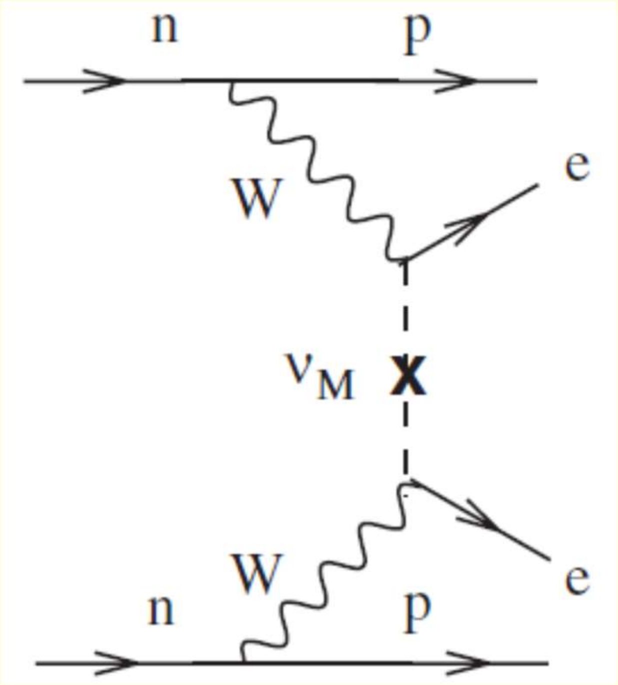
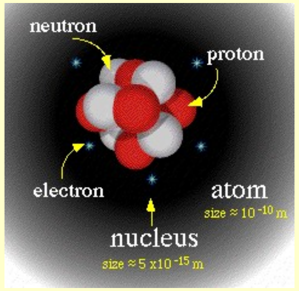
Neutrinoless Double beta decay experiments



http://www.tifr.res.in/~tin.tin/

Beta decay & birth of neutrino



Nucleus A = N + Z; strongly bound system

not all N, Z combinations are stable

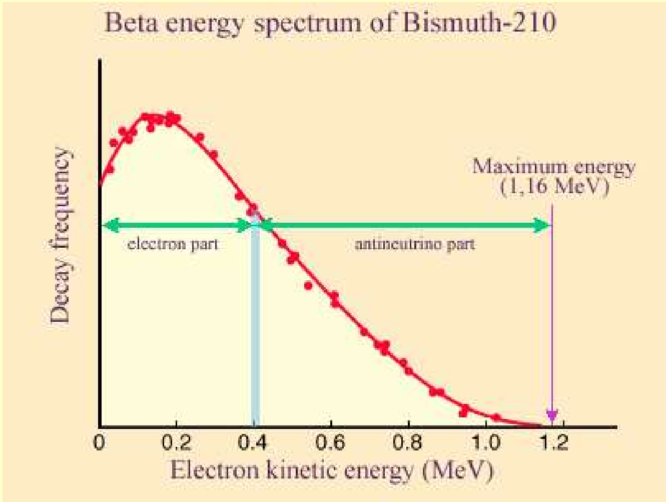
$$(A, Z) \rightarrow (A, Z+1) + e^- + \bar{\nu}_e$$

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

m_n = 939.565 MeV

m_p = 938.272 MeV

m_e = 0.511 MeV



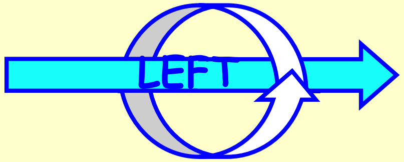
The puzzle of continuum spectra in beta decay

$$n \rightarrow p + e^- + ? + 0.78MeV \ (T_{1/2} \sim 10min)$$

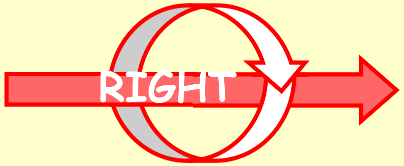
postulated by W. Pauli in 1930
mass-less spin ½ neutral particle

named as neutrino by E. Fermi
theory for β-decay in 1933

ν:



$\bar{\nu}$:



$\nu \neq \bar{\nu}$

$\nu = \bar{\nu}$

Dirac

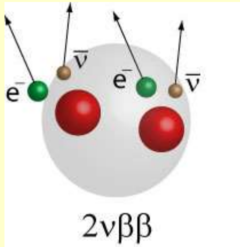
Dirac particle

ν

Majorana particle

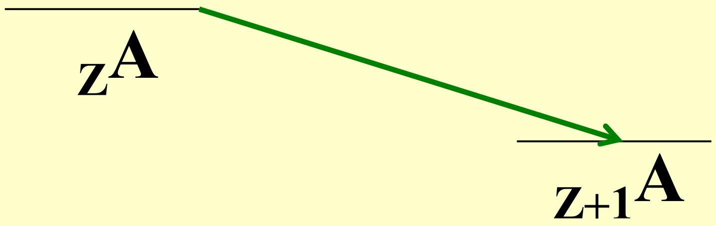
Majorana (1937)

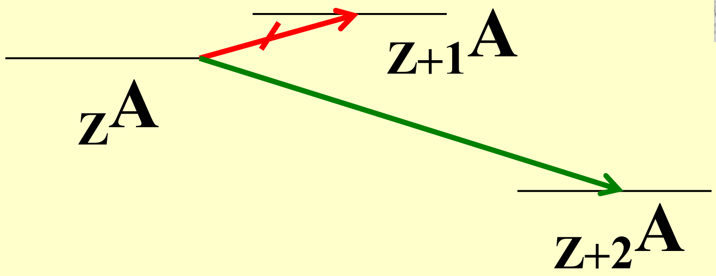
Is neutrino a Majorana or Dirac particle ??



Nuclear Double Beta Decay : early history

$n \rightarrow p + e + \bar{\nu}$

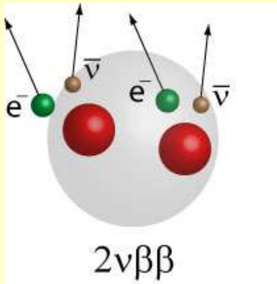


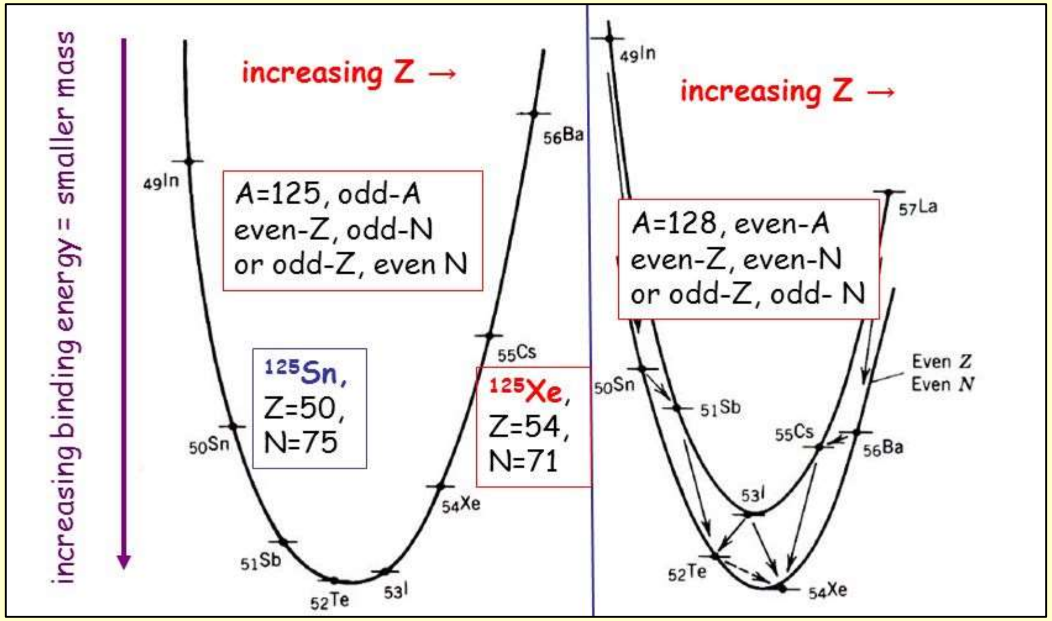


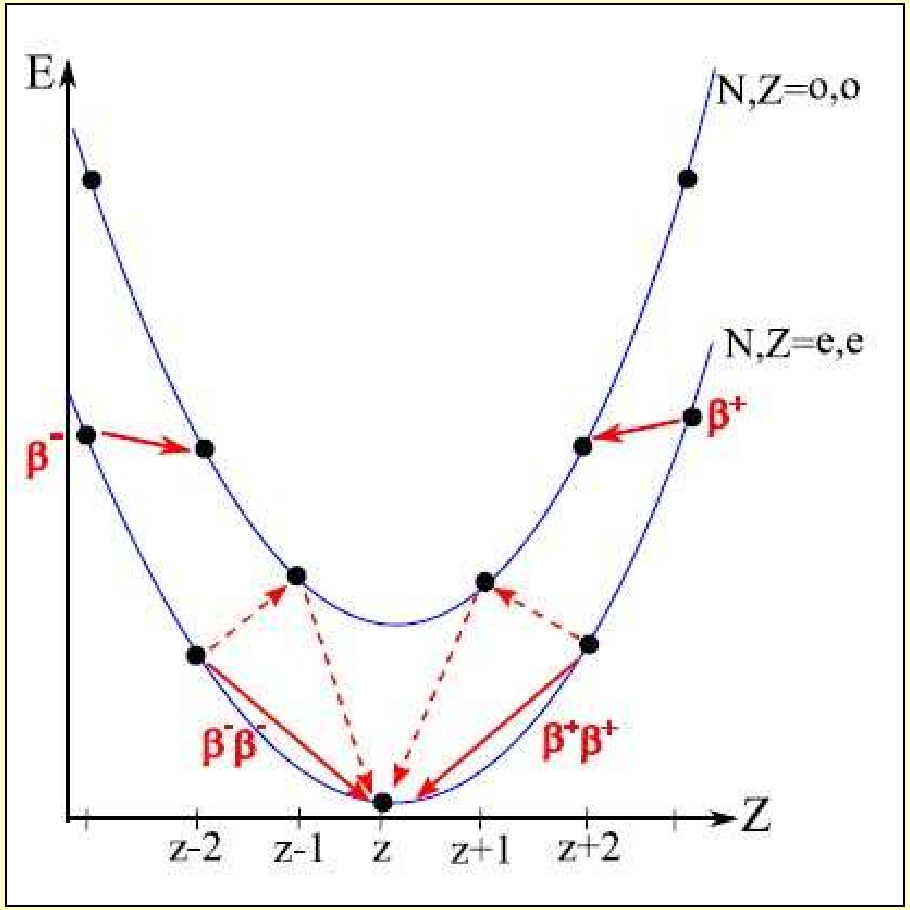
$2\nu\beta\beta$: 2nd order weak interaction normal beta decay ($\beta\nu$) suppressed by Q-value or J^{π}

- First suggested by Maria Goeppert- Mayer (1935) $T_{1/2} \sim 10^{17}$ yrs
- First geochemical observation of DBD $T_{1/2}$ (^{130}Te) ~$1.2x\ 10^{21}$ yrs (Ingram & Reynolds, 1950)
- First DBD Experimental evidence in laboratory: ^{82}Se (Elliot et al. 1987)

Double beta decay







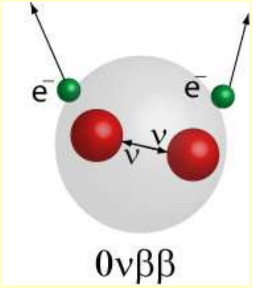
Simultaneous emission of four particles $(2e^{-}\ \&\ 2\bar{\nu}_e)$

Possible in only 35 even-even nuclei

Seen in 13 cases till date

Lifetime $T_{1/2} \sim 10^{18}$ *to* 10^{24} *years*

Neutrinoless Double Beta Decay



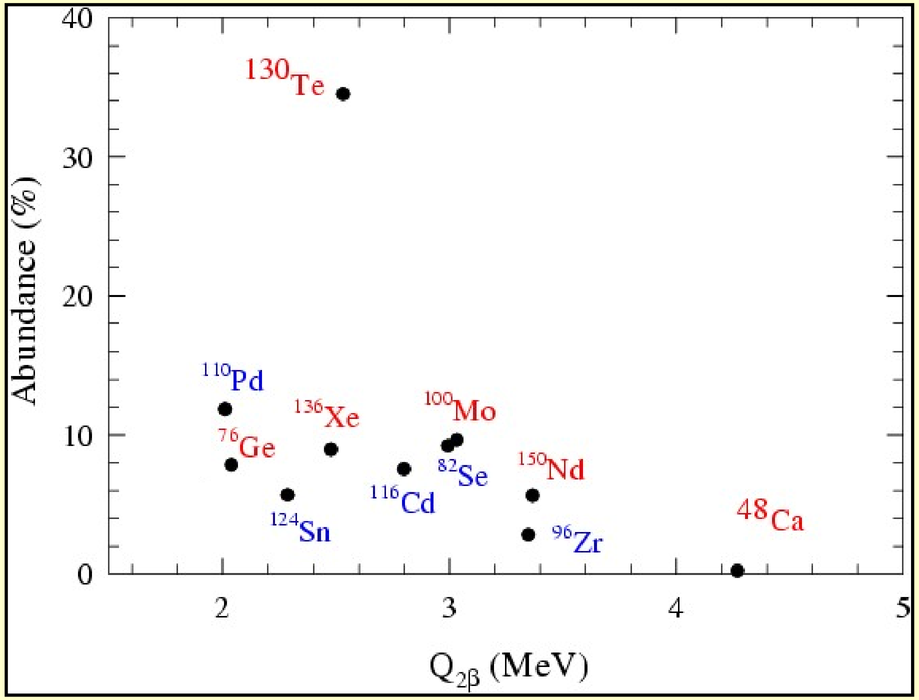
0νββ : Lepton number violating process occurs if neutrinos have mass and are their own antiparticles

