Characterization of Gaseous-Ar Operations of the ALICE TPC for the DUNE near detector

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APS April 2021 Meeting

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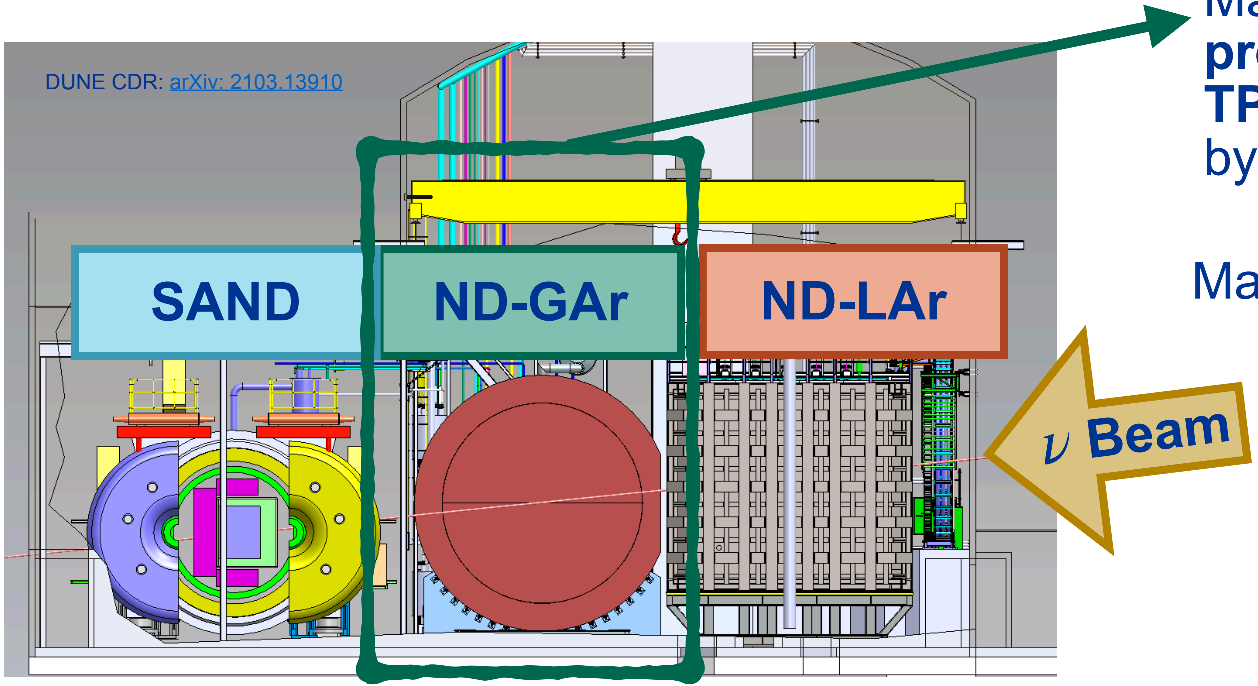
University of Pittsburgh

GOAT

DUNE

DEEP UNDERGROUND NEUTRINO EXPERIMENT

DUNE Near Detector Complex

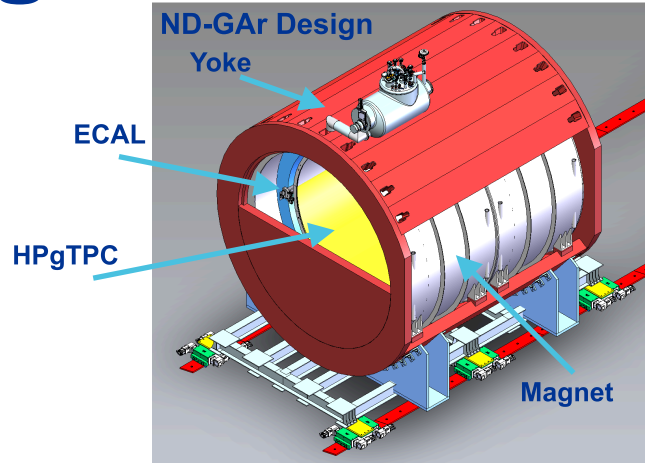


Magnetized (0.5T) **high pressure gaseous argon TPC (HPgTPC)** surrounded by ECAL calorimeter

