DRAFT NEXT-100 PMT (Energy Plane) System Requirements

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1 Purpose and Summary

This is a document listing the requirements for the PMT energy plane system for the NEXT100 Xe double beta decay experiment.

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2 Introduction

NEXT (Neutrino Experiment with a Xenon TPC) is an institutional collaboration formed for the purpose of either discovering, or setting new exclusion limits on neutrinoless double-beta decay. The existence of neutrinoless double beta decay will indicate the neutrino is its own antiparticle and allow calculation of its mass, as well as indicate the next direction for physics beyond the Standard Model. A partial list of current collaborating institutions is: Instituto de Física Corpuscular(IFIC), in Valencia, Spain, Lawrence Berkeley National Laboratory, Berkeley, California, and Texas A&M University. Xenon 136 is an isotope of Xenon which can undergo double beta decay; if the neutrino is its own antiparticle, as some theories suggest, a small fraction of these double beta decays will be neutrinoless, instead of the more common 2-neutrino type. NEXT100 is a detector which will contain and observe 100 kg of enriched Xe 136 (EXe) in gas phase, for double beta decay events, measuring both decay energy to high accuracy and event topology by imaging the decay tracks which ionize the surrounding Xenon gas.

3 Description

The detector consists of a pressure vessel, with Xe 136 gas filling the entire volume. Inside the vessel is a field cage, to drift electrons to an electroluminescent mesh system (EL) where each electron is used to produce 10000 photons of 172 nm wavelength via excimer excitation mechanism. This light is measured by the PMT system. In addition primary scintilallation light also occurs (S1) during initial ionization, and the time difference between this light and the EL light is used to compute the location in Z (axial direction)

Below is a cross section **??** showing the detector:

Figure 1: NEXT100, detector cross-section

Inside the pressure vessel, mounted to one head of the pressure vessel is the array of (60 total) photomultiplier tubes (PMTs). The PMT's cannot withstand the 15 bar Xe pressure, so each one enclosed in titanium tube pressure-proof enclosure having a sapphire window on one end. Cables from the PMT exit through a flare fiting into a copper tube that connects to a central manifold that is bolted to the underside of the axial flange of the pressure vessel head. A vacuum of 0.1

millitorr or better is maintained inside this central manifold (and thus to the inside of the PMT enclosures); this allows both the PMTs operate normally, with no flashover, and the enclosures to be sniffed for Xe leakage. PMT base reistor heat is dissipated by thermal conduction to the pressure vessel through the mounting plate.

4 PMT System Requirements

The PMT system must be capable of pressurizing, circulating, purifying, and depressurizing the detector with either EXe, NXe, DXe, He, Ar (for leak checking) with negligible loss, and without damage to the detector. There is a high priority on avoiding loss of EXe, due to its cost and availability. A list of requirements in approximate decreasing order of importance is shown below:

1. Pressure resistance: (16.4 bard (bar differential) external, 1 bard internal, max allowable pressures)r
2. Radiopurity: 0.5 Bq max for system
3. Leak tightness: 1* $10^{-}8$ torr*L/s max for system
4. Xe conservation in case of window failure
5. Compatibility with HV cable/feedthrough, Xe circulation flow, perhaps other services sharing axial nozzle
6. Adjacent PMT protection from isolation from pressure in fault event: 2 bara max pressure pulse in any adjacent can upon
7. No damage to pressure vessel from enclosure failure; minimal damage to other detector internals
8. PMT body must be maintained at photocathode voltage; assume body not insulated
9. Insensitivity to external HV fields
10. Dissipate base resistor chain heat, 5C max temp rise

Preface:

The ANGEL design calls for 30% end coverage (photocathode area/active volume end area). An array of PMTs at the cathode end is required. Our preferred PMT is a state of the art low background 3 inch dia. PMT, Hamamatsu R11410-10 (AKA R11410MOD), which can only tolerate an external pressure of 3 bar absolute. 60 will be needed for the required coverage (actually, for 64 mm photocathode dia. I get 18%). These PMTs will thus need an enclosure system to operate inside the pressure vessel. We propose to provide individual enclosures for each PMT and duct the cables into a common low pressure internal volume to feedthroughs that are located behind a first wall or shielding. We call this the baseline design for the energy plane. The baseline individually canned PMT concept is attractive in that there is little else to develop once the PMT modules and connections are developed. The concept scales well up to 60 PMT's arranged in a concentric ring pattern, but would likely be difficult to go beyond this. We have considered common chamber concepts, and have arrived at a concept which works well for greater than 60 PMTs, up to 84 PMTs, but unless we need these extra PMTs, it does not appear worthwhile to pursue this concept, as the pressure resistant chamber design is then size dependent. Small scale prototyping is possible, but there is more risk that sealing issues and other problems could arise in a full system design, while not appearing in a small prototype. The repairability of such a system, with many sapphire windows sealing into one large plate entails much more time and cost risk. Also, the PMT pattern is fixed with this concept. Therefore, this common chamber concept is abandoned at this time, and development now proceeds to the individual can design. First we look at the system. We have three main subsystems:

1. PMTs in pressure resistant "cans" 2. Cable/vent piping, 3. Central manifold interfacing to torispheric head nozzle with either 1 bar N2 or vacuum inside, continuously sniffed for Xe presence. 4. Standard CF feedthroughs

We have several main criteria: 1. 2. 3. - is this correct? 4. 5. 6. 7. 8.. 9.

Before discussing the above criteria , we present the baseline system as currently envisioned

The baseline design uses the simplest, most readily available technology. There are options that may improve performance which can be implemented should a parallel development effort for them be successful. Very briefly:

–Cans are titanium, grade1 for radiopurity and weight; copper is a present option, niobium is a future option (w/diffusion bonded sapphire windows and feedthroughs). Ti grade 1 require 2mm min thickness; NPS sch. 80 (3.5" OD, 2.9" ID) can be used, if window seals to end. The present can design is based on using this pipe size, to save material cost. –Sapphire windows are sealed to one end of can using PEEK pressure rings (these are not gaskets) and a PCTFE O-ring; compression is via threaded ring ("Mason jar") and nonrotating washer. An option is to use an epoxy bonded window, possibly from a vendor, Precision Sapphire, who make windows this way. I am goingot prapare a preliminary drawing for them –Backplate seals to other end of can via same mechanism –PMT clamped against sapphire window inside using spring mechanism and silicone optical pad interface; waveshifting coating on outside of window. Options are to use a grease (perhaps for –PMT cables (2 coax, 1-2mm dia. ea.) exit through side port in can. Port is a welded on boss NPT w/Torrseal or similar epoxy). Fitting is either flare, phos-bronze or 304 VCR (316 has 2% Mo). Option: welded in Ti-ss transition tube; copper can, Ag brazed boss. Possible flow restrictor "grommet" around cables, resistant to backflow pressure pulse. –copper tubing w/flare fittings both ends carries cabling to central manifold. Cu tubes are prebent to drawings then installed, slight bending OK to fit –central manifold, Ti w/welded on bosses w/NPT female) threads. Seals to underside of Axial nozzle flange on torispheric head via an internal clamp ring –octagon attached to topside of axial flange of torispheric head, having (8) DN40 CF flanges and one DN150 for feedthroughs (5 x 41 pin), burst disk, Hv cable, if present, and Xe circulation flow, if present –cans are assembled to a PEEK baseplate; this baseplate attaches to a mating flange on the inside of the torispheric head, near the periphery.

