Upgrade of ALICE TPC and its readout electronics for the LHC RUN3 and beyond

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on behalf of ALICE Collaboration

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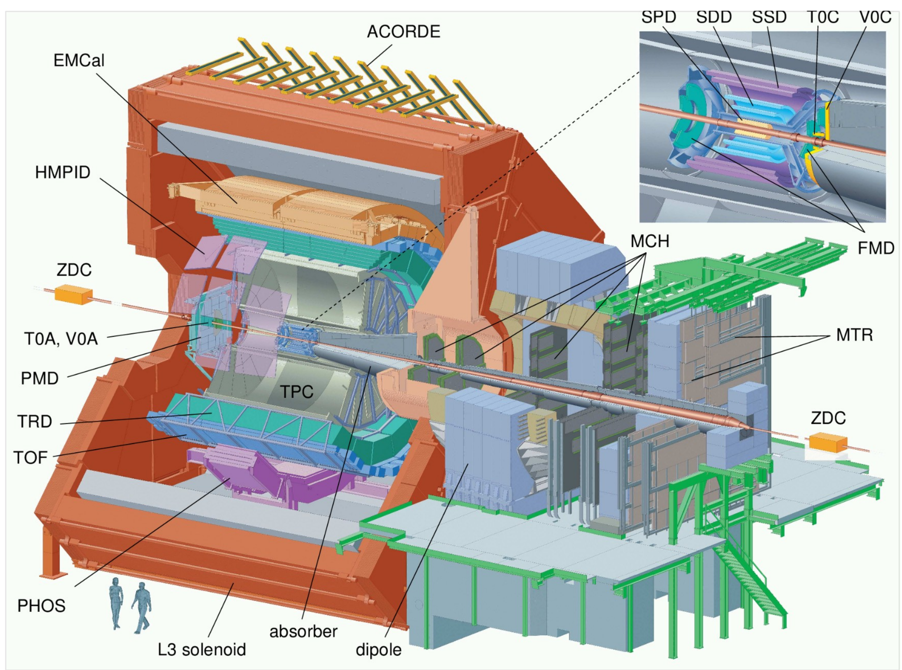
ALICE Experiment

- Studies the outcome of heavy ions (Pb-Pb), p-Pb and pp collisions at LHC
- Main goal is to characterize the strongly interacting matter at extreme energy densities where Quark-Gluon Plasma (QGP) is produced



Schematic view of ALICE Detector system.

It consists of 18 different types of particle-detectors such as tracking system, time-of-flight, calorimeters, muon chambers.

