SuperCDMS: Recent Results for low-mass WIMPS

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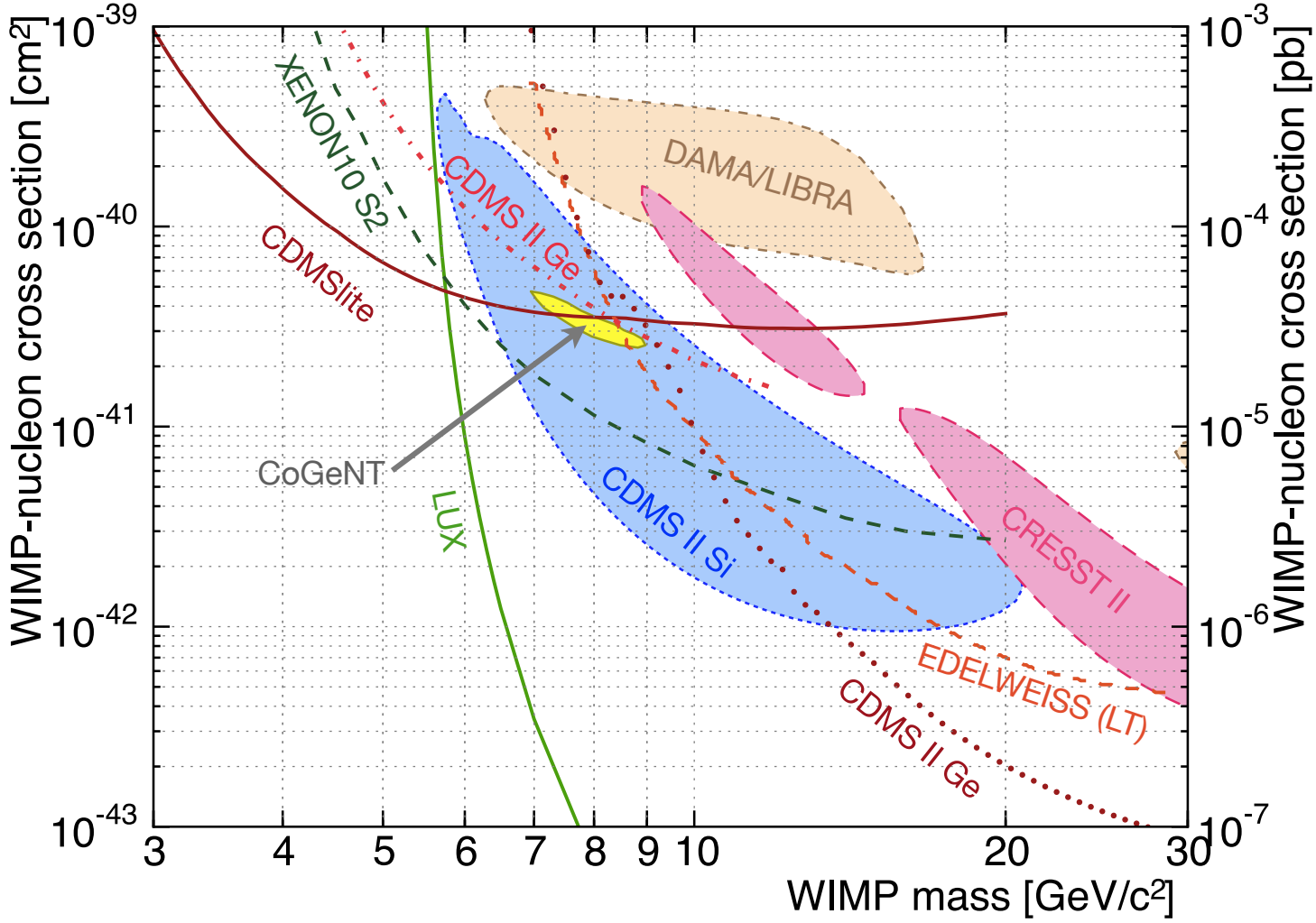
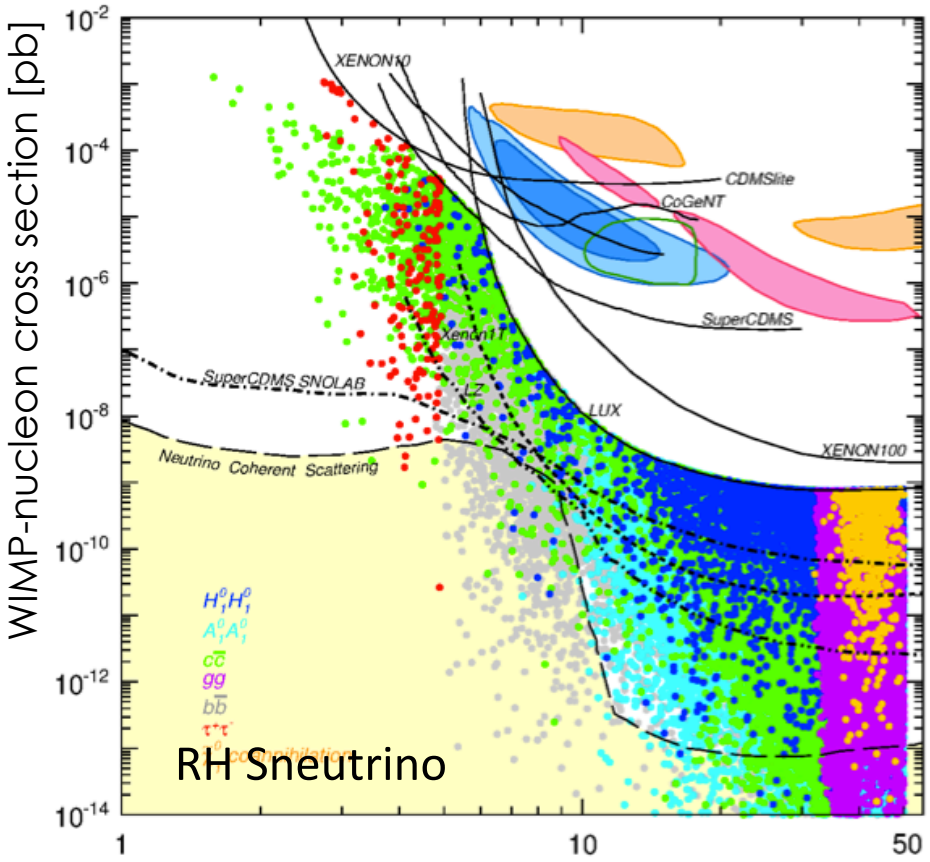
"Hints" for low-mass WIMPs in direct detection experiments



CDMS II Si: Phys.Rev.Lett. 111 (2013) 251301
CDMSlite: Phys.Rev.Lett. 112 (2014) 041302

Particle Physics models provide candidates for light DM



Cerdeño, Peiró, Robles
arXiv:1404.2572

Among other possibilities:

- Supersymmetry
  neutralino in the MSSM or NMSSM
  sneutrino in extended models

- Asymmetric DM

Are these theoretical predictions within the reach of our detectors?

