Geant4 FLUKA Simulation Comparison Update

Geant4/FLUKA Simulation Comparison Update
AARM Collaboration Meeting at SDSM&T

May 21, 2015

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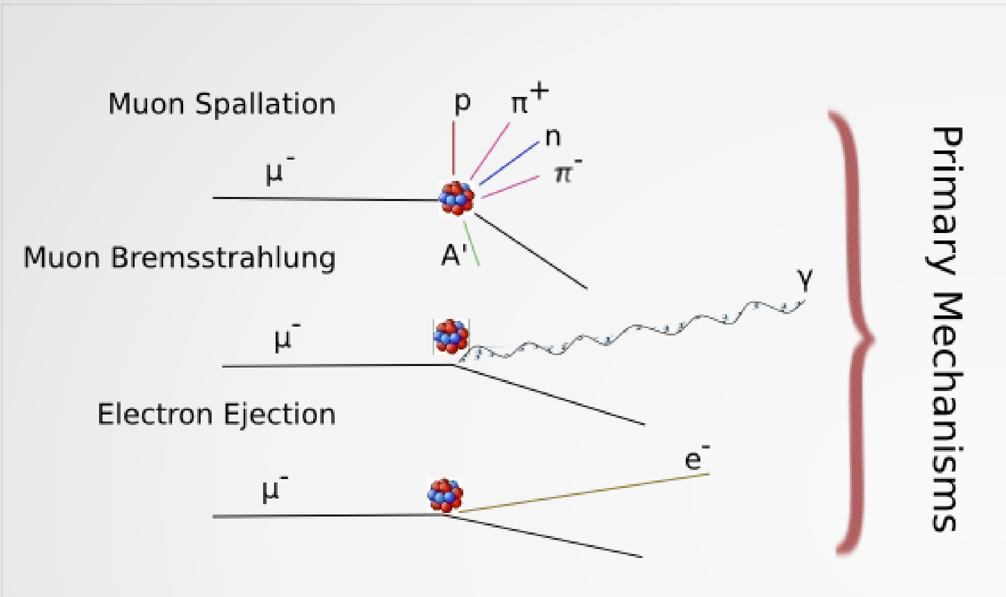
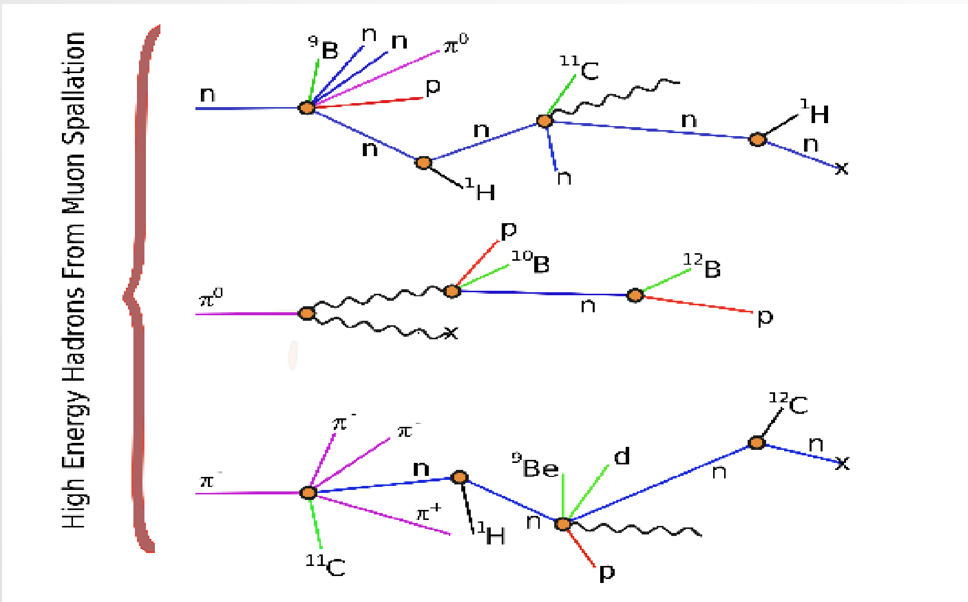
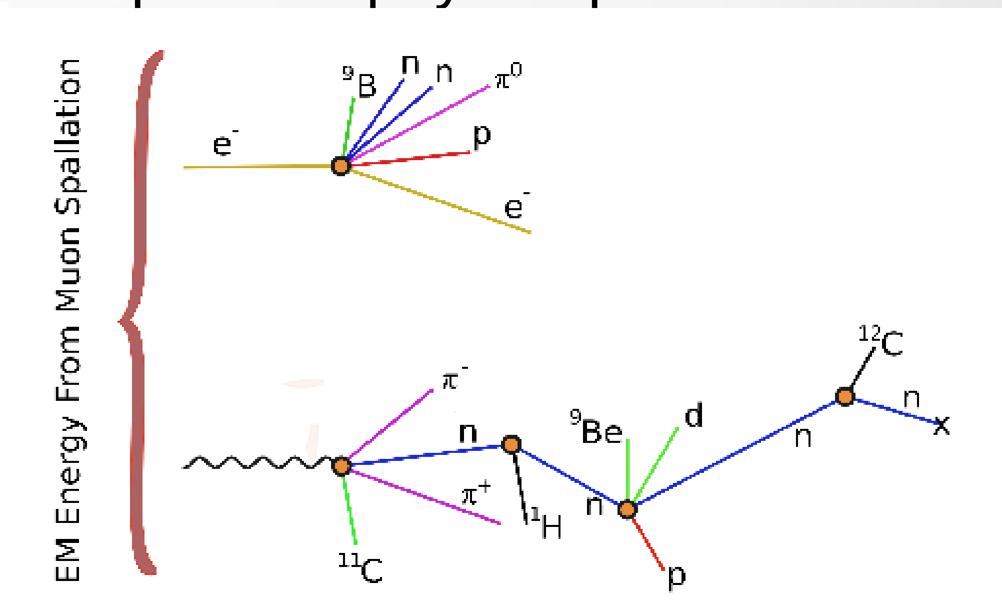
Introduction to Cosmogenic Showers



Underground experiments utilize various simulation packages to quantify cosmogenic muon-induced backgrounds, particularly neutron backgrounds. Simulated backgrounds are dependent on package's ability to implement physics processes.