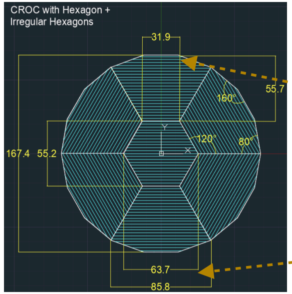
Main Purpose:

- Spectrometry for ND-LAr
- Measure charge of final state particles
- Lower detection threshold than LAr

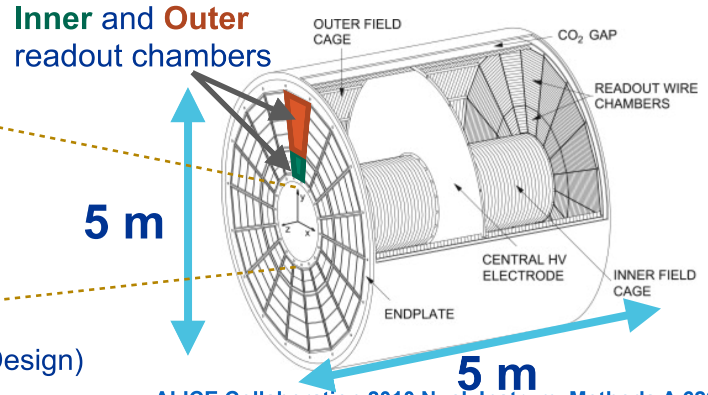
HPgTPC



- HPgTPC design will be a copy of the ALICE TPC
  - Using the ALICE readout chambers to construct the HPgTPC
  - Readout chambers are currently being tested
- A few modifications:
  - **Higher pressure: 10 atm** instead of 1 atm
  - Reference gas mixture: 90:10 Ar:CH_4
    - 1 ton fiducial mass
    - **97% of fiducial neutrino interactions on Ar**
  - Need to build a central readout chamber

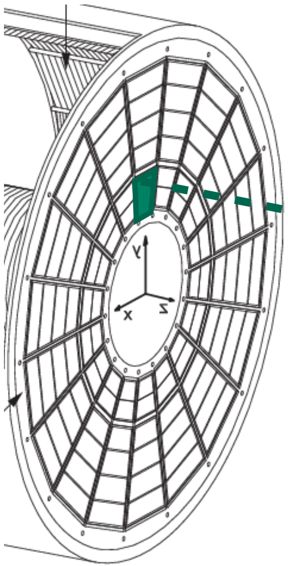


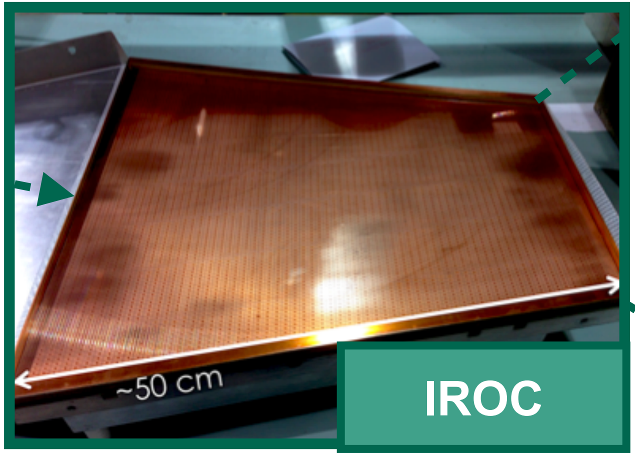
Central Readout Chamber (Design)

