UNO
(Underground Nucleon decay and Neutrino Observatory)

See UNO home page: http://ale.physics.sunysb.edu/uno/

Jeffrey Wilkes
University of Washington, Seattle

Neutrino Telescopes
25 Feb 2005

Outline

- Overview
  - what, who, how
- Physics goals, briefly
- Where UNO could go
- Neutrino beams to UNO
- Outreach and education
- DUSEL?

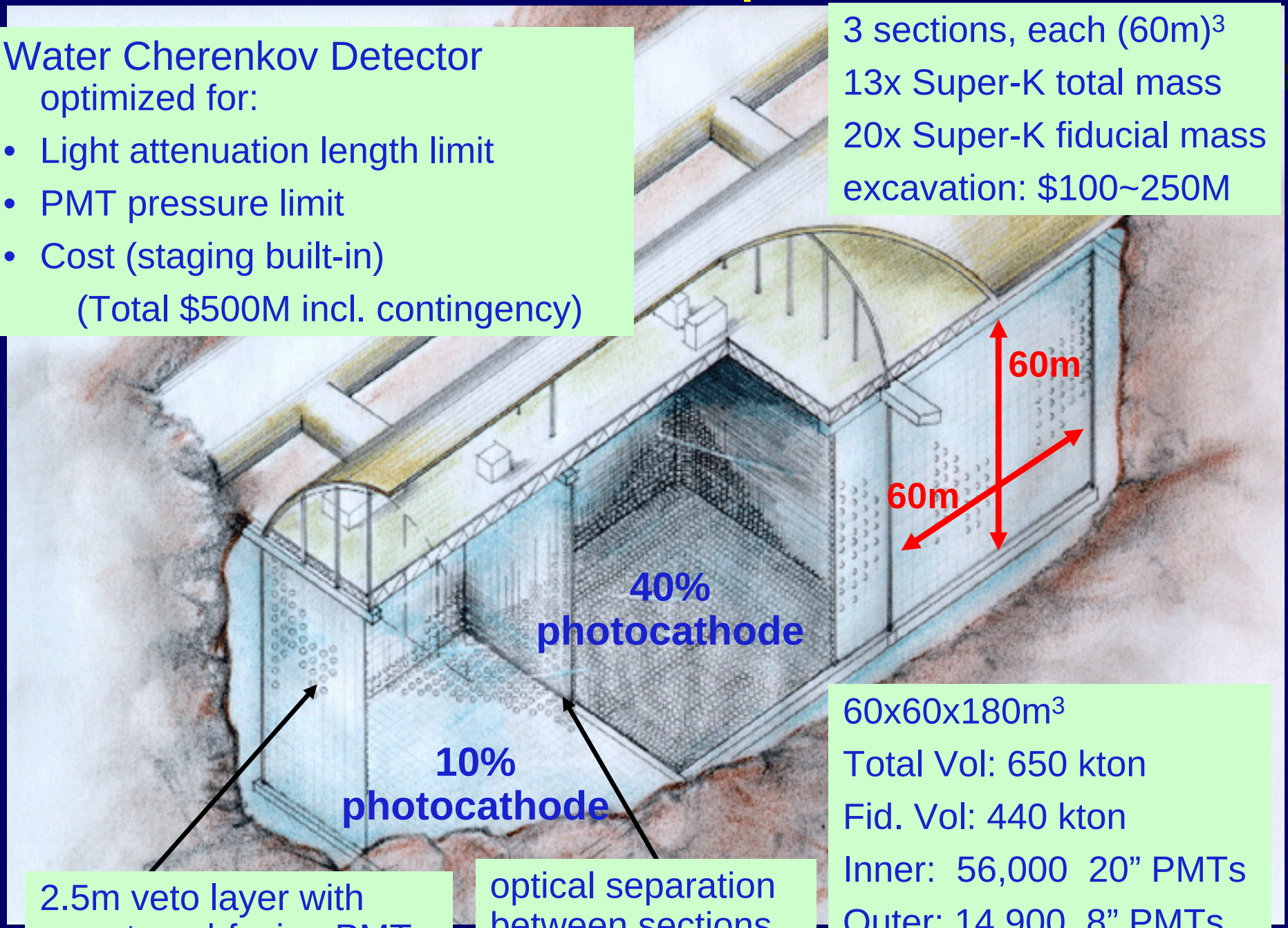
UNO Detector Concept

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!
  - Will use one potential site to illustrate numbers involved
  - More or less independent of DUSEL site selection process
    - Most proposed sites do not address megaton detector anyway
  - Physics goals can be met at any site with $\geq$3000 mwe depth

UNO Collaboration (4/04): 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)

HEPAP Facilities Committee (2003)

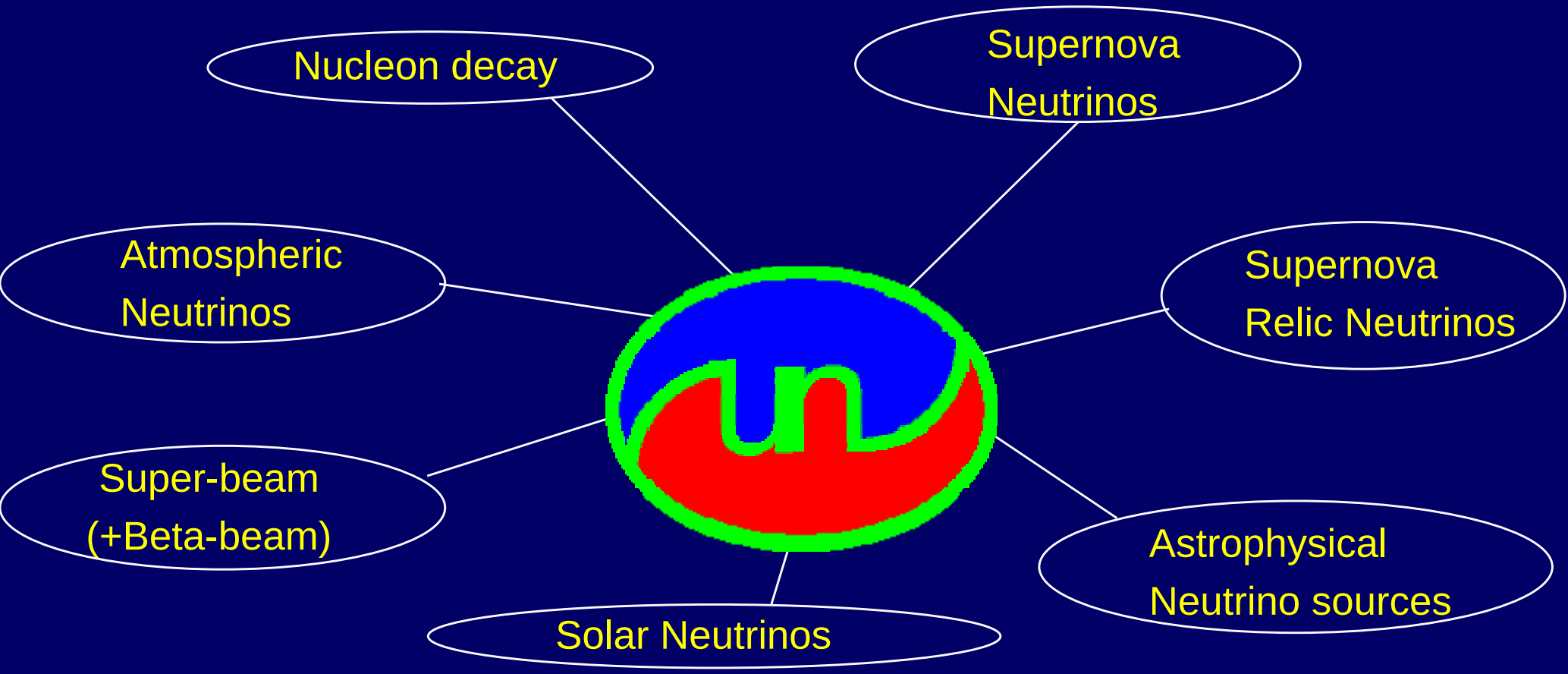
"Nice, but …?"

