Fermilab

Magnetizing LArTPCs

a.k.a. **ArCS** (**Ar**gon detector with **C**harge **S**eparation)

FNAL-LDRD-2022-001

Marco Del Tutto

Neutrino Division All-Hands Meeting

Fermilab

18th April 2023

Introduction

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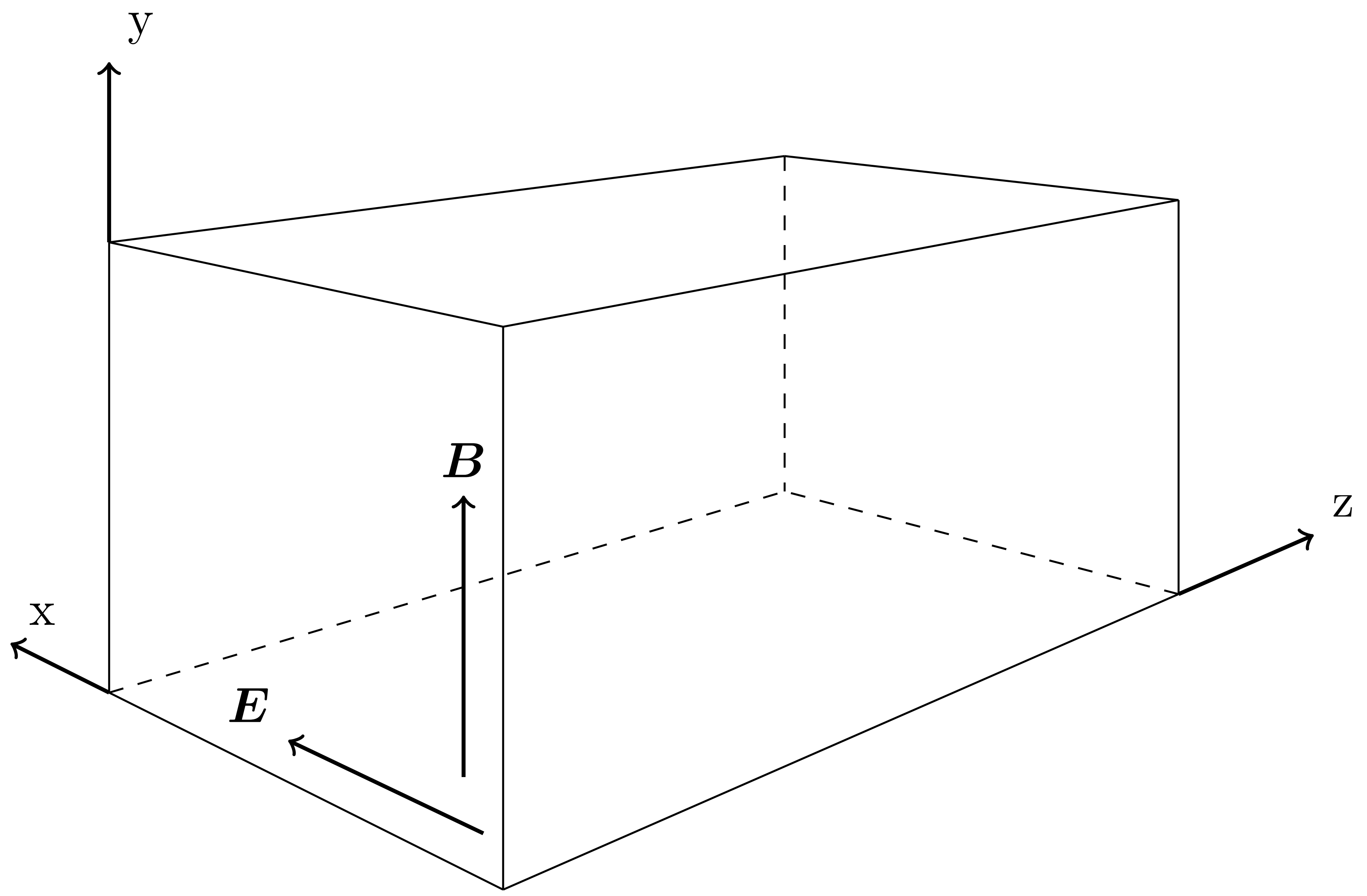
- LArTPCs
- The benefits of a magnetized LArTPC
- ArCS
- Current status:
  - Cryostats
  - Beamline
  - TPC

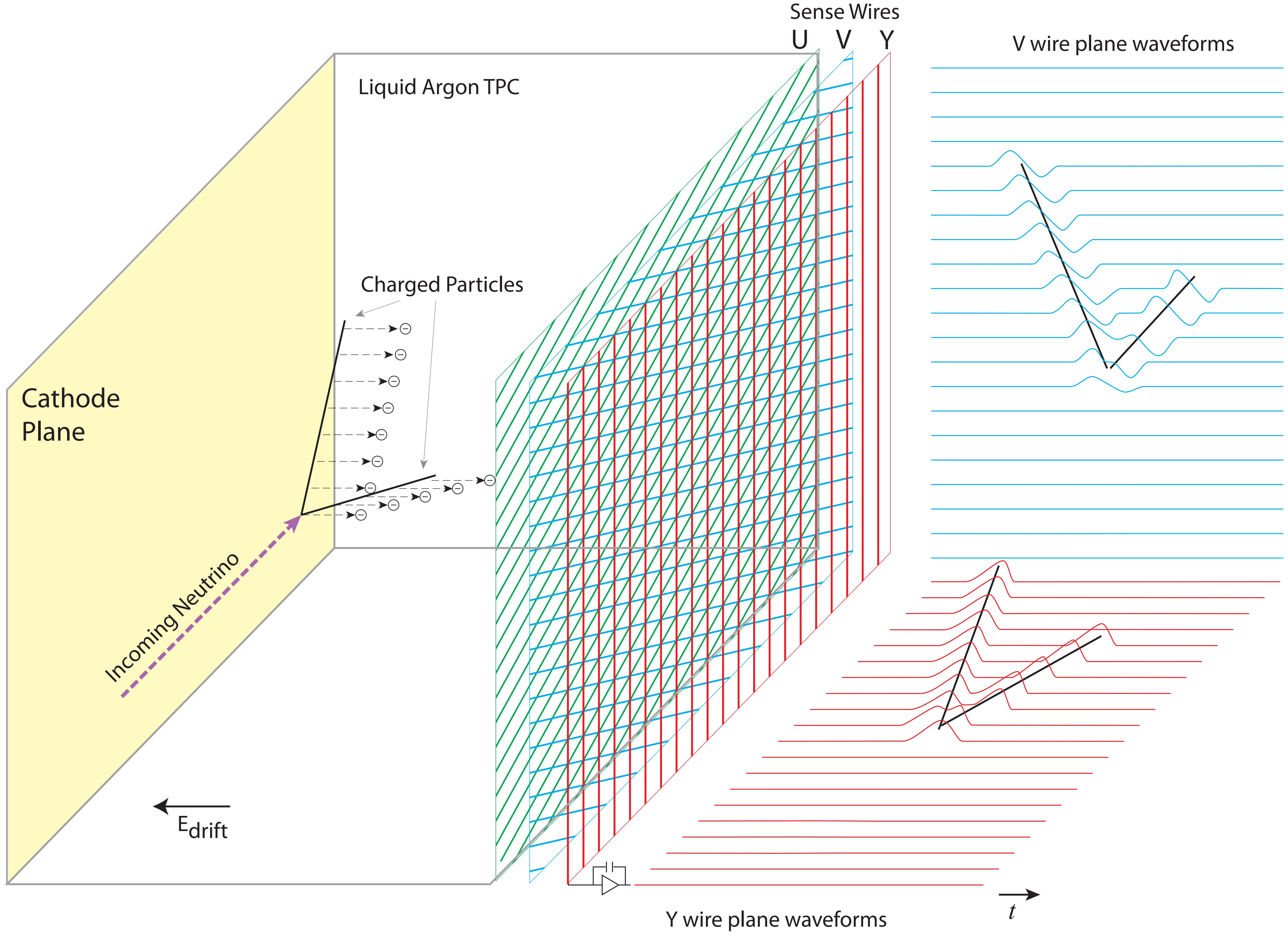
Introduction



ArCS in an LDRD-funded project

The scope of ArCS is to demonstrate that a **LArTPC** detector can operate in a **magnetic field** and establish the minimum field required to measure the sign of particles' charges and momenta.