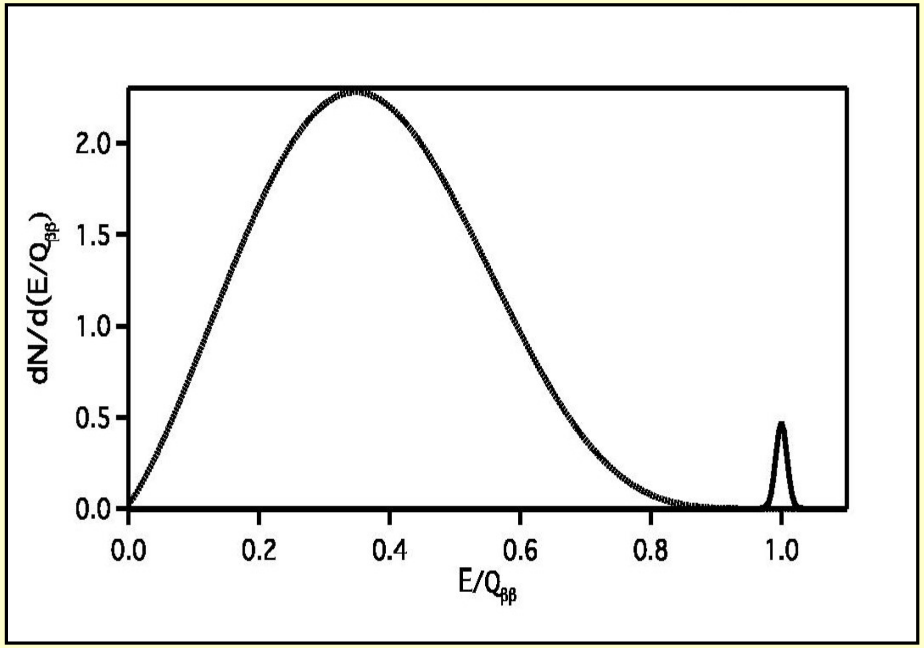
- **test the true nature of neutrino** *Dirac/Majorana*
- **the measurement of effective neutrino Majorana mass.**

$$\Gamma_{0\nu 2\beta} \propto [\text{phase-space } (\propto Q^5)] \times [\text{Nuclear ME}]^2 \times |\langle m_\nu \rangle|^2$$

Rarest amongst the rare

How to Search for NDBD





High $Q_{2\beta}$ and abundance desirable

- Simultaneous emission of two electrons
- Constancy of the sum energy of the two emitted electrons

} *Identification experiments*

Sum energy peak ⇨ High resolution
Extremely low event rates ⇨ very large sources and detector

For a conclusive proof, 0νββ measurement in several isotopes is essential

Experimental Considerations

- *Active source (DBD nuclei integral part of the detector)*
- *Passive Source (DBD source external to the detector)*

$$T_{1/2} \sim \frac{\ln 2 \bullet N_A \bullet M \bullet i \bullet \varepsilon \bullet t}{A(B \Delta E t)^{1/2}}$$

B :background (cts/keV/yr)
ΔE : energy resolution of the detector
t : data taking period
i : isotopic abundance of the element
ε : detection efficiency

$$N_{0\nu\beta\beta} \sim \sqrt{N_{bkg}}$$

$$N_{bkg} = B(c/kev/t) \bullet \Delta E \bullet t$$

Present Status

•2νββ detected in several (~13) nuclei, half life measured.

•Improvement in sensitivity possible by background reduction in some cases

•**No 0νββ observed**

Small scale experiments ~ kg ; $T_{1/2} \sim 10^{24}$- 10^{25} years, $\langle m_\nu \rangle \sim 0.75$ eV

Many new experiments (~ton scale) are planned/proposed, R&D in progress

Experimental Considerations

Background reduction

$N_{0\nu\beta\beta} \sim \sqrt{N_{bkg}}$

$N_{bkg} = B(c/kev/t) \bullet \Delta E \bullet t$

- Underground location (reduce cosmic ray background)
- Careful choice of materials (detector & environs- $^{235,238}U$, ^{232}Th, ^{40}K, radiative impurities) and shielding

  Natural radioactivity $T_{1/2} \sim 10^9 - 10^{10}$ yrs

- Electronic rejection of background events
- Neutron background minimization (U/Th induced and muon induced)

Major ongoing and proposed $0\nu\beta\beta$ experiments

Experiment	Isotope	$Q_{\beta\beta}$ (MeV)	Technique	Expected $\langle m_{ee} \rangle$(meV)*
GERDA	^{76}Ge	2039.6	Semiconductor HPGe detector; good energy resolution and efficiency	15-35
MAJORANA	^{76}Ge	2039.6	Semiconductor HPGe detector; good energy resolution and efficiency	15-35
SuperNEMO	^{82}Se	2995.0	Tracking + calorimeter; Good background rejection Possibility of DBD in multiple isotopes (^{150}Nd)	44-140
LUCIFER	^{82}Se	2995.0	Scintillating bolometer; Good energy resolution and efficiency	~76
AMoRE	^{100}Mo	3034.0	Scintillating bolometer, Good energy resolution and efficiency	20-60
MOON	^{100}Mo	3034.0	Tracking + Scintillator; Background rejection	~100
COBRA	^{116}Cd	2802.0	CdZnTe Semiconductor detector; good energy resolution, particle ID	
CUORE	^{130}Te	2533.0	Cryogenic bolometer, Good energy resolution and efficiency	50-130
EXO	^{136}Xe	2479.0	liquid TPC, ionization + scintillation; high efficiency, Particle ID, daughter identification (^{136}Ba) proposed	14-33
KamLAND-Zen	^{136}Xe	2479.0	liquid Scintillator, ultra-low background	25-60

*for about 5-10 years of running time for full scale detector.

Current Science **112**, 1375 (2017)

GERDA (^{76}Ge)

Located at LNGS

(2013-20)

~86% enriched

liquid Ar – detector coolant + shield

Muon veto – water Cernekov

•Detector segmentation

•Pulse shape discrimination

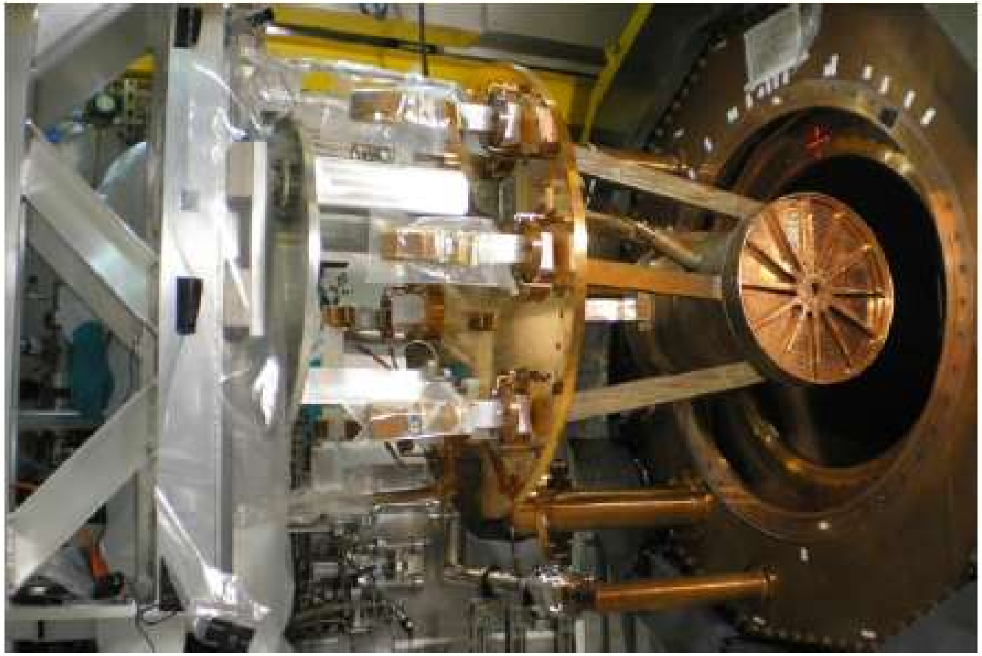
•Energy resolution (ROI)~0.15%

•Background ~ 0.02 cts/(keV-Kg-yr)

http://www.mpi-hd.mpg.de/gerda/

EXO-200 (^{136}Xe)

Located at WIPP, USA (1580 mwe)



Liquid Xenon TPC

~80% enriched

TPC – ionization and scintillation signal.

Electronic rejection of multihit background signals

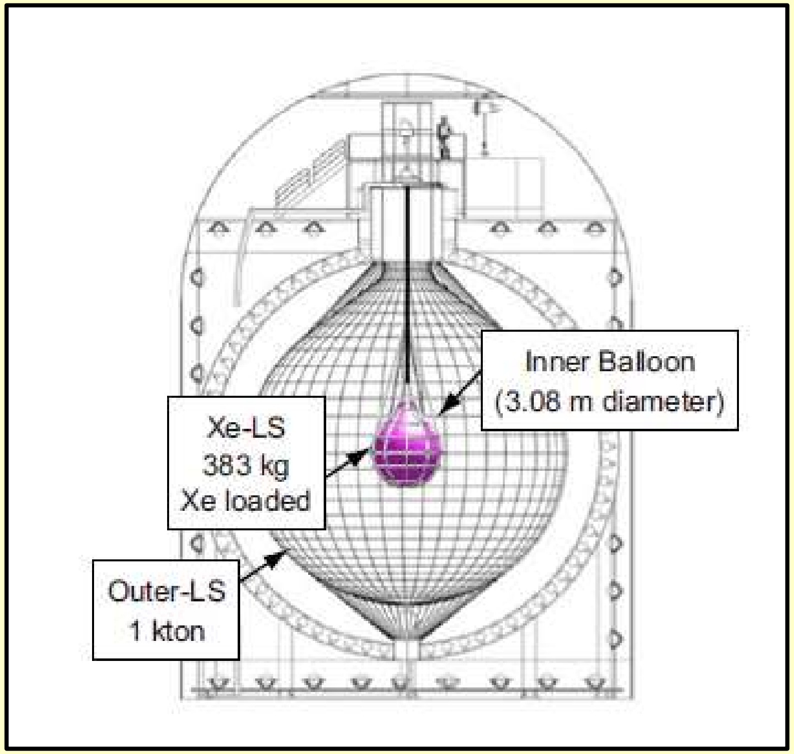
Background ~ 0.0017 cts/(keV-Kg-yr) – considerably smaller than GERDA

G. Anton et al. (EXO-200 Collaboration) Phys. Rev. Lett. 123, 161802 (2019) with 234.1 Kg-yr exposure

$T_{1/2} > 3.5 \times 10^{25}$ yr (90% C.L.), effective neutrino mass 78-239 meV

Kamland-Zen (^{136}Xe)

Located in Japan (2700 mwe)



arXiv:1409.0077v1

Liquid Xenon loaded scintillator

~91% enriched

Water Cerenkov for muon veto

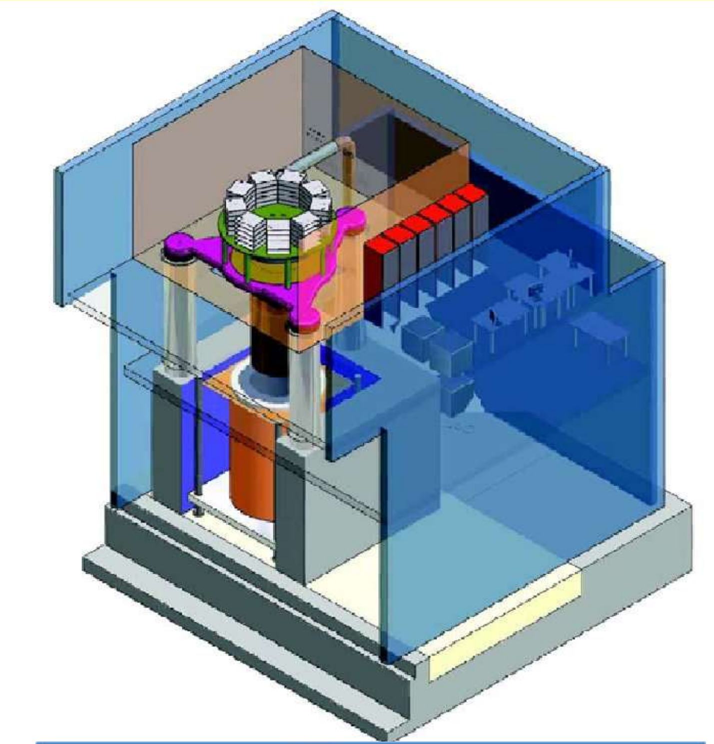
Resolution ~ 4%

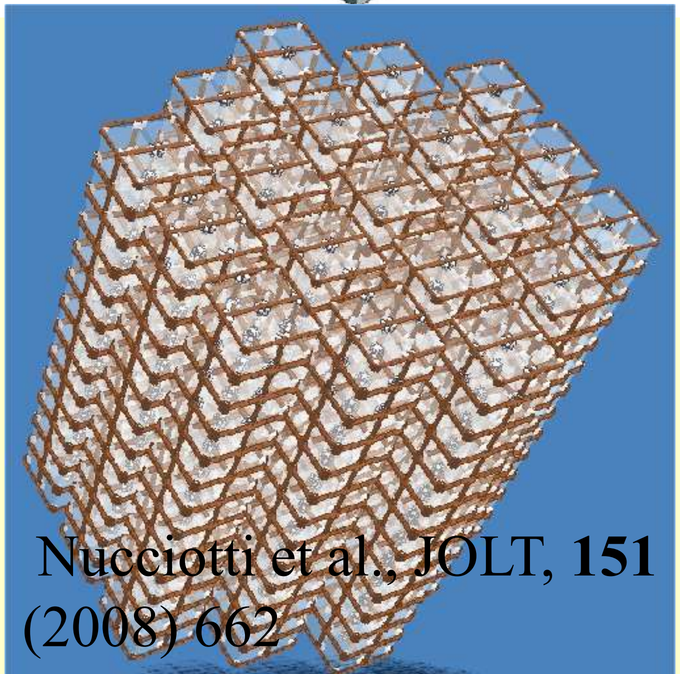
Phase I : Background in the ROI limited by ^{110m}Ag

Phase II: after purification with improved background

Phase I+II: $T_{1/2} > 2.6 \times 10^{25}$ yr (90% C.L.)

