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Execution times for B-physics simulation

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Abstract

In this paper, we report on the execution times obtained for ATLAS detector simulation assuming four types of B-physics events, different detector components and two sets of data-cards. The software used was DICE 1.3.0 and the jobs were executed on the CERN Linux cluster.

1 Introduction

The Large Hadron Collider (LHC) is the world's biggest accelerator, being built at the European Particle Physics Laboratory, CERN. By the time of its completion in 2006, it will be capable of accelerating and colliding beams of protons at centre of mass energies of 14 TeV. The collider ring will be equipped with several experimental installations, dedicated to studies of various physics phenomena. These detector installations are prepared by international collaborations, involving thousands of researchers from hundreds of institutions, distributed worldwide.

Physics analysis performed at the LHC will involve inclusive and exclusive measurements of various observables, related to the proton-proton collision events. To fulfil such tasks, not only event reconstruction based on the electronic signals should be done, but also a full computer modelling, including event generation, detector simulation, and subsequent analysis and evaluation of acceptance, inefficiency and other corrections should be completed.

The ATLAS collaboration is currently engaged into a study of the experiment's Computing Model (Data Challenges). The first phase of this study, DC0, will be taking place in November-December 2001. It aims at testing the continuity of the code chain. In view of this project, we would like to stress a few points concerning the execution times for full detector simulation as they came to our attention in the course of a MONARC [1] simulation study for the Nordic countries [2].

2 Execution times for detector simulation

The simulation runs reported here were performed using the DICE 1.3.0 program. The program uses the GEANT3 package to perform full detector simulation. In our study, we simulated (a) the inner detector, calorimeters and muon chambers and (b) only the inner detector. The runs for the case (a) are refered to as 'ALL' in the Tables below and the runs for the case (b) are referred to as 'ID'. All runs had 10 events.

The pseudorapidity range was specified by a cut assuming the following values: $|\eta| < 2.5, 2.7, 3$. A few runs with no pseudorapidity cut were also made as an illustration of the reduction of the execution time that can be induced by a pseudorapidity cut. Two sets of data-cards were used, called A and B in the following. The set A [3] was used both for ALL detector simulation (called set A1 in the following) and for ID simulation (called set A2 in the following). The difference between set A1 and set A2 was restricted to detector selection and will be discussed in detail below. The data-cards A1 and A2 were considered to be our standard data-cards. The data-cards B were used only as an example for investigating the effect on the execution times that can be caused by seemingly minor modifications of the data-cards.

The types of B-physics [4] events considered in the simulations were the following:

- $B_s \to J/\psi\eta$ where $J/\psi \to \mu 6\mu 3$ [1] and $\eta \to \gamma\gamma$,
- $B_d \to J/\psi K^0{}_S$ where $J/\psi \to \mu 6\mu 3$ and $K^0{}_S \to \pi^+\pi^-$,
- $b\bar{b} \to J/\psi X$ where $J/\psi \to \mu 6\mu 3$ and requiring that the transverse momentum of the b decaying to the J/ψ was above 50 GeV and
- $B_s \to J/\psi\varphi$ where $J/\psi \to \mu 6\mu 3$ and $\varphi \to K^+K^-$.

The log files of all jobs described in this paper are available at http://www.quark.lu.se/~christin/ext.html.

2.1 Full detector simulation with standard data-cards

We first address the simulation runs where all detector components were included and for which the standard data-cards were used, i.e. set A1. The pseudorapidity cuts and event types were those described above. The data-card set A1 is given in the Appendix. The execution times for the various runs are summarized in Table 1. In the Table, column 2 gives the event type, column 3 gives the machine on which the job was executed, column 4 contains the CPU of the machine, column 5 contains the total execution time (for 10 events), column 6 gives the normalized execution time per event, column 7 shows the detector composition and the last column gives the η cut considered in the simulation.

The normalized execution time was calculated taking into account the CPU power of the executing machine as follows [5,6]:

norm. ex. time per event = (real time per event) *x* (20 SI95) *x* (CPU factor).

