FLUKA-based cosmogenic background predictions for Darkside

Anton Empl, Ed V. Hungerford and Riznia J. Jasim

University of Houston

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Outline

- With strong focus on FLUKA

  Darkside

  Muon-induced Backgrounds

  Remarks about FLUKA

currently proposed logo

we are still new to the deep underground regime

- Version

  Fluka2008.3d patch release October 15th 2010
  next release: mid/end March 2011
  FLUKA collaboration member

  http://www.fluka.org

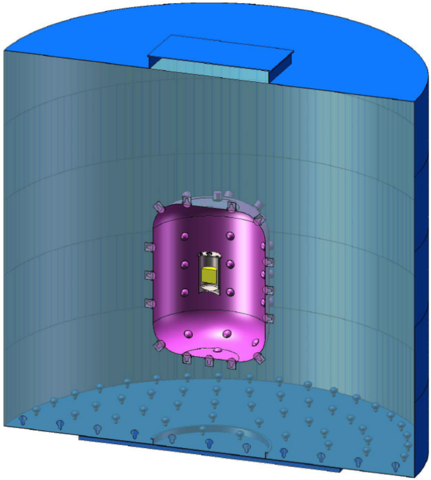
Darkside, inner detector configuration

- MAX R&D,
  test bed for new technologies
  in respect to the ’A’ in MAX
- 50 kg depleted argon, dual phase TPC
- QUPIDS
- change in desired materials for inner detector
- housed inside a liquid scintillator neutron veto

graph: courtesy of Darkside collaboration

Darkside, at Gran Sasso - CTF

- currently proposed to be installed at Gran Sasso
  good for us since we are still learning
- strong ties to BOREXINO collaboration
- will be placed inside CTF screening water tank
- 11 m diameter x 10 m height pure water shield (plus 10cm steel in floor)
- active muon (and neutron) veto with about 140 PMTs (3% coverage)



graph: courtesy of Darkside collaboration

FLUKA setup

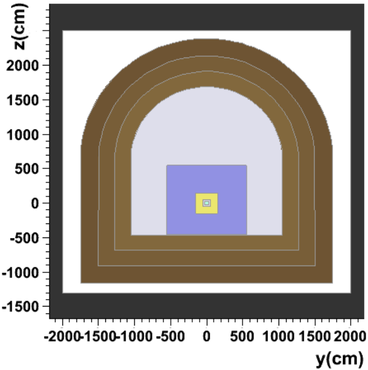
- Simulation of cosmogenic backgrounds for Darkside 50
  really: A careful implementation of muon radiation field for hall C

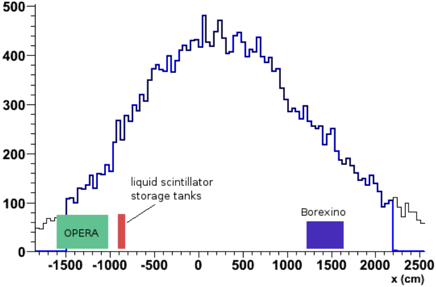
  - total flux of 1 muon per m^{-2} per hour ($= 2.77 \times 10^{-8}\ cm^{-2}\ s^{-1}$) at cavern
  - average muon kinetic energy of 270 GeV
    muon kinetic energy was sampled from parameterized differential spectrum (see T.K. Gaisser)
  - muon angular distribution for Gran Sasso *(MACRO, FLUKA, → Borexino)*
  - average chemical composition of Gran Sasso rock
  - actual geometry of cavern with 7m thick outer rock layer

DEFAULTS option: PRECISION

electromagnetic effects turned on gradually towards the cavern

Implemented Geometry





left) Cross section through the setup

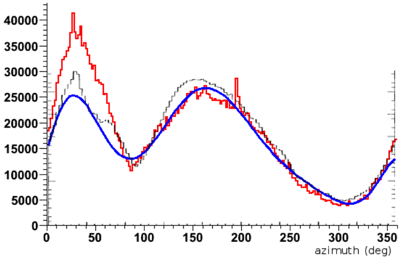
right) The length of the cavern was selected to contain the muon origin for 95% of all events where particles reached the CTF water tank.

