UNO
Status and Future Outlook

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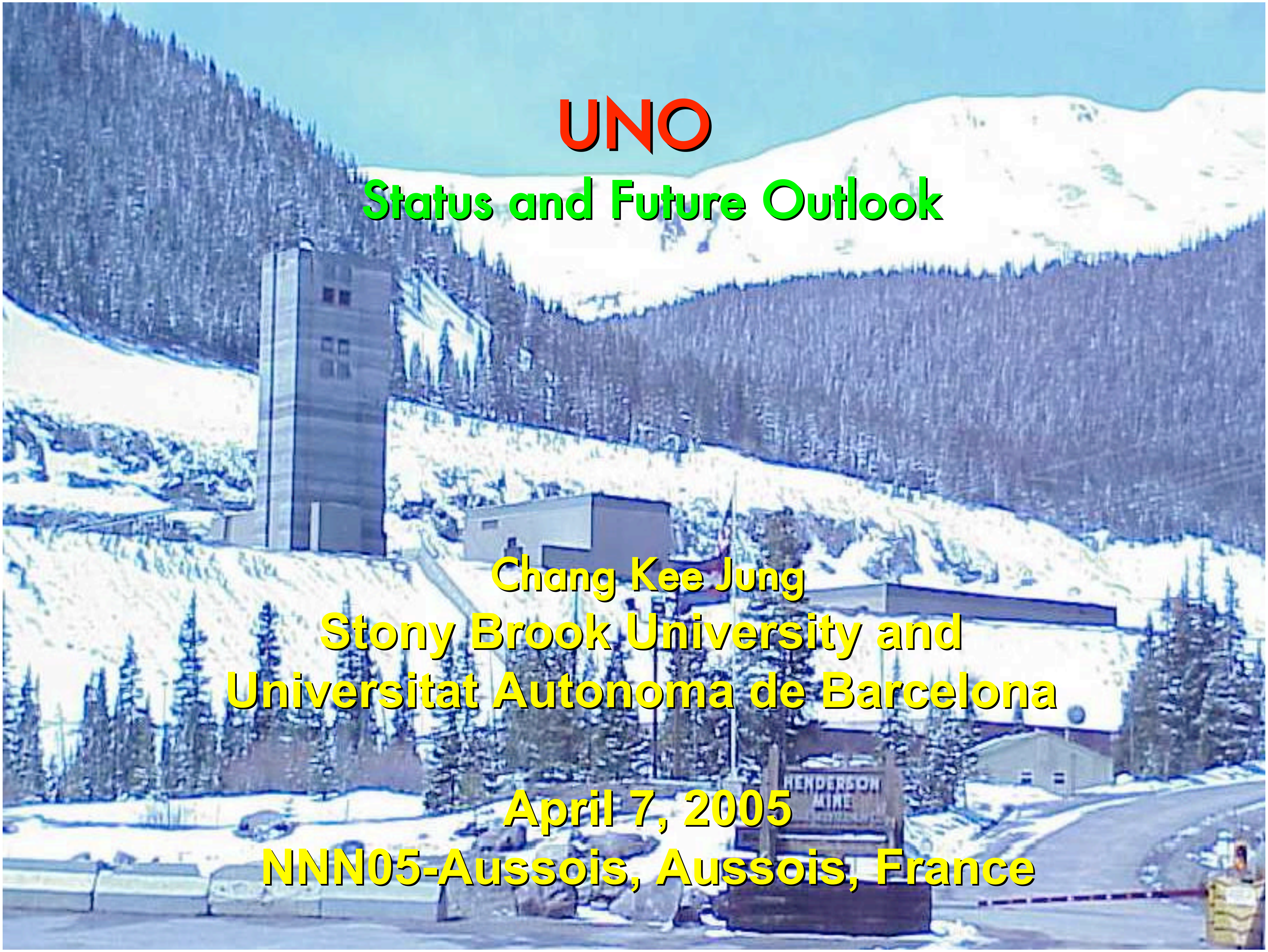
Universitat Autonoma de Barcelona

April 7, 2005
NNN05-Aussois, Aussois, France



A Bit of Look Back…

- UNO was proposed in September 1999 at the NNN99 conference (the first one of the series) at Stony Brook
- UNO Whitepaper, Snowmass, June 2001
- UNO Collaboration
  - ~100 collaborators from ~40 institutions
- UNO EOI R&D proposal, being prepared
- Progress is rather slow…

Are we making enough progress?

What are the difficulties?

What do we need to do?

Necessary Ingredients for UNO

- Science
  - Non-accelerator phyiscs
    - ⇒ Proton decay
    - ⇒ Supernova neutrino studies
    - ⇒ atm nu, solar nu, astro nu, …
  - Accelerator physics
    - ⇒ LBL NO experiments for θ_{13} and CPV
- Technical Feasibility and Reasonable Cost
- Site
- Community support
- Government support

Status in US

Although the UNO collaboration is committed to supporting international effort of building a next generation large water Cherenkov detector somewhere in the world, this talk concentrates on the status and effort in US.

No time to review all activities, some samples…

See UNO05-Aussois Presentations at:
http://nngroup.physics.sunysb.edu/uno

Establishing Science Case

A great amount of work has been done by the HyperK working group and the UNO Collaboration as reported in this conference.

Most of the topics are covered by the other speakers.

Sometime in Early 1970's…
Pati-Salam Model of Grand Unification

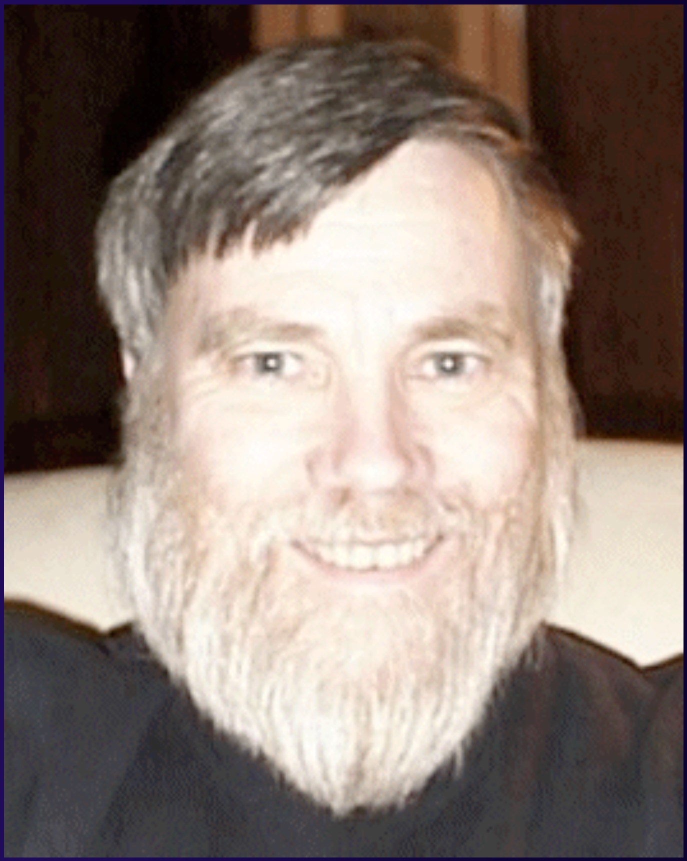
Prof. Salam,
my GUT feeling is that
protons must decay.

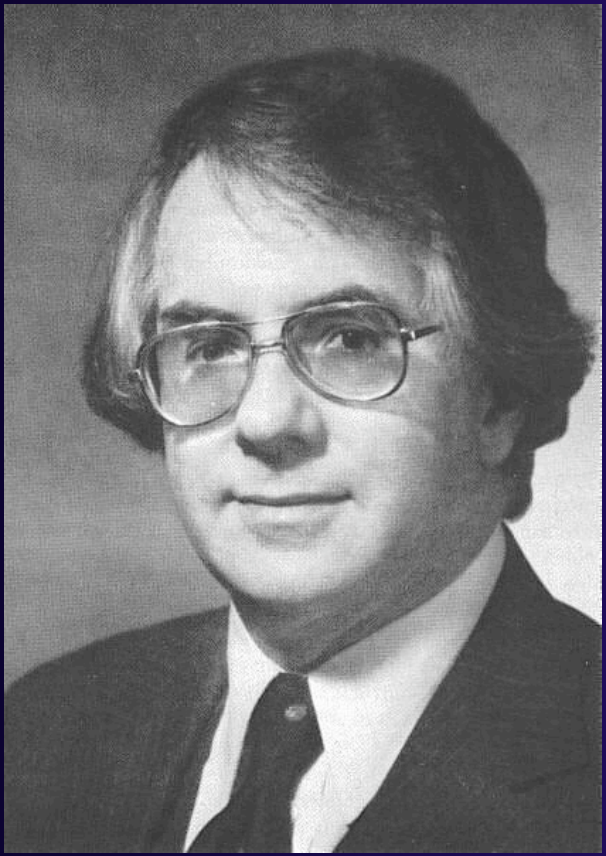
I don't think so.
Experimental results
Indicate otherwise.
Let me think about it…

