Supported in part by: U.S. DEPARTMENT OF ENERGY | Office of Science

Wright Laboratory

Yale

A GridPix-based TPC with CO2 Cooling

EIC Users' Group Early Career Workshop
Lehigh University, PA

Isaac Mooney, Yale University / Brookhaven National Laboratory

7/22/2024

What is GridPix?

- TPC operating principle: charged particle → gas ionization → drift (→ amplification) → readout
- Want to count ionization clusters

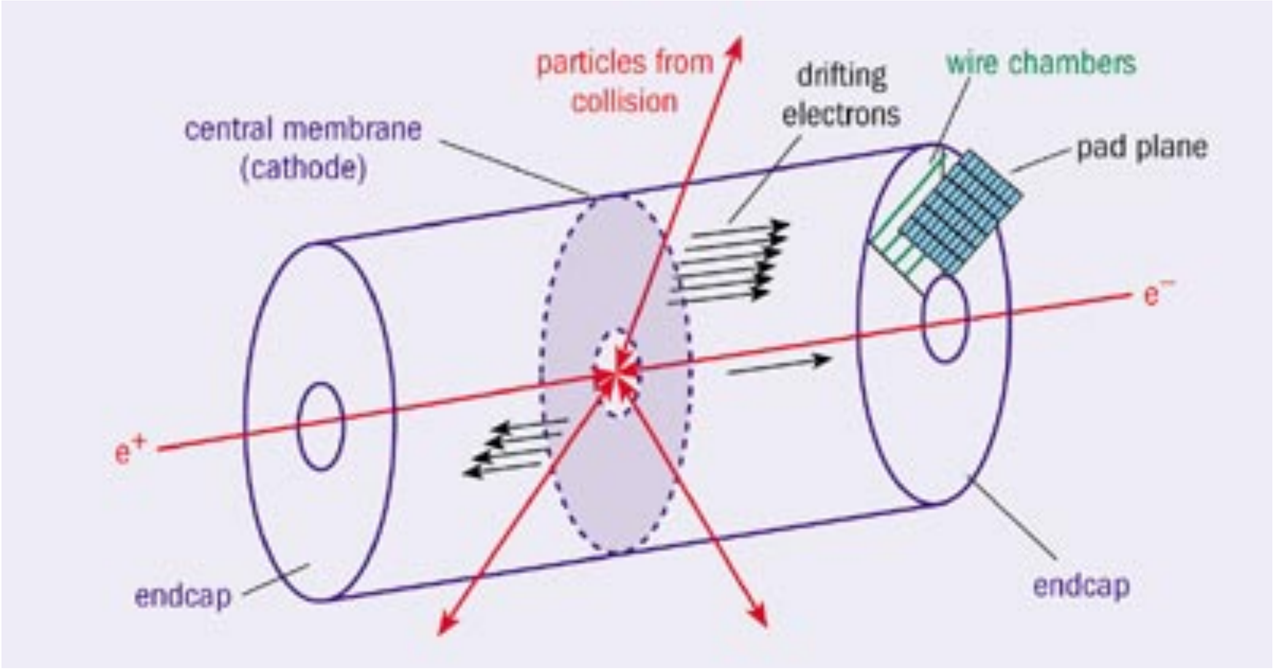

Image: CERNCourier

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  Pad planes sum charge over large area → samples many clusters of unknown $N_{primary}$

