Proton Decay and VLBL Neutrino Detectors for DUSEL

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1. Plans for DUSEL in the USA
2. Liquid Argon Detectors, Progress
3. The LANNDD Detector – Tests at WIPP and CERN
4. Future Search for Proton Decay
5. VLBL Neutrino Beam is the USA CP Violation and $\mathrm{Sin}^2 2\theta_{13}$

- Summary-

DUSEL

NSF – NAS BOARD ON PHYSICS ....

DEC 2002

"A DEEP UNDERGROUND LABORATORY CAN HOUSE A NEW GENERATION OF EXPERIMENT THAT WILL ADVANCE OUR UNDERSTANDING OF THE FUNDAMENTAL PROPERTIES OF NEUTRINO'S . . . .

... MAKES THE TIME RIPE TO BUILD SUCH A UNIQUE FACILITY"

LAB

THREE SOLICITATIONS: S1, S2, S3 — DUE FEB 28

S1/ Consider Small/Deep: Modules — Solar ν, ββ Decay, Dark Matter Detectors etc

{Berkeley, Boulder Co meetings}

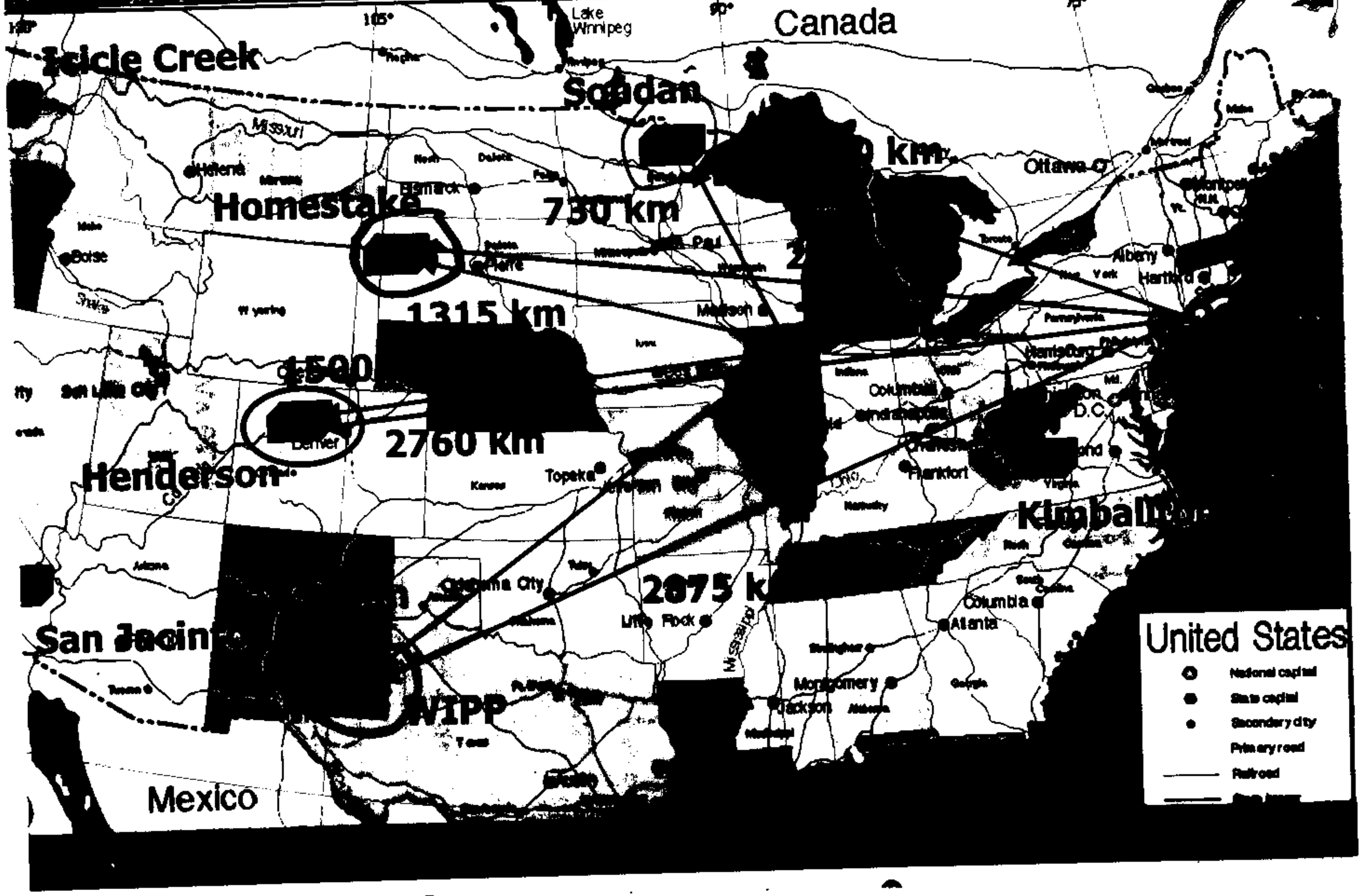
Large Modules: (possibly not so deep) — Proton Decay, VLBL ν Beam, Super Nova Detector etc

S1 Pre conclusion: Proton Decay and VLBL ν Experiments lead to a "Multi purpose Detector" Concept

