Performance of GridPIX Detector in Magnetic Field with low mass and high efficiency CO2 cooling

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Question #1

Please summarize the progress made last year on this project.

- Nikhef refurbished and repaired DAQ computer.
- Nikhef wrote DAQ documentation and trained all the other groups how to run it.
- Nikhef tested and verified the functionality of the module.
- Nikhef packed the module for shipping.
- A draft of the loan agreement was written and is approved by Nikhef & SBU.
- The customs paperwork for shipment and the insurance have been done. (Shipment this week or so)
- **SBU and Yale traveled to Fermilab to inspect MCenter.**
- Yale is negotiating with TOAD time-of-flight regarding use of beamline PID detectors.
- Some of the possible gas mixtures have been identified by Yale group.
- TPC end-plate has been designed to adopt the module.

Specify which goals were not completed from last year's proposal (due to the delay in funding, etc.)

- Because of the delay in funding and uncertain timeline of FNAL test beam facility we haven't got to test beam.
- GridPIX hasn't been shipped to USA (Shipment this week or so).

Question #2

Clarify the importance of the development of the CO2 cooling system at this stage of the GridPIX detector R&D.

- The possibility of He-based gas mixture with "modern" CO2 cooling will guarantee the extremely low mass detector special for low momentum particles momentum reconstruction and PID including the best track finding for a barrel setup.

- Low mass cooling is a critical part of the “TPC” setup, and might be interesting for EIC in general.

Question #3

Can you quantify the advantage of the test beam at 0.7 T with respect to the cosmic test at 4T?

- The proposed R&D is for low momentum PID and tracking.
- The FNAL option is more interesting because the test can be done for low momentum particles (not Cosmic) with PID at the same time.
- Diffusion will be smaller at 4T so “might not” be best to show performance at realistic Mag. Field (cluster merging)

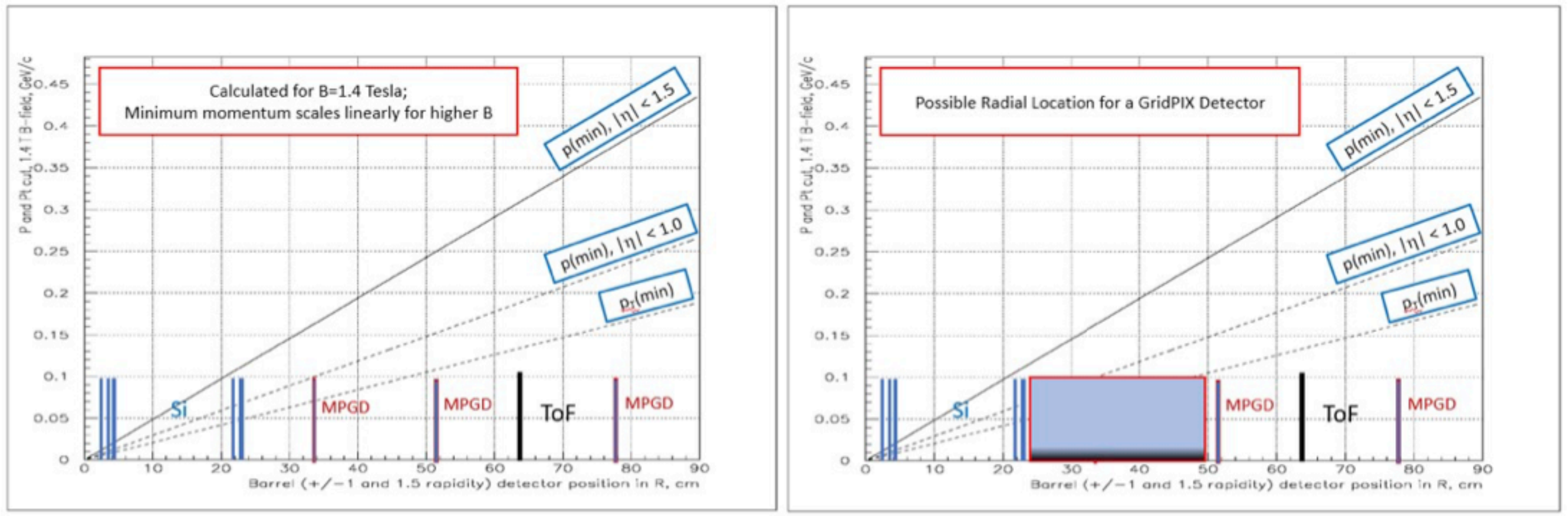


Figure 2: Low momentum particles will form tight spirals in a high magnetic field. As a result, there exists a linearly rising ”minimum” transverse momentum required for particles to reach a detector plane at any given radius. PID thereby acquires a minimum momentum due simply to the geometric placement of the first PID layer.

Continuation Proposal for next cycle

Mainly, two additions (in the same MCenter test beam area)

- The tracking and PID performance in the magnetic field.
- A low mass, high efficiency CO2 cooling to significantly reduce the material budget in the hadron going direction (Important to show deployability)

Brief Introduction

- Originally as "upgrade path" for ATHENA.
- Not discussed in current EPIC baseline.
- Ideally suited for Detector 2.

Provides:

- PID (pi-K-p) from 100 MeV/c to 800 MeV/c
- ROBUST tracking (enormous number of hits per track)
- Virtually immune to synchrotron background.

Field Cage

1% radiation length, entrance and exit

High Voltage (-10kV)

Low radiation Length

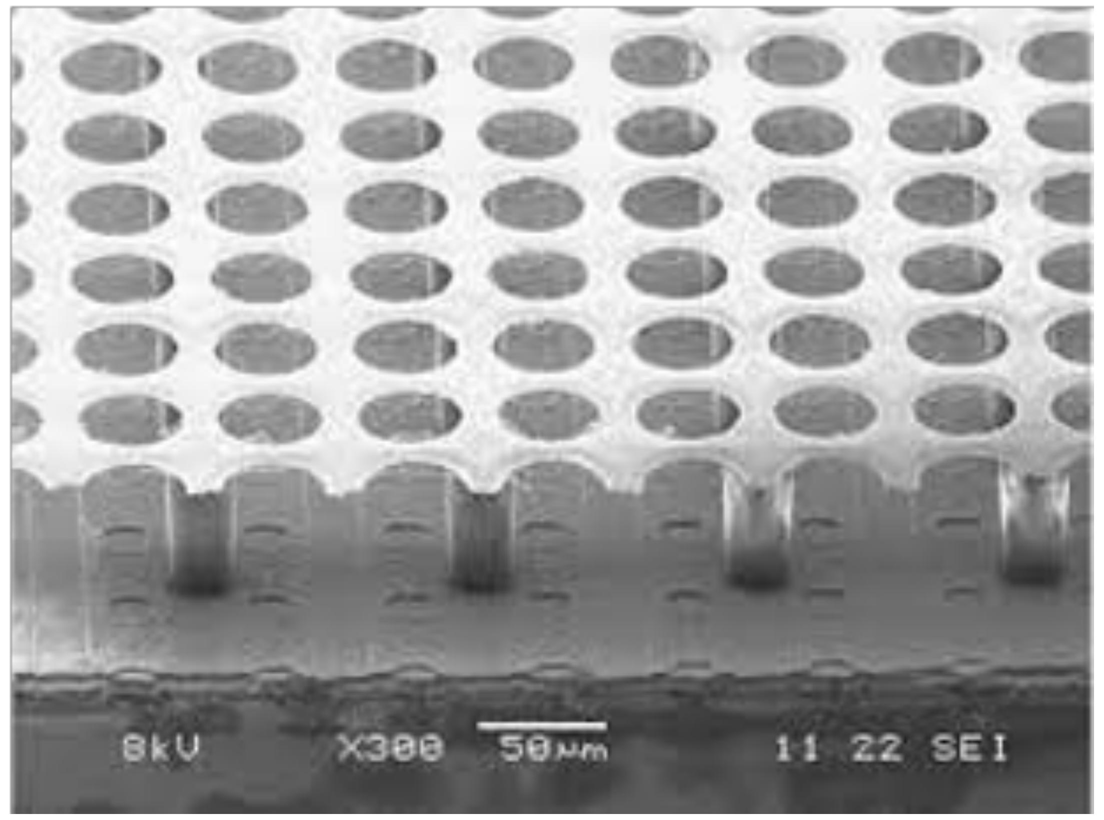
T2K gas (low diffusion)

