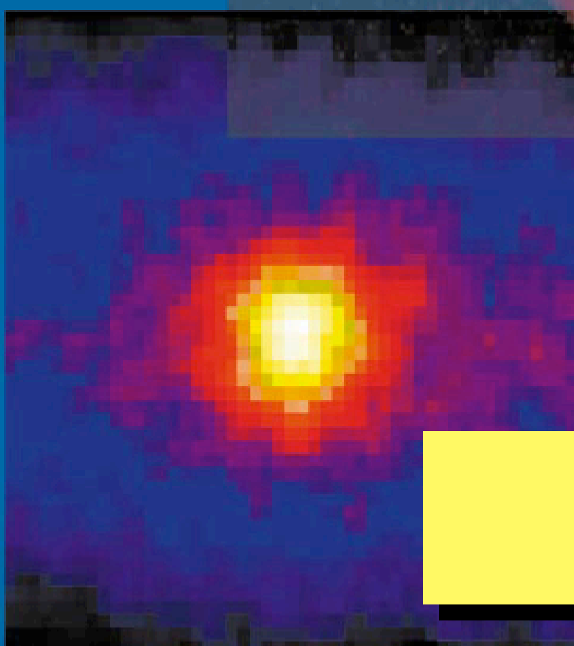
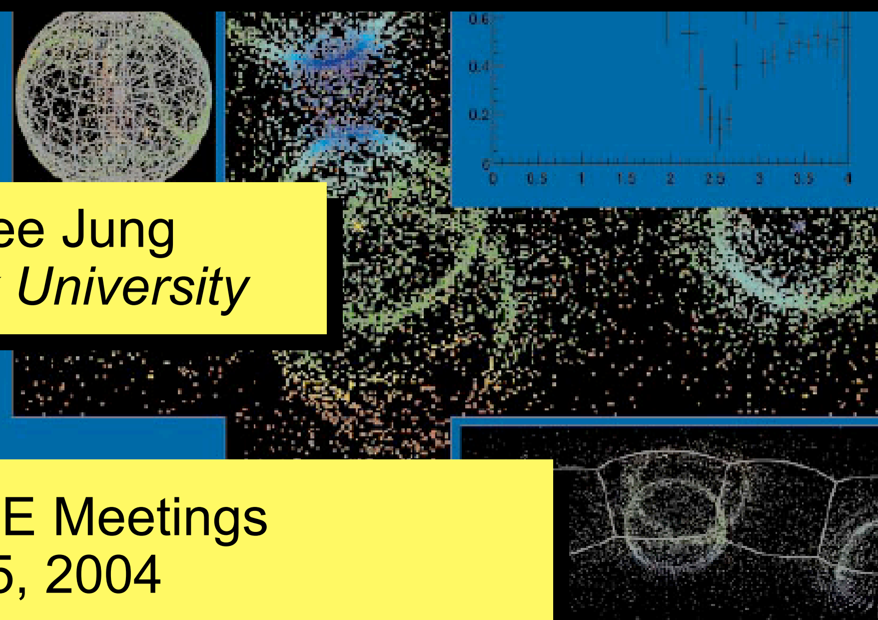
http://nngroup.physics.sunysb.edu/nngroup/pub/whitepaper.ps

Physics Potential and Feasibility of UNO

UNO
(Physics, Status and R&D Plans)





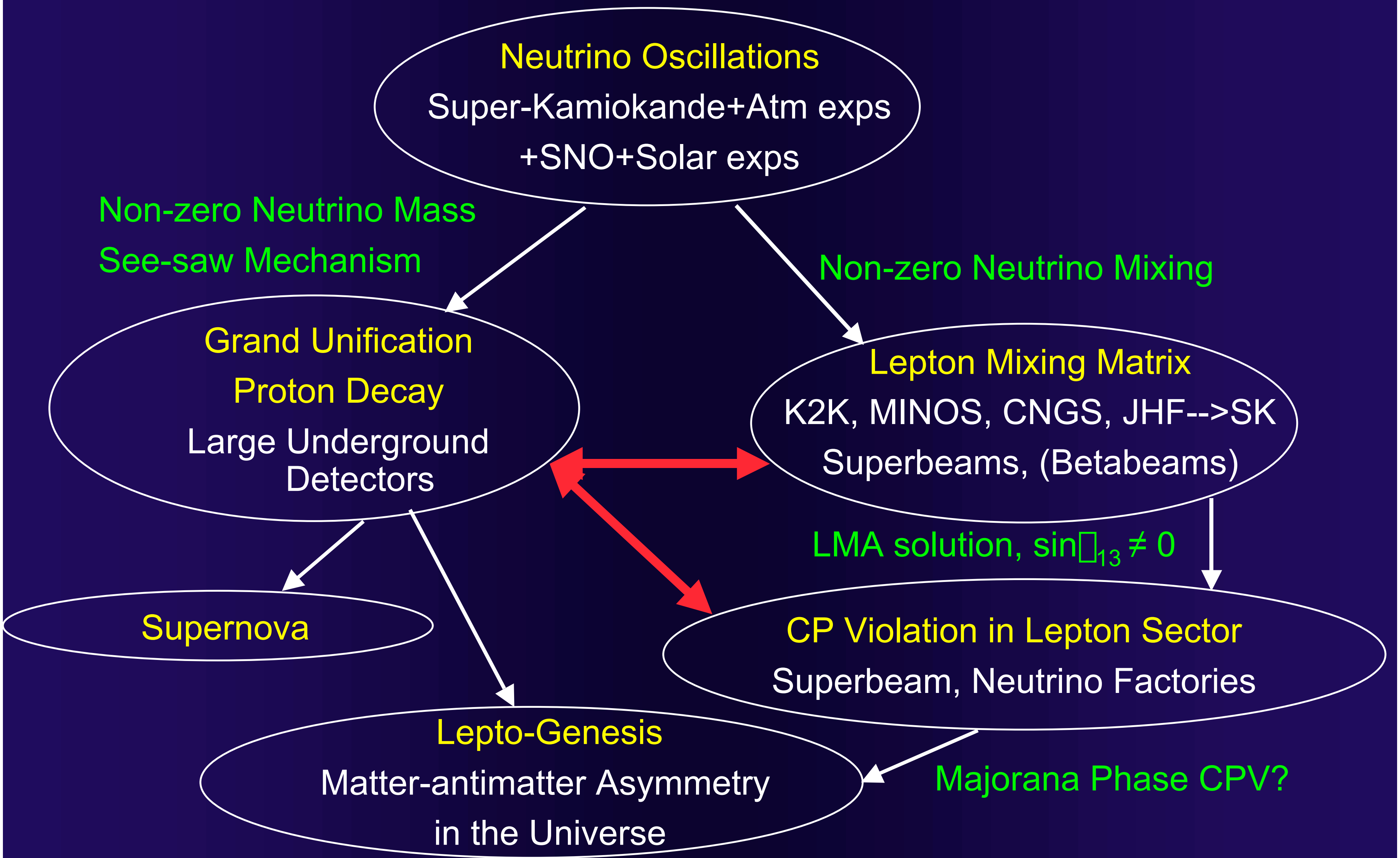
Chang Kee Jung

Stony Brook University

ECFA/BENE Meetings

May 25, 2004

1998 Neutrino Revolution and Physics Goals for NNN Experiments

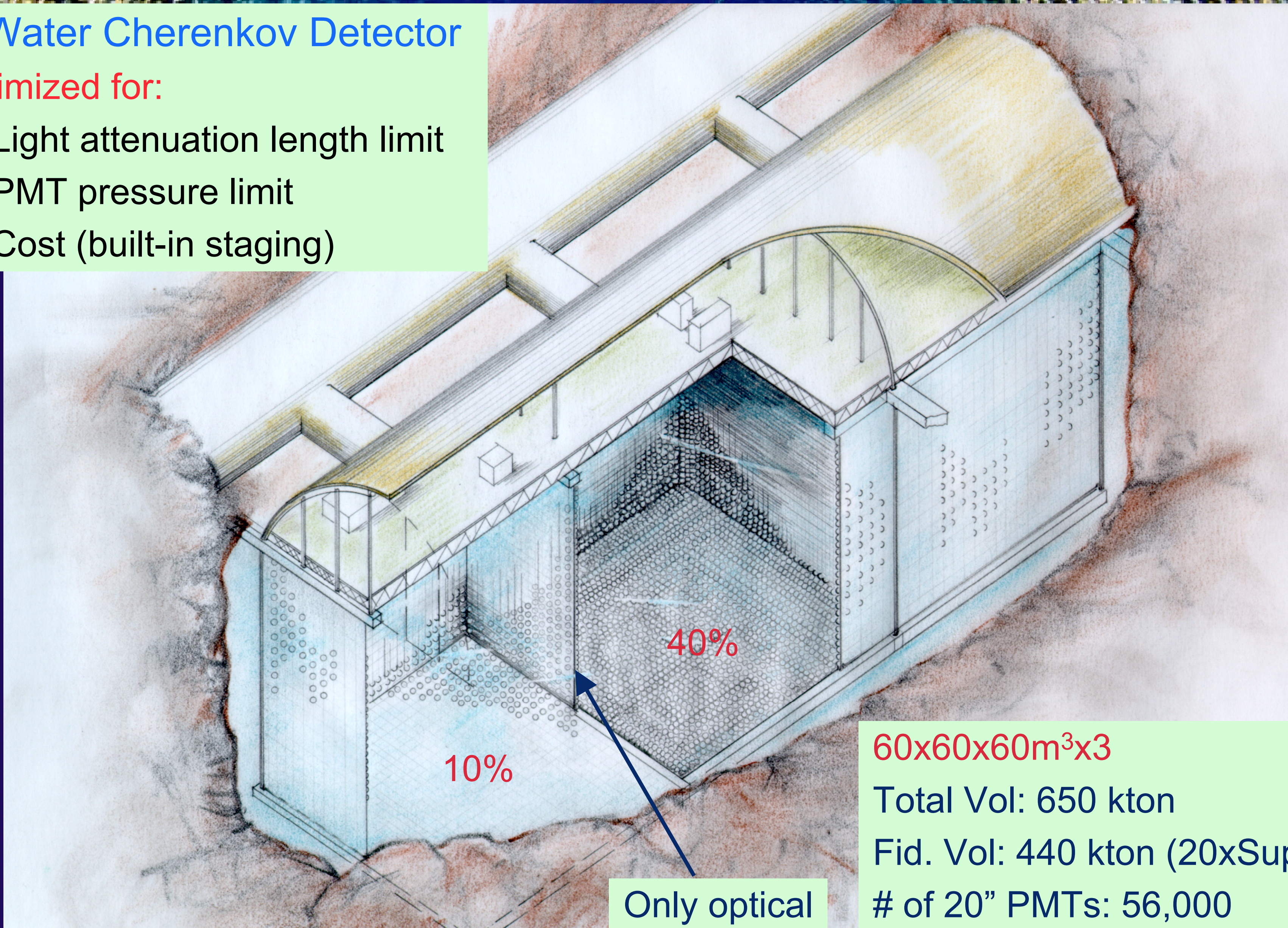


UNO Detector Conceptual Design

A Water Cherenkov Detector

optimized for:

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



Only optical separation

60x60x60m³x3

Total Vol: 650 kton

Fid. Vol: 440 kton (20xSuperK)

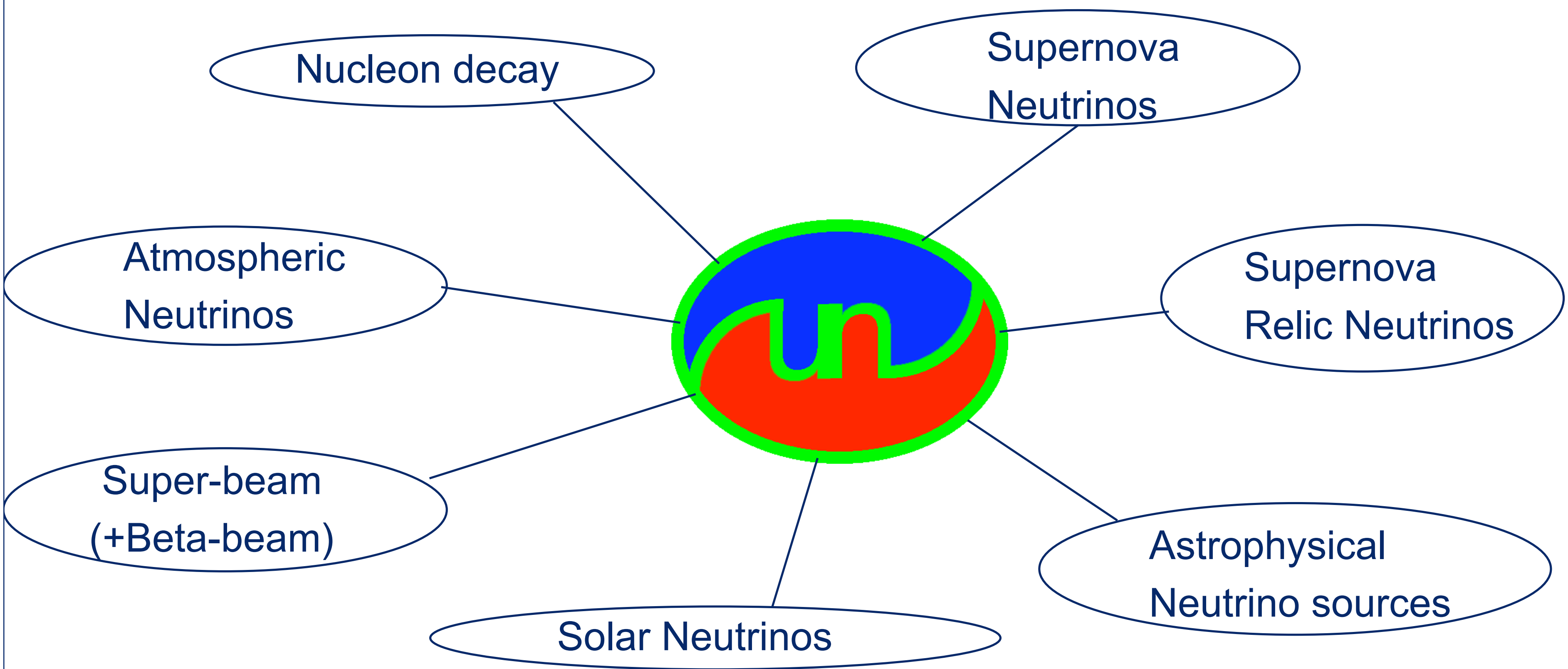
# of 20" PMTs: 56,000

# of 8" PMTs: 14,900

Why not smaller multiple detectors?

- More Expensive
  - Larger surface area to fiducial volume ratio
    - Need more PMTs
  - Smaller fiducial to total volume ratio
  - Need more drifts and auxiliary/service space
    - typically excavation costs for drifts are more expensive than for large volume excavation
- Smaller Energy Containment
- Poorer Pattern Recognition Capability with same photocathode coverage
  - More detailed discussion later

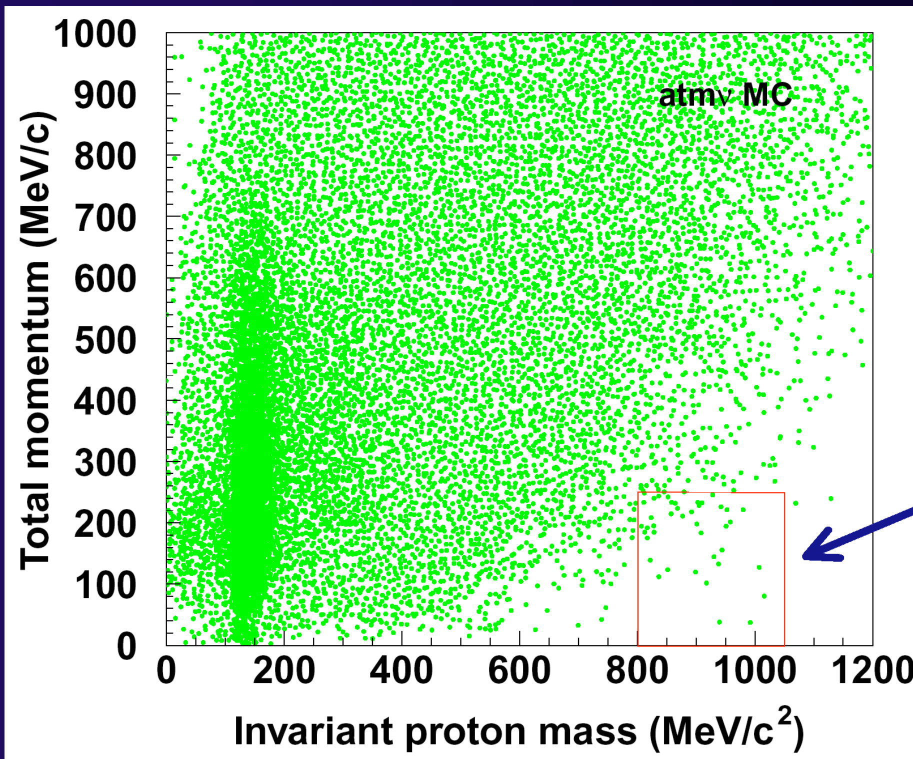
UNO Physics Goals

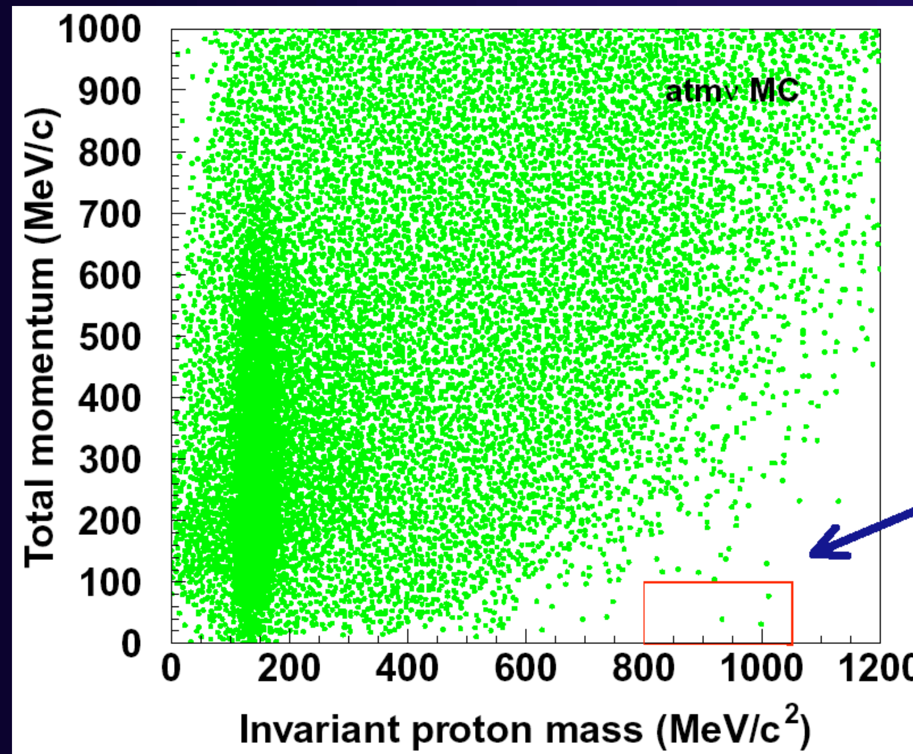


- **Multi-purpose detector with comprehensive physics programs for astrophysics, nuclear physics and particle physics**
- **Synergy between accelerator physics and non-accelerator physics**

