ALICE FIT data processing and performance during LHC Run 3

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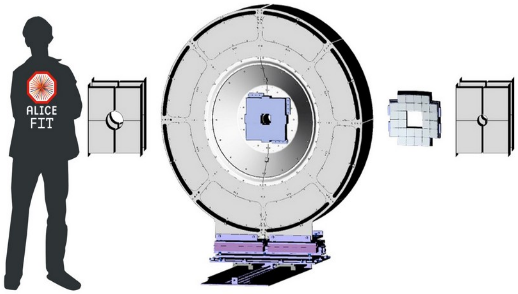
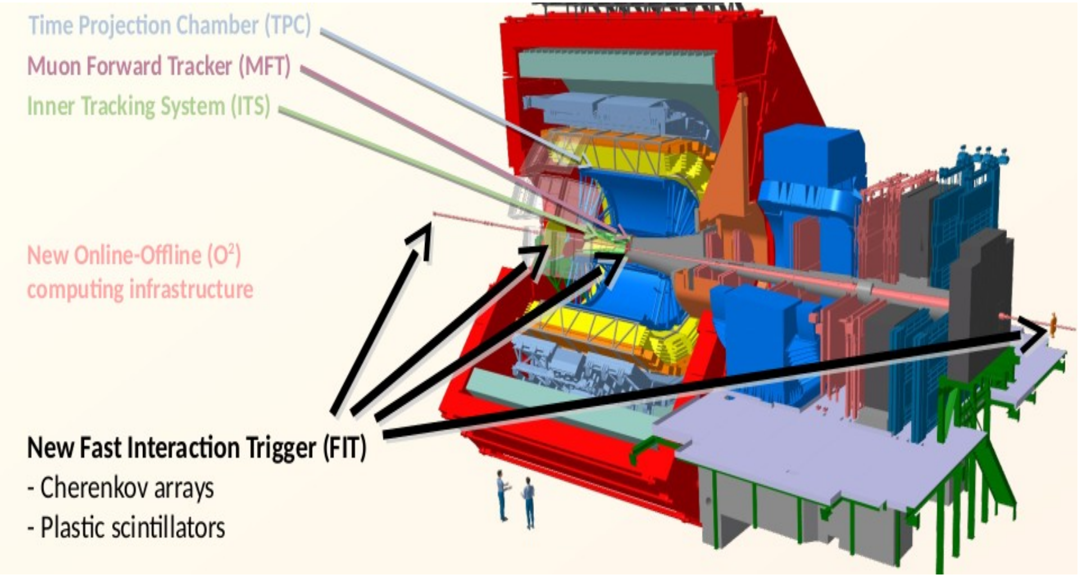


The 5th International conference on particle physics and astrophysics,
October 5-9, 2020, NRNU MEPhI

ALICE upgrade



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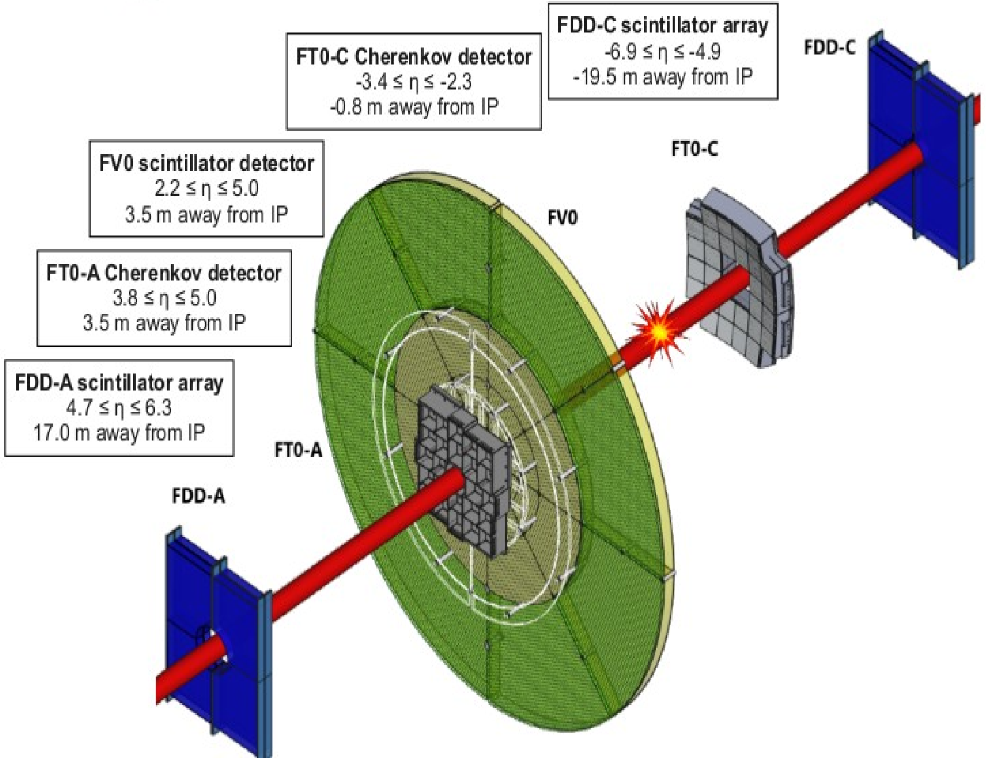
Focus on rare probes

