Relativistic nuclear collisions at the Terascale: status and future plans for the ALICE TPC

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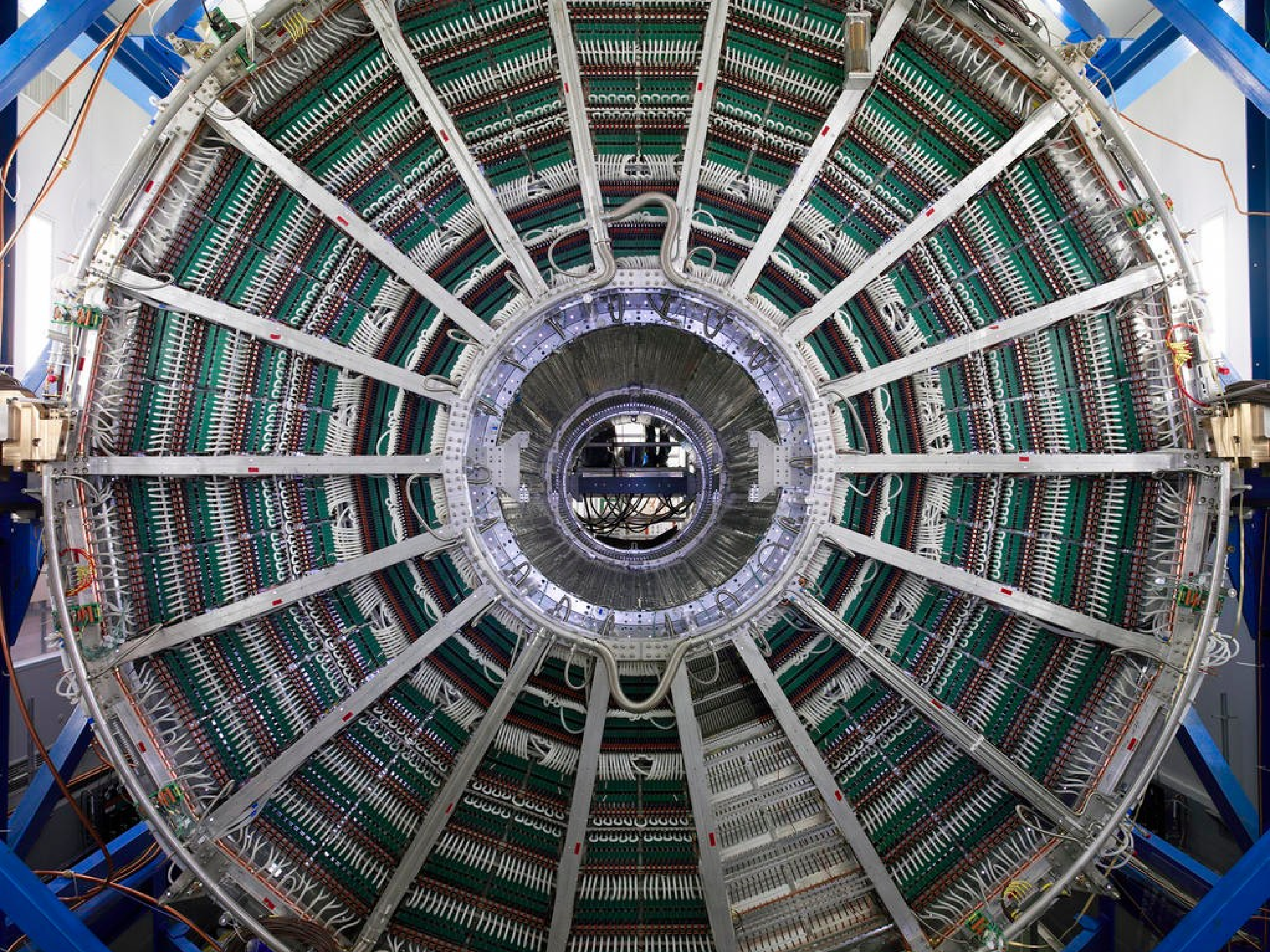
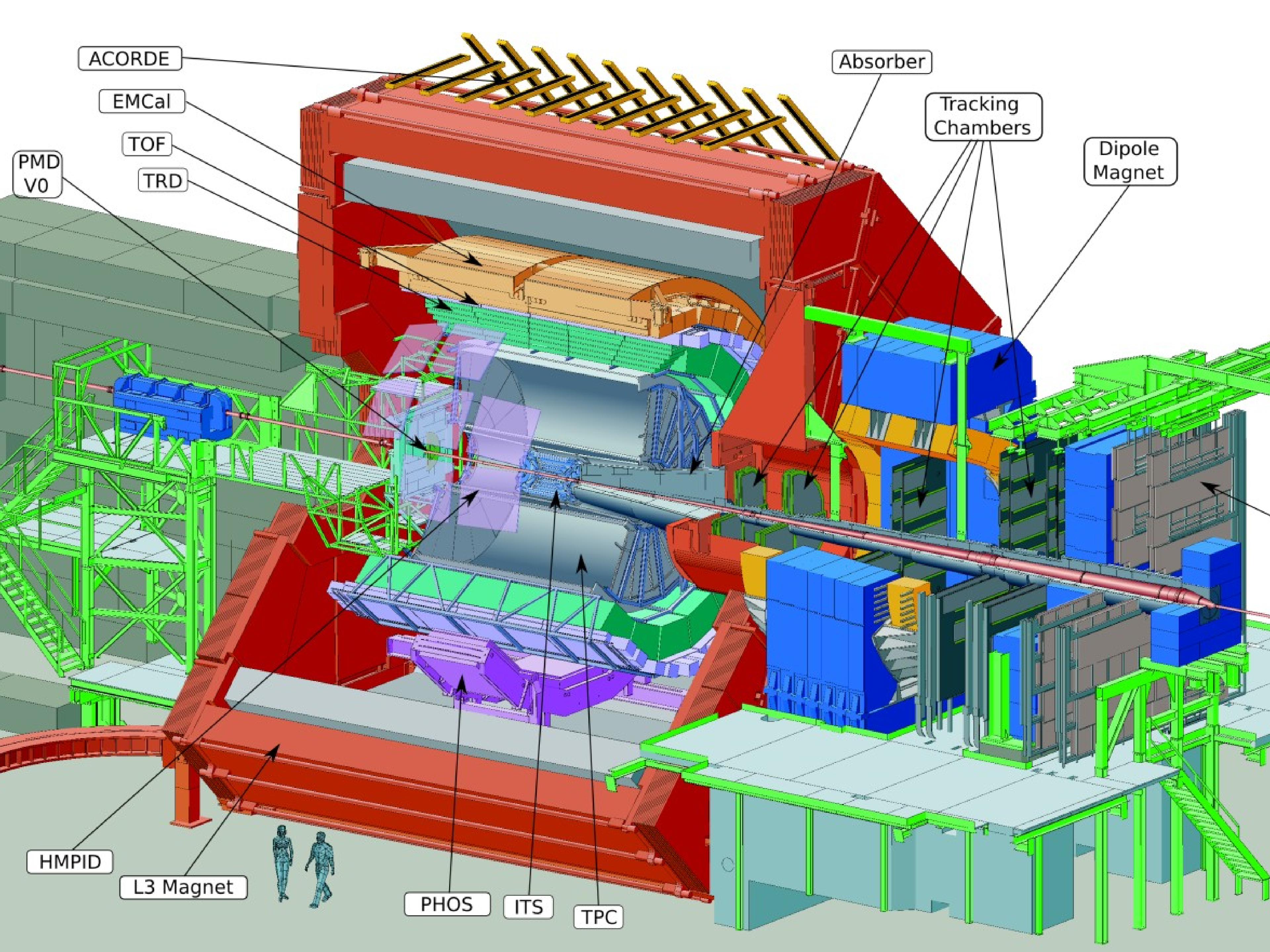
EMMI/GSI Darmstadt/FIAS

the Art of Experiment
Symposium to honor David Nygren
LBNL, May 2-3, 2014




ACORDE
EMCal
TOF
PMD
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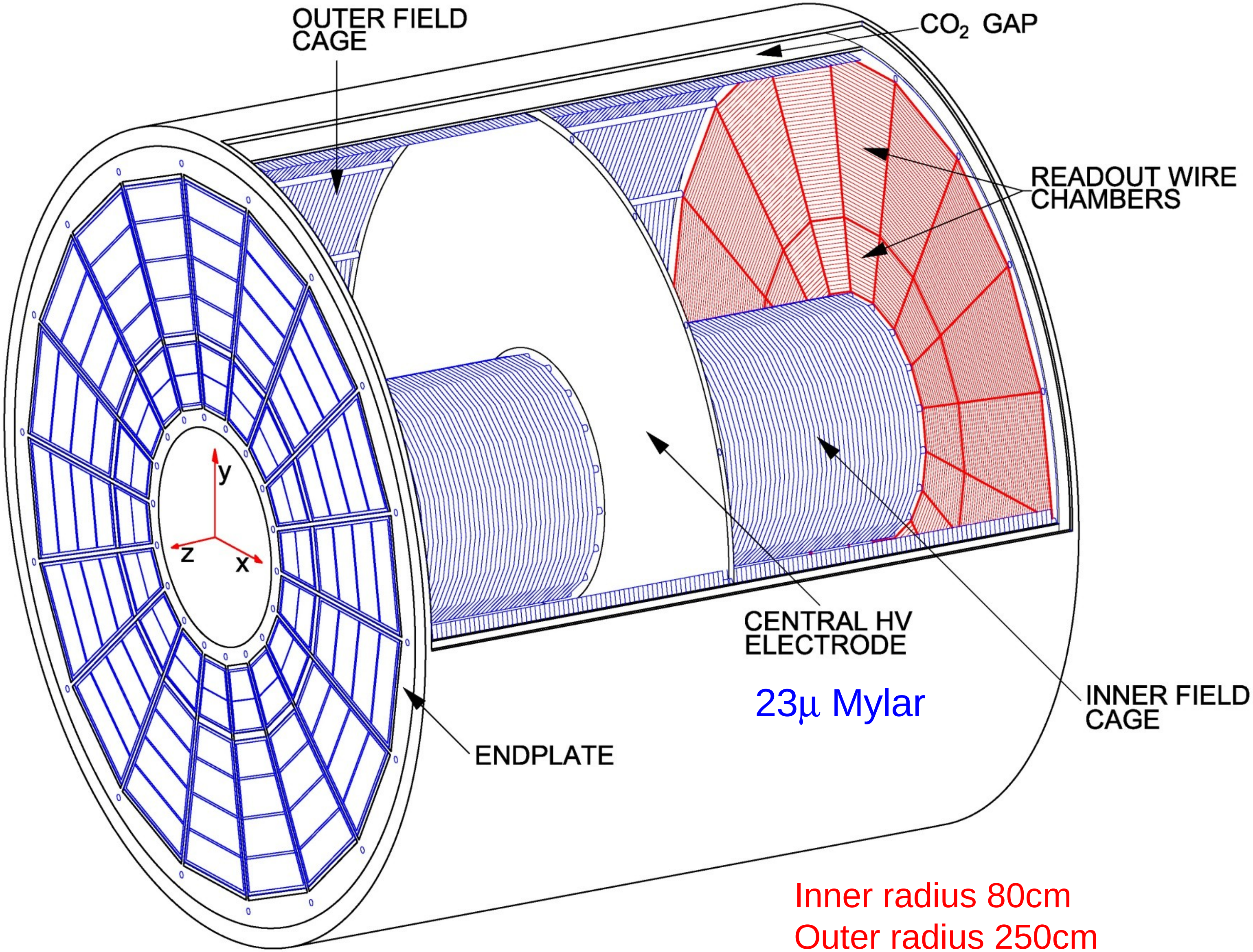
TRD
Absorber
Tracking Chambers
Dipole Magnet
HMPID
L3 Magnet
PHOS
ITS
TPC

ALICE TPC



23μ Mylar

Inner radius 80cm
Outer radius 250cm
Length 2x250cm

ALICE TPC is a large volume Time Projection Chamber with overall 'conventional' lay-out but designed for extreme high track density expected in Pb-Pb collisions at LHC energy.

GAS CHOICE

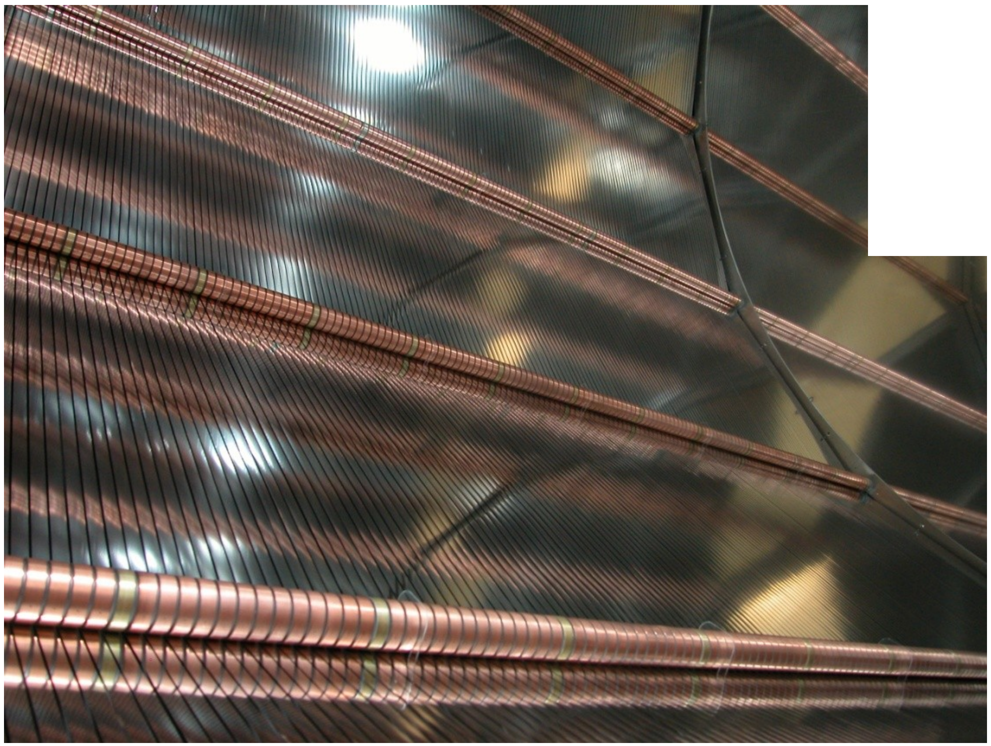
Ne because:
less material, faster ion mobility (less space charge effect), low diffusion
Quencher: **CO_2** (minimized aging)+ N_2.

