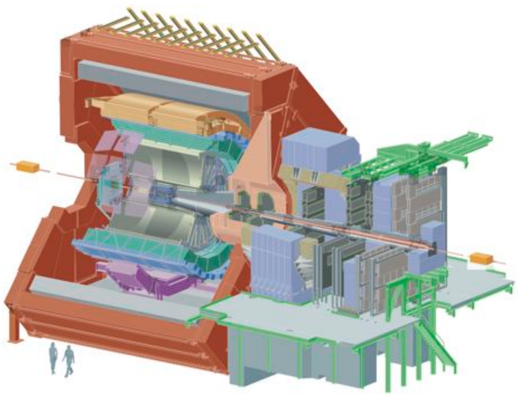
TEST BEAM RESULTS FOR ALICE TPC UPGRADE PROTOTYPES



James Mulligan, Yale University
for the
ALICE TPC-Upgrade Collaboration

APS April Meeting
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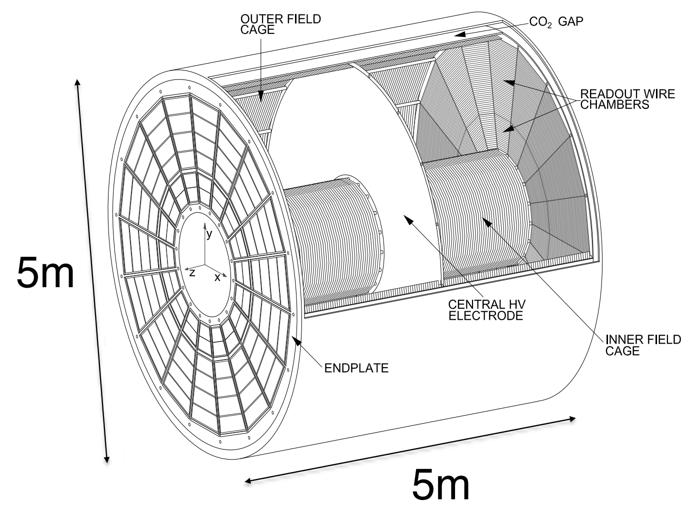
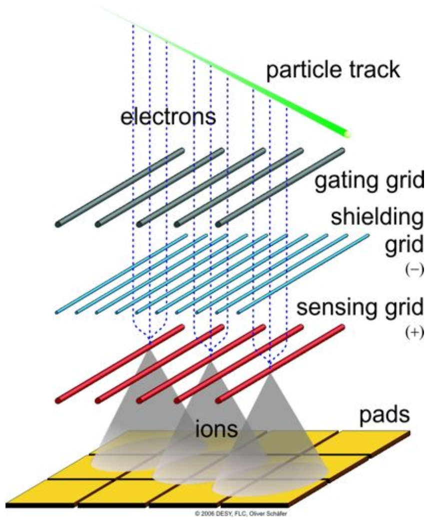
J. Mulligan[1], N. Smirnov[1], R. Majka[1], O. Grachov[1], S. Aiola[1], R. Ehlers[1], J. Wiechula[2], J.W. Harris[1]
[1] Physics Department, Yale University
[2] Physikalisches Institut, Eberhard Karls Universität Tübingen

ALICE TPC

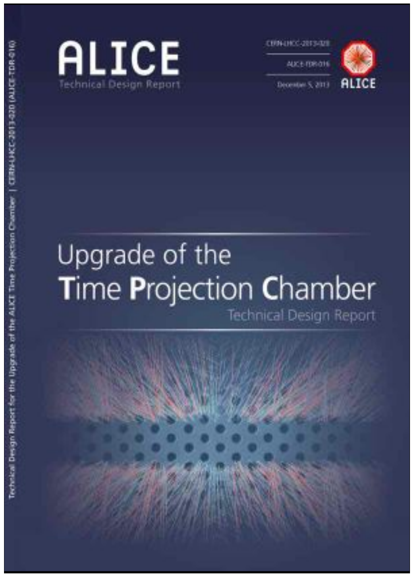
- Specs:
  - ~92m^3 active volume
  - Ne-CO_2 (90-10)
  - B = 0.5 T
  - 72 readout sectors
    - 18 inner/outer sectors, 2 ends
  - ~560,000 readout pads
    - 4x7.5mm^2 pads for inner chambers
- Gas amplification: MWPC
- Gating grid (to prevent ion backflow) limits rate to ~3 kHz
  - ~100μs max e$^-$ drift, ~200μs grid closure

