DAVID CLINE
UCLA
Feb 27, 99
Venice

Relic Neutrinos and Super Novas

1) Relic Neutrinos From the Big Bang:

- A) Properties Today
- B) Open Questions about Relic Neutrinos
- C) Methods to Detect
  - a) By Forces
  - b) By UHE Neutrino Interactions
  - c) From CMBR Fluctuation (HDM) / Large Scale Structure

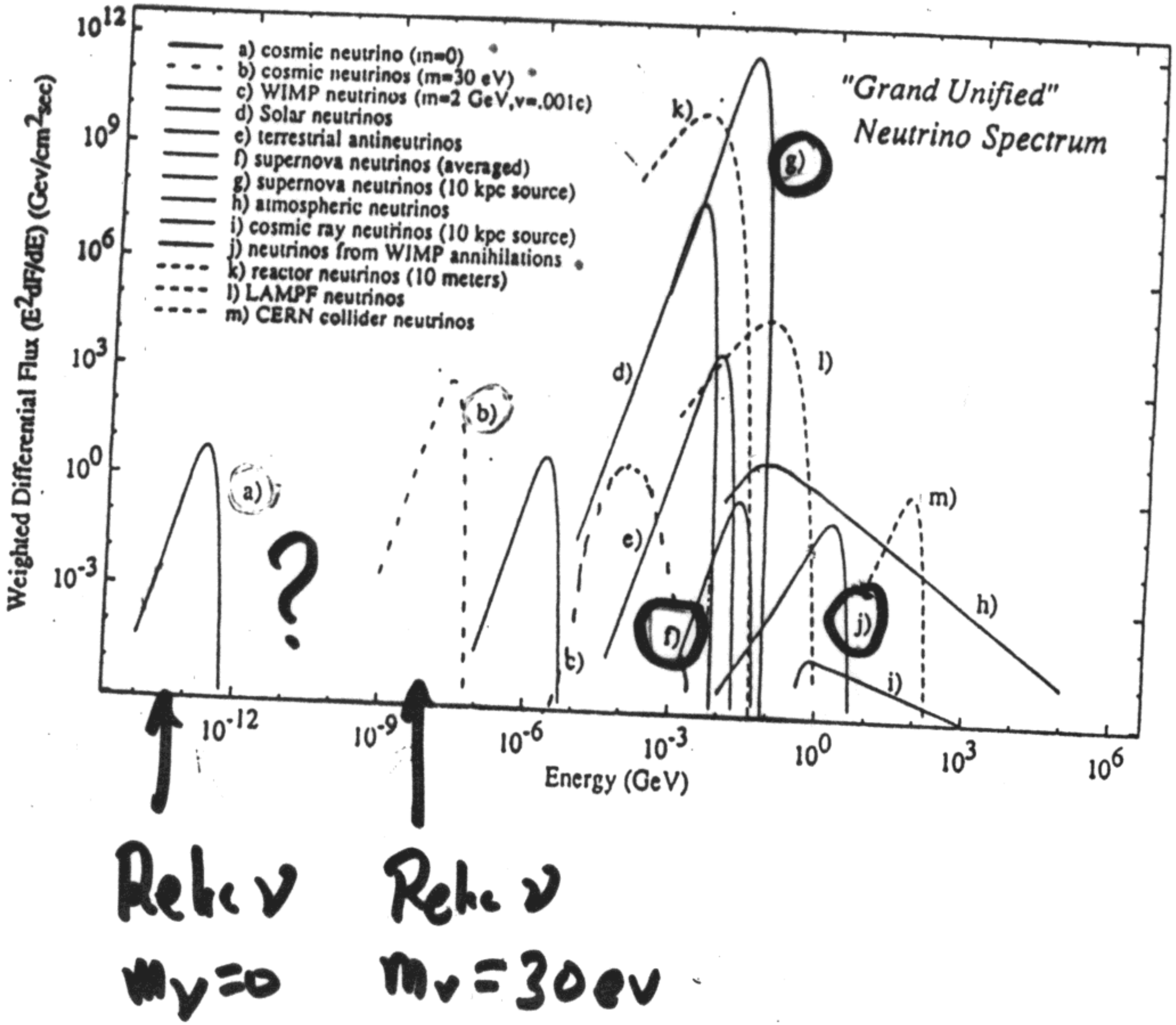
2) Relic Neutrinos From Past Super Nova

- A) Properties Today
- B) Possible Effects of Neutrino Oscillations
- C) Method to Detect
  - a) $\bar{\nu}_e$ - Super K
  - b) ν_e - ICARUS

3) Real Time Super Nova Neutrino Detection

- A) Super Nova Neutrino Properties
- B) Real Time Detection
- C) OMNIS 3 Site Observatory
- D) Extracting Maximal Information

4) SUMMARY



"Grand Unified"
Neutrino Spectrum
Weighted Differential Flux (E²dF/dE) (Gev/cm²sec)
Energy (GeV)
10^12
10^9
10^6
10^3
10^0
10^-3
10^-12
10^-9
10^-6
10^-3
10^0
10^3
10^6
a) cosmic neutrino (m=0)
b) cosmic neutrinos (m=30 eV)
c) WIMP neutrinos (m=2 GeV,v=.001c)
d) Solar neutrinos
e) terrestrial antineutrinos
f) supernova neutrinos (averaged)
g) supernova neutrinos (10 kpc source)
h) atmospheric neutrinos
i) cosmic ray neutrinos (10 kpc source)
j) neutrinos from WIMP annihilations
k) reactor neutrinos (10 meters)
l) LAMPF neutrinos
m) CERN collider neutrinos
?
Relic ν
mν=0
Relic ν
mν=30ev

TECHNIQUES TO SEARCH FOR RELIC NEUTRINOS

Options for Relic Neutrinos – Examples

1. **STANDARD MODEL**

$m_{\nu_{e_{\mu\tau}}} \approx 0$, $T_\nu \approx 1.9°K$, $\mu_\nu \approx 10^{-18}(m_\nu)\,\mu_B$,

$P_\nu \approx (5-2) \times 10^{-4}$ eV/c , $\alpha\nu_e = 3 \times 10^{12}$ cm^2 s

$$n_\nu = \frac{3}{4} n_\gamma$$

2. **MASSIVE NEUTRINOS**

$m_{\nu_{\mu,\tau}} \approx 30$ eV (either μ or τ; $m_{\nu_e} = 11$ eV)

(A) Unclustered in Galaxy (B) Clustered in Galaxy

3. **NEUTRINOS WITH UNUSUAL PROPERTIES**

$\mu_\nu \approx 10^{-10}\,\mu_B$, $\mu_\nu \approx$? (30 eV) , (Transition ν_B or ν_μ)

(i.e., clustered and with a large magnetic moment)

4. **(RELIC NEUTRINOS) FROM THE DECAY OF MASSIVE RELIC NEUTRINOS**

Example: $M_{\nu_\tau} = 1$ MeV

Assume dominant decays:

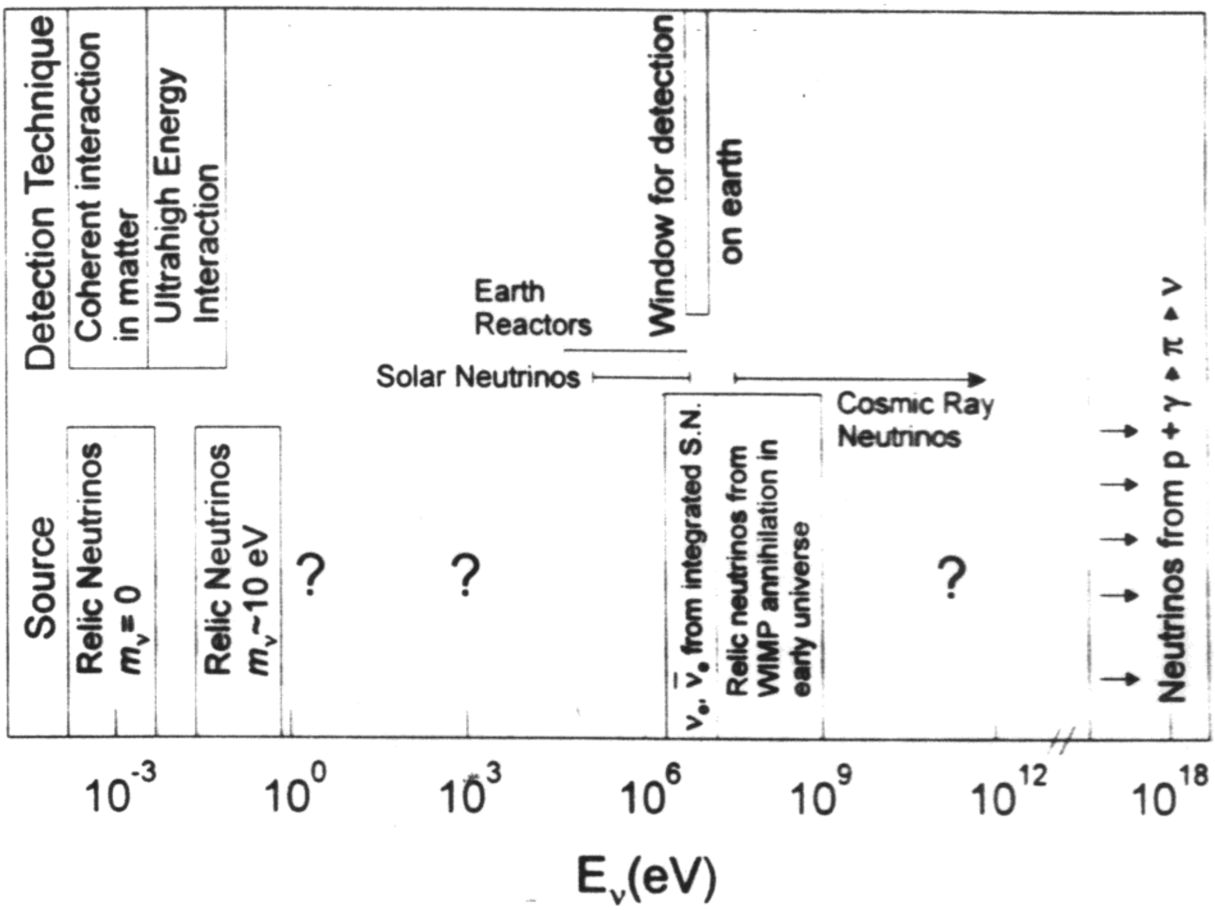
$\nu_\tau \rightarrow \nu_\mu + \phi$ if $\tau_{\nu_\tau} \geq 10^{16}$ s

$\rightarrow 3\nu$, (Assume $m_{\nu_\mu} \sim 0$)

$E_{\nu_\mu} \approx \dfrac{1/2 \text{ MeV}}{1+z}$, Flux

MORAL: RELIC NEUTRINOS HAVE NOT BEEN DETECTED; HENCE WE DO NOT KNOW THE SPECTRUM

Search for Cosmic Diffuse Neutrinos



COSMOLOGICAL NEUTRINO BACKGROUND REVISITED

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AND

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Received 1998 February 11; accepted 1998 July 20

ABSTRACT

We solve the Boltzmann equation for cosmological neutrinos around the epoch of the electron-positron annihilation in order to verify the freeze-out approximation and to compute accurately the cosmological neutrino distribution function. We find the radiation energy density to be about 0.3% higher than predicted by the freeze-out approximation. As a result, the spectrum of the cosmic microwave background anisotropies changes by ~0.3%–0.5%, depending on the angular scale, and the amplitude of the mass fluctuations on scales below about $100\ h^{-1}$ Mpc decreases by about 0.2%–0.3%.

Subject headings: early universe — elementary particles — cosmic microwave background — nuclear reactions, nucleosynthesis, abundances

CMBR ⇄ Relic ν

– LEPTON # CONSERVATION ASSUMED –

$\Omega_\nu h^2 = \sum_{i=1}^{3} \frac{m_i}{93\,\mathrm{eV}}$ – $m_\nu \gtrsim$ few eV
Hot-Dark Matter

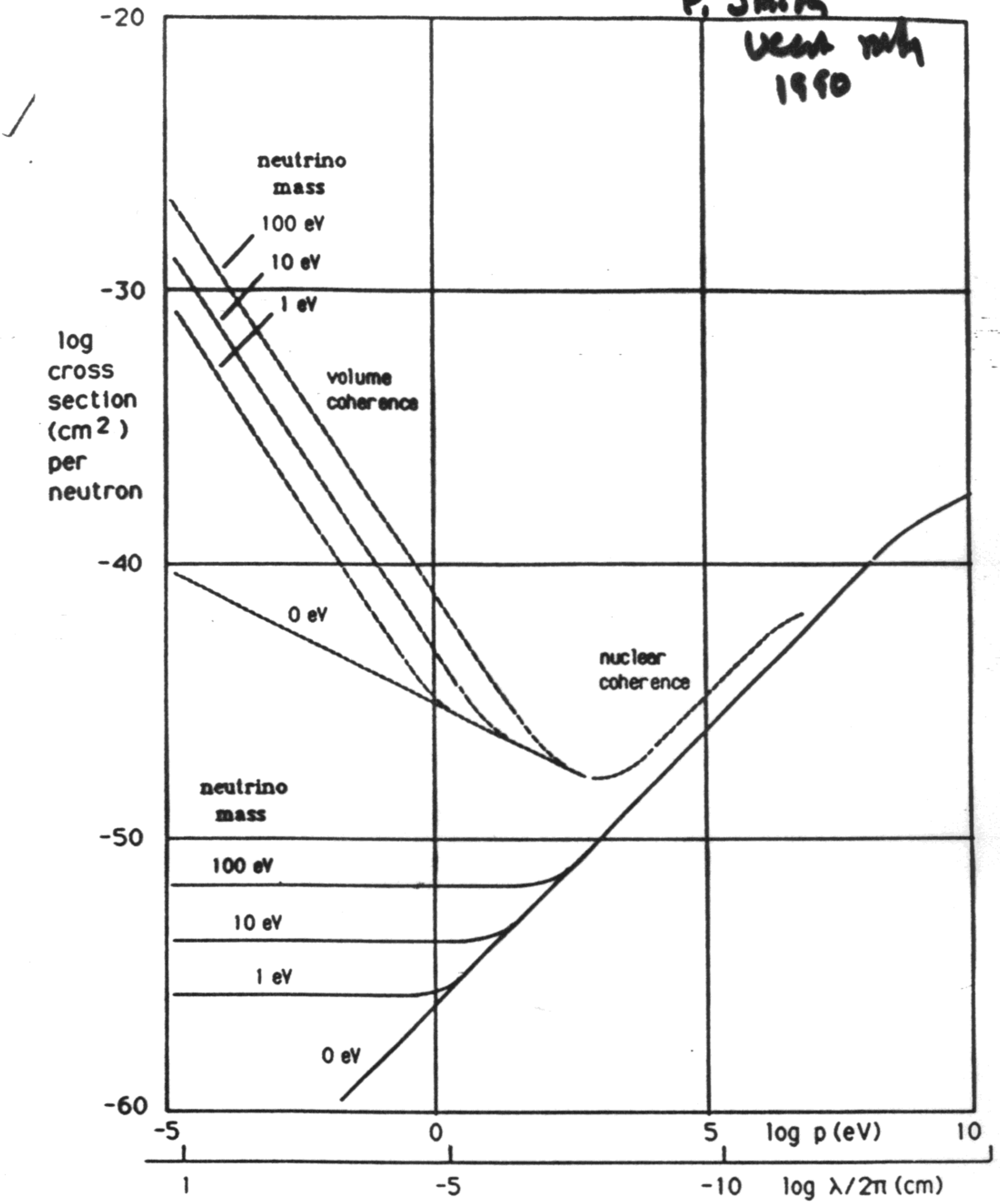


FIG 1 Neutrino elastic scattering cross section versus momentum p and corresponding wavelength λ.
Full lines: single particle scattering.
Dashed lines: coherent scattering.