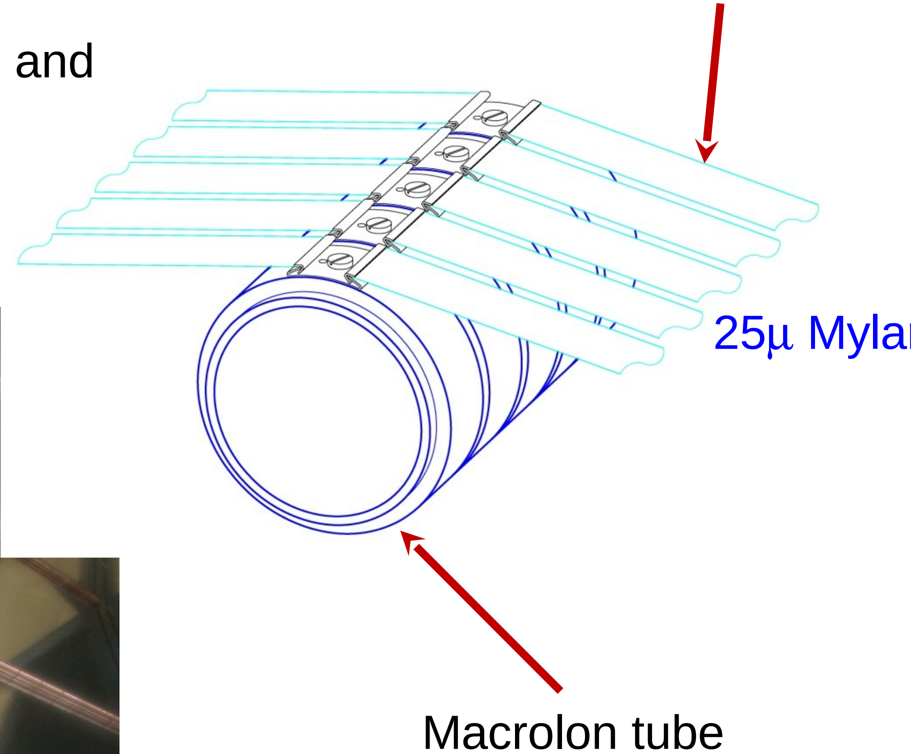
Active volume: 90 m^3
Final gas mixture: Ne-CO_2-N_2: 85.7% - 9.5% - 4.8%
(N_2 added to improve quenching at high gain)
Cool gas - low diffusion
Non-saturated drift velocity: temperature stability and homogeneity $\leq$ 0.1 K
Gain ~ 10^4

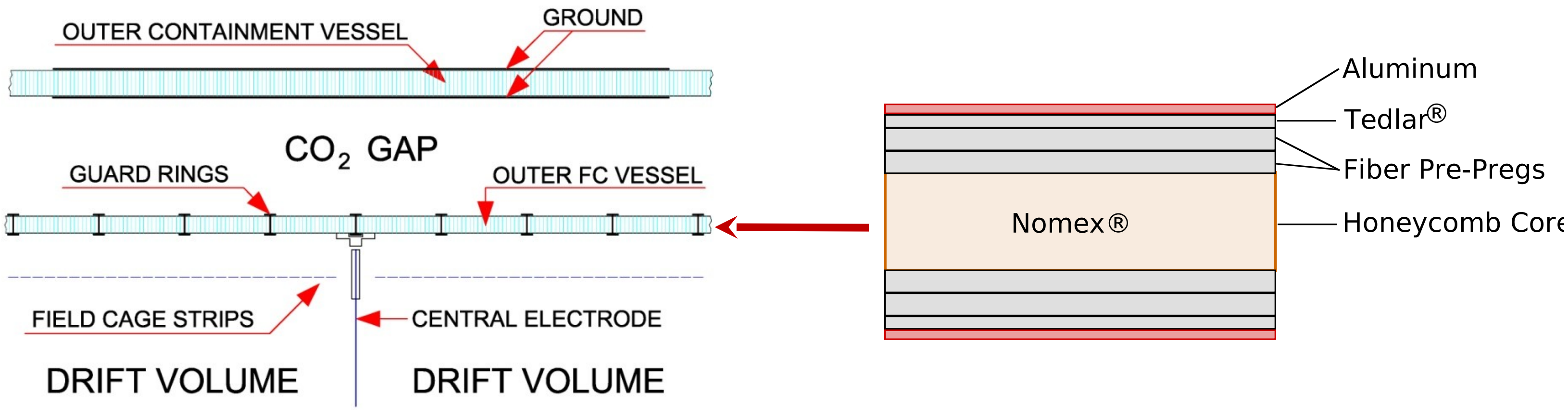
With this gas mixture we need 400V/cm in the field cage!

ALICE TPC Field cage is made of free standing aluminized Mylar strips

More complicate system but very stable and reliable for high drift voltages.



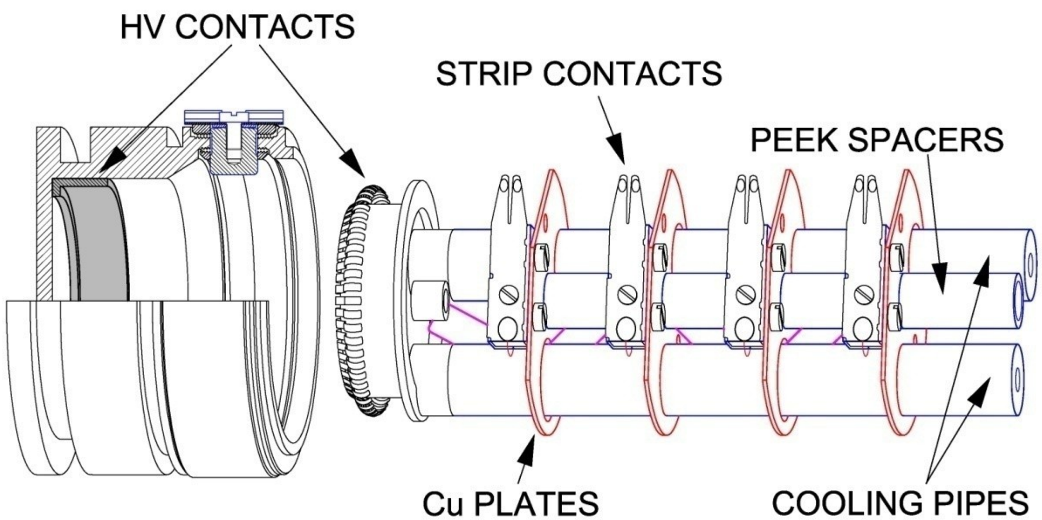




The ALICE field cage consists of two parts; a field cage vessel with a set of coarsely segmented guard rings and finely segmented field cage which is located inside the field cage vessel.

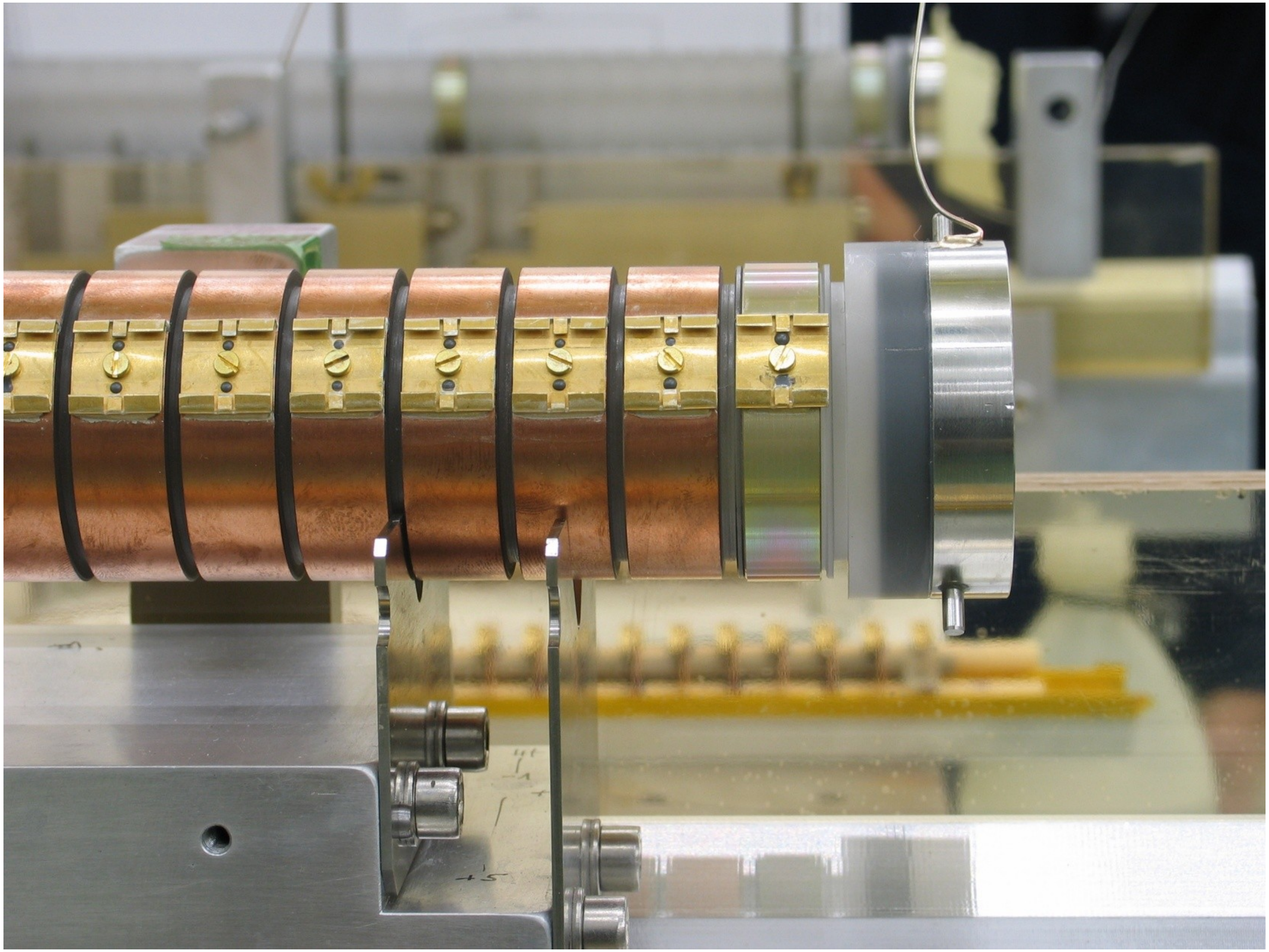
For temperature stability and homogeneity ≤ 0.1 K

Leakless cooling system including FC Resistor rod

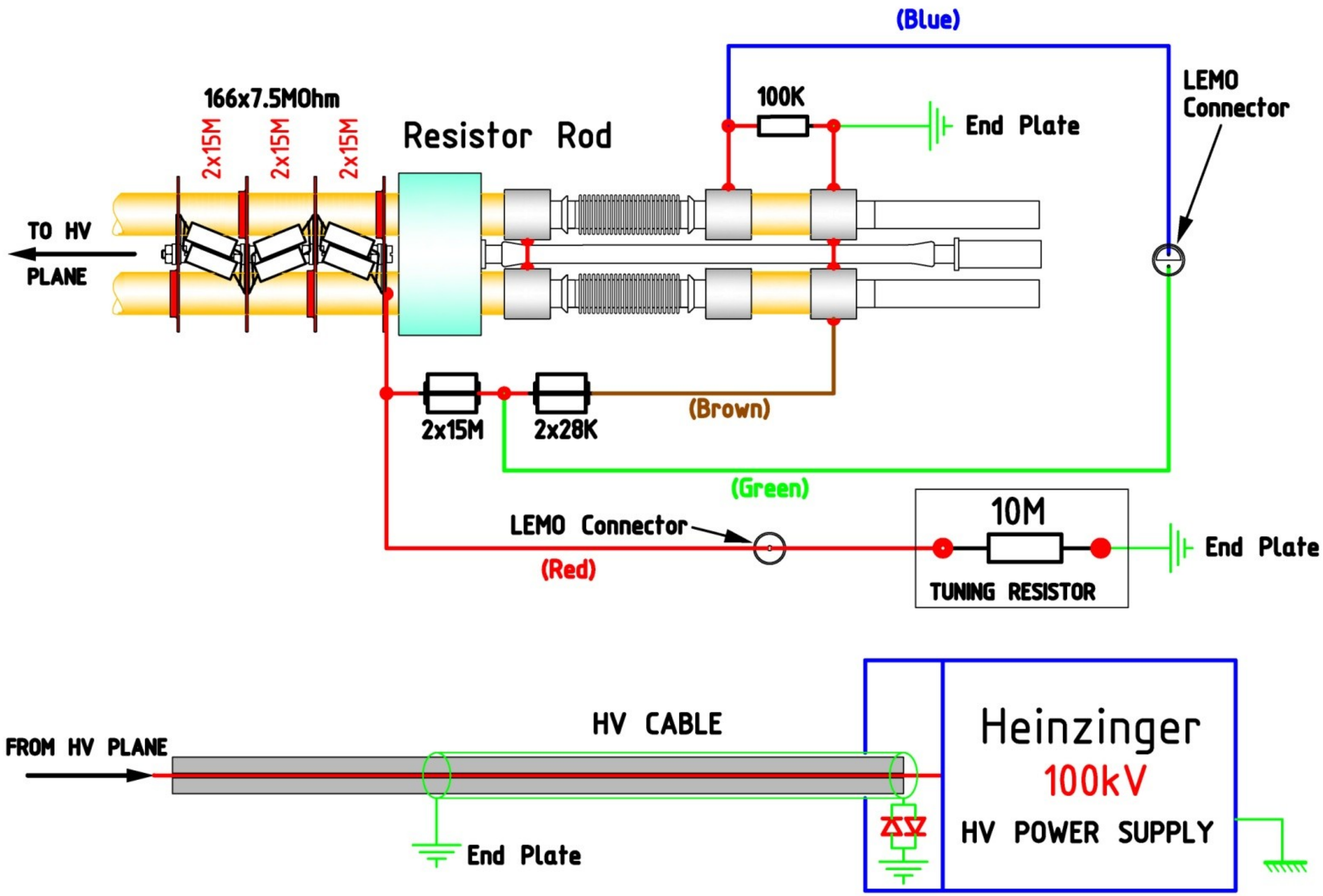


To monitor the temperature distribution
~500 PT1000 sensors are mounted both inside and outside of the gas volume

