Direct Dark Matter Detection

Experiments and Results

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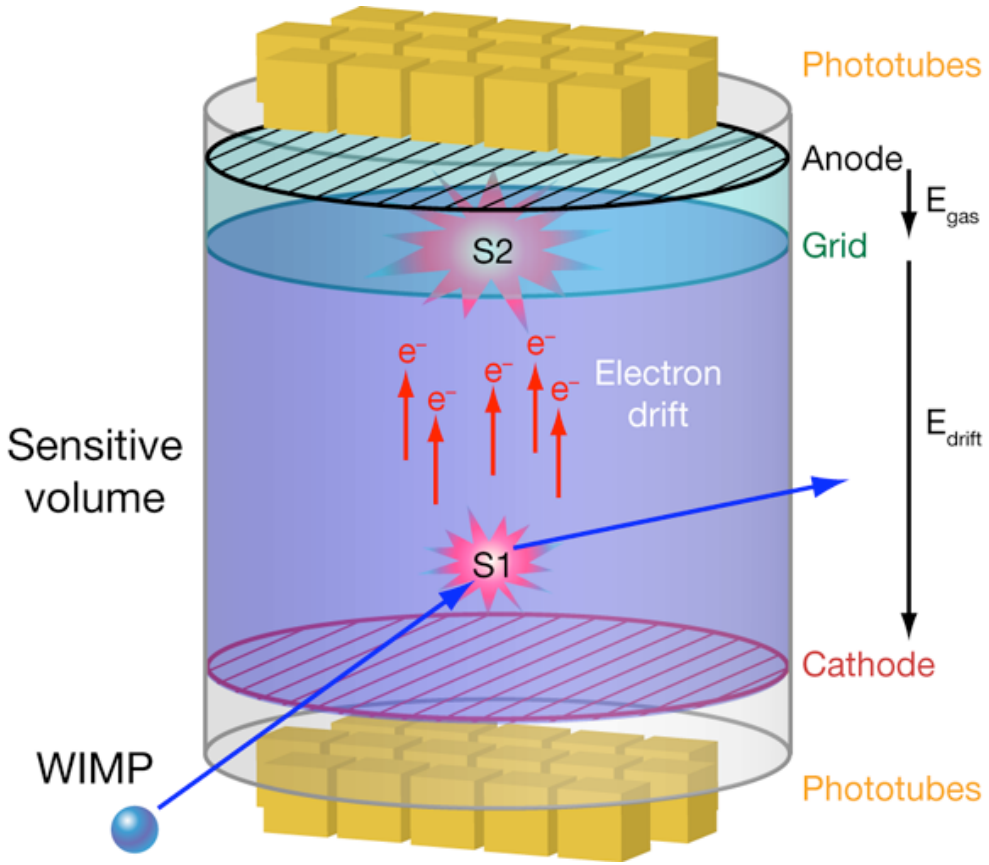
Outline

