WIMP search status

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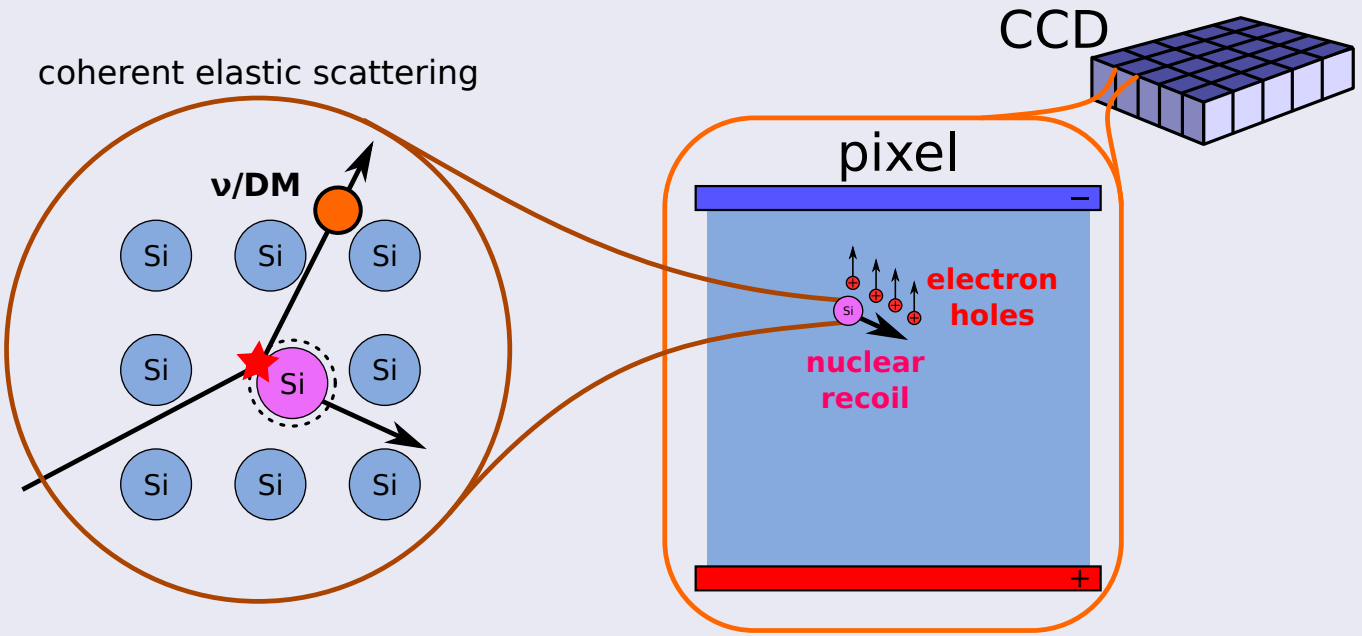
⋆DAMIC Collaboration: Fermilab, U Chicago, U Zurich, Snolab, U Michigan, UNAM, FIUNA, CAB, UFRJ, U Paris VI & VII

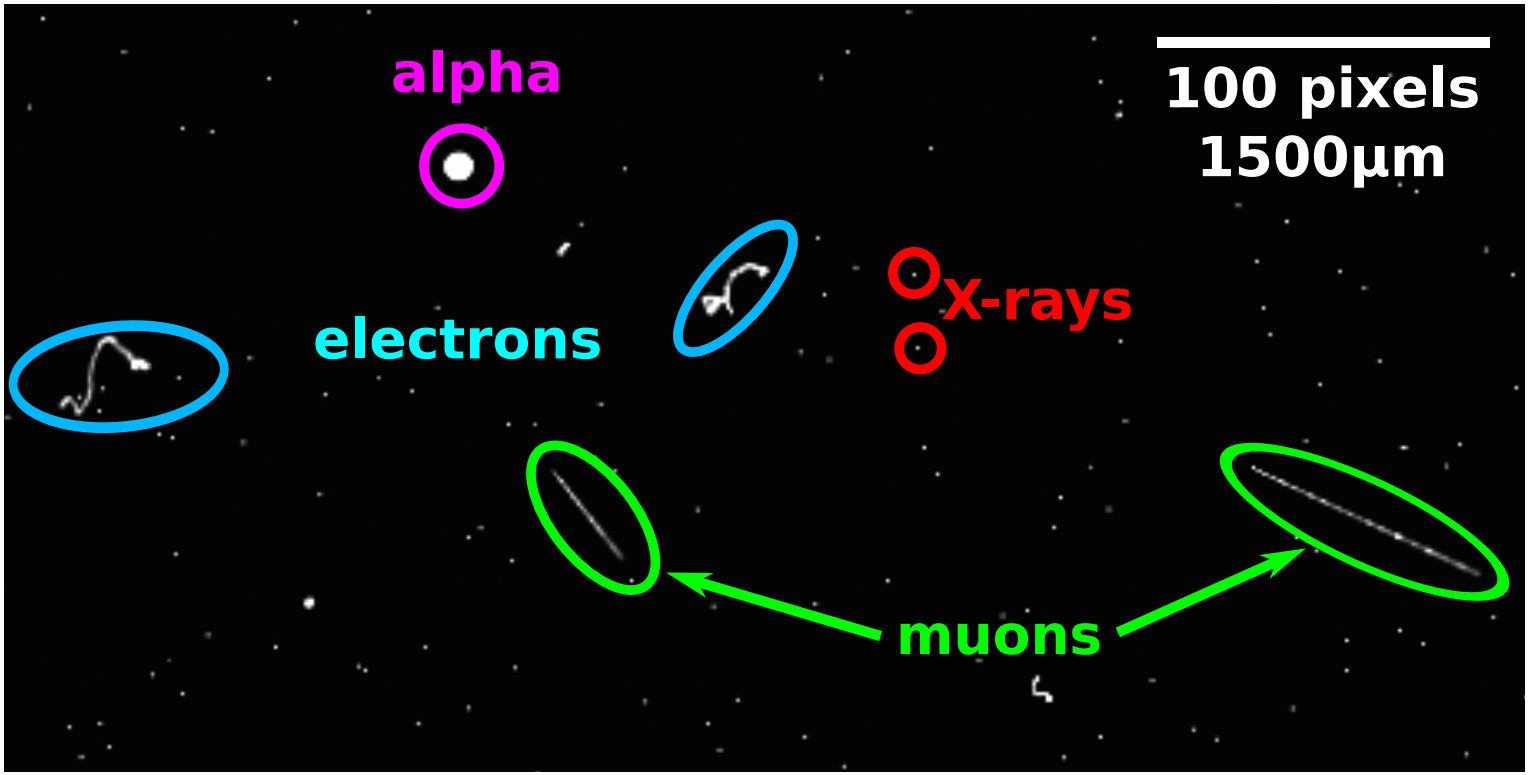
Goal: lower the energy threshold in Si detectors

