

Geant4 FLUKA Simulation Comparison Update

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

May 21, 2015

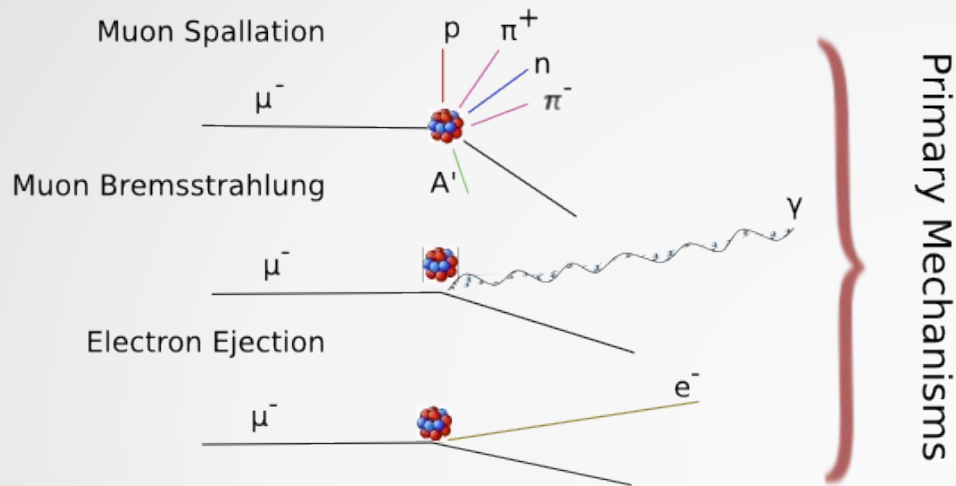
Allison Kennedy - University of Minnesota

Anthony Villano - University of Minnesota

Sarah Lindsay - University of Arkansas @ Little
Rock

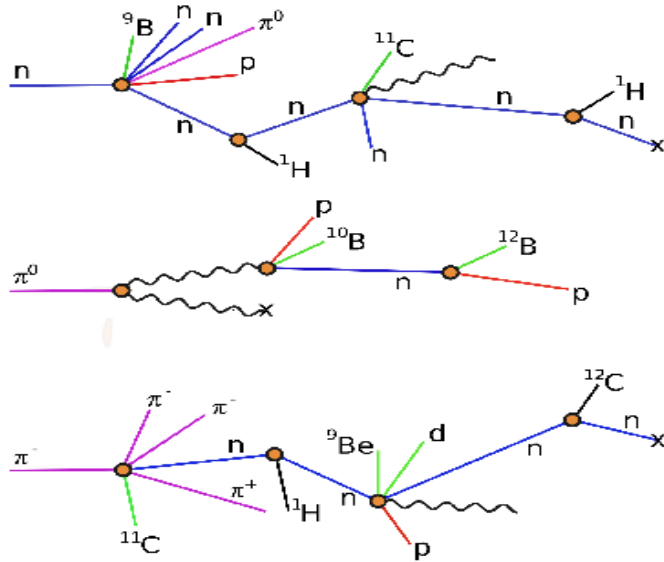
Anton Empl - University of Houston

Introduction to Cosmogenic Showers

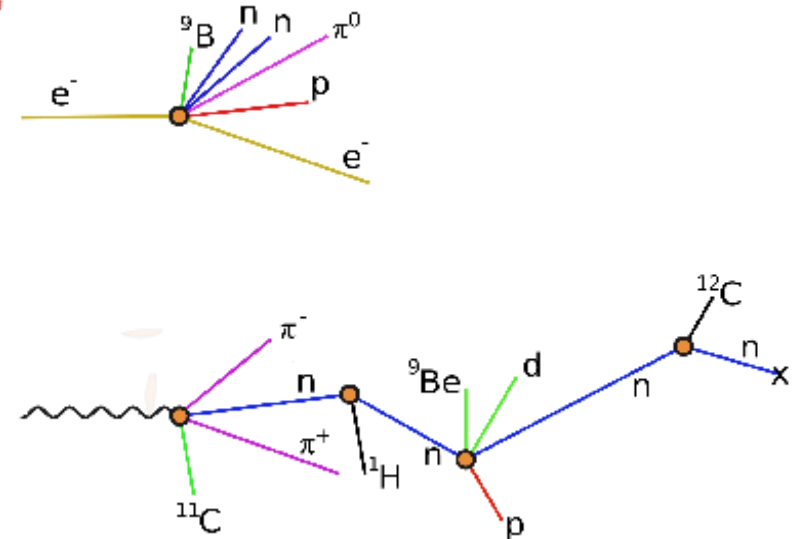


Underground experiments utilize various simulation packages to quantify cosmogenic muon-induced backgrounds, particularly neutron backgrounds. Simulated backgrounds are dependent on package's ability to implement physics processes.