Cryogenic Underground Observatory(for) Rare Events



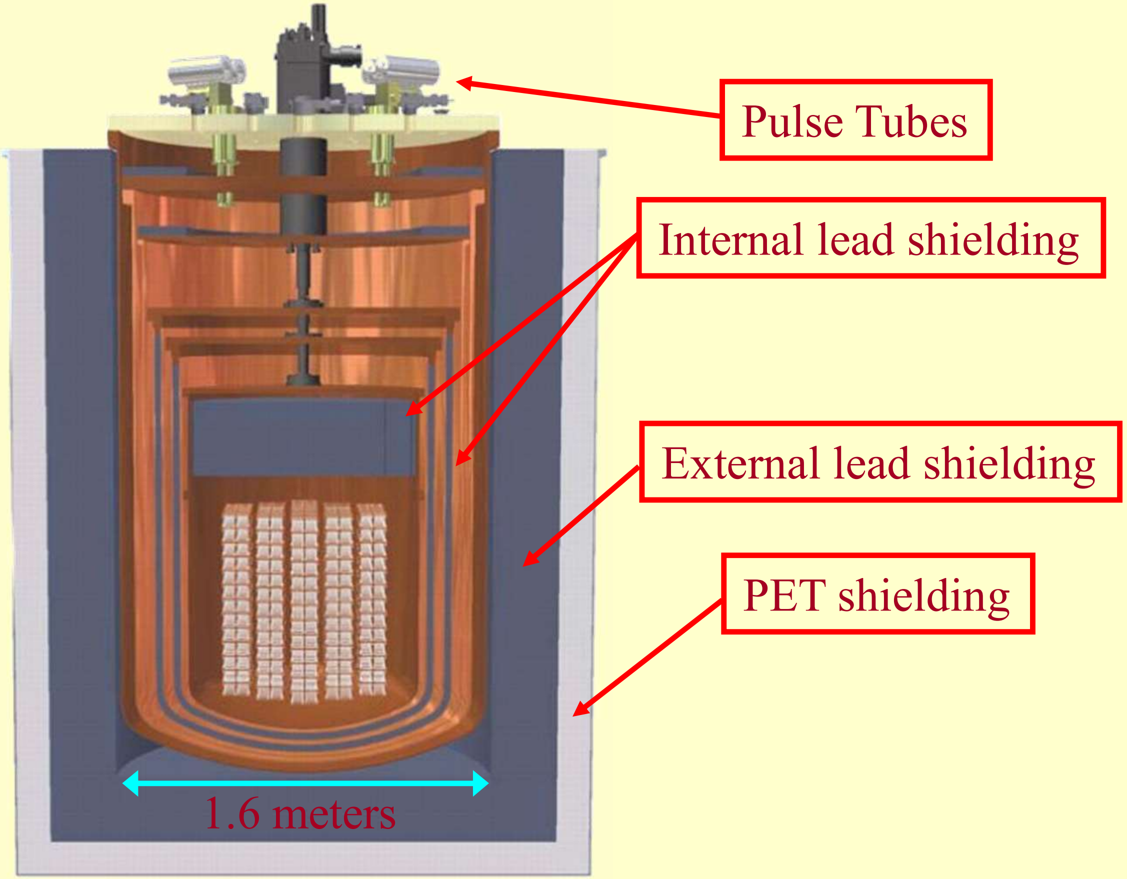


Nucciotti et al., JOLT, **151** (2008) 662

M = 0.75 ton

bkg~0.01 counts/(kev-kg-yr)

Expected: $T_{1/2} \sim 2.5 \times 10^{26}$ yrs, $\langle m_\nu \rangle \sim 0.04$ eV



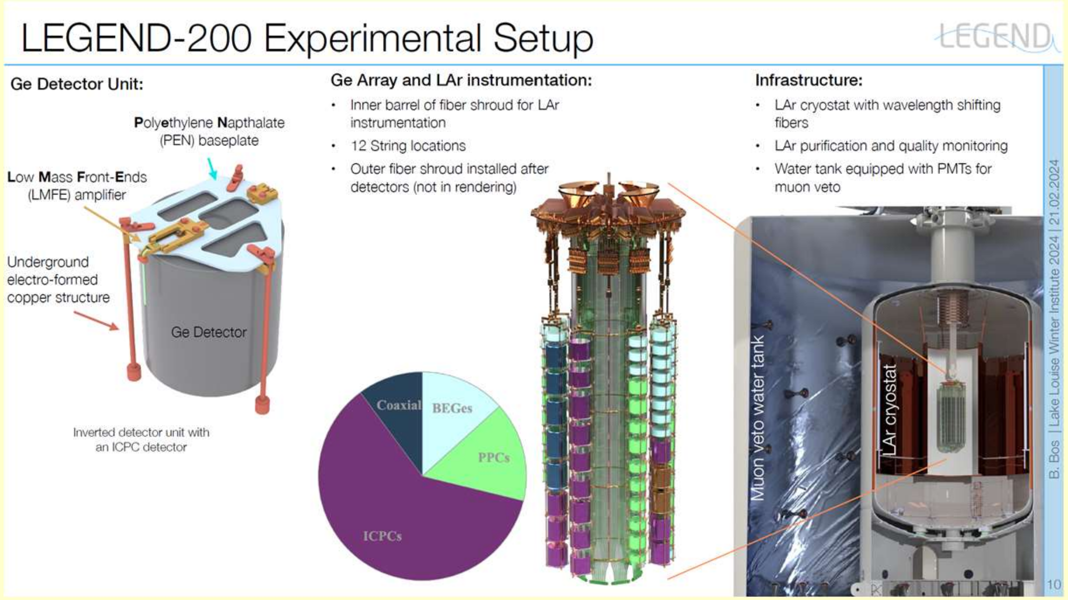
Array of 988 detectors:

19 towers , 13 modules/tower, 4 detectors/module

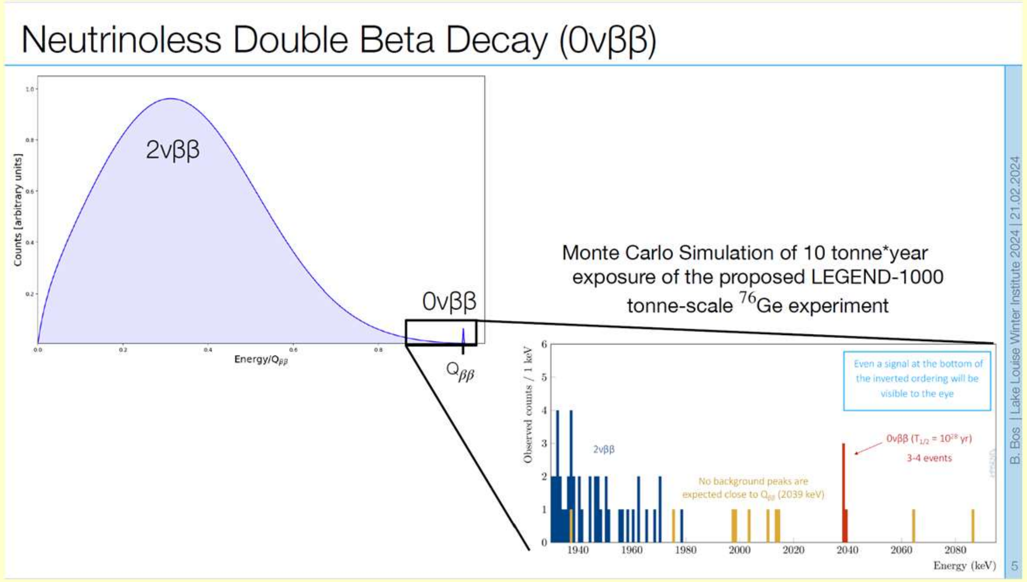
LEGEND (^{76}Ge)

The Large Enriched Germanium Experiment for Neutrinoless double-beta Decay

Develop a phased, ^{76}Ge based double-beta decay experimental program with discovery potential at a half-life beyond 10^{28} years (ton scale enriched germanium detector)



Measured Background index (LEGEND@LNGS) is compatible with LEGEND-200 Background goal:
2×10^{-4} cts / (keV $\times$ kg $\times$ yr)



From the presentation of Brady Bos (UNC-CH/TUNL) On behalf of the LEGEND collaboration @ Lake Louise Winter Institute 2024

Best Limits so far…

GERDA : $T_{1/2}^{0\nu\beta\beta} > 1.8 \times 10^{26}\ y$ **(90% C.L.), ⟨*m*⟩ < 0.079-0.180 eV**

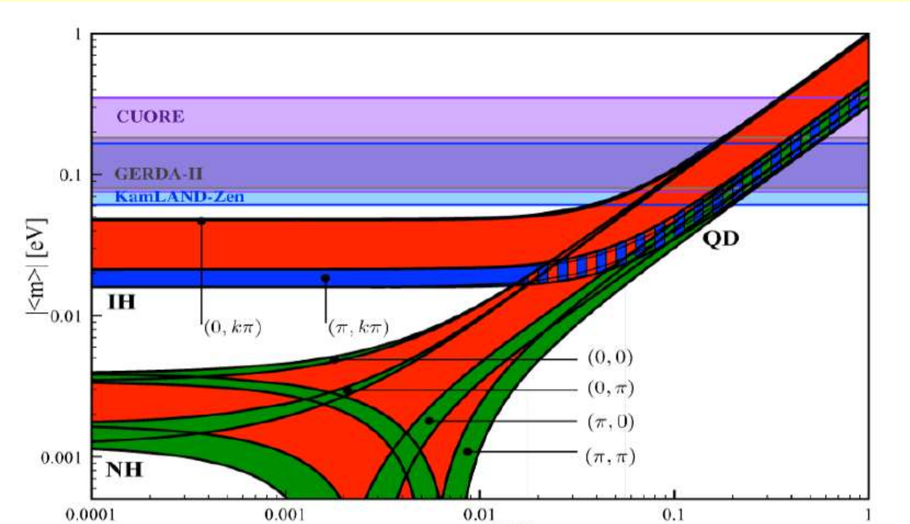
Phys. Rev. Lett. ***125****, 252502(2020)*

KamLANDZen 800 **:** $T_{1/2}^{0\nu\beta\beta} > 2.3 \times 10^{26}\ y$ **(90% C.L.),⟨*m*⟩ < 0.036-0.156 eV**

arXiv:2203.02139

CUORE **:** $T_{1/2}^{0\nu\beta\beta} > 2.2 \times 10^{25}\ y$ **(90% C.L.),⟨*m*⟩ < 0.090-0.305 eV**

Nature ***604****, 53–58 (2022)*



Sergei Petcov, doi: 10.5281/zenodo.4134015

Direct neutrino mass measurement –

KATRIN (^{3}H, Q~18 keV , sensitivity ~ 0.2 eV),

HOLMES +ECHO (^{163}Ho- EC, Q ~ 2.55 keV, sensitivity < 2 eV),

MARE (^{187}Re, Q ~2.49 keV , sensitivity <0.2 eV)

Initiative for DBD experiment in India

A multi-institutional effort

Proposal for an experiment at underground laboratory

^{124}Sn (Q =2292.64 ± 0.39 keV)

- Sn has T_C ~ 3.7 K
- Electronic specific heat falls off exponentially below T_C
- Only lattice specific heat ($\sim T^3$) present below ~ 500 mK
- Z=50 shell is closed
- Simple metallurgy

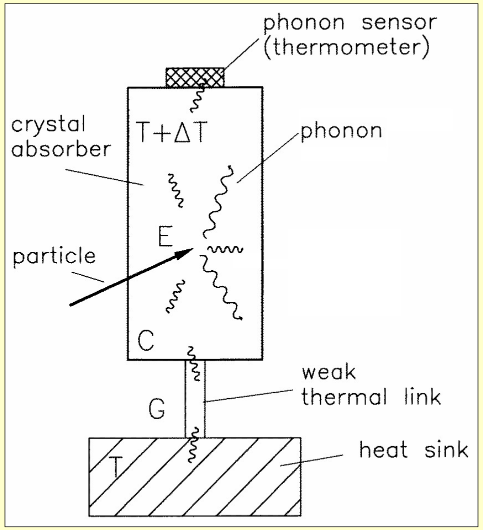
^{124}Sn: $T_{1/2} > (0.8\text{-}1.2) \times 10^{21}$ yrs Nucl. Phys. A **807,** 269(2008)

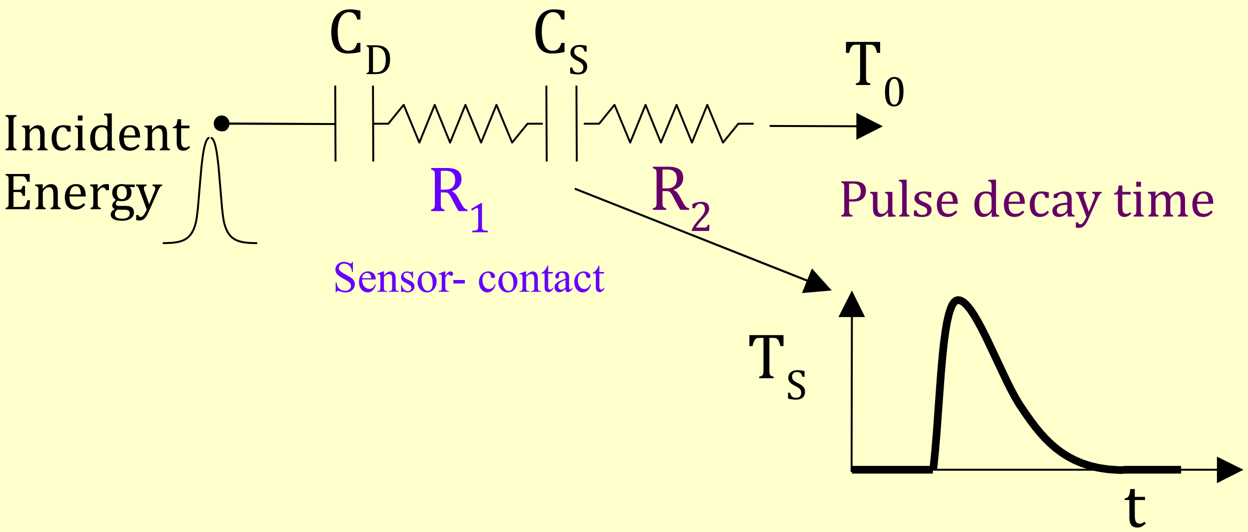
Low Temperature Bolometry

A bolometer is a calorimetric detector.

Energy of particle → Thermal energy in detector → measurable temperature rise if net heat capacity is very low

Bolometer Schematic





Resolution of Bolometer

- Limited by Thermodynamical fluctuation noise $\{\delta E=(kT^2C(T))^{1/2}\}$
- Depends only on operating temperature and specific heat
- Independent of incident Energy

Challenge: to make measurements in time domain at mK temperature

What needs to be done ??

