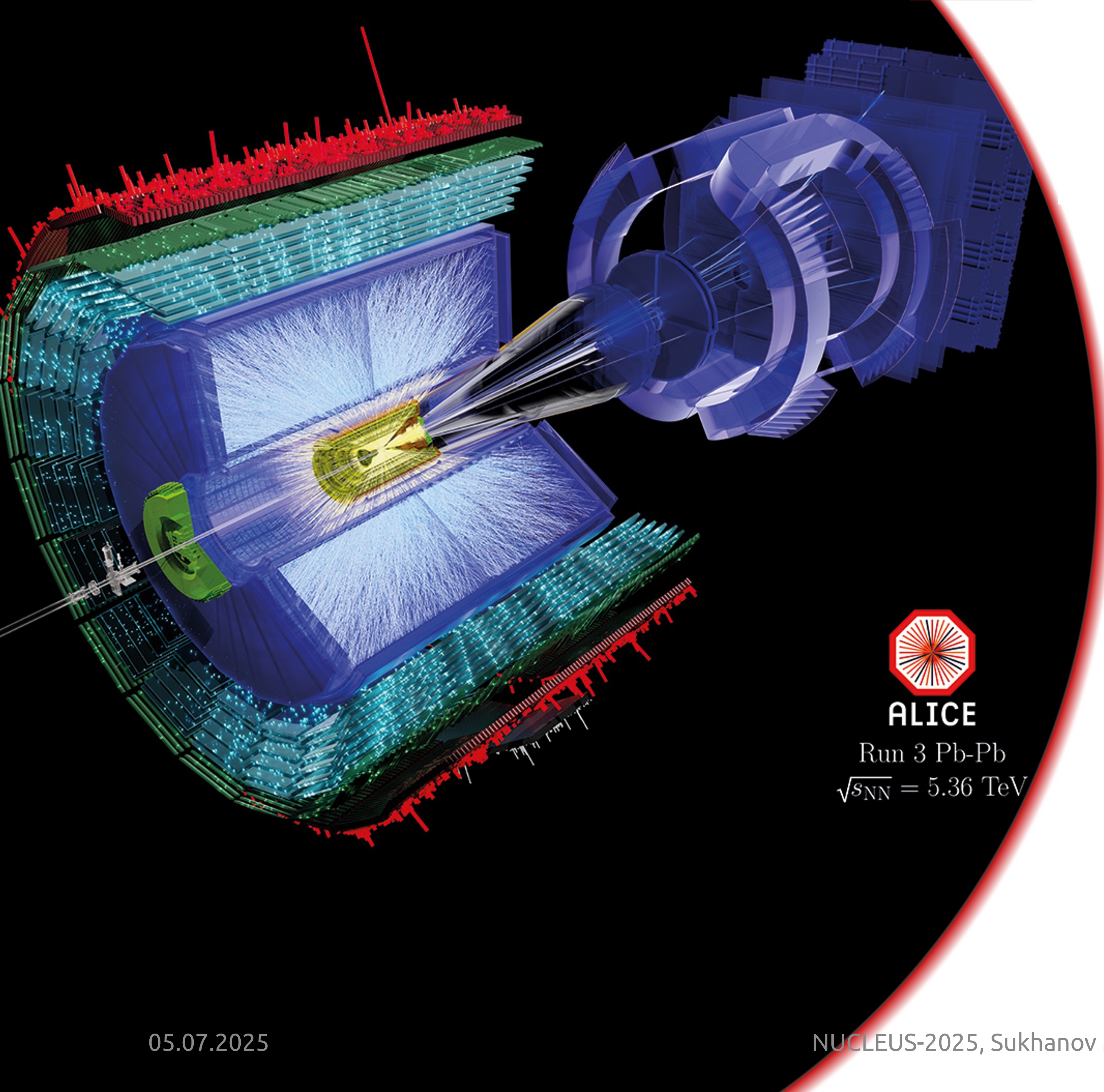
ALICE Fast Interaction Trigger Detector Control System for the LHC RUN3

Sukhanov Mikhail on behalf of the ALICE Collaboration
Joint Institute for Nuclear Research, Dubna
Institute for Nuclear Research of the Russian Academy of Sciences, Moscow

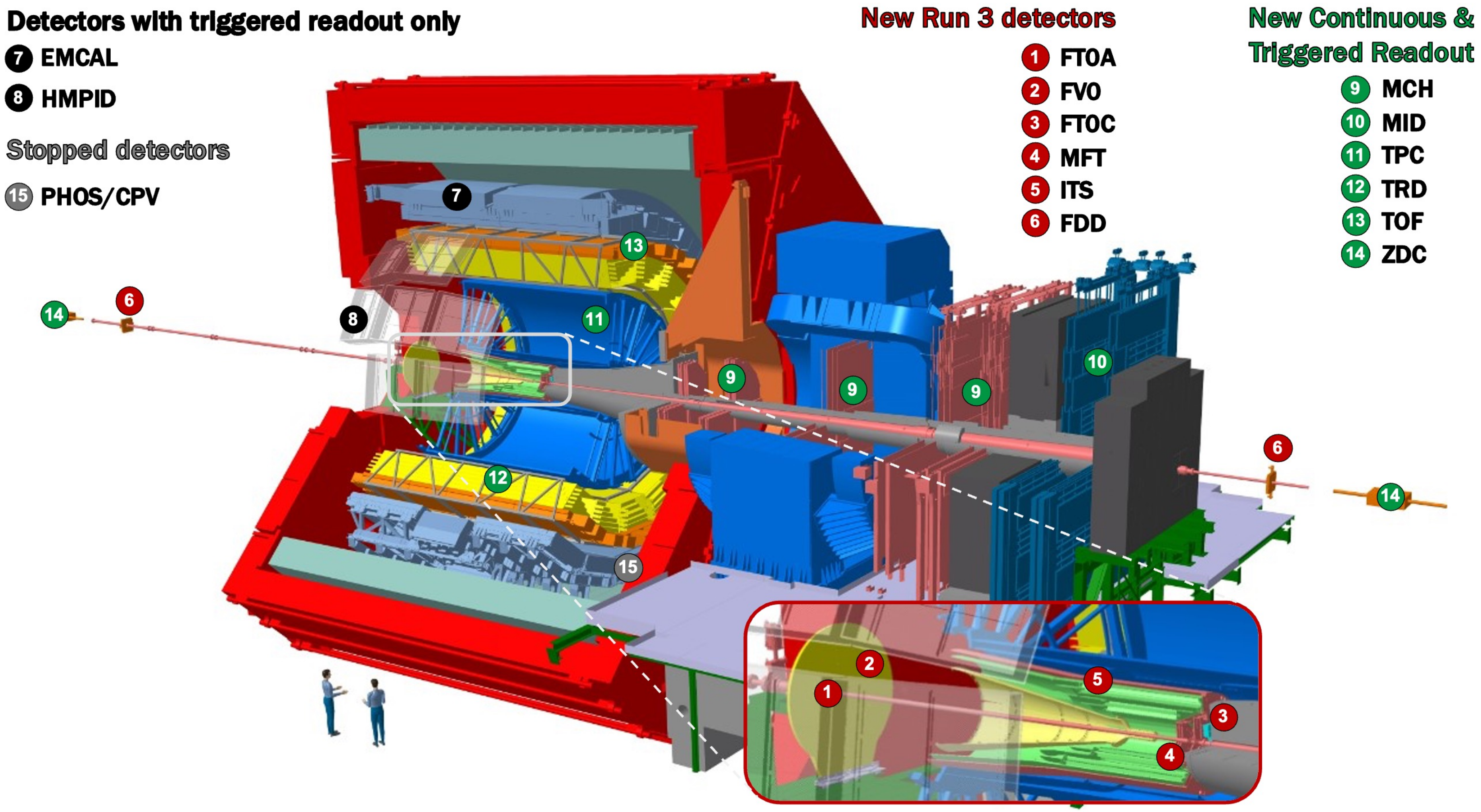


Outline

- ALICE RUN 3 & 4
- **F**ast **I**nteraction **T**rigger system (FIT)
  - FT0
  - FV0
  - FDD
- FIT control facilities
- Detector Control System
- Finite State Machine
- Hardware safety and configuration
- Automatized processes
  - Luminosity and Background online monitoring
  - Ageing monitoring and channel response
- FIT during LHC fill cycle

A Large Ion Collider Experiment (ALICE) for Run 3 and Run 4

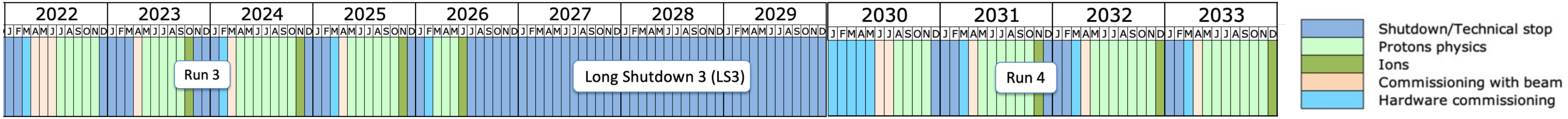
- **ALICE** is designed to study properties of Quark-Gluon Plasma (QGP) created in ultrarelativistic heavy-ion collisions



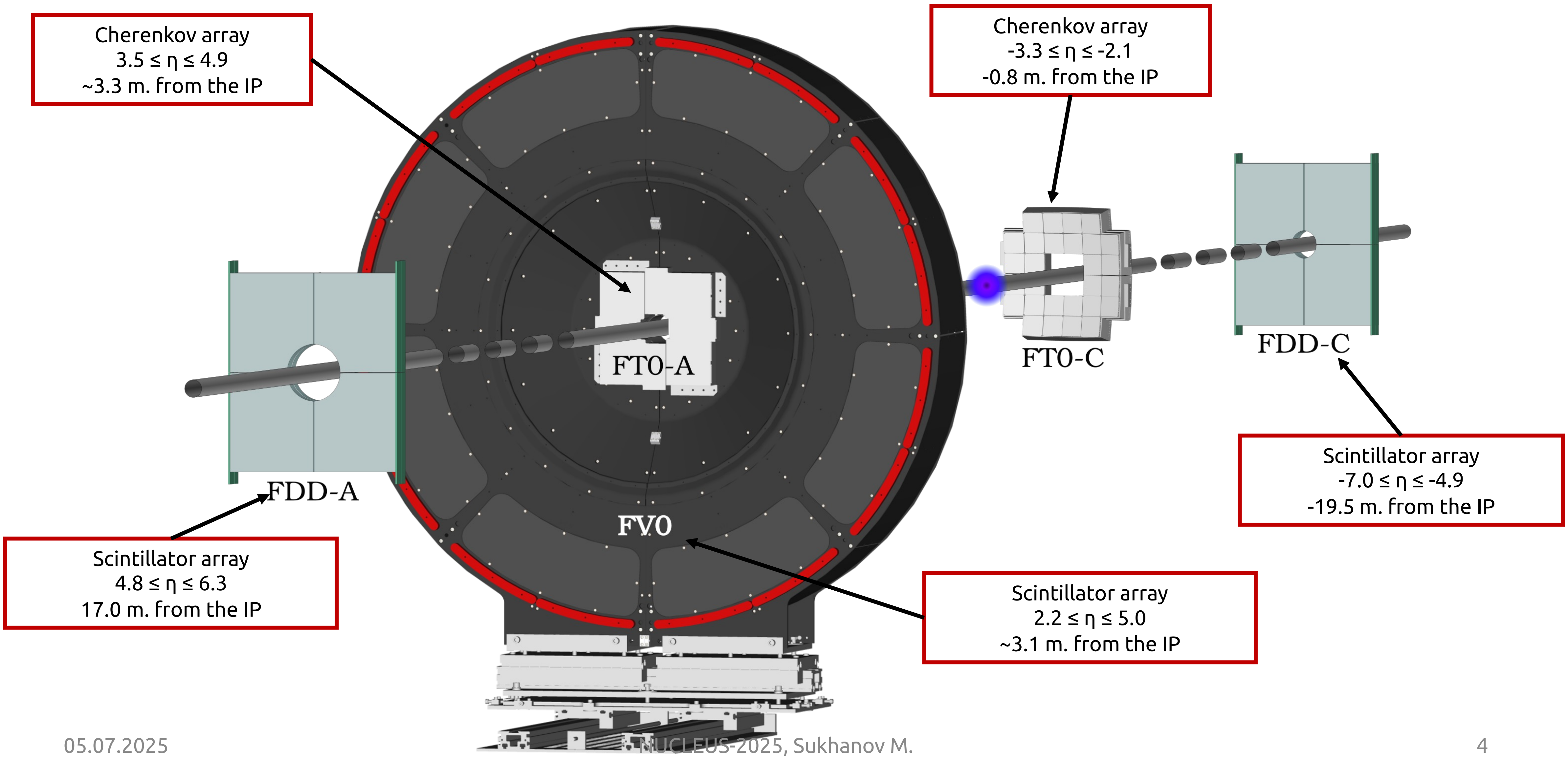
Upgrades:

- New detectors (see fig.)
- Continuous readout and corresponding central system upgrades

LHC running schedule:



Fast Interaction Trigger (FIT) detectors



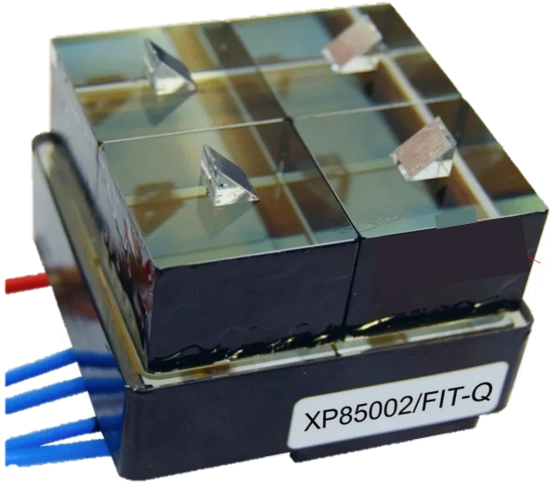
FT0 Cherenkov detector

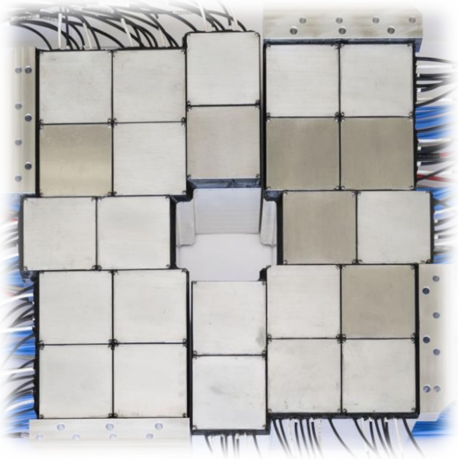
Purposes

- Collision time (used for TOF PID) and vertex determination
- Multiplicity/Centrality and event plane determination
- Vertex and multiplicity trigger production
- Luminosity and background events online monitoring and feedback to LHC
- Veto for ultra-peripheral collisions, used for diffractive physics

Construction

- One FT0 module is assembled with:
  - Modified MCP-PMT Planacon XP85012/FIT-Q
  - 4 quadrants quartz radiators optically coupled with MCP-PMT photocathodes
  - Quartz prisms for laser calibration system
- FT0-A (24 modules, 96 channels, flat surface)
- FT0-C (28 modules – 112 channels, curved surface)
- Single channel time resolution ~13 ps (σ)





FV0 scintillation detector

Purposes

- Multiplicity/Centrality determination with corresponding trigger production
- Event plane determination

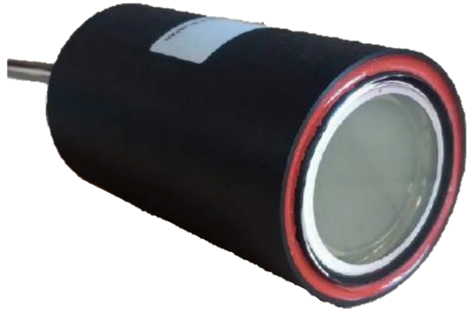
Construction

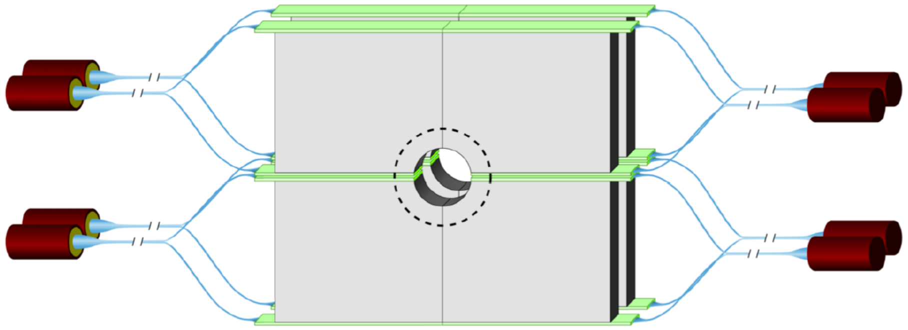
- 5 concentric EJ-204 scintillator rings 4 cm width
  - 4 inner rings are separated to 8 sectors
  - Outer one to 16 sectors
- Fine mesh PMT H6614-70-Y001 for readout
- Direct light collection with clear Asahi fibres
- 48 analog channels
- Time resolution ~250 ps

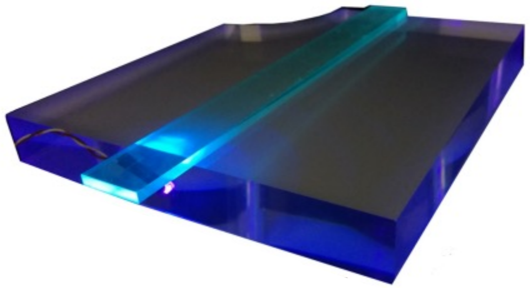
FDD scintillation detector

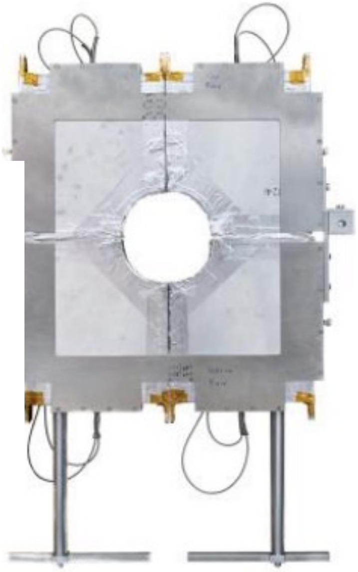
Purposes
- Veto for diffractive physics
- Luminosity monitoring and measurement

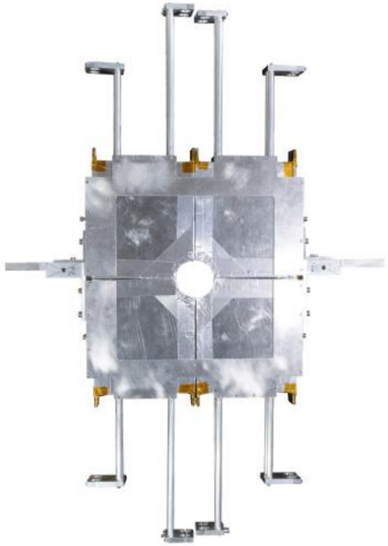
Construction
- 8 BC-420 scintillation channels on each side
  - One plane contains 4 channels
  - Two planes for each side
  - Signal acquisition with fine mesh PMTs H8409-70 with WLS plastic bars and clear fibers
- 16 analog channels



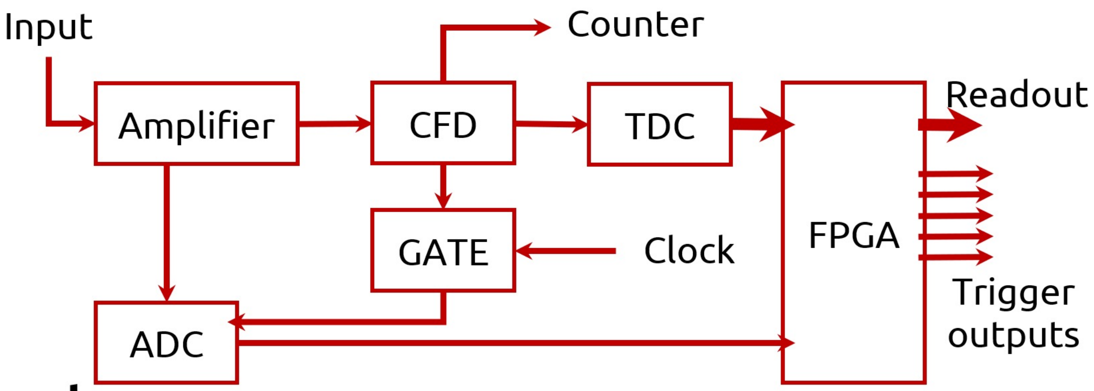








Front-End Electronics

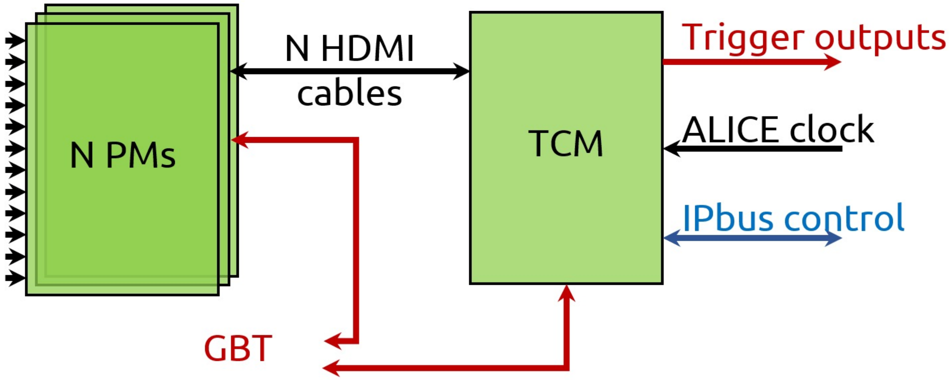


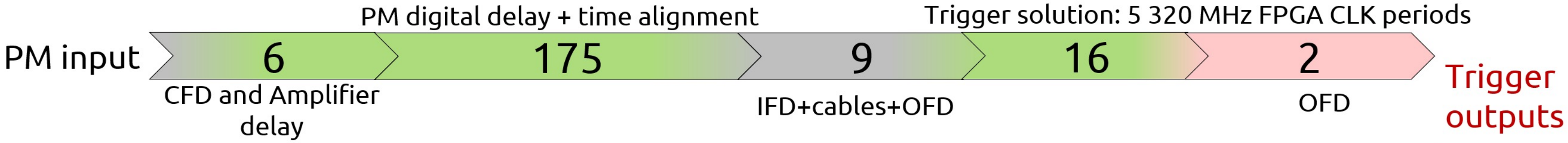
All FIT detectors have the same FEE modules

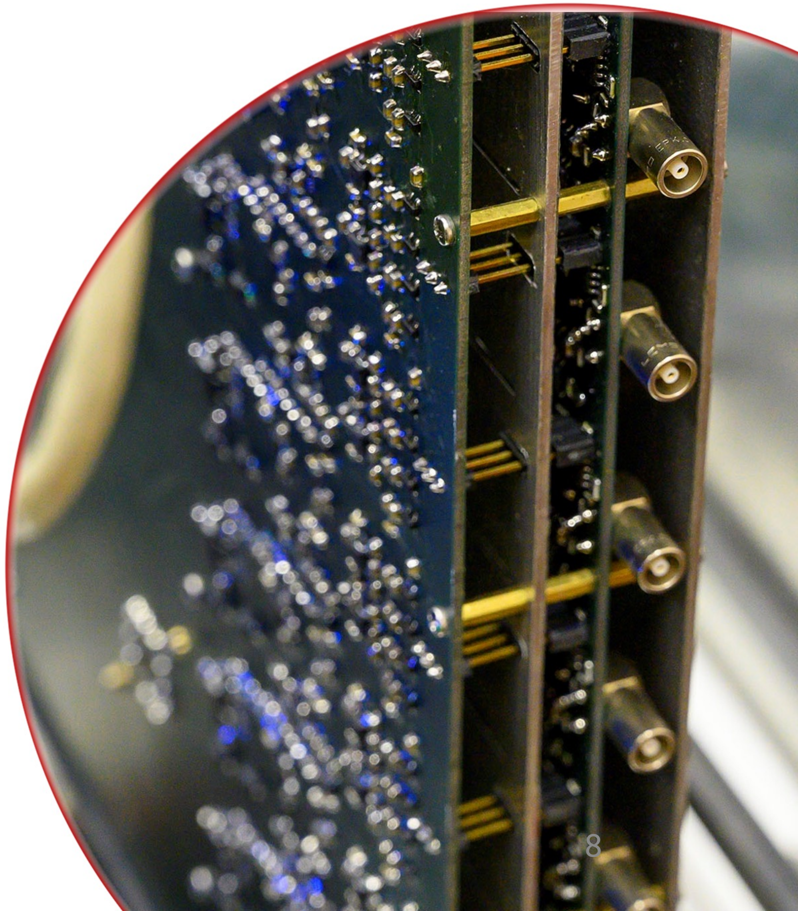
- Processing modules (PM)
- Trigger Clock and Control module (TCM)

- Overall latency less than 425 ns (LM trigger level)
- One TCM per detector – Trigger solution based on **digital signal**
- Trigger forms from multiple channels
- Event by event processing (each 25 ns.)

