Dark Matter Depth Task Force

Originally formed in the throes of the 7400' decision

Can all dark matter experiments be performed at 4850' ?

Simulations required to answer the question disagreed with each other by several orders of magnitude !

Subsidized by the AARM NSF S4 and INPAC (Berkeley)
Neither of whom are supporting this work now.

A Collaboration emerging from the Dark Matter Writing Group

Minnesota: Cushman, Reisetter, Villano, Pepin, Roth
Brown: Gaitskell, Pangilinan, Malling
LANL: Hime, Hennings-Yeomans
USD: Mei, Zhang
Davis: Tripathi
UALR: Empl
LLNL: Bernstein, Sweany
Caltech: Golwala
Berkeley: Sadoulet

We targeted cosmogenic simulation as the key

Differences between predictions can be due to

** poorly-understood physics processes (e.g. μ-induced neutrons)*
** effects of secondary particles & multiplicities under differing implementations*
** validity of muon and neutron parameterizations, differing interpretations*

And… in the end… how do you compare to data?

We have implemented the following plan to

** Identify the uncertainties in cosmogenic simulations*
** Establish a rubric to compare Sims and Experiments*

The following steps will be performed at multiple sites:

* Establish a common GEANT4 version and physics list *(Minnesota, Brown, USD)*
* Establish FLUKA at 2nd site *(LANL, UALR → Houston)*

* Validate all simulations with a simplified geometry (LZ water shield)

* Compare existing simulations with respect to
event generation *depth parameterization* *implementation strategy*

* Compare to data
Geant4 vs Neutron Multiplicity Meter @ Soudan
Fluka vs Borexino

* Feedback to
Geant4 collaboration (thru SLAC Geant4 Collab)
Fluka (through A.Empl, Darkside)

Details can be found at the Task Force Wiki
http://zzz.physics.umn.edu/lowrad/dm_task_force

Tied in with ongoing AARM study (Kudryavtsev, Villano, Empl)
Detailed Fluka vs Geant4 comparison of muon-induced physics

Agree on Same Cosmogenic Backgrounds at Homestake 4850'

Same process to generate Backgrounds

- Muons MUSUN Program with Homestake Overburden and Rock
- GEANT4 propagation through 7m of rock, keeping all secondaries
- Into 10m x 10m x 10m Cavern

