Low Energy Neutrino Astrophysics

- Solar neutrinos
- Supernovae neutrinos

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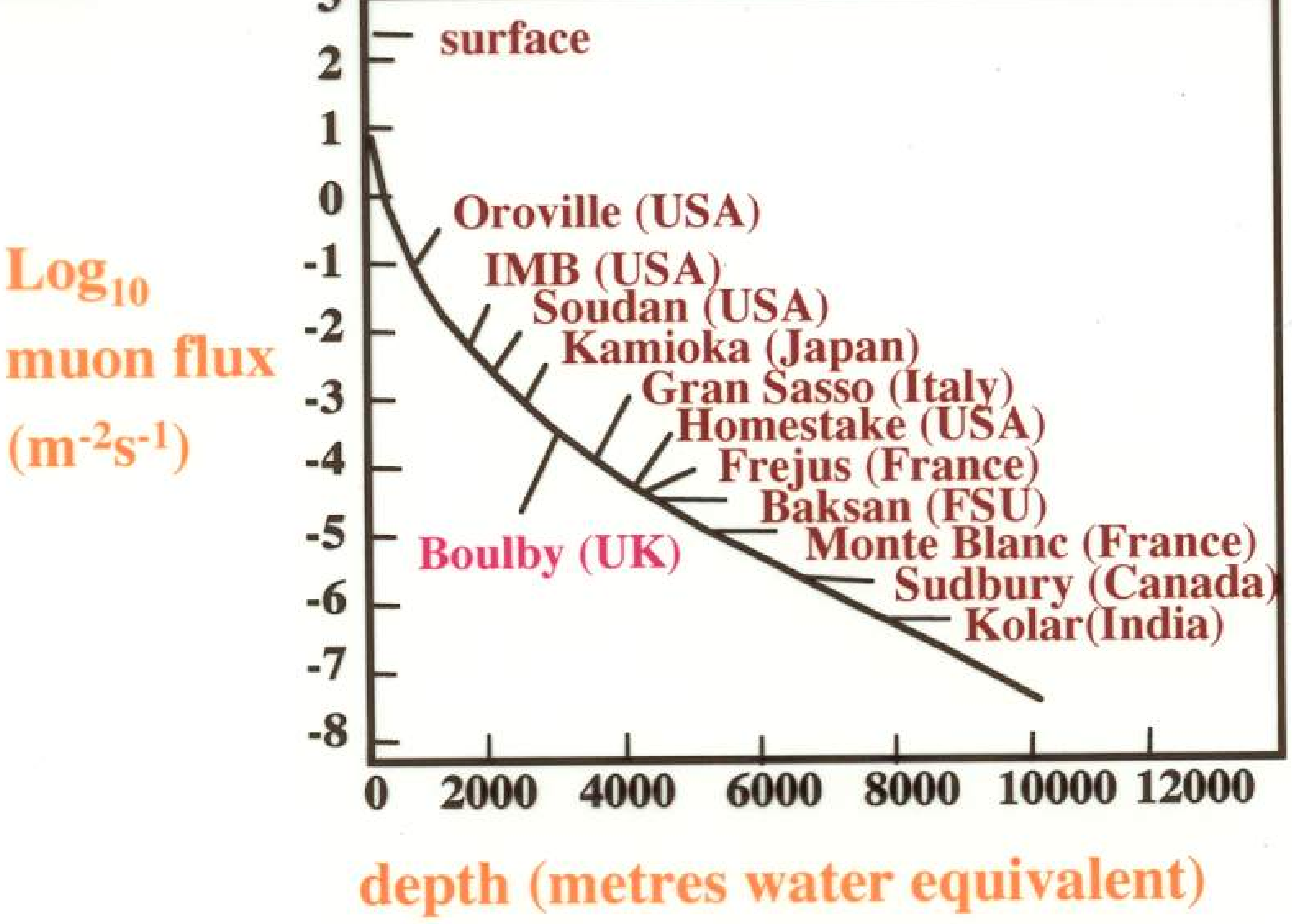
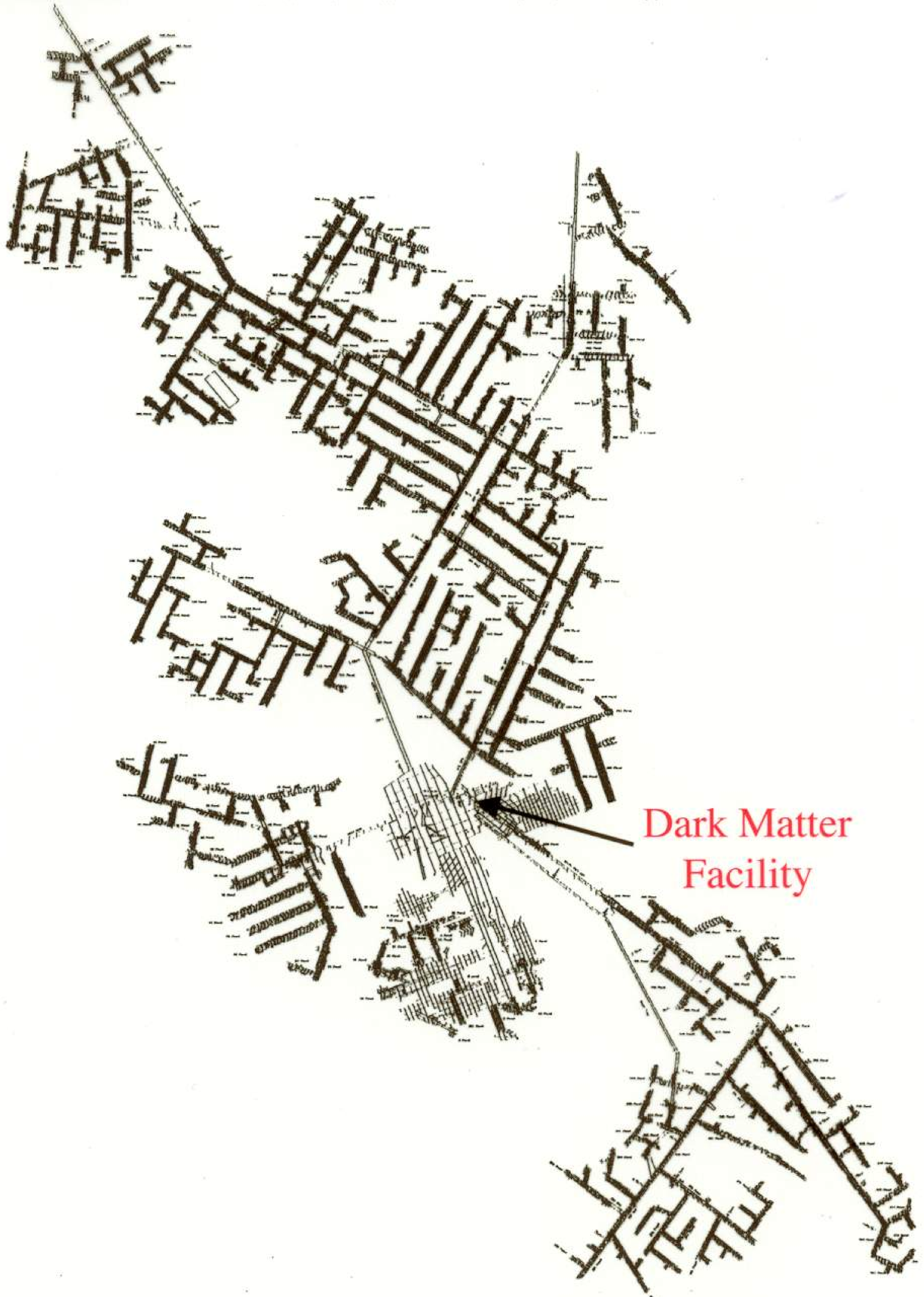

Log10 muon flux (m-2s-1)
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
surface
Oroville (USA)
IMB (USA)
Soudan (USA)
Kamioka (Japan)
Gran Sasso (Italy)
Homestake (USA)
Frejus (France)
Baksan (FSU)
Monte Blanc (France)
Sudbury (Canada)
Kolar(India)
Boulby (UK)
0
2000
4000
6000
8000
10000
12000
depth (metres water equivalent)


