

# Giving up S2/S1 discrimination in exchange for a lower energy threshold

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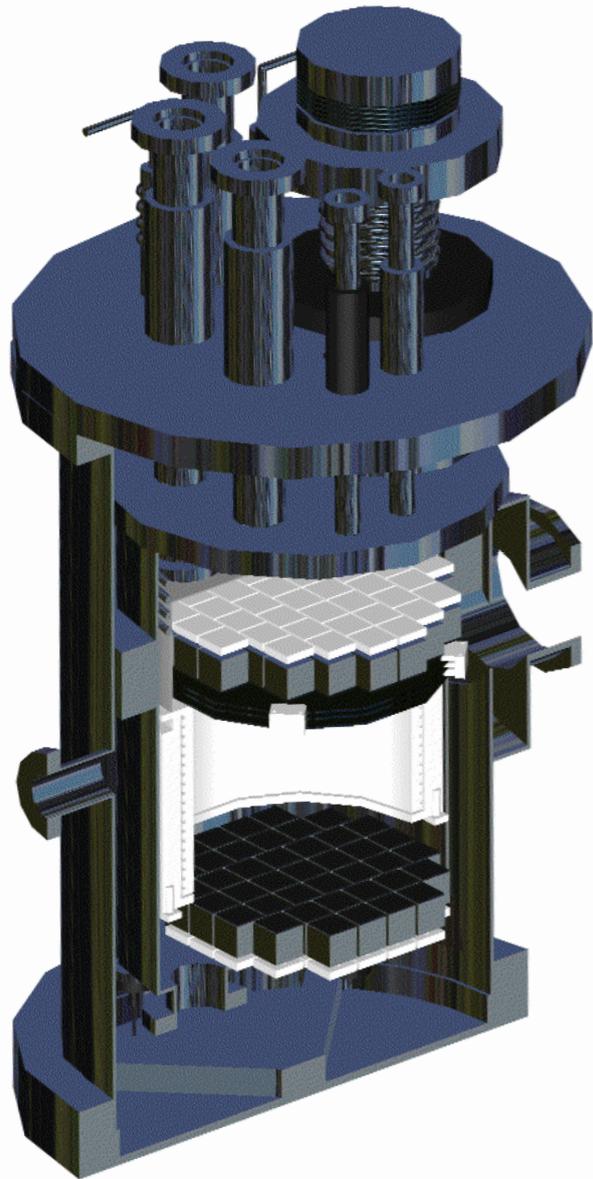
Peter Sorensen

*on behalf of the XENON10 Collaboration*

*Identification of Dark Matter 2010, Montpellier*

## Talk Overview

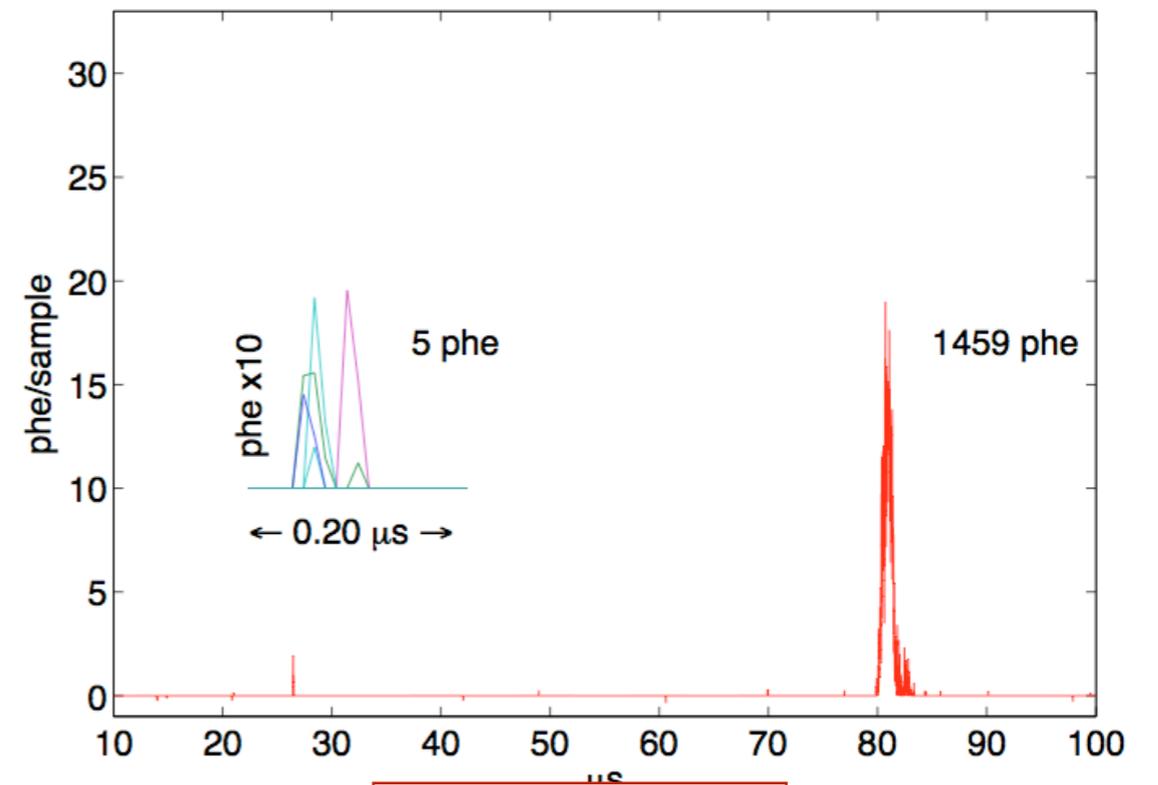
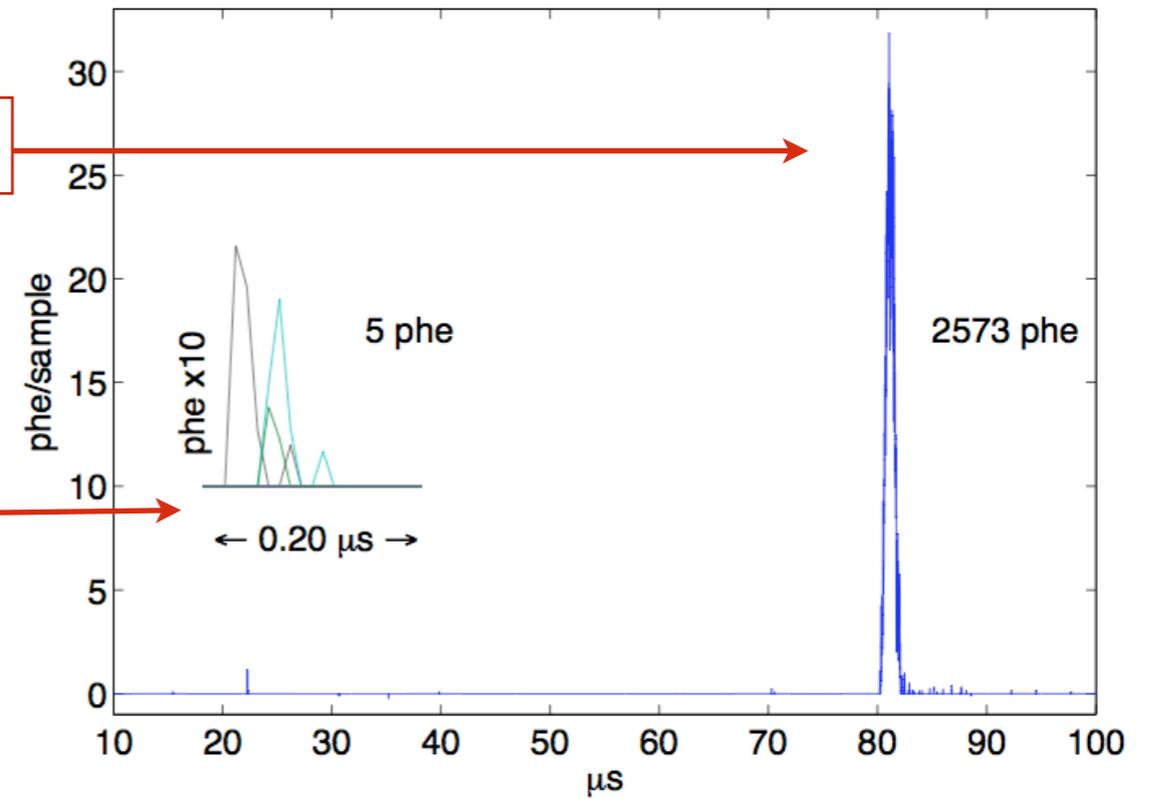
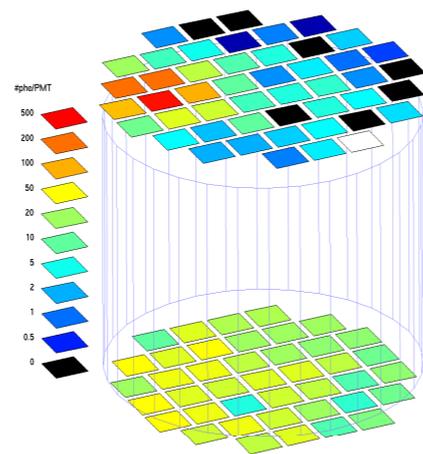
- the XENON10 direct detection experiment
- limitations of S1 (scintillation signal) threshold
- new analysis of S2 (electron signal) energy scale
- using S2 width to obtain approximate z coordinate
- S2-only (no discrimination) dark matter limits