{ALSO BOULDER MTG}

8 DUSEL SITES — REASONABLE DISTANCES FOR SUPERBEAMS OR NEUTRINO FACTORIES

US DUSEL Candidate Sites and Potential Superbeam Experiments



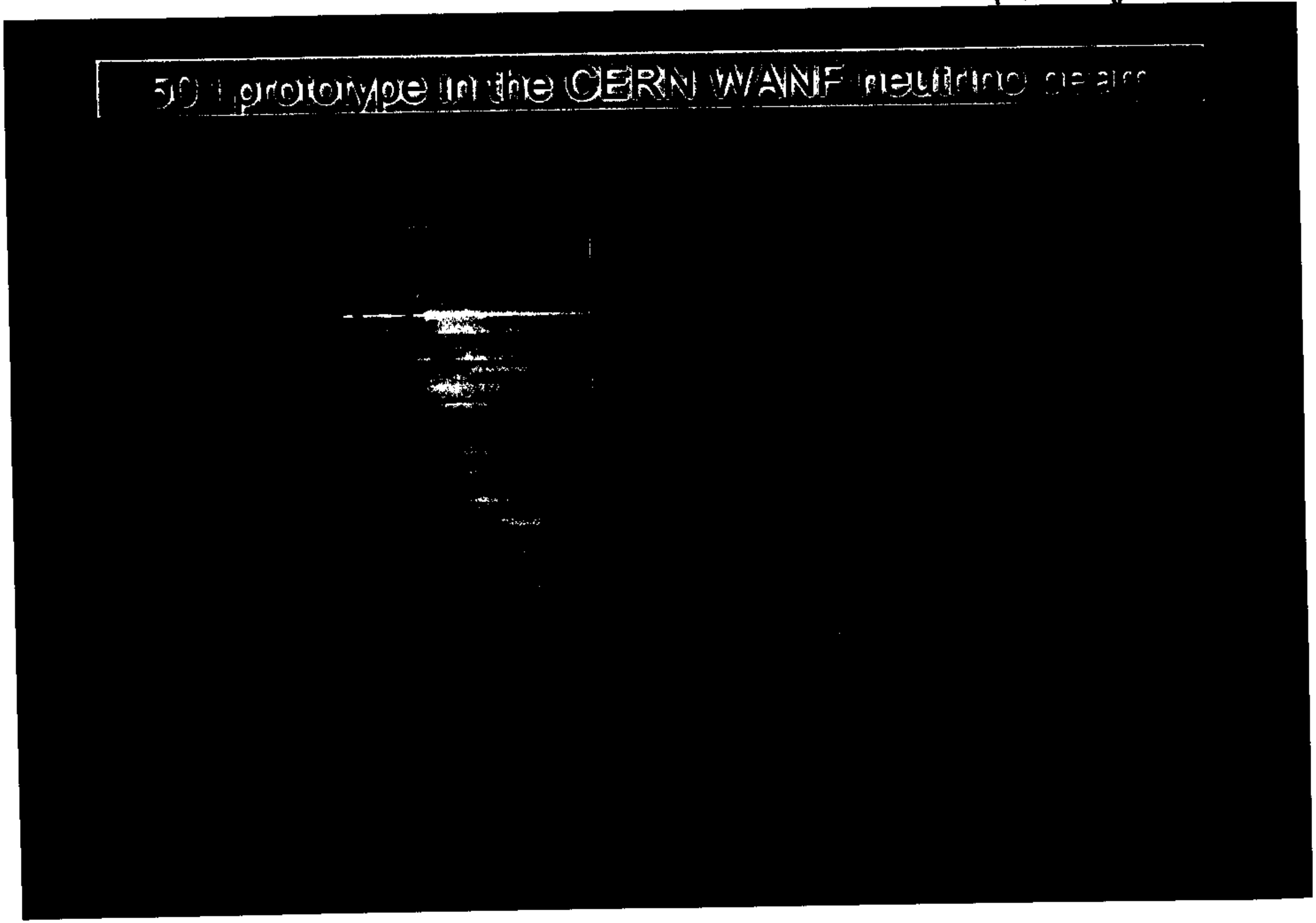
Liquid Argon TPC Overview

BNL/UCLA WORKSHOP #2

- A liquid argon time-projection chamber is a total-absorption tracking calorimeter = An electronic bubble chamber.
- **It's efficiency for detection of ν_e appearance events will be greater than 90% for GeV energies.**
  (This is $\gtrsim 3$ times the efficiency of low-Z sampling detectors.)
- A large (> 10 kton) liquid argon TPC, if in a single cryostat, will cost very nearly the same as a low-Z sampling detector of the same mass.
  (There is highly competitive industry support for production, purification and storage of large quantities of liquid argon.
  Liquid scintillator costs 2.5 times as much as liquid argon, per unit mass.)
- **The hardware of a liquid argon TPC is in a mature state, and readily scalable to large masses.**
- More in need of further development is the software
  – in the style of bubble chambers.
  (Human scanning of event displays if necessary.)

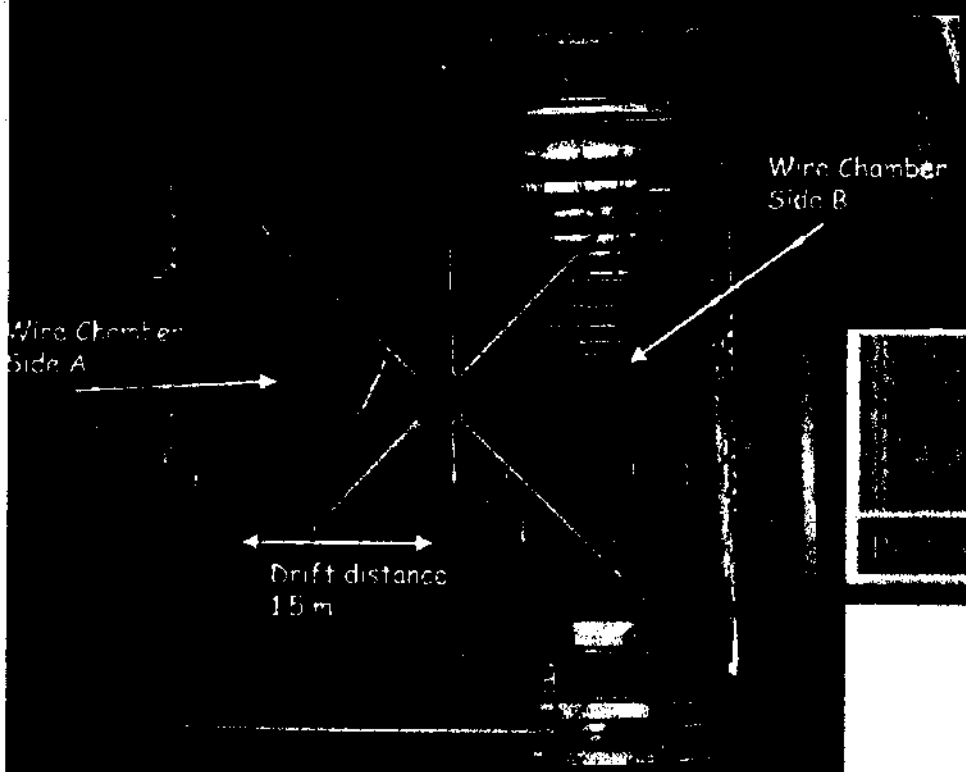
A long History ~ 2 Alvarez proposal
~ H Chen .. 1970's
C Rubbia ..
~ First ICARUS Proposal : { Harvard, Wisconsin, CERN ..

– Some Real Events – ICARUS Prototype in CERN SPS Beam in Front of NOMAD

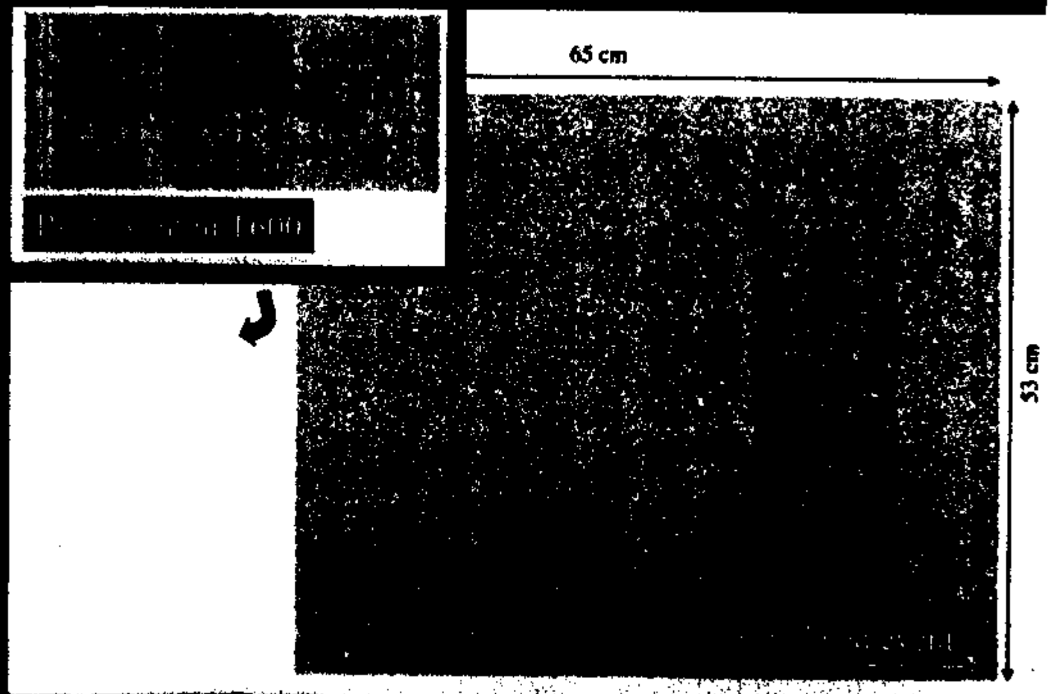


AtPAVIA

(A)

