J. BOUCHEZ
DAPNIA.
CEA-SACLAY

Neutrino Telescopes
VENEZIA
23/2/1999

The LENS project

A real-time measurement of the solar ν_e spectrum below 1 MeV.

- Motivations
- The detection principle
- Possible implementations
- The backgrounds
- Status of the R & D

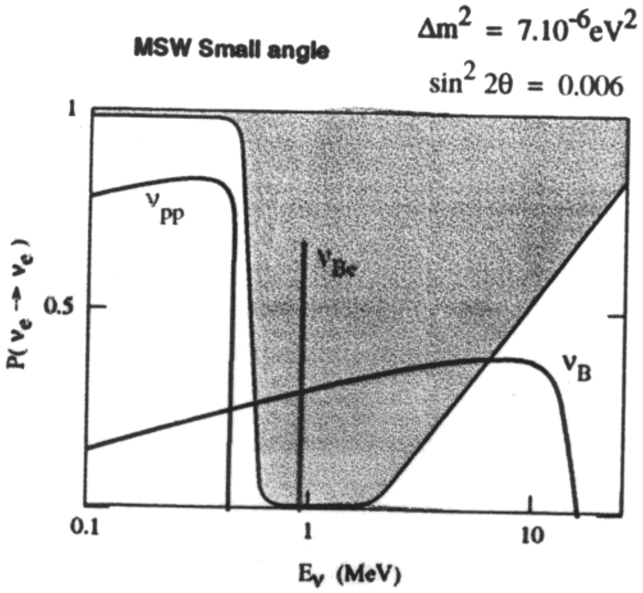
MOTIVATIONS

- The solar ν deficit is now well-established
- Most probably due to flavor oscillation of massive neutrinos
- Several scenarios can explain the observations:
  - Just-so vacuum oscillations
  - Adiabatic flavor conversion (MSW) inside the sun

    SMA, LMA, (Low Mass)
- These 4 solutions exhibit different patterns at low energy (pp, Be^7)

