Possible DUNE FD Field Calibration Device

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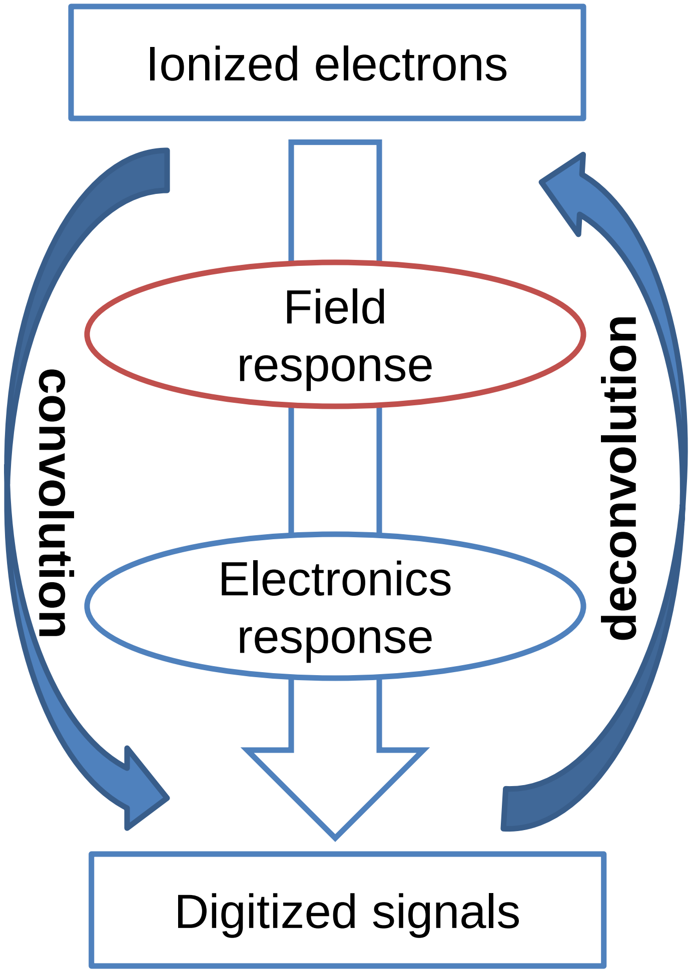
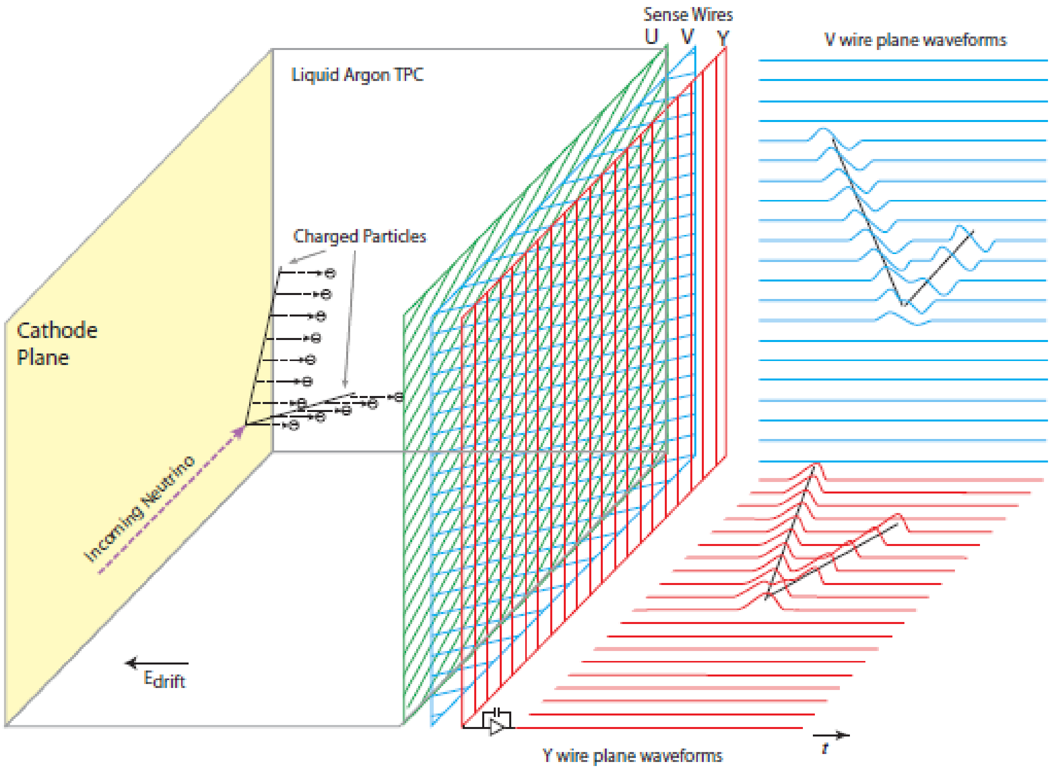
Outline

- Physics Motivation
- Planned local R&D at BNL
  - LAr Field Calibration System (LArFCS)
- Possible DUNE FD in-situ calibration concept
  - Feedthrough requirement

