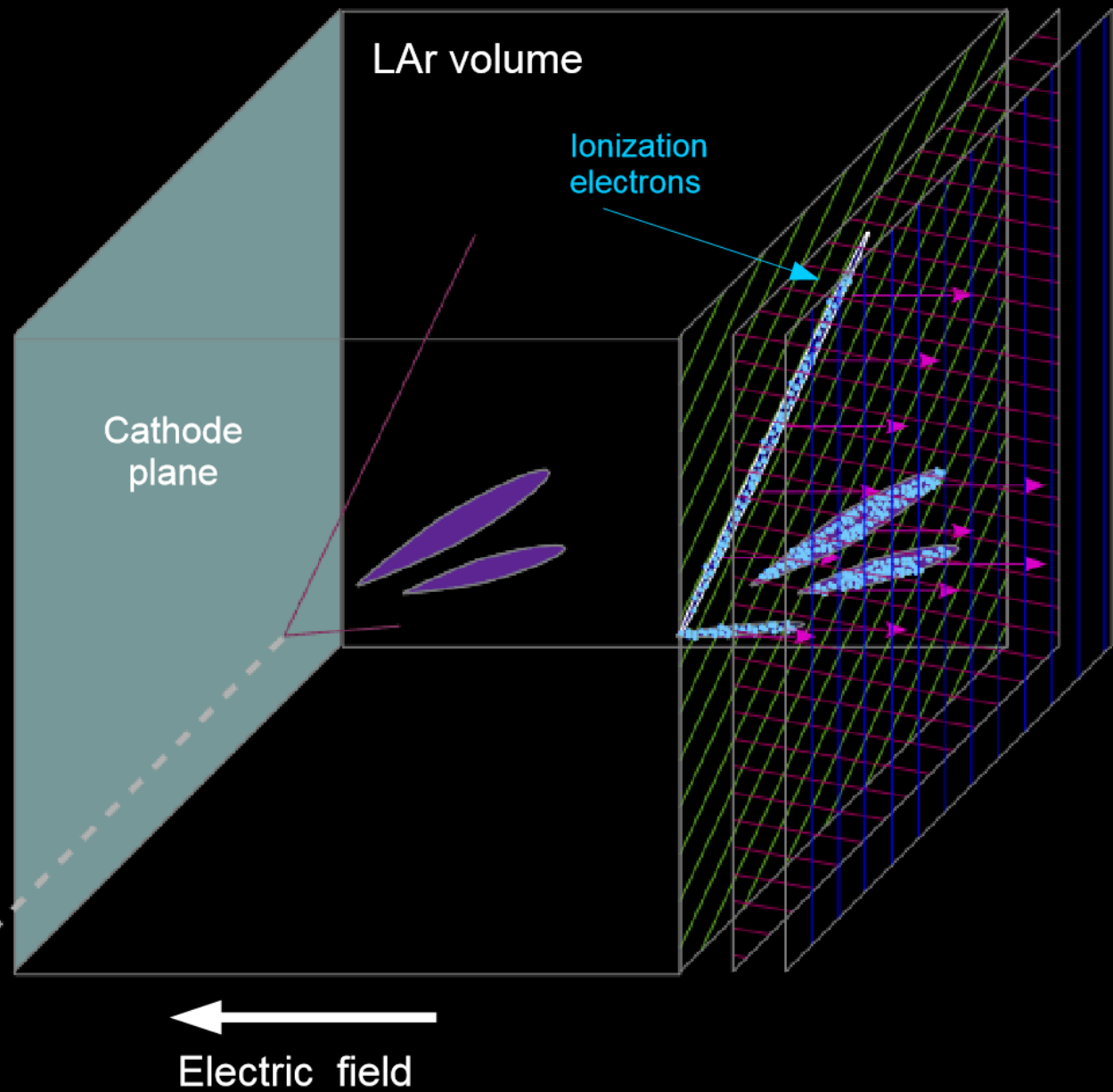


Max drift time ~ ms!!

←
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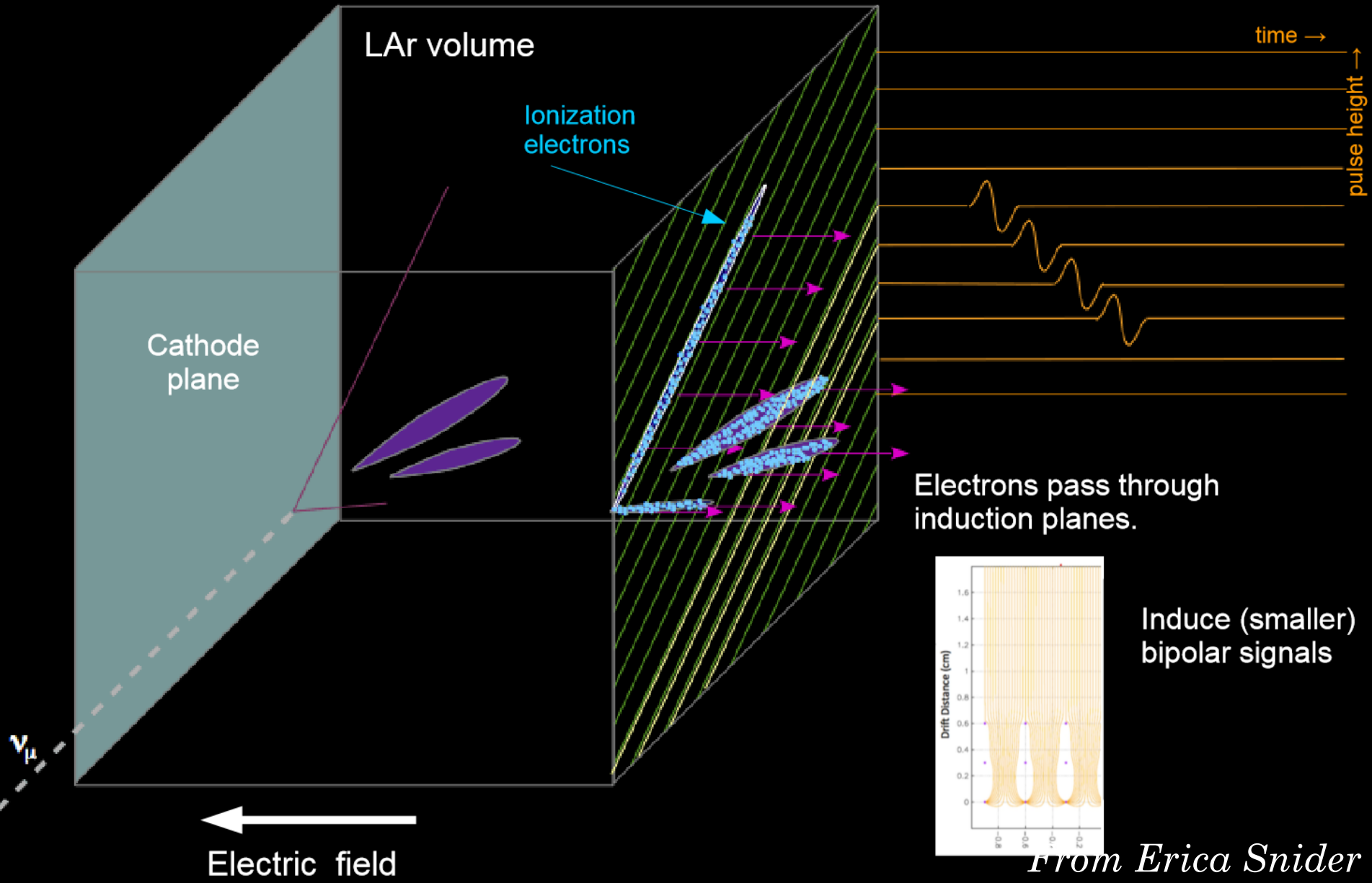
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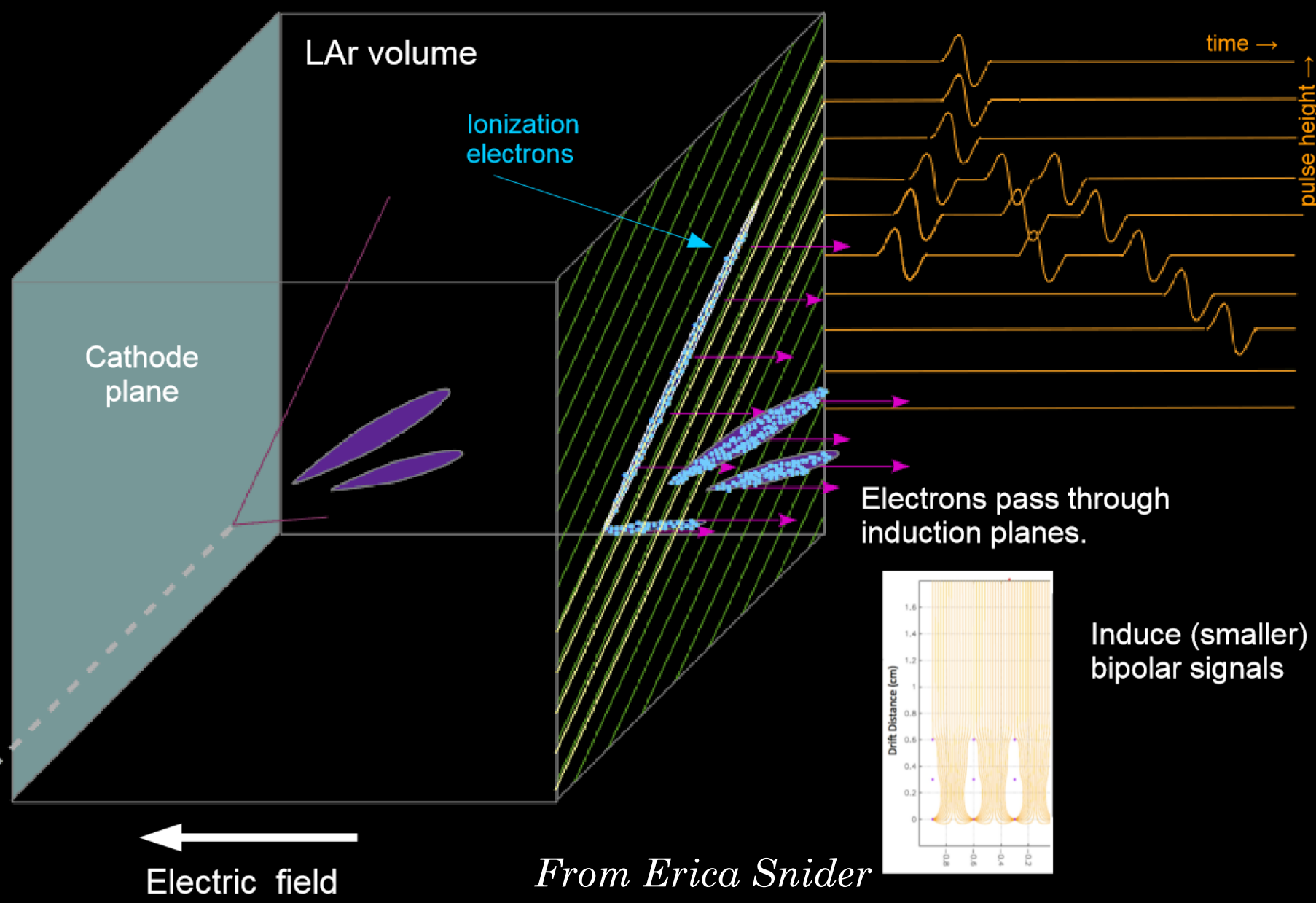
Max drift time ~ ms!!

