Calibrations of the LUX Detector on the Surface

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on behalf of the LUX collaboration

IDM 2012

Refresher: the LUX experiment

- Two-phase Xenon TPC direct detector for collecting primary and secondary scintillation
- Total mass of 350* kg (100 kg est. fiducial mass)
- Completed a successful surface engineering run in February of this year in Lead, SD
- Detector just moved underground a few weeks ago to the -4850 ft. level at Sanford Lab

- Please see Karen Gibson's (plenary) and Carmen Carmona's talks for more information

Surface Calibrations

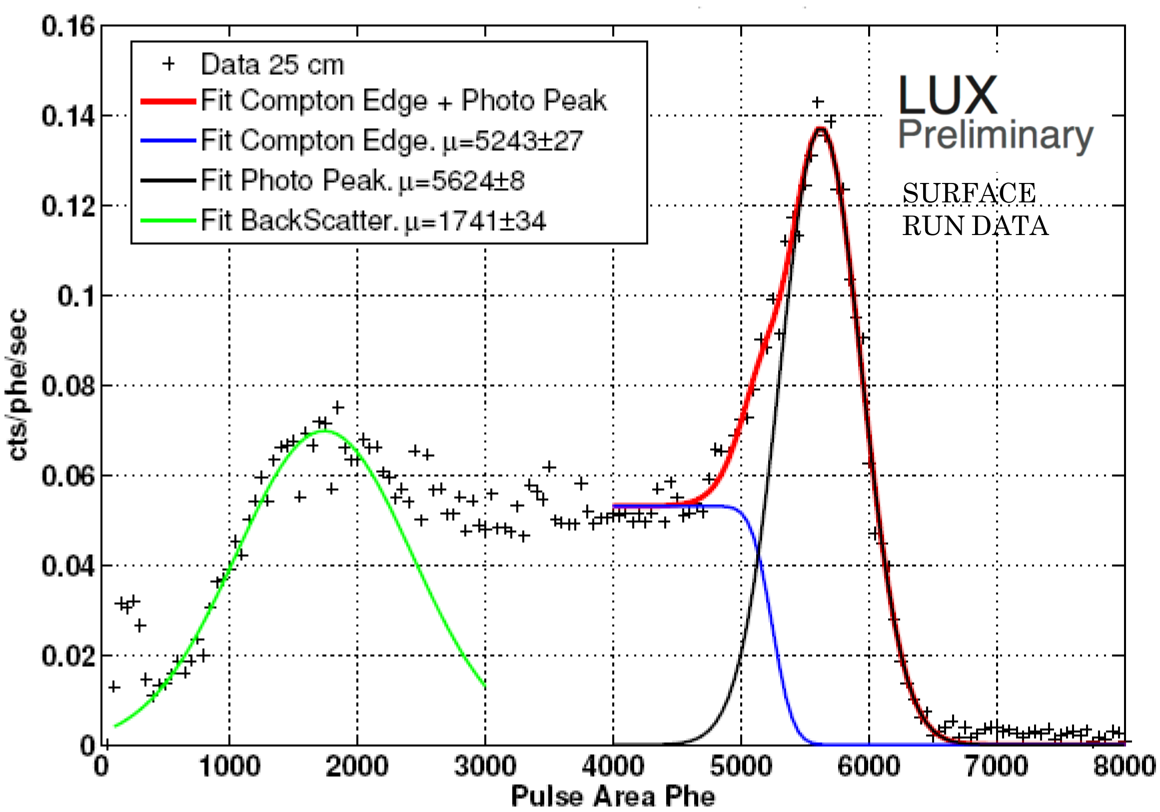
- Several unique sources purposefully employed or capitalized on, both internally and externally
  - Cs-137 662 keV gamma rays
  - Rn-222 chain alphas (5.5, 6.0, and 7.7 MeV)
  - Xe activation lines at 164 and 236 keV
  - Muons with O(5 GeV) mean energy
- Both zero and non-zero electric field data taken
  - Fields kept low to avoid PMT saturation with electroluminescence from muons
  - Gains kept low for the same reason
- Data presented here are not the best LUX will be able to take (yet are already good…)

