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DETAILED GEANT DESCRIPTION OF THE SDC CENTRAL CALORIMETERS

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Описание центрального калориметра SDC в рамках программы GEANT

Представлено описание модели центральных калориметров SDC в рамках программы GEANT и некоторые результаты, которые были получены при использовании этой модели. Геометрия э.м. и адронных калориметров была закодирована на базе GEANT в рамках общей программы SDCSIM моделирования SDC установки. При описании геометрии калориметров использовались чертежи из FNAL и ANL и файл данных для адронного barrel калориметра. Детальное описание центральных калориметров SDC необходимо для различных задач моделирования, для настройки параметров программы быстрых симуляций ливней, для изучения влияния различных геометрических особенностей на характеристики калориметра и для создания программы анализа данных. Эта модель полезна при решении задач калибровки калориметров: как в тестовом пучке, так и в составе установки.

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Detailed GEANT Description of the SDC Central Calorimeters

This article represents the very detailed simulation model of the SDC central calorimeters and some results which were obtained using that model. The central calorimeters structure was coded on the GEANT 3.15 base in the frame of the SDCSIM environment. The SDCSIM is the general shell for simulation of the SDC set-up. The calorimeters geometry has been coded according to the FNAL and ANL engineering drawings and engineering data file.

SDC central calorimeters detailed description is extremelly useful for different simulation tasks, for fast simulation program parameters tuning, for different geometry especially studing (local response nonuniformity from bulkheads in the e.m. calorimeter and from coil supports and many others) and for the interpretation of the experimental data from the calorimeters. This simulation model is very useful for tasks of the test beam modules calorimeter calibration and for calorimeter in situ calibration.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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1 Development of the Calorimetry Package in the SDCSIM environment

1.1 Introduction

The basic functions of the calorimeter systems on the collider experiments are to identify electrons and photons and measure their energies (in conjunction with the tracking system), to measure the energies and directions of jets, and to provide hermetic coverage for measurements of missing transverse energy. For SDC the central pseudorapidity range ($|\eta| < 3$) is covered by barrel and endcap calorimeters surrounding the solenoid and tracking volume. Hermetic coverage is completed by the forward calorimeter system, which covers $3 < |\eta| < 6$.

1.2 Highly detailed GEANT description of the SDC central calorimeters

About one hundred engineering drawings from ANL and data file from FNAL were obtained earlier 1993 year. These drawings and data enabled us to understand the absorber geometry of the barrel hadron calorimeter wedges and barrel electromagnetic calorimeter wedges. We coded the detailed barrel calorimeter structure. Also we coded the end cap calorimeters.

The level of detail of the barrel wedges is very high (see Figure 1). This reflects the fact that the design of the modules is advanced because actual prototypes are being manufactured and readied for assembly by the end of 93 year. The end cap description is more idealized and reflects the current level of engineering detail but the description is sufficient for physics studies.

The description of the SDC central calorimeters (calorimetry package (CP) in the SDCSIM frame) includes :

- A detailed plate structure in the barrel hadron calorimeter, with the dog-leg feature in the wedges

- The fine structure of the barrel e.m. calorimeter including wedge subdivision, honeycomb support plate, $\eta = 1.4$ module end plates, side skins, adapter plates, bulkheads and hadronic calorimeter plates in the electromagnetic modules

- The end cap hadron and e.m calorimeter detailed geometry

- The structural supports of the solenoid cryostat
- Description of the barrel and end cap shower maximum detectors
- Some cracks between wedges and tiles are put in, as estimated

Although CP is written in general structure of SDCSIM, it uses regular GEANT (version 3.15). The energy depositions are recorded for both active and inactive material. There is possible to see the energy deposition for active and passive material of each calorimeter tower and the energy deposited in the wedges skin, bulkheads of the e.m. calorimeter, coil supports, front plate and others constructive elements of the central calorimeters.

1.2.1 Barrel calorimeter

The barrel calorimeter has a modular structure. The electromagnetic and hadronic sections touch each other without a gap.