From Erica Snider

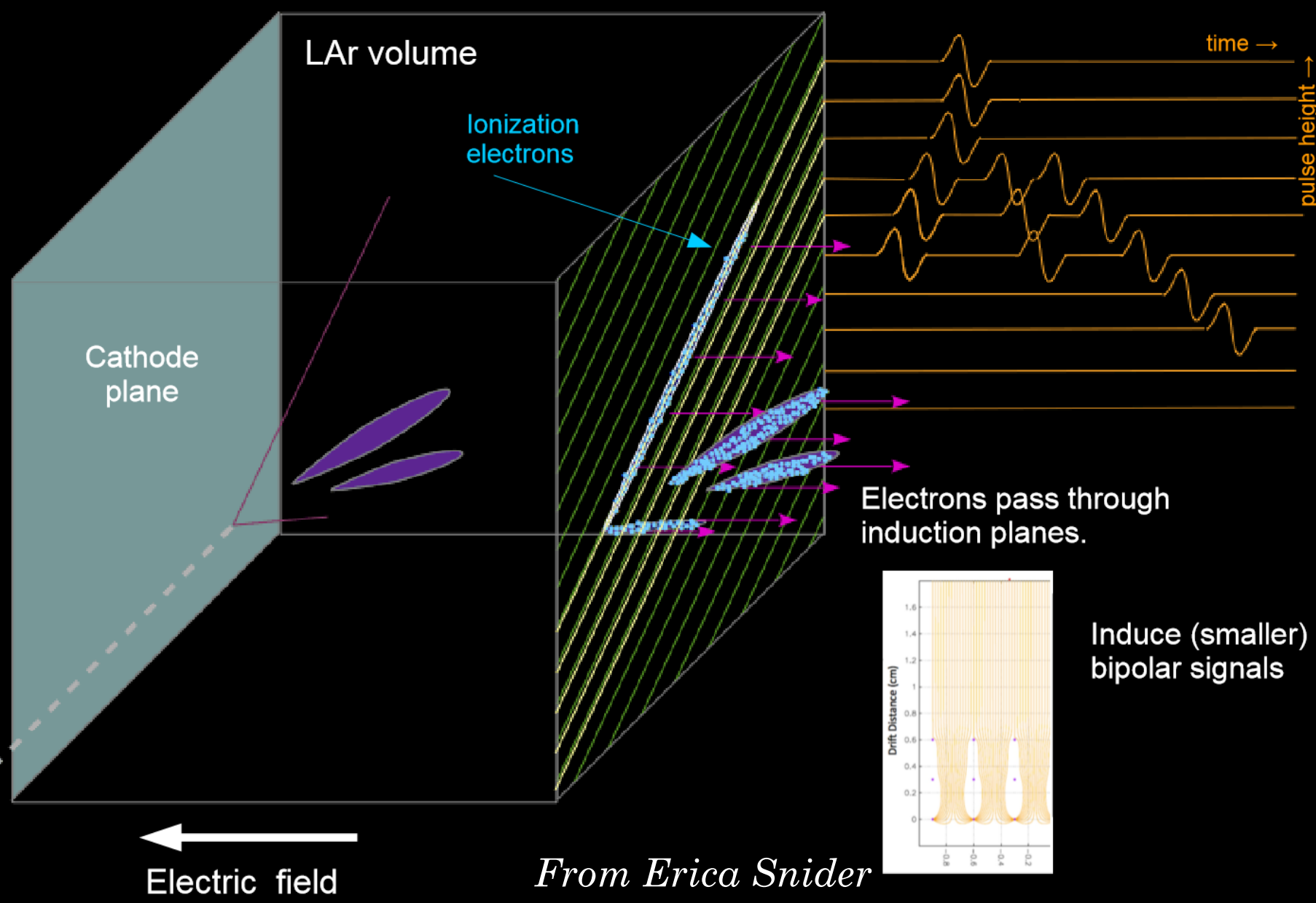
Operation of single-phase LAr TPC



Operation of single-phase LAr TPC



Operation of single-phase LAr TPC



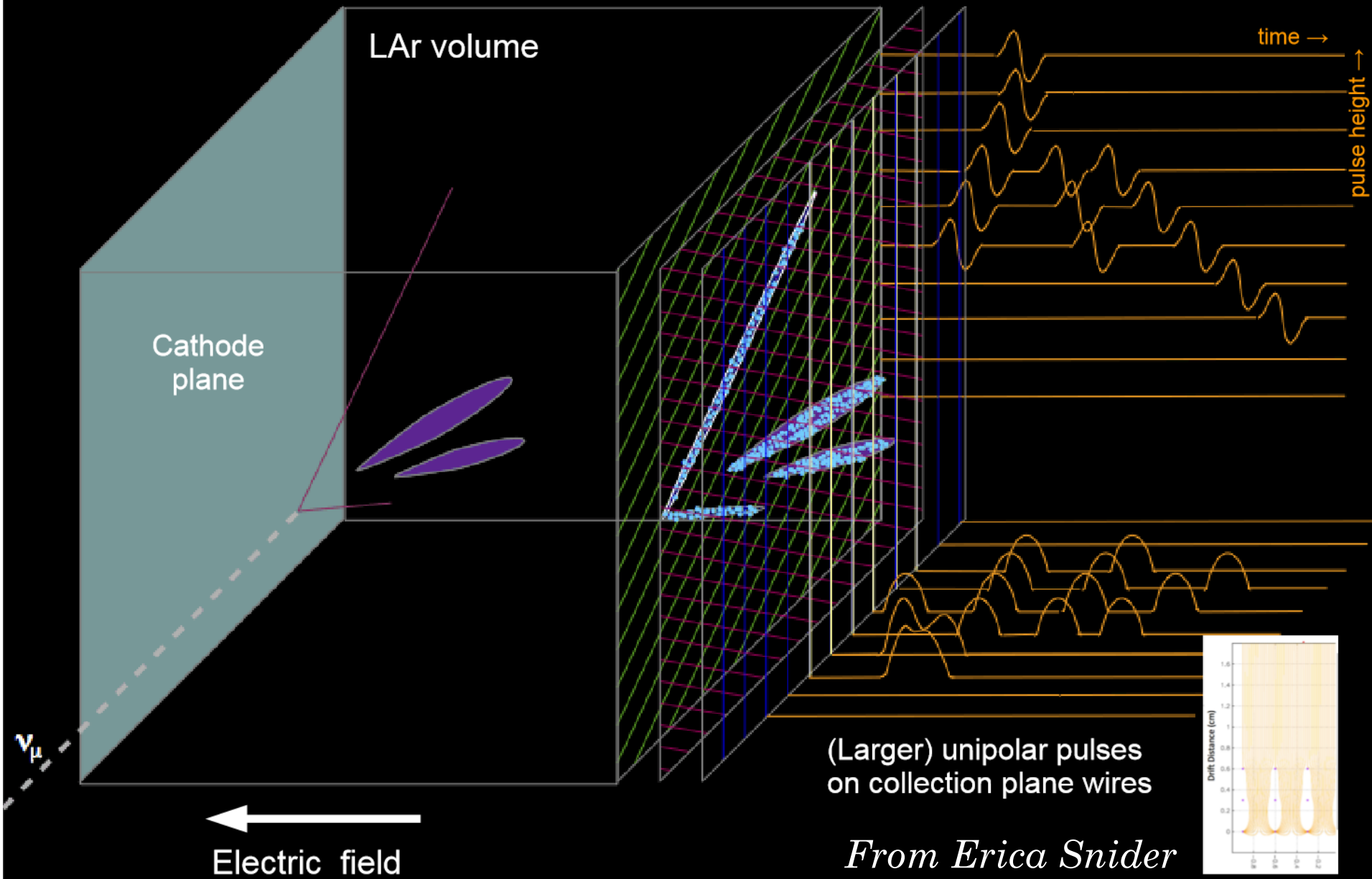
Electric field

From Erica Snider

Electrons pass through induction planes.