$\mu_\nu = 0$

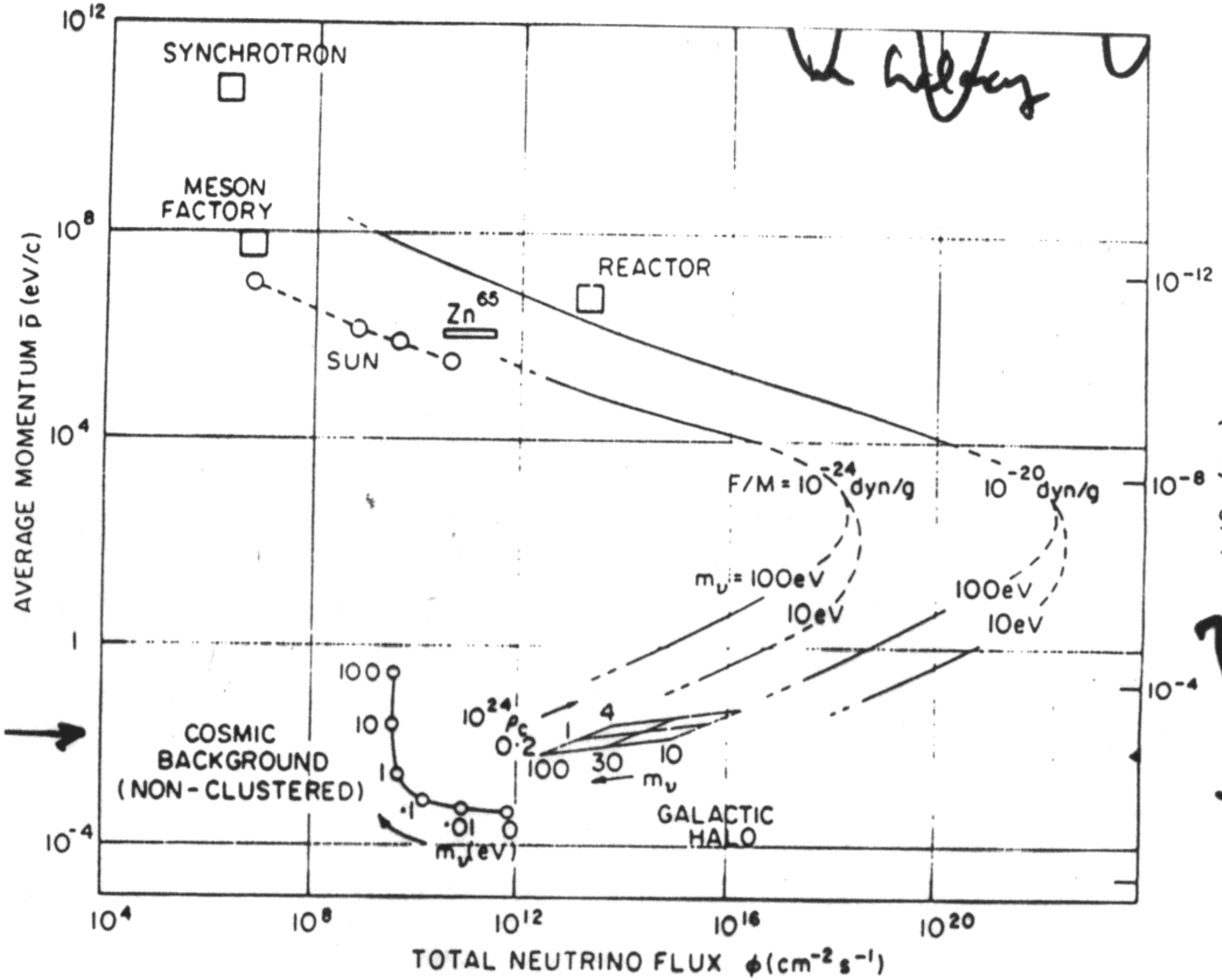


Fig. 1. Typical momentum and flux values for various natural and artificial neutrino sources. Right hand curves show calculated dependence of second order force on neutrino momentum, flux, and mass. Lower branches ($\lambdabar > 10^{-8}$ cm) correspond to the coherent interactions, and upper branches to normal incoherent scattering from single atoms (or, with decreasing $\lambdabar$, the atomic constituents).

P. Smith
UCLA mtg
1990

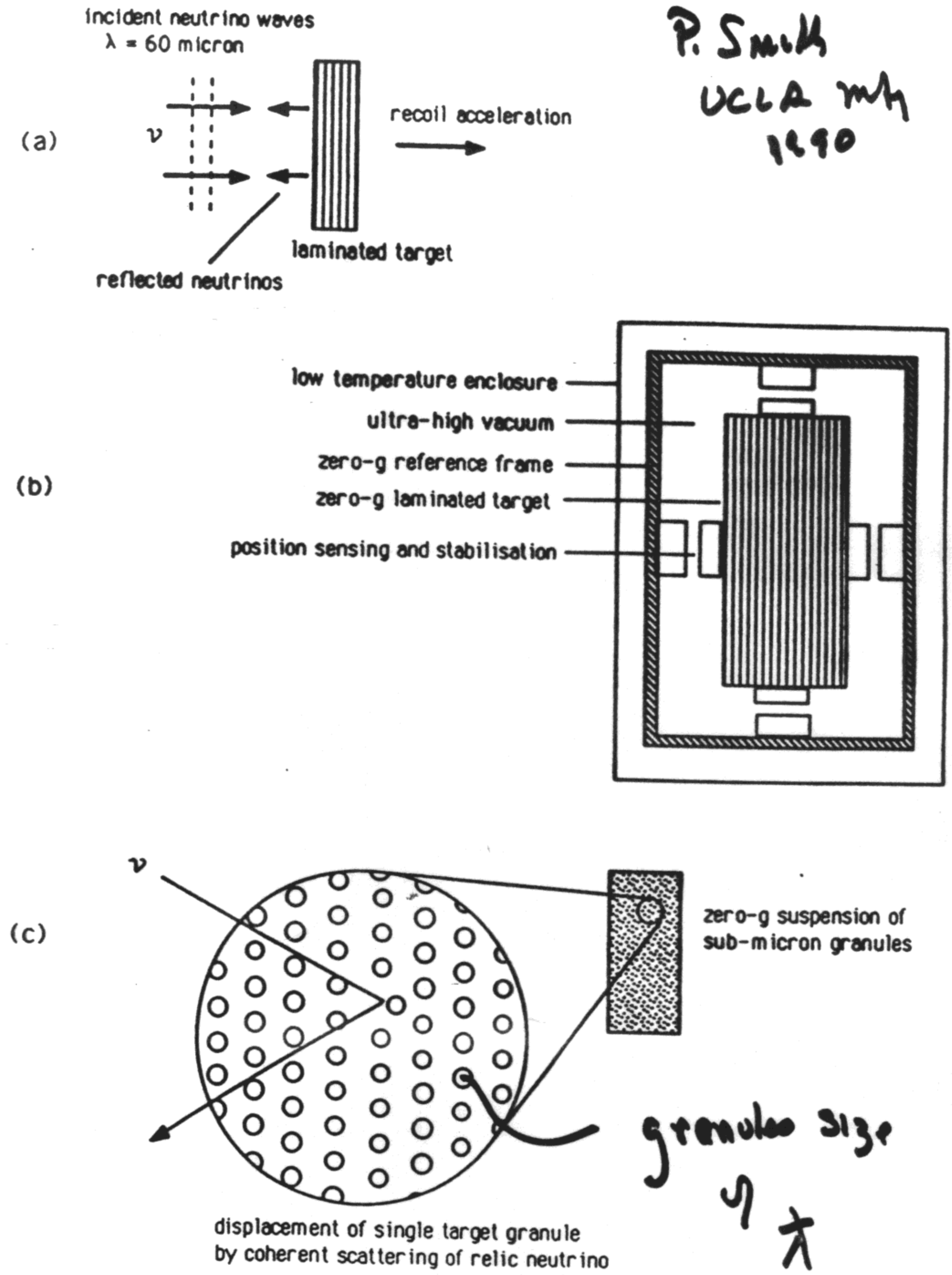
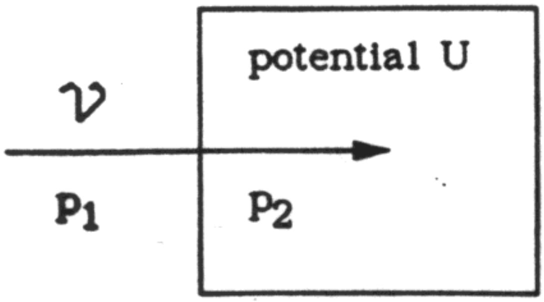


Fig 6 (a) Force proportional to $(n-1)^2$ from neutrino reflection.
(b) Conceptual zero-g experiment to detect second order force.
(c) Conceptual zero-g experiment with multiple granule target.

Focus of Relic ν's

Neutrino optics



$U = 2.10^{-13}$ eV for neutrinos

($U = 2.10^{-7}$ eV for neutrons)

Refractive index

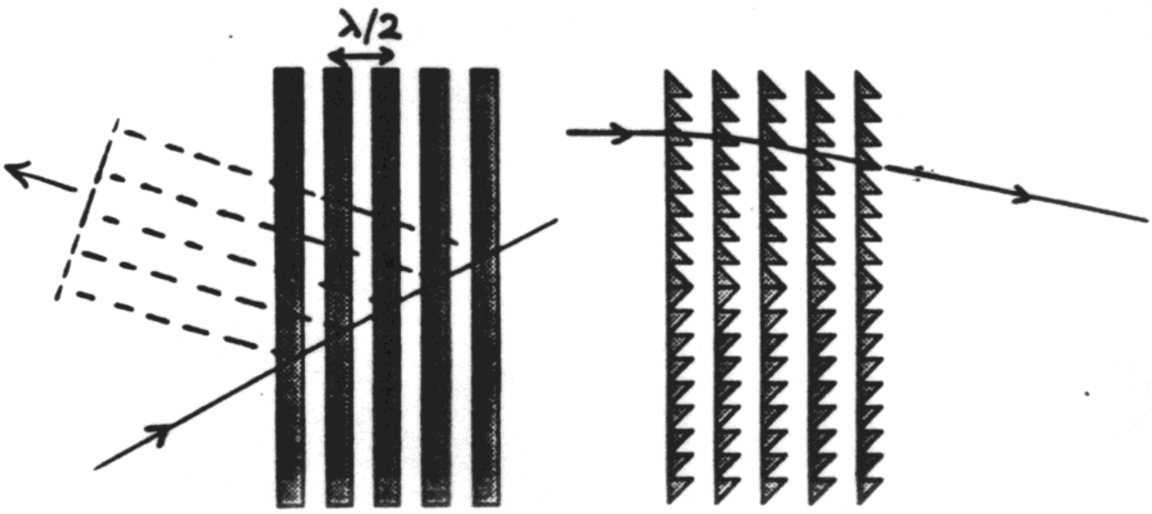
$n = 1 + G_F \, m_\nu / p_\nu^2 \quad = 1 + 10^{-8}$ for galactic ν

or $= 1 + 10^{-4}$ for cosmic ν

Consequences

- Reflection coefficient gives force on bulk matter ~ 10^{-17} dyn/tonne

- Bragg mirrors or Fresnel lenses possible



Search for Relic Neutrinos

UCLA DPF mtg Jan 99

C. Hagmann

Lawrence Livermore National Laboratory

7000 East Avenue, Livermore, CA 94550

Abstract

Probably the most promising way of detecting cosmic neutrinos is measuring the mechanical force exerted by elastic scattering of cosmic neutrinos from macroscopic targets. The expected acceleration is $\sim 10^{-23}\mathrm{cm/s^2}$ for Dirac neutrinos of mass $\sim 10\,\mathrm{eV}$ and local density $\sim 10^7/\mathrm{cm}^3$. A novel torsion balance design is presented, which addresses the sensitivity-limiting factors of existing balances, such as seismic and thermal noise, and angular readout resolution and stability.

