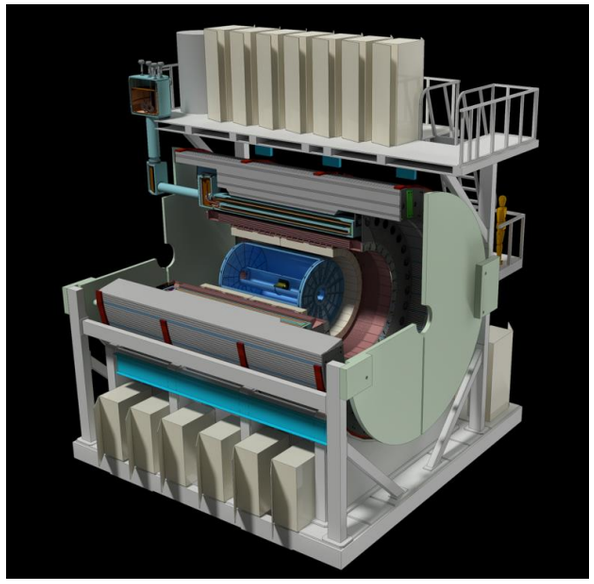


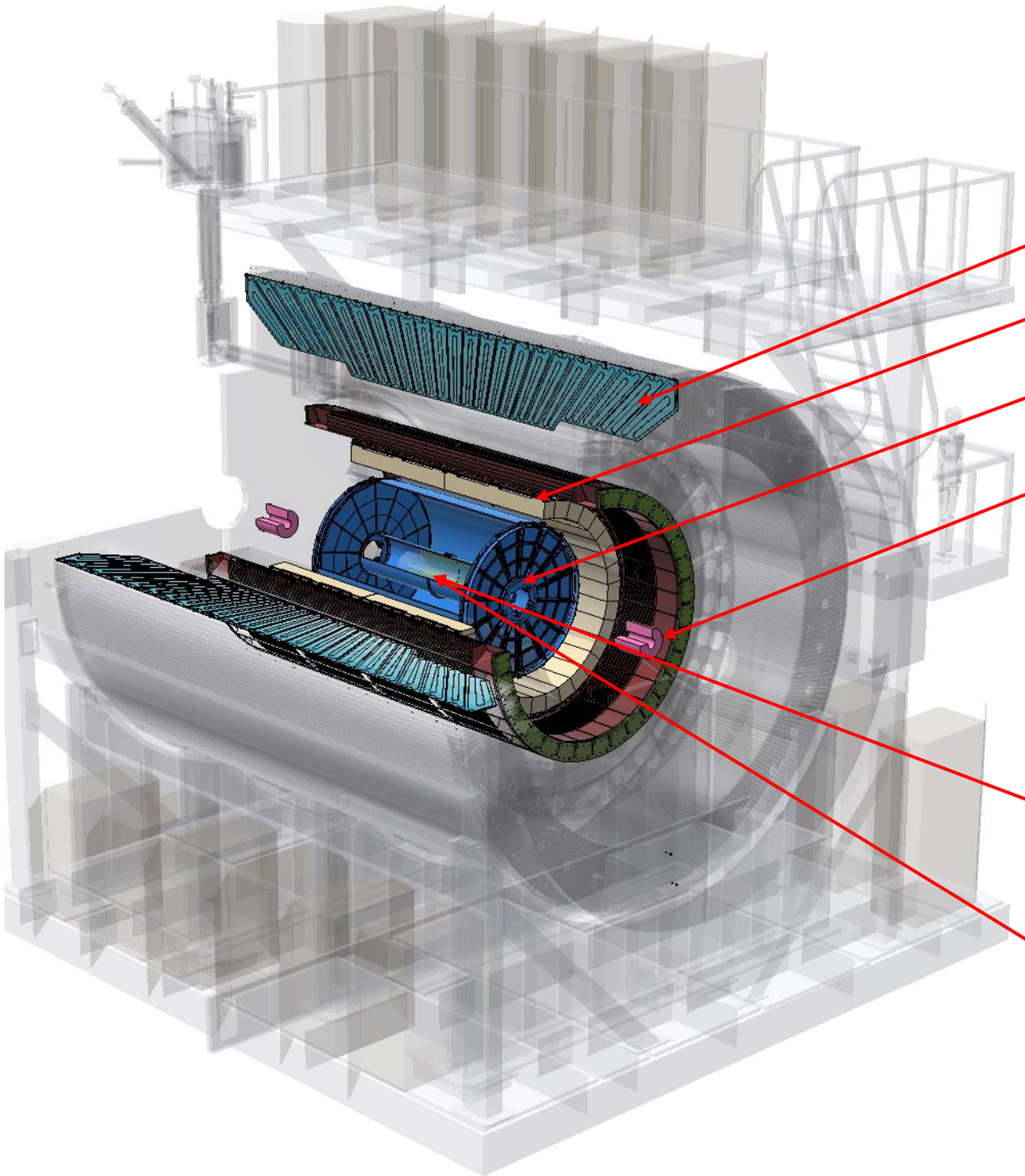
Combining Triggered and Streaming Readout – The sPHENIX DAQ System

Martin L. Purschke

Long Island, NY

RHIC from space

sPHENIX – the Concept



Hadronic Calorimeter(s)

Electromagnetic Calorimeter

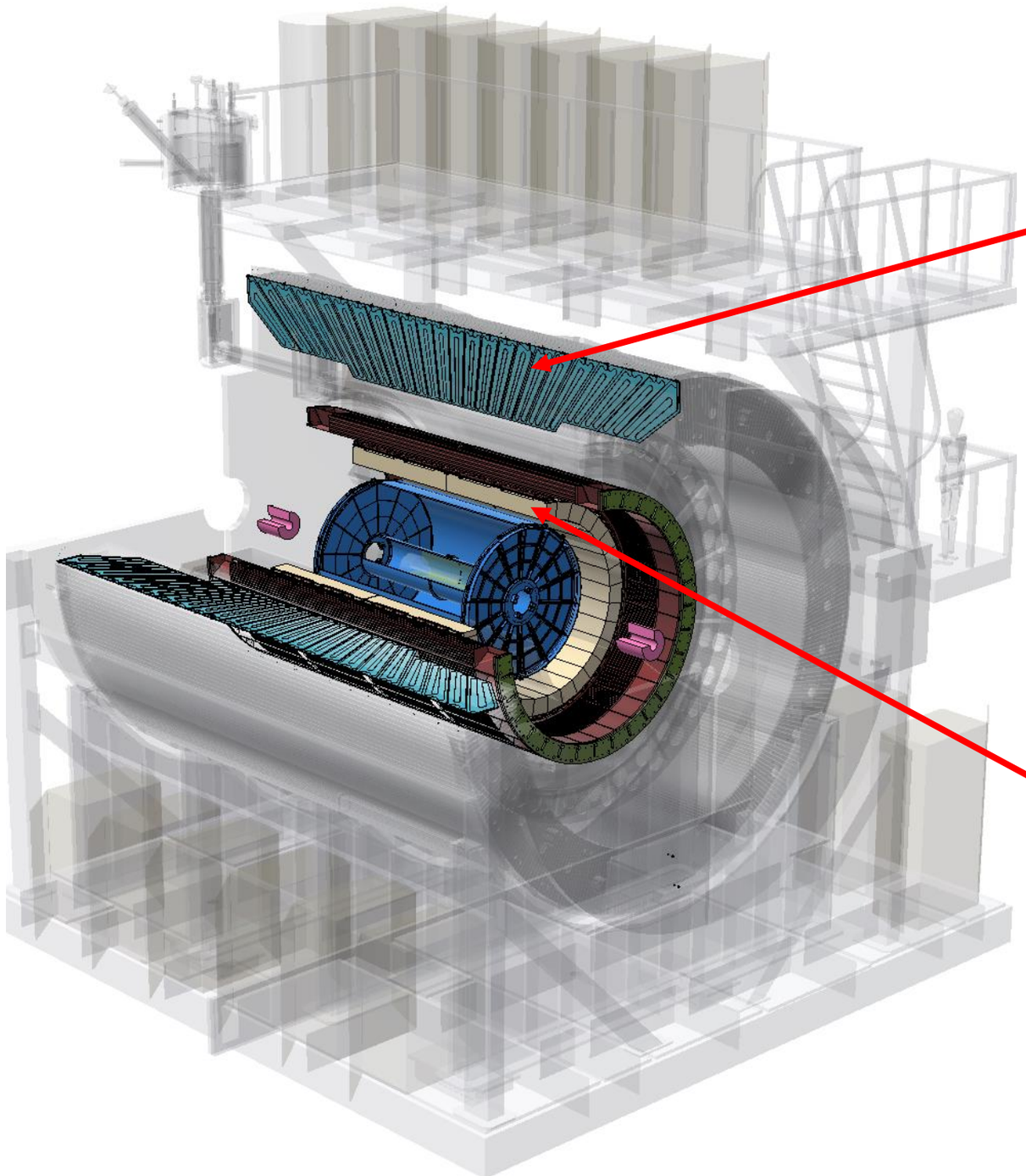
Time Projection Chamber (TPC)

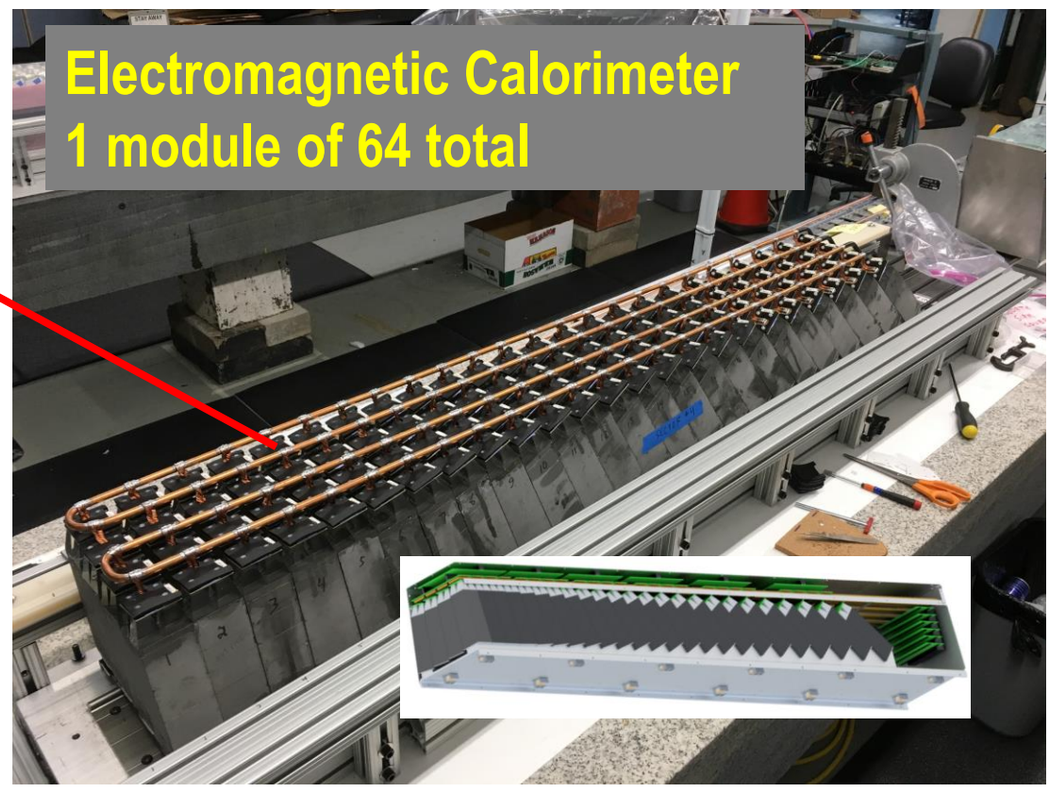
Minimum Bias Detector (MDB)

Intermediate Tracker (INTT)