It is an appealing window of the DM parameter space that is essential to explore

The search for low-mass WIMPs is challenging

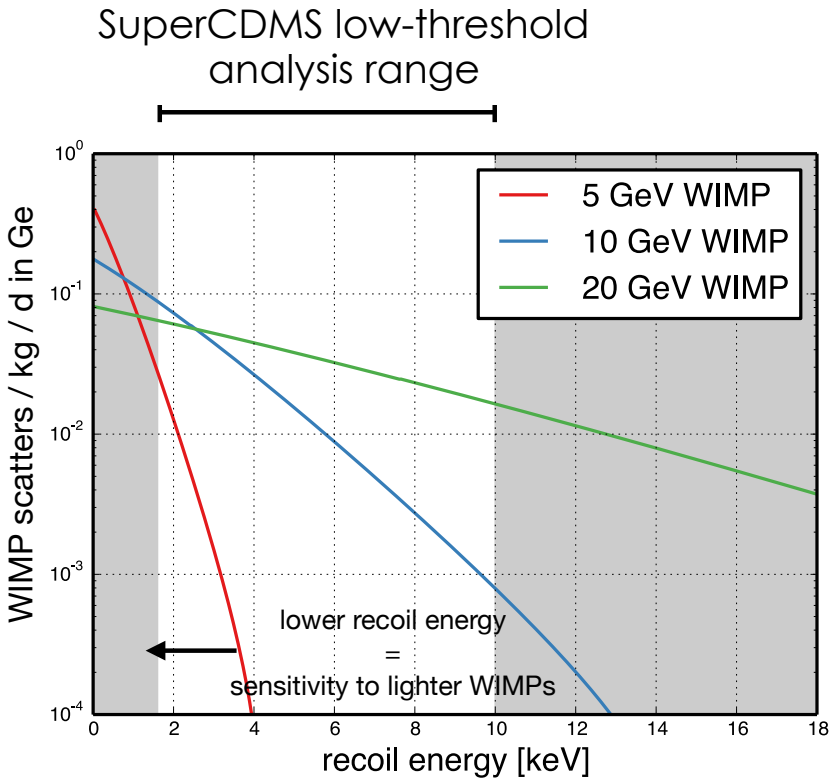
- The signal is expected at very low recoil energies

  Favours light targets

  Low-threshold searches

- Ge is relatively heavy so the threshold has to be just above the noise to be sensitive to 5 GeV WIMPs

  trigger threshold 1.6 keVnr



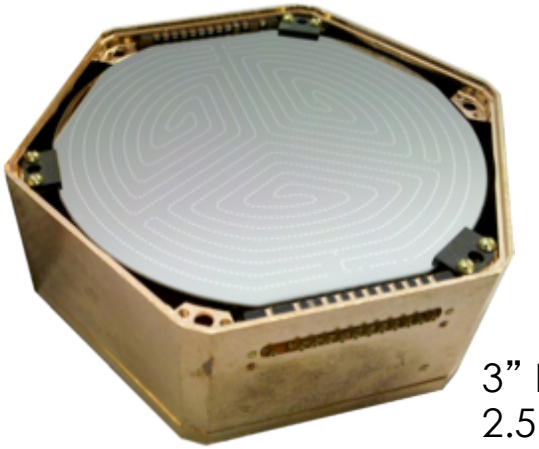
- Backgrounds are more difficult to discriminate (this is not a background free search)

SuperCDMS at SOUDAN

Operational since March 2012

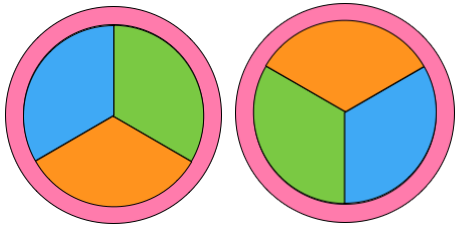
iZIP

interleaved Z-sensitive
Ionization & Phonon detectors

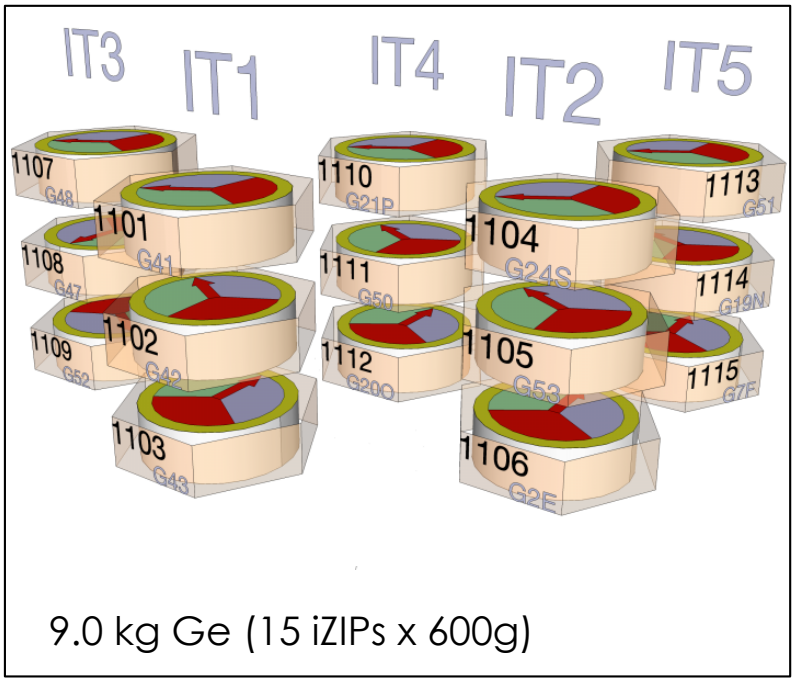


3” Diameter
2.5 cm Thick

Instrumented on both sides with
2 charge+ 4 phonon sensors



Side 1 Side 2



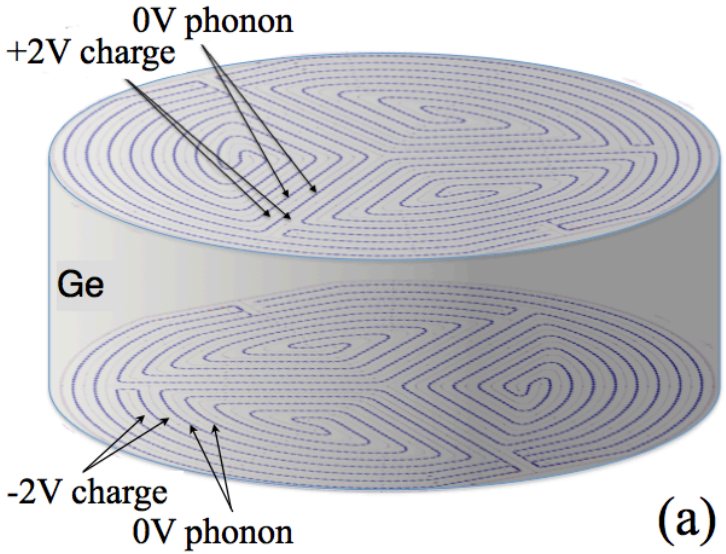
9.0 kg Ge (15 iZIPs x 600g)