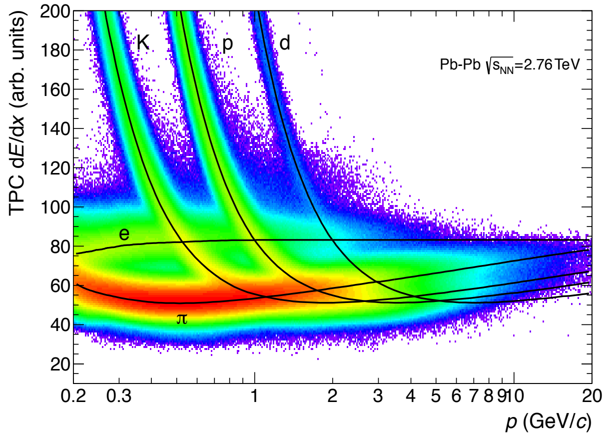




ALICE TPC Upgrade

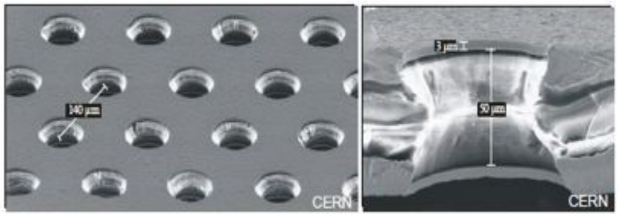
- LHC will be upgraded during LS2 (2018-2019) to have Pb-Pb collision rates up to 50 kHz
- Need for continuous TPC readout
  - Maintain PID performance
    - $\sigma_E/E < 12\%$ for ^{55}Fe
  - Limit ion backflow
    - <1% at gain 2000

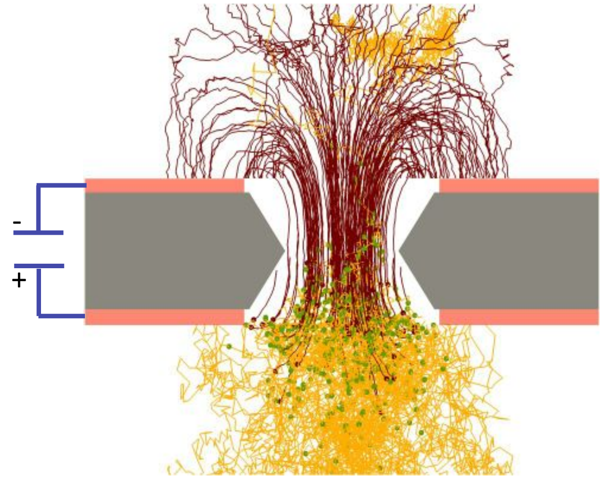


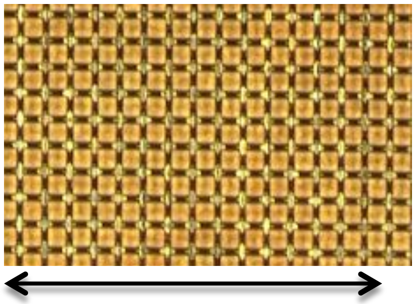


Micro-Pattern Gas Detectors

- MPGDs allow continuous operation due to their innate ion backflow suppression
- Gas Electron Multiplier (GEM)
- Micro-Mesh Gaseous Structure (MMG or Micromegas)