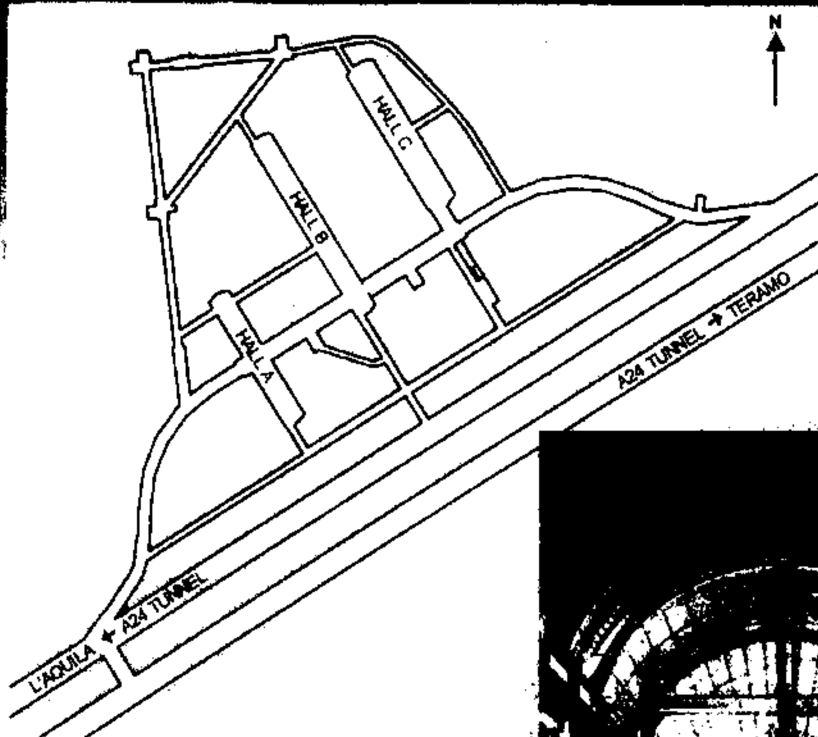


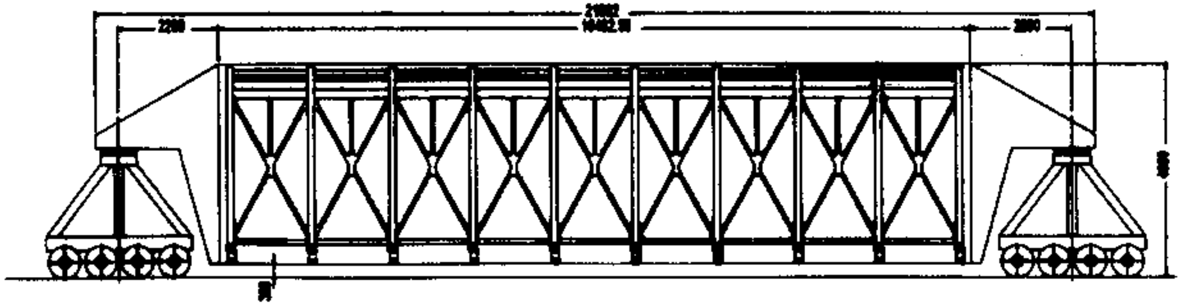
K+ visible in Liquid Argon
⇒K+ modes efficiency ~ 10 times that of water Cherenkov.



Installation and operation at LNGS 2004-2005

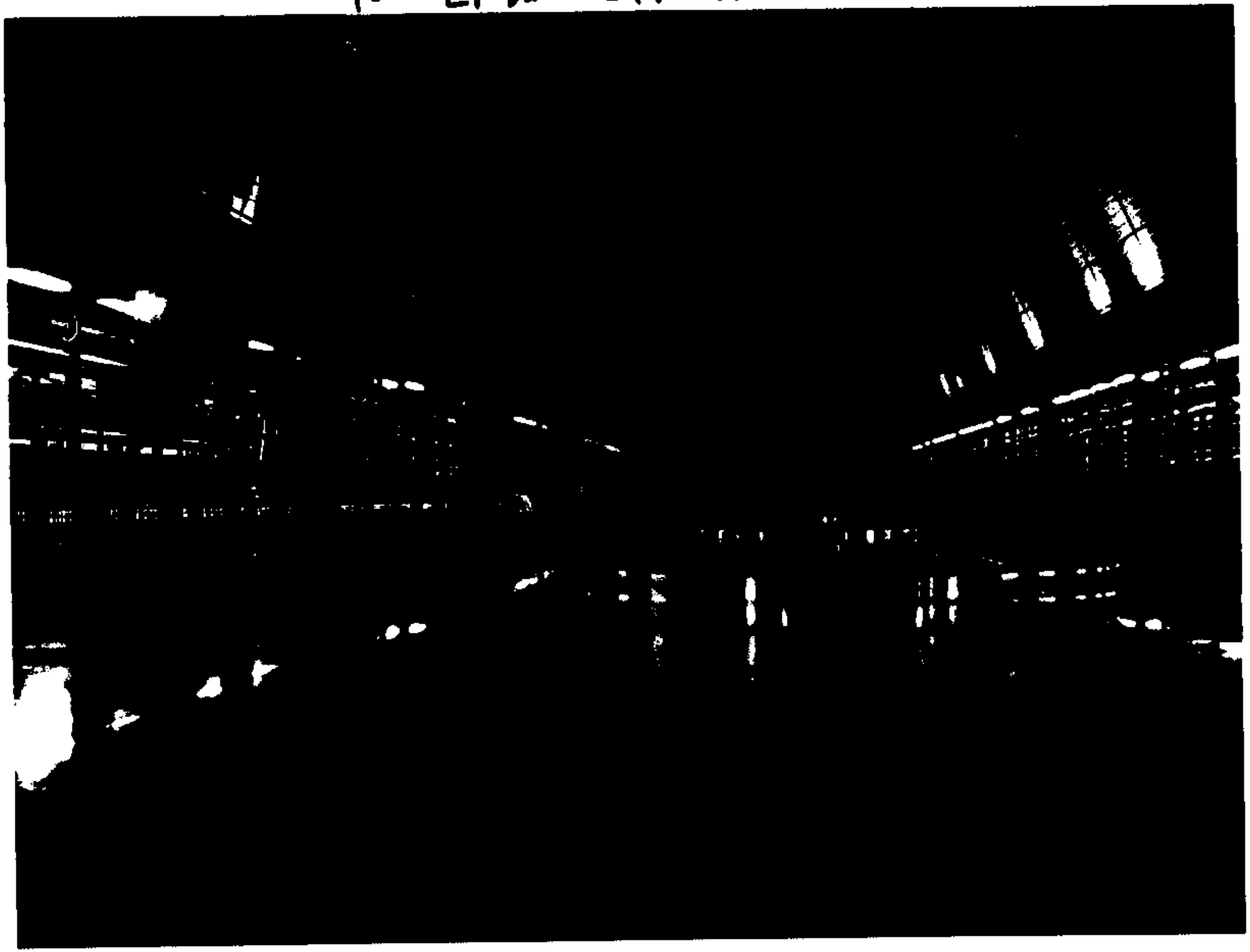
Nov 2004

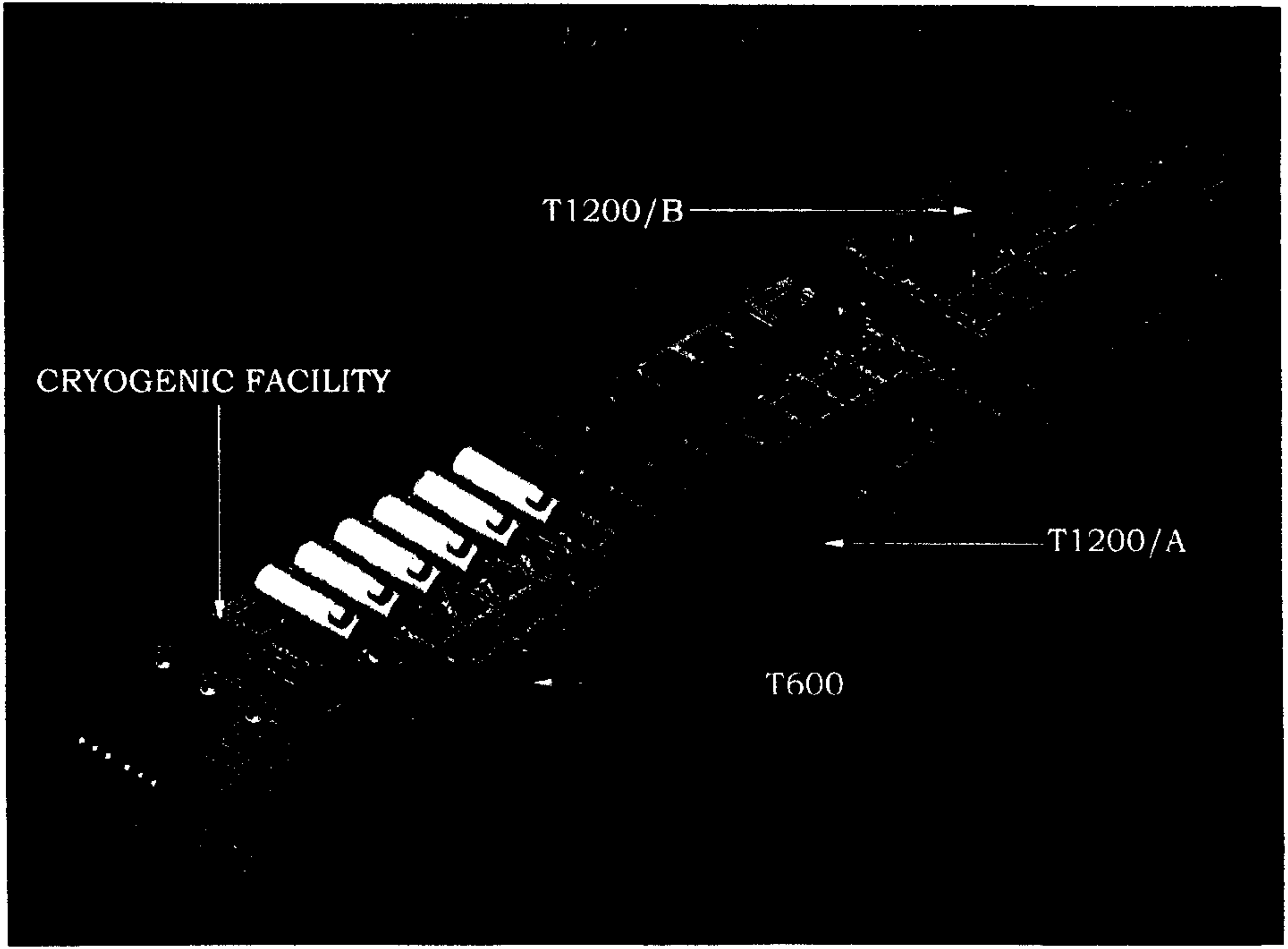




Nov 25, 94 ICARUS – BEING MOVED ACROSS ITALY 4

FIRST CNGS NEUTRINO BEAM,
TO LNGS SPRING 2006!




