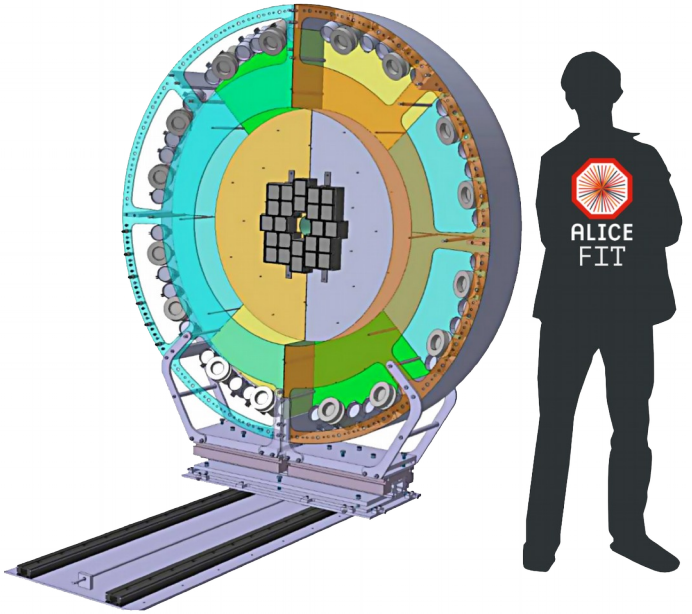
Fast Interaction Trigger

for the upgrade of the ALICE experiment at CERN: design and performance

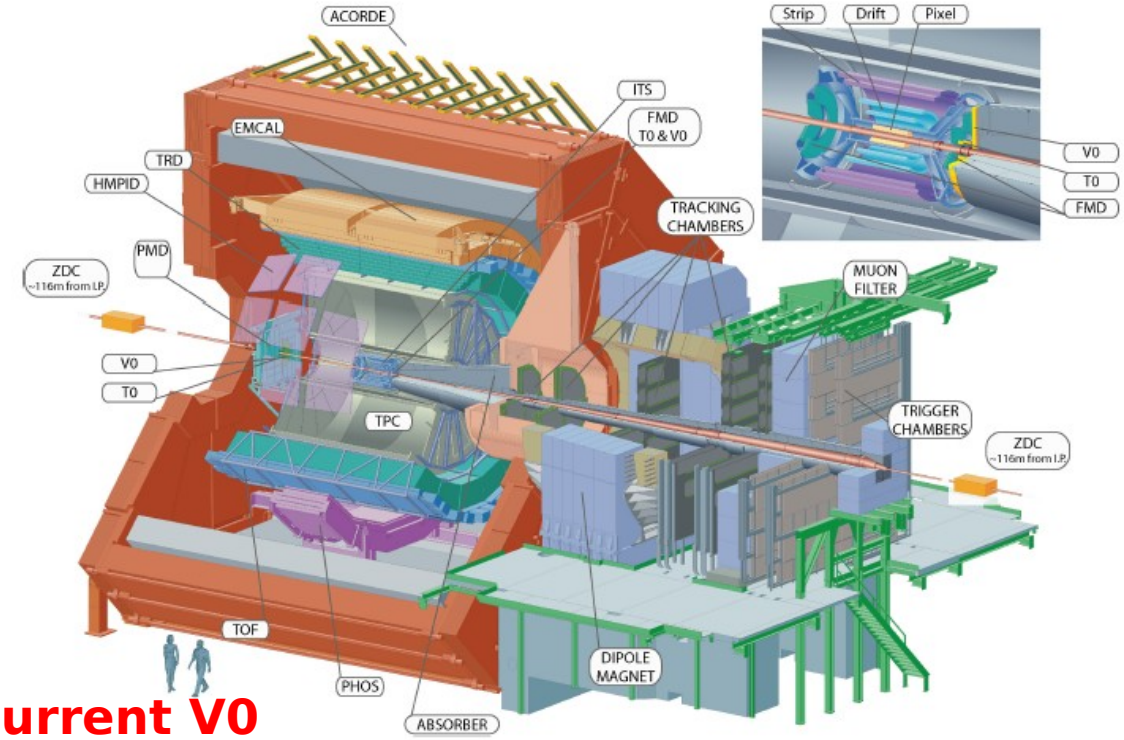


Alla Maevskaya *on behalf of the ALICE collaboration*

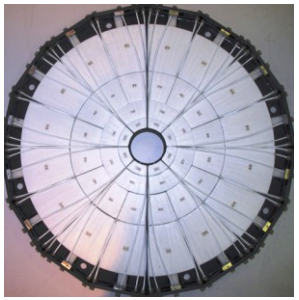
Outline

- **Introduction**
  - ALICE now (Run2)
  - ALICE upgrade (Run3)
- **Fast Interaction Trigger (FIT) detector**
  - Required functionality
  - Detector design
  - Test results
    - Using PS beam
    - With a prototype installed in ALICE
  - Simulated performance
- **Summary**

The ALICE detector



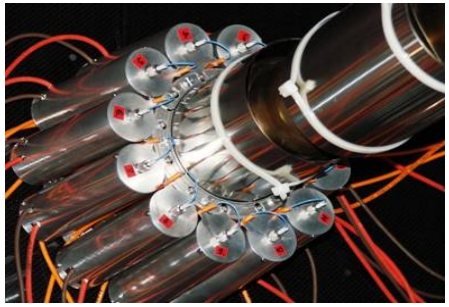
Current V0



- V0 consists of two arrays of 32 scintillating counters
- Installed on opposite sides of IP
- Scintillators coupled to PMTs by fibers $-3.7 < \eta < -1.7$, $2.8 < \eta < 5.1$

Time resolution: 450 ps and 350 ps for V0-A and V0-C, respectively

Current T0



- T0 consists of two arrays, placed on the opposite sides of the IP
- Cherenkov radiators, each coupled to PMTs (12 per side)
- $-5 < \eta < -4.5$, $2.9 < \eta < 3.3$

Time resolution of ~ 40ps for protons and ~25ps for Pb-Pb collisions

V0 & T0 Provide triggers, luminosity monitoring, background reduction, collision time (for PID), centrality, and event-plane determination

ALICE physics plans

LHC plans after 2020

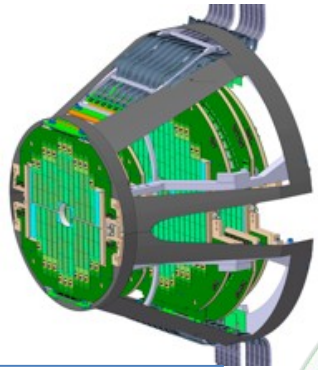
- Pb-Pb - interaction rates 50kHz, pp – 200kHz (up to 1-2 MHz).

- Focus on rare probes
  - heavy-flavour mesons and baryons,
  - quarkonium states,
  - low-mass dileptons,
  - jets,
  - their correlations with other probes.