Signal Formation and Processing

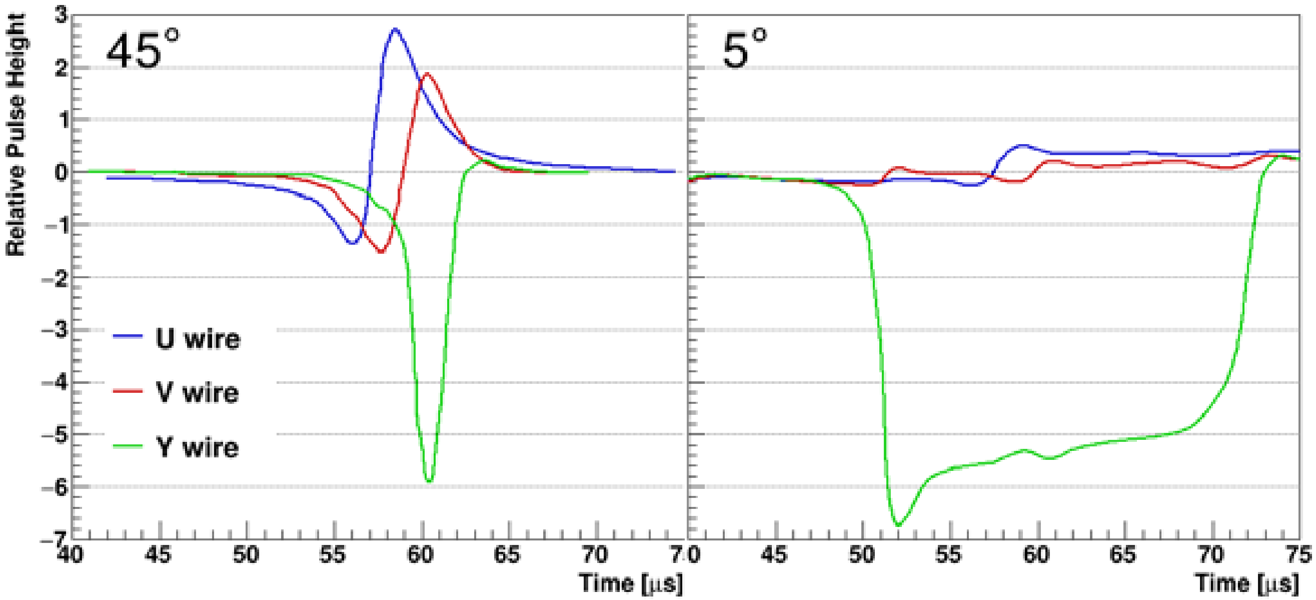




- Electronics response: pulser calibration
- Field response: relied on simulation

Impact of Field Response

- Most significant on Induction planes due to the bi-polar signal cancellation for “prolonged” events

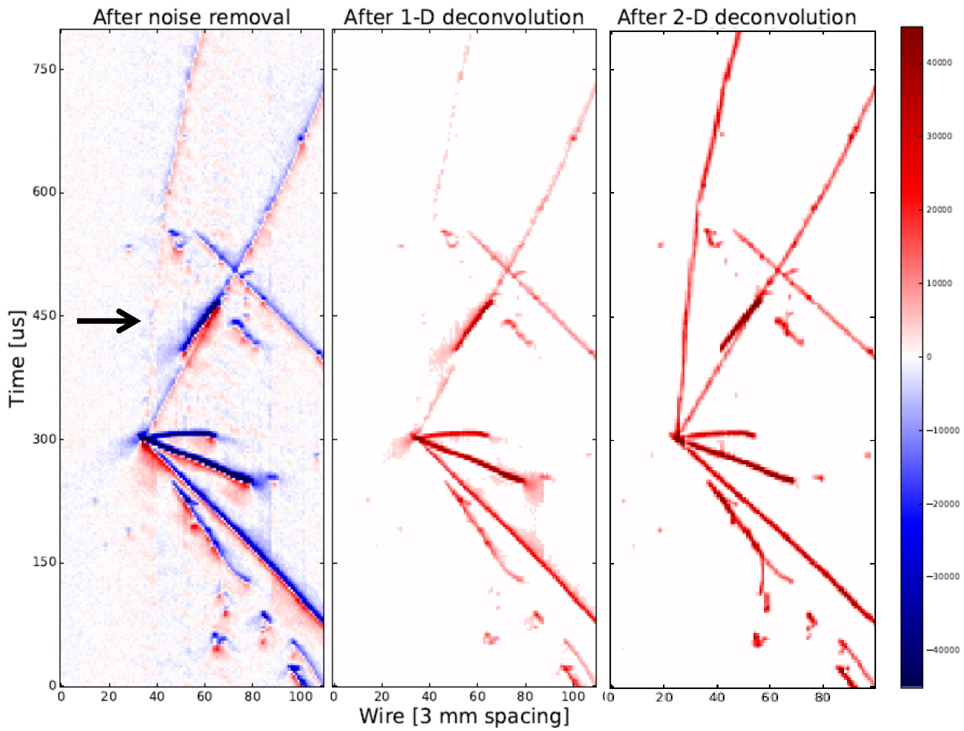


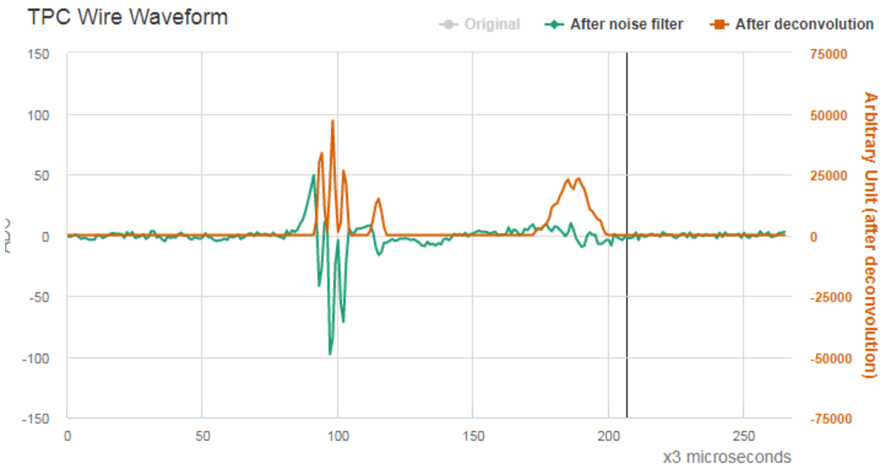
Note that we do need the induction plane signals to reconstruct 3D tracks

Simulated using Garfield by B. Yu.
(Angle is w.r.t. E-field.)