p –> $e^+ \pi^0$ Search Background

20 Mton-yr Atm nu Background MC



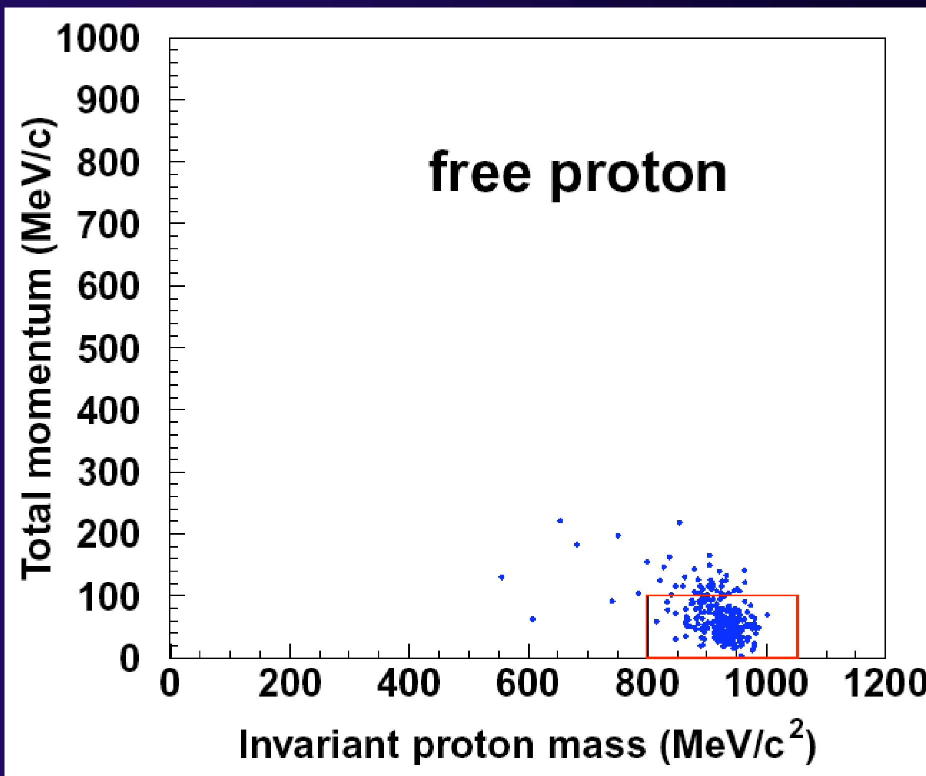


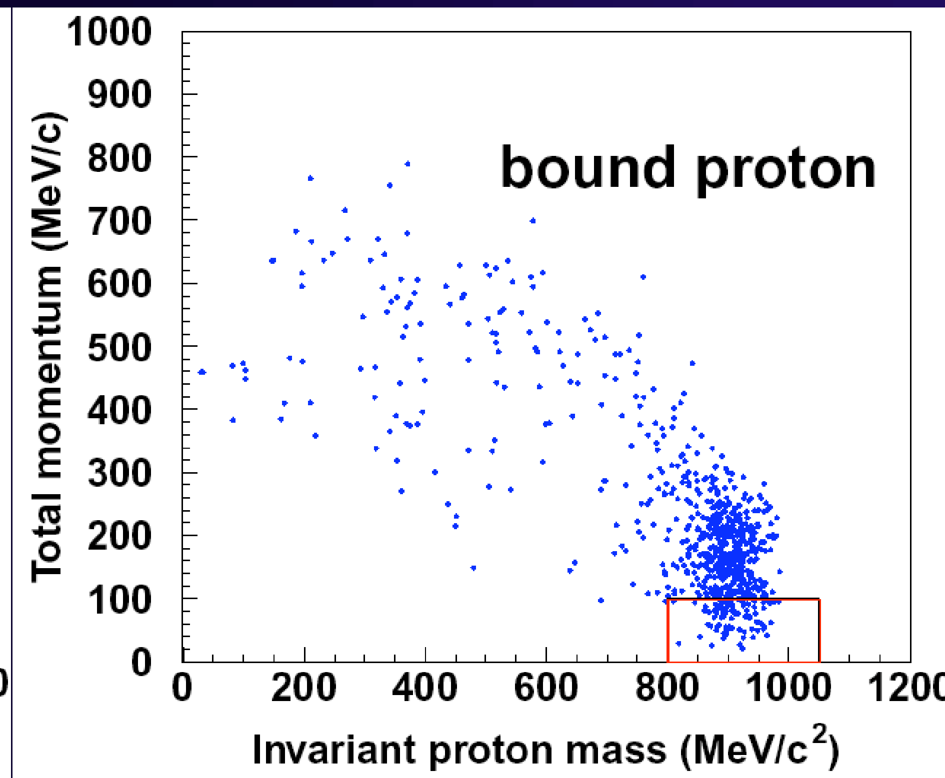
SuperK Standard Cuts
==> 2.2 events/Mton-yr
==> signal eff.: 43.0%

Tighter Momentum (UNO) Cut
==> 0.15 events/Mton-yr
==> signal eff.: 17.4%

$p \rightarrow e^+ \pi^0$ Search Signal

Signal Events w/ Tighter Momentum (UNO) Cut





No Fermi Momentum

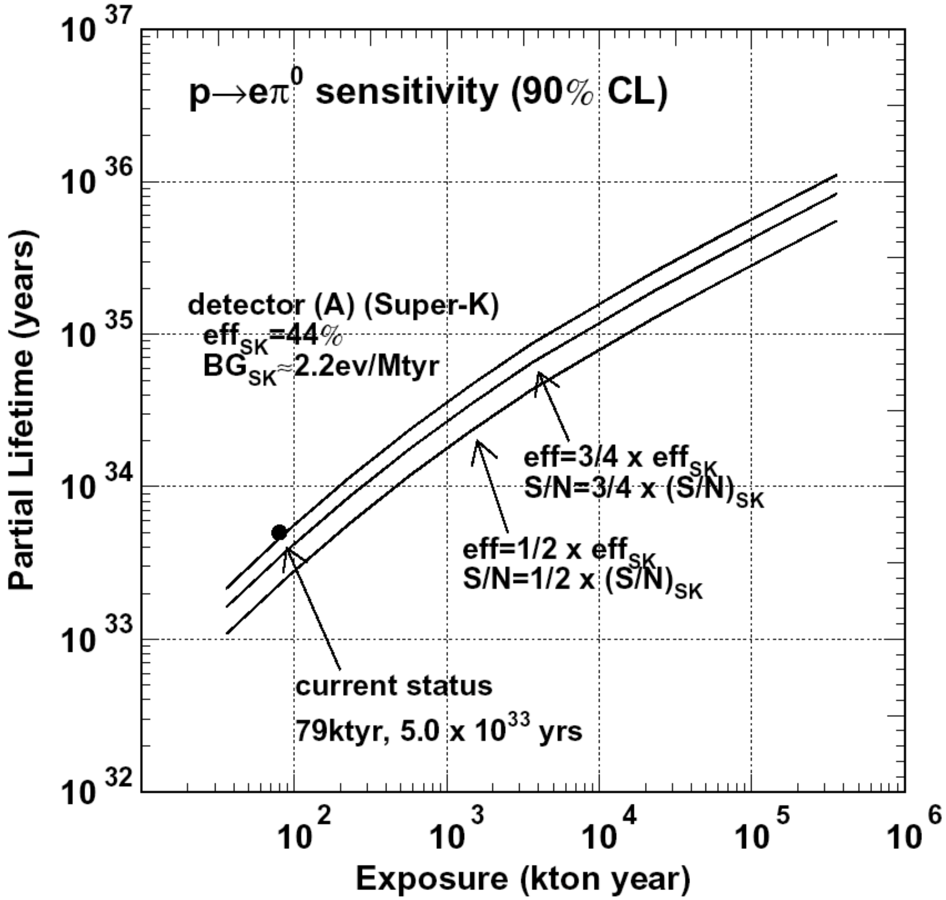
No Binding energy

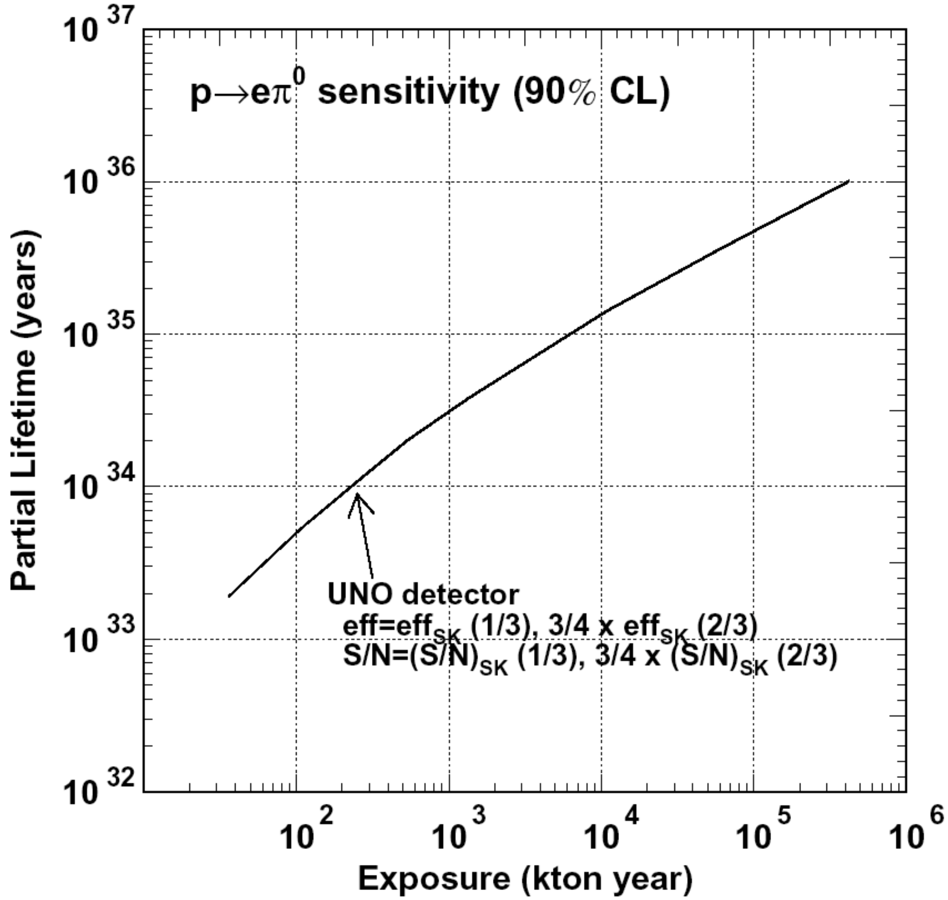
No Nuclear effect

Argon has no free protons

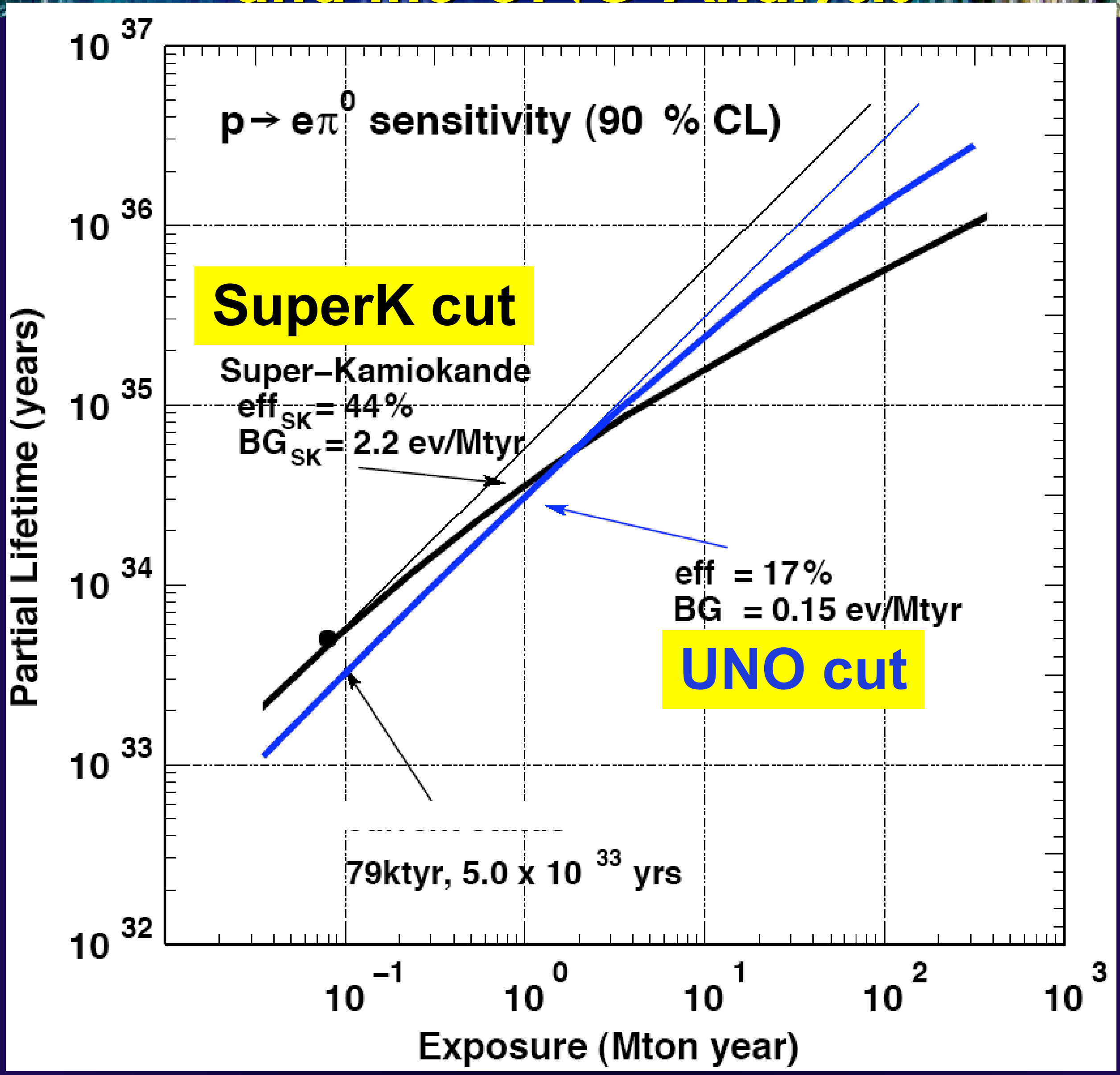
UNO Sensitivity for $p \rightarrow e^+ \pi^0$

