DUSEL

(U.S. Deep Underground Science and Engineering Lab)

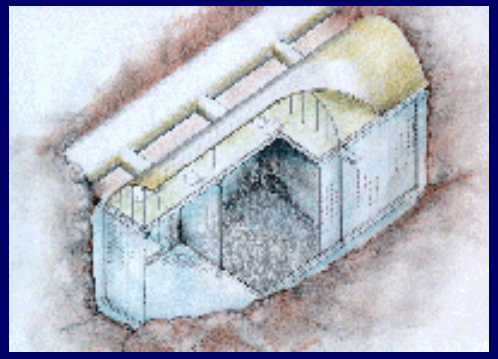
and

UNO

(Underground proton decay and Neutrino Observatory)

Jeffrey Wilkes
U. of Washington, Seattle

KEK
1 Nov 2005



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

http://ale.physics.sunysb.edu/uno/

Outline

- DUSEL in USA
- DUSEL @ Henderson Mine (Colorado)
- UNO, and where it could go
  - Overview
  - Physics goals, briefly
  - Neutrino beams to UNO?
  - Outreach and education

DUSEL: Deep Underground Science and Engineering Lab

- A long-standing dream in USA! e.g., see

PROPOSAL FOR A NATIONAL UNDERGROUND SCIENCE FACILITY.
By Alfred K. Mann (Pennsylvania U.). Presented at Workshop on Science Underground, Los Alamos, N. Mex., Sep 27 - Oct 1, 1982. Published in **AIP Conf.Proc.96:16-36,1983**

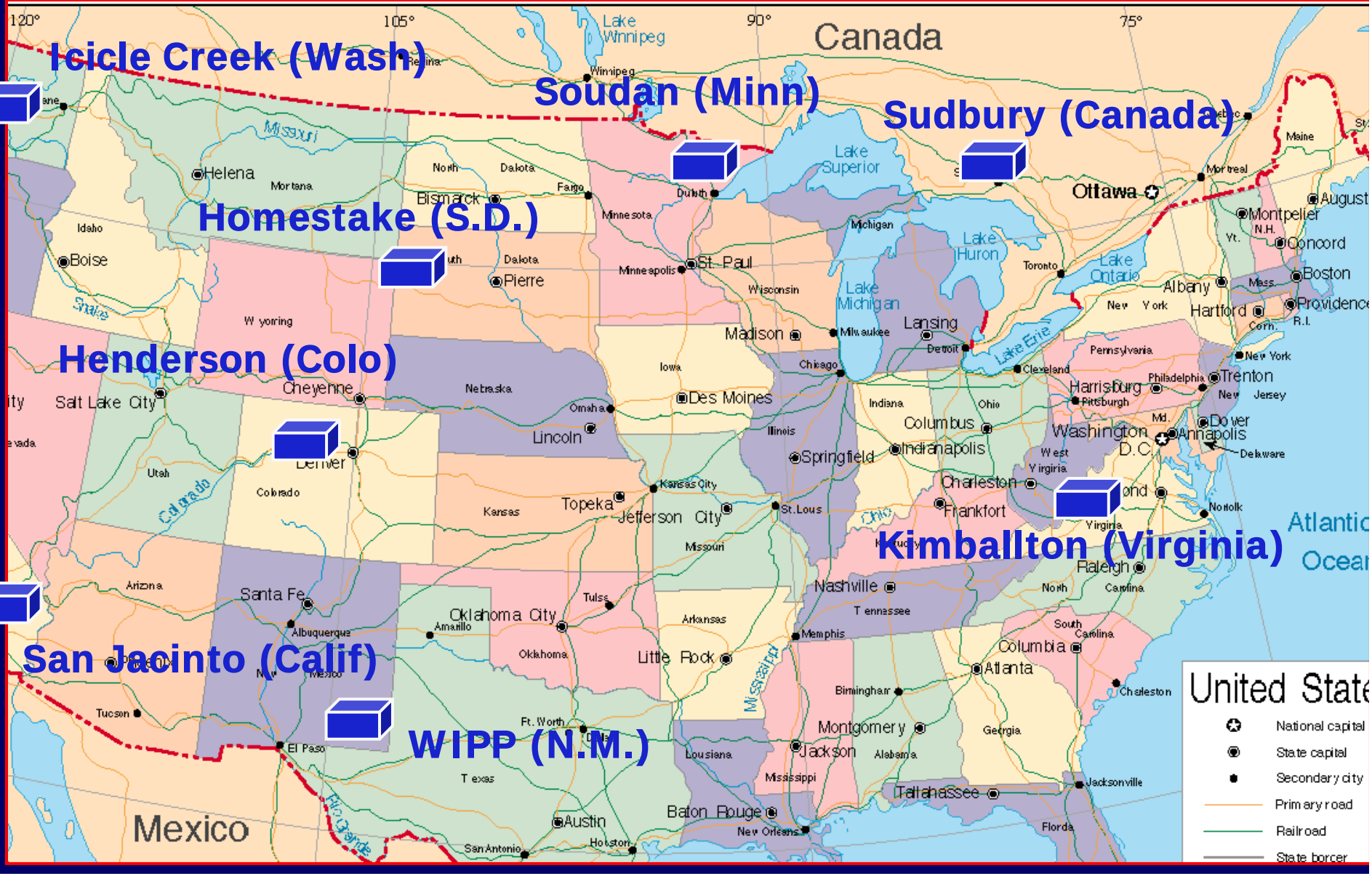
- Initiative by US National Science Foundation (NSF)
  - Create a new national lab for underground science
  - Supports research on physics, geology, biology (life in extreme environment), mine/tunnel engineering
- 2nd (recent) attempt to do this!
  - 2003: Bahcall and Haxton led "NUSEL" process
    - Conclusion: Homestake mine is best site
      - But: many thought selection process was biased
    - South Dakota government failed to act promptly – mine was sold to company in Canada, closed, and allowed to flood!
      - Estimated cost to restore = $50 million

U.S. DUSEL process now

- Solicitation 1 (2004): Define requirements for *potential* underground experiments in physics, geosciences, biology, & engineering
  - 14 working groups established
  - Meetings and workshops (too many!): final report due soon
- Solicitation 2 (2005): Different sites respond: conceptual designs for DUSEL
  - Proposals from sites in California (San Jacinto), Washington (Icicle Creek), Minnesota (Soudan), and several others
  - Two finalist sites: Homestake Mine and Henderson Mine
  - Funding of 0.5M$ each provided to prepare proposal
- Solicitation 3 (2006): submit construction proposals
  - final choice of site in late 2006 ?

Work on S-2 is going on NOW!

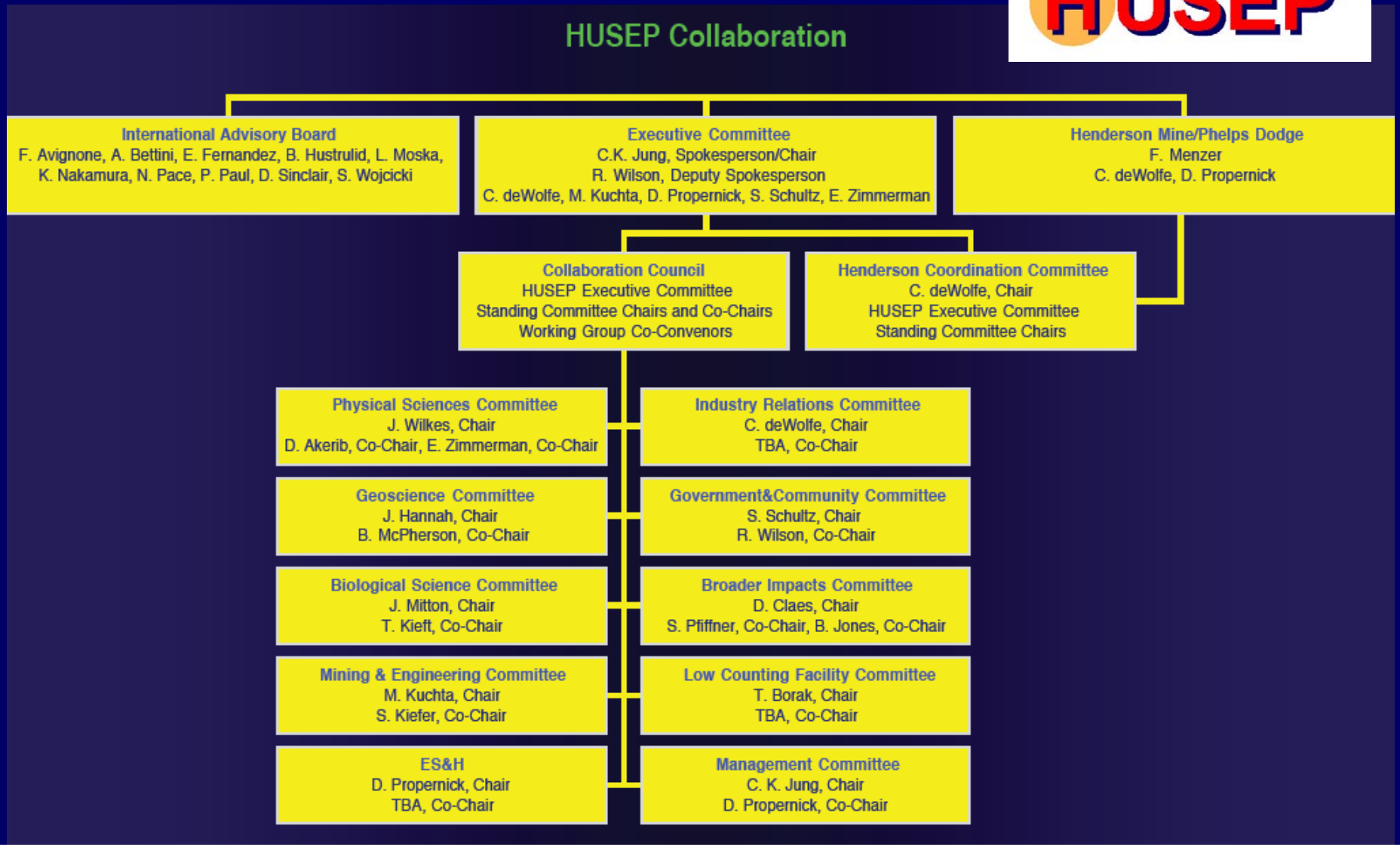
DUSEL Candidates: first round (2004)



DUSEL Candidates: July, 2005

Henderson Underground Science/Engineering Project

- HUSEP = Colorado's team



Henderson Mine (near Denver, Colorado USA)