UNO

HEP Facilities Summary Table

Project	Type	Physics	Cost	Scientific Potential	Proposed Facility	State of Readiness	Possible Time Scale
Linear Collider	Facility	Energy Frontier	$5B – $7B	Absolutely Central	Absolutely Central	R&D	2015 Operation
LHC Luminosity Upgrade	Facility	Energy Frontier	$150M (US Part)	Absolutely Central	Absolutely Central	R&D	2014 Operation
LHC Energy Upgrade	Facility	Energy Frontier	Unknown	Don't Know Enough Yet	Don't Know Enough Yet	R&D	Decision in Next Decade
SNAP	Experiment	Cosmology	$400M – $600M	Absolutely Central	Absolutely Central	R&D	2009 Launch
BTEV	Experiment	Quark Physics	$120M	Important	Important	Ready for Decision on Construction	2008 Operation
CKM	Experiment	Quark Physics	$100M	Important	Important	Ready for Decision on Construction	2008 Operation
Super-B Factory	Facility	Quark Physics	Unknown	Don't Know Enough Yet	Don't Know Enough Yet	R&D	Decision Later This Decade
Double-Beta Decay	Experiment	Neutrino Physics	$100M	Absolutely Central	Don't Know Enough Yet	R&D	2005 Prototype
Off-Axis Neutrino Detector	Experiment	Neutrino Physics	$120M	Important	Important	Project Engineering and Design	2010 Operation
Neutrino Super Beam	Facility	Neutrino Physics	$250M – $500M (Accelerator and Beam Only)	Absolutely Central	Don't Know Enough Yet	Project Engineering and Design	Decision Later This Decade
Underground Detector	Facility	Neutrino Physics and Proton Decay	$500M	Absolutely Central	Don't Know Enough Yet	R&D	Decision Later This Decade
Neutrino Factory	Facility	Neutrino Physics	Unknown	Don't Know Enough Yet	Don't Know Enough Yet	R&D	Decision in Next Decade

UNO Physics Goals



- Multi-purpose detector
- Comprehensive programs in astrophysics, nuclear and particle physics
- Synergy between accelerator and non-accelerator physics
- Nominal cost: $500M total (for strawman site @ Henderson mine)

Recent Collaboration meeting (Oct 2004)

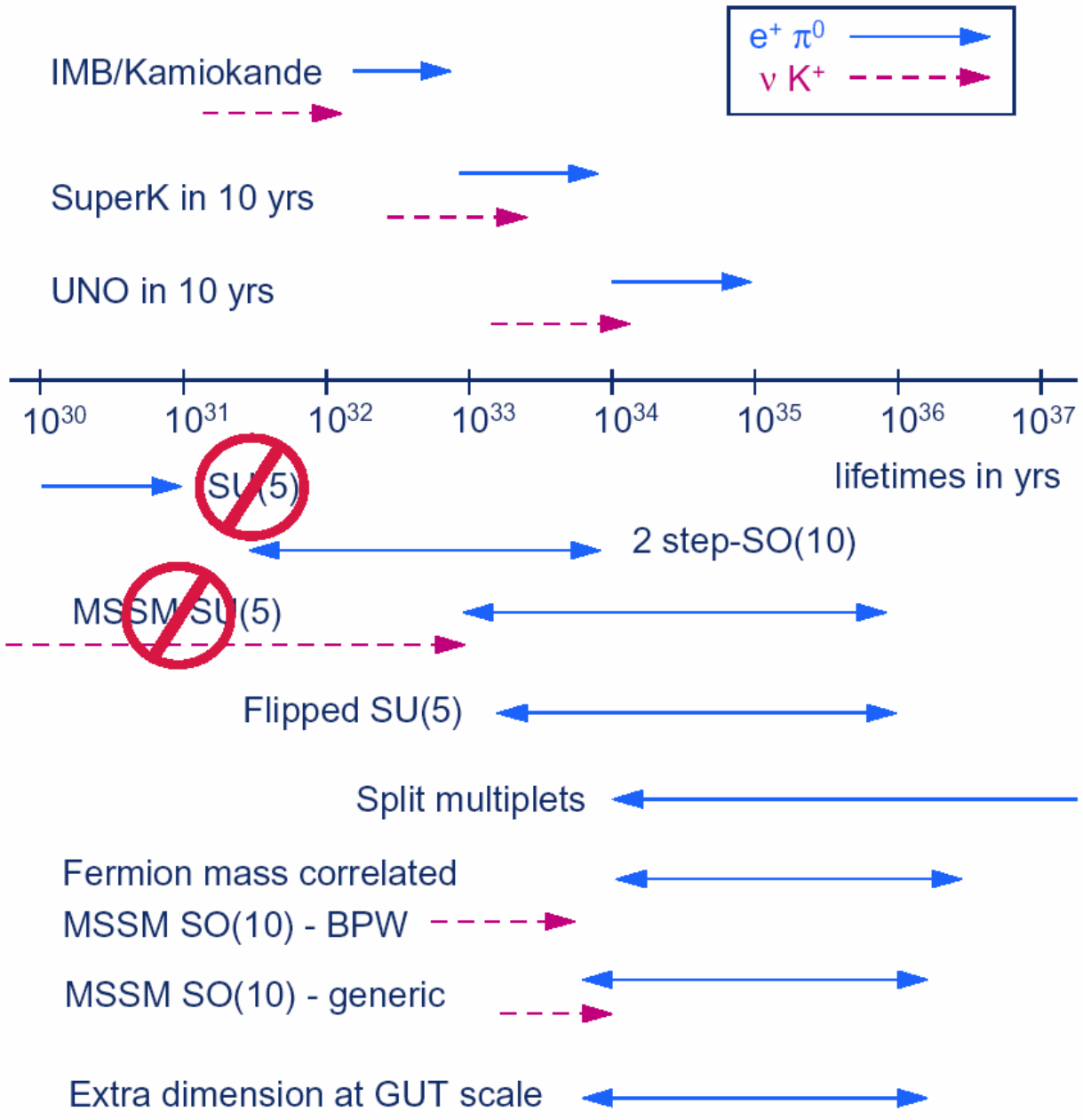
- Theorists interested in UNO physics lured to a special session organized by Ed Witten
- Goal: trick them into providing latest info needed for our R&D proposal (next slide)

Friday, October 15, 2004

Unification Day Workshop

		Chair: B. Marciano
08:30-09:00	Experimental Status of the Proton Decay Searches	C. K. Jung
09:00-09:30	Proton Decay In String/M-Theory Unification	E. Witten
09:30-10:00	Unification in String Theory	J. Maldacena
10:00-10:30	Splitting SUSY	S. Dimopoulos
10:30-10:45	Coffee Break	
		Chair: K. Babu
10:45-11:15	Three family models from the Heterotic string	S. Raby
11:15-11:45	No GUTs Needed: Planck Scale Nucleon Decay	D. Larson
11:45-12:15	Gauge Boson Mediated Proton Decay Rates	B. Marciano
12:15-13:30	Lunch	
		Chair: E. Witten
13:30-14:00	Proton Decay: From (the) MSSM to SUSY SO(10)	Q. Shafi
14:00-14:30	Predictive minimal SO(10) for neutrinos and proton decay	R. Mohapatra
14:30-15:00	The Flavor Puzzle and its implications for Proton Decay	K. Babu
15:00-15:30	Proton Decay In Minimal Susy and Ordinary GUTs	G. Senjanovic
15:30-15:45	Coffee Break	
		Chair: C.K. Jung
15:45-16:15	Proton Decay: A Compelling Feature Within a Unified Picture	J. Pati
16:15-16:45	Unification and Proton Decay in Higher Dimensions	K. Dienes
16:45-17:15	Unified Theories in Higher Dimensions and Proton Decay	Y. Nomura
17:15-17:45	Raising Higgs boson mass and its implication to proton decay	I. Gogoladze
17:45-18:30	Conclusion/Discussion	E. Witten/C.K. Jung

