Improved Web Tool for Studying CMS Simulated Radiation Data

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Abstract

With high energy collision experiments, detector elements are susceptible to radiation damage. The radiation environment of the CMS detector is extremely intense. Radiation data is simulated and the web tool allows one to access and study this data in a number of ways. Improvements to this tool have been made and make it much more useful and therefore can help in pursuits to optimally protect the detector and it's electronics.

Introduction

The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator. The LHC experiments consist of proton-proton beam collisions with a design energy of 7 TeV per beam for a center of mass collision energy of 14 TeV and a design luminosity of 10^{34} cm^{-2}s^{-1}. The collisions make the surrounding radiation environment extremely intense and can compromise the performance quality of detector subsystems. In the 2010/2011 and 2012 operations, beam energies were set to 3.5 TeV and 4 TeV, respectively [1]. Scheduled upgrades for 2015 operations will have the beams running at 6.5 TeV [2]. The Compact Muon Solonoid (CMS) detector will also undergo upgrades to work with these higher energies, and recursively. Even after upgrades, some inner layers of the detector centimeters from the beam line will be replaced every couple of years [3]. By studying simulated events we can better understand how these intense radiation environments interact with detector elements, and therefore optimally prepare and maintain the CMS detector for future runs. The web tool provides a powerful interface for accessing & examining the simulated radiation data. Numerous improvements have been made to the tool to further its usefulness and capabilities.

Simulations Software & Data Generation

Radiation dose and particle fluxes are tracked in the CMS detector using two different Monte Carlo packages: MARS and FLUKA. Obvious differences between MARS and FLUKA data are the number of statistics, granularities, and scoring thresholds [4]. Both Simulations score radiation dose and the following fluences throughout the detector: Neutral Hadron, Charged Hadron, Photon, Electron/Positron, and Muon. Separate data is generated for both tracker and full regions of the detector. The calorimeter region has now been phased out of the process, and instead can be studied using the full detector data. Currently the data bin sizes are 2x1 cm and 8x3 for the Tracker & Full volume, respectively. Once the data is generated from the simulation runs it is stored into an SQL database and can then be accessed by the web tool.
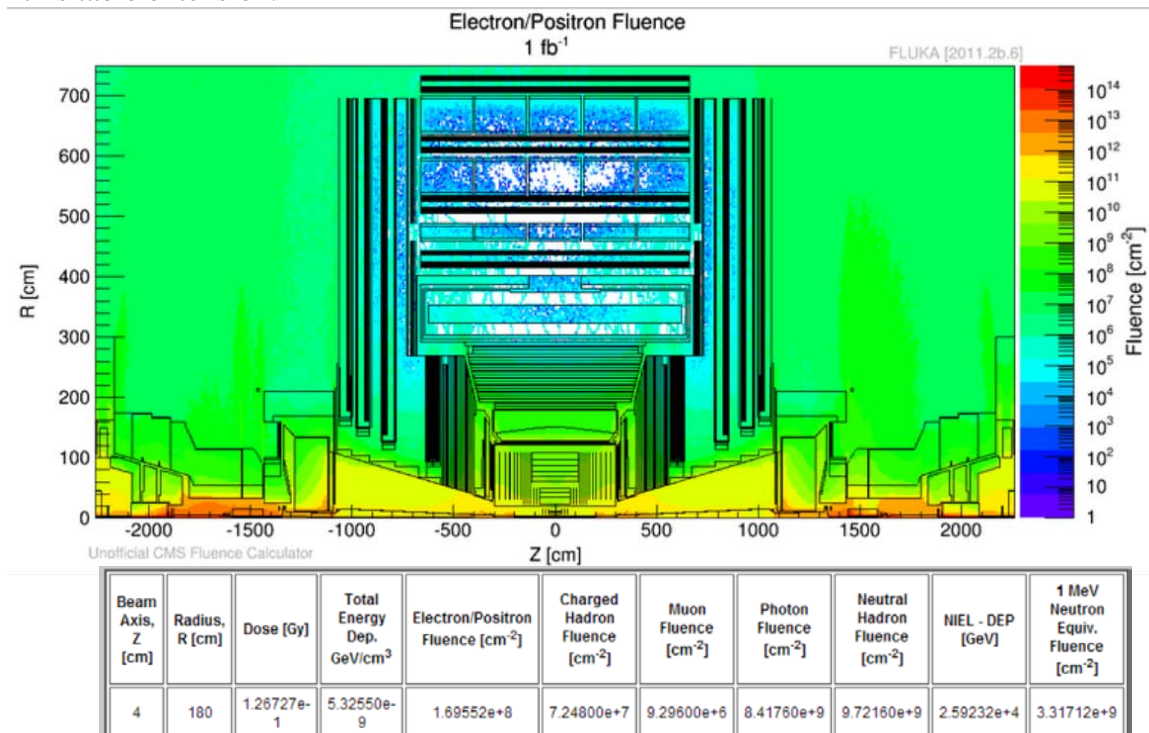
Web Tool

