Assay and Acquisition of Radiopure Materials

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CNA Engineering

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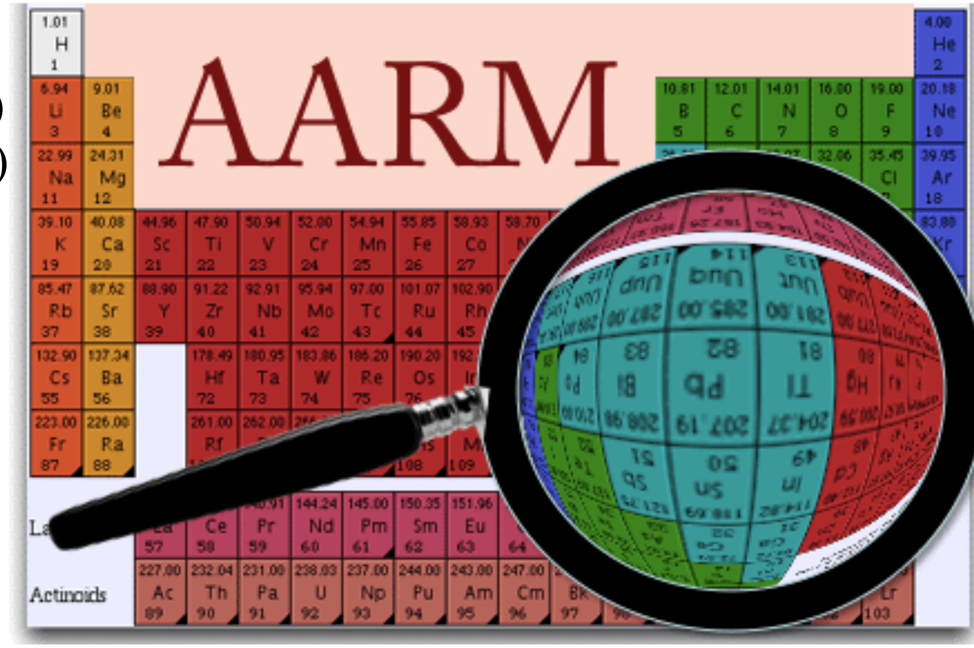
NSF Review

PRESENTATION OUTLINE

Overview
FAARM Engineering & Project
Simulation & Backgrounds
Neutron Benchmarking
Early Screening

Assay and Acquisition of Radiopure Materials



Principle Investigators

Priscilla Cushman (University of Minnesota)
Dongming Mei (University of South Dakota)
Kara Keeter (Black Hills State University)
Richard Schnee (Syracuse University)

Engineering Consortium

CNA Consulting Engineers (Lee Petersen)
Dunham Associates
Miller Dunwiddie Architecture, Inc

- Characterize radon, neutron, gamma, and alpha/beta backgrounds at Homestake
- Develop a conceptual design for a common, dedicated facility for low background counting and other assay techniques: **FAARM**
- Assist where appropriate in the creation of common infrastructure required to perform low background experiments.
- Perform targeted R&D for ultra-sensitive screening and water shielding

Integration & Infrastructure Concerns require a Broader Collaboration

Scientific Collaboration

Craig Aalseth
Henning Back
Tim Classen
Jodi Cooley
Darrin Grant
Yuri Efremenko
Brian Fujikawa
Reyco Henning
Jeff Martoff
Robert McTaggart
Eric Hoppe
Andreas Piepke
Andrew Sonnenshein
John Wilkerson
Tullis Onstott

International Scientific Advisory Panel

Laura Baudis (Zurich University)
Richard Ford (Queen’s University, SNOLab)
Gilles Gerbier (CEA Saclay)
Gerd Heusser (Max Planck Institute, Heidelberg)
Andrea Giuliani (University of Insubria (Como), Coordinator of ILIAS Continuation)
Mikael Hult (European Commission: JRC Inst. for Reference materials and Measurements)
Vitaly Kudryavtsev (University of Sheffield)
Pia Loaiza (Laboratoire Souterrain de Modane)
Matthias Laubenstein (INFN, Gran Sasso Laboratory)
Neil Spooner (University of Sheffield)

Tasks and Schedule: the Past

Year 1: Driven by early timetable for the PDR ➔ concentrated on engineering

Met all our "integration deliverables" to DUSEL
Design Low Bkgd Facility for AARM = FAARM
Resource-loaded schedule & bottoms-up cost
S4 ➔ early screening ➔ MREFC funding
➔ construction , installation and commissioning

Year 2: Design work continued until NSB decision Dec 2010

Detailed Engineering, e.g. finite element analysis, construction

Redirect to Backgrounds & Simulation in 2011

Coordinate all S4 Assay requirements & Radon requirements

AARM Collaboration Meeting (Nov 2010)
http://zzz.physics.umn.edu/lowrad/meeting2/talks

Create standardized Homestake Geant4 for all experiments

AARM Collaboration Meeting (Feb 2011)
http://zzz.physics.umn.edu/lowrad/meeting3/talks

Tasks and Schedule: the Future

Year 3: Convert design for staged, dedicated excavation

Most elements remain the same, but Civil construction cheaper
Water shield: SS tank ➔ cavity + liner, top-access only
Dedicated MC and engineering for the Immersion Tank

Continue with Simulation & Bkgds Integration

Modular, flexible framework for all Homestake experiments
muon propagation code + site-specific overburden & rock
cavern characterization for each level
improve physics, add cross sections/processes, compare to FLUKA
Benchmark with a series of neutron measurements
universal materials screening database

Beyond S4: Final Design and Construction of a US Gen3 Low Bkgd Facility

Extend Modular Geant MC to all underground sites

International underground Sim group (tied to GEANT4 collab)
Each lab will contribute site data, coded into the standard framework
Users can request the Background Module for their lab
Enter your experiment's geometry & Press go

Funding Profile for AARM

	FY2010 (k$)	FY2011 (k$)	FY2012 (k$)
TOTAL Budgeted	386.8	389.0	324.2
Actual Total	166.9	~ 350.	~ 400.
CNA Budgeted	67.5	97.5	87.9
CNA Actual	66.1	~ 120	~100.

Significant Delay in BHSU Postdoc ➔ Moved to end of FY2011, FY201
better match with Immersion Tank Studies

Syracuse Postdoc for FY2011, just hired 2 months ago

Kiesel subcontract (ILIAS bkgd measurements) redirected to Neutron
Benchmarking (student travel, simulation support)

Workshops very successful
(2 per year, no registration fee, up to $600 travel reimbursement)

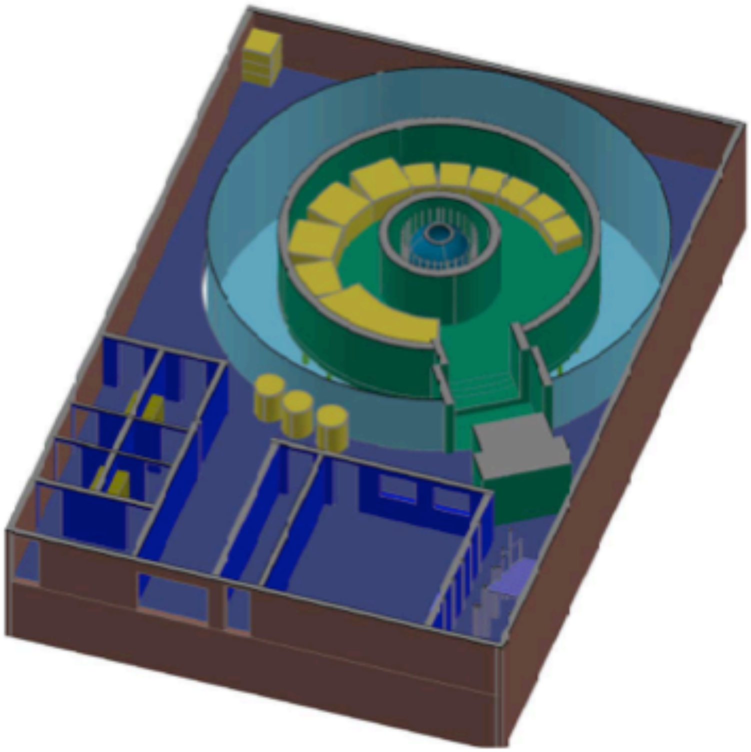
Elements of FAARM (Design Goals)

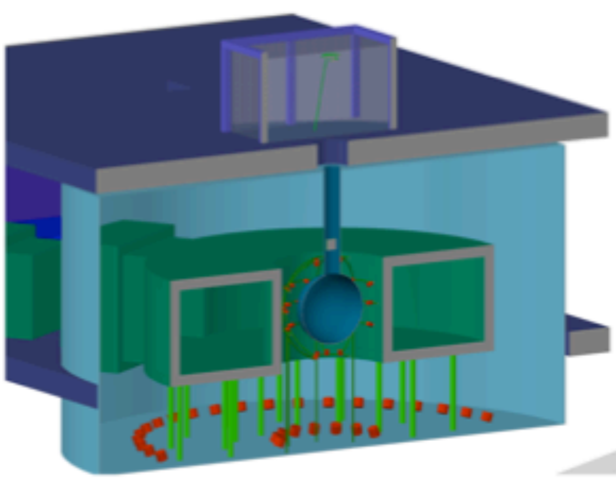
- Entire facility is class 10,000 clean room, < 20 Bq/m^3
  - Class 1000 clean rooms
  - Ateko (NEMO facility provided 0.01 Bq/m^3 breathable air at 150 m^3/h)
  - Radon-mitigated zones (<1 Bq/m^3) and assembly areas (<0.1 Bq/m^3)
  - Radon-free storage and unified LN system
  - Wet benches, clean machining, hoods, etc

- Instrumented Water Shield with toroidal interior acrylic room
  - Houses ultra-sensitive screeners (GeMPI style, BetaCages)
  - Reduce cost of individual lead shielding ($2M savings)
  - Active Muon veto, Neutron & Gamma shielding
  - Outer shield of Immersion Tank, Space for Experiments & R&D

- Top-loading Immersion Tank
  - Modeled on the Borexino CTF
  - Whole body counting with 0.1 counts/day, E > 250 keV
  - U/Th at .01/.04 ppt, surface α,β at < 1 count/m^2/day (unsealed)
  - and 6 x 10^{-6} cts/kg/keV/day from Compton continuum
  - OPTION: Could be replaced by highly segmented germanium

Original FAARM Design 3-D rendering





Inner Tunnel Lab

γ-flux	7.974×10^{-5}	$cm^{-2}\ s^{-1}$
n-flux	4.817×10^{-10}	$cm^{-2}\ s^{-1}$

4 < ppt (GeMPI, arrays)
6 < ppb (well, clover, coax)
2 Beta Cages
Prototyping Space
(DM or $0\nu\beta\beta$ or novel assay)

Radon Mitigation
Common cryogen plumbing and
LN boil-off for screeners

Central Pool

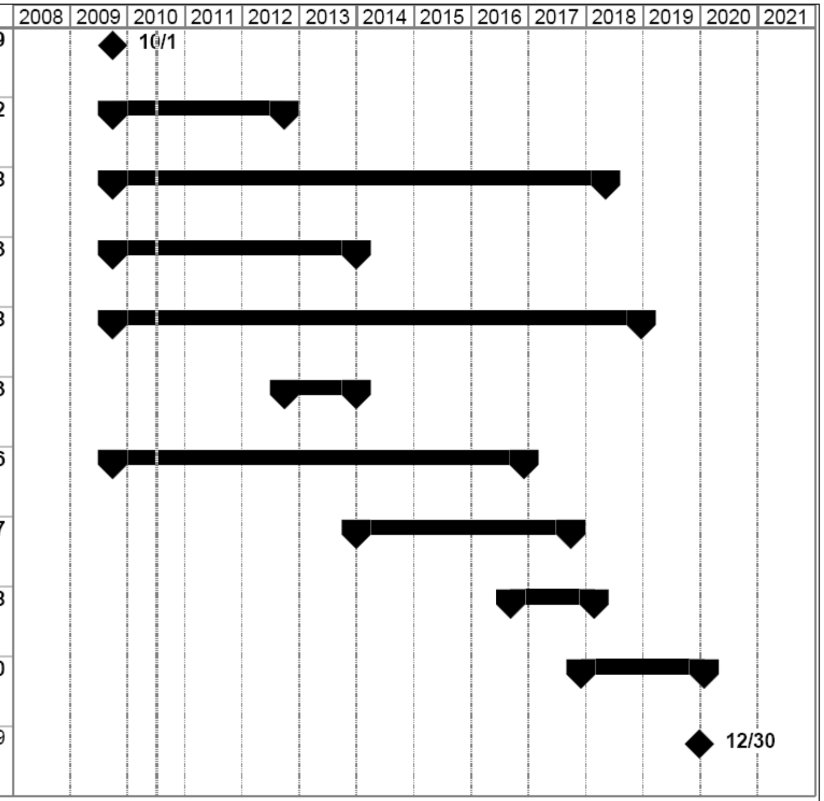
0.1 counts/day, E > 250 keV
sensitivity of 10^{-14} g/g U/Th 10^{-12} g/g K
modeled on Borexino CTF
2m diam nylon vessel filled with LS
Observed by low rad QUPIDs
Top-loading from dedicated Clean Room

FAARM Engineering
Resource Loaded Schedule

- We used MS Project, 356 tasks, 150 resources
- WBS task identification
- Capital costs are MS Project “materials”
- Labor costs are MS Project “work”
- Conventional construction tasks/costs are “materials”
- Costs distinguish ten “color of money” categories
  - S4
  - Post S4
  - Other
  - CDMS
  - DULBCF
  - DUSEL
  - DUSEL R&D
  - FAARM
  - FAARM Ops
  - BGE

FAARM Engineering
All Tasks Rolled Up

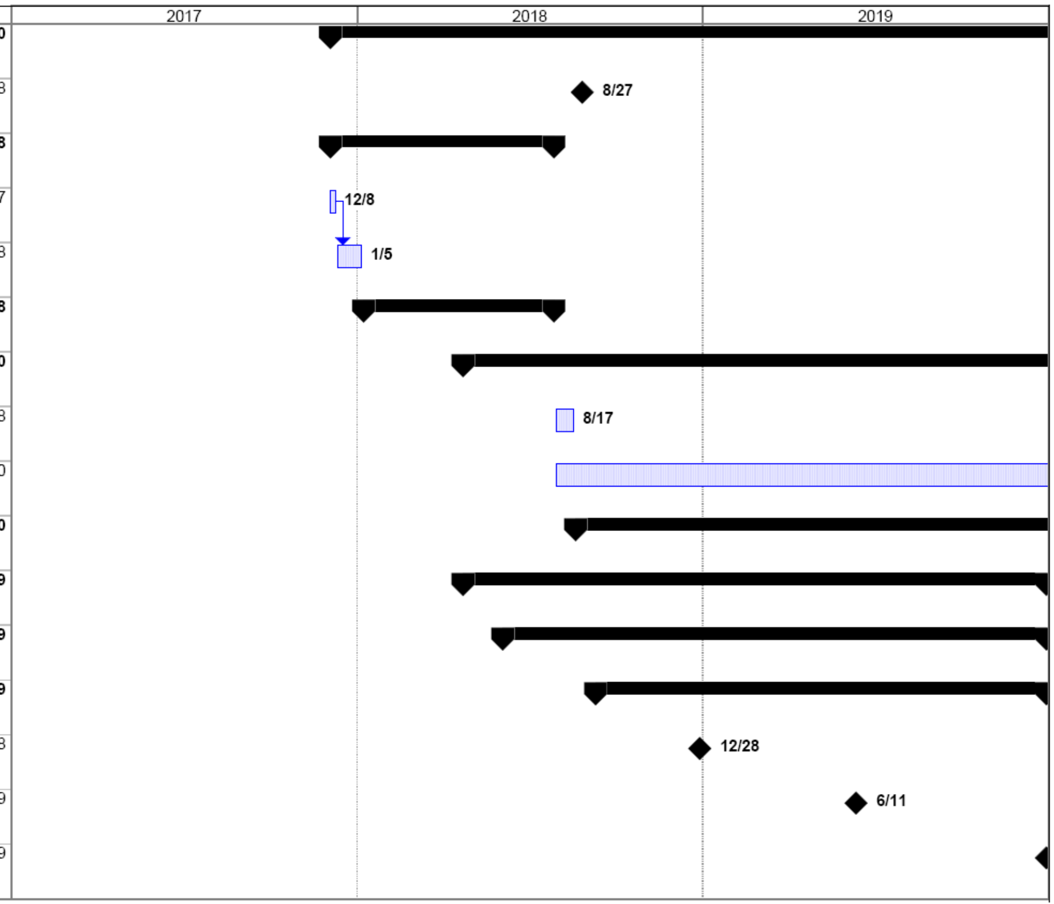
ID	WBS	Task Name	Duration	Start	Finish
1	**1**	**Low Background Counting**	**0 d**	**Thu 10/1/09**	**Thu 10/1/09**
3	**2**	**S4 Science Operations**	**782 d?**	**Thu 10/1/09**	**Fri 9/28/12**
5	**3**	**Homestake Characterization**	**2245 d**	**Thu 10/1/09**	**Wed 5/9/18**
31	**4**	**Shielding and Simulation Studies**	**1109 d**	**Thu 10/1/09**	**Tue 12/31/13**
47	**5**	**Early Screening Activities**	**2407 d?**	**Thu 10/1/09**	**Fri 12/21/18**
181	**6**	**Post S4 Scientific Operations**	**327 d**	**Mon 10/1/12**	**Tue 12/31/13**
183	**7**	**FAARM Design Phases**	**1872 d**	**Thu 10/1/09**	**Mon 12/5/16**
210	**8**	**FAARM Scientific Elements**	**978 d**	**Wed 1/1/14**	**Fri 9/29/17**
239	**9**	**FAARM Conventional Construction**	**381 d?**	**Mon 9/12/16**	**Mon 2/26/18**
302	**10**	**FAARM Installation & Commissioning**	**561 d**	**Mon 12/4/17**	**Mon 1/27/20**
378	11	End of schedule	0 d	Mon 12/30/19	Mon 12/30/19



