HPgTPC Reference Design

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DUNE ND Workshop at DESY

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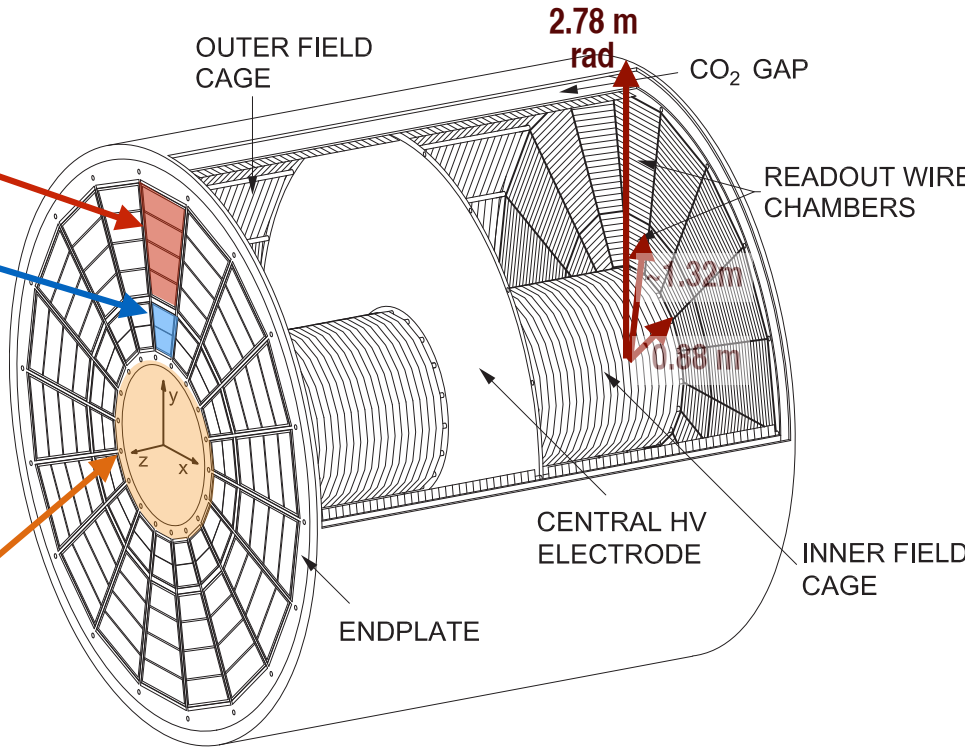
HPgTPC Concept

- 5m wide, 5 m diameter cylinder
- ALICE upgrading their inner and outer readout chambers (ROCs) during the long shutdown, old chambers available now
- Build a copy of the ALICE detector using the available ROCs, but need to build new systems including:
  - Field cage & HV feedthrough
  - Pressure vessel
  - Central ROC (x2)



More details on ALICE TPC:
NIM Paper: Nucl. Instr. A, **622** (2010) pg 316–367
TDR: http://cds.cern.ch/record/451098?ln=en

High Pressure Argon

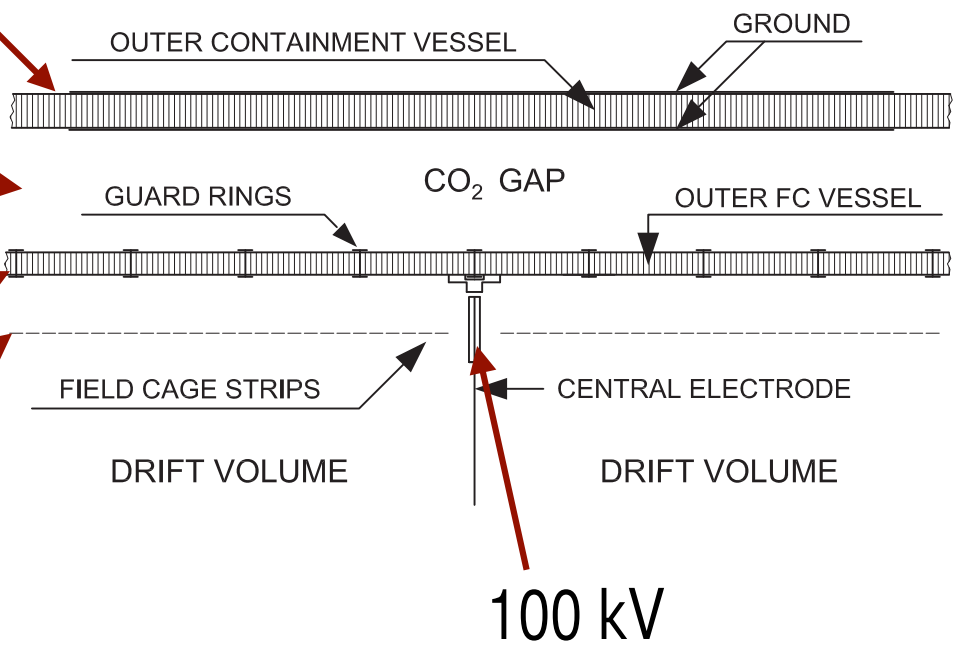
- For a 90%Ar-10%CH_4 mixture at 10 atmospheres
  - 97% of interactions are on Argon
  - 1 ton of Argon in fiducial volume
  - σ_x ~ 250 μm, σ_{pT}/p_T = 0.7% 1–10 GeV/c, 1–2% from 0.1 to 1 GeV/c, σ_{dEdx} ~ 5%
  - ~1.4×10^6 ν_μ CC interactions per year
  - ~500,000 NC interactions per year