The detailed geometry for the barrel hadron calorimeter was coded from the FNAL drawings and from the data in the file 'cpbhplat.dat'. This file of data was created from an EXCEL document using a special translation program. EXCEL is used by engineering staff at Fermilab to generate the actual prints used for absorber components building. It is important to note that in the event of some change in the barrel hadron calorimeter design, those changes should be made in that EXCEL document by FNAL engineers. Then simple electronic transfer of the file gives the possibility of automatic updating the simulation geometry of the hadron barrel calorimeter.

The data file containes information about each plate of the barrel hadron calorimeter such as:

- The type of plate (milled or spacer plates)
- The number of slots in the milled plate
- The dimensions of the plate
- The location of the plate
- The dimensions and location of the scintillator slots in the each plate and so on...

Each barrel hadron calorimeter wedge consists of the milled plates with scintillator slots interspaced by the spacer plates. All plates are made of steel. For better confinement of the shower energy the barrel hadron calorimeter wedges are divided into two types: 'INNIE' and 'OUTIE' and form a dog-leg shape. Figure 2 shows a cut view of the barrel calorimeter. The H1 (part of the barrel hadron calorimeter) differs from H2 by the thickness of both

the milled and the spacer plates. The absorber wedges are machined after the plates are welded. The barrel calorimeter must be assembled after each wedge is instrumented with scintillator tiles, wavelength shifting fibers and photomultiplier tubes for readout.

Barrel hadron calorimeter energy depositions are stored in the arrays BRH1(28,64,2) and BRH2(28,64,2). The first index of the BRH1 and BRH2 '1:28' refers to the η segmentation and the second one '1:64' refers to the ϕ segmentation (ϕ is the azimuthal angle). The last one '1:2' tells where the energy deposition happens: 1 is for the scintillator tiles and 2 is for the absorber (steel) material.

Barrel electromagnetic calorimeter basic structure includes the following features :

- the wedges and subwedges consist of the absorber and scintillator plates
- there are the hadronic plates with the scintillator slots at the top of the electromagnetic calorimeter at the $|\eta| > 0.5$ region
- the adapter plate with the scintillator slots is added on the top of the barrel electromagnetic calorimeter, that plate is the connection between the electromagnetic and hadronic parts of the barrel calorimeter
- the honeycomb support plate of 'light' aluminium is added at the front of the barrel electromagnetic calorimeter
- the steel end plates are added at the $\eta = 1.4$ edges of the e.m. barrel calorimeter
- the aluminium skin is added at the sides of the barrel e.m. calorimeter wedges
- the stainless steel bulkheads are included in the barrel e.m. calorimeter and in the barrel shower maximum detector according to the drawings.

Details of the barrel calorimeter can be seen on Figure 3. The energy deposition from the barrel electromagnetic calorimeter (dE/dx) are accumulated and stored in the correspondig arrays. There are arrays for store energy deposition in the 'massless' gap, in the hadron calorimeter layers which are implanted in the barrel e.m. calorimeter structure, in the aluminium radial skin of the barrel e.m. calorimeter wedges, in the steel bulkheads of the barrel e.m. calorimeter and other parts.

1.2.2 End cap calorimeter

The main features of the end cap e.m. calorimeters (see Fig. 4) are as follows: longitudinally, the structure spans the massless gap detector, the first electromagnetic sector (including the shower maximum detector) and the second electromagnetic sector. The η region coveres $1.4 \div 3.0$ ranges. There is a smal aperture overlap between end cap electromagnetic and barrel electromagnetic sections. The shower maximum detector is located after layer 5, the division between EM1 and EM2 is at layer 8.

There are 16 wedges in the end cap hadron calorimeters. Each wedge is composed of two half wedges. The structure in these two half-wedges is staggered about 2 sm along the z direction between each other, so that the steel structure is continuous and allows magnetic flux to go through. Also there is a similar dog-leg feature as in the barrel to avoid a phi crack going all the way from the front to the back. This helps in the measurement of missing E_t.

There is a phi crack 0.3 cm between wedges and a dead region 0.3 cm between tiles.