Silicon Pixel Readout

55 μm ×55 μm

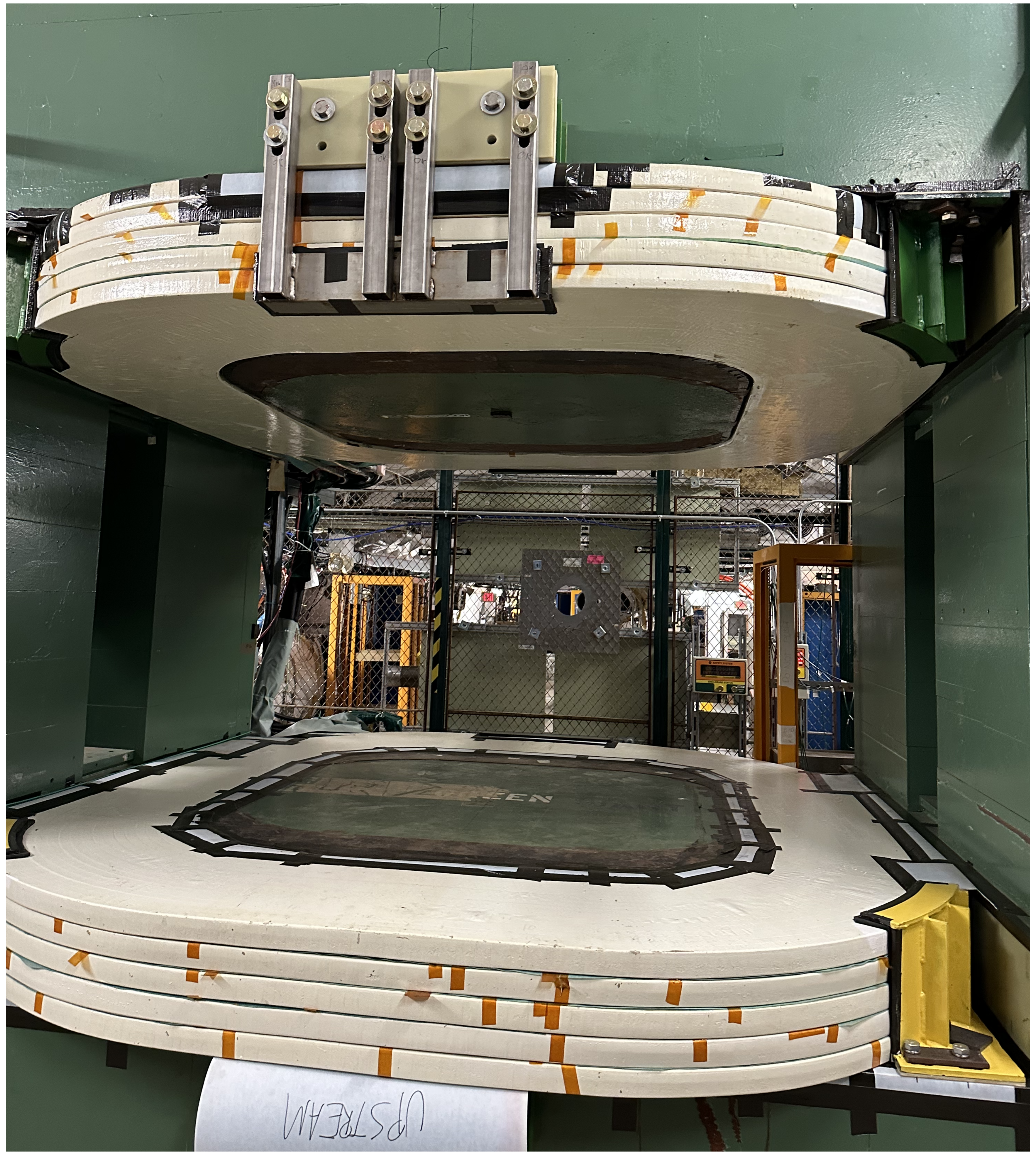
4% radiation length

(dominated by cooling)



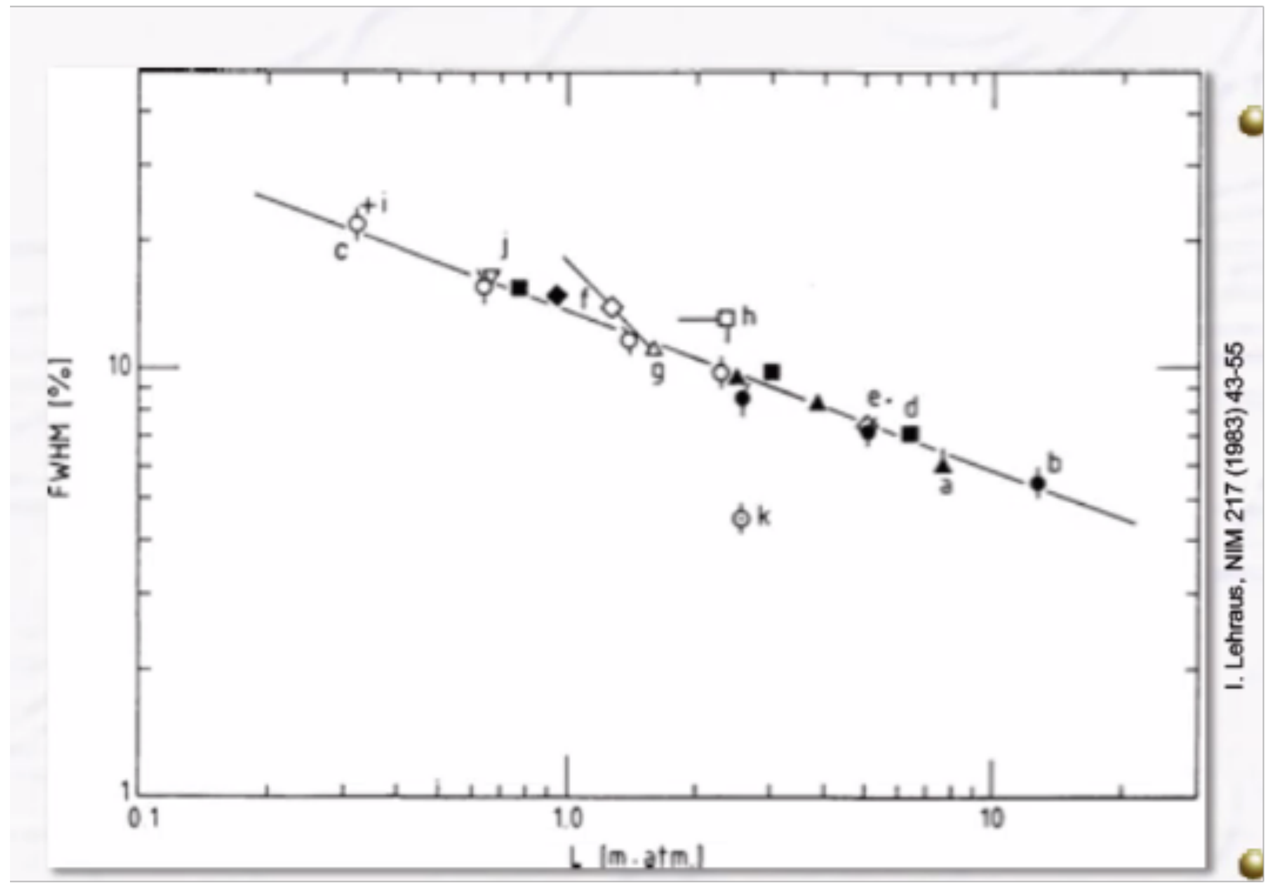
The tracking and PID performance in the Magnetic Field