Argon Gas

- Drift distance is up to 2.5 m
- ALICE operated (mostly) with $Ne/CO_2/N_2$ mixture at 1 atm
  - With an E-field of 400 V/cm ALICE drift velocity is 2.65 cm/μs
- For a 90%Ar-10%CH_4 gas mixture
  - Drift velocity is ~3 cm/μs with a 400 V/cm E-field at 10 atm
  - (In ArgonCube more like 0.4 cm/μs)

ALICE Field Cage Containment

- Surrounded by gas-tight grounded **Outer Containment vessel** which acts as a ground
- Within this is a ~15 cm CO_2-filled insulating gap, gas continuously circulated.
- Field cage housed in a gas-tight **field cage vessel**
  - 2 cm thick Nomex structure
  - Field strips are inside
  - Outside has more coarsely segmented guard rings



ALICE-style Field Cage

- 100 kV operating voltage in 2 drift regions
- ~5m diameter + ~5m long
- No inner field cage for us
- Consider options
  - ALICE design: aluminized mylar strips
- Also need a Central Electrode (which in ALICE was an aluminized mylar foil)

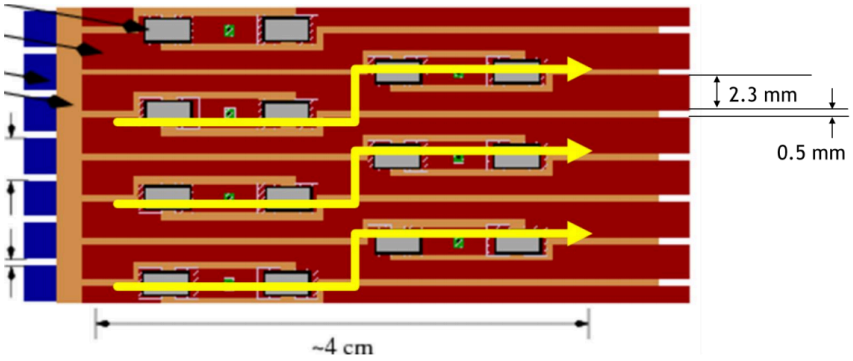
ALICE Field Cage

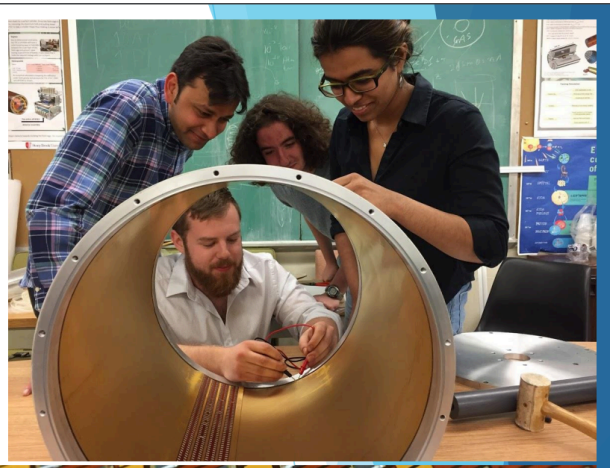
sPHENIX Field-Cage

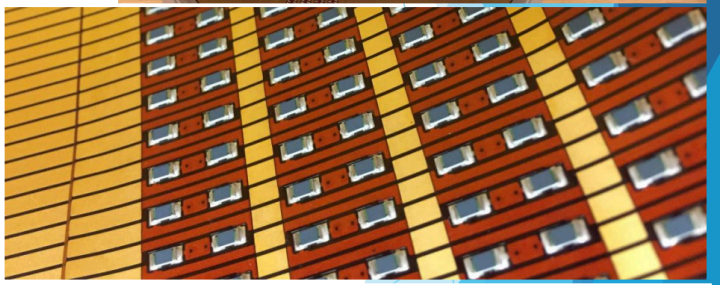
From T. Hemmick's talk at CERN TPC mini workshop