RESISTOR ROD WITH WATER COOLING – OUTER PART



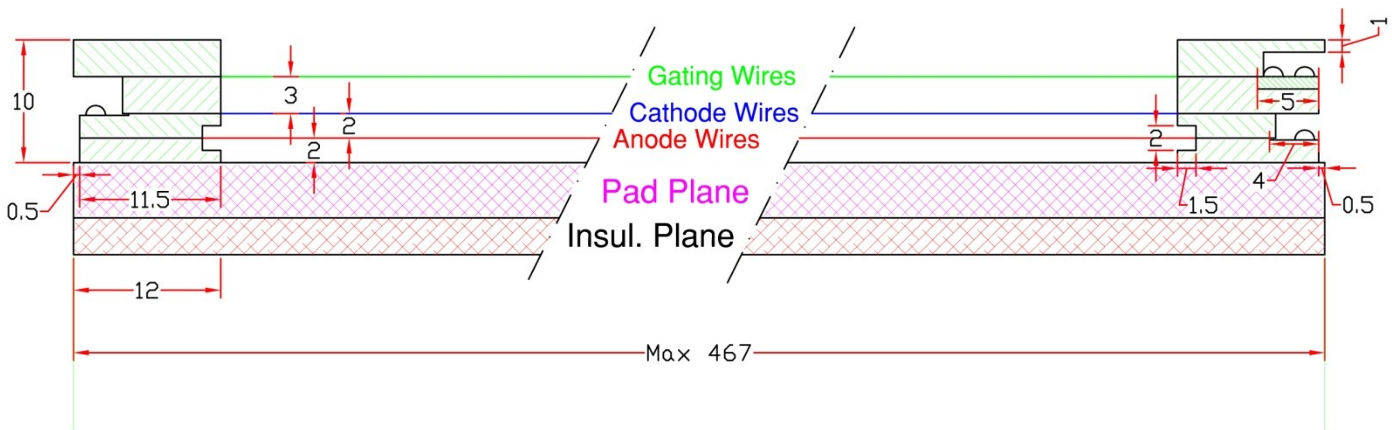
RESISTOR ROD - MECHANICAL AND ELECTRICAL ARRANGEMENT



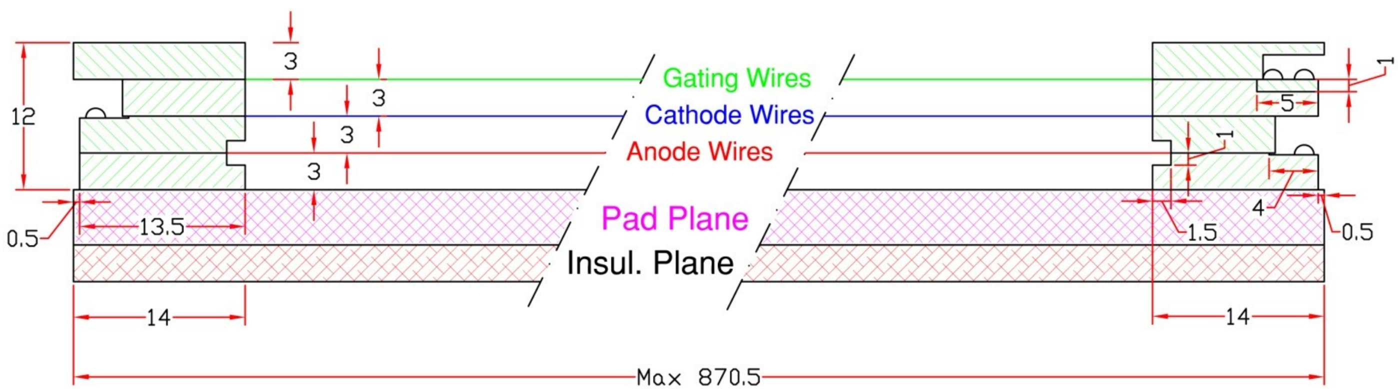
READ-OUT CHAMBERS DESIGN

MWPCs with pad-readout with extra optimization for high rate and high track density.

Inner Chamber

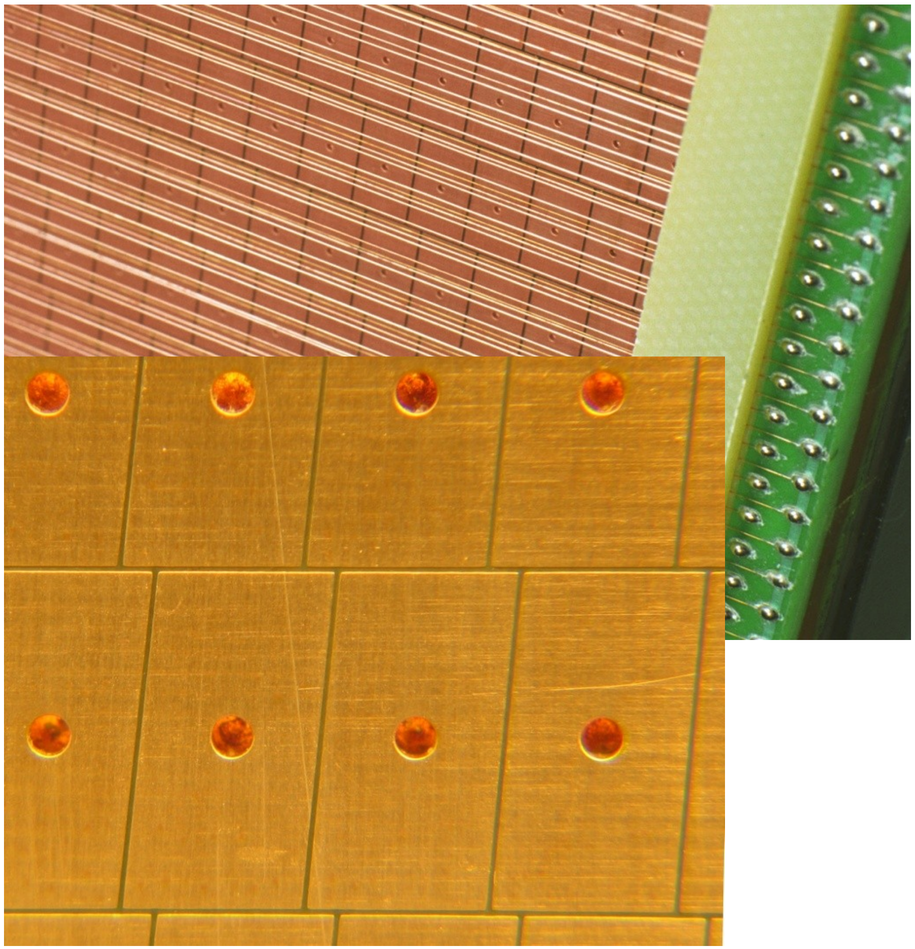


Outer Chamber



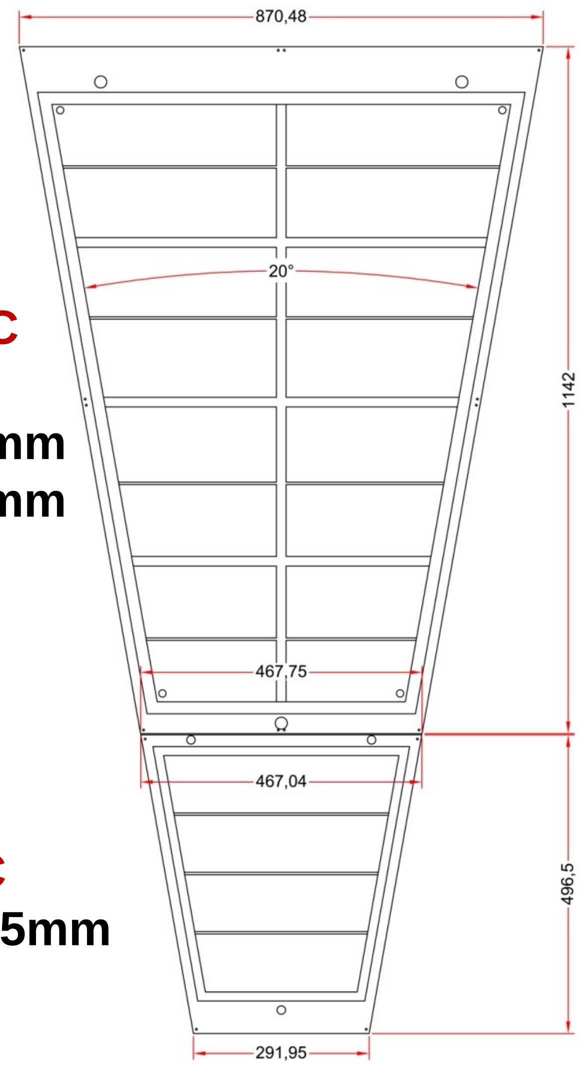
READOUT CHAMBERS

ONE OF THE 36 SECTORS

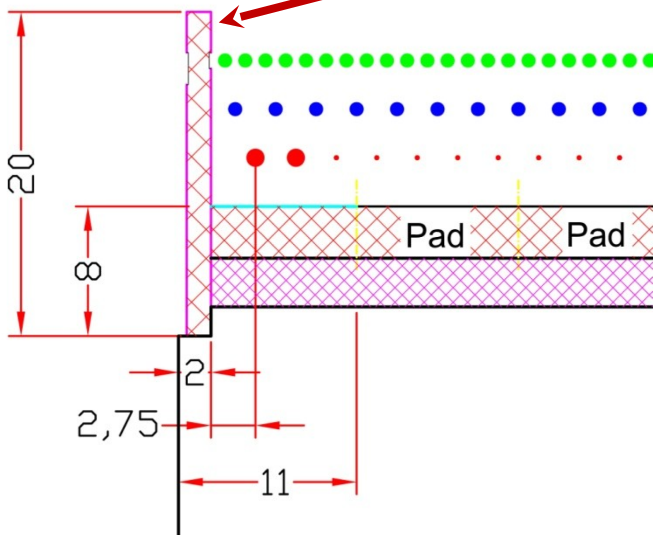


OROC
pads
6x10mm
6x15mm

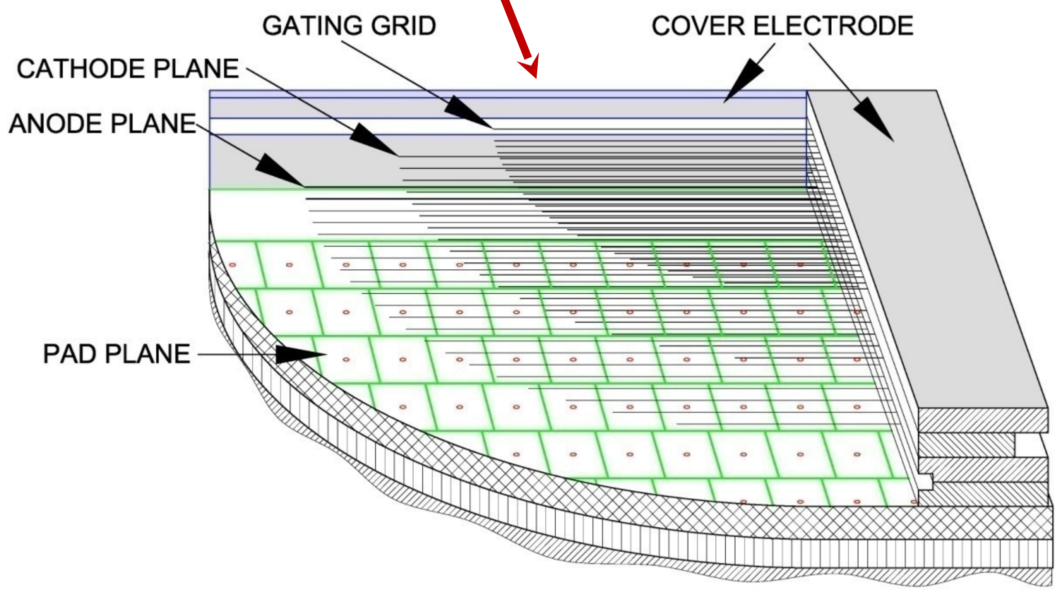
IROC
pads 4x7.5mm



Positive ion leakage protection ('cover electrode')