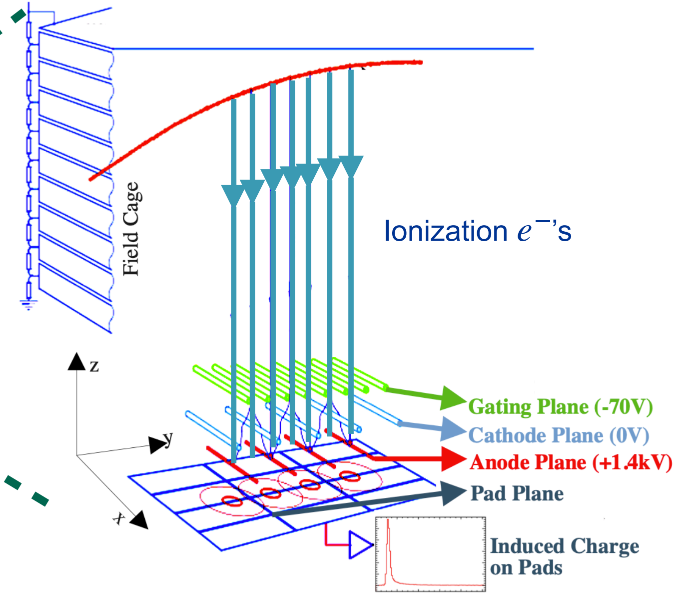


ALICE Collaboration 2010 Nucl. Instrum. Methods A 622 316-367

R&D Strategy





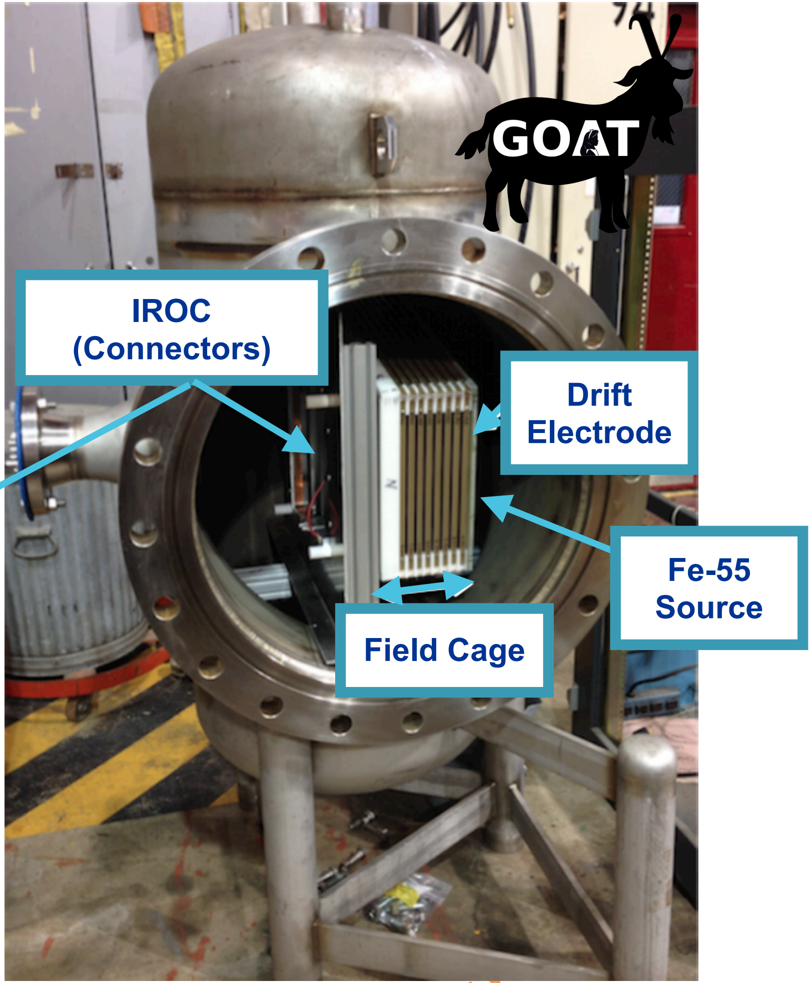


DUNE CDR: arXiv: 2103.13910

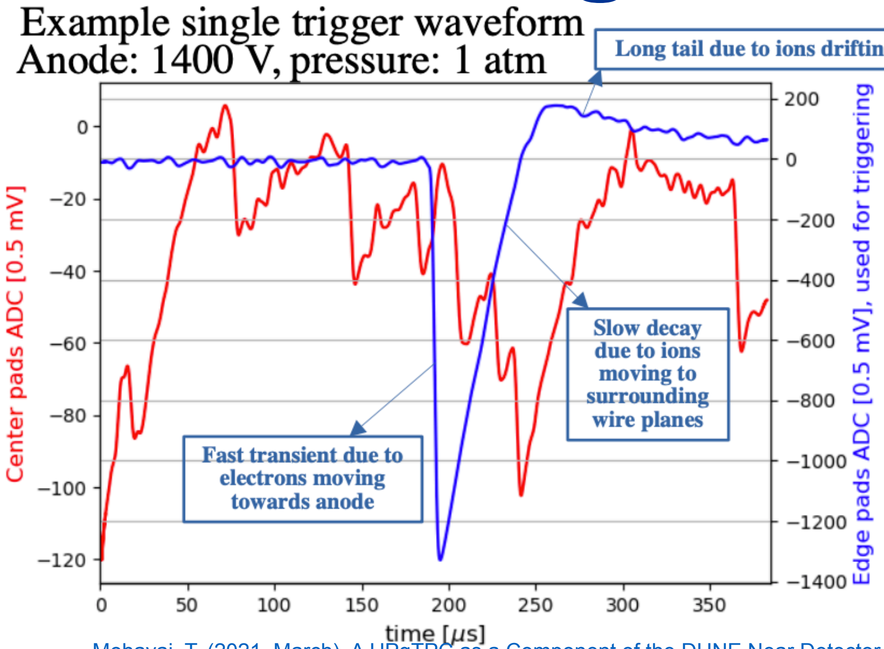
- Readout chambers are multi-wire proportional chambers with cathode pad readout
- Test readout chambers at various **pressure up to 10 atm**
- Define a base gas mixture for them - Ar-CH_4
- **Optimize choices on:**
    - Necessary anode voltages to keep charge deposition constant with change in pressure