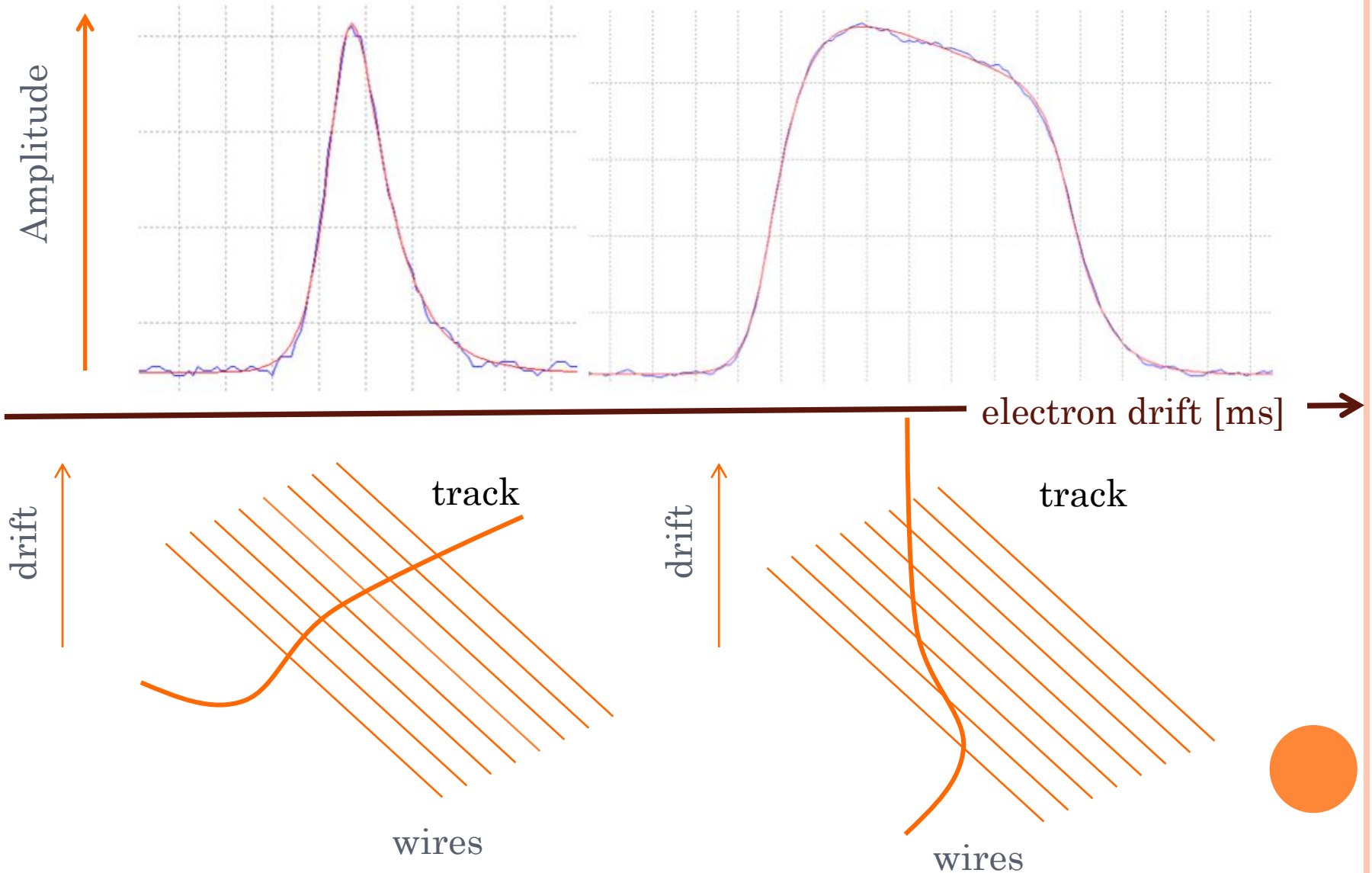
Induce (smaller) bipolar signals

Operation of single-phase LAr TPC



From Erica Snider

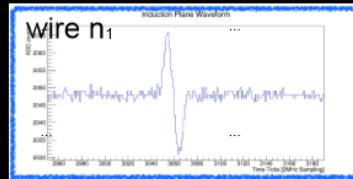
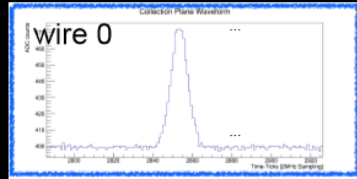
Signal shape/amplitude depends on track inclination



Operation of single-phase LAr TPC

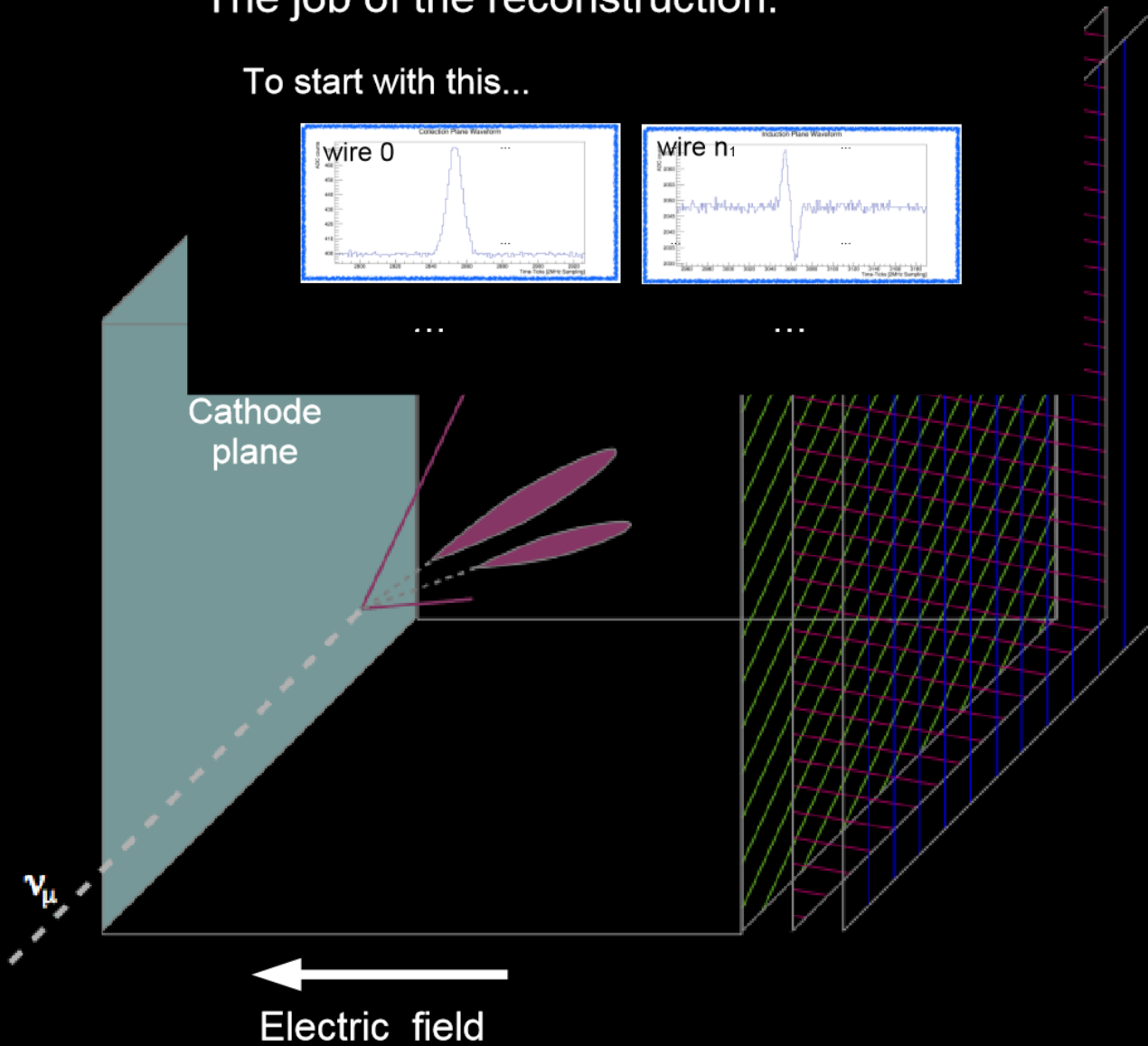
The job of the reconstruction:

To start with this...