Using SuperK Standard Cut





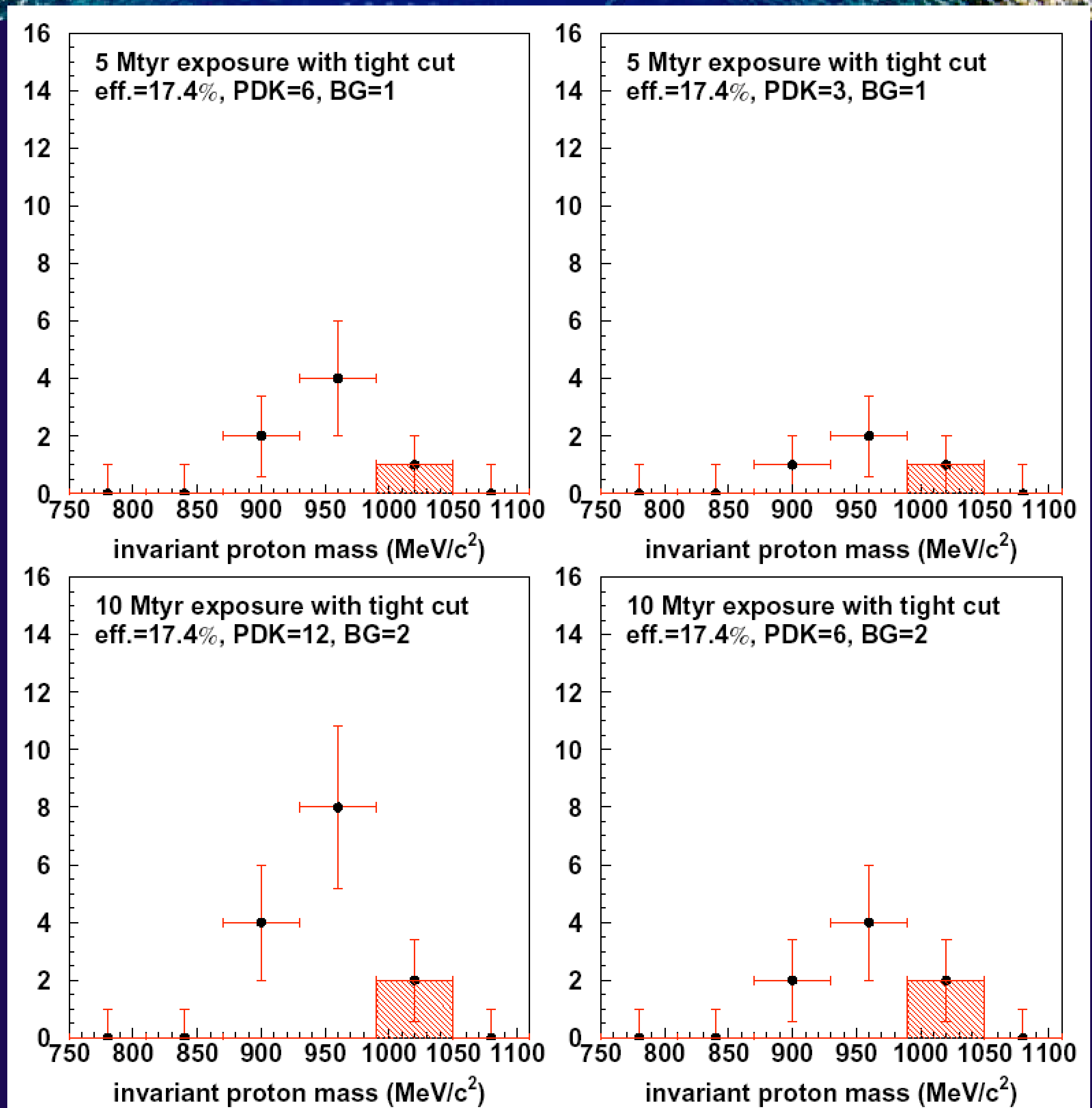
Comparison of the Standard SuperK Analysis and the UNO Analysis



Reconstructed Mass Peak from $p \rightarrow e^+ \pi^0$

$\tau/B(p \rightarrow e^+ \pi^0)$ = 5×10^{34} years

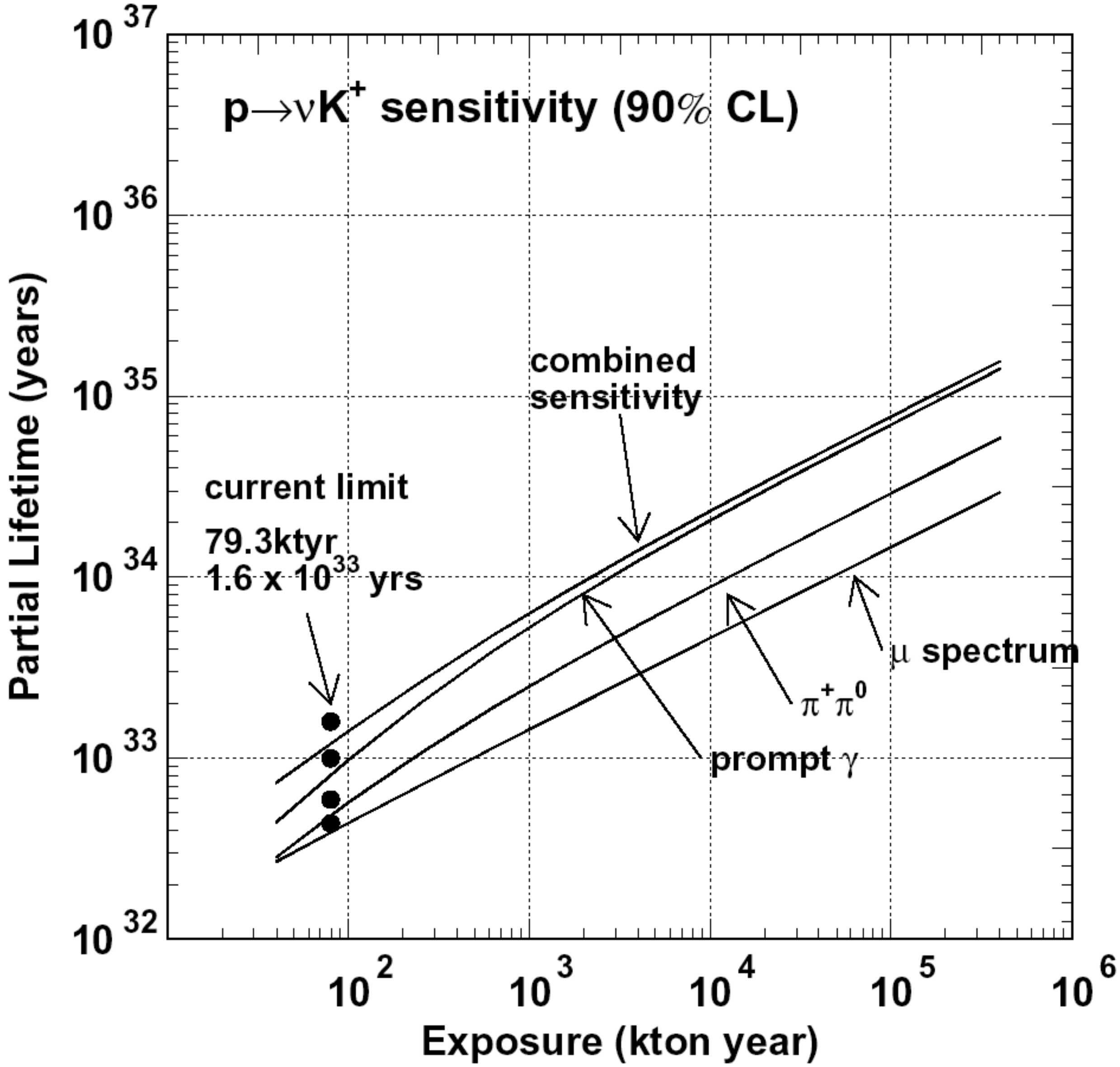
1 candidate event/~1.5 yrs



$\tau/B(p \rightarrow e^+ \pi^0)$ = 1×10^{35} years

1 candidate event/~3 yrs

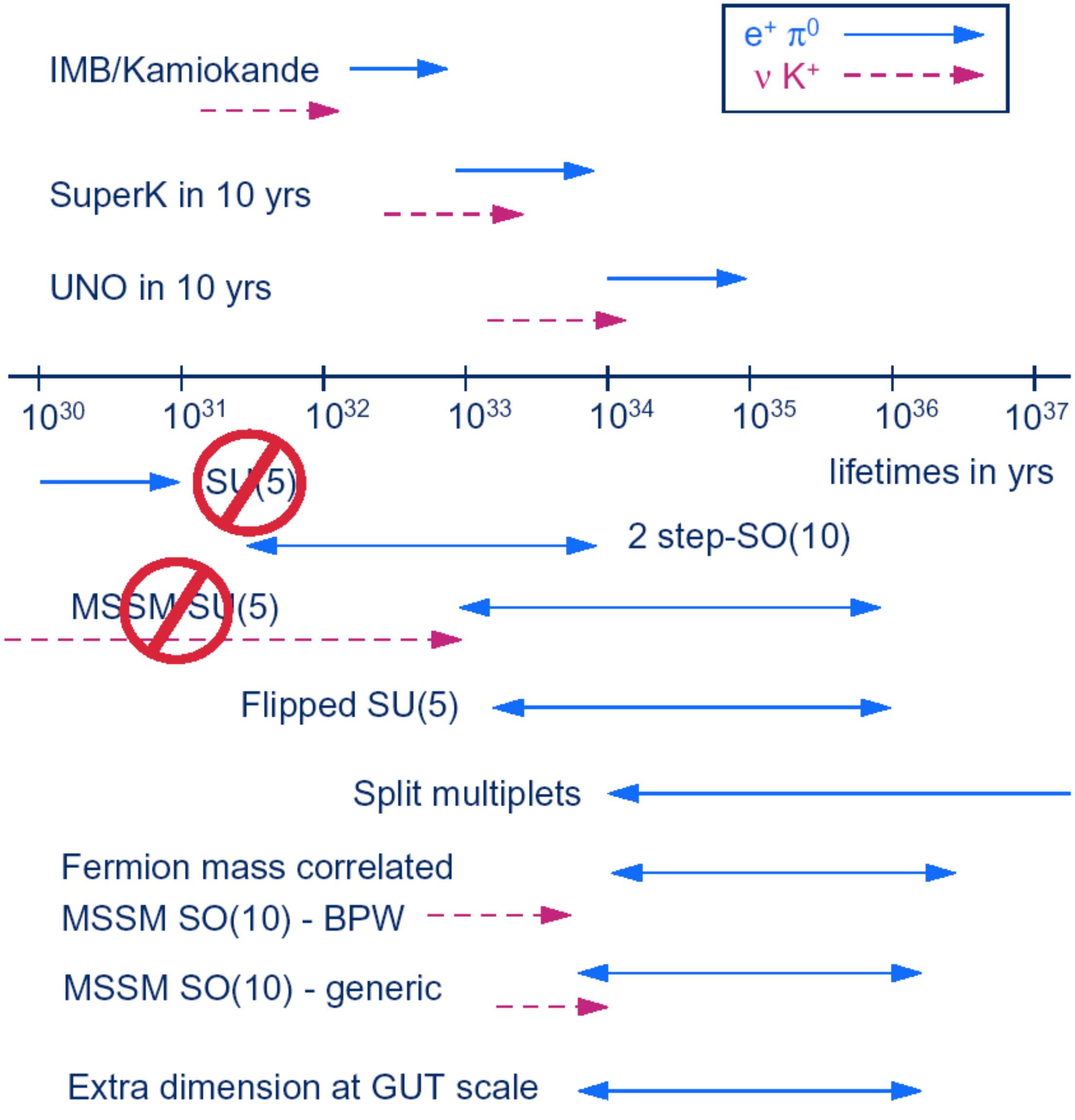
UNO Sensitivity for p K+



Prompt coincidence method most powerful: most backgrounds are mis-fitted vertex events
 can be rejected by improved fitter

Limiting background from p K+
1 event/Mt-yr

UNO Proton Decay Sensitivity



Proton Decay in Superstrings

Edward Witten mentioned "proton decay" about 10 times during his talk on Super-symmetry at the LP2003…

"Proton Decay in Intersecting D-brane Models",
I. Klebanov and E. Witten, hep-th/0304079

→ one of the first few testable calculations/predictions based on string theory
→ urged by Jung

"Unification Day": Oct. 15, 2004, Colorado
being co-organized by Witten and CKJ
Part of the UNO Collaboration Meeting Oct. 14-16

What are the biggest challenges we face for an approval of UNO?

The Challenges

- Ensuring ***Synergy*** between non-accelerator physics and the accelerator based neutrino oscillation physics
  - Influences site location, detector design, and cost
- Determining an ***Optimal Site***
  - Distances to possible neutrino beams, depth, access and environmental issues, local geology
    - influences detector design, and cost
- ***Reducing the cost*** or at least keeping it down
  - Depends on the physics requirements and site
  - Ultimate Question: Is the community willing to pay for this physics?
    - Enormous pressure from the LC community
  - R&D (mostly to reduce cost)

Synergy between Non-accelrator and Accelerator Physics

- Water Cherenkov detector is a natural fit for a superbeam LBL neutrino oscillation experiments
- CPV along with many other crucial oscillation parameters could be measured with a UNO scale detector at various baselines
  - CERN → Fréjus study (130 km, 4MW proton beam)
  - J-PARK → Kamioka study (295 km, 4MW proton beam)
  - BNL → Western sites study (2000 - 4000 km, 1MW proton beam)

  → an elegant idea (Bill Marciano, hep-ph/0108181)

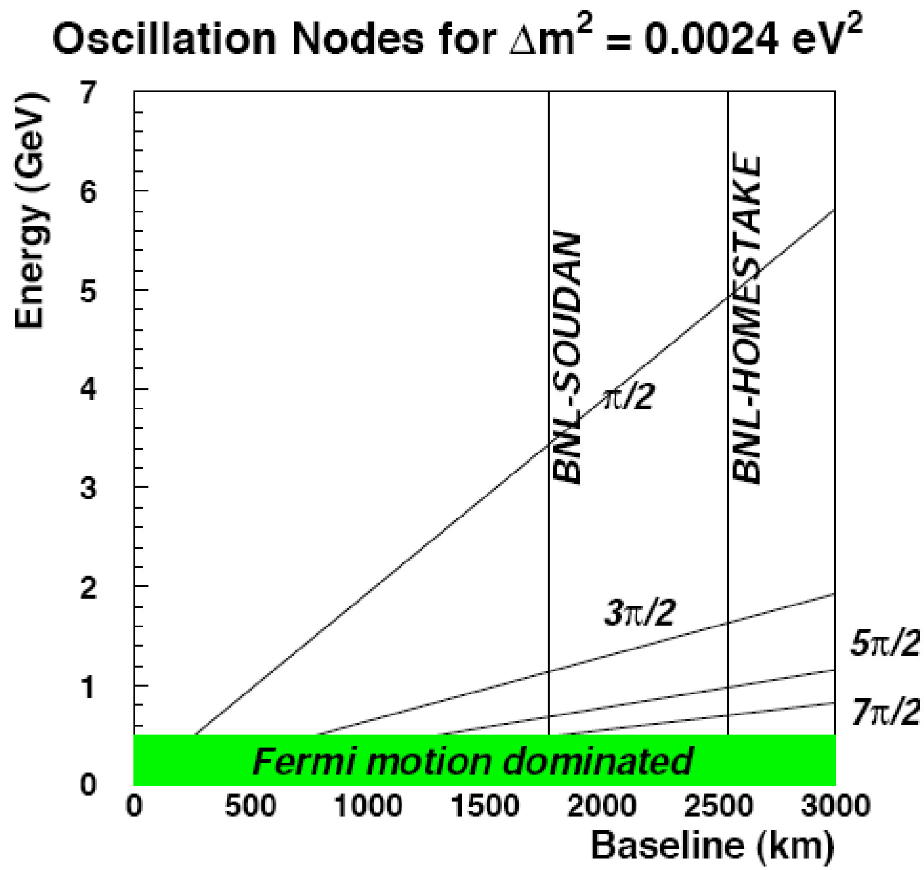
  provides a crucial LBL superbeam exp. option for UNO

BNL Study

Why the V in VLBL?

With Very Long Baselines:

- Multiple oscillations are resolvable.
- Oscillations in an energy region where:
  - Cross sections are higher
  - Fermi motion less detrimental to energy resolution
- For Δm^2 in SK region, need baseline > 2000 km.

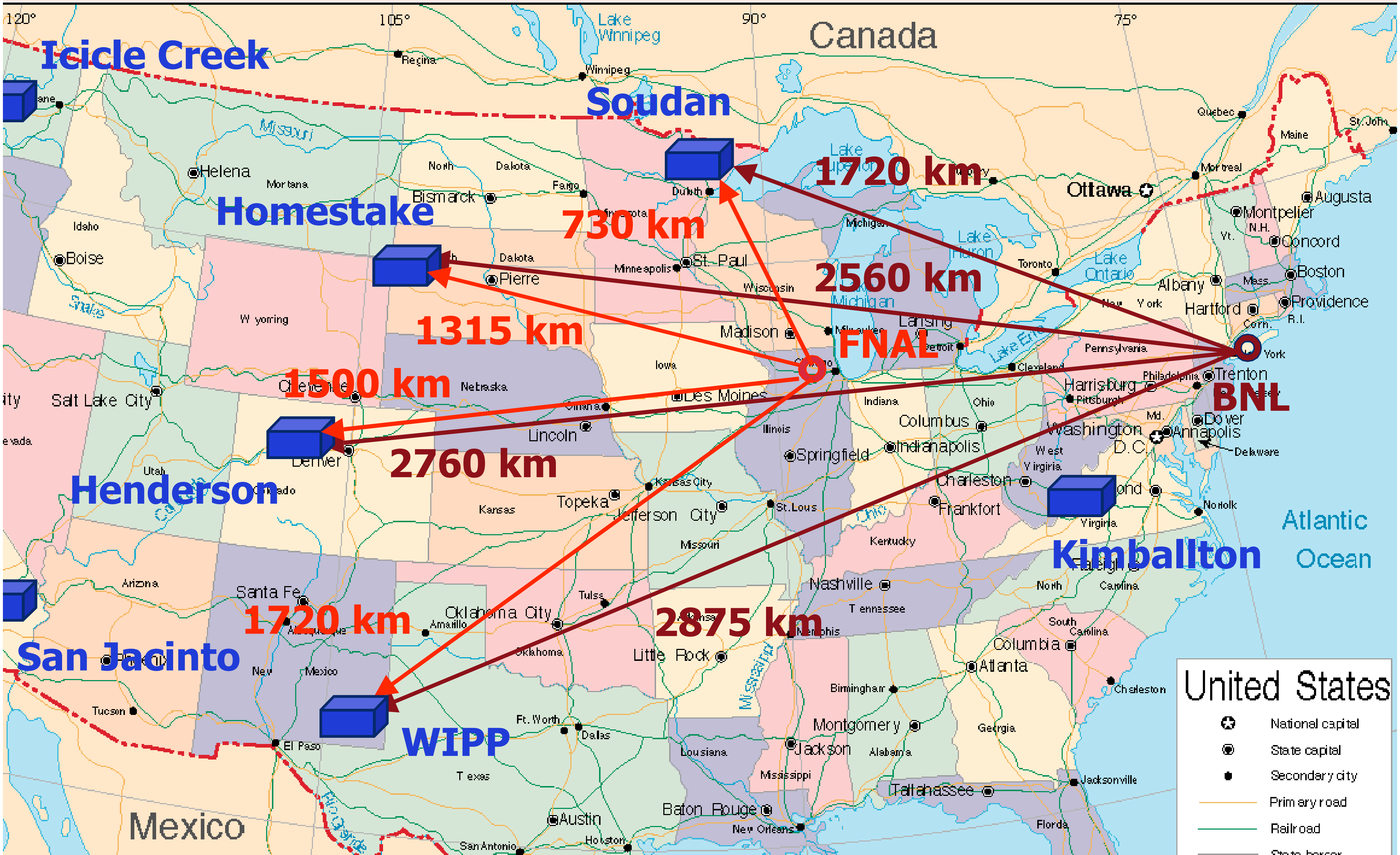


Need wide band, high energy ν beam, but what about NC ν_e bkg? $\longrightarrow$

BNL Plan Overview

- Upgrade BNL AGS proton driver to 1 MW, don't rule out 2 MW.
- Develop target/horn system able to handle >1 MW.
- Produce on-axis wide band high-ish energy neutrino beam ($E_{\mathrm{T2K}} < E_{\mathrm{BNL}} < E_{\mathrm{NuMI}}$).
- Find a 500 kton fiducial mass water Cherenkov detector,
- at a 2000 – 3000 km distance (focus is on 2500 km).
- Run for 5×10^7 secs (over 5 years) in neutrino mode.
- Run 2 MW, 5 years in anti-neutrino mode if needed.

