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 Henderson Mine

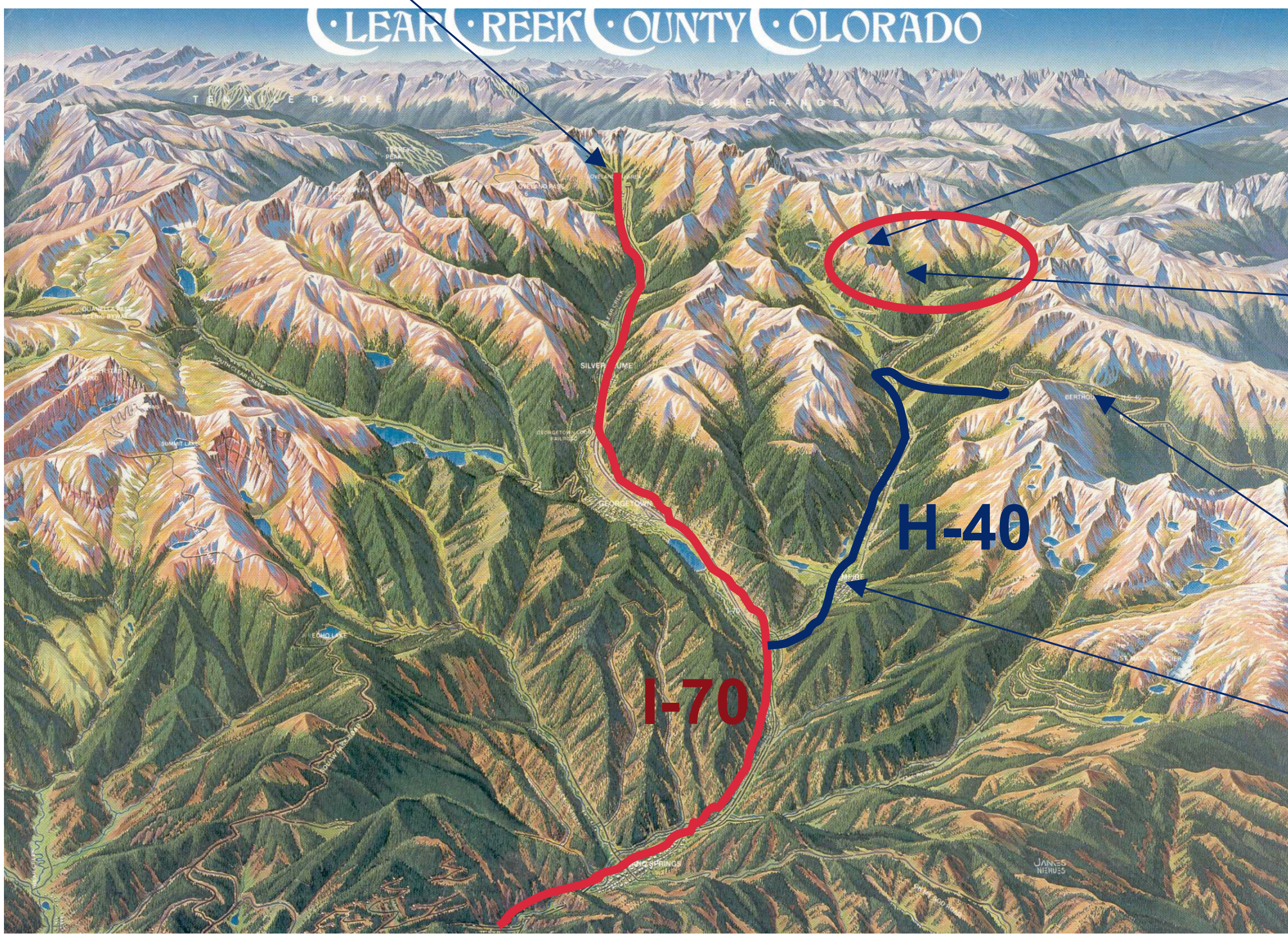
- Owned by Climax Molybdenum Company (CMC), a subsidiary of Phelps Dodge (PD) Corporation
- Established in 1970's
  - A modern mine developed under strict environmental regulation and self imposed high standards
- One of the 10 largest underground hard rock mines operating in the world w/ a vast infrastructure
- Mine Product: Molybdenum (Moly) ore
  - Low grade, high volume mining requiring highly efficient infrastructure
- Mining Method: Panel Caving (Block Caving)
- Mining Capacity: ~40,000 - 50,000 ton/day
  - Actual operation: ~20,000 - 30,000 ton/day

    $\Rightarrow$ under-utilized infrastructure
- Expected Mine Life: another ~20 years

Henderson Mine Location (Empire, Colorado)

Located in the Clear Creek County

I70 Eisenhower Tunnel



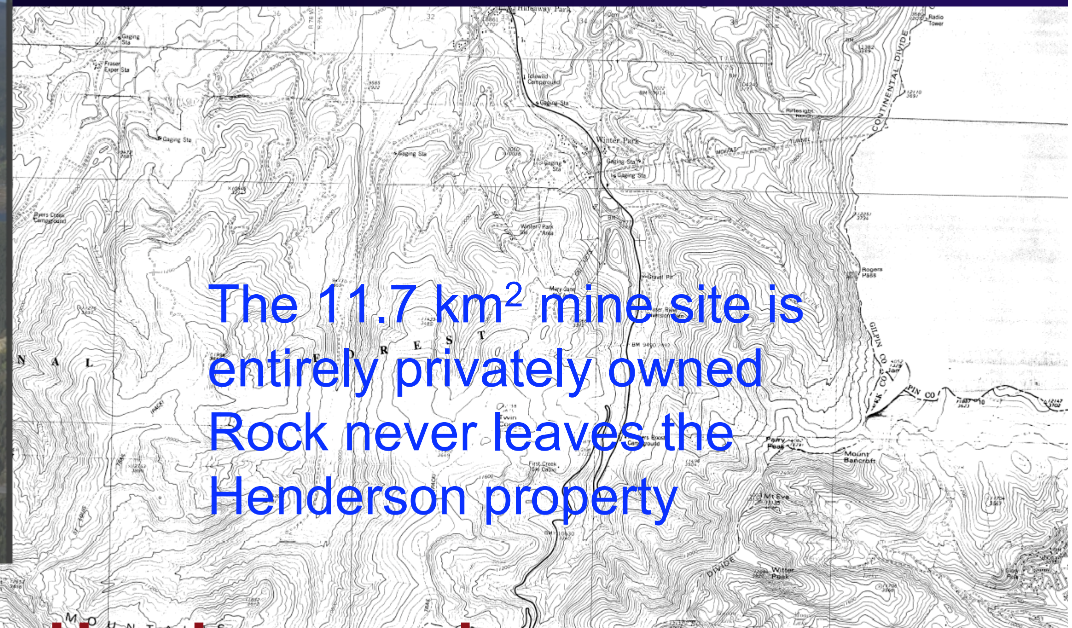
Harrison Mountain

Red Mountain (mining area)

Berthod Pass

Empire

Henderson Mine Complex & Surrounding



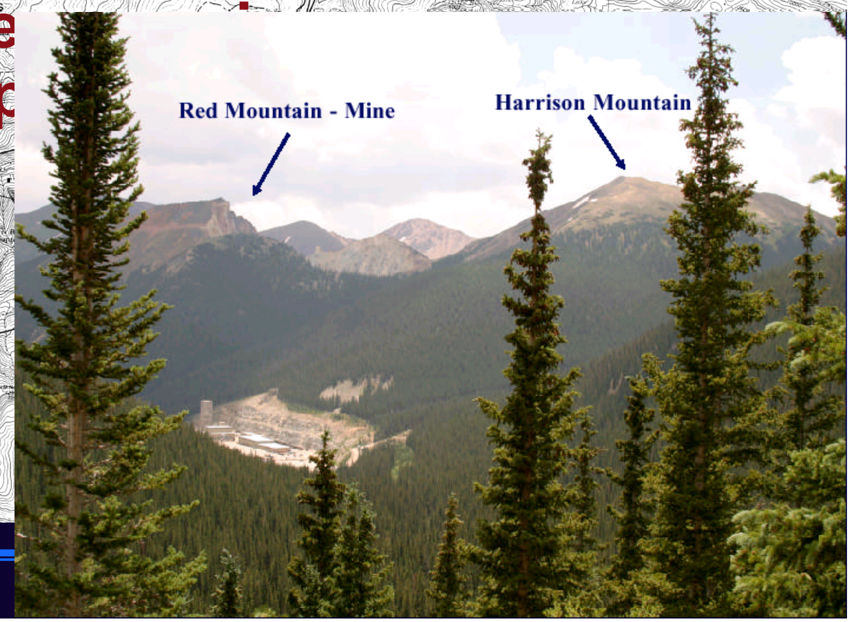
The 11.7 km^2 mine site is entirely privately owned

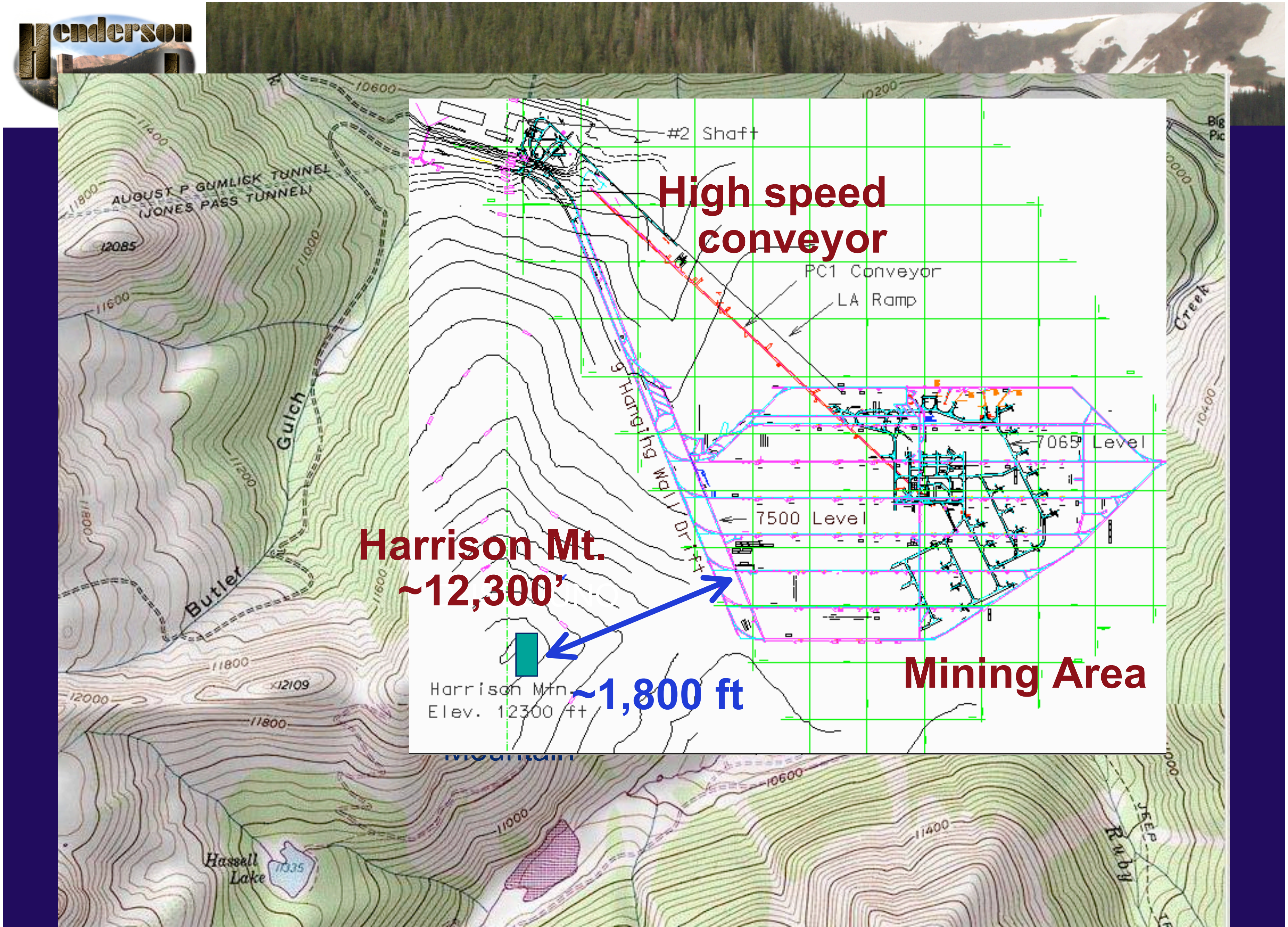
Rock never leaves the Henderson property

