A High Pressure TPC with Optical Readout

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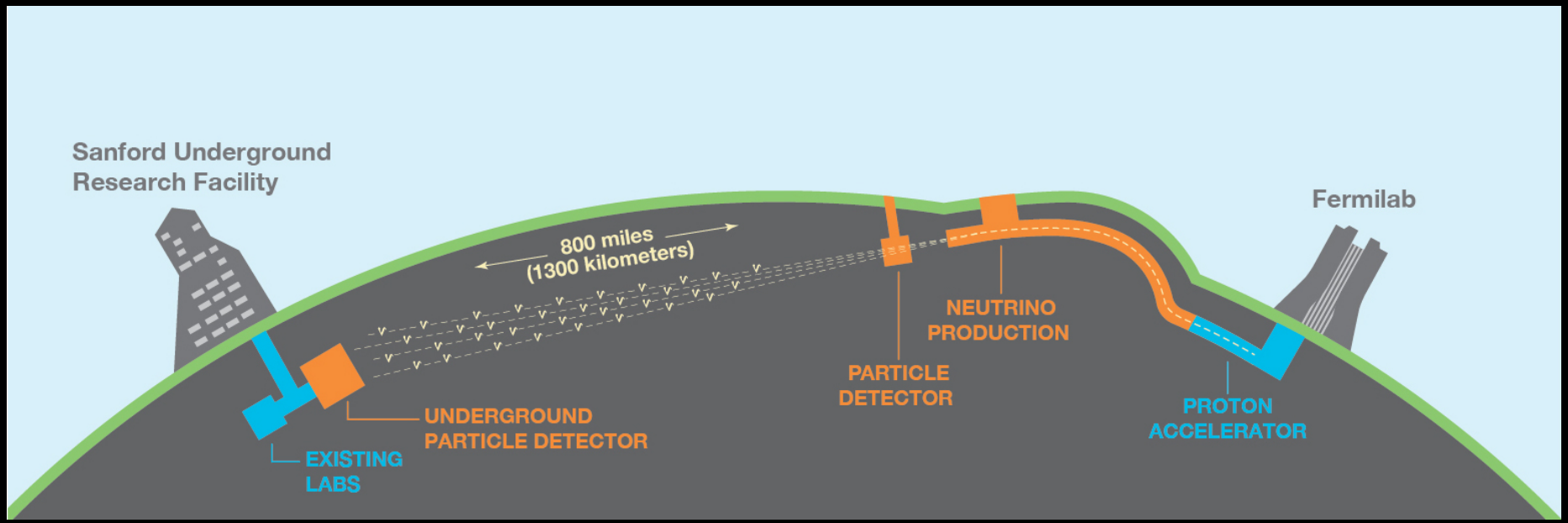
Future Neutrino Oscillation Experiments

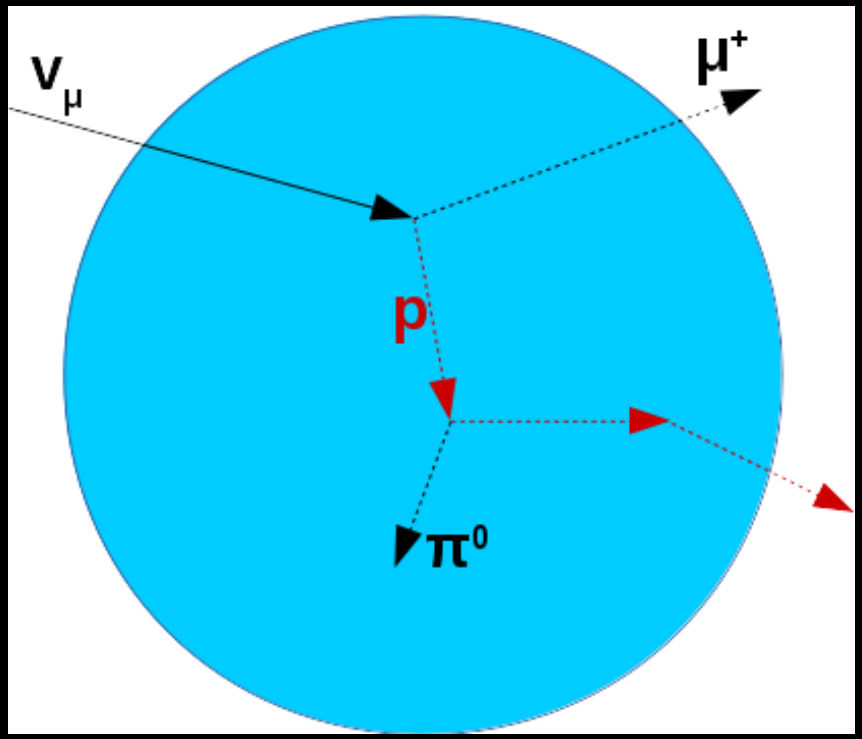
Next generation of long baseline neutrino oscillation experiments will aim to discover leptonic $\mathcal{CP}$-violation.

- Measure difference between neutrino and anti-neutrino oscillations
- Important to understand differences in neutrino-nuclear interactions for neutrinos and anti-neutrinos



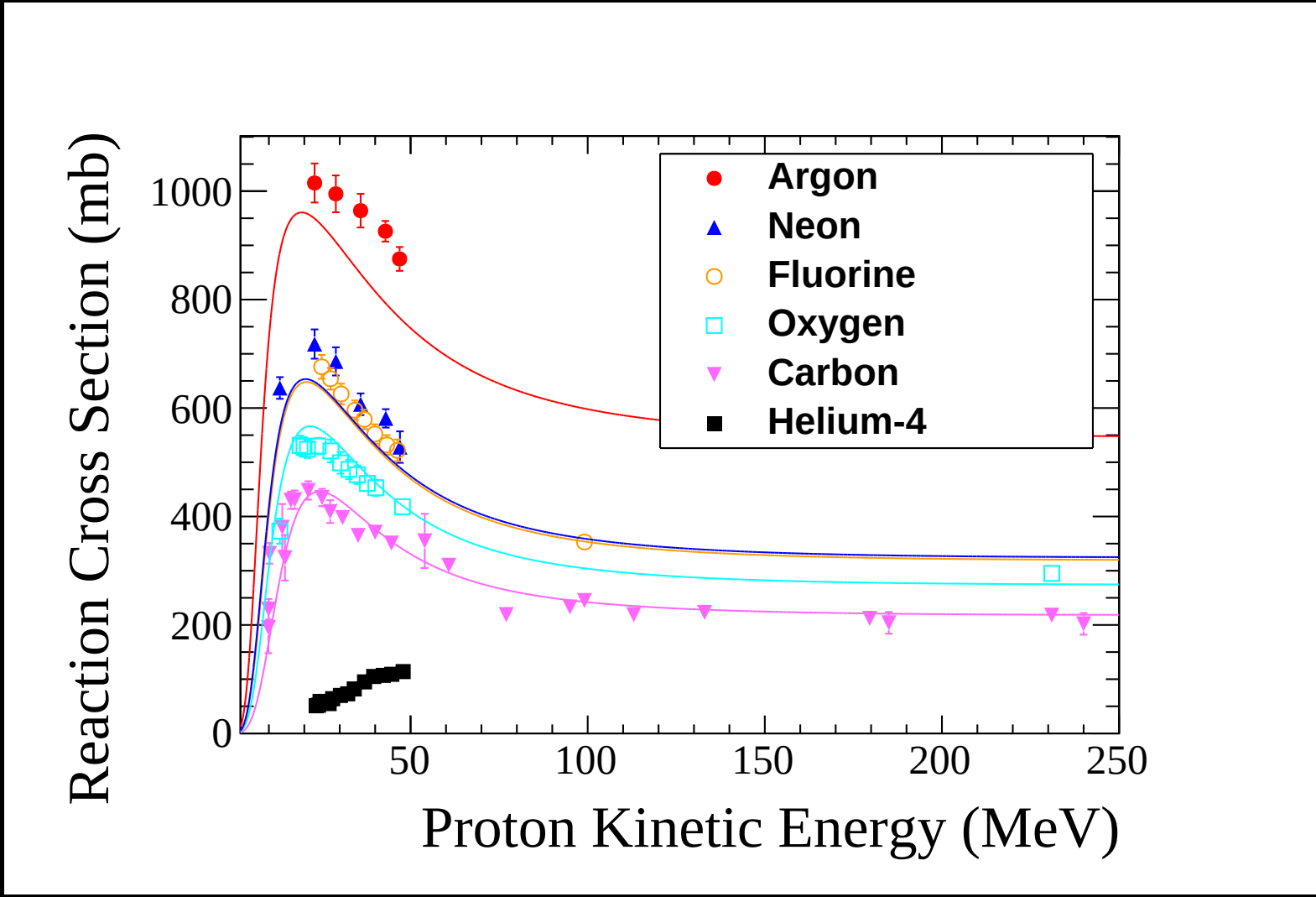
DUNE TDR

Nucleon FSI



- Nucleons produced in neutrino interactions undergo various interactions in the target nucleus (affecting their kinematics)
- The lack of full understanding of nuclear interactions in the nucleus is a source of systematic uncertainty

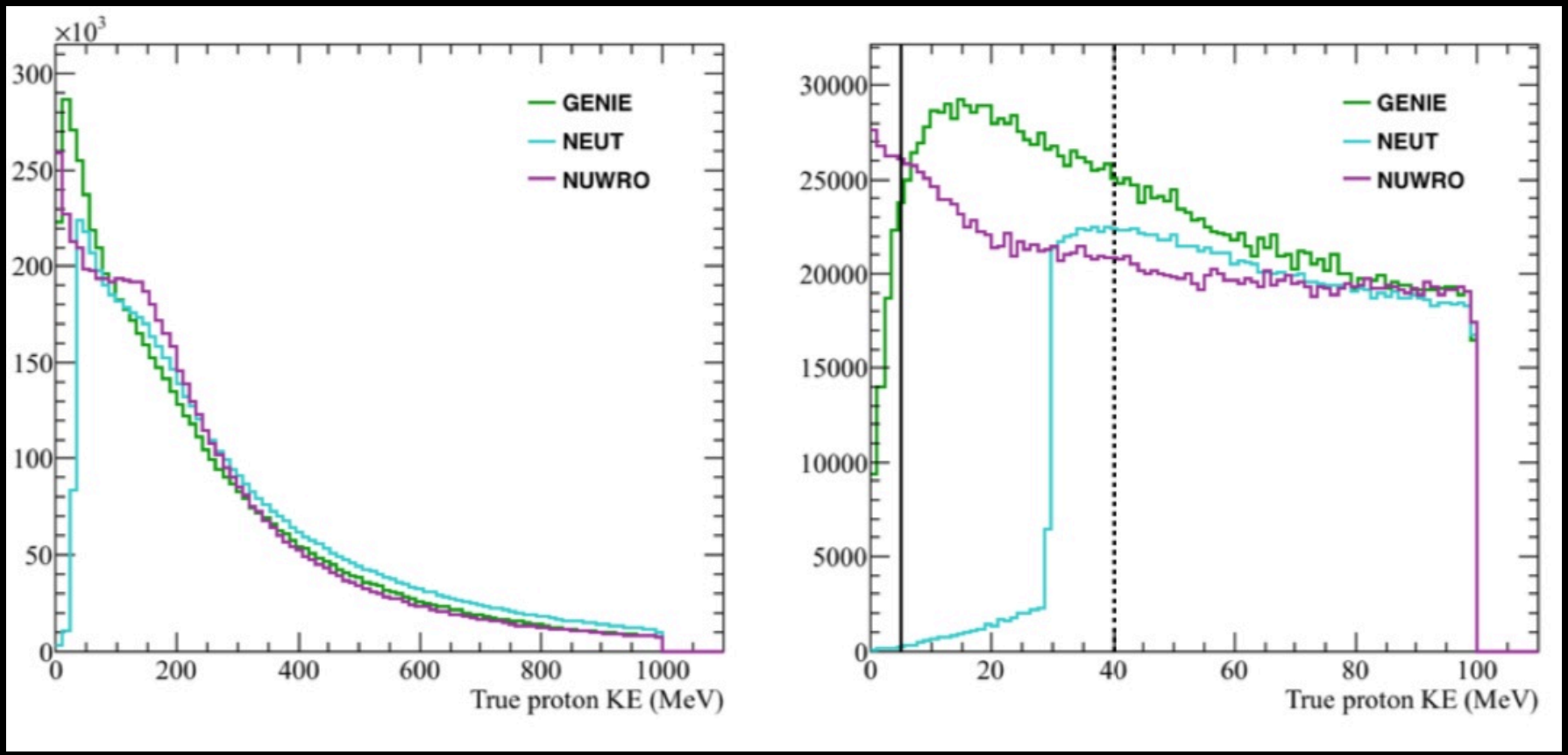
Proton Scattering Cross Sections



Model from Wellisch and Axen, PRC 54, 1329 (1996)