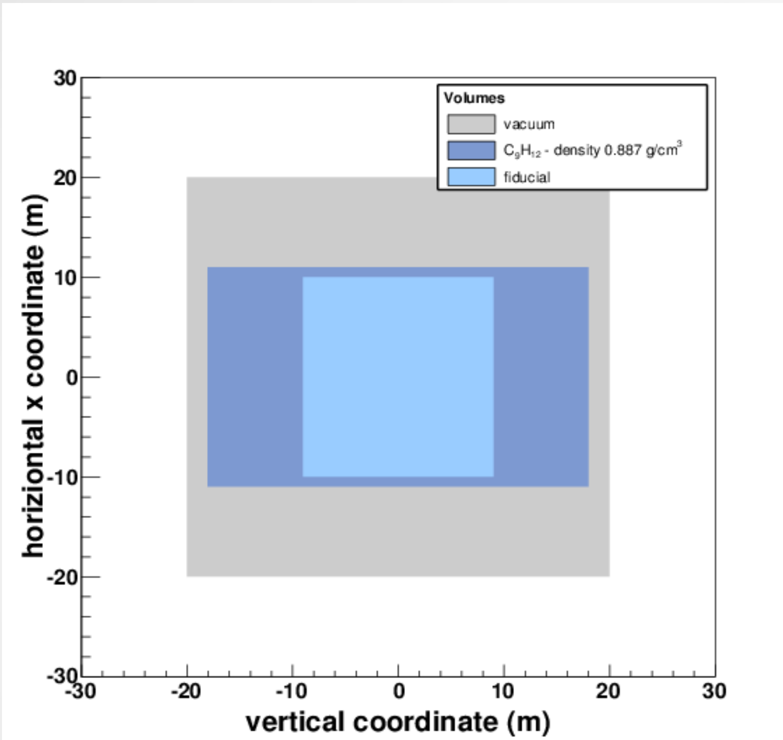


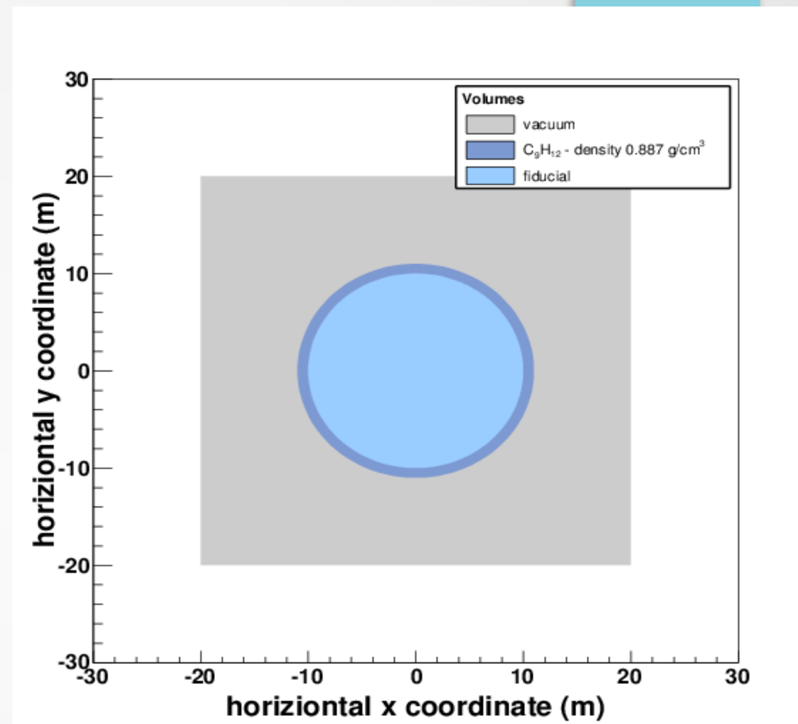


Motivation/Goals

- Use FLUKA:2011.2 patch level 17 and Geant4.9.5 with updated muon nuclear process
- Explore physics of Geant4 and FLUKA and how the physics is implemented.
- Focus on potentially measurable characteristics
  - Neutron Yield
    - Compared to data available from Kamland and Borexino
  - Isotope Production
    - Focus on isotopes of interest, such as Carbon-11

Simulation Geometry, Materials, and Muon Energy

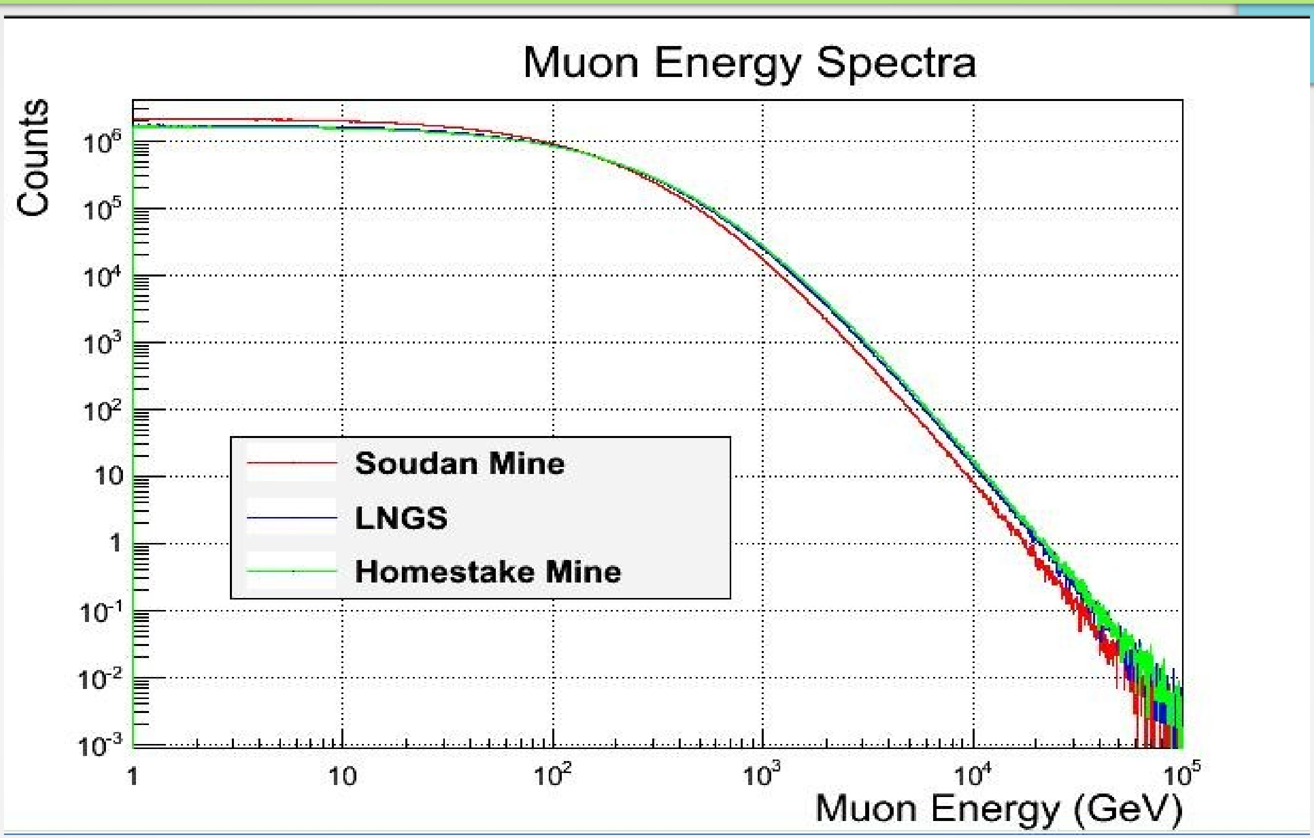




Target Materials	
Liquid Scintillator	Iron
Water	Lead
Calcium Carbonite	Greenstone

