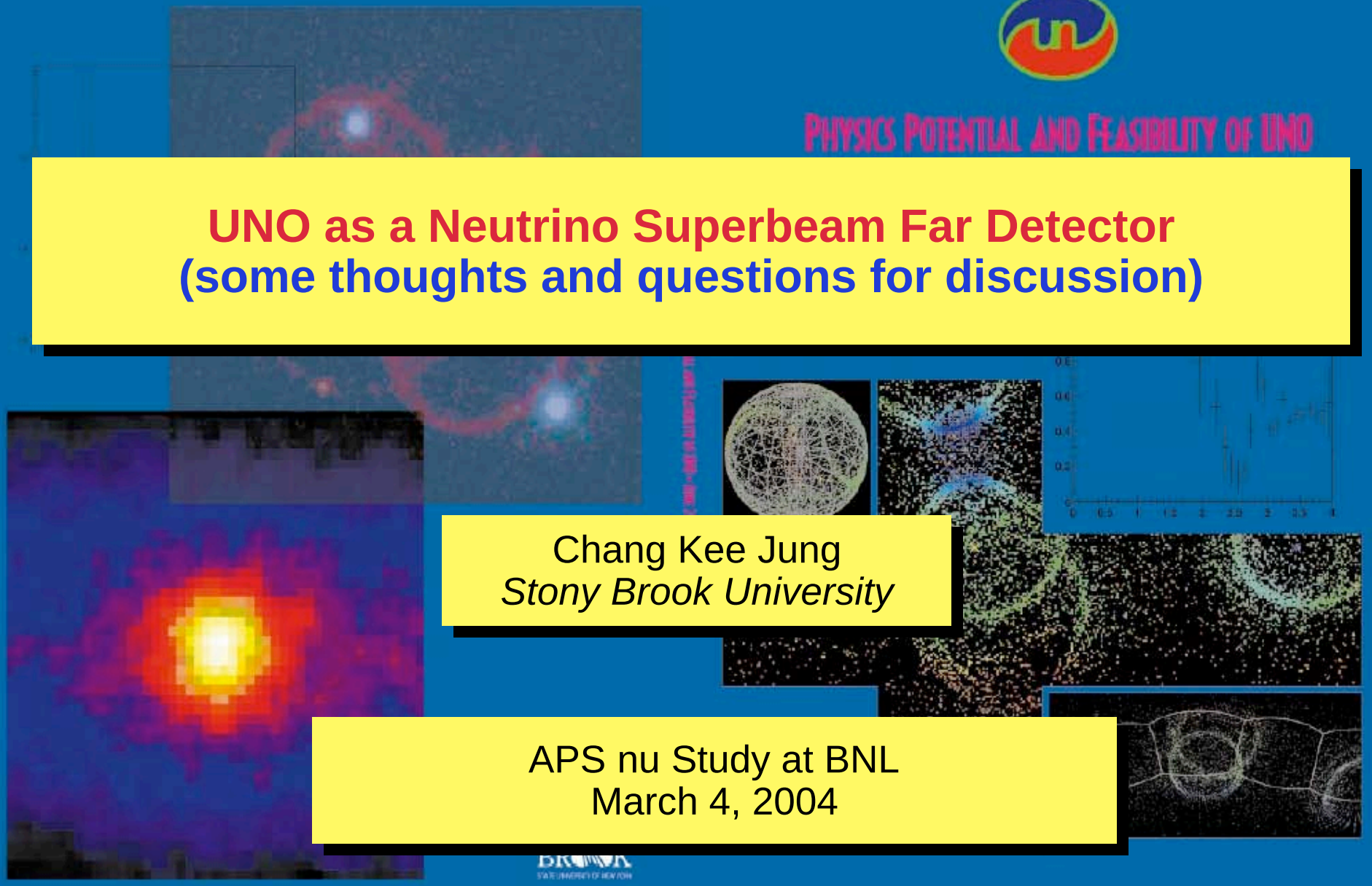
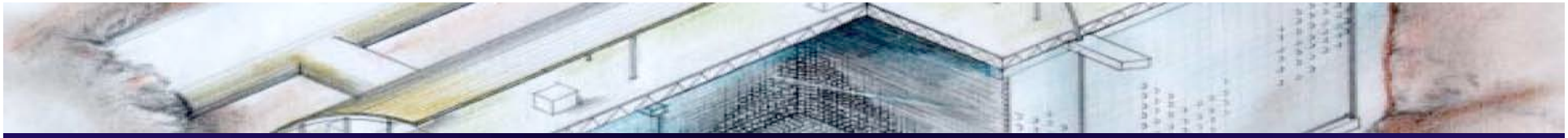
http://nngroup.physics.sunysb.edu/nngroup/pub/whitepaper.ps



UNO as a Neutrino Superbeam Far Detector (some thoughts and questions for discussion)

Chang Kee Jung
Stony Brook University

APS nu Study at BNL
March 4, 2004



Can we justify future long baseline superbeam experiments to measure $\sin\theta_{13}$ and CP Dirac δ?

Neutrino Sociology: Yes, there is no doubt.
These are the next logical step in neutrino physics and these are must-do experiments.

Japanese CSTP: C-rating to T2K
Despite the phenomenal success achieved by the Japanese neutrino experiments in recent years
And the Nobel Prize in 2002

Difficulties (my personal view)

- $\sin\theta_{13}$ and CP Dirac δ are essentially free parameters
  No compelling theoretical predictions
  No connection between Majorana phases and Dirac δ
- No obvious connection to the leptogenesis

No experimental hints for positive $\sin\theta_{13}$ value
- unlikely to measure above 4σ measurements with a next generation experiment

$\sin\theta_{13}$ (U_{e3}) $\leftrightarrow$ V_{ub} in quark sector
CPV has been already observed in quark sector

unlike the over-constrained precision measurements in quark sector, it is difficult to make a case for discovery of new physics from the measurements of lepton mixing matrix elements

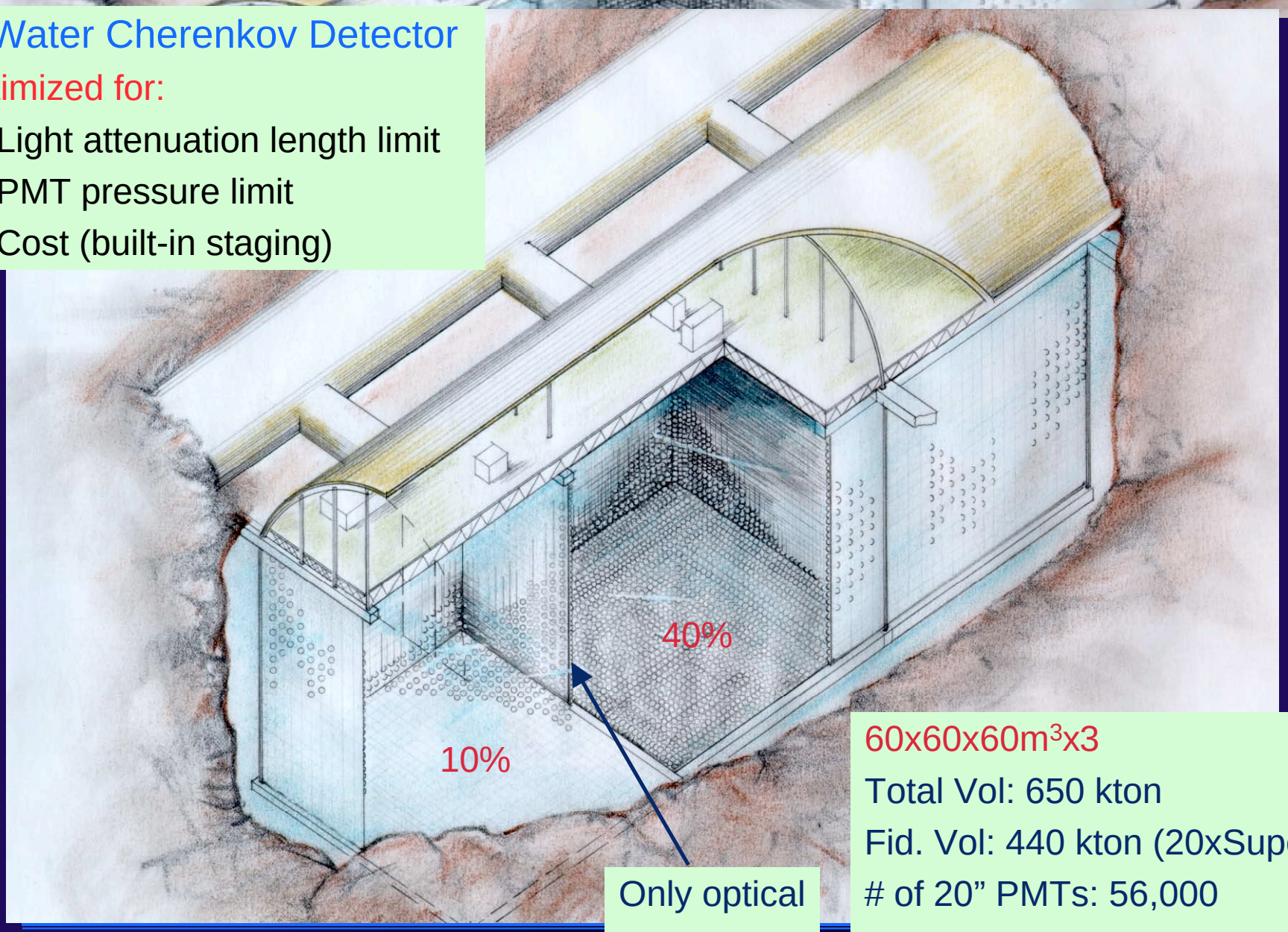
What should we do?