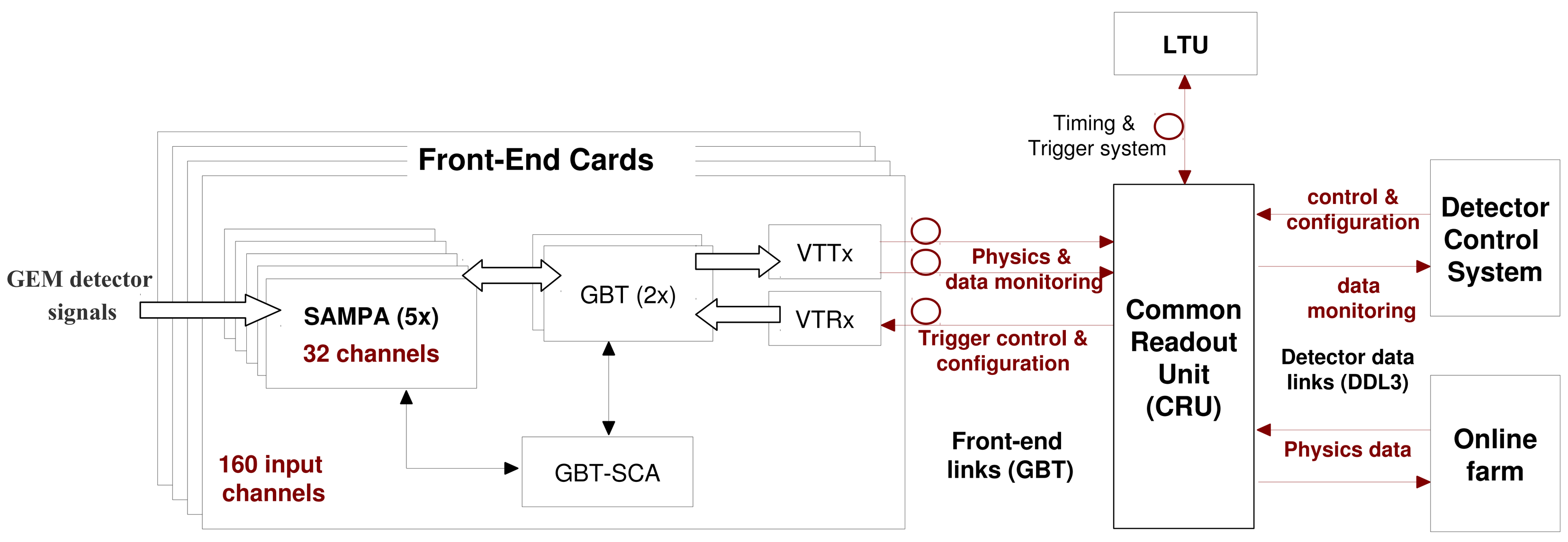
- During RUN1 in 2010-2013:
  - Data collection for all collision systems (Pb-Pb, p-pb, pp) at center-of-mass energy 2.7 TeV (Pb-Pb), 5.02 TeV (p-Pb), 0.9 TeV/ 2.76 TeV/ 7 TeV/ 8 TeV (pp)
  - Valuable data sets were recorded and important results were published

ALICE-TPC Upgrade

- Data collection of the ALICE experiment is synchronized with the operation of the LHC
- Therefore, the ALICE experiment will progress in two (or more) phases namely RUN2 and RUN3 (and beyond) after the long shutdowns of the LHC in 2015 and 2018, respectively
- In RUN1, Pb-Pb collisions were performed at 2.76 TeV per nucleon pair and reached integrated luminosity (L_i) of 0.16 nb^{-1}
- The RUN2 is ongoing and data-collection for pp collisions at 13 TeV is in progress
- During **RUN2** and **RUN3**, the **Pb-Pb collisions** will take place **at 5.2 TeV** center-of-mass energy, aiming to reach L_i of 1 nb^{-1} and 10 nb^{-1}, respectively

- ***In the RUN3,*** *while achieving high luminosity,* ***the collision rate of 50 kHz is expected***
- *To cope with the high collision rate, the present ALICE TPC and its readout system needs to be upgraded*
  - The present Multi-Wire Proportional Chamber based TPC will be replaced with the **Gas Electron Multiplier (GEM) based TPC**
  - The Front-End Electronics (FEEs) and the readout system will also be replaced from the present triggered readout to **continuous readout**

