Performance of the Fast Interaction Trigger (FIT) detector system for global observables at ALICE in Run-3

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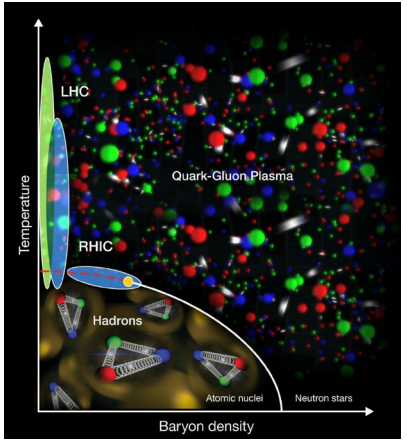
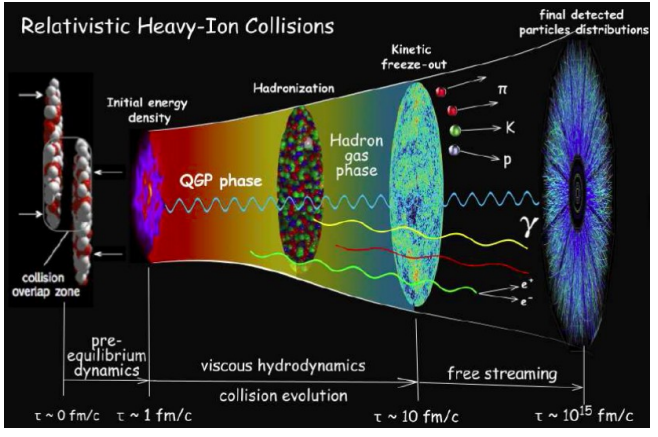
On behalf of the ALICE collaboration

ALICE experiment

Main goal of the ALICE experiment is to study property of quark-gluon plasma matter – deconfined strongly-interacting QCD matter with color degrees of freedom.

- Nuclei
- Quarkonia
- Jets
- Photons, low-mass dileptons
- Light flavour production
- Heavy flavour production



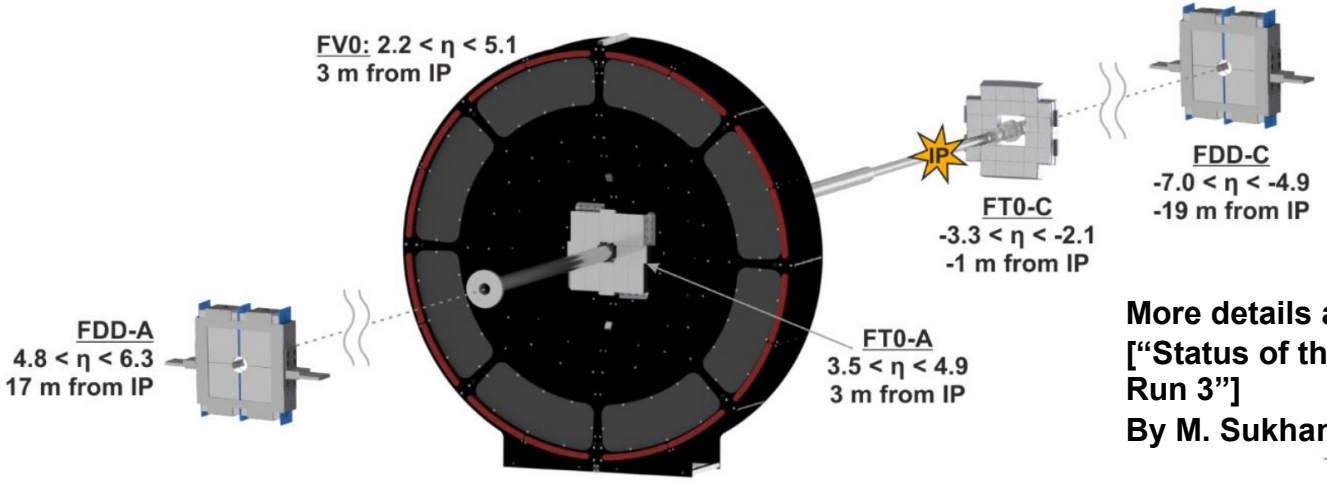


System of forward detectors - FIT

- **FT0:** two arrays of Cherenkov counters, 96(A side) + 112 (C side) quartz radiators(channels) coupled to 52 multianode microchannel plate-based PMTs (MCP-PMTs);
- **FV0:** circular arrays of plastic scintillator tiles at A-side, 48 channels.
- **FDD:** double-layered plastic quadric scintillator, read out by fine-mesh PMTs

4 channels per layer -> 2 layers per side -> 16 channels in total.

- Each **FIT** sub-detector provides **amplitude and time information** per array's element in given event, with **precise detection of the event's bunch-crossing ID** (BCID).