pp: unaffected

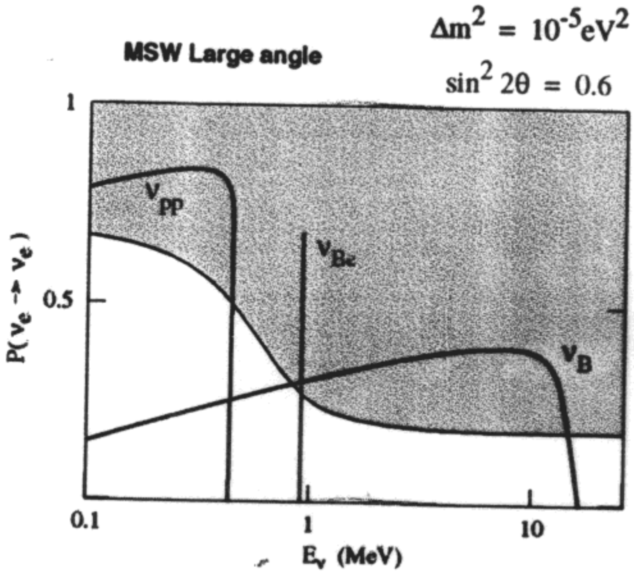
^{7}Be: disappears



MSW SMA

pp: 30-40% decreased

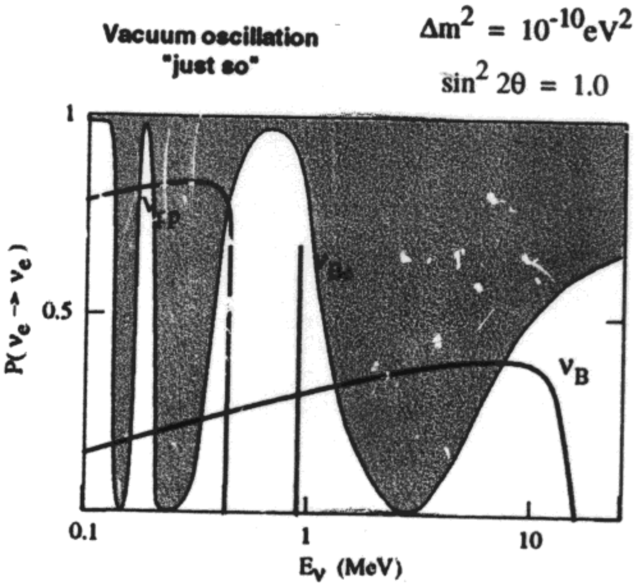
^{7}Be: ~70% decrease



MSW LMA

Effect depends on fine-tuning of Δm^2

SEASONAL EFFECTS EXPECTED



JUST-SO

THE DETECTION PRINCIPLE

Use the reaction :

$$\nu_e + (A, Z) \rightarrow (A, Z+1)^* + e^-$$

$$\text{DELAYED} \;\llcorner\!\rightarrow (A, Z+1) + \gamma$$

→ Sensitive only to ν_e (complementary to Borexino)

Real-time meas^t:

→ The e^- energy gives the ν energy

→ The delayed γ gives a discriminant signature

Requisits :

→ transition to ground-state forbidden

→ Excited state has to be metastable

→ Threshold low enough to detect pp neutrinos.

→ Cross-section large enough

THE DETECTION PRINCIPLE

Use the reaction :

$$\nu_e + (A,Z) \rightarrow (A,Z+1)^* + e^-$$

$$\text{DELAYED} \hookrightarrow (A,Z+1) + \gamma$$

→ Sensitive only to ν_e (complementary to Borexino)

Real-time meas[t]

→ The e^- energy gives the ν energy

→ The delayed γ gives a discriminant signature

Requisits :

→ transition to ground-state forbidden

→ Excited state has to be metastable

→ Threshold low enough to detect pp neutrinos.

→ Cross-section large enough

3 candidates recently identified by R. Raghavan:

^{160}Gd , ^{176}Yb , ^{82}Se

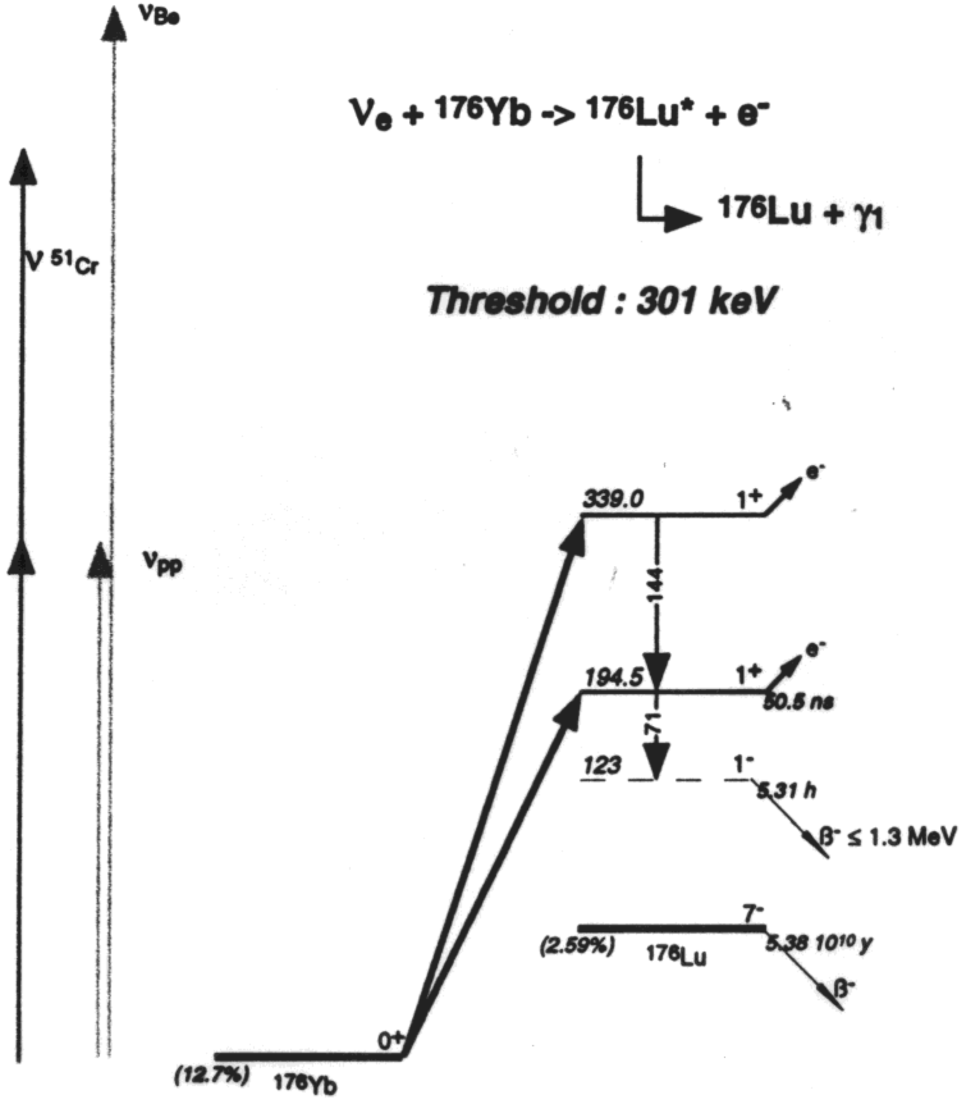
(22%) (13%) (9%)*

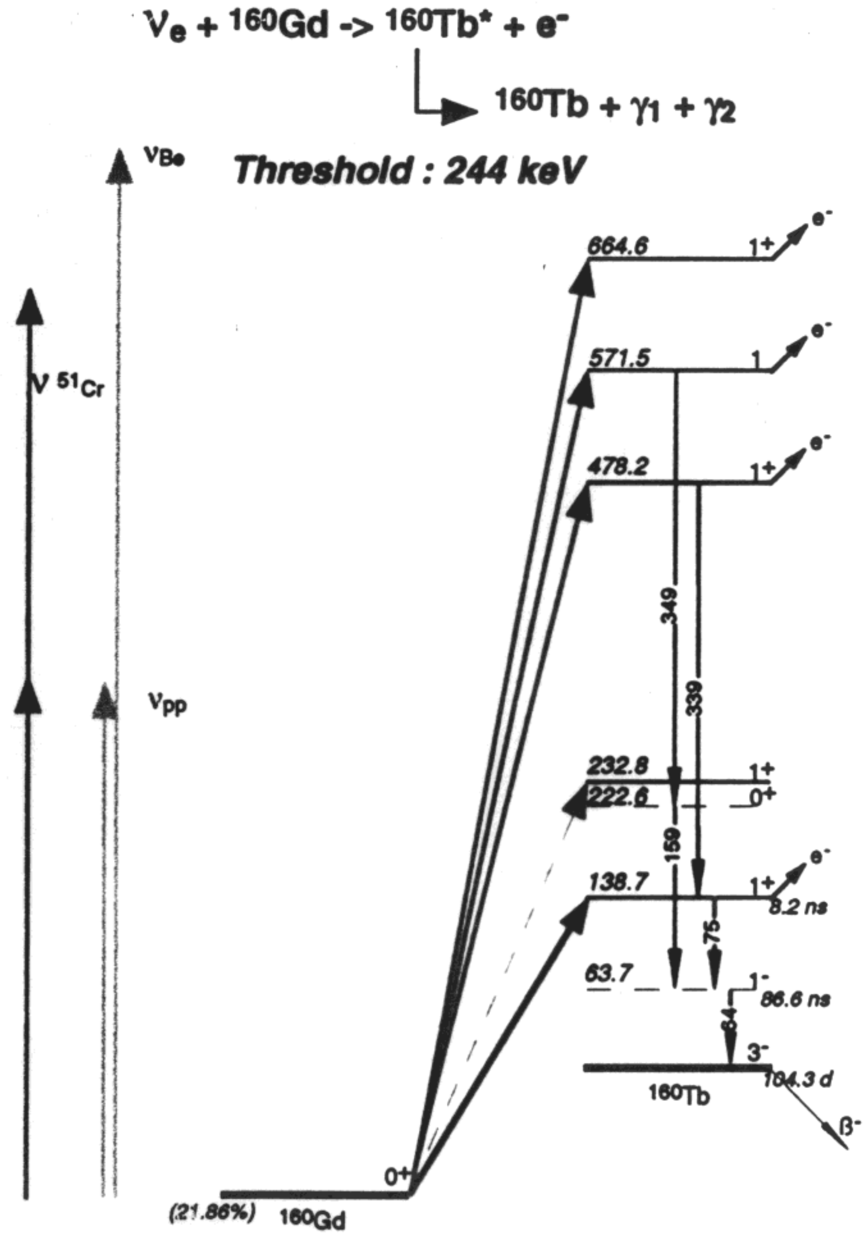
*Enrichment possible.