Detect coherent DM-nucleus interactions by measuring the ionization produced by the nuclear recoils

Idea: use CCDs as target and record the ionization produced



Particle ID

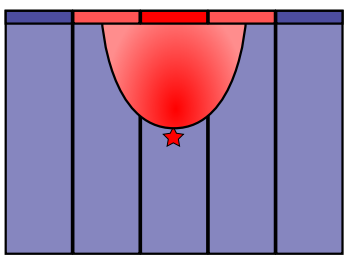


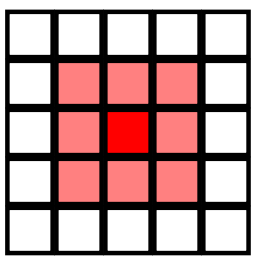
Data taken at Fermilab (sea level, no radiation shielding)

Detectors:

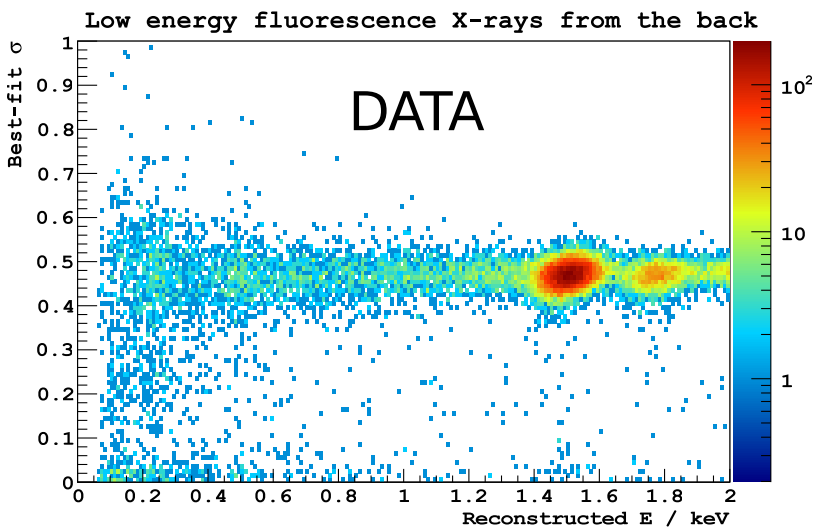
We use scientific CCDs developed by LBNL microdectors group

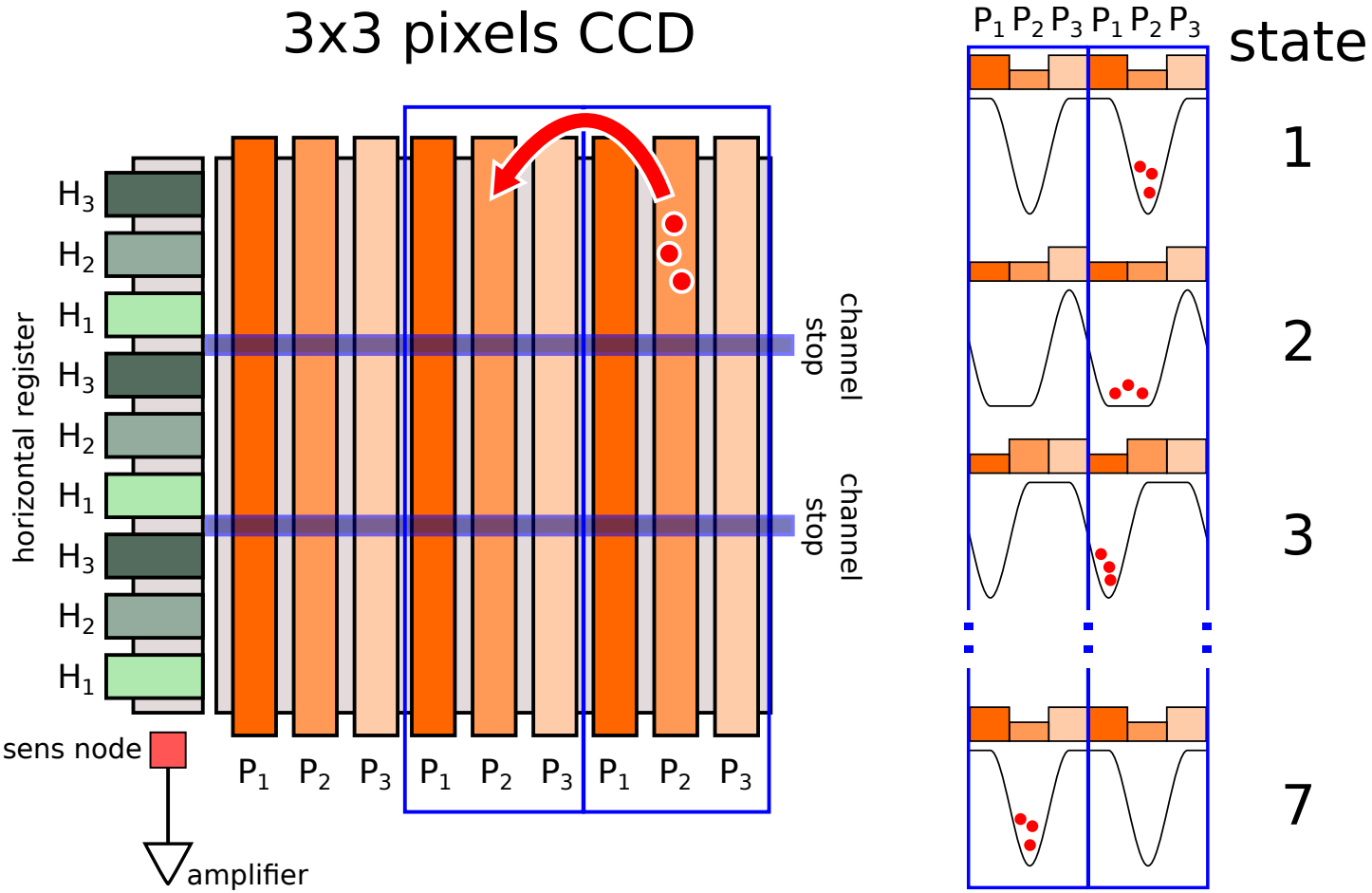
- CCDs cooled to 150 K to achieve readout noise RMS $\sim$ 2 e^-
- Energy threshold of $\sim$0.06 keVee
- pixel size of 15 μm
- 27x thicker than most CCDs, 675 μm
  - 5.5 gr per CCD
  - diffusion $\rightarrow$ 3D rec $\rightarrow$ identification of surface events



