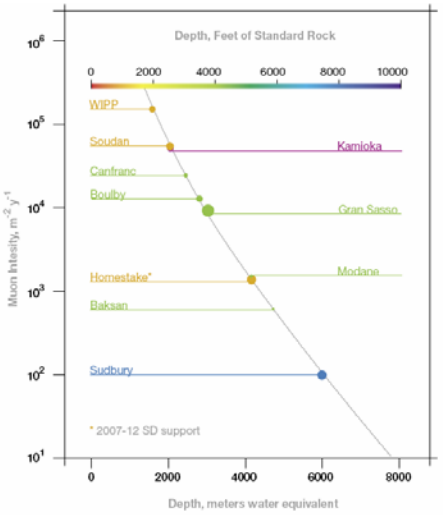
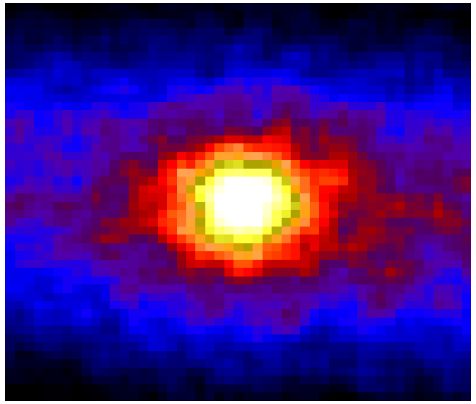
Deep Underground Science and Engineering Laboratory (DUSEL)

Jon Kotcher
National Science Foundation
Boulby Workshop
21-22 October 2006

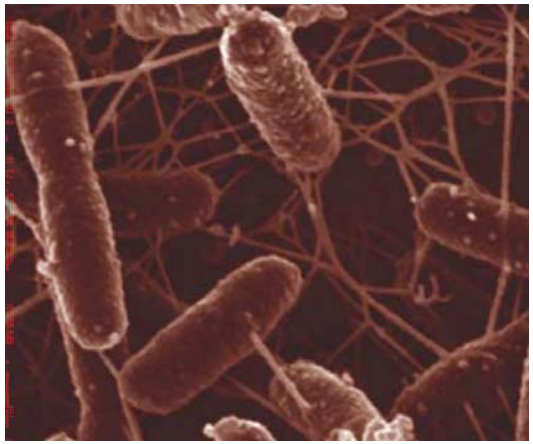
Physics: protection from μ's



Neutrino picture of the Sun

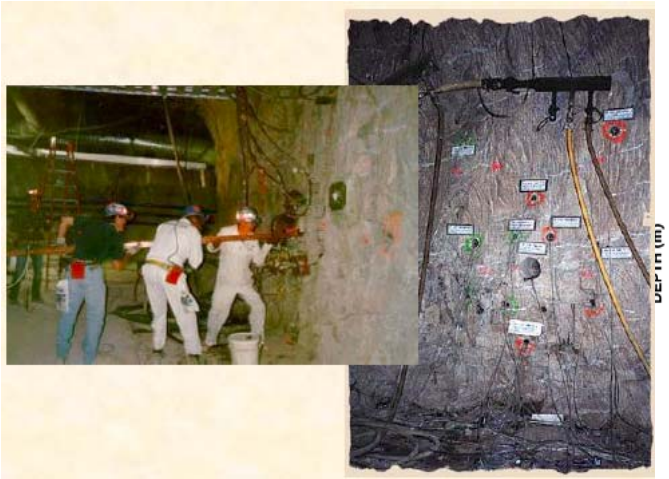


Geo-microbes

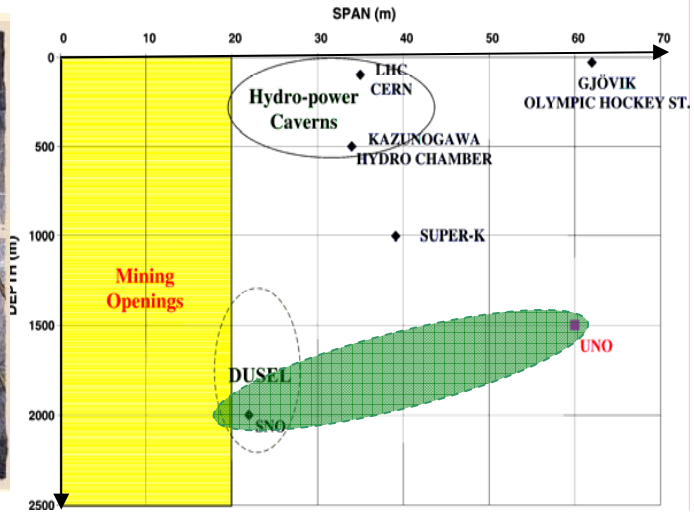


Deep Science

Frontier Science and Engineering Deep Underground



Large Block Geo Experiment
Coupled Processes



Size of cavity vs depth

Undergraduates in South Africa mine

Outline

- DUSEL Community Planning
- Vision, Approach
- Scientific Program
- DUSEL Process, Timeline
- Concluding Remarks

Glossary:

Deep Underground Science & Engineering Laboratory (DUSEL)
National Science Foundation (NSF), Department of Energy (DOE)
NSF Particle & Nuclear Astrophysics Program (PNA)
NSF Experimental Particle Physics Program (EPP)
High Energy Physics (HEP), Nuclear Physics (NP)
Major Research Equipment and Facilities Construction (MREFC)

A Few Recent Advisory Panels

- National Research Council (NRC) Neutrino Facilities Assessment Committee, *Neutrinos and Beyond (2003):*
  - "A deep underground laboratory can house a generation of experiments that will advance our understanding of the fundamental properties of neutrinos and the forces that govern elementary particles, as well as shedding light on the nature of the dark matter that holds the Universe together. ***Recent discoveries about neutrinos, new ideas and technology, and the scientific leadership that exists in the U.S., make the time ripe to build such a unique facility***."
- NRC Committee on *Physics of the Universe (2004):*
  - "Recommendation: Determine the neutrino masses, the constituents of dark matter, and the lifetime of the proton. ***The committee recommends that the DOE and NSF work together to plan for and fund a new generation of experiments to achieve these goals. It further recommends that an underground laboratory with sufficient infrastructure and depth be built to house and operate the needed experiments***."
- High Energy Physics Advisory Panel Sub-Panel Report: *Quantum Universe – The Revolution in 21st Century Particle Physics (2004)*
  - NSF-DOE HEPAP Sub-Panel Report ***identifies key science drivers, identifies need for DUSEL to address key questions***
- National Research Council Report: *EPP2010: Revealing the Hidden Nature of Space and Time (2006),*
  - ***strongly endorses and supports underground science***, e.g., dark matter, neutrino-less double beta decay, etc., placing it in international context

DUSEL Community Planning Activities

Bahcall report (2001): **NSF-DOE sponsored ad hoc committee of scientists strongly recommended that Homestake Mine**

NSAC Long-Range Plan (2002): **Strongly supported development of an underground laboratory to enable some aspects of nuclear research, e.g., double beta decay.**

NESS 2002: **An NSF sponsored conference on Underground Science showcases the wide variety of science that would be enabled with an underground laboratory.**

Connecting Quarks to the Cosmos (2003): **Known as Turner Report, NRC panel recommended development of an underground laboratory to enable a number of fundamental science experiments.**

HEPAP Long-Range Plan (2003): **Supported development of an underground laboratory to enable some aspects of high energy research, e.g., long baseline neutrino detector and proton decay**