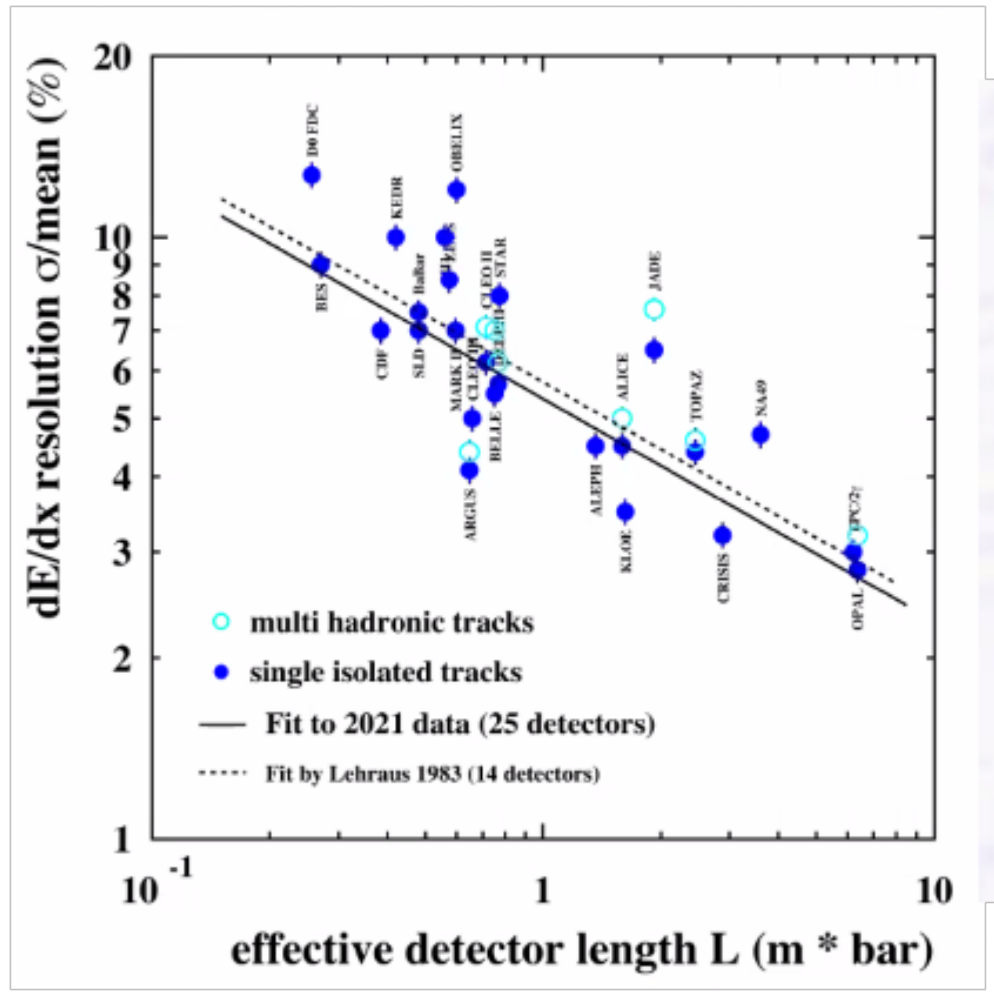
- High statistics to perform pi/K/p seperation
- Magnet availability [newly refurbished FNAL magnet at 0.7T] -> Cost effective as it will be just next to our setup



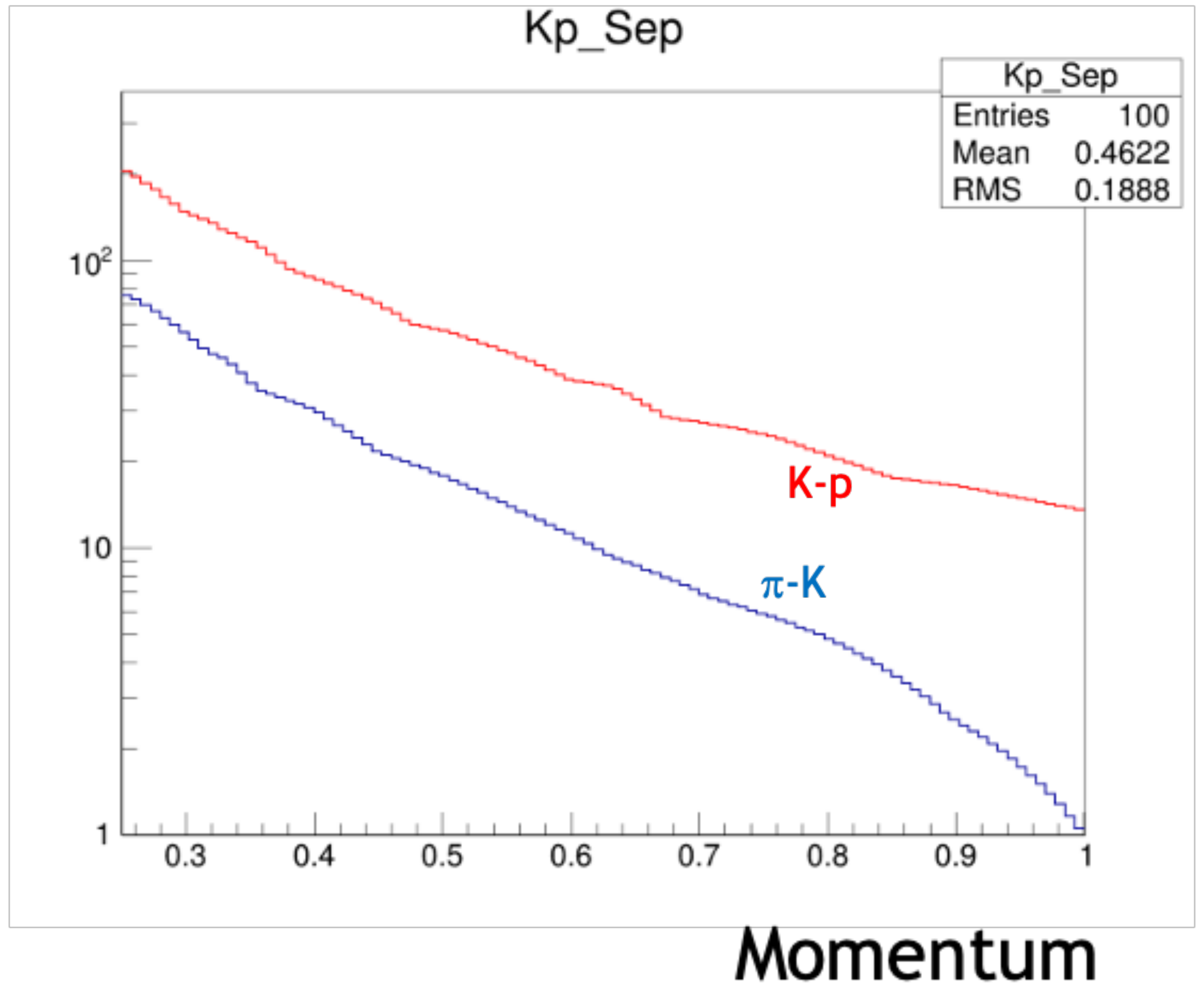
"Jolly Green Giant" dipole magnet (up to 0.7 T) at FNAL MCenter