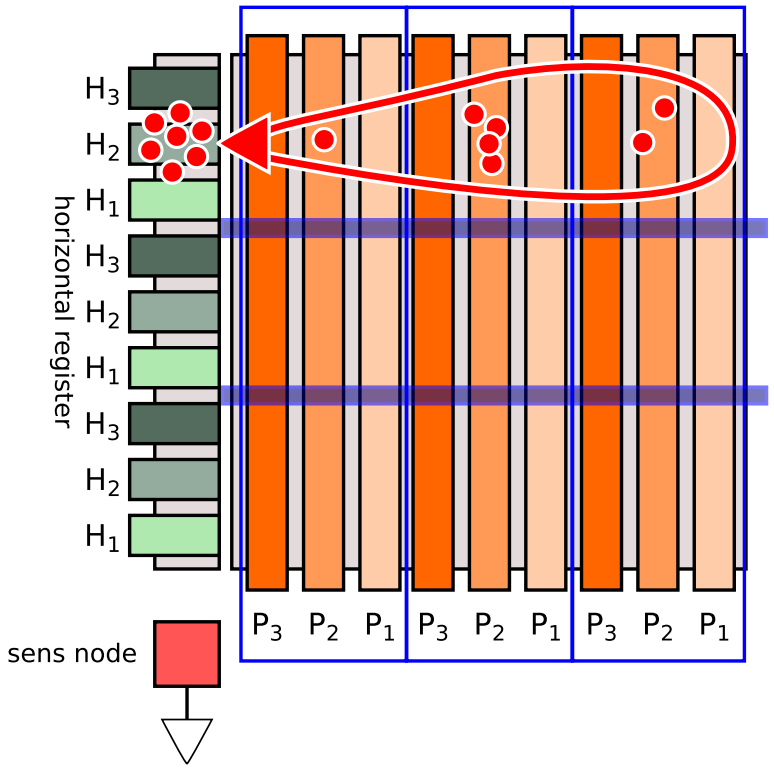


The charge diffuses towards the CCD pixels gates. Depth can be reconstrected from diffusion.





capacitance of the system is set by the SN:
C=0.05pF$\rightarrow$ 3μV/e

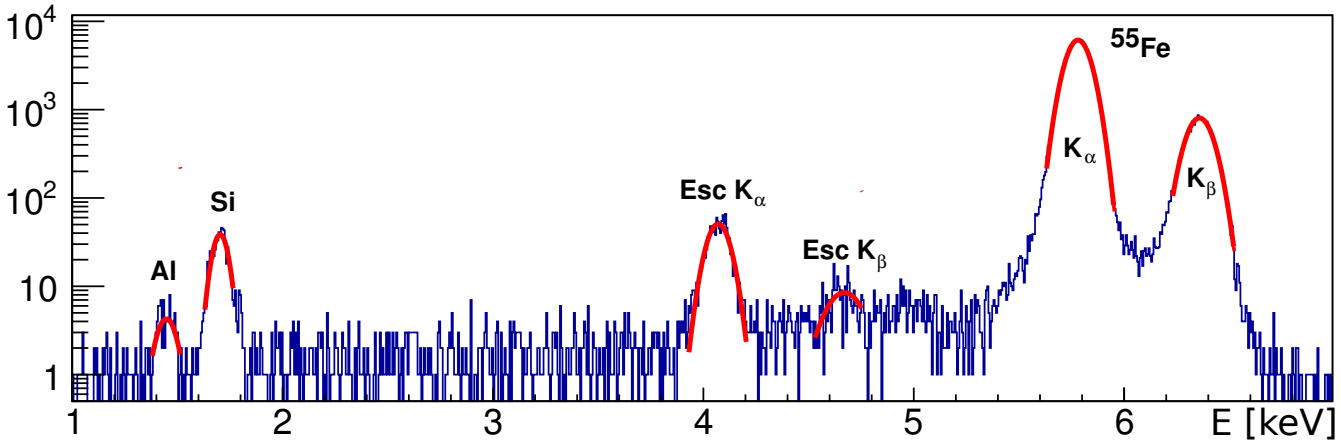


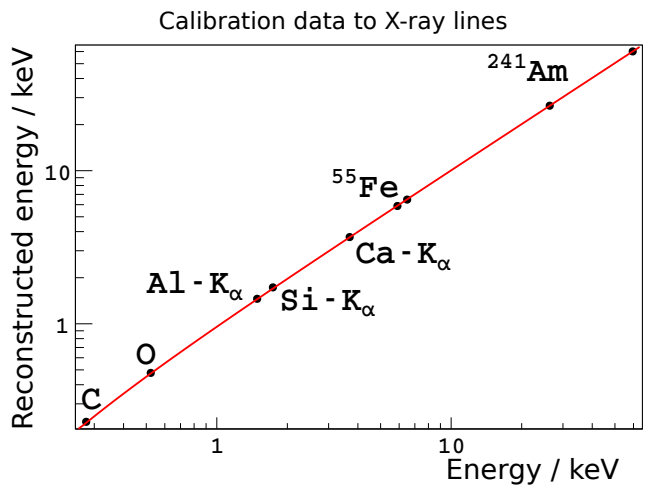
- Every readout introduces a $2e^-$ noise
- The CCD allows you to add charge in the sensor (binning) and then readout many pixels as a single one
- This improves signal to noise, effectively increasing the efficiency at low energy

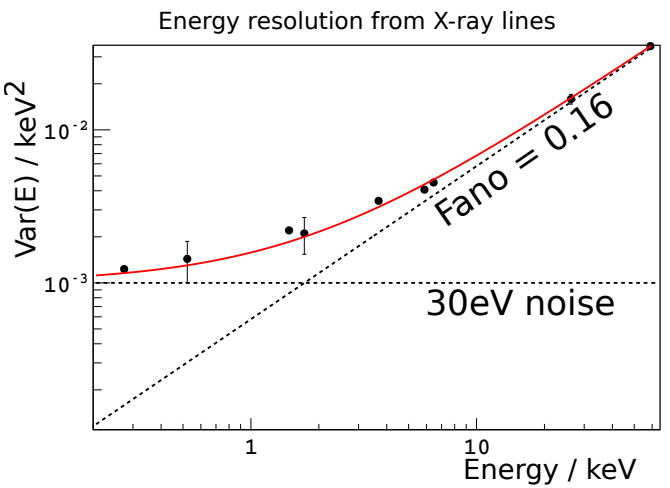
$$\mathbf{S/Noise} = \frac{\mathbf{Q}}{\mathbf{N_{reads}}}\sigma$$

Reading the charge in less pixels is good!