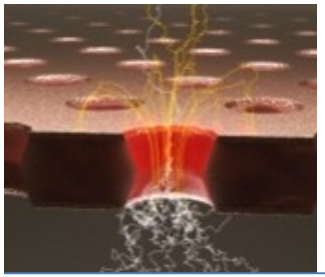
- Detector upgrades
- New readout and trigger systems
- 2 operation modes for detectors: **triggered and continuous**

Key ALICE upgrades for Run 3

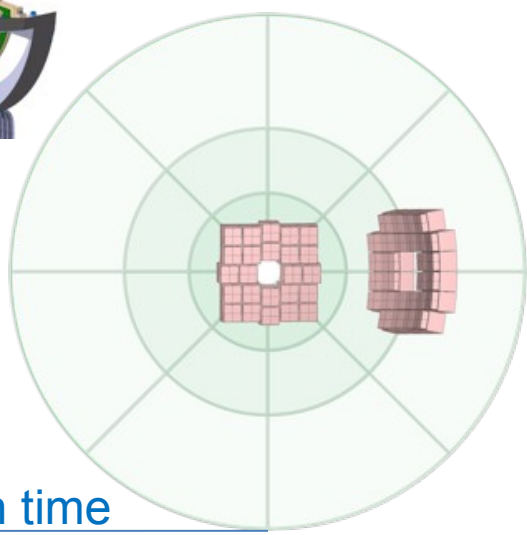
New Inner Tracking System (ITS)
- CMOS pixel, MAPS technology
- Improved resolution, less material, faster readout



New Muon Forward Tracker (MFT)
- CMOS Pixels, MAPS technology
- Vertex tracker at forward rapidity



New TPC Readout Chambers (ROCs)
- Gas Electron Multiplier (GEM) technology
- New electronics (SAMPA), continuous readout



New Fast Interaction Trigger (FIT) Detector
- Centrality, event plane, luminosity, interaction time

Readout upgrade
- TOF, TRD, MUON, ZDC, Calorimeters

Integrated Online-Offline system (O^2)
- Record MB Pb-Pb data at 50 kHz

Fast Interaction Trigger: requirements

Online

- Luminosity monitoring and feedback to LHC
- Trigger signals
  - Online Vertex determination
  - Minimum Bias and centrality selection
  - Rejection of beam-gas events
  - Veto for Ultra Peripheral Collisions
  - Minimal trigger latency <= 425 ns

Offline

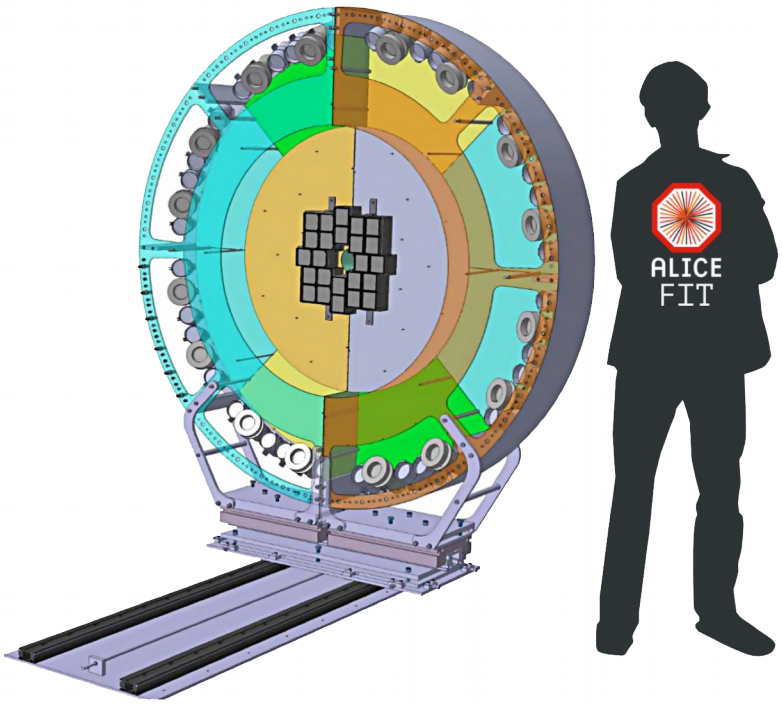
- Collision time for Time-Of-Flight particle ID determination
- Multiplicity, centrality and event-plane measurements

Designing FIT

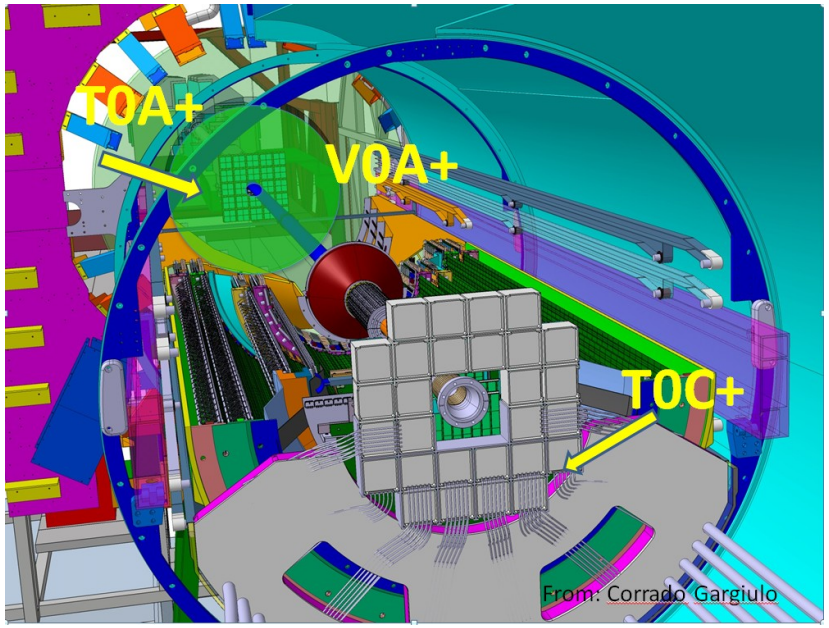
- How to make **FIT fast** (σT < 50 ps)
  - ✓ **Cherenkov radiators (quartz) + MCP (T0 – like)**
- How to make **FIT big** (large acceptance)
  - ✓ **large area scintillators (V0 – like)**

