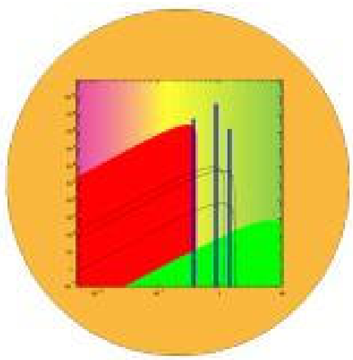
Future LowNu Projects

LowNu: low energy (solar) neutrino

Summary (selective and biased) of the

LowNu2002 Workshop at MPIK Heidelberg



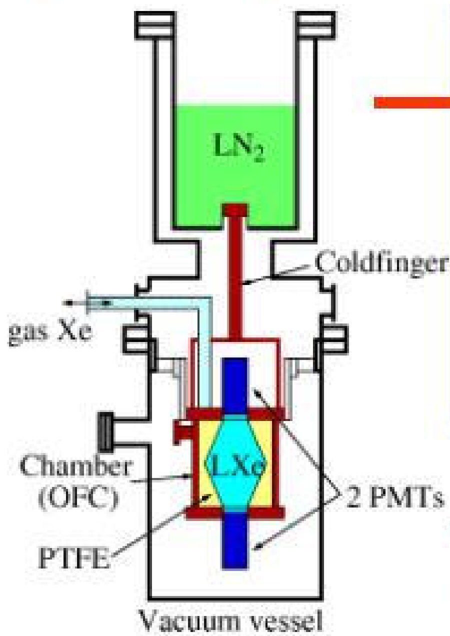
Stefan Schönert, MPIK Heidelberg

Neutrino 2002

25.5.02

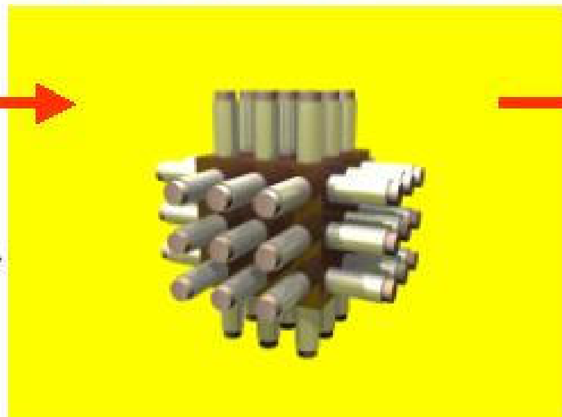
XMASS: Status

- **3kg detector (finished)**



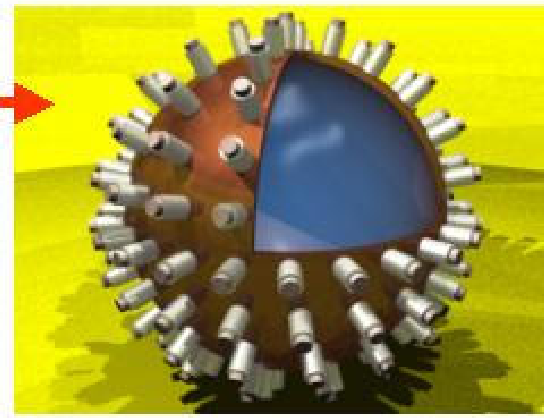
Fundamental study of LXe
PMT improvement (QE, radioactivity)

- **100kg detector (under construction)**



Low background setup
Vertex, energy reconstruction
Demonstration of self-shielding
purification
e/gamma separation
attenuation length (special setup)
neutron BG study

- **10t scale detector**

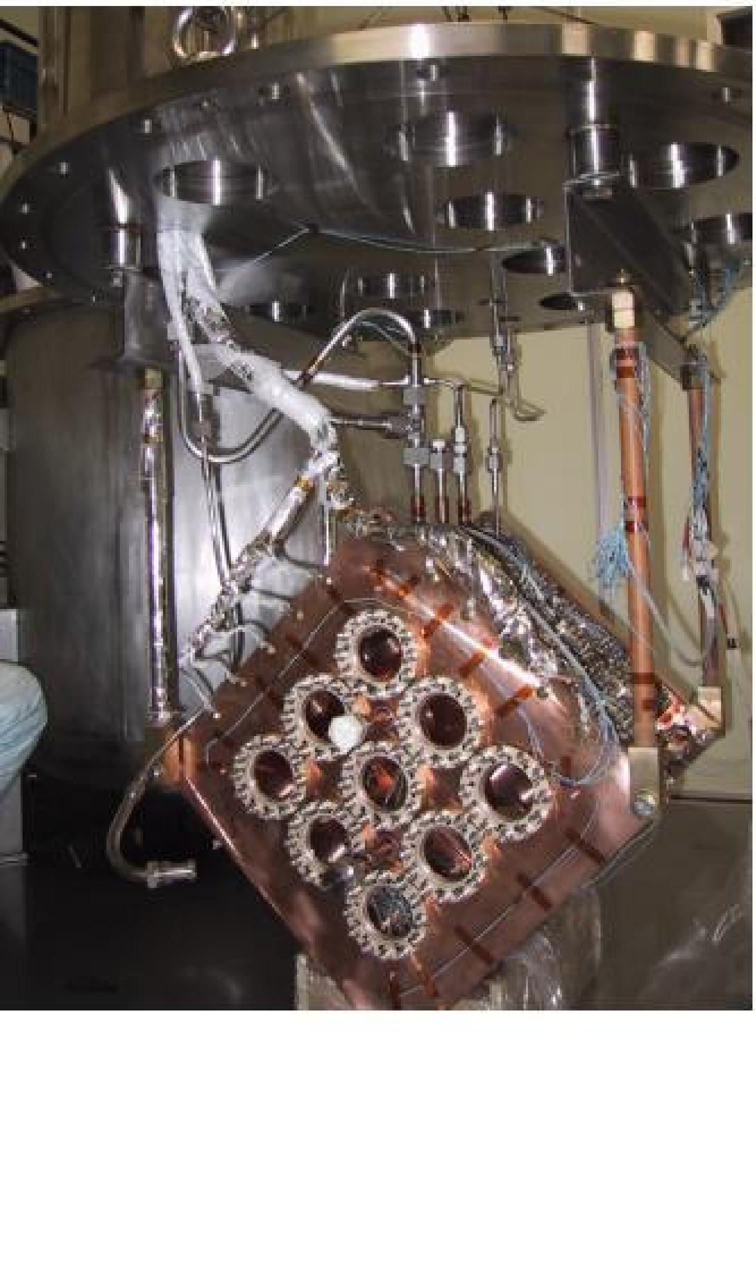


Achievement of super low bg in FV!