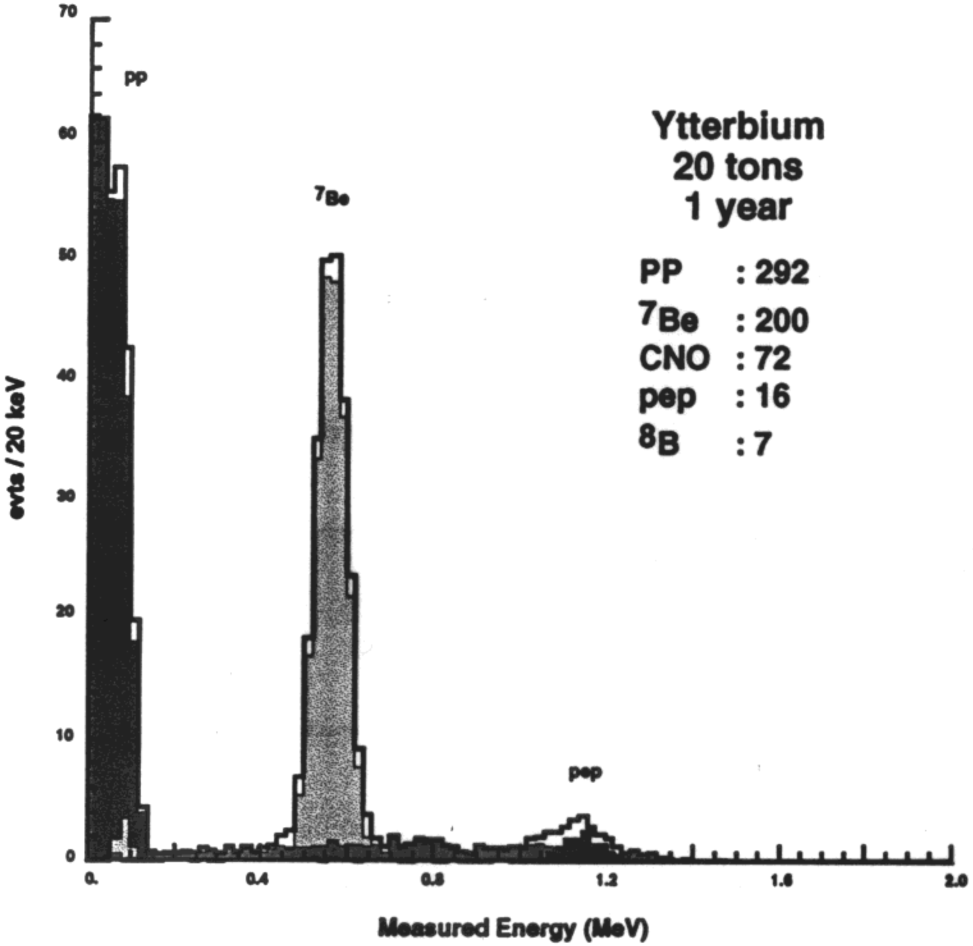
	THRESH. (keV)	DELAYED γ's
Gd	244	γ_1 75 keV, 8 ns γ_2 64 keV, 87 ns ←
Yb	301	γ 71 keV, 51 ns ←
Se	173	γ_1 29 keV, 10 ns γ_2 46 keV, 9 mn