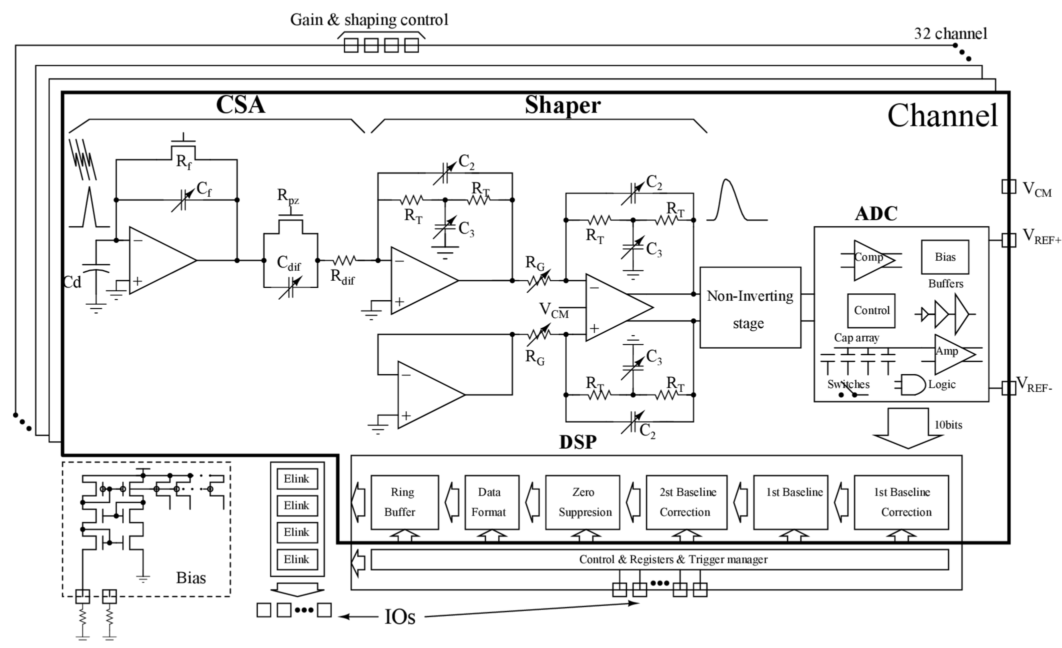
TPC Readout System upgrade

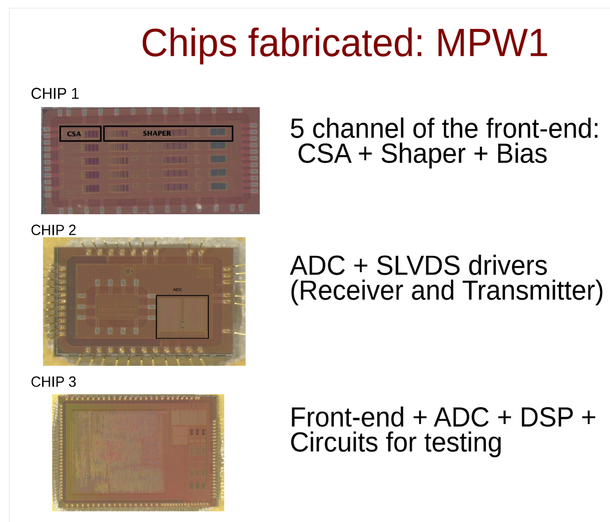


In the upgraded TPC readout,

- The GEM detector signals will be readout using the Front-End Cards (FECs)
- In the FECs, five custom-made ASICs, named SAMPA chips will process the data from its 160 readout channels (32 channels/each)
- The data from SAMPA will then be multiplexed and transmitted using GigaBit Transceiver (GBT) via optical links to a Common Readout Unit (CRU)
- The CRU is an interface to the on-line farm, trigger and detector control system

Frond End Electronics - SAMPA



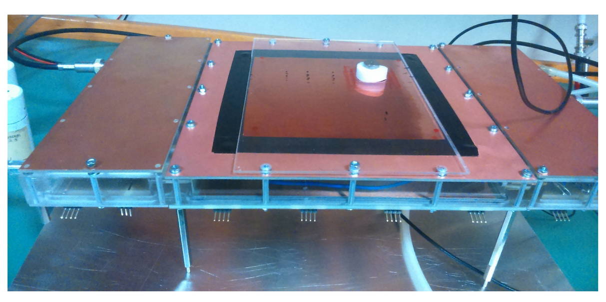


- The SAMPA contains
  - Charge-Sensitive preAmplifier (CSA), Shaper, 10 bit/10 MHz digitizer (ADC) and Digital Signal Processing (DSP) part
- The acquired data from the SAMPA is transferred at 1.2 Gbps over four 320 Mbps serial links
- 32 channels continuous as well as external triggered readout is possible
- The first version of the SAMPA chip (MPW1) is produced in 2014