⇒ poster session

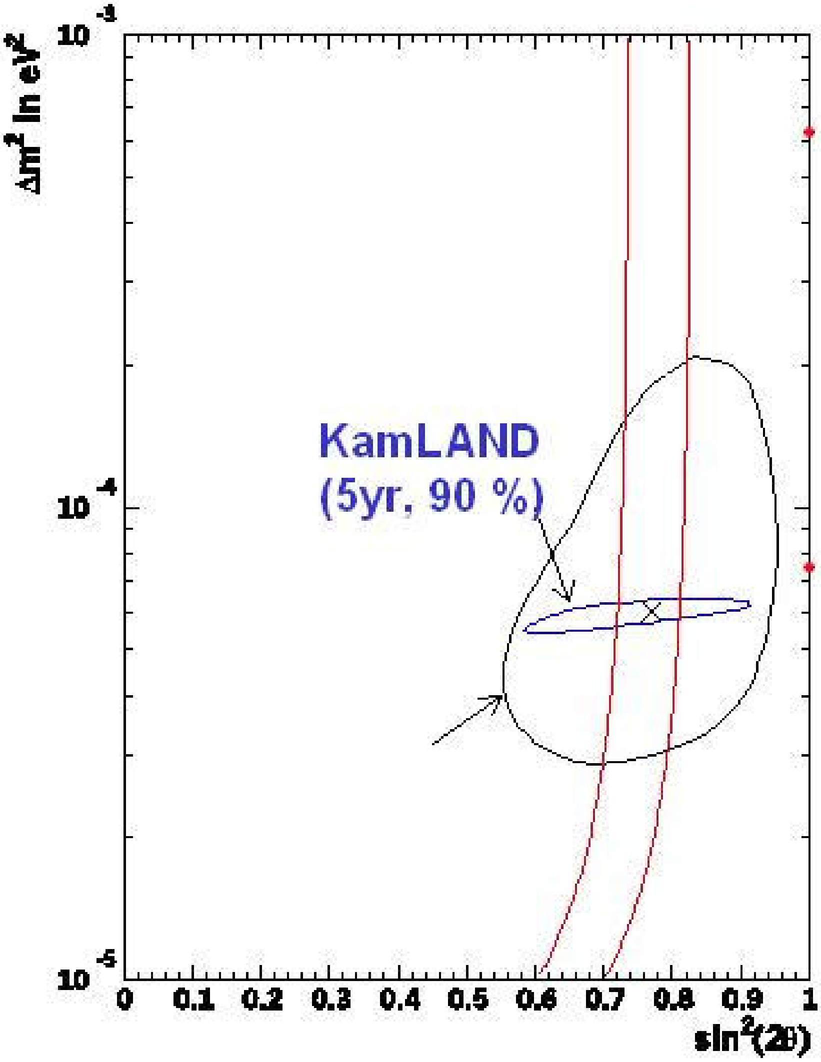
Drawings: T. Namba

100kg detector LXe vessel



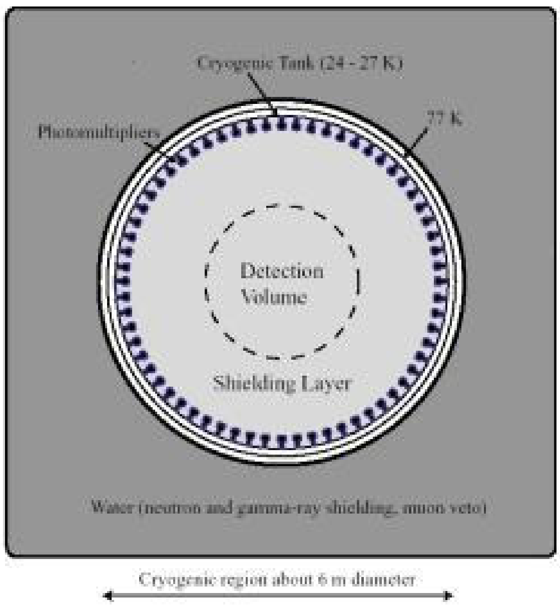
Transported into the mine on May 13, 2002

MgF_2 window



- pp neutrino flux measurement (90 % C.L.) by :
  - 10 ton detector
  - νe scattering experiment
  - 5 years data
  - Statistical error + SSM flux error(1%)
- Accuracy of mixing angle : $\sin^2 2\theta = 0.77 \pm 0.03$ (stat.+SSM)

CLEAN – liquid neon scintillation detector



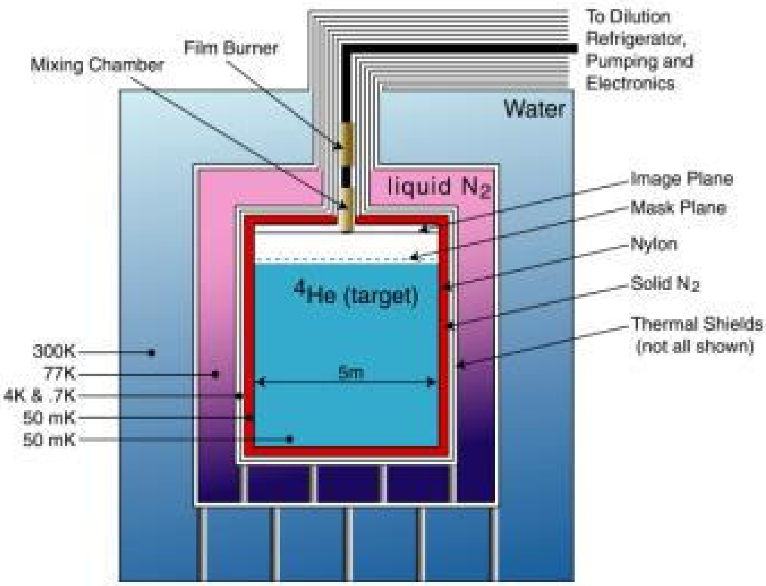
- Detection reaction: ES ($\nu + e^- \rightarrow \nu + e^-$)
- ~140 t (10 t fid.) detector (neon/neon)
- 1-2 m self-shield (ρ=1.20 g/cm³)
- 15,000 (or more) scintillation photons/MeV
- active buffer
- Light detection with PMTs: wave length shifter in front of PMT´s

Possible schemes:

buffer	active target
liquid Ne	liquid Ne
solid Ne (ρ=1.4)	solid Ne
Ne	He
He	He

Plan: submission of R&D proposal in autumn (McKinsey et al. Princeton/Boston/....)

HERON – liquid helium scintillation and phonon/roton detector

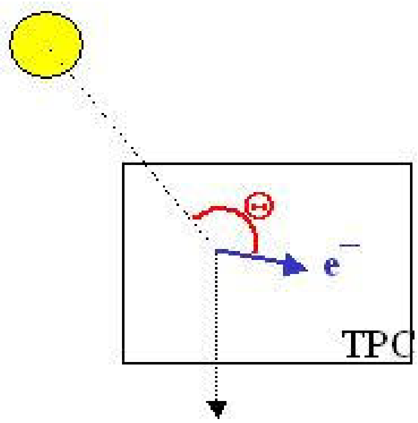


- **Target:** Superfluid He (~20t)
- **Detection reaction:** ES ($\nu + e^- \rightarrow \nu + e^-$)
- **Signal:** UV scintillation (80 nm; 15,000/MeV), delayed rotons/phonons (1 meV; 10^8/MeV)
- **Detection of photons, phonons/rotons** with saphire/silicon wafer calorimeters,
- ~2400 SQUID read-out channels

Virtue: Superfl. ^{4}He (50mK) `**self-cleaning**´ (gravity>kT) ⇒free of internal bgd
Challenge: He **limited self-shielding**
⇒ radio purity of cryostat
⇒ background discrimination: point-like events (ν) vs. mult. compton scattering
⇒ position recontstruction by coded aperture

(Lanou et al.)

TPC´s – ES with full kinematic information for pp- and Be-7 ν



Goal:
measurement of e^{-} recoil **angle** and **energy**
⇒ **ν-energy**

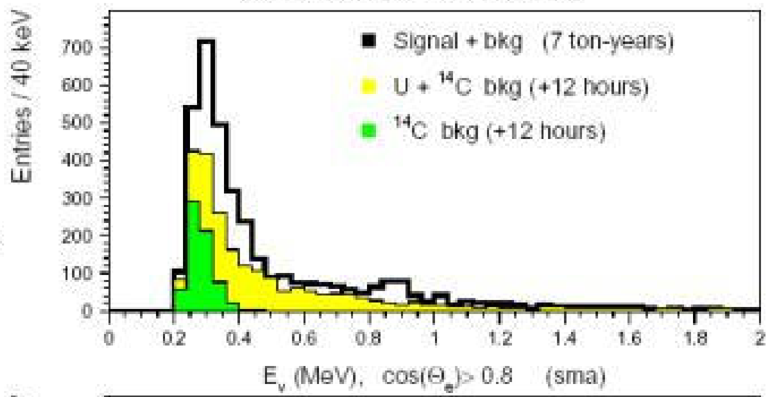
Challenge:
angular resolution at low energies
⇒low multiple scattering ⇒**He,C**
⇒minimal self-shielding

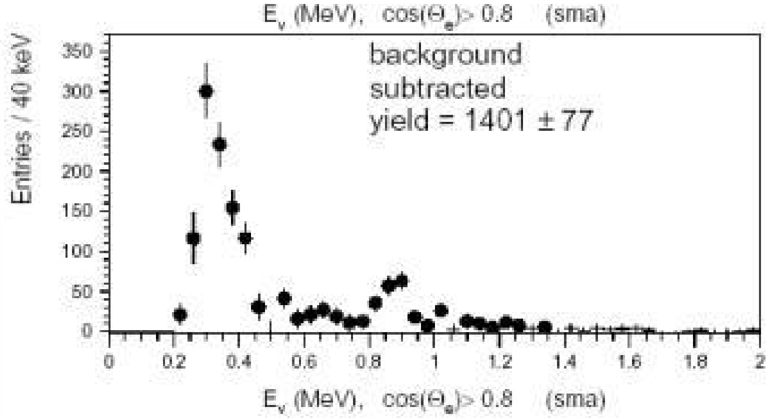
TPC – He/methane for Homestake

Hellaz follow-up:
- ~4000m³, 10bar, 7t He
- Methane instead of isobutane ⇒(^{14}C),
- He-methane gaseous at 112K ⇒cold trap Rn

