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Supplement 2

Further Errors in the Reconstruction of Photons in the JADE Detector

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During 1986 several errors were discovered in subroutines and functions which are concerned with Lead Glass calibration, reconstruction of photons and Monte Carlo simulation of photons. Most of these errors were reported in various JADE Meetings; they are summarized here for convenience and clarity.

The function ELGOBS and the subroutine LGECOR:

The function ELGOBS is used in the Monte Carlo tracking program to determine the amount of shower energy that reaches the lead glass blocks, after absorption loss in the material in front of the lead glass. ELGOBS uses for this purpose the subroutine ENGLOS, which for a given thickness of absorber and for a given shower energy calculates the loss. ENGLOS is also called in an iterative way by the subroutine LGECOR, which is used by LGCDIR to estimate the amount of correction energy to be added to a cluster in order to compensate for the absorption loss. ELGOBS and LGECOR thus are closely related.

Both ELGOBS and LGECOR have the absorber thicknesses (at 90°) explicitly stated in the program code and are not affected by any update of COMMON variables in a BLOCK DATA. Such an update was done in 1982, with a general revision of thicknesses of absorber in front of the lead glass, both for the Barrel part and the Endcap parts. The absorber thickness values are stored in COMMON/CGEO1/, which is BLOCK DATA set in the member JADEBD, on F11LHO.JADEGS/JADEGL. The updates were however only partly carried out in the system ELGOBS–LGECOR and the following sad situation resulted:

Absorber Thickness in front of the Lead Glass Barrel (X_0)			
Period	ELGOBS	LGECOR	Reality
1979–82	0.88	0.88	0.978
1982–84	0.88	0.97	0.978
1984–86	0.88	0.97	1.041
Absorber Thickness in front of the Lead Glass Endcaps (X_0)			
Period	ELGOBS	LGECOR	Reality
1979–82	0.0	0.0	1.17
1982–86	0.0	1.17	1.17

The periods in the table are understood to indicate real time, i.e. LGECOR was updated in 1982; when used after 1982 for data taken before 1982, it of course gave the updated thicknesses. Thus, for data from 1979–84, LGECOR has absorber thicknesses which are practically identical to reality values.

For the time 1984–86 there is a small systematic deviation in the Barrel region (due to the z–chamber). This has by purpose not been changed in LGECOR, since lots of data have been reconstructed already with the value 0.97 X_0 and the difference is only slight.

Since ELGOBS was forgotten in the update 1982, with absorber thicknesses which are $\sim$ 10 % too thin in the Barrel region and non–existent in the Endcap regions, loss and correction do not match in terms of absorber thickness, in particular for the Endcap parts. This clearly gives systematic deviations in corrected Monte Carlo photon and electron energies, severely so for the ones in the Endcap regions.

This bug has far–reaching consequences: Other programs for reconstruction of photon and electron energies have been optimized using the combination ELGOBS–LGECOR and may compensate these systematic errors by adjustment of internal scales and tuning variables. Thus the correction of ELGOBS with respect to LGECOR may necessitate new tuning of such programs. This is in particular true for the so called Meier–Magnussen SF5–SF6 program, which gives a fast 3–dim. simulation of EGS showers[1].

Calibration of Lead Glass Gain Constants:

The calibration of the lead glass gain constants is also affected by the bug in ELGOBS: In the calibration procedure (see Jade Note 86) deposited energy from Bhabha electrons is compared to the "expected" energy, which is calculated from the beam energy, using the function ELGOBS to subtract absorption losses. Since these losses are underestimated by ELGOBS, *the Gain Constants are systematically high.* This may again be compensated for by the leakage loss for high energy electrons, which is not considered in the calibration procedure.

In the reconstruction of cluster energies (photons) a third effect enters, namely the readout threshold: of all blocks which are hit by a shower only those with an energy above a certain threshold are actually read out in the raw data. This threshold was in 1979–1982 about 25 MeV, corresponding to 5 ADC–counts and an average gain constant of $\sim$ 5 MeV/count. In 1983–1986 this threshold was 6 ADC–counts, corresponding to 30–36 MeV, since the gains were also raised to cope with the higher beam energies at PETRA. This loss of energy is not compensated for in the reconstruction programs (and also not in the calibration procedure). Photon energies will therefore be systematically low, although the relative error will be smaller with higher photon energy. Note that this systematic effect is compensated (at least partly) by the too high gain constants!

In view of these effects it is clear that reconstructed photon energies will have systematic errors which vary with the photon energies. This is demonstrated by e.g. the absolute value of the π° peak in various data samples: with low energy photons dominating, the mass will be low (as seen in two–photon physics data), while with higher energy photons the mass will agree with the table value or even be higher (as seen in e.g. multi–hadronic annihilation events). This variation of the π° mass with photon energies is of course also present in Monte Carlo data, since the readout threshold is simulated. However, the agreement of the Monte

[1] EGS is a well known program for electromagnetic shower development (Electron Gamma Shower).