S2: secondary scintillation

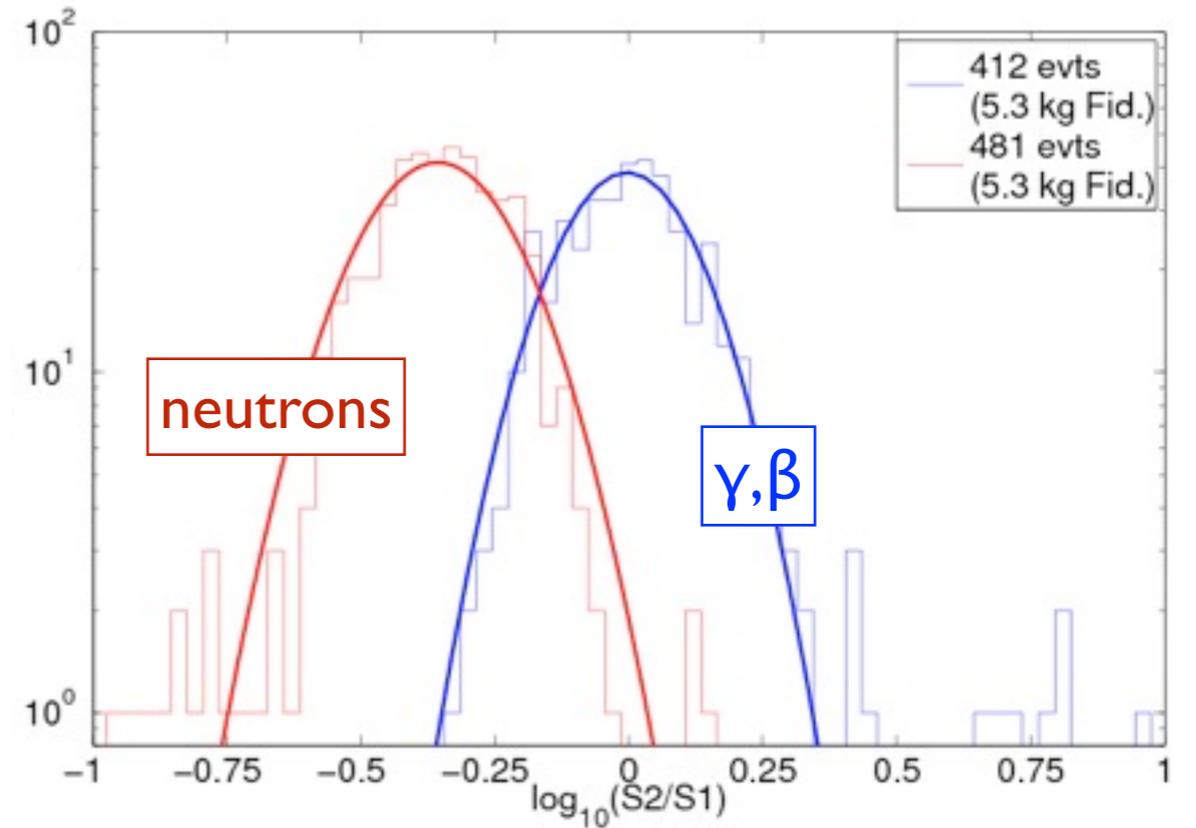
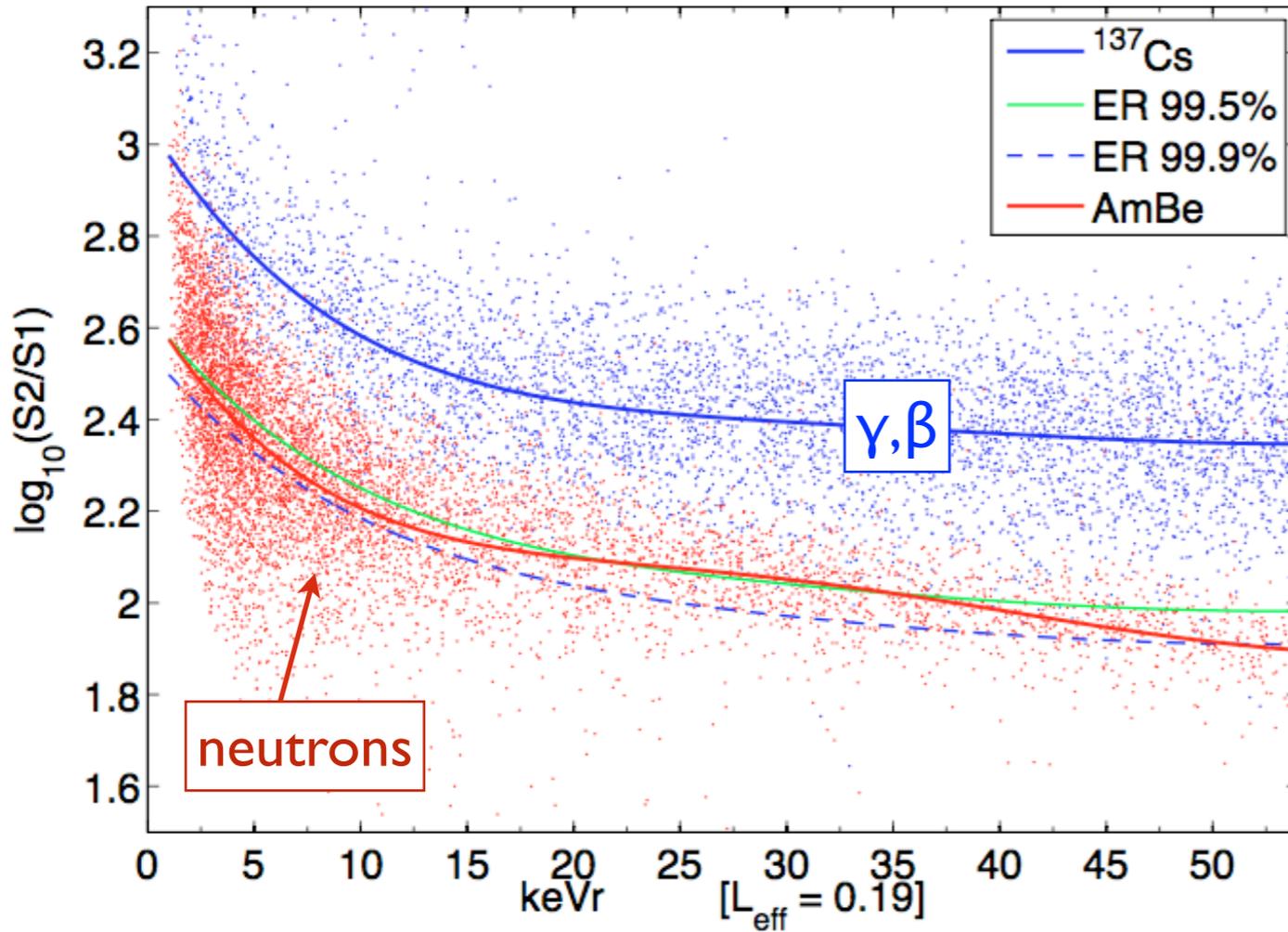
S1: primary scintillation

S2 hit pattern gives (x,y)



$t_{s2} - t_{s1}$  gives z

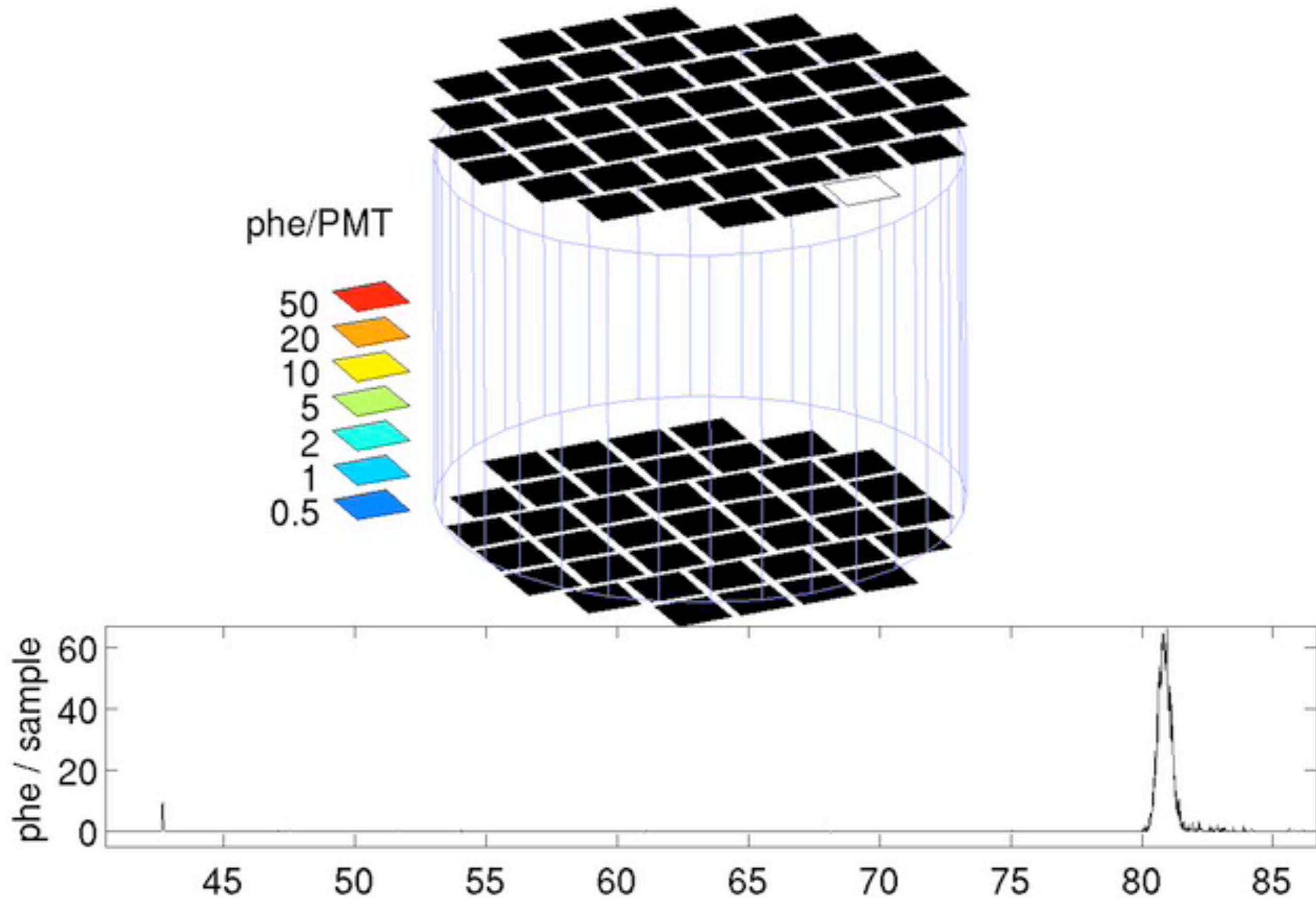
# Discrimination (old news)