Some months later…

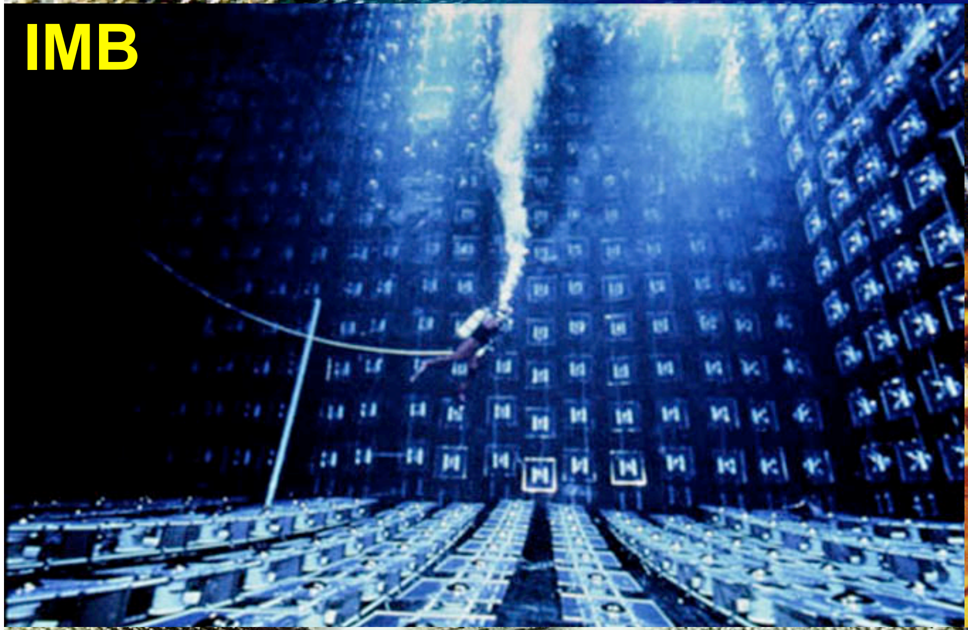
My GUT feels the same.
Let's publish it.

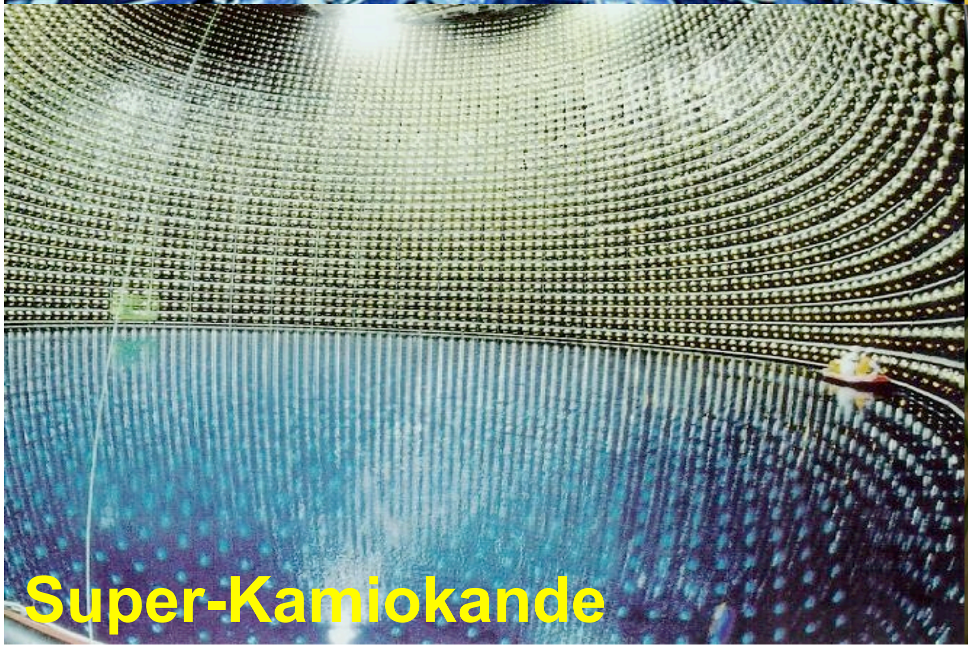
SU(5) by Georgi and Glashow (1974)





Proton Decay Detectors





UNO-Keystone Unification Day Workshop Speakers List

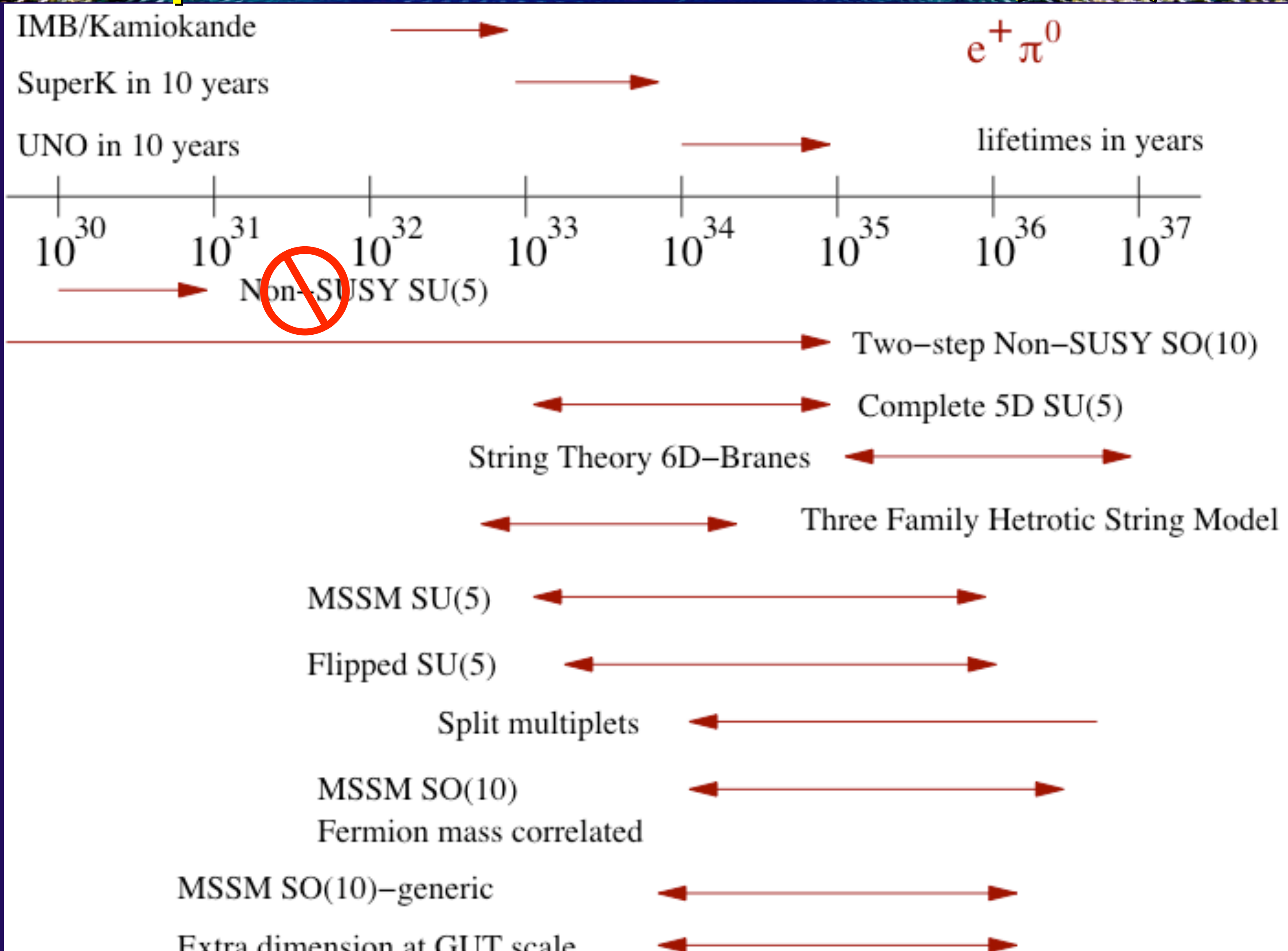
Name	Institution
E. Witten	IAS
Juan Maldacena	Harvard
Savas Dimopoulos	Stanford
Stuart Raby	Ohio State
Daniel Larson	Berkeley
Bill Marciano	BNL
Qaisar Shafi	Bartol Inst.
Rabi Mohapatra	Maryland
J. Pati	Maryland
Kaladi Babu	Oklahoma State
Yasunori Nomura	Berkeley
Keith Dienes	Arizona
Ilia Gogoladze	Notre Dame
Goran Senjanovic	ICTP, Trieste

