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A study of neutron pairing correlations using ^{138,136}Ba(p,t) reactions

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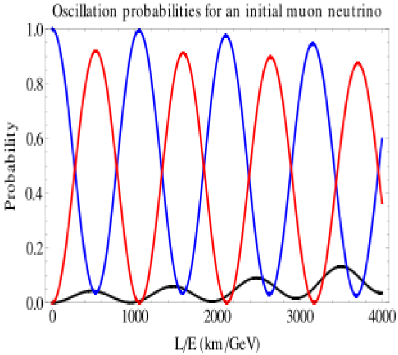
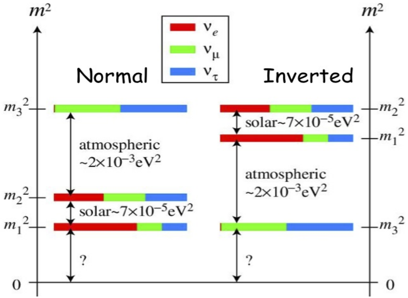
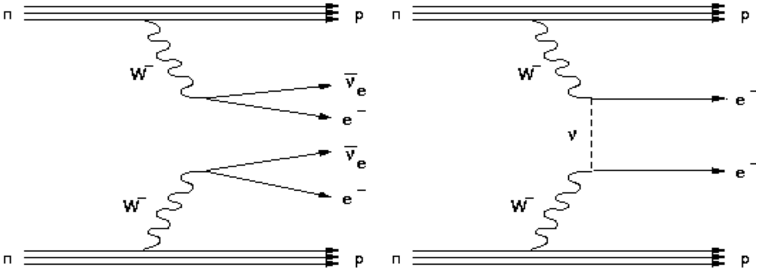
Neutrino Physics and Motivations





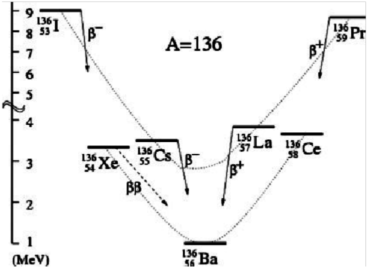
$0\nu\beta\beta$ & $2\nu\beta\beta$ decays

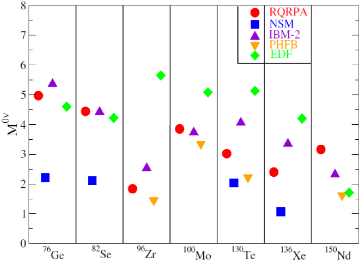
What is the nature of neutrinos?



$0\nu\beta\beta$ decay only possible if the neutrino is the same as the antineutrino

$0\nu\beta\beta$ NMEs





$$\left[T^{0\nu}_{1/2}\right]^{-1} = G^{0\nu}(Q,z)|M^{0\nu}|^2\left(\frac{\langle m_{\beta\beta}\rangle}{m_e}\right)^2$$

Where, $M^{0\nu}$ is the nuclear matrix element for the decay, $G^{0\nu}$(Q,z) is the phase-space factor, $m_{\beta\beta}$ is the effective Majorana neutrino mass and m_e is the electron mass.

^{136}Xe $\longrightarrow$ ^{136}Ba $0\nu\beta\beta$ features

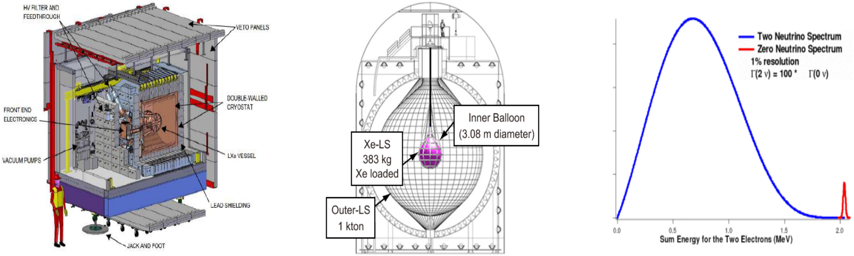
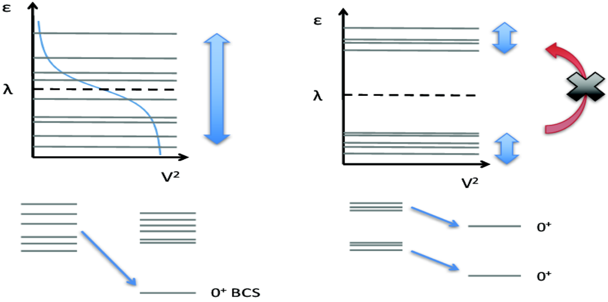


Figure : Schematic of EXO-200 (left), KamLAND-Zen (middle)

1. ^{136}Xe is relatively abundant, affordable and easy to purify.
2. One can attain maximal background rejection via Barium ion-tagging.
3. Most importantly, $2\nu2\beta$ decay background is highly suppresed.