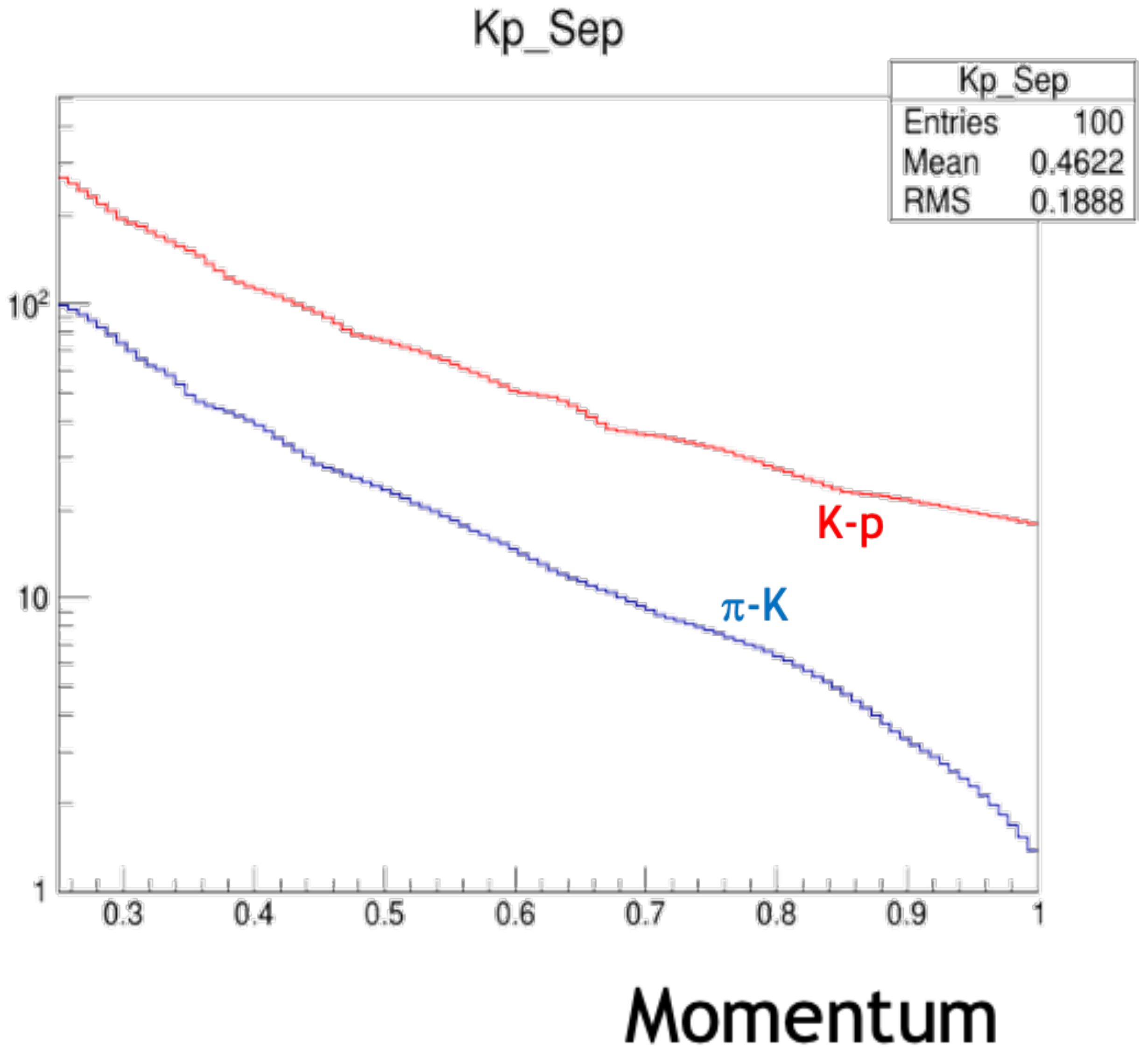
Anticipated dE/dx Performance

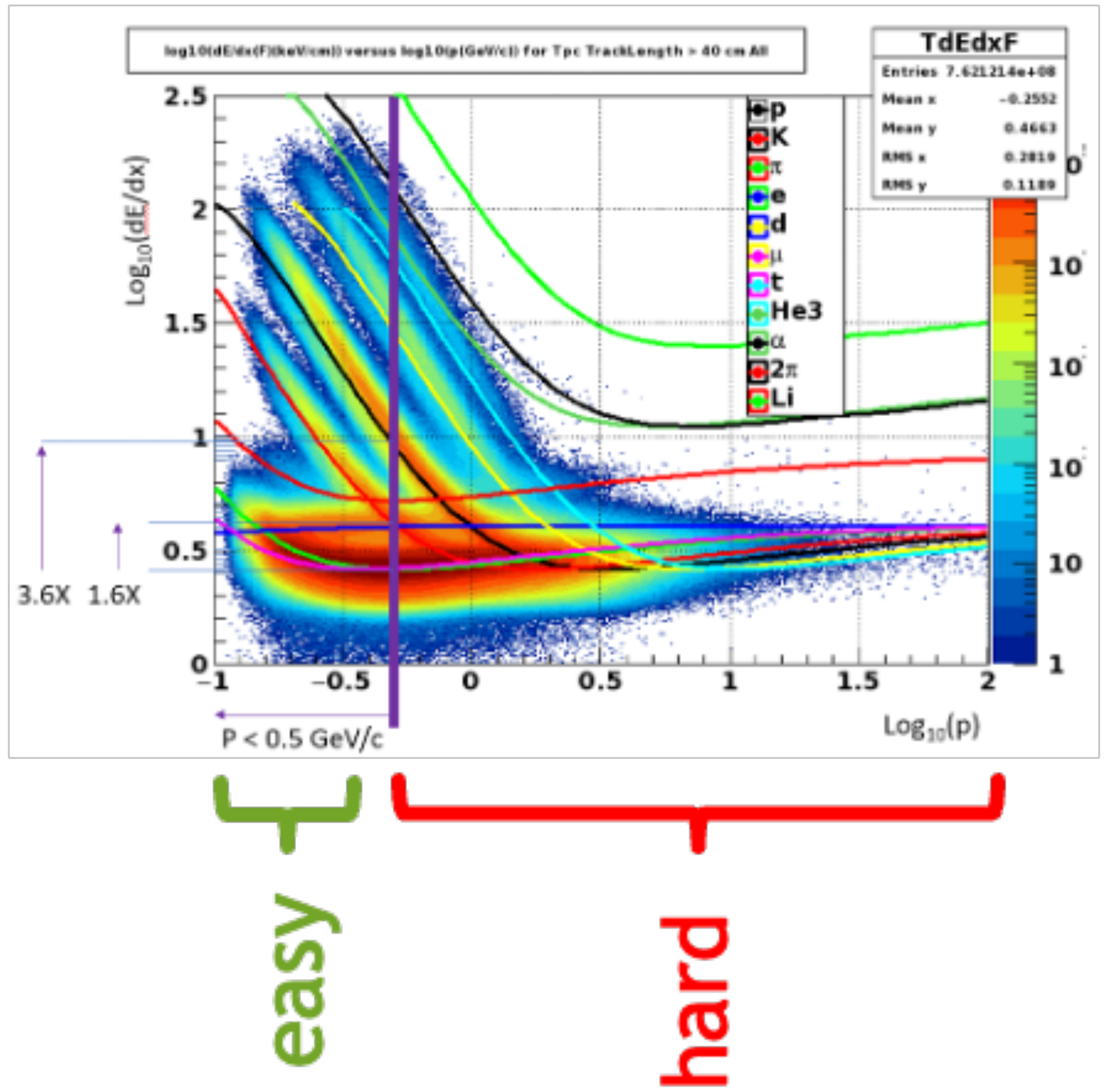




- **Fit by *Lehraus* 1983:**
  dE/dx res. = 5.7 * $L^{-0.37}$ (%)
- **Fit in 2021** (25 large detectors):
  dE/dx res. = 5.4 * $L^{-0.37}$ (%)