Light Collection Parameters

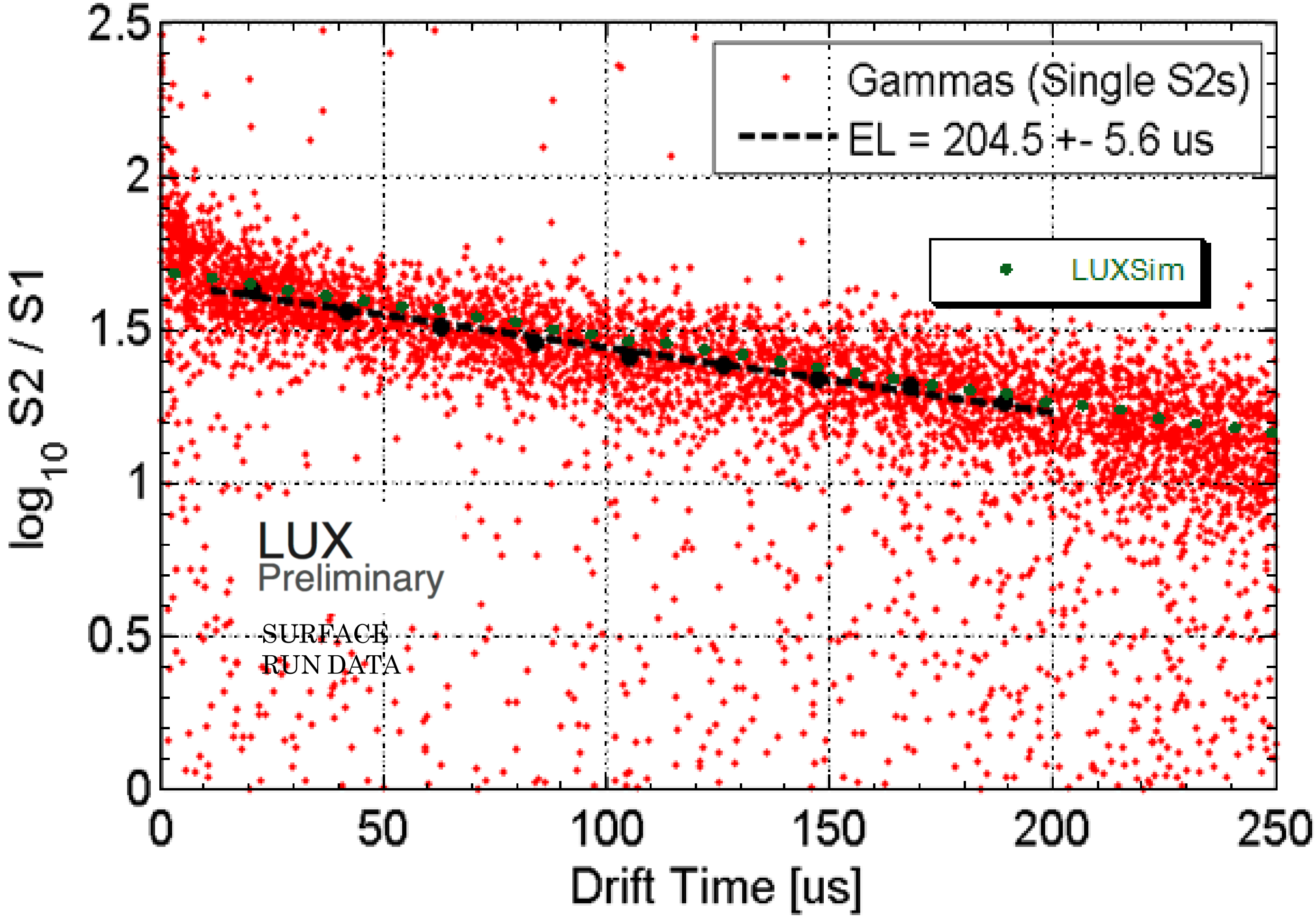
- Based on the data presented in this talk, we have the following preliminary results:
  - >95% reflective PTFE in LXe lower limit, with the best fit to the data occurring for 100 (+0 -2)%
  - >5 m photon absorption length in LXe lower limit, with the best fit at 11 (+2 -1)m
- One model is able to explain the data, consisting of different particles and energy ranges

CESIUM-137 GAMMA RAYS

- Two language-independent analysis chains to cross-check
- A the heart of LUX, the yield is ~8 phe/keVee, ~thrice as good as XENON100 even after adjusting for electric field LY quenching