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

Pb-Pb - interaction rates 50 kHz,
pp – 200 kHz (up to 1-2 MHz).
Goal: L ~10 nb^{-1} (B = 0.5 T) + 3 nb^{-1} (B = 0.2 T)

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

FIT detector: FT0, FV0, FDD



Online

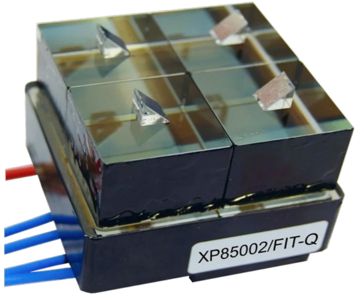
- Luminosity monitoring and feedback to LHC
- Trigger signals
- Online vertex determination
- Minimum bias and centrality selection
- Veto for ultra peripheral collisions
- Minus one level (LM) trigger latency less than 425 ns

Offline :

- Collision time for time-of-flight for particle identification
- Multiplicity, Centrality and Event Plane
- Diffractive physics
- Rejection of beam-gas events

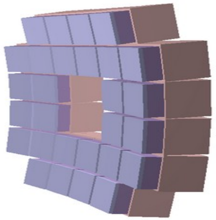
FIT FT0 subsystem

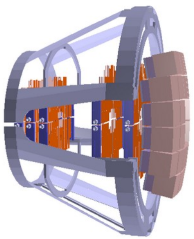
Each Cherenkov module consists of a 2 cm-thick quartz radiator, divided into 4 sectors and coupled to a customized PLANACON MCP-PMT (XP85002/FIT-Q)



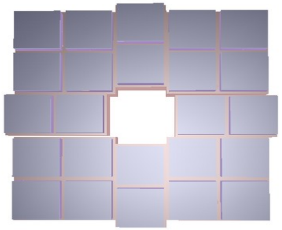
The 64 MCP anode outputs are grouped into quadrants with16 pads (4 × 4) each, operating as four independent readout channels

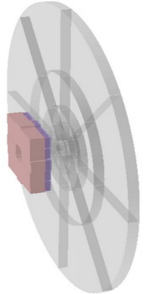
FT0-C
28 modules
→ 112 channels
concave shape



