The ALICE Time Projection Chamber Upgrade

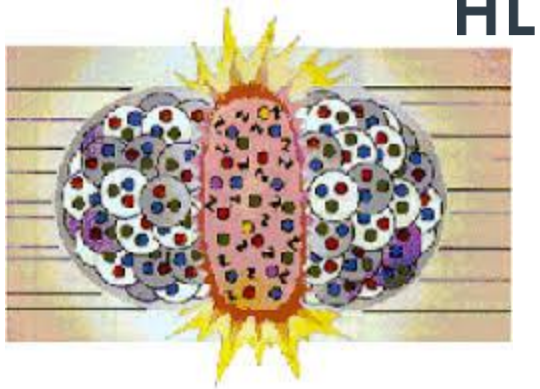
Presented by Charles Hughes on behalf of the ALICE Collaboration

PHYSICS MOTIVATION FOR UPGRADES

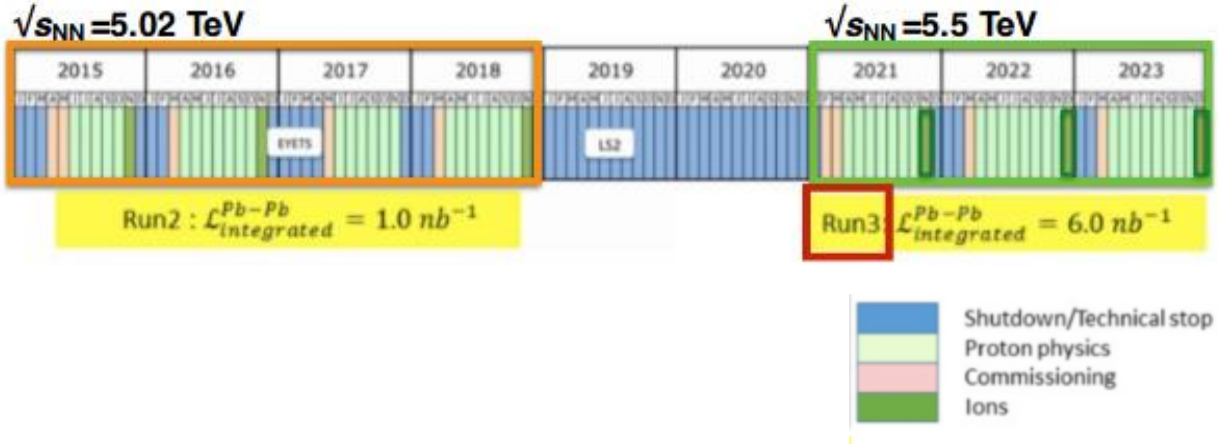
- Quark Gluon Plasma (QGP) - hot, thermalized partonic state of matter

- Wish to study QGP thermodynamic properties

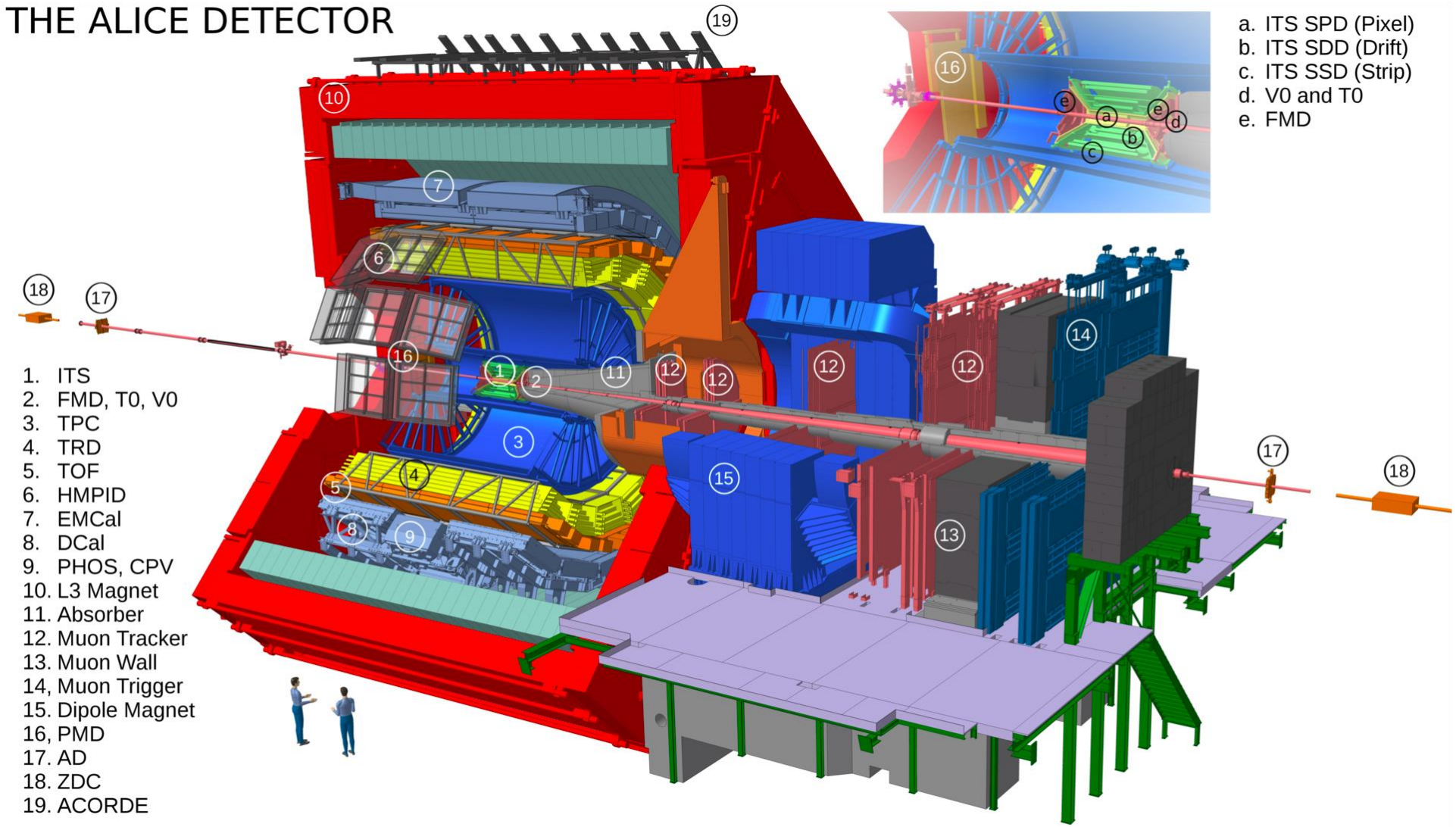
- Higher luminosity
  - More hard probes (increase in triggered data -> 10x)
  - More soft probes (increase in min. bias data -> 100x)



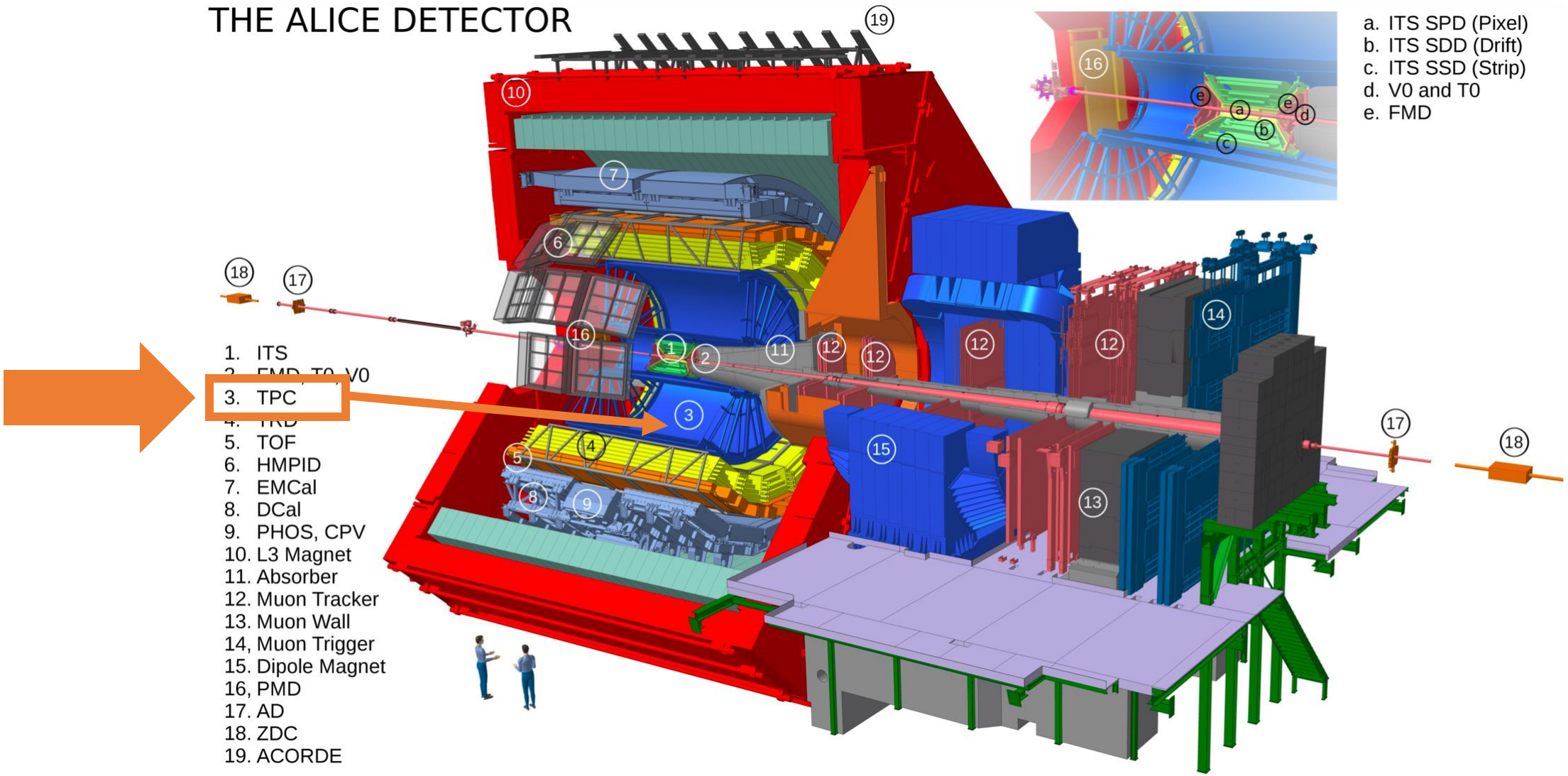
Run 3 Instantaneous Luminosity
-> 6 x 10^{27} cm^{-2} s^{-1}



