ALICE FIT trigger requirements

This document collects information related to the FIT trigger requirements for Run3 and Run4.

FIT detector consists of FT0 (FT0A and FT0C), FV0 (FV0A) and FDD (FDDA and FDDC) detectors, having different granularity, size, pseudorapidity coverage and working parameters.

1. FIT detector has been designed to deliver:

- Luminosity monitoring
  - Feedback to the LHC
  - Feedback to ALICE
- Trigger generation
  - Vertex selection
  - Centrality/multiplicity selection (including Minimum Bias)
  - Rejection of beam-gas events
  - Veto for ultra-peripheral (electromagnetic) collisions of heavy ions
- Collision-time measurement
- Required for time-of-flight based particle identification
- Forward multiplicity/centrality determination
- Event plane, estimate of the reaction plane of heavy-ion collisions

2. FIT trigger requirements from Physics Coordination (13 Dec 2016)

- **TRIGGER WITH CHARGE-AMPLITUDE RANGE**: FT0 and FV0A should have a trigger with programmable lower and upper charge-amplitude limits (as we have now in V0).
- **TRIGGER ON FIRED CELLS IN GIVEN TIME WINDOW**: It should also be possible to have, at trigger levels L0 and LM, the information of how many CELLS (both for FV0A and FT0) saw a hit, in a given BC, in the time windows corresponding to beam-beam (BB-flag) and beam-gas (BG flags) interactions. The current V0 allows one to use a trigger signal of the type ($n < BB < N$ && $m < BG < M$), where n, N, m, M are integer numbers and can be set via DCS.
- **MASKING CELLS FROM THE TRIGGER**: It should be possible to mask out one or more channels from the trigger logic.
- **TRIGGER WITH CHARGE-AMPLITUDE RANGE FROM INDIVIDUAL FV0A RINGS**: It would be very useful if the V0A+ had the possibility to trigger using the signal (or absence of signal) from individual rings; this would open new possibilities, like triggering pp events with high multiplicity in different eta intervals (using the 5 rings).

- **OTHER USEFUL IMPROVEMENTS**: As possible further improvement, it would be worth to look into the possibility of storing, in case of multiple hits, the times of all hits for a given cell (for FV0A and FT0). In the present V0, only the leading time is stored. Another interesting possibility would be to decrease the integration time to below 25 ns, again in order to catch multiple hits (as of now, in case of pile-up the measured charge is given by the sum of all hits). All of this is of course subject to what will be the actual detector time resolution.

3. Detector survey (31 May 2019)

A survey based on the following questions was conducted among ALICE detectors (ACO, ZDC, ITS, TPC, TRD, TOF, EMCAL, HMPID, PHOS + CPV, MFT, MCH+MID) to collect requirements:

- What FIT hardware triggers do you consider?
- What FIT information (online/offline) do you need?

Summary from survey

<table>
<tr><td>Detector</td><td>FIT hardware trigger</td><td>FIT offline information</td></tr>
<tr><td>ACO</td><td>NO</td><td rowspan="12">signal amplitude & time / channel
→ collision time, event multiplicity/centrality

time for each hit (in case of multiple hits in the channel)
→ pileup rejection</td></tr>
<tr><td>ZDC</td><td>~L0, MB</td></tr>
<tr><td>ITS</td><td>~LM, MB</td></tr>
<tr><td>TPC</td><td>NO</td></tr>
<tr><td>TRD</td><td>~LM, MB</td></tr>
<tr><td>TOF</td><td>~L1, MB (only cosmics)</td></tr>
<tr><td>EMCal</td><td>~L0, MB, mult.</td></tr>
<tr><td>PHOS</td><td>~L0, MB, mult.</td></tr>
<tr><td>CPV</td><td>~LM, MB, mult.</td></tr>
<tr><td>HMPID</td><td>~LM, MB, mult.</td></tr>
<tr><td>MCH</td><td>~L1, MB</td></tr>
<tr><td>MID</td><td>~L1, MB</td></tr>
<tr><td>MFT</td><td>~LM, MB</td><td></td></tr>
</table>