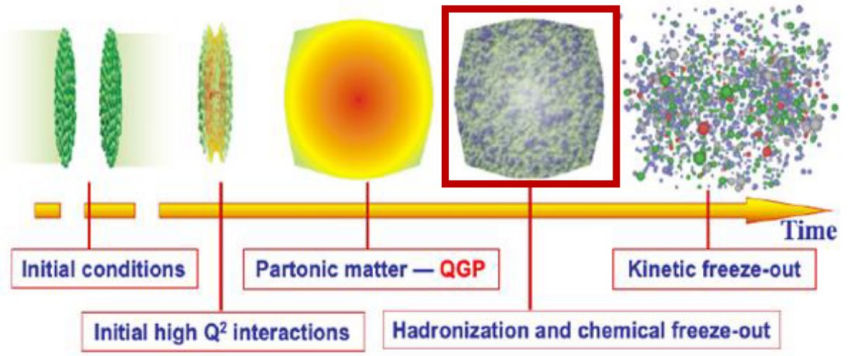


More details about FIT can be found in presentation ["Status of the ALICE Fast Interaction Trigger for the Run 3"]
By M. Sukhanov on behalf of the ALICE collaboration

ALICE experiment

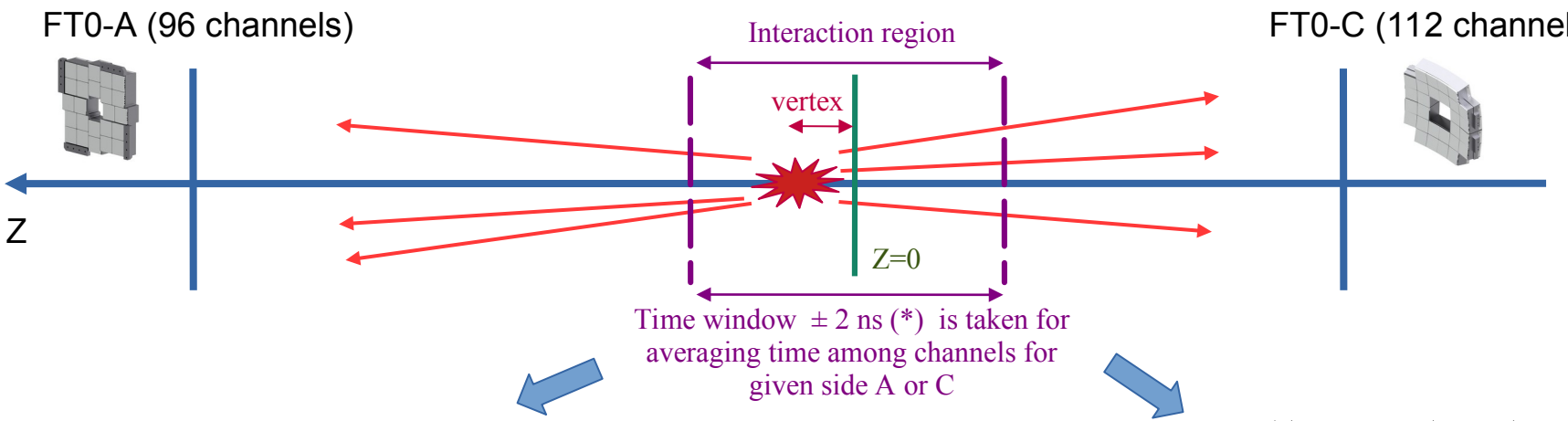
Basic global observables, provided by new FIT detector system:

- **Minimum bias** trigger production for physics selection;
- **Luminosity** determination;
- **Multiplicity** in forward rapidities;
- **Centrality** and **event-plane** determination (based on multiplicity info);
- **Collision time** and **vertex position** (based on time info);
- **Veto** for diffractive and ultra-peripheral heavy-ion collision – based on multiplicity and time info;



- Nuclei
- Quarkonia
- Jets
- Photons, low-mass dileptons
- Light flavour production
- Heavy flavour production

Vertex and collision time



$$collTime = (\langle Time_A \rangle + \langle Time_C \rangle)/2$$

$$\text{vertex} = (\langle Time_C \rangle - \langle Time_A \rangle)/2$$

PV - primary vertex, measured by tracking detectors, for defining collision time resolution:

$$TimeRes_{FT0} = \sigma(vertex - PV)$$

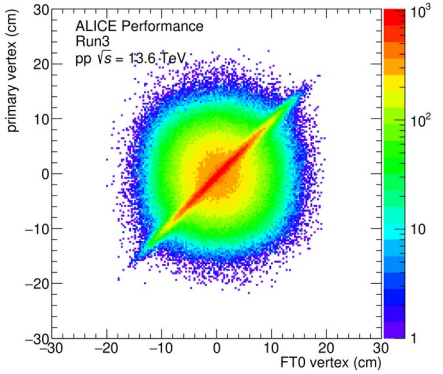
PV resolution is much higher than FT0's, PV's deviation can be ignored.