    - Low diffusion → better spatial resolution
    - Purity requirements → minimal O_2 and H_2O to prevent electron attachment

IROC Test Stand

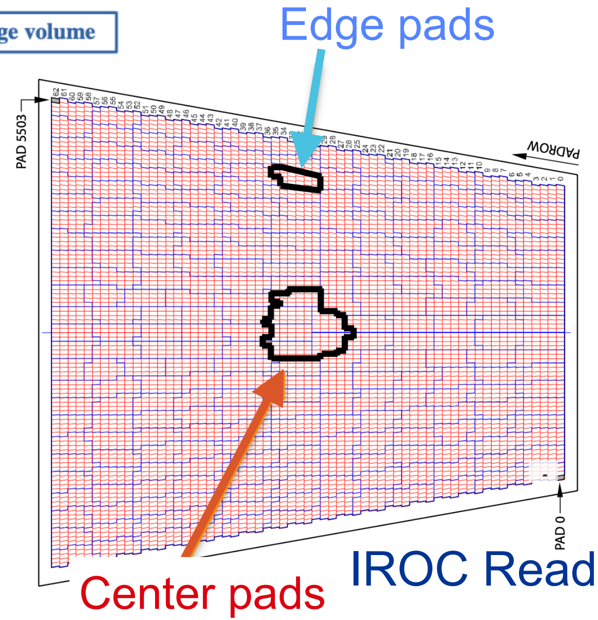
- Test stand at Fermilab
  - GOAT - **G**aseous-Ar **O**peration of **A**LICE **T**PC
- Pressure vessel rated to 10 atm.
  - Can accommodate 1 IROC with 10 cm drift region



IROC Testing



[Mohayai, T. (2021, March). A HPgTPC as a Component of the DUNE Near Detector.]