Using site details for simulations and proposal

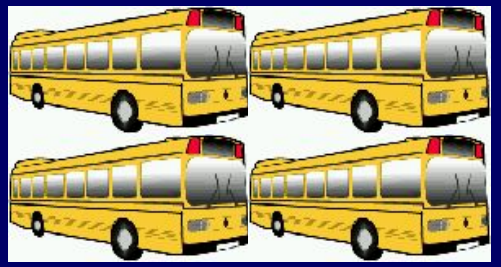
- Working molybdenum mine; 150M$ modernization completed in 2000
- Easily accessible; near expressway, roads kept clear in winter
- Near major urban/industrial area and airline hub
  - < 1.5 hr drive from Denver International Airport
  - Nearby research infrastructure, institutes and universities:

    U. Colorado, NIST, Colorado State U., Denver U., USAFA, Colorado College, Aspen Center for Physics
  - Direct flights to cities around the world

Henderson Mine, Empire, Colorado

Henderson Mine

- Owned by Climax Molybdenum Company, a subsidiary of Phelps Dodge Corporation
- Opened in 1970's
  - modern mine, developed under strict environmental and safety regulations: company just spent $150M updating
- Mining molybdenum (Mo) ore, by 'Block Caving'
- Huge elevator/hoist for vertical access
  - 8.5 m diameter shaft with with two hoisting compartments
  - Elevator: 7m long X 2.5m wide X 4m tall, 50 tons capacity
    - Can carry a ship container
    - Or 200 people…



- Now:>1000m deep, minimum overburden ~3000 mwe
  - Can go deeper…

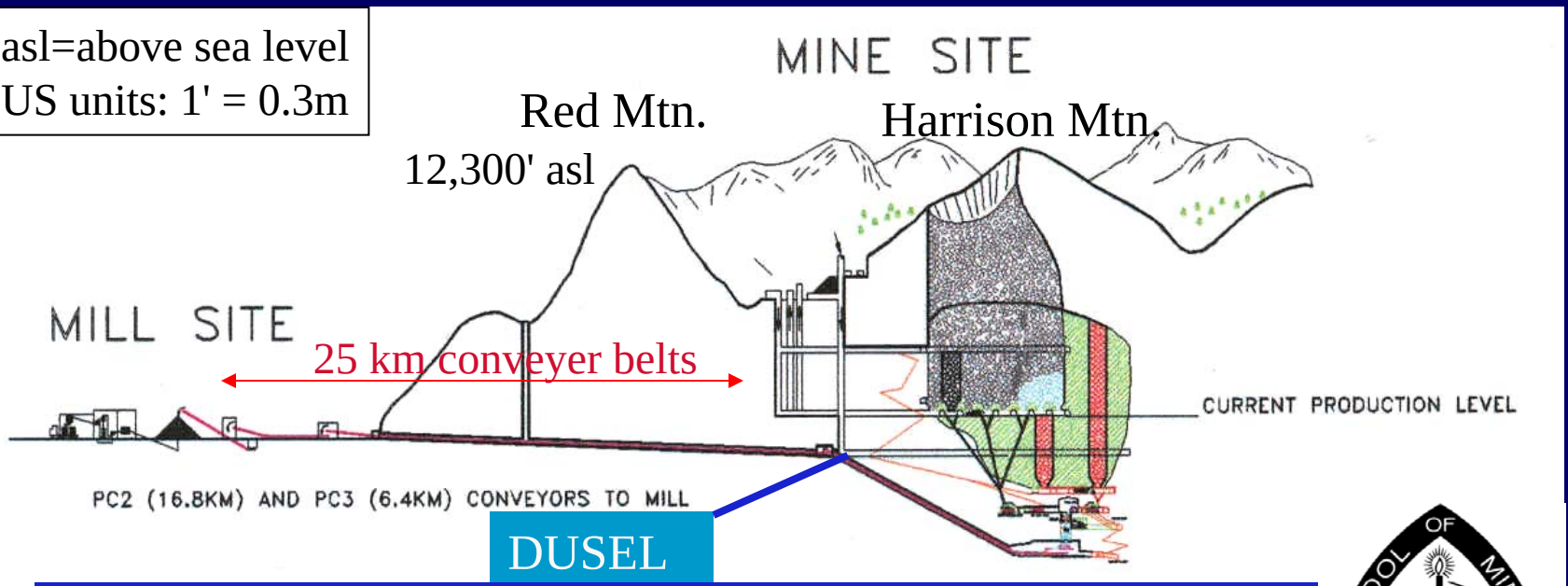
Elevator and office space

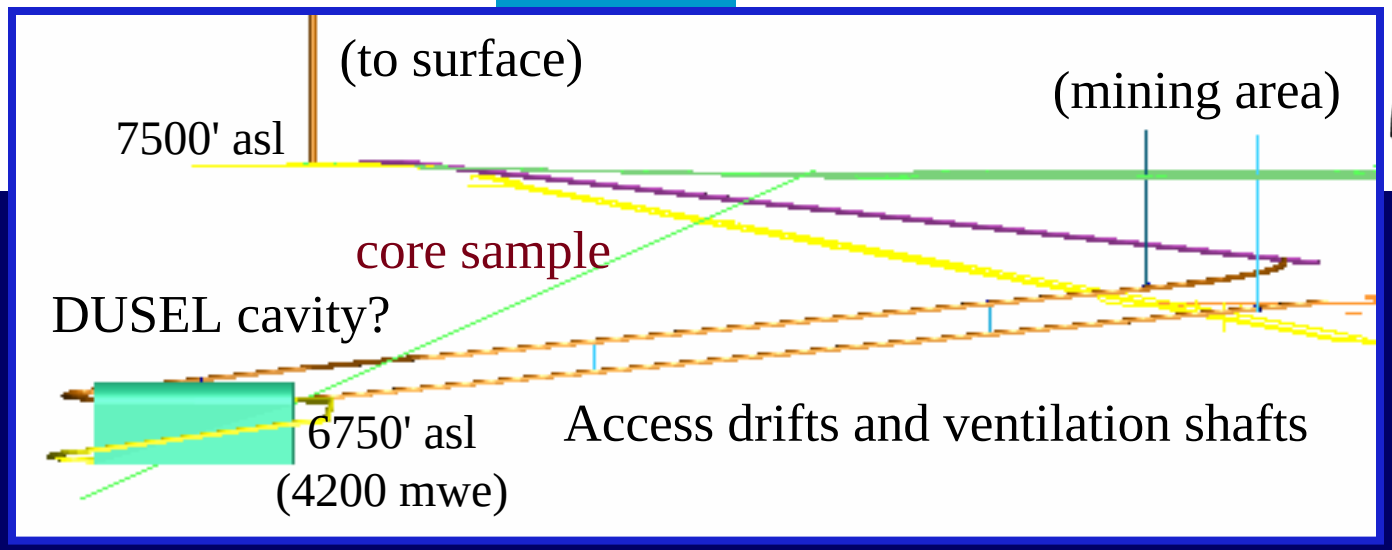
Surface buildings

[Thanx to R. Wilson for photos]

Excellent DUSEL Site

asl=above sea level
US units: 1' = 0.3m





Colo. School of Mines = engineering university near Denver

Henderson Mine parameters

- Excavation Capacity: ~40,000 - 50,000 ton/day
  - Actual operation: ~20,000 - 30,000 ton/day
    - under-utilized capacity
- 15km tunnel with high speed conveyor and train track
  - Conveyor belt: 50kton/day max capacity, 20kton/day normal operation
- Electric power station: 2 x 30 MW
- Rock disposal site (approved) with huge capacity
- Large office buildings and warehouses
- Anticipated mine closing in 10~20 years
  - Mine Co. and local politicians see underground science as way of retaining employment, revitalizing local economy, etc
  - Local residents are supportive: most are miners!

Henderson: Big toys for big boys (and girls) !

10 ton underground loader.

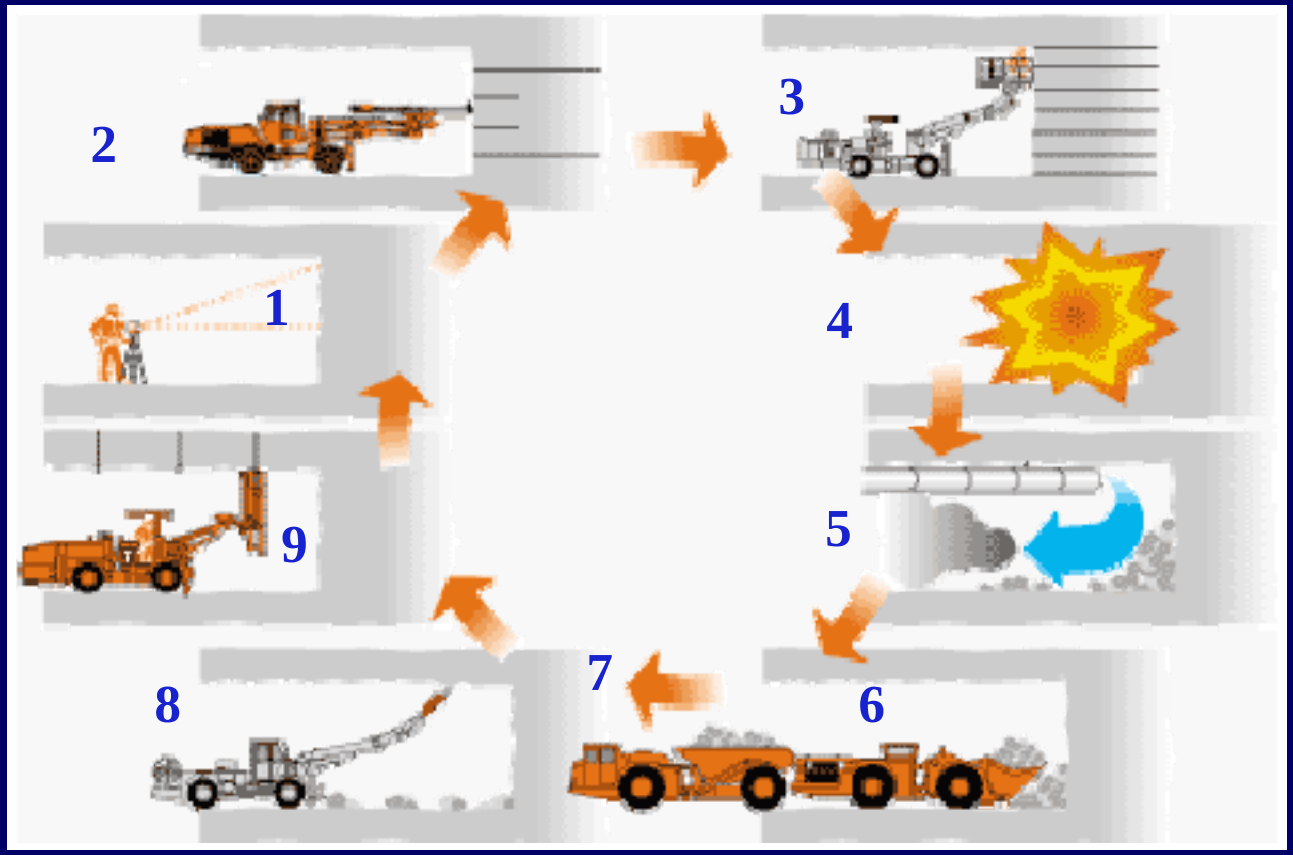
80 ton side-dump truck.