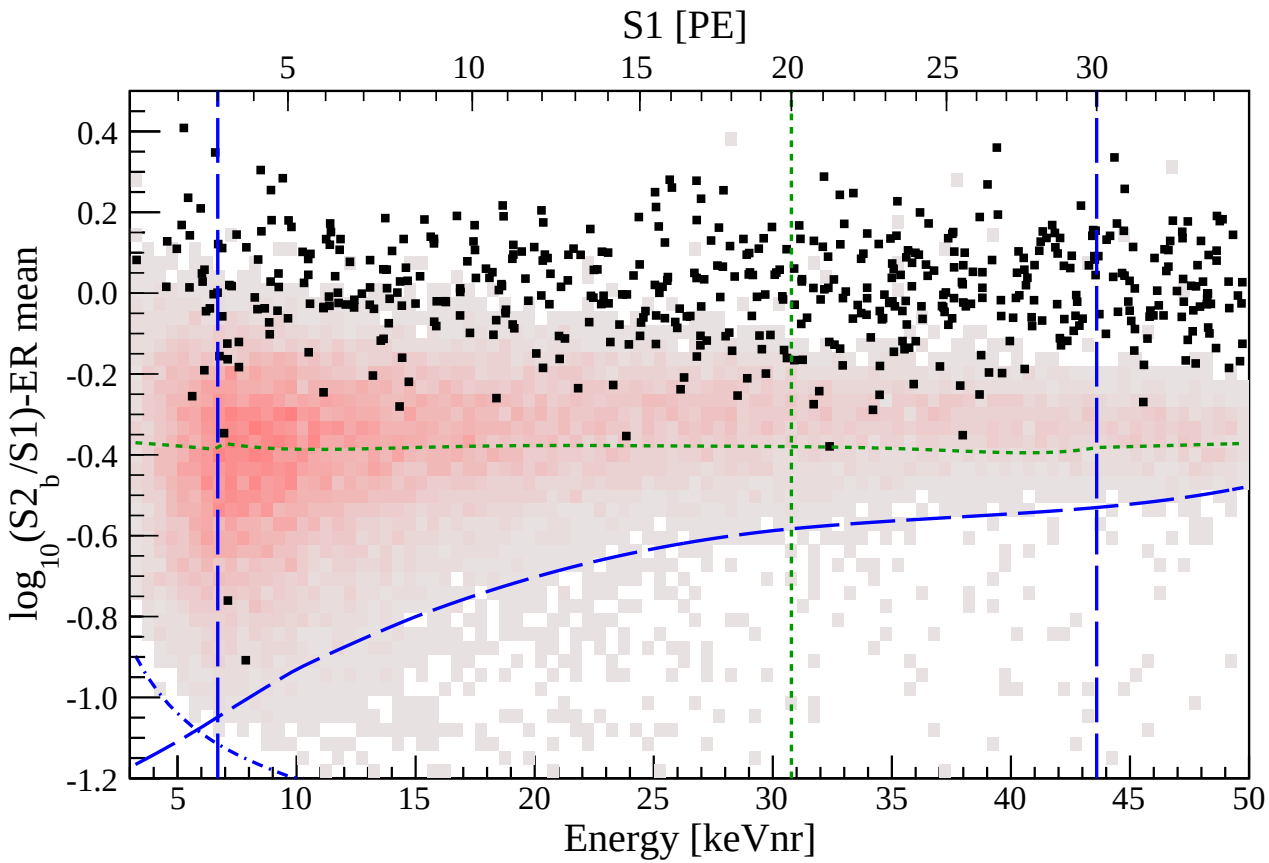
1. Xenon100
2. LUX
3. CRESST
4. DAMA

The Xenon-100 detector



- Two-phase (liquid + gas) xenon detector
- *S1* signal: scintillation
- *S2* signal: ionization
- *S1*/*S2* different for nuclear recoils (= signal) and electron recoils (= background)

Xenon-100 data

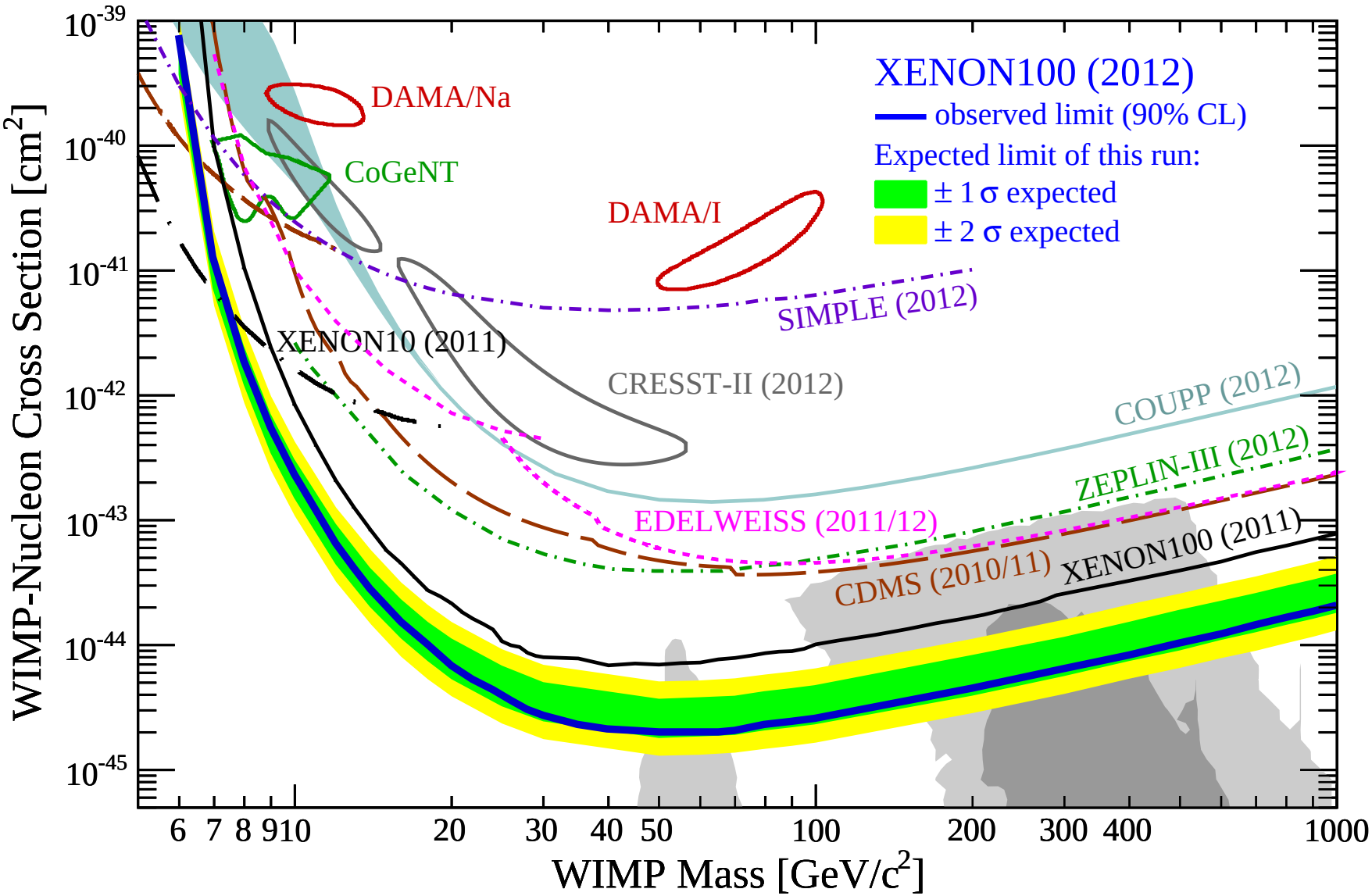


black = electron recoil events

red = nuclear recoil calibration data (neutron scattering)