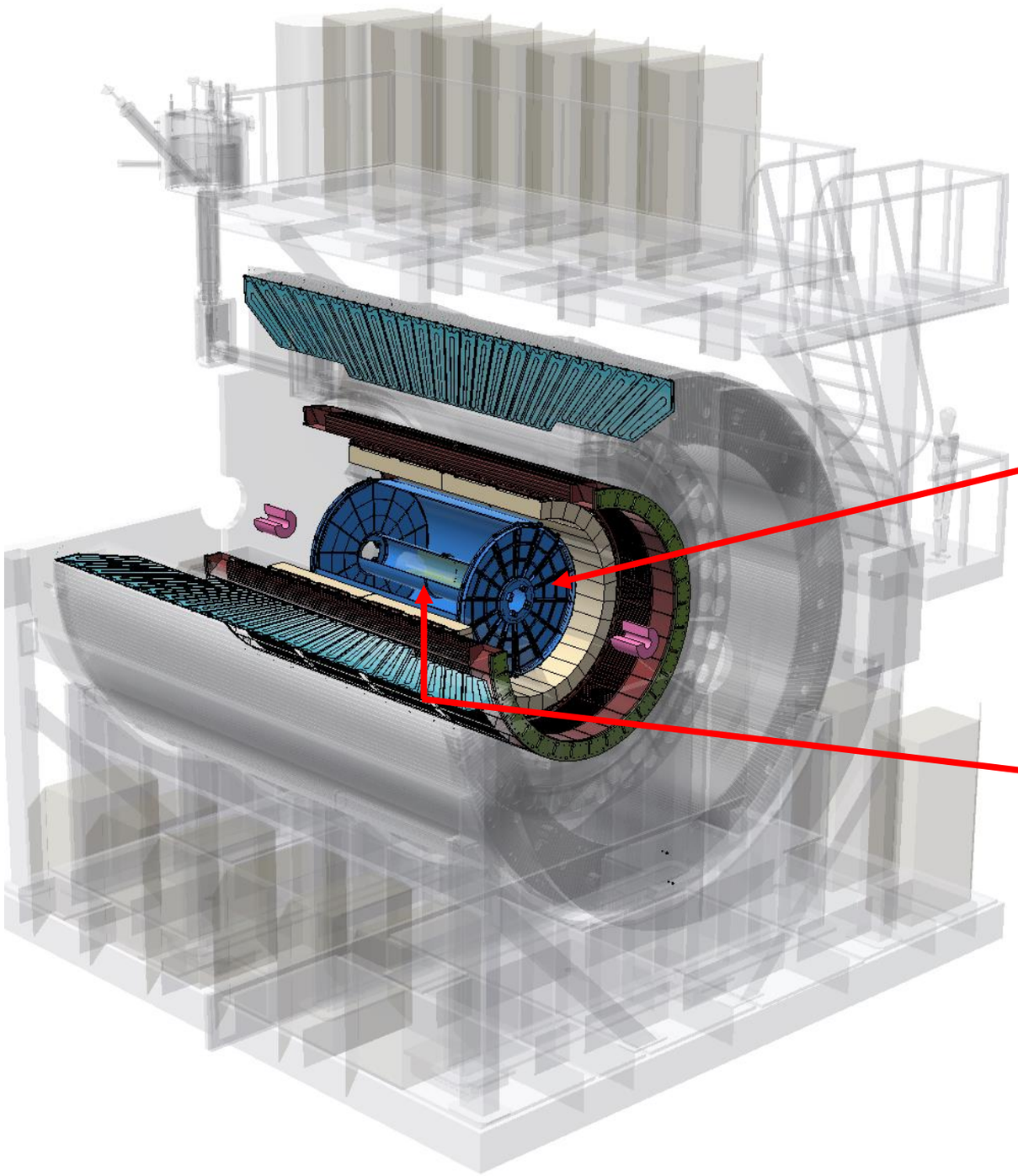
MicroVertex Detector (MVTX)

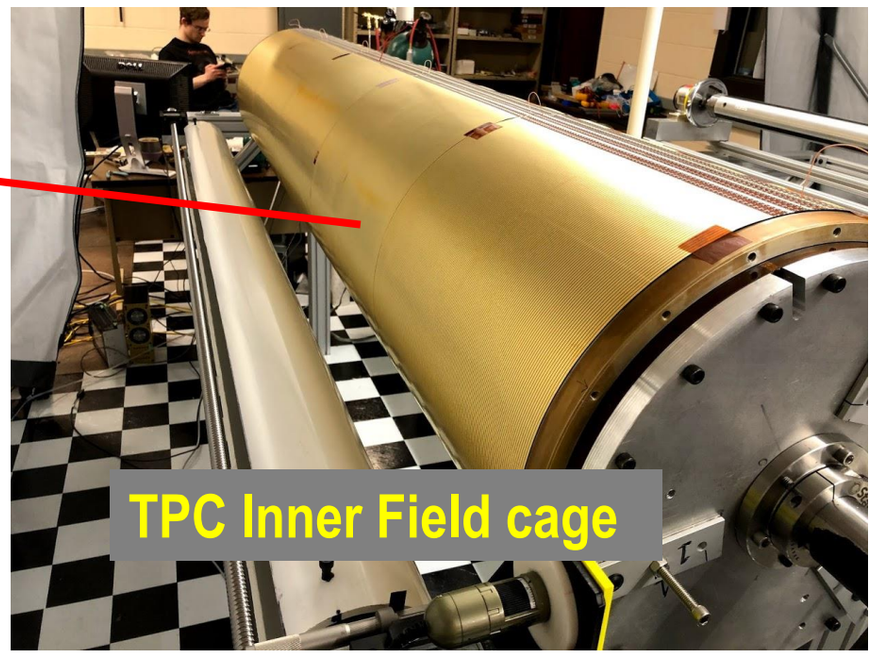
sPHENIX … getting real



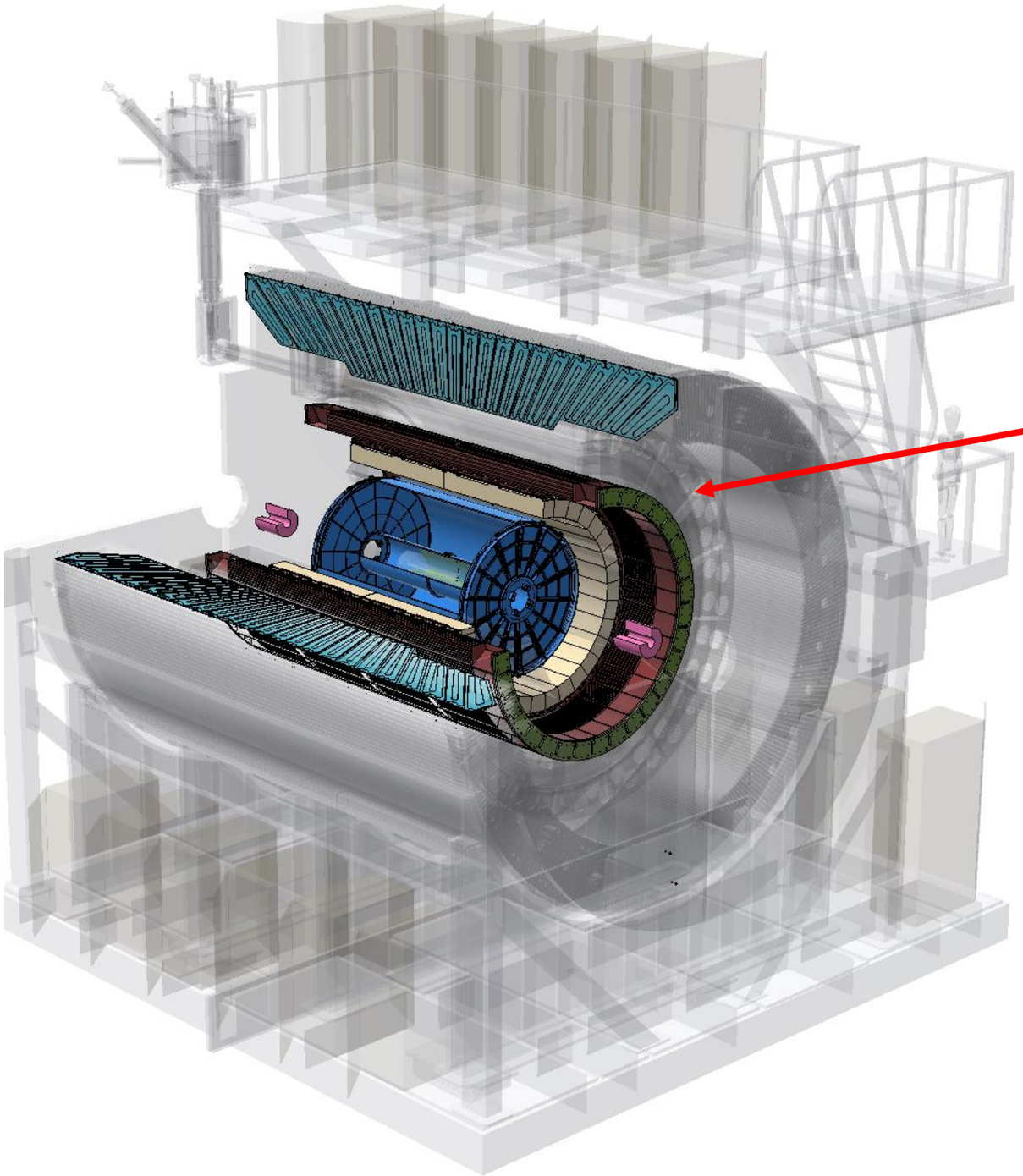


sPHENIX … getting real

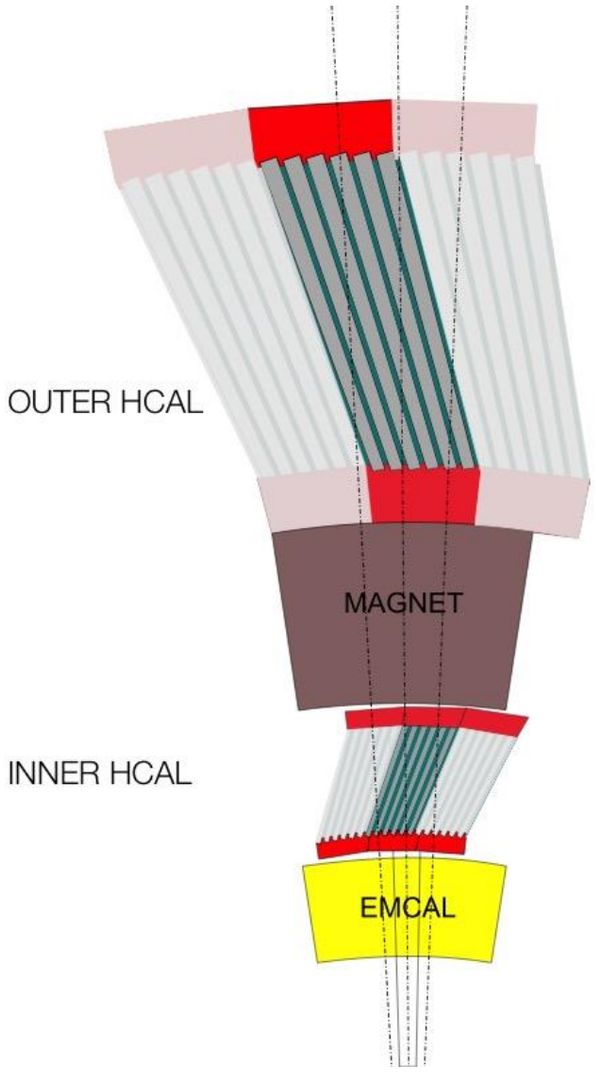


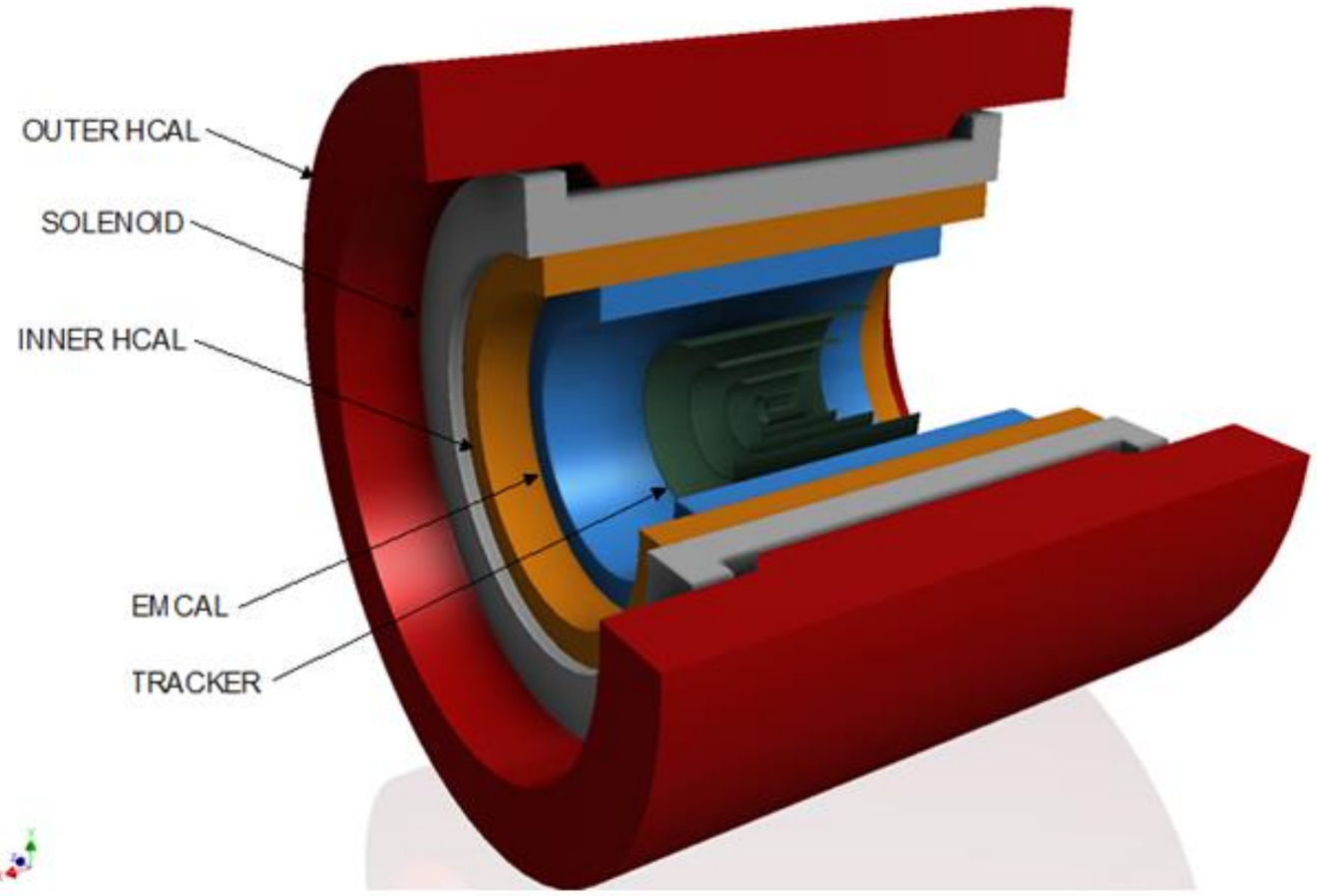


sPHENIX … getting real



sPHENIX – Calorimetry





- Outer HCAL ≈3.5λ_I
- Magnet ≈1.4X_0
- Inner HCAL ≈1λ_I
- EMCAL ≈18X_0≈1λ_I

We have already presented the calorimeters last time, I'll focus on the tracking (and the TPC) today

s with

oid.

enoid.