Liquid Argon Time Projection Chamber

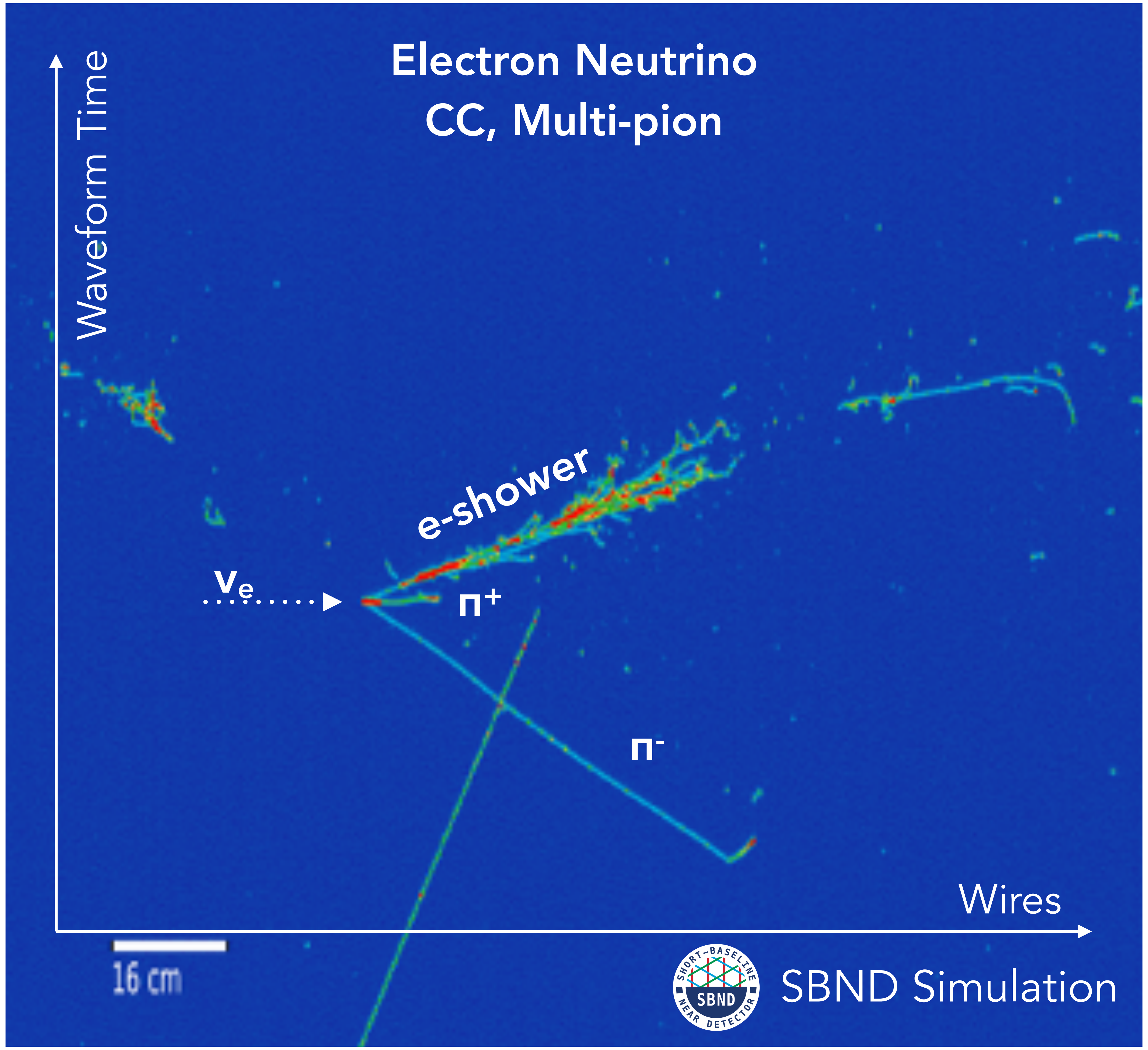


- Charged particles in LAr produce ionization electrons.
- The ionization is drifted in a uniform electric field.
- And is then read out using wires.

Scintillation light is also produced, read out by PMTs

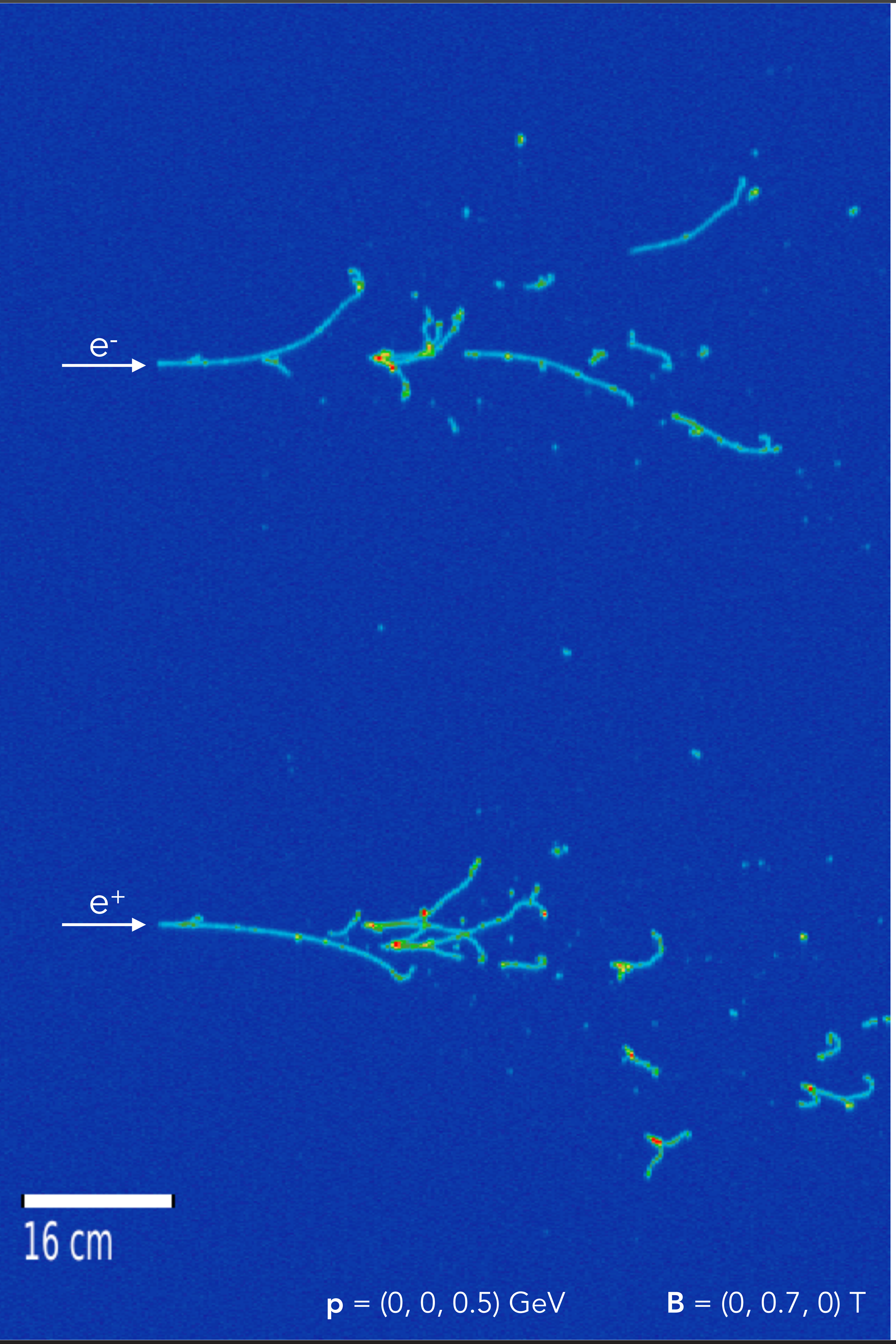
Liquid Argon Time Projection Chamber

LArTPCs allow recording image-quality snapshots of neutrino interaction with high resolution (~3mm)



One limitation of current LArTPCs: inability to discriminate the **charge sign** of particles

A Magnetized LArTPC: Electron/Positron Discrimination



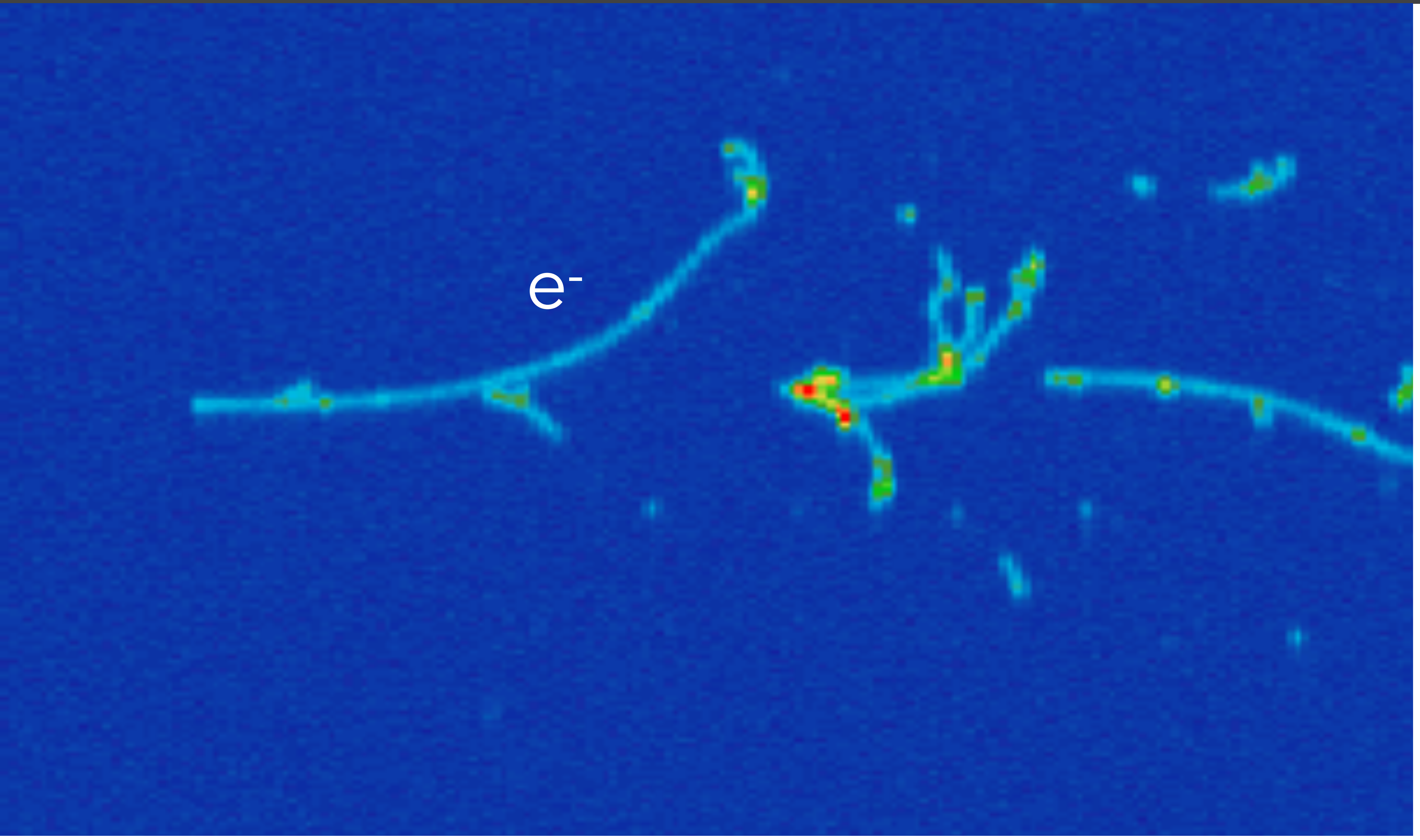
Shown here is a simulation of LArTPC in a 0.7 T field. The field is perpendicular to the drift direction of the electrons.