Data for this analysis:

577 kg-days
taken from March 2012 – July 2013
using the 7 lowest threshold iZIPs

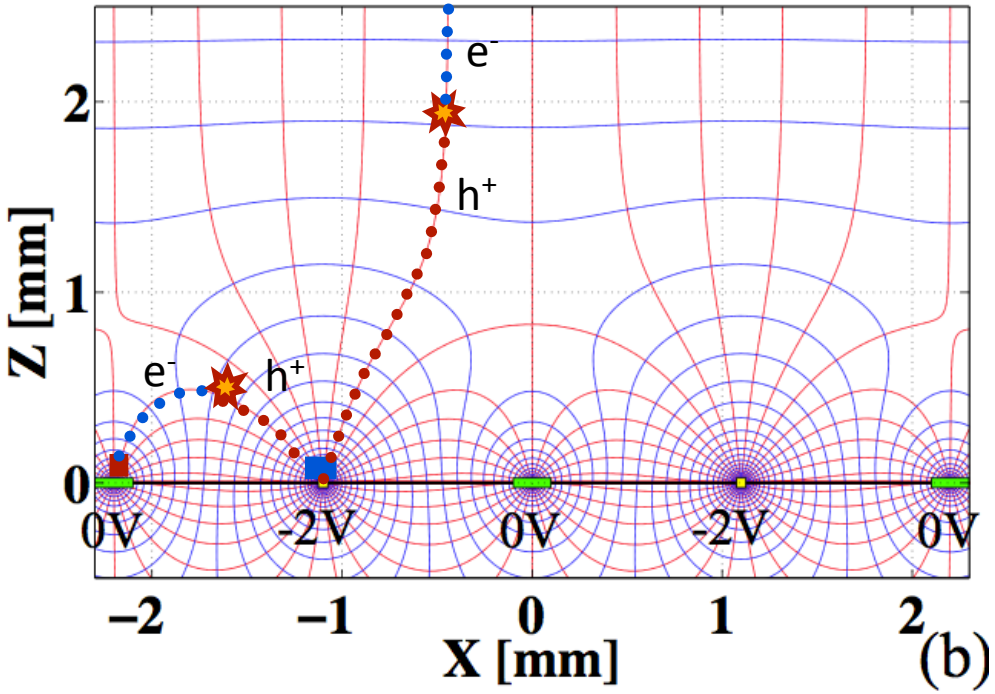
iZIP discrimination of surface events

In the new iZIPs the ionization lines (±2V) are interleaved with phonon sensors (0V) on a ~1mm pitch



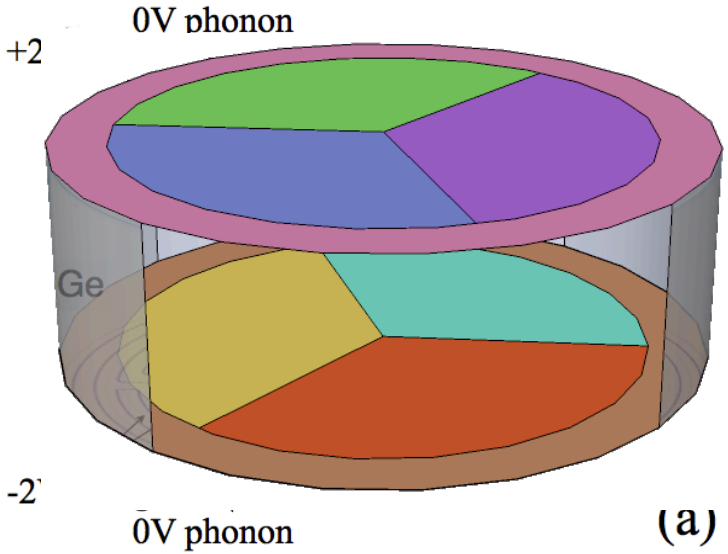
Bulk events:
charges (e,h) drift to **both sides** of the crystal

Surface events:
charges (e,h) drift to **only one side** of the crystal



Z-PARTITION:
The resulting **symmetry**/**asymmetry** on charge collection in sides 1 and 2

iZIP discrimination of surface events



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Surface events:
charges (e,h) drift to **only one side** of the crystal

Sidewalls

Surface events on the sides of the detector leave more energy in the outer sensors.

Z-PARTITION:
The resulting **symmetry**/**asymmetry** on charge collection in sides 1 and 2

RADIAL PARTITION:
division of energy between inner and outer sensors

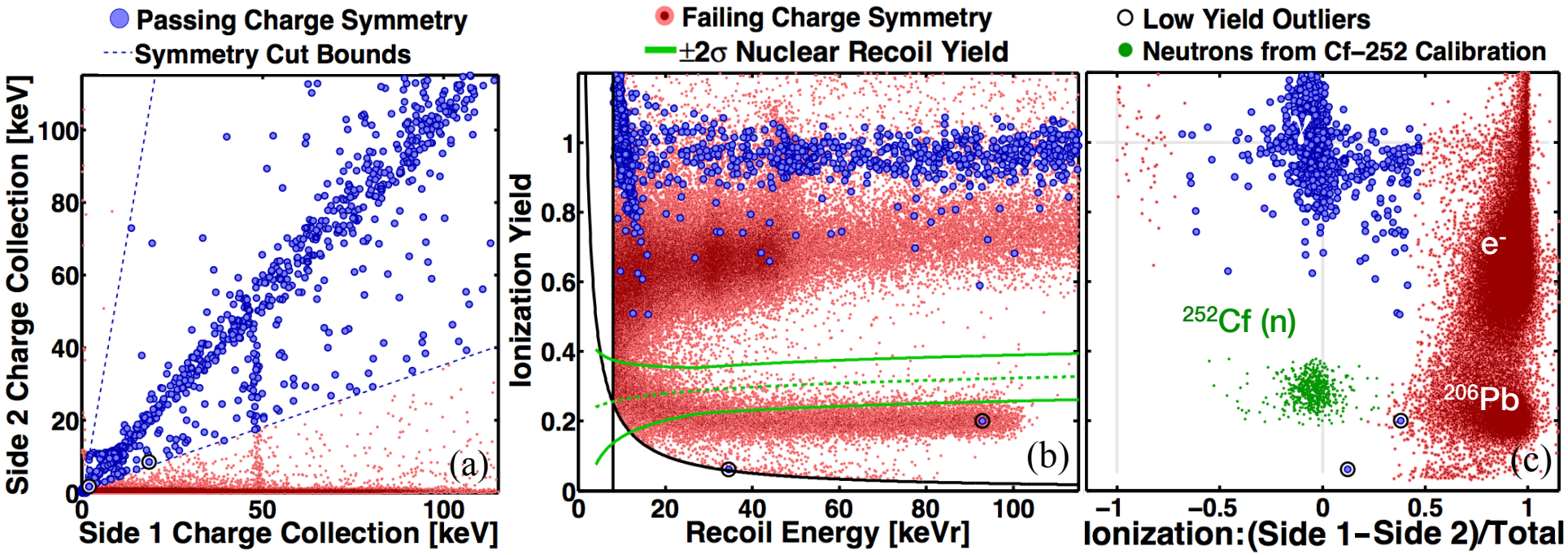
The rejection of surface events with the new iZIPs using Z-partition has been demonstrated with data from exposure to betas from ^{210}Pb sources

