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The TOSCA-GEANT Interface Tools

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Abstract

To imply a nonuniform magnetic field into GEANT package, the interface programs are developed to prepare the solenoid and dipole field maps from 3-d magnetic field calculations performed with the Vector Fields code TOSCA. The several tens patches in some planes of the magnetic system are used to create the tables of the magnetic flux density. The tables are converted into the ZEBRA data base structure which can be used in any kind of the UNIX machines to be read by subroutine GUFLD created to obtain the magnetic flux density in any point of magnetic system during GEANT simulations. The size of the invariant data base structure is small. The algorithm of the field linear interpolation over eight neighboring grid points is enough fast. The programs are tested for the CMS magnetic system at IBM/AIX, DEC/Digital UNIX, HP/HP-UX, SGI/IRIX machines and could be used for the ALICE magnetic system as well.

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1 Introduction

The Vector Fields code TOSCA [1] is popular to perform the three-dimensional finite-element magnetic field calculations for the LHC experimental setups. One task of such the calculations is to prepare the map of the nonuniform magnetic flux density, **B**, to be used in the GEANT [2] detector simulations. The magnetic flux density grid data base and the user routine GUFLD, which can work with this data base, should be created as the tools for this task.

Author's experience in the modeling the magnetic systems in framework of the Vector Fields system OPERA-3d [3], which includes TOSCA as the electromagnetics analysis program, tells that the OPERA-3d data base is too huge to be used in GUFLD routine directly. To describe the CMS magnetic system [4] or the ALICE one [5] it takes to use $\sim 10^5$ nodes of the finite-element mesh [6, 7].

Basing on the ideas expressed in [8], the minimum number of the magnetic system cross sections by planes is used to tabulate the values of **B** and to prepare the ZEBRA [9] data base structure which can be read in any kind of the UNIX machines. The user routine GUFLD, which can obtain the values of **B** in any point of magnetic system using the data base, is developed.

2 Invariant data base structure

An interleaving the iron and air in such a magnetic system, as the CMS one is, or combination of the solenoid and dipole magnetic fields, as is done in the ALICE magnetic system, makes the task of the field map extracting as nontrivial one. To do this for the CMS magnetic system, one eighth of the magnetic flux return yoke is used for the computations as shown in Figure 1. This is a minimum configuration to adjust the geometry of the barrel and end-cap yoke to the geometry of the hadronic forward calorimeter and to use the same boundary conditions on the magnetic scalar potential in both these parts.

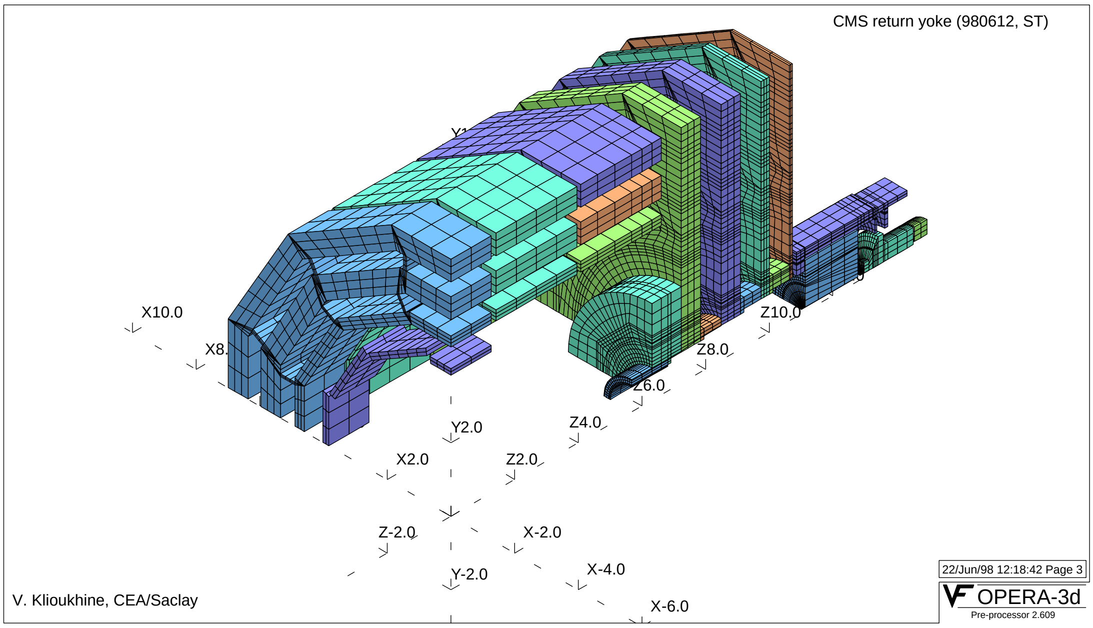

Figure 1: TOSCA computer model of the iron yoke of the CMS magnetic system.

