“The relevance of XENON10 constraints in this low-mass region has been questioned [15]”

C.E. Aalseth et al. arXiv:1001.2834v1

Peter Sorensen
LLNL

on behalf of the XENON10 Collaboration

at

UC Davis HEFTI Workshop

“Light Dark Matter 2010”

Historical Note: last HEFTI workshop

Some concluding remarks

ON DAMA:

- what does the modulation signal look like in individual detectors? Is it similar in all 25 modules ?
- what if pulse-shape discrimination is employed (to select NR) ?
    - what about the quenching for nuclear recoils?
- what about a "blank" run with a different scintillator (or none at all) ? *(idea credit: J Collar)*
- what does the modulation signal look like 1-2 keV ?

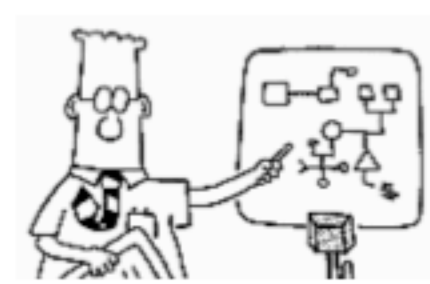
What to look for in 2009:

- new results from XENON100 (mid-2009 ?) check
- new results from LUX (late 2009 - early 2010 ?) not yet
- longer exposure / deeper / more shielding results from CoGeNT (?) check
- analysis of CDMS ER data (axions?) check

Some predictions:

- possible observation of channeling effect in laboratory scattering experiments (?)
- ruling out all DAMA-allowed regions**, with or without channeling
- continued emphasis of alternative dark matter candidates / non-standard halo models

*** for standard MB halo models / neutralino dark matter particles*

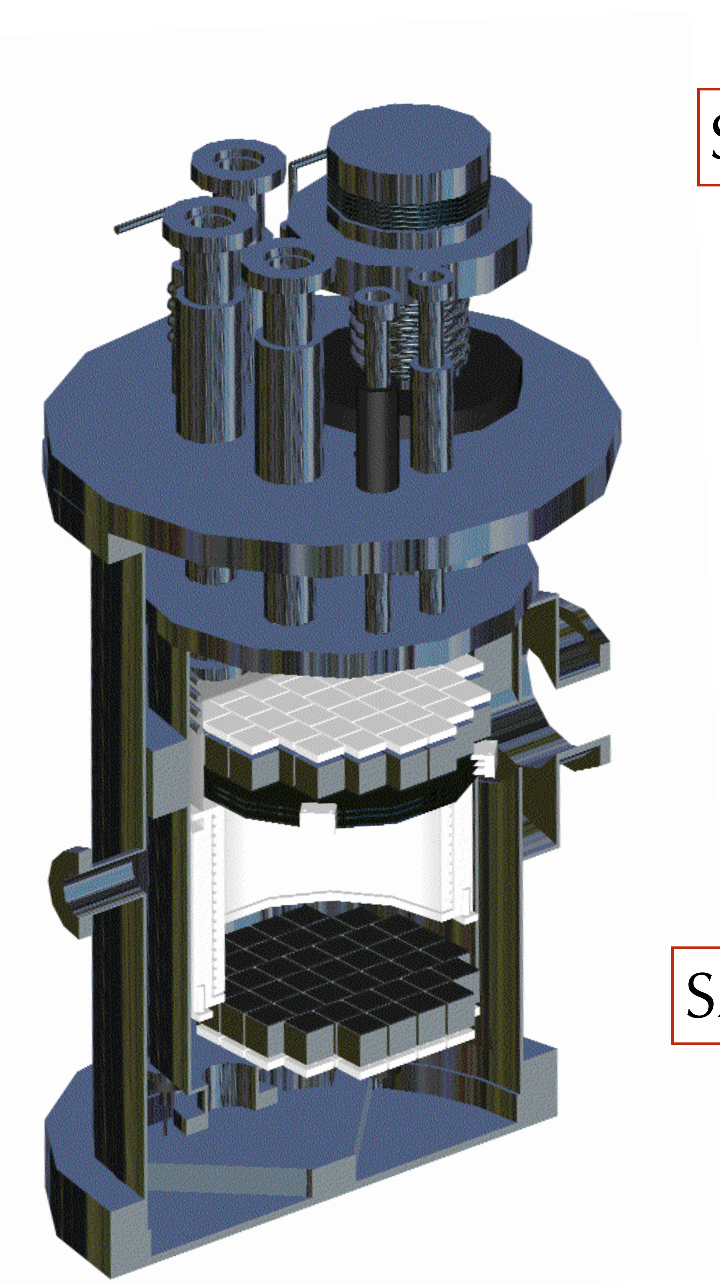


Thank You

Peter Sorensen (LLNL) UC Davis workshop: New paradigms in dark matter, 5-6 December 2008