Jumbo Boom Drill

Mining @ Henderson: how to make tunnels cheaply

Basic drilling cycle for drill and blast tunneling:

1. Survey and setup
2. Drilling
3. Charging
4. Blasting
5. Ventilation
6. Scaling
7. Mucking
8. Scaling
9. Bolting

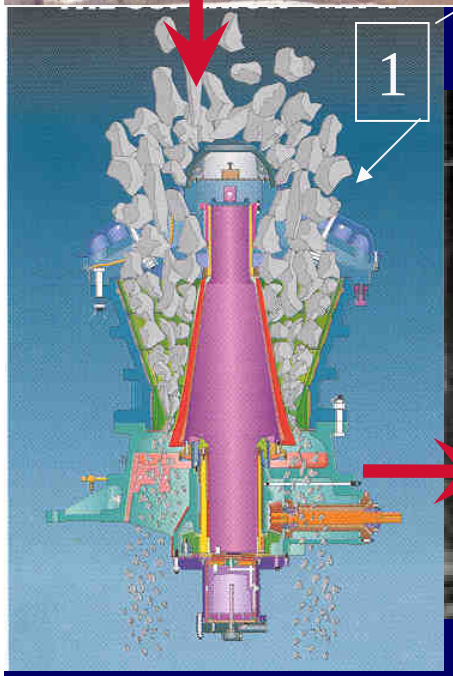


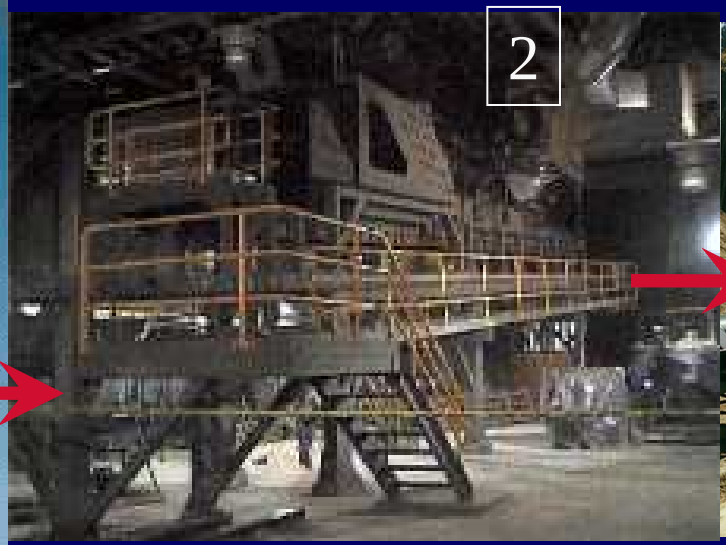
Gigantic Rock Handling/Removal System

1. 80 ton trucks dump rock at crusher.
2. 17 km underground conveyors belts remove rock.
3. 7 km surface conveyor to mill site.

40~50 kton/day capacity

Cheapest excavation cost: ~ $60/ton





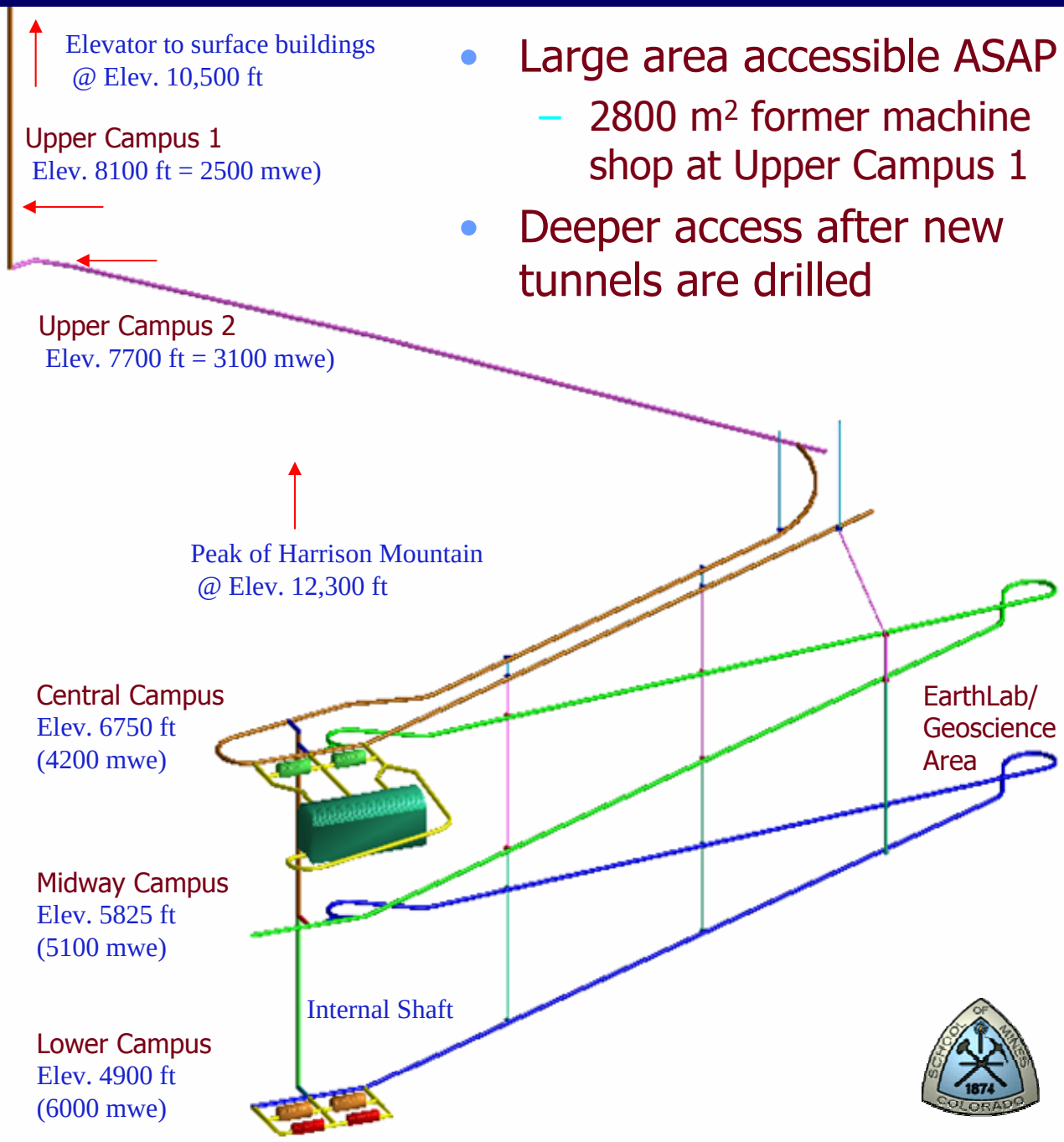
Conveyer belts total 25 km

Ore conveyer tunnel can give horizontal access after mining is finished

Last year: core sample from DUSEL area

- Universities and Colorado government funded exploratory core drill into the proposed DUSEL site
  - 750 m long, inclination of 26 degrees, right through proposed Central Campus area
- Results = good news:
  - 'Extremely competent' porphyry (granite)
  - Very hard with a high percentage of quartz.
  - Expected to have high compressive strength
  - 'No evidence of mineralization'
- No Mo: company won't want to mine here!
  - No problem foreseen for constructing DUSEL

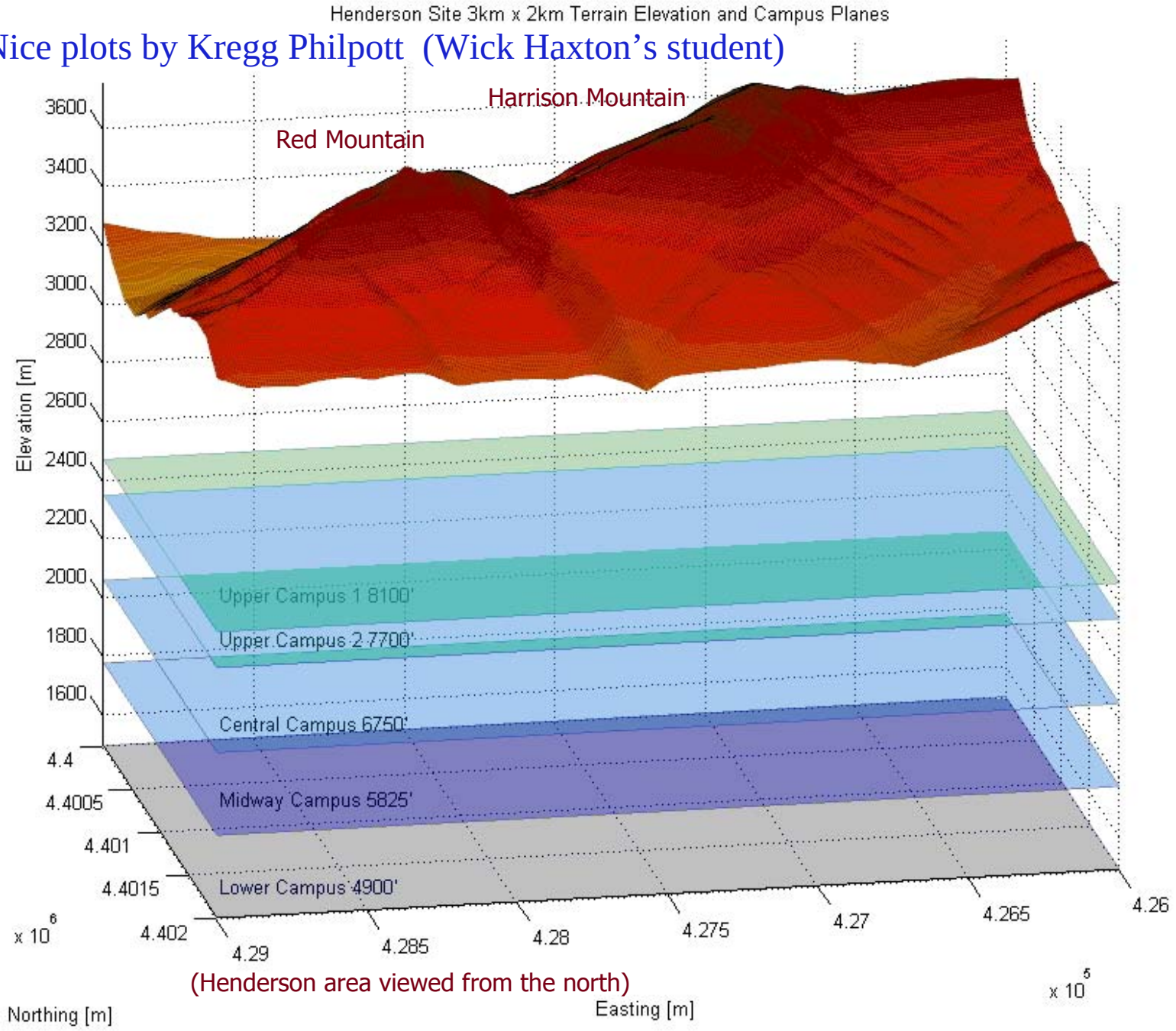
- Large area accessible ASAP
  - 2800 m^2 former machine shop at Upper Campus 1
- Deeper access after new tunnels are drilled