Hende

prop

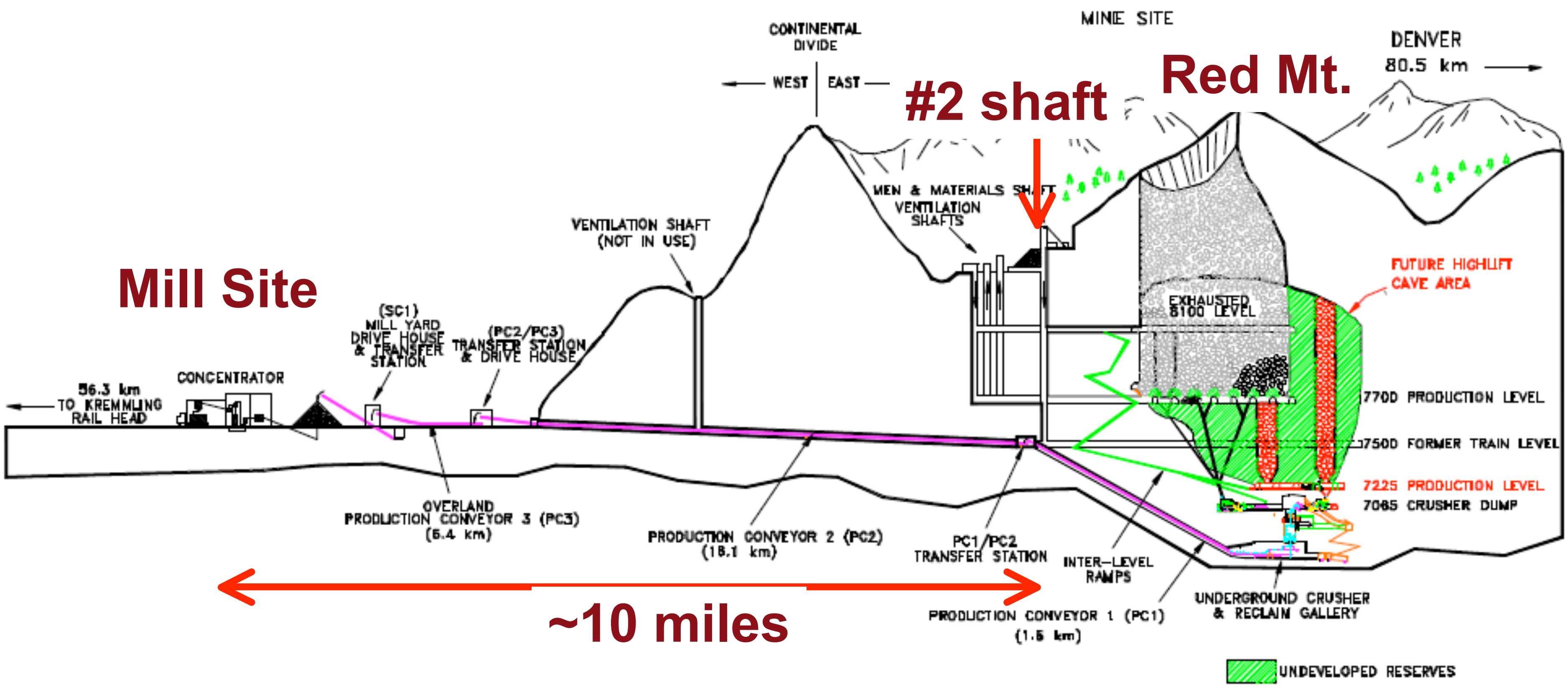
High speed conveyor ~10 miles





Chang Kee Jung

Vast Infrastructure



- Existing tailing site and all necessary environmental permits
- Henderson 2000 modernization project: ~$150M

Rock Handling/Transfer System

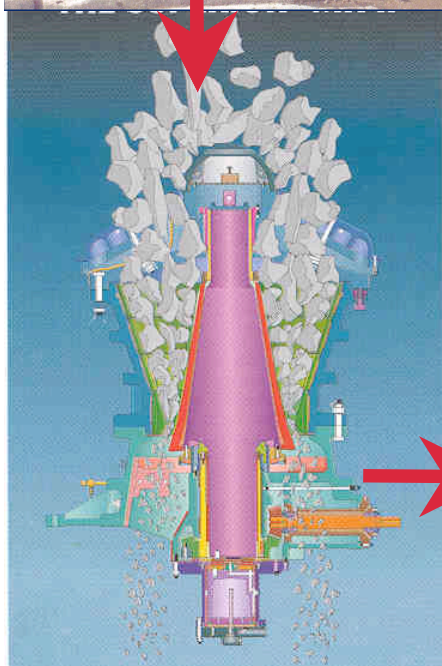
80 ton trucks dump rock at crusher.

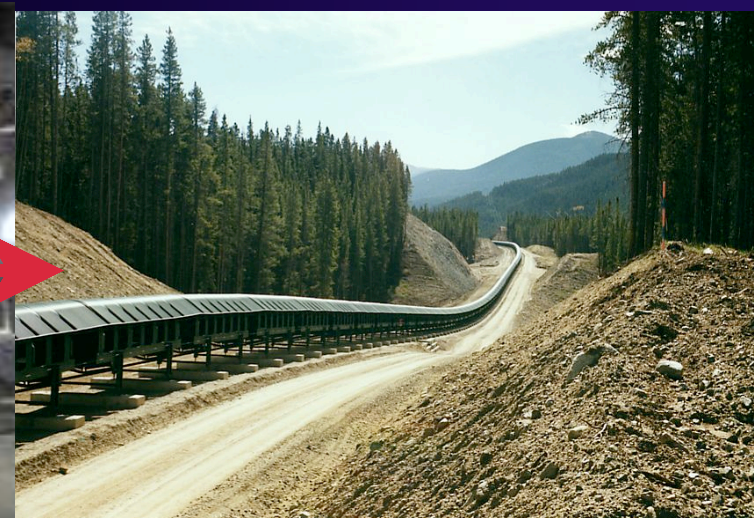
Gyratory crusher reduces to – 4 in.

1 mile PC1 and 10.5 mile long PC2 underground conveyors.

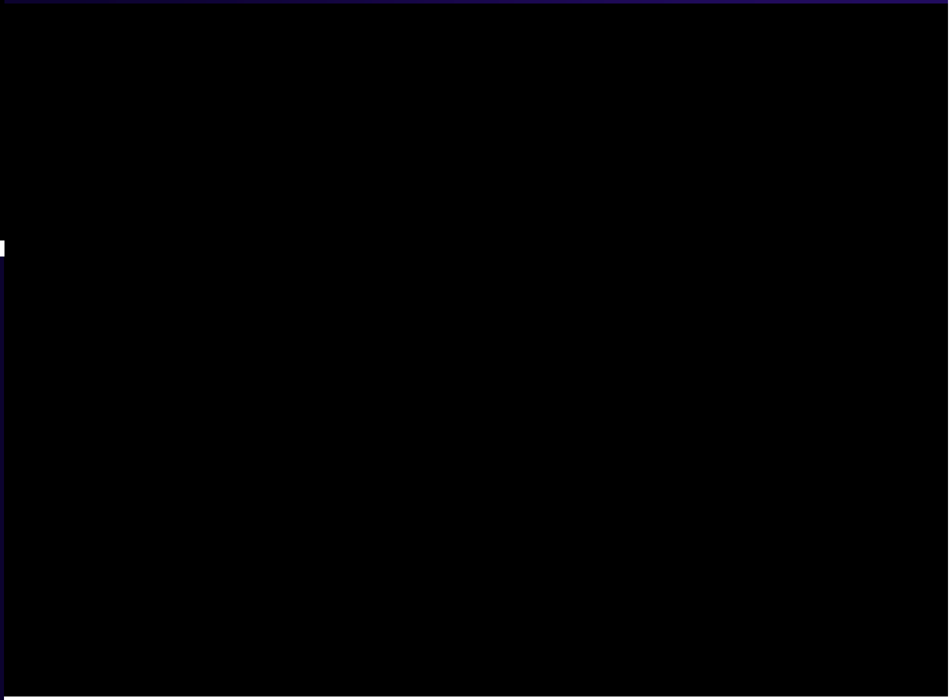
4 mile long PC3 surface conveyor to mill site.

~40k - 50kton/day capacity





Henderson Conveyor and Rock Crusher



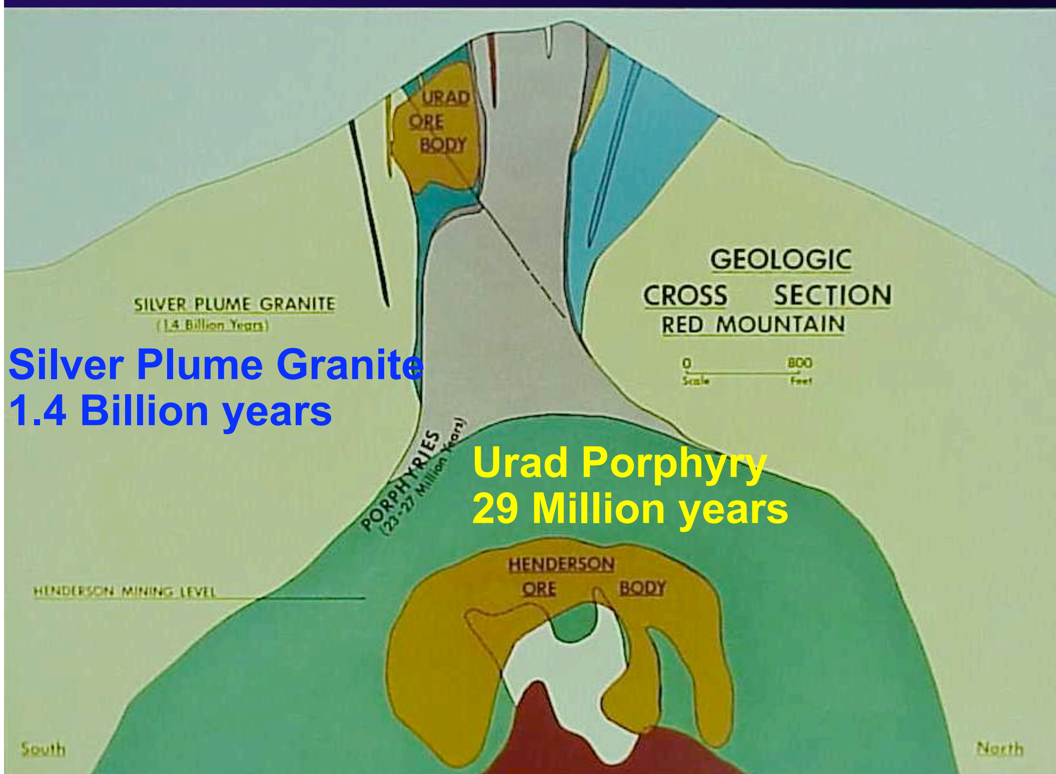
Infrastructure Information

- #2 Shaft for hoisting (a total of 5 shafts)
  - Collar at 10,350 ft above sea level down to 7,500 ft
    - ⇒ 5 min trip
  - 28 ft diameter w/ two independent hoisting compartments
  - The large hoist: 23' long by 8'6" wide by 13' tall
    - ⇒ accomodates a standard-size ISO container
    - ⇒ Maximum load: 30 tons (50 tons w/o cage)
    - ⇒ 200 people can transported at once
  - Fiber communication down the shaft to the other underground areas
- High capacity water and sewage treatment plant
- Electric power station: 2 x 24 MW feeds
- Tailing site: existing permit allows the deposition of over 340Mton
  - ~338Mton expected to be deposited during the mine life

Comments on Infrastructure

- Modern
  - Mine established in 1970's
  - Henderson 2000 modernization project: ~$150M
    - ⇒ High speed conveyer, etc.
- Vast and Underused infrastructure
  - Henderson operation in 1980's: ~2,000 employees
  - After Henderson 2000: ~500 employees
    - ⇒ shaft cages, water treatment plant, etc. underused
- Separate rock removal and person/equipment moving systems
- Henderson mine: low grade, high volume operation
  - Must be efficient
    - ⇒ low cost operation

Red Mountain Geology



Stockwork molybdenite deposit (porphyry).

15 stages of igneous activity

Chemically and mineralogically similar granitic rocks, differ mostly in texture.

474,000 ft of core drilling

Ore body 2200x3000x600 ft, approximately 360 million tons.
Second largest known molybdenum deposit in the world.

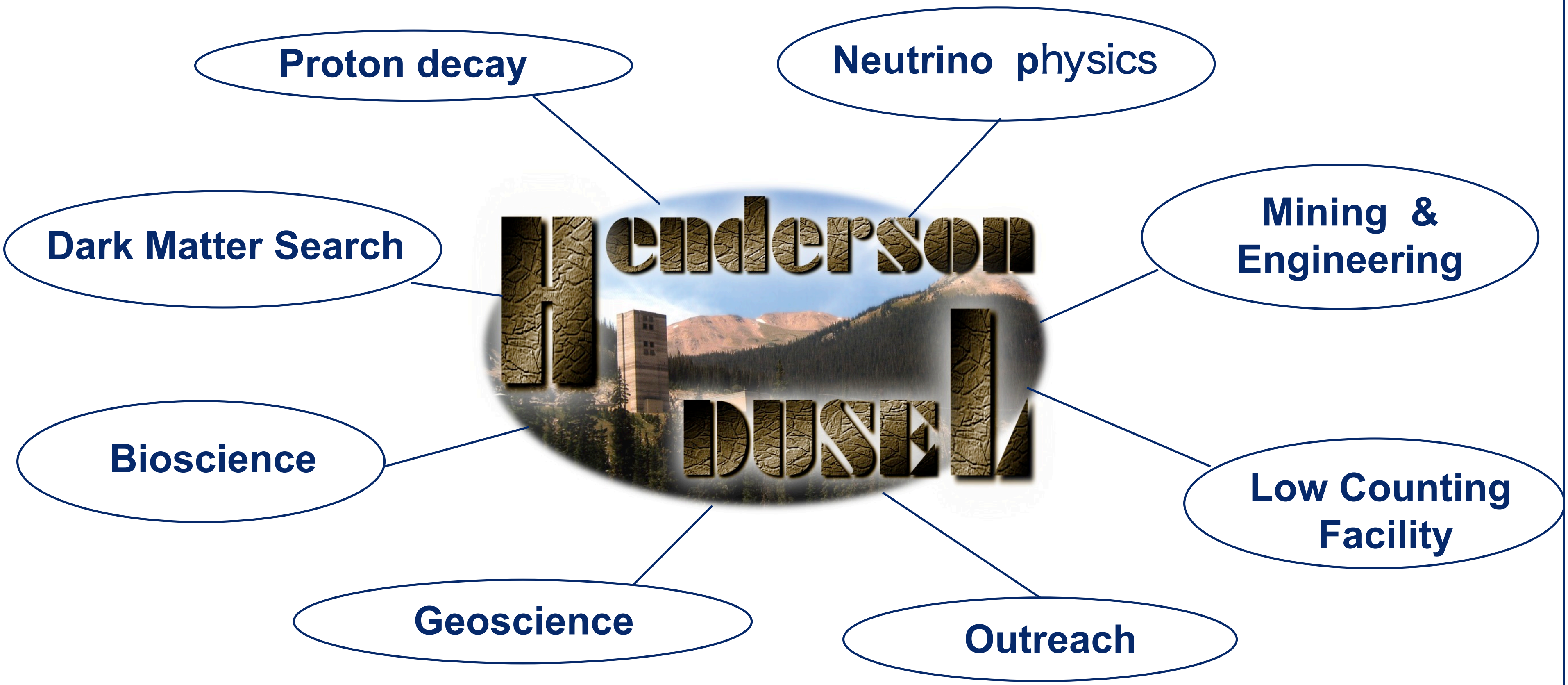
Henderson DUSEL Vision

- Create an underground lab that is unique and optimizes science output
  - – Careful conceptual design to meet all science and engineering demands
  - – Recognize other existing labs internationally
- Create a lab that is truly national and international and will last many decades
  - – Long term stability and access
  - – Dynamic scientific program
- Create a lab that will serve as an intellectual center
  - – Permanent staff
  - – Surface facility

