EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Precise measurements of the β-decays of ^{9}Li and ^{8}He for reactor neutrino experiments

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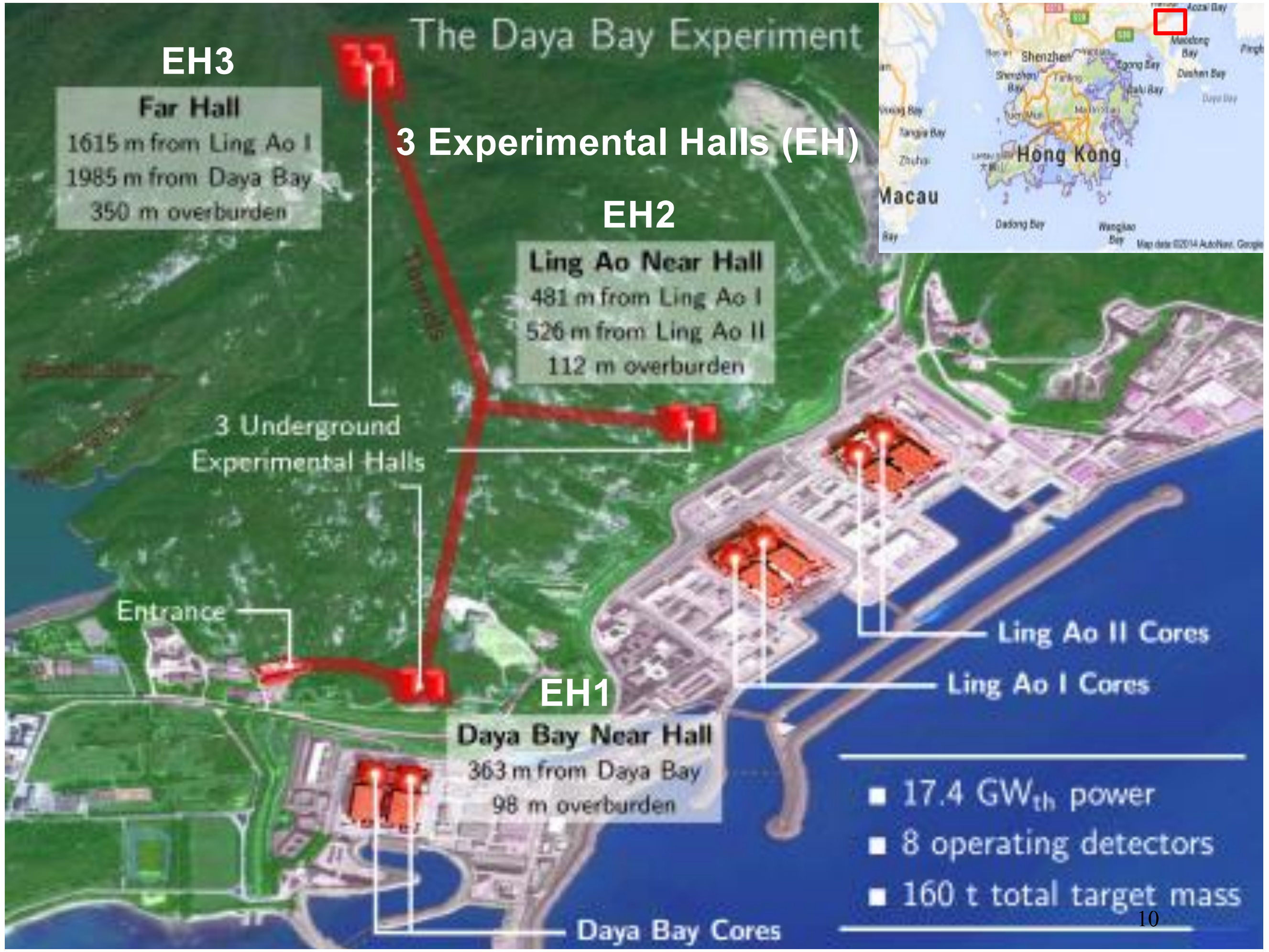
