E831 Collaboration Meeting **Dan Pantea**
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Hadron Shower Library for Rogue

Motivation

full GEANT MC simulation of hadron showering in calorimeters requires a lot of CPU time

Main idea

- Store in a shower library the calorimetric information from **real or simulated showers** produced by particles with momenta in a wide kinematic range.
- When simulating an event, for each secondary hadron hitting the calorimeter front face, fetch randomly from HSL a shower with appropriate characteristics.

Requirements and chosen solutions

- fast access to selected shower information

  ⇒ HSL structured as a direct access file
- easy portability to different computing platforms of E831 collaboration

  ⇒ possible options:

  i. ascii file
  ii. ZEBRA RZ file
- disk space necessary to store HSL

  ⇒ it will be unavoidable large, but we should prevent it from becoming huge
- easy to use

  ⇒ minimal actions of the user, to be reduced at changing some flags in Rogue control files and seting the values of two environmental variables.

Problems

- the multiparametric labeling of the showers. HSL shower population increases as a power of the number of parameters. If one takes into account a labeling on energy, impact point coordinates and incident angle, with:

  /a/ n_E steps in the shower energy

  /b/ n_C values for the impact point coordinates (x, y)

  /c/ n_A steps in the angle of incidence

  and n_S the mean number of showers in each point of the parameter space, the necessary number of showers N in the library is:

  $$N = n_S \times n_E \times n_C \times n_A$$

  Considering 25 values of energy, a shower per each cm^2 of a $100 \times 100cm^2$ area in the calorimeter central region, $n_S = 250$, $n_A = 1$ and 100 words of calorimeter information per shower one obtains a value of about 6.25Gbytes for the size of HSL.

- the nonuniform structure of FOCUS calorimeters

  /a/ tiles of different sizes

  /b/ not an 100% overlap of IE and HC

  /c/ the existence of a central vertical aperture in IE and of a column of Pb bricks or the BGM detector in the corresponding area in front of HC

  A possible reduction in HSL size is by the decreasing of n_C, taking into account the symmetries in the calorimeter front face plane. The nonuniformity of FOCUS calorimeter structure allows only reflections about symmetry axes which results in a lower value of n_C by a factor of 4. This was already included in the estimation presented above.

Conclusion: a reasonable size in HSL could be achieved if the shower information could be transported from a point to another of the calorimeter. The nonuniform structure of FOCUS calorimeter doesn't allow a significant reduction if we try to do this directly. A special procedure had to be deviced. It works only for Monte Carlo generated showers.

Shower library creation in GEANT

- A way to circumvent the calorimeter nonuniformity

Our goal of providing transportability of a shower to any point on the calorimeter surface is achieved by simulating showers with a more detailed transverse precision than the real calorimeters could provide. The only ingredient is that in GEANT the IE and HC calorimeters have a much finer transversal granularity of the calorimeter cells, while all other construction details remain unchanged.

The response to a hadron in each calorimeter longitudinal section is simulated and with the values of the deposited energy in a certain number of calorimeter cells centered around the impact point a GEANT array was defined. To move the shower, one has to center the array on the new position and to sum the values of deposited energy of those array cells whose centers fall inside a real calorimeter cell.

The procedure is illustrated for HC in the Fig. 1.

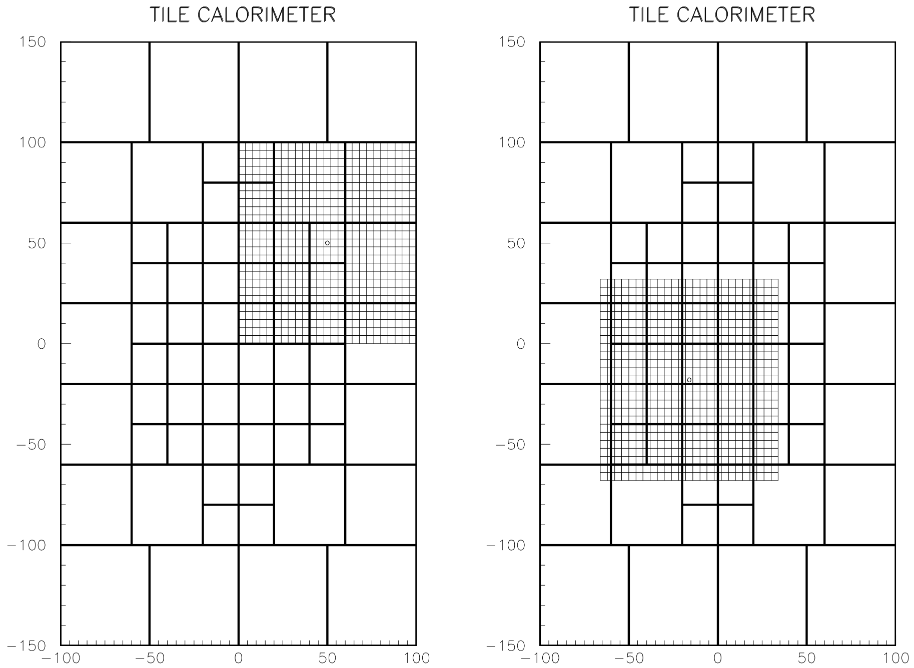

Figure 1: Shower generation and filling the array (left), moving it to an other point and reconstruction the shower information at the level of real calorimetric cells (right)