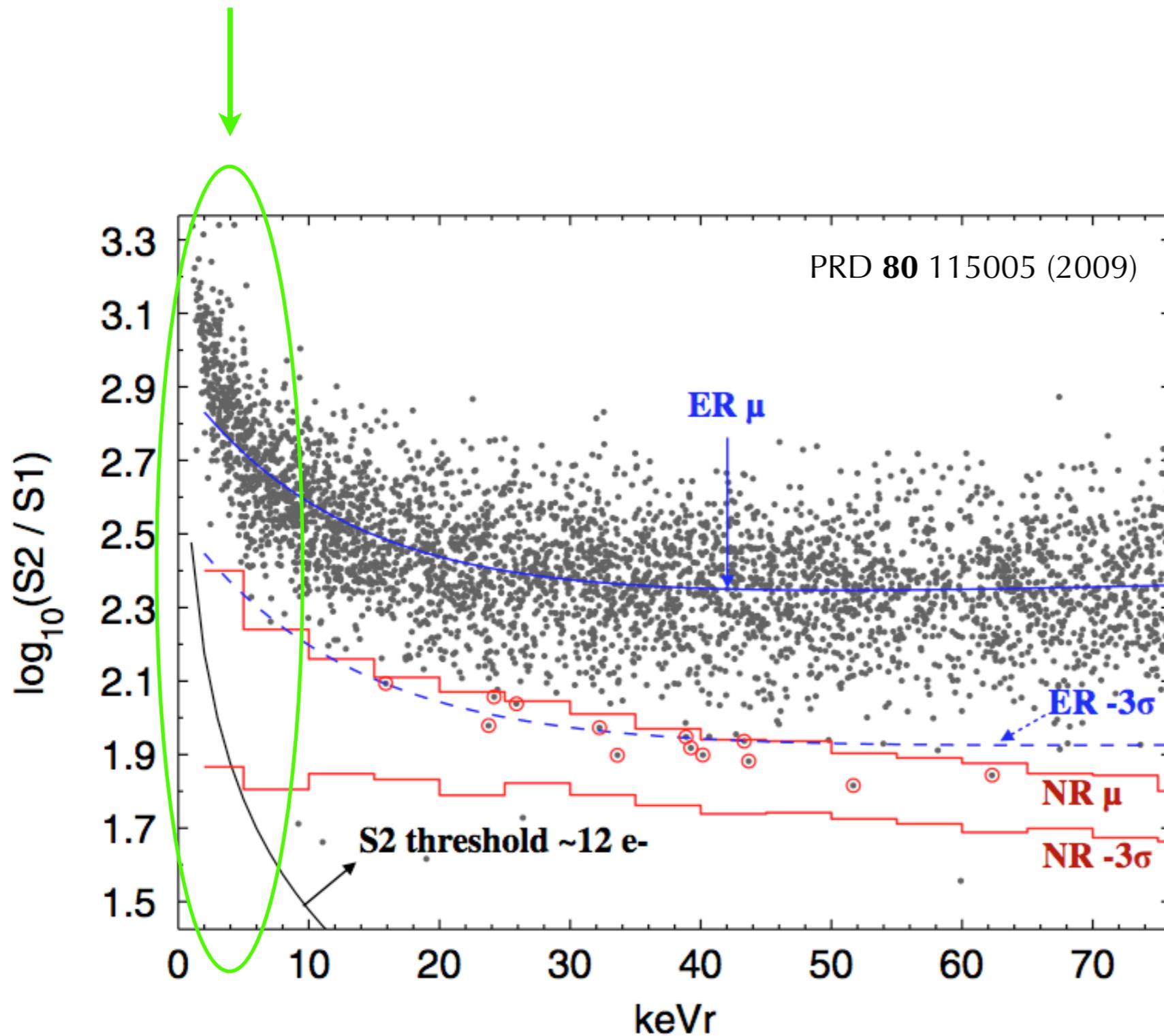
Sorensen PhD Thesis (2008)

# a XENON10 event in slow-motion

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# S1 determines threshold



“...incorporating the S2 threshold, resulting in an energy-dependent acceptance at low energies ... is complicated.”

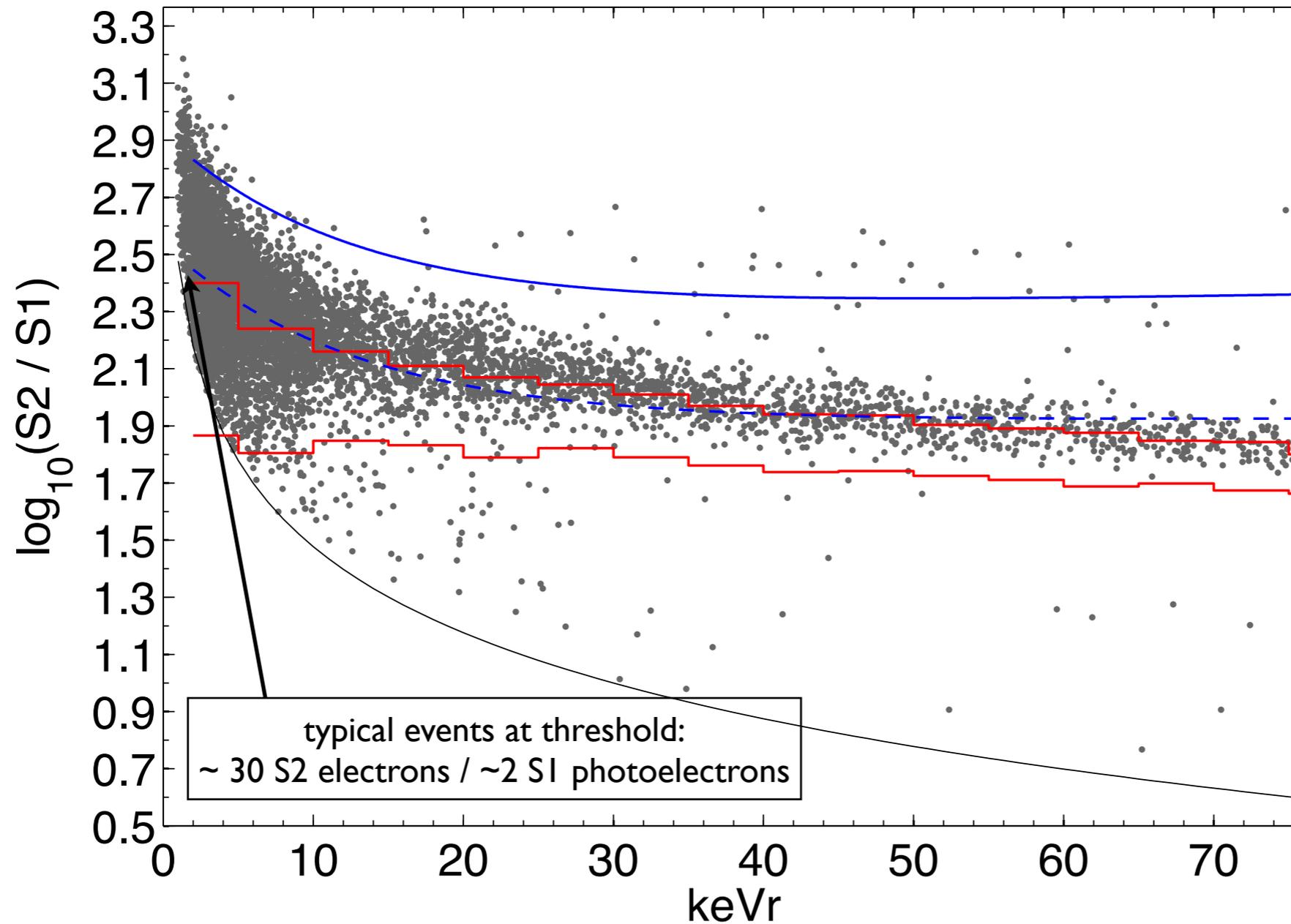
-- M Kuhlen, N Weiner et al. JCAP02 (2010) 030