CRYOGENIC FACILITY
T1200/B
T1200/A
T600

LANNDD Concept

100 KT DETECTOR FOR DUSEL

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Nuclear Instruments and Methods in Physics Research A 503 (2003) 136–140

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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LANNDD—a massive liquid argon detector for proton decay, supernova and solar neutrino studies and a neutrino factory detector

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Abstract

We describe a possible Liquid Argon Neutrino and Nucleon Decay Detector (LANNDD) that consists of a 70 kT magnetized liquid Argon tracking detector. The detector is being designed for the Carlsbad Underground Laboratory. The major scientific goals are:

(1) Search for $p \to K^+ + \bar{\nu}_\mu$ to 10^{35} years lifetime;
(2) Detection of large numbers of solar neutrino events and supernova events;
(3) Study of atmospheric neutrinos;
(4) Use as Far detector for Neutrino Factories in the USA, Japan or Europe.

PACS: 29.40; 96.40.J; 95.85.R; 14.20.D; 14.60.P

Keywords: Neutrino; Nucleon decay; Liquid argon

1. Introduction

One option for next generation nucleon decay search instrument is a fine-grained detector, which can resolve kaons as well as background from cosmic ray neutrinos that are below the threshold for water Cerenkov detectors such as Super-Kamiokande (SK). One option for a next generation nucleon decay search instrument is a fine-grained detector, which can resolve kaons as well as background from cosmic ray neutrinos that are below the threshold for water Cerenkov detectors such as Super-Kamiokande (SK). Such a detector can make progress beyond the *few* $\times 10^{33}$ yr limits from SK for SUSY favored modes because the reach improves linearly with the time and not as

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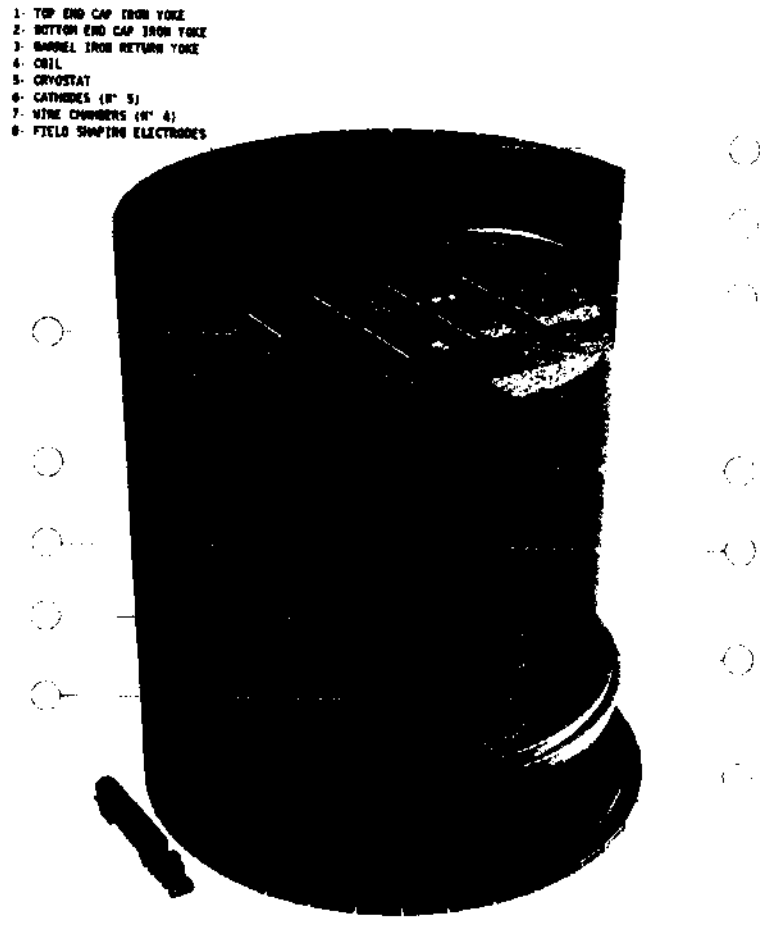
0168-9002/03/$ - see front matter
doi:10.1016/S0168-9002(03)00656-9

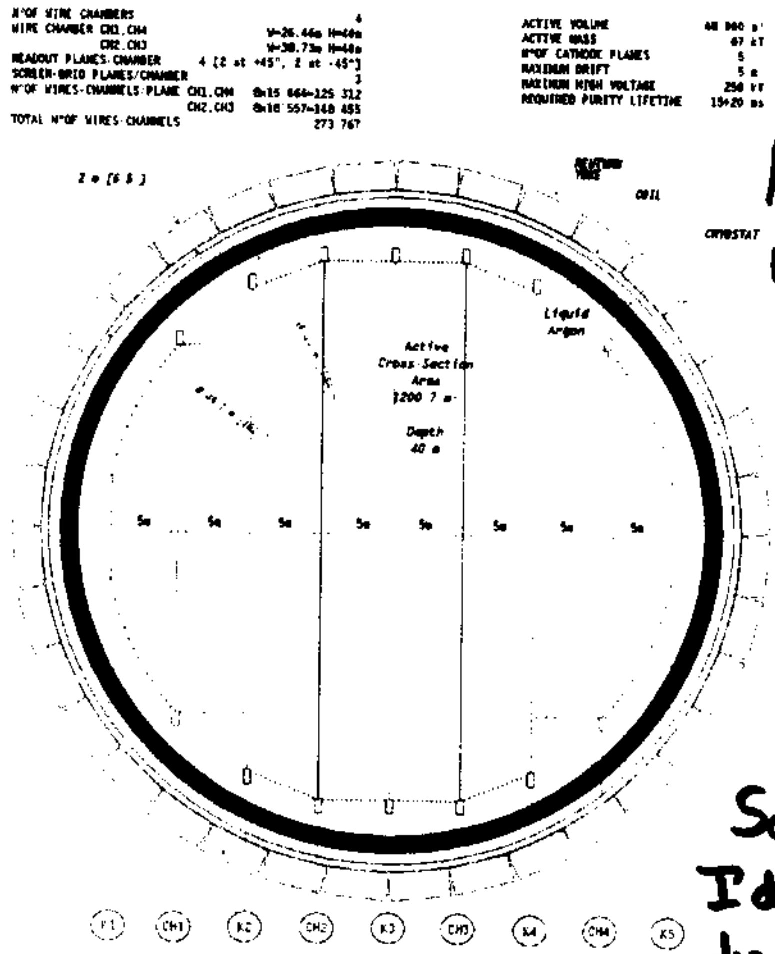
– A 100 Ton Detector for DUSEL –

LANNDD – 100 kton Liquid Argon Neutrino and Nucleon Decay Detector

(astro-ph/0105442, Nucl. Instr. and Meth. A503, 136 (2003))



