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BRAHMS Computing Requirements Report

(prepared for the RCF Requirements Task force)

K. Hagel, F. Videbaek

Introduction

BRAHMS computing requirements reported in ROCOCO II have been re-evaluated in some detail. The computing and storage volume requirements for the initial reduction of raw data have been benchmarked with BRAHMS GEANT output and a prototype tracking program. As in the appendix of ROCOCO II, numbers generated were compared with previous experiments scaled up for BRAHMS. Data volumes and rates for the later analysis stages have larger uncertainties. This is in part because the nature of the BRAHMS detector results in very large variation to computing requirements depending on angle and magnetic field setting. In general the requirements to raw and reconstructed storage and CPU needs are set by the smallest angle and lowest magnetic field settings. The I/O needs for measurements with low rates/ particle densities i.e. large angles and high fields. It is our intention to also assess this aspect in connection with an evaluation of run and analysis plans. This cannot, however, be completed on the time scale for this present requirements task force.

Current Data Storage Requirements

Table 1 shows the ROCOCO II Estimates of BRAHMS requirements. These estimates were made without taking into account the various angle and field settings of the forward and mid rapidity arms of the spectrometer. The estimate for calibrated data storage space was also made using the analysis model of E802/E859 where all of the raw data was carried along in the first pass of the data.

	Storage Tb	CPU SPECint95
Raw Data	40	450
Calibrated Data	40	250
Data Summary Tape	10	100
μDST	1	125

Table 1, ROCOCO II Estimates of BRAHMS requirements

We have performed a re-evaluation of data volume needs and have revised the raw data estimate to account for time spent at various angles and field settings. Table 2 shows the estimated contribution to the event length for the various components of BRAHMS for the 2 degree setting of the Forward Spectrometer and the 34 degree setting of the Mid Rapidity Spectrometer. This is the most severe scenario. We envision ~50 central events and ~200 minimum bias events per second. The average minimum bias events have event lengths of ~20% of the central collisions. We therefore arrive at a data rate estimate of 50 * 77.9 + 20% * 200 * 77.9 = 7.014 Mb/s.

We have performed benchmark tests and observed that the size of the data sample for the forward spectrometer at 6° is 50% of the size of the sample at 2° and 7% at the larger angles. If we assume a representative scenario that we will run 1/6 of the time at 2°, 1/3 of the time at 6° and the rest of the time at larger angles, we arrive at an average data rate of 1/6*7 + 1/3*3.5 + ½*.5 ≈ 2.6 Mb/s.

Detector	Compressed kbyte
T1	19.44
T2	6.5
T3	0.7
T4	0.2
T5	0.2
H1	0.1
H2	0.1
C1	0.2
RICH	0.9
M-TPC1	38.9
M-TPC2	9.7
TOFW	0.2
Beam-Beam	0.1
Mult	0.8
Total	**77.9**

Table 2 , Estimated Detector Event Lengths for central collisions at the 2 ° F. S., 34° MRS setting

This results in a downward revision from ROCOCO II of the estimate of the amount of raw data in a nominal RHIC year from 40 Tb to 30 Tb. We have also revisited our estimates of the calibrated data. The 40 Tb in table 1 was arrived at by assuming that most of the raw data would be carried along in the first pass of the experiment. We are now assuming an analysis model where only extra track reconstruction information would be written out along with references back to the original data. This would revise our estimate down to 20 Tb for the calibrated, reconstructed, or processed data. We will then have a pass in which we add particle identification information, again saving references, but not writing the original data.

Table 3 shows these revised estimates.

Raw Data	30 Tb
Processed Data	20 Tb
PID,.. (DST)	10 Tb
μDST	1 Tb

Table 3, Revised storage requirements for BRAHMS

Disk vs Robotic storage in MDS.

The following is a list of requirements of what we would need to have on disk in the MDS system.

1. One week of Raw data. Based on generating 30 Tb per year, this would lead to 1.3 Tb.

2. A data base of "event information" for all the data. This would be a data base that contains references to the event wherever it might happento be in the MDS, global information on the event, for example the centrality trigger information and information on our Beam Beamcounters as well as a list of hit detectors. Such a data base will be about 2% of the total data set. This would lead to 800 Gb.

3. Ten percent of all the data acquired during a week of RHIC running. This would be used during the experiment to make quick analysis on small data sets to check the integrity of the data in more detail than the experimental monitoring will allow. This would lead to 120 Gb.

