Combining Results from Dark Matter Searches: CDMS and EDELWEISS

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for the CDMS and EDELWEISS collaborations

CDMS-EDW, PRD 84 (2011) 011102(R), arXiv:1105.3377
see also S. Yellin, arXiv:1105.2928

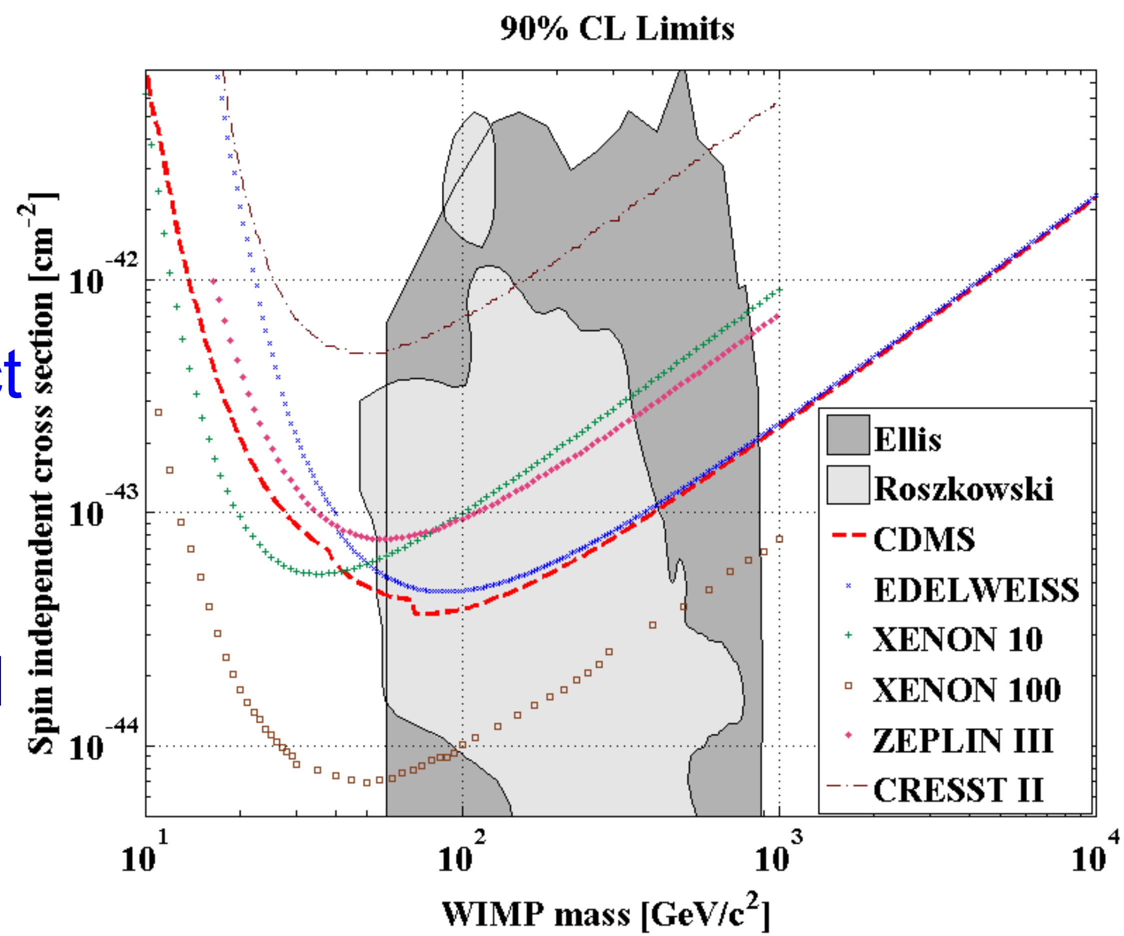
The Dark Matter Mystery

(Zwicky, 1933)

- Most of the matter in the Universe only visible via gravitational interactions
- Particle physics may provide a solution: Weakly Interacting Massive Particles (WIMPs)
- Many experiments trying to detect WIMPs directly, using many different techniques and targets:
  - XENON, LUX: Xe
  - DEAP: Ar
  - PICASSO: F
  - COGENT: Ge
  - ...
- Subkelvin Ge ionisation-phonon detectors have provided competitive limits on WIMPs over the past decade
- Two experiments use this technique: CDMS and EDELWEISS
- Combine their results to see what can be learned about
  - WIMPs
  - Backgrounds
- Formal agreement
  - Authorship, procedures …
  - Combination method
  - Make data public (arXiv)

The CDMS Experiment (Science 327, 1619, 2010)

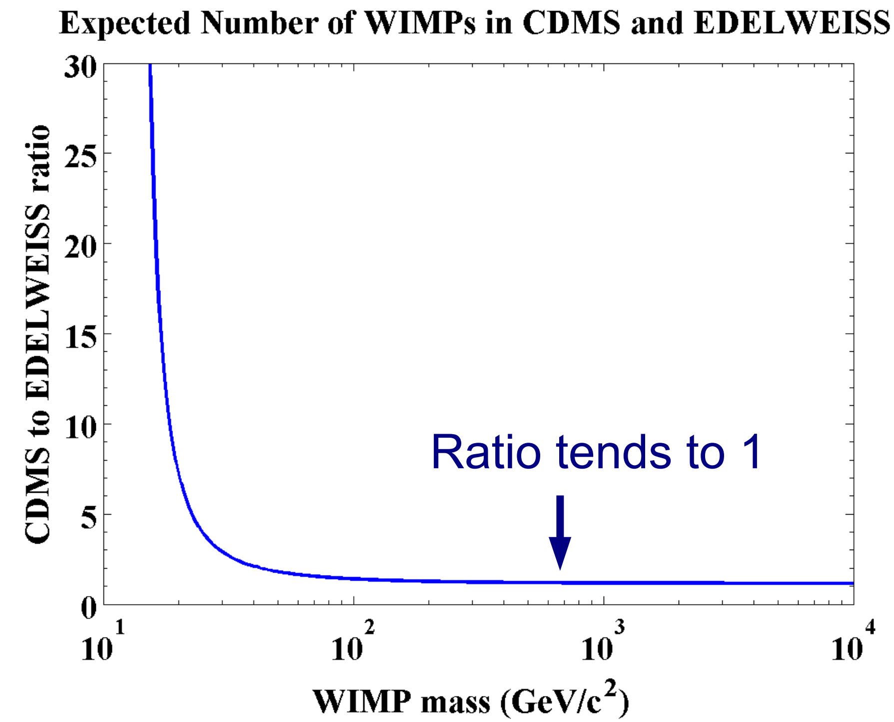
- Located at Soudan MN (2100 mwe)
- Up to 19 Ge ionisation-phonon detectors, 230 g each
- Athermal phonons to reject surface events
- Total:
  - Max exposure 379 kg.d
  - Threshold 5 keV
  - Blind analysis
  - 4 candidate events
  - 2 expected from bckgd