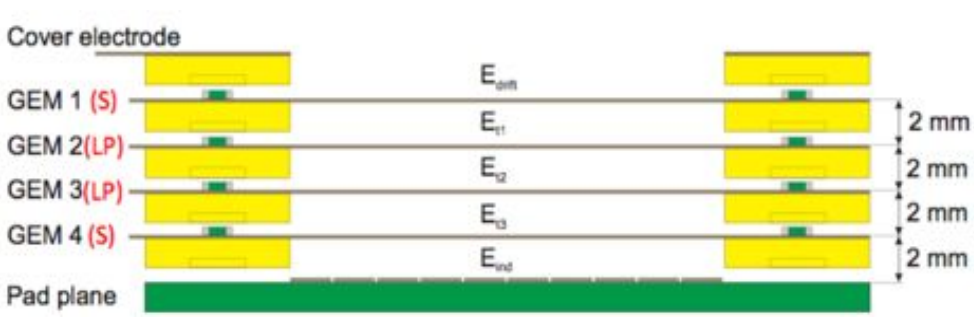






Upgrade Prototypes

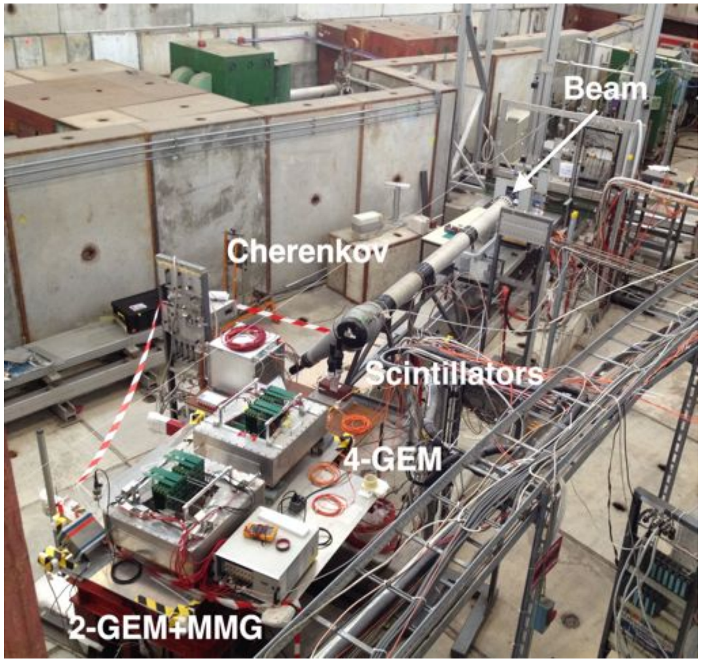
- 4-GEM configuration (baseline upgrade choice)
  - Full-sized inner-readout chamber, 2nd test beam campaign
- 2-GEM+MMG configuration
  - Yale Prototypes: Two 21x26cm 2-GEM+MMG chambers
    → This is the main focus presented here



- Beam test: November-December 2014 at CERN
  - PS beam for dE/dx, SPS for sparking rate