FAARM Engineering

FAARM Installation & Commissioning

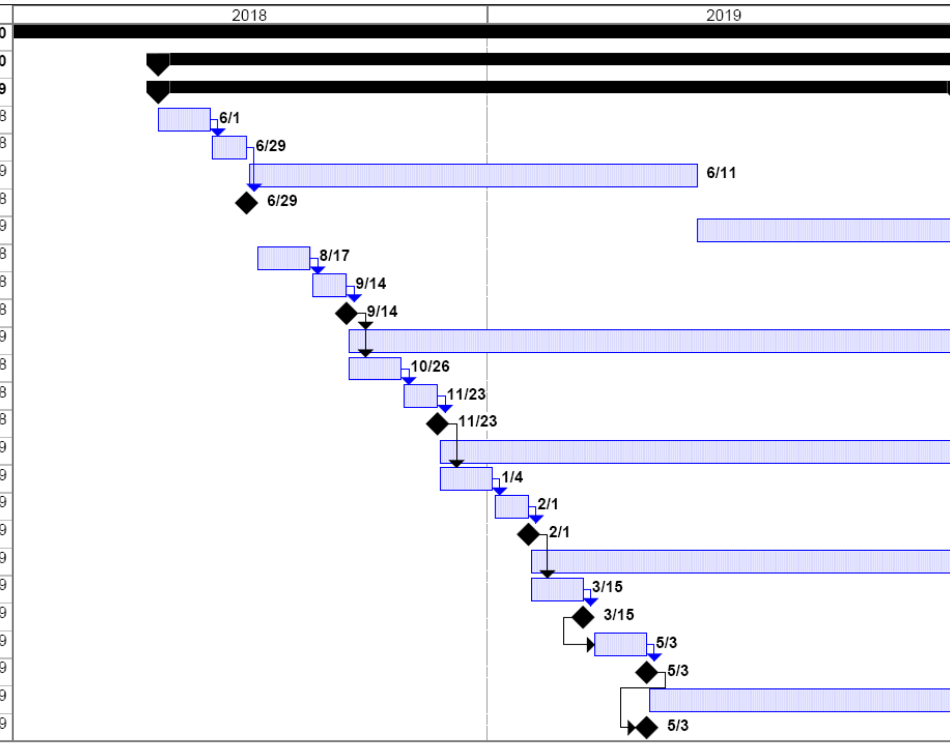
ID	WBS	Task Name	Duration	Start	Finish
302	**10**	**FAARM Installation & Commissioning**	**561 d**	**Mon 12/4/17**	**Mon 1/27/20**
303	10.1	FAARM screening starts 1	0 d	Mon 8/27/18	Mon 8/27/18
304	**10.2**	**Phase 1: Moderate Cleanliness**	**170 d**	**Mon 12/4/17**	**Fri 7/27/18**
305	10.2.1	Establish moderate cleanliness protocols	5 d	Mon 12/4/17	Fri 12/8/17
306	10.2.2	Clean entire FAARM	20 d	Mon 12/11/17	Fri 1/5/18
307	**10.2.3**	**Water Shield Commissioning**	**145 d**	**Mon 1/8/18**	**Fri 7/27/18**
317	**10.3**	**Phase 2: Tight Cleanliness**	**461 d**	**Mon 4/23/18**	**Mon 1/27/20**
318	10.3.1	Establish tight cleanliness protocols	15 d	Mon 7/30/18	Fri 8/17/18
319	10.3.2	Monitor particulate level and radon	391 d	Mon 7/30/18	Mon 1/27/20
320	**10.3.3**	**Immersion Tank Commissioning**	**376 d**	**Mon 8/20/18**	**Mon 1/27/20**
333	**10.3.4**	**Gamma screener installation and commis**	**440 d**	**Mon 4/23/18**	**Mon 12/30/19**
357	**10.3.5**	**Beta Screener Installation and Commissi**	**410 d**	**Mon 6/4/18**	**Mon 12/30/19**
371	**10.3.6**	**Alpha Screener Installation and Commiss**	**340 d**	**Mon 9/10/18**	**Mon 12/30/19**
376	10.4	Decommission Soudan LBCF	0 d	Fri 12/28/18	Fri 12/28/18
377	10.5	FAARM Fully Operational	0 d	Tue 6/11/19	Tue 6/11/19
378	11	End of schedule	0 d	Mon 12/30/19	Mon 12/30/19



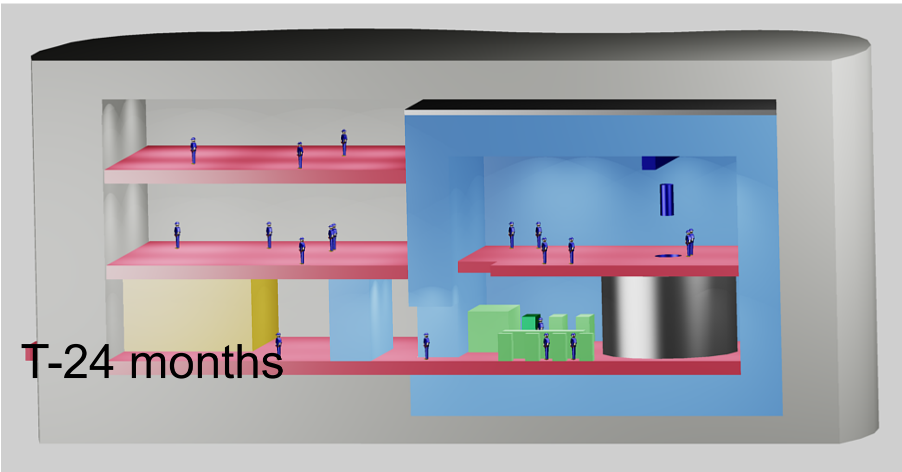
FAARM Engineering

FAARM Installation & Commissioning (detail)

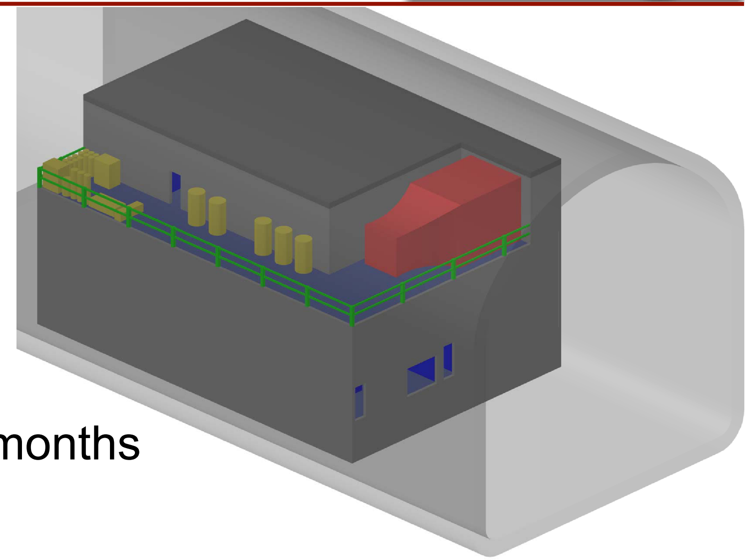
ID	WBS	Task Name	Duration	Start	Finish
302	**10**	**FAARM Installation & Commissioning**	**561 d**	**Mon 12/4/17**	**Mon 1/27/20**
317	**10.3**	**Phase 2: Tight Cleanliness**	**461 d**	**Mon 4/23/18**	**Mon 1/27/20**
333	**10.3.4**	**Gamma screener installation and commissioning**	**440 d**	**Mon 4/23/18**	**Mon 12/30/19**
334	10.3.4.1	Move GeMPI-1 from Soudan to FAARM	30 d	Mon 4/23/18	Fri 6/1/18
335	10.3.4.2	Commission GeMPI-1	20 d	Mon 6/4/18	Fri 6/29/18
336	10.3.4.3	Run GeMPI-1 as Monitor	247 d	Mon 7/2/18	Tue 6/11/19
337	10.3.4.4	GeMPI-1 Screening begins at FAARM	0 d	Fri 6/29/18	Fri 6/29/18
338	10.3.4.5	GeMPI-1 Screening	143 d	Wed 6/12/19	Fri 12/27/19
339	10.3.4.6	Move GeMPI-2 from Soudan to FAARM	30 d	Mon 7/9/18	Fri 8/17/18
340	10.3.4.7	Commission GeMPI-2	20 d	Mon 8/20/18	Fri 9/14/18
341	10.3.4.8	GeMPI-2 Screening begins at FAARM	0 d	Fri 9/14/18	Fri 9/14/18
342	10.3.4.9	GeMPI-2 Screening	335 d	Mon 9/17/18	Mon 12/30/19
343	10.3.4.10	Move GeMPI-3 from Soudan to FAARM	30 d	Mon 9/17/18	Fri 10/26/18
344	10.3.4.11	Commission GeMPI-3	20 d	Mon 10/29/18	Fri 11/23/18
345	10.3.4.12	GeMPI-3 Screening begins at FAARM	0 d	Fri 11/23/18	Fri 11/23/18
346	10.3.4.13	GeMPI-3 Screening	285 d	Mon 11/26/18	Mon 12/30/19
347	10.3.4.14	Move GeMPI-4 from Soudan to FAARM	30 d	Mon 11/26/18	Fri 1/4/19
348	10.3.4.15	Commission GeMPI-4	20 d	Mon 1/7/19	Fri 2/1/19
349	10.3.4.16	GeMPI-4 Screening begins at FAARM	0 d	Fri 2/1/19	Fri 2/1/19
350	10.3.4.17	GeMPI-4 Screening	235 d	Mon 2/4/19	Mon 12/30/19
351	10.3.4.18	Move conventional HPGe's from Davis to FAAF	30 d	Mon 2/4/19	Fri 3/15/19
352	10.3.4.19	Davis LBCF available for other exper.	0 d	Fri 3/15/19	Fri 3/15/19
353	10.3.4.20	Commission HPGe's	30 d	Mon 3/25/19	Fri 5/3/19
354	10.3.4.21	HPGe screening begins at FAARM	0 d	Fri 5/3/19	Fri 5/3/19
355	10.3.4.22	HPGe Screening	170 d	Mon 5/6/19	Mon 12/30/19
356	10.3.4.23	All gamma screening at FAARM	0 d	Fri 5/3/19	Fri 5/3/19



