Performance and future plans of the ALICE experiment

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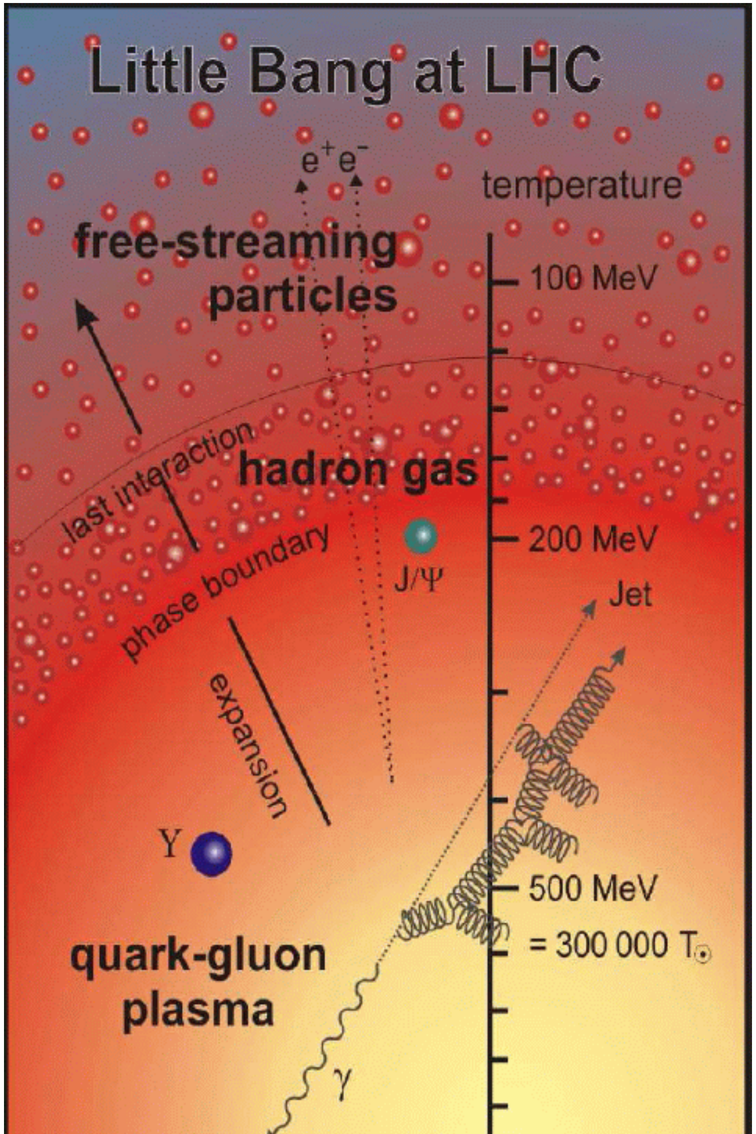
ALICE, only dedicated HI experiment at LHC



soft

hard probes

☞ What do we measure?

- global observables:
  multiplicities, rapidity distributions
- geometry of the emitting source:
  HBT, impact parameter via zero-degree energy flow
- early state collective effects:
  elliptic flow
- chiral symmetry restoration:
  neutral to charged ratios, resonance decays
- fluctuation phenomena - critical behavior:
  event-by-event particle composition and spectra
- degrees of freedom as a function of T:
  hadron ratios and spectra,
  dilepton continuum, direct photons
- deconfinement:
  charmonium and bottonium spectroscopy
- energy loss of partons in QGP:
  jet quenching, high p_t spectra,
  open charm and open beauty

Heavy Ion Challenges Guide Design of ALICE

☞ Experimental Challenges & ALICE Solutions

1. Extreme particle densities (Pb+Pb $dN_{ch}/d\eta$ ~2000)

   1000 times pp at LHC, 2-4 times Au+Au at RHIC

➔ ALICE solution for particle densities: high granularity 3D tracking, long path-length from interaction vertex (e.g. EMCal at 4.5m)

2. Large dynamic range in p_T

   from very soft (0.1 GeV) to fairly hard (>100 GeV)

➔ ALICE solution to extend p_T range: thin detectors, modest fields (low p_T), large lever arm for tracking & resolution at large p_T
ALICE: < 10% X_0 inside r <2.5m, B=0.5T, BL^2 ~CMS

3. Measure & ID many hadrons

   requires: secondary vertices, leptons ID, hadron ID

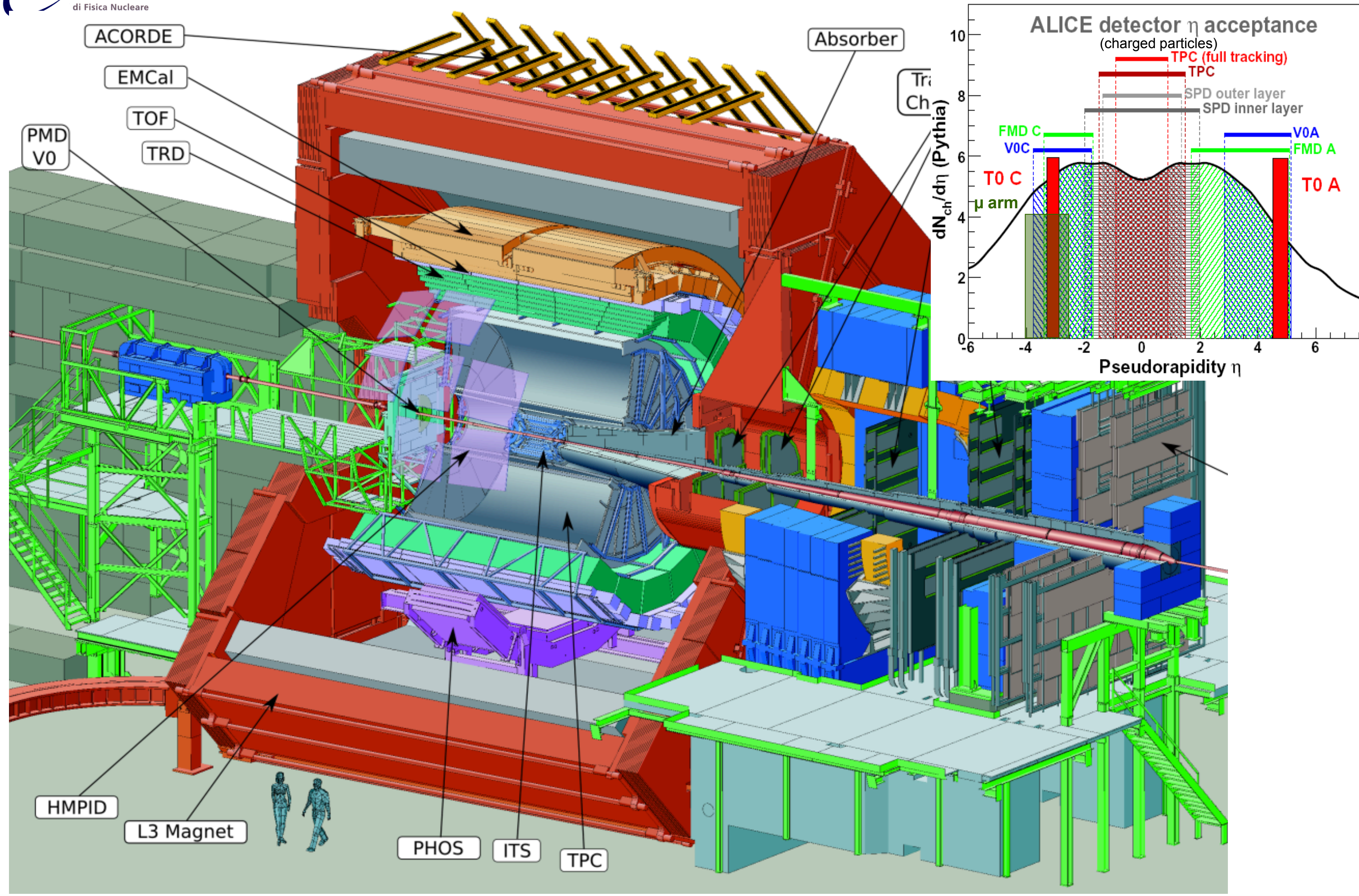
➔ ALICE solution for extended particle ID: employ many technologies dE/dx, Cherenkov & transition rad, TOF, calorimeters, muon filter, topological, …