blue = boundary of signal region in analysis

Xenon-100 results – 2012



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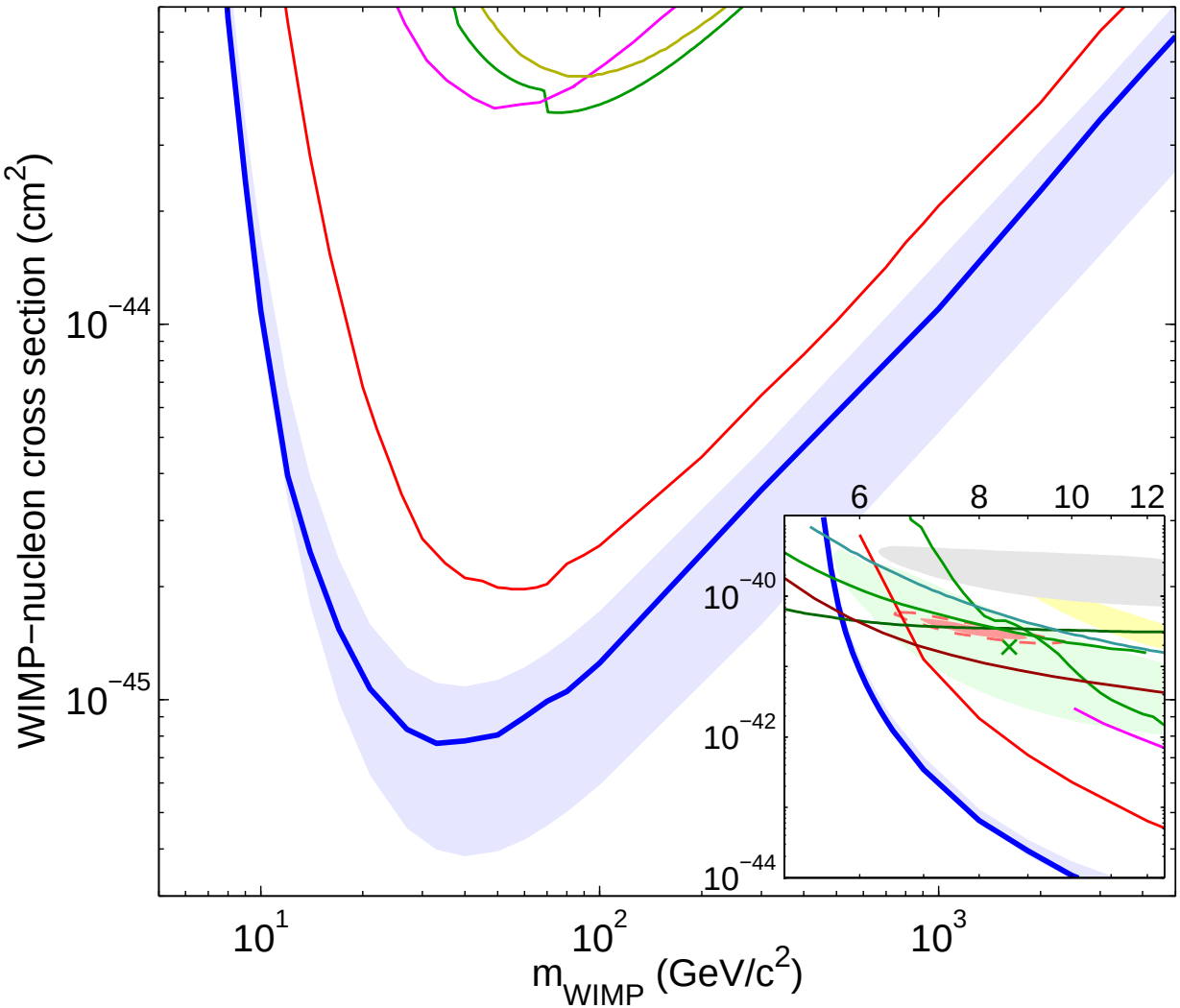
LUX (Large Underground Xenon Detector) – 2013

Detector and analysis very similar to Xenon100
(somewhat larger target volume)