Events From MicroBooNE

- http://lar.bnl.gov/magnify





Raw bipolar signal

1D (time-only) deconvolution

2D deconvolution

In order to properly deconvolute the induction signal, we need <u>precise knowledge of 2D field response</u>

$$M(x',t') = \int_{-\infty}^{\infty}\int_{-x_0}^{x_0} \boldsymbol{R(x-x',t-t')} S(x,t)\,dx\,dt$$

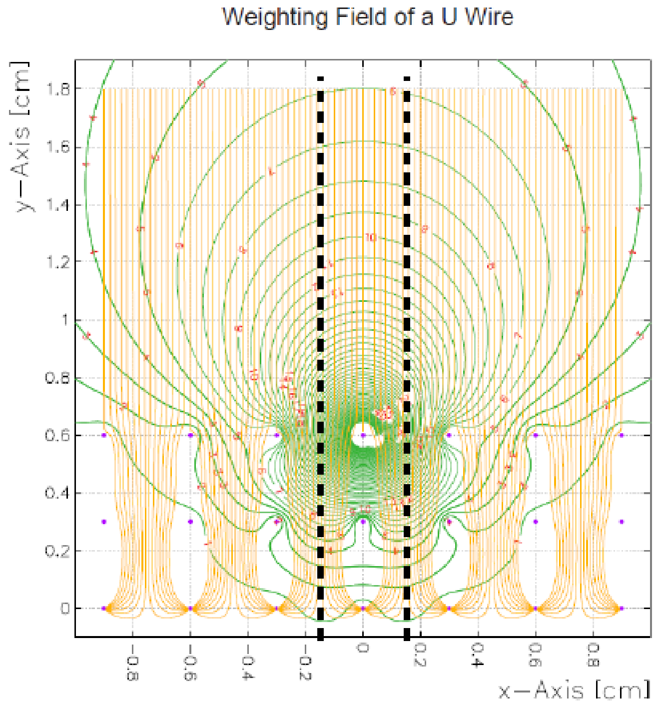
We are preparing a paper detailing the signal formation and processing in LArTPC in the context of MicroBooNE work.

Physics behind Field Response Function

- The induction current is described by Shockley-Ramo theorem:

$$i = -q\vec{E}_w \cdot \vec{v}_q .$$

q-charge; E_w-weighting field; *v*-velocity

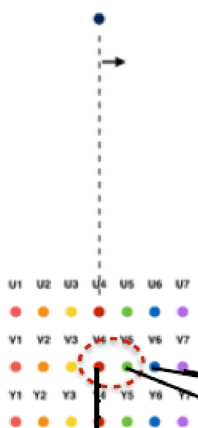


- $\boldsymbol{E_w}$ is the electric field for electrode with induction current at unit potential; and all other electrode at ground
- $\boldsymbol{E_w}$ extends beyond the boundary of wires (±half pitch), i.e., electrons pass through the adjacent wires can also produce induction current on the wire of interest
- $\boldsymbol{v}$ depends on electric field + location…..
- Induction current strongly depends on the local charge distribution

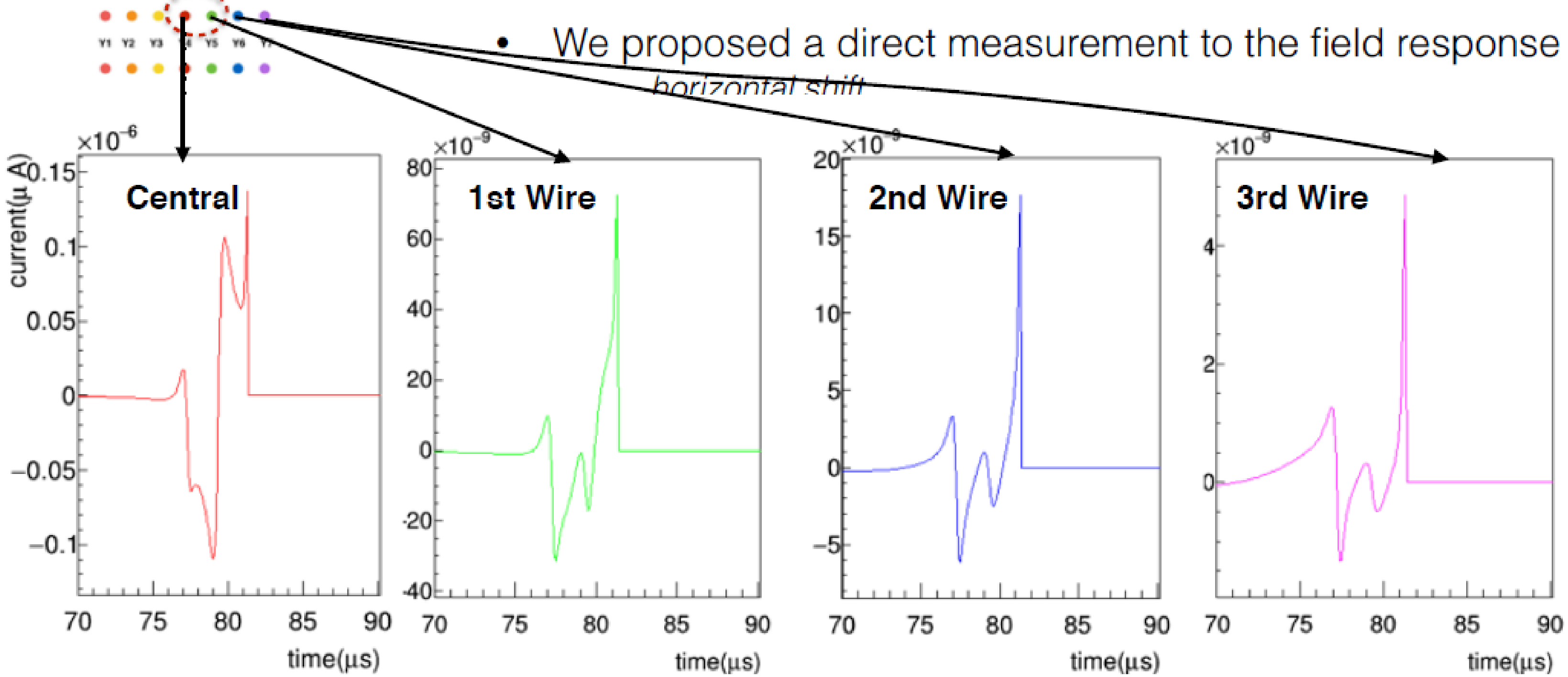
Prediction of Field Response Function

- Current prediction of field response function is based on Garfield-2D

V Plane



- 2D results don't agree with data (e.g. time offset). 3D is most likely needed
- Due to various numerical difficulties, there is no realistic field response function in 3D available. Brett is currently working it
- We proposed a direct measurement to the field response