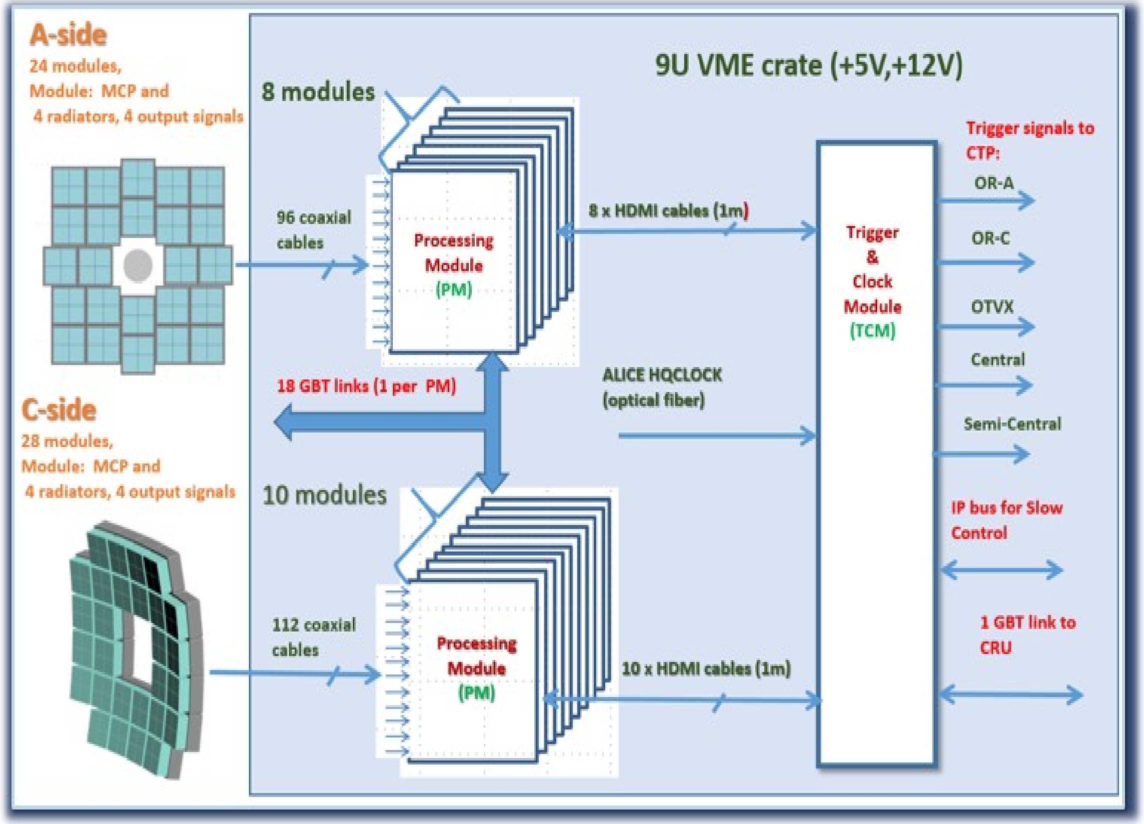


FT0-A
24 modules
→ 96 channels
planar shape





FIT electronics



FT0, FV0 and FDD utilize the same electronics scheme with only two custom-designed modules:

- •Processing Module (PM) – one per up to 12 analog inputs
- •Trigger and Clock Module (TCM) – one per subdetector

PM processes the input signals, converts them to digits, packs the data for readout (in continuous or triggered mode), and makes the first stage calculations for trigger decision.

TCM processes data from PMs, makes the final trigger decision, provides accurate clock and slow control to the connected PMs. Generated triggers: OrA, OrC, vertex, central, semi-central

ALICE O² data processing cycle

Continuous readout to cope with the 50 kHz interaction rate

- Upgrade of all detector readout boards
- Data (1.1 TB/s) transferred to First Level Processors (FLP)
- Heart-Beat triggers from CTP to chop data in Sub-Time Frames (STF)
- STF are assembled into Time Frames (TF) in the

Event Process Nodes (EPN)

- Synchronous data volume reduction on-the-fly by EPN
    - online calibration
    - Global reconstruction using GPU
    - Data compression

Compressed Time Frames (CTF) are stored on the tapes permanently

- Further reconstruction performed asynchronously (EPN farm/ GRID)
- Final refined reconstruction → Analysis Object Data (AOD)
- Data storage bandwidth: 85 GB/s for Pb-Pb at 50 kHz

FIT online data processing

FIT simulation chain

Event generator

Transport through ALICE geometry

Digitization with real detector response

Conversion to RAW data format

First Level Processors FLP

Detector readout

Read RAW data

Merge data belonging to the same BC/orbit in Digits

QC

Calibration

Create sub-time frames (STF)

Data arrive at the FLP from the detectors’ readout links.
First data compression (zero suppression) is performed inside FPGA-based readout cards (Common Readout Unit).
The continuous data are divided into Sub-Time Frames (TFs) on each FLP, 1 TF = 10-20 ms long (128-256 orbits) packets.

Event Process Nodes (EPN)

Assembly of STFs in Time Frames (TF)

Calibration

Synchronous reconstruction

Create Compressed Time Frame (CTF)

QC

Permanent storage

FIT offline Data Processing

At asynchronous stage, a second (and possibly third) reconstruction with final calibration will be run on the O^2 EPN farm and on the GRID. Final Analysis Object Data (AOD) will be produced and saved on permanent storage.