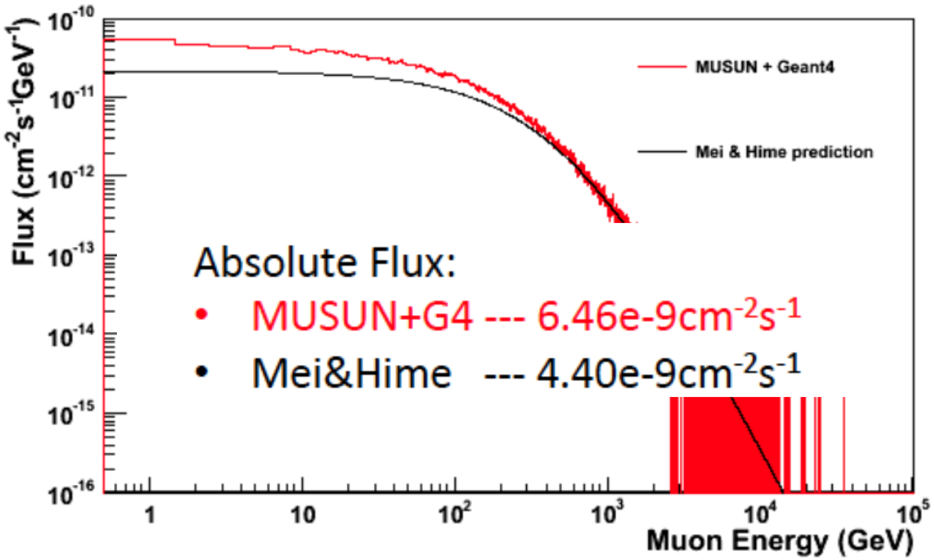
Same Physics Lists

http://zzz.physics.umn.edu/lowrad/dm_task_force/physics_lists

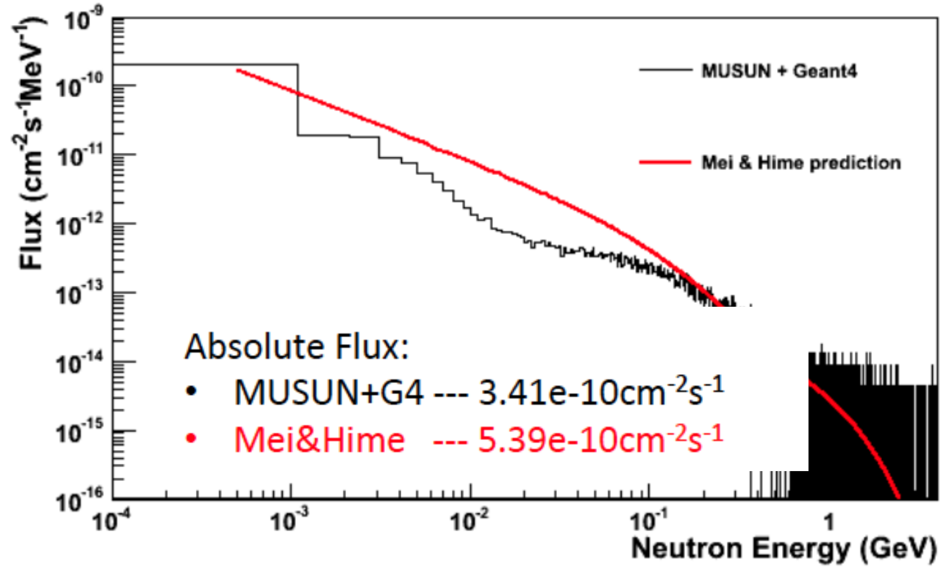
Geant 4.9.3 P02 + Shielding List + MuNuc
Geant 4.9.5 QGSP_BERT_HP

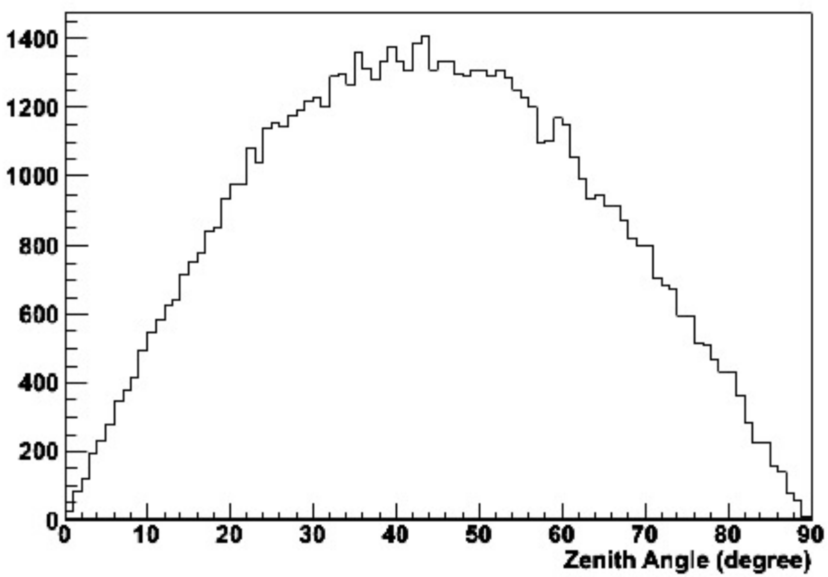
Much Better Cosmogenic Background Model at Homestake 4850’

Muon flux at 4850-level

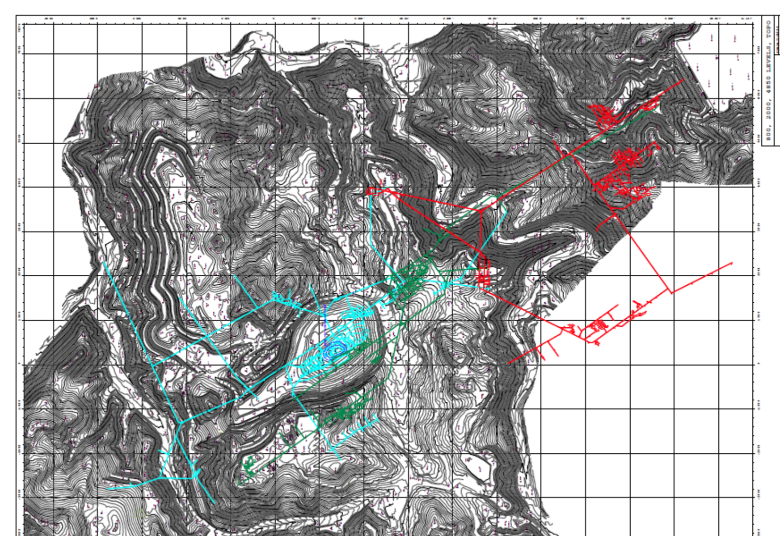


Neutron flux at 4850-level





Mountain Profile of Homestake



Huge discrepancies between the first LZ simple Monte Carlo compared to the more careful work we are doing now.

Problems:

Assuming a simple neutron parameterization based on Mei and Hime
Assuming isotropic incidence and spherical volume of Xe
Neglecting secondaries produced in the rock
Removing parent muons from continued interactions.