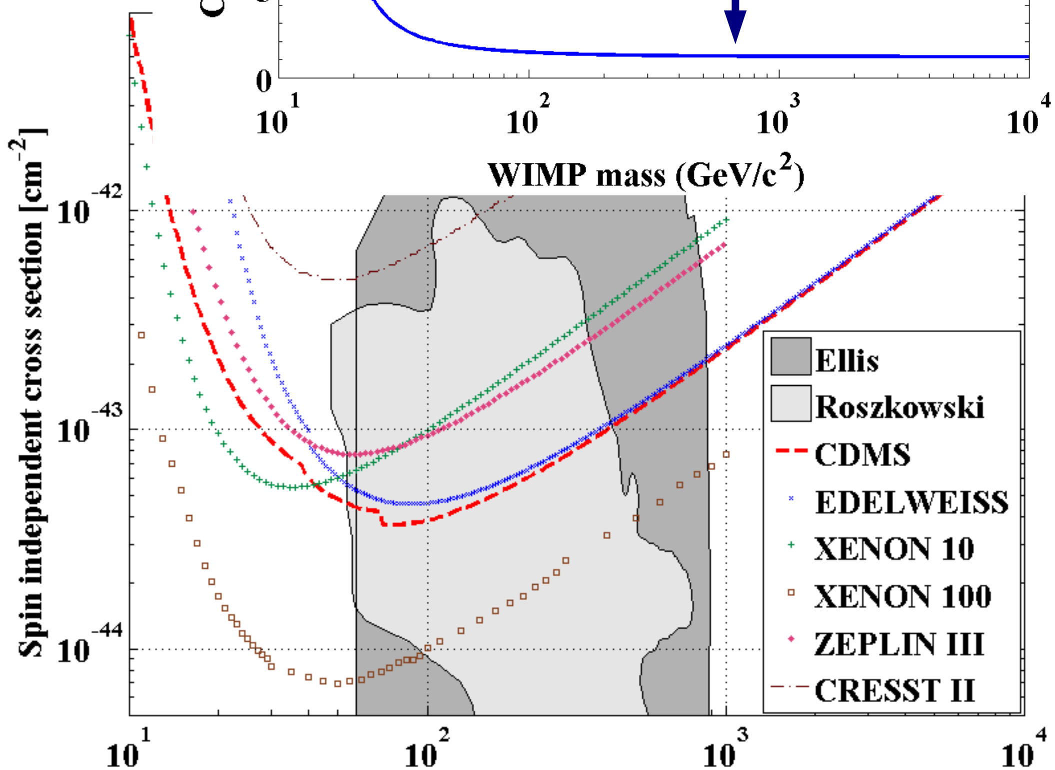


The EDELWEISS Experiment

(arXiv:1103.4070, submitted PLB)

- Located in Modane Underground Lab, France (4800 mwe)
- 10x400 g Ge ionisation-phonon detectors
- Patterned electrodes to identify surface events
- Total:
    - Max exposure 384 kg.d
    - Threshold 20 keV
    - Purblind analysis
    - 5 candidate events
    - Known backgrounds contribute <= 3 events



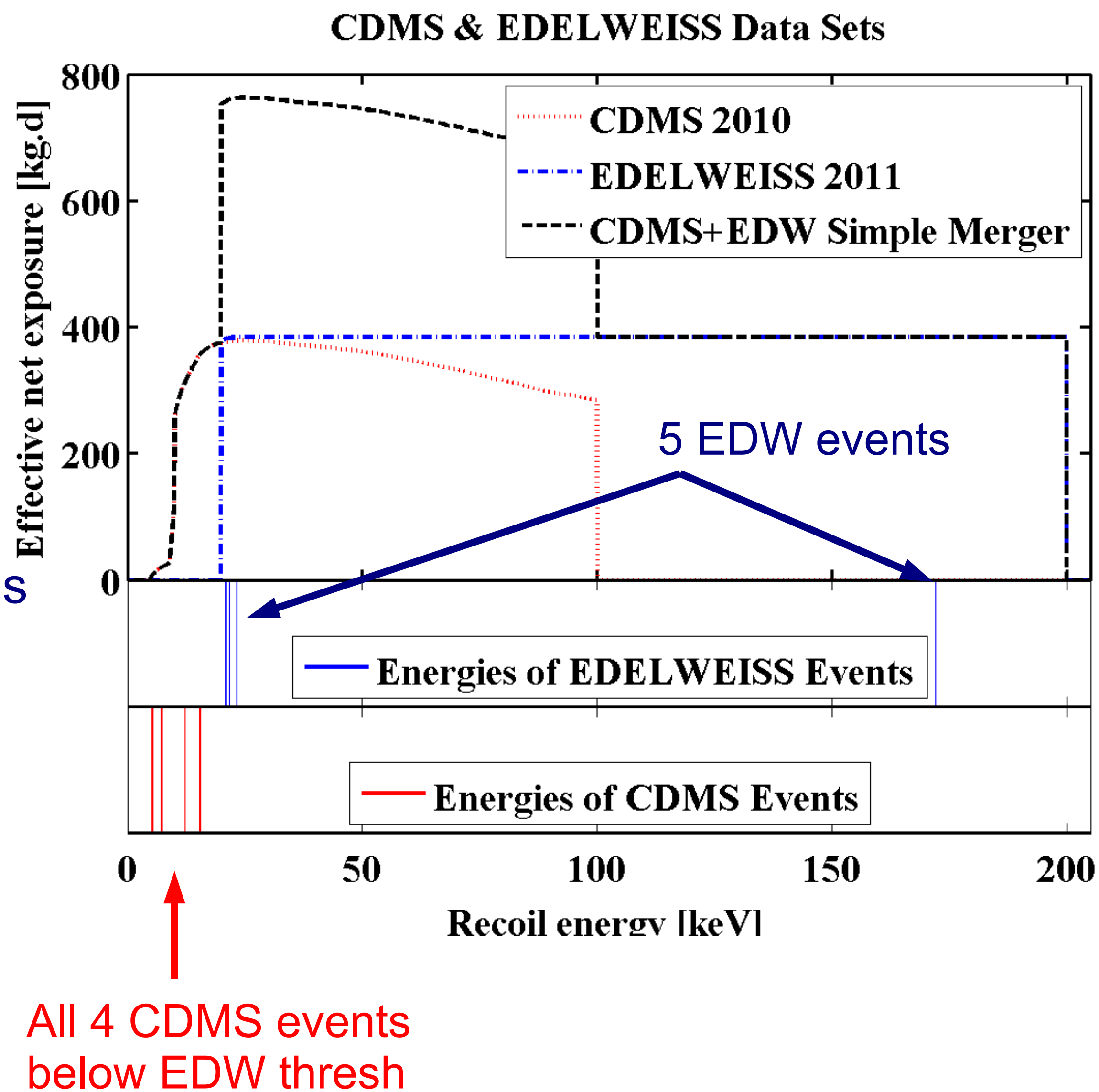


Similar physics, systematics to CDMS

Simple Merger (S. Yellin, arXiv:1105:2928)