**TRUE... but for a clear account see arxiv: 1007.3549**

reminder: keVr = phe in this case, i.e. assumption that  $L_{\text{eff}}=0.19$

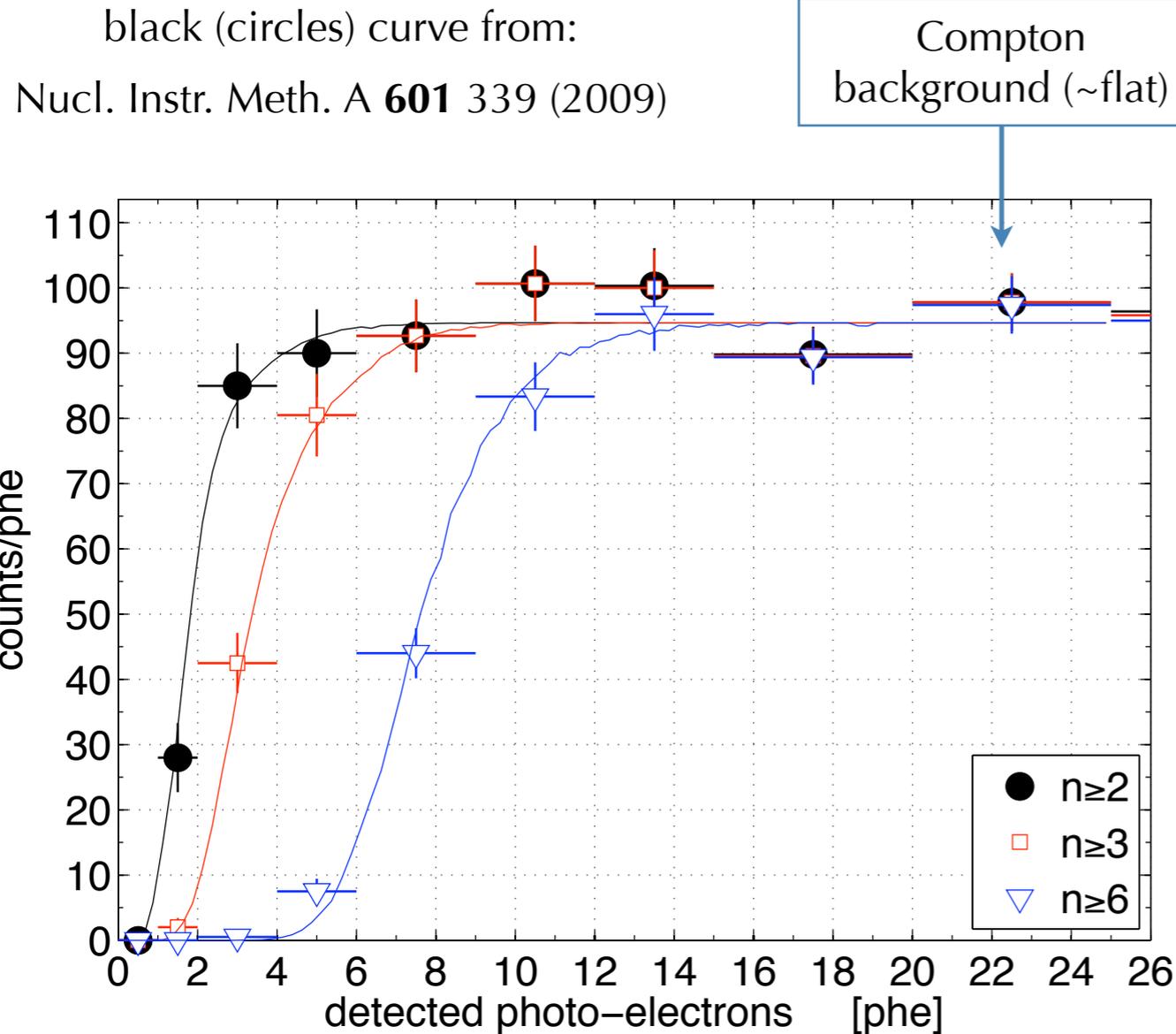
# Nuclear recoils from AmBe neutrons

5.4 kg fiducial target

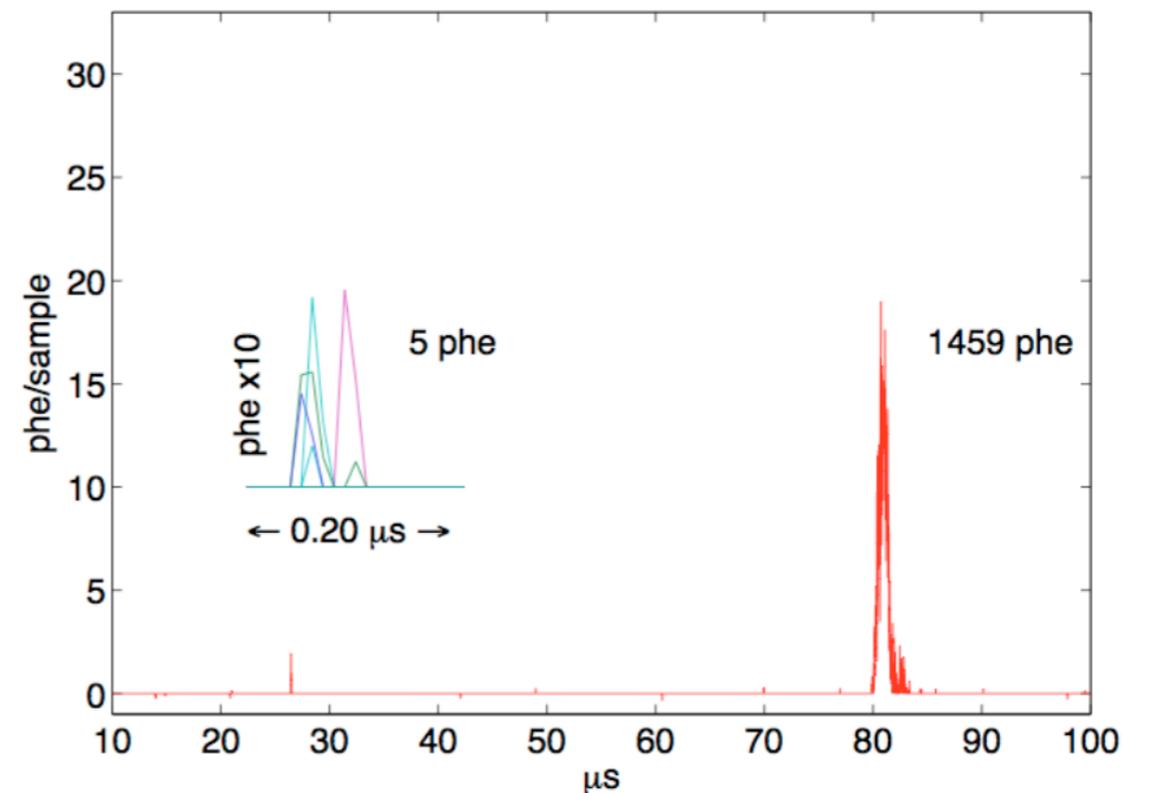


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# S1 detection efficiency in XENON10



- we measure 7 eV photons (175 nm)
- roughly 10% total detection efficiency for scintillation photon => PMT photo-electron
- require n-fold PMT coincidence :
  - XENON10:  $n > 1$
  - ZEPLIN III:  $n > 2$
- efficiency predicted by Poisson stats. in PMT photo-electrons (simulation)



*S1 detection limits threshold...  
what about S2?*

# Single electron pulses $\sim 25$ phe

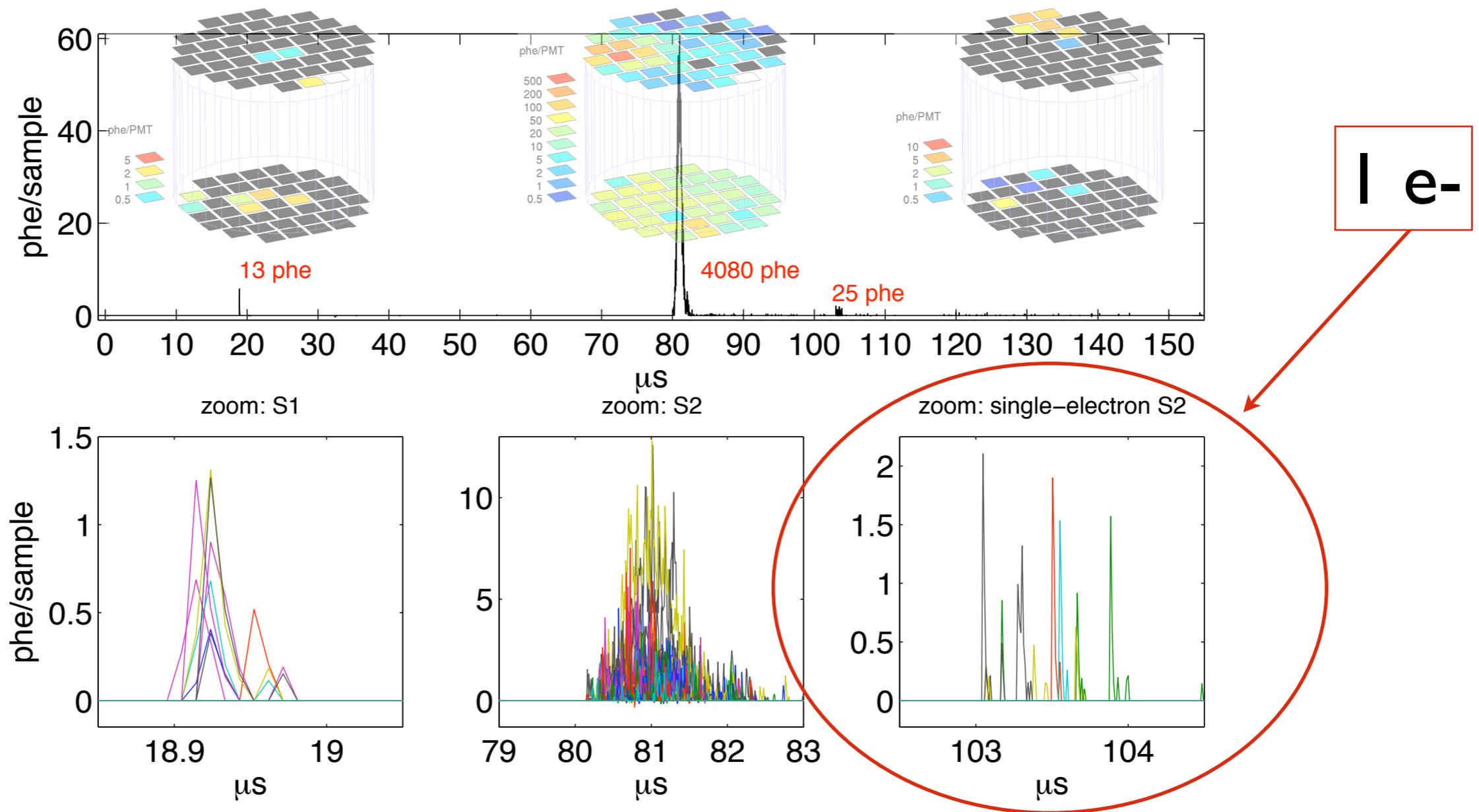
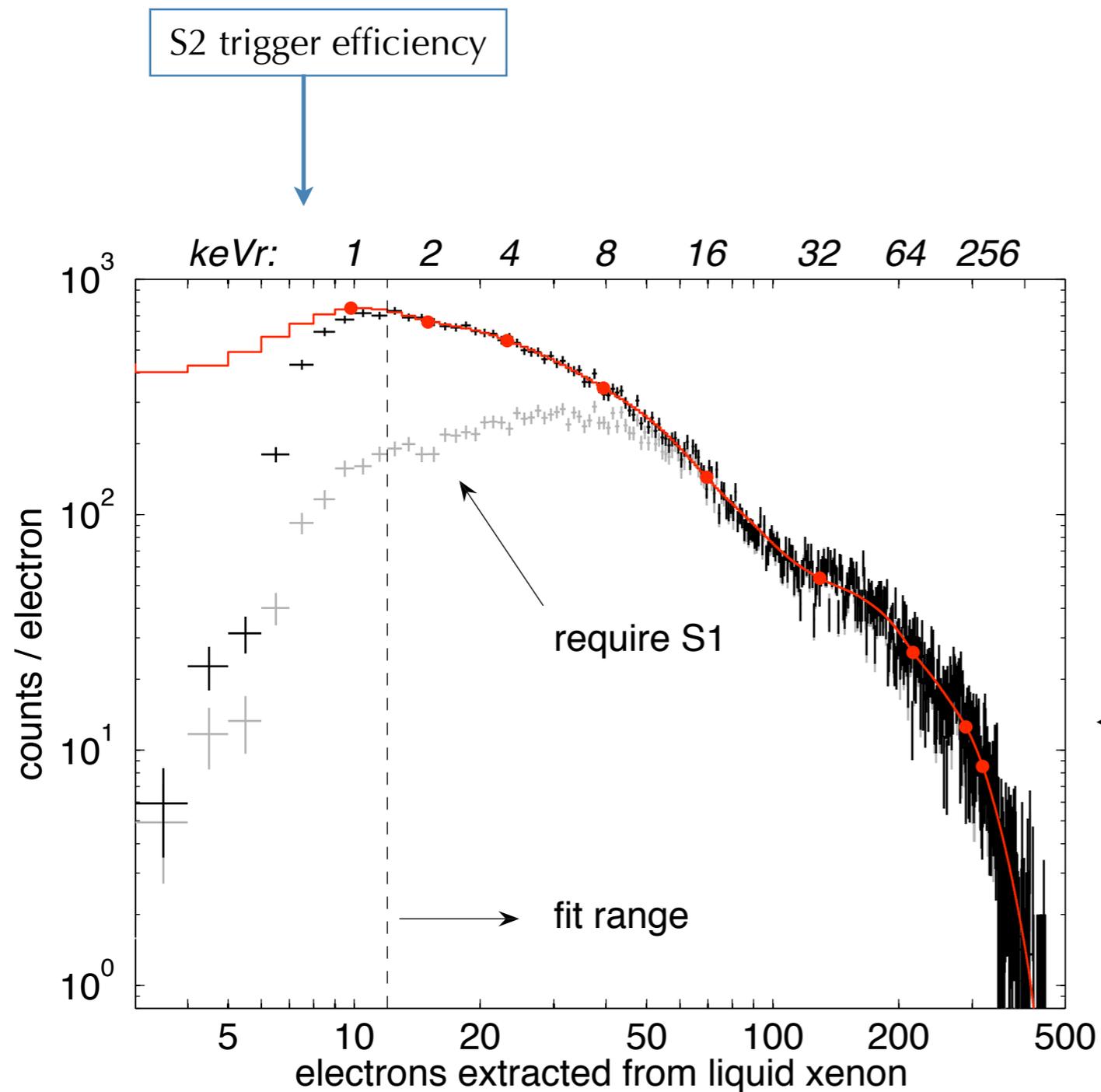