Energy calibration using X-rays

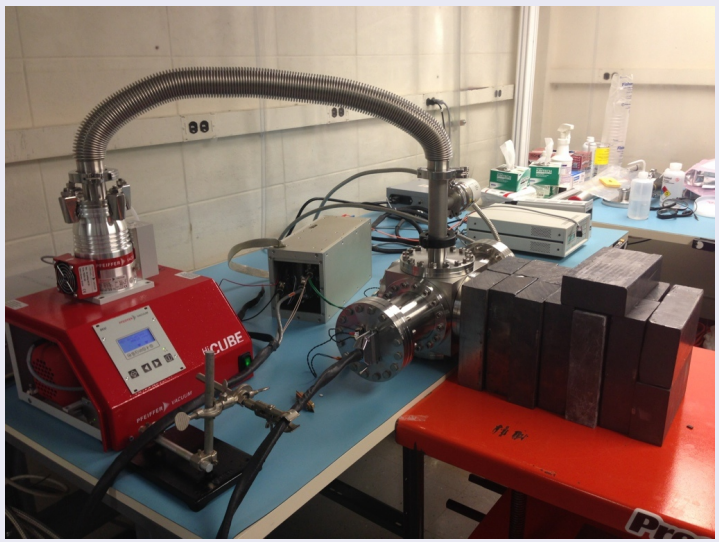






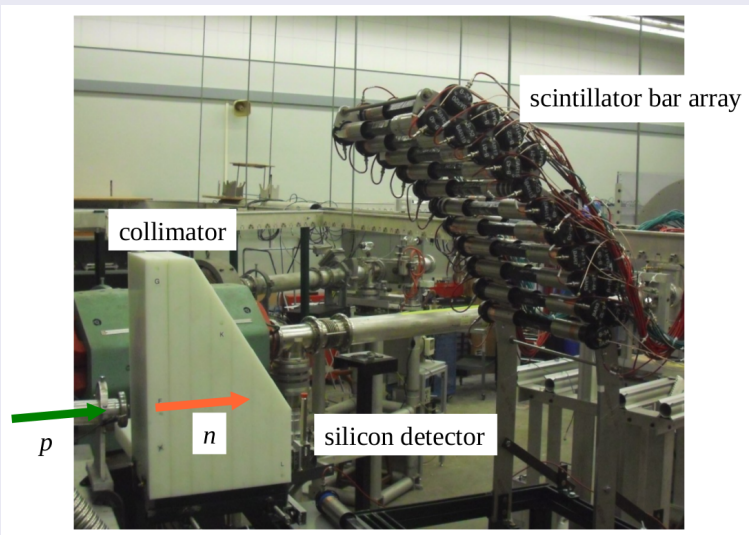
Nuclear recoil calibration program

Am/Be source



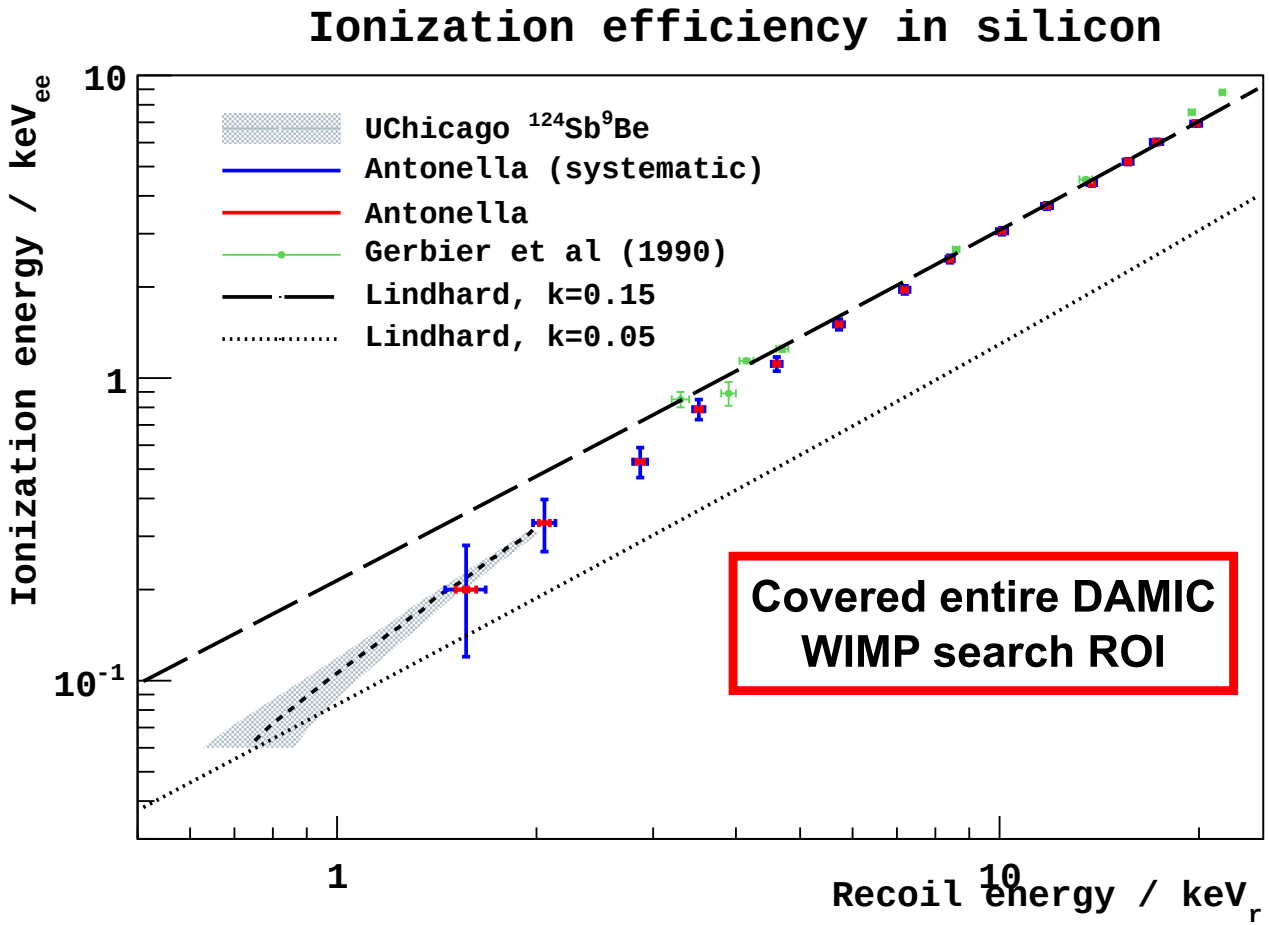
- Photo-neutron source at U. of Chicago
- 0.7 - 2 keV NR