- Explore synergy between the superbeam experiment and the non-accelerator experiments
- Vigorous theoretical efforts
  - Establish compelling physics case
  - e.g. TeV scale extra-dimensions for LC
- Avoid duplications even international scene
  - Find experiments complementary to each other
- Keep the cost down

UNO Detector Conceptual Design

A Water Cherenkov Detector optimized for:

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



$60x60x60m^3x3$

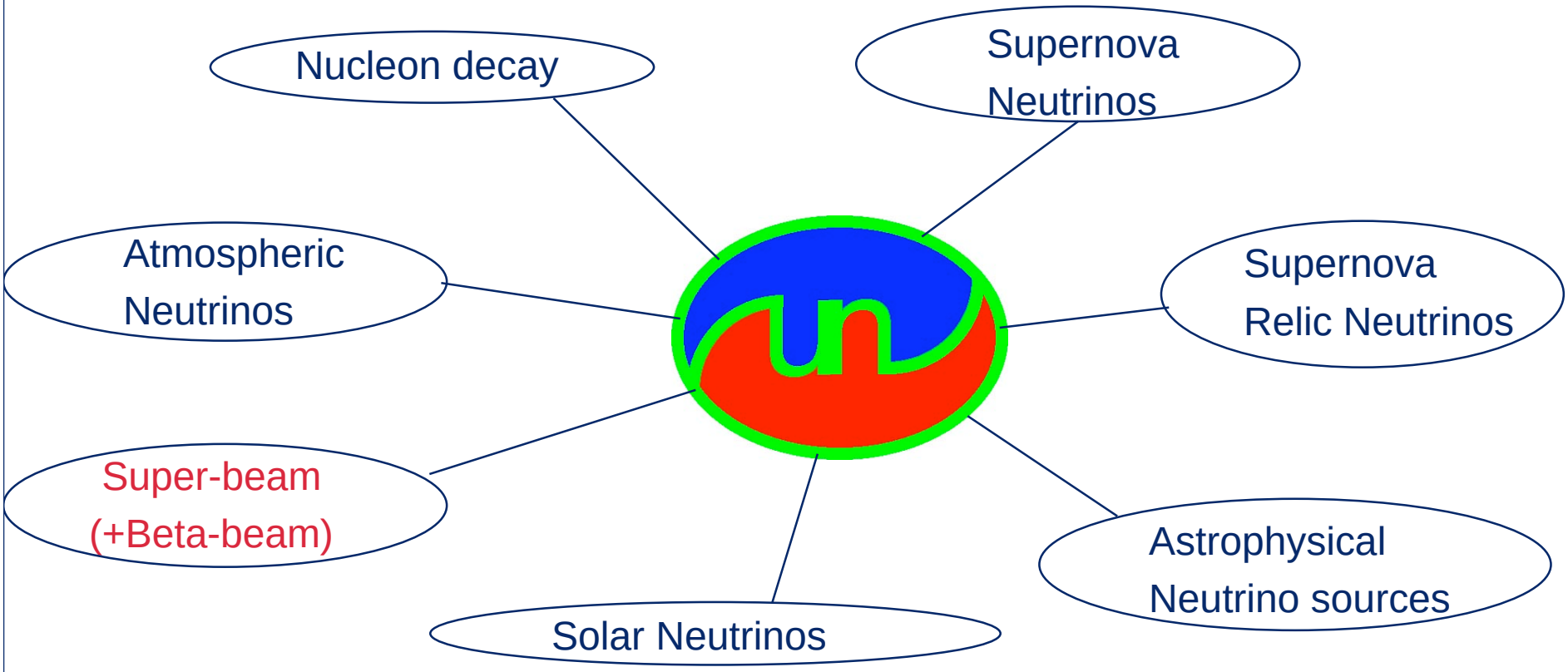
Total Vol: 650 kton

Fid. Vol: 440 kton (20xSuperK)

# of 20” PMTs: 56,000

# of 8” PMTs: 14,900

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**

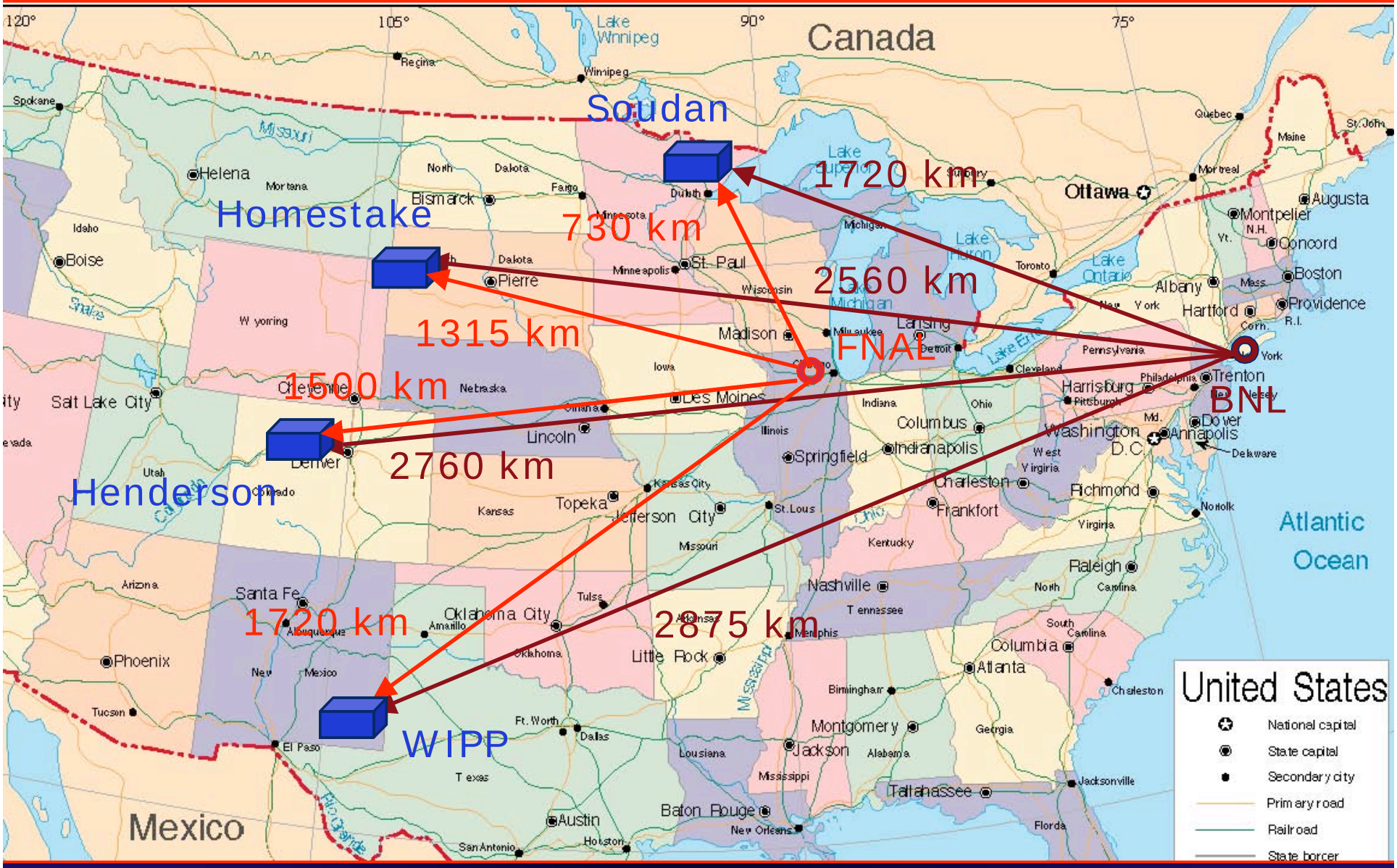
UNO as a Distant Detector for a Superbeam Experiment