A Large Ion Collider Experiment



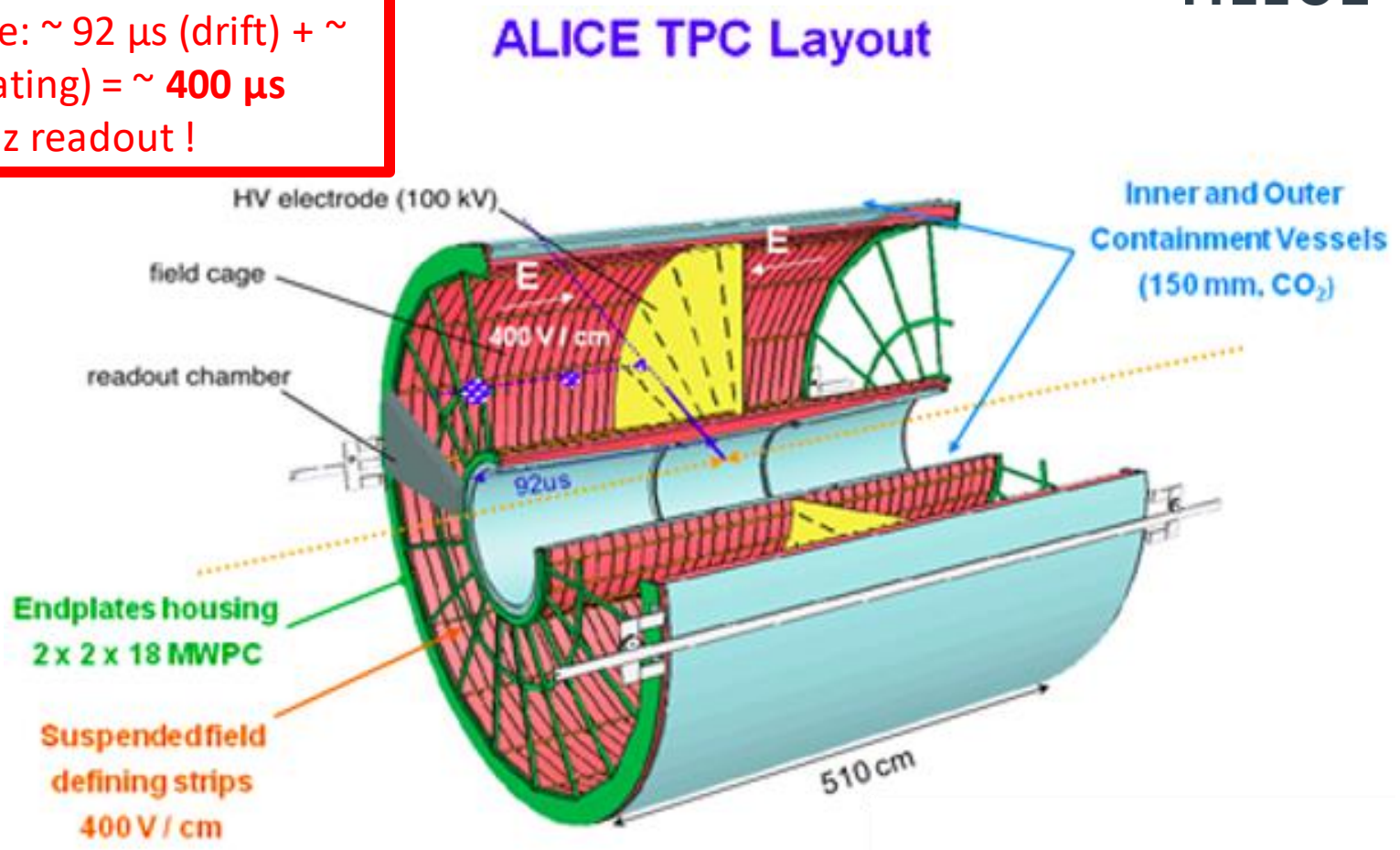
A Large Ion Collider Experiment



ALICE TIME PROJECTION CHAMBER

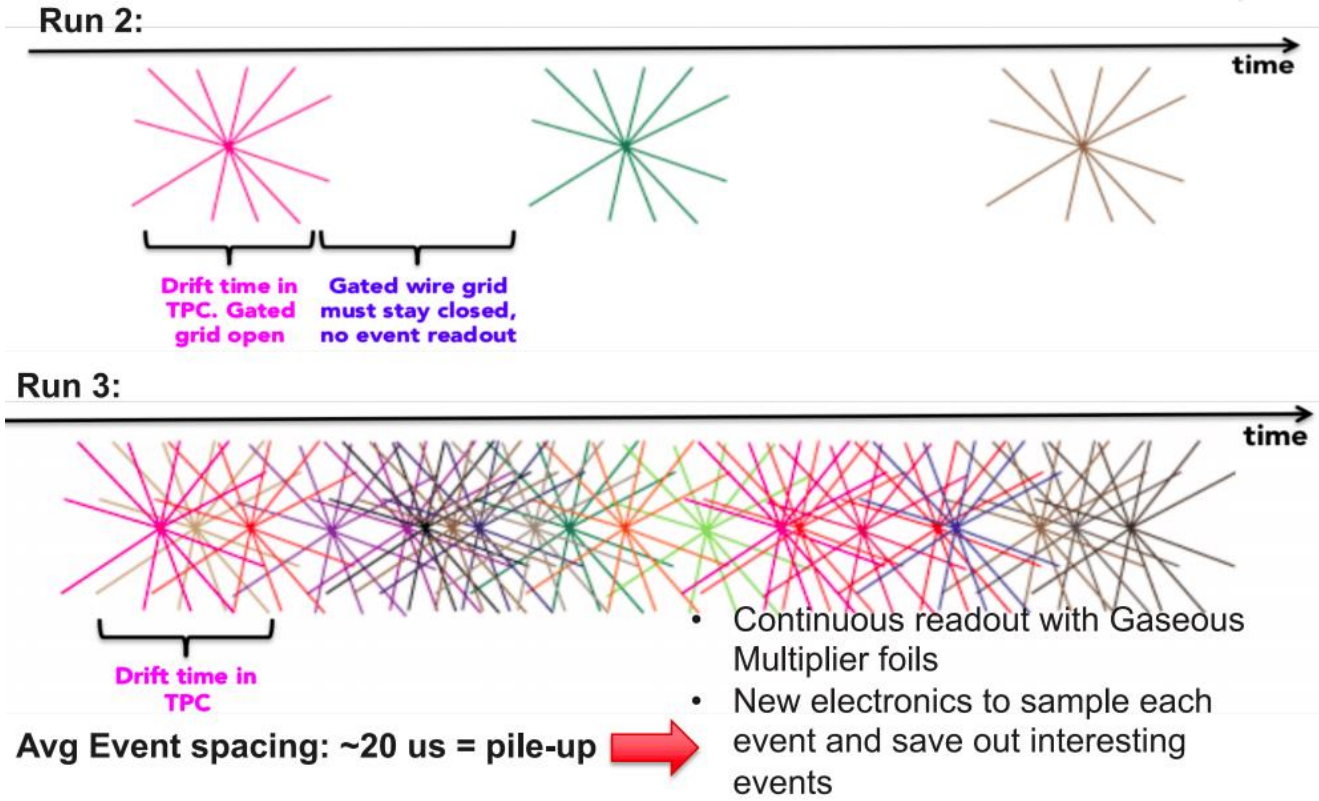
- Gaseous Drift Detector
- Used for tracking and PID
- MWPC + gating grid to reduce ionic backflow
- ~ 5 m diameter x ~ 5 m length
- 400 V/cm Electric Field
- Readout Chambers
  - Inner 18 x 2 (IROC)
  - Outer 18 x 2 (OROC)

Dead Time: ~ 92 µs (drift) + ~ 280 µs (gating) = ~ **400 µs**
MAX 3 kHz readout !