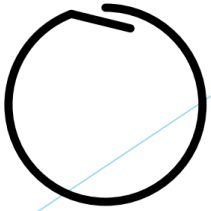
https://indico.cern.ch/event/827540/

Field Shaping Stripes









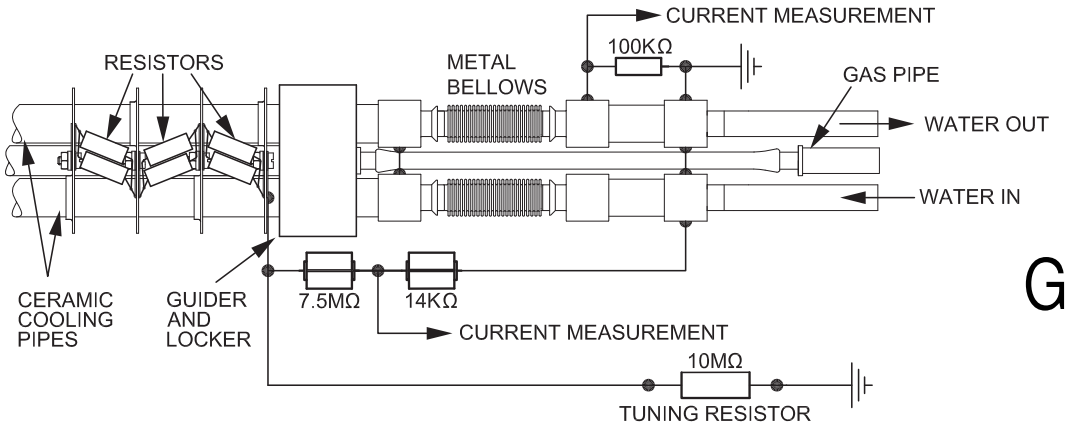
ALL Flex Company
65 flaws from 7200 resistors

- Small pitch makes useful drift space closer to cage.
- ½ voltage on the back-side protection stripe
- Stripe-to-stripe ~1250 V in air (100 V required in service)
- High Voltage Pulse Withstanding (HVPW) resistors.
  - Survives surges of 15 kV
  - Nominal running at 50 V
- Redundant chains @ 1.06 Watts/chain (0.6 mW per resistor).
- Circuit card covers full circumference (over 5 meters long)
- Incomplete ring (magnet quench consideration)

- DUNE ND TPC would have a much larger diameter though

Field Cage Structure

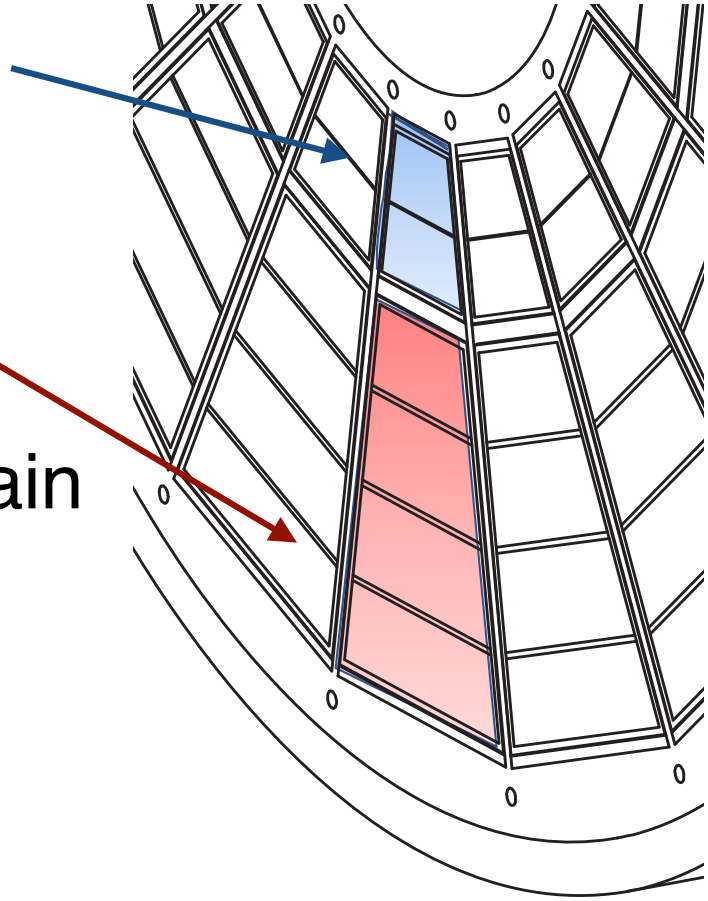
- The octadecagonal outer field cage has 18 rod per side:
  - 1 resistor rod per side provided a chain of resistors.
  - 6 laser calibration rods
  - 1 rod to provide the HV to the central cathode (spare on the other side)
  - 10 rods were gas outlets (inlets on inner field cage)
- Resistor rods were water cooled