High Energy Hadrons From Muon Spallation



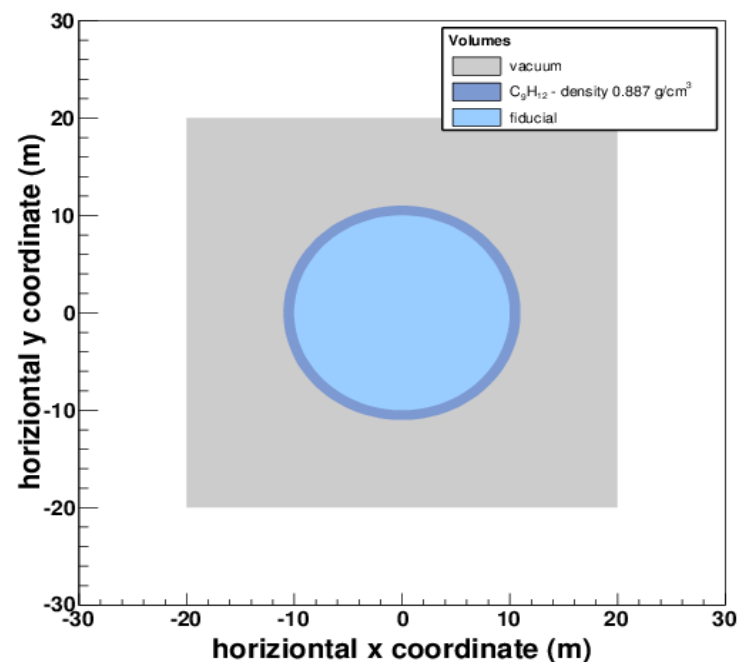
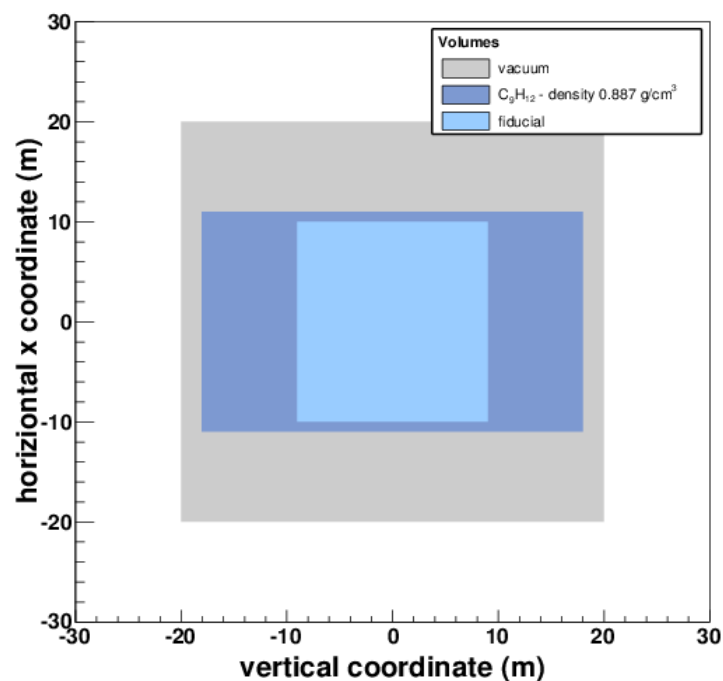
EM Energy From Muon Spallation



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
-------------------	------------