Continue: Henderson DUSEL Vision

- Staged approach that allows scientific experiments to be carried out <u>concurrent with the construction</u>
  - Flexible "meet the need" approach
  - Upper campus + experiments (within a year)
  - Central campus + experiments (within three years)
  - Lower campus + experiments (within five years)
  - Geo/bio Outposts + experiments
- Optimize the usage of the vast existing infrastructure and mining expertise
  - Cost effective facility
- Create a laboratory that is environmentally sound and absolutely safe
  - Utilize the tremendous amount of expertise that exists in the Henderson mine

Envisioned Mission of Henderson DUSEL



⇒ Multi-disciplinary National Lab

HUSEP (Henderson Underground Science and Engineering Project) Collaboration

- Collaboration of Scientists, Industry Partners, Community Leaders and Members
  - Science-first

    ⇒ broad representations in biology, geology, mining&engineering and physics
  - Strong Industry Partners

    ⇒ Henderson Mine/Phelps Dodge

    ⇒ Consultants

      CNA Consulting Engineers

      Dunham Associates

      Miller-Dunwiddie Architects

      ILF Consultants

      ARUP

HUSEP Collaboration Organization Chart

HUSEP Collaboration

International Advisory Board
F. Avignone, A. Bettini, F. Calaprice, E. Fernandez, H. Holland,
B. Hustrulid, R. McKeown, L. Mosca, M. Nakahata, K. Nakamura
N. Pace, P. Paul, D. Sinclair, M. Wiescher, S. Wojcicki

Executive Committee
C.K. Jung, Spokesperson/Chair
R. Wilson, Deputy Spokesperson
C. deWolfe, M. Kuchta, D. Propernick, S. Schultz, E. Zimmerman

Henderson Mine/Phelps Dodge
F. Menzer
C. deWolfe, D. Propernick

Collaboration Council
HUSEP Executive Committee
Standing Committee Chairs and Co-Chairs

Henderson Coordination Committee
C. deWolfe, Chair
HUSEP Executive Committee
Standing Committee Chairs

Physical Sciences Committee
D. Akerib, Chair
J. Wilkes, Co-Chair, E. Zimmerman, Co-Chair

Industry Relations Committee
C. deWolfe, Chair
TBA, Co-Chair

Geoscience Committee
J. Hannah, Chair
B. McPherson, Co-Chair

Government&Community Committee
S. Schultz, Chair
R. Wilson, Co-Chair

Biological Science Committee
J. Mitton, Chair
T. Kieft, Co-Chair

Broader Impacts Committee
D. Claes, Chair
S. Pfiffner, Co-Chair, B. Jones, Co-Chair

Mining & Engineering Committee
M. Kuchta, Chair
L. Petersen, Co-Chair, E. Westman, Co-Chair

Low Counting Facility Committee
T. Borak, Chair
TBA, Co-Chair

ES&H
D. Propernick, Chair
TBA, Co-Chair

Management Committee
C. K. Jung, Chair
D. Propernick, Co-Chair

138 members

International Advisory Board Members (As of Mar. 2006)
(total: 15 members)

Name	Institution
Frank Avignone	U. of South Carolina
Alessandro Bettini	U. of Padua, Italy
Frank Calaprice	Princeton U.
Enrique Fernandez	U. Autonoma de Barcelona, Spain
Heinrich D. Holland	Harvard U.
William Hustrulid	U. of Utah
Robert McKweon	Caltech
Luigi Mosca	CNR, Saclay, France
Masayuki Nakahata	ICRR, U. of Tokyo, Japan
Kenzo Nakamura	KEK, Japan
Norman Pace	U. of Colorado
Peter Paul	Stony Brook U.
David Sinclair	SNOLab/Carleton U., Canada
Michael Wiescher	U. of Notre Dame
Stan Wojcicki	Stanford U.

HUSEP Physics Committee Membership (excluding postdocs and grads)

- Dan Akerib (Case), Chair
- Frank Avignone (South Carolina),
- John Beacom (Ohio State),
- Alessandro Bettini (INFN/Padova),
- Jim Cochran (Iowa State),
- Steven R. Elliott (LANL),
- Enrique Fernandez (Barcelona),
- Maury Goodman (ANL),
- Alec T. Habig (U.Minn/Duluth),
- Karsten Heeger (LBL),
- Chang-Kee Jung (Stony Brook),
- Tony Mann (Tufts),
- Kai Martens (Utah),
- William Louis (LANL),
- Cecilia Lunardini (INT/UWash),
- Clark McGrew (Stony Brook)
- Bob McKeown (CalTech),
- Harry Nelson (UCSB),
- Peter Paul (Stony Brook)
- Andreas Piepke (Alabama),
- Soren Prell (Iowa State),
- Eli Rosenberg (Iowa State),
- Leslie Rosenberg (LLNL),
- David Sinclair (Carleton),
- Walter Toki (CSU),
- Tom Weiler (Vanderbilt),
- Michael Wiescher (Notre Dame),
- Jeffrey Wilkes (UWash), co-chair
- Robert Wilson (CSU),
- Chiaki Yanagisawa (Stony Brook),
- Eric D. Zimmerman (CU), co-chair

Industry Partner: Henderson/Phelps Dodge

- Henderson Mine Operation
  - Mining operation with zero-accident policy

    ⇒ excellent safety record
  - Seasoned staff with expertise in mining
  - Friendly, congenial, cooperative, (even patient) staff
  - Actively participating member of the HUSEP collaboration

    ⇒ eager to bring DUSEL to Henderson
- Phelps Dodge Corporation
  - Sees DUSEL as a good model for productive land use after mine closing, community relations and image
  - Friendly, science sympathetic senior executives

State and Local Support for Henderson DUSEL

- Arapaho non-profit community organization
- State Level: non-partisan support
  - Direct Involvement of Lt. Governor’s Office
  - State Senate-House Joint Resolution
  - Governor’s Letter of Support
  - Support from the Dept. of Local Affairs
  - Support from the Dept. of Natural Resources
  - Support from the Commission for Economic Development & International Trade
- Local Community Level
  - Strong support from Clear Creek County (mine site)
  - Strong support from Grand County (mill site)
  - Many supporting letters
- Creation of Colorado State Special Commission
- No Opposition!

Environment and Safety

- Existing tailing site and all necessary environmental permits
  – Henderson holds excellent environmental record
- DUSEL impact on the environment estimated to be minimal
  – Total rock deposit from the DUSEL excavation in the tailing site will be only a few percent of the total permitted amount
  – DUSEL construction will be largely ‘invisible’ to the community
  – No community or environmental group opposition
- Excellent safety record of Henderson operation
  – Zero-accident policy (pride of the company)
  – DUSEL construction and operation will follow Henderson’s lead and rely on their expertise

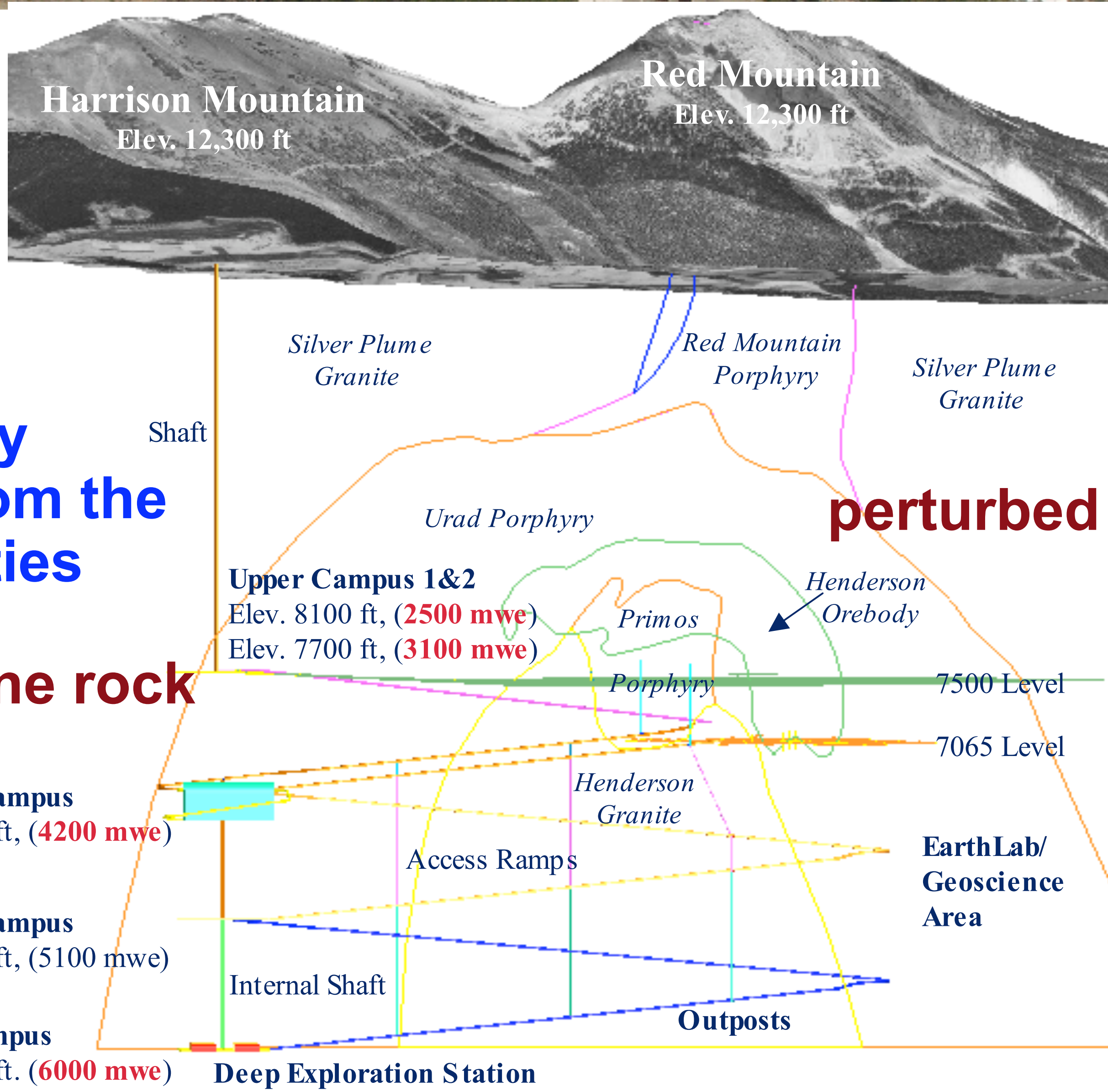
Construction and Operating Costs

- DUSEL construction and operating costs will be low because of the existing and shared infrastructure