Ground side of a resistor rod

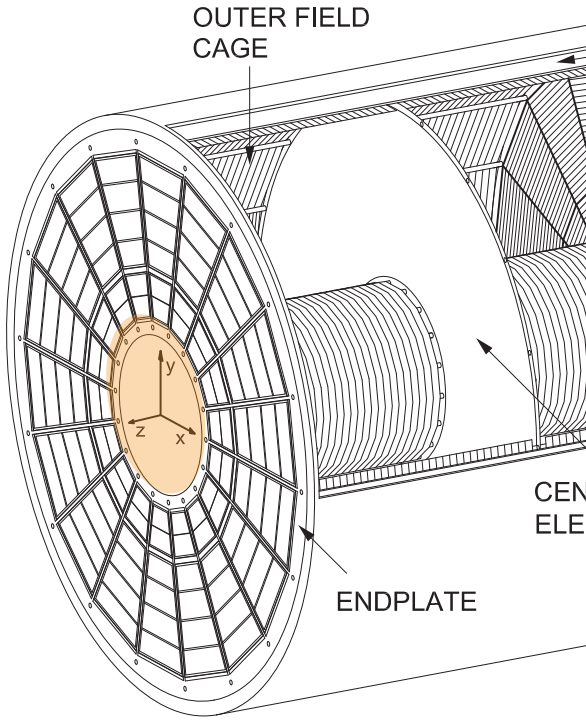
Readout Chamber Testing

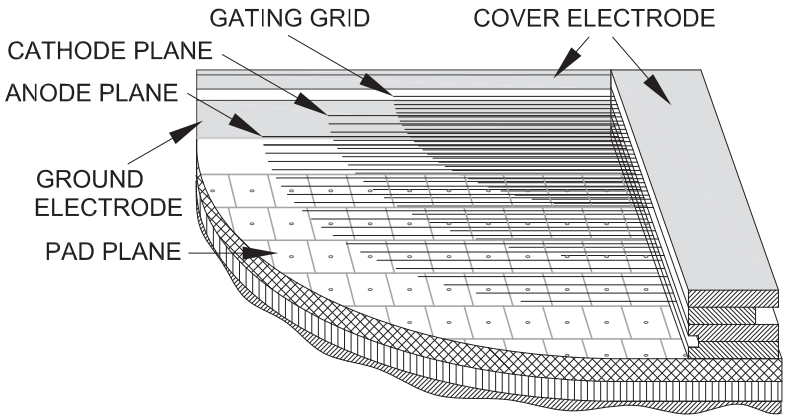
- Spare Inner Readout Chamber (IROC) at Fermilab
- Spare Outer Readout Chamber (OROC) recently shipped to Royal Holloway
- Plan tests of gas mixtures & gas gain

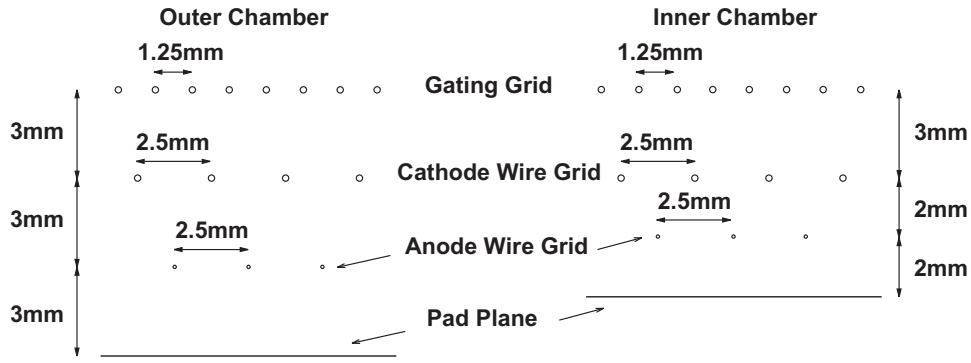


Central Readout Chambers

- Need a set of chambers for each side
- ~84 cm radius
- These must be designed from scratch
- Do we need a gating grid? Ion clearing time ~1/3 sec, so perhaps not.
- In ALICE IROC and OROC wire plane spacings were a bit different
- Anode voltages were 1570 V (1350 V) on OROCs (IROCs). Likely to be lower in DUNE ND