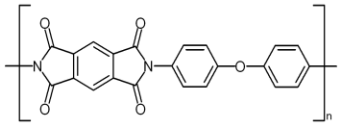
UPGRADING THE TPC

- ~ 3 kHz readout rate not enough to handle higher luminosity
- Heavy ion interaction rate to increase from 1 kHz to 50 kHz
- Eliminate ~400 μs dead time
- Replace MWPCs with GEM foils: 3kHz -> Continuous Readout

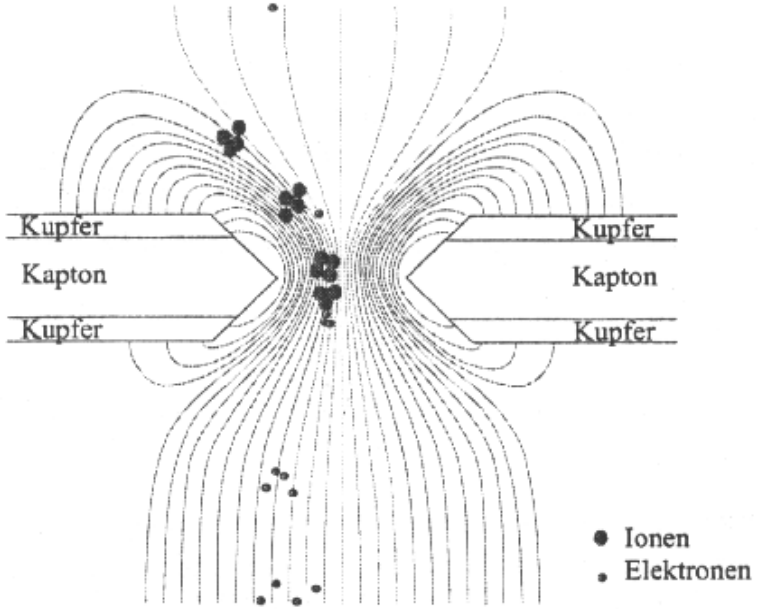


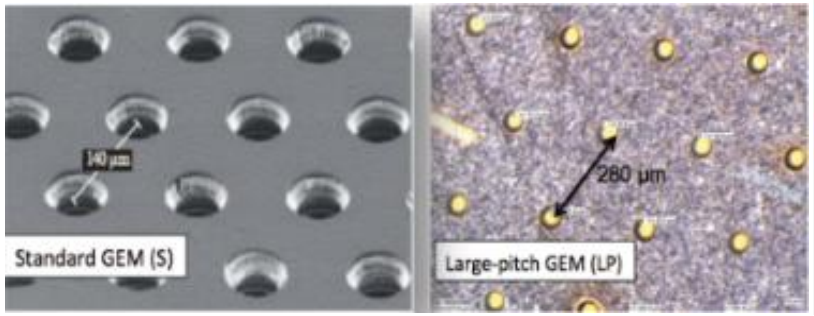
Gaseous Electron Multiplier (GEM) FOILS

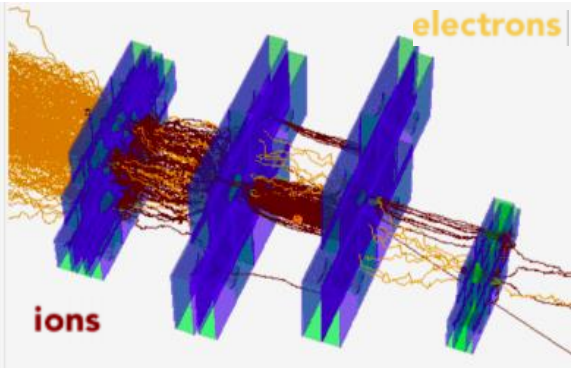
- Kapton Foil – Polyimide film insulator (poly-oxydiphenylene-pyromellitimide



- Upper and lower copper (kupfer) conducting layer
- 70 µm diameter holes
  - etched with photo-lithography
- 4 Layers of foil with varying GEM pitch
  - LP – SP – SP – LP

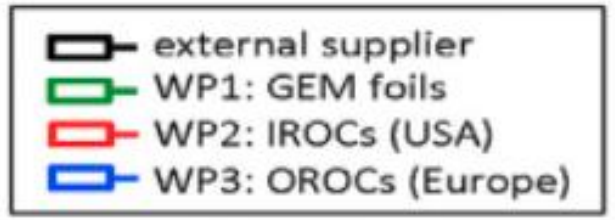




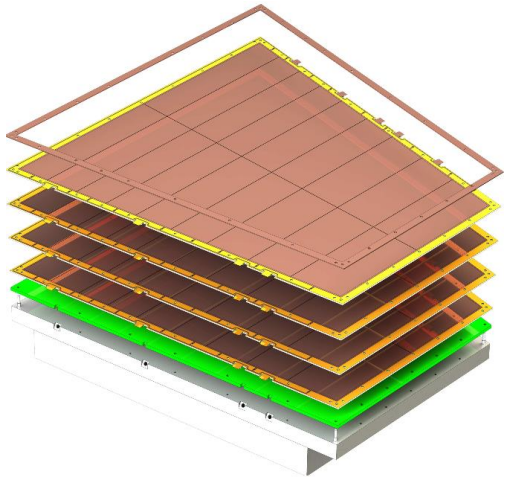


READOUT CHAMBER PRODUCTION

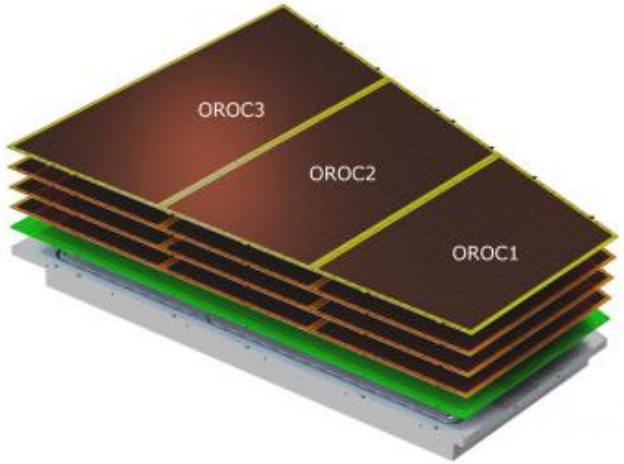
Completed September 1st 2018 !