Criteria discussion:

1. The PMTs (R11410-10) are rated for use at a maximum of 2 bar over atmosphere (2 barg). Therefore a pressure-proof enclosure or "can" is required to operate them with 15 bara Xe in the main vessel. The can will have either: an 1 atm N2 atmosphere inside, or a low vacuum, which will be easier to sniff for presence of Xe. For low vacuum, boththe bases and feedthroughs will need to be encapsulated to prevent flashover between pins. The can should have a reasonable safety factor against collapse, but, to minimize material and background), need not be designed to ASME standards, as, per criterion 4, failure does not result in pressure containment failure nor, per criteria 6, Kamiokande style chain reaction failure of adjacent PMTs. It is likely the affected PMT will be crushed, however, which is acceptable. Full detector disassembly will likely be required to clean up broken window and PMT debris. Thus, all cans will be pressure tested before PMT's are installed; the protocol for this (number of pressure cylcles, percentage overpresure) need to be determined.

2. The PMT's themselves contribute 60 PMTs x 5.6 mBq/PMT (U+Th) = 0.33 Bq to the system total. The main pressure vessel , weighing 1 tonne is the dominant contributor with 1 Bq. 1.5 Bq appears to be an upper limit for acceptable background rejection. Therefore the

enclosure system must have no more than 1.5-(1+0.33)= 0.17 Bq. This will require enclosures to be made from either grade 1 or 2 Ti or radiopure copper, as thin as is reasonable to provide. Each enclosure will be pressure tested before PMT's are installed, so that safety factors can be lower than usual for pressure applications.

3. There will be unavoidable leakage of Xe into the cans, which will be scavenged with a cold panel in either the PMT N2 or vacuum system; keeping the total leakage below this number reduces the required size and frequency of reclamation needed to recover this Xe.

4. Xe conservation means avoiding loss of Xe in case of sapphire window failure, or other leak. The 1.3 barg burst disk in the PMT N2 or vacuum system will open in milliseconds following a pressure rise 30% over atmosphere. The vent will be directly into the evacuated recovery tank of the main gas system. The pressure vessel pressure will fall to 1 bara in seconds, the pressure in the central manifold will fall even quicker, minimizing risk of overpressurizing adjacent PMTs

5. PMT voltage- Can and window can be grounded, anode at HV, according to Dave - do we want to goe this way? one or two coax? What doe the base look like with coupling cap?

6. Do we need a mesh screen over the window? - ITO transmission starts cutting off below 400 nm

Design tasks:

1. Finish initial cable pipe routing. 2. Finish PMT hold-down spring or clamp in side can. Spring pressure? 3. Design baseplate and can interface. 4. Design flange interface, baseplate to torispheric head 5. Design rotating lift lug to torispheric head to allow rotation of head, when removed 6. HV cable compatibility with central manifold - need a design- can it be removed with PMT cables in place? 7. Base design - grounded can? potted or not (cooling required? passive cooling?). Cap coupled or not?

System development will follow several paths:

1. can development - seal reliability, seal leakage, window reliability, optical performance, leak tightness under pressure, interface to baseplate. 2. system testing: Xe sniffing ability, ease of assembly, ease of cabling in-situ, response to window break (burst disk) and pressure isolation of adjacent PMTs 3. PMT performance - waveshifting efficiency, acceptance angle function? - use LBNL 172 nm light source

More specifically:

Cans: – buy Ti pipe, make prototype, make pressure chamber to test (no PMT). Maybe with a (high pressure) sight window to view sapphire window, probably hydrostatic test. – thread coating options - Tiodize type IV (PTFE anodize), Nedox- obtain trial samples and measure for radiopurity, fastening repeatability, galling resistance – pressure required for good optical contact, determine, Maybe Hamamatsu acan advise?

Windows: – determine sapphire strength, factor of safety, look for DUV grade – optical pad or grease for PMT? response under pressure

Window sealing options –Precision sapphire epoxy bonded tubes - submit draft drawing for quote, purchase trial samples? , test, (pressure cycle) –PCTFE O-ring/PEEK washer design- can pipe be used?

Cable conduits –test flare fittings for pressure tightness, repeatability. –make up samples with worst-case bend count- do cable pulling tests- try ASAP –Make bend tests. measure ellipticity and check ext. pressure.

vacuum option- –vacuum pot cables to base (epoxy) then pot base to PMT w/silicone or other flexible compound - radiopure?