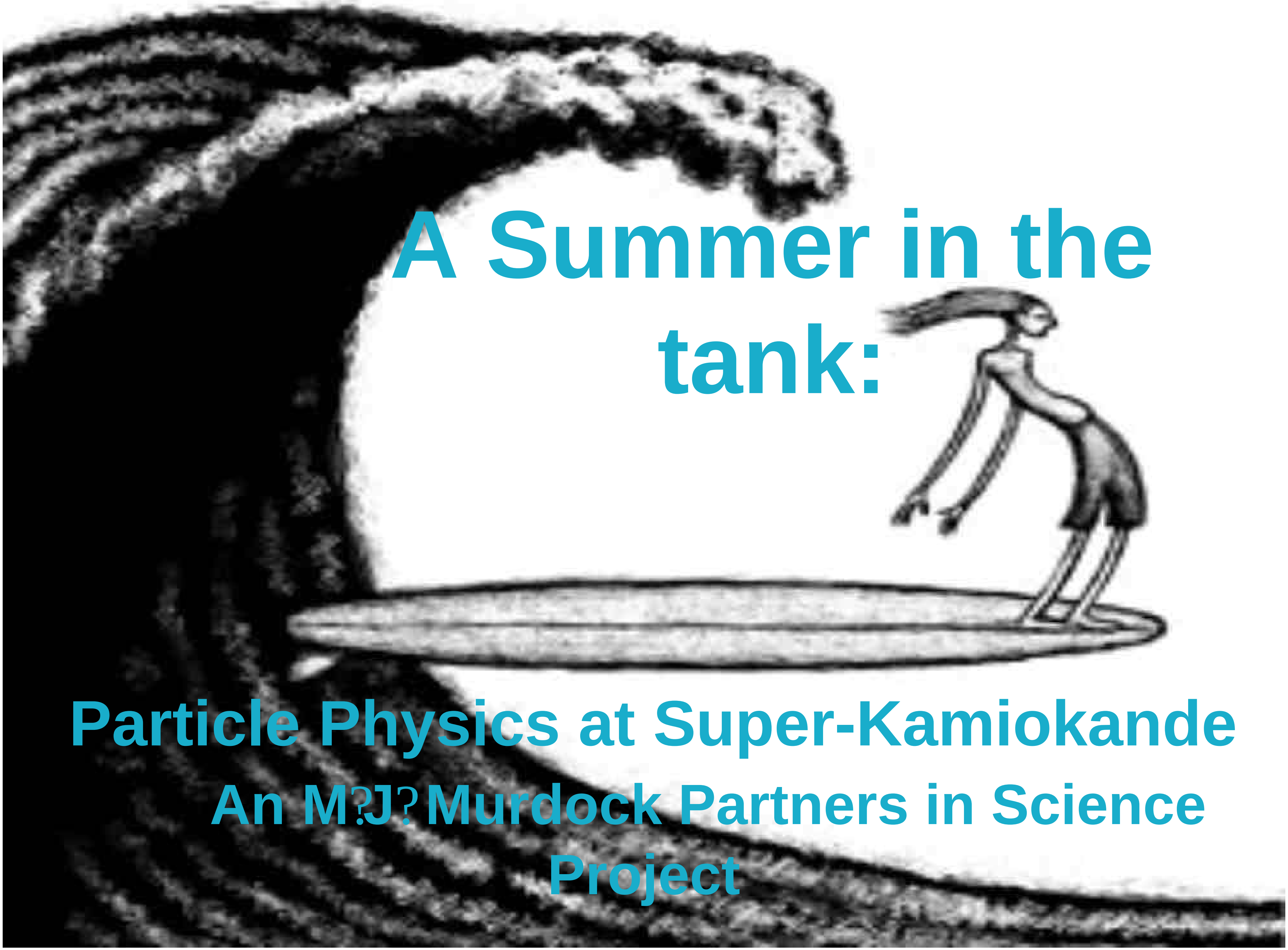
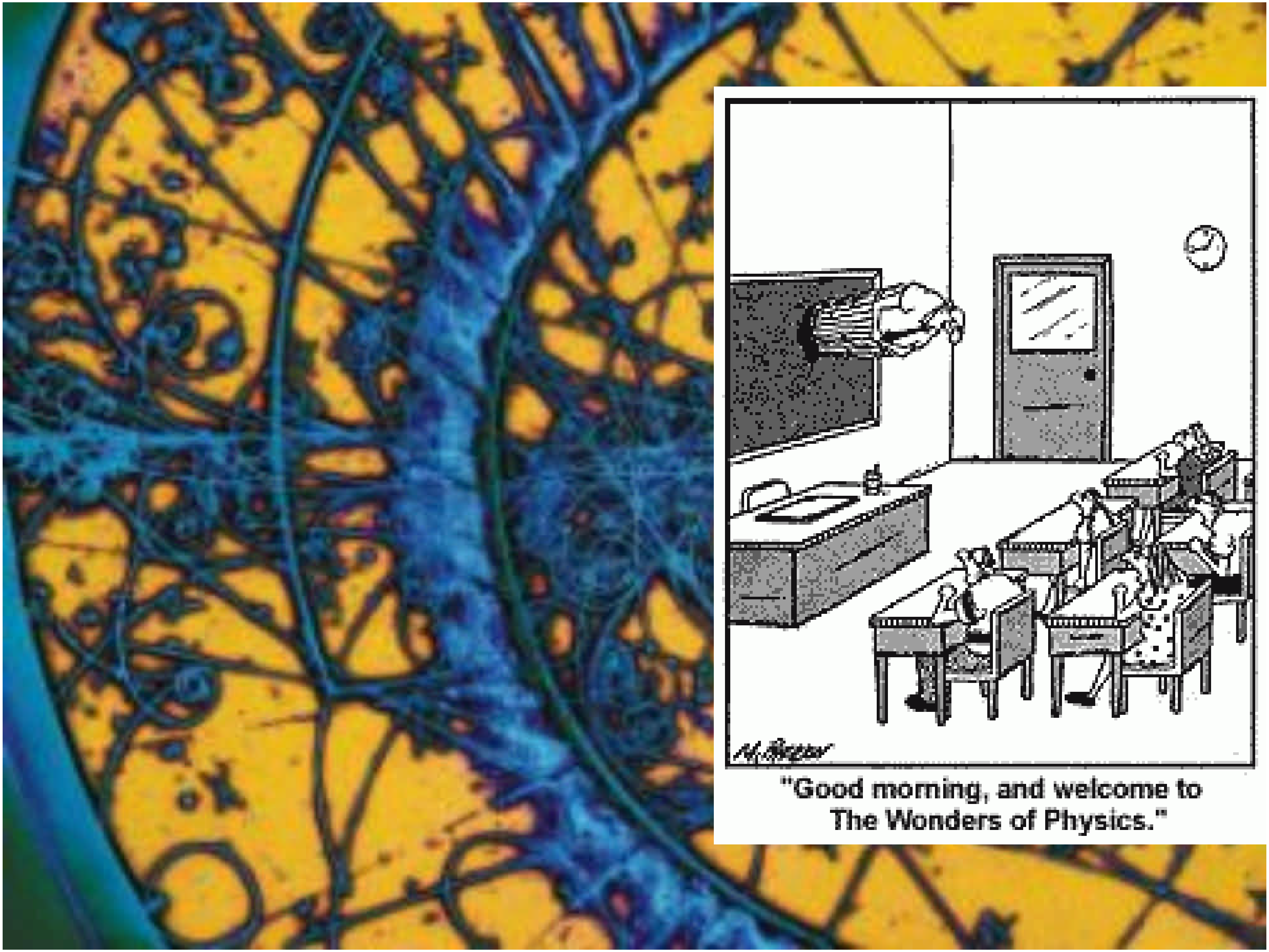


A Summer in the tank:

Particle Physics at Super-Kamiokande

An M.J. Murdock Partners in Science Project



"Good morning, and welcome to The Wonders of Physics."

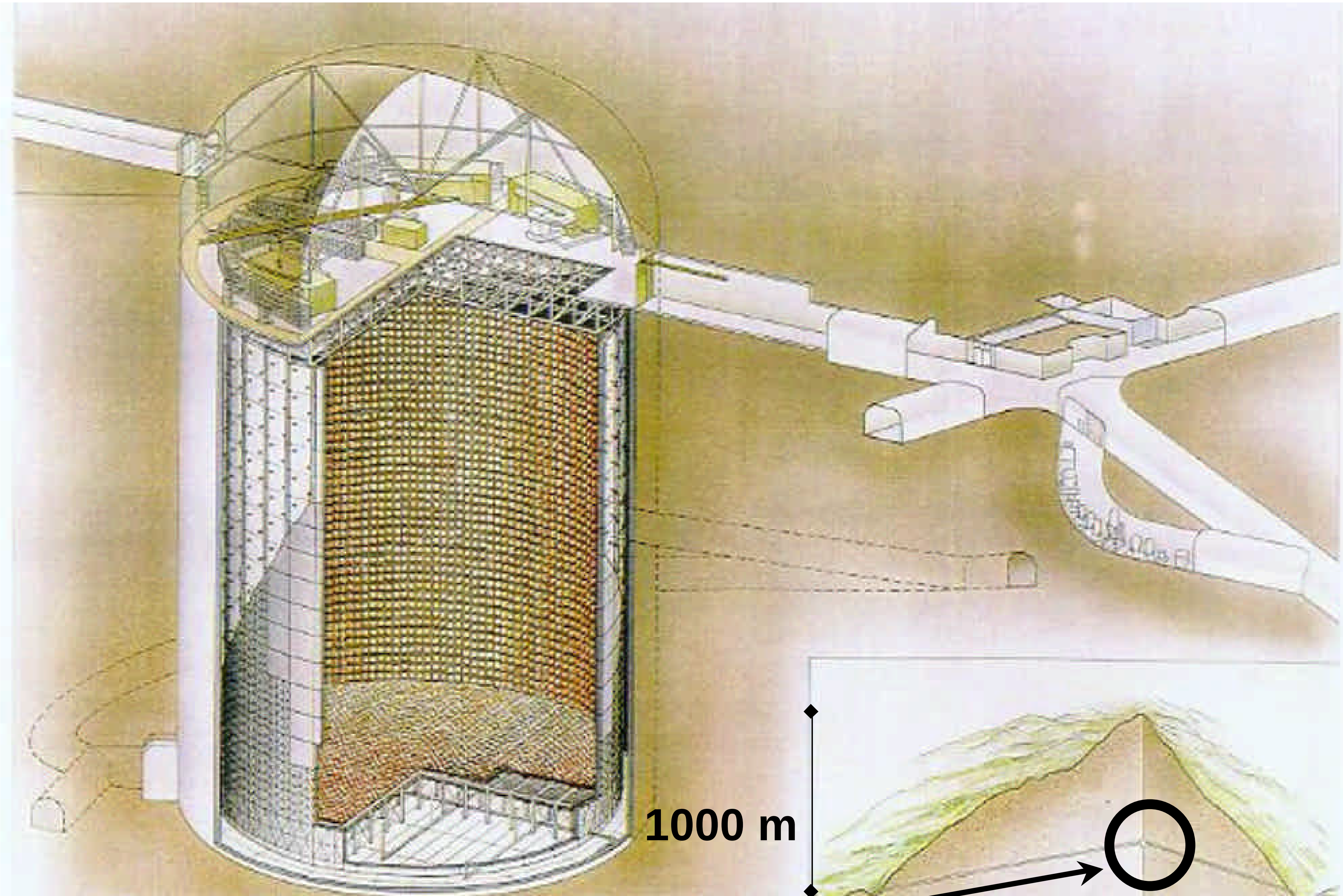
What is Super-Kamiokande (Super-K)?

- **Collaborative project involving Japan, USA, Korea, & Poland with a focus on particle physics**

~Neutrino research

~Proton decay

~Cosmic ray detection (Supernova search)



Here is Super-K!

Technically, Super-K is a:

Cerenkov Radiation Detector –

- contains 50, 000 tons (that's 11.2 million gallons)of ultra-pure water encased in a stainless steel cylinder (40 m high & 40 m in diameter)
- currently contains over 5000 photomultiplier tubes (PMTs) that constitute the inner detector (ID)
- and 1885 photomultiplier tubes

Where is Super-K?

Getting closer!


Expedia
Featuring MapPoint® Technology
Sea of Japan (East Sea)
Toyama-wan
NOTO-HANTŌ
NIIGATA-KEN
ISHIKAWA-KEN
GIFU-KEN
NAGANO-KEN
CHUBUSANGAKU NATIONAL PARK
Notojima
Enome
Nakajima
Kannon-zaki
Shinanta
Nanao
Iorimachi
Itoigawa
Sakai
Nyūzen
Asahi
Kotaki
Kanemaru
Hakui
Isobe
Unami
Kurobe
Wakaguri
Shio
Jūnichō
Himi
Kokubu
Menden
Shinminato
Takamatsu
Takaoka
Nanatsuka
Unoke
Wada
Namerikawa
Tsubata
Kosugi
Toyama
Oyabe
Fuchū
Uchinada
Fukuno
Ōsawano
Kanazawa
Komaki
Yatsuo
Miasa
Fukumitsu
Mattō
Yuwaku
Ōgaya
Toga
Tsurugi
Taira
Mozumi
Ikeda
Kamitaira
Suisho-dake
Nishiakao
Yariga-take
Hotaka
Bekku
Kamioka
Sugō
Toyoshina
© 2002 Microsoft Corp and/or its suppliers.
Here is where we enter the mine.