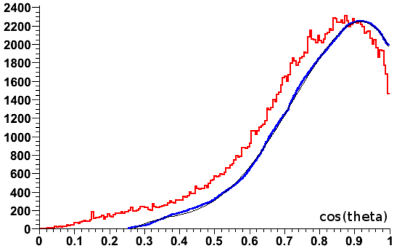
Implemented configuration combined with total muon flux at Gran Sasso yields **0.53 primary muons correspond to 1 second**

Muon Angular Distribution

▷ MACRO and FLUKA (→ Borexino)

We obtained FLUKA predictions[1] for tracking atmospheric muons all the way through the Gran Sasso mountain up to the walls of the laboratory. The FLUKA simulated muon angular distribution at the cavern walls is shown below by the red histograms. At the same time we give the measured distribution as found by the MACRO experiment in (black/)blue.





(manually normalized spectra)

see: arXiv:1101.3101v2 [physics.ins-det] 16 Feb 2011
Muon and Cosmogenic Neutron Detection in Borexino

[1] Massimiliano Sioli and Giuseppe Battistoni, the FLUKA collaboration

Muon-induced Neutron Kinetic Energy Spectrum

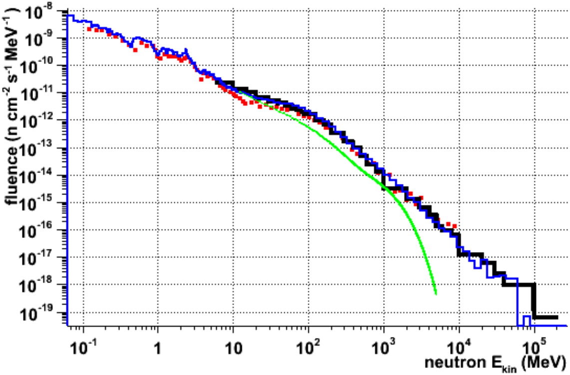
at the rock cavern boundary (geometry: $6m^3$ centered in $20m^3$)

our current result

H. Wulandari etal arXiv:hep-ex/0401032v1 21 Jan 2004 - FLUKA

A. Dementyev etal Gran Sasso note: INFN/AE-97/50, 22 Sep 1997 - Bezrukov and Bugaev + SHIELD

A. Hime and D.-M. Mei, parameterization arXiv:astro-ph/0512125 v2 6 Dec 2005 - FLUKA
(coincident direct muons?, A?)



Note: the FLUKA versions used here differ - in particular FLUKA now features 260 low energy neutron groups rather than the 72 previously.

Muon-induced Neutron Flux at Rock - Cavern Boundary

at Gran Sasso

neutron E_{kin}	> 1 MeV	> 10 MeV	> 100 MeV	total
Hime and Mei (+30% FLUKA scaling)	0.81	0.73	0.201	2.72
without	0.62	0.56	0.155	2.09
H. Wulandari *etal*	0.85			
current configuration	1.503	0.657	0.252	11.2

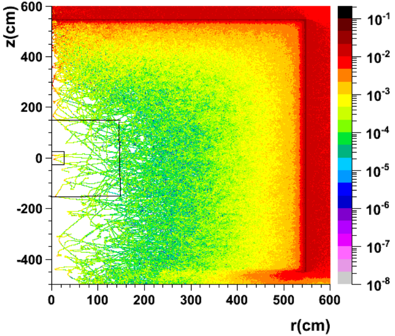
All values for flux are given in 10^{-9} $\mathbf{cm}^{-2}$ $\mathbf{s}^{-1}$.