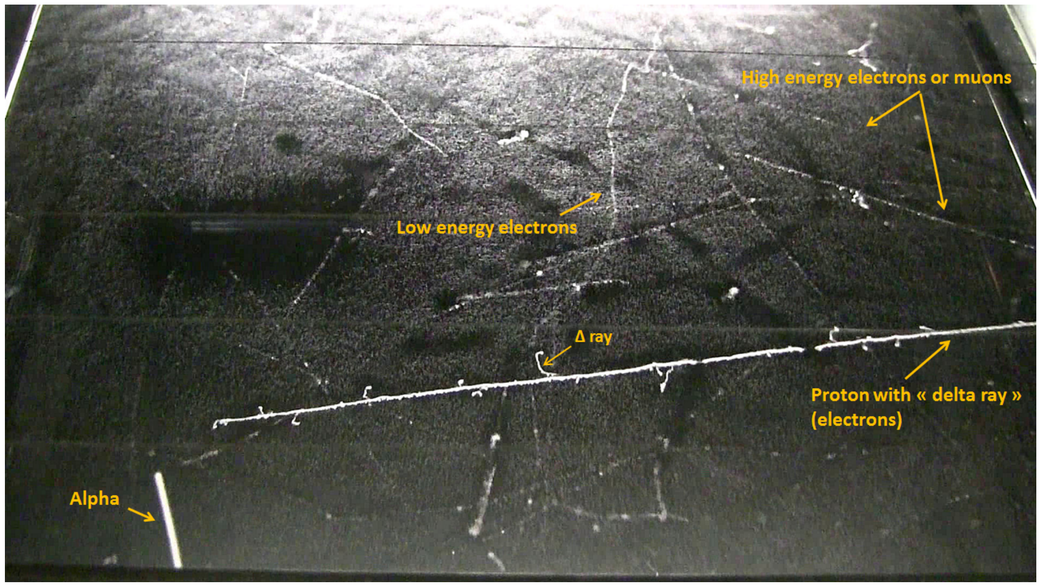

Image: Cloudylabs

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- Problem: secondary ionizations → Landau tail → resolution doesn't scale with $N_{primary}$.
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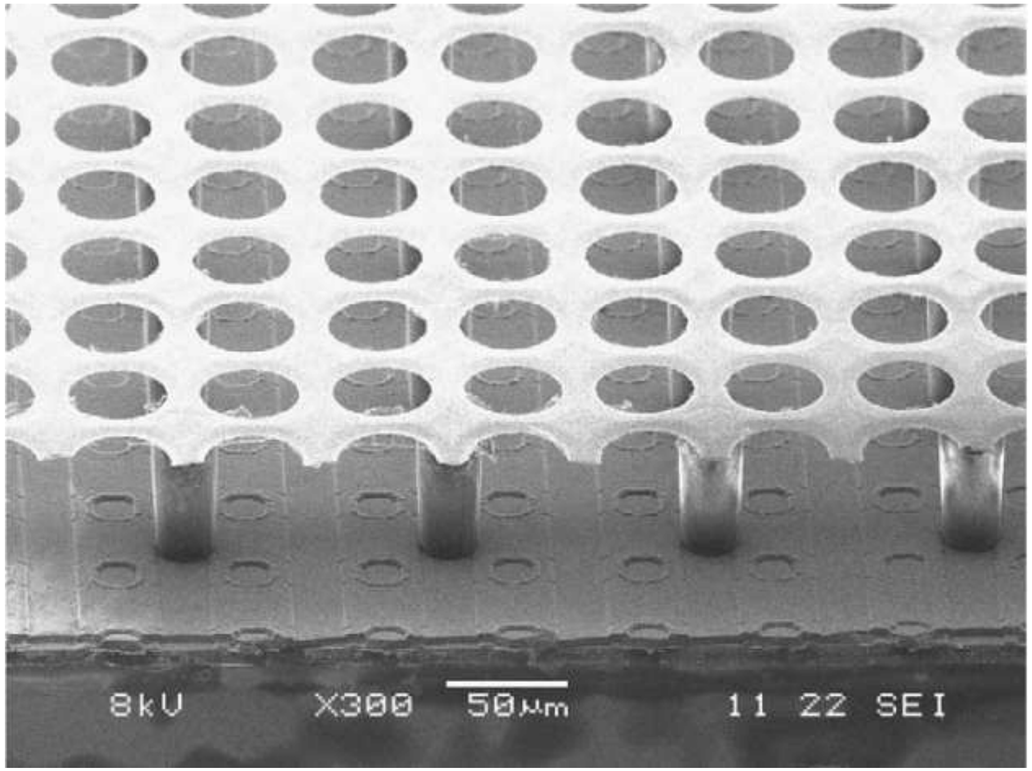
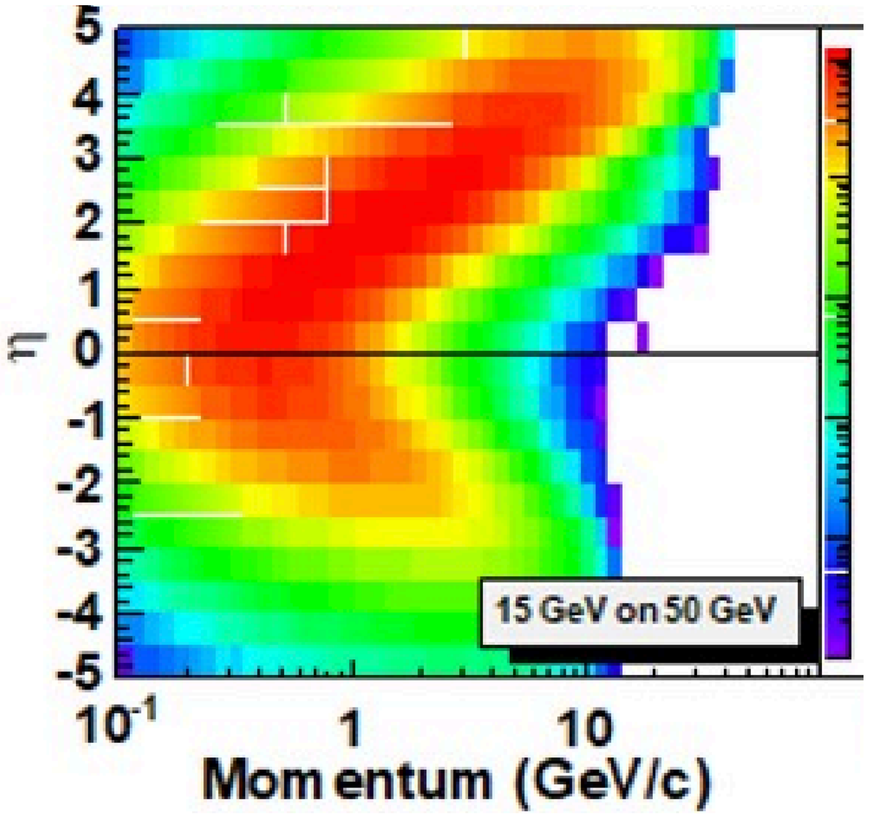
- Solution: MPGD with pixel readout
  (fine pitch ~ 55 microns;
  single electron efficiency > 90%)



Ligtenberg, Bilevych, Desch, van der Graaf, Gruber, Hartjes, Heijhoff, Kaminski, Kluit, van der Kolk, Raven, Schiffer, Timmermans, NIM A 956 (2020) 163331

Why GridPix at EIC?

- At mid-rapidity, most particles produced at low momentum
- *“The strong diversity of EIC science imposes the essential feature that the interaction region and the detector at the EIC are designed so all particles are identified and measured at as close to 100% acceptance as possible and with the necessary resolutions.”*
- To reach a TOF, need some minimum momentum → instead, dE/dx for PID in this kinematic regime



Dehmelt, Garg, Hemmick, Kaminski, Kluit, Smirnov, 2022 EIC-related Generic Detector R&D Proposal #14