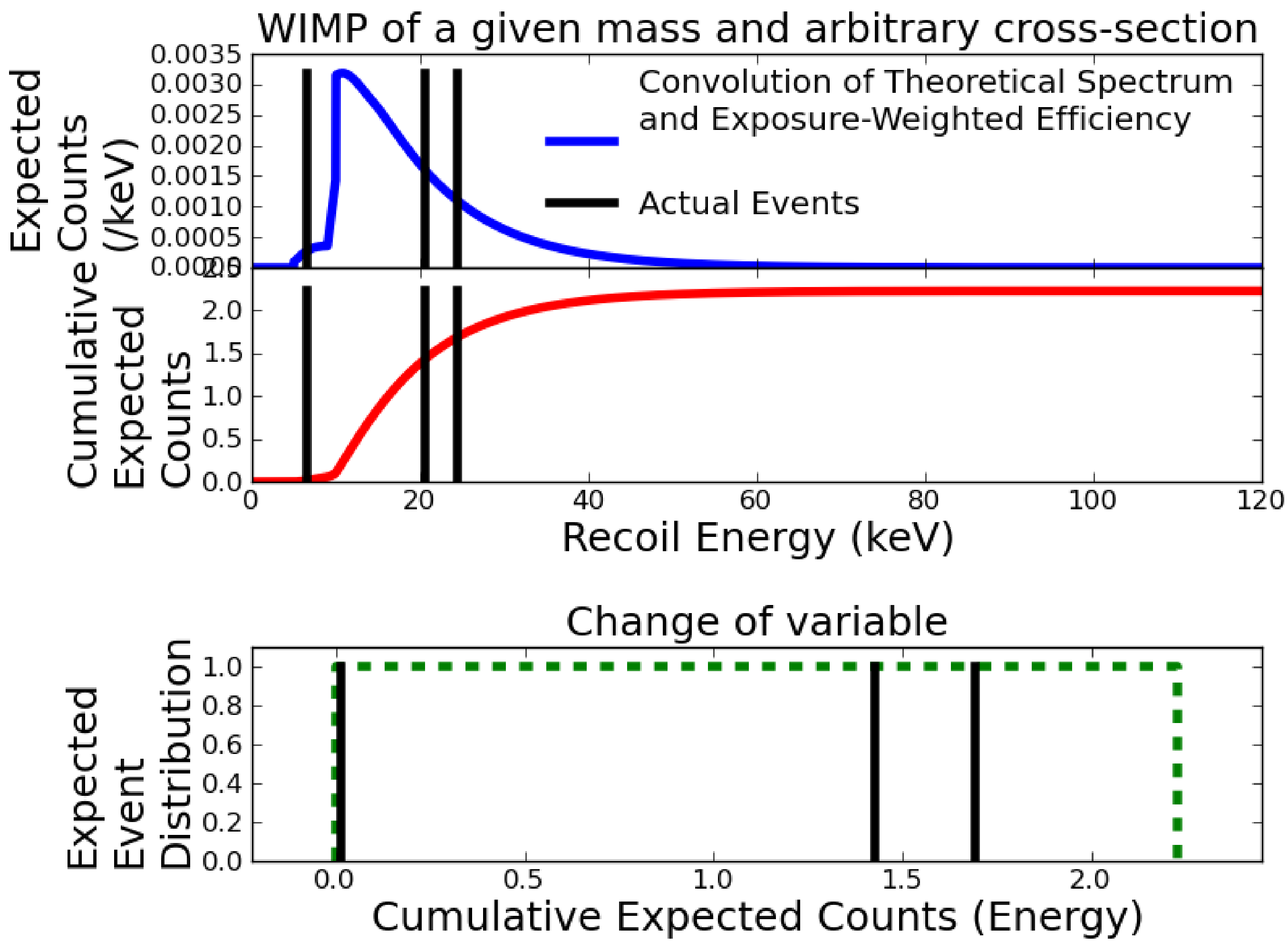
- Agreed upon before data were exchanged between experiments
- Official result of collaboration
- Method:
  - Sum exposure-weighted efficiencies
  - Combine events, regardless of experiment of origin
  - Apply standard "optimum interval" limit procedure (S. Yellin, PRD 66 032005 2002)
- What most experiments already do with their individual detectors, runs ...

- Data:



Optimum Interval/Simple Merger

(S. Yellin PRD 66, 032005, 2002)