FEE structure:





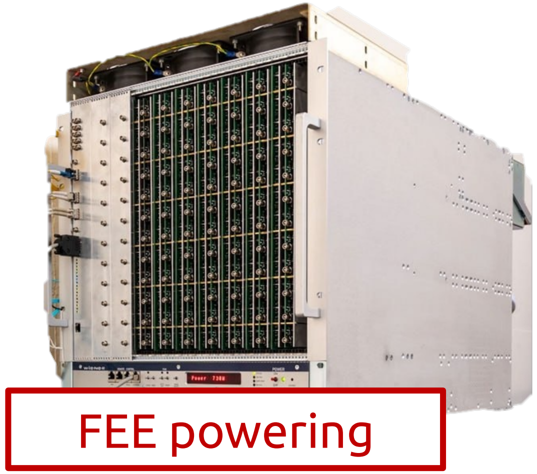


Total FEE delay: 208 ns (w/o cables)

Other equipment

All three detector uses similar hardware and software

- Power suppliers for FEE (WIENER) and HV modules (CAEN)
- Auxiliary cooling system:
  - Fan panels for each FEE crate
- Multitask Fan Control Boards (FCB)
  - Fan panels status monitoring
  - Residual B-field measurements
  - Relay control for laser powering
- Laser calibration system
  - Laser
  - Optical splitters
  - Reference PMTs

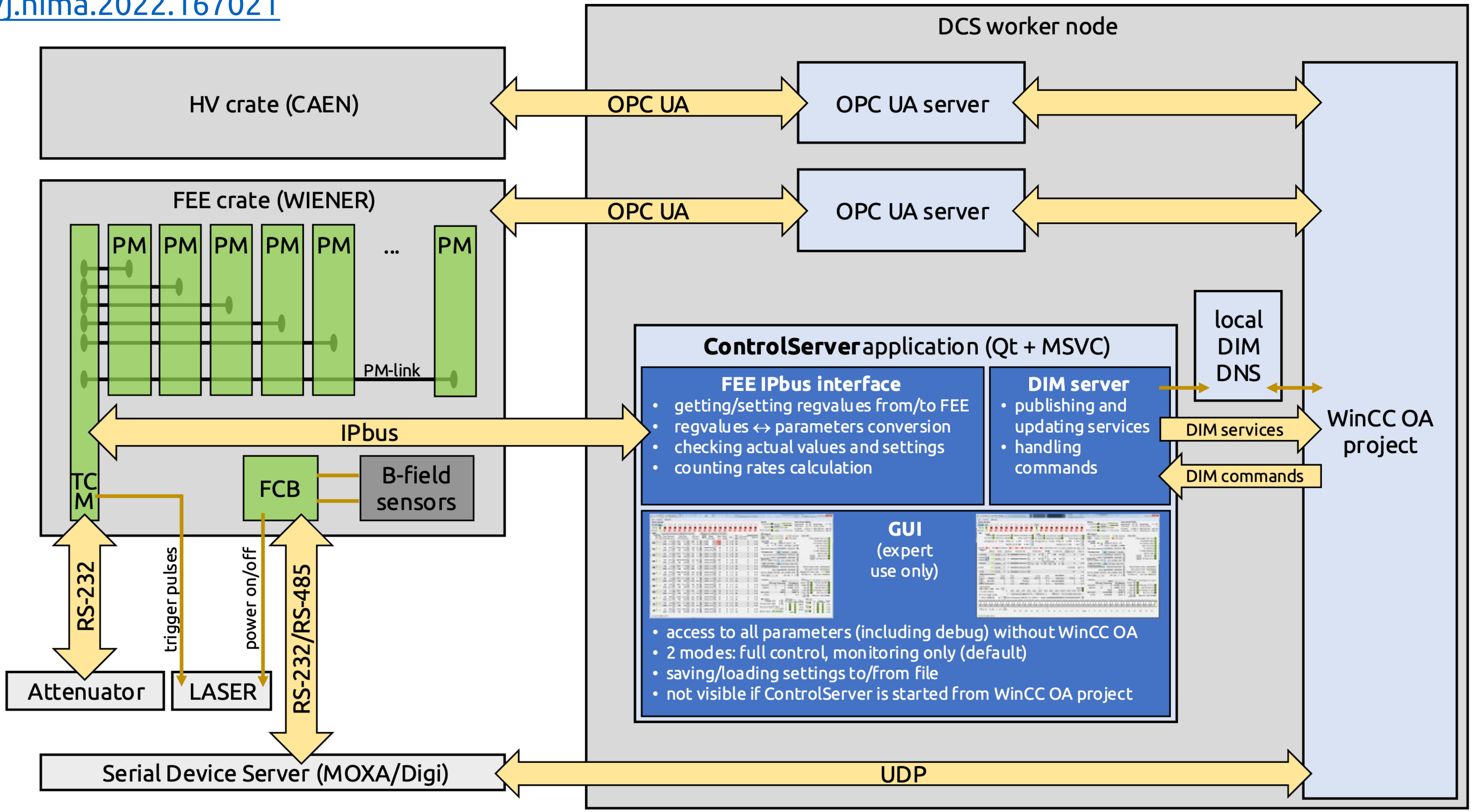


Software solutions

- WinCC OA SCADA projects
- FEE Control Server
  - Serves FEE control for WinCC OA project
  - Standalone usage for debugging

FIT Detector Control System

10.1016/j.nima.2022.167021



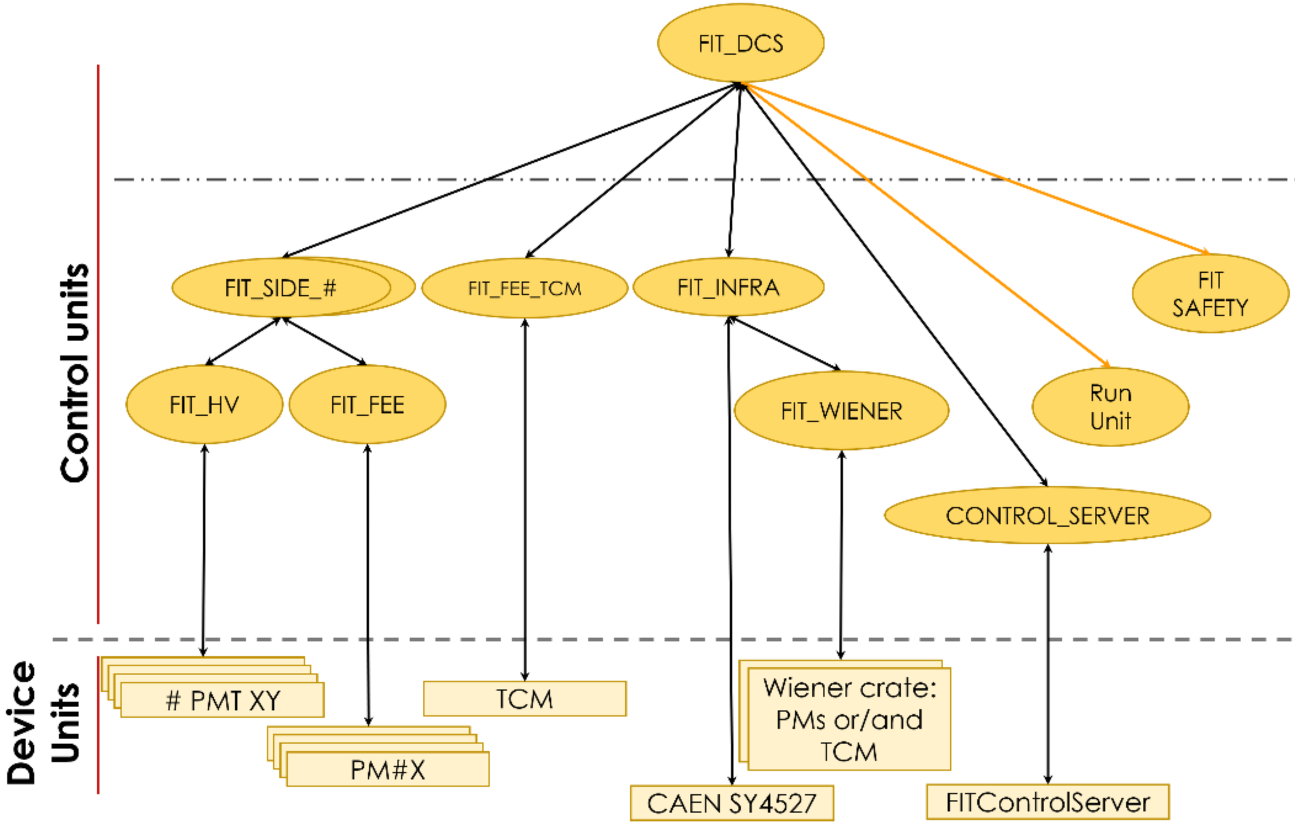
FIT Finite State Machine

Finite State Machine (FSM) – detector representation model as a set of subsystems with determined states, influencing system state

- Nodes are connected in hierarchy
- The commands are propagated to the child devices (down to children)
- The states are propagated to parents (up to parents)

FIT uses 3 similar finite state machines for FT0, FV0 and FDD control

- The same definitions and states
- Similar hardware and software
- Easy to maintain for experts an oncalls



Hardware safety and configuration

For the hardware safety FIT uses:
- Current limits for PMT HV powering
- 3-axis magnet FCB sensors of FCB for FEE
- Temperature sensors for FEE and power suppliers

SAFETY	NOT SAFE	BEAM SAFE	MAGNET SAFE
HV	ON	OFF	OFF
FEE	ON	ON	OFF

Global risk factors:
- Beam injection or instability
- Magnet current transit states trip

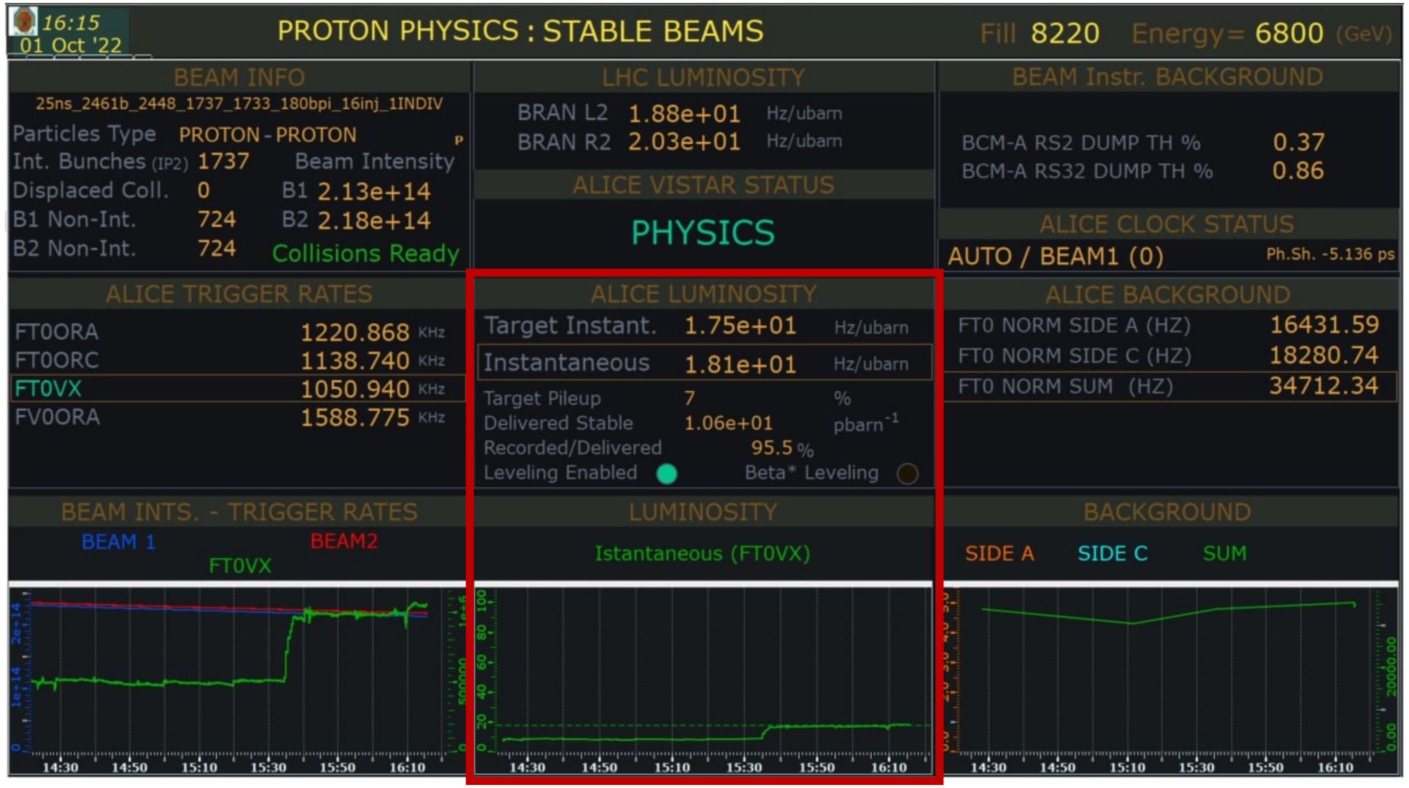
For these cases FIT detectors included in the ALICE safety matrix, which state determines the permission of the beam injection (*Conf. Proc.* C111010 (2011) pp.WEPMU026)