October, 2004

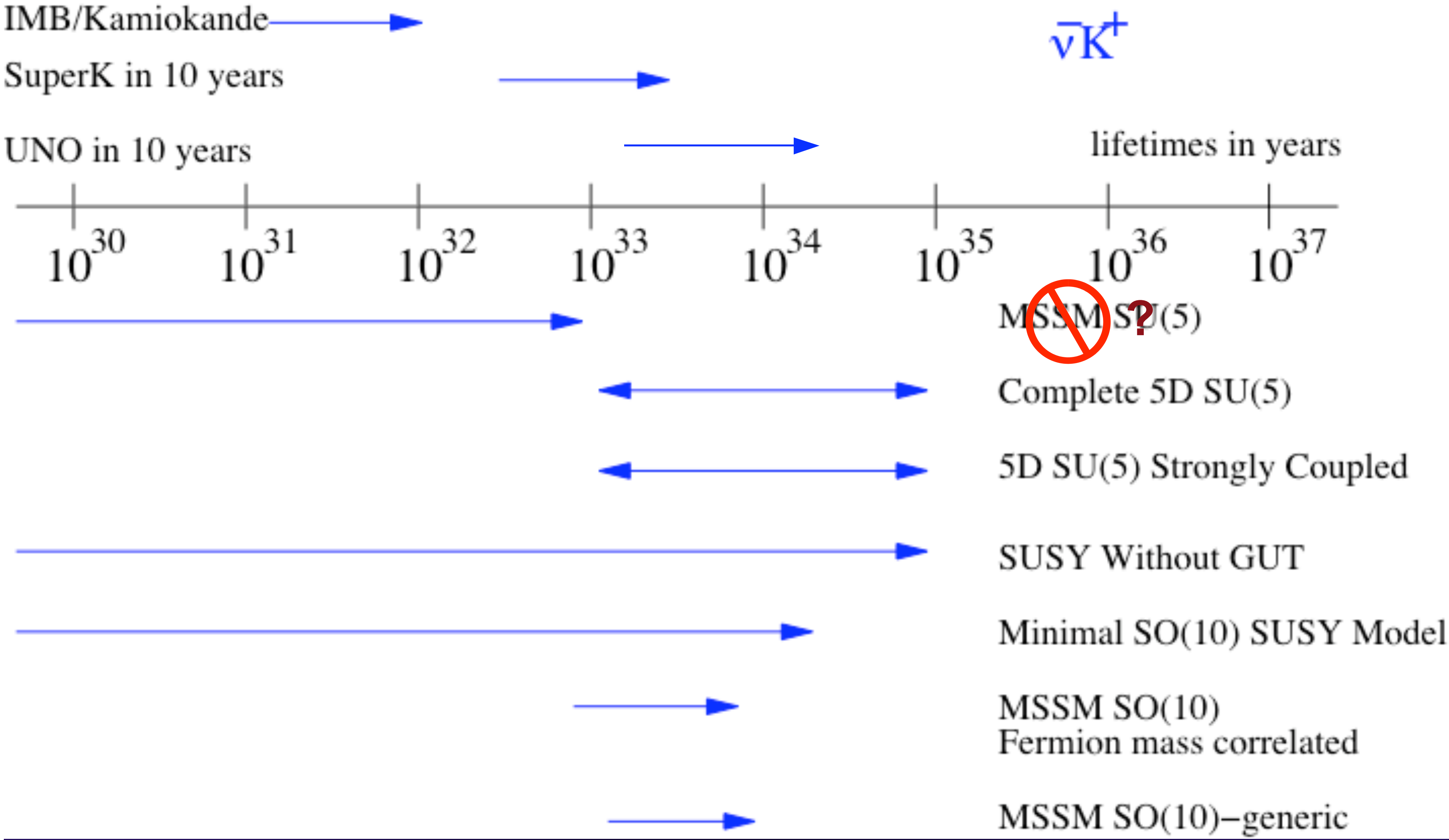
Keystone,Colorado

Co-organized by Witten and Jung

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



UNO Proton Decay Sensitivity and Updated Theoretical Predictions ($K^+\nu$)



VLBNO

- An accelerator based LBL NO experiment for θ_{13} & CPV
  - a necessary ingredients for UNO
  - initial candidate sites for UNO such as WIPP was too far from Fermilab and BNL for a conventional experiment utilizing the 1st oscillation peak

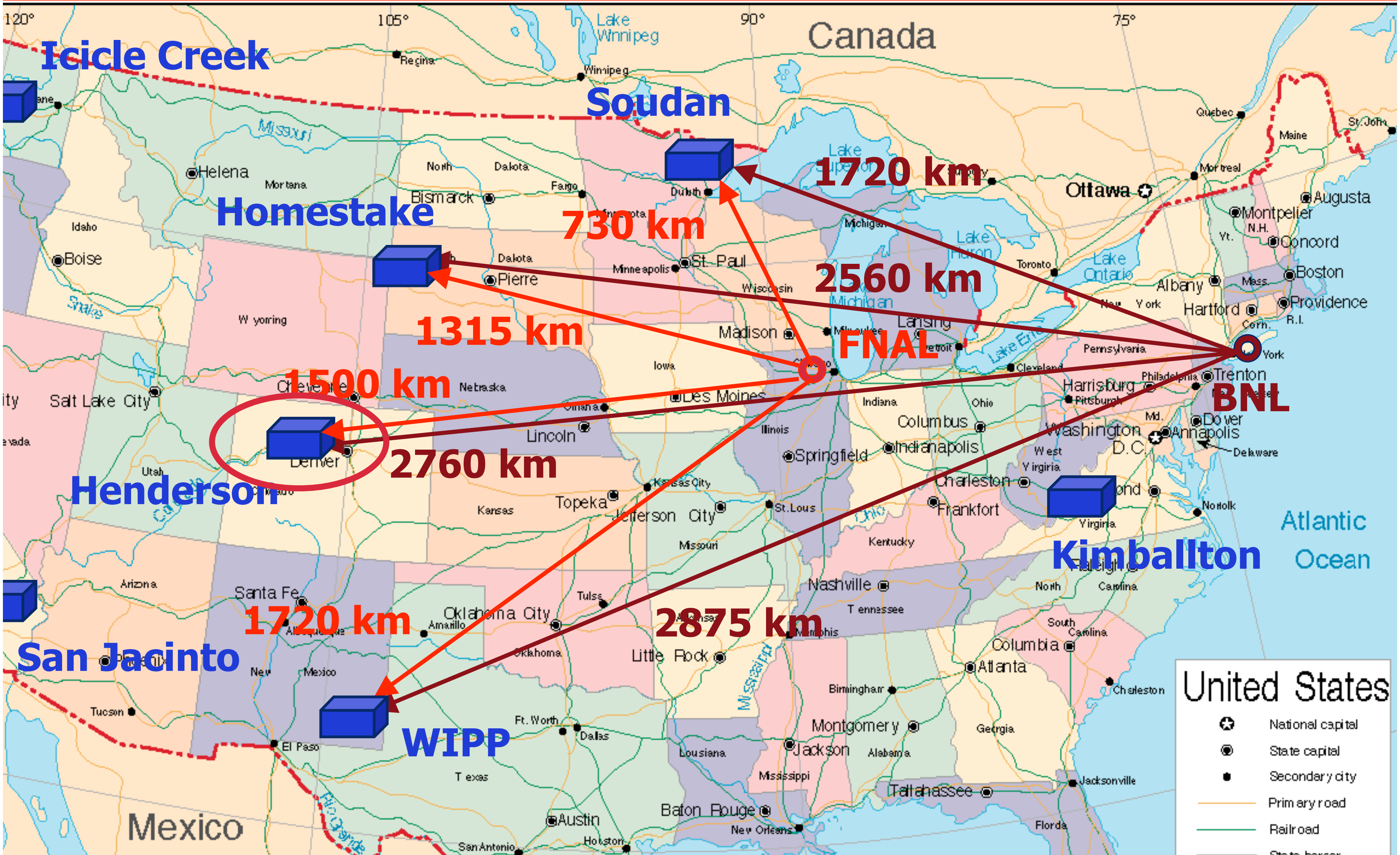
Marciano to the rescue! (hep-ph/0108181)

- Look for oscillation effect on 2nd, 3rd … peaks
- Sensitivity to CPV ~ independent of baseline
- Allow very long baseline superbeam experiment

BNL VLBNO Proposal

- Very long baseline (L > ~1000 km)
- Wide-band 1 MW beam using upgraded AGS
- 500kton Water Cherenkov Detector
- More matter effect, observation of multiple peaks
  - See Bishai's talks (UNO05-Aussois & NNN05)
- Initial BNL sensitivity analysis was criticized for its simplistic treatment of the background
  - Stony Brook analysis using SuperK MC establishes feasibility of BNL VLBNO experiment
  - See Yanagisawa's talks (UNO05-Aussois & NNN05)

DUSEL Candidate Sites and Potential Superbeam Experiments



Technical Feasibility and Reasonable Cost

- Is it feasible to excavate a UNO size cavern?
  - Can it be stable for > 30 years?
  - Can it be done economically?
- Can the water containment be done using liners?
  - Can it be stable for > 30 years?
  - Can it be done economically?
- Can the PMT mounting system be built economically?
- Can the photo-detection be done more economically?
  - Cheaper PMTs?
  - New photo-detectors?