1.3 Fine scan of the calorimeter geometry and the geometry especially

The material in front of the calorimeter influences both the energy and coordinate calorimeter resolution and consequently makes worse the two shower resolution. It is important to obtained the material distribution in front of the calorimeter for correct interpretation of the calorimeter energy and coordinate resolution results coming from the simulation and future in-situ calibration.

The scan of the caloimeter geometry was done in the frame of the SDCSIM shell. The all eta scans at the Figures were performed with the η step 0.005 at the ϕ 5.5 degrees. This phi value was chosen from one hand to avoid different cacks between calorimeter modules and on the other hand to do this scan through the 'warm' supports of the coil. The area of the e.m. calorimeter ϕ cracks is about 1 % of the inner e.m. calorimeter surface. Two pictures on the Figures with and without supports demonstrate the supports material contribution.

In the Figure 05 the e.m. and hadron calorimeter depths are presented.

The two peaks at the $\eta = \pm 1.4$ for the e.m. calorimeter are due to aperture overlaping of the barrel and end cap parts. The stairs - like structure for the e.m. calorimeter in the region $0.5 <| \eta |< 1.4$ reflects the real design of that one. The two pits at the $\eta = \pm 1.38$ for the hadron calorimeter are connected with the hadron calorimeter structure. The sharp hole for the hadron calorimeter at the $\eta = 0$ (see Figure 05) is caused by 1 cm air crack between hadron calorimeter wedges. This hole is clear seen on the bottom picture (Figure 05). Two small peaks at the both side of that hole are related with the absent of the scintillator material in the hadron calorimeter close to the $\eta = 0$ position.

Figure 06 shows that the amount of material before the central e.m. calorimeter, contributed by tracker and coil is increasing from 1 to 2 radiation length within $| \eta |< 1.4$. The warm supports rise the material in front of the end cap e.m. calorimeter up to 3 radiation length in the sharp region at the η about $| 1.4 |$.

The material in front of the hadron calorimeter is presented in the Figure 07 in the term of absorbtion length. One can easily recognize the manifestation of the e.m. calorimeter with its structural specifics. The $\eta = 0$ peak is due to the steel plate between the wedges of the barrel e.m. calorimeter. For the region close to $\eta = 0$ there are about 1 absorbtion length of the e.m. calorimeter material and about 9 absorbtion length of the hadron calorimeter. So the total calorimeter depth for that region is about 10 absorbtion length which is required to provide sufficient containment for high energy jets (see Technical Design Report, [1]).

2 Shower energy sharing between barrel calorimeter modules

Hadron energy leakage between calorimeter modules is discussed in the contexts of a detailed and parametrized descriptions of hadronic shower development.

For the purpose of calorimeter module calibration, it is important to know the relative sharing of shower energy between towers. Here we simulate the development of hadronic showers using a GEANT/GHEISHA based description of the calorimeter (SDCSIM/CP) and several fast shower parametrizations. In the detailed simulations, 50 GeV pions were started at a fixed pseudorapidity $\eta = 0$. The azimuthal angle ϕ was varied from 95.625 to 90.000 degrees corresponding to moving from the one towers boundary to another. The description level of the SDC detector currently is such that it includes minute details of the beam pipe, of all the tracking systems, of the superconducting coil with its cryostat and of the calorimeters. However, to best approximate the test beam conditions, all elements radially inwards of the barrel electromagnetic calorimeter were turned off. Energy cuts were set at 1 MeV. At each scan point, typically 250 full pion showers were generated.

The amount of transverse hadronic energy leakage was also calculated using a fast shower parametrization. The showering algorithm was first implemented by authors of the FLUKA [2] simulation program. The salient feature of this program is that the hadronic transverse energy profile is distributed in a piece-wise manner: energy which is deposited within two interaction lengths of the shower axis is distributed according to a single Gaussian; that outside by a double Gaussian. Here, only rudimentary volumes were used with no effort to reproduce the details of the detector structure. The calorimeter was simulated using a monolithic block of material composed of a mixture approximating the behavior of the proposed lead/scintillator and iron/scintillator designs. A particle gun was used to shoot 50 GeV pions into the simulated SDC calorimeter. A ϕ - scan was performed across the face of a calorimeter wedge. Approximately 2500 pions were generated at each scan point. The energies deposited in the e.m. and hadron sections were summed to obtain the results on the transverse leakage.