Figure 4.6: The summed event record for a typical  $\sim 4$  keVee background  $\gamma$  scatter, showing a  $61 \mu\text{s}$  drift time between  $S1$  and  $S2$ , and also an isolated  $25$  phe single-electron  $S2$  pulse at  $103 \mu\text{s}$ . The primary  $S2$  pulse (at  $80 \mu\text{s}$ ) triggered the DAQ in this event, however the  $S2$  trigger was sensitive to single-electron  $S2$  pulses as small as  $\sim 10$  phe (see Fig. ??). The PMT hit-patterns are indicated for each pulse; the lower subplots show a zoom (and PMT hits on individual channels) on each pulse.

100

# Recent work on S2 calibration



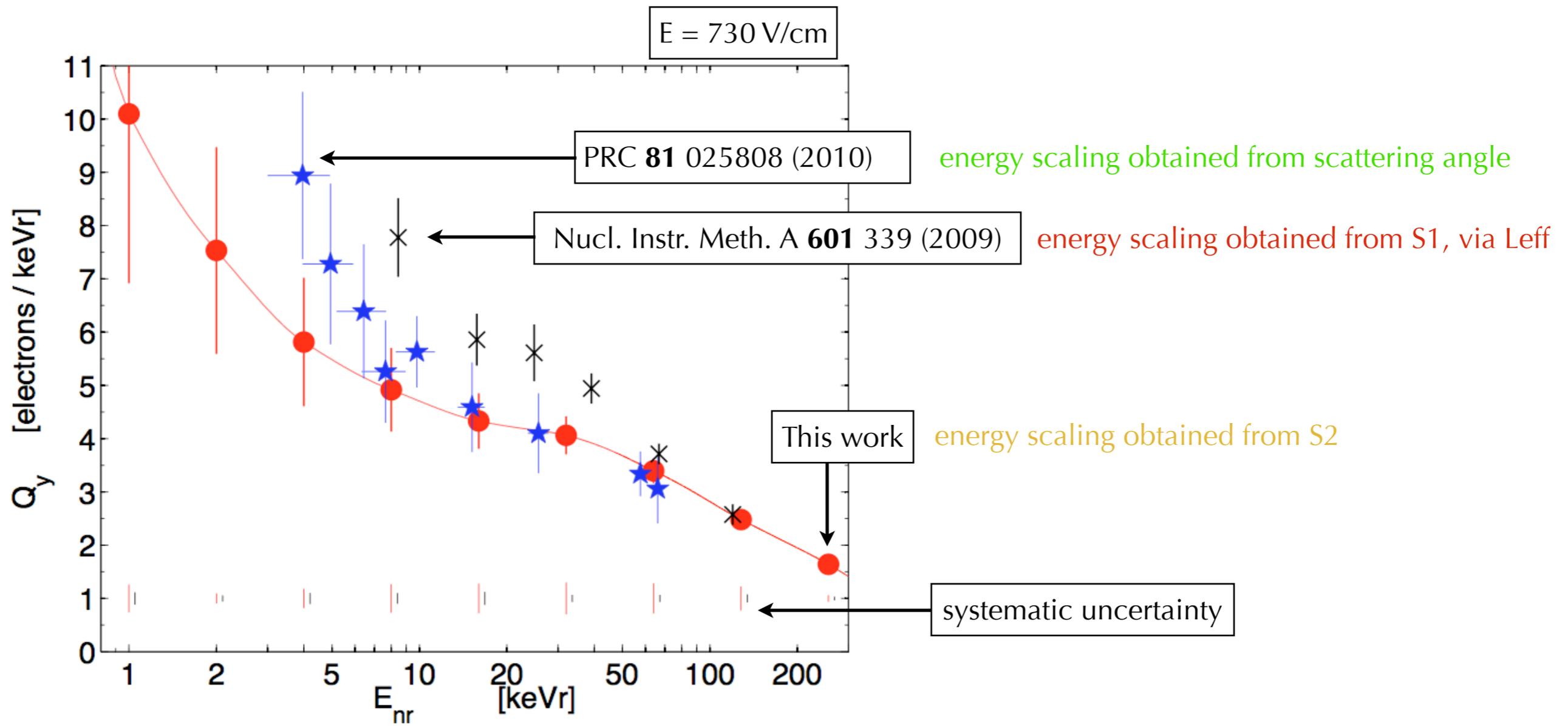
from XENON10 neutron calibration (AmBe).  
The calibration, analysis, etc already described  
in (with focus on S1 signal):

Nucl. Instr. Meth. A **601** 339 (2009)

S2 (electron) response to nuclear recoils,  
rather than S1 (scintillation) response