A preliminary cost analysis is being prepared for CDR

"Build as needed" approach minimizes financial risk

Henderson DUSEL Conceptual Design

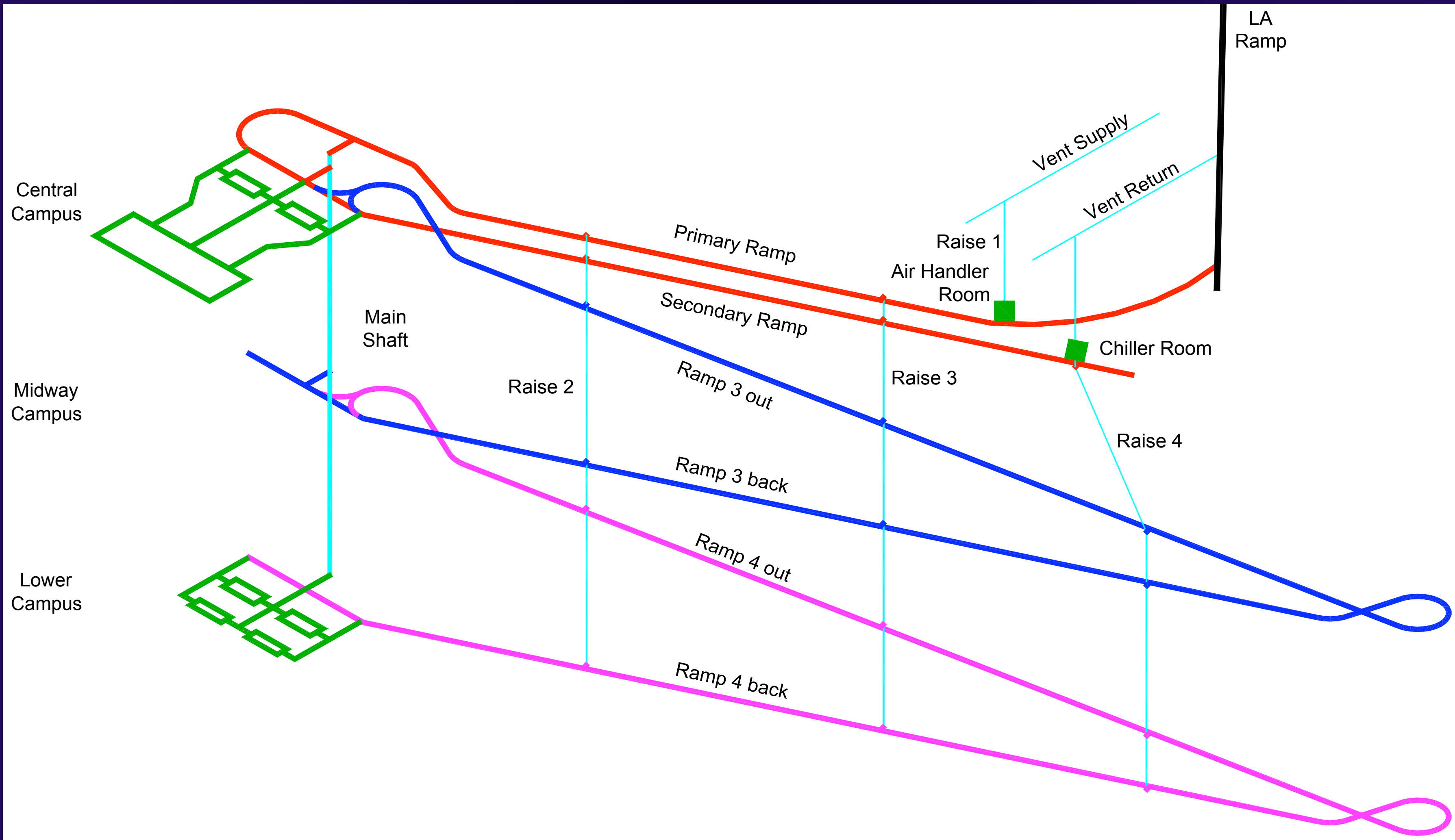


DUSEL mostly decoupled from the mining activities

perturbed rock

pristine rock

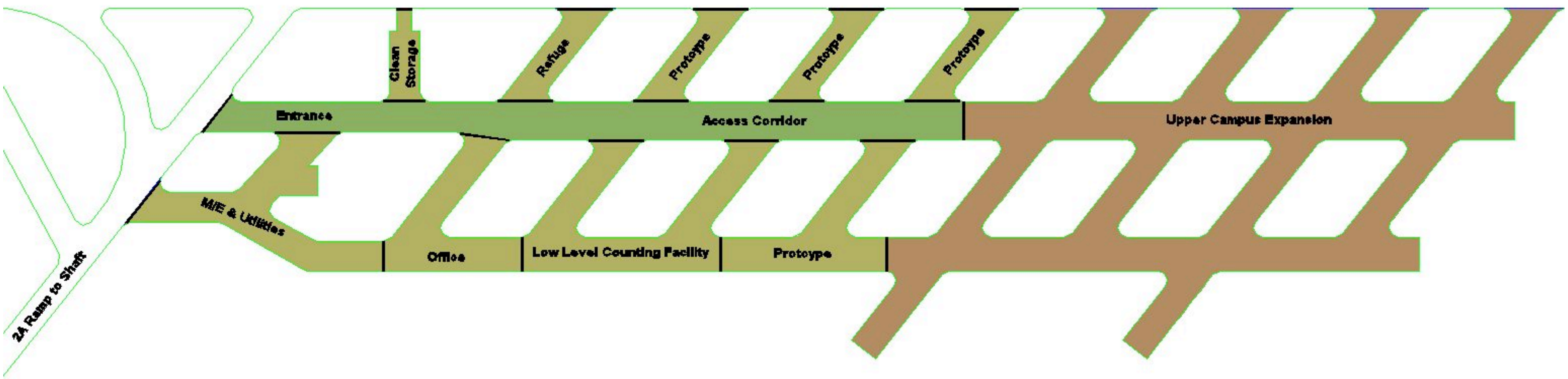
Underground Layout



Upper Campus 1

existing space, 2500 mwe depth

Can be available within a year of an approval by NSF



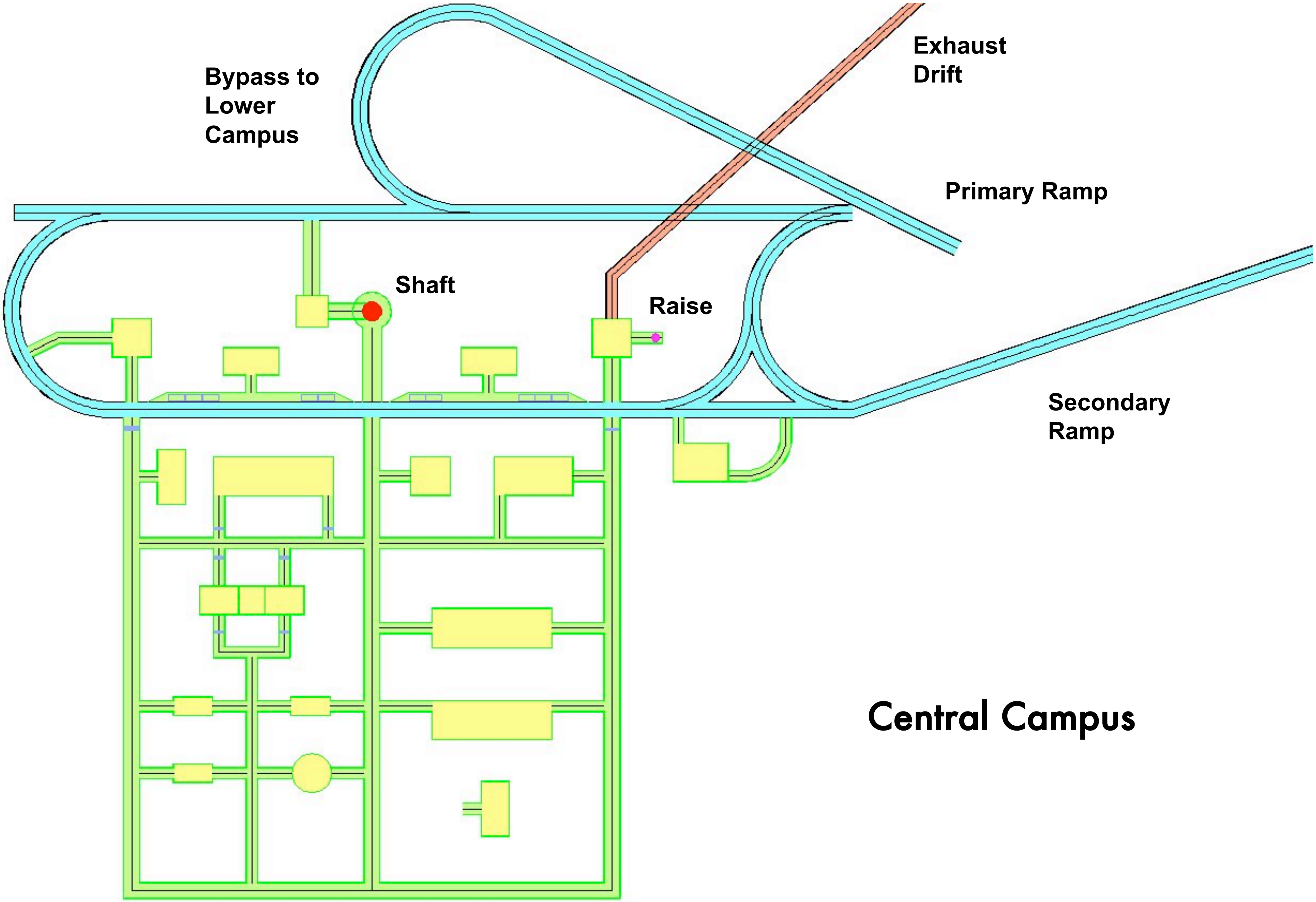
Upper Campus Layout - 8100 Shop

Upper Campus 1 Space Summary

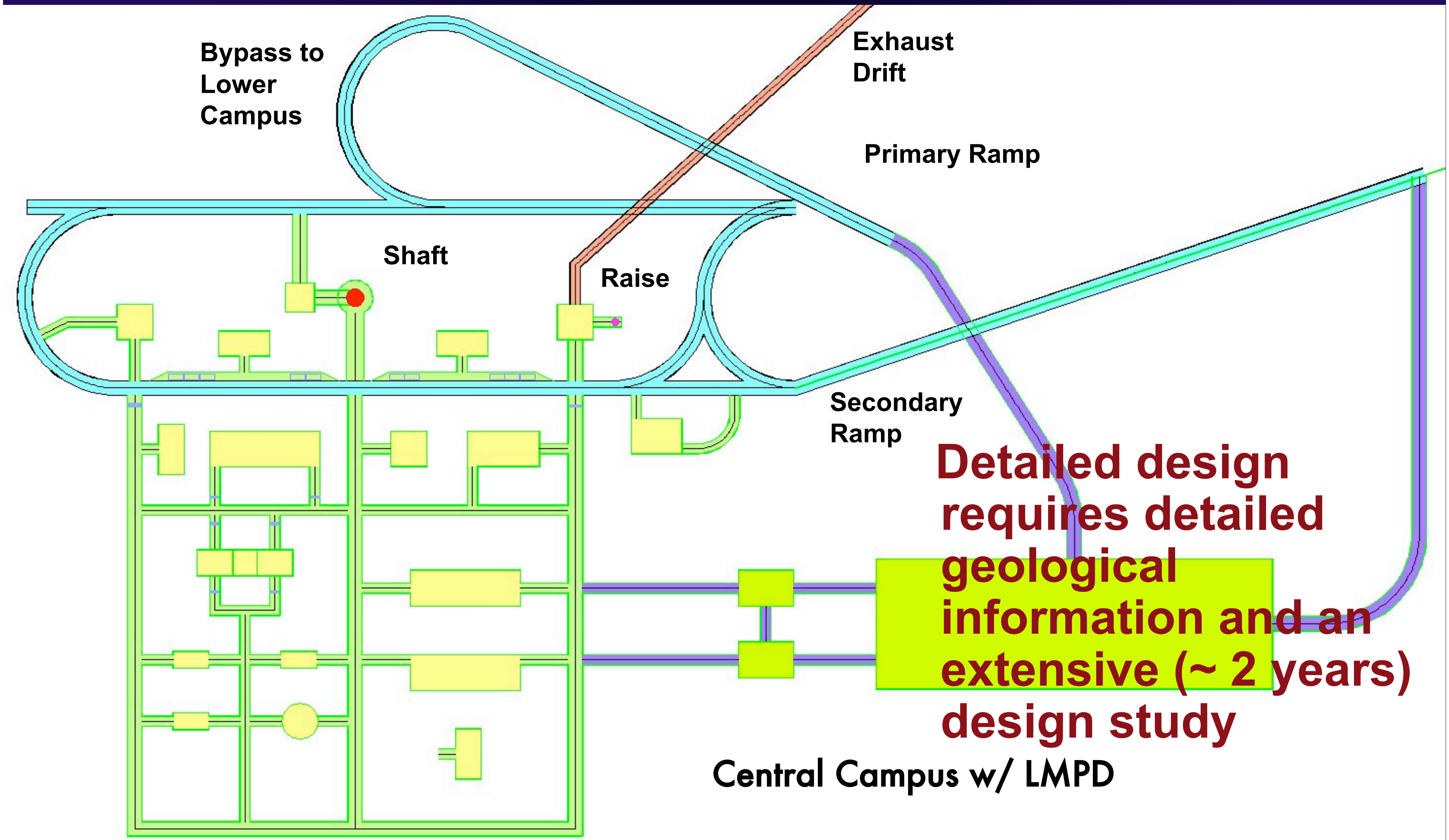
Upper Campus Space Summary

Item	Length (ft)	Width (ft)	Floor Area (sf)
Access Corridor	392	20	7840
Refuge	62	16	992
Prototype	62	16	992
Prototype	62	16	992
Prototype	62	16	992
Prototype	160	16 & 18	2656
Low Level Counting Facility	214	16 & 18	4052
Office	138	16 & 18	2414
M/E & Utilities	194	16 & 18	3344
Clean Storage	49	16	784

Central Campus



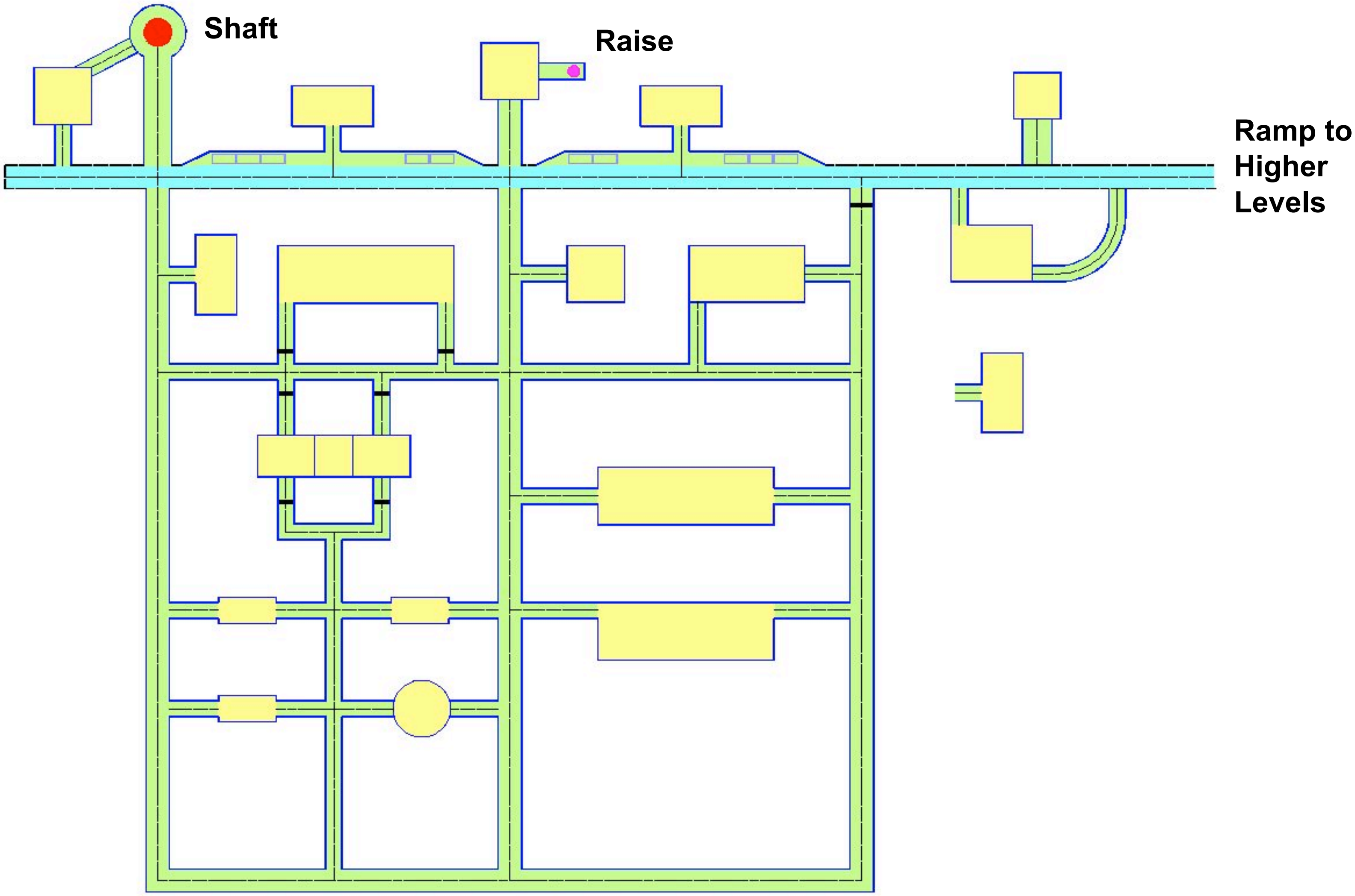
Central Campus with Large Multi-Purpose Detector (LMPD)