Table 4 summarizes the BRAHMS requirements for disk vs robotic storage

1 Week of Raw Data	1.30 Tb
Event Information Data Base	.80 Tb
10% of weekly acquired data	.12 Tb
Total	**2.20 Tb**

Table 4, Estimated Requirements for Front-end disk space

The MDS stated in the ROCOCO II has a total robotic storage of 250 Tb and 40 Tb of frontend disk. BRAHMS had 6.2 % of the total storage estimated for the RHIC storage requirements. The 40 Tb of frontend disk space would lead to 2.5 Tb for BRAHMS. Our requirements are in the same ball park as envisioned allocation in ROCOCO II (10%)

BRAHMS Analysis

BRAHMS is comprised of twelve different institutions primarily from around the United States and Europe. We therefore expect that 12 sets of analysis will be occurring at any given time. It is our expectation that a reasonable number of μDST production passes is around 3 per year. The 10Tb of DST tapes/files will be read using 3 times each by 12 different analyses. Table 5 shows the I/O requirements from the beginning of raw data reduction to the final stages of physics analysis.

Pass 1	
Read 30 Tb in one calender year:	=> 1. Mb/s
Write 20 Tb processed data in one year	=> .63 Mb/s
Pass 2	
Read 20 Tb processed data	=> .63 Mb/s
Write 10 Tb PID (DST) data	=> .32 Mb/s
Pass 3	
Read 360 Tb PID + some processed data (36 analyses)	=>11.4 Mb/s
Write 1 Tb micro DST (~36 times) (write several times (different sub samples) The generation of a Tb micro DST should be done on the time scale of days after selections are done.	=> 1.14 Mb/s
Physics analysis	
This would probably happen using micro DST datasets of 50-100Gb. For these analysis to be efficient, it needs to be accomplished in a time span of the order of several hours, eg 3-6 hours or perhaps overnight (12 hours) This would then require 100Gb/3 hours = 10 Mb/s or 100Gb/12 hours = 2.5 Mb/s. It should also be noted that such analyses will during some periods of time be done by more than one individual. It would certainly not be a constant load but would add to peak load requirements.	=> 10 Mb/s.
TOTAL	**25.12 Mb/s**

Table 5, BRAHMS I/O Requirements. We note that the requirements for analysis shift from more CPU intensive in the beginning stages to more I/O intensive in the final stages

It has also been noted by others that the requirements to the later stages depends very much on how much of previous information which might have been stored on tape (even worse on the shelf). Large gains can be obtained if the 'right' kind of information is carried along in later stages (or clustered separately from more raw and/or detailed information not required in the μDST and physics analysis stage.

CPU Requirements

The BRAHMS CPU requirements stated in ROCOCO II are dominated by the event reconstruction. Those numbers had been estimated by using our prototype tracking program and taking into account increases in efficiency that we expected. We have achieved most of our expected increase in efficiency in the first rewrite of the code.

The estimates in ROCOCO II might have some uncertainties. We had not evaluated, for example, the change in cpu requirements with angle and magnet field settings which would most likely lower the overall number.

An attempt to improve this shortcoming has been made by using the new prototype tracking program to reconstruct tracks for the 2.3 and 6 degree settings of the forward spectrometer at ½ and ¼ field settings. The simulations were done for central collisions an estimate made that the average minimum bias event would take 35% of the CPU of a central event to analyze.

Table 6 summarizes the results of these benchmarks.

Angle	field	Central CPU/event (from benchmark)	Minimum Bias CPU/event (estimate 35% of central)	Storage Volume (from benchmark, 100 evts)
2.3	½	4.63 sec	1.6 sec	5.7 Mb
2.3	¼	5.35 sec	1.8 sec	4.6 Mb
6.0	½	1.6 sec	0.6 sec	2.5 Mb

Table 6, Benchmark results for various settings of the Forward Spectrometer

The prototype code does not have complications like dead channels or magnet maps to name a few that could increase the CPU requirements. This work has not been done yet. We can, however, apply these numbers to the total number of expected events to see where we stand. Table 5 shows these results assuming that 1/3 of the running time is spent at 2.3 degrees with half at the full and half field settings and the other 2/3 of the running time spent on the 6 degree setting. A 34 week RHIC year has been assumed to estimate a total of 1.8×10^9 minimum bias events with ≈10% of them being central collisions.

Angle	field	central (specint95)	Estimated Minimum bias (specint95)
2.3	½	215*1/6	742 * 1/6
2.3	¼	248*1/6	835 * 1/6
6	¼	74*2/3	278 *2/3
Total		**127**	**448**

Table 7, BRAHMS CPU estimates from benchmarks

Summary

In the following we summarize the estimates shown in tables 3 through 7 for the purpose of this report to the RCF Requirements Task Force. In addition to the information above is included some extra “derivations” of relations of estimated CPU to I/O bandwidth. The text explains the quantities in tables 8 and 9.