2 x 24 x 64 readout channels

$\sigma_E/E < 100\%/\sqrt{E}$ (single particle)

SiPM Readout

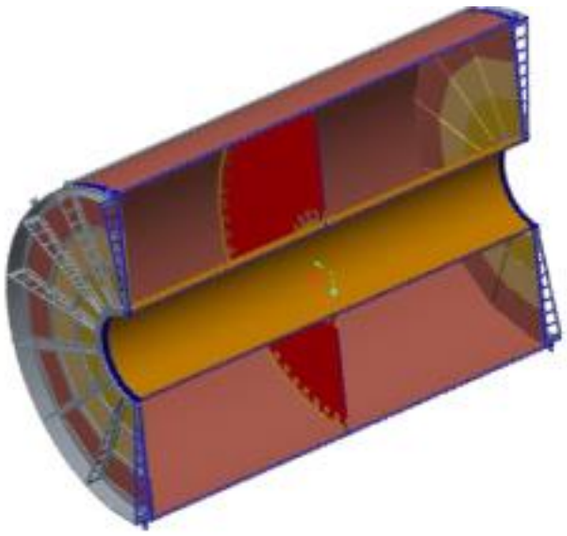
Three Tracker Components

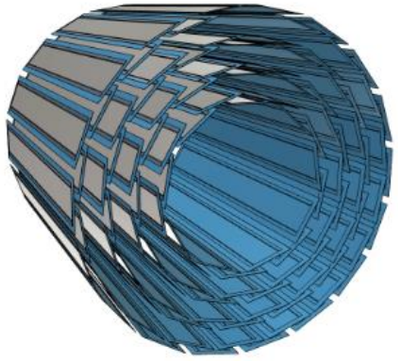
Micro-Vertex Detector (MVTX) Three-layers identical to Inner ALICE ITS (r = 2.3cm, 3.1 cm, 3.9 cm)

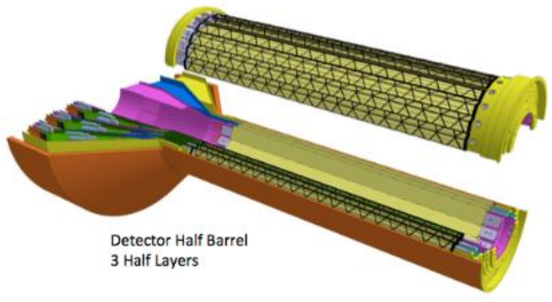
Intermediate Silicon Strip Tracker (INTT) Four layer Si strip detector. (r = 6 cm, 8 cm, 10 cm, 12 cm)

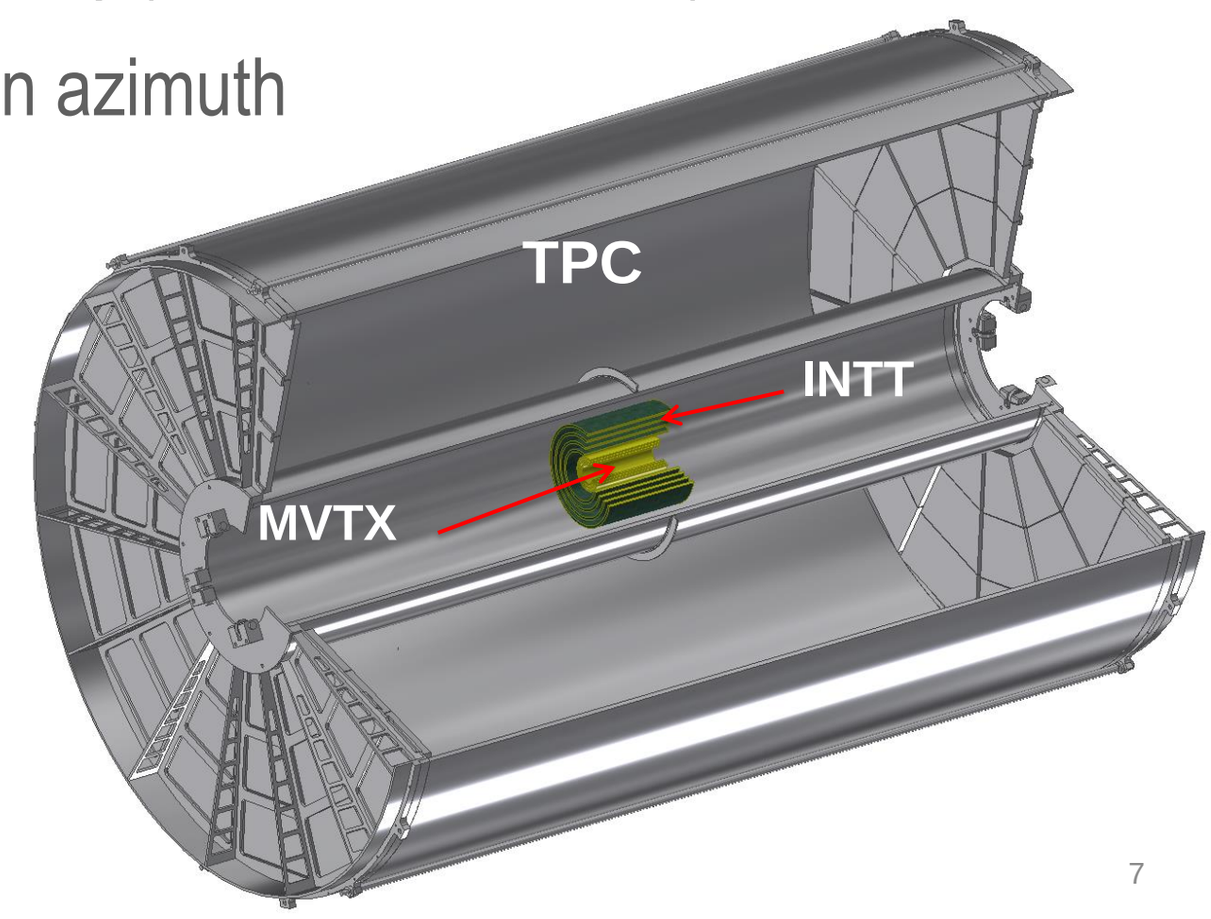
Compact Time Projection Chamber (TPC) (20 cm < r < 78 cm)

All cover at minimum | η | < 1.1 and 2π in azimuth





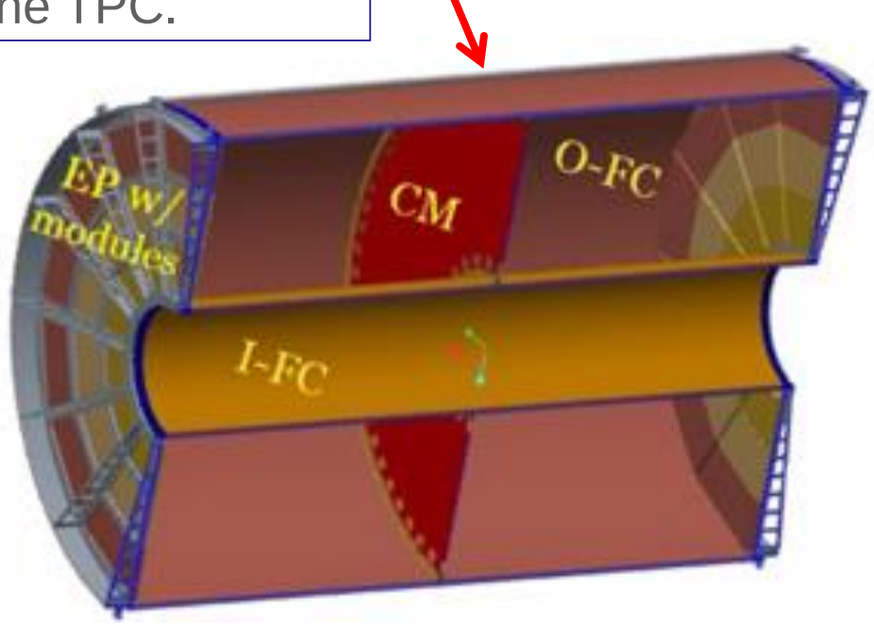




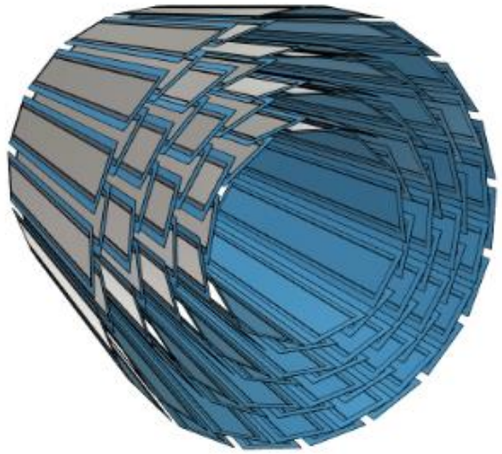
Streaming Readout Detectors

TPC

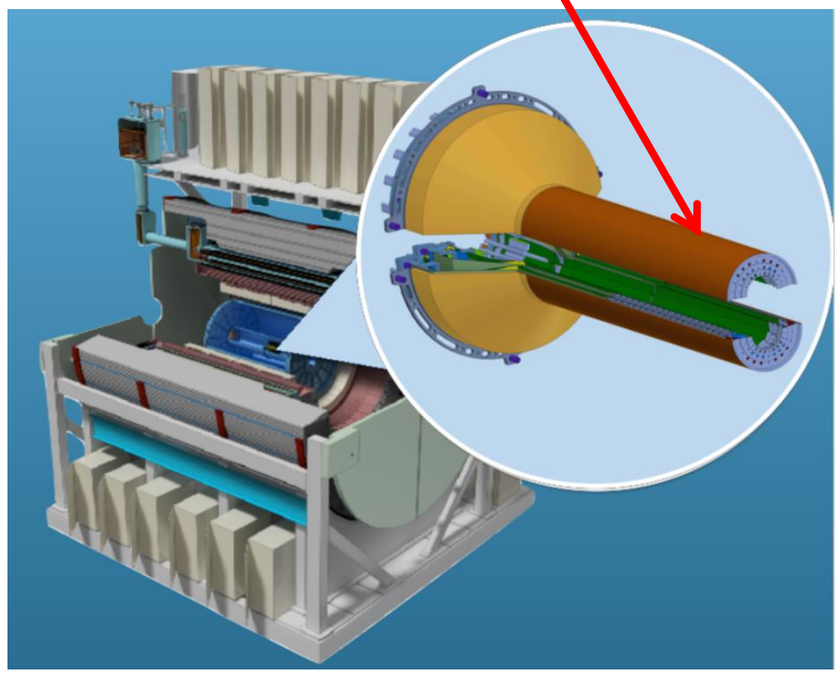
I will mostly concentrate on the TPC.