Nucl.Phys.A 1026 (2022) 122447

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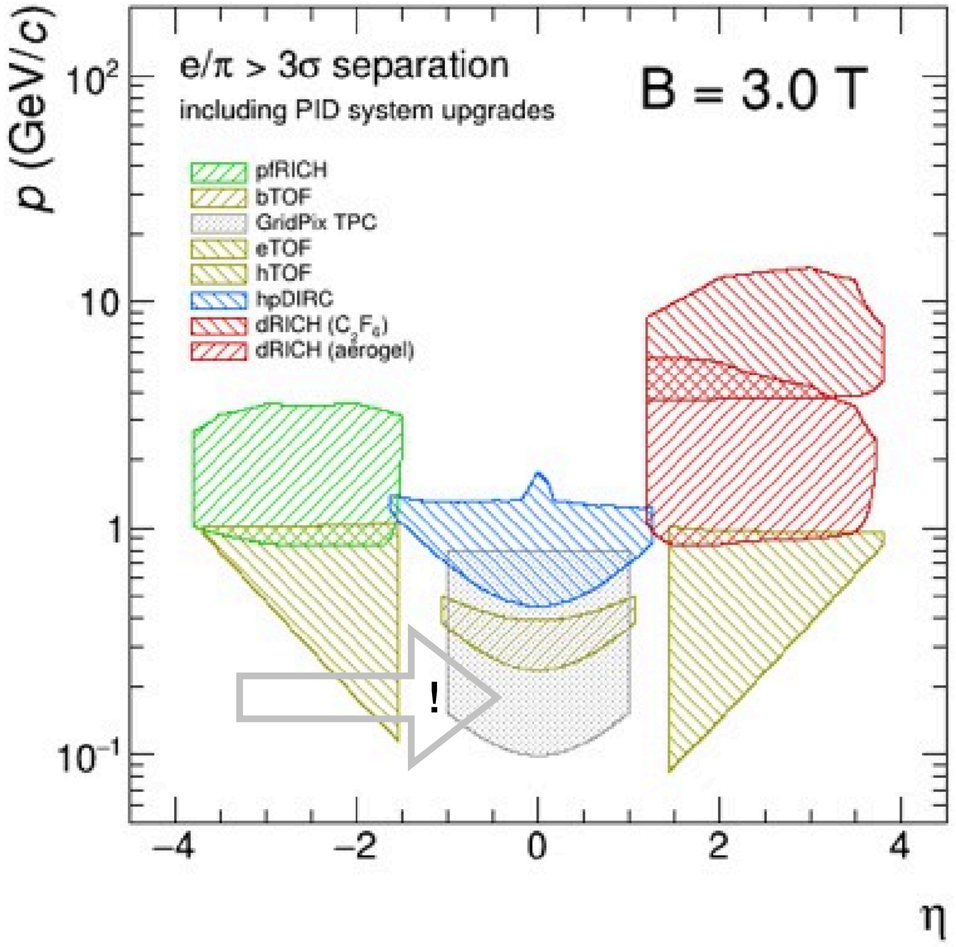

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3.5. TWO COMPLEMENTARY DETECTORS

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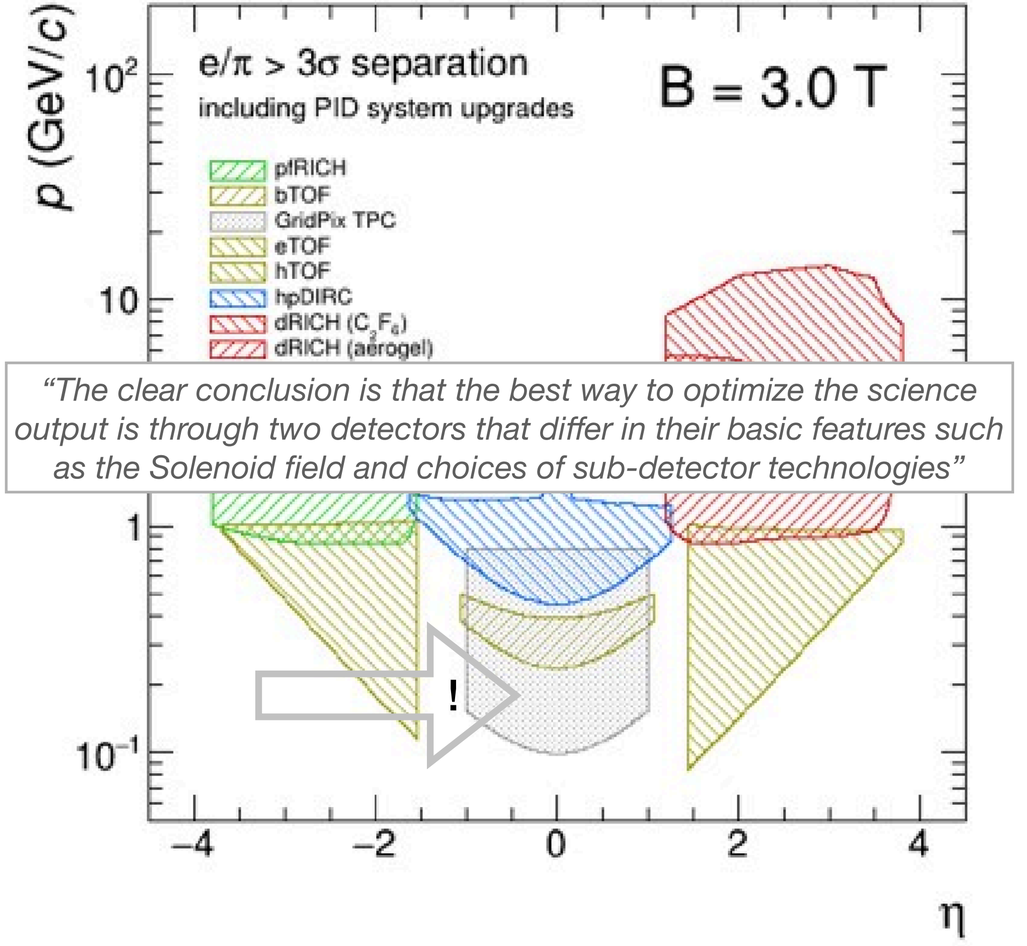

"The clear conclusion is that the best way to optimize the science output is through two detectors that differ in their basic features such as the Solenoid field and choices of sub-detector technologies"