Protons from Neutrino Interactions on Argon

Neutrino interaction generators disagree at low energies



J. Raaf

Aims and Objectives

- A High Pressure Time Projection Chamber is a novel possibility for a neutrino detector
  - The DUNE Near Detector will include a high pressure gas TPC
- Capable of measuring low momentum outgoing hadrons (typically a few hundred MeV) required for neutrino-nucleus interaction modelling
- To test the HPTPC: Beam test was performed at the T10 Beamline in CERN in August/September 2018
- Innovative off-axis beam technique and moderator used to increase signal to background fraction and reduce proton momentum measured

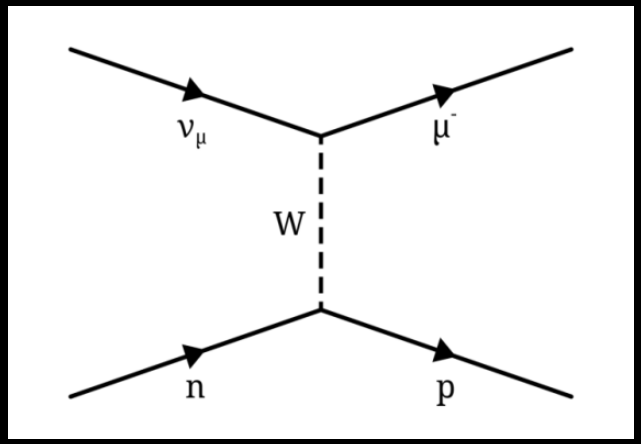
Motivation for HPTPC as a Neutrino Detector

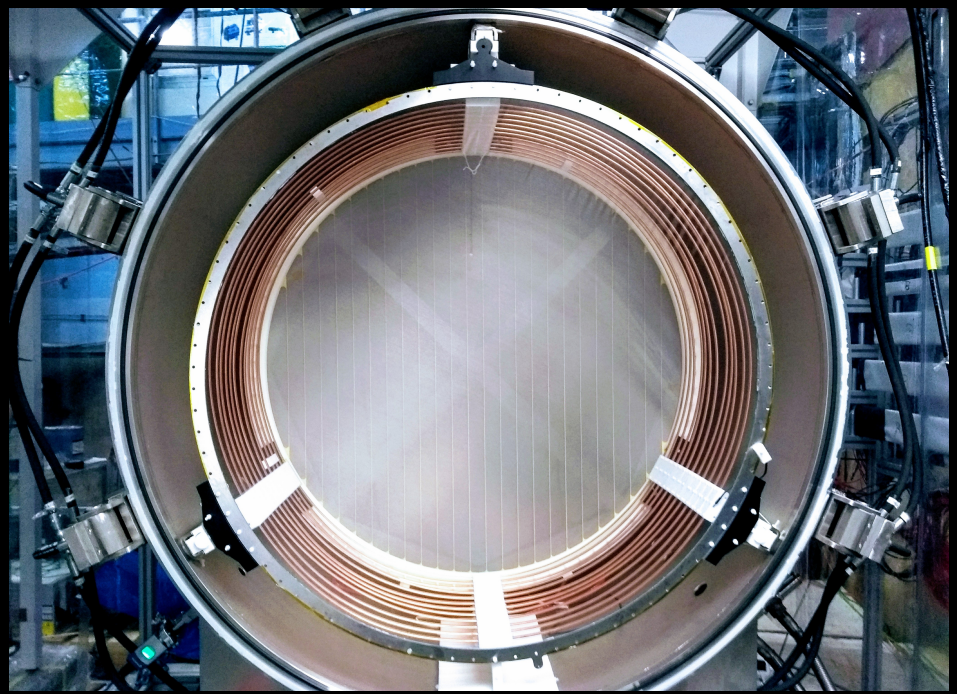
Gaseous detectors:

- Low momentum threshold for final state particles
- Fewer readout channels required to resolve a track
- Ability to change target gas

High pressure:

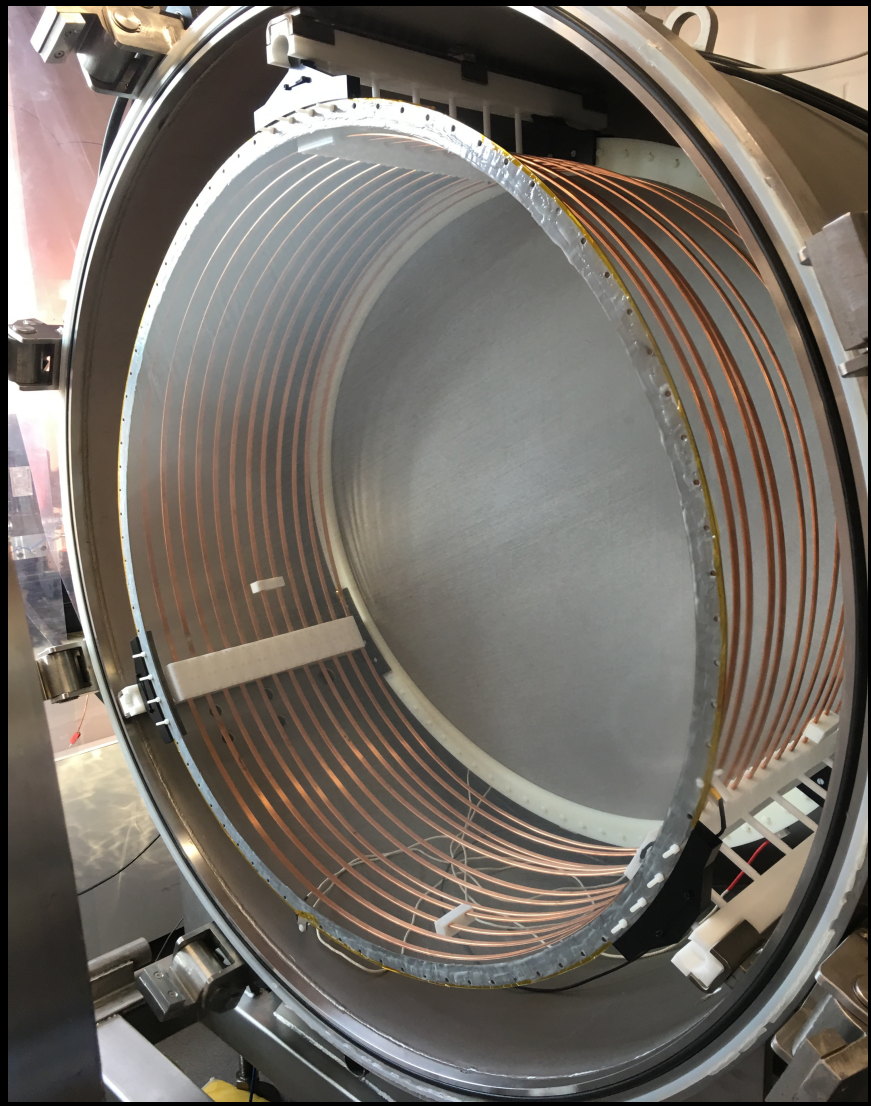
- Increases target mass $\rightarrow$ sufficient events when combined with neutrino beams from MegaWatt facilities



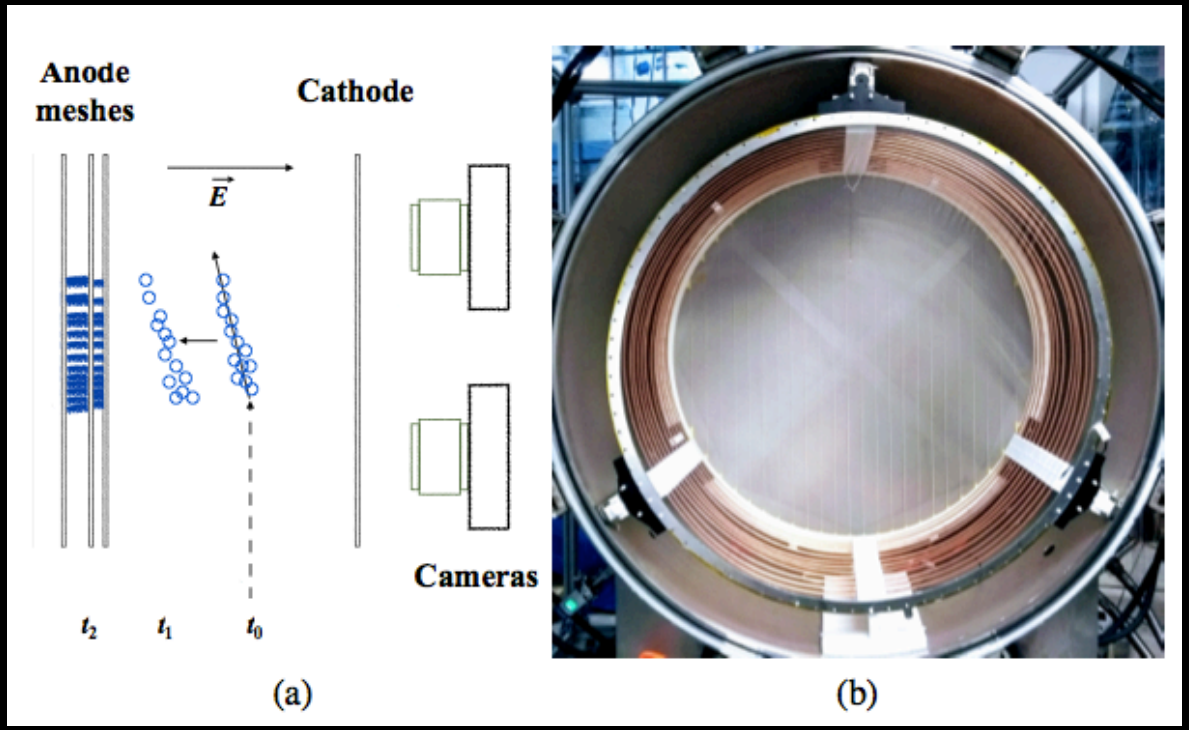


Prototype HPTPC

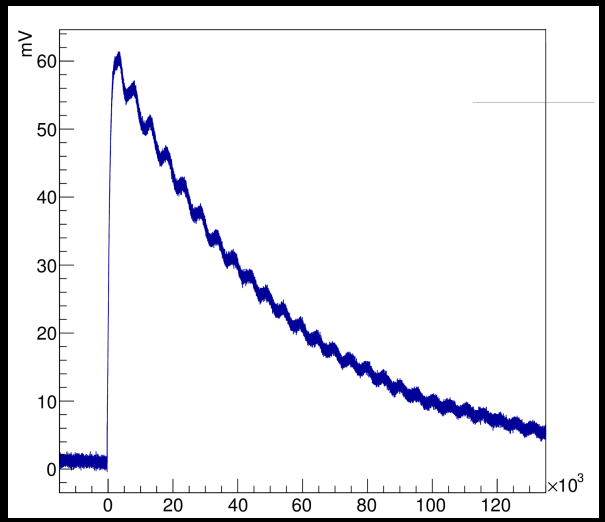
- Vessel rated to 5 barG of pressure
- Steel mesh cathode and anodes create drift field and amplification region respectively
- Field cage: 12 copper rings maintain uniformity of the drift field
- 4 CCD cameras image a quadrant of amplification region