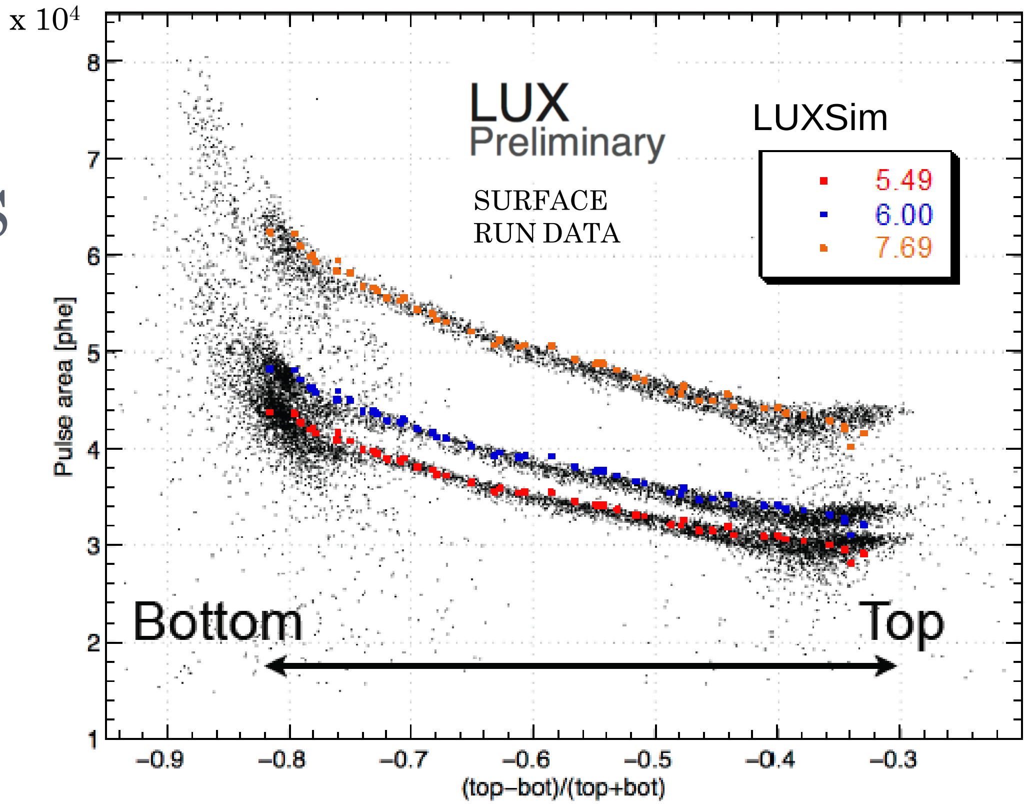
ELECTRON LIFETIME

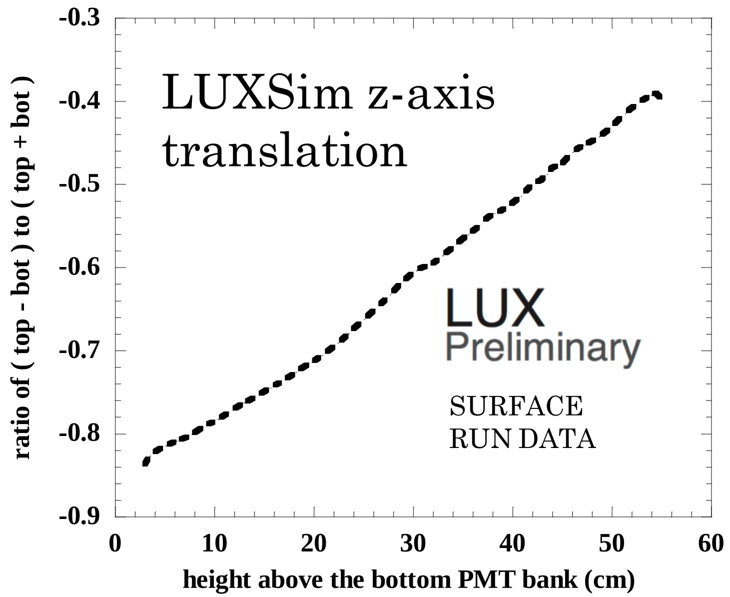


Simulation described in Akerib et al., "**LUXSim: A component-centric approach to low-background simulations**", Nuclear Instruments and Methods in Physics Research A (675) (2012) p.63-77.

Radon-222 Alphas

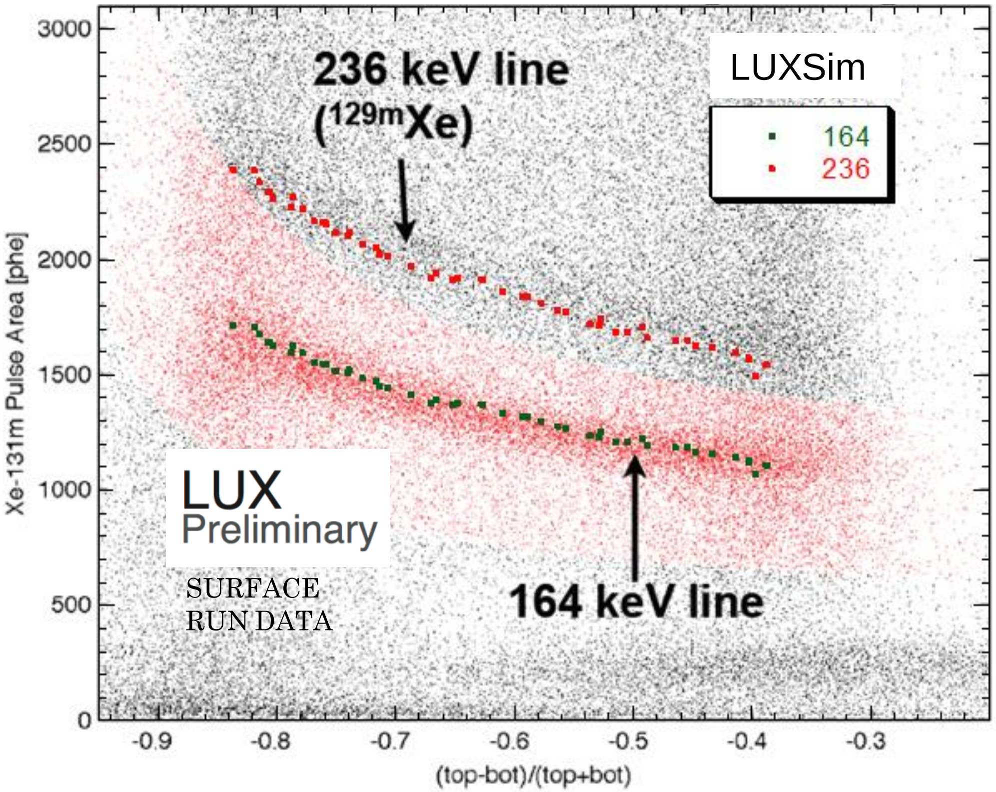
- Isotropic internal source of scintillation
- The top-bottom asymmetry is used as the height variable
- "LUXSim" is the comprehensive Geant4-based LUX simulation package, with NEST
- See Carlos H. Faham's LUX talk for more α info….





Xenon Activation Lines

- Natural Xe gets cosmogenically activated and produces Xe-129m and Xe-131m and thus provides another isotropic internal source
- Same behavior as radon alphas
- Average yield exceeds 8 phe/keVee (*10*+ at bottom of the detector!)

