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Physics Requirements for the ALICE DAQ system

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Abstract:
The goal of this note is to review the requirements for the DAQ system originated from the various physics topics that will be studied by the ALICE experiment. It summarises all the current requirements both for Pb-Pb and p-p interactions. The consequences in terms of throughput at different stages of the DAQ system are presented for different running scenarios.

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1. Introduction

The goal of this note is to review the requirements for the DAQ system originated from the various physics topics that will be studied by the ALICE experiment. This review is needed because these requirements have considerably evolved since the Technical Proposal [1, 2, 4] in the different Technical Design Reports and Internal Notes [5-10] and because the addition of one trigger detector (the Transition Radiation Detector) [3] allows new types of triggers. A first version of this note was issued input to a discussion in the collaboration. All the comments received have been included in this second version.
It is well understood that the requirements will continue to evolve in the future either by a better estimation of the trigger rates and the data volumes, by the addition of new types of trigger and by the addition of new detectors. This evolution will carry on while a better understanding of the detectors behaviour will build up. The trigger and DAQ systems must therefore be flexible enough to accommodate new requirements in the future and to switch between different running conditions during data taking periods. It is however crucial for the trigger and DAQ projects to have at their disposal an agreed set of requirements.

2. The Pb-Pb run conditions

The estimation of the event size is directly proportional to the multiplicity of the beams interactions. We have assumed in this note the usual maximum expected multiplicity of 8000 for Pb-Pb interactions at the LHC. The event size is also directly proportional to the centrality of the interaction. The event size estimations are based on a centrality of 85% for central triggers and 25% for minimum bias triggers.
All the tables presented in the annexes have been established for a proportion between central and minimum bias triggers that remains equal during a run. The experience at STAR has shown that with the variation of luminosity during a machine fill, it might be more interesting to collect more central triggers at the beginning of the fill and more minimum bias at the end. These variations can only be made in a proportion that is the inverse of the event sizes given the limitation on the overall bandwidth.
The total available storage bandwidth is one important boundary condition of the ALICE DAQ. This limit is dictated by the cost of the media that is needed to store the data and the cost of the computing needed to reconstruct and analyse these data. ALICE was originally estimating that 1.25 GBytes/s would provide adequate physics statistics within the construction and exploitation budgets. The CERN management has then agreed that a Central Data Recording facility of the corresponding maximum bandwidth would be provided. This has therefore been arbitrarily set as the maximum throughput that the ALICE DAQ could produce to mass storage. However, all the efforts will be made to reduce the data throughput below this limit without jeopardise the physics performance is obviously welcome.

3. The user's requirements for Pb-Pb runs

The event size

Compared to the Technical Proposal, three major changes have been introduced in the area of event sizes.
First, the latest simulations show that the TPC average occupancy will be higher than originally anticipated with a value of the order of 25 % instead of 15 %. In the meantime the number of samples per channel has been reduced from 1024 to 512. The TPC electronics is however designed such that this number can be adapted at run-time at up to 768 samples per channel. This will most probably still evolve between now and the beginning of the data-taking. It will

also be adapted once a first experience has been gained with the detector. In this paper, we have adopted the value of 512 samples per channel.
The second modification concerns an increase of the Pixel event size. This has a significant impact on the total throughput because the pixel is read out with the dimuon trigger.
The third change consists of the addition of a Transition Radiation Detector to the ALICE experiment. This addition induces the following consequences:

- The TRD detector will add an additional data volume to an event whose size has already considerably be increased since the original estimation. The updated total event sizes for the different trigger types are summarised in Annex A.
- With the TRD, ALICE is now equipped with a fast electron detector. This new input will be used as input for the trigger level 1. This new trigger input will be used to create a new class of trigger and of events for the study of dielectron events. This study will require a large number of events containing data from all detectors. However, the raw data needed for these events could however be limited to a fraction of the total by reading out the region of interest. A summary of the event size is presented in Annex A.

