New Experiments at the New Underground Laboratories

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Physics & Astronomy

1. Physics Potential of Very Large Underground Detectors
2. New Experiment with a LAR Detector at DUSEL. The ICARUS Experiment at the LNGS.
3. The status of DUSEL.
4. Long Term Xenon Dark Matter Experiments

Summary

We report on a variety of proposal experiments on proton decay. Dark Matter detector and Long Base Line neutrino experiments at some new Labs (DUSEL) and some existing labs.

Overview of the Development of very large LAR detectors

1. 2002- Concept of LANNDD (D. Cline, J. Learned, K. MacDonald, F. Sergiampietri. Published: NIM A 503, 136, 2003.)
2. 2006- Study of the Scaling Laws for very Large Detectors. (D. Cline, F. Raffaelli, F. Sergiampietri. Published: JINST, T09001, 2006).
3. 2005- Proposal to construct a 5m test detector LANNDD-5M. Now ready at CERN.
4. A series of meetings on Proton Decay Neutrino Physics organized by BNL (Nick Sanios) and UCLA (DBC). 2003-2006.

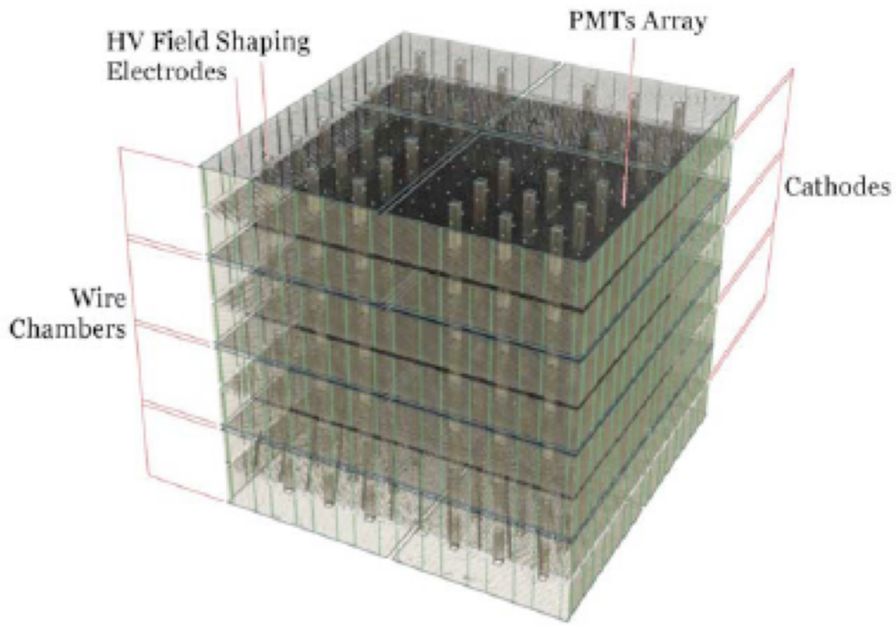


Figure 5a. The LANNDD detector (inside view). Active LAr volume: $44\times44\times44$ m^3. Total active mass: 119 KTons

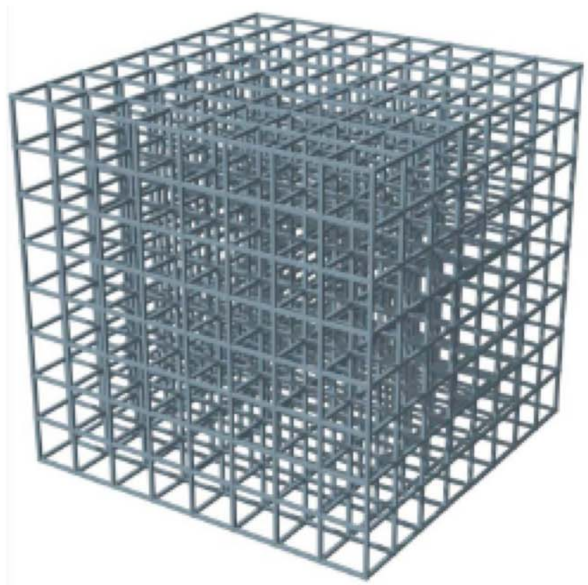


Figure 3b. The inner 3-d lattice mechanical structure

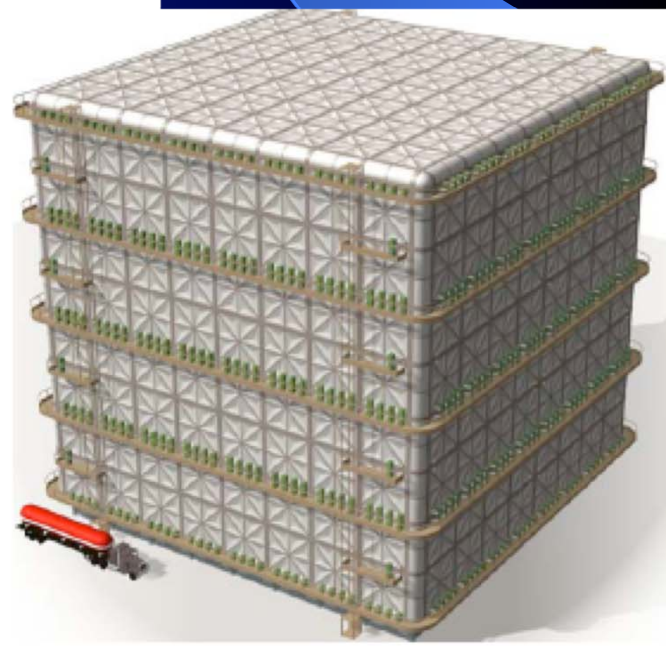
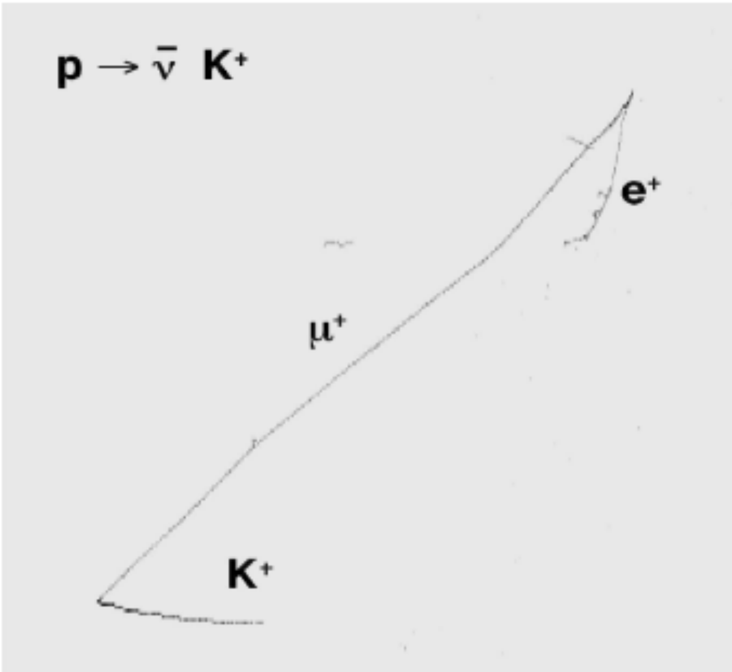
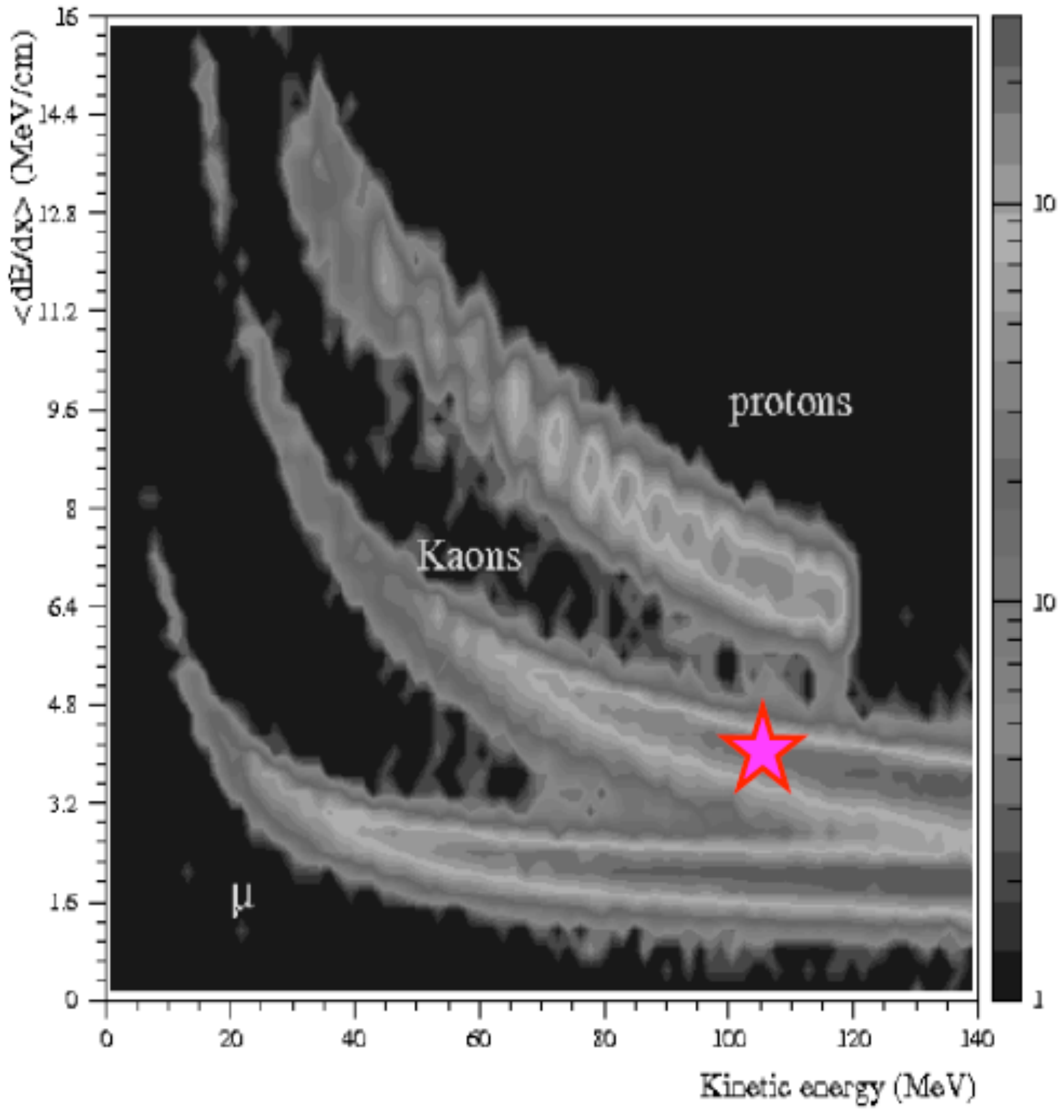


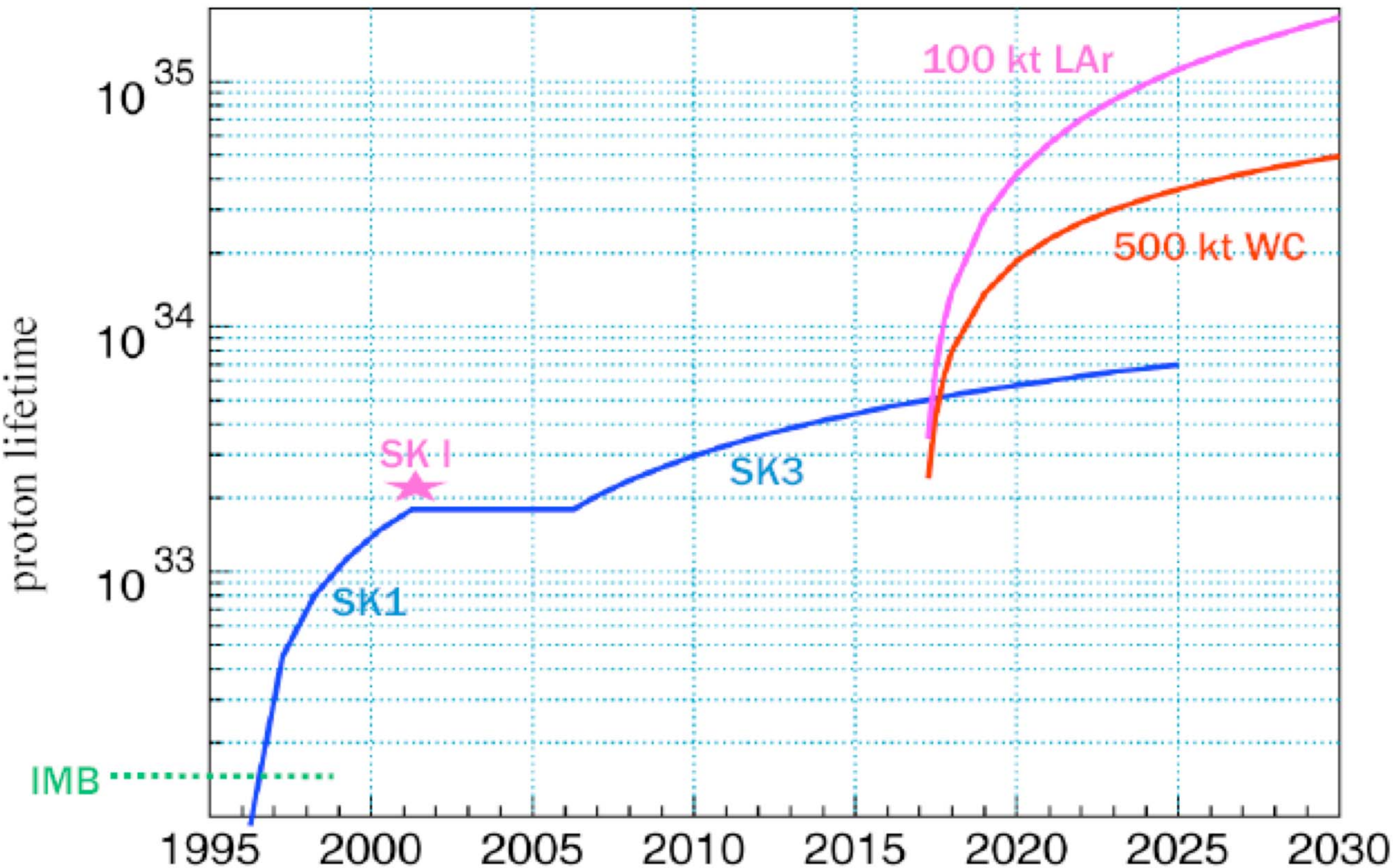
Figure 5c. The LANNDD detector (outside view). The LAr truck is shown to get an idea of the sizes.





Cuts	(p3) $p \to K^+ \bar{\nu}$	ν_e CC	$\bar{\nu}_e$ CC	ν_μ CC	$\bar{\nu}_\mu$ CC	ν NC	$\bar{\nu}$ NC
One kaon	96.8%	308	36	871	146	282	77
No other charged tracks, no π^0	96.8%	0	0	0	0	57	9
$E_{vis} < 0.8$ GeV	96.8%	0	0	0	0	1	0

$$p \rightarrow K^{+}\nu$$



Supernova Neutrinos in Liquid Argon

CC $\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$ $E_{thr}=1.5$ MeV

$\bar{\nu}_e + {}^{40}Ar \rightarrow e^- + {}^{40}Cl^*$ $E_{thr}=7.48$ MeV

NC $\nu_x + {}^{40}Ar \rightarrow e^- + {}^{40}Ar^*$ $E_{thr}=1.46$ MeV

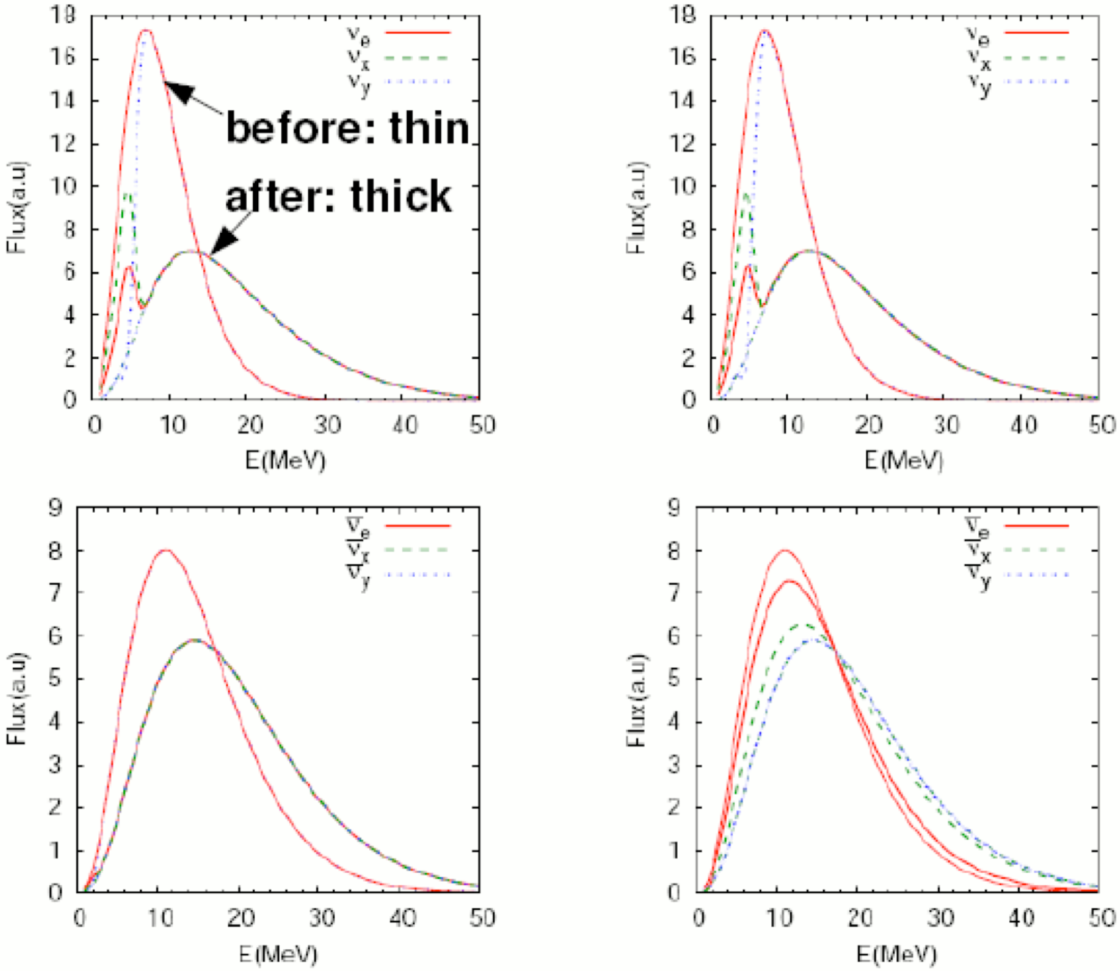
ES $\nu_{e,x} + e^- \rightarrow \nu_{e,x} + e^-$

Tag modes with gamma spectrum (or lack thereof)

Example: A. Dighe Neutrino 2008 talk

Final spectra for inverted hierarchy w/ collective effects

Note: interesting features <~10 MeV!