Other fast simulation methods we have used rely on simulations of the transverse energy profile of hadronic showers and are detailed elsewhere [3].

Comparison of wedge energy containment using different simulation approaches is shown on Figure 08. Triangles describe the result of detailed simulations. The 16-th and 17-th towers are formed the calorimeter wedge (Fig. 08). Squares and other symbols indicate the results obtained by fast shower parametrization. In these approaches, different radial energy profile slopes were used in the integration.

The detailed simulation results are close to the UA1 parametrization and all methods give more than 90 % containment at the center of the hadron wedge ($\phi = 0.1$).

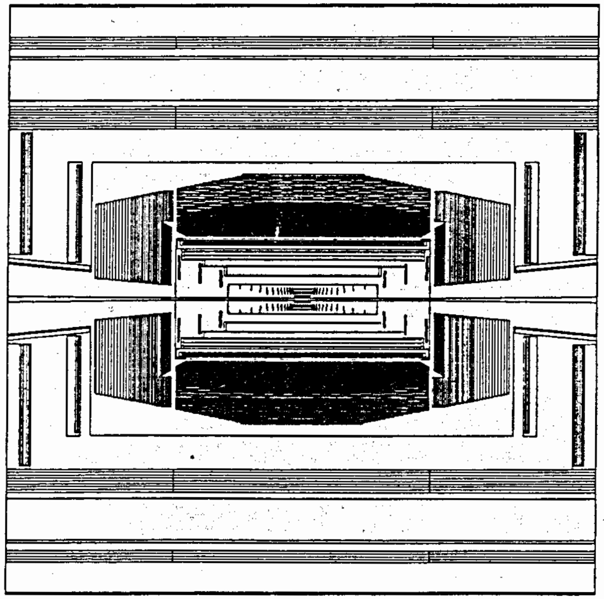

Figure 1. - Side view of the SDC detector featuring the highly detailed central calorimeters produced by the CP package.

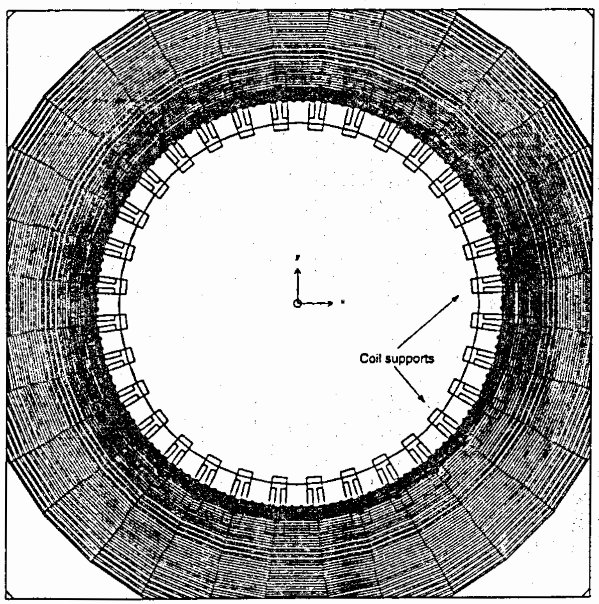

Figure 2. - Cut view of the SDC barrel calorimeter. The details of the electromagnetic and hadronic compartments are visible. The tracking systems are not displayed.

