Double Beta Decays & Neutrinos

–Perspectives of ββ Experiments--

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JASRI Spring-8; RCNP Osaka Univ.

TMU-WS 2002

Thanks

- **Prof. H. Minakata**
- **& WS Organizers**

- **for invitation to this workshop**

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II. Double Beta Decays and Neutrinos

ββ schemes

2νββ ΔL=0

M(τστσ) Res.

0νββ ΔL=2

Majorana

$< m_\nu > = \Sigma\, m_j c_j v_j^2$

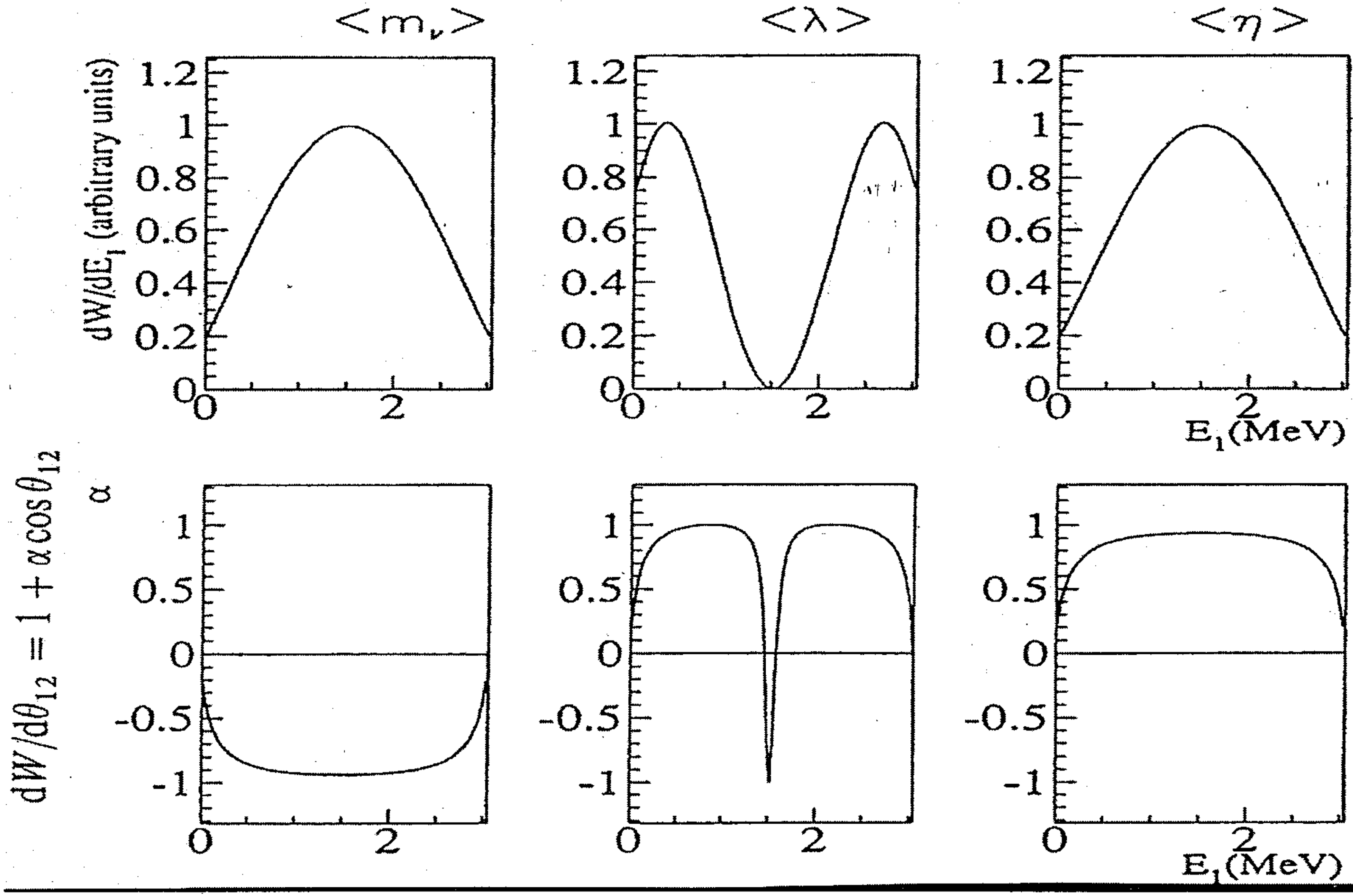
Absolute mass scale

CP phase

R-Weak Currents

$M^{0\nu}$ is crucial

Energy and Angular Correlations



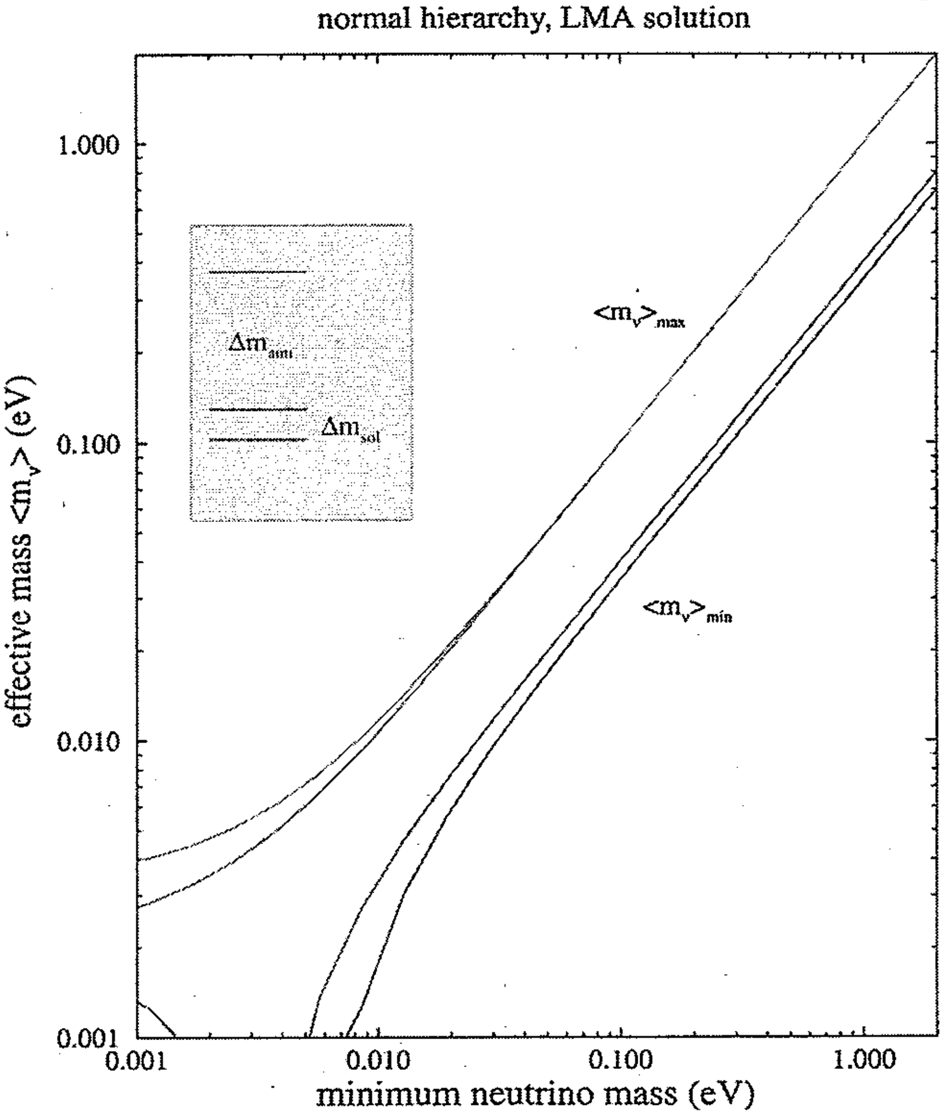
Neutrino masses by ββ

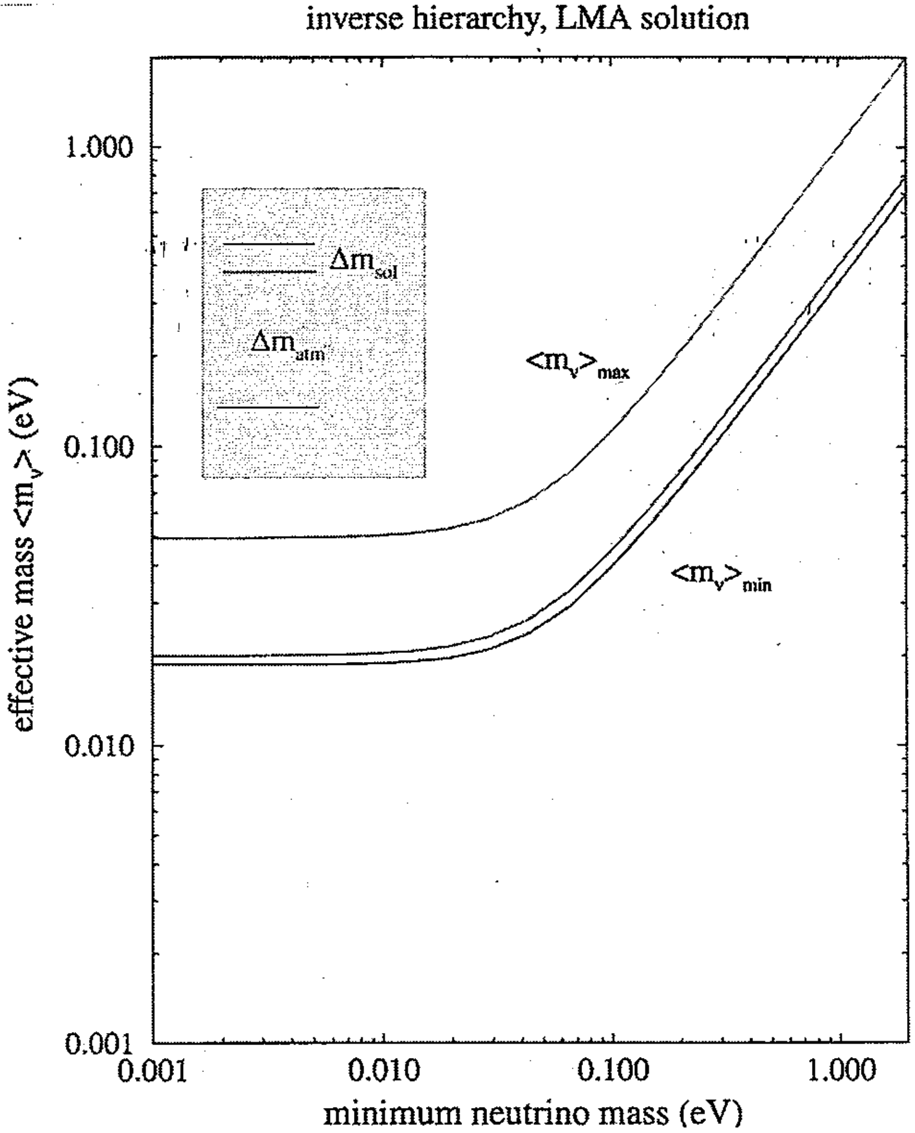
- **Absolute mass scale & CP phases**
- $\langle m_\nu \rangle = \Sigma m_j \, |U_{ej}|^2 \, \xi$
- **0.01 ~ 0.06 eV range,which is quite interesting from recent solar atmospheric and accelerator neutrino oscillation data.**

Effective ββ Neutrino masses

P.Vogel 2001

Normal and Inverse hierarchy



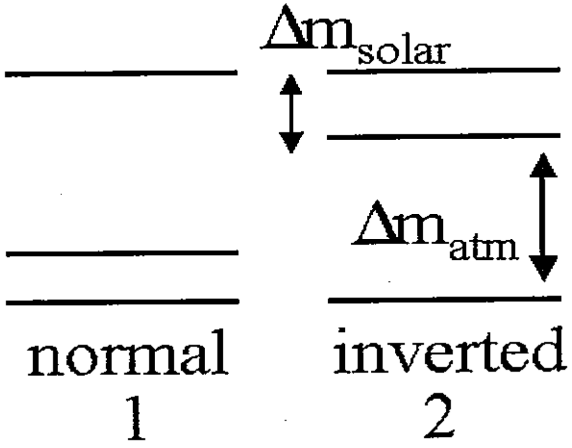


E. Takasugi All approximately equal mass. <mν> ~ 0.03 eV

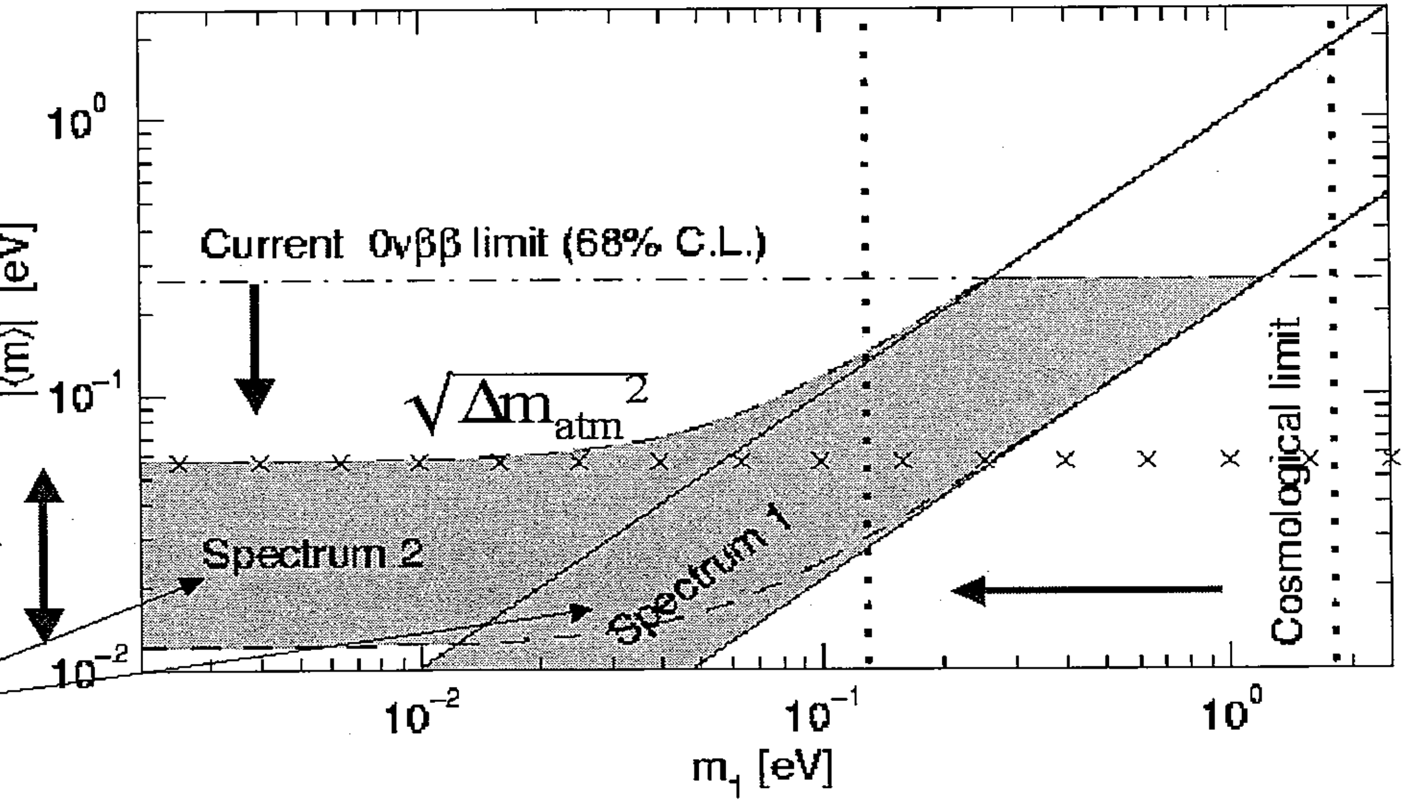
Neutrino mass and ββ.

Experimental evidence for oscillations in the ν_{atm} & ν_{solar} strongly indicate ν have mass and mixing, but tell only Δm^2

The absolute ν mass ⇒ Single and double beta decay



P. Osland & G. Vigdel, hep-ph/0107161



$<m_\nu> \sim$ **0.01-0.06 eV**

LMA region

II. Nuclear Responses for $0\nu\beta\beta$

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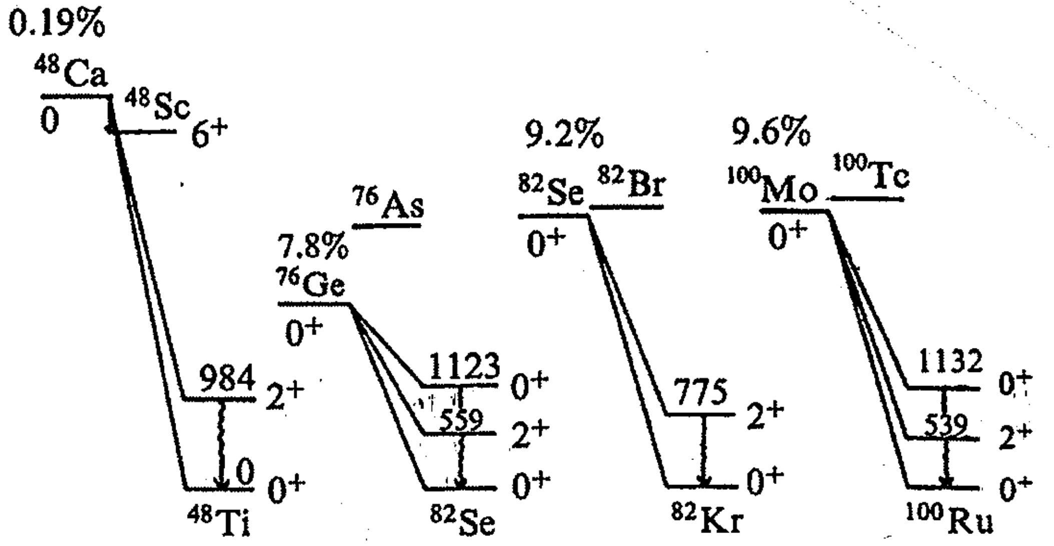
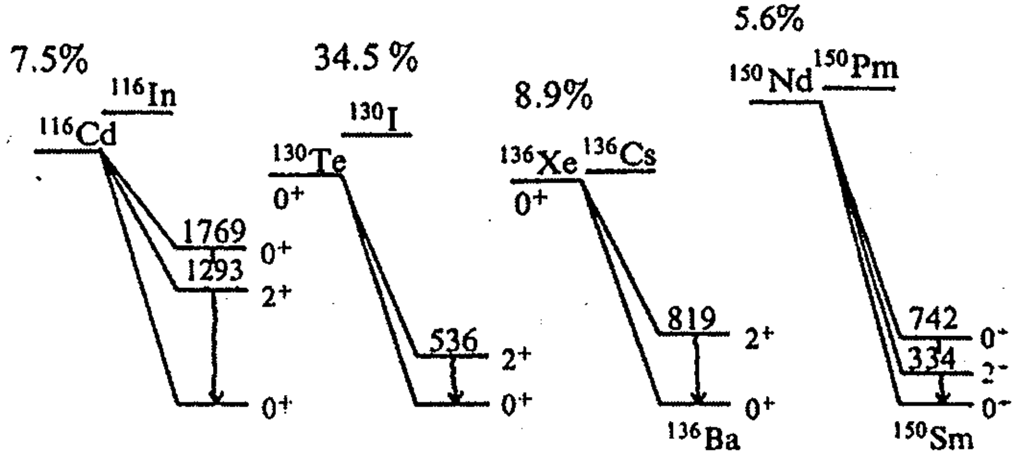
ββ nuclei

Mostly
$\beta^- \beta^-$
decays with large
$Q_{\beta\beta}$
to get large phase
space ~$Q_{\beta\beta}^5$