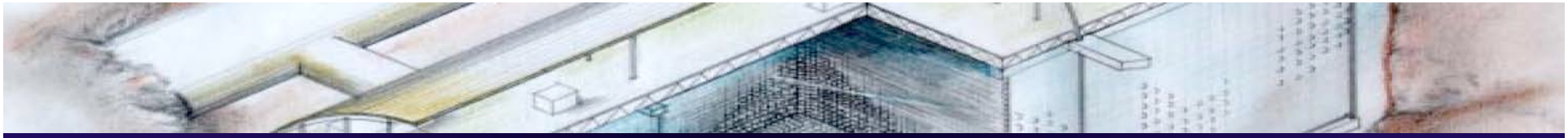
- Water Cherenkov detector is a natural fit for a superbeam LBL neutrino oscillation experiments
- CPV along with many other crucial oscillation parameters could be measured with a UNO scale detector at various baselines
  - CERN Fréjus study (130 km, 4MW proton beam)
  - J-PARK Kamioka study (295 km,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

  an elegant theoretical idea by Marciano

  provides a crucial LBL superbeam exp. option for UNO

Candidate Sites and Possible Baselines





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

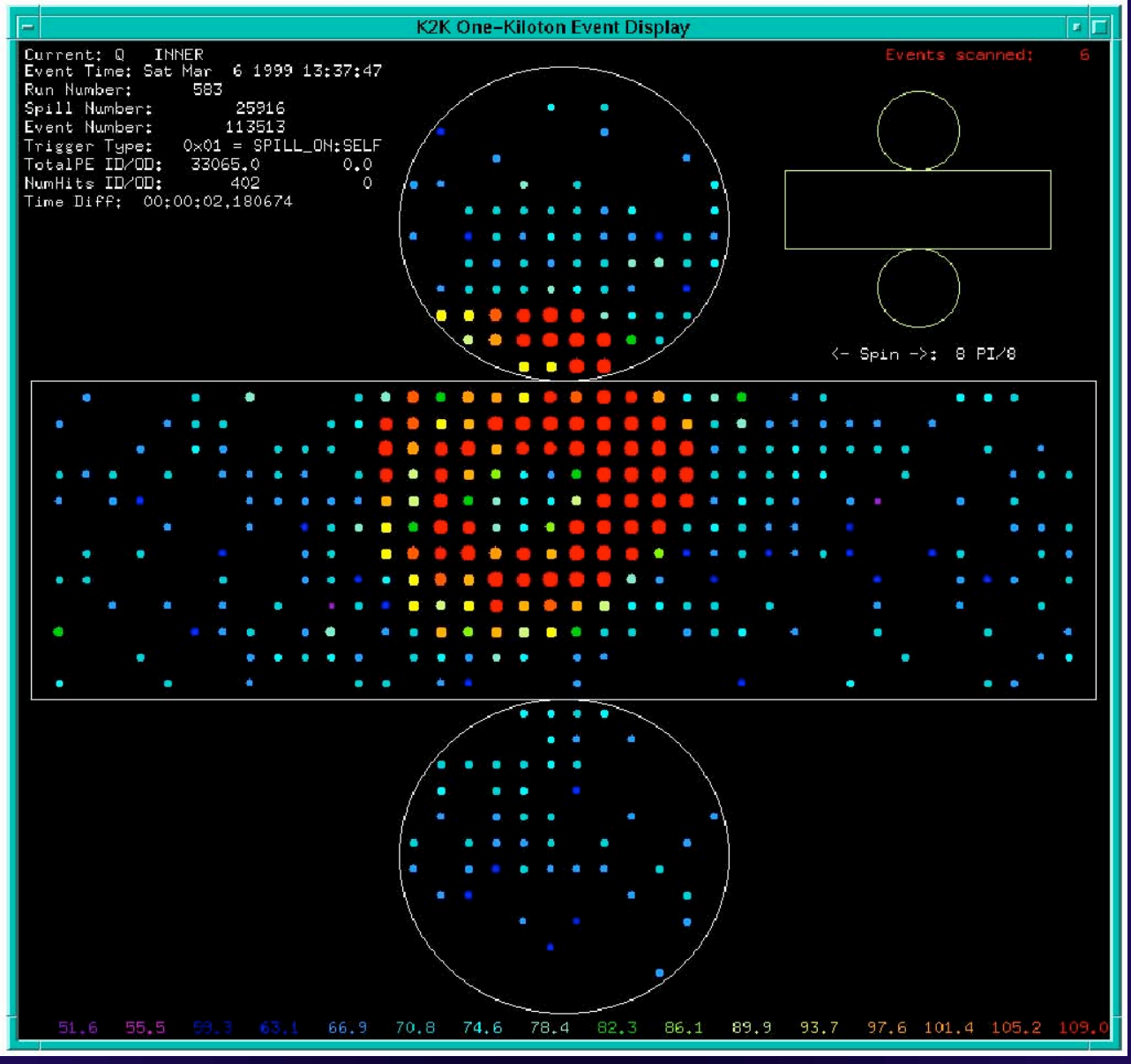
Continue: Background Study at Stony Brook

