ALICE

The ALICE detector upgrade

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for the ALICE Collaboration

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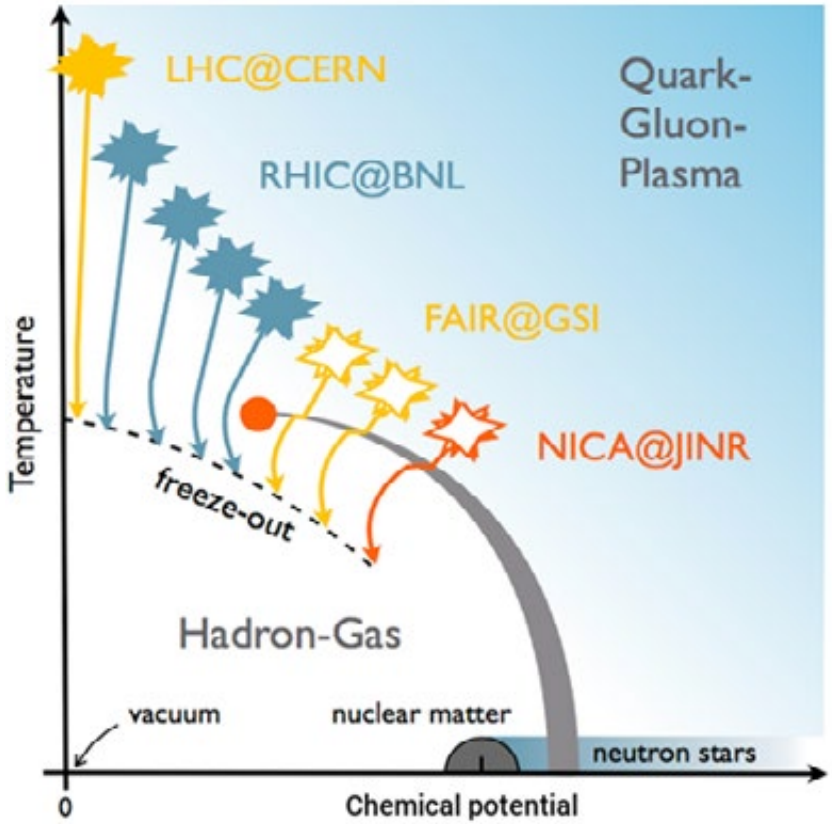
Valparaiso, Chili

ALICE primary goal : Quark Gluon Plasma (QGP)

QGP study via heavy ion collisions at the LHC: ε_0~10-40 GeV/fm^3



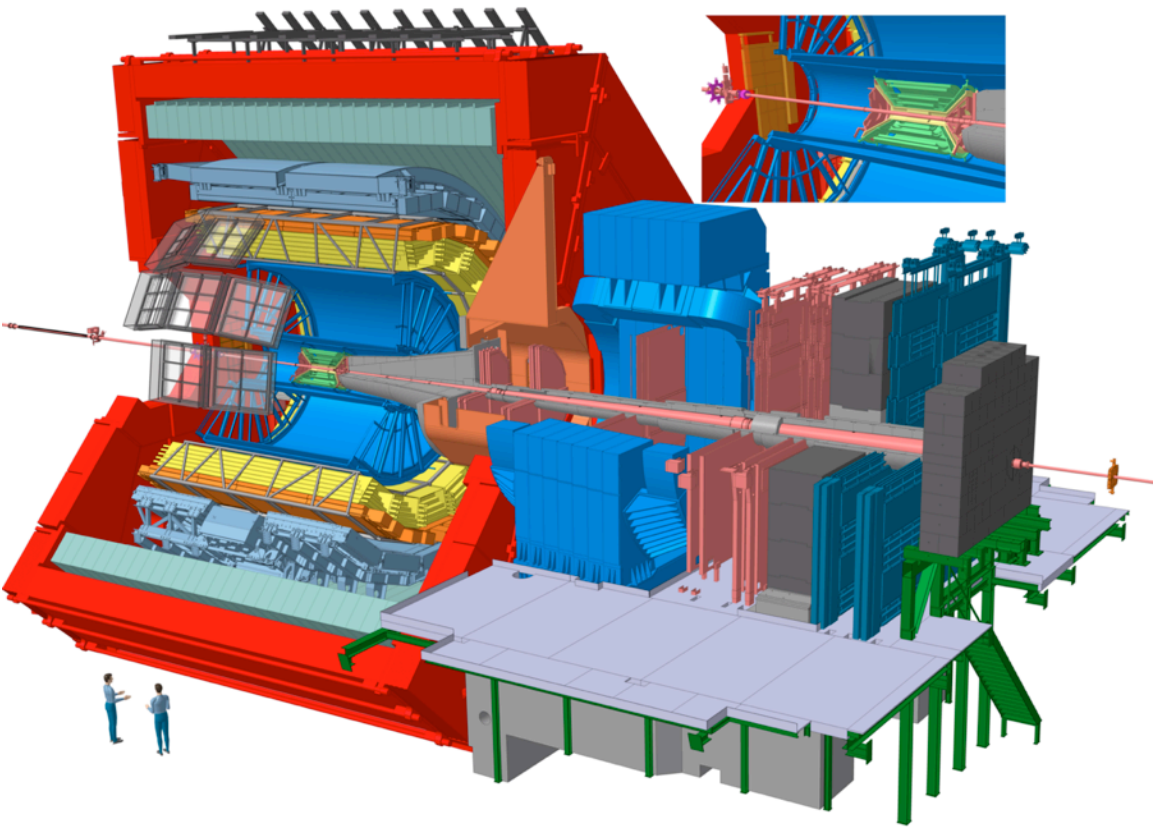
QGP probes

- Global observables
- Light hadrons
- Strange hadrons
- Quarkonia
- Open heavy flavours
- Electromagnetic probes
- Jet and high p_T hadrons
- Hypernuclei

As a function of rapidity, transverse momentum, azimuthal angle, centrality, centre of mass energy, reaction plane, fluctuations, small systems (pp and pA), correlations …

NuPECC Long Range Plan 2017
http://www.nupecc.org/lrp2016/Documents/lrp2017.pdf

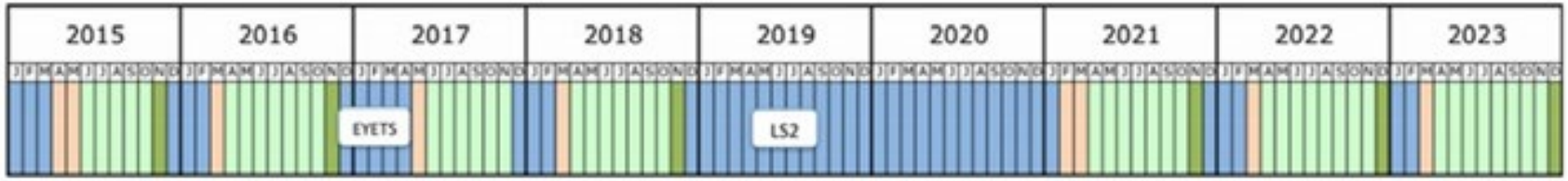
ALICE Detector (Run1 and Run2, 2009-2018)



- Excellent (low p_T) tracking performances
- Excellent particle identification performances
- Good secondary vertex reconstruction
- Electromagnetic calorimeters
- Muon spectrometer at 2.5<y<4
- ALICE computing grid: up to 180k jobs, 100 PB

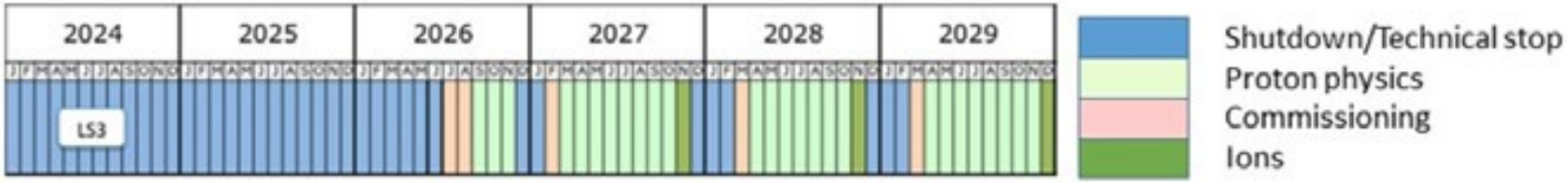
JINST 3 (2008) S08002
J. Mod. Phys. A 29 (2014) 1430044

The LHC roadmap (heavy ion runs)



Run2 : $\mathcal{L}^{Pb-Pb}_{integrated} = 1.0\ nb^{-1}$

Run3: $\mathcal{L}^{Pb-Pb}_{integrated} = 6.0\ nb^{-1}$



Run4 : $\mathcal{L}^{Pb-Pb}_{integrated} = 7.0\ nb^{-1}$

- 10-fold higher integrated luminosity in Pb-Pb collisions at the highest centre of mass energy (5.5 TeV)
- All 4 experiments will take part in the LHC heavy ion runs
- Possible interest on lighter ion run (e.g. Ar-Ar) – Under discussion

ALICE strategy for Run3 and Run4 2021-2029

Higher precision, low signal/background observables, low p_T heavy quarks, rarest probes

Global observables…….