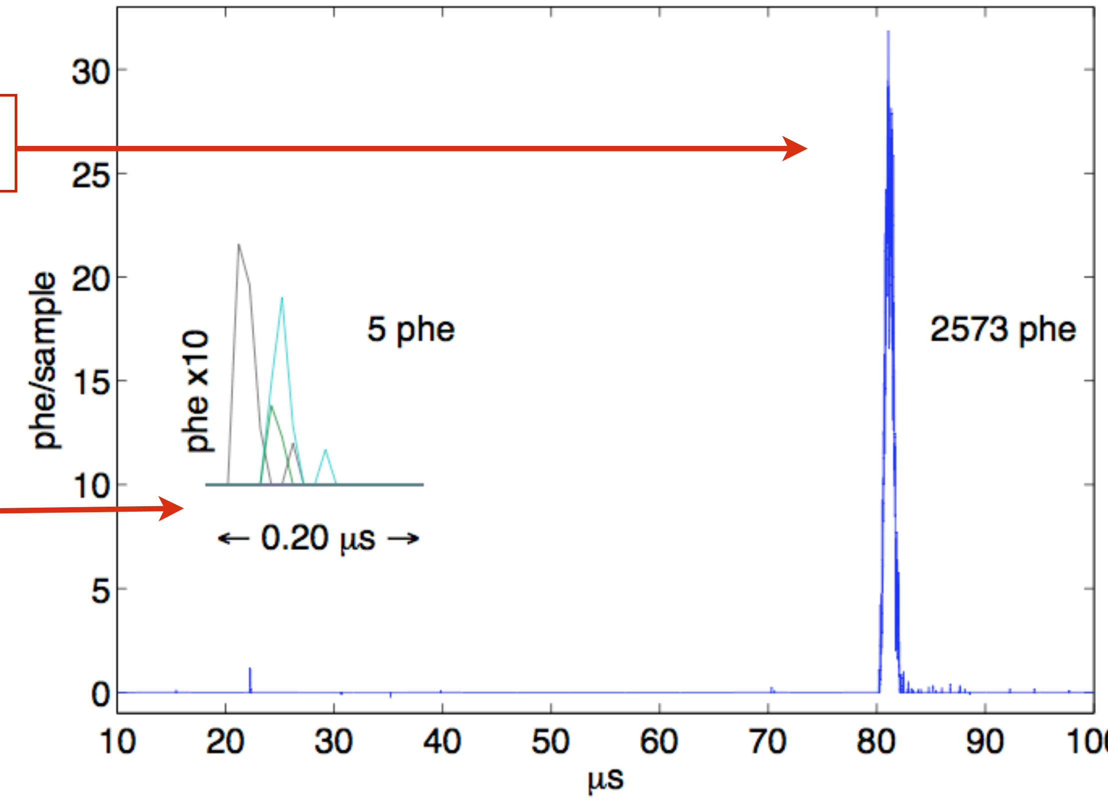
XENON10 detector

14 kg Xe

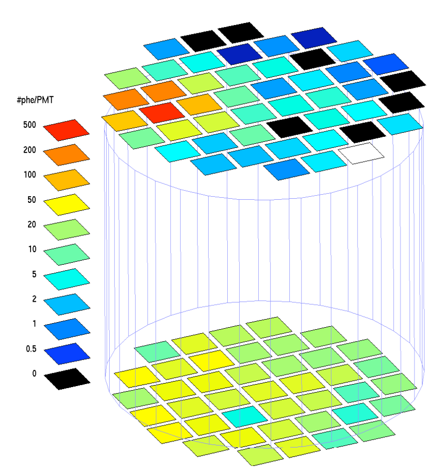


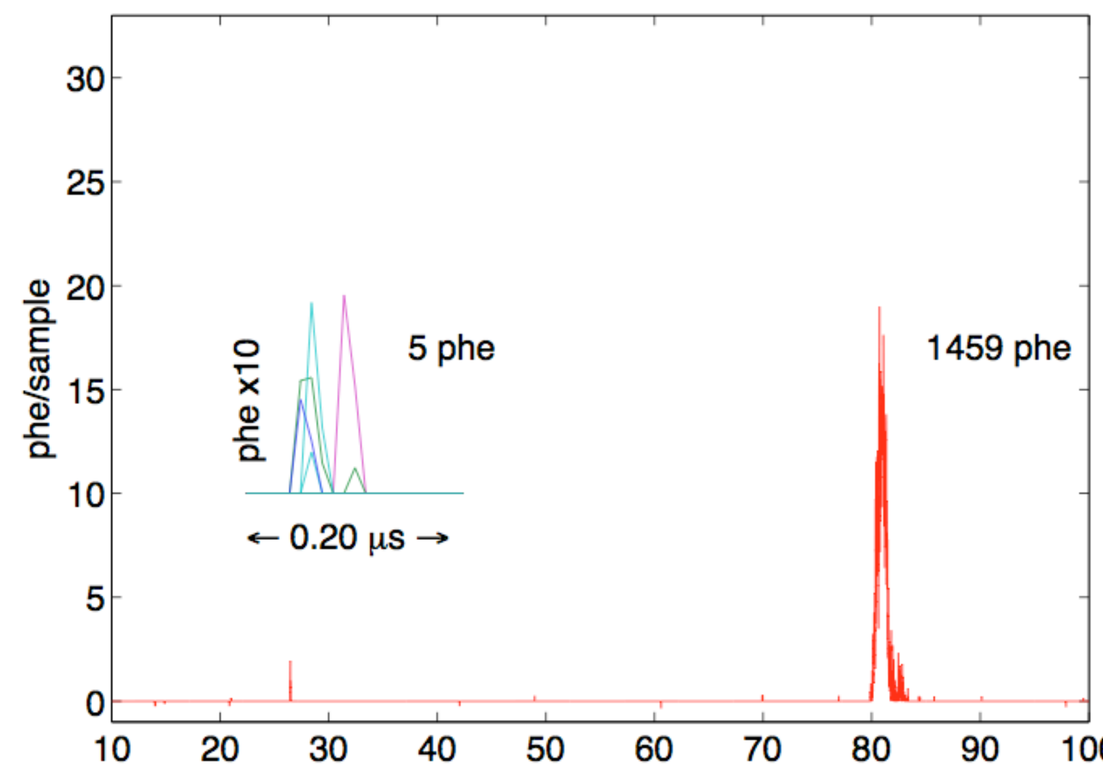
S2: secondary scintillation

S1: primary scintillation



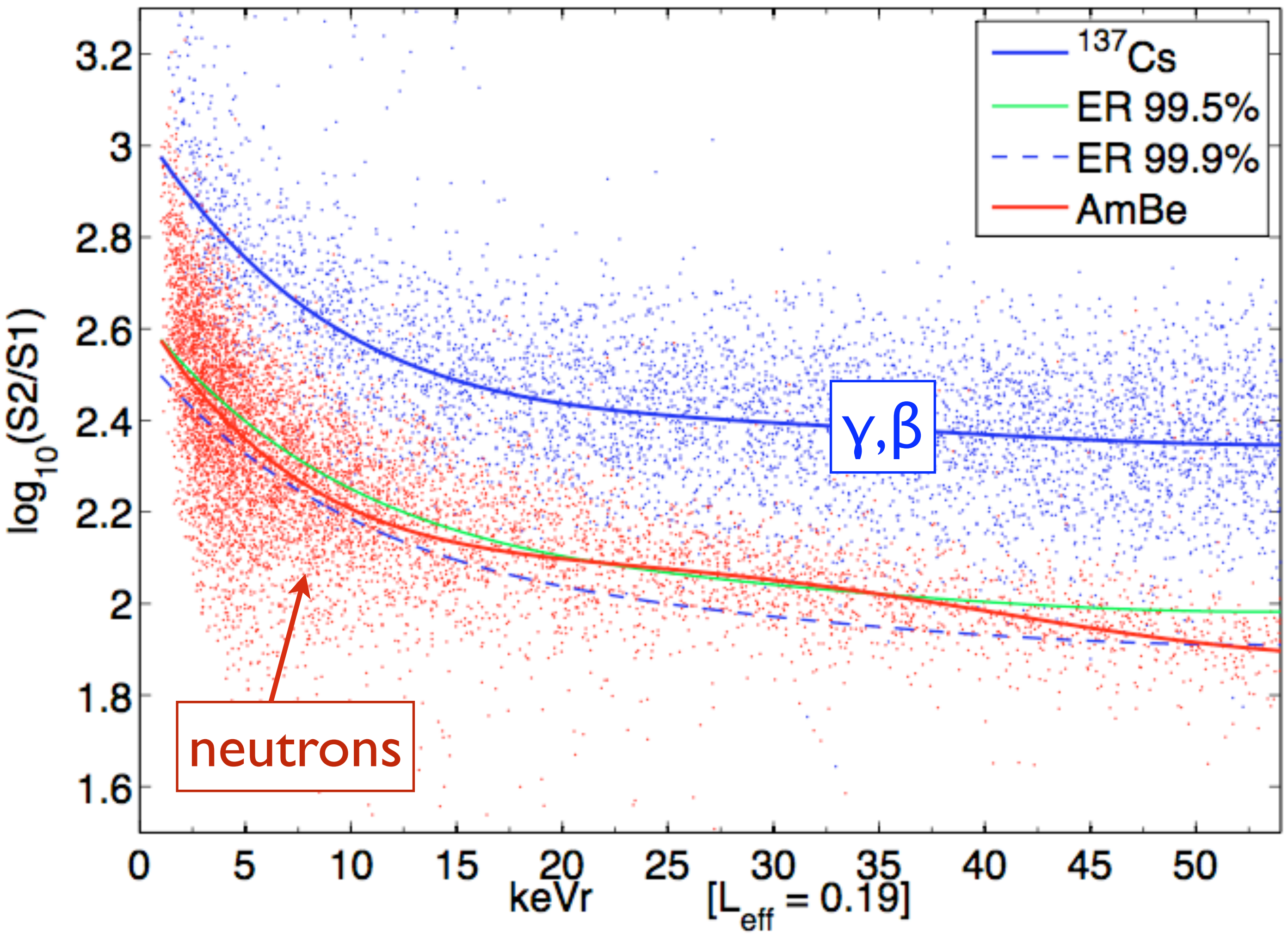
S2 hit pattern gives (x,y)

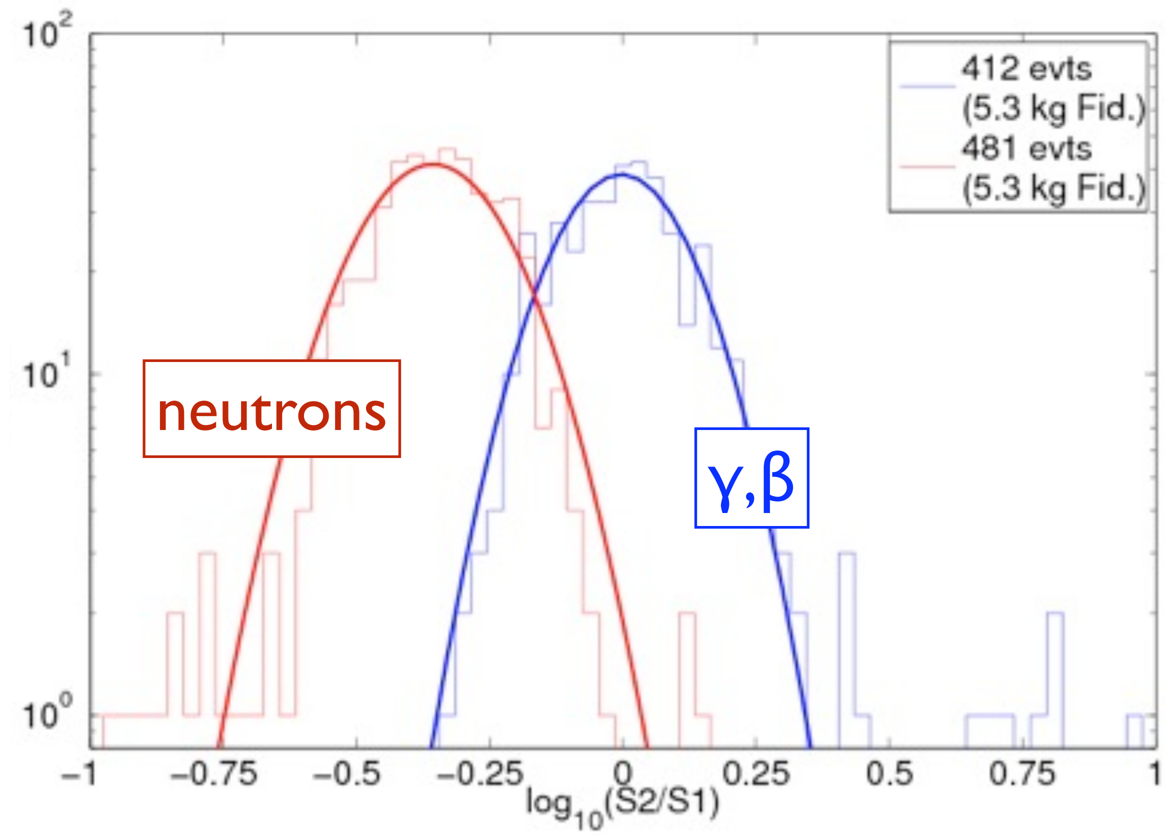




t_{S2} - t_{S1} gives z

Discrimination (old news)



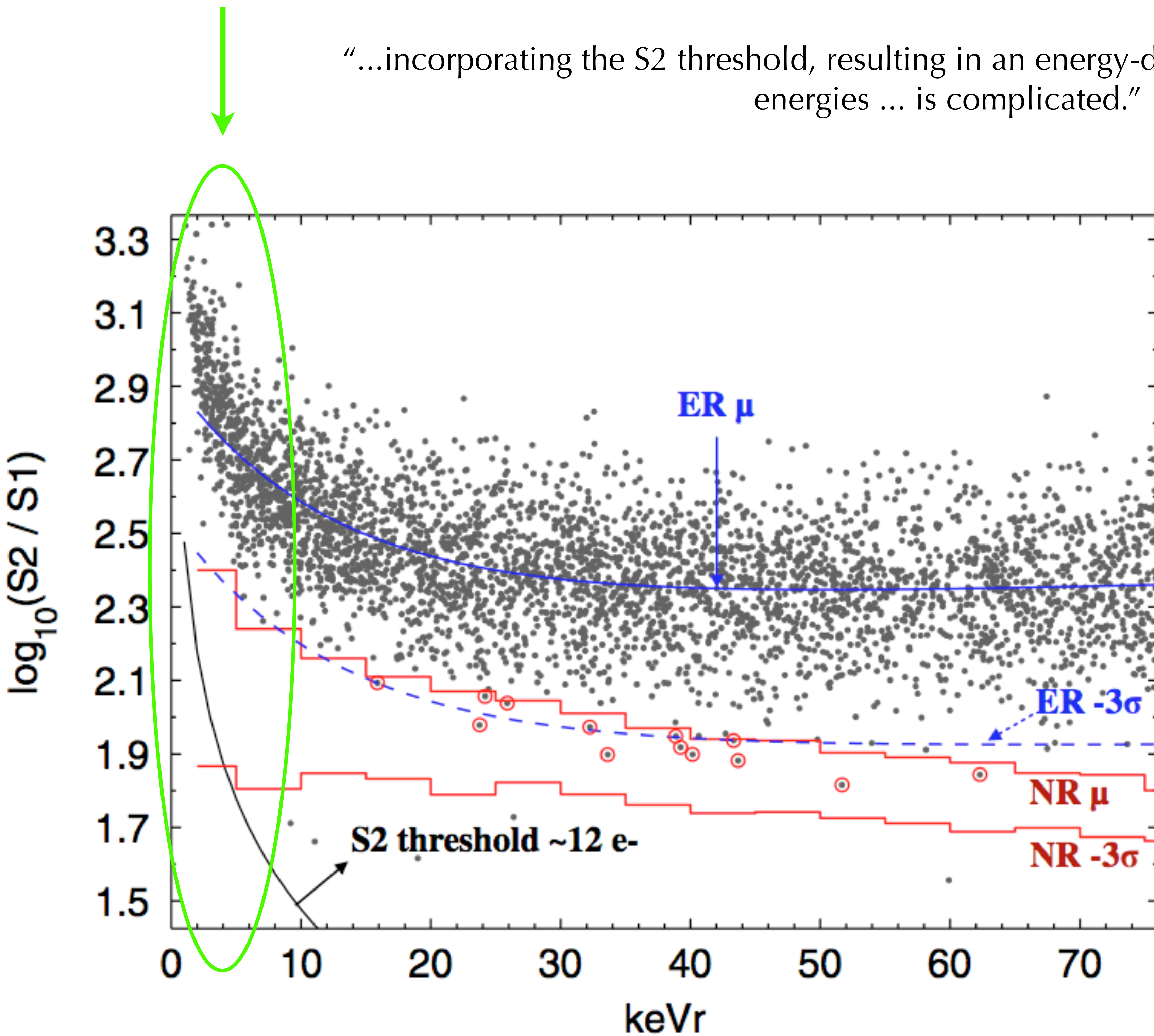


Sorensen PhD Thesis (2008)