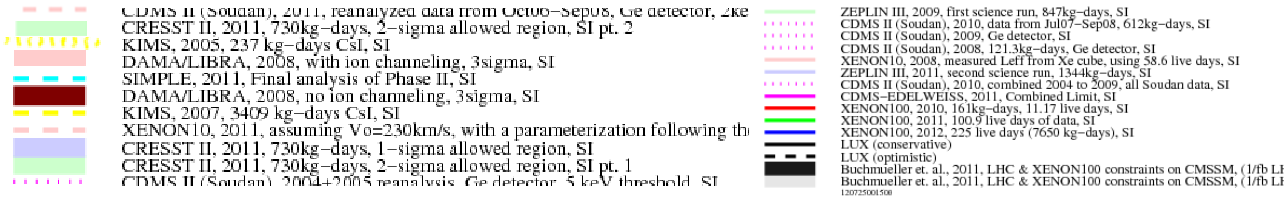


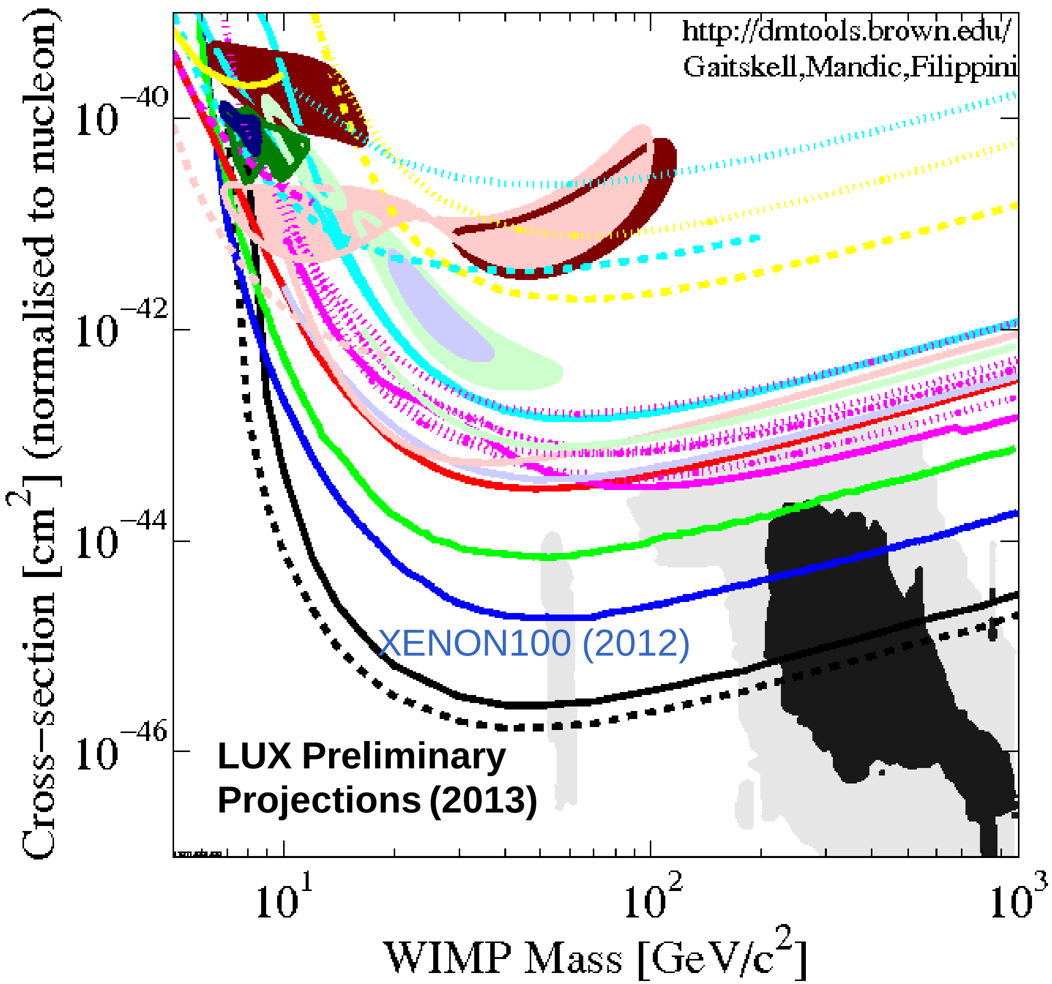
(similar axis translation as from previous slide)

Consequences

- The high light yield of LUX bodes well for the dark matter result to be achieved underground, especially in terms of low-mass WIMPs
- We present limit projections here with differing assumptions, based on the surface data
  - 15% and 20% overall photon collection efficiencies, the former realistic and conservative, and the latter optimistic but still realistic, and 30,000 kg-days
  - 50% nuclear recoil acceptance window for log(S2/S1) (60% for the optimistic case) and 1 kV/cm field
  - A WIMP search window of 3 phe (3.4 keVnr optimistic and 4.3 keVnr conservative) to 30/40 phe (held fixed at ~25 keVnr in each case)