$Q_{\beta\beta}(0^+ \to 2^+) = 3287$ keV 1481 2220 2495

$Q_{\beta\beta}(0^+ \to 0^+) = 4271$ keV 2045 2995 3034



$Q_{\beta\beta}(2^+) = 1509$ keV 1997 1660 3033

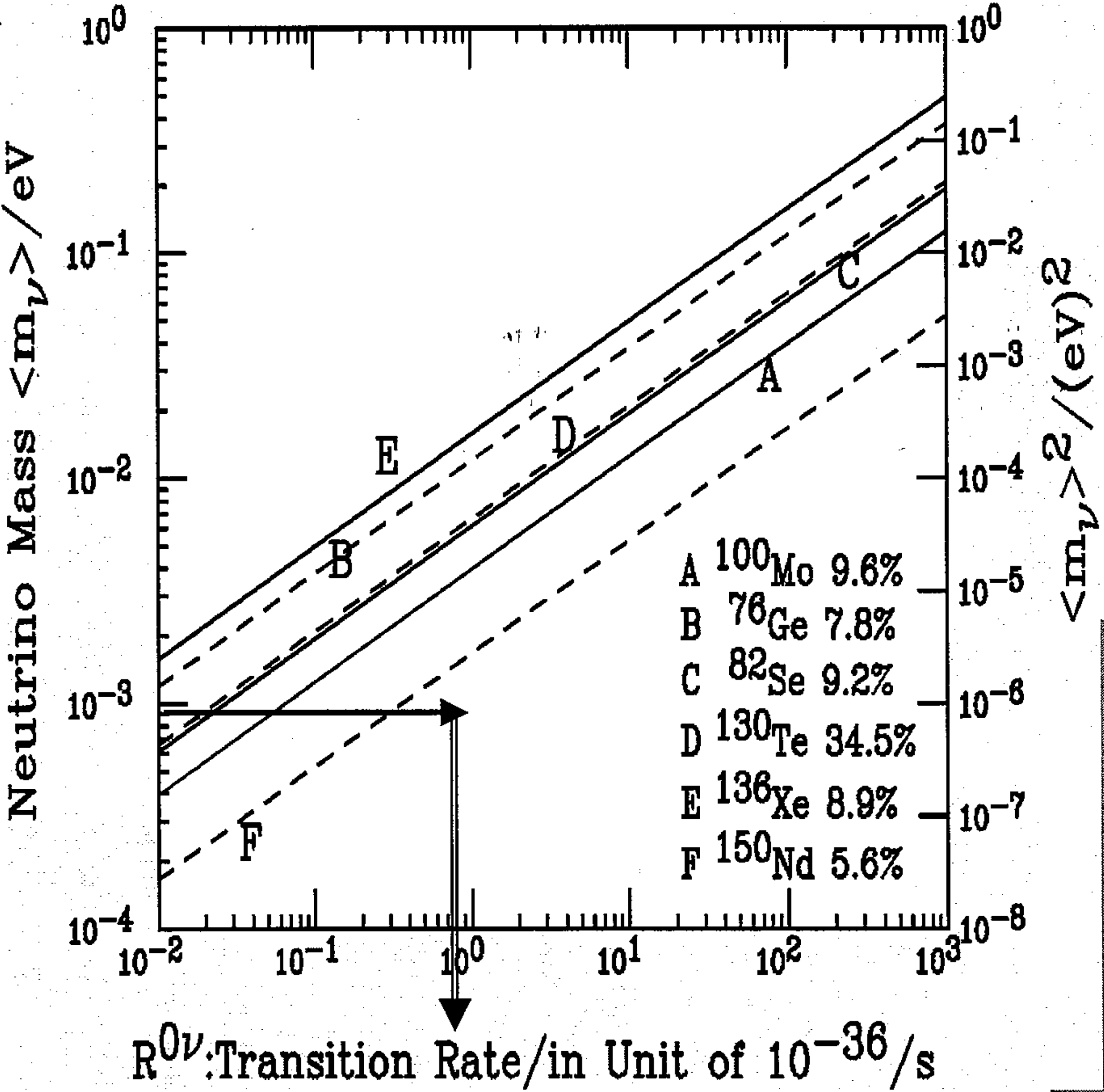
$Q_{\beta\beta}(0^+) = 2802$ keV 2533 2479 3367

ββ nuclei

	$Q_{\beta\beta}$ MeV	A %	Detector:Int./Ext	
^{48}Ca	4.271	0.19	Scinti.	Int.
^{76}Ge	2.045	7.8	Semi-con.	Int.
^{82}Se	2.995	9.2	Track	Ext.
^{100}Mo	3.034	9.6	Track	Ext.
^{116}Cd	2.802	7.5	Scin/Sem.	Int.
^{130}Te	2.533	34.5	Bolom.	Int.
^{136}Xe	2.479	8.9	Track	Int.
^{150}Nd	3.367	5.6	Track	Ext.

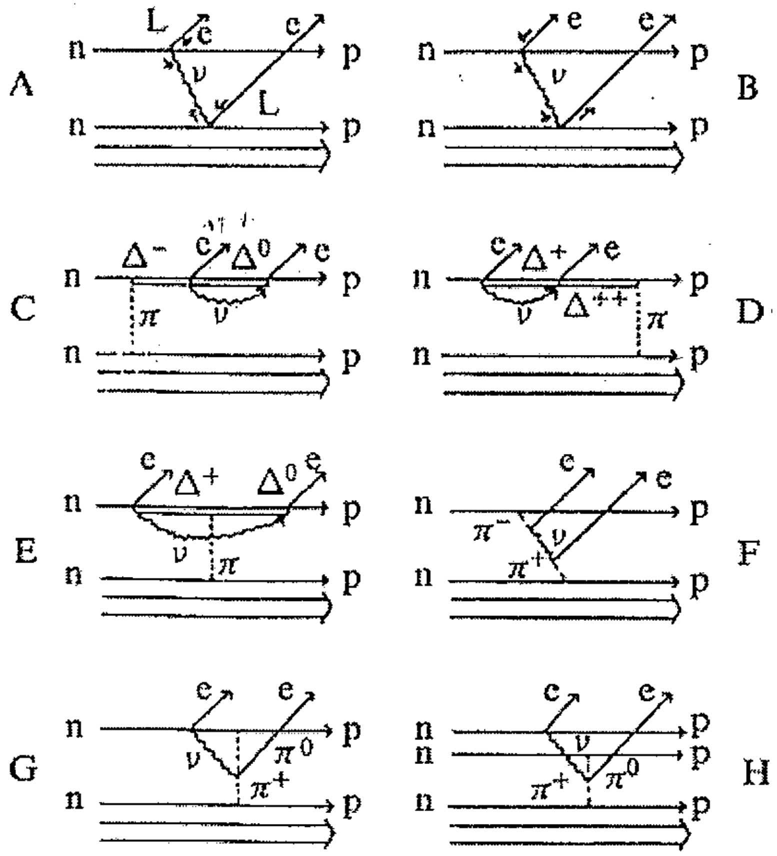
Nuclear response for ββ

- $T(0\nu\beta\beta) =$
- $S_N[\langle m_\nu \rangle^2]$
-
- $S_N = G\,|M^{0\nu}|^2$
- $G \sim Q_{\beta\beta}^5$



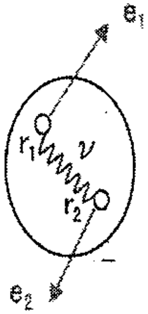
ββ processes

Two nucleon process.
Isobar process
Pion process



Nuclear Responses ($M^{0\nu}$) for ββ by Double Charge Exchange Reactions

Nuclear Responses for $0\nu\ \beta\ \beta$



q=04.GeV/C

ℓ=0-6

$H(r_1, r_2, \tau_1, \tau_2, \sigma_1, \sigma_2) \sim f(r_1, r_2)\ \tau_1 \tau_2 \sigma_1 \sigma_2 \ldots$

$f(r_1, r_2) = 1/|r_1 - r_2|$

Separable Form for Nucleon $r_n < r_i, r_j <$ Nuclear R_N

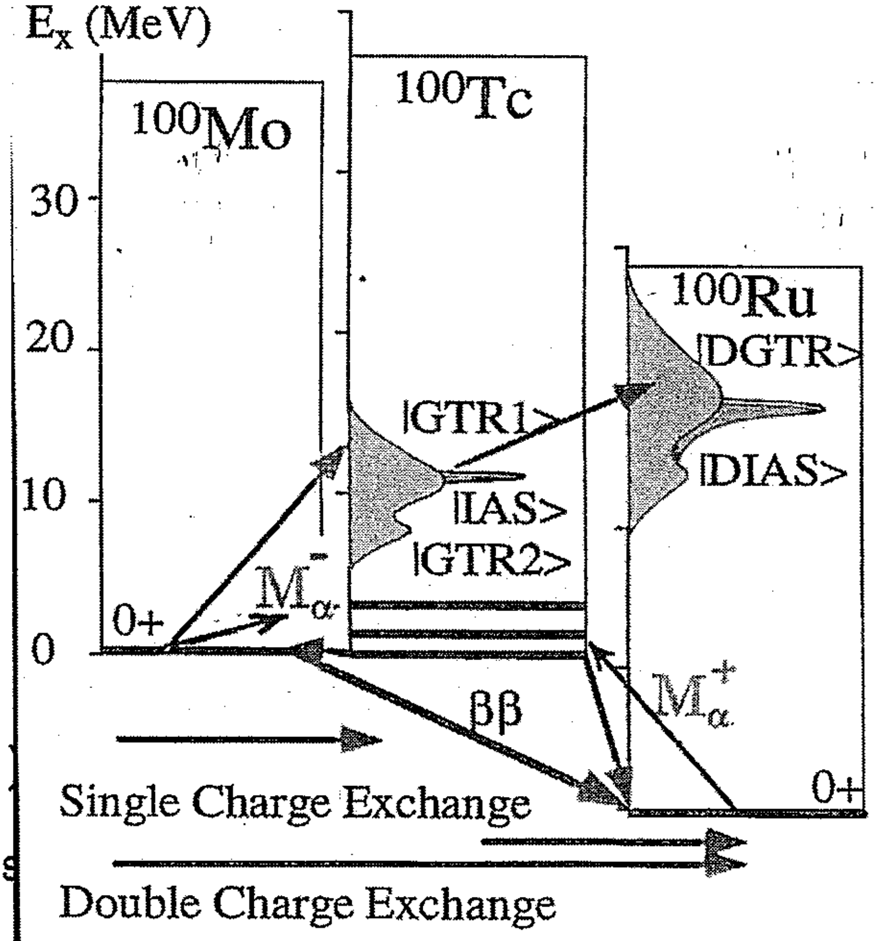
$f(r_1, r_2) \sim \sum_\ell f_\ell h_\ell(r_1) h_\ell(r_2)$ Ejiri, Belyaev

$M^{0\nu} \sim \sum f_\ell \langle 0_f | T_\ell^+ | i \rangle \langle i | T_\ell^+ | 0_i \rangle \quad T_\ell = h_\ell(\gamma)\, \tau\, \sigma$

$M^{0\nu} \sim \sum M_\ell^+(SP) M_\ell^-(SP) + (M_\ell^+(GR)\ M_\ell^-(GR) \to \varepsilon$

Studied by τ^- and τ^+ Charge Exchange Reactions

(^{3}He,t) and (t.^{3}He) reactions



- **^{100}Mo (^{11}B, ^{11}Li) ^{100}Ru at RCNP**

• III. Perspectives of ββ Experiments

Present Status of ββ for ν mass

- **Effective Mass limits**
- **Inclusive ββ**
- **^{76}Ge H.M. IGEX , Ge Detectors 0.3-1.3 eV,**
- **^{130}Te Cryogenic Bolometor 1.3-2.5 eV**
- **^{128}Te Geo-chemical 1.2—2.4 eV**
- **Exclusive ββ spectroscopic studies.**
- **^{100}Mo ELEGANT, ^{150}Nd, 1.5 – 3 eV**
- **NEMO ^{100}Mo ^{82}Se others Sub eV**

Depend on nuclear matrix elements, factors 2.

Limited by the detector sensitivities of S_D~ 0.3-1.5 eV.

Perspectives of $<m_{\nu}>$ by ββ

- Sensitivity $S = S_n$(nuclear) x S_d(detector)

- $m_{\nu}^{-1} \sim S\,t^{1/4}$
- $S_n = M^{0\nu}\,k(Z)\,Q_{\beta\beta}^{2.5}$
- $S_d = N_{\beta\beta}^{1/2}/[\Delta E\,N_{BG}]^{1/4}$

- Large Sensitivity: Large Detector with $N_{\beta\beta} \sim$ tons to get the ν-mass sensitivity of 0.01~0.05 eV.

- $N_{BG} \sim N(2\nu\beta\beta) + RI$

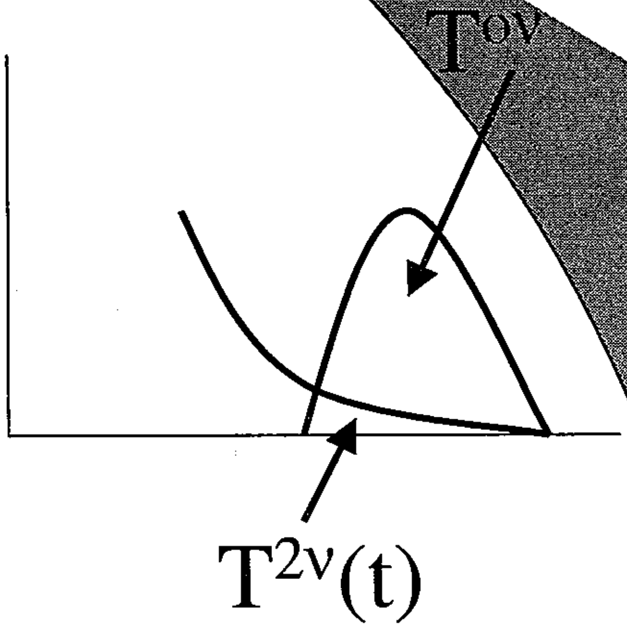
Future ββ Experiments

- ^{48}Ca CANDLES
- ^{76}Ge GENIUS MAJORANA
- ^{100}Mo MOON
- ^{116}Cd COBRA CAMEO
- ^{130}Te CUORE
- ^{136}Xe EXO
- ^{150}Nd DCBA

$2\nu\beta\beta$ & RI BG in $0\nu\beta\beta$ window

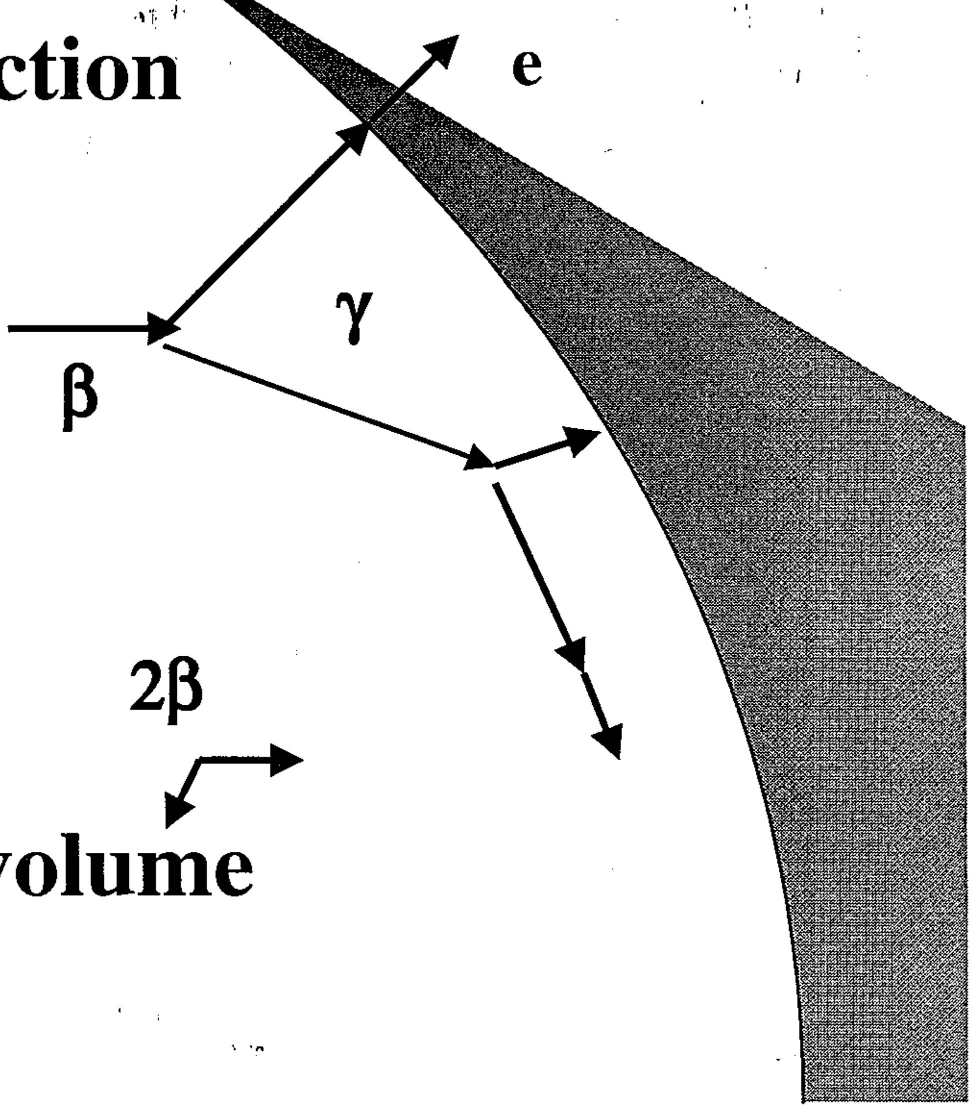
- $T^{0\nu} \sim k_0\, Q^5$, $T^{2\nu}(t) \sim k_2\, Q^{10}(\Delta E/Q)^6$
- $T^{0\nu}/(T^{2\nu}(t))^{1/2} \sim k\, Q^3/\Delta E^3$
-
- ^{76}Ge Semiconductor ,
- ^{130}Te Bolometer:
- $\Delta E/Q \sim 1.5\ 10^{-3}$
- $T^{2\nu}(t) << BG(RI)$
- at 2~2.6 MeV
- Tracking Detectors
- $\Delta E/Q \sim 5\text{~}10\ 10^{-2}$
- $T^{2\nu}(t) >> BG(RI)$
- at 3~3.3 MeV

$E_\beta + E_\beta$ spectrum



Localization / Segmentation of detector

Event selection



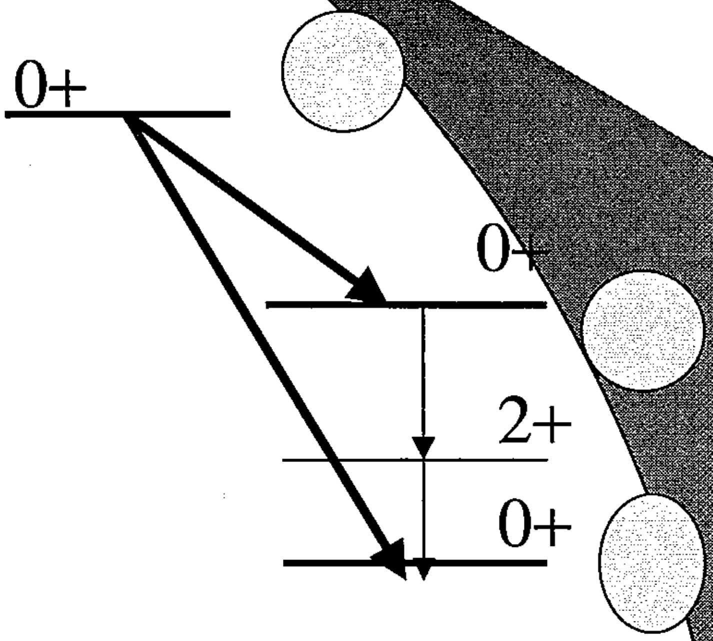
- β–γ
- e E0, IC
- 1γ Compton-e γ
- 2γ Cascade γ
- γ: Multi e in a large volume

$M^{0\nu}$, $M^{2\nu}$, and Nuclear Shapes

Possible Shape Change

**Excited 0+ state transition
with deduced BG
by γ–γ coincidence**

**^{100}Mo 1.132 keV 0+
$T^{2\nu}$ ~7 10^{20}y
(DeBraekelee et al, Barabash et al.)
Ratio to the g.s is 0.01,
same as the phase space.
Not two phonon state ?**