- 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

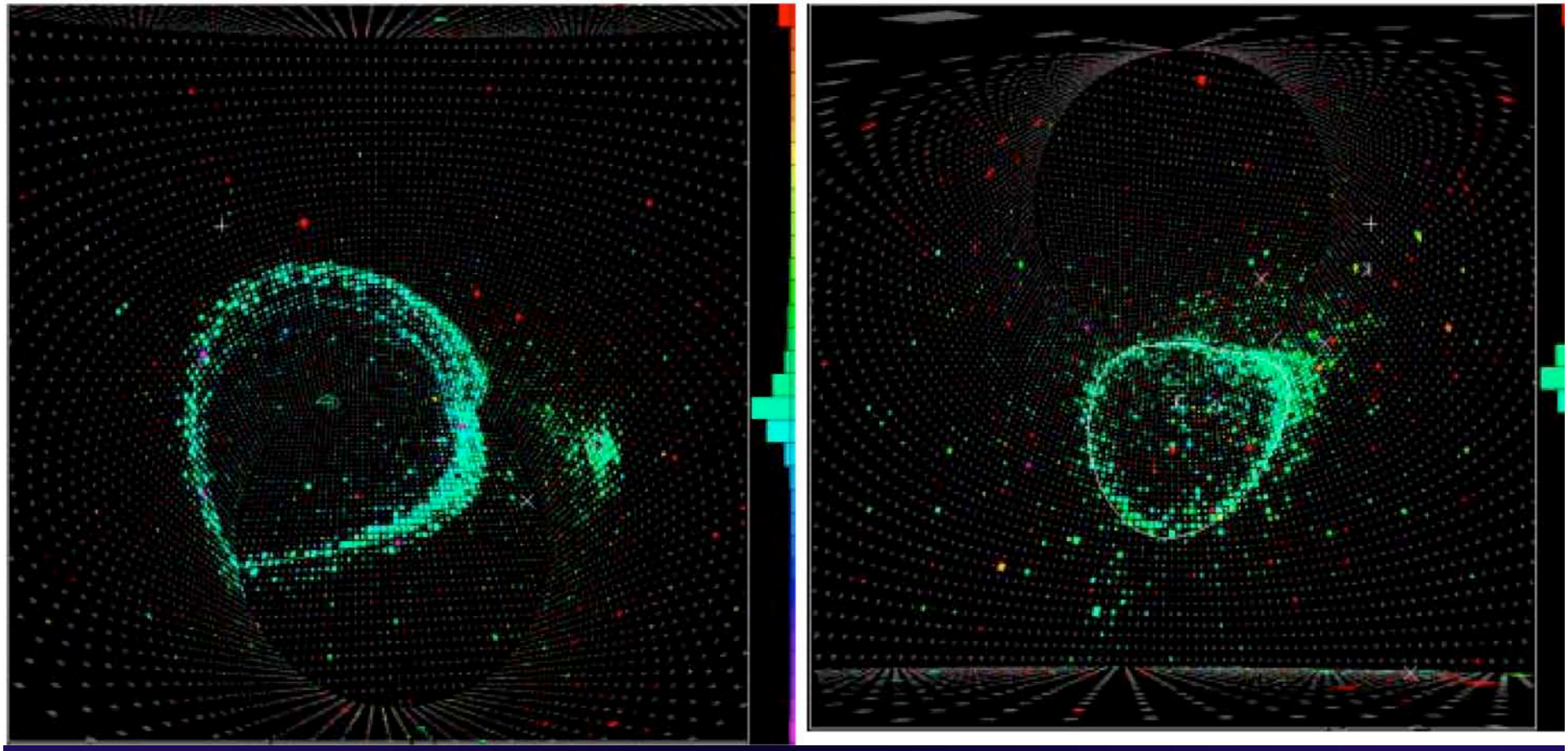
- For the same photo-cathode coverage, the larger detector has effectively finer granuality
  - Better pattern recognition capability
    - Better Particle ID
  - Better position and angular resolutions
  - SuperK vs K2K 1kt detector **
- We expect UNO central module will be better than the SuperK-I (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