$\Rightarrow$ UNO R&D Proposal

UNO EOI and R&D Proposal

- EOI + R&D (Site Independent)
- Proposed Planning and R&D Activities
  - Excavation R&D (CSM/CNA Engineers)
  - Cavity Liner R&D (CSM/CSU)
  - PMT Mounting R&D (UW)
  - UNO software R&D (BNL/CSU/Stony Brook)
  - Planning (Stony Brook)

Continue: UNO EOI and R&D Proposal

- (photo-detector R&D)
  - ⇒ Referenc Tube R&D, already funded

    DOE Advanced Detector R&D and DOD (~$600k)

    (See Ferenc's talk)
  - ⇒ Burle Large PMT R&D, already funded

    DOE SBIR

    (See Burle talk at UNO05-Aussois)
  - ⇒ U. of Denver, new initiative
  - ⇒ (U. of Tokyo HPD R&D, already funded ($4M))

    (See Aihara's talk)

- Submit to DOE and NSF by this summer
  - The timing is right for us to make a move…

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

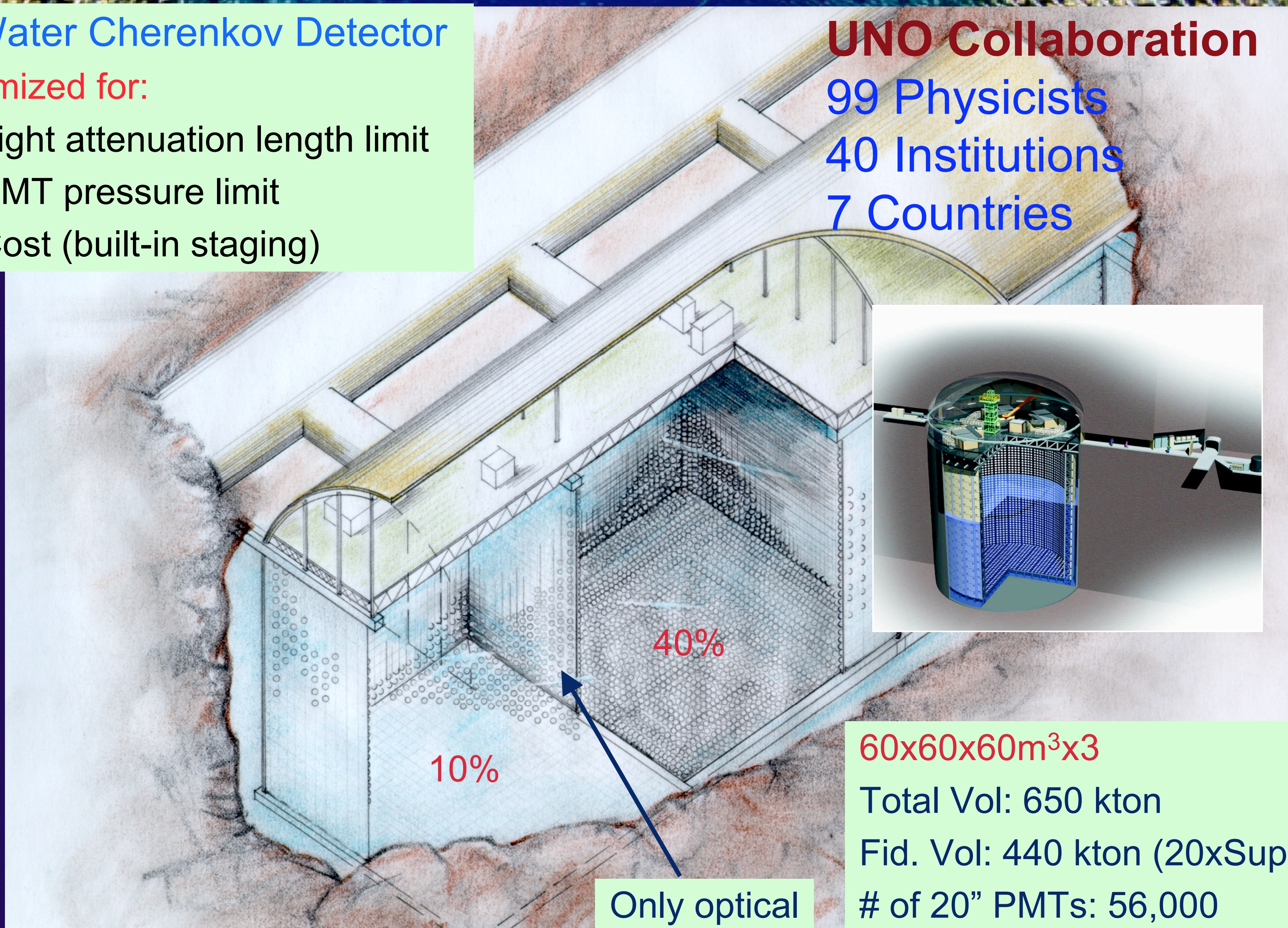
Possible application in the future:
Large underground facility/storage
Large underground living space

UNO Detector Conceptual Design

A Water Cherenkov Detector
optimized for:

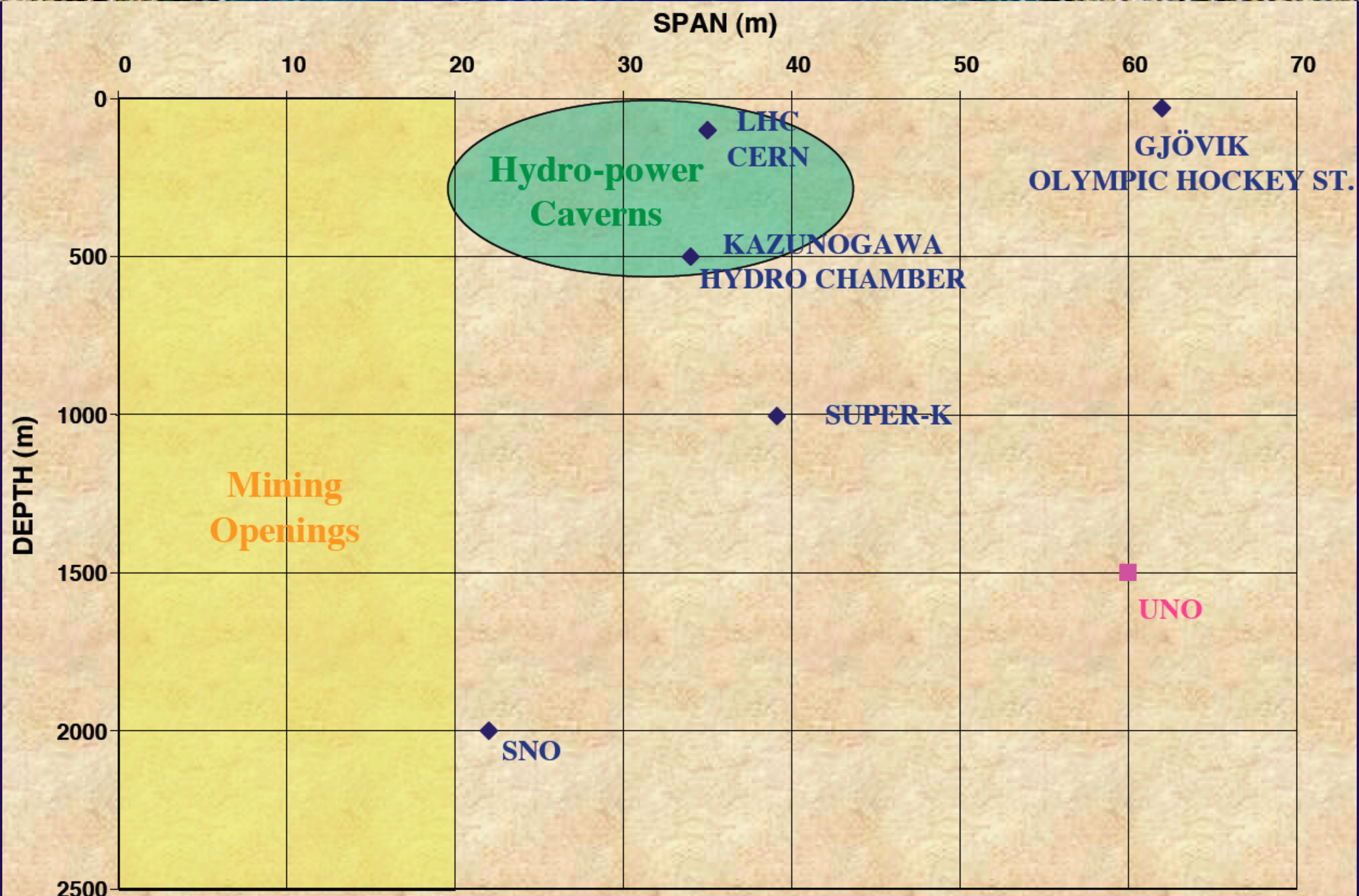
- Light attenuation length limit
- PMT pressure limit
- Cost (built-in staging)