The automatic configuration depends on:
- Data taking type (PHYSICS, LASER, TECHNICAL, etc…)
- L3 solenoid B-field
- Spare parameters in detector configuration

Auto-configuration application stages:
1. After the FEE is on → FEE configuration
2. After the HV is on → HV configuration
3. Before starting the data taking → both

Instantaneous luminosity estimation

FT0 is primary ALICE luminometer in pp runs



Sources of luminosity:

- Vertex trigger for pp runs
- Vertex & (Central | Semi-Central) for Pb-Pb runs

Online estimation:

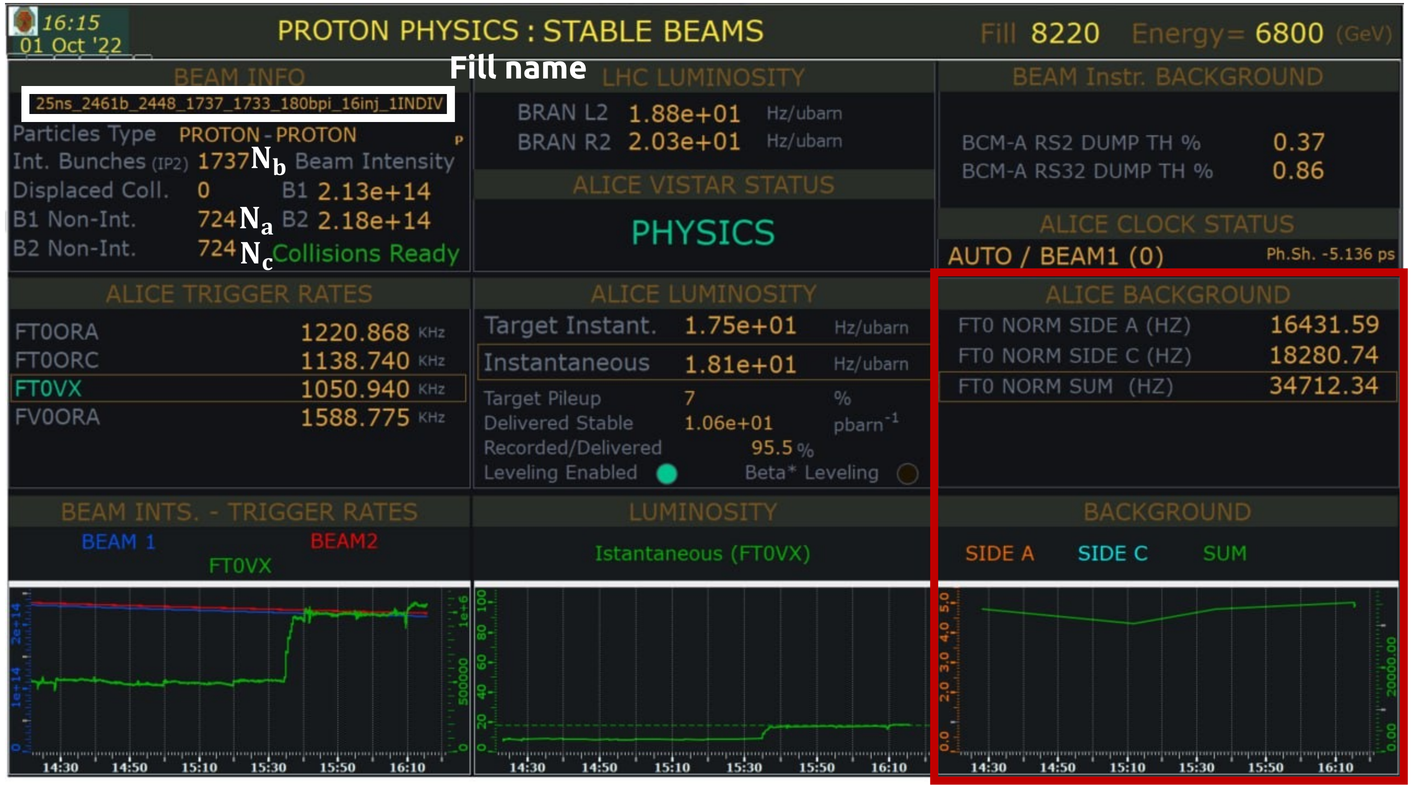
$$L = -\frac{N_r N_b \ln\left(1 - \frac{n}{N_r N_b}\right)}{\sigma_{vis}}$$

n – source trigger rate
σ_{vis} — visible cross section
N_r – number of LHC orbit revolutions per sec (11223 for pp @ $\sqrt{s} = 13.6$ TeV)
N_b – number of colliding bunches

- **σ_{vis} auto adjustment depending on collision energy and FT0 working mode (full, corona)**

Background events rate estimation

For the first time the orbit fill map is used by forward detector to trigger background events



Background events rate determination algorithm:

1. The numbers of buckets with injected bunches are transmitted to DCS
2. DCS calculate orbit fill map and send it to FEE through IPbus Control Server
3. Control Server calculates the rates of background counters and publishes ones by DIM for DCS

4. Background rate normalized in DCS and published for the LHC interface:

$$R_{bg} = n_{bg}^{a} \frac{(N_a+N_b)}{N_a} + n_{bg}^{c} \frac{(N_c+N_b)}{N_c}$$

$n_{bg}^{a(c)}$ – background rate from side A(C) given by Control Server
$N_{a(c)}$ – the number of single (non-colliding) bunches from A(C) side
N_b – the number of colliding bunches

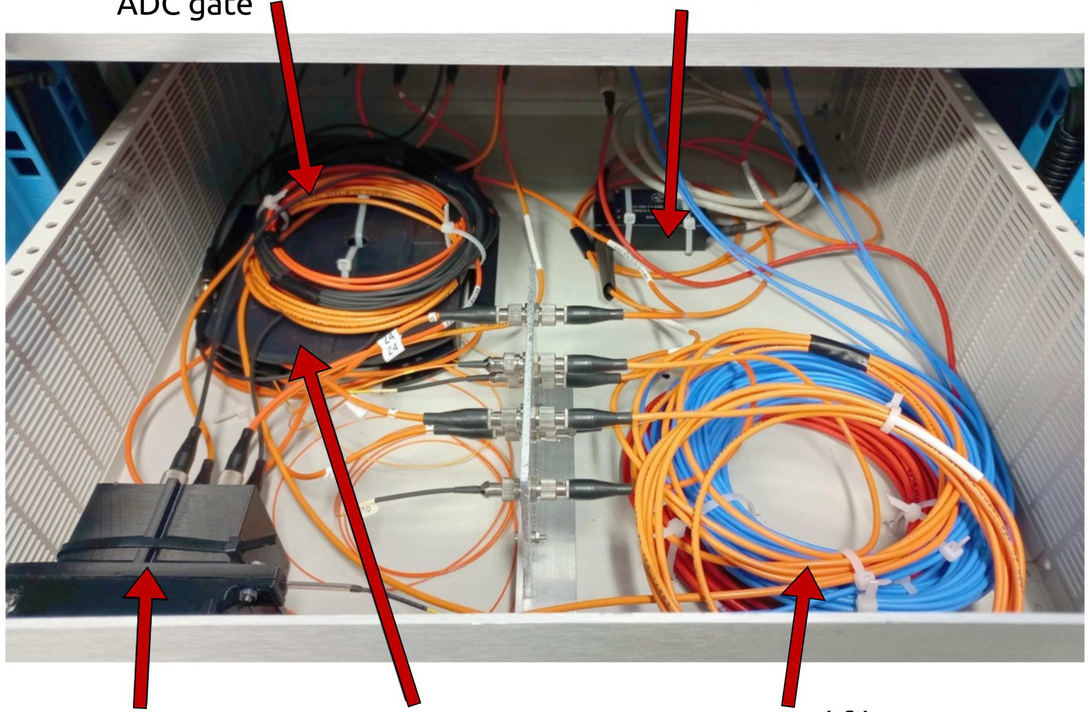
Laser calibration system

Purposes:

- Amplitude and time detector parameters adjustment
- Ageing control for PMT photocathodes and optical fibers
- Channels counters check

Output optical fibers, compensating delay before ADC gate

Optical attenuator

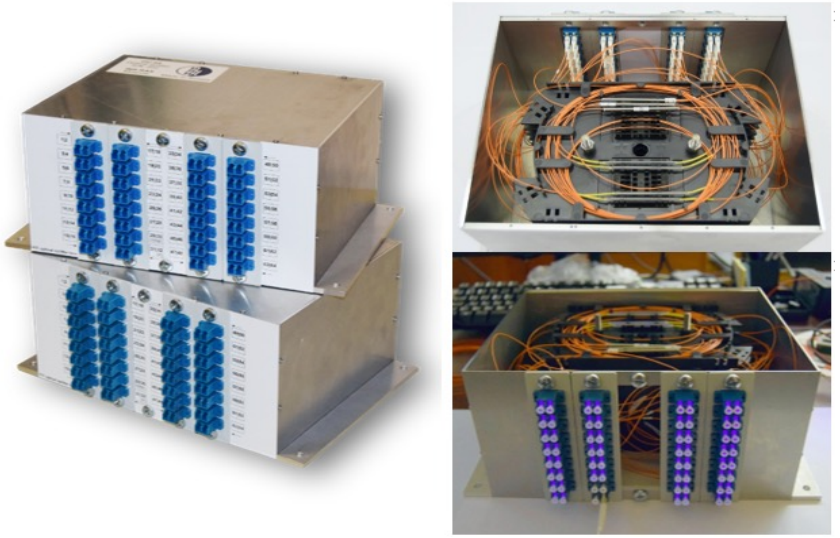


Reference MCP-PMT

Splitter 1:4

Input optical fibers compensating A and C side delays

Reference MCP-PMT



Optical splitters

Ageing control and monitoring

Since the beginning of Run 3:

- FT0 MCP-PMTs are most vulnerable to radiation
- Critical in High Rate runs (up to 4MHz for pp in 2023-2024)
- Innermost modules affected (up to 3 times drop in amplitude since the beginning of the Run 3)

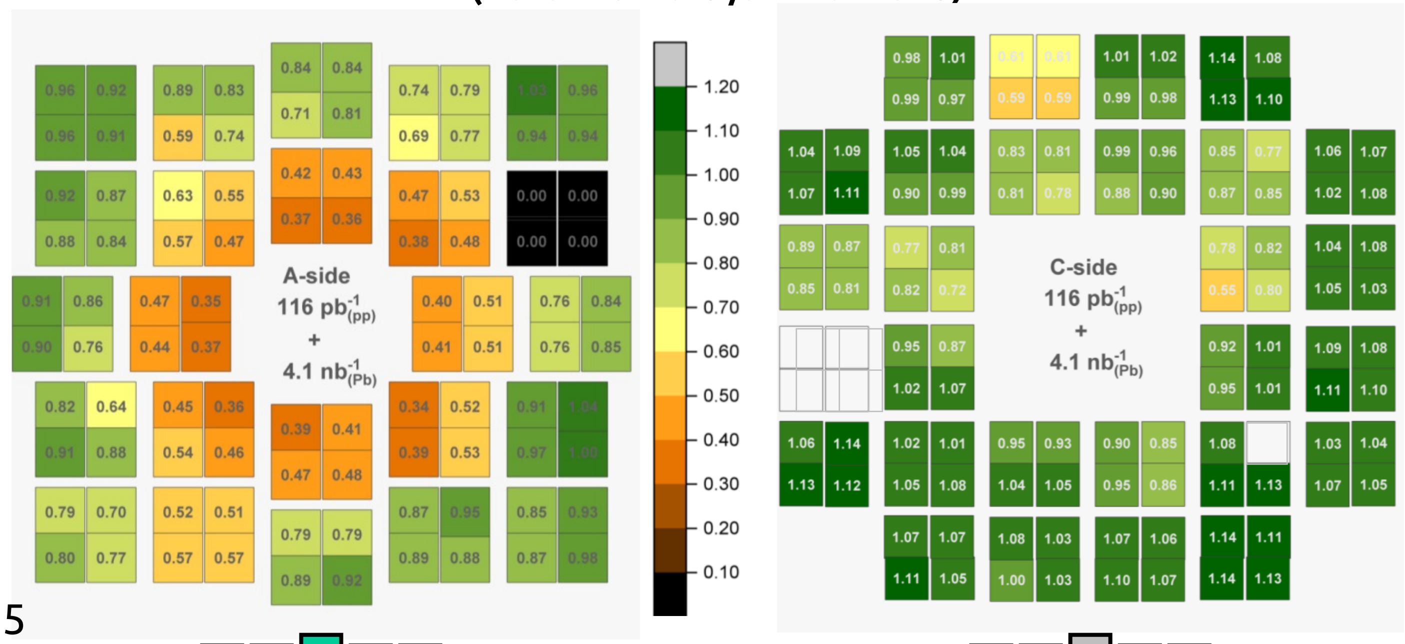
Full and Corona mode operation:

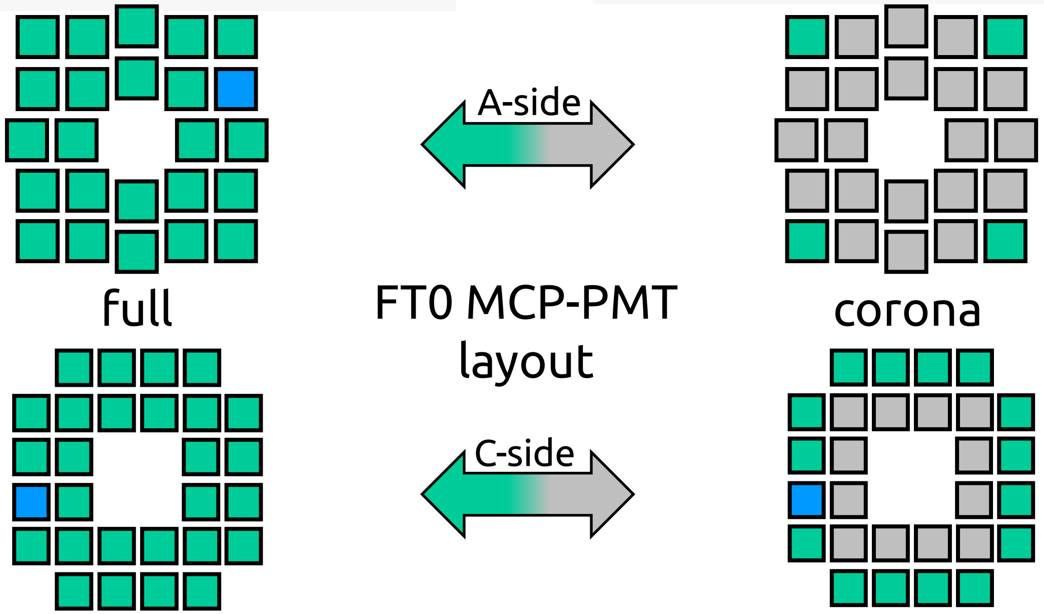
- Switch from full to corona mode for event rate > 1.5 MHz
- Insignificant efficiency loss
- Available for luminosity monitoring
- Control from the ALICE site

Ageing monitoring scans

- Conducted after each beam dump (for Pb-Pb)
- Uses LCS to take data for ~1 minute at 1 KHz laser pulses
- Controlled from ALICE site

MCP-PMT signal amplitude ratio (November 2025 /start of RUN3)



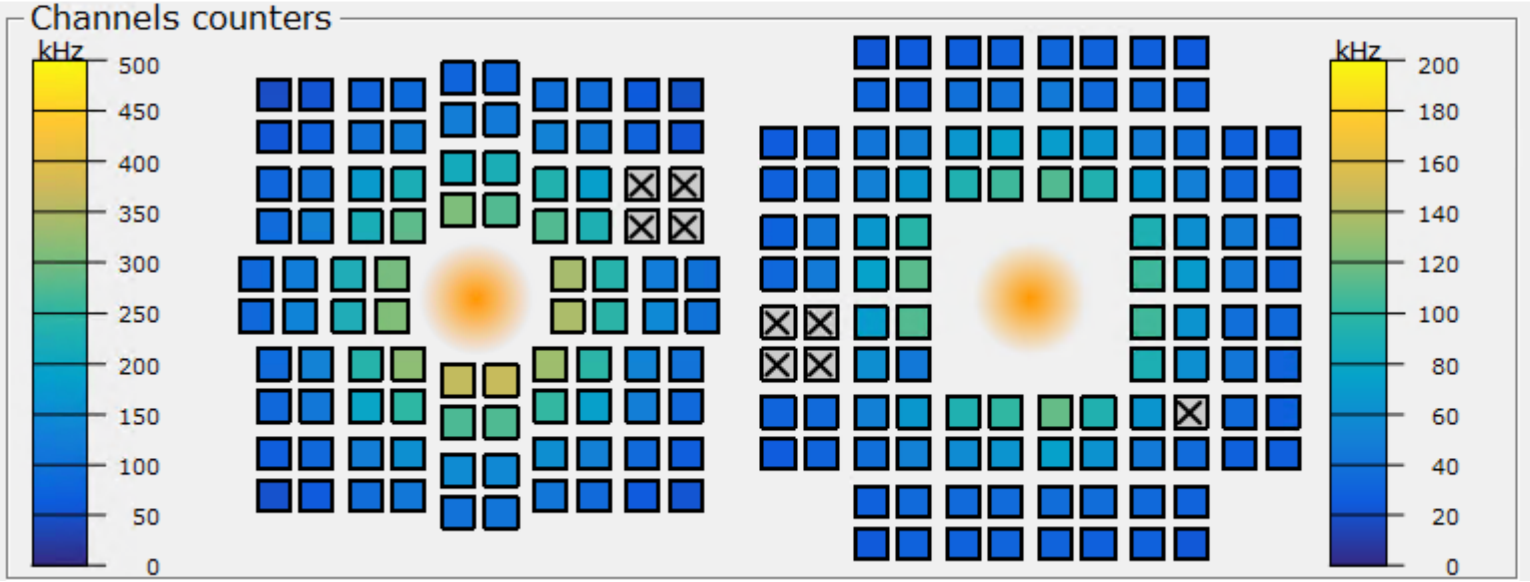


FT0 channels map

To check the availability of the FT0 channels DCS conducts a short laser scan to detect dead channels:

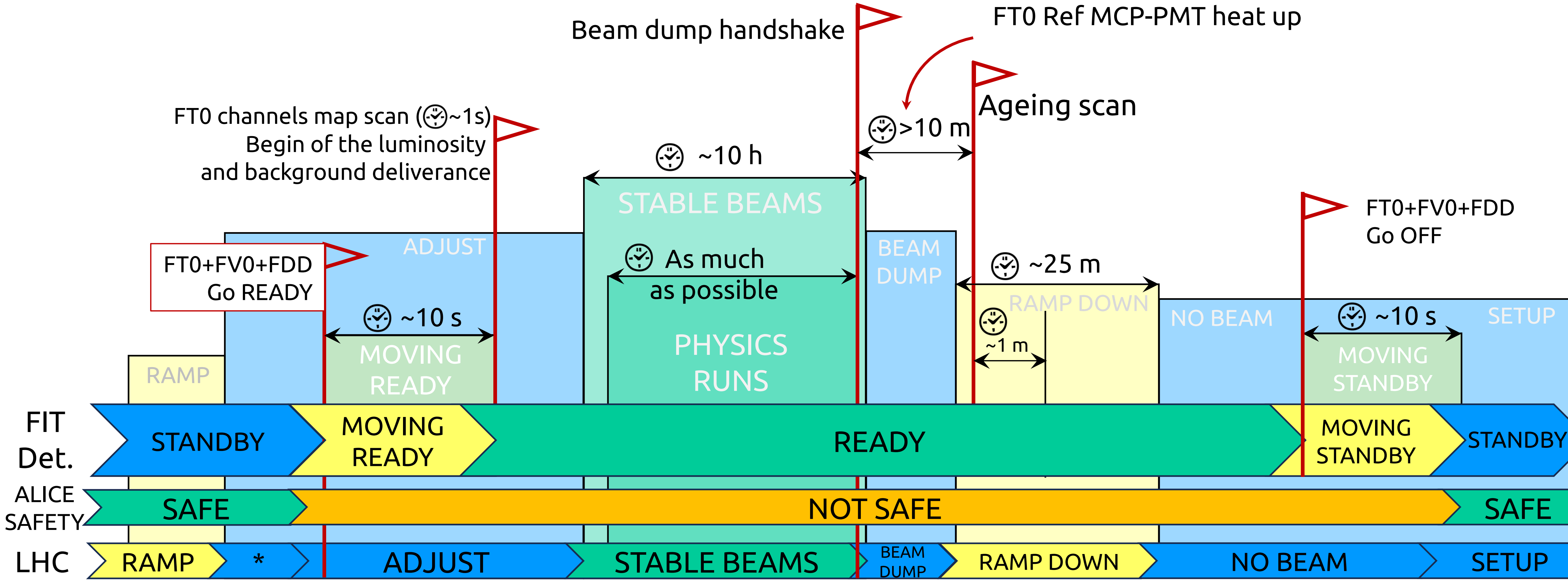
- Scan is performed after each full power cycle of FT0 MCP-PMTs
- Check of the channels count rate
- Could be performed with / without beam
- The channel quality criteria:
  - Counter rate within appropriate range
- No significant effect on instantaneous luminosity – very short scan (~ 1 s) at 1 KHz.
- Fully automatized

Fast health check procedure after accident (magnets trip / power outage)



Central FT0 DCS panel counter rate channel map

FIT normal operation at LHC fill cycle



Summary and Conclusions

FIT running is essential for the ALICE experiment

FIT DCS ensures reliable and safe detector operations

- Delivering instantaneous luminosity and background monitoring
- The automatic configuration and preparation for the data taking
- Operations with laser calibration system (ageing monitoring, channels availability check)

Basic DCS – universal solution for all three detectors

- Same FSM scheme
- The same safety conditions

Fast Interaction Trigger

ENG RU

Thank you for your attention!

Backup slides

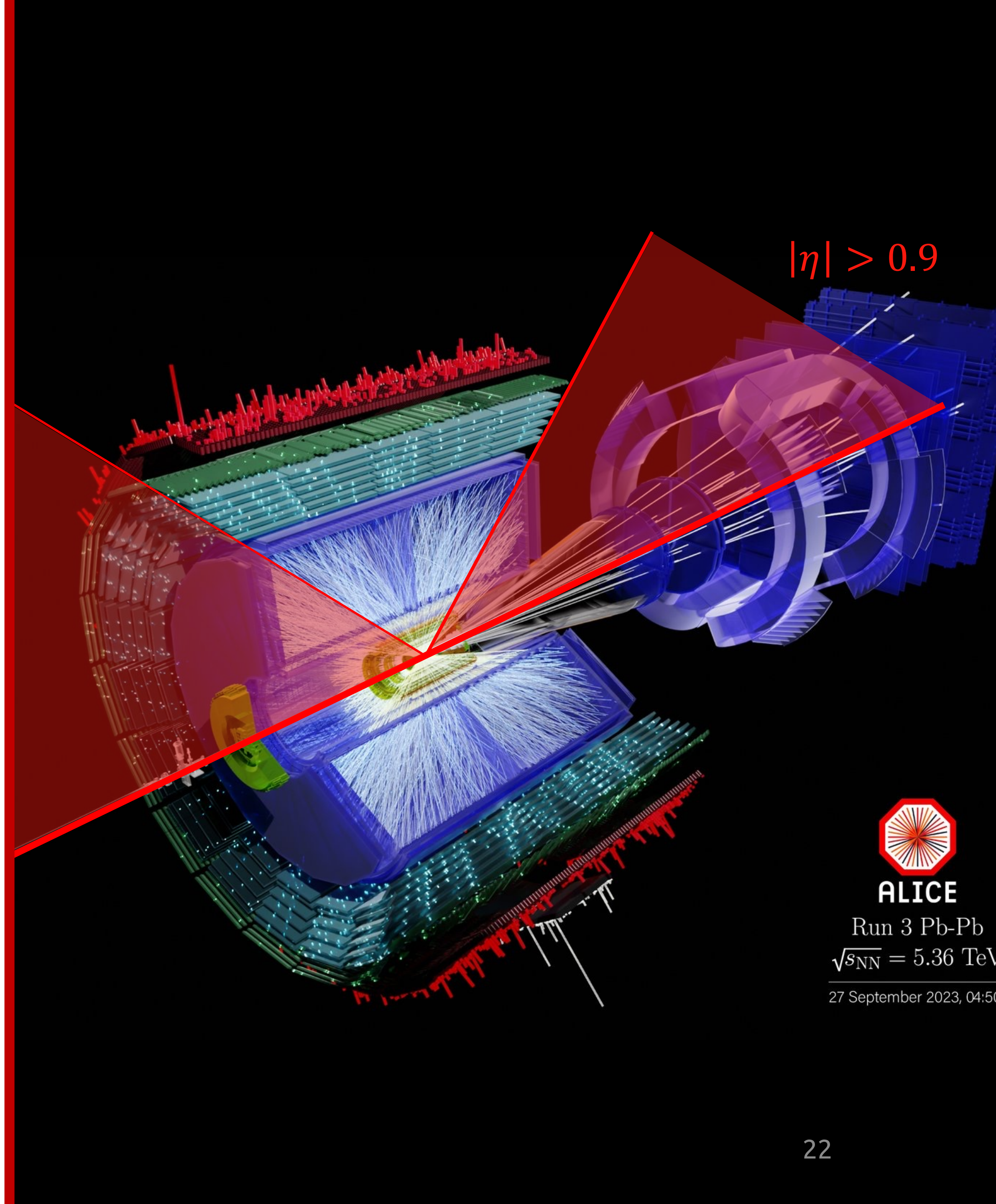
ALICE experiment

- **A L**arge **I**on **C**ollider **E**xperiment (**ALICE**) primary purpose is QGP properties research, induced by collision of ultra relativistic nucleus at LHC.