Small Meeting at UCLA April 6 to discuss the feasibility of this experiment

FIGURES

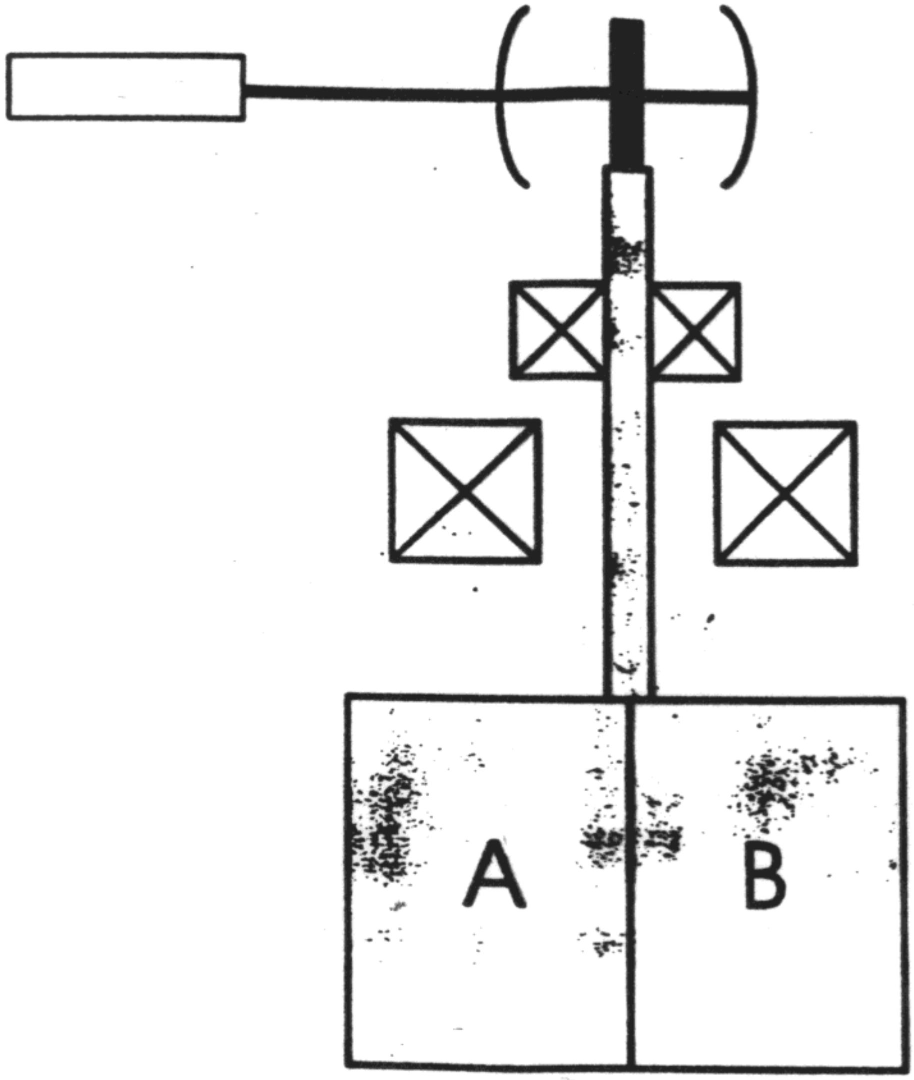
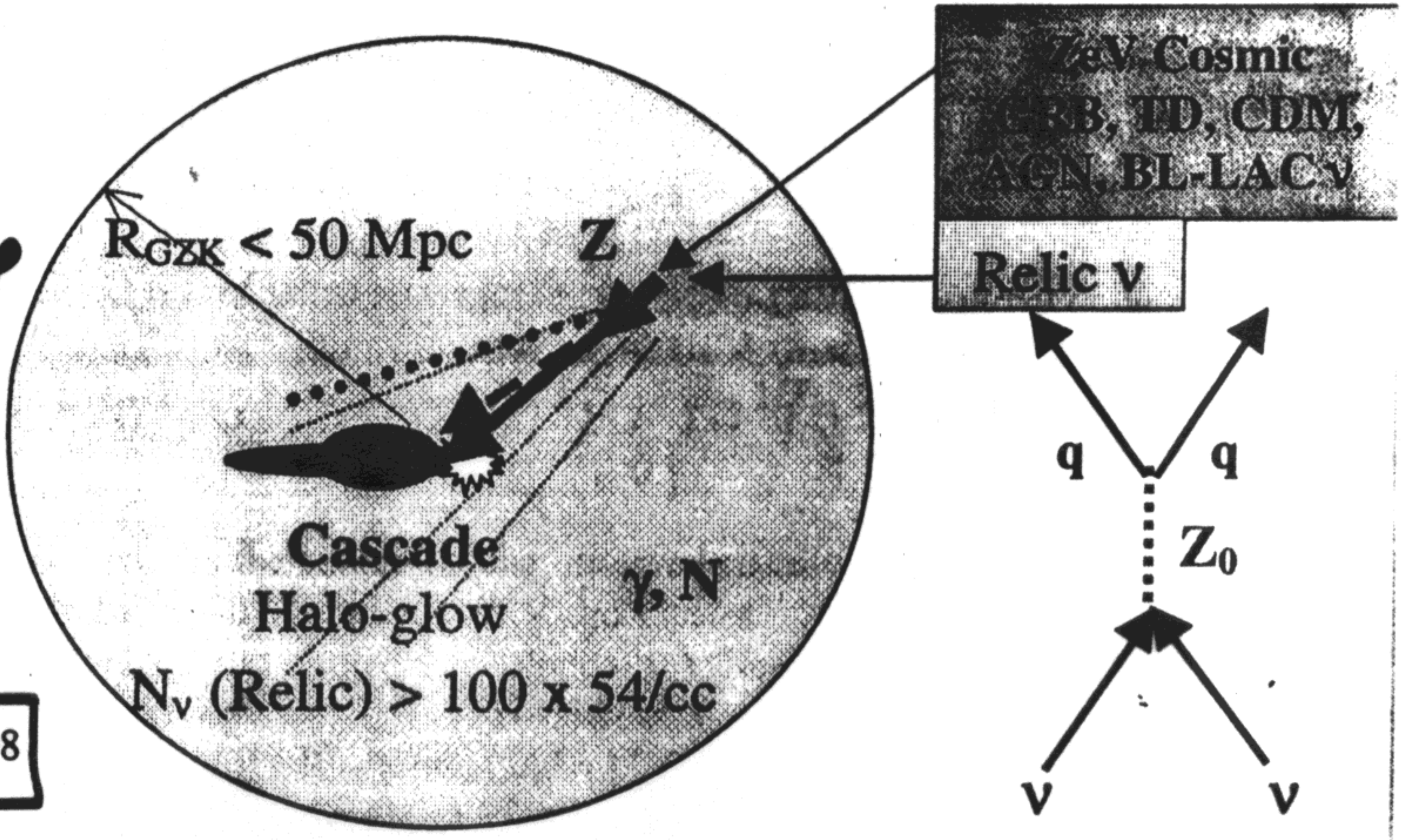


FIG. 1. Schematic diagram of the torsion oscillator. The target consists of two hemicylindrical masses with similar densities but different neutrino cross section. The mass is suspended by a "magnetic hook" consisting of a superconducting magnet in persistent mode floating above a stationary magnet. The rotation angle is read out with a tunable optical cavity and an ultra-stable laser.

$\nu\ (> ZeV) + \textbf{anti-}\nu_{1.95^{\circ}K} \rightarrow Z_0 \rightarrow 30\ \gamma + 2.7\ N + 28\ \pi$

- **HDM in cluster** ($L/\lambda_{\nu\nu} \approx 1\%$) generates **Super-GZK** cosmic rays
- cascades make Halo-glow in EUV and soft X-rays

Detection?
Relic ν
By Ultra
High Energy
ν Interaction



After Tom Weiler, 1998

"ν-tomography" of Hot Dark Matter of Virgo cluster with cosmological neutrinos

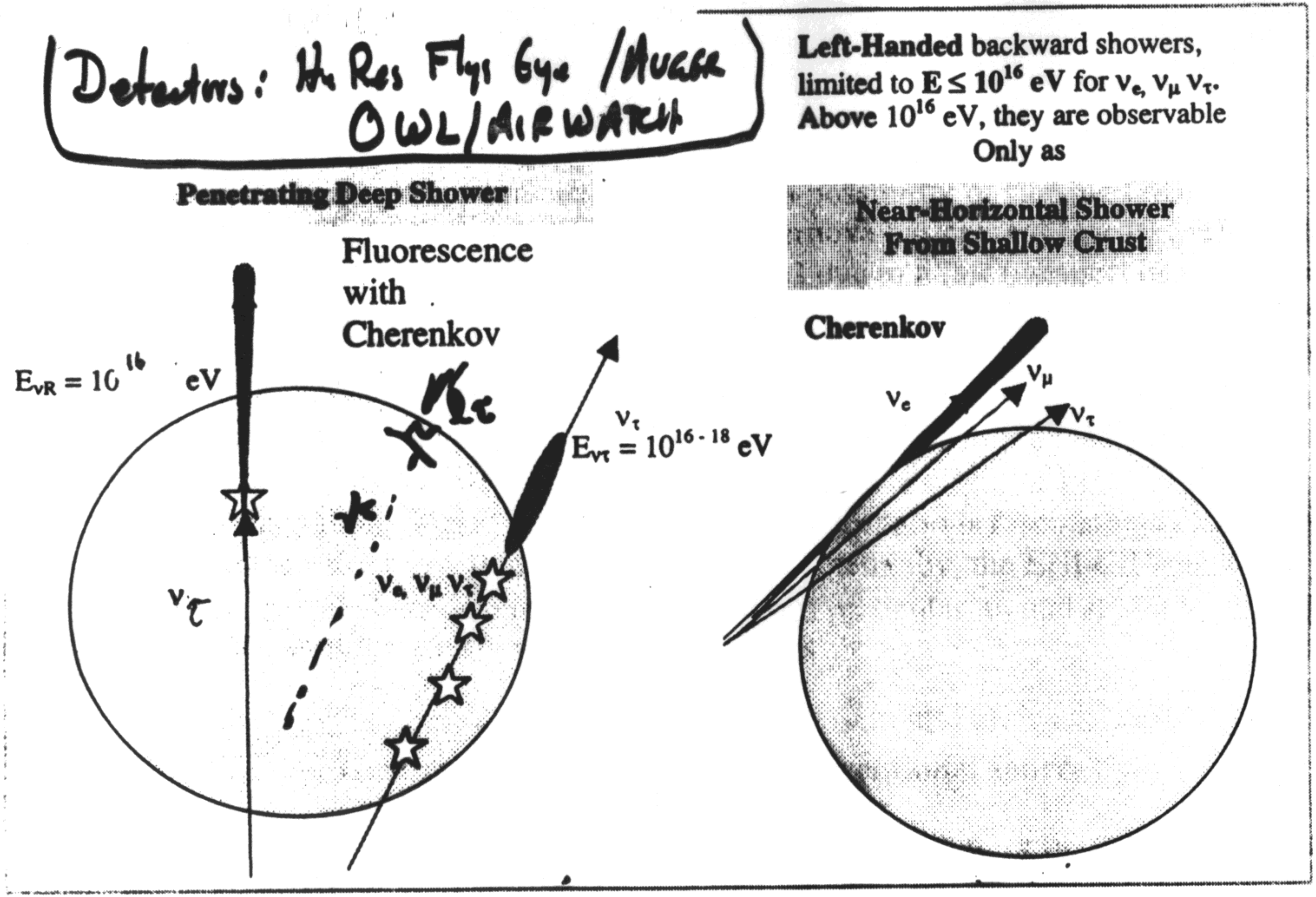
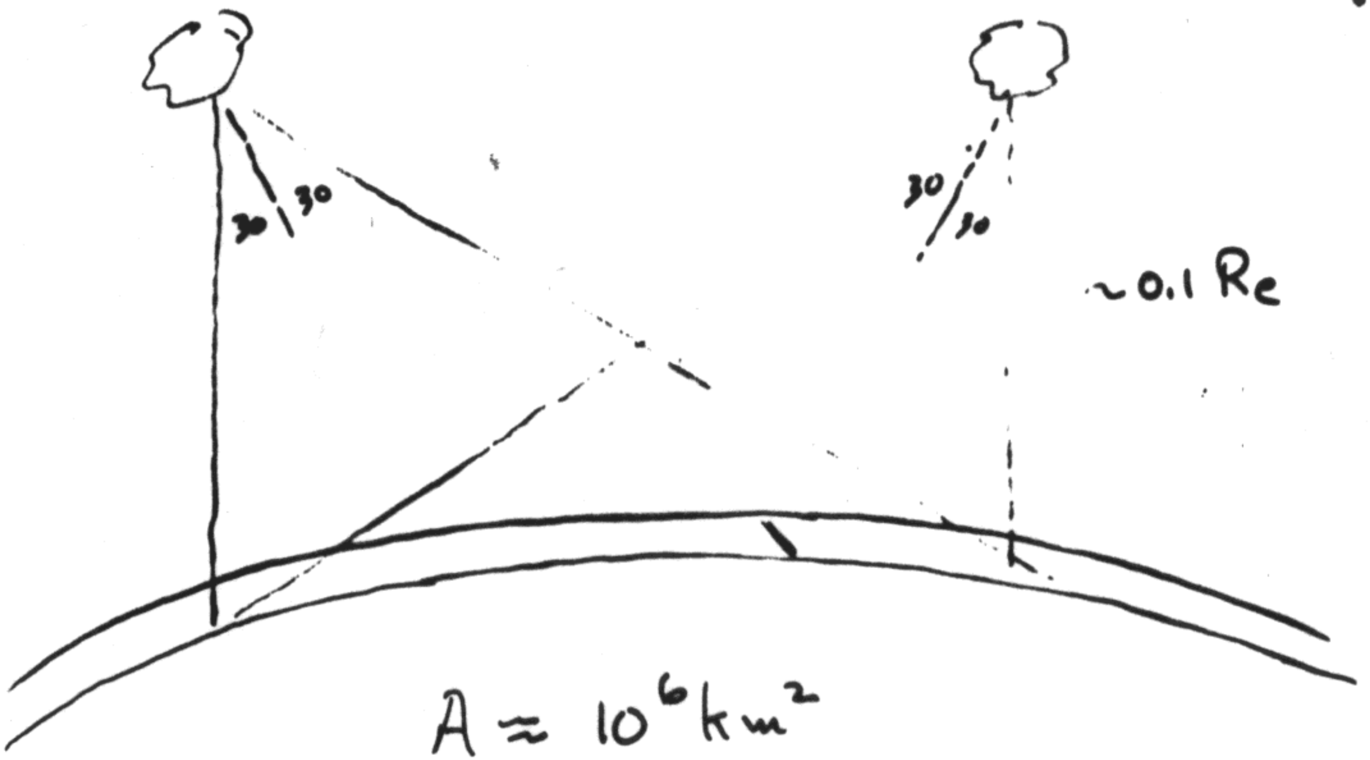


Illustration of Backward Showers initiated by **earth-penetrating** cosmological neutrinos.

OWL / AIRWATCH

Detect ν_τ
by Double Bang
etc etc



$A \approx 10^6 \, km^2$

$A \Omega \epsilon = 10^6 \, km^2 \cdot \pi \cdot 0.1 \approx 3 \times 10^5 \, km^2 \, sr$

AN UNUSUAL MODEL of RELIC NEUTRINOS

UCLA/99/TEP/6

Hignest-energy cosmic rays from Fermi-degenerate relic neutrinos consistent with Super-Kamiokande results

Graciela Gelmini and Alexander Kusenko
Department of Physics and Astronomy, UCLA, Los Angeles, CA 90095-1547
(February, 1999)

Relic neutrinos with mass $0.07^{+0.02}_{-0.04}$ eV, in the range consistent with Super-Kamiokande data, can explain the cosmic rays with energies in excess of the Greisen-Zatsepin-Kuzmin cutoff. The spectrum of ultra-high energy cosmic rays produced in this fashion has some distinctive features that may help identify their origin. Our mechanism does not require but is consistent with a neutrino density high enough to be a new kind of hot dark matter.