Experimental Data Summary

The μDST production, as noted above, will consist of reading the DST dataset 3 times per year in each of the 12 BRAHMS collaborating institutions. Reading that 360Tb of data with 125 specint95 leads to 11 specint95-sec/Mb. BRAHMS analysis will tend toward being mostly I/O intensive. The only analysis likely to be CPU intensive is the HBT analysis which we estimate that 30% of all of our analysis. The data sizes for the HBT analysis are expected to be of the order of 1Gb and the data sizes of the rest will be around 30Gb. Assuming 20% of the CPU will be used for CPU intensive projects and the remaining 70% for the I/O intensive, using the same argument as above leads to 84 specint95-sec/Mb for the CPU intensive and 4 specint95-sec/Mb for the I/O intensive analyses.

Applying the same sort of reasoning for the simulation data shown above leads to similar numbers for simulation CPU and I/O rates. These numbers for the experimental data are summarized in table 8.

	BRAHMS
Raw Data Recording Rate	7 Mb/s peak, 2.5 Mb/s average
Raw Data Volume	30Tb
Calibration Data Volume	2.0Gb
Required Reconstruction Latency	<168 hrs
Raw Data Reconstruction CPU, 1 Pass	450 SPECint95
Average Number of Reconstruction Passes	1.2
DST volume	10Tb
Processed Data volume	20Tb
Typical Analysis Data Mining	
Passes per year	3
Required Input DST volume	10Tb
CPU-sec Required/Mb DST	11 SPECint95-sec/Mb
Output μDST volume	30Gb
Number of concurrent useful μDST’s	8
Typical CPU Intensive Analysis	
Passes Required per day	3
μDST Volume	1Gb
CPU-sec Required/MB of μDST	84 SPECint95-sec/Mb
Typical I/O Intensive Analysis	
Passes required per day	3
μDST Volume	30Gb
CPU-sec Required/Mb μDST	3.9 SPECint95-sec/Mb

Table 8, Experimental data computing estimates summary

Modeled Data Summary

Table 9 summarizes the requirements for Modeled and Simulated data. It was written in ROCOCO II that modeled data will mostly be shared between the experiments. We plan to use shared data whenever the calculation exists. However, there will inevitably arise model calculations that the BRAHMS collaboration is interested in which the other collaborations have no interest in. We therefore feel a need to specify some CPU and storage space for such calculations. If we assume one such calculation, we would arrive at 50 Gb for 100k events covering all of phase space. One such event using the VENUS code as an example requires 50 seconds on the current RCF Pentium Pro's which implies 400 SPECint95-sec per event. A processing capability of 15 SPECint would be required if 100k events are to be calculated in the time period of one month. Our benchmark in table 6 indicates for 100 events a volume of 8.2 Mb for the 3 settings tested. If we assume that we will perform calculations for several more settings and 10 different impact parameter settings, we arrive ≈200Gb for the simulated storage space. Each event in the detector simulation requires about 480 SPECint95-sec (1 minute on Pentium Pro) leading to 100 SPECint95 if a 100k event dataset is to be simulated in the course of one week. The CPU required to reconstruct these events is 37 SPECint95-sec per event as shown by the benchmarks in table 6 leading to 15 SPECint95 if such a dataset is to be analyzed in the course of two days. We assume that the simulated DST volume scales with CPU in the same way as the experiment. This is similar to the answer one would obtain if the Simulated DST Volume would scale with the Simulated Data Volume with some extra storage added to account for extra relations that might be carried along in a simulation that do not exist in the experiment. We assume the CPU power and I/O bandwidth required for analyzing the simulated data to scale in the same way as the experiment.

	BRAHMS
Modeled Data Volume	50 Gb
Modeling Data CPU	15 SPECint95
Simulated Data Volume	200 Gb
Simulation CPU	100 SPECint95
Simulated Data Reconstruction CPU	15 SPECint95
Simulated DST Volume	150 Gb
Typical Simulated Data Mining	
Passes per year	3
Required Input DST volume	150 Gb
CPU-sec Required/Mb DST	12 SPECint95-sec/Mb
Output μDST volume	15 Gb
Number of concurrent useful μDST's	8
Typical CPU Intensive Simulated Analysis	
Passes Required per day	3
μDST Volume	1Gb
CPU-sec Required/MB of μDST	84 SPECint95-sec/Mb
Typical I/O Intensive Simulated Analysis	
Passes required per day	3
μDST Volume	10Gb

CPU-sec Required/Mb μDST	3.9 SPECint95-sec/Mb

Table 9, Simulated data computing estimates summary