LIMIT PROJECTIONS

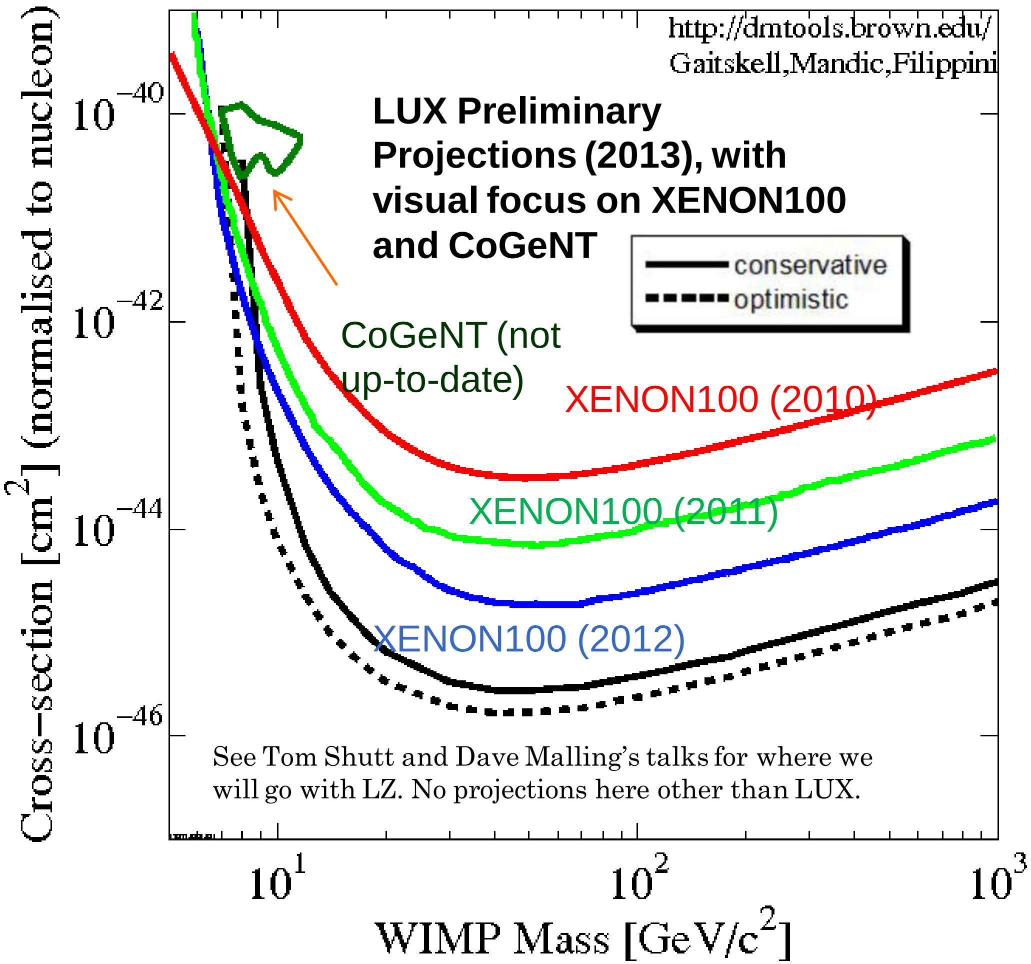




- We do not allow below-threshold fluctuations, effectively setting the scintillation efficiency to zero below the LUX threshold
- With this method we do not rely on understanding the efficiency below where data exists (3 keVnr)
- In the optimistic scenario, we exclude most of the CoGeNT region, but in a less controversial fashion perhaps

Note: XENON100 WIMP limit, light yield, and threshold from **Aprile, Dark Attack 2012** and/or **Melgarejo, IDM 2012**

Limit Projections

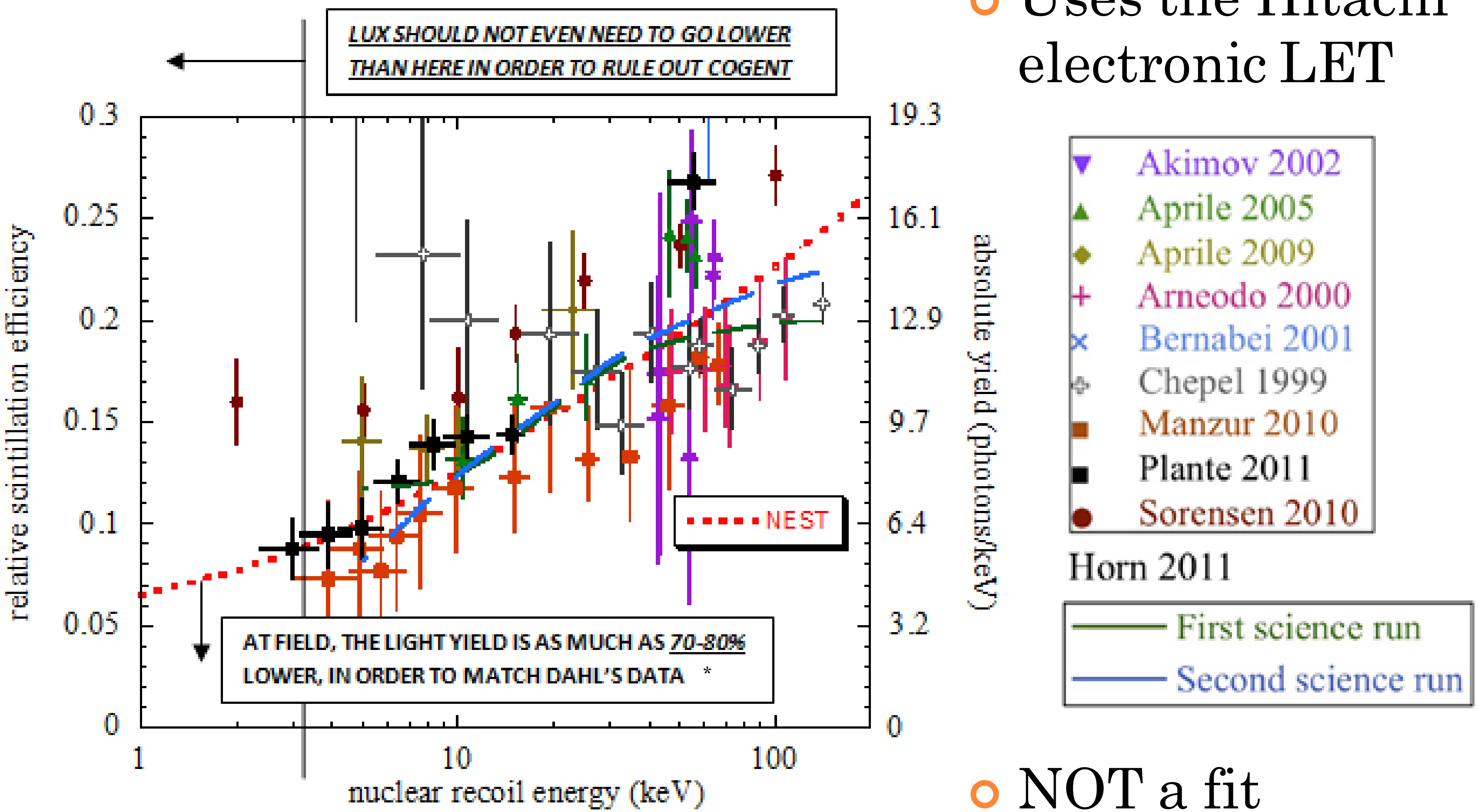


XENON100 WIMP limit, light yield, and threshold from **Aprile, Dark Attack 2012** and/or **Melgarejo, IDM 2012**

- We can do a similar analysis ("sub-threshold") to that of XENON100's but with a model (NEST) instead of an extrapolation (neither are shown here)
- We then have full sensitivity in the region favored by the CoGeNT experiment, but given the large low-E theoretical uncertainties, hard to go low until there is data (at field)
- We take an average light collection, ignoring the known improvement near the bottom PMTs

