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The Release of CBGEANT 5.00

News and Added Features

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Abstract

CBGEANT 5.00 has just been released. This note explains the new features and physics which have gone into both the CBGEANT code, and the upgraded GEANT 3.21. It also presents a few simple bench-marks of timing and performance relative to previous codes.

1 Introduction

It has been a long time since a new version of CBGEANT has been released. The reasons are many. Under Roy Bossinghams guidance the code was greatly improved and was linked to GEANT 3.14. After the departure of Bossingham as the responsible, the code maintenance has had a lower priority. New improvements to the code were originally designed to be linked with 3.15, but by the time it was properly prepared version GEANT 3.16 was being promised. It was decided not to release what was to be CBGEANT 5.00 until the release of 3.16. This was due in part to the fact that there was not much new in 3.15 in terms of physics, whereas 3.16 promised many improvements directly related to us. However 3.16 was rather longer in coming than expected, and proved to be a rather dud version of GEANT. Simple put, no experiments were using it due to the large number of bugs introduced by all the new physics. These were slowly ironed out, and the next release was GEANT 3.21. It has all the new physics, now properly coded, plus a new geometry definition designed to improve the speed. Our code is now linked with GEANT 3.21, and the first release is as CBGEANT 5.00.

If new to CBGEANT and/or GEANT there are manuals available (even an up to date GEANT manual !) [1, 2].

2 New Features in CBGEANT: Version 4.06/09 to 5.00

2.1 PWC Improvements

There were several bugs found in the treatment of the PWC which have now been fixed;

- The most serious was that the wire numbering was wrong, by 1, so that all hits were displaced by a rotation of one wire in ϕ. This was pulling the tracks in the wrong way, and was responsible for the bias previously observed between positive and negative tracks in the Monte Carlo.
- There was a problem with some wires when an algorithm was invoked to calculate the probability that an adjacent wire had fired. In these cases, rather than calculate for the two wires on either side, it was putting hits on wires 2 wires away, and on one side only. This often led to the wrong PWC multiplicity.
- There were also some minor corrections to the way noise was being handled.

2.2 JDC Improvements

There have been numerous changes implemented in the code with respect to both the tracking in general, and the implementation of the new JDC design.

- To use the new JDC one must provide an additional card called JDCD. If one sets JDCD 1 then one gets the old JDC, setting it to 2 gets the new design. By default the old JDC is used, although a warning is written to inform the user that s/he hasn't selected a design.

- There has been substantial work done on the "physical JDC". Normally users were using the "FASTJDC" mode which uses a very quick and simple algorithm to simulate the signal. The more physical Monte Carlo was a bit slower, and had not been fully implemented. Now the Berkeley group have greatly improved the "physical JDC". It is important to note that the new JDC design is not yet supported with the "physical JDC".

There have been many bug fixes and improvements in algorithms, mostly by the Berkeley group, involving things like JDC drift time algorithms, improvements to the calculation of drift times near the sense wires, gas material and avalanche factors etc. These are detailed in the history patch of the code. Hence one should expect an improvement in the JDC handling in the Monte Carlo.

2.3 Crystal Improvements

- The main change in our coding has been the implementation of lookup tables for the crystals. In the old version of the Monte Carlo, the crystals were ordered in a different way to the data. This had no effect if one only wanted to use CBOFF in offline analysis, but it could not be used for the trigger simulator where the FERA data is expected to have the same order found in standard lookup tables. In addition, in the lookup tables, there is a threshold value, which represents the energy a crystal must have if it is to be written out, as in the real data. This threshold was not being implemented in the old Monte Carlo. The lookup tables required are provided with the code, and can be read in with cards using the keywords LUTF and LUT2, as outlined below.

- There is now some test code available which is designed to mimic the non-uniformity of the crystals. When the crystals were being installed in the barrel, each was tested for light non-uniformity. A typical response curve for a crystal was approximately sinusoidal, with variations of up to about 5% in light yield along the length of the crystal. The curves were measured be depositing energy at discrete points along the crystal with a source, and then measuring the light yield with a photomultiplier. There were 1380 slightly different curves to be parameterized, stored on paper, and possibly on diskettes if we could find a computer able to read this old format. However, it was decided to just average the results of about 20 crystals, and use this parameterization, which is shown in figure 1. This was because of the amount of work involved to fit all channels, and as the light output has probably changed a bit with time, but most importantly, the measured curves were taken with photo-multipliers, not the photodiodes, and these have a different frequency response, so the measured curves probably have little to do with the actual non-uniformity as seen by the photodiodes. The use of this code can be selected by card input, as discussed below.