Light hadrons…….....

Strange hadrons…….....

Quarkonia…….....

Open heavy flavours…..

Electromagnetic probes.

Jet and high p_T hadrons.

Hypernuclei.....

Better significance

New observables

PbPb 50 kHz

New read-out electronics

New TPC GEM chambers

New computing system

Inner tracker (ITS) upgrade

New forward tracker (MFT)

New forward calo (2024)?

100-fold larger statistics than Run1+Run2

Low signal over background: hardware trigger filtering nearly impossible at low p_T

ALICE Detector Upgrade

Increase of luminosity and improve vertexing and tracking at low p_T

New RO architecture
(TPC, Muon Spectrometer, TRD, TOF, PHOS, EMCAL/DCAL, ZDC)

New MB trigger
(FIT)

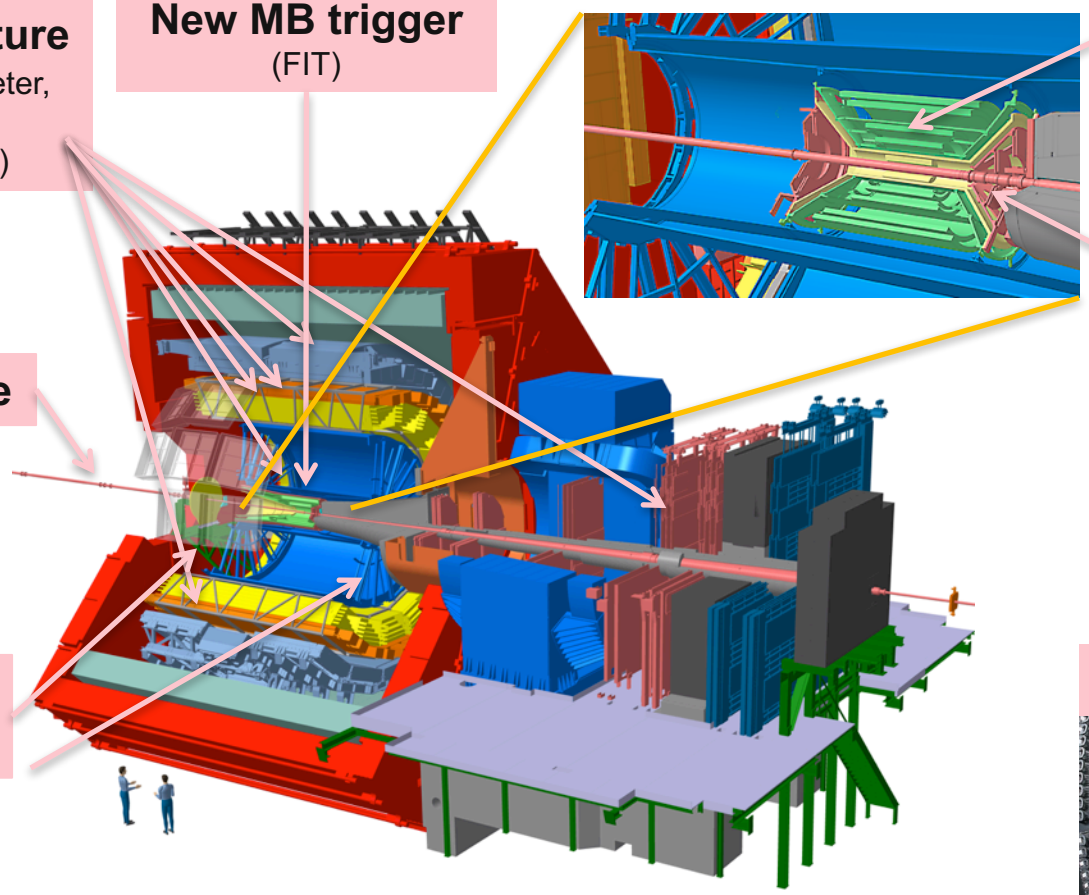
New Inner Tracking System

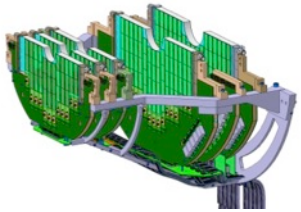
New Muon Forward Tracker

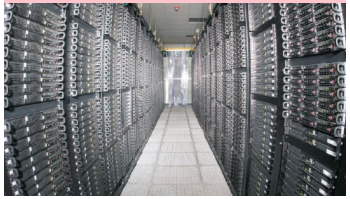
New Be beam-pipe

New TPC GEM-based chambers

Computing O^2







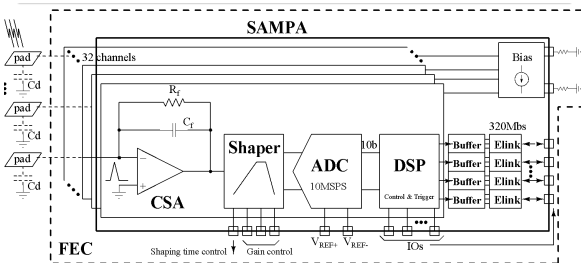
New Read-Out Architecture

Several sub-projects

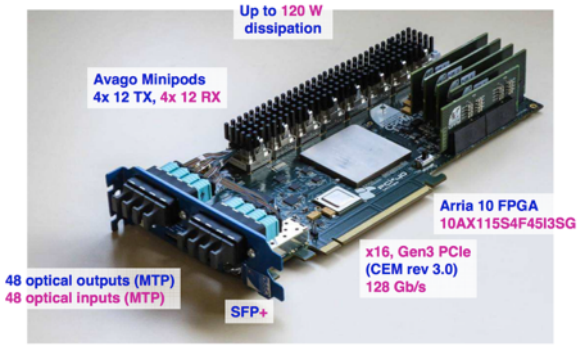
- Central Trigger Processor (CTP)
- SAMPA: new ASIC for the TPC and muon tracking system
- Common Readout Unit (CRU): FIT, ZDC, ITS, TPC, TRD, TOF, MFT, MCH, MID
- Upgrade of most FEE ALICE subsystems : continuous and triggered RO

CTP proto boards

SAMPA



CRU

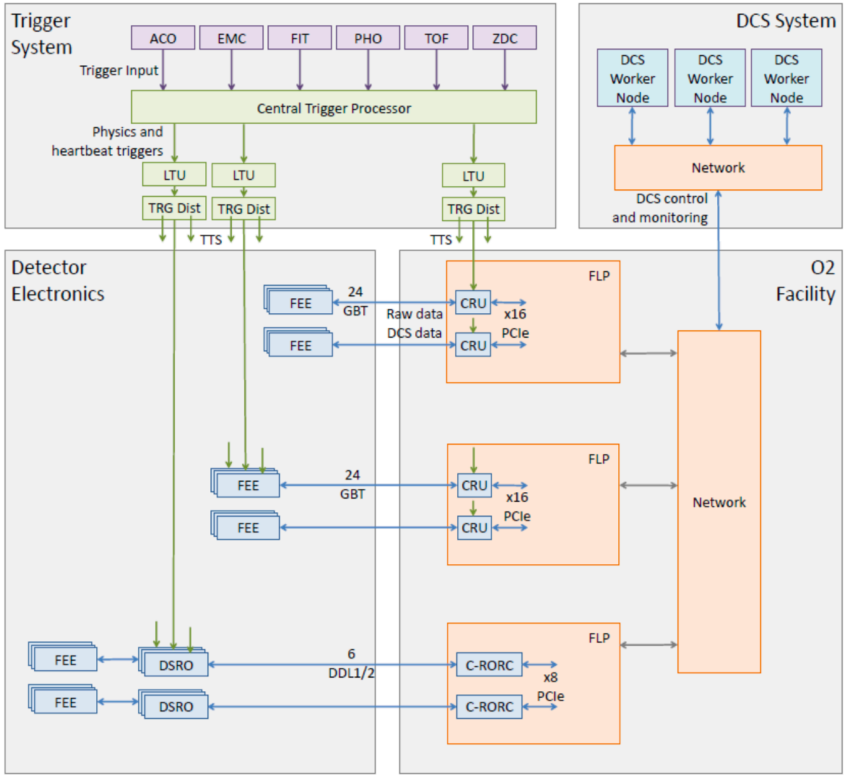


ALICE O² project

- Continuous readout to stand 50 kHz interaction rate

- Data (1.1 TB/s) transferred to First Level Processors (FLP)
- Heart Beat triggers to chop data in Sub-Time Frames
- STF are assembled into Time Frames in the Event Process Nodes (EPN)

- Synchronous data volume reduction on-the-fly by EPN
  - Calibration
  - Global reconstruction
  - Data compression
- Further reconstruction performed asynchronously