- Some details of GEANT simulation

1. the transversal area of an IE block in GEANT is $1.16 \times 1.16 cm^2$ i.e. 1/25 from the transverse area of a real IE block and of an HC block is $4 \times 4 cm^2$ which represents also 1/25 from the area of the smallest real HC tile ($20 \times 20 cm^2$).
2. simulated IE and HC have an uniform granularity
3. It is simulated the response of calorimeter (IE+HC) to single particles hitting it perpendicularly in a fixed point, chosen in such a way that showers starting in IE do not have lateral leakage. The deposited energy in all cells within an area: $29 \times 29\ cm^2\ (IE)$ and $100 \times 100\ cm^2\ (HC)$, centered on the impact point positions, define a grid consisting from four 25×25 arrays: one for IE and three for HC (one for each longitudinal section of HC).
4. The GEANT grid defines the shower information which is stored in HSL.

- Additional improvement

There is a rotational symmetry around the shower axis, which for the 25×25 shower library arrays corresponds to 8 discrete symmetry transformations. Along the procedure of shower random selection from HSL, one can further increase the randomness by a random application of one of the 8 symmetry transformations (thanks to Phil Yager for this suggestion).

In the fig. 2 one can see with dash dotted lines the symmetry axes and an illustration of one of these transformations.

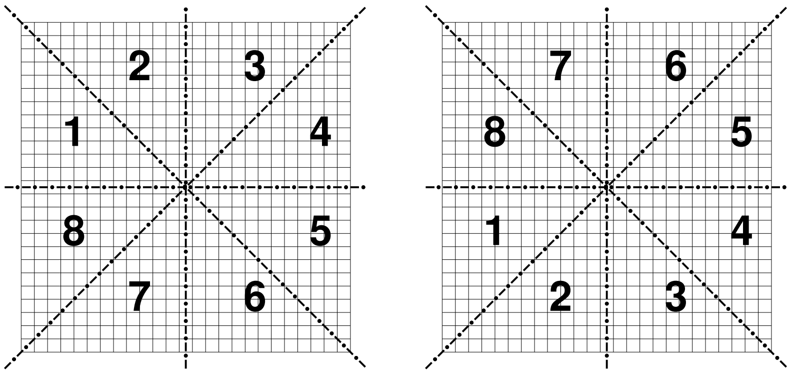

Figure 2: The array in the standard form stored in HSL (left) and after the application of the reflection about the horizontal symmetry axis (right)

• Different classes of showers and their simulation with HSL

In the Fig. 3 the FOCUS calorimeter front face is divided in three distinct regions shown with different hatch modes. Showers generated by hadrons whose impact point (x, y) are located inside of one of these regions show common characteristics.

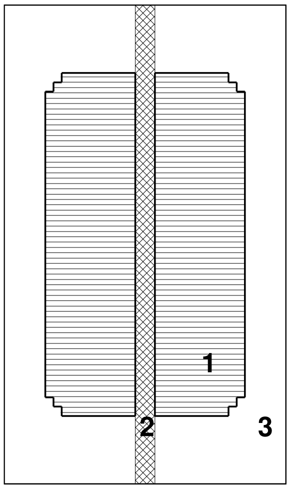

Figure 3: The regions on the calorimeter front face

The showers could by divided in three classes:

/1/ for the impact point in region 1, showers which start in IE and continue in HC

/2/ for the impact point in region 2 showers which can start in Pb column or BGM detector, and only that part which develops in HC is registered.

/3/ for impact point in the region 3, showers developing to full extent in HC

An estimation of the relative population of these classes, based on simulated $\gamma p \to c\bar{c} + anything$ events at $E_\gamma = 300$ GeV, is: 84.4%, 15.3% and 0.3%.

Only the showers of class /1/ were generated. These are the most numerous and they can be used to simulate the showers of other two classes.

a) showers of class /2/ could start in Pb or BGM. The energy they deposit there is not sampled and for them there is only information about the energy they deposit in HC. The thickness of Pb or BGM measured in interaction lengths being comparable with that of IE, these showers could be described using class /1/ showers, keeping only HC information and suppressing IE information.

b) for about 20% of class /1/ showers the parent hadron passes through IE behaving as a mip and starts showering in HC. This subclass of /1/ could be used to describe the class /3/ showers.

Observation: A comparison between HSL and GEANT shown a good agreement for all three classes of showers. A special situation is when the impact point is on IE, but near its edge. The procedure used in this case is to fill only the blocks of that IE half where the impact point is located and to ignore all elements of IE GEANT array which are outside it. How well this approximation works is still under test.

- Distribution of shower energies in HSL

The hadron momenta don't populate uniformly the allowed kinematic range. The distribution obtained in ROGUE by taking into account all of hadron tracks surviving the calorimeter acceptance tests is given in fig. 4.