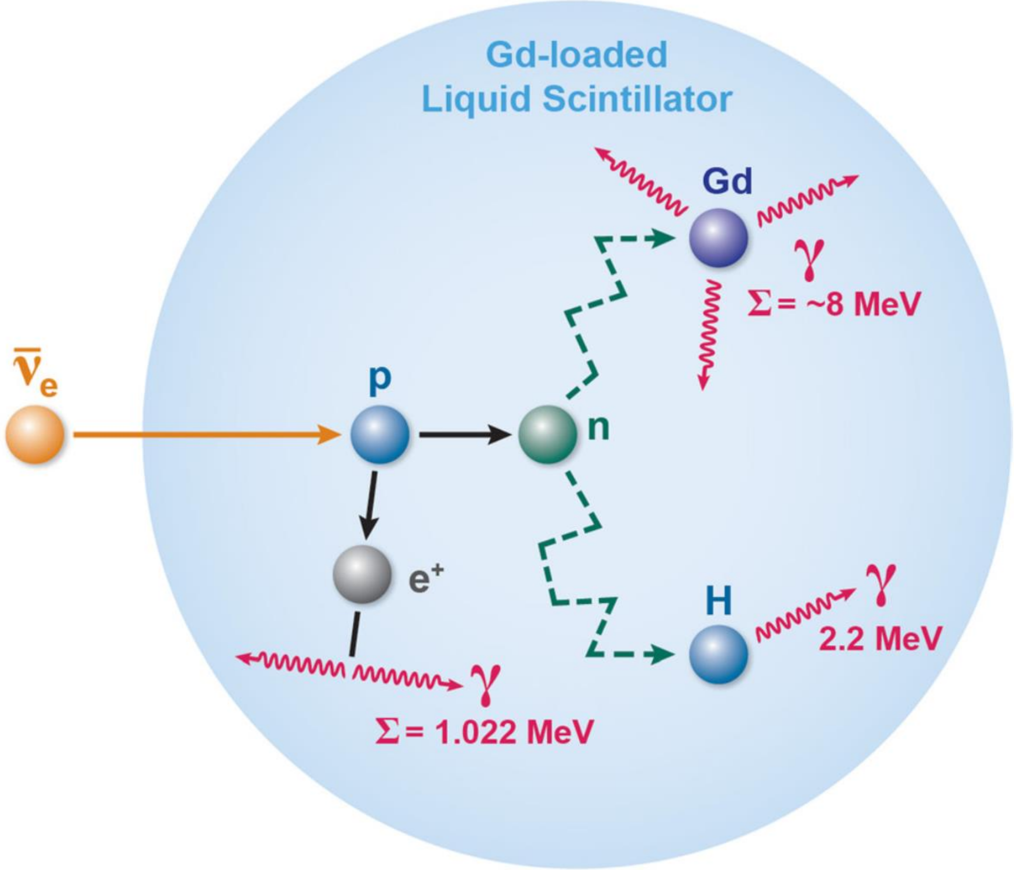
Summary of requested shifts: Based on this, we request 10 shifts of beam time of ^{8}He produced from a CaO target, and 8 shifts of beam time of ^{9}Li produced from a Ta target.