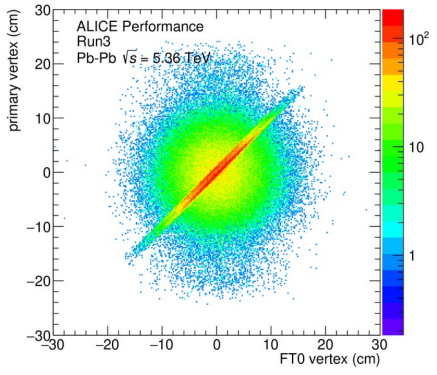
Difference between FT0 vertex and PV contains only FT0's time deviation.

(*) Configurable value, ±2 ns stable for 2022-2024

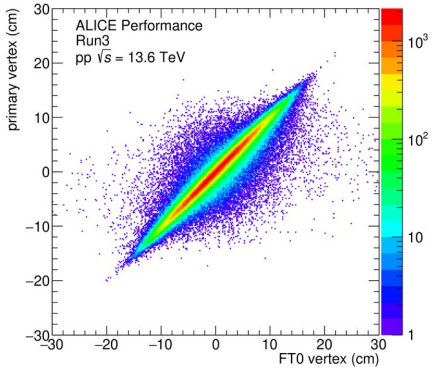
FT0 vertex vs primary vertex

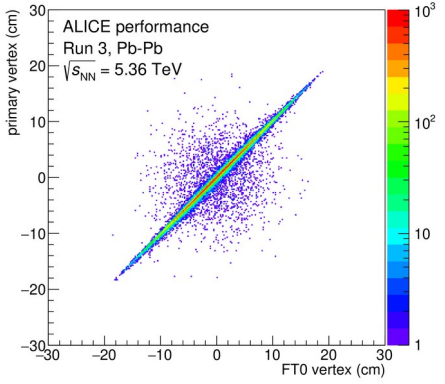
Before calibration





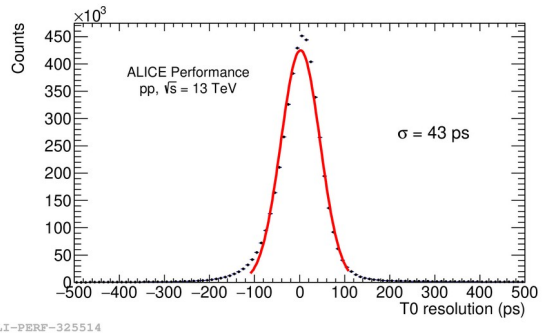
After calibration



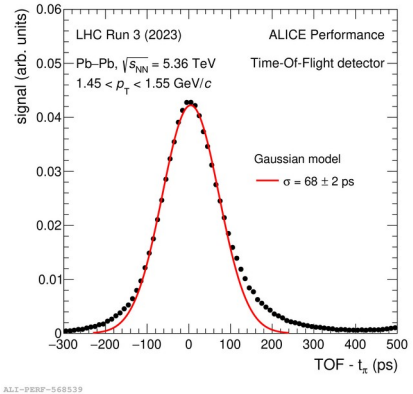


- Presented vertex position correlation measured by FT0 and ALICE tracking detectors (primary vertex).
- Global event reconstruction is based on anchoring of detected by FT0 events with precise BCID.
- For checking quality (QA) of the event reconstruction, FT0 vertex vs PV, and width of its difference(collision time resolution) is used. Also is used for event selection.
- Calibration shows much improvement FT0 vertex vs PV correlation.