Exposure	7&70 t yr
Energy res. (σ)	5% @ 100 keV
Angular res.	15° @ 100 keV
Uranium	0.5 μg (surface) (0.7×10^{-16} if mixed)
$^{14}C/^{12}C$	**10^{-19}**

simulation for SMA

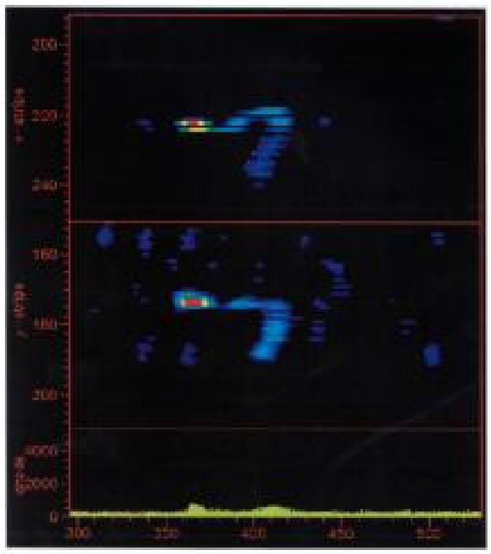




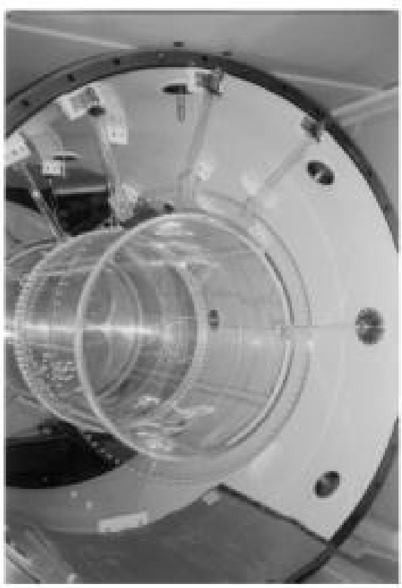
Proposal submitted,
Plan for 9m³ prototype R&D
(G. Bonvicini, et al.)

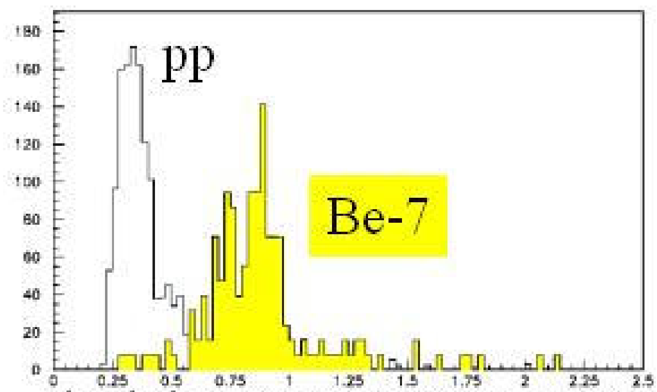
TPC – MUNU: a prototype for solar ν detection

- Low background TPC ($1 m^3$) for ν-magnetic moment
- CF_4 @ 3 bar (3.7 g/l @ 1bar)
- angular resolution: 23° @ 300-600 keV
- Sensitivity $<10^{-10}$ Bohr magnetons
- **Prototype for solar ν-TPC**



Range 14cm
E=190 keV
p=1bar





Simulation: 10y $200 m^3$ CF_4-TPC @ 1bar(=7t-year)

(Broggini et al.)

CC – LowNu detection

pp - ν

inv-β (CC):

LENS
MOON
SIREN

^{7}Be- ν

inv-β (CC):

LENS
MOON
SIREN
LITHIUM

Candidate nuclei for real time CC solar neutrino detection

SIREN

LENS

MOON

Isotop	$T_{1/2}$	Häufig.	Tochter	Q [keV]	E_γ [keV]	$T_{1/2}$
^{115}In $(9/2^+)$	$5 \cdot 10^{14}$ a	95,7%	^{115}Sn $(7/2^+)$	128	116	3,26 μs
					498	
^{176}Yb (0^+)	stabil	12,7%	^{176}Lu (1^+)	301	72	50 ns
				445	(144)	
^{160}Gd (0^+)	stabil	21,9%	^{160}Tb (1^+)	244	75	6 ns
					64	60 ns
				339–771	diverse	
^{82}Se (0^+)	$1 \cdot 10^{20}$ a	9,4%	^{82}Br (1^+)	173	29	10 ns
					46	
^{100}Mo (0^+)	stabil	9,6%	^{100}Tc (1^+)	168	3202 (β)	15,8 s
^{71}Ga $(3/2^-)$	stabil	39,9%	^{71}Ge $(1/2^-)$	229	–	–
			^{71}Ge $(5/2^-)$	404	175	79 ns
^{137}Ba $(3/2^+)$	stabil	11,2%	^{137}La $(5/2^+)$	611	10,6	89 ns
^{123}Sb $(7/2^+)$	stabil	42,7%	^{123}Te $(7/2^+)$	541	330	31 ns
					159	
^{159}Tb $(3/2^+)$	stabil	100%	^{159}Dy $(5/2^+)$	543	177	9,3 ns
					121	9,3 ns
					56	

Further isotopes proposed (K. Zuber)

LowNu 2002

3^{rd} International Workshop on Low Energy Solar Neutrinos
May 22-24, 2002
MPI für Kernphysik
Heidelberg

(1stday:May 22)

13:00-14:15Registration
14:15-14:30(15)Welcome and introductory remarks, *S. Schönert (MPIK)*

Session I: (Chairperson: S. Schönert)
14:30-15:00 (25+5)Why do solar neutrino experiments below 1 MeV?, *J.N. Bahcall (Princ*
15:00-15:30 (25+5)Actuality and potentiality of neutrino mixing, *C. Giunti (Torino)*

Session IIa: ν-e scattering experiments (Chairperson: J. Bouchez)
15:30-16:05(30+5)The KamLAND detector and backgrounds for solar neutrino detection, *K. Furuno (Tohuko Univ.)*
16:05-16:30 coffee break
16:30-17:05(30+5) Status of the BOREXINO experiment, *L. Perasso (INFN Milano)*
17:05-17:40(30+5) Status of XMASS, *M. Nakahata (Kamioka Observatory, ICRR, Tokyo)*
17:40-18:05(20+5)CLEAN, *D. McKinsey (Princeton Univ.)*

(2nd day: May 23)

Session IIb: ν-e scattering experiments (Chairperson: C. Cattadori)
09:30-09:55(20+5) The HERON Project, *R. Lanou (Brown Univ.)*
09:55-10:20(20+5)MUNU results on low energy ν-e detection with a gas TPC, *C. Broggini, (INFN))*
10:20-10:45(20+5) Solar Neutrino TPC, *G. Bonvicini (Wayne State Univ.)*
10:45-11:00(10+5)GENIUS, a real-time detector for solar pp-neutrinos, *C. Tomei (L'Aquila/MPIK)*
11:00-11:20 coffee break

Session IIIa: Experimental techniques: scintillators and backgrounds (Chairperson: G. Heusser)
11:20-11:50(25+5) Organic liquid scintillators for solar-ν detection, *F.X. Hartmann (MPIK)*
11:50-12:20(25+5) Metal impurities in liquid scintillators – backgrounds in KamLAND, *A. Piepke (Univ. of Alabama)*
12:20-12:50(25+5)Noble gas impurities: Argon, Krypton, Radon and its progenies, *H. Simgen (MPIK)*
13:00-14:30 lunch break

Session IIIb: Experimental techniques: facilities and neutrino sources (Chairperson: W. Hampel)
14:30-14:50(15+5)A proposal for a new underground facility at SNO, *T. Noble (Triumf/Carleton Univ.)*
15:00-15:55(45+10)Artificial neutrino sources for LowNu experiments,
a) Cr-51, *T. Kirsten (MPIK)*
b) Se-75, *V. Kornoukhov (INR Moscow)*
cAr-37, *V. Gavrin (INR Moscow)*
15:55-16:15 coffee break

Session IVa: Charged current experiments (Chairperson: M. Cribier)
16:15-16:40(20+5) Neural network analysis for GNO events: methods and results, *L. Pandola (INFN - LNGS)*
16:40-17:00(15+5)Low temperature detectors: an alternative counting technique for GNO, *T. Lachenmaier (TUM)*
17:00-17:25(20+5)The Lithium project, *A. Kopylov (INR Moscow)*
17:25-17:55(25+5)Evidence for solar neutrino flux variability and its implications, *D. Caldwell (Santa Barbara)*

Workshop Dinner 20.00

- Why low energy ?
- ν-e scattering
- Experimental techniques/ ν-sources
- Charged current experiments
- Reactor oscillation exp.
- What next?