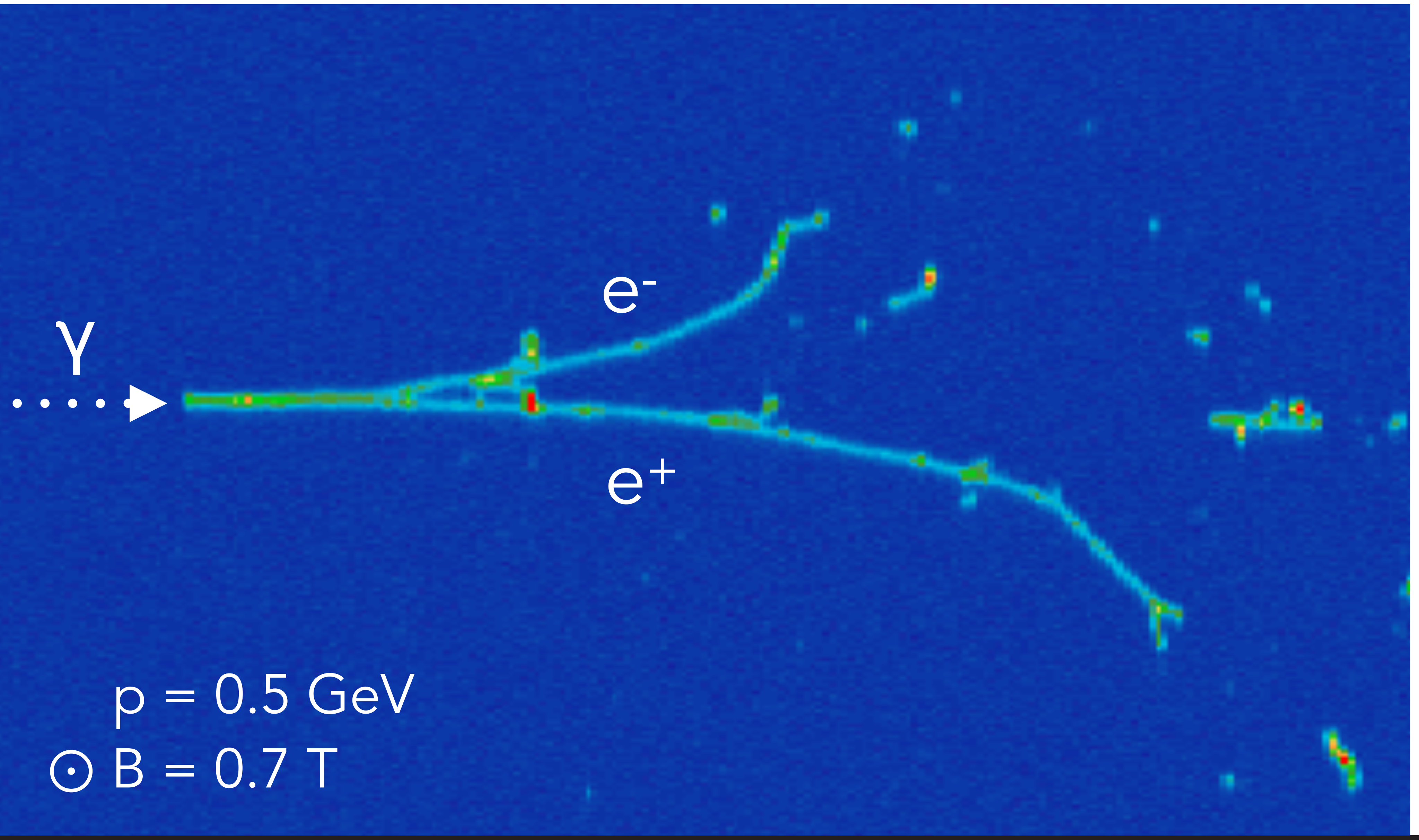
The collection plane is shown.

The first part of the electromagnetic shower can be used to measure the curvature of the primary electron or positrons.

Important to remove "wrong-sign" background contamination.

A Magnetized LArTPC: Electron/Photon Discrimination





The magnetic field provides an extra handle to discriminate electrons from photons.