2.4 General Improvements

- Following a study on the different hadronic tracking packages available [3], it was decided that the use of GHEISHA [4] with a correction term was definitely wrong.

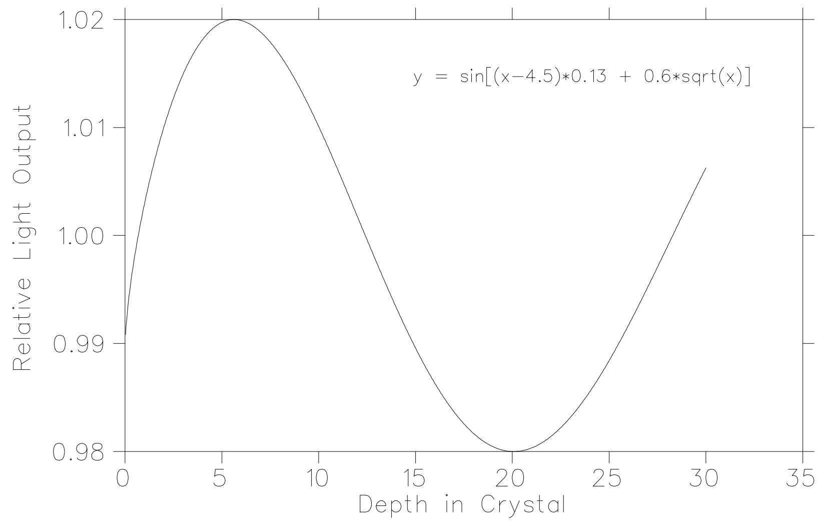

Figure 1: The parameterization used to describe the light output as a function of length along the crystal.

The correction term had the effect of blowing up the cross-sections unrealistically at low momenta (below 1 GeV/c). There have not been enough studies with real data on the problems of hadronic split-offs, shower sizes, etc, to make a sensible decision as to whether FLUKA or the regular GHEISHA preforms better. The user may now select any of these packages, based on the requirements of their analysis. The selection is made via the card HDCB as outlined below.

- For debugging purposes there are now some new user switch options which allow one to follow tracks a bit easier. Switch 3 allows detailed information about each step to be printed out, and the user may select a threshold in energy deposition above which he is interested in, and may opt to switch off printing the electromagnetic shower part so that other interactions can be seen. Switch 4 allows the user to select an energy threshold for the drawing of tracks in the interactive version. Then instead of a huge mass of tracks, most of which are of very low energy, one can follow the more interesting tracks. This is useful for studying, for example, split-offs.

3 New Features in GEANT between 3.14 and 3.21

3.1 GEANT 3.15

The first new version of GEANT was 3.15, which was released around March 1992. The main purpose of this was the consolidation of all the correction cradles from 3.14. In our own code we had about 10 routines meant to override standard, but flawed, GEANT routines. These were all fixed in 3.15. In addition, some new features were introduced, as listed below.

- An interface with the hadronic interaction package FLUKA [5].

- A new algorithm to calculate the energy deposition.

- The first introduction of a scan geometry which was intended to allow users to parameterize showers in order to build a shower library, rather than having to track each time.

  There were also some new graphics options introduced.

3.2 GEANT 3.16

The main features added to GEANT 3.16 which concern us are listed below;

- The proper treatment of the photoelectric effect. Prior to 3.16 there was a global parameterization for $E_\gamma > 10$ keV and $Z > 5$ which had typically only about 10% accuracy. In the final state there was only a photoelectron, emitted along the γ direction. Finally shell effects were poorly treated. In 3.16, the accuracy was much improved through the use of cross-section tables to be about 1% over most of range. The handling of the shell was properly introduced, and the final state could have in addition to the photoelectron, Auger electrons, fluorescence etc. Most importantly, the photoelectrons were given an angular distribution.

- Similarly, the handling of Bremsstrahlung has been changed to get more a more accurate representation. It now uses a new parameterization for cross-sections. Improvements were also made on the angular distributions and on synchrotron radiation.