NUSEL Candidate Sites and Potential Superbeam Experiments



Is BNL Superbeam Very Long Baseline Experiment feasible?

Background Study at Stony Brook

- Study done so far with SuperK detector geometry and configuration
  - Initial results were discouraging
  - Recent analysis improves the results (hopeful)

Analysis	Signal	Bkg	Comments	Signal	Bkg
BNL Rep	ν_e QE	ν_μ NC $1\pi^0$		303	146
I	ν_e QE	ν_μ NC $1\pi^0$		242	380
II	ν_e QE	ν_μ NC $1\pi^0$	likelihood	228	233
III	ν_e CC	ν_μ, ν_e NC ν_μ CC	Δlikelihood		
			< 0.0	501	1102
			< -0.4	450	853
			< -0.8	397	617
			< -2.0	251	253

Summary of Yanagisawa's work

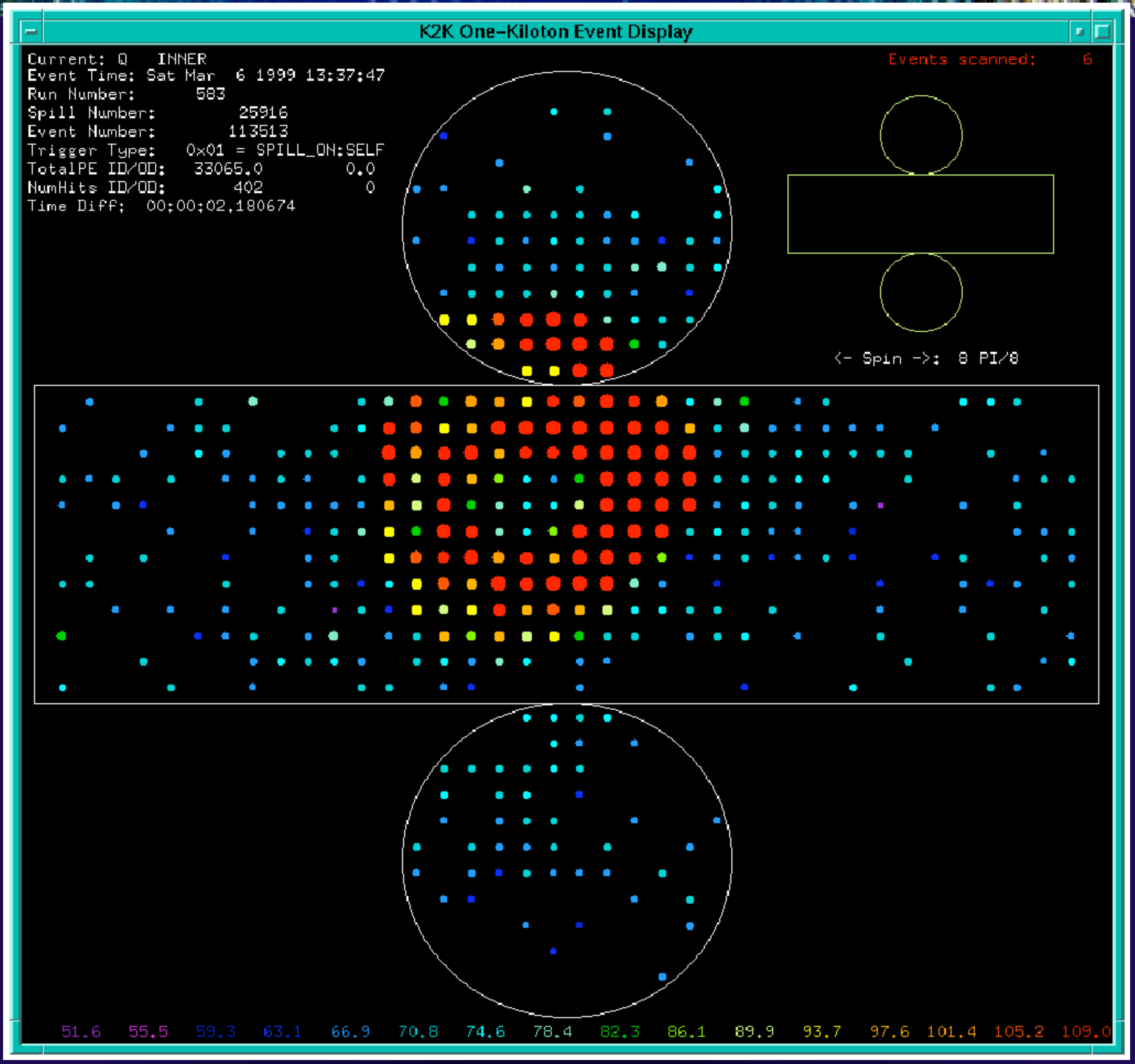
Continue: Background Study at Stony Brook

- More room to improve in analysis
  - For example, look for crisp electron ring against other garbage rather than positively identifying pi-zeros
- Can the UNO detector characteristics be approximated with the SuperK geometry
  - UNO central module: 40% photo-cathode coverage
    - same as the SuperK-I
    - Are the two detectors have the same detector performance?
  - UNO wing modules: 10% photo-cathode coverage

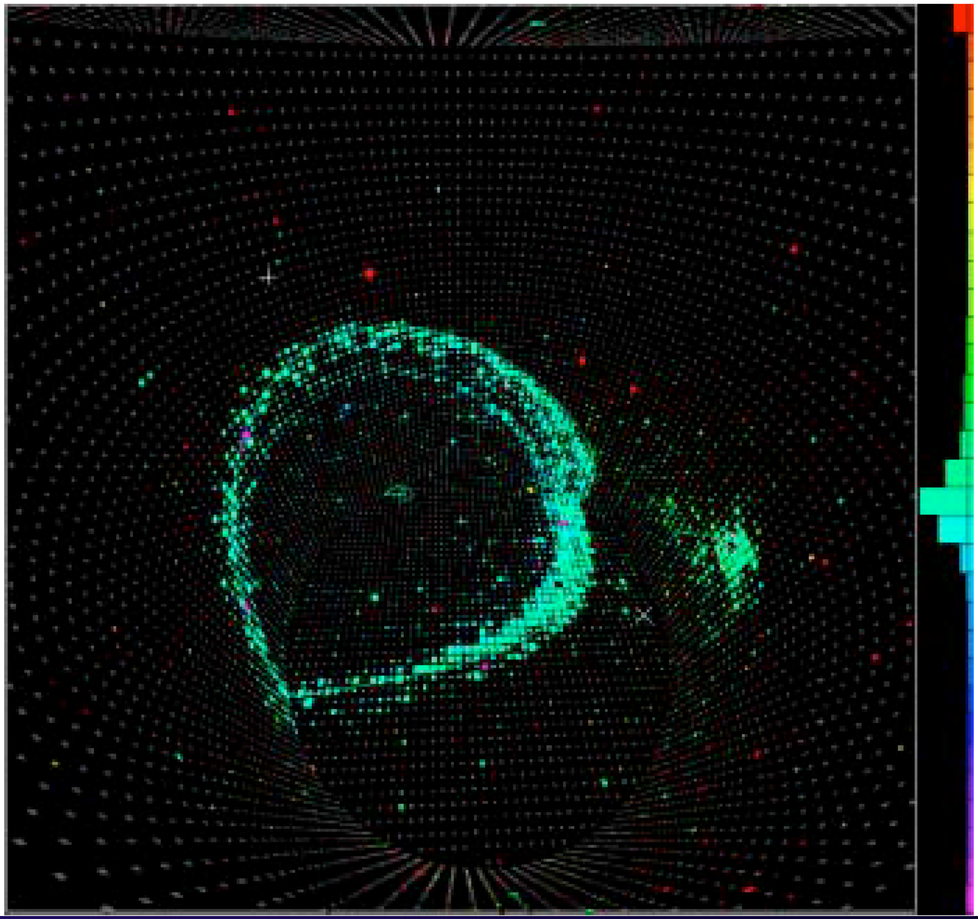
Detector Size Effects

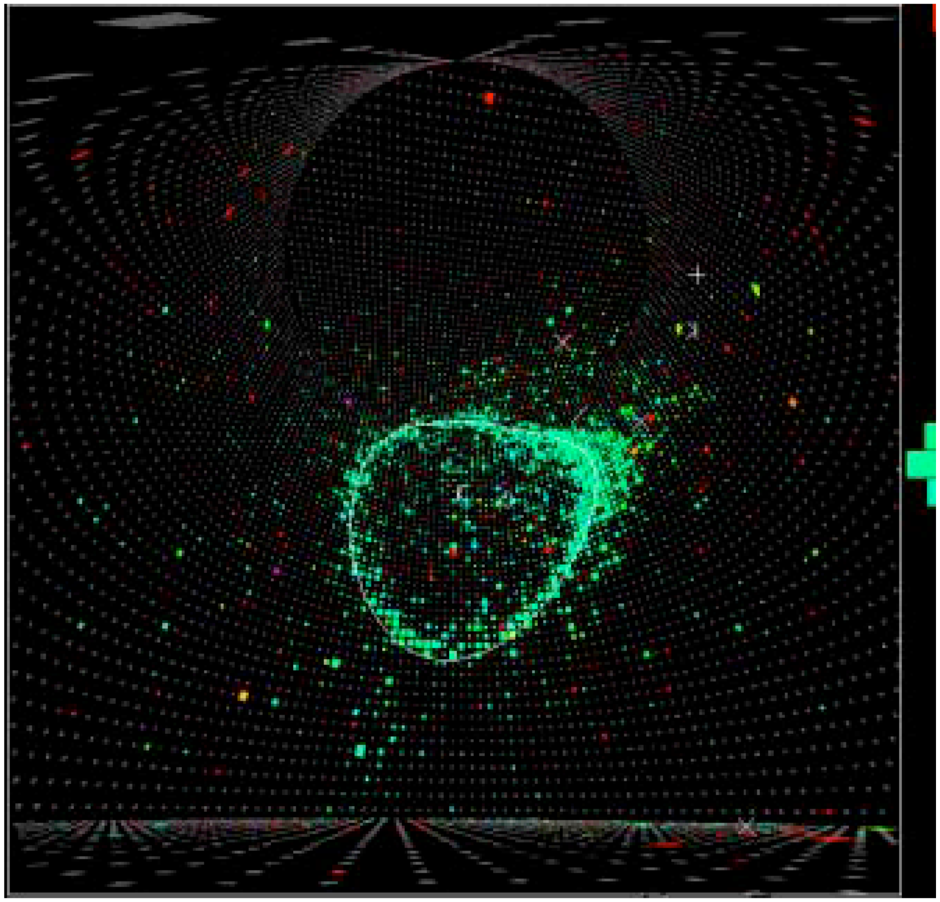
- For the same photo-cathode coverage, the larger detector has effectively finer granuality
  - Better pattern recognition capability
    - Better Particle ID
  - Better position and angular resolutions
  - SuperK vs K2K 1kt detector **
- We expect UNO central module will be better than the SuperK-I (about 4:1 granuality ratio)
  - Need detailed MC to verify this
  - Preliminary study with SuperK geometry MC
  - Loss of Cherenkov light due to light attenuation need to be taken into account

Muon-like Event in 1kt

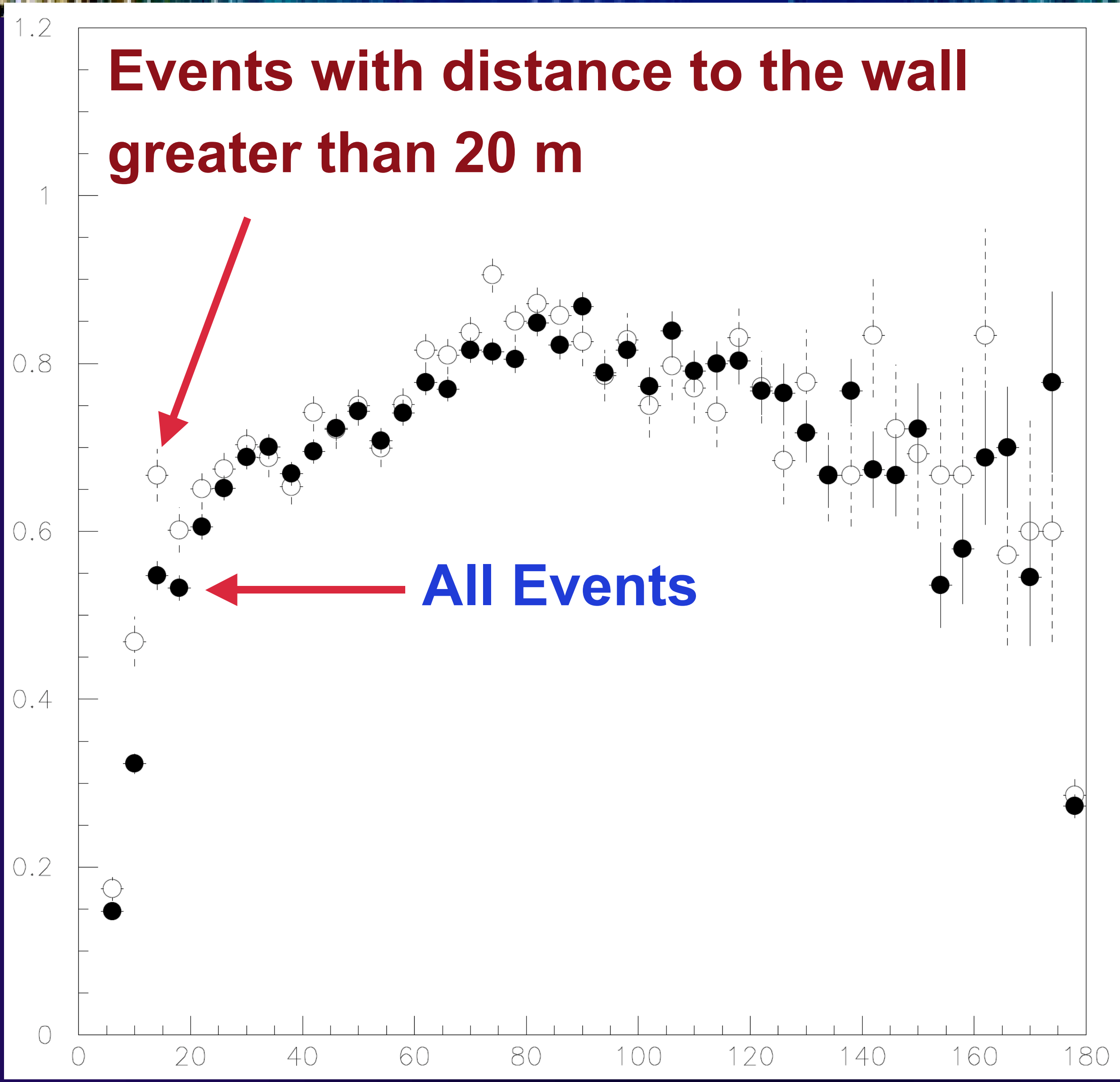


K2K Events in SuperK





Pi-zero Finding Efficiency



True openning Angle (degrees)

What can be done in the future?

Overriding principle: Keep the cost down

- Detector

1. Development of more sophisticated software
   - Improvement in computing will most likely come without increase in cost
   - SuperK Tau appearance analysis, L/E analysis **…
2. Possible employment of more sophisticated electronics
   - waveform digitizer
   - Narrower PMT integration time
     - Reduce scattered light

Q: Is BNL Superbeam Very Long Baseline Experiment feasible?