The CPU factor of the machine is a measure of the CPU of the processor. A CPU factor of 1 corresponds approximately to 20 SI95. The normalized execution time calculation should allow comparison of execution times of simulations run on different machines.

1. $\mu 6\mu 3$ refers to the event selection cuts of $p_T(\mu)>6$ GeV and $p_T(\mu)>3$ GeV for the two muons.

For the present study, the Linux machines of the CERN cluster were used. The CPU factors of the processors used are given in Table 2.

Input	Event type	Executing host	CPU (SI95)	Total ex. time (s)	Time/evt (SI95.s)	Detectors included	h cut
1	$B_s \to J/\psi\eta$	lxbatch259	22	10970	24000	ALL	no
2	$B_s \to J/\psi\eta$	lxbatch327	32	1148	3700	ALL	$\|\eta\|<2.7$
3	$B_s \to J/\psi\eta$	lxbatch327	32	1463	4700	ALL	$\|\eta\|<3$
4	$B_d \to J/\psi K^0{}_S$	lxbatch268	22	14149	31000	ALL	no
5	$B_d \to J/\psi K^0{}_S$	lxbatch326	32	932	3000	ALL	$\|\eta\|<2.5$
6	$B_d \to J/\psi K^0{}_S$	lxbatch263	22	1646	3600	ALL	$\|\eta\|<2.7$
7	$b\bar{b} \to J/\psi X$	lxbatch327	32	6815	22000	ALL	no
8	$b\bar{b} \to J/\psi X$	lxbatch327	32	1492	4800	ALL	$\|\eta\|<2.7$
9	$b\bar{b} \to J/\psi X$	lxbatch319	32	1703	5400	ALL	$\|\eta\|<3$
10	$B_s \to J/\psi\varphi$	lxbatch326	32	914	2900	ALL	$\|\eta\|<2.5$

TABLE 1. Execution times for full detector simulation and standard data-cards.

Host name	Type	Model	CPU (MHz)	CPU factor
lxbatch250	Linux	SMNSP3_5	551	1.1
lxbatch251	Linux	SMNSP3_5	551	1.1
lxbatch257	Linux	SMNSP3_5	551	1.1
lxbatch259	Linux	SMNSP3_5	551	1.1
lxbatch263	Linux	SMNSP3_5	551	1.1
lxbatch268	Linux	SMNSP3_5	551	1.1
lxbatch319	Linux	ELO2P3_8	797	1.6
lxbatch326	Linux	ELO2P3_8	797	1.6
lxbatch327	Linux	ELO2P3_8	797	1.6

TABLE 2. Specifications of the machines used in this study.

It is clear from Table 1 that the pseudorapidity cut can reduce the execution time dramatically. For B-physics full detector simulation, the interesting range is $\eta<2.7$, which, from Table 1, corresponds to execution times in the interval 3500-5000 SI95.s per event.

2.2 Inner detector simulation with standard data-cards

In order to obtain the standard data-cards for simulation of the inner detector only (set A2), the following changes have to be applied to the full detector simulation standard data-cards (set A1) (the line numbers refer to the line numbering of the Appendix):

- The pseudorapidity cut is set to $|\eta|<2.7$ in line 50,
- R and z coverage is defined in line 54,
- The maximum allowed values for R and z are specified in lines 74-75,
- The calorimeters and muon system are switched off in lines 87-96.

It should be noted that switching off the calorimeters and muon chambers is not enough to restrict the simulation to the inner detector only. The execution times obtained for ID simulation are shown in Table 3. It is clear from the Table that the pseudorapidity cut reduces the execution time by a factor 2.