Neutrinos and Beyond (2003): **Known as Barish Report, OSTP charged NRC panel emphasized neutrino physics, much of which requires an underground laboratory; placed in international context.**

EarthLab 2003: **An NSF sponsored report of the GeoSciences and GeoEngineering opportunities that would be enabled by an underground laboratory.**

Physics of the Universe—A Strategic Plan for Federal Research at the Intersection of Physics and Astronomy (NSTC) 2004: **Strongly supported development of an underground laboratory for science and engineering**

Quantum Universe—The Revolution in 21st Century Particle Physics, 2004: **NSF-DOE HEPAP Sub Panel report identifies key science drivers and indicates need for DUSEL to address key questions**

Many more activities: **NuSAG (HEPAP, NSAC, AAAS sub panel), Dark Matter sub panel, EPP2010, Deep Science,…**

The NSF DUSEL Vision

- DUSEL is a joint initiative within NSF between Physics (lead), Engineering, and Geosciences
  - Biology currently serving in advisory capacity
- Broad, evolutionary & multidisciplinary scientific program
- New opportunity for growth, diversity, interdisciplinary research
- Intrinsically strong program for education, outreach
- Well-matched to NSF mission
- Multi-purpose national laboratory that will serve variety of scientific communities over many decades
- Addresses worldwide need for extensive space at depth, for all programs
- Will enable new, long-term partnerships between disciplines, organizations (public + private, international)
- DUSEL is centerpiece of increasing NSF investment in US underground science program
- #1 priority for new project start in NSF Physics Division

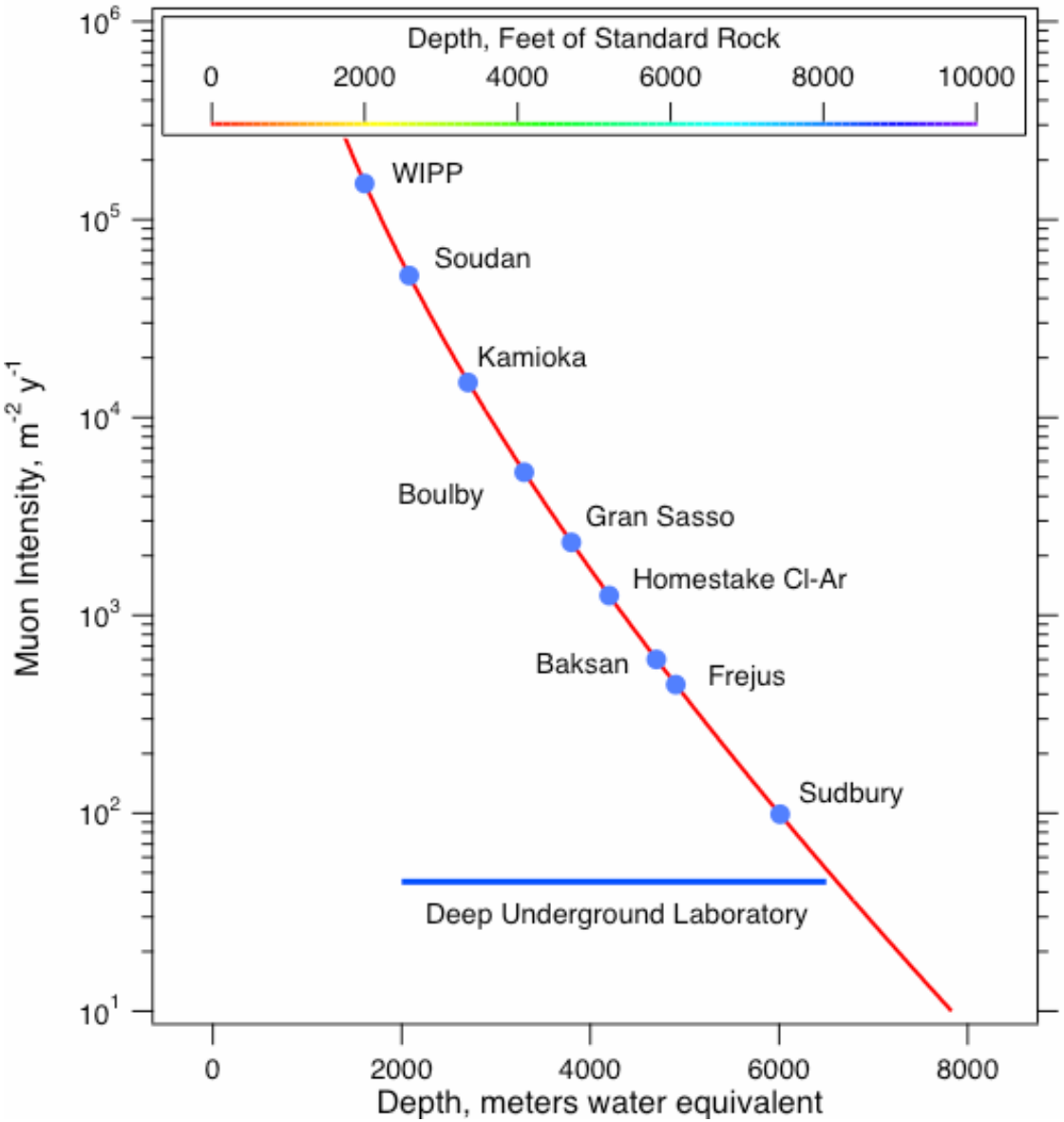
DUSEL Scientific Program

- Multidisciplinary, diverse suite of experiments:
- Life at Depth
  - Aseptic environment at depth
  - Study of subsurface biosphere, isolated underground life forms
  - Life at high temperature, pressure, microbial activity at low respiration rates; associated genomic features
  - Lower campus: platform to drill deeper – 12000ft (120°C)
- Rock formation at depth
  - Large scale rock mechanics, slippage mechanisms
  - Scale/stress dependence of rock properties
  - Seismic transmission, closer approach to earthquake conditions
- Fluid flow and transport at depth
  - Applications include stability of water supplies, hazardous waste disposal, remediation of contaminated groundwater
  - Stuides of rock/water interface underground; high pressure, temperature
- Mineral resources and environmental geochemistry