The event rate

An estimation of the total bandwidth needed in the DAQ requires evaluating the data throughput for each type of trigger. The rates required to accumulate enough statistics in one year period of data taking is of the order of few 10^6 events for hadronic physics, at least few 10^7 events for charm and dielectron physics and at least 10^9 events for dimuon events. Given a lead-lead run of few weeks per year (10^6 s.), the rates are of the order of few Hz for hadronic physics, few tens of Hz for charm and dielectrons and few hundreds for dimuon.

The data throughput

The total data throughput is the addition of the throughput generated for the different physics topics that will be studied by ALICE. Each physics studies will require different data sets. Each data set is the combination of a given statistics (number of triggers of a given type) and a set of detectors read out with this trigger type.
The hadronic and charm physics require data from all the detectors while the dimuon and dielectrons needs the data from some of them. The sets of raw data used for different types of physics might sometimes overlap. In this case the same data set is used for the different physics topics. The charm and dielectron physics both need data from all the detectors but the introduction of the TRD input to the central trigger may introduce a bias for the charm physics. In this case, the two data sets do not overlap. Moreover, in the case of charm physics, no simple physics probe allows to perform online event selection. This point is going to be investigated in the collaboration. In this note we have assumed that the triggers for these two types of physics are different.
Different types of physics use raw data from all detectors collected after a central trigger and a minimum-bias trigger. This is the case for the full events triggered by a central trigger that are used for hadronics, charm and dimuon physics. It is also the case for the full events triggered by minimum bias events that are used for hadronics and charm physics.
The method to express the updated user's requirements is to list for a typical data taking year, the physics topics that will be explored and, for each of these physics topics, to list the data sets required together with the corresponding trigger types and the detectors read-out.

Data taking scenarios in Pb-Pb

Some typical scenarios are presented here in order to evaluate the consequences of some of the new data processing proposed for the trigger/DAQ system. The system architecture will allow to select these data processing in an independent manner. Other scenarios are therefore possible and will be studied in the future.

In the current scenarios, some realistic values have been chosen for key parameters. The simplest data compression applied to all the data has been evaluated to reduce the data volume by a factor 2 and the TPC full reconstruction to provide a factor 15 [10]. The partial readout has been estimated as the readout of 4 sectors of the TPC and of the TRD. The filtering reduction has been assumed to select 1/7 of the central triggers and 1/15 of the minimum bias events. The future studies should provide a better estimation of these parameters.

Scenario 1: Simple data-acquisition mode

This scenario corresponds to the acquisition of data at the maximum possible throughput and without selecting further of modifying the data. There is no dedicated dielectron trigger: the same events are used for dielectrons and charm studies. In this scenario, the dimuon trigger provokes the readout of the muon arm and the pixel. The option 1 is used to compute the bandwidth if one would keep the same event rate (40 Hz) for central and minimum bias triggers as in the TP. The result is that the global throughput is too high (2.4 Gbyte/s) for the available bandwidth.
In order to come to an acceptable throughput, the rate of central and minimum bias triggers has to be decreased to 20 Hz and the dimuon rate to 500 Hz as presented in option 2.

Scenario 2: with dielectron trigger and ITS readout for high pT dimuon triggers

This scenario introduces two main differences.

- A new trigger type is added: the dielectron trigger. We have assumed that the events used for charm physics would be different from the ones combining central and dielectron trigger to avoid any bias. Moreover, the charm physics requires to perform a complete readout of the whole experimental apparatus, whereas the dielectron events could include data resulting from a partial readout.
- The physics that will be studied with the muon events require the readout of the muon arm, the pixel and the trigger detectors (FMD and ZDC). The readout of the full ITS would allow better tracking performances. However, the event size (2.4 MByte/event) for the muon and the ITS (see Annex A) would result in an unacceptable large fraction of the available bandwidth (780 MByte/s). Therefore, a proposal has been done to separate the dimuon triggers in two different categories: low pT triggers that will involve a readout of the Muon arm and the ITS pixel and the high pT triggers that will also include a readout of the two other layers of the ITS: the drift and the strips.