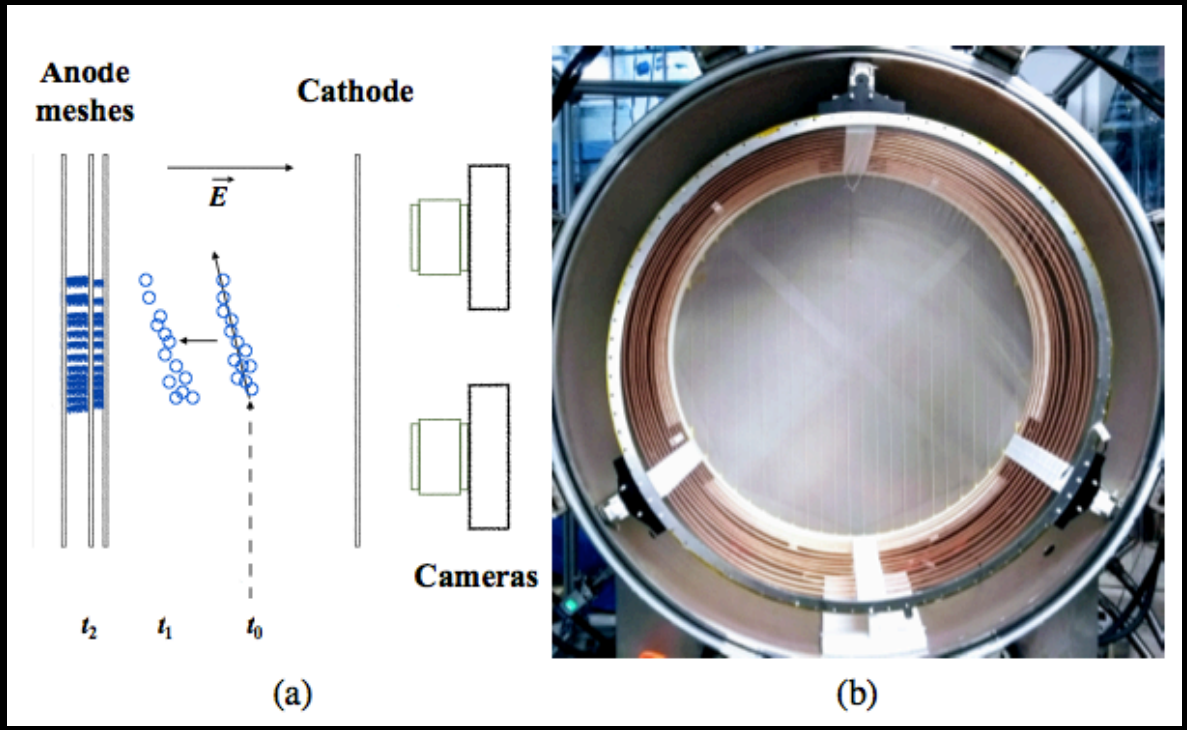
Charge Readout



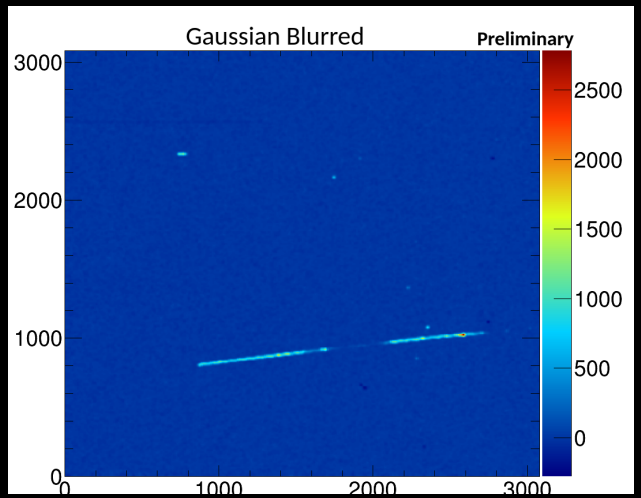
- Charged particles ionise gas
- Electrons drift to amplification region
- Electron avalanche in the amplification region



Optical Readout



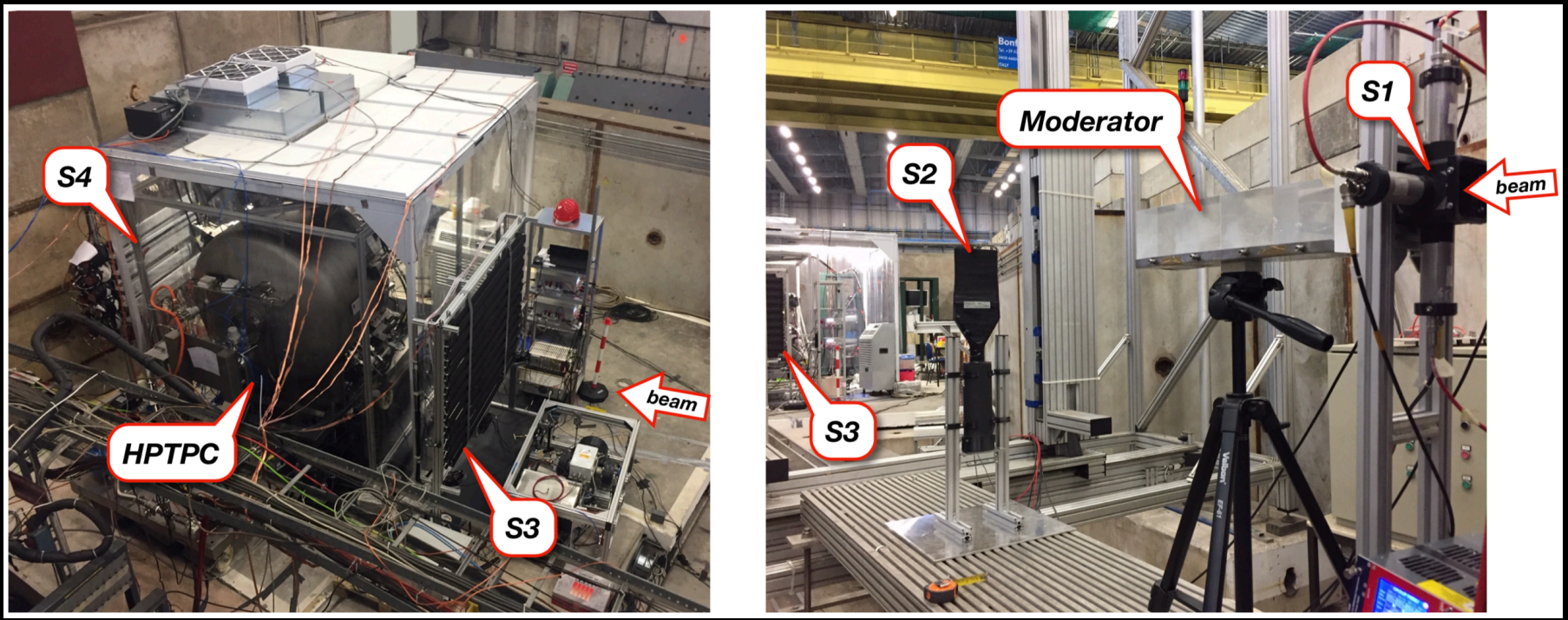
- Avalanche excites gas $\rightarrow$ emits scintillation light
- Optical signal is read by CCD cameras
- CCD cameras sensitive in the 300-800nm range



Beam Test Overview

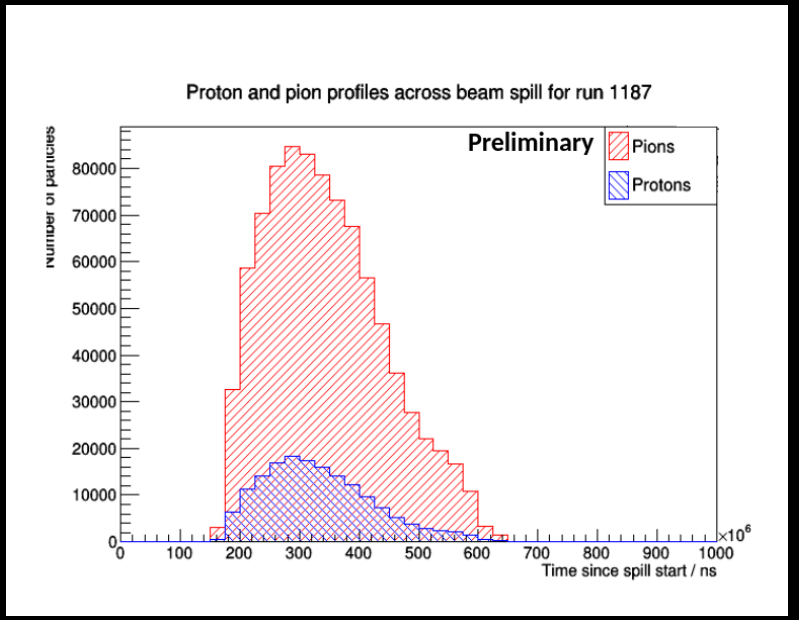
- Beam Test took place at the T10 beamline, East Area at the PS in CERN
- 1 Month of beam from 15 August to 18 September
- Primary beam configuration used 0.8 GeV/c beam
- R&D goal: Test HPTPC prototype to provide proof of concept

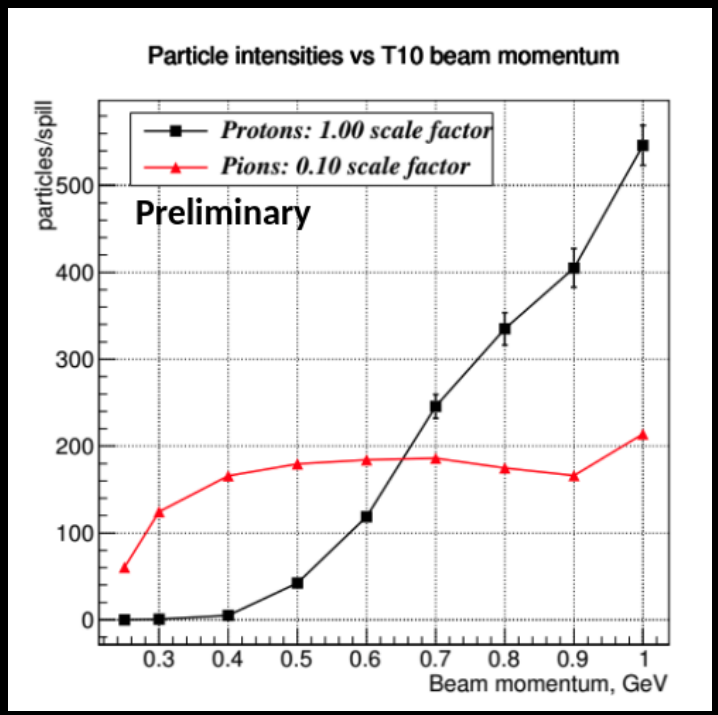
Test Beam Set Up



Beam Test: Beam conditions

- Beam spill on the order of 500ms
- Approximately 5-10s between spills

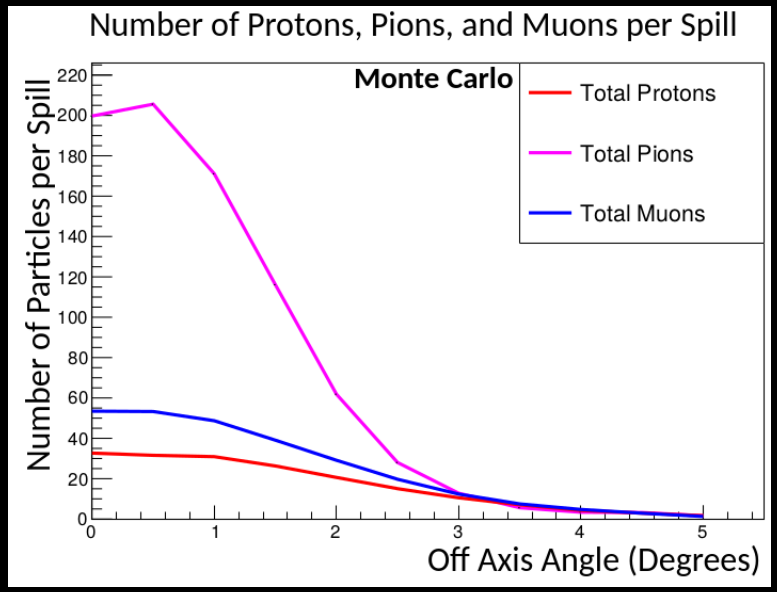


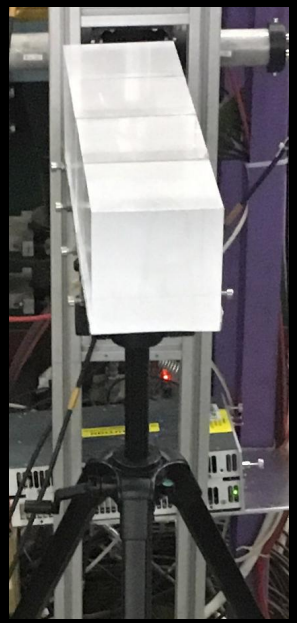


- Beam has high pion component at low momentum settings
- Pions are a background for $p - Ar$ cross-section measurement