Reactor neutrino experiments

Double Chooz, Daya Bay, Reno, Juno, …



$$E_{\bar{\nu}} \approx E_{\text{prompt}} + 0.78\ \text{MeV} + T_n$$



Several running and planned experiments addressing fundamental questions in the standard model.

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^{9}Li and ^{8}He decays in GEANT4

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ABSTRACT

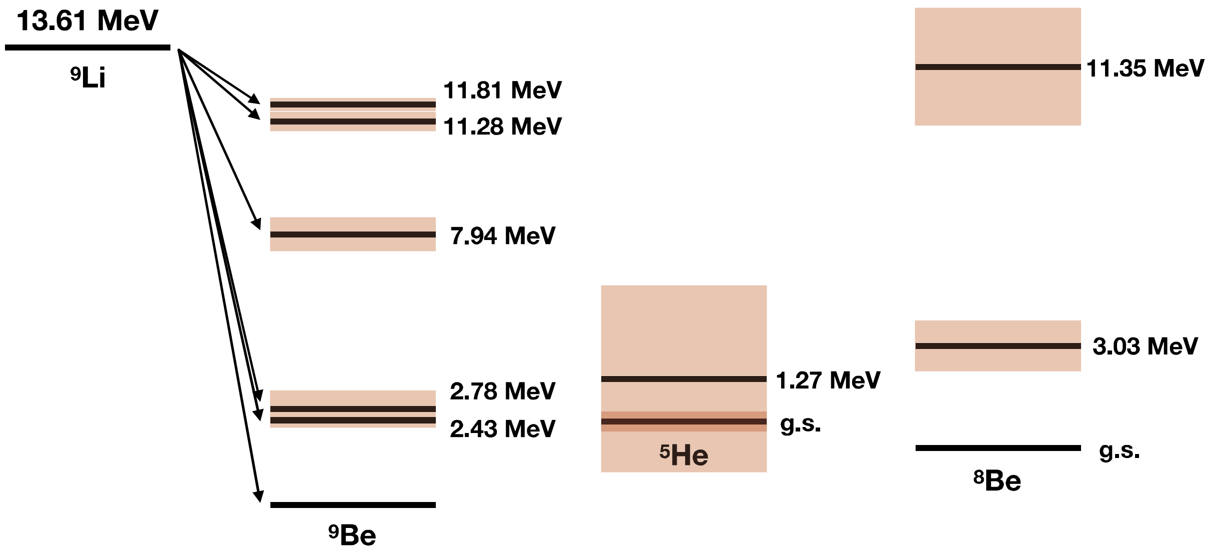
The decays of cosmogenic nuclei such as ^{9}Li and ^{8}He represent one of the largest irreducible backgrounds for reactor antineutrino experiments. The correct treatment of such decays are of fundamental importance in the study of cosmogenic backgrounds and in their rejection, hence the full chain of intermediate excited states must be accounted for. Currently the treatment in GEANT4 of the modelling of de-excitation of ^{9}Be and ^{8}Li, which are the daughter nuclei of ^{9}Li and ^{8}He respectively, is not correct. ^{9}Be excited states should break into a neutron and two α's, and ^{8}Li excited states should emit a neutron and possibly an α and a triton depending on the decay chain, whereas in GEANT4 they both reach the ground state by emitting a gamma. Based on the available nuclear measurements we included the correct treatment of ^{9}Li and ^{8}He decays in GEANT4 and compared the obtained results with the spectra published by the Double Chooz collaboration finding an excellent agreement.

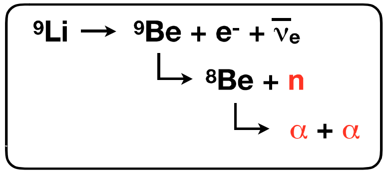
Our motivation:

Additional nuclear experiments studying these nuclei aiming at a better knowledge of the energy levels and branching ratios of ^{9}Li, ^{8}He and their decay products would be beneficial in order to further improve the simulation tools used by reactor antineutrino experiments.

Present status for ^{9}Li

Uncertainties presently 10-30% or not given





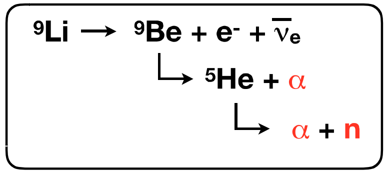


Table 1
Branching ratios and relative errors for the different decay channels of ^{9}Li. In the last column the references are quoted.