Dehmelt, Garg, Hemmick, Kaminski, Kluit, Smirnov, 2022 EIC-related Generic Detector R&D Proposal #14

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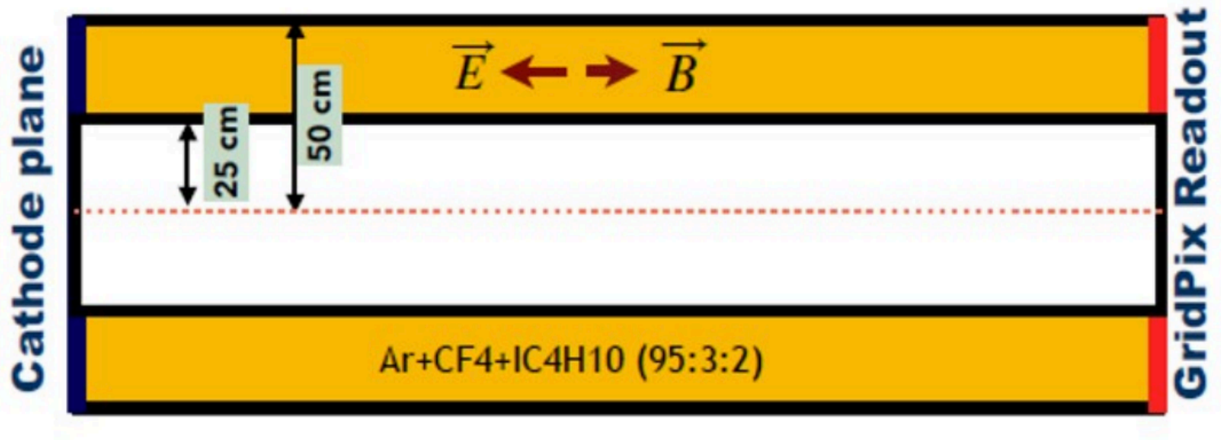
A proposed TPC with GridPix

- Single-sided TPC, with readout at anode [minimal electron-going material]
- Gas mix: initially T2K [low diffusion @ high field ✅]
  but also test with Ar → Ne, He (“Ne/He2K”) due to larger ion backflow in heavier Ar.



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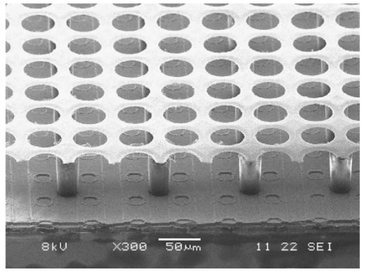
- Gas mix: initially T2K [low diffusion @ high field ✅]
  but also test with Ar → Ne, He (“Ne/He2K”) due to larger ion backflow in heavier Ar.
- GridPix:
  - Micromegas-style aluminum mesh at voltage [avalanche] on SU-8 pillars
  - Few-μm resistive layer [prevents sparking]
  - TimePix3 ASIC: pixel readout
    (fine pixel pitch ~ 55 microns; single electron efficiency > 90%)



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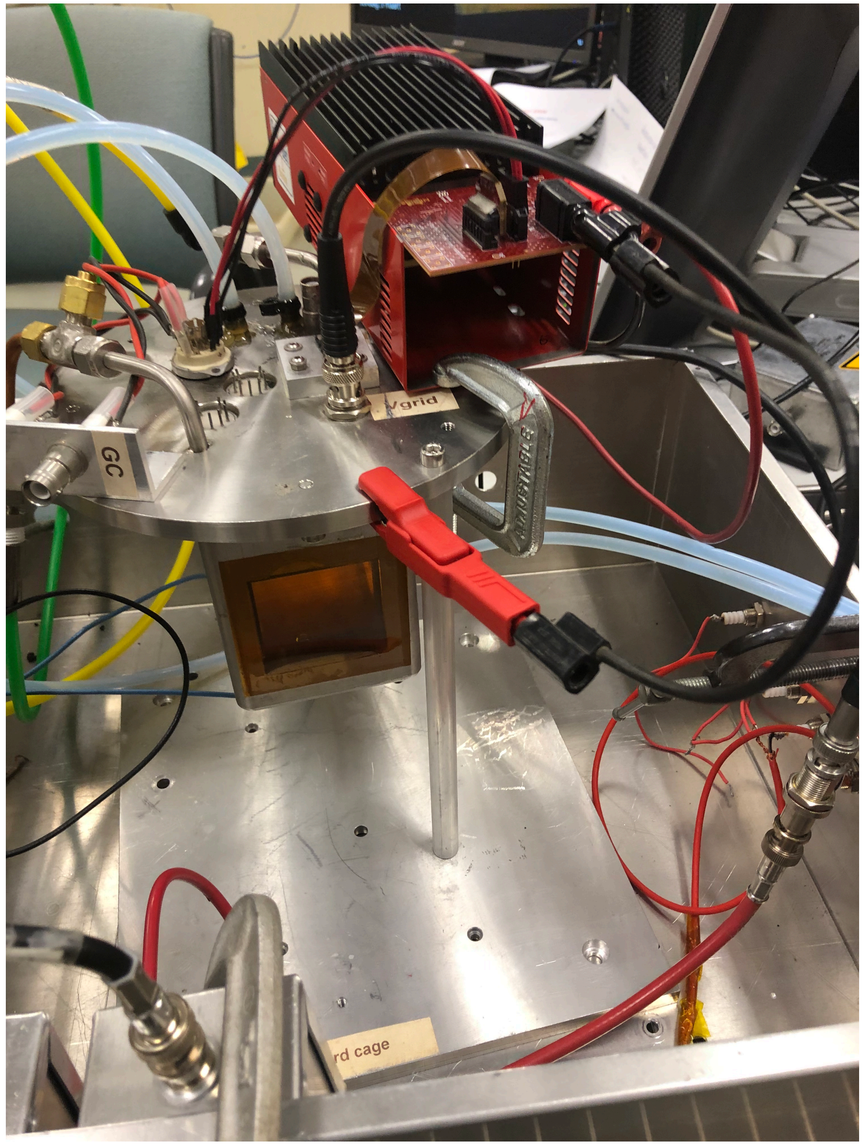
Yale group’s involvement