A: We do not have an answer yet, but, I believe, It deserves a serious consideration

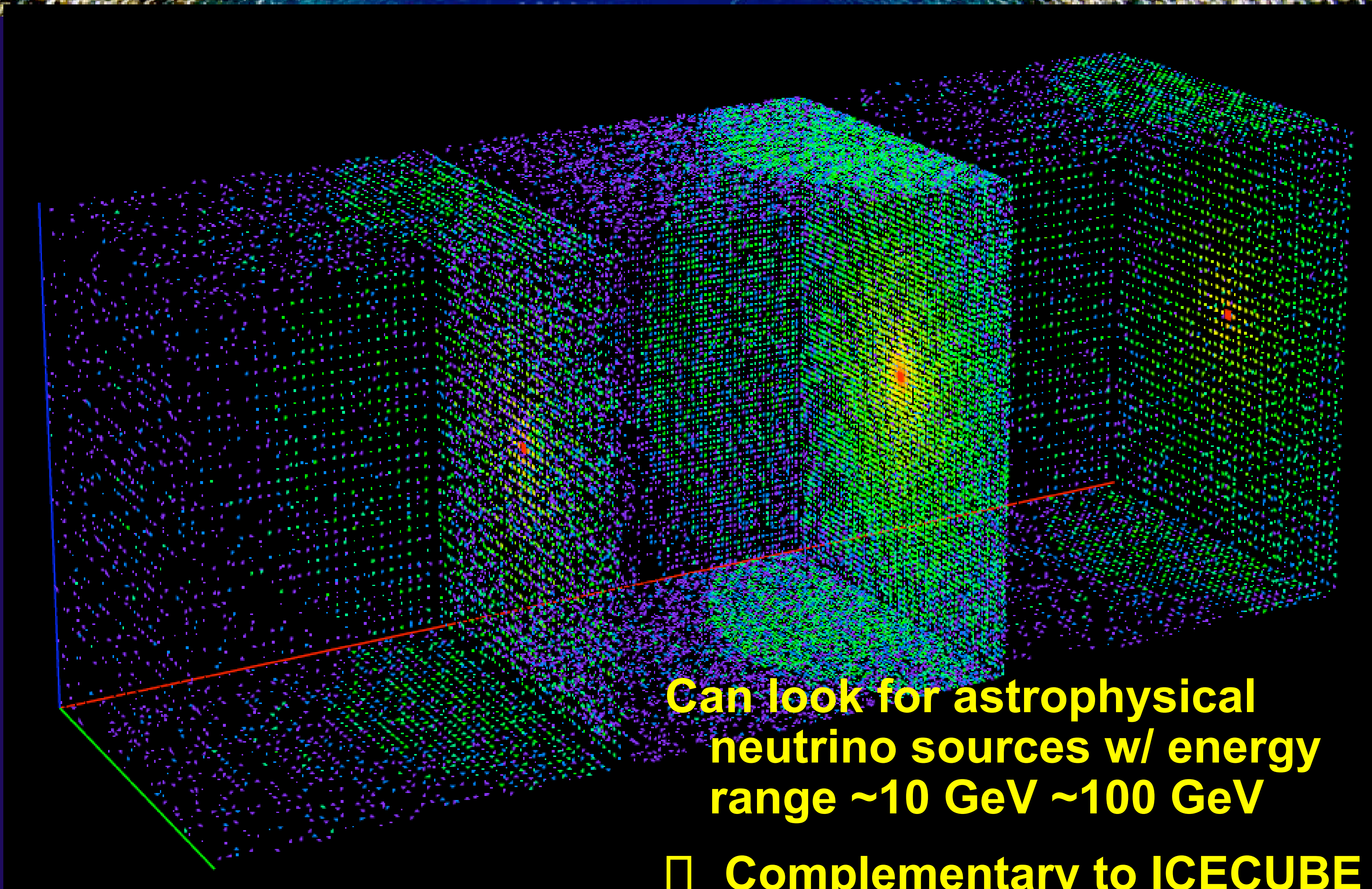
- With critical and careful simulation work
- This could be the idea most fashionable 10 years later
  - recall original BNL off-axis long baseline experiment proposal in the early 1990's
    - Wrong baseline (due to imprecise knowledge on oscillation parameters)
    - But was proven to an ingenious idea (credit to TRIUMF)
- The basic idea can be used for an experiment at Fermilab or any other accelerator labs

Status of UNO Software

(work done mostly McGrew and Viren (BNL))

- Detector Simulation
  – Mostly done
  – A useable version exist
- Event reconstruction
  – Still in infancy
  – Much more work need to do

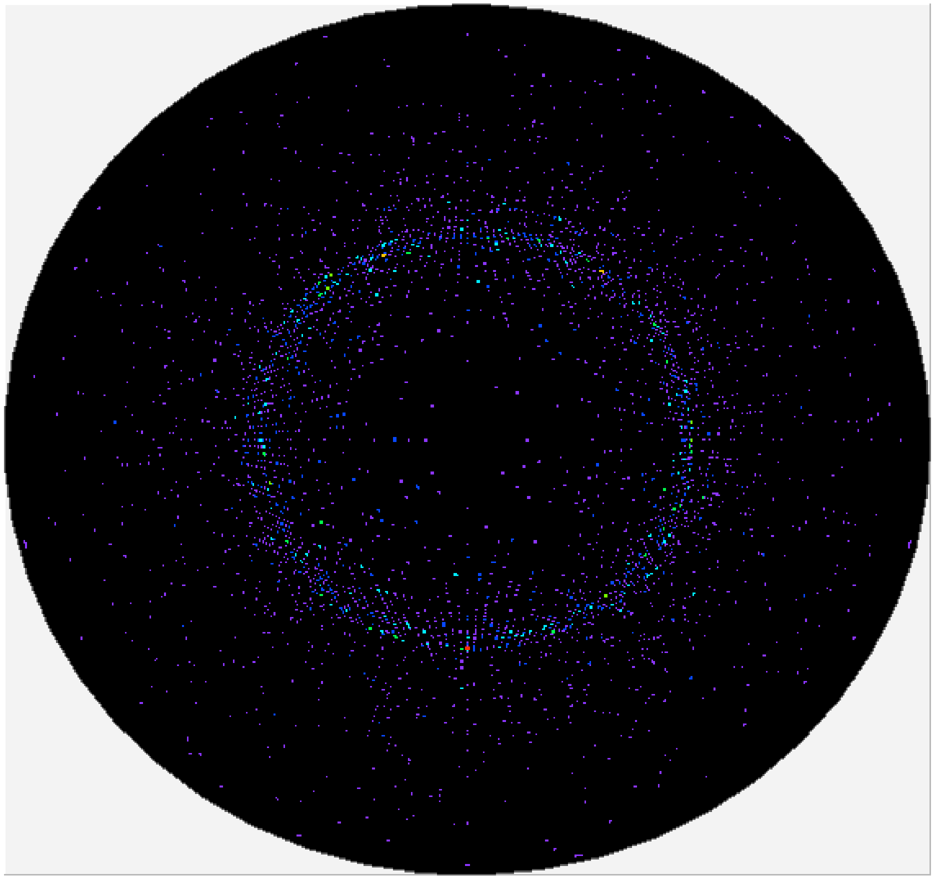
Through-going Muon Event in UNO



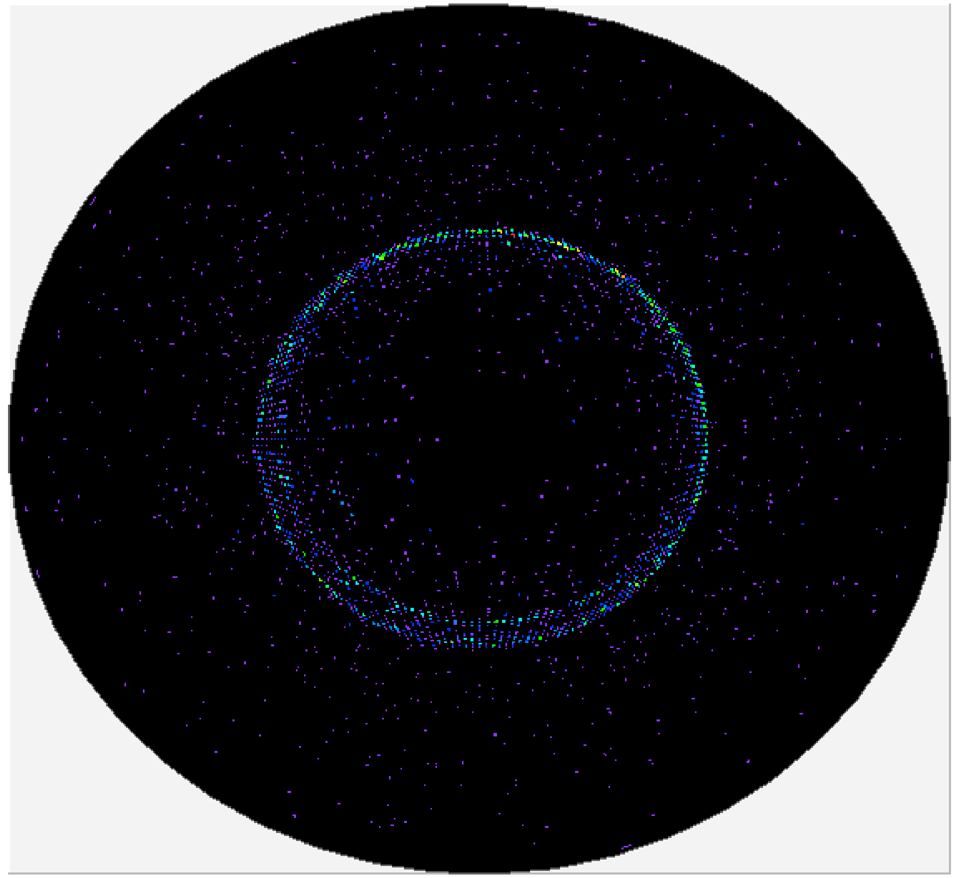
Can look for astrophysical neutrino sources w/ energy range ~10 GeV ~100 GeV

