SPECTROSCOPY OF SOLAR NEUTRINOS
WITH

LENS: Low Energy Neutrino Spectroscopy

Stefan Schönert, MPI-Heidelberg, on behalf of the LENS Collaboration

Goal:
- direct measurements of solar ν_e from pp, Be7, pep, CNO, B8
- energy-resolved
- real time
- ν_e – flavour specific

⇒ **prove solar neutrino oscillations** (sub - MeV!)
⇒ **determine ν-mixing parameters**
complementary to Borexino (Be-7: cc+nc vs. cc)

Method:
- charged current transition (inverse β-decay) to excited level
- low-energy threshold
- ν_e – tag to discriminate against background

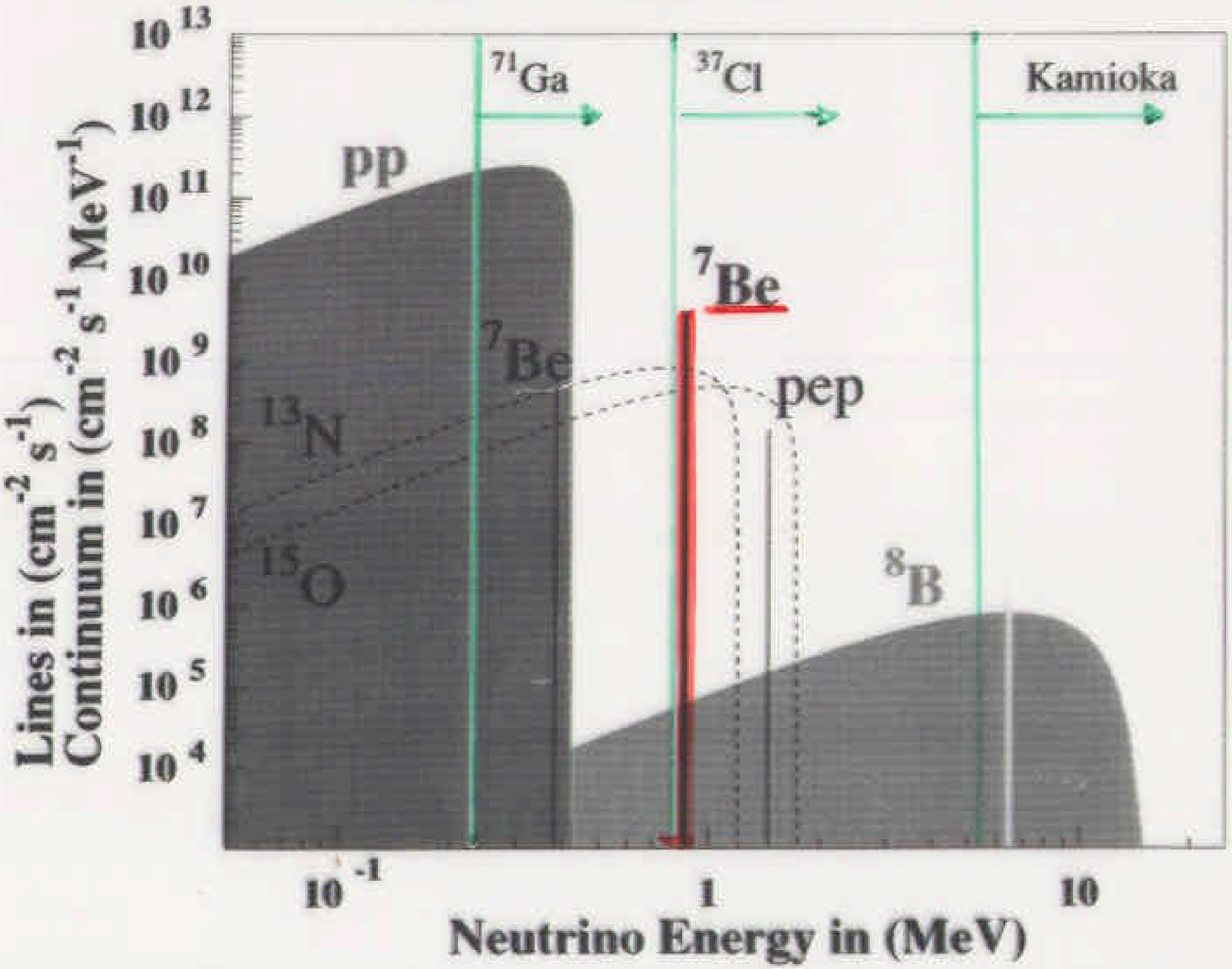
$$E_e = E_{\nu e} - E_{thr}$$

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

delay

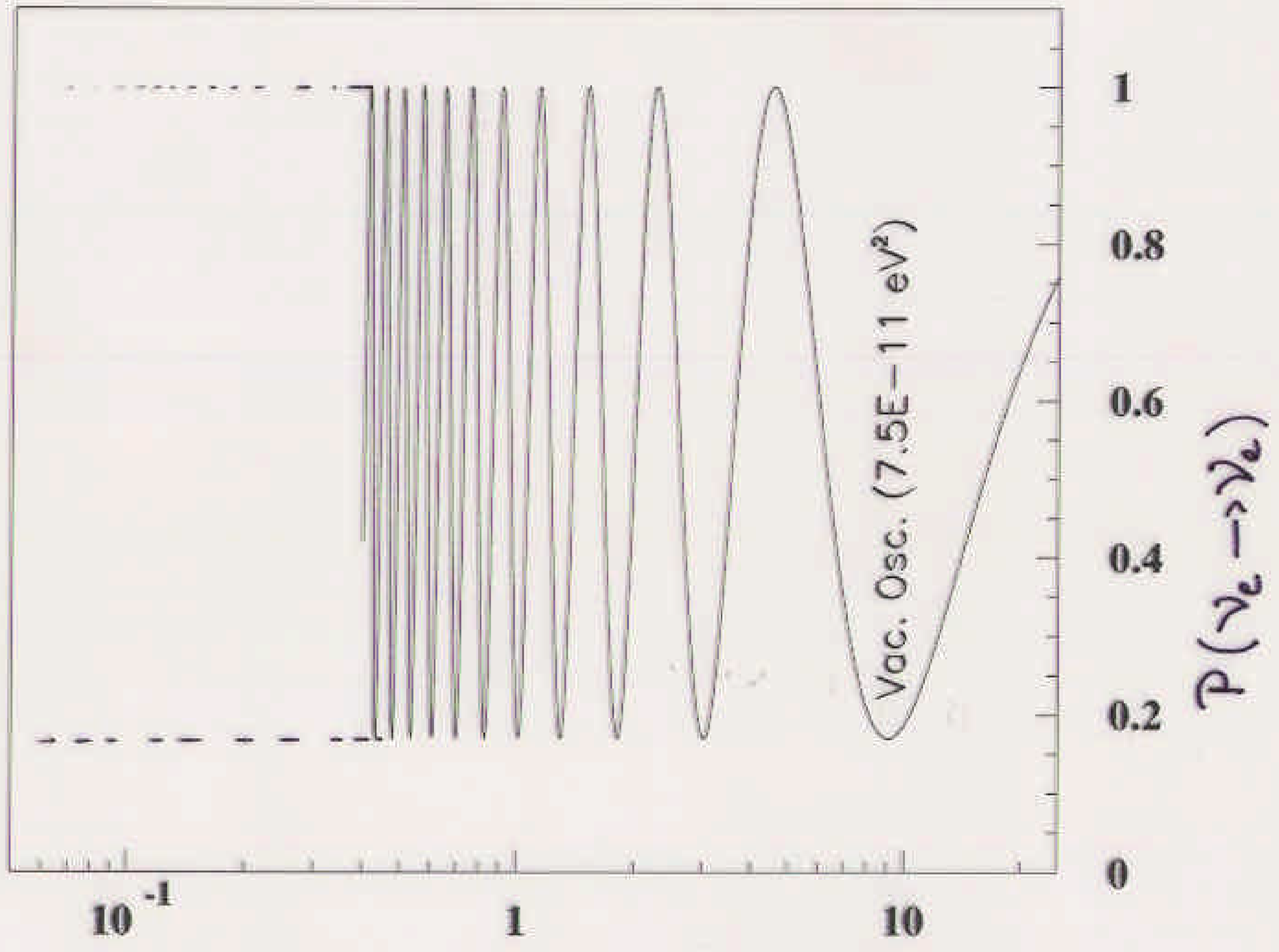
$$(A,Z+1) + \gamma$$

Solar Neutrino Flux

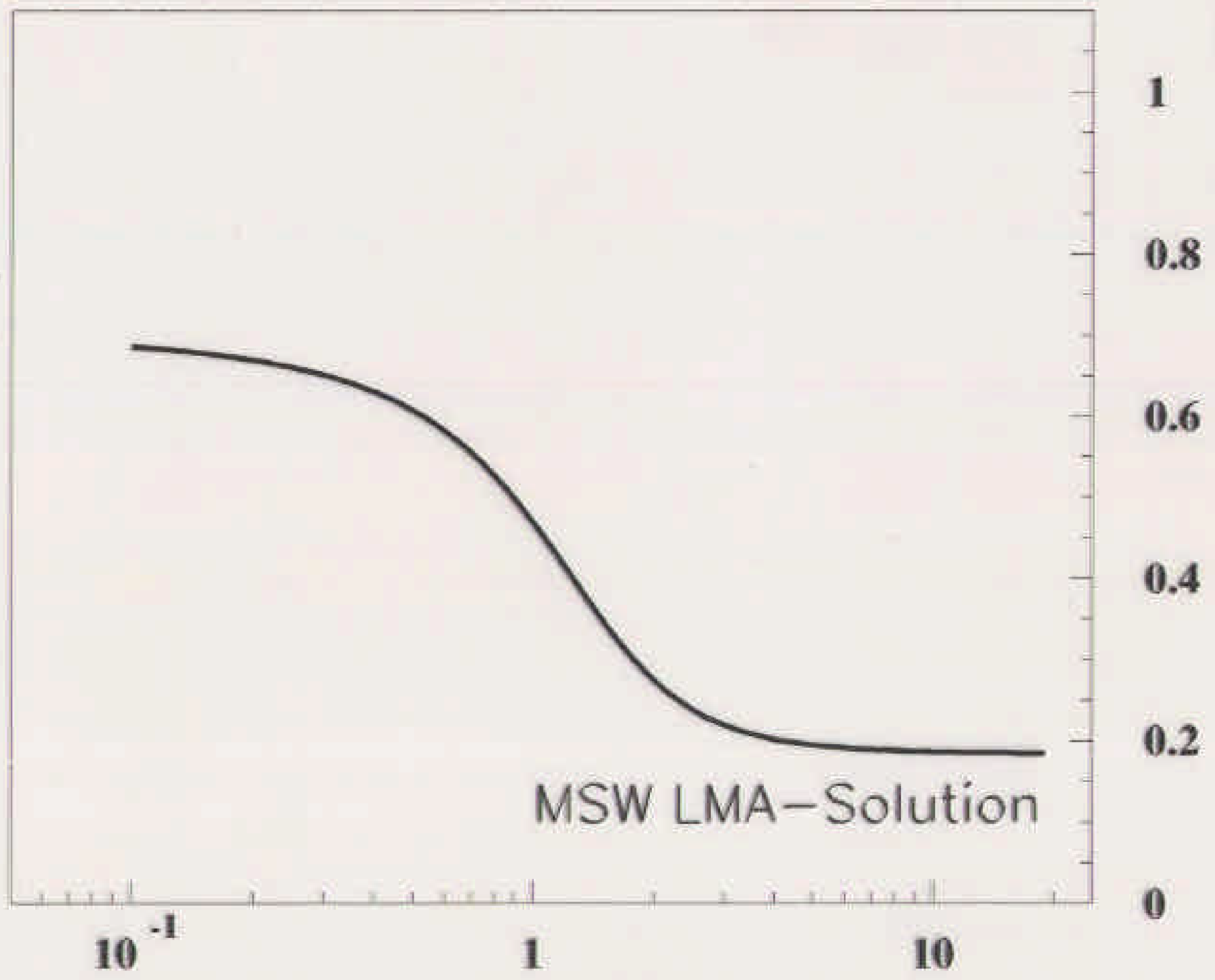


VAKUUM OSZ.