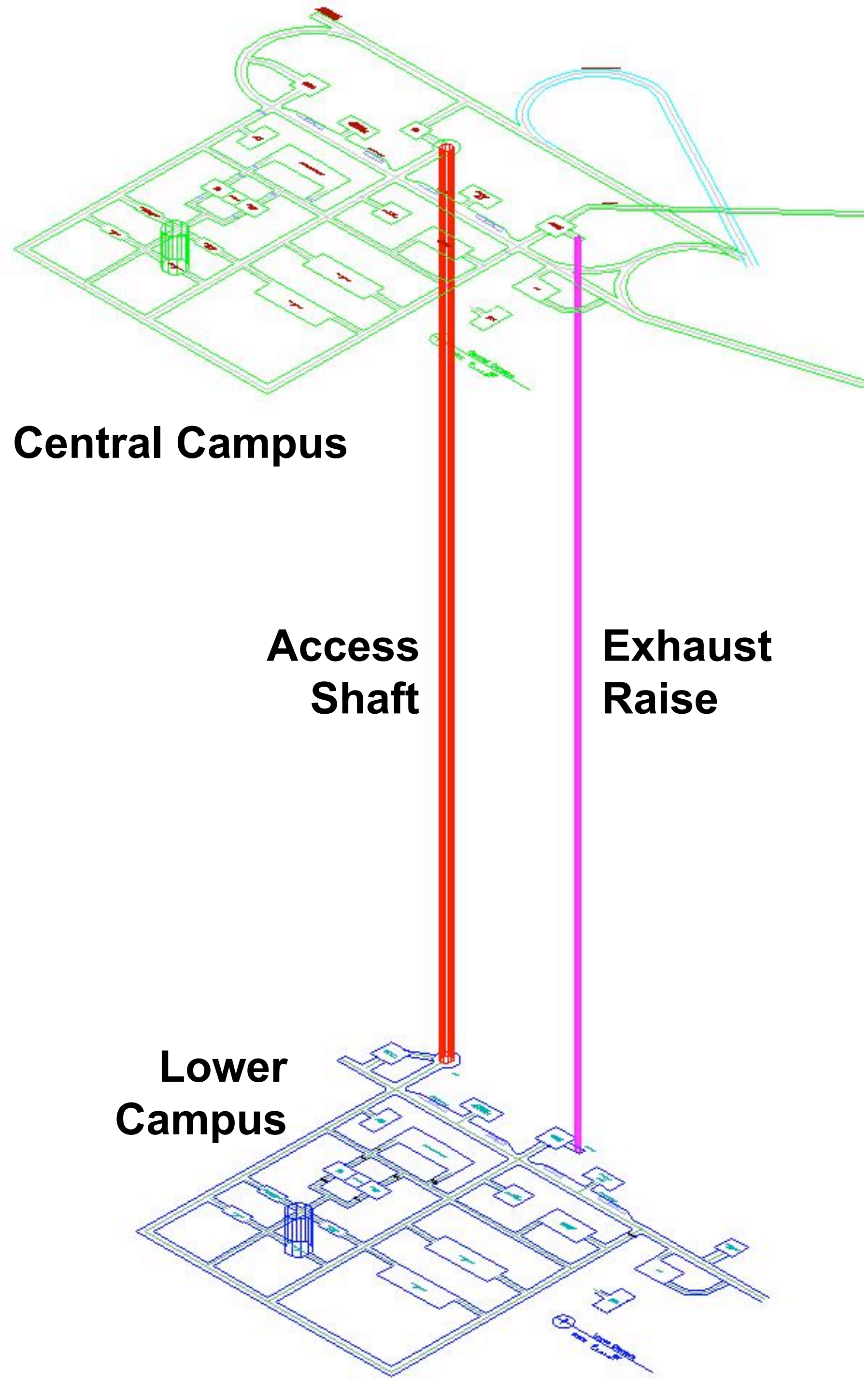
Detailed design requires detailed geological information and an extensive (~ 2 years) design study

Central Campus w/ LMPD

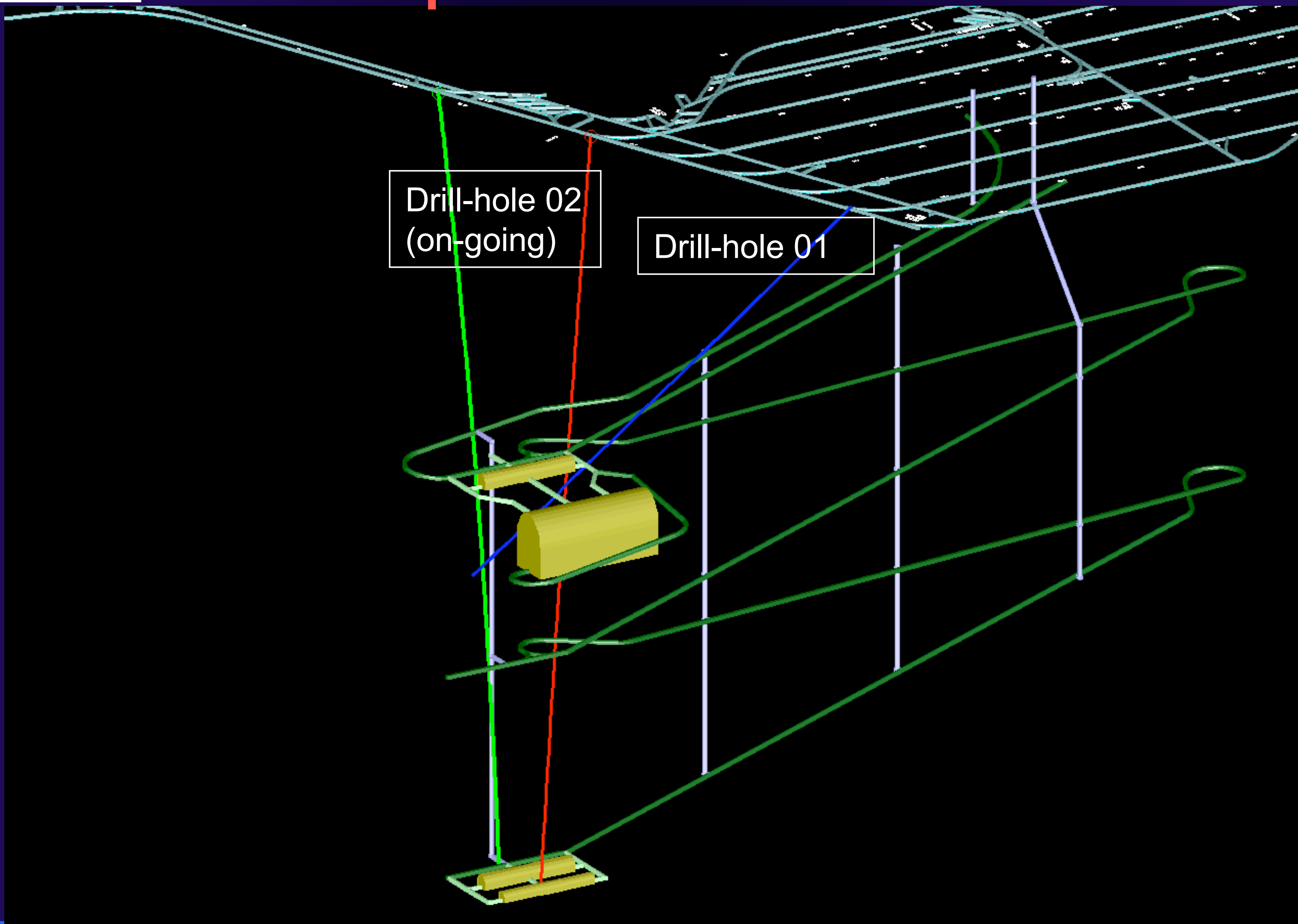
Lower Campus



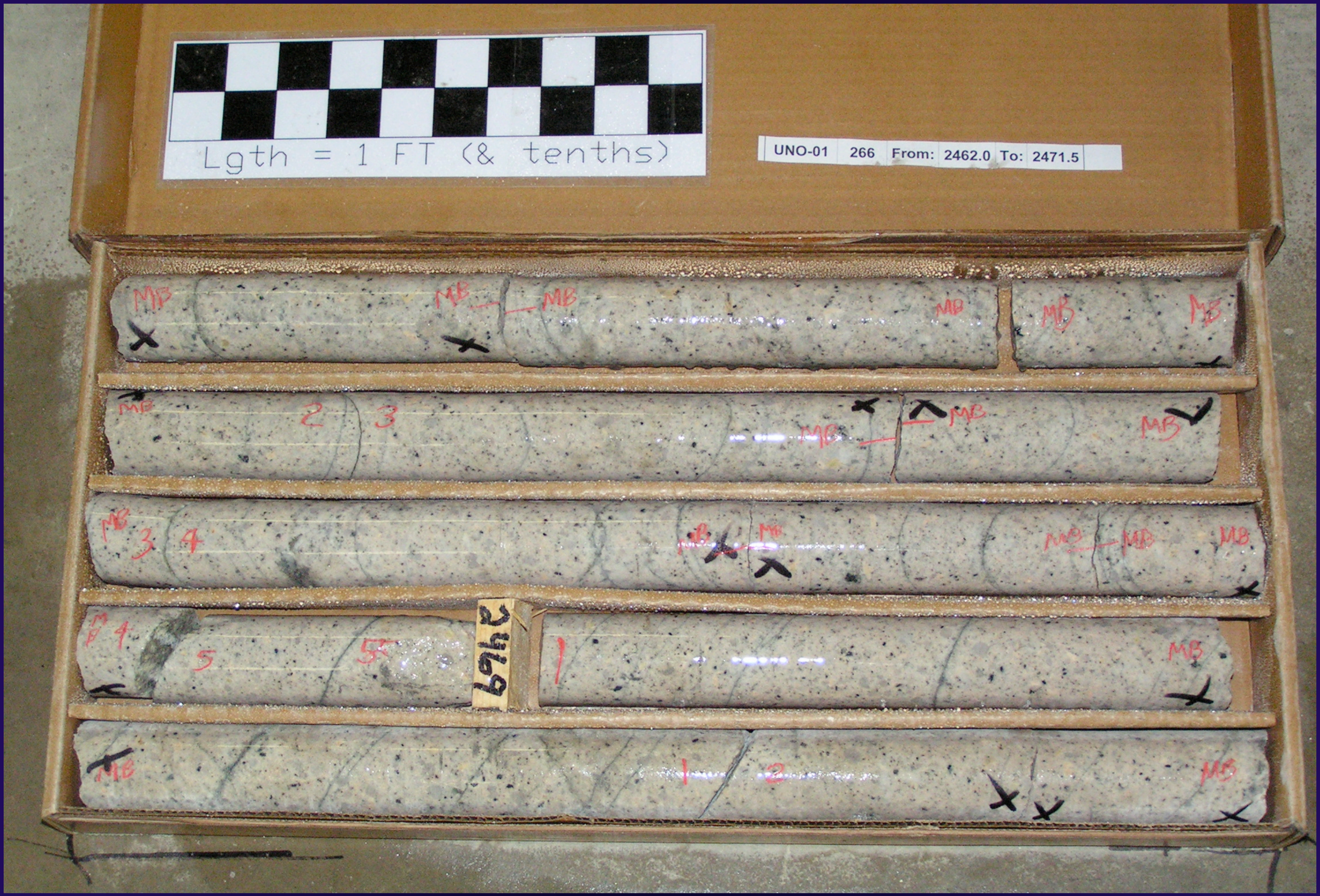
Layout Isometric



Henderson DUSEL
Exploration Core Drill Holes

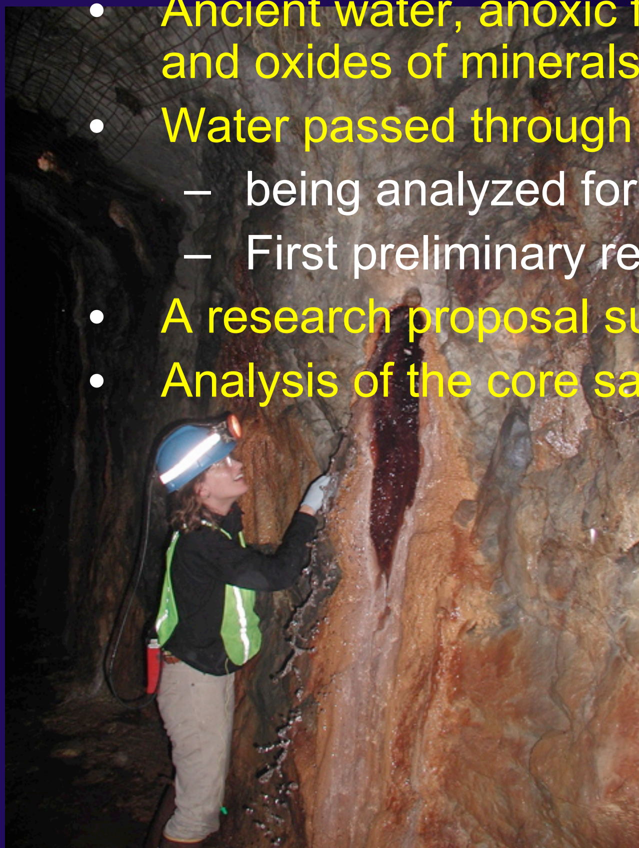


Cores from the Henderson DUSEL Core Drill #1



Bio-sampling at Henderson

- Ancient water, anoxic for thousands of years, meets oxygen in the shaft, and oxides of minerals precipitate
- Water passed through filters for several hours to collect samples
  - being analyzed for DNA
  - First preliminary results obtained
- A research proposal submitted to NSF by an Assis. Prof. at U. of Colorado
- Analysis of the core samples for biological study also on-going



Henderson DUSEL Management Plan

- A management plan based on a university consortium (Henderson DUSEL Consortium: CSM, CSU, CU, SBU) is established and endorsed by all parties involved
  - MOU among four university Presidents being drafted
- License and Lease Agreements
  - Between CMC/Henderson and Henderson DUSEL
  - Critical Documents for CDR
    - ⇒License Agreement: deals with underground DUSEL construction and other experimental projects, liability and indemnification issues, safety and environmental issues, shared infrastructure and post mining DUSEL operating issues, etc. (50 pages)
    - ⇒Lease Agreement: deals with aboveground ground lease for the lab facilities (45 pages)
  - Drafts being finalized
  - Expect to sign an interim conditional agreements before the CDR submission
  - According to the lawyers involved: No show-stoppers!