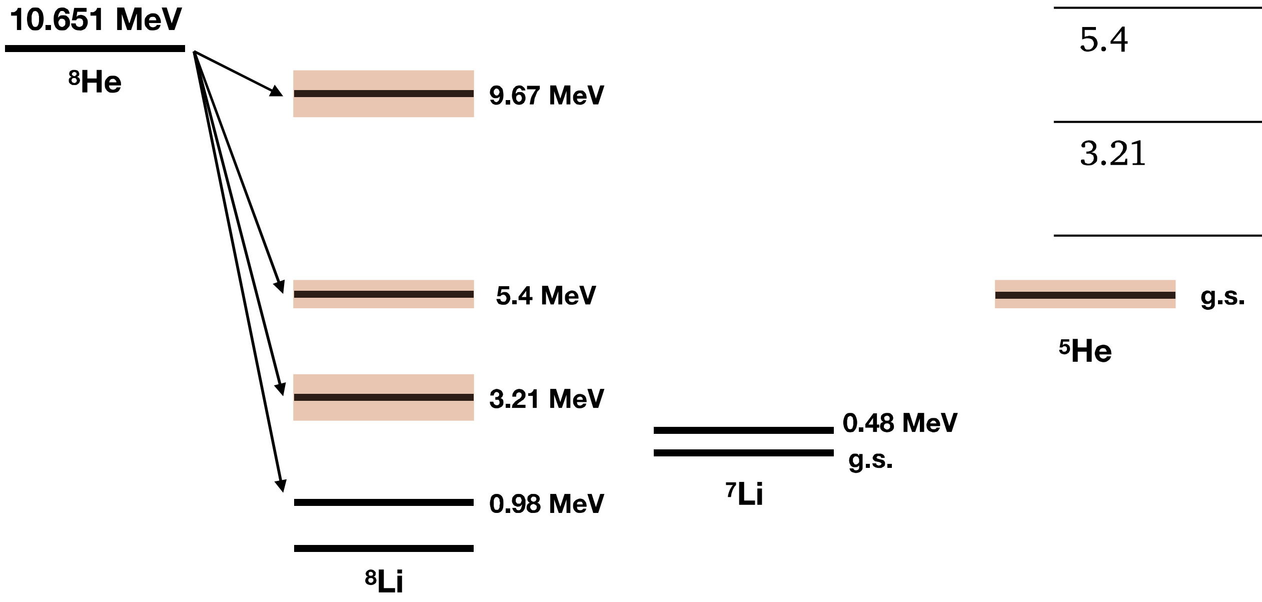
^{9}Be state (MeV)	ΔE (MeV)	β decay BR	Decay mode	Decay mode BR	Reference
11.81	0.4	2.7%	^{5}He (g.s.) $+\alpha$ ^{5}He (1.27) $+\alpha$ ^{8}Be (g.s.) + n ^{8}Be (3.03) + n ^{8}Be (11.35) + n	28% ± 6% 47% ± 6% 2% ± 1% 11% ± 6% 12% ± 8%	[8,9]
11.28	0.58	1.1%	^{5}He (g.s.) $+\alpha$ ^{8}Be (g.s.) + n ^{8}Be (3.03) + n	76% ± 30% 3% ± 1% 21%± 8%	[8,10]
7.94	1.	1.5%	^{5}He (g.s.) $+\alpha$ ^{8}Be (g.s.) + n ^{8}Be (3.03) + n	80% 10% 10%	[6,8] + our Assumptions
2.78	1.1	15.8%	^{5}He (g.s.) $+\alpha$ ^{8}Be (g.s.) + n ^{8}Be (3.03) + n	25% 15% 60%	[6,8] + our assumptions
2.43	<0.01	29.7%	^{5}He (g.s.) $+\alpha$ ^{8}Be (g.s.) + n ^{8}Be (3.03) + n	2.5% ± 2.5% 11%. ± 2% 86.5%± 4.5%	[8,11] + our Assumptions

Goal of our experiment 1-3% precision on transitions down to 1% branching ratio

Present status for ^{8}He

Table 3
Branching ratios and relative errors for the different decay channels of ^{8}He. In the last column the references are quoted.