III. Future ββ Experiments

- 1.GENIUS for ^{76}Ge
- 1.MAJORANA for ^{76}Ge ββ→ afternoon
- 2. COBRA & CAMEO for ^{116}Cd ββ
- 3. 2. CUORE for ^{130}Te ββ
- 4. MOON for ^{100}Mo→ details by Pr.Nomachi
- 5.EXO for ^{136}Xe
- 6. DCBA

- NEMO: afternoon by NEMO group

GENIUS

- H.M. aims at 0.01 eV
- Ge 76 crystals in liquid nitrogen

MAJORANA for ^{76}Ge

F. Avignone et al.,US Europe

- Segmented ^{76}Ge semiconductor detector.
- High E-resolution leads to large S/N
- Low Q=2 MeV, BG of ^{214}Bi, ^{208}Tl
- Based on IGEX: 0.3~1.3 eV

- Enriched ~ ton ^{76}Ge
- Sensitivity of 0.02 ~0.05 eV

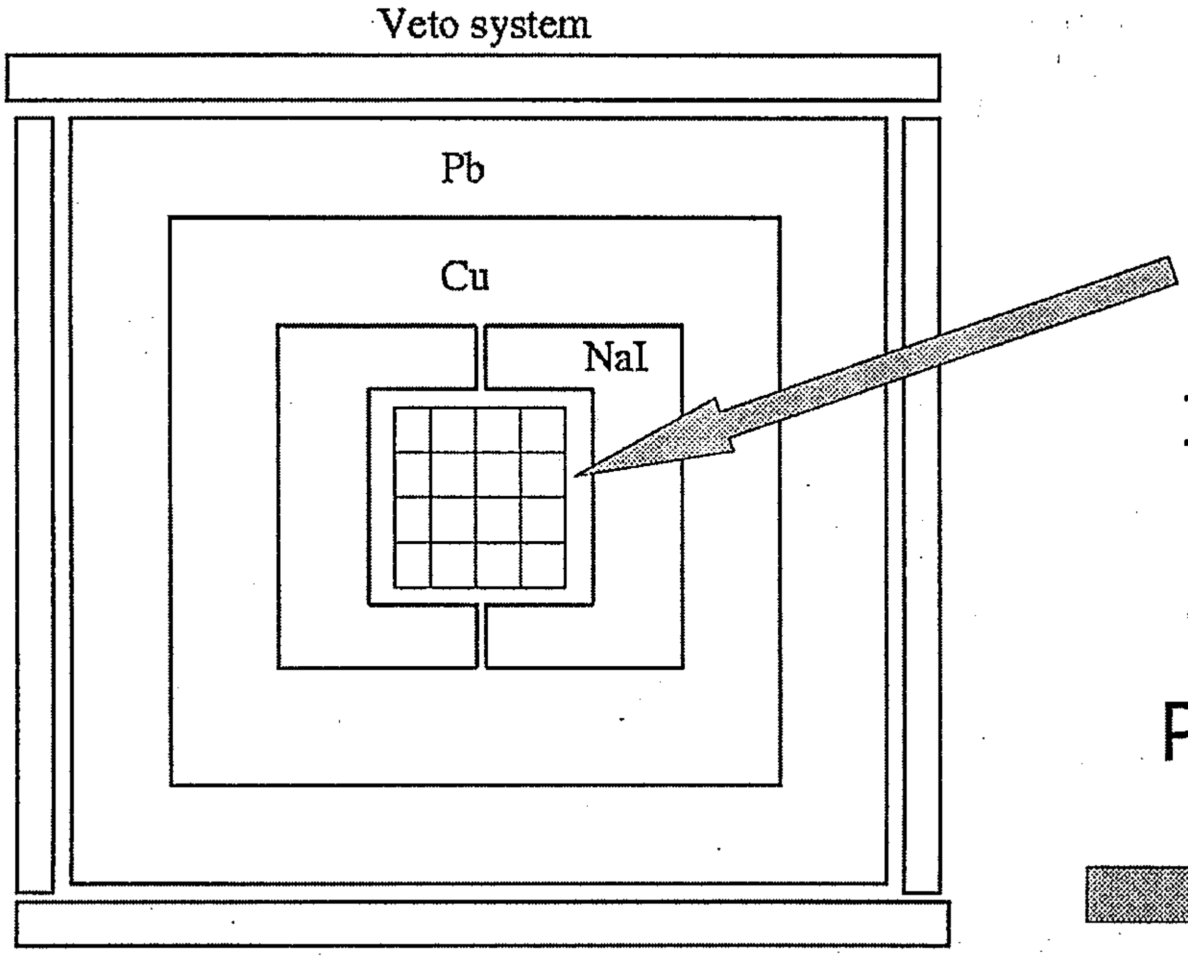
- Details afternoon by Ejiri

^{116}Cd-^{130}Te COBRA

K. Zuber

- 1. Good E-resolution (1%) Semiconductors
- 2. ^{116}Cd, ^{130}Te and other elements
- 3. Potential of tracking by pixel detectors
- 4. $\beta^+\beta^+$ by ^{106}Cd with 1.2 % and Q=2.77 MeV
- 5. Points are enriched isotopes and total volume

COBRA K. Zuber, nucl-ex/01050



CdTe - Array

1 ccm crystals

Option:

Pixel detectors

⇒ Tracking

COBRA - Isotopes

+ Zn64, Zn70

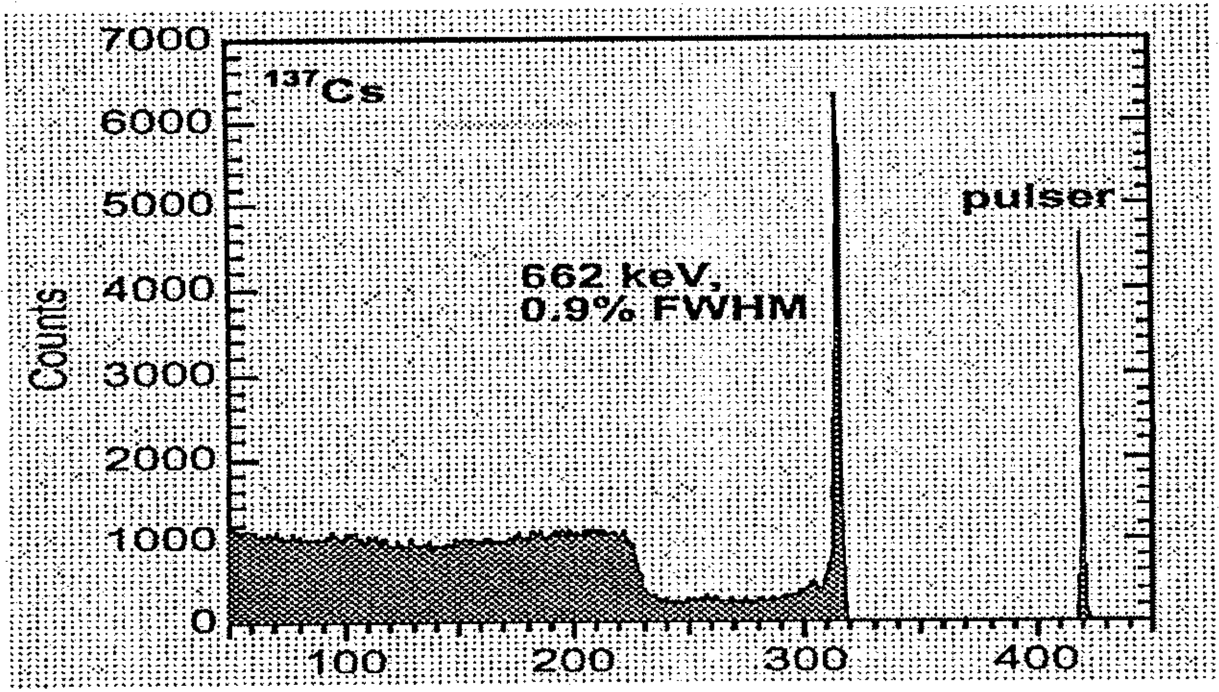
	nat. ab. (%)	Q (keV)	Decay mode
Cd114	28.7	534	ß-ß-
Cd116	7.5	2805	ß-ß-
Te128	31.7	868	ß-ß-
Te130	33.8	2529	ß-ß-
Cd106	1.21	2771	ß+ß+
Cd108	0.9	231	EC/EC
Te120	0.1	1722	ß+/EC

Energy resolution

McConnell et al., astro-ph 0106047

CdZnTe semiconductors

0.9 % FWHM at 662 keV



^{116}Cd CAMEO

Kiev INFN,Queen,TUM

- 1. Enriched ^{116}Cd WO_4 scintillators
- 2. Use of existing CTF
- (Liquid scintillator Borexino
- Counting Test Facility)
- 3. $N \sim 10^{26}$ =15kg, BG ~ 3-4, t ~ 5-8 y,
- 4. $m_\nu \sim 0.05 \sim 0.07$ eV

CUORE for ^{130}Te

Milano Gran Saso

- **Thermal detector at low temperature: E. Fiorini**

- **Heat capacity**
- **$C_v \sim k\,(T/\Theta)^{3}$,**
- **Θ:Deby temperature**
- **High energy resolution (10 eV for kg mass) in principle,**
- **in practice 5 eV for 6 kev X ray.**

- **CaF_2 Thermal scintillation pulses coincidense**

Fiorini

ν2000

● .

ΔE @ 5 keV ~100 mk ~ 1 mg <1 eV ~ 5 eV
@ 2 MeV ~10 mk ~ 1 kg <10 eV ~ keV

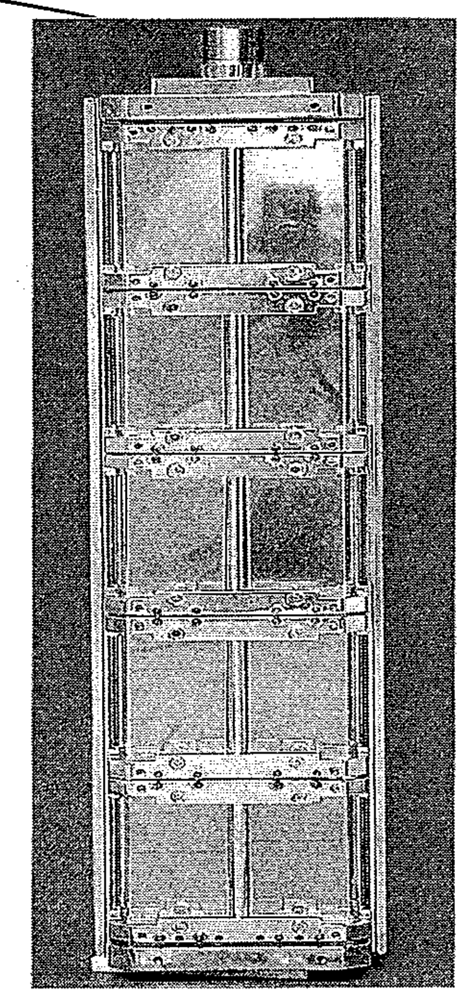
Compound	**Isotopic abundance of the candidate nucleus**	**Transition energy**
^{48}CaF$_2$ a	.0187 %	4272 keV
^{76}Ge b	7.44 "	2038.7 "
^{100}MoPbO$_4$ c	9.63 "	3034 "
^{116}CdWO$_4$ c	7.49 "	2804 "
^{130}TeO$_2$ d	34 "	2528 "
^{150}NdF$_2$e	4.64 "	3368 "

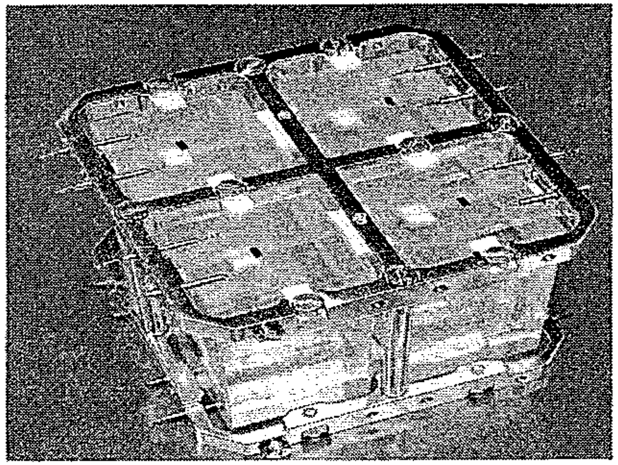
Bolometric Method for ^{130}Te

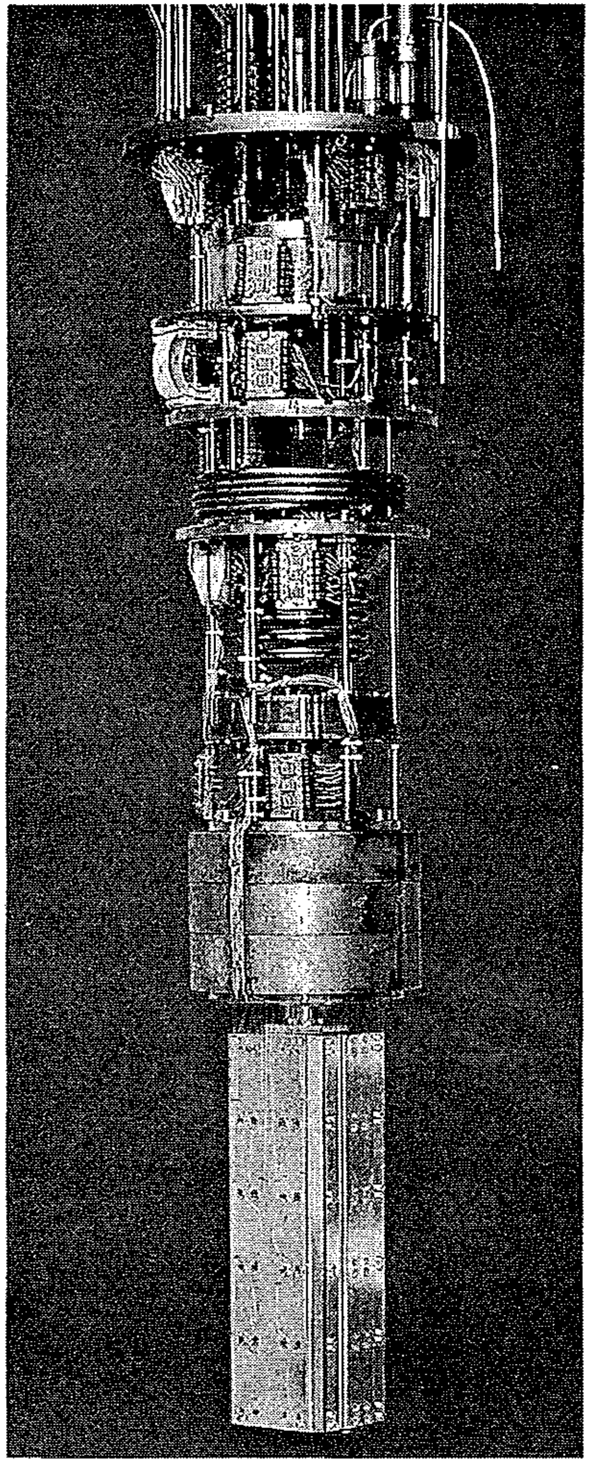
- TeO_2 Bolometer

- ^{130}Te dominance 27% in crystal (isotope 34 %)
- Q=2.53MeV, between ^{208}Tl photo peak and Compton

	CUORICINO	CUORE
Weight	42 kg	1K of 1kg
BG/keV.kg.y	0.1	0.001
Sensitivity $T_{1/2}$ y	8 10^{24}	1.1 10^{26}
m_n eV	0.15~0.3	0.04~0.09







CUORE

- .

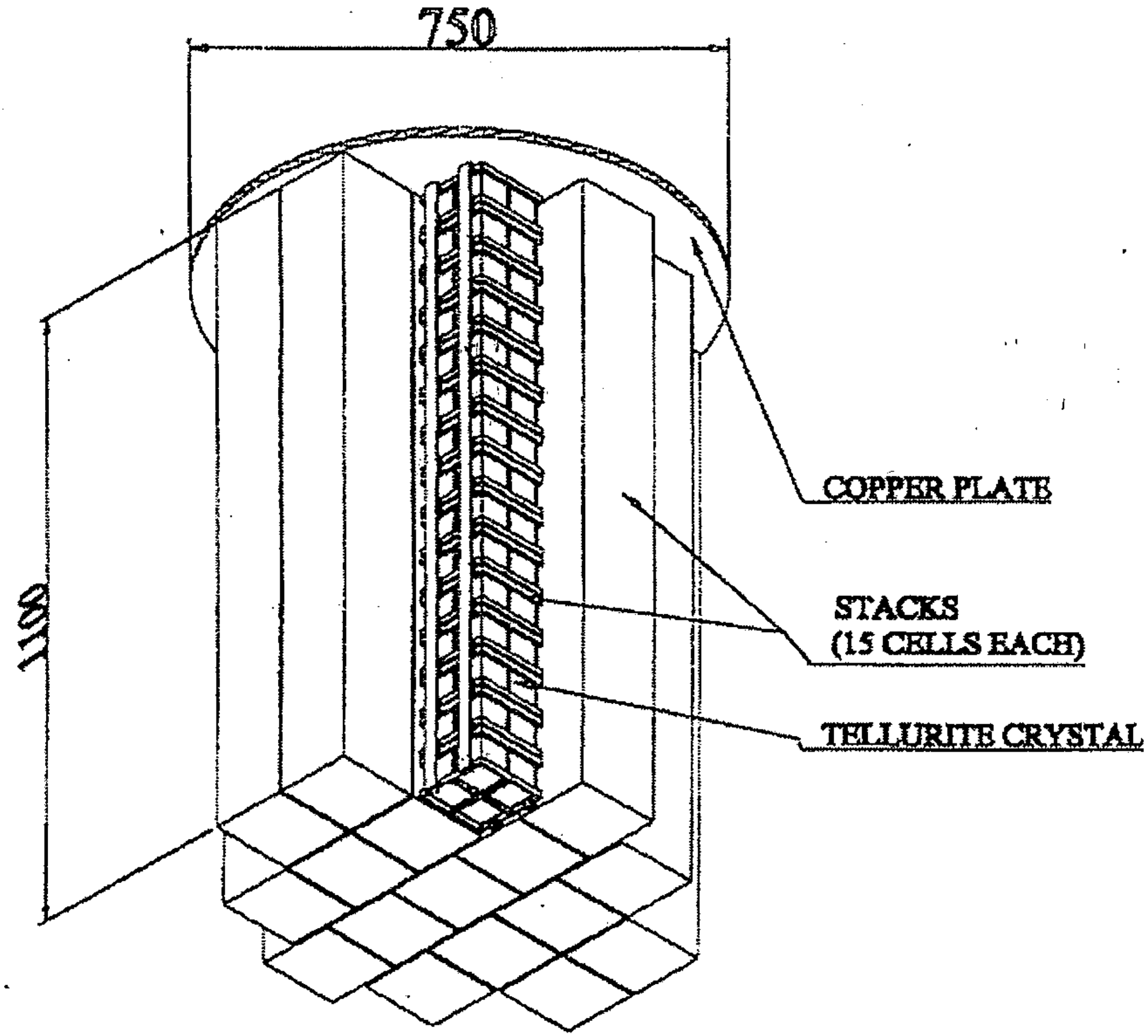


Figure 4. Scheme of CUORE and CUORICINO (essentially one column of CUORE)