IROC Readout Pads

- Edge pads - used to reject cosmic background
- Center pads - each peak correspond to Fe-55 x-ray conversion

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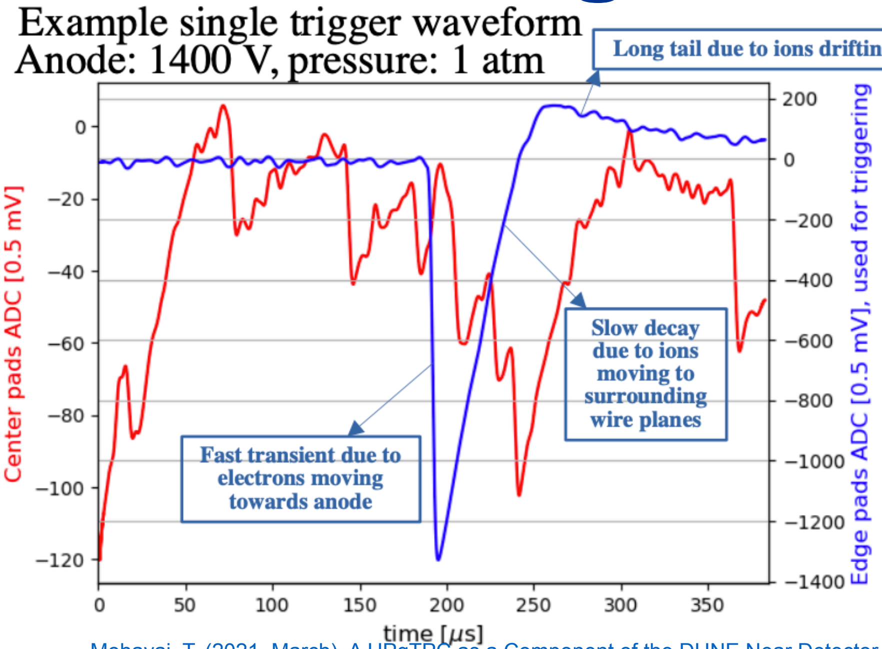
IROC Testing



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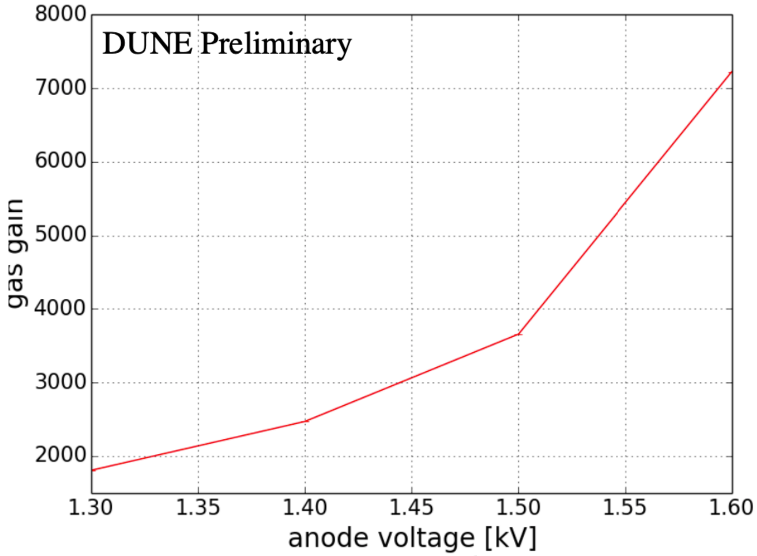
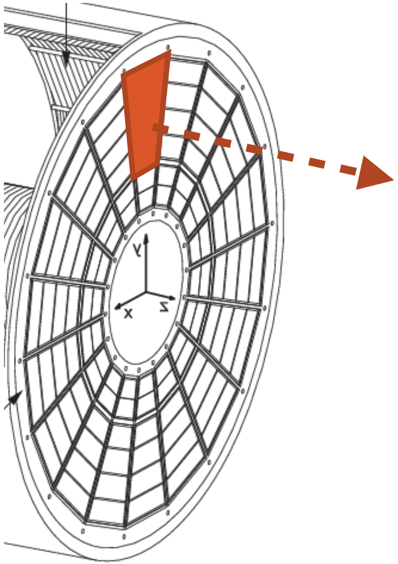
90:10 Ar:CO_2 @ 1 atm

