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LiquidO: First Opaque Detector for $\beta\beta$ Decay?

LiquidO Collaboration

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The novel LiquidO detection for neutrino and rare decay physics has been released for the first time to the international community in the NOW conference (Sept. 2018) in Italy. The presentation summarised the LiquidO $\beta\beta$ potential only and the new detection principle. This document aims to briefly summarise the most important features of LiquidO in the context of its $\beta\beta$ application. Further details are to be provided in forthcoming publications.

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In the 1950's, Reines & Cowan paved much of the technical ground behind a large fraction of today's neutrino detection along with the discovery of the neutrino. Large instrumented volumes can and have been achieved via a detection principle of effective transparency. This is still dominant in much of today's state of the art technology for neutrino fundamental research. This technology has yielded historical success, including many discoveries. The discovery of the Neutrino Oscillation phenomenon [1], thus solving the long standing "solar" and "atmospheric" anomalies, is one of the latest examples where transparent detectors such as SNO and SuperKamiokande – together with many other experiments – are at the core of today's knowledge about neutrinos.

Despite the stunning success, this transparent detector technology is known to suffer from some key limitations. The challenging condition for neutrino detection to yield both large cost-effective detection volumes as well as active background rejection has proved very difficult – sometimes even impractical. Indeed, most transparent detectors, such as liquid scintillator detectors, have limited intrinsic native particle identification capability, even in the MeV range. This translates into the necessity for shielding as key strategy, including expensive deep overburden articulation in dedicated underground laboratories. Another consequence of transparency is a limited detector isotopic loading capability. The loading implies the dissolution of a certain element in the detector liquid medium, as originally done by Reines & Cowan with Cd, thus extending the detector native composition for further neutrino detection exploitation. Instead, the **LiquidO novel detection technique** – under intense R&D by a dedicated scientific collaboration – aims to address and possibly overcome some of those limitations. The basis of this potential is that LiquidO's detection principle relies heavily on the exploitation of an opaque detection medium – actually translucent – thus abandoning transparency. Indeed, LiquidO suggests that one of the most promising way forward implies a departure from the core detection principle embedded in most of the neutrino detection technology for ~70 years.

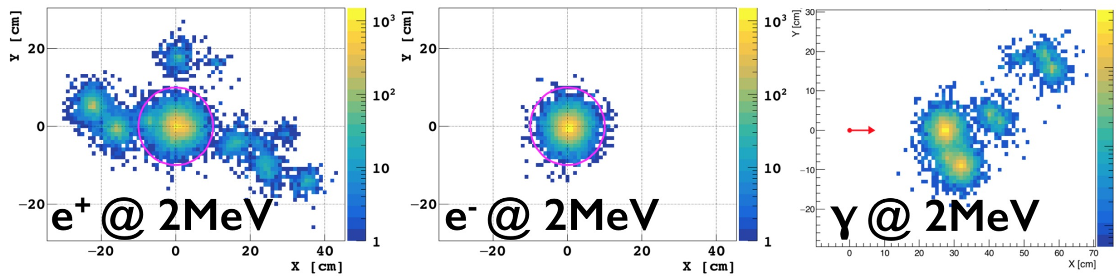

Figure 1: LiquidO Event Pattern. The detector intrinsic ability to identify the energy deposition pattern of 2 MeV e^+ (left), e^- (center) and γ (right) is illustrated. The x-y axes correspond to position (cross-section view of the detector) while the z axis indicates the number of optical photons collected by wave-shifting fibres in a standard liquid scintillator. Each entry is one fibre. LiquidO translucide medium yields a **stochastic light confinement** of each energy deposition, whose "light ball" topology allows the disentangling of particle event pattern in the cm-scale. Hence, an e^- looks like a point-like (Bragg peak dominated) and a γ looks like a sequence of points, upon each Compton-scatter. A e^+ is the composite signature of an e^- like in between two 0.5 MeV back-to-back annihilation γ's. The low-z radiation length of the scintillator medium (only H and C atoms) aids to maximise identification.

If successful, LiquidO appears to be particularly suitable for $\beta\beta$-decay physics via its remarkable potential to articulate both multi-ton isotopic loading (no enrichment) and a major background rejection from natural radioactivity; i.e. the reduction of the dominant radiogenic background. The potential of the latter feature is illustrated in Fig. 1. LiquidO's $\beta\beta$ programme aims to the exploration of the Normal Ordering range, should the control of the background be good enough. However, the ongoing remaining R&D is not expected to be completed in time for a competitive approach in the order "1-ton" isotopic mass range – in preparation. Indeed, several other experiments are expected to dominate that range, as their respective R&D efforts had started many years before.

Both LiquidO intense detector R&D and physics programme exploration efforts are led by the LiquidO collaboration with 16 institutions in 10 countries. Preliminary ongoing physics potential studies suggest unprecedented performance to address several standing challenges in neutrino physics – specially in the MeV range – and rare decay physics, including proton decay. LiquidO's $\beta\beta$ potential only and its detection principle were both first presented[1] to the international community in the **NOW-2018 Conference** (Italy). This conference proceeding has been made minimal, in agreement with the organisers, since a detailed LiquidO publication is in preparation for publication [2]. Other publications with the further physics studies are also in preparation.

References

[1] Physics Nobel Prize (2015)

[2] LiquidO Collab.(Cabrera A. *et al.*) LiquidO Detection Principle First Publication (2019)

[1]We strongly thank the NOW-2018 organisers for this opportunity.