$\Delta m^2 = 7{,}5 \cdot 10^{-11}\,eV^2$



MSW: LARGE MIXING ANGLE

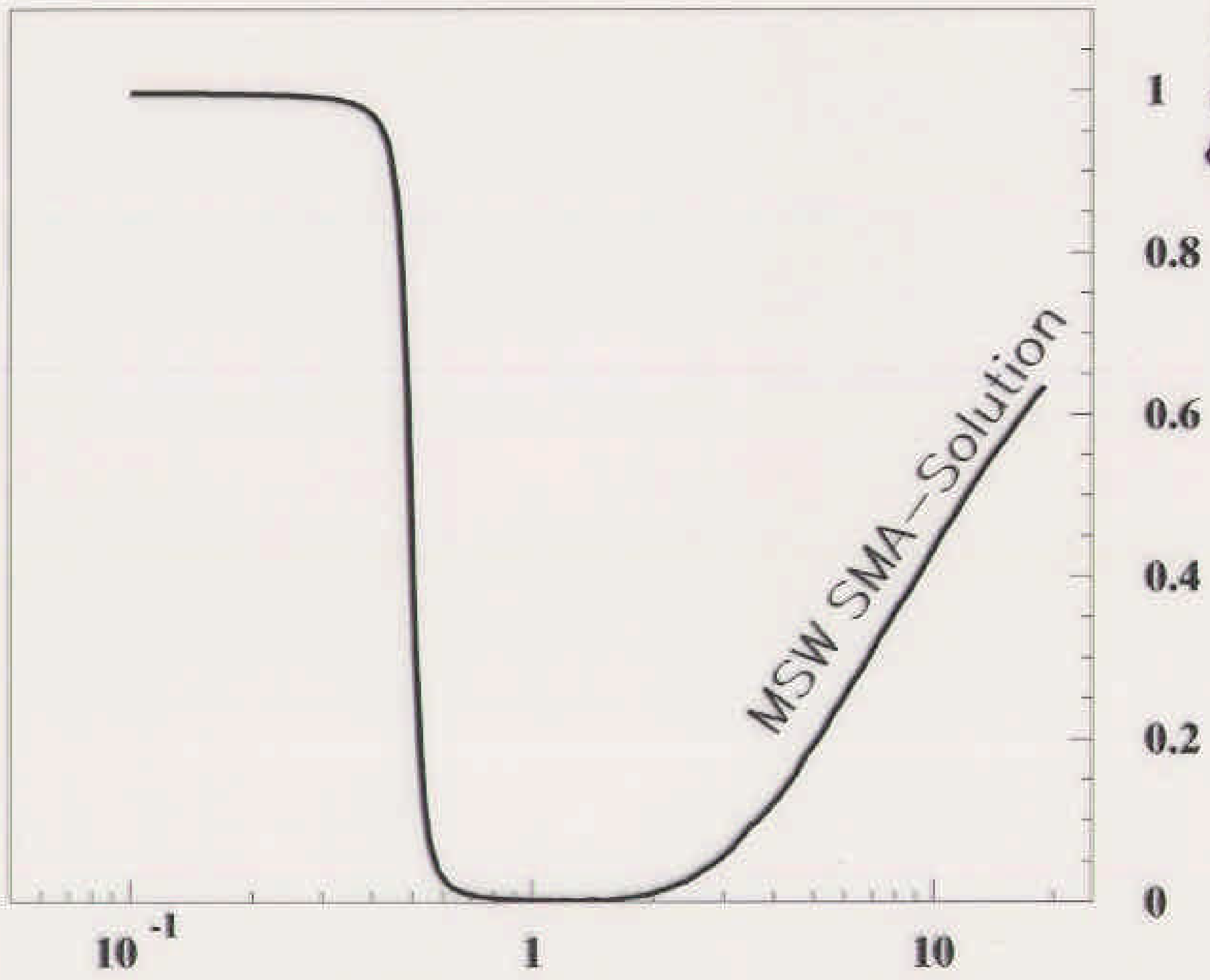


LMA

$\Delta m^2 = 2 \cdot 10^{-5}\, eV^2$

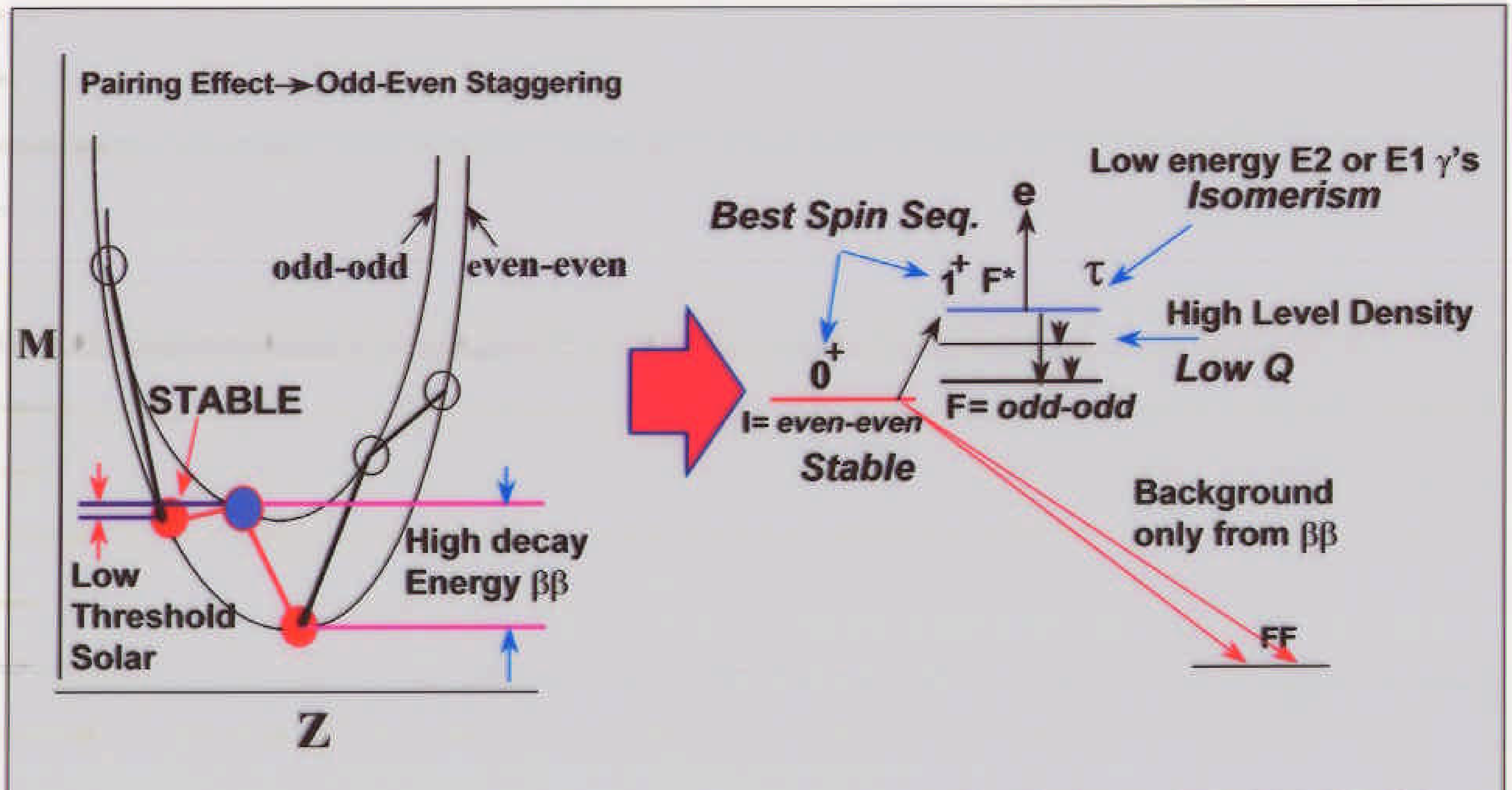
$\sin^2 2\theta = 0{,}6$

MSW: Small Mixing Angle

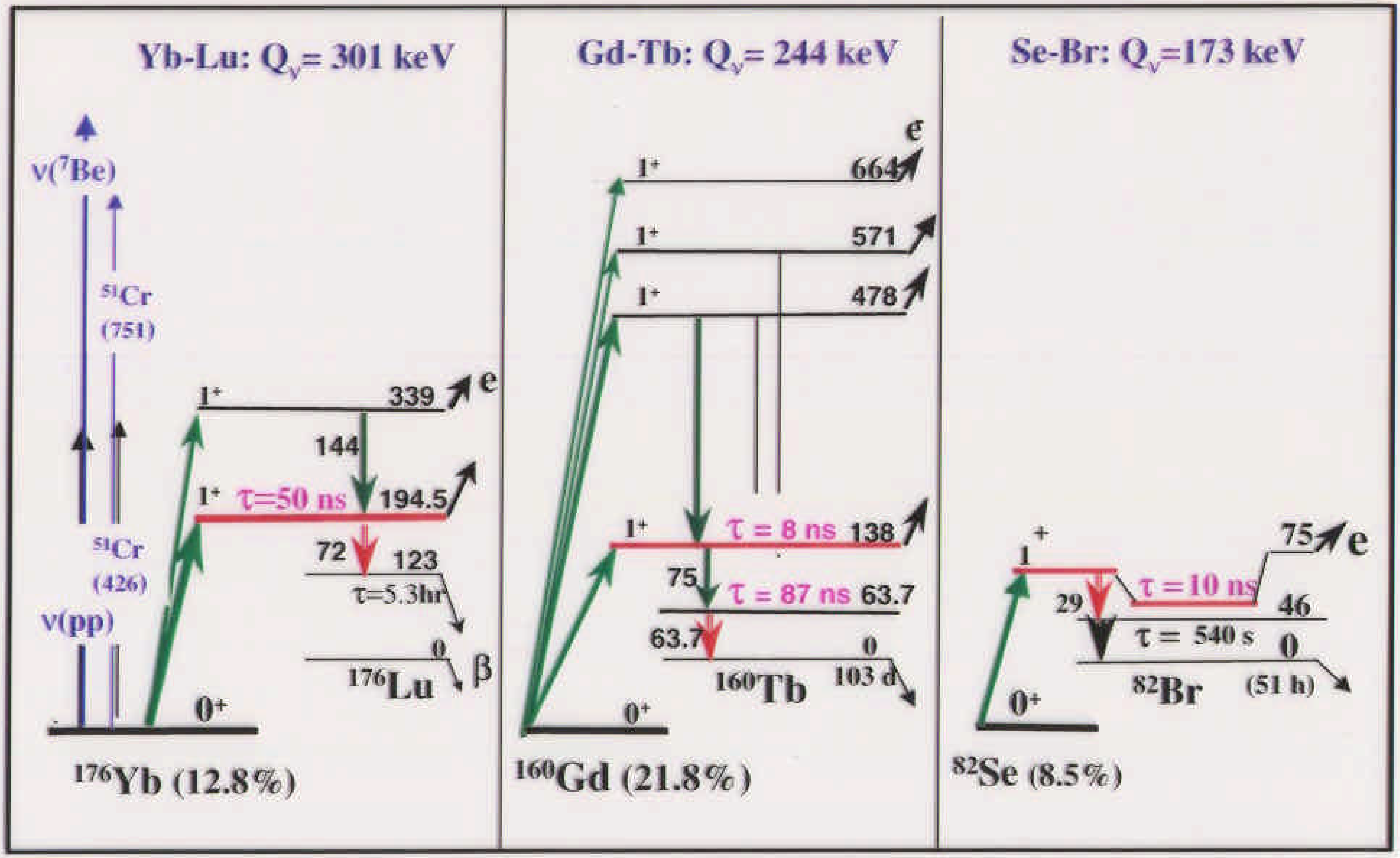


SMA:
$\Delta m^2 = 8 \cdot 10^{-6}\ eV^2$
$\sin^2 2\theta = 5 \cdot 10^{-3}$

Double Beta Candidate Nuclei for ν_e Detection



R.S.Raghavan, PRL 78, 3618 (97)


Yb-Lu: Qν= 301 keV
ν(7Be)
51Cr (751)
51Cr (426)
ν(pp)
1+
339
e
144
1+ τ=50 ns
194.5
72
123
τ=5.3hr
0
176Lu
β
0+
176Yb (12.8%)
Gd-Tb: Qν= 244 keV
e
1+
664
1+
571
1+
478
1+
τ = 8 ns
138
75
τ = 87 ns
63.7
63.7
0
160Tb
103 d
0+
160Gd (21.8%)
Se-Br: Qν=173 keV
1+
75
e
τ =10 ns
29
46
τ = 540 s
0
82Br
(51 h)
0+
82Se (8.5%)