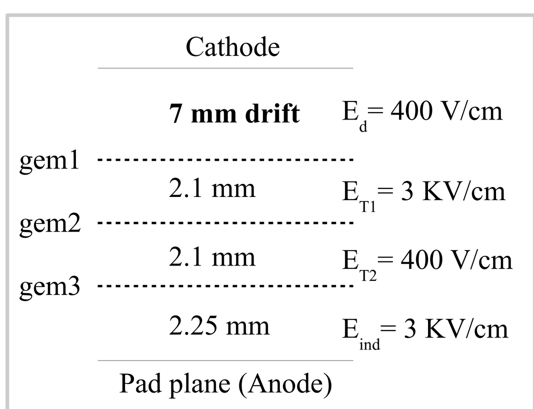
SAMPA (chip1) Test with GEM Detector Prototype

GEM prototype detector and its gain

GEM chamber



Detector Schematic

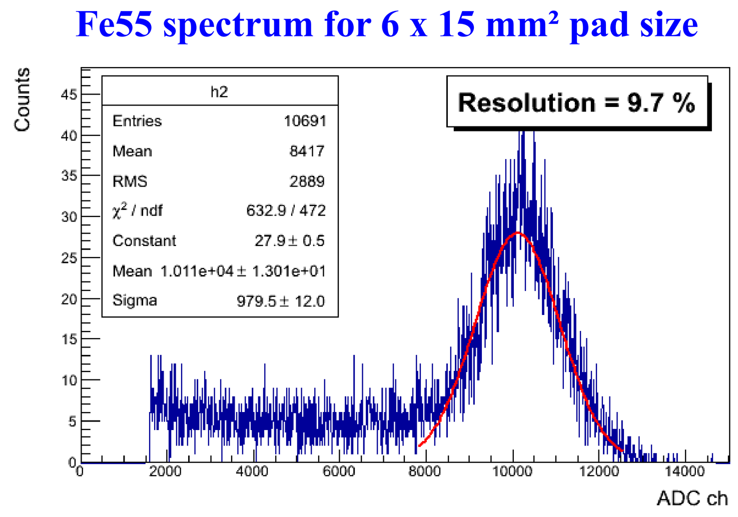


Operational parameters

- GEM detector (3 GEM foils – 10 x 10 cm²):
  - HV = -2.97 KV (-297 V @ Foil)
  - Fe55 source (R) = 1.1 kHz
  - Anode current (I_a) ~ 60 pA
  - **Gain = R / (I_a * N_{pri} * e⁻) ~ 2000**

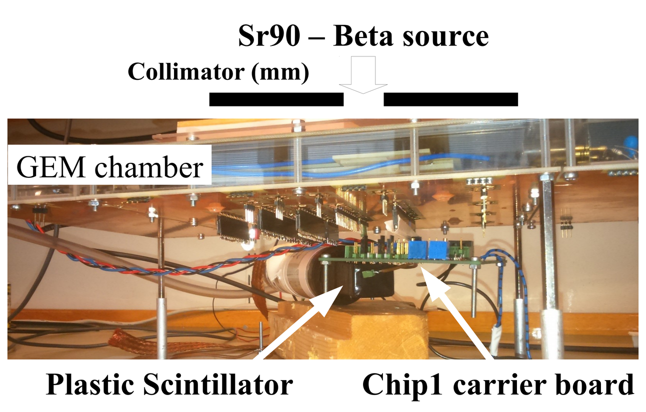
    N_{pri} is 165 for Ne mix
  - $Ne+CO_2+N_2$ (90 % +10 % +5 %)
  - Sr90 for MIPs
- MPW1 – chip1:
  - Diff. channel #2, Gain 20 mV/fC @ 160 ns
- VME DAQ:
  - CAEN ADC: 1 GHz, 14 bit, LSB = 0.125 mV