Additional information

- ZDC – trigger at ~L0 in MB Pb-Pb collisions
- ITS – trigger at ~LM in MB collisions
- TPC – trigger mode is foreseen (TPC time buffer including previous and next time intervals +/-100 μs), but not FIT required
- TRD - pre-trigger at LM
- TOF - during commissioning FIT trigger required at ~L1 in MB events
- EMCAL – trigger at ~L0 in MB and with centrality selection
- PHOS - trigger at ~L0 in MB and with centrality selection
- CPV – trigger at ~LM in MB and with centrality selection

- HMPID – trigger at ~LM in MB and with centrality selection (mistake in the CTP table 5.2 below)
- MCH – trigger at ~L1 in MB
- MID – trigger at ~L1 in MB, needs to be corrected in the CTP requirements
- MFT – trigger at ~LM in MB

4. Summary of trigger inputs (based on TDR R&E upgrade) https://cds.cern.ch/record/1603472

Level	Trigger Input to CTP [ns]	Trigger output at CTP [ns]	Trigger decision at detector * [ns]	contributing detectors
LM	425	525	775	FIT
L0	1200	1300	1500	ACO, EMC, PHO, TOF, ZDC
L1	#6100	#6200	#6400	EMC, ZDC

- TOF will probably provide trigger only for cosmics (but continuous mode is also foreseen)

5. Trigger system – Design Review 2017

https://twiki.cern.ch/twiki/pub/ALICE/EngineeringDesignReview%28June2016%29/CTPLTU18.pdf

Remark: updated trigger notes for developers can be found in https://www.overleaf.com/read/dchwzqqfbtyn

- CTP will accept and process LM, L0 and L1 trigger inputs
- Trigger inputs will be synchronous with BC (edge jitter ~ +/- 1 ns)
- CTP will align all trigger inputs
- All signals must reach the CTP in 400 ns window to be aligned

Table 5.1 Summary of trigger inputs

Input Latency	Input to CTP [ns]	Contributing detectors
LM	425	FIT
L0	1200	ACO,EMC,PHS,TOF, ZDC
L1	6100	EMC,ZDC, PHS