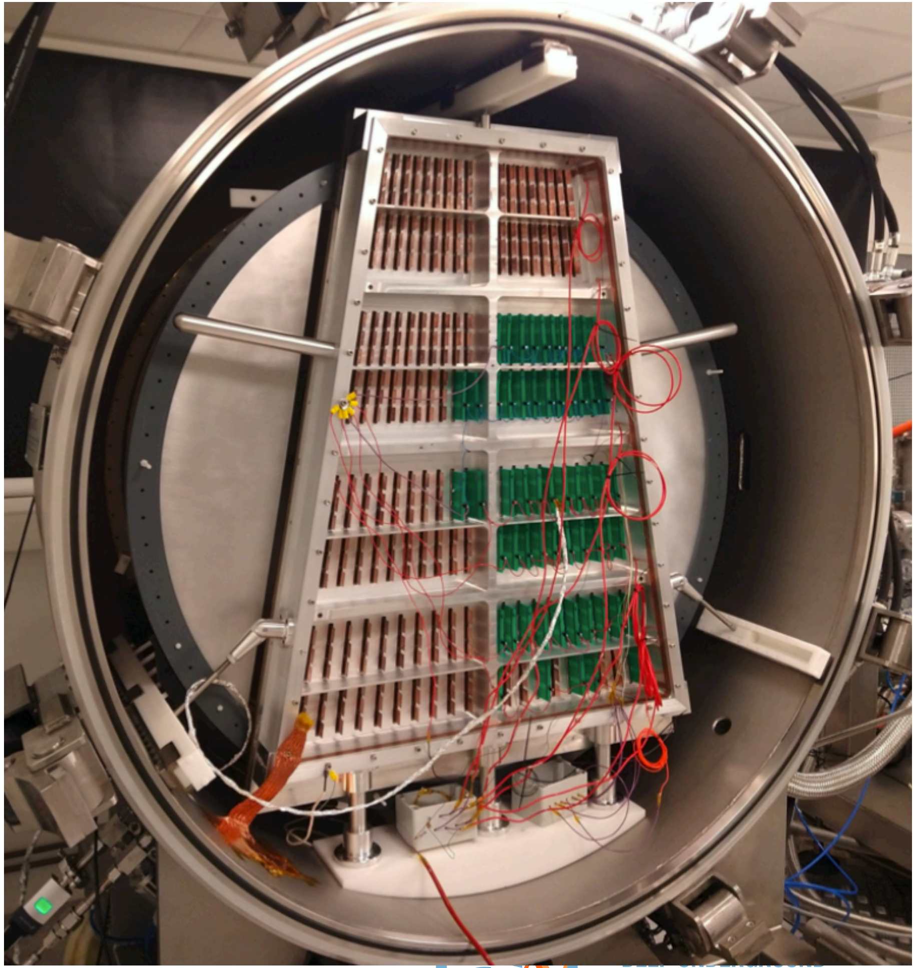


- Edge pads - used to reject cosmic background
- Center pads - each peak correspond to Fe-55 x-ray conversion
- Use x-ray signal to calculate the gain (right)