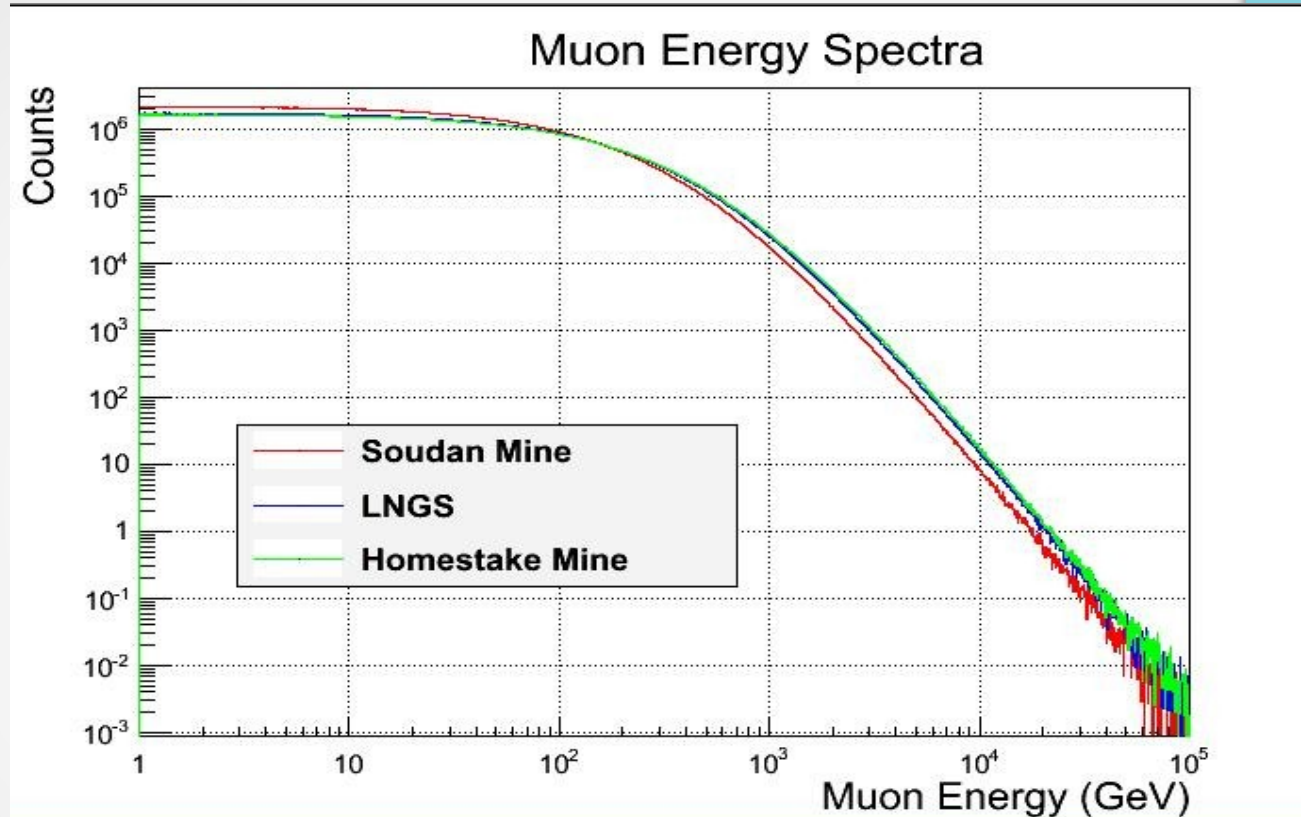
Muon Energies

30 GeV	100 GeV
--------	---------

200 GeV (Greenstone)	
----------------------	--

280 GeV	1 TeV
---------	-------

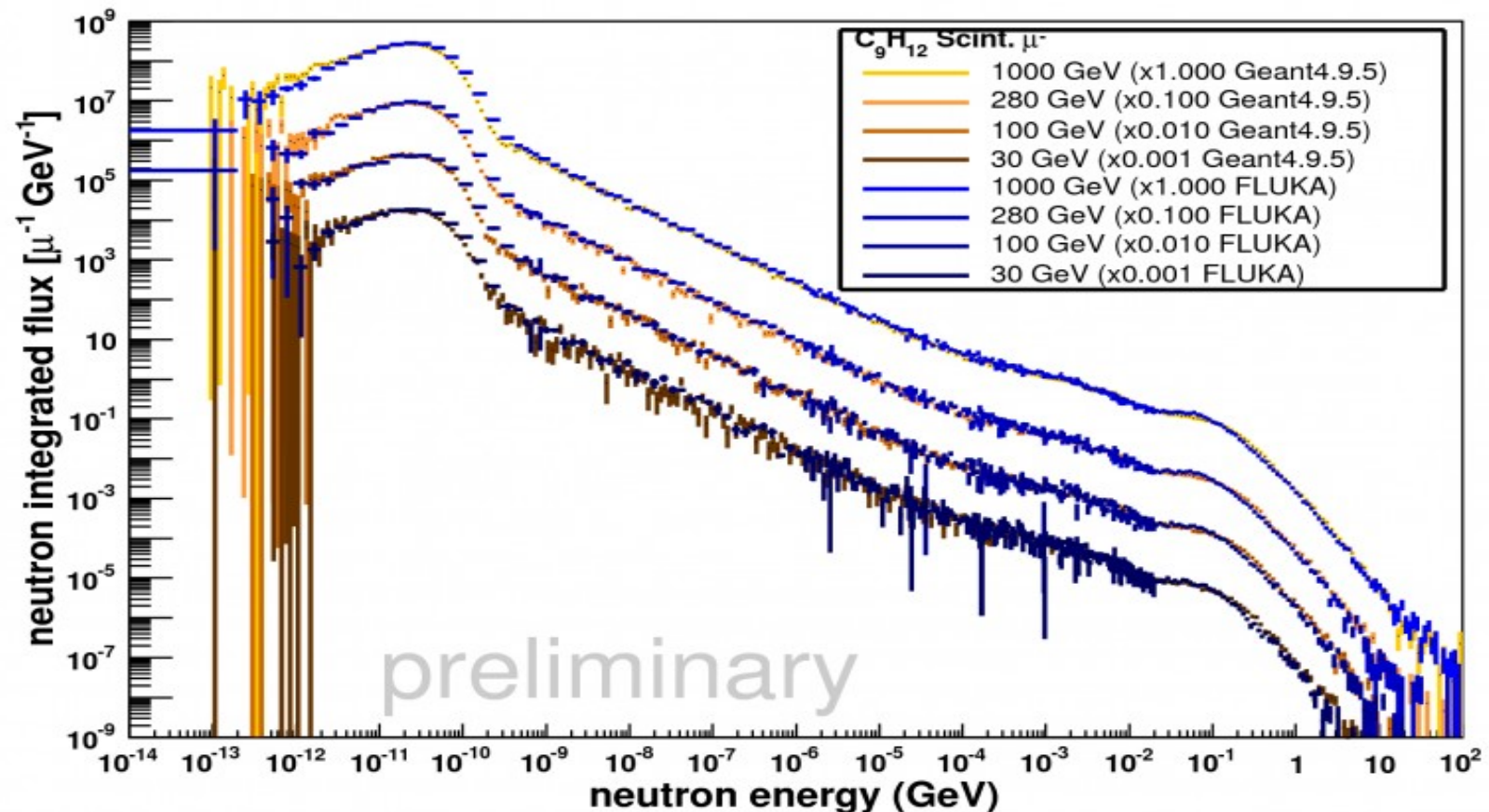
Additional Muon Energy Spectra



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

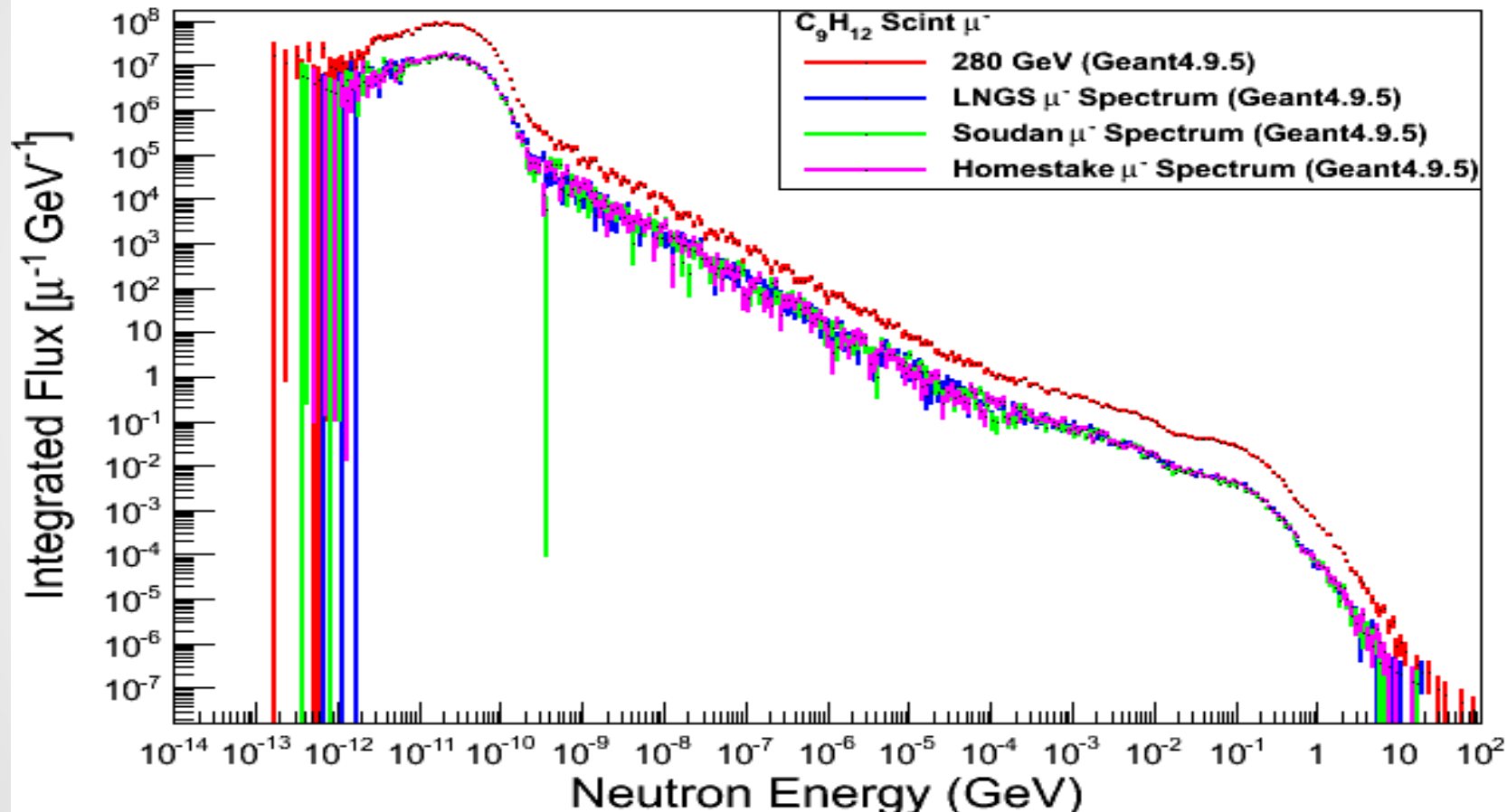