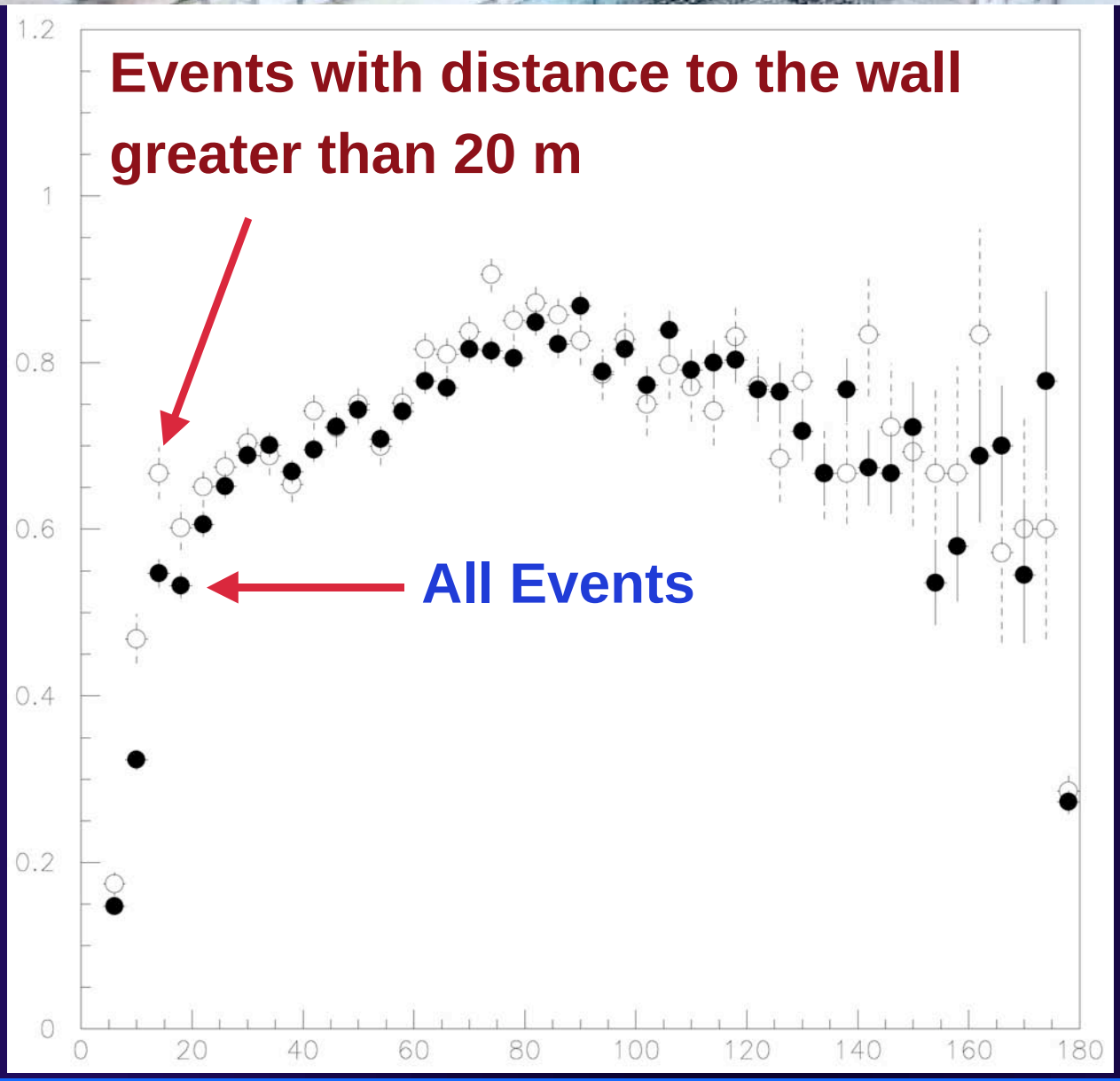


Q

K2K Events in SuperK

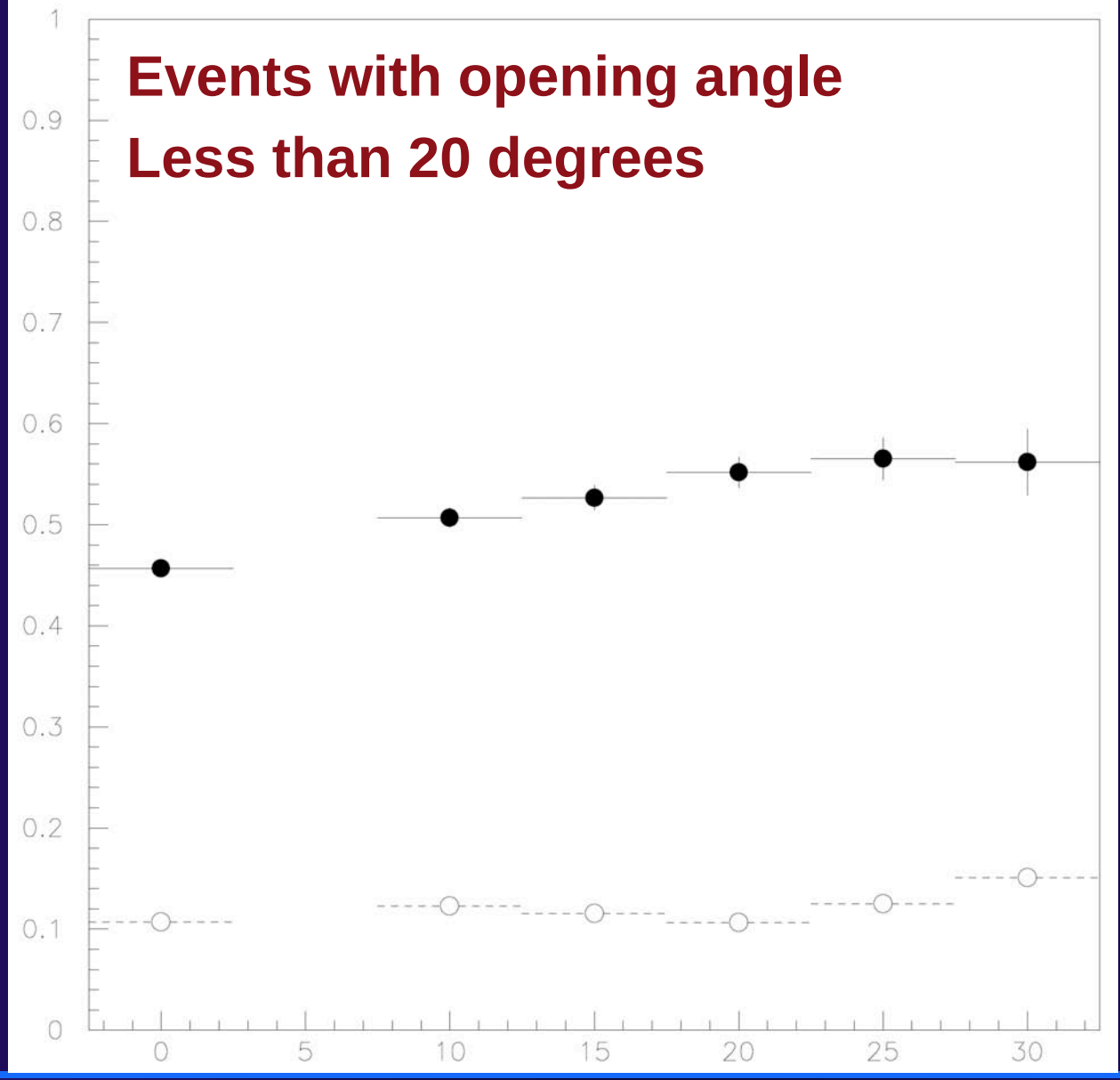


Pi-zero Finding Efficiency



True openning Angle (degrees)

Pi-zero Finding Efficiency

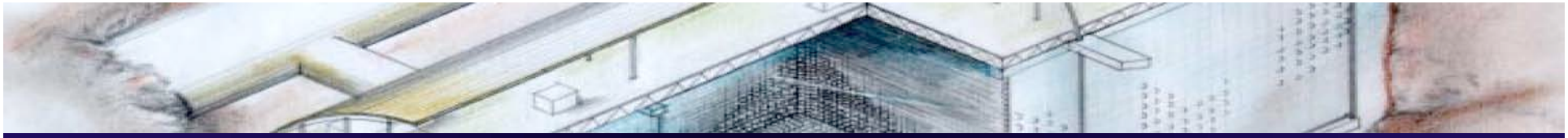


What can be done in the future?

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

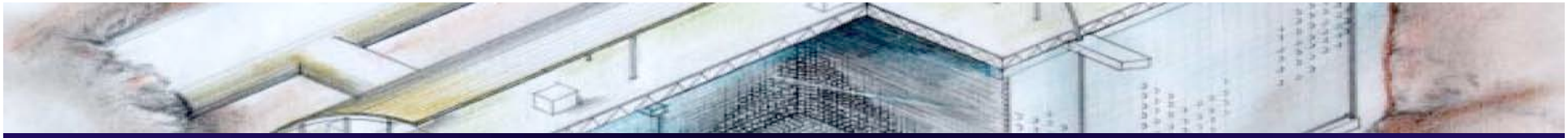


3. Additional optical elements
4. New photo-detectors
   - HPD: ICRR - U-Tokyo - Hamamatsu
   - Referenc Tube: UC Davis
5. Other detector technology

   such as ~100kt class liquid argon