PACS numbers: 98.70.Sa, 95.85.Ry, 14.60.Pq, 95.35.+d

ASSUME $$\frac{n_{\nu_i} - n_{\bar{\nu}_i}}{\langle n \rangle} \neq 0 \approx 1$$

LARGE LEPTON NUMBER VIOLATION IN EARLY UNIVERSE — now η_ν or $\eta_{\bar{\nu}}$ can be much larger — even low mass (0.07 eV) neutrinos can now provide an adequate target for $\nu_{UHE} + \nu_R \to X$ to explain UHECR events ← now some HDM

⇒ Need to study UHECR in $10^{21} - 10^{22}$ eV Range

DETECTION OF ν / $\bar{\nu}$ RELIC NEUTRINO FLUX FROM TIME INTEGRATED SNII

1) **Relic ν / $\bar{\nu}$ From all SNII back to Z ~ 5**

$$< E_\nu > \sim \frac{1}{1+Z} < E_\nu >$$

2) **Detection would give integrated SNII Rate From Universe**

- Window of Detection $\left\langle \begin{array}{l} \text{DBC 1984} \\ \text{ICARUS Proposal} \end{array} \right.$

3) **Neutrino Oscillations in SNII would give $\nu_x \rightarrow \nu_e$ With higher energy than $\bar{\nu}_e$**

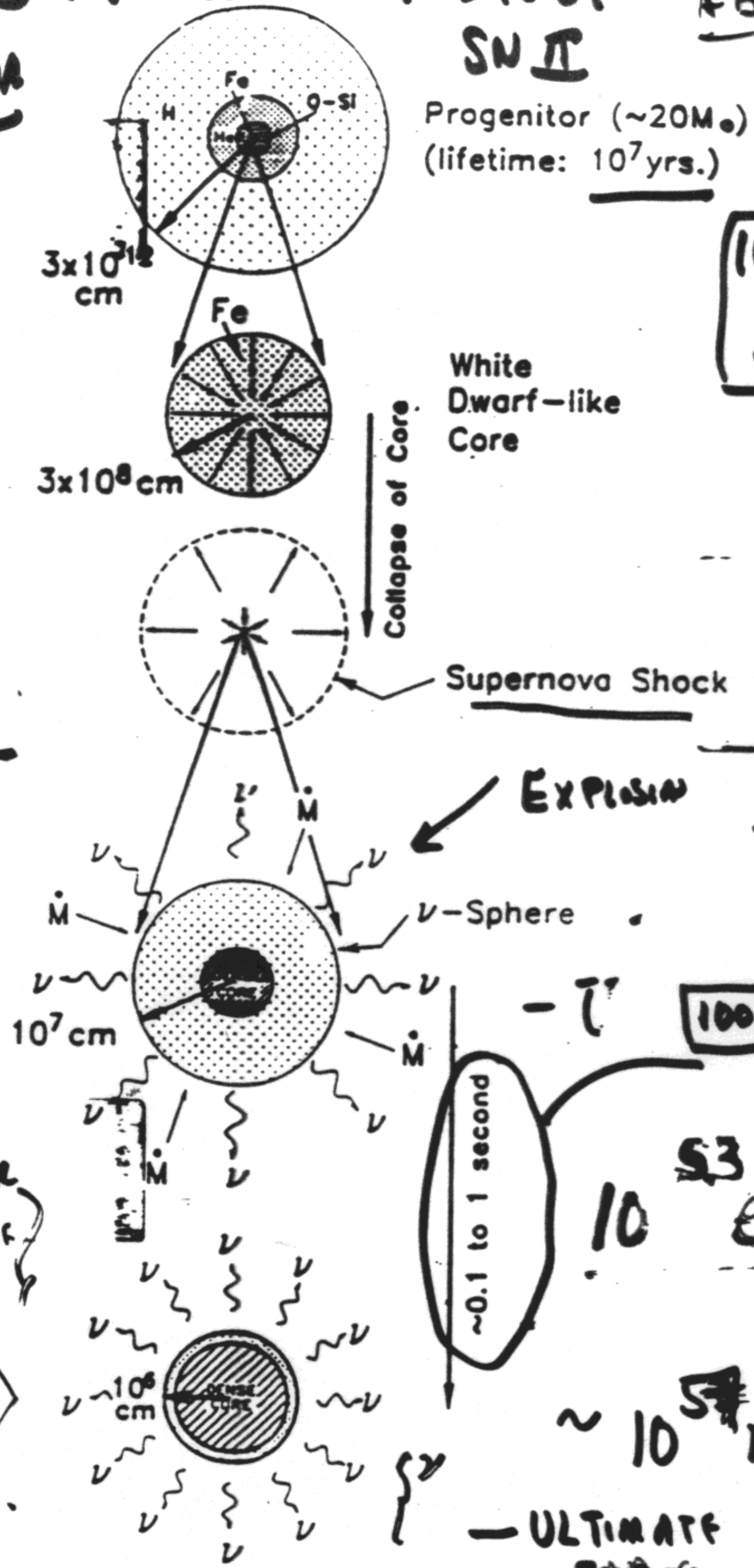
4) **Super K - Detect $\bar{\nu}_e$ ICARUS. Attempt to detect $\left\{ \begin{array}{l} \nu_x \\ \nu_e \end{array} \right\}$ Detection**

OVERVIEW: WHY STUDY SN II

A Bu[illegible]

SUPERNOVA ~~TYPE~~ II

PROCESS
CORE
COLLAPSE
AND
EXPLOSION



10 million years

EXPLOSION

– τ 100 MS

10^{53} ERGS

$\sim 10^{57}$ ν's NEUTRINOS

— ULTIMATE ν SOURCE

WE CONSIDER THIS AS THE ULTIMATE ν SOURCE TO MEASURE ν MASS

$N(\bar{\nu}_e \sim \nu_e \sim \nu_\mu \sim \bar{\nu}_\mu \sim \nu_\tau \sim \bar{\nu}_\tau)$

— ALL FLAVORS — UNLIKE SOLAR ν

General Behavior of SN Parameters

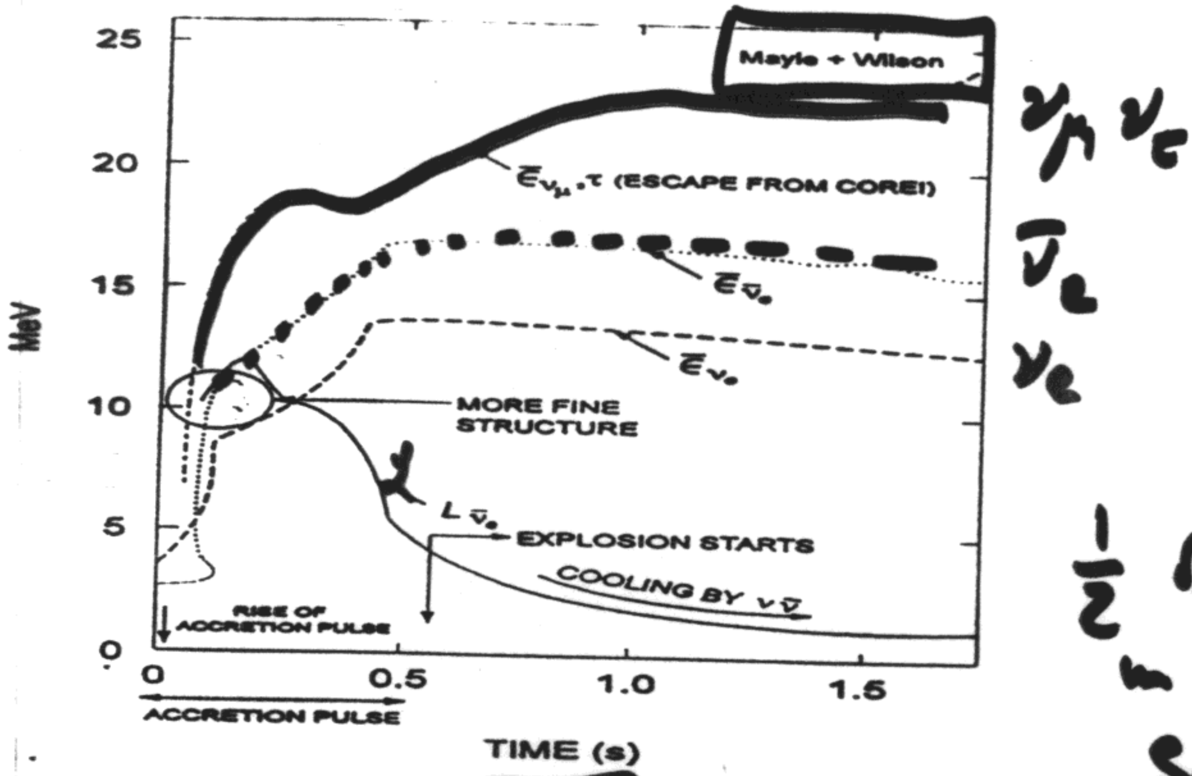


Figure 2: Schematic of the supernova ν burst properties.

$\frac{1}{2}$ of events in 1/2 sec!

$\mathcal{L}$ = Neutrino Luminosity

ϵ_{ν_x} – average energy of τ, μ, e, $\bar{\nu}_e$

Particles with Line

USE Jim Wilson Models of SN II

$\langle E_{\nu_\tau} \rangle > \langle E_{\nu_e} \rangle$

$\langle E \rangle_{\nu_{\mu,\tau}} > \langle E \rangle_{\nu_e, \bar{\nu}_e}$

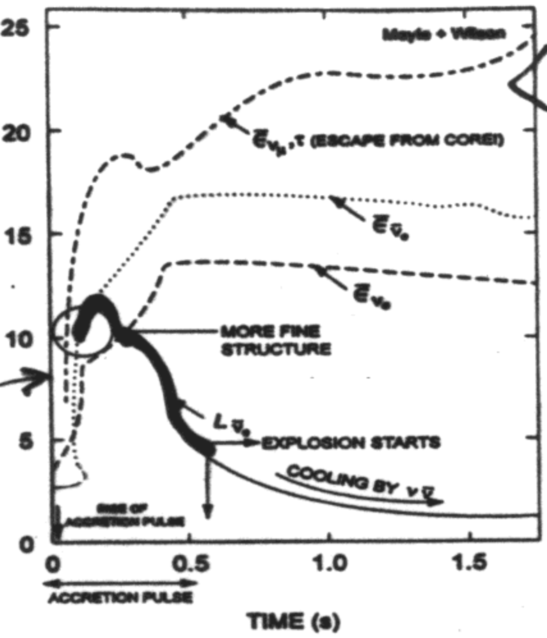


Fig. 2. Schematic of the Supernova ν Burst Properties.

Rise time < 50 ms

'sharp' structure for Timing

$\langle \tau \rangle \sim 500$ ms SN

→ Real Time Detectors

Burrows

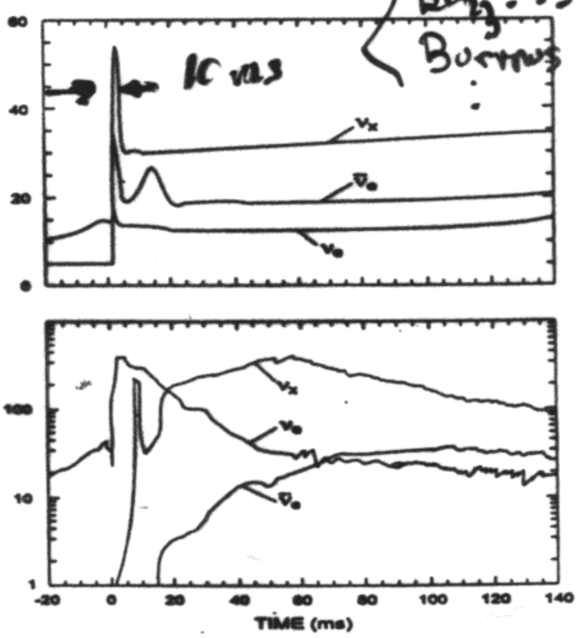


Fig. 3. Possible Fine Structure in the Supernova ν Burst from Recent Calculations.[7]

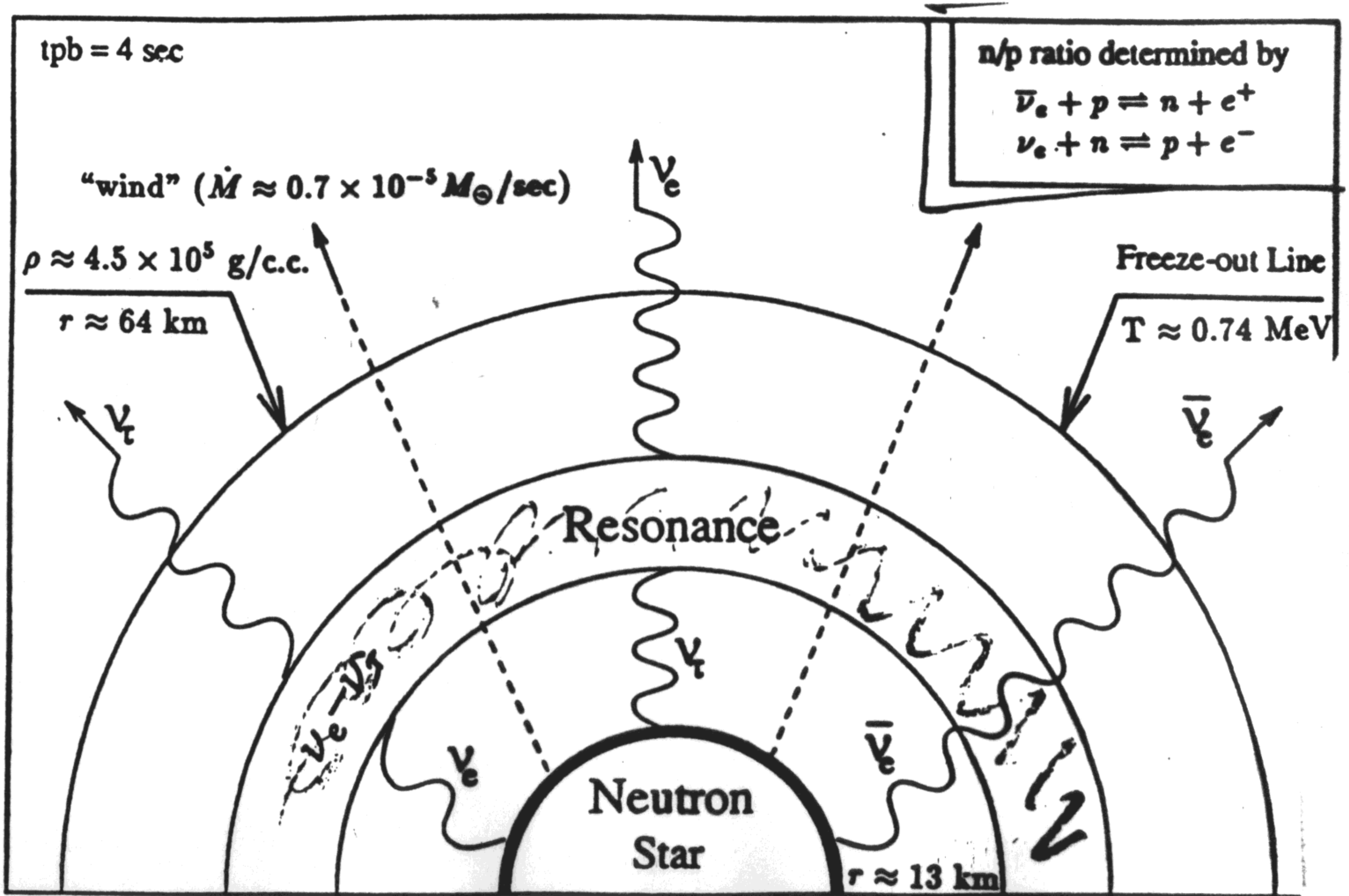
There could be sharp fine structures

⇒ FOR Time of Flight

$\Rightarrow \delta m^2$

– Any sharp time structures (Rise time, structure) provide a better signature for TOF Mass measurement –

G Fuller et al



1. Mixing matrix

$$\nu_\alpha = \sum_i U_{\alpha i}\, \nu_i$$

↑ flavor ↑ mass

Essential to OSG 3 ν Mixing Matrix

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \times \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