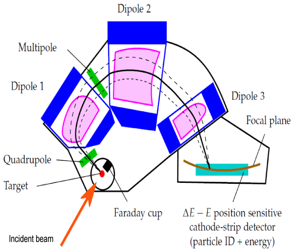
Pairing and BCS approximation

1. Many of the NME calculations use the BCS approximation to describe ground state of even-even parent and daughter nuclei. If BCS approximation were true we would see strong population of ground states in (p, t), (t, p), $(^3\mathrm{He}, n)$ two nucleon transfer reactions.
2. Large shell gap or differences in deformation between the parent and daughter nuclei will indicate a breakdown in BCS approximation.

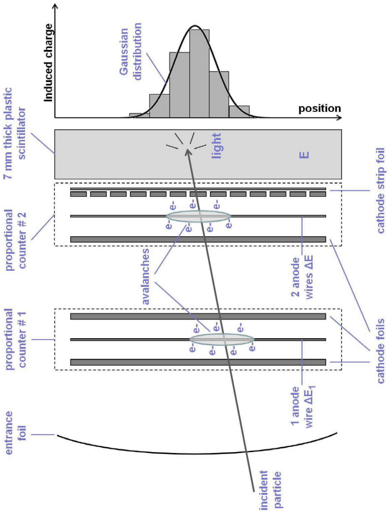


Experimental setup

1. Facility : High resolution Q3D Magnetic Spectrograph at Maier-Leibnitz Laboratorium (MLL), Garching (Germany)
2. Reaction : ^{136}Ba(p,t)^{134}Ba, ^{138}Ba(p,t)^{136}Ba.
3. Targets : 40 $\mu g/cm^2$ ^{136,138}BaO on 30 $\mu g/cm^2$ of ^{12}C backing

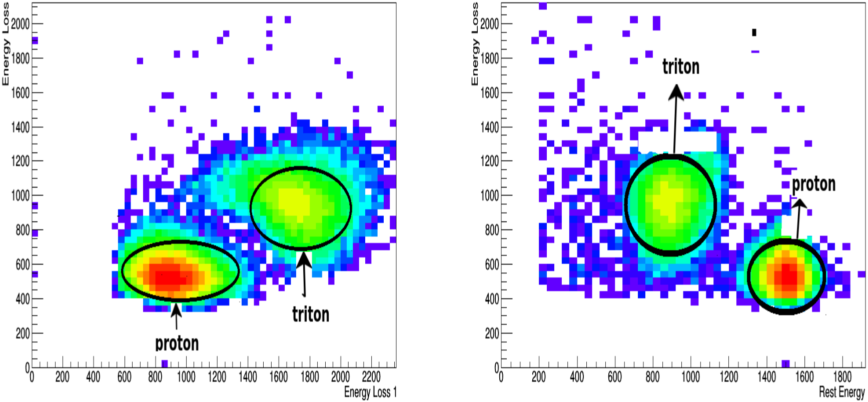


Focal plane detector



1. three components: two proportional counters, one plastic scintillator
2. particle identification: ΔE_1-ΔE and ΔE-E
3. position measurement: cathode-strip foil.
4. strip multiciplity: three to five for valid event.

Particle identification



DWBA Analysis for the cross section angular distributions

We collected data at different Q3D angles, varying from 5°-50° with increment of 5 in order to get cross section angular distribution and identify 0^+ states in ^{136}Ba and ^{134}Ba.

1. Natural parity states are preferably selected in (p,t) reactions, $J = L$, $\pi =$ (-1)^L.
2. L transfer obtained by comparing experimental cross-sections with Distorted-Wave Born approximation (DWBA) predictions.
3. DWBA done using DWUCK4 code. DWUCK4 calculates cross-section amplitudes using the Optical Model Potential (OMP).
4. R. L. Varner OMP for proton, and X. Li, C. Liang & C.Cai OMP for triton have been used for the present calculations.