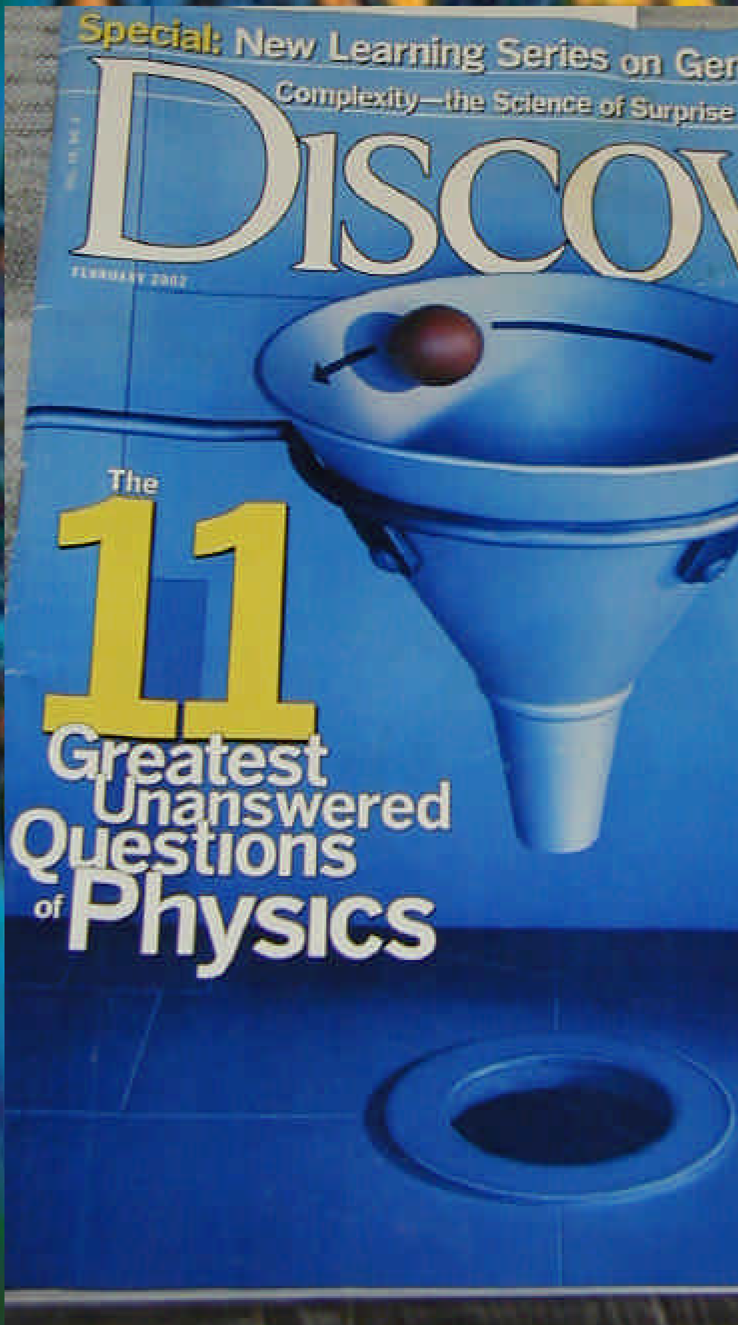

Route 41 to the mine

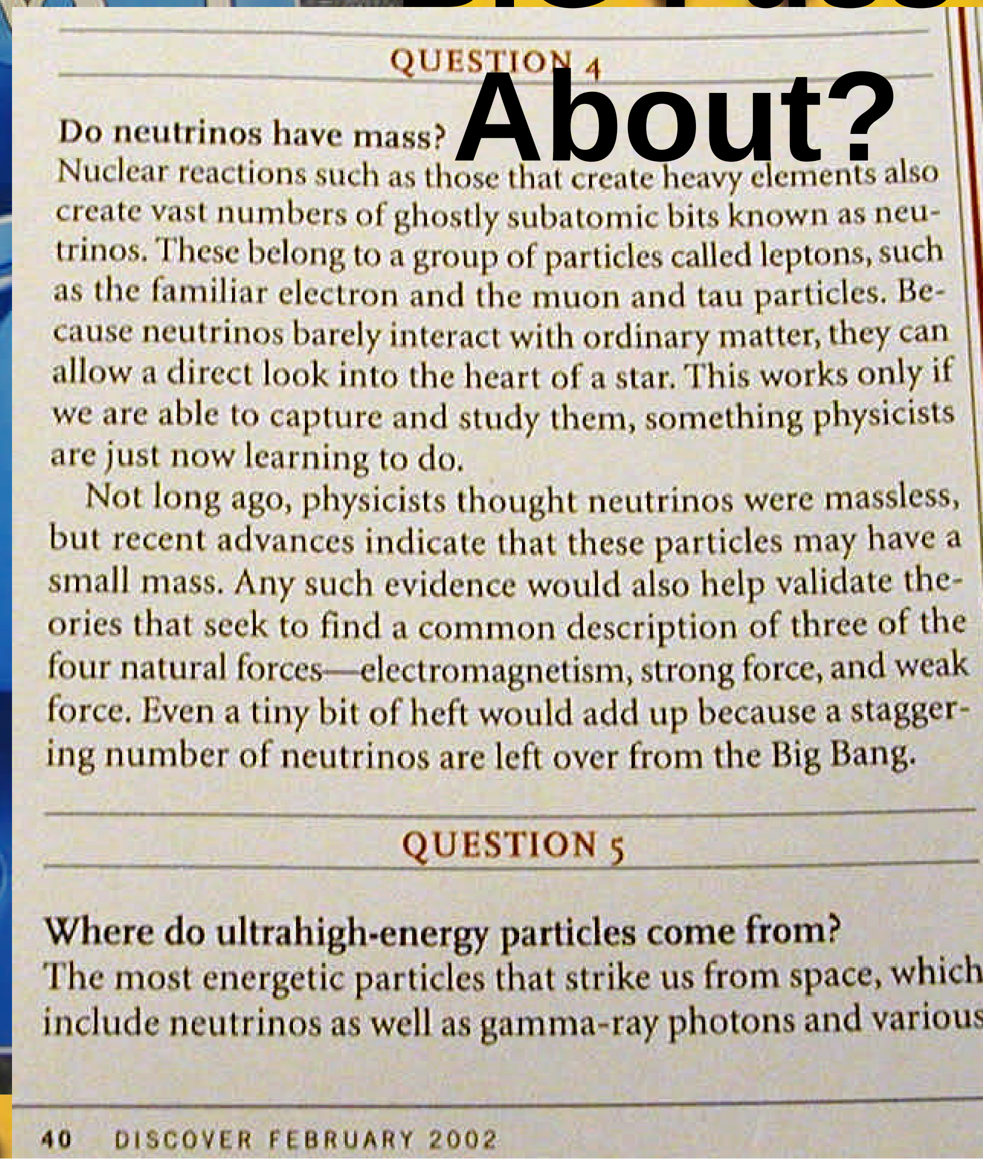

Lovely shoes park
washingto


Toyama Town

A quick overview of how Super-K works

What's The BIG Fuss About?





QUESTION 4

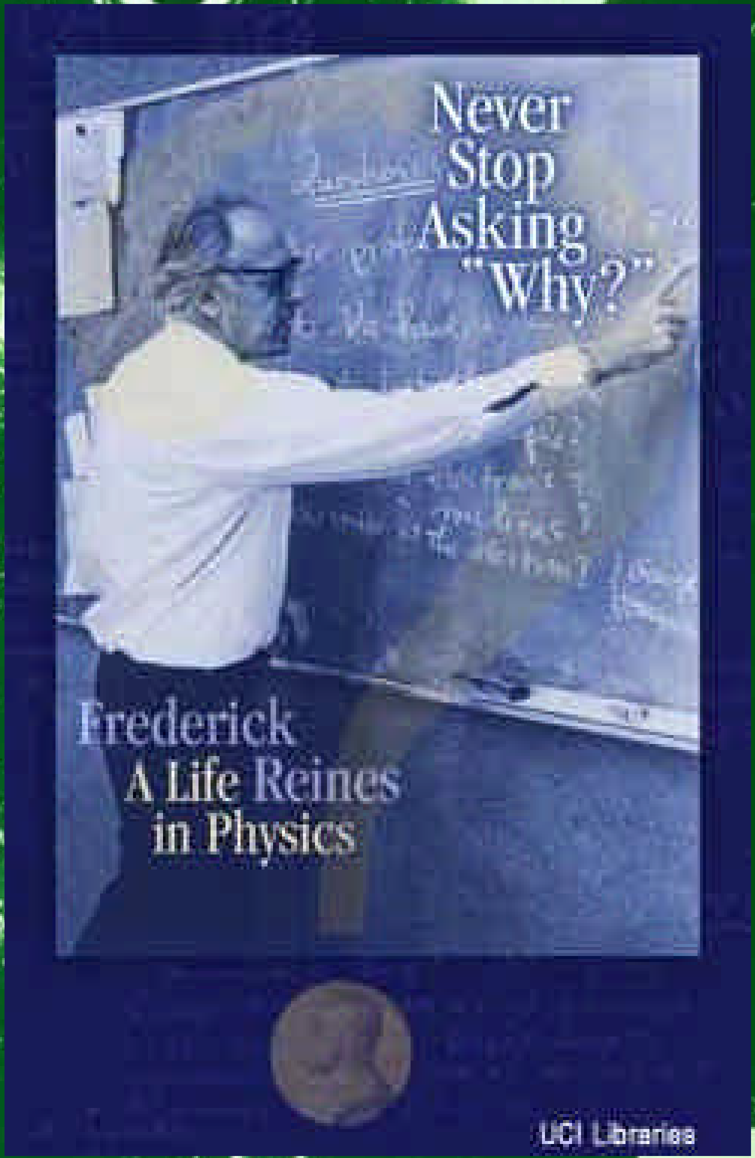
Do neutrinos have mass?
Nuclear reactions such as those that create heavy elements also create vast numbers of ghostly subatomic bits known as neutrinos. These belong to a group of particles called leptons, such as the familiar electron and the muon and tau particles. Because neutrinos barely interact with ordinary matter, they can allow a direct look into the heart of a star. This works only if we are able to capture and study them, something physicists are just now learning to do.

Not long ago, physicists thought neutrinos were massless, but recent advances indicate that these particles may have a small mass. Any such evidence would also help validate theories that seek to find a common description of three of the four natural forces—electromagnetism, strong force, and weak force. Even a tiny bit of heft would add up because a staggering number of neutrinos are left over from the Big Bang.

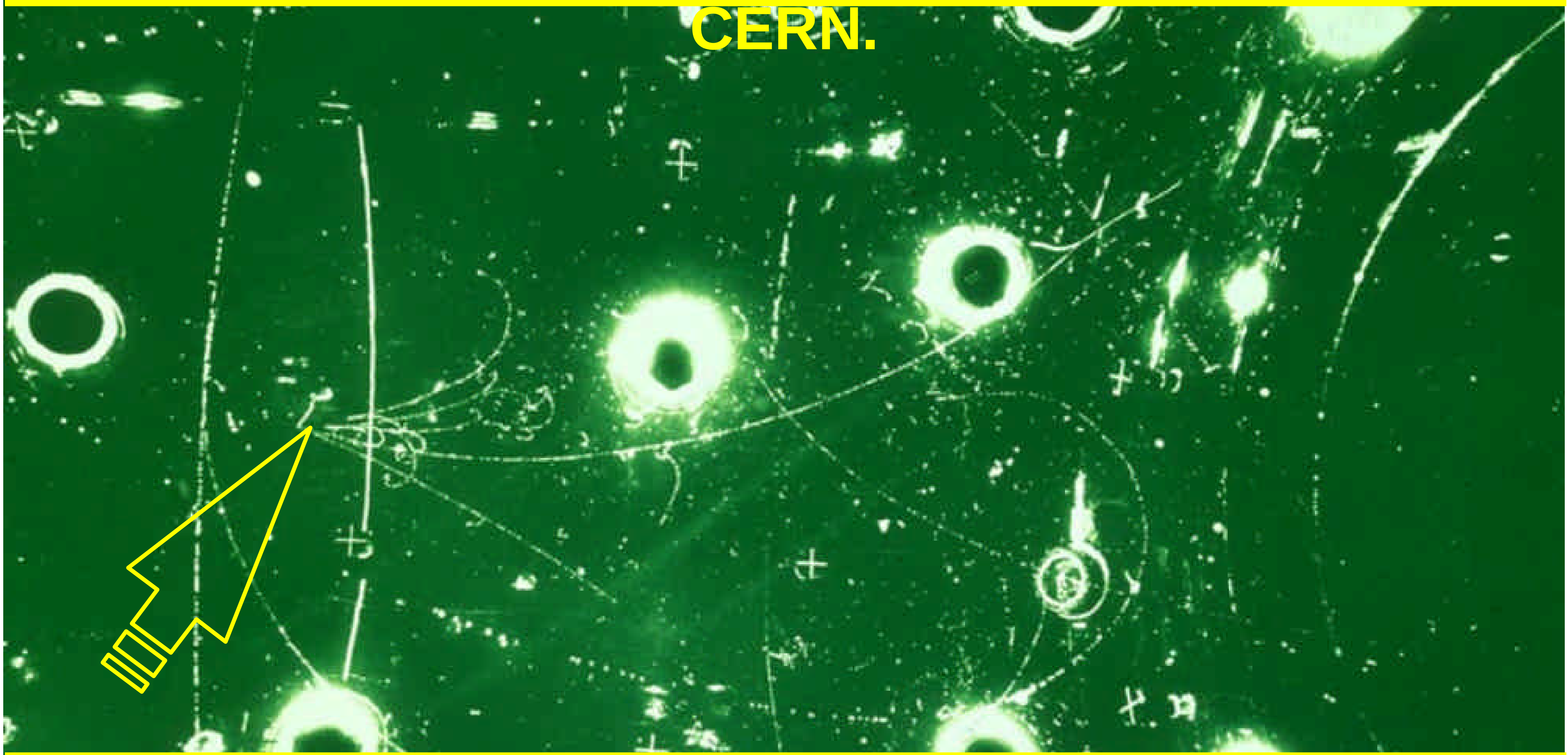
QUESTION 5

Where do ultrahigh-energy particles come from?
The most energetic particles that strike us from space, which include neutrinos as well as gamma-ray photons and various

Frederick Reines (1995 Nobel Laureate) and the Neutrino

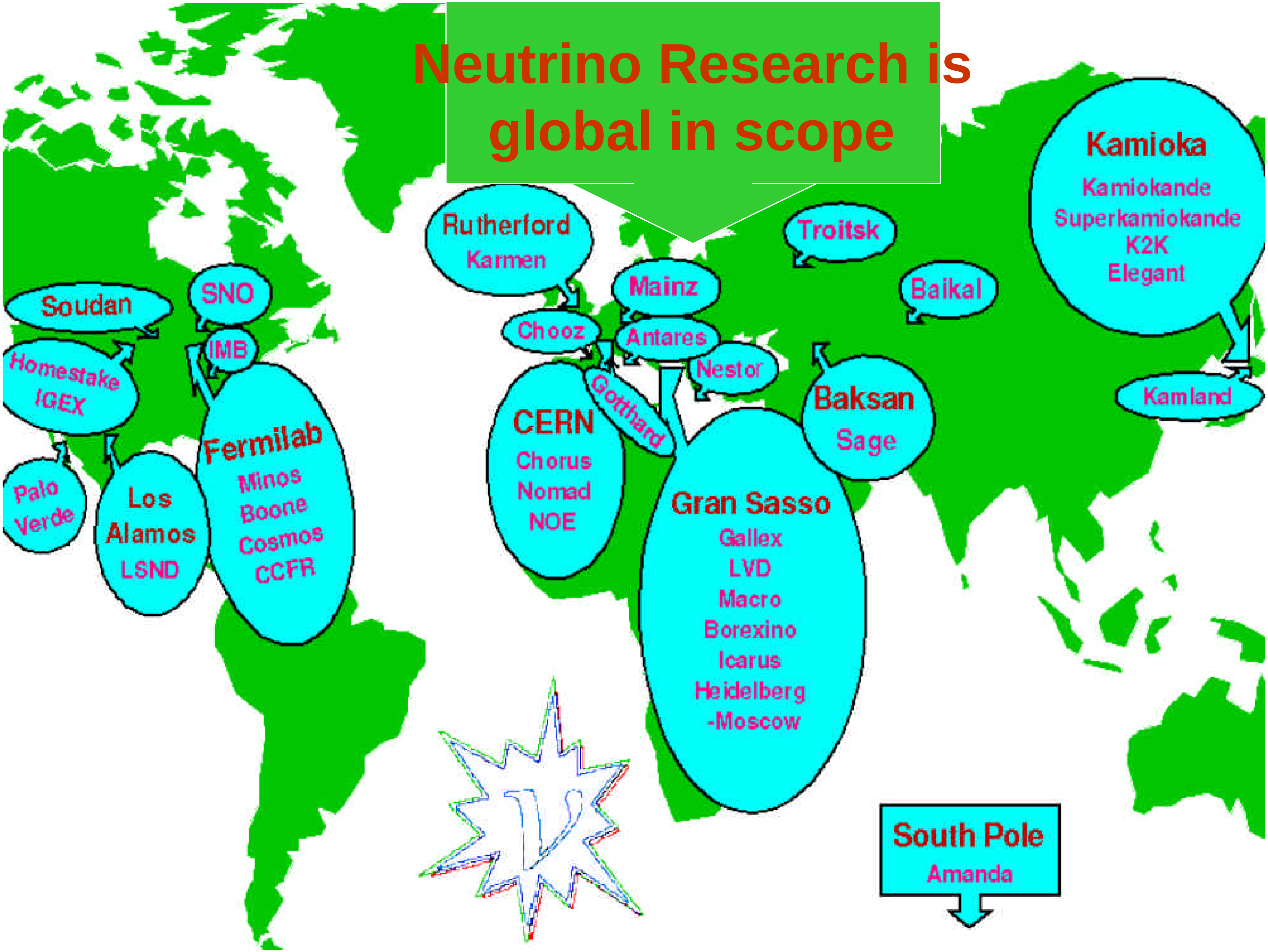


On September 3rd ,1973, the first observation of "neutral current" interactions, were recorded at CERN.

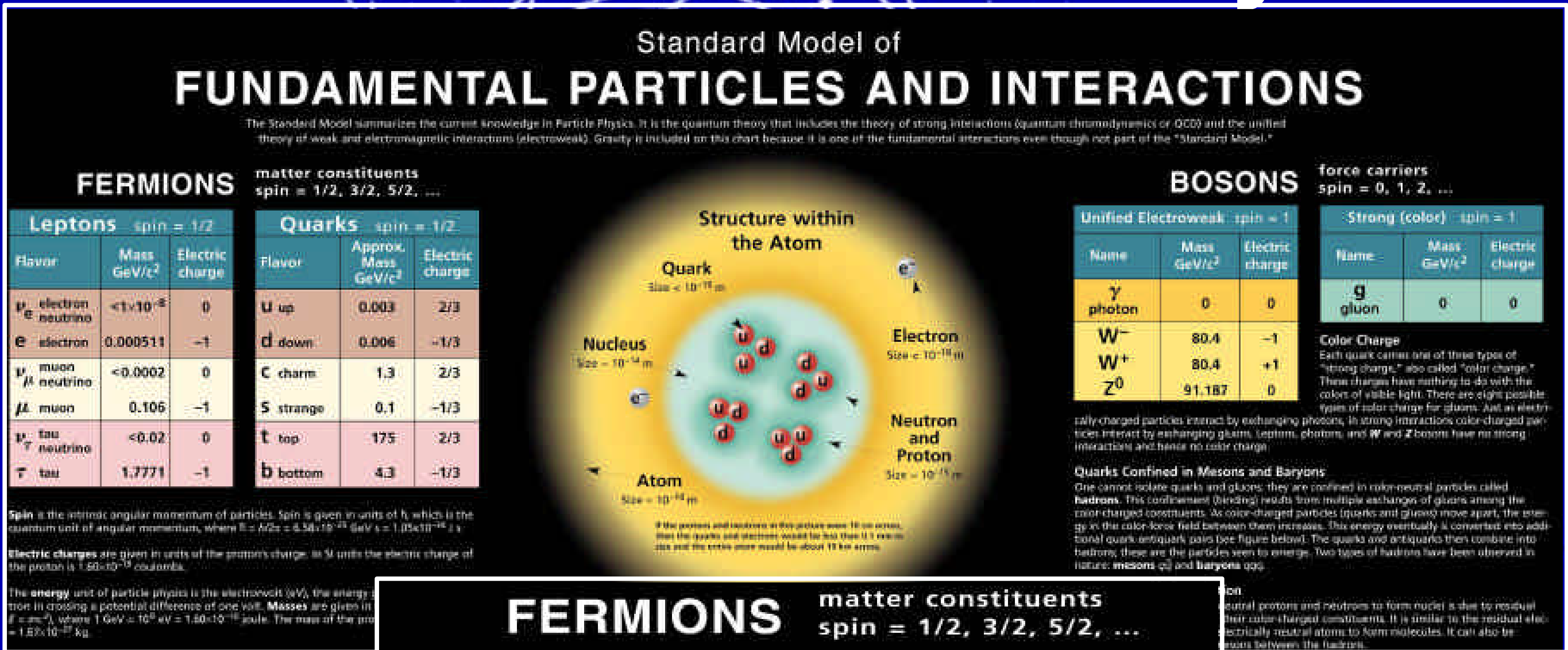


These particles are the debris of a nucleus in the bubble chamber liquid, which has been struck by one of the energetic, but invisible neutrinos.