S2 energy resolution assumed  
Poisson in number of electrons

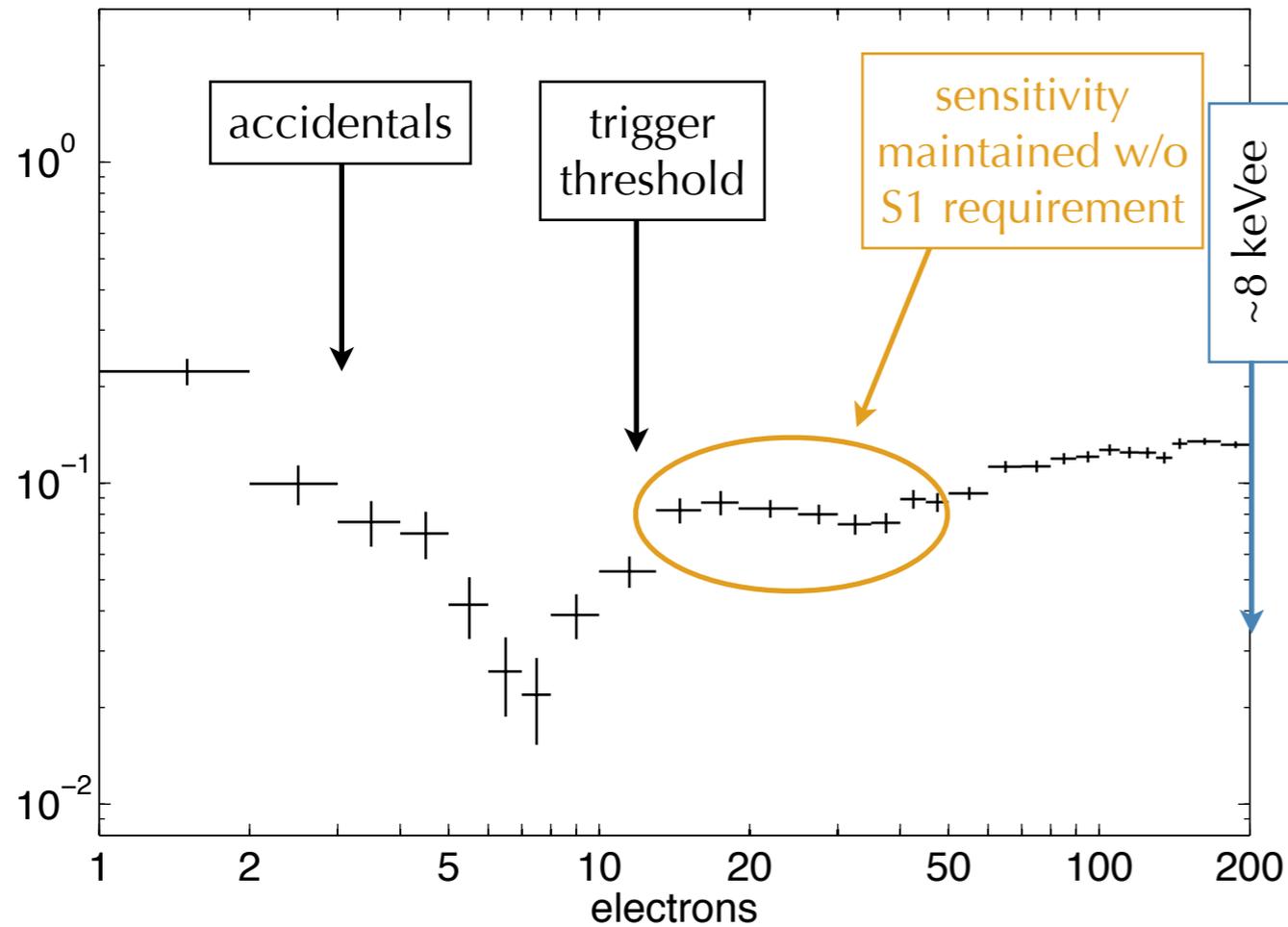
# Result of monte carlo best fit



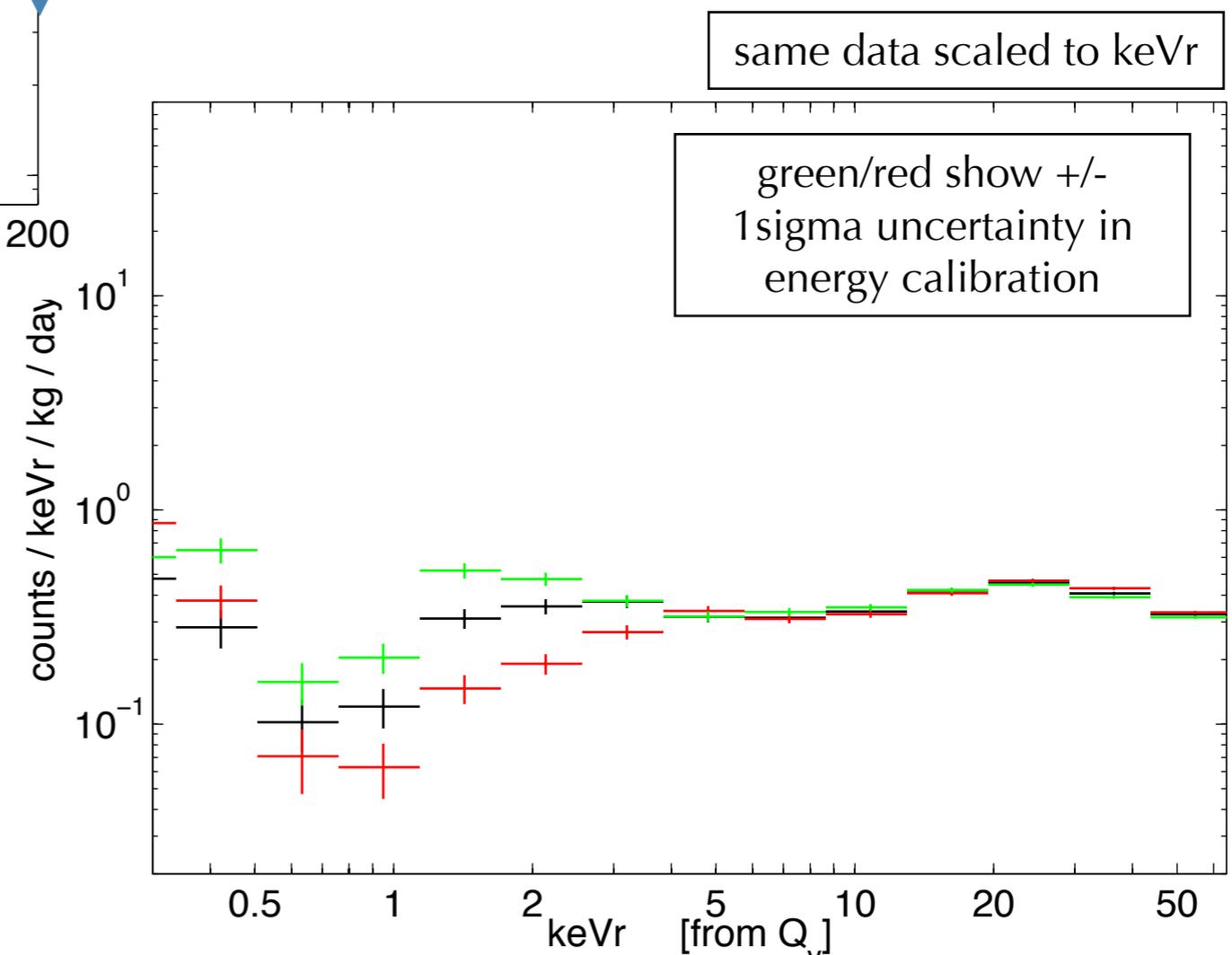
The  $Q_y$  curve allows us to assign a keVr value to every event, based on its S2

NOTE: conservative  $1\sigma$  stat. uncertainties given by  $\sqrt{N_e}$

# single-scatter Compton background in XENON10

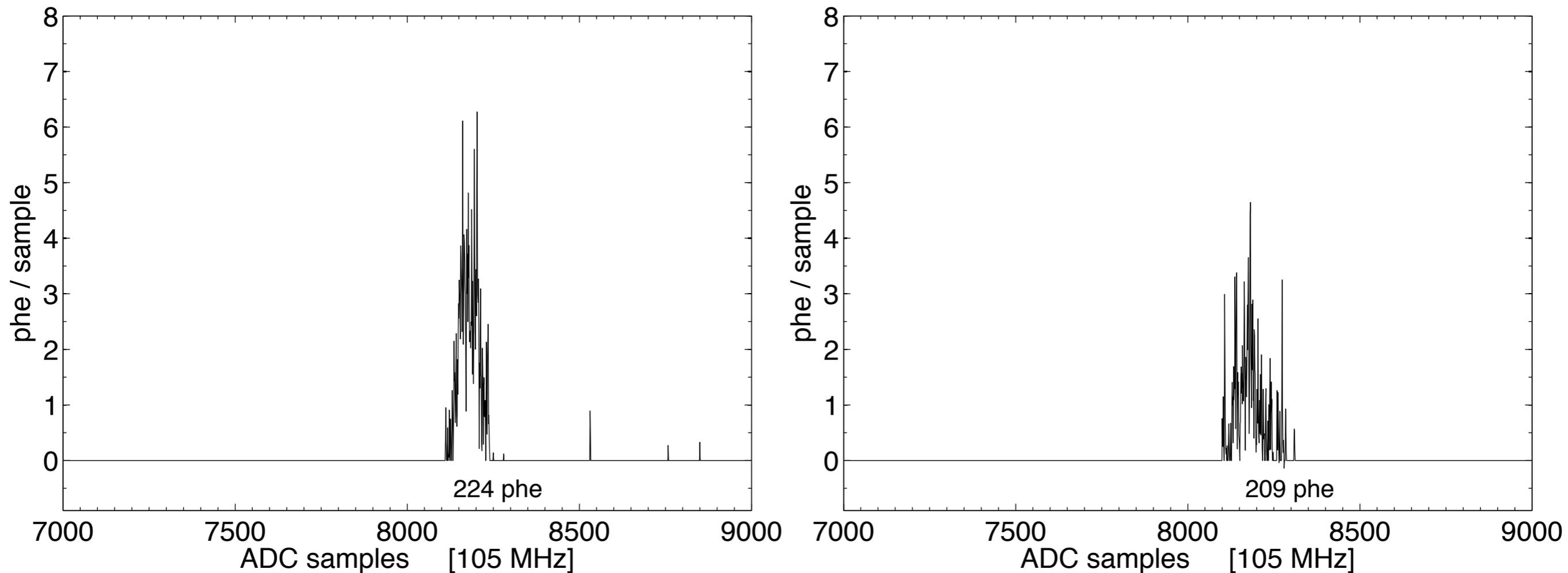


same data as previously reported in  
 PRD **80** 115005 (2009)  
 PRL **100** 021303 (2008)  
 except no S2/S1 discrimination  
 (hence Compton-dominated)



# Typical nuclear recoil events at threshold

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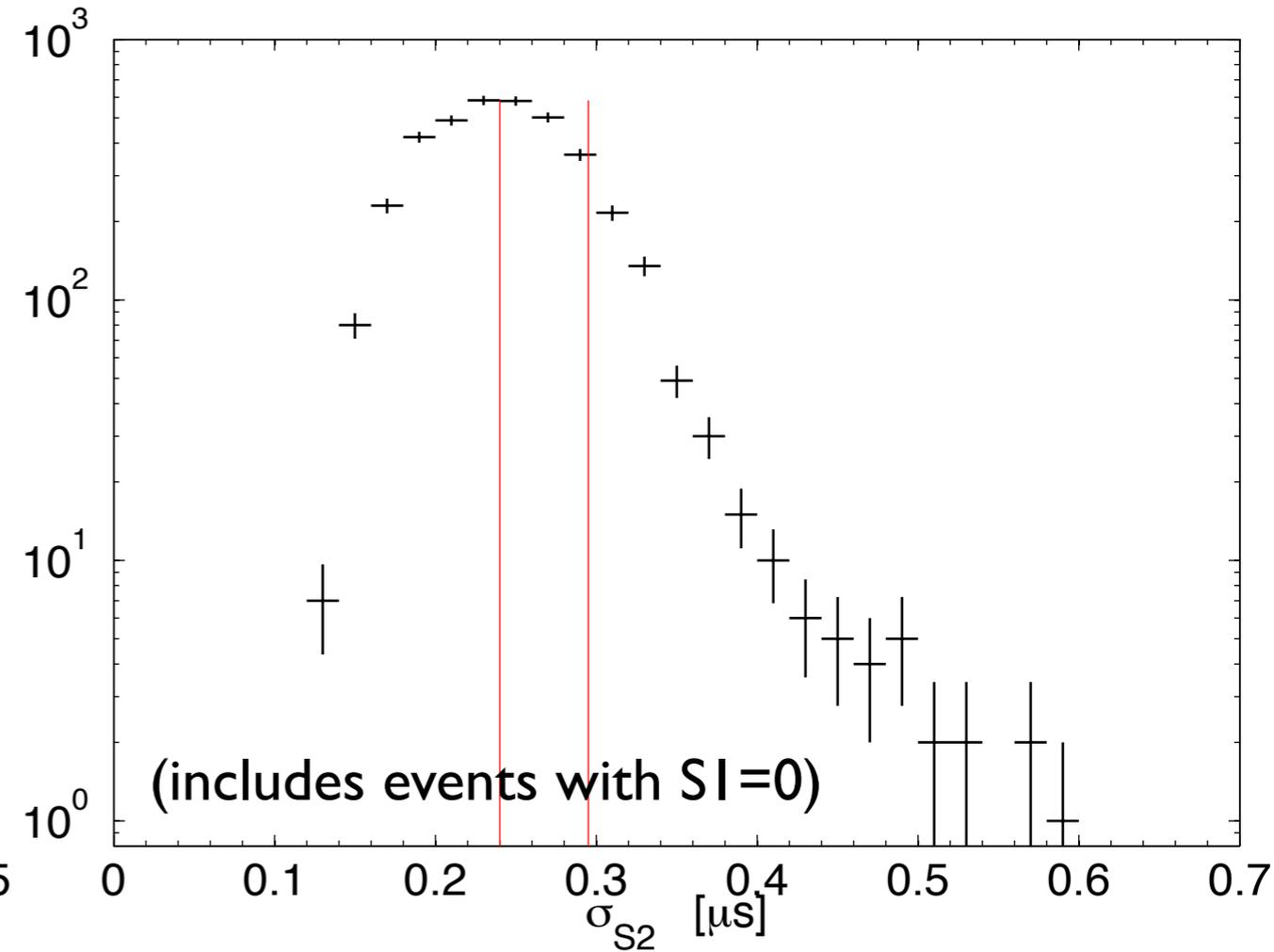
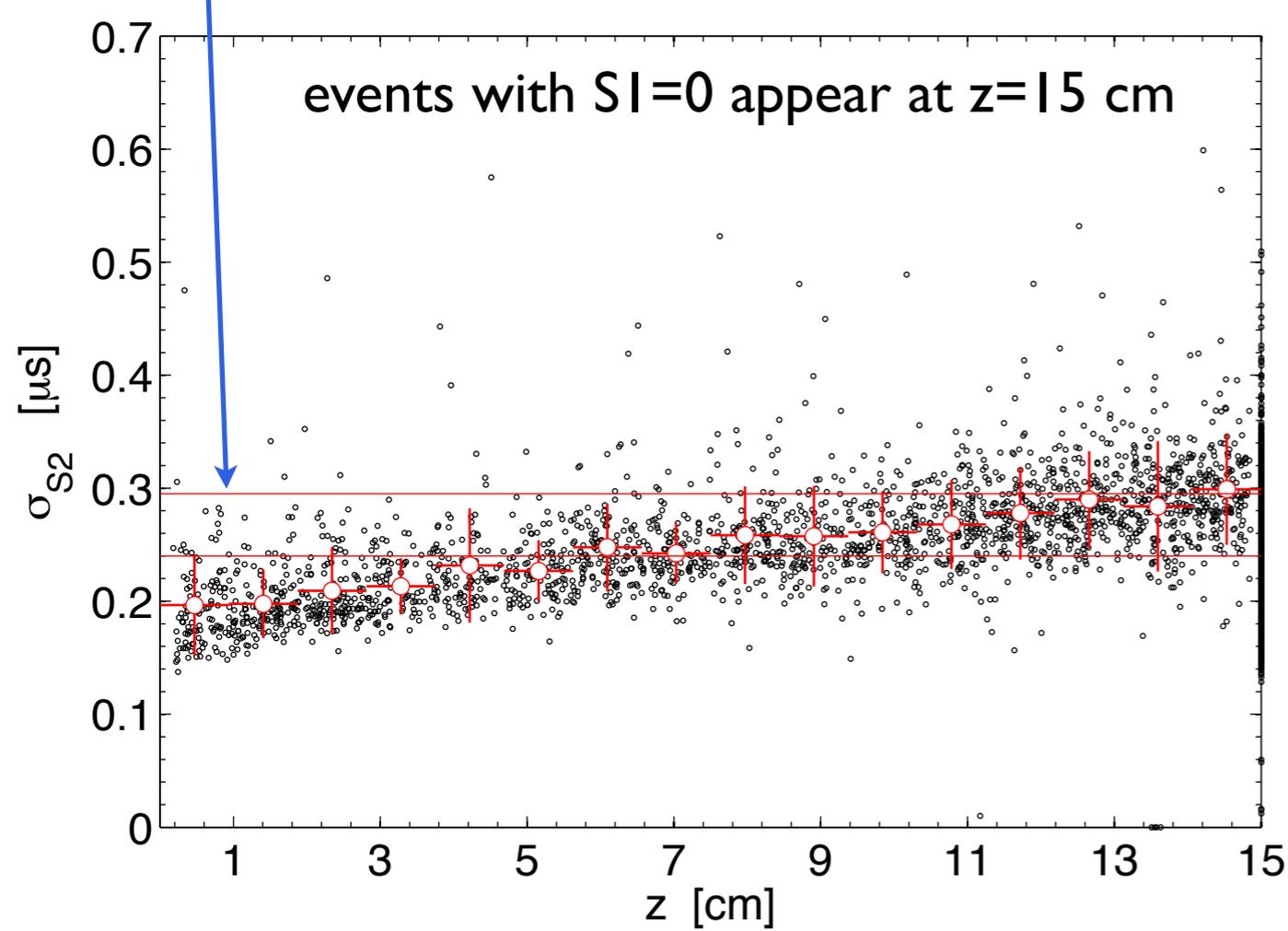
These are 9 electron (about 1 keVr) S2 single scatter nuclear recoils. Clean events, but no SI found.  
Note width variation (from electron diffusion)