In Figure 1 the origin of the Cartesian coordinate system is placed in the center of the CMS solenoid (not shown), the direction of Z-axis is along the solenoid and beam axis, the direction of Y-axis is upward.

To prepare the grid data base the only ten azimuthal RZ-planes are used: five from $0°$ to $15°$ through the barrel and end-cap yoke and five from $0°$ to $22.5°$ through the hadronic forward calorimeter. The rotations and reflections are used to propagate these grid planes to all the magnetic system.

Along z-axis the RZ-planes cover 10×16 m^2. This is too large to use the standard OPERA-3d map extraction procedure. As shown in Figure 2, in this case the field map resolution is poor because the number of the plane map points is restricted by 4096, so, the map grid cell can not be smaller than 0.2×0.2 m^2. To resolve this problem, we use the OPERA-3d command language to construct the map in each grid plane from several tens of patches. Thus, XOZ-plane shown in Figure 3 is prepared from 89 patches, that gives a good field resolution and permits to use finer grid in the regions with the high field gradient.

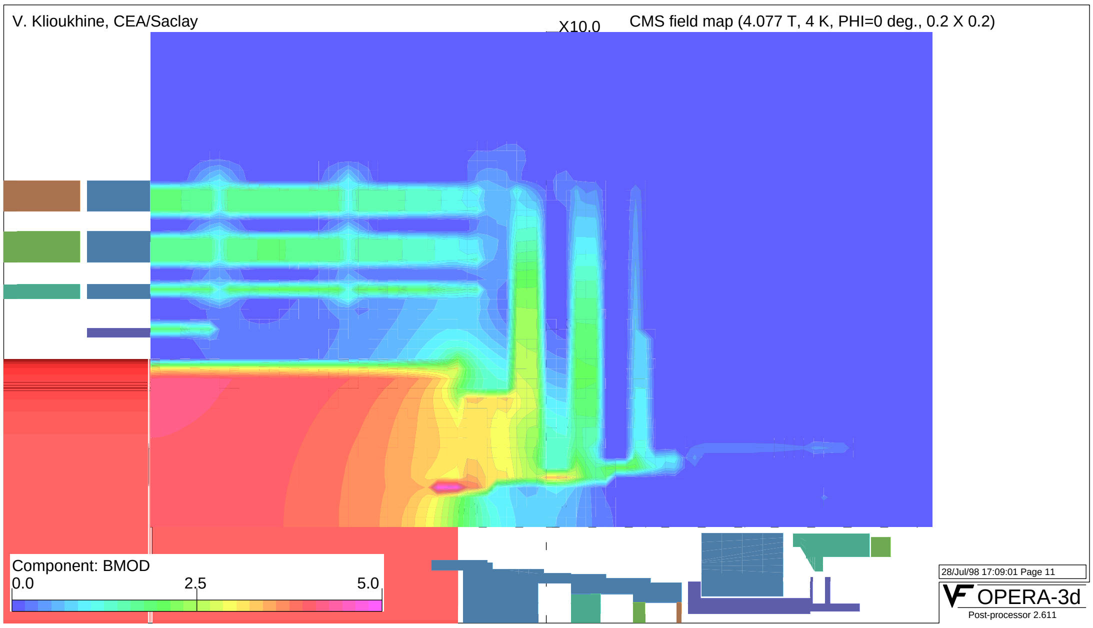

Figure 2: The CMS magnetic flux density map extracted in a standard way.