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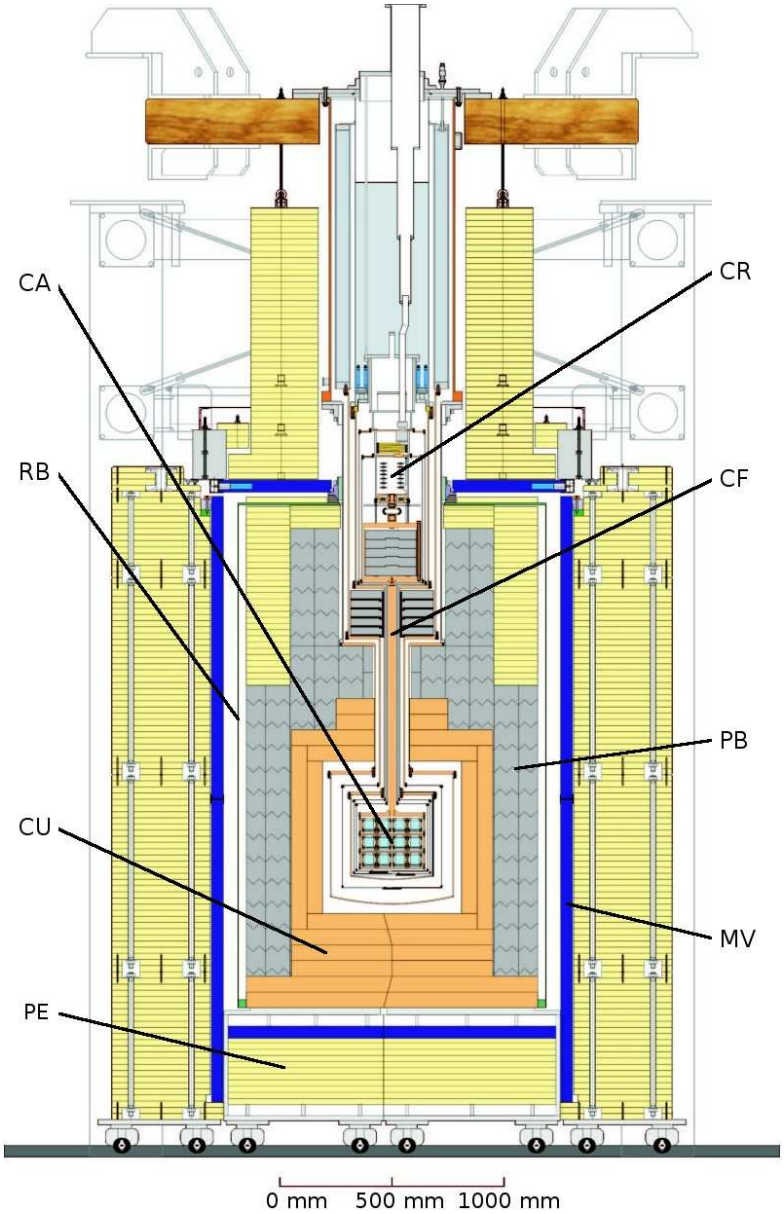
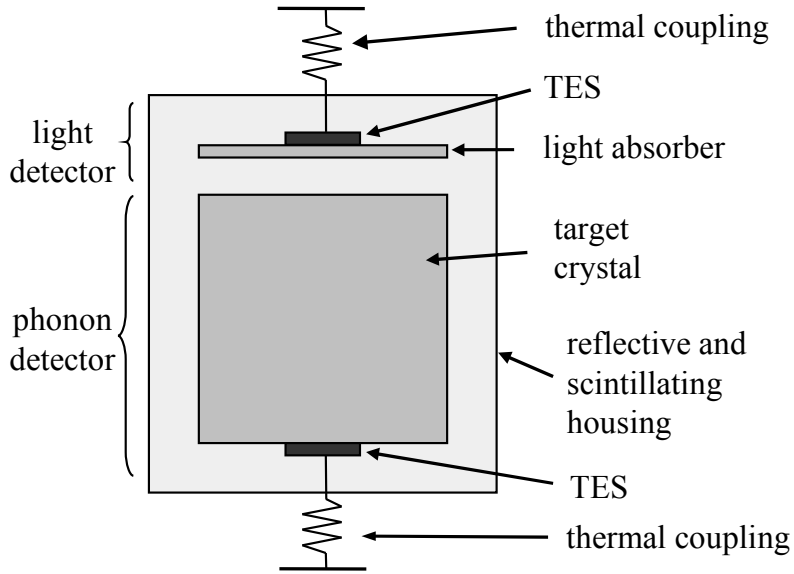
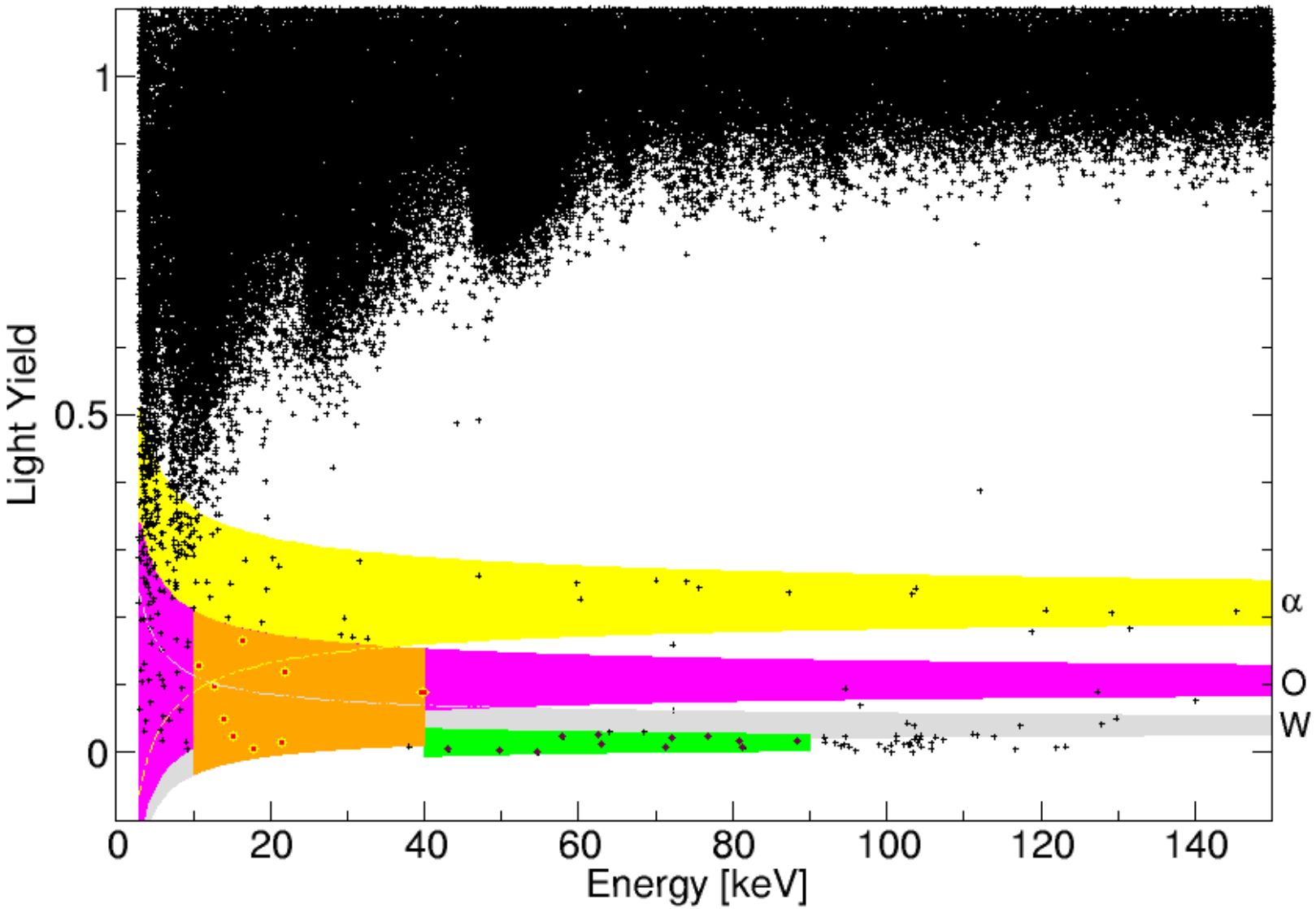
The CRESST setup