Concept History

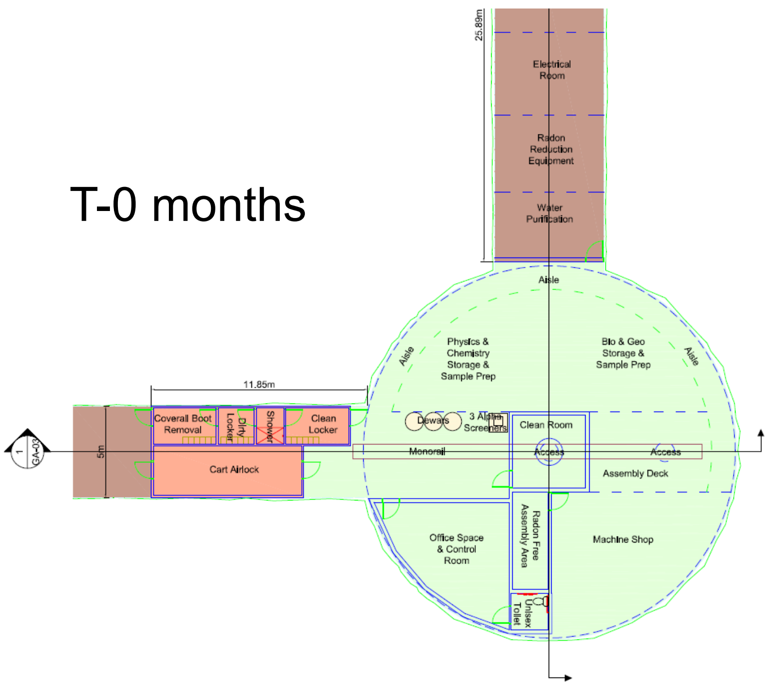


T-24 months

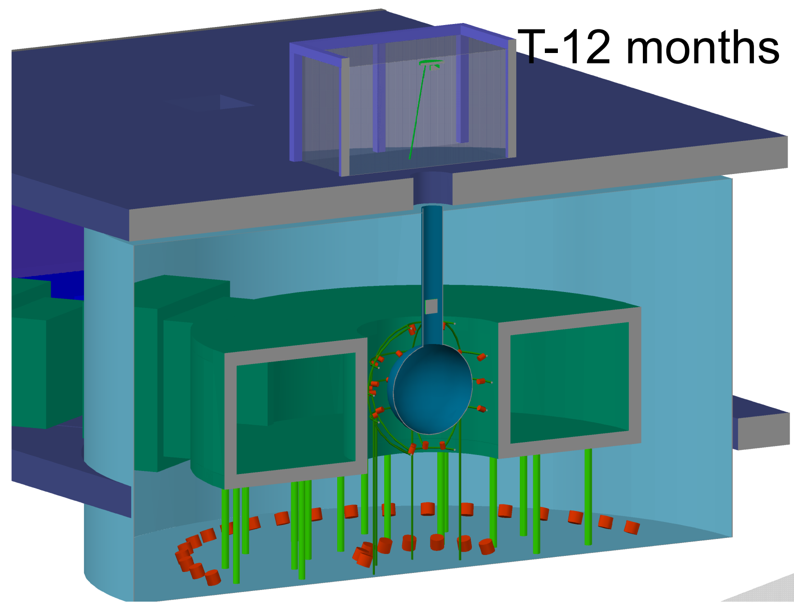


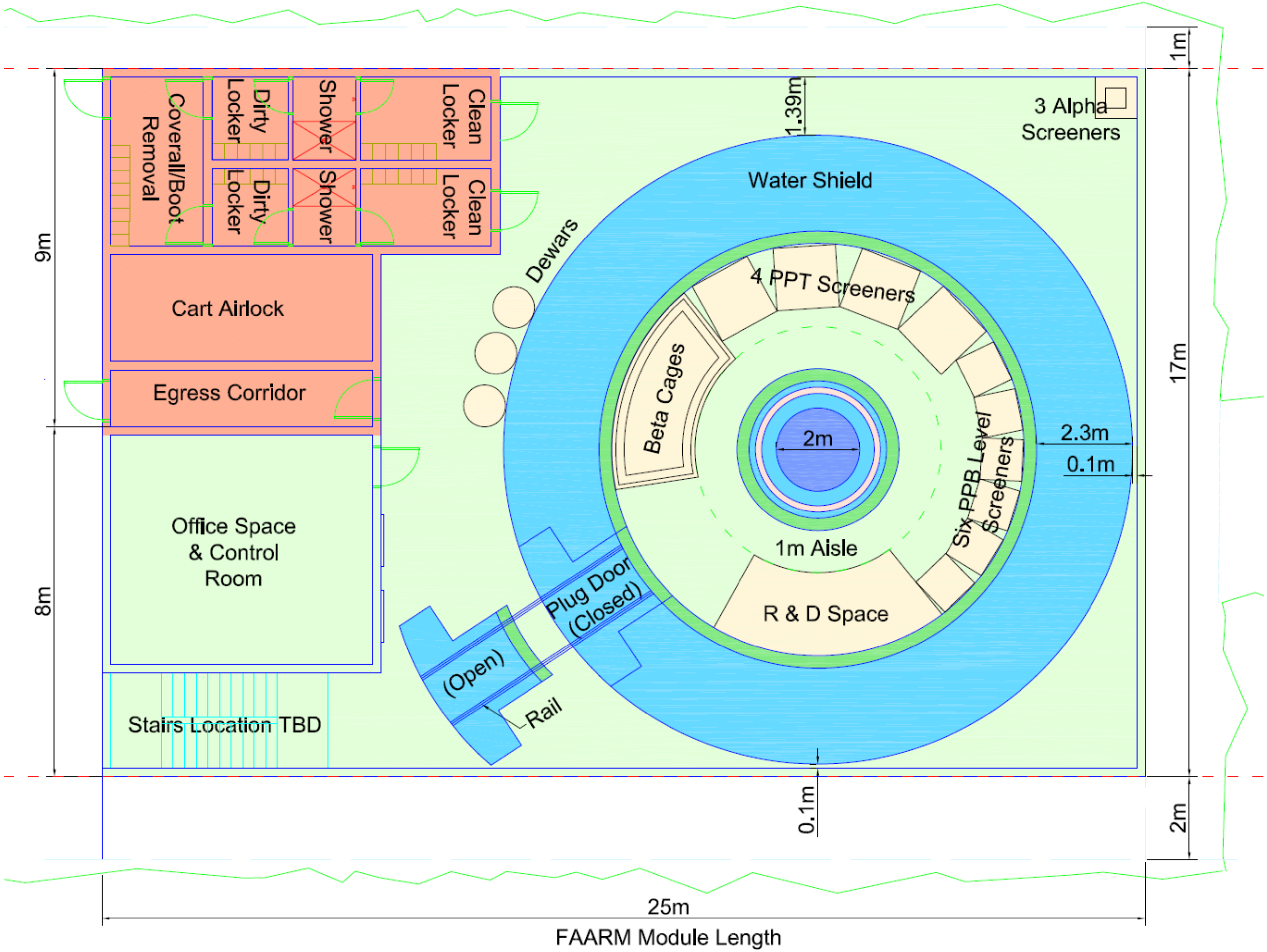
T-12 months

T-0 months

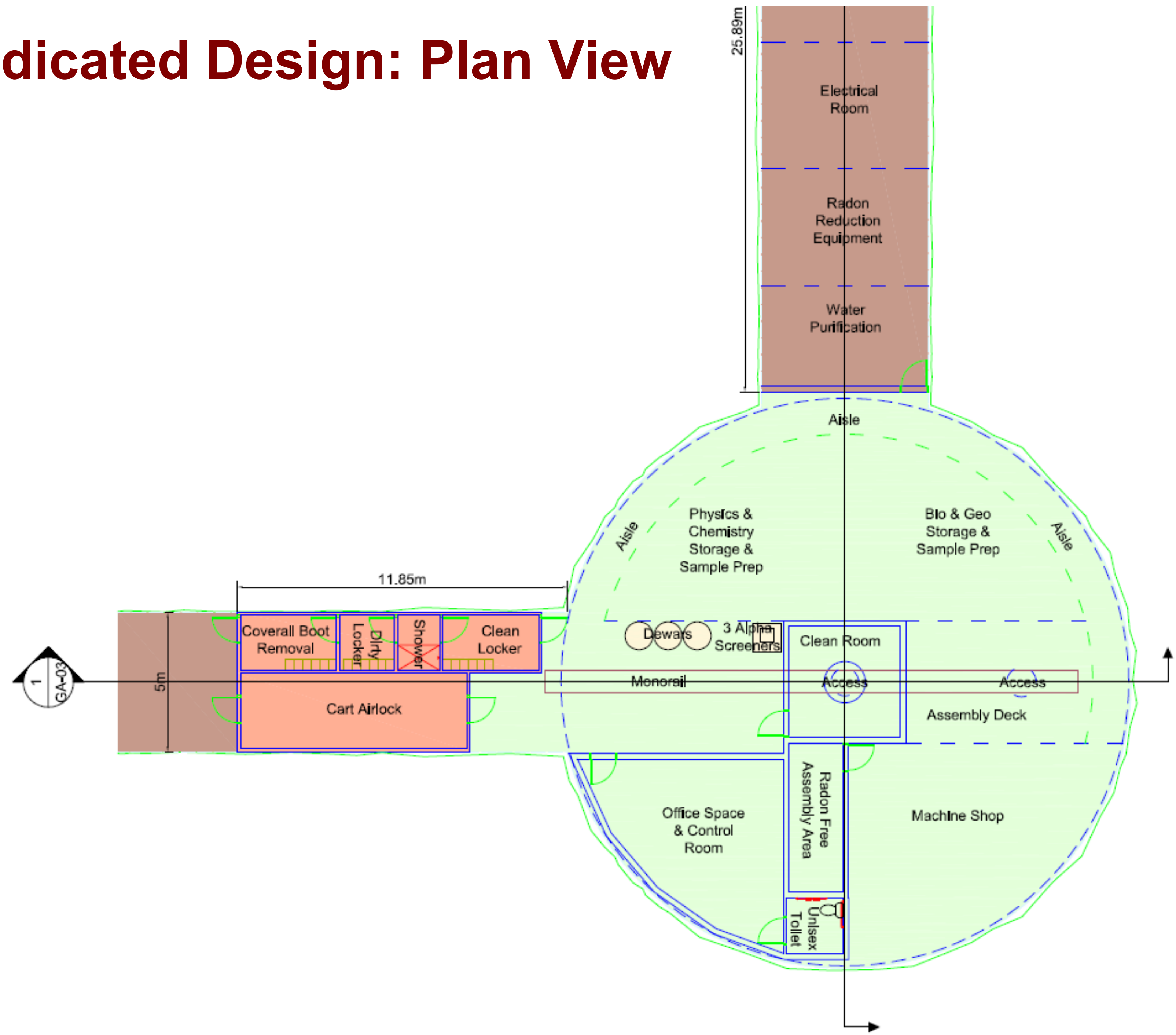


T-12 months



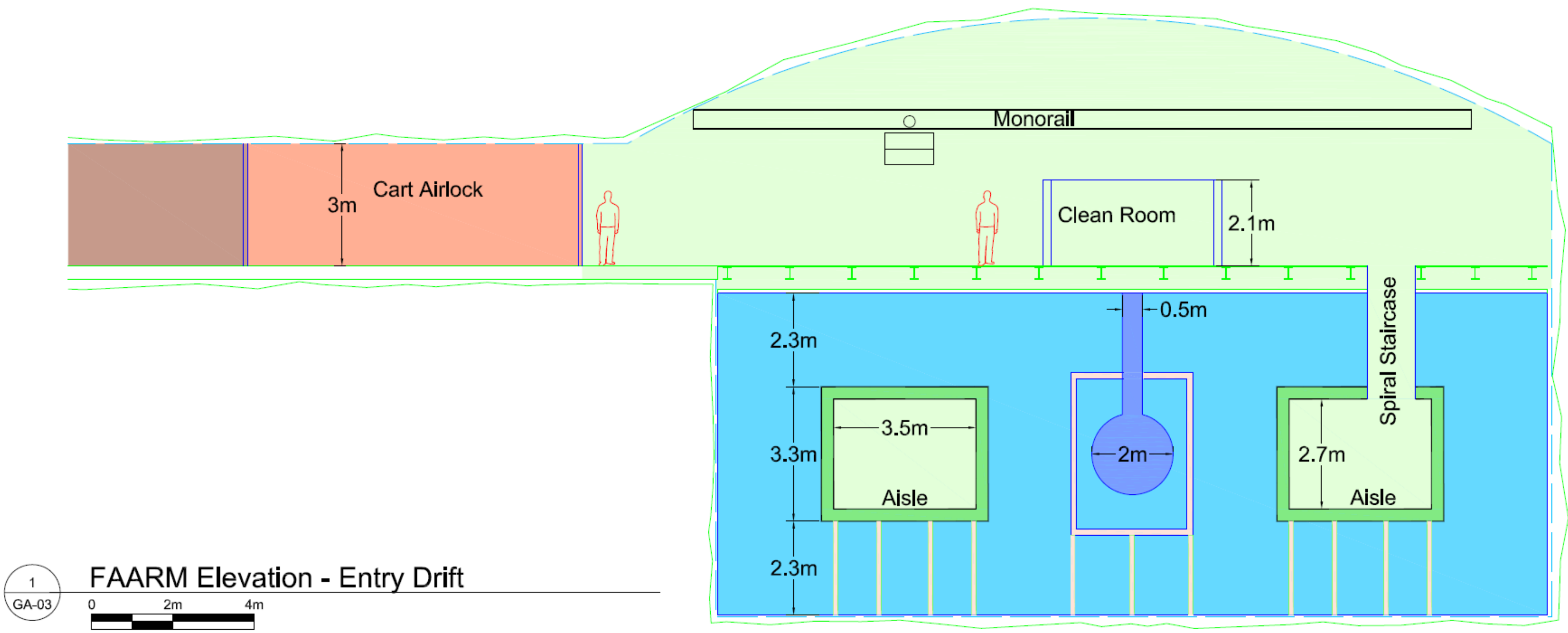

Coverall/Boot Removal
Dirty Locker
Shower
Clean Locker
Dirty Locker
Shower
Clean Locker
Cart Airlock
Egress Corridor
Office Space & Control Room
Stairs Location TBD
Dewars
Water Shield
3 Alpha Screeners
4 PPT Screeners
Beta Cages
2m
1m Aisle
Six PPB Level Screeners
R & D Space
Plug Door (Closed)
(Open)
Rail
1.39m
2.3m
0.1m
0.1m
1m
9m
8m
17m
2m
25m
FAARM Module Length

Dedicated Design: Plan View



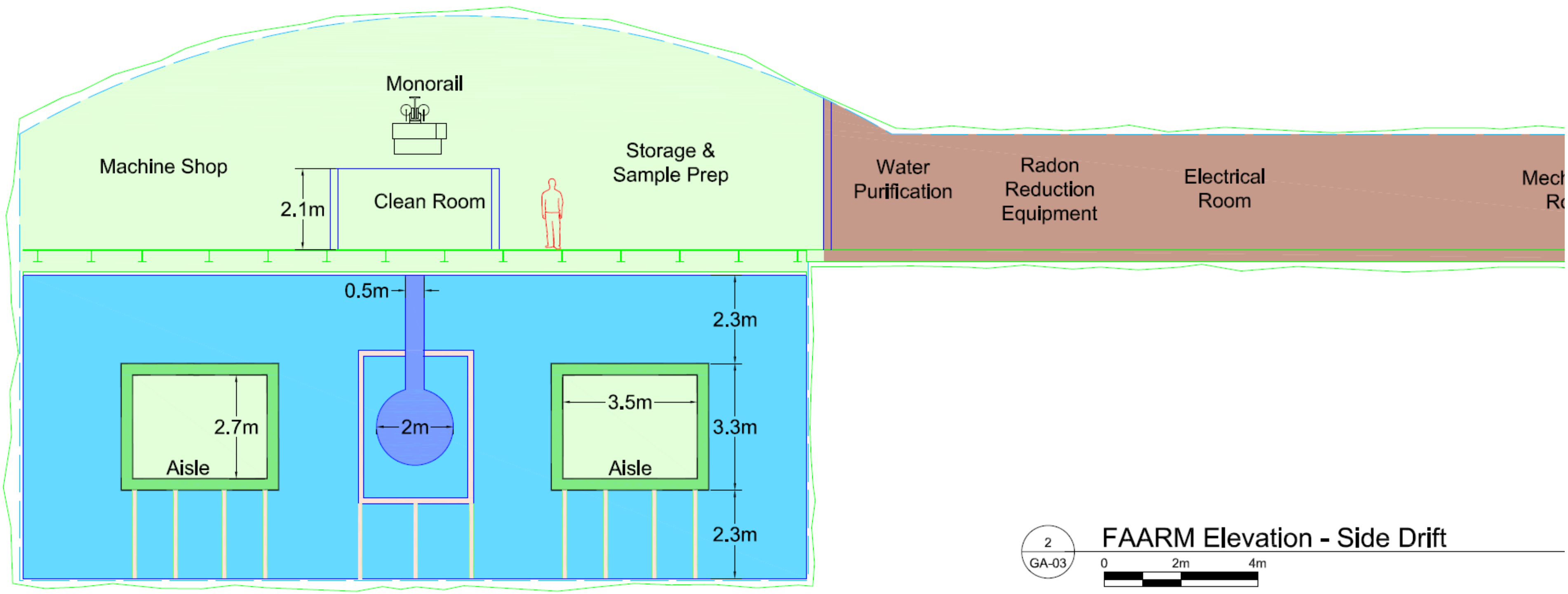
Dedicated Design: Elevation

FAARM Entrance



Dedicated Design: Elevation

Mechanical Entrance



Bottoms-up Cost Estimate for all phases

S4: 1 M received to make a Preliminary Design of FAARM
and associated R&D

PostS4: 200 k for design completion

DULBCF: 8M, includes 9 years of staff & students at 5M
and most of the screeners

FAARM: 7.2 M in equipment, M&S, contracted structures
1.6 M in labor: *0.7M scientific staff*
0.9M engineering

FAARM Operations at ~ 500k/year labor

Also included tasks/cost from DUSEL R&D, BGE, CDMS, etc

Cost Implications in new design

FAARM in a DUSEL module

Allowance is 25 meters (not incl. access needs)
Cost was not charged against FAARM
Rough cost for 25 meters is $2.n million

FAARM in a custom configuration

Cost is charged against FAARM
Rough cost is $2.1 to $2.5 million
Save most of the building cost of $0.3 million
Save most of the water tank cost of $0.6 million

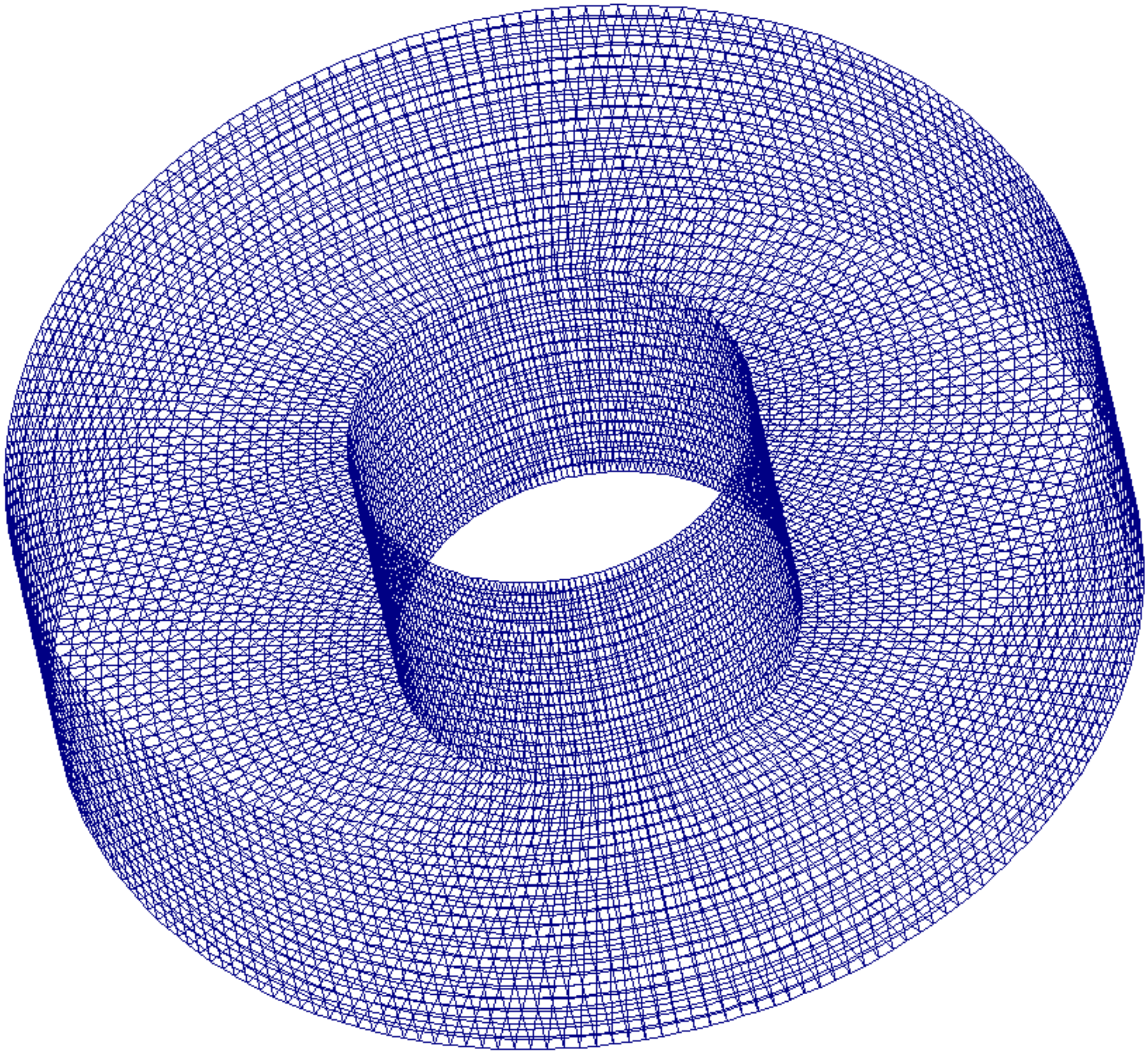
The result is an actual saving approaching $1 million