Neutrinos

spectral swap for neutrinos (not for NH)

Antineutrinos

Small θ_{13}

Large θ_{13}

B.Dasgupta, AD, arXiv:0712.3798, PRD

100 kt of LAr, SN @ 10 kpc

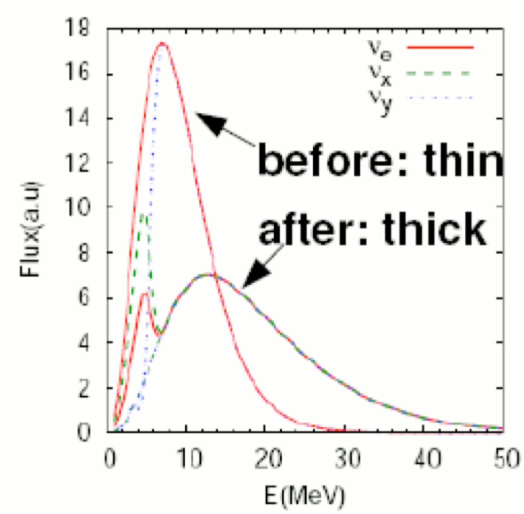
Interaction	Rates ($\times 10^4$)
ν_e CC (^{40}Ar, ^{40}K*)	2.5
ν_x NC (^{40}Ar*)	3.0
ν_x ES	0.1
anti–ν_e CC (^{40}Ar, ^{40}Cl*)	0.054

A. Bueno, NP 2008 talk

- ν_e **tagging** (excellent oscillation sensitivity)
- **low energy threshold**
- **pointing**

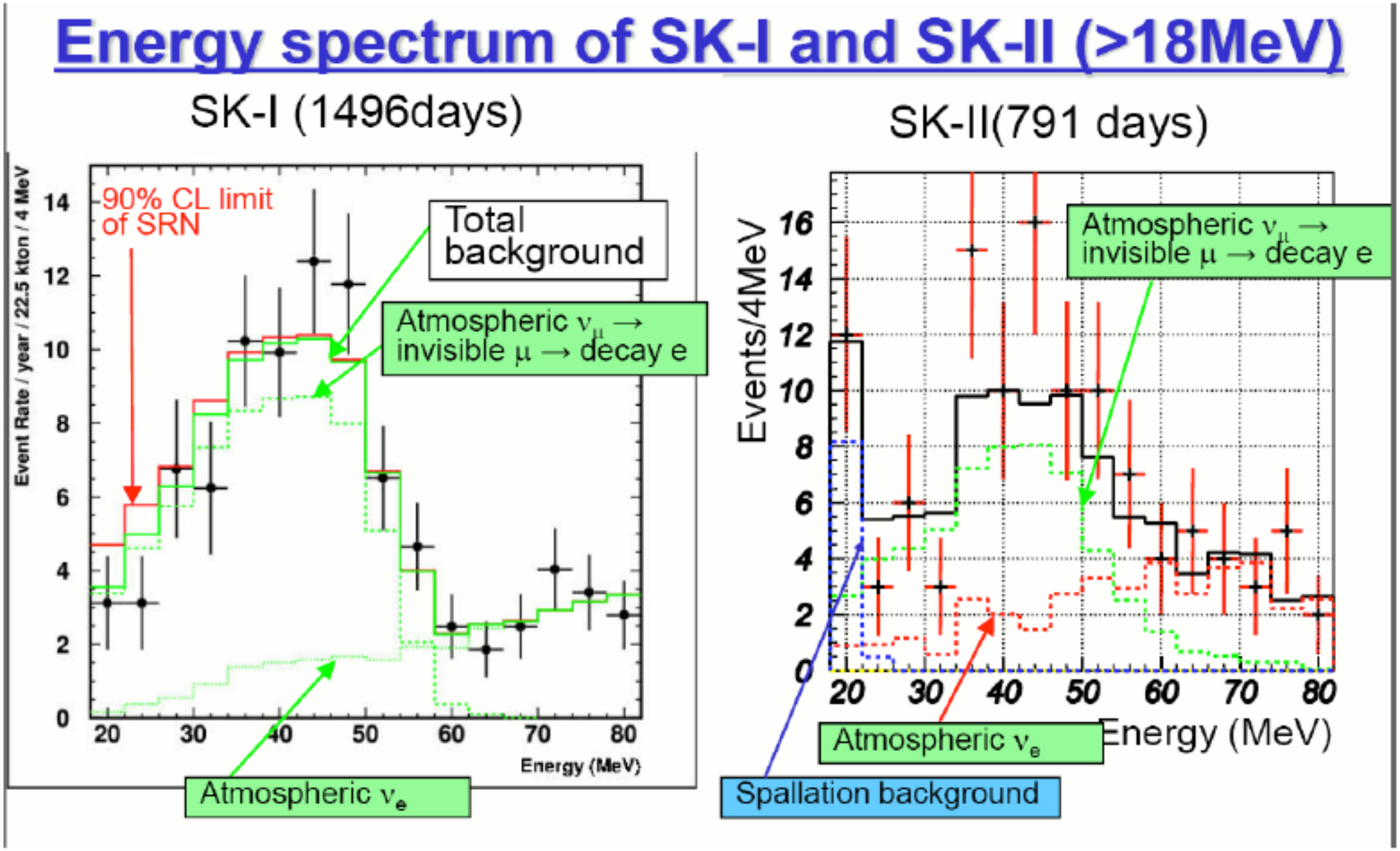
$$\delta\theta \sim \frac{30^o}{\sqrt{N}}$$

A. Bueno et al.
hep-ph/0307222



In water: $\bar{\nu}_e + p \rightarrow e^+ + n$

M. Nakahata, Neutrino 2008 talk



- **Worst background is 'invisible muons' below Cherenkov threshold from atmospheric neutrinos**
  → *reduce by tagging electron antineutrinos with Gd*
- **LAr is also promising (no Cherenkov threshold): ν_e**

The ICARUS Collaboration

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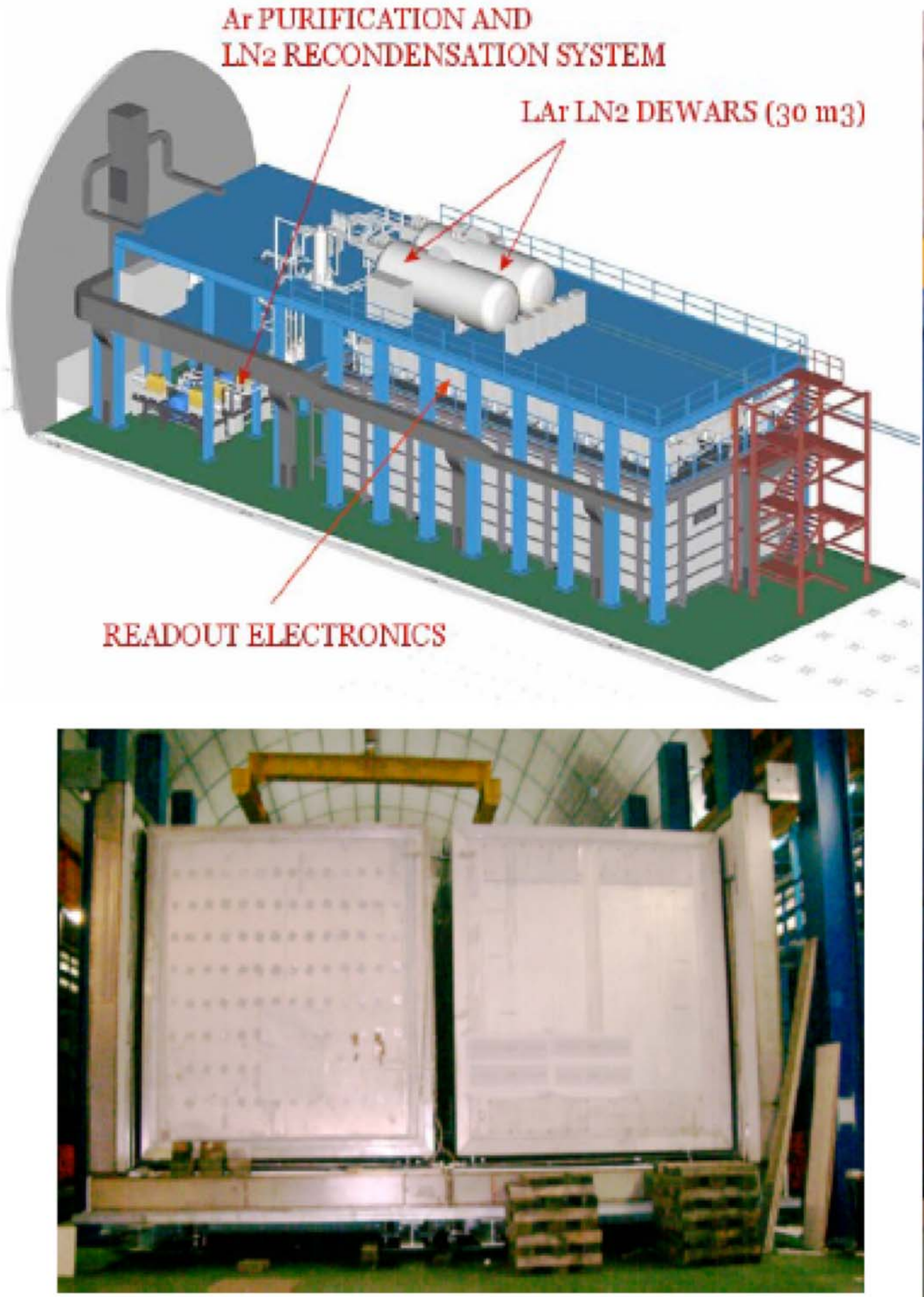


Figure 38. ICARUS T600 on June 2007

Figure 39. ICARUS T600 on July 2008

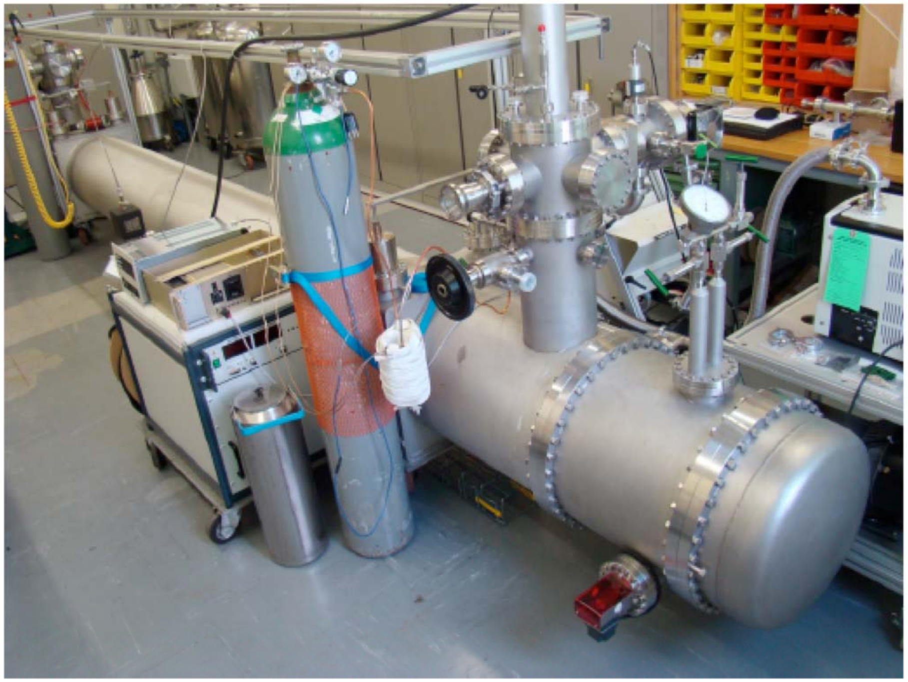


Figure 24. Fluxing hot argon inside both inner and outer vessels. HV end.

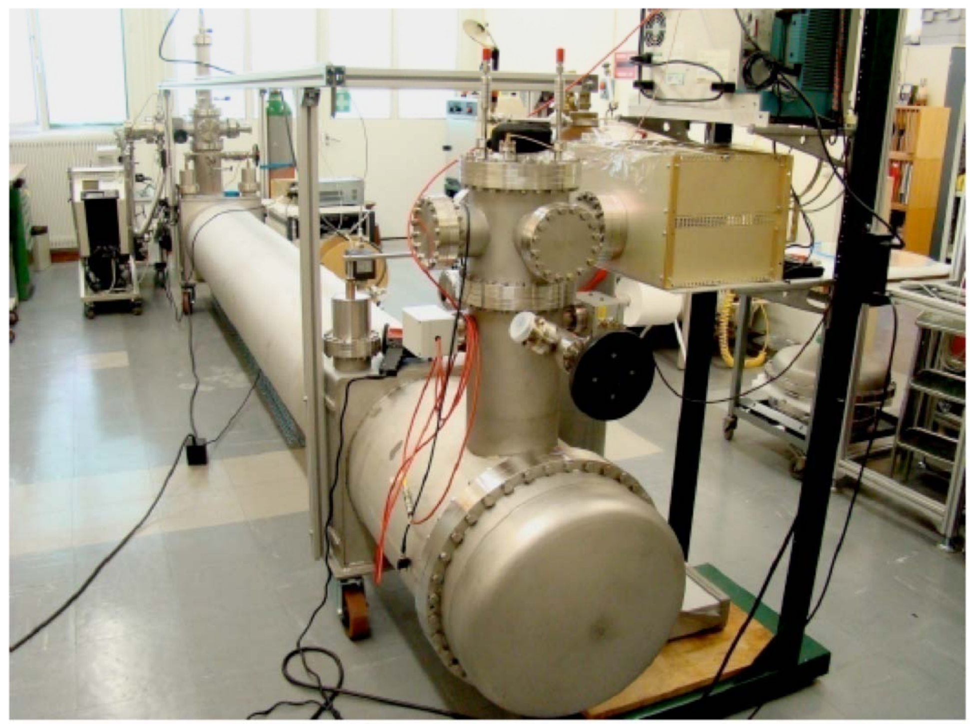


Figure 25. Low voltage end with the read-out electronic crate in its final position.