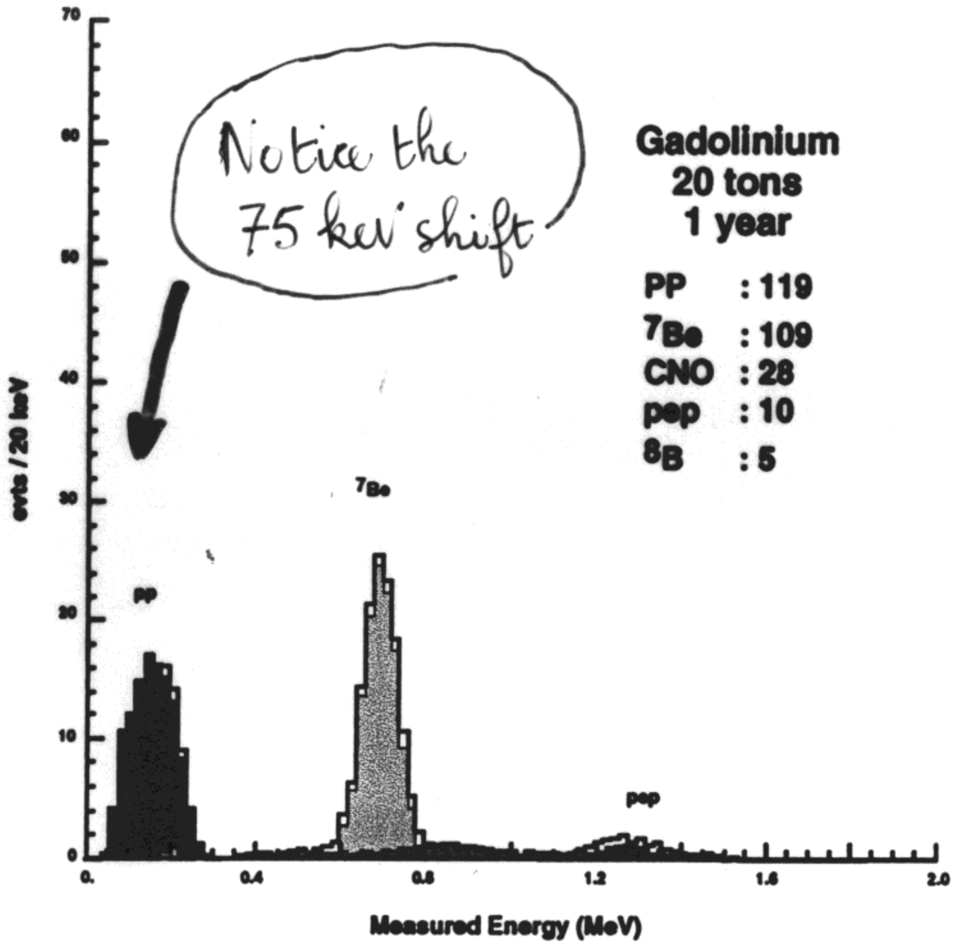
20T Gd
10T Yb
few T ^{82}Se

} give 1 solar ν_e / day (SSM)