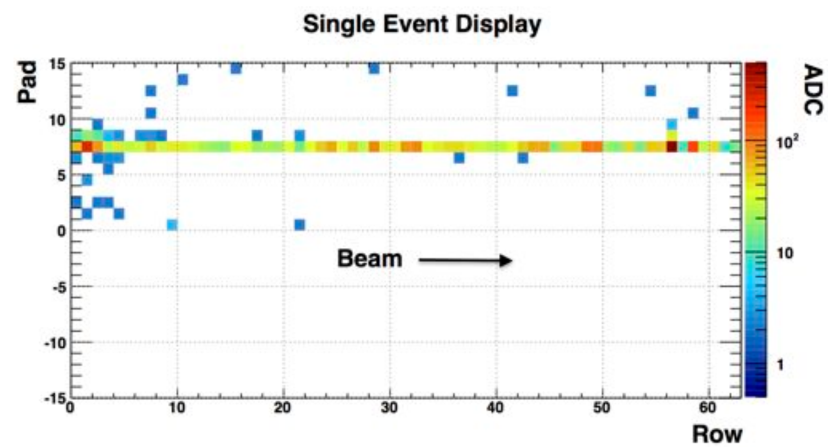
Beam Test: PID Performance

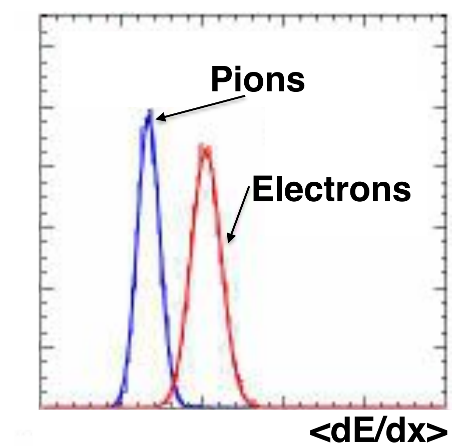
- Goal: Determine dE/dx separation of electrons from pions
- Setup:
  - PS secondary beam: 1-3 GeV pions and electrons
  - Cherenkov counter to distinguish electrons from pions
  - Scintillators for trigger
  - Readout electronics from LCTPC collaboration
- ~380,000 events usable (before cuts) for 2-GEM+MMG Yale prototypes



PID Performance: Analysis

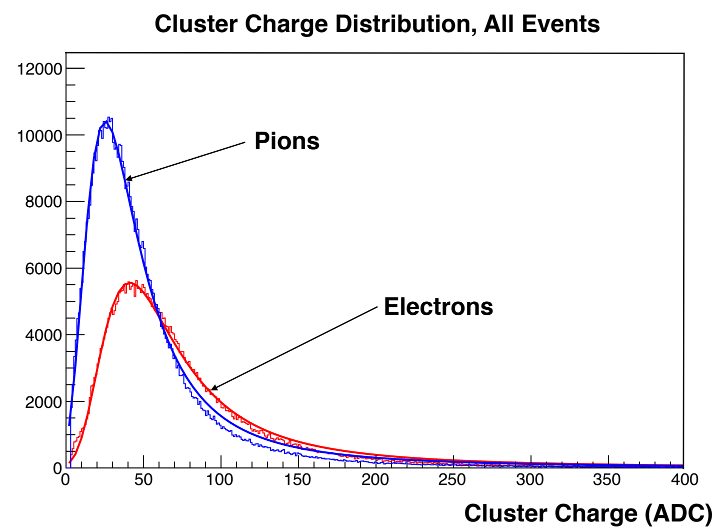
- Procedure to determine dE/dx:
  - Clustering: For fixed padrow, find local maximum charge, then sum surrounding 3 bins in pad/time space
  - Tracking: Iteratively search rows for nearest cluster, within tracking pad/time window
  - Combine tracks from our two chambers
    - 32 padrows each
  - For each track, take 70% truncated mean of cluster charges, divide by number of clusters, and add to <dE/dx> histogram
  - Gaussian fit dE/dx histogram
- Analysis code adapted from Jens Wiechula (used in 4-GEM beam tests) for our 2-GEM+MMG analysis