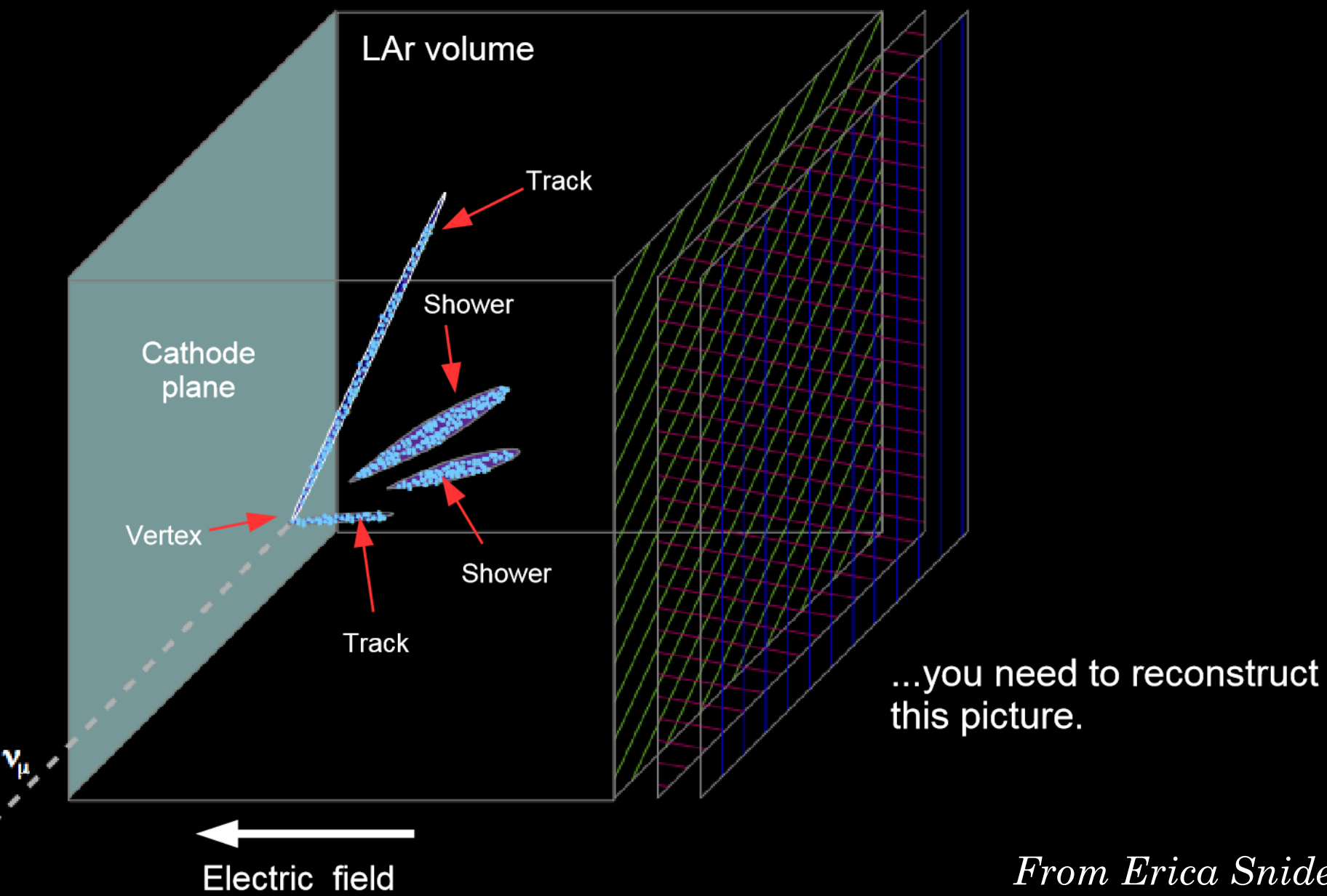
...

...



From Erica Snider

Operation of single-phase LAr TPC



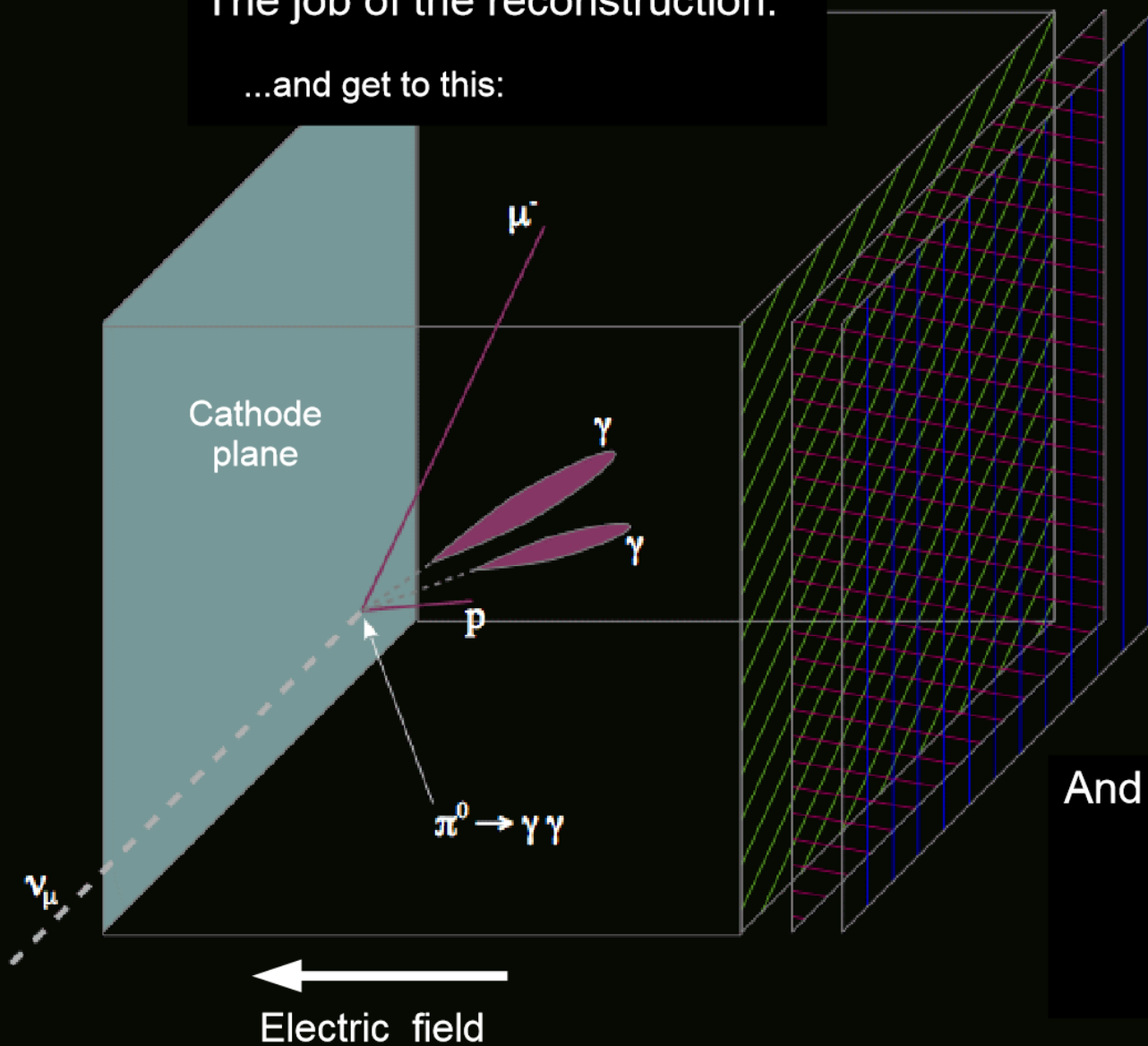
...you need to reconstruct this picture.

From Erica Snider

Operation of single-phase LAr TPC

The job of the reconstruction:

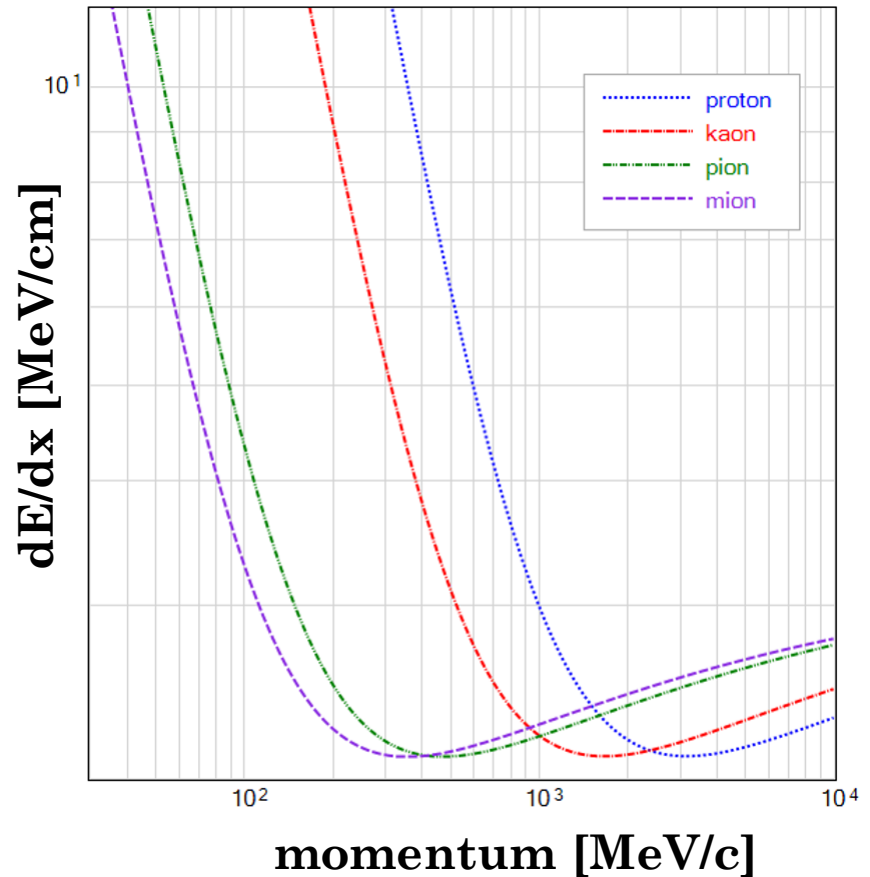
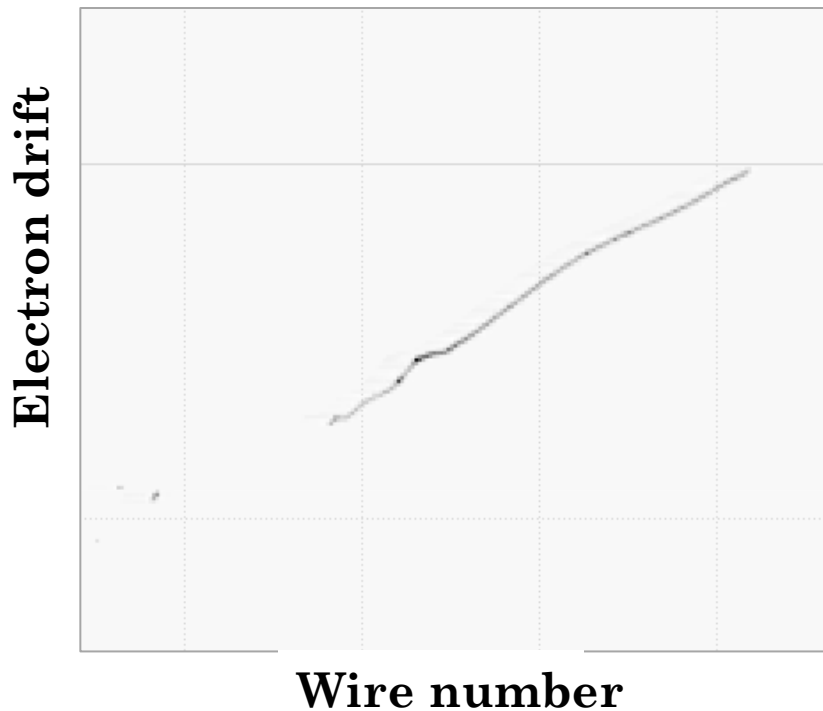
...and get to this:



And to get here...

From Erica Snider

Stopping/decaying particle identification

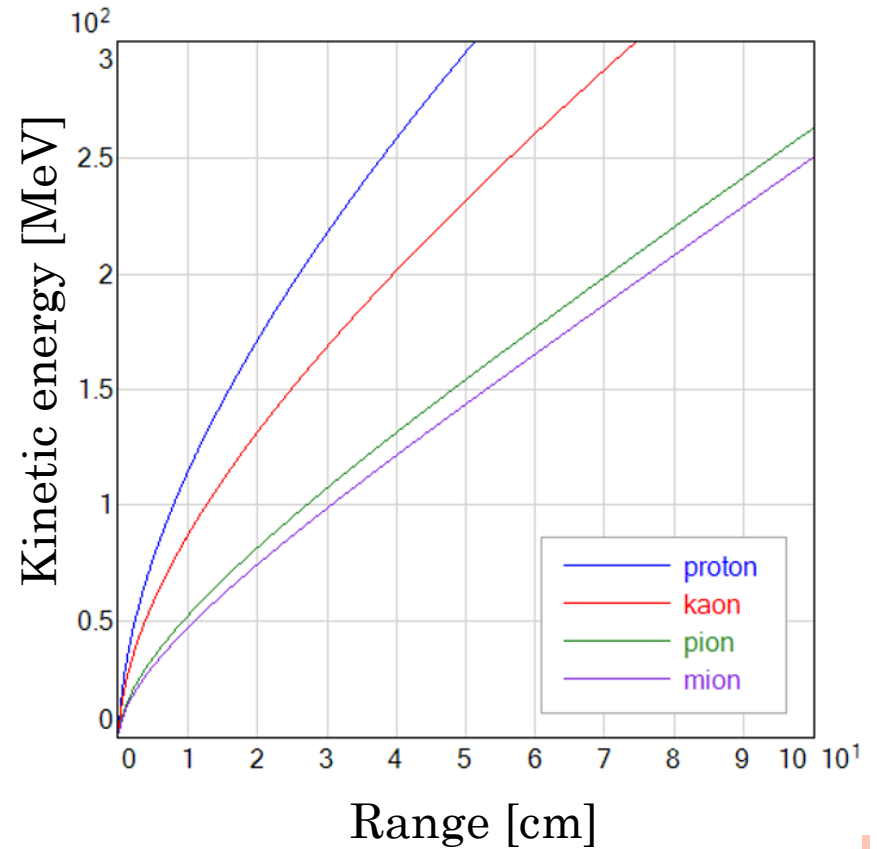
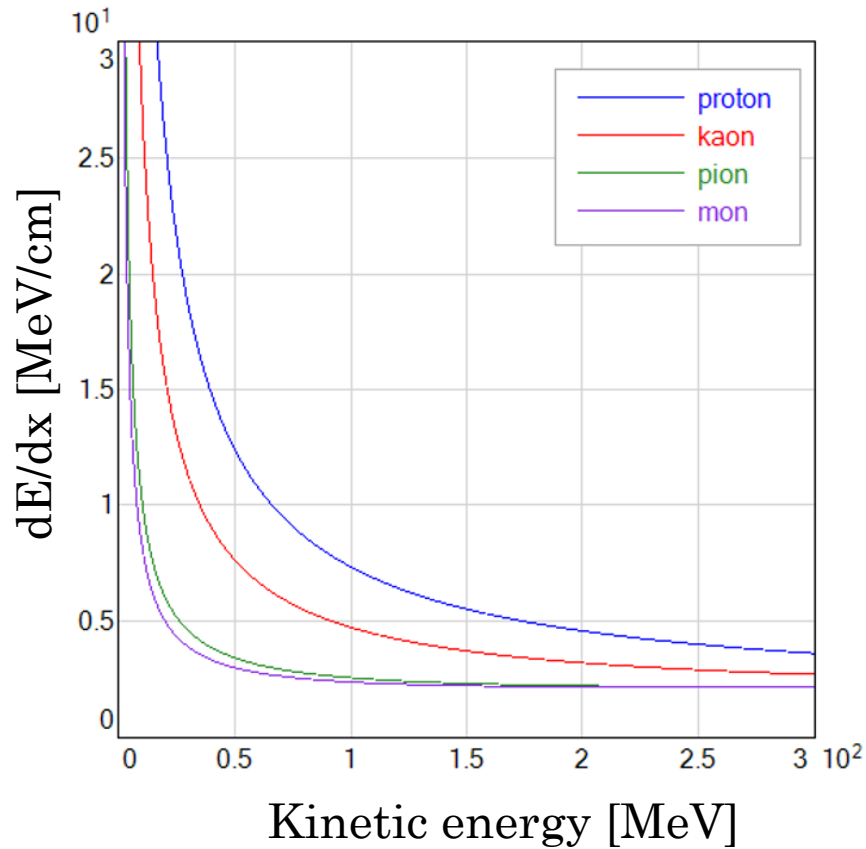


Bethe-Bloch equation

$$- \langle dE/dx(\beta) \rangle = 2\pi N_A r_e^2 m_e c^2 \frac{Z}{A} \frac{z^2}{\beta^2} \rho \left[\ln\left(\frac{2m_e c^2 \beta^2 \gamma^2 W_{max}}{I^2}\right) - 2\beta^2 - \delta - 2\frac{D}{Z} \right]$$