Manchester
Sheffield
RAL
Imperial College

Boulby



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JIF Underground Facility

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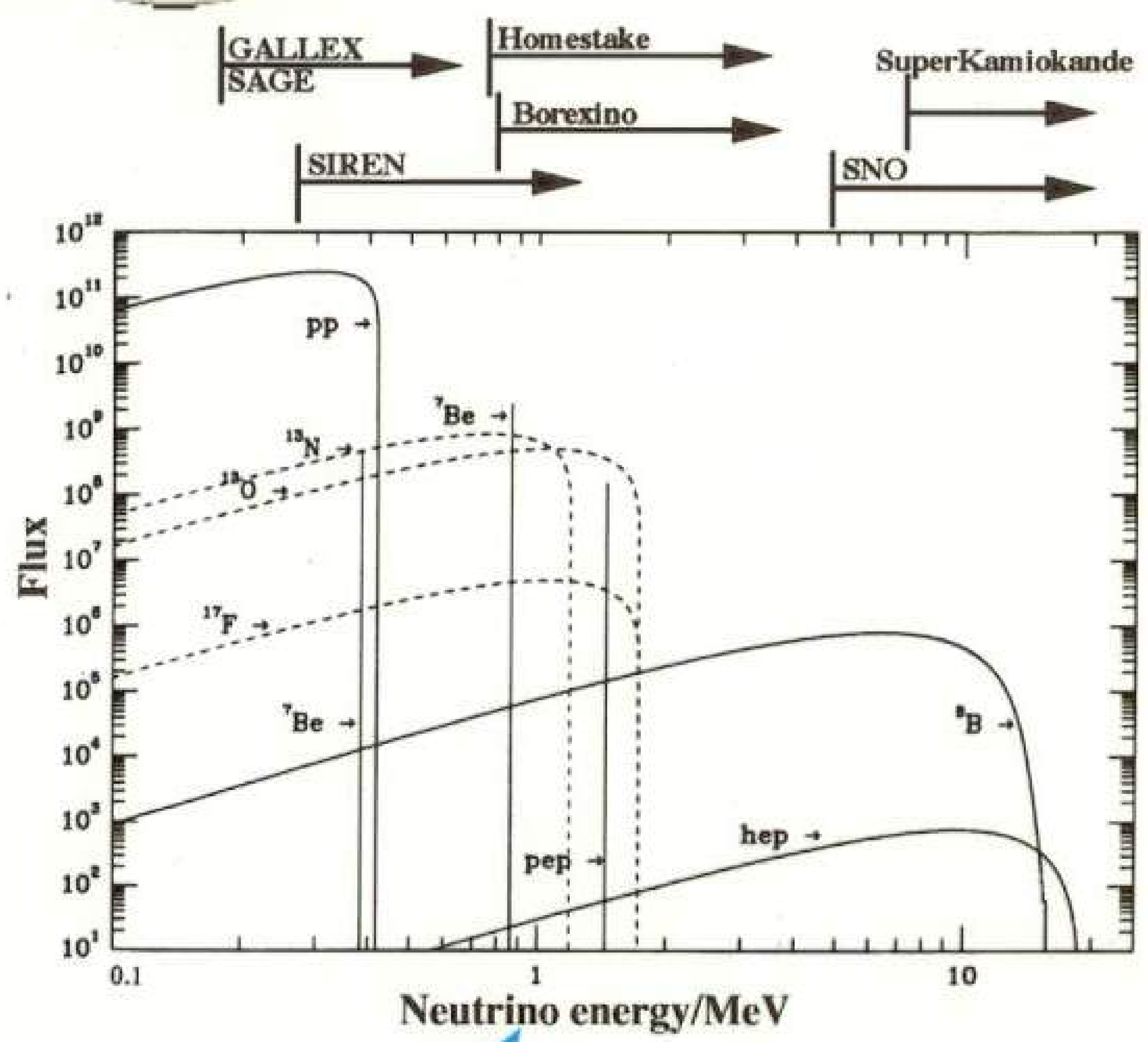
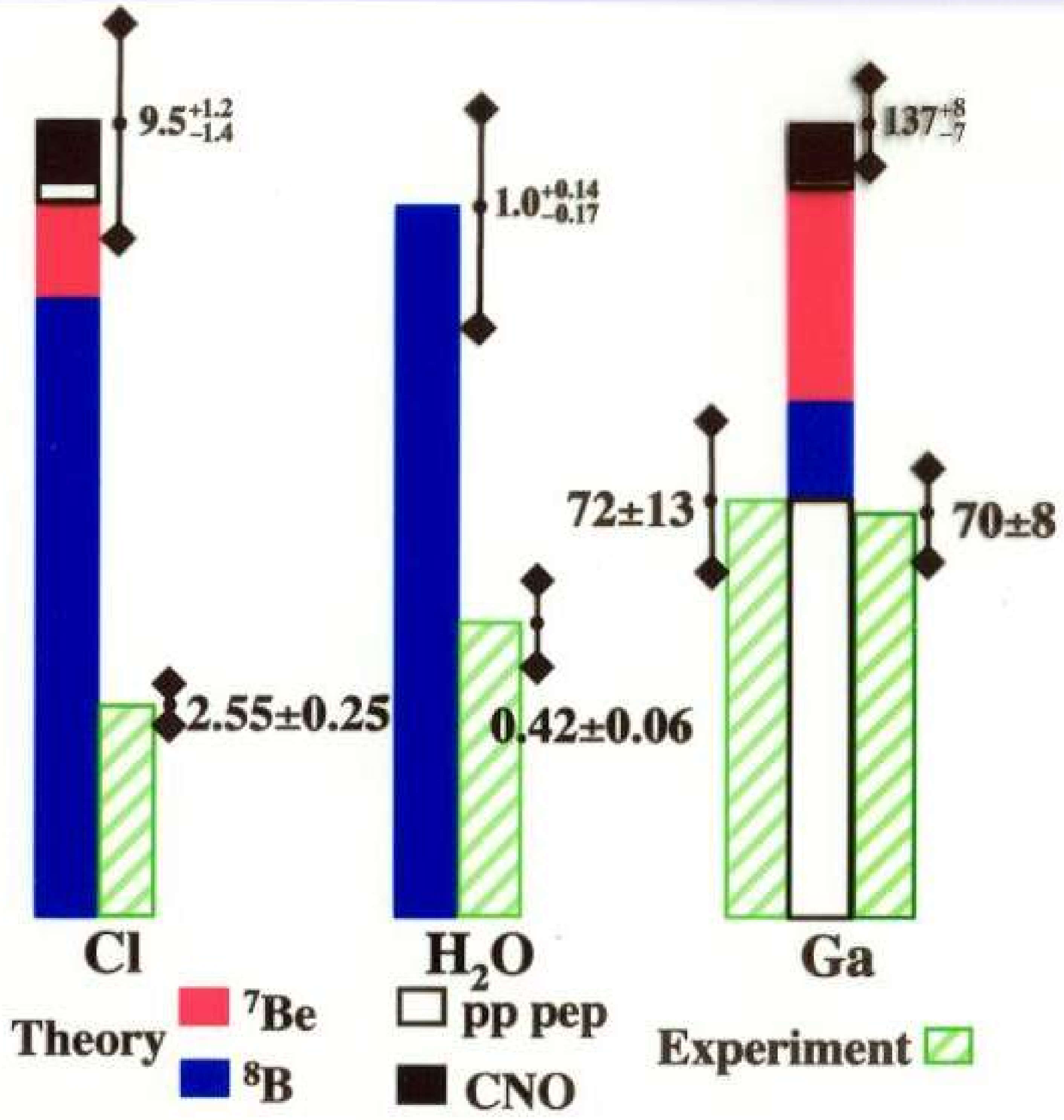
JIF Surface Buiding

Solar Neutrino Problem

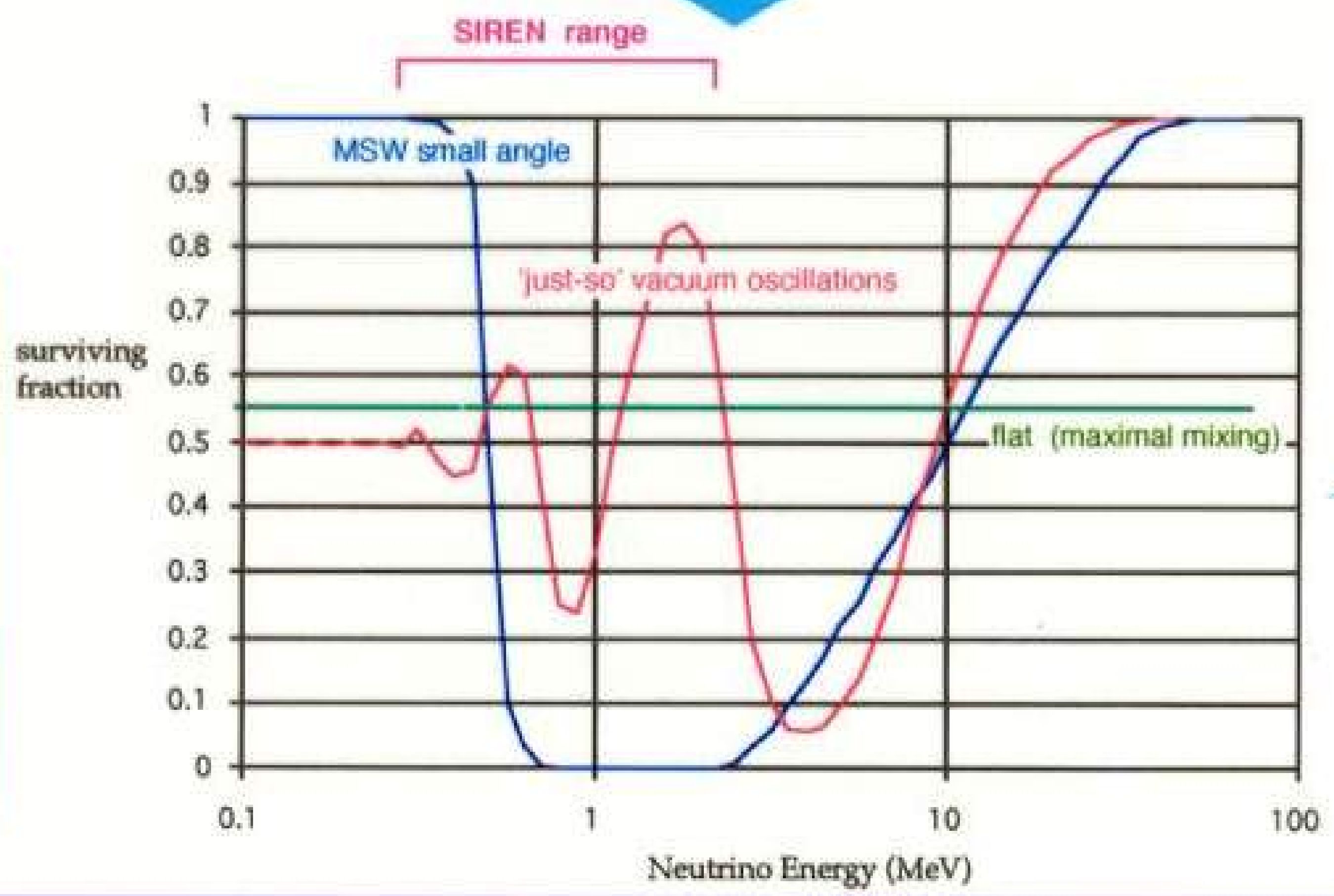


No acceptable solution at a 99% C.L. (J. Bahcall *et. al.*, Phys. Lett. B 433, 1 (1998))