\+ Modest luminosity and interactions rates

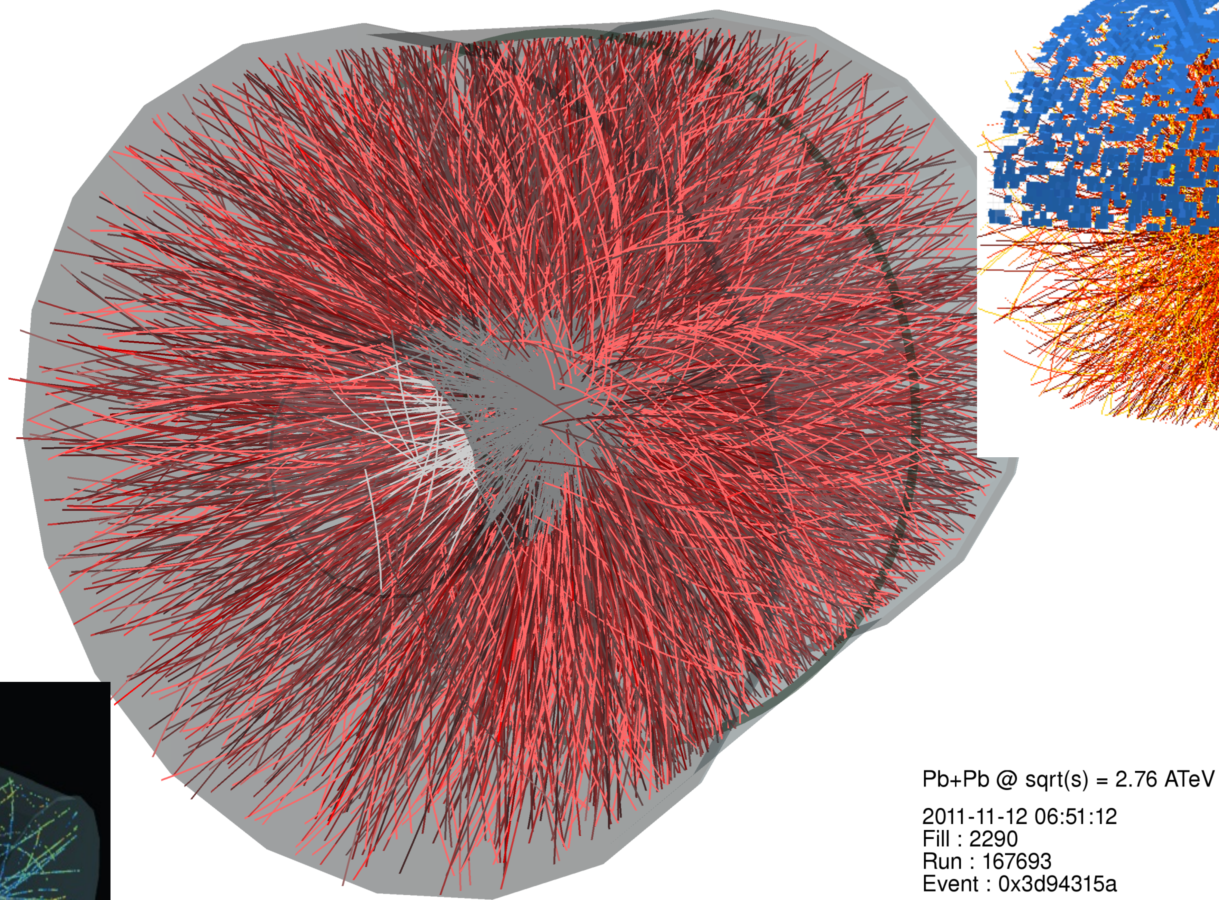
   10 kHz (Pb+Pb)

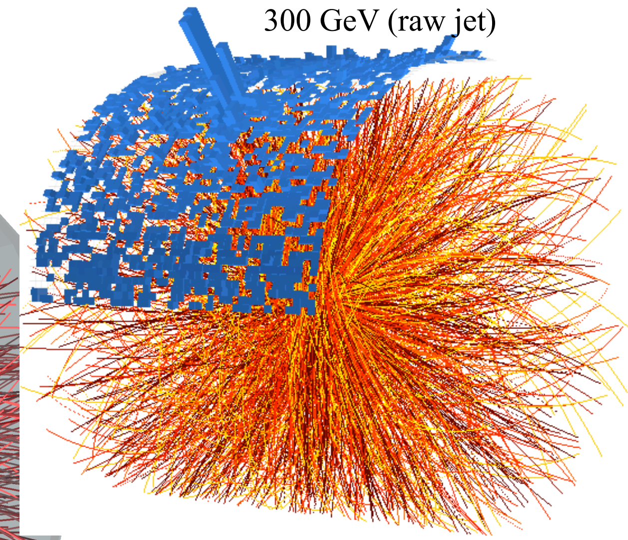
➔ ALICE rates allow slow detectors (TPC, SDD) and moderate radiation hardness