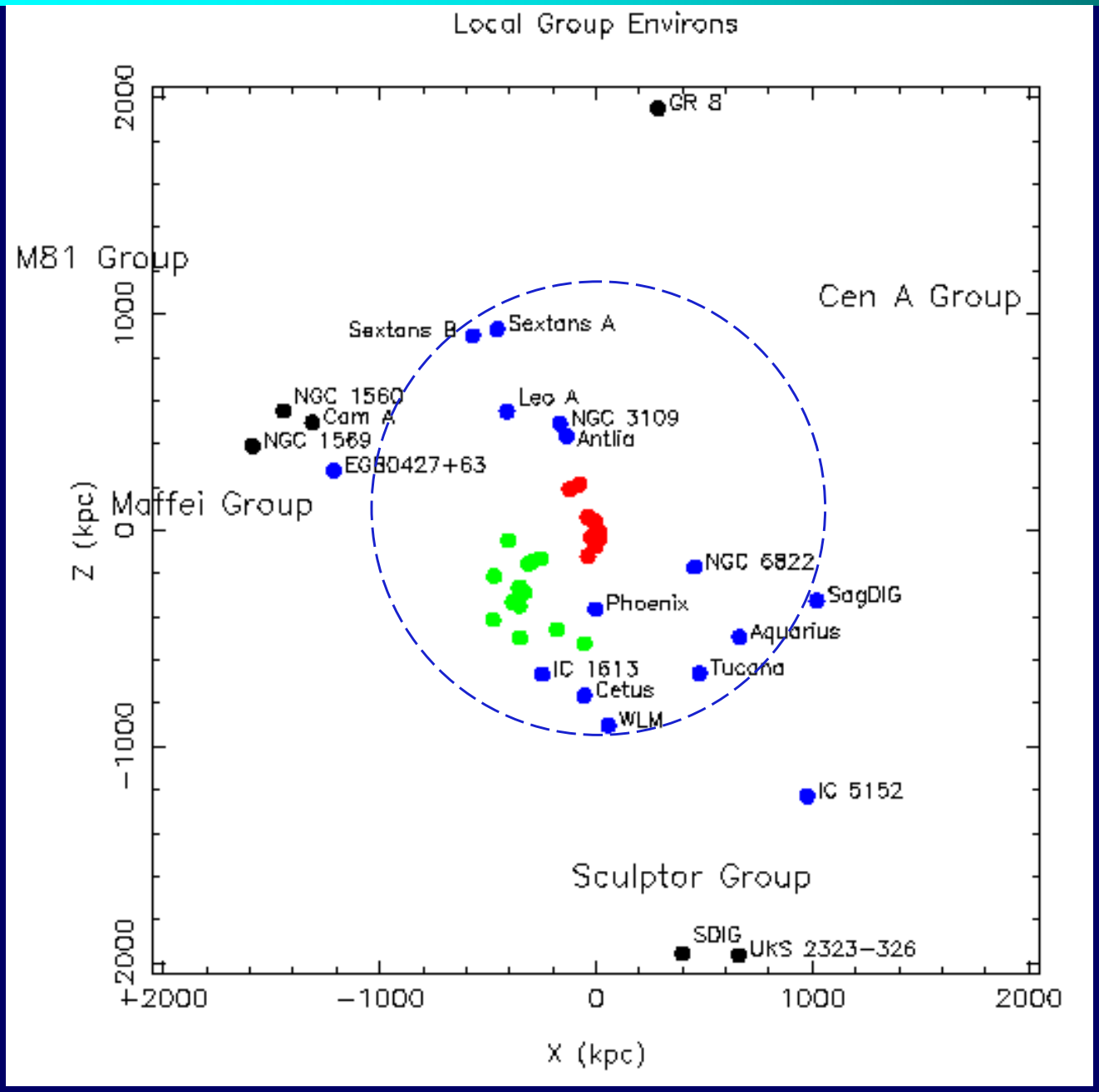
UNO Proton Decay Sensitivity



Not yet updated!)

Conclusion
Theorists are smarter than experimentalists

Supernovae



UNO's Supernova Reach:

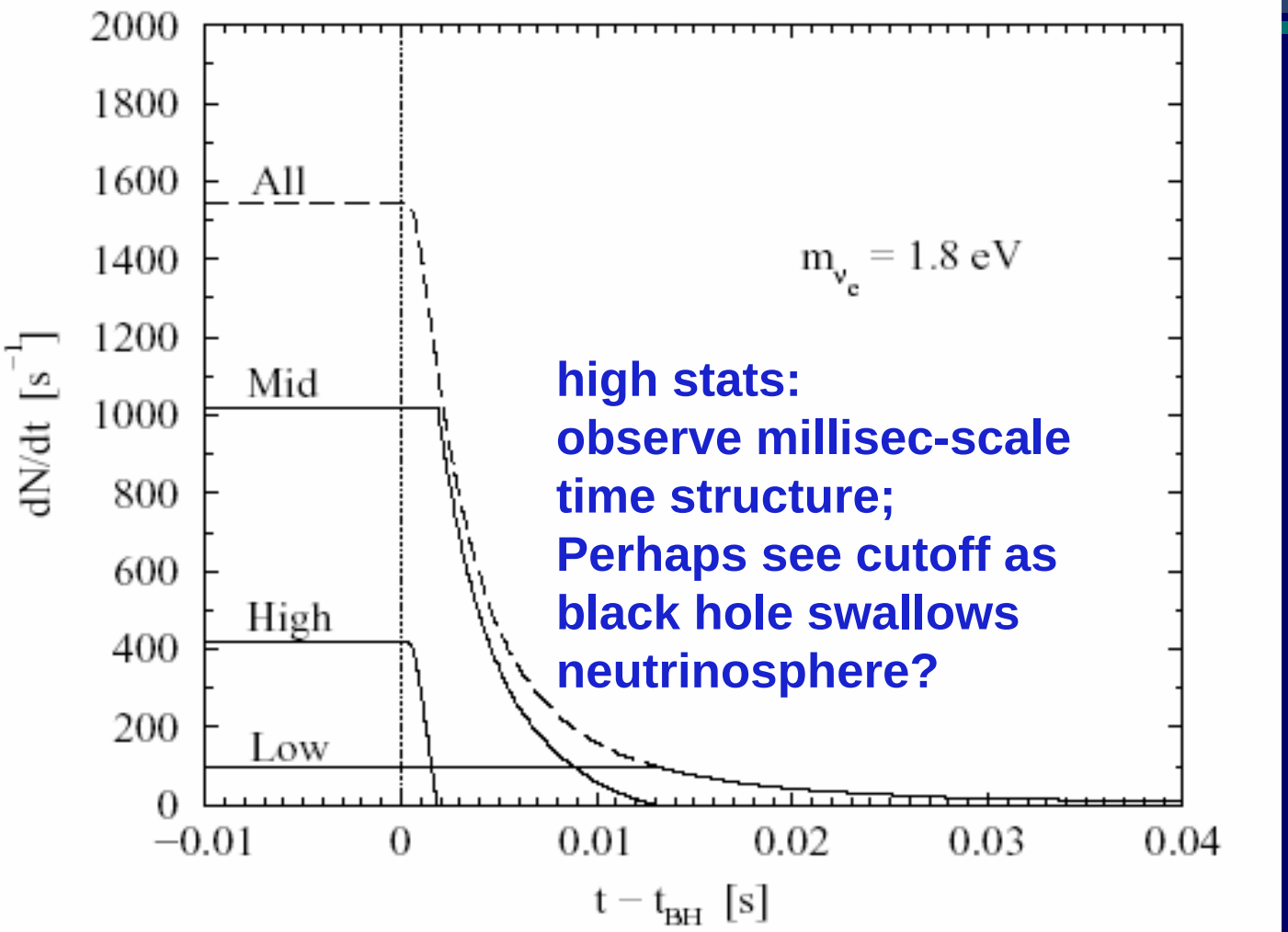
~ 1 Mpc (Local Group of galaxies)

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:

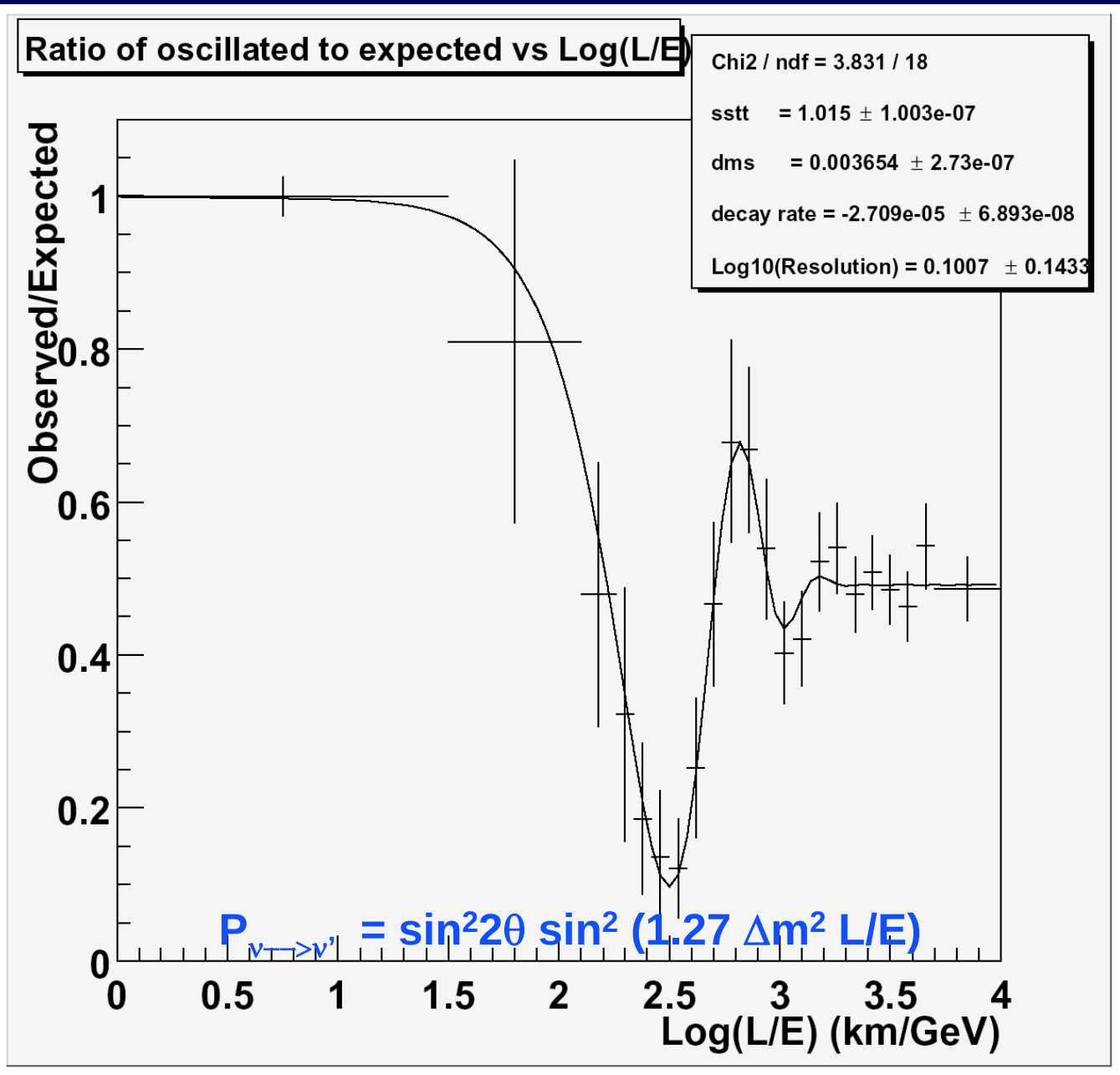
msec timing structure of the flux ⇒ Determination of core collapse mechanism

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

Baseline site for study: Henderson Mine (Colorado)

Use site details for simulations and proposal

- Working molybdenum mine; 150M$ modernization completed in 2000
- Easily accessible, roads kept clear in winter
- Near major urban/industrial area and airline hub
  - ~1 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 major cities around the world

Henderson Mine

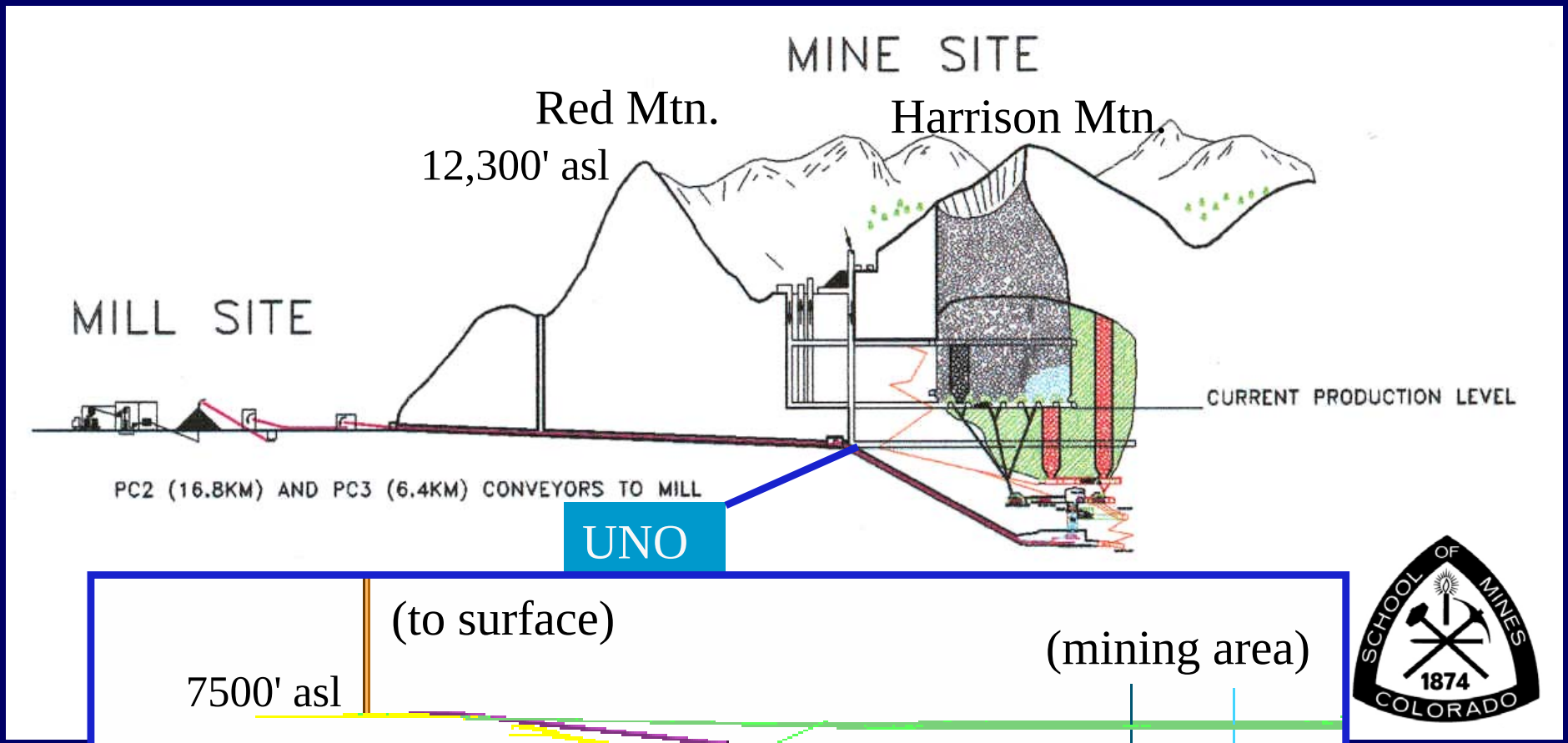
- Owned by Climax Molybdenum Company, a subsidiary of Phelps Dodge Corporation
- Established in 1970's
  - modern mine developed under strict environmental and safety regulations: company just spent $150M updating
  - 10th largest underground hard rock mine operating in the world
- Mining: Molybdenum (Moly) ore, via Panel Caving (Block Caving)
- Huge elevator/hoist available (1 of a total of 5 shafts)
  - Collar at 3,100 m above sea level
  - 8.5 m diameter shaft with with two hoisting compartments
  - Large hoist: 7m long X 2.5m wide X 4m tall, 20 tons normal capacity
    - fits a ship container!
- Mining levels 2100 m and 2500 m above sea level
    - ~1000m deep, minimum overburden ~2700 mwe
    - Can go deeper...