Gating-wire grid
Cathode-wire grid
Anode-wire grid

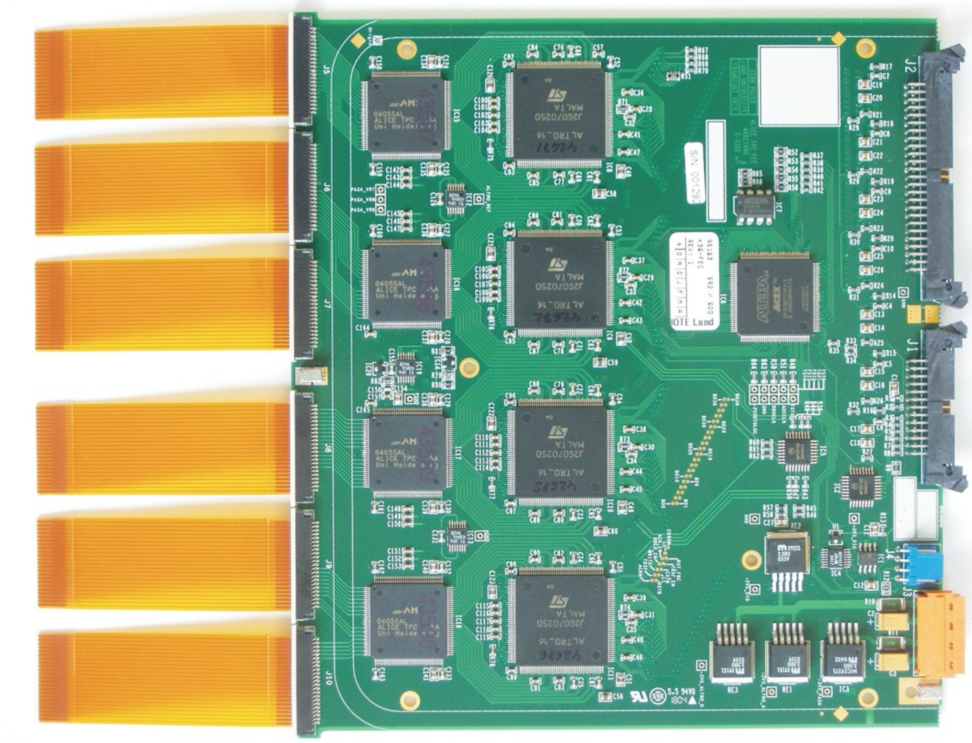


Very important to minimize ion leakage into drift volume

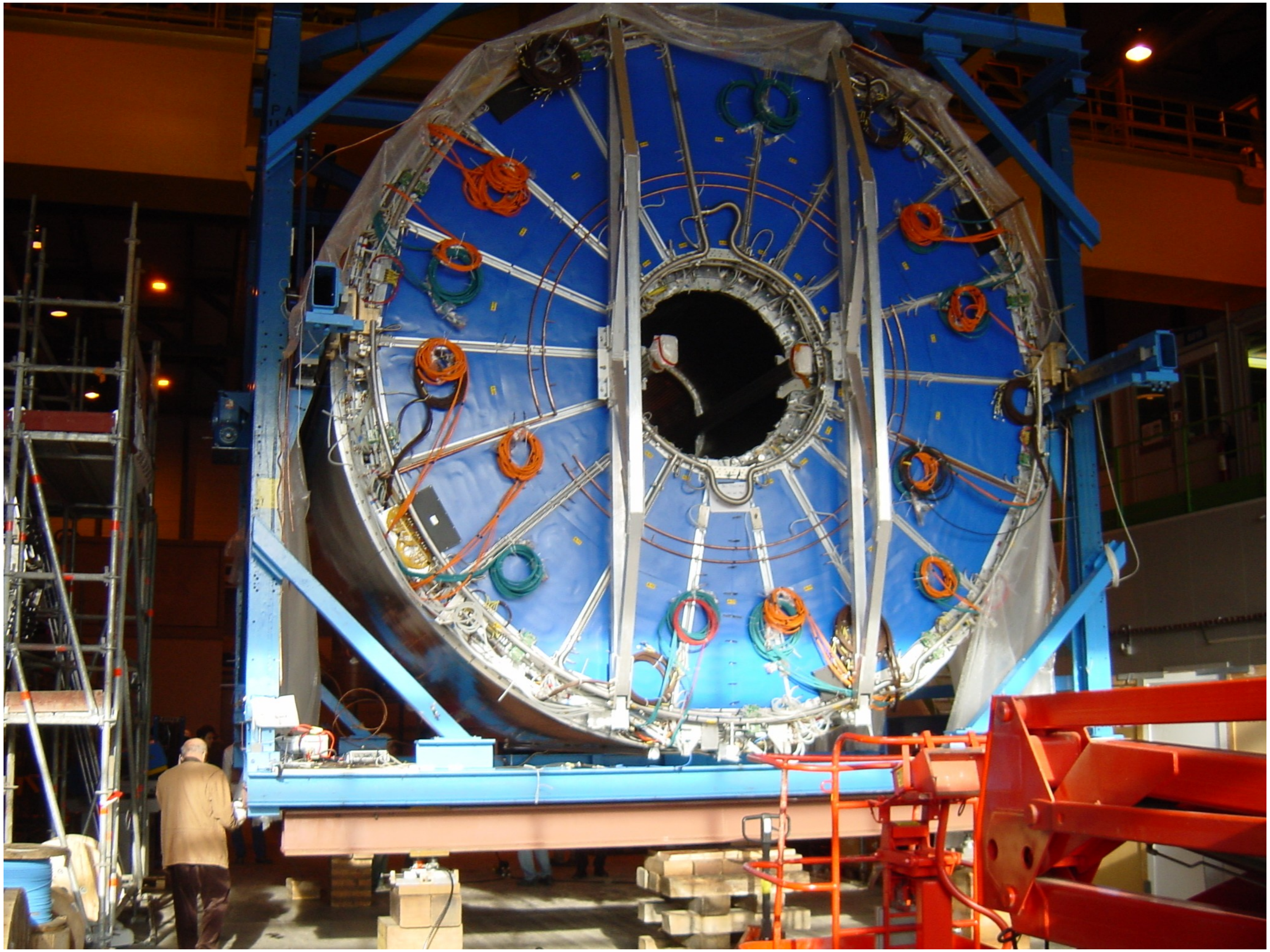
FRONT END ELECTRONICS AND READOUT

The signals from 557 568 pads are passed to Front-End Cards (FEC) via 7cm long flexible Kapton cables.
FEE is designed to cope with a signal occupancy as high as 50%. Furthermore the extremely large raw data volume (750MB/event) requires the zero suppression already in the FEE in order to fit events at the foreseen event rate into the DAQ bandwidth (216 links at 160 MB/s)

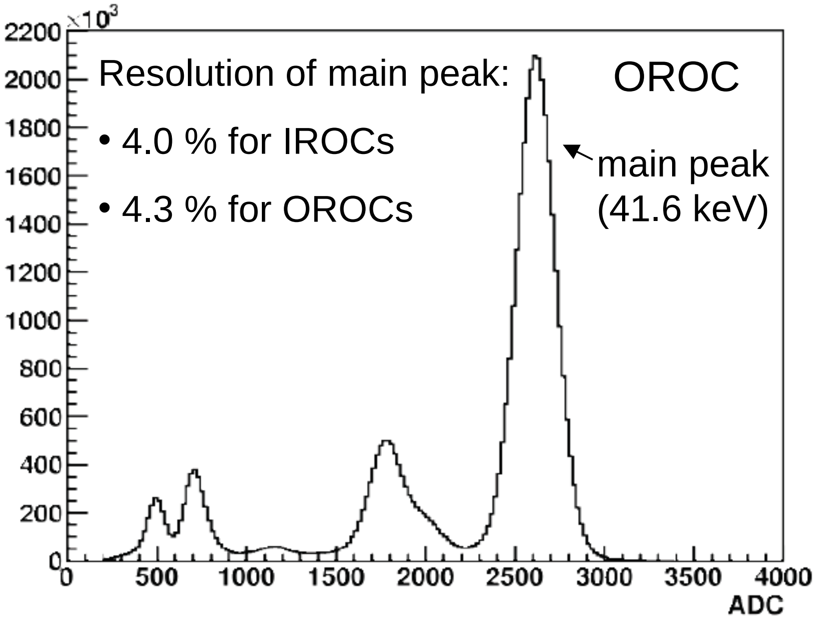
FEC with Kapton cables for 128 inputs.



Ready to move into the experiment



Gain calibration using Kr



Determine gain for each pad

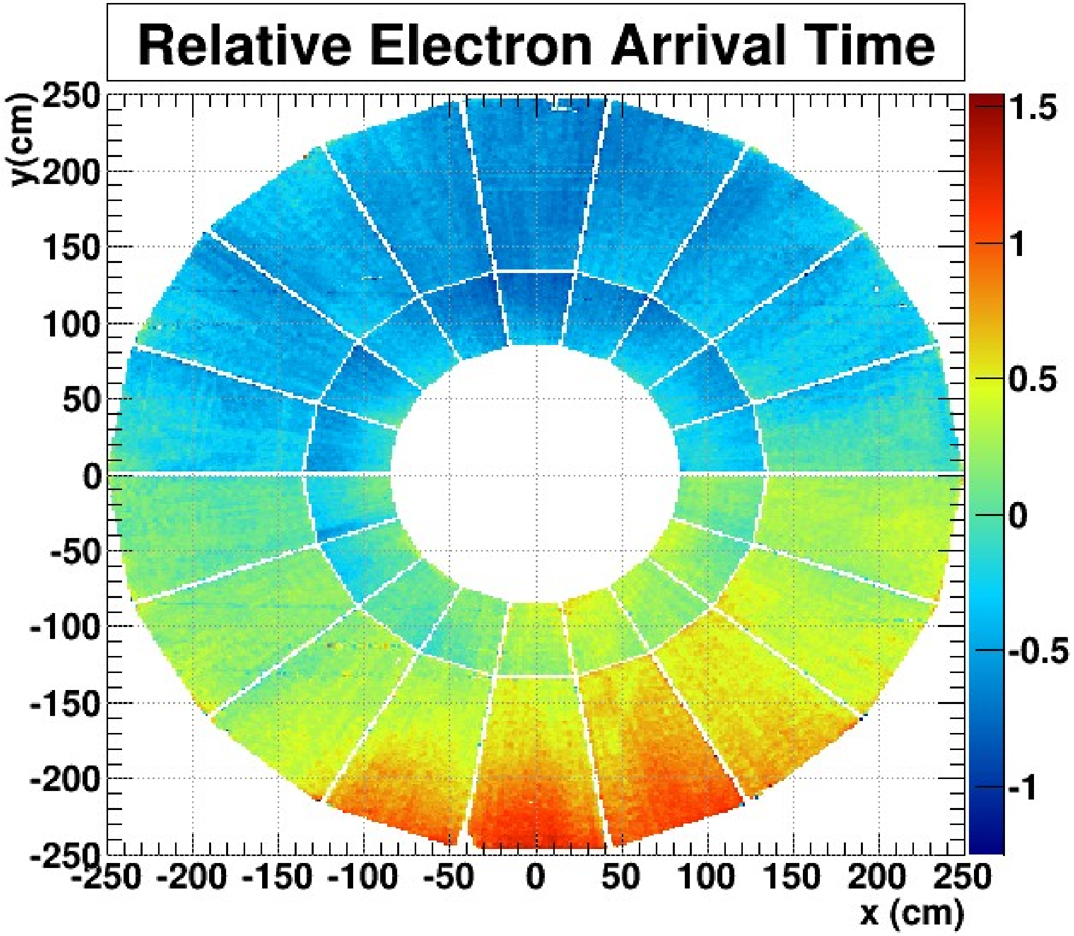
- 3 different HV settings (gains)
- High statistics: several 10^8 Kr events
- Accuracy of peak position: << 1% (design: 1.5%)

-> recent development:

Equalization on the sector-voltage level

Drift velocity calibration

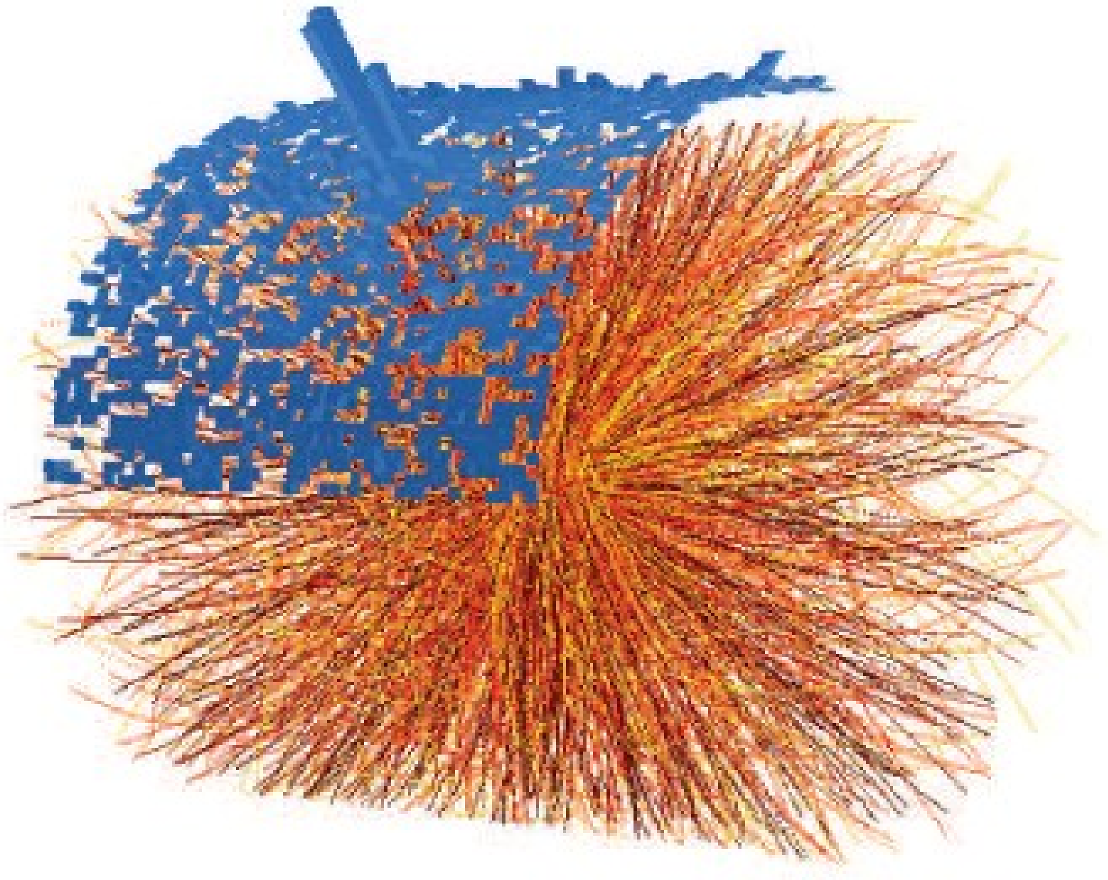
achieved temperature stability: < 50 mK
drift velocity precision: < 10^{-4}