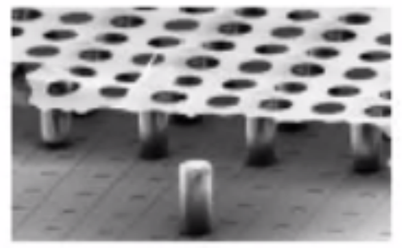




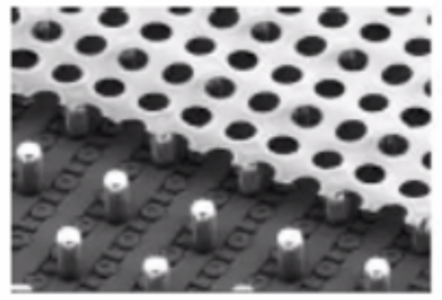


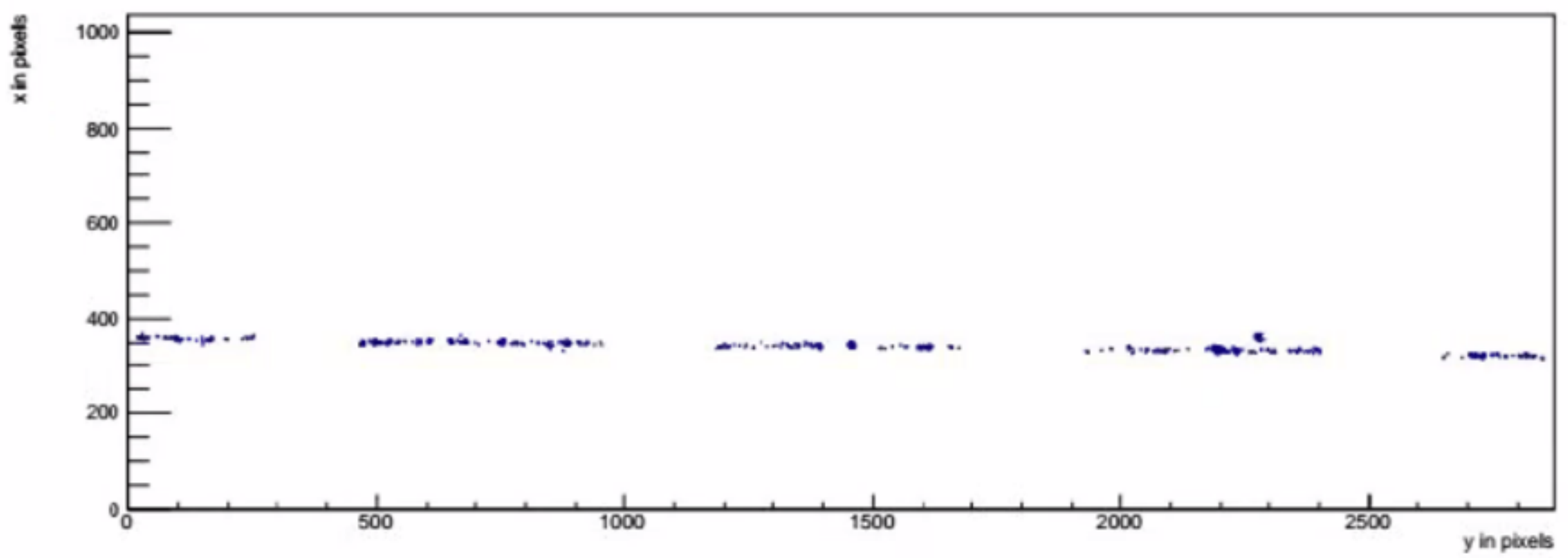
Anticipated Tracking Performance

June 2021



Event Pictures at B = 0.5 T

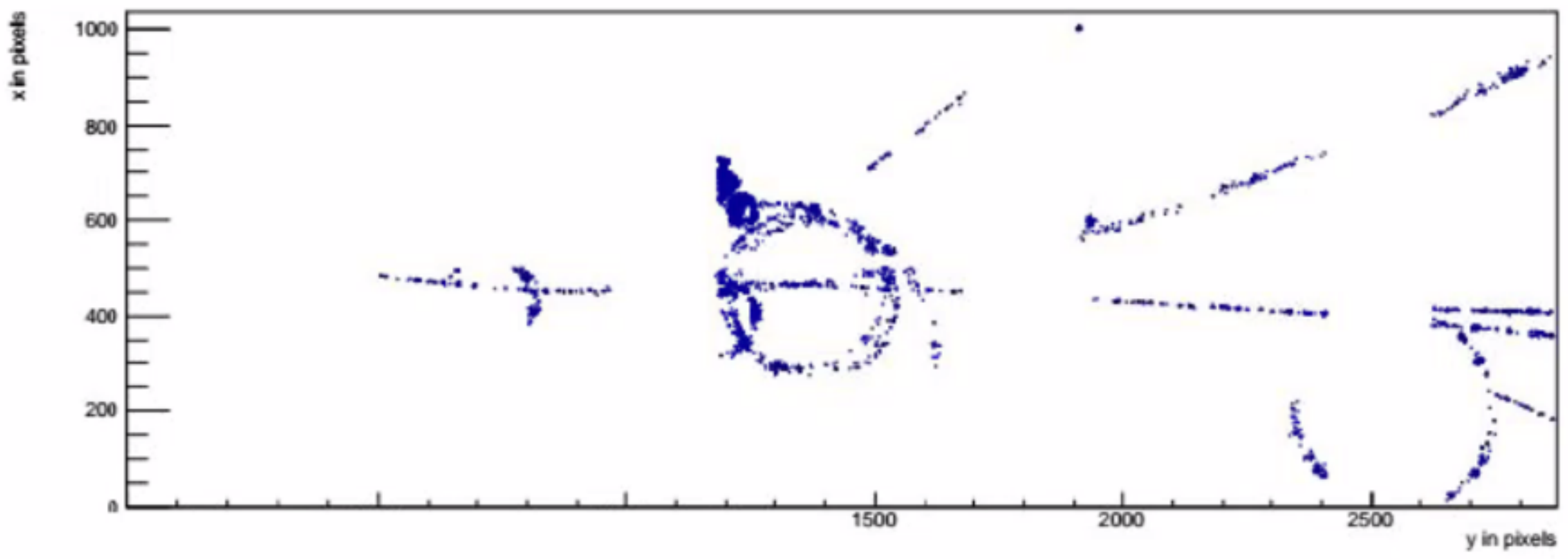


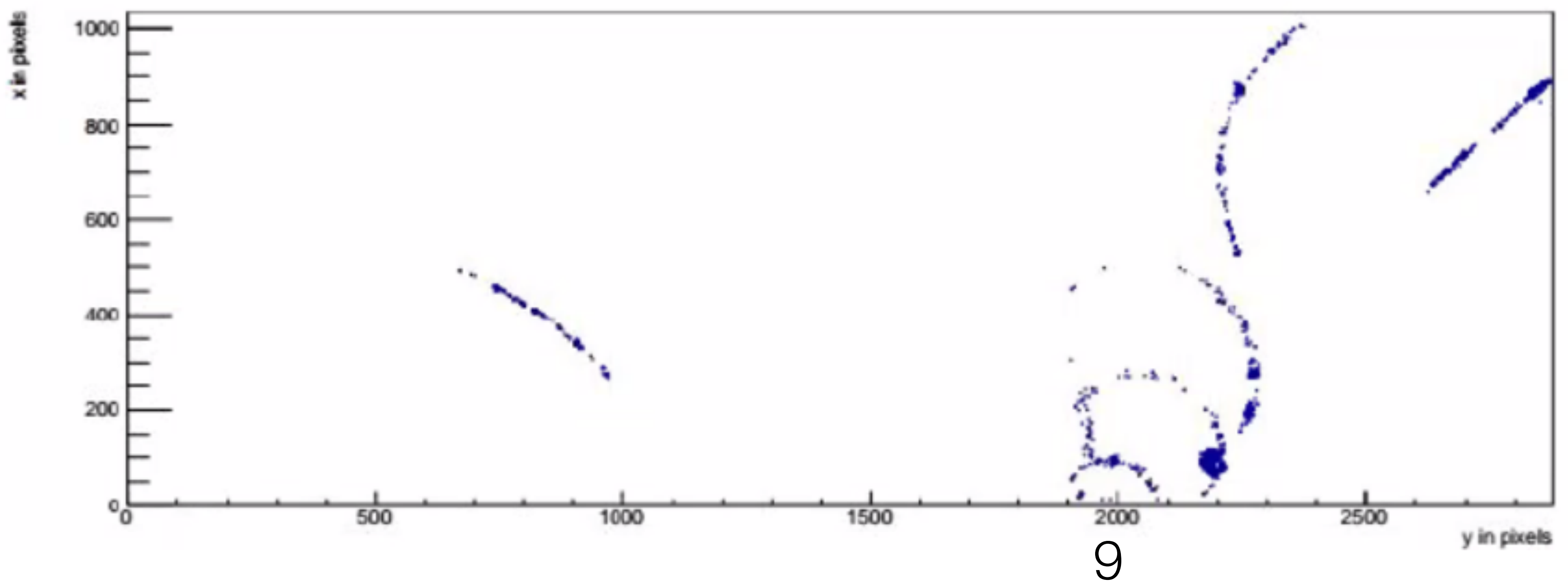


Tracks at
Drift d = 0.5-1.5 cm
T2K gas
B =0.5 T
p = 6 GeV/c

Overview:

- **Segmentation:** $\frac{55\ \mu m}{25\ cm} = 4500$
  - 70% active area → 3150 "rows"
- 2400 primaries in 25 cm for a MIP.
  - Thousands of hits per track.
- Extremely robust patterns.