Henderson Mine, Empire, Colorado

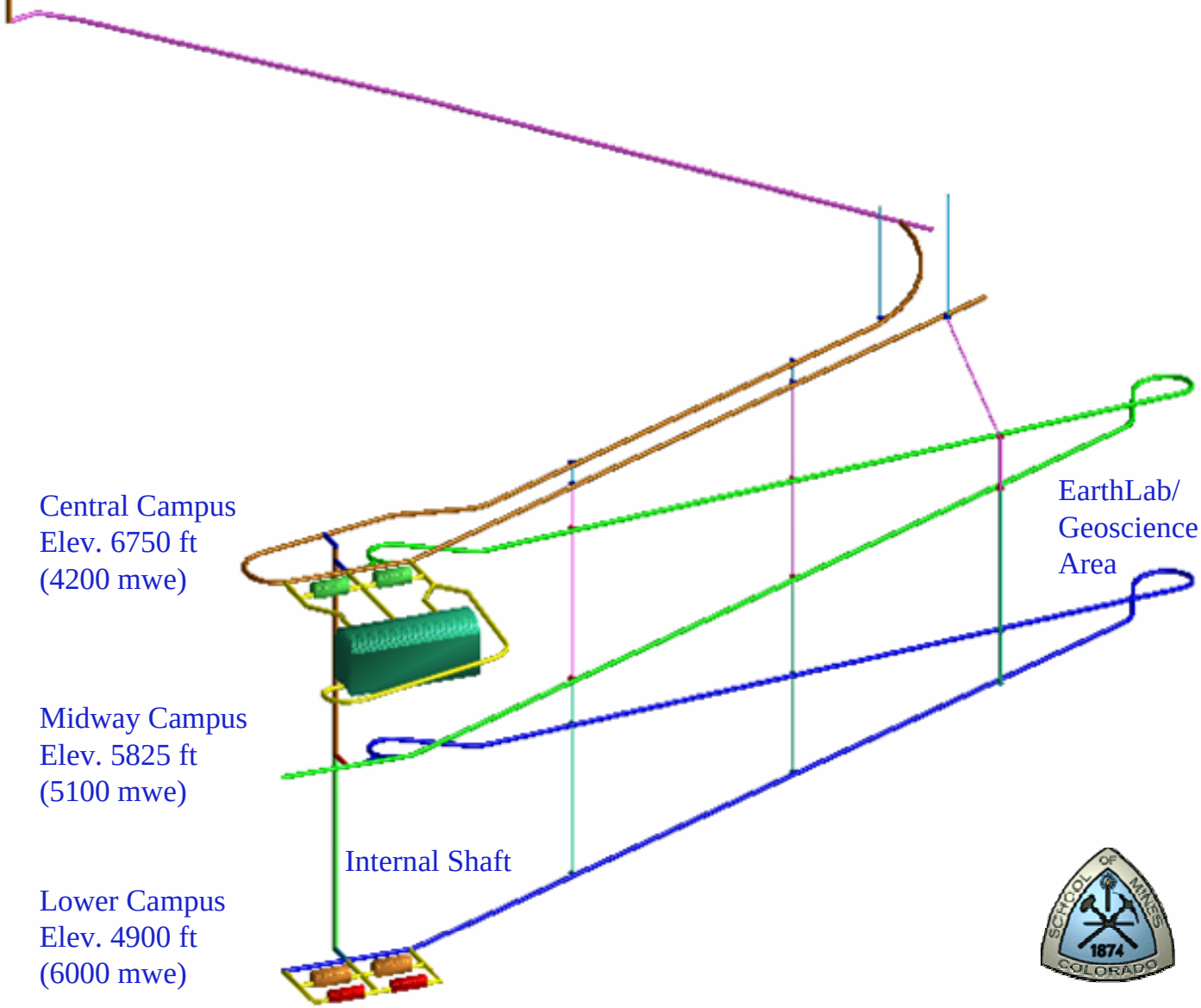
Henderson Mine

- Excavation Capacity: ~40,000 - 50,000 ton/day
  - Actual operation: ~20,000 - 30,000 ton/day: under-utilized capacity
- 10 mile tunnel with high speed conveyor and train track
  - Conveyor belt: 50kton/day max capacity, 20kton/day normal operation
- Moderate temperature - cool air available year round
  - no mechanical cooling necessary
- High capacity water and sewage treatment plant
- Electric power station: 2 x 30 MW
- Tailing site owned by mine company
  - existing permit allows the deposition of over 340Mton
- Large office building and warehouses
- Anticipated mine closing in 10~20 years
  - Mine Co. and local politicians see science as one possible way of retaining employment, revitalizing the area, etc

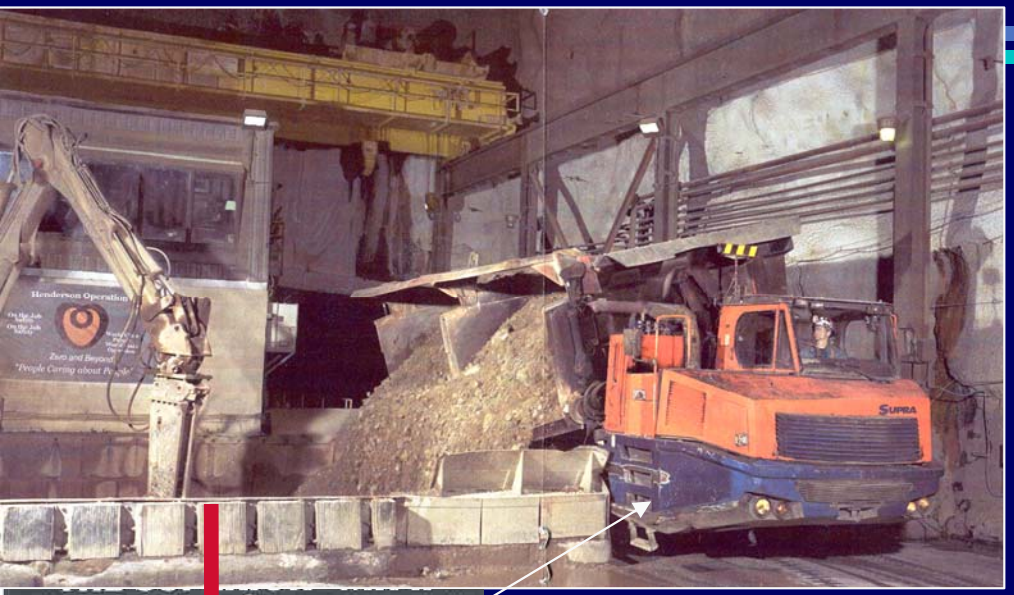
possible UNO Site



Deep Access Capability

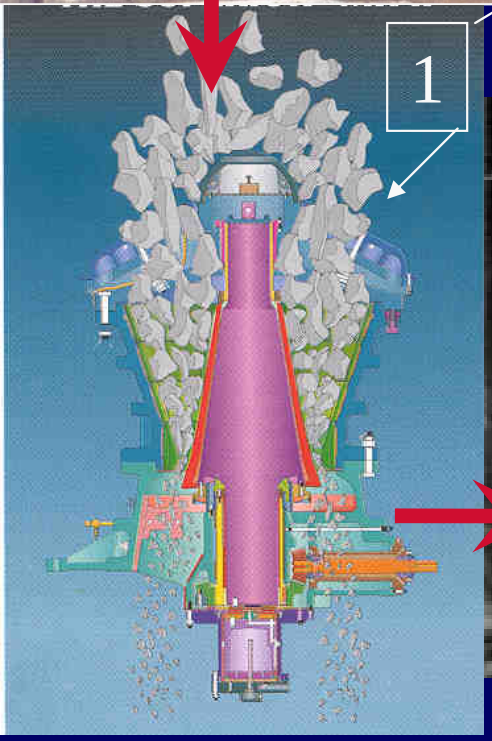


Huge Rock Handling/Removal System



1. 80 ton trucks dump rock at crusher.
2. 10 mile long underground conveyors belts remove rock.
3. 4 mile long surface conveyor to mill site.