The global throughput is again higher (2.0 GByte/s) than the maximum of 1.25 Gbyte/s. The next scenario is therefore introduced to present a potentially more realistic combination.

Scenario 3: with dielectron trigger and online filter

In this scenario, the trigger level 3 includes an online filter that reduces the trigger rate by one order of magnitude. This has the consequence of reducing the throughput to a value of 1.4 Gbyte/s.

Scenario 4: with dielectron trigger, online filter and online tracking

This scenario includes the introduction of several new capabilities:

- Data compression based on an online tracking is introduced for the TPC data.
- An online background rejection is introduced for the Muon data.

shows the potential benefit of by reducing the throughput to 0.5 GByte/s.

4. The user's requirements for p-p runs

Event size

The estimated event size for one pp collision is of the order of 60 kBytes. In average, 20 events will pile-up during the drift time of the TPC (see [11]). So the total event size is estimated to be of the order of 2 MBytes.

Event rate

The statistics required for soft proton physics is of the order of 10^9 events. The event rate will vary with the available luminosity. The requirement is therefore to be able to collect the data at the maximum possible rate for the ALICE detectors: 500 events/s.

Data taking scenarios in p-p

Two different scenarios are proposed for pp data-taking.

Scenario 1: Simple data-acquisition mode

This scenario corresponds to the acquisition of data at the maximum possible throughput and without selecting further of modifying the data.

Scenario 2: events pile-up suppression

As indicated earlier, each event will contain the space points of 20 interactions. An online tracking would allow selecting the track belonging to the interesting interaction.

5. References

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2. ALICE collaboration, Addendum to the Technical Proposal, CERN/LHCC 96-32.
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4. O.Villalobos Baillie, D.Swoboda and P.Vande Vyvre, Data Acquisition, Control and Trigger: Common Report for the preparation of the ALICE Technical Design Reports, ALICE/98-23, Internal Note DAQ.
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6. ALICE collaboration, TDR of the Photon Spectrometer, CERN/LHCC 99-4.
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9. ALICE collaboration, TDR of the Photon Multiplicity Detector, CERN/LHCC 99-32.
10. ALICE collaboration, TDR of the Time Projection Chamber, CERN/LHCC 2000-001.
11. P.Giubellino et al., Day one proton proton physics in ALICE, ALICE Internal Note 2000-xx.

6. Appendices

Appendix A: Event size in Pb-Pb
Appendix B : Scenario 1 (Simple data acquisition mode with Pb-Pb interactions)

Appendix A: Event size in Pb-Pb

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ALICE year	Eff. Beam time
Pb run	1.00E+06
p run	1.00E+07

Max. Central Event Size MBytes	Proportion to total event size	Comment		
0.42	0.48%	ITS TDR, Pixel workshop, ITS DAQ 05/00		
1.50	1.73%	ITS TDR p.112		
0.16	0.18%			
75.90	87.56%	TPC TDR p.123	66.00	0.15
8.00	9.23%			
0.18	0.21%	TOF TDR		
0.02	0.03%			
0.12	0.14%	HMPID TDR p.122		
0.15	0.17%	DIM TDR p.250, 254		
0.12	0.14%	PMD TDR p.64		
0.12	0.13%			
86.69	**100.00%**			

ALICE year	Storage Bandwidth
1	25%
2	50%
n	100%

Reduction Factor	Value	Min	Max
Compression	2		
Recontruction	15		
L3 trigger on central events	10	5	10
L3 filter on min. bias events	15	10	20
L3 filter on dimuon events	4		

Max. Dielectron Partial Ev. Sz. MBytes		Comment		
0.42	6.10%			
1.50	21.80%			
0.16	2.33%			
4.22	61.28%	Partial readout	2.00	36.00
0.18	2.58%	Partial readout	2.00	90.00
0.02	0.32%			
0.15	2.18%			
0.12	1.74%			
0.12	1.67%			
6.88	**100.00%**			