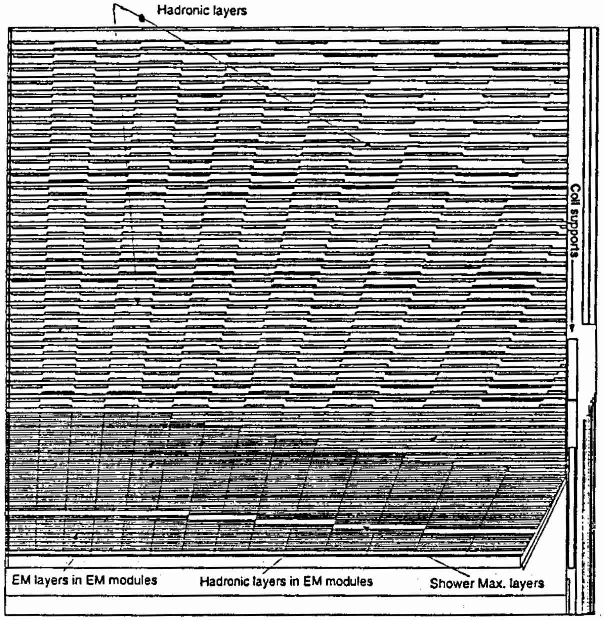

Figure 3. - Side view of the barrel calorimeters modules. The EM and hadronic layers are visible. The bulkheads in the EM modules and the tile staggering in the hadronic modules outline the tower structure. The shower maximum layers are visible.

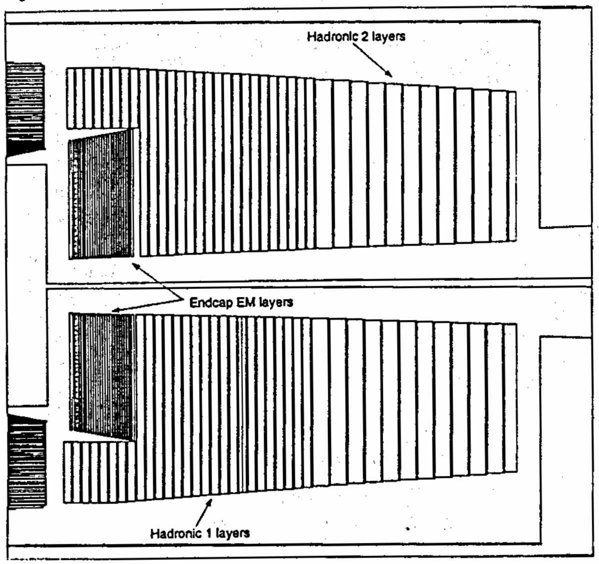

Figure 4. - Details of the endcap calorimeters. The monolithic EM calorimeter is visible, backed by the hadronic calorimeter. The z- axis runs left to right. The tracking systems are not displayed.

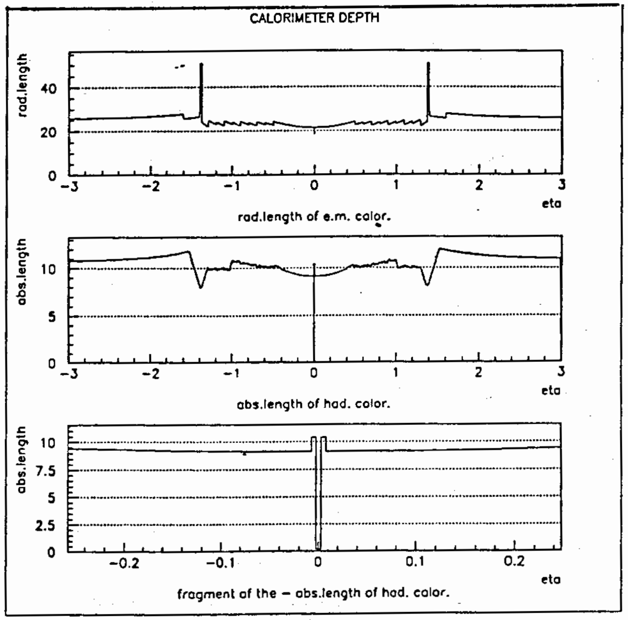

Figure 5. - The amount of the material in the central calorimeters.