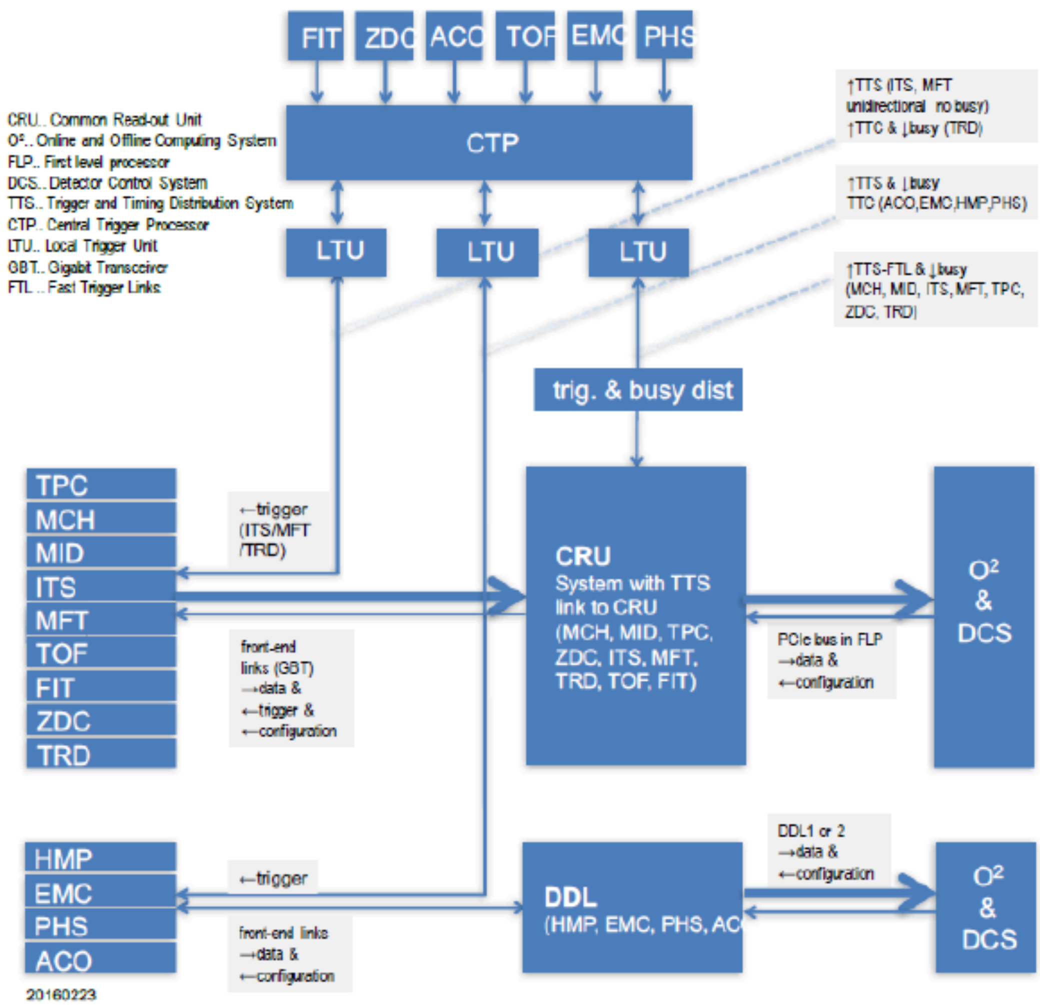


Figure 5.1 Summary of trigger distribution

Table 5.2 Summary of detector requirements

Detector	Trigerred by ()=optional	Pb-Pb RO Rate [kHz]	Trigger	CRU used	BUSY IN
TPC	(L0 or L1)	50	PON via CRU	yes	PON/CRU
MCH	(L0 or L1)	100	PON via CRU	yes	PON/CRU
MID	LM	100	PON via CRU	yes	PON/CRU
FIT	L0 or L1	100	PON via CRU	yes	PON/CRU
ACO	L0	100	PON via CRU	yes	PON/CRU
TOF	L0 or L1	>100	PON via CRU	yes	PON/CRU
ITS	LM	100	GBT	yes	PON/CRU
MFT	LM	100	GBT	yes	PON/CRU
TRD	LM	39	TTC	yes	PON/CRU
ZDC	L0	>100	PON via CRU	yes	PON/CRU
EMC	L0&L1	42	TTC	no	LVDS
PHS	L0&L1	42	TTC	no	LVDS
CPV	L0&L1	50	TTC	no	LVDS
HMP	L0&L1	7.5	TTC	no	LVDS

Table 8.1 Trigger Input Latencies

Detector	#CTP inputs	Time-of Flight [ns]	Processing [ns]	Cabling [ns]	Cable To CTP	Total [ns]
FIT	5	12	192	175	46	425
ACO single/mult	2	110	75/125	160	240	585/635
EMC L0	2	15	732	0	96	843
EMC L1	8					6100
PHS L0	4	15	732	0	96	843
PHS L1	3					6100
TOF	4	12	800	0	50	862
ZDC ZNA L0	1	375	92	694	5	1166
ZDC ZNC L0	1	375	92	549	5	1021
ZDC L1	4	375	268	966	500	2110

Table 8.2 Estimated Latencies for trigger distribution via GBT e.g. for ITS

Time (ns)	Total Latency (ns)			Description
	L1	L0	LM	
6100 / 1200 / 425	6100	1200	425	L1 / L0 / LM inputs to CTP board
100	6200	1300	525	CTP processing time
125	6325	1425	650	CTP-LTU fan-out time
25	6340	1450	675	LTU processing time
175	6525	1625	850	Transmission via 35 metres of optical cable
150	6675	1775	1000	GBT downstream latency (decoding time)
250	6925	2025	1250	Distribution of triggers from ITS readout module to detector
TOTAL: 6925 / 2025 / 1250				**Total latency from interaction to detector for L1 / L0 / LM trigger**