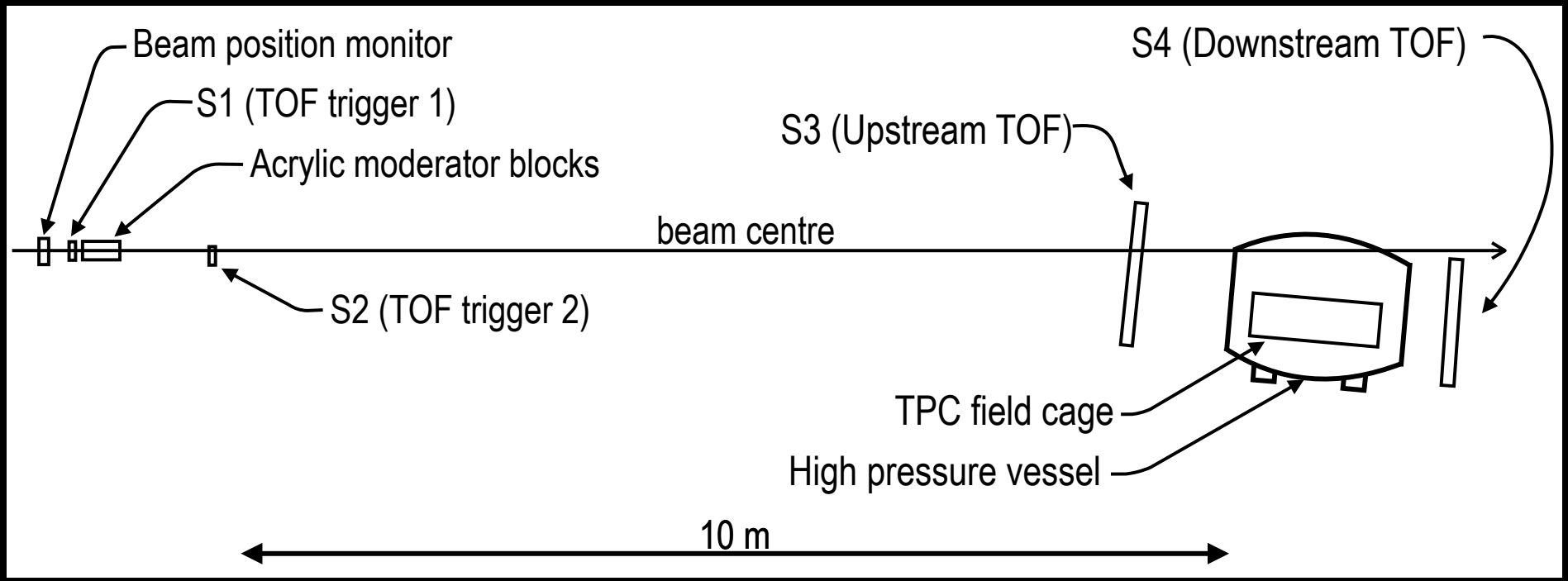
Off-axis angle technique

- Seek to increase the proton ratio while decreasing the proton energy of the beam
- Use of acrylic moderator blocks in front of beamline
- Causes protons to scatter at wider angles than pions
- Moving off axis increases proton:pion ratio
- Trade off between improved Proton:Pion ratio and raw number of particles
- Range of 3-4 degrees chosen for beam test



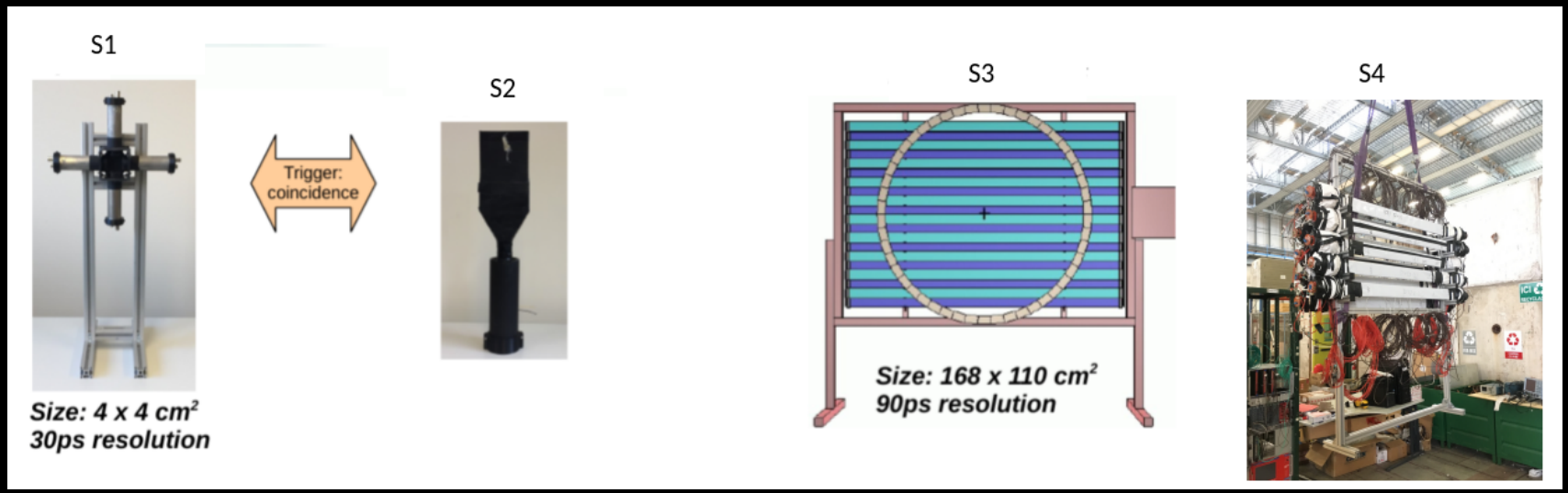


Beam Test Layout

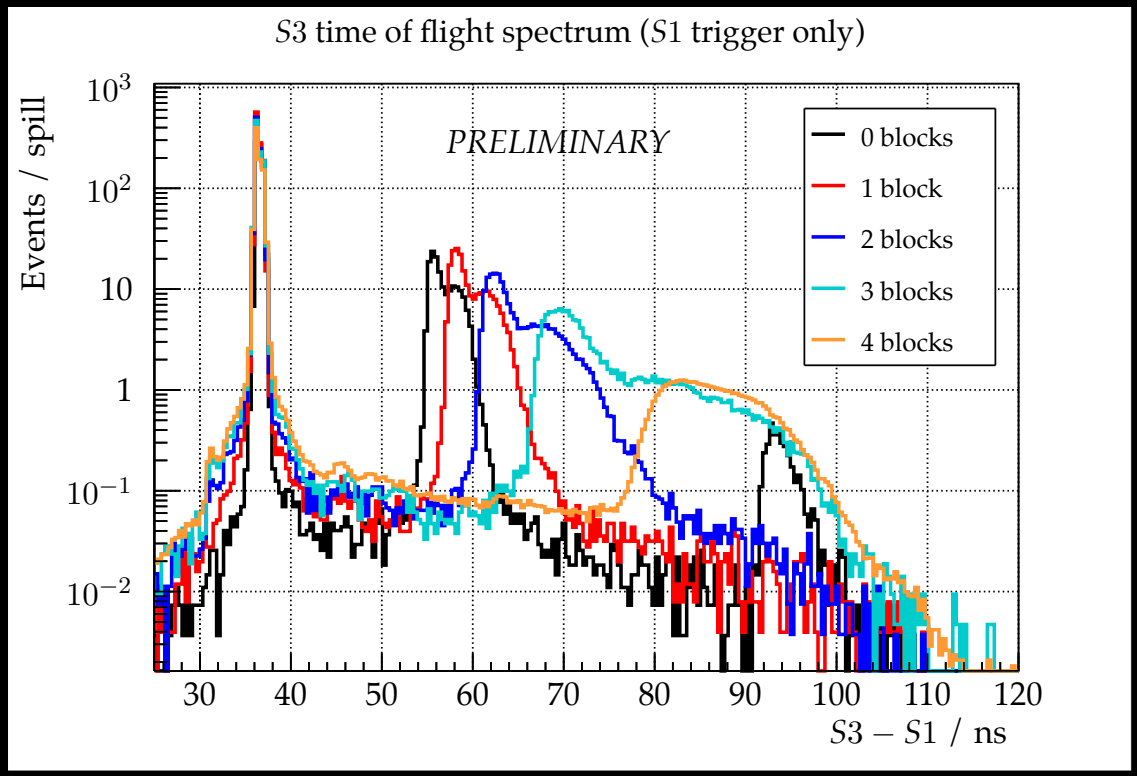


Time of Flight Systems

- 3 constituents upstream of TPC (S1-3):
  - Plastic scintillator upstream counter (S1) of 4cm x 4cm with trigger counter (S2)
  - Further downstream timing detector (S3) with 20 bars of plastic scintillator with 90ps timing resolution - a SHiP prototype from the Université de Genève
- 1 constituent directly behind the TPC vessel
  - Bars are 1cm x 10cm x 140cm plastic scintillator with Timing resolution of ∼1ns, built by UCL