Input	**Event type**	**Executing host**	**CPU (SI95)**	**Total ex. time (s)**	**Time/evt (SI95.s)**	**Detectors included**	h **cut**
1	$B_s \to J/\psi\eta$	lxbatch327	32	323	1000	ID	no
2	$B_s \to J/\psi\eta$	lxbatch327	32	164	530	ID	$\|\eta\|<2.7$
3	$b\bar{b} \to J/\psi X$	lxbatch319	32	341	1100	ID	no
4	$b\bar{b} \to J/\psi X$	lxbatch327	32	193	620	ID	$\|\eta\|<2.7$

TABLE 3. Execution times for inner detector simulation and standard data-cards.

2.3 Cross-check of full simulation execution times

The jobs with input number 2, 7 and 8 of Table 1 were repeated as a cross-check of the execution times and in order to see what might be their variation. The results are shown in Table 4.

Input	**Event type**	**Executing host**	**CPU (SI95)**	**Total ex. time (s)**	**Time/evt (SI95.s)**	**Detectors included**	h **cut**
2	$B_s \to J/\psi\eta$	lxbatch326	32	1160	3700	ALL	$\|\eta\|<2.7$
7	$b\bar{b} \to J/\psi X$	lxbatch250	22	11194	25000	ALL	no
8	$b\bar{b} \to J/\psi X$	lxbatch257	22	2412	5300	ALL	$\|\eta\|<2.7$

TABLE 4. Execution times for repeated full detector simulations with standard data-cards.

The first repeated job was run on the same type of machine both times and the execution times agree. The two other repeated jobs were run on a 32 SI95 machine the first time and on 22 SI95 machines the second time. The execution seems to have taken longer the second time for these jobs. This discrepancy is currently under study.

2.4 Full detector simulation with non-standard data-cards

In order to exemplify the effect of using different data-cards for the full simulation, the data-card set B was used for the runs given in Table 5. The datacard set B has seemingly small differences when compared to the datacard set A.1 (with no η cut). The execution times are, however, significantly different. The data-card set B can be found in http://www.quark.lu.se/~christin/ext.html.

Input	**Event type**	**Executing host**	**CPU (SI95)**	**Total ex. time (s)**	**Time/evt (SI95.s)**	**Detectors included**	**h cut**
'1'	$B_s \to J/\psi\eta$	lxbatch259	22	13403	30000	ALL	no
'4'	$B_d \to J/\psi K^0{}_S$	lxbatch251	22	16144	36000	ALL	no

TABLE 5. Execution times for full detector simulation and non-standard data-cards.

3 Conclusions

In order to evaluate the execution time for B-physics simulations, a number of jobs have been run on the CERN Linux cluster. In the jobs, we varied the type of simulated events, the pseudorapidity cut and the composition of the detector (all components and inner detector only). All jobs were run for 10 events.

It was established that the pseudorapidity cut is crucial since the execution times increase rapidly with the allowed η-range. With |η|<2.5, we obtain approximately 3000 SI95.s per event as the execution time of full simulation. With |η|<2.7, the time increases to about 4000-5000 SI95s. With no η-cut, the execution time per event exceeds 20000 SI95.s. Inner detector only simulation requires execution times of about 500-600 SI95.s per event (|η|<2.7)

In order to investigate the uncertainties in the execution time, simulations were run with two types of PCs corresponding to 797 MHz (32 SI95) and 551 MHz (22 SI95) of CPU capacity. It would seem that if the same job is run on the slower machine, the "normalized" execution time is 10% more, indicating that with this software there is a 10% systematic bias in the definition of SI95.

In the high-p_T sample (p_T(b)>50 GeV), we simulate more energy in the central part of the detector. The execution time is 30% more than for other types of events if the central part is simulated (|η|<2.7). For |η|<3, the difference is 15%.

In the inner detector simulation, we found that it is mandatory to use explicity cuts on the maximum values of R and z. It is not sufficient to switch the calorimeters and muon chambers off.

The execution times are critically dependent on the set of data-cards used, so for any production one should use a strictly standard set of data-cards. The execution times can easily increase by 15-20% by apparently innocent changes.