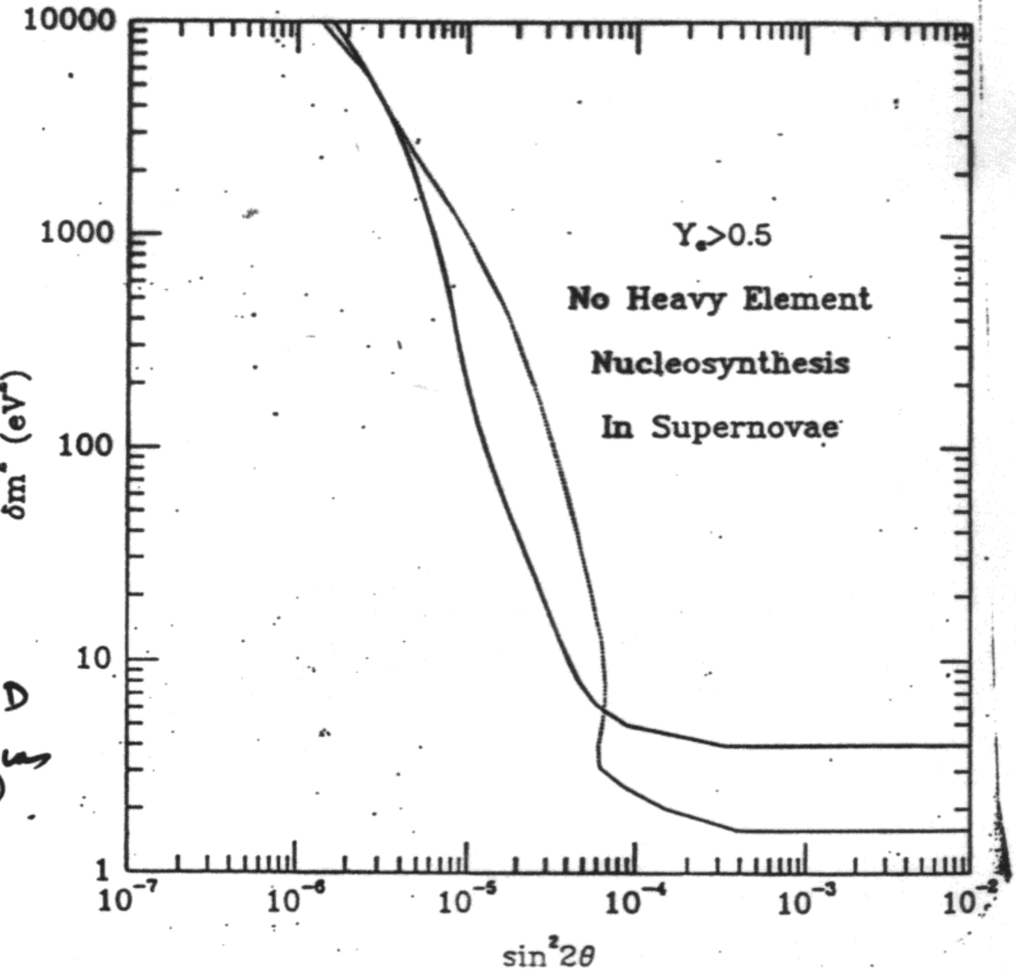
$$c_{23} = \cos\theta_{23}, \quad s_{23} = \sin\theta_{23}, \text{ etc.}$$

$\nu_e \rightleftarrows \nu_\tau$

$\nu_e \rightleftarrows \nu_\mu$

$\nu_\mu \rightleftarrows \nu_\tau$

Qian & Fuller 1994



If heavy elements made at SN II site - Strong constraints on $\nu_e \to \nu_x$ (Much of LSND effect region ruled out)

Prospects for Detecting Supernova Neutrino Flavor Oscillations

George M. Fuller,[1] and Wick C. Haxton,[2] and Gail C. McLaughlin[2*]

[1] *Department of Physics, University of California, San Diego, La Jolla, CA, 92093-0319*

[2] *Institute for Nuclear Theory, Box 351550, and Department of Physics, Box 351560, University of Washington, Seattle, WA 98195, USA*

(September 13, 1998)

Abstract

The neutrinos from a Type II supernova provide perhaps our best opportunity to probe cosmologically interesting muon and/or tauon neutrino masses. This is because matter enhanced neutrino oscillations can lead to an anomalously hot ν_e spectrum, and thus to enhanced charged current cross sections in terrestrial detectors. Two recently proposed supernova neutrino observatories, OMNIS and LAND, will detect neutrons spalled from target nuclei by neutral and charged current neutrino interactions. As this signal is not flavor specific, it is not immediately clear whether a convincing neutrino oscillation signal can be extracted from such experiments. To address this issue we examine the responses of a series of possible light and heavy mass targets, ^{9}Be, ^{23}Na, ^{35}Cl, and ^{208}Pb. We find that strategies for detecting oscillations which use only neutron count rates are problematic at best, even if cross sections are determined by ancillary experiments. Plausible uncertainties in supernova neutrino spectra tend to obscure rate enhancements due to oscillations. However, in the case of ^{208}Pb, a signal emerges that is largely flavor specific and extraordinarily sensitive to the ν_e temperature, the emission of two neutrons. This signal and its flavor specificity are associated with the strength and location of the first-forbidden responses for neutral and charge current reactions, aspects of the ^{208}Pb neutrino cross section that have not been discussed previously. Hadronic spin transfer experiments might be helpful in confirming some of the nuclear structure physics underlying our conclusions.

14.60.Pq, 26.50.+x, 25.30.Pt

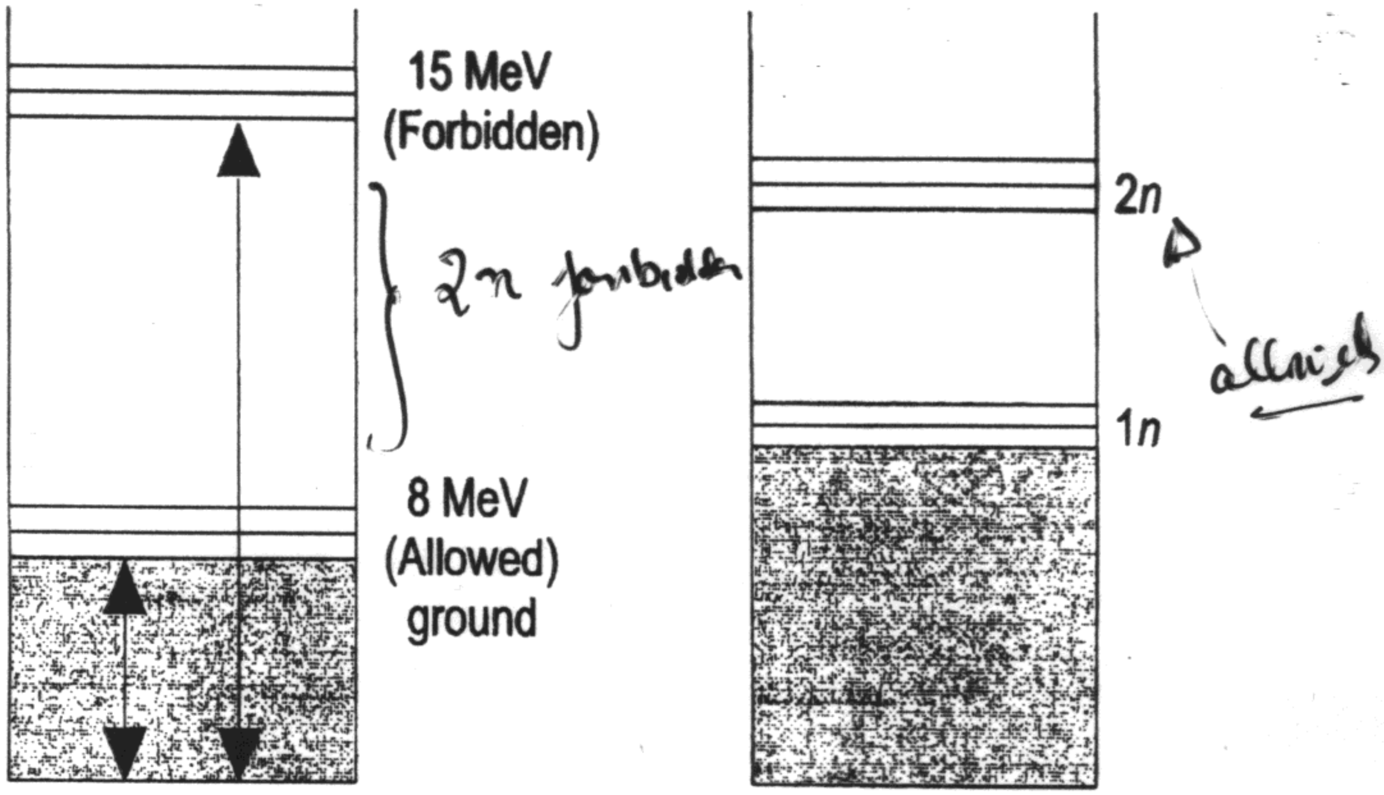
Real time detection of $\nu_x \to \nu_e$ in SN II

*Current Address: TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C. Canada V6T2A3. Electronic address: gail@alph01.triumf.ca

Aspen 98

TWO NEUTRON SIGNAL FOR $\nu_{\tau,\mu} \rightarrow \nu_e$

(G. McLaughlin, G. Fuller, W. Haxton)



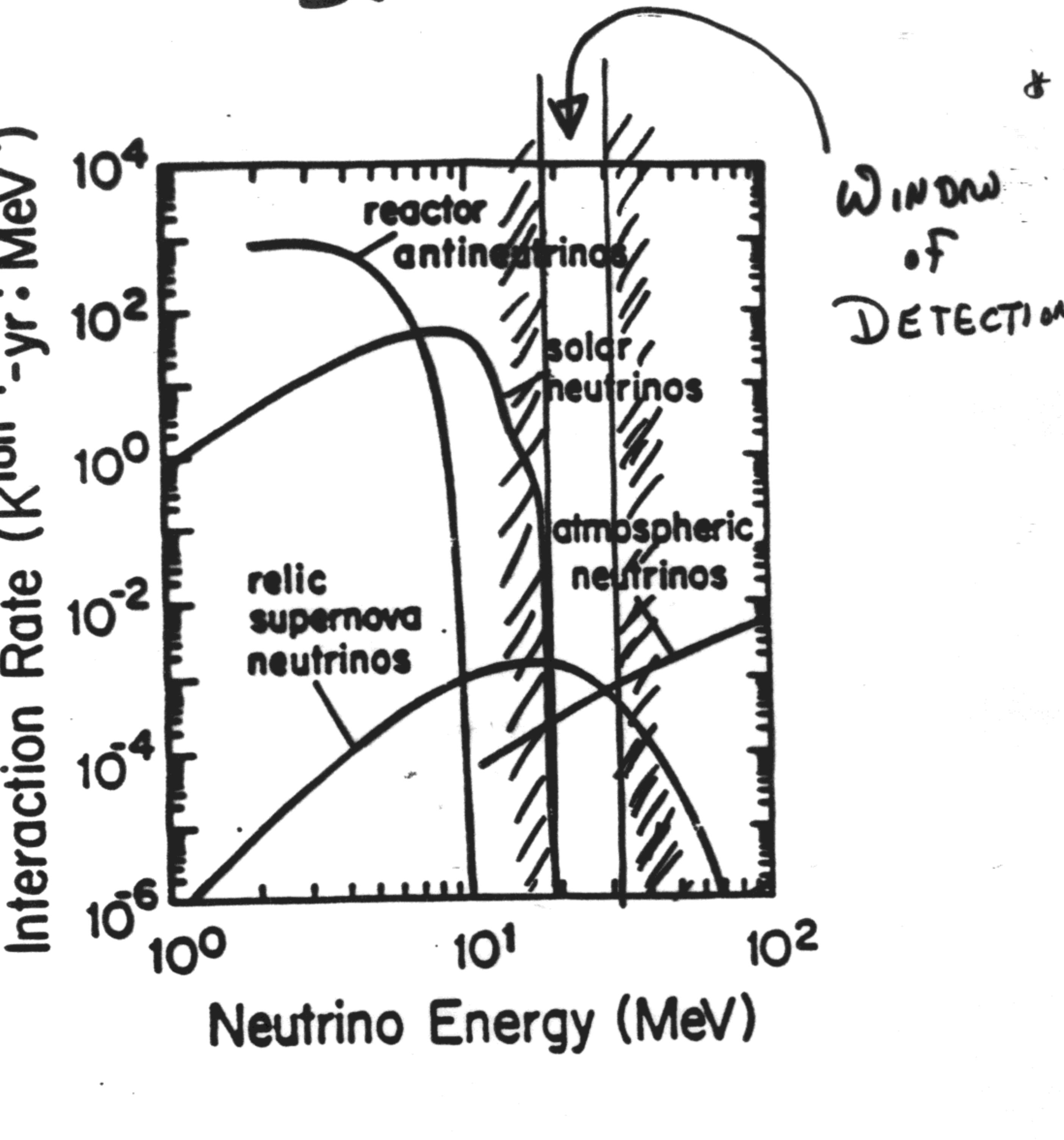
$\nu_x + Pb \rightarrow \nu_x + x$
↳ 1n
↳ 2n

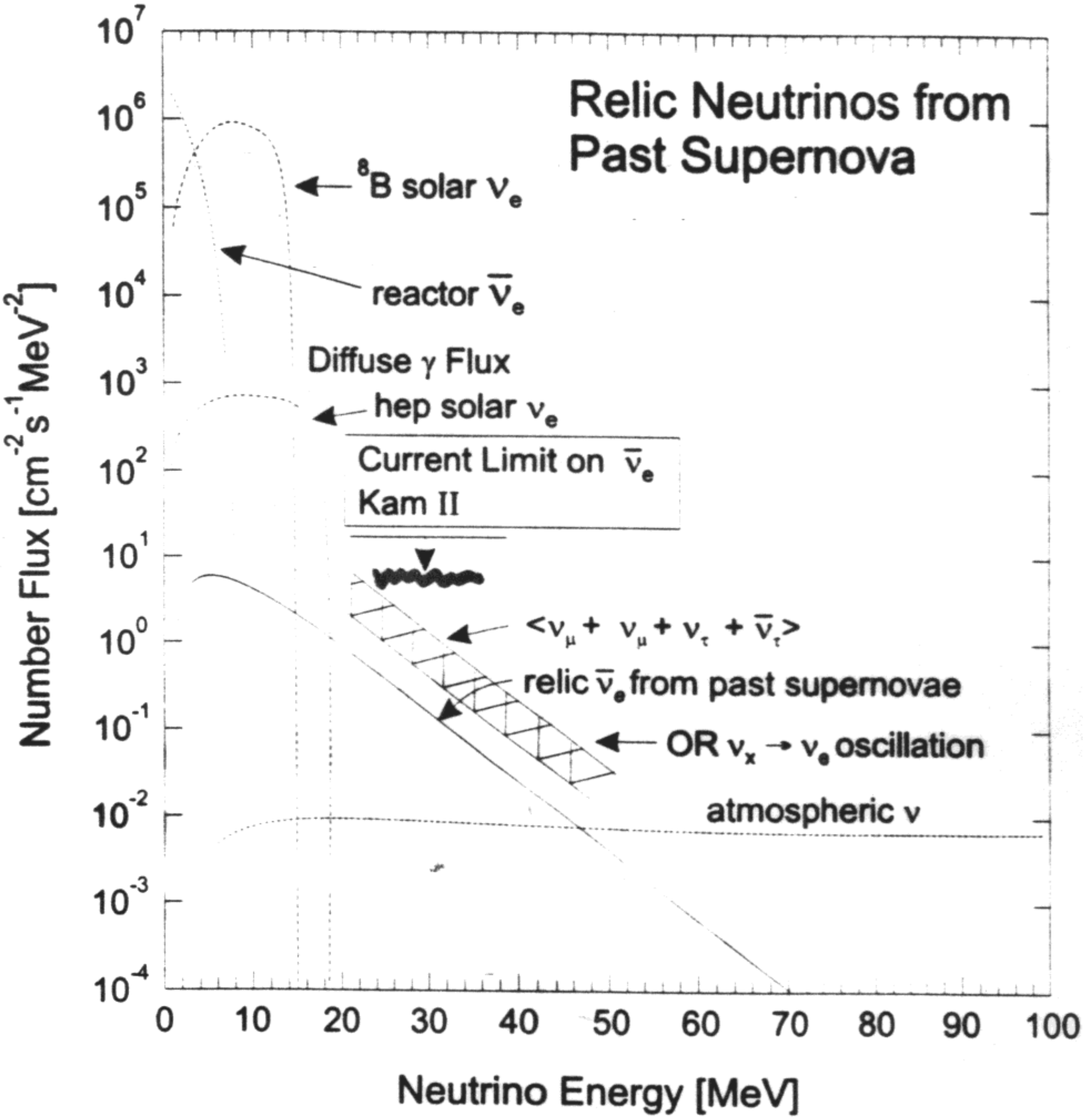
$\nu_e + Pb \rightarrow e + x$
↳ 1n
↳ 2n Signal

MSW $\nu_X \rightarrow \nu_e$ in the Super Nova MSW

The $2n|1n$ signal is much larger for ν_e interactions.
A signature for $\nu_{\tau,\mu} \rightarrow \nu_e$ in the SNII environment.