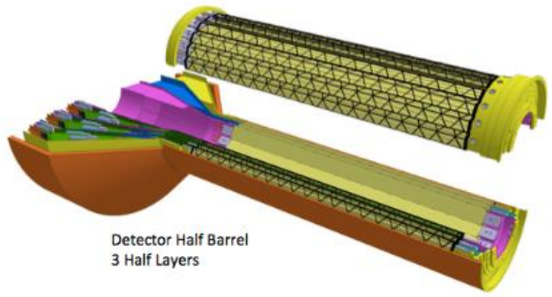
INTT



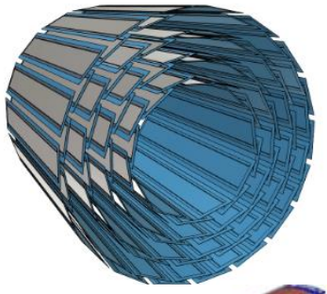
MVTX



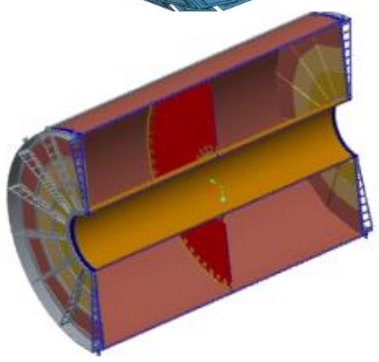
Data and more data



MVTX (MAPS) **~ 20GBit/s**

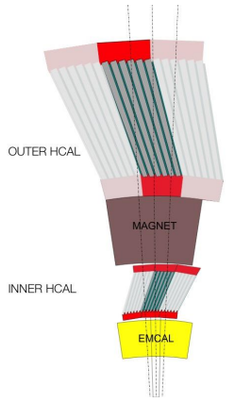


Intermediate Silicon Strip Tracker (INTT) **~ 7GBit/s**



Compact Time Projection Chamber (TPC) **~ 100Gbit/s**

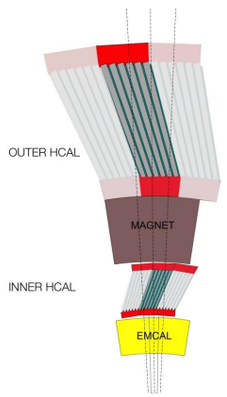
Calorimeters (primarily Emcal, hadronic cal.) **~ 8GBit/s**

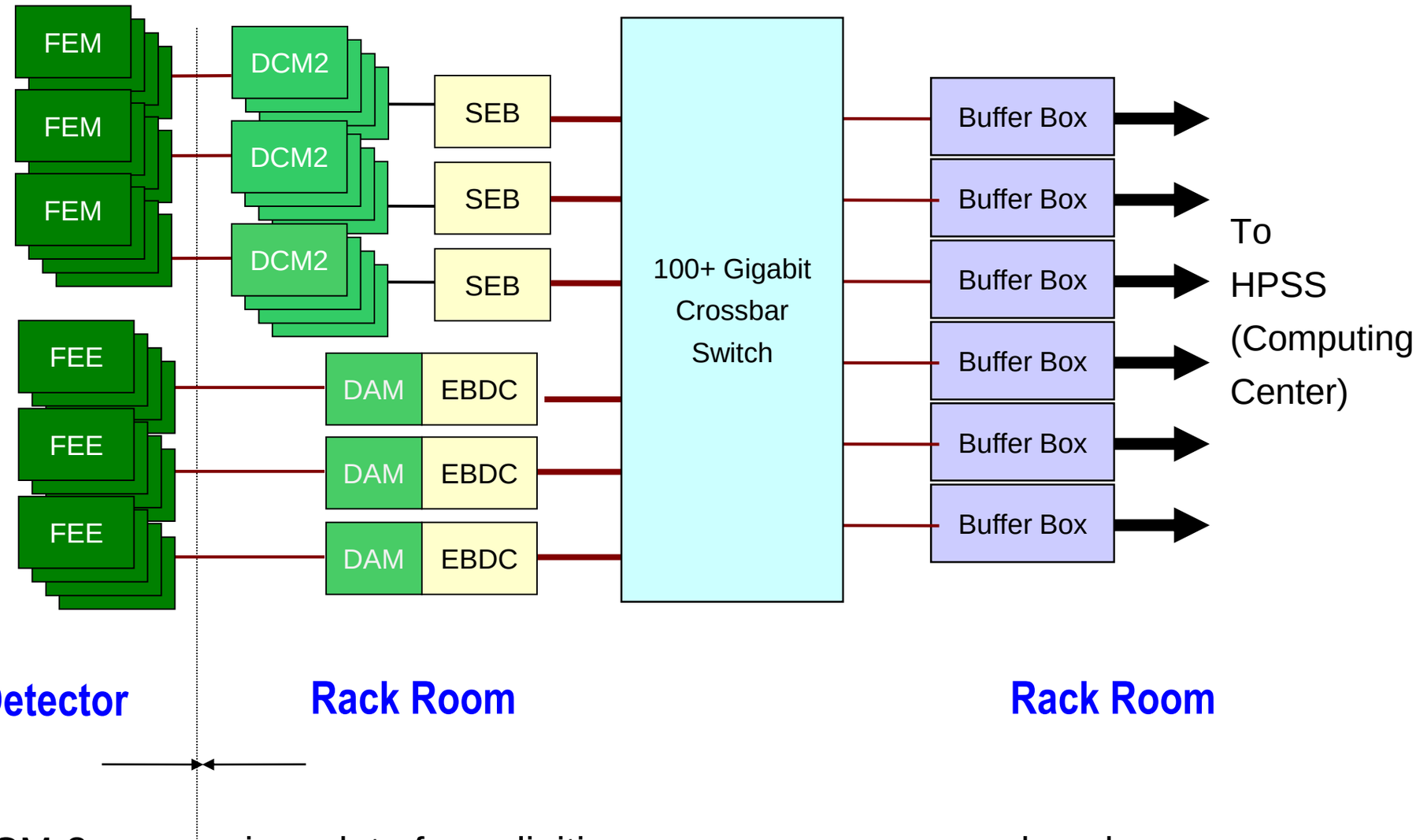


135GBit/s

Easy to remember number: 1.4 PetaByte/day

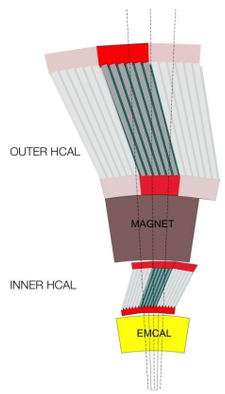
DAQ Overview

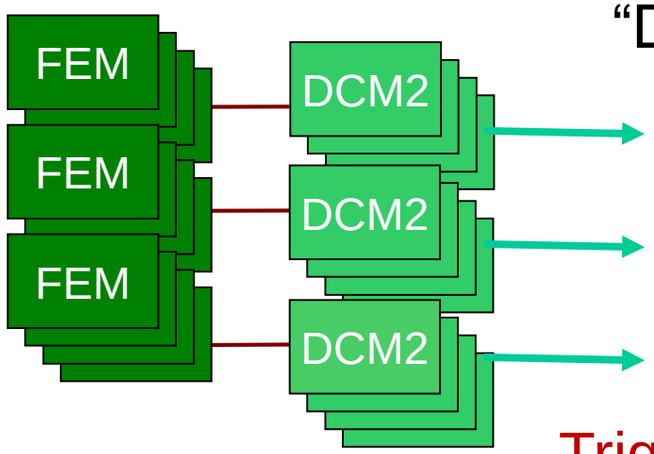




- DCM-2 receives data from digitizer, zero-suppresses and packages
- SEB collects data from a DCM group (~20)
- EBDC Event Buffer and Data Compressor (~40)
- Buffer Box data interim storage before sending to the computing center (6-8)

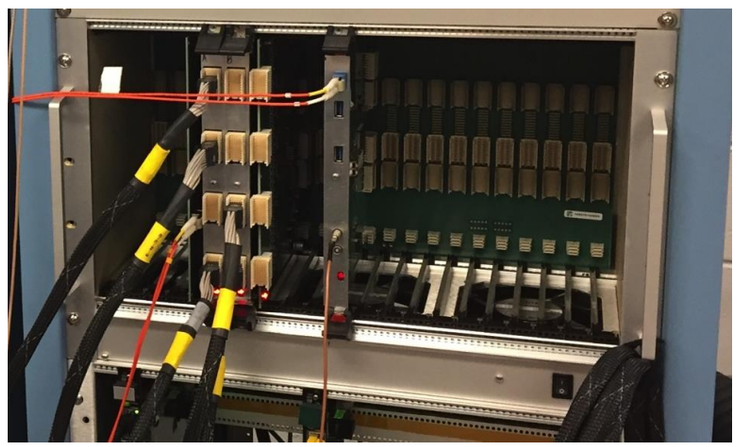
Triggered and Streaming Readout

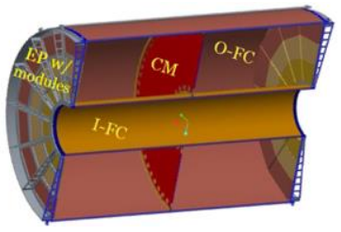


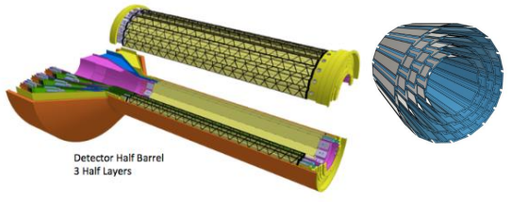


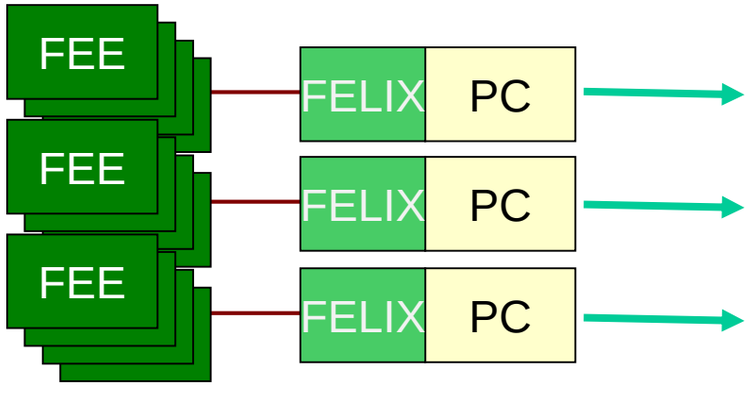
The calorimeters and the MBD re-use the PHENIX "Data Collection Modules" (v2)

Triggered readout



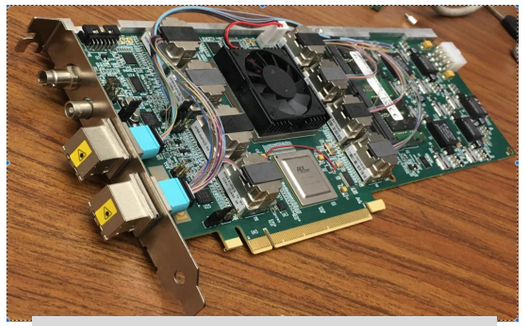




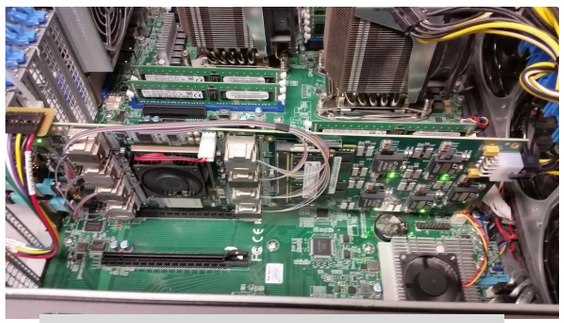


The TPC, the MVTX, and the INTT are read out through the ATLAS "FELIX" card directly into a standard PC

Streaming readout



ATLAS FELIX Card



Installed in a PC

How I explain Streaming Readout to the Public Affairs guys

Think of the recordings of a shopping mall's security cameras

You keep, say, a month worth of video

Most of the time, absolutely nothing of interest happens

But when there's something going on, a burglary or so, you go back and cut out the 15 minutes of video in question for the cops

Think of those 15 minutes as the long-term stored data

Translation to sPHENIX…

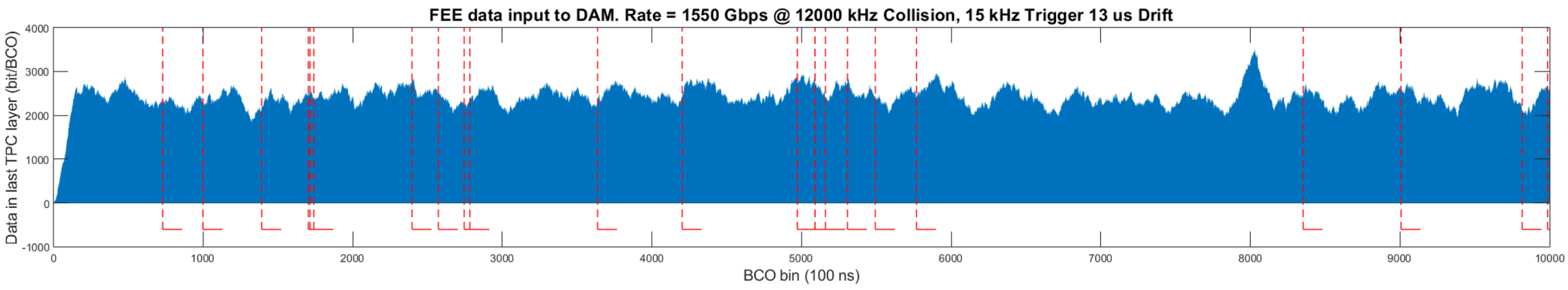
We record the arrival of charge continuously