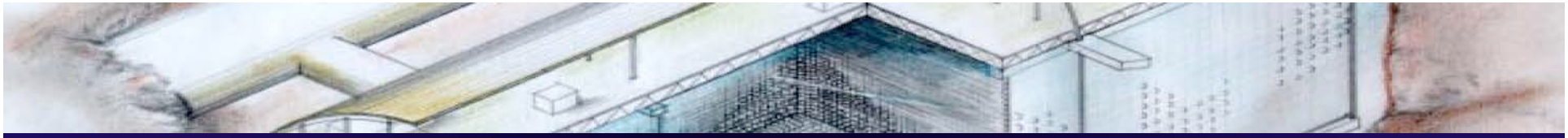
   First physics results crucial

   - To establish basis for extrapolation



- Neutrino Beam

1. Optimize beam energy and energy spectrum
2. Off-axis beam
3. Increase beam intensity
   - 2 MW?
   - High intensity proton driver has diverse applications
     - ⇒ may justify the cost by itself
4. Incorporate anti-neutrino running



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)

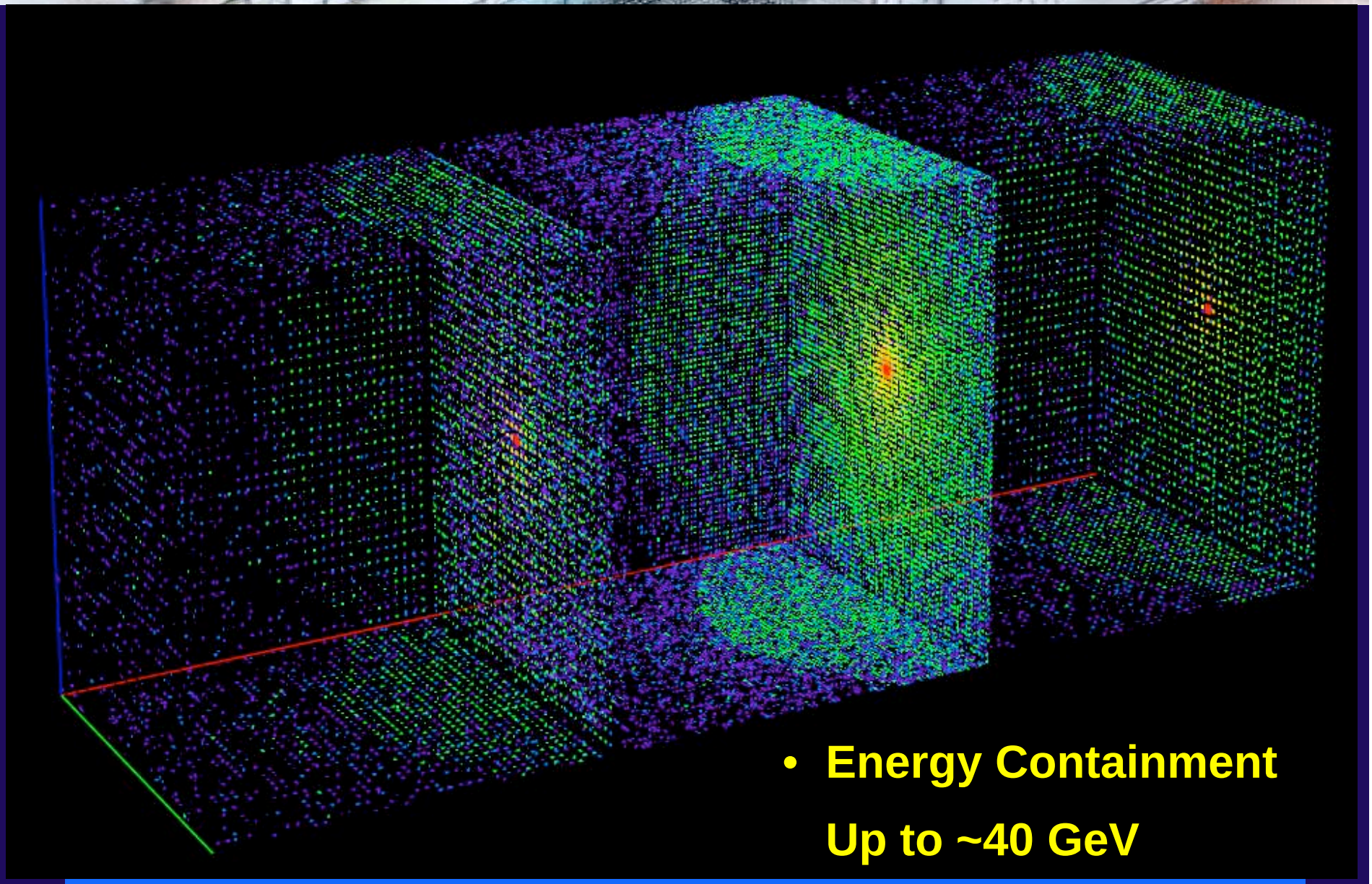
- The basic idea can be used for an experiment at Fermilab or any other accelerator labs