- Were shipped a quad (module of 4 GridPix chips) from Nikhef
- Cooling, gas mix, DAQ, etc. all working now
- Taking noise, Fe55 source tests (next slide)



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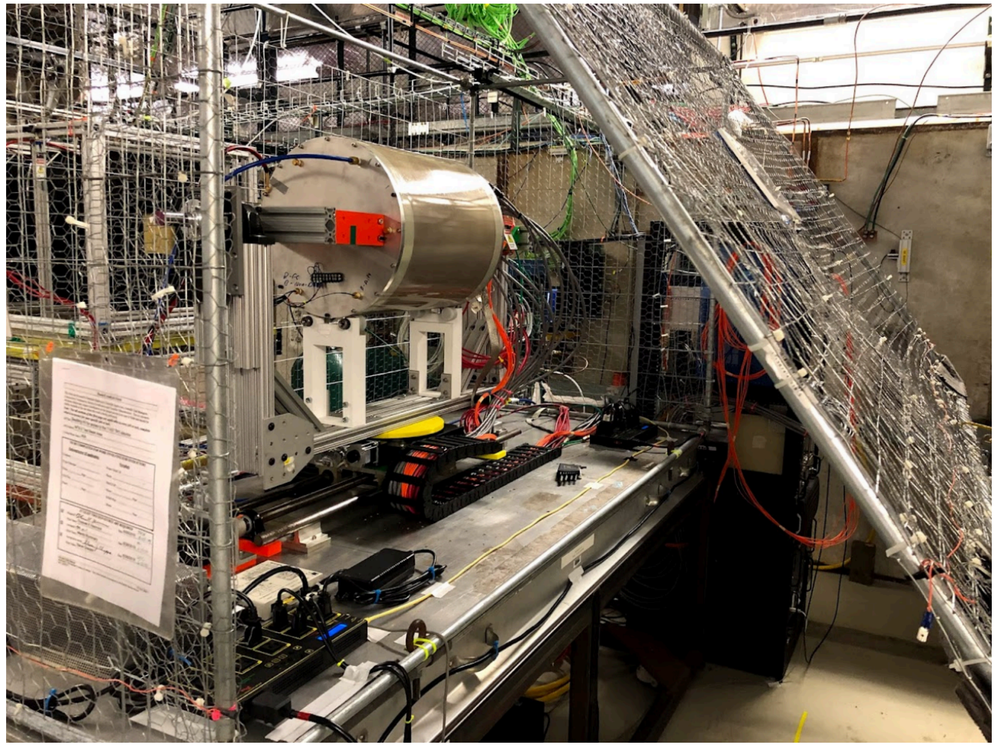
- Were shipped a quad (module of 4 GridPix chips) from Nikhef
- Cooling, gas mix, DAQ, etc. all working now
- Taking noise, Fe55 source tests (next slide)
- Eventual goal: test beam using MCenter beamline at Fermilab test beam facility (FTBF) with GridPix mounted to sPHENIX prototype TPC
- Requires new machined endplate to accept GridPix modules instead of GEMs



Dehmelt, Garg, Hemmick, Kaminski, Kluit, Smirnov, 2022 EIC-related Generic Detector R&D Proposal #14

A few early plots

- Information from TimePix3 ASIC [using TDC w/ clock frequency 640 MHz]:
  - **Hitmap**: which pixels fired above some threshold
  - **ToA**: time of arrival = edge time of the collected signal for each fired pixel, measured backward from the end of the trigger signal
  - **ToT**: time over threshold = signal duration $\propto$ induced charge

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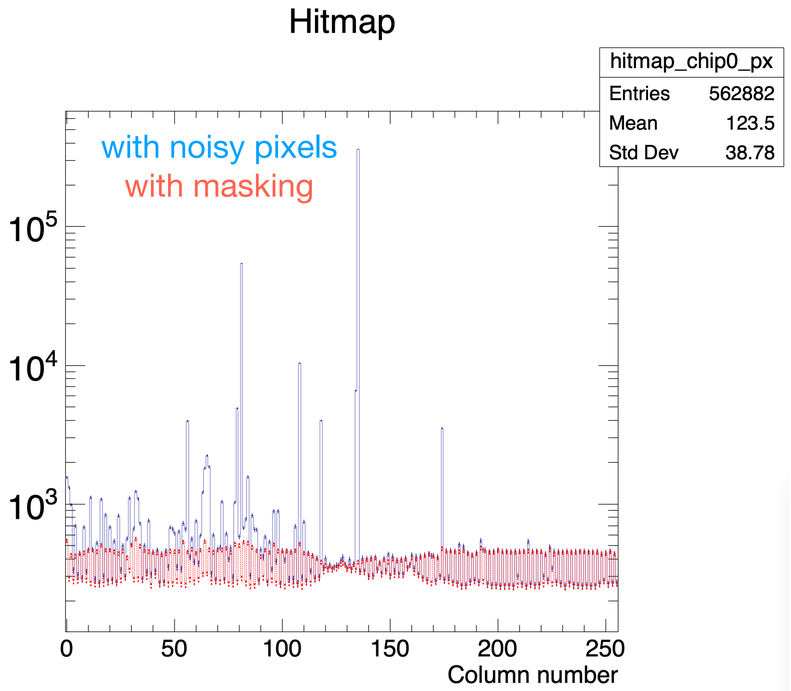