280 GeV monoenergetic muon beam often substituted for complete LNGS spectrum

Integrated Neutron Flux in Liquid Scintillator



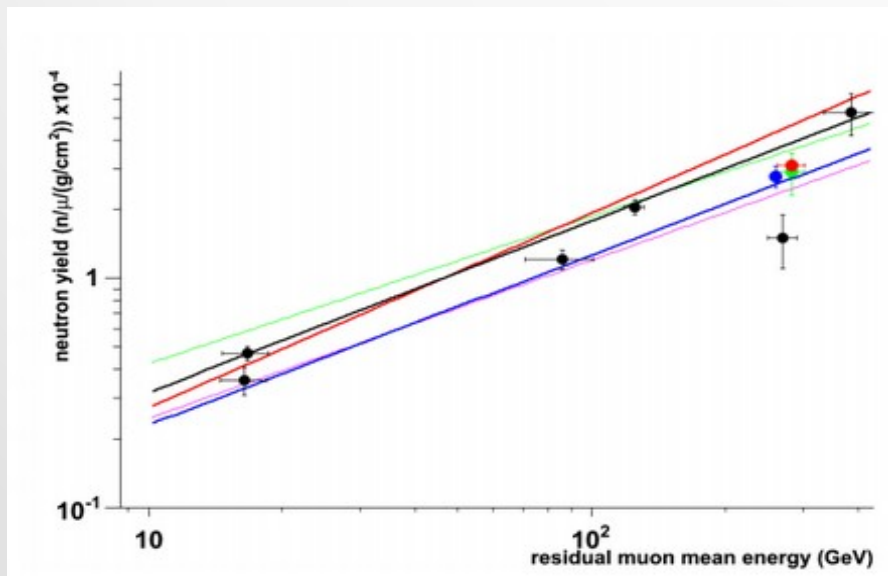
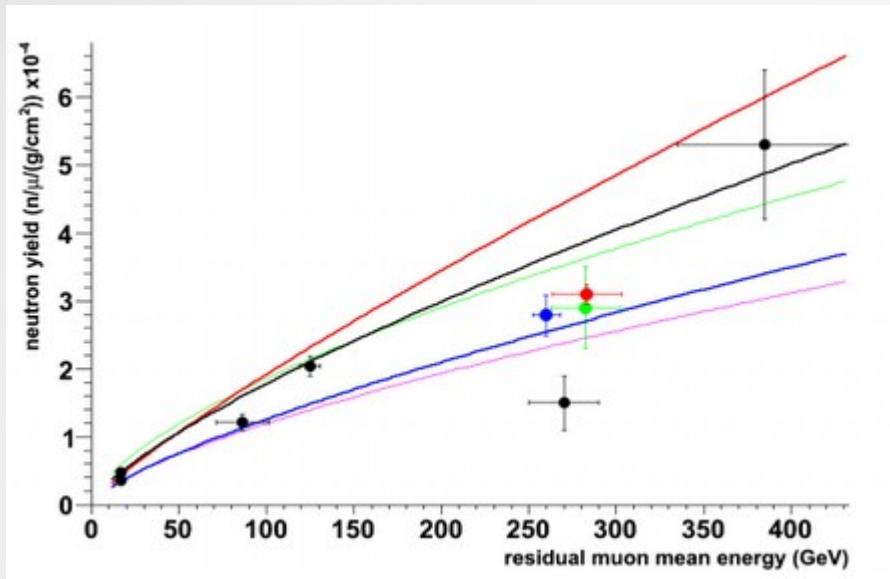
Liquid scintillator is within 30% over most of the energy range with the largest discrepancies near 100 MeV neutron energy.