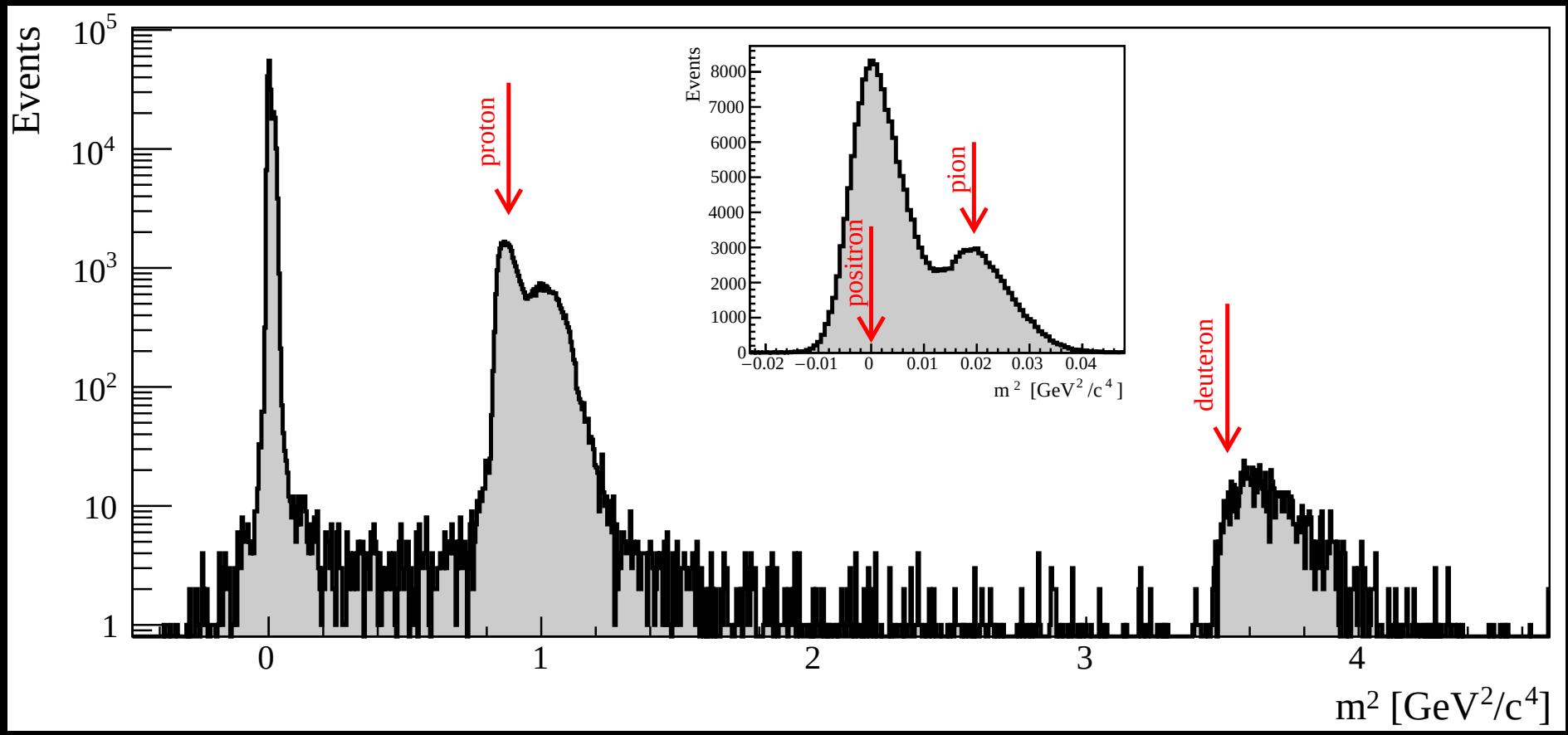


Time of Flight Results: S1 to S3

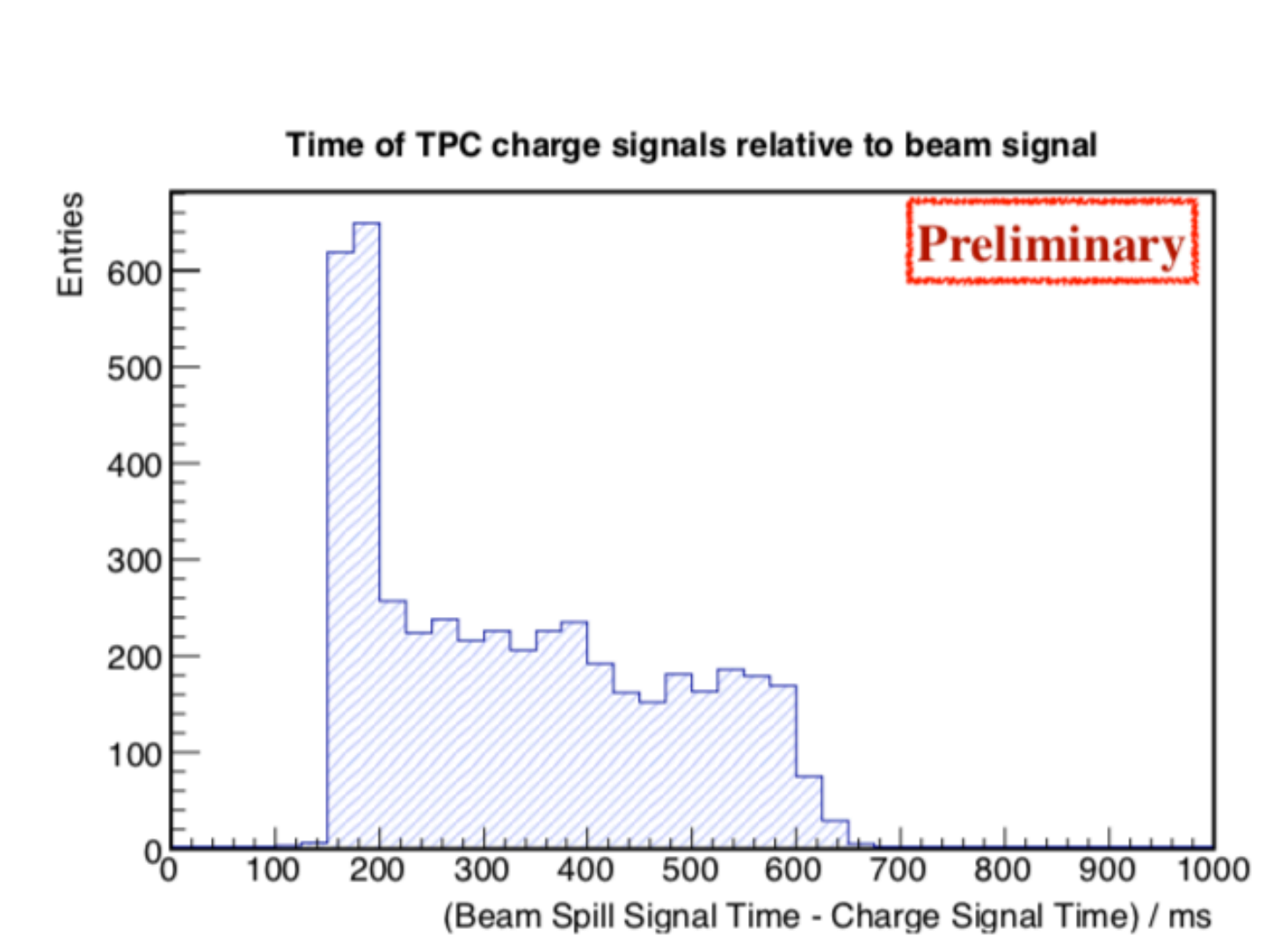


- Proton and Pion peak spread further apart with increased number of moderator blocks
- Protons experience momentum spread

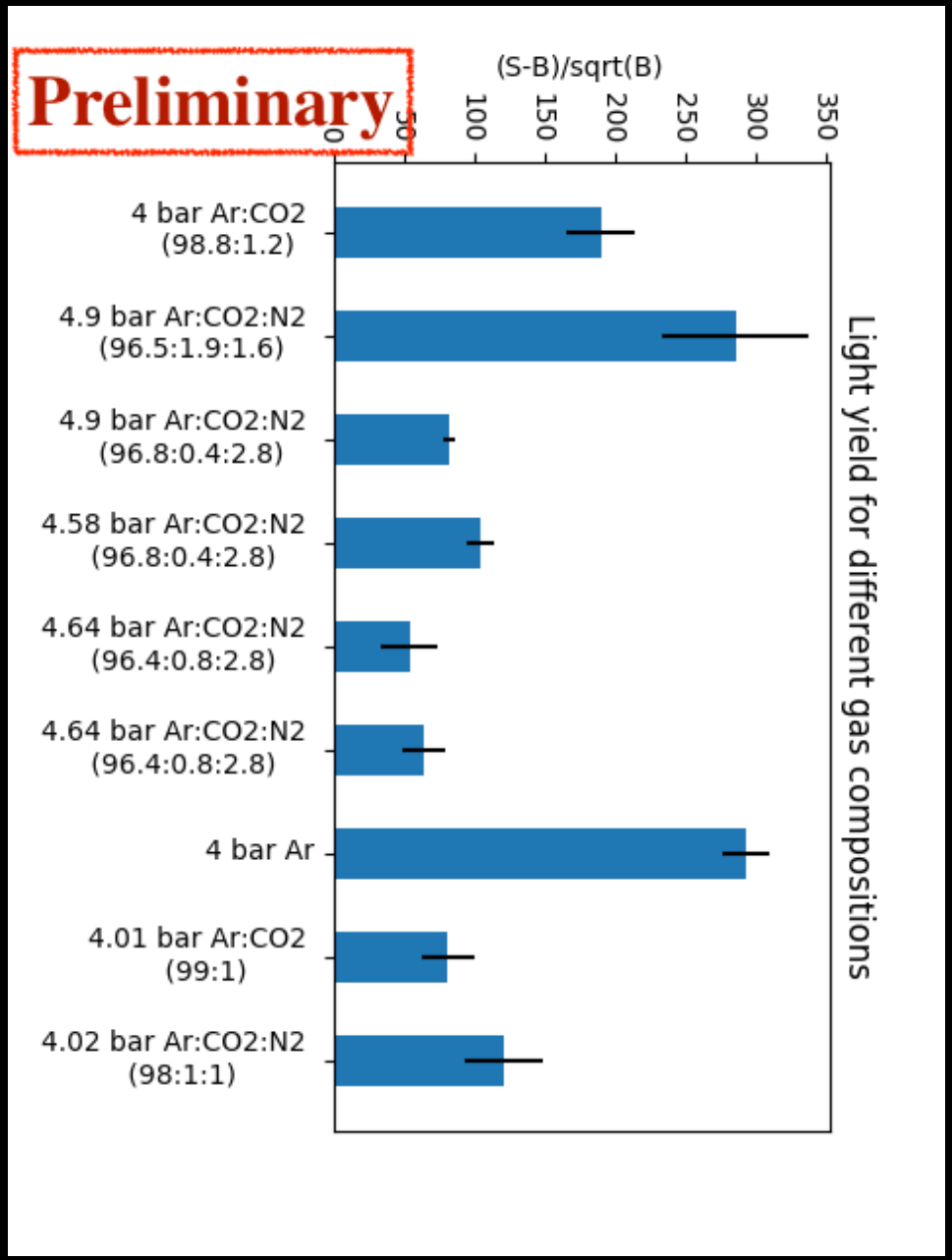
Time of Flight Results



HPTPC Charge Signals



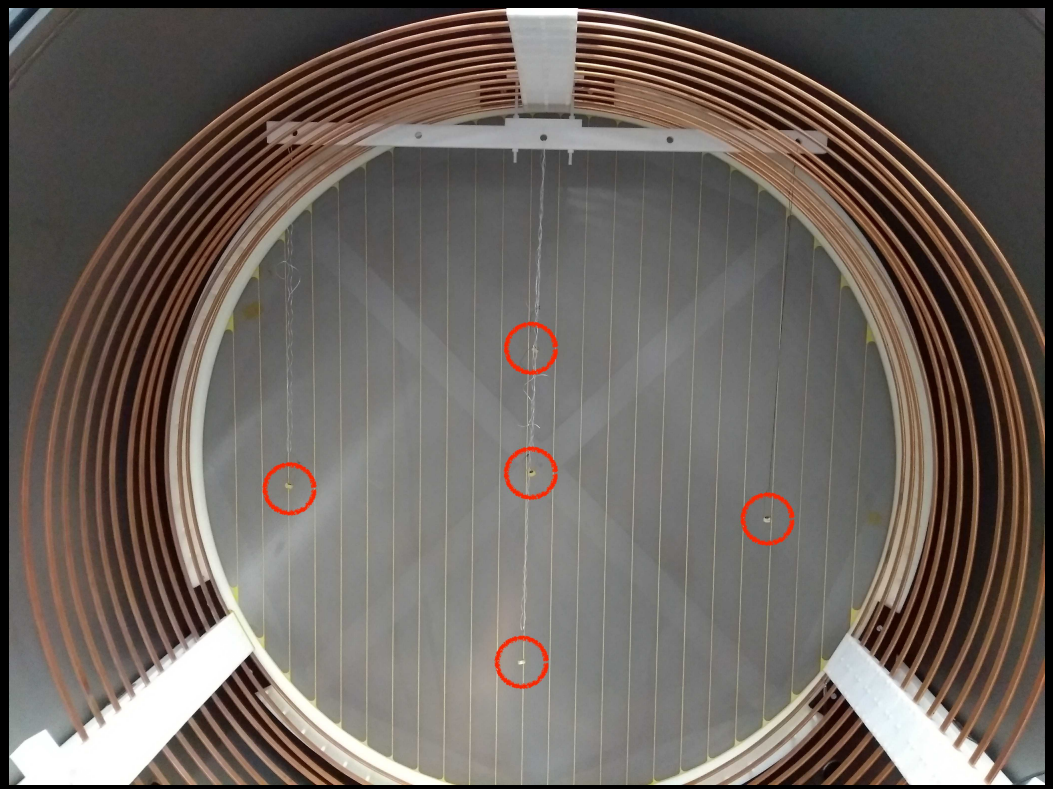
Light Yields for Different Gas Mixes



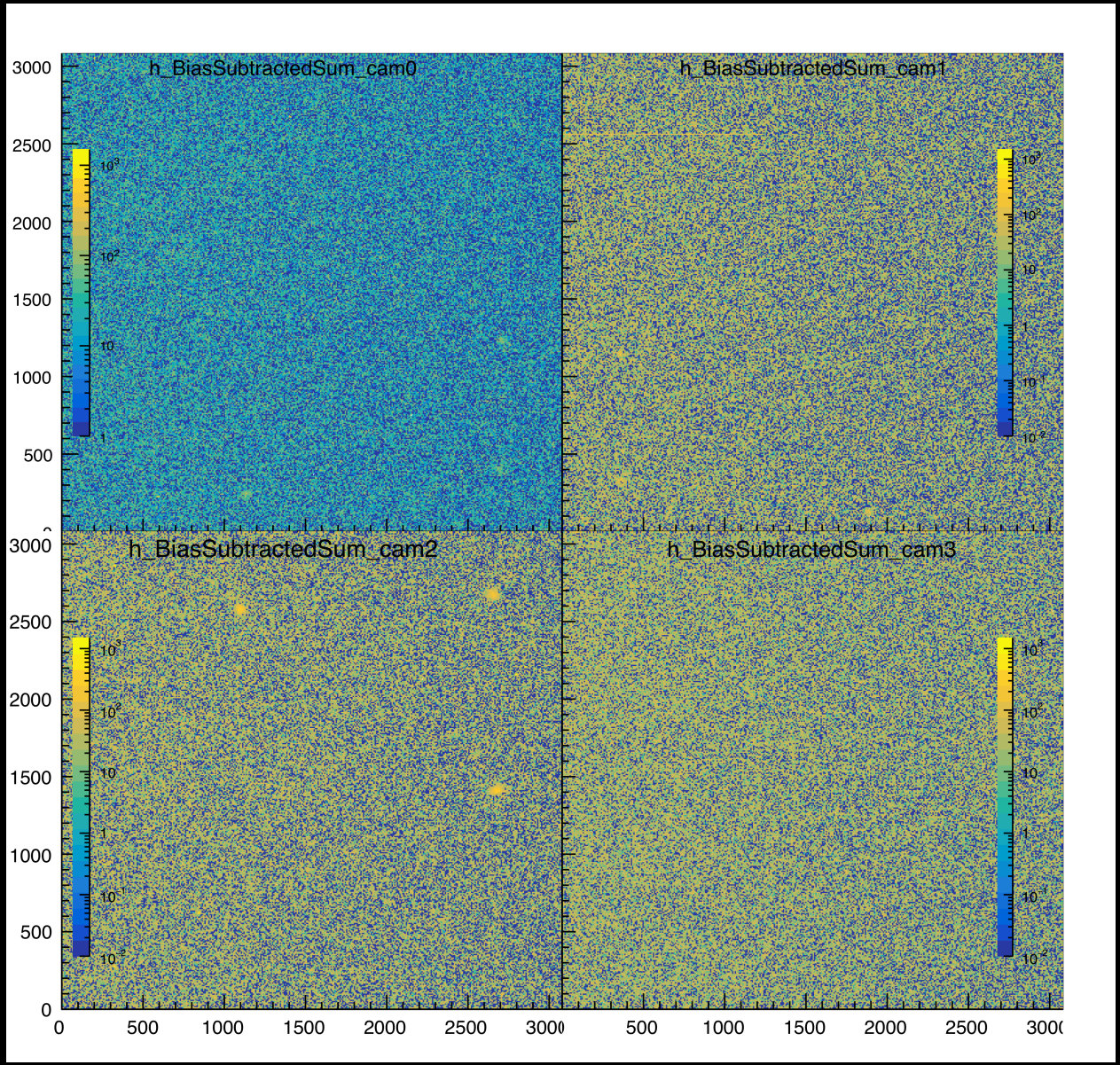
Calibration Sources

During and since the CERN test beam we have also been placing different radioactive sources inside the detector volume.