Optimum Interval/Simple Merger

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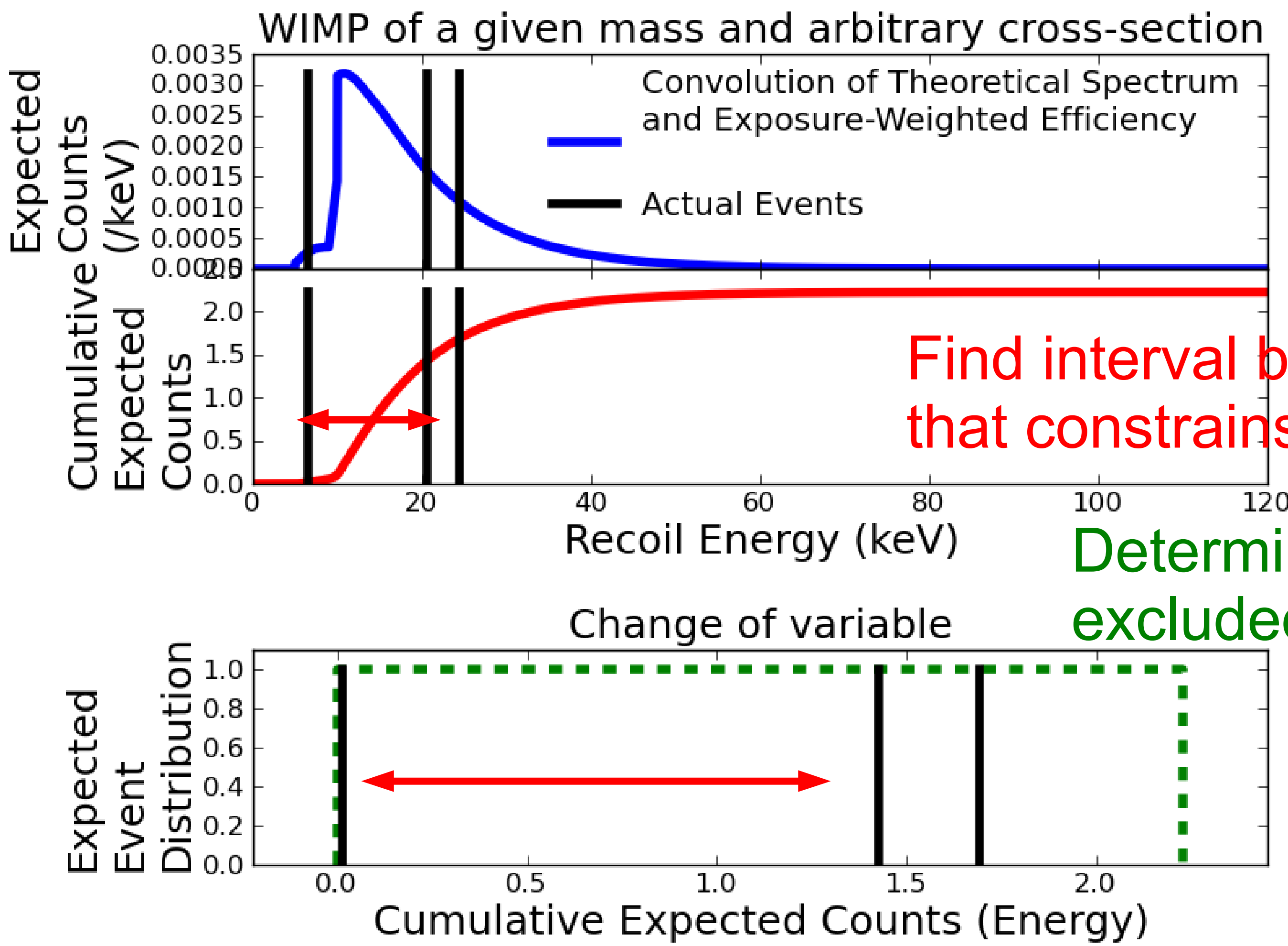
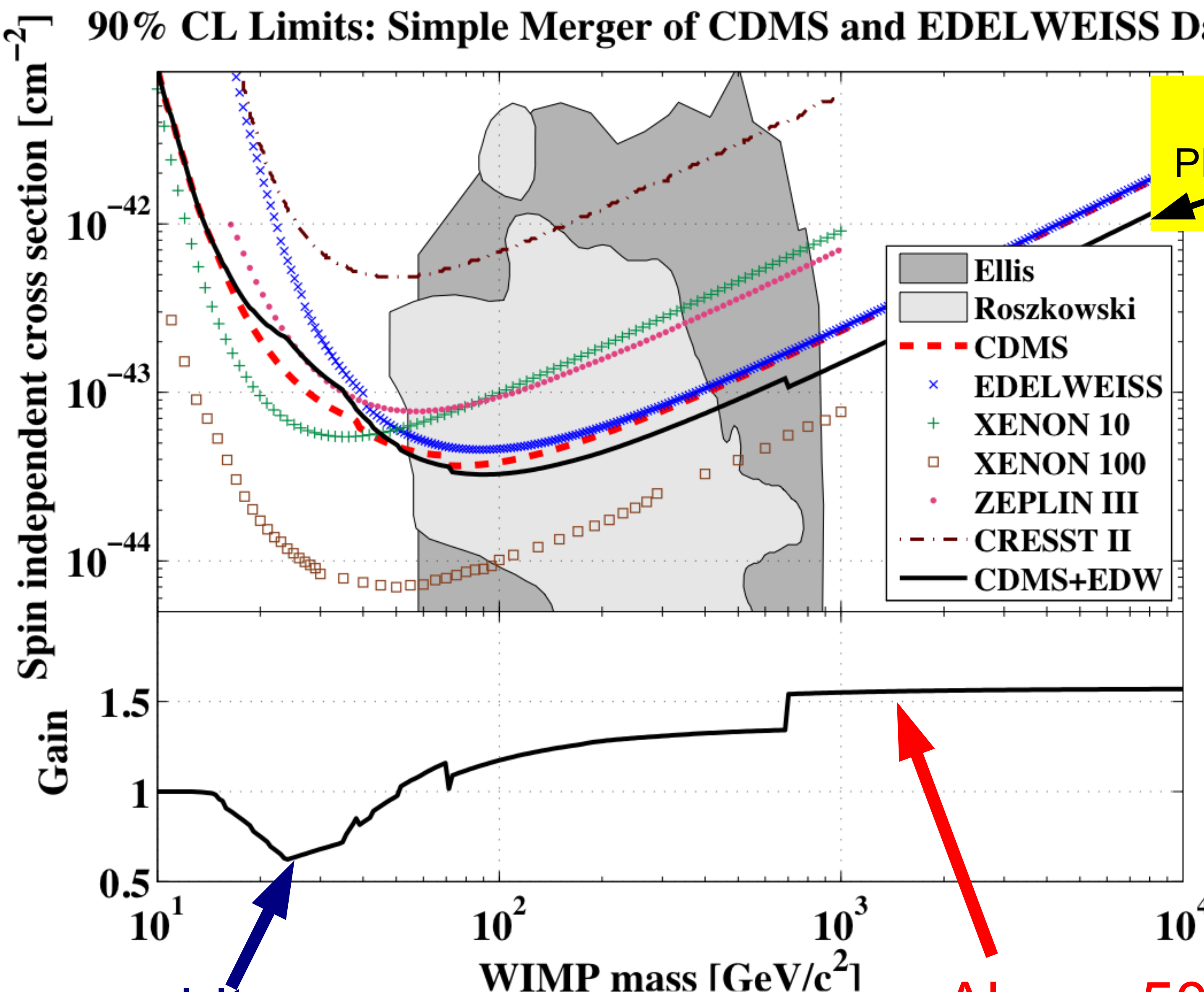


Find interval between events that constrains cross section the most

Determine greatest cross section excluded at 90%CL

Must pay statistical price for choosing interval

CDMS-EDW Combined Limits: Main Result



Combined Limit
PRD 84 (2011) 011102(R)
arXiv:1105.3377

For heavy WIMPs, roughly factor 2 behind XENON (arXiv:1104.2549)