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



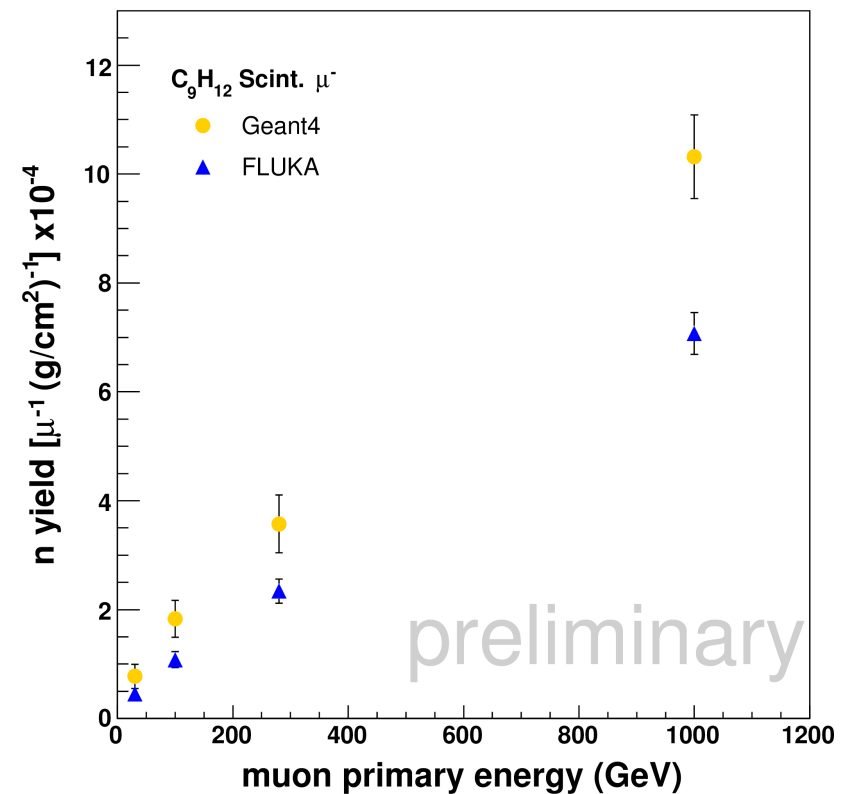
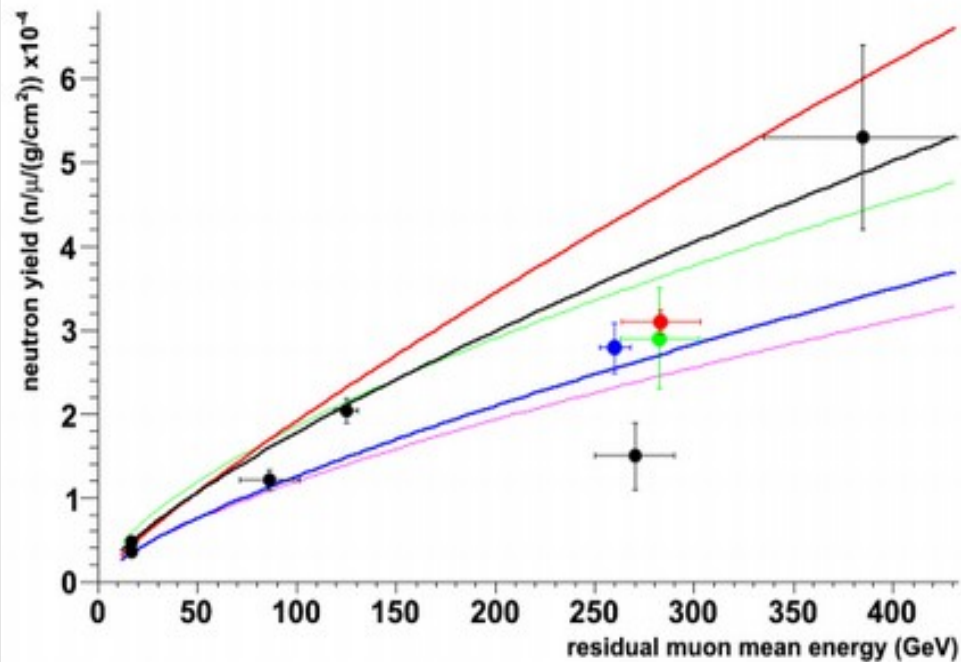
Experimental Results