FITprovides

- collision time to be used by TOF detector for PID
- vertex position
- centrality
- event plane based on amplitude in individual channels
- multiplicity

FIT O^2 status

Simulation:

- ✓ Geometry;
- ✓ Collection of Cherenkov photons crossing MCP-PMT photocathode
- ✓ Digitization with real detector response
- ✓ Digitization include pile-up processing and embedding procedure
- ✓ Digits→raw conversion according to PM and TCM data format

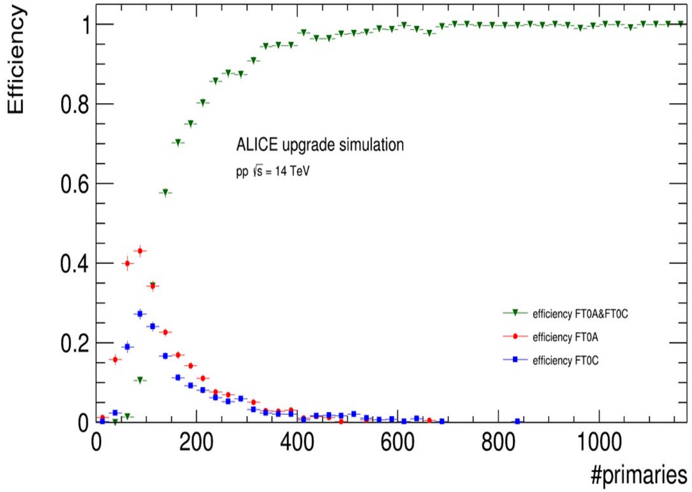
Data processing and reconstruction cycle based on O^2 Data Processing Level (DPL)

- ✓ Data reader →conversion to digits→STF → reconstruction→ CTF → AOD

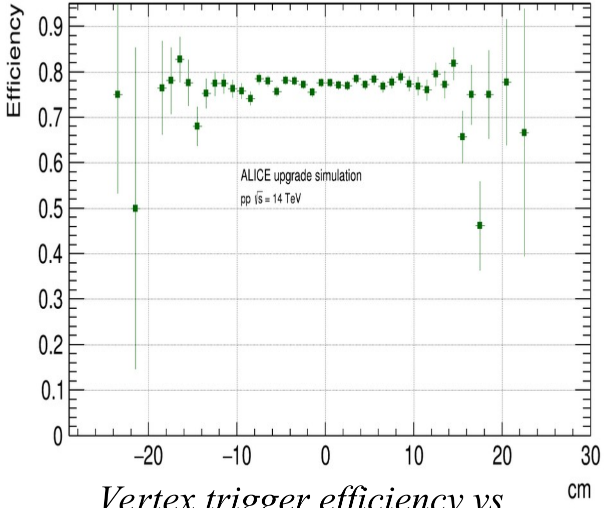
FIT FT0 performance: pp 14 TeV
Min bias trigger efficiency

FT0 can produce trigger signals every 25 ps
Registration efficiency is 100%; drops due to limited acceptance

Generator Pythia8, pp, 14 TeV, σ_{vertex} (0,0,6) cm
Simulation set-up: FT0, FV0, ITS, MFT, beam PIPE