Relic SN Neutrino Detection

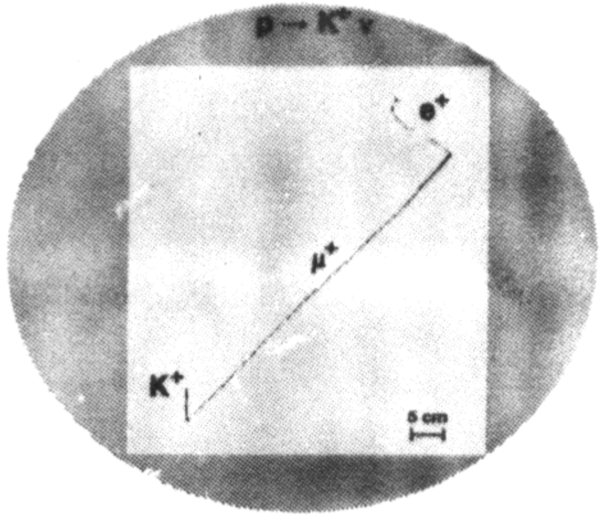




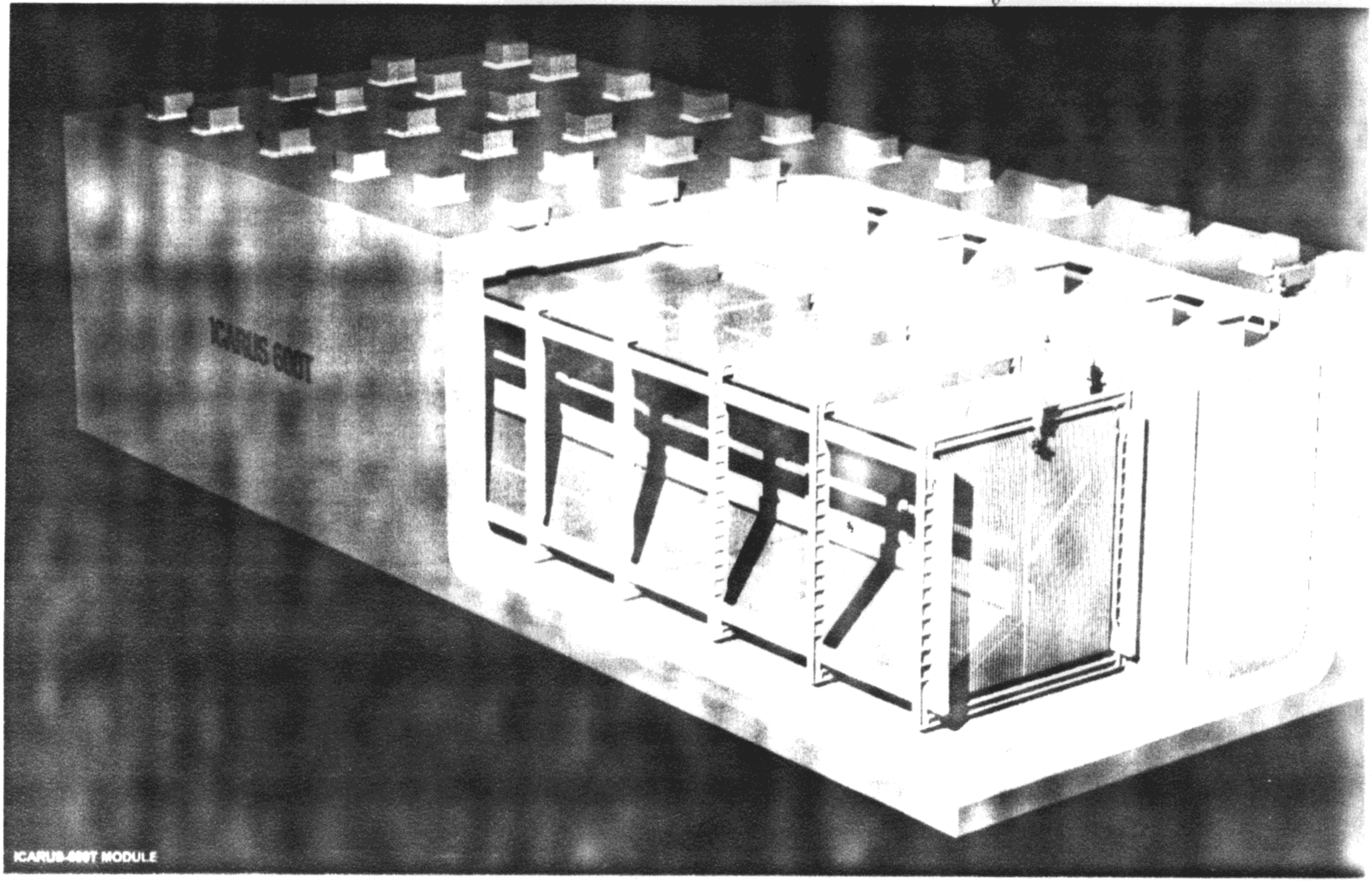
NOTE: $\nu_x \rightarrow \nu_e$ **in the supernova can boost the energy of the** ν_e **if we find** $<E\nu_e> \; > <E\bar{\nu}_e>$. **This will be a signal for neutrino oscillation in supernovae! and measure** $\sin^2 \theta x_e$.

ICARUS

A multipurpose detector for the years 2000



– FIRST 600 Ton Module of ICARUS –



Absorption Event Simulation

Relic $\bar{\nu}_e$ Detection with ICARUS

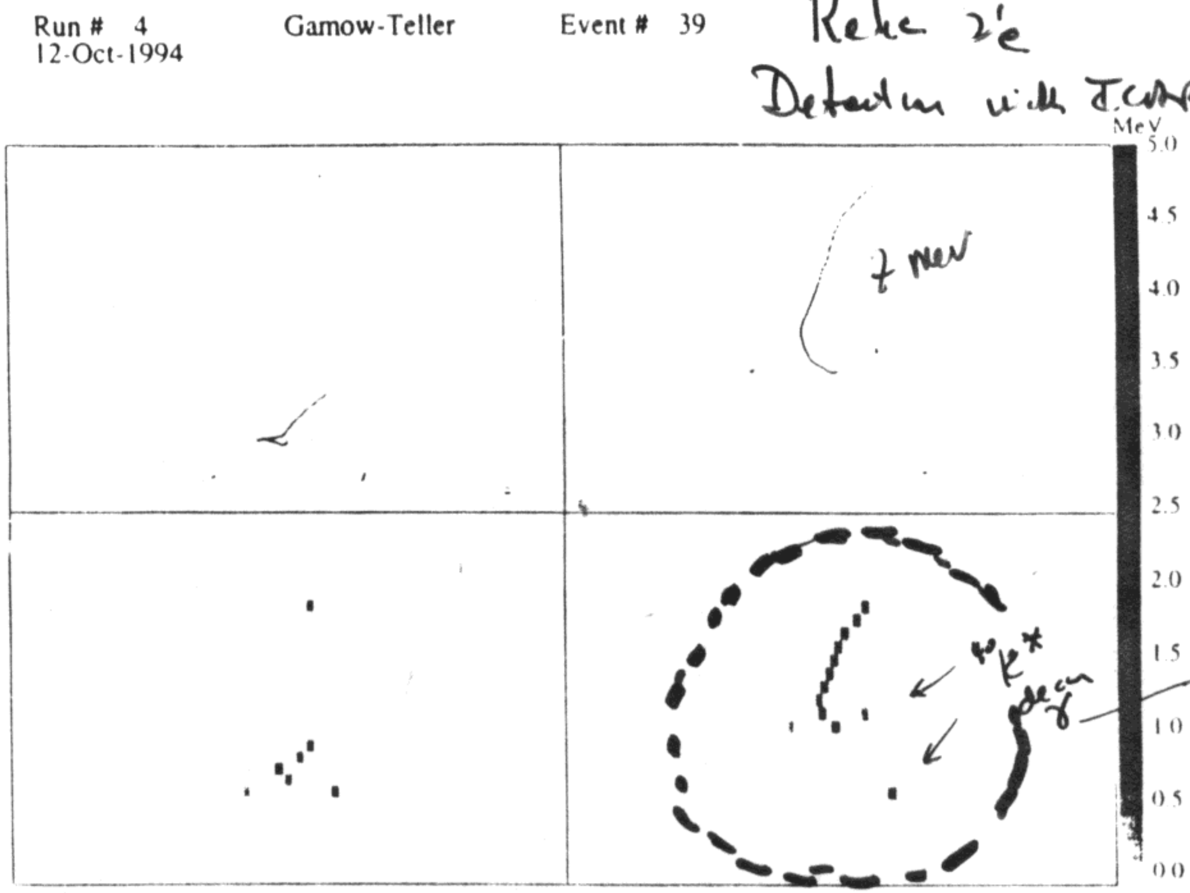


Fig. 2 Absorption event as generated by the GEANT Montecarlo program in two wire planes put at an angle of 60°. In the bottom it is shown the same event after digitisation. The grey scale of each pixel is proportional to the deposited charge. The resolution in the horizontal axis (drift direction) is 0.1 mm, and in the vertical axis is 3 mm (wire pitch). The projected track length is about 3 cm, the main electron energy is 7 MeV, the associated energy is 2 MeV and the associated multiplicity is 3.

ICARUS Detection of $\nu_e + {}^{40}Ar \to {}^{40}K^* + e$

$\hookrightarrow \gamma$

$\sum E_e + E_\gamma > 15$ MeV

$\gamma + e \to \gamma + e$ — Could also detect

$\nu_x + {}^{40}Ar \to {}^{40}Ar^* + \nu_x$

$\hookrightarrow \gamma$

$\hookrightarrow \gamma$

? multi γs

?

$\sum E_\gamma > 10$ MeV

Relic $\bar{\nu}_e$ ~ few events/year

Real Time SN Detection ? 300 events

3) REAL TIME SN II DETECTION

REQUIREMENTS OF A SUPERNOVA OBSERVATORY

1. **Life of Observatory ≥ Rate (yr) for SNII on Milky Way Galaxy**

   ≥ 20 - 40 years

   (Detectors will have other physics — Not in this talk)

   <KEY>

2. **EVENT RATE:**

   ~ 5 - 10 K $\bar{\nu}_e + P \rightarrow e^+ + n$

   ~ Few K $\nu_x + N \rightarrow \nu_x + N^*$ ↳ γ n …

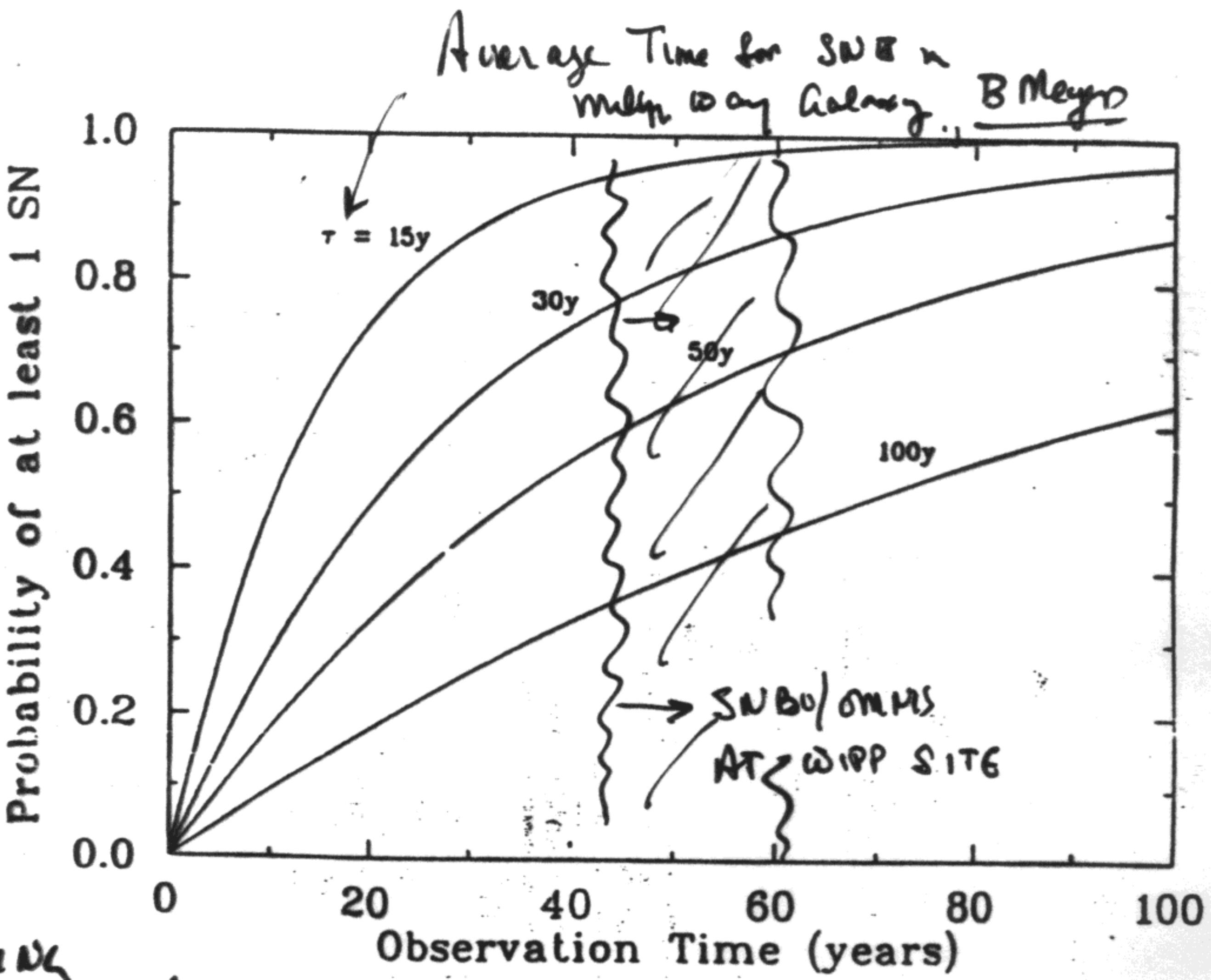
   $$\nu_x = \nu_\mu + \nu_\tau$$

TO:

A) **FIT MODEL OF SNII PROCESS**

B) **EXTRACT A NEUTRINO MASS OR NEUTRINO OSCILLATION** ****

C) **LEARN ABOUT SNII EXPLOSION PROCESS** AND R PROCESS SITE ??? *



KEEPING AN OBSERVATORY GOING 50 years IS NONTRIVIAL ⟷ LENGTH of TIME DOE HAS EXISTED

AT LEAST ONE DETECTOR MUST OPERATE CONTINUOUSLY FOR $\geq$ 40 YEARS FOR A

Detector Study Effort

SUPER**N**OVA **O**BSERVATORY!