- 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**

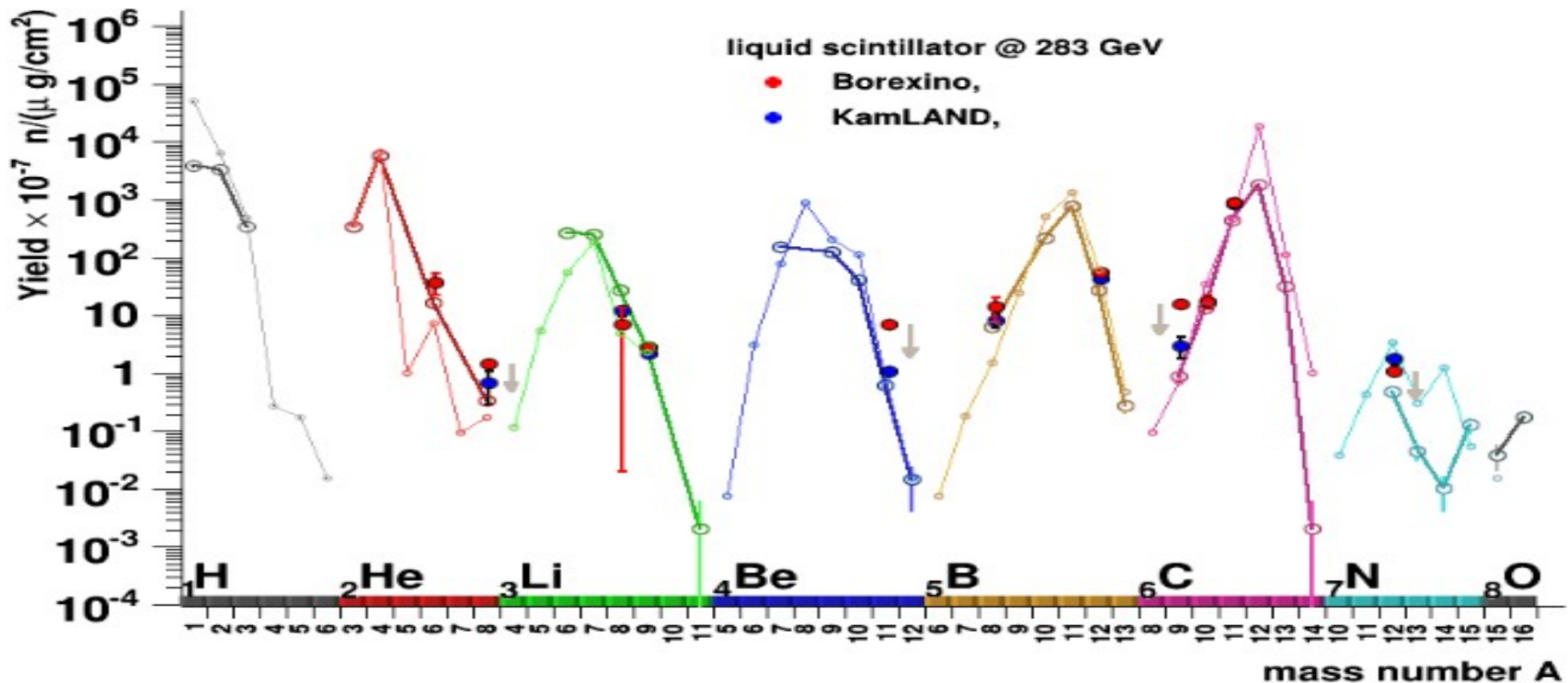
Cosmogenic Neutron Yield in Liquid Scintillator



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

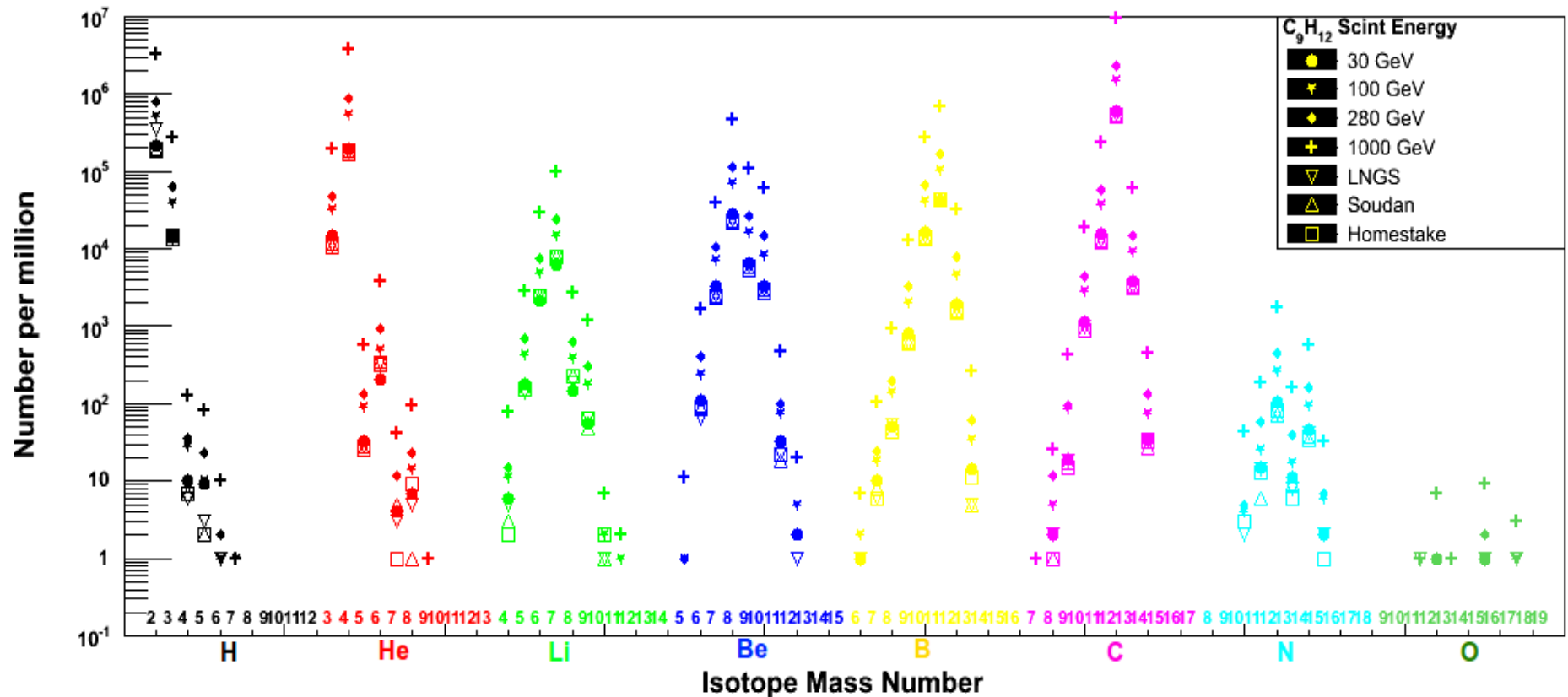
Geant4 and FLUKA Isotopes in Liquid Scintillator for 280 GeV