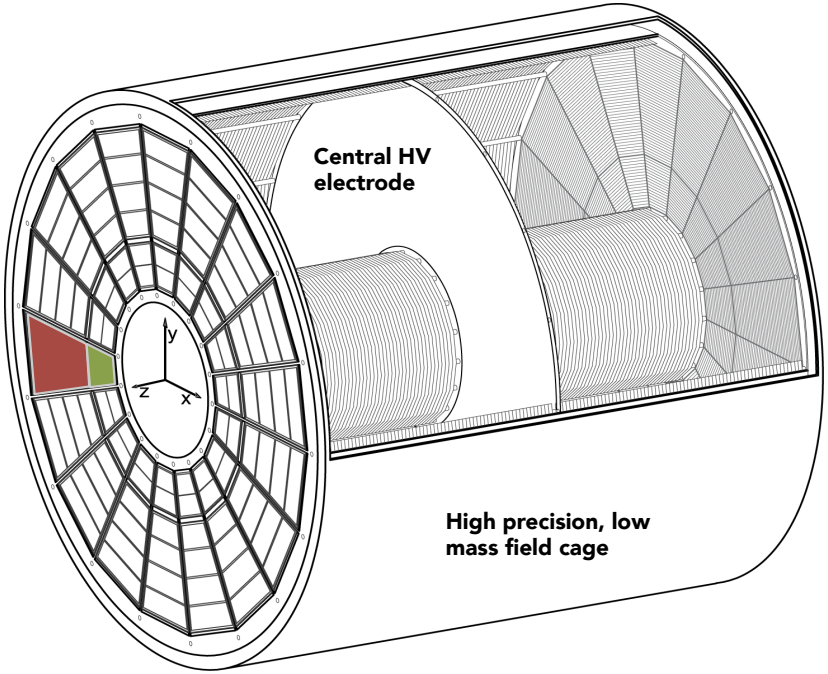


- Data storage: 85 GB/s for Pb-Pb at 50 kHz

New TPC RO chambers

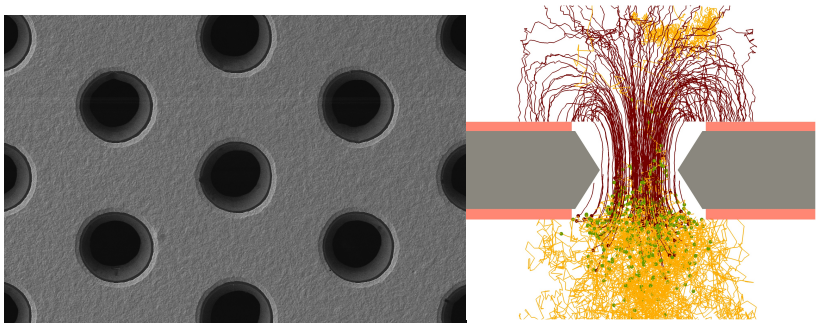
Limitation of the ion backflow

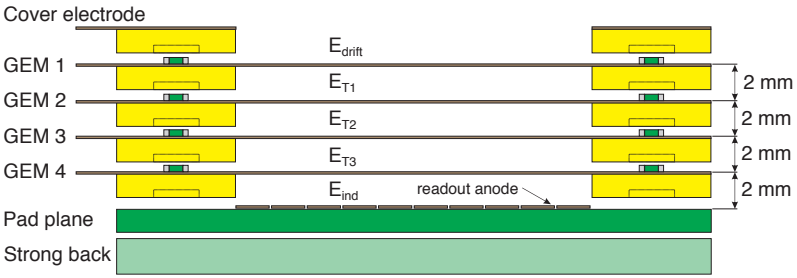
- TPC diameter 5 m, length 5m
  - Electron drift time 100 μs
  - Ion drift time 160 ms
- Gating grid to collect ion back flow needs 300 μs
- Intrinsic limitation at 3 kHz interaction rate
  - Present RO limits to 1 kHz for central PbPb
- Low ion backflow of **Gas Electron Multipliers (GEM)** to avoid the gating grid
- Continuous readout (~3 TB/s)
- Online calibration, reconstruction and data compression needed (O2 project)

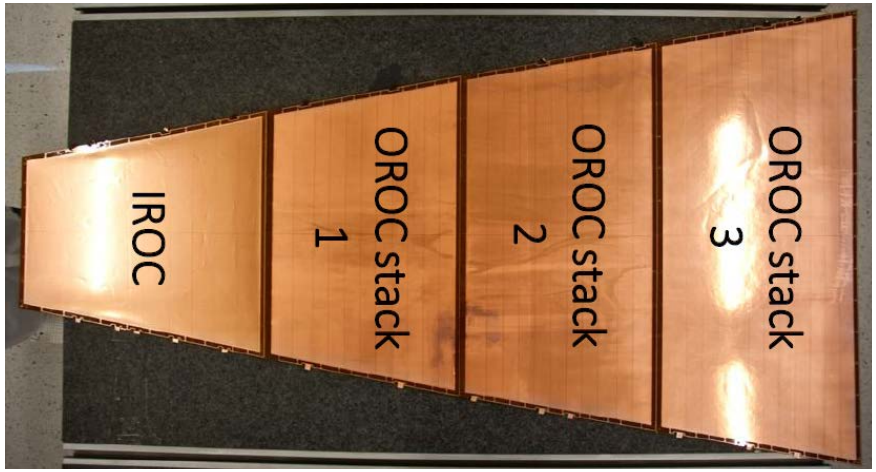


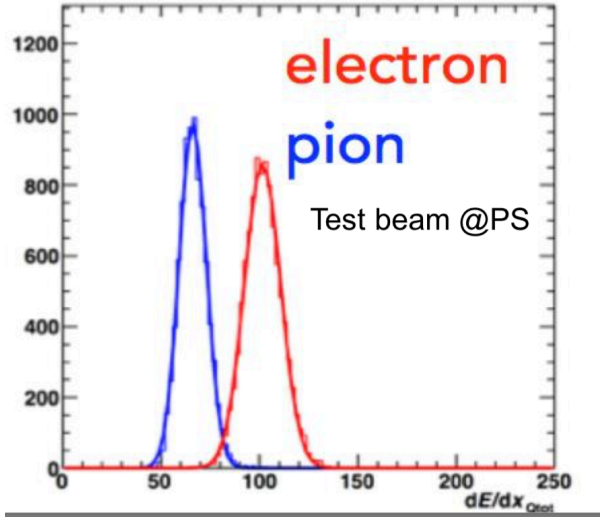
Quadruple GEM

- Quadruple GEM chambers
- GEM technology designed to suppress ion backflow
- Similar tracking and *dE/dx* precision as present MWPCs
- 640 GEM foils needed for the whole TPC