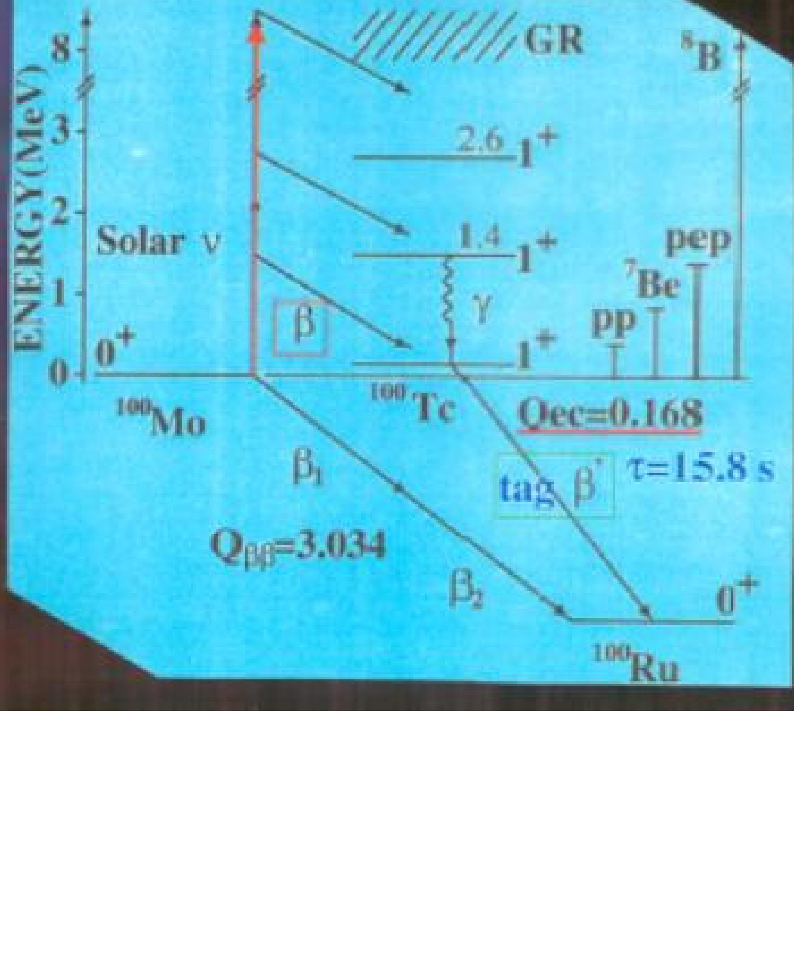
MOON (Mo Obvatory Of Neutrions) for Low energy solar ν.

Hiro Ejiri

- MOON collaboration (Osaka-Tokushima-USC-UW)

  H.Ejiri, J.Engel, G.Hazama, O.Krastev, N.Kudomi, R.G.H.Robertson, PRL, 85 (2000) 2917
  H.Ejiri, Phys. Report, 338 (2000) 265; H.Akimune, H.Ejiri, et al., Phys. Lett. B394 (1997) 23.

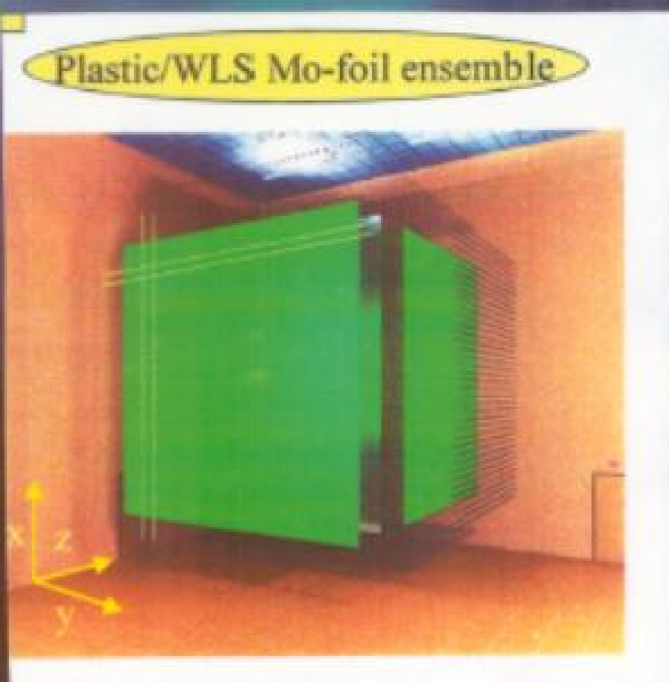
- CC realtime spectroscopy.
- Large responses with low Q_β
- Ground state contributes to pp-ν and ^{7}Be-ν. B(GT) by EC and (^{3}He, t) reaction.
- Two β correlation, β from solar-ν and successive β for tagging, to reduce BG.
- Used for ββ and supernova ν

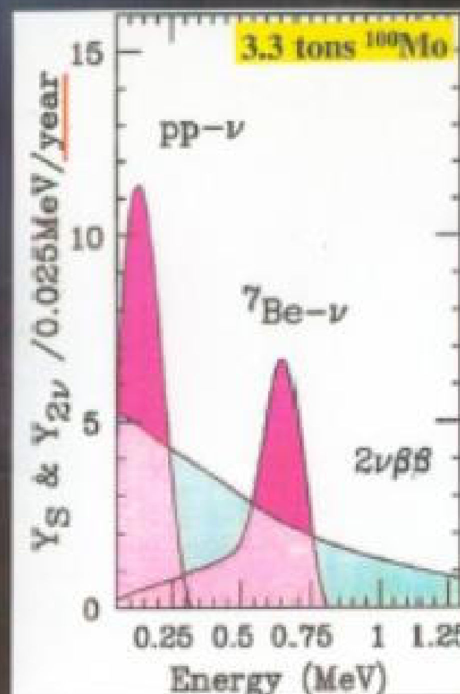


MOON Detector

Supermodule of Mo-Scintillator

- Realistic Purity of 10^{-3} Bq/ton(0.1 ppt) U-Th. Position read 3mm
- Options 1. Plastic fibers Mo-foils Ensemble,
- 2.5m-2.5m-1m with 0.8 ton ^{100}Mo. Multi-Anode PM.
- 2. Liquid scintillator with WLS Read out.





Charged-Current sub-MeV Real-Time:

LENS: Low Energy Neutrino Spectroscopy

Method

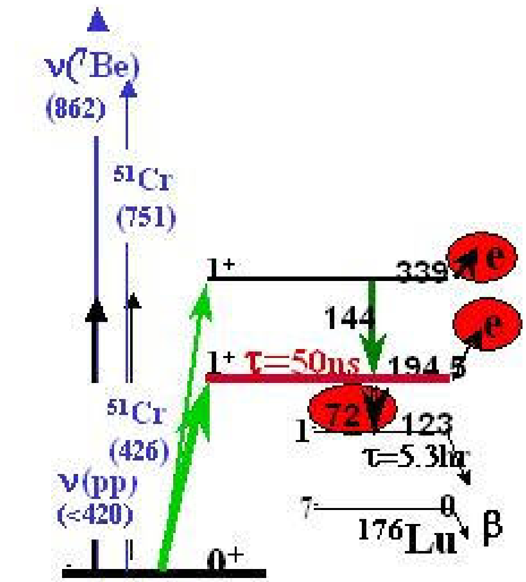
- charged current **(CC)** transition (inverse β-decay) to excited level (ν_e – only!)
- low-energy threshold: **pp-, Be-7, pep,...**
- ν_e – tag to discriminate against background
- ν_e –target (=Yb, In) loaded into liquid scintillator

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

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

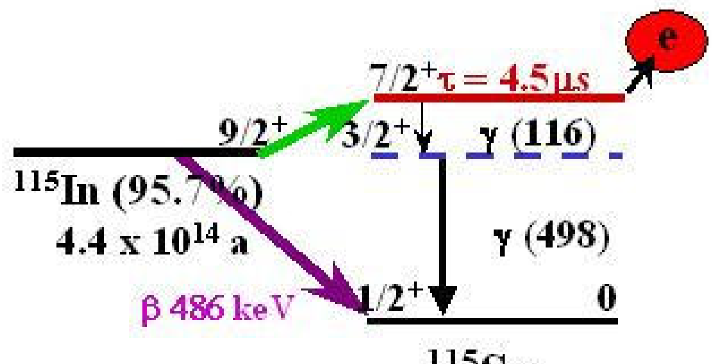
delay

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



^{176}Yb (12.8%)