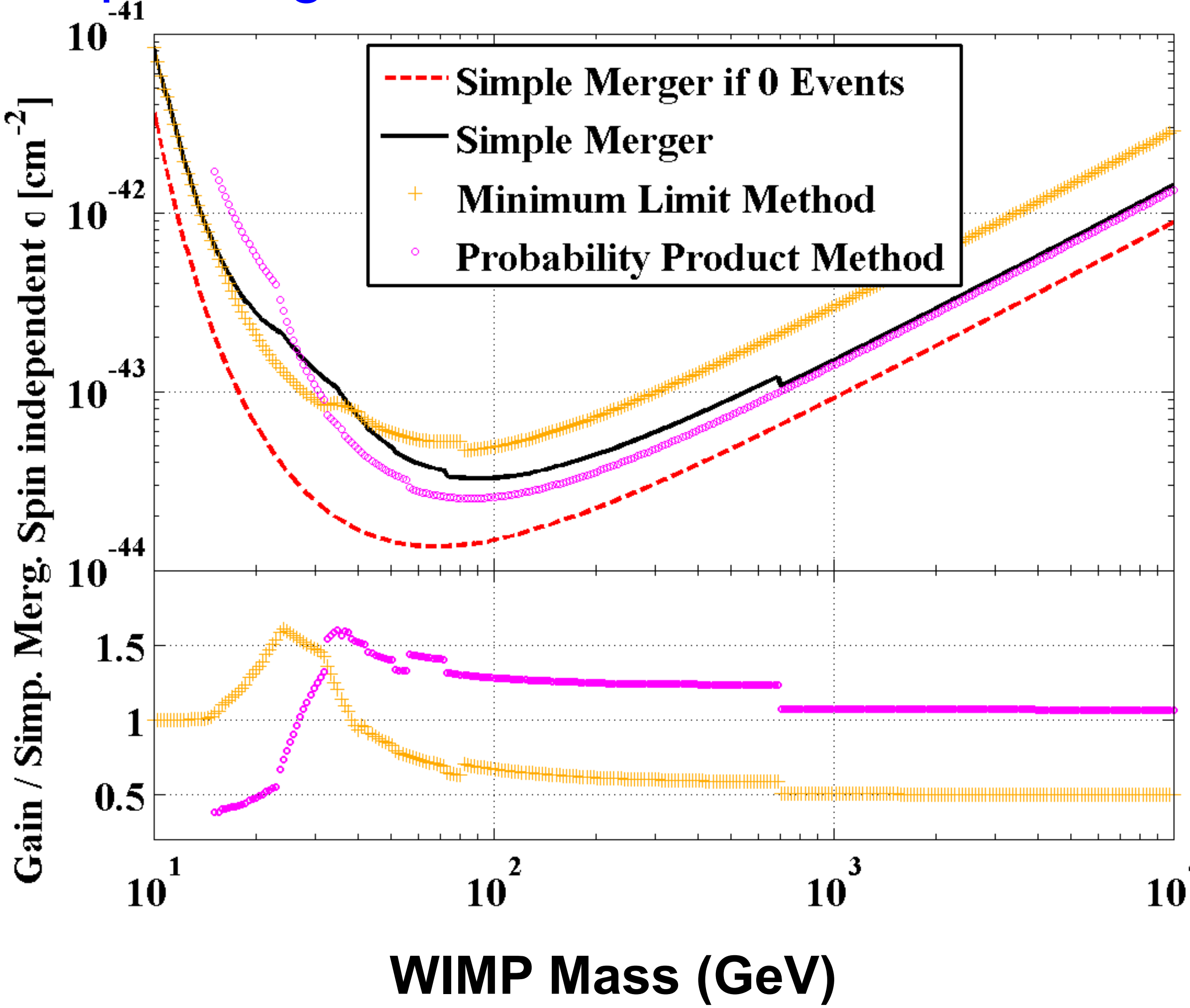
Lose a bit for light WIMPs

Above 50 GeV, improve up to factor 1.6

Alternative Methods (S. Yellin arXiv:1105.2928)

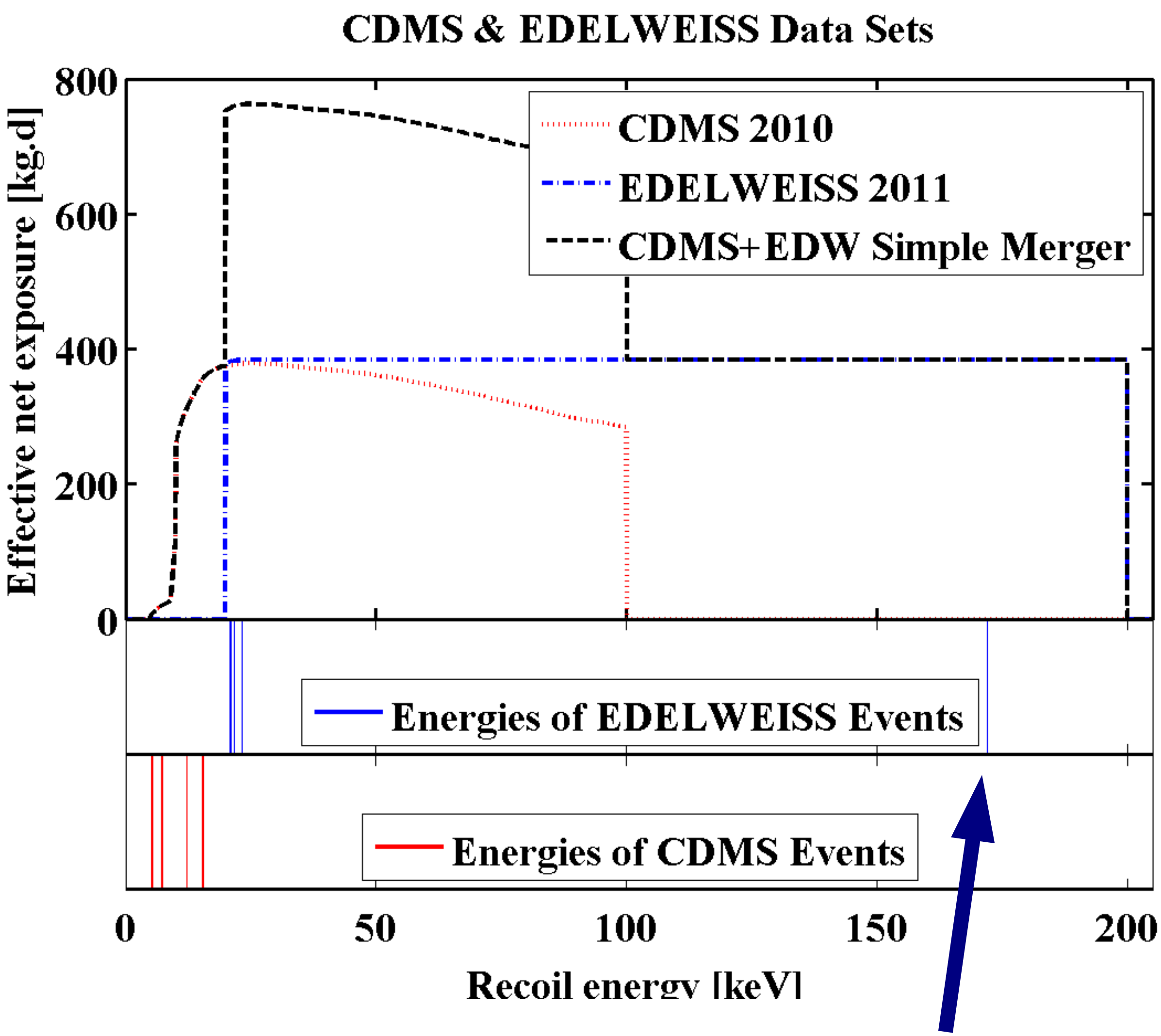
- Other methods that exploit the provenance of events are possible
- E.g. different ways to combine the probabilities of the optimum interval method applied to individual experiments
  - "Minimum Limit": Choose most constraining expt, but pay statistical penalty – appropriate for background limited cases
  - "Probability Product": - appropriate for low background cases

- Constraints can be stronger/weaker depending on method, WIMP mass



- Method should be chosen based on what is known of backgrounds a priori

Insight into Backgrounds



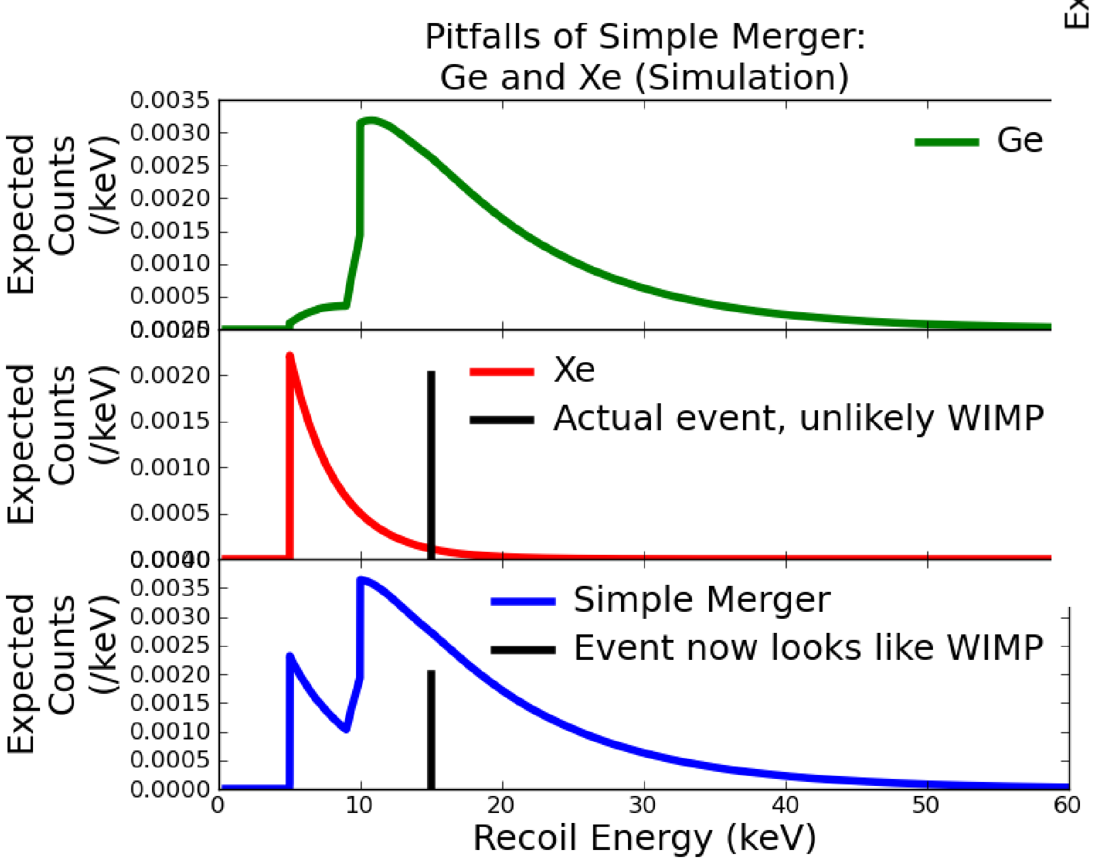
172 keV EDW outlier
considered background ab initio