UNO Collaboration
99 Physicists
40 Institutions
7 Countries



$60 \times 60 \times 60\,m^3 \times 3$
Total Vol: 650 kton
Fid. Vol: 440 kton (20xSuperK)
# of 20” PMTs: 56,000
# of 8” PMTs: 14,900

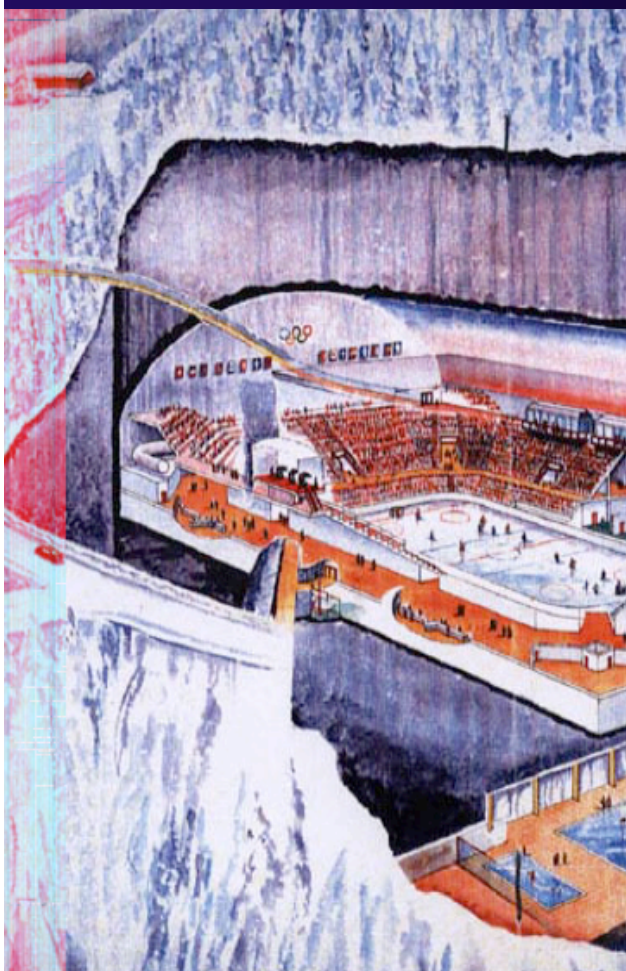
Bench Marking
(P. Varona, Itasca)



Norwegian Hockey Arena
Gjøvik, Norway

Dimensions: L=91m, W=61m, H=25m, Ar=15,000m^2

Construction Cost: $20M USD (1992)



The Largest Manmade Underground Chamber in the World!

Good Luck Cave
Sarawak, Borneo

Gunung Mulu National Park, a Karst cave (limestone)

Dimensions: L=600m, W=400m, H=100m, Ar=162,700m^2

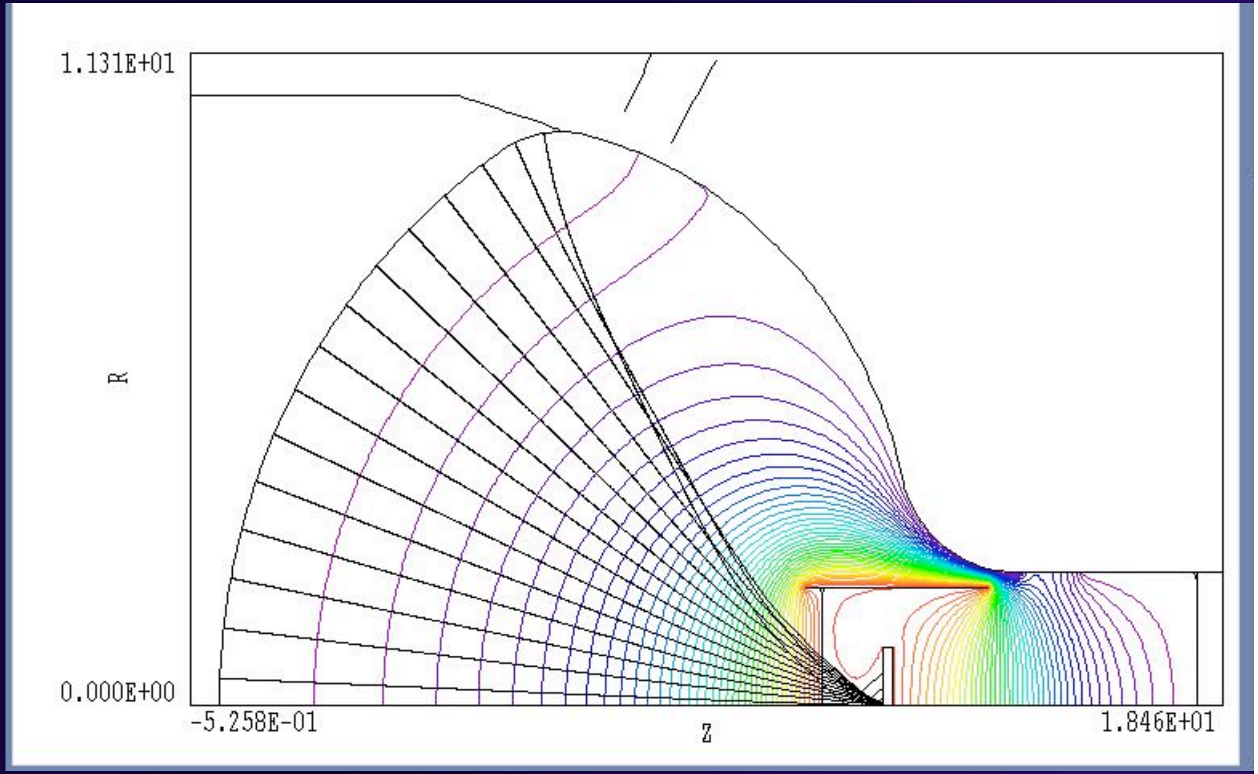
Can PMT's be manufactured at a much lower cost?

A challenge to the photo-detector/PMT manufacturers

Burle 20" PMT R&D

New bulb design: "Truncated bulb"

- Uniform E-field in front of cathode
- Small neck
- TTD ~ 1.5 ns



Goal:

- Fully automatic production of 20" PMTs
- Aim ~$1,500/PMT

Identifying a Suitable Site

DUSEL Process

(See Sadoulet's talk for more details)