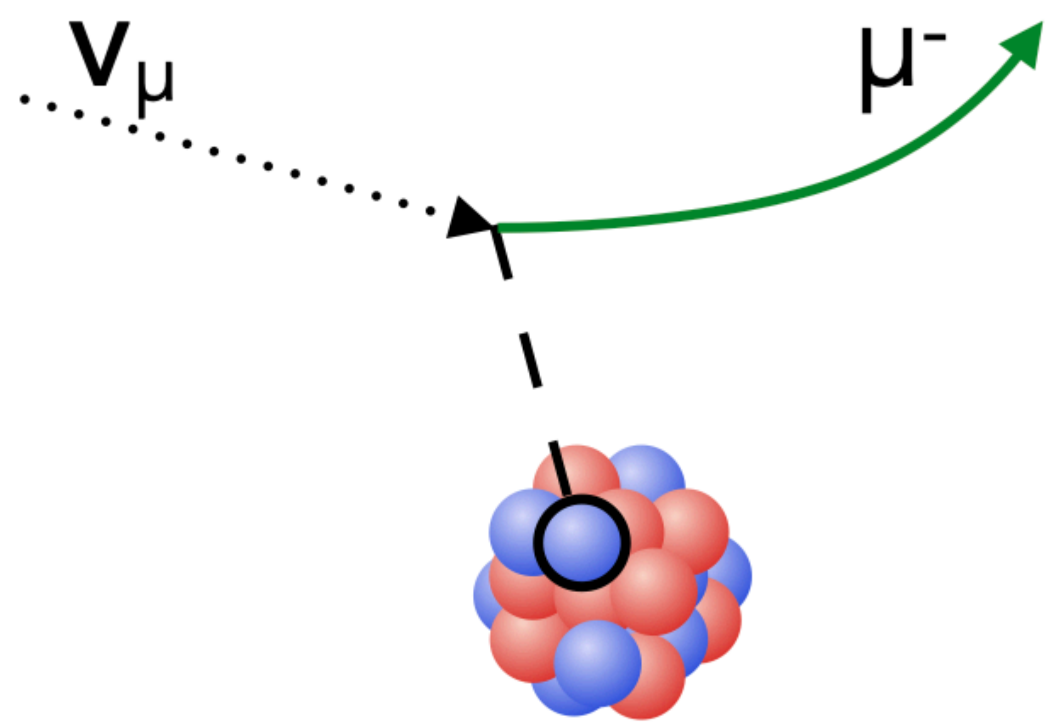
Electrons

Single track bent by the field, then shower

Photons

Two tracks bent by the field in a V-like shape, then shower

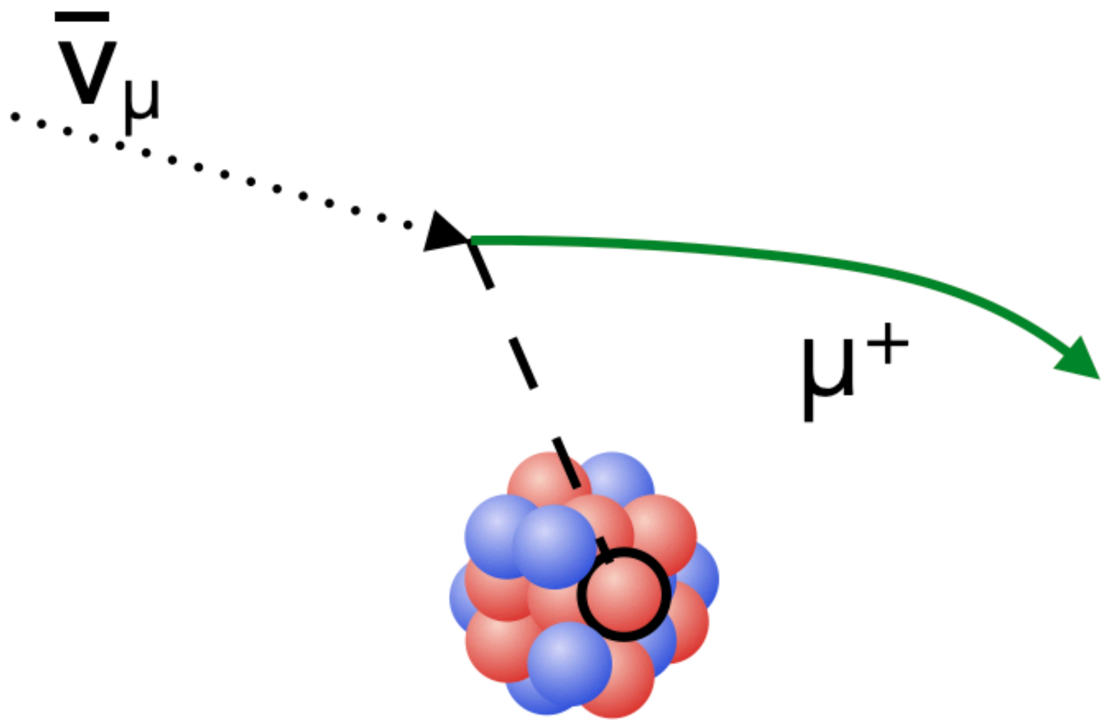
Benefits of a Magnetized LArTPC 1/n



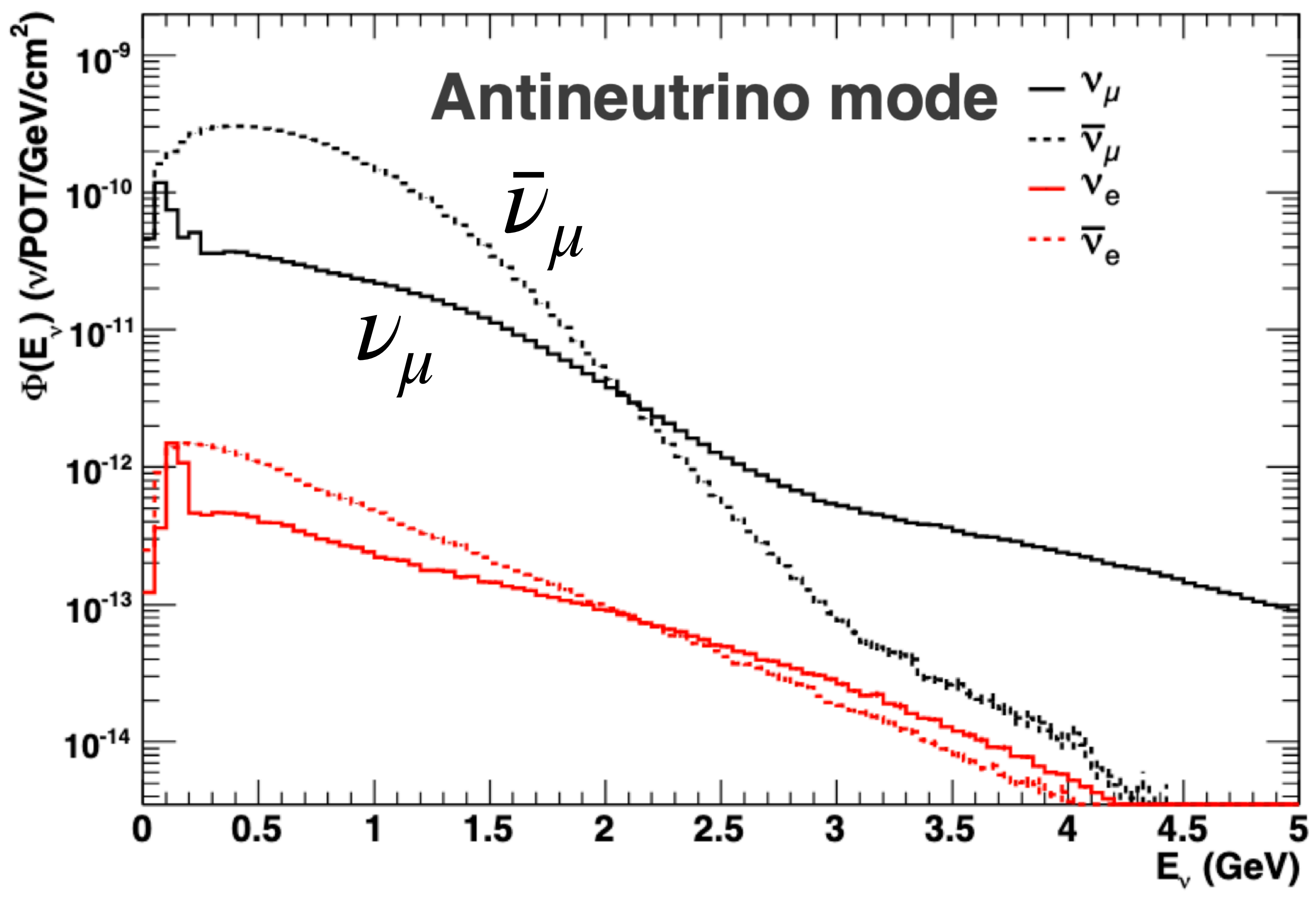
Can measure neutrino and anti-neutrino **cross section** separately

Magnetic field crucial if running in **anti-neutrino mode**

The BNB beam suffers from a **large wrong-sign background contamination** when running in anti-neutrino mode

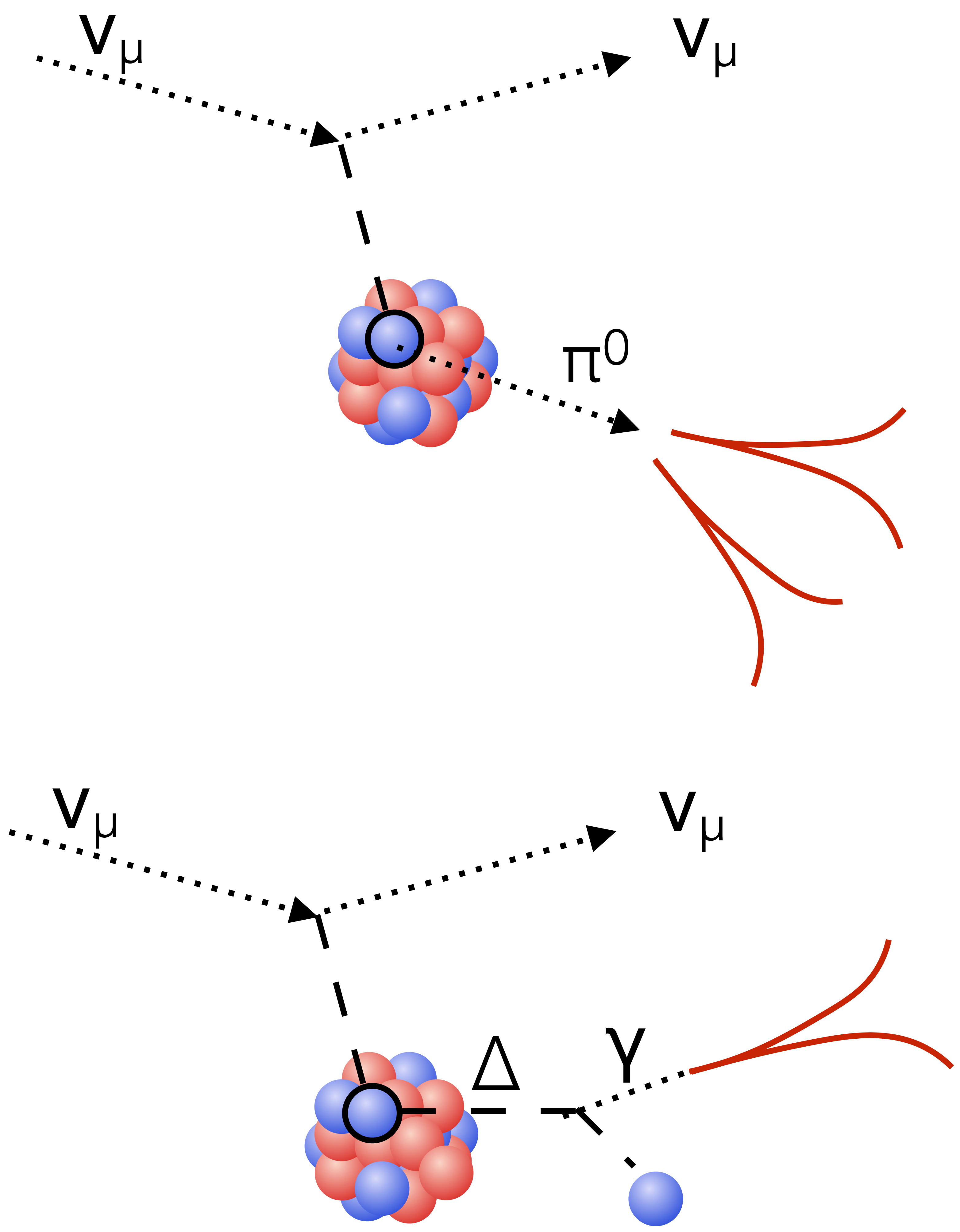


$$\frac{\sigma_{CC}(\nu_\mu N \rightarrow \mu^- X)}{\sigma_{CC}(\bar{\nu}_\mu N \rightarrow \mu^+ X)} \approx 2$$