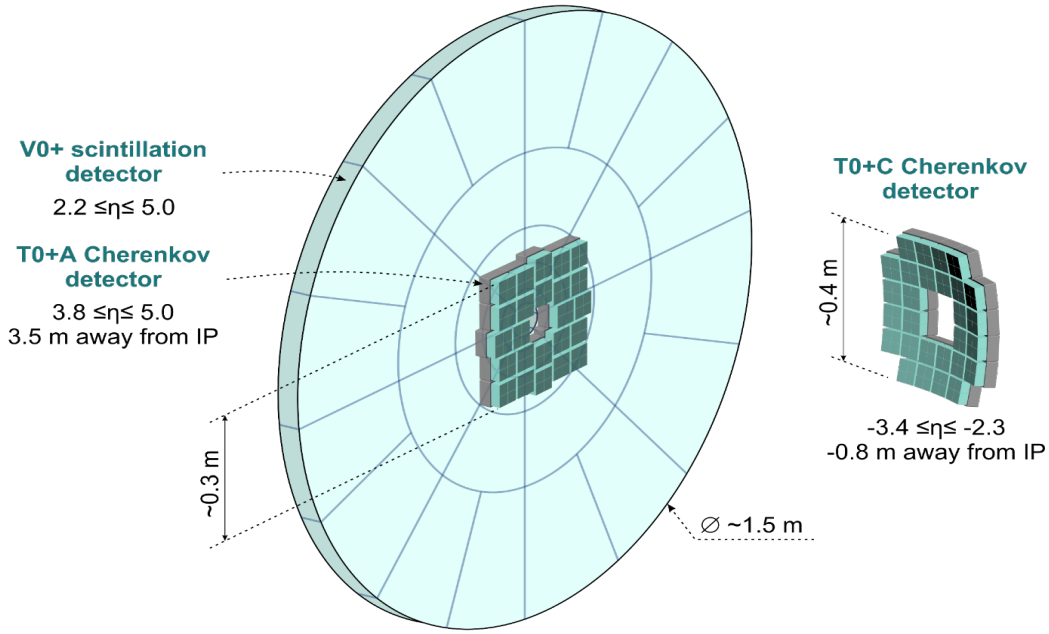
To fulfill all of ALICE requirements FIT must

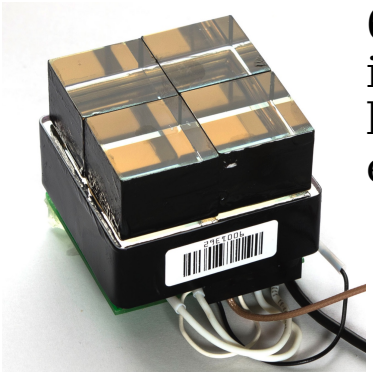
- **T0 and V0**
- For reliable operation both elements must be well **integrated**



FIT detector







The **MCP-PMT XP85012** with 64 anode pads is transformed into the 4-channels detector by merging 16 pads (4 × 4) of each cell into a single channel

Each V0+ sector is based on

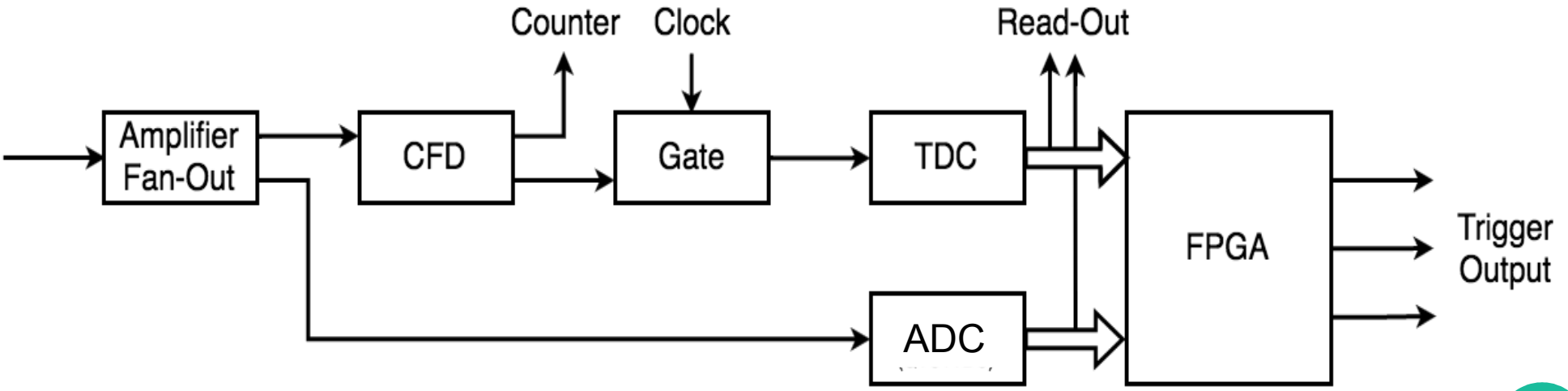
- 4cm of EJ-204 plastic scintillator
- clear Asahi fibers with recessed ends
- 2” Hamamatsu R5924-70 fine-mesh PMTs.

FIT electronics

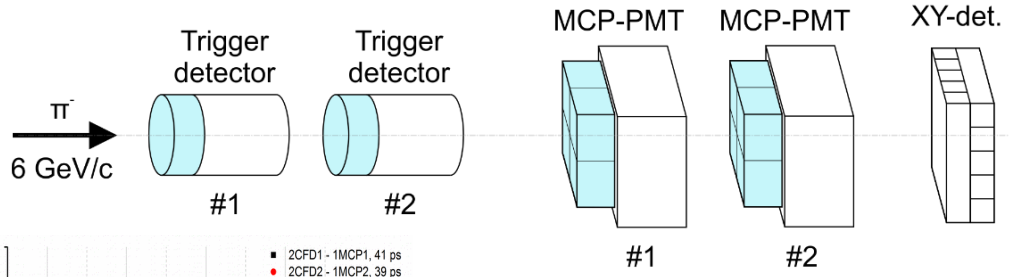
Custom readout and signal processing electronics.
The main board is a fully integrated system :

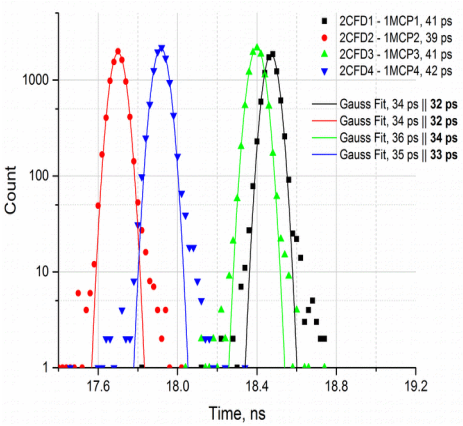
- an amplifier,
- a Constant Fraction Discriminator (CFD),
- on-board Time and Amplitude to Digital converters (TDC/ADC) and FPGA processors,
- GBT based read-out.

Trigger decision to be based on digitized data (after TDCs & ADCs).