Neutrino Research is global in scope



Overview of Particle Physics



FERMIONS

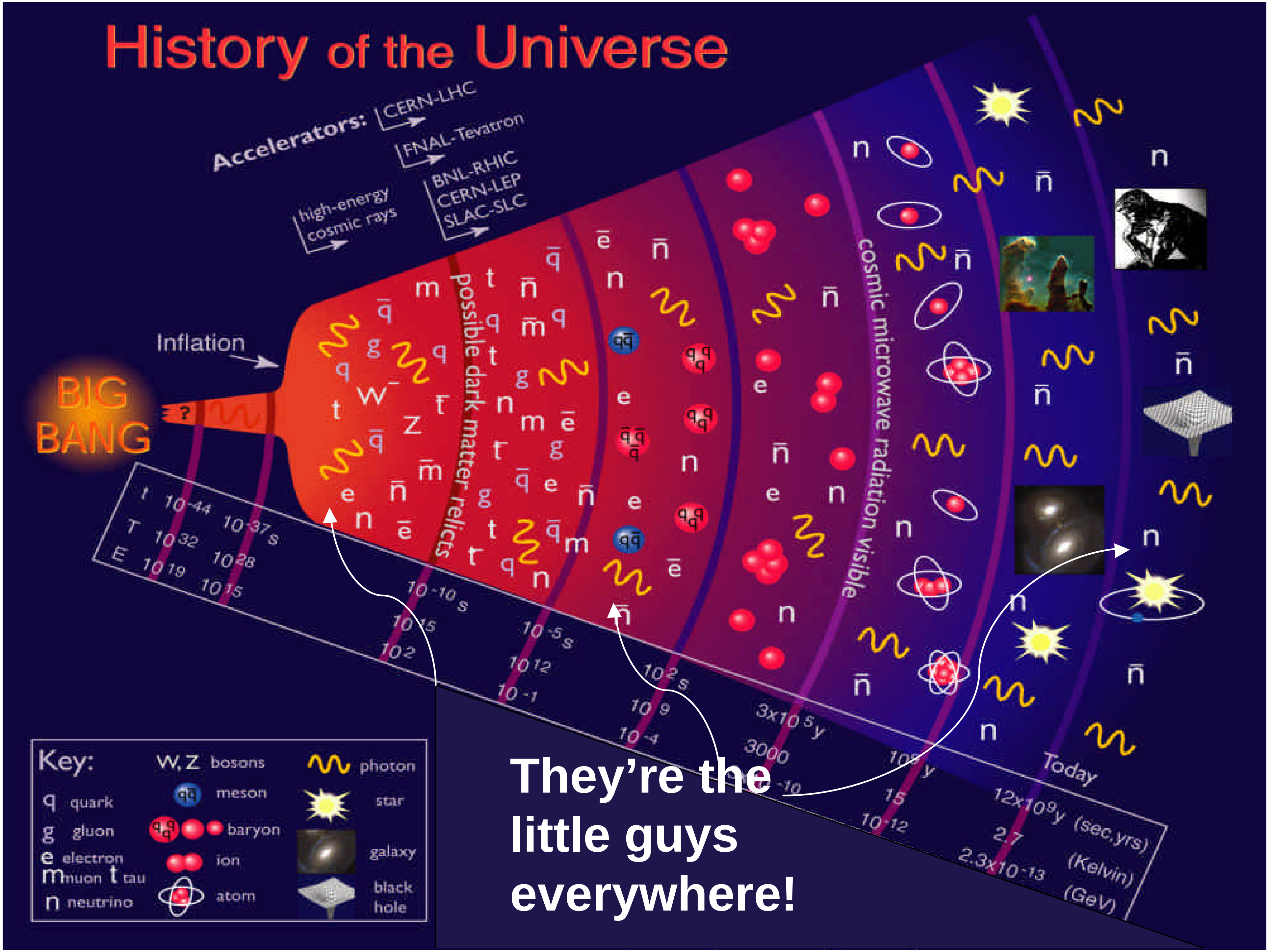
matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

Flavor	Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	–1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	–1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	–1

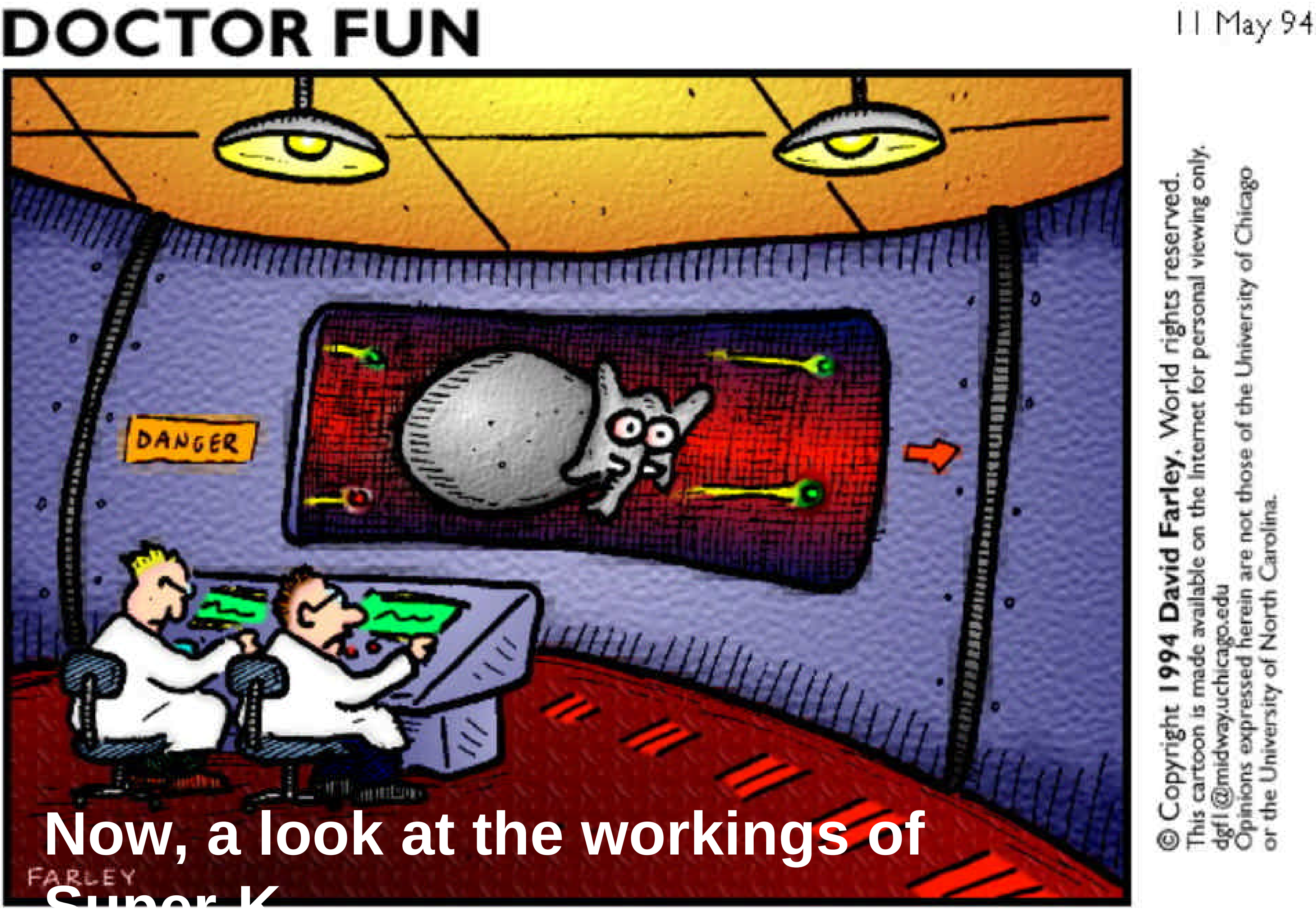
Quarks spin = 1/2

Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.003	2/3
d down	0.006	–1/3
c charm	1.3	2/3
s strange	0.1	–1/3
t top	175	2/3
b bottom	4.3	–1/3

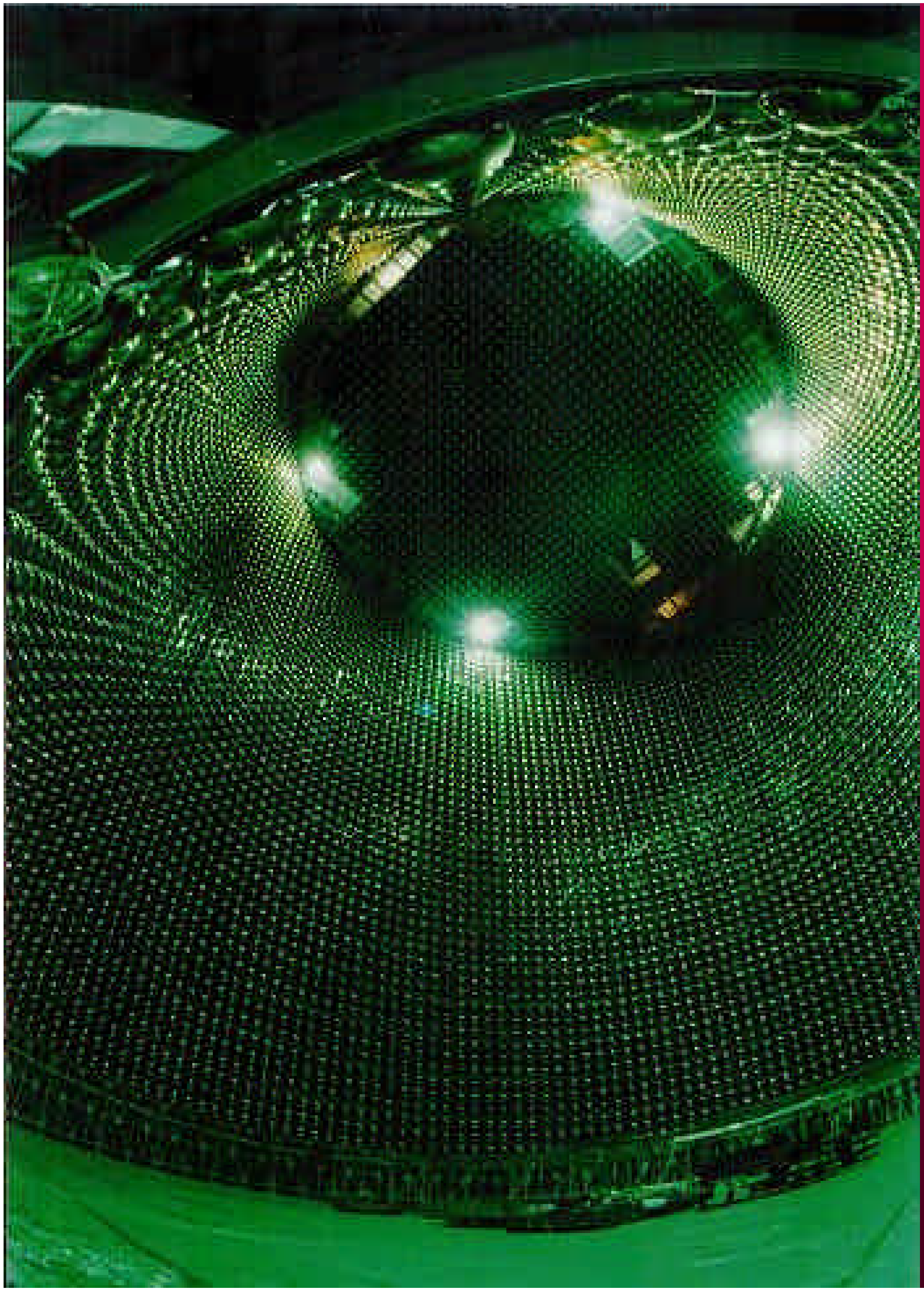


They’re the little guys everywhere!

Now, a look at the workings of Super K



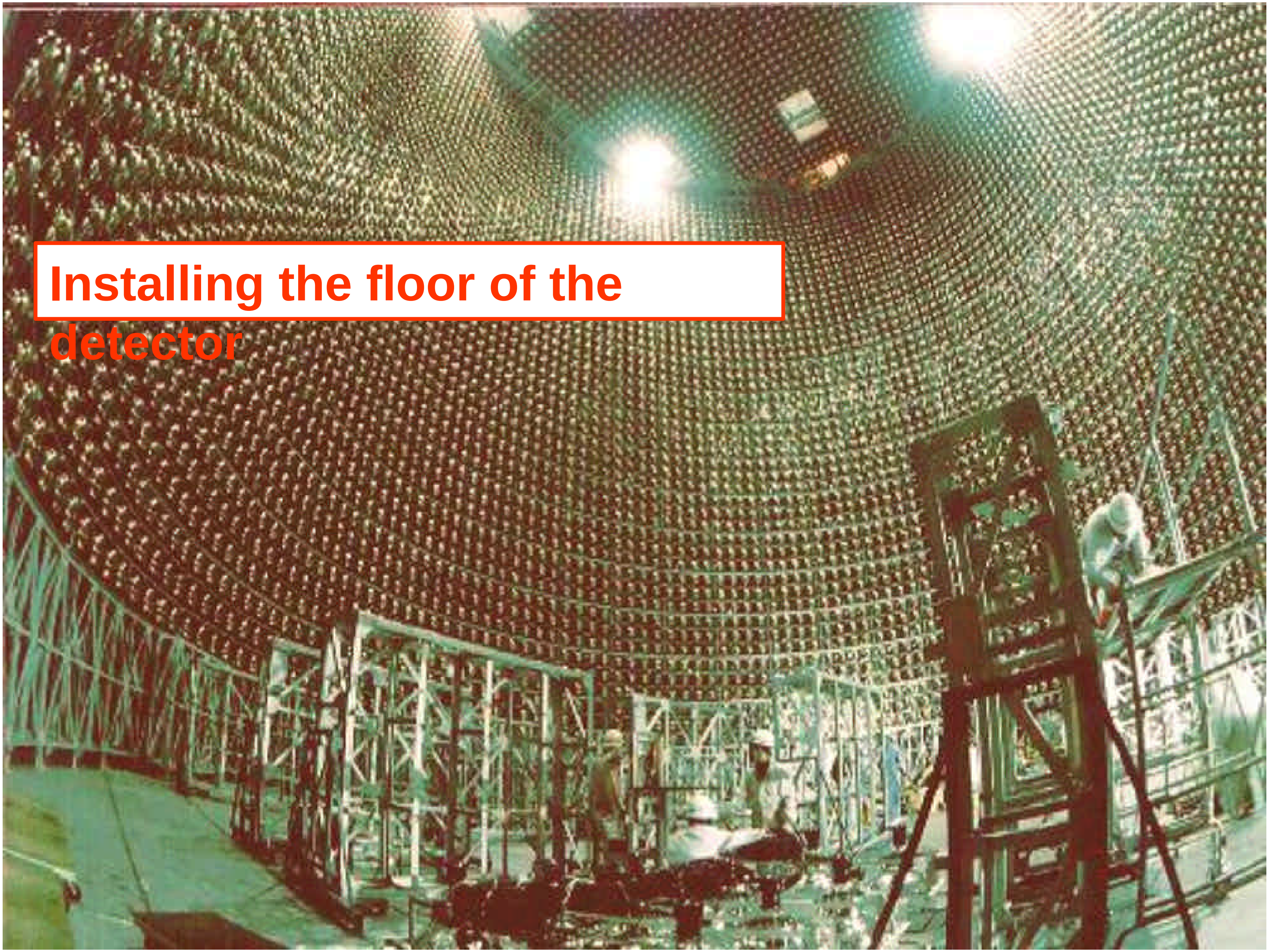
Deep within the atomic supercollider, the search continues for the elusive elephantino.