~40k - 50kton/day capacity

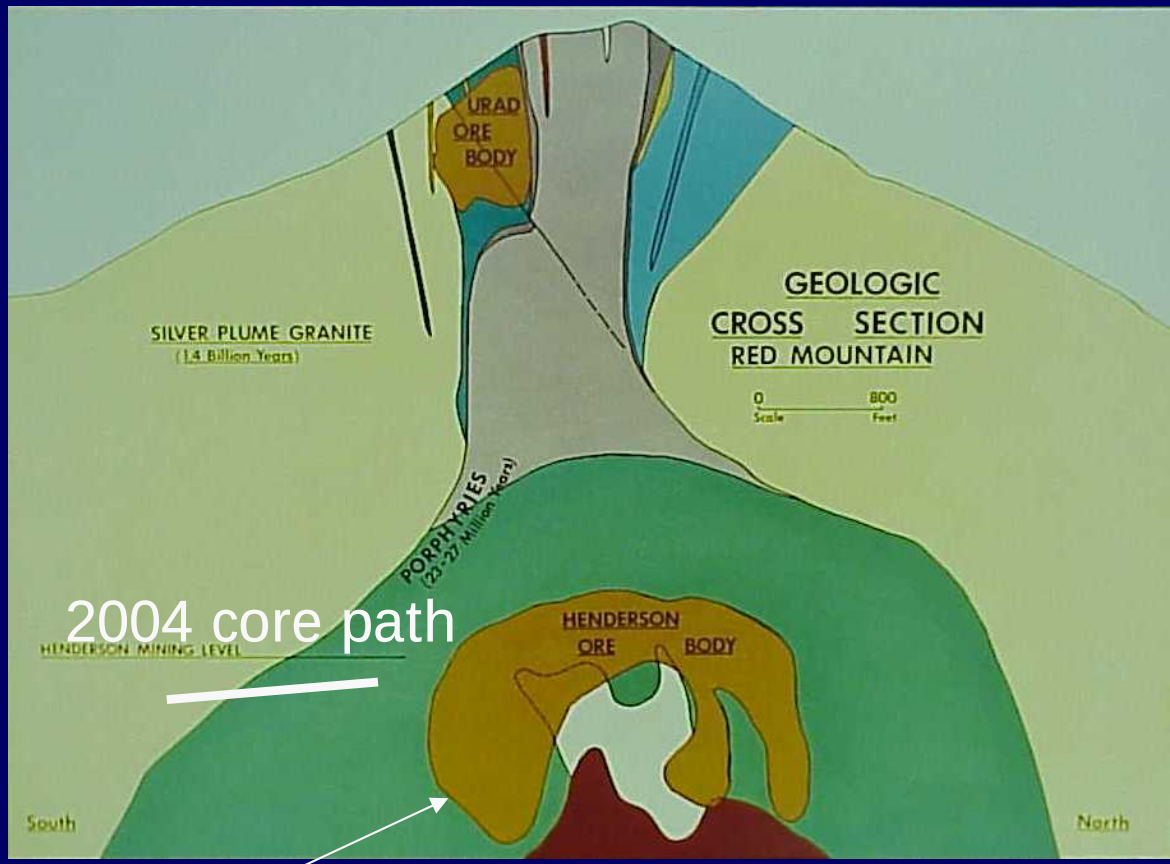


Red Mountain Geology: an instructive case study

Molybdenite deposit (porphyry).

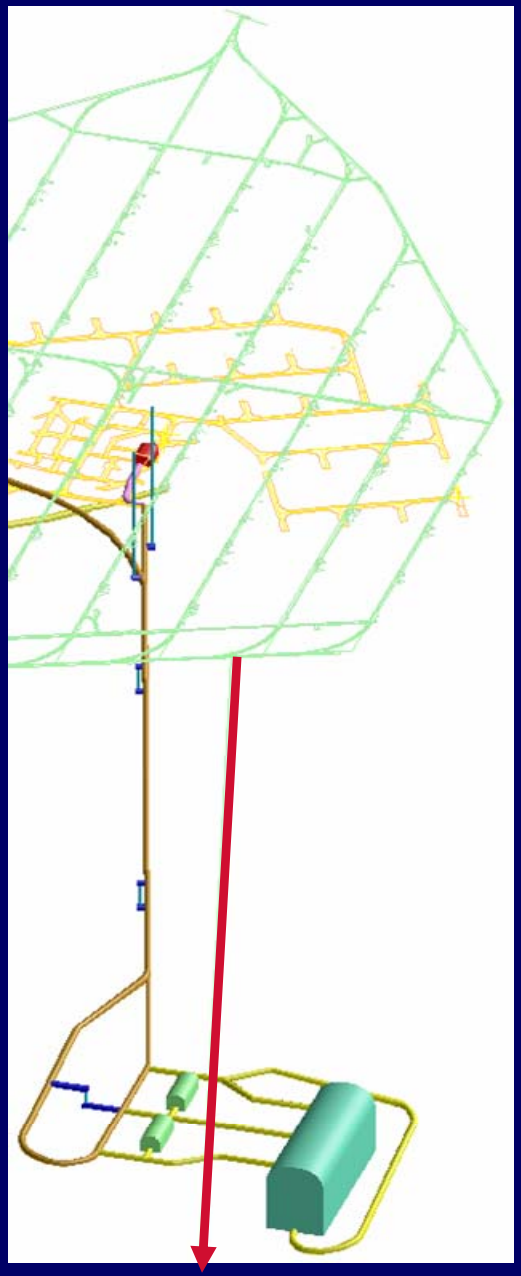
Chemically and mineralogically similar granitic rocks, differ mostly in texture.

150,000 m of core drilling over the past 40 year: "No surprises…"



Ore body 700x900x200 m^3, approximately 360 million tons.
Second largest known molybdenum deposit in the world.

Core Sample Drilling 2004: results

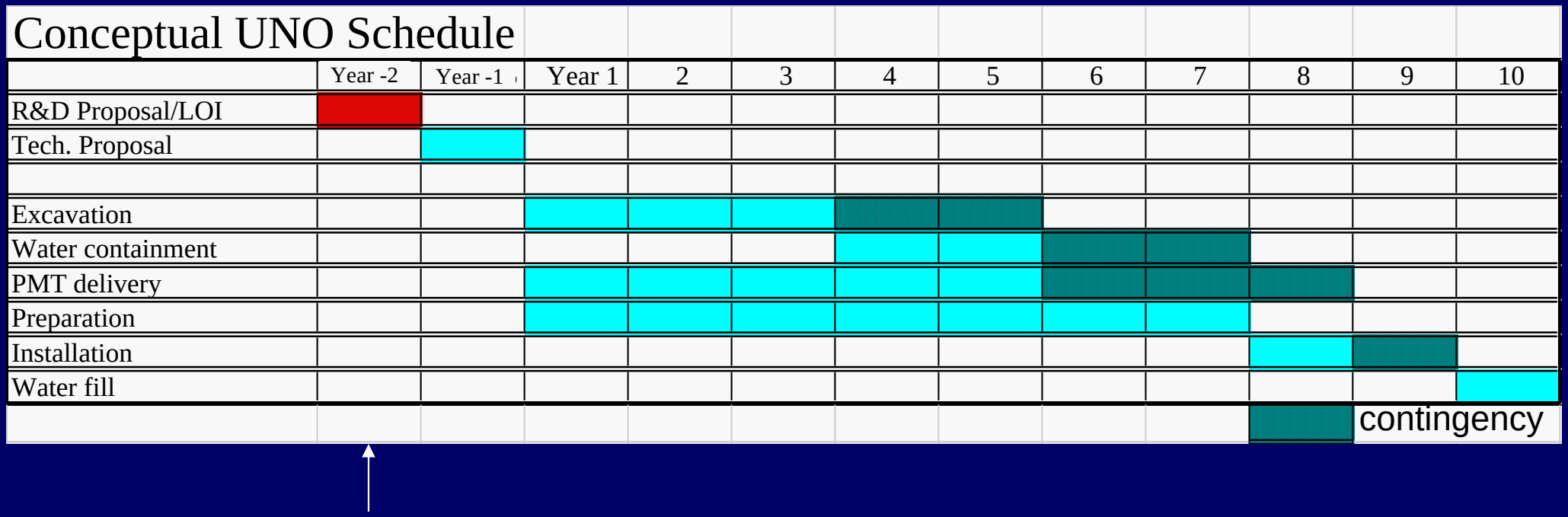


- 750 m long, inclination of -26 degrees, from top at 7,500' elevation to bottom at 6,300' (past UNO site)
- Surprise! Did *not* enter silver plume granite as expected!
  - demonstrates need for actual sampling...
- Results (good news):
  - Extremely competent Urad Porphyry (Granite)
  - very hard with a high percentage of quartz.
  - expected to have high compressive strength
  - RQD is quite high, 70 – 100.
  - no evidence of mineralization
    - Good news!
    - No problem foreseen for constructing UNO