FT0 time resolution

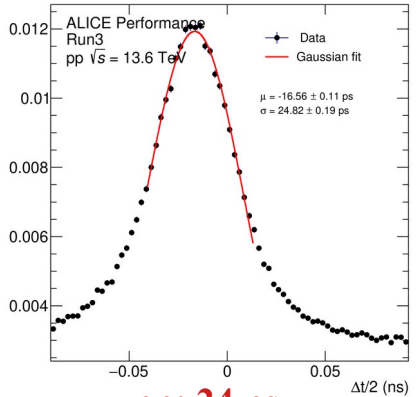


T0 (Run 2) pp : 43 ps

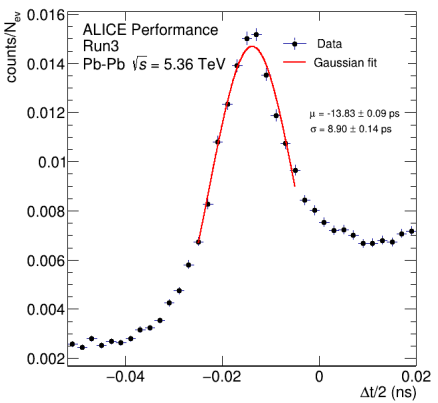


TOF PbPb (Run 3) on π: 68 ps

before calibration

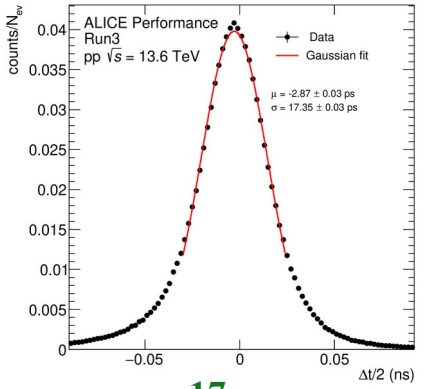


pp: 24 ps

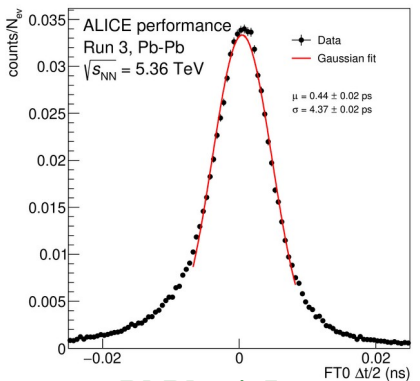


PbPb: 9 ps

after calibration



pp: 17 ps

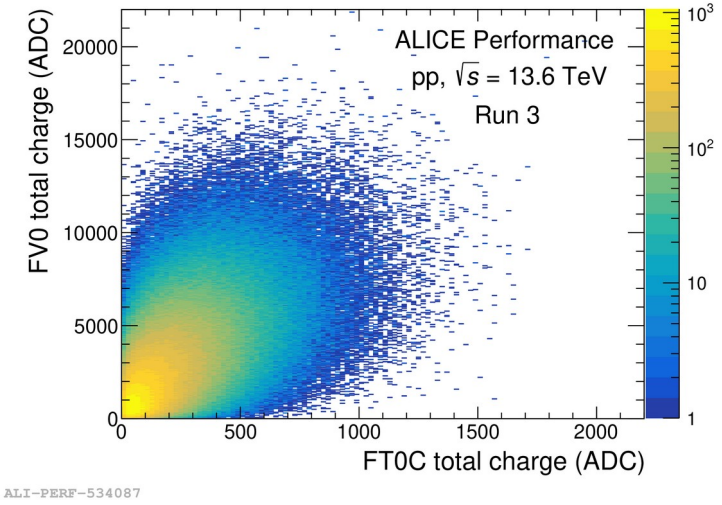


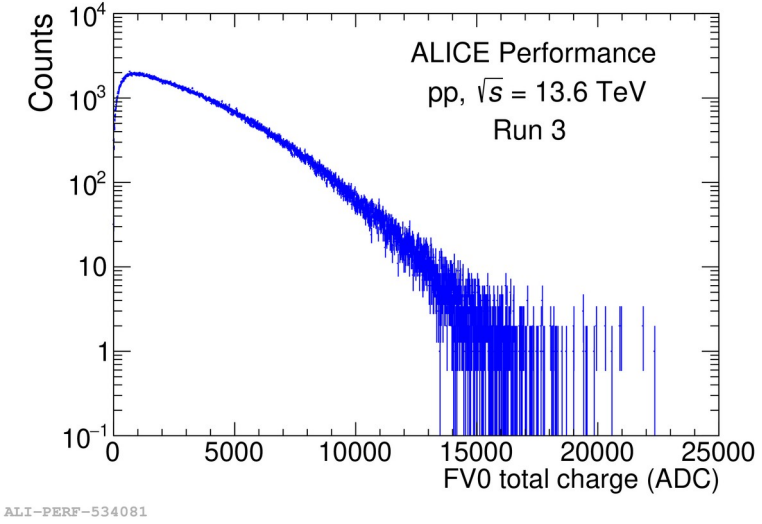
PbPb: 4-5 ps

FT0 in Run 3

- Calibration significantly improves time resolution.
- FT0's time resolution is much better that in its ancestor – T0
- Calculated collision time is used for TOF PID.