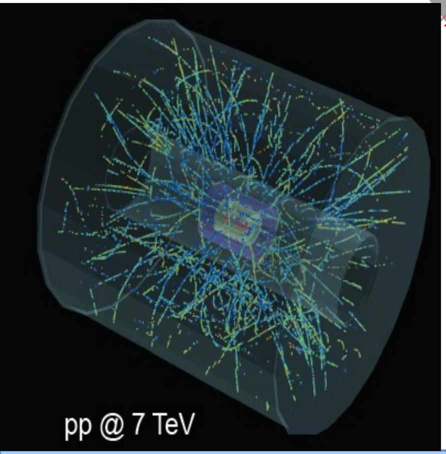
The ALICE Detector



Events in ALICE

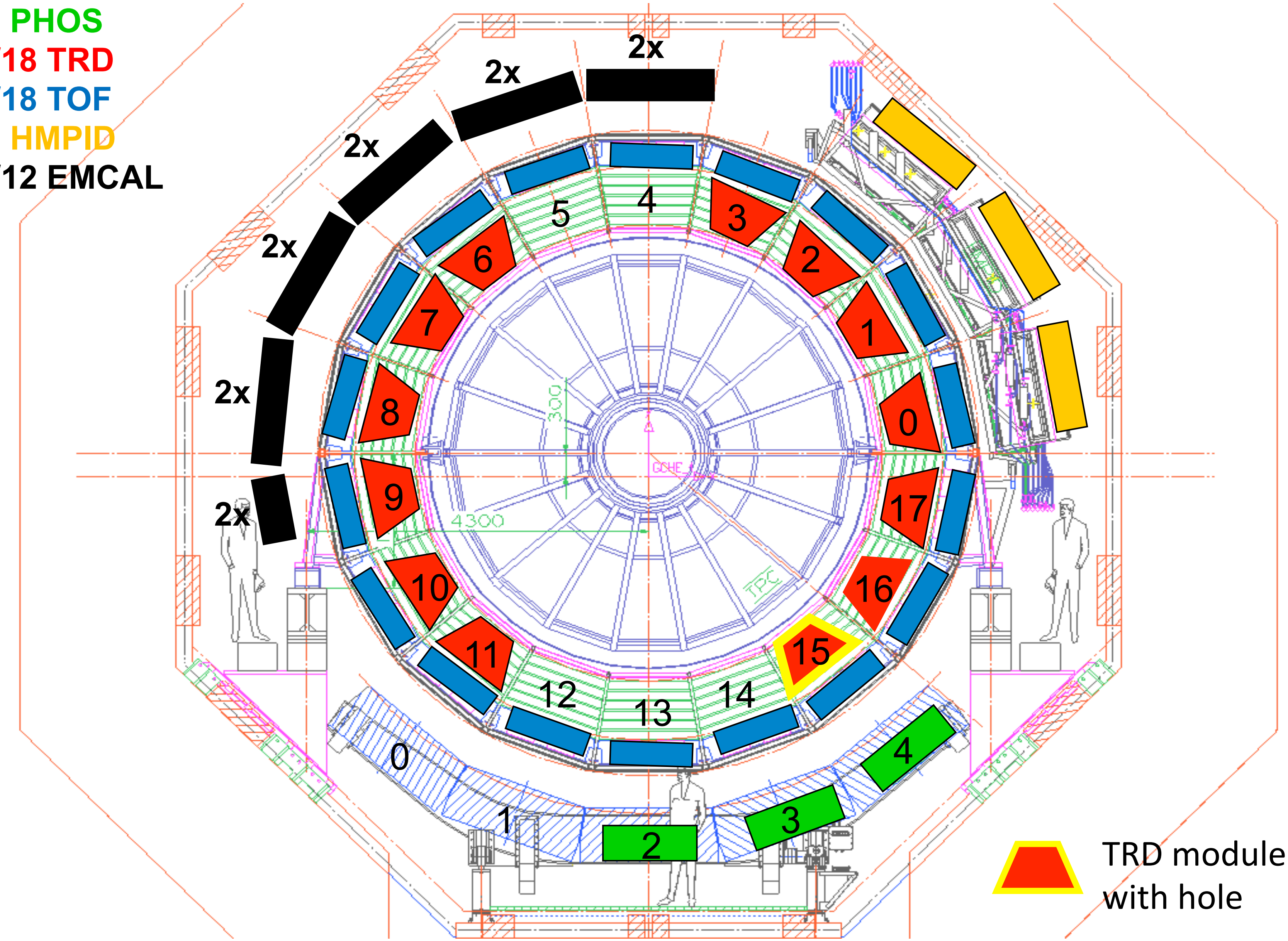






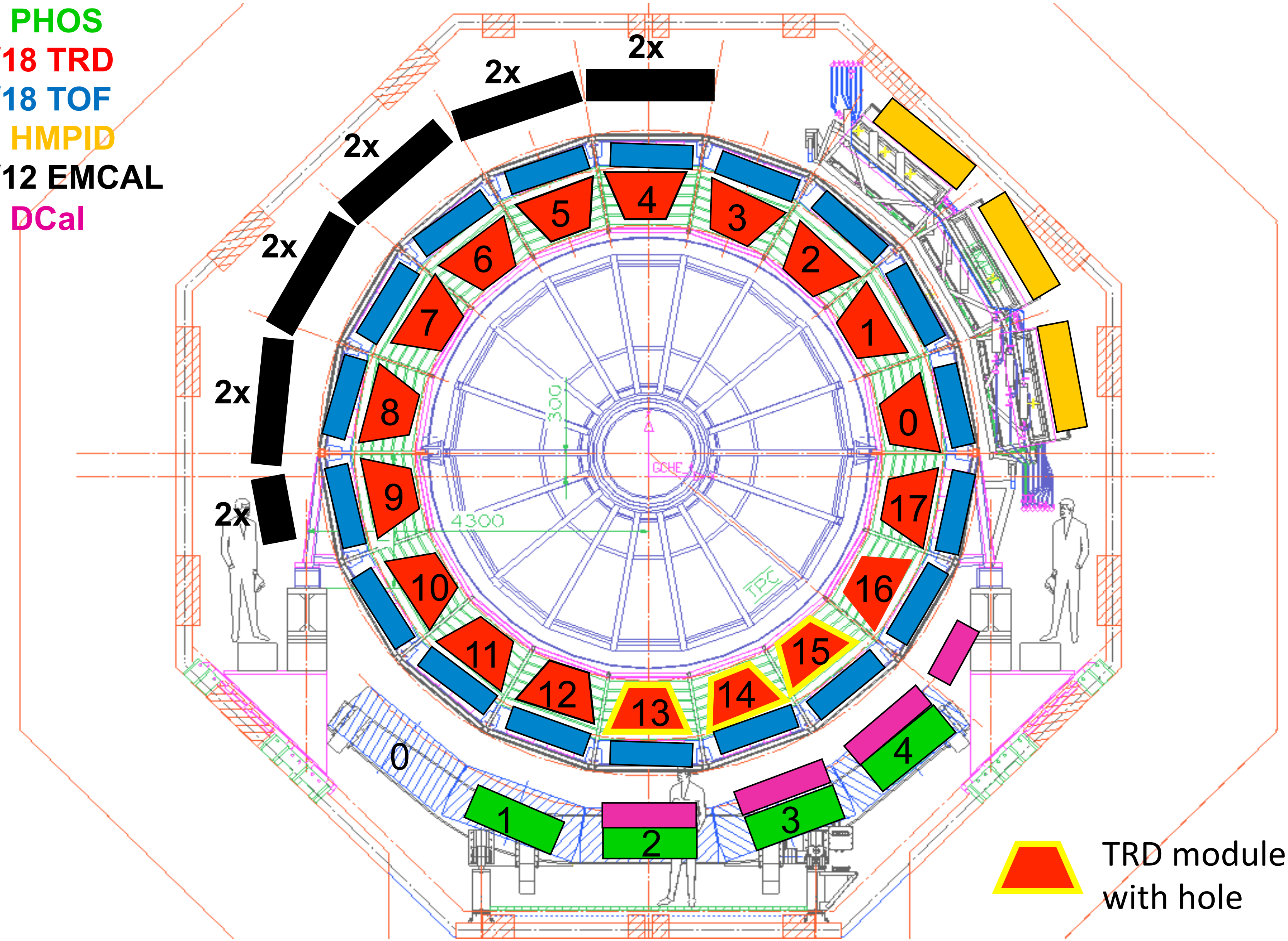
2012 ALICE setup

3/5 PHOS
13/18 TRD
18/18 TOF
7/7 HMPID
12/12 EMCAL



ALICE setup after LS1

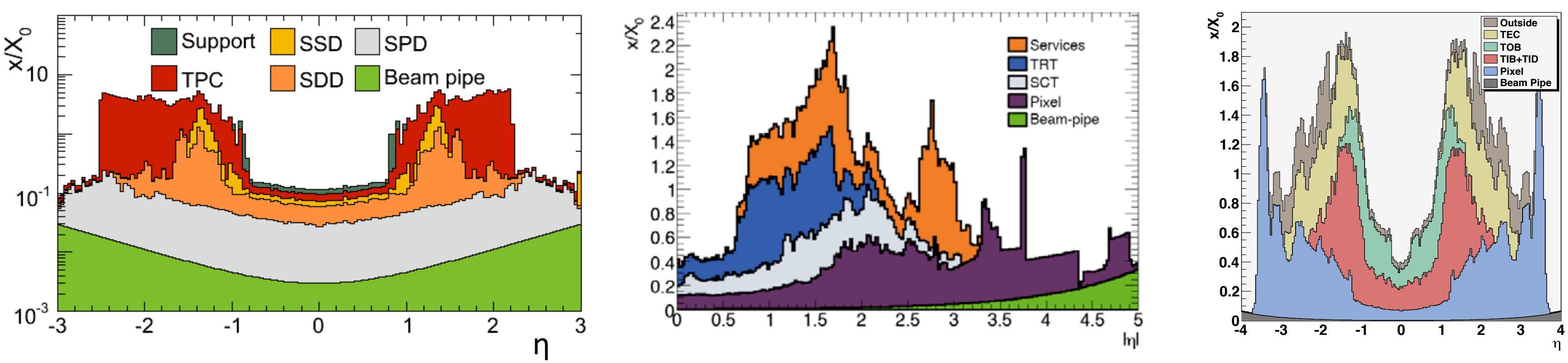
4/5 PHOS
18/18 TRD
18/18 TOF
7/7 HMPID
12/12 EMCAL
6/6 DCal



Material budget

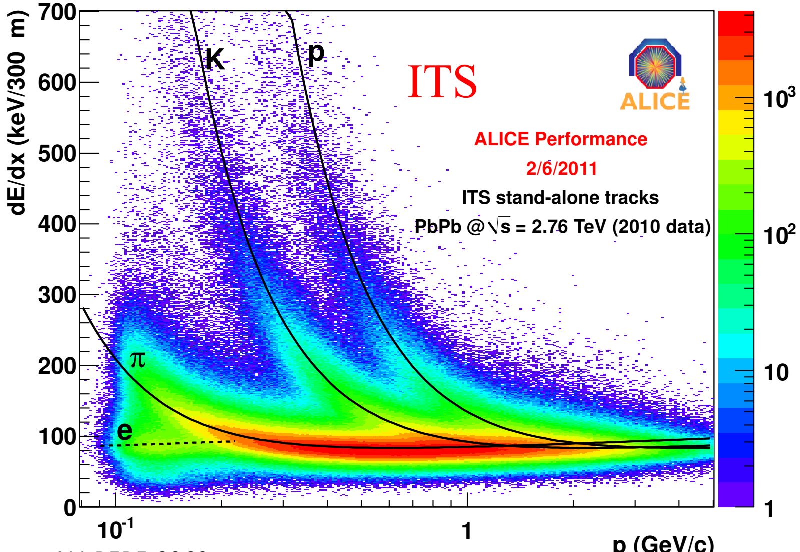
☞ Cumulative mid-rapidity material budget for ALICE, ATLAS and CMS

ALICE	x/X_0 (%)	ATLAS	x/X_0 (%)	CMS	x/X_0 (%)
Beam pipe	0.26	Beam pipe	0.45	Beam pipe	0.23
Pixels (7.6 cm)	2.73	Pixels (12 cm)	4.45	Pixels (10.2 cm)	7.23
ITS (50 cm)	7.43	SCT (52 cm)	14.45	TIB (50 cm)	22.23
TPC (2.6 m)	13	TRT (1.07 m)	32.45	TOB (1.1 m)	35.23