Neutron scattering (beam)



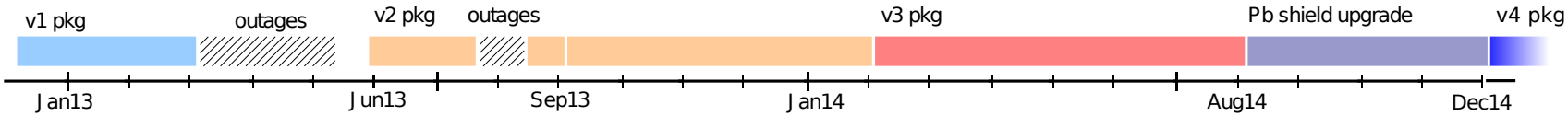
- Neutron beam at U. of Notre Dame
- 2 - 20 keV NR

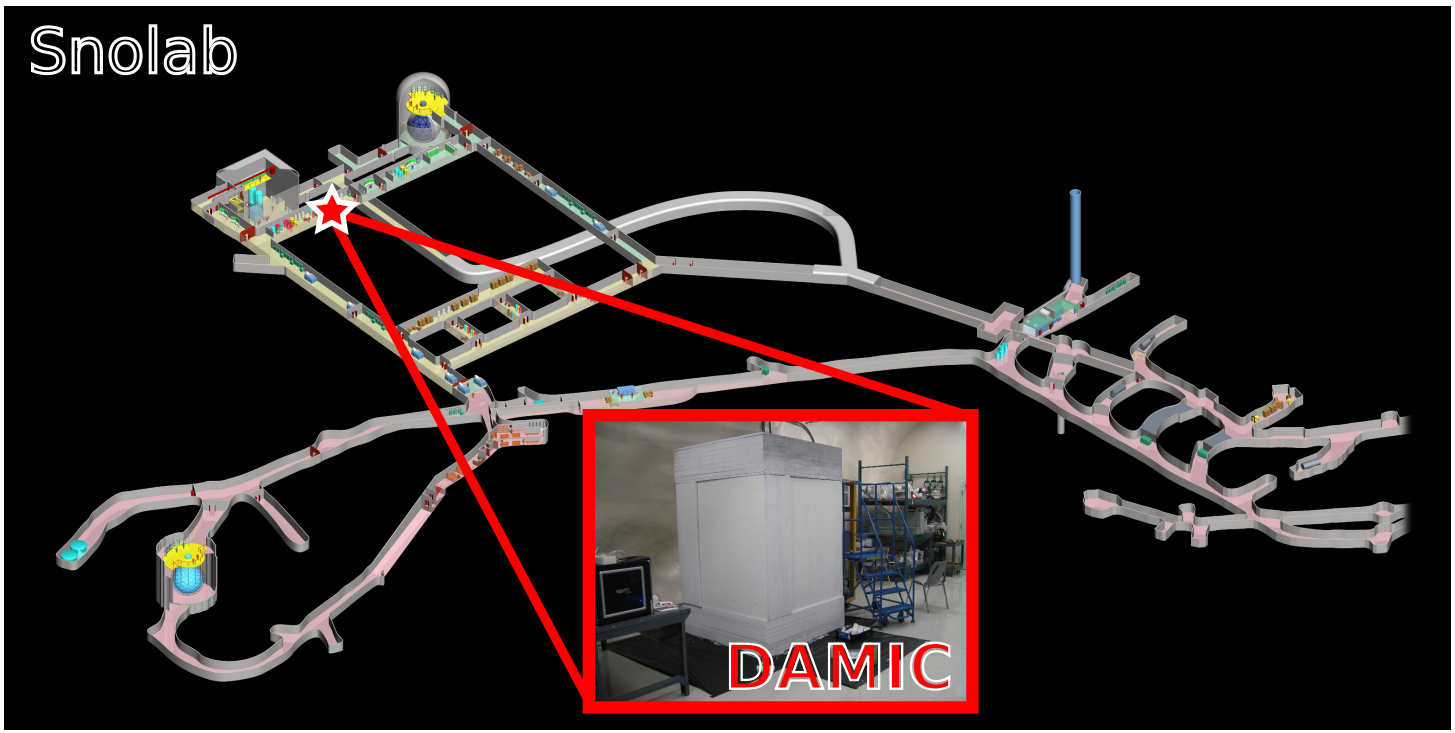
Nuclear recoil calibration



Discrepancy with Lindhard model below 5 keVee