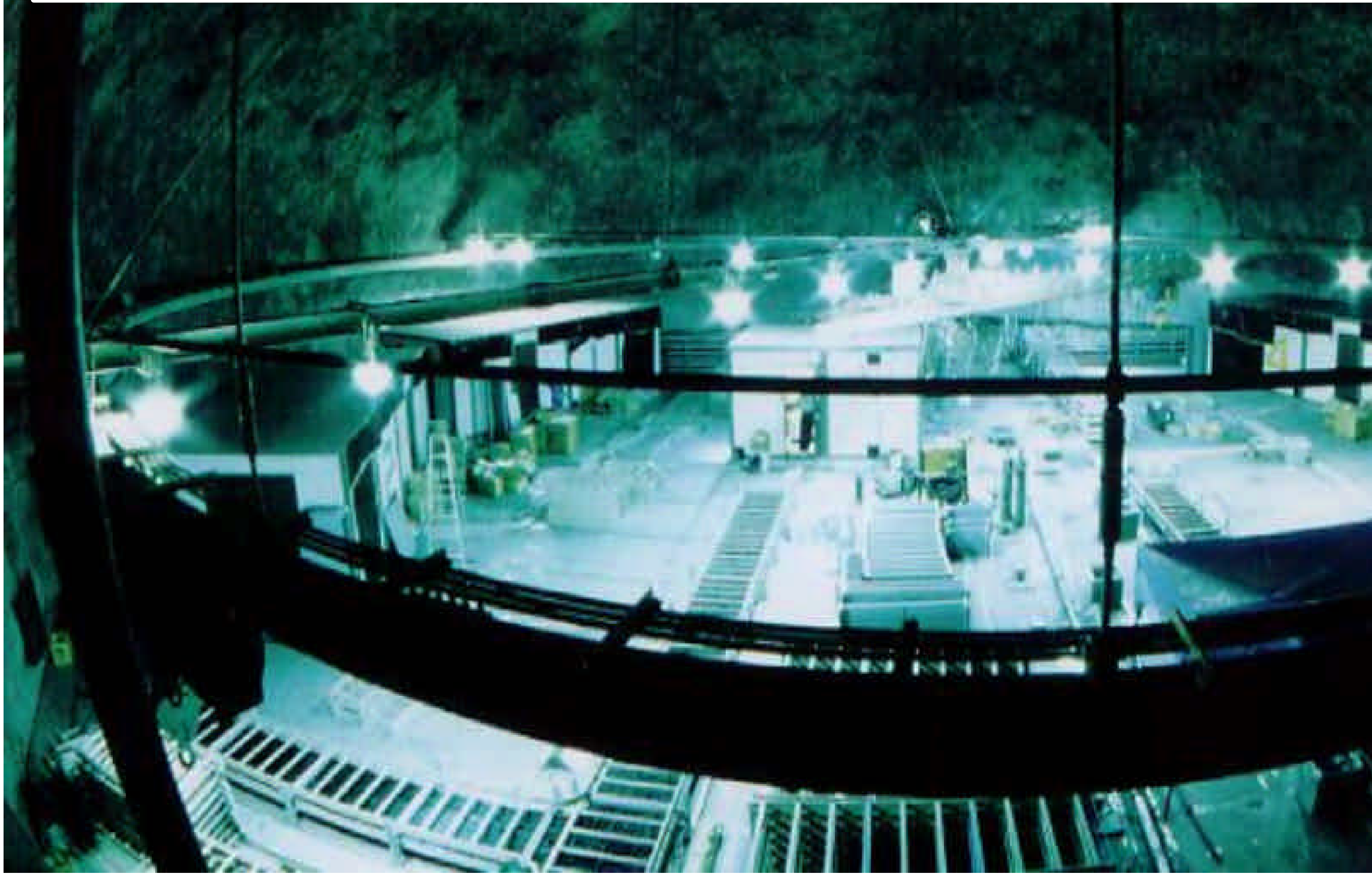
When the floor is completed, the ID will house 11,146 PMTs, each with a diameter of 52 cm (20 in)

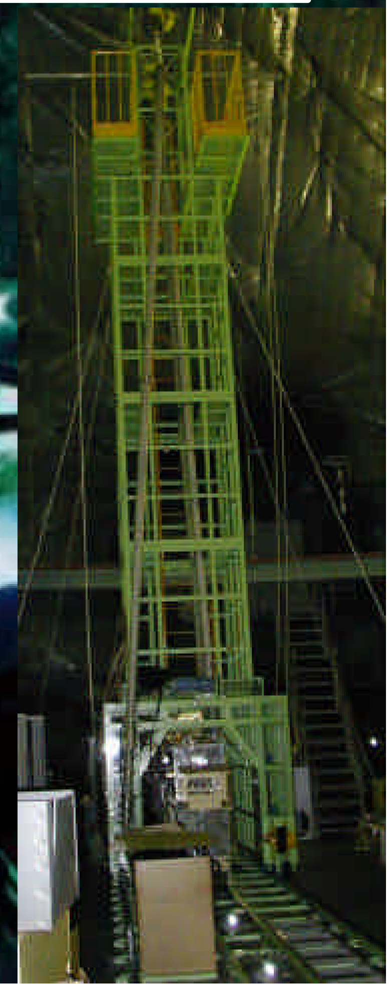
大口径光電子増倍管
3-D STRUCTURE of
PHOTOMULTIPLIER TUBE
R3600-05
各部の名称
DESIGNATION
電子増倍部(11段)
DYNODE:11stages
ガラスバルブ
GLASS BULB
電圧分割回路
VOLTAGE DIVIDER
防水アッセンブリ
WATER PROOF
ASSEMBLY
集束電極
FOCUSING ELECTRODE
光電面
PHOTO CATHODE
全長:695mm(ケーブル含まず)
OVERALL LENGTH (without cable)
直径:518mm (MAX.)
DIAMETER
重量:13kg (ケーブル含む)
WEIGHT (with cable)
My job is to change light into electrical current

Installing the floor of the detector

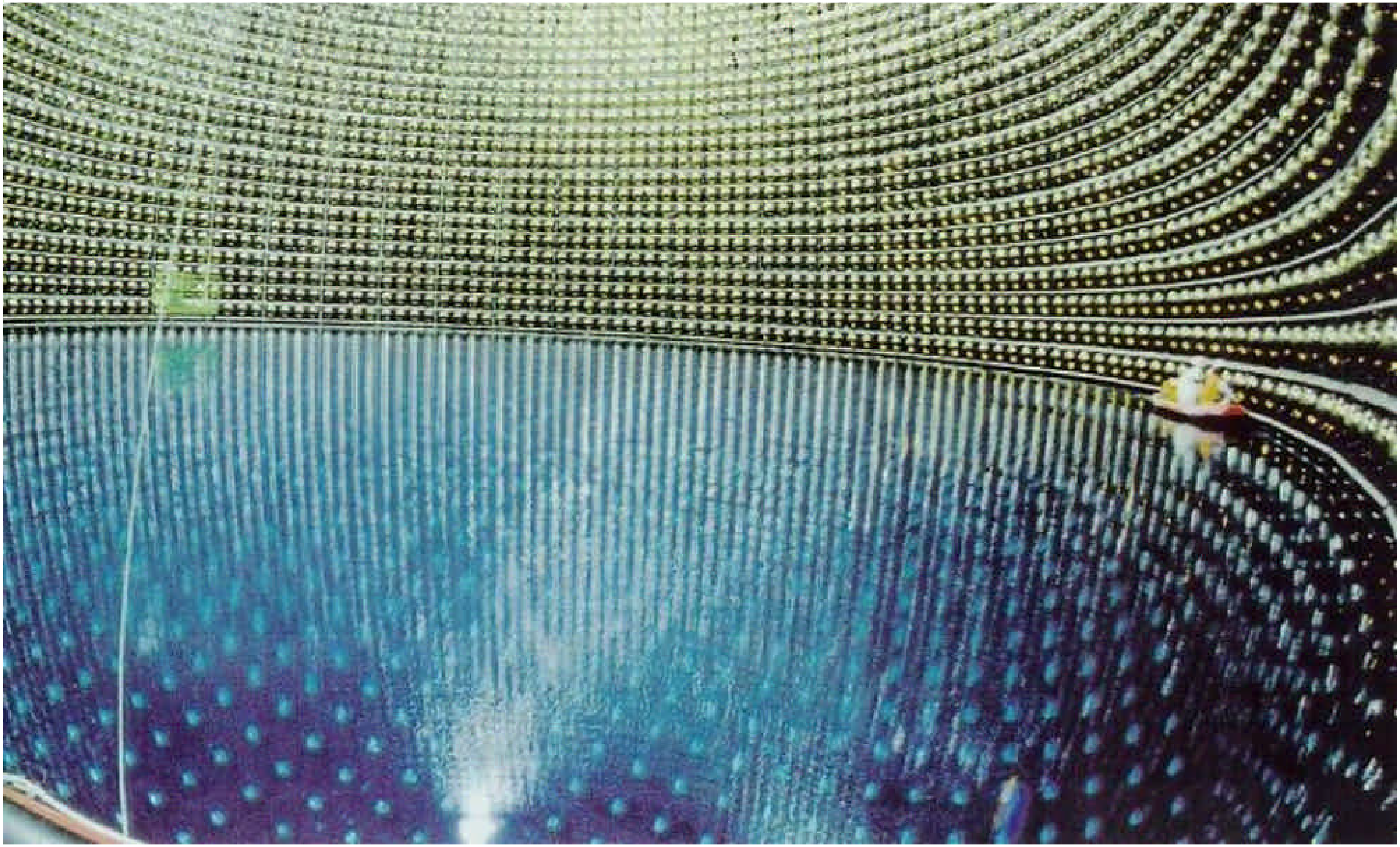


The dome above the tank houses data acquisition electronics & a linear particle accelerator





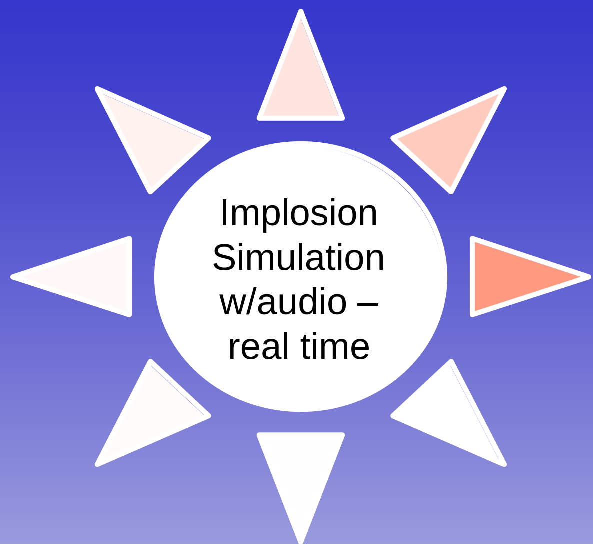
Filling the tank with 11.2 million gallons of ultra-pure H_2O



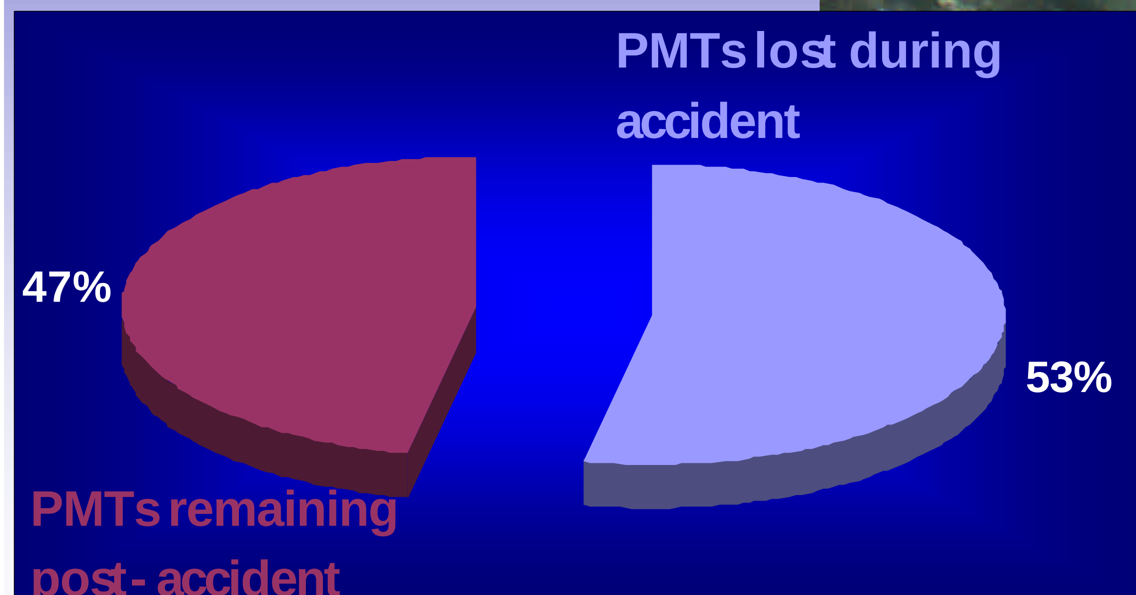
How the ultra-pure water is created

A bank of filters

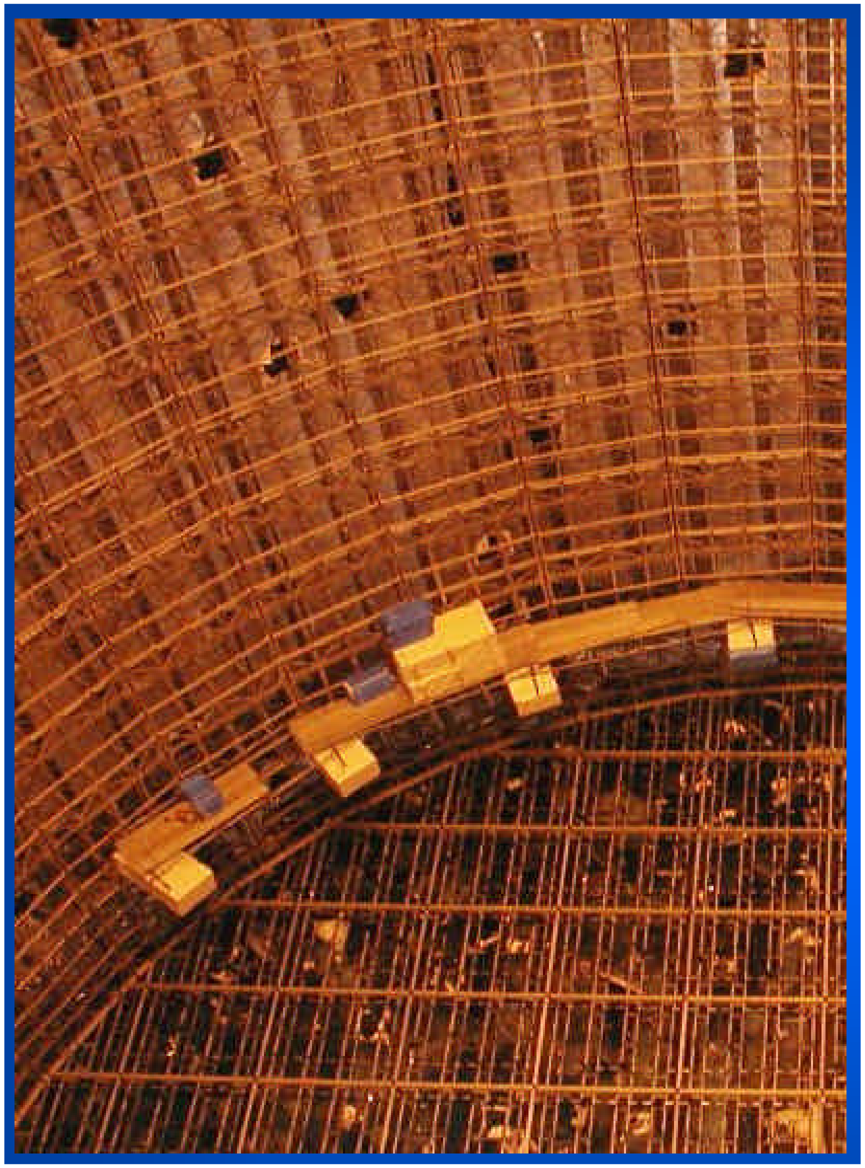
Views of the OD before the tank is sealed up