Experimental areas

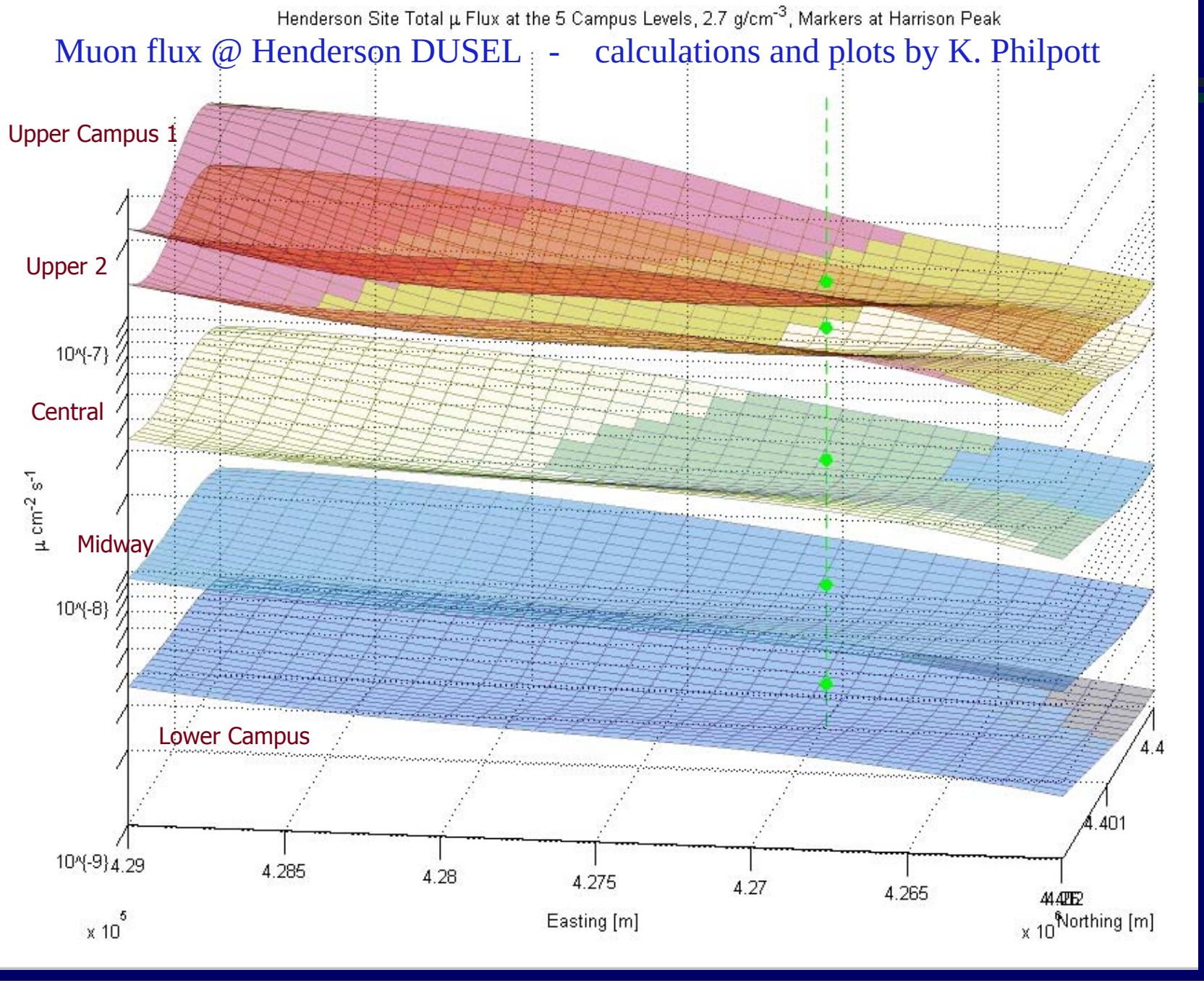
- Upper campus
  - Old company machine shop (32k ft^2 area) at UC-1 level (8100' asl, 2500 mwe) can be ready for experiments within a few months, at cost of 100K$
  - Slightly deeper UC-2 (7700' asl, 3100 mwe) also possible quickly
- Central Campus
  - 6750' asl, 4200 mwe overburden
  - Accessed by new ramps from existing shaft area, ~2 years
  - Several large, multipurpose rooms (~20x20x100 m^3)
  - Natural location for megaton-scale proton decay/neutrino detector UNO (not part of official DUSEL scope)
- Possible: Midway Campus at bend in access tunnels
  - 5800' asl, 5100 mwe overburden
- Lower Campus
  - 4900' asl, 6000 mwe overburden
  - In ~5 years: several rooms sized ~20x20x50 m^3
  - For projects requiring lowest background
    - double-beta decay, dark matter, solar neutrinos
  - Second core drill in planning stage, to confirm geology

Nice plots by Kregg Philpott (Wick Haxton's student)

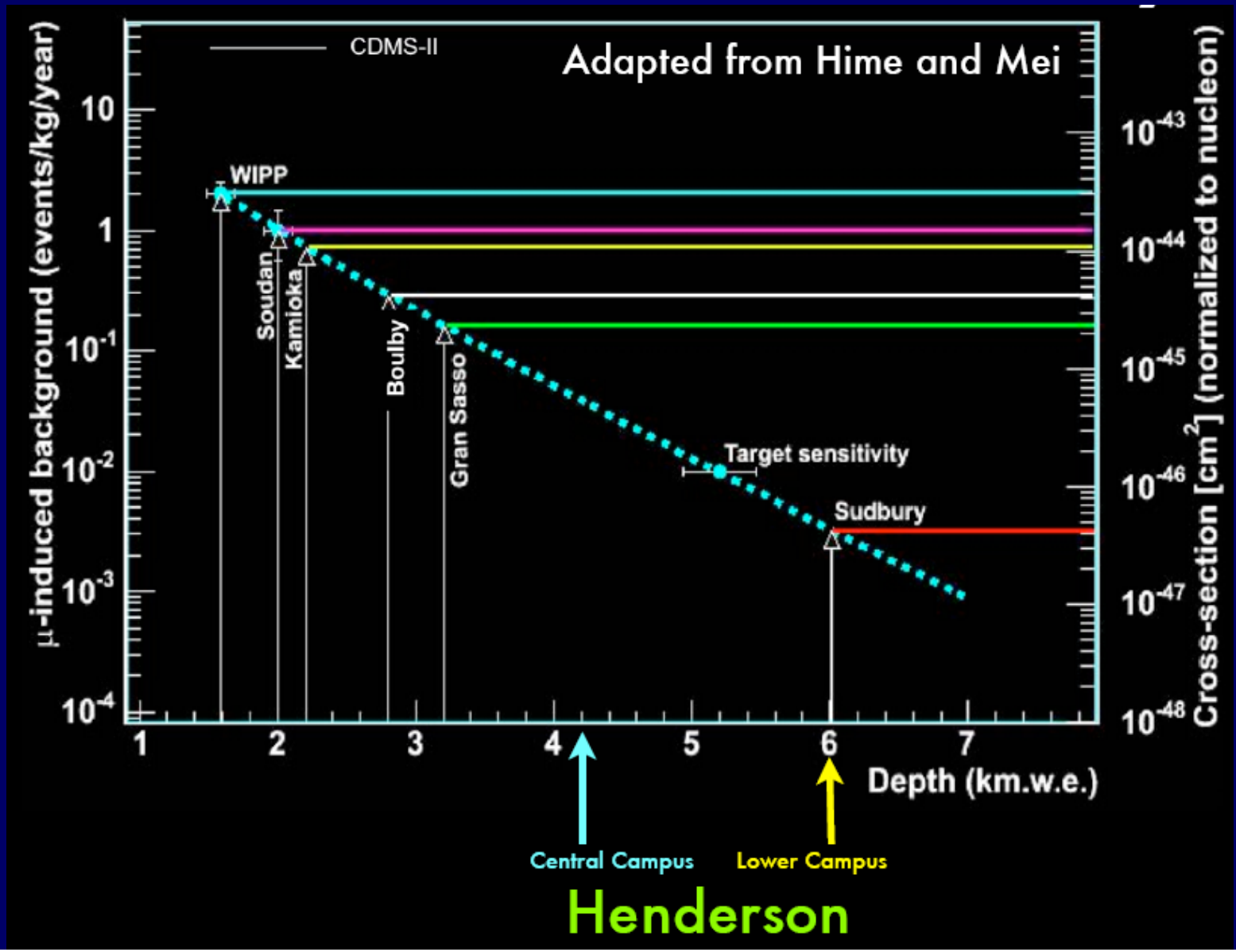


(Henderson area viewed from the north)

Muon flux @ Henderson DUSEL - calculations and plots by K. Philpott



Compare Dark Matter Sensitivity to other mines:



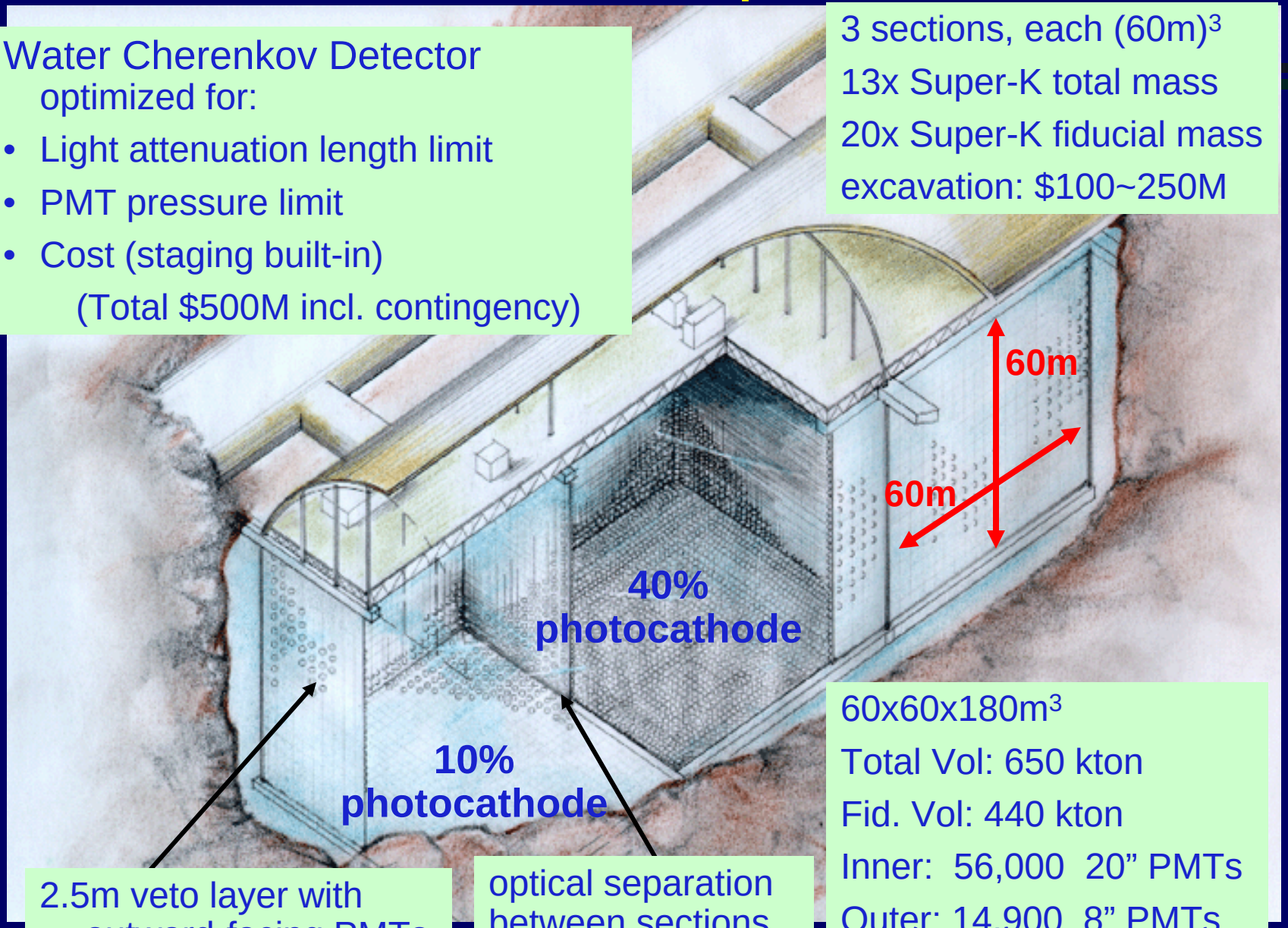
UNO Detector Concept

Water Cherenkov Detector
optimized for:

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

(Total $500M incl. contingency)

3 sections, each $(60m)^3$
13x Super-K total mass
20x Super-K fiducial mass
excavation: $100~250M



2.5m veto layer with
outward-facing PMTs

optical separation
between sections

$60x60x180m^3$
Total Vol: 650 kton
Fid. Vol: 440 kton
Inner: 56,000 20” PMTs
Outer: 14,900 8” PMTs
Detector cost: $250M

Salient features

- ~ 20X Super-K fiducial mass
- Build on well-known water Cherenkov techniques
  - Significant new detector development not *required*
    - Cost estimates can be made with reasonable confidence, BUT
    - Detector R&D may reduce costs significantly
- Site independent proposal!
  - Henderson Mine site would be ideal, but…
  - More or less independent of DUSEL site selection process
    - DUSEL will not include funding for UNO anyway
  - Physics goals can be met at any site with $\geq$3000 mwe depth

UNO Collaboration: 98 members, 40 institutes

ANL	GRPHE / UHA - Mulhouse, France	LANL	SUNY at Stony Brook
Maury Goodman	Yann Benhammou	Todd J. Haines	Marcus Ackerman
D. Reyna	Gyeongsang National Univ., Korea	Louisiana State Univ.	John Hobbs
R. Talaga	S. H. Kim	Bob Svoboda	Chang Kee Jung
J. Thron	I. G. Park	Univ. of Minesota, Duluth	Tokufumi Kato
BNL	C. S. Yoon	Alec Habig	Dan Kerr
Milind Diwan	Indiana Univ.	Univ. of Minesota, Minneapolis	Kenkou Kobayashi
Maurice Goldhaber	Rick Van Kooten	Marvin Marshak	Matthew Malek
Dick Hahn	INFN-Napoli	Earl Peterson	Bob McCarthy
Brett Viren	Vittorio Paladino	Univ. of Nebraska	Clark McGrew
Minfang Yeh	INFN-Padova	Dan Claes	Michael Rijssenbeek
Caltech	Mauro Mezzetto	NHMFL	Antony Sarrat
Christopher Mauger	INR (Institute for Nuclear Research), Rusia	John Miller	Ryan Terri
Univ. of California, Davis	Leonid Bezrukov	Univ. of New Mexico	Chiaki Yanagisawa
Daniel Ferenc	Anatoly Butkevich	Sally Seidel	IRES / ULP - Strasbourg, France
California State Univ., Dominguez Hills	Marat Khabibullin	Northern Illinois Univ.	Chantal Racca
Ken Ganezer	Yury Kudenko	Gerald C. Blazey	Jean-Marie Brom
Jim Hill	Stanislav Mikheyev	Dhiman Chakraborty	Tuft Univ.
Bill Keig	Iowa State University	David Hedin	Tomas Kafka
Univ. of Cantania, Italy	Jim Cochran	Northwestern Univ.	Tony Mann
Renato Potenza	Univ. of Kansas	Heidi Schellman	Univ. of Utah
Colorado School of Mines	Phil Baringer	Okayama Univ., Japan	Kai Martens
John Fanchi	Dave Besson	Makoto Sakuda	Warsaw Univ., Poland
Uwe Greife	Kansas State Univ.	Purdue Univ.	Danka Kielczewska
Murray Hitzman	Tim Bolton	Wei Cui	Univ. of Washington
D. Scott Kieffer	Eckhard von Toerne	John Finley	Rick Gran
Mark Kuchta	Ron A. Sidwell	Saclay, France	Jeff Wilkes
James McNeil	Noel Stanton	Jacques Bouchez	Tianchi Zhao
Fred Sarazin	KEK, Japan	Luigi Mosca	College of William and Mary
Colorado State Univ.	Taku Ishida	Francois Pierre	Jeff Nelson
John Holton	Kenzo Nakamura	Sejong University, Korea	WIPP
Jim Sites	Kyungpook National Univ., Korea	Yeongduk Kim	Roger Nelson
Walter Toki	Wooyoung Kim	Jungyeon Lee	Bill Thompson
Dave Warner	Vitaly Batourine	Jungil Lee	
Bob Wilson	Seungwook Jin		
	Dmitriy Nekrasov		