- Sensor development for mK thermometry
- Radiation background studies
- Detector and background simulations
- Make a natural Sn bolometric detector ~ 0.5–1 Kg
- Reliable NTME calculations
- Precision Q value measurement
- Enrichment of ^{124}Sn
- Constraining NTME, GT measurement in NDBD nuclei

Strongly Multi-disciplinary project

Nuclear Physics, Neutrino Physics, Low Temperature Physics, Material Science, Physical Chemistry

Challenges for ^{124}Sn cryogenic bolometer

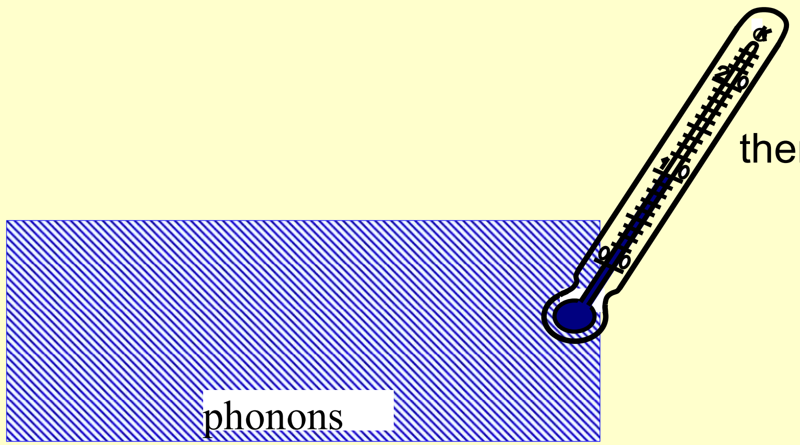
- Thermalization issues

  between the electronic and phononic systems

  ballistic phonons, single crystal vs polycrystalline Sn
- Vibration effect
- Allotropic transition in Sn : the sample disintegrates due to a sudden increase in the volume, affects the longevity

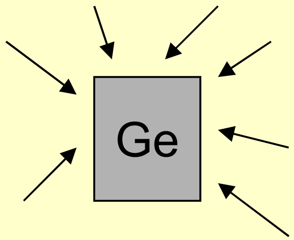
Cryogen free dilution refrigerator installed at TIFR

Thermometer



Energy deposited by Particle
→ Heat
→ rise in Temperature - ΔT
→ read by thermometer

- Change in physical property – e.g. resistance with T



thermal neutrons

^{71}Ge, ^{75}Ge → decay As, Se, Ga

$$R(T) = R_0 \exp(T_0/T)^{0.5}$$

NTD Ge Sensor R&D

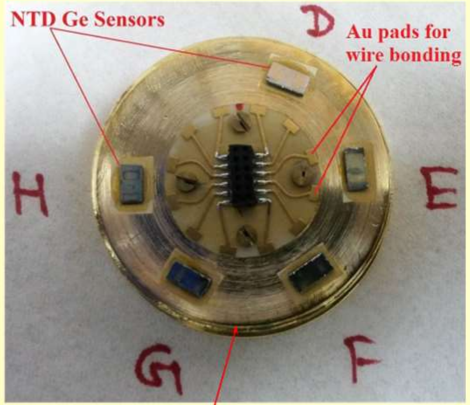
Neutron irradiation at Dhurva Reactor (BARC, Mumbai)

Isotope	Isotopic Abundance (%)		Products (half-life)	Stable end product (mode)	Dopant Type
	Set 1	Set 2			
^{70}Ge	21.5	21.9	^{71}Ge* (11.43d)	^{71}Ga (e^- capture)	p
^{72}Ge	26.8	27.0	^{73}Ge (stable)	^{73}Ge	-
^{73}Ge	10.8	8.8	^{74}Ge (stable)	^{74}Ge	-
^{74}Ge	34.1	35.1	^{75}Ge* (82.78min)	^{75}As (β-decay)	n
^{76}Ge	6.8	7.2	^{77}Ge* (11.3,38.8hrs)	^{77}As*,^{77}Se (β-decay)	n

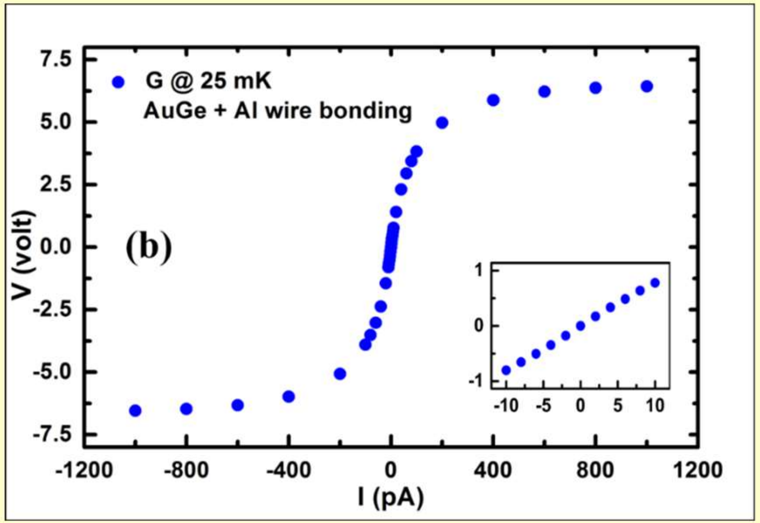
- Radioactive impurity studies (~2 year cooldown period)
- Fast neutron induced defect studies (PALS, Channeling)
  - Annealing at 600 ^{o}C for 2 hrs in vacuum cures defects
- Sensor Fabrication

S. Mathimalar *et. al.*, NIM A **774** (2015) 68,
S. Mathimalar *et. al.* NIM B **345** (2015) 33.

NTD Ge fabrication & characterisation



Au plated Cu thermal sink.



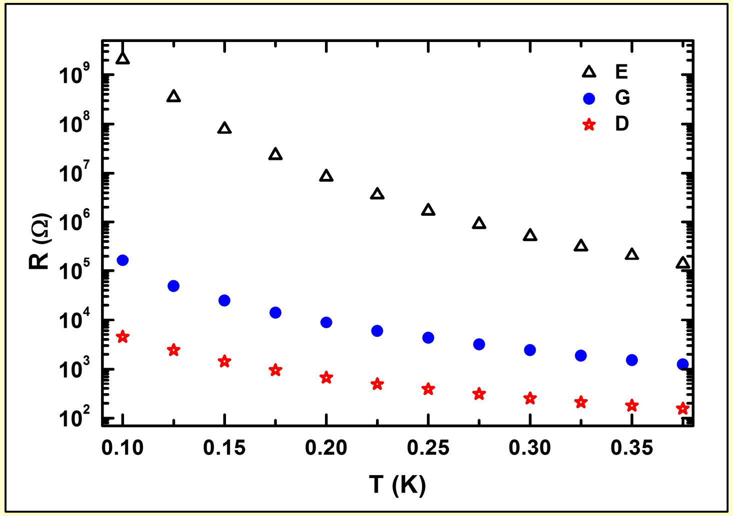
Characterization of NTD Ge at T < 300 mK

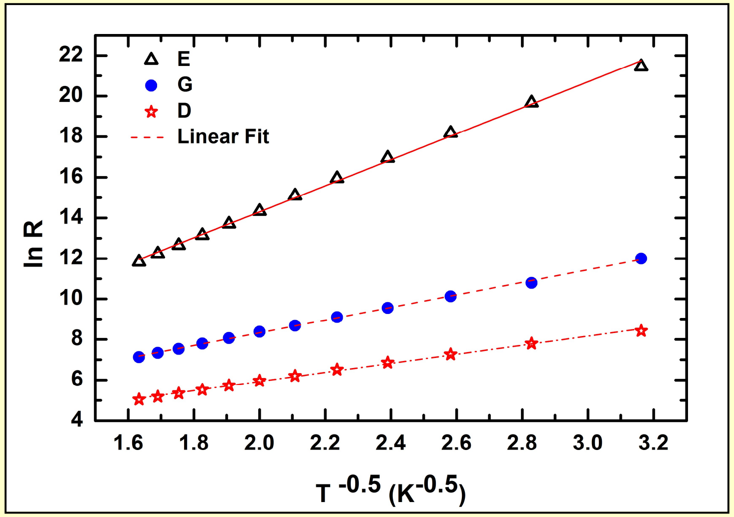
Resistance of the NTD Ge samples were measured in the temperature range 100 mK – 350 mK

For NTD Ge $R = R_0 \exp[\frac{T_0}{T}]^{\alpha}$

(E. Pasca *et al*., Proc. 8th Int. Conf. Adv. Tech. Part. Phys. **2** (2004) 93)

R_0 depends on intrinsic properties of Ge, T_0 depends on the doping level and constant α ~ 0.5 (A.L. Woodcraft *et al.,* J. Low Temp. Phys. **134** (2004) 925)



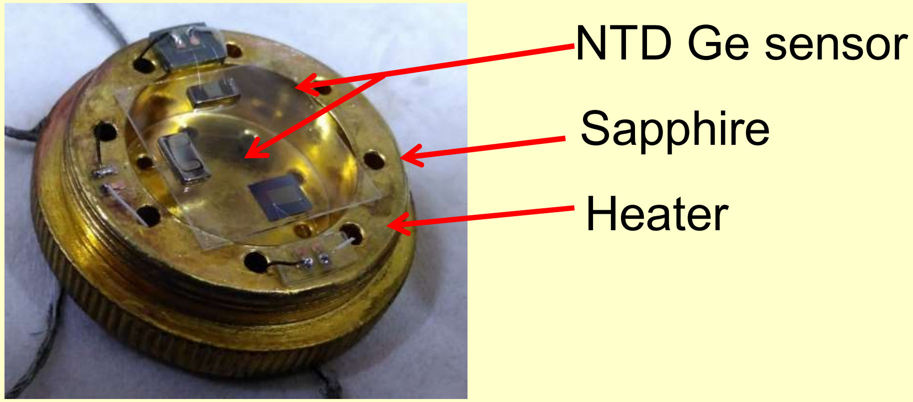


ln R varies linearly with $T^{--0.5}$

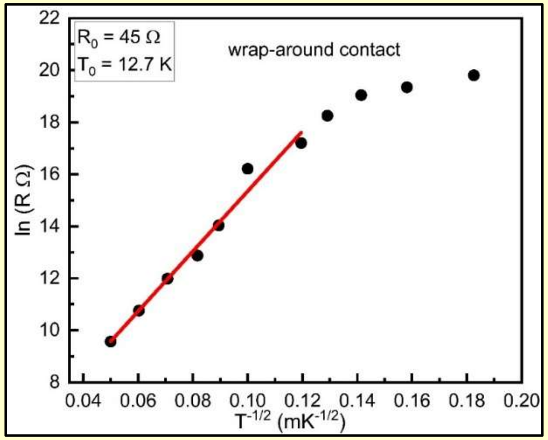
Mathi *et al*. 10.1109/WOLTE.2014.6881014

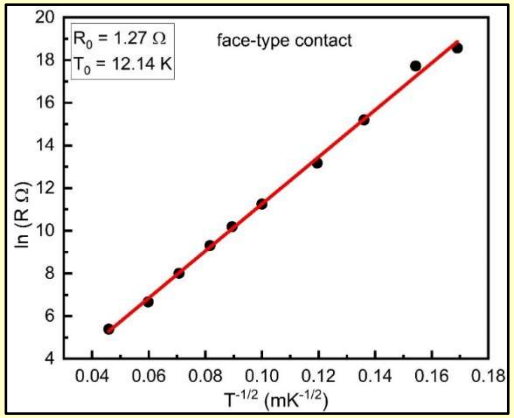
A. Garai *et al*. Journal of Low Temp. 10.1007/s10909-015-1379-6

Test with blank sapphire bolometer

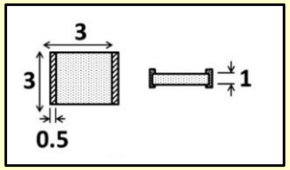


Detailed noise characterization, investigation of various noise sources, and its mitigation to improve the performance of a cryogenic bolometer detector have been studied

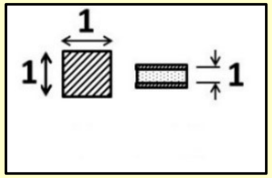




- Samples from wrap-around geometries show deviation below T = 50-70 mK
- Overall performance of the face-type contact is found to be better.



3x3 wrap-around contacts

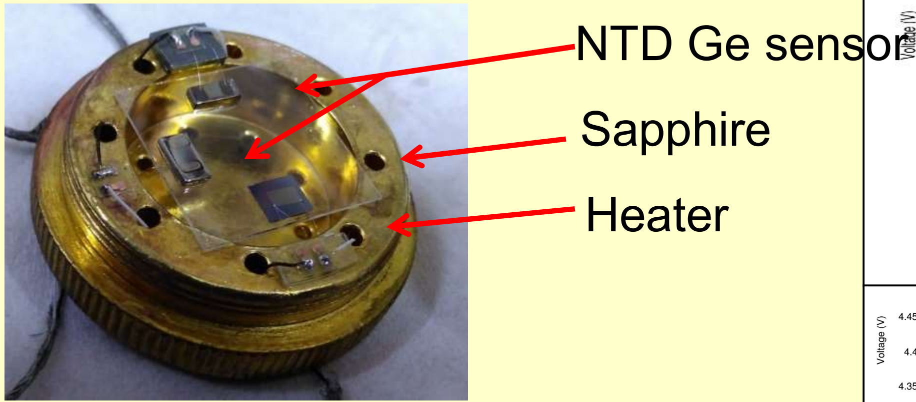


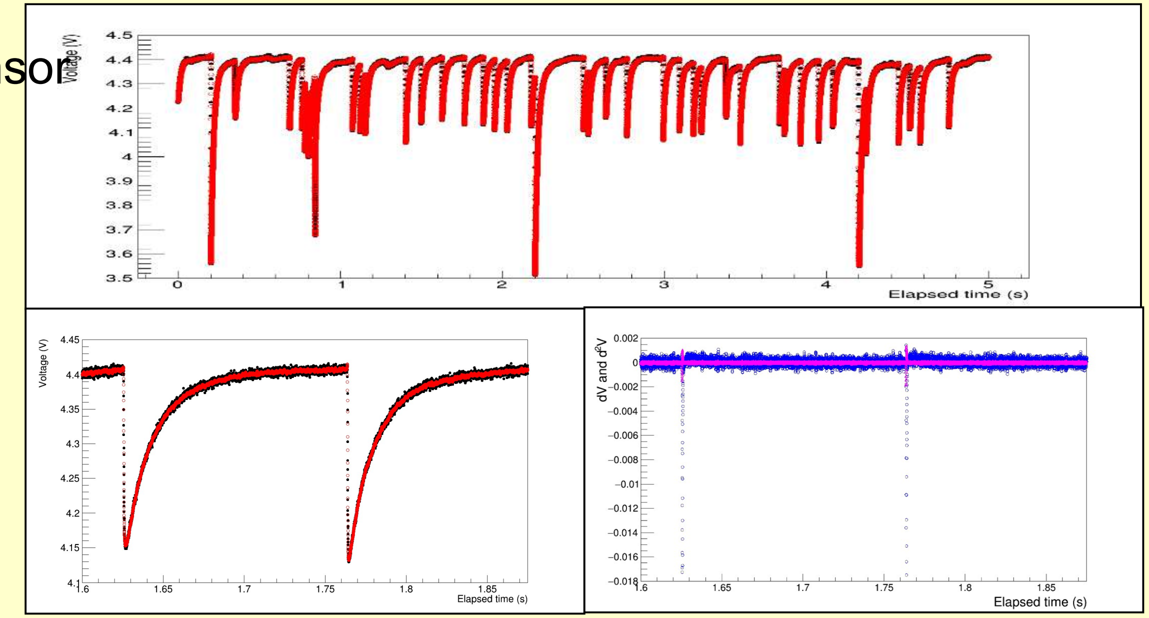
1x1 face-type contacts

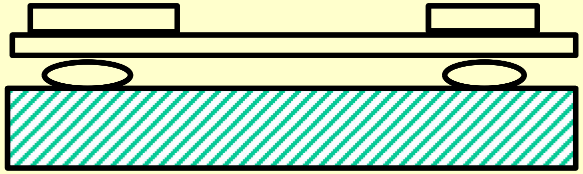
A. Garai,et al, J Low Temp Phys **199**, 95 (2020)