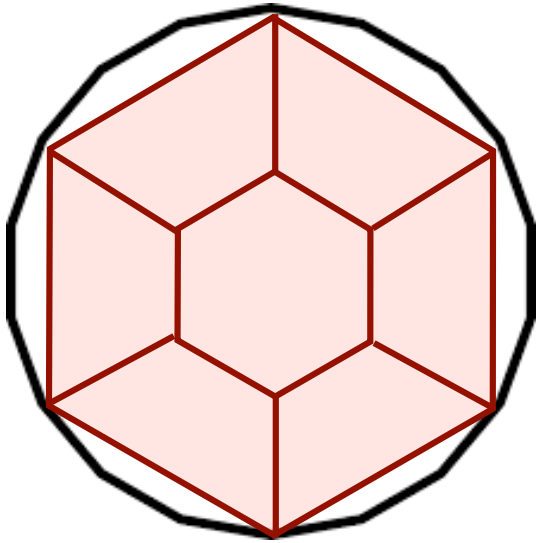


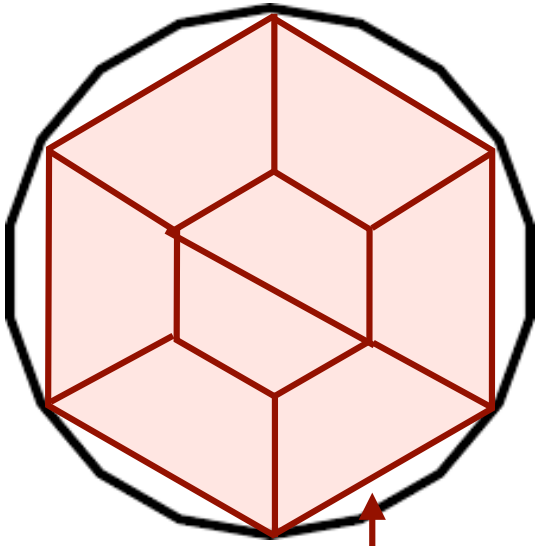


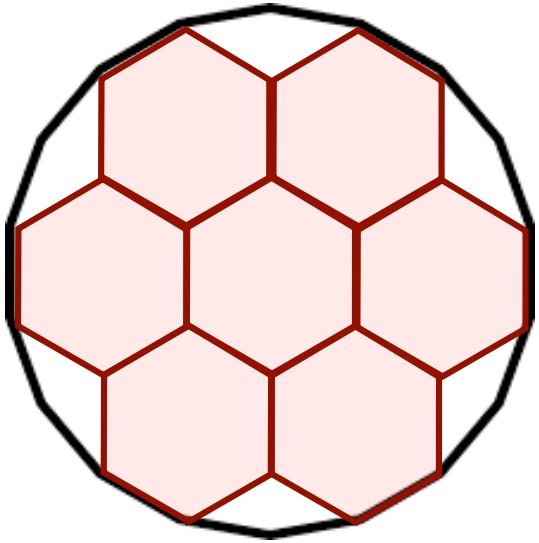


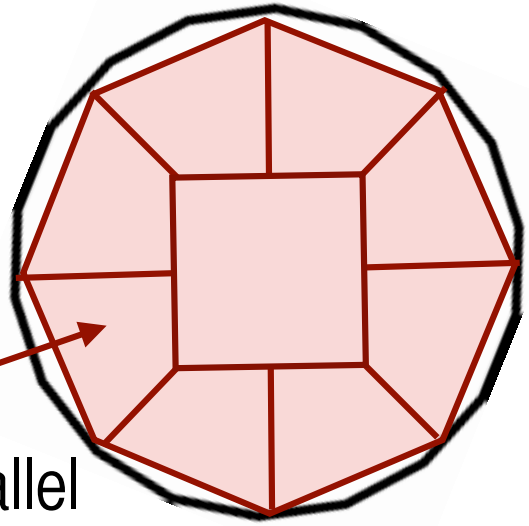
CROC Infill Ideas

Entire ROC plane must be gas tight.