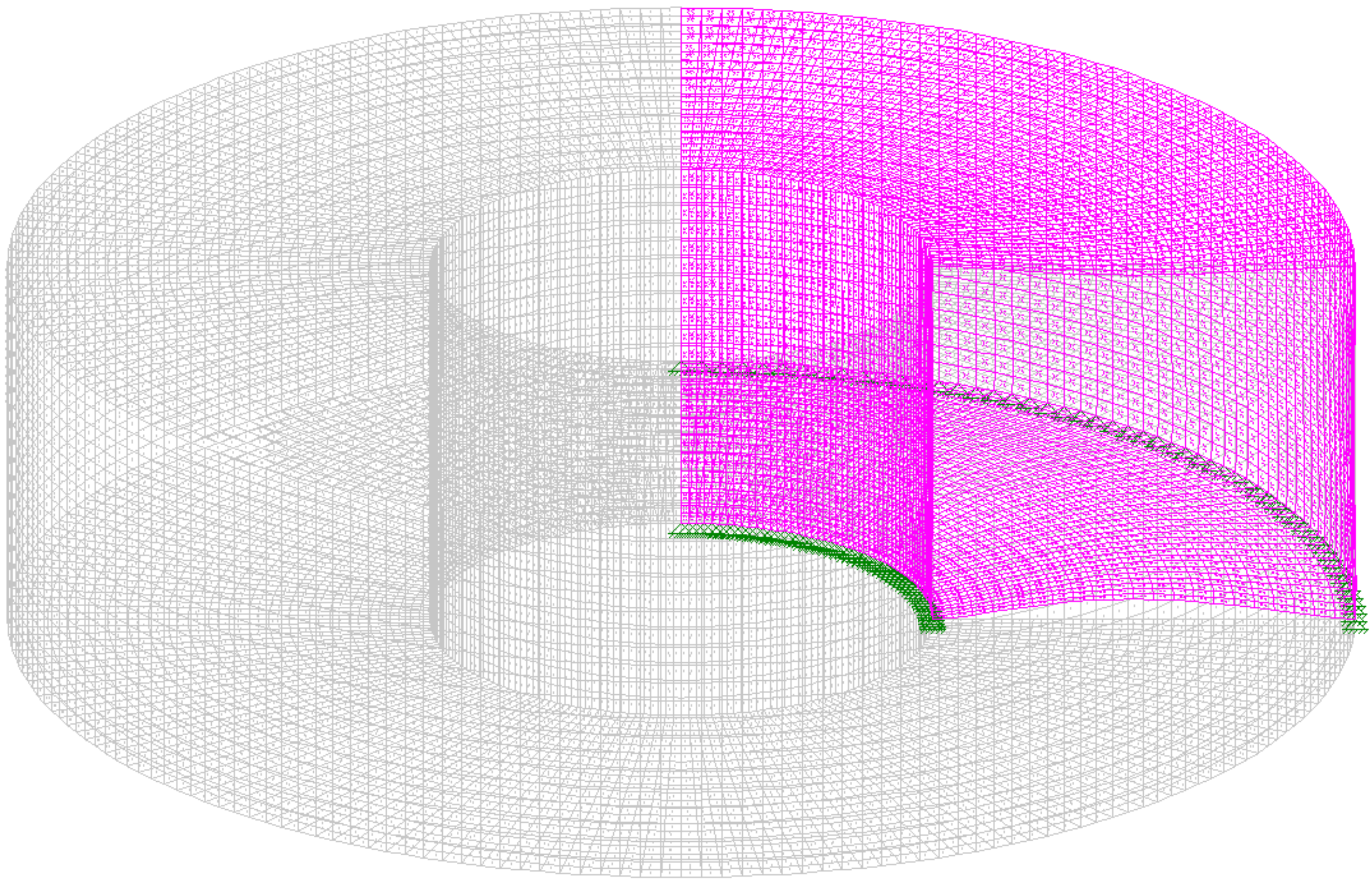
Finite Element Model—Part 1

Finite Element Model (RISA3D, RISA Technologies)

17056 Finite Elements (shells)

Simple, symmetrical load cases used initially to detect modeling errors and other abnormalities





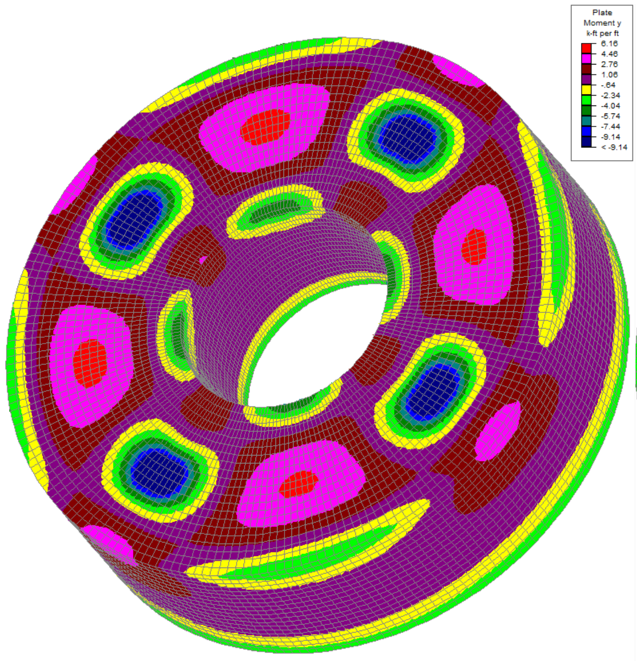
Finite Element Model—Part 3
Effect of Supports

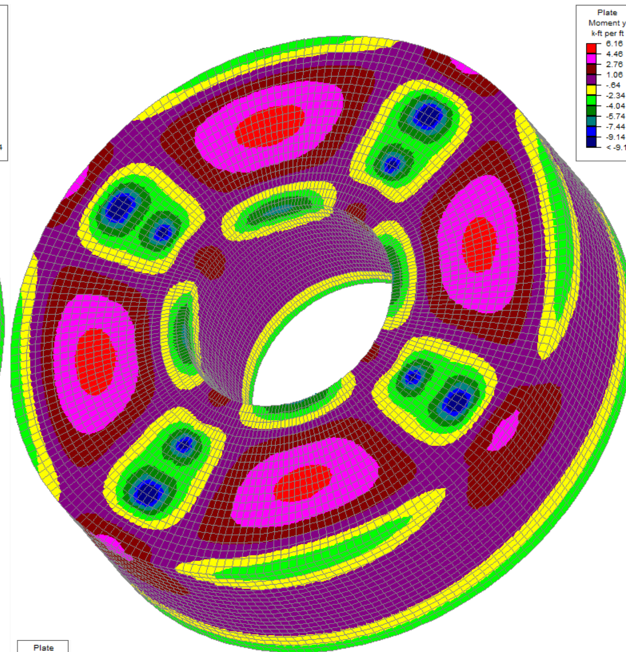
Number of supports:

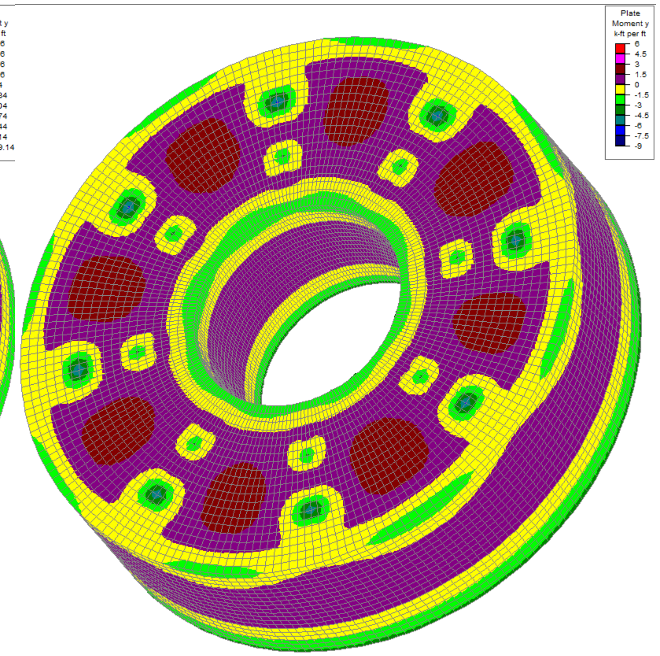
- 4 supports at mid-span of floor spaced at 90°
- 8 supports at third-points of floor spaced 90°
- 16 supports at third-points of floor spaced 45°
- 32 supports at third-points and near walls of floor spaced 45°

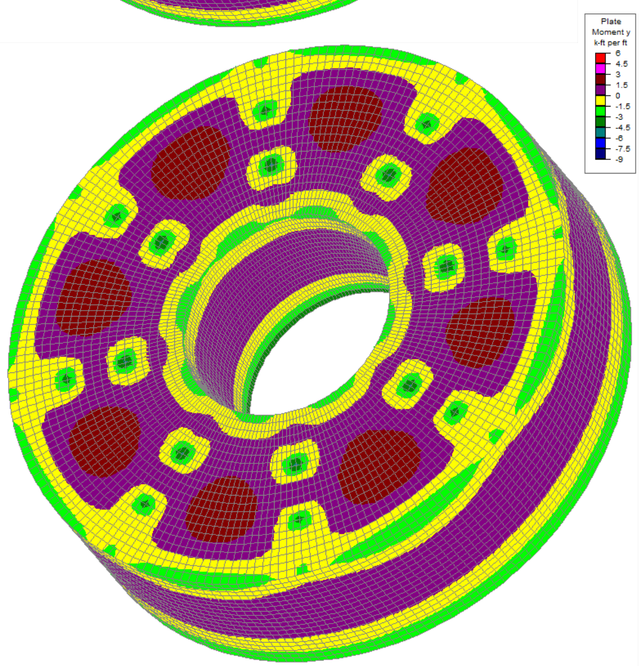
Part 2 explored arched roof
No obvious advantage

Moments









- Torus floor shown with supports in tension (buoyancy uplift)
- Supports in regions of yellow-green-blue transition

Simulation

Identified the following task as a priority

Validate and improve the Physics in current Simulations
Create a Common Simulation Framework for underground experiments.

Begin work by comparing simulations

- across collaborations
- across simulation packages (GEANT4 vs FLUKA)
- across caverns (rock composition, overburden)
- across muon distributions (site-specific MUSIC vs Groom parameterization)

Detailed plans (working groups) were formulated in the areas of

- Cosmogenics
- Radiogenics (alpha-n, fission, material screening)
  and Universal Materials database
- Modular Geant4 Framework for Underground Science

Much of the recent planning was done in
AARM Collaboration Meeting (Feb 2011)
http://zzz.physics.umn.edu/lowrad/meeting3/talks
Berkeley Comos Workshop (April 2011)
https://docs.sanfordlab.org/docushare/dsweb/View/Wiki-141

SLAC GEANT4 Collaboration (esp. Dennis Wright)

New Physics List called "*Shielding*" in Geant 4.9.4

designed for use in shielding applications, and also in high energy

similar to QGSP_BERT_HP, except

uses a different string fragmentation model (FTF instead of QGS)

better handling of ions (Binary cascade for light, QMD for heavy)

improved neutron cross sections from JENDL database

use G4 builder classes to extend physics list

- add radioactivity model to all recoil ions with option to de-activate
- could also add optical photons

improved light-ion-induced reactions

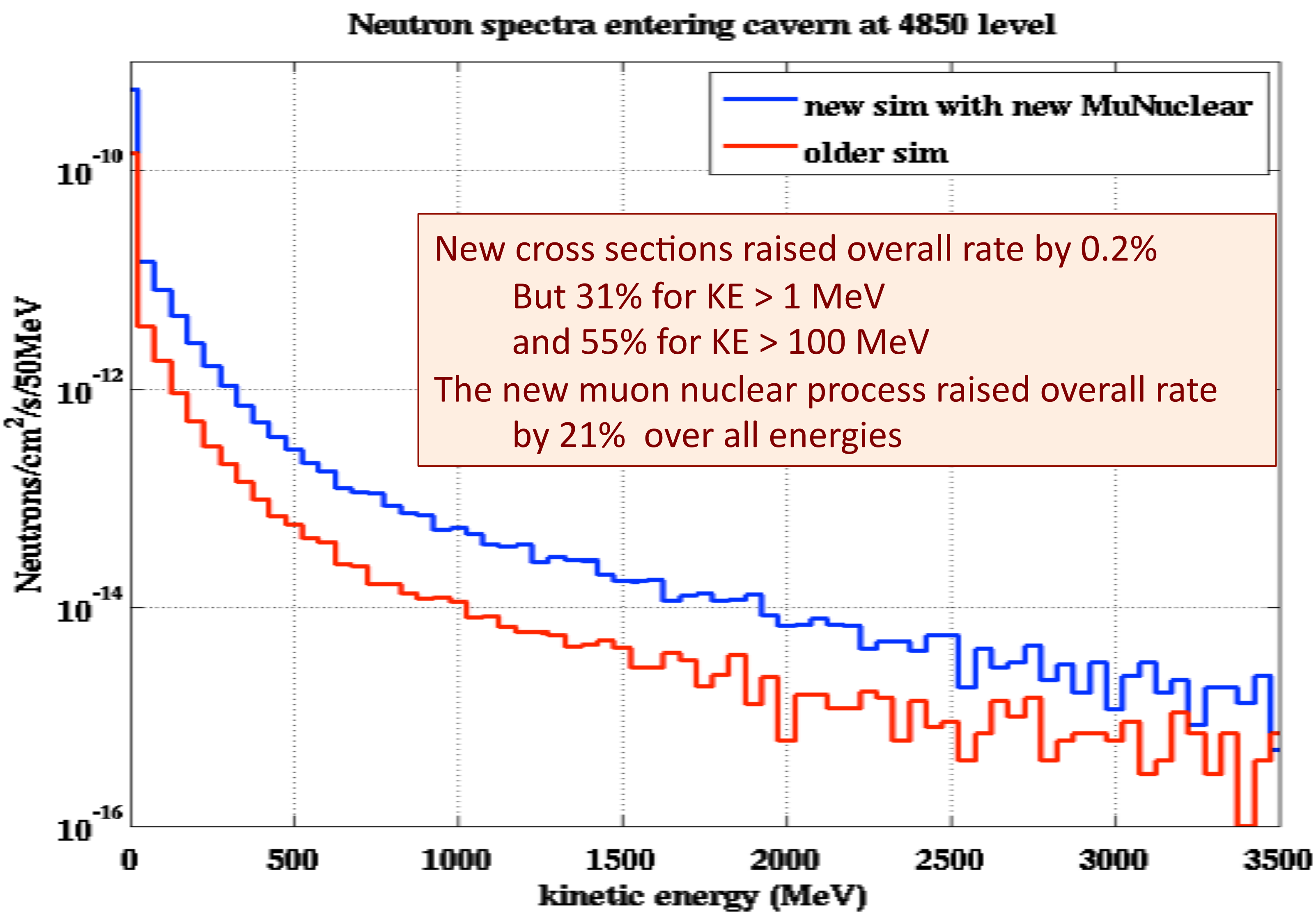
- Shielding already replaces old GHEISHA-style models with G4BinaryLightIon and QMD models

new muon-nuclear process, model and cross section developed

- Muon exchanges virtual photon with nucleus
- Virtual photon treated as "0" to initiate cascade
- Bertini cascade (0–10 GeV), FTFP (> 10 GeV)

GEODM/AARM Simulation (new Geant4 Physics)

study by A. Reisetter for AARM



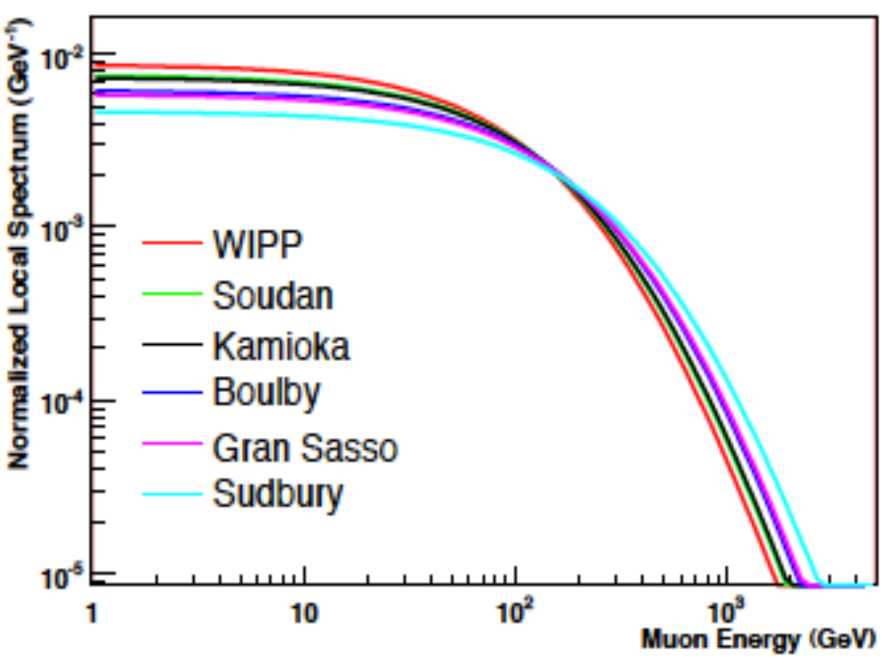
GEODM/AARM Simulation (new Geant4 Physics)