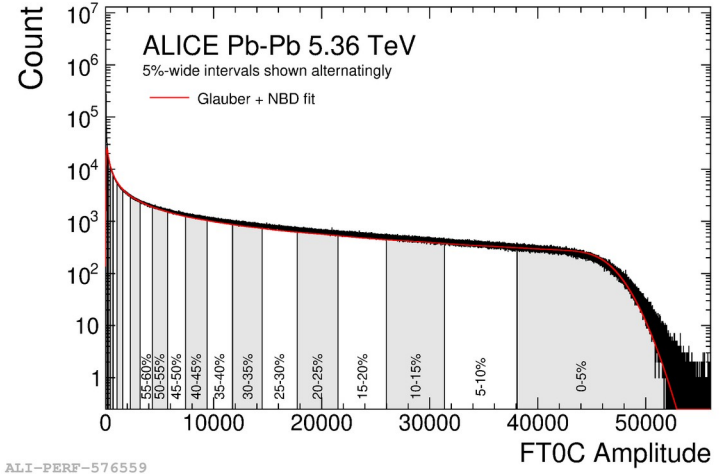
Multiplicity in p-p collisions

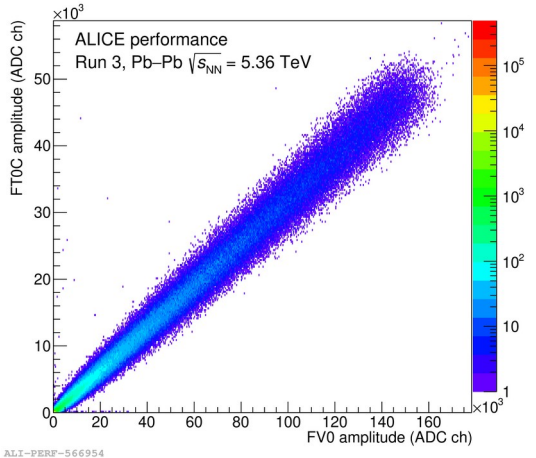


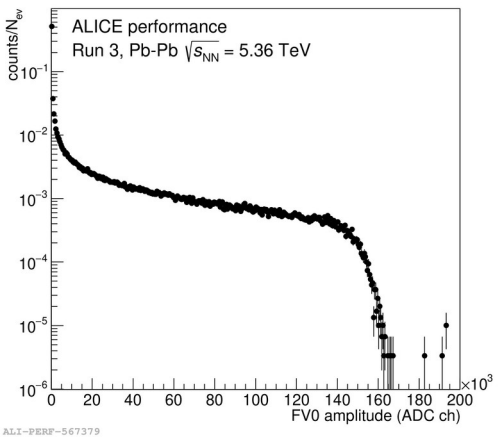


- Event selection for plots above: vertex trigger applied.
- Multiplicity measured by FIT detectors in forward rapidities, shows distribution as expected.
- For high multiplicity event studies in p-p collisions.

Multiplicity in Pb-Pb collisions

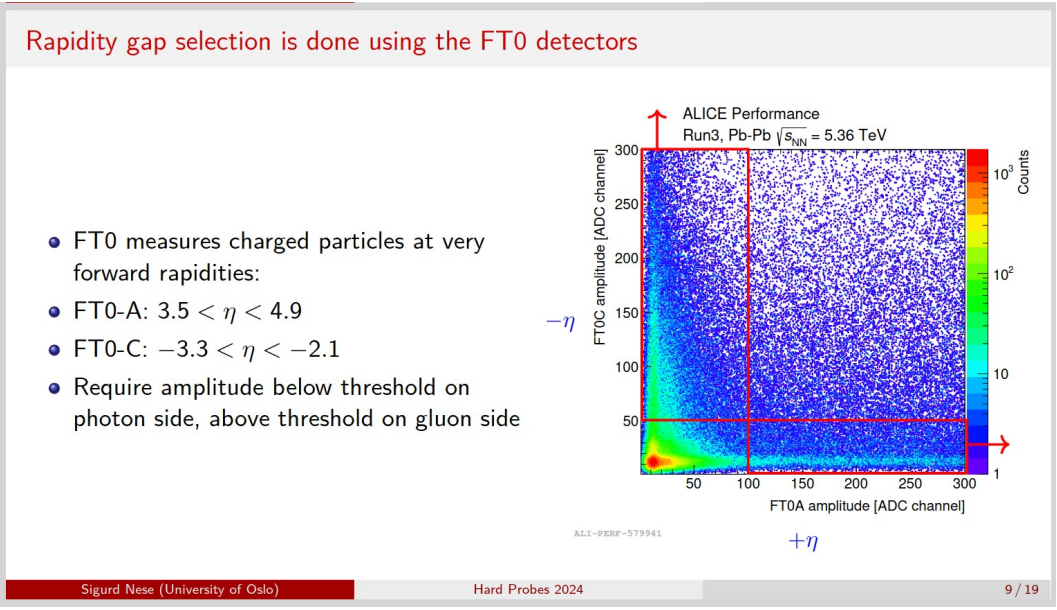






- At hardware level FT0 produces central and semi-central centrality triggers, based on sum of the amplitudes from both sides (configurable settings).
- Event selection for plots above: minimum bias (vertex and central or semi-central) trigger applied.
- FV0A and FT0C shows good multiplicity correlation as expected.
- In Run-3 FT0C multiplicity is currently expected to be used in centrality determination.
- FV0A multiplicity is secondary item for control and cross-checks.