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Bibliography

[1] MONARC Collaboration, *Multi-threaded, discrete event simulation of distributed computing systems*, presented by I. Legrand in CHEP2000, to be published in CPC Journal special edition CHEP2000.

[2] S. Almehed et al., *Regional research exploitation of the LHC: a case-study of the required computing resources*, LUNFD6/(NFFL-7196)2001.

[3] M. Smizanska, private communication.

[4] Y. Nir and H. Quinn in *B Decays* (ed. S. Stone), World Scientific 1994.

[5] T. Smith, private communication.

[6] http://www.specbench.org.

Appendix: Data-cards.

Below comes the listing of the standard data-cards for full detector simulation (set A1).

```
line1:    LIST
line2:    C  ----- TRAP handling has been added into SLUG -------------
line3:    TRAP  0  3  10 10  1 0 10 1 4 10
line4:    C ------ number of triggers to be processed and part. generation (# 170) -----
line5:    C TRIG NUMBER_OF_TRIGGERS
line6:    TRIG 10
line7:    C read PYTHIA events
line8:    KINE -1
line9:    *FILE 'P' 'LIST' 'ZEBRA.P'
line10:     *NEWV 'P' 1

line11:   C  ----- SLUG/GEANT debugging parametrs/modes -------------
line12:   TIME 2=10. 3=1
line13:   DEBU 0 0 1
line14:   SWIT 0 2

line15:   C ----  digitization and simulation and analysis status
line16:   SIMULATION    1
line17:   DIGITIZATION  1
line18:   RECONSTR      0
line19:   ANALYSIS      0
line20:   OUTP          1
```

```
line21:   C --- when Phytia ---
line22:   *BKIO 'P' 'EVNT'
line23:   *BKIO 'P' 'RUNT'
line24:   *BKIO 'O' 'RUNT'
line25:   *BKIO 'O' 'EVNT'
line26:   *BKIO 'O' 'KINE'
line27:   *BKIO 'O' 'VERT'
line28:   *BKIO 'O' 'HITS'
line29:   *BKIO 'O' 'DIGI'

line30:   C ------- GEANT TRACKING CARDS -----------------
line31:   AUTO 0
line32:   OPTI 2
line33:   DCAY 1
line34:   MULS 2
line35:   PFIS 1
line36:   MUNU 1
line37:   LOSS 3
line38:   PHOT 1
line39:   COMP 1
line40:   PAIR 1
line41:   BREM 1
line42:   DRAY 1
line43:   ANNI 1
line44:   HADR 6
line45:   ABAN 0

line46:   CUTS 1=.0001 2=.0001 3=.0001 4=.0001 5=.0001
line47:   CUTS 6=.001 7=.001 8=.001 9=.001
line48:   CUTS 11=100.E-9

line49:   C--- Eta cut
line50:   *TFLT 'ETAP' -2.7 2.7

line51:   C SIMU=1 for TRAC means save part of stack on KINE
line52:   *MODE 'TRAC' 'SIMU' 1 'HIST' 0 'PRIN' 0 'DEBU' 0 'RAND' 1

line53:   C to store secondary particles from decay in KINE & VERT through all detector
line54:   *DETP 'TRAC' 2='DCAY'   3=1200.  4=2300.    5=0.3       6=0.0
line55:   *DETP 'TRAC' 7='PAIR'   8=110.  9=340.   10=0.3      11=0.0
line56:   *DETP 'TRAC' 12='BREM' 13=110. 14=340.   15=0.0      16=0.01
line57:   *DETP 'TRAC' 17='HADR' 18=110. 19=340.   20=0.3      21=0.0

line58:   C------------------------------------------------------------------------------------------C
line59:   C----GEOMETRY DEFINITION OF ATLAS  (FULL LAR + COIL IN FRONT+ AIR T)----C
line60:   C------------------------------------------------------------------------------------------C
line61:   *MODE 'INIT' 'PRIN' 0
line62:   *MODE 'GEOM' 'PRIN' 1
line63:   *MODE 'DOCU' 'PRIN' 1
line64:   *MODE 'CLOS' 'PRIN' 1
line65:   *MODE 'DIGI' 'PRIN' 1 'RAND' 1
line66:   *MODE 'RECO' 'PRIN' 1
line67:   *MODE 'CONS' 'PRIN' 0
line68:   *MODE 'GENE' 'PRIN' 1 'RAND' 1
```

```
line69:   *MODE 'INPU' 'PRIN' 0
line70:   C  Magnetic field
line71:   *MODE 'MFLD' 'GEOM' 1 'MFLD' 1 'PRIN' 0 'HIST' 0
line72:   C  The Atlas geometry
line73:   *MODE 'ATLS' 'GEOM' 1 'PRIN' 1 'GRAP' 0 'MFLD' 1

line74:   C *DETP 'ATLS' 'ATLS(1).Rmax='115. 'Zmax='345. 'CALOOR='115. 'CaloZmx='345.
line75:   C            'MuonOR='115.  'MuonZmx='345.

line76:   *MODE 'PIPE' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1
line77:   *MODE 'CRYO' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line78:   *MODE 'COIL' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line79:   C      Inner tracker - version 95-1 on   (Morges layout)
line80:   *MODE 'PIXB' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line81:   *MODE 'PIXE' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line82:   *MODE 'SCTT' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line83:   *MODE 'ZSCT' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line84:   *MODE 'XTRT' 'GEOM' 1 'PRIN' 0 'HIST' 1 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line85:   *MODE 'INAF' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1
line86:   C      Calorimetry
line87:   *MODE 'CALO' 'GEOM' 1 'PRIN' 0 'RECO' 1 'ANAL' 0
line88:   *MODE 'COPS' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line89:   *MODE 'ACCB' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line90:   *MODE 'ENDE' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line91:   *MODE 'HEND' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line92:   *MODE 'TILE' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
line93:   C      Muon  (Parameters read from AMDB muon database)
line94:   *MODE 'MINT' 'GEOM' 1
line95:   *MODE 'AMDB' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 0 'SIMU' 1 'DIGI' 1 'RECO' 0
line96:   *MODE 'MUCH' 'GEOM' 1 'PRIN' 0 'GRAP' 0 'MFLD' 1 'SIMU' 1 'DIGI' 1 'RECO' 0
```