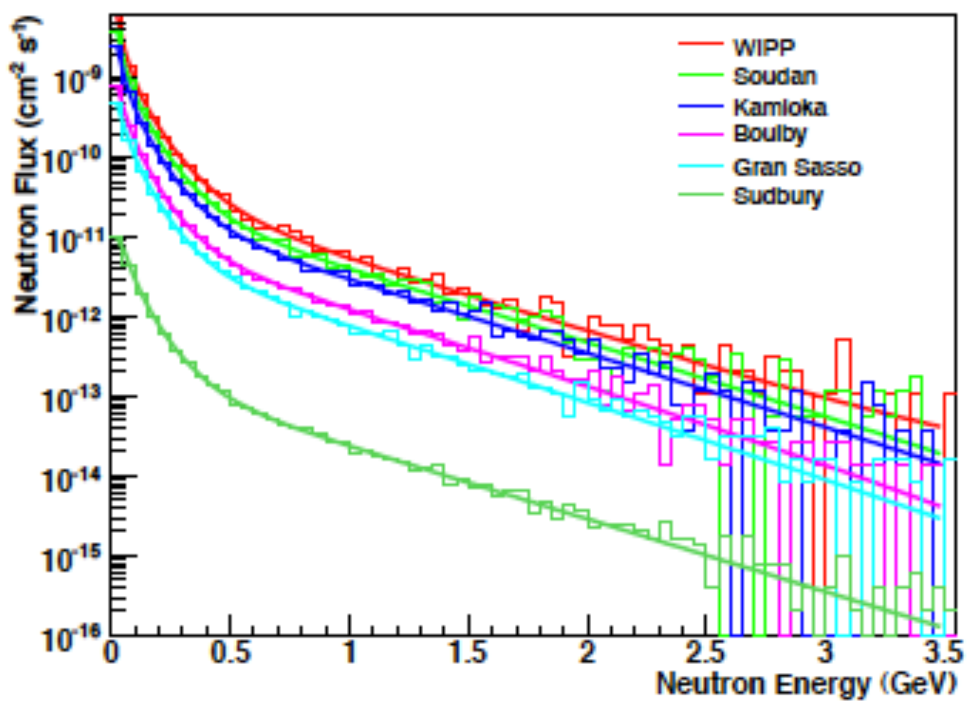
Mei & Hime (arXiv:astro-ph/0512125)

An early attempt to parameterize cosmogenic neutrons wrt depth

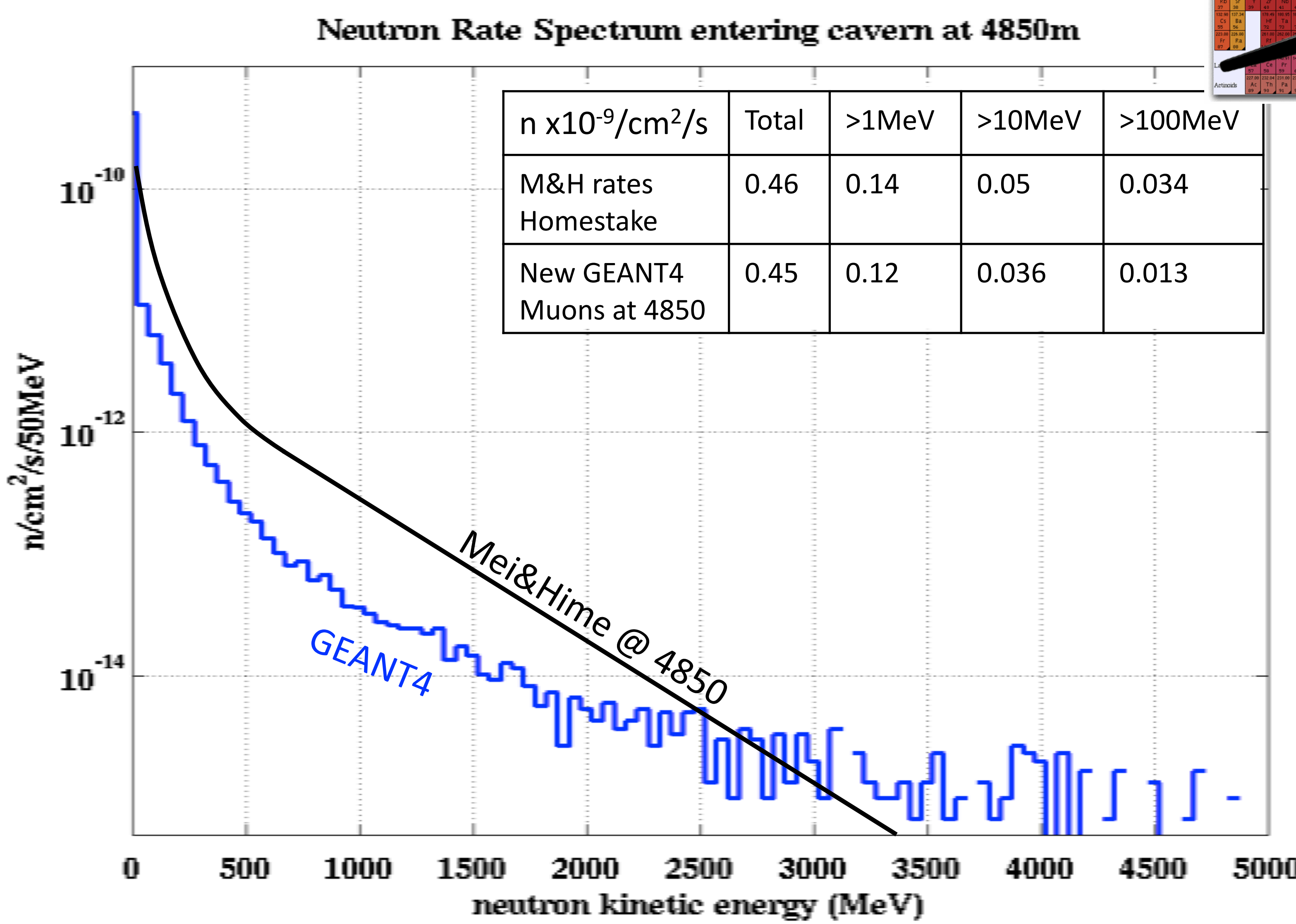
Input well-known muon spectra and flux wrt depth

Resulting neutron spectra: Parameterization of a FLUKA simulation, adjusted upward to match data



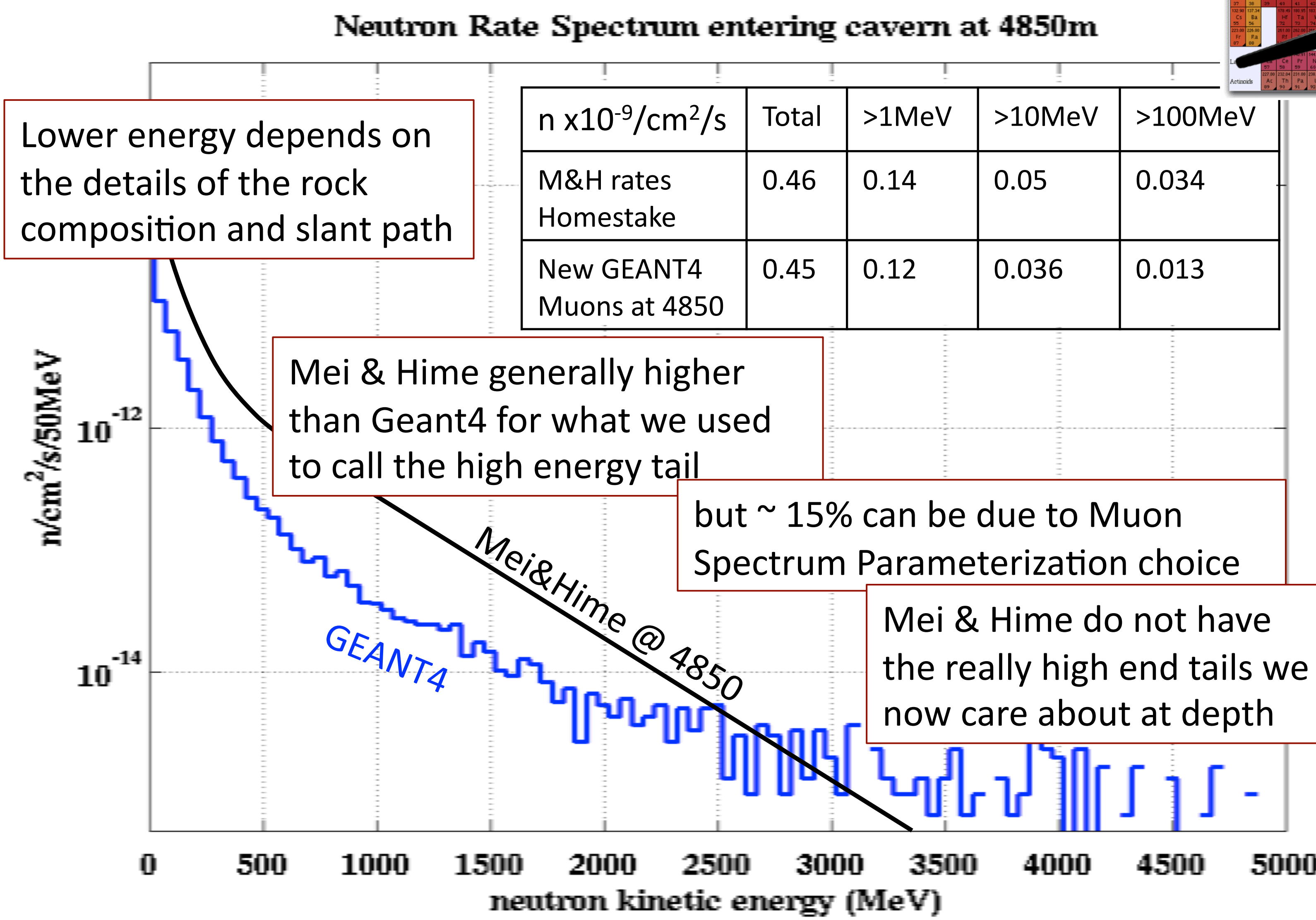


GEODM/AARM Simulation (new Geant4 Physics)



n $x10^{-9}/cm^2/s$	Total	>1MeV	>10MeV	>100MeV
M&H rates Homestake	0.46	0.14	0.05	0.034
New GEANT4 Muons at 4850	0.45	0.12	0.036	0.013

GEODM/AARM Simulation (new Geant4 Physics)



n x10^{-9}/cm^2/s	Total	>1MeV	>10MeV	>100MeV
M&H rates Homestake	0.46	0.14	0.05	0.034
New GEANT4 Muons at 4850	0.45	0.12	0.036	0.013

Lower energy depends on the details of the rock composition and slant path

Mei & Hime generally higher than Geant4 for what we used to call the high energy tail

but ~ 15% can be due to Muon Spectrum Parameterization choice

Mei & Hime do not have the really high end tails we now care about at depth

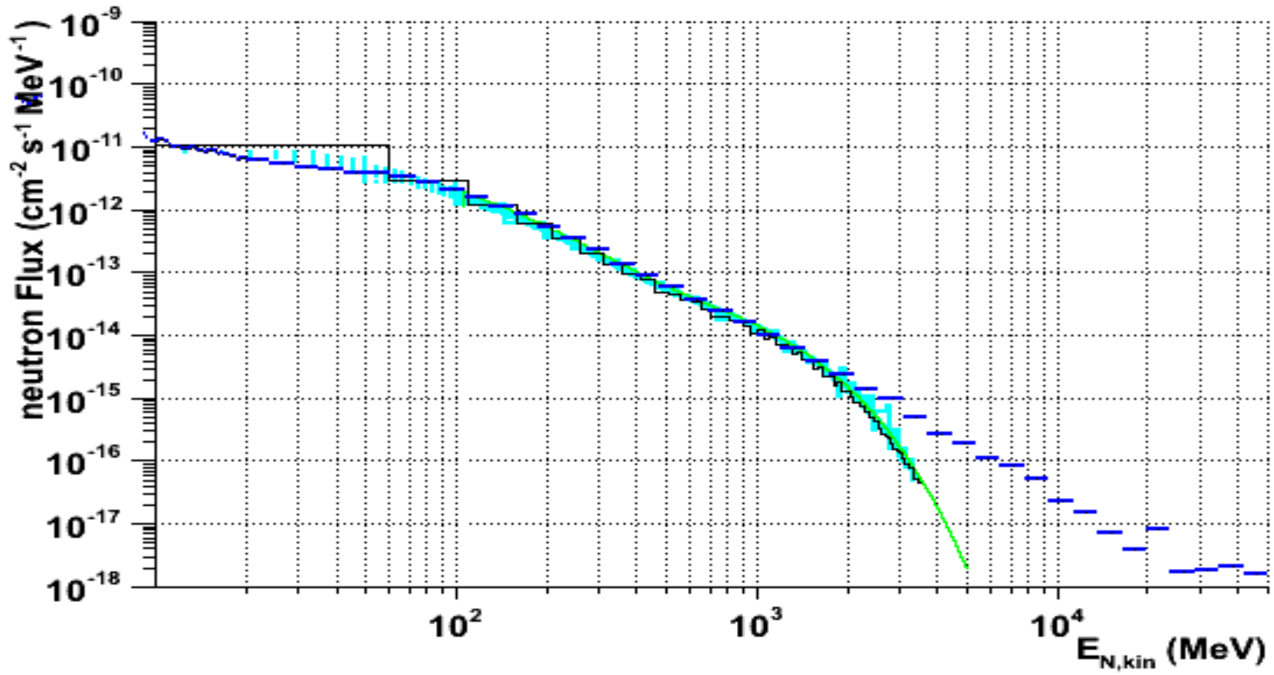
FLUKA also predicts a high energy neutron tail (blue), compared to Mei & Hime spectrum (green)

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

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.

COSMOGENICS Standardizing Muon and Neutron Distributions

An Object Lesson in the importance of Mutually Acceptable Input Parameters.

Question from DUSEL planning "Can GEODM (7400 level) be redesigned to work at 4850?"

The results of the GEODM 4850 Sim	were in	direct contradiction to LZ20 Sim
3 m water shield reduced # evts with n (KE>200keV) by only .16		3-4 orders of magnitude reduction 0.3 $nDRU_r$ μ-induced bkgd evts *before* analysis cuts

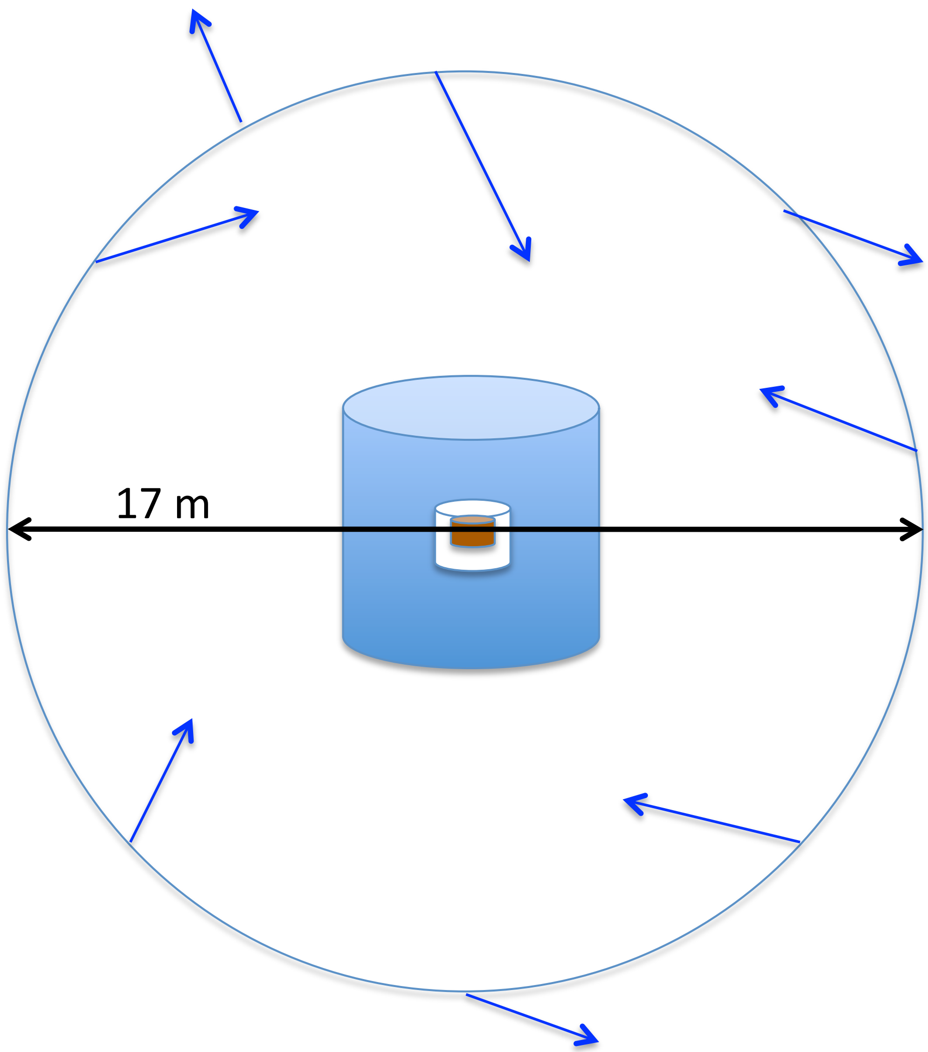
Turned out to hinge on details of the INPUT neutrons and accompanying shower particles (next few slides show why)

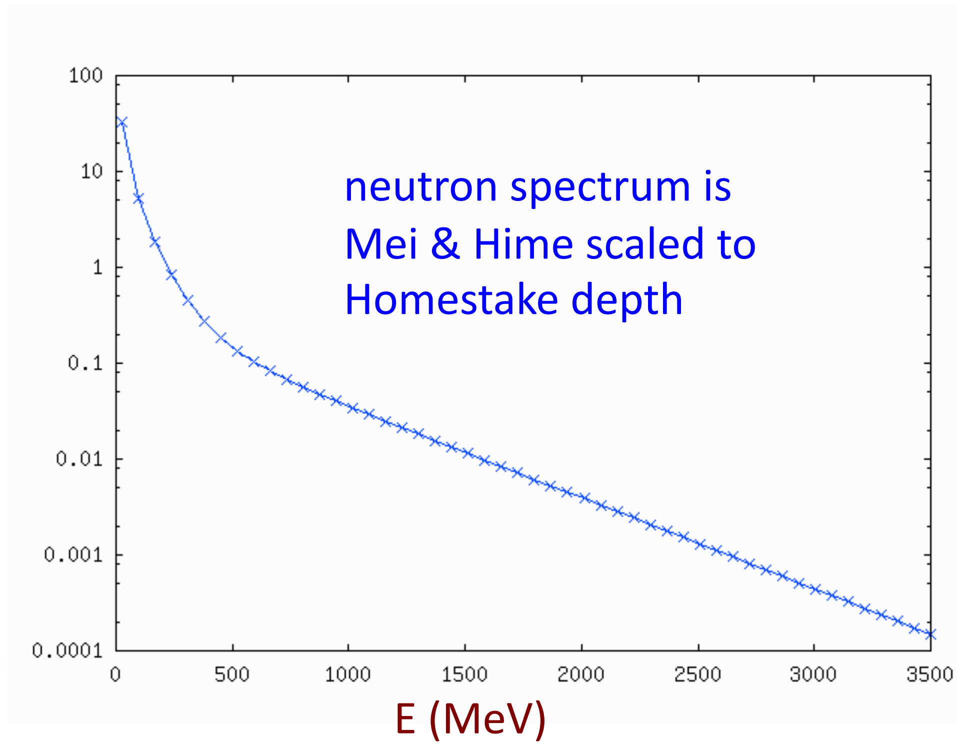
Solution:

Everybody MUST AGREE on the same set of backgrounds for the same cavern.
Need to produce and validate and make available a background environment for each lab.