Major HUSEP Activities Since S2 Award

- Workshops
  - Henderson DUSEL Management Workshop: August 25
  - Biological Science at Henderson DUSEL Topical Workshop at CU, Boulder: October 20-21
  - Outreach Workshop at CU, Boulder: October 20
  - Strategic Vision and Design Criteria Workshop at CU, Boulder: October 20-22
  - Physics at Henderson DUSEL Topical Workshop at CSU, Fort Collins: November 18
  - Geoscience at Henderson DUSEL Topical Workshop at CSU, Fort Collins: November 18
  - Outreach Workshop at CSU, Fort Collins: November 18
  - Engineering at Henderson DUSEL Topical Workshop at CSM, Golden: December 15
  - Outreach Workshop at CSM, Golden: December 15
- Monthly Collaboration Meetings

Future HUSEP Activities

- Science and Engineering at Henderson DUSEL Capstone Workshop at Stony Brook, New York
  - May 4 - 7, 2006
  - 74 registrants as of April 14
  - Accompanying outreach workshop for high school teachers
    - ⇒ additional xx registrants as of April 14

P5 Questions

Q1: For the DUSEL talks, Bernard Sadoulet on the second day will cover general science for an underground lab. I would like the first day speakers to cover separately what the neutrino science (for example supernovas, careful measurement of the neutrino spectrum for solar neutrinos) would be in the absence of an accelerator beam of neutrinos, as well as proton decay, and then what would we get by also having an accelerator based neutrino beam (you may wish to coordinate the two talks in some way to avoid too much repetition)

$\Rightarrow$ For the case w/o a LMPD and a neutrino superbeam: solar neutrinos covered by Lesko; Jung covers supernova neutrinos

$\Rightarrow$ For the case w/ a LMPD and a neutrino superbeam: Long baseline neutrino oscillation physics covered by Lesko; Jung covers non-accelerator physics potential

Supernova (Type IIa) Neutrinos

- Galactic supernovae (Milky Way)
  - Rate: ~3/century
  - High statistics event (~9,000 events in SuperK for a supernova at 10 kpc)
- Nearby extra-galactic supernovae (d ~ a few Mpc, including local group of galaxies)
  - No sensitivity for SuperK, requires a LMPD
  - Rate: ~1/a few years for UNO
  - Require two-neutrinos or optical coincidence (Beacom)
- Distant extra-galactic supernovae (z < 1)
  - No correlation to specific supernova possible: known as Supernova Relic Neutrinos (SRN) or Diffuse Supernova Neutrino Background (DSNB)
  - Large backgrounds from atm nu's, spallation products, etc.

Importance of Observing Supernova Neutrinos

- The only observed neutrinos from astrophysical origin are:
  - – Solar neutrinos and neutrinos from SN1987a
  - – Observation of any neutrinos from an astrophysical origin will be a breakthrough
- Understanding supernovae contributes significantly to particle physics, nuclear physics, astrophysics and cosmology
- New Optical Survey
  - – NO SWEAT (Neutrino-Oriented Supernova Whole-EArth Telescope)

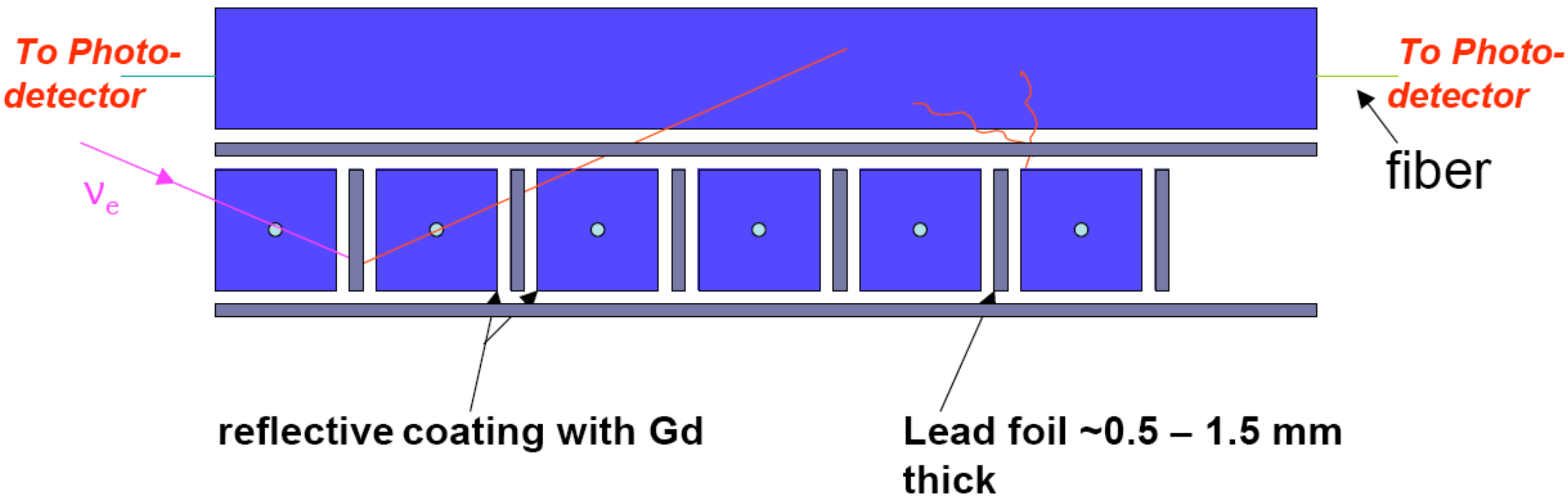
    ⇒ Monitor 12 large nearby galaxies nightly for Sne
    Avishay Gal-Yam, et al.
    http://www.astro.caltech.edu/~avishay/nosweat.html
- Well funded modeling projects

Galactic Supernova Neutrino Detection at DUSEL w/o a LMPD

- OMNIS
  - By R. Boyd et. al.
  - No current effort
- ADONIS Lead Foil Detector
  - By R. Talaga (ANL)
  - Off-shoot from OMNIS (?)
  - Emphasis on detection of Electron Neutrinos
    - ⇒ Complementary to SuperK detection of (primarily) Electron *Antineutrinos*
  - Total volume: 2 x (8m x 8m x 8m)
  - Concept stage

ADONIS Lead Foil Detector

2 cm x 2 cm x 8m scintillator



How it works:

- CC electrons pass through several Scint/Pb-foil
- Neutrons are moderated in scintillator and captured in Gd
- Gammas from n-capture detected by scintillator

Galactic Supernova @10kpc

Experiment	Total # of Observed Events	Status
UNO	140,000	proposed
SuperK	9,000	running
OMNIS	~2,000	inactive
ADONIS	~1500	proposed
SNO	1,000	running
KamLAND	~500	running
Borexino	~500	commissioning
LVD	~200	running

Summary of Supernova Neutrino Detectors at DUSEL w/o a LMPD

- Galactic Supernova Neutrino Detection
  - ADONIS proposal
  - No known other proposals
- Extra-galactic Supernova Neutrino Detection
  - Requires a LMPD
  - No other choice
    - ⇒ flux x cross-section limit

Long Term Vision

Henderson DUSEL with a Large Multi-Purpose Detector (LMPD)

and

a Neutrino Super Beam

Physics Beyond SuperK, T2K, NOVA

- Requires a LMPD with physics sensitivities an order of magnitude better than those of SuperK, T2K and NOVA
  - Water Cherenkov Detector: > 500 kton
  - LAr Detector: ~100 kton

    ⇒ a great technical challenge
  - by the time a LMPD is built at DUSEL, SuperK will have accumulated more than 20 years of data

    ⇒ DUSEL Timeline

    S2 Report due: June 23, 2006

    Expected S3 award decision: ~Fall 06

    Expected S3 report due: ~Fall. 07

    Expected DUSEL final decision: ~2008

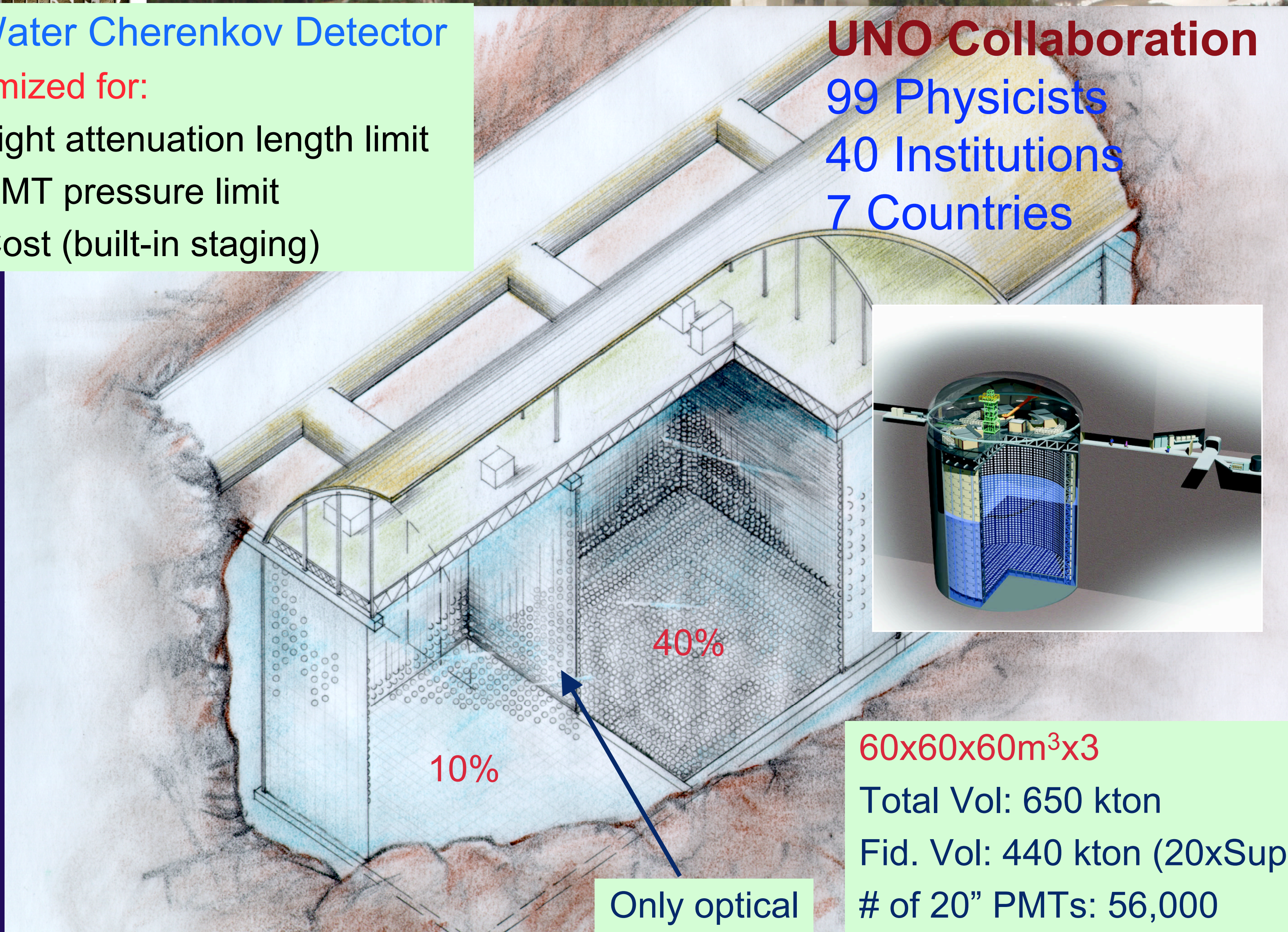
    Expected DUSEL ground breaking: ~2009

UNO Detector Conceptual Baseline Design

A Water Cherenkov Detector
optimized for:

- Light attenuation length limit
- PMT pressure limit
- Cost (built-in staging)