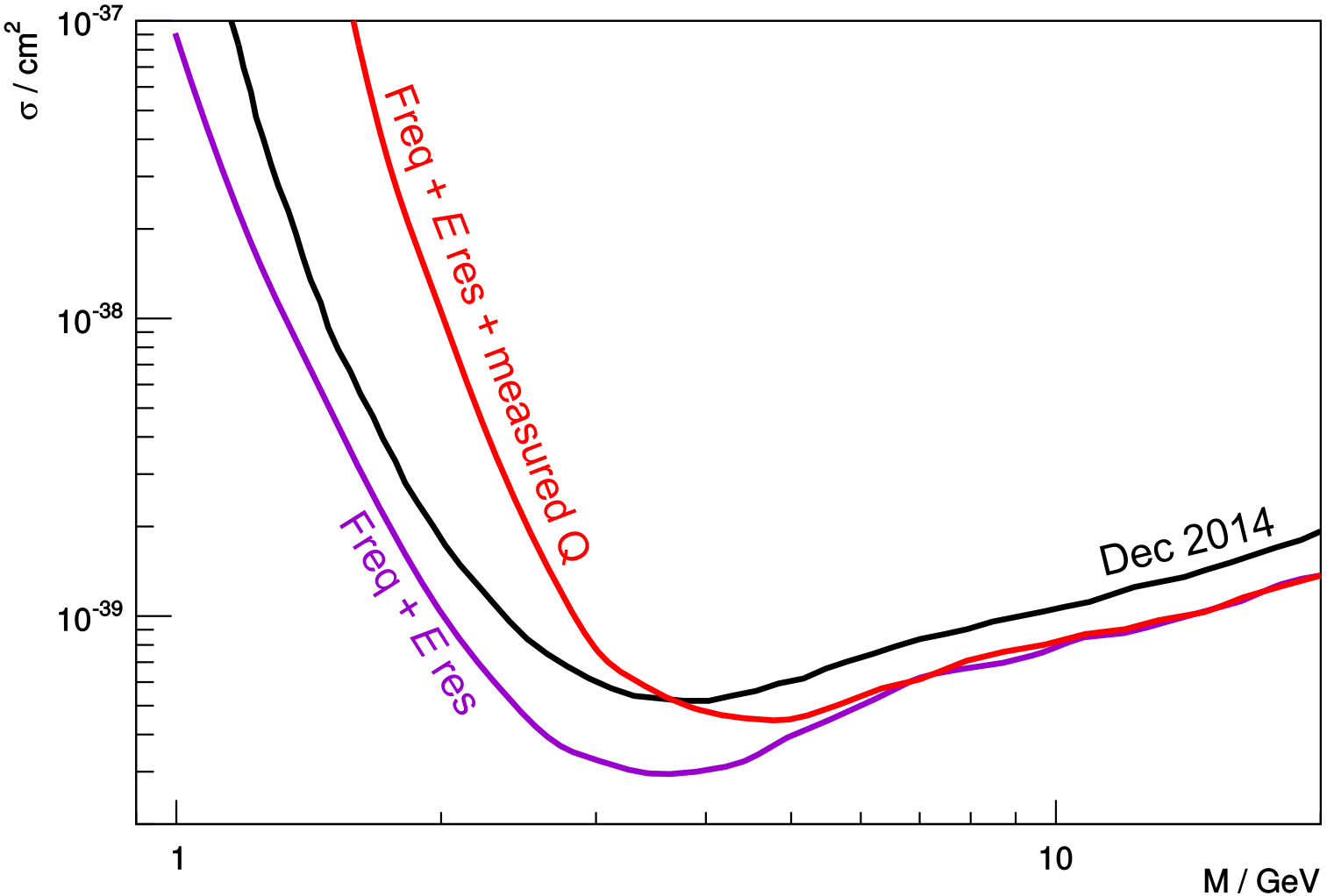
DAMIC @Snolab (installed Dec12)



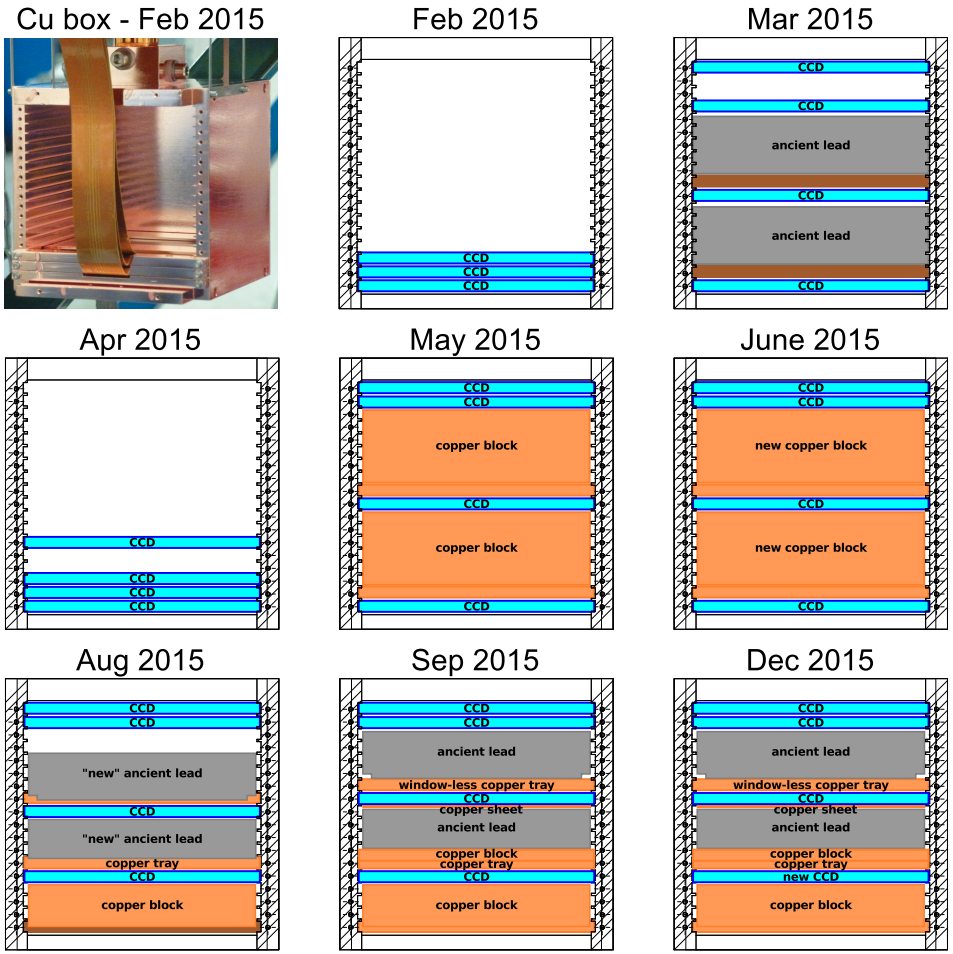


Installed at Snolab: 2km of norite overburden $\rightarrow$ 6000m water equivalent

