present in the S1-based scale. The energy deposited by each event is determined by combining $S1$ and $S2$ signals as following,

$$E = (\frac{S1}{\alpha} + \frac{S2}{\beta}) \cdot W_{tot} \quad (5)$$

where $S1$ and $S2$ are in units of number of photo-electrons (N_{pe}). α and β are experimentally determined parameters in units of N_{pe}/photon and N_{pe}/electron, respectively. W_{tot} is the average energy required to produce either a scintillation photon or an ionization electron in LXe. In XENON10, β is determined from the $S2$ corresponding to the single-electron emission peak (see Fig. 22). The anti-correlation between $S1$ and $S2$ is due to electron-ion recombination fluctuation in LXe. Each recombined electron-ion pair will create one UV photon. Thus, α in equation 5 can be determined by β and the slope θ in Fig. 26, according to the relation $\alpha = \beta/\tan\theta$. From the 164 keV calibration peak, we obtain,

$$W_{tot} = 14.0 \text{ eV} \quad (6)$$

in good agreement with a study in a small LXe detector [54]. The energy resolution of the XENON10 detector was investigated with gamma ray sources (^{57}Co, ^{22}Na, ^{137}Cs, ^{228}Th) covering the energy range between 122 keV to 2.6 MeV. An example, from ^{137}Cs 662 keV gamma rays, is shown in Fig 27. For comparison, we also plot the energy resolution, in Fig. 28, obtained by using only $S1$, only $S2$ and the sum of these two signals. At 1 MeV, the resolution from the combined energy measurement is about a factor of seven better than that from $S1$ alone, and a factor of three better than that from $S2$ alone. The energy determined from the combination of S1 and S2 signals show a much more linear response than that based on S1 or S2 alone (see Fig. 29).

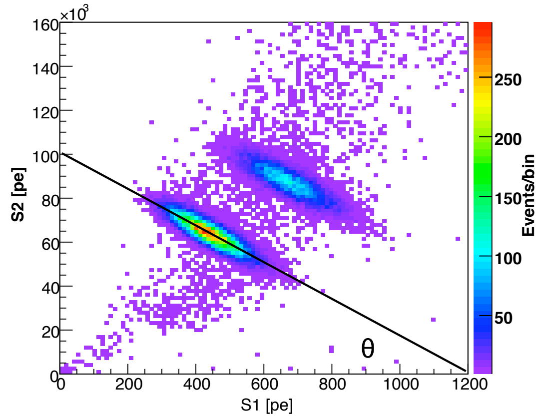

FIG. 26: (Color online) Anticorrelation between $S1$ and $S2$ for 164 keV and 236 keV γ rays from activated xenon isotopes (^{131m}Xe and ^{129m}Xe).

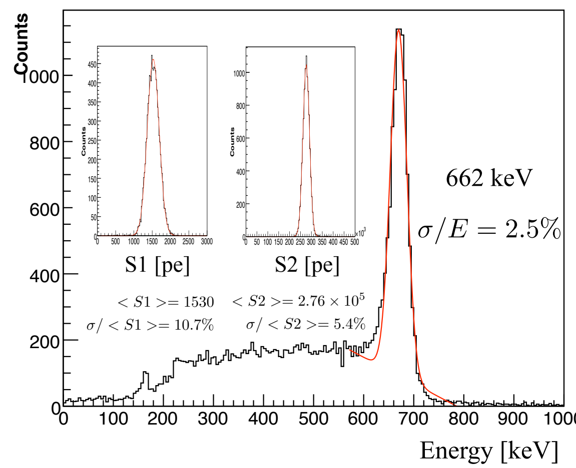

FIG. 27: Combined energy spectrum for single-scatter events from 662 keV gamma rays interacting within the 5.4-kg fiducial mass of XENON10. Insets: S1 and S2 distributions for 662 keV photo-absorbed events (events within 2-σ around the 662 keV peak in the combined energy are selected). The energy resolution at 662 keV is 10.7%, 5.4% and 2.5% for S1, S2 and the combined energy, respectively.

B. Neutron Calibration

To understand the XENON10 response to nuclear recoils, a neutron calibration was performed using a 3.7 MBq ^{241}AmBe source, emitting $\sim$220 neutrons/second. The calibration was done by exposing the XENON10 detector to the source for approximately 12 hours, with a live time fraction of 0.92. The ^{241}AmBe source (attached to a steel rod) was inserted through a 7 mm diameter hole in the XENON10 shield. The source was positioned next to the cryostat, between two 5 cm thick Pb bricks used to block high energy (a few MeV) gamma rays produced by the source.

The emitted neutrons have energies ranging from 0.1 MeV to 11 MeV, with a mean at 4.3 MeV. The calibration data were recorded at a constant rate of 6.5 Hz during the exposure. The trigger setup was the same as used for the WIMP search, with the addition of a high energy veto to reject events with energies above $\sim$120 keV.

Figure 30 shows the $\log_{10}(S2/S1)$ vs. $S1$ distribution from the neutron calibration run, after applying the quality cuts discussed in Section V C. Two regions are clearly distinguished in Figure 30: region a) which defines the nuclear recoil band corresponding to single elastic scatters, and region b) which corresponds to inelastic neutron scatters with ^{129}Xe, which produce 40 keV gamma rays. Neutron inelastic scatters with ^{131}Xe will produce 80 keV gamma rays, however the data do not show a peak around this value because of the events rejection by the high energy veto. The nuclear recoil band is used to determine XENON10 discrimination power, described in Section VI C.