^{8}Li state (MeV)	ΔE (MeV)	β decay BR	Decay mode	Decay mode BR	Reference
9.67	1	0.9%	^{3}H + ^{5}He (g.s.) ^{7}Li (0.48) + n ^{7}Li (g.s.) + n	80% 10% 10%	[8,14] + our assumptions
5.4	0.65	8.0%	^{7}Li (0.48) + n ^{7}Li (g.s.) + n	50% 50%	[8,14] + our assumptions
3.21	1	8.0%	^{7}Li (0.48) + n ^{7}Li (g.s.) + n	50% 50%	[8,14] + our assumptions



Uncertainties presently 10-30% or not given

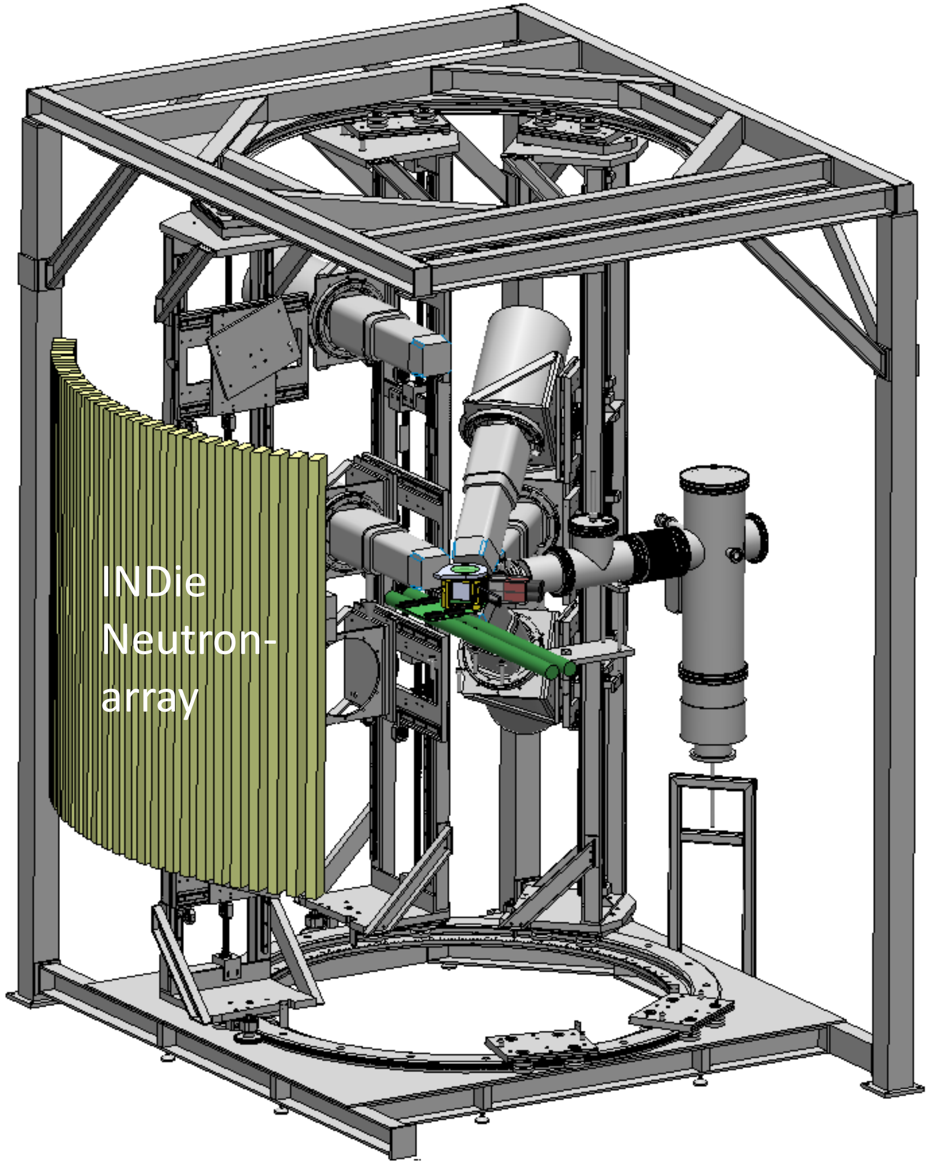
Goal of our experiment 1-3% precision on transitions down to 1% branching ratio