Inner Read Out Chamber

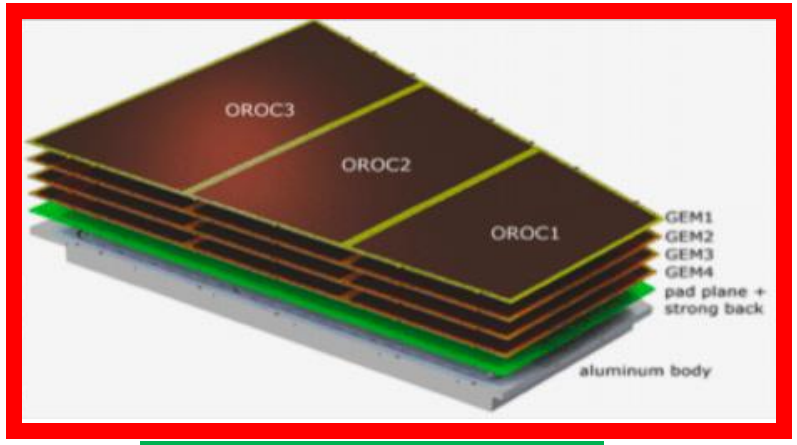


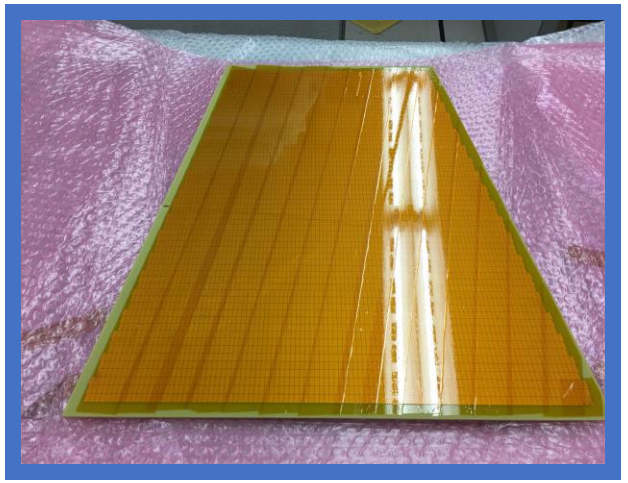
Outer Read Out Chamber

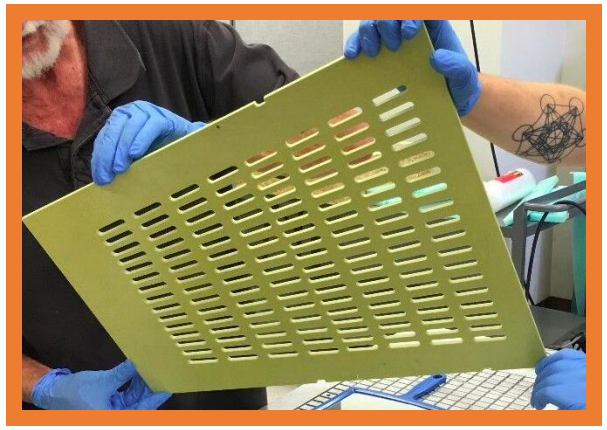


INNER READ OUT CHAMBER PRODUCTION

- Ingredients:
  - 4 GEM STACK
  - PAD PLANE (SENSORS)
  - ALUBODY
  - STRONG BACK

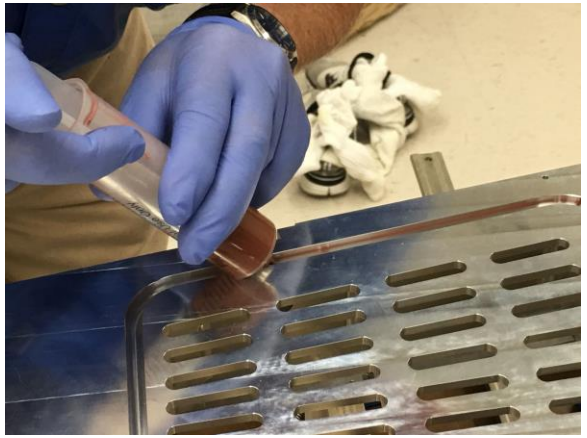
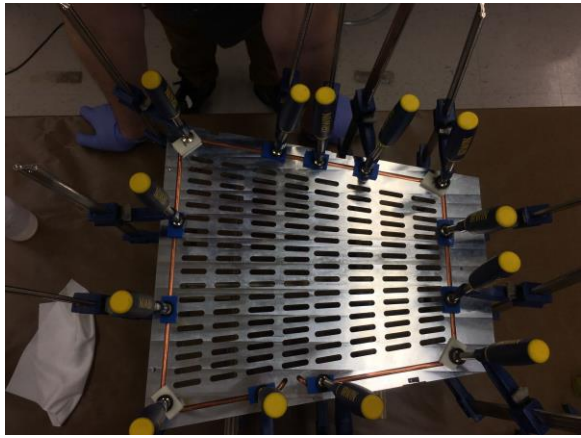


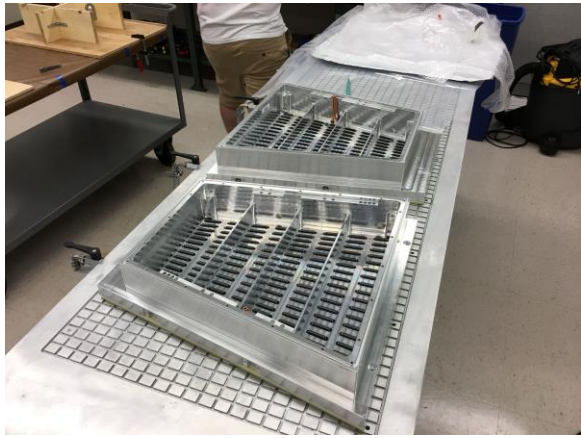




INNER READ OUT CHAMBER ASSEMBLY

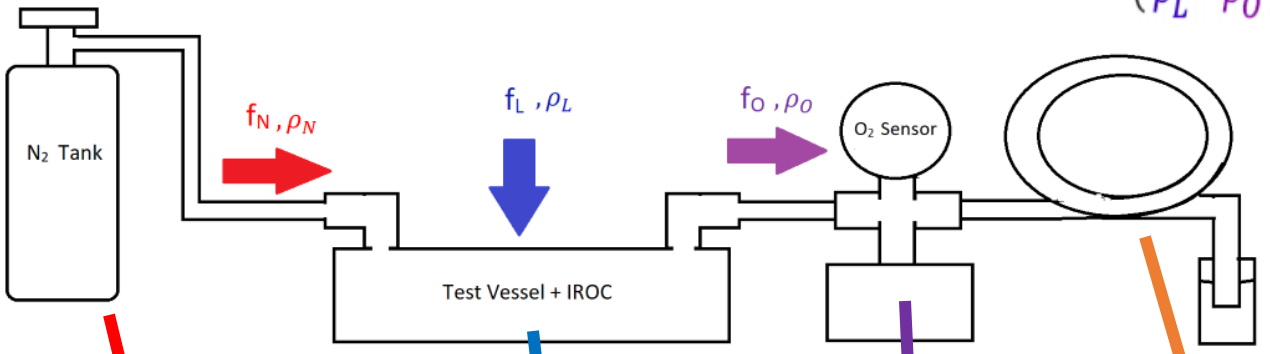
- Cooling System
- Epoxy:
  - Padplane + Strongback + Alubody
- LEMO connectors

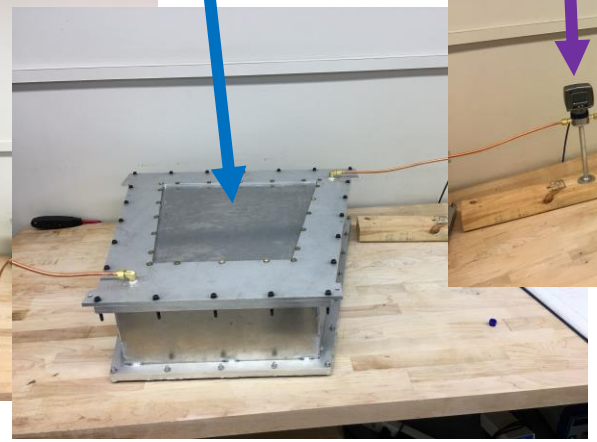




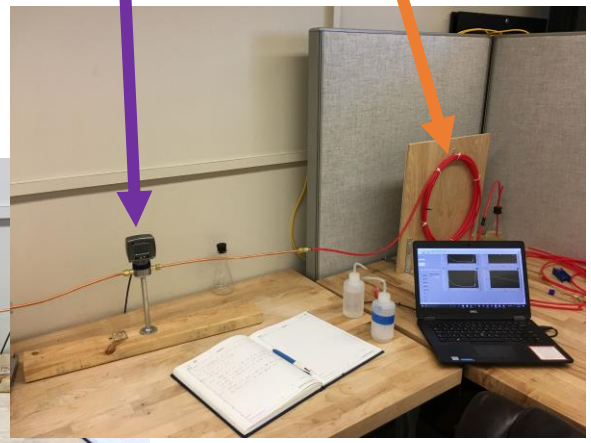



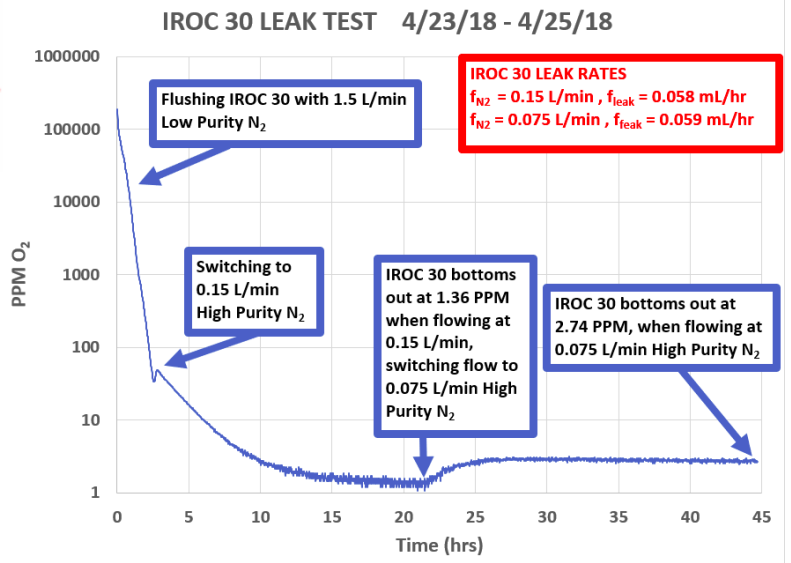
IROC LEAK TESTING

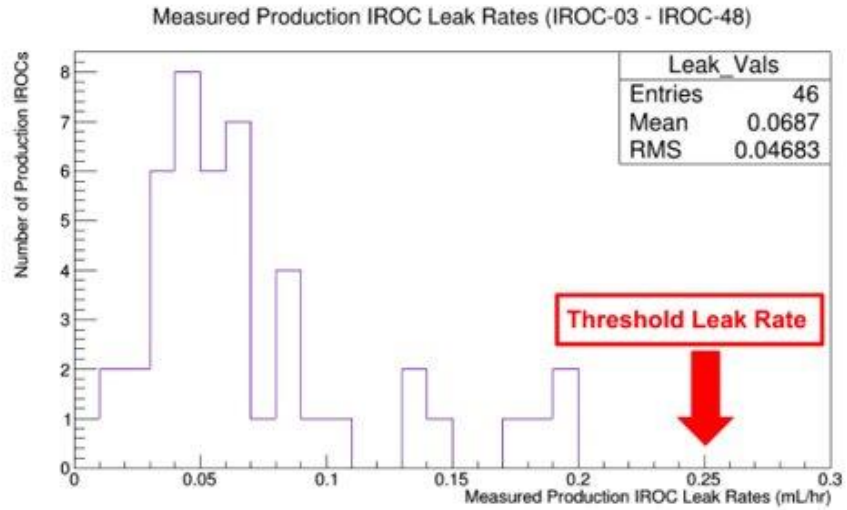
$$f_L = \frac{(\rho_O - \rho_N)}{(\rho_L - \rho_O)} * f_N$$