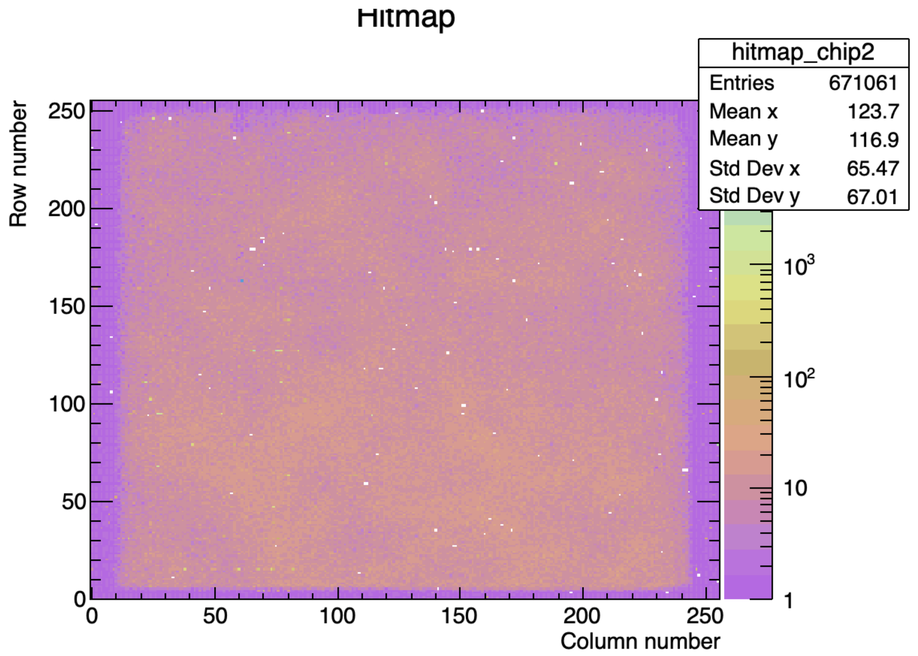

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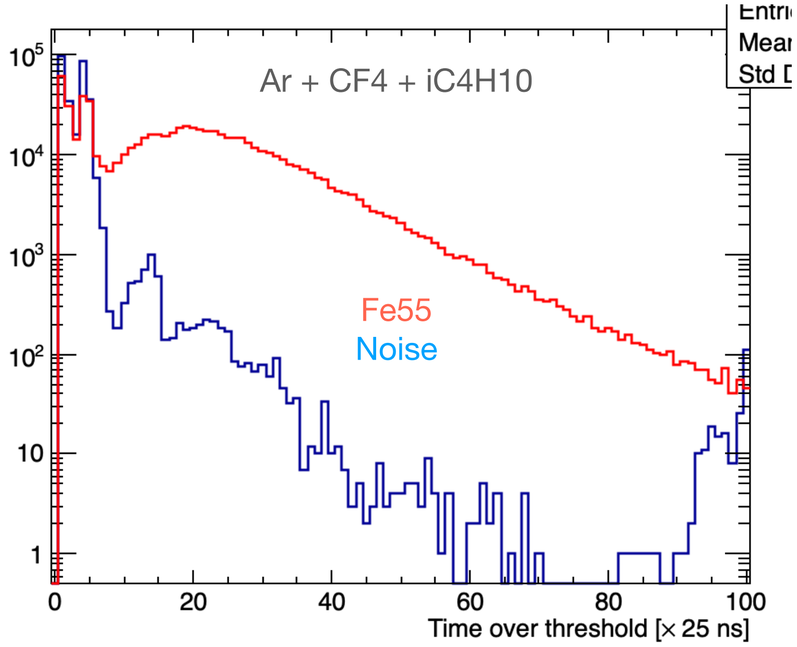
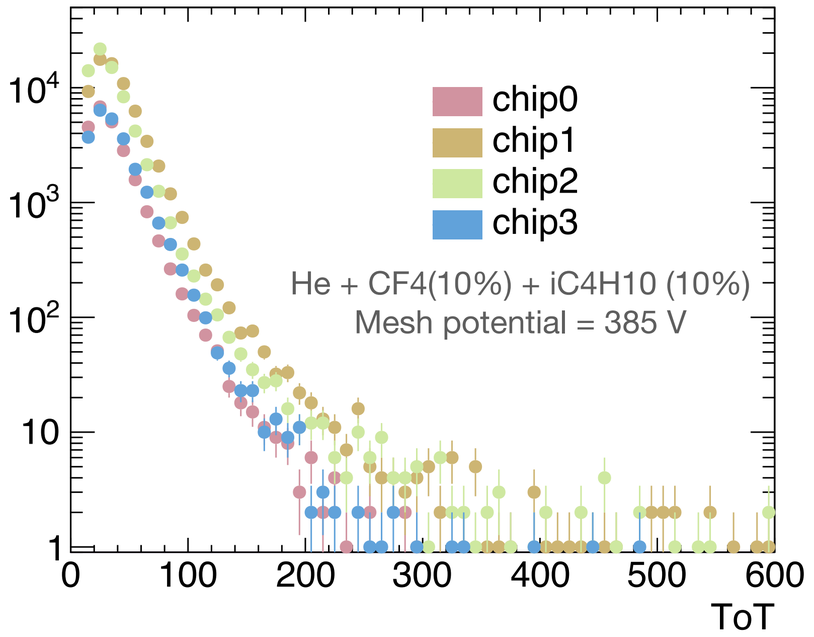
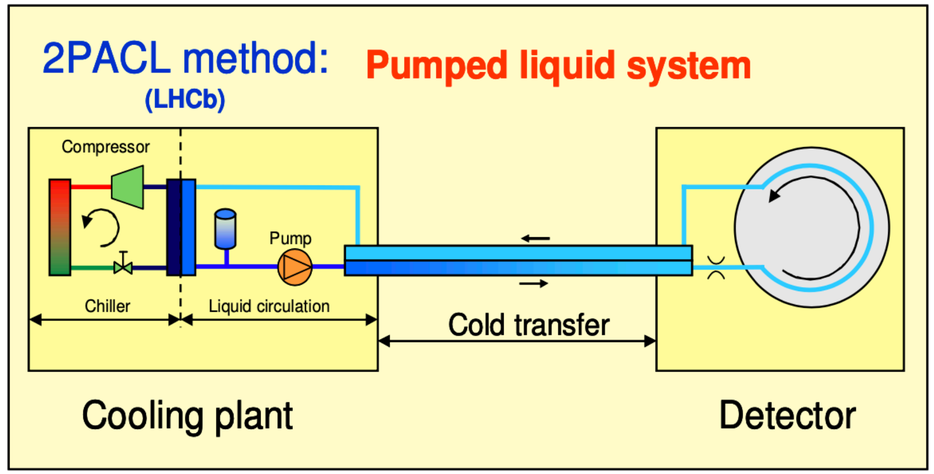
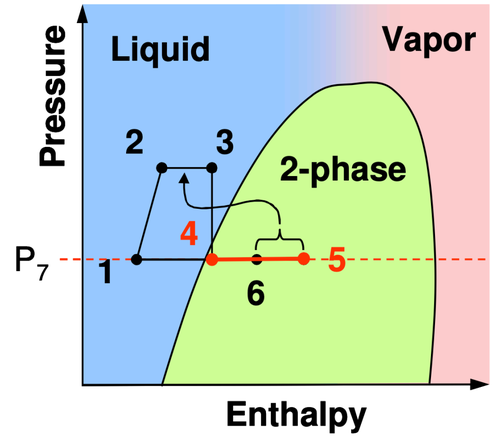