New LZ has the better geometry, angular distribution, and complete showers.
Normalized to muon flux (M&H at 4850)
Using our new geometry, Chao also compared parameterization of throwing single neutrons with throwing single muons at the water tank.

	old LZ	new LZ	Chao single n	Single muons
$\mu/s/m^2$ into water tank	1.8 E-5	4.4 E-5		
$n/s/m^2$ (E>100KeV) into tank	1.7 E-6	3.6 E-6		
$n/s/m^2$ (E>100KeV) into LXe	9.7 E-6	3.4 E-10	1.0 E-8	1.4 E-6
NR Events/s	4.8 E-5	5.4 E-8	1.1 E-8	5.8 E-5

➔ **Three orders of magnitude more events with at least one nuclear recoil**

Compare Different Technologies

Start with a common water shield based on the LZ20 design:

12 m diameter, 12 m high cylindrical water tank

Inside, place a 2 m diameter, 2 m tall experiment

Detailed geometry moving from the outside in to the detector volume as follows:

L Ar

2.5 cm thick SS Outer Vessel of 4 m diam + vac
2.5 cm thick SS Inner Vessel of 3 m diam + vac
0.5 cm thick PMT shell + 1.0 cm of Acrylic
2m x 2m Liquid Argon Volume

L Xe

75 cm thick Liquid Scintillator
3 mm thick Titanium shell
2m x 2m Liquid Xenon Volume

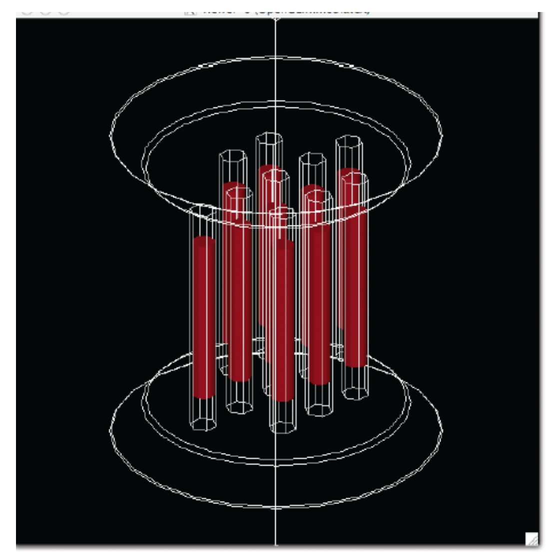
Ge

1 cm thick SS outer Vessel of 2.2 m diam
20 cm thick poly
3 cm thick Cu cryostat

1.5 Ton Payload

10 Towers of 30 detectors each

Each detector is 6” diam, 2” thick



Find Rejection on Bkgd-induced Nuclear Recoils for each analysis cut
Find veto ratios for singles and multiples

L Xe

- Energy ROI is 5 - 25 keVnr
- veto on electron recoil energy < 50 keVee deposited in liquid Xe,
- fiducial cut: r < 93cm & |z| < 84 cm
- multiples cut - σr < 3cm & σz < 0.2cm
- veto on muon entering water shield

Ge

- Energy ROI is 5-100 keVnr
- Yield cut = no ER of more than 10%
- single detectors of 10cm diam and 1 inch thickness, multiples down to 2 keVnr
- veto on muon entering water shield

L Ar

- Energy ROI is 50-100 keVnr (energy resolution 8%)
- 55 cm from wall (resolution of a couple cm)
- de-excitation gamma - fPrompt from inelastic scatter
- multiples are included in the timing cut = >6 cm
- veto on muon entering water shield,

Some Preliminary Findings

Careful Simulations take a loooong time.

Now at 8 live years with the more complete LZ Simulation

Less with L Ar and Ge

Un-vetoed Cosmogenic neutron backgrounds at 4850’ are unacceptable for ton-scale DM

A simple Muon veto surrounding the tank is not sufficient

However, if the cavern is large enough, an umbrella veto over the entire ceiling is.

Rejection of electromagnetic energy and multiples becomes more important

Whether such discrimination is sufficient on its own will depend on the technology

Strict Cosmogenic Neutron rejection requires many of the same techniques that

Radiogenic detection and shielding require. A neutron veto looks very similar at 7400’

White Paper or Journal Paper

1. Present our best understanding of Simulation and Measurement of cosmic muon-induced neutron background in underground labs.
2. Define what restrictions that places on depth as a function of technology and shielding.
3. Identify the remaining systematic errors and suggest means for reducing them

I. Introduction

II. Existing Measurements of Underground Neutron Backgrounds
LSD, LVD, Borexino, Kamland, Zeplin II/Boulby, Edelweiss/LSM, SNO, Soudan NMM

III. The Simulation Challenge
  A. Simulation Overview
  B. Muon Flux Estimations
  C. Muon-induced Secondaries

IV. Implications for Dark Matter experiments at Homestake 4850

V. Scaling to Different Depths

VI. Conclusion