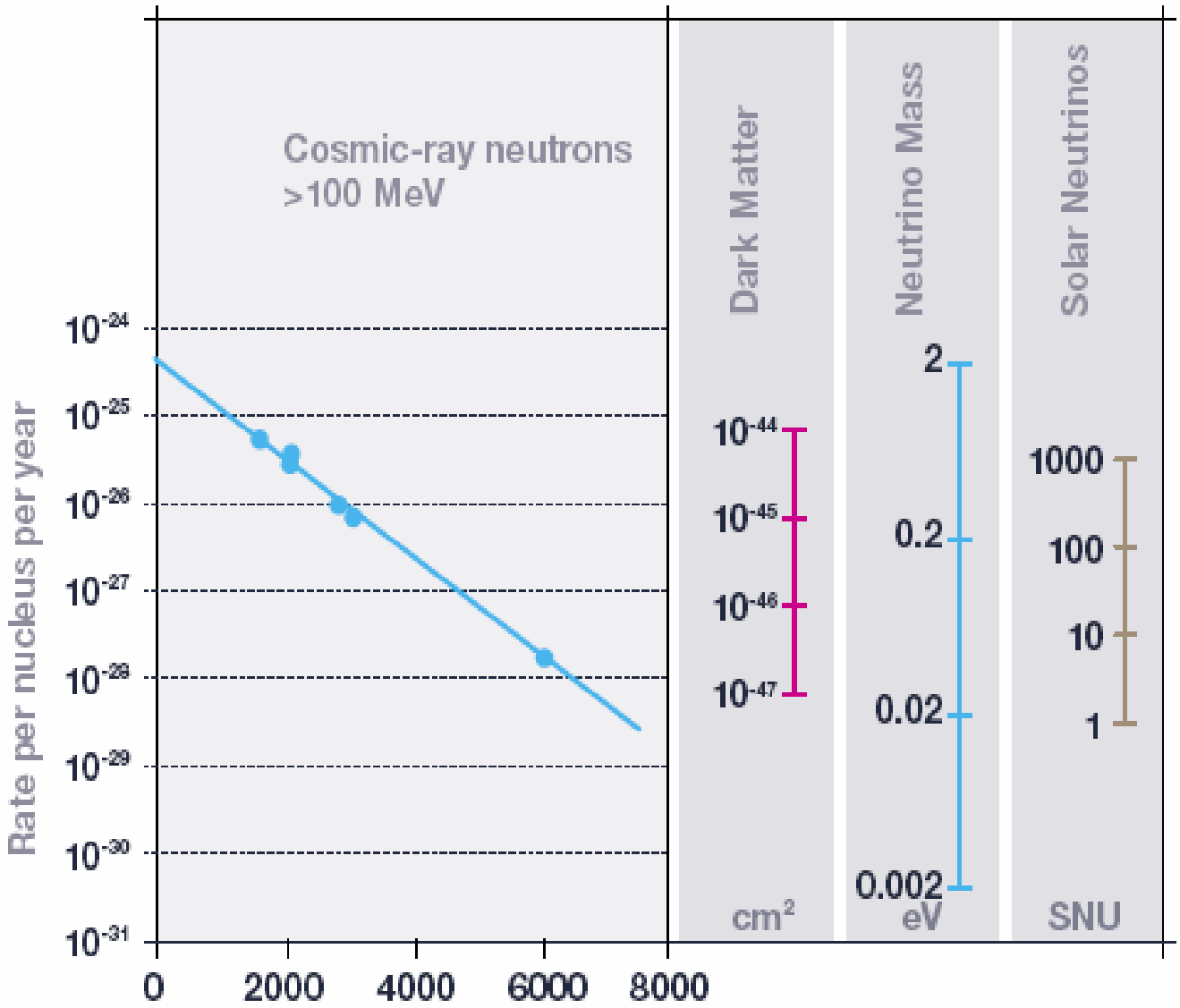
DUSEL Scientific Program

- Very low level counting facility, experiments
  - Low background, underground physics, cosmogenics
  - Applications to homeland security
- Science, technology and engineering innovation
  - Novel microorganisms, analytic techniques for geomicrobiology, drilling and excavation technology, environmental remediation, subsurface imaging, …
  - Creation of pure crystals without cosmic ray induced "impurities"
  - Research in underground and mining safety
  - Excavation of very large stopes at depth
- Neutrino physics
  - Neutrino-less double beta decay
  - Solar neutrinos
  - CP violation, long baseline experiment
  - Neutrino mixing angles
  - Nuclear astrophysics, low cross section measurements
- Dark matter searches
- Proton decay
- Supernovae neutrino observations