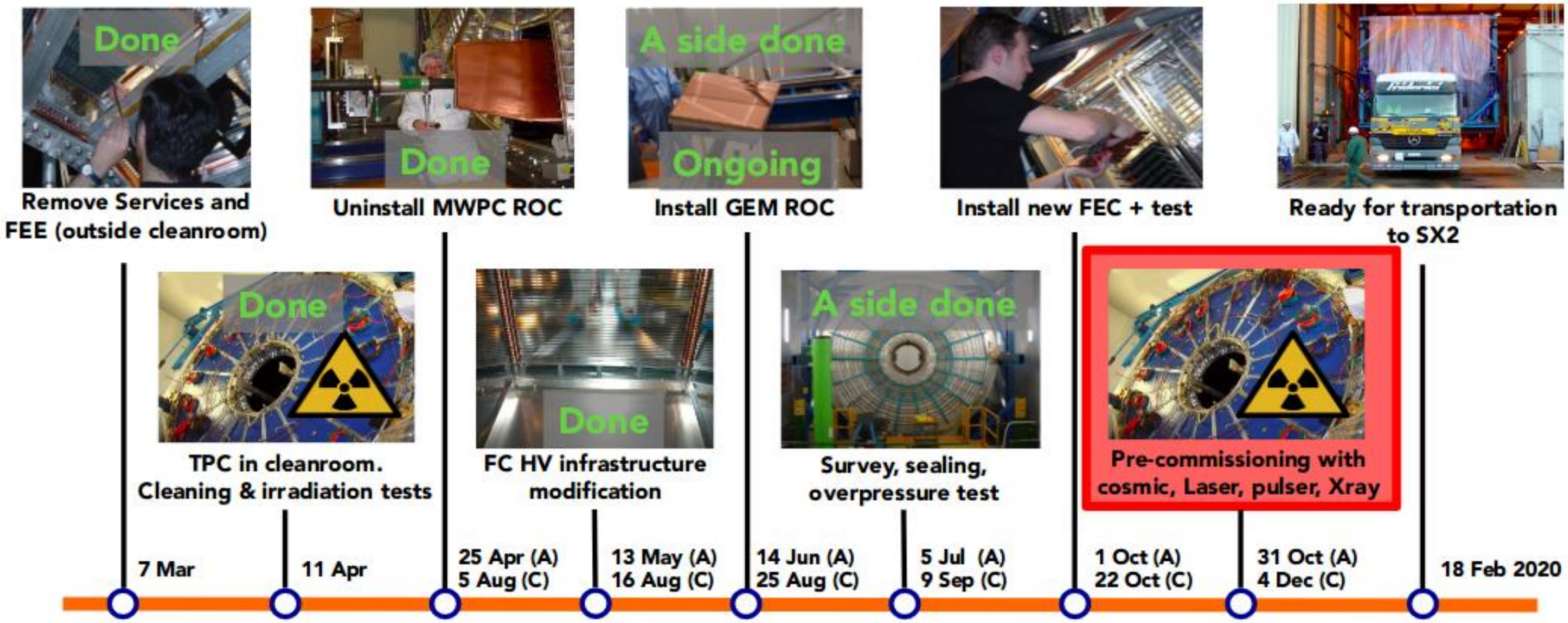








UPGRADE STATUS

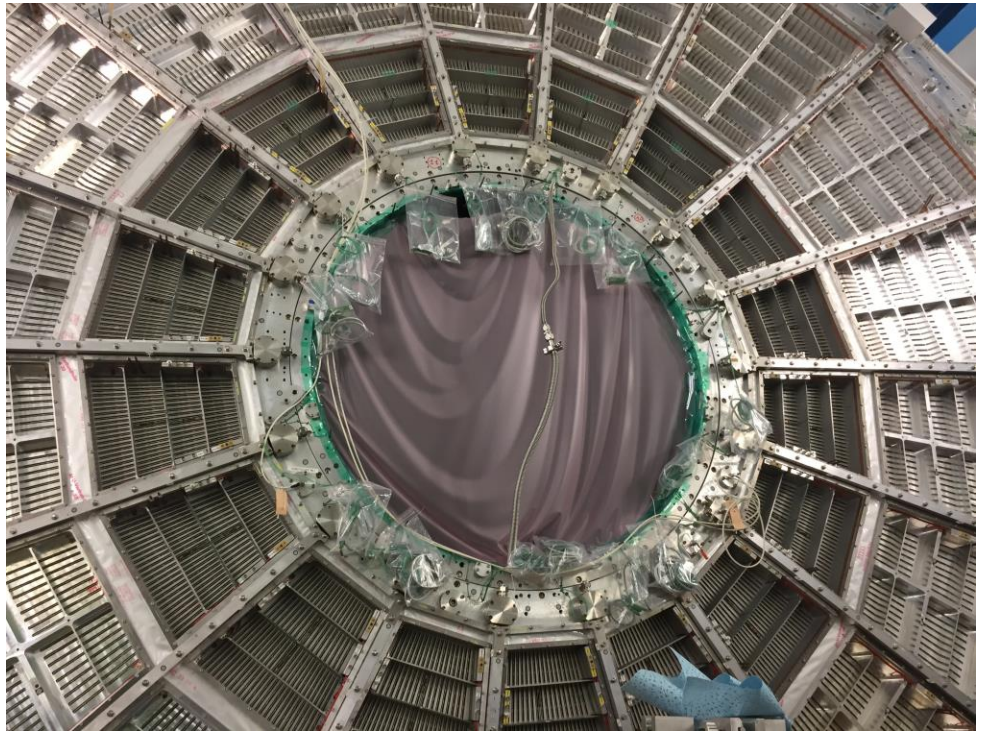


SUMMARY

- ALICE: 1 kHz interaction rate -> 50 kHz interaction rate (in heavy ion)

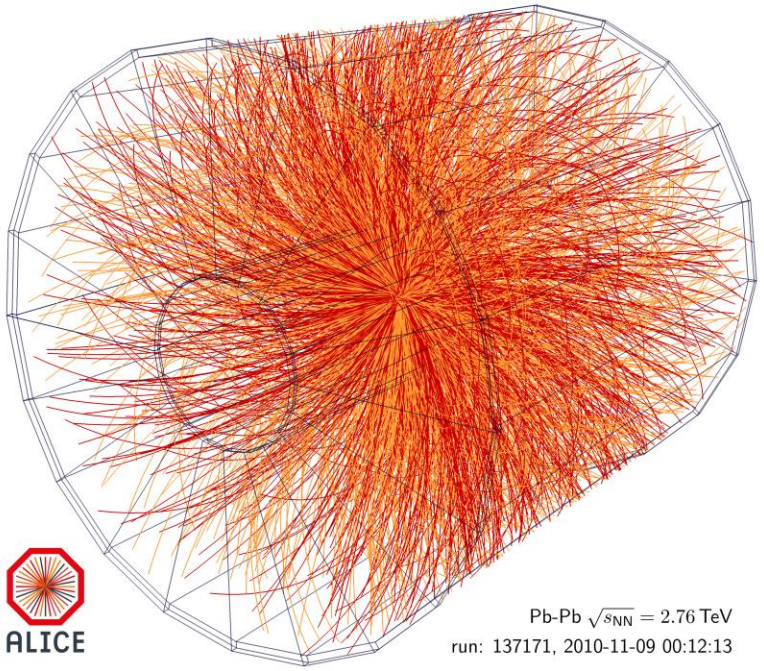
- ALICE TPC rebuilt
  - Replace MWPCs with GEM foils
  - New readout electronics

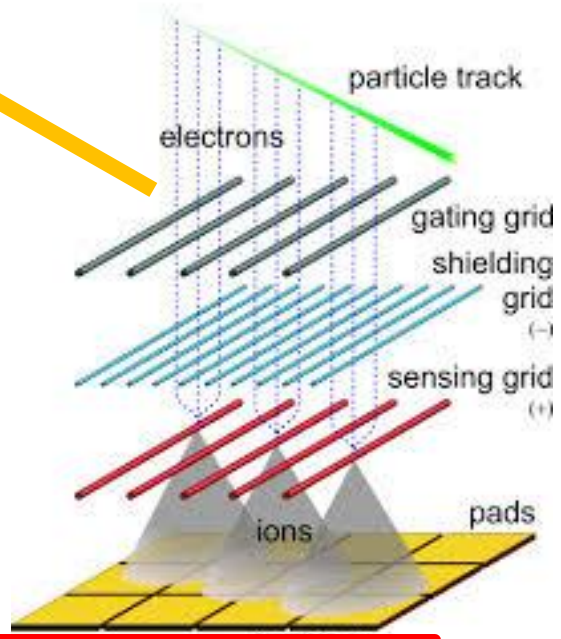
- New ROCs installed in TPC, FEC testing underway