Methodology of the LZ20 Simulation:

Single neutrons from a parameterized spectrum. Thrown isotropically from a sphere surrounding detector.
Whole thing is in a vacuum without walls



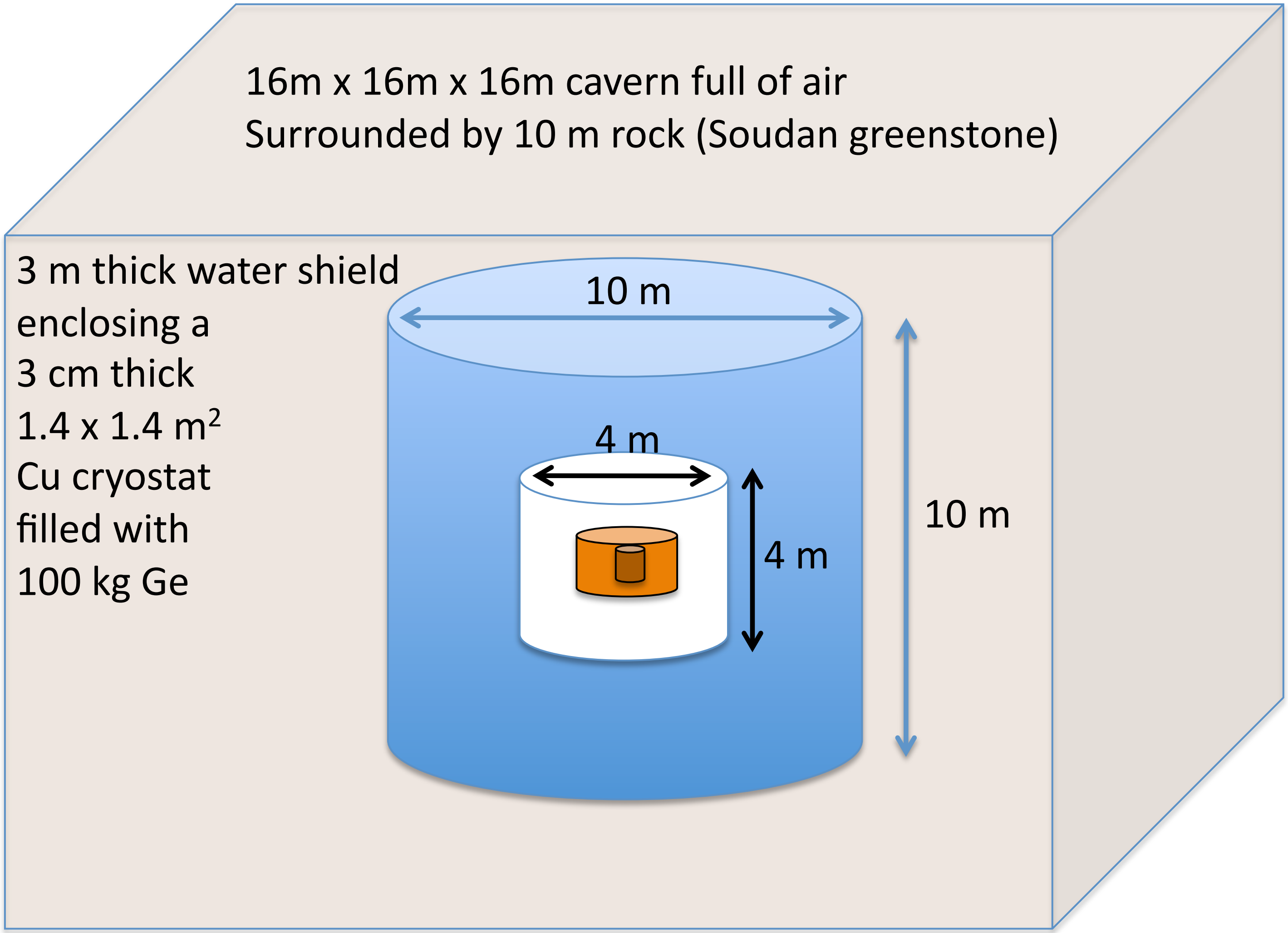


Advantage: Easy to get lots of stats

Disadvantages:

- No shower particles or 2^{ndry} n's
- No parent muons
- No correlations
- No multiplicity
- Flaws in spectrum itself

GEODM 4850 full G4 MC has extremely simple model of Detector, but a sophisticated generation of neutrons



Muon Parameterization (> 1000 mwe)

Phys.Rev.D7 p2022 (Cassiday et al.)

- g(E) is energy loss rate
- x(E) is muon stopping distance
- θ is zenith angle (uniform φ)

$$\frac{dN}{dE} = \frac{A}{g(E)}\left[e^{-Bx(E)} + Ce^{-Dx(E)}\right]$$

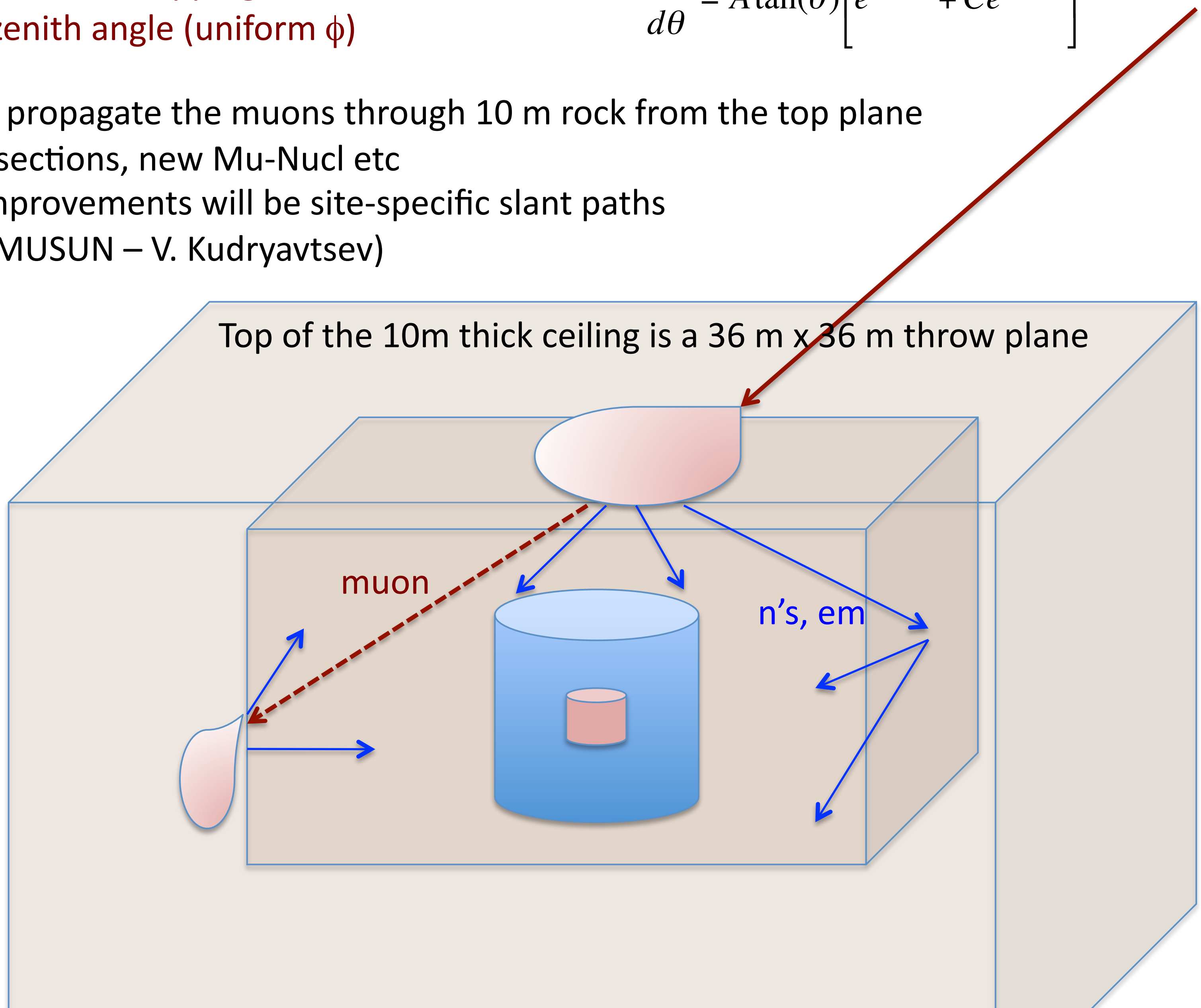
$$\frac{dN}{d\theta} = A\tan(\theta)\left[e^{\frac{-B}{\cos(\theta)}} + Ce^{\frac{-D}{\cos(\theta)}}\right]$$

Let Geant4 propagate the muons through 10 m rock from the top plane

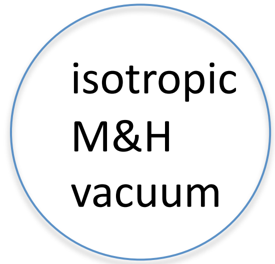
New cross sections, new Mu-Nucl etc

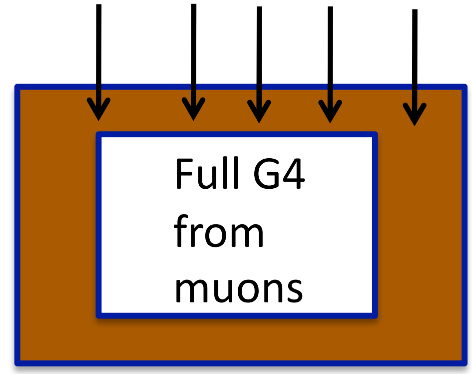
Eventual improvements will be site-specific slant paths

(MUSUN – V. Kudryavtsev)



Try different generators in the GEODM geometry





GEODM geometry with Different n Generators	Isotropic Sphere (8.75 ton-y) scaled to 1	Multiplicity	Full Rock Sim (1.25 ton-y) scaled to 1	Multiplicity
neutrons in Ge	76 n 11 evts	6.7	2,754 n 224 evts	12.3
nuclear recoils in Ge (10 – 100 keV) (Veto not yet applied)	14.5 NR 4.46 evts	3.3 **(1.5 singles)**	787 NR 145.6 evts	5.4 **(8 singles)**

By neglecting secondary neutrons, hadronic and EM showers, and muons in cavern, One predicts far fewer recoils and a lower multiplicity than you will really get.

AARM creates the integrative structure:
GEODM-style neutron files sent to LZ20 to directly compare in their geometry.

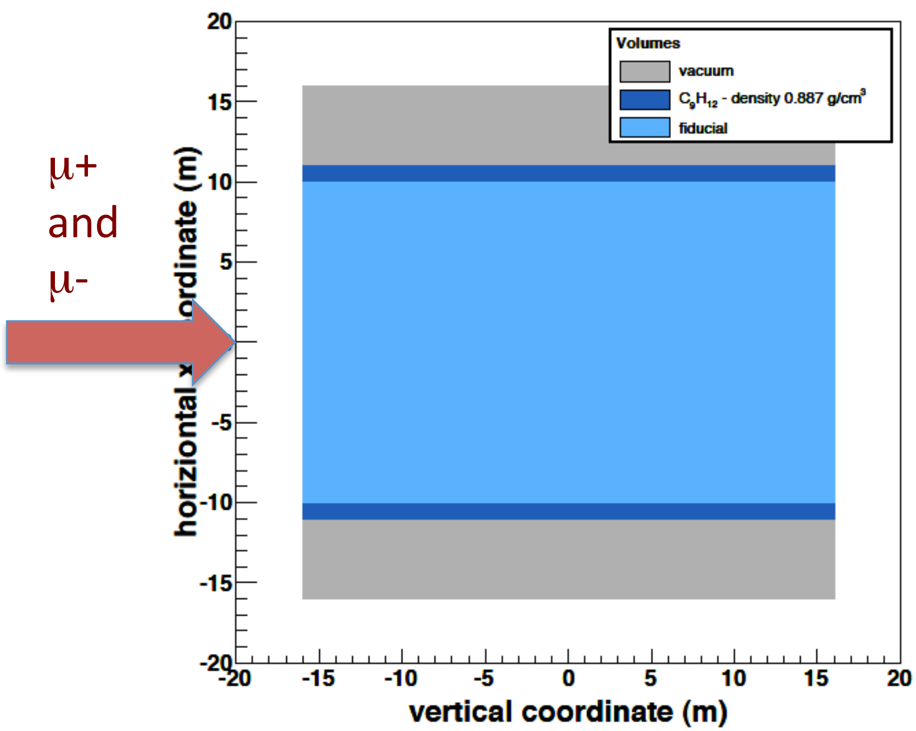
COSMOGENICS Comparing GEANT4 vs FLUKA

Neutron Yield is a key uncertainty. Mount a careful Study

Muon energies: 10, 30, 100, 280, 1000 GeV.
Materials: C, CH_2, H_2O, $CaCO_3$, NaCl, Fe, Pb.

Tony Empl (FLUKA)
Anthony Villano (GEANT4)
Vitaly Kudryavtsev (Advisor)

Simple Fiducialized Geometry



Neutron production rate per muon per g/cm^2

All neutrons produced inside the material are counted, but only those produced in the middle are included in the final neutron yield.

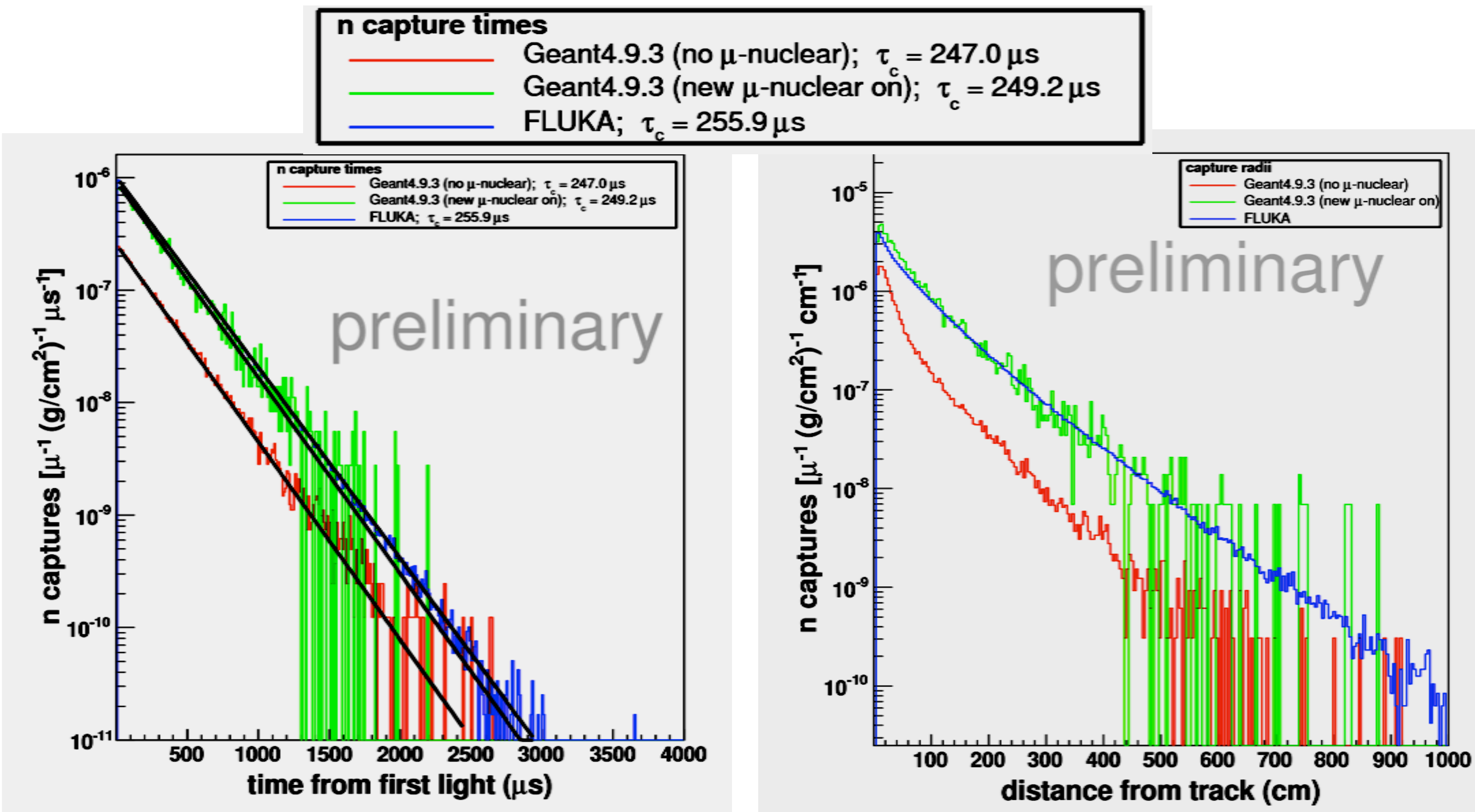
All vertices fully reconstructed
All physics processes recorded
Care taken to avoid double counting

First try with Liquid scintillator chosen in order to be able to compare with Borexino and Kamland. *(and LVD)*
C_9H_{12} at density ρ = 0.887 g/cm^3.