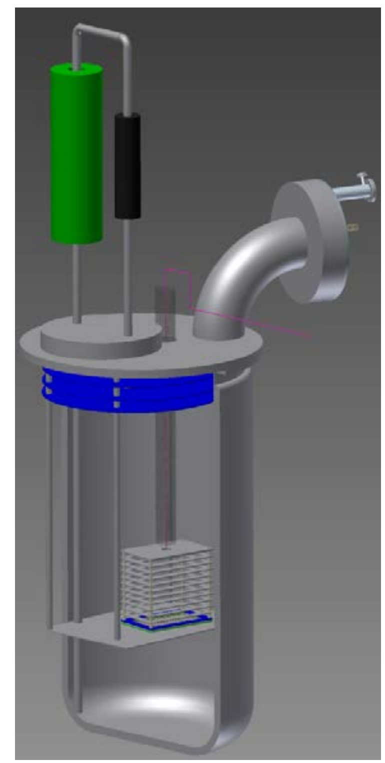


Experimental Setup

- 2L test stand is cooled by LN_2+Dry ice bath and LAr is formed by liquefying purified commercial GAr
- 20L test stand is an upgraded and improved apparatus with LAr circulation and GAr purification
- The LArFCS for demonstration of primary gas purification for LArTPC and field response calibration is currently under construction

2 L Test Stand

20 L Test Stand



LArFCS (300 L)

Local Setup @BNL

Illuminate Au-photocathode with precise scan of electron locations

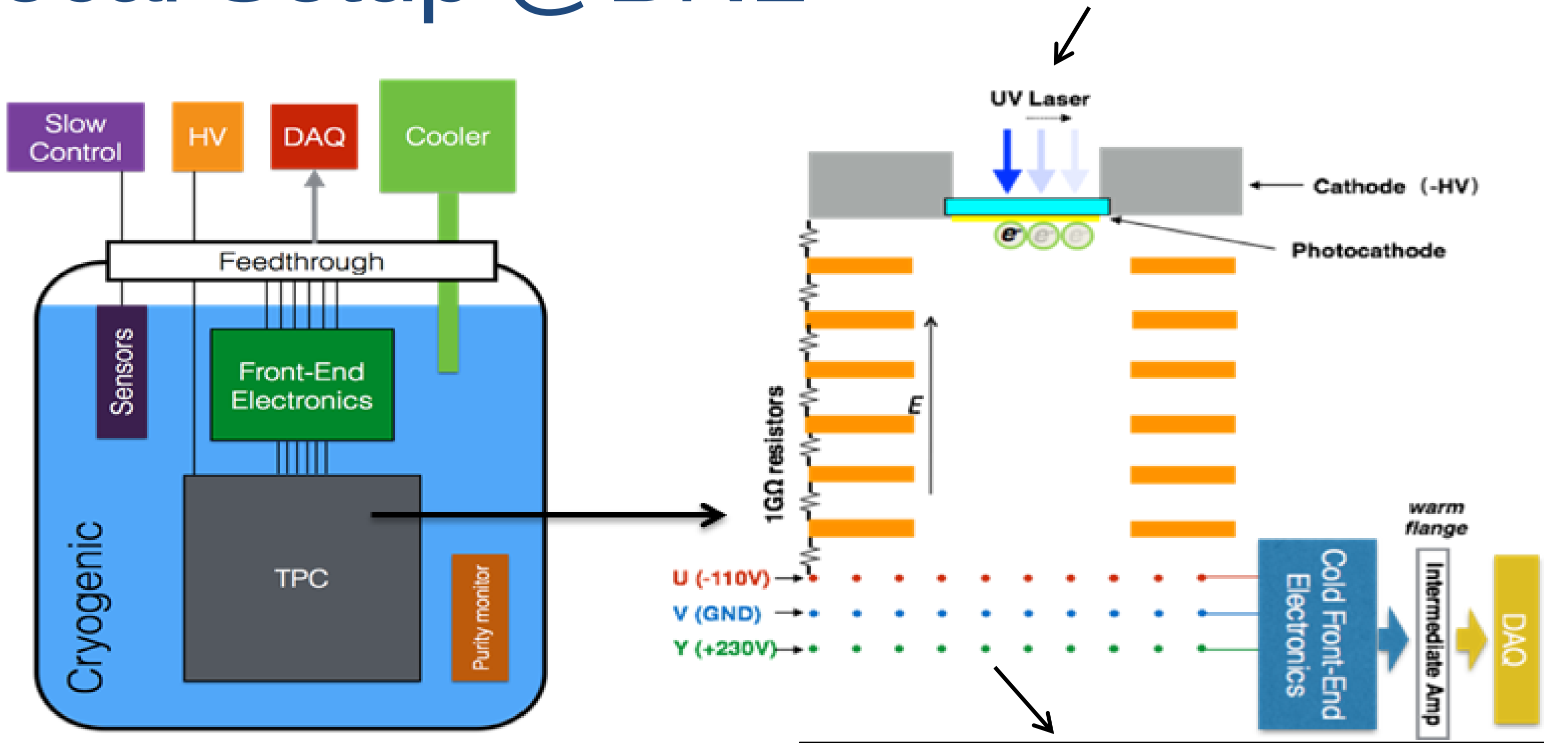


Figure 6. Schematic of the liquid argon field calibration system (LArFCS).

Reproduce MicroBooNE and DUNE wire patterns and configurations

- Sub systems: Cryogenic, TPC, Laser, Front-end electronics, DAQ, etc.
- Goal: precisely measure field response function versus position, compare with 2D and 3D simulations such as Garfield and BEM

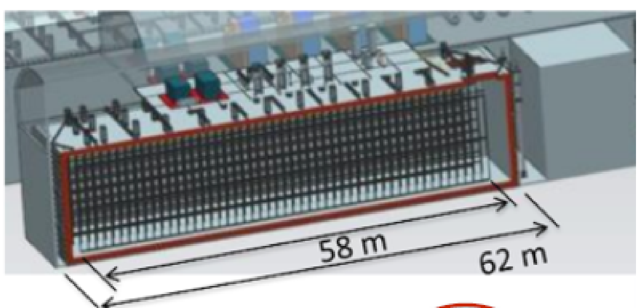
Possible DUNE FD in-situ calibration

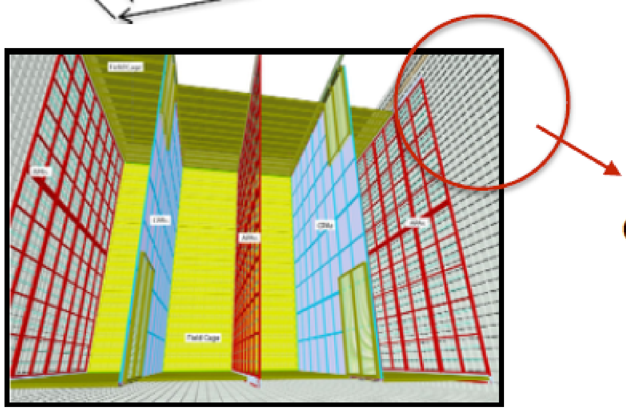
- Do we need an in-situ calibration device at DUNE FD?