Choice of Target Nuclei and Detection Technique

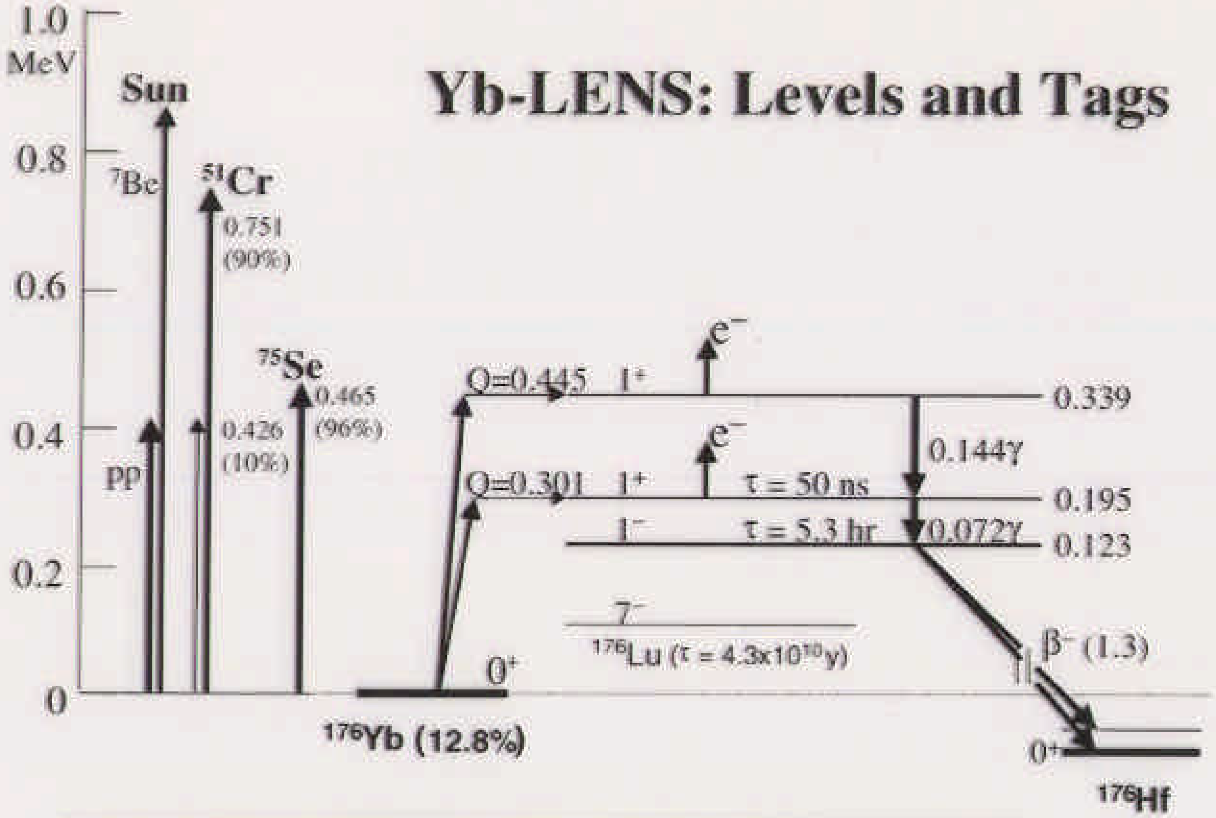
Gd non-favoured:
- Gd-152 alpha-decay rate (1.5E4 Bq/10t (nat Gd))
- Large number of final states (5 states E<0.86 MeV)
- GSO: slow pulse (τ =20 nsec), high Uranium levels (0.01ppm)
- Muon-induced background: Eu-159, Eu-157,..

Se non-favoured:
- fast tag (10 nsec)
- low tag energy

Yb favoured:·loaded Liquid-Scintillator (LS)
- two final states for E < 2 MeV (calibration!)
- fast timing properties of LS (few nsec)

·YAG - Yb crystalls ?