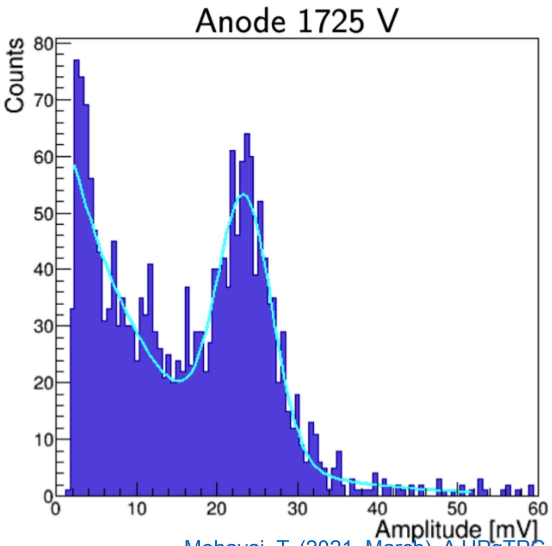
OROC Test Stand

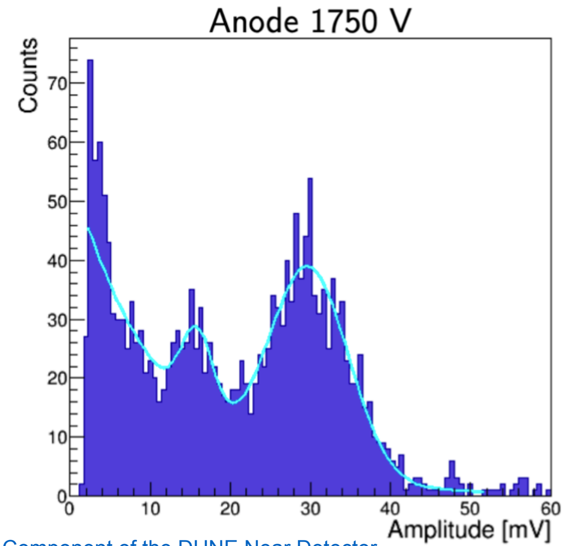
- Test stand located at Royal Holloway, University of London
- Pressure vessel rated to 5 atm.
- Accommodates 1 OROC with 40 cm drift region





OROC Testing





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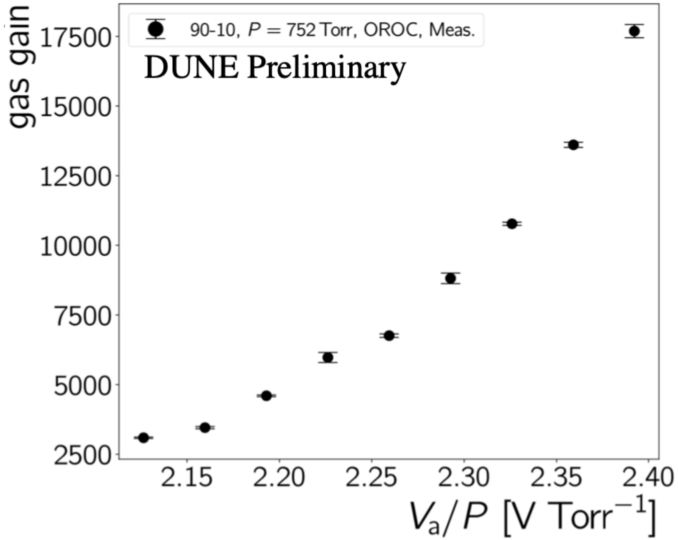
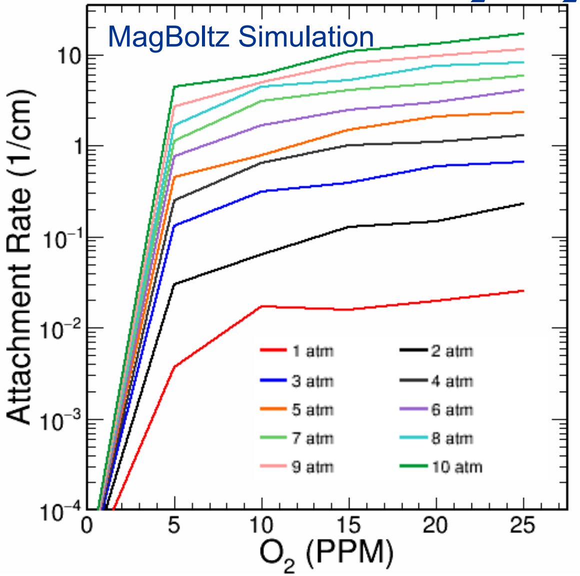


- Typical amplitude spectrum of Fe-55 is observed
- Peak position shifts to higher amplitude as anode voltages increases
- Gain distribution on right shows the expected trend

What's Next?