Why two-phase CO2 cooling could help

- Heat production from GridPix chips is high
- Need to cool **uniformly** while keeping material budget low
  → **two-phase cooling:** *"heat transfer happens during phase change and so the temperature remains constant. This property allows to maintain a very stable temperature during experiment."*





Bhattacharya, Attié, Colas, Mukhopadhyay, Majumdar, Bhattacharya, Sarkar, Bhattacharya, Ganjour, JINST 10 (2015) 08, P08001

Why two-phase CO2 cooling could help

- Heat production from GridPix chips is high
- Need to cool uniformly while keeping **material budget low**
  → **CO2 cooling:** *“total mass (tube+fluid) is lower when using a high pressure fluid as compared to a low pressure fluid.”*

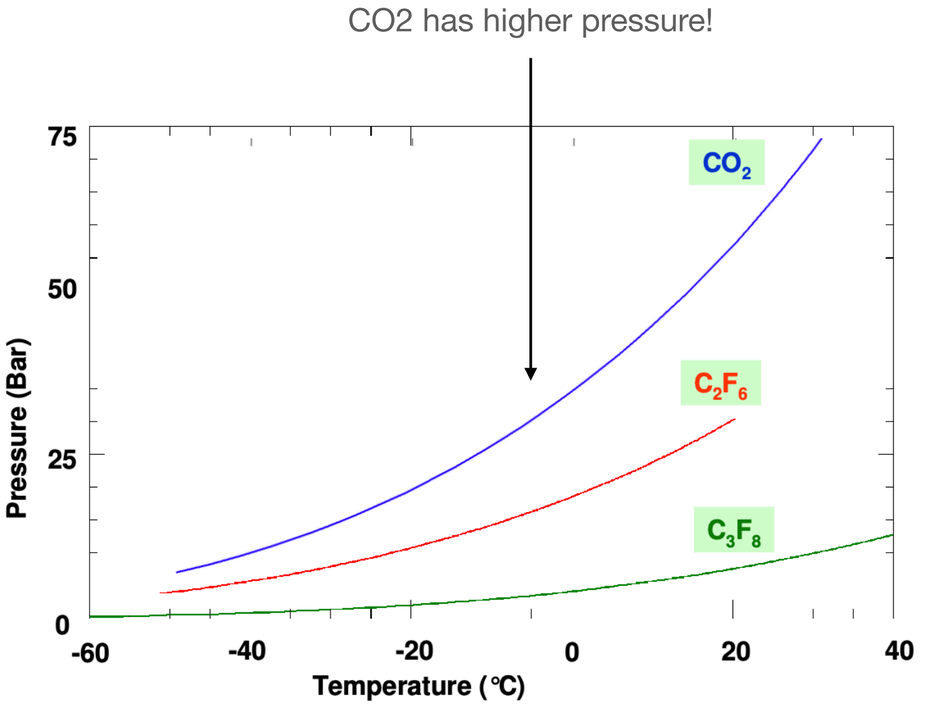


Figure 1: Saturation curves of radiation hard cooling fluids

Verlaat, Van Beuzekom, Van Lysebetten, TWEPP08, 328-336

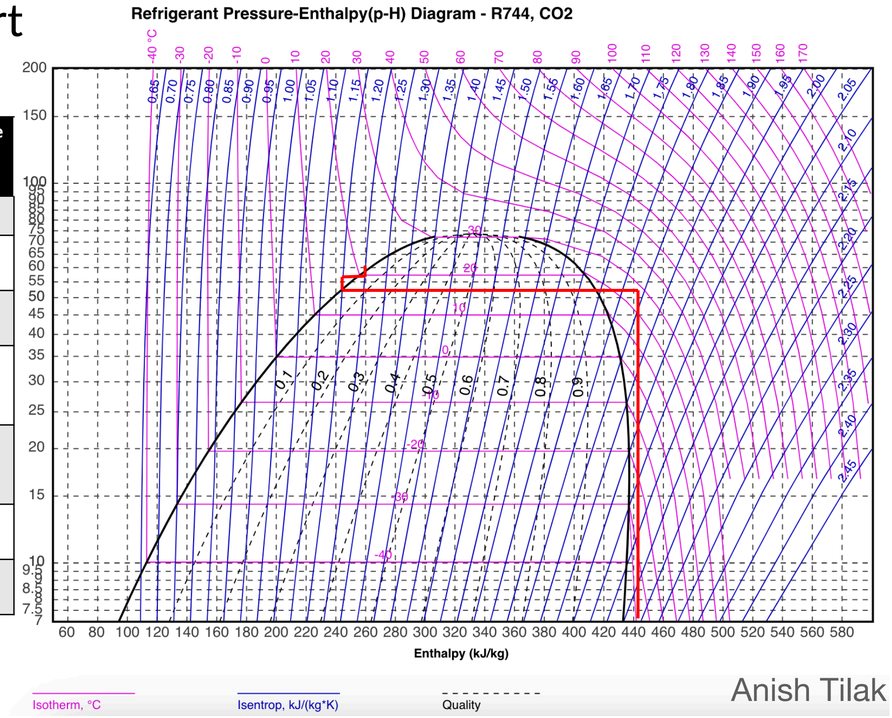
Work done at Purdue

- Purdue group [Andreas Jung, Sushrut Karmarkar, Anish Tilak] has assembled a cooling rig