What 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



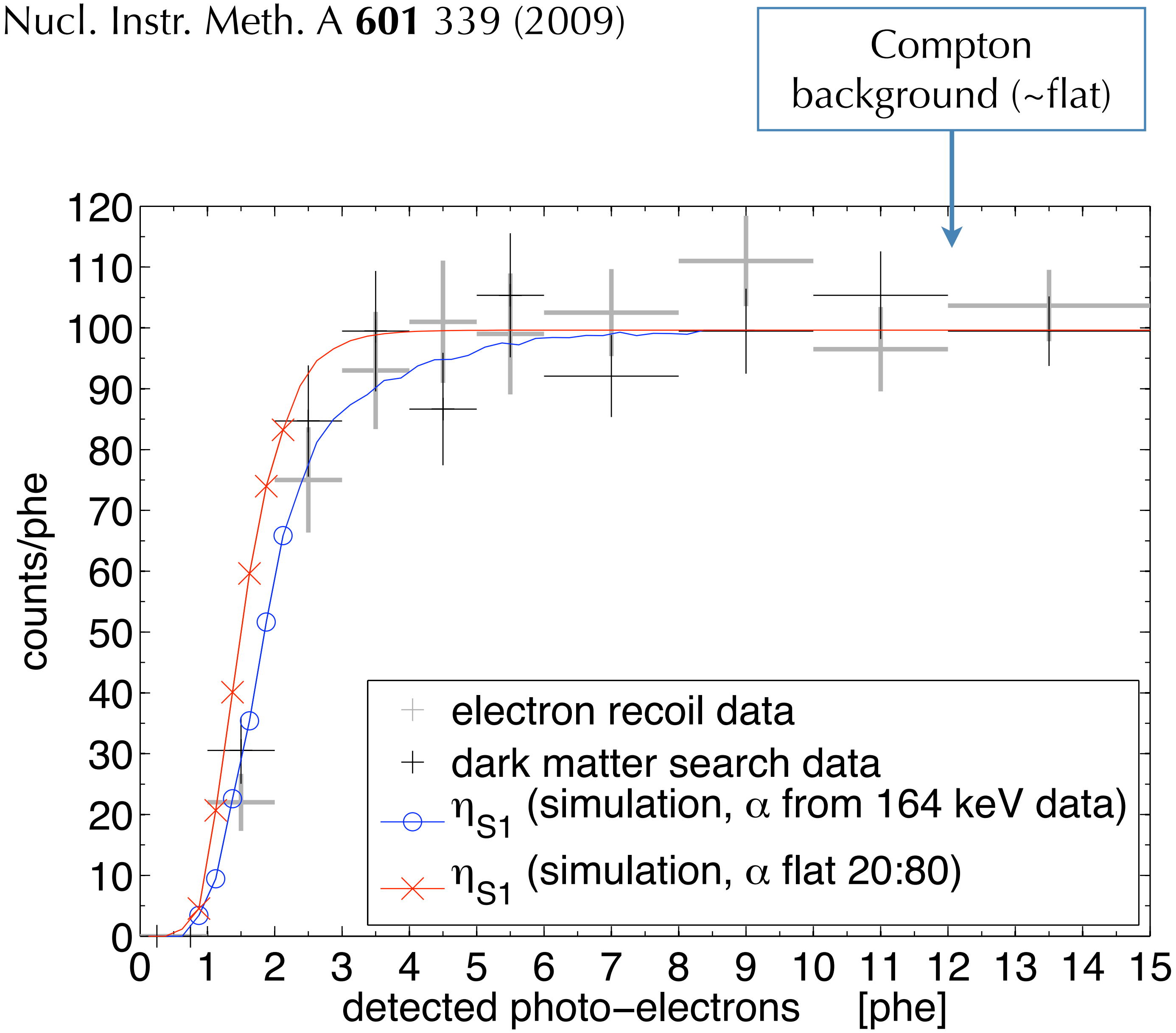
PRD **80** 115005 (2009)

reminder: keVr = phe in this case, i.e. assumption that Leff=0.19

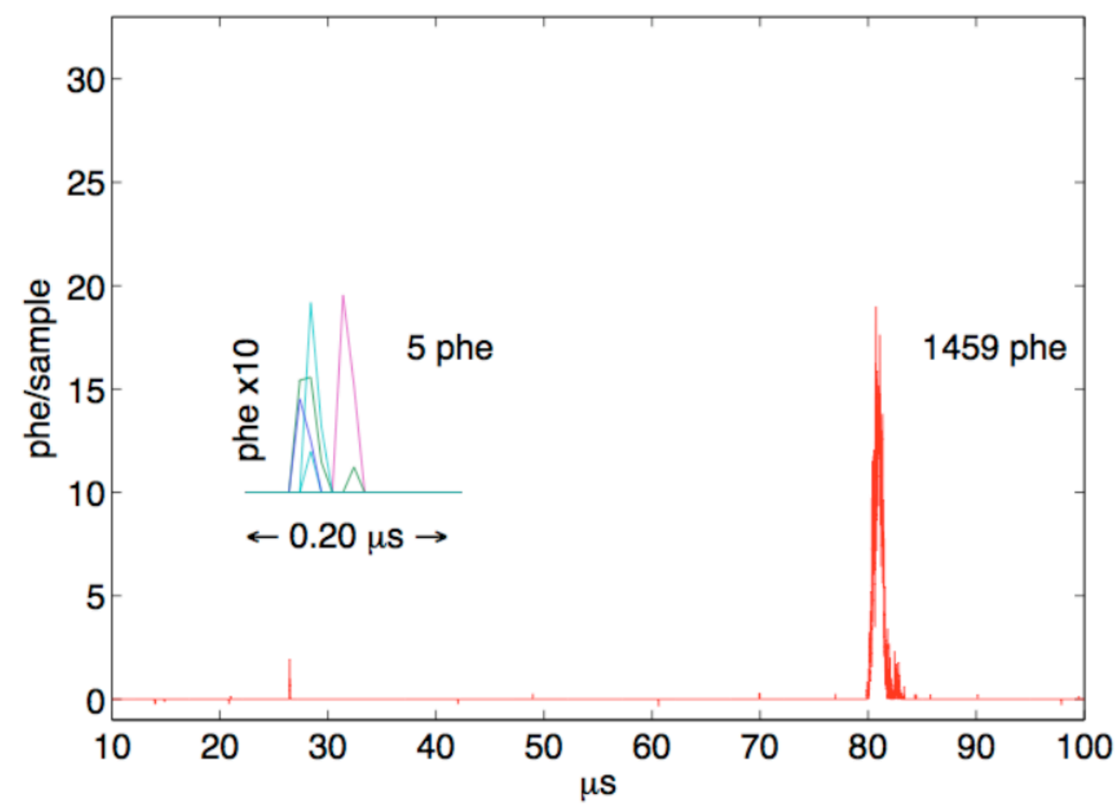
S1 detection efficiency in XENON10

red (x) curve originally appeared in:

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



- 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 ~25 phe

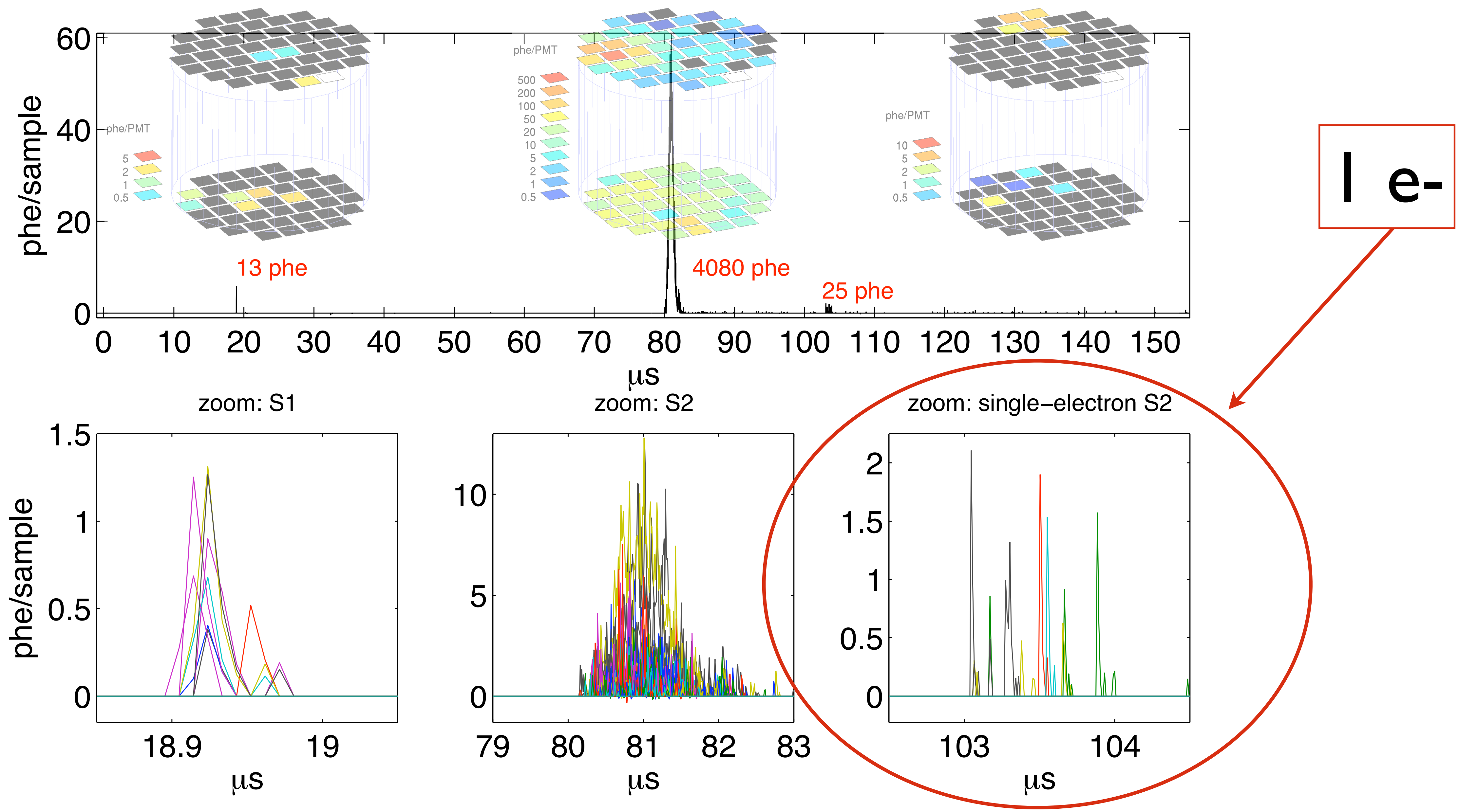
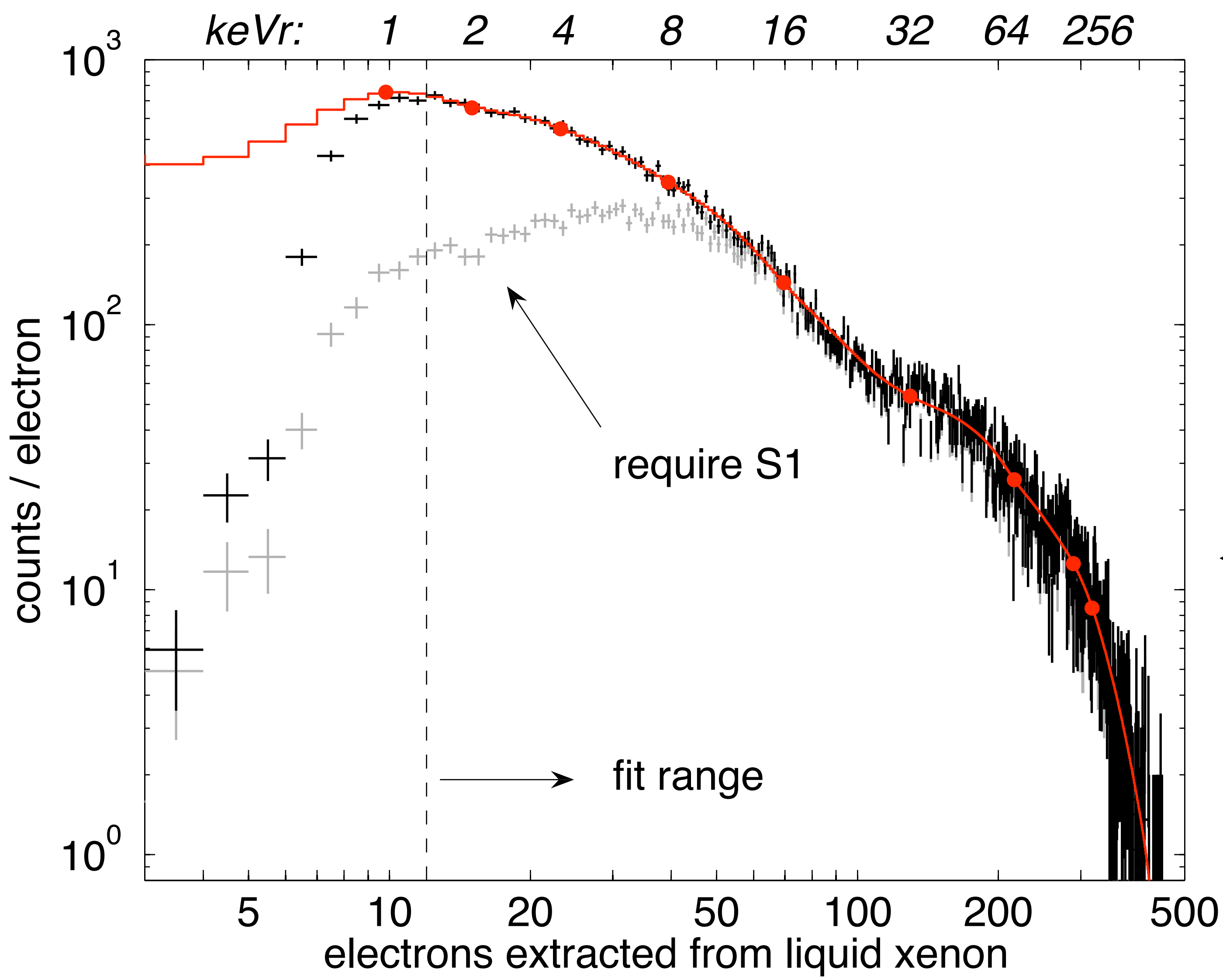


Figure 4.6: The summed event record for a typical ~ 4 keVee background γ scatter, showing a 61 μs drift time between $S1$ and $S2$, and also an isolated 25 phe single-electron $S2$ pulse at 103 μs. The primary S2 pulse (at 80 μs) triggered the DAQ in this event, however the S2 trigger was sensitive to single-electron $S2$ pulses as small as ~ 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 & threshold

S2 trigger efficiency



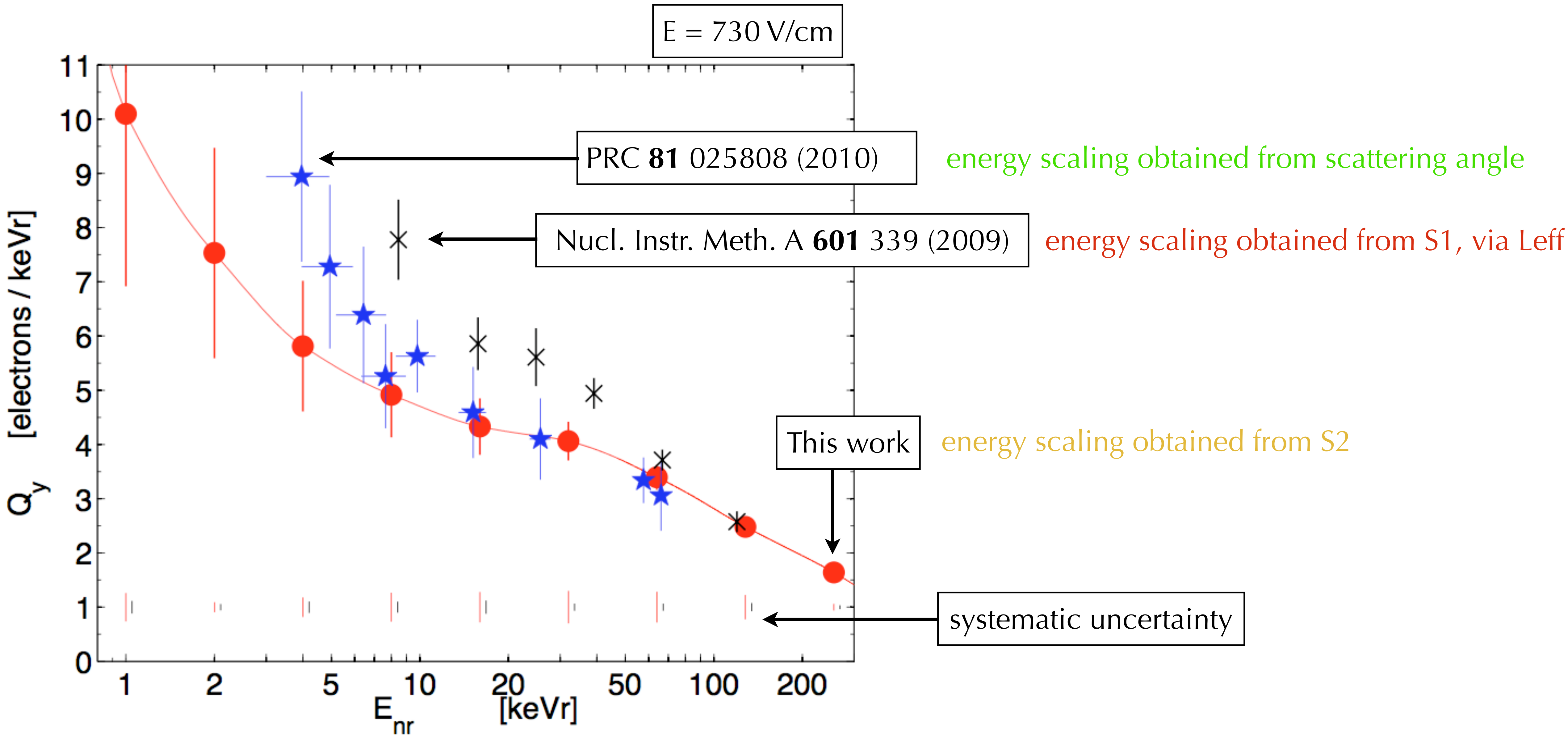
from XENON10 neutron calibration (AmBe). The calibration, analysis, etc already described in (with focus on S1 signal):