COSMOGENICS Comparing GEANT4 vs FLUKA

Time from 1st interaction to n-capture.
Borexino takes data only after around 200 μs
Kamland after about 1300 μs.

Position from primary track to n-capture.
Possible observable for delayed captures



Standardized Monte Carlo FRAMEWORK: Start with Homestake

Each experiment has its own strengths and physics modules

Glean useful information from them, e.g.

MaGe has a waveform library

DEAP/CLEAN incorporated RAT (Reactor Analysis Tool – Braidwood)

SuperCDMS phonon physics add-on

Many experiments pushing on cross sections relevant to their experiment

Each experiment has evolved specific classes and macros for running jobs

Choose one of the good ones

Workshop defined what we mean by “good”

e.g. LUXSim (Kazkaz), SuperCDMS (Kelsey): Choose LUXSim

The basic structures of the package are finished and initialized to SVN repository

The package is divided into 6 sub-systems: management & physics, input/output, SVN administration, geometry & materials, event generator, tracking & visualization.

Additional Jobs

- extend G4 materials to have associated properties in a common way
- develop an even more general “object library” of things like PMT structures, etc.
- develop a general-purpose TPC track reconstruction library (possible LLNL/NNSA funds)

RADIOGENICS & SCREENING

Materials Database (James Loach – Majorana)

-begin with a database "Couchdb" and a search engine "Lucene"
-structure has a main database – this database copied and sync to institutions
-"users" and "developers" write code to access information for their purpose

Decision taken (Feb 2011) to adopt it and add

-new counted materials (by experiment)
-legacy materials (e.g. ILIAS database)
  need volunteers/resources
-Organizing entities: AARM, LRT Workshop, SNOLab
-functionality,
  e.g. contaminated materials automatically incorporated into Geant4

Software with a "sanctioned" database made available Loach ➔ Villano

- begin software distribution, starting with a "test" database from Majorana

Some Details about the Materials Database

CouchDB relax

Open source non-relational database

A flat collection of JSON **documents** of named fields

```
"sample": {
    "name":          "Fused silica",
    "description":   "Corning 7940, lot 56667",
    "source":        "Mark Optics Ltd.",
    "owner":         "LBNL LBF",
}
```

Data aggregated and displayed using **views**

Schema-free so structure can be varied and extended

Distributed (can self-replicate between machines)

Speaks HTML

Widely-used (CERN, BBC etc.)

Future-safe data format (JSON text)

Commercial online hosting services available

http://couchdb.apache.org

http://guide.couchdb.org/

http://www.couchbase.com

http://www.cloudant.com

MAJORANA
Material Assay
Database

tin

⊞ Tin, LANL
⊞ Tin, LANL
⊞ Tin, Canberra

MAJORANA
Material Assay
Database

tin

⊟ Tin, LANL

sample	description	Tin, 99.9998% purity				
measurement	technique	Gamma				
	results	U chain	<	1.7		mBq/kg
		Th chain	<	3.1		mBq/kg
		K-40		25	(14)	mBq/kg
		Co-60	<	1.5		mBq/kg

⊞ Tin, LANL
⊞ Tin, Canberra

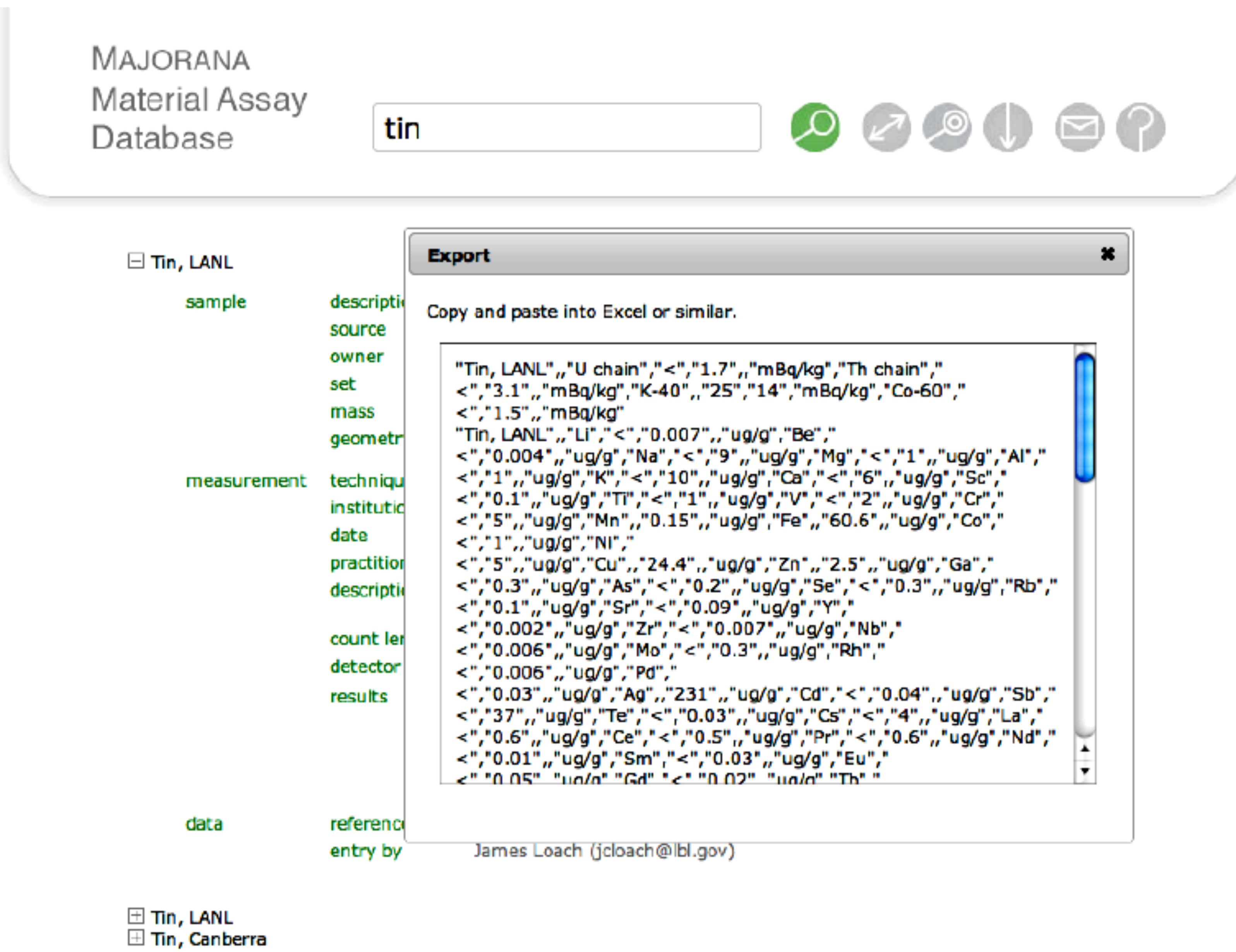
MAJORANA
Material Assay
Database

tin

⊟ Tin, LANL

sample	description	Tin, 99.9998% purity
	source	Adam Montoya, LANL
	owner	LANL
	set	Majorana
	mass	710 g
	geometry	Block of metal
measurement	technique	Gamma
	institution	LANL / WIPP
	date	5 / 2010
	practitioner	Steve Elliot, LANL (elliotts@lanl.gov)
	description	The tin was placed inside two nested plastic bags and put inside the WIPP-n cavity. Background spectrum 66.78 days.
	count length	99.2 d
	detector	WIPP-n
	results	U chain < 1.7 mBq/kg
		Th chain < 3.1 mBq/kg
		K-40 25 (14) mBq/kg
		Co-60 < 1.5 mBq/kg
data	reference	Majorana report M-TECHDOCDET-2010-110
	entry by	James Loach (jcloach@lbl.gov)

⊞ Tin, LANL
⊞ Tin, Canberra


MAJORANA
Material Assay
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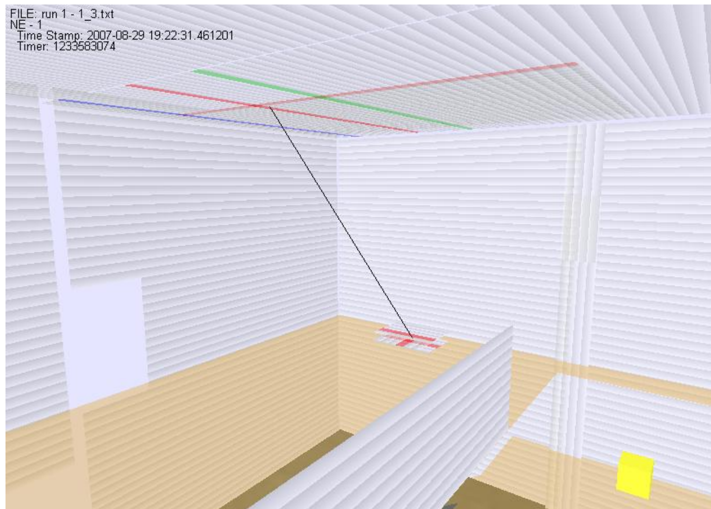
entry by
James Loach (jcloach@lbl.gov)
Tin, LANL
Tin, Canberra
Export
Copy and paste into Excel or similar.
"Tin, LANL",,"U chain","<","1.7",,"mBq/kg","Th chain","
<","3.1",,"mBq/kg","K-40",,"25","14","mBq/kg","Co-60","
<","1.5",,"mBq/kg"
"Tin, LANL",,"Li","<","0.007",,"ug/g","Be","
<","0.004",,"ug/g","Na","<","9",,"ug/g","Mg","<","1",,"ug/g","Al","
<","1",,"ug/g","K","<","10",,"ug/g","Ca","<","6",,"ug/g","Sc","
<","0.1",,"ug/g","Ti","<","1",,"ug/g","V","<","2",,"ug/g","Cr","
<","5",,"ug/g","Mn",,"0.15",,"ug/g","Fe",,"60.6",,"ug/g","Co","
<","1",,"ug/g","Ni","
<","5",,"ug/g","Cu",,"24.4",,"ug/g","Zn",,"2.5",,"ug/g","Ga","
<","0.3",,"ug/g","As","<","0.2",,"ug/g","Se","<","0.3",,"ug/g","Rb","
<","0.1",,"ug/g","Sr","<","0.09",,"ug/g","Y","
<","0.002",,"ug/g","Zr","<","0.007",,"ug/g","Nb","
<","0.006",,"ug/g","Mo","<","0.3",,"ug/g","Rh","
<","0.006",,"ug/g","Pd","
<","0.03",,"ug/g","Ag",,"231",,"ug/g","Cd","<","0.04",,"ug/g","Sb","
<","37",,"ug/g","Te","<","0.03",,"ug/g","Cs","<","4",,"ug/g","La","
<","0.6",,"ug/g","Ce","<","0.5",,"ug/g","Pr","<","0.6",,"ug/g","Nd","
<","0.01",,"ug/g","Sm","<","0.03",,"ug/g","Eu","

Benchmarking the Monte Carlo: Neutron Measurements

New experiments at Soudan to characterize hadronic showers underground

Muons tracked by proportional tubes lining walls & ceiling

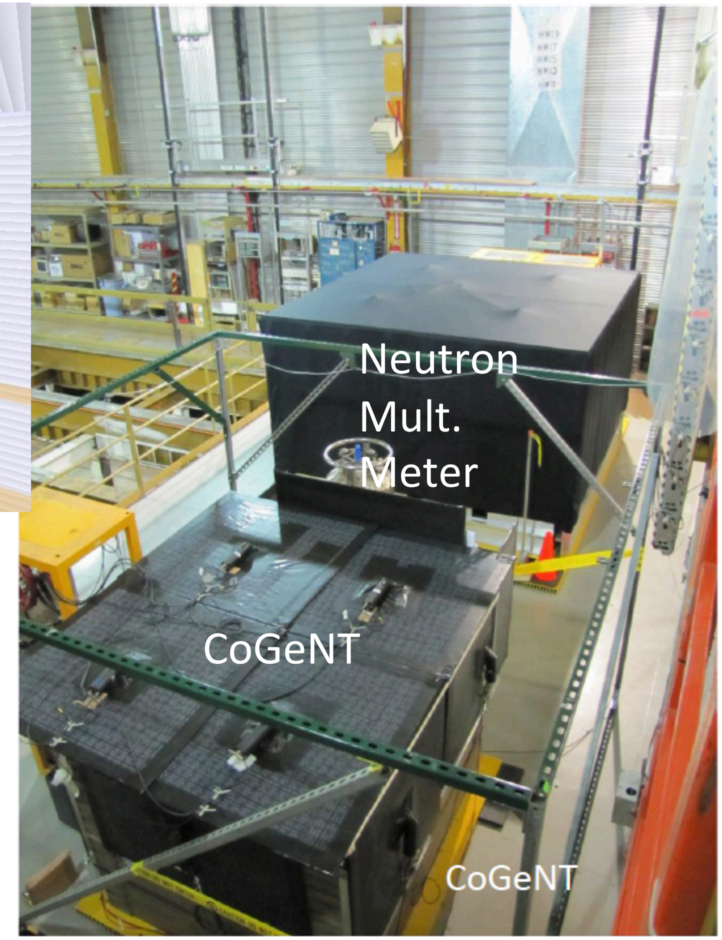
gps time-stamps to correlate with



Neutrons

as detected by

* Liquid Scintillator neutron detectors (USD)
* Neutron Multiplicity Meter (UCSB, Case, Davis)



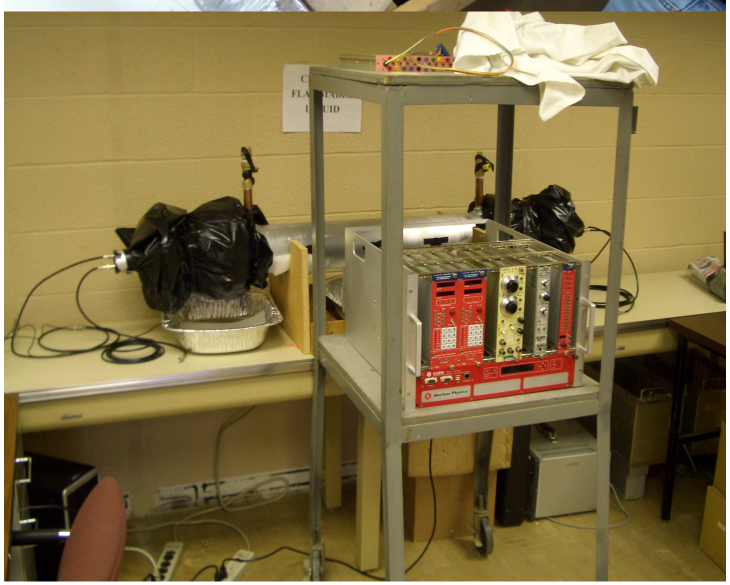
AARM S4 provides integration and travel money

Extensive simulation for comparison

Observables: Distance between parent muon & n, multiplicity, shower configuration

Large Liquid Scintillation Neutron Detector

1m long LS neutron detector filled with 12 liters LS EJ301.



Internally covered with diffusive paint EJ520.