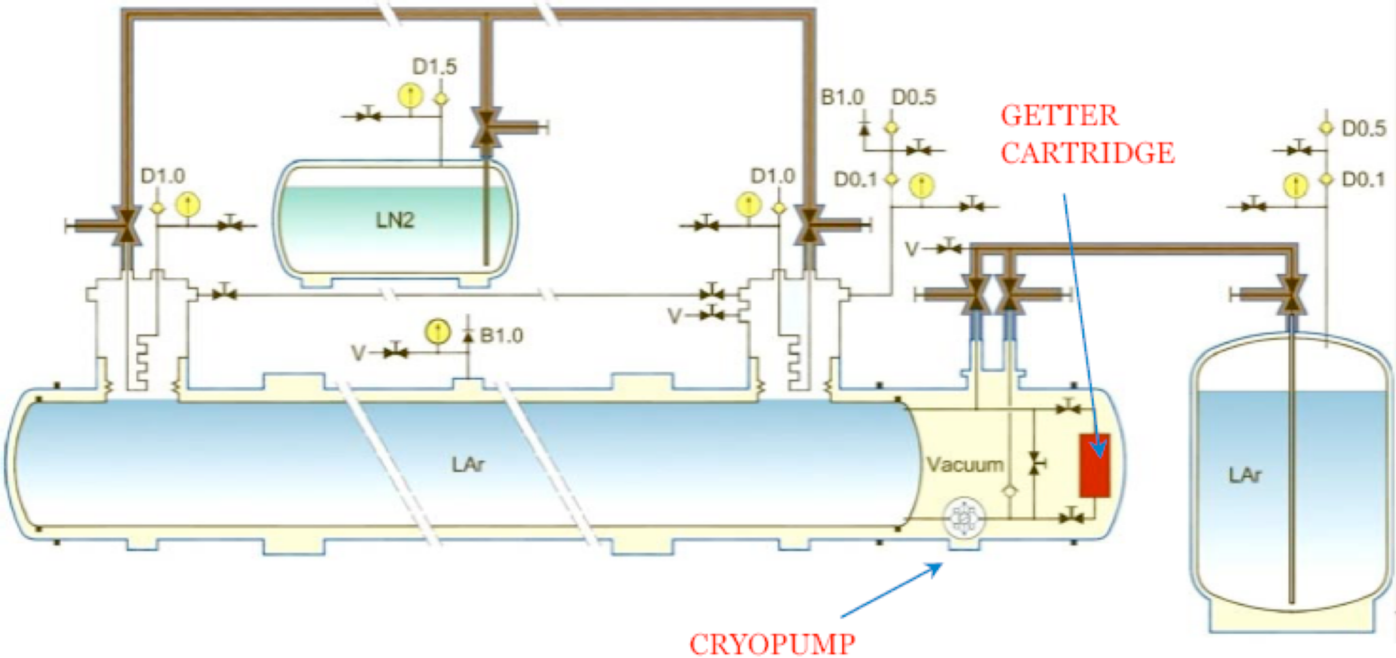


Figure 21. Diagram of the cryogenics

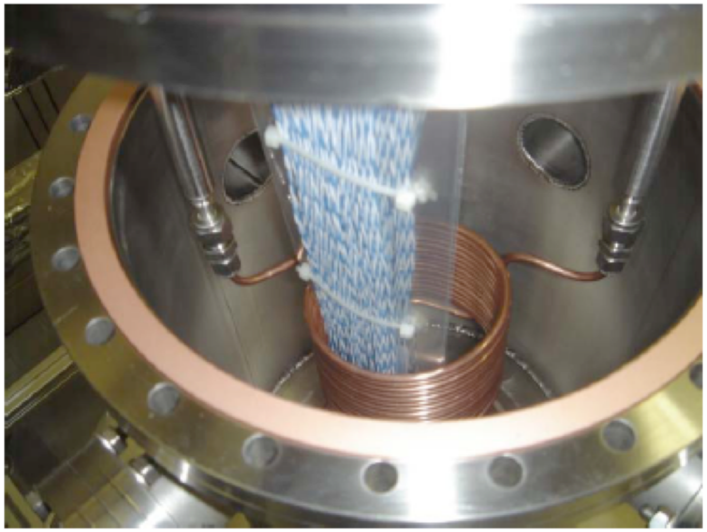


Figure 22. Assembling the low voltage chimney with signal cables and the heat exchanger.

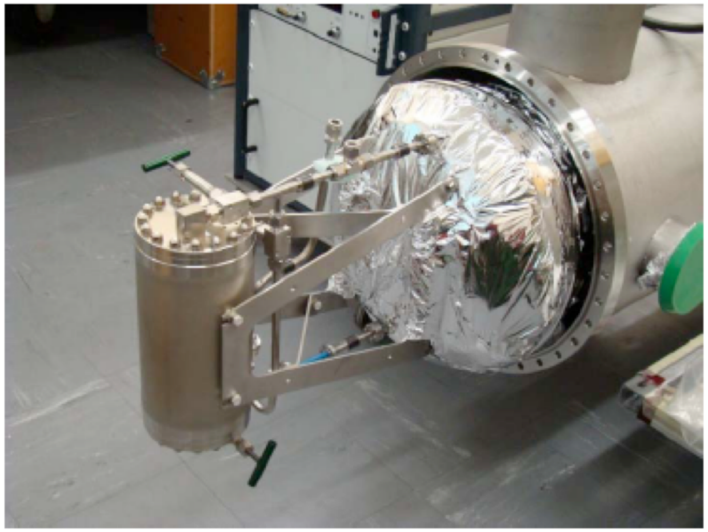
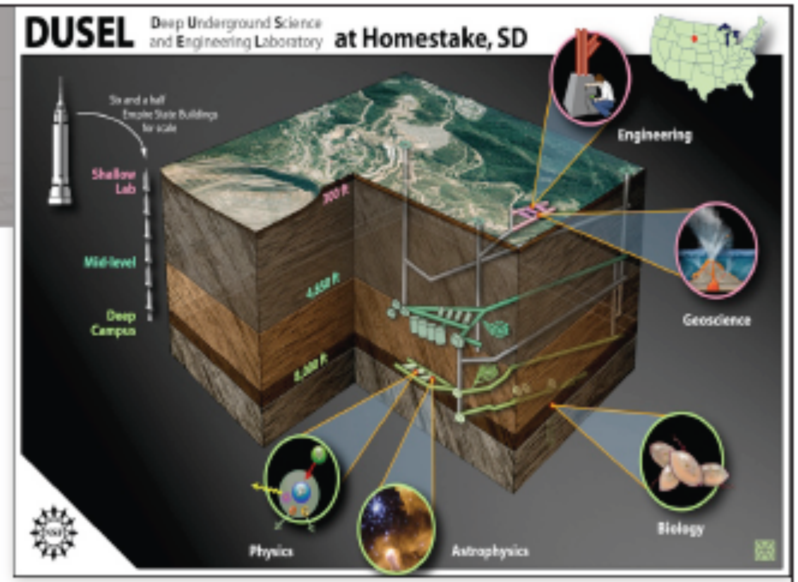


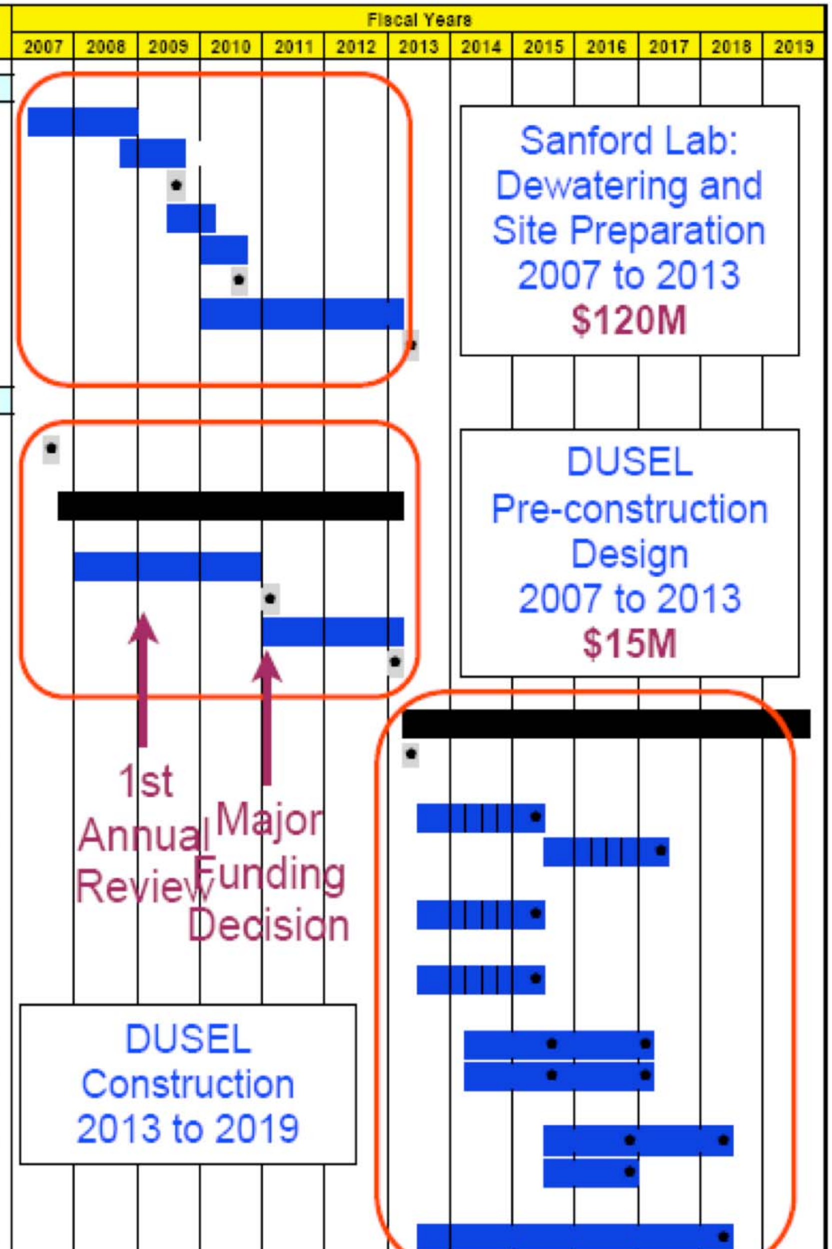
Figure 23. The integrated purification system during assembling.

Outline of Presentation

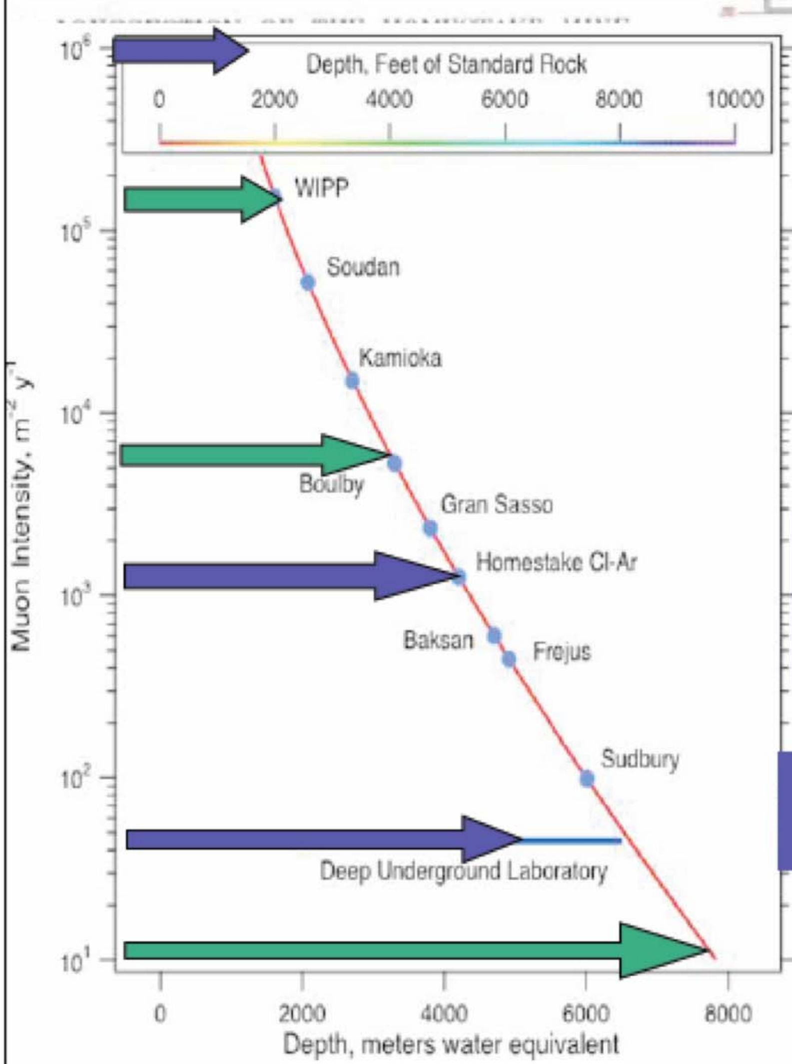


- The DUSEL Project
  - Major Milestones
  - Key Facility Parameters
  - Facility Conceptual Design
- DUSEL's Scientific Programs
- Developing DUSEL and Preparing Facility Designs
  - Progress in Developing Advanced Designs
  - Progress in Preparing Homestake and its Early Science Programs
- Summary

Proposed Timeline for Sanford Laboratory and DUSEL Facility Development	Start	Finish
Sanford Laboratory at Homestake		
Ross Shaft Rehab and Pumping Column Commissioning	Jan-07	Sep-08
Yates Shaft Rehab.	Aug-08	Aug-09
Gain safe access to 4850L for EIP construction start, and hold water level at 5000L		Jun-10
Install facility infrastructure for Davis Lab early experiments	Jun-10	Dec-10
Install and commission research instrumentation in Davis Lab	Sep-09	Jun-10
Early experiments in Davis Lab ready for operation		Jun-10
Continued rehabilitation and infrastructure upgrades for Sanford Lab		Dec-12
Transition from Sanford Lab to DUSEL Operations		Jan-13
NSF Deep Underground Science and Engineering Laboratory at Homestake		
Homestake site selection announcement		Jul-07
DUSEL Preconstruction Planning and Development (R&RA)	**Oct-07**	**Dec-12**
Preliminary Design Phase to develop Baseline Cost and Schedule	Oct-08	Dec-10
Preliminary Baseline Design Review and National Science Board Recommendation		Mar-11
Final Design Phase	Jan-11	Dec-12
Final Design Review and Authorization for Construction Start		Dec-12
DUSEL Facility - Construction and Commissioning (MREFC)	**Jan-13**	**Sep-19**
Proposed Construction Start		Jan-13
Surface Campus Construction		
Phase 1 Offices and Laboratories, Education and Outreach	Apr-13	Mar-15
Phase 2 Offices and Laboratories	Apr-15	Mar-17
Near-Surface Campus Construction at 300L		
300L Labs and Education and Outreach Facilities	Apr-13	Mar-15
Infrastructure Development to support underground construction		
Mid-Level and Deep-Level Campuses	Apr-13	Mar-15
Mid-Level Campus Construction at 4850 Level		
4850L Common Facilities and Lab Module #1 (Excavation & Lab Build-out)	Jan-14	Dec-17
4850L Davis lab Alterations and Lab Module #2 (Excavation & Lab Build-out)	Jan-14	Dec-17
Deep-Level Campus Construction at 7400 Level		
7400L Common Facilities and Lab Module #1 (Excavation & Lab Build-out)	Apr-15	Mar-18
7400L Lab Module #2 (Excavation Only)	Apr-15	Sep-16
Large Cavity Excavation and Facility Infrastructure		
Infrastructure Development and Excavation	Apr-13	Mar-18