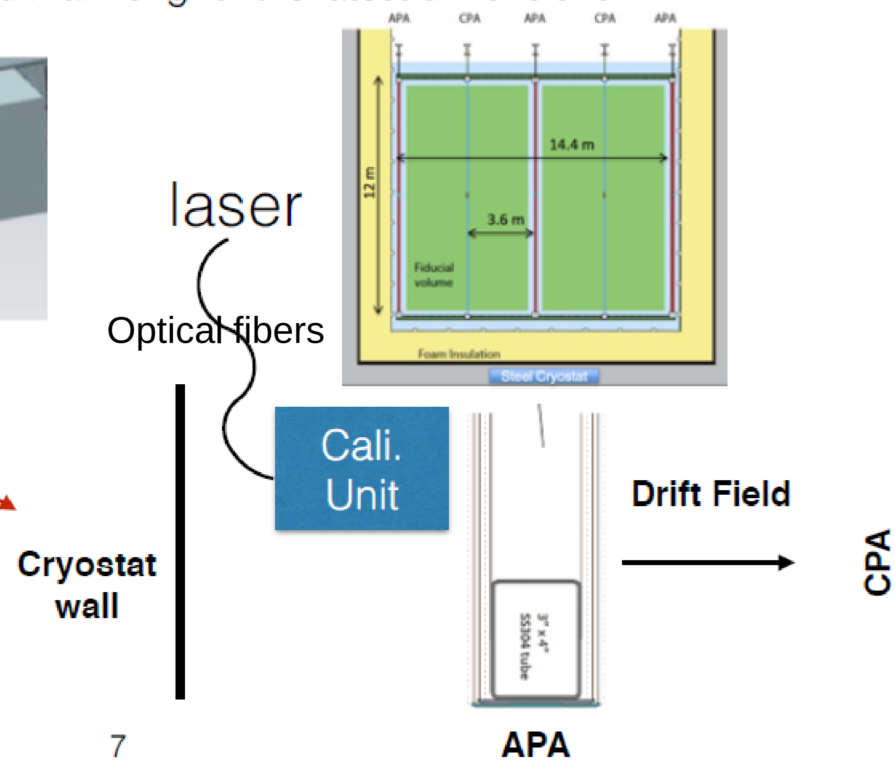
- Assuming that we would like to keep this option, we worked out the concept and minimum requirement on feedthrough
  - Work by Yichen Li.

DUNE in-situ field response calibration

- DUNE Calibration TaskForce is asking for requirements for calibration system to reserve the portals on the cryostat for later instrumenting the in-situ calibration device
- Active dimensions of the DUNE FD single-phase 12 m x 14 m x 58 m
- The optical arrangement of the laser to generate point-like source is challenge considering the long distance from top flange to the device optical fiber seems to be the only solutiion?
- The dimensions are taken from *DUNE-doc-158-v2* DUNE Far Detector 1 Parameters spreadsheet and consulted Jim and Manhong for the latest dimensions







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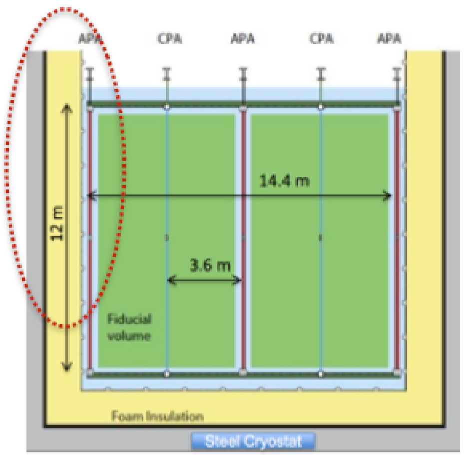
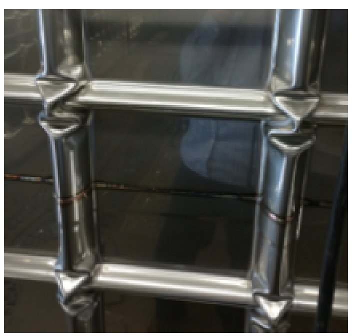
Space Available for the device