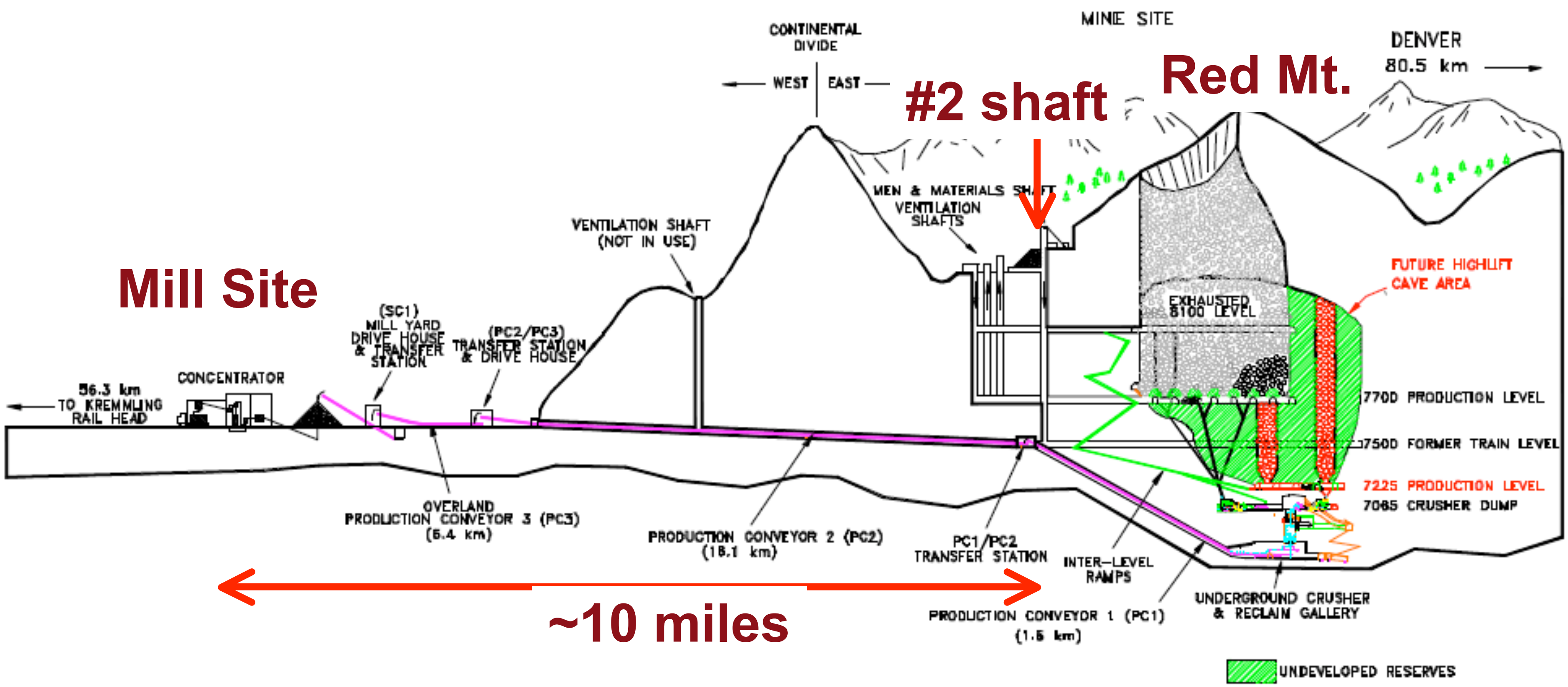
$\Rightarrow$ A great opportunity for UNO!

The Henderson Mine
(UNO Preferred Site)

- Owned by Climax Molybdenum Company, a subsidiary of Phelps Dodge 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
- 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)

Vast Infrastructure



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

Rock Handling/Transfer System

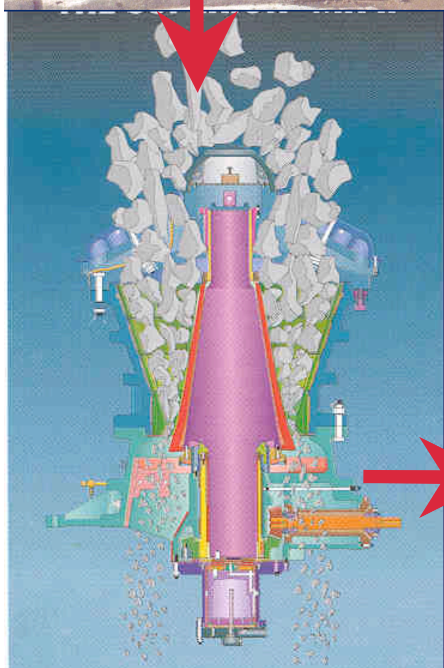
80 ton trucks dump rock at crusher.

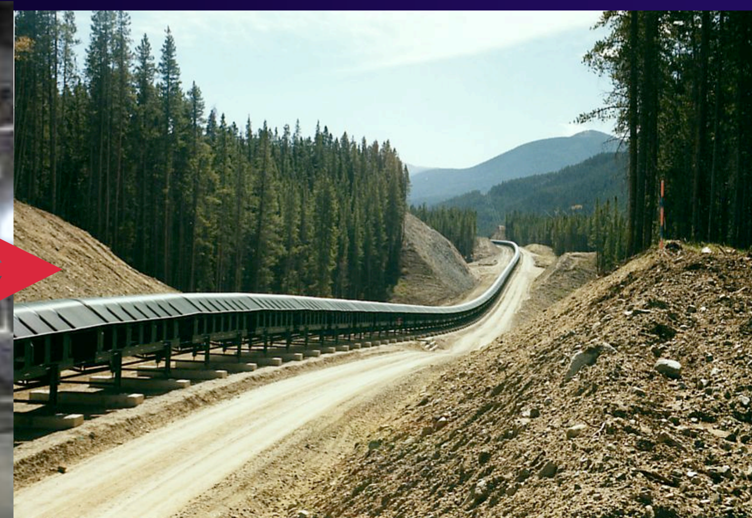
Gyratory crusher reduces to – 4 in.

1 mile PC1 and 10.5 mile long PC2 underground conveyors.

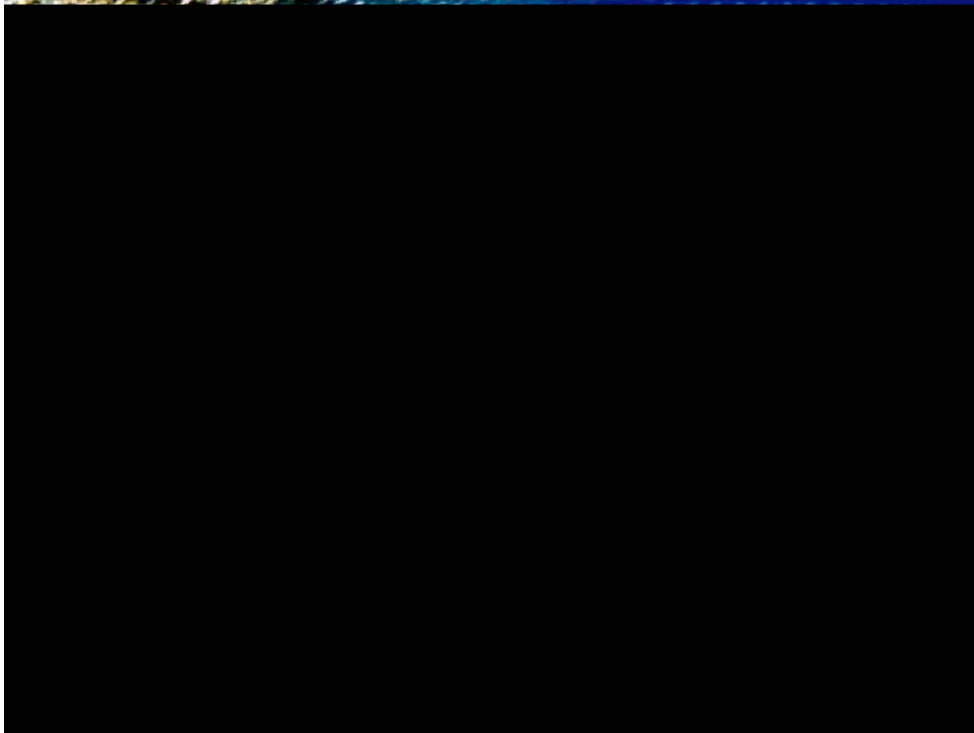
4 mile long PC3 surface conveyor to mill site.