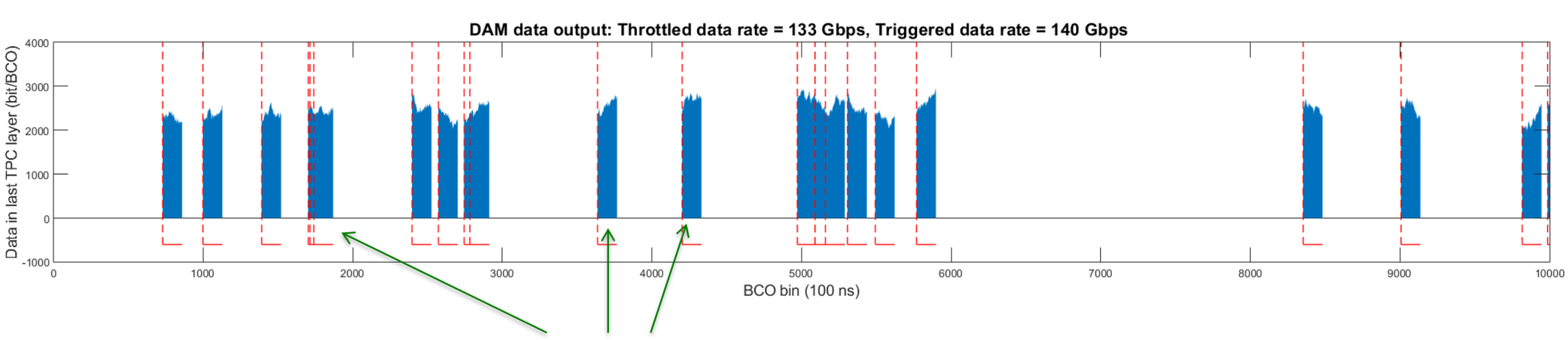
But at the end, we are really mostly interested of the piece of "recording" at the time we triggered an actual event

So stored "events" for the TPC will be a series of short "charge recording segments" covering the times when we triggered the rest of the experiment.

12

“Must-have” Triggered+Streaming events…

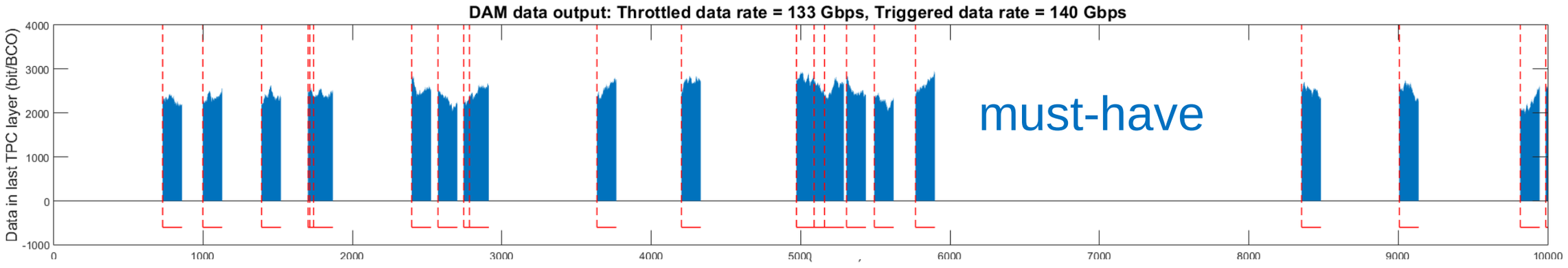


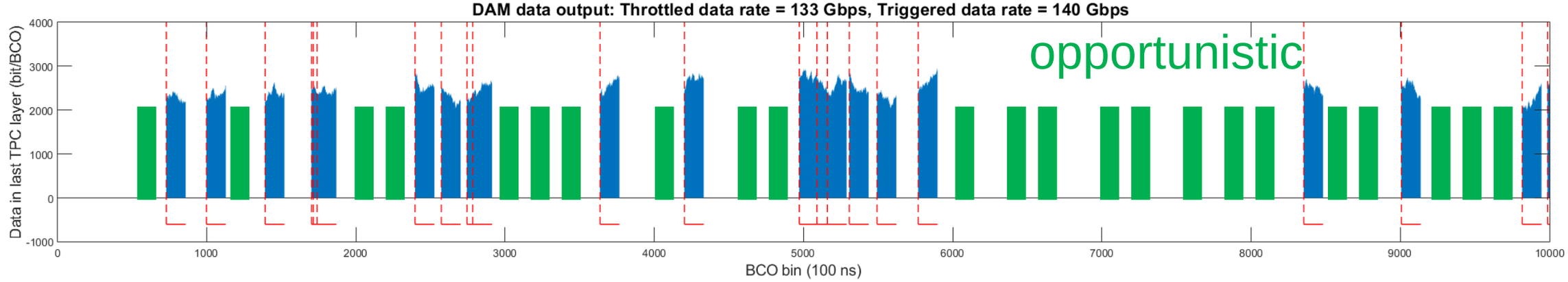


Chunks correlated with triggered events

In this way, we guarantee that we are reading “full” events here with information from all detectors
These are really our “baseline” data.
But there are ”reserves”!

… plus “opportunistic” streaming-only events





In addition, we can read “tracking-only” events without the calorimeters
Greatly enhances the statistics for several physics signals
Our Heavy Flavor group paved the way, others will soon discover the benefits
We can “back-fill” our storage limit with those events, open/close throttle as needed

Combined Triggered/Streaming readout tests

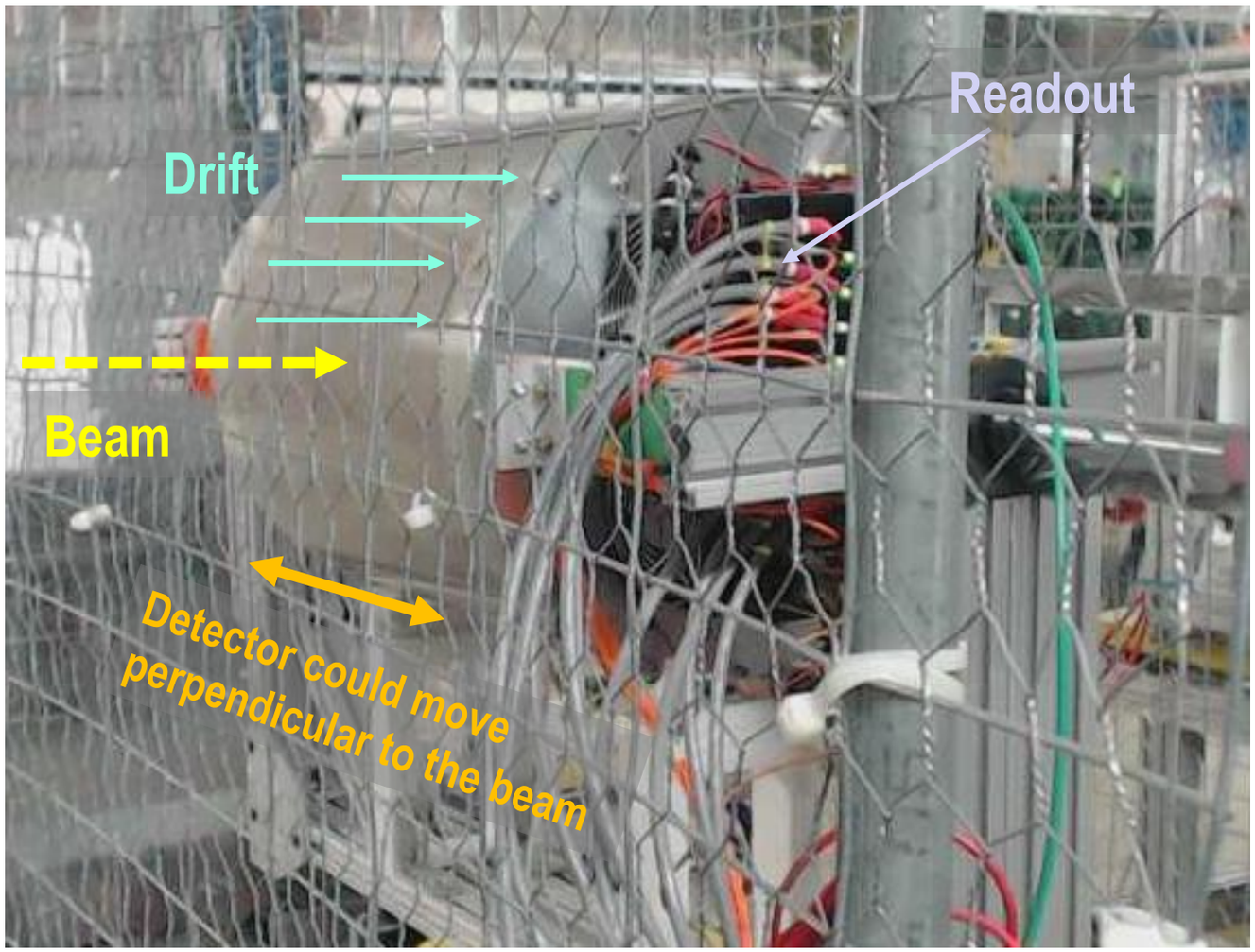
- This wasn’t actually even formally planned at that stage…
- We took a TPC prototype to the FermiLab test beam last year, FELIX readout, multiple front-ends…
- Running in triggered-only mode would severely limit our event rates
- We still needed to read out the Facility-provided beamline instrumentation (Cherenkov detectors, etc), triggered
- But we “flipped” the TPC into streaming-readout mode
- Our data acquisition system, “RCDAQ”, has support for streaming readout built in

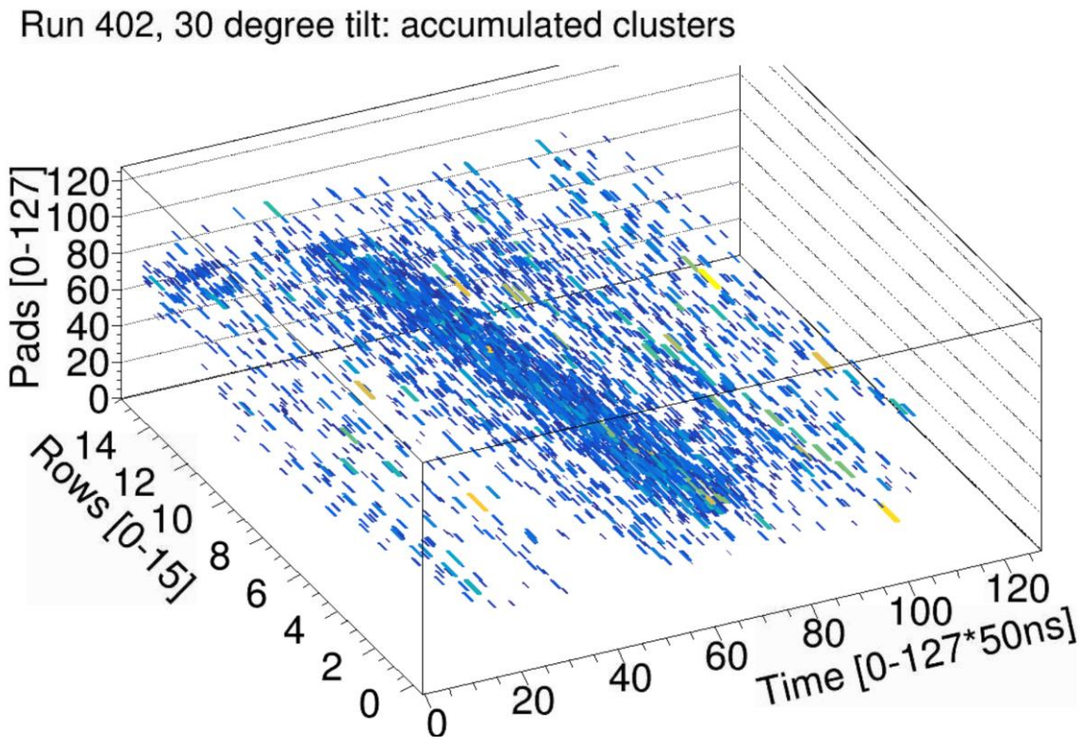
```
$ dlist  tpc-00002343-0000.evt -i
 -- Event     1 Run:  2343 length: 5242872 type:  2 (Streaming Data)  1550500750
Packet  3001 5242864 -1 (sPHENIX Packet)  99 (IDTPCFEEV2)
$
```


15

TPC Prototype

The prototype in the beam. Can move and rotate to make different tracks though the volume





And it worked!

