XMASS, present and future development

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XMASS: LXe single phase detector

- Many interesting physics targets, including EM interactions
  - Dark matter: elastic, inelastic $^{129}\text{Xe}$, super-WIMPs, ALP, HP, ...
  - Solar axions, $2\nu$DEC, SN, and other unexpected signal

- Intrinsic BG of XMASS I: $O(10^{-4})$/kg/keV$_{ee}$/d @40keV dominated by $^{214}\text{Pb}$, w/o part. ID (arXiv: 1401.4737)

- Larger size is advantageous. Surf. BG, Kr, & Rn
• BG originated at the inner surface was observed.
  • Al seal btw window and its body contain $^{238}\text{U}$, $^{210}\text{Pb}$, and Th.
  • Clean Al material for future PMT production in hand.
  • Radon daughters ($^{210}\text{Pb}$) on the surface of PMT & holders.
  • Surface events need to be identified in a much efficient way.
Key component to see the surface

• One of the most simple and straightforward way to see the surface events is the use of PMTs with a convex, dome shape photocathode.

• Similar shape can be seen in many examples.

From PMT handbook (HPK)
Configuration of a future detector

- To evaluate performance of surface ID, PMTs of our simulation for the XMASS-I were replaced. \(\sim 15 \text{pe/keV}_{ee}\)
Identification performance

- 3 PMTs accept 40-50% of total
- One example of surface ID: 3 PMTs > 10% of total PE
- Assume surface RI 8mBq $^{210}\text{Pb}$, $10^7$ events $\sim 42$y. In 2-2.5keV$_{ee}$ 0.1 events/y w/o dead tube 0.3 events/y w/ 15 dead tubes
- DM signal efficiency $\sim 20\%$ of all volume.

Surface events can be identified and rejected effectively.
Beyond the surface: solar ppν, Kr and Rn

- Internal background, future goal $<10^{-5}$/kg/keV\textsubscript{ee}/d
  - e scat. by solar pp ν $\sim 10^{-5}$/kg/keV\textsubscript{ee}/d $\Rightarrow$ irreducible
  - $^{212}\text{Pb}$, $<0.3\mu$Bq/kg $\sim 10^{-5}$/kg/keV\textsubscript{ee}/d=dru $\Rightarrow$ 1/10
  - $^{85}\text{Kr}$ ($Q_\beta=687$keV, $\tau_{1/2}=11$yr), 1ppt $\sim 10^{-5}$dru $\Rightarrow$ 1/10
  - $^{214}\text{Pb}$, 10mBq/kg $\sim 10^{-4}$dru $\Rightarrow$ <1/10

- γ ray and neutron contribution will be evaluated.

- Prediction of these background are accurate and will be taken into account in analyses to search for DM signal. $<\sim 10^{-46}$cm\textsuperscript{2} would be searched for.
Distillation tower for reducing Kr

- Distillation tower was proved to remove Kr efficiently.
  - Utilize the difference of boiling point of Kr and Xe
- 0.1ppm $\rightarrow <2.7$ppt (9days for 1t)
- Not yet seen any limitation on the reduction. Another order of magnitude improvement, 0.1ppt $\sim 10^{-6}/$kg/keV$_{ee}$/d would be achieved by the 2$^{nd}$ pass (must be confirmed).
Current $^{222}$Rn and protection in future

- XMASS-I ~ 10μBq/kg ($\sim 10^{-4}$/kg/keV$_{ee}$/d).
  - EXO-200~3.7μBg/kg, XENON100 & LUX 10~20μBq/kg
- Using a Rn detector important parts were measured and some of them had large Rn emission. Window (quartz) and copper are almost free from $^{226}$Ra.
- In the next design, better tightness between PMT holder and PMTs (quartz window) must be achieved using good sealing (under development).
XMASS in future

XMASS-I
DM
100kg FV (800kg)
0.8mφ, 642 PMTs
2007-
To discover DM

XMASS-1.5
DM
1ton FV (5ton)
1.5mφ, ~1000 PMTs
Requesting budget
DM, pp solar ν
~10^{-46}cm^2
Annual/spectral info.

XMASS-II
DM, solar, ββ
10ton FV
Detailed study of DM
pp solar ν
ββ ~30meV(IH)
• LXe single phase detector is forced to have extreme low EM background: unique and advantageous to search for a wide range of dark matter candidates.
• Based on the experience of XMASS-I (0.1t fid. mass), a larger detector is planned (e.g. 1t FM, total 5t)
• Surface events are expected to be identified by new, convex shape PMTs, and reduction of internal background is important. $10^{-5}/\text{kg/keV}_{ee}/d \sim 4/\text{keV}_{ee}/\text{t/y}$
• Sensitivity $\sim 10^{-46}\text{cm}^2$ is expected for the next stage.