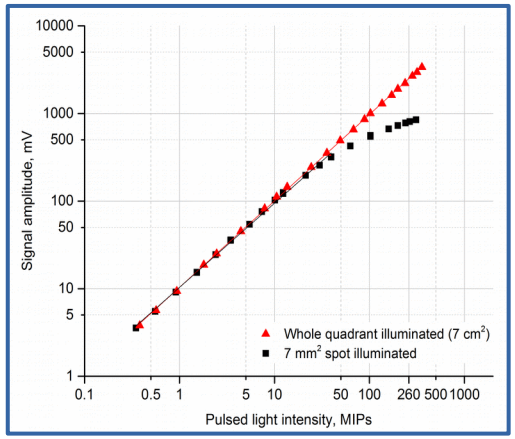
MCP-PMT test results: module properties





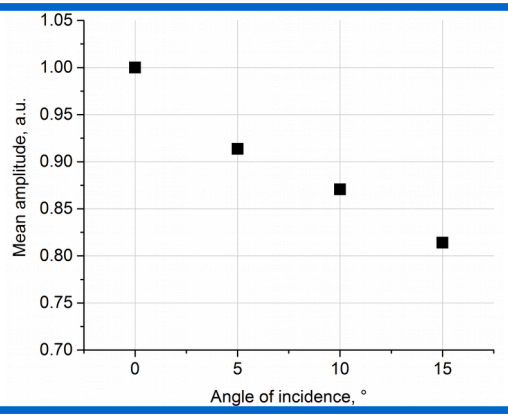
Time resolution of the whole system (Cherenkov module, 40 m cables, analog readout Electronic) 33 ps

Amplitude linearity



Linear amplitude for full dynamic range even for T0+A modules around beam pipe with average particle load from 1.2MIP/q for pp 14TeV and 260MIP/q Pb-Pb 5.5TeV

1 MIP (Minimum Ionizing Particle) signal amplitude is dependent on the angle of incident particle – one of the reasons of concave shape of T0+C

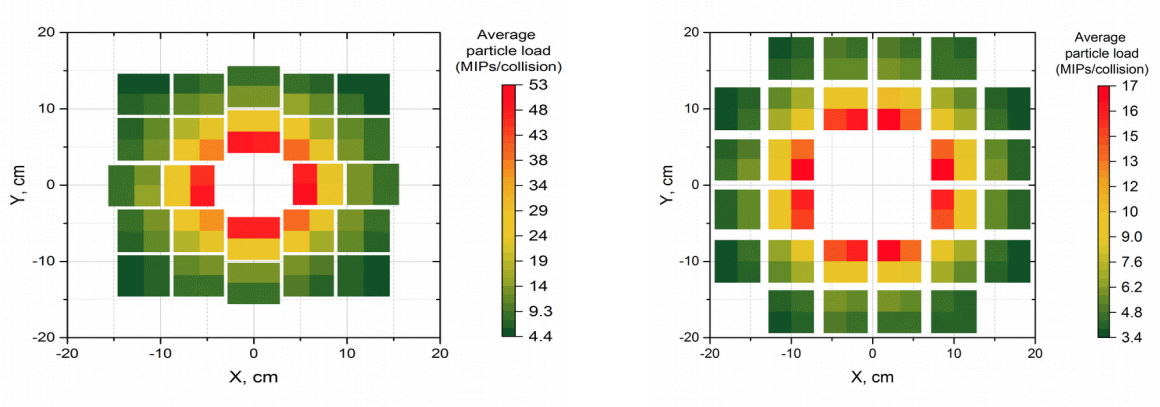


Calculating the lifetime needed for T0+ modules

	pp	p-Pb	Pb-Pb
Standard scenario	$5.6*10^{11}$ ($8.4\ pb^{-1}$)	10^{11} ($50\ nb^{-1}$)	$1.1*10^{11}$ ($13\ nb^{-1}$)
Alternative scenario	$1.7*10^{13}$ ($250\ pb^{-1}$)	$2*10^{12}$ ($1\ pb^{-1}$)	$1.1*10^{11}$ ($13\ nb^{-1}$)
Average particle load / anode current of the most central T0+A quadrants	0.84 MIP/q 0.11 μA/q	3.3 MIP/q 0.36 μA/q	52 MIP/q 1.63 μA/q

The Total Integrated Anode Charge (IAC) will range from 0.03 C/cm² for the peripheral sensors up to 0.59 C/cm² for the central sensors

Particle load for Pb-Pb collisions, centrality 0-90%



MCP-PMT aging tests

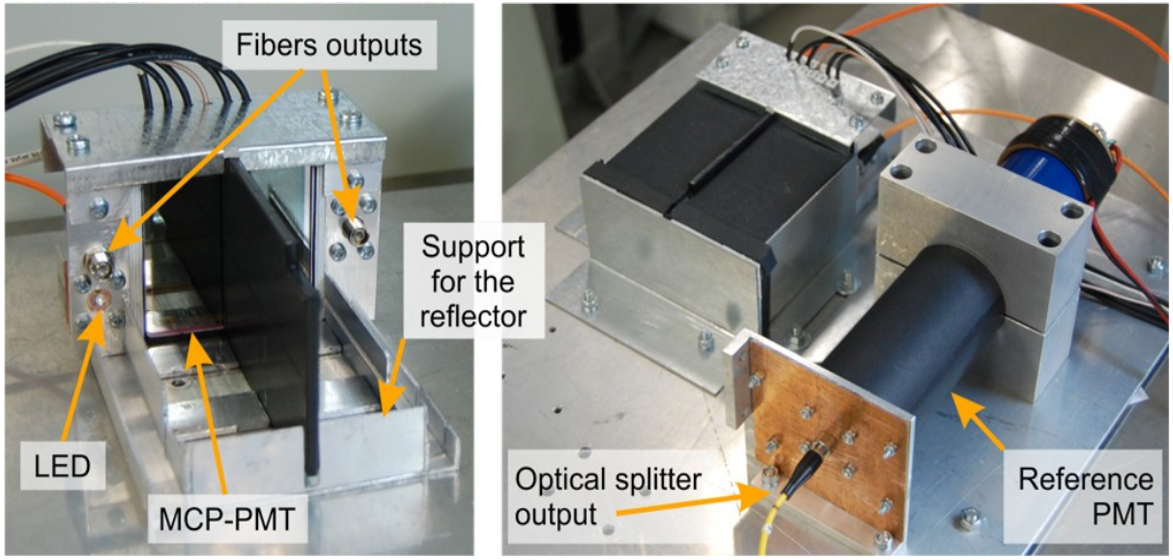
NRNU MEPhI April-October 2017 ~0.5 C/cm² IAC

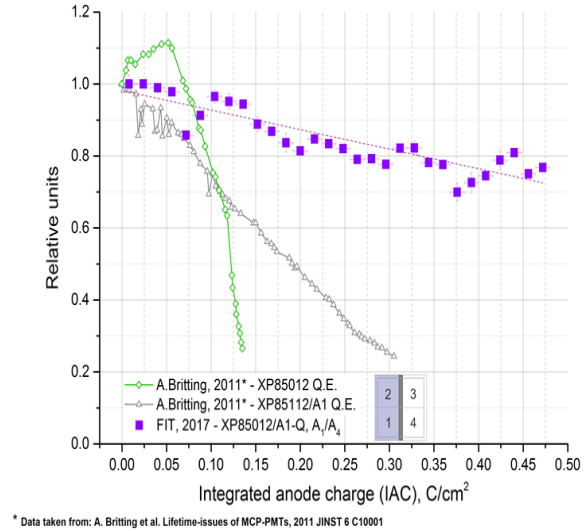
MCP-PMT with shielded half and the reference PMT