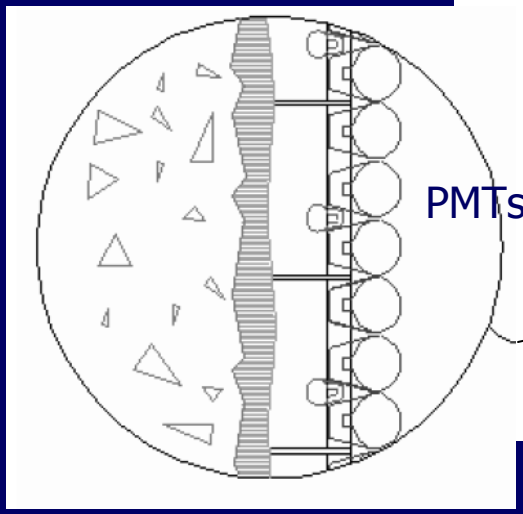
joined in past year

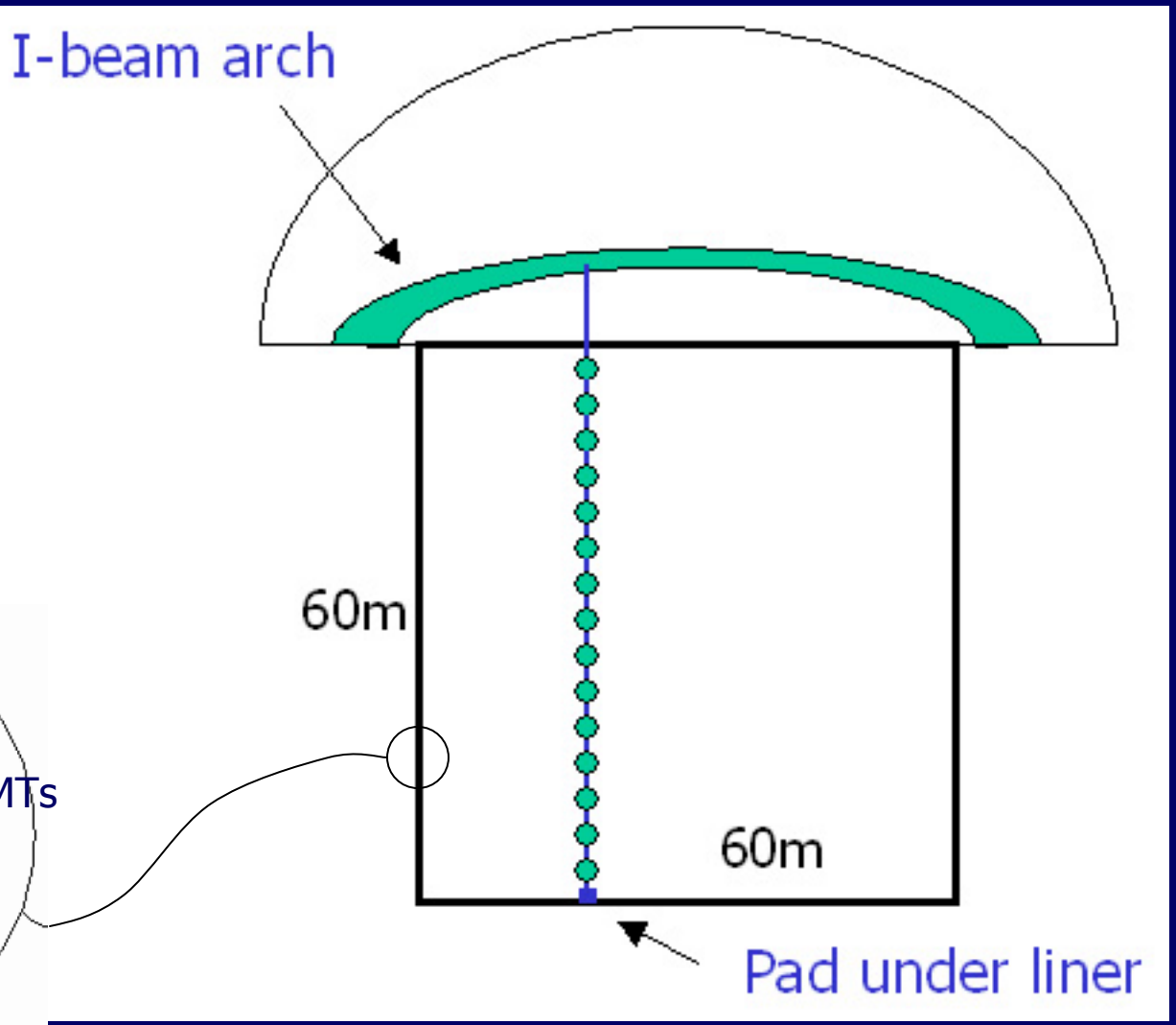
Advisory committees

- UNO advisory committee
  - Jacques Bouchez (Saclay)
  - Maury Goodman (ANL)
  - Tom Kirk (BNL)
  - Takahaki Kajita (ICRR)
  - Tony Mann (Tufts)
  - Kenzo Nakamura (KEK)
  - Masayuki Nakahata (ICRR)
  - Yoichiro Suzuki (ICRR)
  - Jeff Wilkes (U. of Washington)
  - Bob Wilson (Colorado State U.)
- Theoretical advisory committee
  - John Bahcall (IAS/Princeton)
  - John Beacom (FNAL)
  - Adam Burrows (U. of Arizona)
  - Maria Concepcion Gonzales-Garcia (Stony Brook)
  - Jim Lattimer (Stony Brook)
  - Bill Marciano (BNL)
  - Hitoshi Murayama (Berkeley)
  - Jogesh Pati (U. of Maryland)
  - Robert Shrock (Stony Brook)
  - Frank Wilczek (MIT)
  - Edward Witten (IAS/Princeton)

Tank liner and concept for PMT mounting

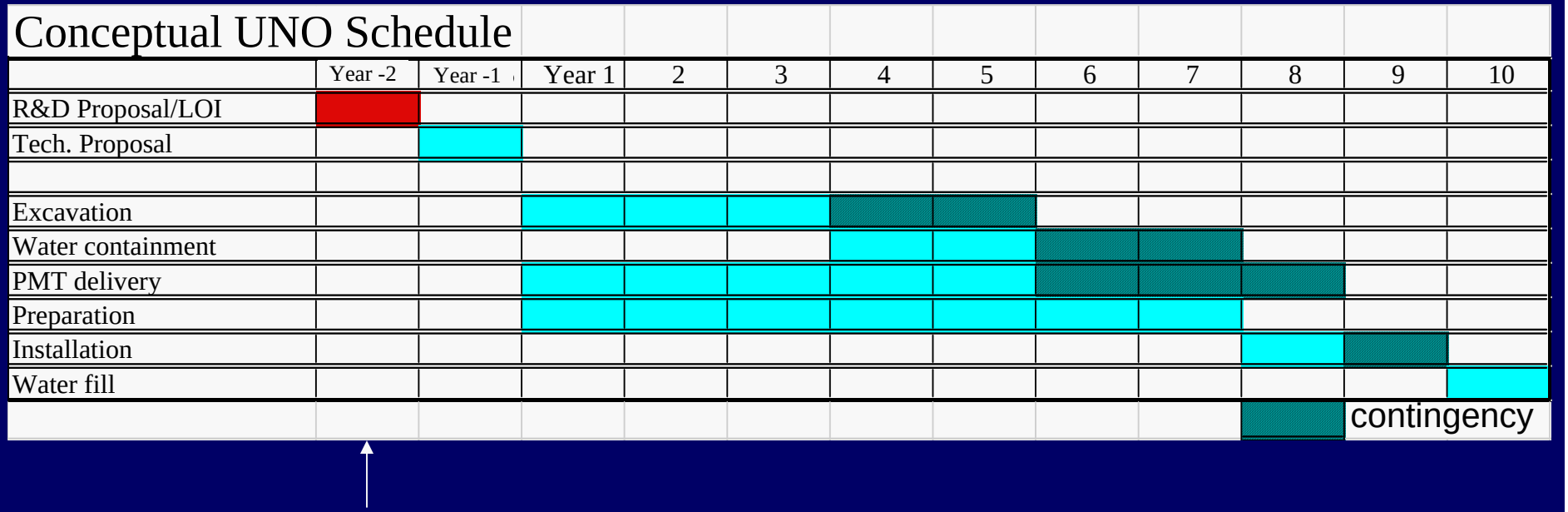
- Suspend strings of PMTs from 'strongback' beam
- Use standoff beams between strings and at walls, but no penetrators through tank lining
- Liner = multilayer plastic coating over concrete: waterproof + Rn barrier





(this and other ideas to be studied over next 2 years)

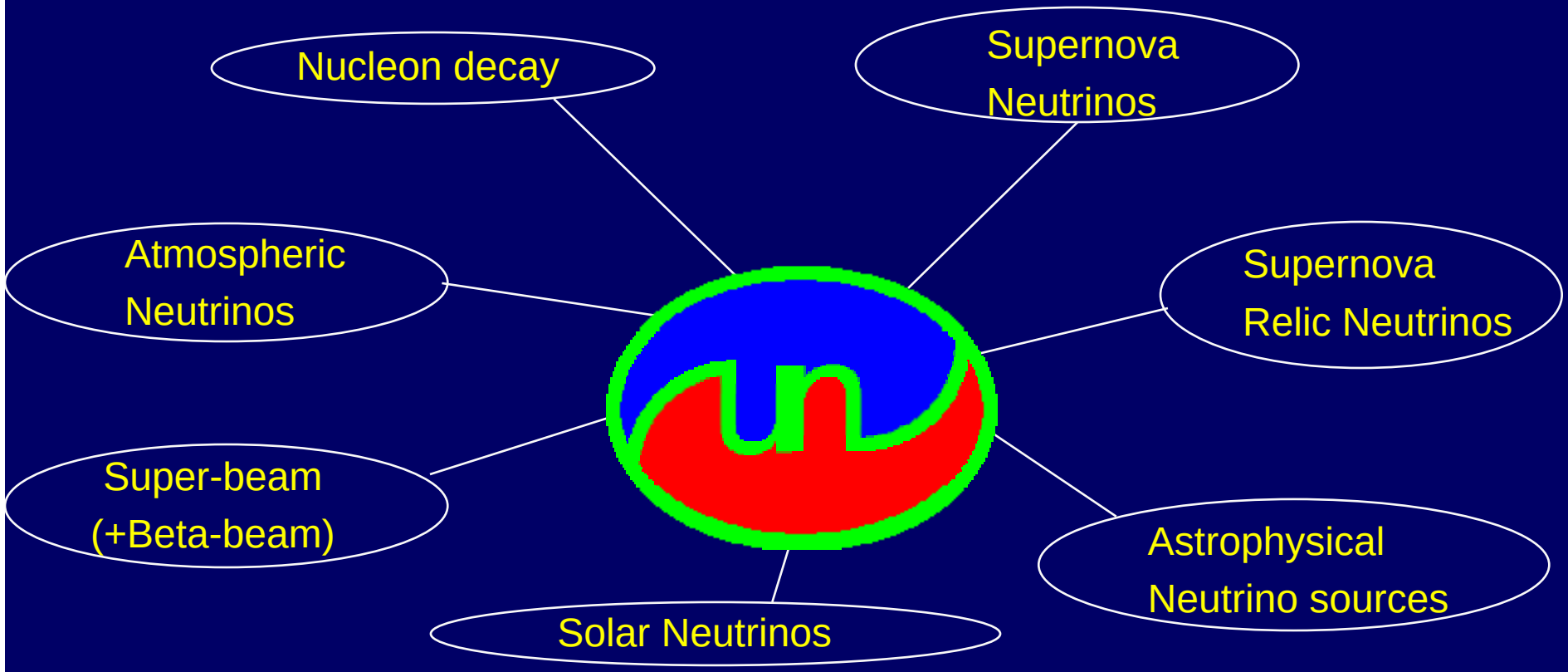
UNO Design and Construction Timeline



Two years of rigorous detector design needed

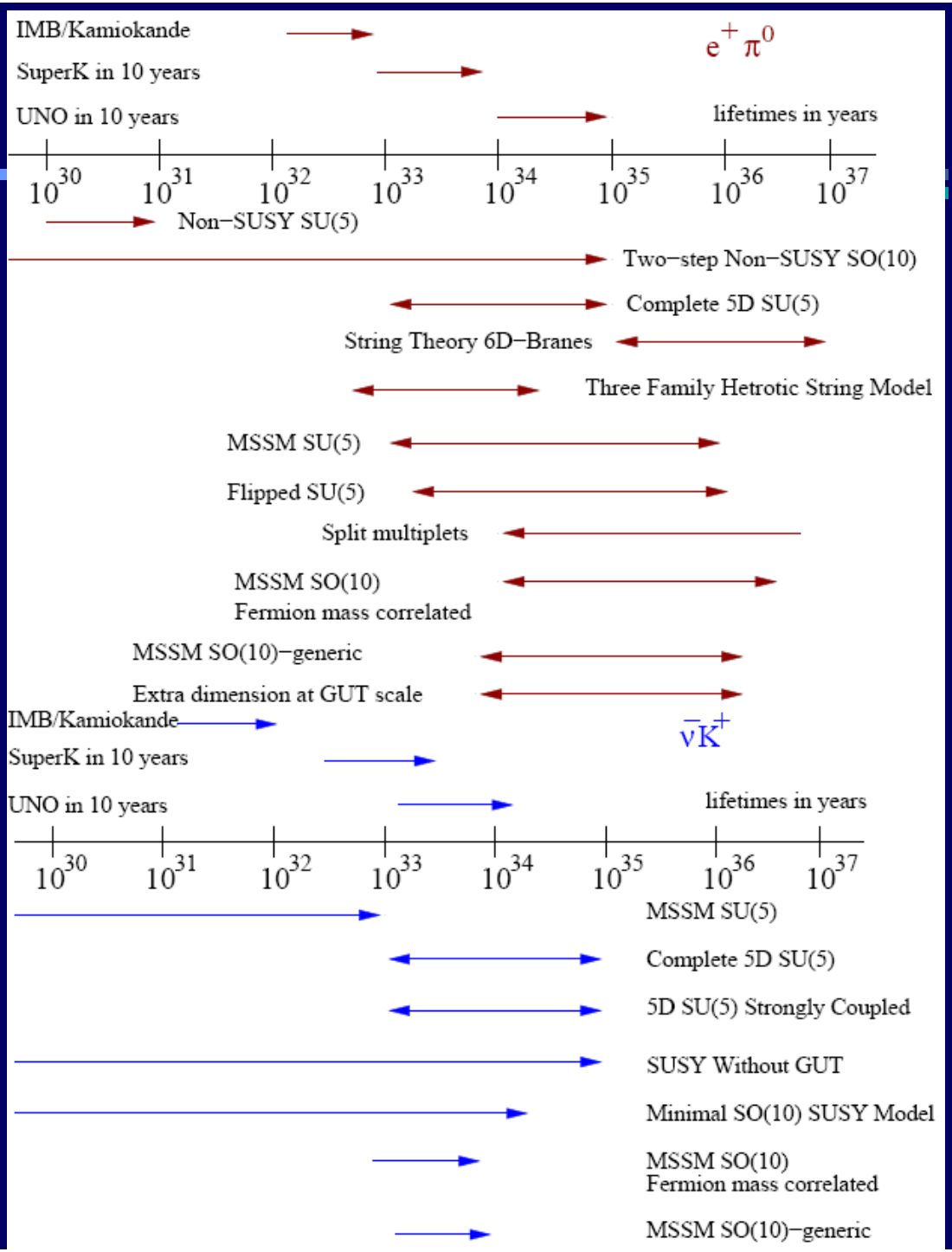
Proposal just submitted (10/05) for R&D funding