Complementary to ICECUBE

UNO Central Module Events

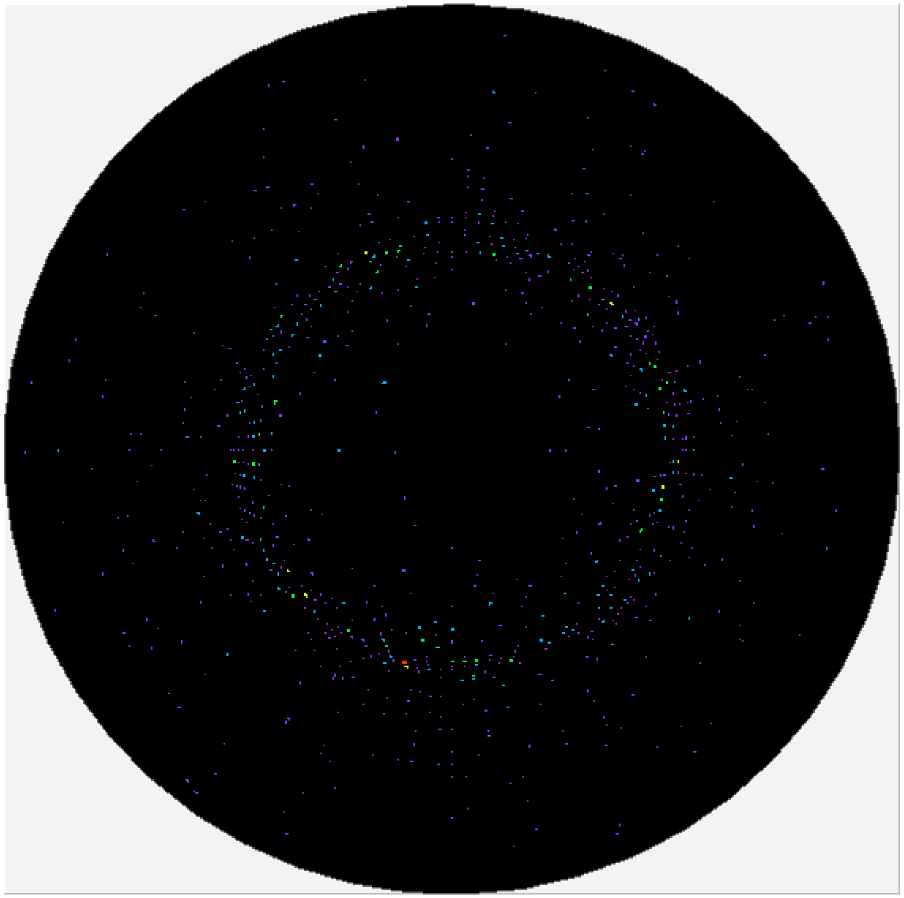


1 GeV electron

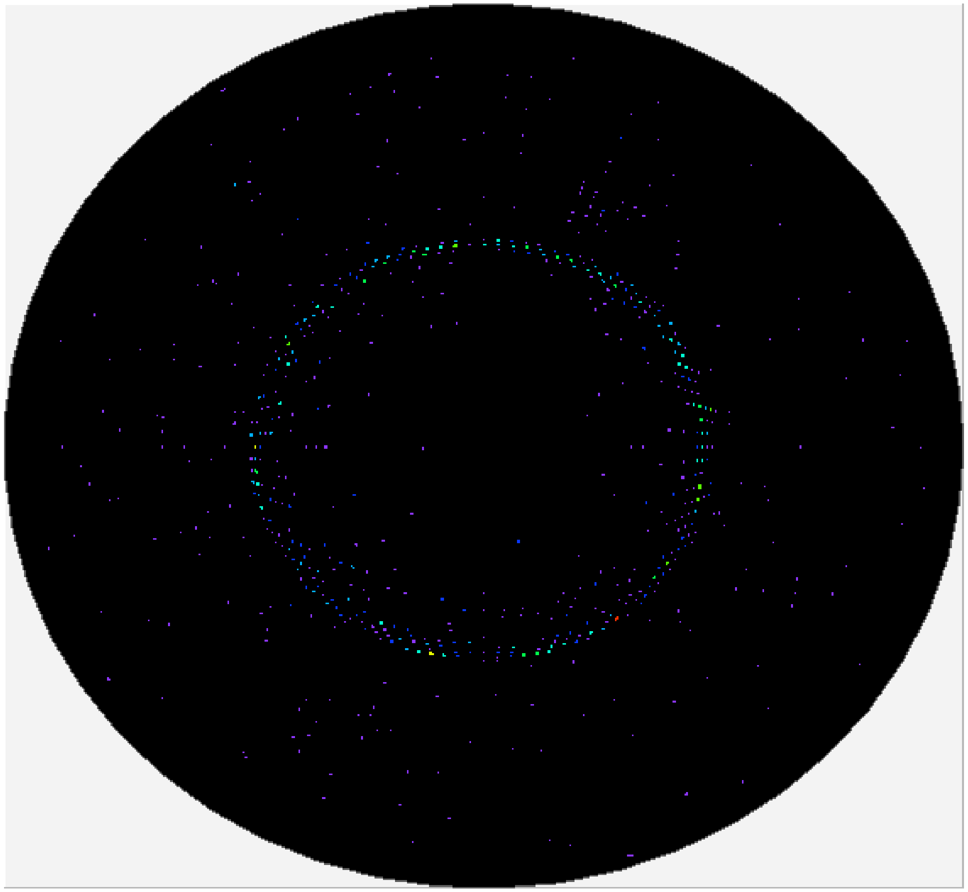


1 GeV muon

UNO Wing Modules



1 GeV electron



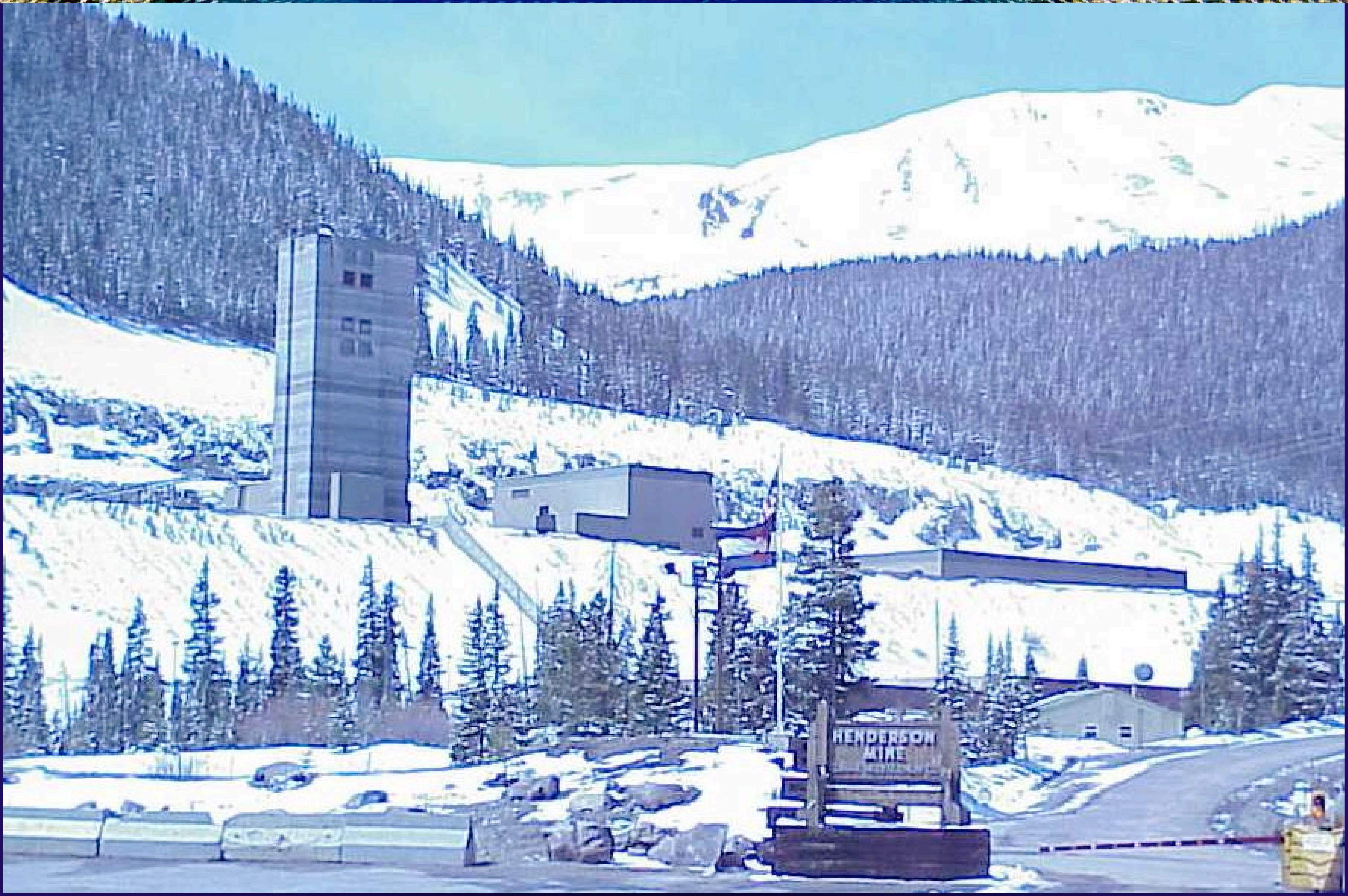
1 GeV muon

Detector Site Issues

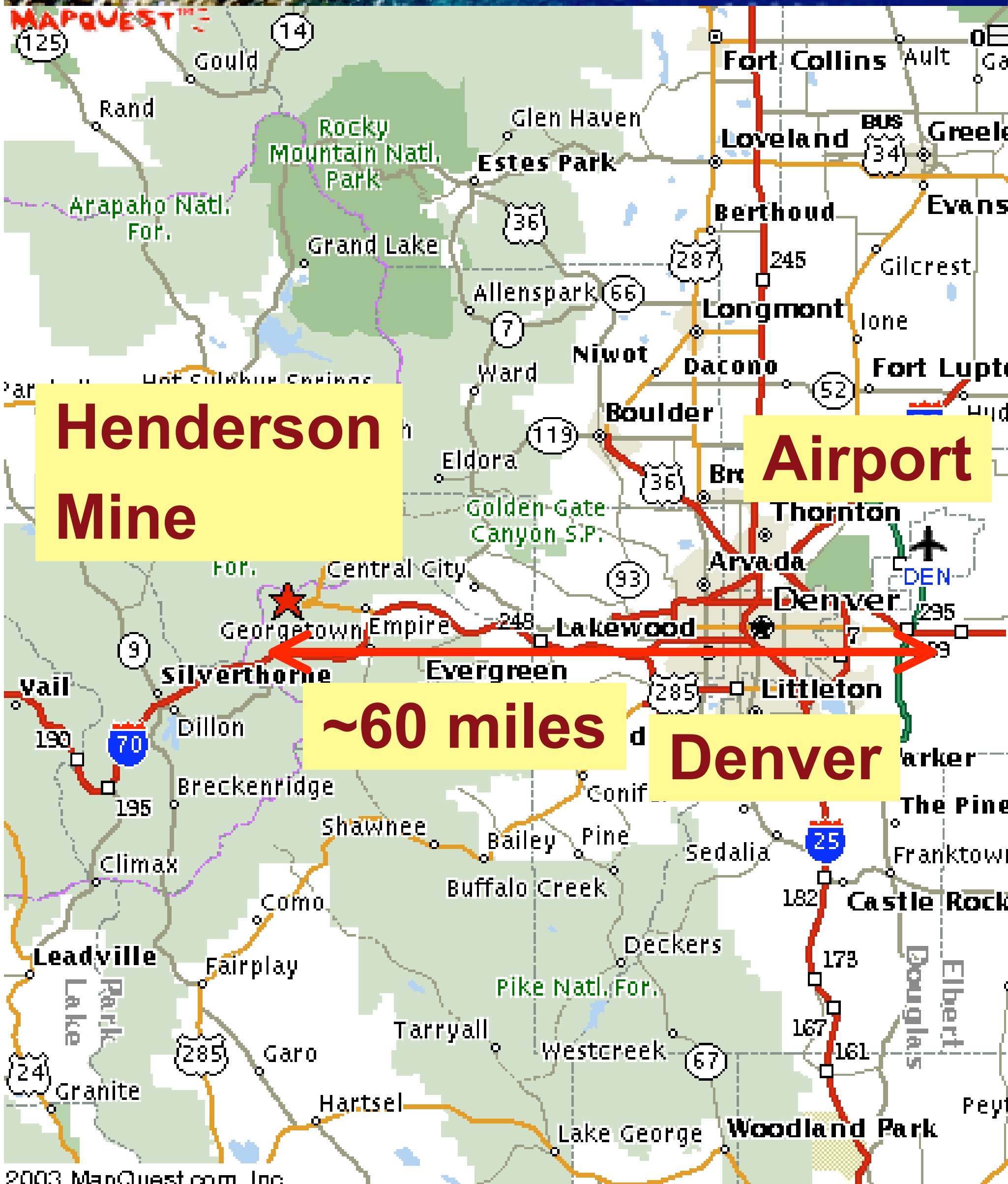
- The most pressing issue for UNO
  - We must secure a site within next a years or so
  - No site No experiment!
- Optimal Depth
  - 4000 mwe (~5000 ft) or deeper
     Driven by the SRN search and Solar nu study
     also reduce the risk of unknown B.G. to PDK searches at shallow depths
- Distance from Major Proton Accelerator Labs
  - Need flexibility
- Environmental Issues
  - Case of Gran Sasso: http://news.independent.co.uk/europe/story.jsp?story=411011

NUSEL/UNO at Henderson Initiative

Henderson Mine, Empire, Colorado



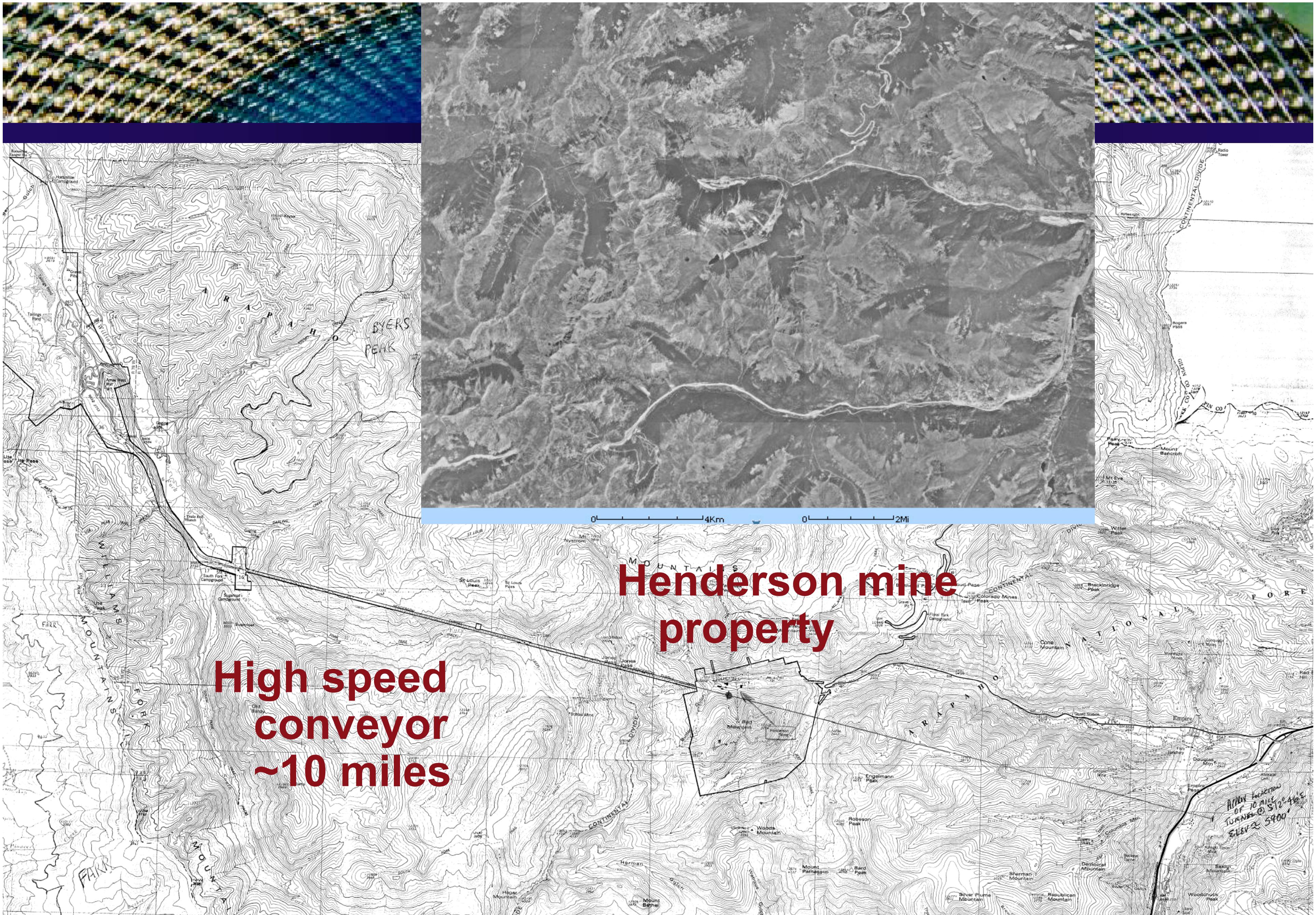
The Best Location (Empire, Colorado)



- Excellent Access
  - Near an international airport
  - Near a major highway
- Excellent Environment
  - Near major universities
  - Near a major city
  - Strong community support
  - Friendly and enthusiastic mining company
  - Near many resorts with conference facilities

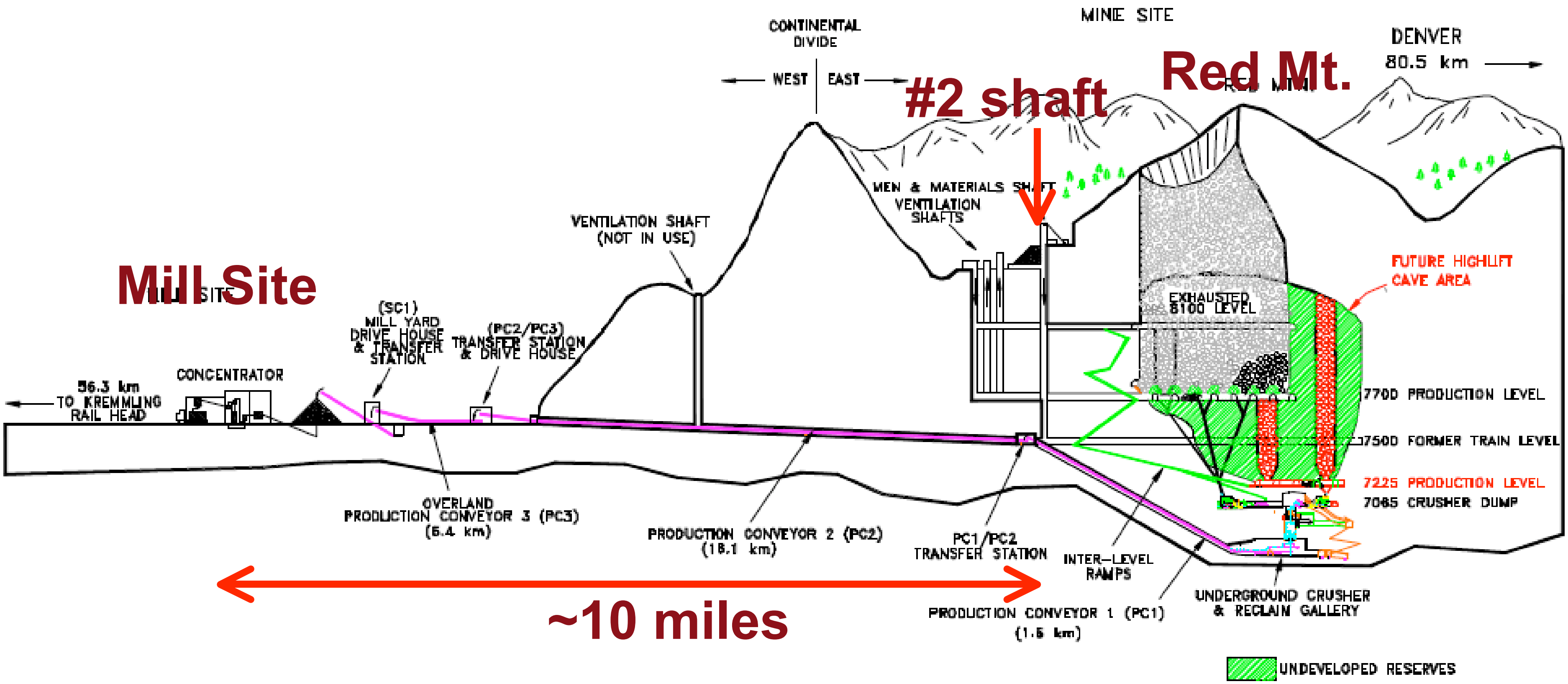
Henderson Mine

- Modern Molybdenum (Moly) mine owned by Phelps-Dodge
  - Established in 1970’s
    - Better environmental control
- Block-caving operation under Red Mountain
- #2 Shaft for hoisting (a total of 5 shafts)
  - Collar at 10,350 feet above sea level
  - 28 feet diameter w/ two hoisting compartments
  - The large hoist: 23' long by 8'6" wide by 13' tall w/ 20 tons normal capacity
    - fits a sea container
- Mining level
  - 6930 feet (~3000 mwe) and 8100 feet above sea level