Plans for Research Campuses Optimized for Science



300L R&D
E&O 10k ft^2

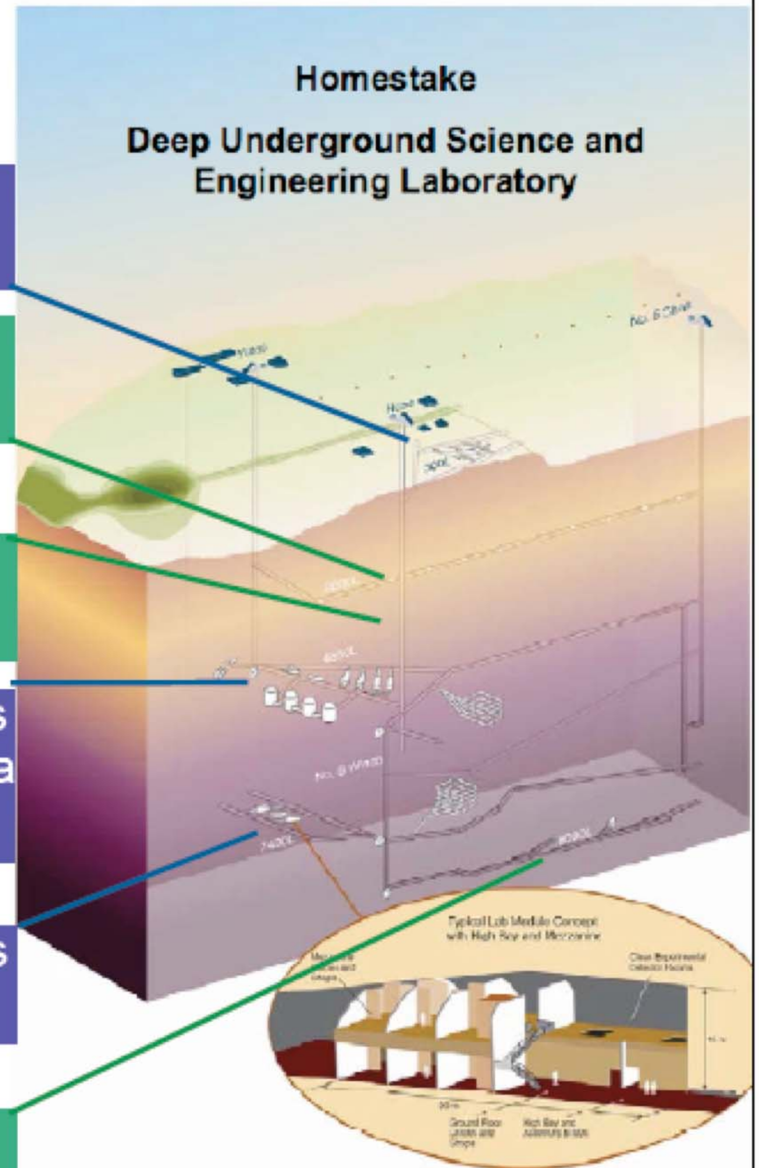
2000L BGE
Level

3800L BGE
Level

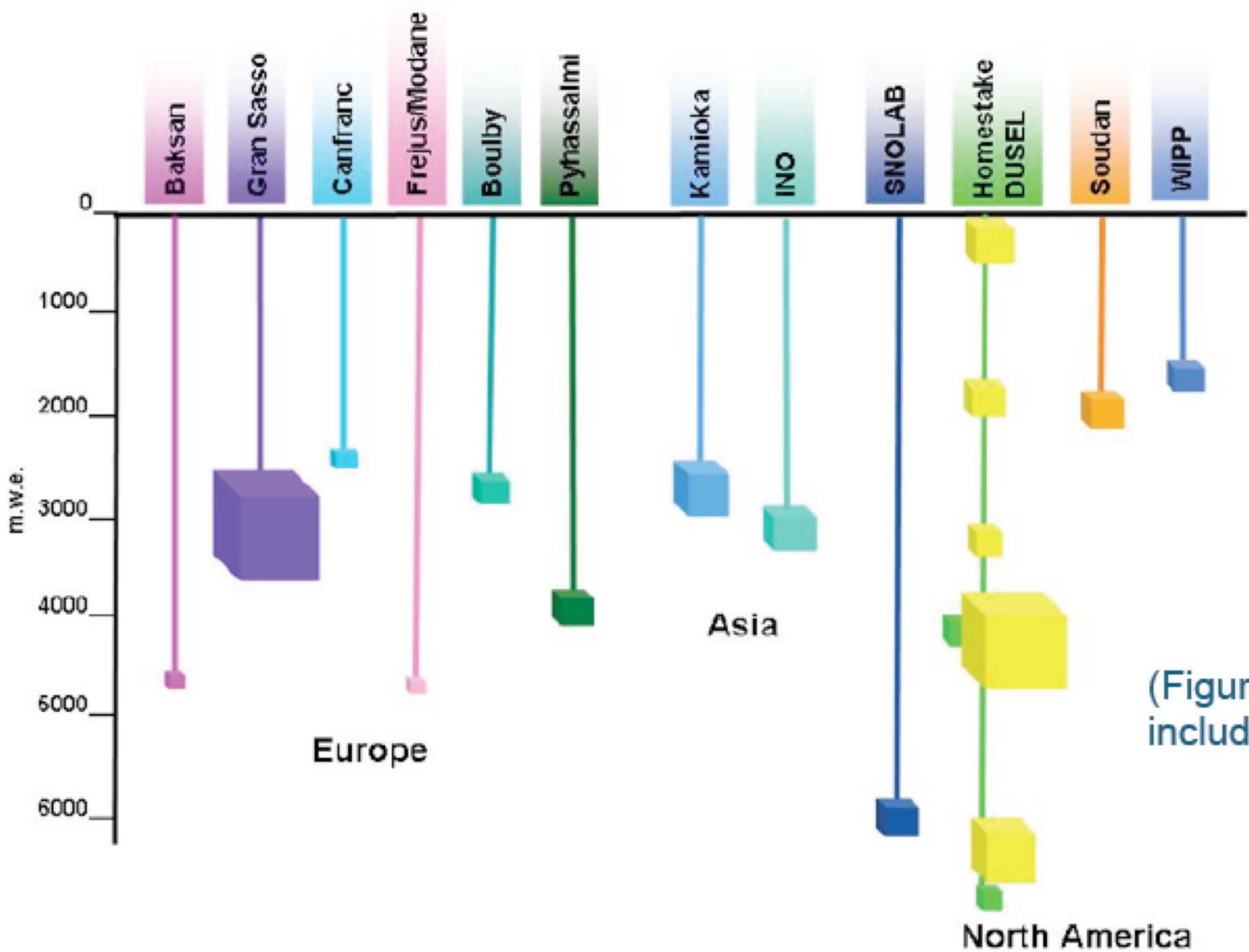
4850L Campus
100k ft^2 + Mega
Cavities

7400L Campus
65k ft^2

8000L BGE
Lab

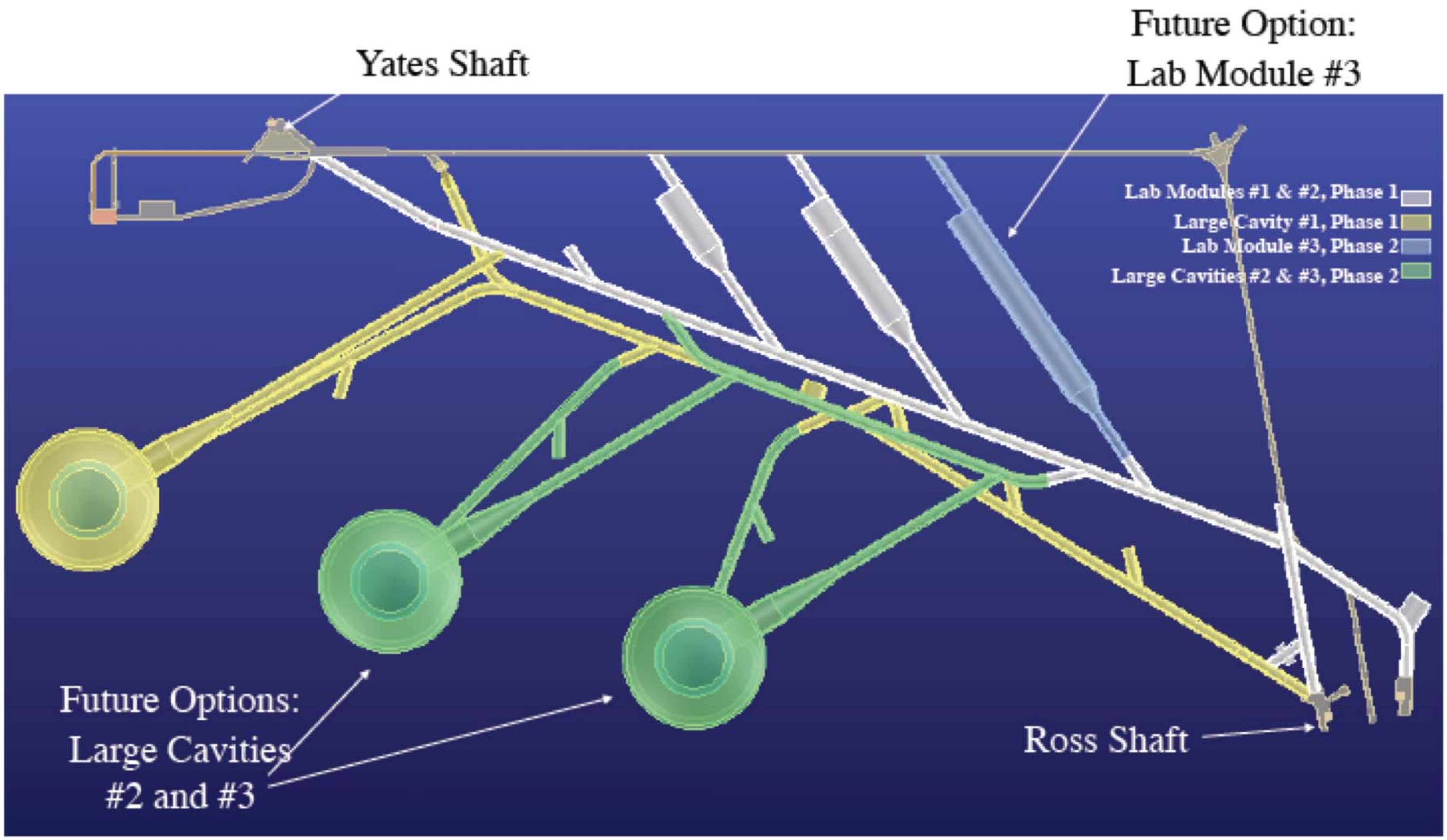


Providing Critical Research Space, Especially at Great Depths

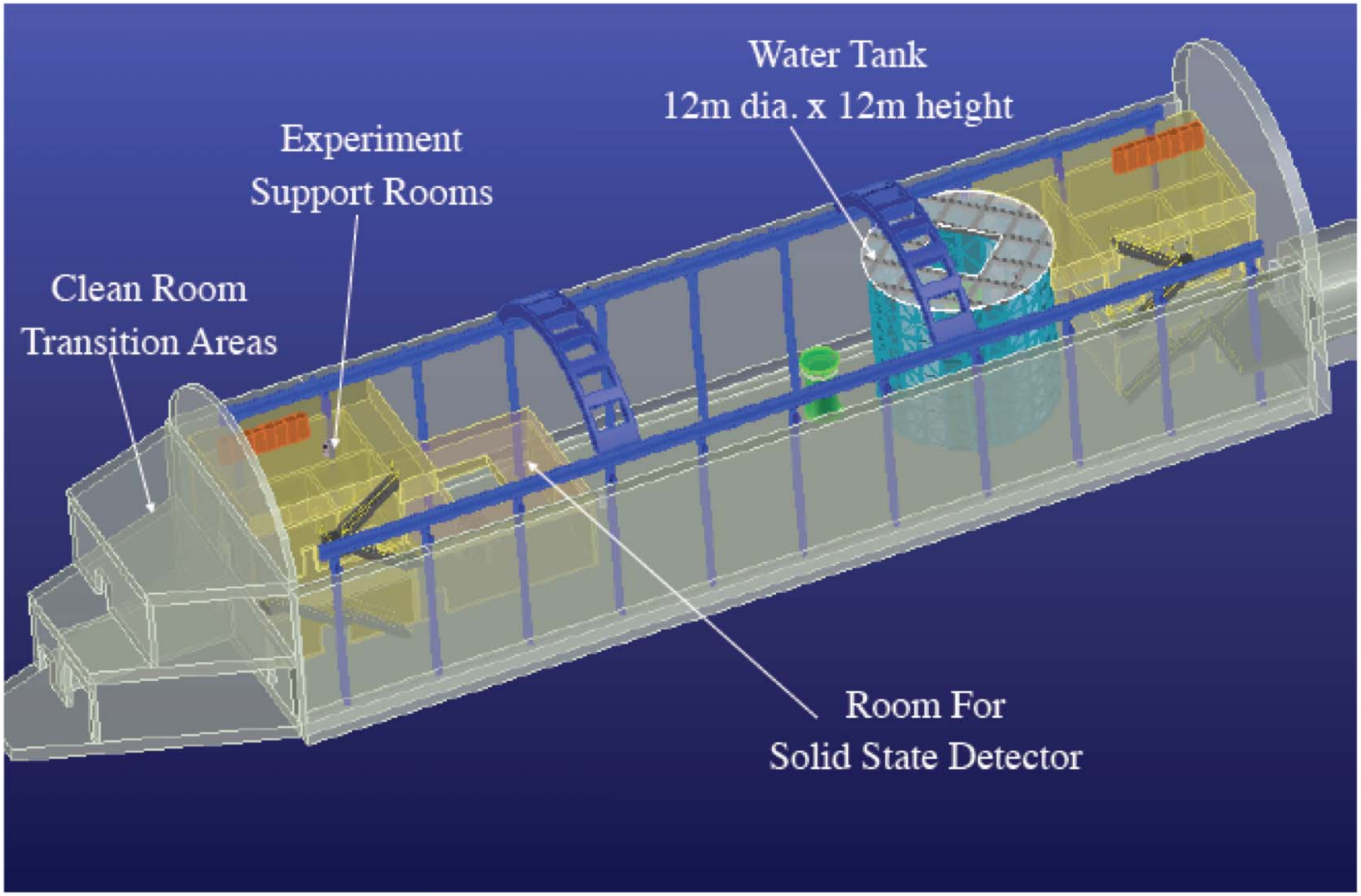


(Figure does not include large cavities)

Sequential Development of Space at 4850L:
Future Expansion Options for Mid-level Campus



Conceptual layout of laboratory space



Depth Requirements Summary

Physics	Water Cherenkov (mwe)	Liquid Argon (mwe)
Long BaseLine Accelerator	1000	0-1000
$p \to K^+ \tilde{\nu}$	>3000	>3000
Day/Night ^8B Solar ν	~4300	~4300
Supernova Burst	3500	3500
Diffuse ν from Supernova	4300	>2500
Atmospheric ν	2400	2400

Detector Sensitivity versus Size and Exposure: Neutrino Accelerator Physics

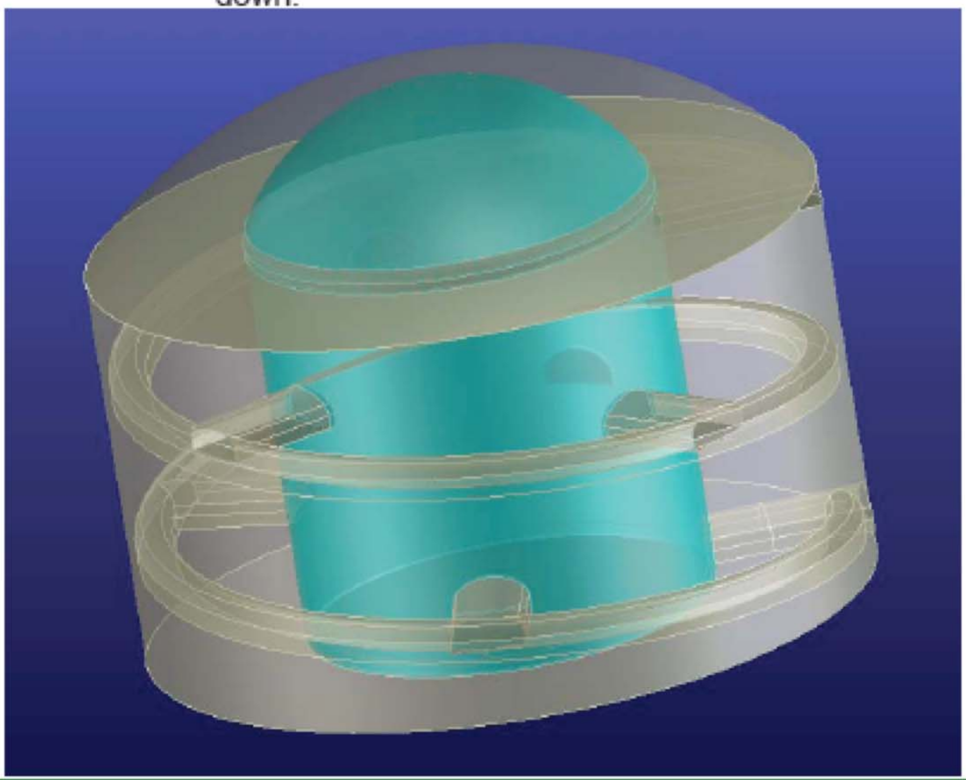
Detector Size (kT)	POT ($\times 10^{20}$) @120GeV (1MW = 10^{21}/yr)	Years $\nu+\tilde{\nu}$	3 σ Sensitivity Minimum value of $\sin^2 2\theta_{13}$		
			$\sin^2 2\theta_{13} \neq 0$	Mass Hierarchy	CPV (50% of δ_{cp} coverage)
H20 100 Bishai	30+30	3+3	0.014	0.031	>0.1
H20 300 Bishai	30+30	3+3	0.008	0.017	0.025
H20 600 Bishai	30+30	3+3	0.005	0.012	0.012
H20 300 Bishai	60+60	3+3	0.005	0.012	0.012
LAr 50 Dierckxsens	60+60	3+3	0.005	0.011	0.010