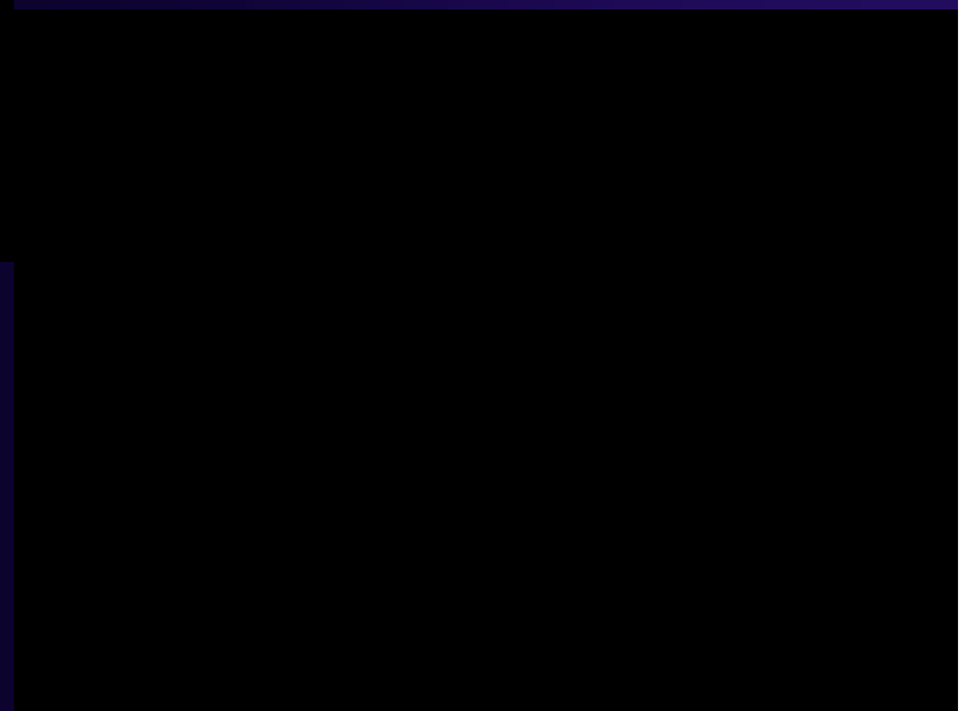
~40k - 50kton/day capacity



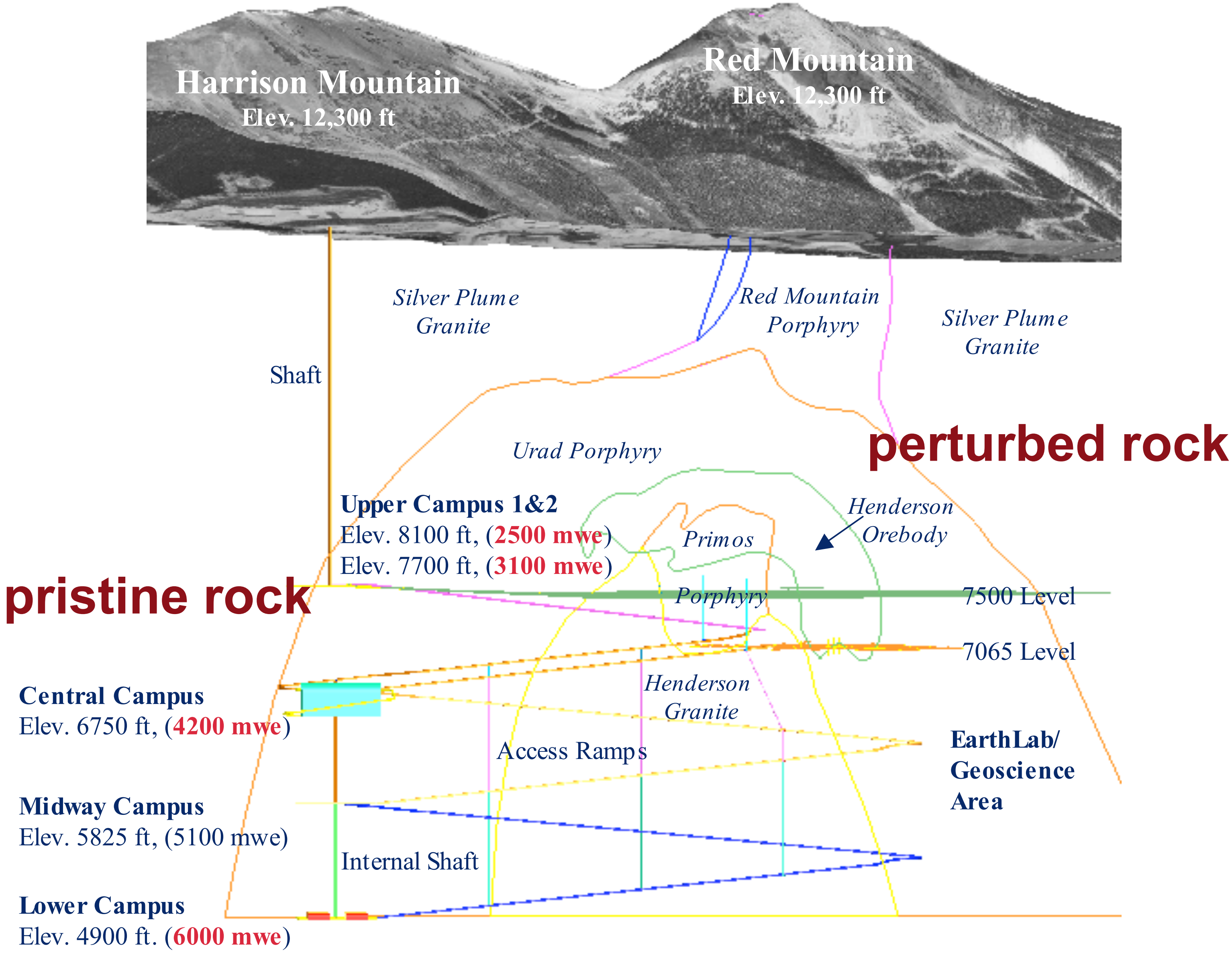


Henderson Conveyor and Rock Crusher

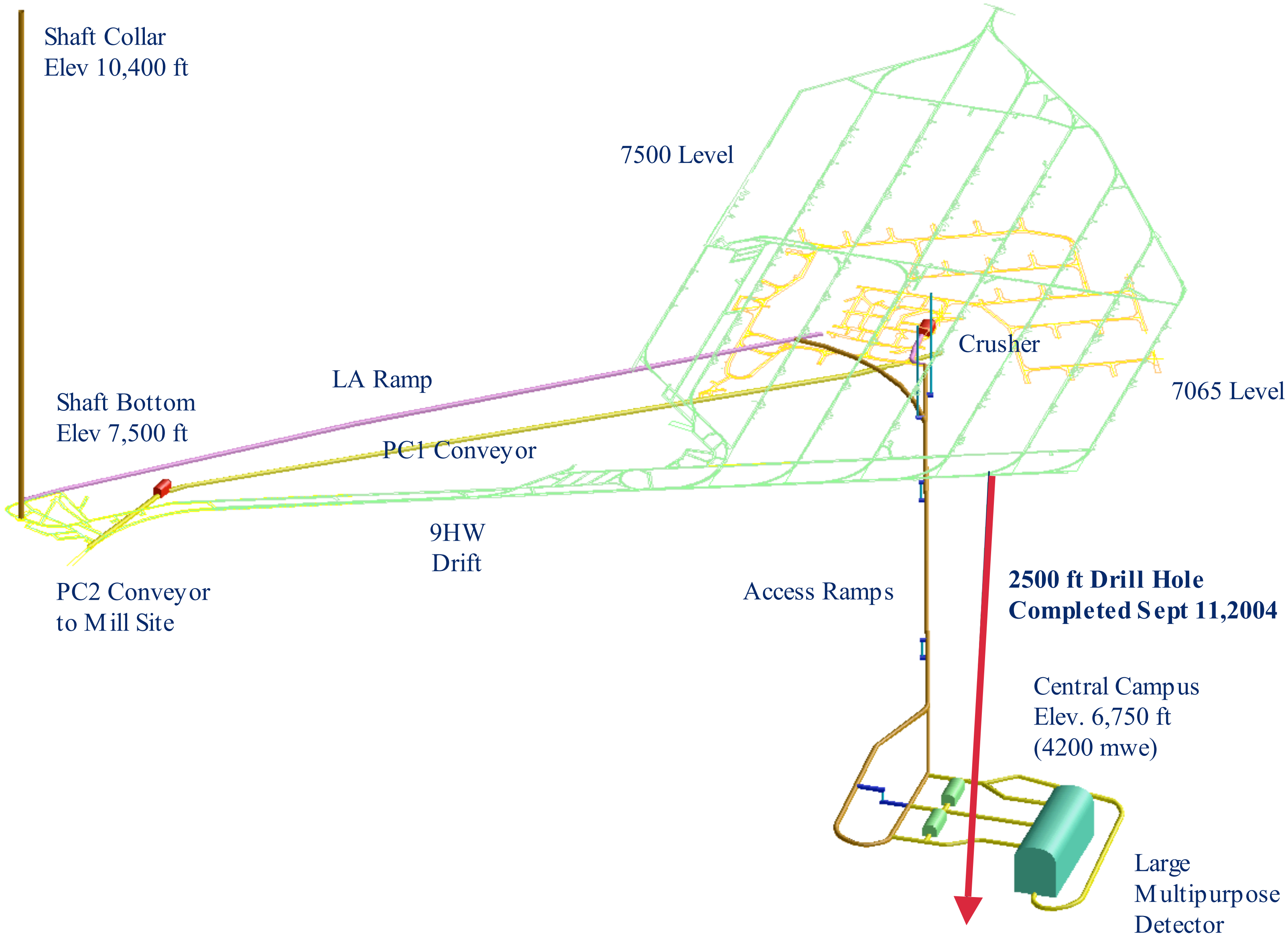




Henderson DUSEL Conceptual Design



Exploration Core Drill Hole

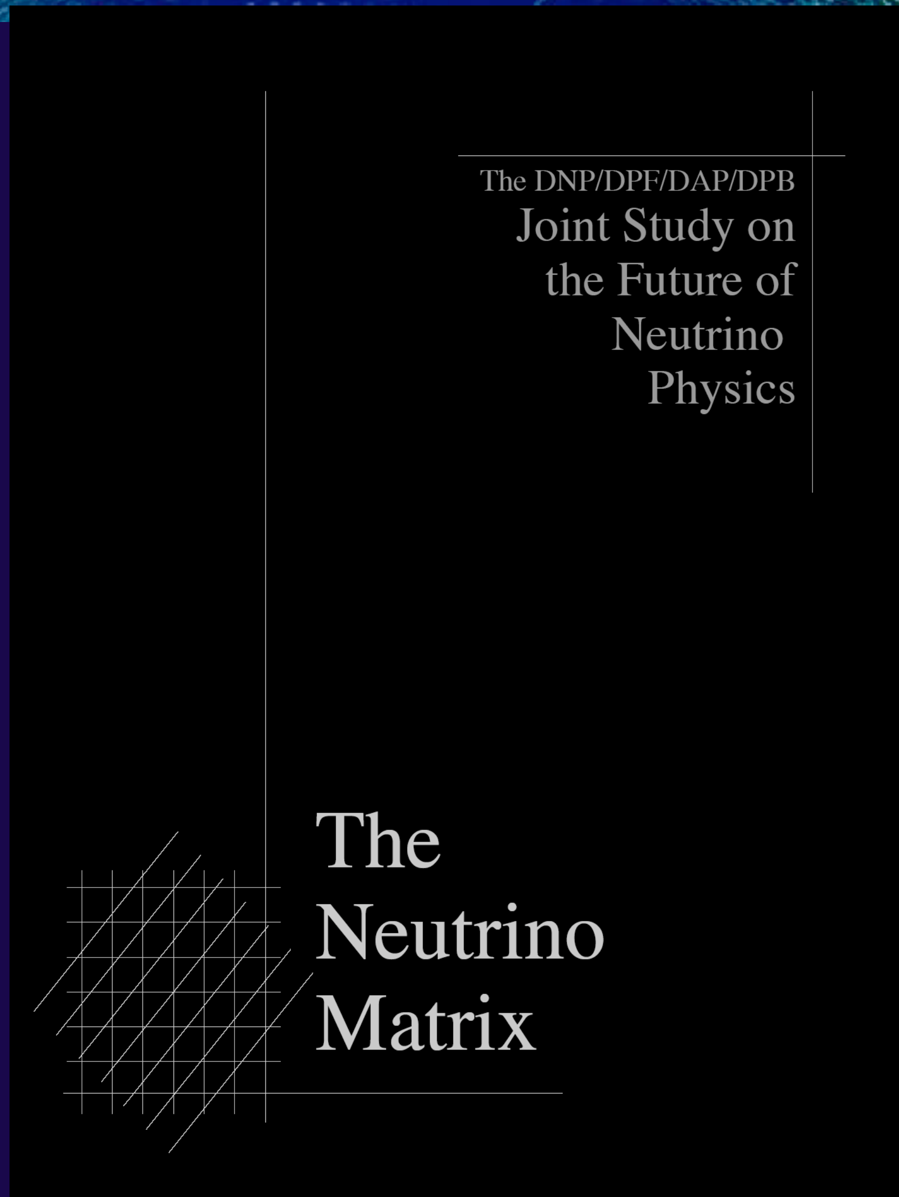


Community Support/View

National Committee Reviews

- HEPAP Long Range Plan Sub-panel (2001)
- CPU: Quarks to Cosmos (2002)
- NFAC, NRC/NAS (2002)
- HEPAP Facilities Sub-panel (2003)
- Physics of Universe (2004)
- APS Neutrino Study (2004)
  - All positive recommendations

APS Neutrino Study Report 2004



Recommendations

We recommend, as a high priority, a phased program of sensitive searches for neutrinoless nuclear double beta decay. *In this rare process, one atomic nucleus turns into another by emitting two electrons. Searching for it is very challenging, but the question of whether the neutrino is its own antiparticle can only be addressed via this technique. The answer to this question is of central importance, not only to our understanding of neutrinos, but also to our understanding of the origin of mass.*

We recommend, as a high priority, a comprehensive U.S. program to complete our understanding of neutrino mixing, to determine the character of the neutrino mass spectrum and to search for CP violation among neutrinos. *This comprehensive program would have several components: an experiment built a few kilometers from a nuclear reactor, a beam of accelerator-generated neutrinos aimed towards a detector hundreds of kilometers away, and, in the future, a neutrino 'superbeam' program utilizing a megawatt-class proton accelerator. The interplay of the components makes possible a decisive separation of neutrino physics features that would otherwise be commingled and ambiguous. This program is also valuable for the tools it will provide to the larger community. For example, the proton accelerator makes possible a wide range of research beyond neutrino physics.*

The development of new technologies will be essential for further advances in neutrino physics. On the horizon is the promise of a neutrino factory, which will produce extraordinarily pure, well-defined neutrino beams. Similarly challenging are the ideas for massive new detectors that will yield the largest and most precise samples of neutrino data ever recorded. These multipurpose detectors can also be used for fundamental and vitally important studies beyond the field of neutrino physics, such as the search for proton decay.

We recommend development of an experiment to make precise measurements of the low-energy neutrinos from the sun. *So far, only the solar neutrinos with relatively high energy, a small fraction of the total, have been studied in detail. A precise measurement of the low-energy neutrino spectrum would test our understanding of how solar neutrinos change flavor, probe the fundamental question of whether the sun shines only through nuclear fusion, and allow us to predict how bright the sun will be tens of thousands of years from now.*

Some Relevant Comments from the Executive Summary

- **Underground laboratory facilities.** The extreme rarity of neutrino interactions requires that experiments that are central to our proposed program, including double beta decay, studies with the multipurpose very large detector, and solar neutrino research, be carried out deep underground in appropriately designed laboratories.