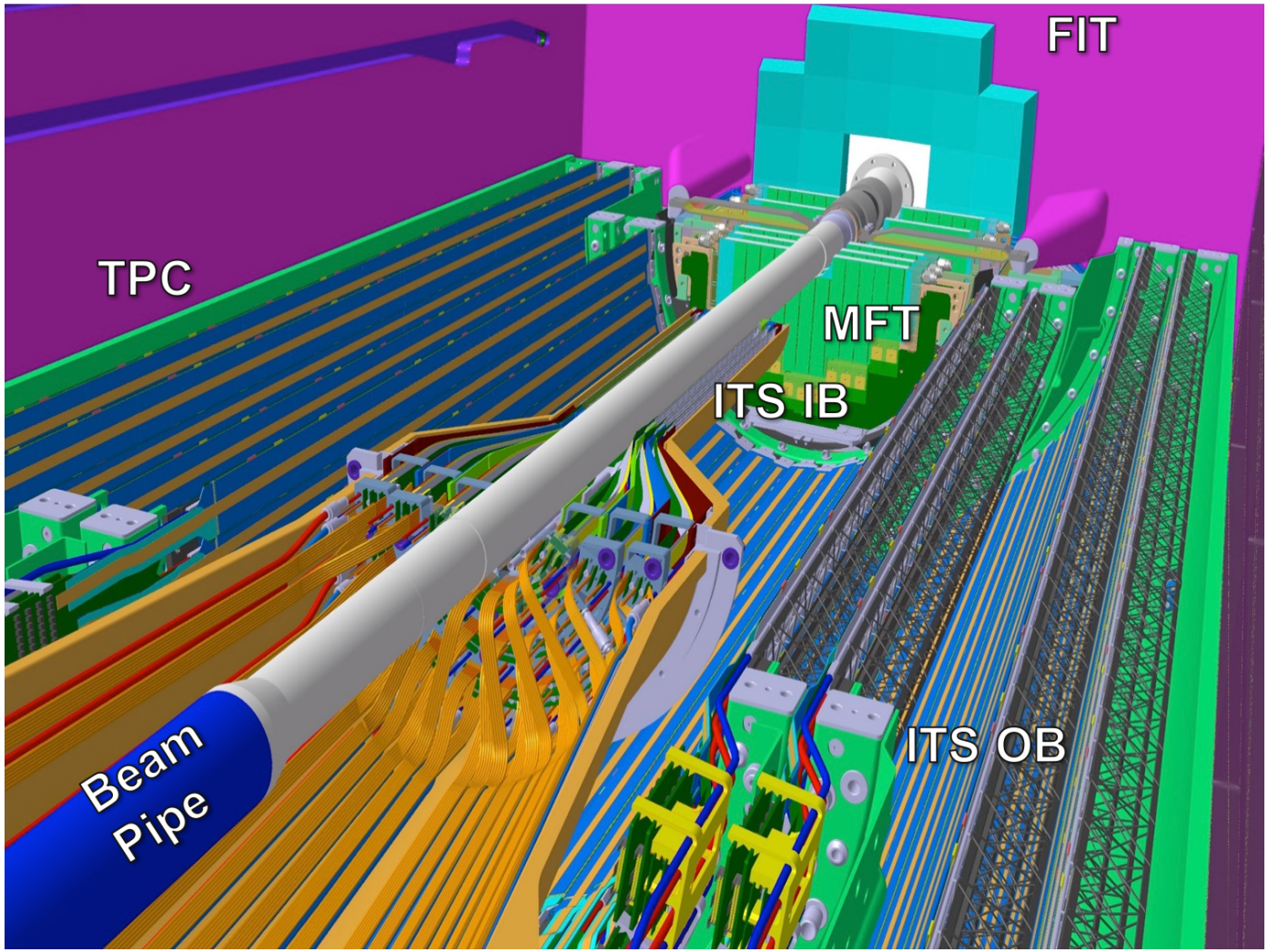








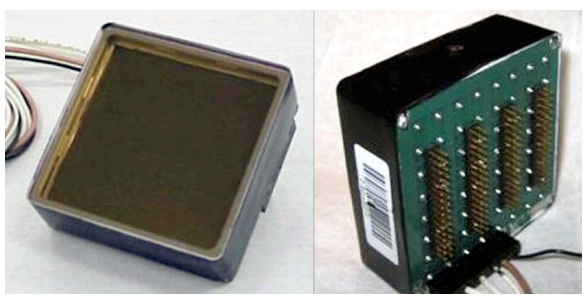
Inner central region upgrade

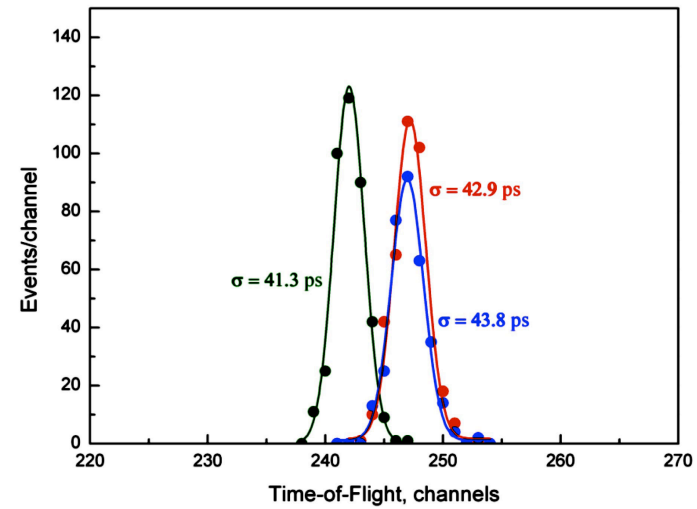


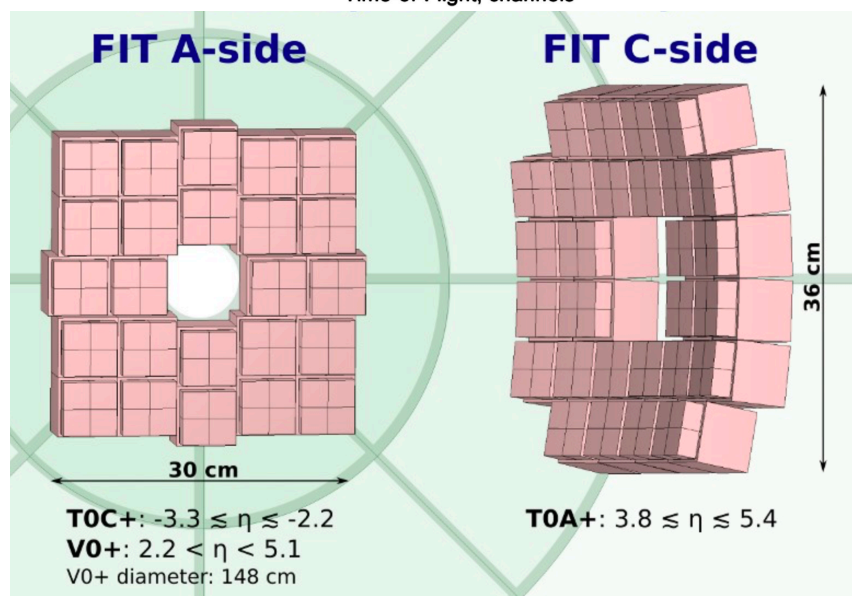
FIT: Fast Interaction Trigger for ALICE

Minimum Bias Trigger

- **MCP-based detector** (59x59x28 mm^3)
- Efficiency 100% (~83%) in Pb-Pb (pp) collisions
- Centrality triggering
- Vertex online location
- **Time resolution <50 ps**
- Event plane determination
- No aging over Run3 and Run4



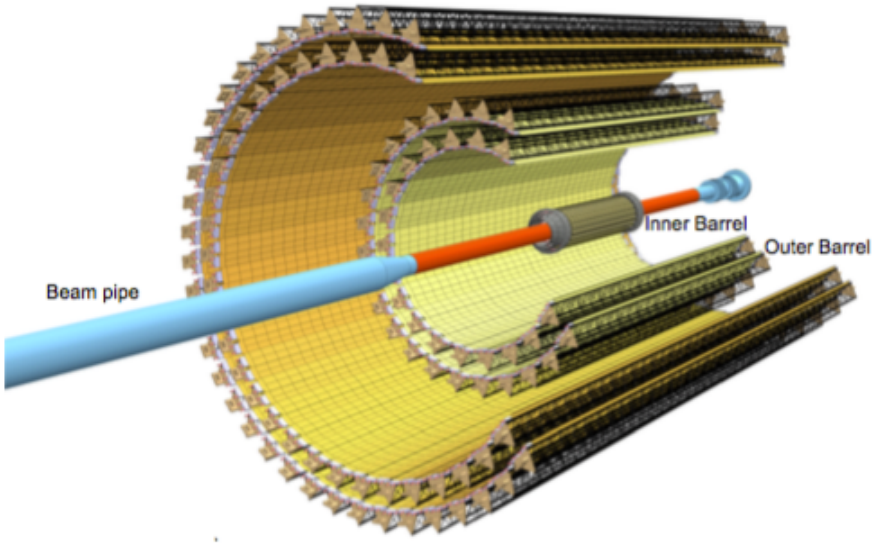


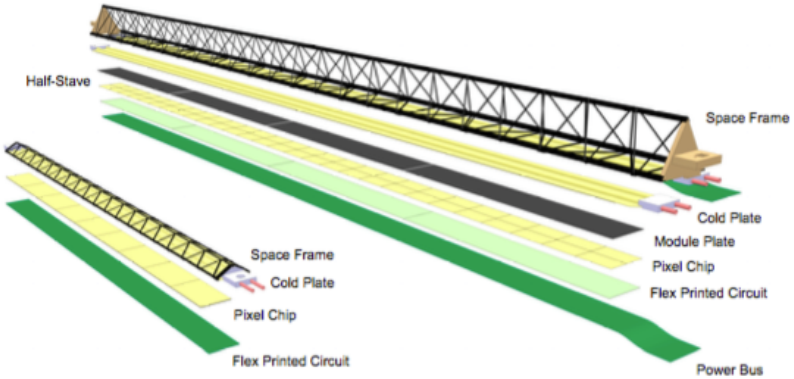


Inner tracking system (ITS) upgrade

Improving tracking performance at low p_T

- Large area (10 m^2) tracker made of monolithic active silicon pixel sensors ($|\eta|<1.22$)
- 7 layers from R=22 mm to R=400 mm Inner Barrel, Outer Barrel (Middle layers & Outer layers)
- Spatial resolution O(5 μm)
- First layer closer to IP (smaller beam pipe radius)
- 0.3%X_0 per layer in the inner most 3 layers (light mechanical structure)