- Operating readout chambers at high pressures for further gain calibration
- Impurities can have a much greater impact at high pressure
  - Attachment increases by a factor of 1000
  - ND-GAr will require stringent impurity limits (< 1 ppm O_2)
- Need to understand these types of factors to refine gain calibration

$90 : 10 : X \quad Ar : CO_2 : O_2$



$$\text{Gain} = \frac{V}{N_0 1.6 \times 10^{-19} e^{-ad} G_e}$$

a: attachment coefficient
G_e: electronics gain
V: Anode voltage

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Summary

- The HPgTPC is an important part of the near detector suite
- Two test stands are testing ALICE's inner and outer readout chambers as a part of the ongoing R&D efforts for the DUNE ND complex
- Both test stands have observed the expected gain calibration at 1 atm.
- Working towards operating these readout chambers at higher pressures

Backups

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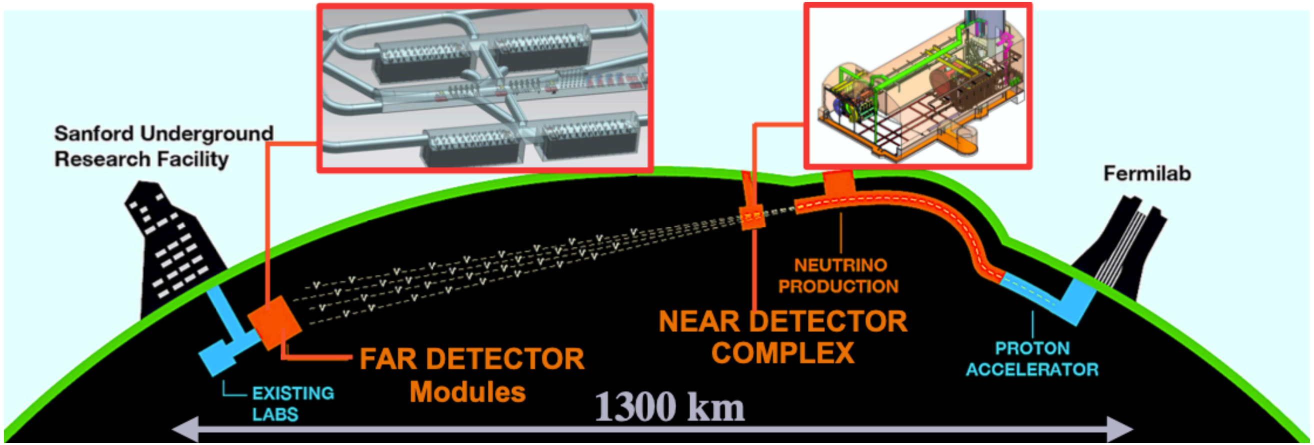
Deep Underground Neutrino Experiment (DUNE)



- Primary goal of DUNE is to **reduce the uncertainties of oscillation measurements** to the few % level
- Dominant sources of uncertainty include:
  - ν Flux
  - $\nu - \mathrm{Ar}$ cross section

} **Constrained by the Near Detector Complex**

Benefits of ND-GAr

- Can constrain $\nu - \mathrm{Ar}$ interaction and cross section uncertainties
  - Lower detection threshold than LAr, so sensitive to lower energy charged particles that may not be seen in LAr.
  - Explore differences between simulation and data for these lower energy
- Measure particles that leave ND-LAr and enter MPD
- Reconstruct neutrino energy via spectrometry and calorimetry
- Measure all components of the neutrino flux $(\nu_\mu, \bar{\nu}_\mu, \nu_e, \bar{\nu}_e)$