Example of mineralized core from ore-bearing area

UNO does not look like this!
3' segment had no fractures

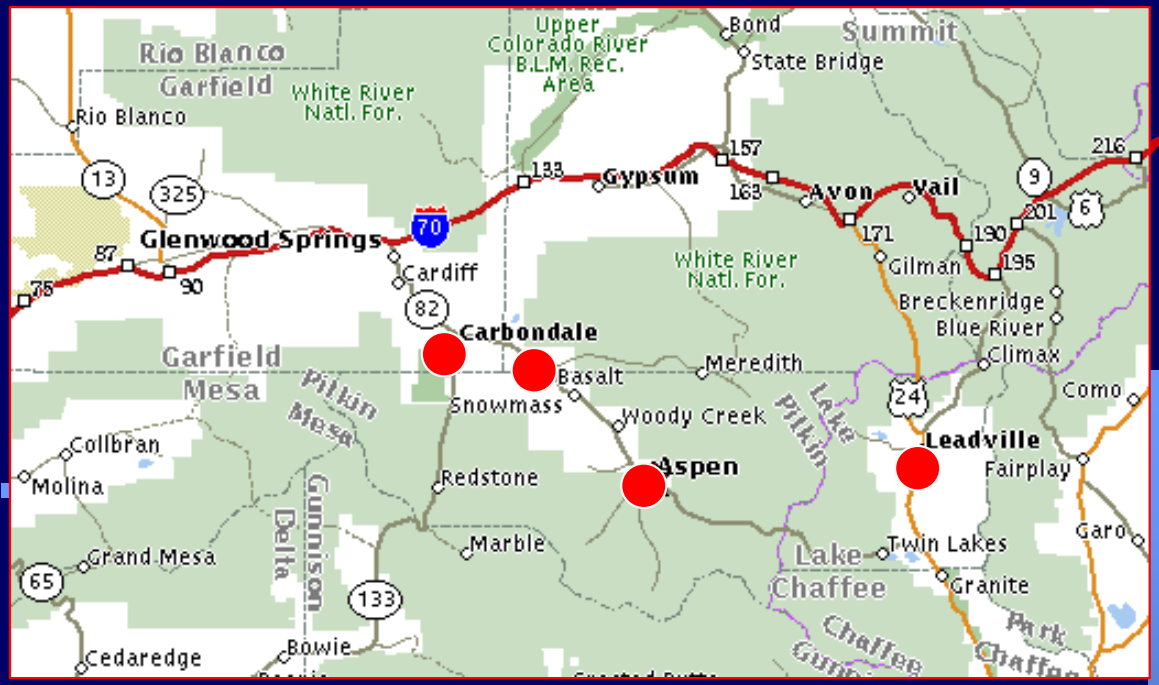
UNO Design and Construction Timeline

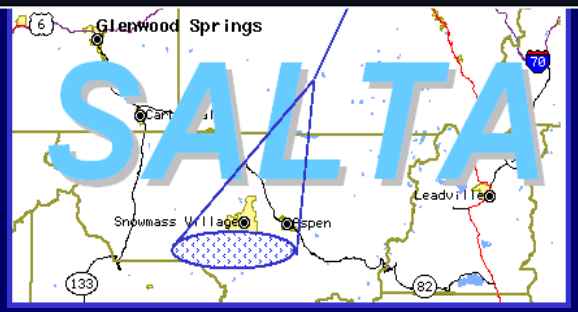


Two years of rigorous detector design needed

UNO already has an active outreach program!

SALTA: Snowmass Area Large Time-Coincidence Array



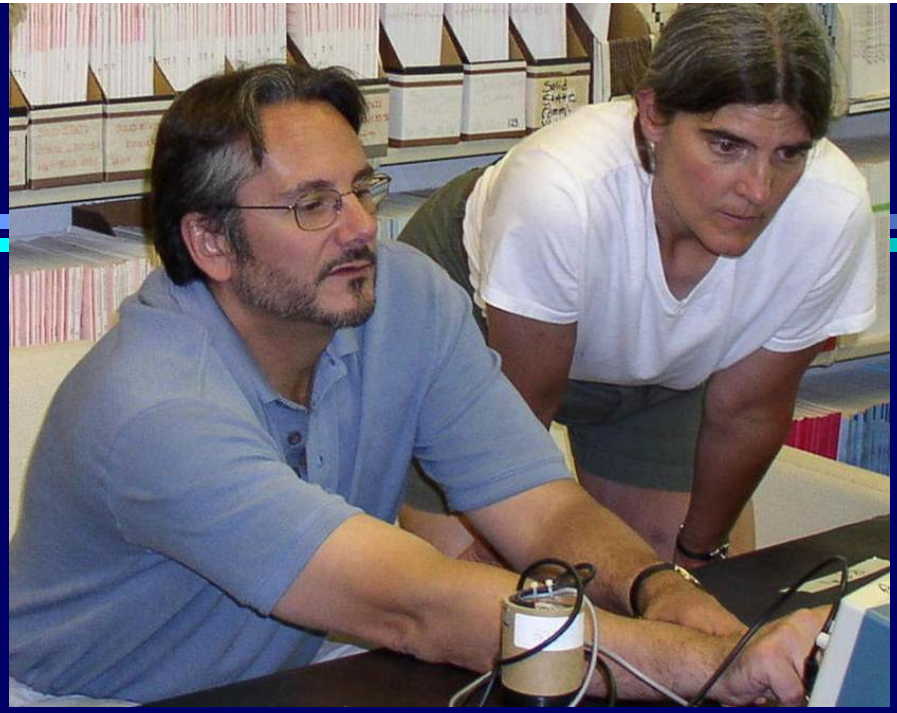


Empire

SALTA began independently of UNO, as part of Snowmass 2001

Secondary-school students and teachers are now collecting underground muon data

- **Aspen High School, Aspen, CO**
- **Basalt High School, Basalt, CO**
- **Roaring Fork Valley High School, Carbondale, CO**
- **Lake County High School, Leadville, CO**
  The highest-elevation school in U.S. -- 10,152 feet above sea level
- **Clear Creek High School, Empire, CO**



Aspen Center for Physics *Education & Outreach Workshop*

July 6-8, 2004: SALTA schools ***take over the library***, setting up cosmic ray telescopes, for training in the new DAQcard that will be used in all their data-taking.

A portable stand holds each muon telescopes.

with dust a problem for a PC

we house a low-power serial digital data logger



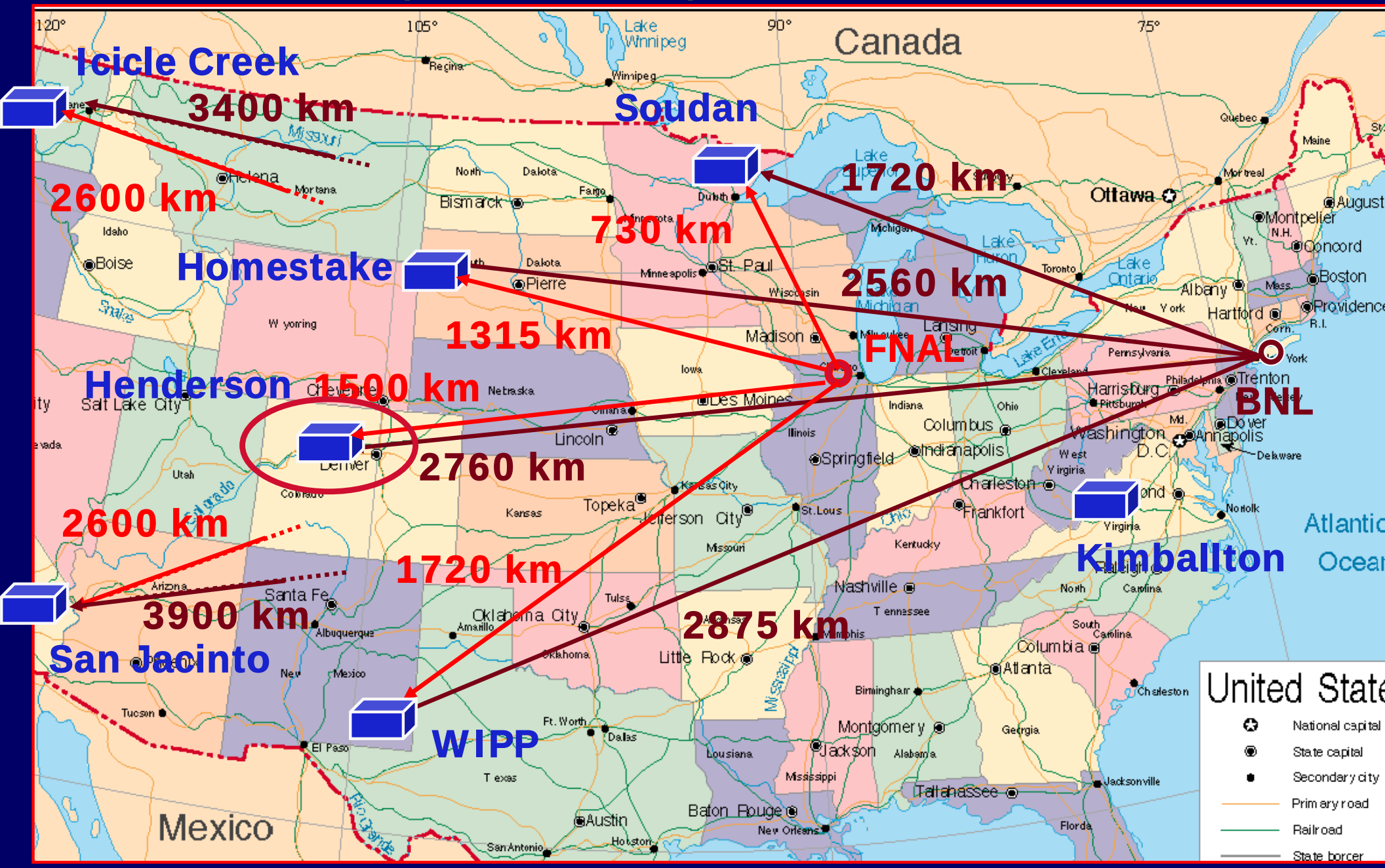
SALTA's underground muon effort is launched September, 2004


US DUSEL process under way

- Solicitiation 1: Gather infrastructure requirements for *potential* experiments in physics, geosciences, biology, & engineering
  - 14 working groups established
  - Held meetings and workshops: deliver final report 3/05(?)
- Solicitation 2: Site specific responses to solicitation 1 requirements: Conceptual designs
  - Proposals due Feb 28 (postponed from Jan), selection in Sept ?
  - "3 to 5 awards", total funding of 1.5M$
- Solicitation 3: full site proposal, selection (end of '05 ?)