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

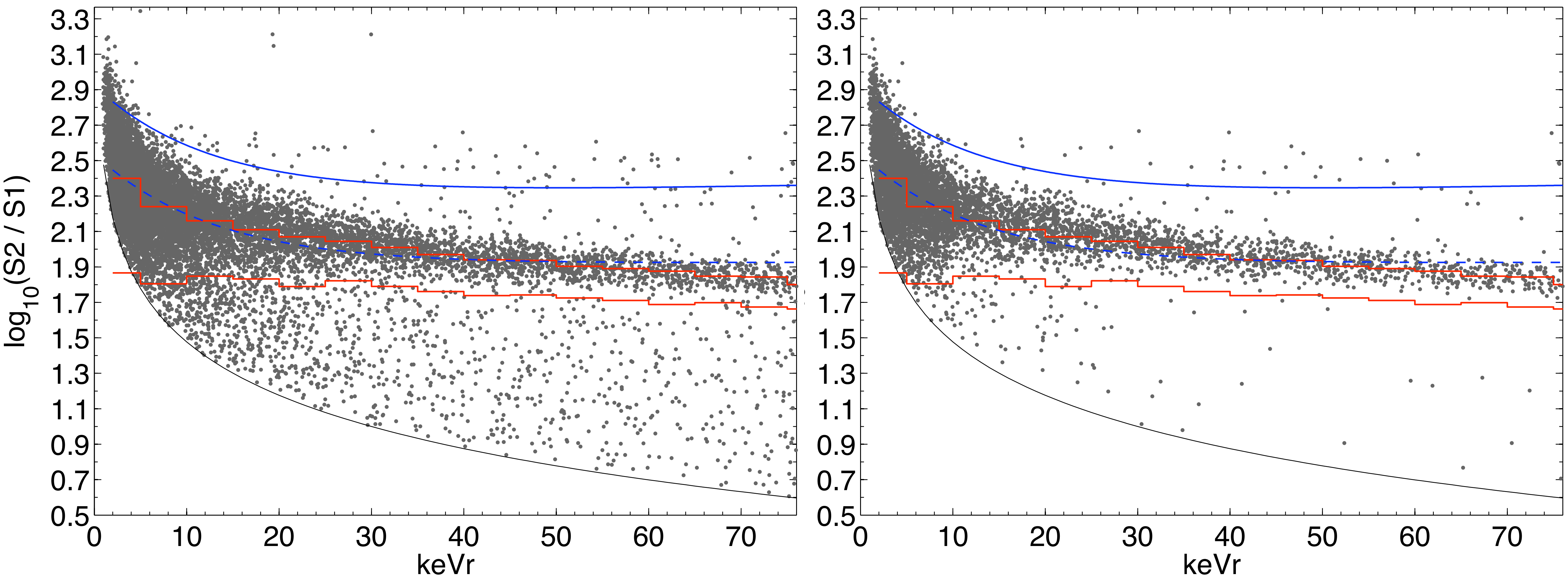
Result of monte carlo best fit



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

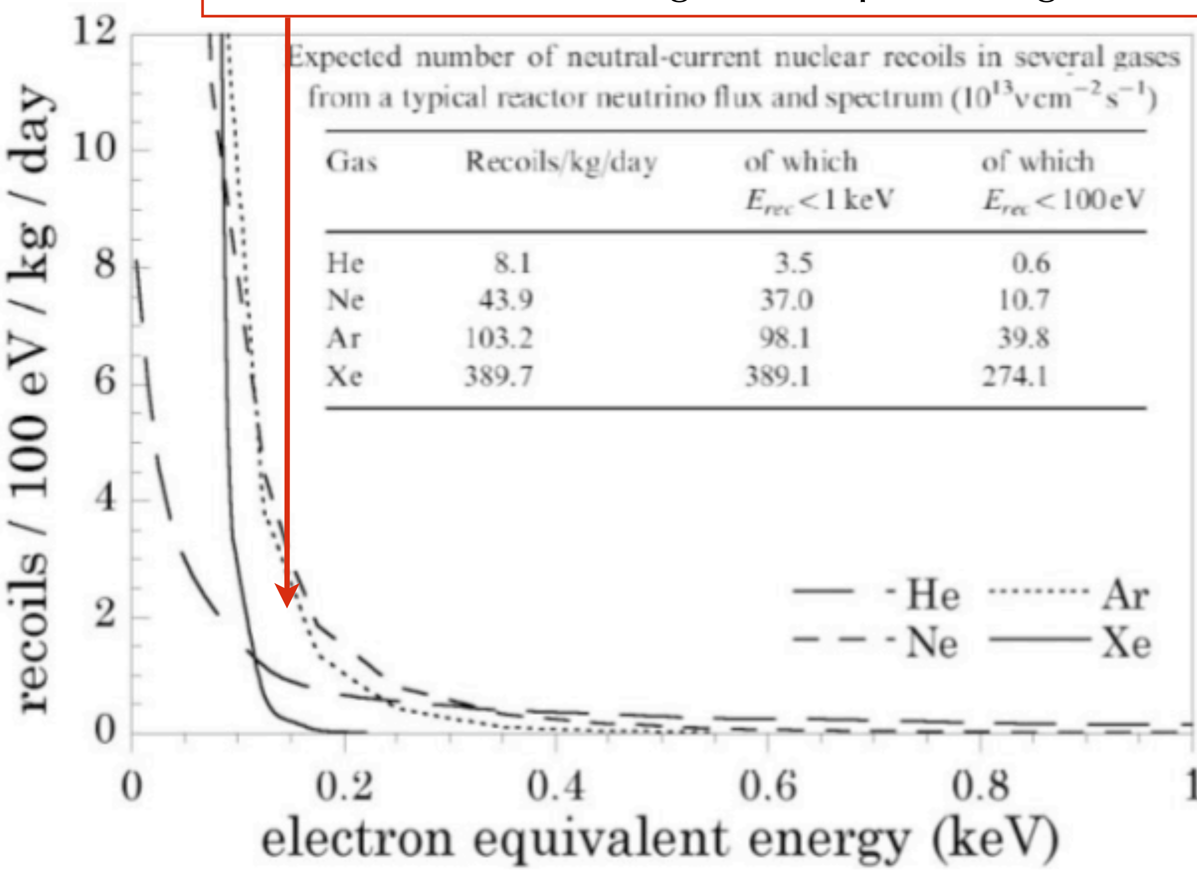
Nuclear recoils from AmBe neutrons

all valid events in the 5.4 kg target | the same data after all cuts



P.S. Barbeau, J.I. Collar et al.
IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 50, NO. 5, OCTOBER 2003

~ 1 keVr, assuming ~0.15 quenching of ionization signal...

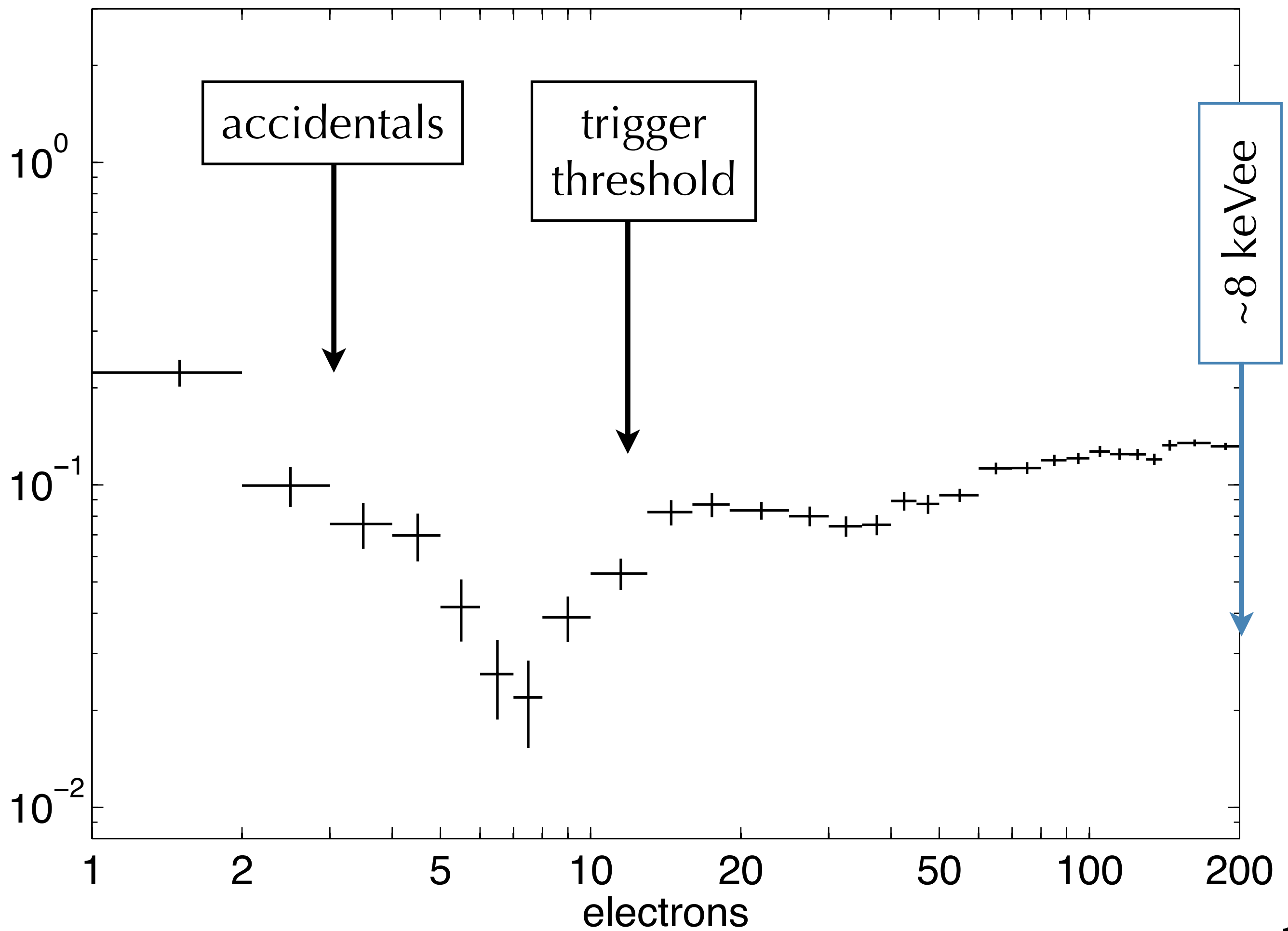


Gas	Recoils/kg/day	of which $E_{rec}<1$ keV	of which $E_{rec}<100$ eV
He	8.1	3.5	0.6
Ne	43.9	37.0	10.7
Ar	103.2	98.1	39.8
Xe	389.7	389.1	274.1

Fig. 1. Detectable signal in different gases from neutral-current nuclear scattering of reactor antineutrinos (10^{13} $\bar{\nu}$ cm^{-2} s^{-1}), obtained by folding of the differential cross section in [8] with the reactor spectrum in [24] and applying quenching factors derived from SRIM [25]. The tradeoff between endpoint energy and rate with increasing atomic mass is evident. *Table*: total coherent recoil rate in different gases under the same conditions.

Yikes.

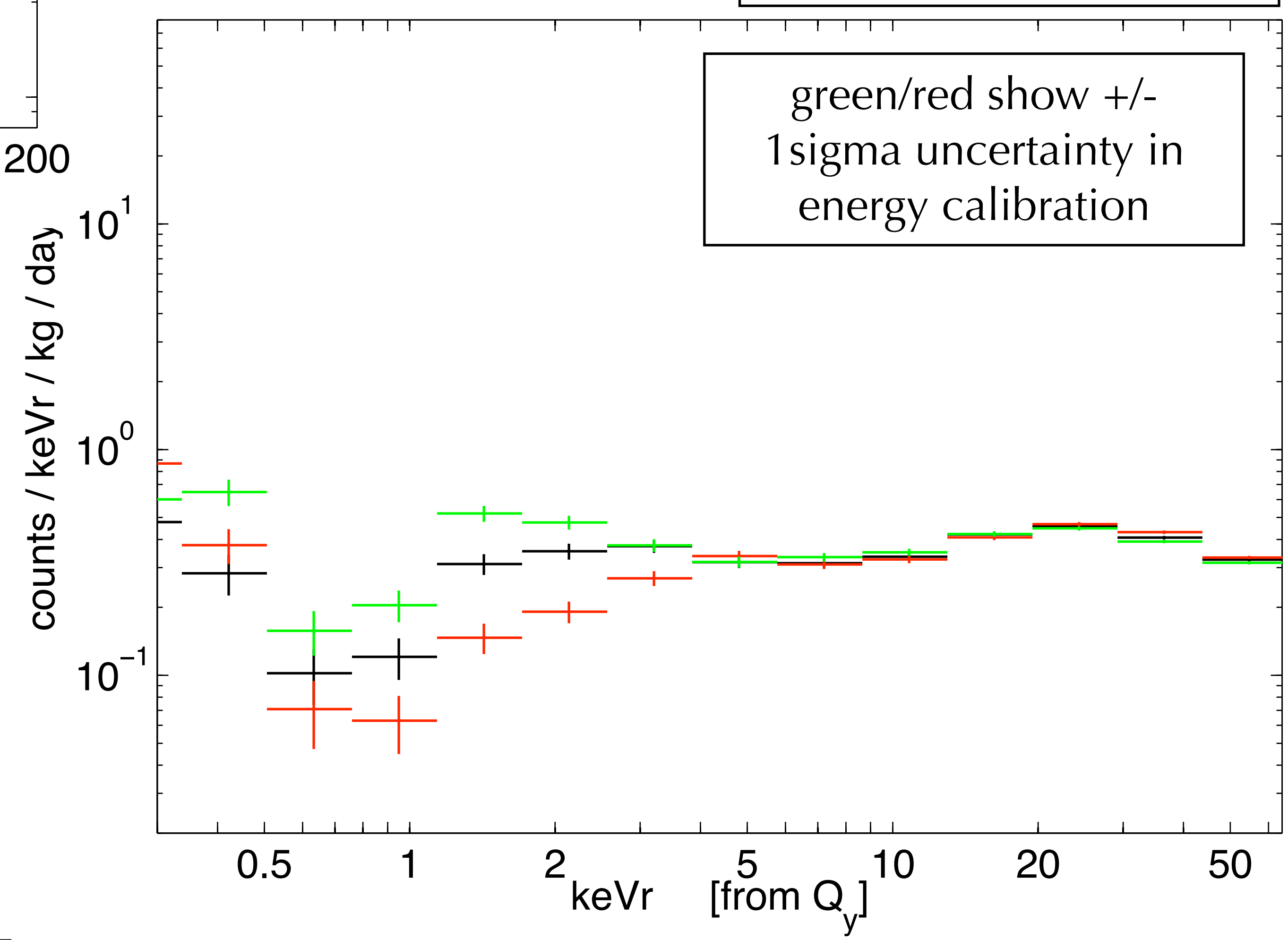
single-scatter Compton background in XENON10