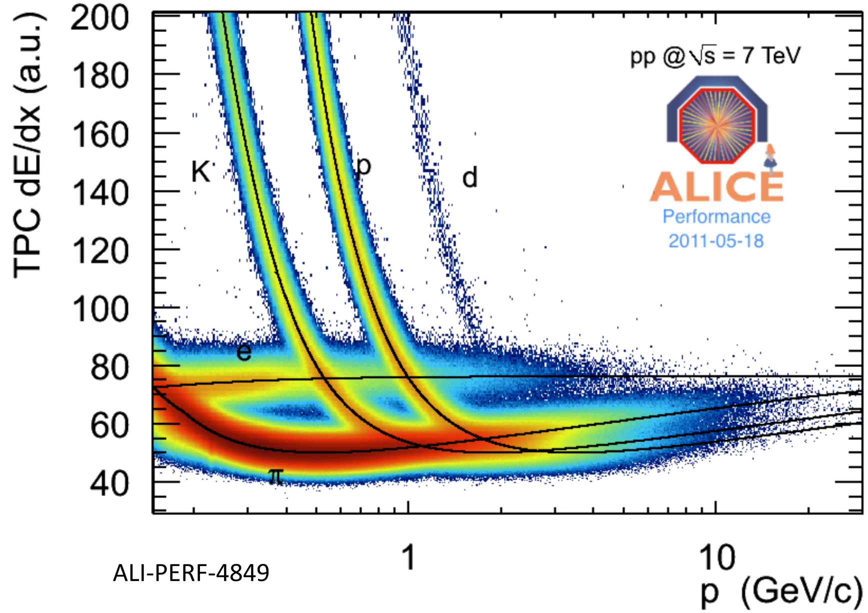


Reconstruction and identification at low p_T due to low material budget

PID with different detectors (1/2)



ALI-PERF-8369



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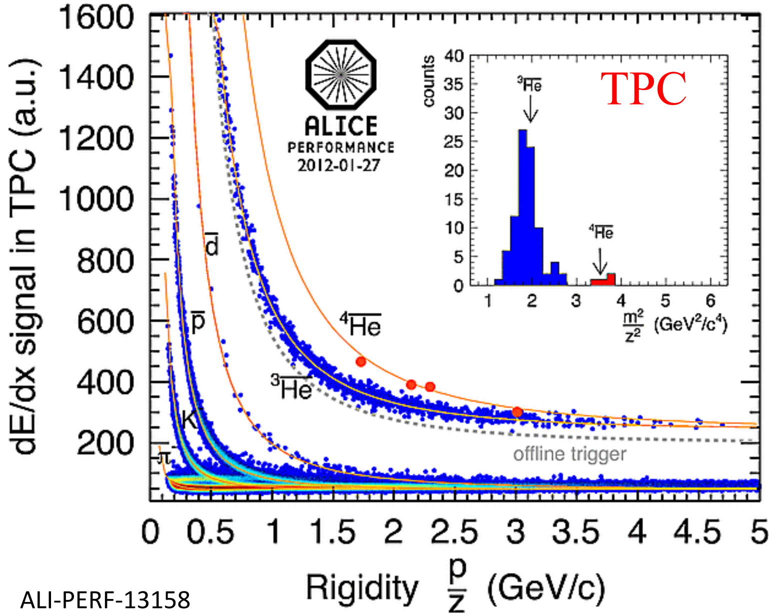
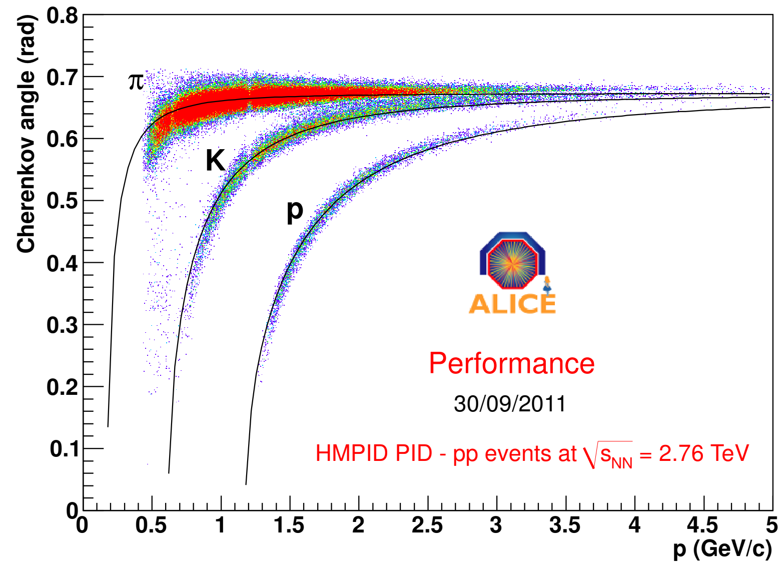
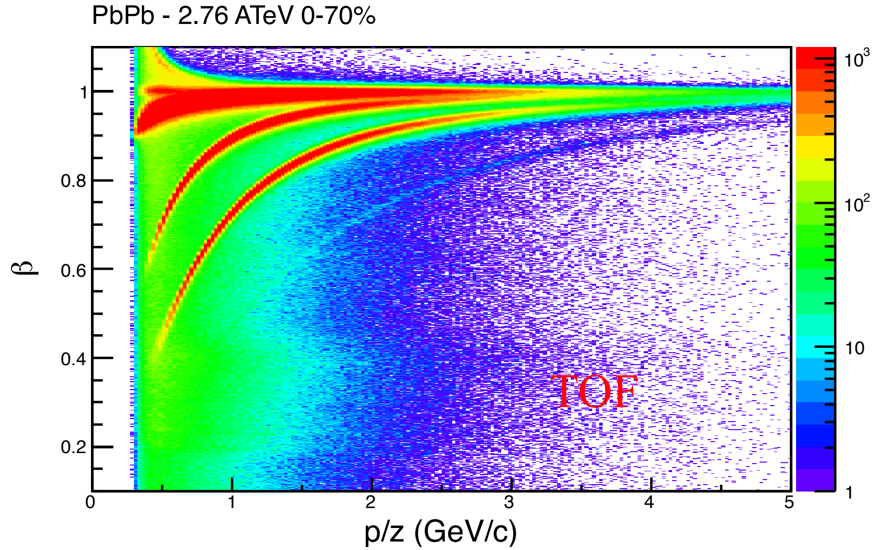


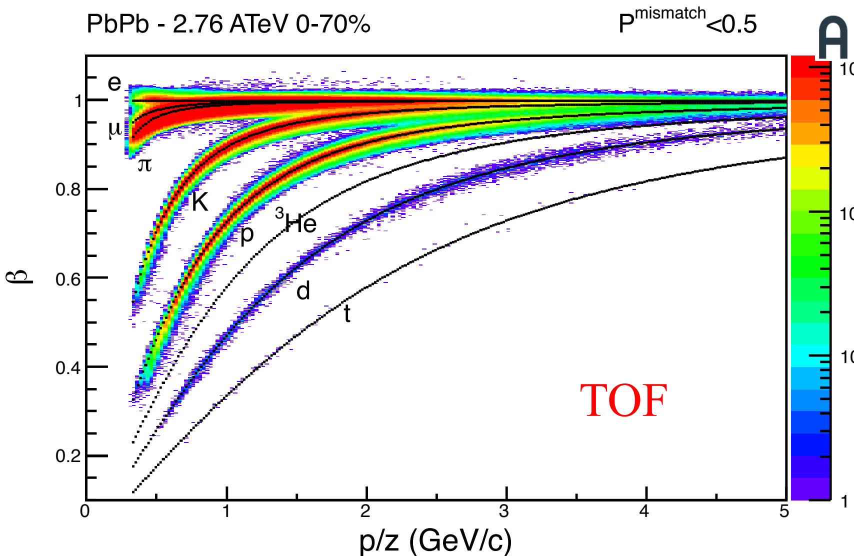
ALI-PERF-13158



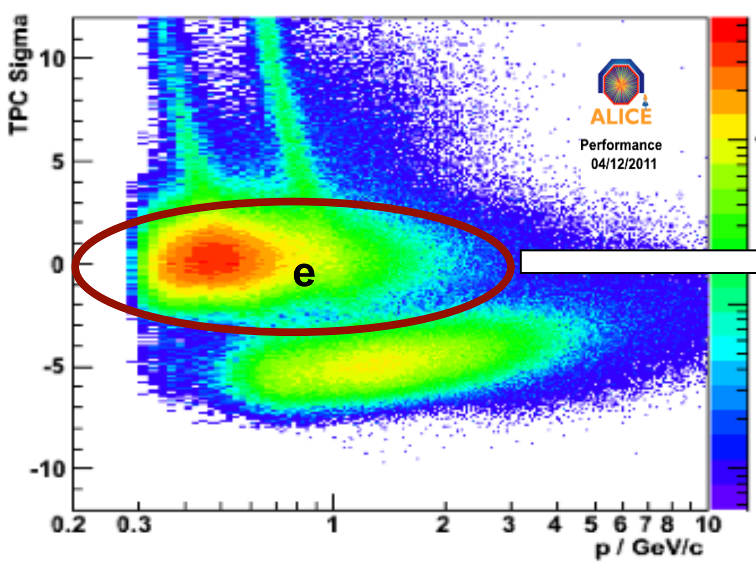
ALI-PERF-11634

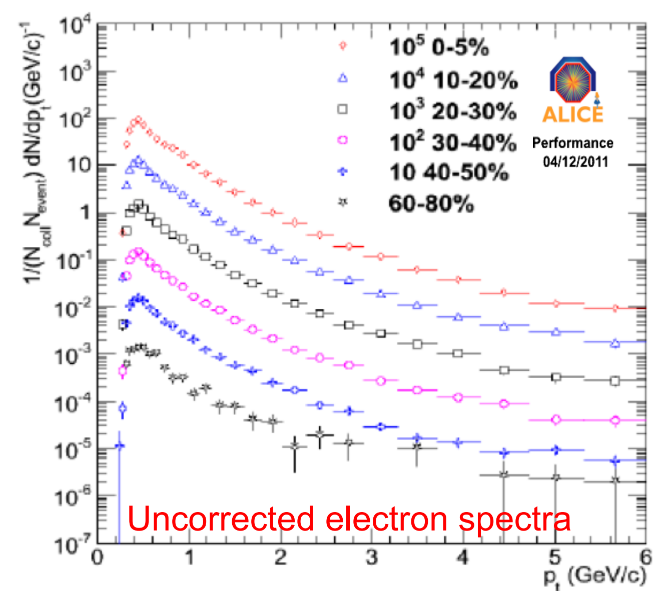
PID with different detectors (2/2)