Unless Oscillation



SSM from standard nuclear physics, constrained by luminosity and helioseismology



Suppression factor due to ν oscillation

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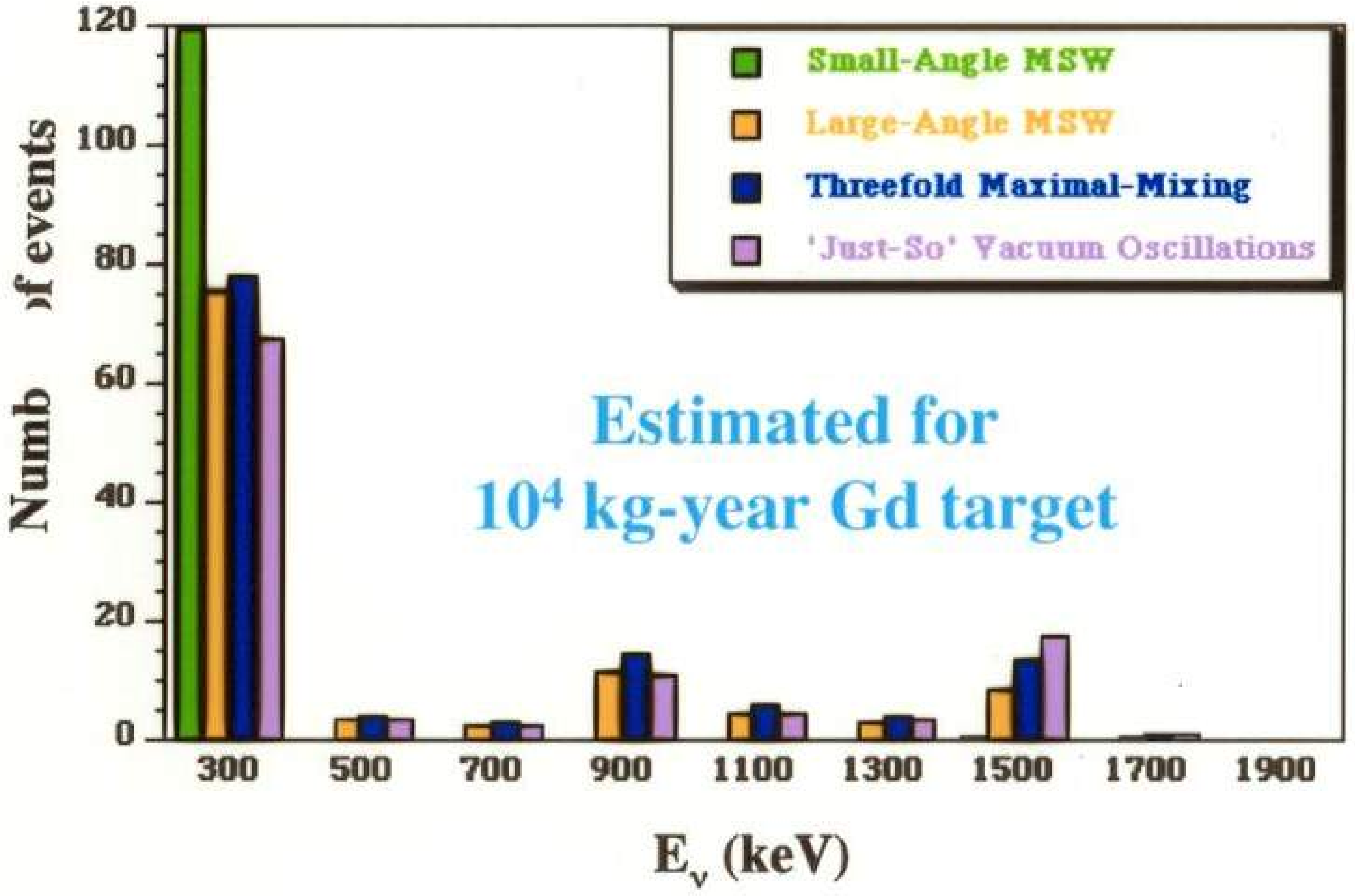
Solar Neutrino Problem

- Based on ν_e-capture on ^{160}Gd reaction (Raghavan)
  - Real-time signature and E_ν (spectroscopy)
- Requires means of reading the signal
  - Gd loaded scintillator
  - Gd loaded plastic scintillator
- Currently work
  - Preparing vessels for background messurments
    - Surplus Palo Verde materials



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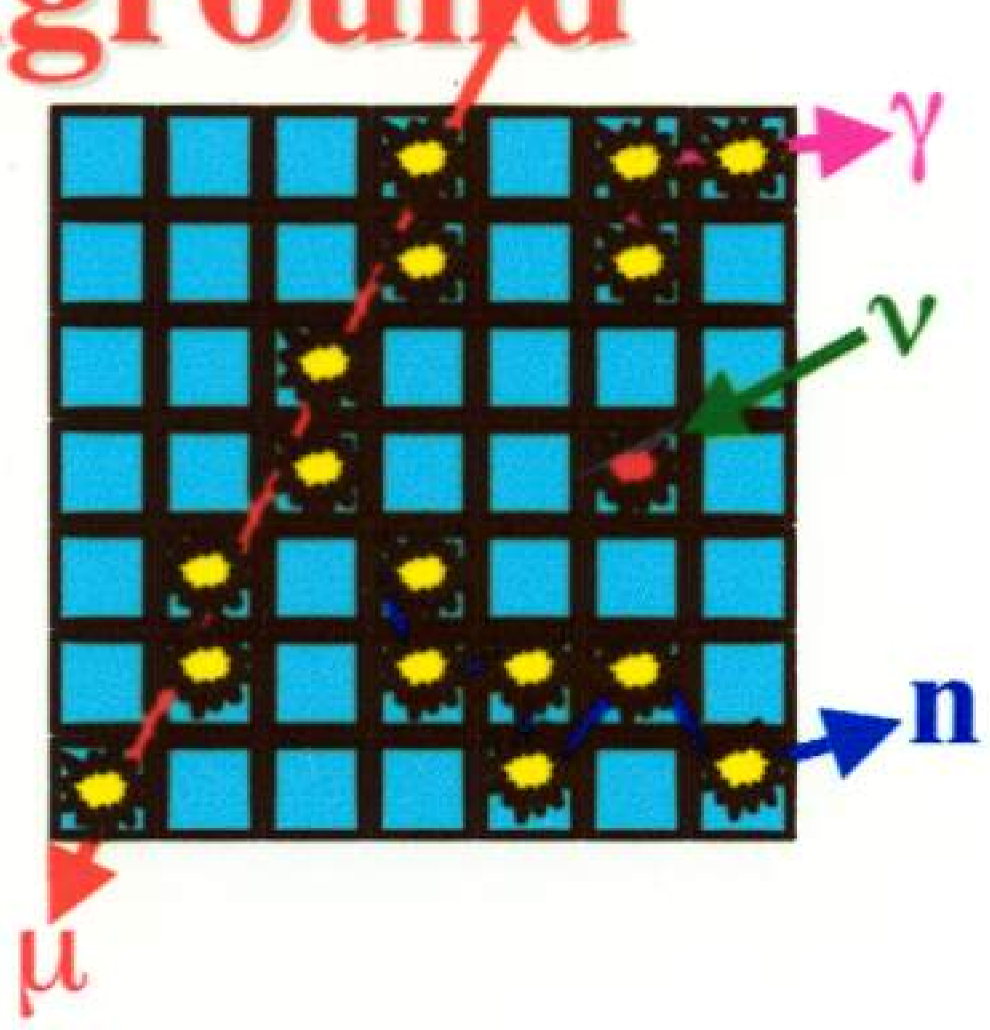
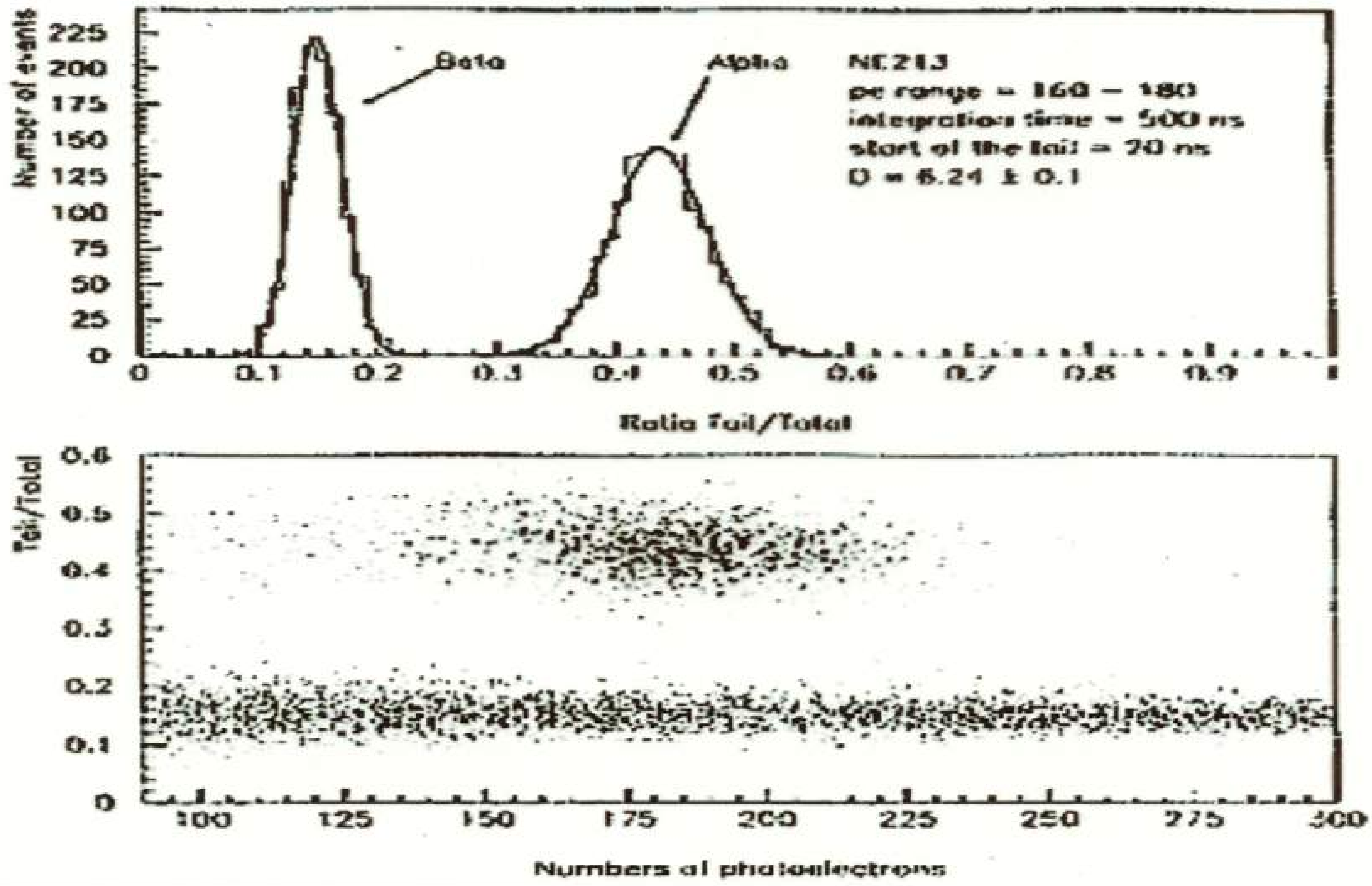
SIREN