Max. Dimuon Event Size MBytes	Comment
0.42	
1.50	
0.16	
0.02	
0.15	
0.12	
0.02	
0.73	
2.23	
2.39	

Appendix B : Scenario 1 (Simple data acquisition mode with Pb-Pb interactions)

Assumptions

-Pb-Pb beam
-In the option1, the number of events is given by the statistics needed.
-In the option 2, the number of events is reduced to stay in max. bandwidth allowed.
-The different sets of events are assumed to be exclusive. When one set is included in another one, this is indicated in the last column.
-There is no dielectron trigger.

Physics Requirements to the DAQ with Pb-Pb beams (Scenario 1)

Physics Topic	# Events	L1 Trigger Rate Events/s	L2 Trigger Rate Events/s.	DAQ Event Rate Events/s.	Trigger Types	Detectors Set	Max. Event Size in DDL MBytes	Max. DDL Throughput MBytes/s	Max. Event Size in EB MBytes	Max. EB Throughput MBytes	Max. Storage Throughput Mbytes/s	Remarks	Compr. factor
Option 1													
Hadronic	2.00E+6	2	2	2	Central	All						See Charm	
physics	2.00E+6	2	2	2	Min. Bias	All						See Charm	
Charm	4.00E+07	40	40	40	Central	All	86.69	3467	86.69	3467	1734	Compr.	2
	4.00E+07	40	40	40	Min. Bias	All	21.67	867	21.67	867	433	Compr.	2
Electrons	4.00E+07	40	40	40	Central	All						See Charm	
	4.00E+07	40	40	40	Min. Bias	All						See Charm	
Dimuon	6.50E+08	650	650	650	Central+Dimuon	Muon	0.73	476	0.73	476	238	Compr.	2
	4.00E+07	40	40	40	Central	All						See Charm	
Total								**4810**		**4810**	**2405**		

Option 2

Hadronic	2.00E+06	2	2	2	Central	All						See Charm	
physics	2.00E+06	2	2	2	Min. Bias	All						See Charm	
Charm	2.00E+07	20	20	20	Central	All	86.69	1734	86.69	1734	867	Compr.	2
	2.00E+07	20	20	20	Min. Bias	All	21.67	433	21.67	433	217	Compr.	2
Electrons	2.00E+07	20	20	20	Central	All						See Charm	
	2.00E+07	20	20	20	Min. Bias	All						See Charm	
Dimuon	5.00E+08	500	500	500	Central+Dimuon	Muon	0.73	366	0.73	366	183	Compr.	2
	2.00E+07	20	20	20	Central	All						See Charm	
Total								**2533**		**2533**	**1267**		

Appendix C: Scenario 2 (With dielectron trigger and ITS readout for some dimuon events)

Assumptions

-The number of events is given by the statistics needed or the maximum interacton rate if it is a limiting factor.
-The different sets of events are assumed to be exclusive. When one set is included in another one, this is indicated in the last column.
-The dielectron trigger is introduced
-The charms and dielectrons event sets are different to avoid biasses generated by the dielectron trigger.
-The dielectrons events are read partially to reduce the data volume.
-Two types of dimuon events are distinguished: high pT cut 90Hz, low pT cut 560Hz
-The full ITS is read-out for high pT dimuon events

Physics Requirements to the DAQ with Pb-Pb beams (Scenario 2)