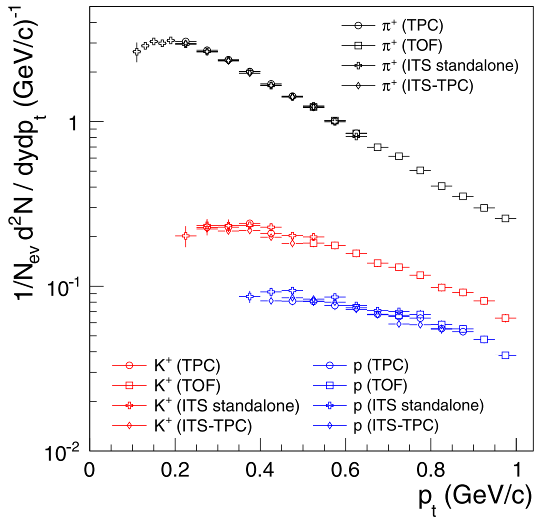


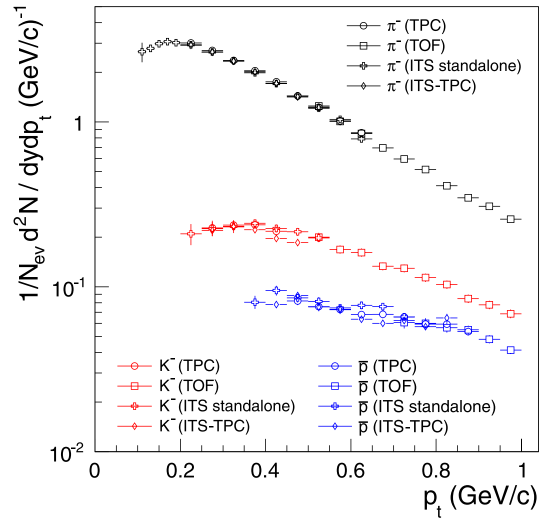
Electron identification in TPC + TOF





PID at work

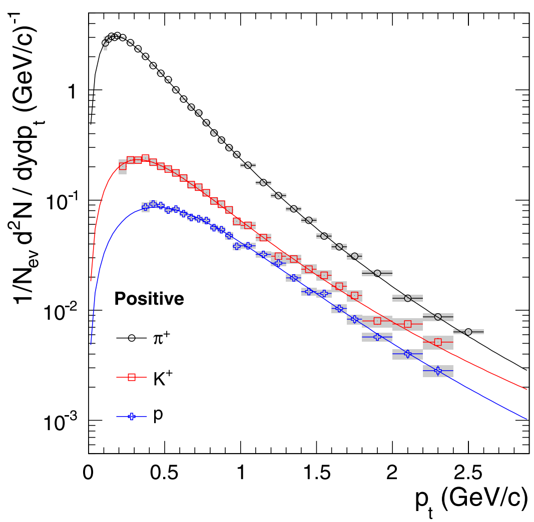


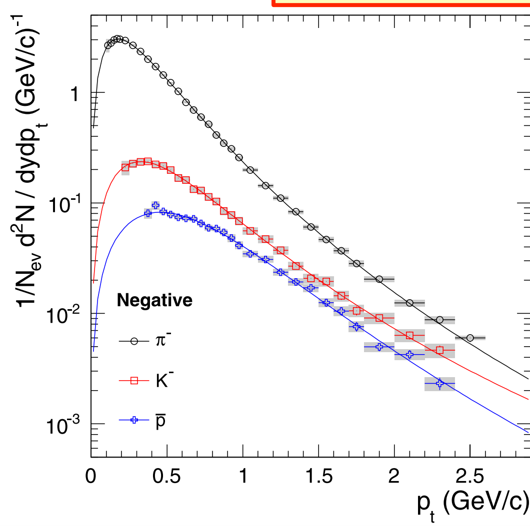


☞ Transverse momentum spectra of positive and negative hadrons $d^2N/(dp_t dy)$ for $|y|<0.5$

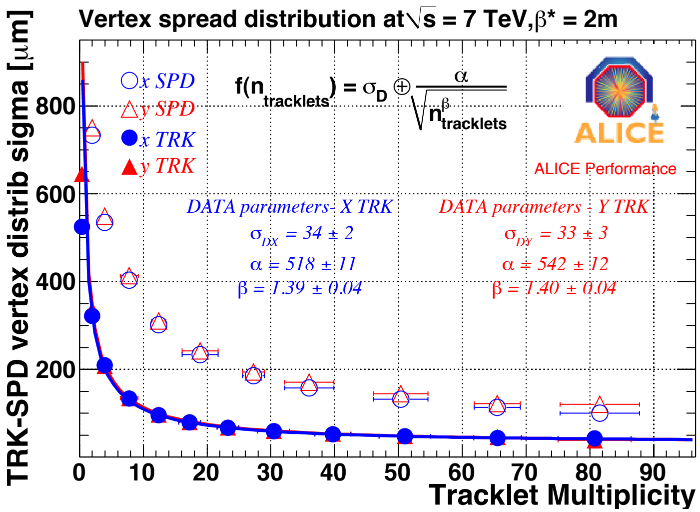
- Comparison of different analysis (top) and combined spectra (bottom)