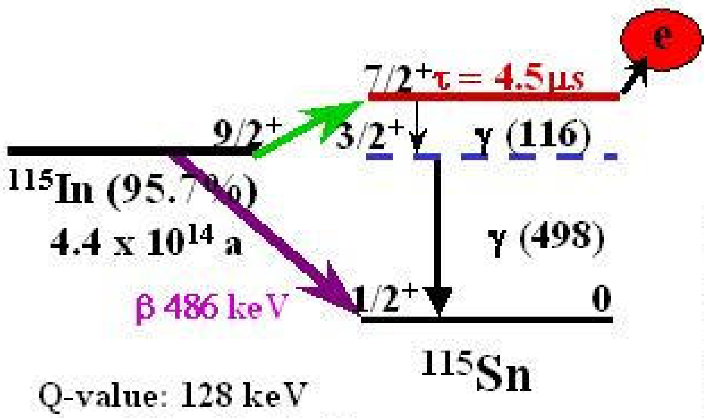
Q-value: 301 keV

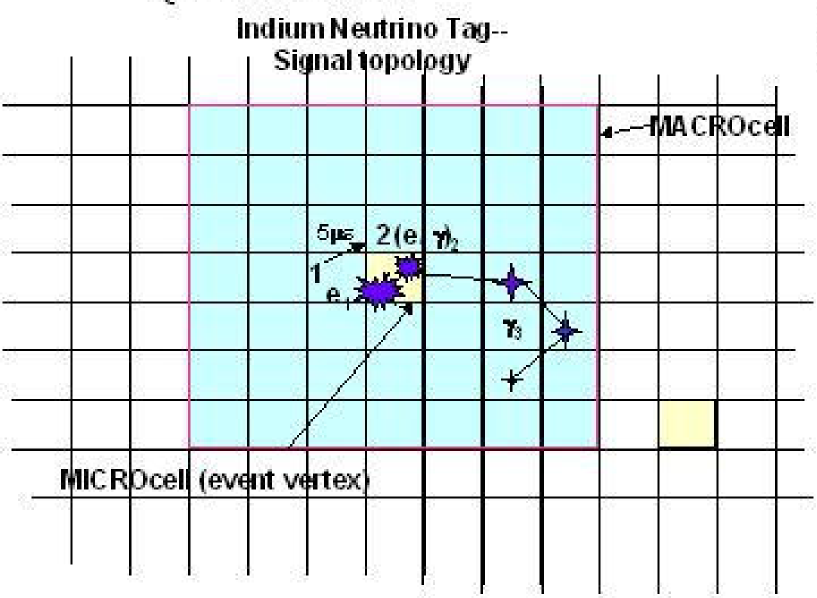


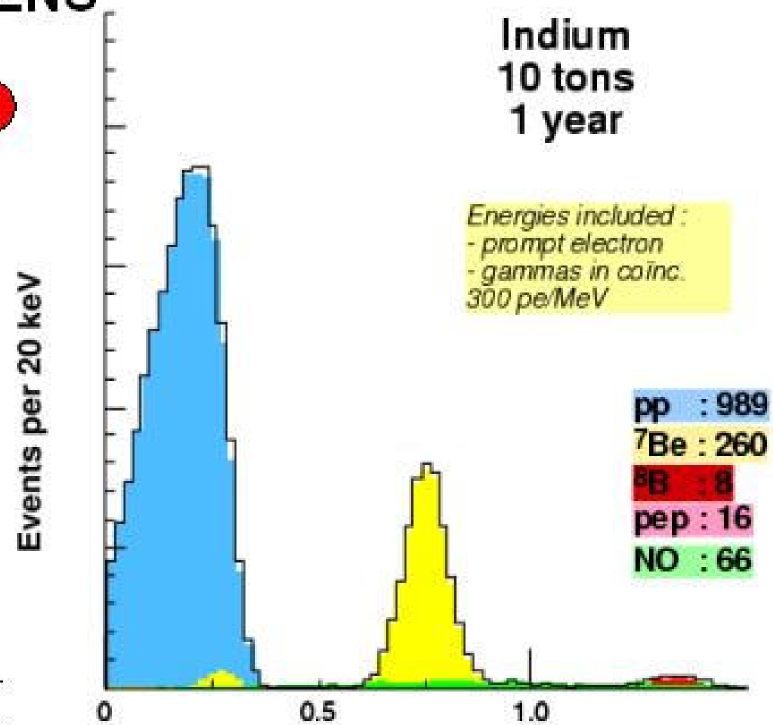
^{115}Sn

Q-value: 128 keV

In-LENS







Challenge:

Bgd from **^{115}In β-decay** 486 keV

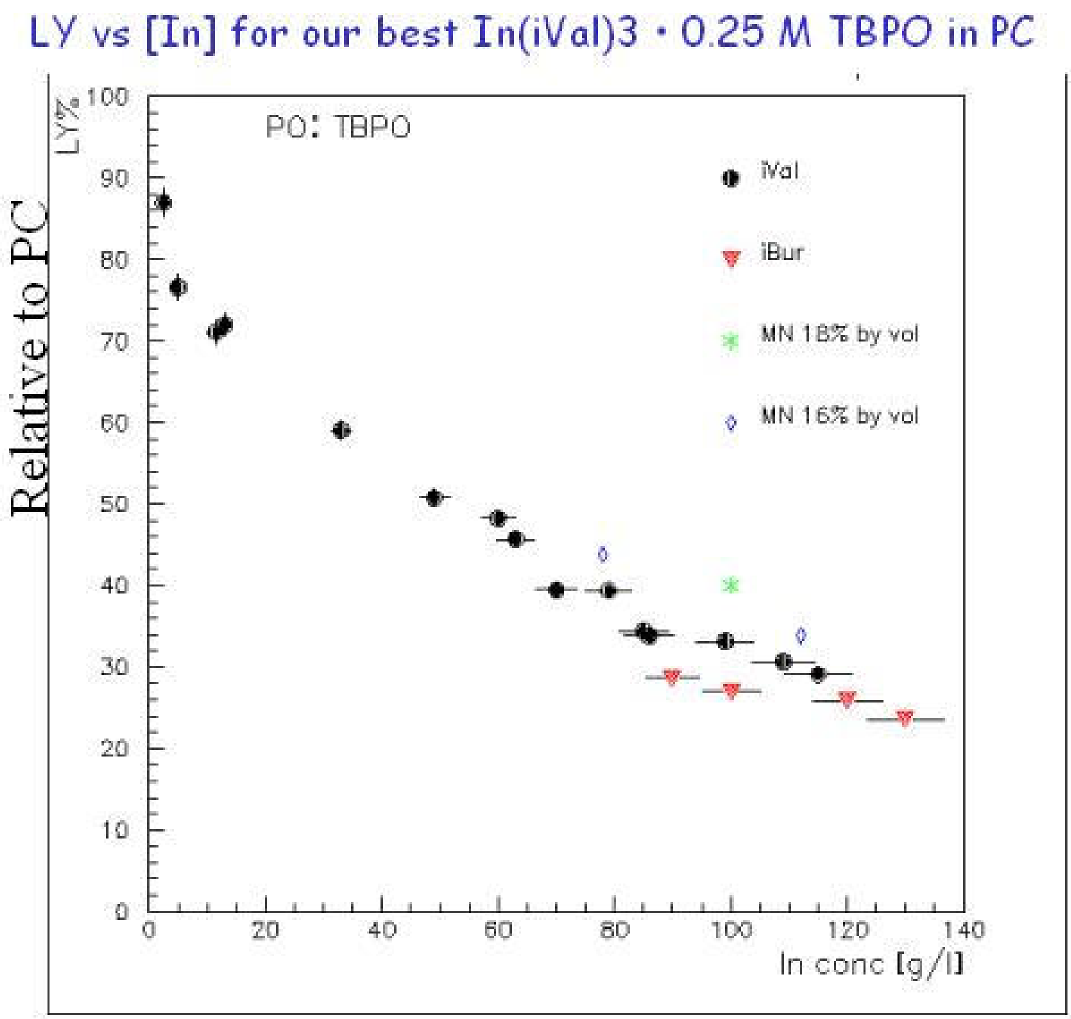
& Bremsstrahlung

⇒ ^{7}Be ok!