MOON

Mo Observatory Of Neutrinos
for
Neutrinos Studies in ^{100}Mo

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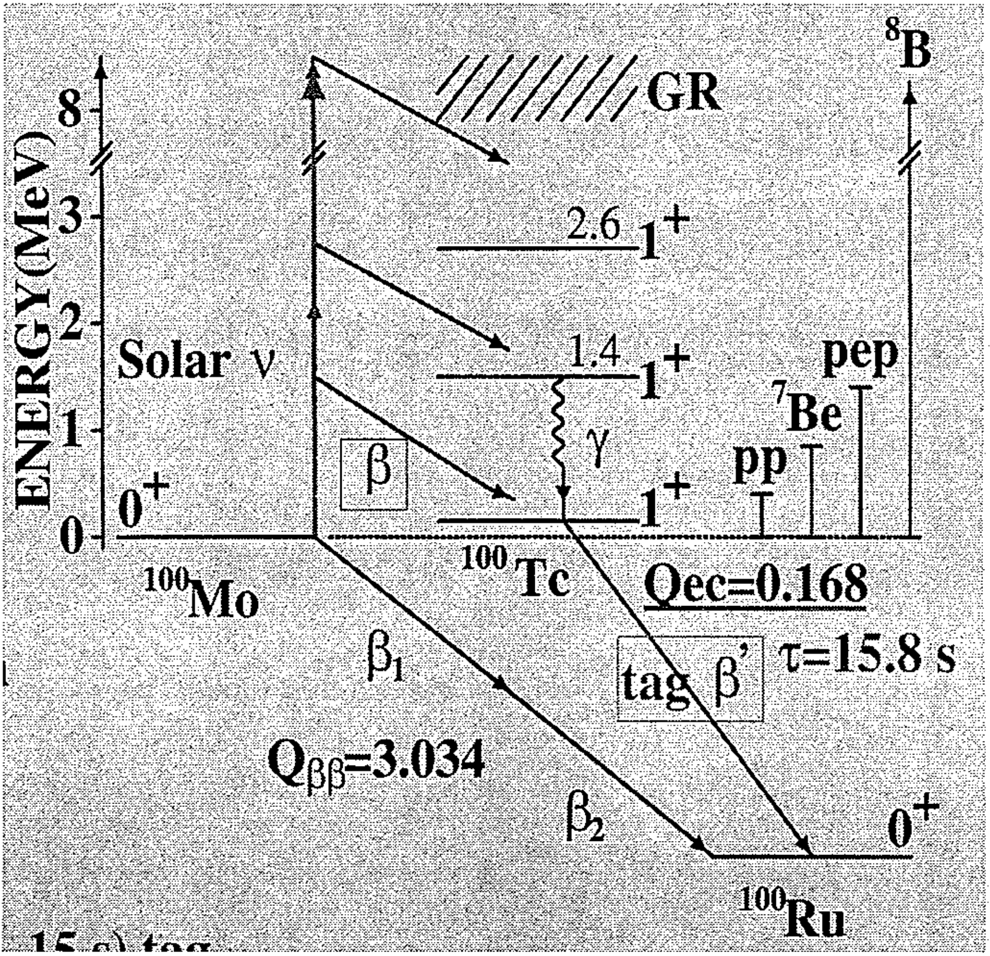
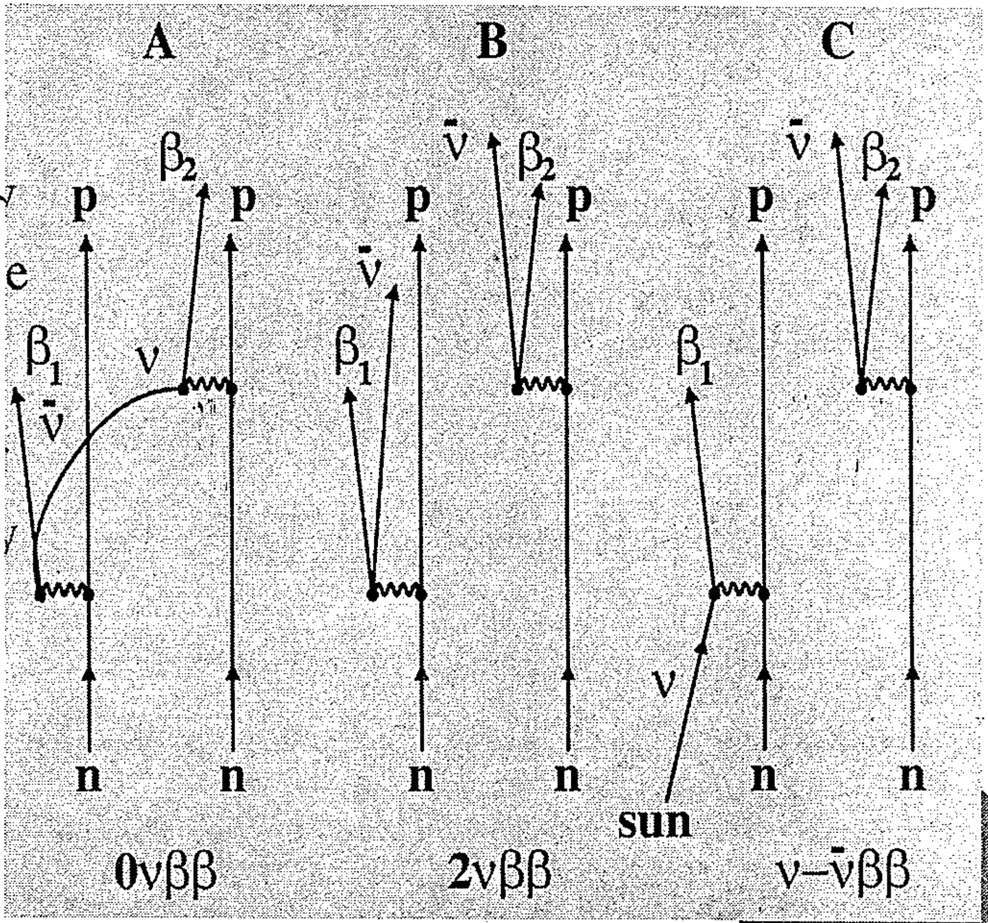
http://ewi.npl.washington.edu/moon/

MOON with ^{100}Mo for ββ and solar/supernova ν





Correlated ββ and solar/supernova ν induced β and successive β

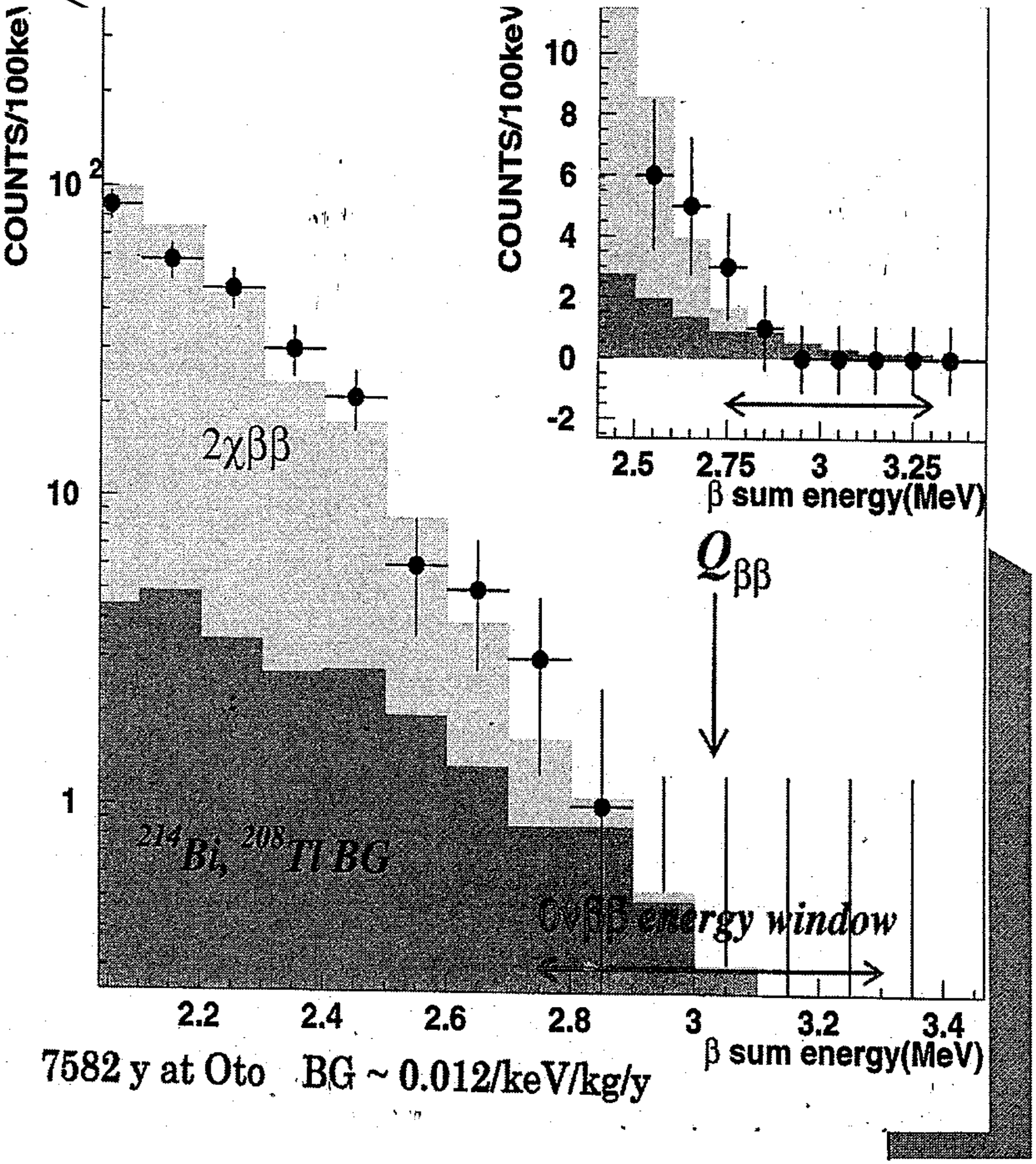
MOON Objectives

- Spectroscopy of two β rays from ^{100}Mo with
- large responses for $\beta\beta$–ν and low energy solar/supernova ν_e and low threshold(Q_β)
- Double beta ($\beta\beta$) decays with m_ν~0.03 eV.
- Low energy pp&^{7}Be solar ν_e and supernova ν_e by inverse β followed by successive β
- Two charged particle(β,β) spectroscopy with high localization(resolution) in time and space.
- MOON, a super modules of ^{n}Mo/^{100}Mo with 1 ton ^{100}Mo & scintillators(liquid/solid Mo loaded) with modest volume and realistic purity

^{100}Mo 0νββ by ELEGANT V

- $T^{0\nu} > 1.0\ (0.55)\ 10^{23}$y
- 68(90)%CL
- BG 10^{-2}/keV.kg.y
-
- $<m_\nu> \ < \ 1.5\ (2.1)$ eV
- $<g_B> \ < \ 9\ (11)\ 10^{-5}$
- ELEGANT V / Oto Lab.

H.Ejiri, N.Kudomi, et al.,
Phys. Rev. C 63 '01, 65501



7582 y at Oto BG ~ 0.012/keV/kg/y

Nuclear Responses for solar and supernova Neutrinos

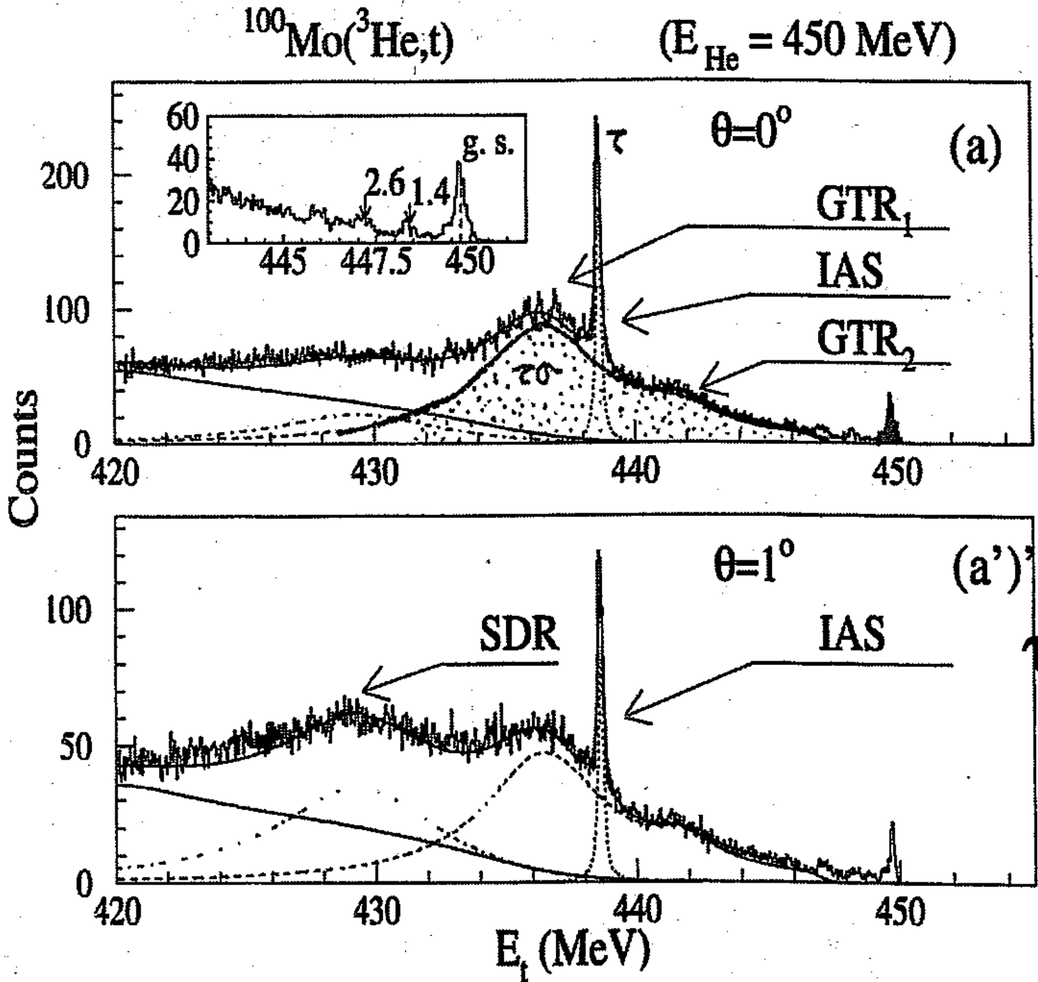
H. Akimune, H. Ejiri et al.
Phys. Lett. 394B (1997) 23

Nuclear Responses for Neutrinos:

Charged Current Spin ($\tau\sigma Y_1$)

Charge Exchange Spin-flip Reactions

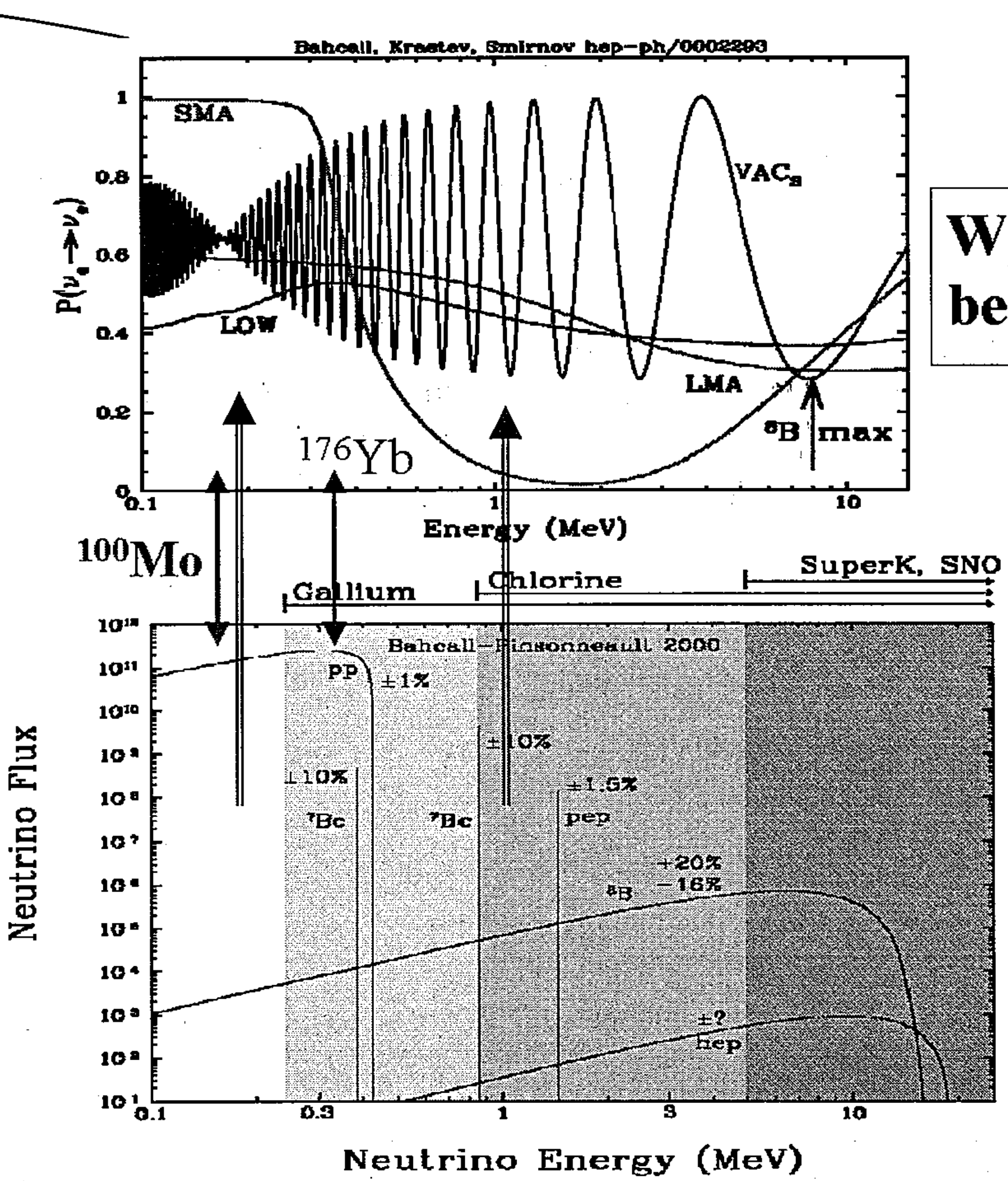
H.Ejiri, Phys. Rep. 338 (2000) 265



$\tau\sigma$

$\tau\sigma Y_1$

Why ν_{solar} below 1 MeV



Solar-ν capture rates in units of SNU

Nucleus	-Q(MeV)	pp	^{7}Be	^{13}N	pep	^{15}O	^{8}B	Total
^{2}H[a]	1.442	0	0	0	0	-	6	6
^{37}Cl[a]	0.814	0	1.1	0.1	0.2	0.3	6.1	7.9
^{40}Ar[b]	>1.505	0	0	0	0	0	7.2	7.2
^{71}Ga[c]	0.236	70.8	35	3.7	2.9	5.8	12.9	132
^{100}Mo[d]	**0.168**	**639**	**206**	**22**	**13**	**32**	**27**	**965**
^{115}In[a]	0.120	468	116	13.6	8.1	18.5	14.4	639
^{127}I[e]	0.789	0	9.4	-	-	-	13	24.6

GT Strength & Capture rate	I_i	Spin factor	*B(GT)* g.s.	1st	Sum
^{71}Ga	(3/2)+	0.25	0.089	0.005 (0.175MeV)	3.8
^{100}Mo	0+	1	0.33	↑0.13 (1.4MeV)	3.3

$1/(2I_i+1)$

a; Bahcall 88 b; Bhattacharya 98 c; Ejiri 98 d; Ejiri 99 e; Engel 91

MOON for Supernova ν_e , ν_{xe}

1.Large response for CC by

GTR, low E_{th}~2 MeV.