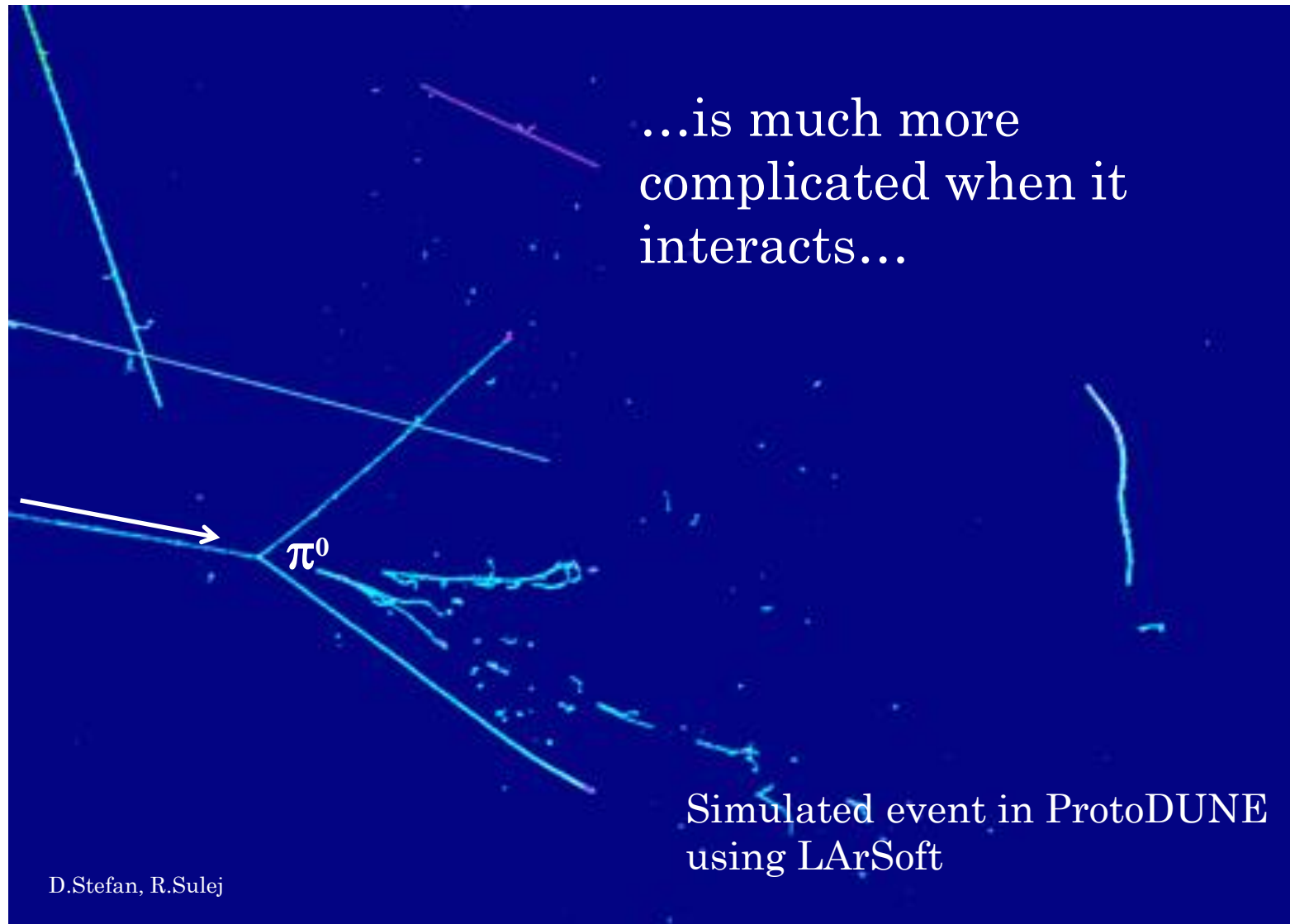


Stopping particle identification



Particle identification of incoming particle...

...is much more complicated when it interacts...



D.Stefan, R.Sulej

Simulated event in ProtoDUNE
using LArSoft



Attenuation: electron lifetime

- Infinite electron lifetime is only possible in perfectly purified liquid argon.
- Electronegative impurities capture electrons, decreasing electron lifetime.

Energy
corrected for
electron lifetime

$$E_{\tau_e} = e^{(t-t_0)/\tau_e} \Delta E$$

Energy from
signal on wires

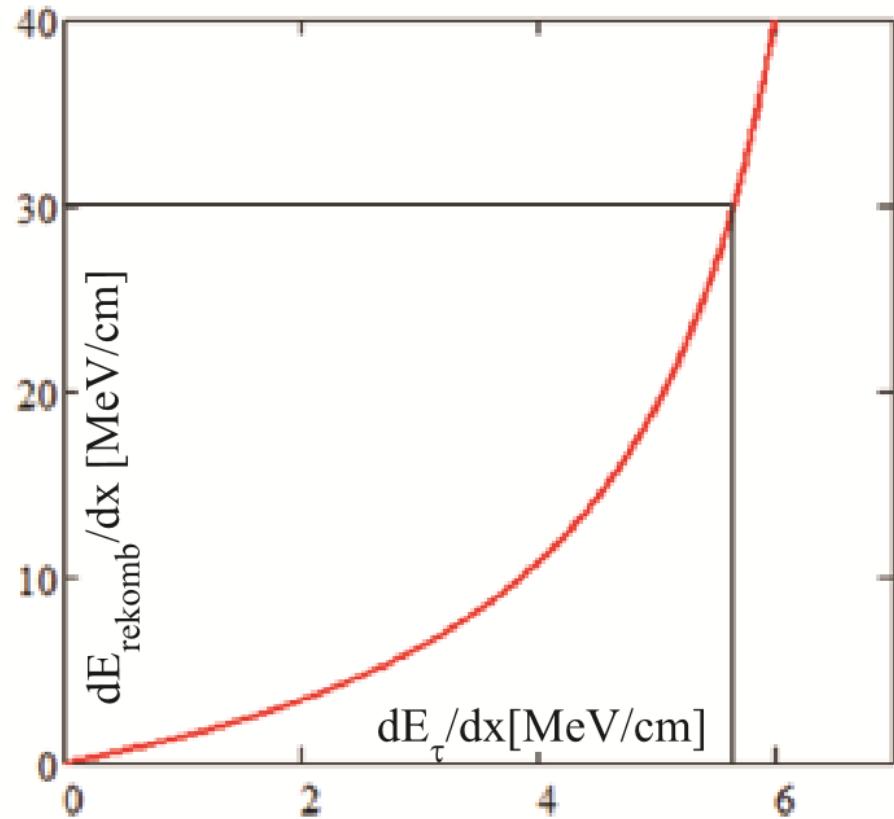


Attenuation: recombination effect

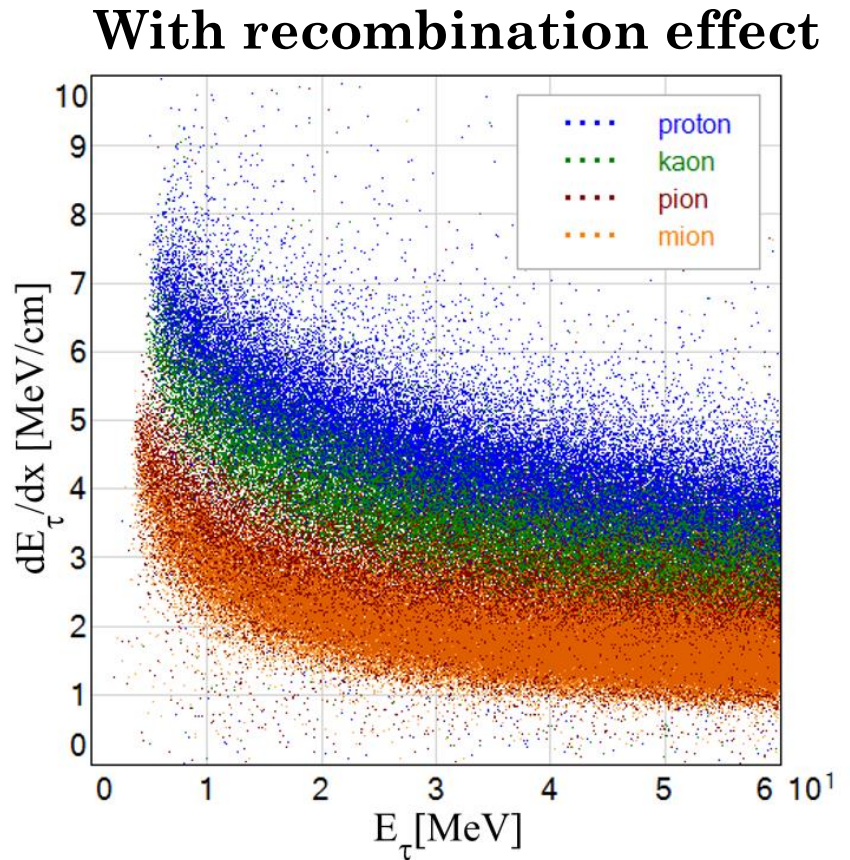
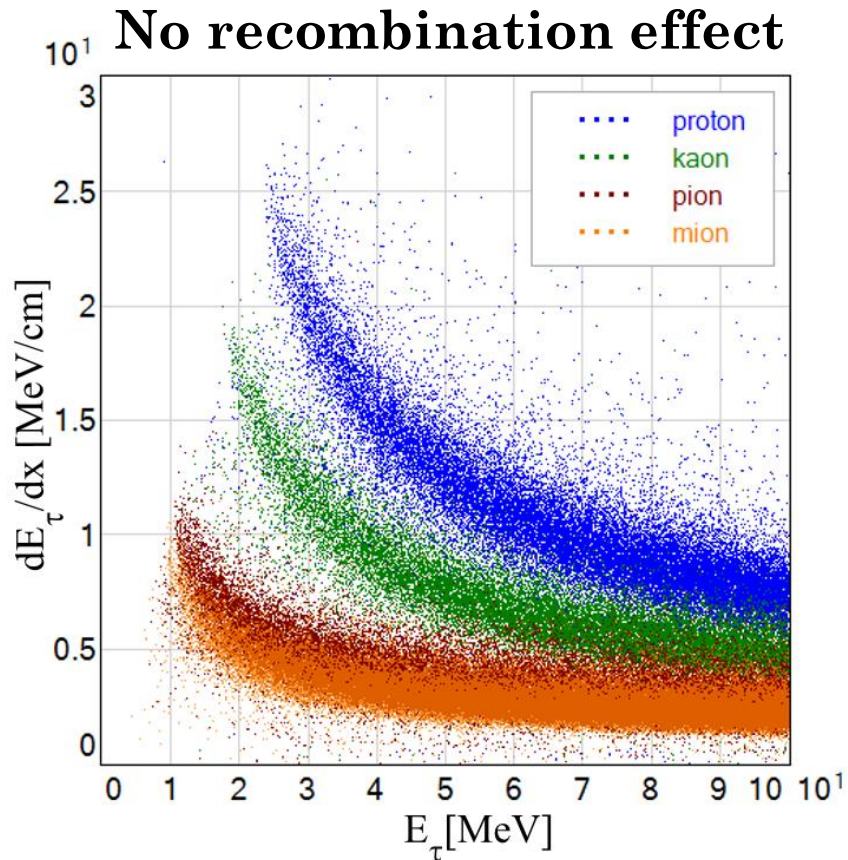
Part of electrons will recombined with the positively charged molecules of argon.