Carlo peaks with those in the real data is clearly a matter of luck!

Considering all of the above, the following corrections have been done: ELGOBS is given the same absorber thicknesses as LGECOR, i.e. 0.97 X_0 in the Barrel region and 1.17 X_0 in the Endcap region. LGECOR is left as it is. The corrected ELGOBS is effective since 19.1.1987.

The programs TRLGSH and TRLGS6:

These 2 program packages are also known as the Meier–Magnussen SF5–SF6 3–dim. shower simulation programs (see Jade Computer Note 70 and Jade Note 136). They are called in the standard Monte Carlo tracking program by the subroutine TRLGL, which handles the tracking of all particles in the lead glass system. For simulation of the period 1979–1982, the program TRLGSH is called (pure SF5 type of lead glass) and for 1983–1986 TRLGS6 is called (mixed SF5–SF6 setup). Although these programs are fast compared to the full EGS code, they are still rather slow compared with the standard 1–dim. simulation in the tracking program; therefore their usage is not default and has to be switched on by the logical flag LFLAG(4) (default .FALSE.).

Both programs suffered, since their introduction in the JADE software ($\sim$ 1982), from a couple of logical bugs, apart from the problem of the dependence on the systematic errors in the combination ELGOBS–LGECOR described above.

The outstanding bug was the fact that the position 3–vector for photons and electrons going into the Endcap regions was not properly updated. As a result these photons and electrons were tracked a second time, i.e. first a 3–dim. simulation in TRLGSH/TRLGS6 and then the standard 1–dim. simulation in TRLGL. The energy was thus deposited twice, with disastreous consequences for single photons (and electrons) and with strong bias in cuts which depends on the total lead glass energy (e.g. the Multihadron selection). This bug was corrected on 20.8.1986.

The other bug is more subtle. The block energies from each shower were multiplied by a correction factor in the program. This factor was calculated from the ratio of total shower energy to seen shower energy, the latter quantity being determined by the blocks with energy above the hardware readout threshold, which was fixed to 28 MeV in the program. The purpose of this factor was to compensate for the loss of shower energy due to the readout threshold; in a 3–dim. simulation this loss is much larger than in a simple 1–dim. simulation where only a few blocks are hit. This correction has no clear correspondence in reality and must be considered an artefact of the program; it has consequences for the trigger simulation, which works with the deposited (i.e. uncorrected) shower energies. Moreover, it is logically wrong when several showers hit the same block. Clearly, the readout threshold is effective only on the total energy of each block and not on the individual block contributions from each shower.

The correction of this logical error (by setting the correction factor to 1.) affects the internal normalization constants of TRLGSH/TRLGS6. The necessary new tuning of these constants has been performed during autumn 1986 but was complicated and delayed by the other errors in the combination ELGOBS–LGECOR described above. The final versions, without this artificial correction and with newly tuned internal constants, were introduced as standard versions on F22ELS.JMC.S/L on 19.1.1987, together with the corrected function

ELGOBS (on JADELG.SOURCE/LOAD)[1].

The subroutine LGCDIR:

This is the main steering routine for calculating energies and directions of the observed clusters in the lead glass. These clusters are stored in the banks ALGN and LGCL (see Jade Computer Note 14) and LGCDIR updates the latter bank. LGCDIR performs the task of energy correction, i.e. an amount of energy is added to the observed cluster energy in order to compensate for the absorption loss in the material in front of the lead glass (pressure vessel, magnet, heatshields, TOF counters, etc.). This is done for real data as well as for Monte Carlo data. In the latter case it is only done if a corresponding energy loss was imposed in the tracking of the Monte Carlo data. As is well known, this is steered by the LOGICAL*1 flag LFLAG(3) in COMMON /CFLAG/ LFLAG(10). Normally this flag is .TRUE., absorption is imposed and all is well in LGCDIR[1]. However, for certain studies one might switch this flag to .FALSE. and expects then no absorption corrections done by LGCDIR.

Due to faulty logic in LGCDIR absorption corrections were in this case nevertheless done, but not for all clusters. Affected were clusters nr. 5–8,13–16, 21–24, etc., and the others were correctly treated, i.e. got no absorption correction. The bug in LGCDIR was present since the beginning of JADE and was corrected on 3.9.1986.

[1] the old version is available as ELGOBS0, to be included if one needs it.

[1] LGCDIR knows about this via a marker in the bank descriptor word of the bank ALGN.