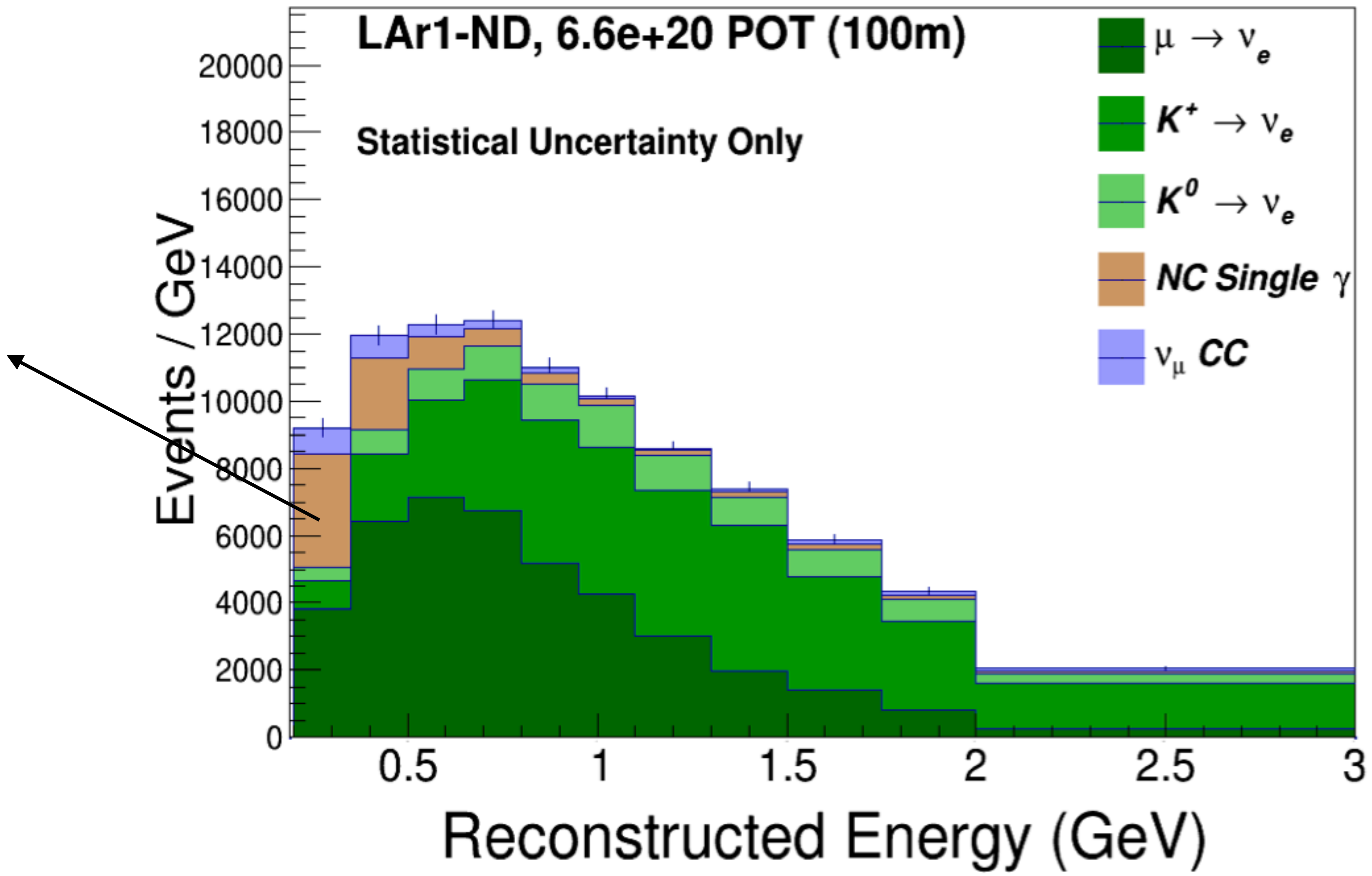
Marco Del Tutto
18th April 2023

Benefits of a Magnetized LArTPC 2/n

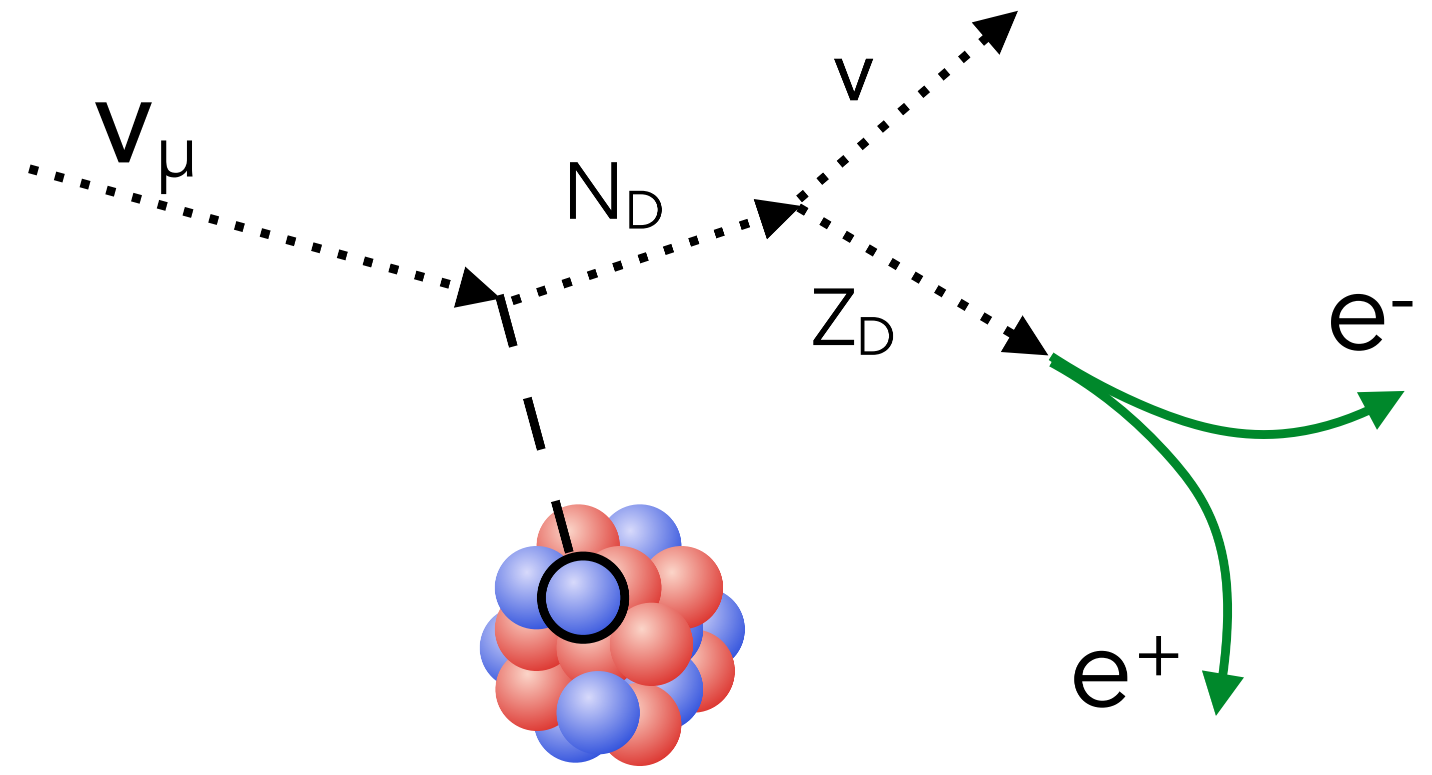


SBN Sterile Neutrinos

Electron/photon separation enables a further background reduction from π^0 or Δ production



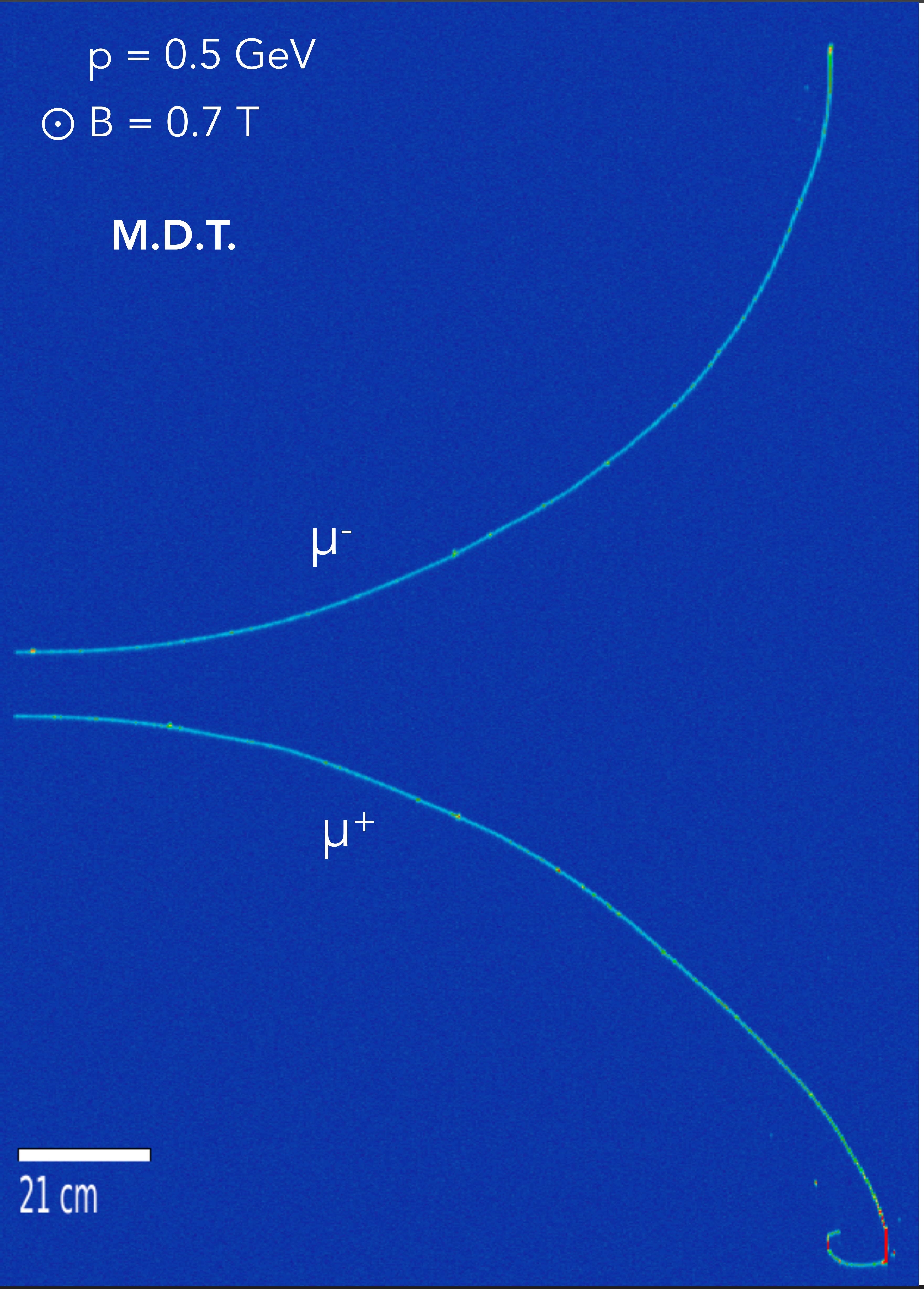
Benefits of a Magnetized LArTPC 3/n



Beyond Standard Model Physics:

- Charge ID crucial to identify **l^-/l^+** in the final state, typical of many BSM physics models
- Magnetization gives extra sensitivity when the pair is boosted and has a small opening angle

Benefits of a Magnetized LArTPC 4/n



Can use track curvature to measure momentum

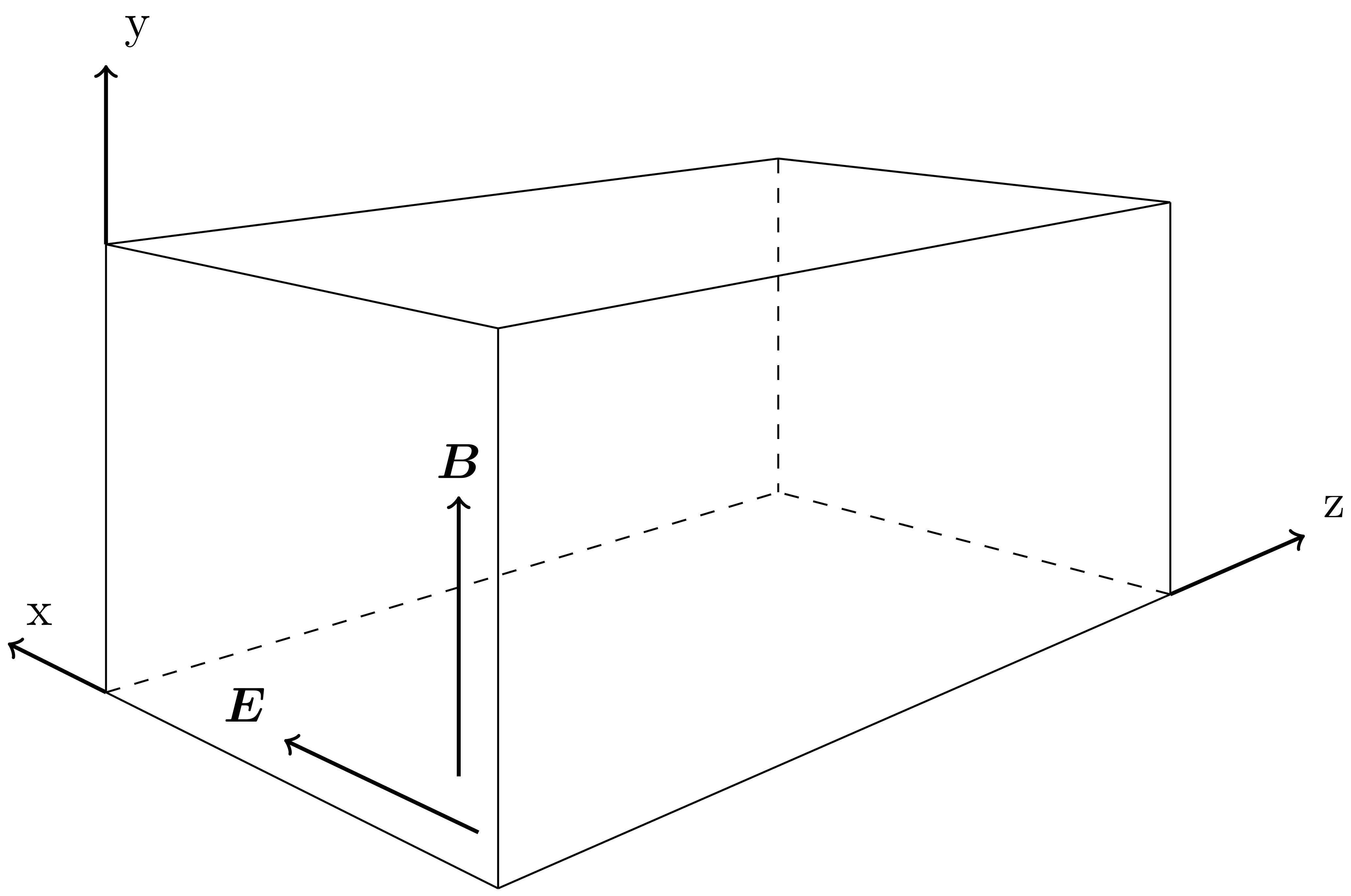
- Especially important for muons and pions exiting the detector.
- Momentum resolution:
  - 9% for a 5 m muon (SBND)
  - 4% for a 30 m muon (DUNE)

ArCS: Argon detector with Charge Separation

ArCS

Funded as Fermilab LDRD Project

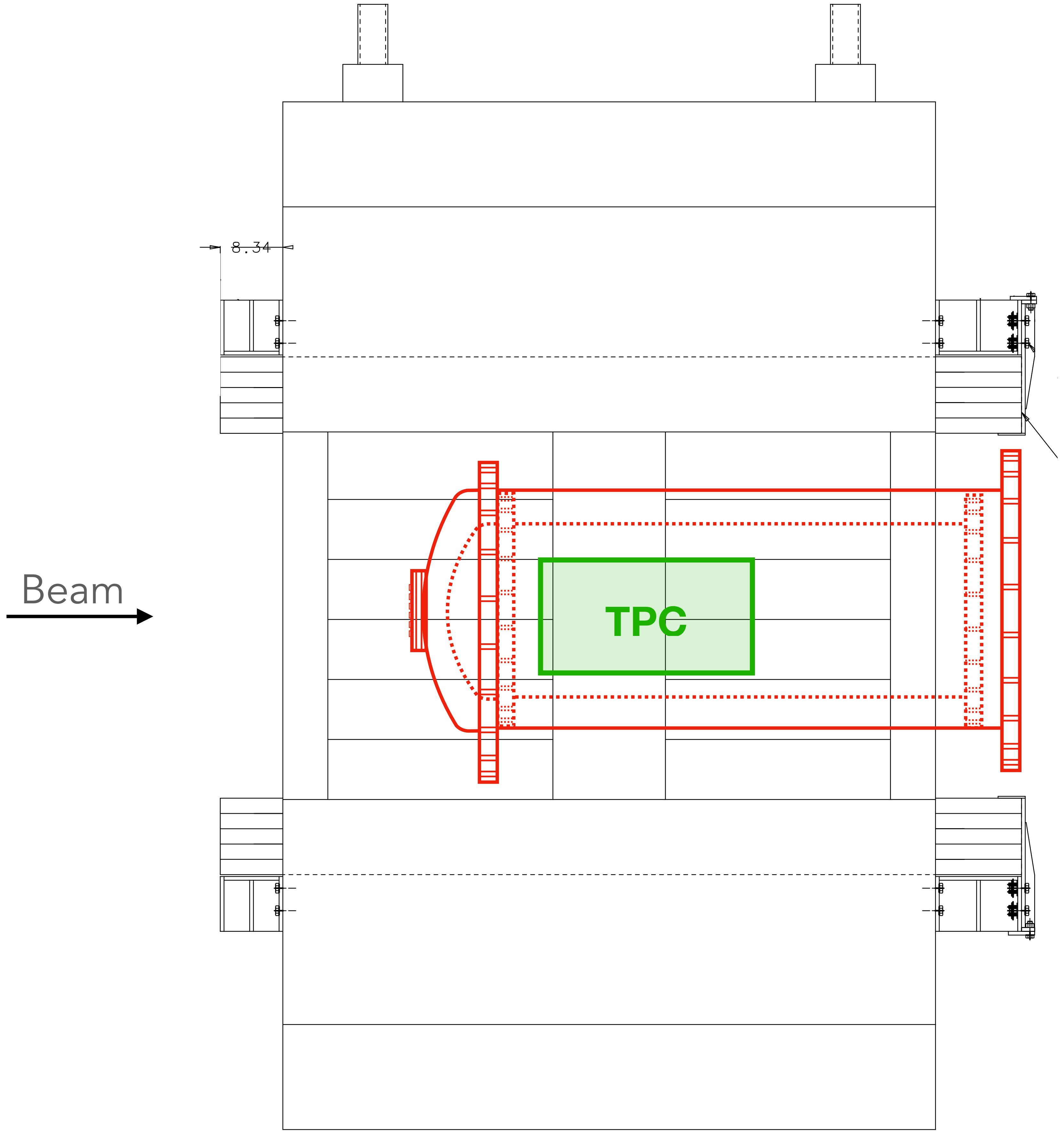
FNAL-LDRD-2022-001



This project's scope is to demonstrate that a LArTPC detector can operate in a magnetic field and provide measurements of **particle charge sign** and **momentum** for particles of 100s of MeV

ArCS: Argon detector with Charge Separation

We will re-use the LArIAT TPC and insert it inside the Jolly Green Giant Magnet at Fermilab



250-ton magnet, 0.7 T field

ArCS: Argon detector with Charge Separation

We will run the ArCS detector at the Fermilab Test Beam Facility

Current efforts are ongoing to optimize the beamline.