Reconstruction of tracks at a particular setting (several overlaid)

16

Let’s go back here for a sec

“*Running in triggered-only mode would severely limit our event rates*.”

Why?

When you have a “classic” triggered event, you accept the trigger, read out the detectors, done. Next event. One event is a well-contained thing.

I have come to regard a particular feature of SRO as the defining property, even if you ultimately trigger your front-end:

There is no synchronized end to a given event!

While “event” *n* is streaming, in other places, event *n-1* (or -2) isn’t finished yet

Events are interleaved in this way. No need to wait for an event stream to be finished – do it offline. Just stream!

Disentangle the “Event” chunks that belong together by their distributed clock counter or similar (for us: RHIC beam clock counter)

17

Summary

sPHENIX is on a good track to taking data in 2023

We got a jump start taking streaming data last year, good

We have demonstrated that we can reconstruct the TPC data taken in SR mode

We have a good concept combining triggered and streaming data in the experiment.

Thank you!

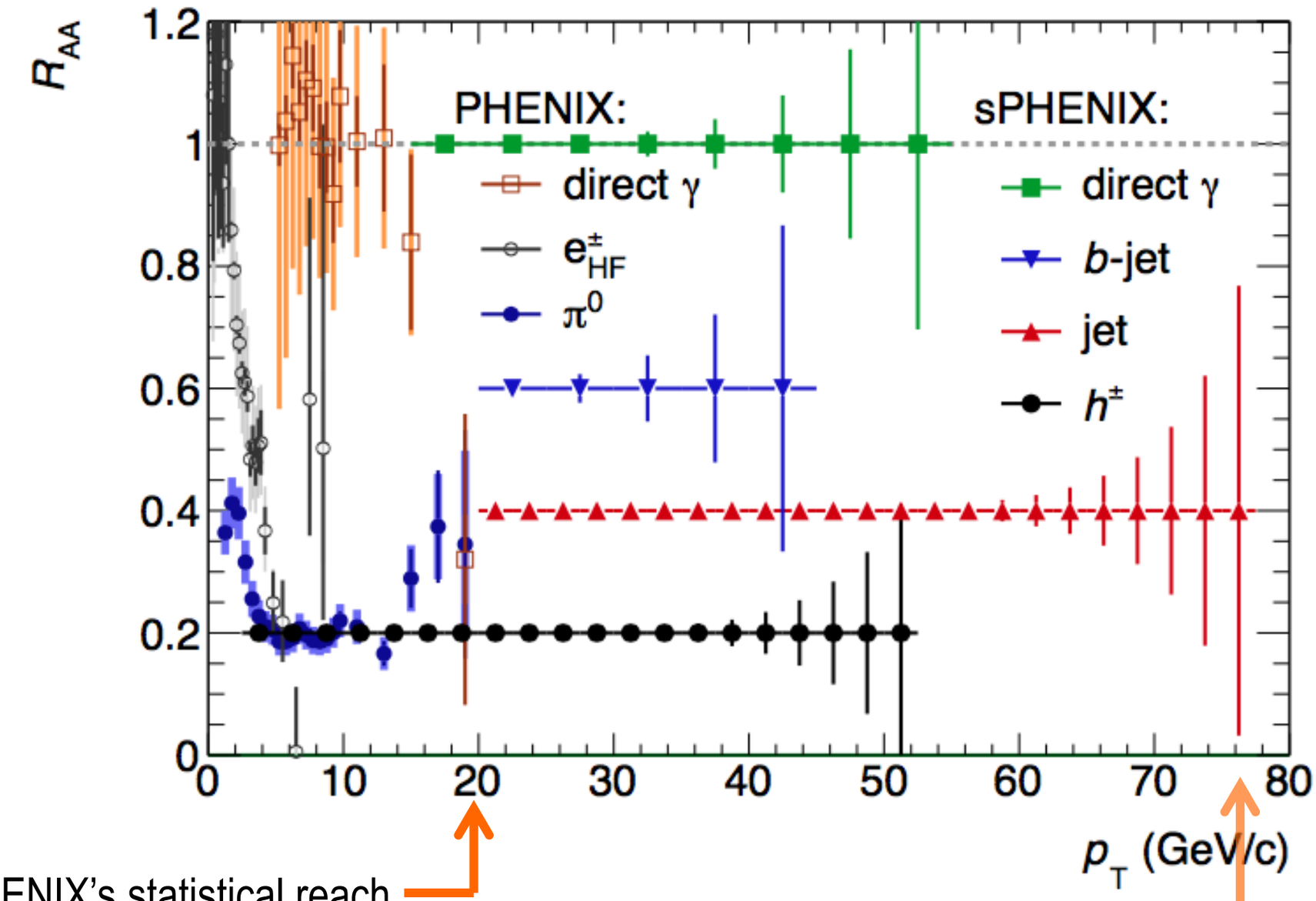
Intermission

T-Shirt Plot: Statistical Reach for some probes

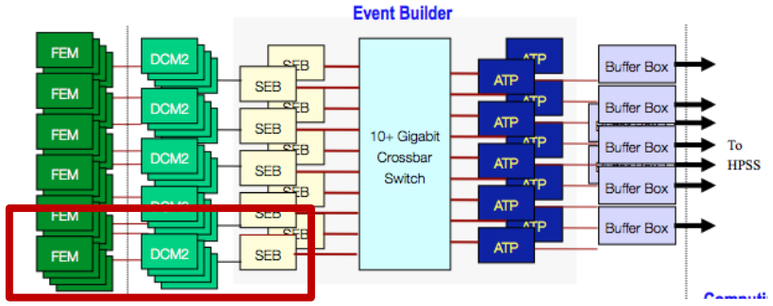
The way PHENIX gets to high PT is through π^0s

That reaches to ~20GeV/c

In sPHENIX, we can get to 4x that with jets

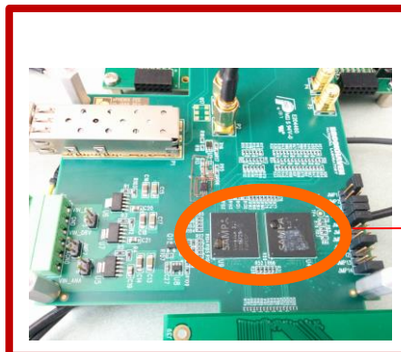


RCDAQ - R&D-themed part of the system



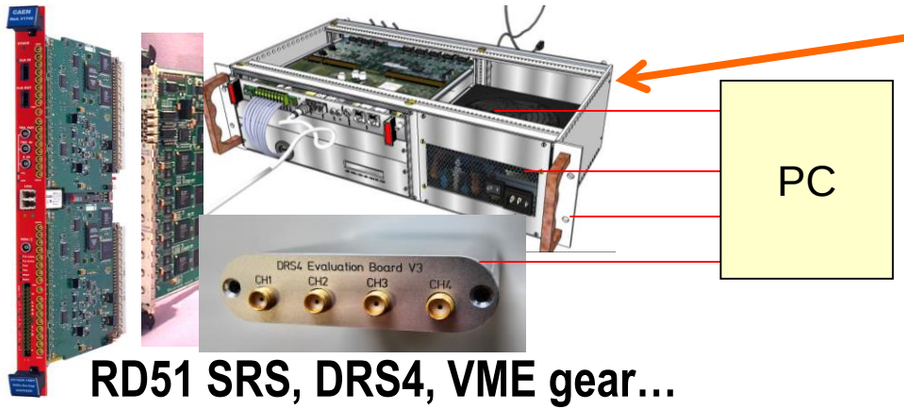
sPHENIX Calorimeter electronics

DCM — PC



TPC SAMPA Chip and ATLAS Felix Board

DAM — PC



RD51 SRS, DRS4, VME gear…
some 40 supported devices

- **The RCDAQ DAQ System**
- Cut out the event builder (not much need right now)
- Log data at the EVB “input point” instead
- Same technology, reading out our front-end here will seamlessly integrate into the big thing
- Powerful scripting/automation features
- “Real” online monitoring often has it roots in test beam code
- Addt’l support for a large variety of non-sPHENIX gear
- ~20 RCDAQ copies around in the sPHENIX orbit
- About a dozen more systems in use by external groups
- Supported on high-end 32core PC to Raspberry Pi

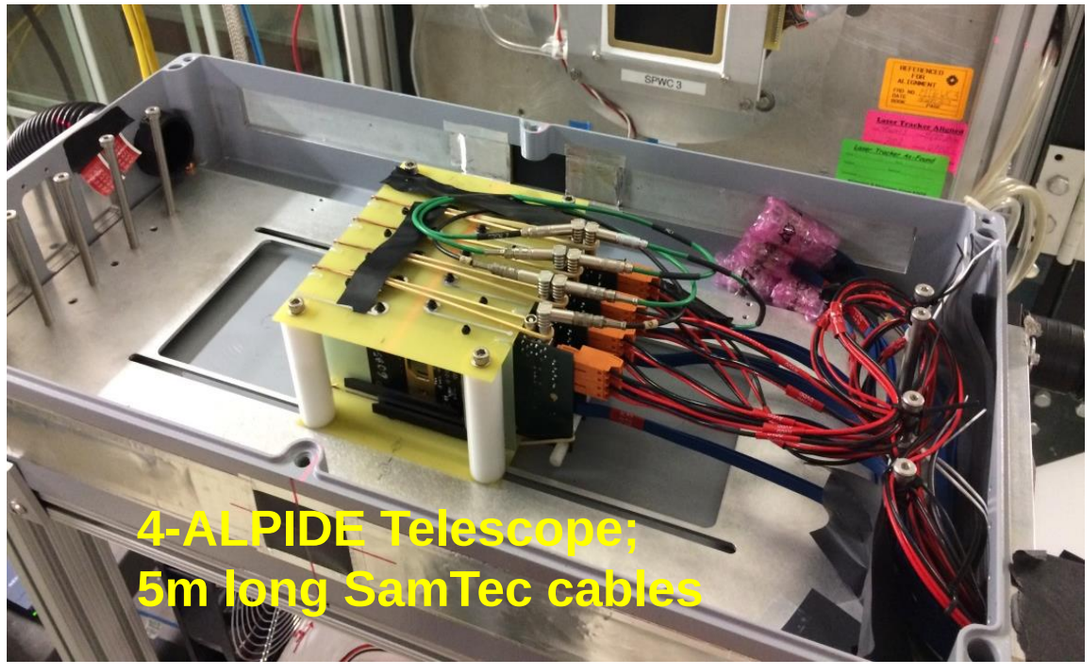
MVTX, briefly

The MVTX prototype was taken to the FermiLab test beam

ALICE “ALPIDE cards”

MVTX also uses the FELIX card (and RCDAQ)

4-layer “MAPS telescope”



And it worked…

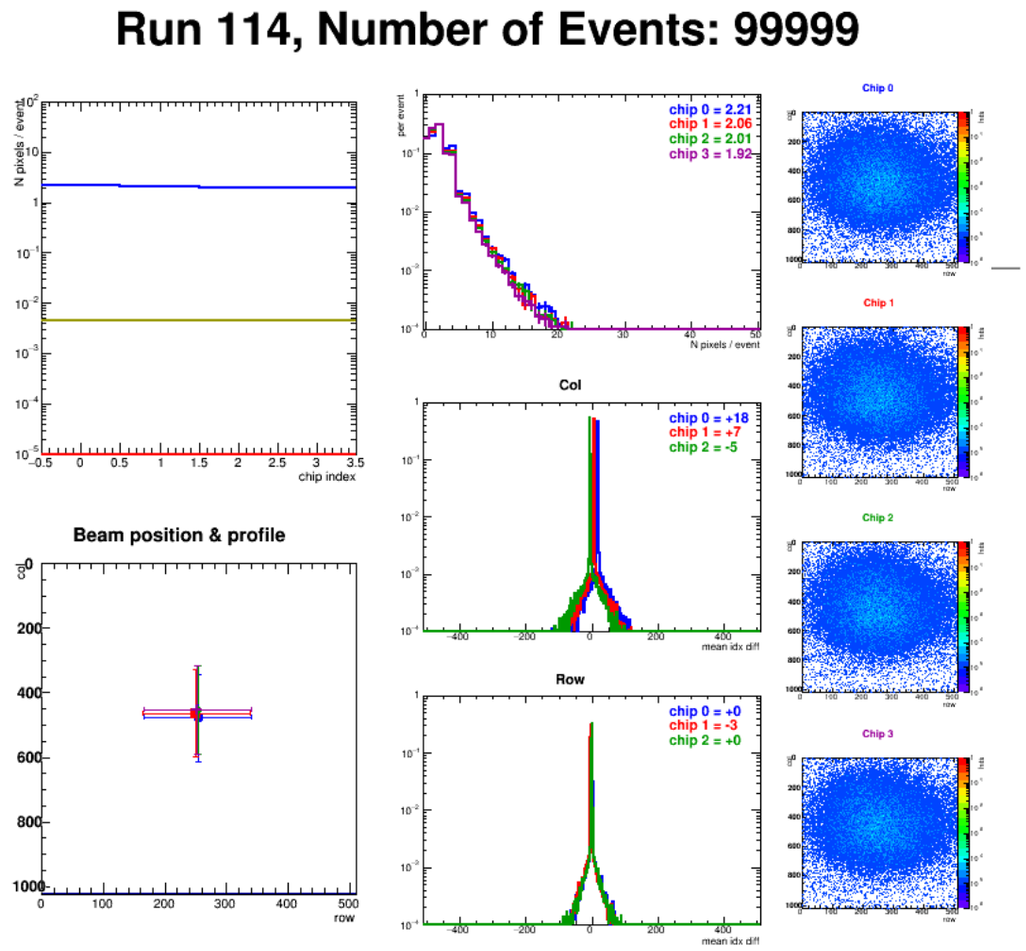
- **Successfully operated the full readout chain**
  - **RU Configured and readout 4 ALPIDEs**
  - **FELIX successfully integrated into RCDAQ**