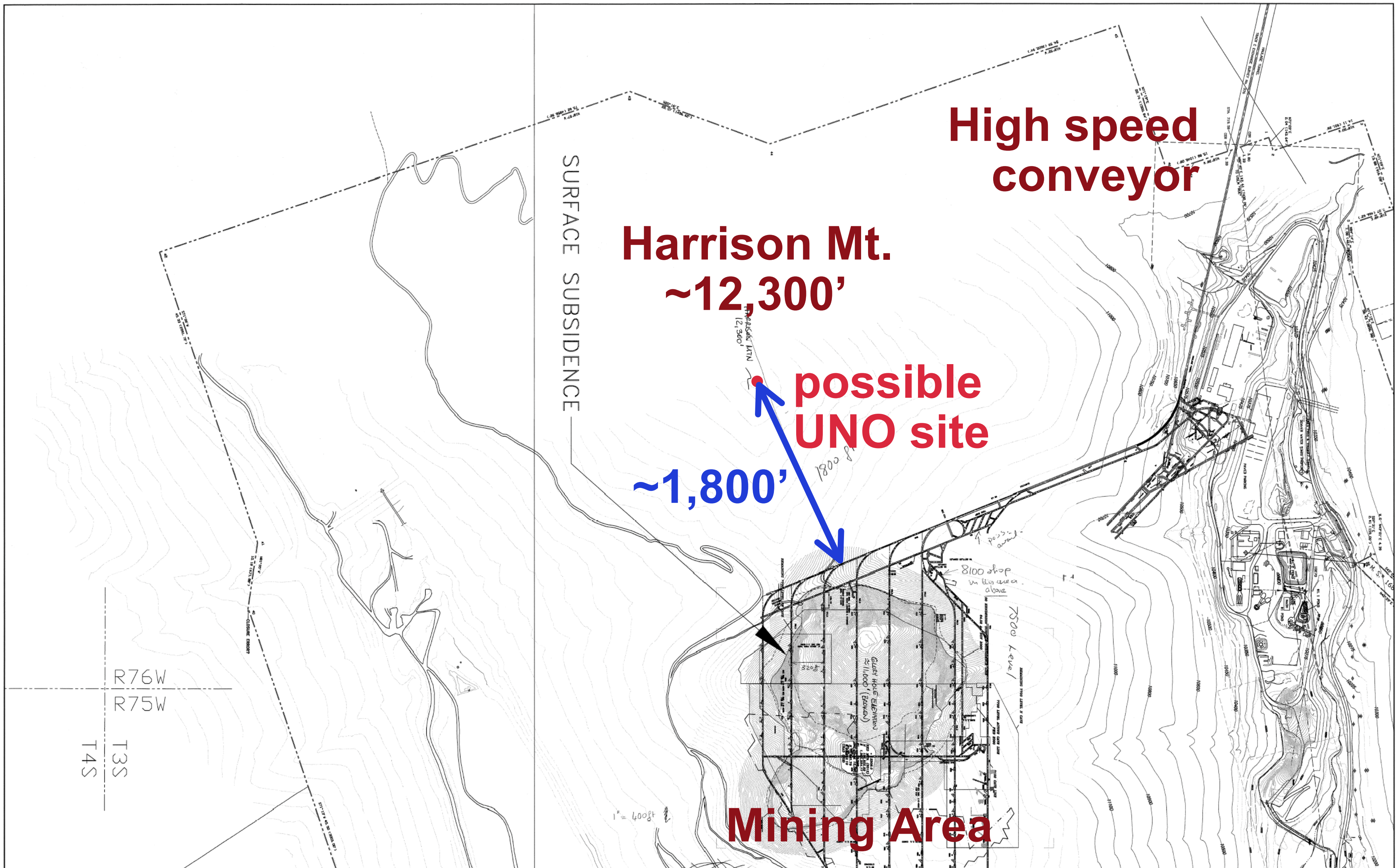


Henderson mine property
High speed conveyor ~10 miles
0 4Km
0 2Mi

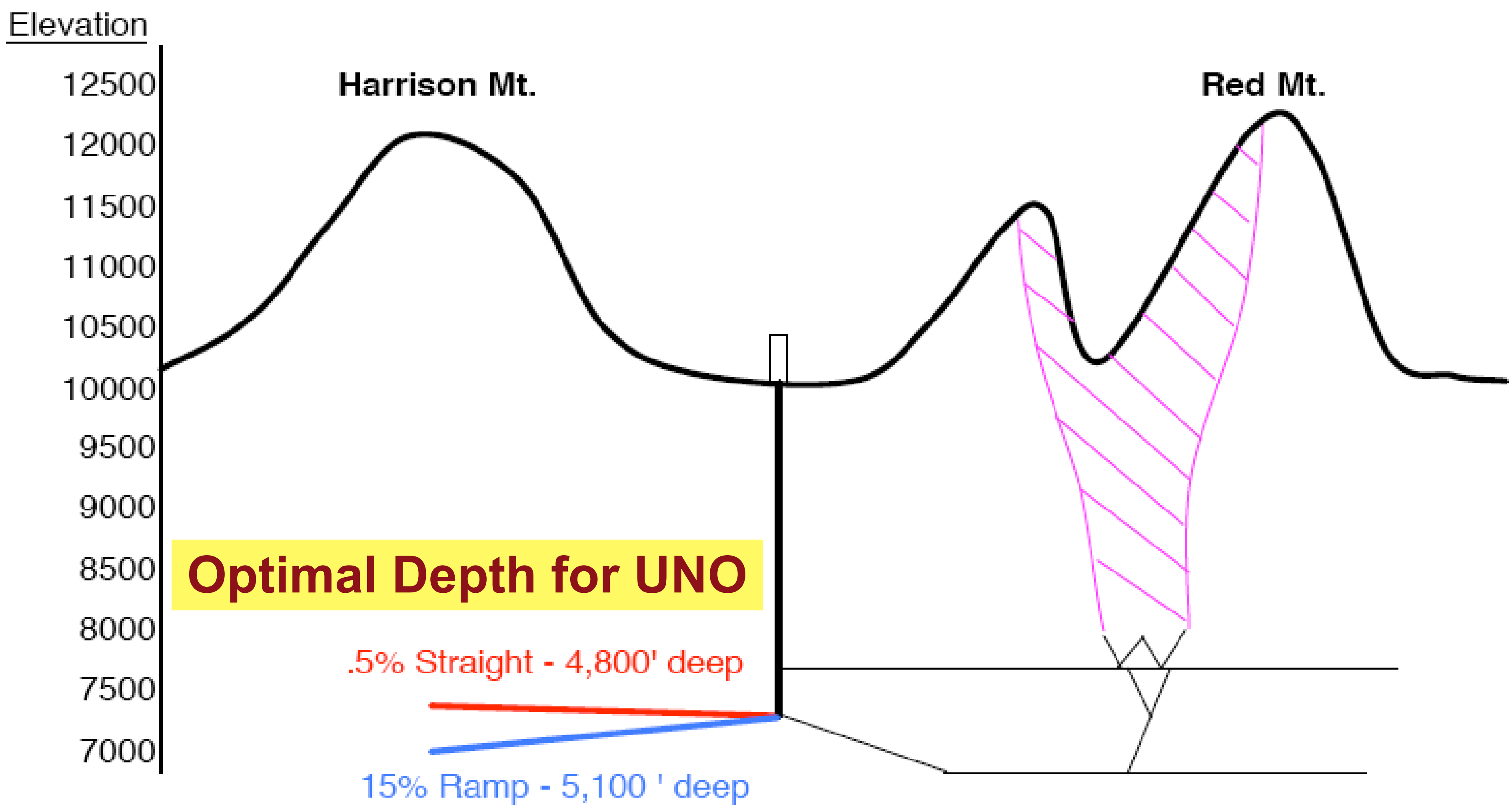
Vast Infrastructure



- One of the largest mining operation with large modern shafts
- Large capacity high speed conveyor system
- Existing tailing site and all necessary environmental permits


High speed conveyor
Harrison Mt.
~12,300'
possible UNO site
~1,800'
Mining Area
SURFACE SUBSIDENCE
R76W
R75W
T4S
T3S

Possible Depths for UNO at Henderson



Preliminary Discussions and Future

- Harrison Mt. Geology
  - A detailed surface mapping in 1980's
    - Competent Precambrian Silver Plume Granite (PSPG) w/ a broken zone
  - A exploratory drill hole: made in 1968
    - Vast majority of the core: PSPG
    - competency: ~6 to 8 (w/ 9 being maximum)
      More competent at deeper depth
  - Expect highly competent rock at the proposed UNO site
    - need new drilling to verify ($100k/drilling)
- Preliminary excavation cost estimate: $116M (30% contingency)
  - 1M m^3 volume w/ two access drifts & surface treatment

Recent NSF Action

- All four unsolicited NUSEL proposals submitted in the past years have been returned to the proponents w/ an accompanying letter from Mike Turner which says:
  - Altered circumstances
  - Serious concerns about the Homestake expressed by the panel that named Homestake “the most favorite site”
    - uncertainty associated with the flooding, a major concern

- Start a new process for selecting a NUSEL
  - Consider all possibilities again
  - Three step approach
    1) one or more interdisciplinary teams to develop a preliminary plan

       Requirements for Physics Modules

       "deep" experiments (double-beta, dark matter, solar, etc.)

       "large" experiments (proton decay, superbeam)

       "Solicitation 1" to be announced in early May

2) Fund grants for conceptual planning of infrastructure as related to the site

“Solicitation 2” to be announced in early May

Fast track (3 months)?

Down select candidate sites (1 - 3?)

Award ~$500k for initial site study for 6 months

3) Fund technical designs including initial research projects

“Solicitation 3” to be made at a later time

Down select candidate sites (1 - 2?)

First budget to appear for NUSEL ~FY2008

UNO Detector Components Estimated Unit Costs (Update)

Item	Unit Cost	Source
Excavation	$260/m^3$ *	L. Peterson
	$200/m^3$ **	K. Nakamura
	$150/m^3$ ***	S. Patchet
	$200/m^3$ ****	Homestake Mining Co.
	$116/m^3$ ****	C. deWolfe
20" PMTs	$2,775 *****	Hamamatsu
8" PMTs	$1,200 *****	Hamamatsu

* Hard Rock Environment, Horizontal Access, Q=100
(MINOS excavation cost ~ $280/m^3$)

** @Kamioka site, based on 1 Mton excavation

*** @WIPP site (Excavation costs include access tunnel and service area + 25% contingency, depth@1100m, w/ a new shaft)

**** @Homestake site (quoted by K. Lande, pure mining cost)

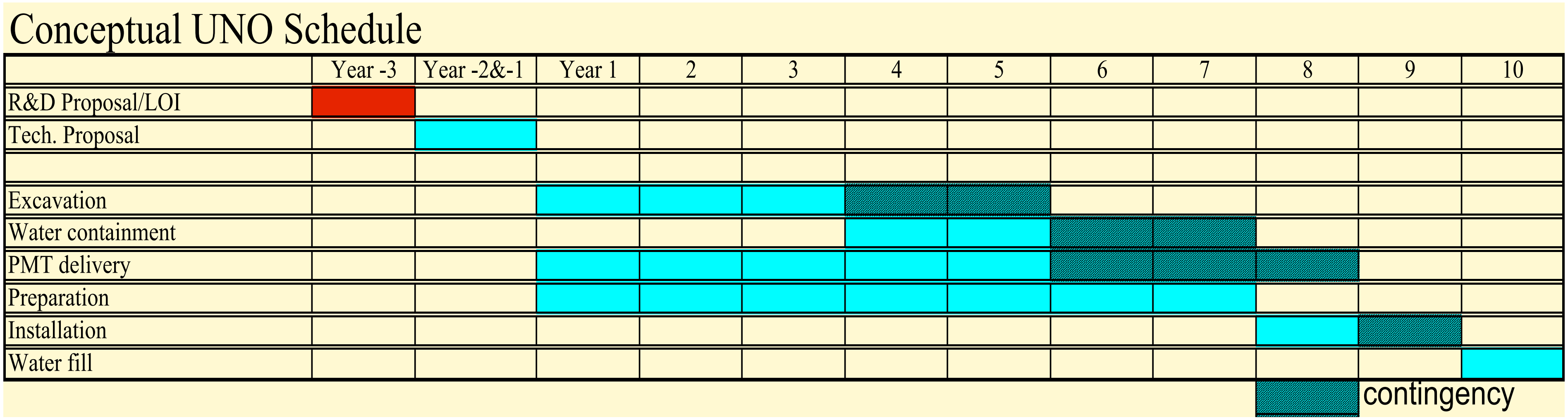
***** for 56k 20" PMT + 15K 8" PMT order ($1.00 = 100 Yen) (includes $50/PMT transportation cost, 100 m cable cost, 8 year delievery time, previously it was $3,100)

Preliminary Cost Estimates

Item	SuperK		UNO Hard Rock*	Henderson Mine
Cavity Excavation	27,640	v	168,000	116,000
Water piping and pumps	630	v	4,082	
Water Purification System	1,850	v	11,988	
Power Station	720	v5	2,160	
Crane	760	v5	2,280	
Cavity Treatment/Water Tank	18,400	s	25,000	
PMT support structure	4,580	s	23,019	
Counting Room	330	s5	990	
Computer Building	1,860	s2	2,232	
Main Building	3,000	s2	3,600	
20" PMT (including cables)	34,670	s	155,457	
Electronics	6,330	s5	9,495	
DAQ	1,090	s5	1,635	
Air Conditioning	210	s5	315	
Veto instrumentation	3,000	s5	9,000	
8" PMT (including cables)	2,262	s	17,881	
Total	**102,070**		**437,135**	**385,135**
(1$ = 100 Yen)				
* Q=100, Horizontal Access				

(in thousands of US $) (as of Dec. 2003)

Conceptual UNO Schedule



Two years of rigorous professional detector design needed

Future Plan and R&D

- UNO Planning and R&D Proposal, Sep. 2004
  - UNO generic R&D and Planning (DOE and NSF)
    - Water containment/rock surface treatment method
      - Being carries out at Colorado State University
    - PMT mounting scheme
    - PMT cost reduction scheme
      - Burle (DOE small business detector development award)
    - Alternative photo-detector R&D
      - HPD (Hamamatsu): See Nakamura's talk
      - Referenc Tube: U.C. Davis
    - Preliminary technical design of the detector
    - more rigorous cost estimates
    - software development for MC simulation and physics study

Continue: Future Plan

- Exploratory Work at the Henderson Mine
  - Detailed geological survey to determine candidate site
  - drilling and rock characterization
  - Computer modeling/numerical analysis of the cavern
  - cosmic ray flux measurements
    Utilize high school outreach program (UW, UNL)
  - radon concentration measurements
- Preliminary Cost estimates (excavation, etc.)
- Environmental assessment (EPA)
- Long term liability issues

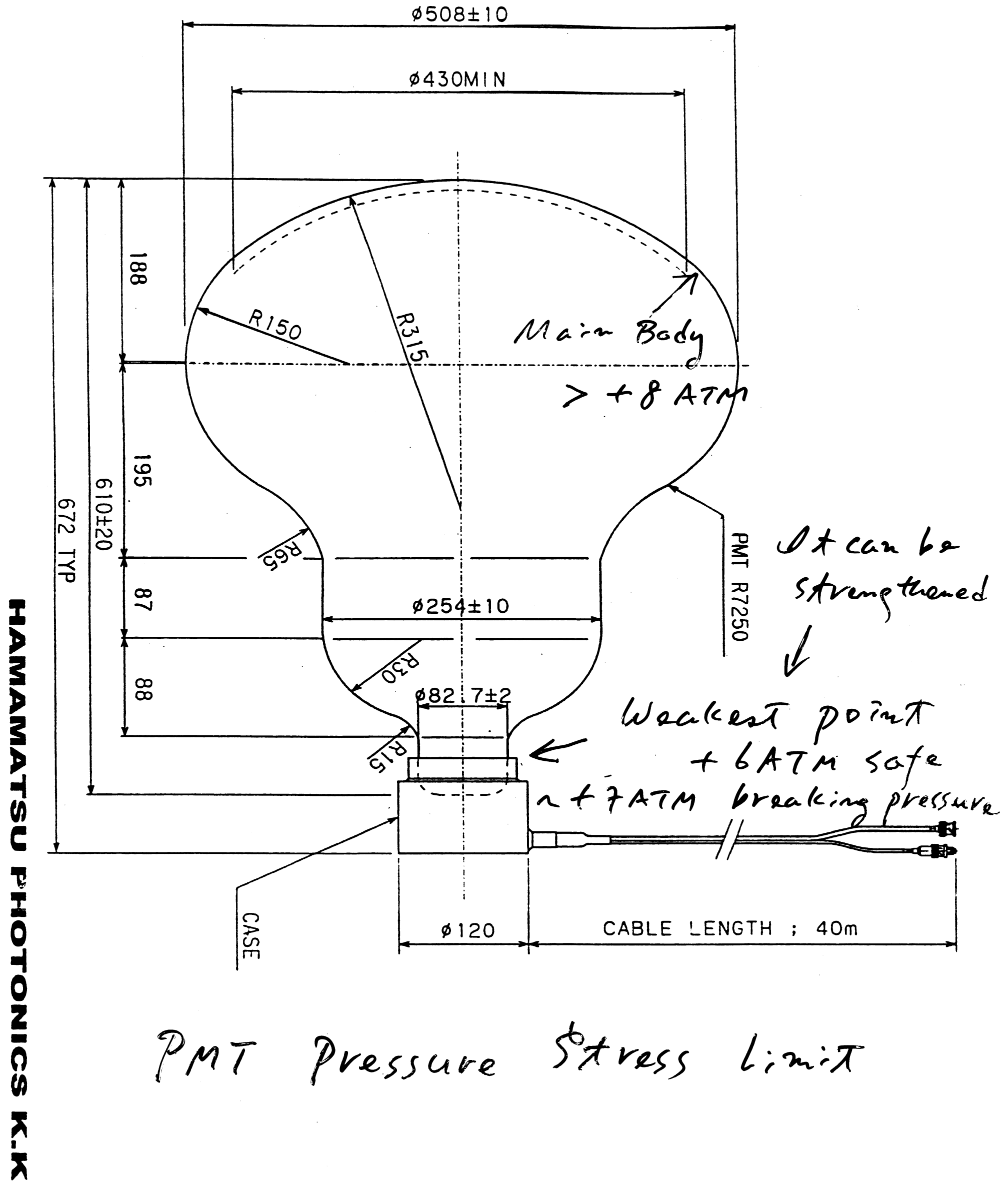
• Expand the Collaboration
  - 2004 target: over 100 members

Cavity Treatment/Water Containment System

- Initial estimate in 2001 (in the narrative)
  - $5M (estimated by the Golds Associates) for hard rock site for a simple geo-membrane liner
- Revised estimate in 2003
  - $25M for a more durable surface treatment (combination of Minegard coating + a steel frame lattice work + concrete treatment + Geothane membrane seal).
    - The Minegard coating alone: ~$10M for the entire surface of the UNO cavity including the dome area.

      a straight extrapolation from the actual SuperK cost including material, labor and scaffolding.
    - The estimate still quite uncertain