Vertex trigger, OrA&noOrC, OrC&noOrA efficiencies vs number of primaries



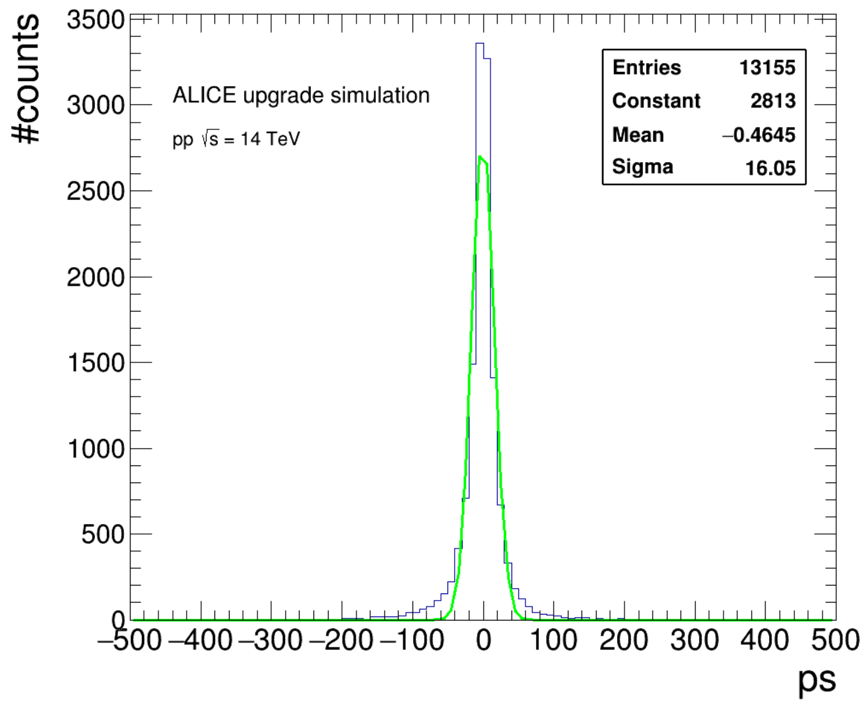
Vertex trigger efficiency vs z-position of vertex

Trigger signals are:
OrA – signal only from the A side;
OrC – signal only from the C;
Vertex – signals from both sides and vertex within given range.

FT0 trigger efficiencies

OrA	OrC	vertex
86%	83%	77%

FIT FT0 performance: pp 14 TeV collision time resolution



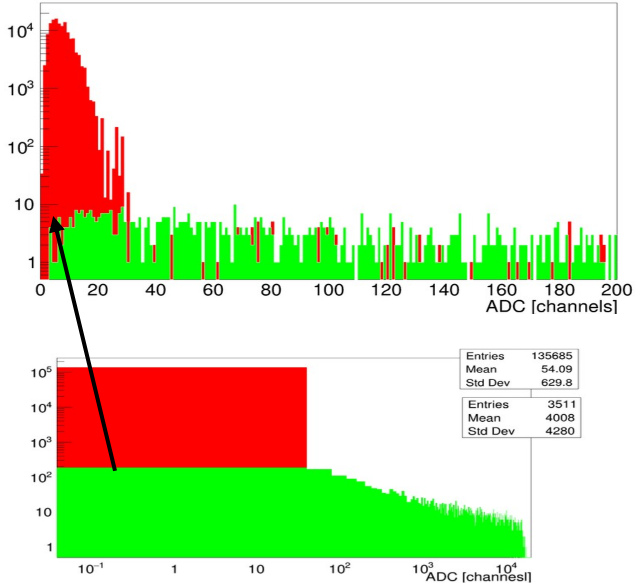
Collision time is half of the sum of the average arrival times at T0A and T0C and does not depend on primary vertex.
Resolution can be estimate as the sigma of Gaussian fit of distribution of the difference between average arrival times on each side corrected with the primary vertex.

If **(T0A+T0C)/2** can not be measured due to FT0 limited acceptance, **T0A** and **T0C,** corrected with primary vertex, can be used for particle identification by Time-Of-Flight detector for low multiplicity events.

FIT FT0 performance: Pb-Pb 5.44 ATeV+ QED

Pb-Pb 5.44ATeV; PYTHIA8hi generator; σ_{Had}=**8 b**

ALICE QED generator with parameters: σ_{QED}=**179507 b**



Multiplicity trigger sum amplitude A and C sides for Pb-Pb with embedded QED and pure Had

All heavy ion hadron (Had) collisions are accompanied by electromagnetic interactions **(QED)** with very high cross-section (σ_{QED}). Electromagnetic collisions occur with almost every bunch.

TCM (Trigger and Clock Module) provides the sum of the amplitudes on each side and can be used for rejecting QED contributions.