LANNDD
Liquid Argon Neutrino and Nucleon Decay Detector



LANNDD
Liquid Argon Neutrino and Nucleon Decay Detector
Horizontal Cross-Section

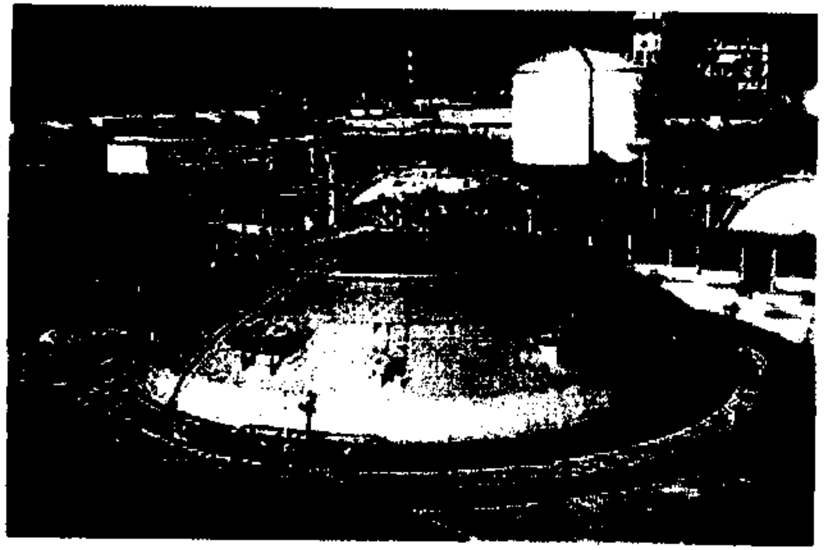
Assume 5 meter Drift Distance (must be tested)

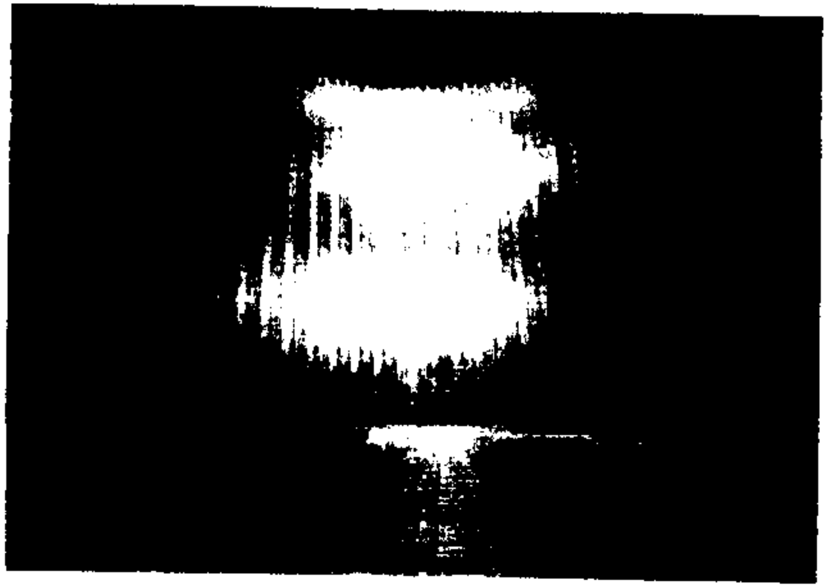
Some New Ideas to drift 20 m with a 2 phase system
A Rubbia

Max drift length of 5 m (limited by O_2 purity). ⇒ Several drift cells.

VERY LARGE CRYOGENIC TANKS ROUTINE AROUND THE WORLD

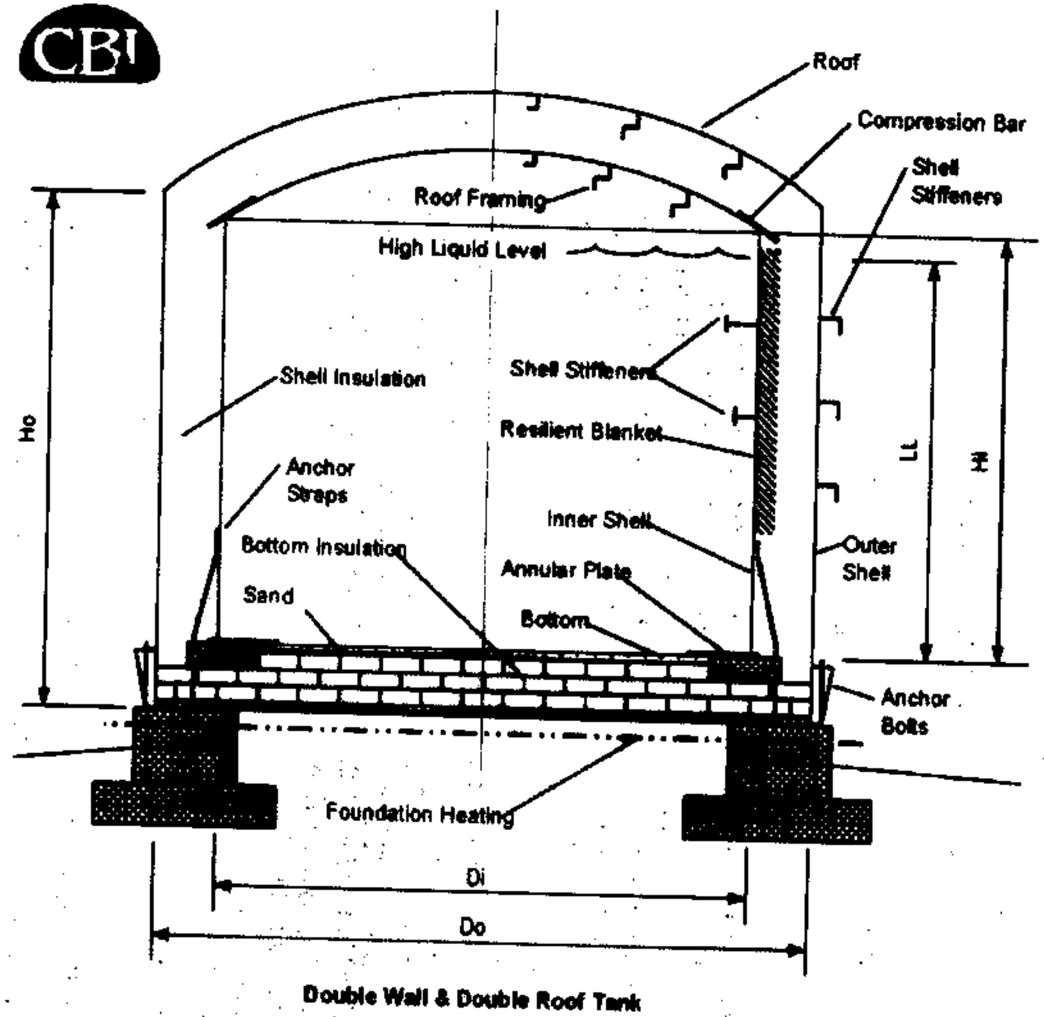
- Large modules ($\gtrsim$ 100 kton) can be built using technology of liquid methane storage.
  (Total cost of a 100-kton detector is estimated to be \$200M.)





- **Detector is continously "live" and can be "self-triggered" using pipelined, zero-suppression electronics.**
- Operates at the Earth's surface with near zero overlap of cosmic ray events.
- **Detector is compatible with operation in a magnetic field.**

200-kton Cryogenic Tanks Used for LNG Storage

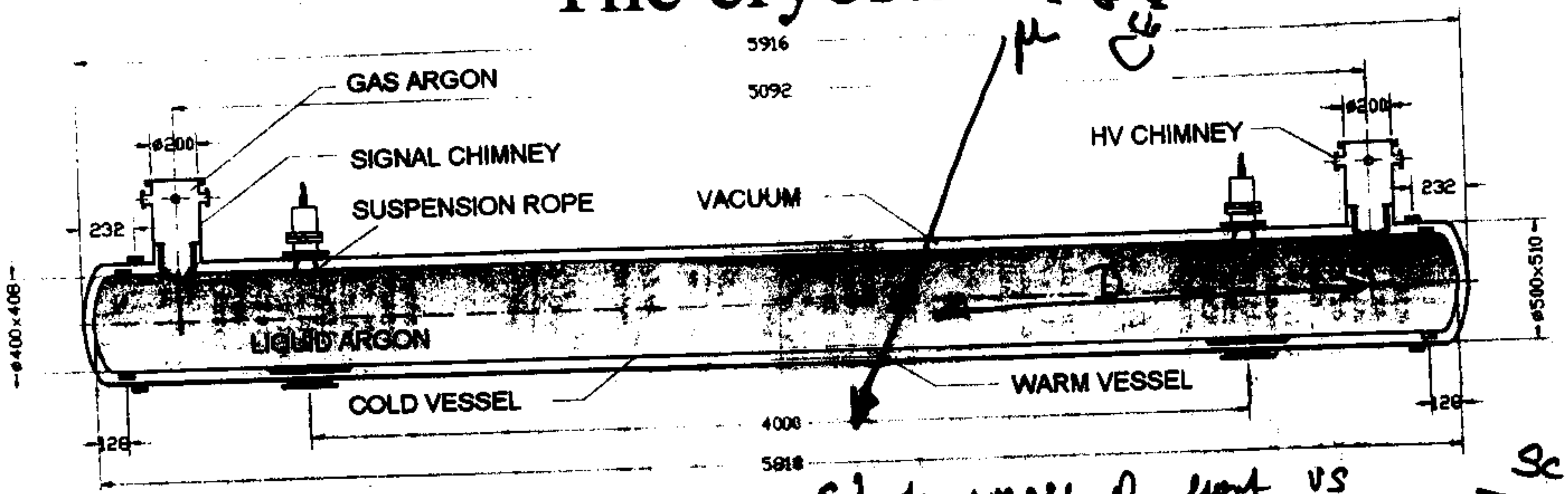


K McDonald
CBI
Study for LANNDD

	Feet
Di =	165
Hi =	117.9803
LL =	117.7303
Do =	173
Ho =	118.0443

Chicago Bridge & Iron: can build 100-kton LAr tank for < $20M.