In ~800 live hours, no events leaked into the 8-115 keV signal region

Leakage < 1.7×10^{-5}

This could allow a background free search for 5 yr of operation in SuperCDMS @ SNOLAB (~100 kg)

Appl.Phys.Lett. 103 (2013) 164105



(the low threshold analysis corresponds to smaller energies and some leakage is expected)

Background		Rejection
• Bulk electron recoils Compton background 1.3 keV activation line	→	Yield = Ionization/phonon helps discriminating NR from ER
• Sidewall & surface events betas and x-rays from ^{210}Pb, ^{210}Bi, recoils from ^{206}Pb, outer radial Comptons, ejected electrons from Compton scattering	→	Z-Partition and Radial partition define a fiducial volume
• Neutrons (cosmogenic & radiogenic)	→	Use active and passive shielding. Cut on multiple hits. Simulation determines remaining irreducible rate

Analysis: Selection criteria and efficiencies

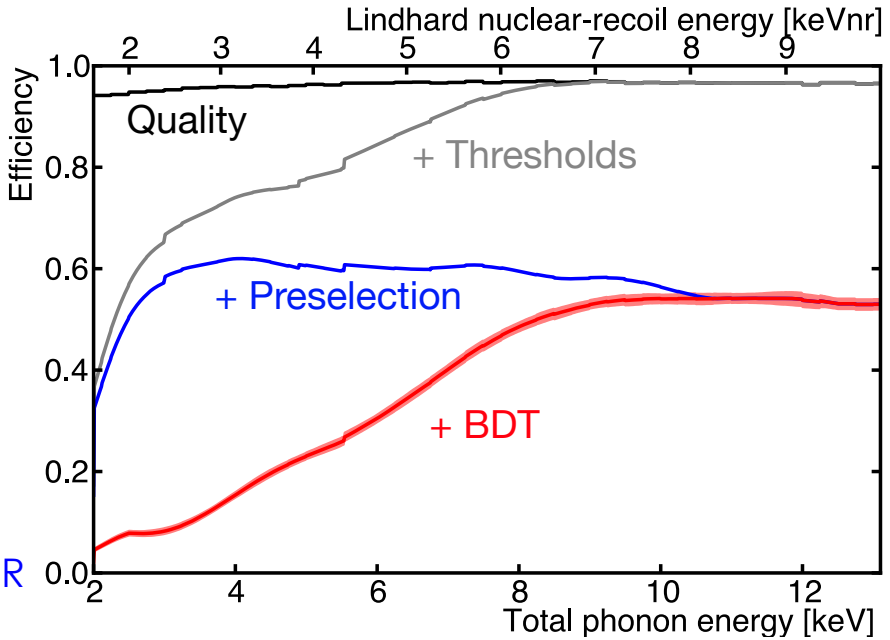
We carry out a blind analysis, with cuts set by examining only events that will never be accepted as WIMP candidates (multiple scatters, calibration events, and periods following high activation from ^{252}Cf calibration)

Data Quality:
Reject periods with poor detector performance
Remove misreconstructed and noisy pulses
Measure efficiency with pulse MC

Trigger and analysis threshold:
Select periods with stable well-defined trigger threshold
Measure efficiency from ^{133}Ba calibration data

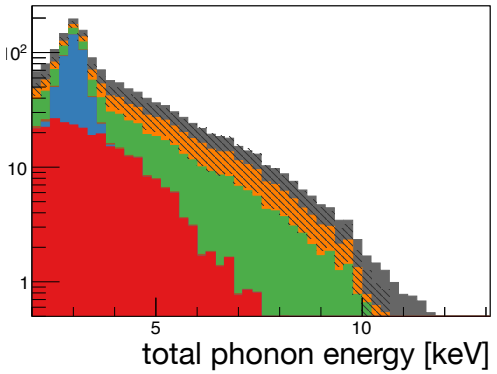
Preselection:
Single-detector scatter
Remove events coincident with muon veto
Ionization fiducial volume
Ionization and phonon partitions consistent with NR

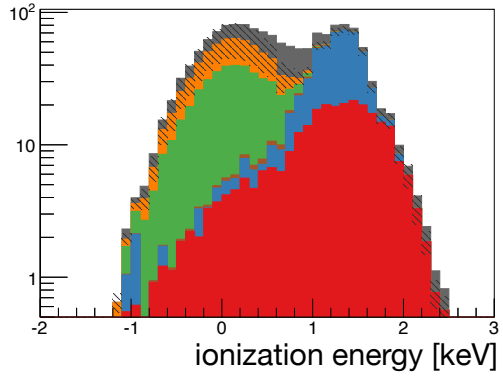
Boosted Decision Tree:
Optimised cut on the phonon fiducial volume and ionization yield at low energy
Efficiency estimated from fraction of ^{252}Cf passing

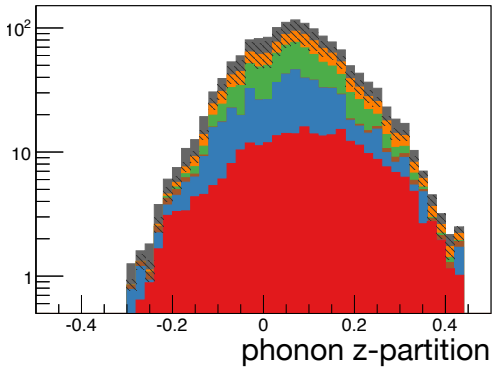


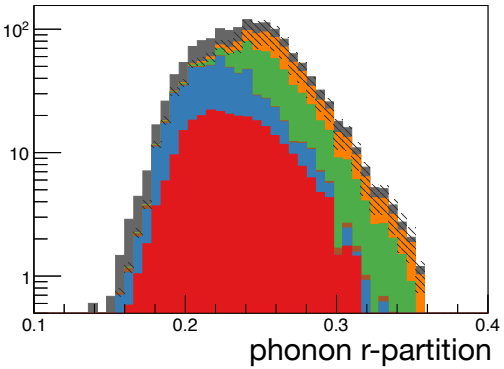
Boosted Decision Tree (BDT)