Sources of Background



- Uncorrelated
  - ☛ μ, γ and n.
    - Shielding and depth (3000 m w.e.).
    - Detector segmentation.
    - Coincidence signature.
  - ☛ α from ^{156}Gd
    - Small segmentation.
      - ✧ <0.1m^3 noise falls bellow 10^{-1} of signal.
    - Raise threshold.
      - ✧ 2.14 MeV α ≈ 60 keV γ (depends on quenching)
    - PSD [G. Ranucci *et. al.*, NIM A 412 (1998) 374]



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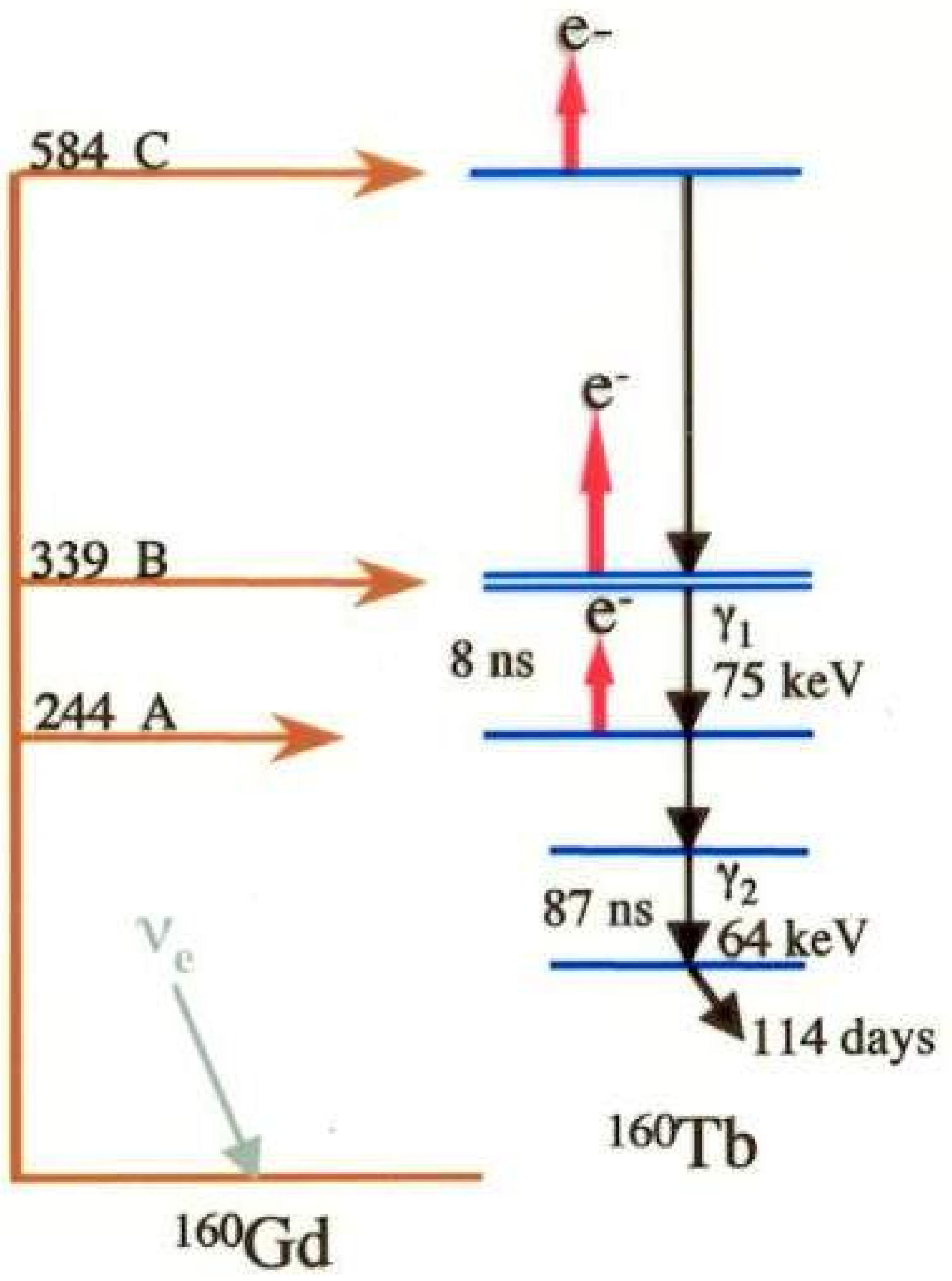
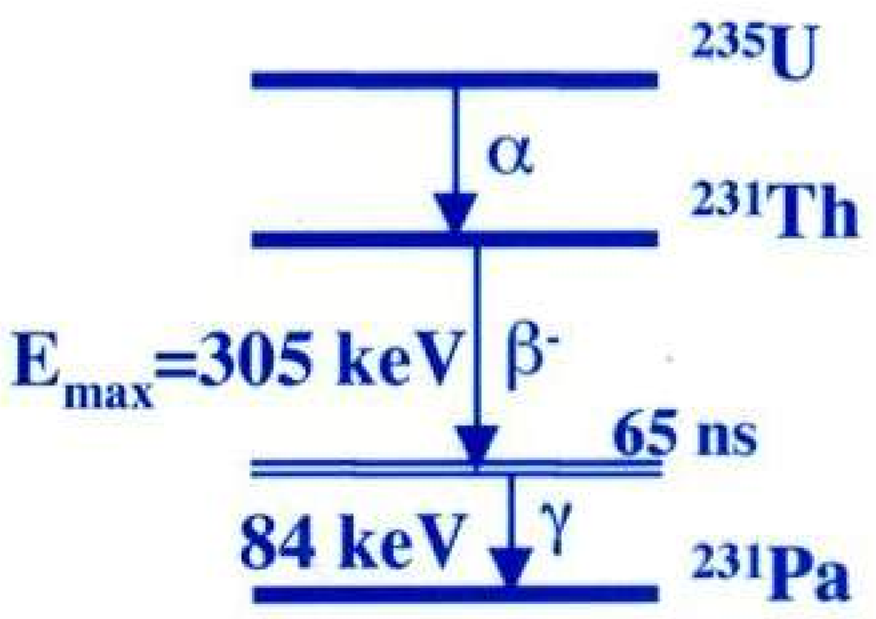
SIREN-Calibration

- Expect β^- in (delayed 87 ns) coincidence with 64 keV γ
  - ☛ **threshold energy 244 keV**



- Use correlated reaction in ^{235}U chain to simulate ν_e+^{160}Gd signal
  - ☛ **Contaminate scintillator if necessary**
    - get 305 keV β^- in (delayed 65 ns) coincidence with 84 keV γ