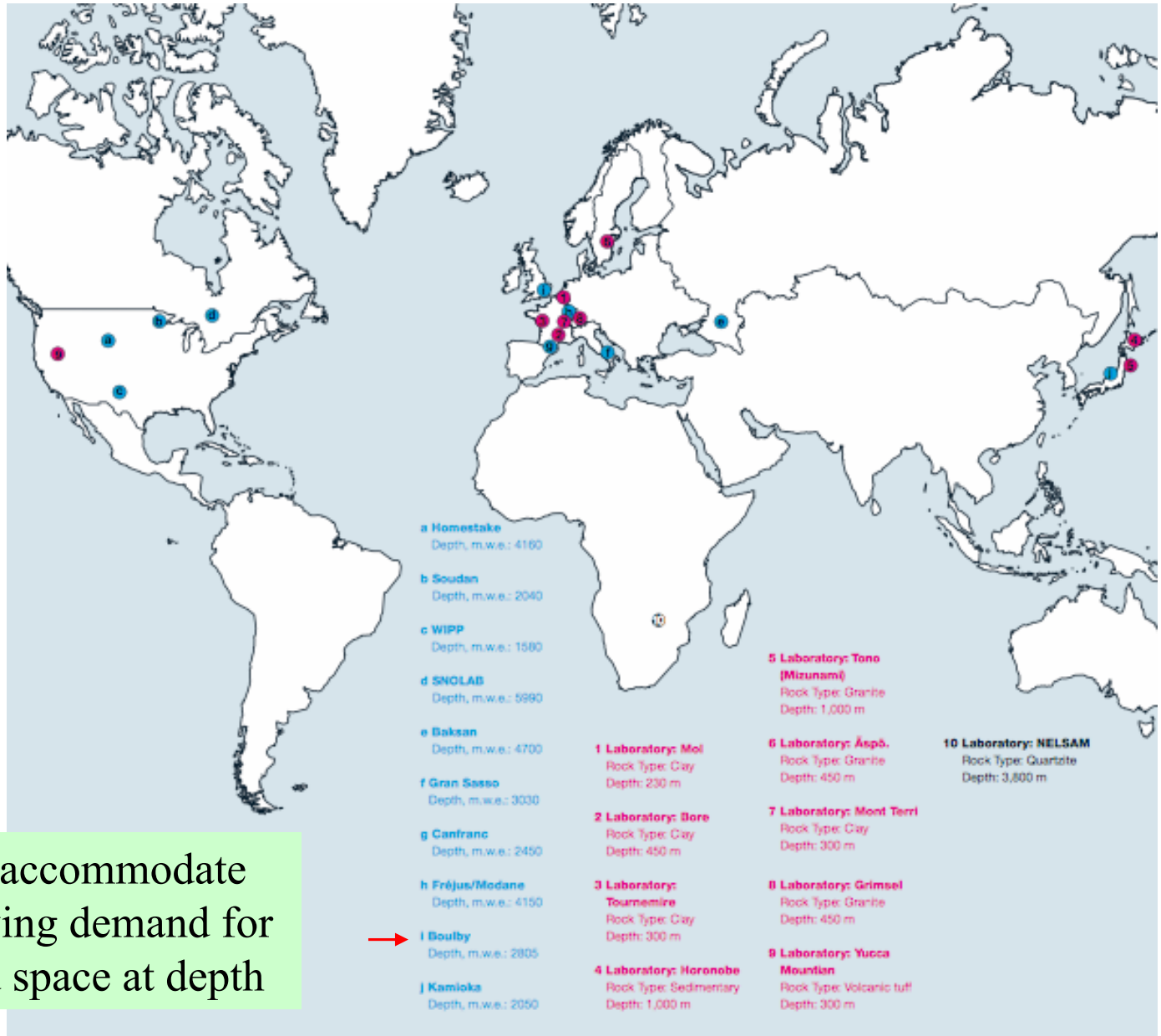
Underground Laboratory Depth



Physics Sensitivity vs. Depth

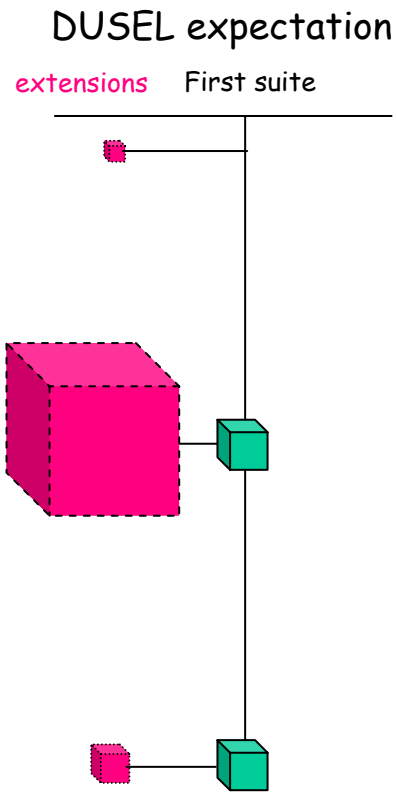


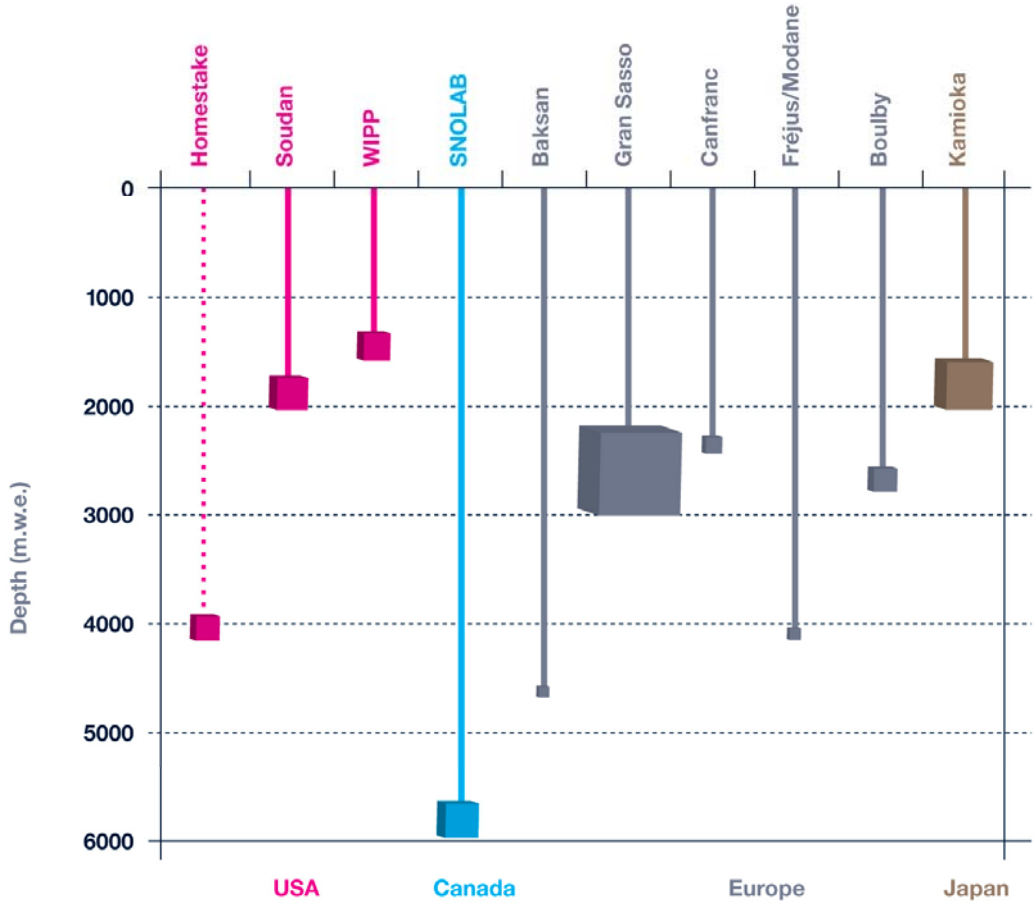
Underground Facilities Worldwide



Need to accommodate ever growing demand for dedicated space at depth

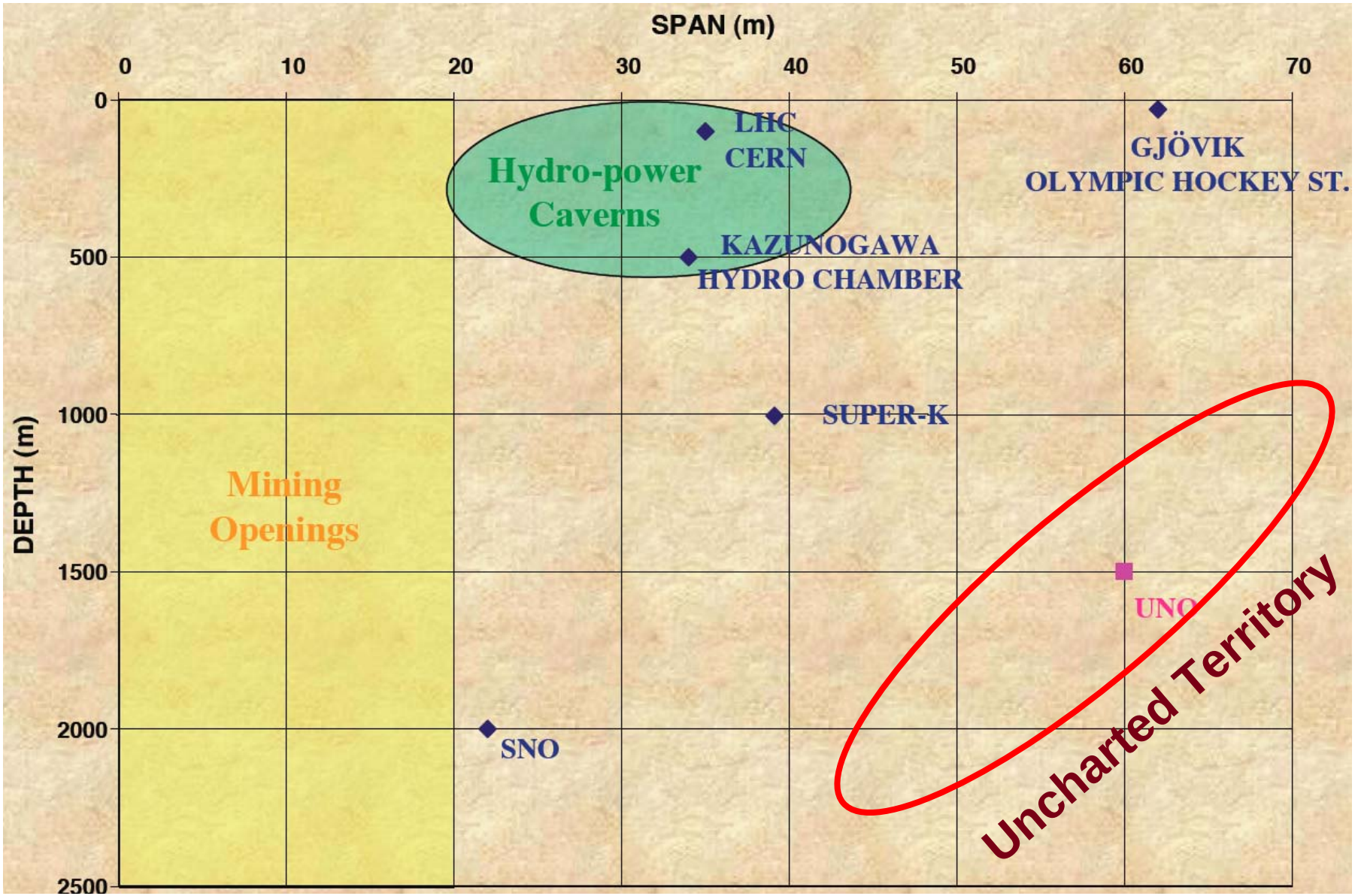
Depth vs Volume Underground



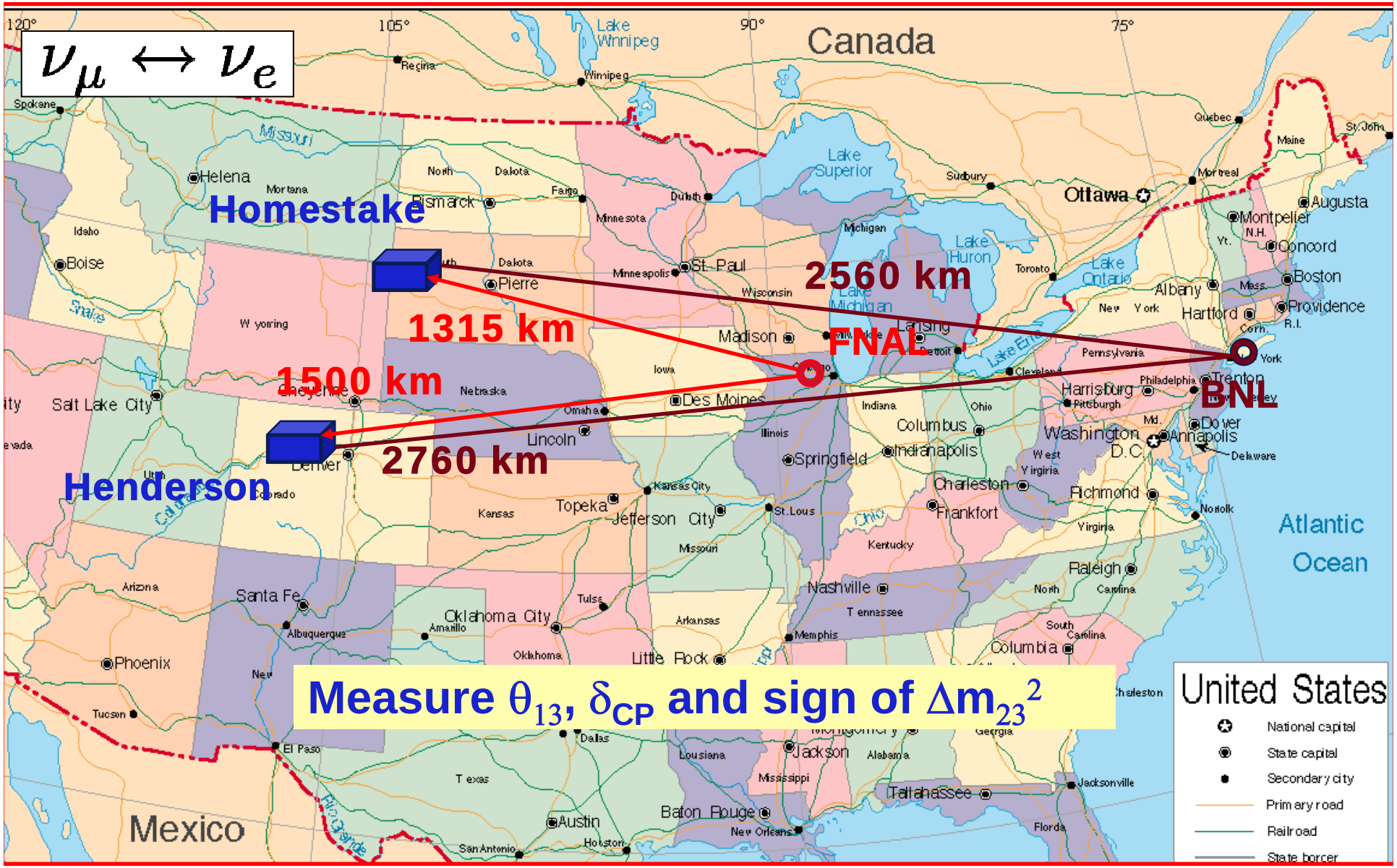


From *Deep Science (2006)* Report

Large Underground Cavities



Very Long Baseline Neutrino Oscillations

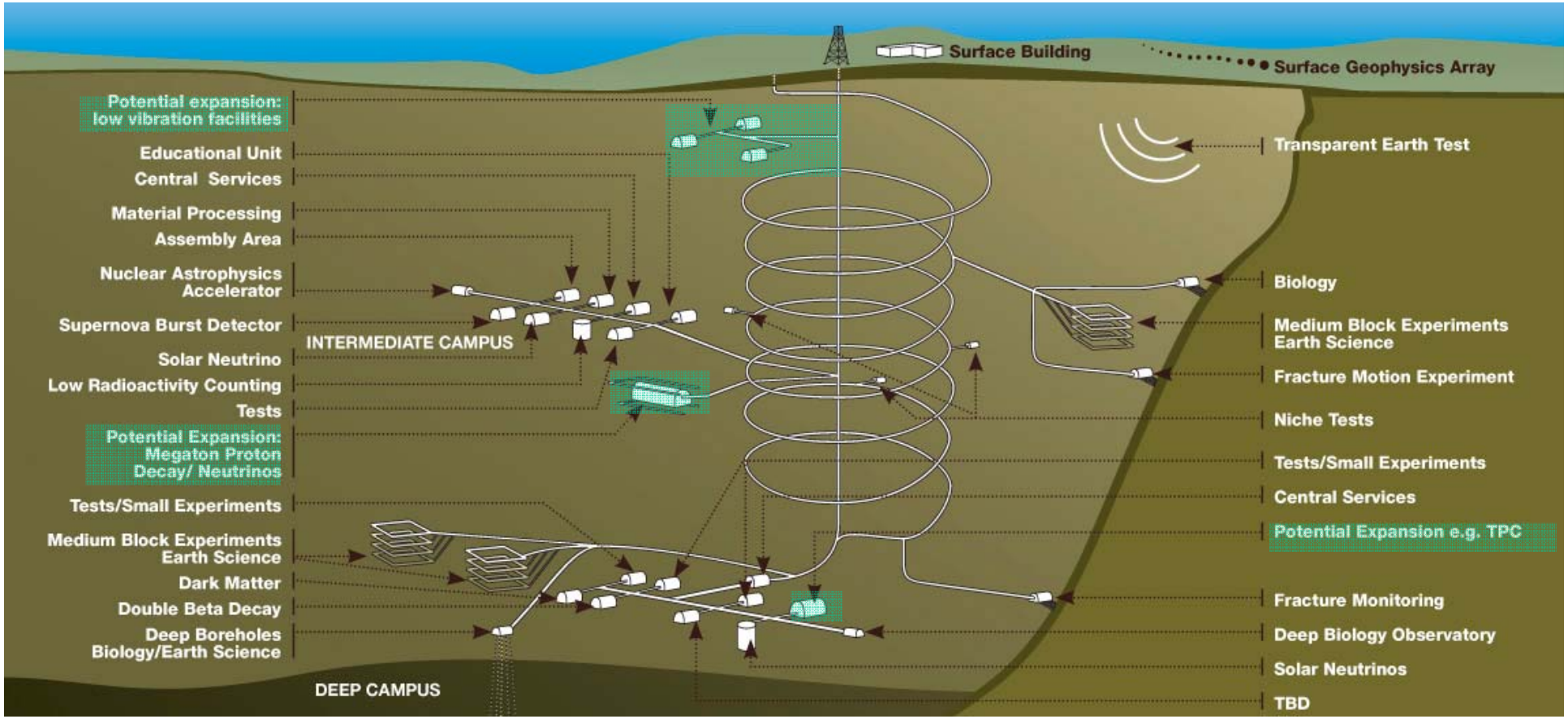


Some Attributes of a DUSEL

- Depth
  - Example: Dark matter, double-beta, solar, mega-detector all suggest min ~ 4500 mwe
  - More depth as experimental sensitivity increases
  - Relevant in all disciplines of interest
- Detector & Experimental Halls
  - Capability to customize underground space, experimental areas
- Cleanliness
  - Natural underground radiation backgrounds, clean facilities, etc.
- Importance of round-the-clock access
- Safety, special materials, and materials handling
- Environmental assessments, considerations
- Access for large and heavy equipment
- Quietness and stability: electrical, mechanical, seismic
- Adequate support facilities and strong scientific environment
- The capacity to accommodate a mega-detector at appropriate depth
  - Excavation, integrity of rock, etc.
- Baseline for high intensity neutrino beam, CP violation
  - >1000 km baseline
- Education and outreach

Schematic View of a DUSEL

A schematic view circa 2015 + possible expansions



From *Deep Science (2006)* Report

DUSEL Plan

- Scale, scope, uniqueness of DUSEL suggest a phased approach