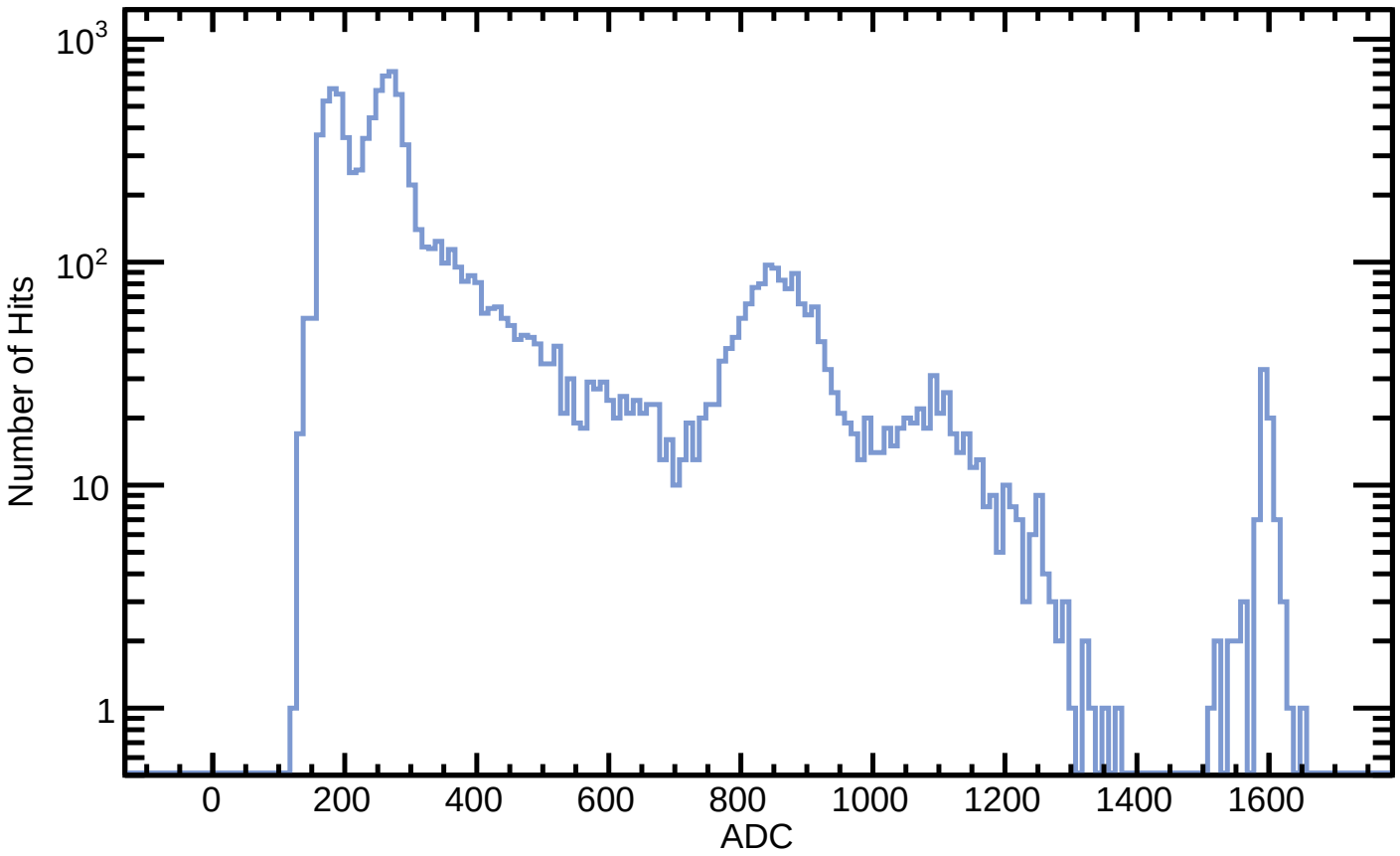
- ^{137}Cs and ^{241}Am
- ^{55}Fe



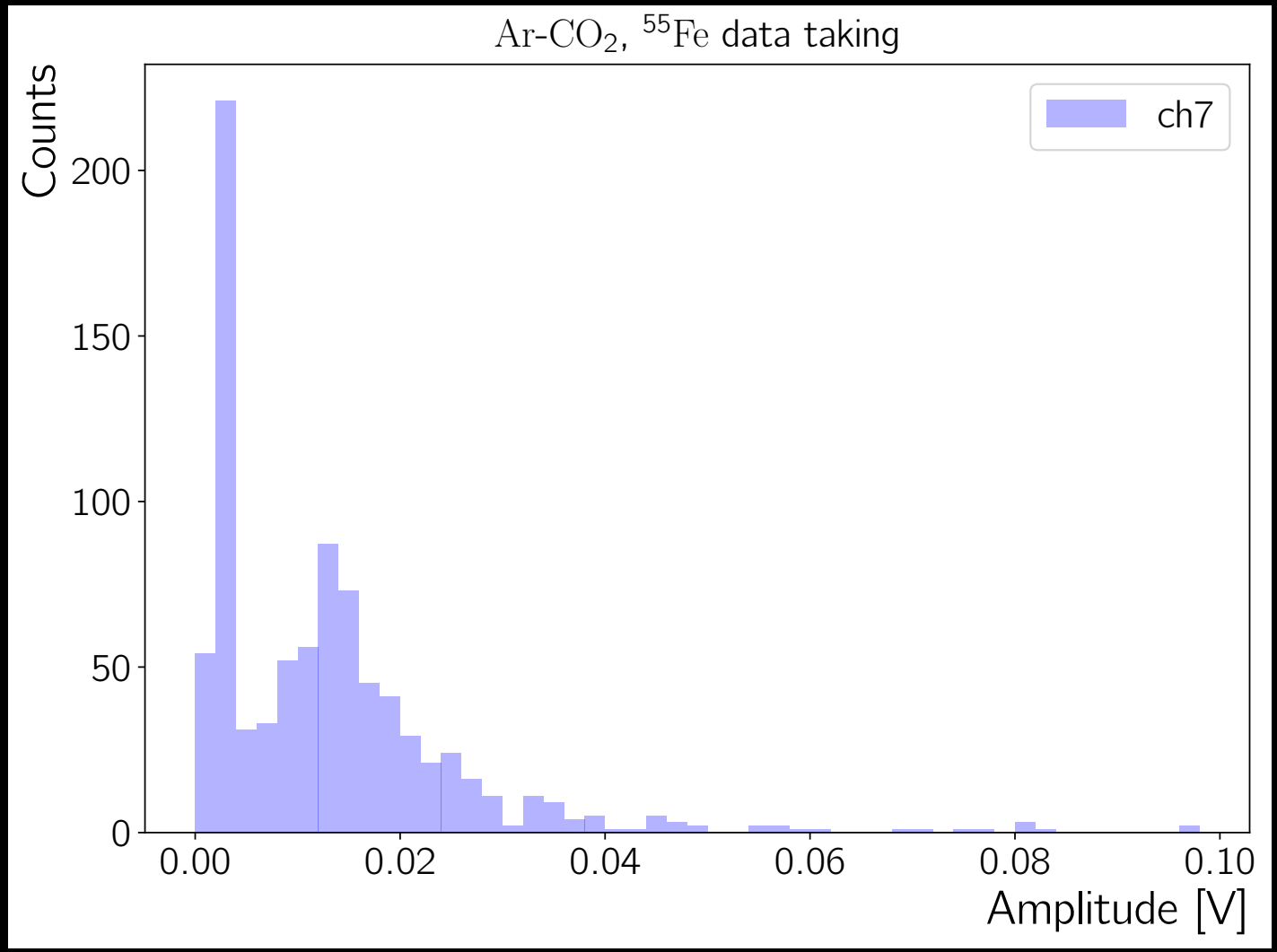
Light from Calibration Sources (^{241}Am and ^{137}Cs)



Charge Readout (^{241}Am and ^{137}Cs)



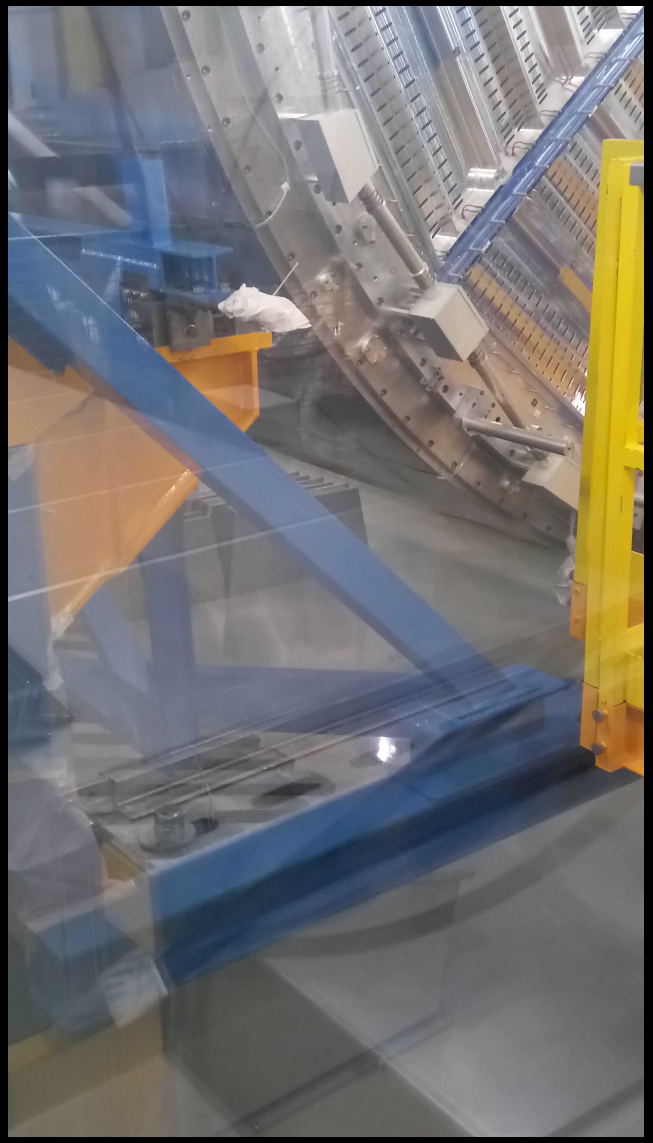
Charge Readout (^{55}Fe)