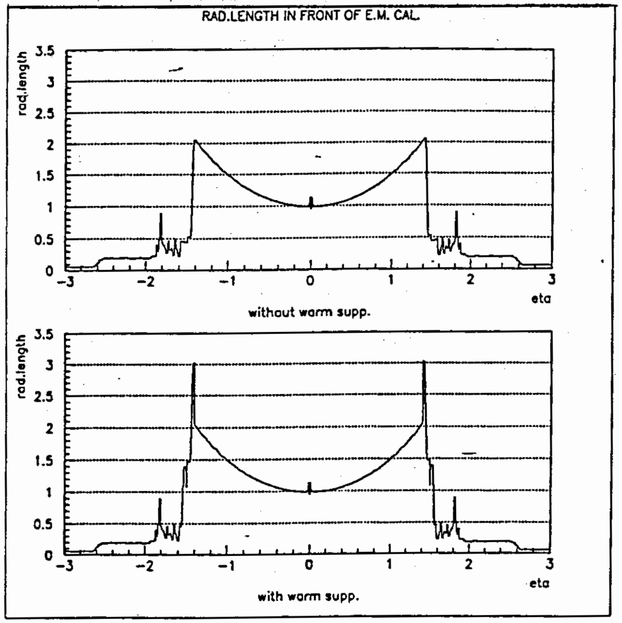

Figure 6. - The amount of the material before the central e.m. calorimeter.

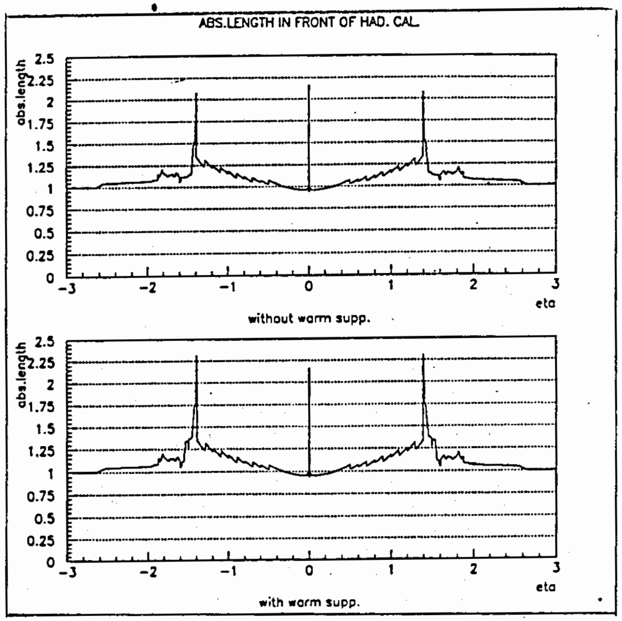

Figure 7. - The amount of the material in front of the hadron calorimeter.

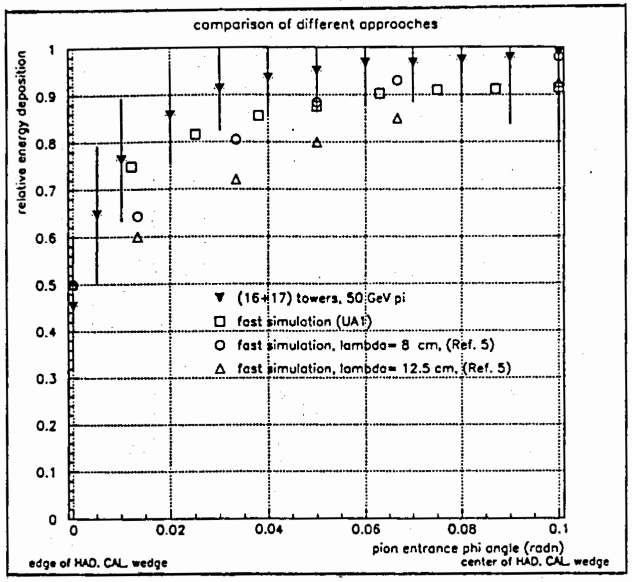

Figure 8. - Relative energy deposition in the calorimeter wedge. Triangles depict full GEANT simulations. Squares depict UA1 fast parametrization simulations. The other two sets of points were obtained by integration of the simulated energy profile.

3 Conclusion

Detailed GEANT 3.15 description of the SDC central calorimeters was done in the frame of the SDC set-up simulation program. We write a special translation program to transfer data from the engineering data file to the simulation code. This is a step in the solution of the big problem: how to use the same data base for engineer designer programs (like AUTOCAD) and for simulation programs (like GEANT).

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