- First phase is expected to fund initial infrastructure required and initial suite of experiments
  - Process in place targets FY10 construction funding start that will include funds for both
  - Includes engineering, studies required for future expansions
  - Initial suite will encompass all disciplines
- Following phases expected to support subsequent experiments & associated expansion of infrastructure
  - i.e., "Megaton" detector, "next-generation" experiments, new interdisciplinary efforts, etc.
- As currently envisioned, first phase:
  - ~ $500M total, ~ half for infrastructure, ~ half to experiments
  - ~ 7-8 years duration
  - Project baseline Dec 07 will define with more specificity

DUSEL Process

- Three-tier process, announced to community March 2004:
- Solicitation 1 (S1): January 2005, $400k awarded for site-independent study to:
  - Bernard Sadoulet, UC Berkeley, Astrophysics/Cosmology, Chair
  - Eugene Beier, U. of Pennsylvania, Particle Physics
  - Charles Fairhurst, U. of Minnesota, Geology/Engineering
  - Tullis Onstott, Princeton, Geomicrobiology
  - Hamish Robertson, U. Washington, Nuclear Physics
  - James Tiedje, Michigan State, Microbiology
- Charged by NSF with:
  - Organizing a dialogue within the community about a multidisciplinary DUSEL
  - Determine whether there is a compelling justification for such a laboratory
  - If there is, to specify the infrastructure required for such a laboratory that will address the needs of a broad cross section of science over the next 20-30 years and complement other facilities worldwide

S1 Findings