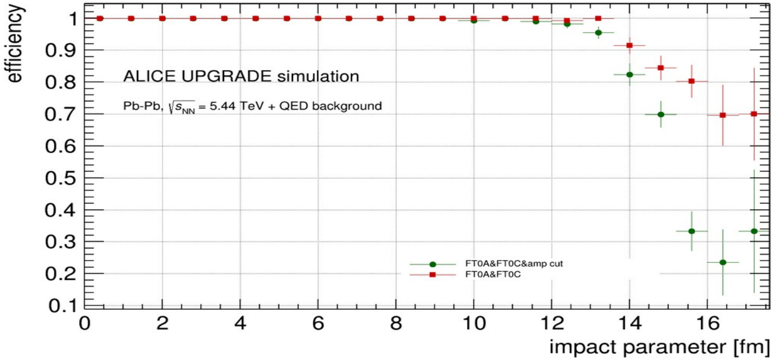
Multiplicity cut on sum ~ 30 ADC channels removes all QED

Pb-Pb + QED: trigger efficiency

Pb-Pb (5.44ATeV; PYTHIA8hi generator; σ_{Had}=8 b) with embedded

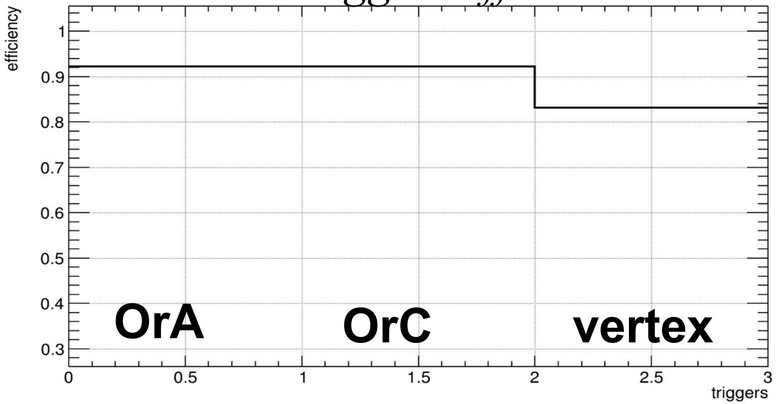
QED (ALICE QED generator with parameters: σ_{QED}=179507 b)

All QED interactions can be rejected with multiplicity cut while vertex trigger efficiency drops for very peripheral events.



Trigger OrA&OrC efficiency ***with*** *and* ***without*** *multiplicity trigger (SumA+SumC)>30 channels vs impact parameter*