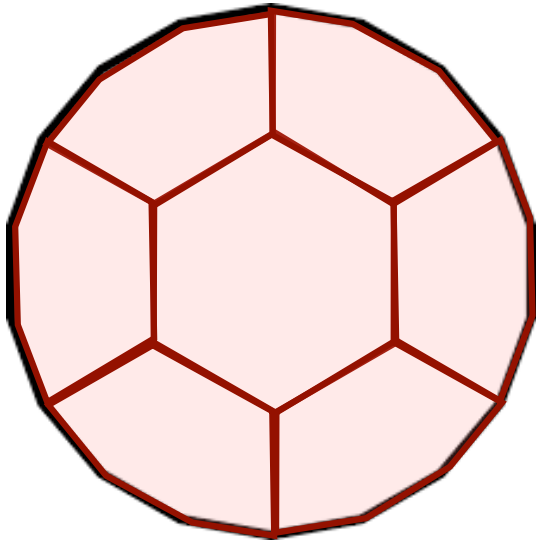






No parallel sides

Exploit gaps for light injection and/or light collection?

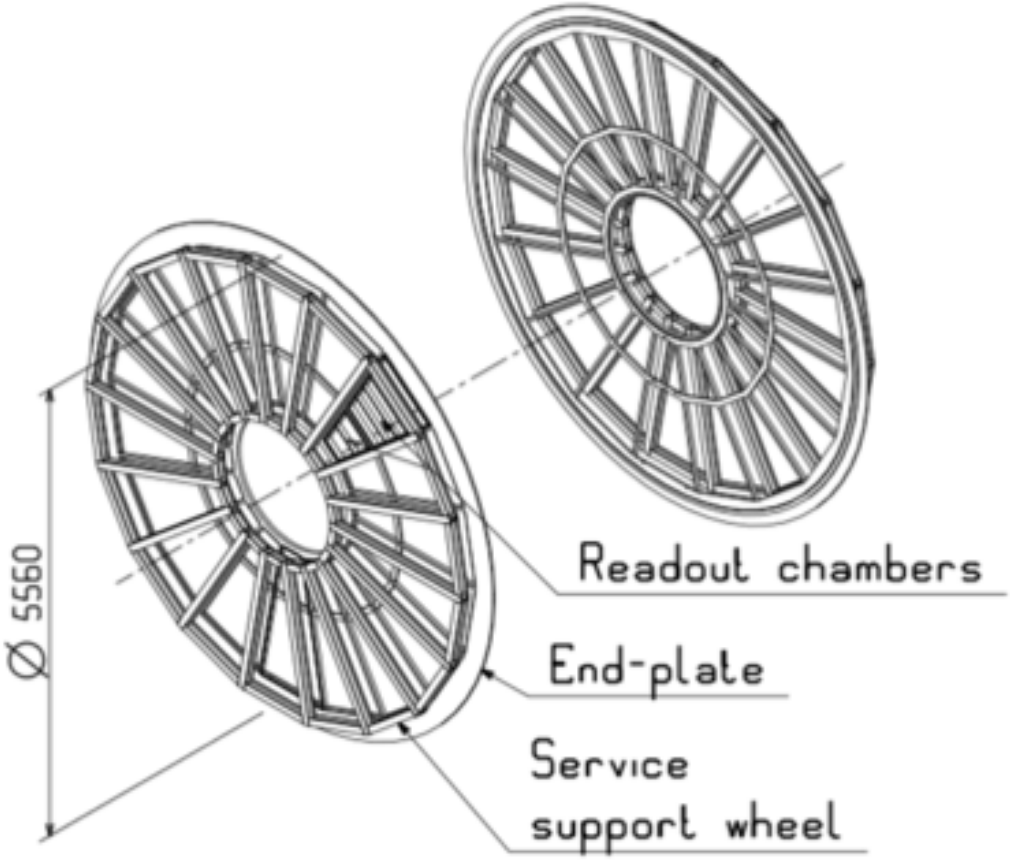


Gas + Water System

- Gas system
  - Need Argon+CH_4 system for inside field cage
  - Perhaps also a CO_2 recirculation system to voltage buffer region between containment vessel and pressure vessel
- Water System
  - Cooling water for resistor chains?
  - Cooling water for electronics
  - In ALICE this ran below atmospheric pressure

Detector Support Structures

- Will need to fabricate new support structures.
- Can start with the ALICE design to hold the readout chambers
- But maybe need some modifications to accommodate central readout chambers
- Need an articulated arm to insert chambers into structure. (Could borrow an arm at BNL.)



Electronics + DAQ

Table 4.2: Readout pads.