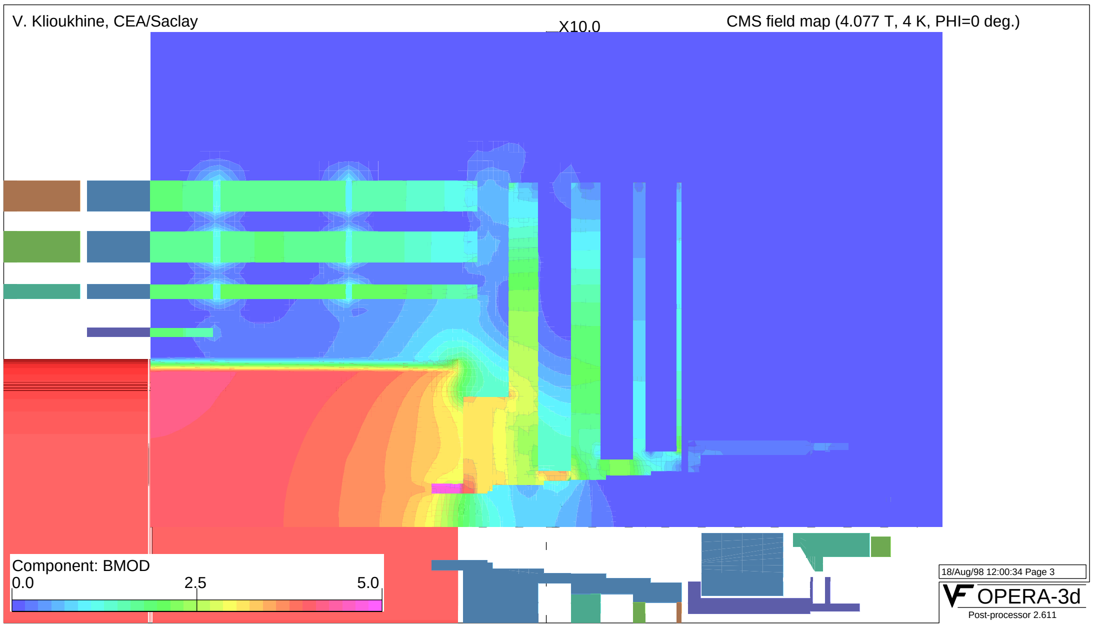

Figure 3: The CMS magnetic flux density map constructed from patches.

In such a way the values of **B** are tabulated in 66 490 space points. To calculate the field in a right way, the gap of 0.2 mm between the patch boundaries is used along the iron-air interface surfaces.

A special program TOSGT is written to convert the tables of **B** into the ZEBRA data base. The structure of this data base shown in Figure 4 includes the banks of the coil parameters and two trees of the field map grid patches in RZ- or XY-planes. The XY-plane tree is reserved to be used in the magnetic systems of the ALICE type. The way of preparing the field map grid in this case is shown in Figure 5.

```
         +---------------+
         |     MFLD      |
         |  Header bank  |
         +---------------+
             |   |   |
             |   |   |
    +--------+   |   +--------+
    |            |            |
+-------+    +-------+    +-------+
| COIP  \    | RMAP  \    | XMAP  \
|  -1   /    |  -2   /    |  -3   /
+-------+    +-------+    +-------+
                 |            |
             +-------+    +-------+
             | RPAT  \    | XPAT  \
             |  -1   /    |  -1   /
             +-------+    +-------+
```

Figure 4: ZEBRA structure of the magnetic field map.