- Resulted in high-level report *Deep Science (2006)*, in final draft, available at www.dusel.org. Three recommendations:
- Rec1: Strong support for pursuit of deep underground science
  - We recommend that the U.S. strengthen its research programs in subsurface sciences to become a world leader in the multidisciplinary exploration of this important new frontier.
- Rec2: Develop a cross-agency Deep Science Initiative in the US
  - The Deep Science Initiative should be coordinated with other national initiatives and take full advantage of international collaboration opportunities.
- Rec3: A Deep Underground Science and Engineering Laboratory
  - The U.S. should complement the nation's existing assets with a flagship world-class underground laboratory providing access to very great depth (6000 mwe) and ample facilities at intermediate depths (3000 mwe) currently not available in the U.S.

Solicitation 2

- Solicitation 2 (S2): 8 proposals received to develop DUSEL sites
- April 2005 Panel selected Henderson, Homestake as most promising
- 15 September 2005: Cooperative Agreement for two $500k awards:
  - SUNY Stony Brook for Henderson Mine, Empire, CO – C.K. Jung, PI
  - UC Berkeley for Homestake Mine, Lead, SD – K. Lesko, PI
- Site-specific conceptual designs developed, detailing:
  - How the site will accommodate the science and engineering objectives;
  - Management and organizational plan for construction and operations;
  - Geologic, environmental, permitting and safety issues;
  - Risk analysis and mitigation;
  - Initial scientific program and timeline;
  - Engineering needs for accommodation of longer-term scientific program.
- Conceptual designs submitted to NSF in June 2006