- ✓ **44% drop in pulse amplitude with respect to the reference PMT for 405 nm laser**

Decrease in illuminated half relative to shielded one

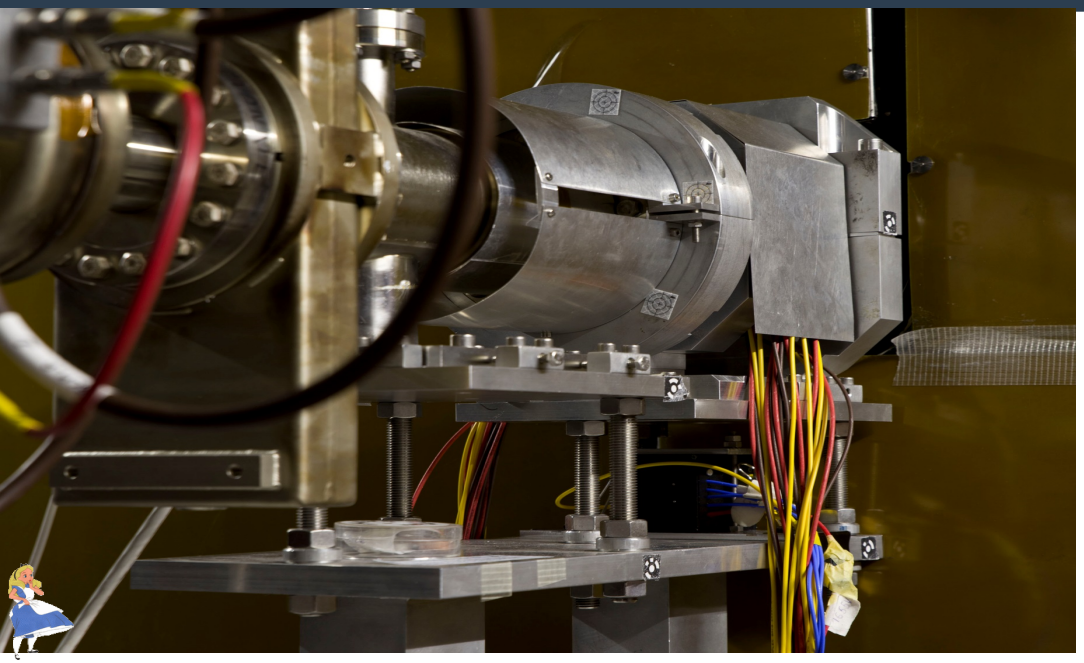
- ✓ **27% for 405 nm laser**
- ✓ **15% for Cherenkov light (160…300nm)**





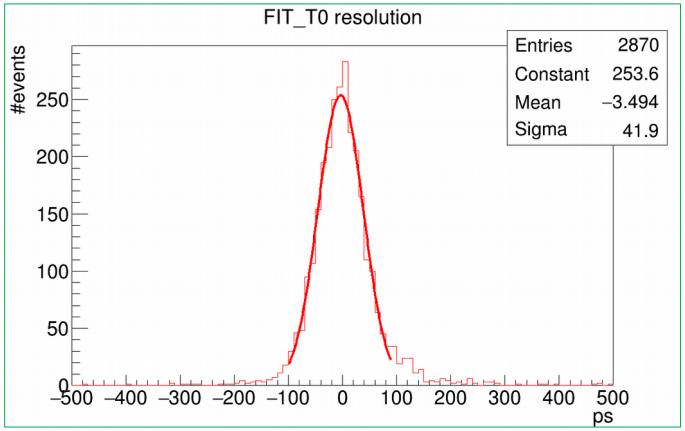
Pulse amplitude as a function of integrated anode charge (IAC) in comparison with data from *A. Britting et al. 2011,* Lifetime-issue of MCP-PMT

FIT module installed in ALICE

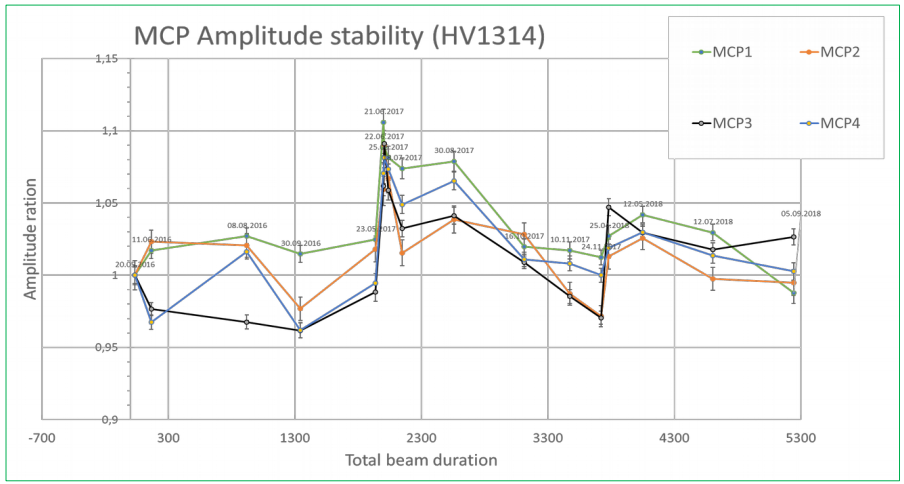


2.5 years operations in ALICE near T0A position:

- **Timing resolution better than 50 ps for single MIPs**
- **No signs of aging – stable amplitude for all 4 channels**



Collision time resolution

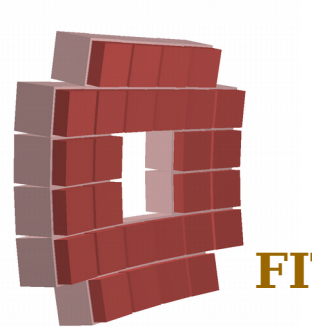


Trend of amplitudes 2016-2018years

FIT performance studies

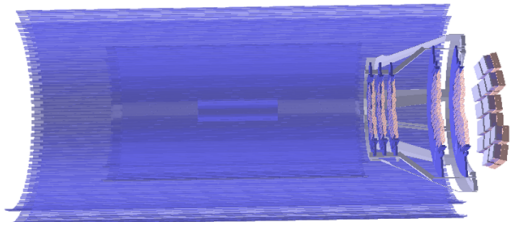
AliRoot simulation of ALICE upgrade involving the following components:

- upgraded ITS
- MFT
- beam pipe
- **FIT**
- Solenoid field 0.5T and 0.2T

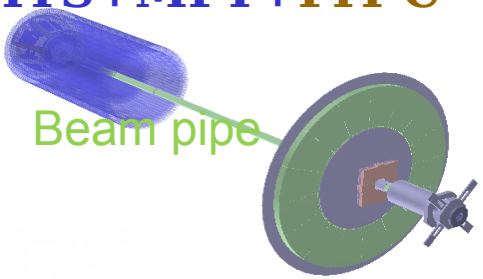


FIT-C

ITS+MFT+FIT-C



ITS+MFT+FIT-C



V0A+ T0A+ support

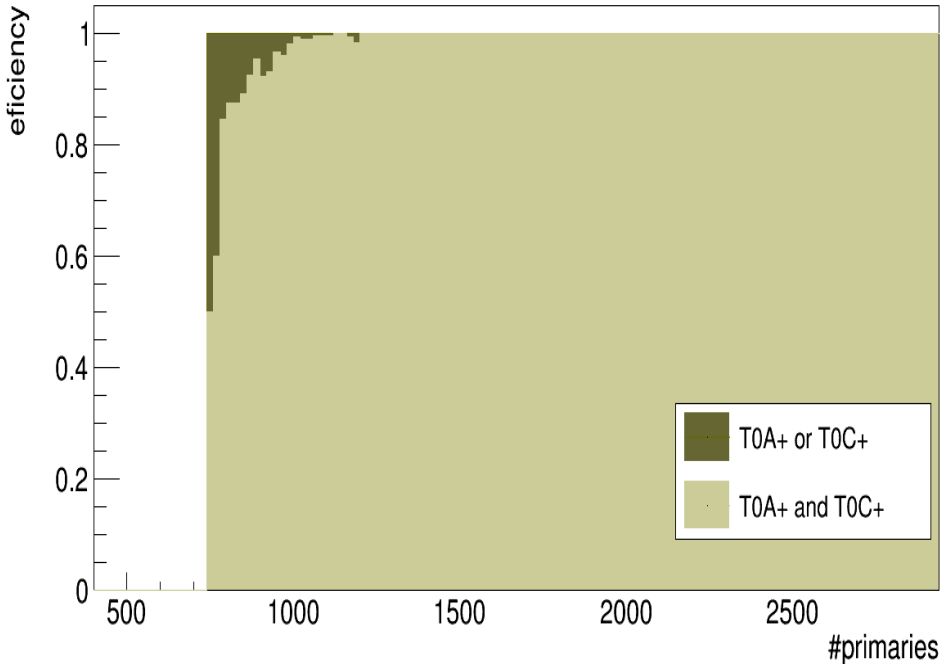
Generators tuned for Run3 simulations:

- ✘ pp -> Pythia8 + QED, 14TeV
- ✘ Pb-Pb -> HIJING + QED, 5.5TeV

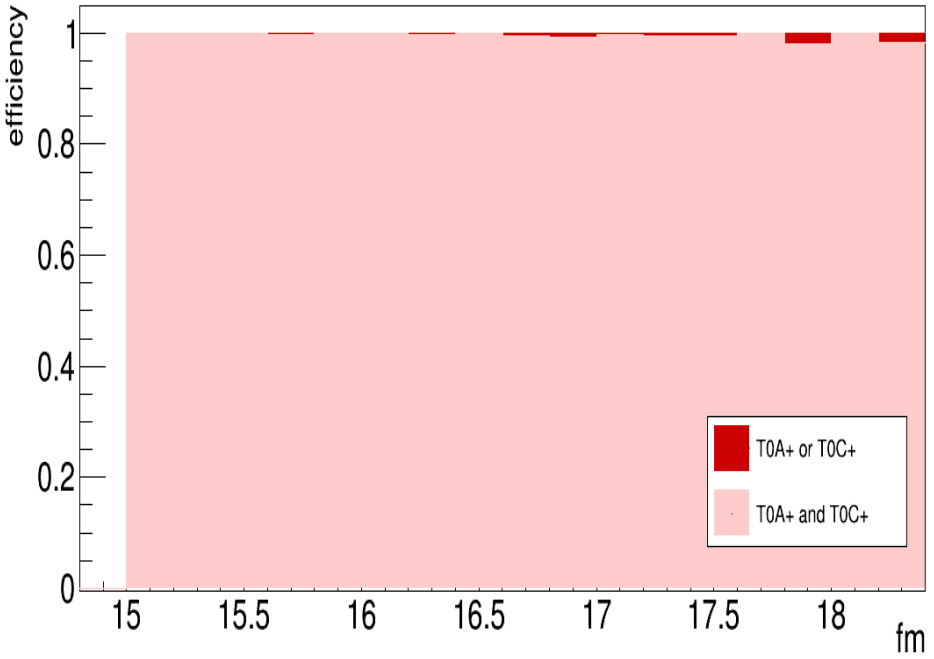
V0A+ T0A+ support

T0+ MB trigger efficiency

pp 14TeV
Pythia8 + QED

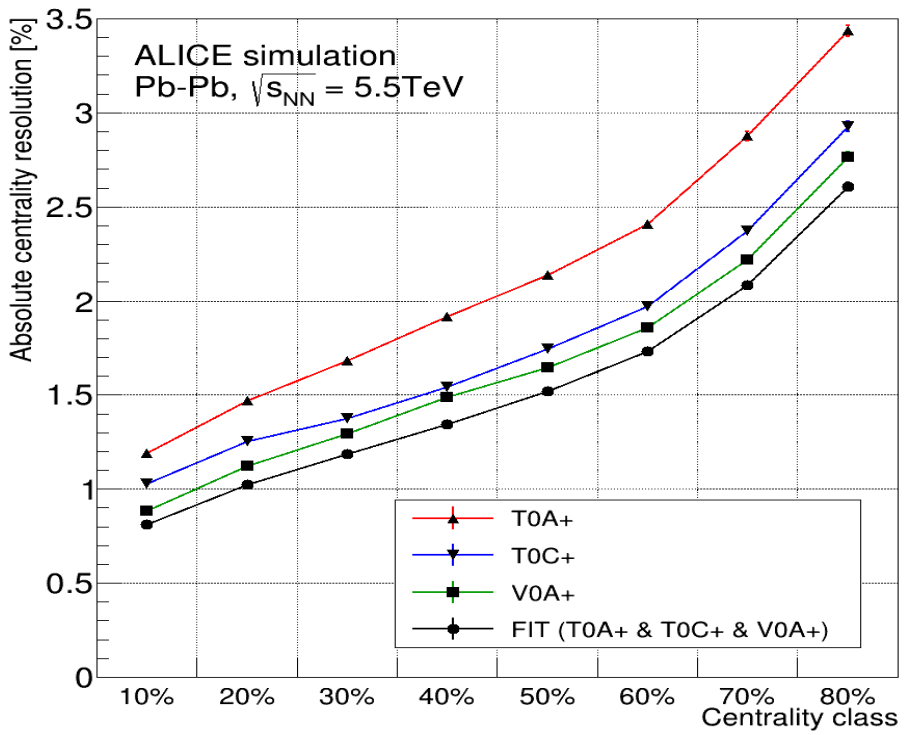


Pb-Pb, 5.5TeV, HIJING + QED
Impact parameter 15-20fm
(centrality 90-100%)