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

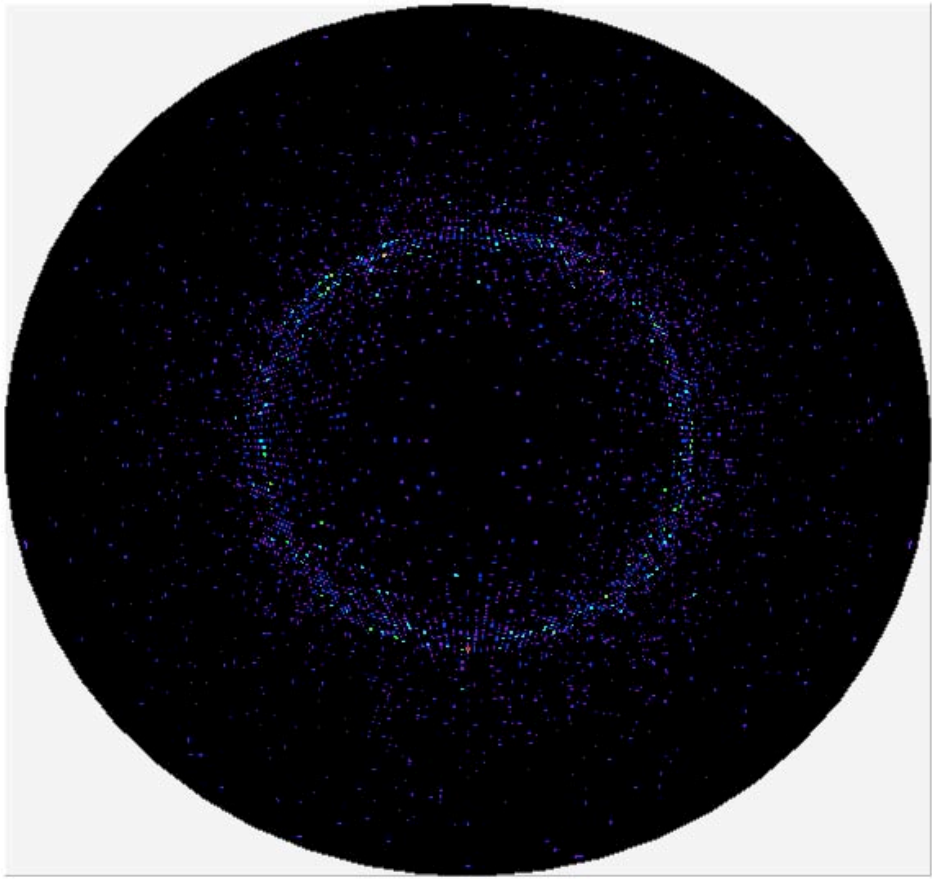
Through-going Muon Event in UNO

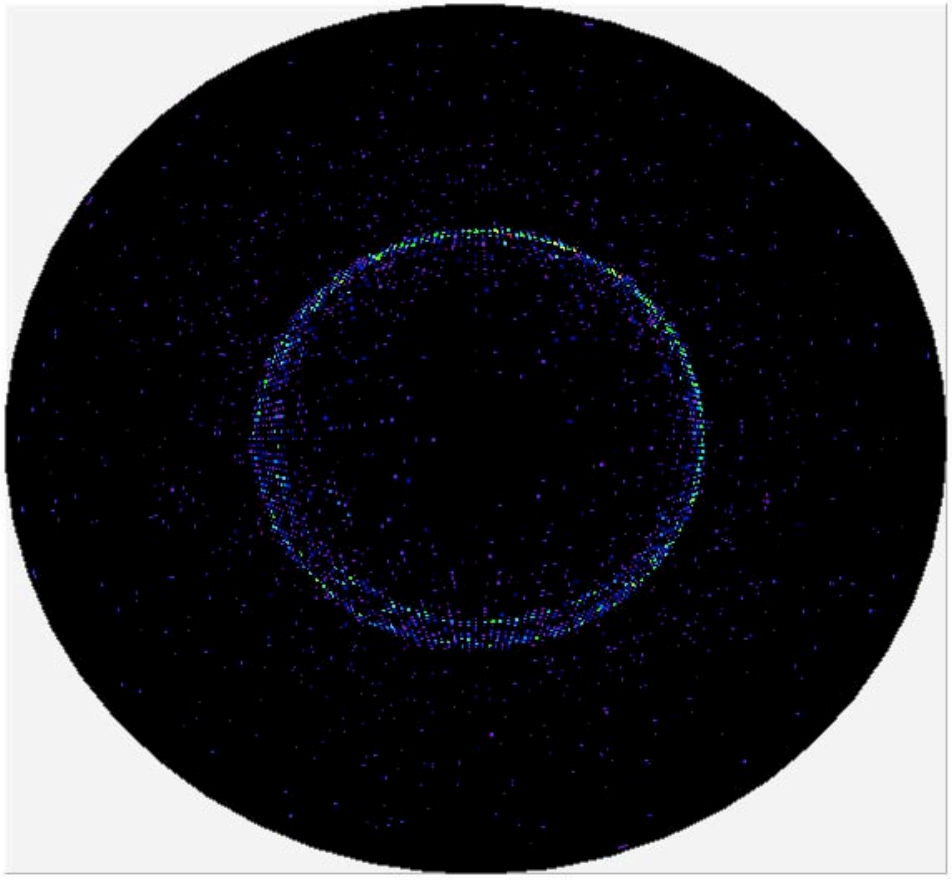


- **Energy Containment**

  Up to ~40 GeV

UNO Central Module Events

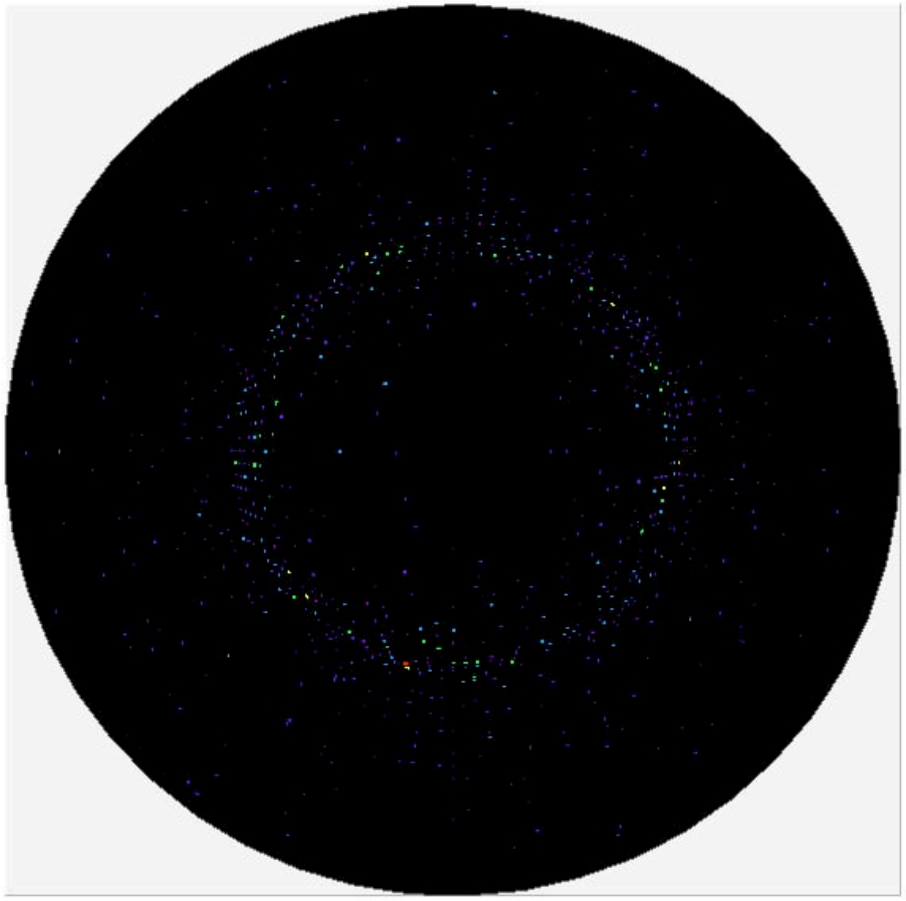


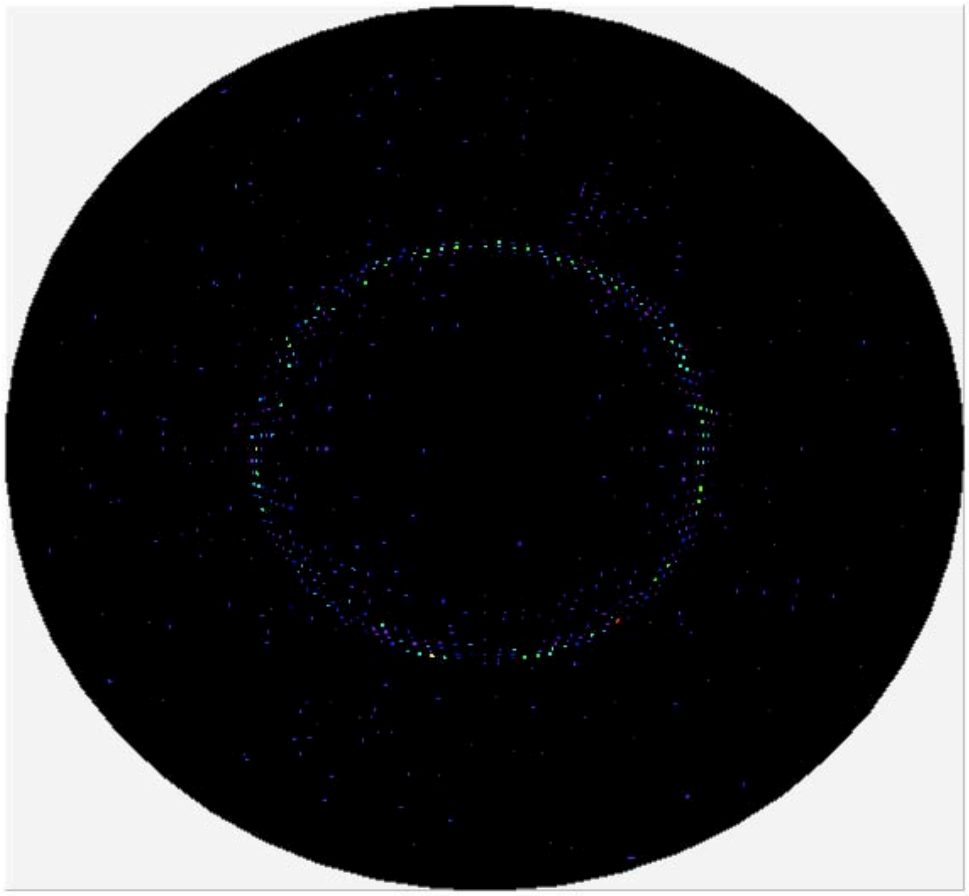


1 GeV electron

1 GeV muon

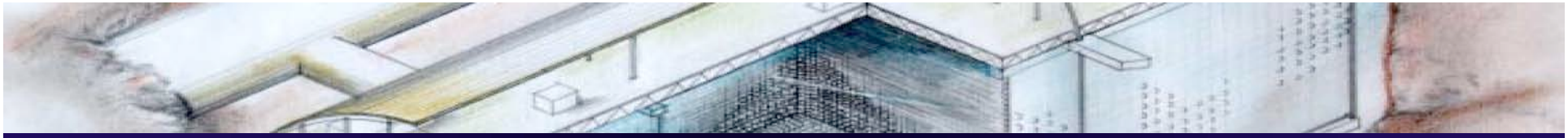
UNO Wing Modules





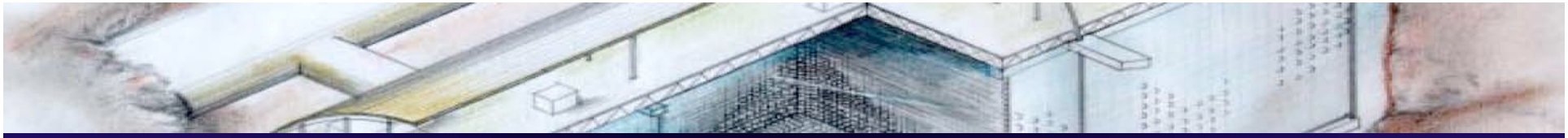
1 GeV electron

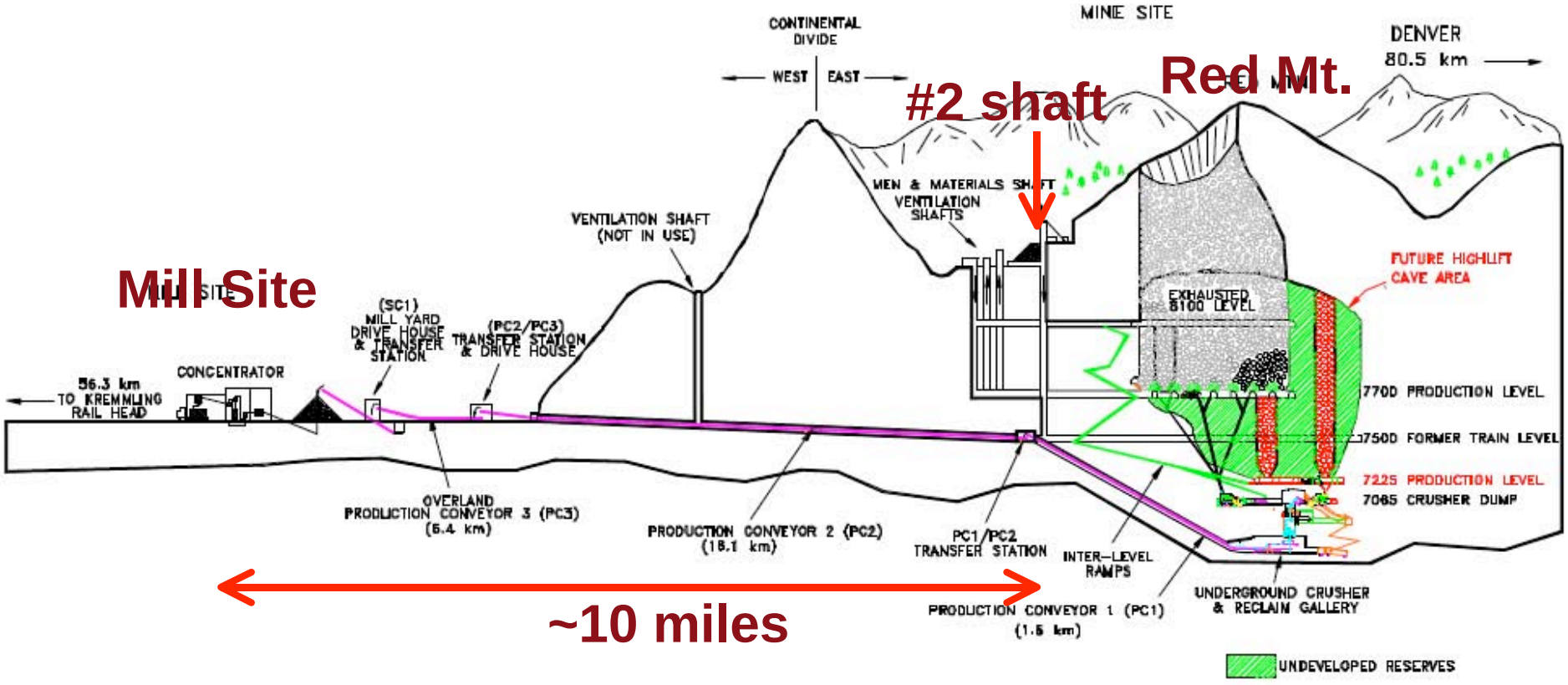
1 GeV muon



UNO at Henderson Initiative

Henderson Mine Location




MINE SITE
CONTINENTAL DIVIDE
WEST
EAST
DENVER
80.5 km
#2 shaft
Red Mt.
MEN & MATERIALS SHAFT
VENTILATION SHAFTS
VENTILATION SHAFT (NOT IN USE)
Mill Site
MILL SITE
(SC1) MILL YARD DRIVE HOUSE & TRANSFER STATION
(PC2/PC3) TRANSFER STATION & DRIVE HOUSE
CONCENTRATOR
56.3 km TO KREMMLING RAIL HEAD
FUTURE HIGHLIFT CAVE AREA
EXHAUSTED 8100 LEVEL
7700 PRODUCTION LEVEL
7500 FORMER TRAIN LEVEL
7225 PRODUCTION LEVEL