NEST (Noble Element Simulation Technique)

Szydagis et al., **NEST: A Comprehensive Model for Scintillation Yield in Liquid Xenon**, 2011 JINST 6 P10002; e-Print: arxiv:1106.1613 [physics.ins-det]

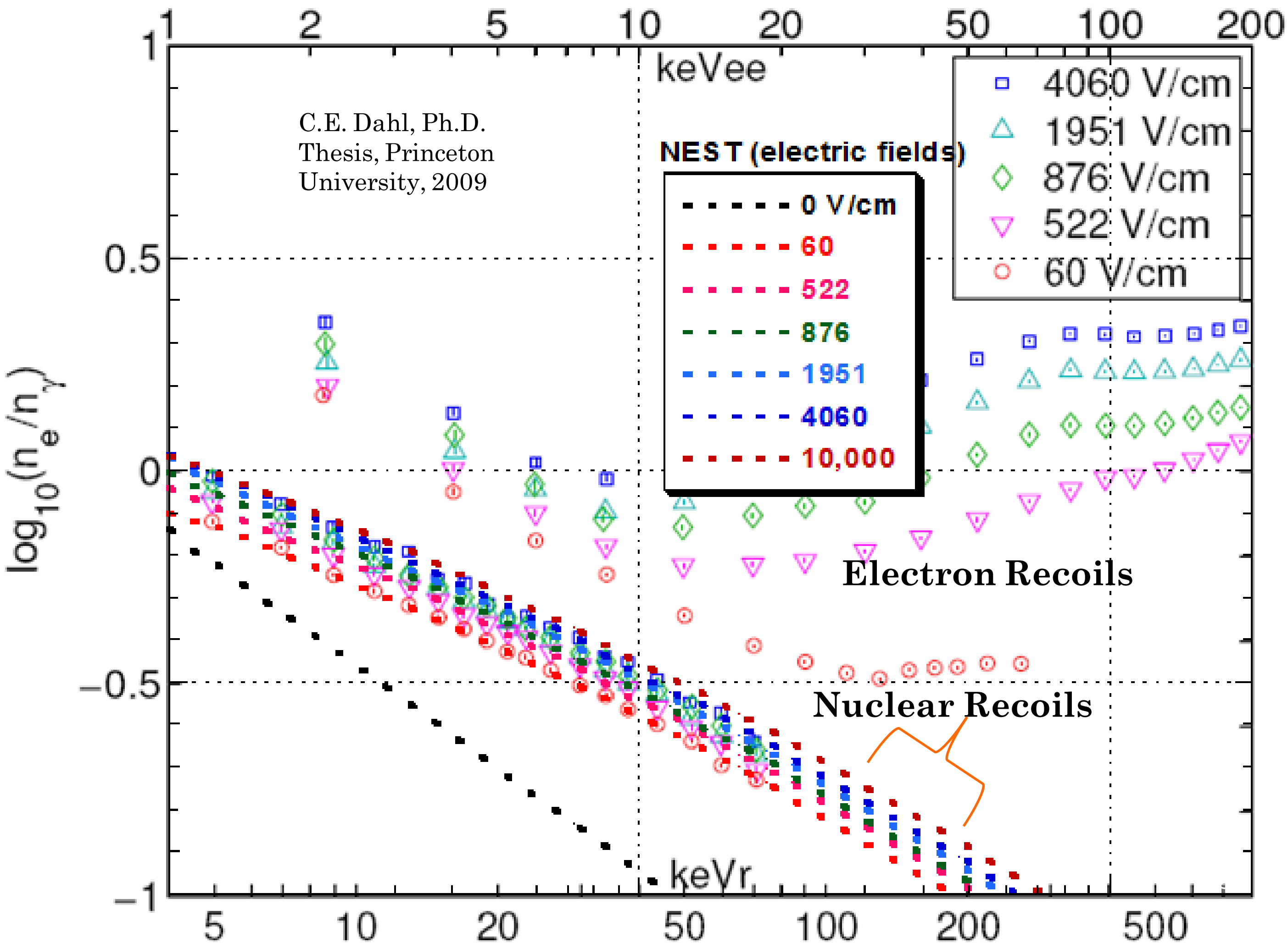


- Uses the Hitachi electronic LET
- NOT a fit

* C.E. Dahl, Ph.D. Thesis, Princeton University, 2009. Paper in preparation…

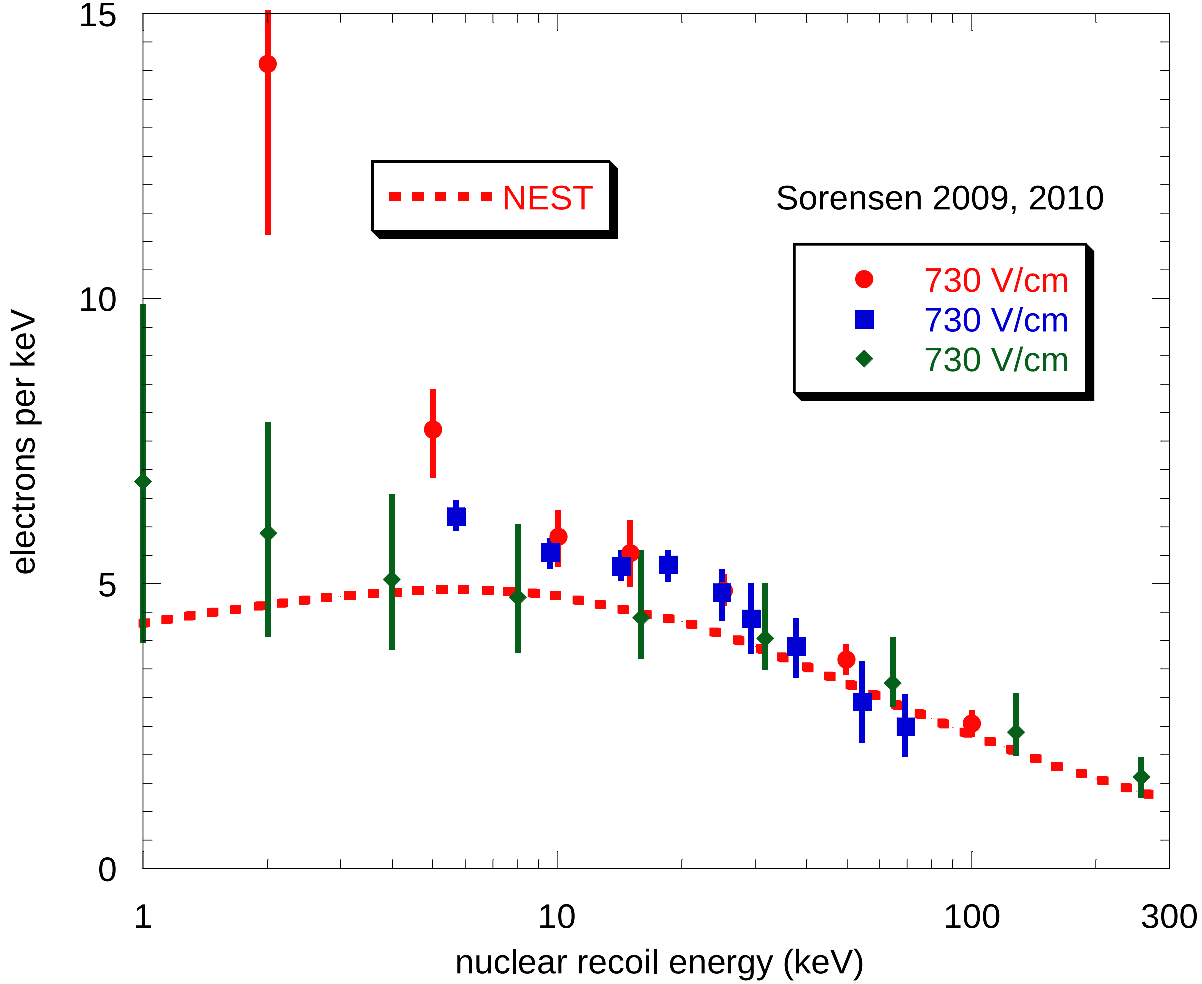
Light and Charge Yields

- By trying to match both non-zero and zero field data with one model one is forced to have a large LY decrease
- So, not true there is no data, but there is uncertainty: need in-situ zero and non-zero field calibration at low energies



keVnr energy scale assumes old L = 0.25: using Hitachi, 5 keVnr point is actually 8.67 and 70 keVnr point is 85.5

CHARGE YIELD (Q_Y) MODEL



P. Sorensen et al., Lowering the low-energy threshold of xenon detectors, PoS (IDM2010)017 [arXiv:1011.6439].

