ALICE Muon Spectrometer upgrade and commissioning for the LHC Run 3

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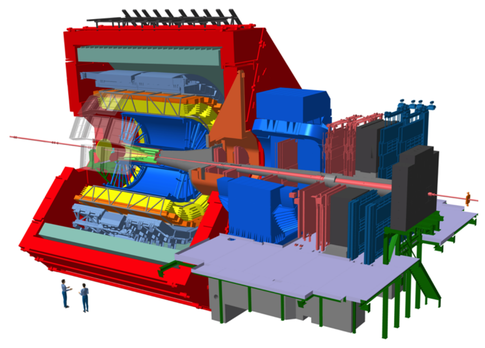
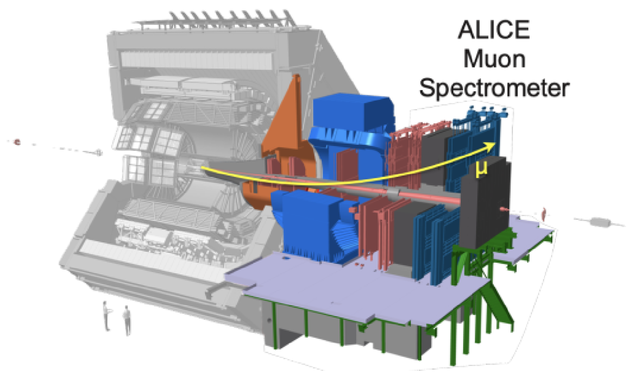
1) Introduction

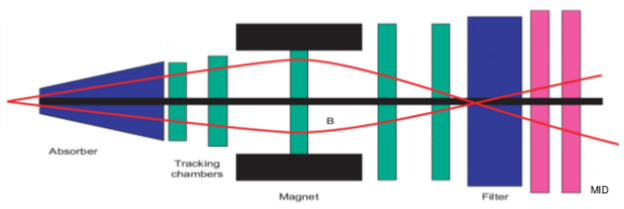
- A Large Ion Collider Experiment (ALICE) at the CERN Large Hadron Collider (LHC) is the experiment specifically designed to study the Quark-Gluon Plasma (QGP) in heavy-ion collisions
- During the long shutdown 2 of LHC, ALICE achieved a major upgrade of its apparatus:
  - to cope with the increased collision rate foreseen for Run 3
  - to allow a new ambitious program of high-precision measurements



2) ALICE Muon Spectrometer (MS)

- Covers the pseudorapidity range $2.5 < \eta < 4$.
  Made up of:
  - **Absorbers**: front absorber, filter iron wall
  - **Muon Chambers (MCH)**, 5 stations of 2 planes of Cathode Pad Chambers (CPC)
  - **Muon Identifier (MID)**, 2 stations of 2 planes of Resistive Plate Chambers (RPC)
- Current muon physics topics:
  - quarkonia production
  - open heavy flavors
  - low mass dimuons
  - single muons and dimuons from $W^{\pm}/Z^0$



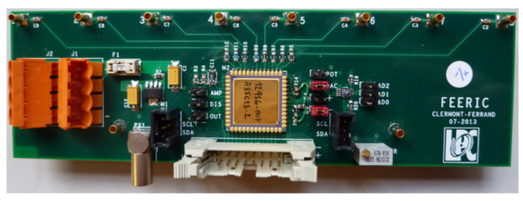


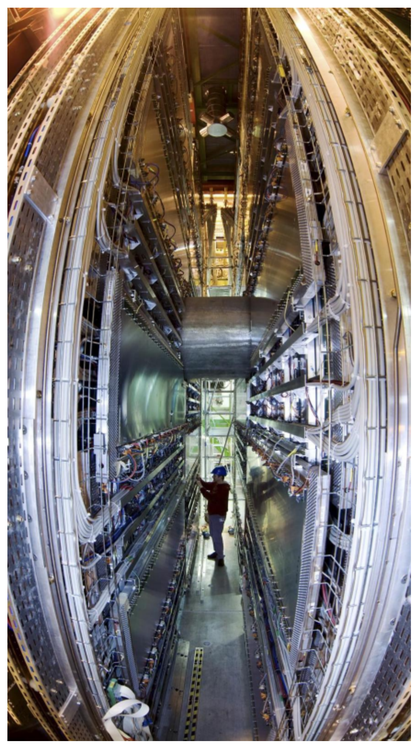
3) MS upgrade motivations

- Determine the muon production vertex
  $\rightarrow$ before the upgrade, no disentanglement of open charm and open beauty production
  $\rightarrow$ separate prompt and non-prompt J/ψ
  $\rightarrow$ reduce background from non-prompt sources (presently there are significant statistical uncertainties in single muon and dimuon analysis due to background coming from combinatorial π/K)
  $\rightarrow$ improved mass resolution for light neutral resonances
- faster read-out needed to cope with the expected interaction rates in Pb-Pb collisions for Run 3 (50 kHz)

4) Muon Identification System (MID)

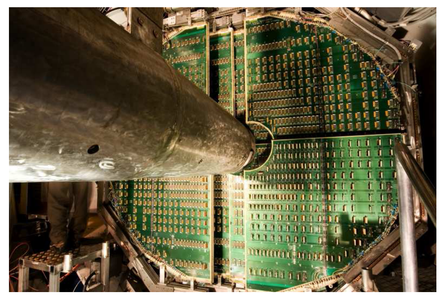
- 72 Resistive Plate Chambers (RPCs) arranged in 4 planes with 21k readout channels
- from Run 3 the RPCs will operate in continuous readout mode
  $\rightarrow$ this required an upgrade of the read-out electronics, which is now completed
- to cope with the increased counting rate and reduce aging effects the RPCs will be operated at a low-gain avalanche mode thanks to a new front-end electronics (FEERIC ASIC) which include a pre-amplification stage
  $\rightarrow$ one RPC in ALICE cavern equipped with FEERIC cards during Run 2 showed similar efficiency w.r.t. the other RPCs