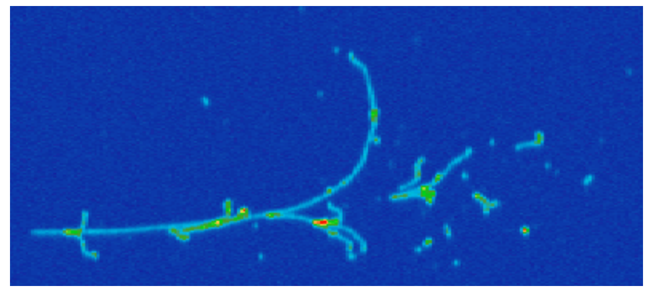
The goal is to study electrons and positrons with O(100 MeV) energy

Team

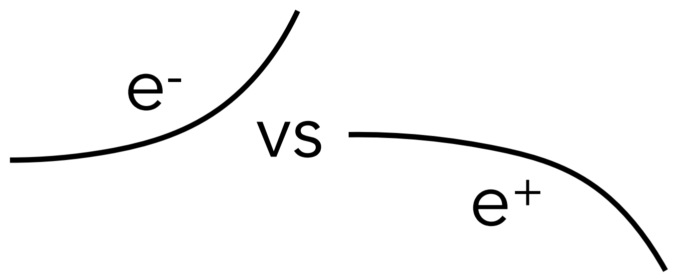
- Roberto Acciarri
- Bill Badgett
- Supraja Balasubramanian
- Flavio Cavanna
- Marco Del Tutto
- Angela Fava
- Will Foreman
- Claudio Silverio Montanari
- Monica Nunes
- Ornella Palamara

ArCS Goals

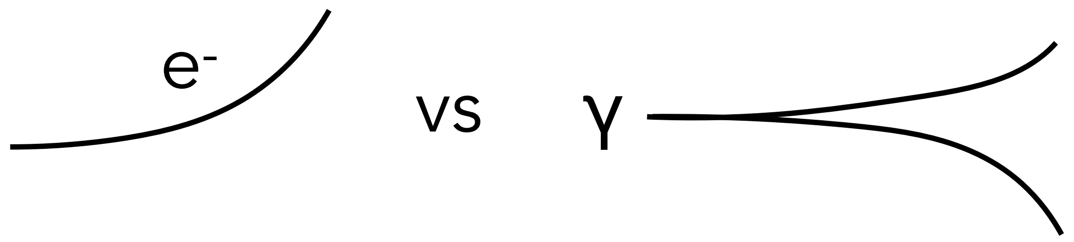
1. Verify that a LArTPC can operate in a magnetic field



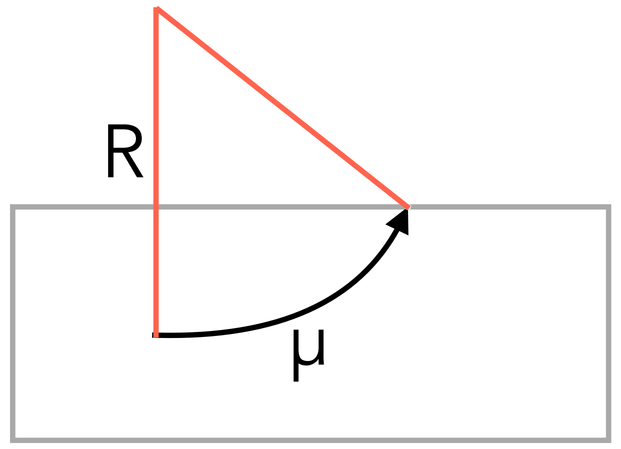
2. Establish minimum field required for electron/positron separation



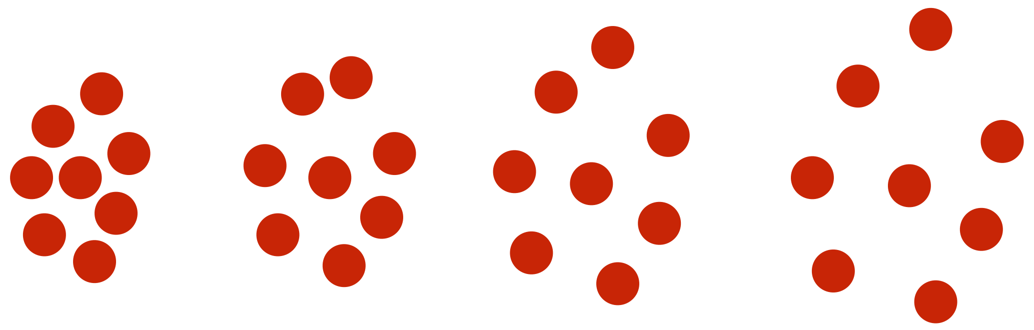
3. Measure the efficiency in electron/photon shower separation



4. Measure muon and pion momentum using their curvature



5. Measure electron diffusion in the presence of a magnetic field



ArCS: Current Status

Cryostat	TPC	Magnet	Beamline

ArCS: Current Status

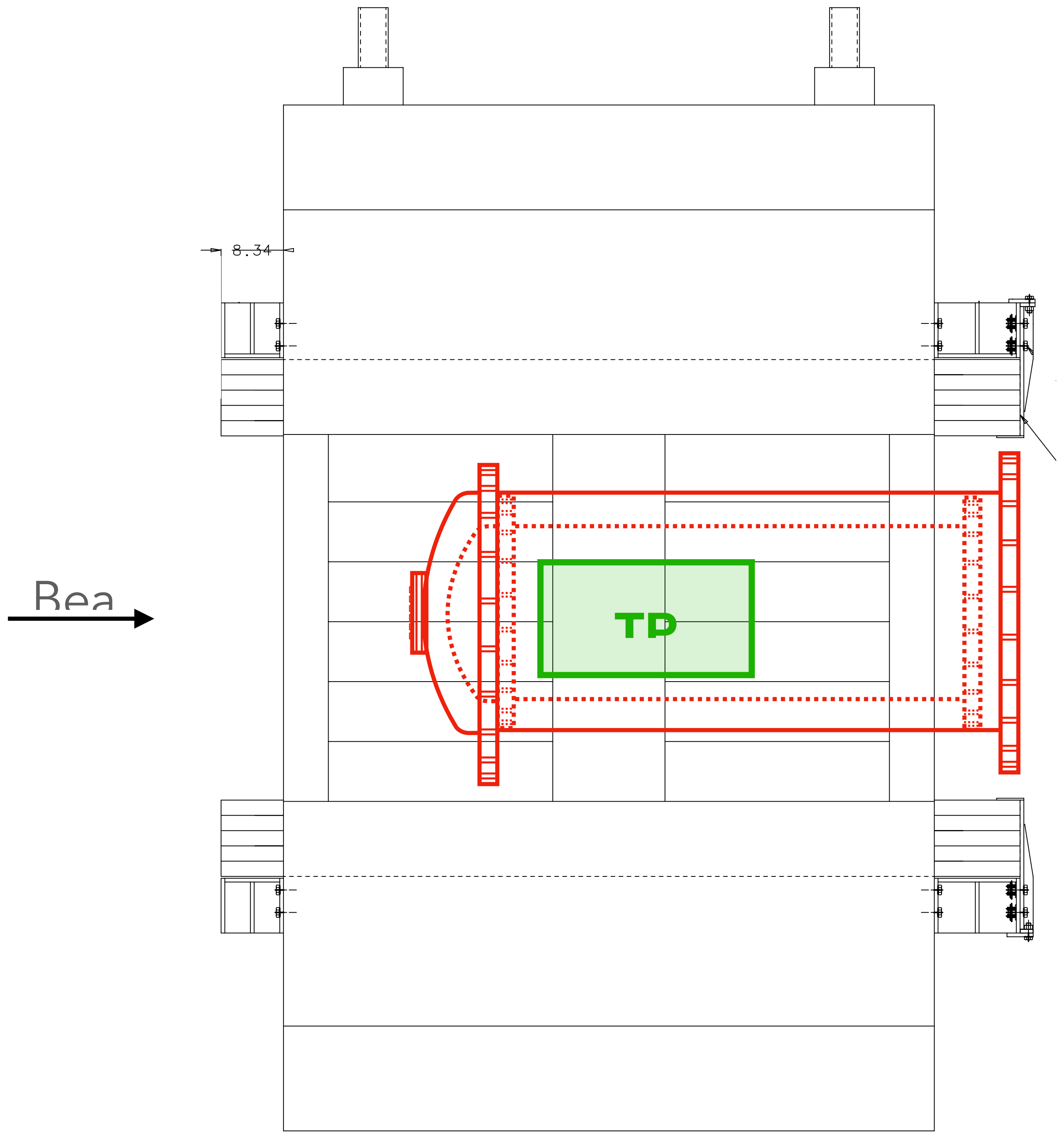
Cryostat | **TPC** | **Magnet** | **Beamline**