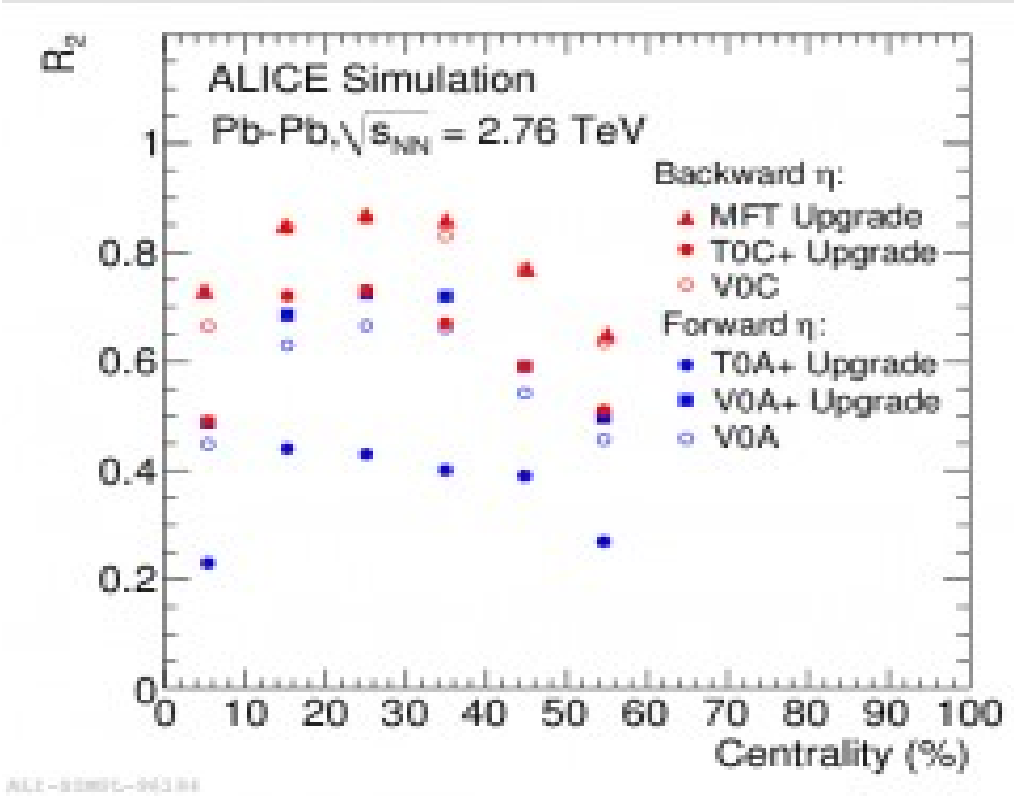


Online Minimum Bias (MB) trigger – interaction in given vertex range

Centrality and event-plane resolution



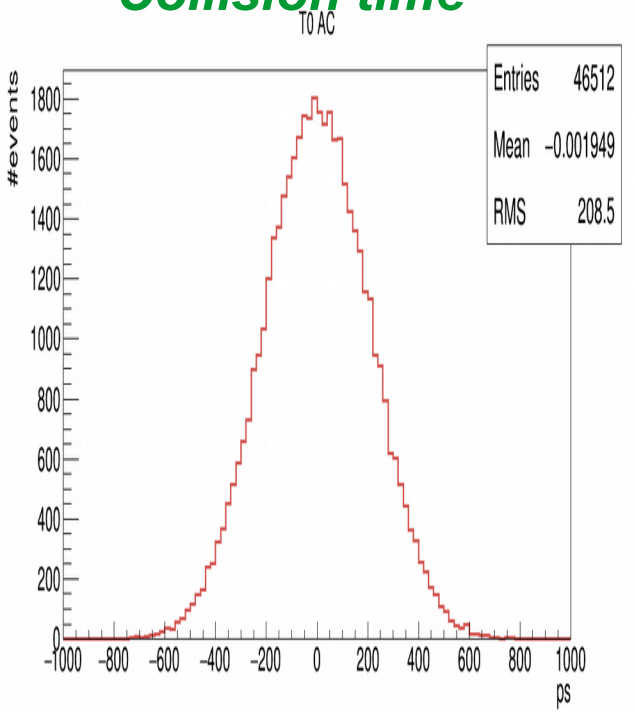
Centrality resolution T0+A, T0+C, V0+ and full FIT detector



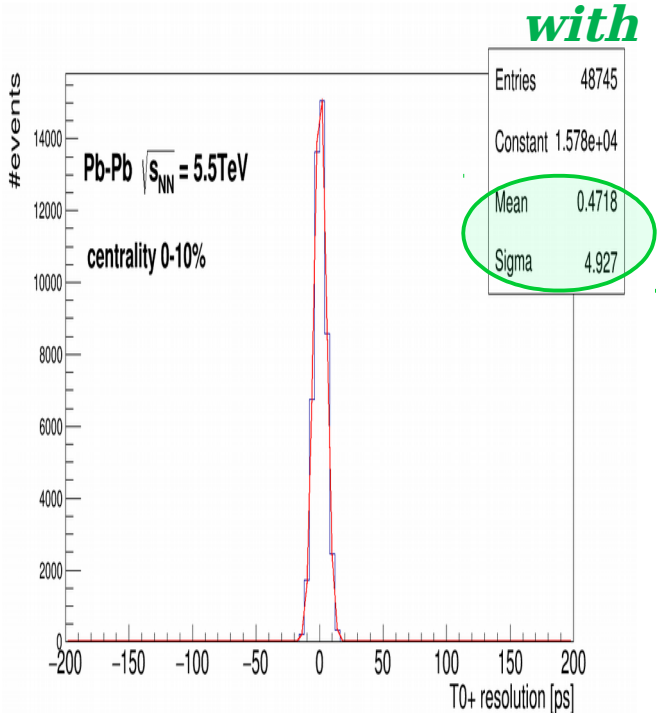
The event-plane resolution of FIT, the comparison is made separately for each side for MFT (applied only in backward eta region), V0+ and T0+ and current V0