⇒ **SNBO**

Detection of ν_μ and ν_τ From SuperNova Neutrinos In REAL TIME

Two Possibilities:

a) $\nu_x + e^- \rightarrow \nu_x + e^-$

- Rate Low because $\sigma_{\nu_x e}$ Small
- Background from $\nu_e e \rightarrow \nu_e e$

b) $\nu_x + N \rightarrow \nu_x + N'$

N = D, C, O, NaCl, Pb, Fe...

$N' \rightarrow n + X$ — SNO / SNBO/OMNIS

$N' \rightarrow \gamma + X$ — Super K / LVD

❑ SIGNAL DEPENDS ON ν_μ, ν_τ ENERGY SPECTRUM

Long Time [SNBO] Detector

"A SUPERNOVA BURST OBSERVATORY TO OPERATE 50-100 YEARS AND DETECT μ AND τ NEUTRINOS"

SNBO / OMNIS

David B. Cline et al.
University of California
Physic & Astronomy Department
Box 951547

ABSTRACT

This group is developing the least expensive SuperNova Neutrino Burst Observatory. That will also be sensitive to μ and τ neutrinos.
Recent progress has been considerable with a site for the detector have been selected at WIPP, Carlsbad, New Mexico. Current plus one to construct the first phase of the detector by 2002 and for the detector to operate out of at least 2040 at possibly 2100.

SITE A + A' (Soudan)

Site A: DOE Carlsbad Underground Site, New Mexico. / Plans

US participants:

USA GROUPS

R N Boyd[1], R L Brodzinski[2], D B Cline[3], S A Colgate[4], E J Fenyves[5], G M Fuller[6], D Knapp[7], S Labov[7], K Lee[3], A Murphy[1], L Nakae[7], M M Nieto[4], W Vernon[5], J R Wilson[7]

[1]Ohio State University; [2]Pacific North West University; [3]University of California, Los Angeles; [4]Los Alamos National Laboratory; [5]University of Texas Dallas; [6]University of California, San Diego; [7]Lawrence Livermore National Laboratory.

SITE B

Site B: Boulby Mine, UK.

UK participants:

UK GROUPS

W G Jones[1], J D Lewin[2], R Marshall[3], N J T Smith[1], P F Smith[2], N J C Spooner[4], J J Quenby[1], K Stevens[3], T J Sumner[1]

[1]Blackett Laboratory, Imperial College, London; [2]Rutherford Appleton Laboratory, Chilton, Oxford; [3]University of Manchester; [4]University of Sheffield.

2 SITES FORM "COINCIDENCE" NOW

⟹ ALERT Super Nova Watch Network — mtg Sept 9/10/12 Boston U.

SN ALERT SYSTEM
→ Astronomers
→ Amateur A

SNBO Concept

OMNIS

D Cline
C Fiala
J Wilson
B Cundy
D Boyd
P Smith

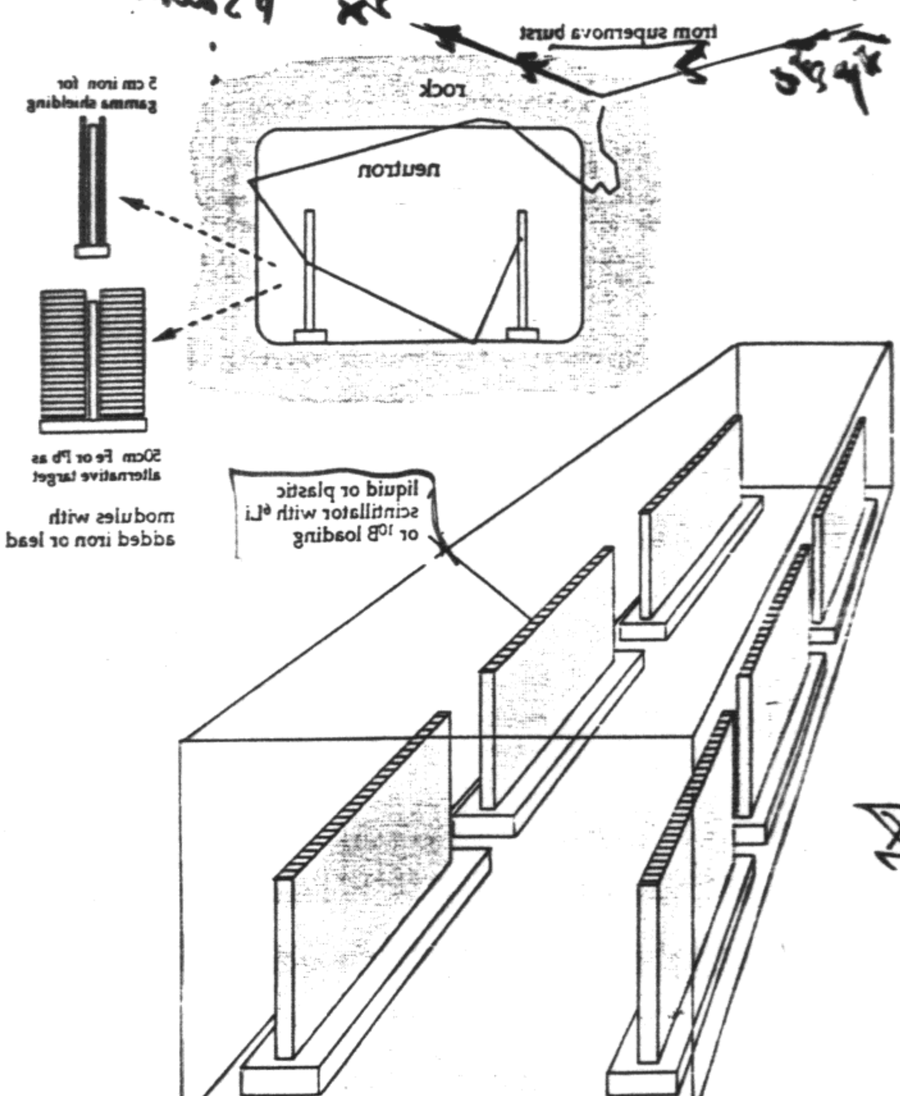


Fig 5 Illustrative arrangement of detector modules along rock tunnel, also showing use of supplementary iron or lead for gamma shielding or as alternative neutrino target

Basic Reaction

$\nu_{\mu,\tau}$ + Nucleus

$\nu_{\mu,\tau}$ + Neutron + X or 2 neutrons

Neutron Detector!

w Inexpensive

Very Stable

Detectors!

Current concept

To Reduce Uncertainty w Energy ...

3 Targets: NaCl, Fe (Mines), Pb

3 Lab:
- WIPP Site – New Mexico – USA
- Soudan Mine – Minn. – USA
- Boulby Mine – UK

CURRENT PLAN

P. Smith
Astroparticle Physics
8, 27 (1997)

Simulation of Galactic SN II
in SNBO Detector
CLear Signal

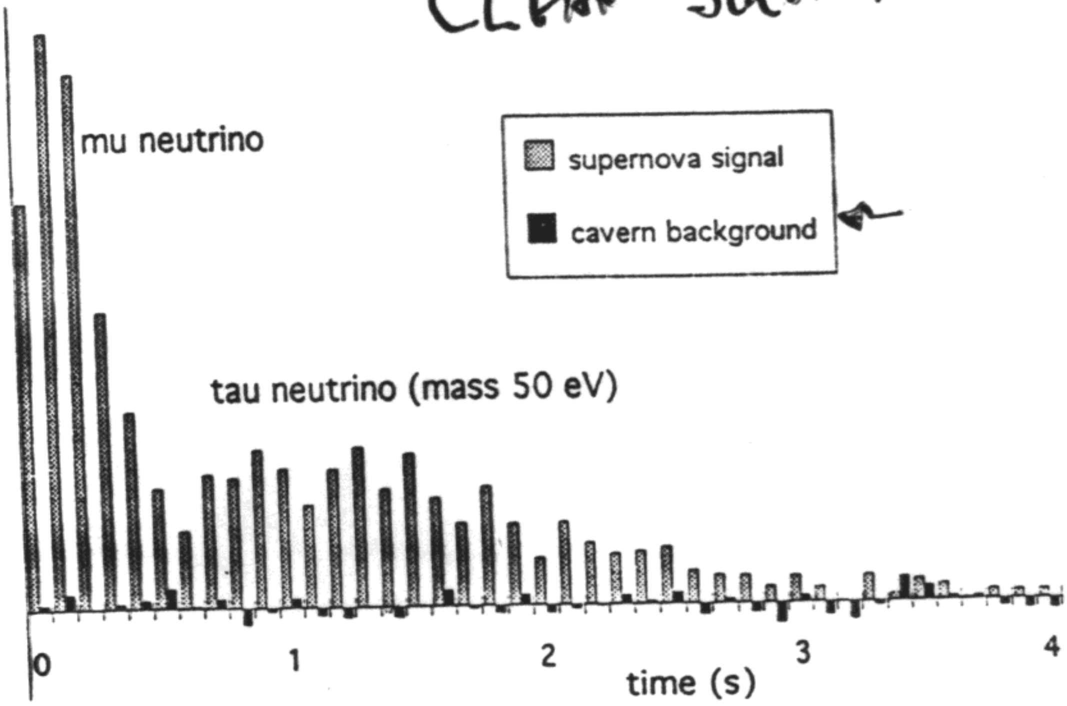
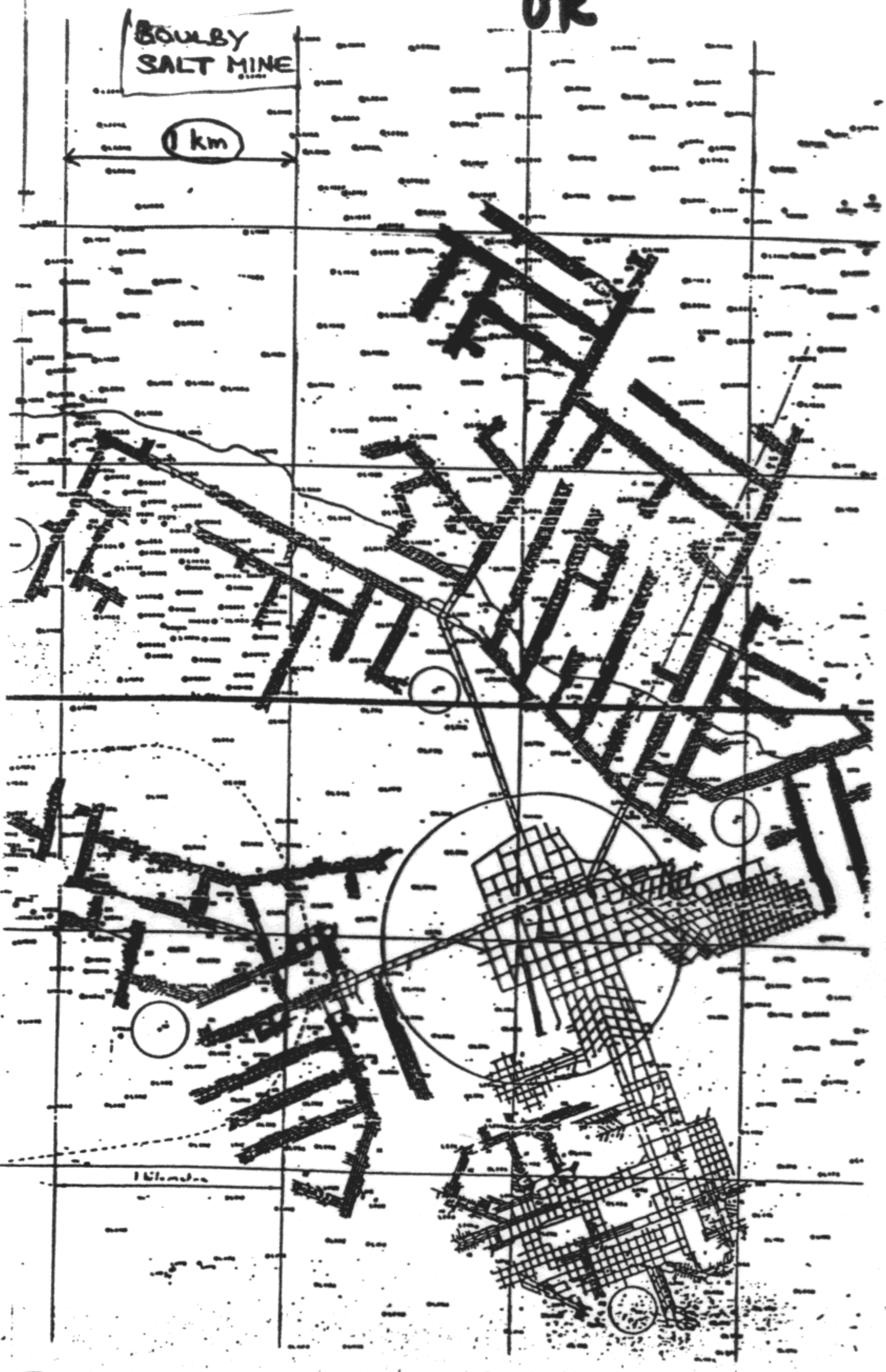


Fig 10 Simulation of 1000-event arrival time profile of mu/tau neutrinos from 8 kpc Galactic supernova, binned in 0.1 s intervals with cavern background fluctuations shown separately for comparison. The profile corresponds to that of Fig 3 for 50 eV tau neutrino mass.

SITE B
UK



Boulby mine

One of deepest mine in Europe/UK...