Yb-LENS: Levels and Tags

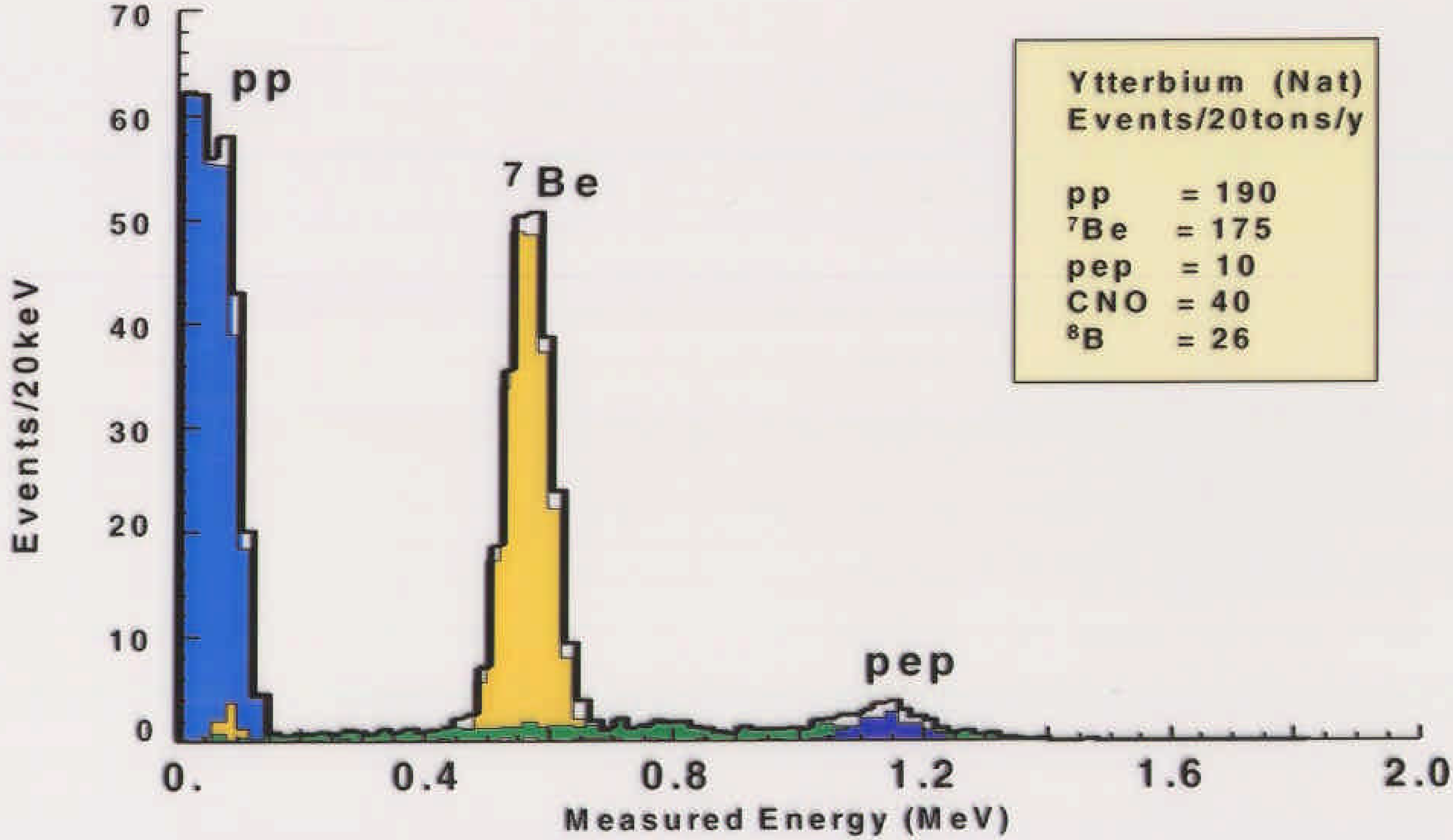


	Yb Level (keV)	B(GT)
1	194.5	0.20(4)
2	338.9	0.11(2)
3	3070	0.62(8)

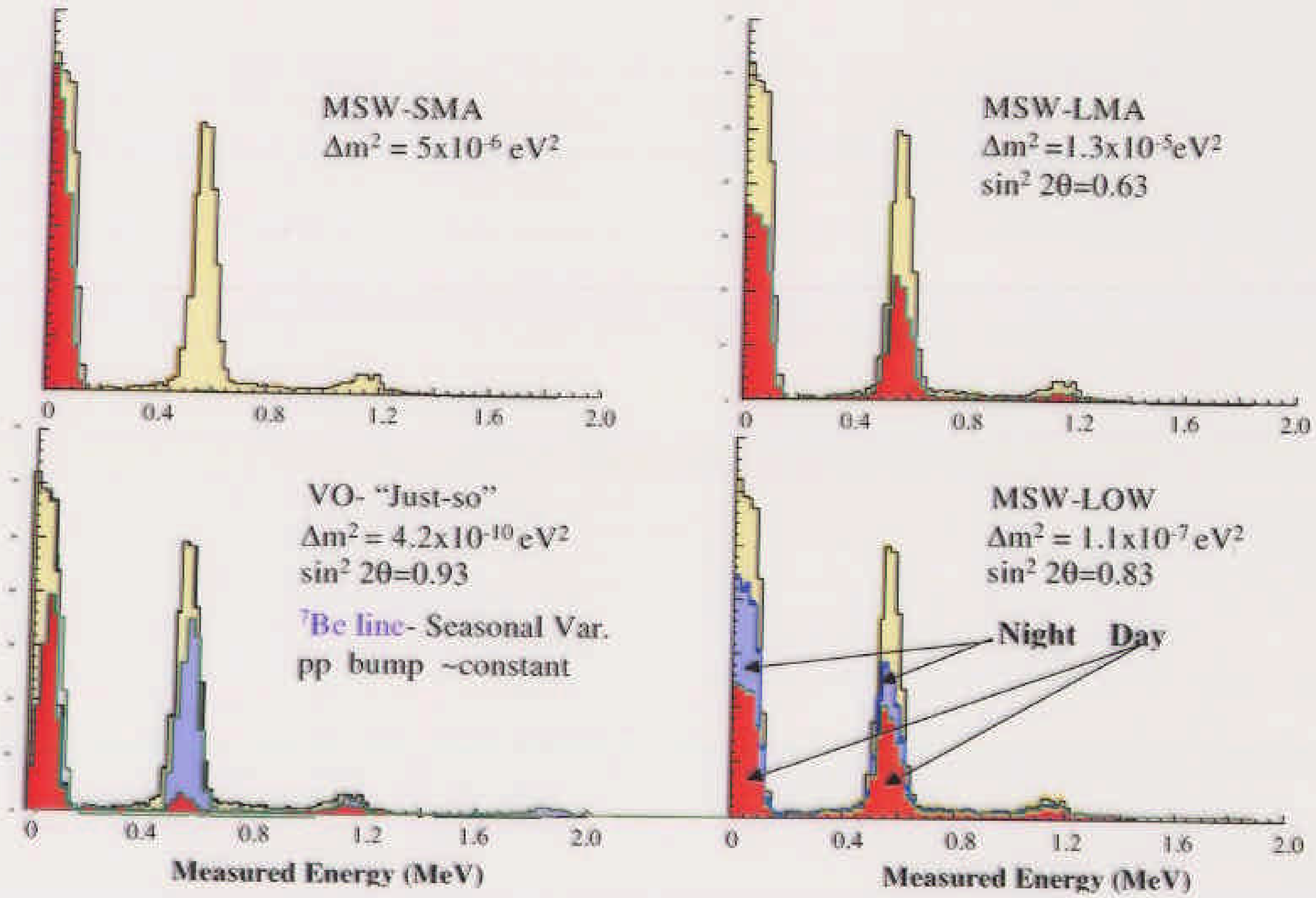
Ref. M. Fujiwara

Gamov-Teller resonance energies and strengths from $^{176}Yb(^{3}He,t)^{176}Lu$; Q_v =E(level)+106.2 keV

Solar Neutrino Spectrum in Yb-LENS (SSM BP98)