- The energy loss algorithms for low energy electrons and positrons have been changed and should be much more accurate.

- Another important feature was a change in the handling of energy losses in very thin layers, where Landau theory is not appropriate.

- The FLUKA interface was updated to the new FLUKA release which included an extension to lower energies. FLUKA now uses a new model, the "pre-equilibrium model" which is a statistical treatment of nuclear thermalization and particle emission.

- Also related to hadrons, the treatment of neutrons was extended to lower energies and some additional packages were included (eg MICAP).

- New dE/dx formulae for low energy hadrons.

- Another, potentially interesting, inclusion to the code was the introduction of the handling of Čerenkov photons and the tracking of optical photons.

Besides these there were of course the consolidation of all bug fixes to GEANT 3.15, and lots of work done on new graphics, and interfaces to Motif and CAD. Version 3.16 was released at the end of 1993.

3.3 GEANT 3.21

Along with the numerous bug fixes to GEANT 3.16, GEANT 3.21 has substantial improvements concerning the tracking and geometry packages. It is not completely backward compatible with previous GEANT versions as a result. For the large LEP and LHC detectors, the new geometry has increased the speed by factors of two or more. There were no new physics items input to the code. GEANT 3.21 was released in March 1993, and like all releases, it has taken a few months for the code to stabilize.

4 Benchmarks

4.1 Computation time.

The time per event for all-neutral events has been measured using cbdec4.cern.ch and with 10000 $\bar{p}p \to \pi^0\pi^0\eta$ events at rest, with the η decaying into 2 photons. Three codes were tried, as outlined below in table 4.1.

CBGEANT Version	GEANT Version	Time per $\pi^0\pi^0\eta$	Time per Geantino
4.06/09	3.14	3.15	0.163
5.00/00	3.14	3.47	0.180
5.00/00	3.21	4.70	0.211

Table 1: Time performance of the Monte Carlo for a typical neutral event. Times are in seconds per event on cbdec4.

One sees that the time per event is about 50% higher with the new coding, most of which is attributable to the new release of GEANT. It is difficult to determine where this extra time comes from. For example the new coding of the photoelectric effect is a likely candidate, but switching this off raises the time per event to 10.3 seconds, as now the shower is tracked for much longer since this mechanism cannot help to stop the shower development. The interplay of all these effects makes it very difficult to isolate where the increased time is.

These results were presented to the GEANT team, who were quite concerned as they have always claimed that GEANT 3.21 should be faster, even for small experimental setups. To investigate the problem further they tracked "geantinos" through our detector system. Geantinos are hypothetical particles with no physics interactions, so they are a way of probing the tracking time for a single track through the detector. From table 4.1 one sees the result obtained on the dec-stations, that the tracking alone is ≈ 1.2 times slower than with the previous code. Of course geantinos pass straight through the detector, and is then an average over the detector, whereas for real events most of the action takes place in the crystals.

However, similar tests on an HP workstation showed the reverse trend. With the same conditions as for my test they found GEANT 3.21 is ≈ 1.2 times faster, and if they remove all user code, as for example that found in GUSTEP, GEANT 3.21 was ≈ 2 times faster. They believe that this may be understood in terms of the code optimization level. In GEANT 3.14, the GEANT libraries were all optimized to the highest level (-O4). For GEANT 3.21, this is true for all machines except dec-stations and OpenVMS, where to run the code, an optimization level of only (-O1) had to be used. They have promised to investigate this further, so that the code can be fully optimized, and hopefully we can have a much faster code on the dec-stations. Users on other machines will hopefully see some improvement in speed.

For the charged events one sees in fact a general improvement in time with the new GEANT. In table 4.1 one sees the results for a number of runs each with 10000 $\bar{p}p \to \pi^+\pi^-\eta$ events at rest, with the η again decaying into 2 photons. To facilitate the comparison with previous versions, all programs were tested using the FASTJDC option, not the more physical description. Also, all but the last entry used the old hadronic package, GHEISHA_C, which was wrongly applying a correction function. One can see here that with the hadronic package GHEISHA, the code is slower. This is natural, as the decreased cross-sections of GHEISHA means the particle must be tracked for longer before it interacts.