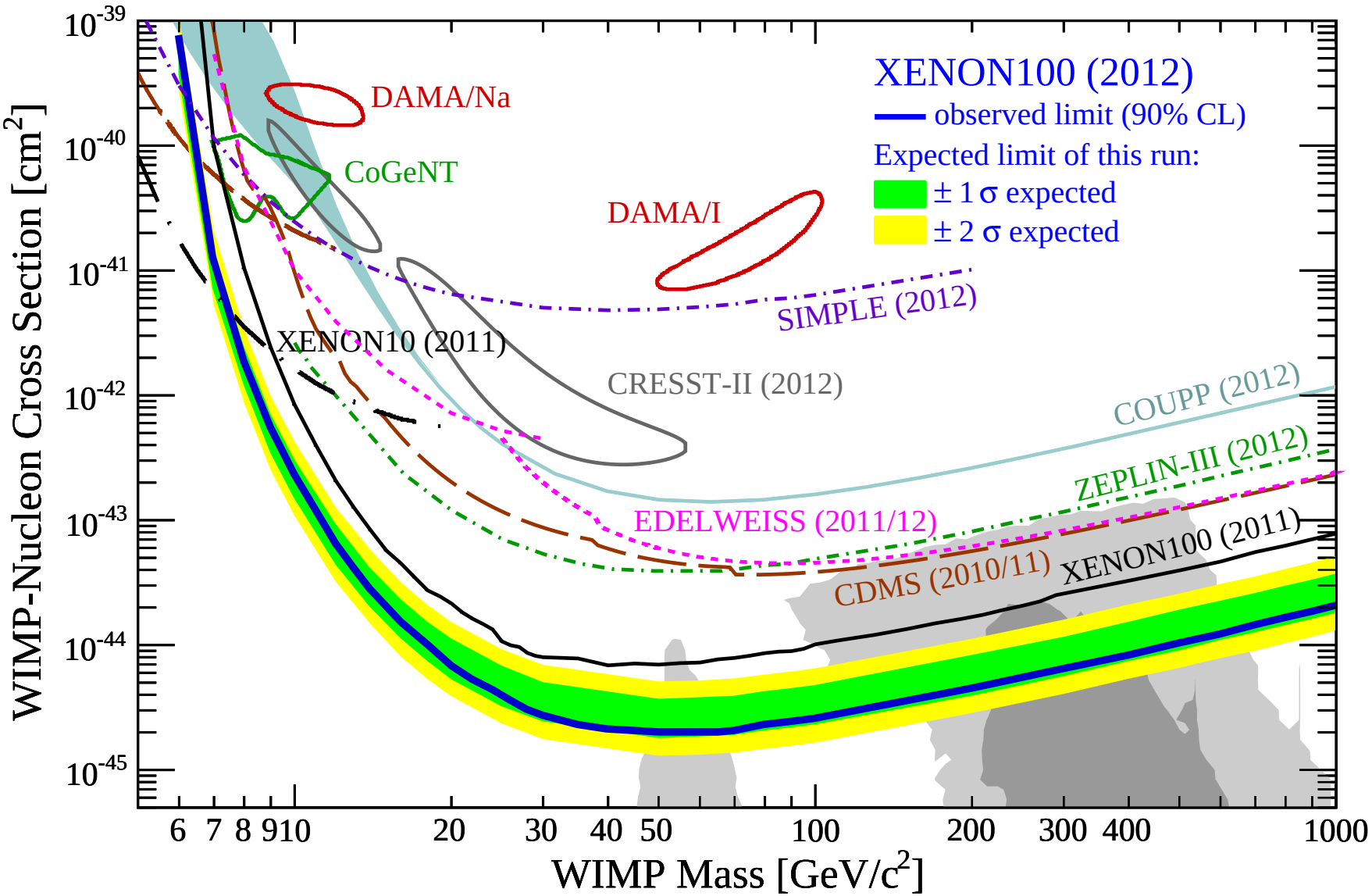
- $CaWO_4$ crystals
- Scintillation and phonon signals
- Superconducting phase transition thermometer
  (use large dR/dT at T_c)
  $\longrightarrow$ cryogenic
- Excess events seen
- Possibly due to mismodelling of Pb-210 background