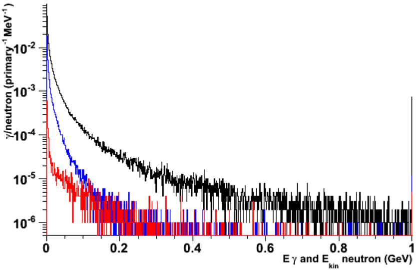
CTF Tank

A total of about 5×10^7 primary muons were thrown which corresponds to about 3 years of operation

left) Neutron fluence at the CTF (R-Z coordinates)

right) Energy spectra (1 MeV - 1 GeV) for gammas at the CTF tank is shown by the black histogram (→ rate) as compared to the blue histogram where only events with no direct muon were selected. In red we show the neutron spectrum for comparison.

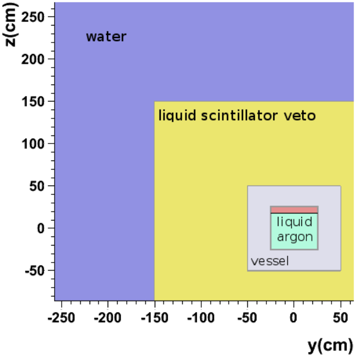




Fluence [primary^{-1} cm/cm^{-3}]

Inside the CTF Tank

In our studies the liquid scintillator veto was implemented with the proposed geometry and chemical makeup, however no signals were generated for it.



For the 3 year period simulated we find events with particles reaching the respective interior parts of the setup:
discounting direct muon events

liquid scintillator veto: **69**
with a cut on low energy gammas

inner detector: **5**

since then ...

FLUKA, remarks

- supported under official agreement between CERN and INFN
- old-fashioned FORTRAN, not fancy
  but *very simple and small installation*
- very consistent framework across all particles/interactions
  with *extremely reproducible results*
- based out of Milan for more than 20 years now
  Alfredo Ferrari etal together with original author Johannes Ranft
  small and active collaboration
- based on (micro) physics models rather than fits to data
  permits robust extrapolations
  models are tested against data
  no user *tweaking* of single aspects of the code
- source is available upon written request under a special licenses agreement - why?
- please do not get confused by Geant-3 / FLUKA hadronic generator

FLUKA, remarks (continued)

- next release is promised for the end of March, Fluka-2011
  (before upcoming FLUKA school at Heidelberg)
- no explicit changes to physics concerning muons, however in general hadronic modeling is always under development
- note: the latest FLUKA release implemented a significant upgrade to the low energy neutron transport/modeling

  still a multi-group approach, but latest data from neutron libraries are used and there are now 260 instead of 72 low neutron energy groups

  low energy neutron simulation requires getting used to

- low energy neutrons
  multi group transport does not provide for realistic recoil energies
  work on C, O and liquid Argon 'point-wise' treatment is scheduled

Conclusion

A detailed understanding of the overburden at Homestake is obviously desired. Good measurements of the muon radiation field will help modeling. Simple but well defined measurements of muon induced neutrons really are missing.

It is good practice to have cross checks for simulation results/codes.

The physics in FLUKA is quite consistent and reliable.

From a user perspective FLUKA is relatively transparent.

Thank you for your attention

http://www.fluka.org

- version: FLUKA 2008.3d.0

Darkside Collaboration

Augustana College - SD, USA
Black Hill State University - SD, USA
Fermilab - Il, USA
INFN Laboratori Nazionali del Gran Sasso - Assergi, Italy
INFN and Universita degli Studi Genova, Italy
INFN and Universita degli Studi Milano, Italy
INFN and Universita degli Studi Naples, Italy
INFN and Universita degli Studi Perugia, Italy
Joint Institute for Nuclear Research - Dubna, Russia
Princeton University, USA
RRC Kurchatov Institute - Moscow, Russia
St. Petersburg Nuclear Physics Institute - Gatchina, Russia
Temple University - PA, USA
University of California, Los Angeles, USA
University of Houston, USA
University of Massachusetts at Amherst, USA