The cryostat



Double wall, vacuum insulated cryostat.

Inner cold cylinder ($D = 400\,mm \times L = 5.8\,m$) hanging from the outer warm cylinder by stainless steel (or Kevlar) ropes.

Two chimneys ($D = 200\,mm$) positioned at the two ends ($d = 5.1\,m$), used for *a)* signal and control **feedthrough**, 1st heat exchanger, **argon** input/output and *b)* high voltage **feedthrough**, 2nd heat exchanger.

Chimney's volume used as argon expansion buffer (~ 2% of the liquid volume).

Heat input (including **conduction** through signal cables and HV feedthrough) reduced to few watts (due to hanging system, warm/cold mechanical connection via stainless steel **diaphragm** bellows, super-insulation wrapping of the cold cylinder). Foreseen LN_2 consumption $< 10\ l/24h$.

Recently Approved as a CERN Experiment by the SPSC

We will test the Ultimate Drift length in this detector

c. Time plan and milestones

Cryostat, inner detector, cryogenic and vacuum circuitry, acquisition electronics, high voltage completed by	half 2005
Functional tests (tightness, thermal insulation, argon purity, high voltages)	October 2005
Cosmic ray	end 2005
Muon beam test	middle 2006
Underground operation at WIPP site	~ 2007

At CERN

CERN BEAM

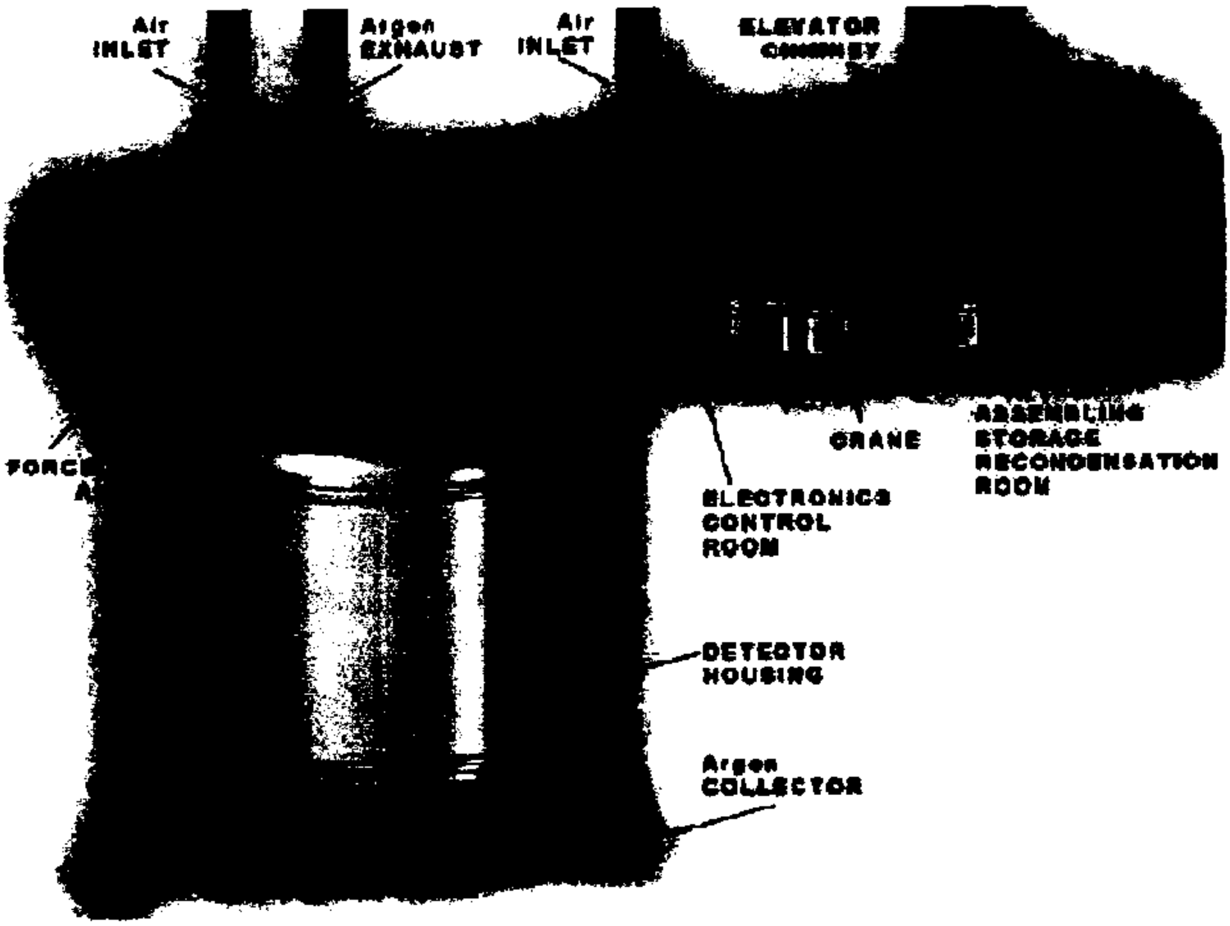
Other R&D Efforts around the World

- ETH / A Rubbia – drift in a magnetic field
  - study of 100 KT Detector
  - 2 Phase system
- FNAL / FLARG effort –
  - New kinds of read out
  - Small module studies

Move to WIPP to study Safety and possible Search for new particles underground

First Liquid Argon Detector Underground in USA

STUDY OF LAMBDA AT WIPP SITE



Very Low Cost of excavation ~ 28$/Ton

[redacted]

Detectors for Proton Decay and VLBL Neutrino Physics 3rd

2004 at BNL

Feb/March 2005 at UCLA

4th Fall 2005 at BNL

Monday Feb 28

800	Registration
830	Welcome: D. Cline
900	Role of Proton Decay in GUT theories: D.V. Nanapolous (Texas A&M)
940	Predictions for proton decay: J. Pati (U. Maryland)
1020	Break
1045	Liquid Argon Detector for Supernova Studies and Variation of Neutrino Masses with Density of the Medium: Danny Marfatia (KU)
1115	Sub-leading effects in atmospheric neutrinos: Sergio Palomares-Ruiz (Vanderbilt)
11:50	Title to come: Yasunori Nomura (LBL)

Organized by N Samios / D Cline + committee

1230 - 1330 Lunch

1330	Relic supernova neutrino background calculations, the present limits, and especially future prospects for both nuebar in water/oil detectors and nue in argon detectors: Shin'ichiro Ando (Univ. Tokyo):
1400	Discussion on DUSEL and APS study: Nick Samios, Moderator (BNL)
1430	Progress on reactor theta_13 experiment: Stuart Freedman (LBL)
1500	Break
1520	*T2K expectations: Clark McGrew (Stonybrook)
1550	Three family models from the heterotic string: Stuart Raby (Ohio State)
1610	*FNAL proton driver study: Steve Geer (FNAL)
1640	BNL neutrino beam status: Milind Diwan (BNL)
1700	Water Cherenkov simulation studies on backgrounds and resolution: Chiaki Yanagisawa (SUNY)

Note Water Scintillator of LAR Detectors Studied

Tuesday March 1

830	Summary of developments on liquid argon technology: David Cline (UCLA)
900	Large liquid scintillator technology: Raju Raghavan (LSU)
930	*Development on NOVA: John Urheim (Indiana)
1000	UNO: Chiaki Yanagisawa (SUNY)
1030	Break
1050	Deep underground accelerator and detector facilities for studying neutrino physics: Takahashi Hiroshi (Brookhaven)
1120	Discussion on R&D items and Dave Cline collaboration document
1230	Lunch or leave for airport.