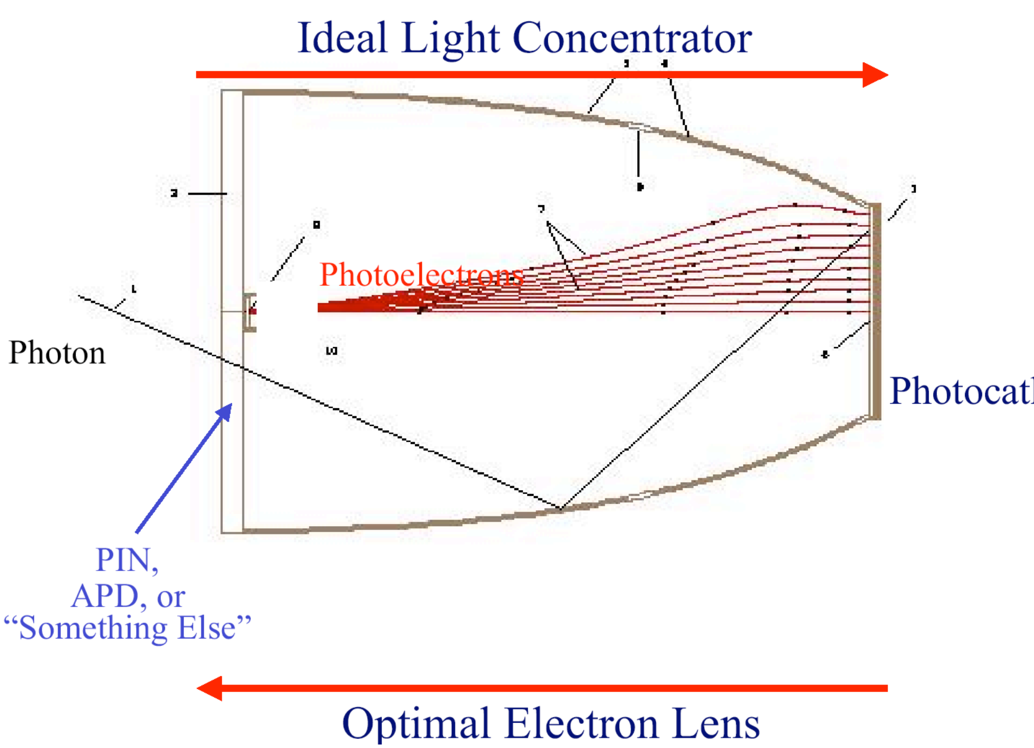
Hamamatsu 20" PMT Pressure Stress Limit

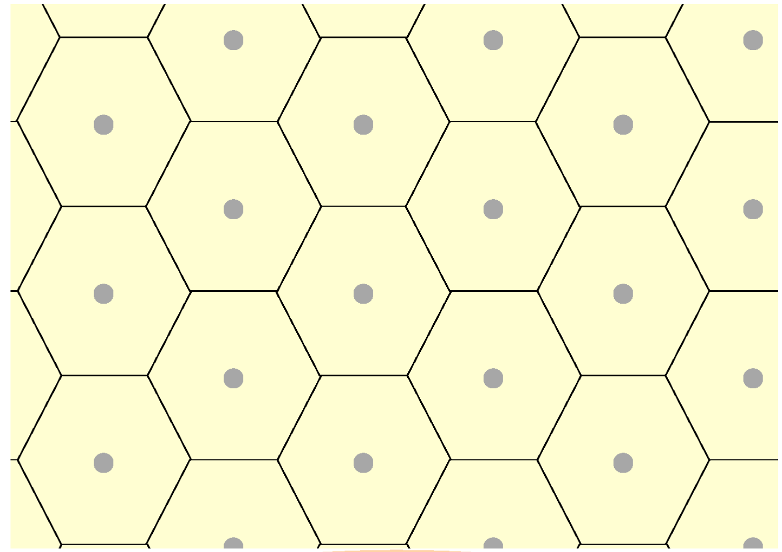


===> Spherical PMT and other photo-detector R&D

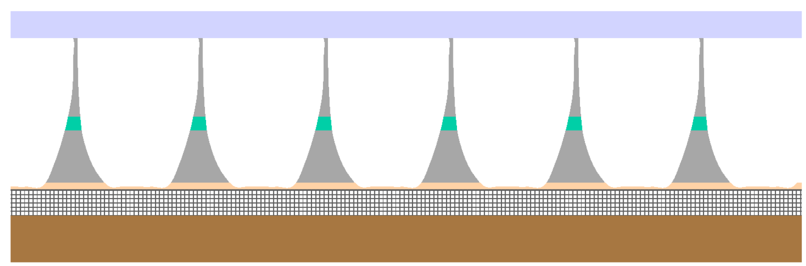
ReFerence Photosensor at UC Davis

- Partly supported by the *Advanced Detector Research Award (DOE)*
- Collaboration w/ IIT Night Vision





Flat-Panel Honeycomb Camera Construction



Industrial Production (no glass blowing etc.)
Mechanical Rigidity

UNO Milestones and Future Plan

- UNO First Proposed at NNN99, Sep. 1999
- UNO Proto-Collaboration established, Sep. 2000
- UNO Whitepaper for Snowmass01, Jun. 2001
- HEPAP Sub-panel on Long range Planning Report, Oct. 2001
- CPU (Committee on Physics of Universe) Report, 2002
- NAS NFAC (Neutrino Facility Advisory Committee) Report, 2002
- HEPAP Facilities Committee Report, Mar. 2003
- The Henderson mine became the primary US site for UNO, 2003
- DOE Orbach List
- Seed funding ($100k) from the Stony Brook University, Nov. 2003
- UNO Proto-Collaboration transformed to a formal Collaboration, Mar. 2004
- NSF Announcement for establishment of DUSEL in US, Mar. 2004
- Formation of HUSEP (Henderson Underground Science and Engineering Project)

UNO Collaboration

(as of May, 2004)
97 Members from 40 Institutions, 7 Countries (Experimentalists Only)

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**
Murray Hitzman	**Kansas State Univ.**	**Purdue Univ.**	Danka Kielczewska
D. Scott Kieffer	Tim Bolton	Wei Cui	**Univ. of Washington**
Mark Kuchta	Eckhard von Toerne	John Finley	Rick Gran
James McNeil	Ron A. Sidwell	**Saclay, France**	Jeff Wilkes
Fred Sarazin	Noel Stanton	Jacques Bouchez	Tianchi Zhao
Colorado State Univ.	**KEK, Japan**	Luigi Mosca	**College of William and Mary**
John Holton	Taku Ishida	Francois Pierre	Jeff Nelson
Jim Sites	Kenzo Nakamura	**Sejong University, Korea**	**WIPP**
Walter Toki	**Kyungpook National Univ., Korea**	Yeongduk Kim	Roger Nelson
Dave Warner	Wooyoung Kim	Jungyeon Lee	Bill Thompson
Bob Wilson	Vitaly Batourine	Jungil Lee	
	Seungwook Jin		
	Dmitriy Nekrasov		

UNO-TAC

- UNO-TAC (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)
  - Jogesh Pati (U. of Maryland)
  - Robert Shrock (Stony Brook)
  - Frank Wilczek (MIT)
  - Edward Witten (IAS/Princeton)

UNO-AC

- UNO-AC (Advisory Committee)
  - Gene Beier (U. Penn)
  - Jacque 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.)

HEPAP Subpanel (2001) on Long Range Planning Remarks on Proton Decay and UNO

A.4.1 Proton Decay

If protons decay, their lifetimes are long, so proton decay experiments require massive detectors. A worldwide collaboration has begun to develop the design for a next-generation proton decay experiment. Such a detector should be at least an order of magnitude larger than Super Kamiokande. A next-generation experiment would extend the search for proton decay into the regime favored by unified theories.

Current thinking favors the use of a large water Cherenkov detector, as in the UNO approach. The detector would be situated underground to reduce cosmic-ray backgrounds. A large water Cherenkov detector could simultaneously serve as the long-baseline target for an accelerator neutrino beam. It would also expand our ability to observe neutrinos from supernovae.

Present estimates suggest a price of about $650M for such a detector. Given its strong science program, and assuming that an affordable design can be reached, we believe it likely that a large proton decay detector will be proposed somewhere in the world, and that U.S. physicists will participate in its construction and utilization. The R&D effort should be completed over the next several years. A decision might be made near the middle of the decade, perhaps in conjunction with a decision on a neutrino superbeam facility.

Roadmap for Particle Physics (HEPAP Subpanel 01)

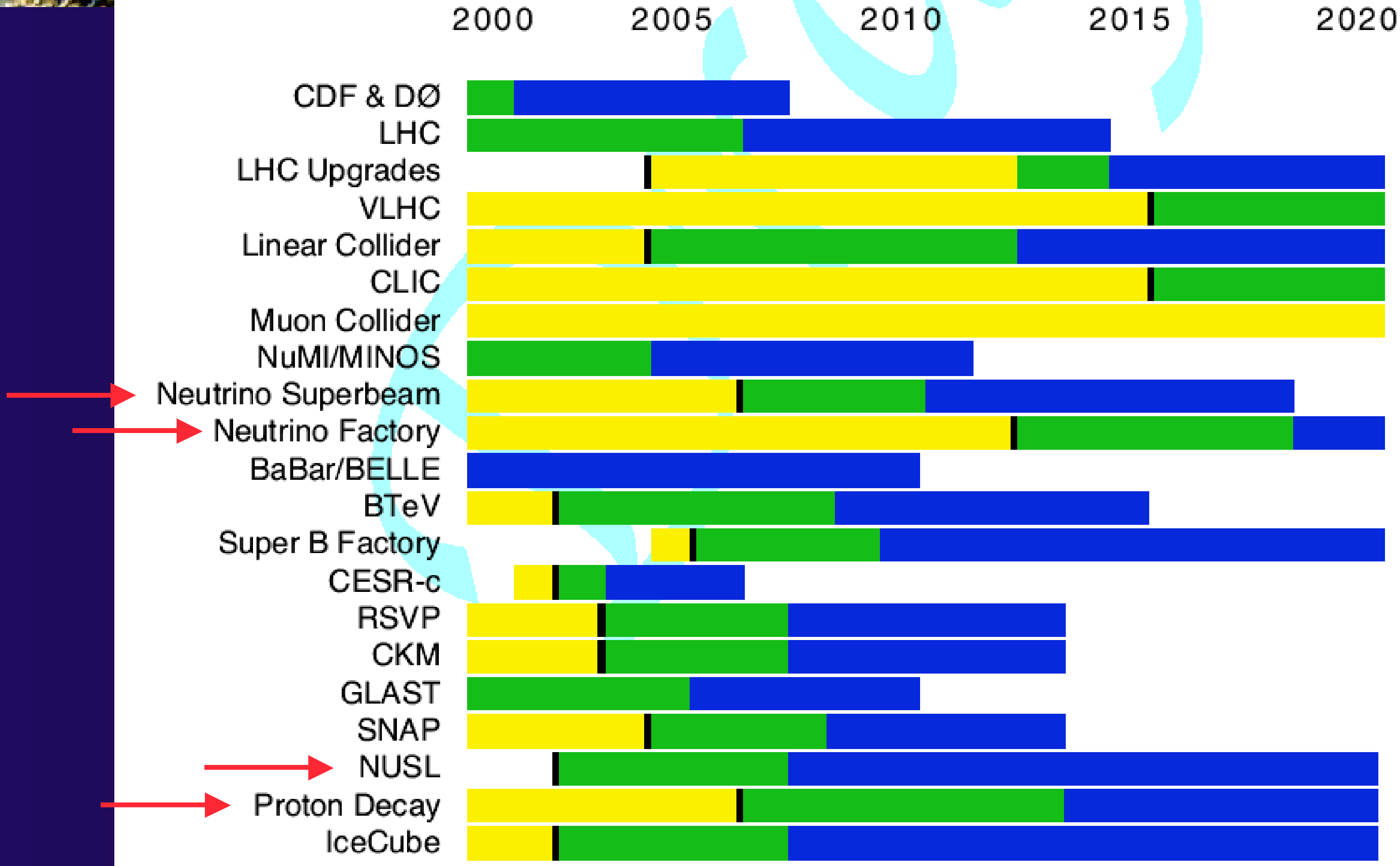


Figure A.1: Timelines for Selected Roadmap Projects. Approximate decision points are marked in black. R&D is marked in yellow, construction in green, and operation in blue. All timelines will be updated as part of the P5 process.

HEPAP Facilities Committee (2003)

UNO

HEP Facilities Summary Table

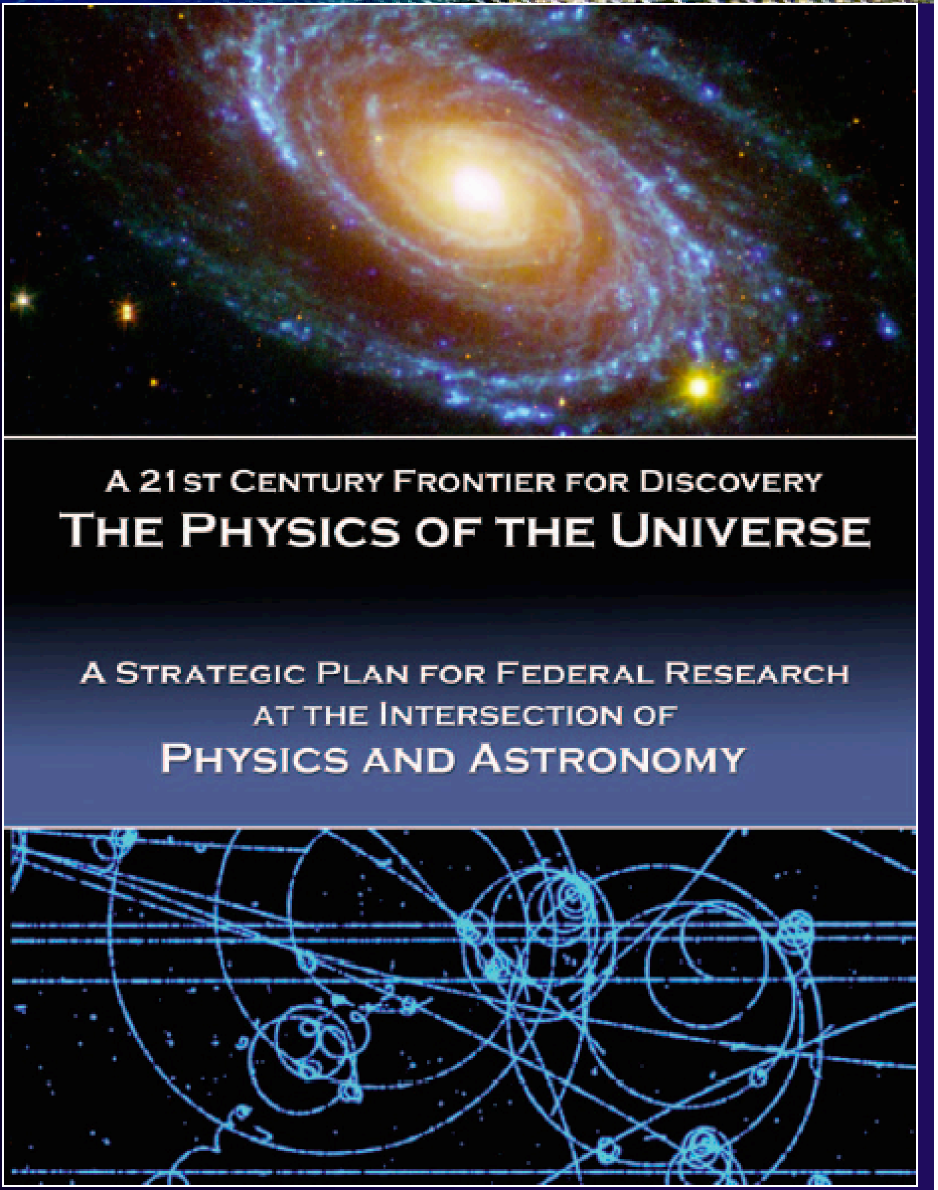
Project	Type	Physics	Cost	Scientific Potential	Proposed Facility	State of Readiness	Possible Time Scale
Linear Collider	Facility	Energy Frontier	$5B – $7B	Absolutely Central	Absolutely Central	R&D	2015 Operation
LHC Luminosity Upgrade	Facility	Energy Frontier	$150M (US Part)	Absolutely Central	Absolutely 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

DOE 20 Year Plan (Orbach List)

- Nov. 2003: Orbach list
  - Based on the HEPAP facilities committee recommendation
    - 1) Joint DOE/NASA mission on Dark Energy
    - 2) BTeV (a lot to learn from this collaboration)
    - 3) Linear collider
    - 4) Neutrino Superbeam
  - (underground facility noted as an NSF initiative)
    - UNO was considered as a facility

A Report of the Intragency Working Group on Physics of Universe

- Released in April 2004
- Response to CPU report
- Coordinated by NSTC
- Intragency Working Group
  - DOE, NSF, OMB, OSTP
- Summary of Recommendations
  - Ready for Immediate Investment and Directions Known
    - Dark Energy
    - Dark Matter, Neutrinos and Proton Decay
    - Gravity



NSTC IWG Priotization

Table I. IWG Prioritization

Quarks with the Cosmos Question	Programmatic Investment Priority
Ready for Immediate Investment Dark Energy Dark Matter Gravity Neutrinos	**Direction Known** Dark Energy Dark Matter, Neutrinos, & Proton Decay Gravity
Further Planning and/or R&D Needed High Density & Temperature Physics Origin of Heavy Elements Proton Decay The Big Bang **Ideas Needed or Investment Adequate** Cosmic Accelerators Extra Dimensions New Theories of Light and Matter	**Roadmap Future Investments or Exploit Existing Facilities** Origin of Heavy Elements Birth of the Universe using Cosmic Microwave Background High Density & Temperature Physics High Energy Cosmic Ray Physics

Conclusions

- UNO tackles some of the most important physics questions today w/ potential of major discoveries
- Mature technology: no critical R&D item
  - Ready to be built
- An excellent site exists at the Henderson mine as well as other candidate sites
  - New NSF process to select a NUSEL site has just begun
- BNL VLBL experiment a unique and original idea not considered by any other labs or countries
  - By definition complementary to any other proposed long baseline experiments
  - It has a lot of good merits which can be used in other applications
  - Needs constructive criticisms & checks from the community If built,it will provide a comprehensive nucleon decay and neutrino physics program for the US and world science community for the 21th century

- Intersection of interests from HEP, NP and AP communities; and international community (Japan: Hyper-Kamiokande, Europe: CERN/Fréjus (133 km) initiatives
  - A well organized international effort with a common physics goals and strong mutual support can bring a (or even two) successful experiment(s) somewhere in the world

Comments on Organizing International Effort on Next Generation WC Detector

- Model 1
  - Regional Collaborations
    - HyperK in Japan
    - UNO in US
    - ??? In Europe
  - Cross referencing of the collaborators
    - mutual support for local proposals
  - Joint R&D effort for non-site specific common items
  - Formation of an International Steering Committee
  - Advantage: focused regional efforts to bring local enthusiasm
  - Disadvantages: smaller collaborations, proposals can be seen as competing with each other

Comments on Organizing International Effort on Next Generation WC Detector

- Model 2
  - Formation of a World-wide Collaboration
    - to build one (or two) detectors somewhere in the world
    - Frejus-UNO-HyperK

      FUHK (!) Bad name
  - Advantage: if formed, it will be a powerful collaboration
  - Disadvantage: can people truly overcome local interests?
    - Can prioritization be done without prejudice?
    - LC dilemma
  - "Internationalization" is a word that should be used very cautiously
    - should avoid making foreign contributions prerequisite

The End