http://nngroup.physics.sunysb.edu/husep/

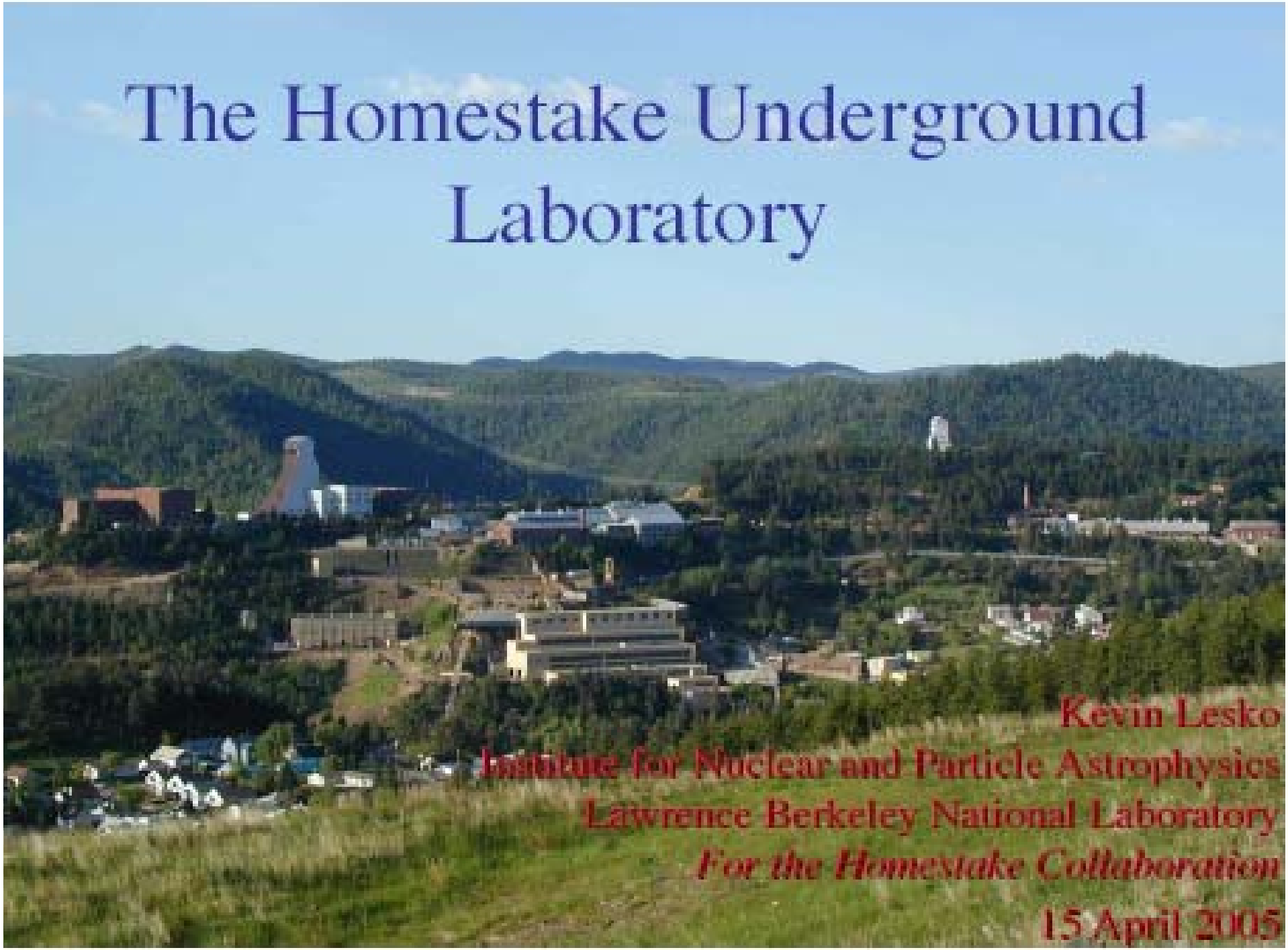
Henderson DUSEL

Unearthing the Secrets of the Universe, Underground

Chang Kee Jung
Stony Brook University

P5 Meeting
Fermilab, April 18, 2006

The Homestake Underground Laboratory



Kevin Lesko
Institute for Nuclear and Particle Astrophysics
Lawrence Berkeley National Laboratory
For the Homestake Collaboration

15 April 2005

Solicitation 3

- Solicitation 3 (S3, in process):
  - Solicits proposals that will consist of formal Conceptual Design Reports, project plan for design phase
  - Proposal deadline 9 January 2007
  - Open competition
  - Single site will be selected for further development, based on panel review in early CY07
  - Chosen site will receive up to $5M award per year for up to three years for technical design development
- Expect to announce results of site selection, award in Spring 2007

DUSEL Target Schedule

Date	Event
July 2006	PHY-ENG-GEO completes draft of S3
August 2006	Panel review of Conceptual Design Reports from S2 awardees
September 2006	S3 clearance process complete, S3 published
January 2006	Deadline for receipt of S3 proposals
January/February 2007	Panel review of S3 proposals; reverse/site visits, as appropriate; recommendation for site selection made
February 2007	Final recommendation from PHY forwarded for review by MPS, ENG, GEO, OD
April 2007	Results of site selection announced
October 2007	Preliminary Technical Design Baseline Pre-Review
December 2007	Preliminary Technical Design Baseline Review
March 2008	DUSEL package presented to NSF MREFC Panel for consideration

Above targets a FY2010 MREFC funding start

Joint Agency Funding of DUSEL-related R&D in FY07

- NSF Physics Division has been preparing to allocate up to $7M for DUSEL-related R&D in FY07:
  - Detector R&D for underground applications
  - Site-specific technical design after the DUSEL site selection (spring ’07)
  - NSF Geomechanics & Geotechnical Systems Program also encouraging submission of R&D proposals for DUSEL-related design & research
  - (As always, as budgets allow…)
- DOE HEP and NP have recently put out a call for proposals for DUSEL-related R&D
- Proposals will be submitted to both agencies; reviewed, prioritized by joint DOE/NSF panel
- NSF PNA, EPP, & Nuclear and DOE HEP, NP will participate
- NSF providing analogous support to DOE highest priority: ILC

Candidate DUSEL R&D Projects in Physics

- Dark Matter Detection
- Neutrino-less Double Beta Decay
- Nuclear Astrophysics (accelerator based cross-section measurements)
- Geoneutrinos
- Solar and Supernovae Neutrinos
- Low Background Counting Facilities (LBCF) and Common Infrastructure
- Long Baseline Neutrinos and Proton Decay: “Megaton” Detectors

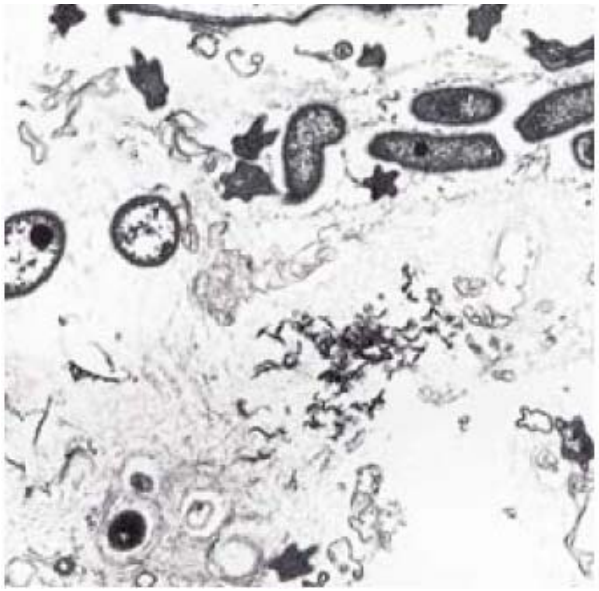
Concluding Remarks

- DUSEL #1 priority new project start in NSF Physics Division
- An international center for multidisciplinary underground research
- Broad opportunities for compelling and new avenues of research, new cross-disciplinary synergies
- Keen and rapidly growing interest across disciplines
- Plan targets site selection spring 07, construction start at end of decade