CRESST data



CRESST results



Possible explanation (arXiv:1203.1576)

Decay of ^{210}Po (decay product of ^{222}Rn, an unavoidable background)

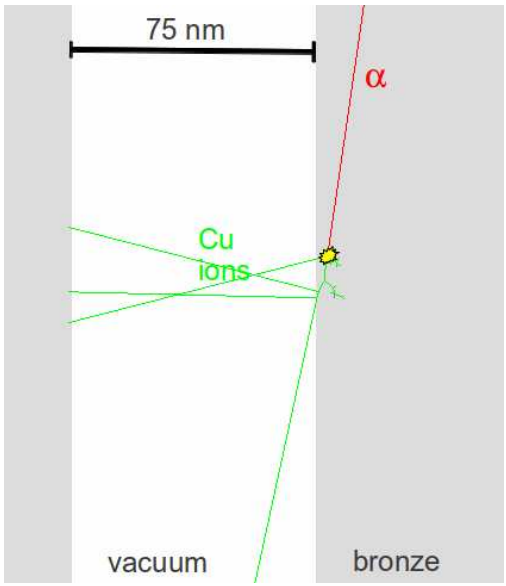
$$^{210}\text{Po} \rightarrow {}^{206}\text{Pb} + \alpha$$

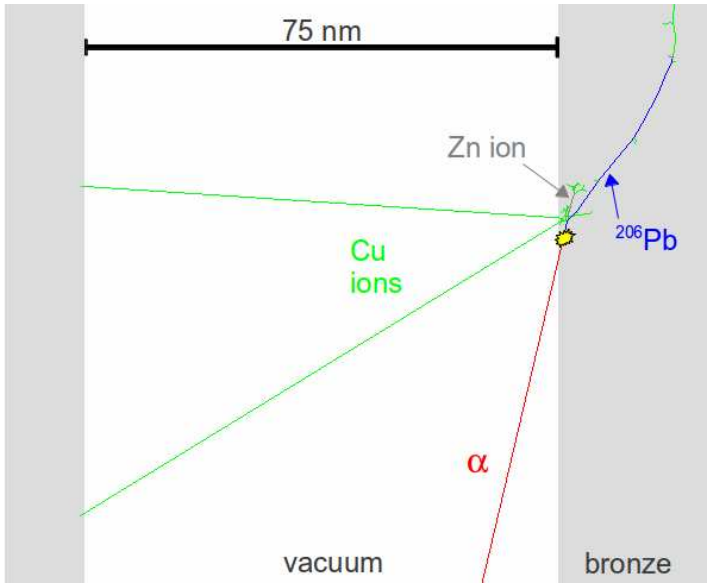
with sputtering of secondary Cu atoms from clamps holding the detector.

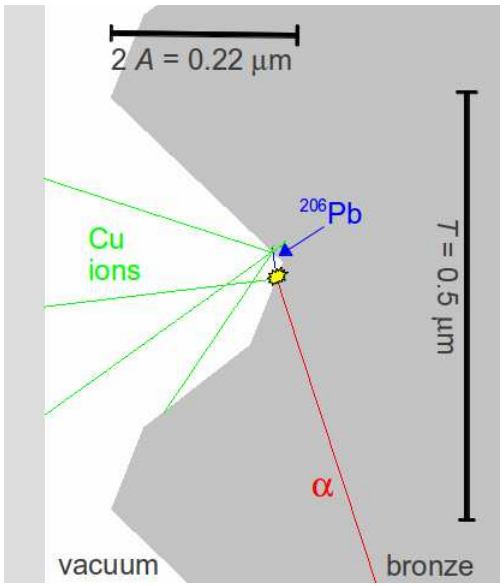
- If α is detected: High E events $\rightarrow$ outside DM signal region
- If α is not detected: Low E events — potential background to DM search

When realistic surface roughness is included:

- Fewer sputtered Cu atoms reach the detector
- Lower energy events — more likely to be background to DM search