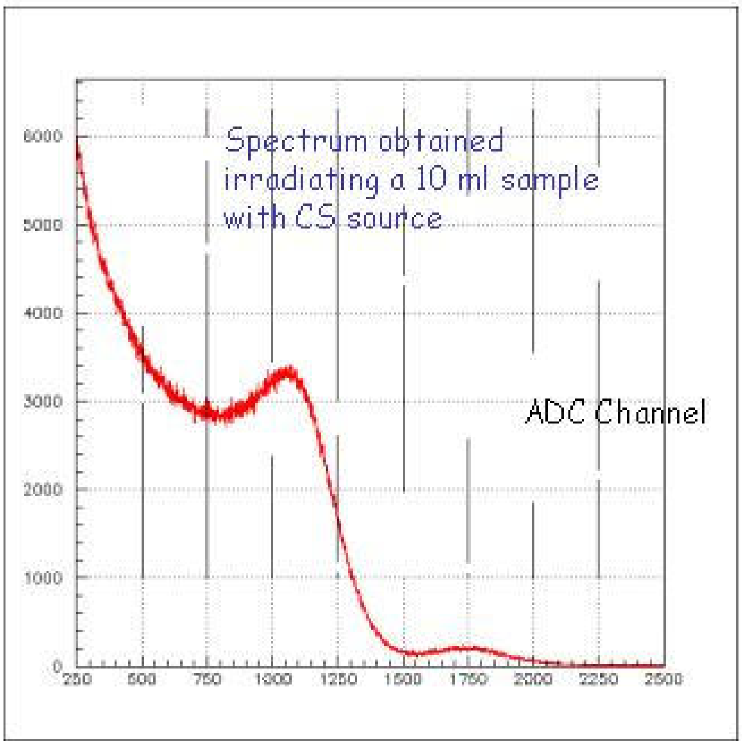
⇒ **pp-ν ???**

(MC: ε_ν ~ 11% i.e. 0.1 ev/day 4t In)

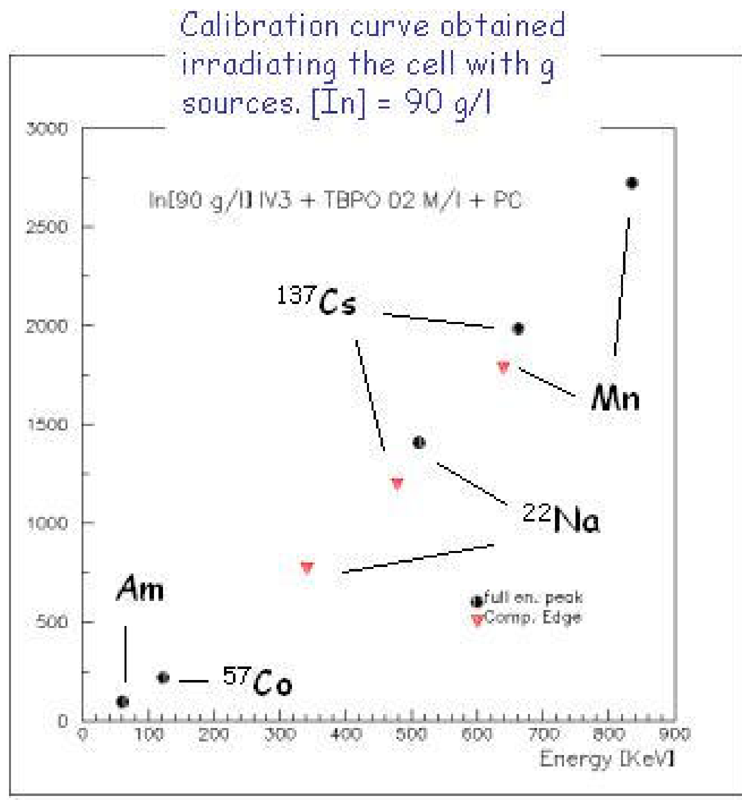
Light Yield of In-loaded scintillators



Absorbtion length ~4m achieved!

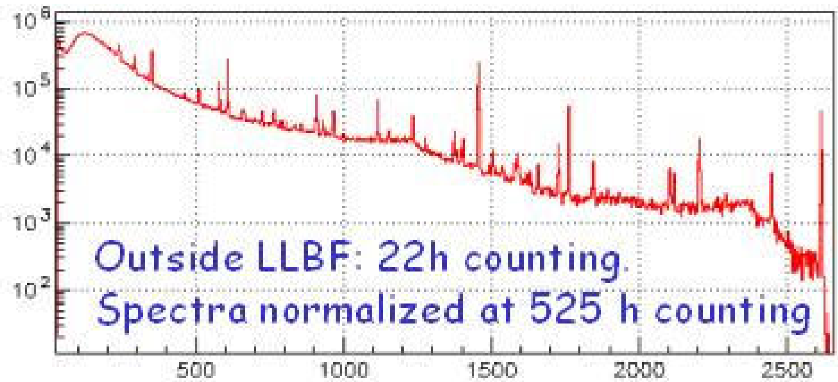


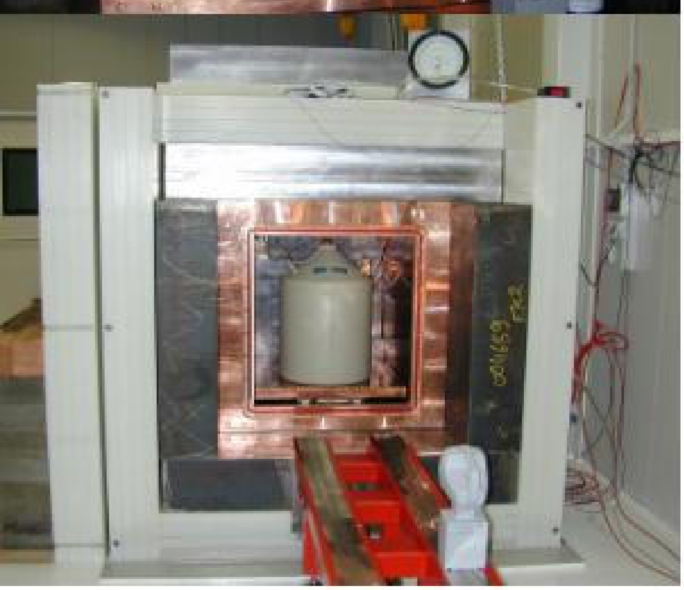
Spectrum obtained irradiating a 10 ml sample with CS source
ADC Channel

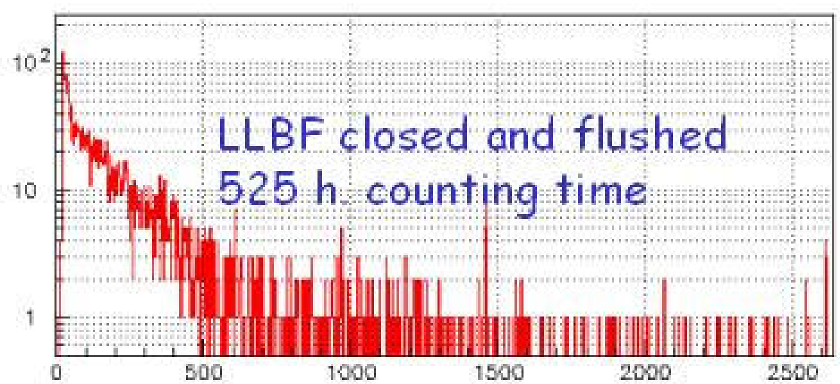


Calibration curve obtained irradiating the cell with g sources. [In] = 90 g/l
In[90 g/l] IV3 + TBPO 02 M/l + PC
137Cs
Mn
22Na
Am
57Co
full en. peak
Comp. Edge
Energy [KeV]

LENS LOW BACKGROUND FACILITY @ Gran Sasso







Reduction factor : 10^5 - 10^6 on lines

Experimental program for LLBF

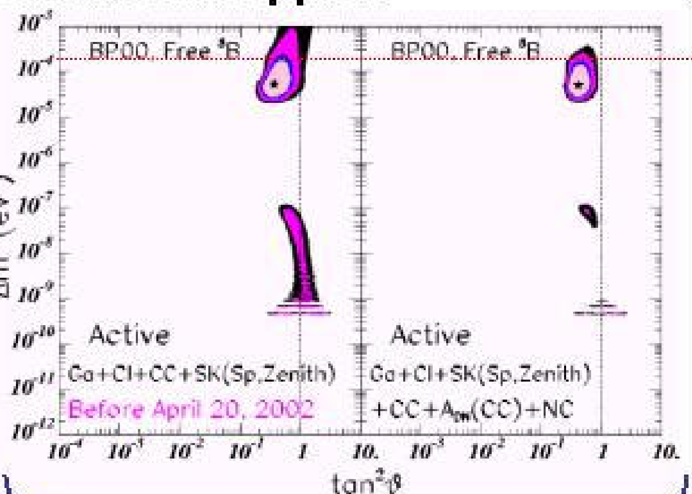
- test prototype cells and scintillators
- Bck study from radiaoctive sources (single rates, correlated signals ....)
- Event reconstruction
- ....