(above coherent neutrino scatter threshold)

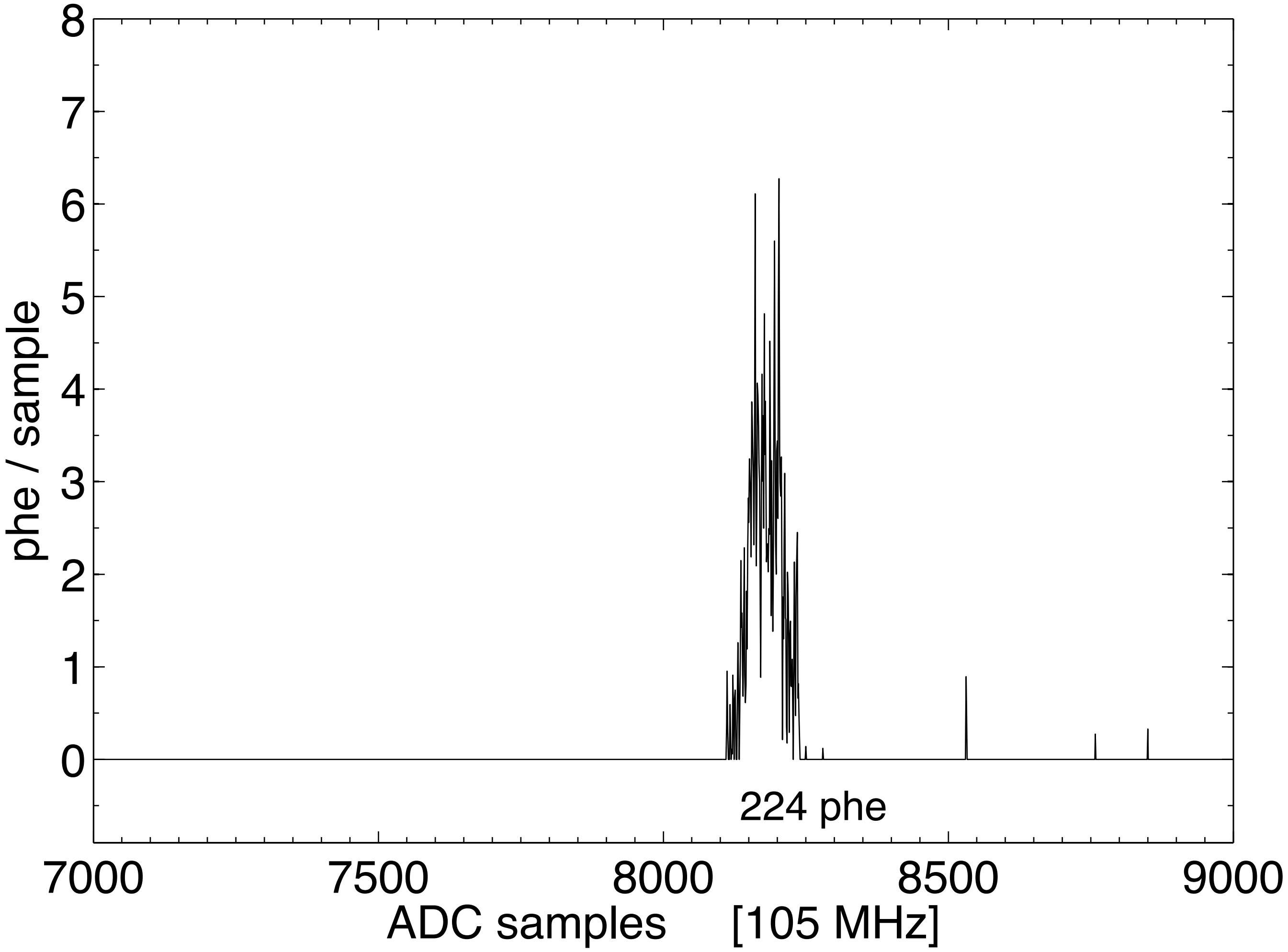
clear need for a mono-energetic energy calibration at low energy