$$dE_{\text{recomb}} = \frac{dE_{\tau e}}{A - \frac{k}{\epsilon \rho} dE_{\tau e}/dx}$$

A, k – parameters
 ρ – argon density
 ϵ – electric field



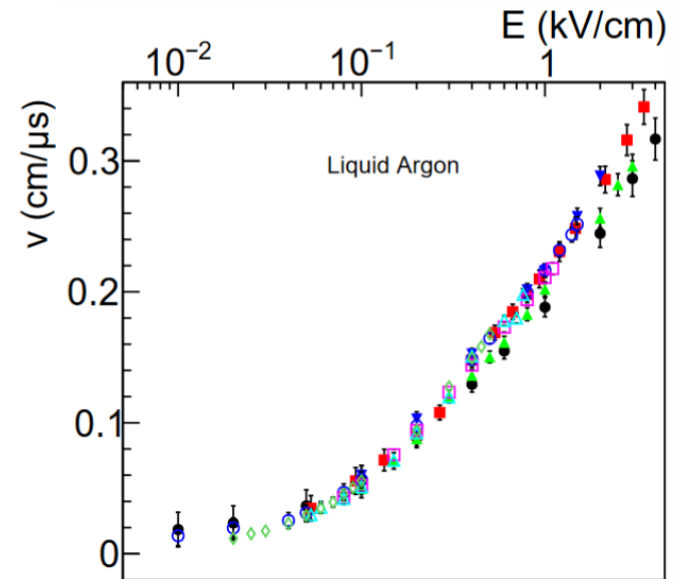
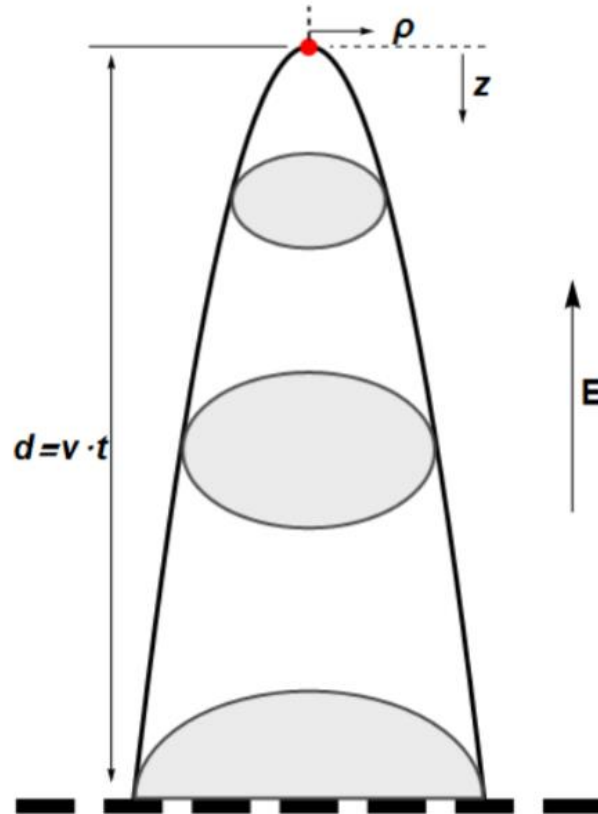
Recombination effect



+the angular dependence of electron recombination, maybe possible to be studied in ProtoDUNE



Diffusion



- Diffusion limits the spatial resolution of tracks with long distances.
- For 3.6 meter drift: 1.8 mm longitudinal and 2.5 mm transverse to the electric field at 500 V/cm.

From arXiv: 1508.07059

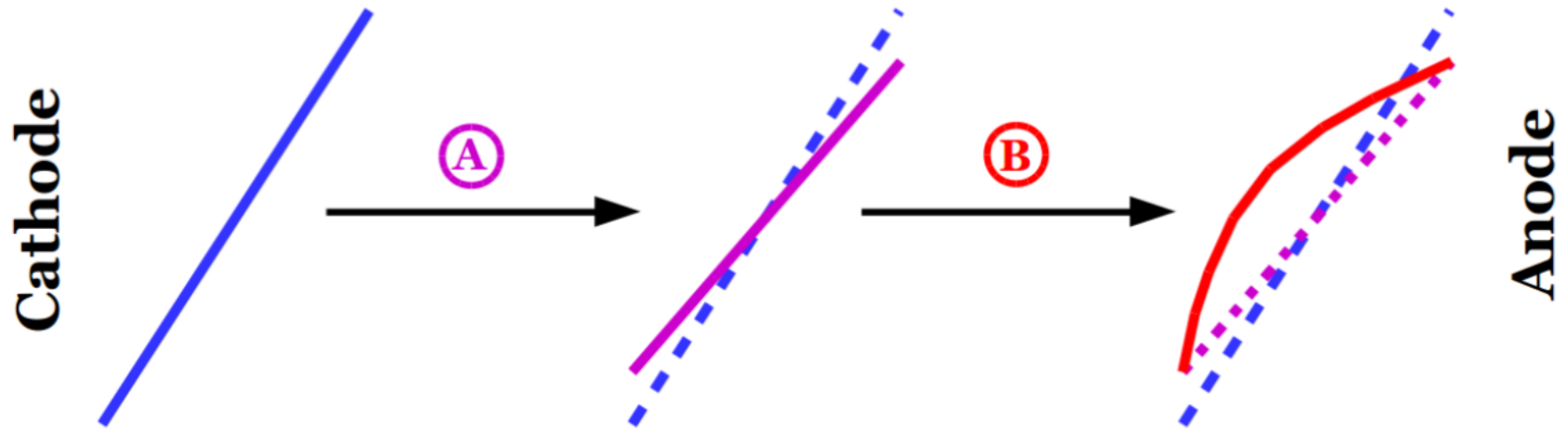


Space charge effect

- Space charge effect is present in the detector on the surface (MicroBooNE, ProtoDUNE).
- Mainly generated by ionization from cosmic rays and it happens due to build-up of slow-moving positive ions in a detector.
- Leads to distortion of the electric field within the detector.