Top



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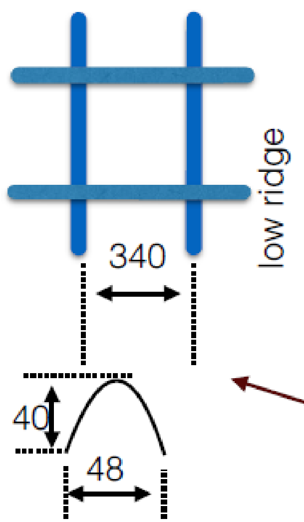
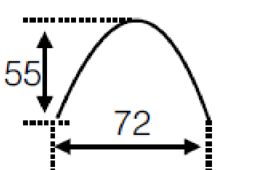
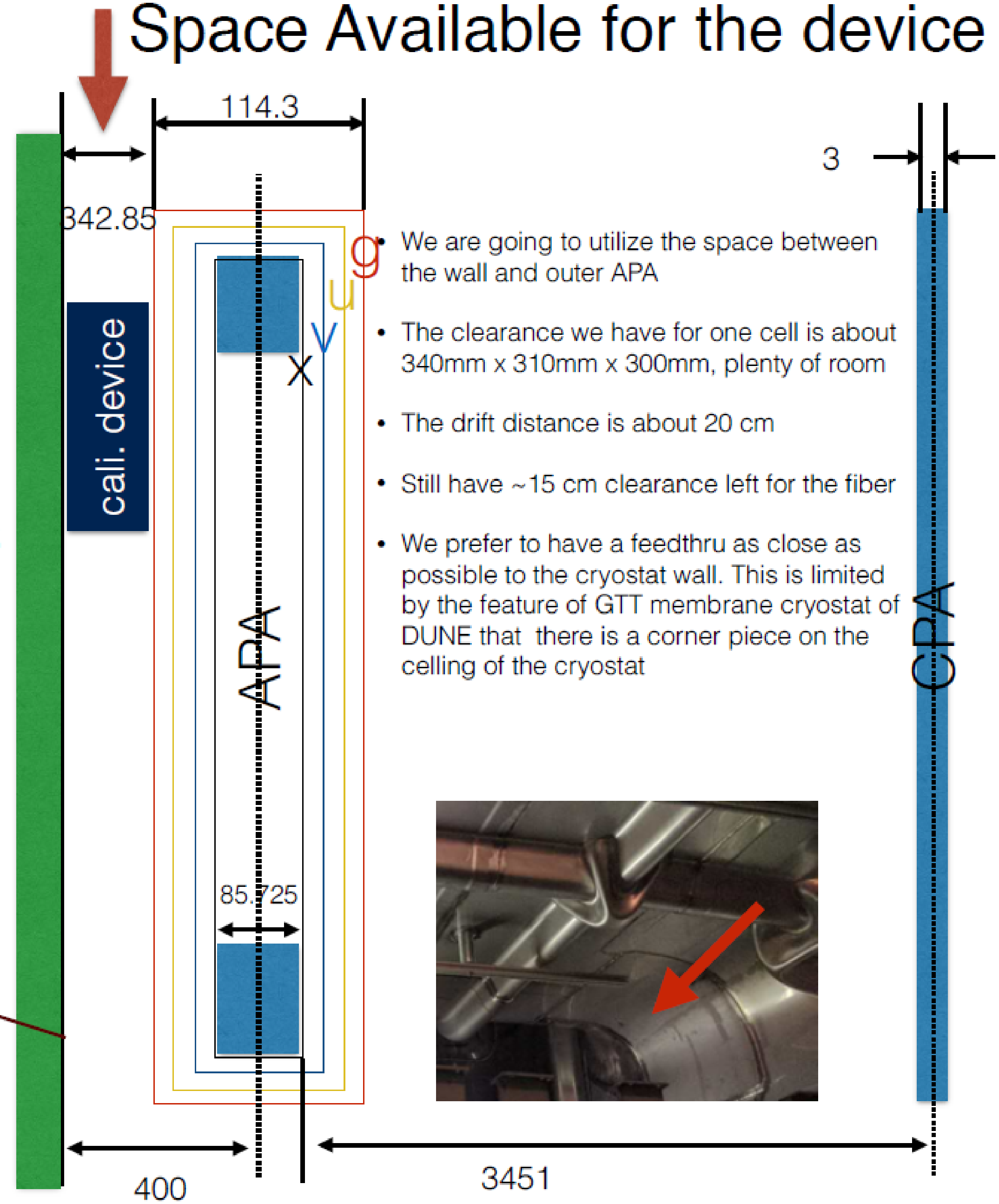
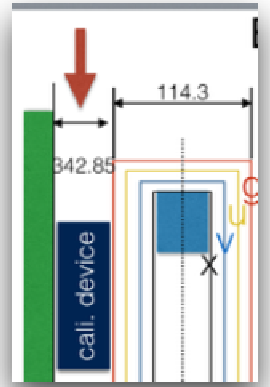



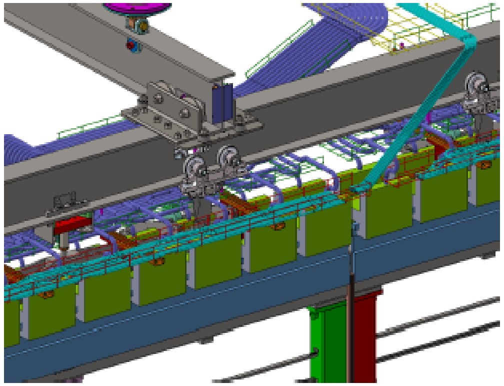


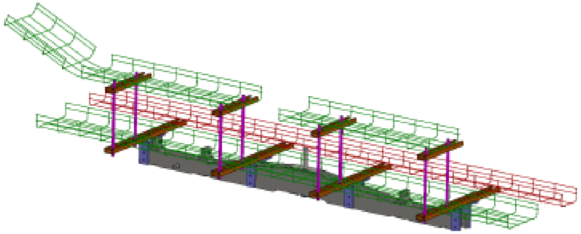
- We are going to utilize the space between the wall and outer APA
- The clearance we have for one cell is about 340mm x 310mm x 300mm, plenty of room
- The drift distance is about 20 cm
- Still have ~15 cm clearance left for the fiber
- We prefer to have a feedthru as close as possible to the cryostat wall. This is limited by the feature of GTT membrane cryostat of DUNE that there is a corner piece on the celling of the cryostat

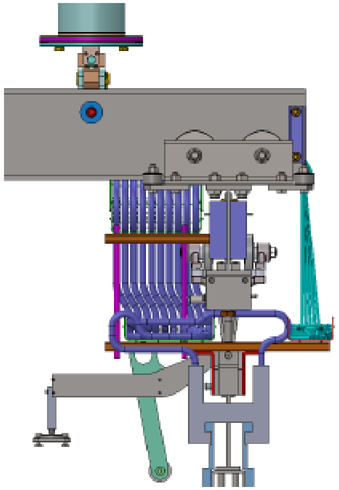
Clearance on top of the calibration device

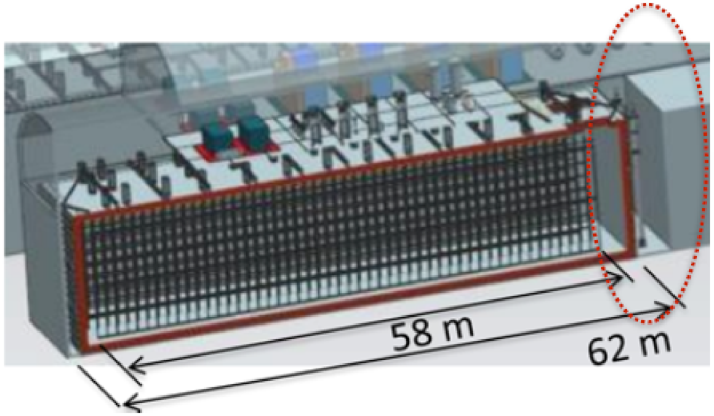
- Another limiting factor is the clearance on top
- Use ProtoDUNE cabling design as a reference
- There are many structures above the proposed position of the calibration device
- A possible location for the feed thru seems to be the gap at the empty side and install the device on the nearest APA