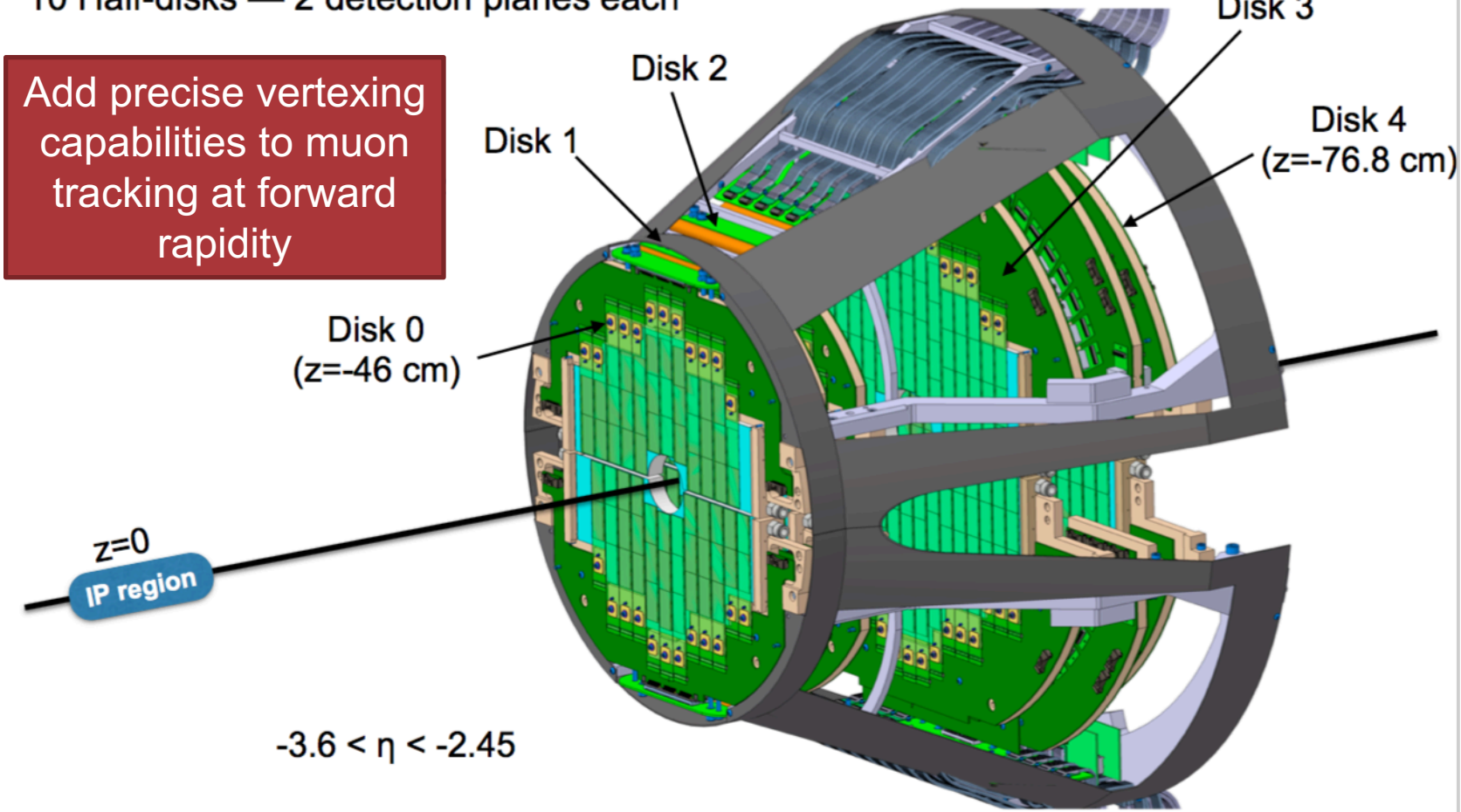


Muon Forward Tracker (MFT)

920 silicon pixel sensors (0.4 m²) on 280 ladders of 2 to 5 sensors each

10 Half-disks — 2 detection planes each

Add precise vertexing capabilities to muon tracking at forward rapidity

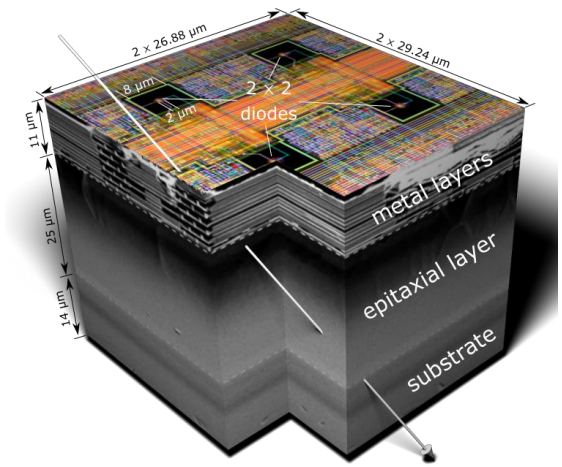


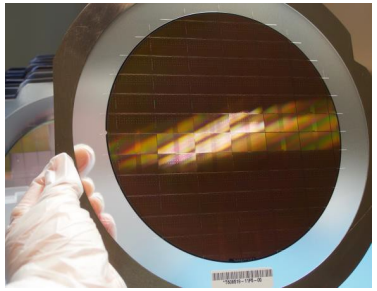
$-3.6 < \eta < -2.45$

ALPIDE pixel sensor (ITS Upgrade and MFT)

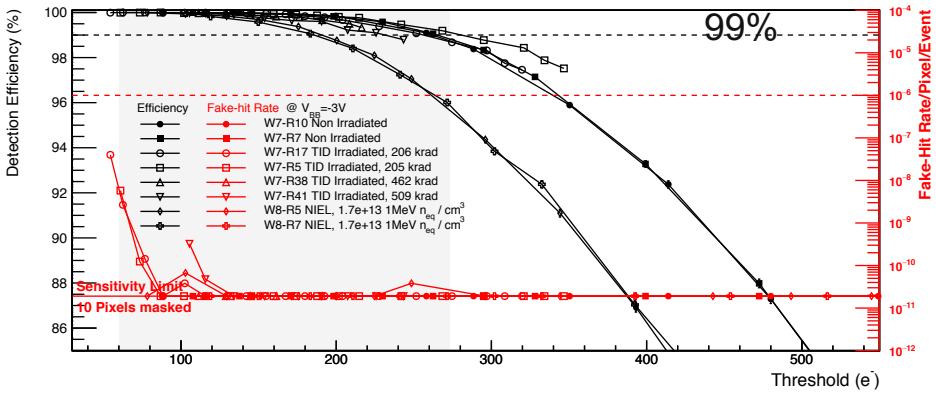
CMOS Monolithic Active Sensors (MAPS), TowerJazz 0.18 μm technology

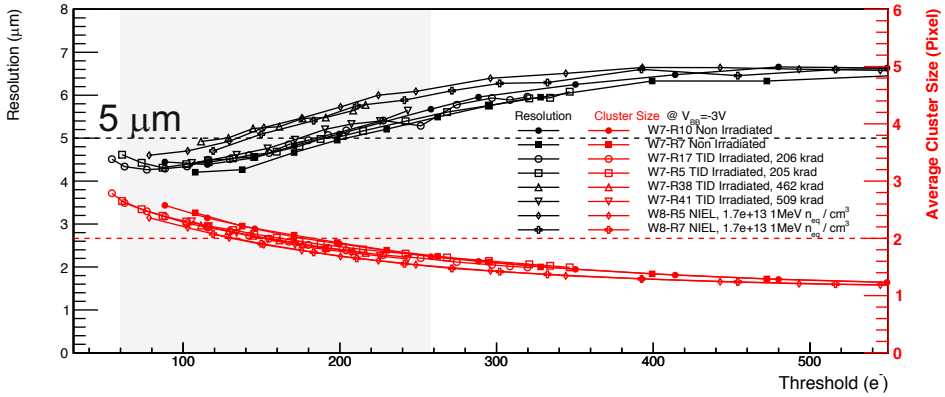
- Sensor size: 15 mm x 30 mm
- Pixel size: 29 μm x 27 μm
- Detection efficiency > 99%
- Event time resolution <4 μs
- Space resolution: 5 μm
- Power consumption: ~40 mW/cm^2
- Radiation dose (Run3+Run4): <300 krad, <2.0x10^{12} 1MeV n_{eq}/cm^2