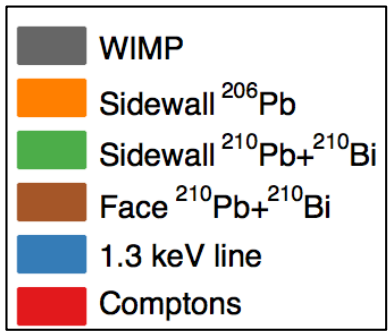
Inputs (per detector)



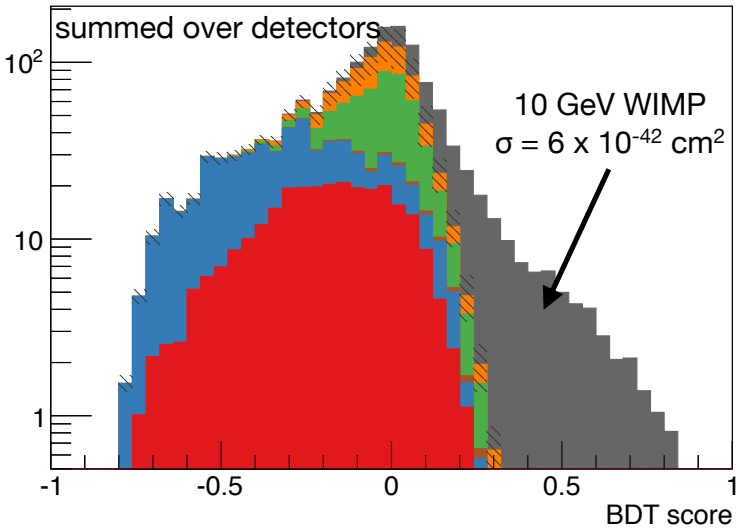








Output

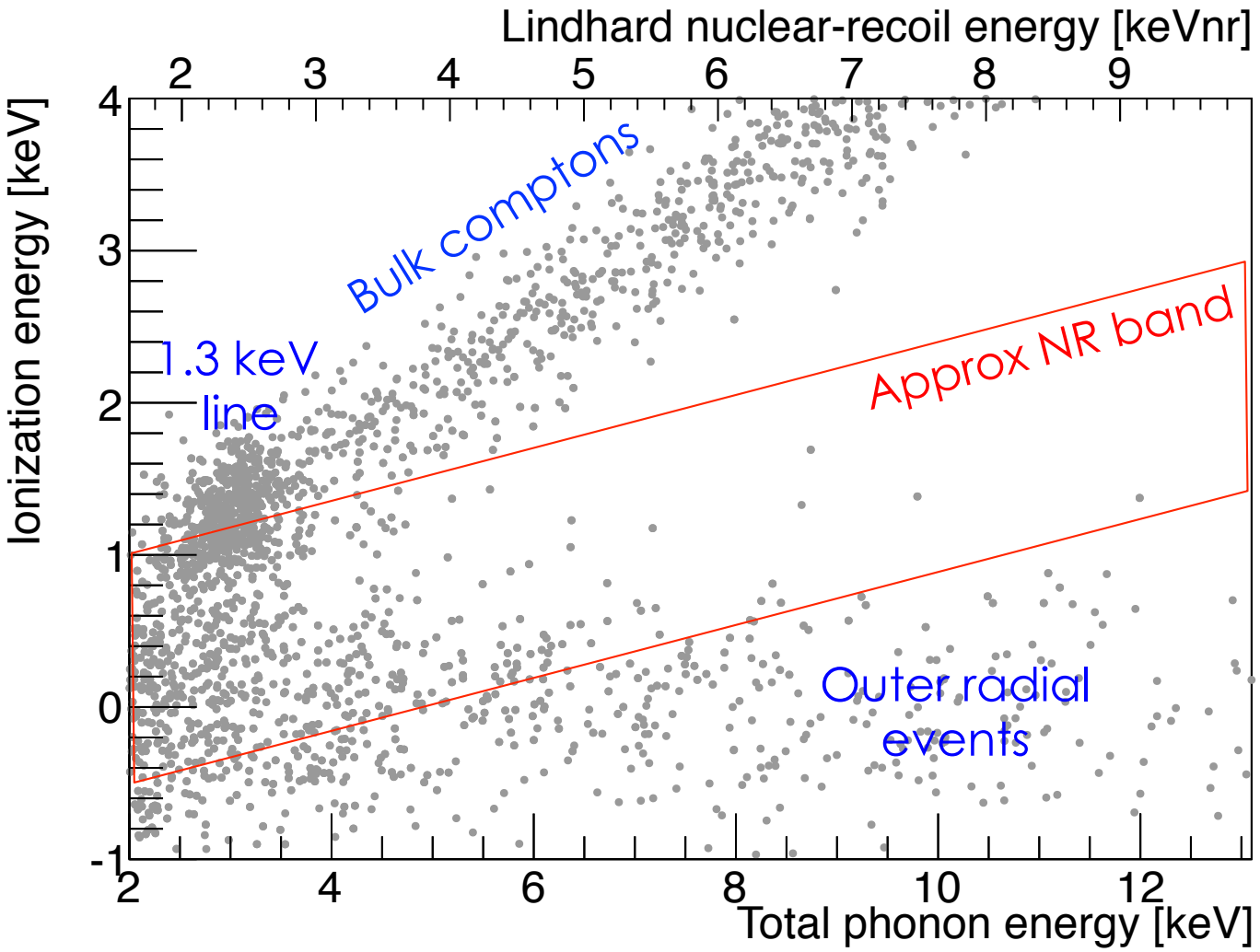


Background: Modelled with simulated data on sidebands and calibration.