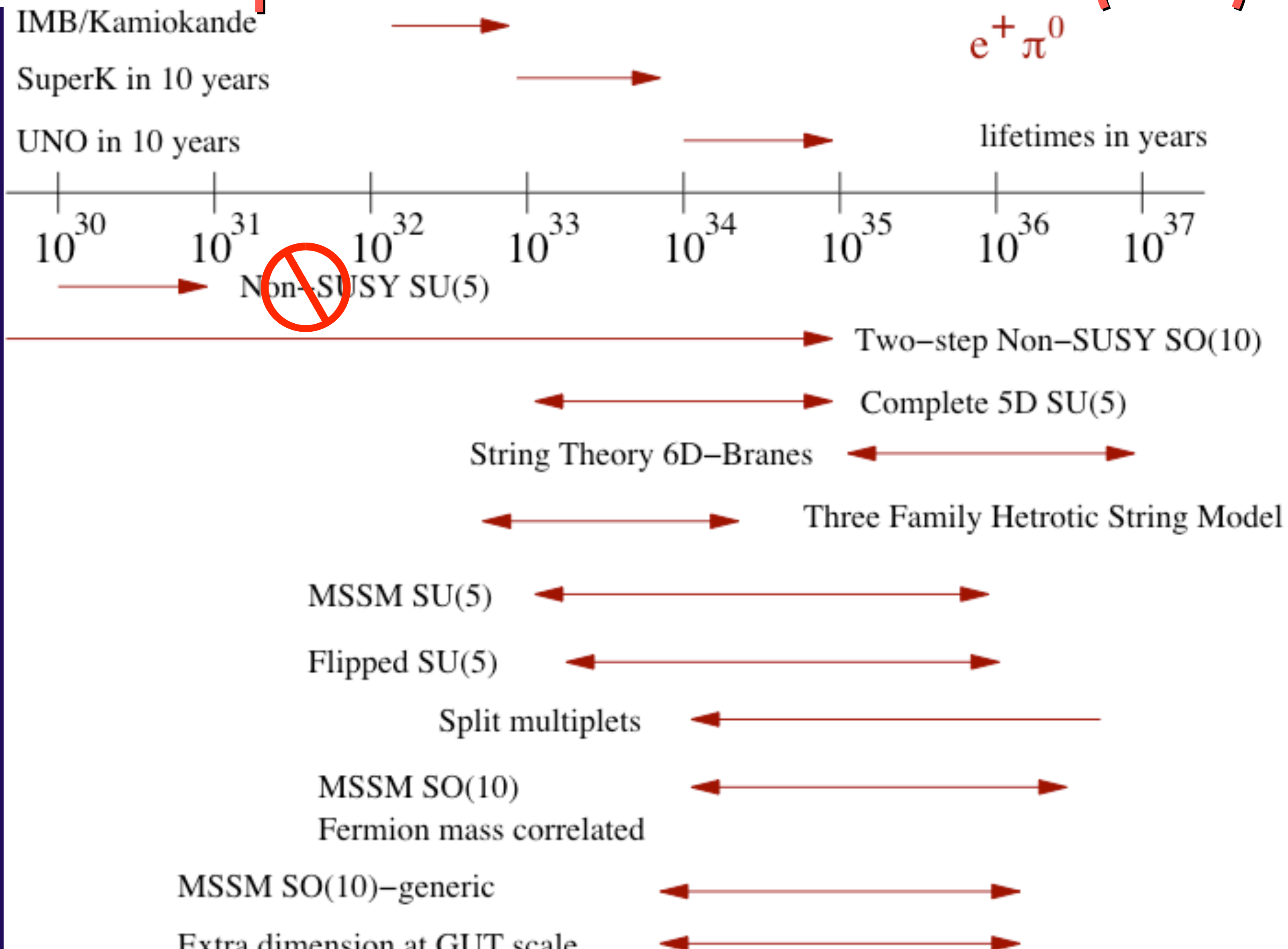
UNO Collaboration
99 Physicists
40 Institutions
7 Countries



Only optical separation

60x60x60m^{3}x3
Total Vol: 650 kton
Fid. Vol: 440 kton (20xSuperK)
# of 20" PMTs: 56,000
# of 8" PMTs: 14,900

UNO Proton Decay Sensitivity and Updated Theoretical Predictions ($e^+\pi^0$)



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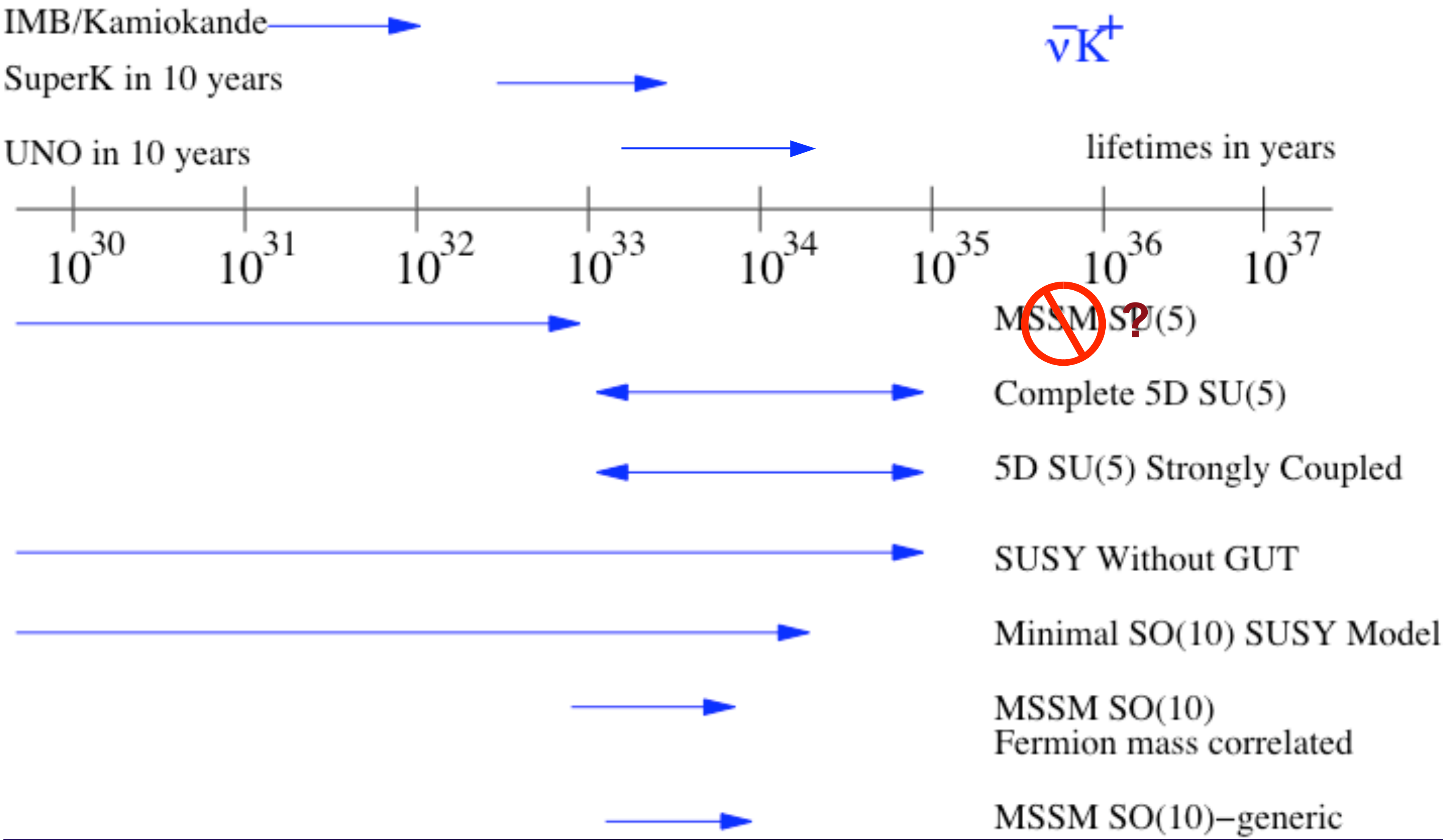
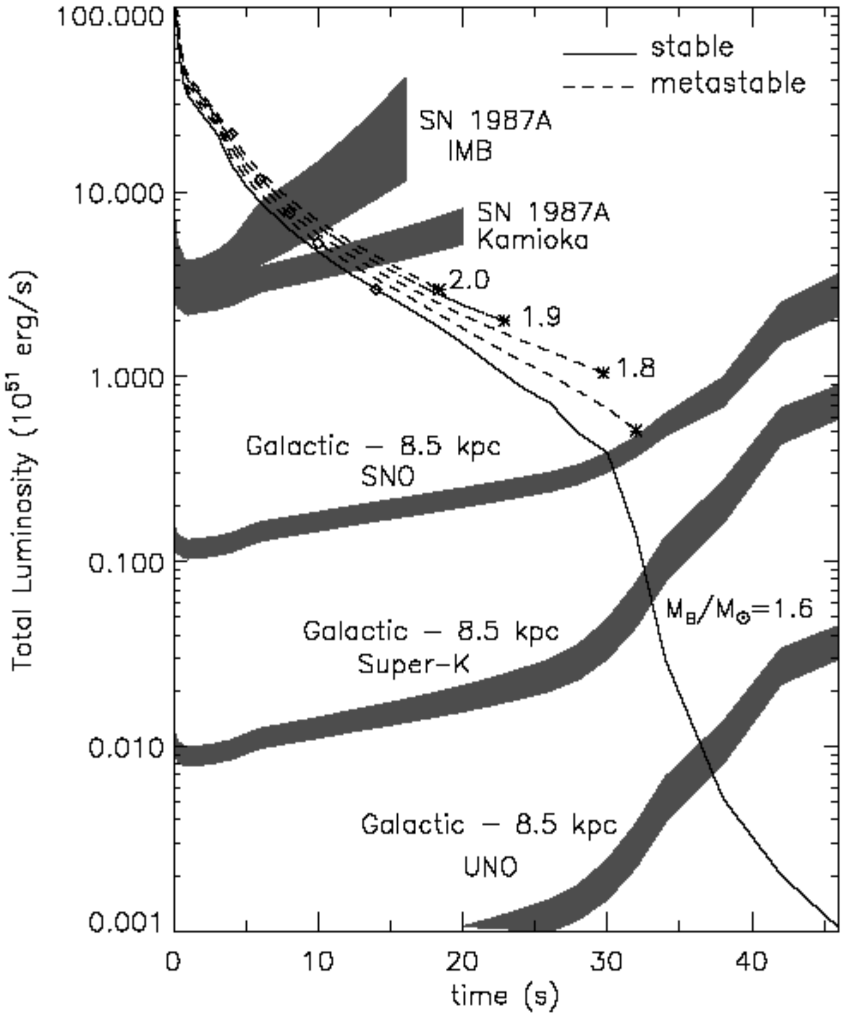


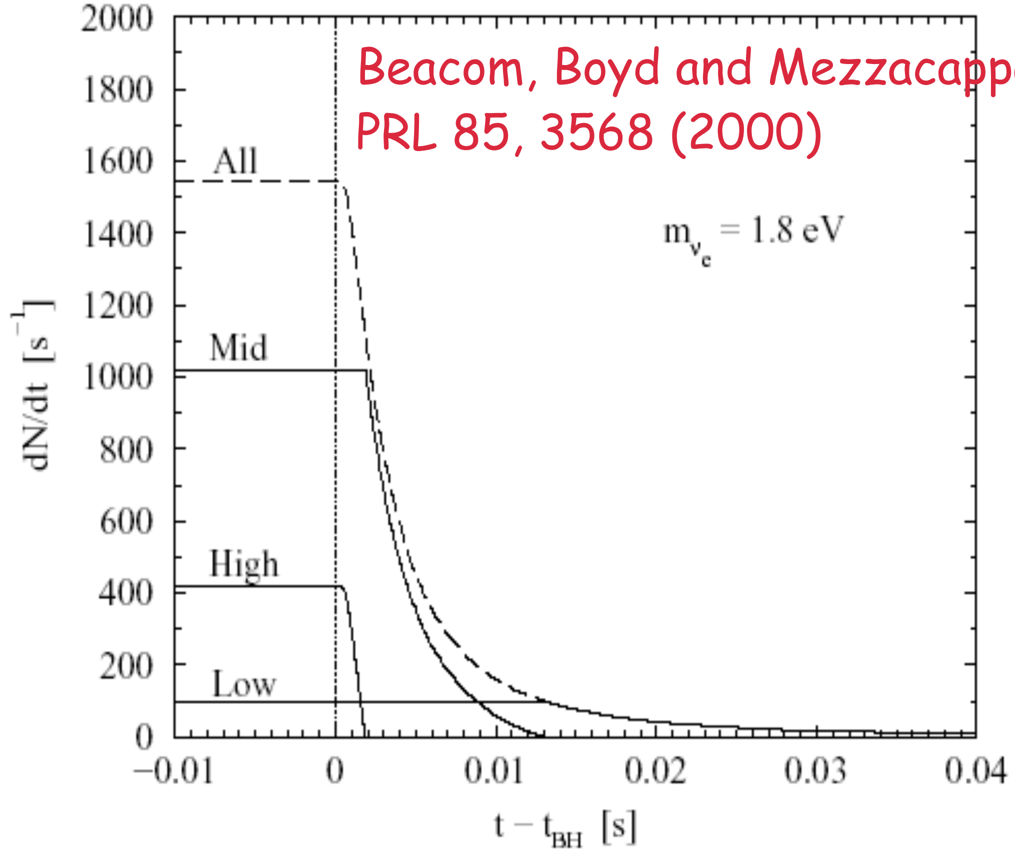
Andromeda Galaxy

Supernova Reach
~ 1 Mpc
(local group of galaxies)
(could be much greater, Beacom et al.)

Supernova Rate
~ 1/10 or 15 yrs

Galactic Supernova





Beacom, Boyd and Mezzacappa
PRL 85, 3568 (2000)

~140,000 events in UNO, ~1/30 years

⇒ msec timing structure of the flux ⇒

⇒ Determination of core collapse mechanism

⇒ Possible Observation of Birth of a Black Hole!