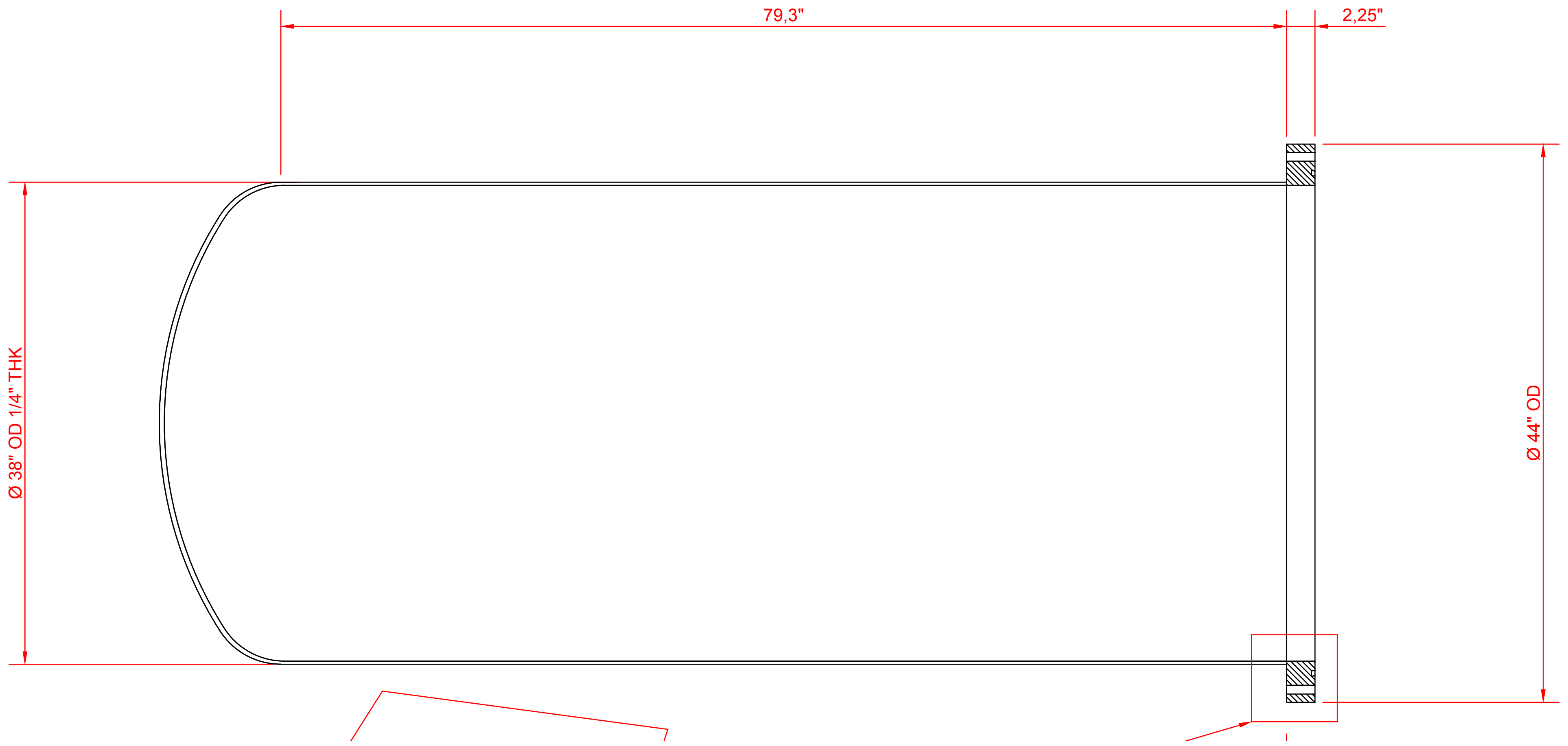
External company is finalizing the drawings

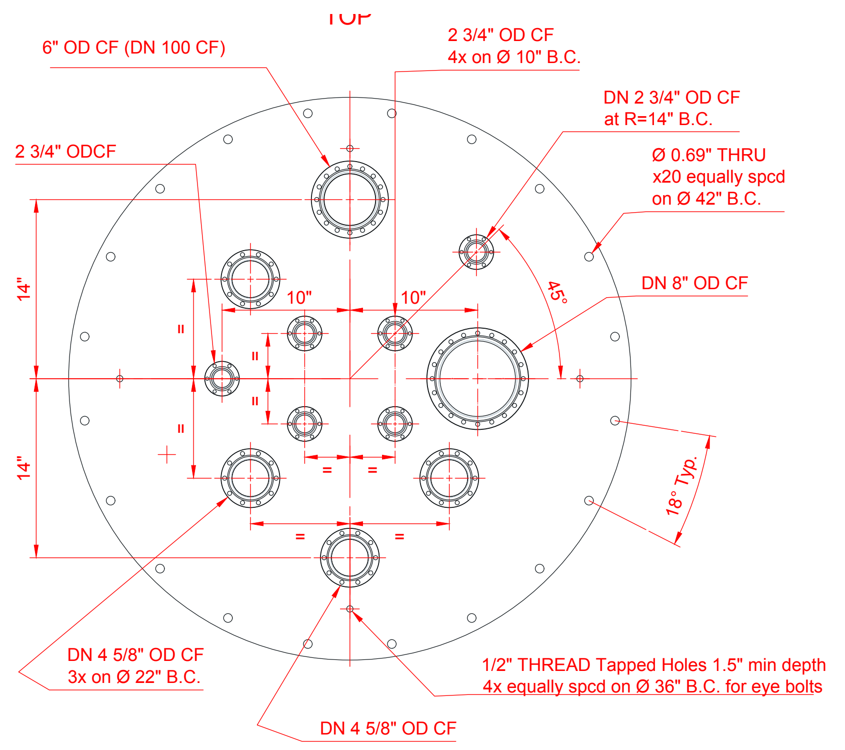
Construction should start soon

Many thanks to

- Claudio Montanari
- Michael Geynisman
- Fritz Schwartz
- Mike Zuckerbrot







ArCS: Current Status

Cryostat	**TPC**	Magnet	Beamline

TPC refurbishment in progress at DAB

Many thanks to
- Monica Nunes
- Angela Fava
- Roberto Acciarri

ArCS: Current Status

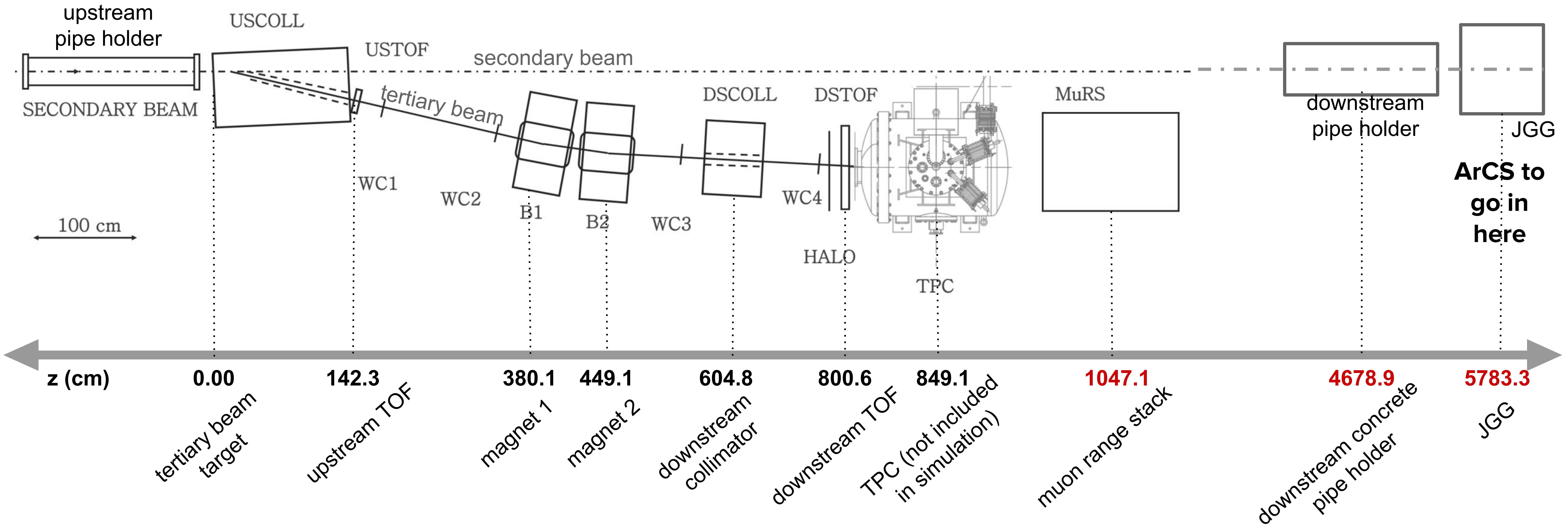
Cryostat | TPC | **Magnet** | Beamline

- Magnet was repaired last year
- Work led by Steve Chappa:
  - Inspected all coils
  - Short was identified and repaired

JGG tested successfully on Dec 22, 2022!

ArCS: Current Status

Cryostat	TPC	Magnet	**Beamline**



- We are putting together a beamline simulation
- We need to optimize the beam at the JGG location

Work done by Supraja Balasubramanian

ArCS: Current Status

Cryostat | TPC | Magnet | **Beamline**

Scintillator paddles were recently installed in front of the magnet to measure rate of punch-through muons.

These muons, coming from the secondary bema, will be a source of background for us.

It's crucial to understand their rate to make plans for mitigation.

Next Steps

- Install cryogenics
- Install TPC
- Install electronics
- Finalize beamline simulation and design
- Commission the system
- Take data!