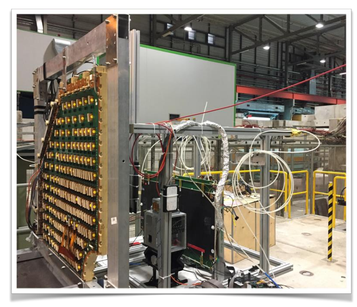




5) Muon Chambers (MCH)

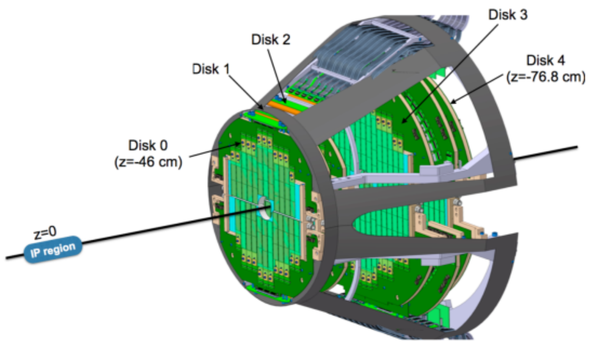
- Tracking chambers based on Cathode Pad Chambers grouped in 10 planes with 1.1 million readout channels; spatial resolution $\sim$100 μm
- new front-end electronics FEE and new read-out chain
  - FE chip – SAMPA
  - FE board hosting two SAMPA chips – Dual Sampa (DS)
  - Concentrator board with GBT links protocol taking data from several DS – SOLAR
  - Common Readout Unit (CRU)
- Full chain successfully tested in test beam in 2017 at CERN SPS

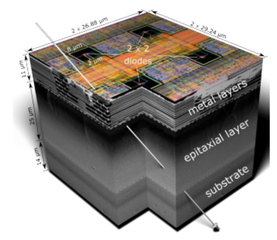




6) Muon Forward Tracker (MFT) design

- New Pixel Tracker at forward rapidity: **Muon Forward Tracker (MFT)**
  - pseudorapidity range $2.5 < \eta < 3.6$, installed before the hadron absorber
  - 936 ALPIDE Silicon pixel sensors (0.4 m^2), based on Monolithic Active Pixel Sensors (MAPS). Sensor size 15 $\times$ 30 mm^2 ; Pixel size 27μm $\times$ 29μm ; 512 $\times$ 1024 pixel matrix; spatial resolution better than 5μm
  - cone structure formed by ten half disks. Each half-disk consists of structures called ladders which host the ALPIDE chips (280 ladders of 2 to 5 sensors).

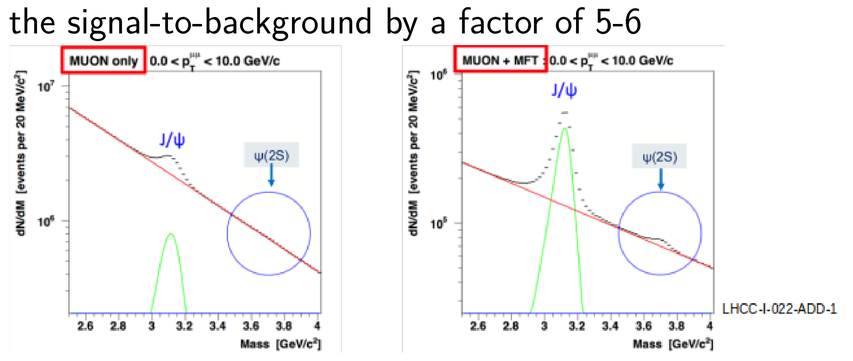




$\rightarrow$ MFT installed in ALICE since Jan '21, now under commissioning

7) Physics measurements with the MFT

- improve vertexing and tracking capabilities $\rightarrow$ matching between extrapolated muon tracks coming from the MCH after the absorber with MFT tracks before the absorber
- separation between prompt and non-prompt J/ψ down to 0 p$_T$, by measuring the pseudo-proper decay time associated to the secondary vertex
- reduce the uncertainties on the ψ(2S) measurements in the Pb-Pb collisions, improving the signal-to-background by a factor of 5-6



- improving low-mass dimuon measurement by reducing the combinatorial background from the semi-muonic decays from kaons and pions and by improving the mass resolution, thanks to the precise measurement of the opening angle of muon pairs

8) Conclusions

- MCH and MID have been upgraded with new FEE to cope with the higher interaction rates in Run 3
- MFT will significantly improve the muon physics program for Run 3
- ALPIDE chips used by the MFT (and ITS) are a result of an intense R&D program and all of them have already been installed
- all the components for the MS data readout chain have successfully been tested and installed

References

1. ALICE Collaboration, The ALICE experiment at the CERN LHC, JINST 3, S08002 (2008).
2. ALICE Collaboration, Letter of Intent for the Upgrade of the ALICE Experiment, CERN-LHCC-2012-012, LHCC-I-022, 2012.
3. ALICE Collaboration, Addendum of the Letter Of Intent for the Upgrade of the ALICE Experiment: The Muon Forward Tracker, CERN-LHCC-2013-014, LHCC-I-022-ADD-1, 2013.