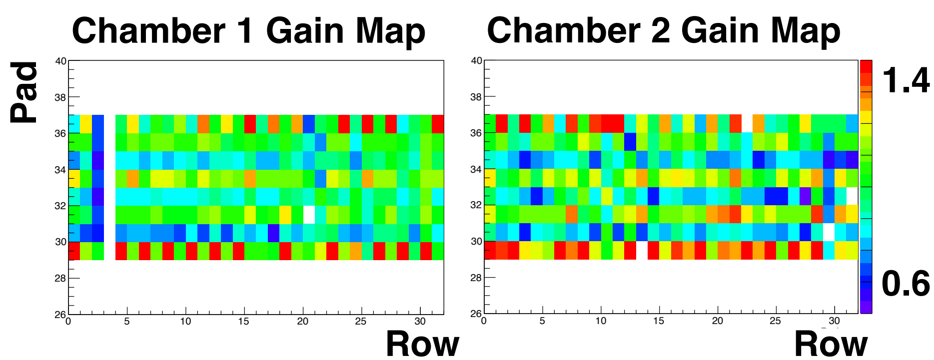




PID Performance: Analysis

- QA: Cherenkov separation, cluster charge Landau distribution, pad occupancy, etc.
- Cuts:
  - Minimum clusters per track: 60
  - Cluster Q_{max} ADC threshold: 3
  - Remove tracks with excess low-Q clusters
    - For pions, >4 clusters with Q<6
    - For electrons, >4 clusters with Q<15
  - Other: one-track events, edge cuts, timing cuts, misses allowed in track, etc.
- Gain Map
  - Apply pad-by-pad gain correction:
    - Average pad signal / Average chamber signal
    - Cause of correlations?
  - Normalize average gain of each chamber



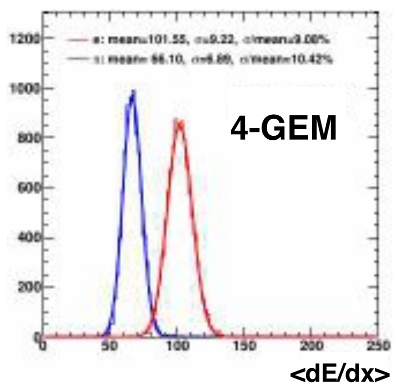


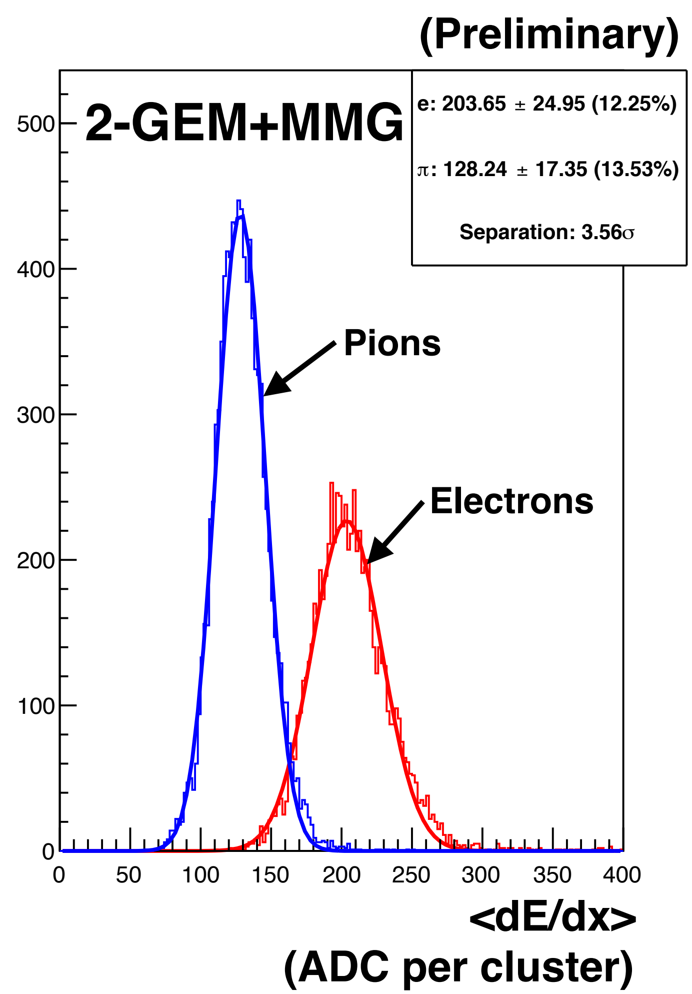
PID Performance: Results

- Separation:

$$S_{AB} = \frac{2\left|\langle dE/dx\rangle_A - \langle dE/dx\rangle_B\right|}{\sigma\left(dE/dx\right)_A + \sigma\left(dE/dx\right)_B}$$