Fe55 spectrum for 6 x 15 mm² pad size

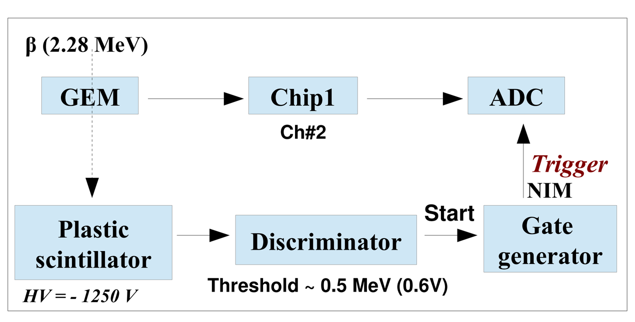


Signal-to-Noise ratio for MIP's in 7 mm drift

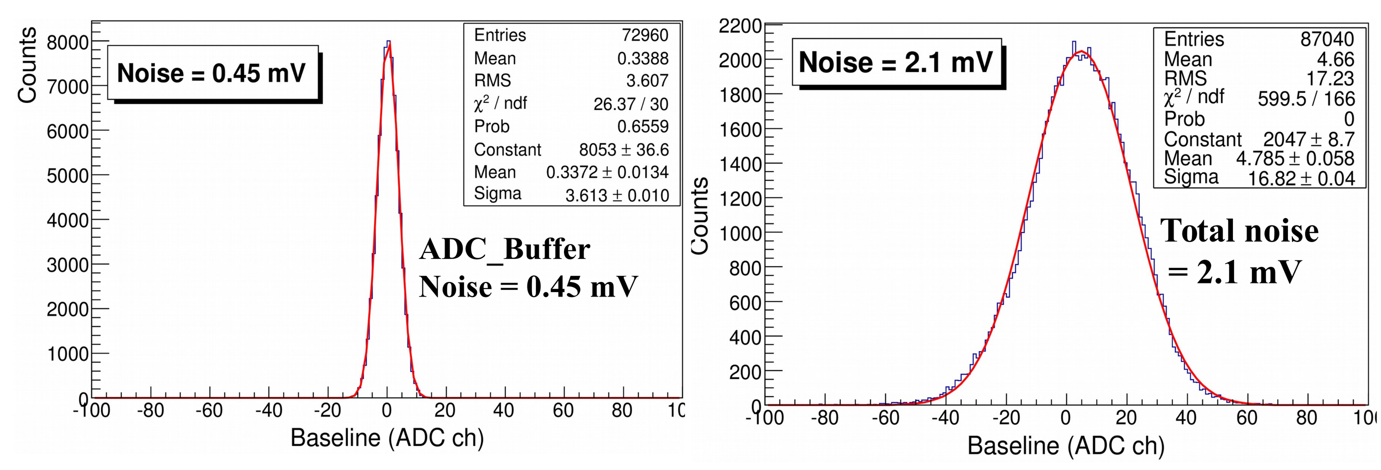
Test setup



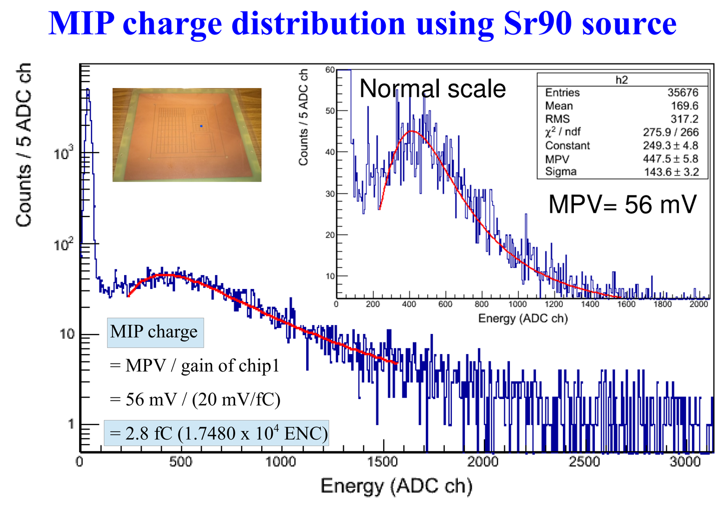
Schematic of Data acquisition



Chip1 noise = $[(ADC\_Buffer\ noise)^2 - (Total\ noise)^2]^{1/2}$ ~ 2 mV ~ 641 ENC



MIP charge distribution using Sr90 source



- **SNR = MIP charge / chip1 noise = (17480 / 641) = 27**
- **Close to the requirement of upgraded ALICE TPC**

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