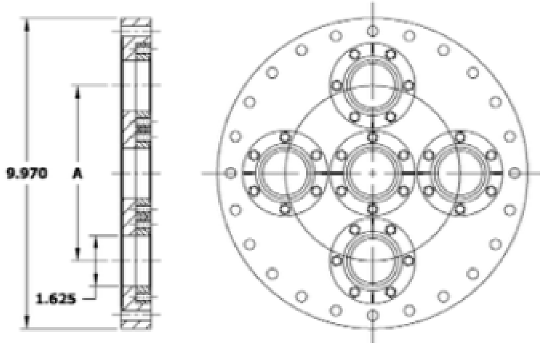


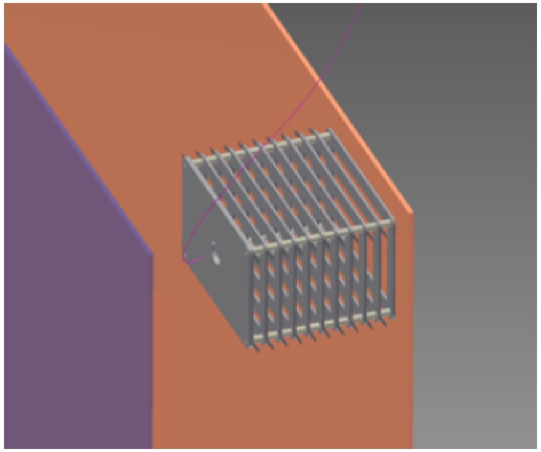


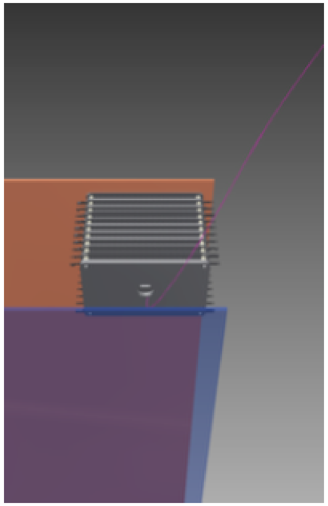


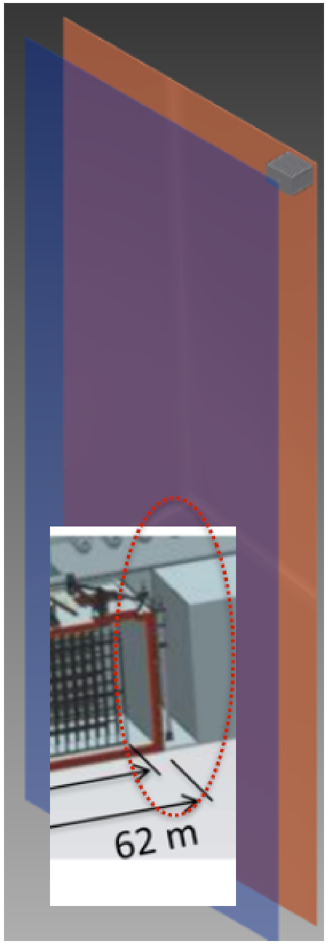
DUNE in-situ Implementation

- Current only consider one single unit at the APA closest to the end
- The laser is brought in by fiber from the side
- This can avoid the cabling and supporting structure on the top
- For on single unit, it requires ~21 channels of laser fiber, 1 HV power supply
- With 7-in-1 fiber flange and 1 SHV HV flange (both in 2-3/4" flange, we are going to require a 10"-OD flange with 7-7/8" opening on the cryostat celling









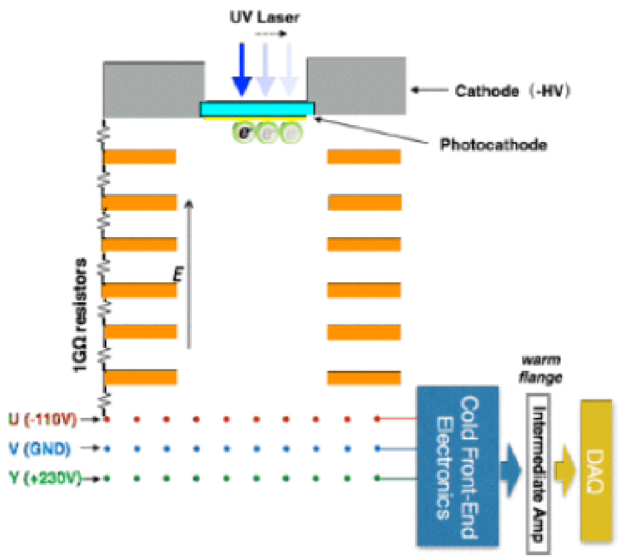
Summary

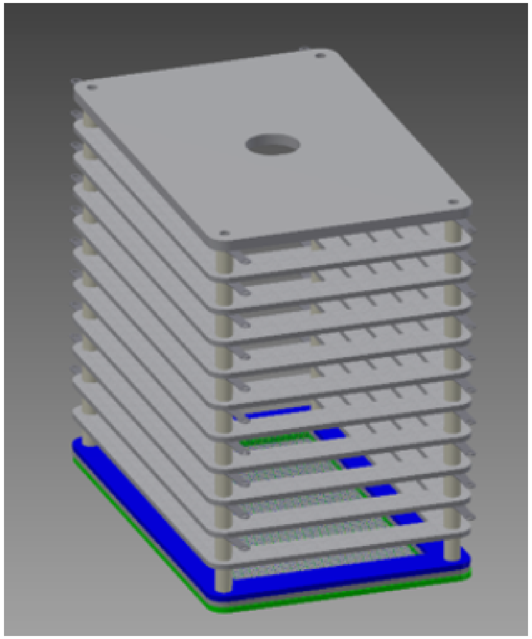
- We are planning a local R&D – LArFCS – at BNL to precisely measure the field response functions and compare with 2D/3D simulation.
- If we would like to keep the in-situ field calibration option, we need a minimum of one feedthrough to fit a 10" OD conflat flange. The location of the feedthrough should be closer to the wall, but can be at the far end of the cryostat if space is limited.