σ~ 6 10^{-41} cm^2 for ν_e

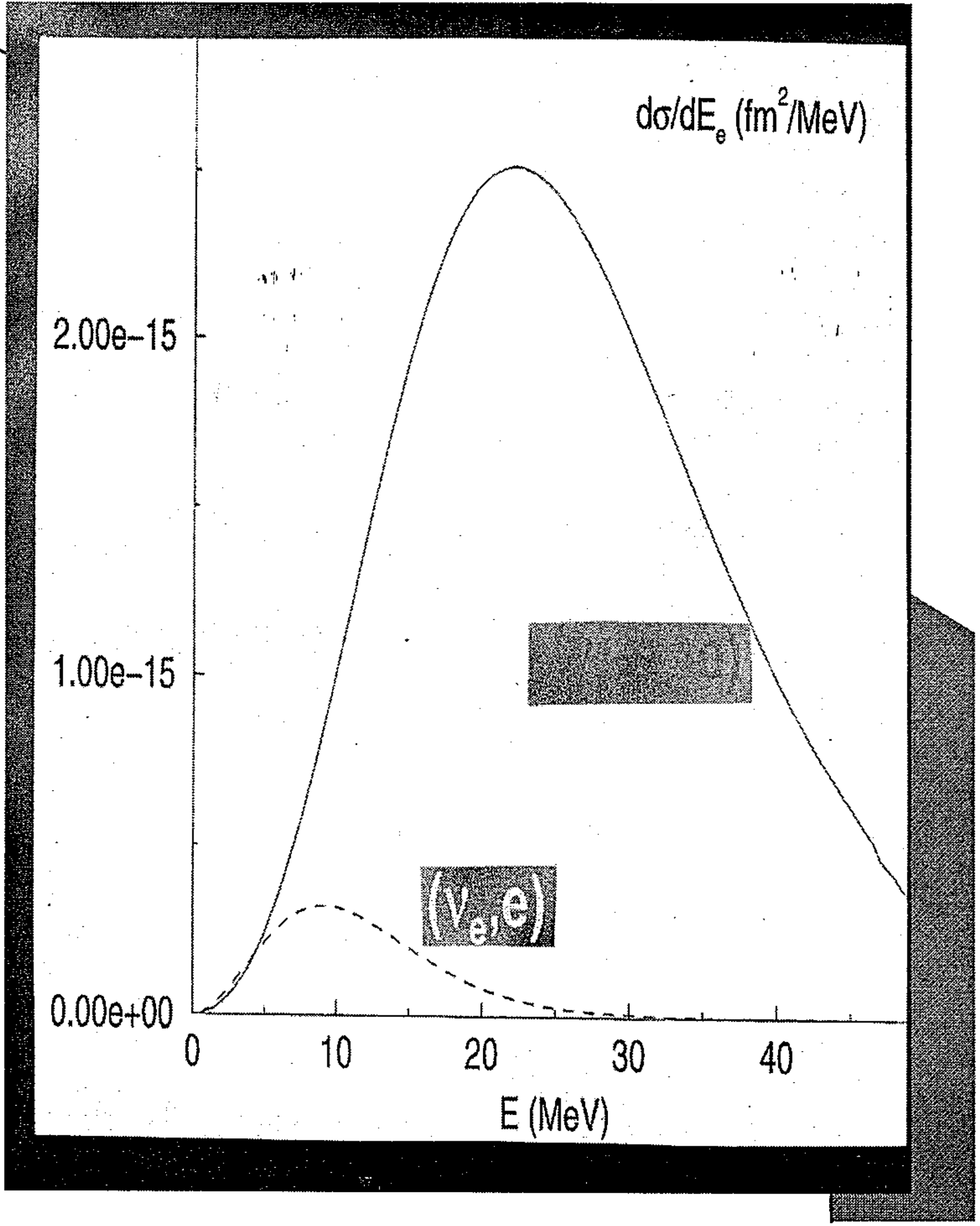
σ~ 7.8 10^{-40} cm^2 for $\nu_x - \nu_e$

2.Energy spectra of ν by measuring energies of e.

3.Sensitive to low energy ν_e and ν_x-ν_e oscillation.

4.Scaled up MOON with

1 K ton natural Mo plates of 2 gr /cm^2 gives 50 ν_e and 300 ν_x-ν_e oscillation events for 10 kps SN.



References

Double β decays.

ELEGANT H.Ejiri, N.Kudomi, et al., Phys. Rev. C 63 2001,65501

Review H.Ejiri, Nucl. Phys.B 91 (2001) 255, v2000 proc.

Nuclear responses.

Review. H.Ejiri, Phys. Rep. 338 (2000) 265.

MOON

ββ and solar ν H.Ejiri,J.Engel, Hazama, P.Krastev,
N.Kudomi, R.G.H. G. Robertson,
Phys, Rev. Lett.,85 (2000) 2917

Supernova ν H. Ejiri, J. Engel, and N. Kudomi, Phys. Lett.B, 02

- arXiv:astro-ph/ 0112379 v2

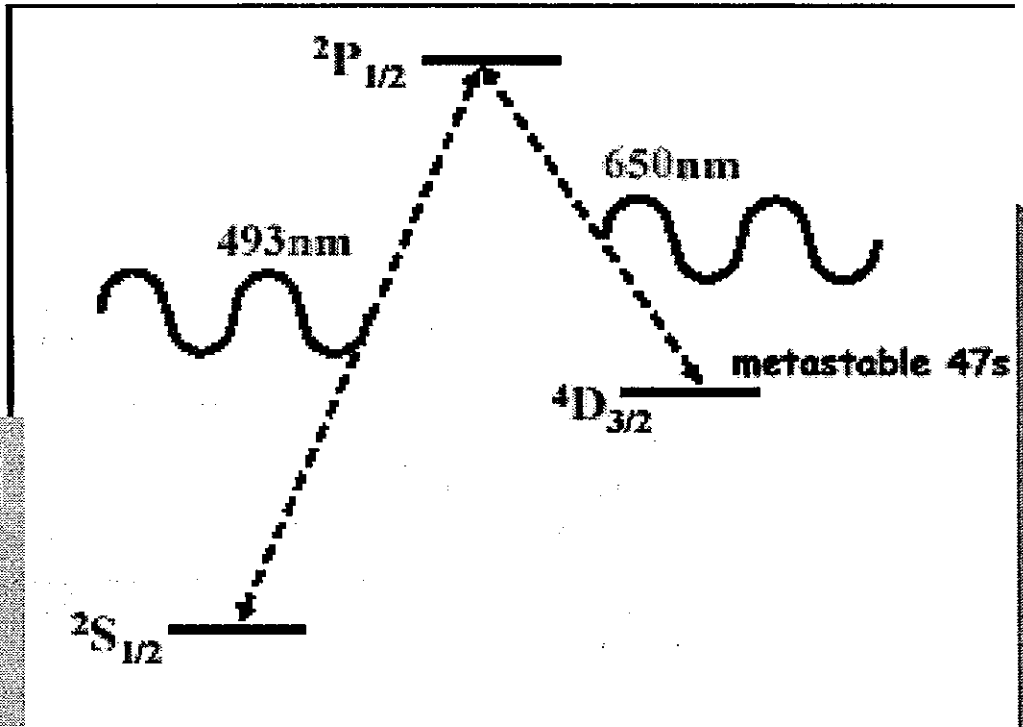
EXO for ^{136}Xe

Xe offers a qualitatively new tool against background:

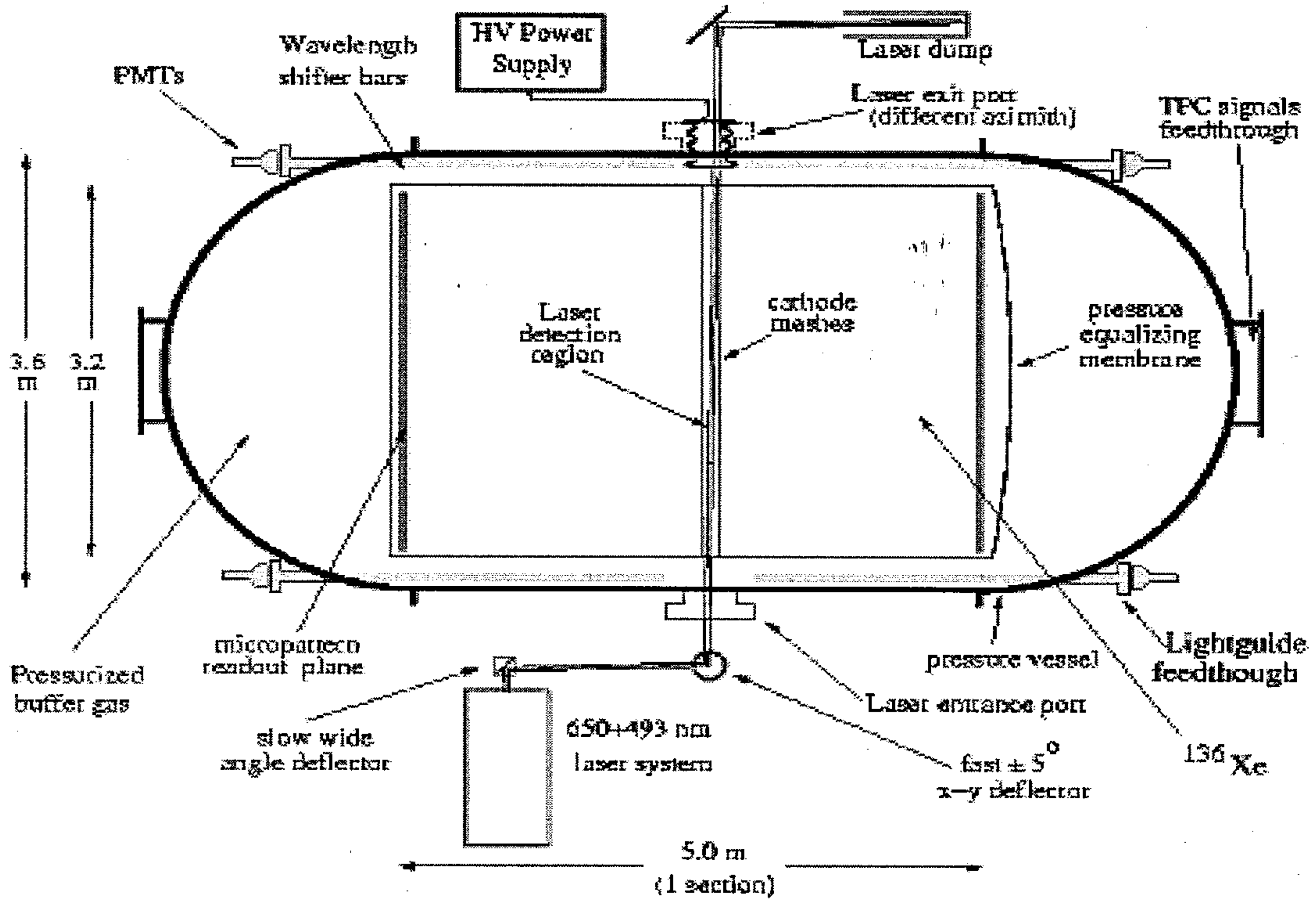
^{136}Xe → ^{136}Ba^{++} e$^-$ e$^-$ final state can be identified using optical spectroscopy (M.Moe PRC44 (1991) 931)

Ba$^+$ system best studied
(Neuhauser, Hohenstatt,
Toshek, Dehmelt 1980)
Very specific signature
"shelving"
Single ions can be detected
from a photon rate of 10^7/s

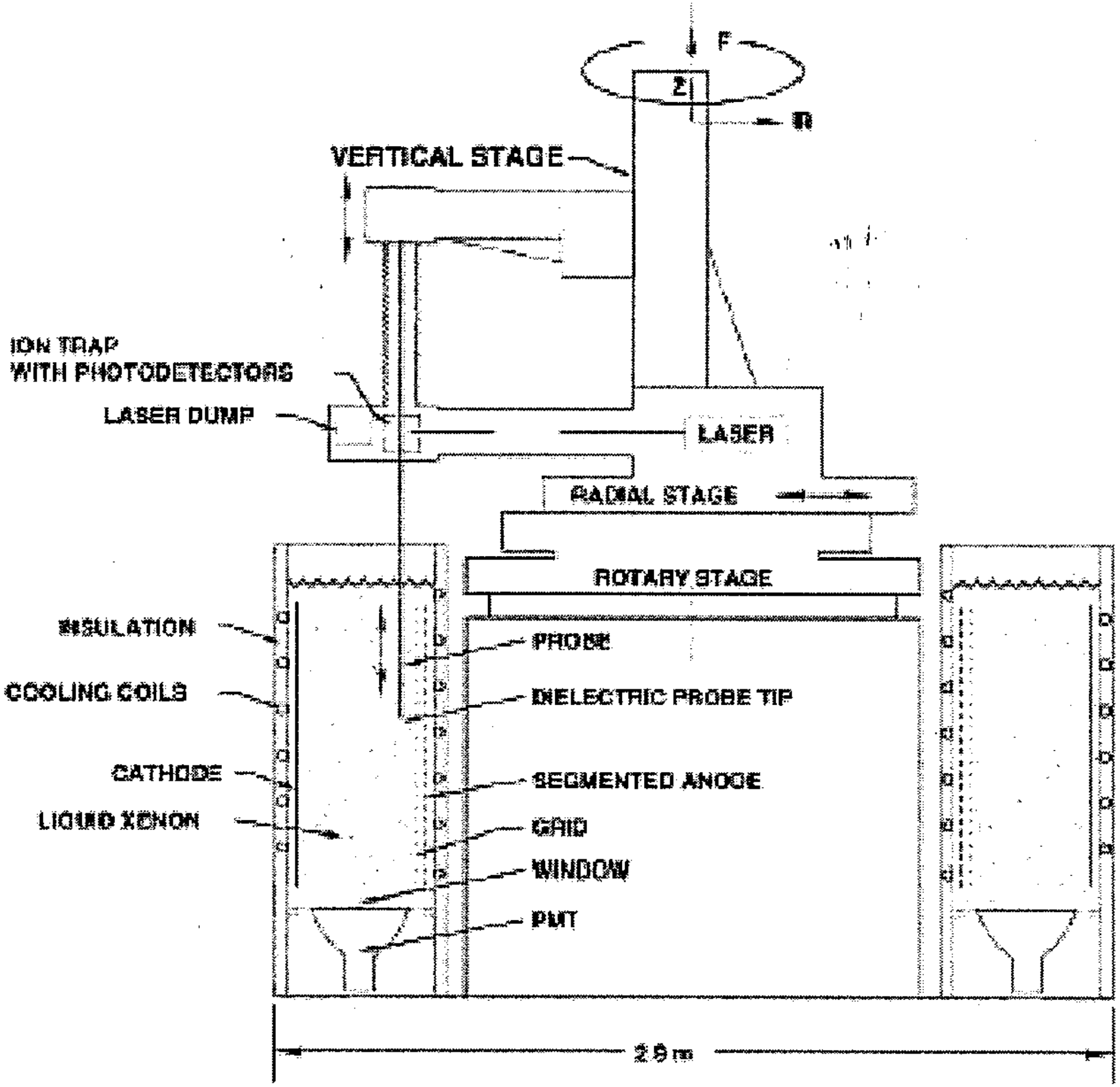
- Important additional constraint
- Huge background reduction



Conceptual scheme of a high pressure Xe gas TPC with laser tagging



Conceptual scheme of a LXe detector with Ba extraction



EXO projected sensitivity

Assuming that the Xe chamber + Ba tagging give 0 radioactive background...

Isotope	Det mass (kg)	Enrich. (%)	Eff. (%)	Measur. time (yr)	Background	$T_{1/2}^{0\nu\beta\beta}$ (yr)	$\langle m_\nu \rangle$ (eV) QRPA	NSM
^{76}Ge	11	86	75	2.2	0.3kg^{-1}yr^{-1}FWHM^{-1}	$1.9*10^{25}$	0.35	1.0
^{136}Xe	3.3	63	22	1.5	2.5kg^{-1}yr^{-1}FWHM^{-1}	$4.4*10^{23}$	2.2	5.2
^{130}Te	6.8	34	84.5	0.125	8.1kg^{-1}yr^{-1}FWHM^{-1}	$1.4*10^{23}$	1.8	3.8
^{136}Xe*	1000	90	70	5	0 + 1.8 events	$8.3*10^{26}$	0.051	0.14
^{136}Xe**	10000	90	70	10	0 + 5.5 events	$1.3*10^{28}$	0.013	0.037

*** $\sigma(E)/E$ = 2.8% R.Luescher et al. Phys. Lett. B434 (1998) 407**

**** $\sigma(E)/E$ = 2.0% Modest improvement on the above...**

DCBA for ^{150}Nd

Drift Chamber Beta Analyser

KEK N. Ishihara et al.

- Track recognition by 3-dimentional drift chamber in a solenoid.
- Momentum by bending curvature
- $\beta^{-}\beta^{+}$ from γ annihilation can be rejected.
- Source foil exchangeable
- Test 46-52-68 cm^3 resolution test
- .
- Points:Total volume, E-resolution, BG.

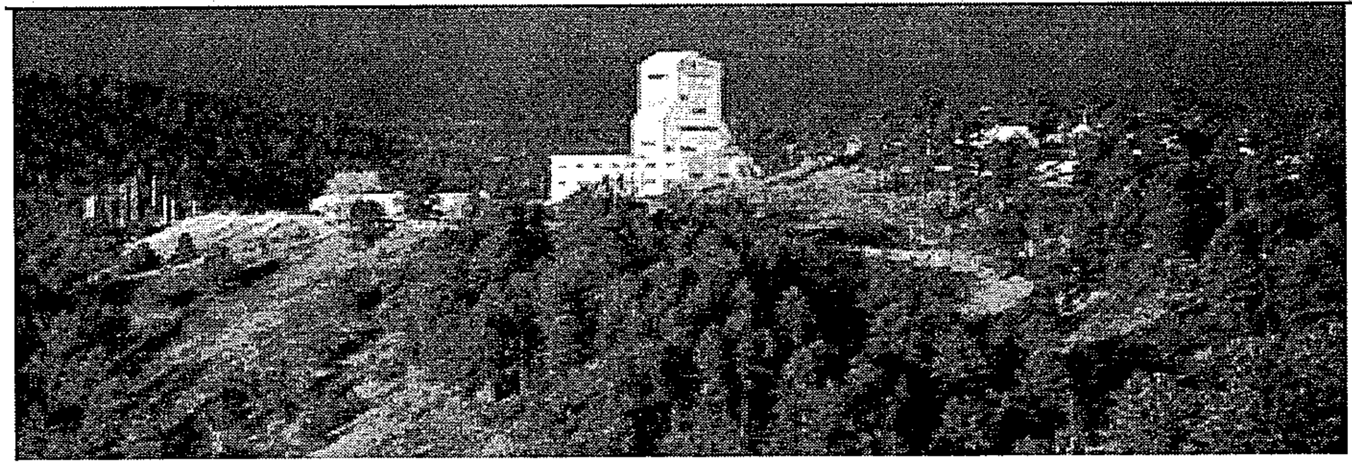
IV. Underground Laboratories.

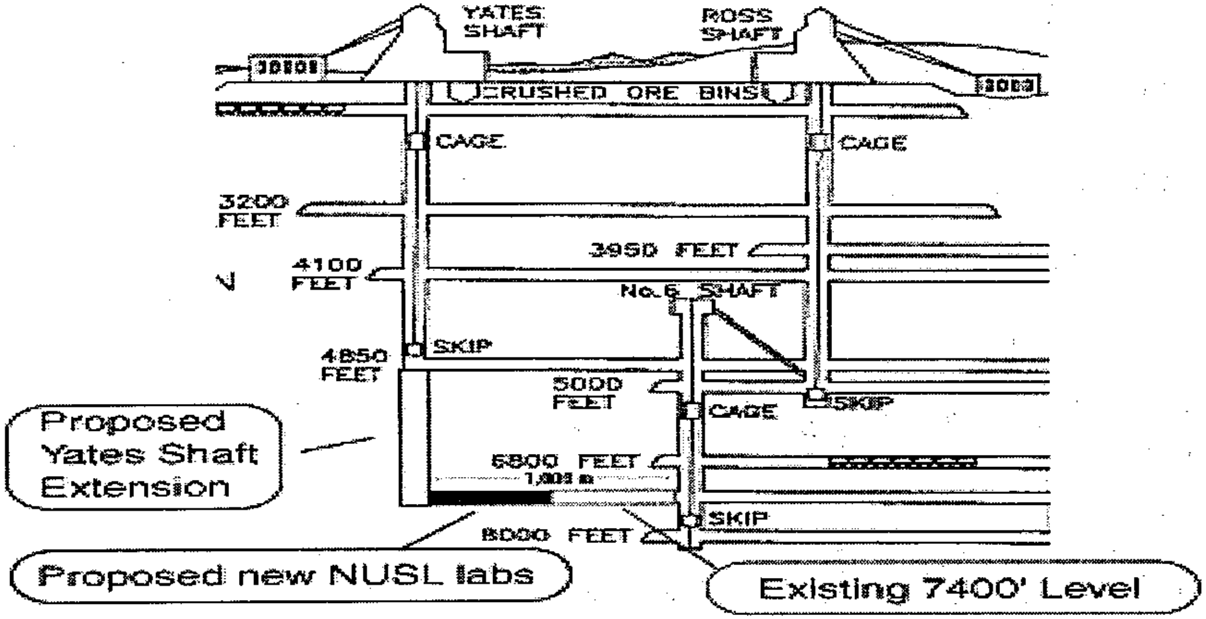
New generation experiments require new experimental sites

- Depth w.e.
- >3 k Gran Saso Calorimetric methods.
- Majorana, Cuore
- >1.5 Oto (1.4k) Spectroscopy for ββ
- MOON.