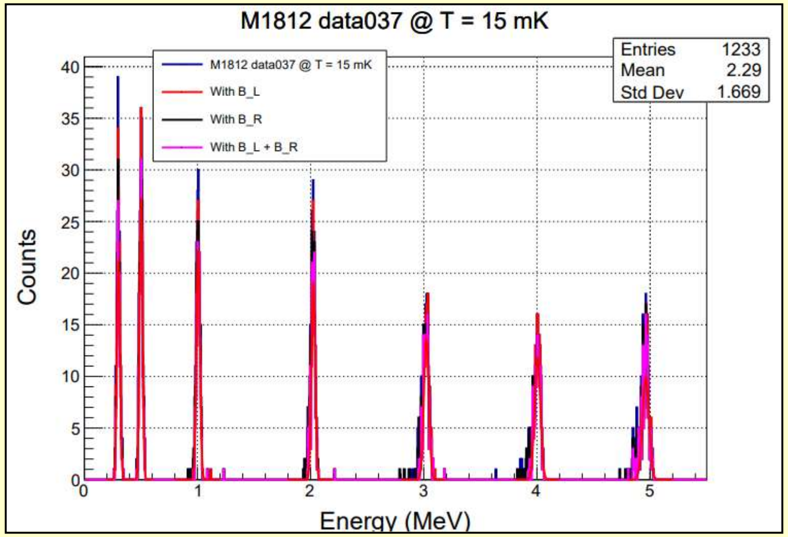
V. Vatsa et al. WOLTE-14, Matera, Italy, pp. 1 (2021)

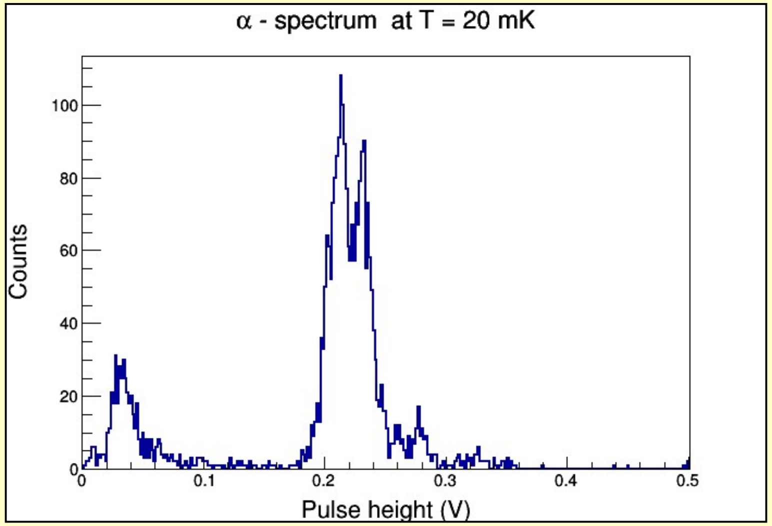
Test with blank sapphire with Sn









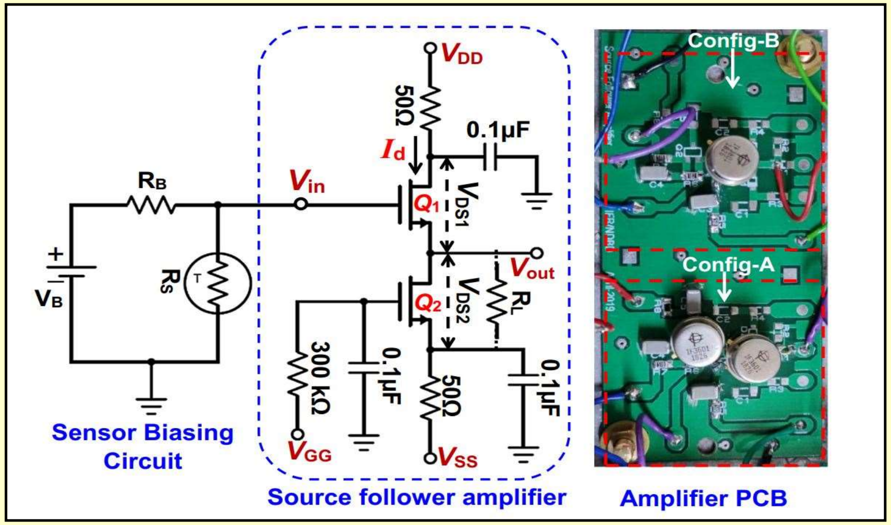


Low temperature electronics R&D

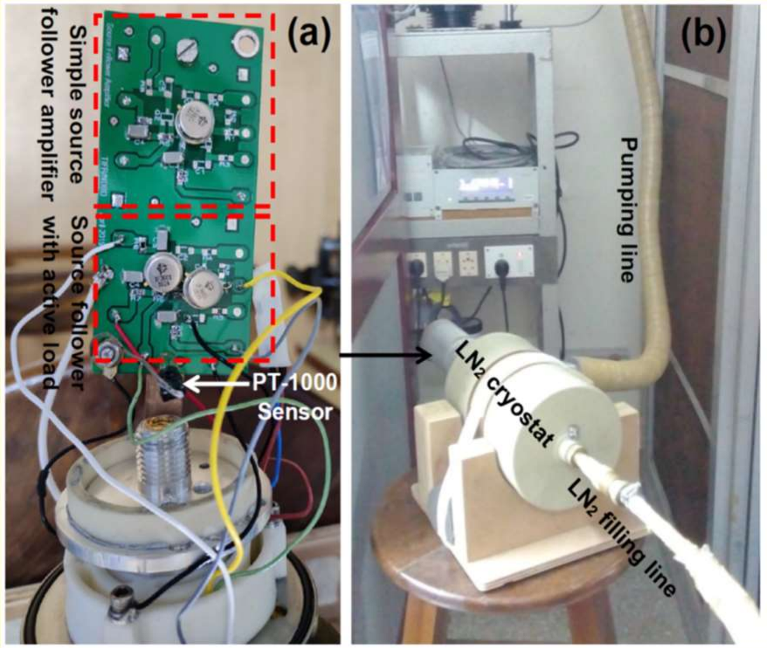
A cryogenic front-end pre-amplifier for bolometer

Ideally the performance of a bolometer detector is expected to be superior due to its good intrinsic resolution. However, electronic noise is the limiting factor.

Signal integration due to large cable capacitance, is prone to EMI noise due to longer length cables



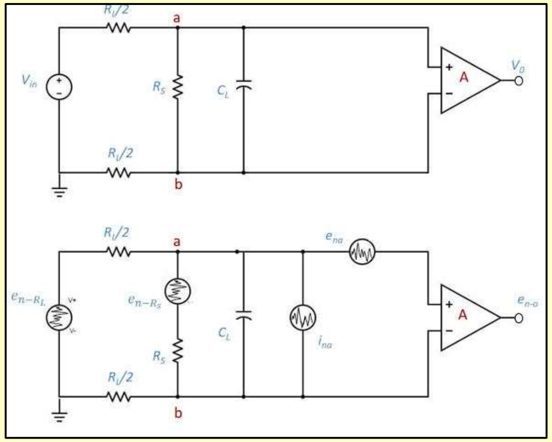
A. Reza, V. Vatsa et al., *J. Low Temp. Phys.*, 199, 200–205 (2020)



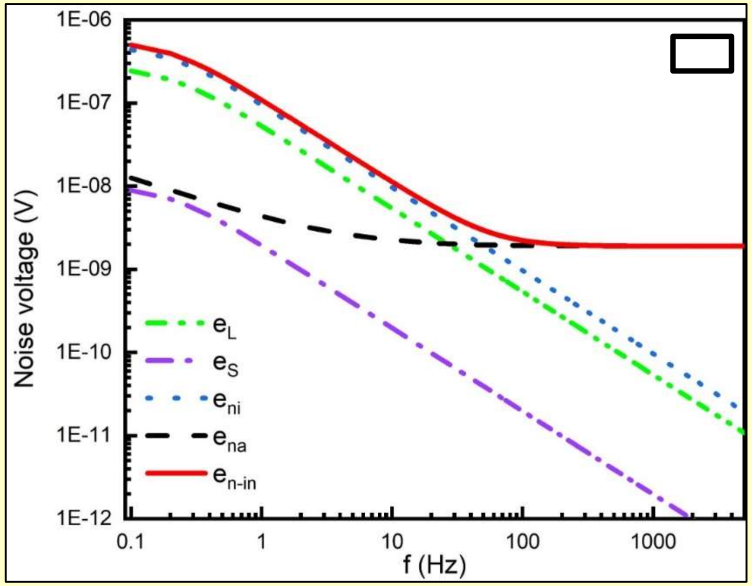
Si-FET at cryogenic temperature of ~120 K intermediate 1st stage amplifier : designed, fabricated, tested in a Ln2 cryostat and in CFDR@~150K

Analytical noise model for NTD sensor readout

To quantify the measured noise in a cryogenic bolometer readout circuit



R_B = 20 GΩ
T_S ~ 20 mK
R_S ~ 10MΩ – 1 GΩ
A = 60 dB



Noise contributions at amplifier input

$$|e_S| = \sqrt{4kT_S B R_S}\frac{1}{R_S}\frac{R_{eq}}{\sqrt{1+(\omega R_{eq}C_L)^2}}$$

sensor resistance

$$|e_L| = \sqrt{4kT_L B R_L}\frac{1}{R_L}\frac{R_{eq}}{\sqrt{1+(\omega R_{eq}C_L)^2}}$$

bias resistance

$$|e_{ni}| = i_{na}\sqrt{B}\frac{R_{eq}}{\sqrt{1+(\omega R_{eq}C_L)^2}}$$

i/p current noise density

$$|e_{na}| = \sqrt{(e_{white}^2 + e_{flicker}^2)B} = e_{white}\sqrt{\left[1+\left(\frac{f_c}{f}\right)^{n}\right]B}$$

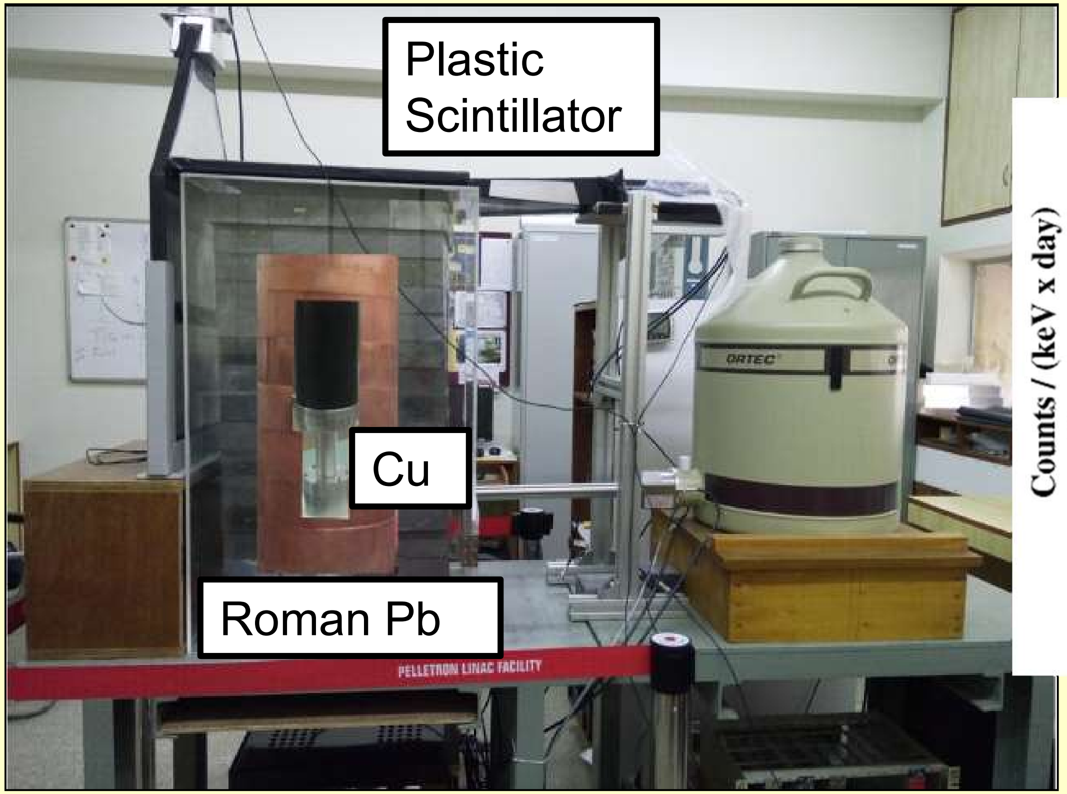
i/p voltage noise density

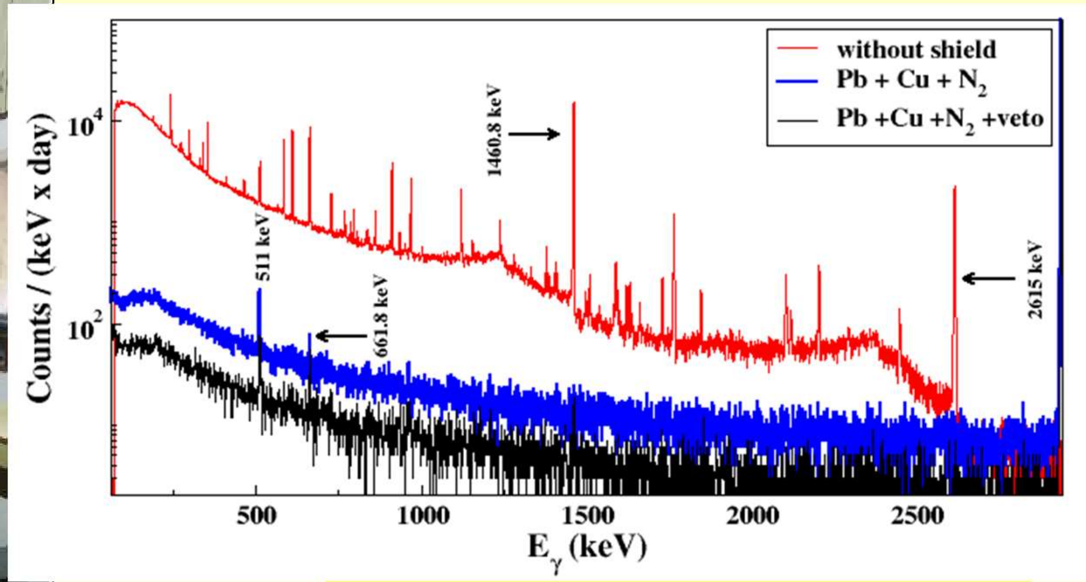
RMS noise at o/p,	$e_{n,o}(rms) = \sqrt{\int_{f_l}^{f_h} e_{n,o}^2\, df} = \sqrt{df \sum_{i=f_l}^{f_h} (e_{n,o})_i^2}$