[redacted]

RECENT DEVELOPMENT

SITE A'

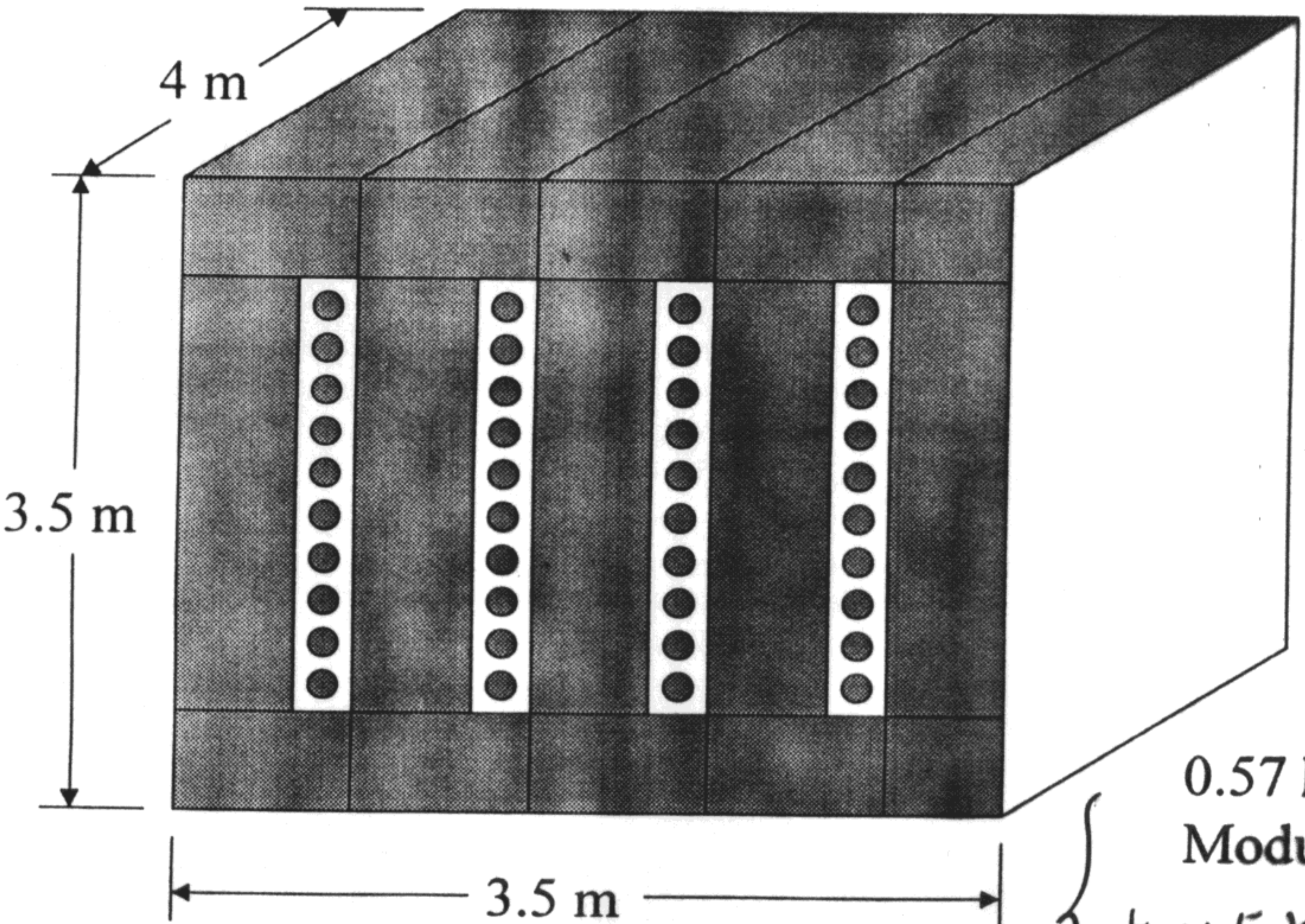
OMNIS Pb-Detector

MINOS + Pb Target in Soudan!

FOR SOUDAN MINE

SITE R Boghdadi (Ohio State)

OMNIS



SOUDAN MINE

0.57 kT Lead Module

+ ~5 KT MINOS DETECTOR

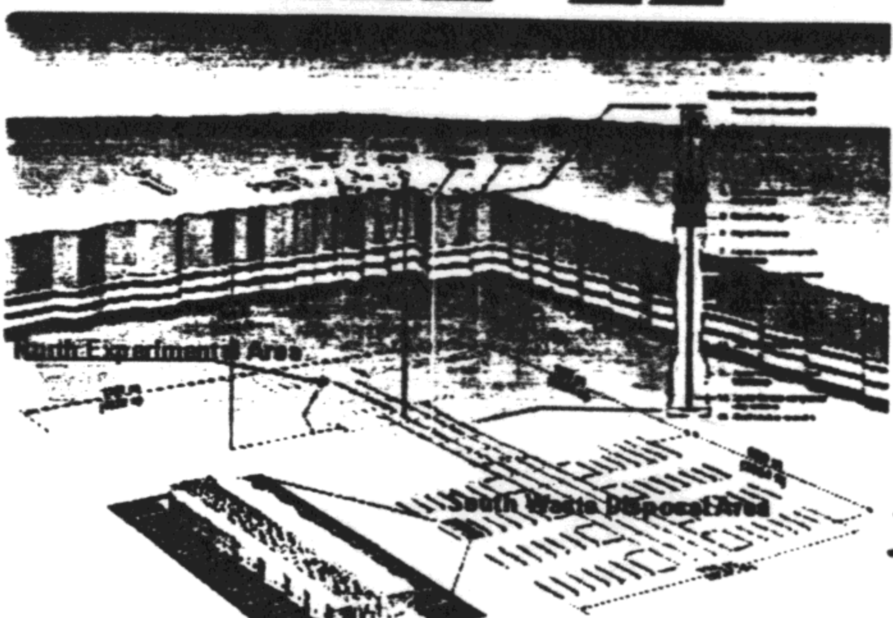
LANL MEETING FEB 99

UC-INPAC PROPOSAL TO KECK FOUNDATION MAY 99

WIPP may be an Ideal Setting for Neutrino Observation Experiments

- Federal Facility operated by the Department of Energy
- 650 m below surface
- About 250 m of essentially pure NaCl both above and below facility horizon - surrounded by >10 km of NaCl on all sides
- Extremely low (and soft) gamma background radiation spectrum (0.3 - 0.5 micro R/hr primarily from K-40)
- Waste Disposal and Experimental Areas separated by over 900 m
- Extensive facility infrastructure already in-place:
  - material transport and personnel/equipment access
  - ventilation systems
  - power and high speed data communications
  - surface support and highway access

FOR UNDERGROUN LAB



⇒ SNBO/OMNIS WOULD BE A KEY PROJECT

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 399 (1997) 269–274

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

Evaluation of the WIPP site for the supernova neutrino burst observatory

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Received 21 June 1996; received in revised form 17 June 1997

Abstract

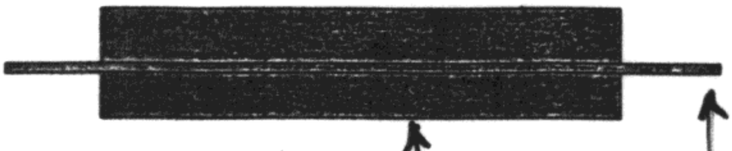
Measurements of the neutron background in a potential underground site for the Supernova Neutrino Burst Observatory (SNBO) have been made. The SNBO will ultimately be capable of detecting μ and τ neutrinos from a supernova. Furthermore masses of the μ and τ neutrinos might be measurable in the range of 10–50 eV. SNBO operates by detecting the neutrons caused by interaction of the supernova neutrinos with rock. It will consist of order ten thousand neutron detectors located in an underground environment having a very low intrinsic radiation level. The limit to the size, hence sensitivity, of SNBO is thus the neutron signal-to-noise ratio, which depends on the neutron background in the environment of SNBO. Thus we have made neutron background measurements at the Department of Energy Waste Isolation Pilot Plant (WIPP) located near Carlsbad, NM. The value of the ambient neutron flux we determined, 332 ± 148 neutrons $m^{-2} d^{-1}$, shows that the background levels in this facility are sufficiently low to warrant construction of a galactic supernova neutrino detector

OSU/UCLA MEASUREMENTS AT THE WIPP SITE

MINOS Plastic Technology for WIPP Site?

2 Detector Scheme
(1) Gd + Liquid Scint. - OSU/Manchester (Absorb Tanks)
(2) ^{6}Li + Plastic - MINOS Tech - UCLA +

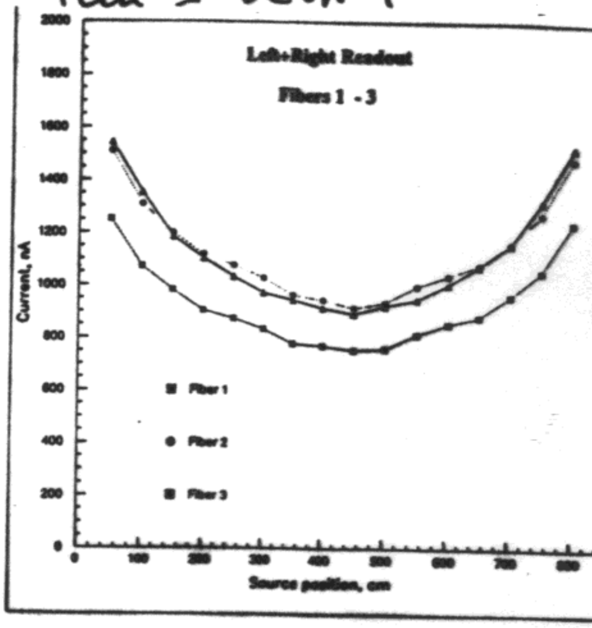
UCLA
Kevin Lee



Load with ^{6}Li

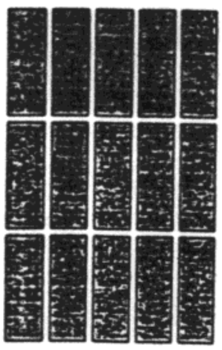
Readout Scan fiber

A Para and FNAL



New Study ^{6}Li loaded Detector

OMNIS Solid Detector
•Load Gd, Li6, or B
•Multi-channel PMT (or multiplexing) not necessary
•Dimensions depend on type of neutron absorber (each plane can be 15 cm thick)



11/18/97

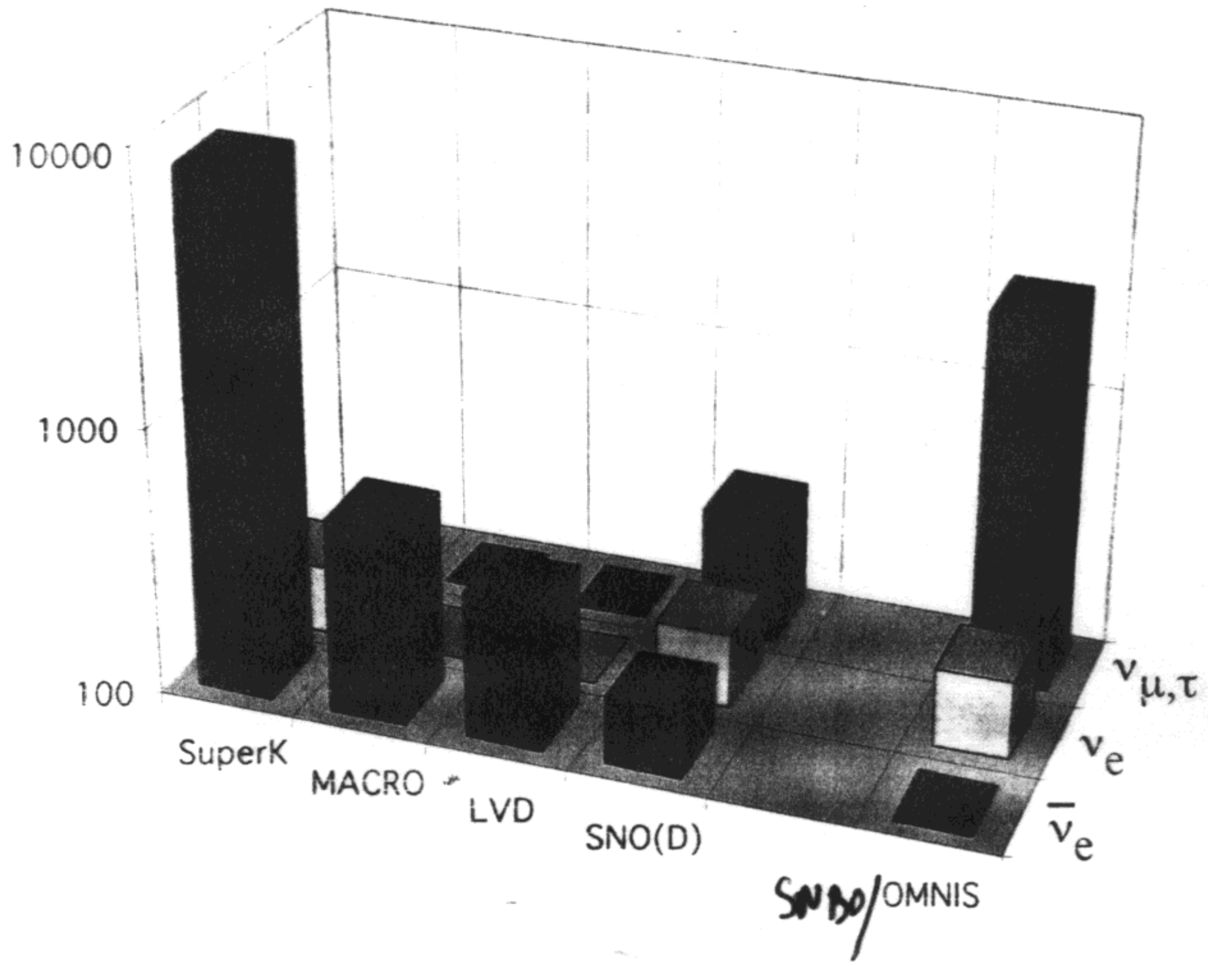
Safety: !! Key for WIPP Site

Plastic scintillator is NOT a fire hazzard and has passed safety review for MINOS (M. Goodman and A. Para)
NO PVC and abestos allowed by the Mine Safety and Health Administration but will review materials for safety (W. Walker)
Acrylic plastics are fire hazzardous (deform at 160 deg. F and working point at 320 deg F, Custom Extrusion)

WANT A DETECTOR TO OPERATE ~50 YEARS!

Comparison of world detectors

Event numbers for supernova at 8 kpc



ASPEN 98

EXTRACTION OF ν MASS OR OSCILLATION SIGNAL

1. **ASSUME ALL DETECTORS GIVE:**

   ~ 8000 $\bar{\nu}_e$ (E_e+) 〉 Super K / ICARUS
   ~ 1000 ν_e (E_e-) SNO ....
   ~ 2000 $\nu_x = (\nu_\mu + \bar{\nu}_\mu + \nu_\tau + \bar{\nu}_\tau)$ SNO + SNBO ...

2. **FIT $\binom{\nu_e}{\bar{\nu}_e}$ TIME AND ENERGY SPECTRUM TO EXTRACT SII MODEL** — Extract $\langle \bar{\nu}_e, \nu_e \rangle$ mass limit

3. **FIT TIME SPECTRUM OF $\binom{\nu_e}{\bar{\nu}_e}$ TO GIVE t_0**

4. **USE ν_x DATA TO SEARCH FOR A ν_τ, ν_μ NEUTRINO MASS BY TOF** (SHARP TIME STRUCTURE ??)

5. **SEARCH FOR MSW OSCILLATION $\nu_x \rightarrow \nu_e$**

   a) 2 Neutron Signal in SNBO/OMNIS

   b) ν_e Spectrum in SNO / ICARUS

Expect to measure m_{ν_x} to ~ 15 eV

↓

5 eV

if sharp time structures in ν_x spectrum