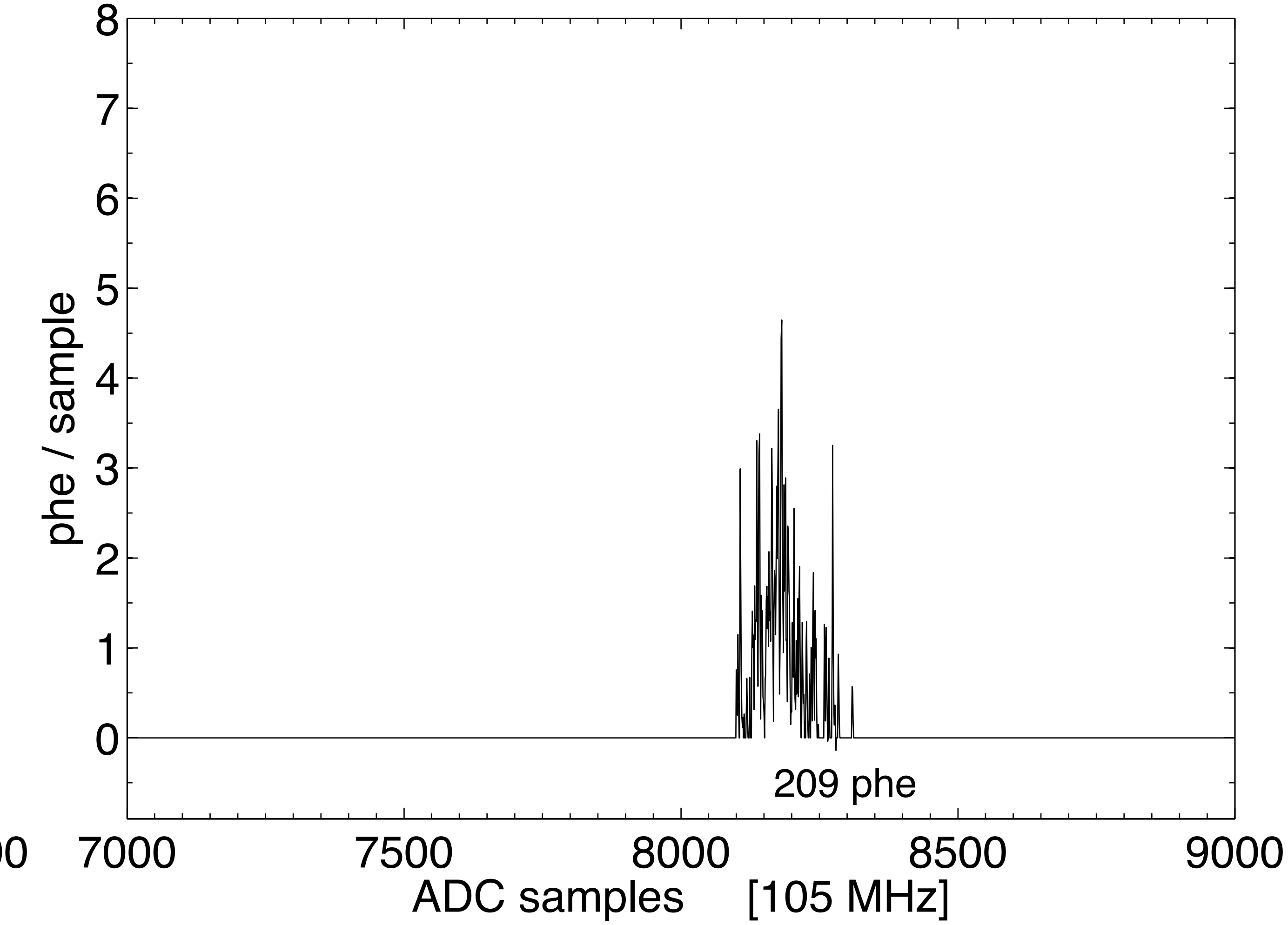
same data scaled to keVr



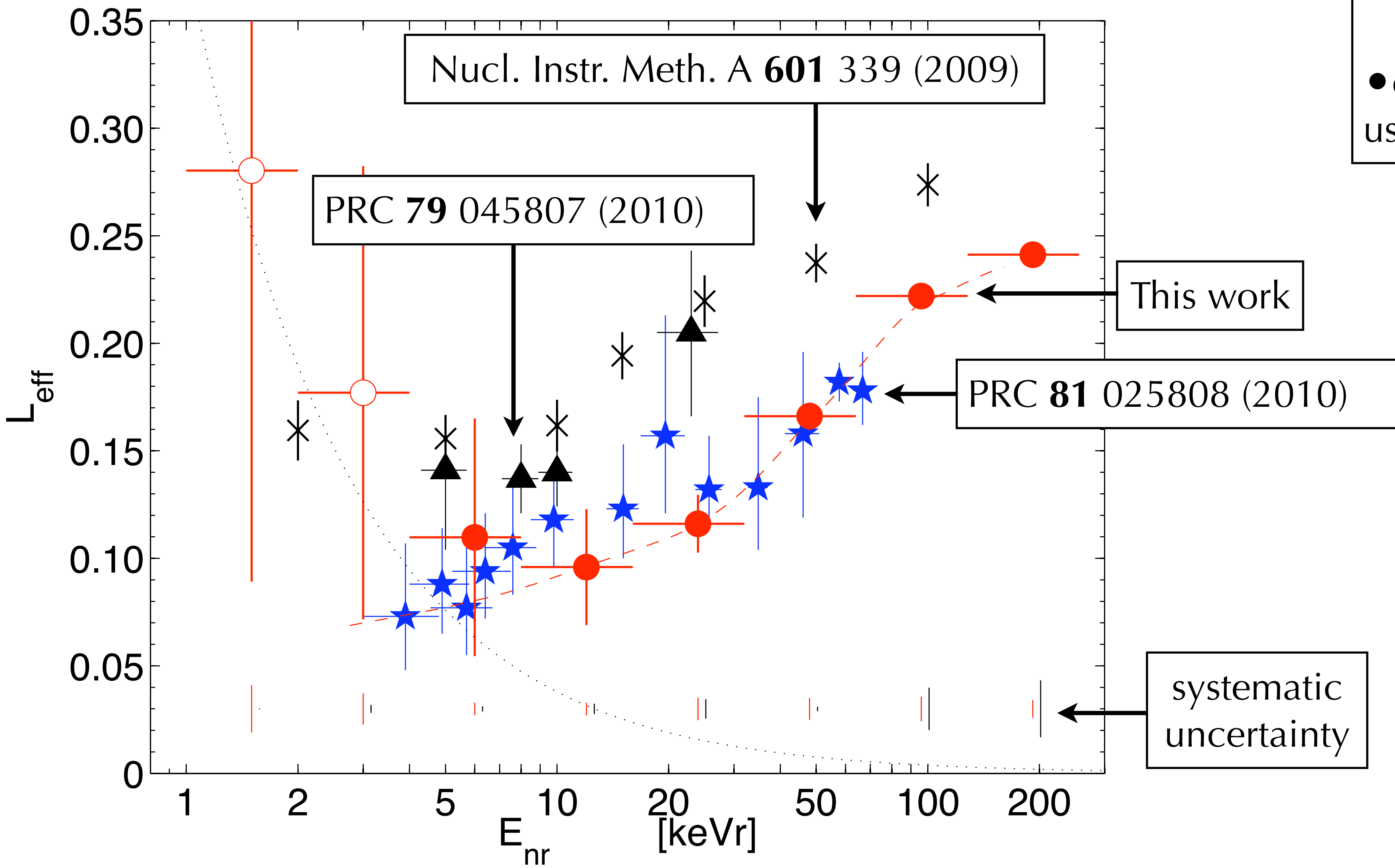
same data as previously reported in
PRD **80** 115005 (2009)
PRL **100** 021303 (2008)
except no S2/S1 discrimination
(hence Compton-dominated)

Typical Events at threshold





Coming back to S1

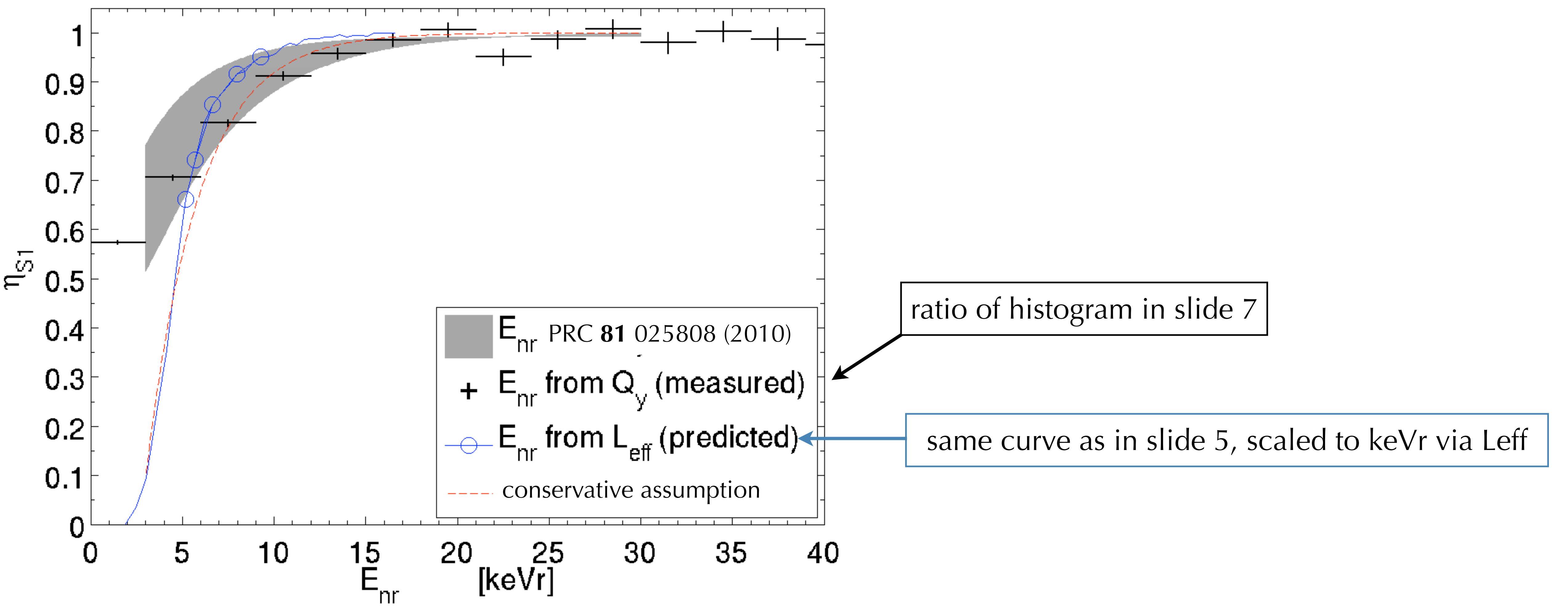


For each nuclear recoil:

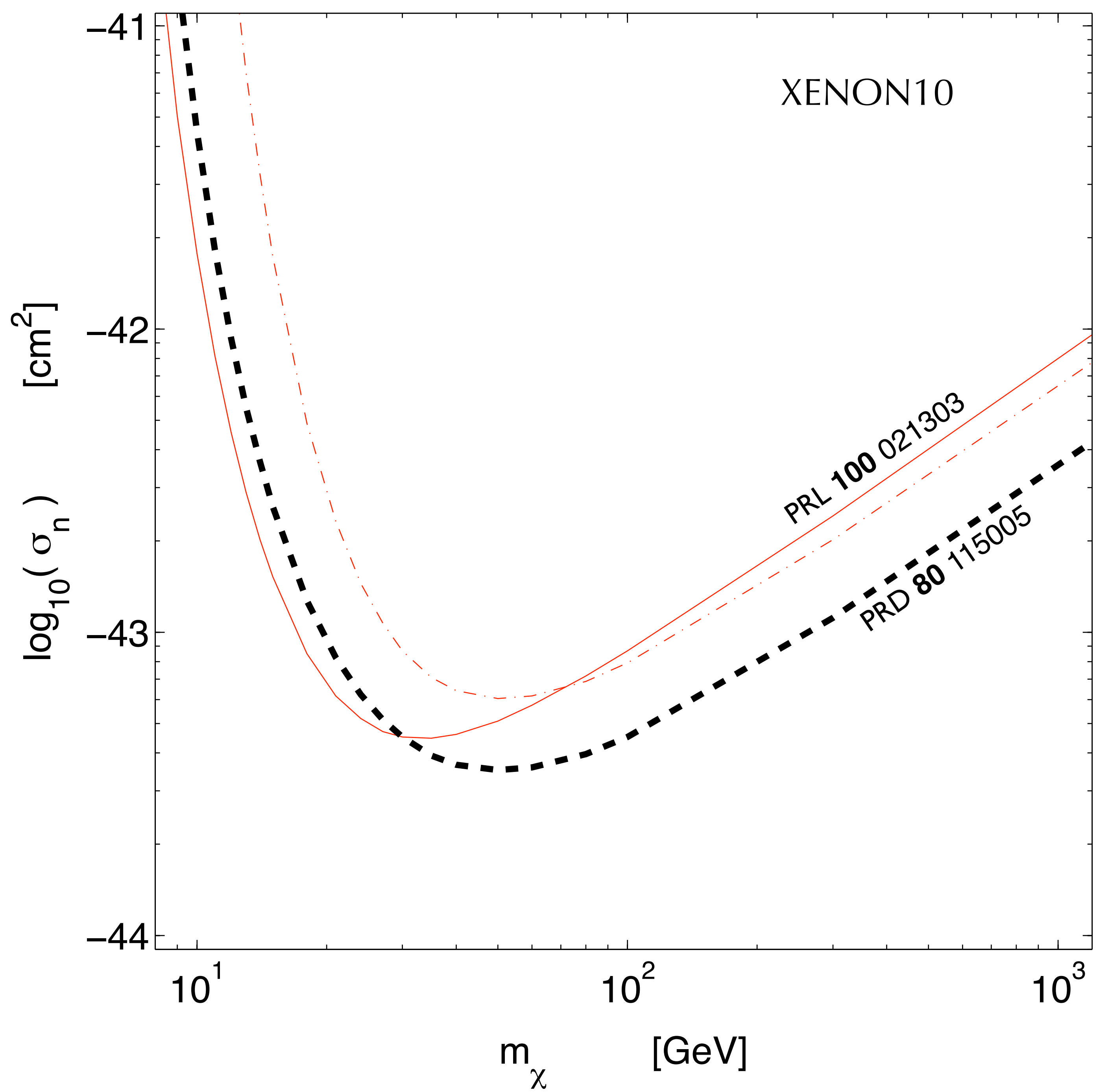
- assign a keVr value based on S2, with scaling taken from
  - PRC 81 025808 (2010), or
  - the present work (very similar results either way)
- obtain Leff from the S1 data, via the usual formula

$$\mathcal{L}_{eff} = \frac{S1}{L_y}\frac{S_n}{S_e}\frac{1}{E_{nr}}$$

S1 detection efficiency (scaled to keVr)