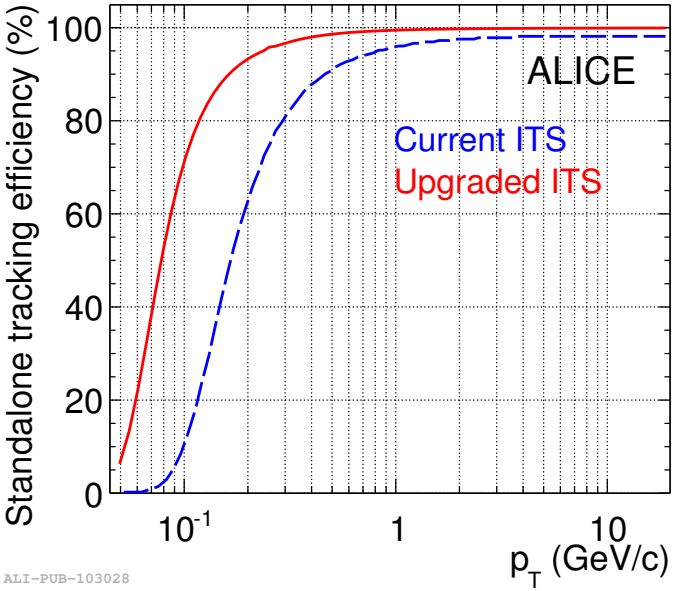


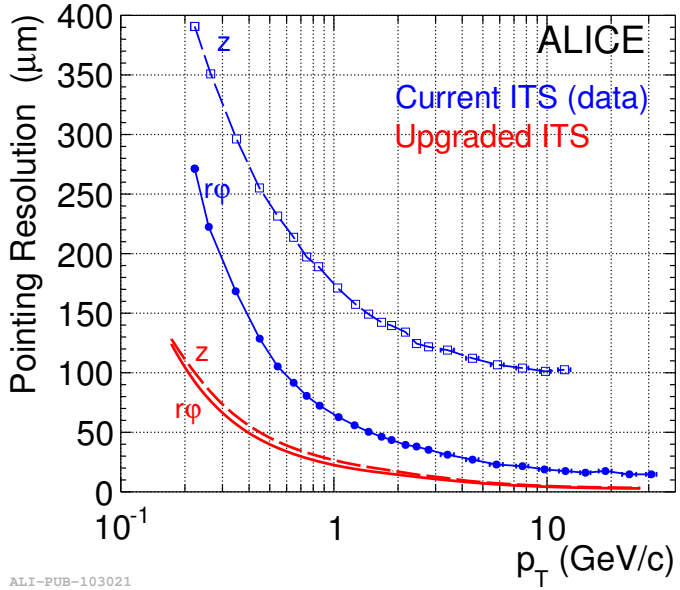
ALPIDE
Production started
December 2016



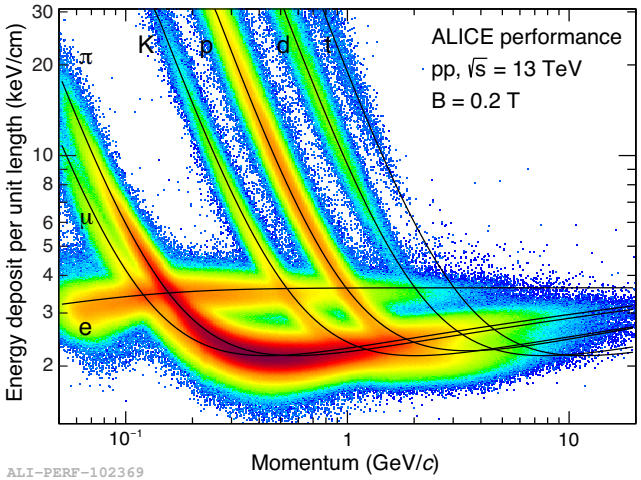


ALICE tracking performances (central barrel)



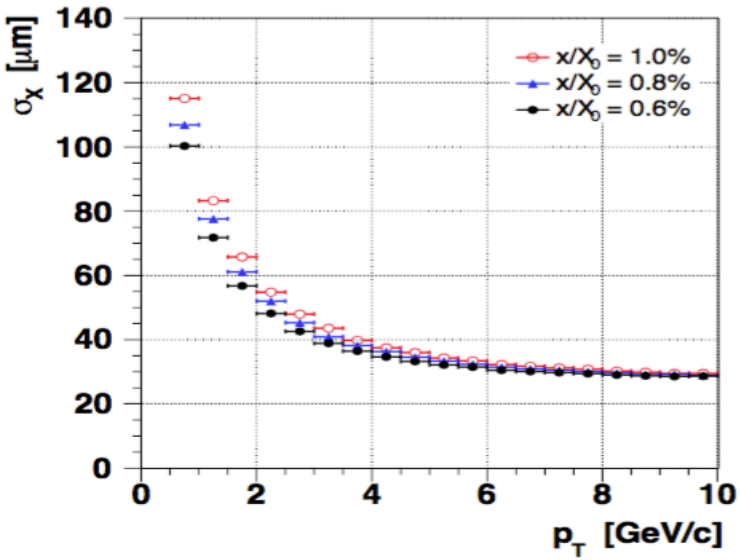


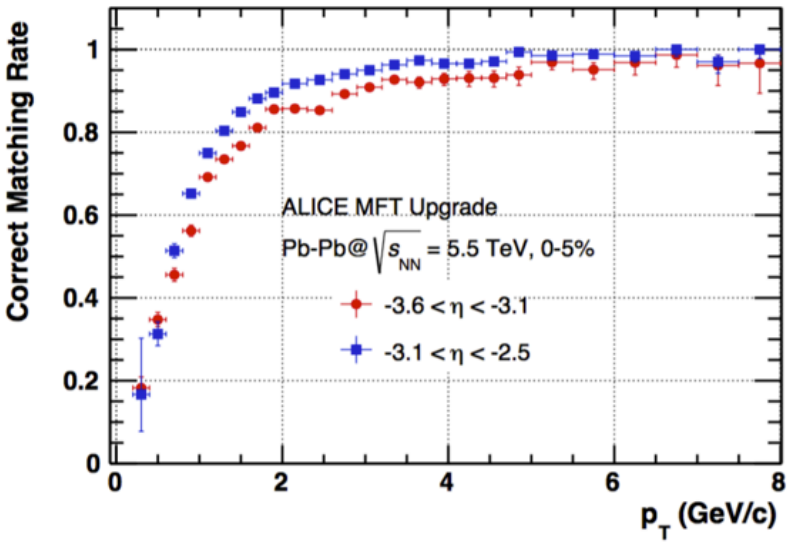
Improved efficiency and resolution (mostly at low p_T)



Keeping unchanged PID performances

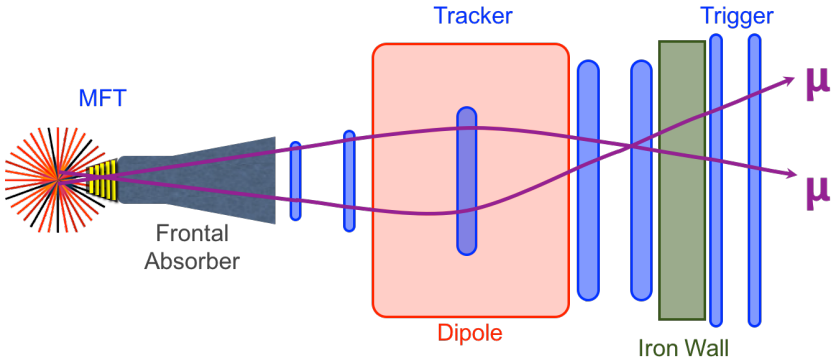
ALICE tracking performances (forward muons)





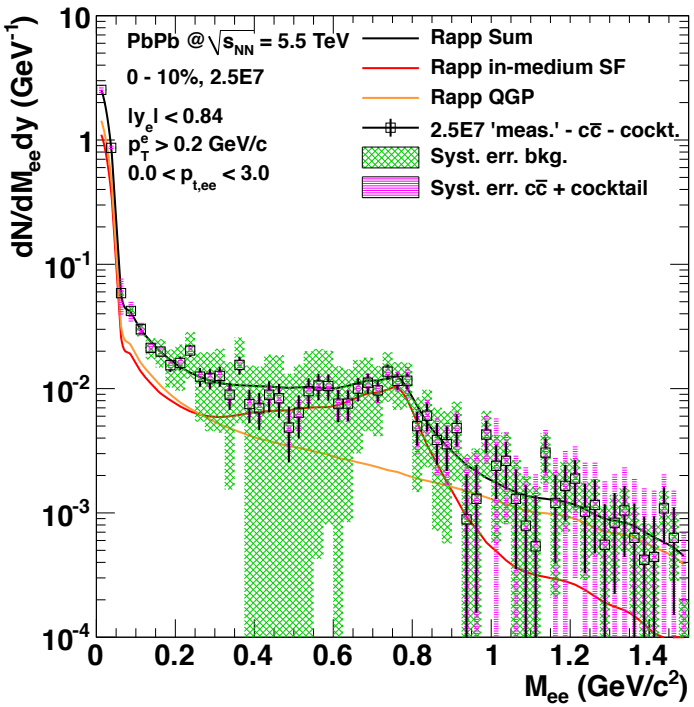
Adding vertexing capabilities (with good pointing resolution)