Large Cavity Preliminary Excavation Design

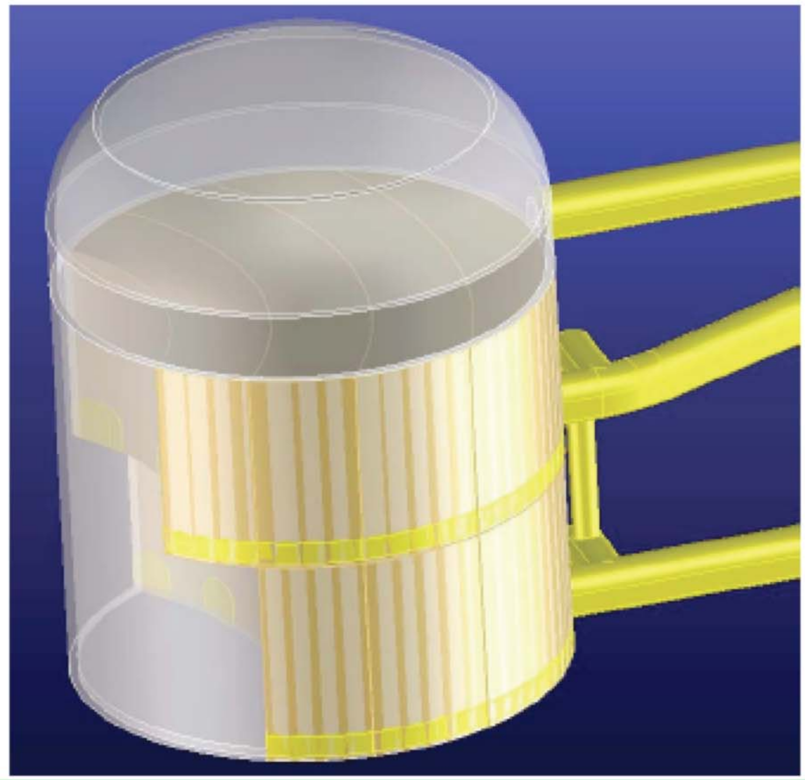
LONGSECTION OF THE HOMESTAKE MINE

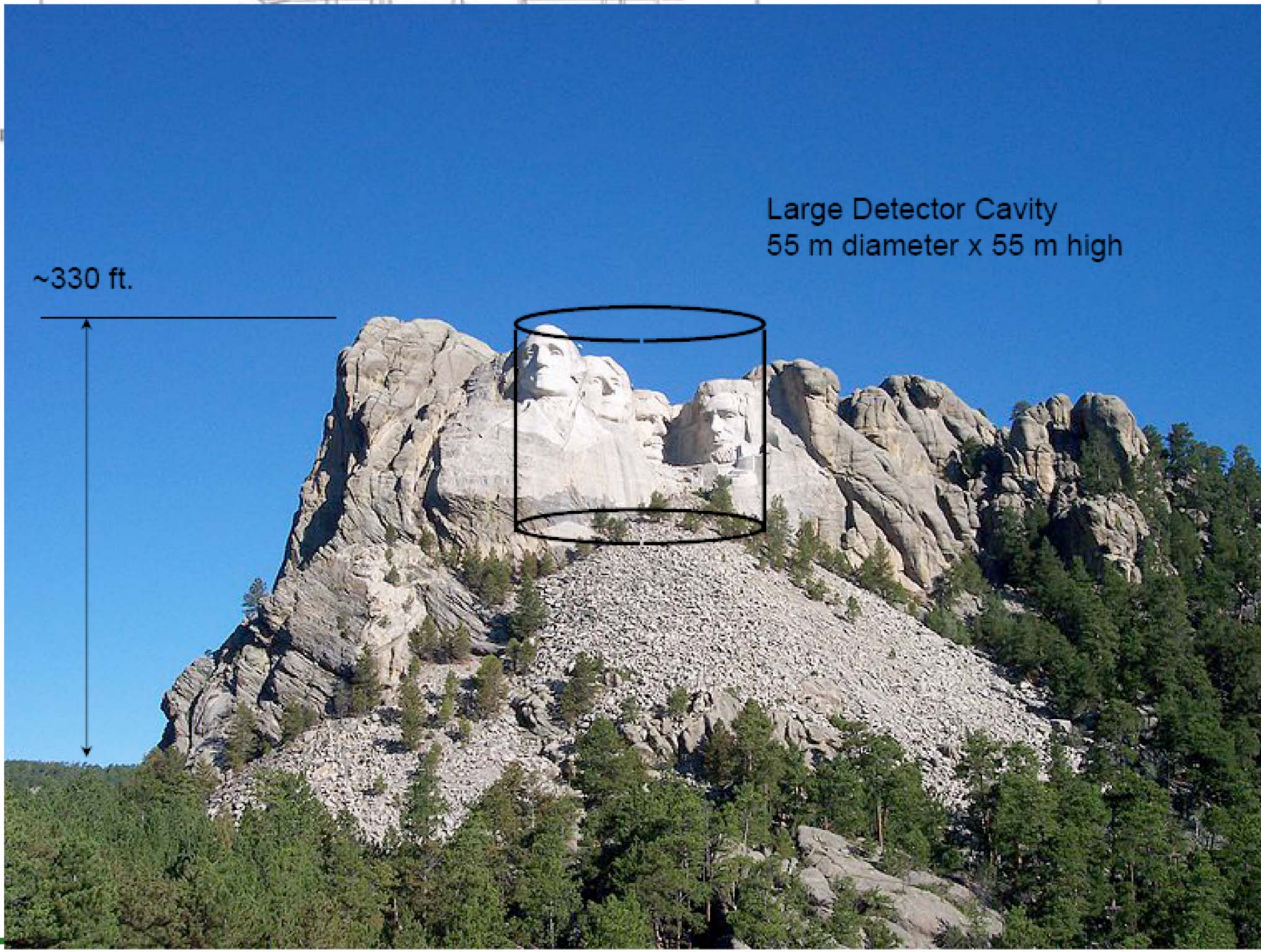
Excavation Options

1. **Benching Method**
   - Top Access at 4850 L, Bottom Access at 5000 L
   - Spiral ramp around Perimeter for Horizontal Accesses every 20 ft
   - 20 ft Vertical Benches excavated from the top down.

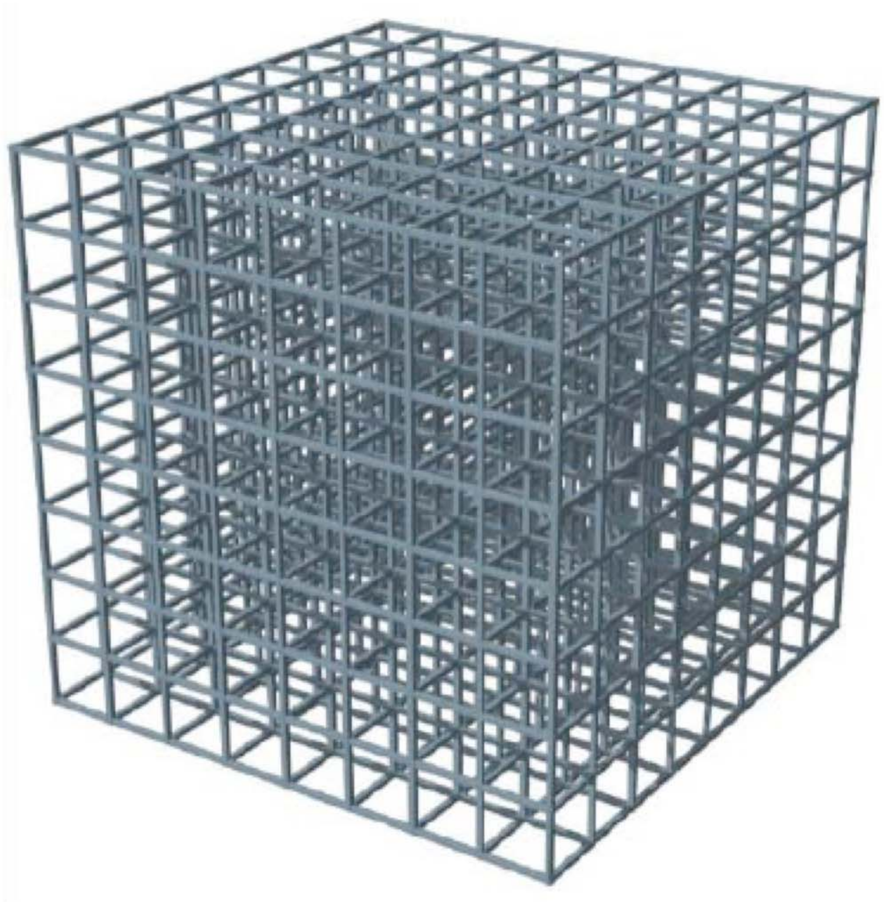


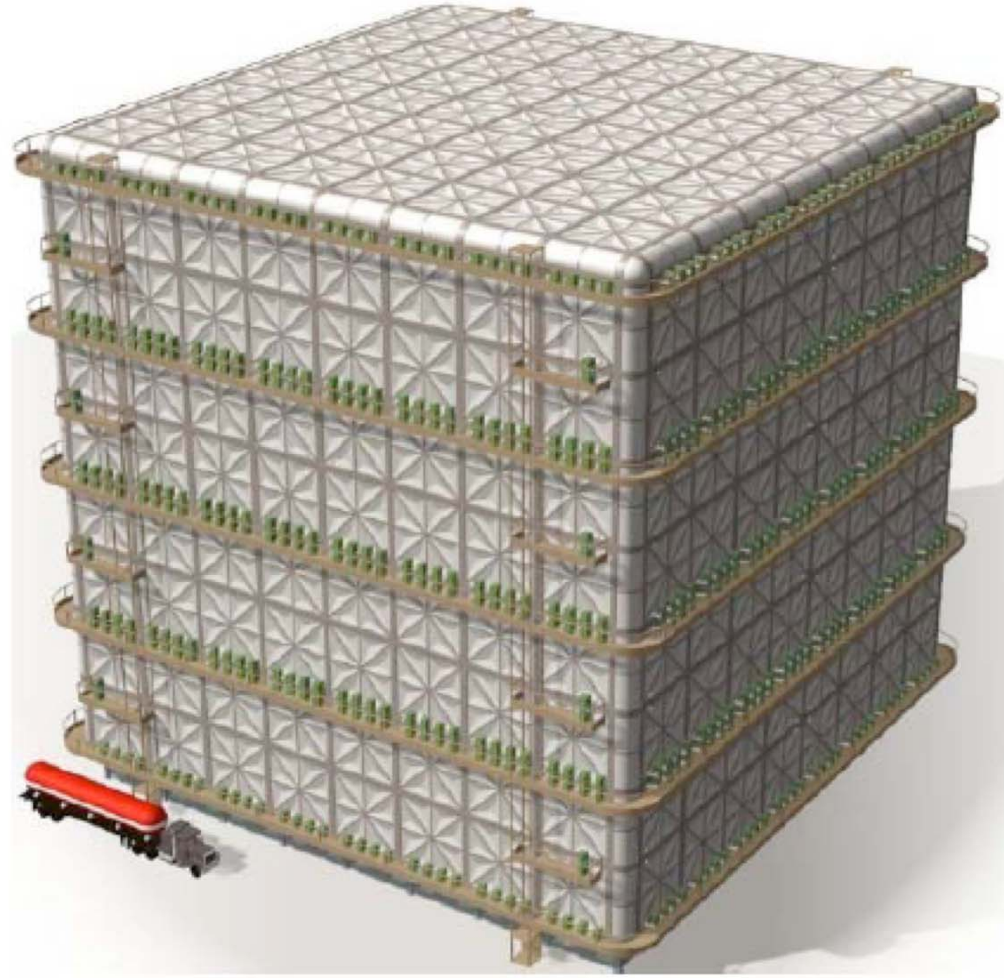
2. **Bulk Excavation Method**
   - Top Access at 4850 L, Bottom Access at 5000L, Center Access at 4925L
   - Long hole drilling from 4850L, 4925L, and 5000L
   - Blasting from 4850L and 4925L
   - Waste rock removal from 4925L and 5000L




Large Detector Cavity
55 m diameter x 55 m high
~330 ft.