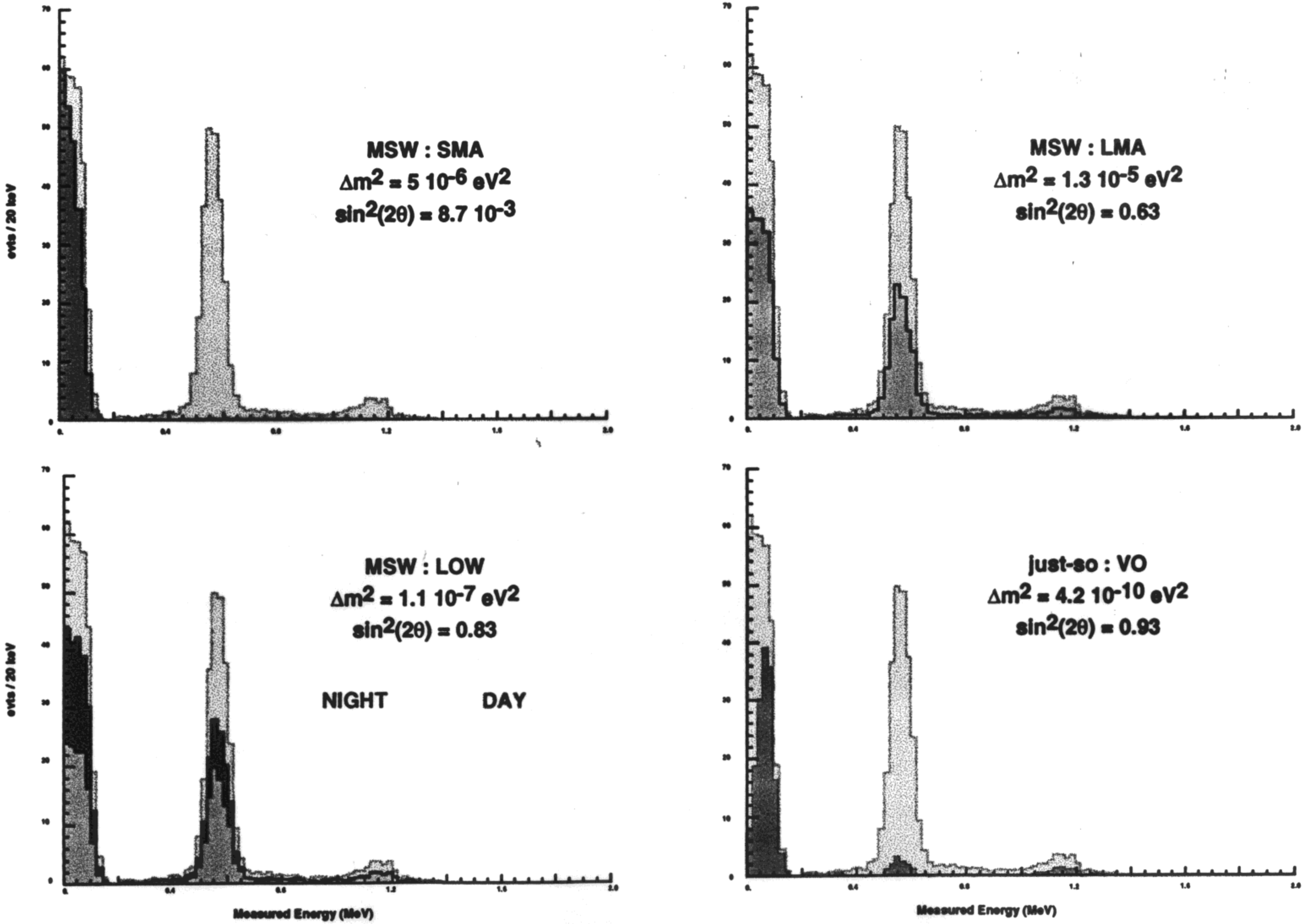

ν_e + 176Yb -> 176Lu* + e⁻
176Lu + γ_1
Threshold : 301 keV
νBe
νpp
ν 51Cr
339.0
1+
e⁻
144
194.5
1+
e⁻
50.5 ns
71
123
1⁻
5.31 h
β⁻ ≤ 1.3 MeV
7⁻
(2.59%)
176Lu
5.38 10¹⁰ y
β⁻
0+
(12.7%)
176Yb