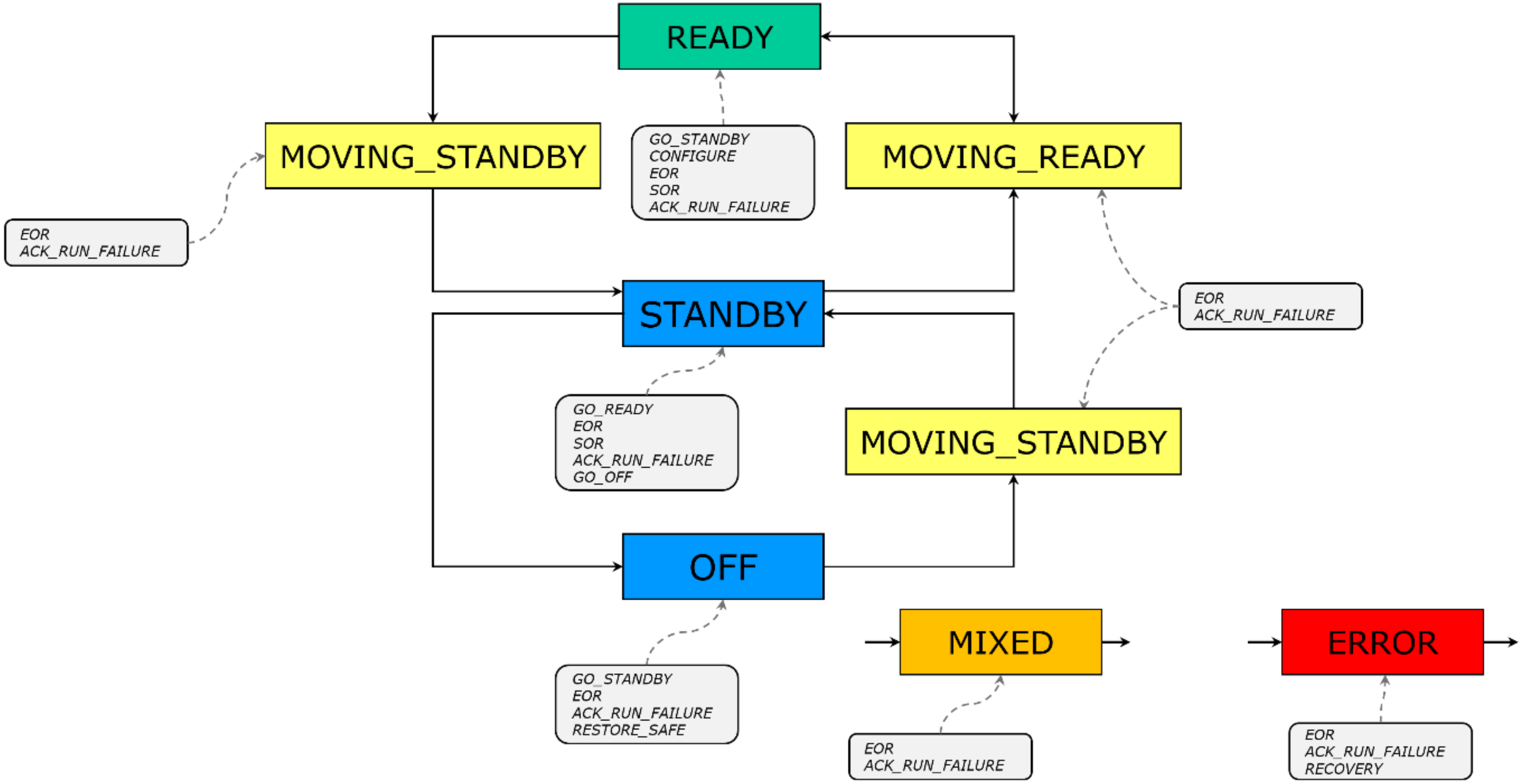
- ALICE at 2023 And 2024:
  - pp collisions up to 1MHz at $\sqrt{s} = 13.6$ TeV.
  - Pb-Pb collisions up to 50 KHz at $\sqrt{s_{NN}} = 5.36$ TeV.
  - Reference pp collision at $\sqrt{s} = 5.36$ TeV.

- Fast Interaction Trigger – one of the essential LS2 upgrades.

- FIT is a hybrid of three forward detectors (FT0, FV0 and FDD).



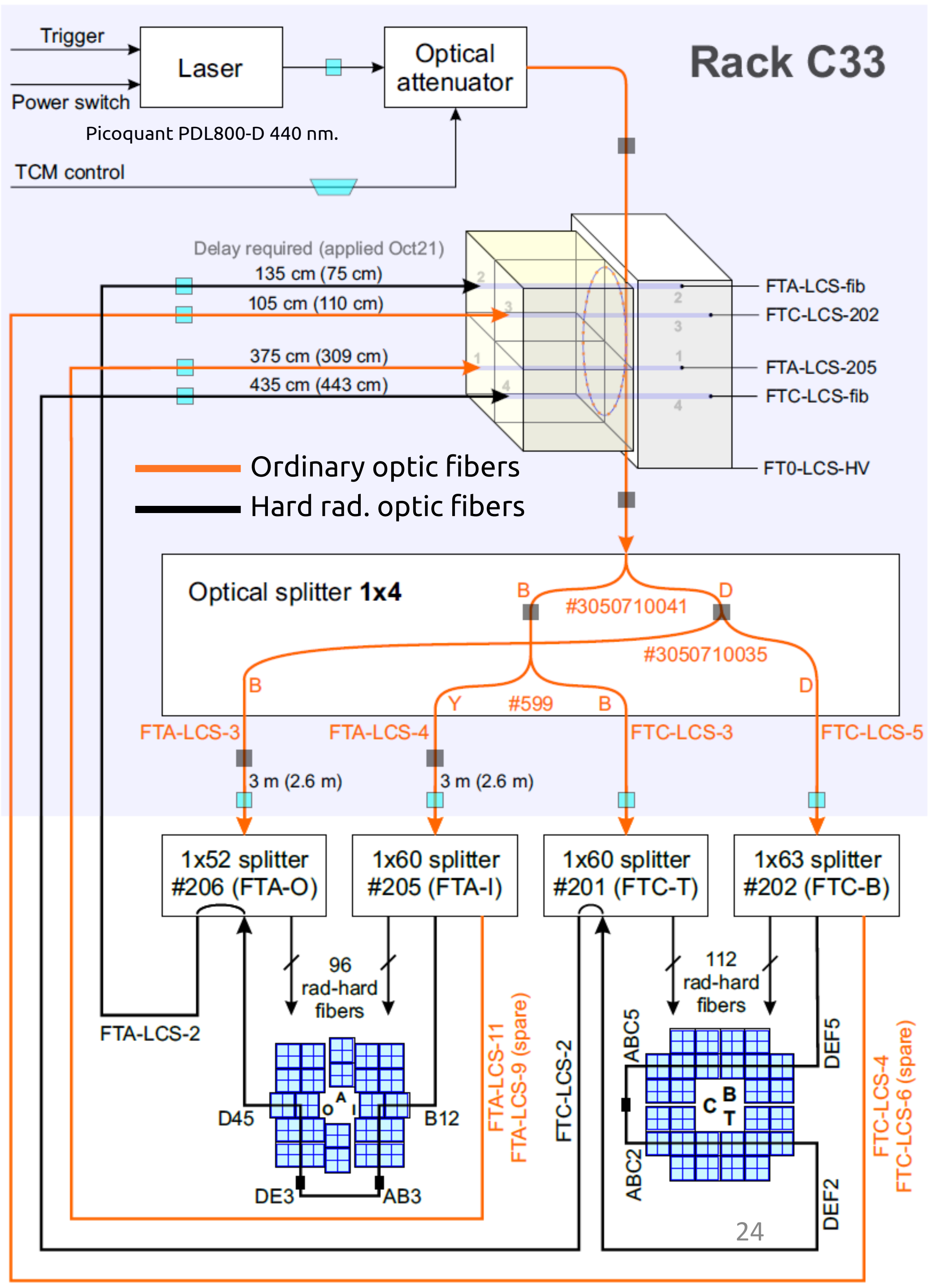
FIT top node FSM states



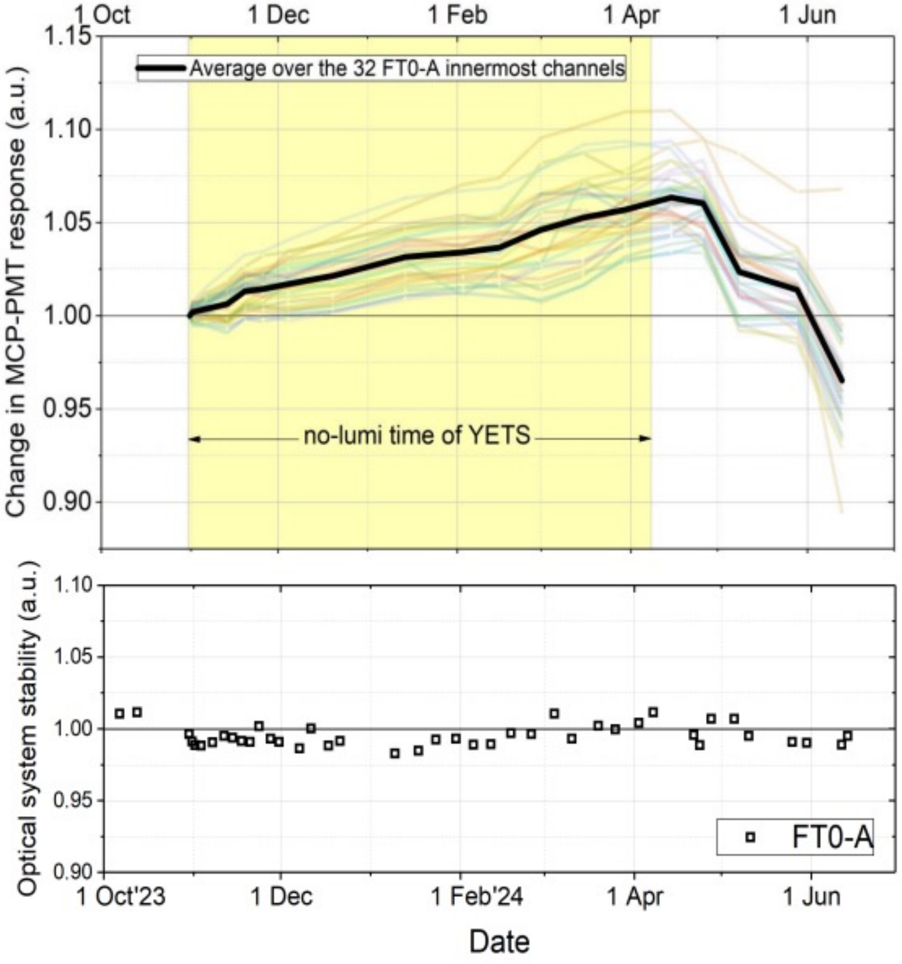
Laser calibration system (FT0)