First test run with 20 cm Φ x 170 cm l quartz cell 70 cm acrylic buffer 8" Hamamatsu PM each side

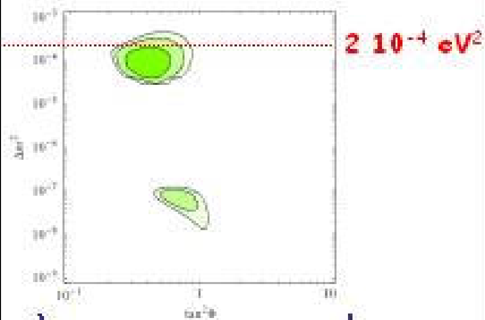
measure total counting rate with well known LS

$\Rightarrow$ poster session

HLMA Project- proposal for a new reactor oscillation exp. if KamLAND sees spectral suppression but no oscillation ripples



Bahcall, Gonzales-Garcia, Pena-Garay



Creminelli, Signorelli, Strumia

<u>LMA favoured by global analysis</u>

Rates, SK(Sp,Zenith), SNO(CC/NC/DN)

@3σ: $2.5\ 10^{-5} < \Delta m^2 < 3.7\ 10^{-4}$ eV^2
$0.24 < tg^2(\theta) < 0.89$

<u>LMA favoured</u>

All Inclusive

<u>Best Fit:</u>
$\Delta m^2 = 8\ 10^{-5}$ eV^2
$tg^2(\theta) = 0.35$

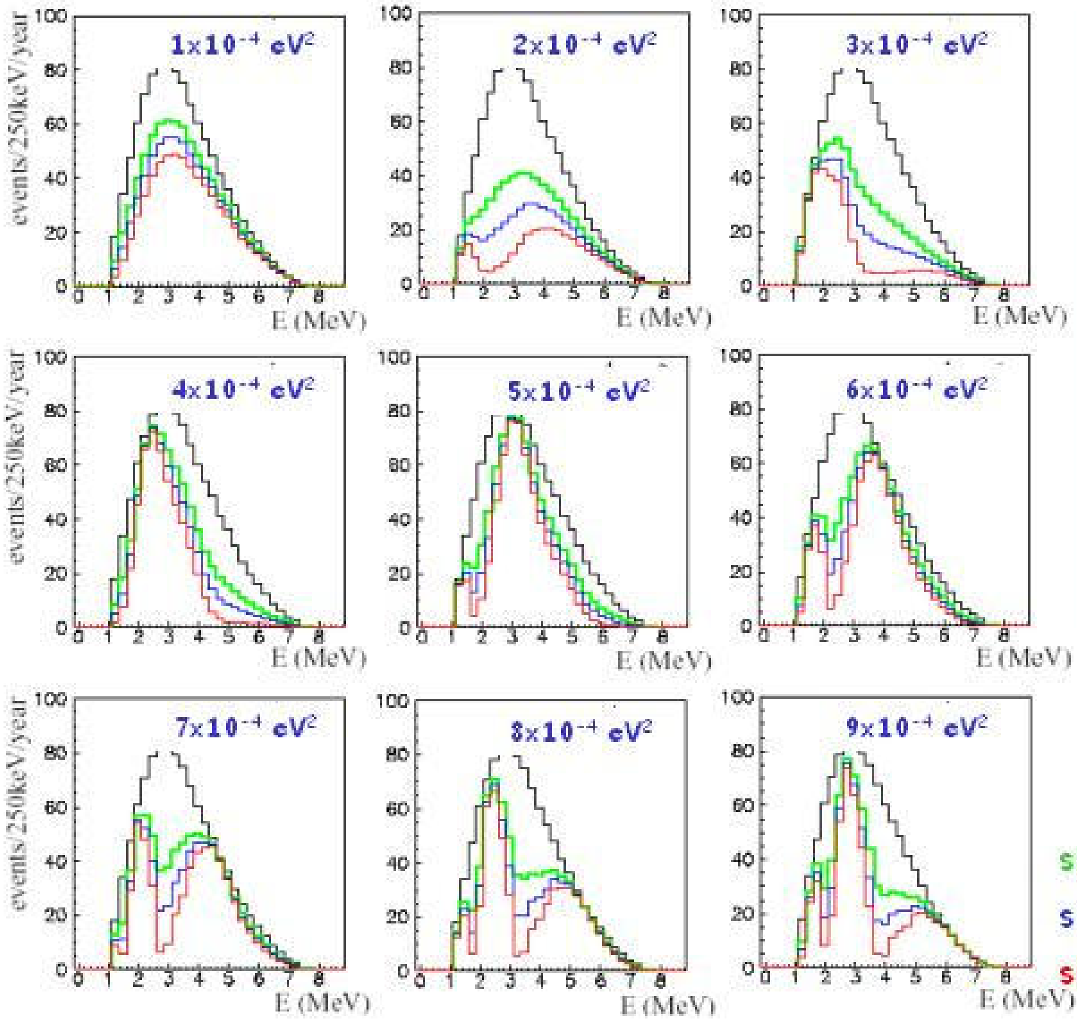
hep-ex/0203013

HLMA region
($\Delta m^2 = 2\ 10^{-4}$ eV^2)
allowed @3σ

But

Now disfavored directly by the latest SNO results since the top part of LMA gives EI solutions with Pee □1/2, and SNO gives Pee<1/2

HLMA Focus: Solar mixing parameters



- **2 neutrino mixing**
- 10^{31} protons
- No energy resolution
- 250 keV bins
- $\Delta m^2 < 10^{4}$ eV^2 only rate suppr.
- Optimised for HLMA region
- High sensitivty to Δm^2

⇒Poster session

(*S.S.*, T. Lasserre, L.Oberauer)

„Schedule“

June	2001	SNO CC data:	SK&SNO: 3.3 σ, large mixing
Dec.	2001	SK 1500 day:	LMA
Aprile	2002	SNO NC data:	5σ , LMA strongly fav.
???	2002	KamLAND:	reactor: **LMA or NOT LMA**
	2003	BOREXINO(KL) Be-7:	**LOW / VAC**
	$\geq$ 2005	next generation „LowNu-experiment“ operational	

...other issues at LowNu2002

Ingredients for success – **experimental art to (re)move atoms**:

- metal removal/loading in LS
- noble gas impurities (Rn/Kr/Ar)
- artificial neutrino sources (workhorse for CC experiments)

Solar flux variability and implication (Sturrocks/Caldwell)

D.C: Ga (Cl) show 13.6 (12.8)/y frequency,

hint for RSFP?

SK?

Summary & outlook

- Ongoing strong experimental R&D in Europe and Japan
- Both for ES and CC several projects proposed
- XMASS (ES) & LENS (CC) most advanced
- None of the projects has proven feasibility yet
- Co-operation across projects important

Physics impact of future LowNu experiments

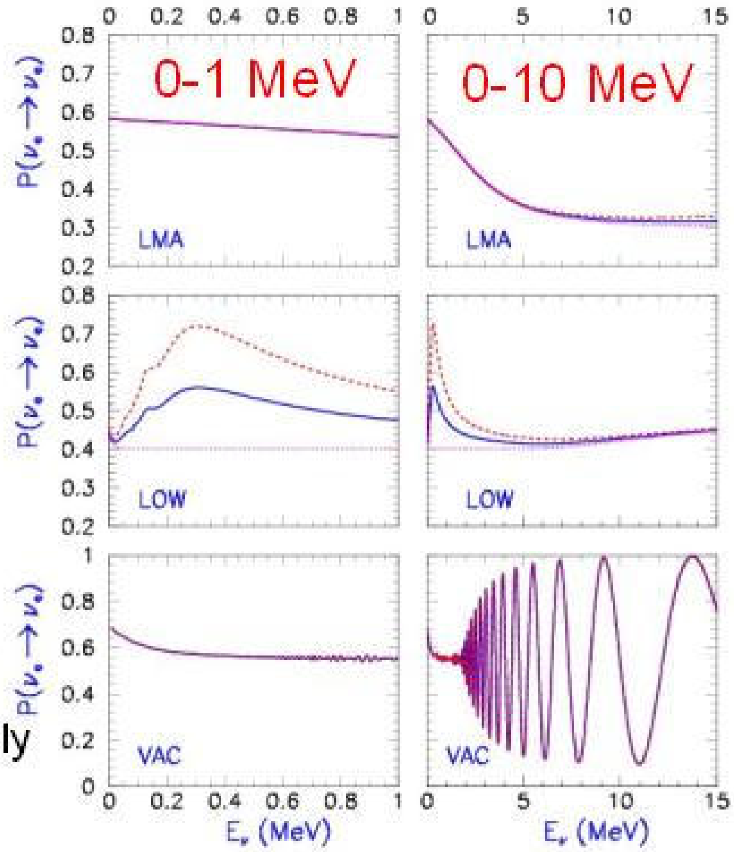
N.B.: mixing parameter range (LMA, LOW, VAC) most likely known after KamLAND and Borexino!

(Bahcall, Giunti, Strumia, ….)

- **Test / refine neutrino oscillation solutions**
  - –Same behavior at high energies
  - –Different behavior at low energies
  - –pp-flux: "precision beam" (1% uncert.)
  - –7Be: monoenergetic line (10% uncert.)
  - –θ_{sol}, $\nu_{sterile}$, CPT test, EM prop., ….