Ne-CO2 mixtures are very sensitive to gas density
The drift velocity is measured with precision via the signal produced by stray laser light on the aluminised central electrode (by photoelectric effect)
The drift time gradient due to the pressure gradient is observed
(1 time bin = 100 ns)

ΔVd ~ 0.35 % per K
Δgain ~ 1 % per K

ALICE TPC performance in beam



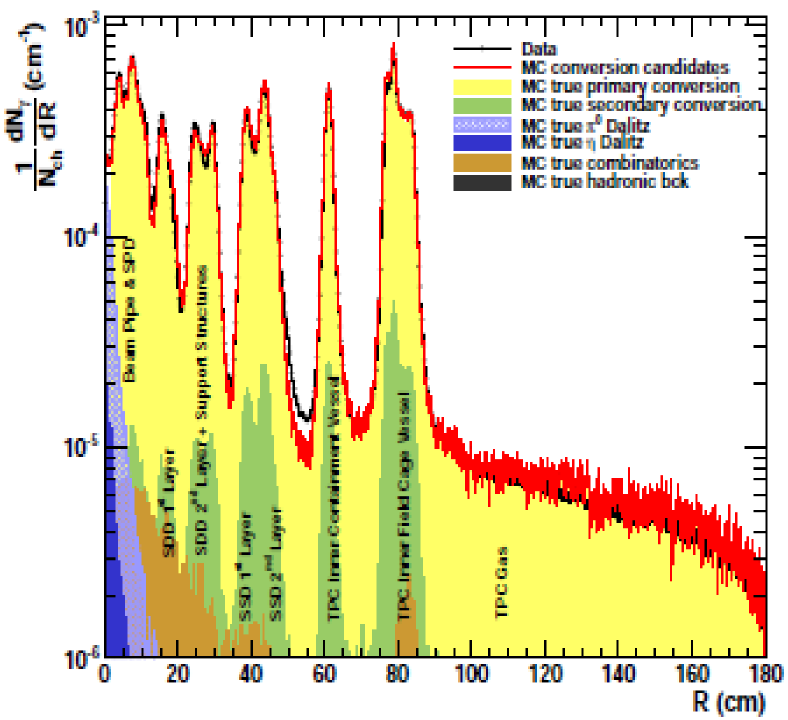
a central Pb—Pb event with a jet
charged particle multiplicity > 3500

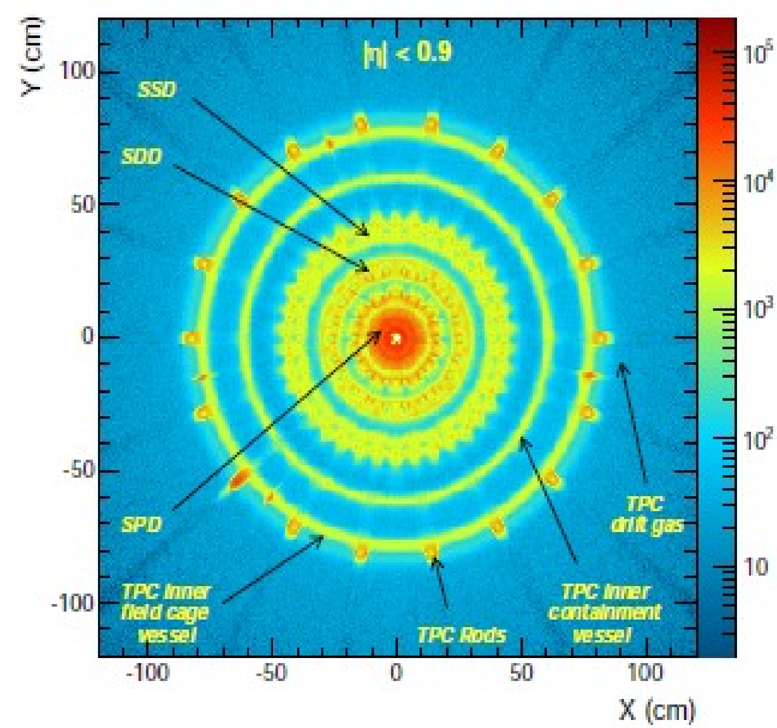
Material budget through photon conversion measurements

Inner FC 1.367% X/Xo

Outer FC 2.153% X/Xo

Radial distribution

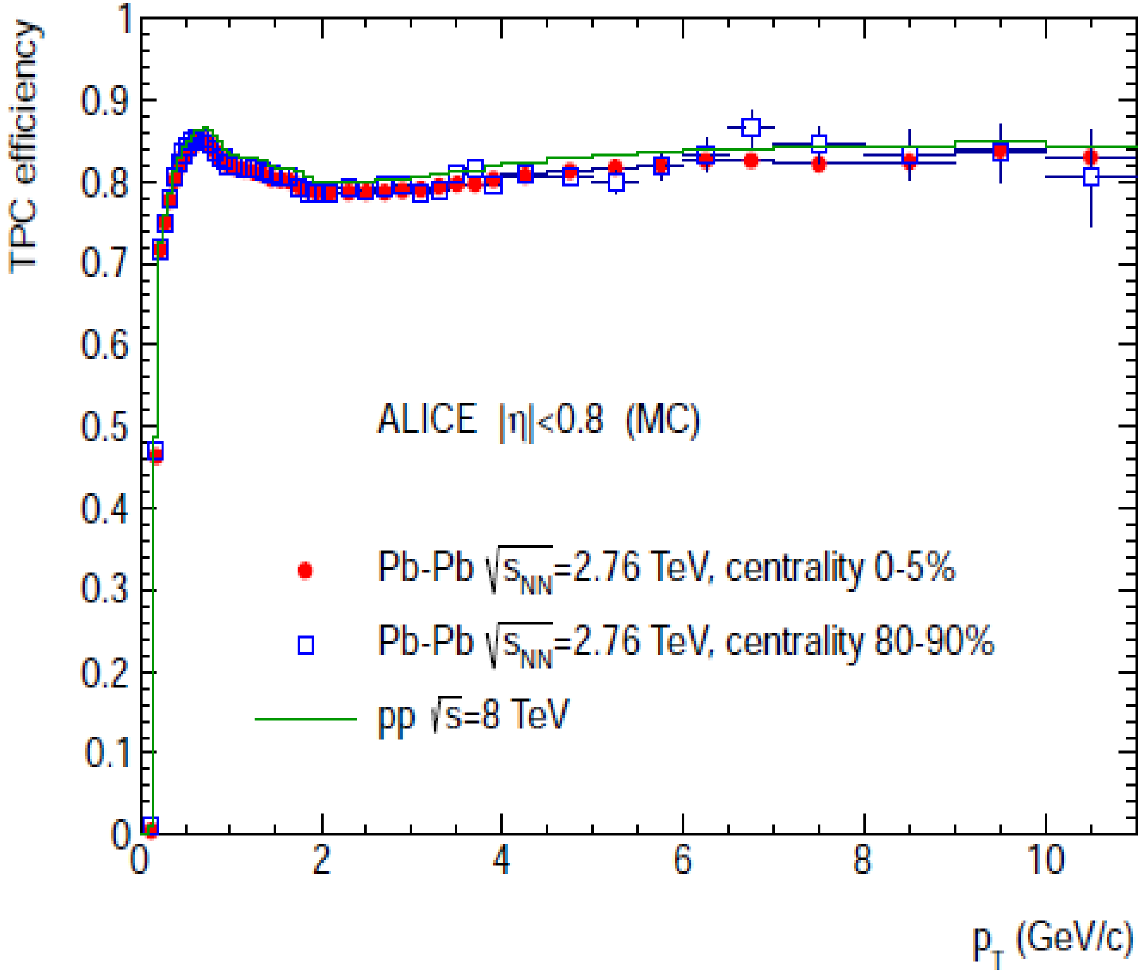




TPC begins here

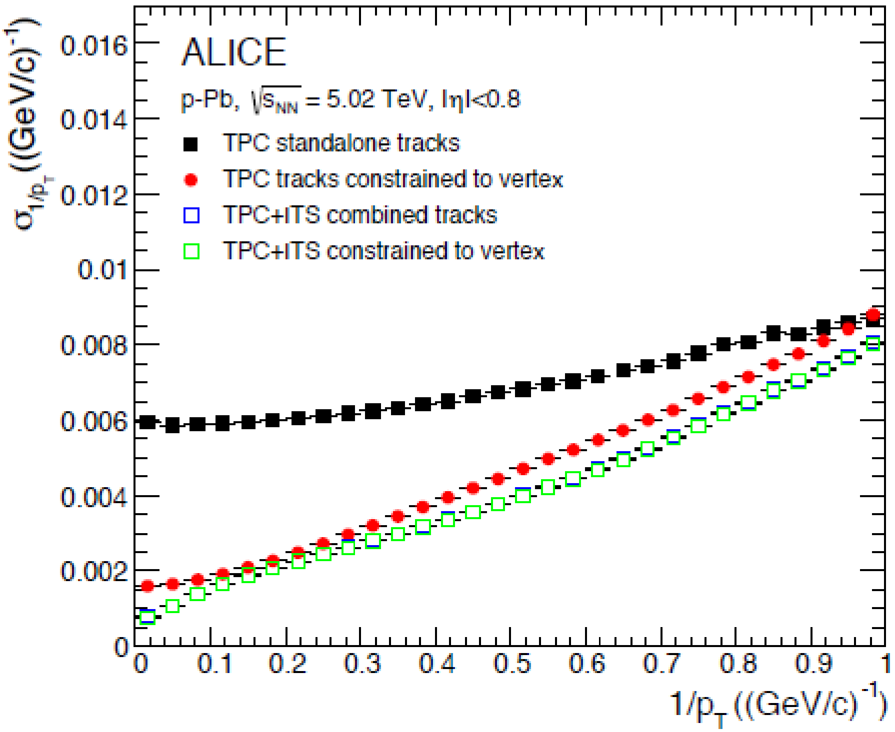
Agreement between MC and DATA: 5.5% in |η|<0.9

Tracking efficiency



Tracking accuracy

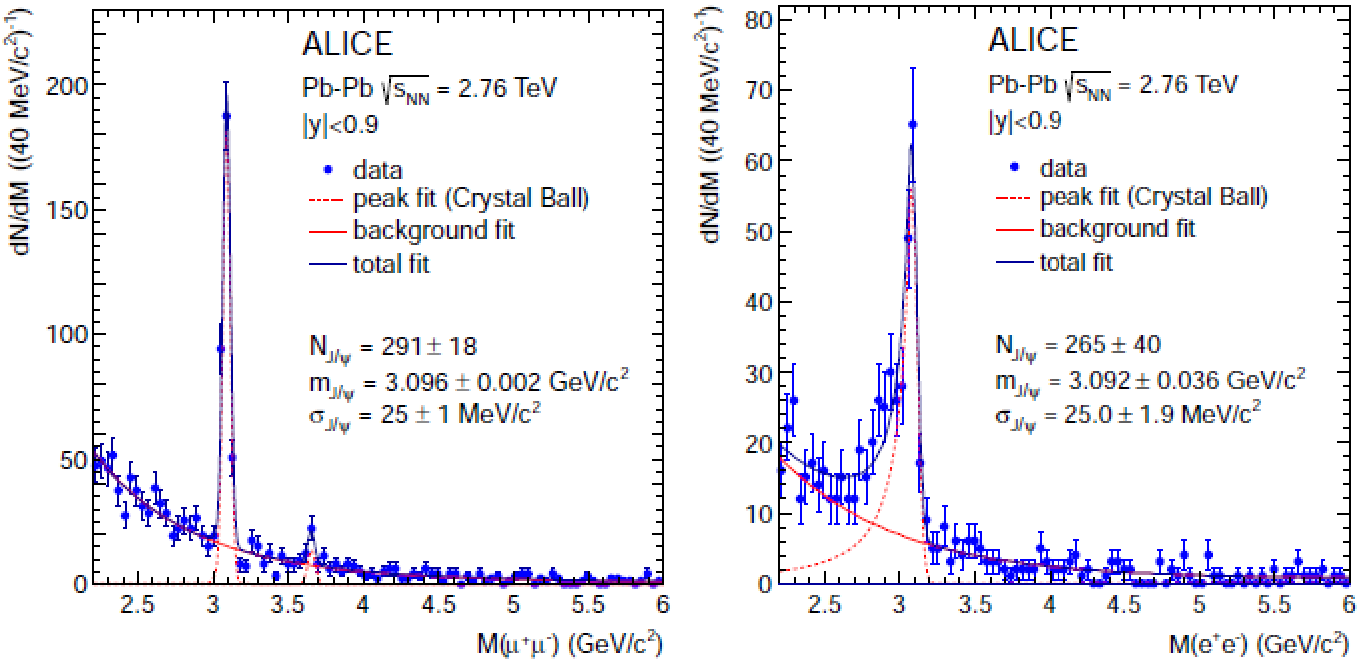
$$\frac{\sigma_{p_T}}{p_T} = p_T \, \sigma_{1/p_T}$$