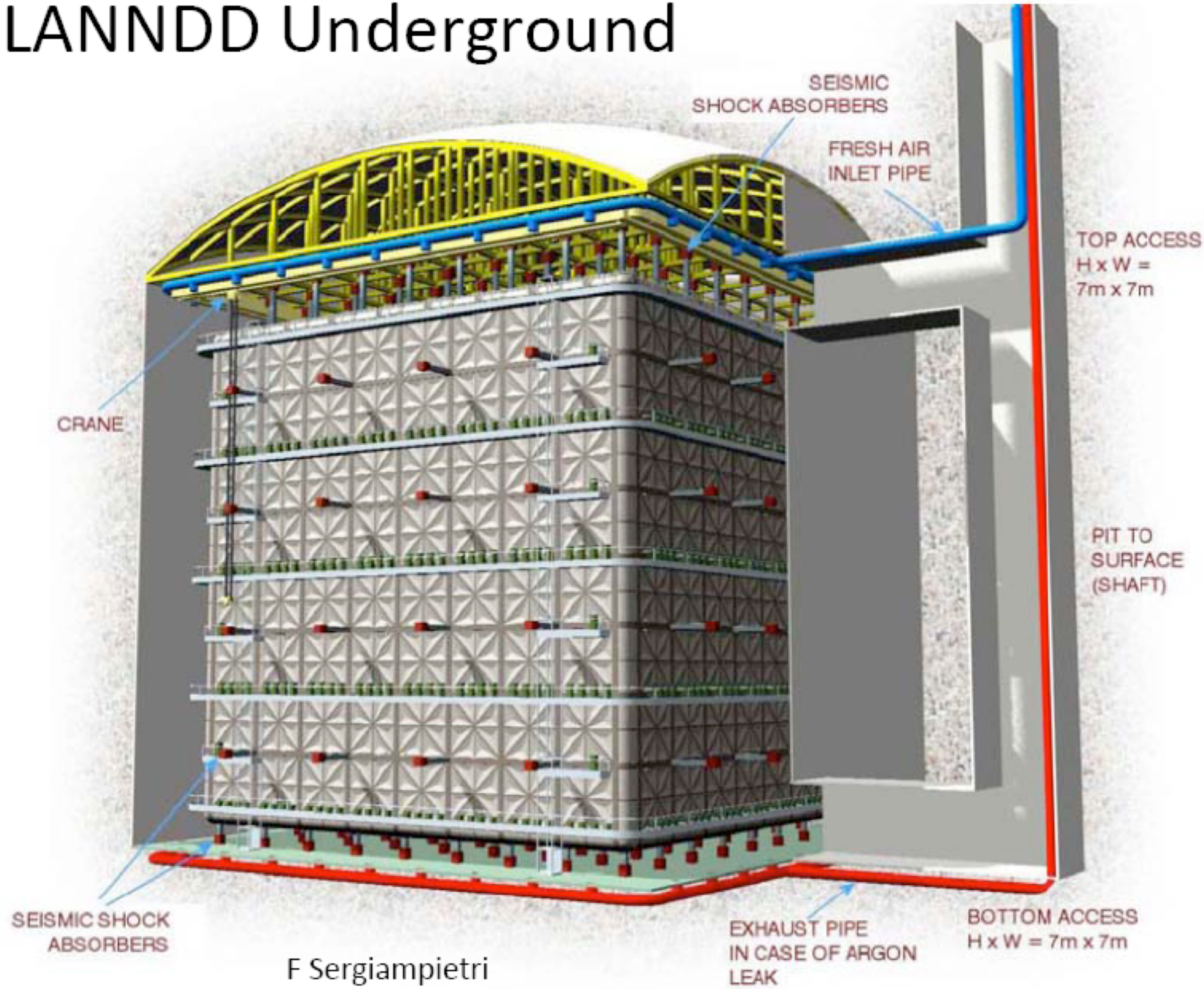
The LANNDD Concept 1



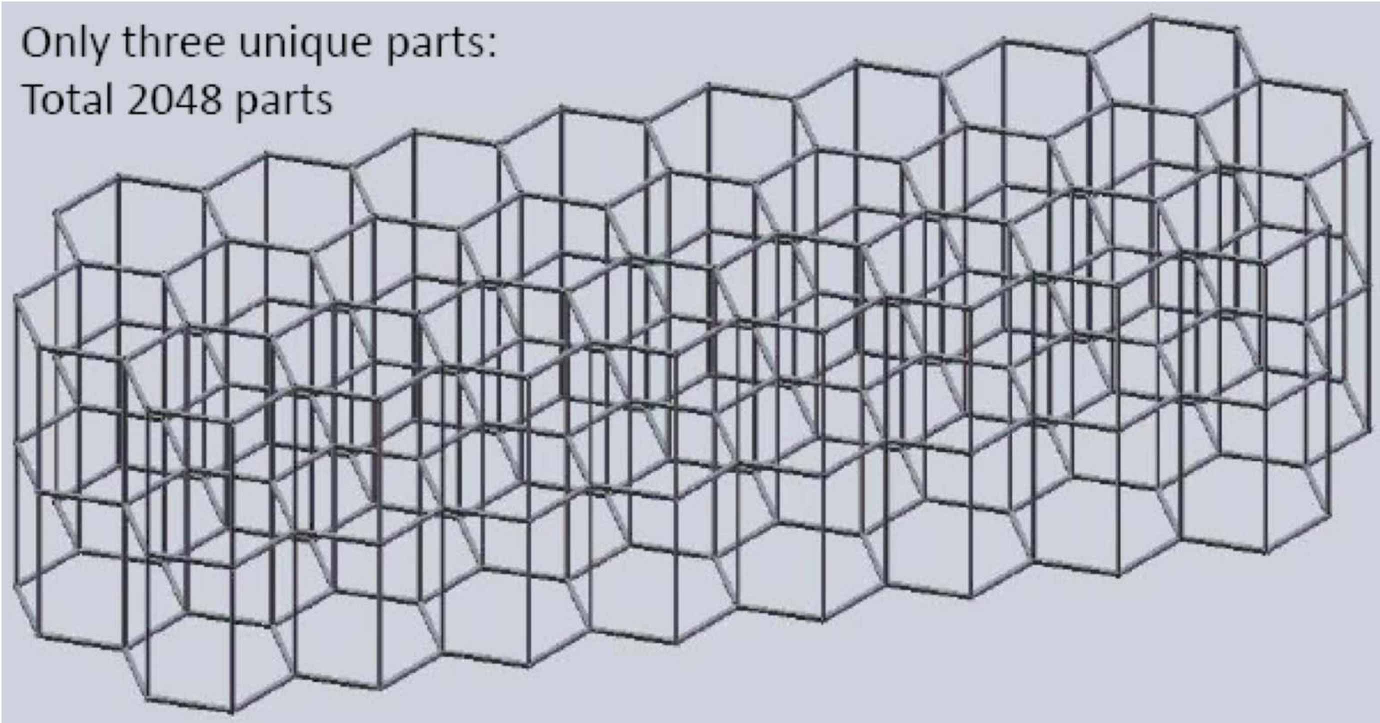


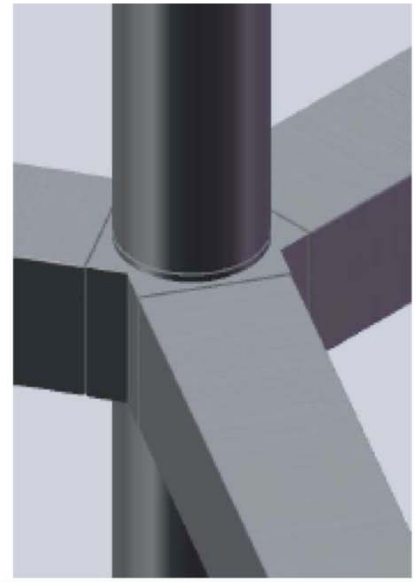
DB Cline, F Sergiampietri

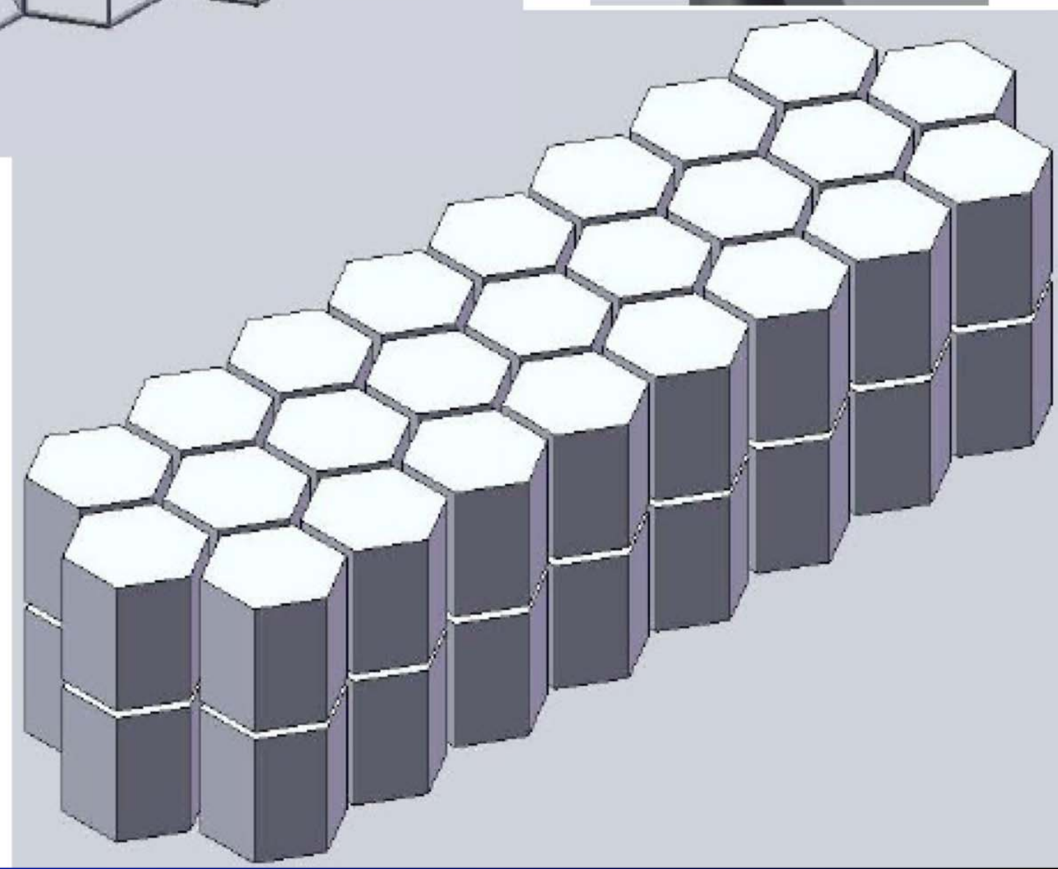
LANNDD Underground



F Sergiampietri



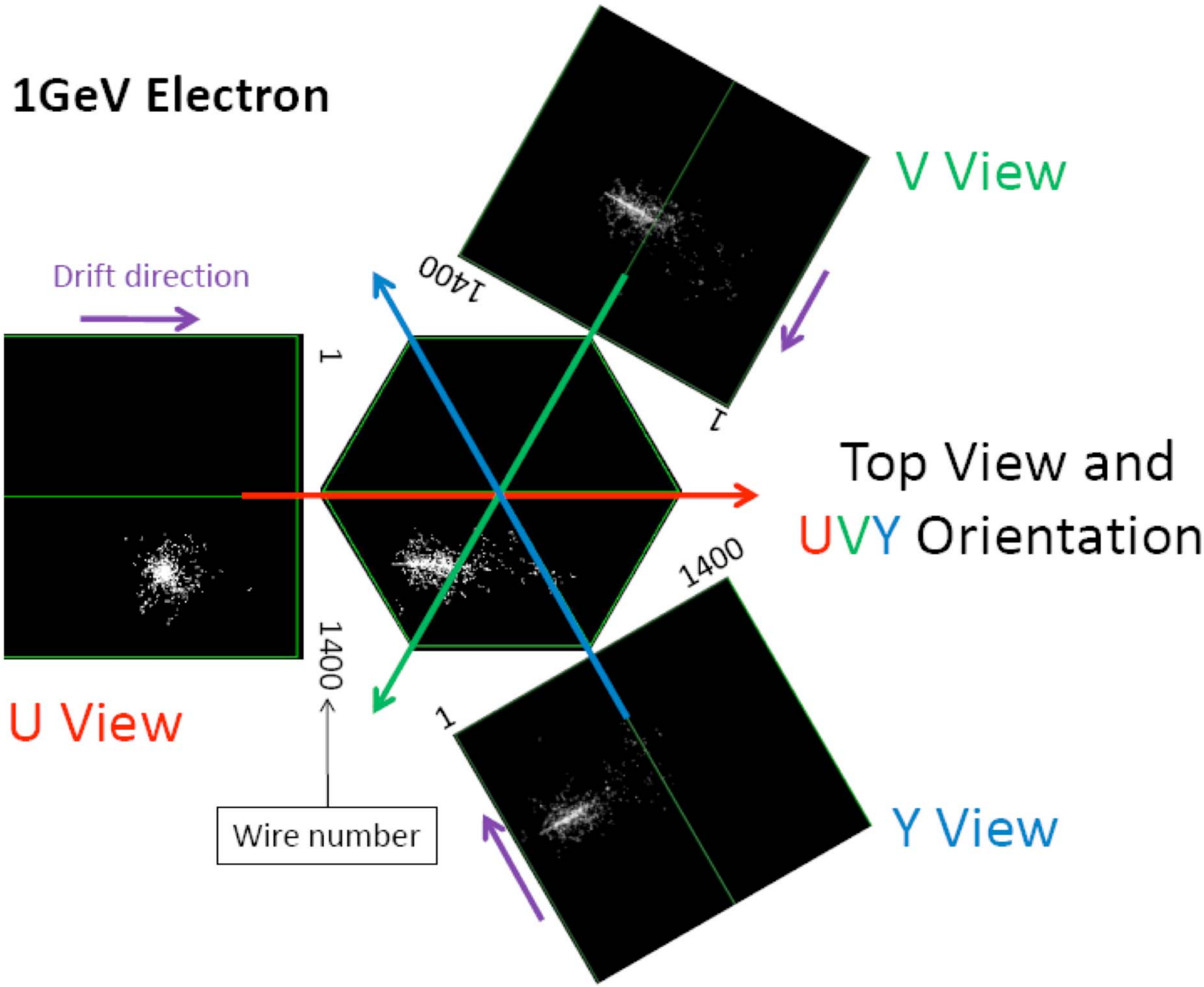


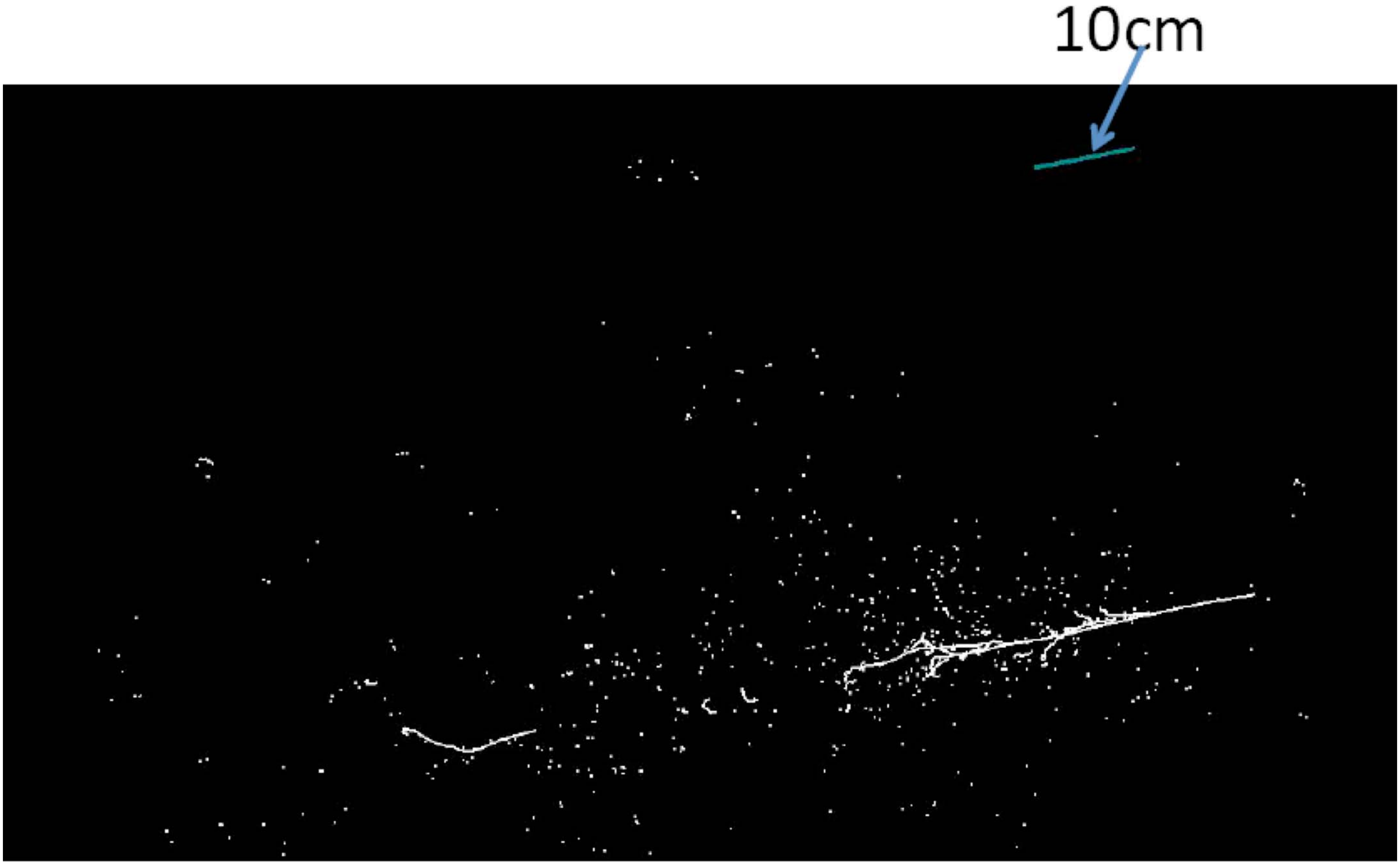


50 modules of 100T each showing the inner self supporting structure and detailed structure link

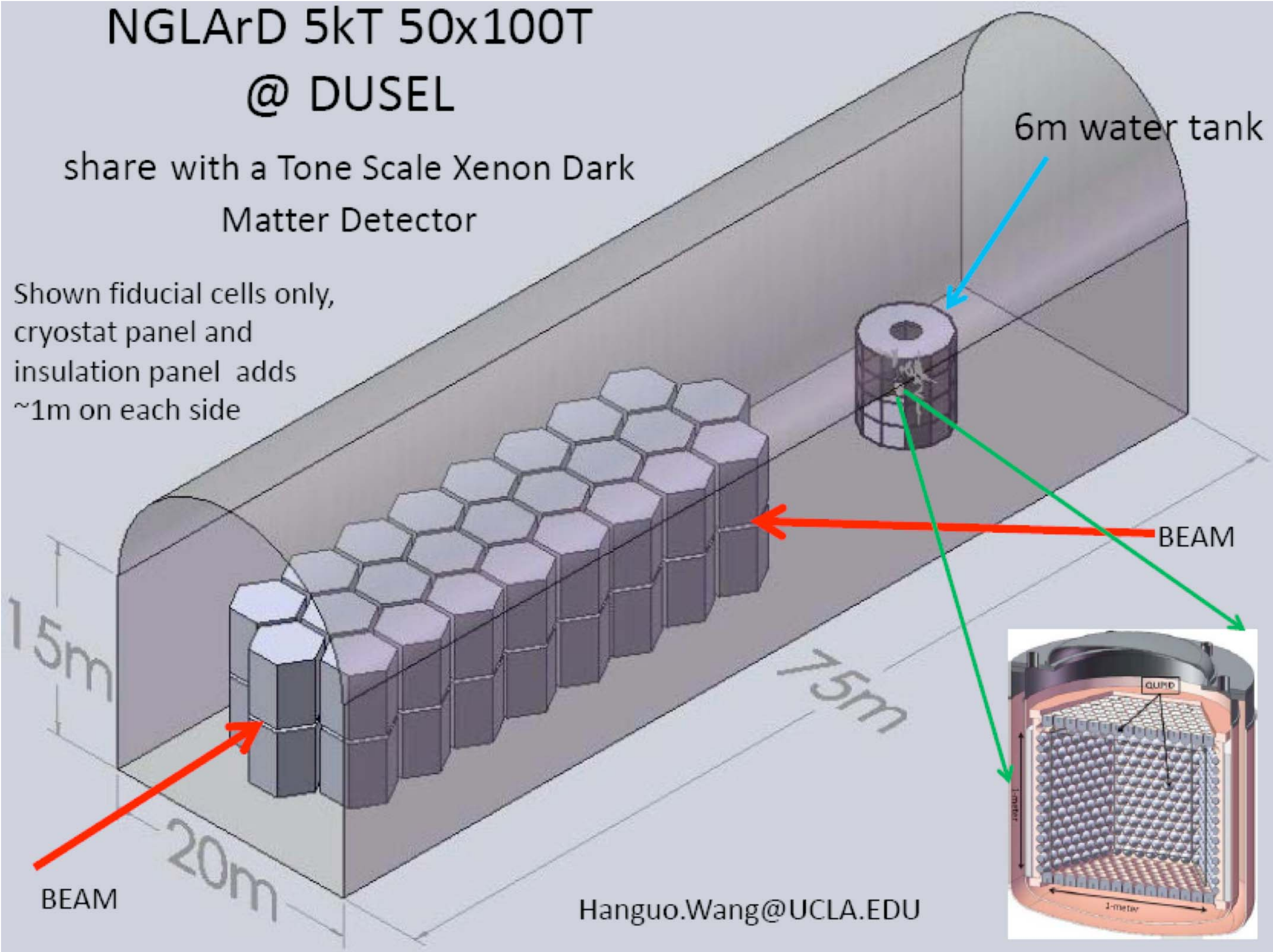
Note: additional small rings on the vertical beam for field, no other materials needed

1GeV Electron



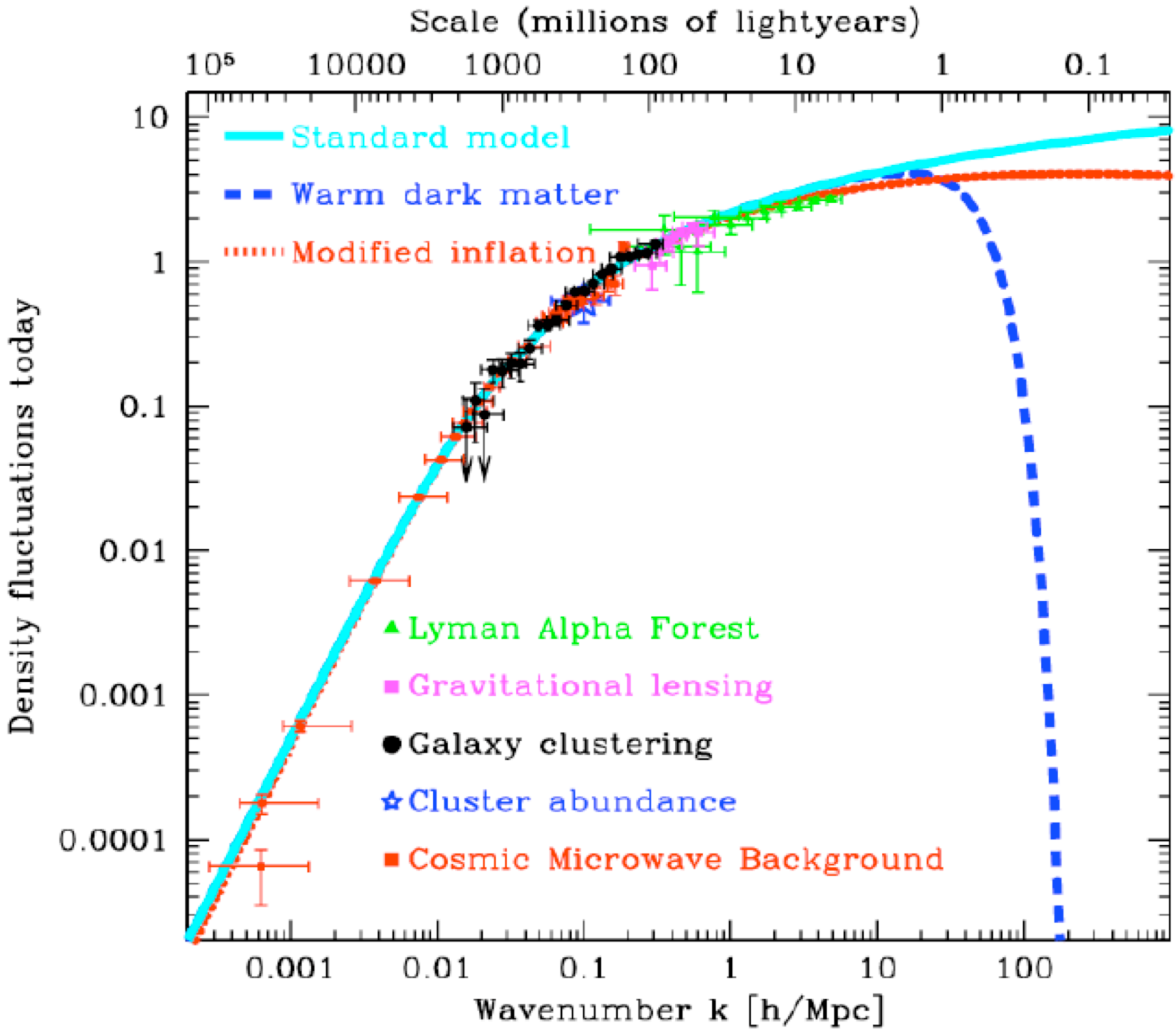


500MeV Electron interaction in Liquid Argon



NGLArD 5kT 50x100T
@ DUSEL
share with a Tone Scale Xenon Dark
Matter Detector
Shown fiducial cells only,
cryostat panel and
insulation panel adds
~1m on each side
6m water tank
BEAM
15m
75m
20m
BEAM
Hanguo.Wang@UCLA.EDU

LSS



Max Tegmark
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DM2008
February 20, 2008

What is DM?