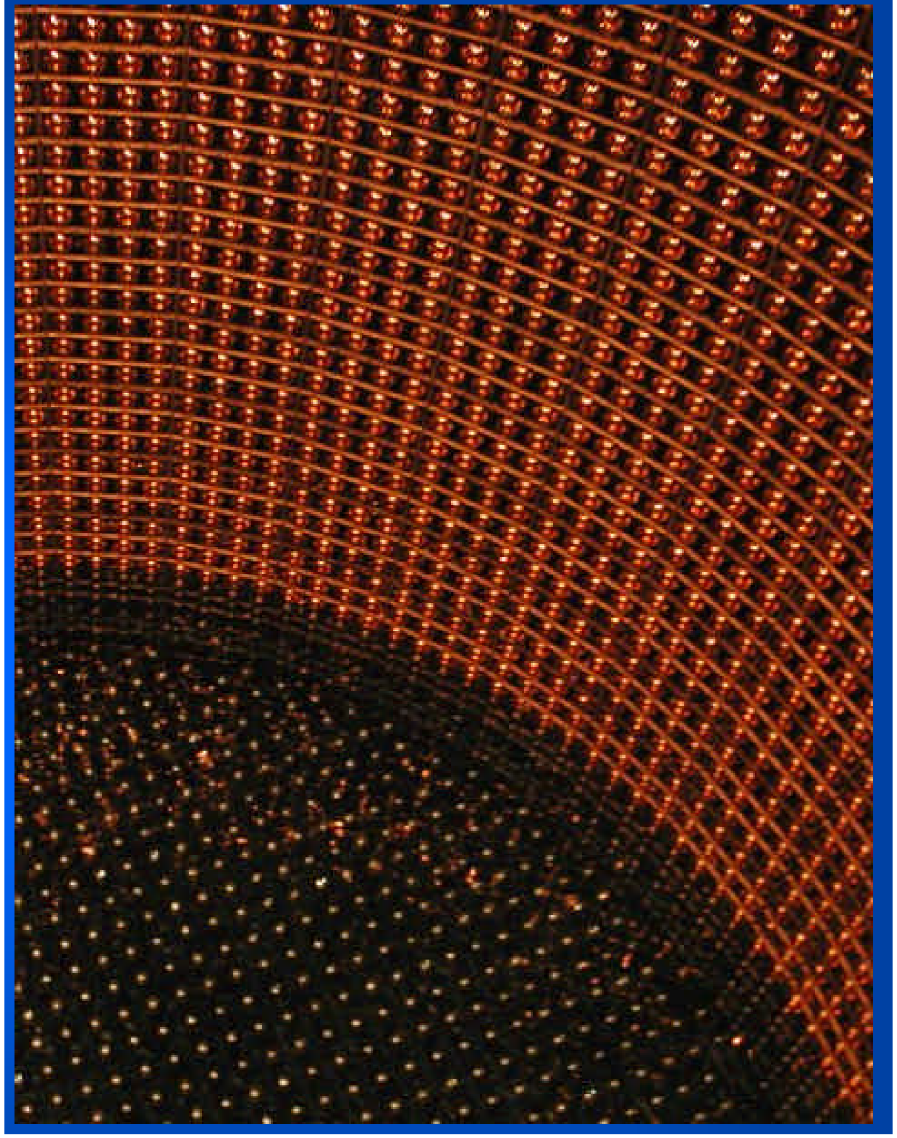


Post–accident – the floor of the inner detector



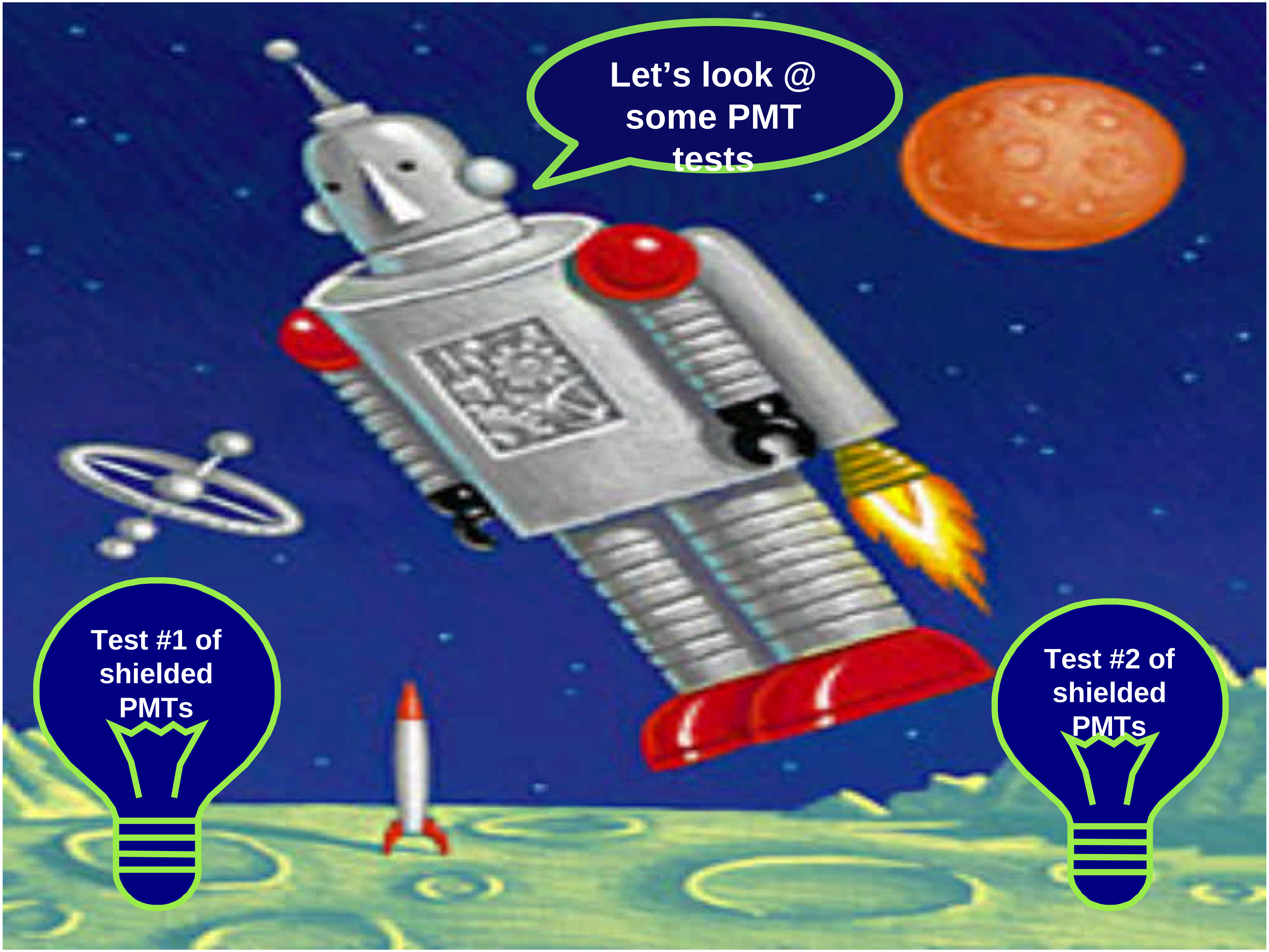
The fateful day occurred on November 12, 2001



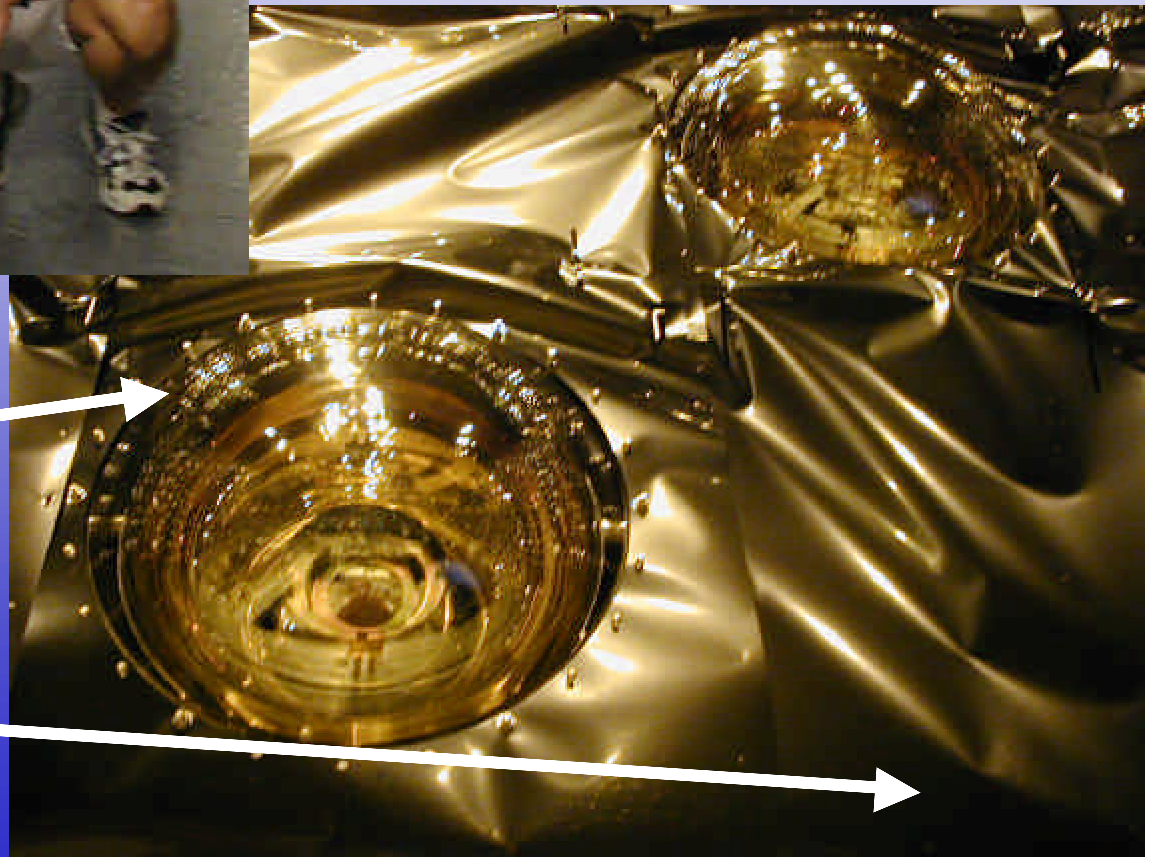


Post-accident &
after initial clean up

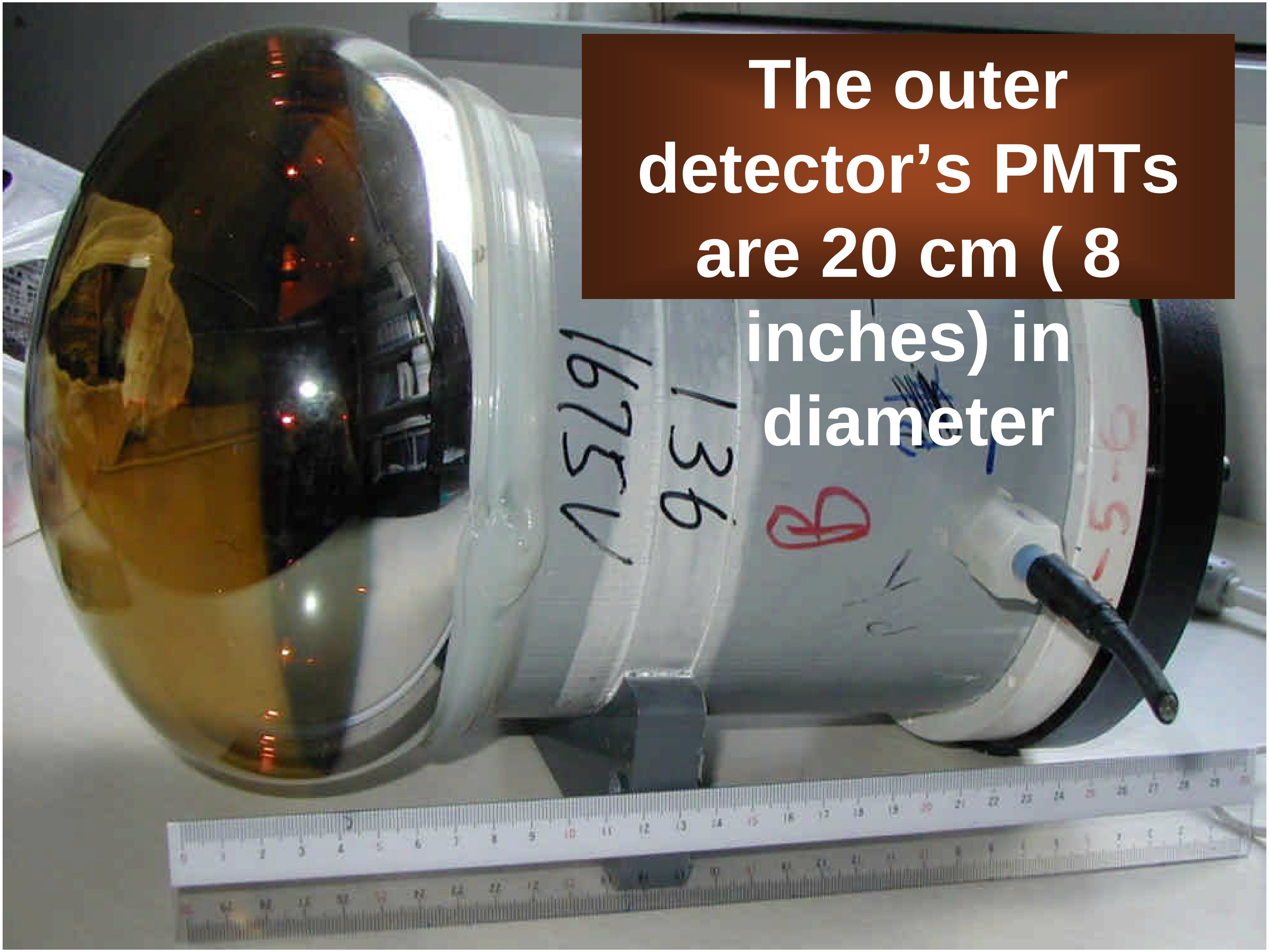
Pre-accident


Let's look @ some PMT tests
Test #1 of shielded PMTs
Test #2 of shielded PMTs

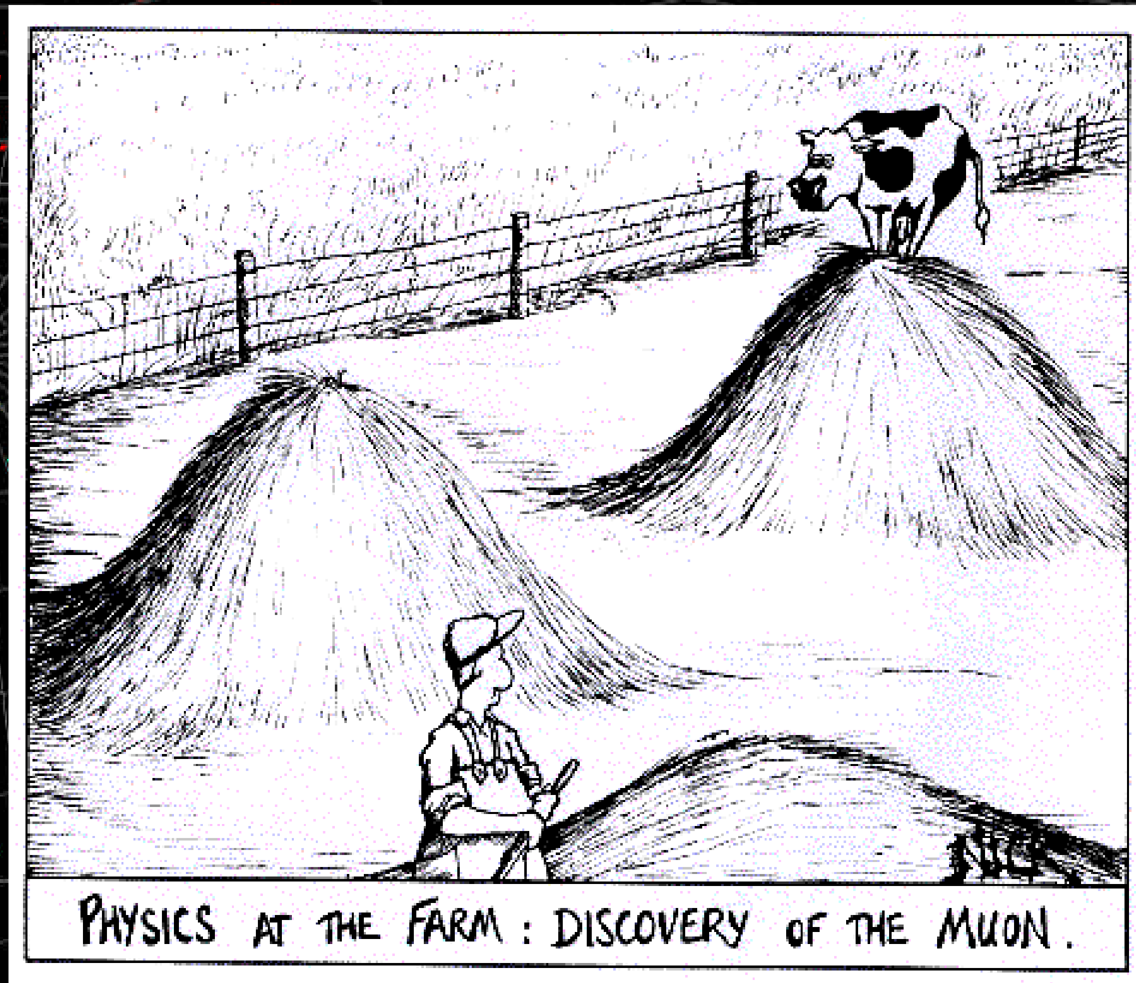
The BIG BOY – world's largest mass - produced PMTs