- New US underground lab. at Homestake mine.
- First priority project in nuclear physics in US

Homestake underground lab.





Proposed Yates Shaft Extension

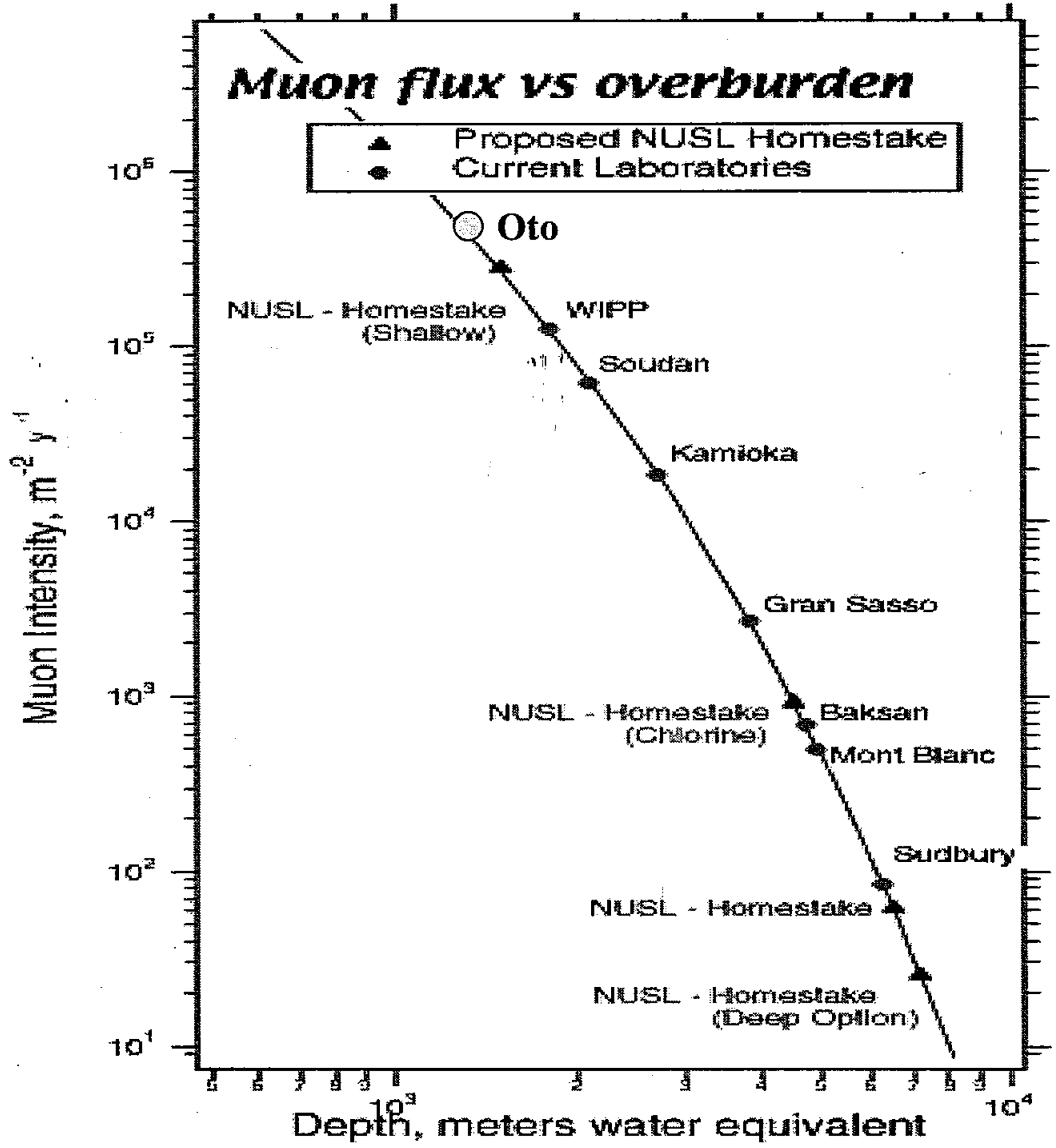
Proposed new NUSL labs

Existing 7400' Level

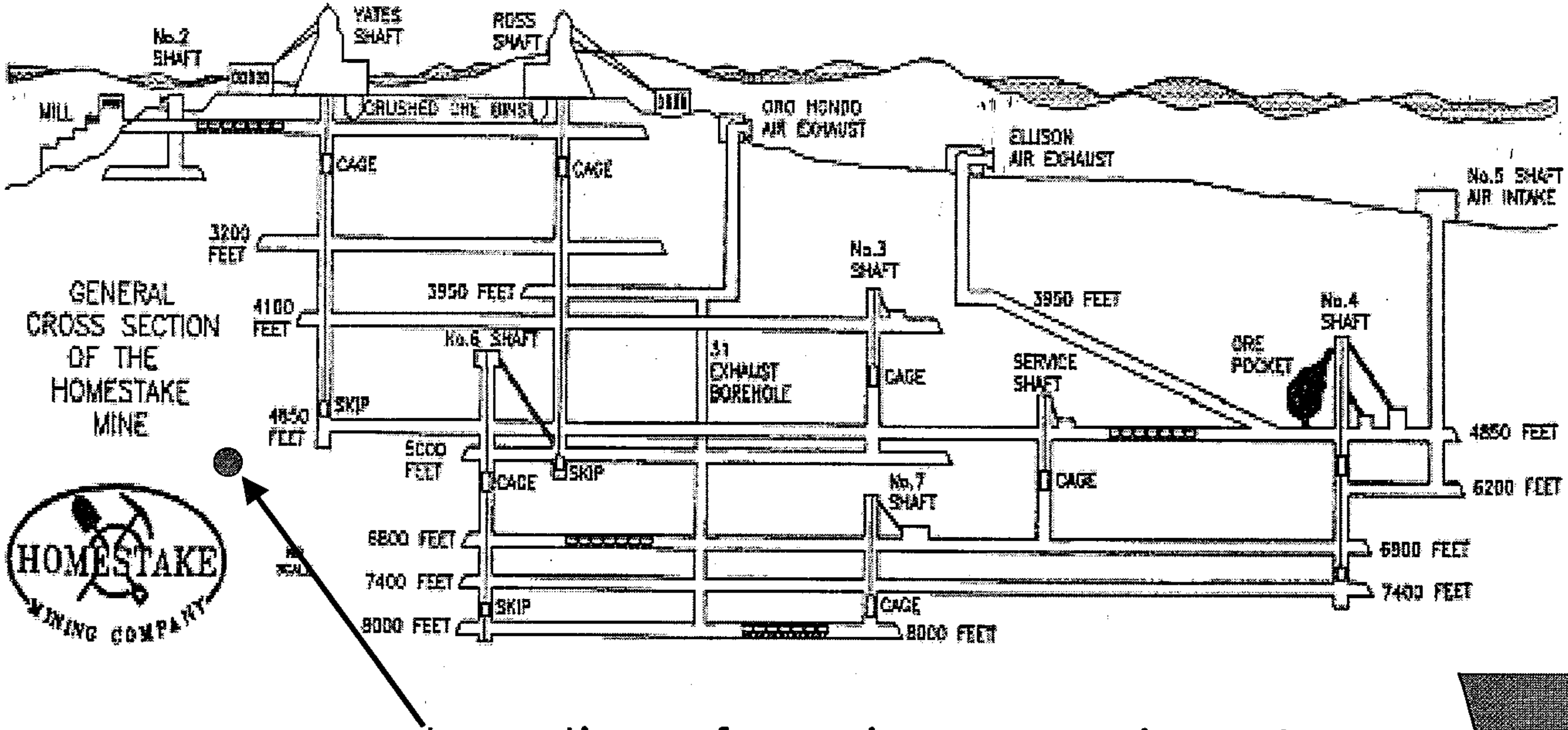
NUSL programs

Double Beta Decay
Craig Aalseth, PNL
Frank Avignone, USC
Hiro. Ejiri, Osaka
Steve Elliott, UW
Giorgio Gratta, Stanford
Steve Elliott, UW
Giorgio Gratta,Stanford

Muon flux


Muon flux vs overburden
Proposed NUSL Homestake
Current Laboratories
Oto
NUSL - Homestake (Shallow)
WIPP
Soudan
Kamioka
Gran Sasso
NUSL - Homestake (Chlorine)
Baksan
Mont Blanc
Sudbury
NUSL - Homestake
NUSL - Homestake (Deep Option)
Muon Intensity, m^-2 y^-1
10^5
10^5
10^4
10^3
10^2
10^1
10^3
10^4
Depth, meters water equivalent

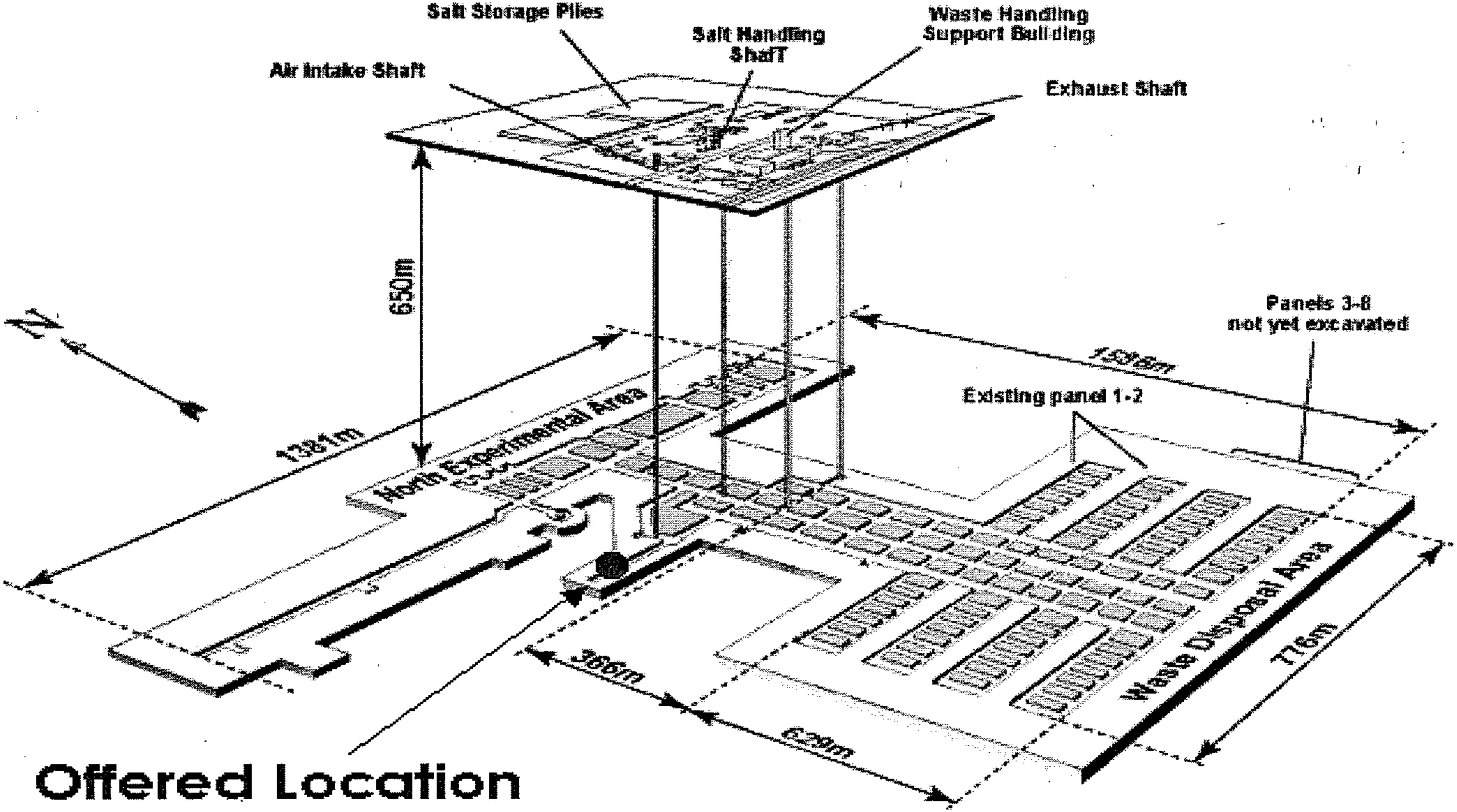
Homestake Layout



Location of previous experiments

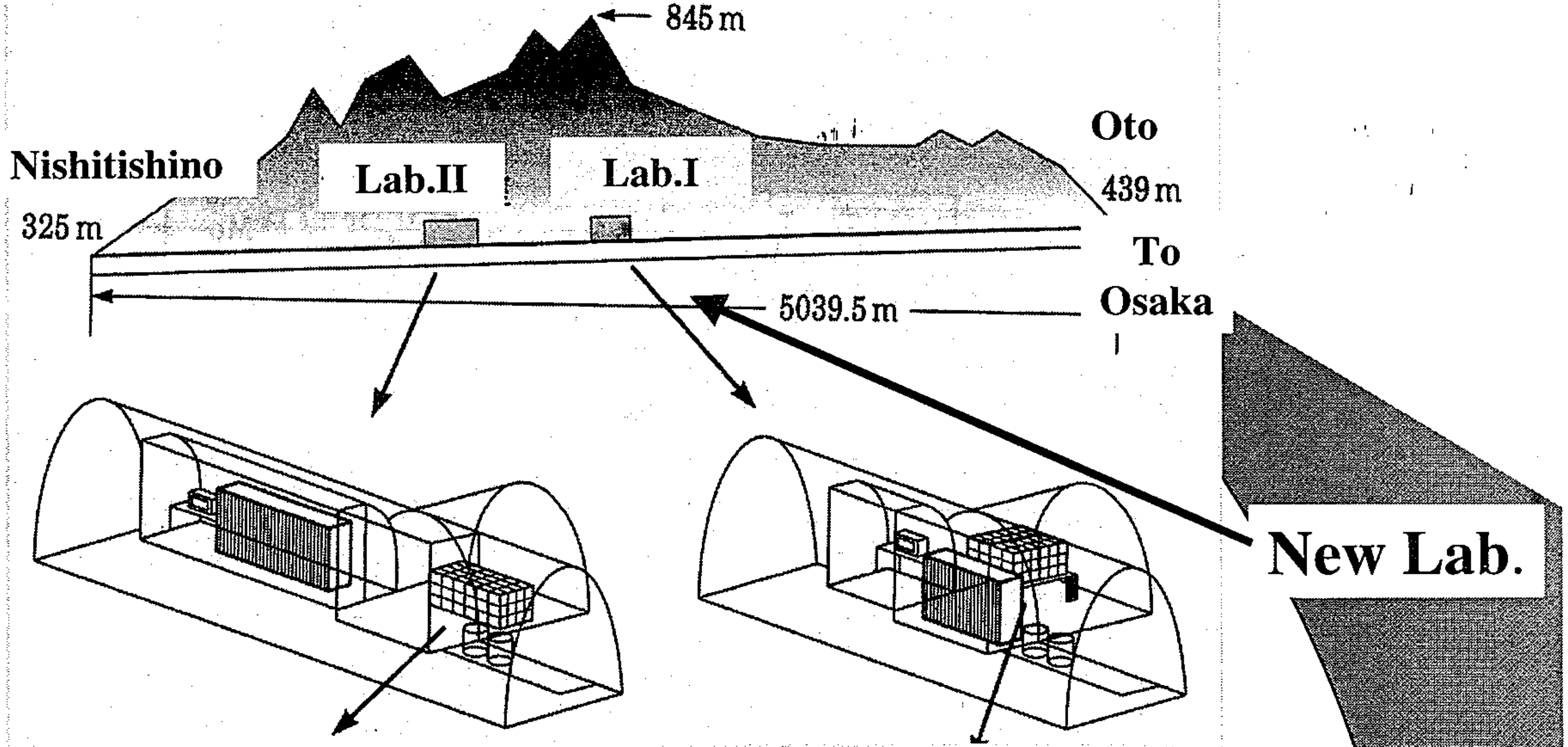
- New US underground lab. at Home stakemine.
- First priority project in nuclear physics in US

WIPP Layout


Salt Storage Piles
Salt Handling ShafT
Waste Handling Support Building
Air Intake Shaft
Exhaust Shaft
650m
N
1381m
North Experimental Area
1518m
Panels 3-8 not yet excavated
Existing panel 1-2
Waste Disposal Area
776m
386m
629m
Offered Location

Oto Cosmo Observatory

100 km south of Osaka, near Int. Airport



ELEGANT V

Double beta decays of ^{100}Mo and dark matters

ELEGANT VI

Double beta decays of ^{48}Ca and dark matters

IV. Concluding Remarks.

Concluding remarks

- **1. $\beta\beta$ is the realistic probe presently able to study**
- **a. Majorana ν : Lepton number $\Delta L=2$.**
- **b. Absolute mass scale with $<m_\nu>=\Sigma m_j c_j U^2{}_j$ in the**
- **0.01~0.05 eV region of interest and CP phase.**

- **2. Present detectors : limited by sensitivities of 0.3-1 eV.**

- **3. Interesting are future detectors with**
- **sensitivity of $<m_\nu>$ 0.01~0.06 eV , i.e. $N_{\beta\beta}$ ~ 1 ton,**
- **a. High resolution studies for ^{76}Ge, ^{130}Te, etc.**
- **b. Low BG β–β correlation studies for ^{100}Mo, ^{82}Se, etc.**

4.Experiments with different nuclei($Q_{\beta\beta}$, $M^{0\nu}$)

- and methods to establish $0\nu\beta\beta$ and ν-mass.

- 5. $M^{0\nu}$:Theoretical calculations and experimental
- studies of hadronic and ν nuclear reactions.

- 6. International collaboration for enriched
- isotopes, detector R&D , underground labs.
- and for nuclear matrix elements.

- 7.Encouragements and supports by theory groups are
- most appreciated aw well.

MOON collaboration

- H.Ejiri, N.Kudomi, K.Matsuoka, M.Nomachi, Y.Sugaya, T.Itahashi, S.Yoshida.
- RCNP, and Physics, Osaka.
- P.J.Doe, S.R.Elliott, R.Hazama, T.L.McGonagle, R.G.H.Robertson, L.C.Stonehill, D.E.Vilches, J.F.Wilkerson
- Phys. CENPA, Univ. Washington.
- J.Engel.
  Phys.Astronomy, Univ. North Carolina.
- M.Finger, Phys. Charles Univ.
- K.Fushimi,
- General Arts Science, Tokushima Univ.
- A.Gorin, I.Manouilov, A.Rjazantsev.
  High Energy Physics, Protvino.
- Kuroda, CERN. P.Krastev, Princeton.
- **Welcome MOON collaboration to give rize to**

Modern Physics Letters A, Feb. 2002

COMMENT ON "EVIDENCE FOR NEUTRINOLESS DOUBLE BETA DECAY"

H.M.Data since 1990 & analyses in 1999, 2001

1. L.Baudis et al				
PRL 83 '99 41.	$> 5.7\ 10^{25}$ y	90%CL	< 0.19 eV	s
2.K-K,et al. Eur.				
Phys. J. A12 '01 147	> 1.9	90	< 0.33 eV	
3. K-K,et al. KDHK				
Mod. Phys. Lett.	0.8—18.3	95	0.11—0.56 eV *	
16 '01 2409	1.5	Best	0.39 eV	

* M^{0v} +-50% → 0.05—0.84 eV should be 0.07—1.1 eV

Large dependence on the analysis method.