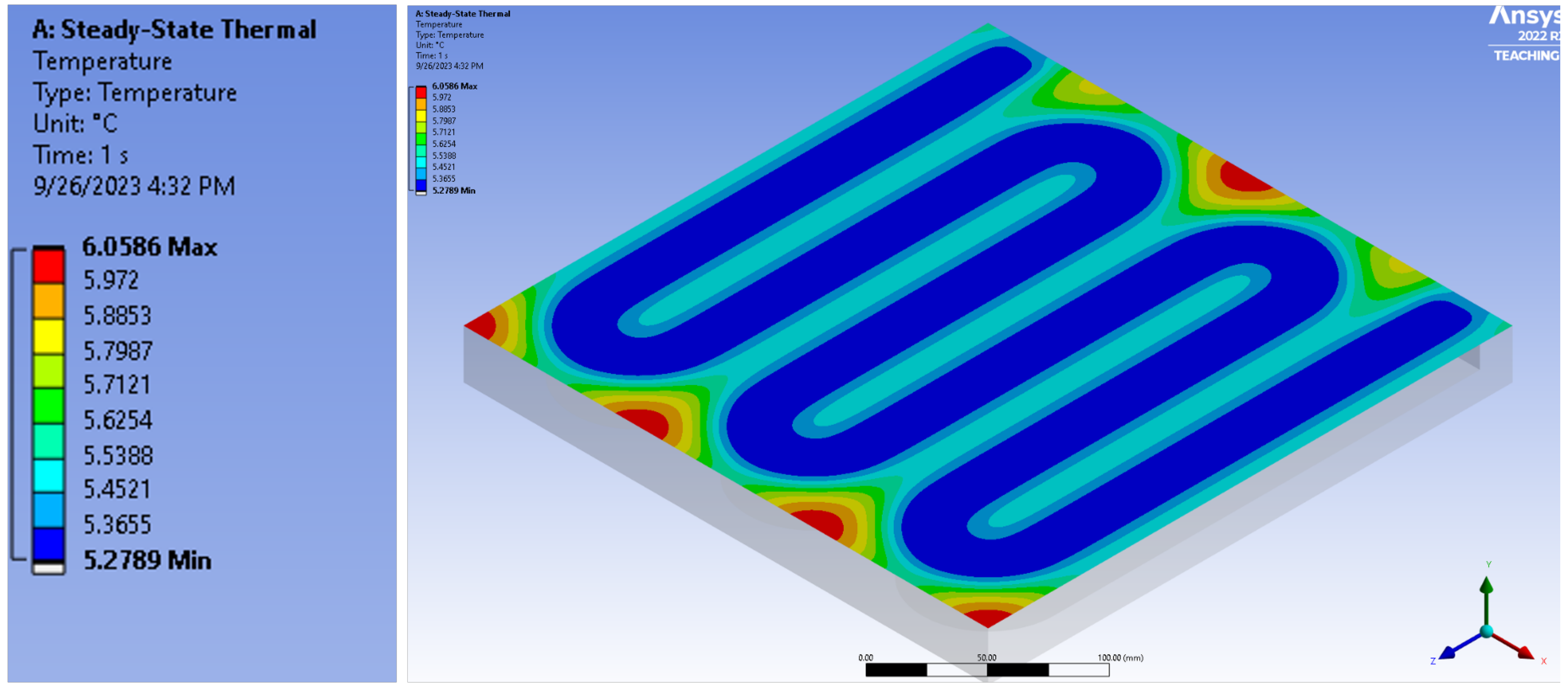


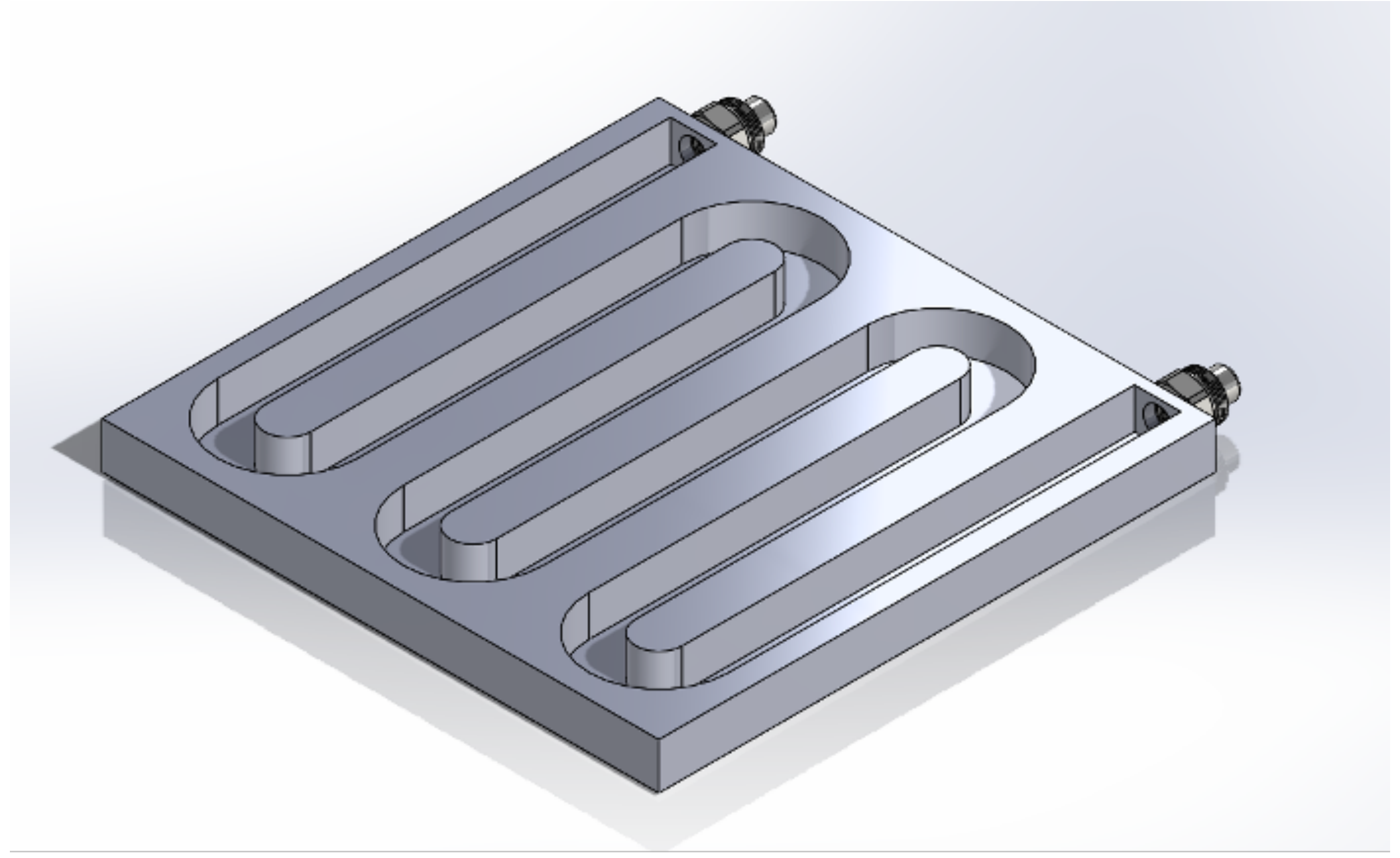


Motivation to CO2 cooling

- Careful: 1.2 - 5.4 kW of power (occupancy dependent)
- Conventional water cooling is bulky
- Water cooling is not uniform (Important for single electron counting)
- Purdue has existing expertise

➡ In general it would be of interest for other detector systems at ePIC too
➡ Plan Is to build a portable CO2 cooling system which can be used by others





Pros:
- Known/Proven Technology
- Active further development (Bonn)
- Best $\frac{dE}{dx}$ possible (~count each electron)
- Affordable for a small area
- High resolution tracking
- Low mass in electron arm
- Continuous (aka streaming) readout

Cons:
- ~3 kW of power:
- Must find a low mass way to handle.
- Services “bulky” (compared to just Si)
  - Gas
  - HV membrane
  - Cooling
  - DC power lines (3kV goes in too)