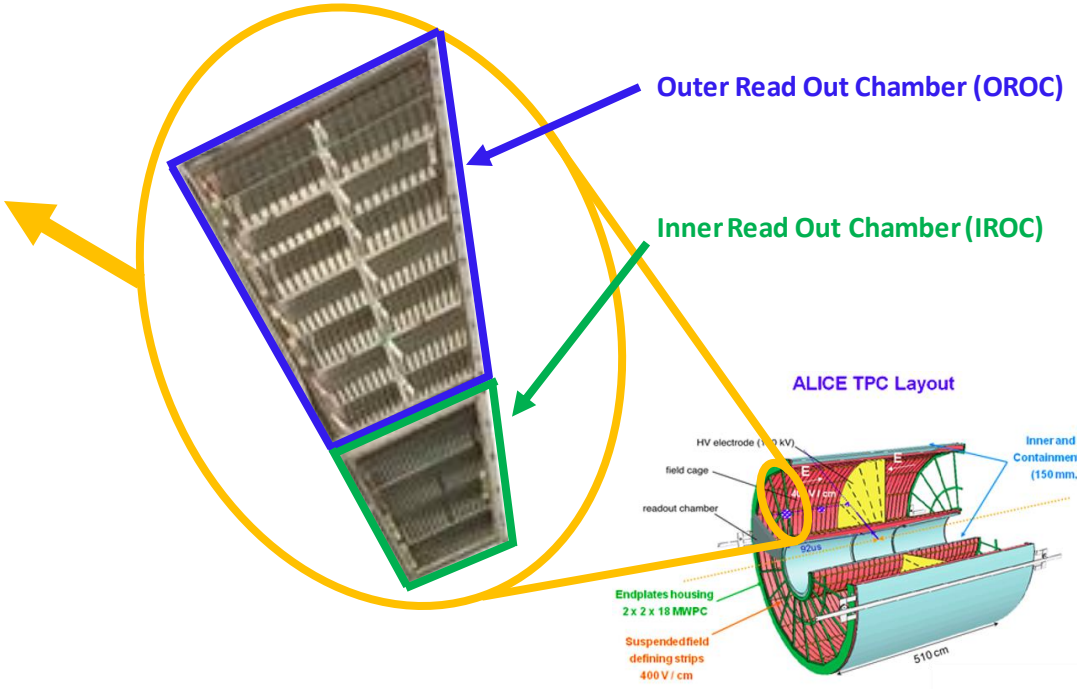


Backup

CURRENT TPC WORKING PRINCIPLE



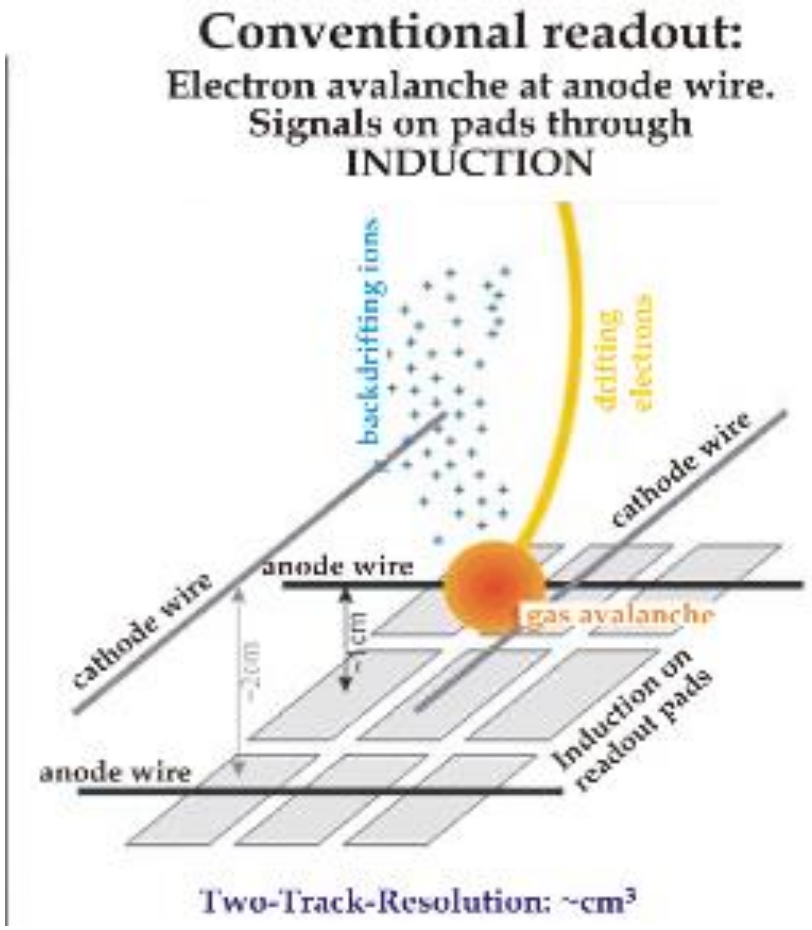


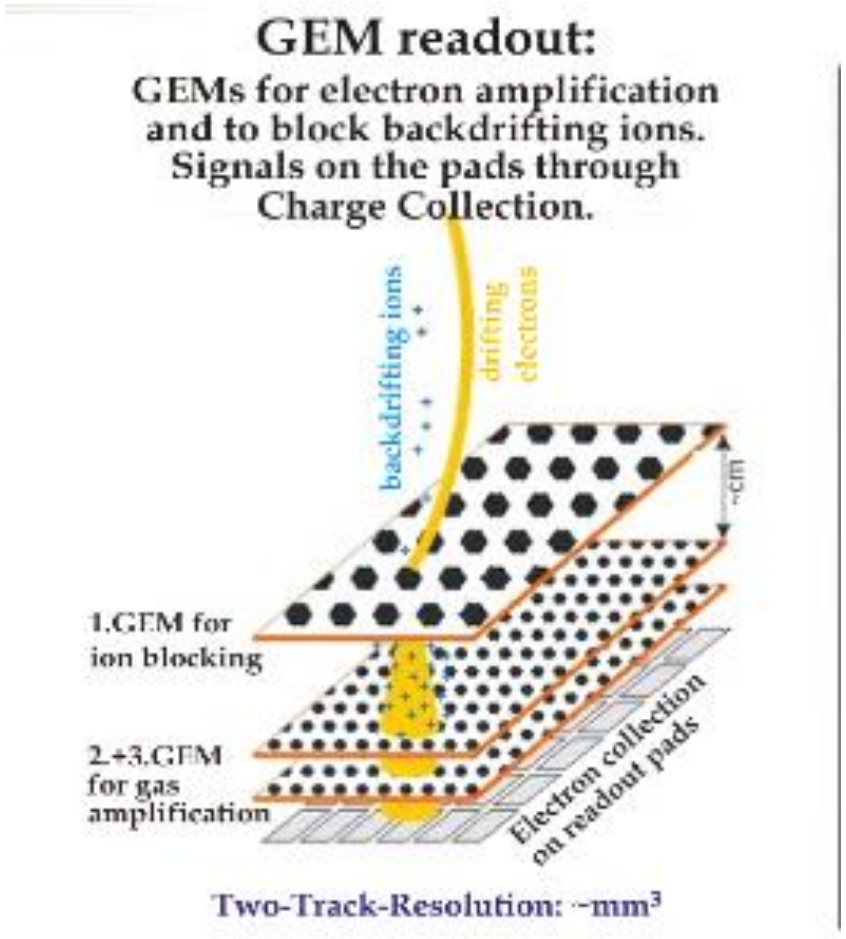


- Readout limited to ~ 3 kHz

- Dead Time: 92 μs (drift) + 280 μs (gating) ~ 400 μs

Comparison of old to new





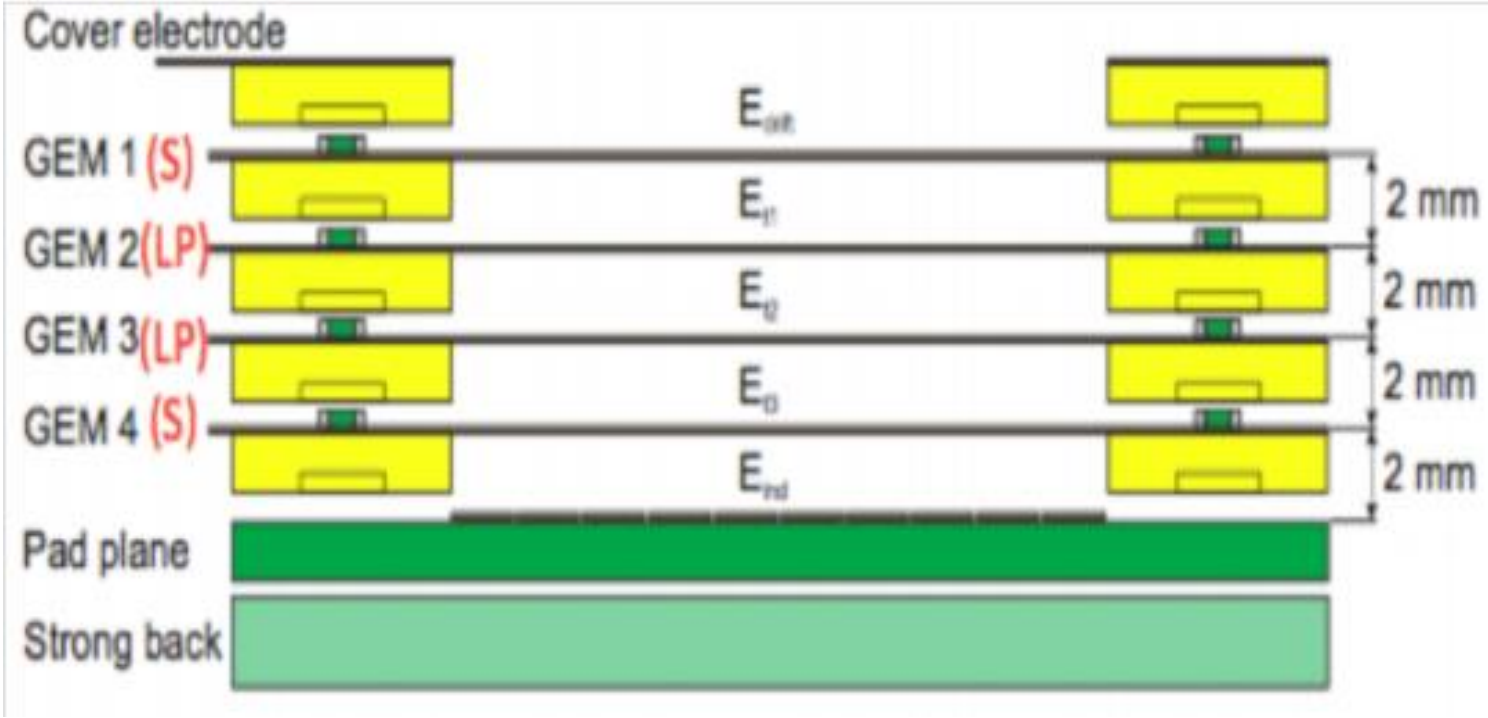
GEM Readout has a significant reduction in ionic backflow compared to the MWPC.

Reduction in backflow allows for CONTINUOUS READOUT !

GEM Configuration and Settings

- Nominal GEM Voltages:
  - GEM 1 TOP: ~ -3.5 kV
  - ΔU_{GEM1} : 270 V