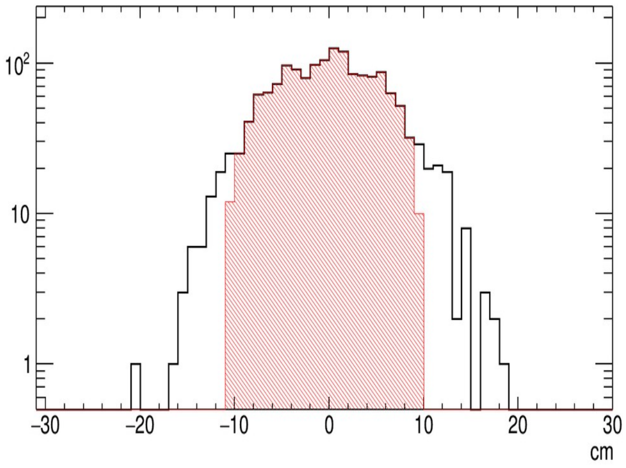
FT0 triggers efficiencies



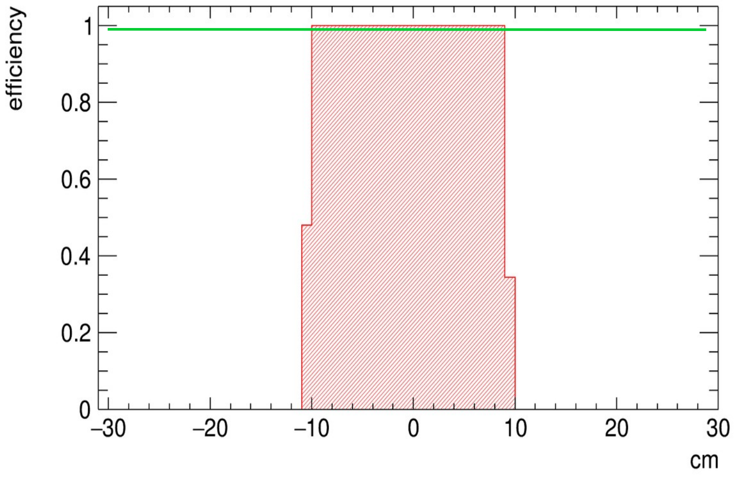
0.92 **0.92** **0.83**

Pb-Pb + QED: vertex trigger efficiency for semicentral and central collisions

Pb-Pb (5.44ATeV; PYTHIA8hi generator; σ_{Had}=8 b) with embedded **QED**

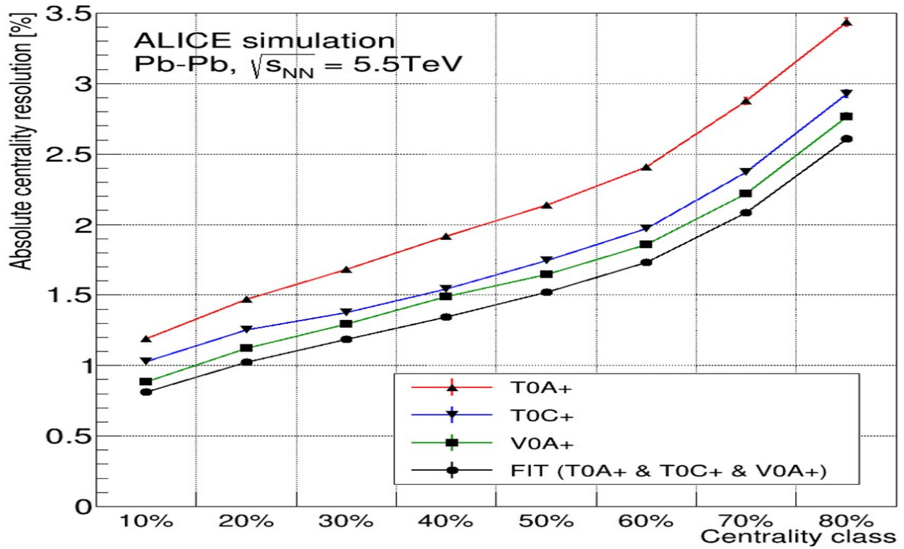


Z-position of vertex with and without vertex trigger

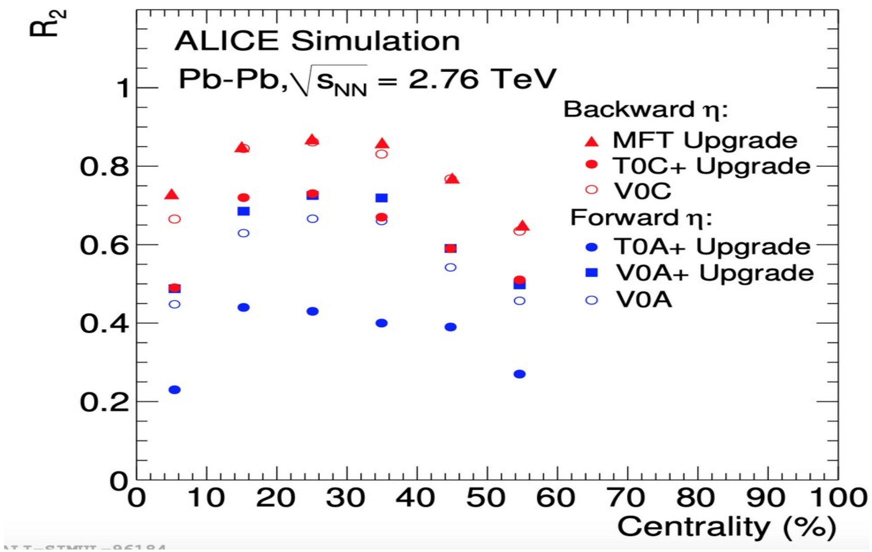


Vertex trigger efficiency

Centrality and event-plane resolution



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



The event-plane resolution (2nd harmonic R_2) of FIT, the comparison is made separately for each side for MFT (applied only in backward region), V0+ and T0+ and current V0

Conclusions

Analysis, based on simulated data, shows that performance of the FT0 detector satisfies the ALICE requirements:

- Min bias trigger efficiency is ~ 80% for pp collisions - similar to V0 during Run 1 & Run 2
- Collision time resolution is below 20 ps – better than T0 during Run 1 & Run 2
- Vertex trigger is 100% efficient for semi-central and central events