Muon Energies	
30 GeV	100 GeV
200 GeV (Greenstone)	
280 GeV	1 TeV

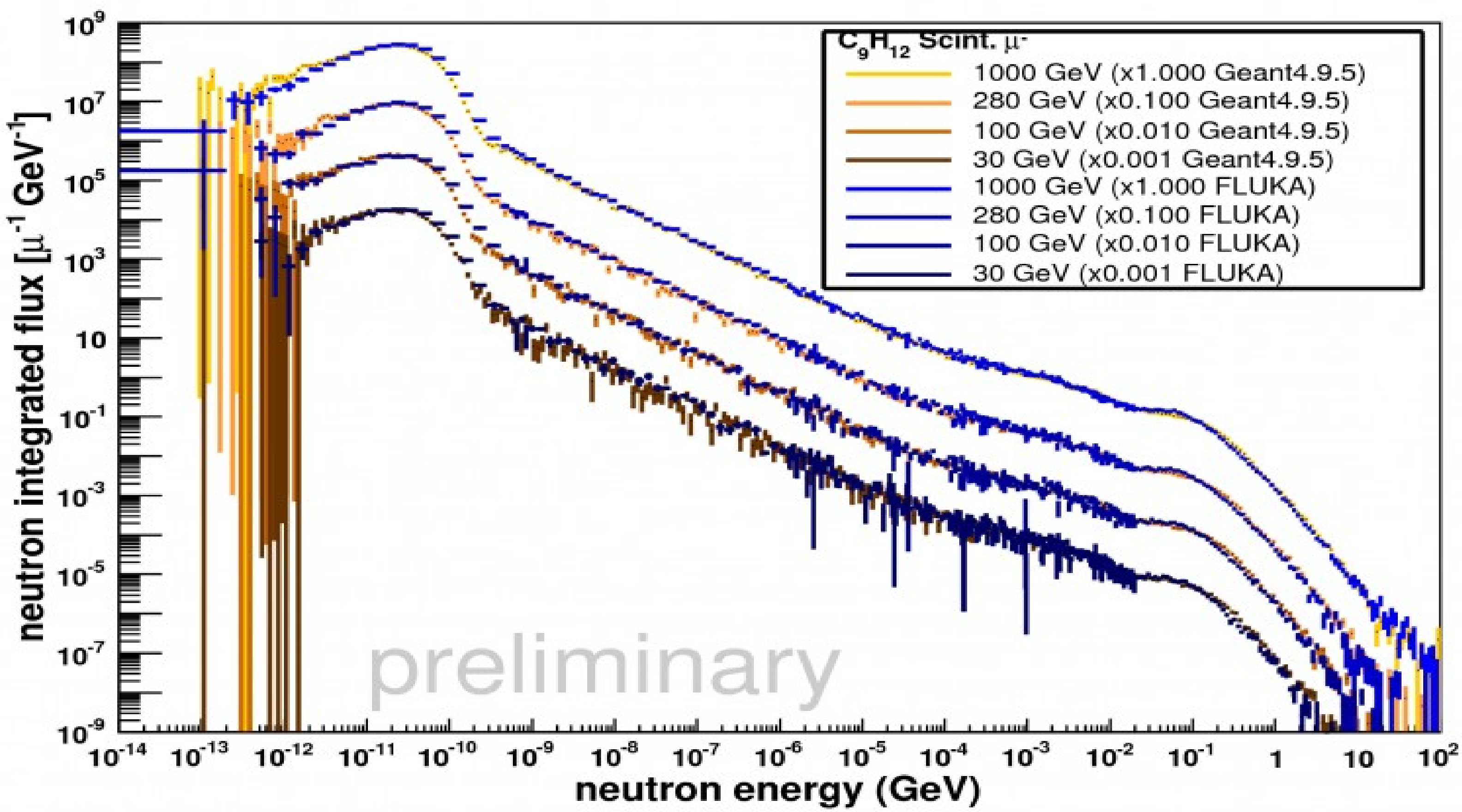
Additional Muon Energy Spectra



Muon energy spectra for Soudan Mine, Homestake Mine, and Laboratori Nazionali del Gran Sasso