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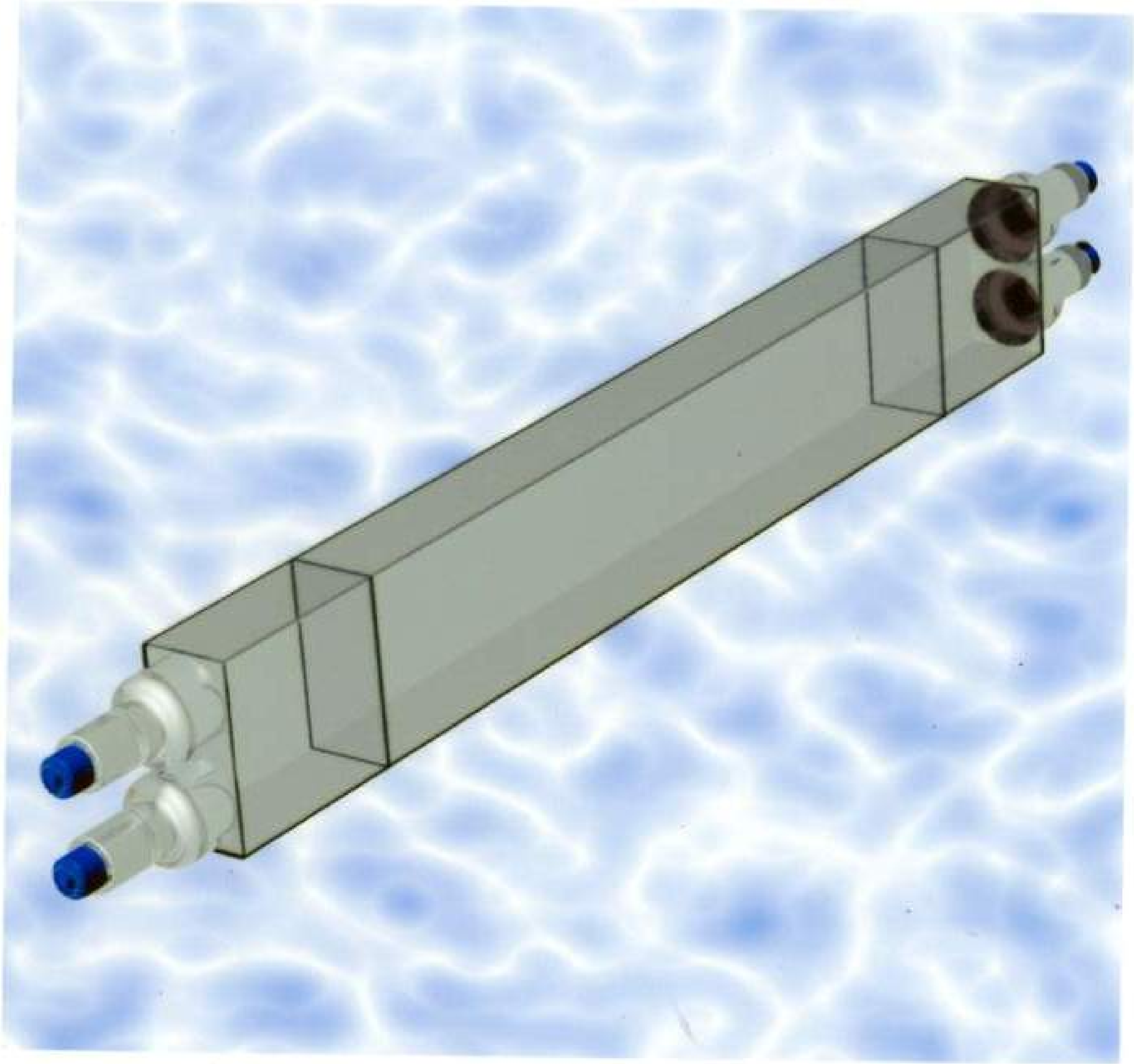
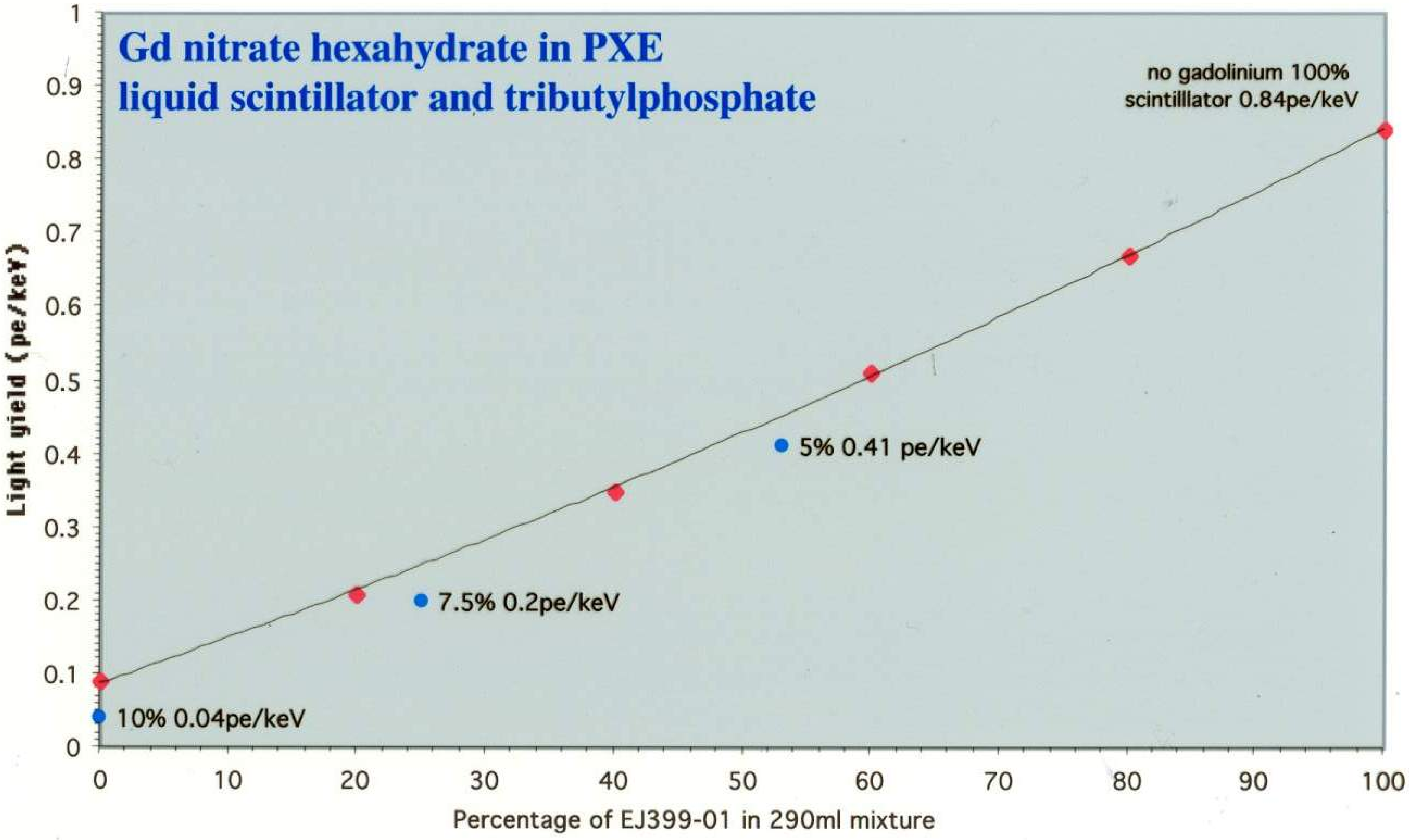
SIREN Test Module

- To be constructed from recycled Palo Verde module
  - ☛Acrylic walls for total internal reflection and radio purity
  - ☛Wrapped in Cu foil to exclude light
  - ☛Fiducial volume of 60 litres
  - ☛viewed by four 5" fast pmts
  - ☛oil buffer to attenuate background due to pmt glass
  - ☛simulation and optimisation in progress



Loaded Scintillator

Light yield using muon telescope of EJ399-01/TBP mixture



Ongoing Work

- Characterisation of scintillation profile
  - ☛ **single photon counting**
    - due to α
    - due to β
- Testing of different scintillator cocktails for Gd loading
    - diisopropylnaphthalene
    - 1-methylnaphthalene

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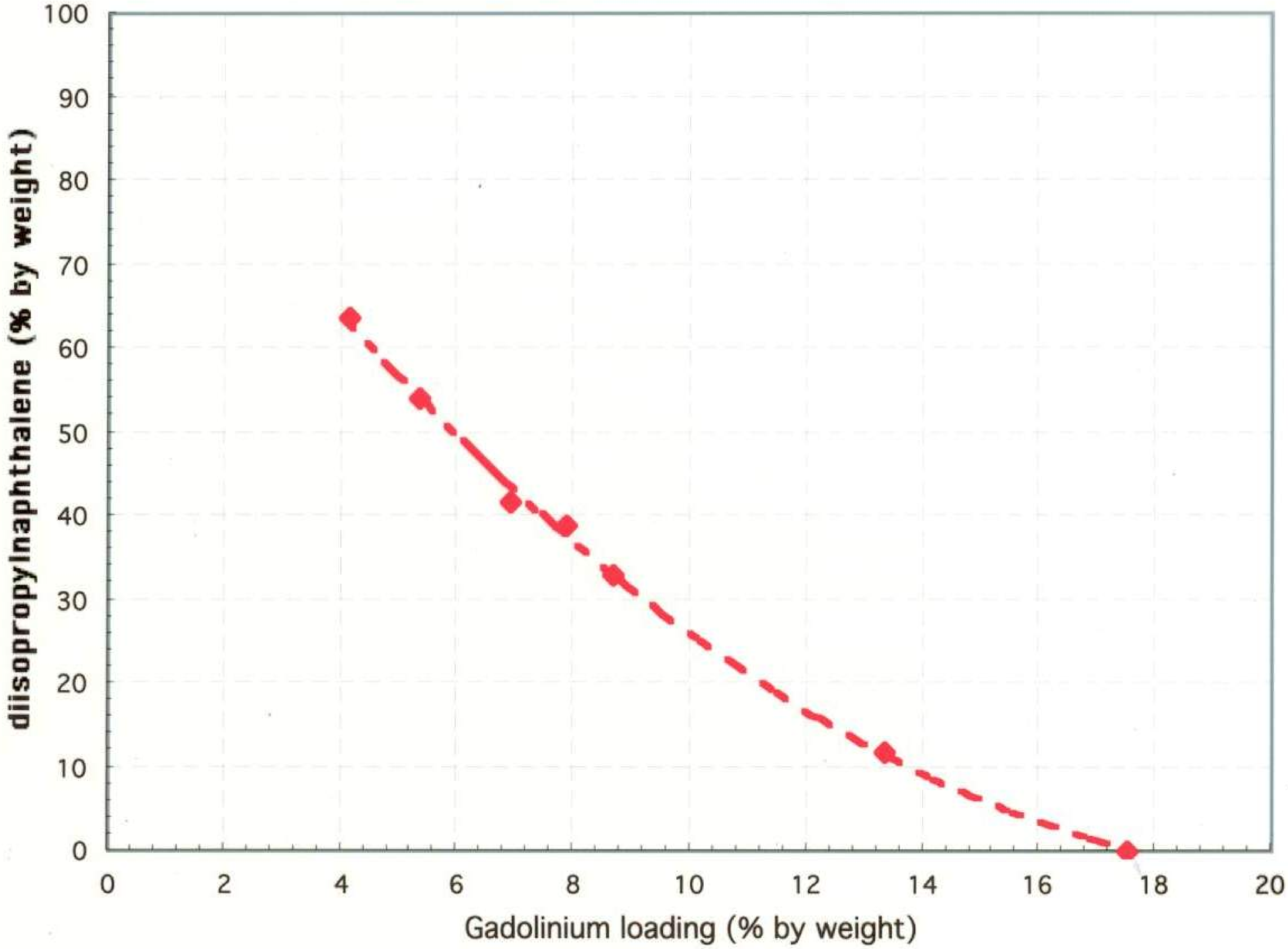
diisopropylnaphthalene vs Gd concentration