Current Status: Preparations for DUNE

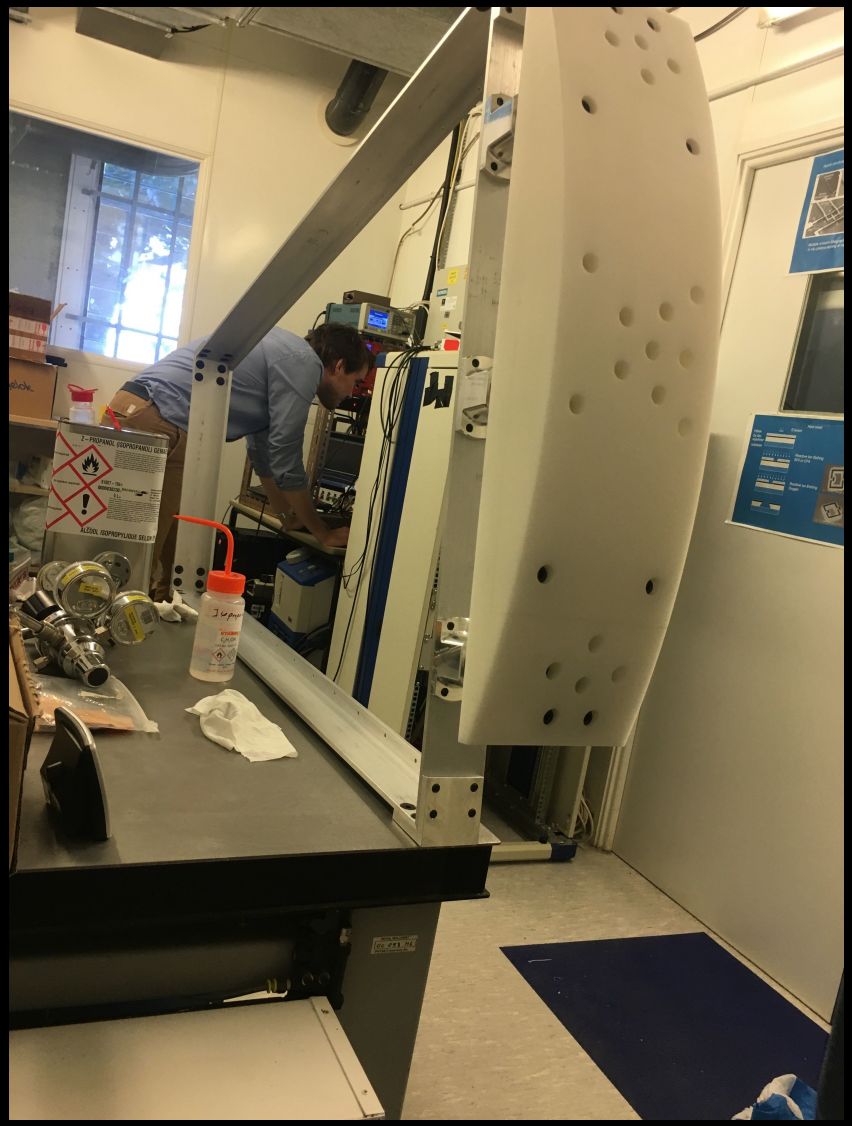
- The DUNE near detector complex will include a HPTPC
- Readout chambers from the ALICE TPC will be used

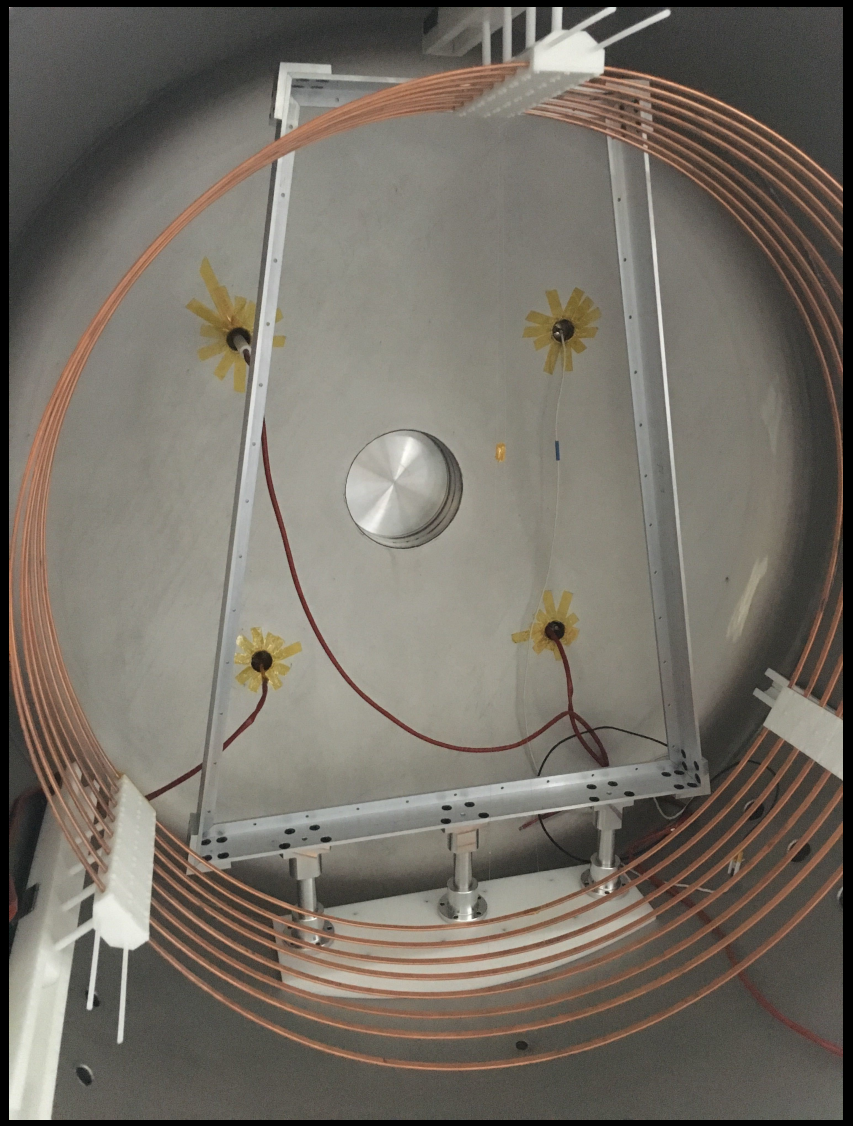
ALICE Readout Chambers (CERN)



ALICE OROC (RHUL, London-ish)

OROC - Preparations for Installation





Summary and Outlook

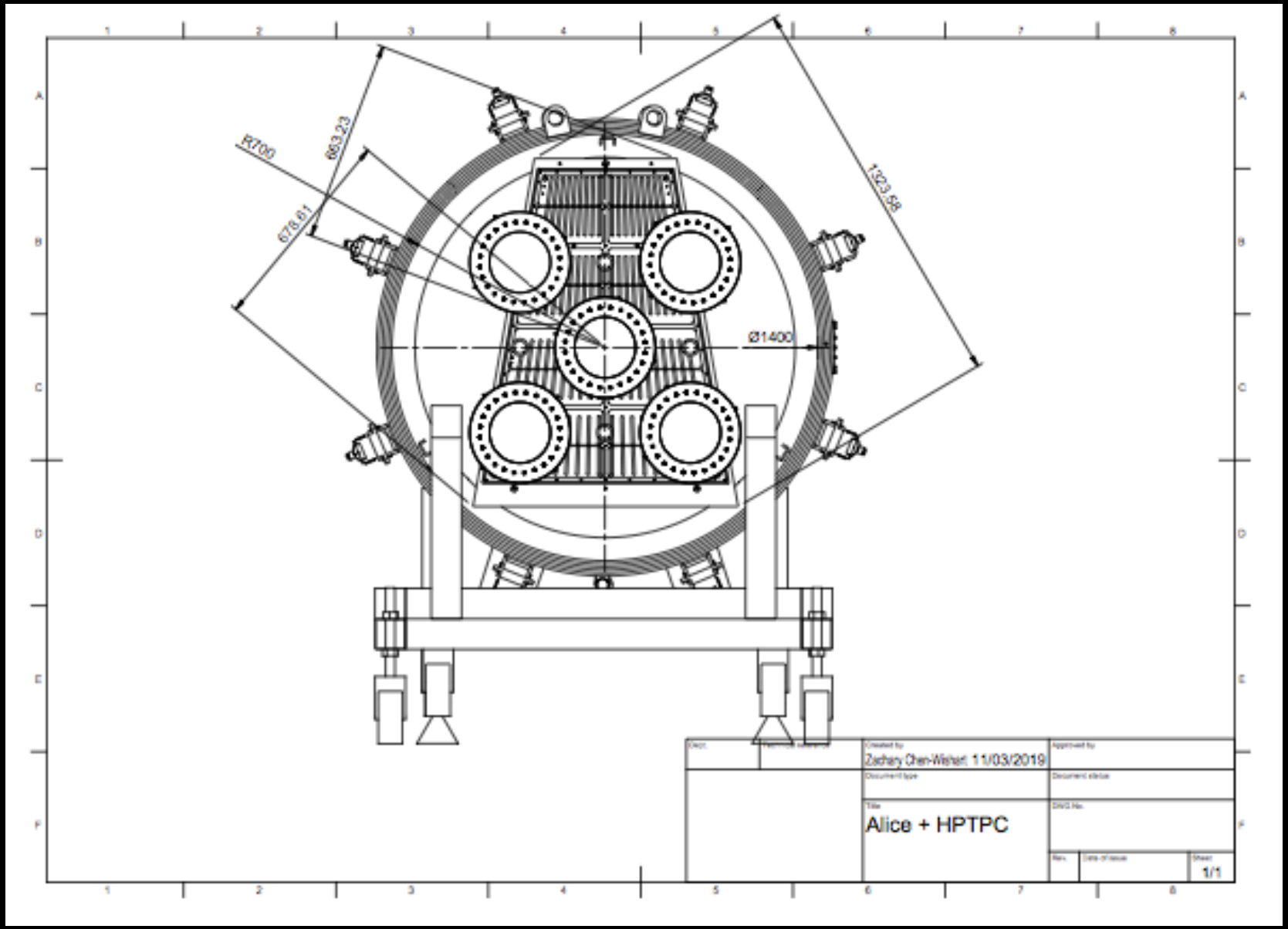
- We have begun testing a prototype HPTPC for use in future neutrino oscillation experiments (DUNE)
- Analysis of data from CERN beam test ongoing
- Testing currently ongoing at Royal Holloway, University of London
- Integration of the ALICE outer readout chambers envisioned for use in DUNE
- In 2020 we will move our prototype detector to Fermilab for a beam test

Thank you!

- CERN
- Imperial College London
- Lancaster University
- Royal Holloway University
- RWTH Aachen University
- University College London
- University of Geneva
- University of Warwick

A. Deisting, E. Atkin, G. Barker, A. Basharina-Freshville, C. Betancourt, S. Boyd, D. Brailsford, Z. Chen-Wishart, L. Cremonesi, A. Dias, P. Dunne, J. Haigh, P. Hamacher-Baumann, S. Jones, A. Kaboth, A. Korzenev, W. Ma, P. Mermod, M. Mironova, J. Monroe, R. Nichol, T. Nonnenmacher, J. Nowak, W. Parker, H. Ritchie-Yates, S. Roth, R. Saakyan, N. Serra, J. Steinmann, A. Tarrant, S. Valder, A. Waldron, M. Ward, M. Wascko, M. Uchida