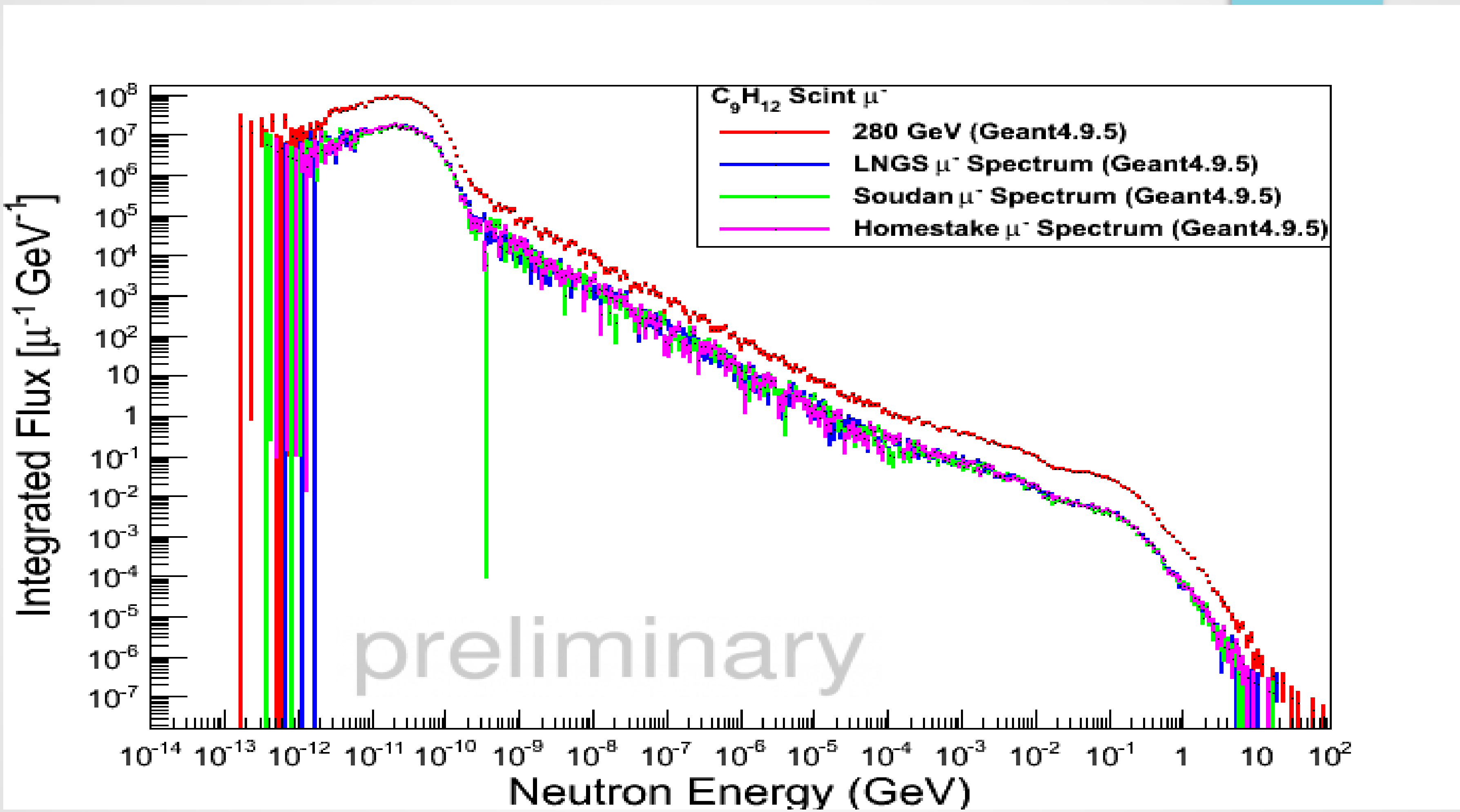
280 GeV monoenergetic muon beam often substituted for complete LNGS spectrum

Integrated Neutron Flux in Liquid Scintillator



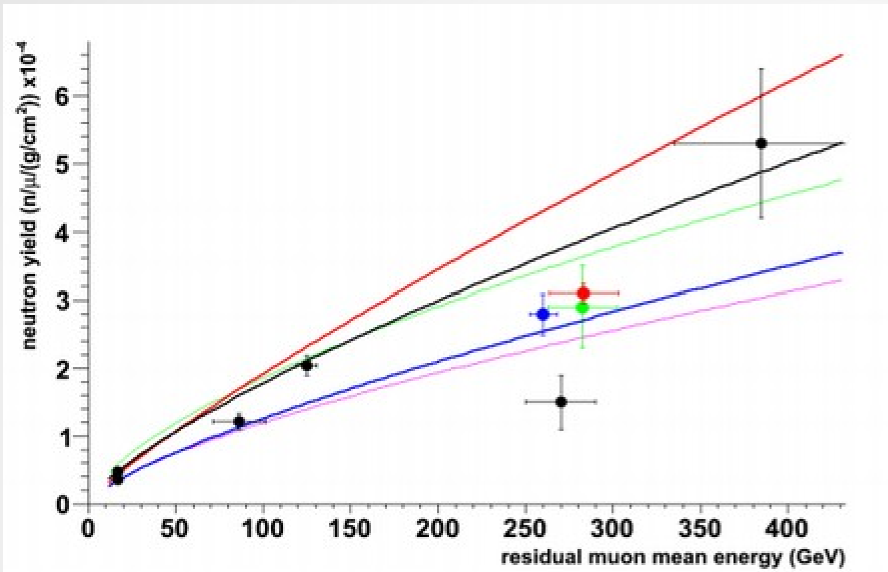
Liquid scintillator is within 30% over most of the energy range with the largest discrepancies near 100 MeV neutron energy.

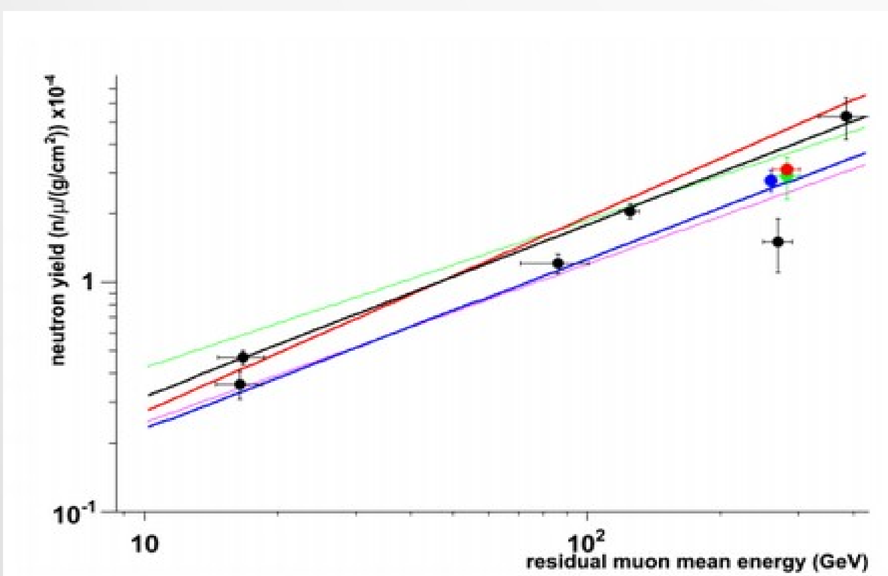
Integrated Neutron Flux in Liquid Scintillator



In Geant4 LNGS, Soudan, and Homestake spectra agree for Liquid Scintillator, but all spectra are almost an order of magnitude lower than 280 GeV monoenergetic neutron flux.