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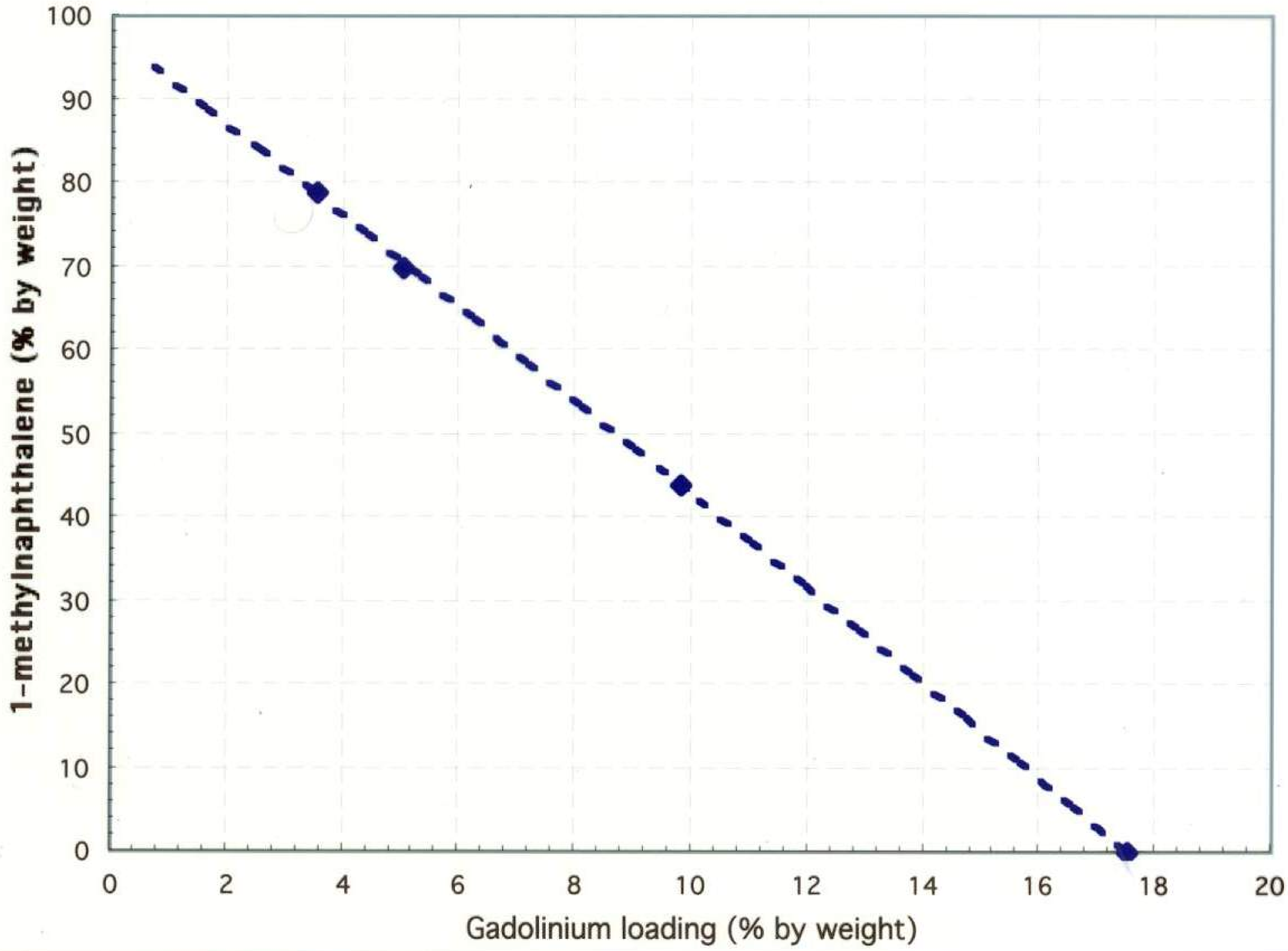
1-methylnaphthalene vs Gd concentration



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OMNIS concept

First proposed by Cline *et al.*

- ☆ **Neutral current excitation**

  $\nu + A(Z, N) \rightarrow A^*(Z, N) \rightarrow A(Z, N\text{-}1) + \nu + \mathbf{n}$

  where natural rock is the target

  - ✧ Energy dependence of excitation cross section $\propto(E-E_0)^2$ gives a signal mainly from the higher energy $\nu_{\mu/\tau}$
  - ✧ Detecting the time profile of the n would yield the time profile of the νs
    - ❍ using embedded BF_3 counters
    - ❍ This would be too expensive > M£*300* per *1000* events
- ☆ **A more economical scheme** (P.F.Smith)
  - ✧ Place scintillator detectors loaded with *Gd* inside a target material lined cavern
    - ❍ ns will multiply scatter through the cavern until thermalised
    - ❍ n production per target mass depends on target material mainly through the branching ratio
      - ● $\sim 10^{-7}/g$ for *NaCl* ;×~2 for *Fe*; ×~4-6 for *Pb*
    - ❍ neutron capture does depend strongly on the target material
      - ● Two competing processes: absorption in the cavern wall and absorption in the detector

        ×~3-4 for *Fe*; ×~10 for *Pb and* has higher sensitivity to $\nu_e \Rightarrow$ combination of targets

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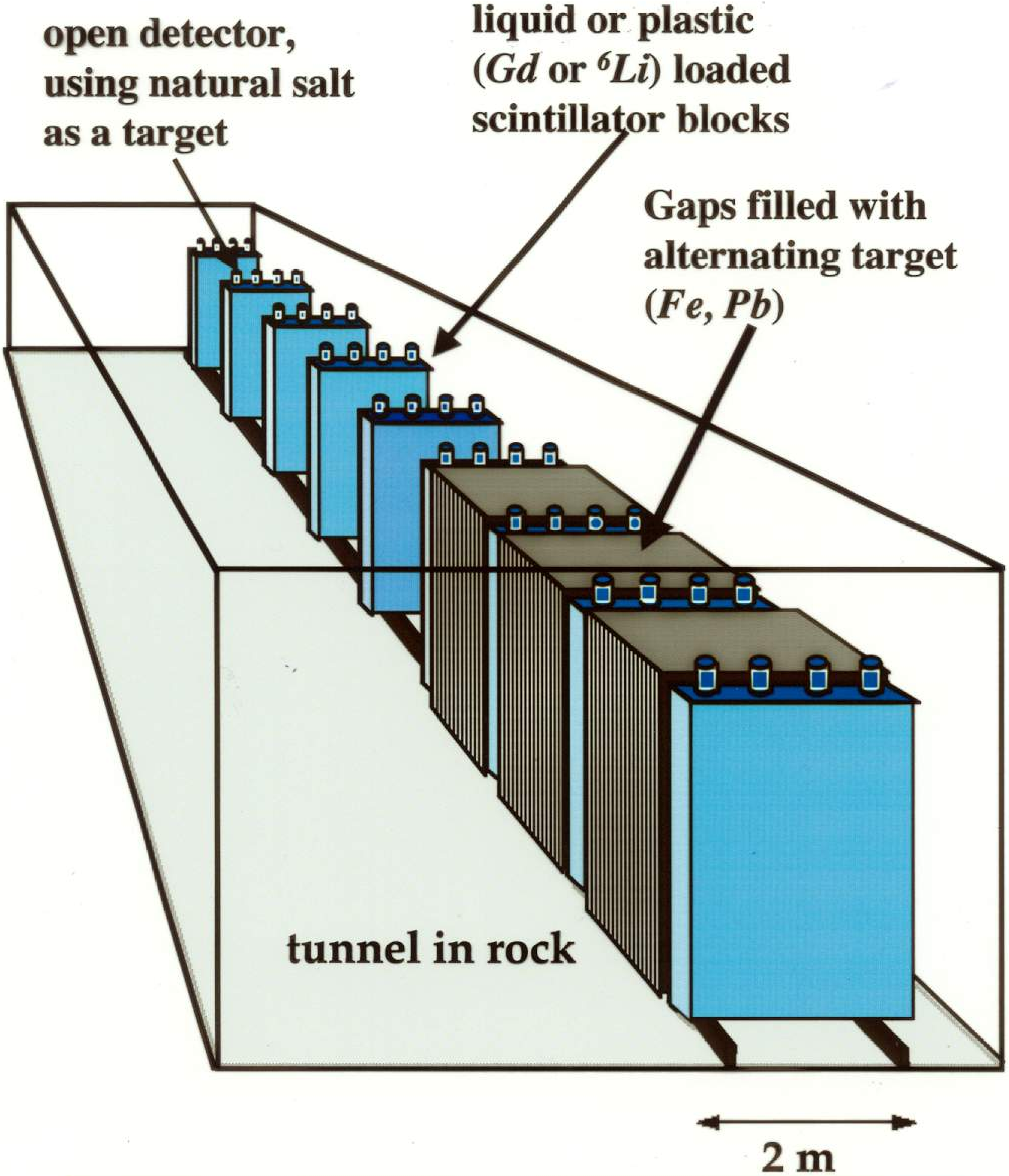
Detector scheme