- Independent likelihood test to CDMS, EDW separately:
  - WIMP mass most likely to cause events is <= 17 GeV in both cases,
  - but cross sections (rates) very different
- Likelihood ratio test of CDMS, EDW, CDMS+EDW:
  - No background hypothesis rejected at > 99.8%CL
  - Robust to variations in halo model

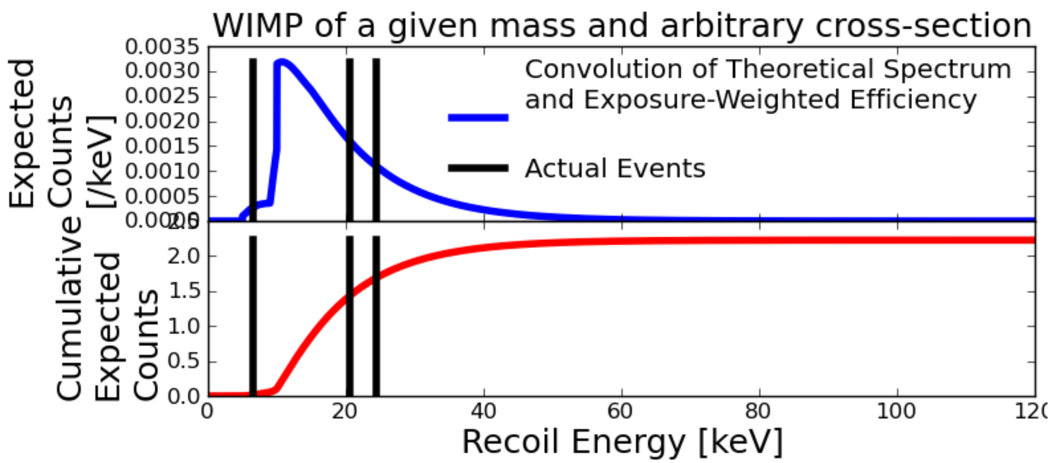
Merging Experiments with Different Targets

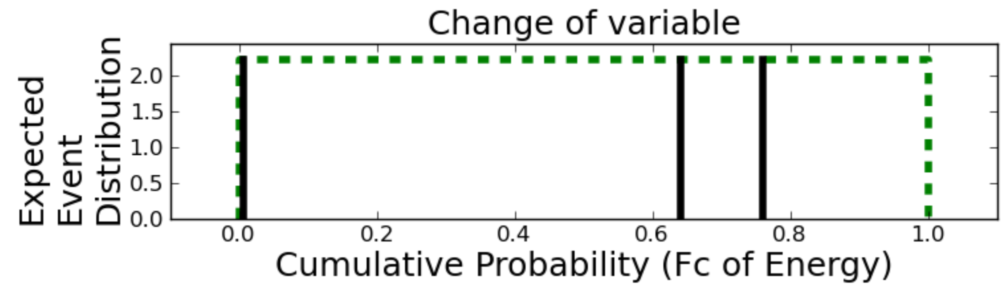
(S. Yellin arXiv:1105.2928)

- Methods that combine probabilities can be used as is
- Simple merger may have drawbacks
- Eg: an event in Xe, at too high an energy to be a WIMP, could look like a WIMP when added to Ge data



- Alternative: merge cumulative probabilities





“If you can't beat'em, join'em”

- CDMS and EDELWEISS collaborations have produced a common analysis of their results
- The method was agreed upon before data were exchanged
- The main result improves constraints from subkelvin Ge detectors on WIMPs heavier than 50 GeV
- Data available on arXiv:1105.3377
- Other methods possible, should be chosen based on what is known about backgrounds a priori, can provide stronger constraints
- Can also be applied to other experiments, targets

Towards LHC-size author lists ?