} Form a Detector Consortium Independent of Technique

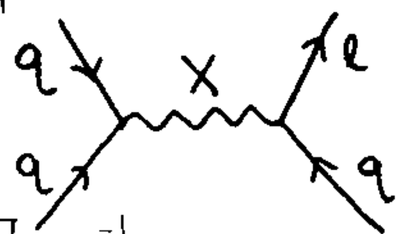
* not yet confirmed

FY 2006 Presidents Budget suggests support for "New Detectors"

UCLA/BNL workshop
Dec 2003 at UCLA

d=6 Gauge Mediated : SUSY SU(5)/SO(10) J Pati

(1)

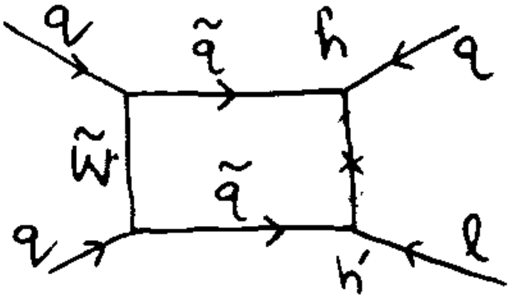


$\Rightarrow$ Amp$(p \to e^+ \pi^0)$ $\propto g^2/M_X^2$

MSSM → GUT $\Gamma^{-1}(p \to e^+\pi^0) \approx 10^{35 \pm 1}$ yrs (Theory)

(2) In Supersymmetry

Color triplet Higgsino Mediated



$qqq \to l$

$\tilde{H}_c \subset 10_H = (2,2,1)_H + (1,1,6)$

$$\text{Amp} \propto \frac{hh'}{M_{H_c}} \left(m_{\tilde{W}}/m^2_{\tilde{q}}\right) \alpha_2$$

$p \to \bar{\nu} K^+$ dominant!

$\to \mu^+ K^0$ (For "standard" d=5, suppressed)

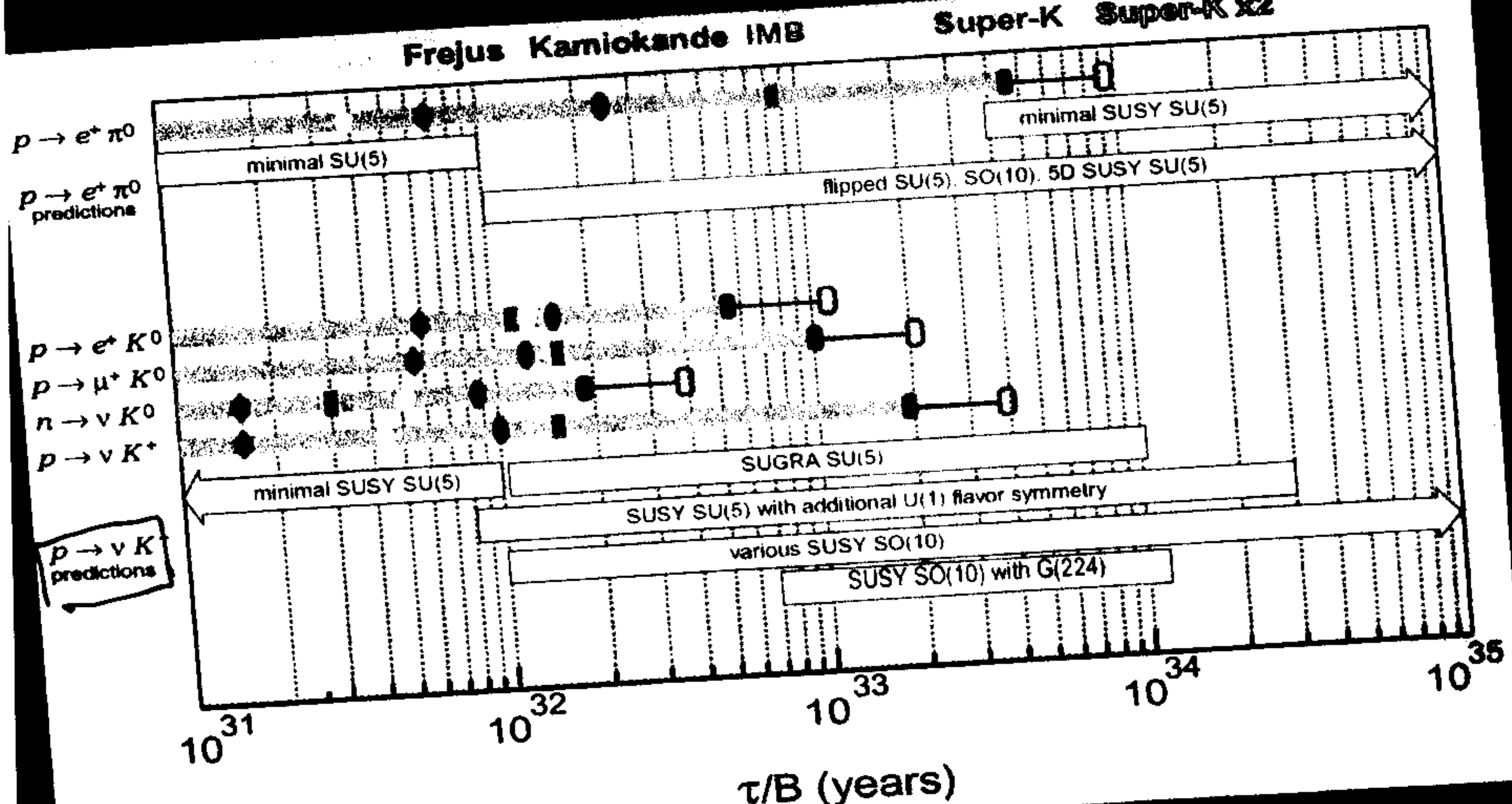
10^{34}–10^{35} y ?

Statement in Bush Budget FY06
" Do All the forces Become One

At the most fundamental level all forces and particles in the Universe are thought to be ~~one~~ related all the forces are thought to be manifestation of a single force. ....."

Other Documents discuss Proton Decay

1979 – present -- Post-GUTs experiments



	$p \rightarrow e^+ \pi^0$		$p \rightarrow K^+ \bar{\nu}$	
	Efficiency (%)	τ_p (years)	Efficiency (%)	τ_p (years)
No nuclear reinteractions	42	1.5×10^{34}	85	[illegible]
Nuclear reinteractions (FLUKA)	19	6.8×10^{33}	85	[illegible]

Exposure: 1000 kTon × year				
15 years @ LANNDD	$p \rightarrow e^+ \pi^0$		$p \rightarrow K^+ \bar{\nu}$	
	Efficiency (%)	τ_p (years)	Efficiency (%)	τ_p (years)
No nuclear reinteractions	42	1.5×10^{34}	85	1×10^{35}
Nuclear reinteractions (FLUKA)	19	2.3×10^{34}	85	1×10^{35}

udy CP Violation at $L/E = (2n+1)500$ km/GeV

ciano, hep-ph/0108181, Diwan *et al.*, hep-ph/0303081]

of ν_2-ν_3 oscillations occurs at $L/E \approx (2n+1)400$ km/GeV.

y grows with distance:

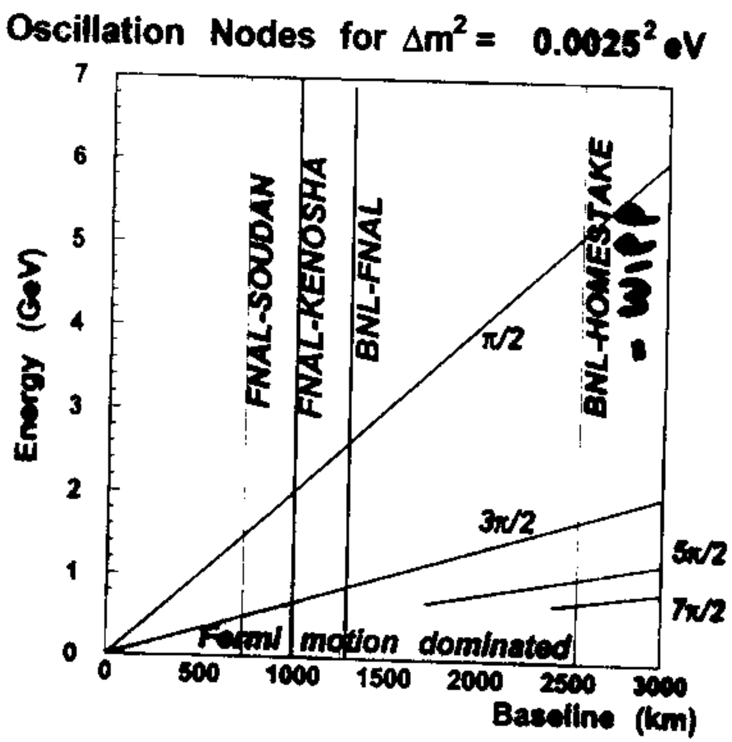
$$\frac{P(\nu_\mu \to \nu_e) - P(\bar\nu_\mu \to \bar\nu_e)}{P(\nu_\mu \to \nu_e) + P(\bar\nu_\mu \to \bar\nu_e)} \approx \frac{2 s_{12} c_{12} c_{23} \sin\delta}{s_{23} s_{13}} \left(\frac{\Delta m^2_{12}}{\Delta m^2_{23}}\right) \frac{\Delta m^2_{23} L}{4E_\nu}$$

$$\frac{\delta A}{A} \approx \frac{1}{A\sqrt{N}} \propto \frac{E_\nu}{L\sqrt{N}} \approx$$ **independent of L at fixed E_ν.**

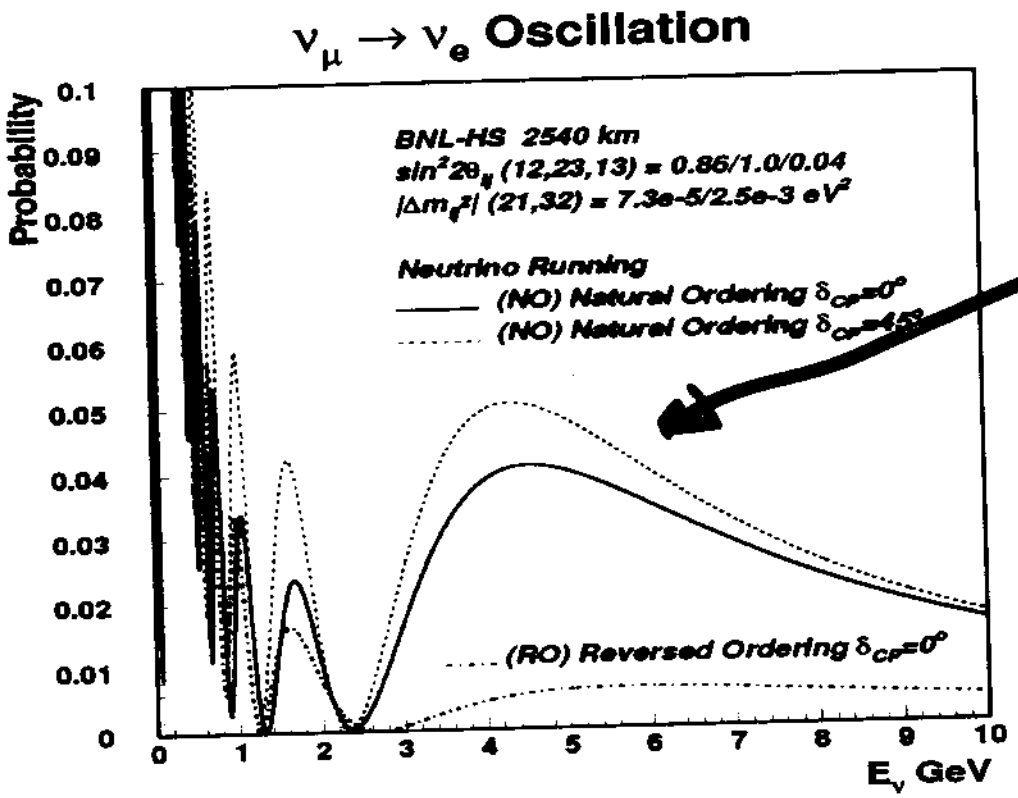
her measurements at large L.

or CP violation measurements.

entangle matter effects from CP
ie $n = 0$ and 1 oscillation maxima
ossible,
a (986 km),
286 km).



SEARCH FOR C̸P̸ WITH ONLY NEUTRINO BEAM



Need to Detect ~ few GeV ν_e

Difficult in H_2O Detectors

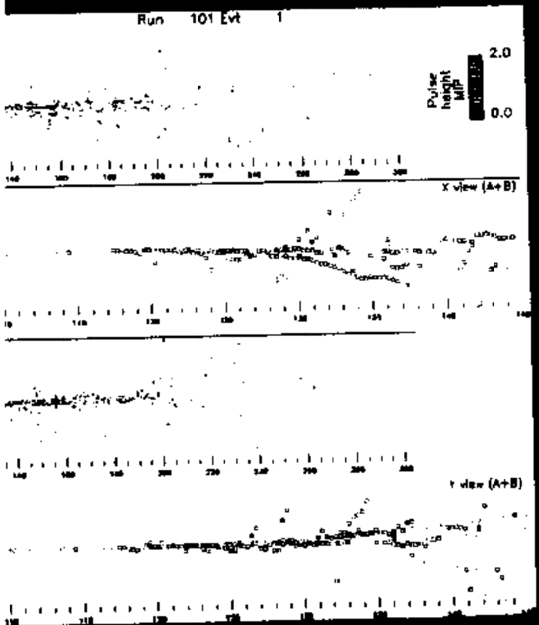
USE Q.E. IN THAT CASE

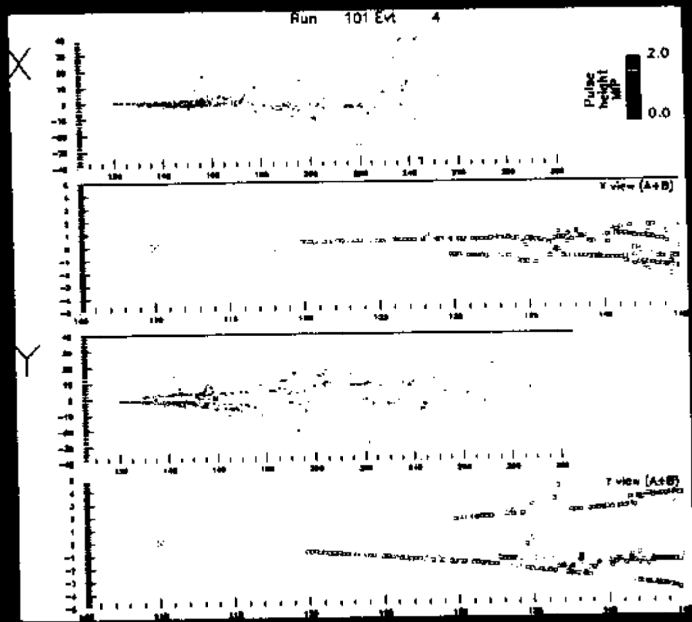
At Berkeley mtg mainly agreed L ~ 2000 km is very desirable for C̸P̸ Search

FINAL STUDY

lectrons vs π^0's (1.5 GeV) in LAr

Pulse height scale : mip=green, 2mip=red





ron:

k starts at the vert

(green) over

SUMMARY

1) DUSEL IN USA – New chance for a major Underground Laboratory (Complex) in the USA / North America
   - SNO LAB – Deep Site – Small Modules
   - 7 Proposals for other Sites – LARGE & SMALL MODULES

2) LIQUID ARGON TPC PROGRESS ! FOR CNGS [redacted]
   - a) ICARUS T600 AT LGNS.
   - 3 KT b) ICARUS T1200 under construction
   - LANNDD Detector R&D (~100 KT or Detector
     - 100 KT a) LANNDD-5m Under construction at CERN
     - b) LANNDD Safety Study
   - – DUSEL S2 Proposals Due Feb 28 } UCLA will Submit for WIPP/DUSEL

3) Proton Decay Search

   $\tau_{p \to K^+\nu} \sim 10^{35}$ years possible

4) VLBL Neutrino Physics

   If $\sin^2 2\theta_{13} > 10^{-2}$ SEARCH FOR CP] IF $\sin^2 2\theta_{13} <$ ... may need Neutrino Factory or β Beam

GREAT HOPE FOR AN UNDERGROUND LAB(S) IN USA PROGRAM AND POWERFUL SCIENTIFIC

THIS SCIENCE IS AROUND MAYBE IN USA FOR LHC AT CERN