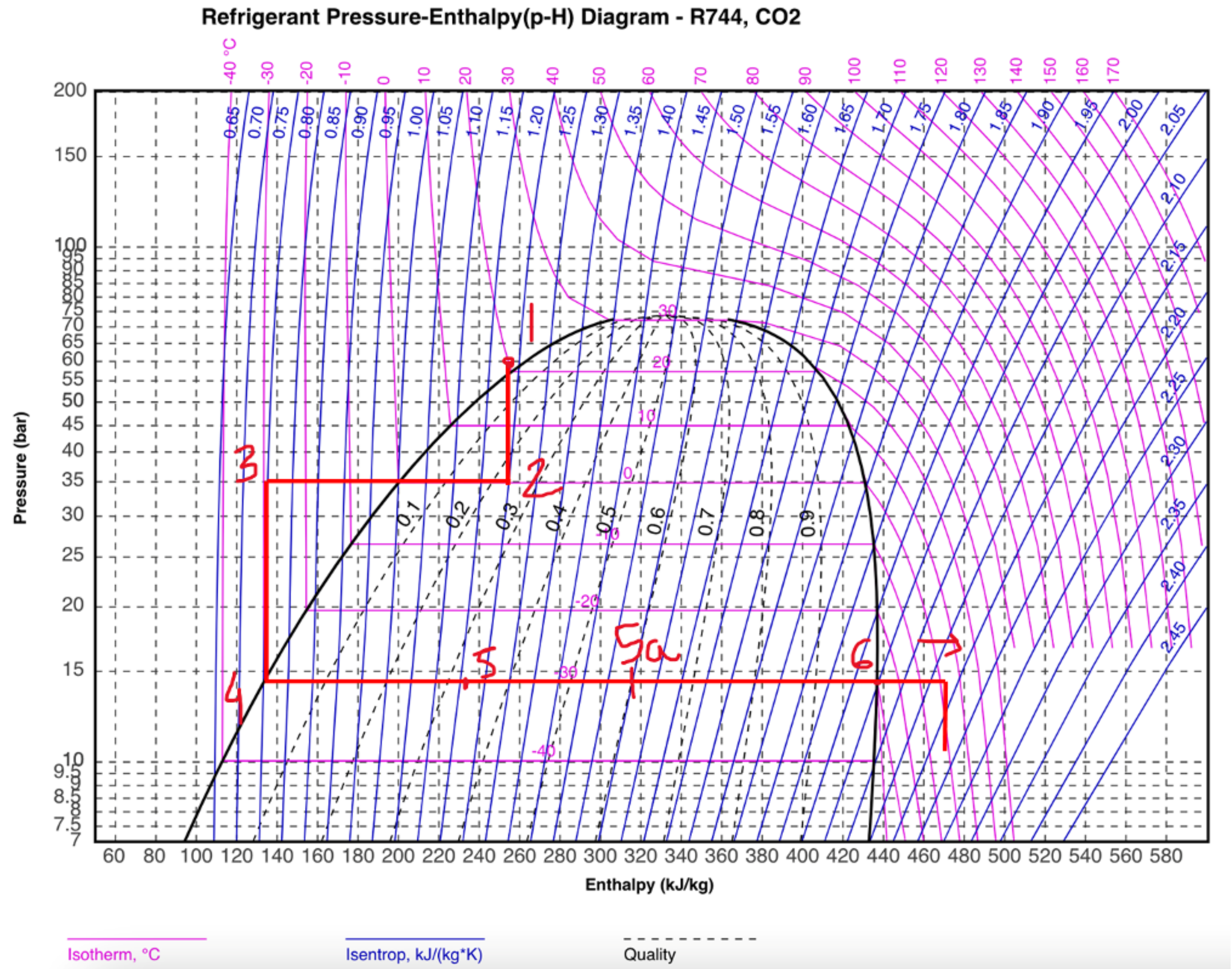
Flow Conditions

CO_2 bottle specifications:
$P = 59\ bar$
$T = 20°C$

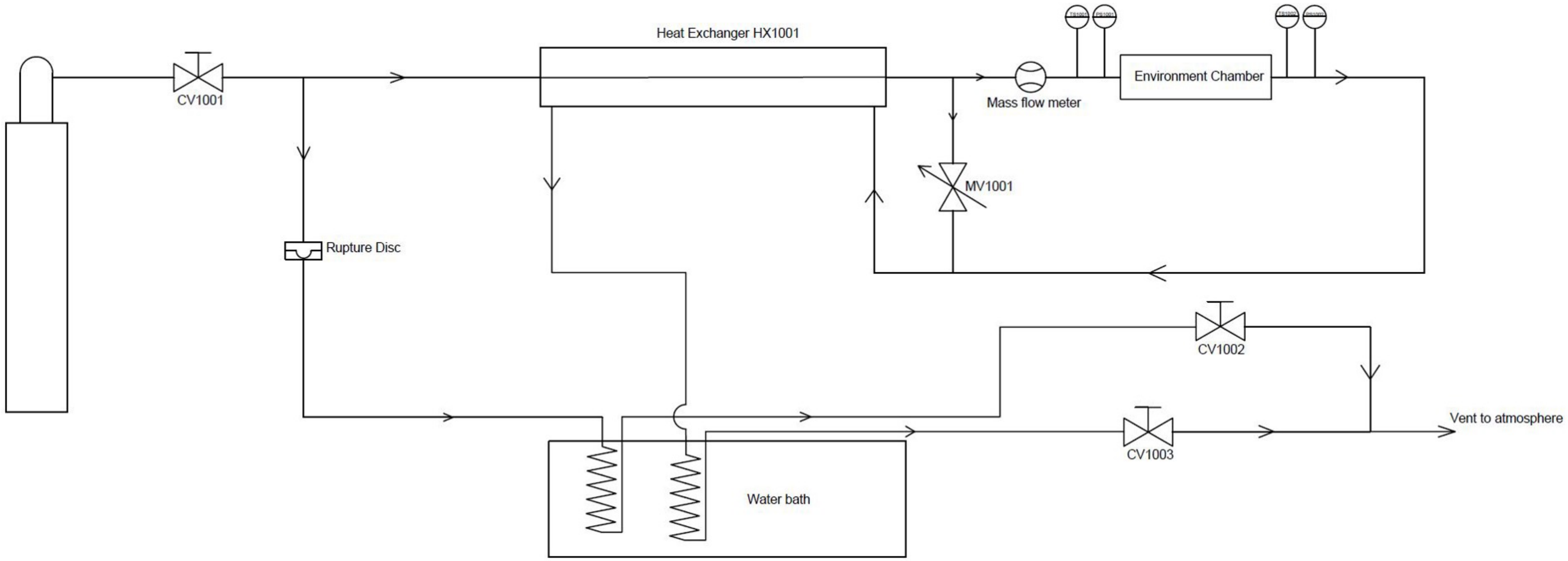
In the annulus of HX:
$P = 35\ bar$ (Assumed)
$T = 0°C\ to\ -29.7°C$

At the entrance of the environment chamber:
$P = 14.2\ bar$
$T = -30°C$
Vapor quality = 0

At the exit of the environment chamber:
$P = 14.2\ bar$
$T = -30°C$
Vapor quality = 33%