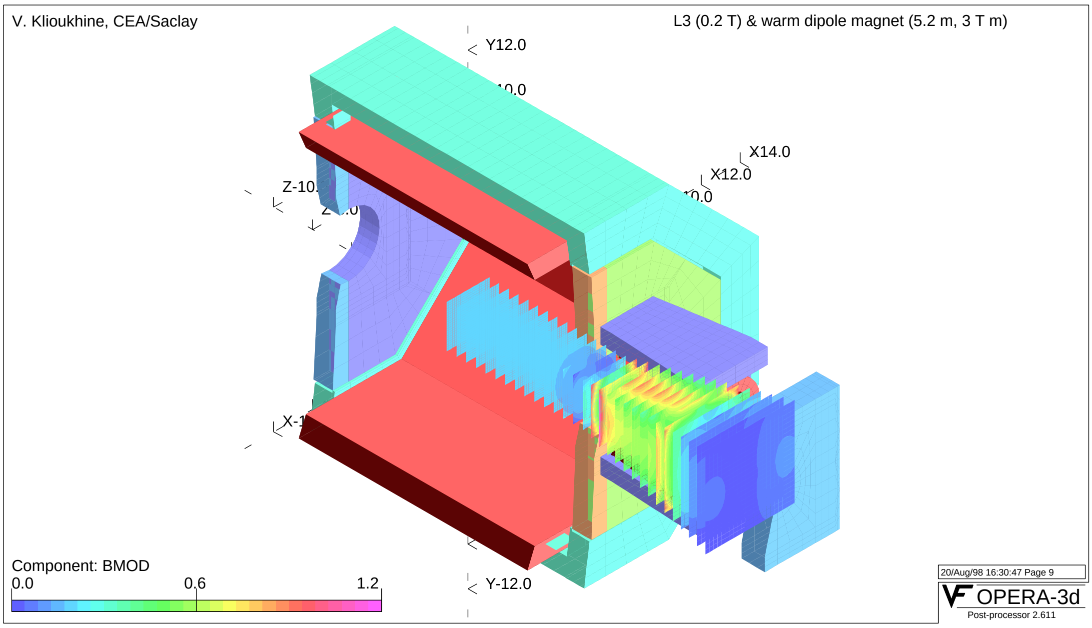

Figure 5: Magnetic flux density planes in the ALICE magnetic system.

To reduce the size of the data base structure, the only components of **B** are stored without storing the space point coordinates which should be computed in GUFLD routine from the stored minimum and maximum coordinate values. To describe the CMS magnetic system, the structure size needed is 0.85 MB.

3 GUFLD Routine

The purpose of GUFLD routine is to return the magnetic flux density components in any space point of the magnetic system. During the first call it reads the data base structure into a special ZEBRA division and then works with it to search for the grid points in two planes surrounding the input space point. To obtain the components of **B**, an input space point is projected onto two neighboring grid planes and then in each plane we use a linear interpolation formula which weights the values of the components in the projected point according to the distances from the four nearest neighboring grid points. For RZ-plane the formula is given by:

$$B_i = \frac{(B_{i1} \cdot \Delta r_2 + B_{i2} \cdot \Delta r_1)\Delta z_2 + (B_{i3} \cdot \Delta r_2 + B_{i4} \cdot \Delta r_1)\Delta z_1}{(\Delta r_1 + \Delta r_2)(\Delta z_1 + \Delta z_2)} \quad \text{for} \quad i = x, y, z.$$

The distances from the planes are used then to obtain the field in the space point.

To estimate a response time of GUFLD routine, the points along the straight trajectories at different polar angles have been used. Depending from the angle, that time is 60–130 μs per point.

4 Conclusion

The TOSCA-GEANT interface tools are created and tested for the CMS magnetic system at IBM/AIX, DEC/Digital UNIX, HP/HP-UX, SGI/IRIX machines. It could be used for the ALICE magnetic system as well.

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References

[1] Vector Fields Limited. 24 Bankside, Kidlington, Oxford OX5 1JE, England.

[2] **CERN Program Library Long Writeup W5013, 1994**, *"GEANT – Detector Description and Simulation Tool"*.

[3] **VF-01-98-D4**, Vector Fields Limited, 24 Bankside, Kidlington, Oxford OX5 1JE, England, *"OPERA-3d Reference Manual"*.

[4] **CERN/LHCC 97-10, CMS TDR 1, 2 May 1997**, *"CMS. The Magnet Project Technical Design Report"*.

[5] **CERN/LHCC 96-32, LHCC P3 Addendum 1, 15 October 1996**, *"Addendum to the ALICE Technical Proposal – The Forward Muon Spectrometer of ALICE"*.

[6] **Internal Note ALICE/MAG 96-44, 1997**, V. I. Klyukhin, W. Klempt, L. Leistam, D. Swoboda, *"The ALICE Dipole Magnet Calculations"*.

[7] **CMS Note 1998/048**, F. Kircher, V. Klioukhine, B. Levesy et al., *"A Review of the Magnetic Forces in the CMS Magnet Yoke"*.

[8] **D0 Note 1310, 1991**; **CERN Report 92-07, 1992, pp. 844-846**, V. I. Klyukhin, *"Interface program for POISSON and GEANT packages"*.

[9] **CERN Program Library Long Writeup Q100 and Q101, 1993**, *"The ZEBRA system"*.