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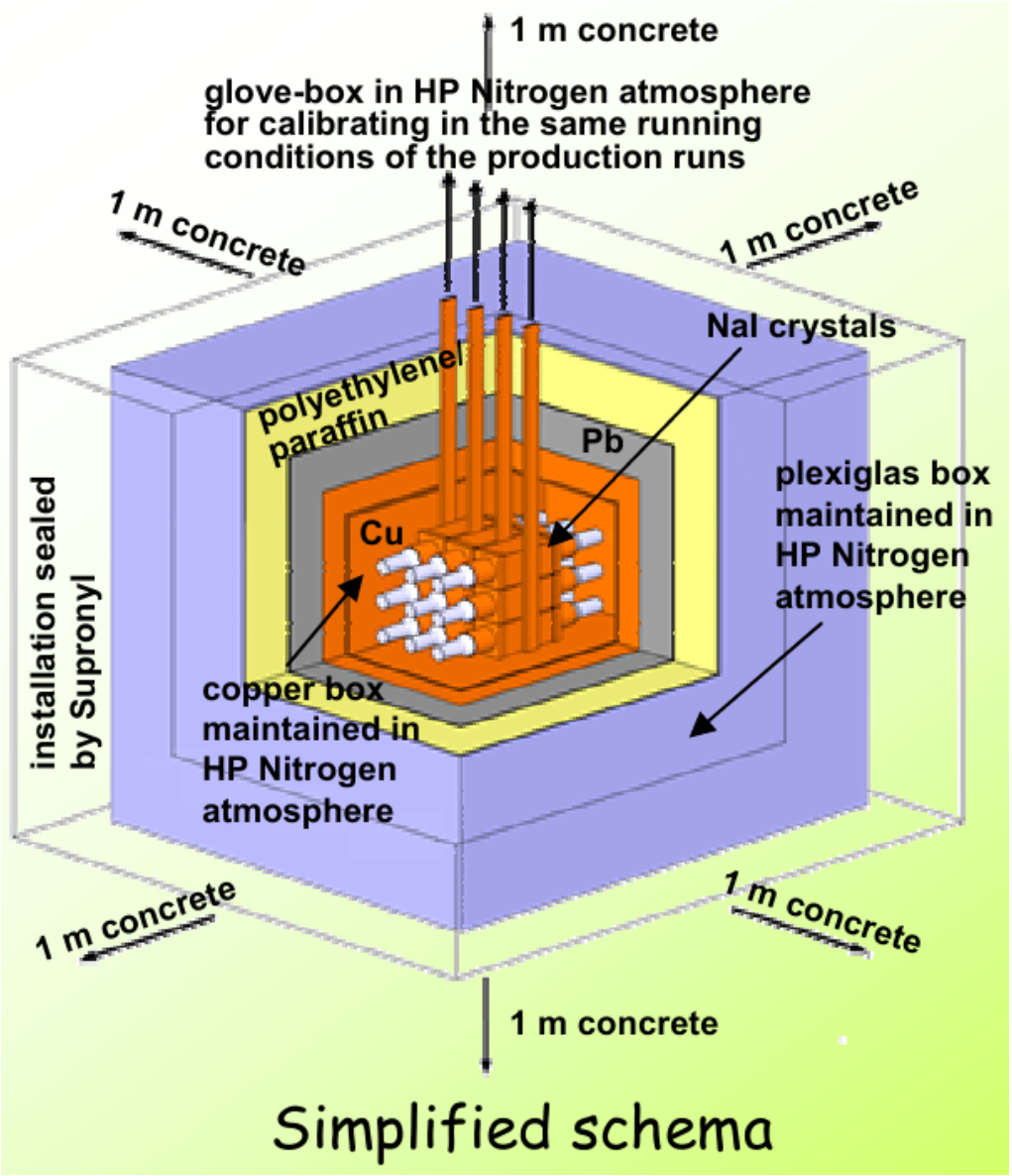
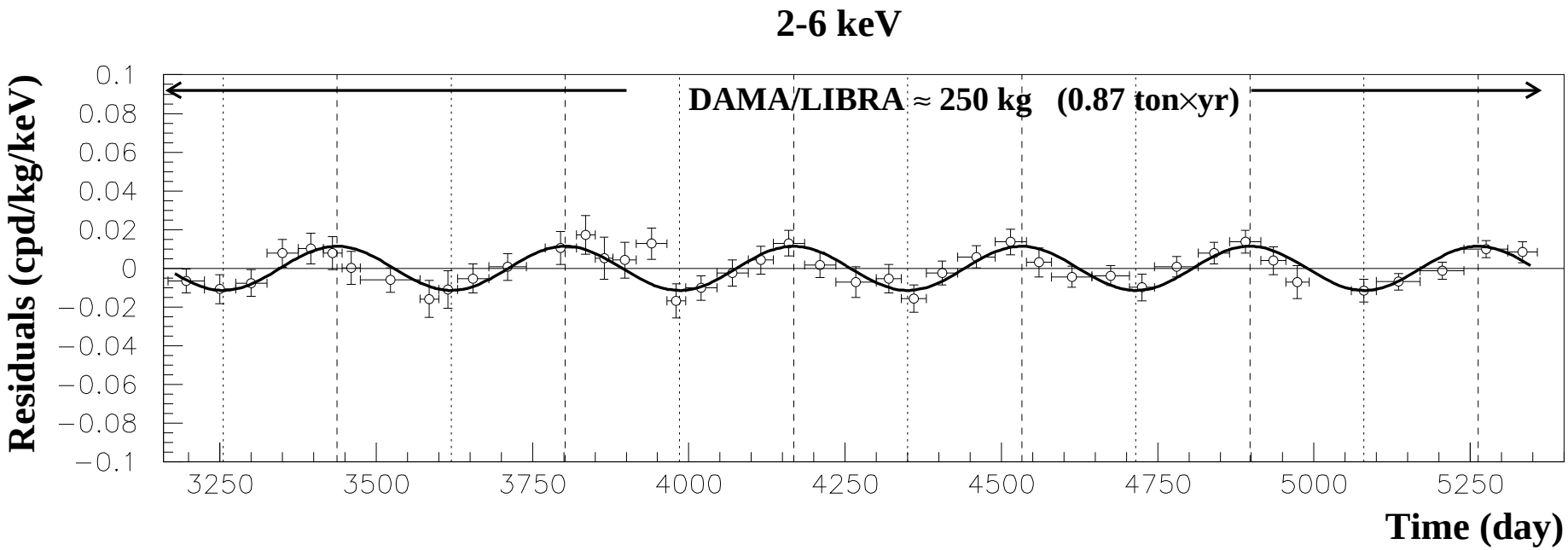
The DAMA setup

