Status of the Space Radiation Monte Carlos Simulation Based on FLUKA & ROOT

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Abreviations and Acronyms:

ALICE—An acronym name for A Large Ion Collider Experiment being constructed at CERN's LHC facility.

AliROOT—The name of a software analysis package developed for use in the ALICE experiment, which is based on the ROOT software infrastructure.

ATIC—AN acronym for a balloon-based cosmic ray experiment named Advanced Thin Ionization Calorimeter.

CERN—The European Organization for Particle Research (originally named for Conseil Européen pour la Recherche Nucléaire in French) in Geneva, Switzerland.

DPMJET—An event generator for high energy nucleus-nucleus interactions based on the Dual Parton Model of particle interactions.

FLUKA—An acronym for a Monte Carlo particle transport code based on the German for FLUctuating Kaskade.

GUI—An acronym for a Graphical User Interface to software applications.

IWSSRR—International WorkShop on Space Radiation Research.

LHC—The Large Hadron Collider project at CERN.

NASA—The Unitred States National Aeronautics and Space Administration.

PEANUT—A Pre-Equilibrium/Intra Nuclear Cascade hadron interaction model.

QMD & RQMD—Acronyms for event generators for a Quantum Molecular Dynamics model high energy nucleus-nucleus interactions and a relativistic version respectively.

ROOT—The name of a data analysis software infrastructure package developed at CERN

Abstract

The NASA-funded project reported on at the first IWSSRR in Arona to develop a Monte-Carlo simulation program for use in simulating the space radiation environment based on the FLUKA and ROOT codes is well into its second year of development, and considerable progress has been made. The general tasks required to achieve the final goals include the addition of heavy-ion interactions into the FLUKA code and the provision of a ROOT-based interface to FLUKA. The most significant progress to date includes the incorporation of the DPMJET event generator code within FLUKA to handle heavy-ion interactions for incident projectile energies > 3GeV/A. The ongoing effort intends to extend the treatment of these interactions down to 10 MeV, and at present two alternative approaches are being explored. The ROOT interface is being pursued in conjunction with the CERN LHC ALICE software team through an adaptation of their existing AliROOT software. As a check on the validity of the code, a simulation of the recent data taken by the ATIC experiment is underway.

At the first workshop in this series in Arona two years ago, we reported on the initiation of a project to develop an integrated software simulation tool for use in space radiation situations.[1] Such a code could also be useful to simulate the environment at aircraft altitudes for comparison with and prediction of the doses received on long duration high altitude flights.[2] The goals of the project are to modify the FLUKA Monte Carlo transport code[3-4] to internally incorporate all inelastic heavy-ion interactions, and to provide a user-friendly interface to the resulting code based on the ROOT data analysis infrastructure.[5-6] The intent is to incorporate a seamless set of input and analysis tools in a single GUI (Graphical User Interface) based package. This final product will also incorporate models of space radiation sources to allow users to rapidly set up simulations of any particular mission or exposure setting.

The most significant progress we have made to date is to integrate the code known as DPMJET[7-8] into FLUKA to provide the event generator for nucleus-nucleus inelastic interactions above 3 GeV/A. A version of FLUKA with this internal event generator is currently available for download through our project's website (http://fleur.cern.ch/~empl/fleur/index.html). The version of DPMJET initially deployed is DPMJET 2.5. We have also been working on a version of FLUKA that incorporates DPMJET 3.0, and we expect to have that available shortly as well. DPMJET does a very good job of fitting the existing data for all laboratory energies above about 30 GeV/A. However, between its lowest practical usable energy of 3 GeV/A and 30 GeV/A we feel that there is still some room for improvement. Several options exist that promise better fits to the data in this region. One of those options is to modify the existing DPMJET implementations

and another is to employ a version of the RQMD code[9] in that energy range. Both of these courses are being currently pursued.

Since the Arona meeting, NASA has determined that there needs to be a dedicated program to both measure and model the nucleus-nucleus cross sections from the threshold for inelastic reactions up through laboratory energies in the range of 1-2 GeV/A.[10] We have joined in a consortium of groups to submit a proposal to participate in that program. As such we have chosen to defer the final implementation of the inelastic nucleus-nucleus interactions until that project bears fruit. In the meat time, in order to be able to provide guidance with the accuracy of the known cross sections, we are in the process of setting up an interim solution. At present we are evaluating the potential use of the RQMD code[9] for such an interim solution. Others have made similar attempts with reported success using the non-relativistic version of this code known as QMD.[11-12] If we determine that this code is too inaccurate, we plan to evaluate producing a modification of the PEANUT approach that is already used within FLUKA to simulate inelastic nucleon-nucleus interactions.[4] This work is progressing and we hope to have a version of FLUKA available for release with an interim event generator functioning all the way down to the threshold energies by the end of this year. At that point we will have, at least in interim form, completed that part of our total project requiring the modifications to FLUKA to allow the complete simulation of heavy ion transport through any arbitrary material. As such, that version of FLUKA will be the only existing integrated transport code that incorporates that full a breadth of the relevant physics.

Our second major goal, namely making FLUKA more user-friendly, is progressing along several paths. Our ultimate plan is to provide a single interface for initiating and running simulations, and to have that same software environment be seamlessly available for

analyzing and visualizing the outputs produced. This goal is shared by the ALICE software team at CERN that is currently developing software to simulate that experiment. Known as AliROOT, their project envisages a universal Monte Carlo simulation GUI interface based on the ROOT data analysis infrastructure.