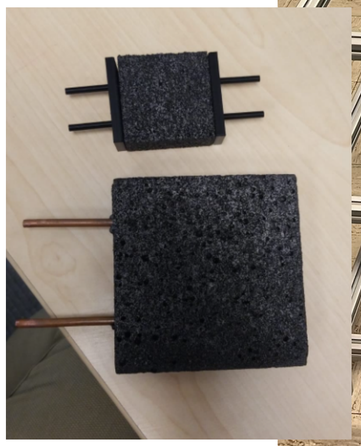
- Pictured right: finished frame before pipe-bending/ assembly; carbon foam with sandwiched pipes

Change in P-h chart

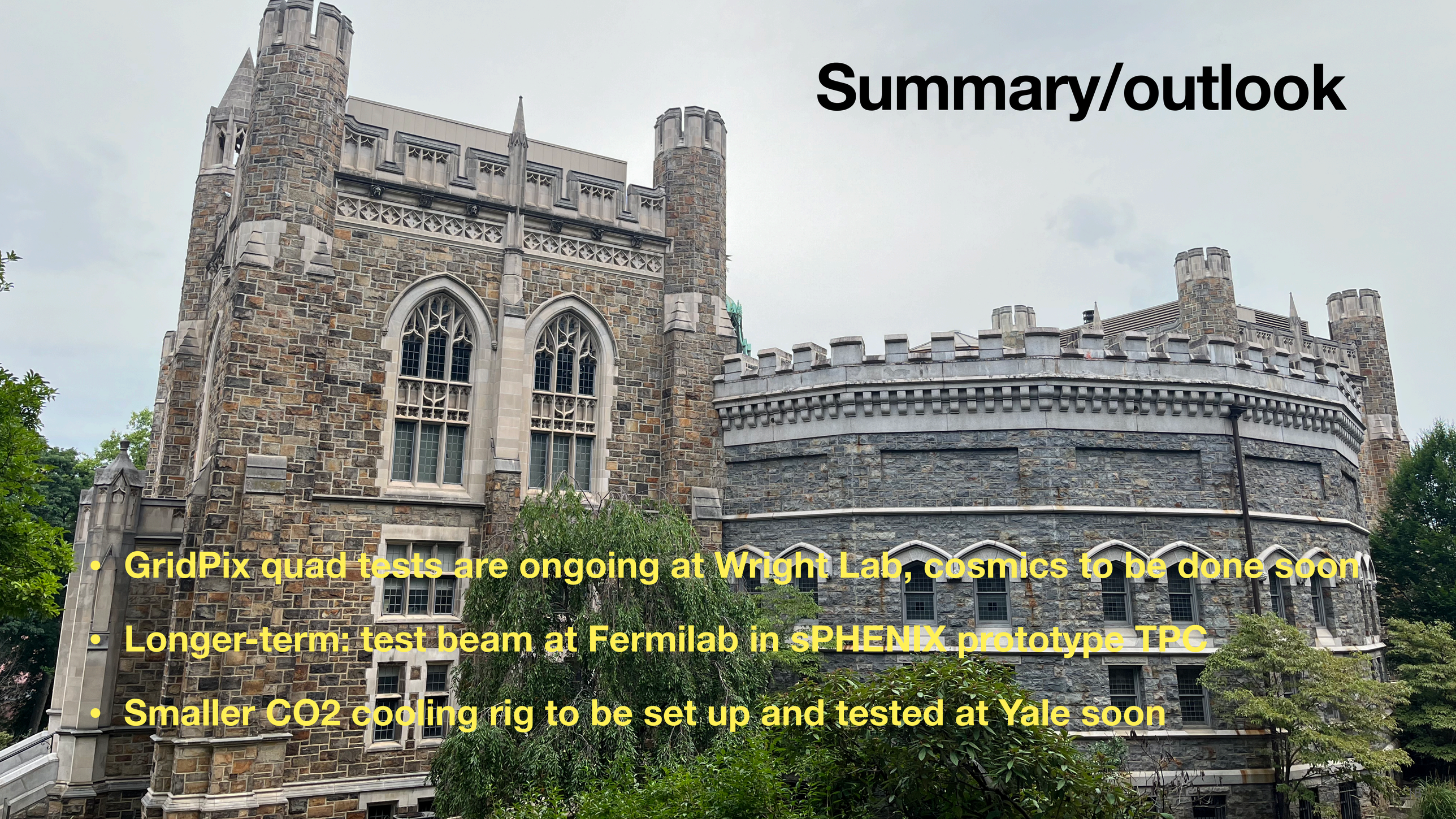
Point on graph	Description	Pressure (bar)	Temperature (°C)
1	CO_2 bottle	59	20
2	Entry to HX annulus	55	18.3
3	Exit from HX annulus	55	15.4
4	Entry to Environment chamber	50.9	15
5	Exit from Environment chamber	50.9	15
5a	Entry to HX shell	50.9	15
6	Exit from HX shell	50.9	15



Anish Tilak



Summary/outlook



- GridPix quad tests are ongoing at Wright Lab, cosmics to be done soon
- Longer-term: test beam at Fermilab in sPHENIX prototype TPC
- Smaller CO_2 cooling rig to be set up and tested at Yale soon