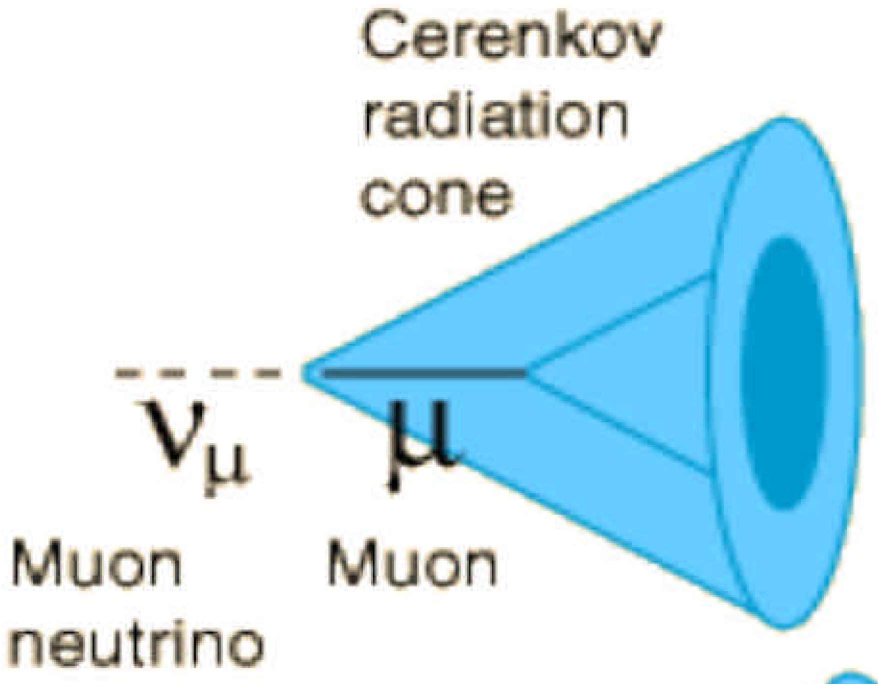
Note acrylic shields and empty spaces



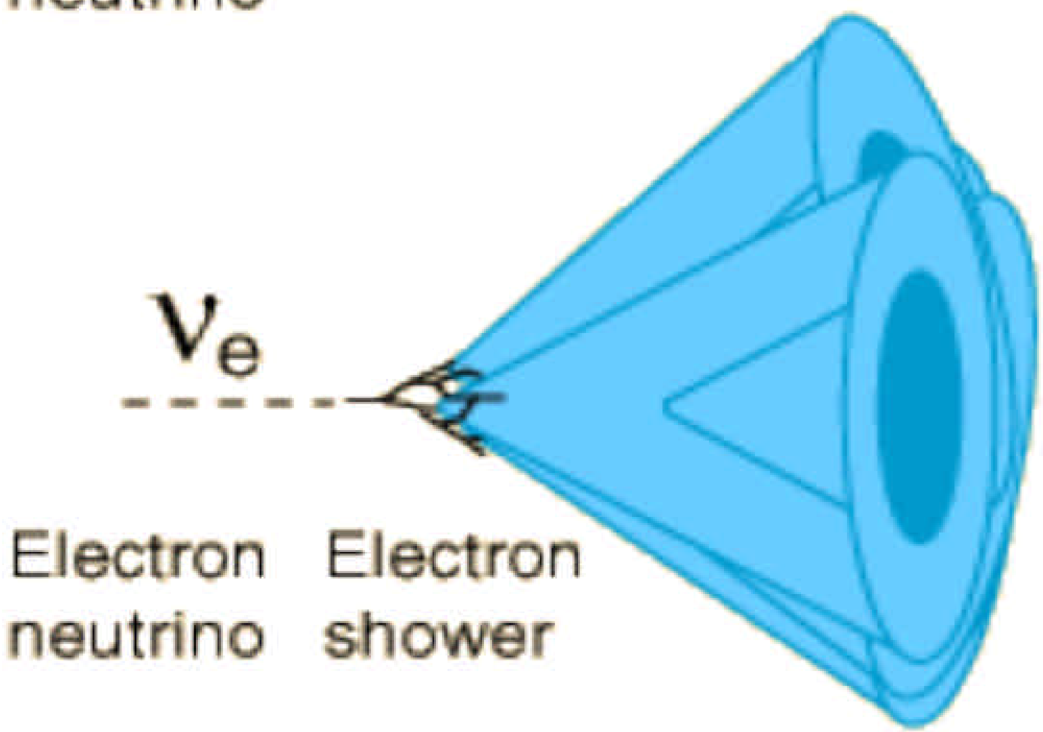
The outer detector's PMTs are 20 cm (8 inches) in diameter



Just what does Super-K measure?

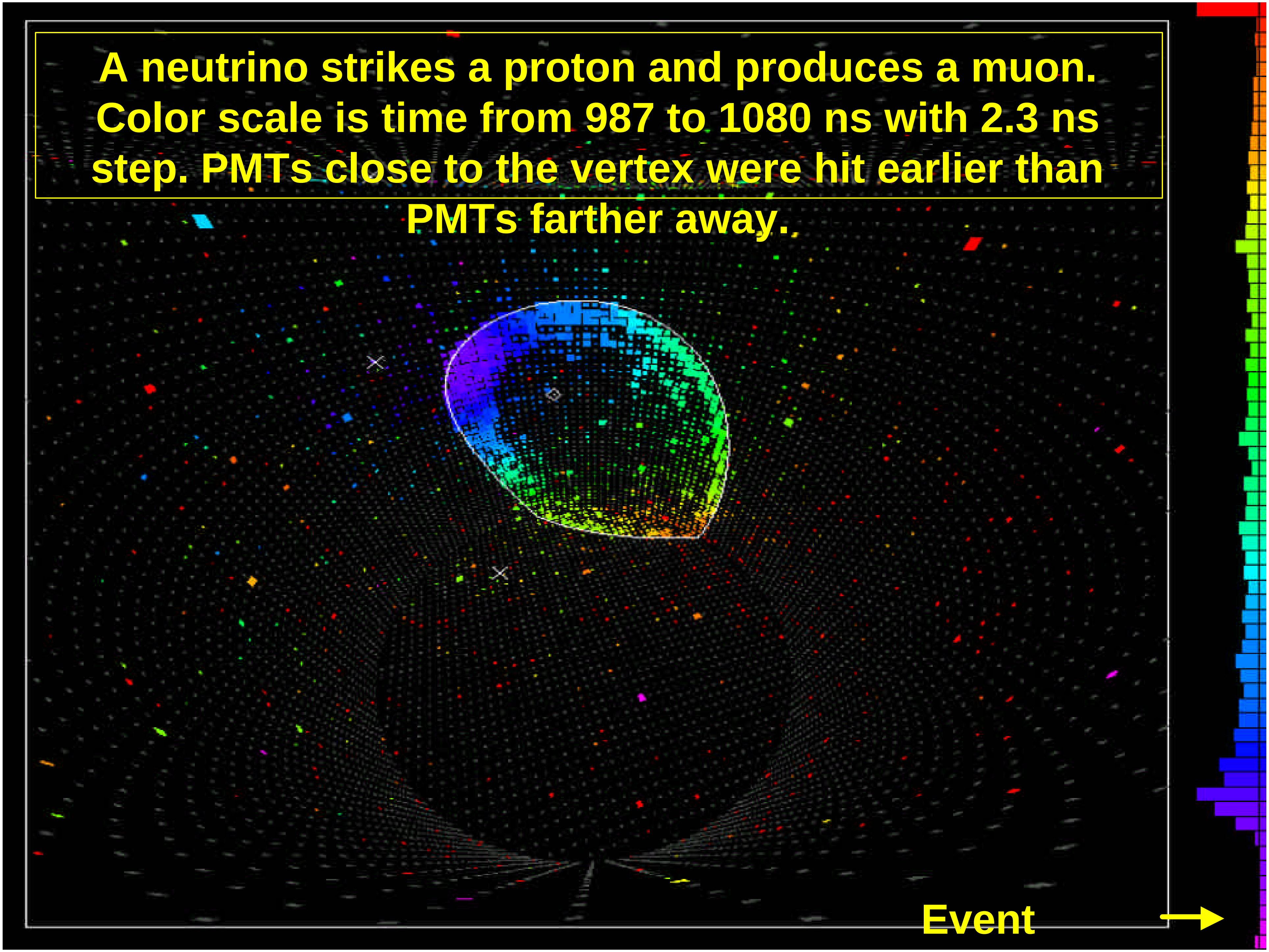


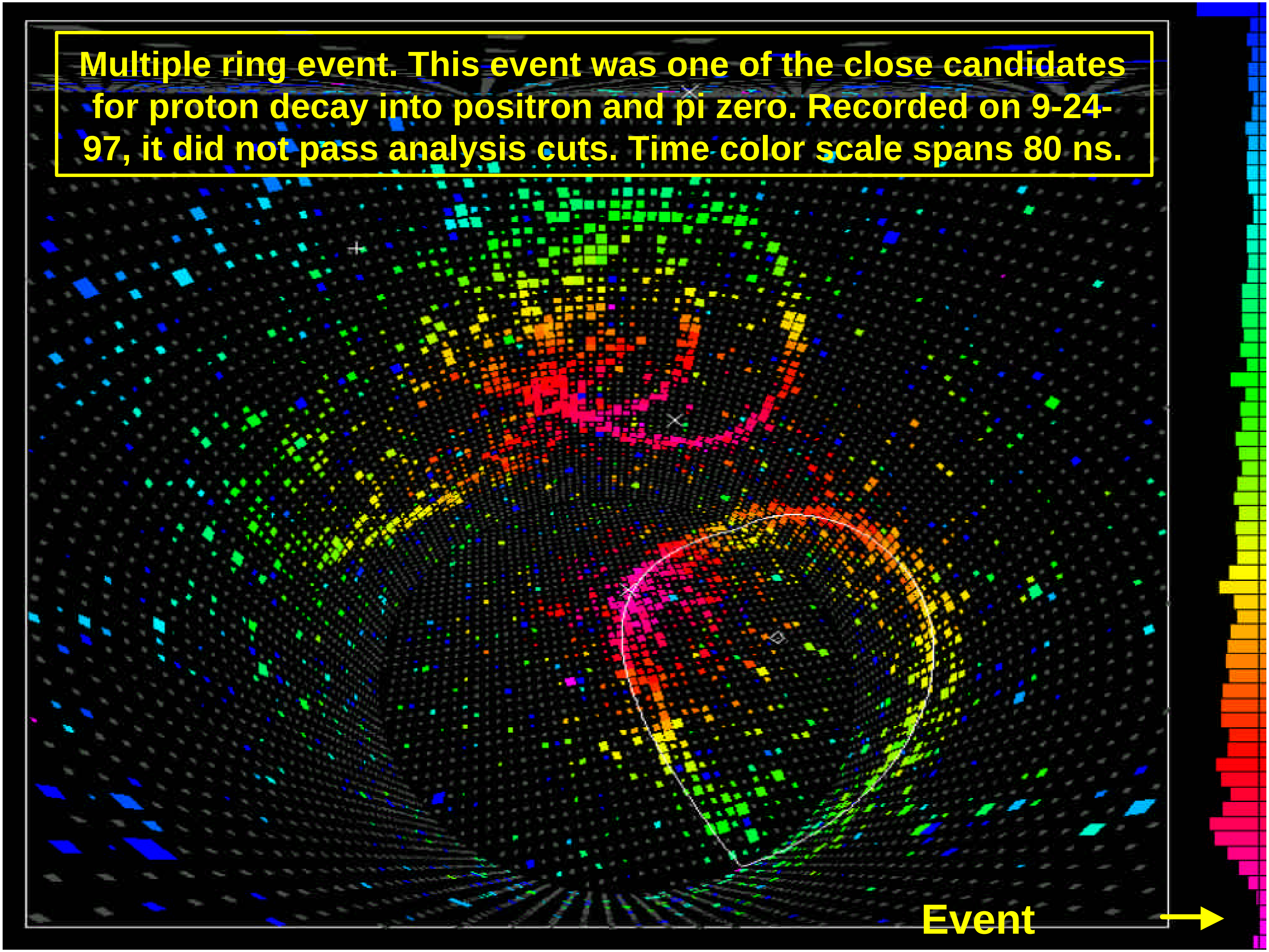
The Cerenkov radiation from a muon produced by a muon neutrino event yields a well defined circular ring in the photomultiplier detector bank.



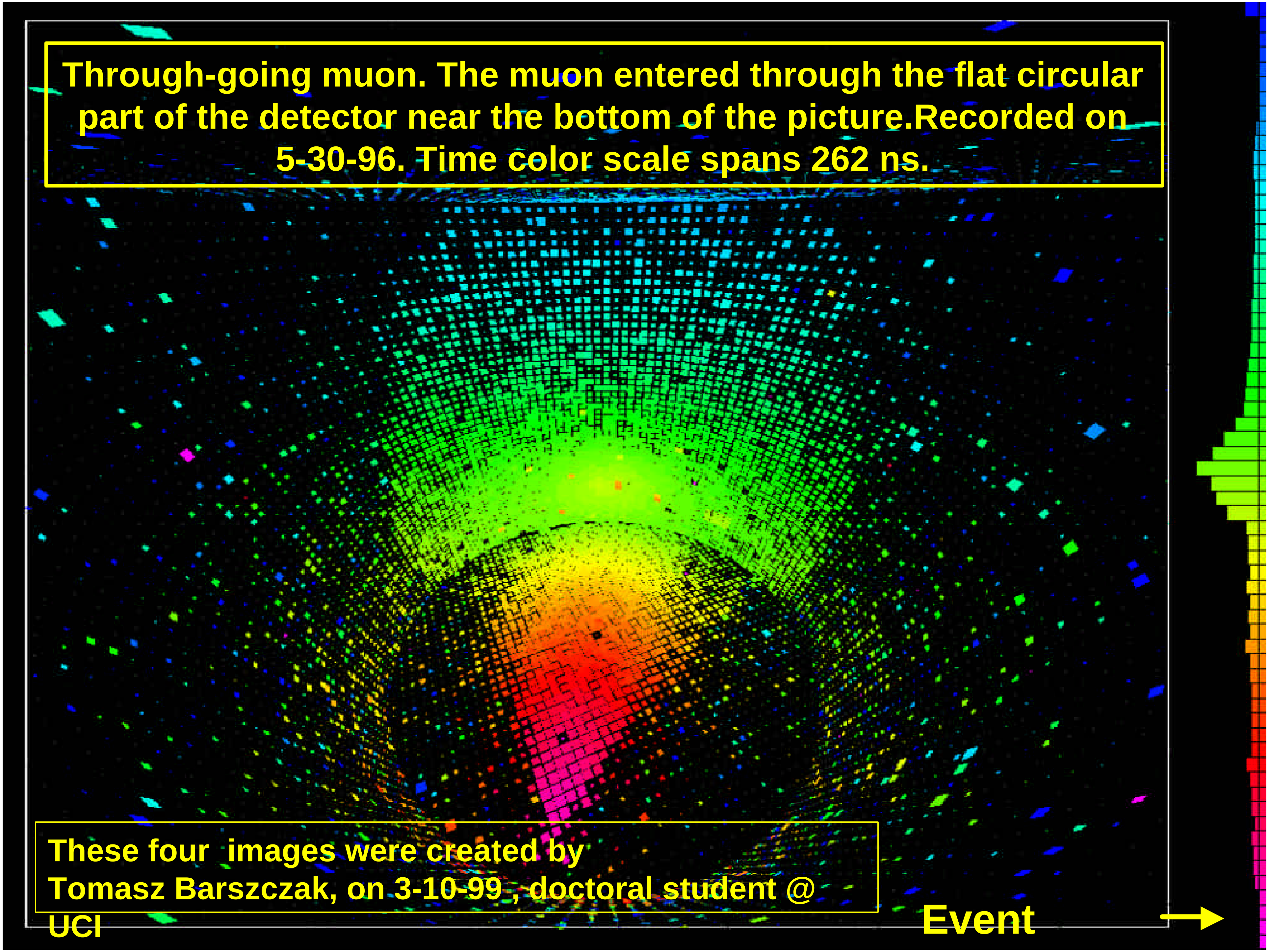
The Cerenkov radiation from the electron shower produced by an electron neutrino event produces multiple cones and therefore a diffuse ring in the detector array.