Large inconsistency among the publications on the same data and among the group menbers, only 4 (KDHK)out of ~20 claim "yes".

Spectra of HM ^{76}Ge

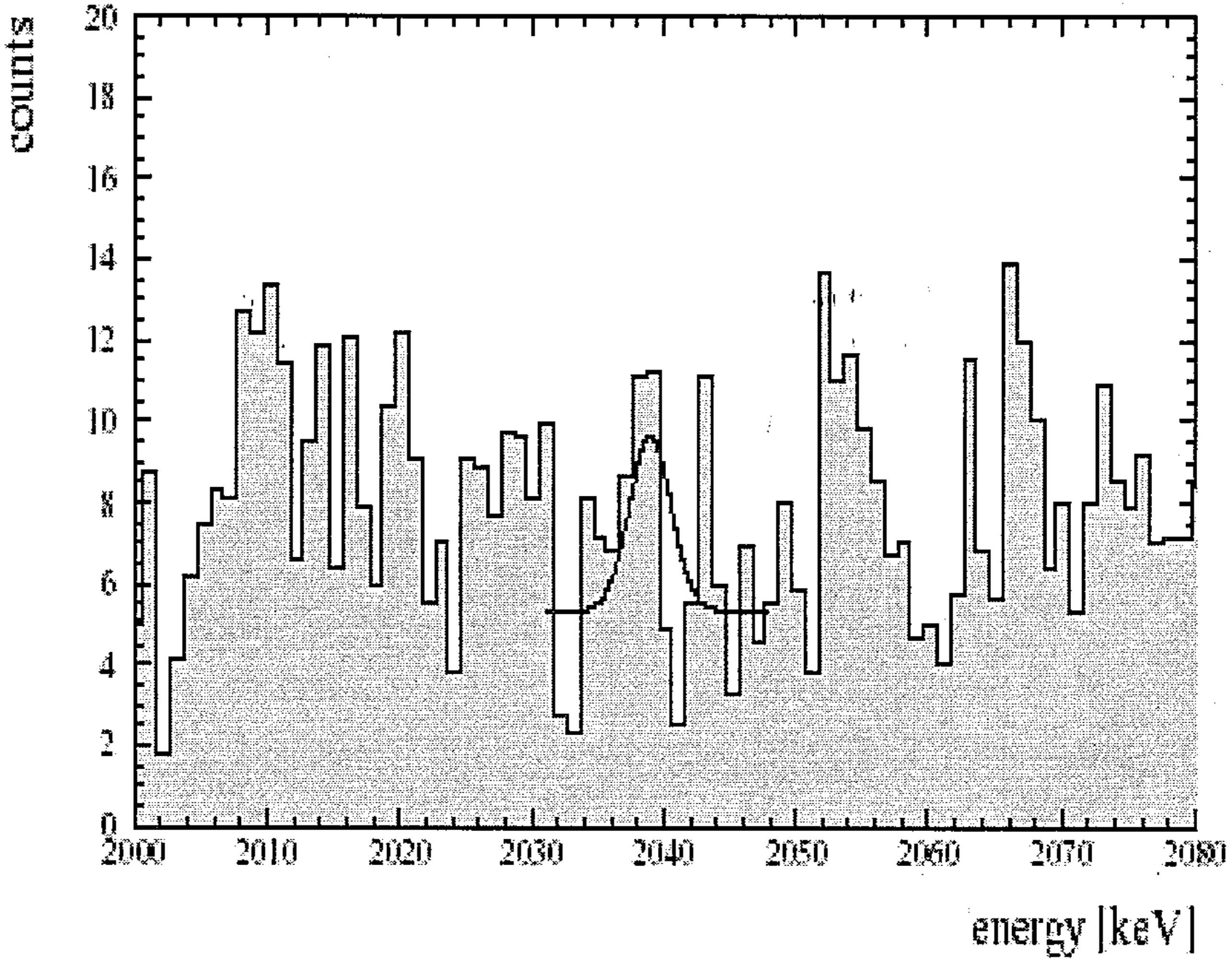


Fig. 2. Sum spectrum of the ^{76}Ge detectors 1, 2, 3, 5 over the period August 1990 to May 2000, 46.502 kg y. The curve results from Bayesian inference in the way explained in the text. It corresponds to a half-life $T^{0\nu}_{1/2} = (0.75\text{–}18.33) \times 10^{25}$ y (95% c.l.).

Single site PSD spectrum

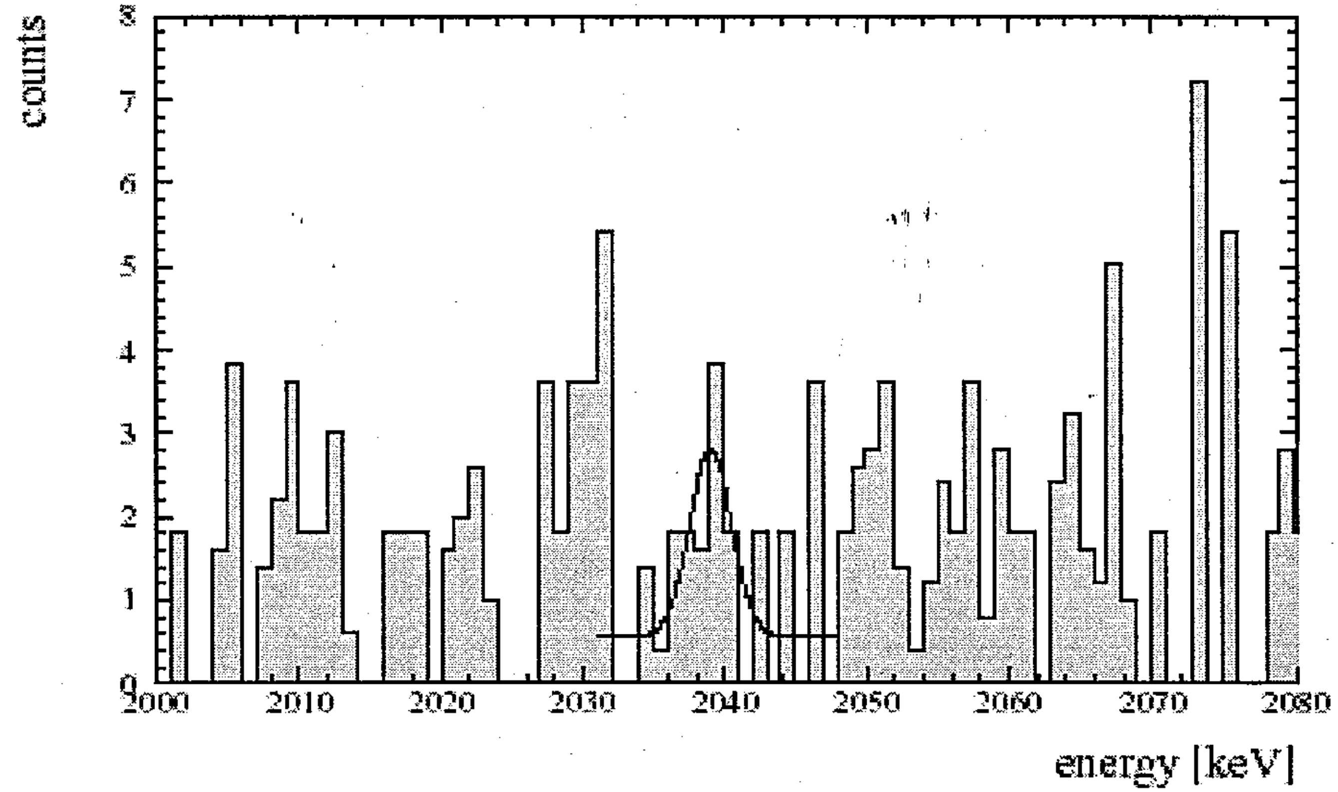


Fig. 3. Sum spectrum, measured with the detectors 2, 3, 5 operated with pulse shape analysis in the period November 1995 to May 2000 (28.053 kg y), in the region of interest for the $0\nu\beta\beta$-decay. Only events identified as single site events (SSE) by all three pulse shape analysis methods[18, 19] have been accepted. The spectrum has been corrected for the efficiency of SSE identification (see text). The curve results from Bayesian inference in the way explained in the text. The signal corresponds to a half-life $T^{0\nu}_{1/2} = (0.88\text{–}22.38) \times 10^{25}$ y (90% c.l.).

Authors from 14 Lab-Univ's

C. E. Aalseth1, F. T. Avignone III2, A. Barabash3, F. Boehm4, R. L. Brodzinski1, J. I. Collar5,

- P. J. Doe6, H. Ejiri7, S. R. Elliott6., E. Fiorini8, R.J. Gaitskell9, G. Gratta10, R. Hazama6, K. Kazkaz6, G. S. King III2, R. T. Kouzes1, H. S. Miley1, M. K. Moe11, A. Morales12, J. Morales12, A. Piepke13, R. G. H. Robertson6, W. Tornow14, P. Vogel4, R. A. Warner1, J. F. Wilkerson6

- 1*PNL* 2*USC* 3*ITEP* 4*Caltech* 5*U.Chicago* 6*UW* 7*IIAS-RCNP* 8 *U.Milano* 9*Brown U.* 10*Stanford* 11*Irvine* 12*U. Zaragoza* 13*Alabama* 14*Duke U.*

No scientific & basic discussions on data analysis and interpretation

- No discussion of how a variation of the size of the chosen analysis window would affect the significance of the hypothetical peak.
- No relative peak strength analysis of all the ^{214}Bi peaks in the region of interest.
- There is no presentation of the entire spectrum to compare relative peak strengths
- There are three unidentified peaks in the region of analysis that have great significance than the 2039-keV peak. No discussion of the origin of these peaks.
- No discussion of the relative peak strengths before and after the single-site-event cut. This is needed to elucidate the peaks'origins
- No simulation to demonstrate that the analysis correctly finds true peaks or that
- it would find no peaks if none existed.
- No discussion of how the conclusions depend on different mathematical models.
- Previous data 2 of lower limit of 1.9×10^{25} y (90%) in conflict with the "best value" of the new KDHK of 1.5×10^{25} y.This indicates a dependence of the results on the analysis model and the BG evaluation.

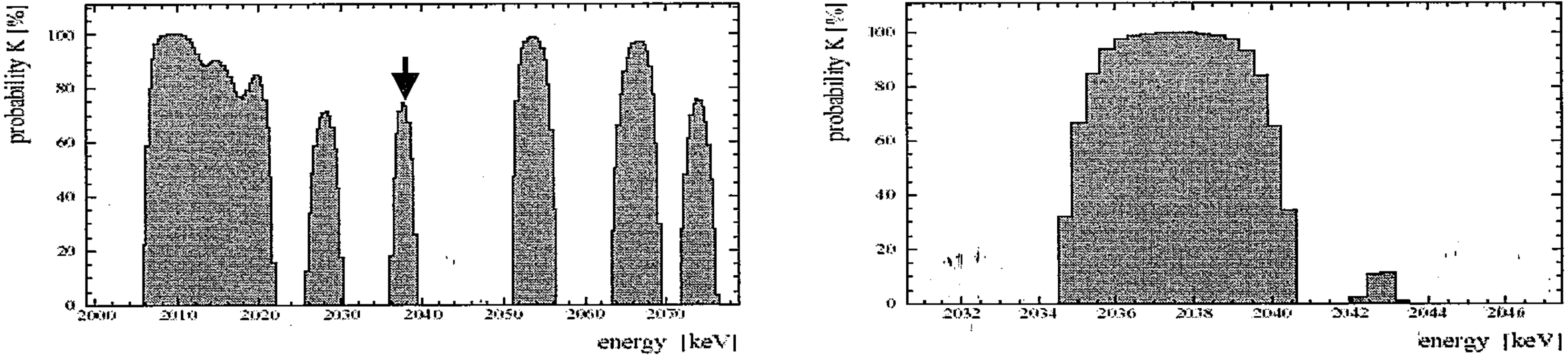
A comparison of the intensities of the ^{214}Bi lines.

- .Ref peak come from Ref.2. The relative efficiency for the peak
- is an interpolated value based on the 3 reference peaks.

(keV)	Peak Rate (c/(kg ·yr)	Branching Ratio3	Relative Effciency	Expected Rate (c/(kg ·yr))
609.3	10.92	44.8%	1	Ref. Peak
1764.5	4.06	15.36%	1.08	Ref. Peak
2010.7	-	0.05%	1.11	0.0135
2016.7	-	0.0058%	1.11	0.0016
2021.8	-	0.02%	1.11	0.0054
2052.9	-	0.078%	1.11	0.021
2204.2	1.34	4.86%	1.13	Ref. Peak

These Bi peaks are too low to be seen above BG :0.17 c/kev.kg.y

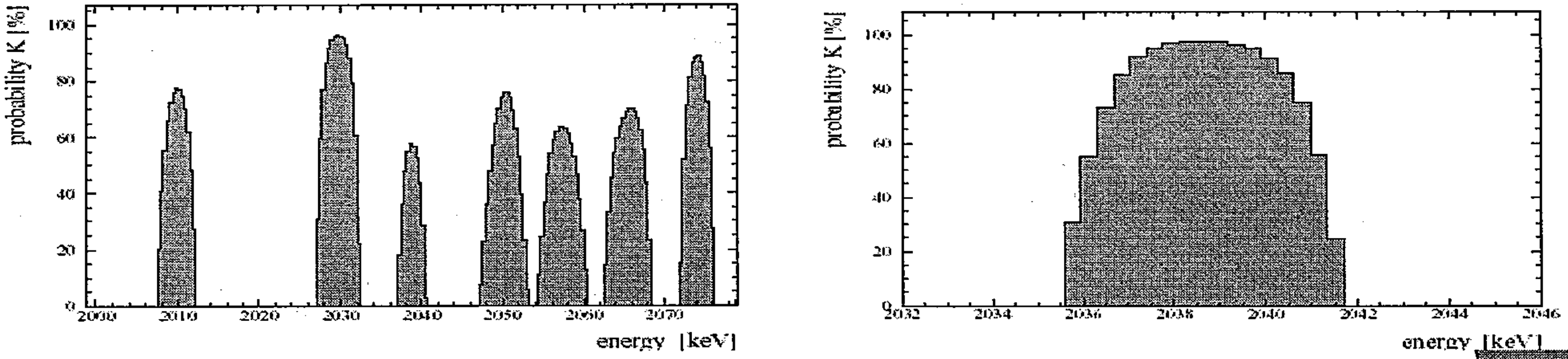
Peak probability



(a)

(b)

Fig. 5. (a) Probability K that a line exists at a given energy in the range of 2000–2080 keV derived via Bayesian inference from the spectrum shown in Fig. 2. (b) Result of a Bayesian scan for lines as in the left part of this figure, but in the energy range of interest around $Q_{\beta\beta}$.



^{214}Bi 2011, 2017, 2022, 2053 are claimed to be observed.

But they should not in the single site. No consistency between non-sc and ss

RI ^{214}Bi (Q:3.27, ^{224}Rn),^{208}Tl(Q:4.992)

- ^{214}Bi lines at E~2 MeV (~$Q_{\beta\beta}$ of ^{76}Ge)

E KeV	e	γ	γγ	Comments
1764.5	-	15.2		
2010.8	-	0.05	1.3	1402+609
2016.7	0.006	-	2.2	1408+609
2021.2	-	-	0.02	2021+609
2039	ee			0νββ
2052.9	-	-	0.07	2053+609
2204.1	-	5.08	-	

-
- e/ee, γ, and γγ modes select relevant signals, and check the origins of peaks.

Summary

- 1.A simple analysis of the ^{214}Bi peaks demonstrates that the
- peak finding procedure used by KDHK produced spurious
- peaks near the $\beta\beta(0\nu)$ endpoint.

2. The existence of these claimed peaks is crucial to the KDHK claim of a peak at 2039 keV interpreted as $0\nu\beta\beta$.

- 3.All the peaks claimed in the 2000-2080 keV region may be spurious leaving the entire count rate due to an uniform BG.
- Alternatively, if all the peaks are real but unidentified, the putative 2039-keV feature may be simply another of those unidentified lines.
- 4.These two examples emphasize the importance of addressing all the items listed in the Introduction.

- By failing to address these issues, the KDHK paper
- does not support its claim of evidence for $\beta\beta(0\nu)$.

Neutrino oscillations and signals in β and $0\nu2\beta$ experiments

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Alessandro Strumia

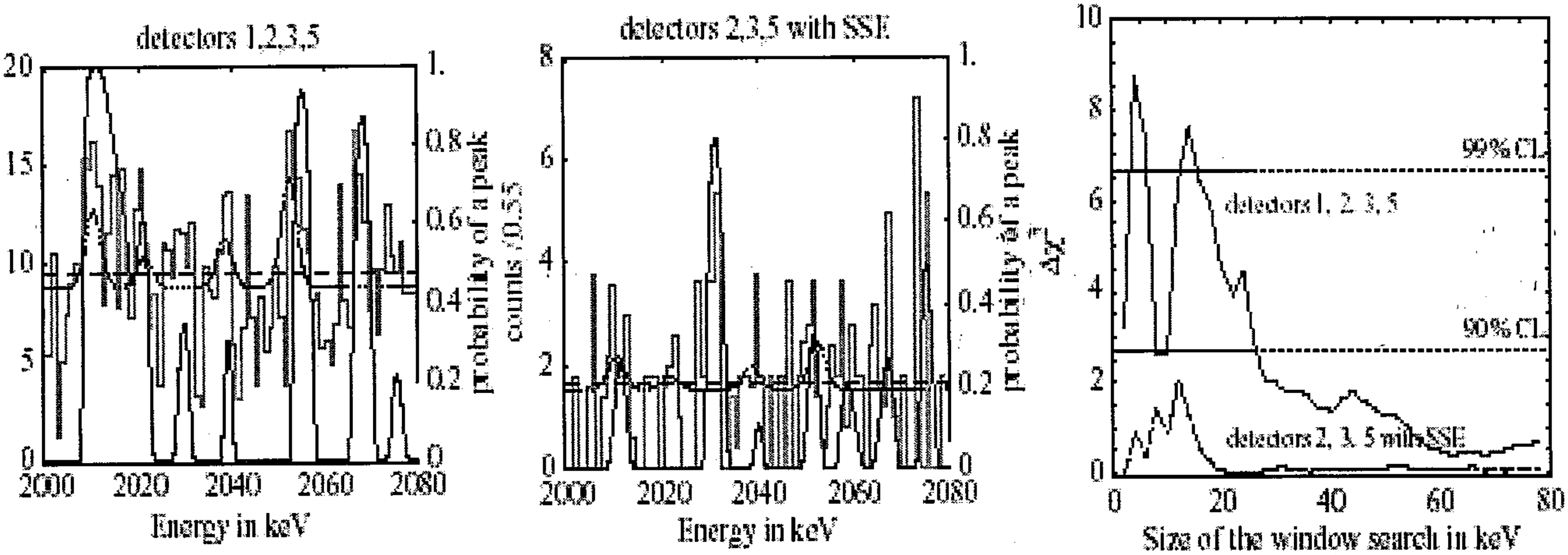
Theoretical Physics Division, CERN, CH-1211 Genève 23, Suisse

Francesco Vissani

INFN, Laboratori Nazionali del Gran Sasso, Theory Group, I-67010 Assergi (AQ), Italy

Abstract

Assuming Majorana neutrinos, we infer from oscillation data the expected values of the parameters m_{ν_e} and m_{ee} probed by β and $0\nu2\beta$-decay experiments. If neutrinos have a 'normal hierarchy' we get the 90% CL range $|m_{ee}| = (0.5 \div 5)\,\mathrm{meV}$, and discuss in which cases future experiments can test this possibility. For 'inverse hierarchy', we get $|m_{ee}| = (10 \div 57)\,\mathrm{meV}$ and $m_{\nu_e} = (40 \div 57)\,\mathrm{meV}$. The $0\nu2\beta$ data imply that almost degenerate neutrinos are lighter than $0.95\,h\,\mathrm{eV}$ at 90% CL ($h \sim 1$ parameterizes nuclear uncertainties), competitive with the β-decay bound. We critically reanalyse the data that were recently used to claim an evidence for $0\nu2\beta$, and discuss their implications. Finally, we review the predictions of flavour models for m_{ee} and θ_{13}.