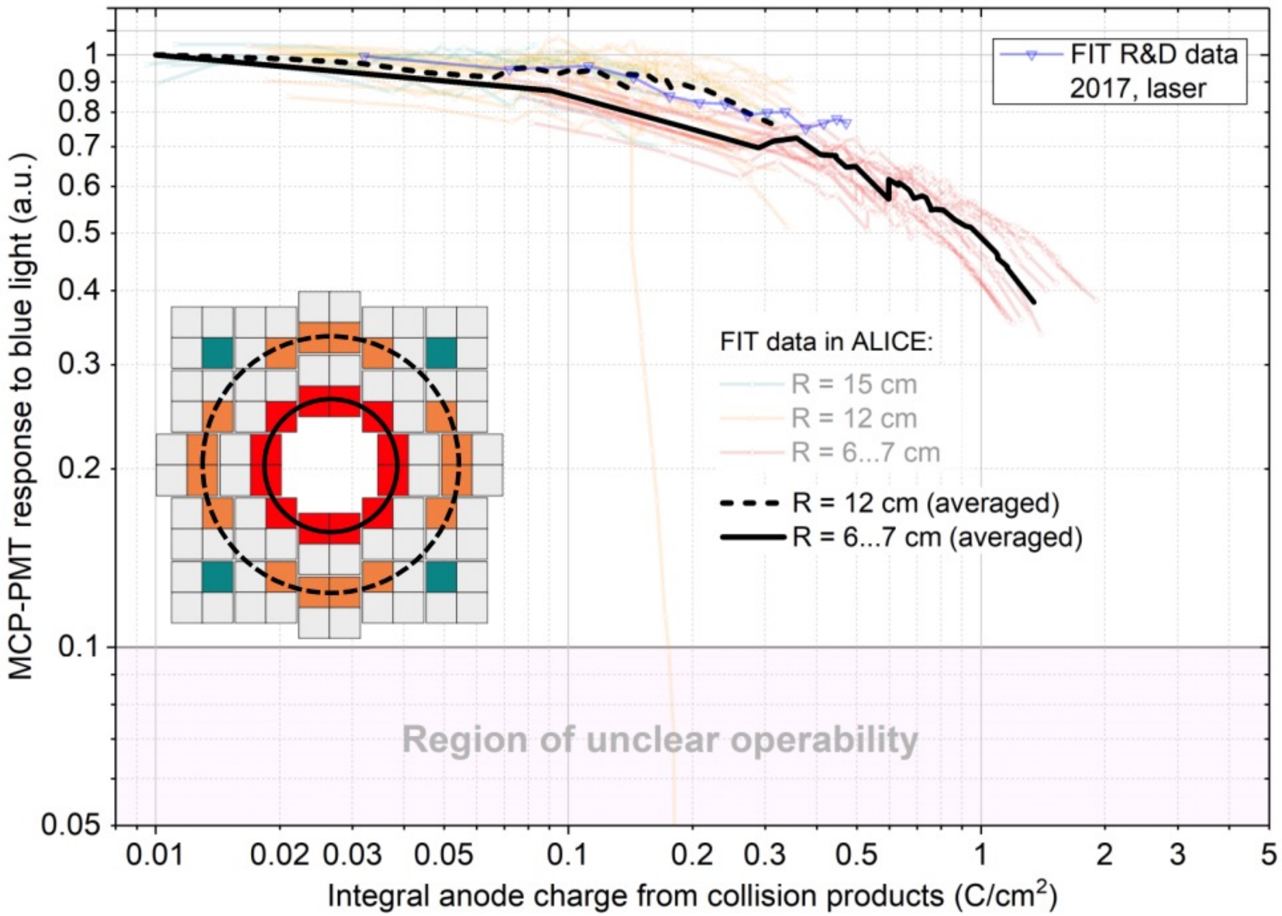
Construction:

- Picosecond laser flash split to the quadrants of reference FT0 module
- The signal reaches the quadrants in four ways
  - Two fibers through sides of detectors inside ALICE barrel
  - Other ones outside the barrel
- The time delay is compensated by the fiber length
- PMT photocathode ageing is determined as ratio of signal amplitude in detector and reference PMTs
- The fiber ageing is determined as ratio of the amplitudes from fiber pairs.

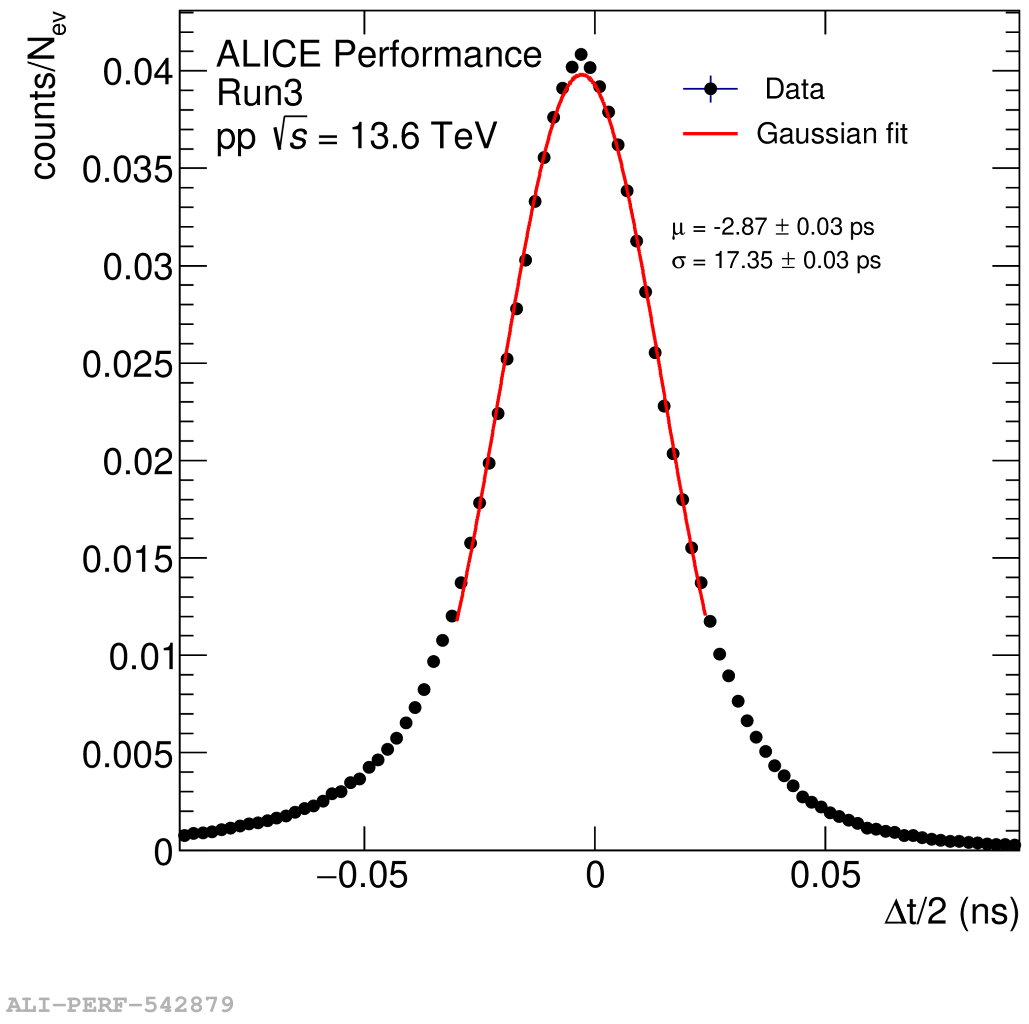


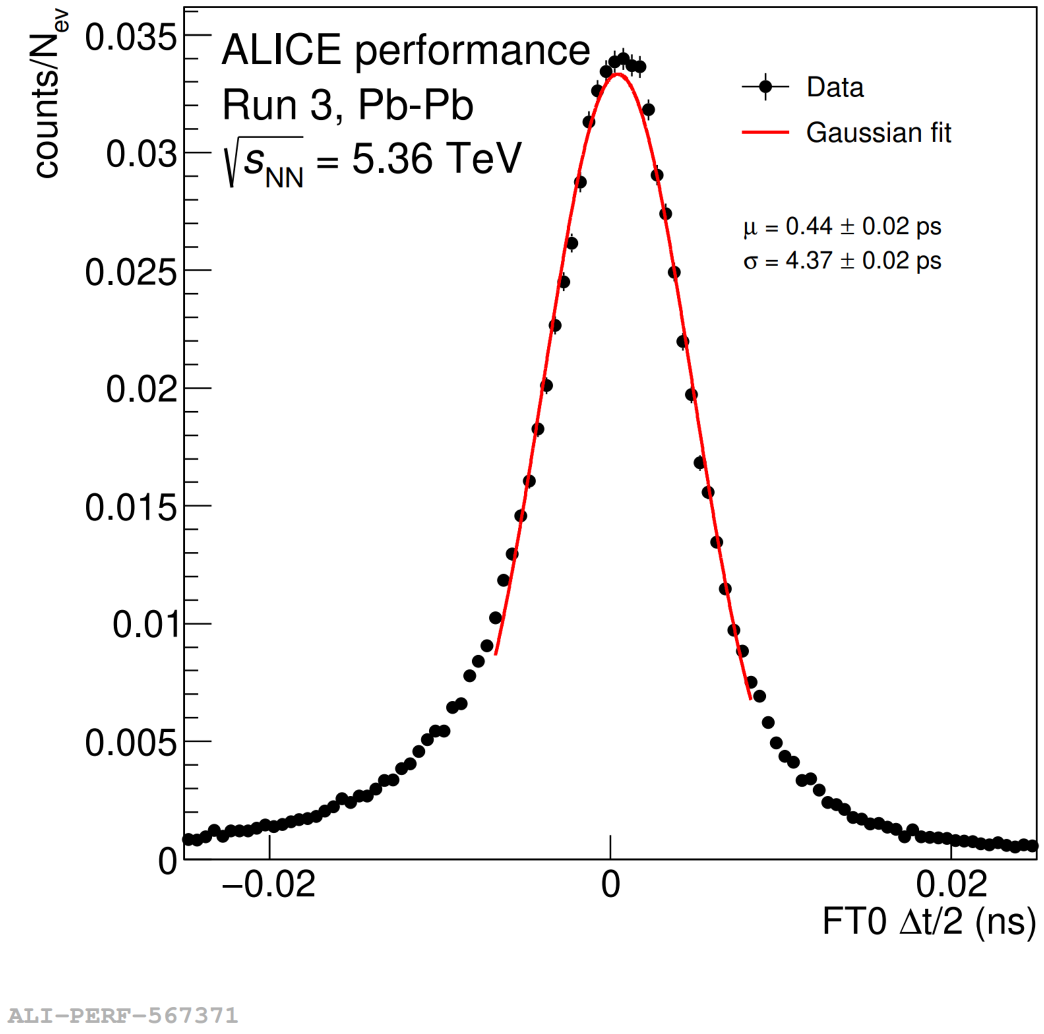
FT0 MCP-PMTs photocathode ageing and “self-annealing”