The web tool, originally developed in 2009 by D. Haznar and P. Bhat, stands as an interface for users to access and study the simulated radiation data [5]. It provides much flexibility and there are numerous options and features available to facilitate all queries. The tool also allows access to both FLUKA and MARS simulations data. There are three different options for accessing the data: Point Calculator, 1D Plots, and 2D Plots. The Point Calculator allows one to view data at any (R,Z) point in the detector region. 1D Plots are graphs as a function of either radial distance from the collision point, R or distance along the beam line, Z, see Figure 3. 2D Plots are interactive color histograms that plot Radial Distance vs. Beam Line Distance, see

Figure 1. The web tool is already powerful and offers a lot to a user, however there is still plenty of room for improvement and many areas can be enhanced. Such improvements that have been made to the tool include interface enhancements, interpolated data calculations, and a multi-file system.

Interface Enhancements

The Web tool presents numerous options and settings permitting a user to be as flexible as possible when accessing data. In order to make the tool more presentable and straightforward there has been some interface enhancements. The web tool now has an input validation system that checks inputs at each step in the forms. All user inputs are validated for correct ranges and values. These ranges vary depending on options such as the volume and data quantity selected. All invalid inputs are prompted for correction before moving to the next step. This ensures that a user can only request data that we have stored and also ensures no errors can be sent to the processing scripts or databases.

Another feature added to the user interface is a number drop down selection for the 2D Plots tool. Based upon the Simulation selected along with the volume, a pre-loaded list of integers populate the range selection list. These integers are loaded to correspond to the bin spacing of the particular data set selected. This takes care of any over or under binning issues that might occur when bins returned do not properly fit in the selected ranges. The 2D plots tool has also been improved alongside the data fetch feature that allows interactive point requests. The data fetch feature now returns all data quantities at that point in a formatted table. This is important when trying to compare fluences or doses quantitatively. Figure 1 depicts an instance of this table extension.

Beam Axis, Z [cm]	Radius, R [cm]	Dose [Gy]	Total Energy Dep. GeV/cm^3	Electron/Positron Fluence [cm^{-2}]	Charged Hadron Fluence [cm^{-2}]	Muon Fluence [cm^{-2}]	Photon Fluence [cm^{-2}]	Neutral Hadron Fluence [cm^{-2}]	NIEL - DEP [GeV]	1 MeV Neutron Equiv. Fluence [cm^{-2}]
4	180	1.26727e-1	5.32550e-9	1.69552e+8	7.24800e+7	9.29600e+6	8.41760e+9	9.72160e+9	2.59232e+4	3.31712e+9

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Figure 1: 2D Plot of Electron/Positron Fluence at 1 fb^{-1}, and a extended data fetch table

An additional enhancement to the interface was the integration of all secondary forms on one page. With the 1D Plots tool where you have more than two forms to complete, this is especially useful. It allows a user to easily backtrack information previously entered.