(p, t) angular distribution

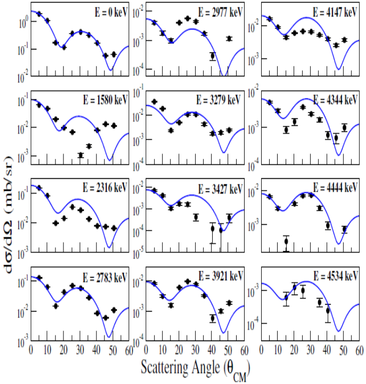


Figure : 12 0^+ states have been identified in ^{136}Ba. 8 new 0^+ states were observed.

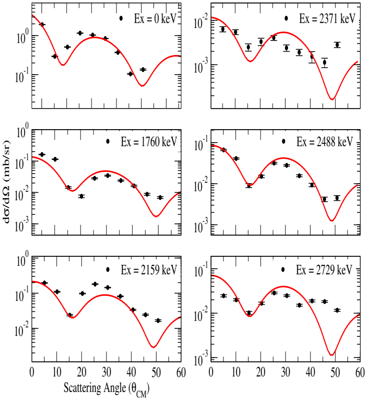


Figure : 6 0^+ states have been identified in ^{134}Ba. We resolved the ambiguity for spin/parity of 2 of these states.

$L = 0$ strength calculations of 0^+ states in ^{134}Ba from the ^{136}Ba(p,t) reaction.

$$\left(\frac{d\sigma}{d\Omega}\right)_{rel} = \left(\frac{\left(\frac{d\sigma}{d\Omega}\right)^{lab}_{0^+_{ex}}}{\left(\frac{d\sigma}{d\Omega}\right)^{dwba}_{0^+_{ex}}}\right)\left(\frac{\left(\frac{d\sigma}{d\Omega}\right)^{lab}_{0^+_{gs}}}{\left(\frac{d\sigma}{d\Omega}\right)^{dwba}_{0^+_{gs}}}\right)^{-1}$$

Ex (keV)	σ (mb/sr)	ϵ (θ_{CM} ~5°)
0	3.038(23)	100
1760.3(2)	0.161(3)	10.72(25)
2159.64(9)	0.196(4)	16.76(35)
2371.5(4)	0.0063(9)	0.63(8)
2488.4(3)	0.066(2)	7.16(27)
2729.0(3)	0.024(1)	3.23(18)
Σ		38.5(1)

Table : Relative strength calculations of all the 0^+ states excited in ^{134}Ba.

Our ^{136}Ba(p,t) results disagree with the results reported in [Phys. Rev. C**81**, 014304 (2010)]

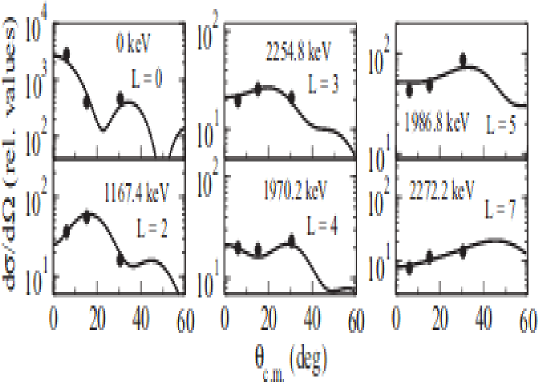


Figure : Experimental angular distributions and DWBA calculations for $L = 0$, 2, 3, 4, 5 and 7 in the ^{136}Ba$(p,t)^{134}$Ba reaction at 25 MeV.

$L = 0$ strength calculations of 0^+ states in ^{136}Ba from the ^{138}Ba(p, t) reaction.

Ex (keV)	σ (mb/sr)	ϵ (θ_{CM} ~5°)
0.0	1.90()	100
1579.7(6)	0.063(1)	4.42(8)
2315.5(6)	0.149(2)	16.0(2)
2783.4(7)	0.130(1)	17.5(2)
2977.1(7)	0.0040(3)	0.61(5)
3278.6(7)	0.0355(8)	6.4(1)
3426.7(8)	0.0072(4)	1.44(9)
3921(1)	0.0084(4)	2.5(1)
4147(1)	0.0160(7)	5.8(3)
4344(1)	0.0048(3)	2.1(1)
4444(1)	0.0066(4)	3.2(2)
4534(2)		
Σ		59.(5)

Summary and Conclusion

1. The results showed significant strength to excited states relative to the ground state in ^{136}Ba and ^{134}Ba.
2. This is an implication of breakdown in neutron BCS approximation in these nuclei.

THANK YOU FOR YOUR ATTENTION