- most DM is non–baryonic

  (DM problem)

- DM is cold (CDM)

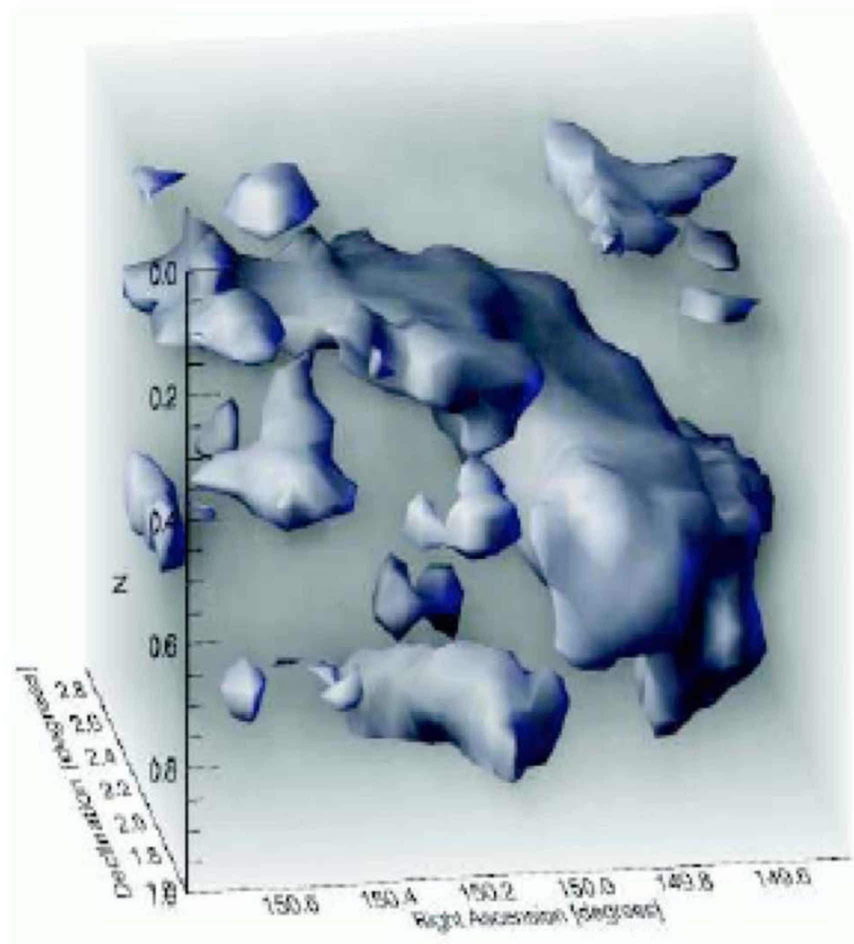
  or possibly (???) warm

- DM is dark

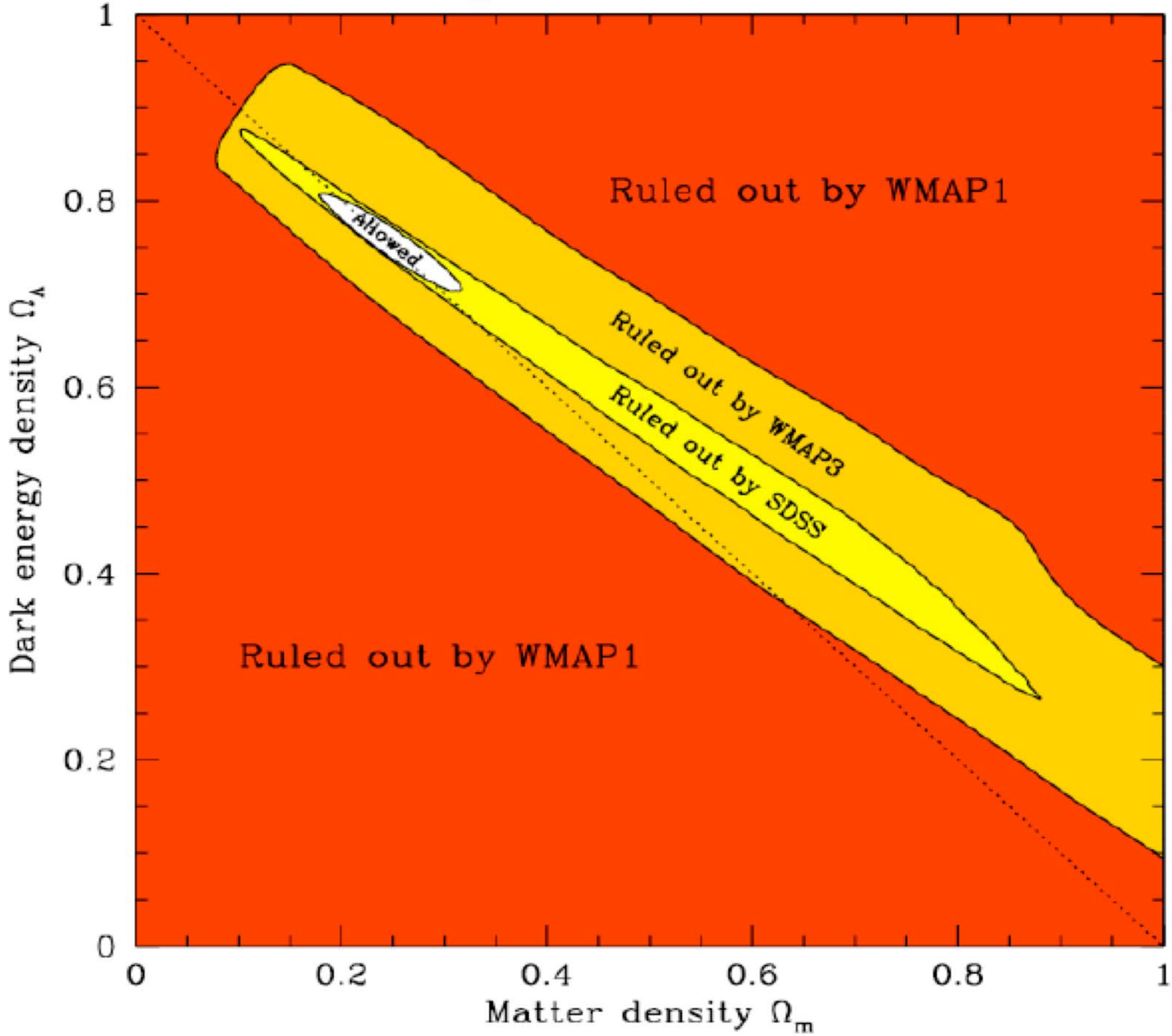
  $\Rightarrow$ no electric nor (preferably) color interactions

- DM clusters

3dim DM dist'n, Massey, et al, 2007



How flat is space? $\Omega_{tot}=1.003\pm0.010$



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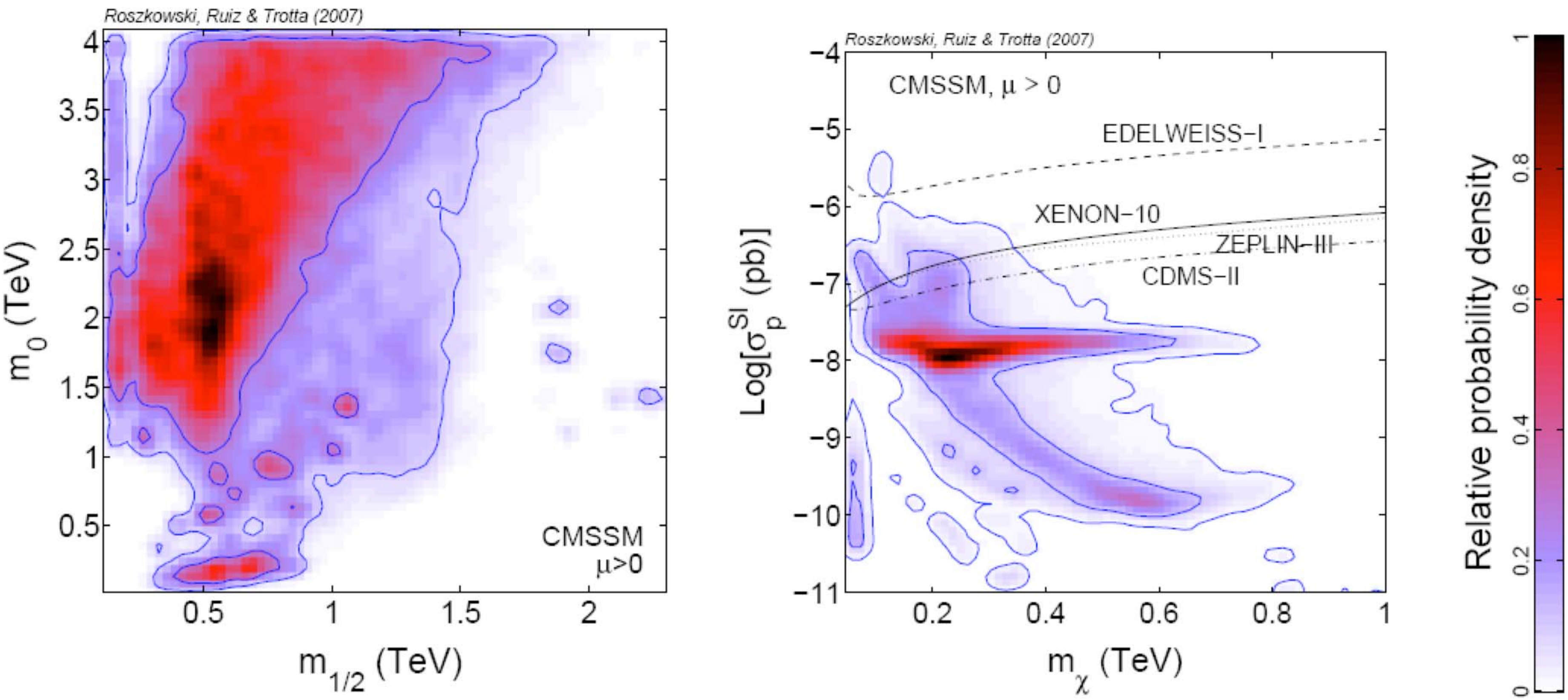
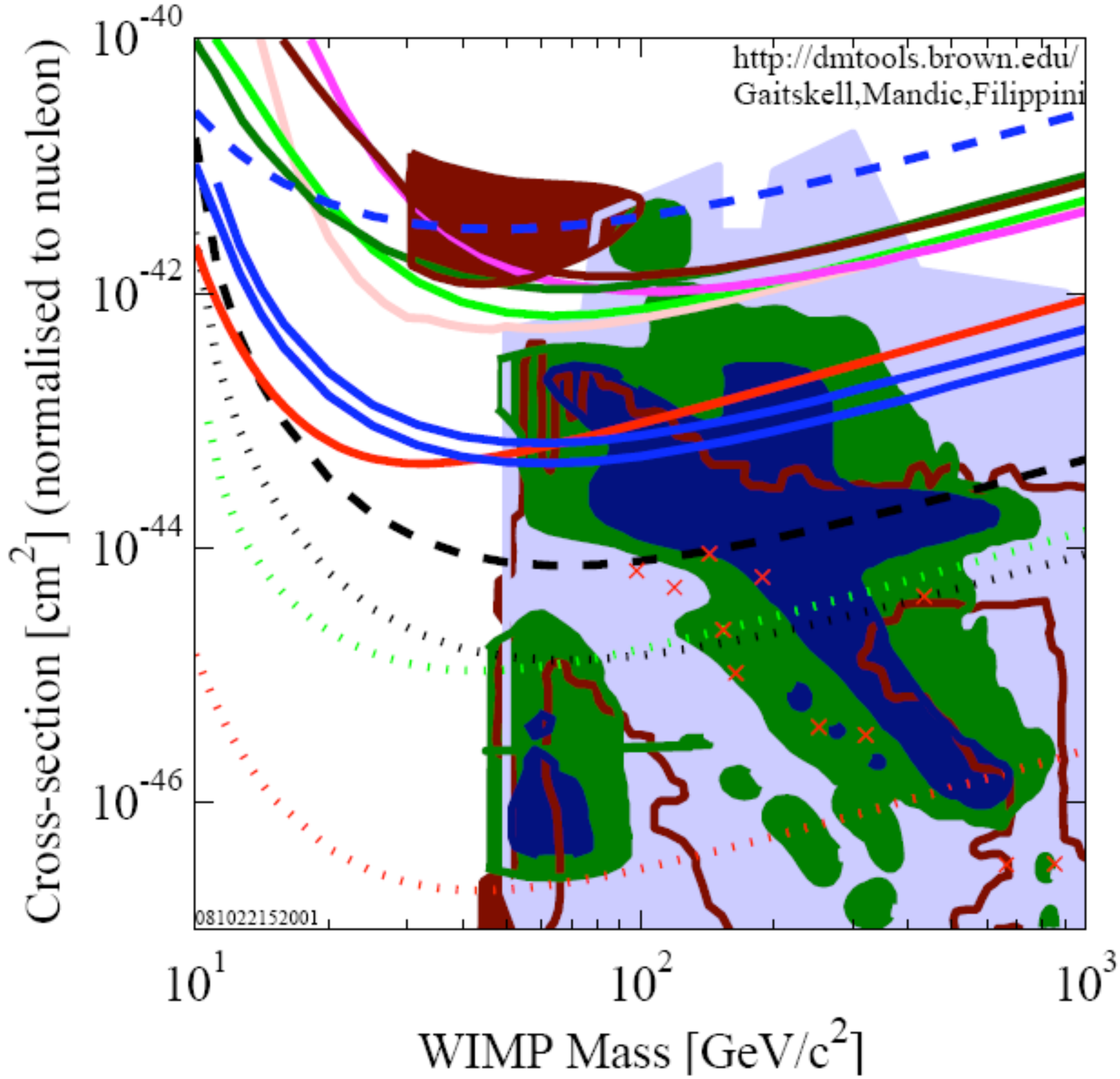
February 20, 2008

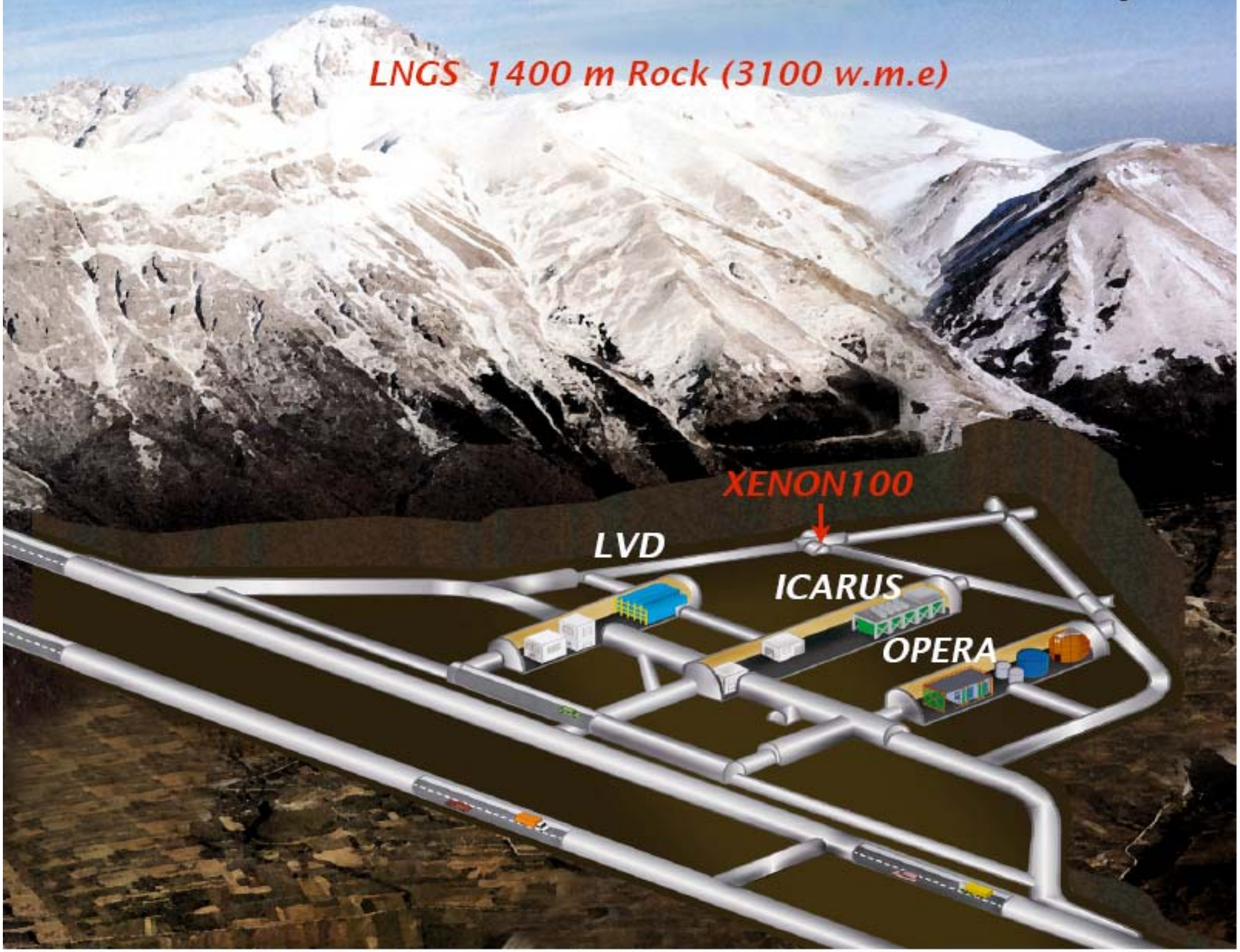


Roszkowski, Ruiz & Trotta (2007)
m_0 (TeV)
m_1/2 (TeV)
CMSSM
μ>0
Roszkowski, Ruiz & Trotta (2007)
CMSSM, μ > 0
EDELWEISS-I
XENON-10
ZEPLIN-III
CDMS-II
Log[σ_p^SI (pb)]
m_χ (TeV)
Relative probability density



http://dmtools.brown.edu/
Gaitskell,Mandic,Filippini
081022152001
Cross-section [cm^2] (normalised to nucleon)
10^{-40}
10^{-42}
10^{-44}
10^{-46}
10^1
10^2
10^3
WIMP Mass [GeV/c^2]