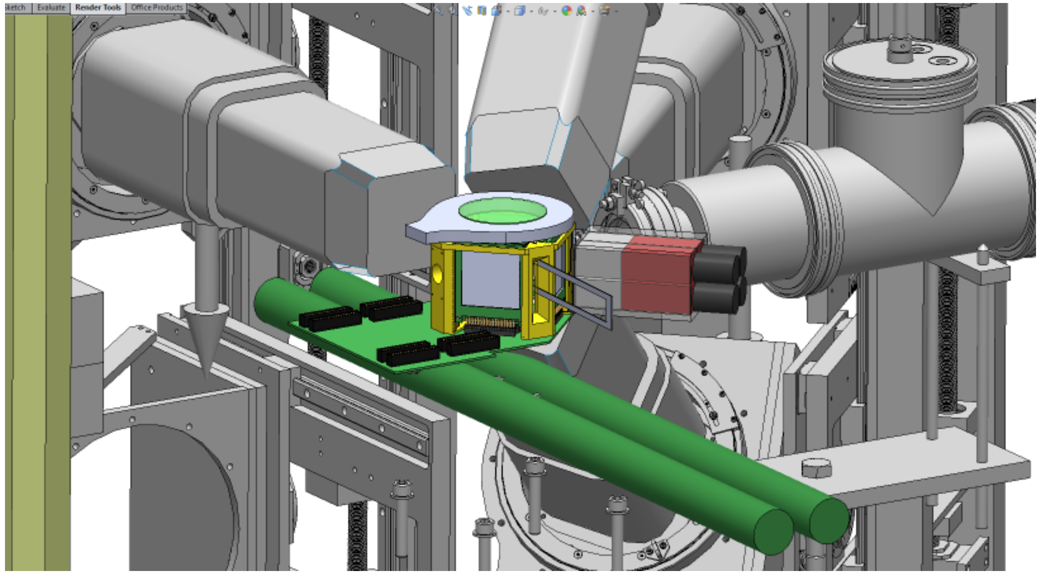
$^{8}He \rightarrow {}^{8}Li + e^{-} + \bar{\nu}_e$
$\quad \hookrightarrow {}^{7}Li + n$

For $^{8}Li^{*}$ of 9.67 MeV only

$^{8}He \rightarrow {}^{8}Li + e^{-} + \bar{\nu}_e$
$\quad \hookrightarrow {}^{5}He + {}^{3}H$
$\quad\quad \hookrightarrow \alpha + n$

Planned setup @ IDS





- Neutrons: INDie + ^{3}He spectrometers
  40% intrinsic + 15% of 4π
- Charged particles (α, t) 10-15% of 4π per DSSSD, 97% intrinsic
- Betas Plastic for TOF 10-15% of 4π
  +Beta energy measurements

Beamtime estimate

Estimate based on requirement to detect :

✓Two charged particles (α or triton)
✓Beta for TOF
✓Neutron in INDie
✓Measure branching ratios down to 1% with precision 1-3%

→ combined efficiency of such events is appr. 6×10^{-5}

Based on known yields of ^{9}Li from Ta target and ^{8}He from CaO we ask for

→ 8 shifts of ^{9}Li beam

→ 10 shifts of ^{8}He beam