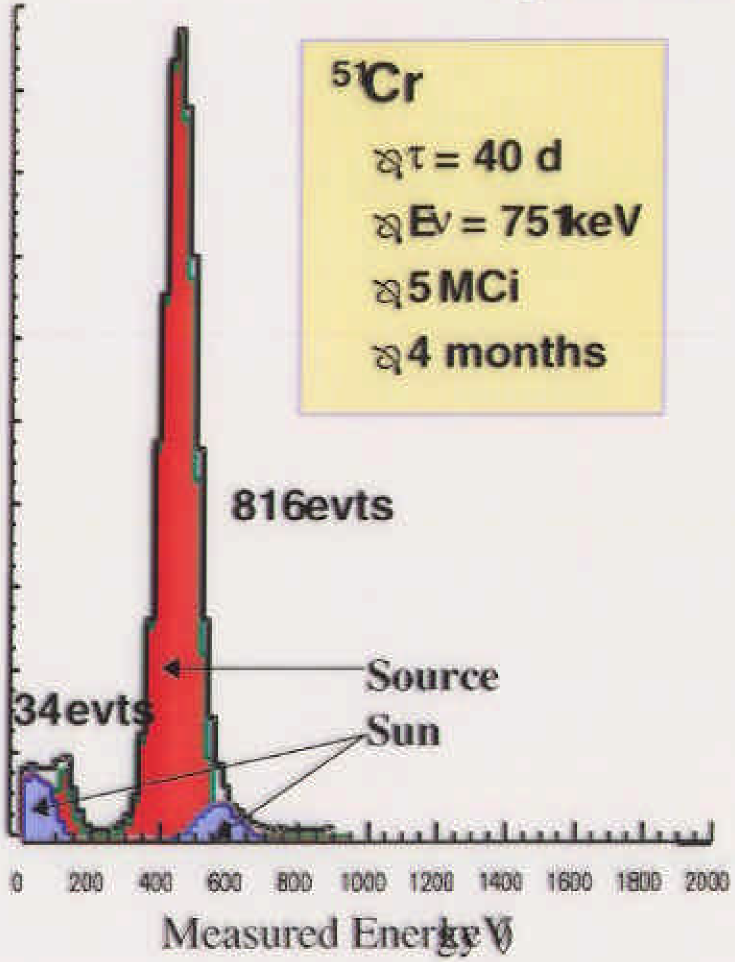


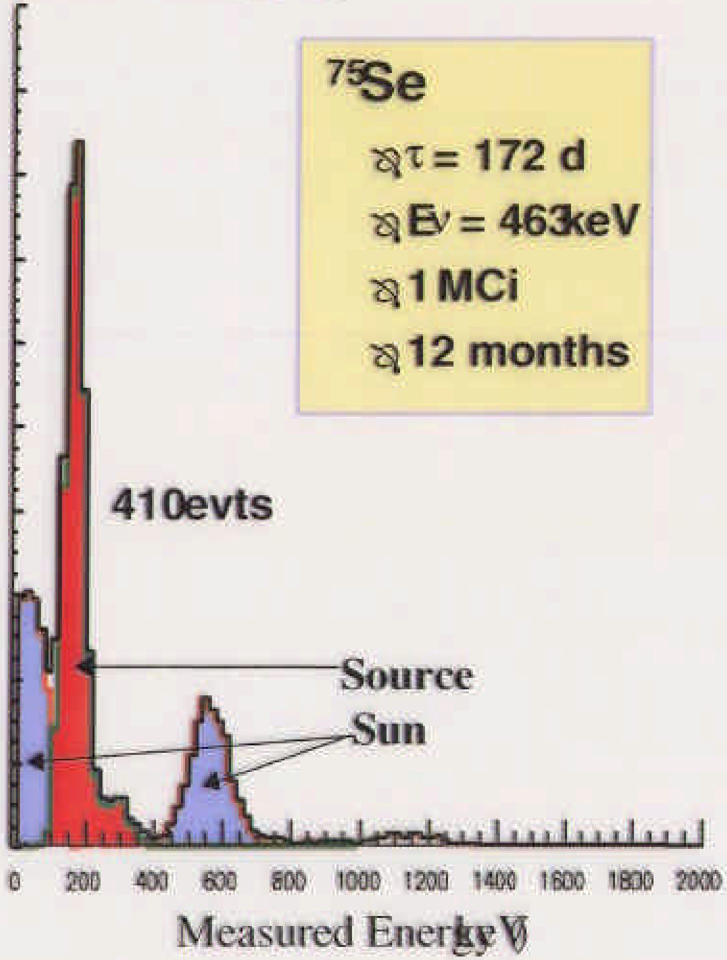
Response of Yb-LENS to Neutrino Flavour Conversion Scenarios



Calibration of ν_e-Capture Cross-Sections

- Response of Yb-LENS to Mega-Curie ν_e-Sources
  - Separate calibration of Be-7 and pp-ν_e





- Irradiation tests of GALLEX Cr-50 material in Russian reactor ongoing
- New isotopical enrichment and irradiation of Se-74 under study

Yb Liquid Scintillator (YLS) Technology

Goal:

- high scintillation efficiency (S) (>300pe/MeV) with high Yb loading, (>5%)
- long attenuation length (>3m)
- long-term stabiliy (years)
- fast pulse timing (nsec, slow component)
- industrial application

Realization of YLS:

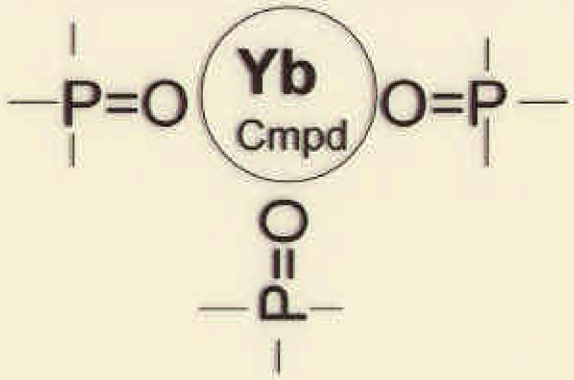
1) chemical compound of Yb (nitrate or chloride)
2) extractant that complexes compound (carboxyl, phosphyl,..)
3) aromatic solvent (PC, Anisole, PXE, 1MN, ...)
4) fluors (PPO, BPO, POPOP, bis-MSB)