The following changes must be applied to the listing above in order to obtain the data-cards for the ID simulation (set A2):

```
line54’: *DEPT ‘TRAC’ 2=’DCAY’   3=110.   4=340.   5=0.3    6=0.0
line74’: uncommented
line75’: uncommented
line87’: *MODE 'CALO' 'GEOM' 0 'PRIN' 0 'RECO' 0 'ANAL' 0
line88’: *MODE 'COPS' 'GEOM' 0 'PRIN' 0 'GRAP' 0 'MFLD' 0 'SIMU' 0 'DIGI' 0 'RECO' 0
line89’: *MODE 'ACCB' 'GEOM' 0 'PRIN' 0 'GRAP' 0 'MFLD' 0 'SIMU' 0 'DIGI' 0 'RECO' 0
line90’: *MODE 'ENDE' 'GEOM' 0 PRIN' 0 'GRAP' 0 'MFLD' 0 'SIMU' 0 'DIGI' 0 'RECO' 0
line91’: *MODE 'HEND' 'GEOM' 0 'PRIN' 0 'GRAP' 0 'MFLD' 0 'SIMU' 0 'DIGI' 0 'RECO' 0
line92’: *MODE 'TILE' 'GEOM' 0 'PRIN' 0 'GRAP' 0 'MFLD' 0 'SIMU' 0 'DIGI' 0 'RECO' 0
line94’: commented
line95’: commented
line96’: *MODE 'MUCH' 'GEOM' 0 'PRIN' 0 'GRAP' 0 'MFLD' 0 'SIMU' 0 'DIGI' 0 'RECO' 0
```