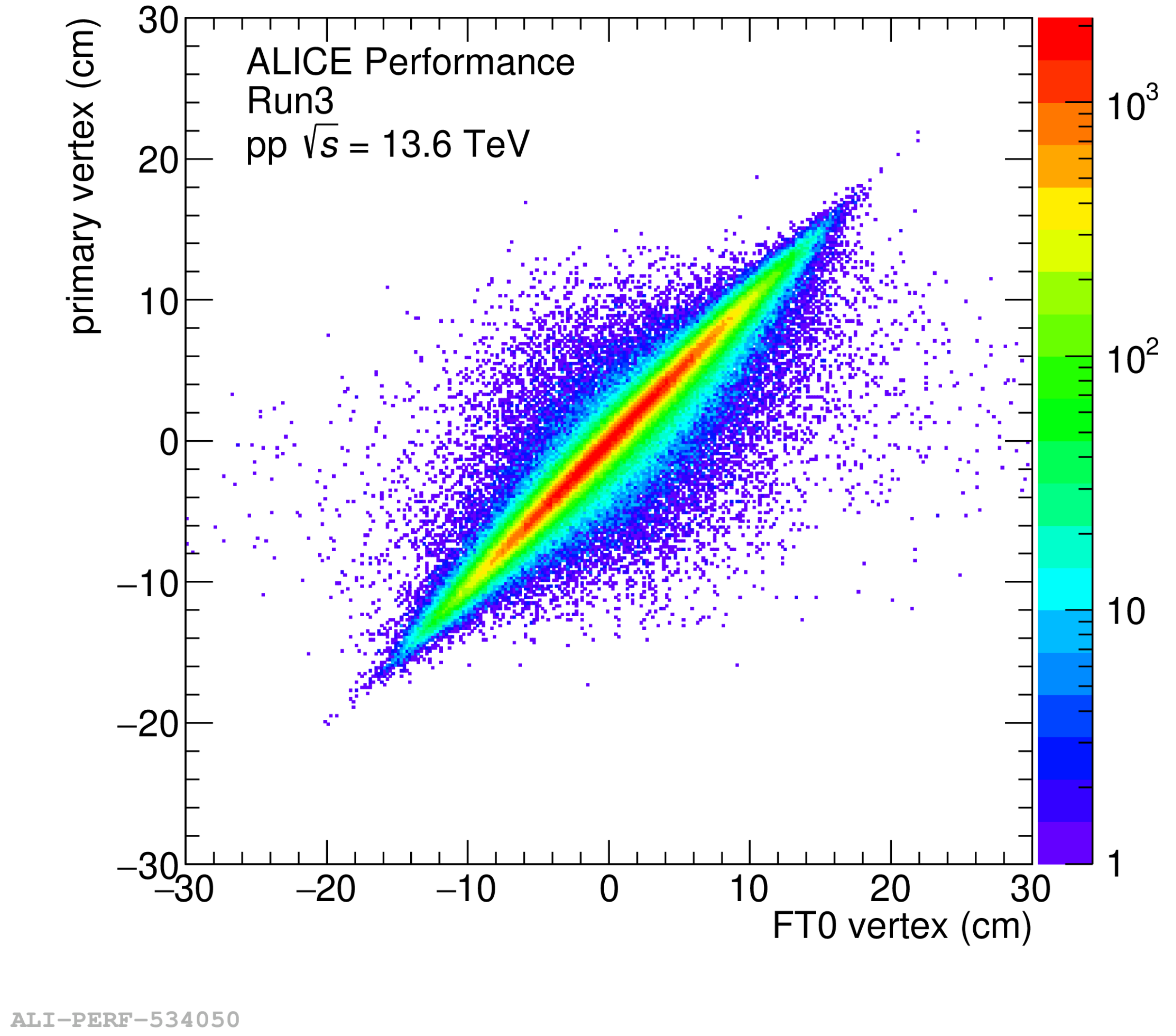


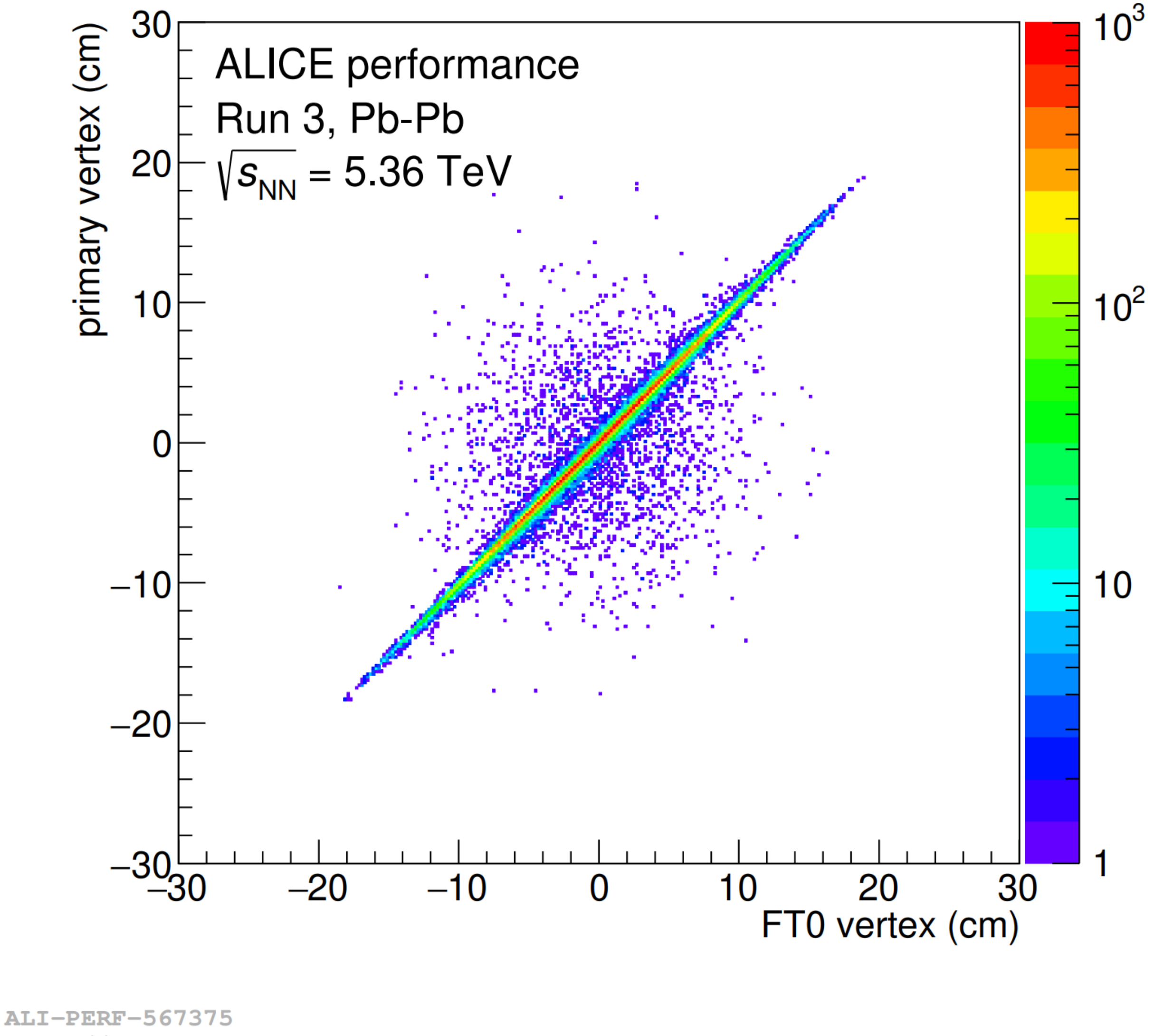
FT0 time resolution for pp и Pb-Pb collisions



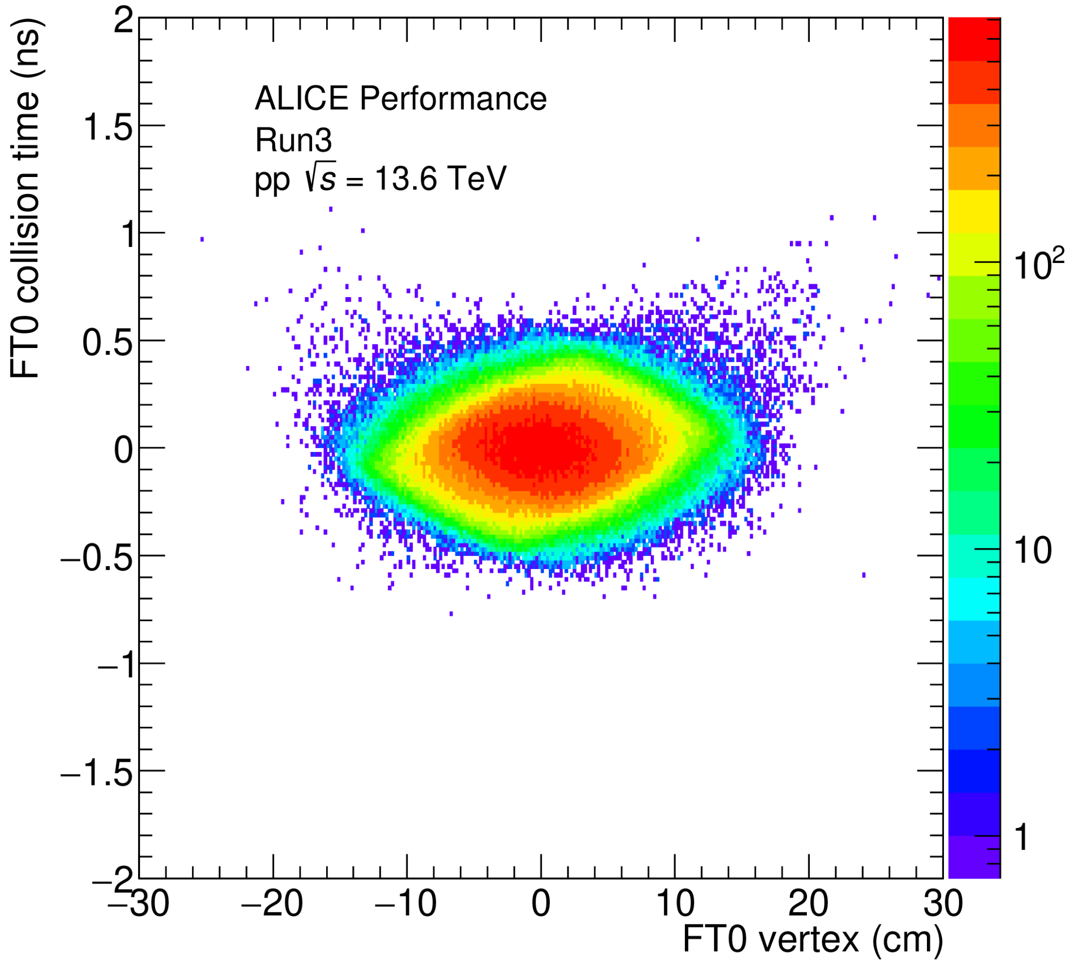


FT0 vertex vs Trackers PV correlation





FT0 vertex vs FT0 collision time



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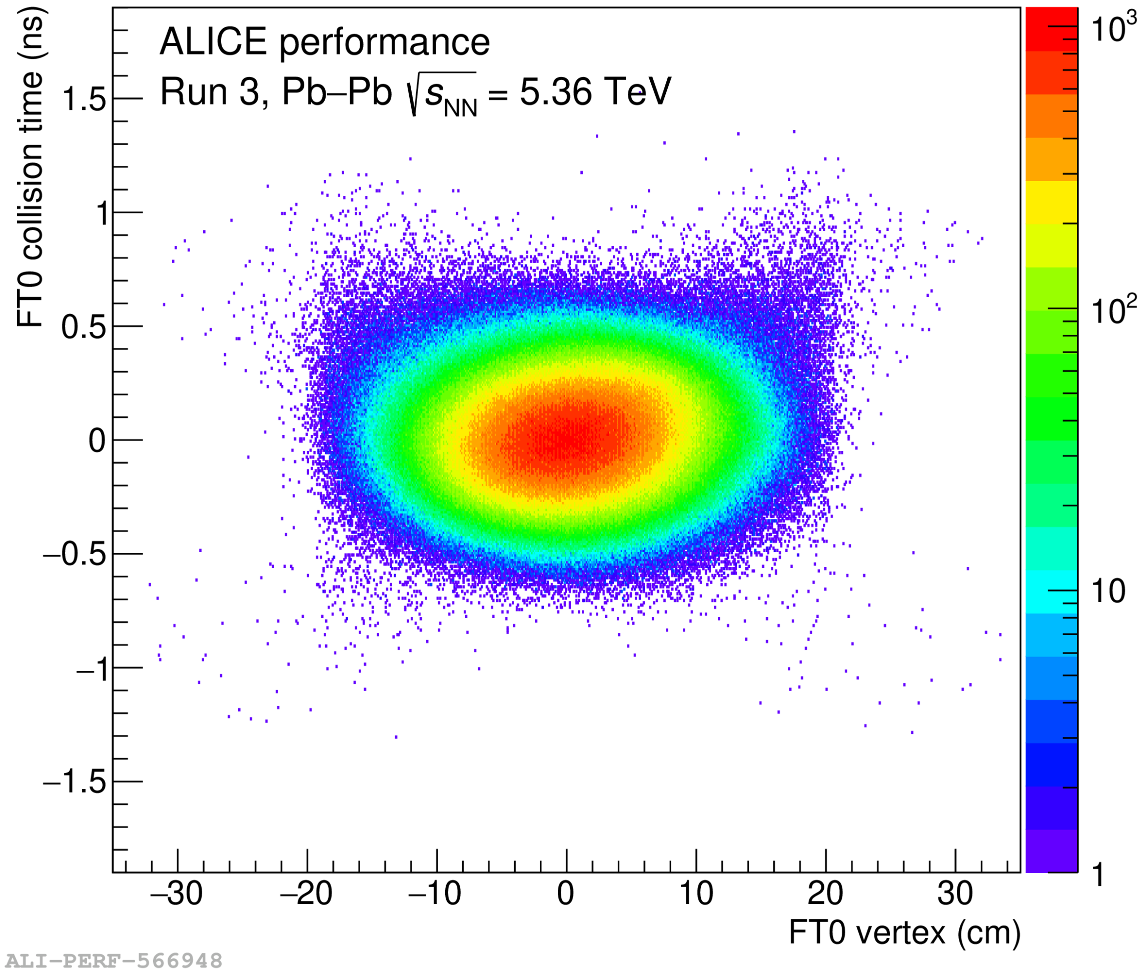

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