some 200 combinations tested

most advanced YLS: TEP(Yb)/1-2-MN/BPO/MSB

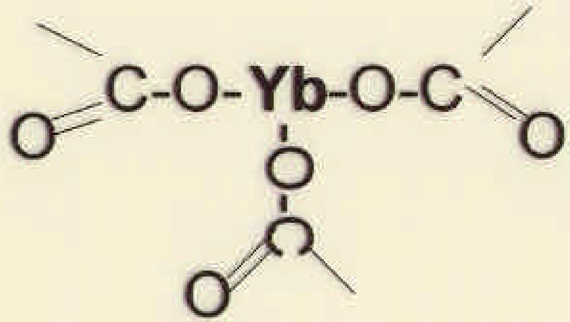
Main Approaches for Yb loading

Phosphates



Yb complex

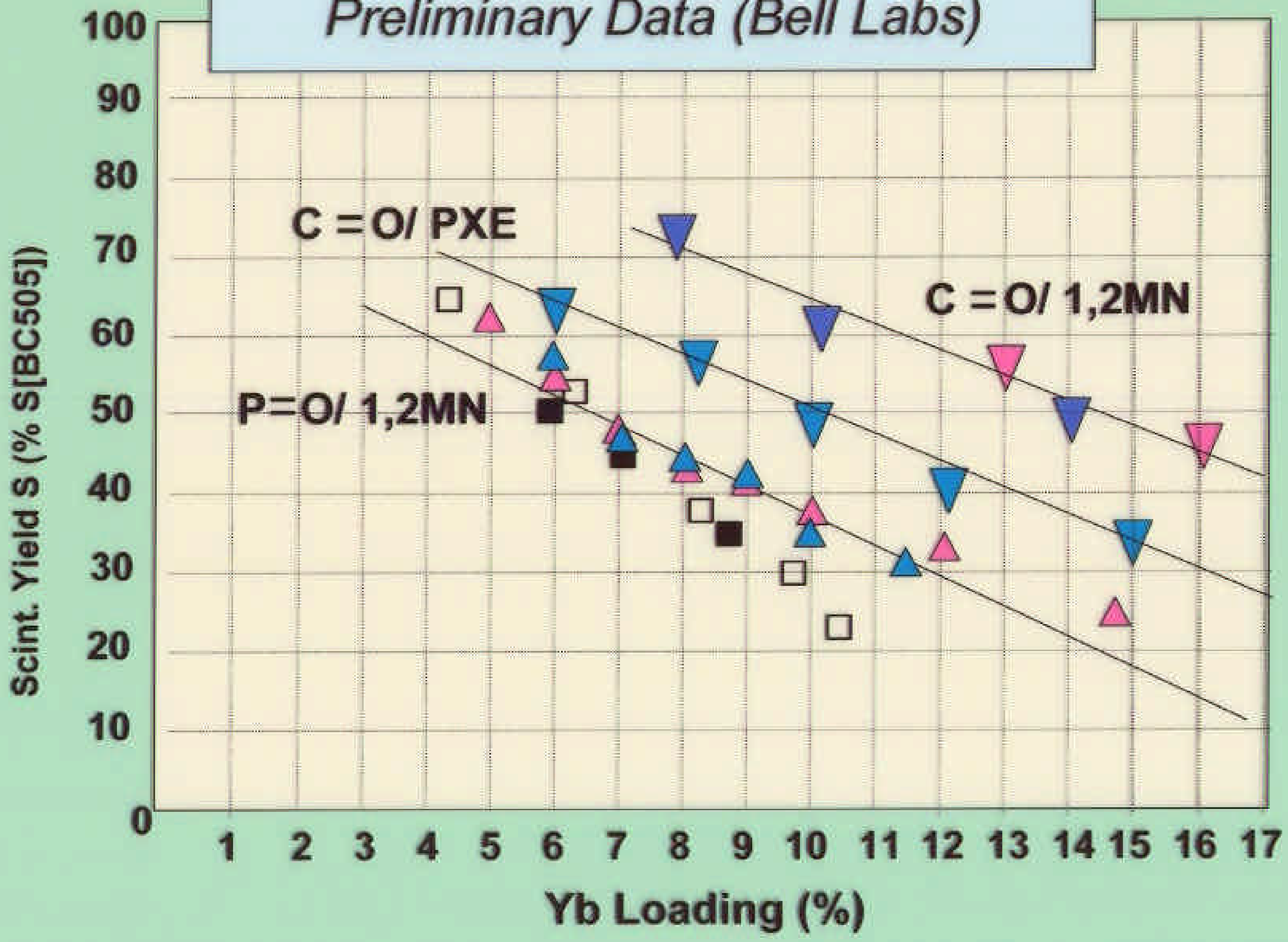
Carboxylates



Yb Organometallic

Yb Scintillator Performance

Preliminary Data (Bell Labs)



RSR /Bell Labs, /LowNu, 6/15 /00

Major Sources of Internal Background

Uncorrelated:

C-14	non removable (C14/C12 ratio in CTF 2E-18)
Lu-176	removable in rare earth production (<0.1ppm)
U/Th	removable from solvent, fluor, rare earth (<0.1ppb)
K	removable from solvent, fluor, rare earth (<0.1 ppm)

Correlated:

Yb-169	cosmic ray induced above ground & in-situ! EC,32d, tripple coincidence
Tm-174,175,...	cosmic ray induced above ground & in-situ
Lu-176	$\beta\gamma$ cascade (1100 keV - τ=2nsec – 88 keV) (<0.1ppm)
U-235	$\beta\gamma$ cascade, <1E-15 g U_{nat}/g, removal under study, analytics for organic materials existing, to be developed for Yb-compound

(Cosmic ray induced backgrounds in LENS and Borexino: next seminar)

Correlated Background for pp neutrinos from ^{231}Th- ^{231}Pa *Delayed Coincidences in the decay chain of* ^{235}U

^{235}U ($\tau = 1 \times 10^{9}$ y)

N(235/N(238) = 0.72%

$\tau(238) / \tau(235)$ = 6.35

@ 10^{-15} g U_{nat}/g

R(235) =360 /y / 20 T

α →

^{231}Th (τ = 37 h)

β_{max} = 305 keV

(→ Affects pp signal only)

τ = 65 ns

γ(84 keV)

^{231}Pa (τ = 1.87x 10^{4} y)

R (Total $\beta - \gamma$) = 0.65 R(235) =
230/year/20 Ton

R (pp ν tag gates)
≈ 95/year/20 T Yb

Ongoing and Future Research Activities

preliminary listing

Scintillator development: Bell Labs, Heidelberg, INR, Rhodia, Saclay, ...
Rare earth purification: INR, Rhodia, ...
Ultra-Trace Analysis: Heidelberg, LNGS, Brookhaven ...
Muon induced Bgd: Heidelberg, München ...
Nuclear Cross Sections: Bell Labs, Osaka, Indiana ...
Neutrino Source: Heidelberg, Russia, Saclay, ...
Detector architecture: Heidelberg, Los Alamos, Saclay, ...
Electronics: College de France, Los Alamos ...
Prototyping (CELL @ GS): Heidelberg, LNGS, INR, Los Alamos, Saclay,....

Status: Letter of Intent (1999)
Pilot phase 2000/2001: prototype detector @ LNGS
Proposal 2001/2002

LENS Collaboration

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