WIMP Signal: Modelled with NR data from ^{252}Cf, then rescaled for WIMPs with mass 5, 7, 10, 15 GeV

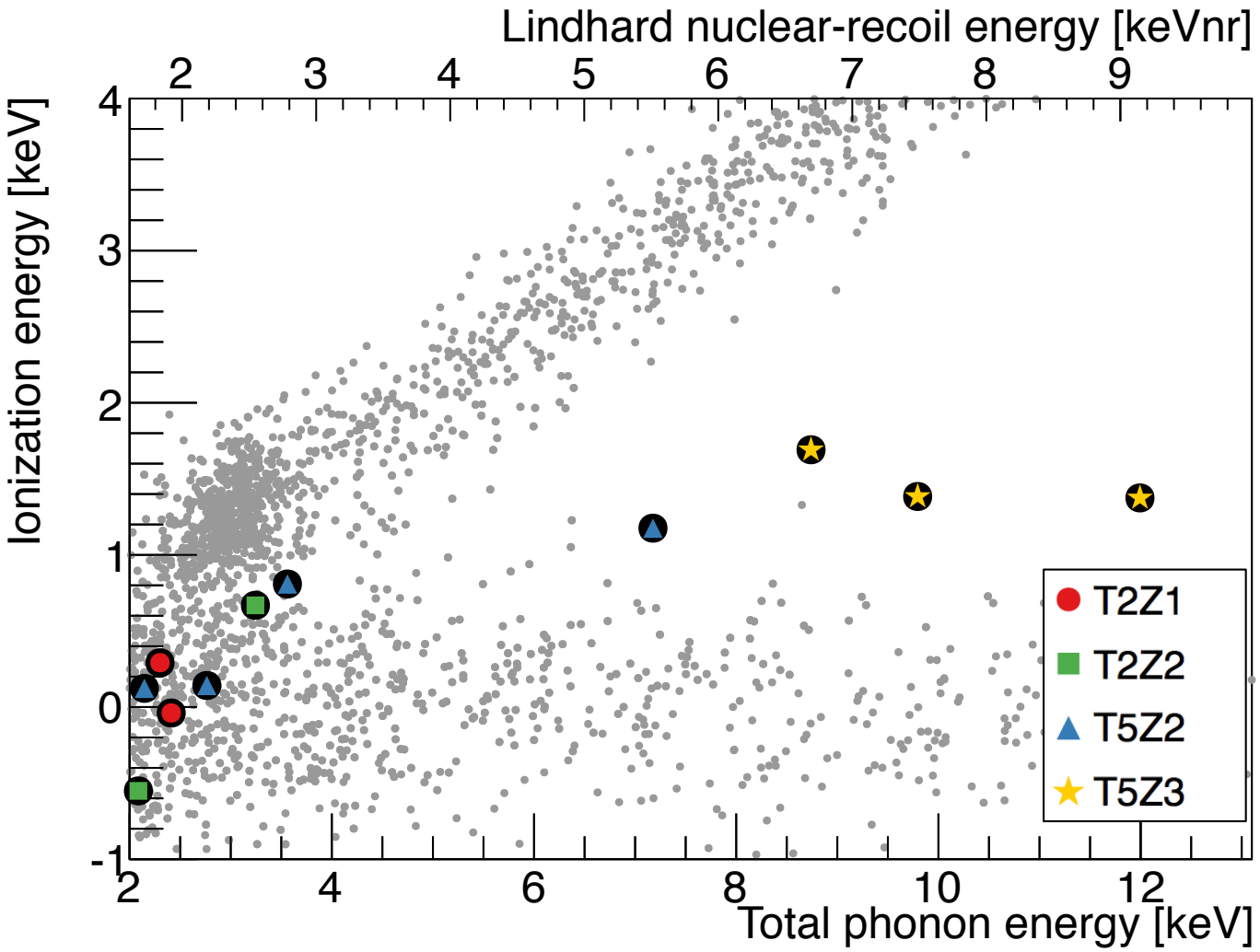
Unblinding: Before BDT cut

Events passing all the cuts prior to applying BDT



Unblinding: After BDT cut

11 candidates (6.2 +1.1 -0.8 expected)



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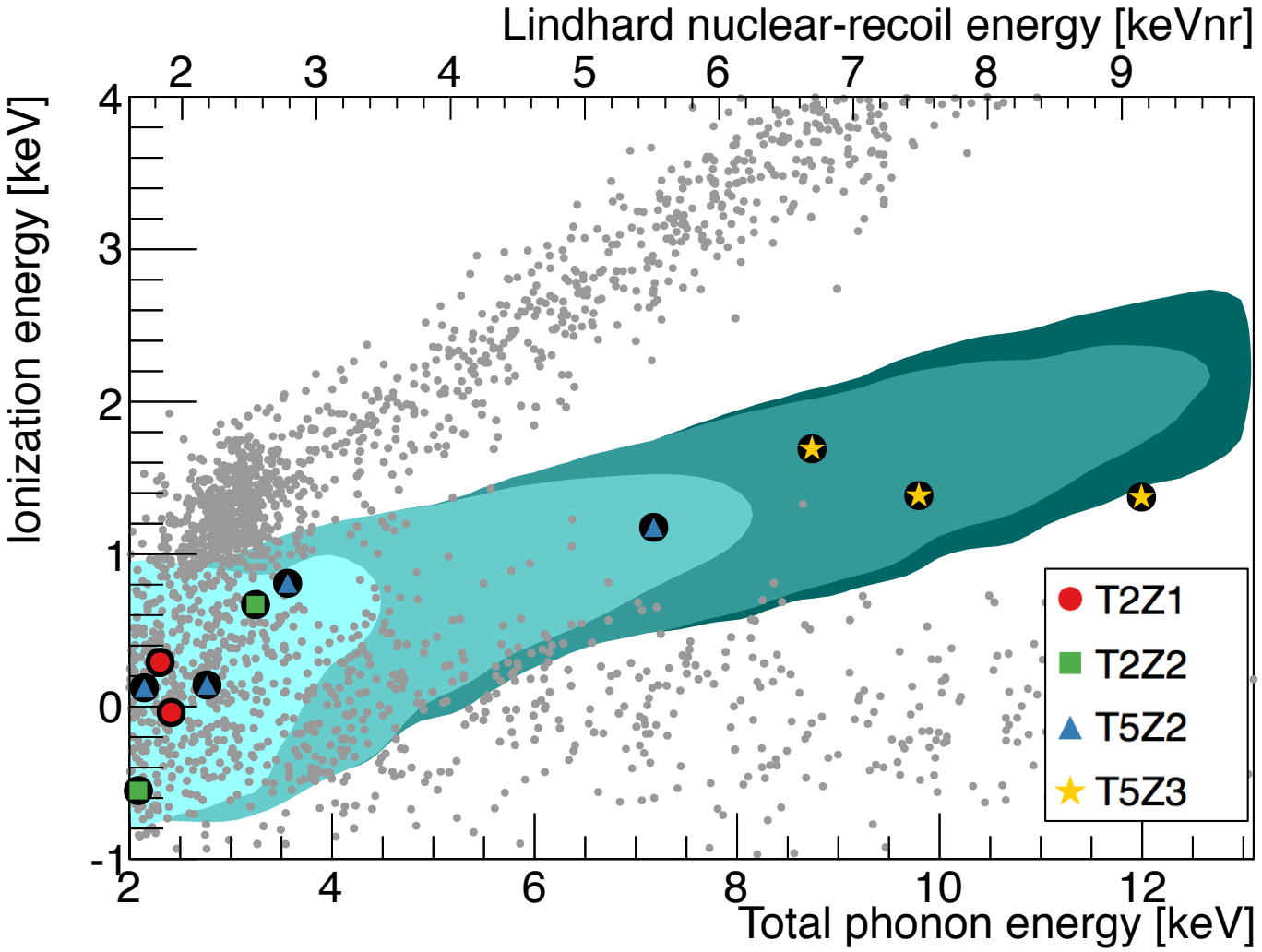