- **desired range of R_S ~0.5 - 1 GΩ.**
- ***i_{na}* is the leading source of the low freq noise, for R_S ~ 350–1000 MΩ and T < 100 mK**

V. Vatsa et al., *JINST* 17 T11013 (2022)

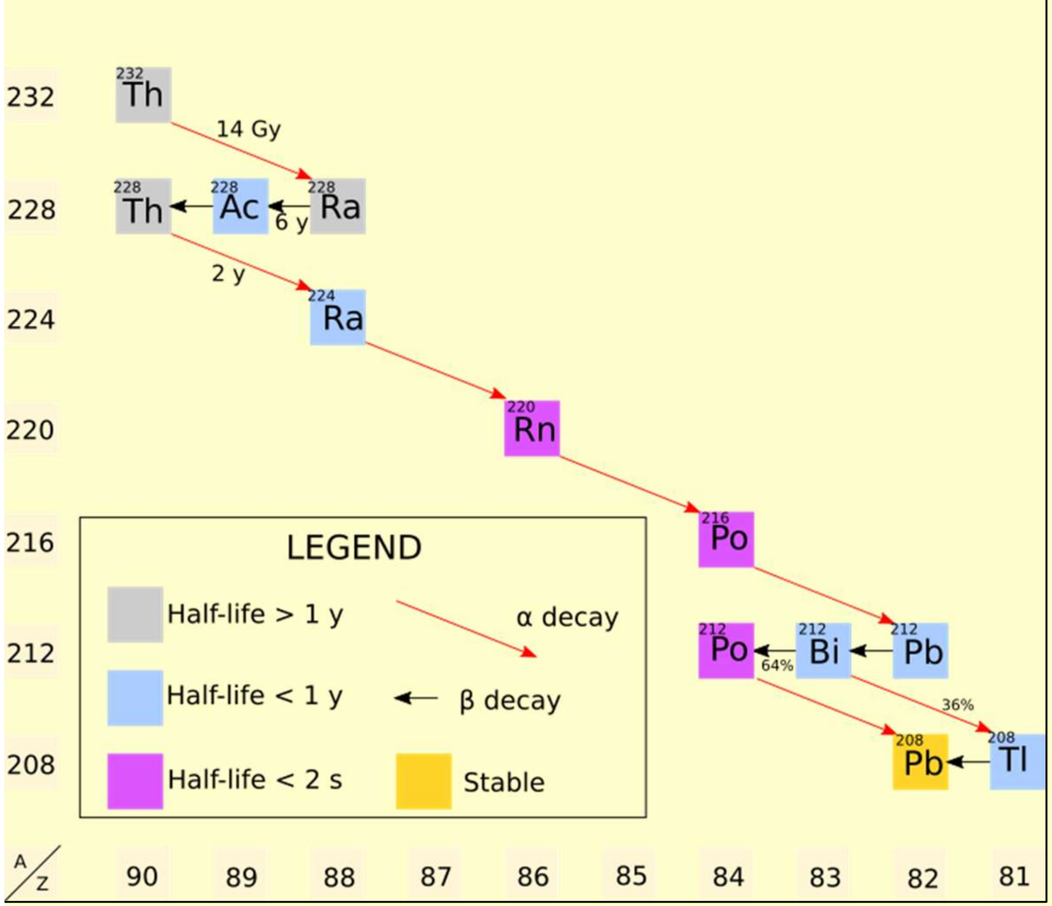
TiLES (Tifr Low background Experimental Setup)



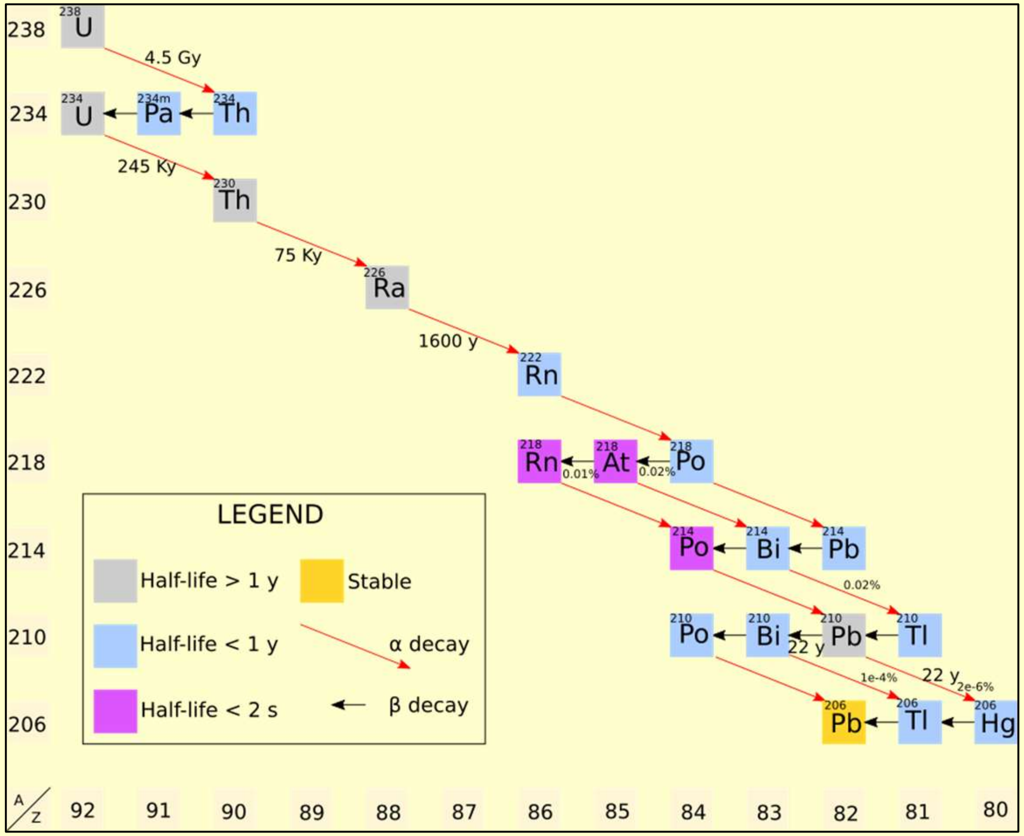


Sensitivity of the setup:
~1 mBq/g (~10 ppb)

- Detector surrounded by **OFHC Cu (5 cm), Pb (10 cm) (^{210}Pb < 0.3 Bq/kg)**.
- N_2 purging system and active muon veto (plastic scintillators)
- TiLES is used for material screening such as ETP Cu, INO site rock, CsI crystals for DINO, etc.



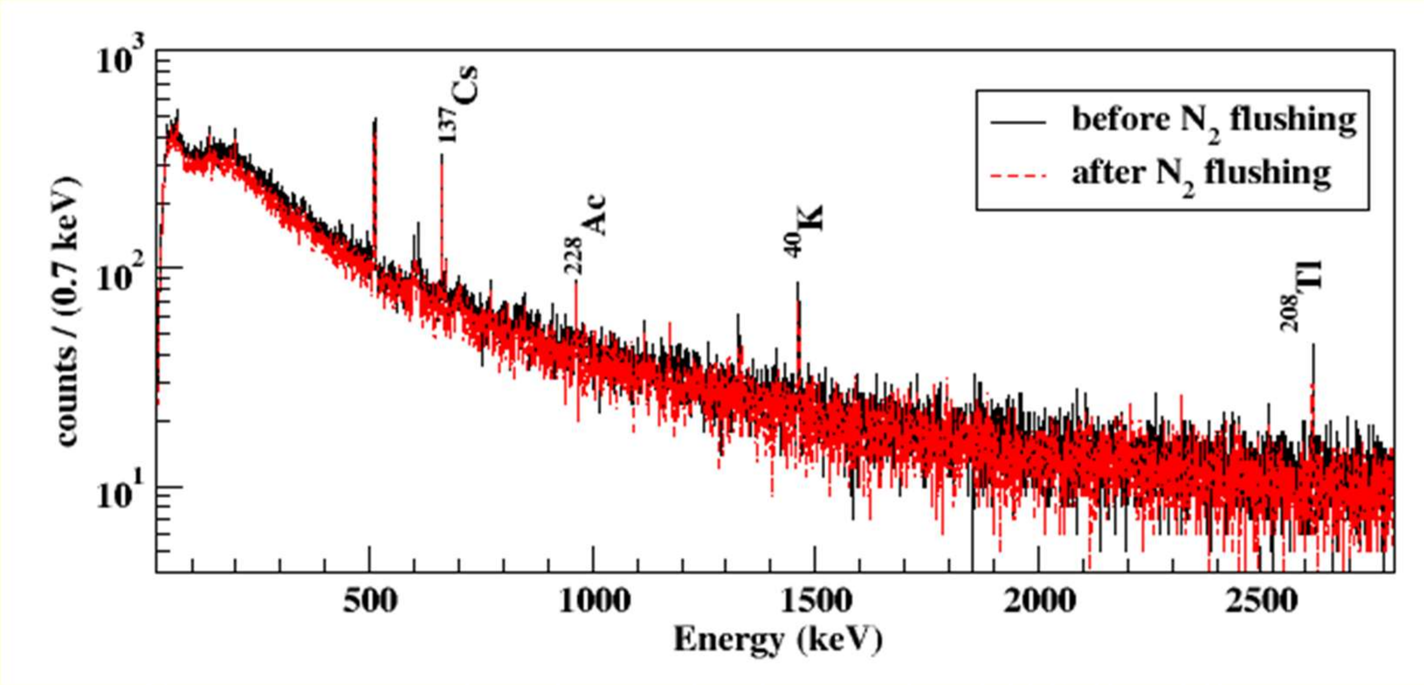
Element	Nat. Abundance (%) [111]
^{232}Th	100
^{235}U	0.7204
^{238}U	99.2742



Neha Dokania, thesis
A. Mazumdar, thesis

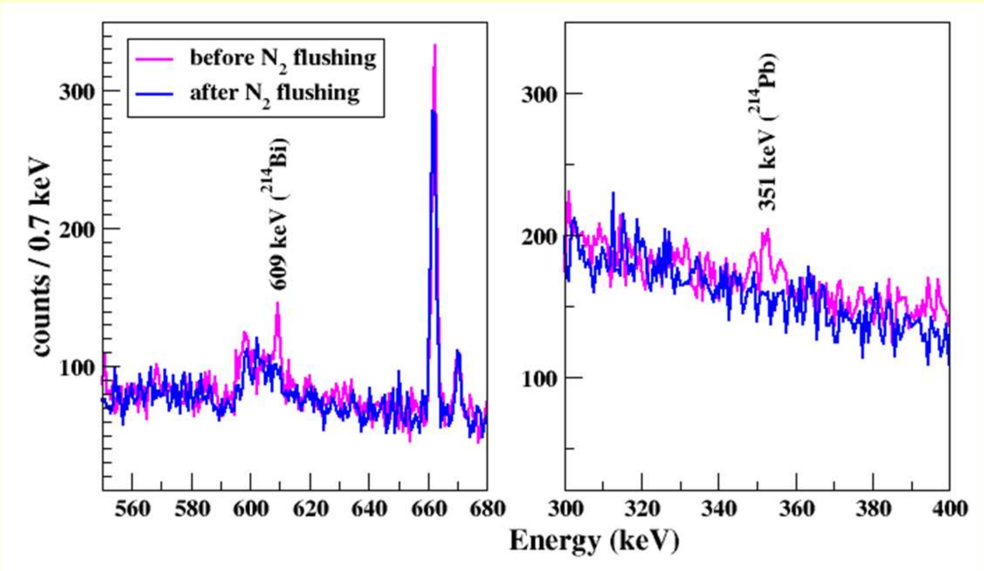
N_2 flushing in the TiLES

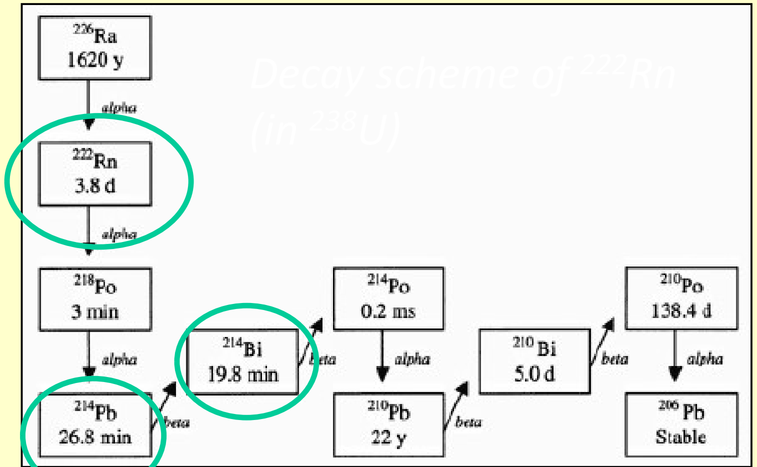
Radon produced in the natural decay chains of U and Th get trapped in the volume of the detector.



Gamma ray spectra of room background in TiLES (t = 7d)

Boil-off nitrogen from LN_2 cylinder at a pressure of ~8 mbar flowed in the volume around the detector setup kept inside a sealed Perspex box.