2014 run (DAMIC-2014): limit reanalysis

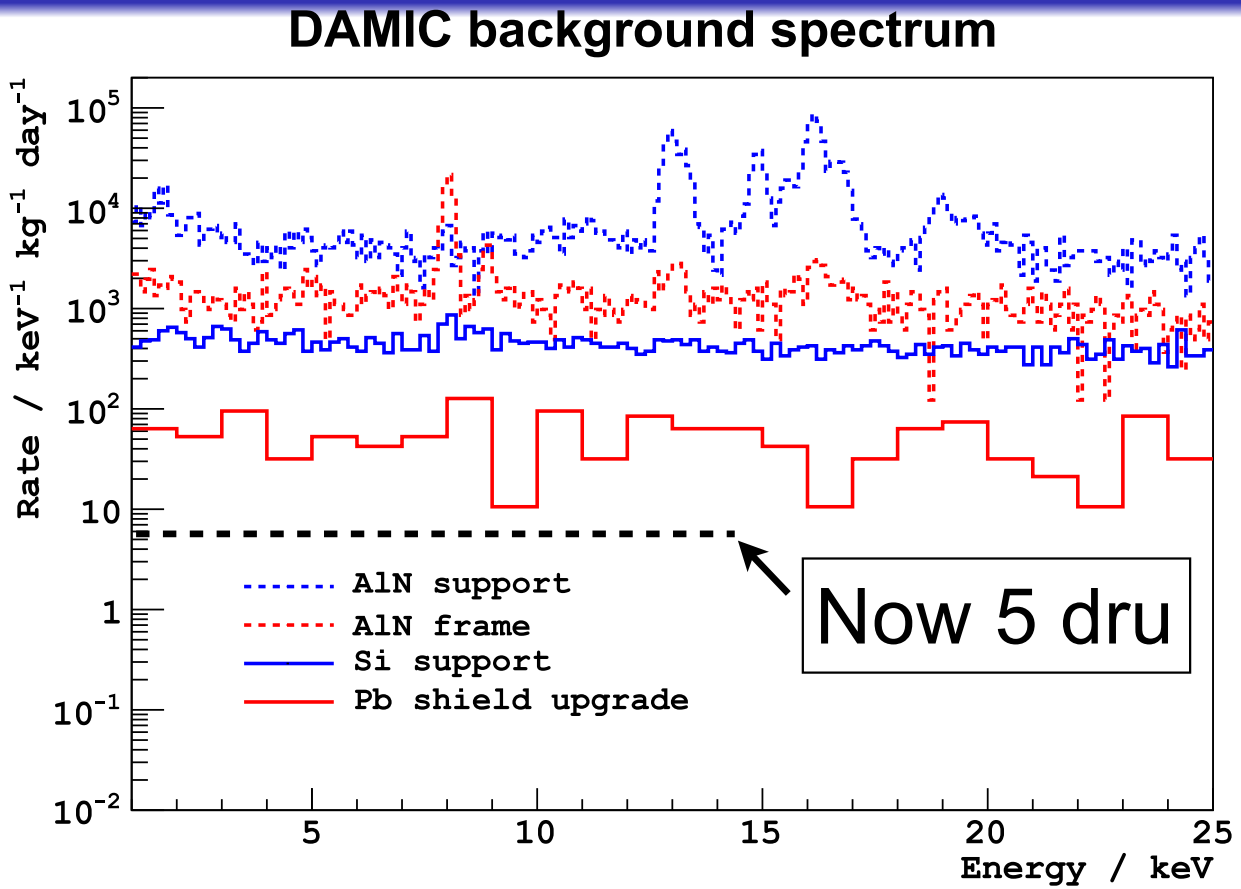


2015 campaign: tracking backgrounds



~80% of the time in low gain mode (high dynamic range) to identify backgrounds. Little time dedicated to science runs.