Multiplicity in Pb-Pb collisions



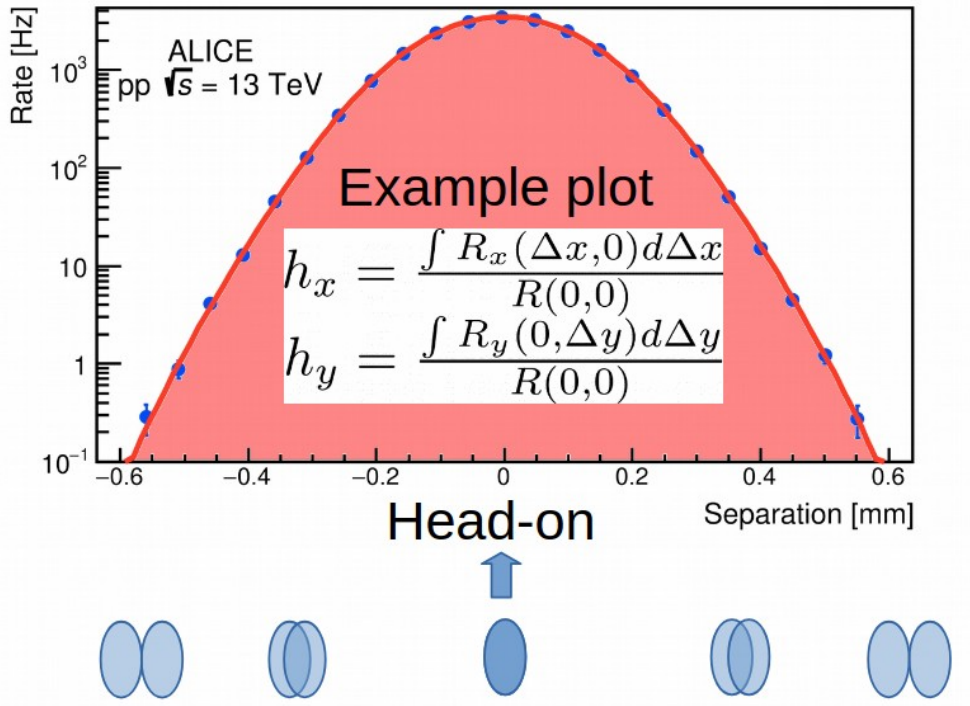
- Tagging events in Pb-Pb collisions by using measured by FT0 low multiplicity cuts, is currently used for ultra-peripheral collision (UPC) studies
- Left screenshot is example slide of the material(*) presented recently at **Hard Probe 2024** conference in **UPC section**.

(*)
"A new class of ultra-peripheral collisions in ALICE: inelastic photonuclear interactions and open charm photoproduction"
by Sigurd Nese for the ALICE collaboration
https://indico.cern.ch/event/1339555/contributions/6040927/

FIT for ALICE luminosity

- Luminosity determination at ALICE is based on the visible cross-section measurements of detectors – luminometers.
- For visible cross-section measurements special dedicated session is required - Van-der-Meer (VdM) scan, with participating luminometers during data taking.
- In VdM scan beams are displace along X/Y axis in both ways – direct and reversed, with constant separation step (*).
- Luminometers provide trigger rate as function of beam separation - which is key for further visible cross-section measurements.

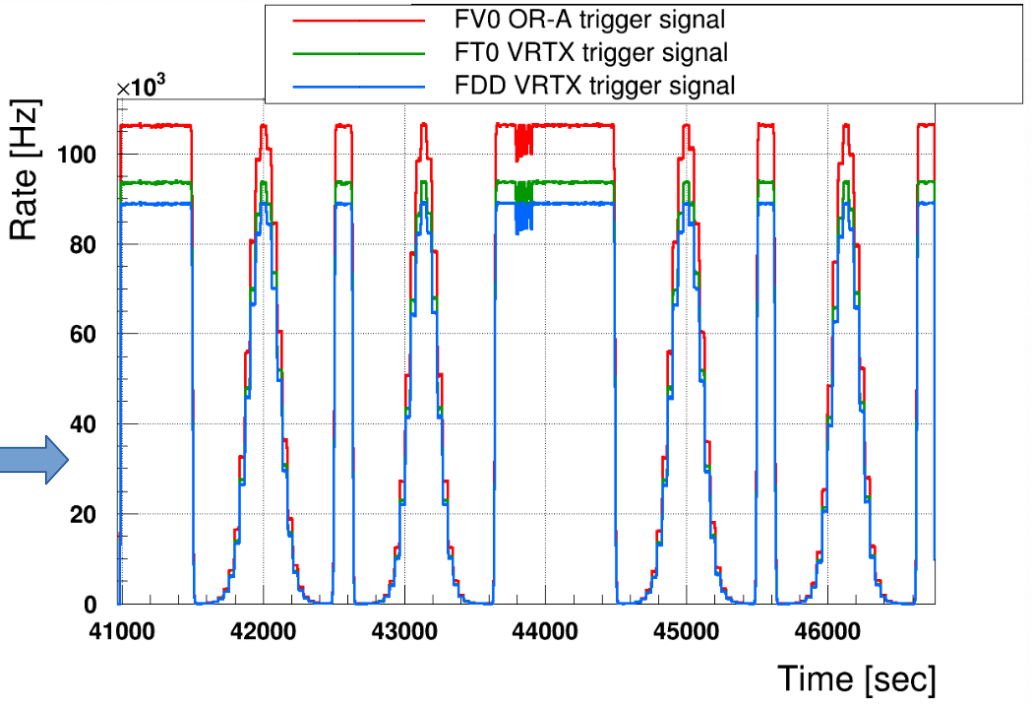
$$L = \frac{R(0,0)}{\sigma_{vis}} = \frac{f_{rev} N_1 N_2}{h_x h_y}$$



(*) VdM also includes special calibration sub-session for data corrections

FIT for ALICE luminosity

- FIT as luminometer(*) is the main key for VdM scan analysis in ALICE Run-3.
- Since the beginning of the Run-3, ALICE have successfully conducted three p-p VdM scans (1 per year) and one for Pb-Pb (*) in 2023.
- At the right plot presented example of the FIT trigger rates in VdM scan session for p-p. Four gaussian-like forms are trigger signal response to beam displacement along X-Y axis in direct and reverse directions (**).