Combined Limits on WIMPs from the CDMS and EDELWEISS Experiments

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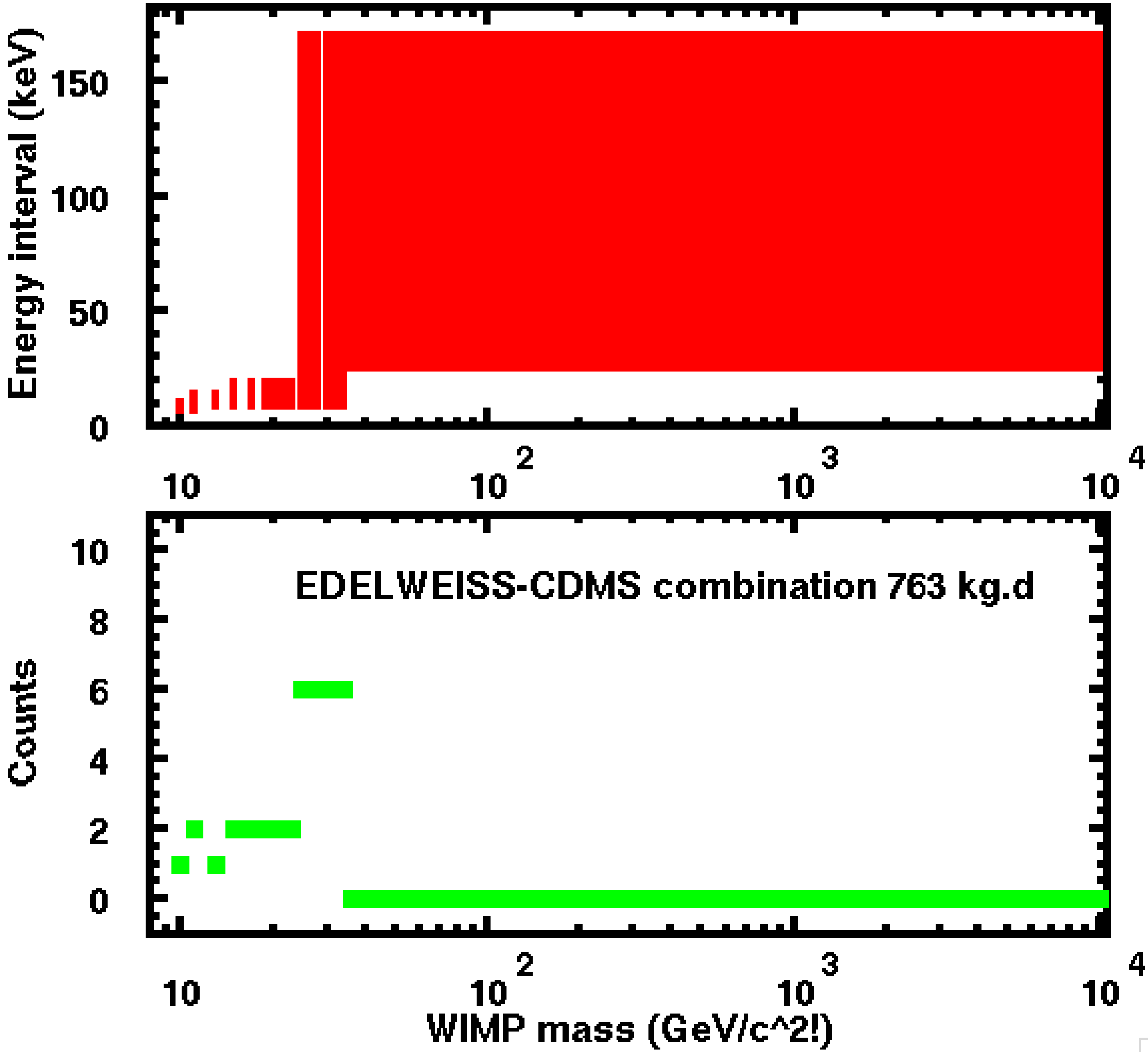
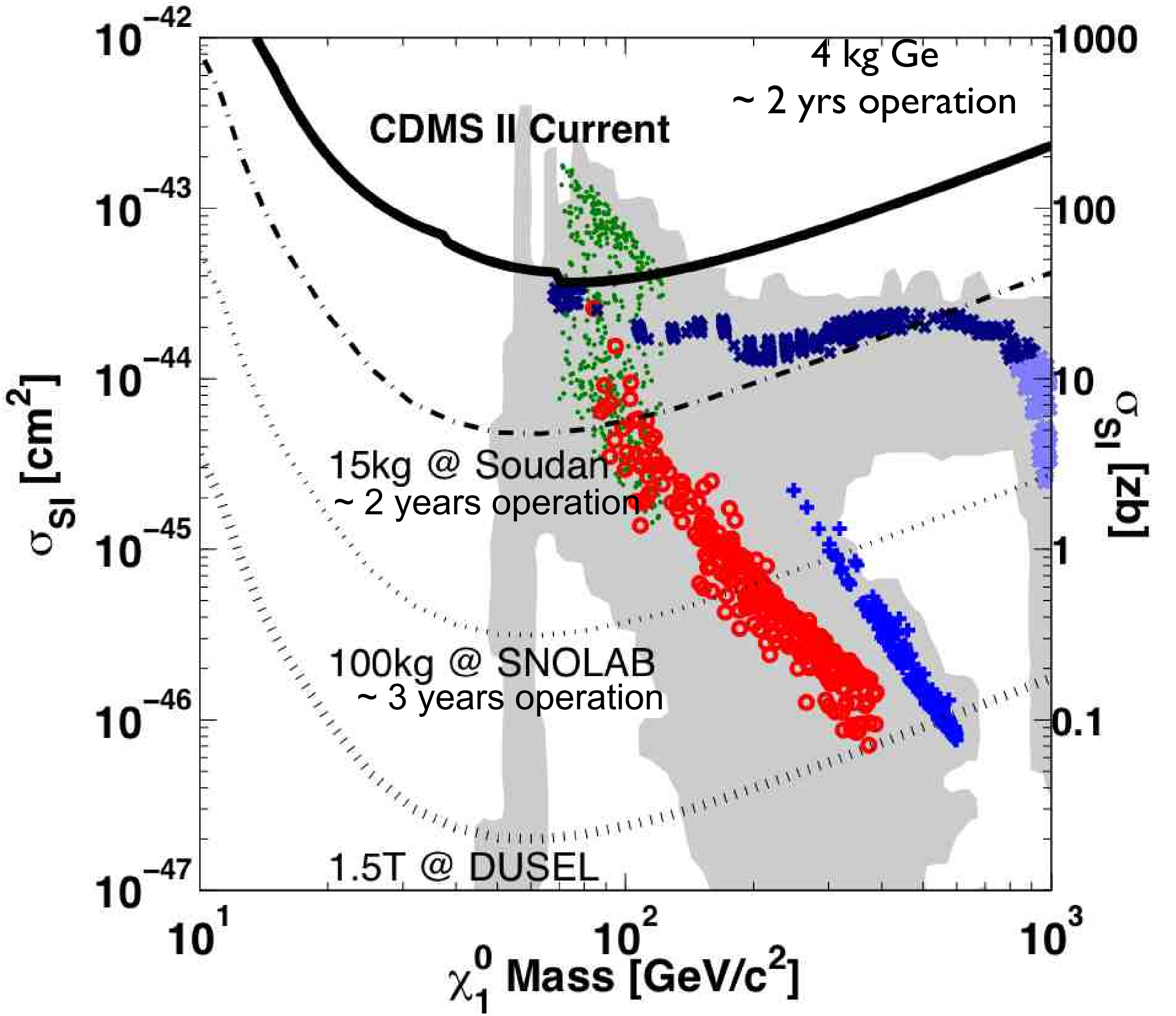
Optimum Interval



From CDMS to SuperCDMS

SuperCDMS:

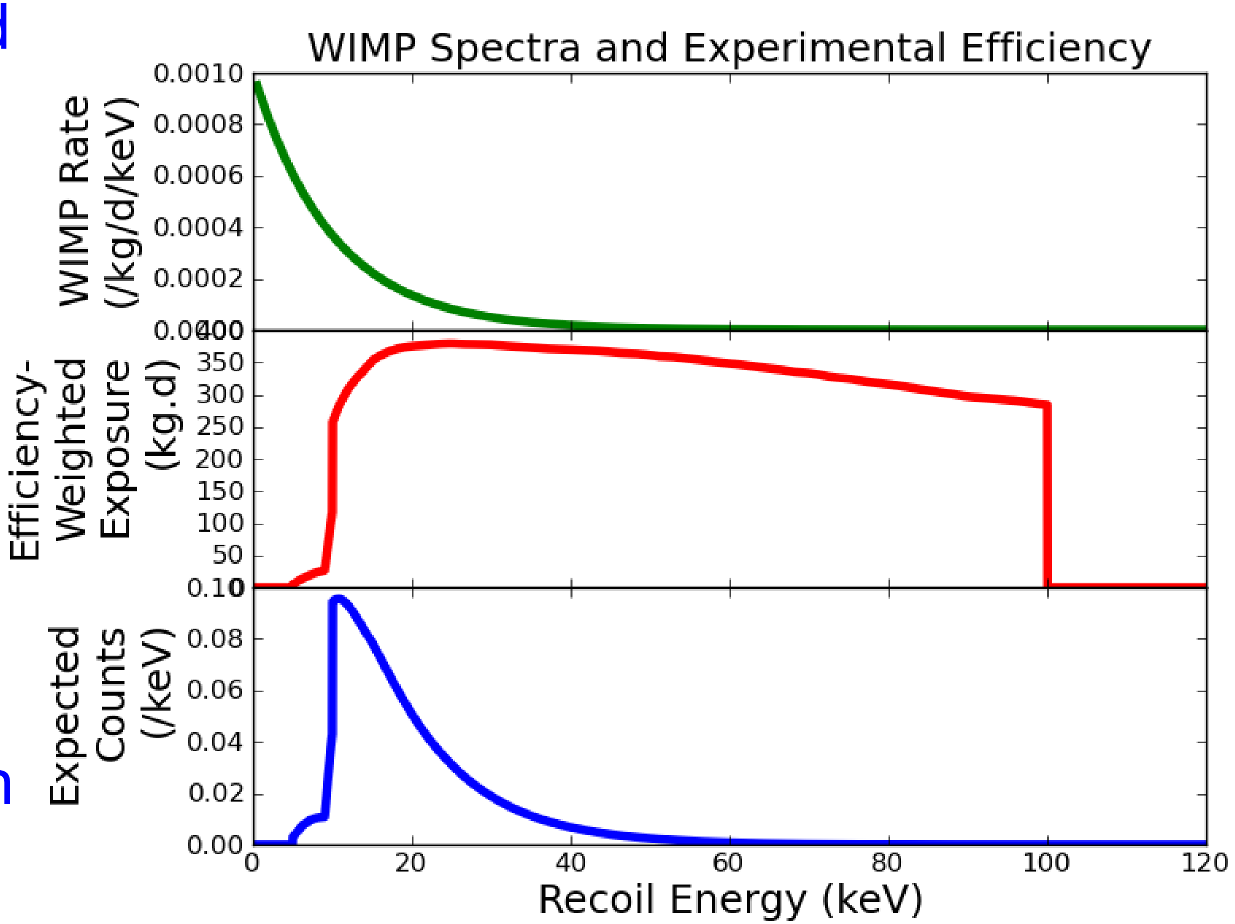
- Improved detectors (also use charge to ID surface evts)
- Larger, deeper experiment at SNOLAB (then DUSEL ?)

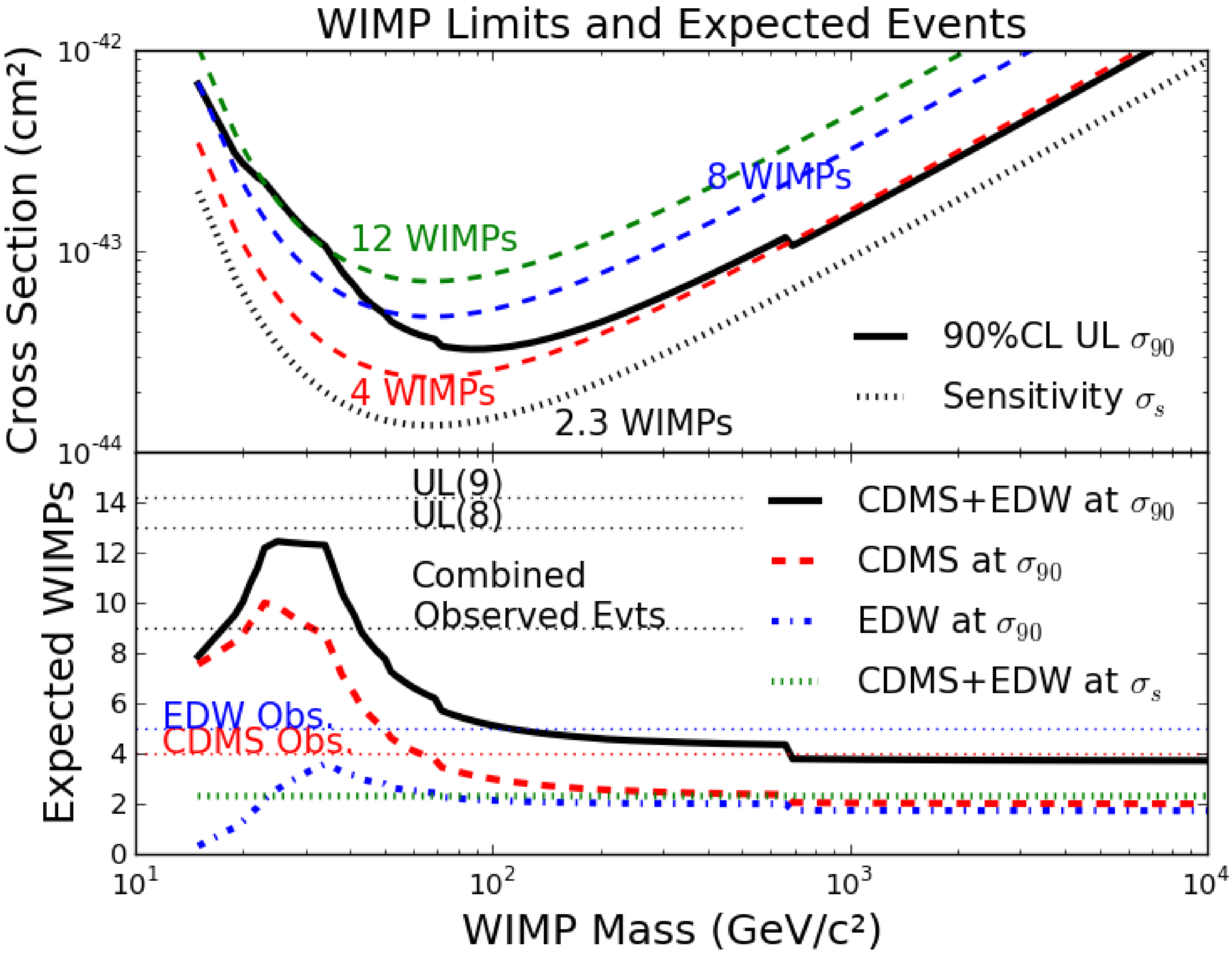


Optimum Interval/Simple Merger

(S. Yellin PRD 66, 032005, 2002)

- For a given WIMP mass, convolve experimental and theoretical data:
- Switch variable from energy to cumulative probability (uniformly distributed)
- Find interval between events with most information
- Find greatest cross section excluded at 90% CL
- Pay statistical price for choice of interval




WIMP Limits and Expected Events
Cross Section (cm²)
10-42
10-43
10-44
12 WIMPs
8 WIMPs
4 WIMPs
2.3 WIMPs
90%CL UL σ90
Sensitivity σs
Expected WIMPs
UL(9)
UL(8)
Combined
Observed Evts
EDW Obs.
CDMS Obs.
CDMS+EDW at σ90
CDMS at σ90
EDW at σ90
CDMS+EDW at σs
0
2
4
6
8
10
12
14
10¹
10²
10³
10⁴
WIMP Mass (GeV/c²)

CDMS and Light WIMPs

- CDMS and light WIMPs (PRL 106 (2011) 131302, PRD 82 (2010) 122004)
- Tension between results of (CDMS, XENON) and (COGENT, DAMA)