  - ΔU_{GEM2} : 230 V
  - ΔU_{GEM3} : 288 V
  - ΔU_{GEM4} : 359 V

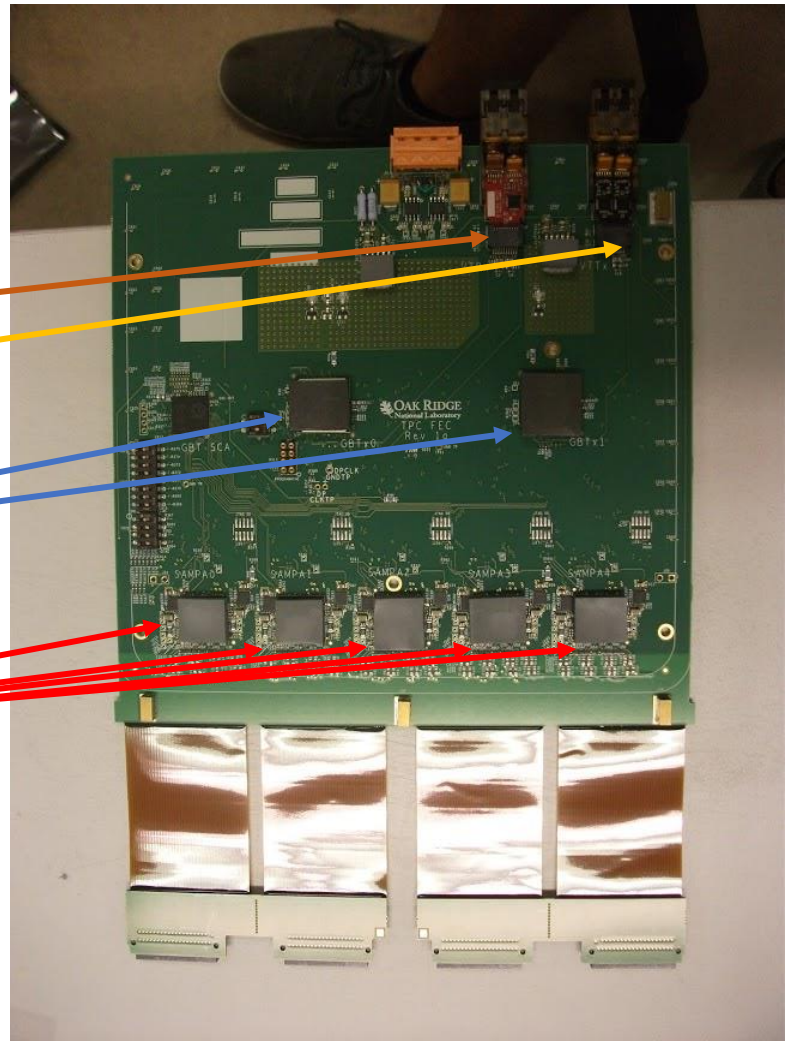
- Nominal Transfer Fields:
  - Gap 12: 4.0 kV/cm
  - Gap 23: 4.0 kV cm
  - Gap 34: 0.1 kV/cm
  - Gap 4PP: 4.0 kV/cm



Nominal Gain: 2000
Nominal IBF: < 1 %

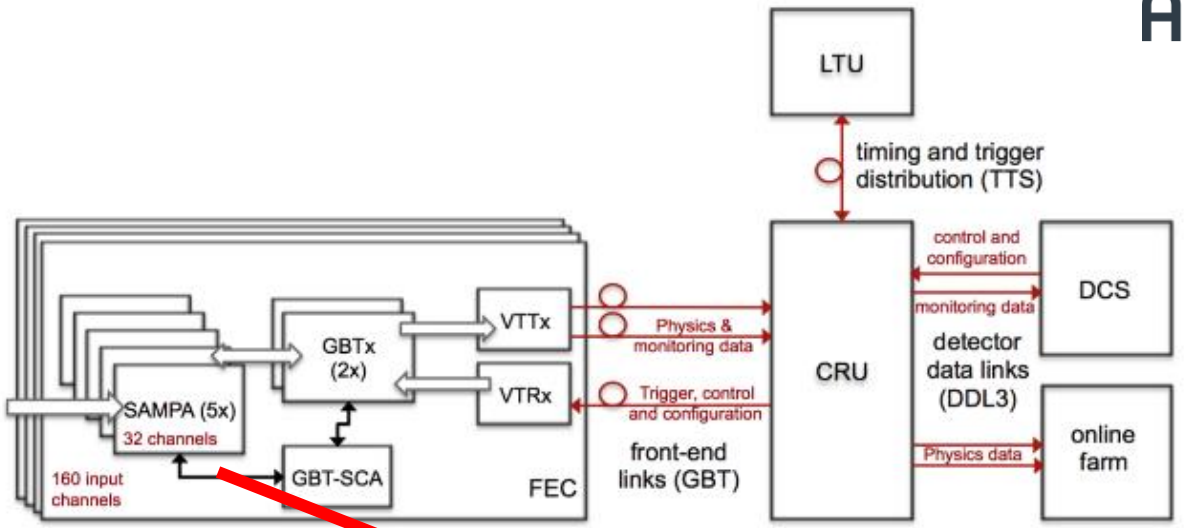
TPC READOUT ELECTRONICS

- Prototyped at Oak Ridge National Lab in Tennessee
- 2 x Versatile Links
  - VTRx
  - VTTx
- 2 x GBTx ASICs
- 5 x SAMPA ASICs
- Thermal Pads + Copper Cooling Jacket

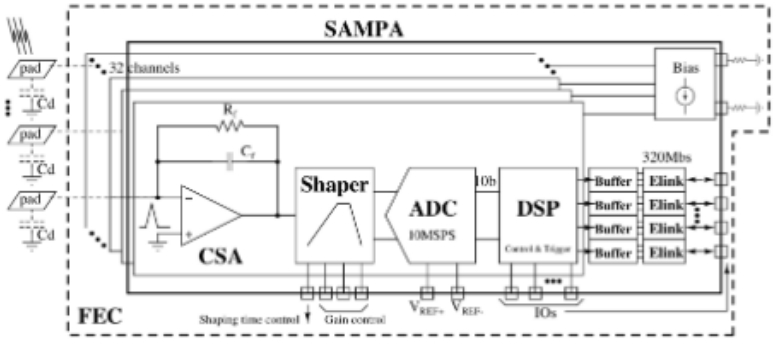


TPC READOUT ELECTRONICS (continued)