ITS, MFT detectors

Table 8.3 Estimated Latencies for trigger distribution to FEE via CRU

Time (ns)	Total Latency (ns)			Description
	L1	L0	LM	
6100 /1200 / 425	6100	1200	425	L1/ L0 / LM inputs to CTP board
100	6200	1300	525	CTP processing time
125	6325	1405	650	CTP-LTU fan-out time
25	6350	1450	655	LTU processing time
600	6950	2050	1275	120 metres of optical cable to CRU (ALI-CR4)
125	7075	2175	1400	PON downstream latency (only active components)
25	7100	2200	1425	CRU latency
130	7230	2330	1555	GBT downstream latency (using Aria 10 FPGA)
600	7830	22930	2155	120 metres of optical cable CRU to detector FEE
TOTAL: 7830 / 2930 / 2155				**Total latency from interaction to detector FEE for L1 /L0 / LM triggers**

TPC, MCH, MID, FIT, ZDC, ACO, TOF detectors

Table 8.4 Estimated Latencies for trigger distribution via TTC

Time (ns)	Total Latency (ns)			Description
	L1	L0	LM	
6100 / 1200 / 425	6100	1200	425	L1 / L0 / LM inputs to CTP board
100	6200	1300	525	CTP processing time
125	6325	1425	650	CTP-LTU fan-out time
25	6350	1450	675	LTU processing time
70	6420	1520	745	TTC latency for L1A signal (TTCex + TTCrx)
140	6560	1669	885	optical cable (28 m long) from CTP to the readout electronics
TOTAL: 6560 / 1660 / 885				**Total latency from interaction to detector for L1 / L0 / LM trigger**

CPV, EMC, HMPID, PHOS detectors

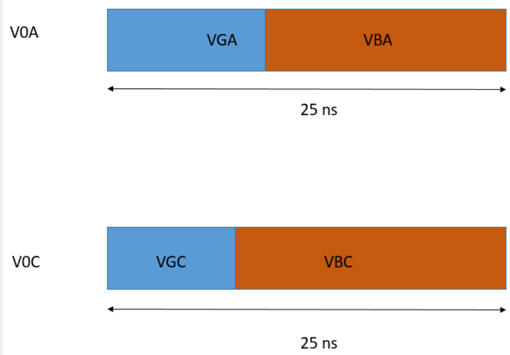
6. FIT luminosity monitoring

- Information from all FIT detectors to be used. Similar approach as in Run2.
- Information to be available online at ~L0

7. FIT LHC background rejection (beam-gas)

- FT0 cannot trigger in beam-gas window (not sensitive to tracks away from the IP, behind FT0)
- Beam-gas background rejection to be done online with FV0 and FDD at ~L0
- The same approach as in Run2 with beam bunch splitting into 2 windows

V0 and beam-gas trigger in Run2



Bunch crossing is split into 2 windows

- beam-beam trigger (VGA and VGC)
- beam-gas trigger (VBA and VBC) (early hits)

In Run2 V0, each channel was able to issue two triggers.
There was then a circuit summing up the trigger flags from various cells, and producing triggers of the type (x < N_VGA < y && x' < N_VBC < y')
x,y,x',y' – limits for beam-gas events

7. FIT trigger menu

- Luminosity: FT0, FV0 and FDD (online at ~L0)
- MB trigger: FT0 and FV0 (online at ~LM)
- Multiplicity/centrality trigger: FV0 and FT0 (online at ~LM)
- LHC background (beam-gas…) rejection: FV0 and FDD (online at ~L0)
- Veto triggers (for UPC and diffractive events): FT0, FV0 and FDD (online at ~L0)

Remark: Several trigger efficiencies to be studied with MC detector simulations in O2 in pp, p-Pb and Pb-Pb collisions. In particular, combinations of FT0 and FV0 detectors for multiplicity triggers should be study taking into account detector overlaps.

Remark: At the moment only 5 triggers can be set in parallel per detector. In Run2, 6 triggers have been used for V0 (centrality trigger in Pb-Pb 2018 collisions) and for AD (0UGA, 0UGC, 0UBA, 0UBC, 0UQA, 0UQC).