An example of unstable Eq. Of State
Pons et al., PRL 86, 5223 (2001)

SuperK SNR ν Search Limits

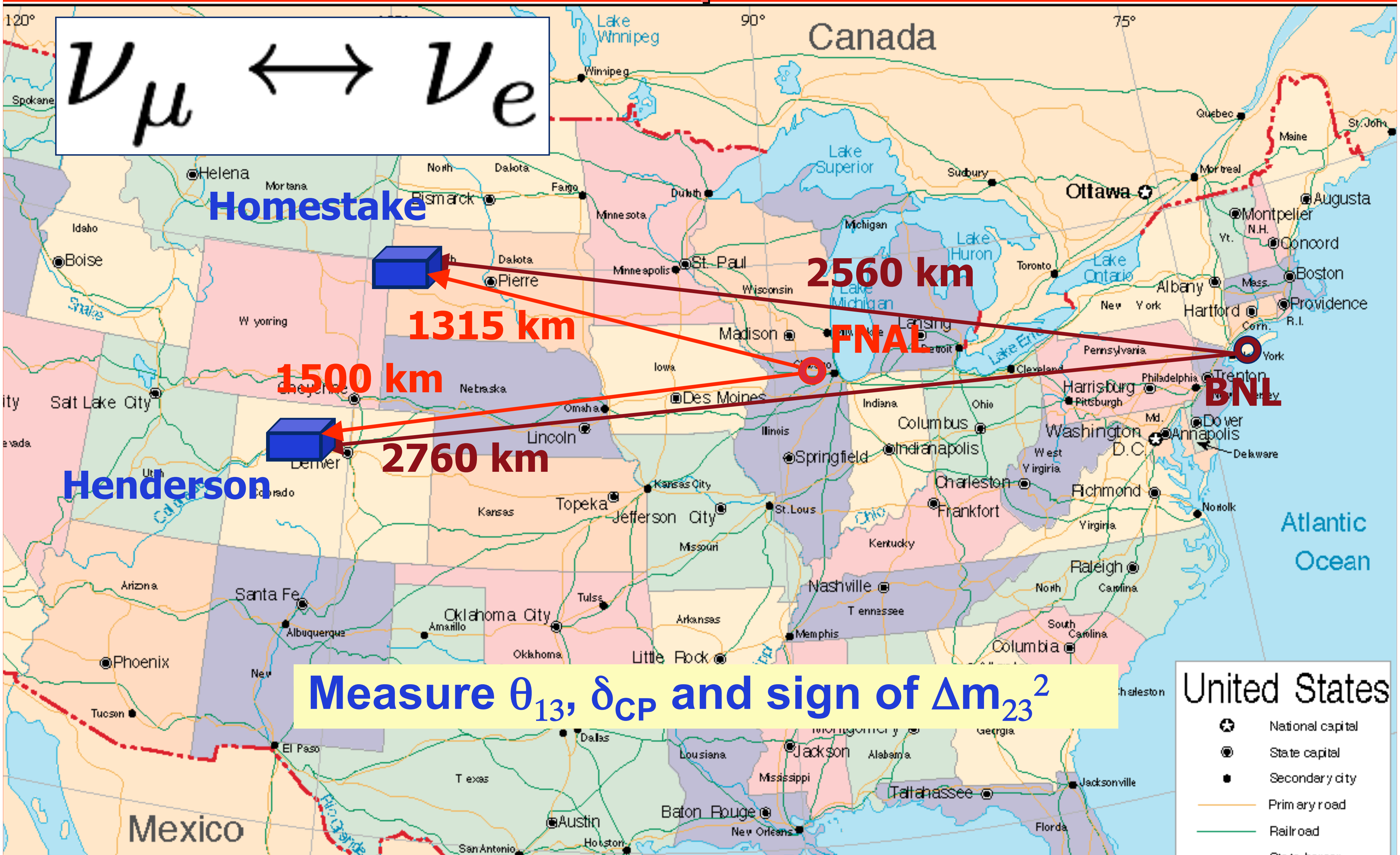
Theory Model	SK SRN Rate Limit (Efficiency Corrected)	SK SRN Flux Limit (18 MeV < Ee < 82 MeV)	SK SRN Flux Limit (Full Spectrum)	Predicted SRN Flux (Full Spectrum)
Galaxy evolution (Totani et al., 1996)	$3.2 \frac{\text{events}}{\text{year } 22.5 \text{ kton}}$	$< 1.2 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$	$< 130 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$	$44 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$
Heavy metal abundance (Kaplinghat et al.,2000)	$3.0 \frac{\text{events}}{\text{year } 22.5 \text{ kton}}$	$< 1.2 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$	$< 29 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$	$< 54 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$
Constant supernova rate (Totani et al., 1996)	$3.4 \frac{\text{events}}{\text{year } 22.5 \text{ kton}}$	$< 1.2 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$	$< 20 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$	$52 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$
LMA neutrino oscillation (Ando et al., 2002)	$3.5 \frac{\text{events}}{\text{year } 22.5 \text{ kton}}$	$< 1.2 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$	$< 31 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$	$11 \frac{\bar{\nu}_e}{\text{cm}^2 \text{ sec}}$

M.S. Malek et. al, Phys. Rev. Lett. 90, E-ID 061101 (2003)

UNO at 4000 mwe can rule out all models within 3~5 years or discover SNR

Very Long Baseline Neutrino Oscillation Experiment

$$\nu_\mu \leftrightarrow \nu_e$$

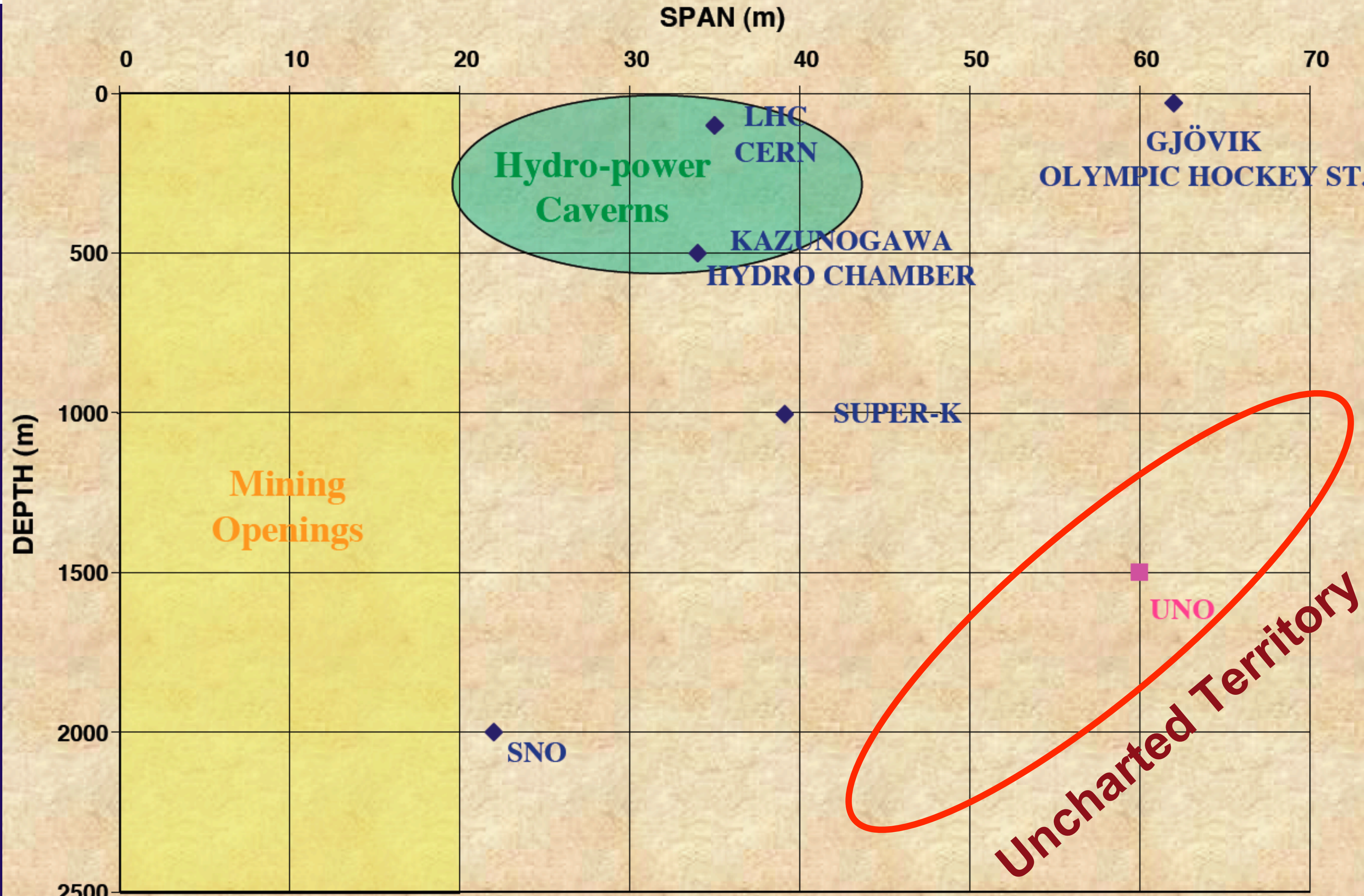


Measure θ_{13}, δ_{CP} and sign of Δm_{23}^2

How big a cavern can we construct underground?
A challenge to the mining engineering community

Possible application in the future:
Large underground facility/storage
Large underground living space

Bench Marking
(P. Varona, Itasca)



P5 Questions

Q2: It has been suggested that instead of DUSEL we should use SNOlab combined with a medium depth (and much less expensive) lab in the U.S. The combination of the two might be adequate for the set of physics experiments we might want to perform. Please tell us why DUSEL is preferred to this scenario.

– An answer will be provided at the meeting.

Summary

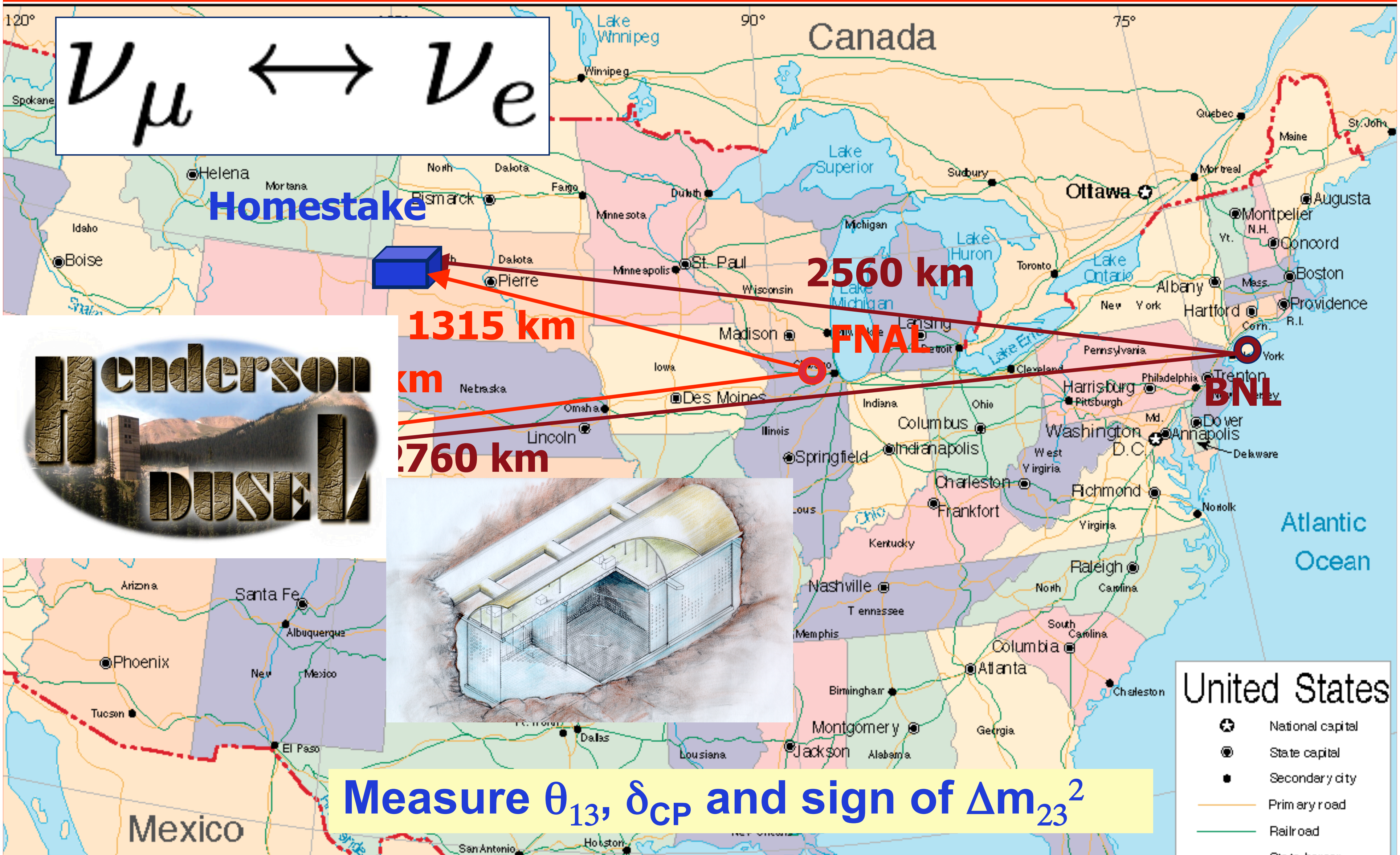
- A National Deep Underground Science and Engineering Lab will house experiments that tackle some of the most important science questions today with potential of major discoveries
  - One of the few hopes for the future of particle and astro-particle physics community
  - DUSEL provides a 4-D observatory for the geo/bioscience community: large scale (km^3) and long term (multi-decade)
  - DUSEL with a truly next generation Large Multi-purpose Detector and a neutrino superbeam will allow US to lead the world community

    $\Rightarrow$ a Unique Facility

- The Henderson Mine presents the best (practical, cost-effective and non-controversial) site for DUSEL
- Operating mine provides vast amount of advantages for DUSEL construction and operation

Beautiful Vision

$$\nu_\mu \leftrightarrow \nu_e$$



Measure θ_{13}, δ_{CP} and sign of Δm_{23}^2

The End