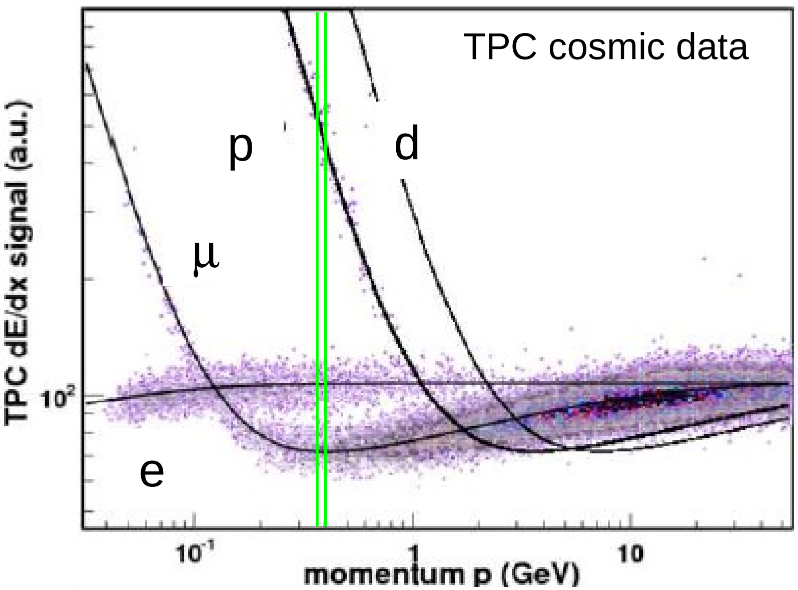
This implies

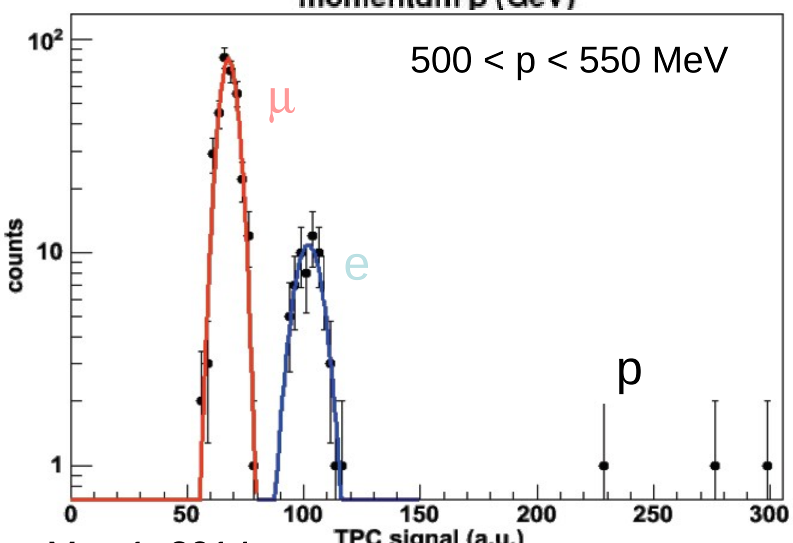
- $\sigma pT/pT \lesssim$ 3.5 % at 50 GeV/c
- $\sigma pT/pT \lesssim$ 1 % at 1 GeV/c
- Matching to external detectors significantly improves resolution at high pT

Tracking accuracy
J/psi measurement in ultra-peripheral Pb-Pb collisions



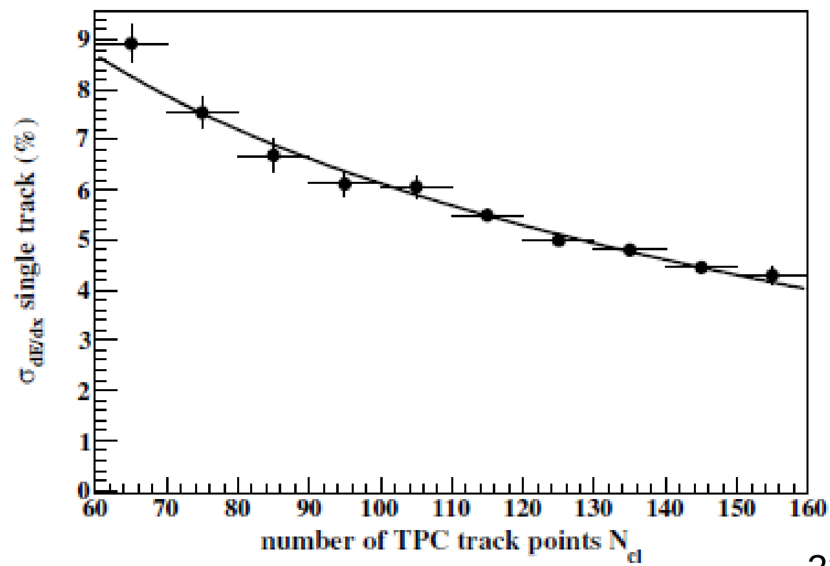
dE/dx resolution - cosmics



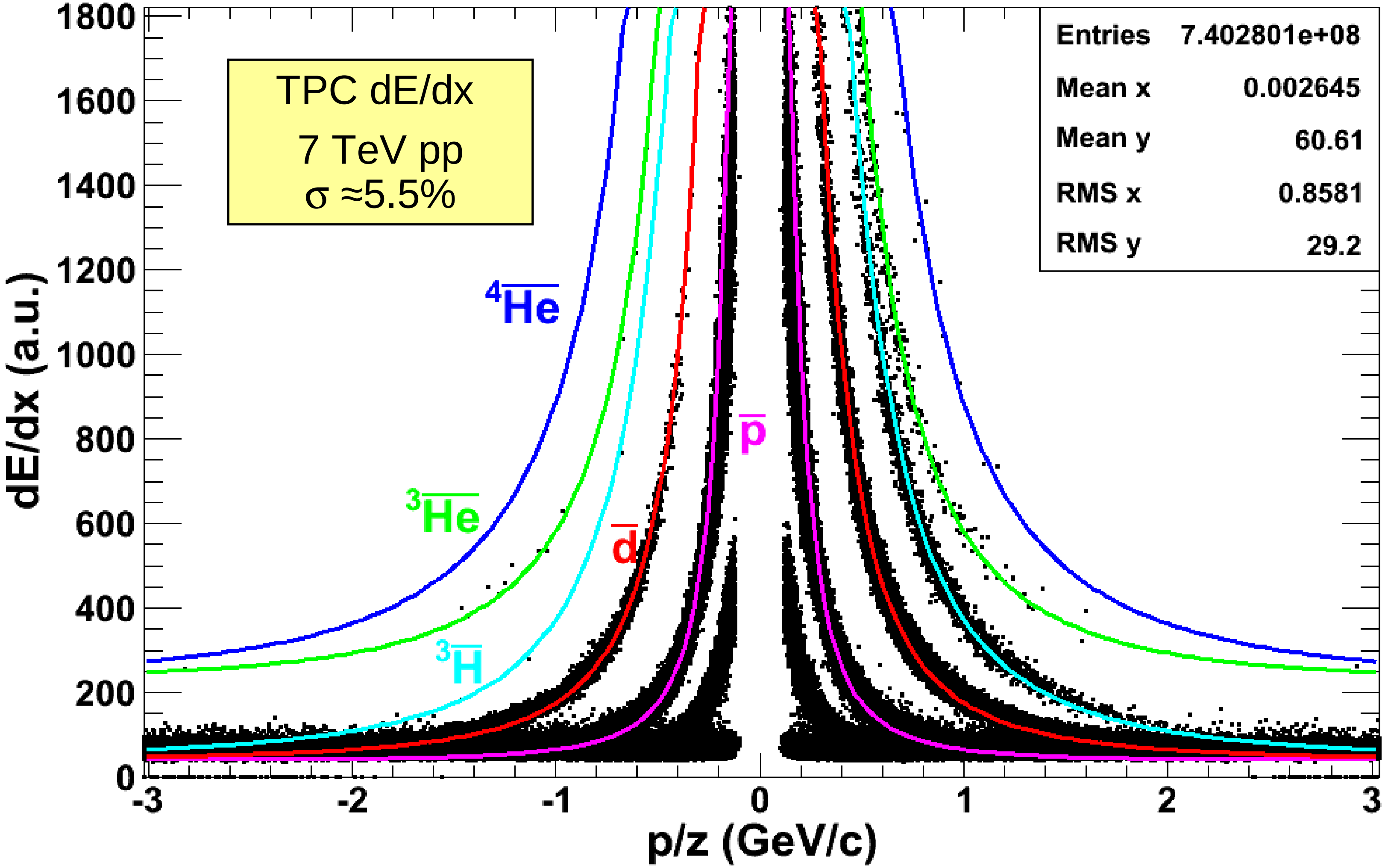


Allows particle identification up to 50 GeV/c

- Statistics: 8.3×10^6 cosmic tracks in 2008
- Design goal: 5.5 %
- Measured: < 5 %