- Just an illustration
- Not fit to the data shown (all from XENON10), but a post-diction based on fits to the data from previous slide
- Excellent description of the latest understanding of the data (green) in the WIMP search region

Summary and Conclusions

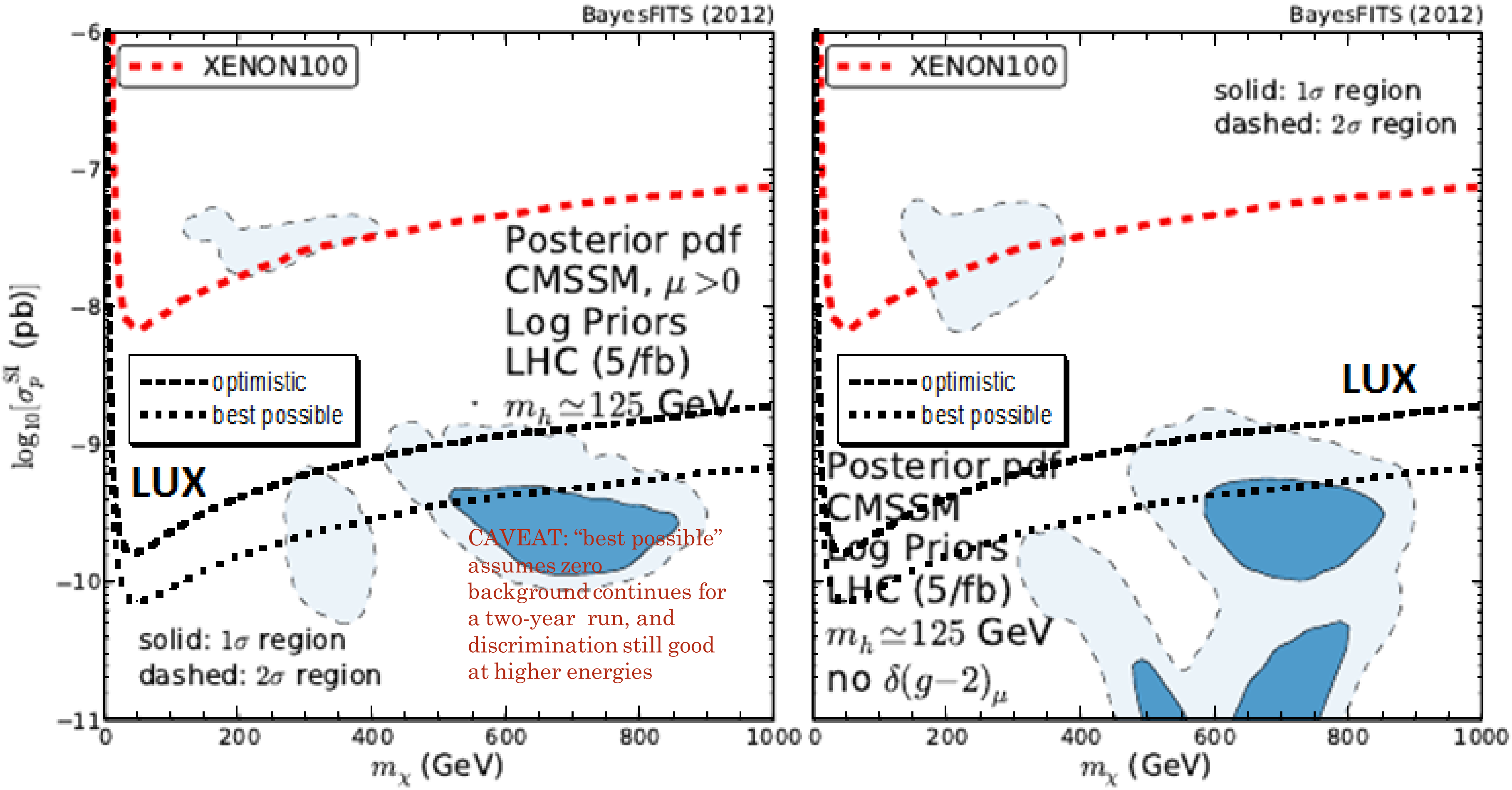
- LUX has achieved a higher light yield than in XENON100 (~6 phe/keVee at 122 keV, field-adjusted for 500 V/cm *which is not necessarily the LUX field*, versus 2.28 phe/keVee*), even without completion of xenon purification
- Consequently, LUX should be able to achieve a nuclear recoil threshold significantly lower than that of XENON100 (~3-4 keVnr vs. ~6.6 keVnr*, but note different assumptions) even with no further improvement, with respect to the surface run purity achievement
- LUX may be able to exclude CoGeNT without relying on $\mathcal{L}_{eff}$ extrapolation or modeling outside of the energy range where data exists