	Pad size [mm^2]	Number of rows	Number of pads
Inner chamber ($84.1 < r < 132.1$ cm)	4×7.5	64	5 732
Outer chamber ($134.6 < r < 198.6$ cm)	6×10	64	6038
Outer chamber ($198.6 < r < 246.6$ cm)	6×15	32	4072
TPC total		160	570 312

ALICE has 570k channels. New central chambers could add ~100k more channels to this

- Signal inverted and faster in GAr compared to LAr
- FNAL designing adapter board to host v1 LArPix, to be tested in GOAT test stand
- If successful, then make branched version: modified LArPix -> FastArPix (faster clock, inverted signals)

- Some interest expressed in DAQ, but no active work yet

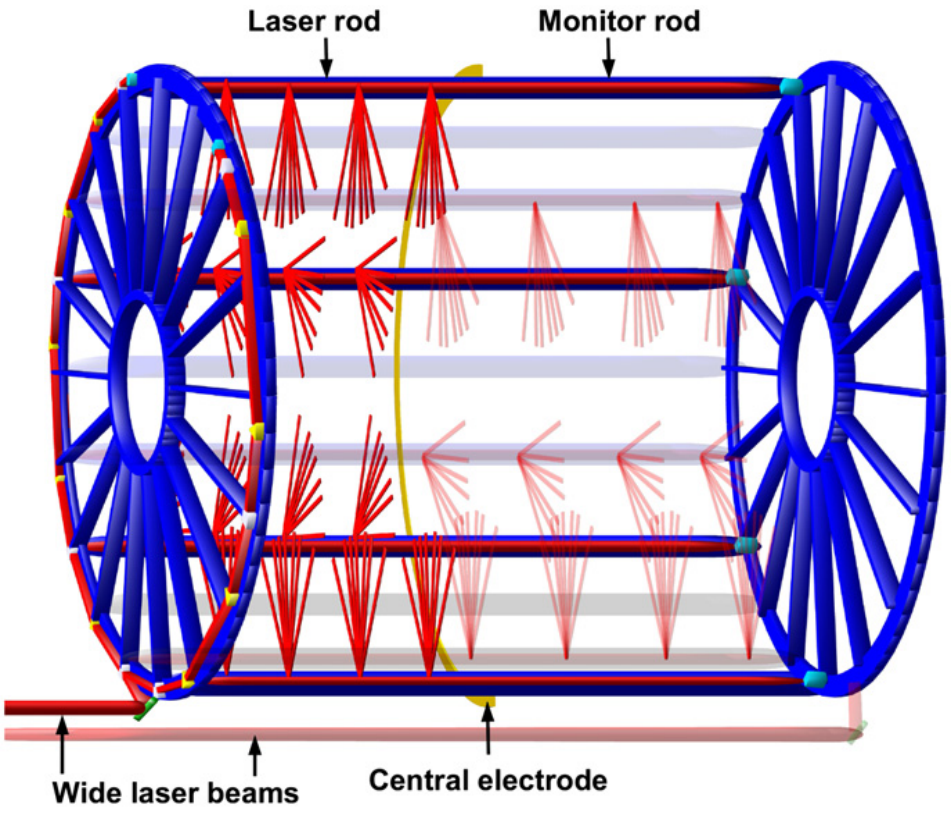
Light Collection and Gas Mixtures

- Ar gas mixtures fluoresce in the near-infrared. Could provide a useful timestamp
- Light is related to choice of gas mixture

- ALICE did not have a light collection system, so if we want to use this light, a light collection system must be designed from scratch (and likely needs to be incorporated into field cage structure as well)

Calibration and Monitoring

- Need detailed maps of internal and external B-field
- Monitor temperature, gas composition, drift velocity, …
- For calibration, can start from ALICE design, or start fresh
- ALICE design:
  - laser calibration system
  - radioactive krypton calibration
  - constant monitoring of temperature and gas composition