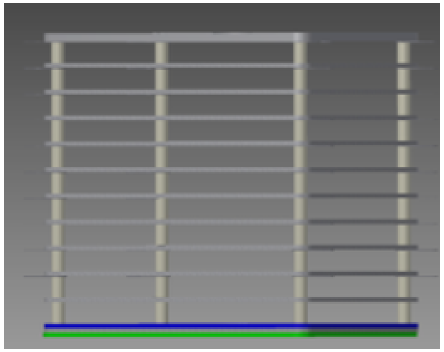
Backup Slides

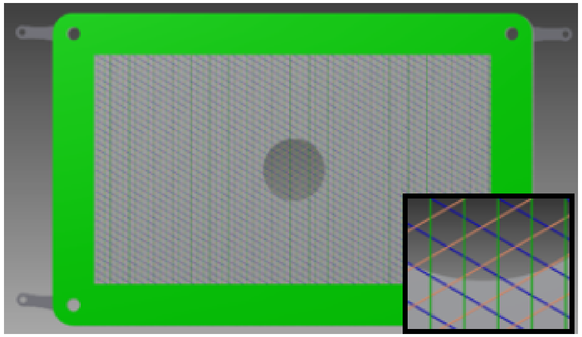
LArFCS TPC Design

- TPC fiducial volume
  192 mm(L) x 111mm(W) x 200 mm(H)
  Nominal volume:
  232 mm (L) x 151 mm(W) x 220 mm(H)
  (The drawing is in the actual dimensions)
- The field cage contains 11 stages
- The photocathode diameter is 30 mm
- Anode wire pattern is the same as MicroBooNE, 3 mm pitch, 60 degrees, 192 wires in total, 64 wires each plance
- Front end motherboard is not included





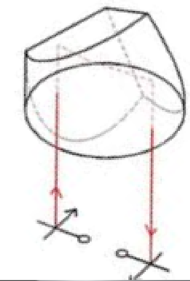




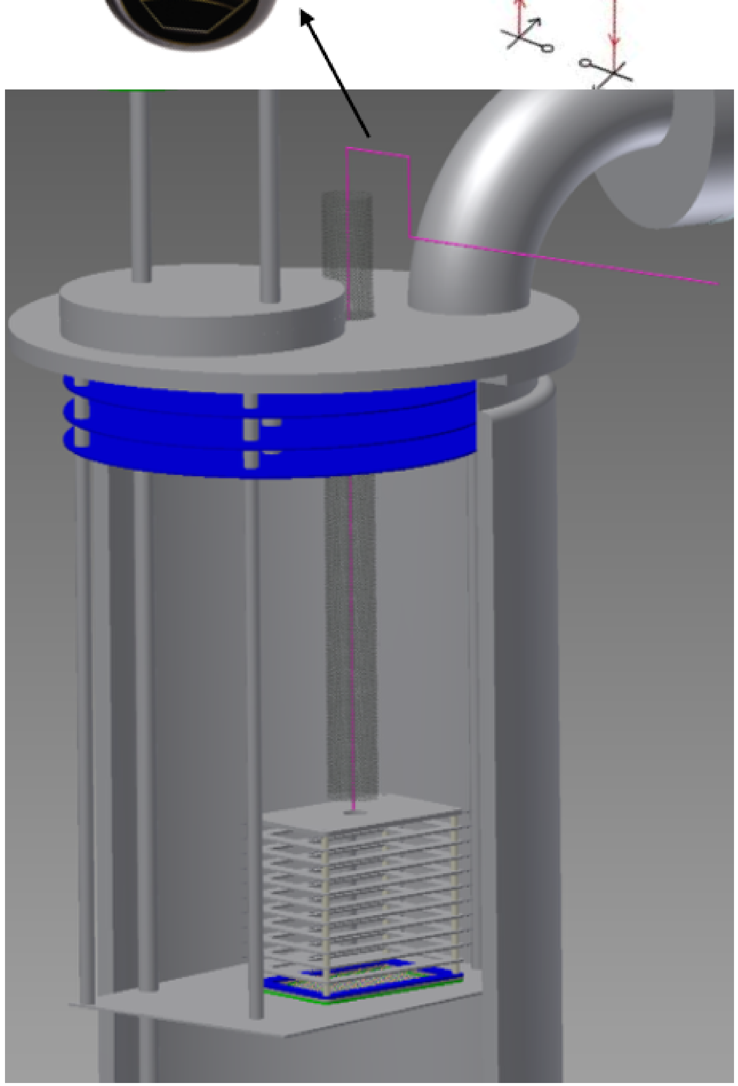
Laser System

- Au-photocathode illuminated by a pulsed UV laser
- Current have a 55 mJ excimer laser, need to enlarge the spot size to 600 um to avoid damage to photocathode.
- Spot motion controlled by mirrors and mobile optical stages from Thorlab.
  - Alternatively, use multiple optical fibers
- Trigger by fast photodiode.

LArFCS Laser Arrangement solution 1: Laser Beam



- Direct feed the laser beam to the photocathode
- The multiple laser location can be achieved by an optical corner cube together with translation stages on top of the optical tube with window on both sides
- The laser need to be brought up to about the same level of the 42" height
- There is another more compact excimer laser also with enough power available in Instrumentation Division
- The spot size can be reduced by focusing lens



LArFCS Laser Arrangement solution 2: Laser through fiber (horizontal)

- Feed laser to photocathode through optical fiber
- The purpose of this solution is for the in-situ calibration device in DUNE
- We are planning to use 600 um fiber, quite flexible with ~ 5 cm minimum bending radius
- Thomas have a lot of experiences with the UV application with 600 um fiber
- Laser flexibility to move the laser spot that multiple fiber channels are needed
- There are many commercial available vacuum fiber feed thru available on the market, 7 channel with 2.75" flange is maximum channels I can find