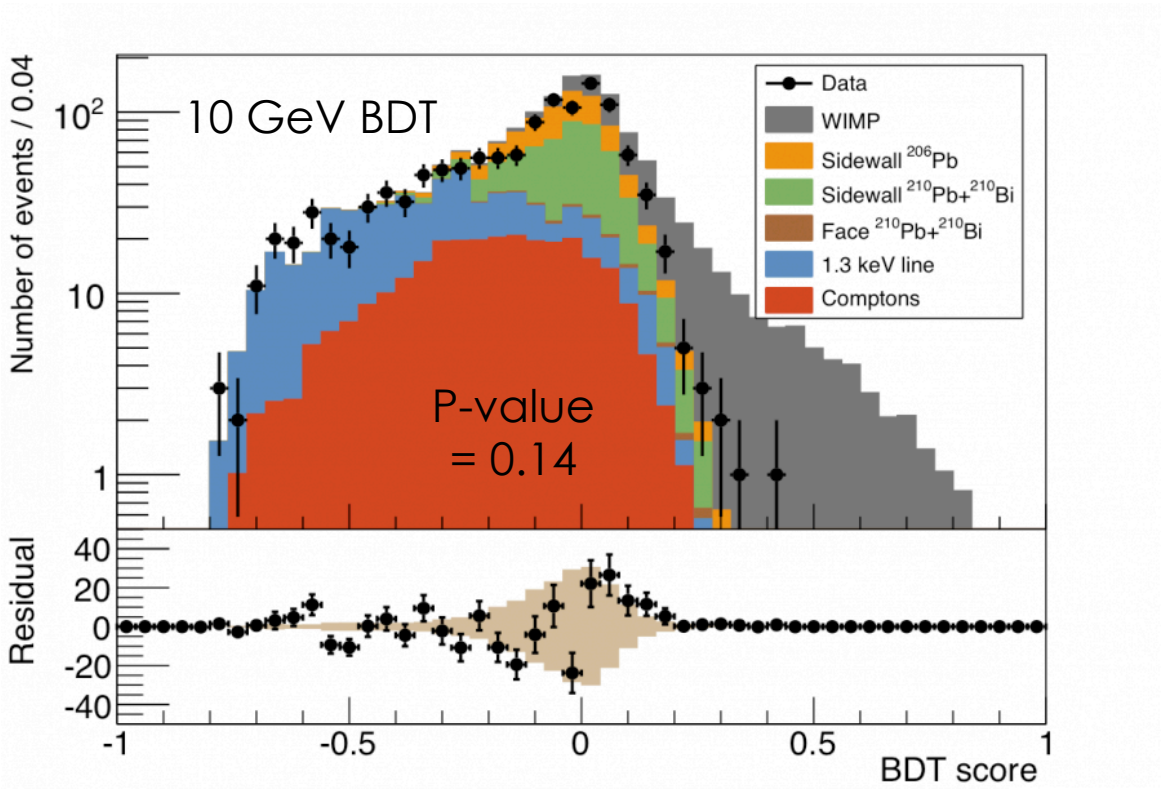
95% CL intervals for WIMPS with

m=5 GeV
m=7 GeV
m=10 GeV
m=15 GeV

Post-unblinding discussion

Events are high in quality. Only the lowest energy candidate looks like spurious noise

- For most of the detectors there is good agreement with predicted background

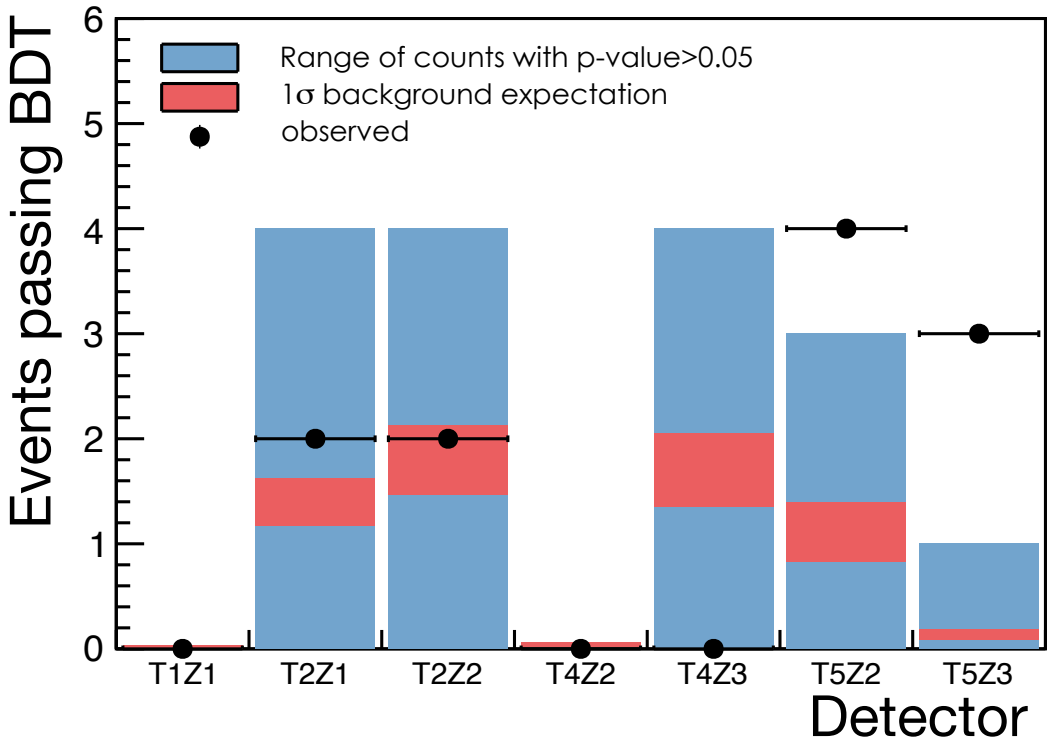


Post-unblinding discussion

Events are high in quality. Only the lowest energy candidate looks like spurious noise

- For most of the detectors there is good agreement with predicted background
- However, T5Z3 observes the 3 highest-energy events

  (Poisson p-value is 0.04%)