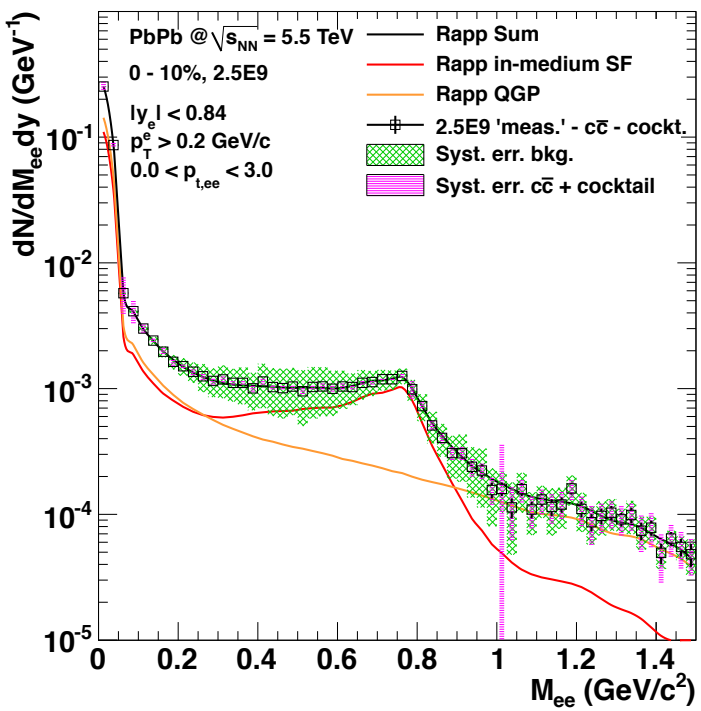
Keeping high tracking efficiency



Physics Performance of the Upgraded ALICE

Low Mass dielectrons |η|<0.9





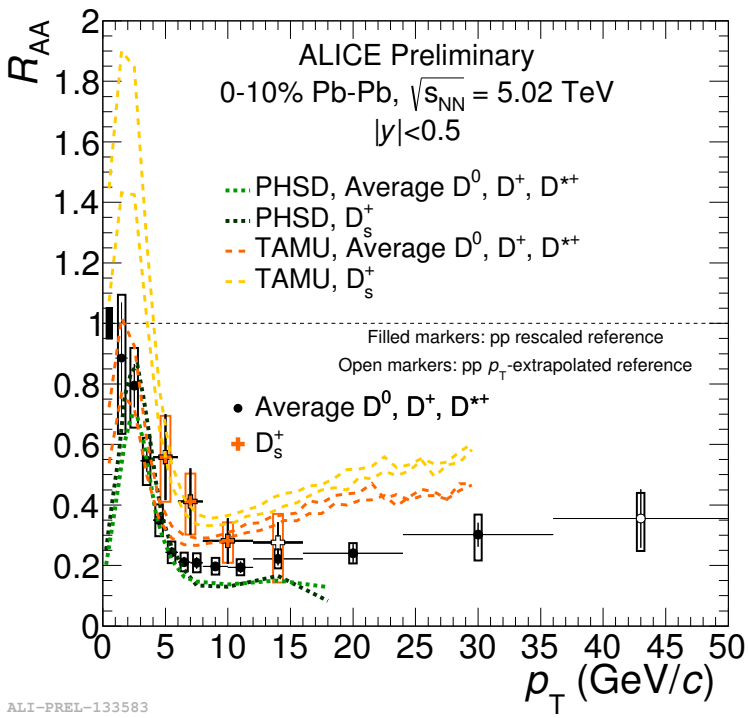
Drastic reduction of statistic and systematic errors on background estimation

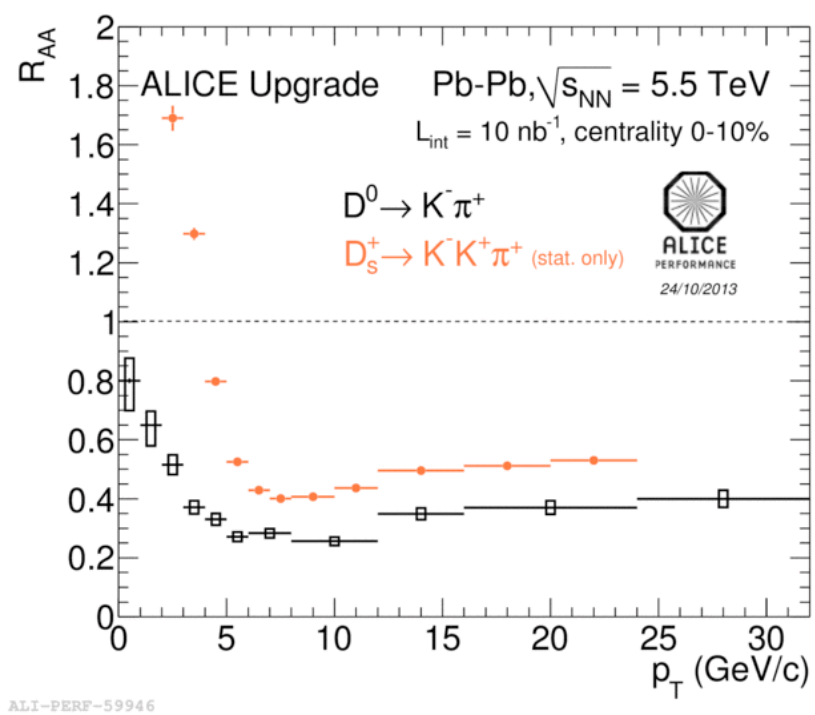
Observable sensitive to:

- *The modification of the ρ meson spectral function due to chiral symmetry restoration*
- *Thermal radiation from the QGP*

Physics Performance of the Upgraded ALICE

Charmed D^0,D^{+-}, D_S mesons $|\eta|<0.9$



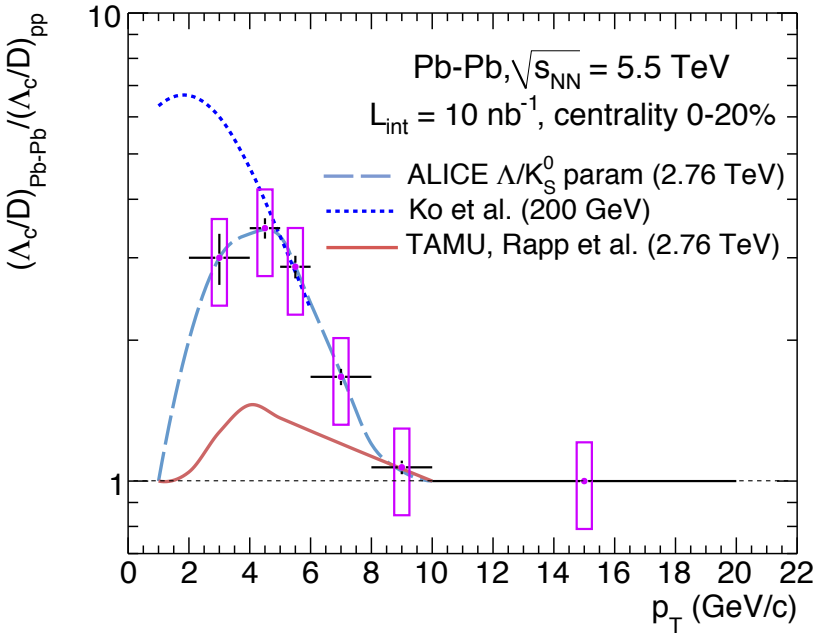


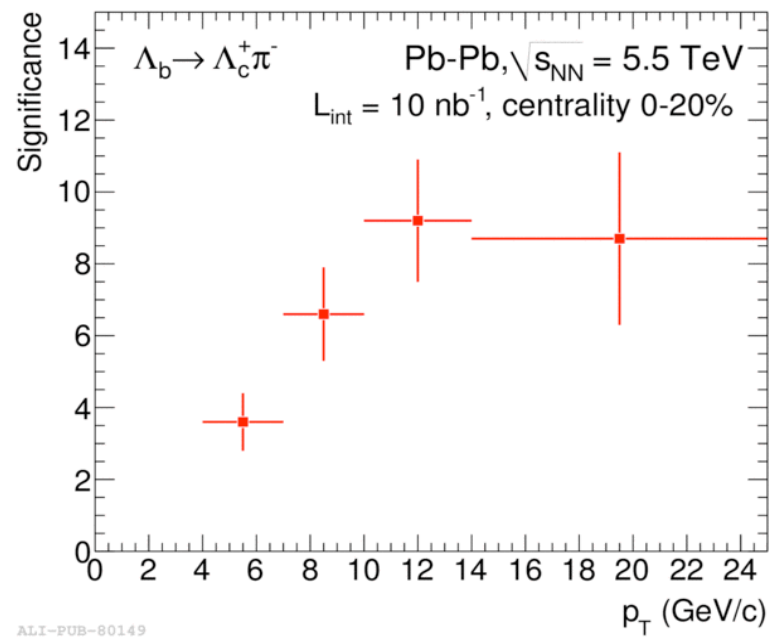
Improvement of the statistical significance on the suppression pattern

Comparison of different D-mesons is sensitive to the hadronization process of c quarks in the QGP