*XENON100 WIMP limit, light yield, and threshold from **Aprile, Dark Attack 2012** and/or **Melgarejo, IDM 2012**

Slide Reserve

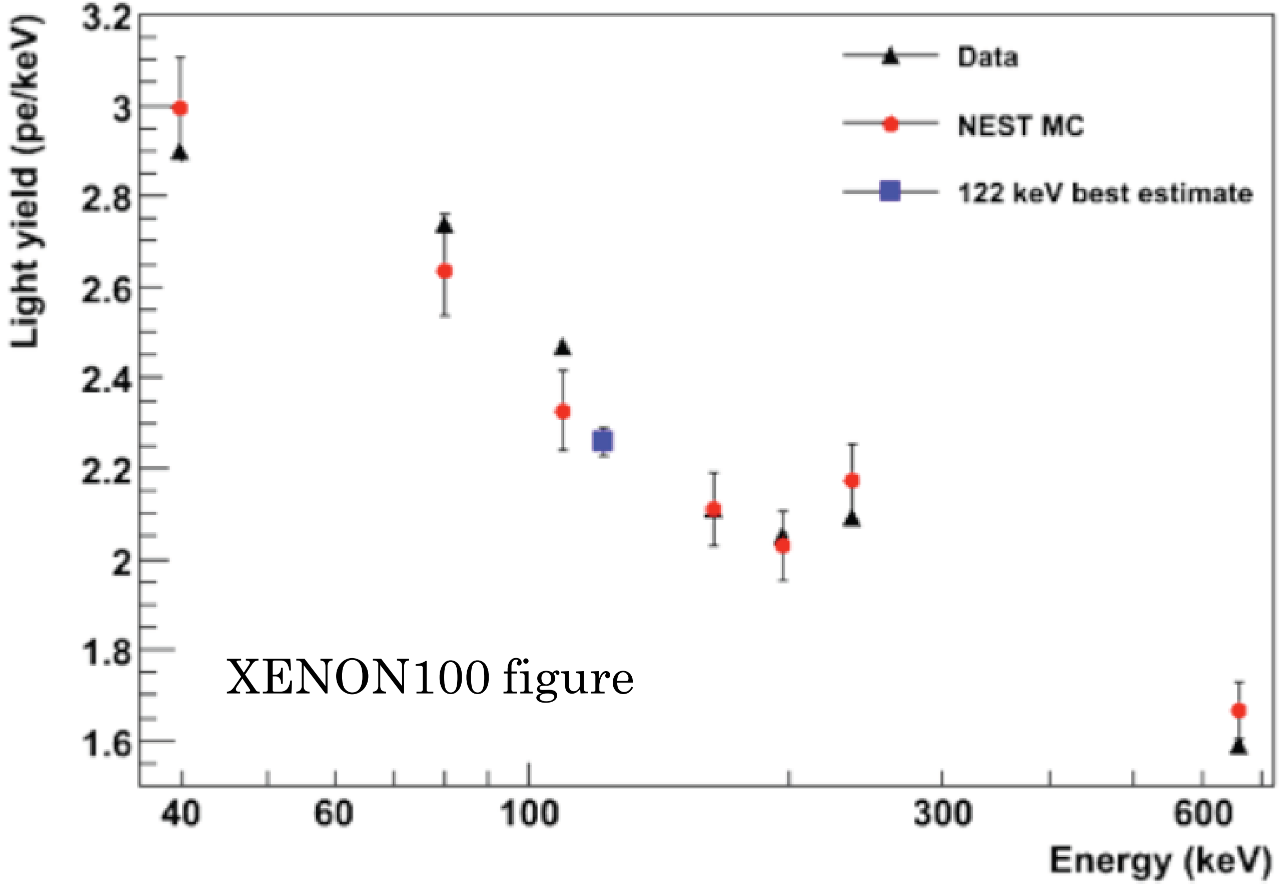
Comparison With LHC

LUX "best possible" is 2 years of running, with a WIMP window upper limit of 50 keVnr



Fowlie et al. 2012

NEST WORKS!



Light yield for different gamma lines