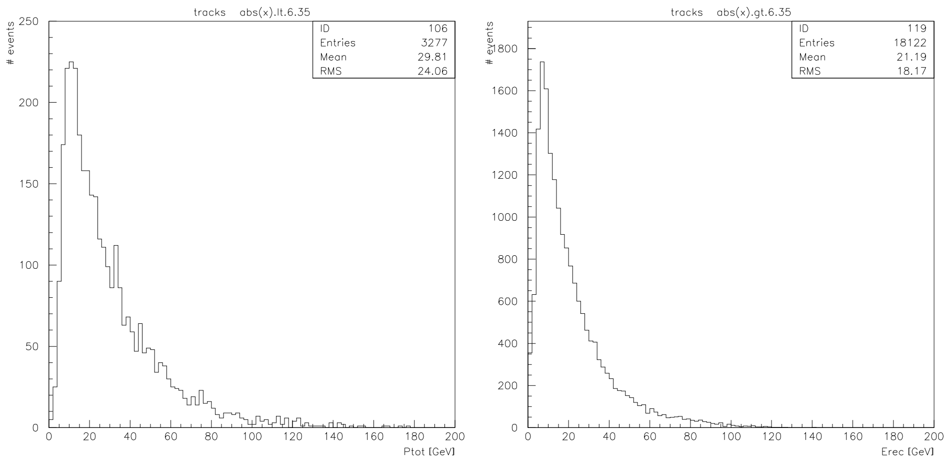

Figure 4: Momentum distribution of hadrons hitting the IE calorimeter (right), or the vertical aperture region (left) as simulated in ROGUE

The distribution of hadron momenta served as a guide in selecting the energies to simulate the showers and the number of showers at each value of energy. The table below summarizes the actual situation in HSL.

range [GeV]	step [GeV]	no. of showers
5 - 30	5	500
30 - 100	10	500
100 - 200	10	200

total: 8500 showers

• Shower selection procedure for a track with total momentum p hitting the calorimeter surface in the point (x, y)

All operations are concentrated in the routine **fetch_shower.sf**. The main steps which are performed by this routine:

/a/ finds in the list of shower energies those which are the closest to p, i.e. $E_i \leq p \leq E_{i+1}$ and from these two, selects the value to which p is closer, say for example E_i.

/b/ fetches randomly from HSL one of the showers with the energy E_i

/c/ position the center of the GEANT arrays on (x, y), applies randomly one of the eight symmetry transforms and spill the cell contents in the corresponding IE and HC blocks, a procedure which as explained before, depends on the region where the incident point falls

/d/ interpolates the HSL values to incident hadron momentum, by applying a scaling factor p/E_i to all entries in IE and HC blocks

/e/ applies the calibration factors to the quantities filled in IE and HC blocks

/f/ adds the contents of filled blocks to the ROGUE arrays $LGENER$ and $NHCMCGEV$.

Hadron Shower Library implementation in ROGUE

- The main principles in implementing the HSL:
  i. to operate minimal changes in the present ROGUE code,
    ⇒ **iesim.sf** modified to make operational HSL option
    ⇒ **rghktrg.sf** modified to allow HSL option (presently this routine forces the use of crude shower parametrisation when HSL is selected)

  ii. to concentrate all new created code in a few routines
    ⇒ in fact is the newly created routine **fetch_shower.sf** which performs all operations related to HSL. Some operations are performed in **simsw.sf** (symmetry transform on the fetched shower) and **findhc.sf** (finding the tile number which corresponds to a given point (x, y)) which are called in fetch_shower.sf. Routine **lettera.sf** is connected to handling of information from the ascii direct access file.

  iii. to conform to the existent concepts and standards of ROGUE.
    ⇒ opens the files using routine **getlun**
    ⇒ HSL was created as an ascii file

⇒ to select the HSL, the procedure is the same as for any other option in ROGUE (see below). What the user has to do in addition is to set the values of two environmental variables to point to the location of the two HSL files:

HSWLIB to hsl.dat (the library file)

HSWPOI to hcslpointer.dat (the auxiliary file)

It is supposed that these two files will be copied on every local node running $e831$code.

- To run ROGUE with HSL, one should use the template created by Harry. There are three options for calorimetry: a crude shower parametrization, HSL and detailed GEANT simulation. To select HSL, one has to set the following flags in the *.mcf control file :

  DOIE T

  DOHC T

  HCSIMLEVEL 1

  IESIMLEVEL 1

- HSL file size for the actual number of 8500 showers

  ascii direct access file: $26Mbytes$, after removing the zeroes in HSL arrays (work done by Marco Merlo). This was done at the price of creating an auxiliary, but small file ($76Kbytes$) (The Zebra file is even lower: $14Mbytes$, probably this is the lowest limit, but using it could produce some complications)

- execution time: only with 10% more than running Rogue with crude hadron shower parametrization and 20 times faster than running with detailed GEANT option

- the tests done sofar have shown a good agreement between the HSL simulated showers and GEANT simulations or real shower data.

Conclusions

1. a hadron shower library based on GEANT simulation was created for ROGUE

2. ROGUE runs fast with the hadron shower library

3. the hadron shower library organized as a direct access file, which is reasonable in size

4. the preliminary tests have shown that it works well