Back Up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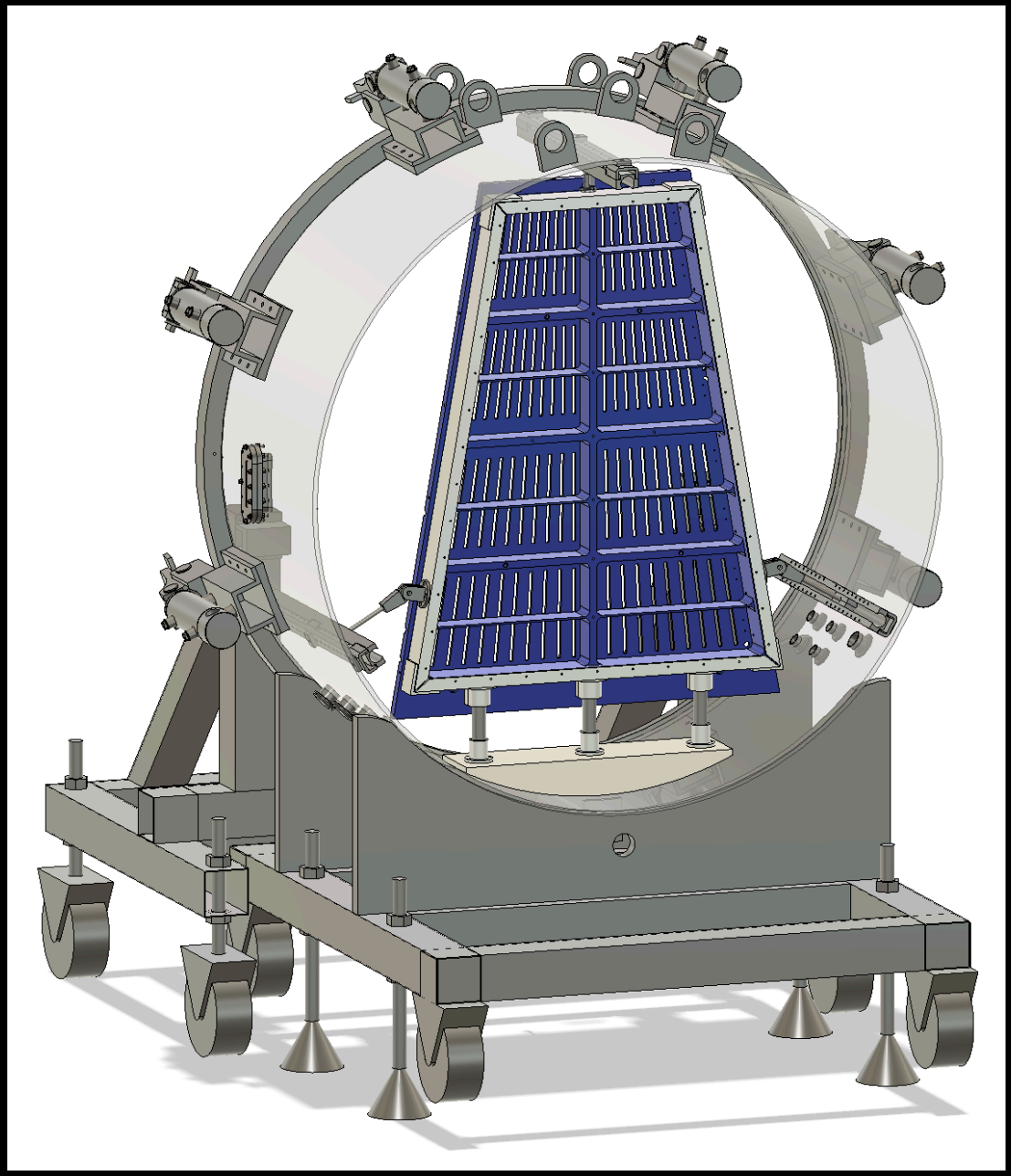
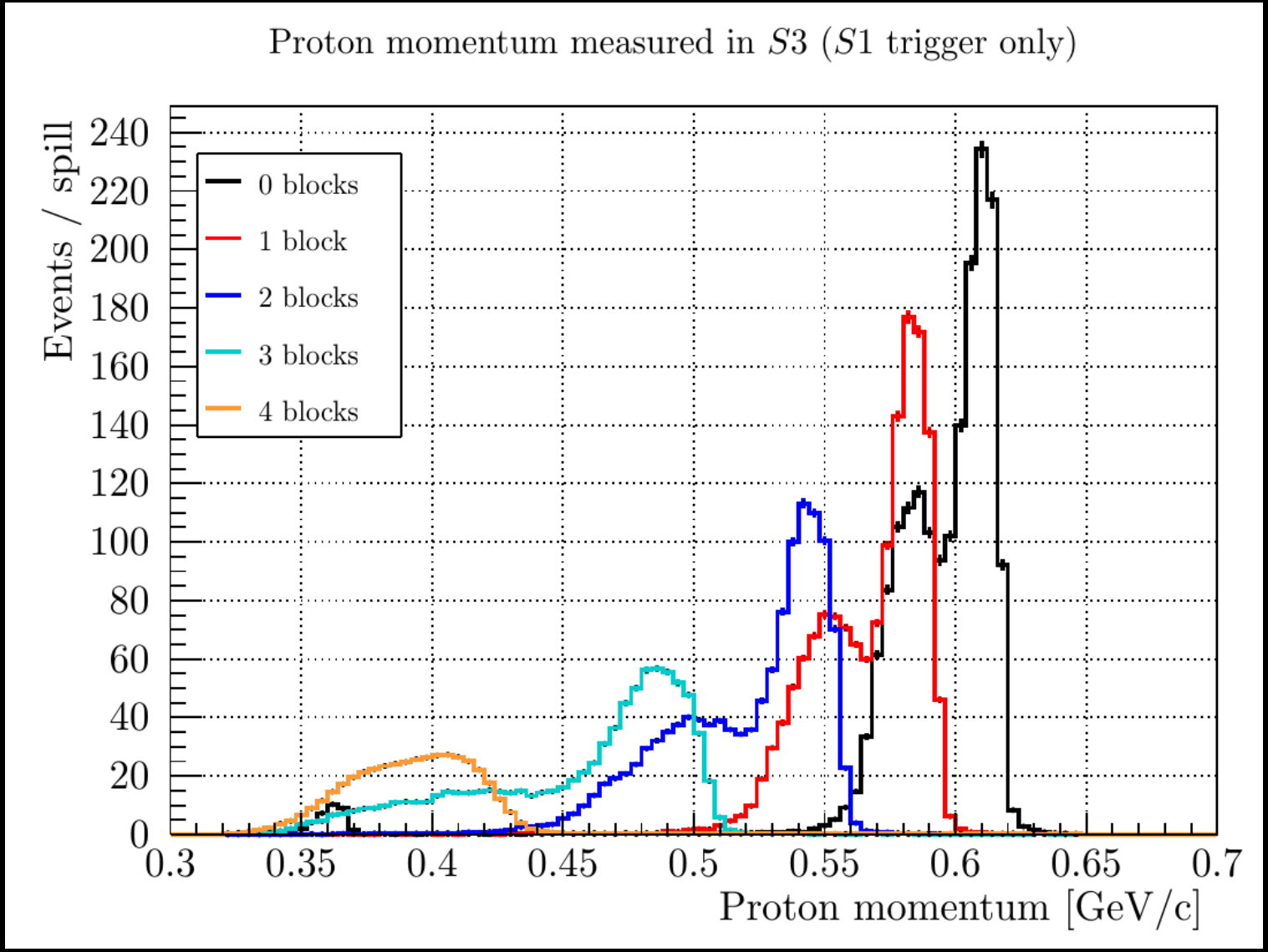
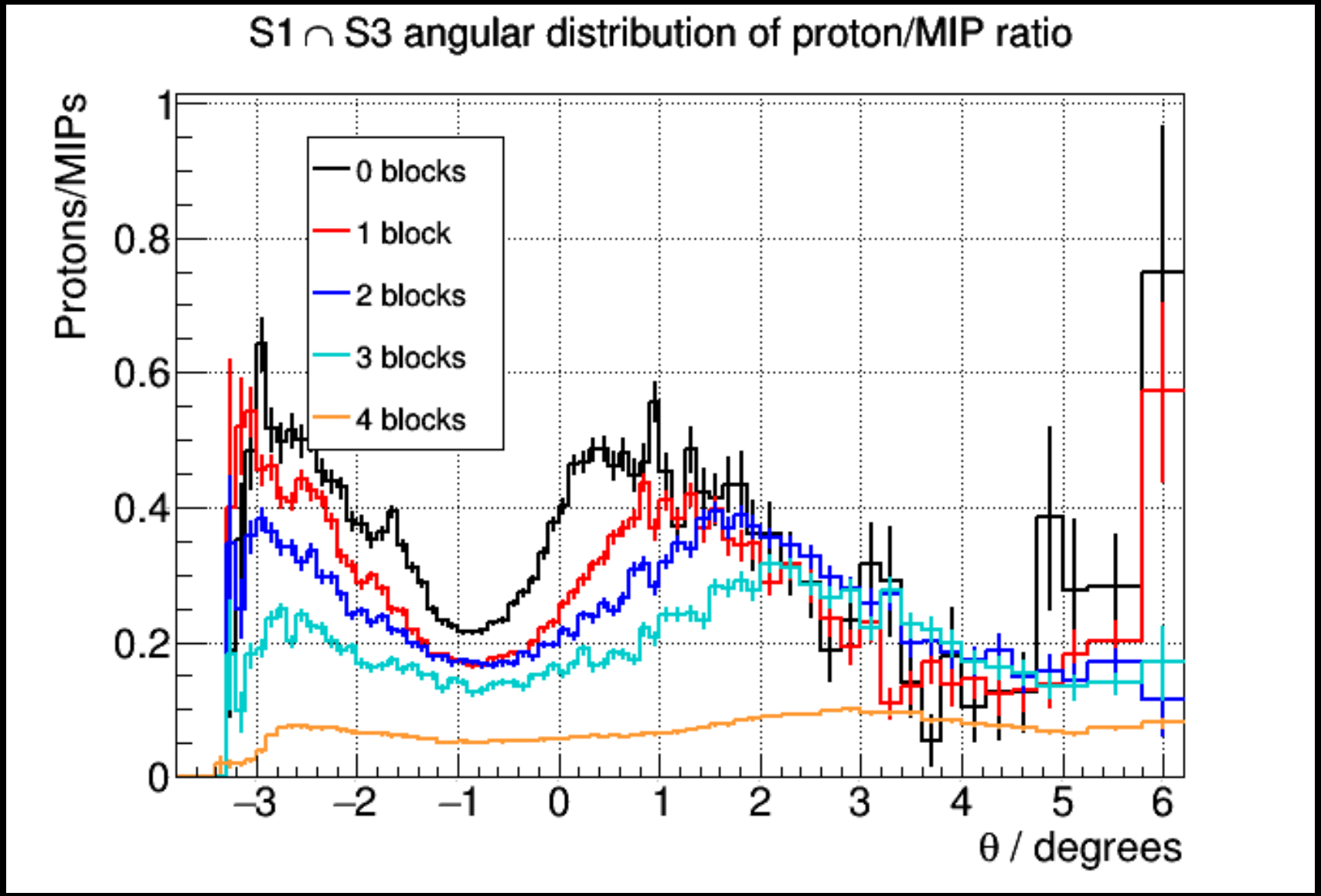
Testing of the ALICE OROCs



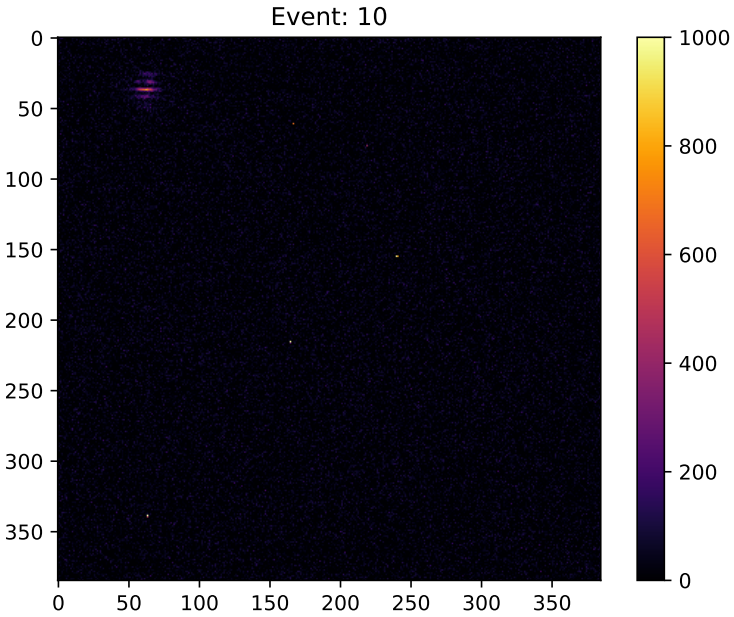
Momentum shift



Particle Ratio



Sparking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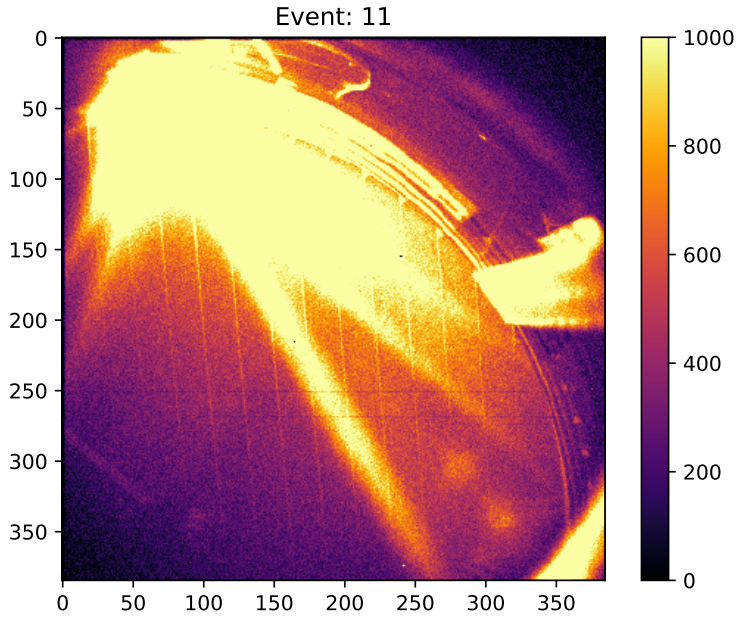
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