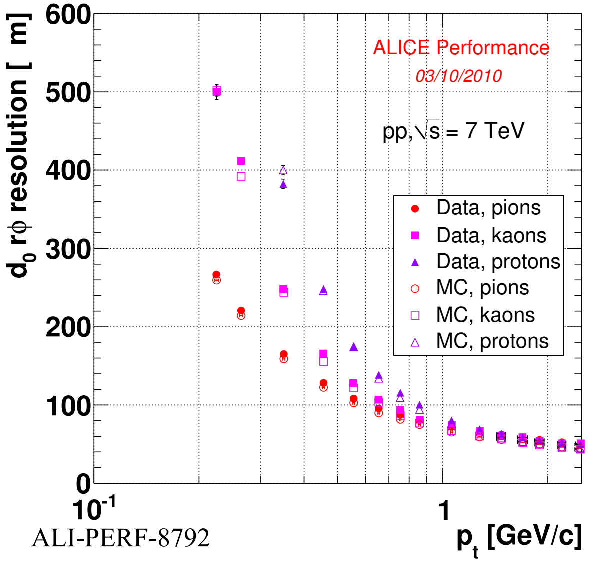
Eur. Phys. J. C (2011) 71:1655

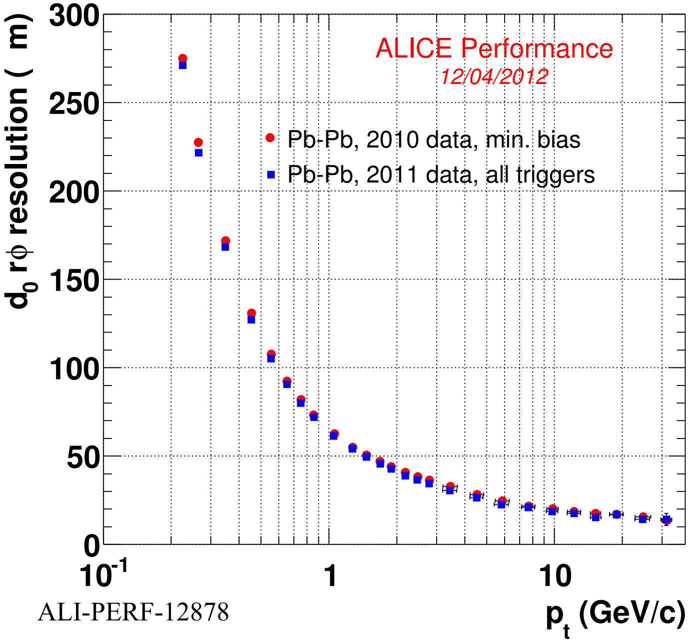


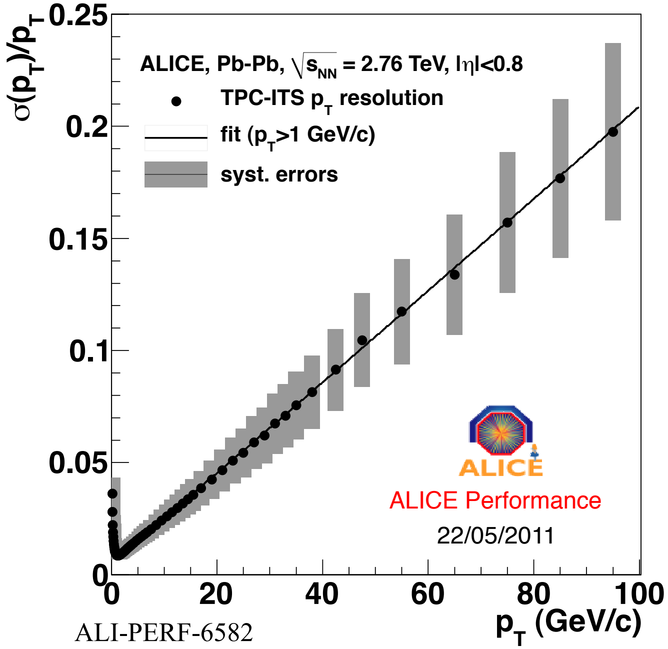


Example of tracking performance









ALICE data taking till 2018 …. and beyond

2010	**Pb-Pb**	O(10) μb^{-1}
2011	**Pb-Pb**	O(100) μb^{-1}
2012	**p-Pb**	~ 30 nb^{-1}
2013-14	**LS 1**	Long shutdown, increase *E*
2015-16	**Pb-Pb**	Design luminosity, ~ 250 μb^{-1}/year,
2017	**p-Pb *or* Pb-Pb**	Depending on integrated luminosity
2018	**LS 2**	install DS collimators to protect magnets **ALICE upgrade**
2019	**Pb-Pb**	Beyond design luminosity => approach total of 1nb^{-1}
2020	**p-Pb**	
2021	**Ar-Ar**	High-luminosity (up to 10^{29} $cm^{-2}s^{-1}$) Yet to be decided
2022	**LS 3**	Stochastic cooling ??
>2022		**PbPb luminosity production**, pA, other ions?

approved program: 1 nb^{-1} PbPb at full E + pPb

goal: 10 nb^{-1}

some further pp running for reference

ALICE beyond approved physics programme

- Progress on the characterization of QGP properties is made by studying multi-differential observables:
  - Flavour, Centrality, Transverse momentum, Reaction plane, …

➡ This requires high statistics (high luminosity)

- Physics plans focused on physics observables where ALICE unique features (PID, low material thickness, precise vertexing down to low p_t, …), are essential
  - precision measurements of spectra, correlations and flow of heavy flavour hadrons and quarkonia at low transverse momenta
  - precision measurements of low-mass lepton pairs emitted from the QGP
  - energy loss and flavour tagging of partons in the QGP via γ-jet and jet-jet with hadron PID
  - search for the existence of heavy nuclear states such as the H dibaryon or Λ-neutron bound states and systematic study of production of anti-matter

➡ This requires high statistics and precision measurements

Standard trigger strategy not applicable in most cases

ALICE Upgrade Strategy

☞ **"ALICE at High Rate"** ➡ submitted to LHCC in March

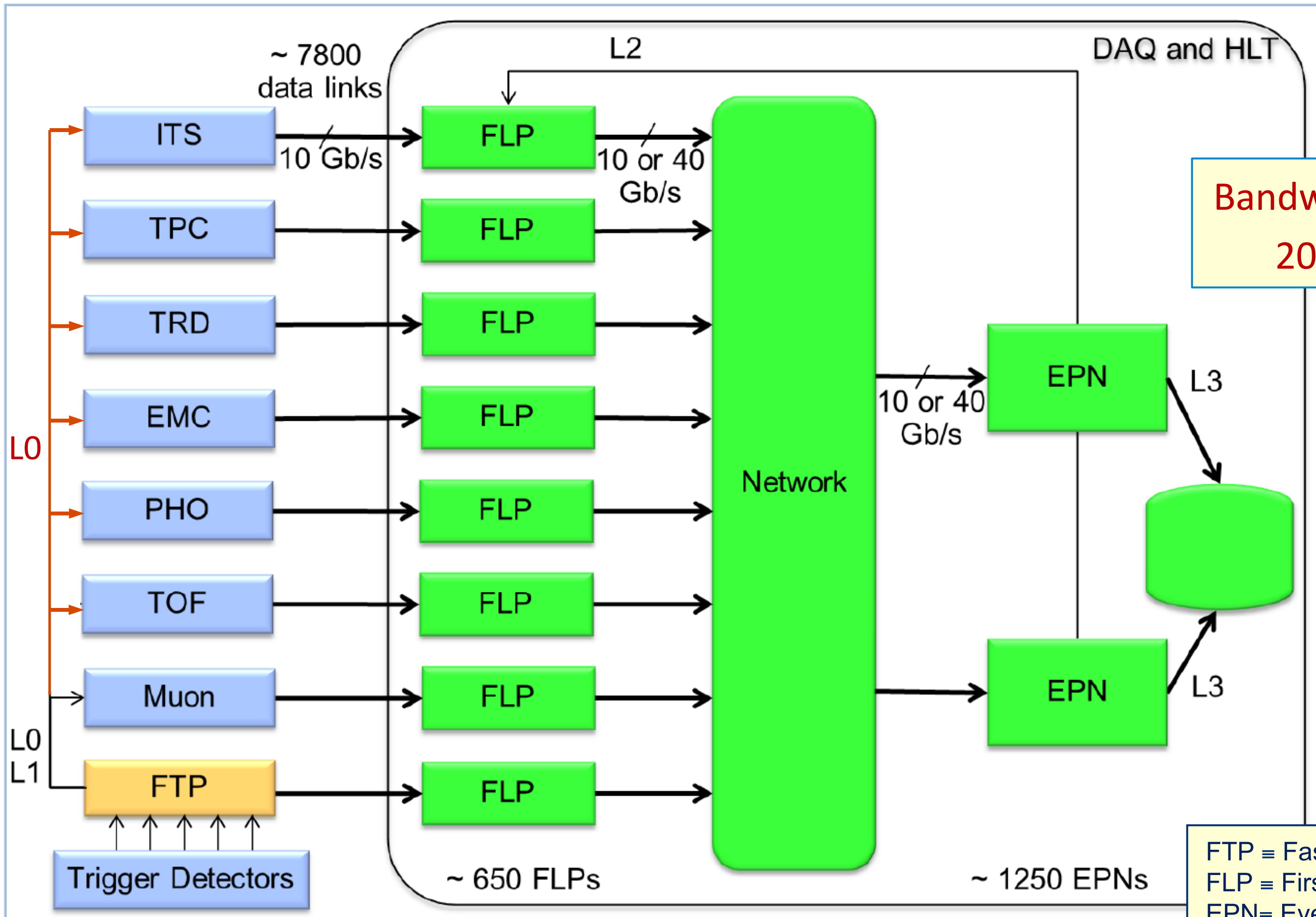
- Run of at least 10 nb^{-1} with PbPb
  - run ALICE at high rates, 50kHz Pb-Pb (i.e. $L = 6 \times 10^{27}\ cm^{-2}s^{-1}$), with minimum bias (pipeline) readout (☹ max readout with present ALICE set-up ~500Hz)
    - The Pb-Pb run would be complemented by p-Pb and pp running
  - Improve vertexing and tracking at low p_t
    - Contextually, submitted to LHCC the CDR for the ITS upgrade which is an essential part of the General Strategy
- It entails building
  - New beam pipe
  - New silicon tracker (improved tracking resolution and readout rate)
  - High-rate upgrade of TPC endplates and readout electronics
  - High-rate upgrade of readout electronics for TOF, CALs, Muons, DAQ/HLT
- This will allow a readout architecture with minimum-bias readout and event selection done by software algorithms in the online systems (DAQ/HLT)
- Targets LS2

ALICE at High Rate - Readout Architecture

- 50 kHz Pb–Pb collisions inspected with the least possible bias
- HI run 2011: online cluster finding data compression factor of ~5 for TPC

  - min. bias event size ~20 MB → ~ 4 MB after data reduction
- We assume for 2018 a bandwidth to mass storage ~ 20 GB/s
- Two HLT scenarios for the upgrade:
  1. Partial event reconstruction (clustering and tracking):
     Factor of ~20 (ready) → Rate to tape: 20 kHz
     ➡ clusters (associated to tracks) information recorded on tape
  2. Full event reconstruction:
     additional reduction factor ~3 → Rate to tape > 50 kHz
     ➡ track parameter information recorded on tape
- If smaller bandwidth or higher interaction rate, matching between data throughput and bandwidth might be achieved with online event selection based on ITS+TRD +TOF