Two options have also been added to the web tool. The first option is a Geometry on/off switch for the 2D Plots, and it gives the user the option to draw the detector outline with or without the data. Figure 2 depicts a 2D Plot with only the geometry plotted at specific ranges.
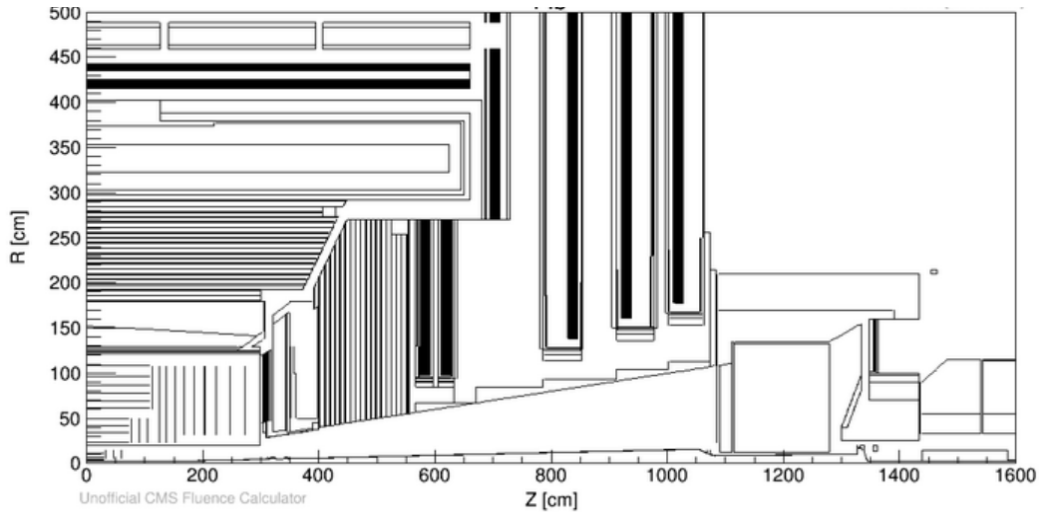
Figure 2: 2D Plot Detector outline only

The second added option gives the user the choice to utilize FLUKA & MARS data with one request. This makes it easy to compare and cross check both simulations. Figure 3 depicts Charged Hadron Fluence plotted as a function of Z at R=250 cm.
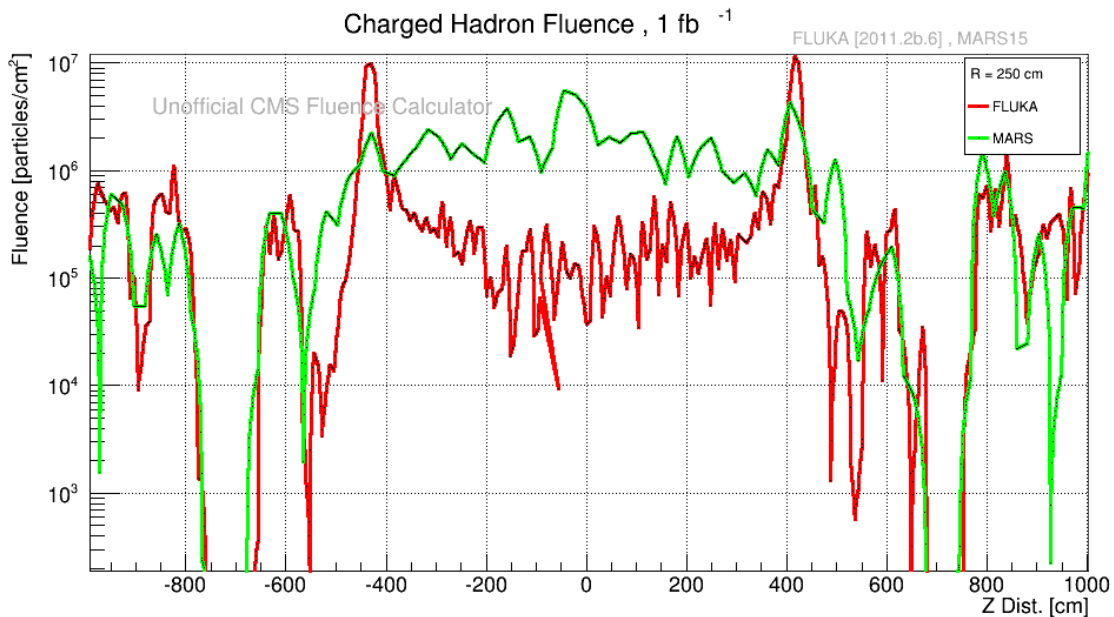