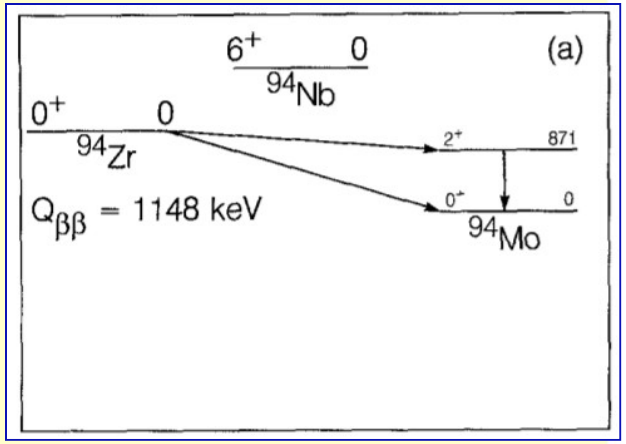


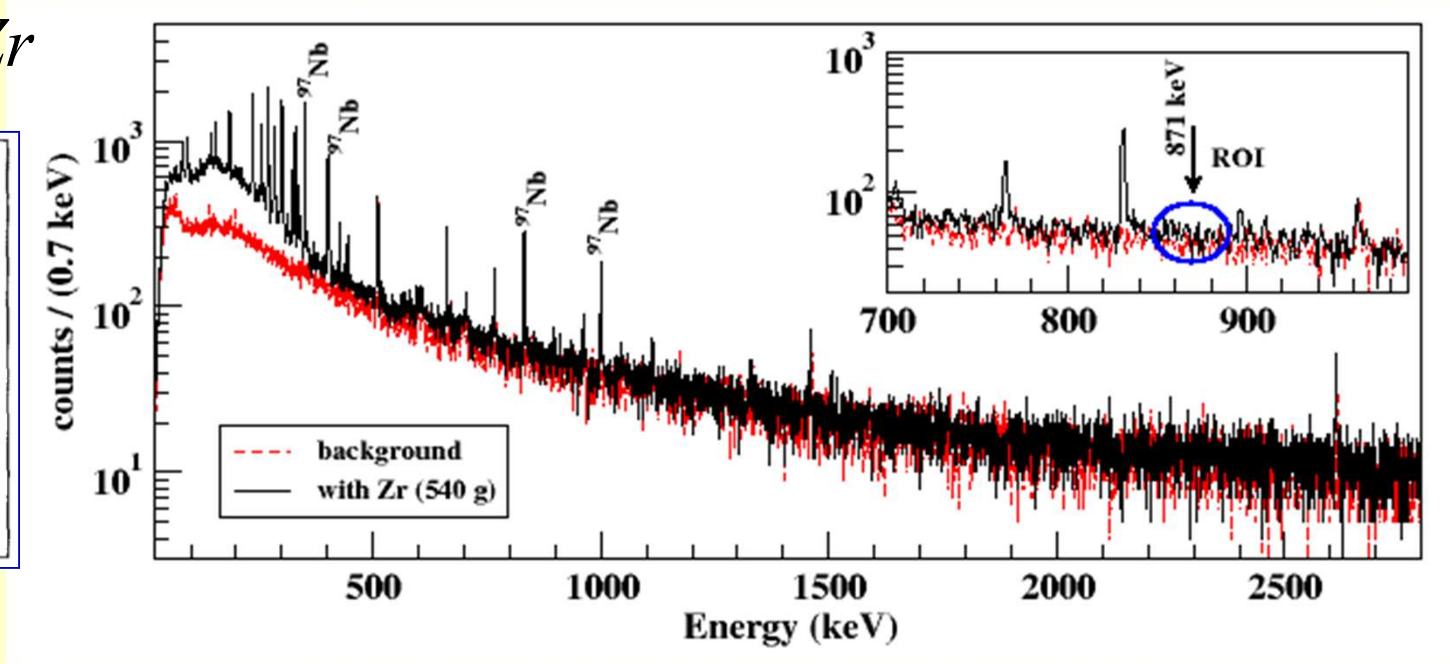


Decay scheme of ^{222}Rn (in ^{238}U)

DBD to excited state in ^{94}Zr

Decay Scheme of ^{94}Zr





Gamma ray spectra of ^{nat}Zr in TiLES for t = 7d

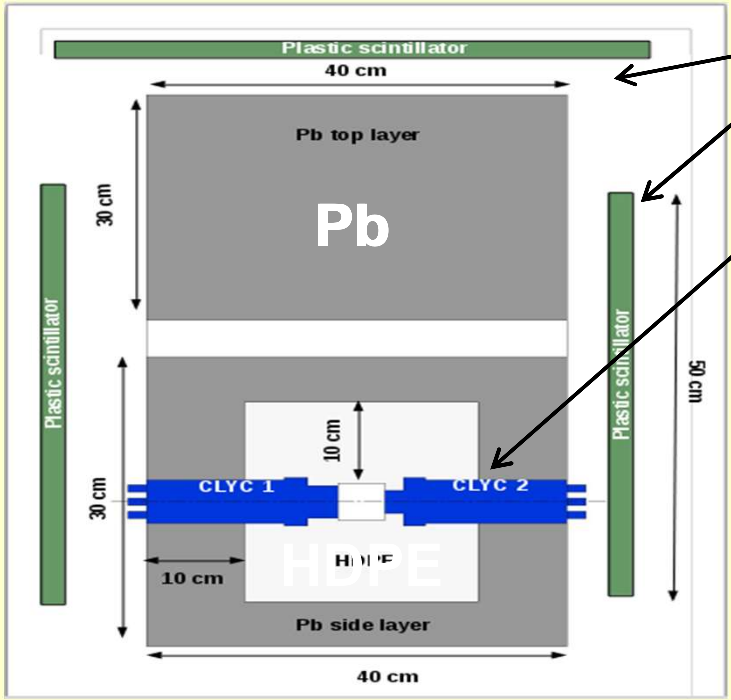
- The current best experimental limits are $\mathbf{T_{1/2} > 1.3 \times 10^{19}}$ **y** (68% C.L.) (***Norman et al., Phys. Lett. B 195*, 126 (1987)).**
- 540 g of ^{nat}Zr (99.5% purity) counted in the TiLES,

Double beta decay of ^{94}Zr to the 1st excited state in ^{94}Mo

$T_{1/2} > 2.0 \times 10^{20}$ y* 68% C.L, *6.12 x 10^{19} y at 90% C.L.

N. Dokania et al EPJ A **53** (2017) 74

MINT: Muon Induced Neutron detector setup at Tifr

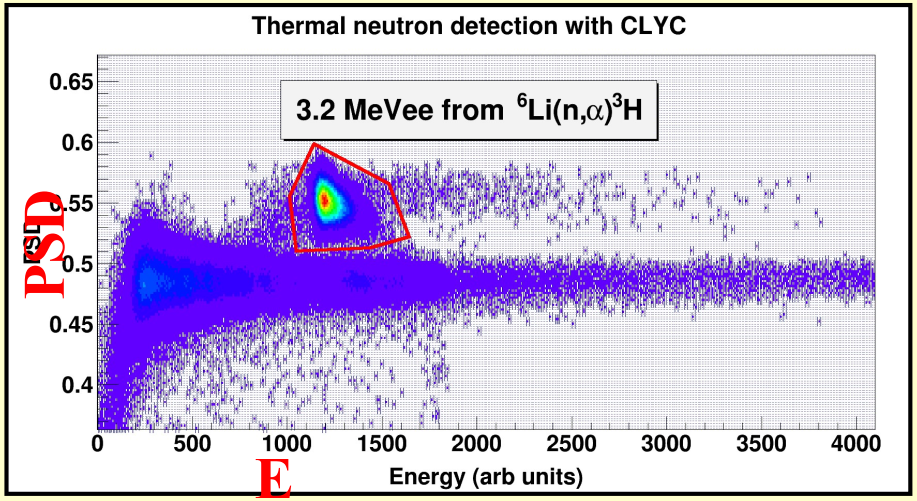


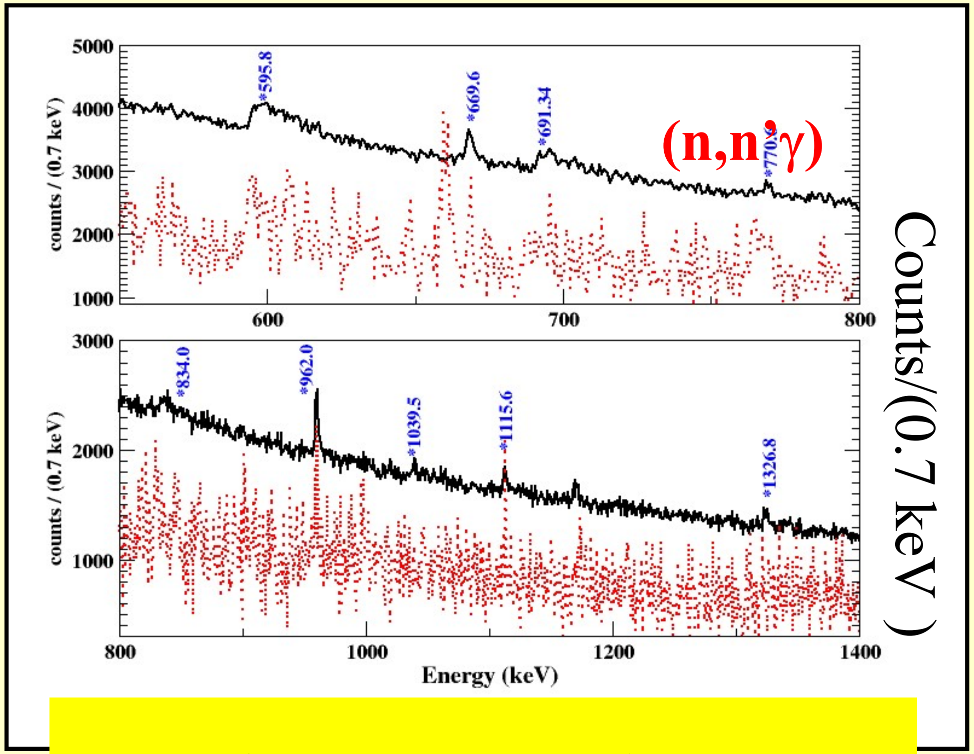
Muon detectors (plastic Scintillators)

Neutron detectors (CLYC)

provides crucial input for validation of GEANT4.10.05 simulation of both muon induced neutron production and neutron inelastic scattering.

Gamma spectrum gated by muons in TiLES





Harisree Krishnamoorthy, NUPHYS2018

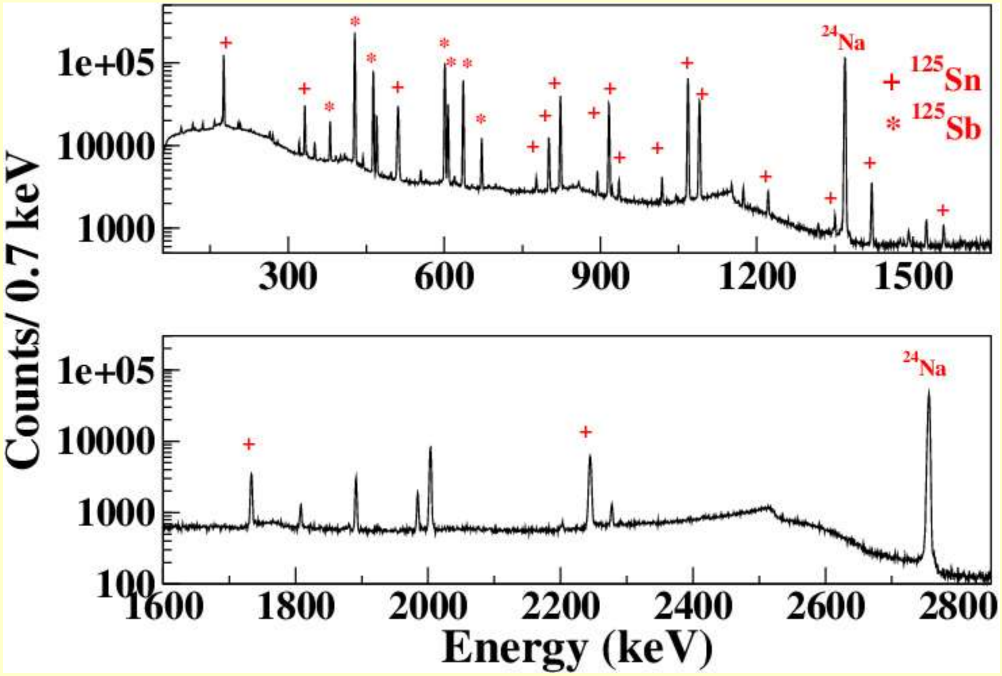
HK et al, EPJA ***55*** *(2019) 136*

n-induced background in ^{124}Sn

- $^{124}Sn\ (n, \gamma)\ ^{125}Sn$
- ^{125}Sn : β decay → ^{125}Sb,
  Q_β = 2357 keV
- $T_{1/2}$ = 9.52m, 9.64 days
- ^{125}Sb β-decay → ^{125}Te
  ($T_{1/2}$ =2.75 y, Q_β=766 keV)

- $^{124}Sn\ (n, \gamma)\ ^{125}Sn\ (n, \gamma)\ ^{126}Sn$
- ^{126}Sn β- decay → ^{126}Sb
  ($T_{1/2}$ = 2.3 X 10^5 years, Q_β = 378 keV)
- ^{126}Sb β-decay → ^{126}Te
  ($T_{1/2}$ =12.35 days, Q_β = 3673 keV)

($Q_{\beta\beta}$ of ^{124}Sn = 2293 keV)



- Simulation studies to estimate neutron flux at INO site based on rock composition carried out.

*N. Dokania et al., JINST, **10** (2015) T12005*

- n-induced reactions in Sn, Pb, Cu are being studied at PLF and Dhruva

*G. Gupta et al. ARI **158** (2020), 108923*

Nuclear Structure Aspect

- Several nuclear models to calculate the NTME
  - Shell-model and variants
  - QRPA and extensions
  - Alternative models
- The NTME ($M_{2\nu}$) is sensitive to details of the nuclear structure
  - Spectroscopic properties of the initial and final nucleus
  - Pairing and Deformation

Observed physical properties of nuclei: *Test of nuclear models*

Uncertainty in estimated neutrino mass upto a factor of 10 due to uncertainty in NTMEs.

Experiments to constrain NTME are essential

Occupational Probabilities of valence orbitals relevant to NDBD of 124Sn

Measurement of transfer cross-sections (d,p) (p,d), (^{4}He,^{3}He), (^{3}He,^{4}He) in ^{124}Sn & ^{124}Te

A. Shrivastava et al. Phys Rev C105, 014605 (2022)

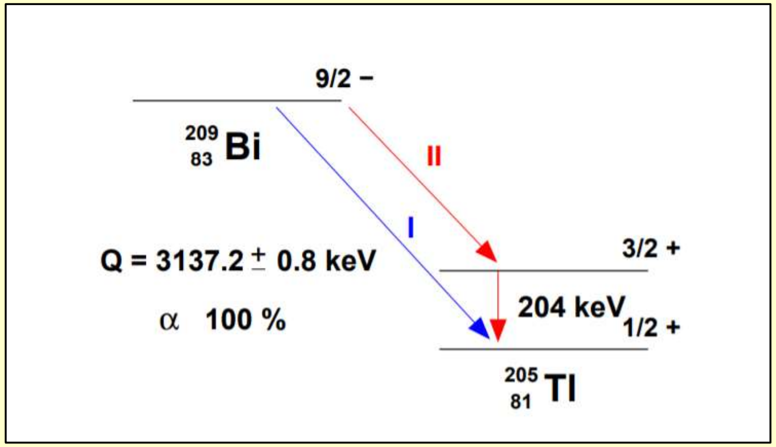
Nuclear matrix elements calculation for $0\nu\beta\beta$ decay of ^{124}Sn using nonclosure approach in nuclear shell model, Shahariar Sarkar et al. Phys Rev C **109**, 024301 (2024)

Sn-Bi alloy for stability

Studies on β <-> α transition in Sn and Sn-rich alloys for a cryogenic tin bolometer (to suppress the Tin pest problem)

- 0.22 % Sn-Bi is suggested as a good candidate for the fabrication of Sn-Bi bolometers
- Baking the TIN.TIN detector for a few minutes at 323 K would reduce the risk of tin pest.