Space charge effect

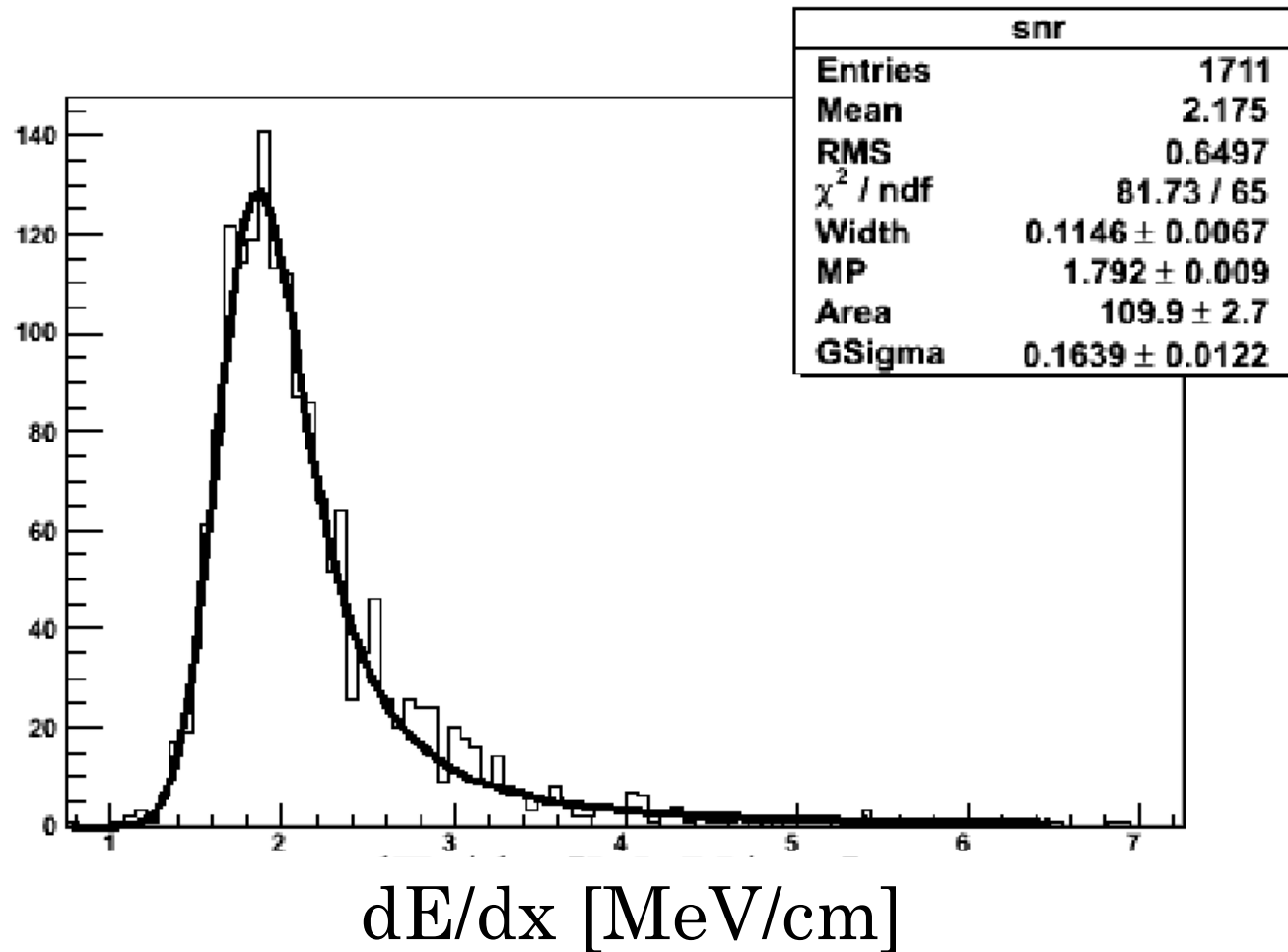


Studies performed in MicroBooNE

<https://arxiv.org/pdf/1511.01563v1.pdf>



Single ionizing particle

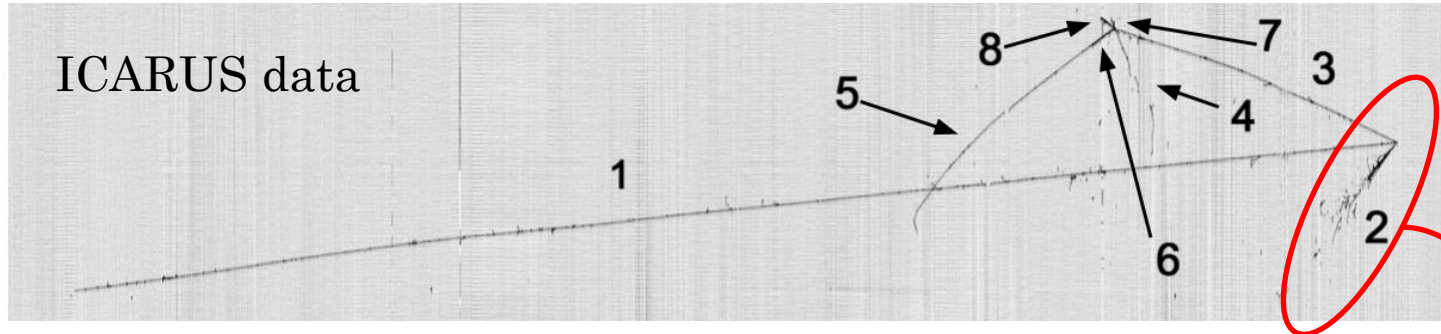


DUNE/ProtoDUNE Goals

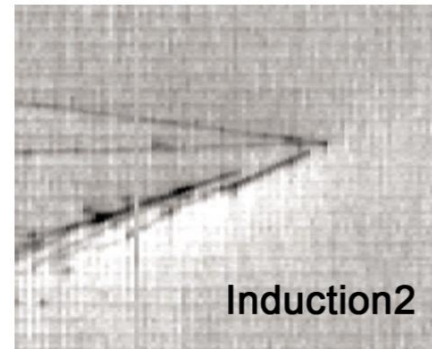
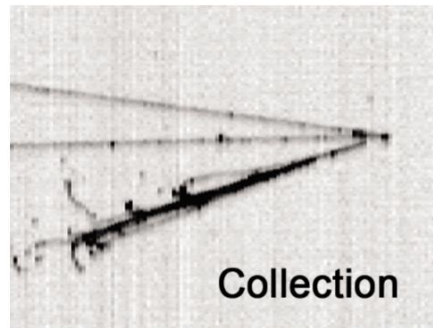
- DUNE: One of the main topic is CP violation in leptonic sector:
 - event classification: needed reconstructed details of the neutrino vertex,
 - neutrino energy reconstruction.more in <https://dunescience.org>
- In ProtoDUNEs: validation of the reconstruction tools. Hadronic shower reconstruction/analysis. Detector performance study for DUNE physics.



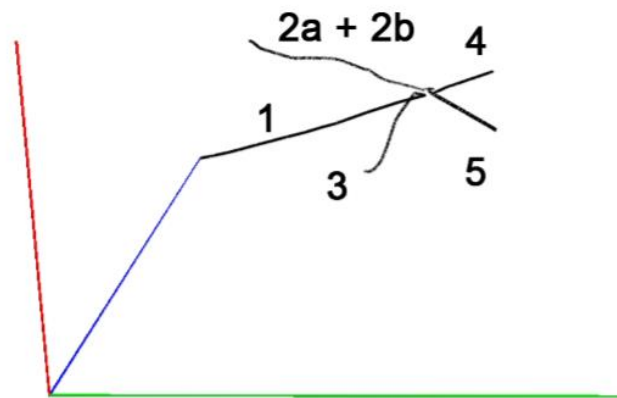
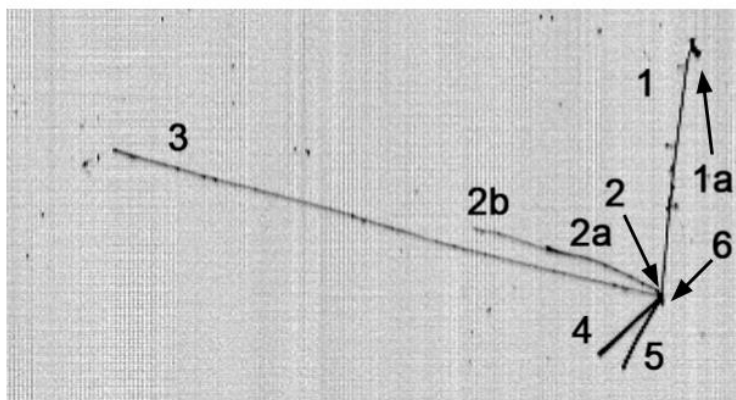
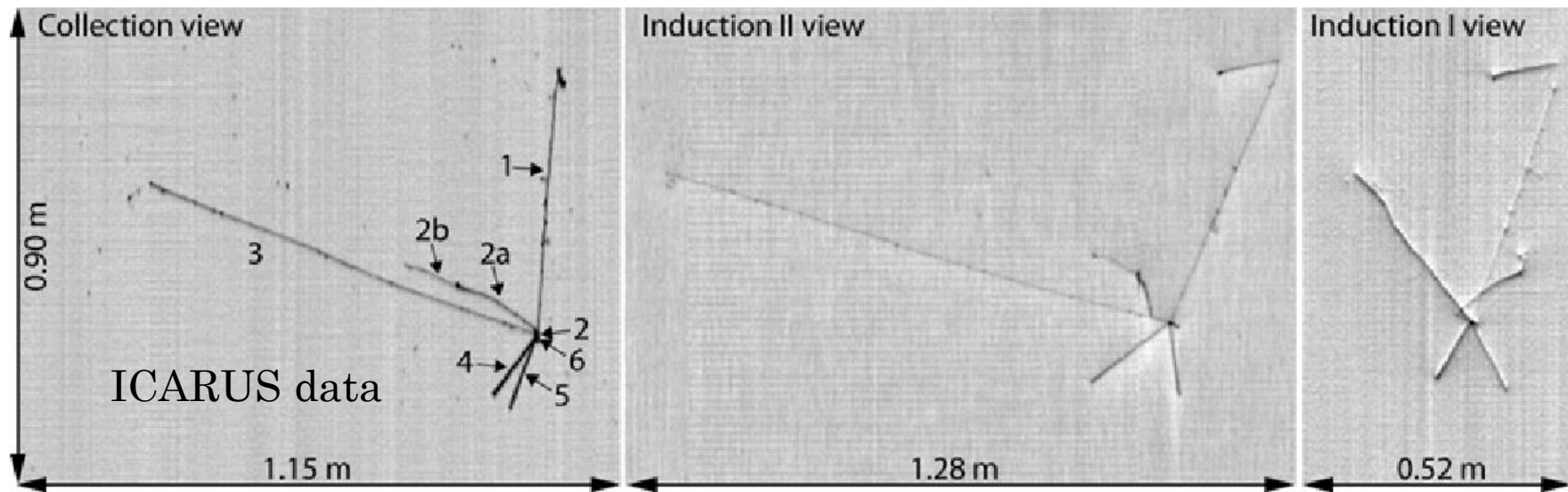
Reconstruction/analysis



Reconstruction of primary vertex is crucial for event classification:



Reconstruction/analysis



- Reconstruction is a key element to perform detector calibration and physics.
- Let's start to look at the simulation and reconstruction output and extract some basic information using LArSoft framework.