Physics Performance of the Upgraded ALICE

Charmed and Beauty baryons |η|<0.9



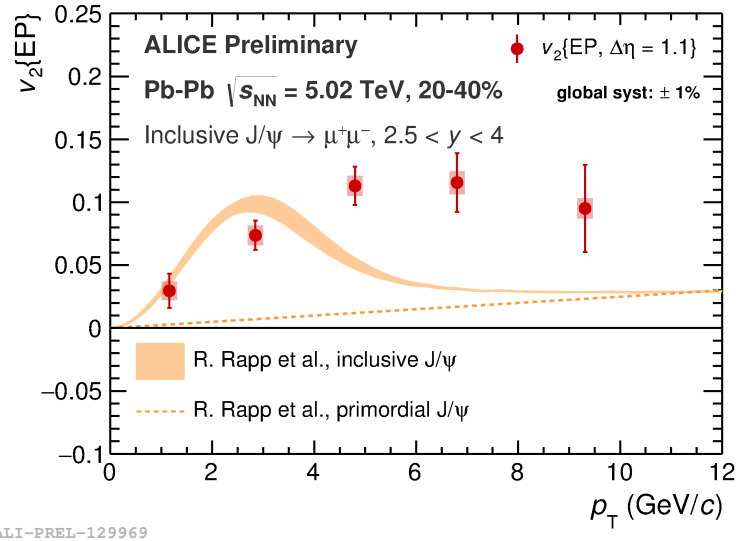


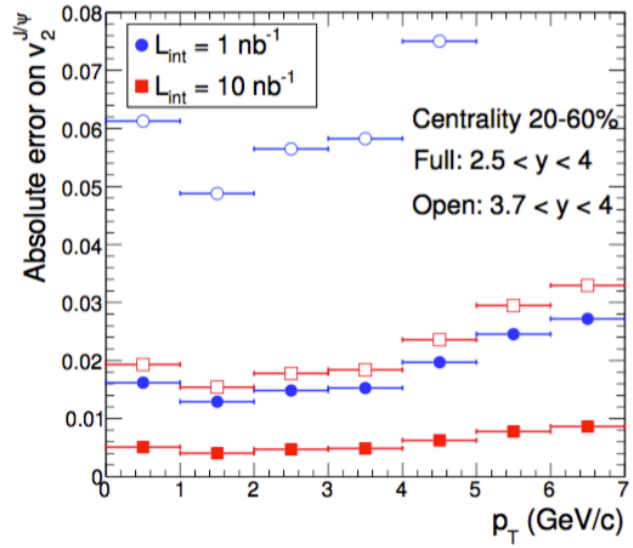
New observables in Pb-Pb: baryon production in the charm and beauty sector!

For the moment, only observed in pp and p-Pb collisions: https://arxiv.org/abs/1712.09581

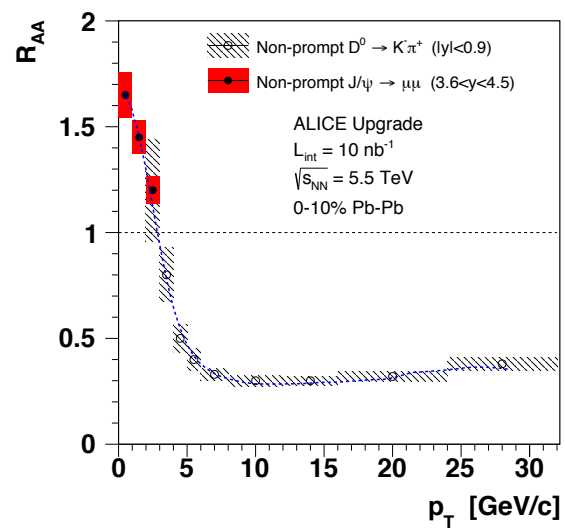
Physics Performance of the Upgraded ALICE

J/ψ elliptic flow 2.5<η<4.0





With ITS and MFT: Prompt - Decay separation



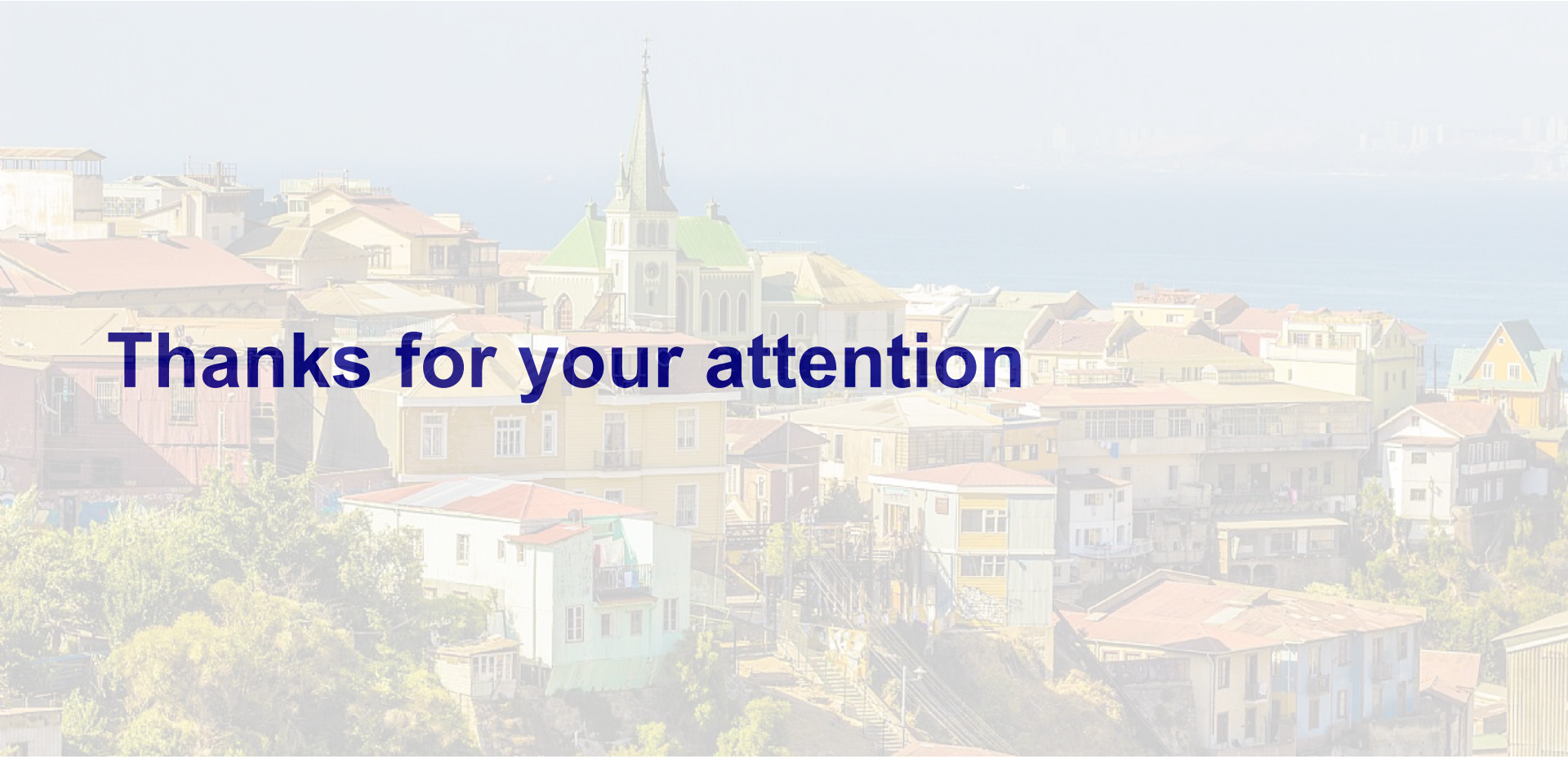
Conclusions

- Factor 10 increase of the Pb-Pb integrated luminosity is planned by the LHC for Run3 and Run4
- ALICE will upgrade its detector to take advantage of the luminosity increase
  - A factor 10-100 increase in Pb-Pb statistics, depending on the observable with respect Run1 and Run2 (10 nb^{-1} integrated Pb-Pb luminosity)
- Full upgrade of the detector readout architecture and computing
- New GEM-based TPC readout chambers
- New pixel trackers (ITS and MFT) based on ALPIDE MAPS sensor
- Better detector performance to study low p_T hadrons and open heavy flavour and quarkonium in Pb-Pb collisions
- Installation is foreseen in 1 year from now, during LS2 (2019-2020)

ALICE Detector Upgrade

Letters of Intent and Technical Design Reports

- ALICE TDR for the Run3
  - CERN-LHCC-2013-019 (System upgrade)
  - CERN LHCC-2013-013 (TPC Upgrade)
  - CERN-LHCC-2013-023 (ITS Upgrade)
  - CERN-LHCC-2015-001 (MFT)
  - CERN-LHCC-2015-006 (O2)
- ALICE upgrade LoI and its addendum
  - CERN-LHCC-2012-012 (LoI)
  - CERN-LHCC-2013-014 (addendum)



Thanks for your attention