Figure 3: 1D Plots of Charged Hadron Fluence as a function of Z at R = 250 cm, FLUKA vs MARS

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Interpolated Data Return

Our data will always be limited to the bin sizes set when generated in the simulation runs. When trying to view data quantized and when using the 1D plots the data can easily be misleading. It is important that any point selected has a data, or if not can be closely approximated. Previously the calculator did not interpolate between quantized binned data, but simply returned data from the bin of the point requested. One can get better estimates of the data for the requested point through bilinear interpolation of the binned data. Through this calculation data is better approximated using the granular data available. The procedure starts by finding the bin for which the point belongs to. The bin is then split into four quadrants and depending on the quadrant that the point is in determines which bins will be selected for the interpolation. The distances from the centers of each bin are used in the final calculation where

$$P(x,y) = \frac{(x_2-x)(y_2-y)}{(x_2-x_1)(y_2-y_1)}P_1(x_1,y_1) + \frac{(x-x_1)(y_2-y)}{(x_2-x_1)(y_2-y_1)}P_2(x_2,y_1) + \frac{(x_2-x)(y-y_1)}{(x_2-x_1)(y_2-y_1)}P_3(x_1,y_2) + \frac{(x-x_1)(y-y_1)}{(x_2-x_1)(y_2-y_1)}P_4(x_2,y_2)$$

Equation 1: Bilinear interpolation used to smoothly approximate binned data

Equation 1 is a result of linear interpolation along the x axis and then along the y axis. Note that x-y coordinates used here corresponds to Z-R coordinates for detector dimensions.

With this method all 1D Plots will be much more accurate especially for regions where data changes sharply. And there is no limit on how small you can set your stepping size. All points requested will now return well defined data. Figure 4 displays a Dose interpolated plot superimposed with a standard. This is a safer case where R=6cm which lines up with the bin.
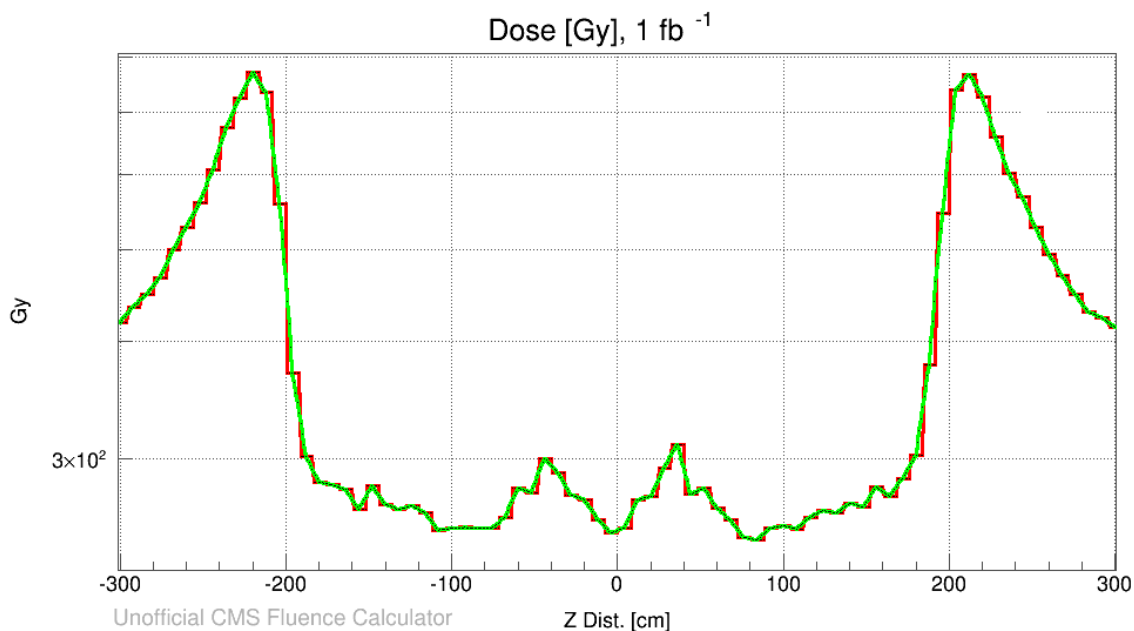