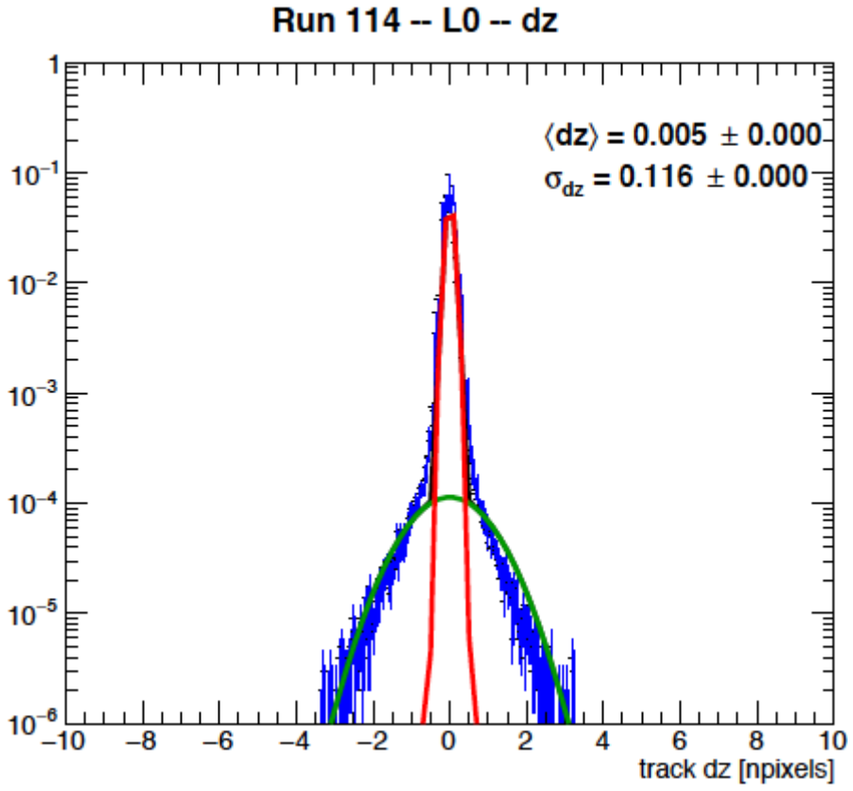
- **Sensor Performance**
  - **Cluster Size**
  - **Threshold parameters**
  - **trigger delay**

- **High multiplicity events**
  - **ALPIDE occupancy runs with 10cm lead bricks**

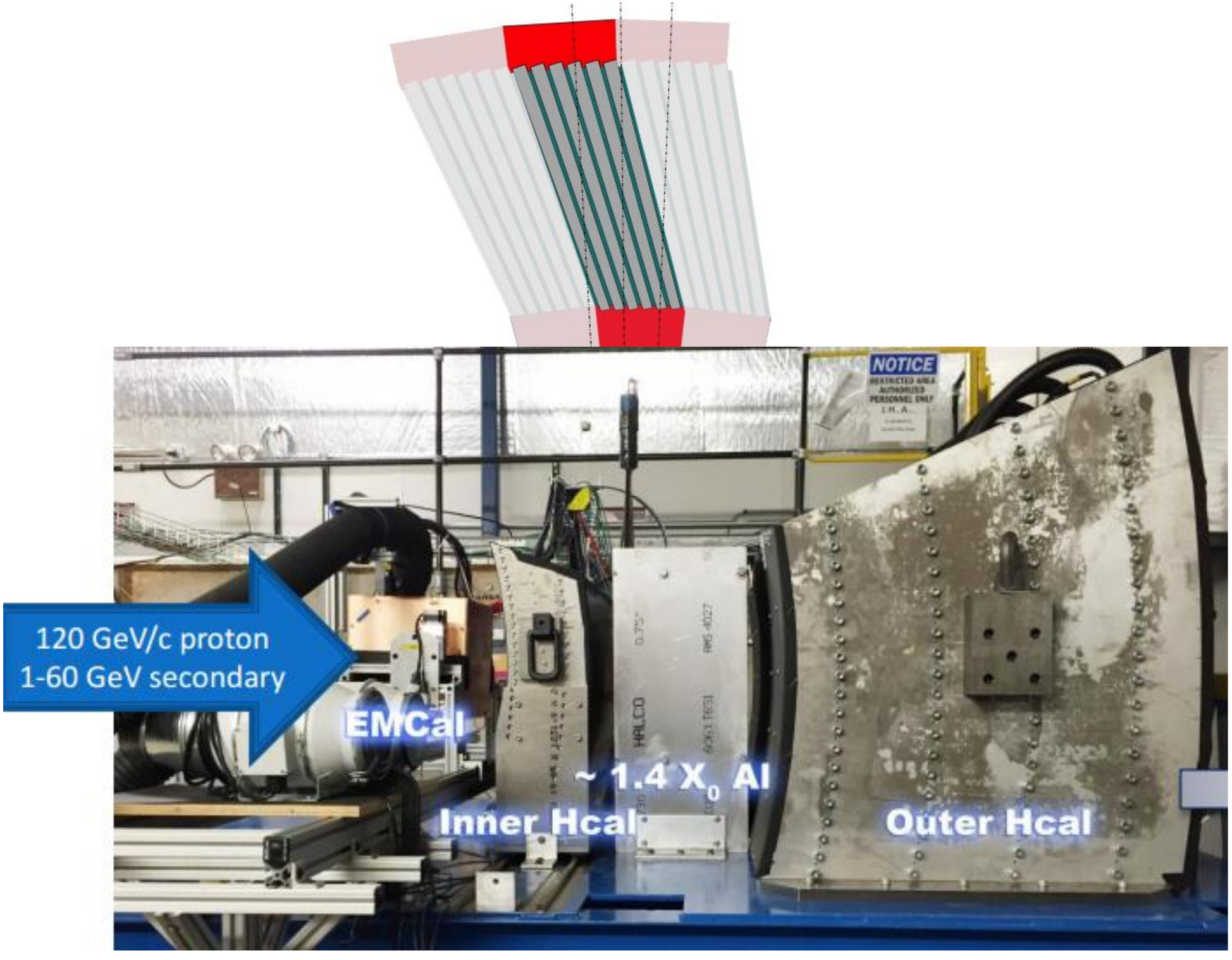
- **Online Monitoring**
  - **Hit distribution, relative alignment**

- **Analysis confirmed telescope performance**
  - **Hit resolution < 5 um**

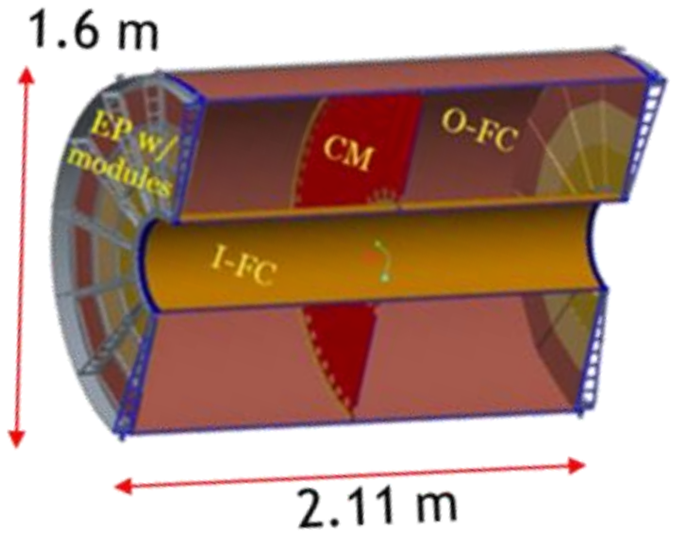


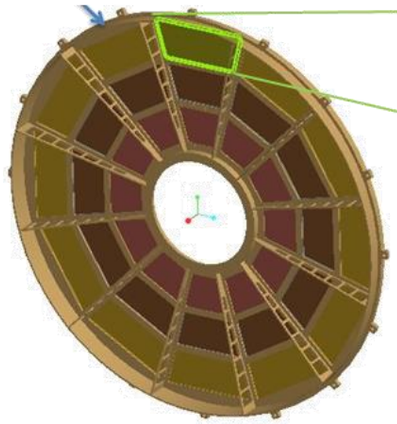


The last Test Beam

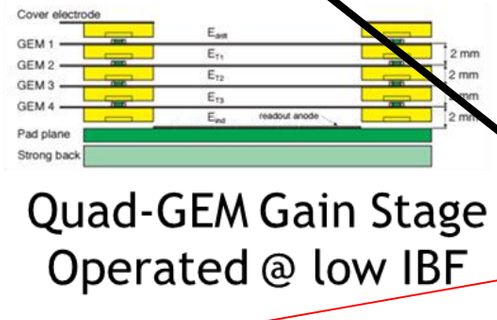


The TPC

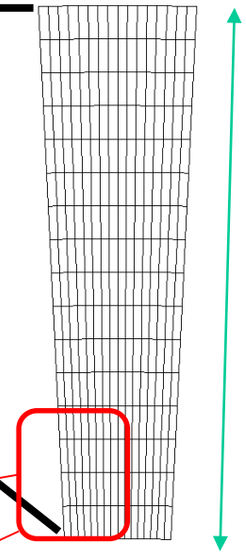




72 modules
2(z), 12(ϕ), 3(r)

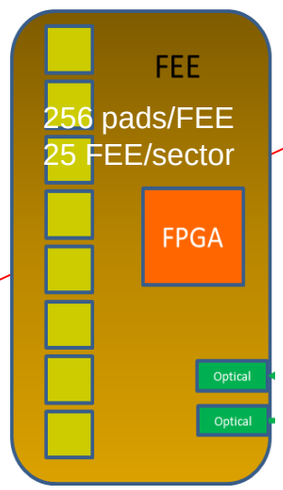


Quad-GEM Gain Stage
Operated @ low IBF

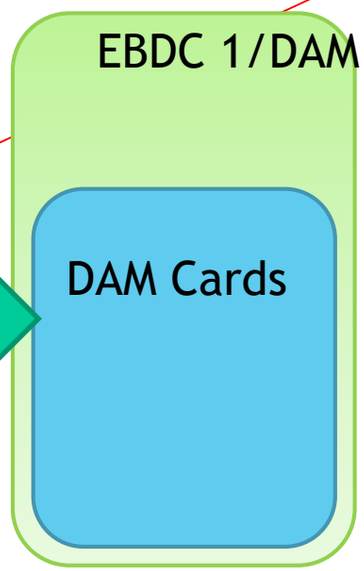


"Wedge"

charge



Digitized

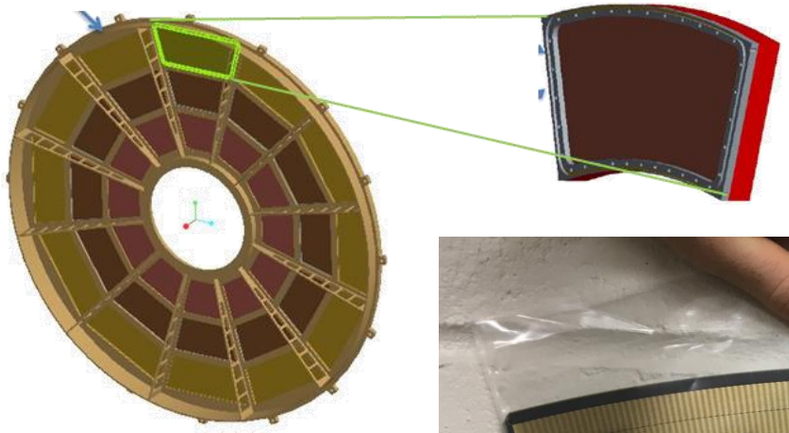


Clustered

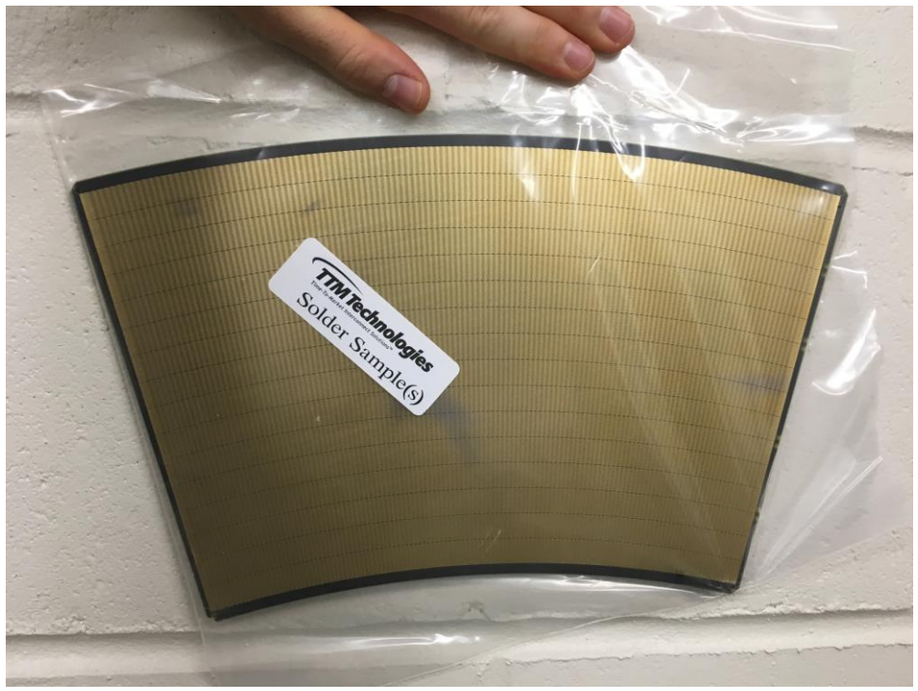
DAM = "Data Aggregation Module"