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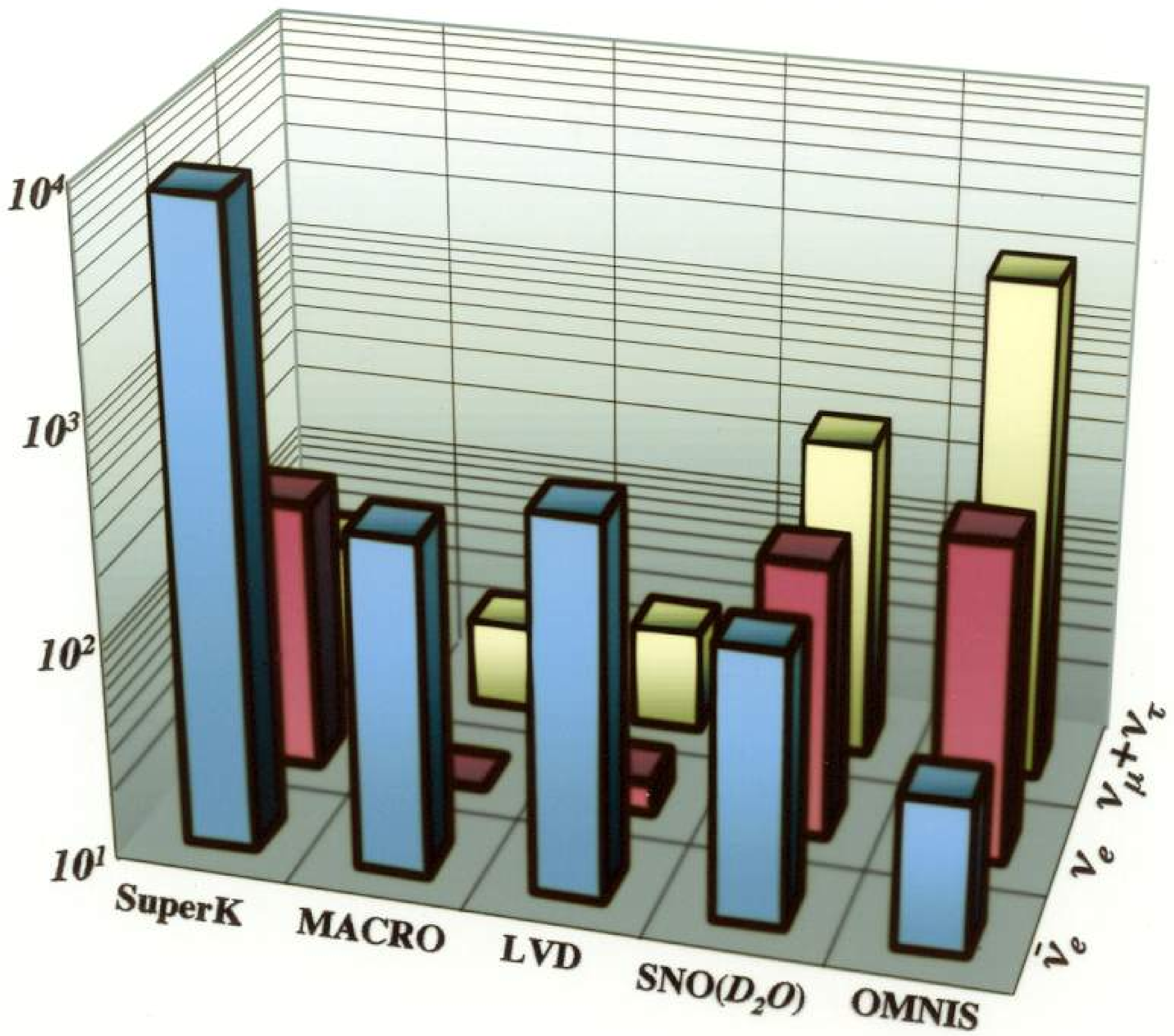
Number of Events for a *SN* at *8 kpc*

~ 2,000 T Pb



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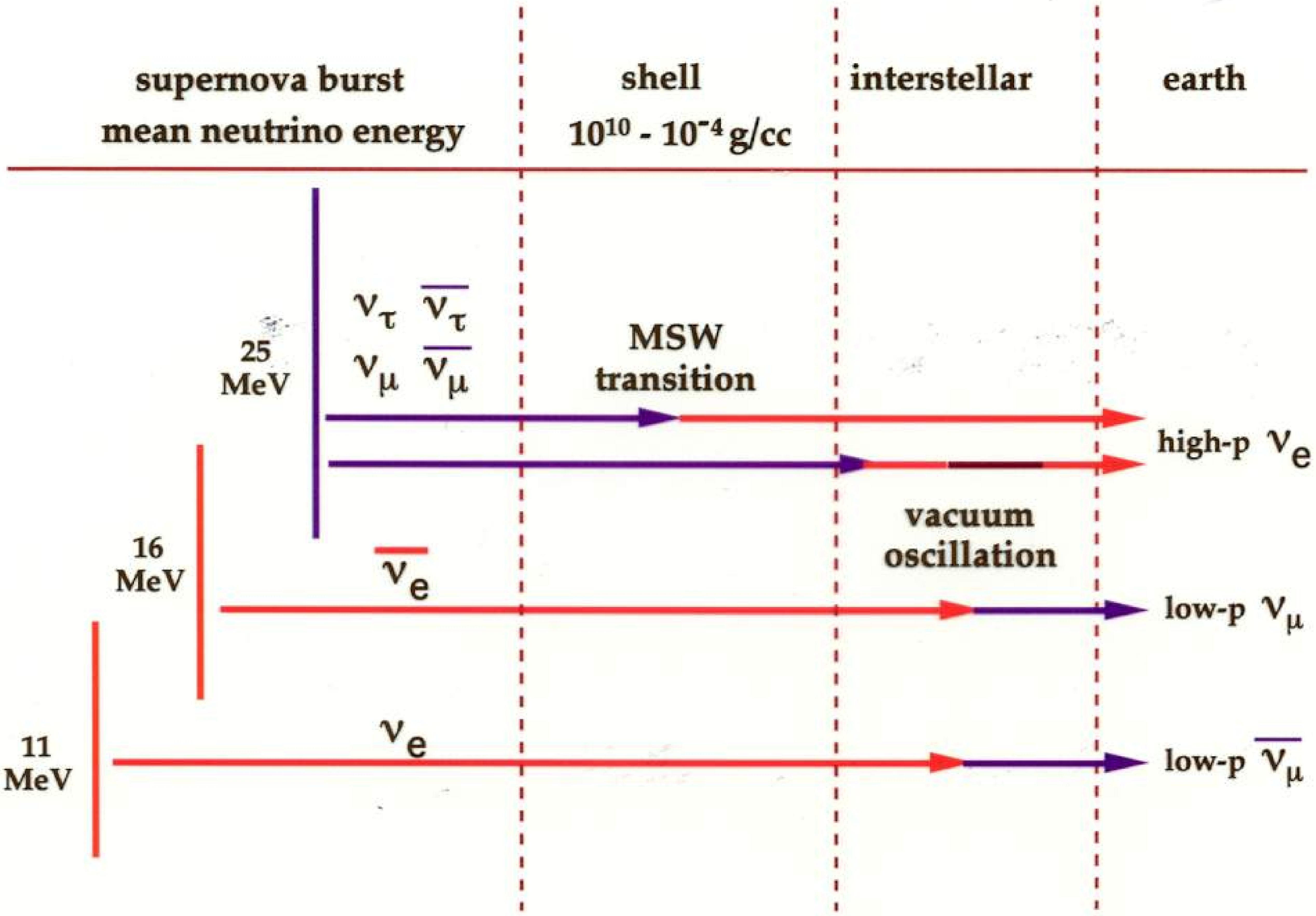
Neutrino mixing



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n production

§ **Neutral and charged current excitation in Pb and Fe**

☆ $\nu_{\mu/\tau} + A(Z,N) \rightarrow A^*(Z,N) + \nu_{\mu/\tau}$

$\rightarrow A(Z,N-1) + n$

[redacted] $\rightarrow$ [redacted]

☆ $\nu_e + A(Z,N) \rightarrow A^*(Z,N) + e^-$

$\rightarrow A(Z,N-1) + n$

OR $\rightarrow A(Z,N-2) + 2n$

G.M. Fuller, at el Phys. Rev. D 59 (1999)