Readout and Online Systems Architecture



Bandwidth to tape
20 Gbyte/s

FTP ≡ Fast Trigger Processor
FLP ≡ First Level Processor
EPN≡ Event processor Node

ITS upgrade options

See P. Riedler

☞ Two design options are being studied

A. 7 layers of pixel detectors
   - better standalone tracking efficiency and p_t resolution
   - worse PID

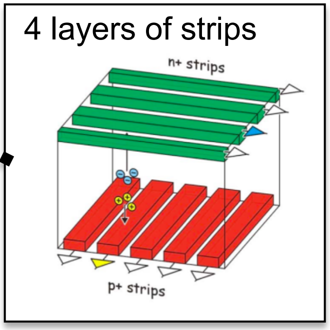
B. 3 innermost layers of pixel and 4 outermost layers of strip detectors
   - worse standalone tracking efficiency and momentum resolution
   - better PID

1 - **Get closer to the IP**
- -present beam pipe: R_{OUT} = 29.8 mm, ΔR = 0.8 mm
- -reduced beam pipe: R_{OUT} = 19.8 mm, ΔR = 0.8 mm

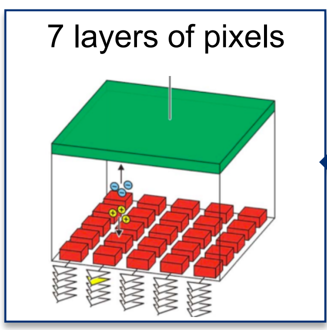
2 - **Reduce material budget**
- -present ITS: X/X_0 ~1.14% per layer
- -target for new ITS: X/X_0 ~0.3 – 0.5% per layer

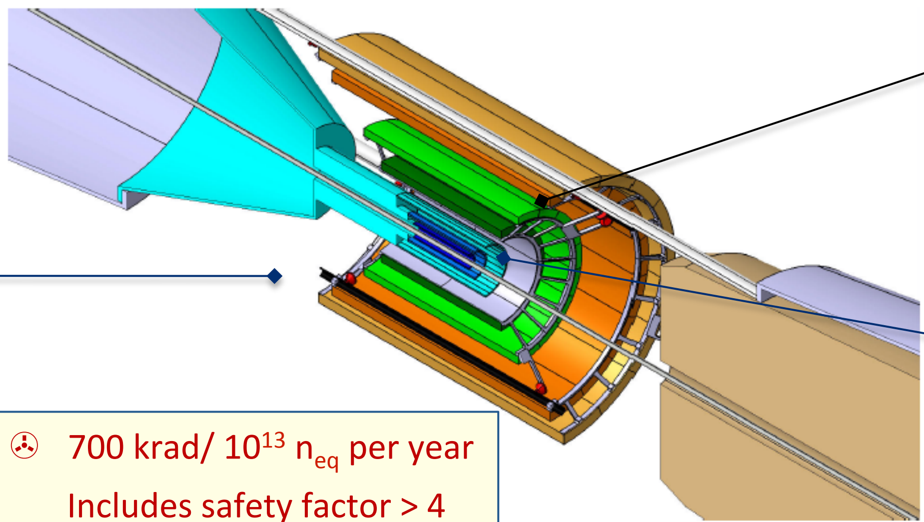
3 - **Reduce pixel size**
- -currently 50µm x 425µm
- -new O(20x20µm^2 – 50 x 50µm^2)

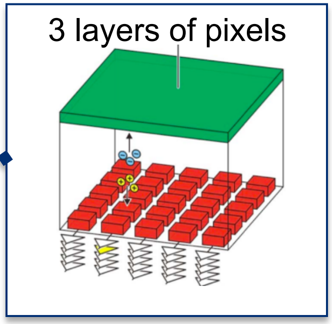
Option B



Option A

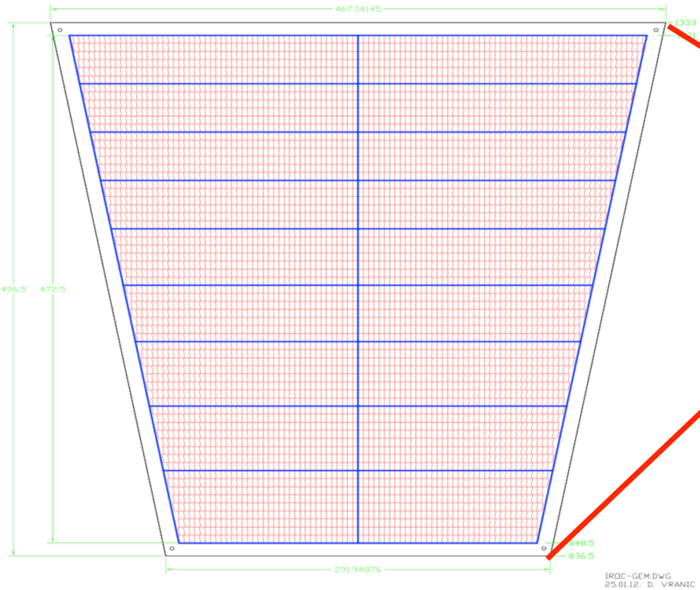


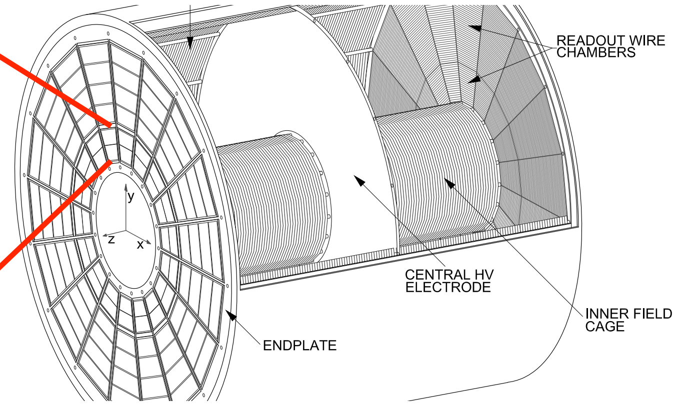


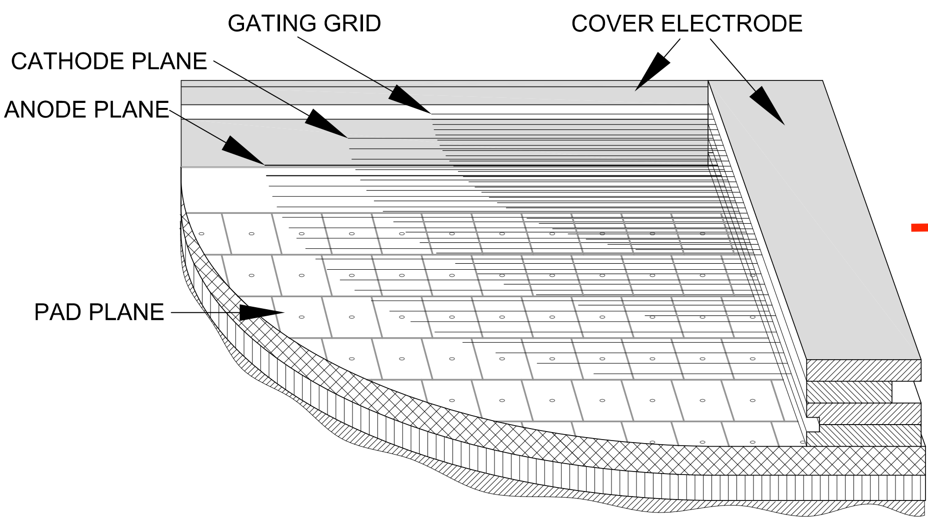


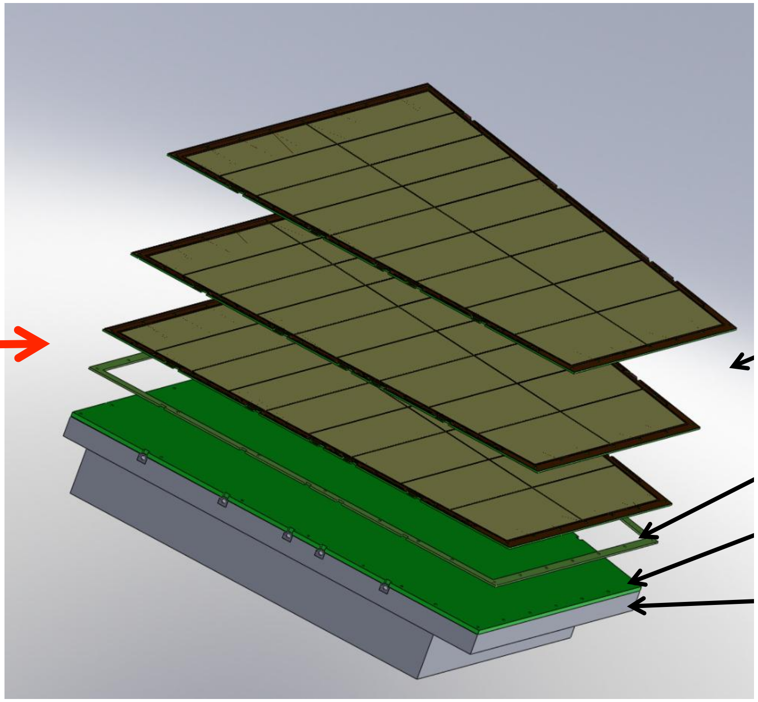
700 krad/ 10^{13} n_{eq} per year
Includes safety factor > 4