7065 CRUSHER DUMP
OVERLAND PRODUCTION CONVEYOR 3 (PC3) (6.4 km)
PRODUCTION CONVEYOR 2 (PC2) (18.1 km)
PC1/PC2 TRANSFER STATION
INTER-LEVEL RAMPS
UNDERGROUND CRUSHER & RECLAIM GALLERY
PRODUCTION CONVEYOR 1 (PC1) (1.5 km)
~10 miles
UNDEVELOPED RESERVES

High speed conveyor

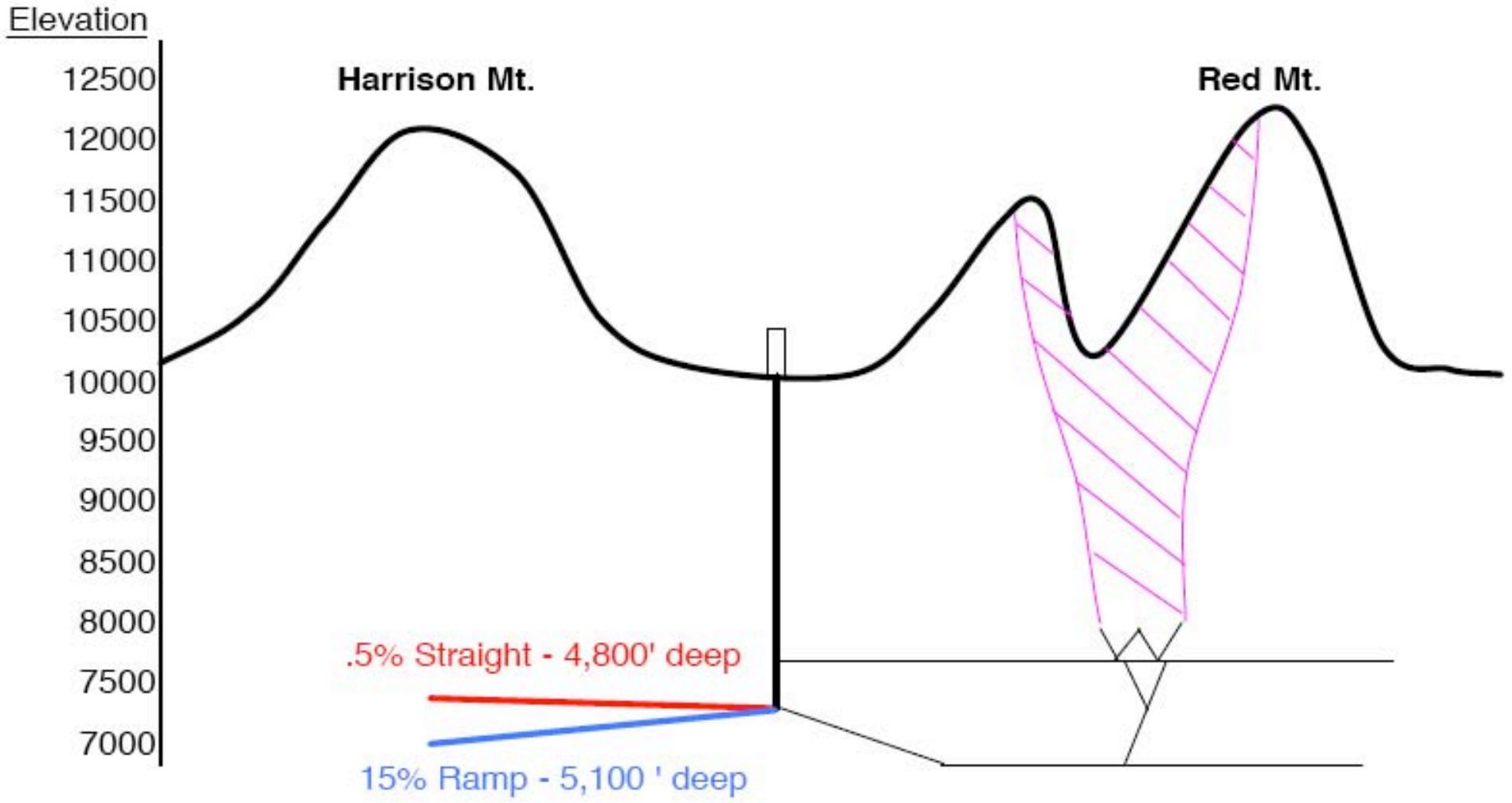
Harrison Mt. ~12,300’

possible UNO site

~1,800’

Mining Area

Possible Depths for UNO at Henderson



Optimal Depth for UNO

Conclusion

- We should not consider the scientific justification of the future superbeam experiments given
  - Need strong contribution from theorists
  - If achieved, combined case for non-accelerator physics and superbeam physics will be compelling
- 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 good merits which can be used in other applications
  - Needs constructive criticisms & checks from the community
- UNO Collaboration is putting our best effort to answer some of the questions, but severely lacks manpower to do a comprehensive and complete work