ν_e + 160Gd -> 160Tb* + e⁻
160Tb + γ_1 + γ_2
Threshold : 244 keV
νBe
νpp
ν 51Cr
664.6
1+
e⁻
571.5
1
e⁻
478.2
1+
e⁻
349
339
232.8
1+
222.6
0+
159
138.7
1+
e⁻
8.2 ns
75
63.7
1⁻
86.6 ns
64
3⁻
160Tb
104.3 d
β⁻
0+
(21.86%)
160Gd





Resolution 5% / $\sqrt{E\,(\mathrm{MeV})}$ [400 pe / MeV]



Ytterbium • 20 tons • 1 year

POSSIBLE IMPLEMENTATIONS

1- Liquid scintillator heavily doped (~10% in mass) with Gd or Yb compound.

2- Crystals (presently, only Gd)

3- (For completeness) gaseous detector, only solution for Se: BUT safety problems.

REQUISITS (1&2):

1- Fast light yield ($\geq 400\ \varphi_e$/MeV)
2- High light yield
3- Transparency
4- Radiopurity

BACKGROUNDS

Signature is a delayed coincidence (by few 10 ns) of 2 pulses at the same place.

1- Accidentals
- good localization (segmentation)
- high radiopurity
- shielding against external radiation
- Continuously measured during data taking

2- Single pulses faking doubles (Poisson fluctuations on φ_e times of arrival)

3- Correlated cascades
- Very long-lived (^{231}Th)
- $\geqslant$ 1 month lifetime cosmogenics
- Short-lived isotopes produced by muons underground.

LIQUID SCINTILLATORS

① ~ 10% loading achievable (Yb, Gd)

- Bell labs (R. Raghavan)
- Rhodia (Rhône-Poulenc) *
- LVD (P. Picchi) *

* Small samples under study at Saclay

② U/Th 10^{-15} g/g achieved by Borexino (CTF)

(sufficiently low for ^{231}Th)

^{14}C : 10^{-18} g/g achieved by BOREXINO

③ Yb case Need $\lesssim$ 0.1 ppm Lu

(1 ppm achieved commercially)

④ Gd case Potential problem with

^{152}Gd (α emitter).

⇒ Measurem^ts foreseen soon to determine the quenching factor.

Near future: Measurem^ts with a few liters (N φ_e/MeV, Absorption length)

CRYSTALS.

GSO available. ($\rho = 6.7\,g/cm^3$ 75% Gd)

A $2 \times 2 \times 30\ cm^3$ crystal presently studied at Grenoble (Cerium doping = 1.5%)

Measured : 500 φ_e / MeV

$\tau_{scint} \sim 30\ ns$

^{152}Gd α falls at 400 keV (between pp & ^7Be)
(needs $\geq 10^{-8}$ rejection on fake doubles)

Acceptable accidental rate should be achievable. (from russian GSO crystal)

In progress U content (Modane)

To be checked ^{32}Si (cosmogenic)
OK from Si photodiodes

Present concerns with Gd :

1- Correlated backgrounds from cosmogenic ^{151}Gd (170 days) and ^{153}Gd (340 days)

2- Production by underground muons of ^{159}Eu (⇒ correlated backg^{d})

1998 - Preliminary measurem^{ts} at CERN

1999 - New measurem^{ts} foreseen.

(No such backgrounds with Yb)

(PRELIMINARY) CONCLUSIONS

- Gd more attractive for the signal (lower threshold, 75 keV boost)
  BUT suffers from more potentially dangerous backgrounds
- Yb looks safer (implies liquid scint.)

⇒ **Much more work necessary to prove the feasibility of LENS and choose the technique.**

LENS is a recent project:

1^{st} meeting one year ago

1^{st} collaboration meeting Dec 98

- FRANCE (Saclay, Grenoble)
- USA (Bell labs, Los Alamos, Indiana, Virginia Tech.)
- RUSSIA (INR, IPC)
- GERMANY (MPI Heidelberg)
- ITALY (LNGS)
- CERN (Crystal Clear)

LOI recently sent to Gran Sasso (positive response)

LENS is open to new collaborators

Contact persons: R. Raghavan (Bell Labs)
M. Cribier (Saclay)