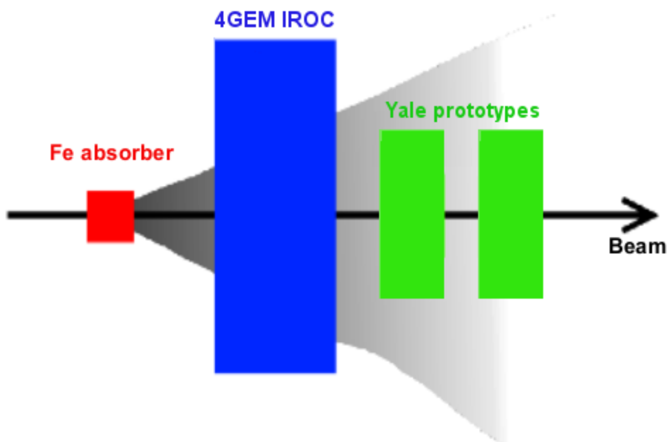
- Yale 2-GEM+MMG Prototypes:
  - $S_{\pi e}$ = 3.6 (Preliminary)
  - Ongoing questions:
    - Origin of excess low-Q clusters
    - Cause of gain map correlations
- 4-GEM:
  - $S_{\pi e}$ = 4.4

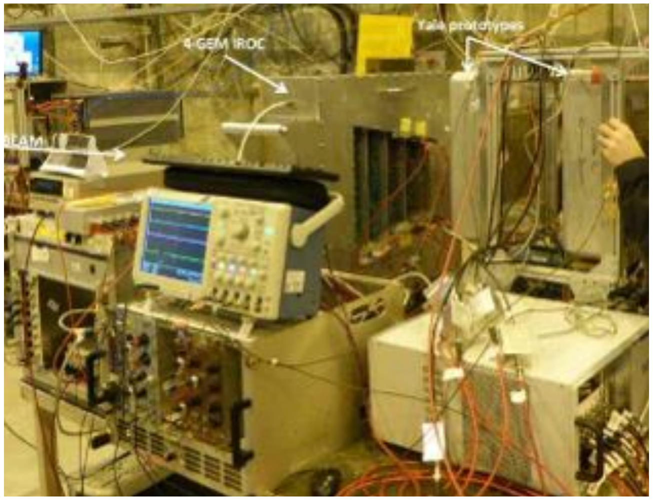




Beam Test: Sparking Rate

- SPS beam: 150 GeV pions incident on Fe absorber (to multiply hadrons)
  - Beam perpendicular to pad plane
  - $Ne\text{-}CO_2\text{-}N_2$ (90-10-5)
- Oscilloscope records spark signal
- ~5 x 10^{11} chamber particles accumulated in test beam
  - 1 month of Pb-Pb in ALICE: ~$7\text{x}10^{11}$ per GEM sector





Sparking Rate: Results

- 2-GEM+MMG:
  - At optimal HV setting: P~3.5 x 10^{-10} per chamber particle
    - Spark rate depends on MMG voltage, since MMG is 125μm from pad plane
  - Spark does not harm MMG, but gives dead time (~μs)

#	ΔU_{GEM1} (V)	ΔU_{GEM2} (V)	V_{MM} (V)	gain	Discharge probability
1	250	210	440	2050	$(2.0 \pm 0.6) \times 10^{-9}$
2	260	220	420	2000	$(3.5 \pm 1.0) \times 10^{-10}$
3	0	0	420	450	$(1.7 \pm 0.5) \times 10^{-10}$

- 4-GEM:
  - ~6.4 x 10^{-12} per chamber particle (3 sparks observed)
  - Dead time ~ seconds to minutes

Conclusion

- Successful test beam campaign demonstrates good PID performance for 4-GEM, 2-GEM+MMG designs
  - 4-GEM slightly better, more mature
- 2-GEM+MMG needs more R&D (e.g. sparking), but worth pursuing due to lower ion backflow
  - Possible second test beam in coming months
- 4-GEM design chosen for ALICE TPC-Upgrade
  - TDR Addendum Feb 2015
- Construction beginning; US building inner sectors, Europe outer sectors