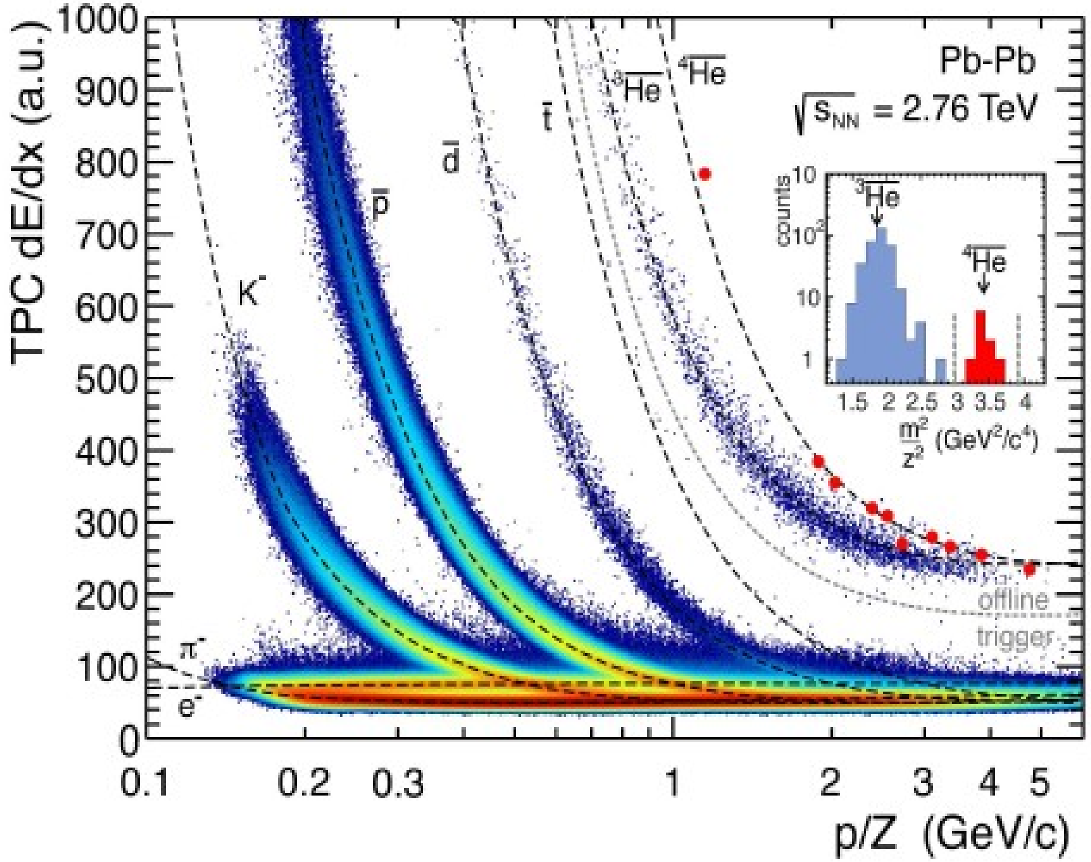
dE/dx resolution - pp



dE/dx resolution - Pb--Pb

TPC dE/dx

Pb--Pb
σ ≈7%



dE/dx resolution - Pb--Pb

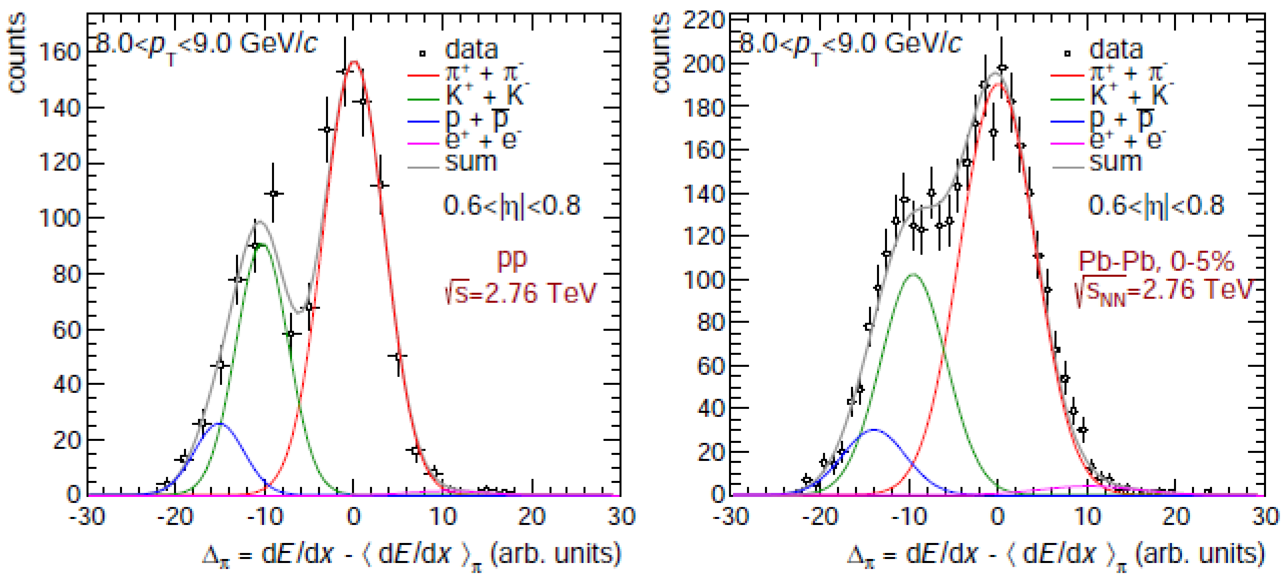
TPC dE/dx

Pb--Pb

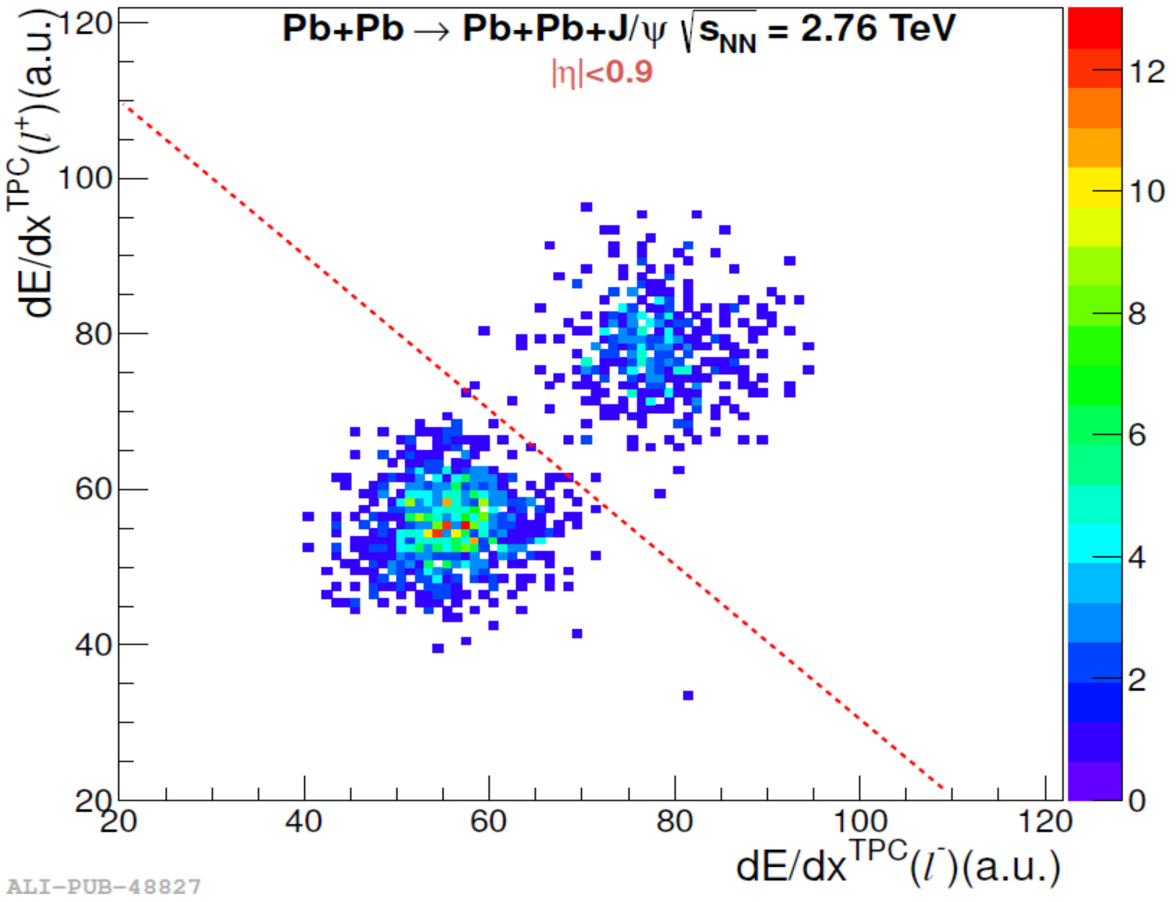
σ ≈7%

Particle identification in the relativistic rise:

pi/K/p separation possible up to 30 GeV

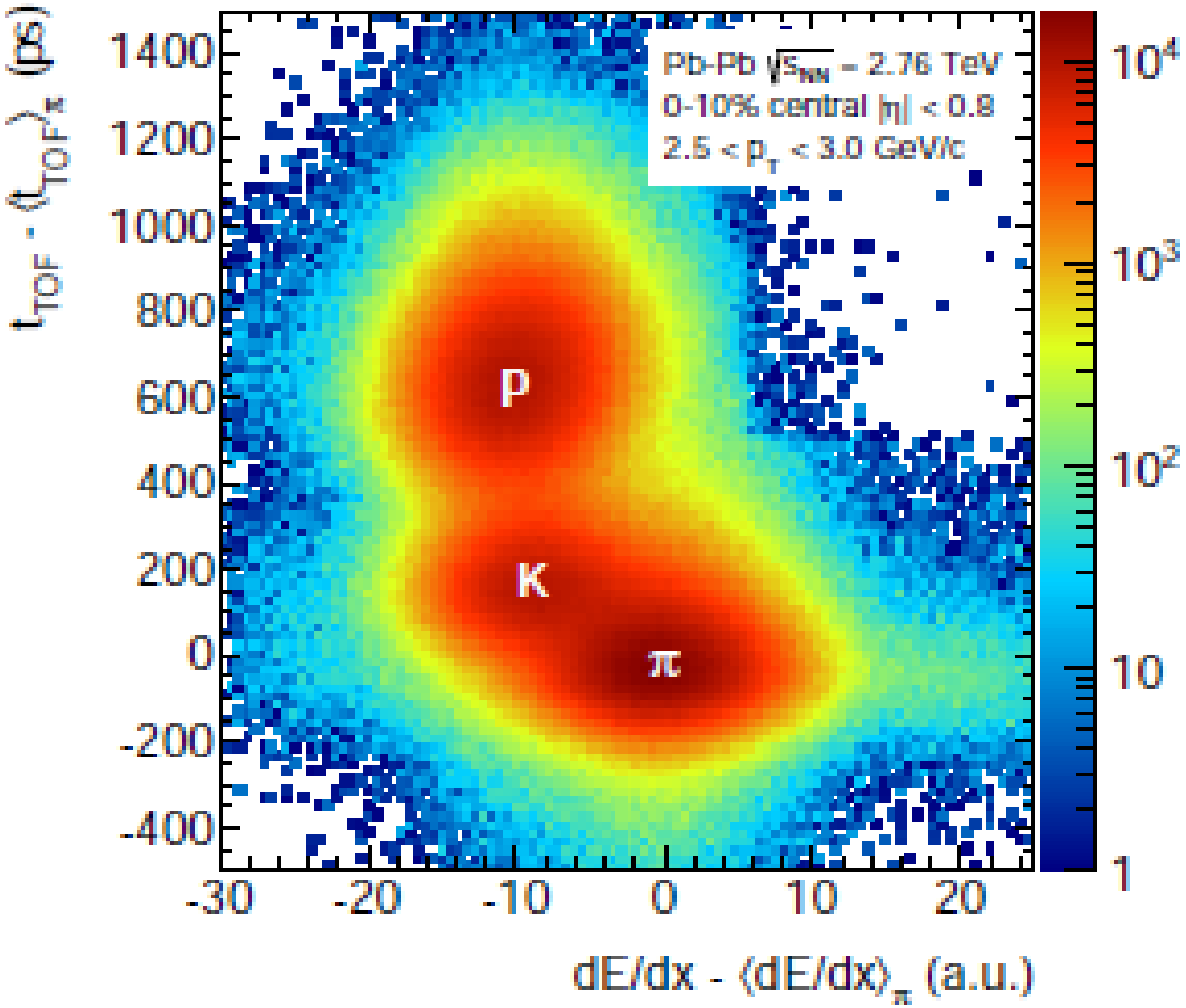


electron-muon separation in the ALICE TPC



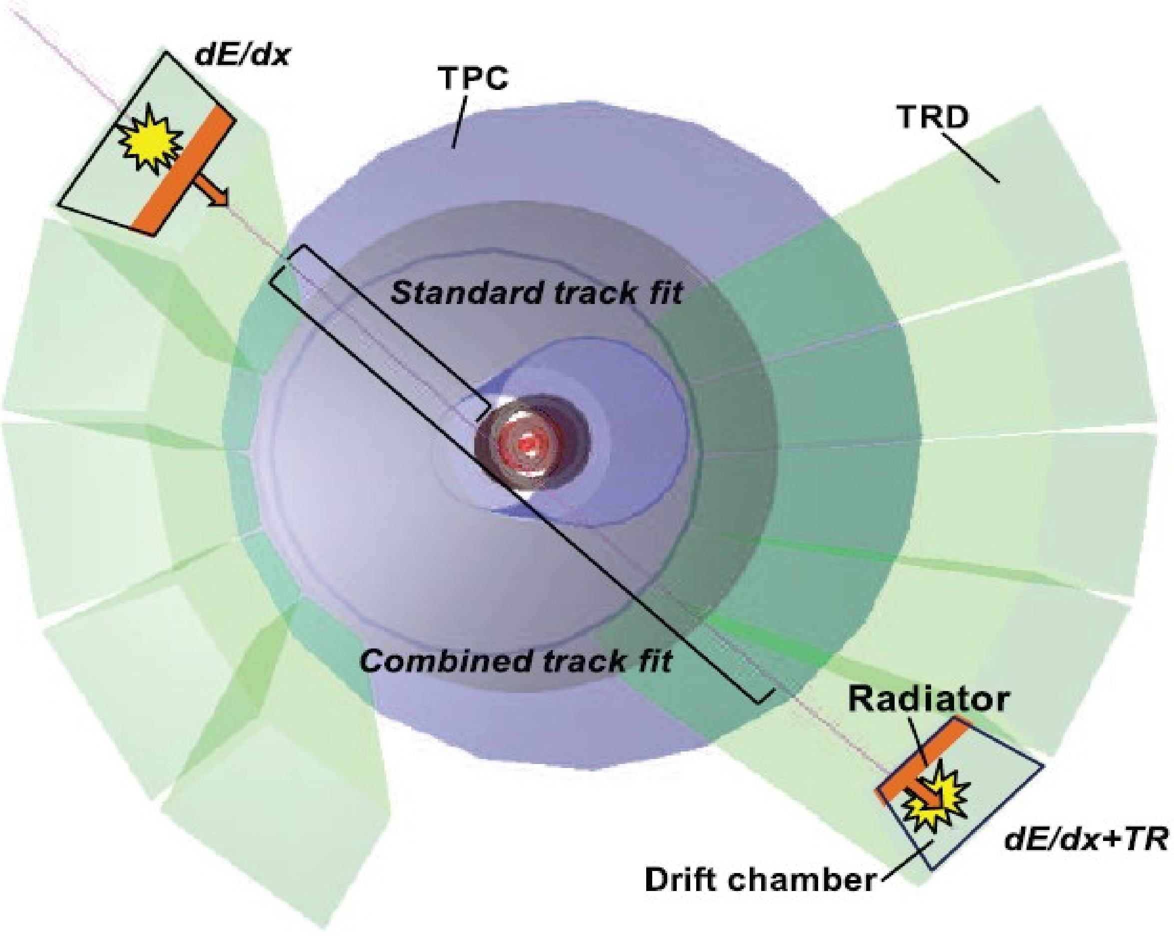
dE/dx of the positive lepton as a function of the negative one, as measured in the TPC for J/ψ candidates

muons and electrons are clearly separated, with the latter showing an higher dE/dx



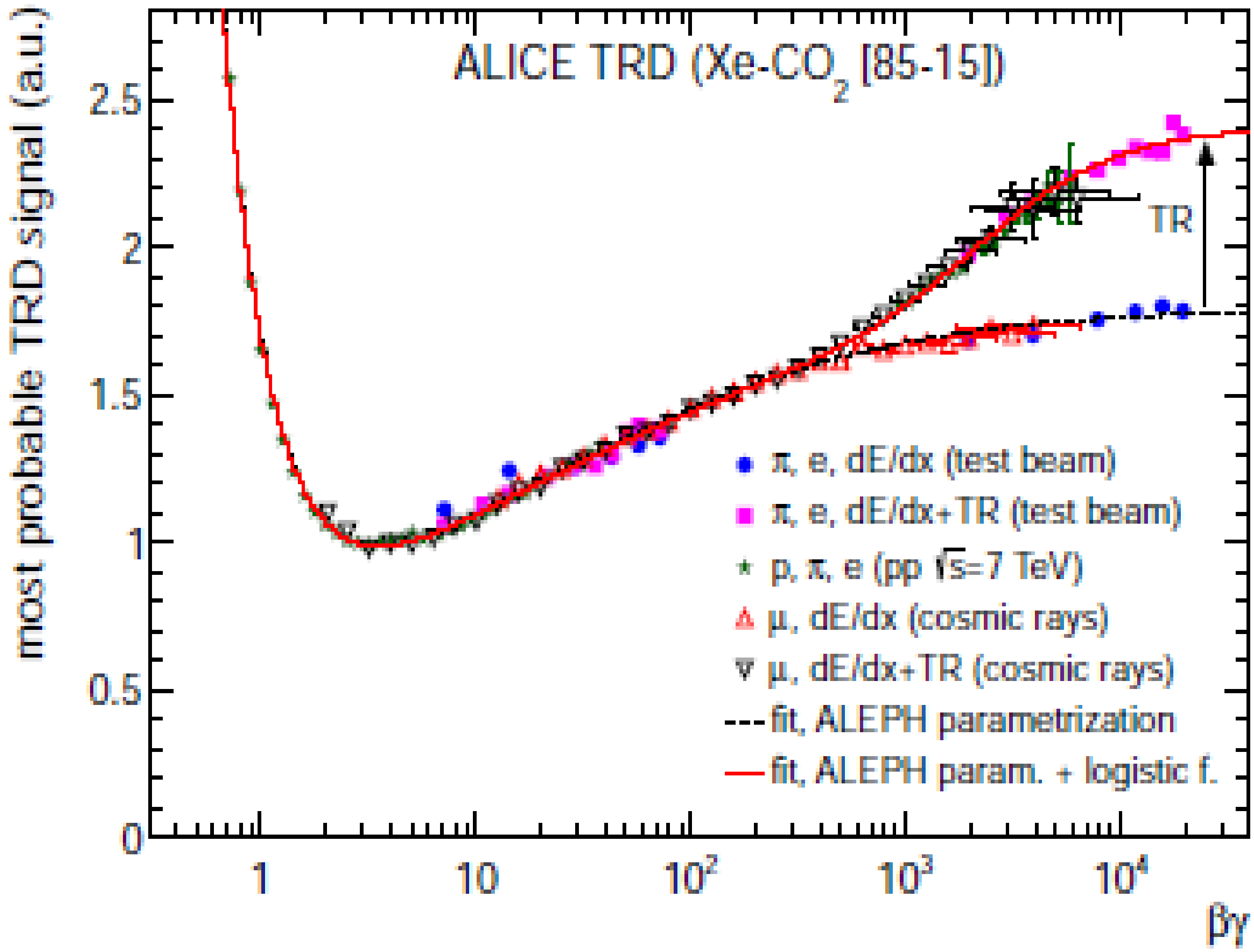
Combined pion identification with TOF and with dE/dx in the TPC.