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

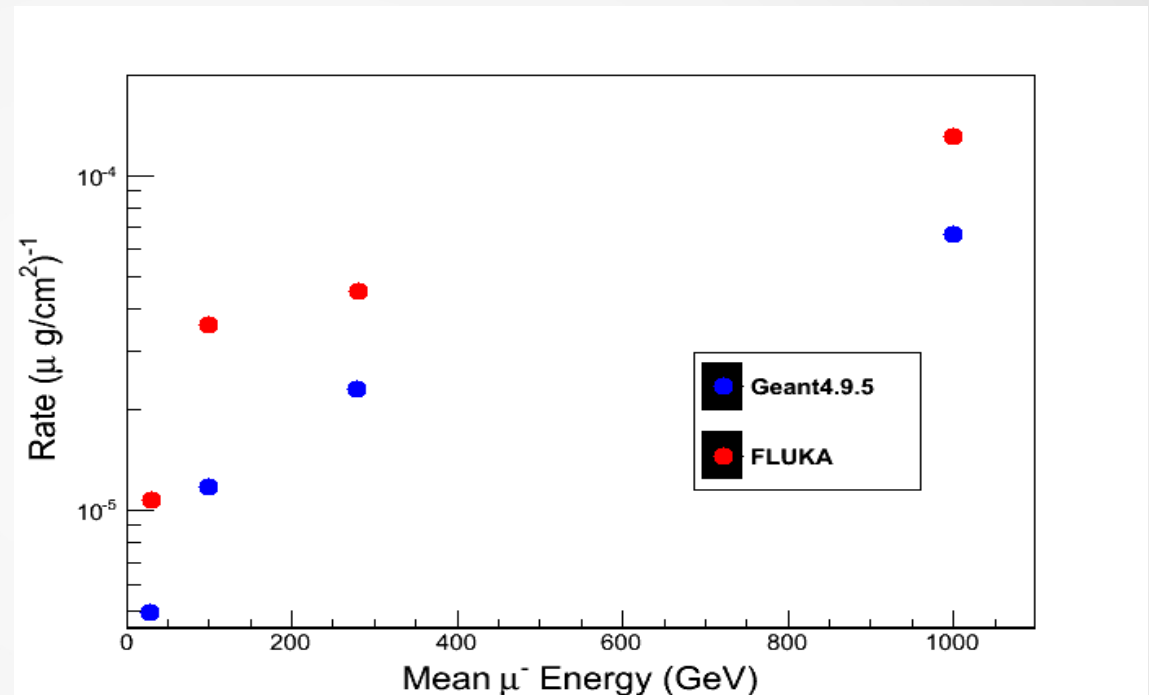
KamLAND agrees as well; Borexino has larger production for some isotopes.