In order to facilitate the inclusion of FLUKA into such a framework, we are proceeding to develop several of the needed software tools separately. For example, we are currently working on a modification to FLUKA that will allow the extraction of information during the transport process at each significant step. In the interim this will allow is to provide what is sometimes known as a "history-file" of each event. This is also needed to allow ALICE to be able to have direct access to the detailed FLUKA results during execution. We are also in the process of porting many of the older existing FLUKA analysis tools into ROOT. An example of that is presented below in the ATIC analysis. These routines will be available in the interim and will be included along with newly developed tools in the final package.

One area that was somewhat outside the scope of the originally funded effort, but which we have been able to contribute to is in the area of the geometry input format currently employed. FLUKA uses a powerful combinatorial geometry that allows for very rapid execution times, but which is unfortunately hampered with cumbersome input formats and procedures. To alleviate that cumbersomeness to some extent we have contributed in two areas. First, we have aided in the deployment of added logical operations for use in the input formats. This addition essentially allows the use of logical parentheses to group logical combinations. Second, we have taken steps to provide a set of tools that can be used to facilitate the direct translation of geometry input statements coded for the earlier GEANT3.21

simulation package into the needed FLUKA geometry input format. This effort holds the promise of making the current version of FLUKA much more readily accessible for the large body of users who already possess well-written GEANT3.21 geometry inputs for their particular situations of interest.

In order to test our current released version of FLUKA with the internal DPMJET event generator, and to simultaneously test our initial ROOT-based ports of existing FLUKA analysis tools, we have elected to explore simulating the ATIC experiment, a cosmic-ray astrophysics collaboration under the lead of Louisiana State University's Department of Physics and Astronomy.[13] ATIC is a balloon-borne instrument designed to look at the cosmic-ray composition in the 100 GeV/A to 10 TeV/A range. It consists of a telescope of silicon strip detectors on top of a set of carbon interaction targets followed by a BGO (Bismuth-Germanium-Oxygen, $Bi_4Ge_3O_{12}$) calorimeter, with triggering scintillators interspersed at various points. The experiment was flown near the top of the atmosphere for an extended time in Antarctica during January 2001. Our interest is in determining if FLUKA with DPMJET is sufficient to simulate the actual flight data accurately, and to develop in the process some of the initial ROOT-based analysis tools that will become part of the eventual final package.

As an example of this simulation testing, Figure 1 presents some of the FLUKA results for a study of ATIC.[13] Figure 1(a) displays a fluence plot for charged particles and Figure 1(b) includes a fluence plot of the neutron backscatter albedo. This latter plot represents the total neutron fluence through a raster of pixels due to 1600 simulated 1 TeV/A carbon nuclei normally incident along the central axis of the experiment. An outline of the ATIC hardware geometry is superimposed on the plot. The color-coded levels are

logarithmic and represent 6 levels per decade. Fluence is the net flux (time integral of flux) and is expressed as the total path-length density of neutrons of all energies through each pixel. One can use this plot to evaluate the possibility for neutron backscatter contamination in the entire detector from events of this type. Such contamination represents a potential background that must be accounted for in the design of the instrument and it may affect triggering schemes as well as the interpretation of certain data. Data from the ATIC experiment have been taken but are not yet analyzed to the point where comparisons with the simulations are possible. When that data become available, we will compare it to our results.

To summarize, our project to produce a Monte Carlo-based tool for the simulation of space radiation based on the FLUKA code has made substantial progress. We are now able to begin to validate it against actual cosmic ray data at higher energies, and we hope to soon have a version that is usable all the way down to the threshold energies for nuclear interactions. Our work towards providing a user-friendly GUI-based interface based on ROOT is proceeding, and some of those tools are already in use. Finally, work is also progressing on the assembly of a sequence of input source models. The current program is targeted for completion towards the end of 2003.

ATIC 1 TeV/A C Chrgd. Part. Fluence
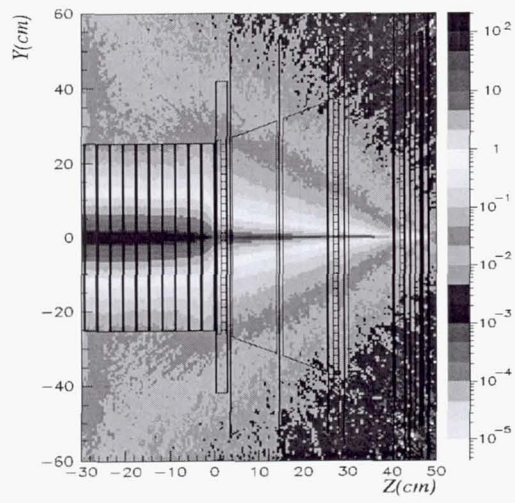
ATIC 1 TeV/A C Neutron Fluence

(a)
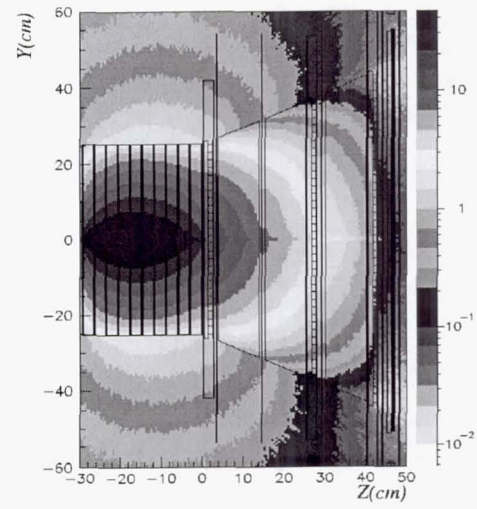
(b)

Fig. 1

Figure Captions

Fig. 1. Color plots of (a) charged particle fluences and (b) of neutron fluences due to 1 TeV/A carbon nuclei incident on the ATIC experiment as calculated with FLUKA/DPMJET II.5.

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