CBGEANT Version	GEANT Version	Time per $\pi^+\pi^-\eta$	Other Details
4.06/09	3.14	3.86	FASTJDC, GHEISHA_C
5.00/00	3.14	2.52	FASTJDC, GHEISHA_C
5.00/00	3.21	2.11	FASTJDC, GHEISHA_C
5.00/00	3.21	3.45	FASTJDC, GHEISHA

Table 2: Time performance of the Monte Carlo for typical charged events. Times are in seconds per event on cbdec4.

4.2 Physics output, $\pi^0\pi^0\eta$ events.

From these events the mass and width of the π^0 and the η were measured. Also a very simple analysis routine examined the events. The analysis required:

Step 1: No charged tracks. (This was just taken from the TTKS banks).

Step 2: Exactly 6 gammas seen according to the "Dolby-C" definition of a good gamma.

Step 3: No split-offs allowed, again using the standard Dolby-C definition.

This last cut is perhaps a bit harsh, perhaps one should rather ignore split-offs or recombine them with their parents. However the purpose here was simply to compare the codes. In all cases the analysis used cuts for ECLUBC and EPEDBC of 10.0 MeV. The results are listed in table 4.2.

One can see that the masses and widths are completely compatible for all code configurations, so I do not believe a new crystal calibration of the Monte Carlo is necessary. One can also see that the new CBGEANT is compatible with the old. However, differences do appear when the new GEANT code is applied. I think the most significant effect here is the angular distribution of electrons in the photo-electric effect, which has somehow led to more electromagnetic split-offs. Hence one sees that the gamma multiplicity cut has the effect of reducing the efficiency by almost 4%, and if one were to reject all split-offs, then the overall efficiency is almost 16% lower. This could have a serious effect on branching ratios.

	CGGEANT & GEANT Versions		
	4.06/09 & 3.14	5.00/00 & 3.14	5.00/00 & 3.21
π^0 Mass	135.69 ± 0.13	135.84 ± 0.13	135.48 ± 0.16
π^0 Width	8.39 ± 0.35	8.28 ± 0.36	8.50 ± 0.43
η Mass	548.88 ± 0.57	547.89 ± 0.46	548.04 ± 0.56
η Width	13.25 ± 0.98	14.08 ± 0.85	13.12 ± 0.91
% After Cut 1	91.5 ± 1.0	92.0 ± 1.0	90.8 ± 1.0
% After Cut 2	63.2 ± 0.8	63.8 ± 0.8	61.2 ± 0.8
% After Cut 3	48.9 ± 0.7	49.5 ± 0.7	41.4 ± 0.6

Table 3: Performance of the Monte Carlo for typical neutral events and a very simple analysis.

Graphically, the effect can be seen by comparing the PED energy distributions for each code, as seen in figure 2. There are many more low energy PEDs in the GEANT 3.21 formalism.

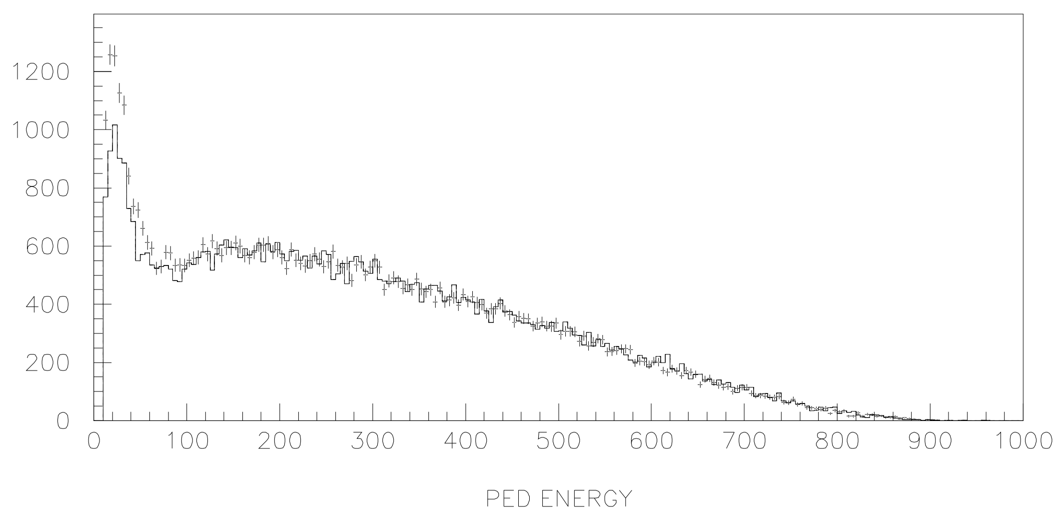

Figure 2: The PED energy distribution for CBGEANT with GEANT 3.21 (points with error bars) and with GEANT 3.14 (solid histogram)