Two Hamamtsu 5” PMTs (R4144) viewing thru pyrex windows

Require coincidence within 30 ns

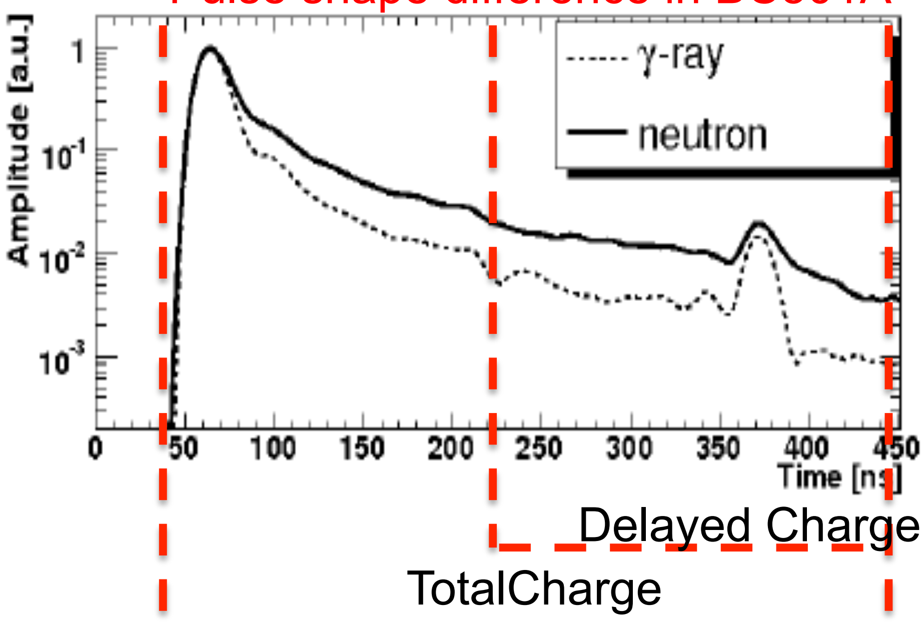
PSD Technique

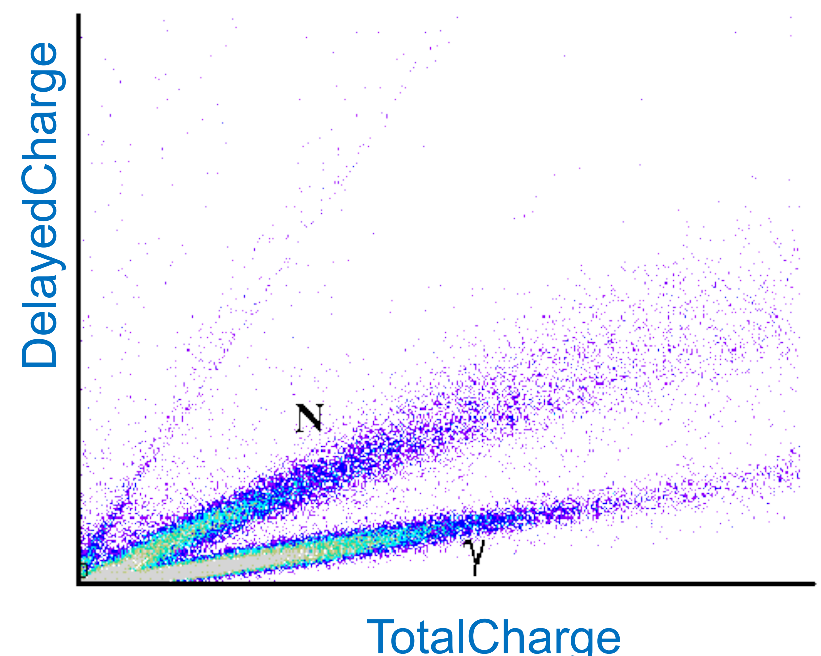
Number of scintillation photons as superposition of two decays

$$N = A \exp\left(-\frac{t}{\tau_f}\right) + B \exp\left(-\frac{t}{\tau_s}\right)$$

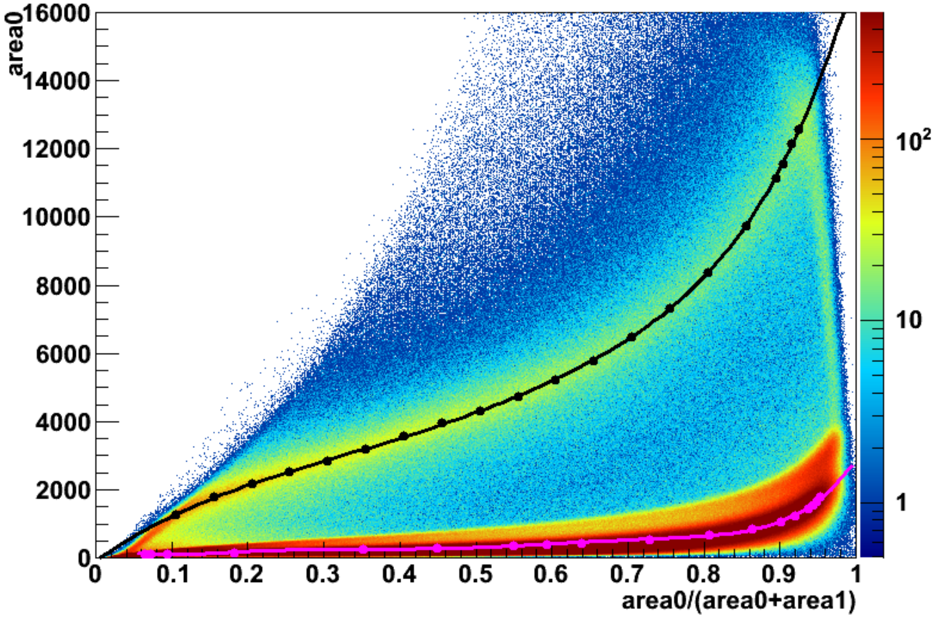
Both "amplitudes" A and B are functions of dE/dx
different dE/dx $\rightarrow$ different signal shape

Pulse shape difference in BC501A

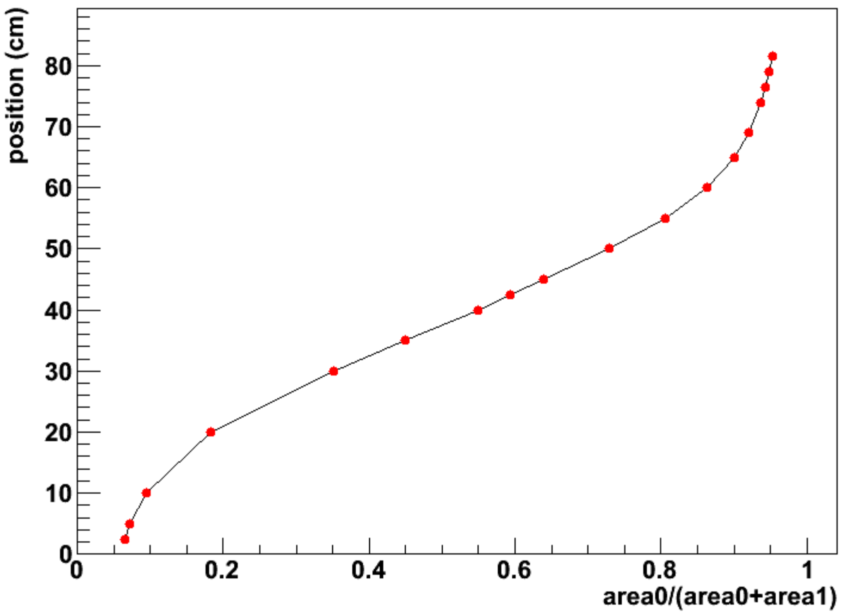




Detector Response Plots



Energy can be calibrated. Shown is the room (surface) background signal.
Muon minimum ionization peak (lower curve)
^{22}Na Source (top curve)



Position can be determined from charge ratio. Plot shows moving the ^{22}Na source along the tube position vs charge ratio response

Benchmarking: Neutron Detector Summary

Detector is working stable at 2000 V with good n/γ PSD. Two weeks surface room background data is accumulated

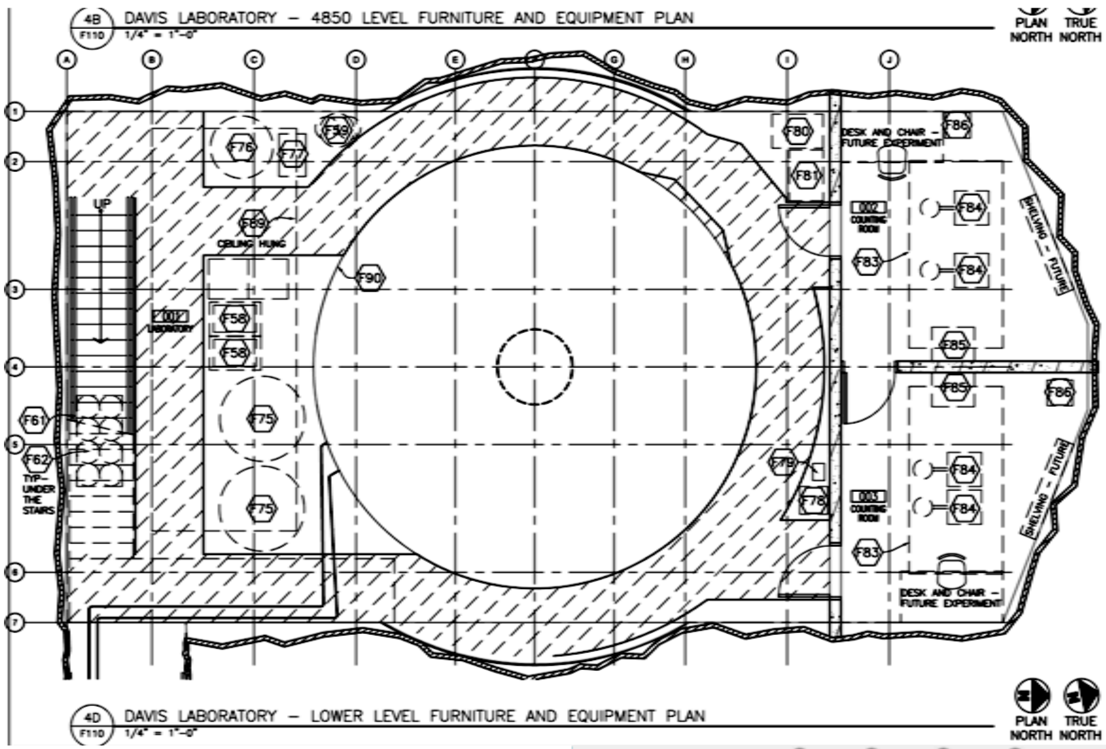
Muon minimum ionization peak is present with 23dB signal attenuation applied to both PMTs. Together with ^{22}Na source, position and energy relations are well understood.

By using AmBe source, the detection efficiency for neutrons with energy below 10MeV is under study.

The detection efficiency for neutrons with energy above 10 MeV will be calibrated with high energy neutron beam.

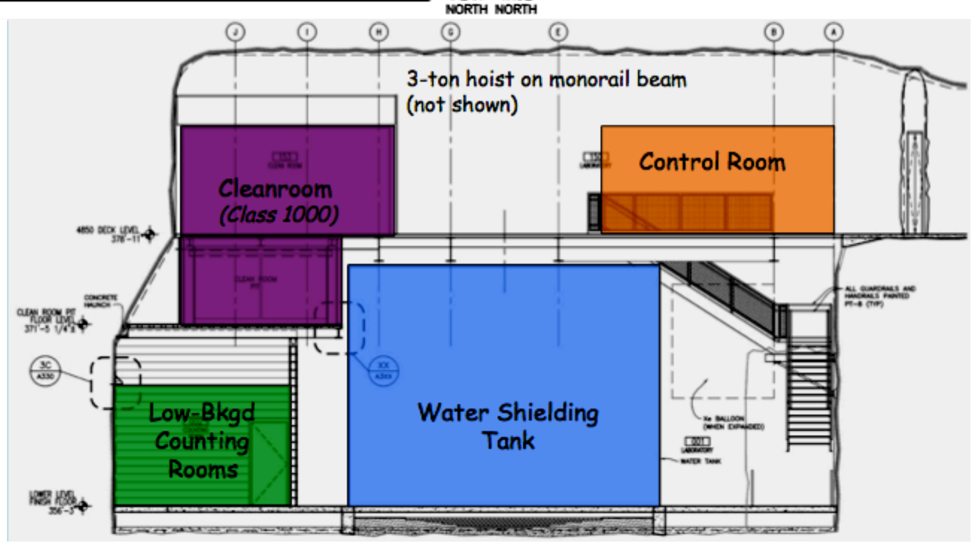
The detector will be deployed to Soudan mine by Aug 21st to measure neutron background underground. Eventually moved to Homestake.

Low Background Counting at Sanford Lab

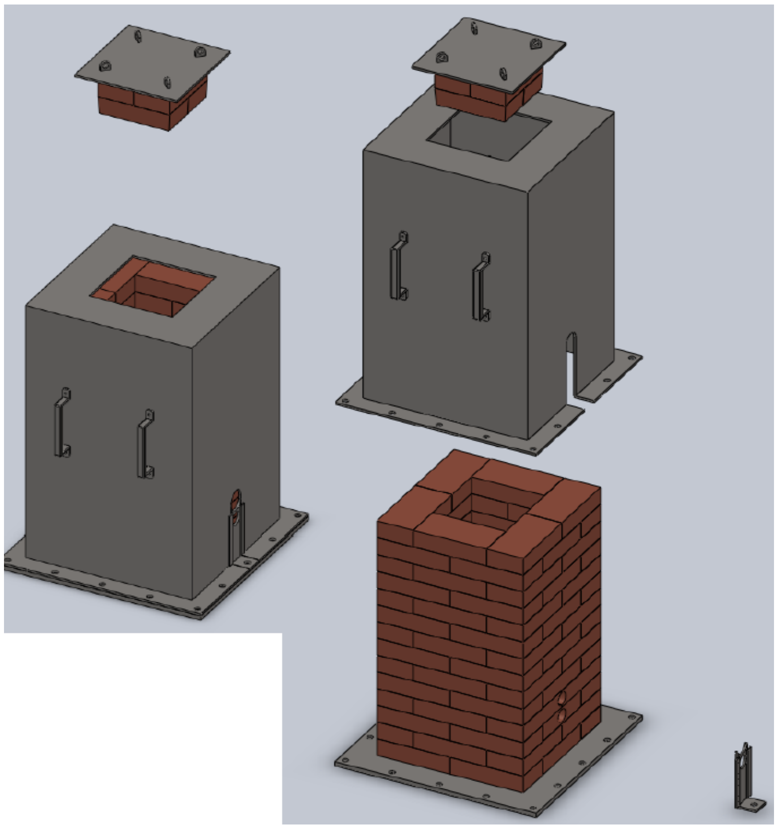


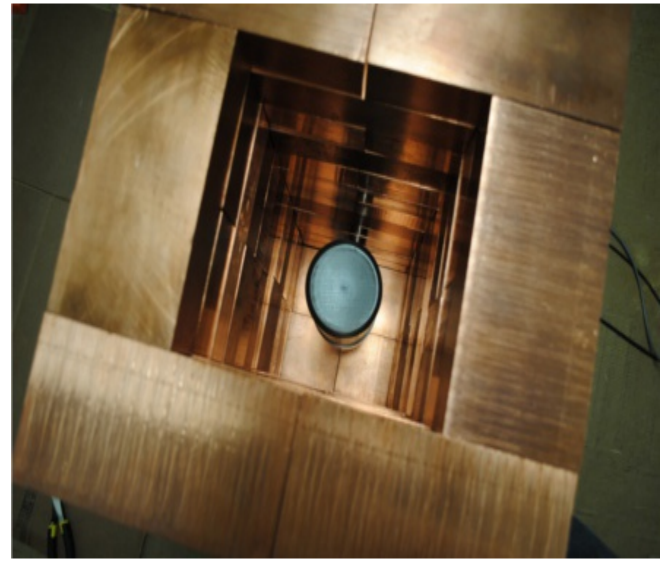
Space reserved for low-background counting with HPGE detectors in the LUX refurbishment of the Davis Cavern on the 4850L.

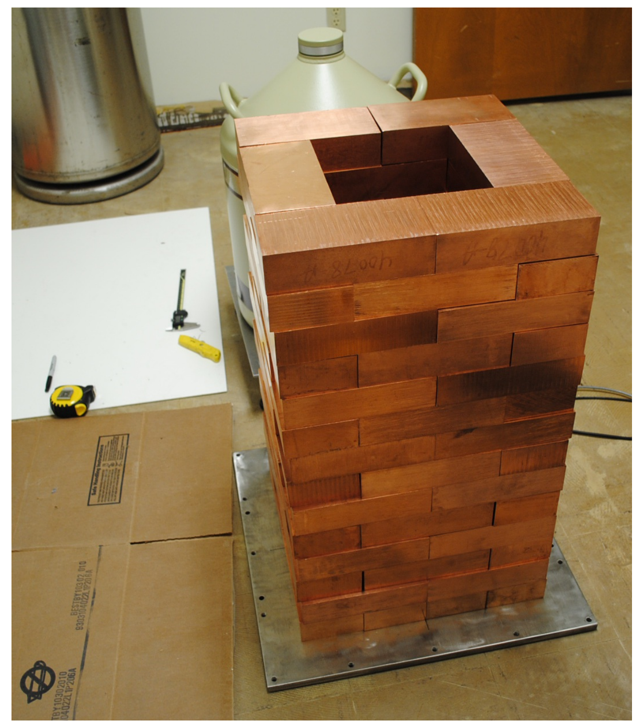
The Davis Cavern is currently under construction.



Low Background Counting at Sanford Lab







Prototype Rn-exclusion shield is built at USD for use with already purchased HPGE detector. Shield will incorporate an inner layer of OHFC copper, stainless steel radon-exclusion box, and outer layer of lead.

Low Background Counting at Sanford Lab
Count rates on the surface

Without shielding 286.44 CPS

without lid shielding 19.92 CPS

Full shielding 4.88 CPS