UNO Physics Goals



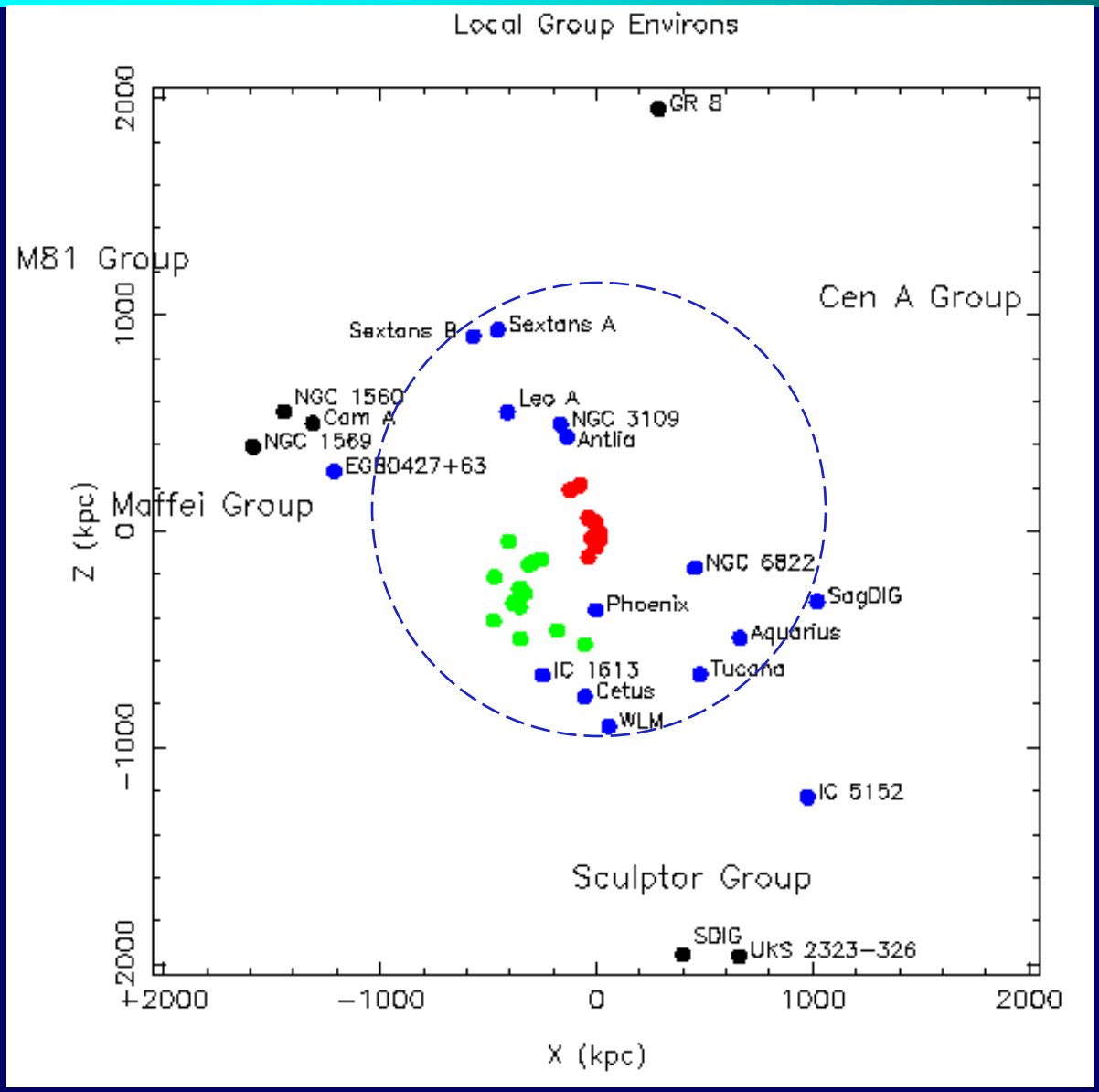
- Multi-purpose detector
- Comprehensive programs in astrophysics, nuclear and particle physics
- Synergy between accelerator and non-accelerator physics
- Nominal cost: ~$450M total (~$400M for site @ Henderson mine)

UNO Proton Decay Sensitivity



Need help from theorists to update this!)

Supernovae



UNO's Supernova Reach:

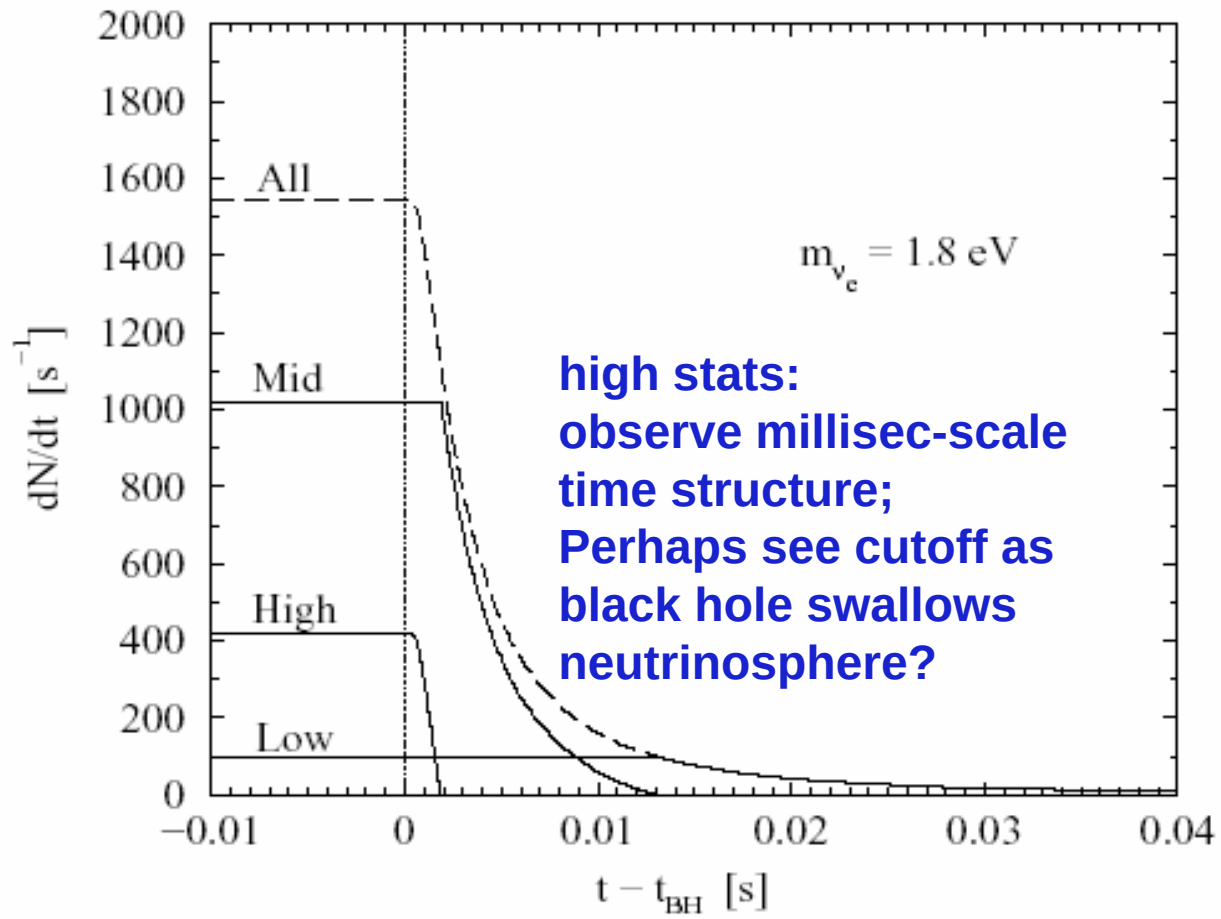
~ 1 Mpc (Local Group of galaxies)

Supernova Rate:

~ 1 per 10 ~ 15 yr

140K events for SN @ 10 kpc

Galactic Supernova



high stats:
observe millisec-scale time structure;
Perhaps see cutoff as black hole swallows neutrinosphere?