5 Summary of new CARD options

	Card	Parameter	Value	Consequence
⋆	HDCB	IHADCB	0	Use GHEISHA hadronic tracking package. This is the default.
			1	Use FLUKA hadronic tracking package.
			2	Use GHEISHA, with correction term. This is not recommended.
⋆	LUTF	XFLOOK	'mcfera.lut'	The FERA lookup table to use if the crystals are to be ordered the right way. This is needed in order to use the trigger simulator.
⋆	LUT2	X2LOOK	'mc2282.lut'	The 2282 lookup table. As above.
⋆	JDCD	JDCD	1	Use old JDC geometry with 30 sectors. (def)
			2	Use new JDC geometry with 30 sectors in the outer, and 15 sectors in the inner layers.
⋆	NUNI	LNUNIF	F	Don't use the non-uniformity code. (default)
			T	Do use the non-uniformity code. Note, this is test code until there has been sufficient testing of it.
⋆	SWIT 3	ISWIT(3)	3=+x	When debugging is on, this switch controls the print out of diagnostics at each step. If positive, it prints information for all steps which deposit at least x KeV in the the detector, and only for tracks other than electrons, positrons and photons.
			3=-x	As above, except when negative, all track types are printed
			3=0	Print nothing. Default.
⋆	SWIT 4	ISWIT(4)	4=x	When debugging is on, this controls which xyz structures are saved for plotting. Only those tracks with a KE > x, in KeV, will be plotted. Default, 0, stores all tracks

6 Code Location and Maintenance

At the moment the official code is stored on the dec-stations at CERN on with directories and file names as follows;

- /cboff/gea_new/cmz cbgeant500.car The officially stamped car file. This will not be changed until the next release.
- /cboff/gea_new/cmz cbgeant500.cmz The cmz file originally used to create the car file above, but as this is the new directory, I will continuously edit this to install bug fixes etc. It is advised to take the car file.
- /cboff/gea_new/bld buildcbg An example file I use to link all code
- /cboff/gea_new/bld cb***.kumac Various example kumac files I use.

7 Future Plans

- Make the code robust. Due to its recent history, it was necessary to stamp and release the code so that there was a common code for all users and developers to compare with. I am sure that some bugs and omissions will appear soon, and these will have to be corrected.
- I fear in particular that more work needs to be done with the code for the physical JDC description. We have already found some minor problems, and I find that the code crashes when testing with large numbers of events. This needs to be tracked down. Until then, I suggest using the FASTJDC option.
- New code is being developed by Ch. Strassburger to make the dE/dx in the JDC more closely represent that seen in the real data. This should be ready in a few weeks.
- There is an ongoing discussion as to which garfield output files should be used, and what JDC tables to use for the new JDC. This should be resolved very soon.
- The coding of the hardware status bit which now appears in the data will also appear in the next software release for Monte Carlo.
- An old bug has been rediscovered, which relates to the branching ratios for channels used in the big-bang simulator. Only the first 20 channels were being taken.
- Some of the particle masses and decay widths have to be updated to the 1994 data book values. (In particular the η).

- There are various other people writing code to implement for instance the vertex detector, a Čerenkov counter, and even at one time BGO endcaps. These are being developed in the old code, and should be brought into the new code.
- And so on ....

References

[1] Roy Bossingham. Monte Carlo Software, CBGEANT 4.06/03. Crystal Barrel Note 169. February 1992.

[2] GEANT 3.21. Detector Description and Simulation Tool, CERN program library long writeup W5013. March 1994.

[3] Anthony Noble. A Study of Hadronic Interactions in CBGEANT. Crystal Barrel Note 258. July 1994.

[4] H.C. Fesefeldt. Simulation of hadronic showers, physics and applications. Technical Report PITHA 85-02, III Physikalisches Institut, RWTH Aachen Physikzentrum, 5100 Aachen, Germany, September 1985.

[5] P.A. Aarnio et al. Fluka users guide. Technical Report TIS-RP-190, CERN, 1990. See also GEANT 3.21 manual for further references.