- **Test solar fusion theory**
  - –SSM: 99.99% of solar neutrinos < 5 MeV
  - –Low energy fluxes predicted more precisely

- **Redundancy / Discoveries**



JNB, CGG, CPG: hep-ph/0204314

Solar-ν : ES vs. CC real time projects

pp - ν

ES (CC+NC)

XMASS
CLEAN
HERON
TPC
MUNU
GENIUS

CC

LENS
MOON
SIREN

^{7}Be- ν

ES (CC+NC)

BOREXINO
KamLAND
TPC
MUNU
LITHIUM

CC

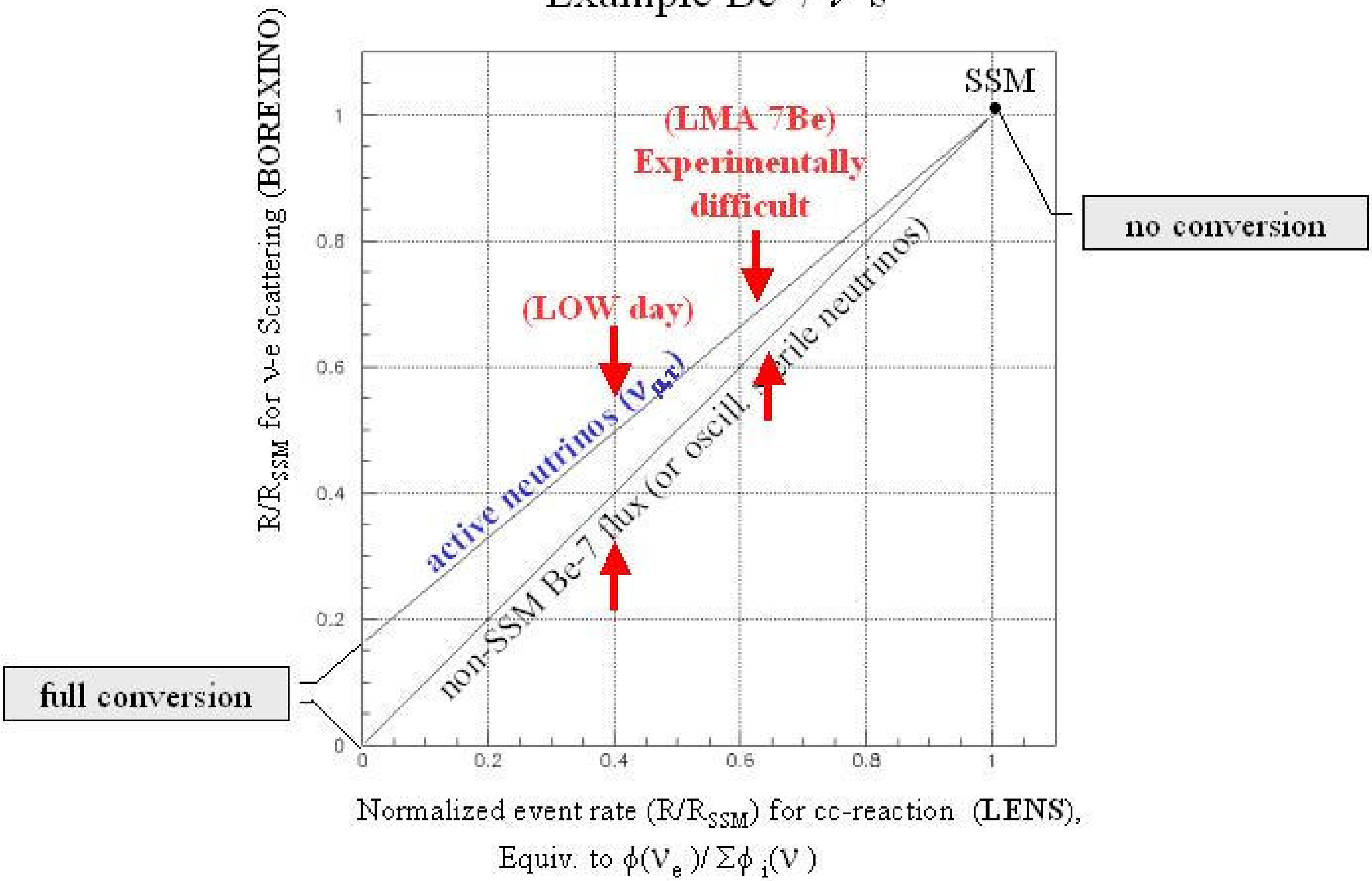
LENS
MOON
SIREN

⇒On R&D level ES and CC detection of pp- and ^{7}Be-ν redundantly covered

Neutral Current Probe

ν_e - capture(cc) vs. ν-e$^-$ Scattering (cc+nc)

Example Be-7 ν's



Projects: pp-ν-ES experiments
Noble gas detectors

pp - ν

ES (CC+NC):

XMASS (Xe)

CLEAN (Ne)

HERON (He)

TPC

GENIUS

LOW-C14

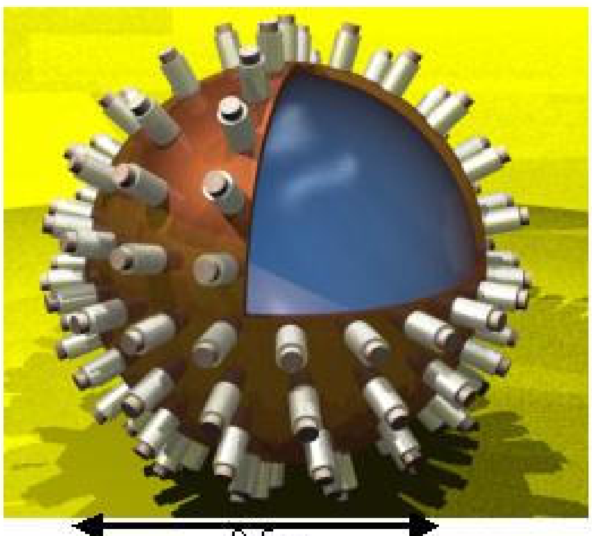
Comparison among noble gas detectors

(Ar & Kr not suitable: ^{39}Ar, ^{42}Ar, ^{85}Kr radio active isotopes)

	Helium	**Neon**	**Xenon**
Boiling temperature	4.2°K	27°K	165°K
Atomic number (Z)	2	10	54
Density (g/cm³)	0.125	1.20	3.06
Radiation length (cm)	756	24	2.7
Scintillation w.l. (nm)	73	80	175
Number of photons / MeV	22,000	15,000	42,000

ES event rate (pp-ν) : ~2/t/d ⇒ ~10t (fid.) target mass

XMASS – liquid xenon scintillation detector
Location: Kamioka



- Detection reaction: ES ($\nu + e^- \rightarrow \nu + e^-$)
- 23 t (10 t fid.) detector
- 30cm self-shield (ρ=3.06 g/cm^3)
- 1350 3´´ PMTs
- 42,000 scintillation photons/MeV
- No inactive buffer (23t volume active)

Background requirements: (<1BG/day)

^{136}Xe 2ν-ββ: $t_{½\ theory}$=8x 10^{-21} y
⇒ 1000 events/d
⇒ isotope separation factor 10-100 !

Trace contaminations:

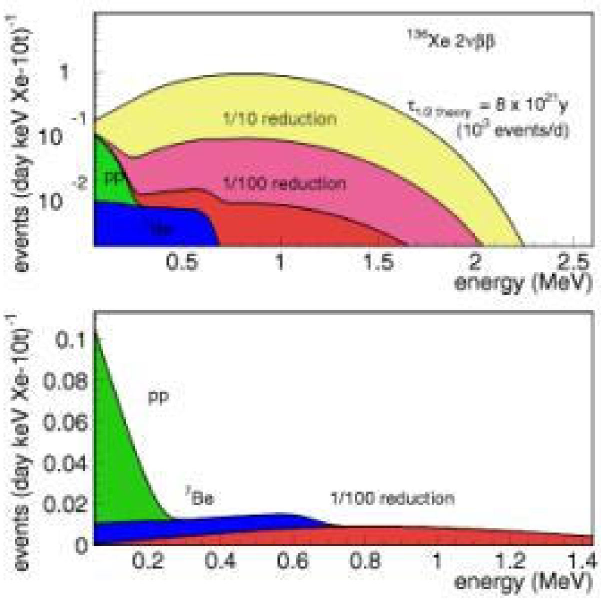
^{85}Kr ($t_{1/2}$=10.7y) :	< **$4x10^{-15}$ gKr/gXe**
^{42}Ar ($t_{1/2}$=33y) :	< $4x10^{-11}$ gAr/gXe
U/Th:	< $4x10^{-16}$

Muon induced:
In-situ spallation: 2/day ??
(assuming 10 mb)

External Background:
Similar to BOREXINO design
Self-shielding ⇒ fiducial volume

(Y. Suzuki et al.)

XMASS: expected ν-signal and **2ν-ββ background of ^{136}Xe**



Isotope separation ~1/100 needed