- 3276 new FECs
- 160 channels, deadtime-less digitization at 5 MHz
- Collective output of FECs is 3 TB/s continuous data stream
- FEC production 97.7 % yield

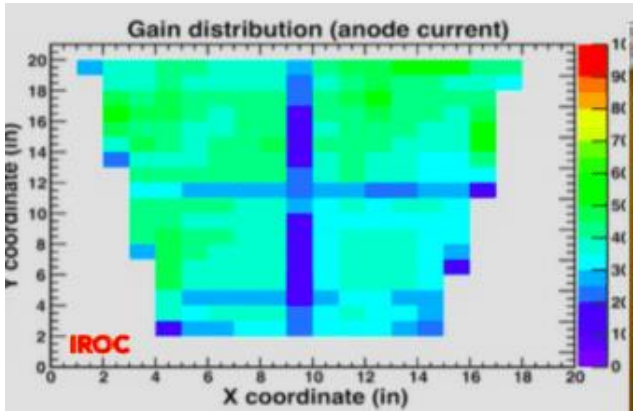


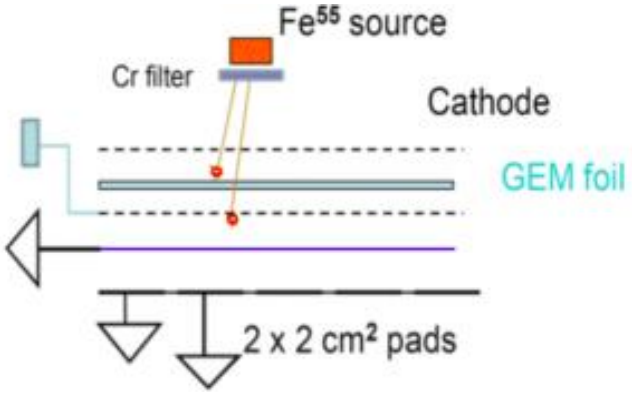
SAMPA chip developed for ALICE

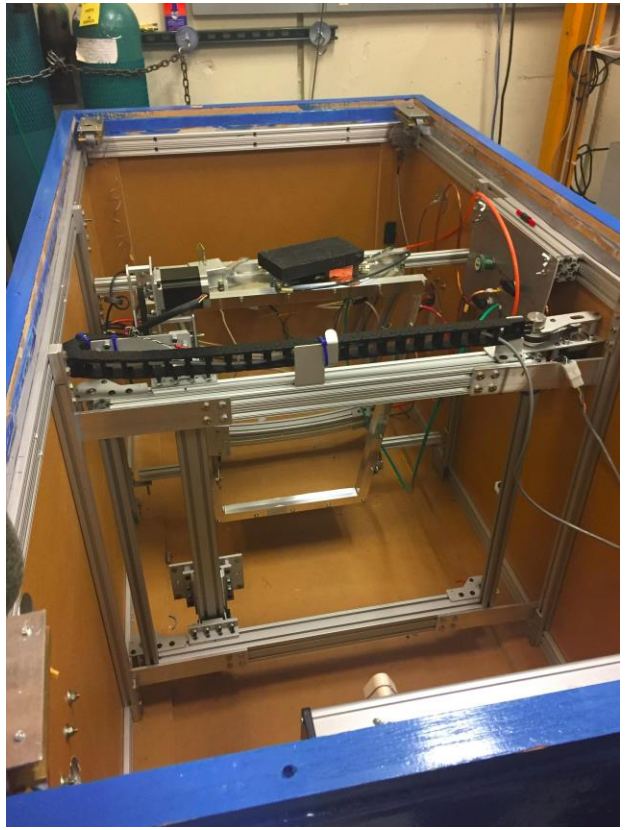


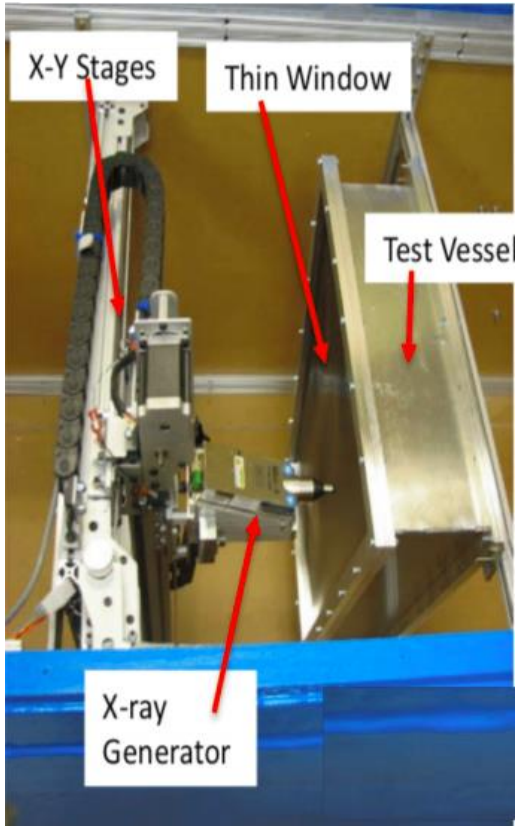
GAIN

- Collimated X-ray source measures cathode and anode current on a per pad basis



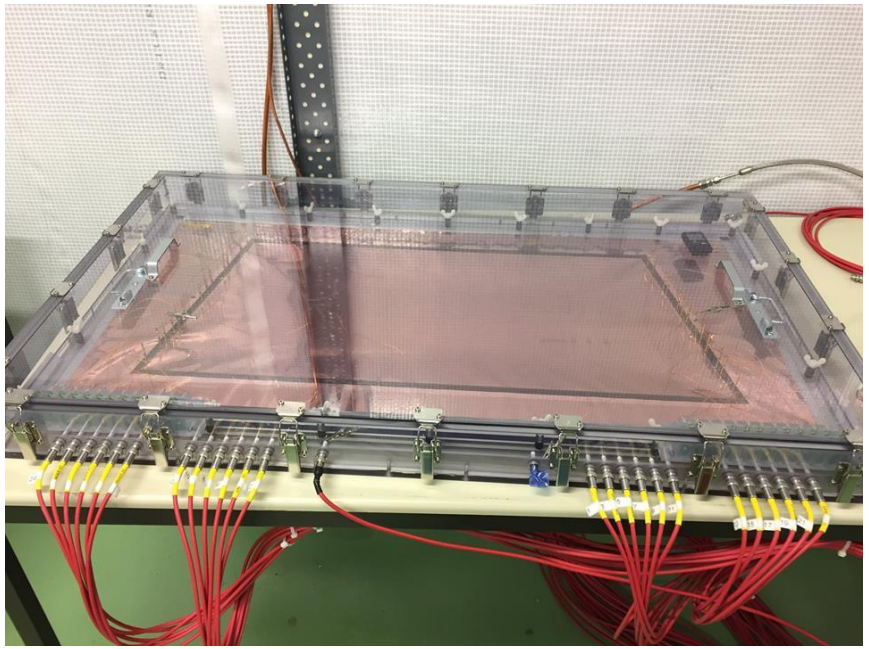


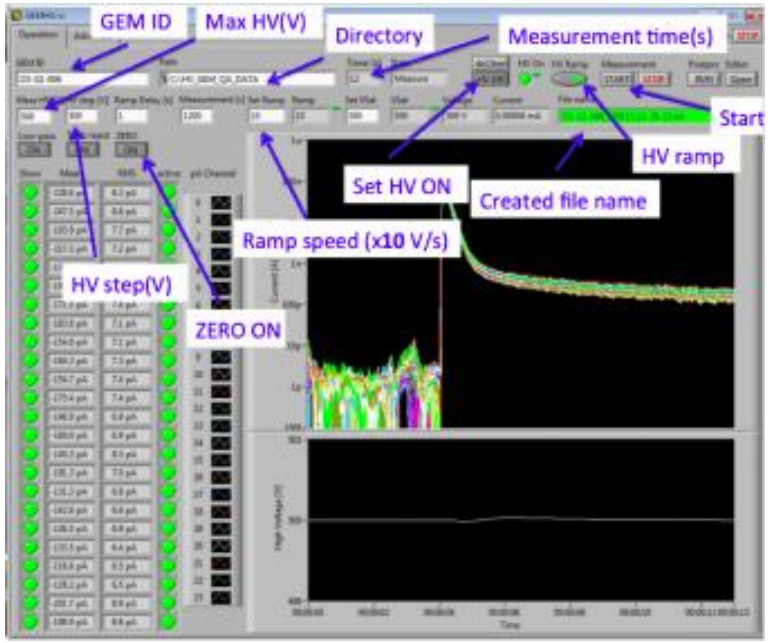




GEM QA: SPARK TEST

- Plexiglass HV drawer flushed with dry N_2
- Multichannel floating pico-ammeter for spark monitoring and current leak
- 10 nA rejection criteria





IN SITU ROC TESTING

- Real time spark rate monitoring as function of nominal GEM voltages
- Rocs just under beam line in front of PMD in mini-frame
- Tested during end of Run 2 in Fall 2018. Includes high luminosity pp run and PbPb run.
- Also tested in GIF++ facility before & after start of LS2