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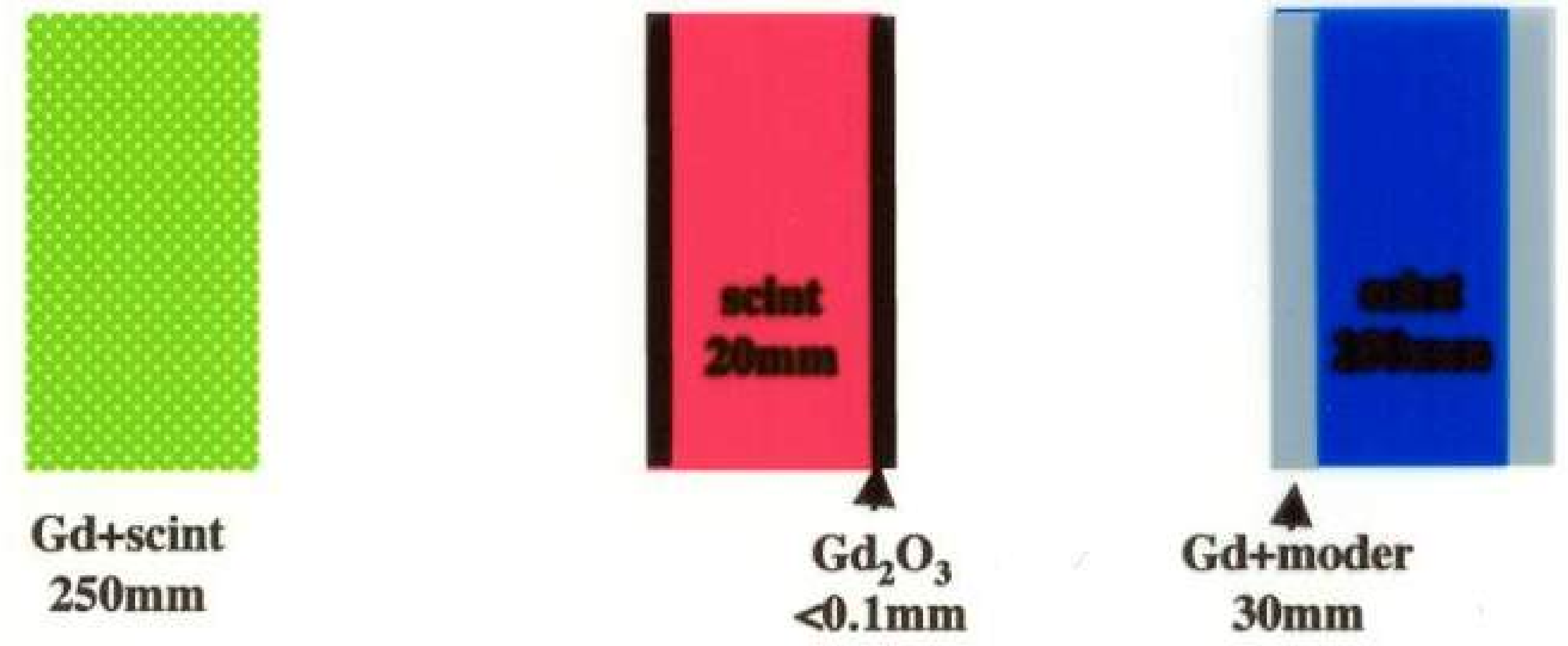
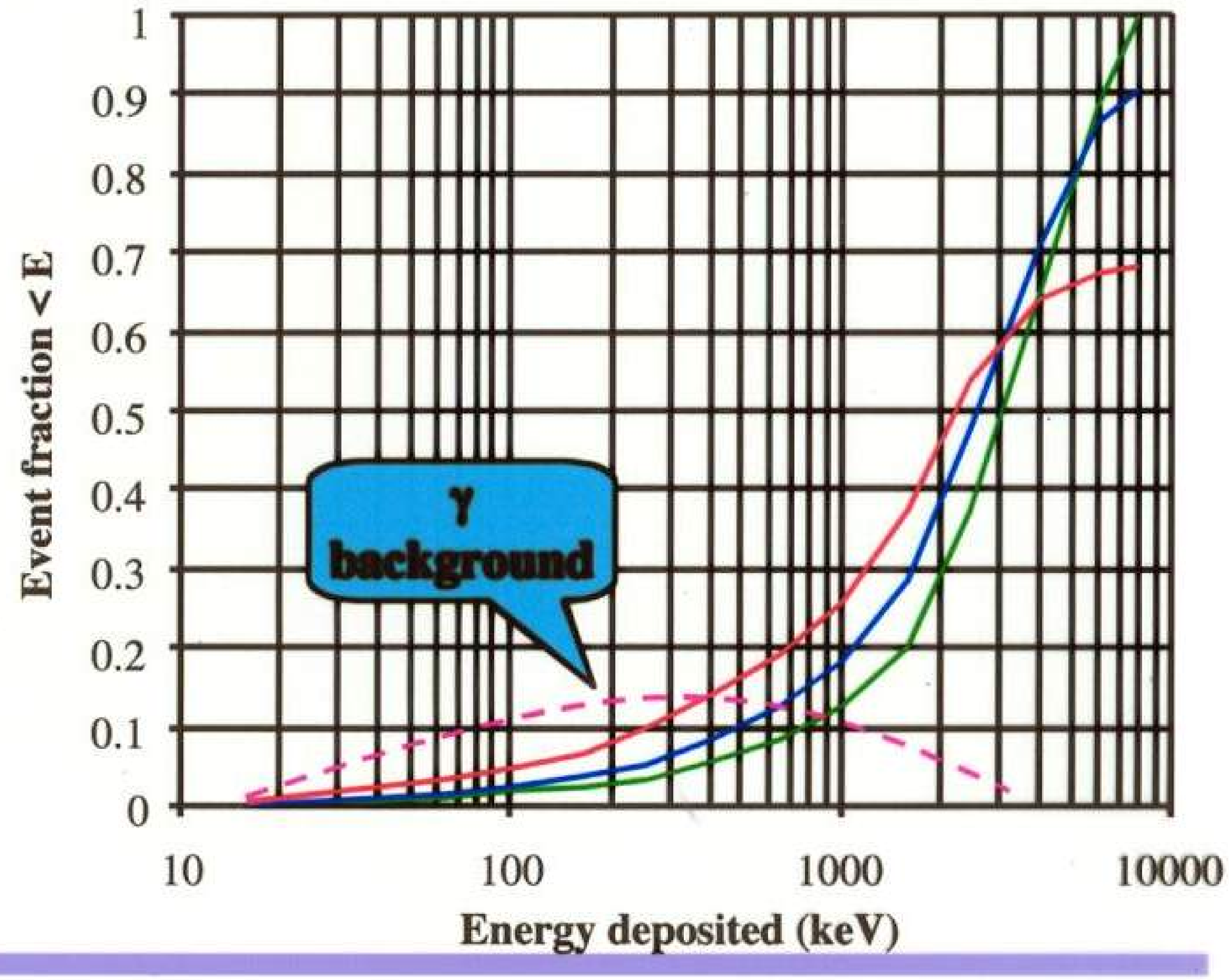
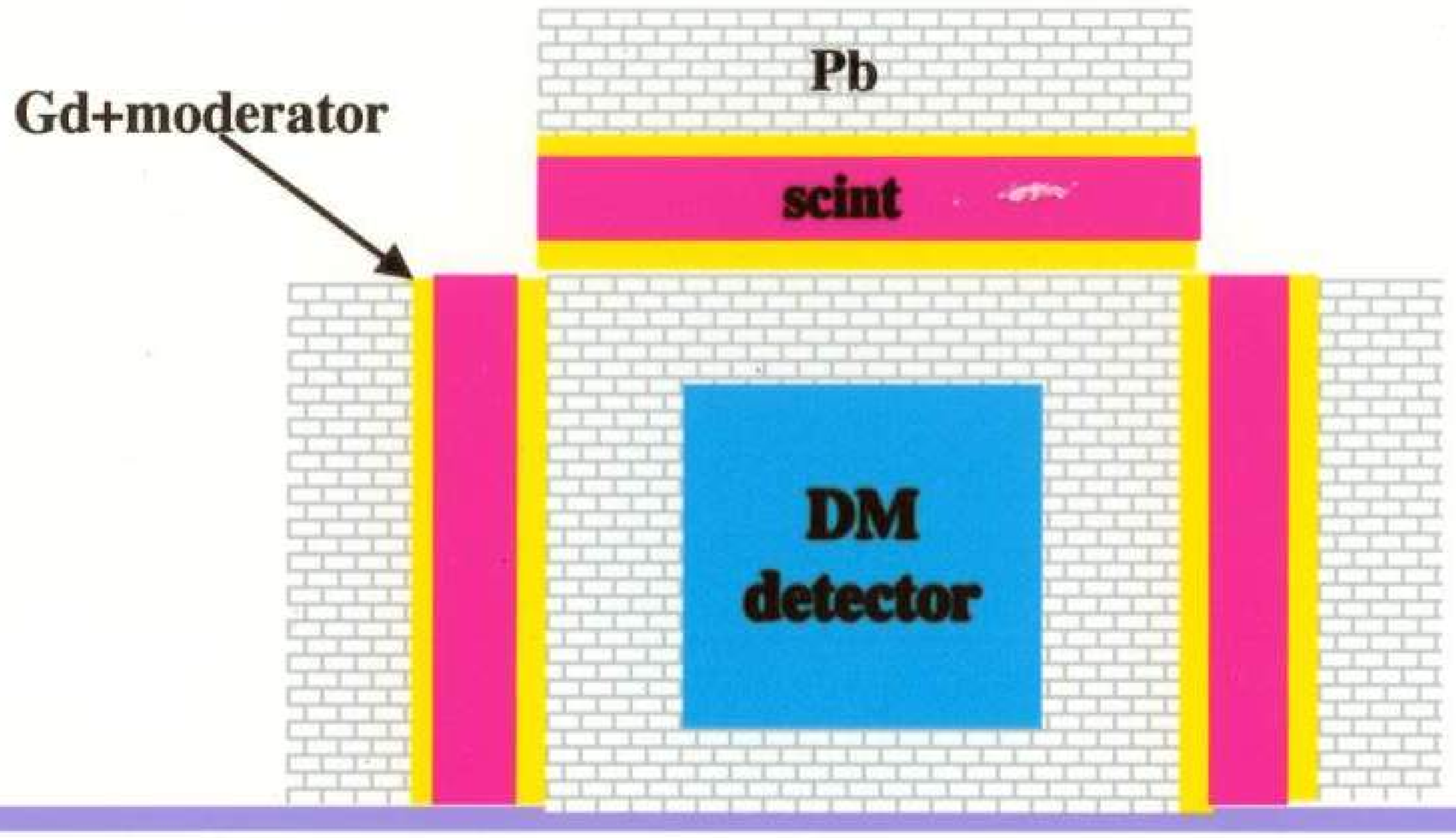
Neutron Collection Efficiencies

- Comparison of Collection Efficiencies
- Can run parasitically on DM search
  - ☛muon veto
  - ☛SN neutrino detector







Conclusions

SIREN

- R&D is ongoing
  - low threshold real-time spectroscopy
  - scintillator work

OMNIS

- long life
- can run as part of other experiments
- high sensitivity to mixing