- **Research and development to assure the practical and timely realization of accelerator and detector technologies critical to the recommended program.** Of particular importance are R&D efforts aimed toward development of a high-intensity proton driver, a neutrino factory, a very large neutrino detector, and techniques for detection of ultra-high-energy neutrinos.

- **International cooperation.** We advocate that the program to answer the outstanding neutrino questions be international. In this report, we recommend a U.S. program that will make unique contributions to this international effort, contributions that will not be duplicated elsewhere. The U.S. program, involving experiments within the U.S. and American participation in key experiments in other countries, has the potential to become the best in the world. But it must cooperate with the programs of other nations and regions. The programs to be carried out throughout the world must complement each other. We explain how they can do this.

Neutrino Scientific Assessment Group (NuSAG)

- New National Committee on Neutrino Programs
  - Established as a joint sub-panel by HEPAP and NSAC (Nuclear Science Avvisory Committee) in March 2005 with a two-year fixed term
  - Requested by DOE and NSF
  - Prioritized recommendation requested
  - Advisory to DOE and NSF
  - First three charges
    - ⇒ Charge 1: nuclear reactor experiments for θ_{13} measurement
    - ⇒ Charge 2: neutrino-less double beta decay experiments
    - ⇒ Charge 3: accelerator based LBL NO experiments for θ_{13} measurement
  - This panel will most likely discuss UNO in near future

EPP2010

- A National Research Council's (NRC) Committee on Elementary Particle Physics in the 21st Century
  - Charge:
    - ⇒ Identify, articulate, and prioritize the scientific questions and opportunities that define elementary-particle physics.
    - ⇒ Recommend a 15-year implementation plan with realistic, ordered priorities to realize these opportunities.
  - http://www7.nationalacademies.org/bpa/EPP2010.html
  - Future meetings:
    - ⇒ may 16-17, Fermilab
    - ⇒ Aug. 2-3, Cornell
  - Need to have physics of UNO, especially the proton decay, represented in the committee considerations

Current US Government Support/View

US Government Agencies Views on Proton Decay Expeirments

- OSTP
  - Proton decay research and detector R&D specifically recommended in the Physics of Universe document
- NSF
  - Language of "proton decay" experiment is included in the possible DUSEL mission statement as part of the "large module" experiments
- DOE
  - No explicit language of "proton decay" appears in recent strategy documents

    ⇒ multi-purpose detector mentioned in context of superbeam

What do we need to do?

- Promote the science case of proton decay research further
  - Proton decay: a Giant Orphan of Particle Physics
  - Need serious assistance of theoretical community
    - $\Rightarrow$ e.g. writing letters to funding agencies
- Do rigorous R&D
  - Establish feasibility and reduce detector cost
  - Engage private industry
- Develop full simulation/analysis software
  - Critical in optimizing the experiment

Continue: What do we need to do?

- Engage accelerator labs
  - – Ownership of the detector
  - – They have the political power and funding flexibility
- Closer/coordinated International cooperation
  - – Rare available resources: funding and manpower
  - – Formation of world-wide NNN committee?
- Engage other region/countries
  - – Initial discussion with S. Korean government just started
- Generate more enthusiasm in the community, especially among junior members
- Continue communicating with the funding agencies
  - – Things can change rapidly!

The End