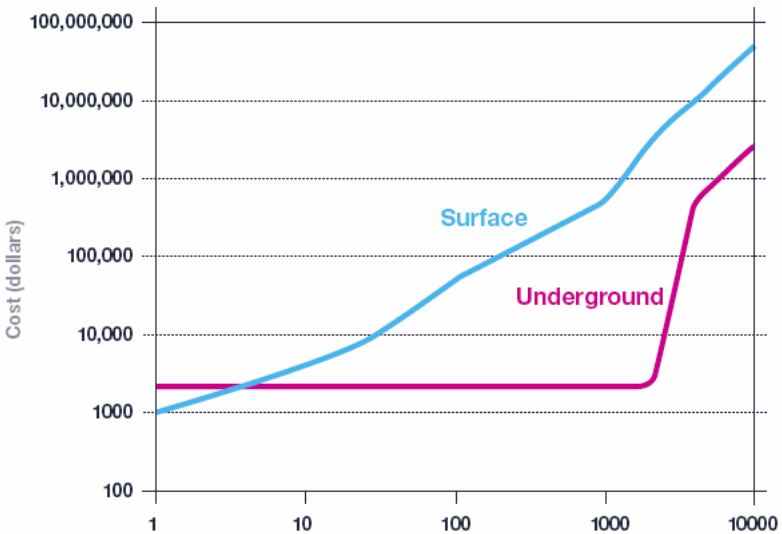
Backup Slides

Example: Biology at Depth

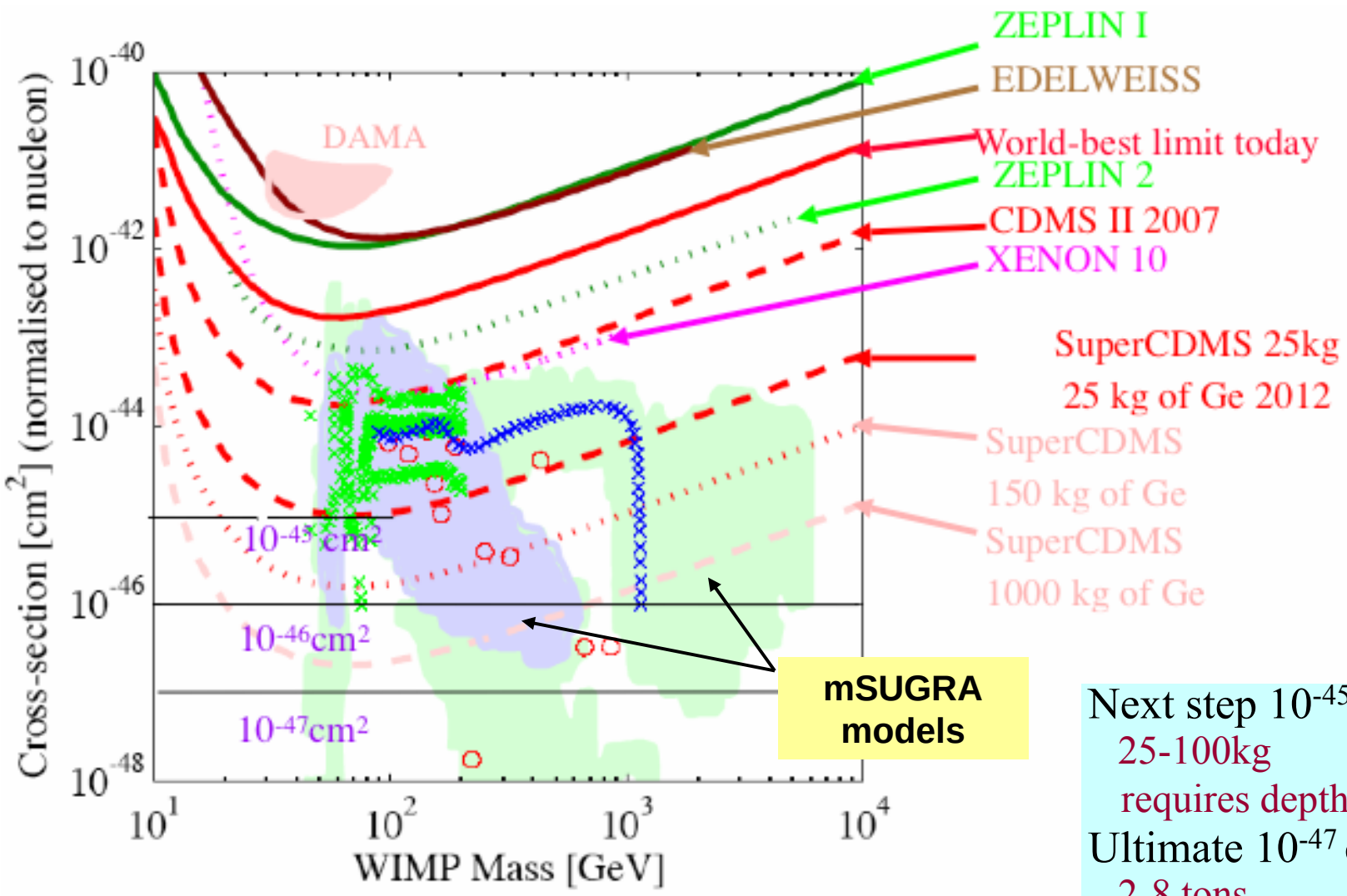
- New type of organisms
  - e.g. star shaped cells collected at 2000m
  - Never seen before!
  - Genome?



- Deep drilling => 80 – 120°C
  - Reduction of cost
  - Higher spatial control
  - Improved control of contamination



Direct WIMP Detection Limits



Next step 10^{-45} cm^2:
- 25-100kg
- requires depth ≥ Gran Sasso

Ultimate 10^{-47} cm^2:
- 2-8 tons
- requires depth ≥ SNOlab
- ~ no background!

Direct Dark Matter Detection Techniques

Growing number of promising new techniques: sensitivity, scalability, redundancy

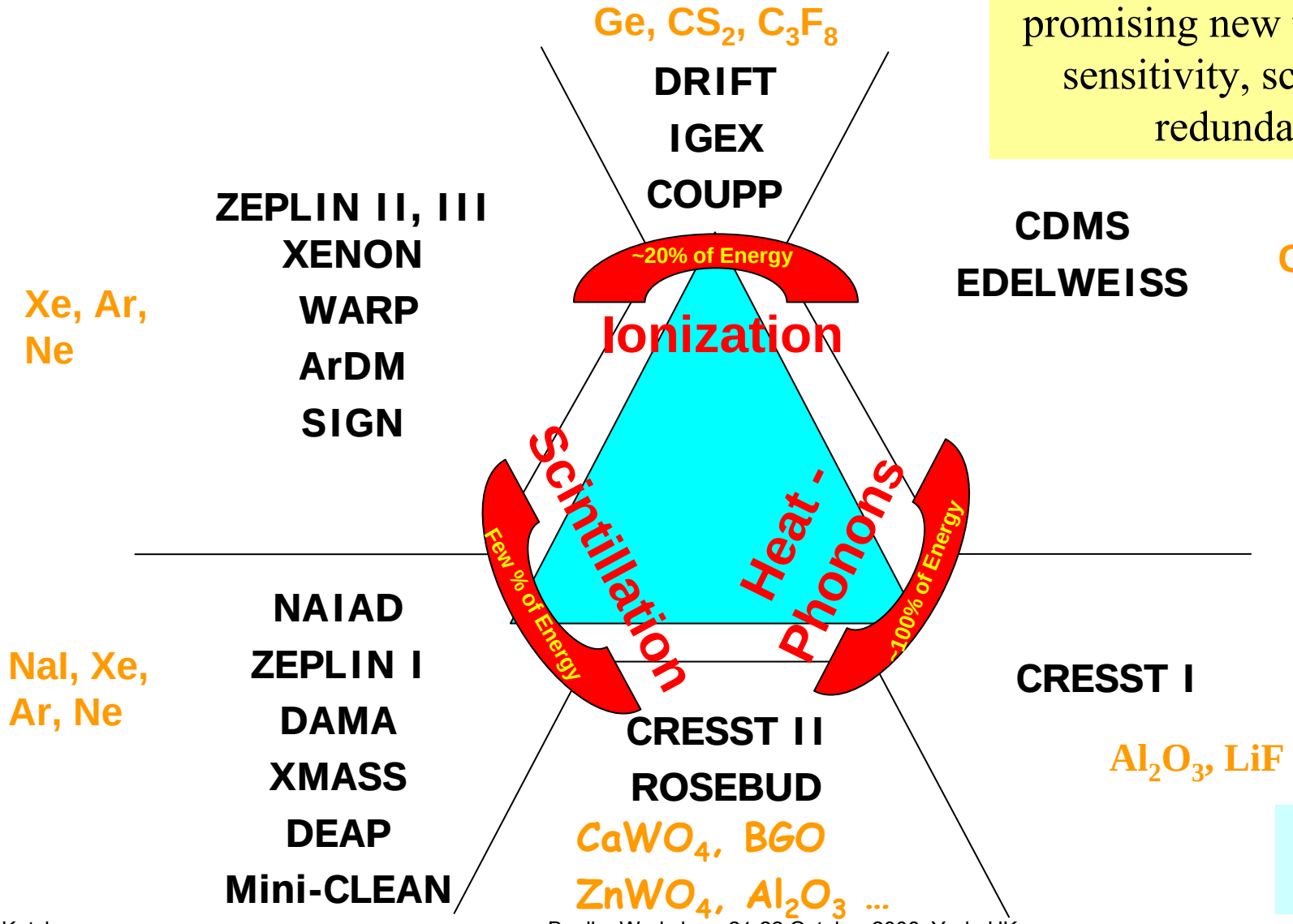


Fig courtesy H. Sobel