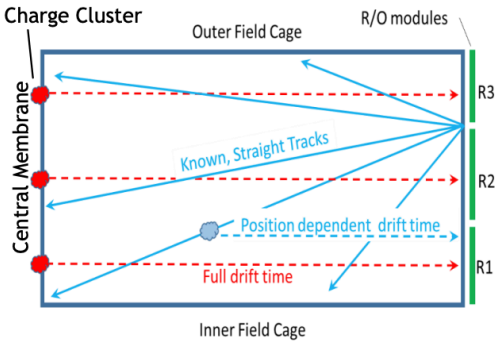


sPHENIX Laser Calibration

From T. Hemmick's talk

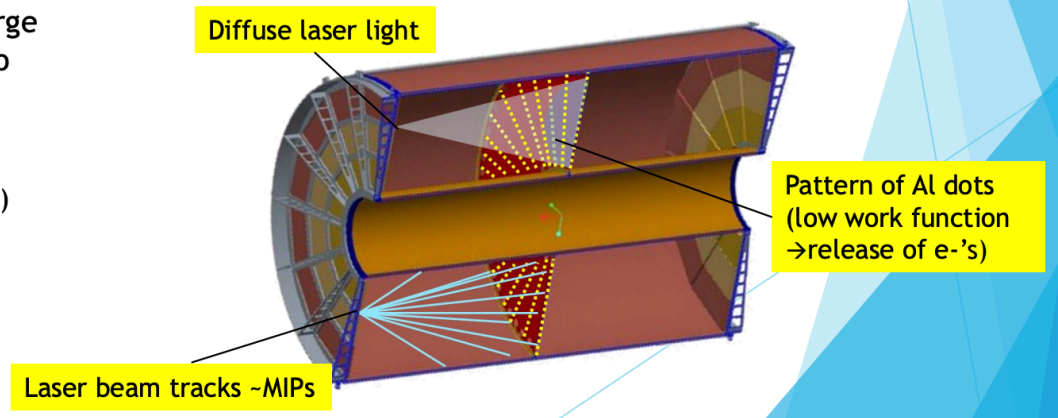
Laser Calibration Overview

PURPOSE: Calibration System
- Determine drift velocity throughout TPC vol.
- Determine electric field distortions
- Determine precise alignment of field cage w.r.t. endcap and magnetic field



- Charge from the central membrane travels the full drift distance and reveals the **absolute integrated drift velocity**
- A single sweeping laser beam allows for a continuous **sampling of the drift velocity** over a quadrant of the TPC volume
- The integrated drift time serves as a **hard constraint** for the point by point determination of the drift velocity (using system of linear equations)

STRATEGY
- Shine **diffuse laser light** onto central membrane to liberate clusters of charge
- Shoot **laser beams** into TPC volume to mimic straight particle tracks
- Compare **straight tracks** to **displaced/distorted tracks**
  - Beam ON vs OFF (space charge effect)
  - B-Field ON vs OFF (**ExB** effect)



- Unlike ALICE, accesses TPC from the sides, not via the support structure

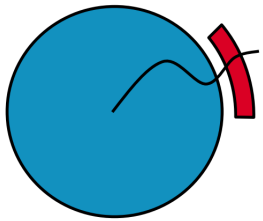
Other Calibration Ideas

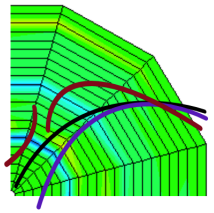
- Can also bounce light off of central electrode (MicroBooNE had a movable mirror)
- X-ray gun (ALICE studying this for run 3)
- External micromegas tracker
  - Could be useful between LAr and ECAL

MICROMEGAS TRACKER FOR TPC MONITORING

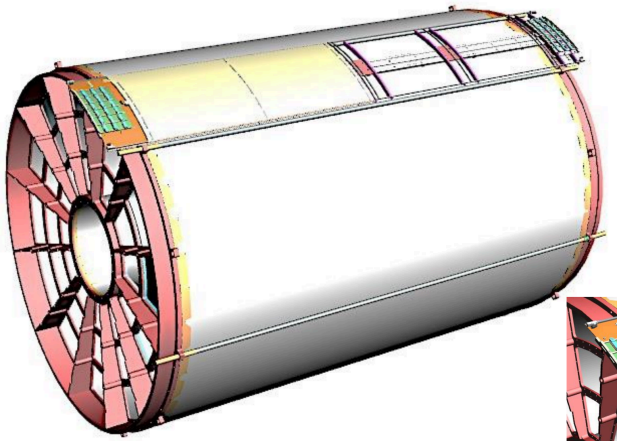
Concept :

- Cylindrical Micromegas chamber on the TPC to provide a good precision point to monitor the TPC tracking
- This would help the correction of all types of distortions (IBF, drift velocity, ExB …) since it's an independent detector
- Will cover the full drift length
- Minimal dead zones
- Relatively cheap with one sector, low X0





From M. Vandenbroucke's sPHENIX TPC monitoring talk at Mini workshop



R&D and Prototyping Needs

- Specific high priority R&D items:
  - Test breakdown voltage of planned gas mixture
  - Light production tests
  - Readout electronics
- Other prototyping
  - Field cage
  - Central readout chambers
  - Calibration system
  - Light collection
  - Integration testing

Summary

- Many large components and systems will need to be engineered and fabricated.
- We will hear more about many of these systems and test stands in the next few talks.

- We **welcome new groups** that might be interested in collaborating on these systems.
  - ~Weekly Tuesday 10 AM Central / 5 PM Central Europe MPD meetings
  - Mailing list: dune-nd-gastpc@listserv.fnal.gov (Can request to join via “DUNE At Work” page.)