Figure 4: 1D Plot of Dose as a function of Z, Interpolated vs Standard

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Multi-File-System

      The Web Tool was previously unable to support multiple request for data at the same time. This was due to only using one file to write the data to for every request. Subsequent requests would then overwrite the previous request. The most straightforward solution to this problem would be to create a dynamic file system in which a uniquely identified temp file is created upon every request. All temp files can then be routinely cleaned up. The obstacle with this solution was permission issues with dynamically creating files from the PHP script. To resolve this issue we could have just figured out how to obtain the appropriate permissions rights for the script or have the files created through the C++ executable that we use to draw the plots. We decided to take neither of those approaches but to just implement a different system. The newly improved system maintains a pool of N files. These files each contain a timestamp which is reprinted every time a file is reused. A function, described in figure 5, was made to seek the "oldest" file out of this pool and recycle it by passing it back to the PHP script for use. This now enables the use of up to N multiple files and up to N multiple requests.
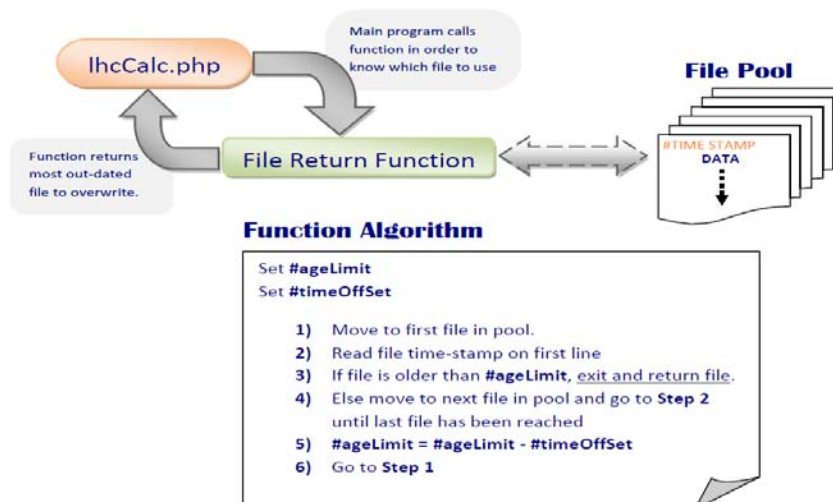

Figure 5: 2D Diagram of Multi-File System

Conclusion

      Simulated radiation data along with the web tool is important for further understanding the radiation environment of the CMS detector. The web tool helps in accessing this data in many ways. Numerous improvements have been made to the web tool such as the interface enhancements, added options, interpolated data calculations, and the multi file- system. These improvements enable the tool to be even more powerful and also sets a platform for further work to be made.

References

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Acknowledgements