Geant4 Isotopes in Liquid Scintillator for All Energies



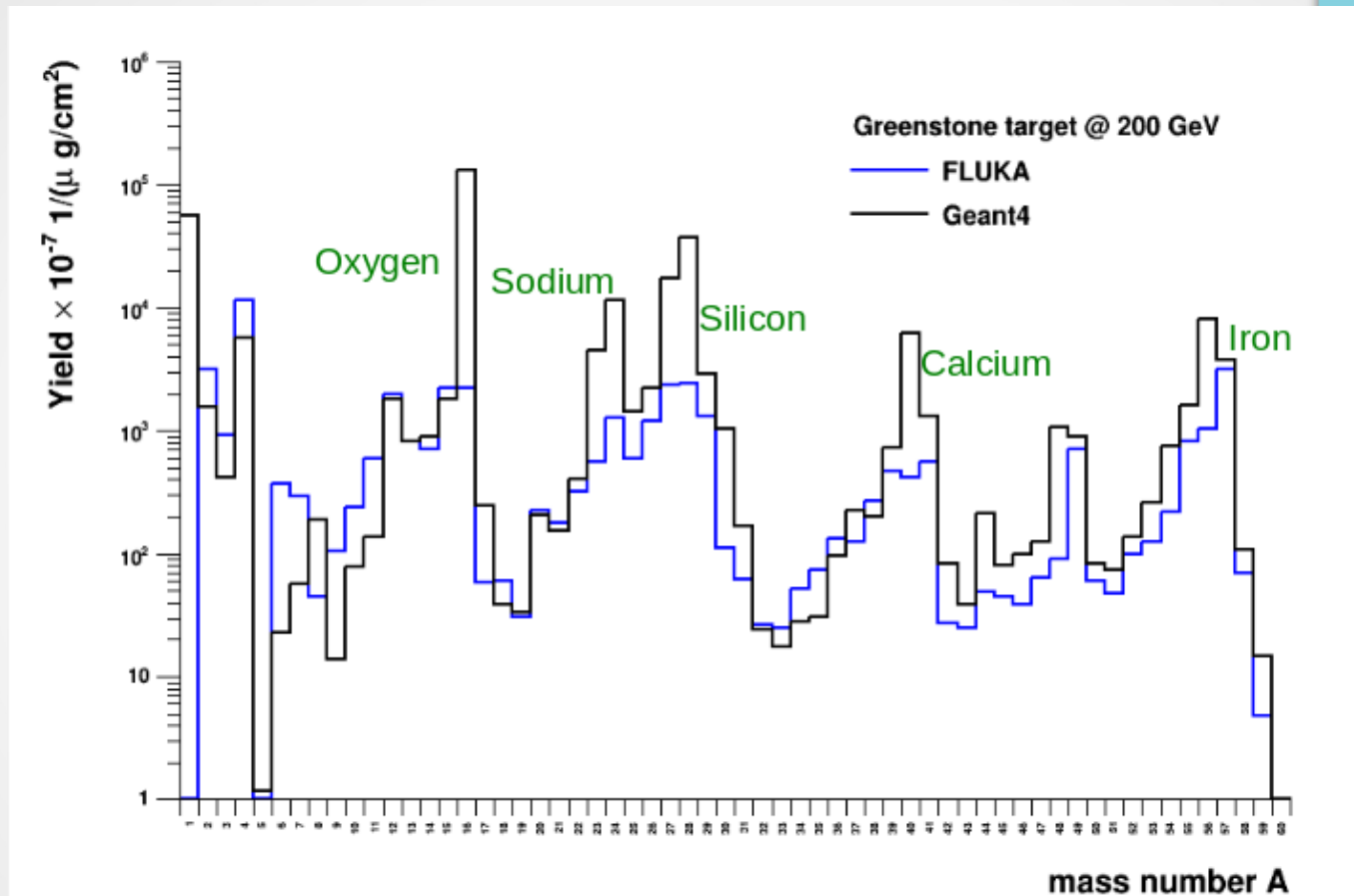
Carbon-11 Production in Liquid Scintillator

- 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

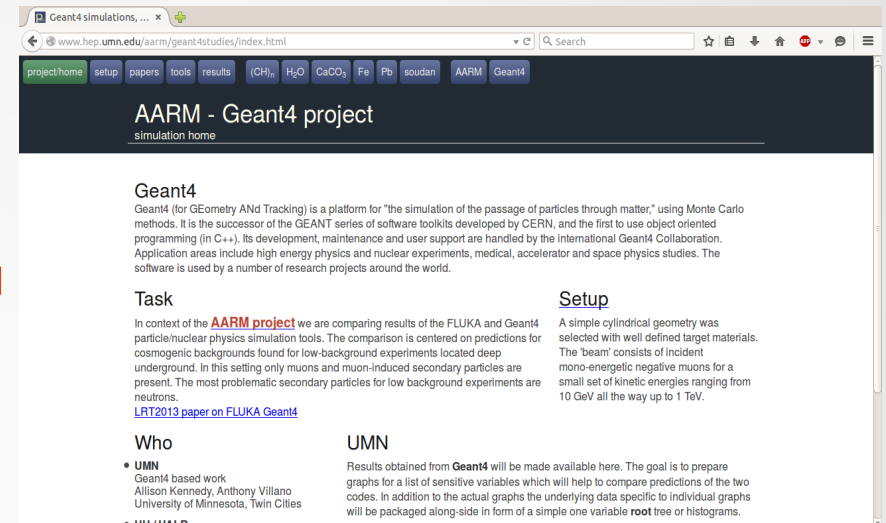
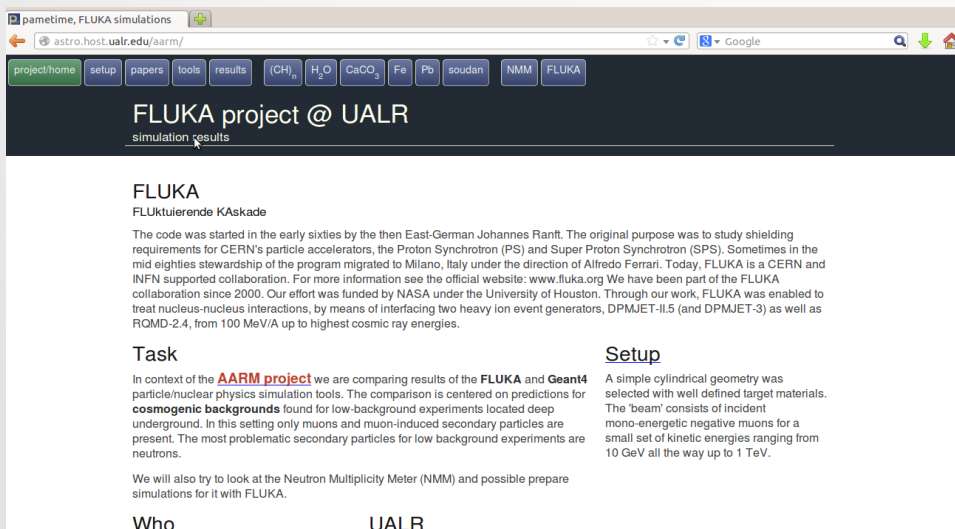
Geant4 Results at

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

Email:

Allison Kennedy, kennedy@physics.umn.edu

Anthony Villano, villaa@physics.umn.edu



FLUKA Results at

astro.host.ualr.edu/aarm

Email:

Sarah Lindsay, sxlindsay@ualr.edu

Anton Empl, anton.empl@gmail.com