(*) In Pb-Pb Zero Degree Calorimeter(ZDC) also is used as luminometer

(**) 2 axis x 2 directions = 4 gaussian-like forms

Conclusions

- As the **luminomeneter** FIT provides important trigger counts of physics events. FIT takes important part in the **luminosity determination** at the ALICE experiment.
- FT0 is the key for the global event reconstruction algorithm, due to **precise BCID detection of the events**.
- FT0's **collision time** is important measurable value for PID analysis via TOF detector.
- FT0's **vertex position** participate in data QA metric calculation and event selection.
- **Multiplicity** measured by FIT in forward rapidities is used for high multiplicity studies, centrality determination and for providing veto in UPC analysis. In the future it is also expected to use for event plane measurements.
- **FIT detector plays important role in the ALICE experiment, i.e. "heart" of the ALICE experiment.**

Backup

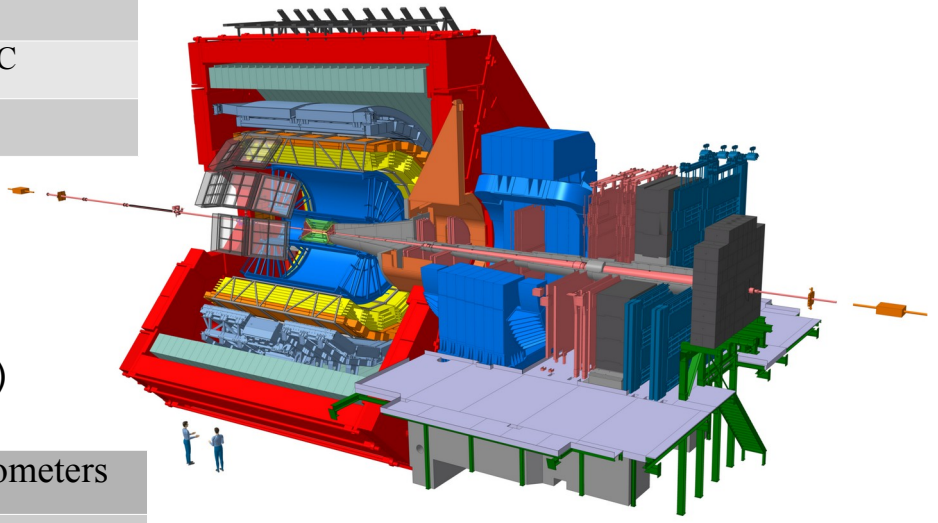
ALICE experiment

- **Run 1-2 (2009-2018):**

System	Energy(TeV)	Collision rate	Luminometers
pp	0.9 , 2.76, 5.02, 13	< 100 kHz	T0 + V0
PbPb	2.76, 5.02	~ 1 kHz	V0 + ZDC
pPb, XeXe	...	...	..

Long-Shutdown 2 ALICE Upgrade:

- ~ x50-x100 statistics increase
- New electronics
- New detectors (FIT)
- New software (Offline-Online O2 package)