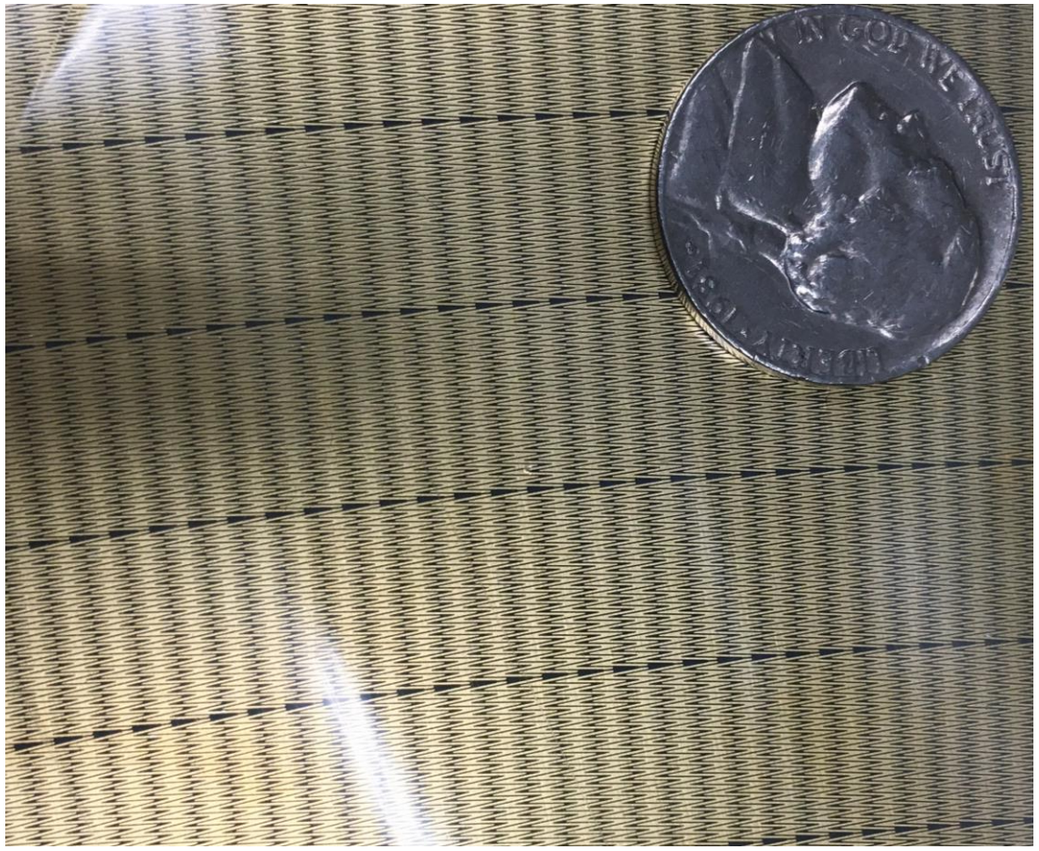
EBDC – "Event Buffer and Data Compression"

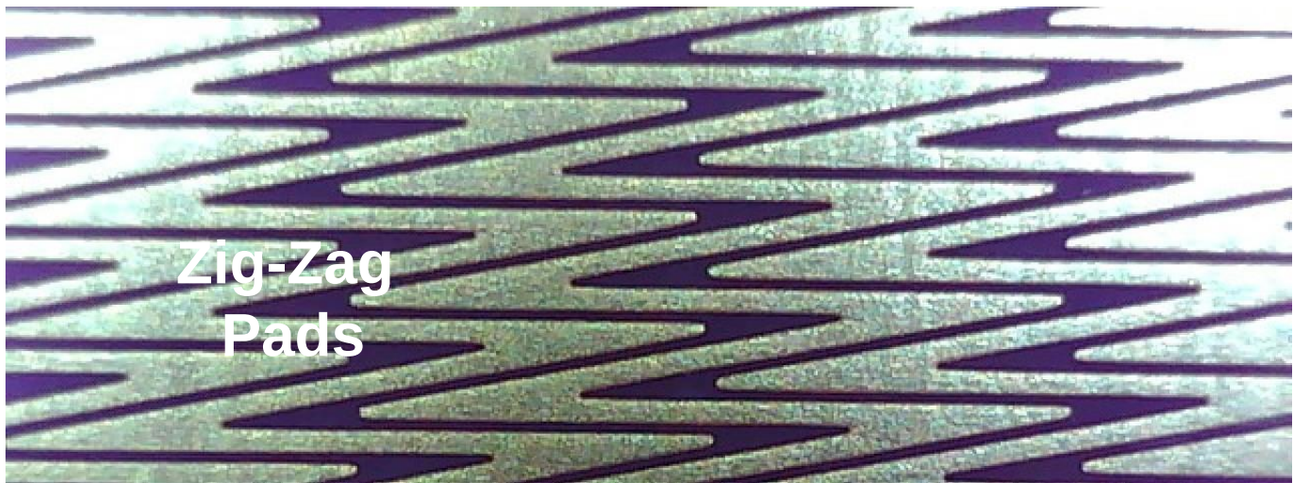
The ZigZag Pads



72 modules
2(z), 12(ϕ), 3(r)







12.5mm resolution in r

150 μm in phi

~160,000 ADC channels

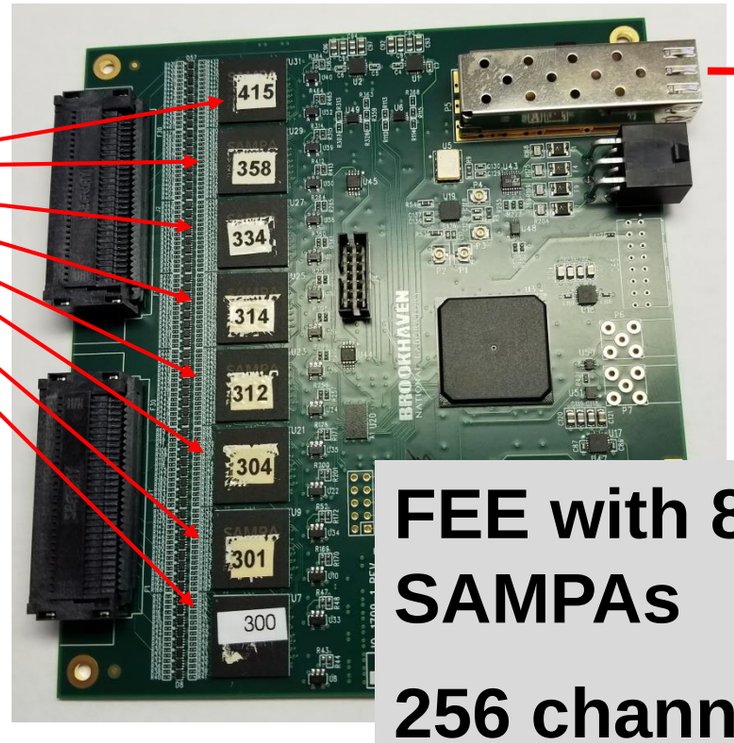
The Readout

ALICE SAMPA chip

32 channels 10bit sampling ASIC

Preamp/shaper, ADC

Optional DSP functions

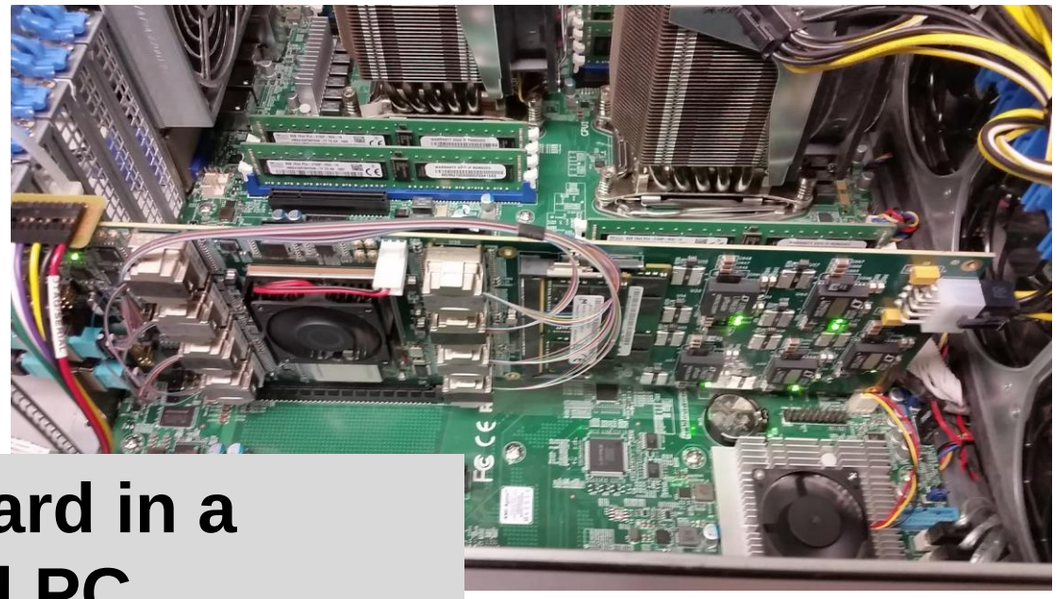


5GBit/s fiber link

FEE with 8 SAMPAs

256 channels

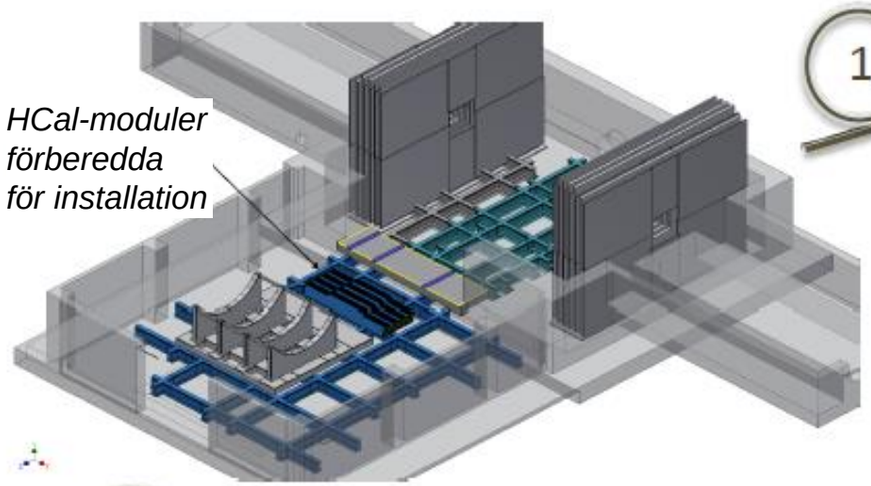
ATLAS FELIX Card (“DAM”) – 24 FEE’s



FELIX Card in a standard PC (“EBDC”)

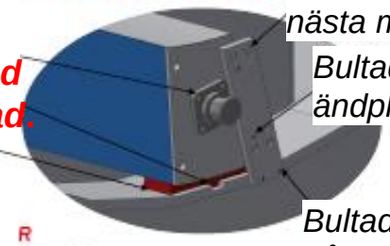
Assembly Instructions ☺

sPHENIX Monteringsföljd



Första HCal-modulinstallationen

Lyftande svängtapp
Första modulen shimsad
undersökt och injusterad.



Yttre HCal fungerar som stödstruktur för detektorn och retur av magnetiskt flöde