Physics Topic	# Events	L1 Trigger Rate Events/s.	L2 Trigger Rate Events/s.	DAQ Event Rate Events/s.	Trigger Types	Detectors set	Max. Event Size in DDL MBytes	Max. DDL Throughput MBytes/s	Max. Event Size in EB MBytes	Max. EB Throughput MBytes/s	Max. Storage Throughput MBytes/s	Remarks	Compr. factor
Hadronic	2.00E+06	2	2	2	Central	All						See Charm	
physics	2.00E+06	2	2	2	Min. Bias	All						See Charm	
Charm	2.00E+07	20	20	20	Central	All	86.69	1734	86.69	1734	867		2
	2.00E+07	20	20	20	Min. Bias	All	21.67	433	21.67	433	217		2
Electrons	2.00E+08	200	200	200	Central+Dielec.	Partial	86.69	17337	6.88	1376	688		2
	2.00E+08	200	200	200	Min. Bias + Dielec.	Partial	21.67	4334	1.72	344	172		2
Dimuon	6.50E+08	650	560	560	Central + Dimuon Low pT	Muon	0.73	410	0.73	410	205		2
			90	90	Central + Dimuon High pT	Muon + SDD + SSD	2.39	215	2.39	215	108		2
	2.00E+07	20	20	20	Central	All						See Charm	
Total								**24464**		**4513**	**2256**		

Appendix D: Scenario 3 (With dielectron trigger and online filter)

Assumptions

-The scenario 2 results in a total throughput that is superior to the acceptable maximum.
-The way to reduce it is:
- L3 to perform filtering for dielectrons trigger (from 200 to 10-20 Hz).

Physics Requirements to the DAQ with Pb-Pb beams (Scenario 3)

Physics Topic	# Events	L1 Trigger Rate Events/s.	L2 Trigger Rate Events/s.	DAQ Event Rate Events/s.	Trigger Types	Detectors	Max. Event Size in DDL MBytes	Max. DDL Throughput MBytes/s	Max. Event Size in EB MBytes	Max. EB Throughput MBytes/s	Max. Storage Throughput MBytes/s	Remarks	Filter. factor	Compr. factor
Hadronic	2.00E+06	2	2	2	Central	All	86.69					See Charm		
physics	2.00E+06	2	2	2	Min. Bias	All	21.67					See Charm		
Charm	2.00E+07	20	20	20	Central	All	86.69	1734	86.69	1734	867	Compr.		2
	2.00E+07	20	20	20	Min. Bias	All	21.67	433	21.67	433	217	Compr.		2
Electrons	2.00E+08	200	200	20	Central+Dielec.	Partial	86.69	17337	6.88	138	69	Filter + compr.	10	2
	2.00E+08	200	200	20	Min. Bias + Dielec.	Partial	21.67	4334	1.72	34	17	Filter + compr.	10	2
Dimuon	6.50E+08	650	560	560	Central + Dimuon Low pT	Muon	0.73	410	0.73	410	205	Compr.		2
			90	90	Central + Dimuon High pT	Muon + SDD + SSD	2.39	215	2.39	215	108	Compr.		2
	2.00E+07	20	20	20	Central	All	86.69					See Charm		
Total								**24464**		**2964**	**1482**			

Appendix E: Scenario 4 (With dielectron trigger, online filter and online tracking)

Assumptions

-The throughput of scenario 3 could be reduced further.
-The way to reduce it is to acquire less data for central and MB events by making full reconstruction
- to acquire less data for central and MB events by making full reconstruction
- to perform background suppression for dimuon trigger

- Basic rate for central and minimum bias could be restored (40 Hz)

Physics Requirements to the DAQ with Pb-Pb beams (Scenario 4)