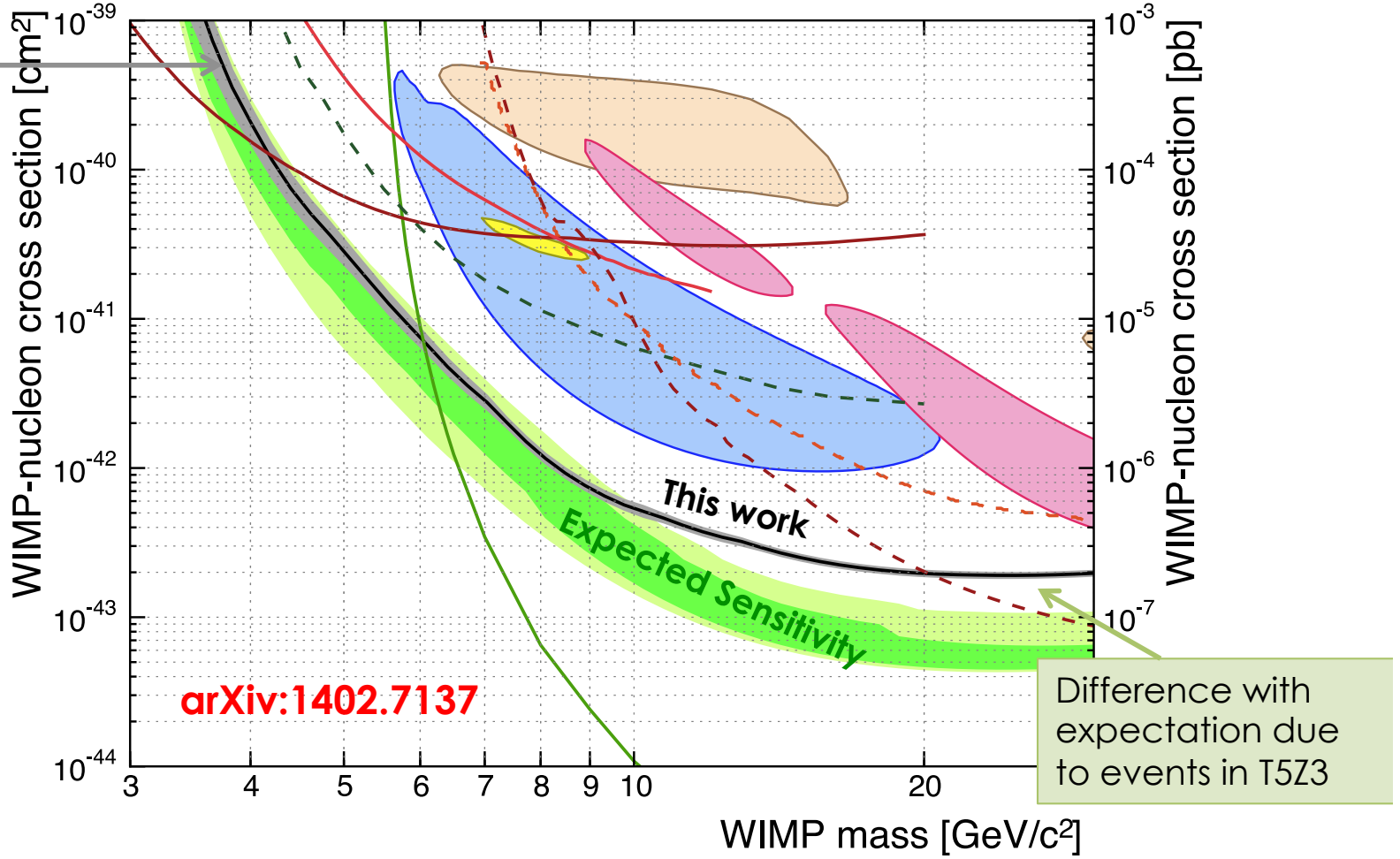


T5Z3 has a shorted ionization guard. This may have affected the background model performance. Additional studies are undergoing.

New limit for low-mass WIMPs

90% C.L. optimal interval method (no background subtraction)

systematics (efficiency, energy scale, trigger efficiency)



Difference with expectation due to events in T5Z3

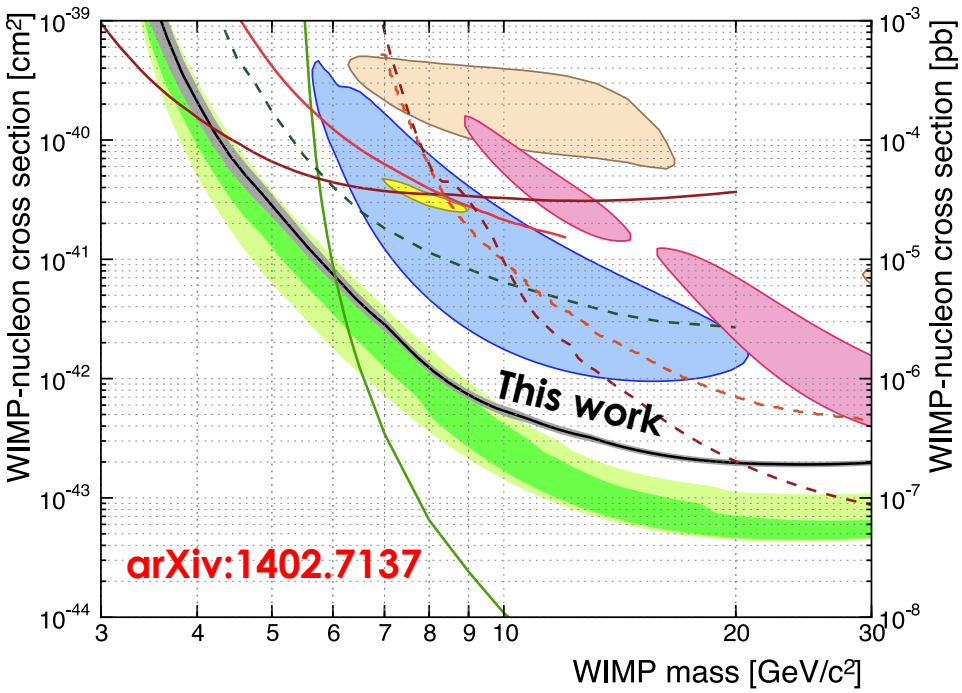
Conclusions

- First result using the background rejection capability of SuperCDMS

  7 iZIPs analysed (threshold 1.6 keV_{nr})
  Exposure: 577 kg day
  $\sigma^{SI} > 1.2 \times 10^{-6}$ pb at 8 GeV

  New limit for WIMPs with masses in the range 4 - 6 GeV

  (below 4 GeV CDMSlite dominates)



- CoGeNT interpretation of WIMP signal disfavoured in model-independent way

  CDMS-II (Si) disfavoured assuming standard WIMP interactions and for the standard halo model.

- High threshold analysis of SuperCDMS ongoing
  SuperCDMS Soudan detectors are a vast improvement over CDMS II