Cosmogenic Neutron Yield in Liquid Scintillator





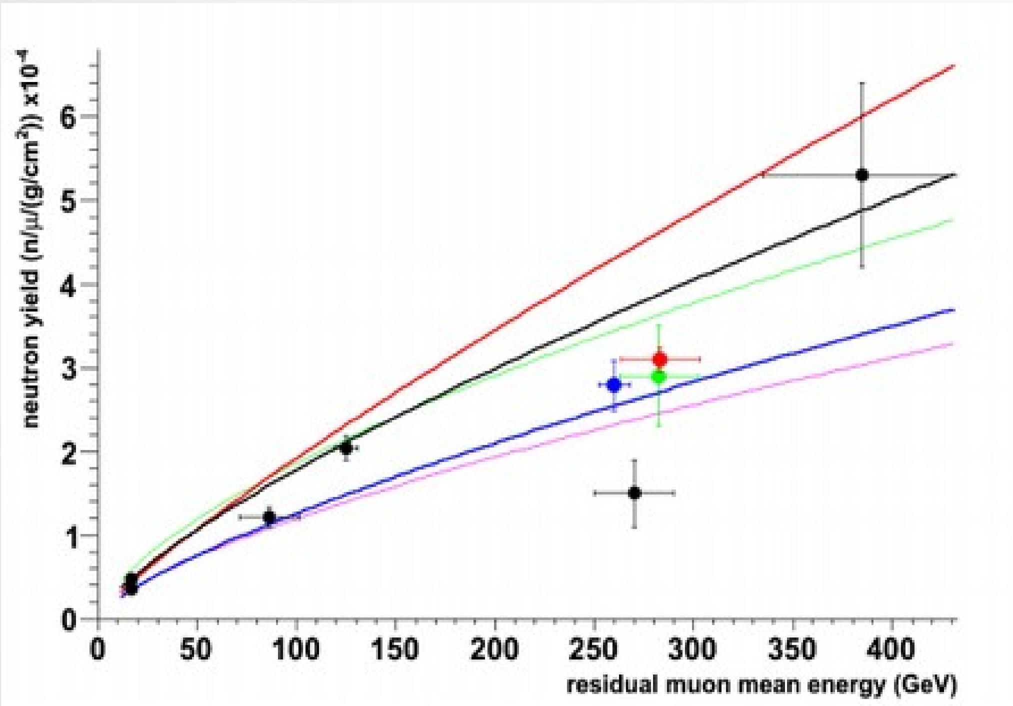
Experimental Results

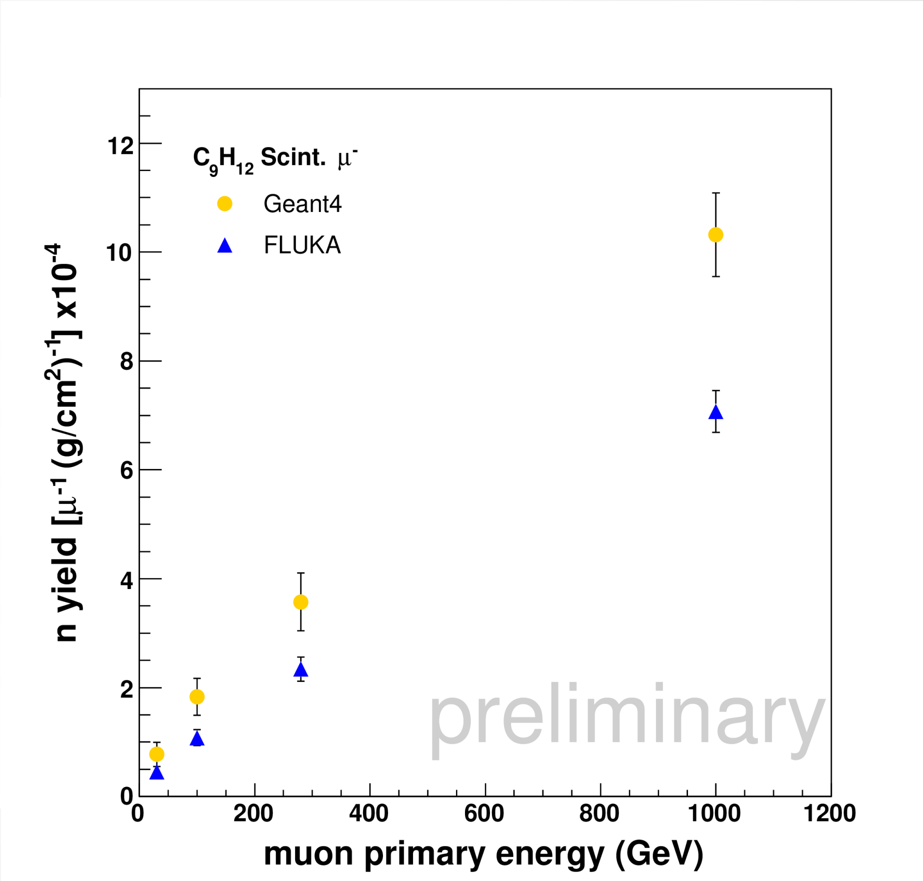
- **Boehm et al, Bezrukov et al,**
- **Enikeev et al, Aglietta et al**
- **KamLand**
- **LVD**
- **Borexino**

Theoretical Predictions

- **G.T. Zatsepin and O.G**
- **Ryazhskaya (1965)**
- **Wang et al (2001)**
- **Mei and Hime (2006)**
- **Geant4 4.9.5p01**
- **FLUKA 2011.2.17**