Laboratori Nazionali del Gran Sasso, Italy



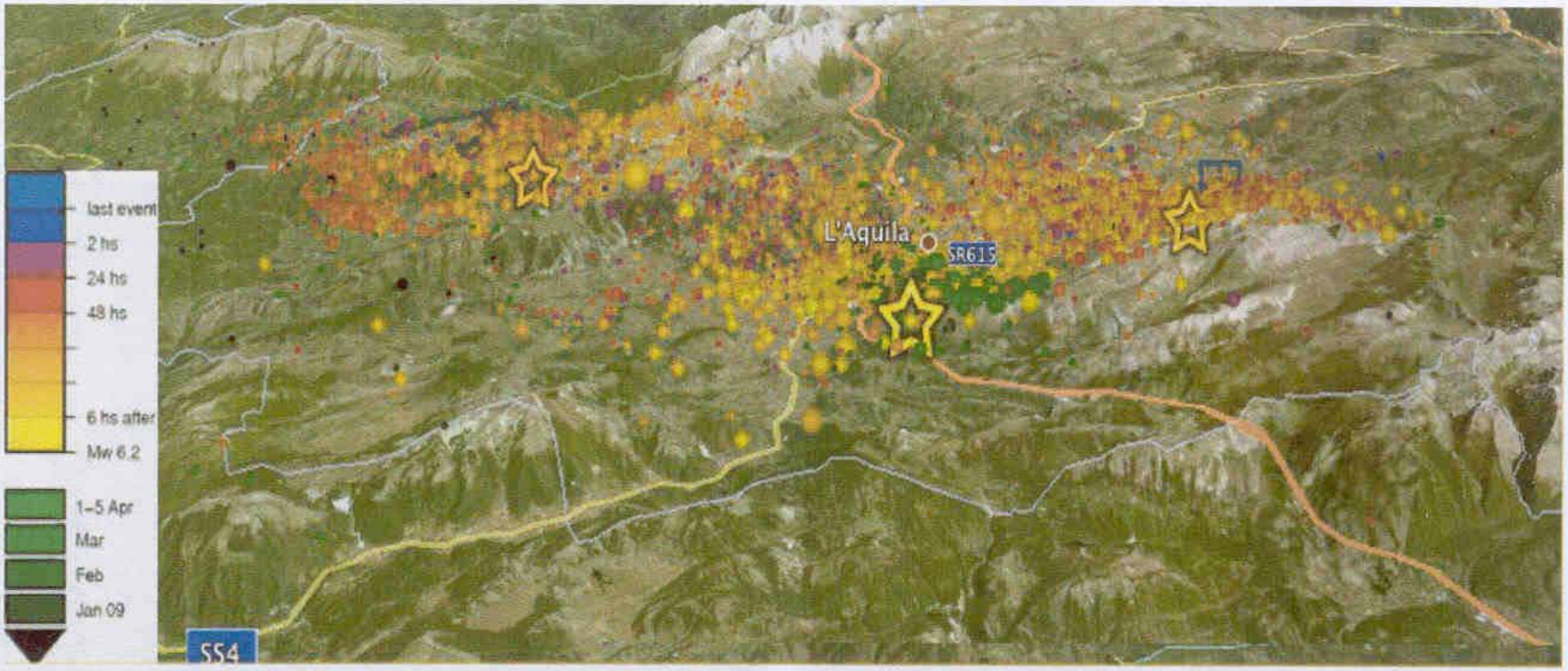
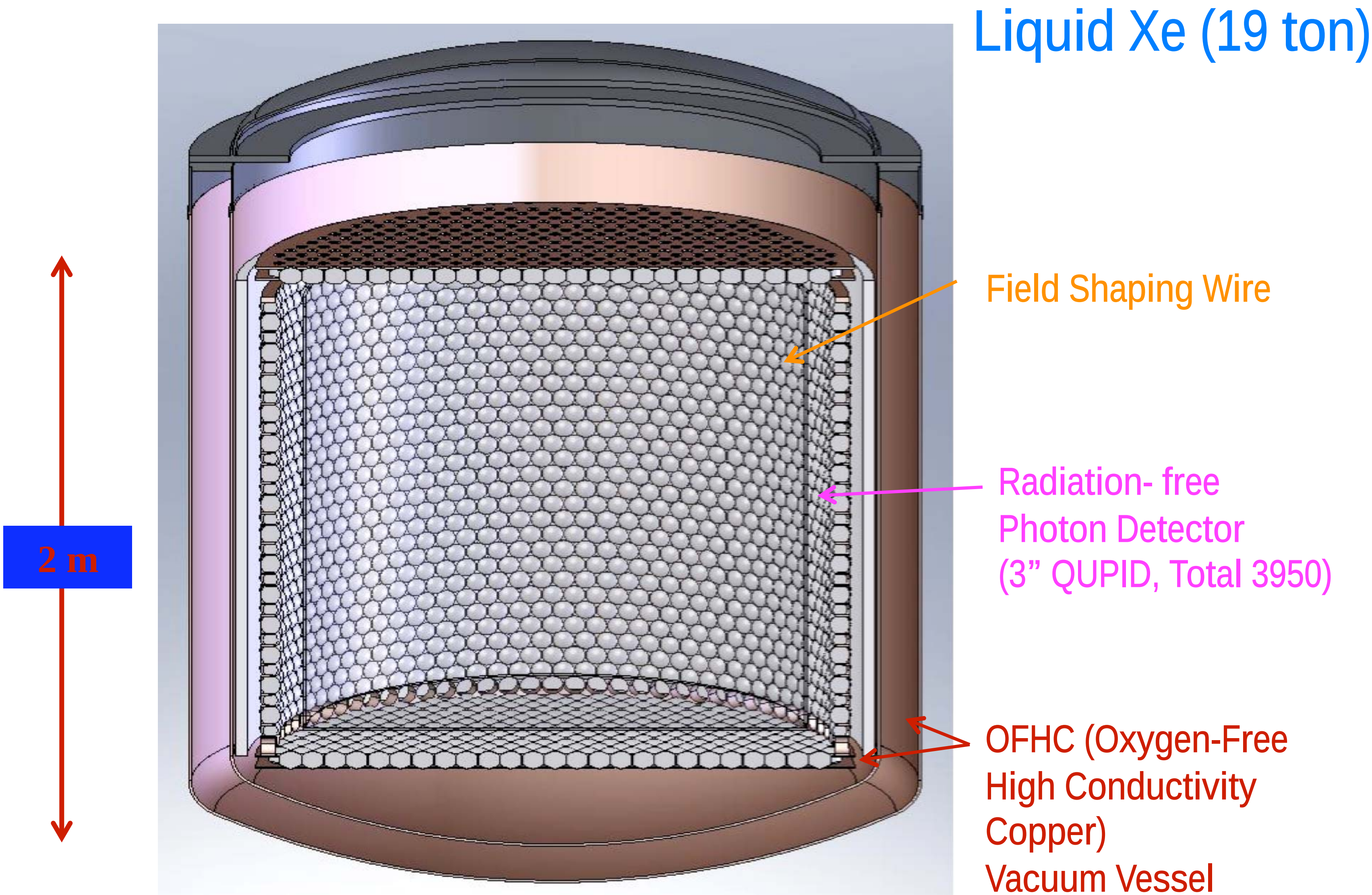


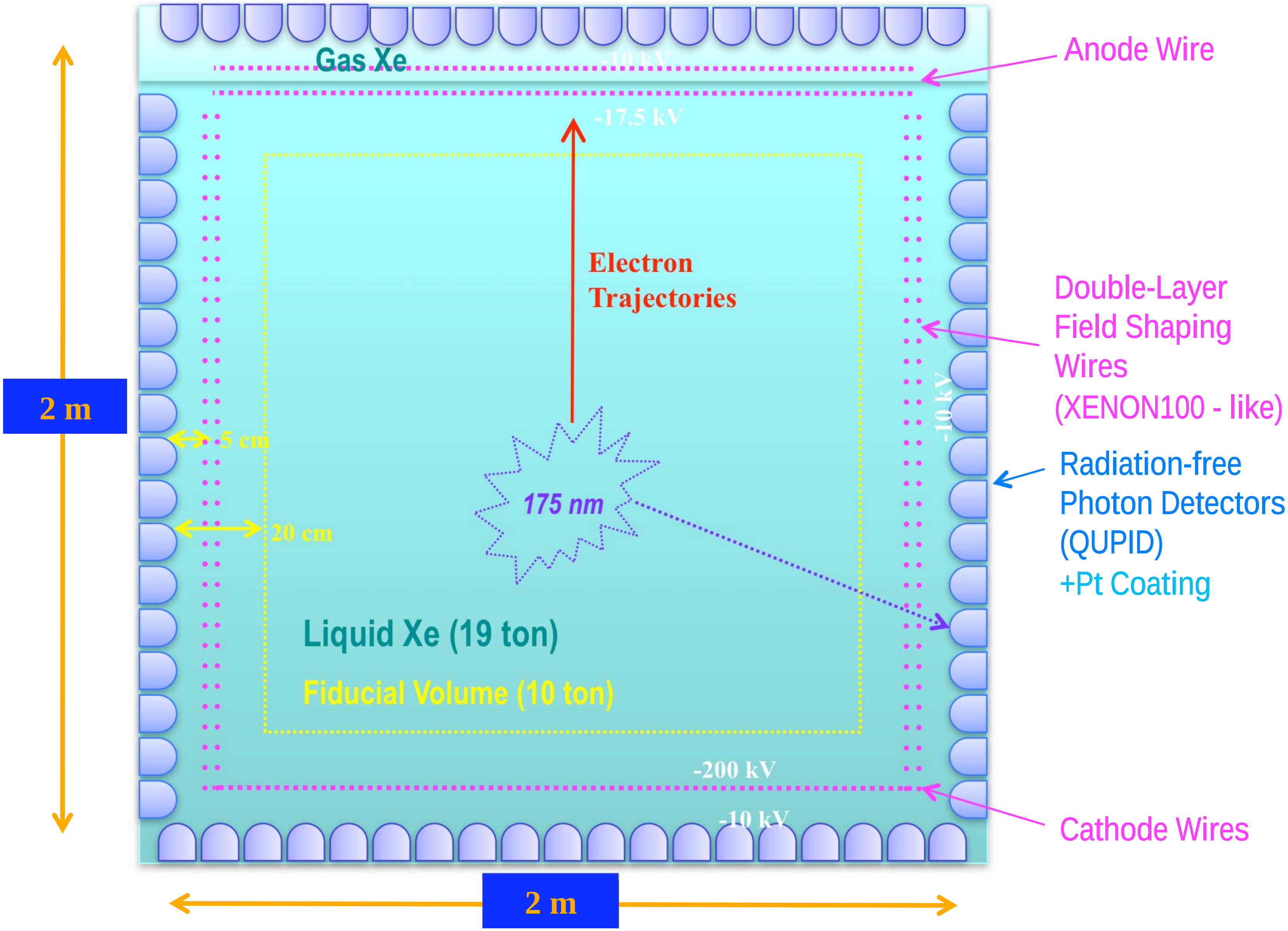
Figure 40. The April 6th 2009 eartquake in the L'Aquila region with epicentre at about 20 km from the LNGS.

Super-XENON

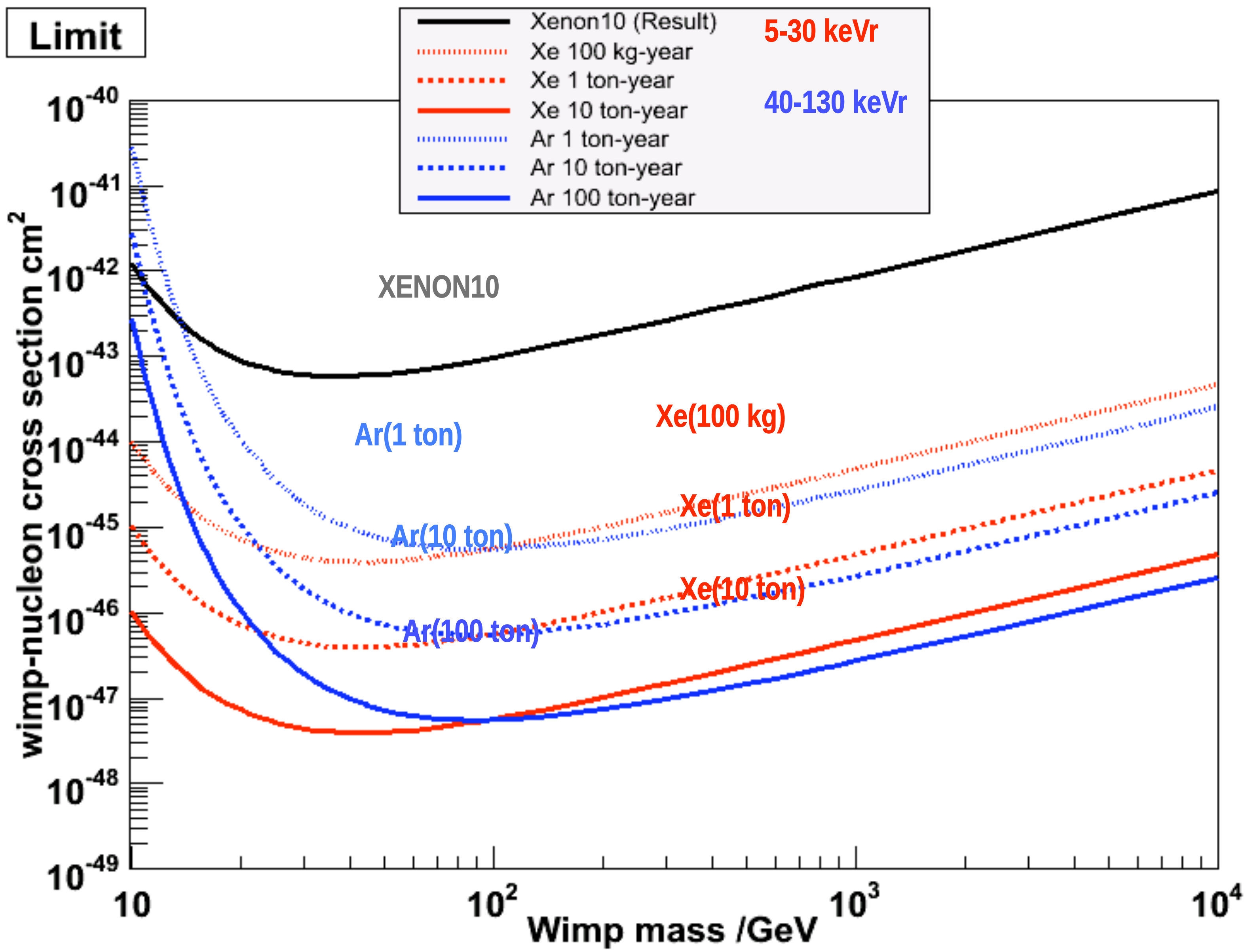


Liquid Xe (19 ton)
Field Shaping Wire
Radiation- free
Photon Detector
(3” QUPID, Total 3950)
OFHC (Oxygen-Free
High Conductivity
Copper)
Vacuum Vessel
2 m

Concept of Super-XENON



90% CL Sensitivity to the Cross Section
(one year, background free)



Prospects for the near future detection of Dark Matter

Direct Search	**Search Status**	**Sensitivity Pb**	**Time**
CDMS II (Super CDMS?)	No Signal	10^{-7}-10^{-8}	2009
XENON 100	No Signal in ZENON 10	10^{-8}-10^{-9}	2009-2010
Lux	No Signal	Construction in 2009	
DAMA/ LIBRA	Signal	Still under study	
Others (Bubble chambers, other Cryogenic Detectors, Z III)	No Signal	All consistent with no signal at 10^{-7}	
Indirect Search $\gamma, \overline{p}, e^{+}$			
GLAST (or FERMI TELESCOPE)		In space now waiting for data	
Gamma Rays		Very sensitive to WIMPS	