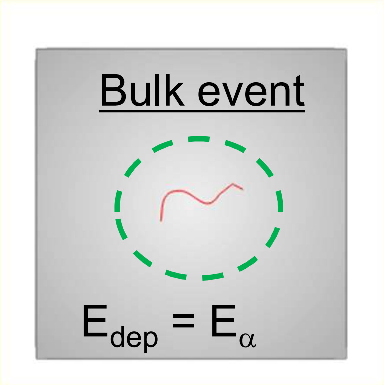
A. Mazumdar, et al. Scripta Materialia **199** (2021), 113858
& Materials Research Express **6** (2019) 076521

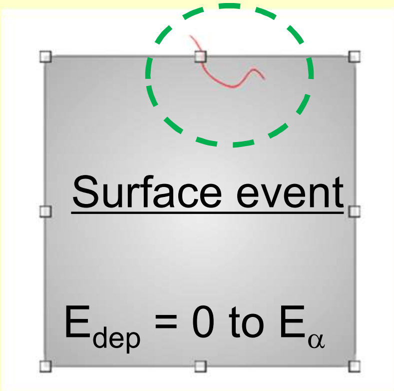


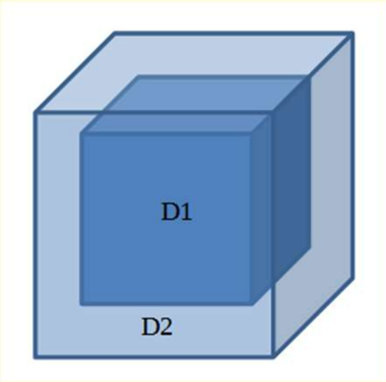
J.W. Beeman et. al., Phys. Rev. Lett. ***108****, 062501*

Estimation of radiation background for Sn-Bi bolometers

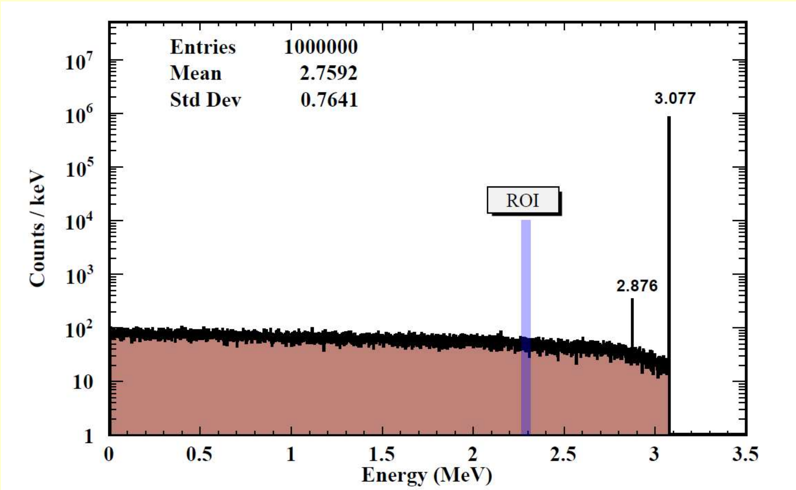
The background is usually limited by backgrounds originating from sources which are internal to the bolometer.







Range of 3 MeV α in Sn: 8 μm; Hence, width D2: 10 μm



A. Mazumdar, thesis

- Surface events can increase the background in ROI (2291 $\pm$ 25 keV) since they can lead to partially contained events.
- Sn-Bi of various concentrations – 0.25%, 0.50%, 0.75% and 1.00% Sn-Bi (Bi by mass %).
- The size of the bolometer was varied – 27 cc, 64 cc and 125 cc.

Estimation of radiation background for Sn-Bi bolometers

- GEANT4 based simulations of two sources – $^{209}\boldsymbol{Bi}\ \boldsymbol{\alpha}\ \boldsymbol{decay}$ and $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ background from $^{238}\boldsymbol{U}\ \boldsymbol{and}\ ^{232}\boldsymbol{Th\ chain}$ (radioimpurities in the Sn-Bi alloy)
- The radioactivity from $^{209}\boldsymbol{Bi}\ \boldsymbol{\alpha}\ \boldsymbol{decay}$ was found to be negligible as compared to the background from $^{238}\boldsymbol{U}$, which dominated by 2 orders of magnitude.
- The total background was within 10^{-2} cts/(keV.kg.y), which is the typical background index for the first generation expt.
- The efficiency of the Sn-Bi bolometers for NDBD was estimated using a GEANT4 based event simulator and detector simulation code.

0.25 % Bi

Volume	Bkg (cts/(keV.kg.y)
27 cc	2.6×10^{-5}
64 cc	2.0×10^{-5}
125 cc	1.6×10^{-5}

125 cc

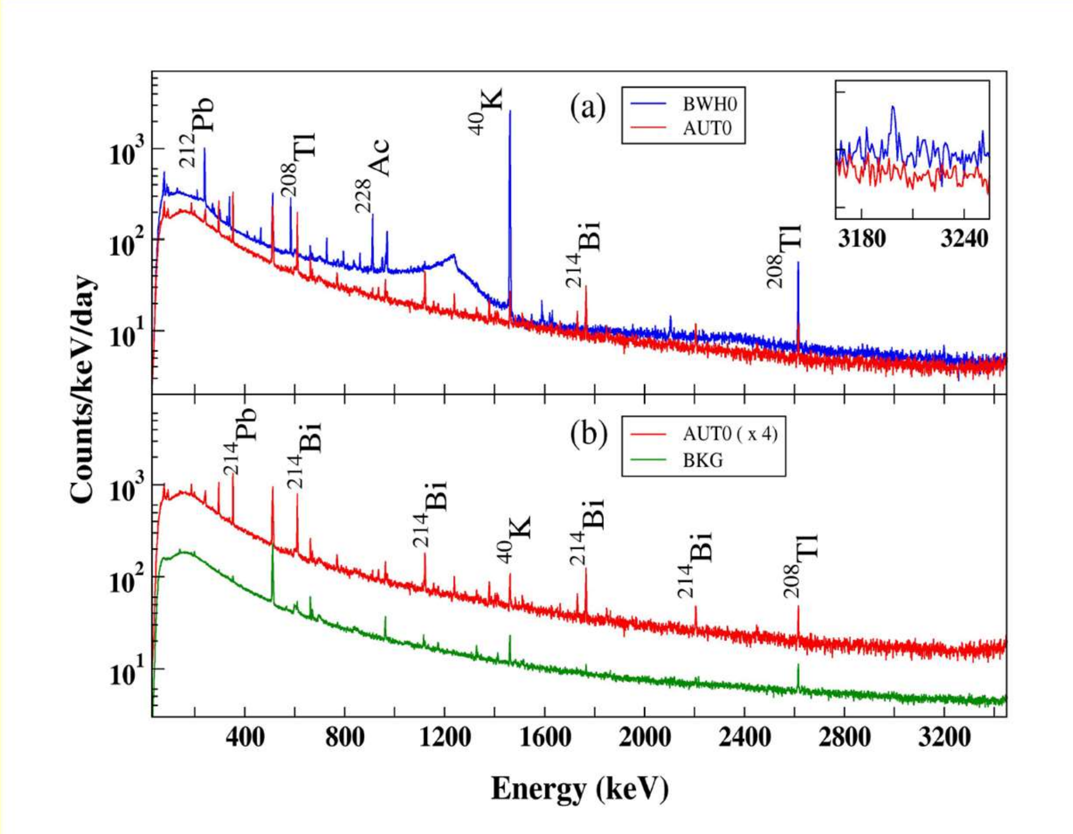
Impurity level	Source	Bkg (cts/(keV.kg.y))
0.2 ppt	Th chain	3.1×10^{-5}
0.2 ppt	U chain	5.8×10^{-3}
0.25%	^{209}Bi	1.6×10^{-5}
Total		5.8×10^{-3}

A. Mazumdar, thesis

Radiation background studies relevant to rare decays

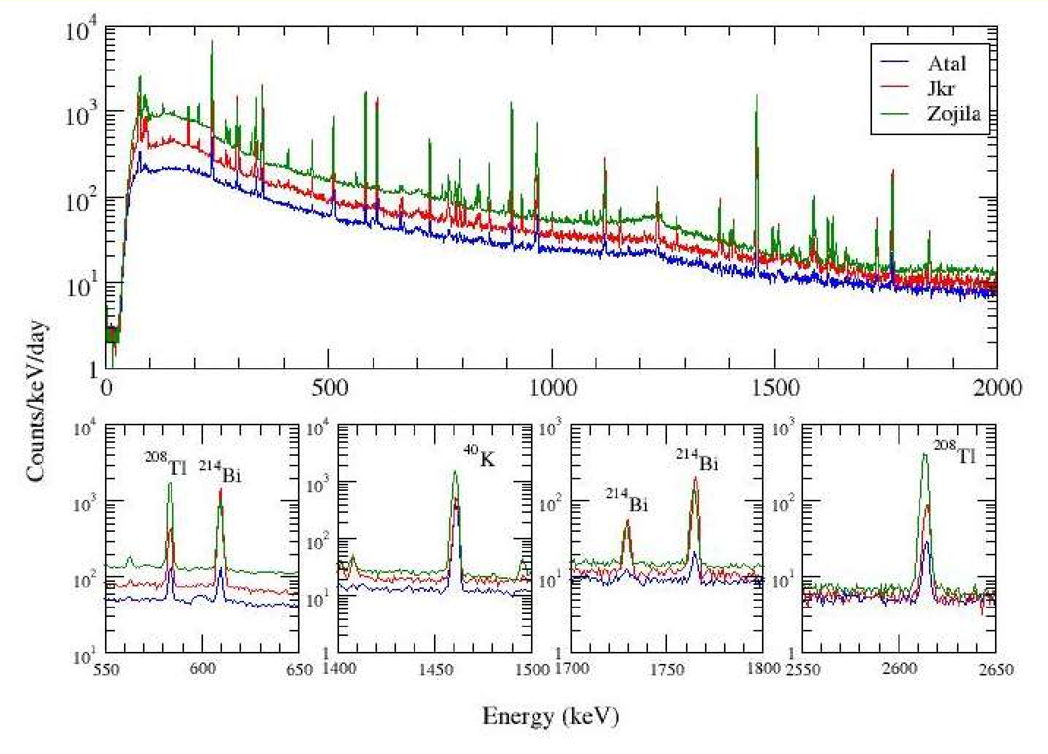
- Aut rock studies (radiopurity and neutron activation) are carried out
- low backgruond counting setup used for qualifying/screening materials :CsI crystals grown at BARC for DINO, Vizag, jadguguda, Jhakri, Atal , Zojila rock samples
- D_2O radiopurity measurements for DLS

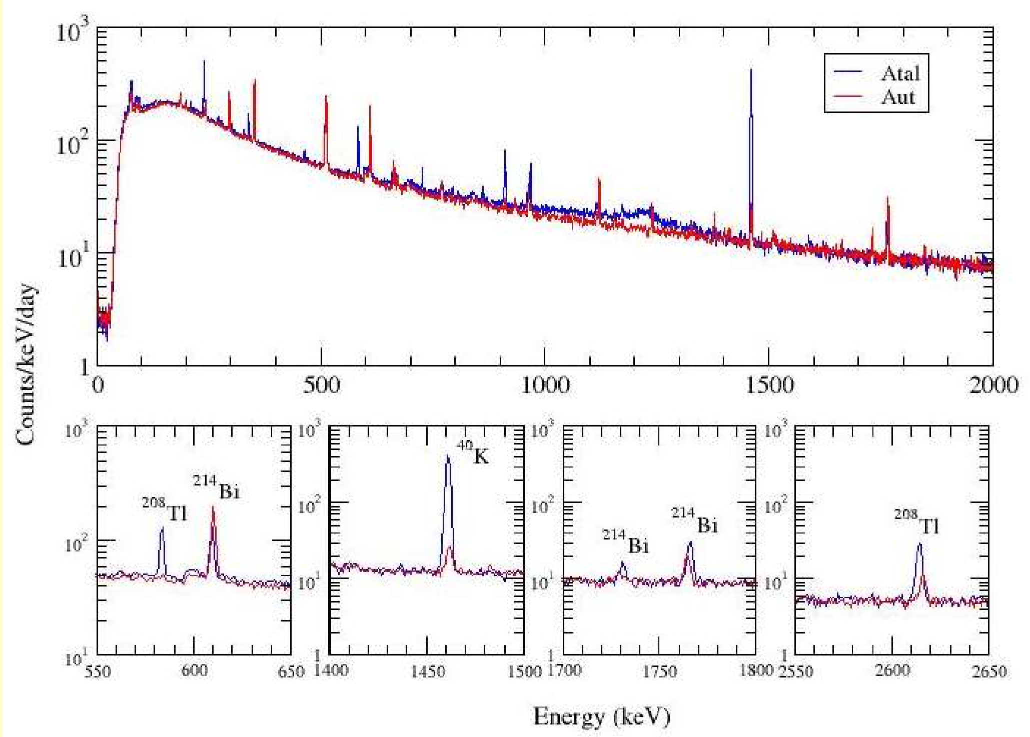
Radionuclide	AUTB	BWH
^{232}Th	12 ± 1 ppb	338 ± 14 ppb
^{238}U	60 ± 2 ppb	9 ± 1 ppb
^{40}K	<2 ppb	2179 ± 139 ppb



S. Thakur et al. , Nucl. Inst. Meth. A 1038 (2022) 166892

Rock sample studies





Sample Name	Mass (g)	Density (g/cc)	Counting time (d)
AUT	27.50	2.93	23.4
Jhakri	10.77	2.12	8.6
Atal	6.89	2.96	28.9
Zojila	130.02	2.75	19.77

Preliminary results

Rock sample	Concentration(ppb)		
	232Th	238U	40K
AUT	*12*	*60*	*<2*
Atal	*580*	*115*	*1304*
Jhakri	*1924*	*1597*	*1334*
Zojila	*1106*	*140*	*491*
BWH	*338*	*9*	*2179*

...Next Step..

- Measurements with ^{nat}Sn bolometer
- Rare decay studies using low BKG setup (DBD to excited state in ^{94}Zr, beta decay in ^{96}Zr).
- NTD Ge Sensor development (contd..)
- $2\nu\beta\beta$ measurements in ^{124}Sn

...Future Goal..

Build a large scale detector (~ 1 ton)

(in a phased manner : 100 Kg, 500 Kg, 1000 Kg)

$Fn = G^{0\nu} |M^{0\nu}|^2 = 8.569 \times 10^{-13}\ yr^{-1}$ *(PHFB)*

$= 1.382 \times 10^{-13}\ yr^{-1}$ *(SM)*

With 90 % enrichment, background ~ 0.01 counts/ keV.kg.yr

m_ν~100 meV in 1 yr (SM) , m_ν~50 meV in 1 yr (PHFB)

Tin.Tin Collaboration

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Tin.Tin Collaboration

INO collaboration

Pelletron Linac Facility

& colleagues from TIFR-BARC

http://www.tifr.res.in/~tin.tin/