immersed in LXe, under prolonged neutron irradiation. The figure also shows the scintillation yield measured with the same detector under 5.5 MeV alpha particles irradiation and under 122 keV gamma-rays irradiation. The ionization yield for alpha particles is shown as well. As previously measured in LXe [22,23], the strong recombination rate along alpha particle tracks is such that only about 6% of the liberated charges are collected even at 5 kV/cm, whereas more than 90% are collected for 1 MeV electrons at the same field.

IV. INTERPRETATION OF RESULTS

For recoils with energy in the range of 10.4 to 56. keV, we find the relative scintillation efficiency to be in the range 0.13 to 0.23. For the lowest recoil energies, our data are the first reported, to our knowledge. Compared to the scintillation yield due to electron or alpha particle excitation, the scintillation yield due to nuclear recoil excitation is significantly reduced. Our results are shown in Fig. 8, along with previous measurements by other groups [13–16]. The predicted curves from theoretical models from Lindhard [24] and Hitachi[25] are also shown as solid and dotted lines, respectively. The scintillation efficiency of LXe is about 15% less than the Lindhard prediction. Hitachi explains this difference by estimating the additional loss in scintillation yield that results from the higher excitation density of nuclear recoils.

Rapid recombination in LXe under high Linear Energy Transfer (LET) excitation[12,26] provides a mechanism for reducing the scintillation yield of nuclear recoils in addition to that of nuclear quenching treated by Lindhard. In order to estimate the total scintillation yield, Hitachi considers biexcitonic collisions, or collisions between two “free” excitons that emit an electron with a kinetic energy close to the difference between twice the excitation energy $E_{ex}$ and the band-gap energy $E_g$ (i.e. $2E_{ex}$–$E_g$):

$$\hat{E} \text{Xe}^+ + \text{Xe}^+ \rightarrow \text{Xe} + \text{Xe}^+ + e^-$$

The electron then loses its kinetic energy very rapidly before recombination. This process reduces the number of excitons available for VUV photons since it requires two excitons to eventually produce one photon. It is therefore considered the main mechanism responsible for the reduction of the total scintillation yield in LXe under irradiation by nuclear recoils. As shown in Fig. 8, our data are in good agreement with the Hitachi prediction.

Simultaneous measurements of scintillation and ionization signals from nuclear and electron recoils in LXe are expected to provide a powerful background discrimination for a LXe dark matter detector such as XENON. Charge collection by an external field is expected to be difficult for nuclear recoils in LXe, since the initial radial distribution of excited species in a Xe recoil track is estimated to be similar to the track core of an alpha particle [12]. This similarity is also implied by our data on the electric field dependence of the scintillation yield for 56.5 keV Xe recoil, which is not very different than that of alpha particles in LXe (see Fig. 7). Even at the highest field of 4 kV/cm, recombination is very strong and the light yield is suppressed by less than 5%. No satisfactory theory exists