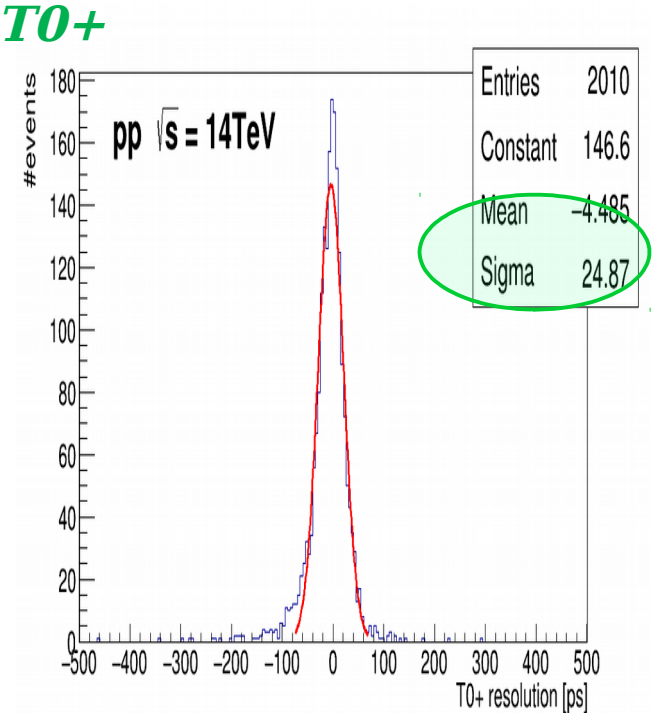
Collision time

Collision time

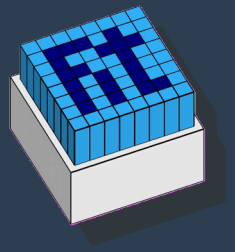


Resolution of collision time as measured with T0+





- Individual CFD time was smeared with Gauss distribution with a width of 50ps.
- Collision time is half of the sum of the average arrival times at T0+A and T0+C.
- Resolution was calculated as a difference between average arrival times on each side corrected with the primary vertex.



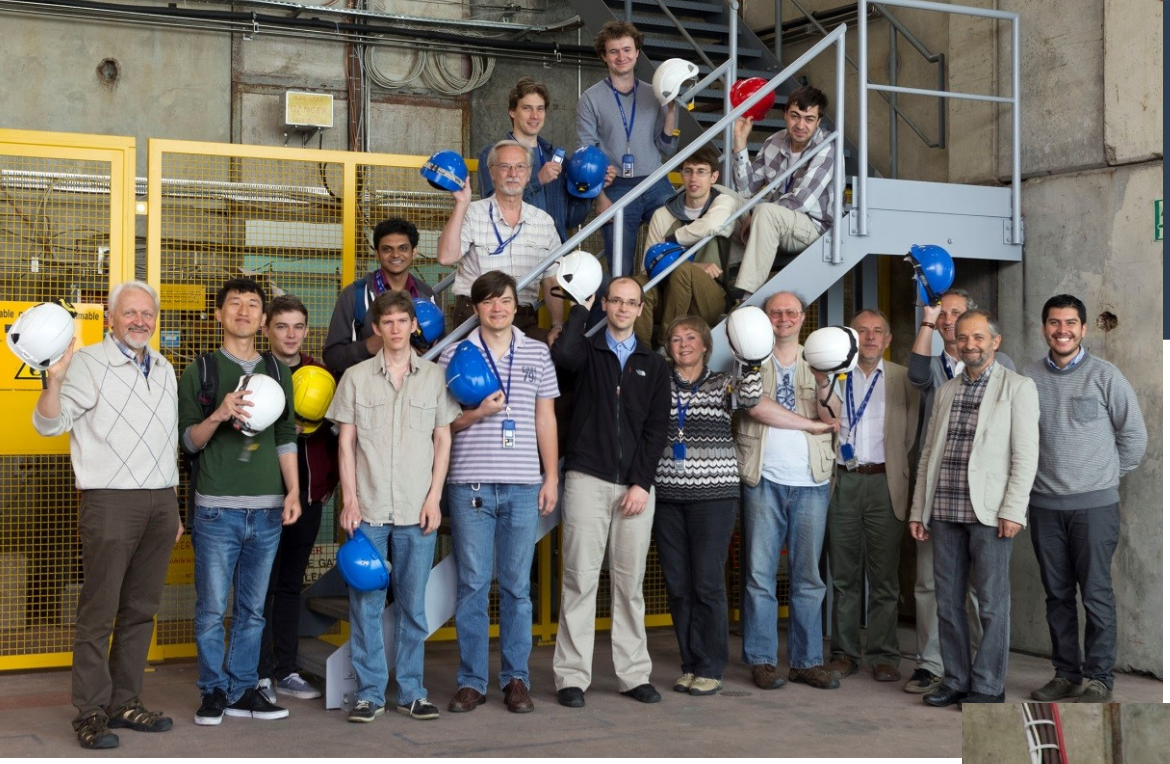
Summary

- During the upcoming LS2 ALICE will upgrade several of the key detectors including the **Fast Interaction Trigger** (FIT).
- FIT will consist of two arrays of **T0+** modules (Cherenkov radiators coupled to MCP-PMTs) and one **V0+** (large-size segmented scintillator ring).

- T0+ prototype has time resolution of 33ps during the tests at CERN PS
- MCP-PMT ageing test predicts a 15-27% drop in amplitude during RUN3 period.
- The modified Planacon XP85012/A1-Q MCP-PMTs shows signal linearity over full amplitude dynamic range.

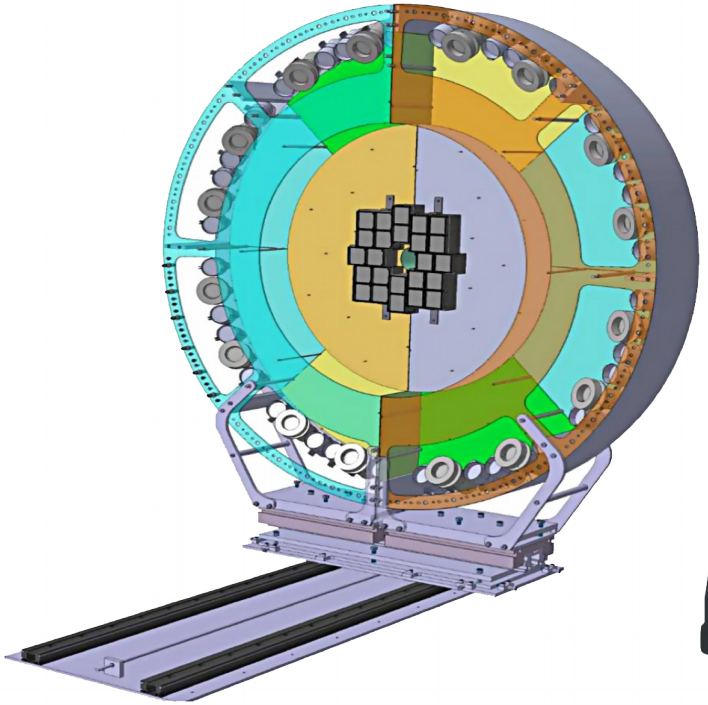
- Simulation results satisfy all requirements of the FIT detector performance
  - MB trigger efficiency >90%;
  - Interaction time resolution better than 50ps – as current T0;
  - Centrality and event-plane resolution similar to the current V0;
  - Vetoing of the ultra-peripheral collisions with efficiency of 99.9%

- The FIT upgrade is on track.



Thank you for your attention!

FIT collaboration involves ~50 people from 14 institutes in 6 counties



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