Cosmogenic Neutron Yield in Liquid Scintillator

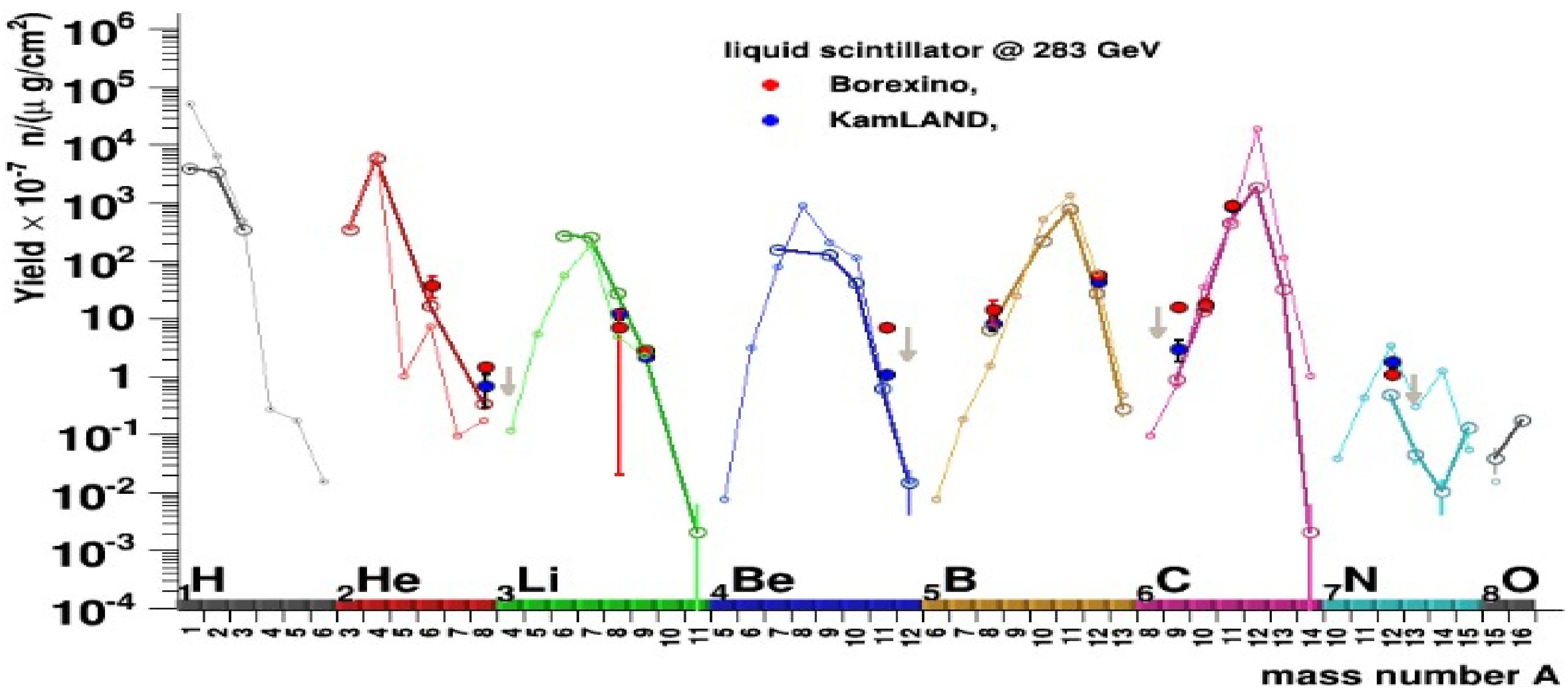




Discussion

- Is there a significant difference between 280 GeV monoenergetic muon and LNGS energy spectrum muon? Can mean energy be used as a surrogate for the spectrum?
- What other parameters are of interest?
  - Capture Time
  - Neutron Multiplicity
- What other target materials and muon energies are of interest?
  - Germanium
  - Silicon

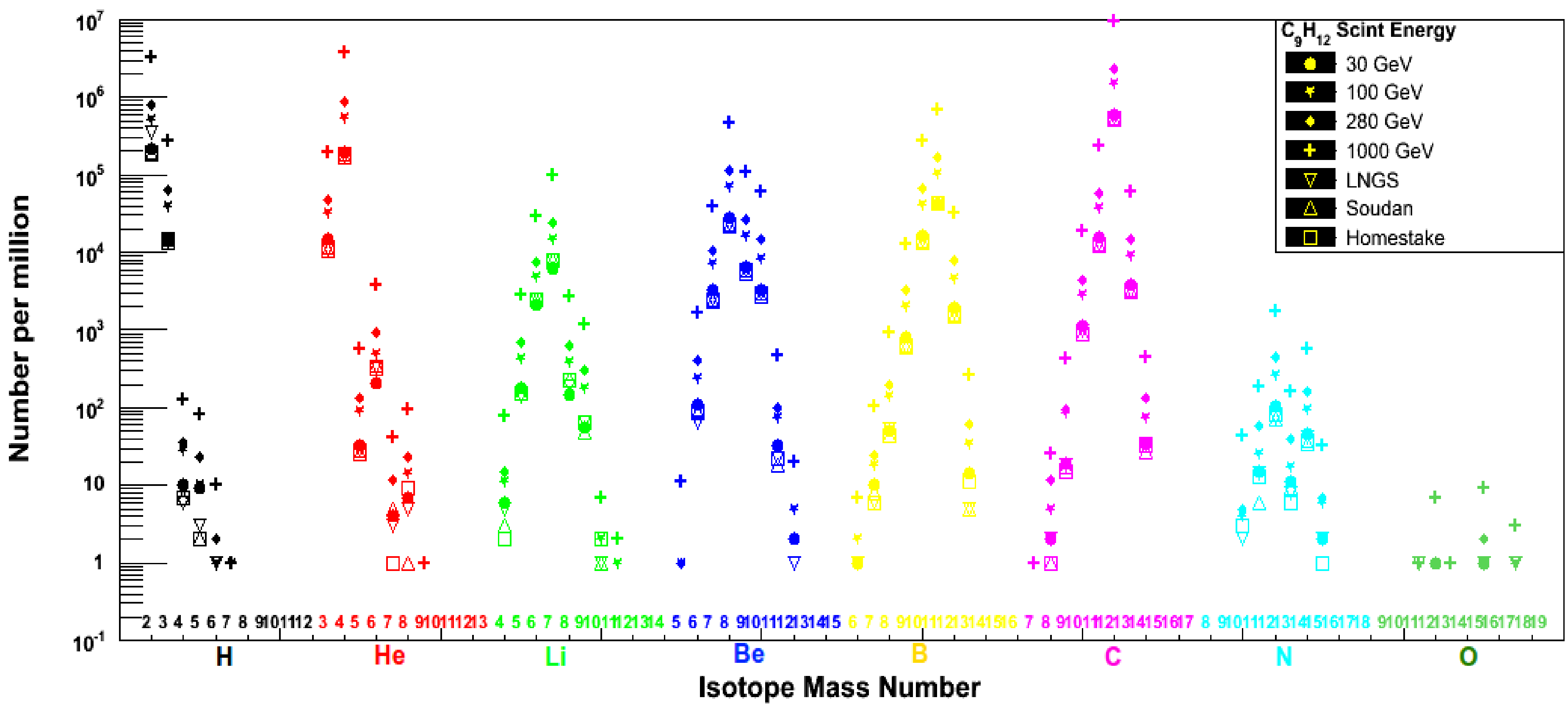
Geant4 and FLUKA Isotopes in Liquid Scintillator for 280 GeV



Reasonable agreement between Geant4 and FLUKA in isotope production. This is common across lighter targets.