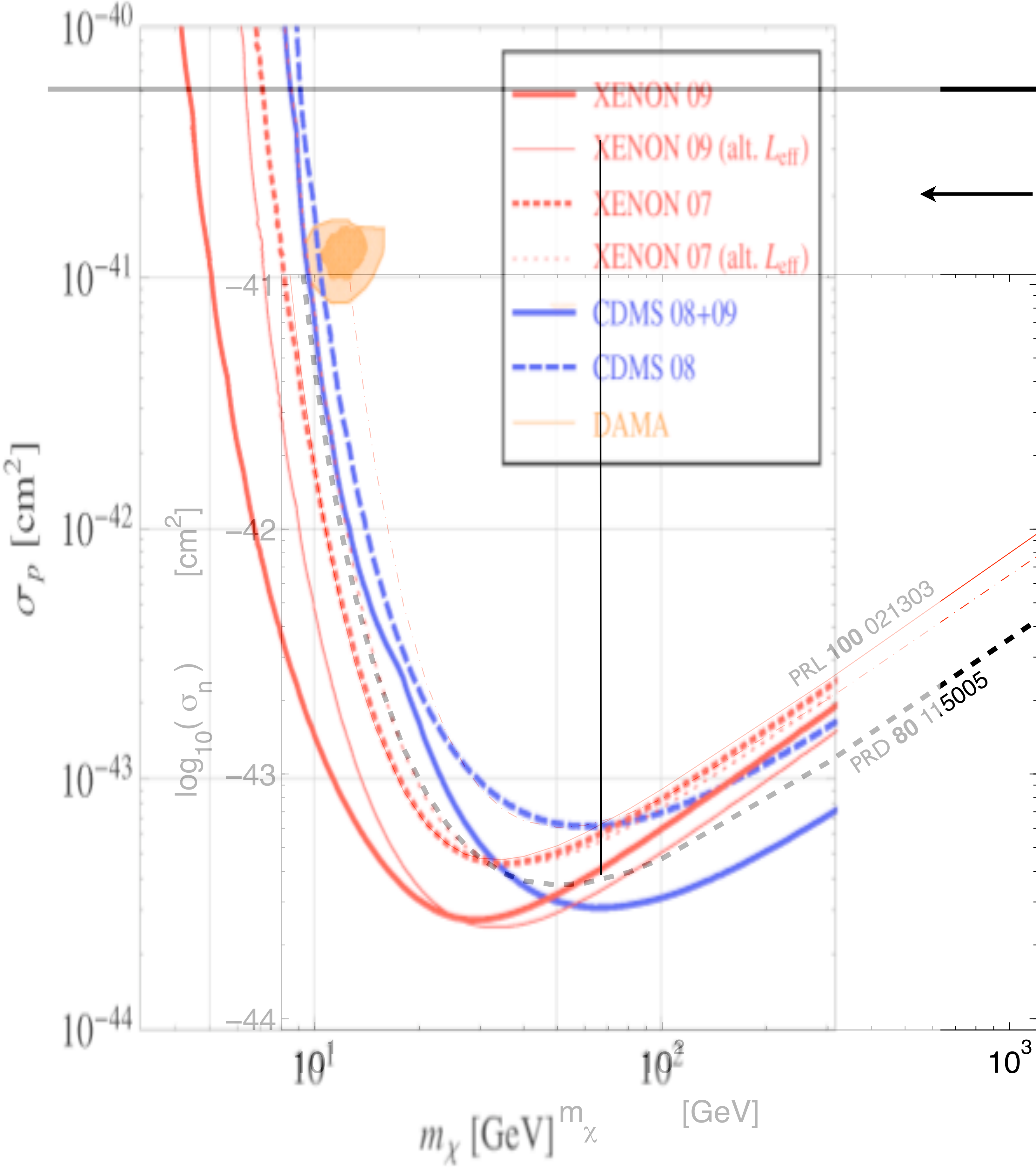
Spin-independent sensitivity doesn’t change (much)



solid curve: S1 efficiency assumed constant above threshold

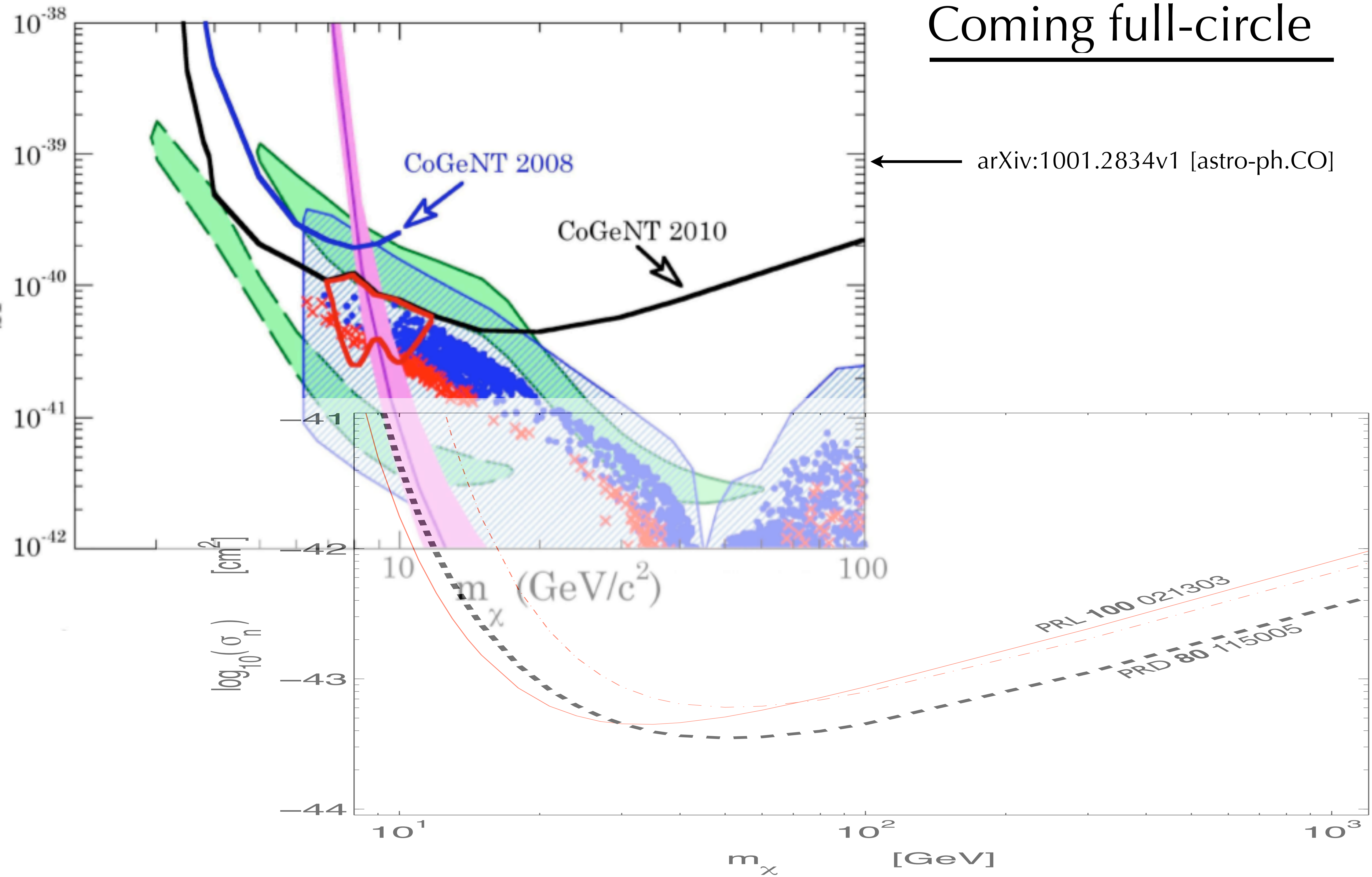
dashed curves: S1 efficiency taken from “conservative assumption” on slide 10

Comparing...



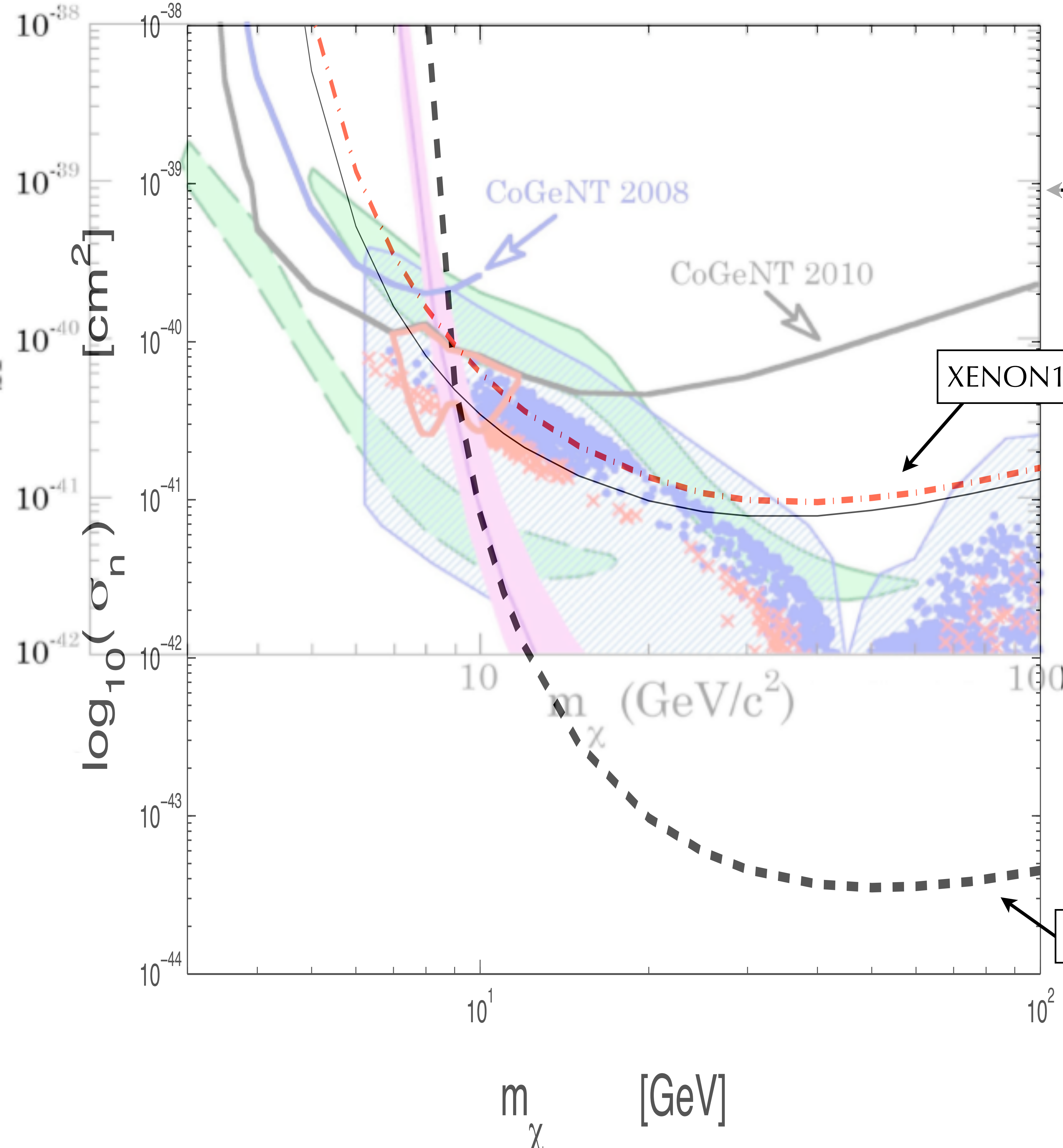
JCAP02 (2010) 014 (appears overly optimistic)

Coming full-circle



arXiv:1001.2834v1 [astro-ph.CO]

and around again



- energy range 1.5 - 20 keVr
- flat 0.35 cts/keVr/kg.day
- red curve: efficiency falling <4 keVr
- 58.6 live days
- 8.6 kg target
- Poisson 90% C.L. upper limit

End