A neutrino strikes a proton and produces a muon. Color scale is time from 987 to 1080 ns with 2.3 ns step. PMTs close to the vertex were hit earlier than PMTs farther away.





Multiple ring event. This event was one of the close candidates for proton decay into positron and pi zero. Recorded on 9-24-97, it did not pass analysis cuts. Time color scale spans 80 ns.


Through-going muon. The muon entered through the flat circular part of the detector near the bottom of the picture.Recorded on 5-30-96. Time color scale spans 262 ns.
These four images were created by Tomasz Barszczak, on 3-10-99 , doctoral student @ UCI
Event

What about background effects?

Dealing with rado

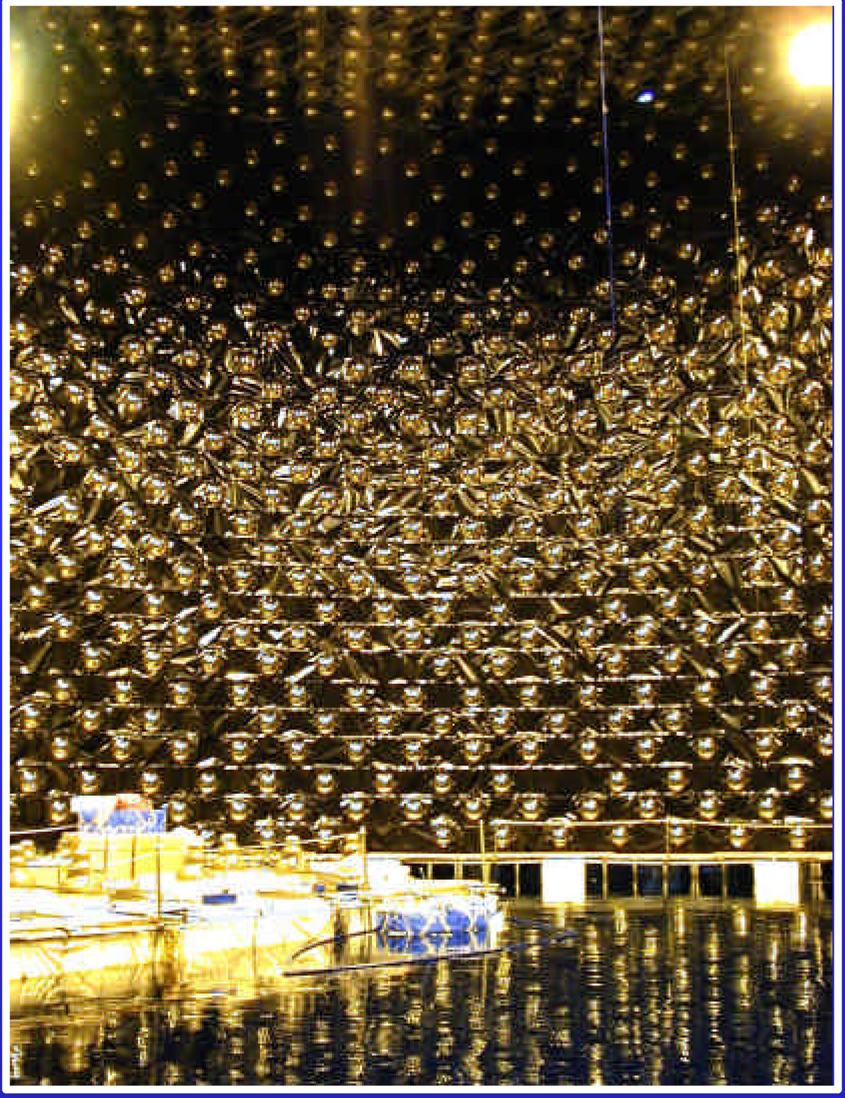
Into the mine we go!

The typical repair cycle for the OD

~Drain the cylindrical tank – 2.1 m of depth across of a diameter of 40 m over 8 hrs

~How many gallons of H_2O is that?

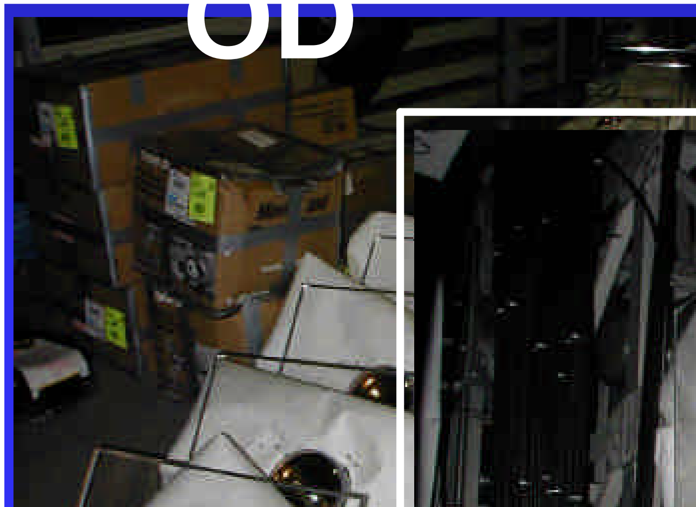
~ 696, 856 gallons

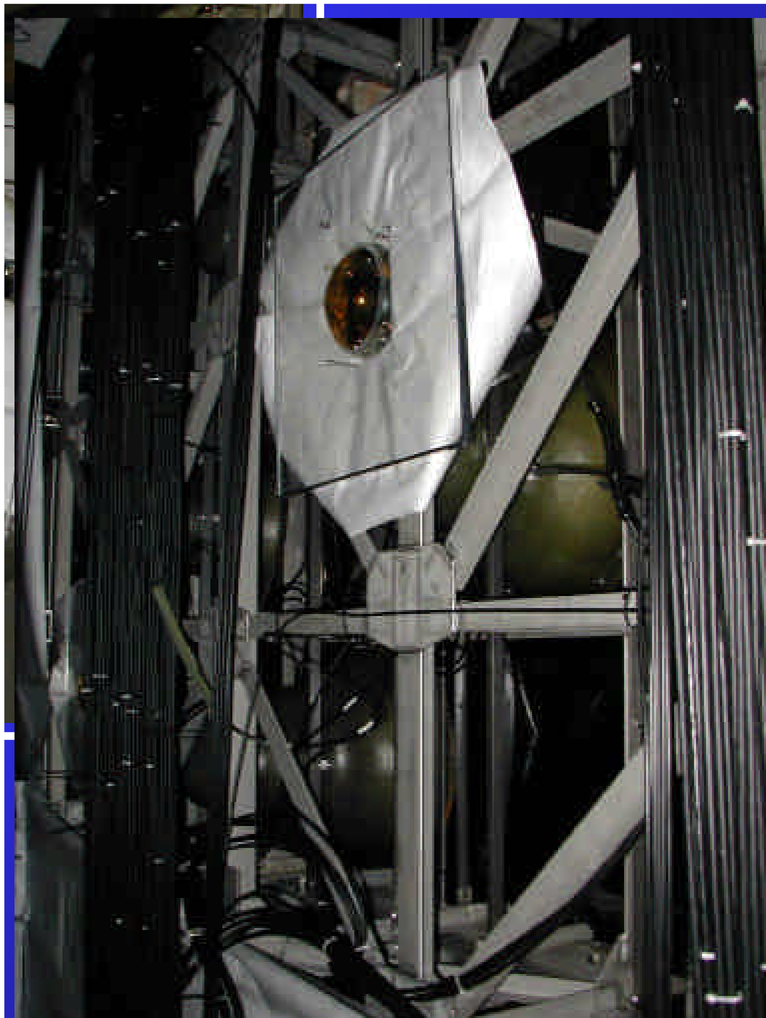


The typical repair cycle for the OD

Day 1 –

~Install newly assembled PMTs w/wave-shifters





The typical repair cycle for the OD

Days 2 & 3 -

~Hang tyvek sheets and expose PMTs

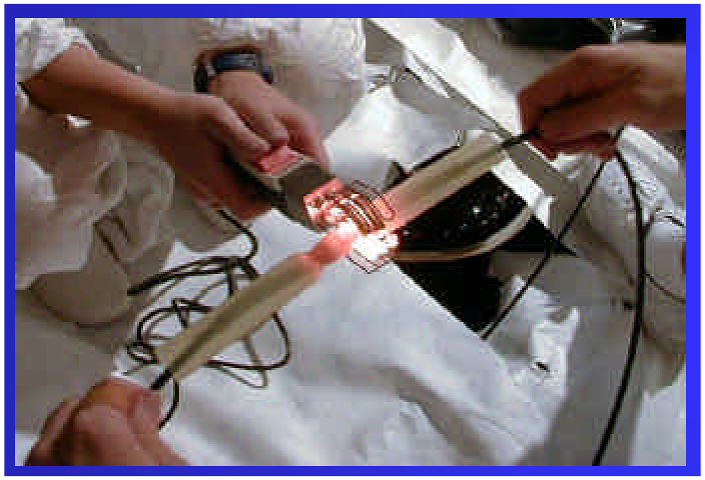
The typical repair cycle for the OD

During the repair cycle, two activities occur simultaneously:

1st - assembly of up to 75 PMT/wave-shifter units

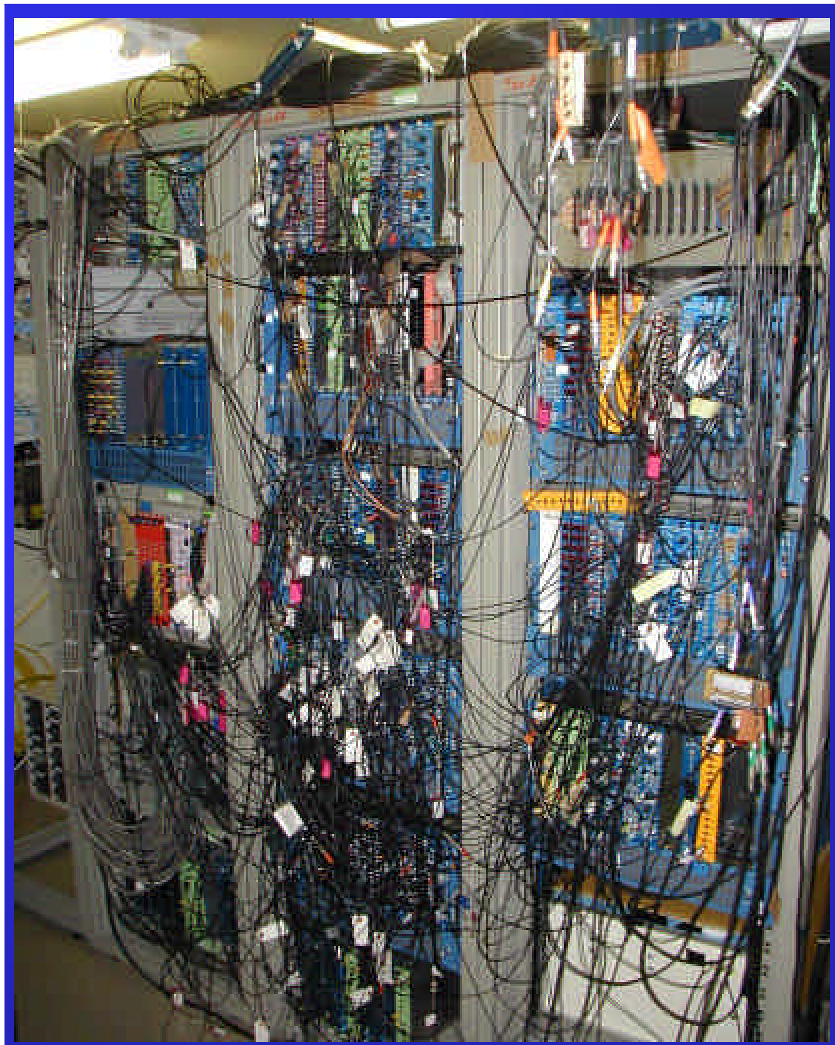
The typical repair cycle for the OD

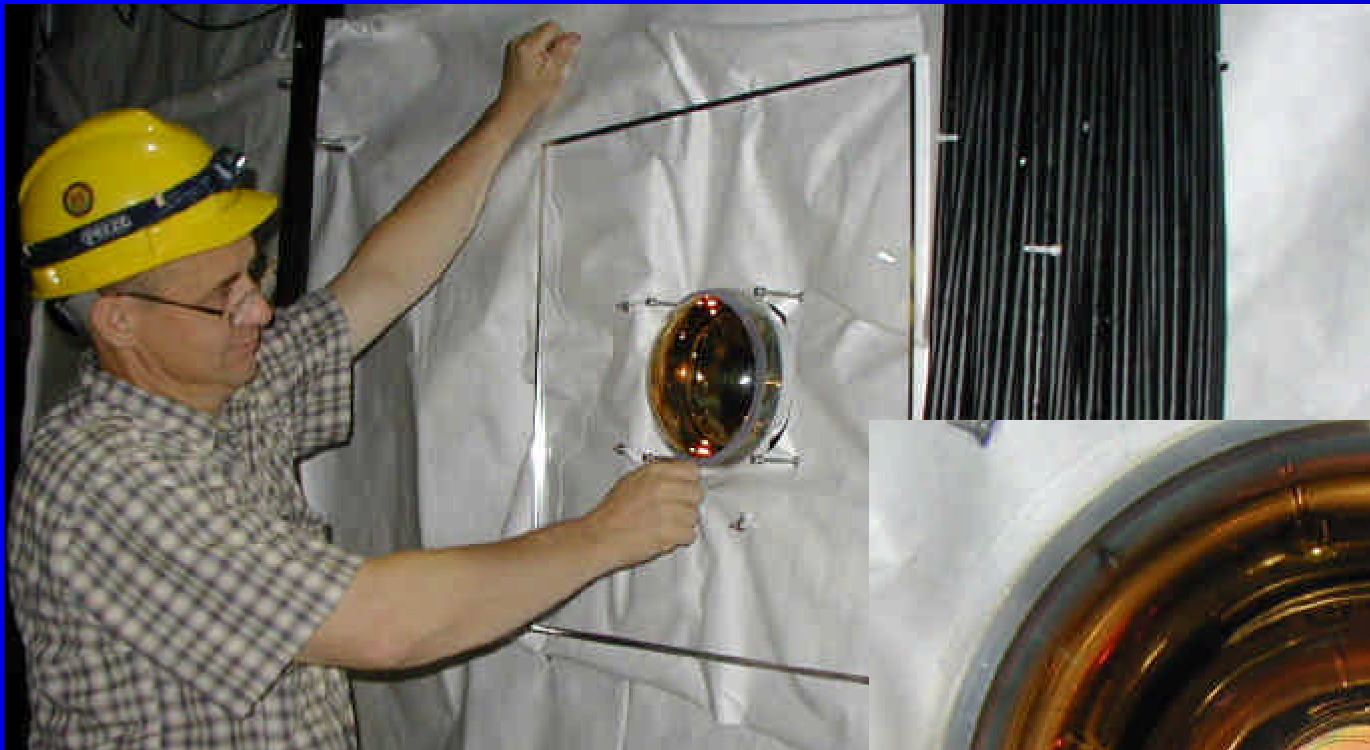
2^{nd} - Splicing in the replacement PMTs with existing cables