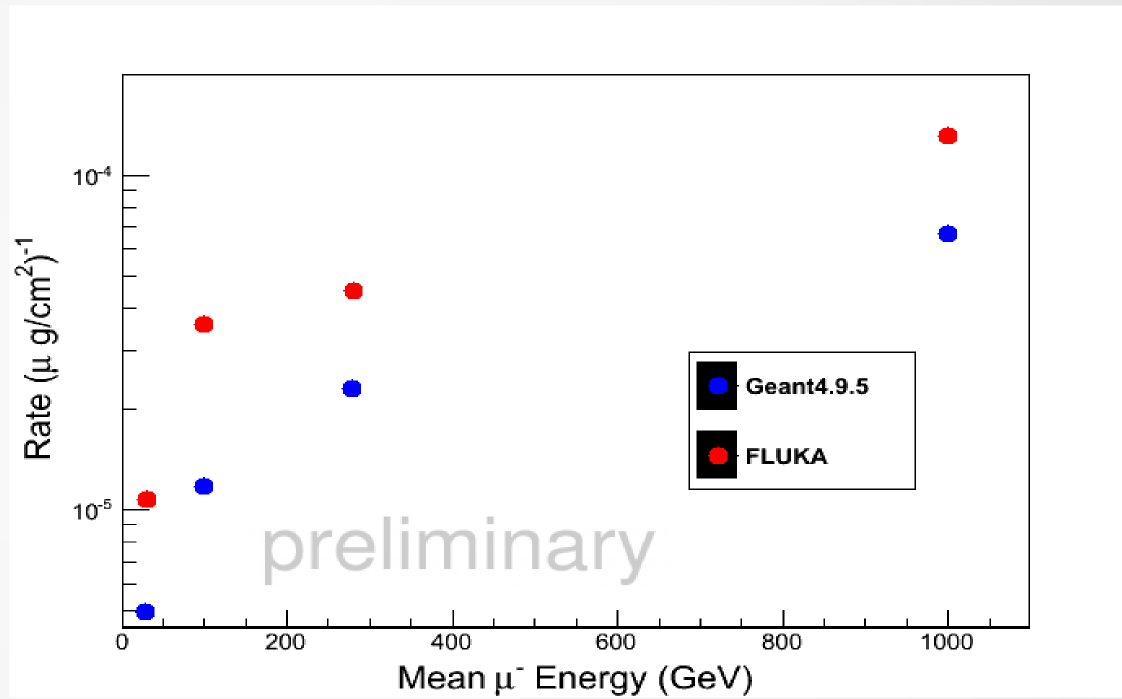
KamLAND agrees as well; Borexino has larger production for some isotopes.

Geant4 Isotopes in Liquid Scintillator for All Energies



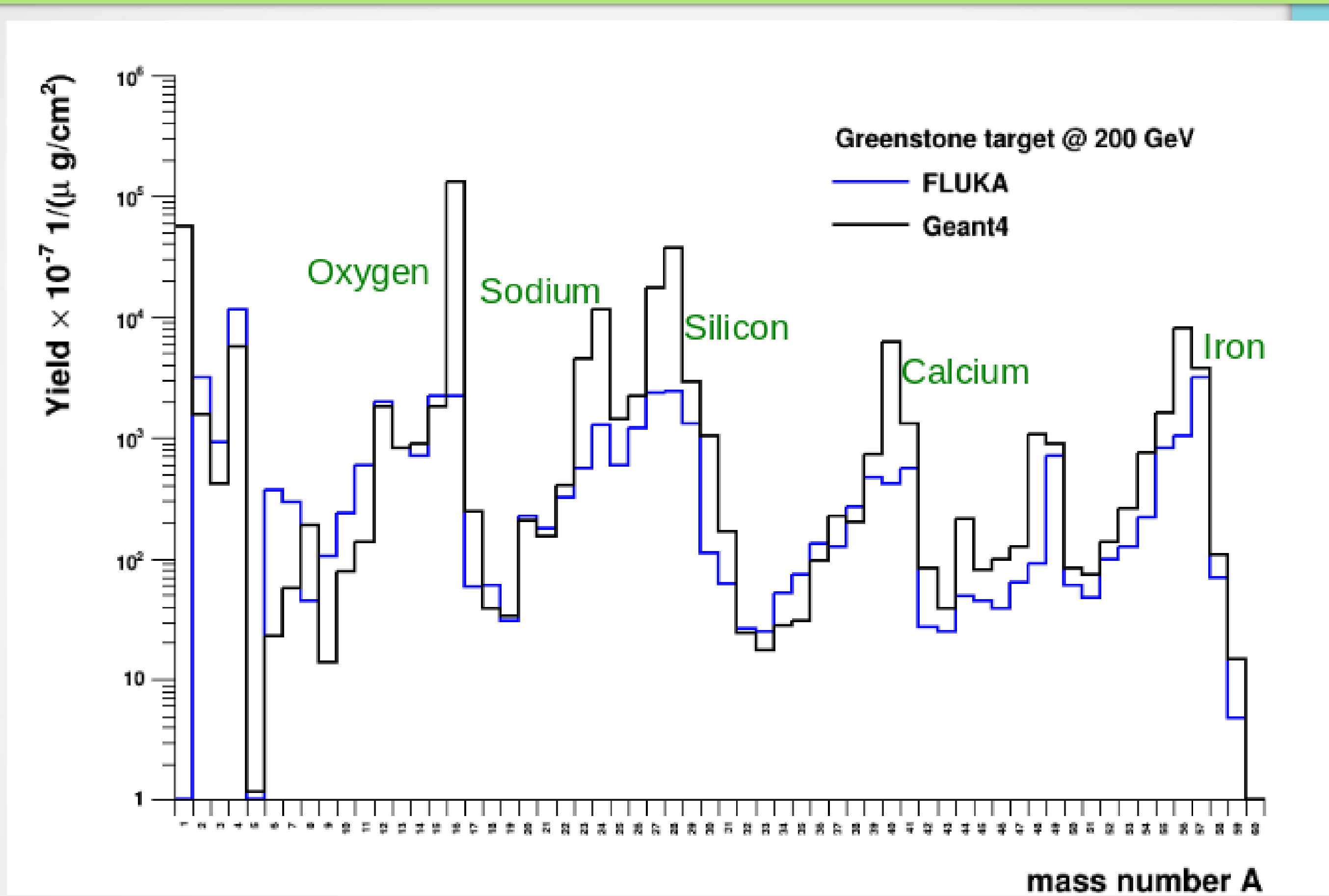
Carbon-11 Production in Liquid Scintillator

- C-11 is expected dominant background source in Borexino
- C-11 decays expected at rate 2.5 times higher than combined pep and CNO neutrinos from 0.8-1.3 MeV
- C-11 is underrepresented by factor of 2 in current FLUKA



Carbon-11 production in Geant4.5.9 is roughly 25-50% lower than in FLUKA

Isotope Production in Soudan Greenstone at 200 GeV



Large discrepancies between Geant4 and FLUKA in some isotope production, particularly in heavy targets

Could be due to differing elastic scattering thresholds in isotopes present in target

Discussion

- How can we further study discrepancies in heavy targets (Iron, Lead, etc.)?
  - How does the physics differ in heavy versus light targets for FLUKA and Geant4?

- What other isotopes are significant?