Schematic Diagram



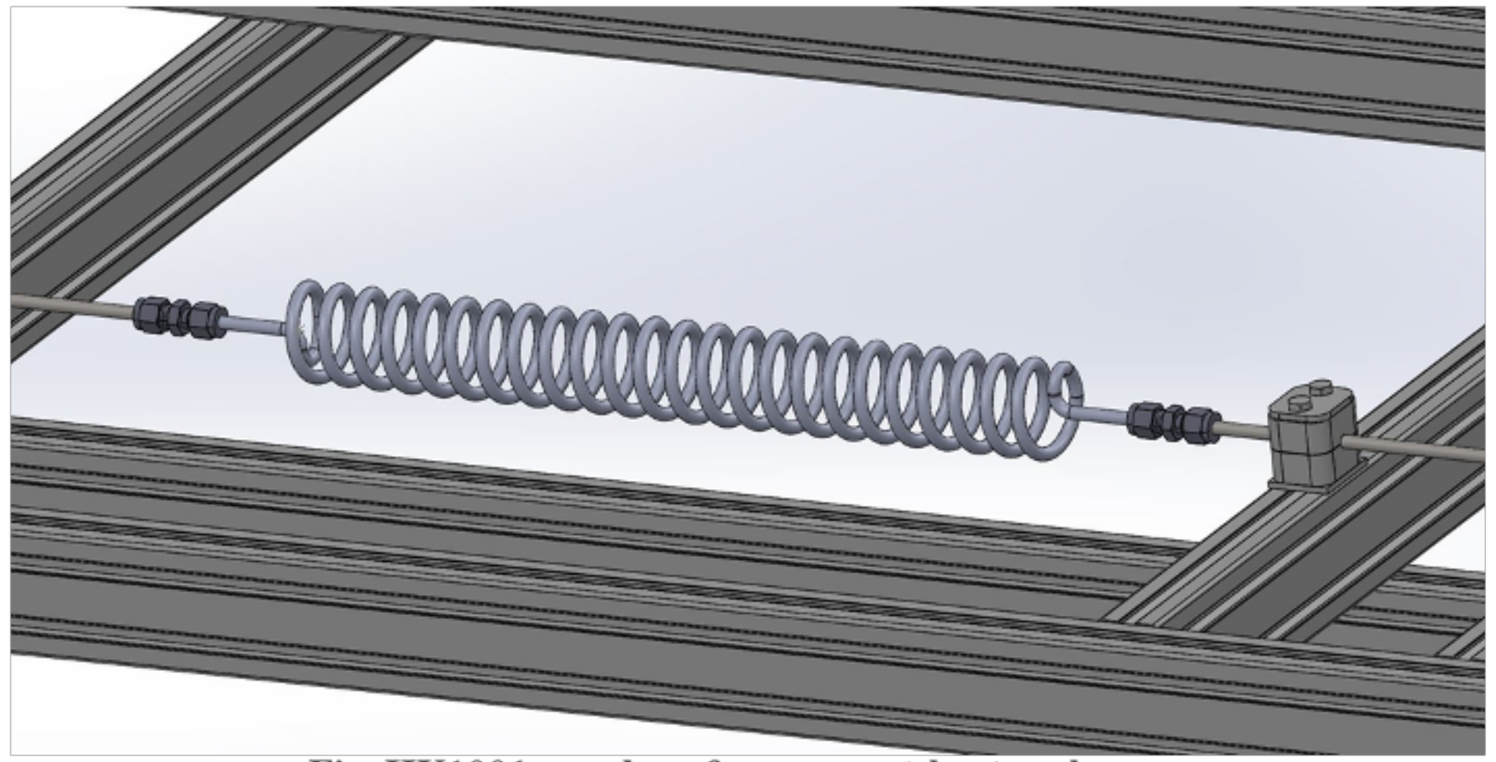
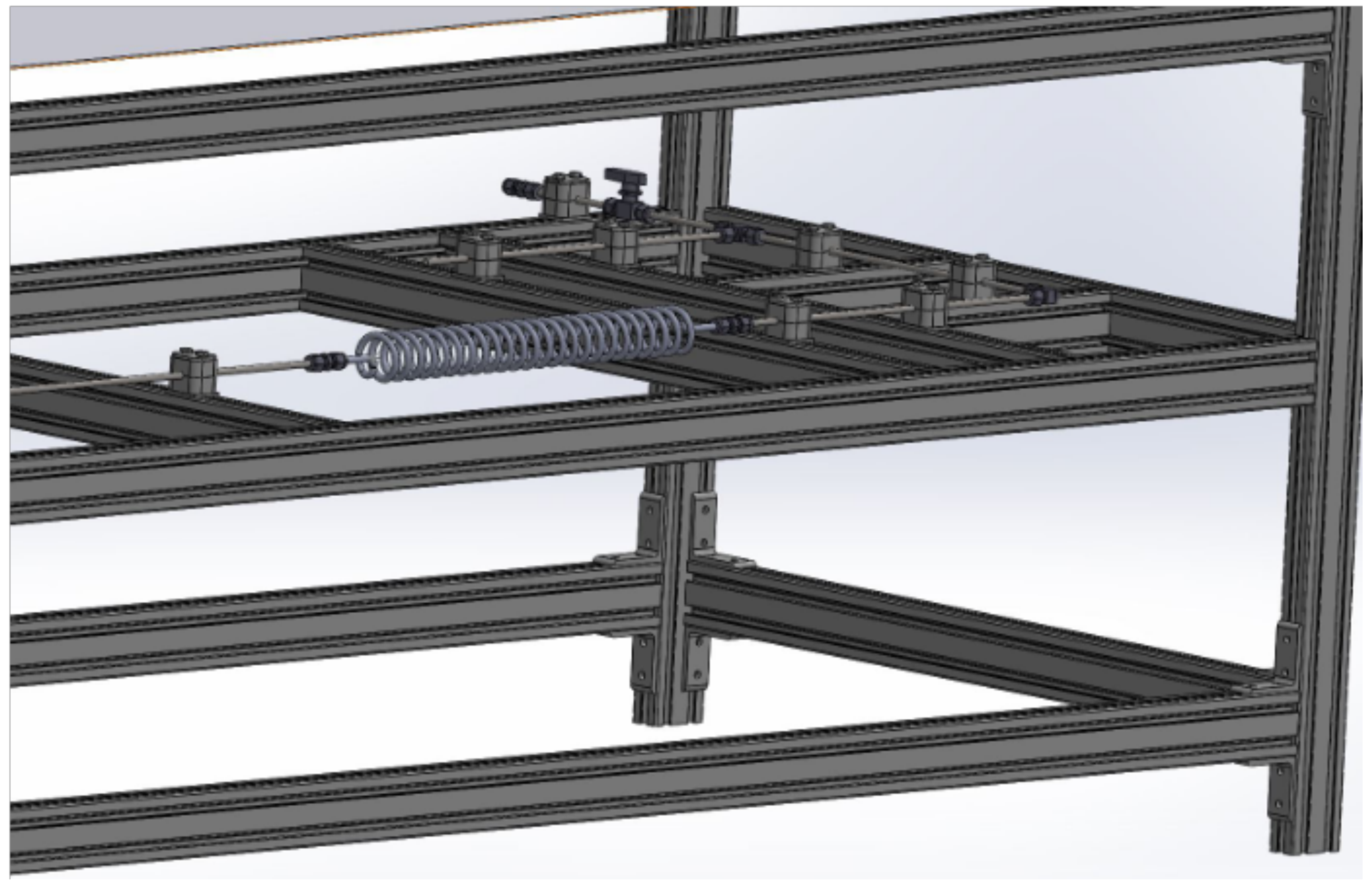
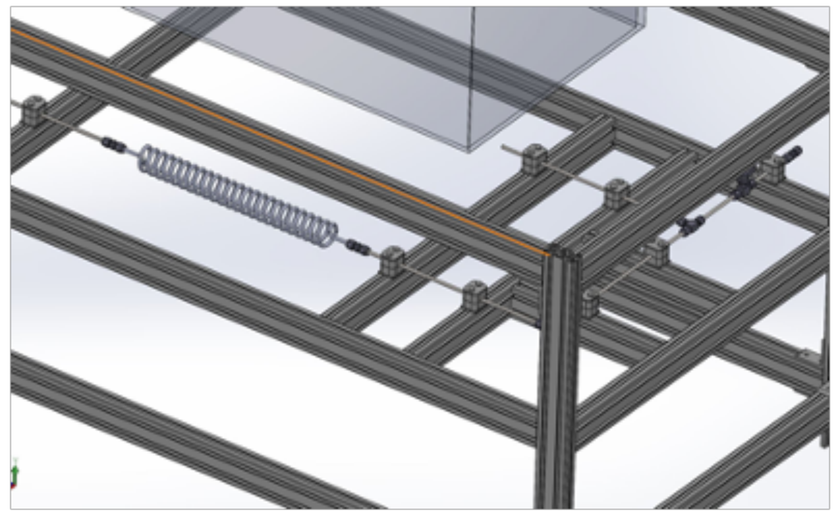


Fig. HX1001 annulus of concurrent heat exchanger





PURDUE UNIVERSITY

Budget Request

Item	Description	Nominal	20% down	40% Down
1	CO_2 Cooling	$50,000	$45,000	$35,000
2	Gas	$1,000	$1,000	$500
3	Travel (SBU)	$15,063	$11,633	$7,017
4	Travel (Yale)	$8,950	$6,170	$4,455
5	Travel (Purdue)	$5,180	$2,590	$1,295
	Total	$ 80,193	$ 66,393	$ 48,267
	Reduction		-17.2%	-39.8%

****External Trackers for Magnetic field Run will be arranged with local resources**

1.Large numbers of students are realistic
2.We have a long tradition of respecting DEI

Budget basis

Item	Description	Cost
1	Vehicles and Fuel (14 day)	$ 7,724
2	Vehicles and Fuel (7 day)	$ 3,862
3	Hotel Rate per Room	$ 155
4	per diem	$ 30
5	Airfare/person (Yale)	$ 190

Item	Description	Request	20% Down	40% Down
1	Test Beam Duration	14 days	14 days	7 days
2	SBU Senior Personnel	2	2	2
3	SBU Junior Personnel	4	1	0
4	Yale Senior Personnel	2	2	2
5	Yale Junior Personnel	2	1	1
6	Purdue Senior Personnel	1	1	1
7	Purdue Junior Personnel	1	0	0

Summary

- A mini-TPC with GridPIX readout seems an ideal technology for EIC
- Especially useful at future luminosity,
- Robust pattern recognition against synchrotron background.
- Data reduction/background suppression to track-lets possible in hardware.
- Excellent PID performance at the lowest momenta and tracking performance.
- Startup costs minimal due to existing equipment and experience.
- Next year emphasis on developing a “deployable” configuration with CO_2 cooling