# z fiducial cut from S2 width

neutron calibration data

7 < S2 < 100 electrons  
R < 3 cm (~1.2 kg)  
S2 width cut  $0.240 < \sigma_{S2} < 0.295 \mu\text{s}$   
(34% acceptance for NR)

S2 width cut selects events  
in middle/bottom of target  
(z cut with blurry edges)

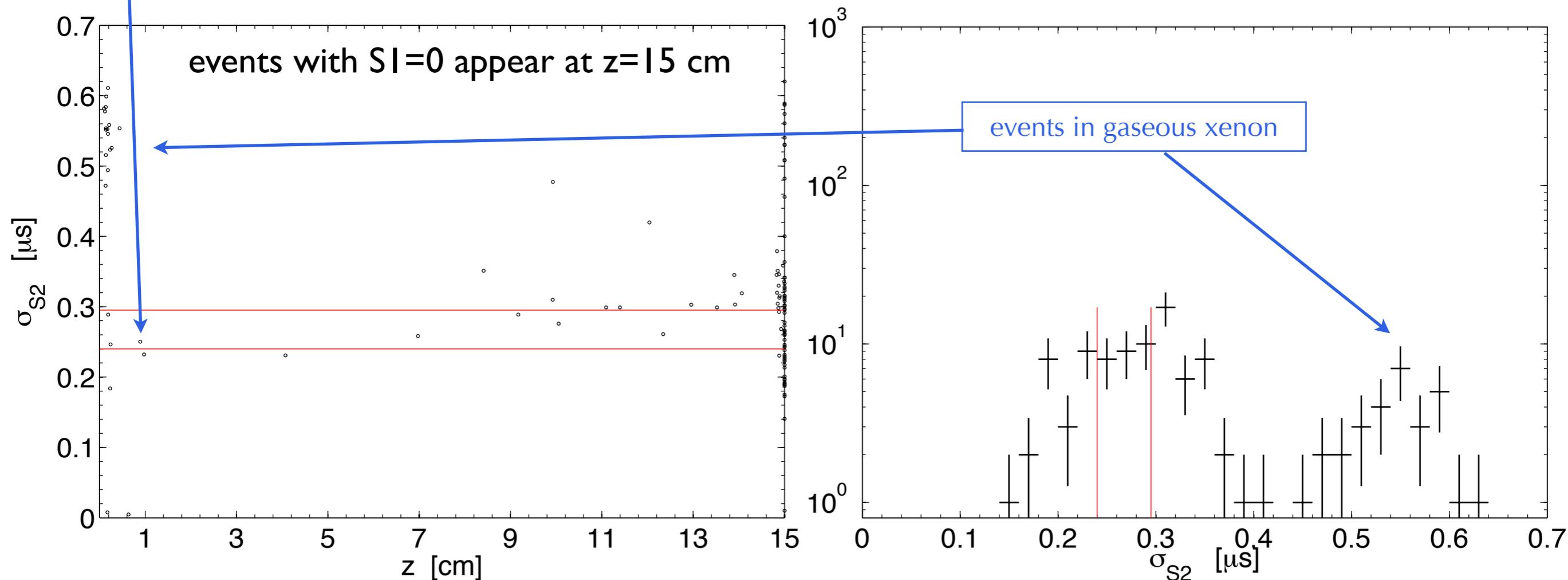


# z fiducial cut from S2 width

12.5 live days of "WS2" dark matter search data  
(Aug/Sept 2006, not blind, not published)