Websites

Geant4 Results at

www.hep.umn.edu/aarm/geant4studies/

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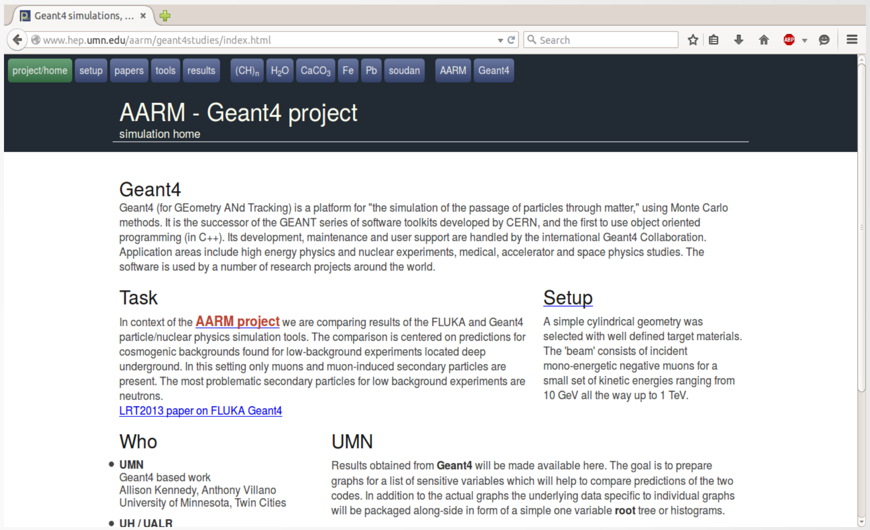


Geant4 simulations, ...

www.hep.umn.edu/aarm/geant4studies/index.html

project/home setup papers tools results $(CH)_n$ H_2O $CaCO_3$ Fe Pb soudan AARM Geant4

AARM - Geant4 project

simulation home

Geant4

Geant4 (for GEometry ANd Tracking) is a platform for "the simulation of the passage of particles through matter," using Monte Carlo methods. It is the successor of the GEANT series of software toolkits developed by CERN, and the first to use object oriented programming (in C++). Its development, maintenance and user support are handled by the international Geant4 Collaboration. Application areas include high energy physics and nuclear experiments, medical, accelerator and space physics studies. The software is used by a number of research projects around the world.

Task

In context of the AARM project we are comparing results of the FLUKA and Geant4 particle/nuclear physics simulation tools. The comparison is centered on predictions for cosmogenic backgrounds found for low-background experiments located deep underground. In this setting only muons and muon-induced secondary particles are present. The most problematic secondary particles for low background experiments are neutrons.

LRT2013 paper on FLUKA Geant4

Setup

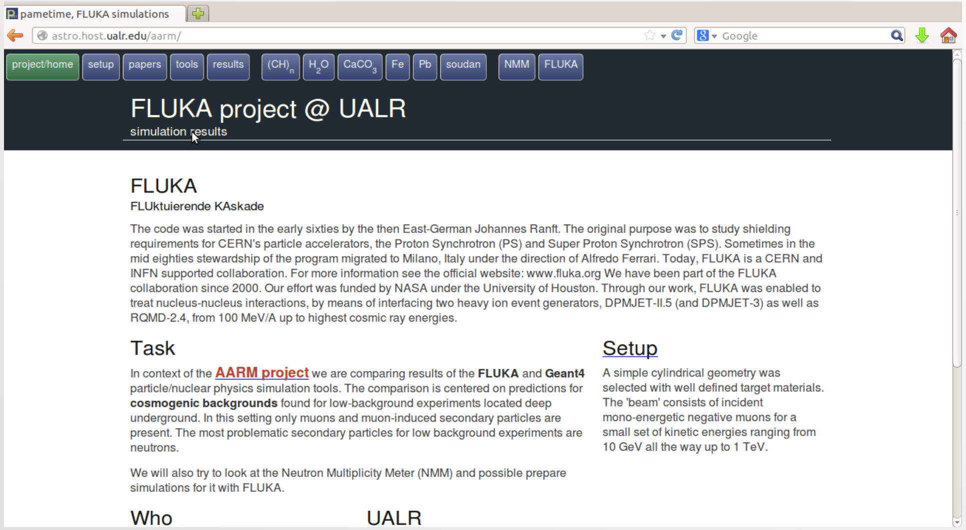
A simple cylindrical geometry was selected with well defined target materials. The 'beam' consists of incident mono-energetic negative muons for a small set of kinetic energies ranging from 10 GeV all the way up to 1 TeV.

Who

- UMN
  Geant4 based work
  Allison Kennedy, Anthony Villano
  University of Minnesota, Twin Cities
- UH / UALR

UMN

Results obtained from **Geant4** will be made available here. The goal is to prepare graphs for a list of sensitive variables which will help to compare predictions of the two codes. In addition to the actual graphs the underlying data specific to individual graphs will be packaged along-side in form of a simple one variable **root** tree or histograms.



pametime, FLUKA simulations

astro.host.ualr.edu/aarm/

project/home setup papers tools results $(CH)_n$ H_2O $CaCO_3$ Fe Pb soudan NMM FLUKA

FLUKA project @ UALR

simulation results

FLUKA

FLUktuierende KAskade

The code was started in the early sixties by the then East-German Johannes Ranft. The original purpose was to study shielding requirements for CERN's particle accelerators, the Proton Synchrotron (PS) and Super Proton Synchrotron (SPS). Sometimes in the mid eighties stewardship of the program migrated to Milano, Italy under the direction of Alfredo Ferrari. Today, FLUKA is a CERN and INFN supported collaboration. For more information see the official website: www.fluka.org We have been part of the FLUKA collaboration since 2000. Our effort was funded by NASA under the University of Houston. Through our work, FLUKA was enabled to treat nucleus-nucleus interactions, by means of interfacing two heavy ion event generators, DPMJET-II.5 (and DPMJET-3) as well as RQMD-2.4, from 100 MeV/A up to highest cosmic ray energies.

Task

In context of the AARM project we are comparing results of the **FLUKA** and **Geant4** particle/nuclear physics simulation tools. The comparison is centered on predictions for **cosmogenic backgrounds** found for low-background experiments located deep underground. In this setting only muons and muon-induced secondary particles are present. The most problematic secondary particles for low background experiments are neutrons.

We will also try to look at the Neutron Multiplicity Meter (NMM) and possible prepare simulations for it with FLUKA.

Setup

A simple cylindrical geometry was selected with well defined target materials. The 'beam' consists of incident mono-energetic negative muons for a small set of kinetic energies ranging from 10 GeV all the way up to 1 TeV.

Who

UALR

FLUKA Results at

astro.host.ualr.edu/aarm

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