Beacom, Boyd and Mezzacappa

~140,000 events in UNO:

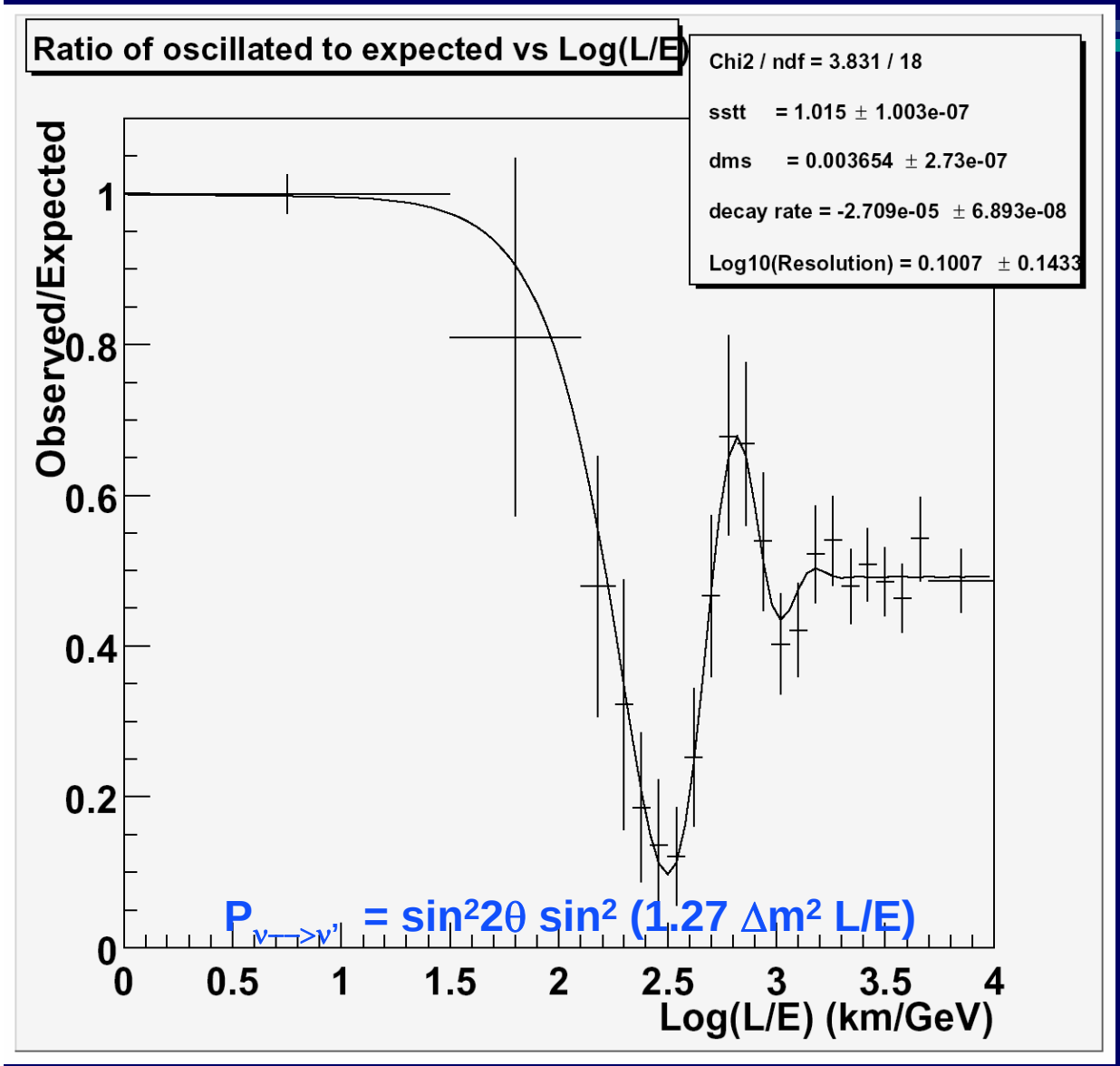
msec timing structure of the flux ⇒ Determination of core collapse mechanism

Possible Observation of Birth of a Black Hole via cutoff

Diffuse supernova relic flux

- Super-K limit (1.2 $\bar{\nu}_e$/cm^{2}s >19 Mev @ 90%CL) must be reduced by factor of ~6 to address all current predictions
- Can be reached by UNO in ~6 yrs @ 4000 MWE depth (longer if shallower)
  - Event rate 20~60 / year for 450 MT fiducial volume
  - BG-limited search

Direct Observation of Oscillatory Behavior in atm ν L/E



~7 years of UNO exposure ($\Delta m^2 = 0.003$ eV^2, $\sin^2 2\theta = 1.0$)

Cuts:

- 1 muon w/ E > 1GeV or
- E_{vis} (μ) > 0.5 E_{vis} (total)
- removal of horizontal events

DUSEL Candidate Sites and Potential VLBL/Superbeam Experiments

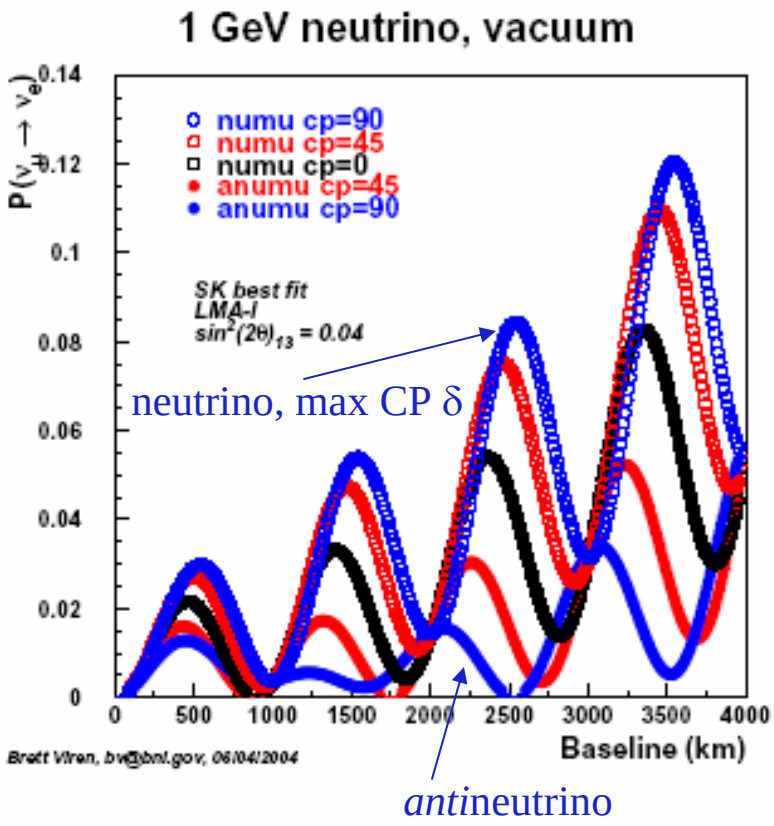
J. Wilkes, 1 Nov '05

Why VLBL?

- Marciano pointed out that for HE neutrino beams, 2nd and 3rd oscillation dips can be very handy...

Marciano (hep-ph/0108181):

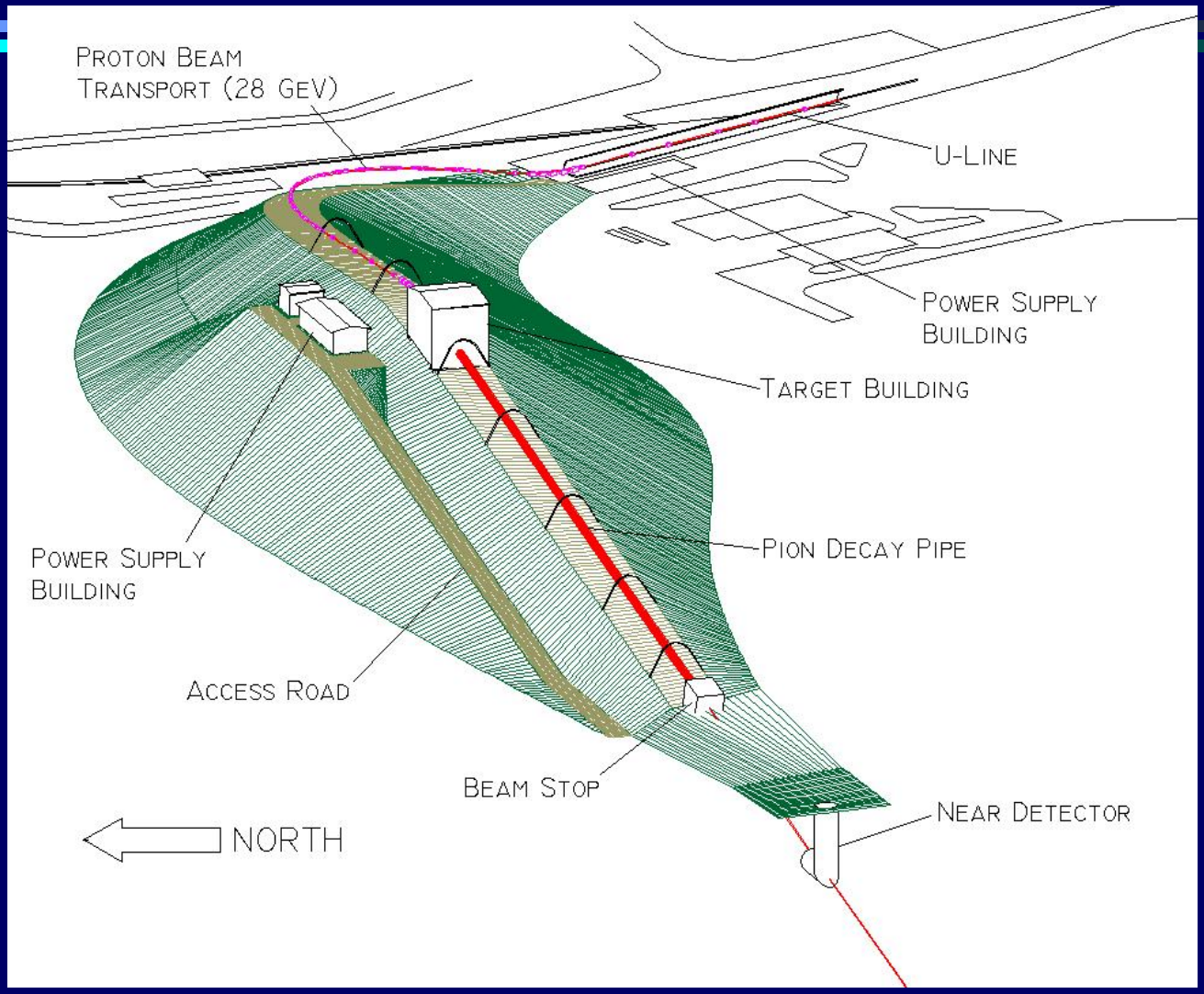
- Yes, statistics fall off with baseline $(1/L^2)$
- but, CP asymmetry grows with baseline (L)
- so, FOM $= A^2 N_\nu/(1 - A^2)$ is $\sim$constant



Message: don't be afraid to get high and go long!

M. Diwan, B. Viren

3-D Neutrino Super Beam Perspective



Now and near future

- UNO R&D proposal submitted to US DOE and NSF
  - UNO is still site-independent
  - Let's build it wherever we can!

- DUSEL @ Henderson Physics Workshop planned for Nov 18-19, 2005 at CSU, Ft. Collins, Colorado

See http://ale.physics.sunysb.edu/husep

and click on "Conferences and Workshops"

  - HUSEP Physics Committee (J.W. = chair)

Working groups:

- Neutrino mass (solar, 0νββ)
- Neutrino mixing (atm ν, LBL)
- Dark matter/nuclear physics
- Nucleon decay
- Astrophysics