TPC upgrade with GEMs

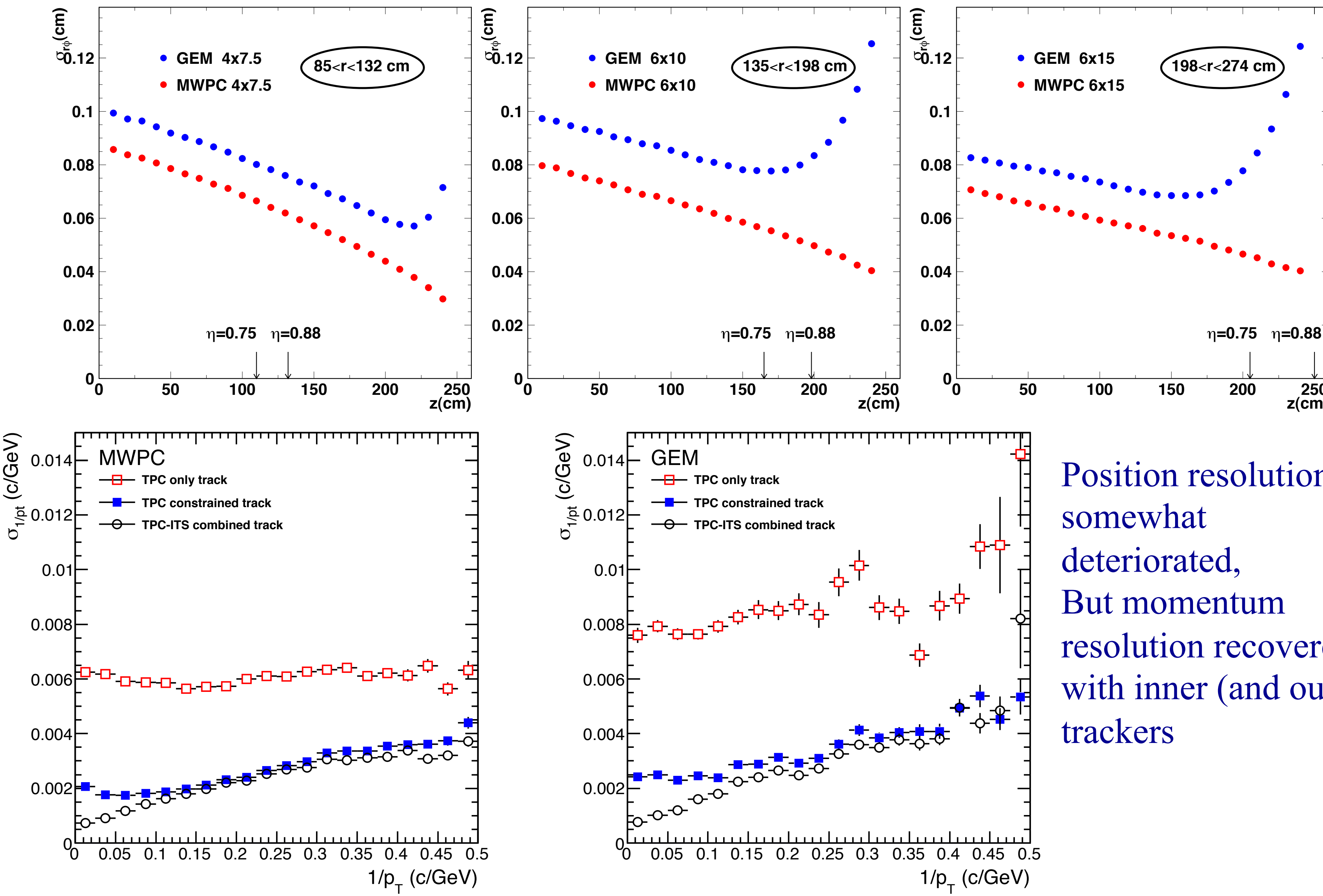








Simulations position and momentum resolution

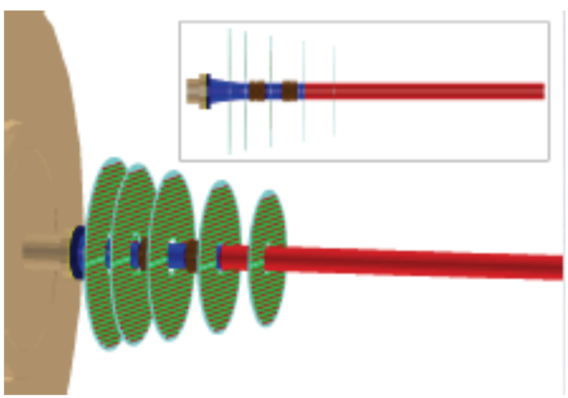


Position resolution somewhat deteriorated,
But momentum resolution recovered with inner (and outer) trackers

ALICE Upgrade

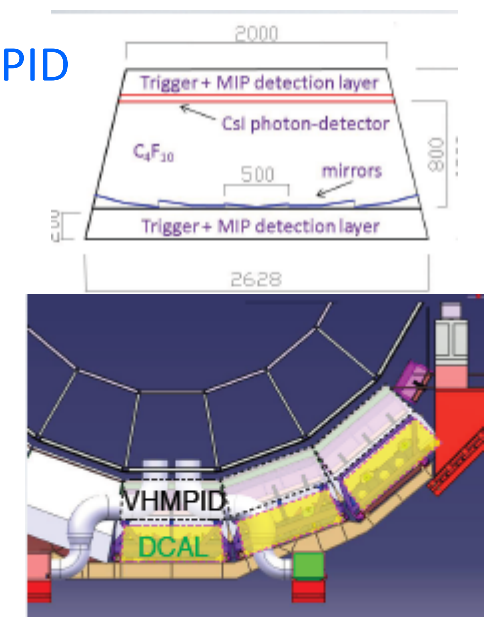
- Furthermore, three major proposals are under consideration to extend the scope of ALICE: MFT, VHMPID and FOCAL (a decision will be taken by September 2012)
  - b-tagging for low p_T J/Ψ and low-mass di-muons at forward rapidities
    - complement muon arm with tracking in front of absorber: secondary vertex measurement, better background rejection, improved mass resolution
  - New high momentum PID capabilities: π, k and p well beyond 10 GeV/c
  - Low-x physics with identified γ/π^0 at large rapidity

MFT



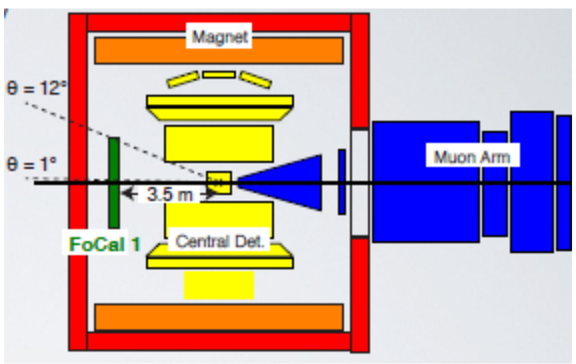
5 layers of high-granularity pixels layers

VHMPID



Focusing RICH with CSI photocathodes combined with DCAL

FOCAL



High-granularity SiW Calorimeter of ≈2 m2 at a distance of 3.5 m coverage: $2.5 < \eta < 4.5$

Conclusions

- After two years of operation with pp and Pb-Pb collisions, ALICE has demonstrated its excellent capabilities to measure high energy collisions at the LHC
  - ☞ Tracking in very high multiplicity environment from very low to very high p_T
  - ☞ Particle identification over a wide momentum range
- ALICE general upgrade strategy:
  - Minimum bias readout of all central detector at 50 kHz
  - Factor ~3 improvement in secondary vertex resolution
  - Very high standalone tracking efficiency down to low p_t
    - Above 95% for $p_T > 200$MeV/c)
- It entails
  - Replacement of ITS
  - Major upgrade of the TPC (replace MWPC with GEM + new readout electronics)
  - Upgrade of readout electronics for TRD, TOF and Calorimeters.
  - Major upgrade of the Hardware Trigger and online systems (DAQ, HLT)
- After a couple of years of studies, ALICE is confident that this ambitious proposal can be turned into a real detector to be ready for physics in 2019
- Strong support from the whole ALICE Coll. and Funding Agencies for R&D phase

Thank you for your attention!