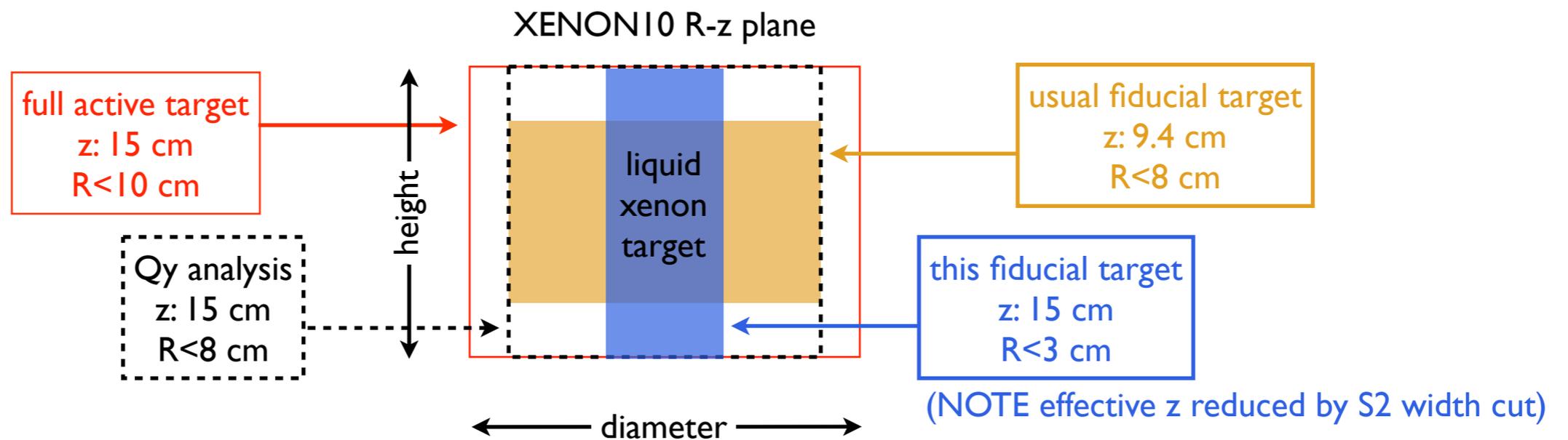
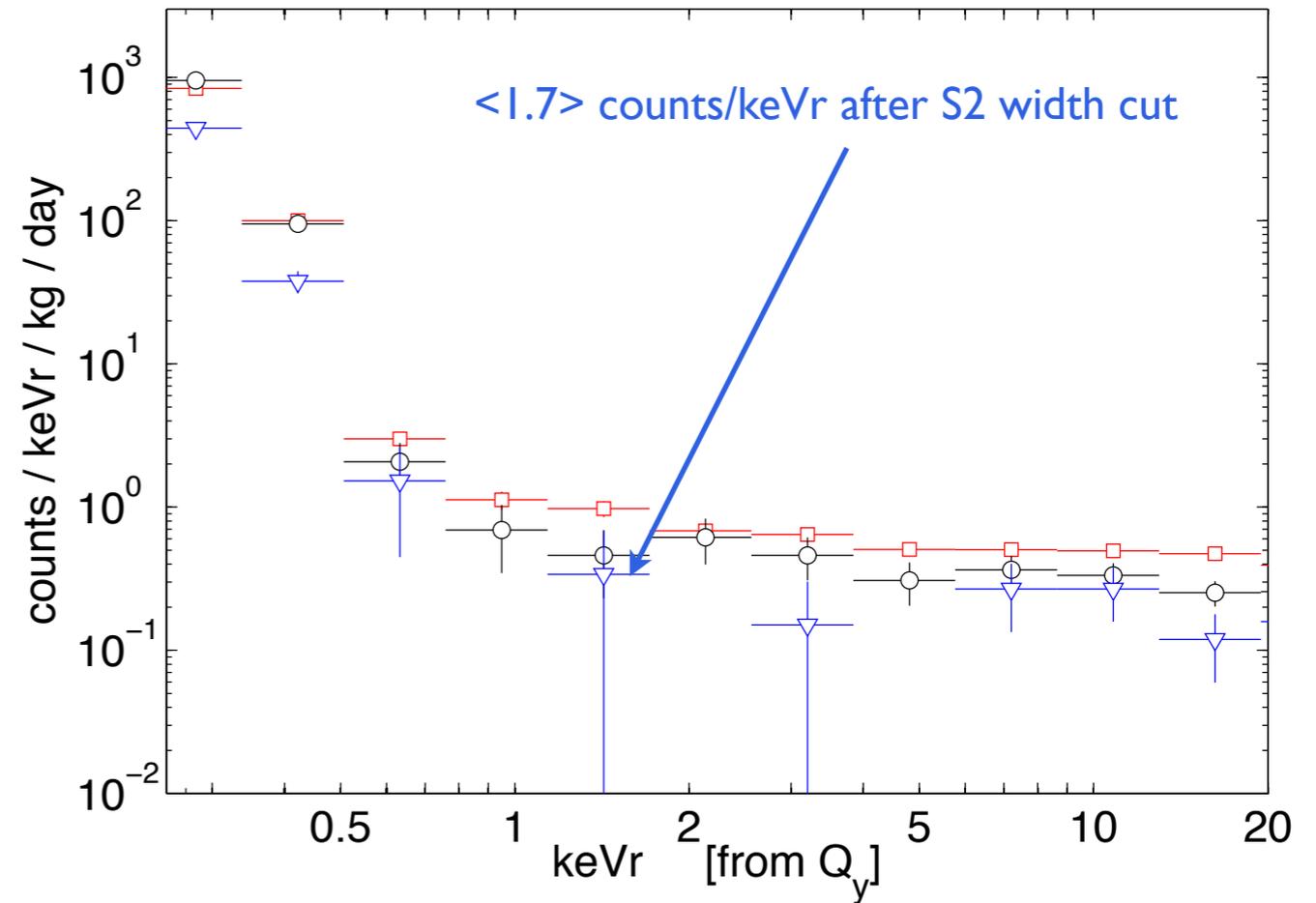
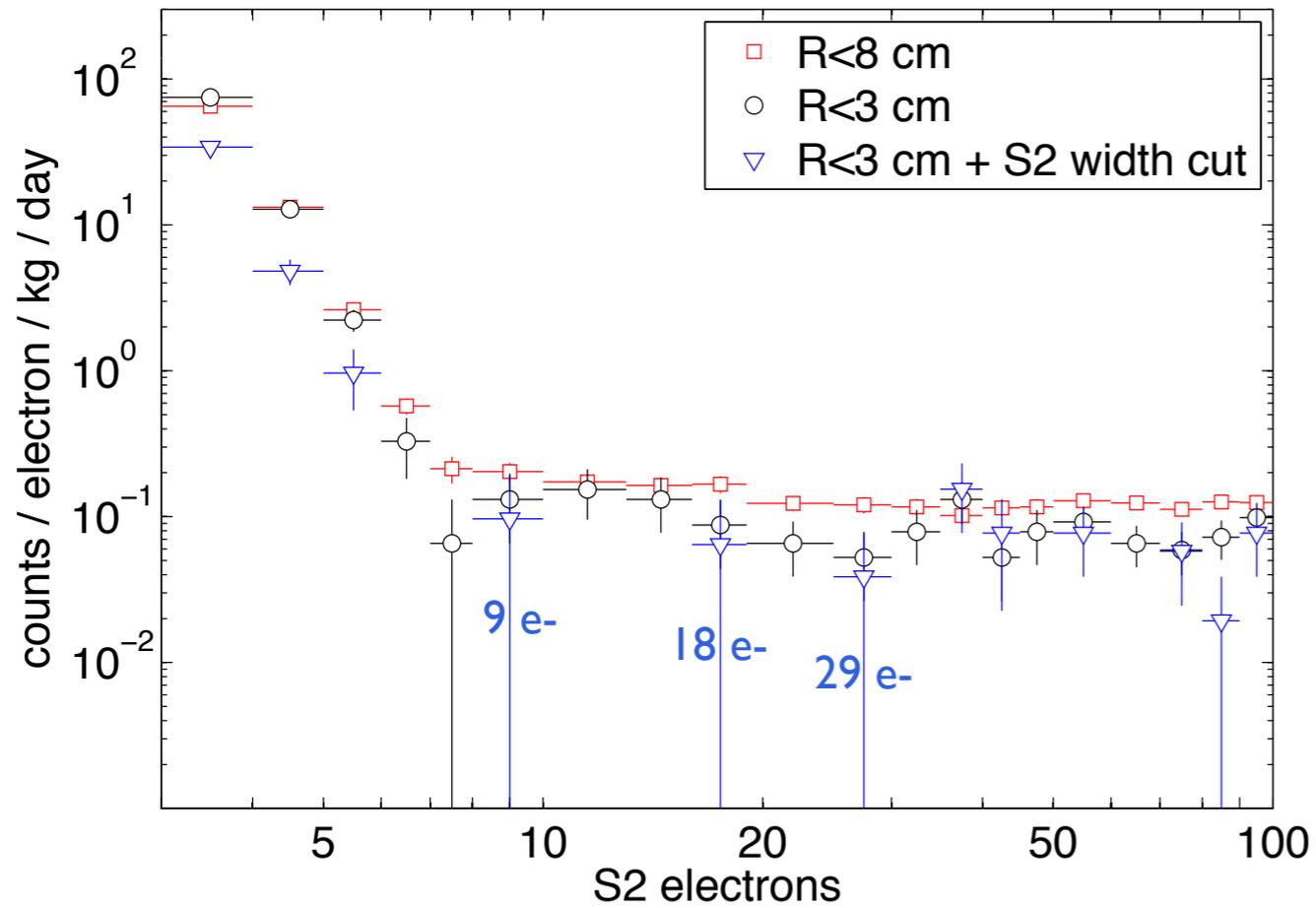
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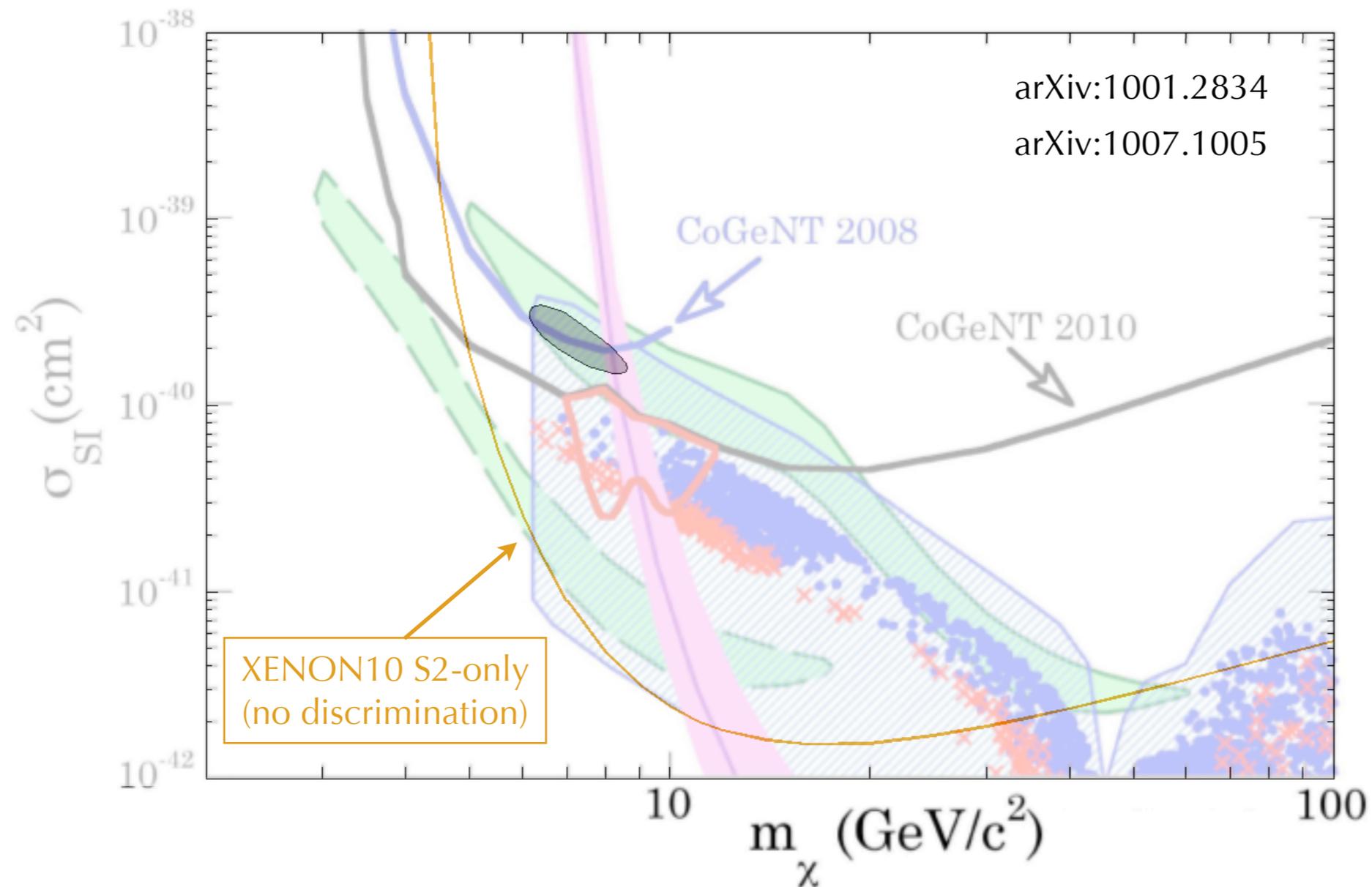
# WS2 data

no explicit z cut because not all events have S1



# (preliminary) dark matter exclusion limits

*Notice: this S2-only exclusion limit curve is preliminary, and has not been fully reviewed by the XENON10 collaboration. Pending review it is subject to change.*



- Max Gap 90% C.L. upper limit between 1.6 keVr and 3.8 keVr
- 12.5 live days
- 1.2 kg target
- conservative  $-1\sigma$   $Q_y$  energy calibration
- no account of resolution (this would improve limits)

# Summary

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- very quiet in the center of liquid xenon detectors (self shielding)
- S2 threshold is LOW,  $\sim 1$  keVr
- need confirmation of S2 calibration at low energies
- more stringent S2-only limits from XENON100 ?