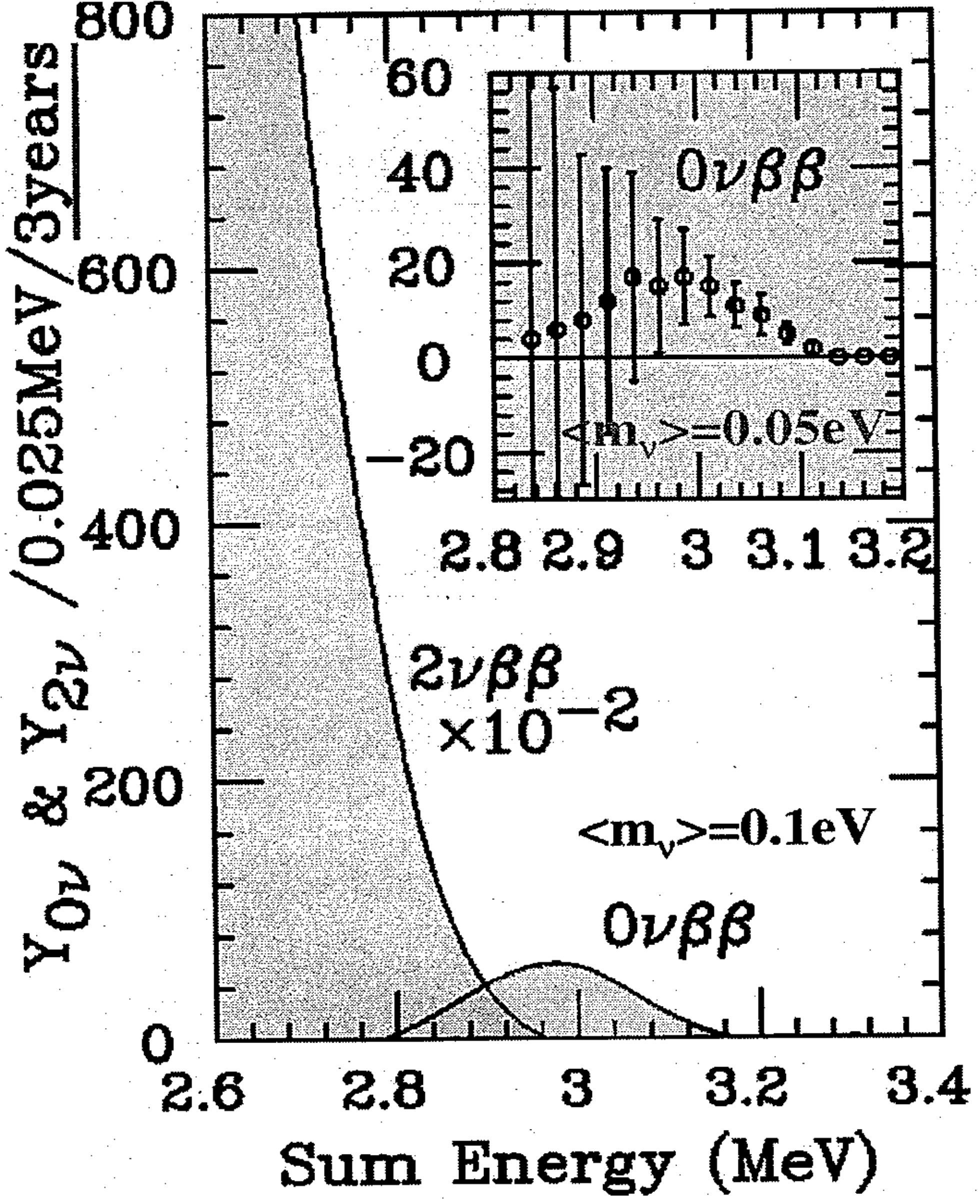
igure 9: *The histograms in the first two figures are two data-sets (the left ordinates show the scale). In ach case we superimpose the best fit in terms of a constant background (dashed line) and in terms of a onstant background, plus a background due to* γ*-peaks of* ^{214}Bi, *plus a* $0\nu2\beta$ *peak at* $E = 2030$ keV. *In ach plot the continuous blue line shows the likelihood (the right ordinates show the scale) of having a eak at energy* E. *The third plot shows how the evidence for a* $0\nu2\beta$ *signal varies if, following [5], one ts the data in terms of* $0\nu2\beta$ *peak plus a constant background, using only data in a restricted window.*

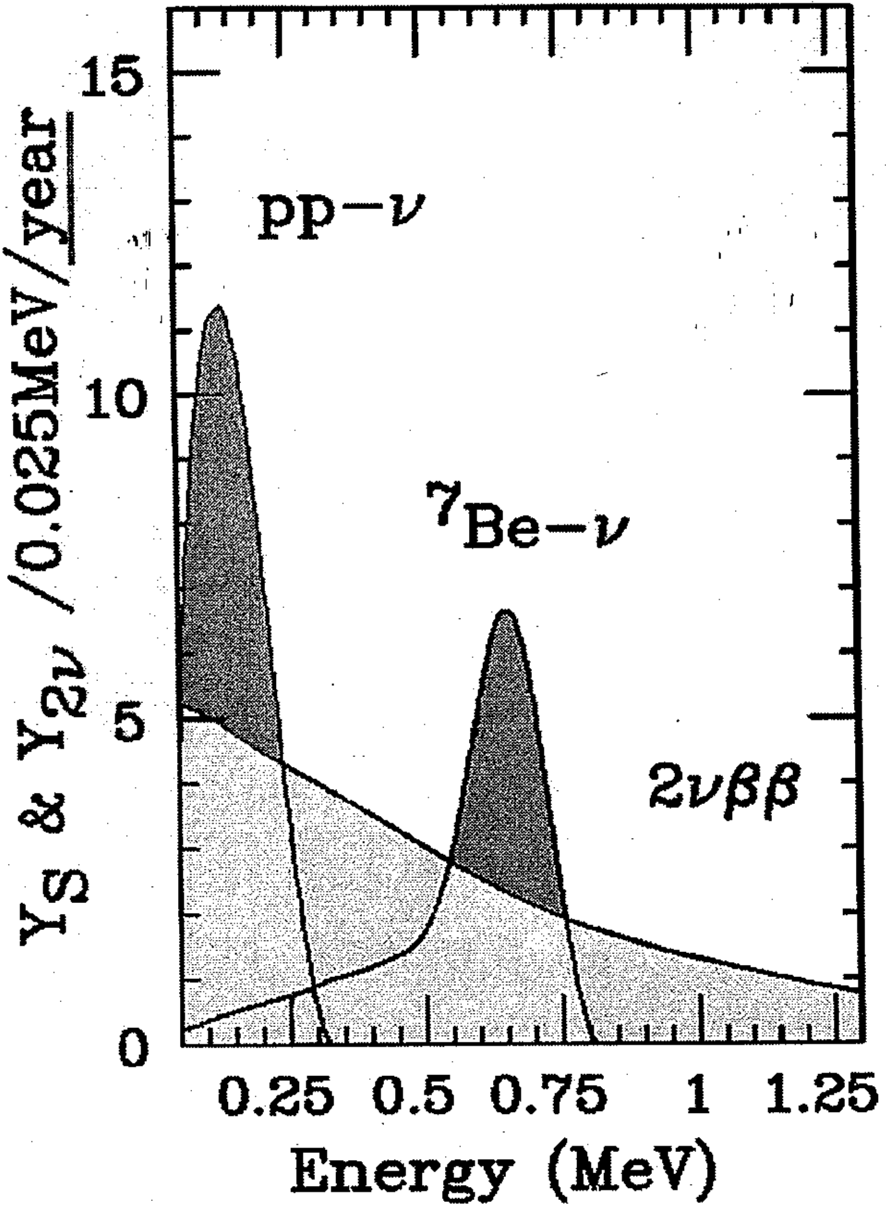
Concluding remarks.

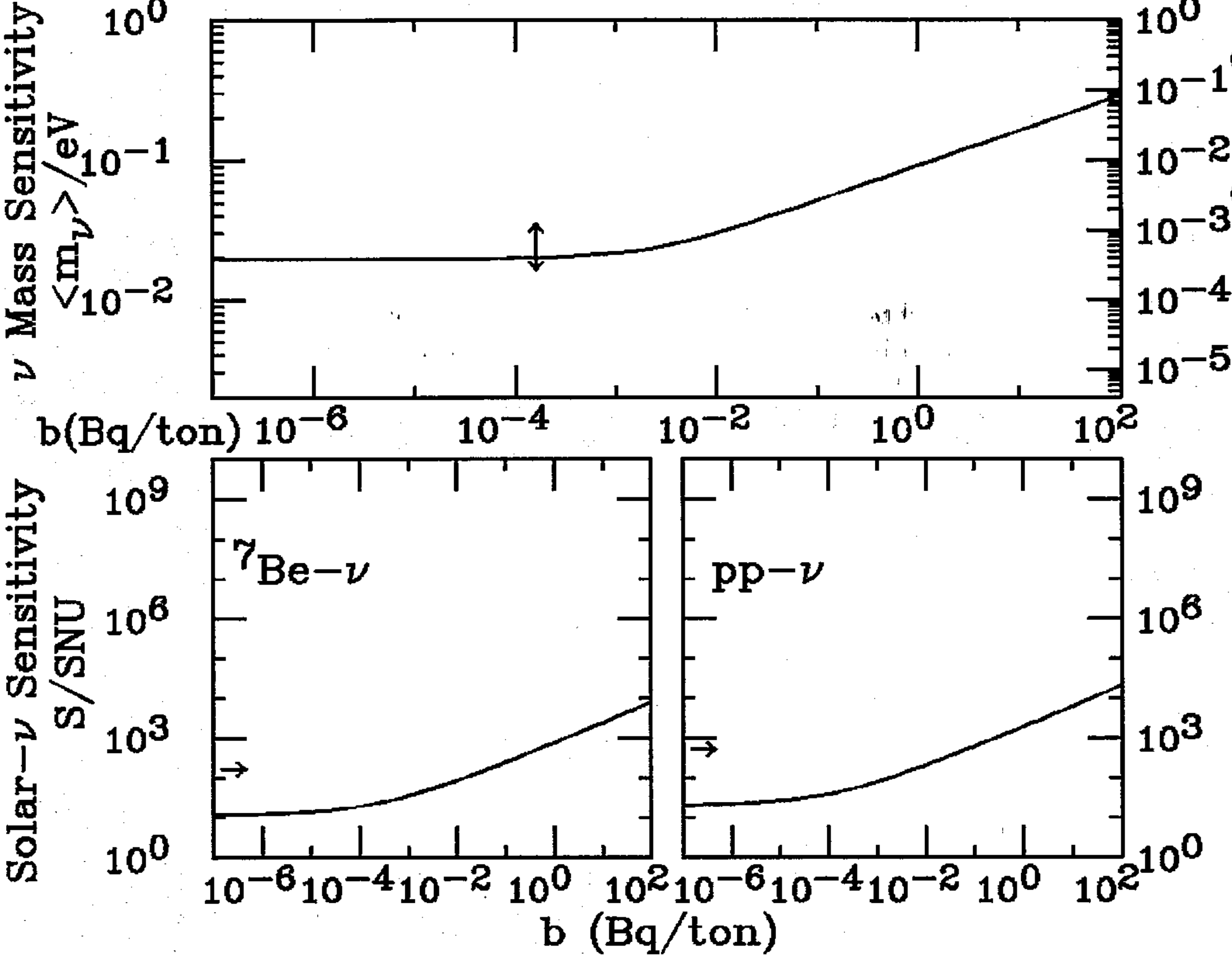
- HDHK does not give any evidences for $0\nu\beta\beta$.
- HDHK should answer for all questions raised by critical papers.
- It is our hope that scientists and science administrators consider courteously critical and other papers as well to be fare for science.

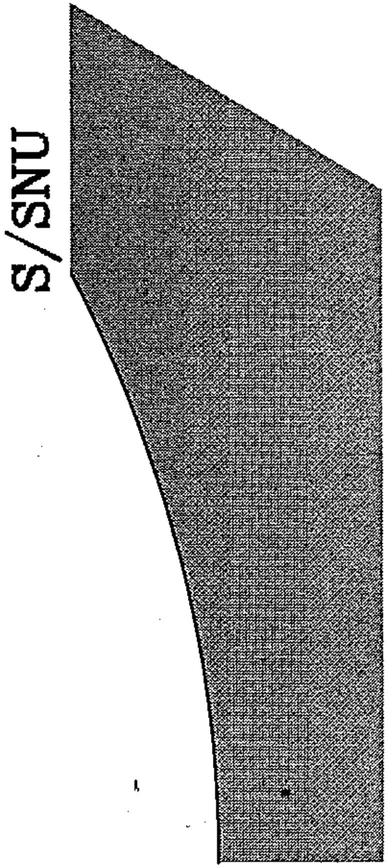
Thank you for attention

^{100}Mo ββ and solar ν

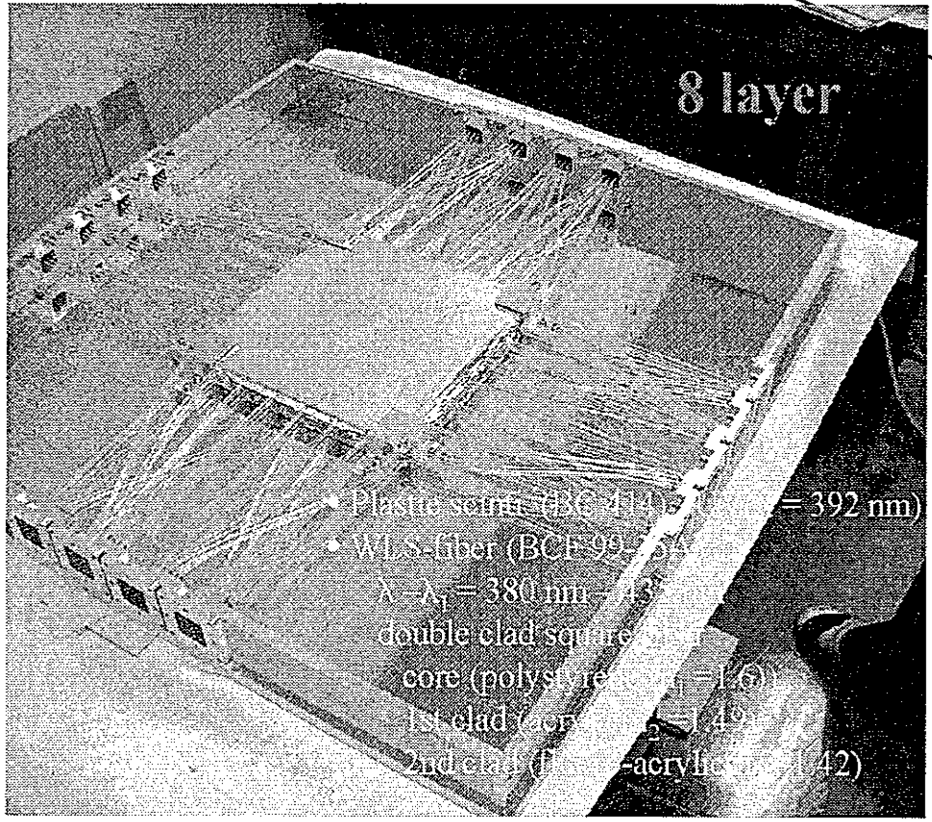





ν Mass Sensitivity
<m_ν>/eV
10^0
10^-1
10^-2
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
<m_ν>^2/(eV)^2
b(Bq/ton)
10^-6
10^-4
10^-2
10^0
10^2
Solar−ν Sensitivity
S/SNU
10^9
10^6
10^3
10^0
^7Be−ν
pp−ν
10^-6
10^-4
10^-2
10^0
10^2
b (Bq/ton)

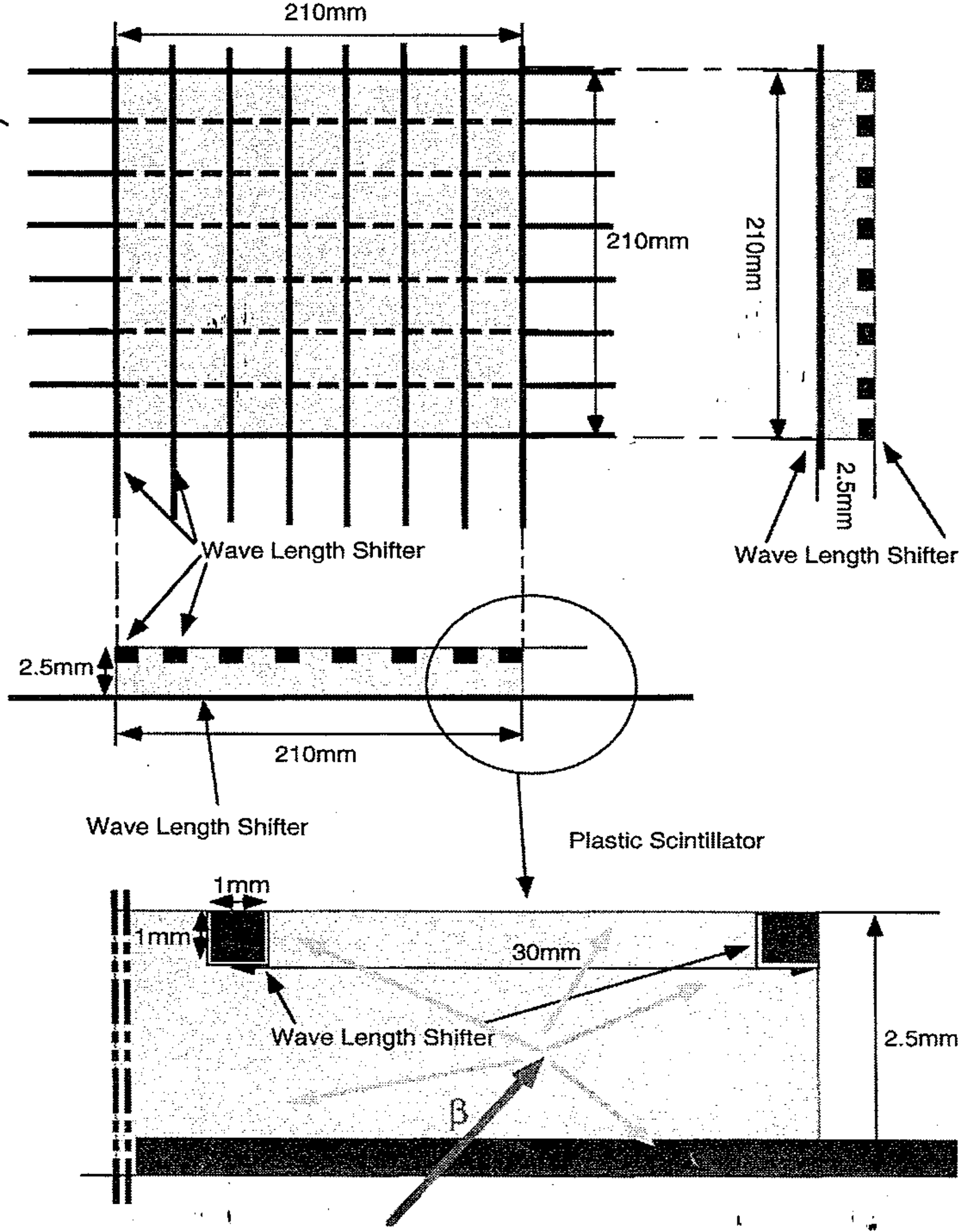

S/SNU

WLS Test



- Plastic scinti. (BC-414 [illegible] = 392 nm)
- WLS-fiber (BCF 99-[illegible]
  $\lambda \to \lambda_1 = 380$ nm $\to$ 43[illegible]
  double clad square [illegible]
  core (polystyre[illegible] $n_1 = 1.6$)
  1st clad (acr[illegible] $n_2 = 1.49$)
  2nd clad (f[illegible]-acrylic [illegible] 1.42)

Good Energy and Position Resolution



Efficiency for light collection of

WLS $\varepsilon_w \sim 0.3.$

Need increase of t : 0.14---0.2

ε_{pe} : 0.25 –0.4

to get a required E resolution

MOON

Plastic fiber-Mo Ensemble