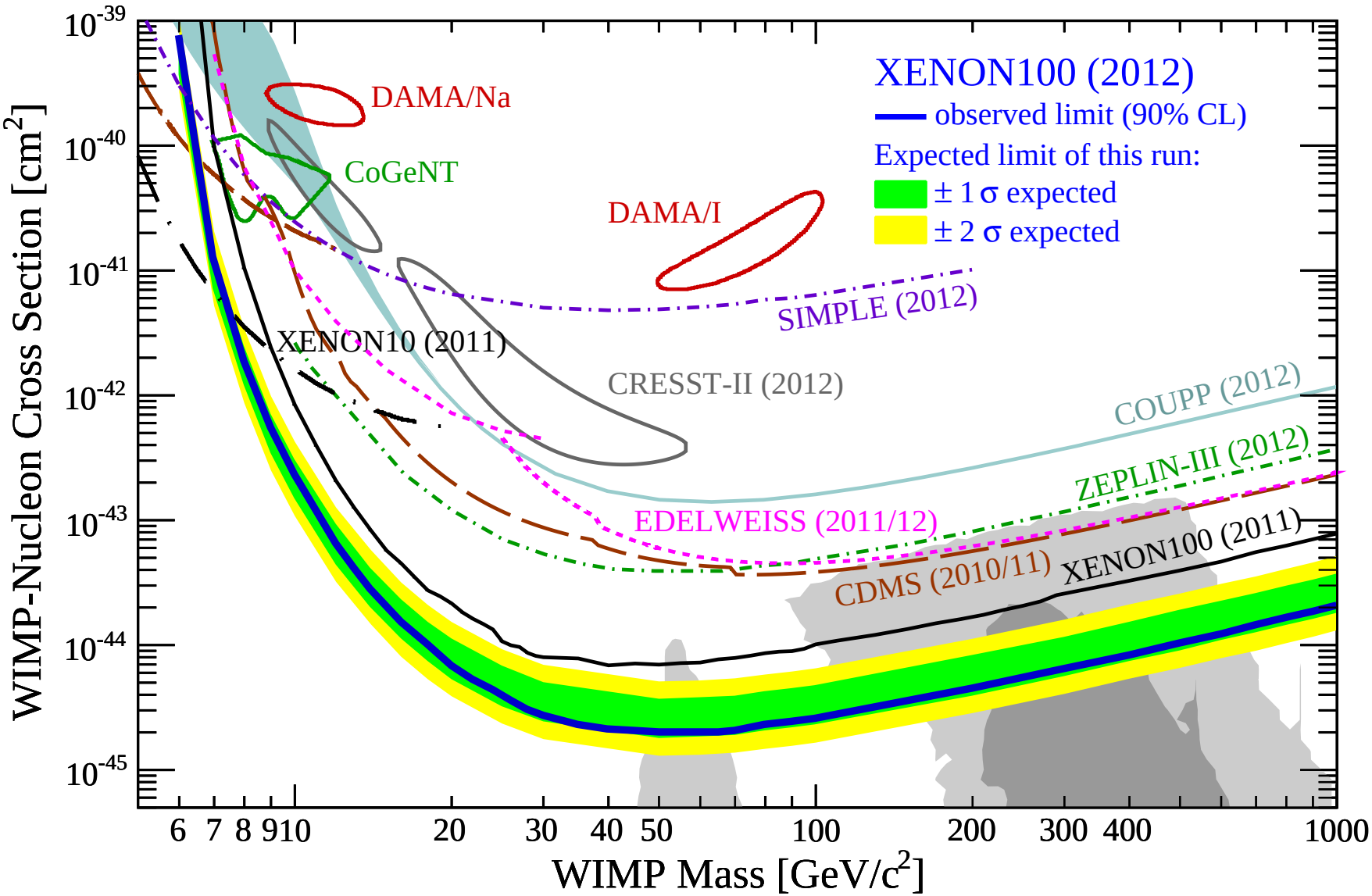


- Very clean NaI(Tl) scintillator detectors
- No signal/background discrimination
- Use annual modulation as signature
- Strong annual modulation observed
- Result highly controversial

DAMA data


2-6 keV
DAMA/LIBRA ≈ 250 kg (0.87 ton×yr)
Residuals (cpd/kg/keV)
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1
3250
3500
3750
4000
4250
4500
4750
5000
5250
Time (day)

DAMA fit


XENON100 (2012)
observed limit (90% CL)
Expected limit of this run:
± 1 σ expected
± 2 σ expected
DAMA/Na
CoGeNT
DAMA/I
SIMPLE (2012)
XENON10 (2011)
CRESST-II (2012)
COUPP (2012)
ZEPLIN-III (2012)
EDELWEISS (2011/12)
CDMS (2010/11)
XENON100 (2011)
WIMP-Nucleon Cross Section [cm^2]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
6 7 8 9 10 20 30 40 50 100 200 300 400 1000