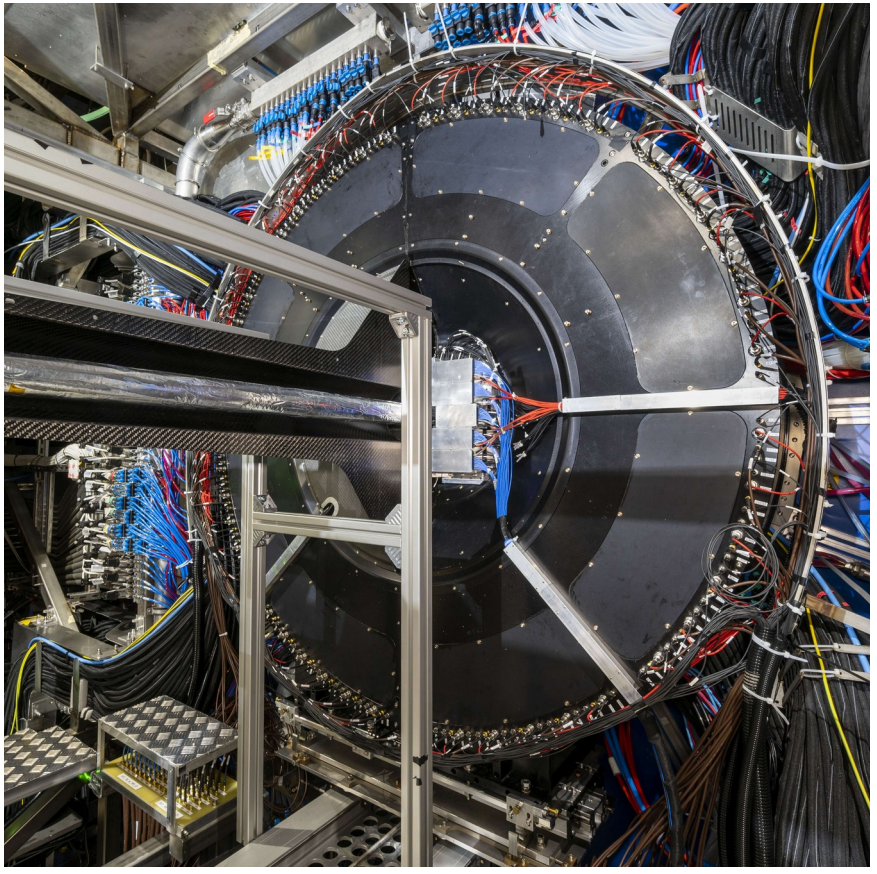
- **Run 3 (2022 – 2026):**

System	Energy(TeV)	Collision rate	Luminometers
pp	13.6	500-1000 kHz	FIT: FT0, FDD
PbPb	5.36	50 kHz	FIT + ZDC

System of forward detectors - FIT

Main purpose of the FIT:

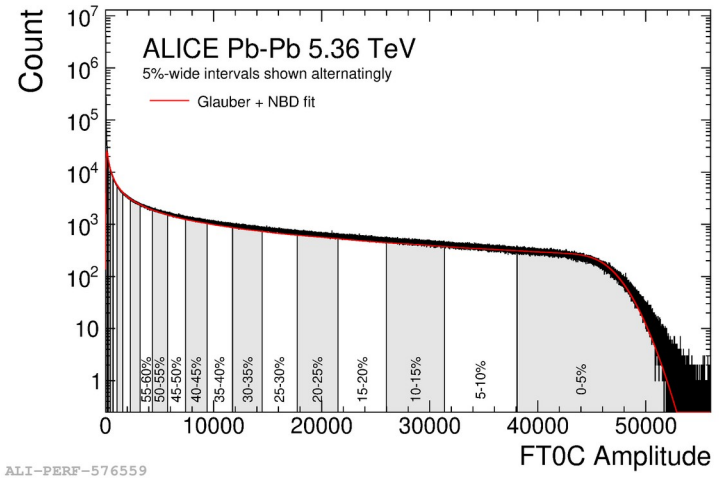
- **On-line trigger;**
- **Precise time-zero detector;**
- **ALICE luminometer & feedback to LHC;**
- Centrality & event plane detector;
- Veto for ultra-peripheral collisions (diffractive physics);
- Background monitoring.

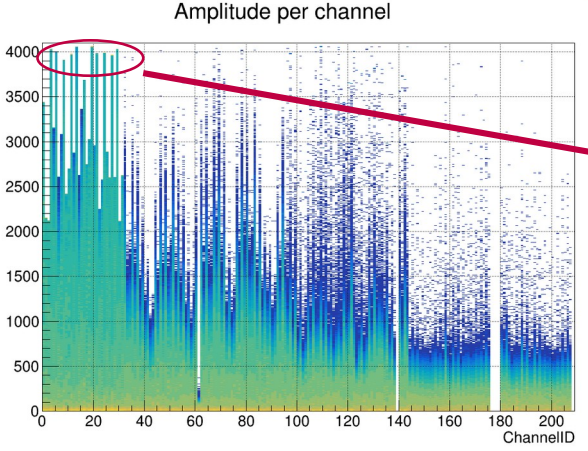


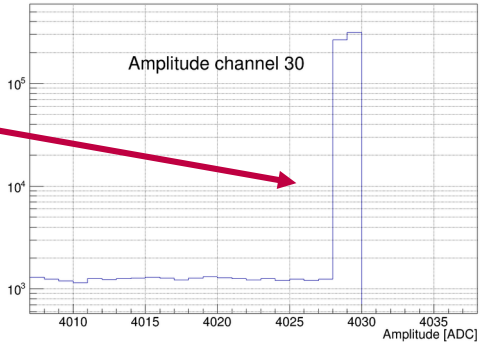
YouTube

FIT youtube videos:
Russian: https://youtu.be/phN0AohEDKI
English: https://youtu.be/PjsBIbKsuO0
Spanish: https://youtu.be/qR_lG7K3pfs
Polish: https://youtu.be/31s8jix2omo

Multiplicity in Pb-Pb collisions







Saturation in channels closest to pipe(first 32 at FT0-A)

- Multplicity is required for centrality determination in Pb-Pb.
- Due to amplitude saturation in first 32 channels(closest to pipe, side A) at FT0-A, ALICE expects to use multiplicity from FT0-C.

Centrality for ALICE in Run-3