Physics Topic	# Events	L1 Trigger Rate Events/s.	L2 Trigger Rate Events/s.	DAQ Event Rate Events/s.	Trigger Types	Detectors	Max. Event Size in DDL MBytes	Max. DDL Throughput MBytes/s	Max. Event Size in EB MBytes	Max. EB Throughput MBytes/s	Max. Storage Throughput MBytes/s	Remarks	Filter factor	Compr. factor
Hadronic	2.00E+06	2	2	2	Central	All	86.69					See Charm		
physics	2.00E+06	2	2	2	Min. Bias	All	21.67					See Charm		
Charm	2.00E+07	20	20	20	Central	All but TPC	10.79	216	10.79	216	108	Compression		2
		20	20	20	Central	TPC	75.90	1518	75.90	1518	101	Online tracking		15
	2.00E+07	20	20	20	Min. Bias	All but TPC	2.70	54	2.70	54	27	Compression		2
		20	20	20	Min. Bias	TPC	18.98	380	18.98	380	25	Online tracking		15
Electrons	2.00E+08	200	200	20	Partial TPC	Partial	86.69	17337	6.88	138	69	Filter+compr.	10	2
	2.00E+08	200	200	20	Min. Bias	Partial	21.67	4334	1.72	34	17	Filter+compr.	10	2
Dimuon	6.50E+08	650	560	560	Central +	Muon +	0.15	84	0.15	84	21	Backg. Suppr.		4
					Dimuon Low pT	Pixel	0.58	326	0.58	326	163	Compression		2
			90	90	Central +	Muon +	0.15	14	0.15	14	3	Backg. Suppr.		4
					Dimuon High pT	SDD + SSD	2.24	202	2.24	202	101	Compression		2
	2.00E+07	20	20	20	Central	All	86.69					See Charm		
Total								**24464**		**2964**	**636**			

Appendix F: Event size in p-p

ALICE year	Eff. Beam time
Pb run	1.00E+06
p run	1.00E+07

Detectors Set	Detectors	Detector	Max. Ev. Sz pp min. bias MBytes	Proportion to total event size	Comment
All	ITS Pixel	ITS SPD	0.01	0.48%	
	ITS Drift	ITS SDD	0.03	1.73%	
	ITS Strips	ITS SSD	0.00	0.18%	
		TPC	1.75	87.56%	Assuming adequate coding for TPC data
		TRD	0.18	9.23%	
		TOF	0.00	0.21%	
		PHOS	0.00	0.03%	
		HMPID	0.00	0.14%	
	Muon TRG+TRK	MUON	0.00	0.17%	
		CASTOR			
		PMD	0.00	0.14%	
	FMD+ZDC+TRG	TRIGGER	0.00	0.13%	
		TOTAL	**2.00**	**100.00%**	ALICE INT-2000-xx on pp runnng

ALICE year	Storage Bandwidth
1	25.00%
2	50.00%
n	100.00%

Reduction Factor	**Value**	**Min**	**Max**
Compression	2		
Pileup suppression	10		
Trigger rate variation		1	5
with luminosity			

Appendix G : Scenario 5 (Simple data acquisition mode with pp interactions)

Assumptions

- The number of events is given by the statistics needed.

Physics Requirements to the DAQ with p-p beams (Scenario 5)

Physics Topic	# Events	L1 Trigger Rate Events/s.	L2 Trigger Rate Events/s.	DAQ Event Rate Events/s.	Trigger Types	Detectors Set	Max. Event Size in DDL MBytes	Max. DDL Throughput MBytes/s	Max. Event Size in EB MBytes	Max. EB Throughput MBytes/s	Max. Storage Throughput MBytes/s	Remarks
Soft proton Physics	1.00E+09	500	500	500	Min. Bias	All	2.00	1000	2.00	1000	500	
Total								**1000**		**1000**	**500**	

Appendix H: Scenario 6 (With events pileup suppression)

Assumptions

- The number of events is given by the statistics needed.
-The supprression of pileup events is introduced

Physics Requirements to the DAQ with p-p beams (Scenario 6)

Physics Topic	# Events	L1 Trigger Rate Events/s.	L2 Trigger Rate Events/s.	DAQ Event Rate Events/s.	Trigger Types	Detectors set	Max. Event Size in DDL MBytes	Max. DDL Throughput MBytes/s	Max. Event Size in EB MBytes	Max. EB Throughput MBytes/s	Max. Storage Throughput MBytes/s	Remarks	Compression or filtering factor
Soft proton Physics	1.00E+09	500	500	500	Min. Bias	All	2.00	1000	2.00	1000	100	Pileup suppression	10
Total								**1000**		**1000**	**100**		