TRD performance with TPC-TRD combination and cosmics

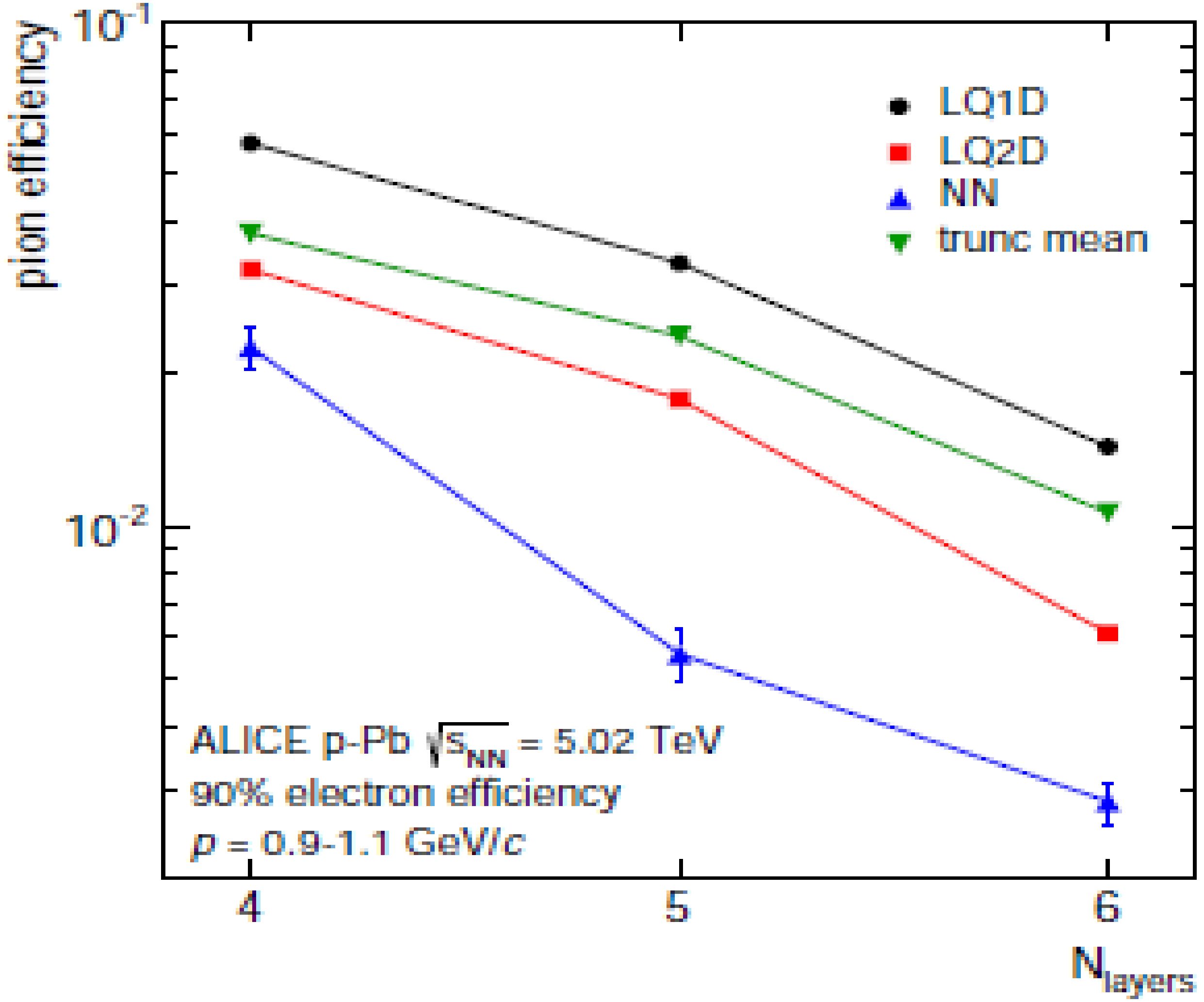


Separation of energy deposit from dE/dx and from transition radiation via measurement of cosmics through the TPC and the TRD

TRD performance with TPC-TRD combination and cosmics



TRD performance – pion rejection



Plans for Run 2   2015 - 2017

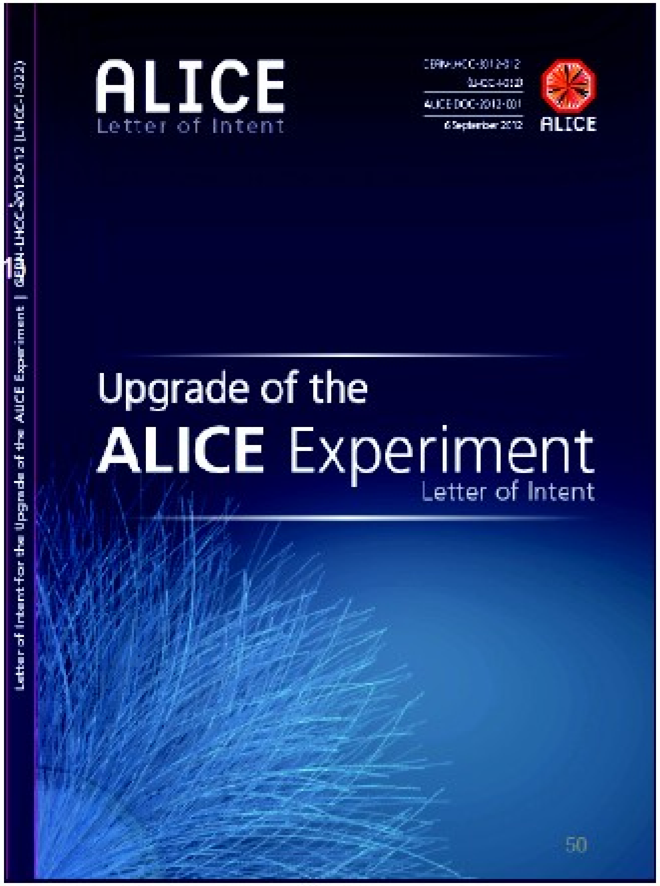
- Pb—Pb interaction rate 20 kHz
- Double read-out rate to about 500 Hz for central collisions by new read-out control unit (RCU2) and increased fiber-optics band width
- Partial on-line calibration and full on-line cluster finding

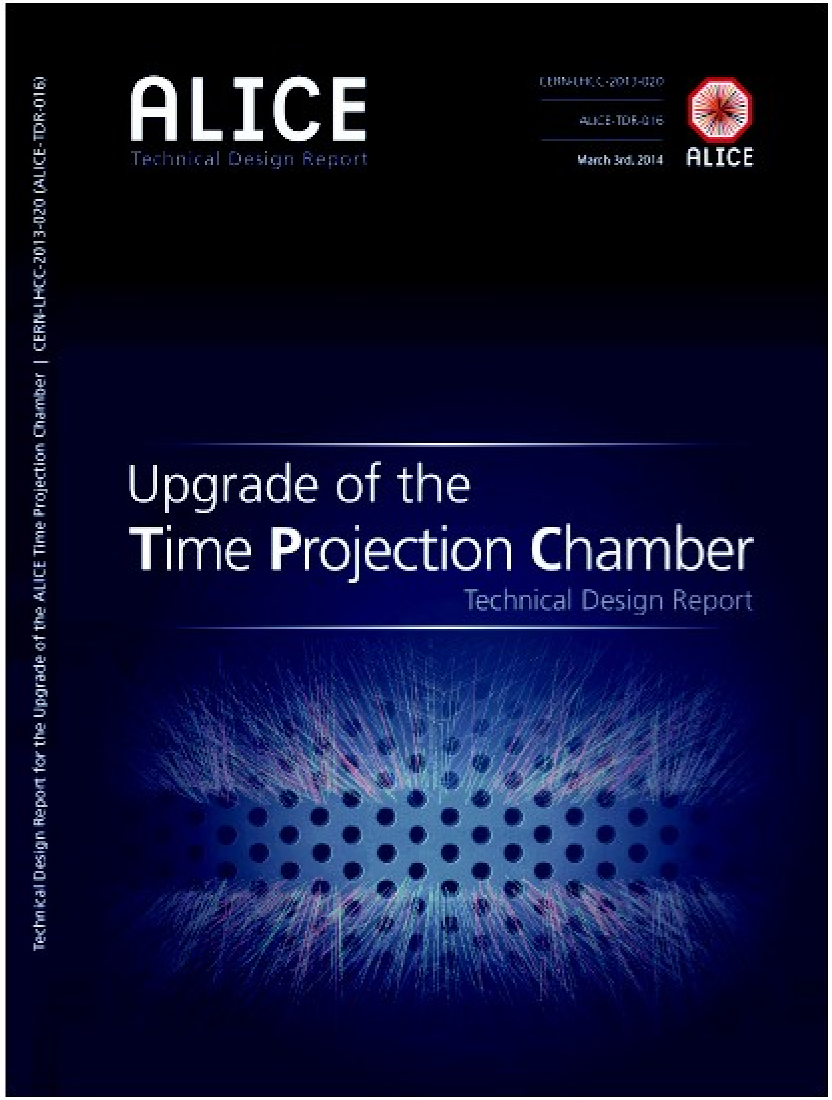
Run 3 plans – 2019 - 202x

- Replace current MWPC read-out chambers with GEM based chambers
- Provide continuous read-out for 50 kHz Pb—Pb collisions
- Complete on-line calibration and partial on-line tracking to correct for space charge distortions on a 1-2 ms basis and to reduce data volume
- Upgrade to take place in 2018-2019 (LS2)

Run 3: upgrade overview

- The ALICE upgrade strategy is outlined in the Letter Of Intent
  - CERN-LHCC-2012-012 ; LHCC-I-022
  - http://cds.cern.ch/record/1475243
- Operate ALICE at high luminosity ($\mathcal{L}$=6x10^{-27} $cm^{-2}s^{-1}$) and record all minimum bias events
  - 50 kHz in Pb-Pb collisions → 100 x larger than the current read-out rate
  - 5 overlapping events in TPC drift volume → TPC can not run in triggered mode
- The TPC upgrade is described in a Technical Design Report




ALICE
Technical Design Report
March 3rd, 2014
ALICE
Upgrade of the
Time Projection Chamber
Technical Design Report
Technical Design Report for the Upgrade of the ALICE Time Projection Chamber | CERN-LHCC-2013-020 (ALICE-TDR-016)

Upgrade design objectives

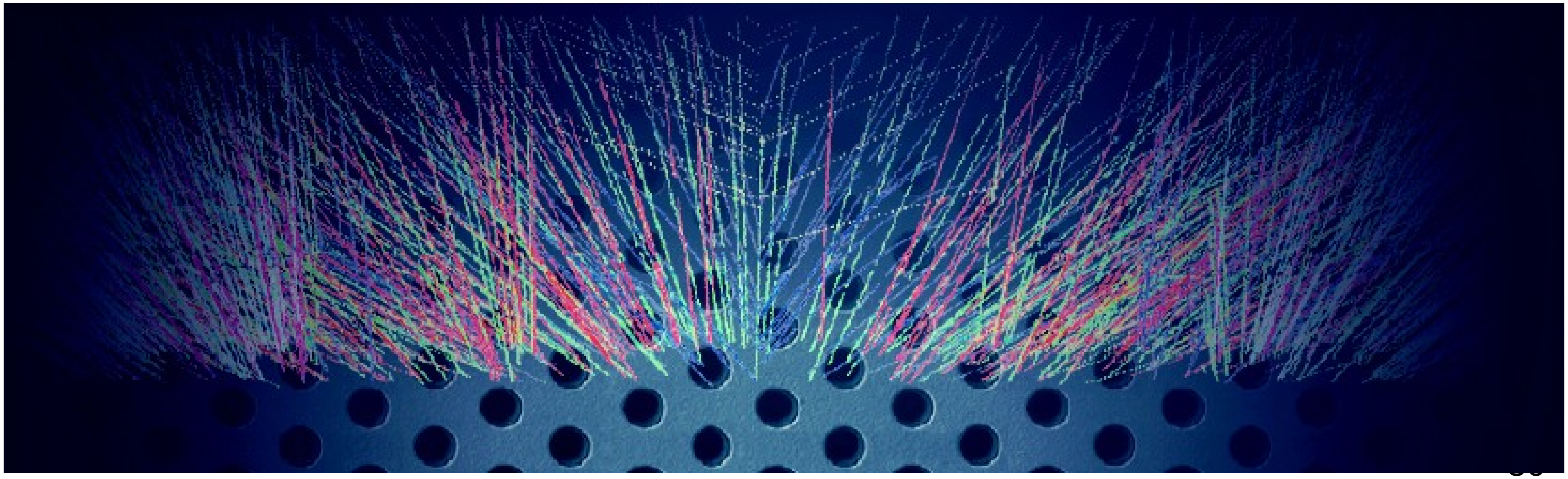
- In order to store all minimum bias events the TPC will have to be read out continuously

➔ A gating grid can not be used to block ions from entering the drift region

- But the space charge in the drift region has to be kept small

➔ Need different ion blocking mechanism (GEMs)

- Detector performance must be retained



summary

- The ALICE TPC is the key detector for particle ID and tracking in the central barrel

- Resolutions in momentum and dE/dx exceeding the original specifications have been achieved at track densities corresponding to dN/dy = 2000 and at interaction rates of 5 kHz for Pb—Pb collisions

- For the upcoming Run 2 at full LHC energy the TPC read-out will be significantly upgraded to record 500 Hz central Pb—Pb collisions

- On-line calibration and data reduction is key to the success of this run

- For Run 3 in 2019+ 50 kHz operation is planned. This implies new end-plate read-out technology (GEMS) and continuous read-out along with on-line calibration and tracking

The anticipated physics output is well worth
the major effort to realize these ambitious plans

We owe much of this success to the original ideas and insights of David Nygren, first realized for the PEP4 TPC

Thank you!