DUSEL Candidate Sites and Potential Superbeam Experiments

J. Wilkes, 25 Feb '05

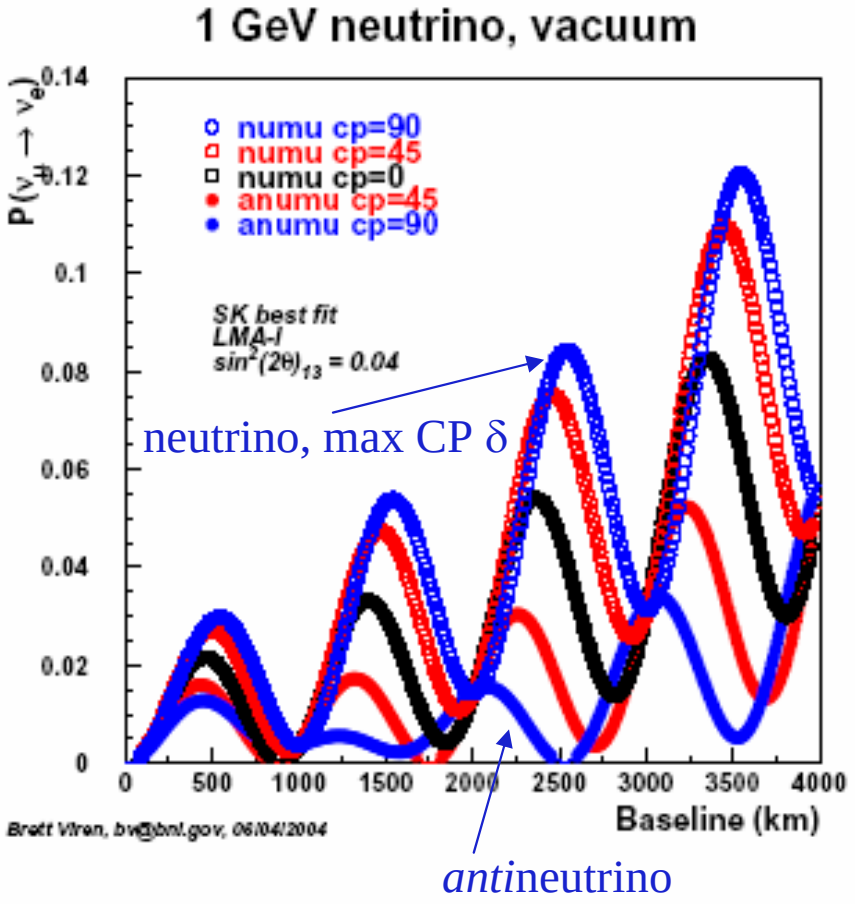


Why VLBL?

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

Marciano (hep-ph/0108181):

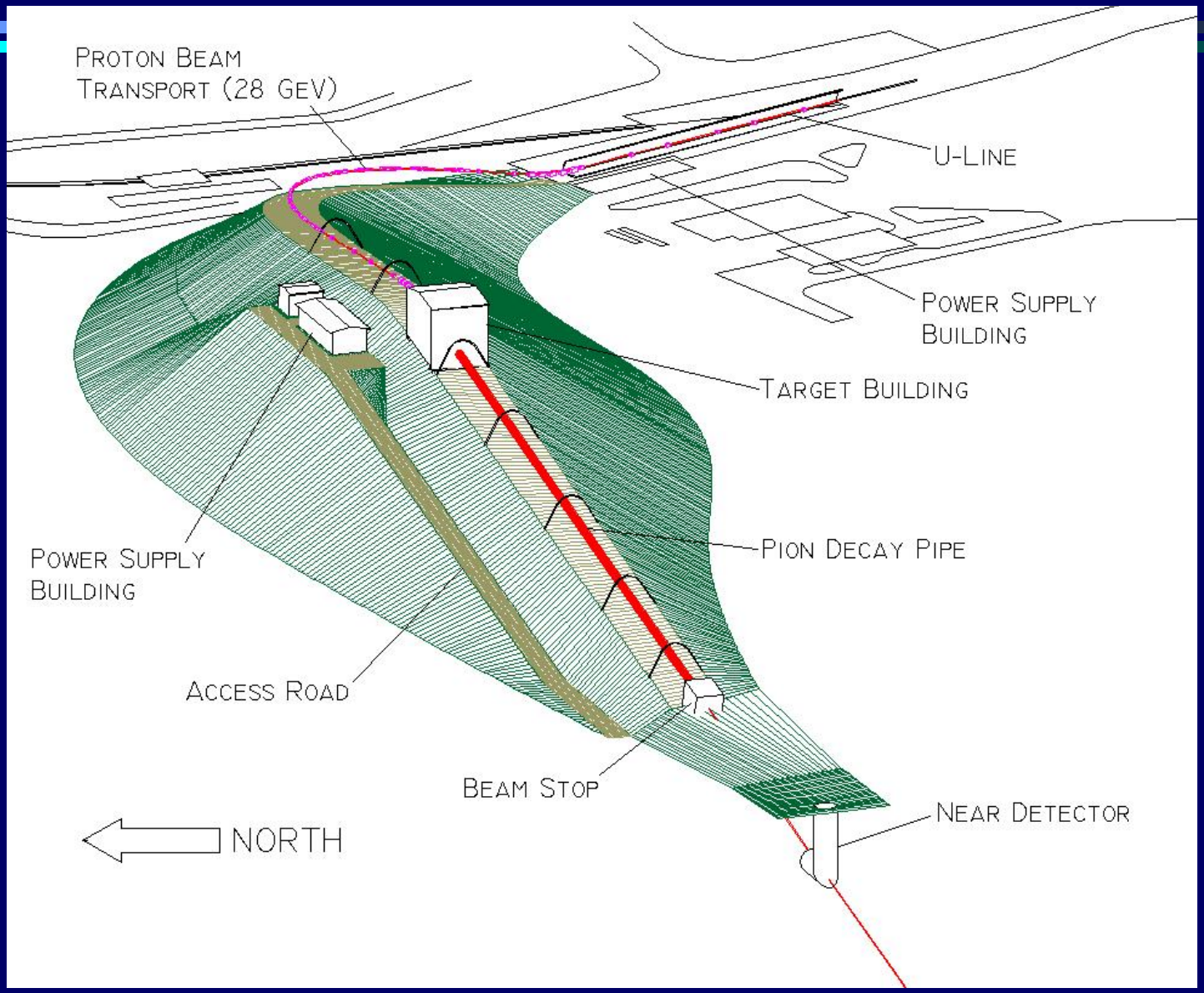
- Yes, statistics fall off with baseline $(1/L^2)$
- but, CP asymmetry grows with baseline (L)
- so, FOM $= A^2 N_\nu/(1 - A^2)$ is $\sim$constant



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

M. Diwan, B. Viren

3-D Neutrino Super Beam Perspective



UNO plans

- Submit UNO R&D proposal to US DOE and NSF
  - R&D for *proposal* : items covered:
    - Site independent rock engineering, surface treatment, water containment
    - Structural and PMT mounting design
    - PMT/photodetector, optical R&D (under way with other funds)
    - Detector detailed-design R&D
    - Professional project management estimates
  - Target date for UNO R&D proposal: late spring
  - Use Henderson Mine (near Denver) as strawman site
    - Need *some* site's parameters for various studies
  - UNO is still site-independent
    - Will build it wherever we can!