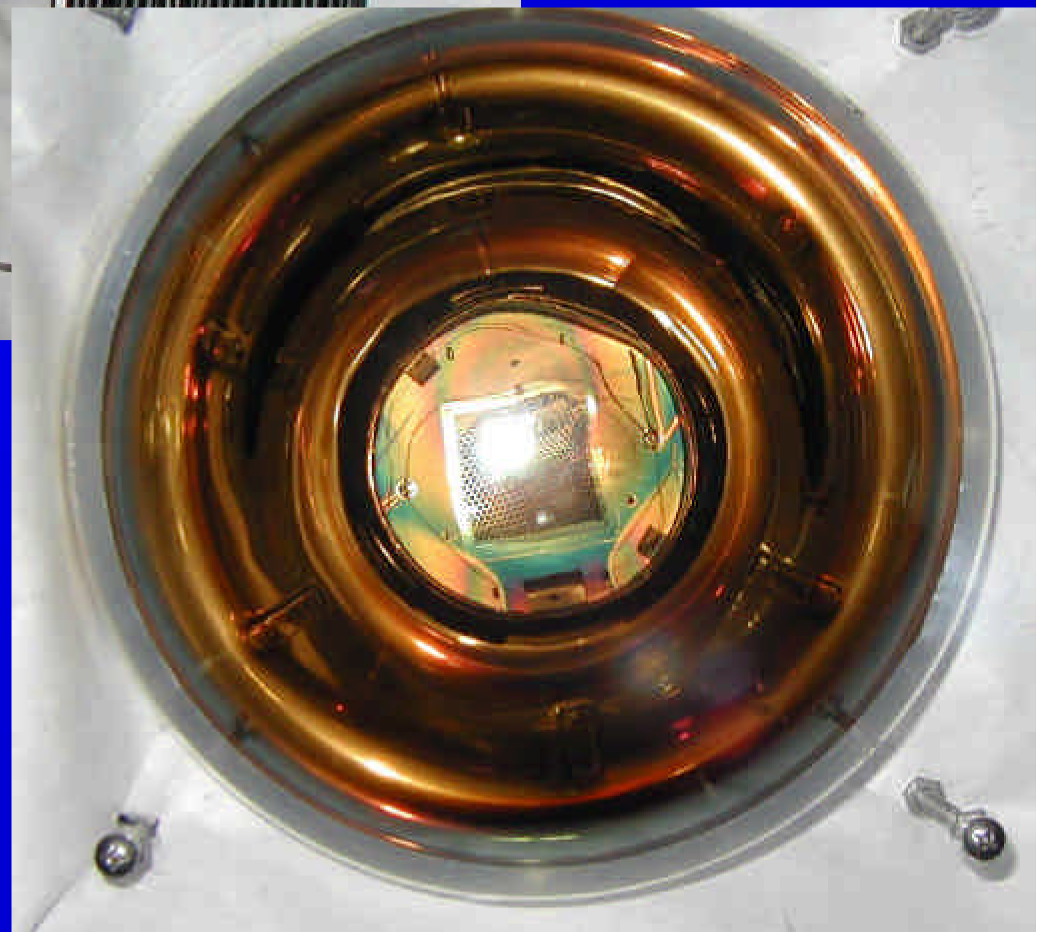


The typical repair cycle for the OD

- and testing cable continuity via the Mother of All NIM Crates!







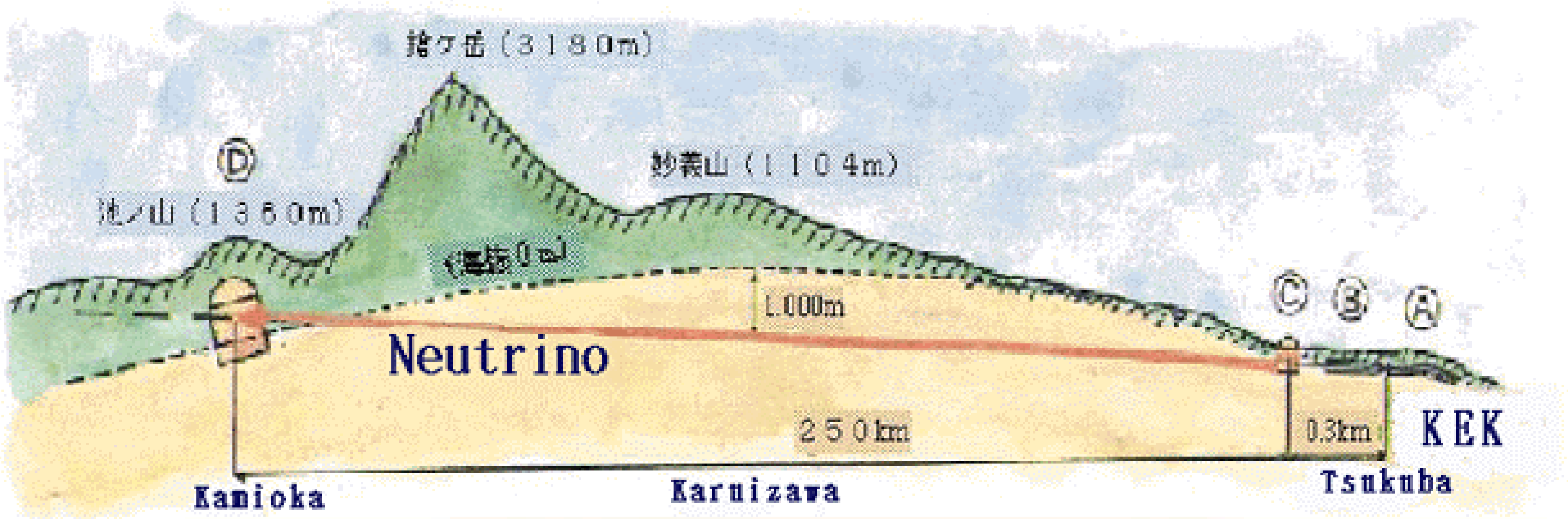
Final touches on installing an outer detector PMT

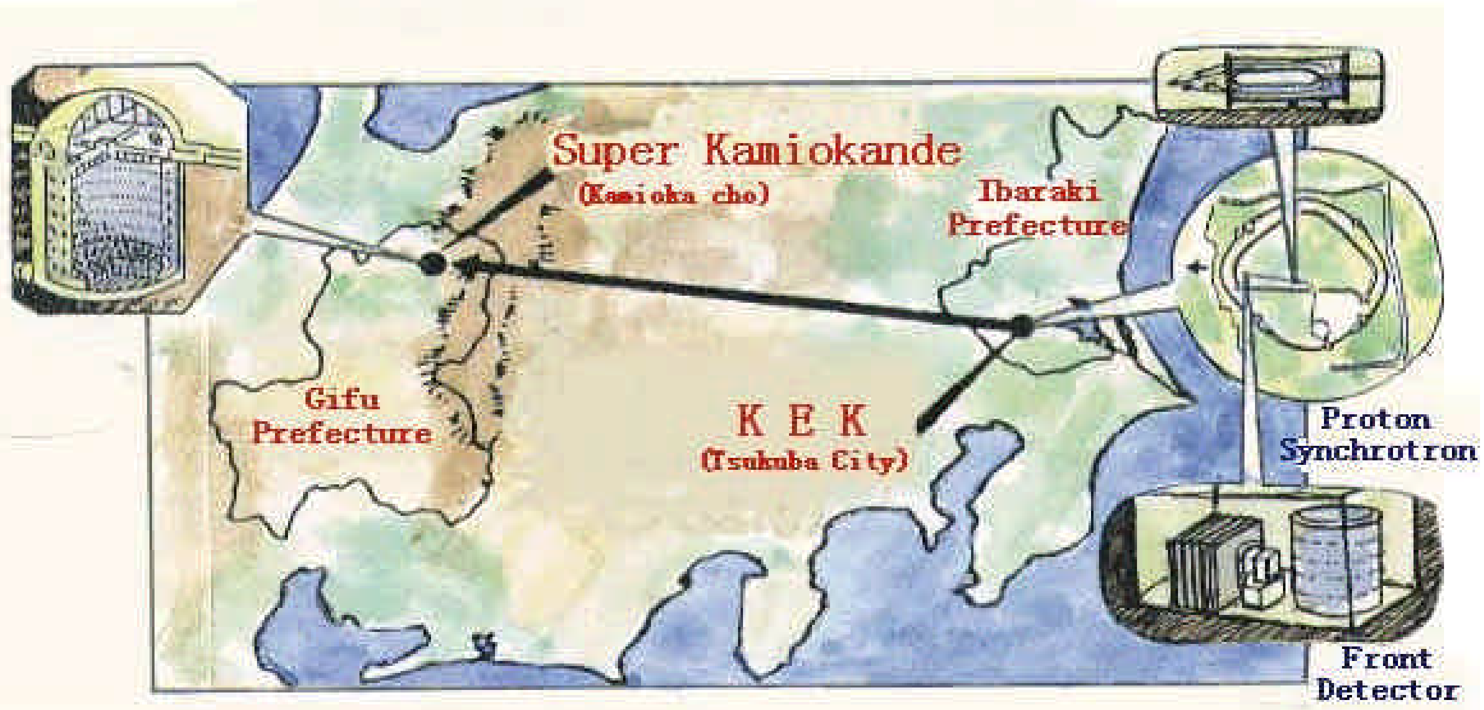
What is next for Super

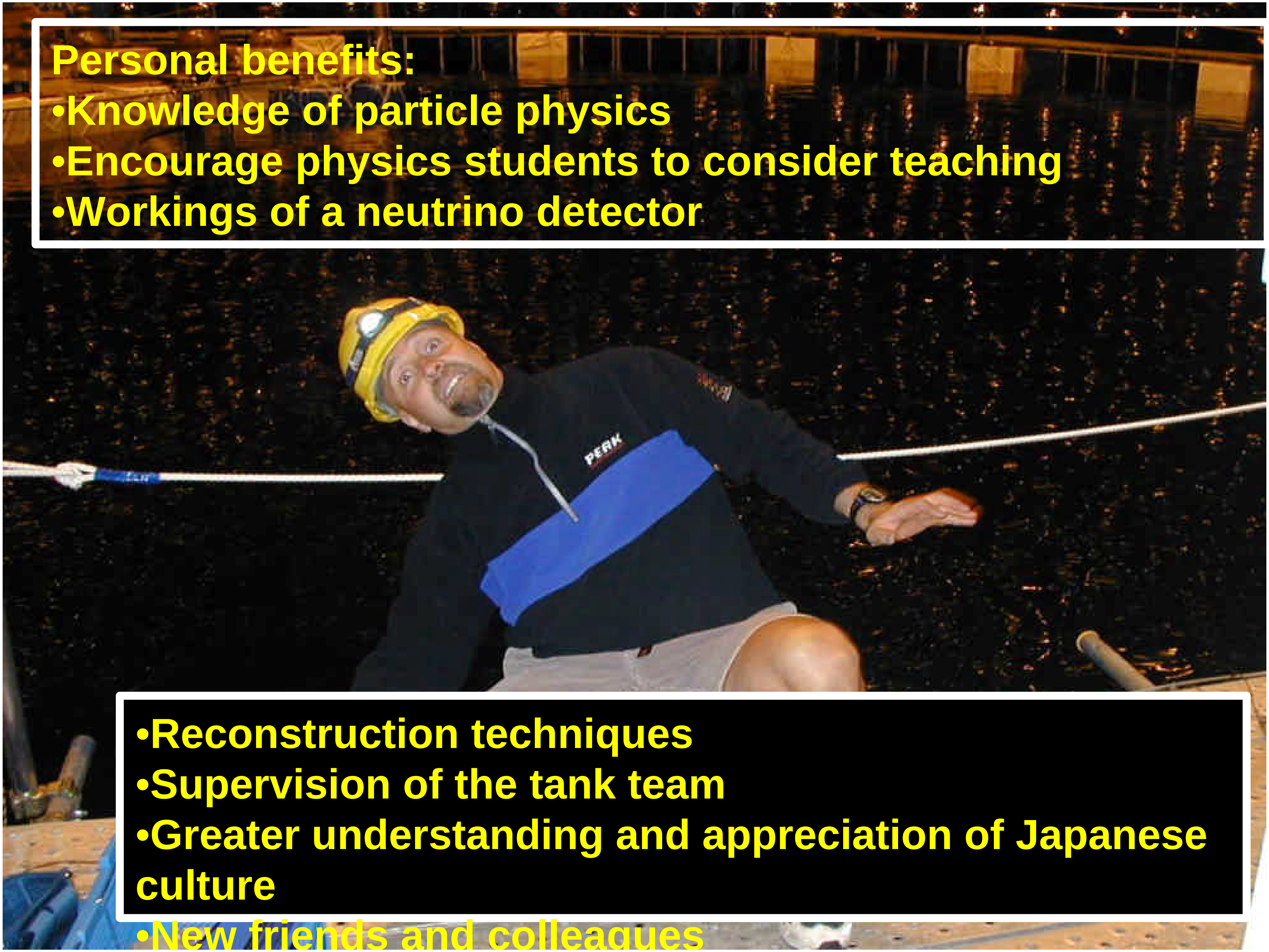
- ☞More neutrino parameters
- ☞Future supernovae

(NASA)

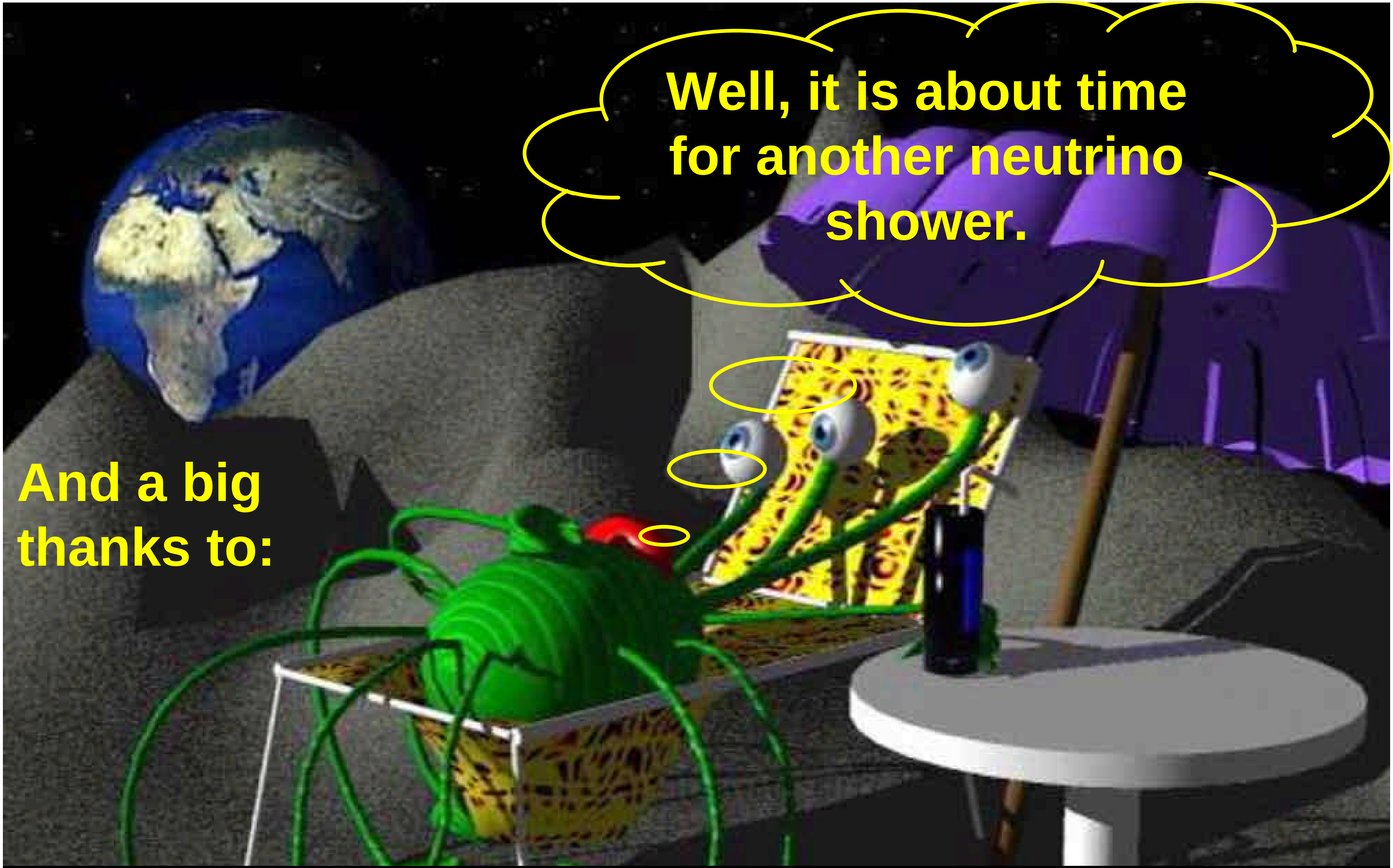
Super-K's Long Baseline Exp.







Personal benefits:
•Knowledge of particle physics
•Encourage physics students to consider teaching
•Workings of a neutrino detector
PERK
•Reconstruction techniques
•Supervision of the tank team
•Greater understanding and appreciation of Japanese culture
•New friends and colleagues



M.J. Murdock Foundation University of Washington

Dr. Jeffery Wilkes Hans Berns