2015 campaign: tracking backgrounds



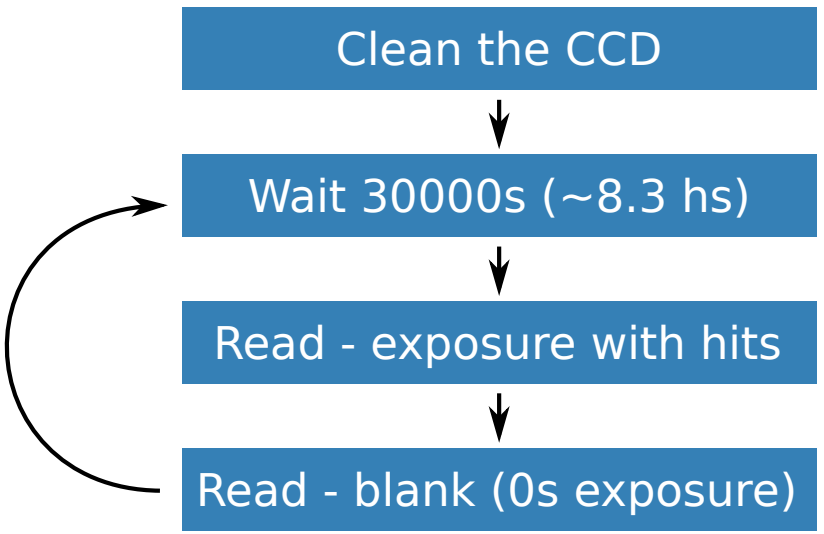
In production mode

Converged on package design and materials

10 detectors tested and ready for deployment

Will commission during April 2015

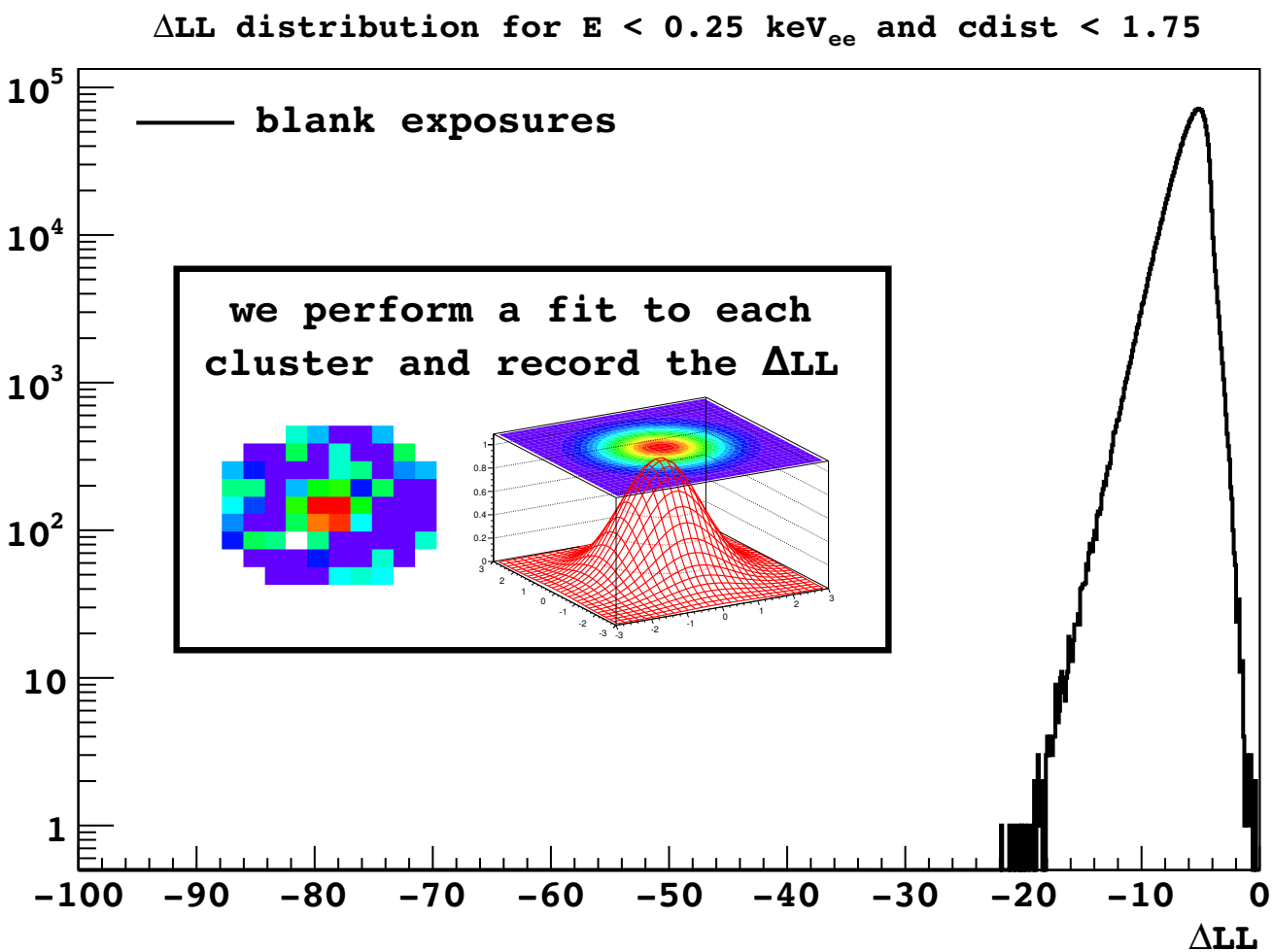
CCD: readout - typical operation for DM searches



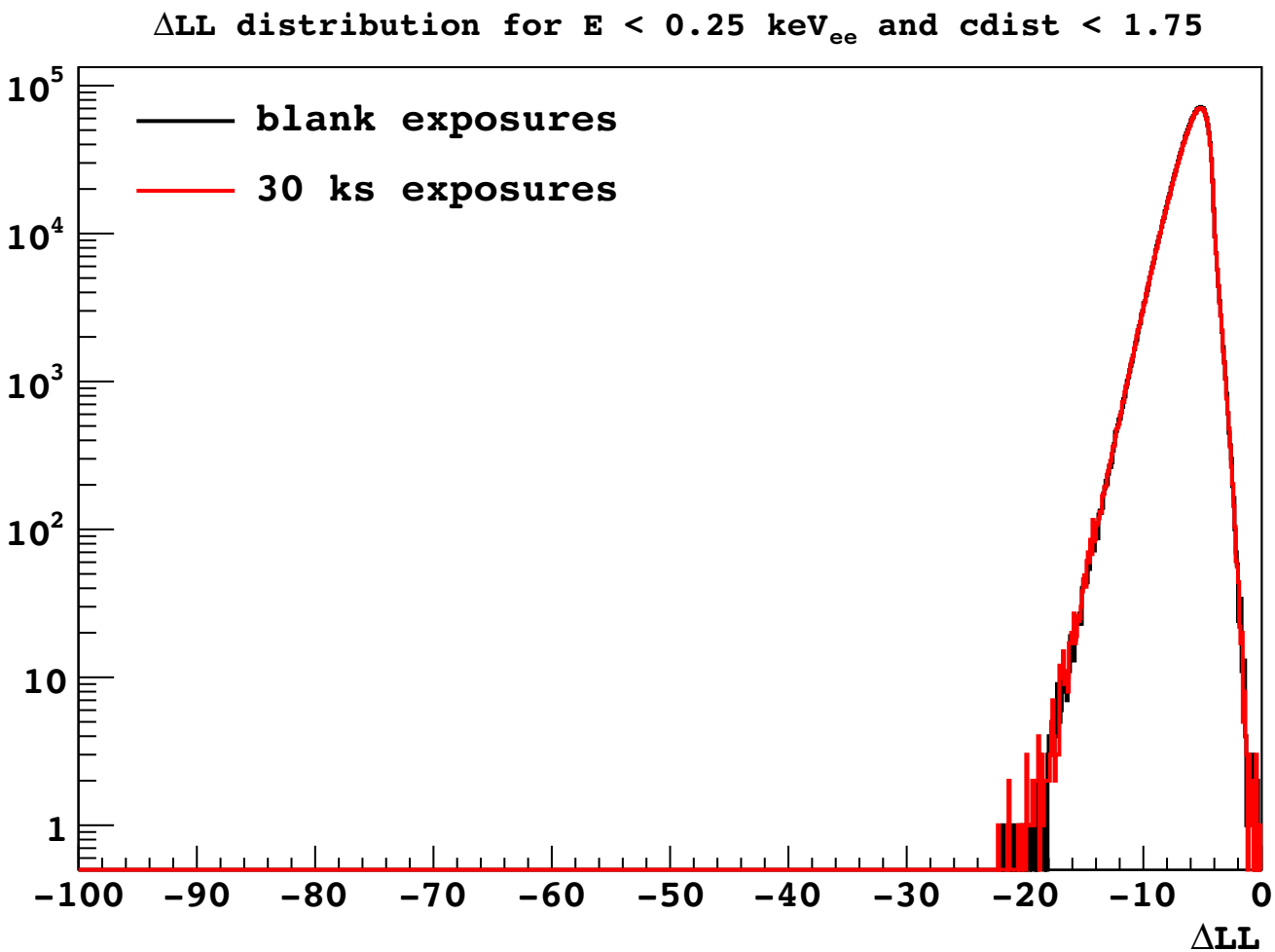
We take long exposures to minimize the number of readouts. The exposure is eventually limited by the dark current.

The blank images provide an excelent measurement of the background produced by readout

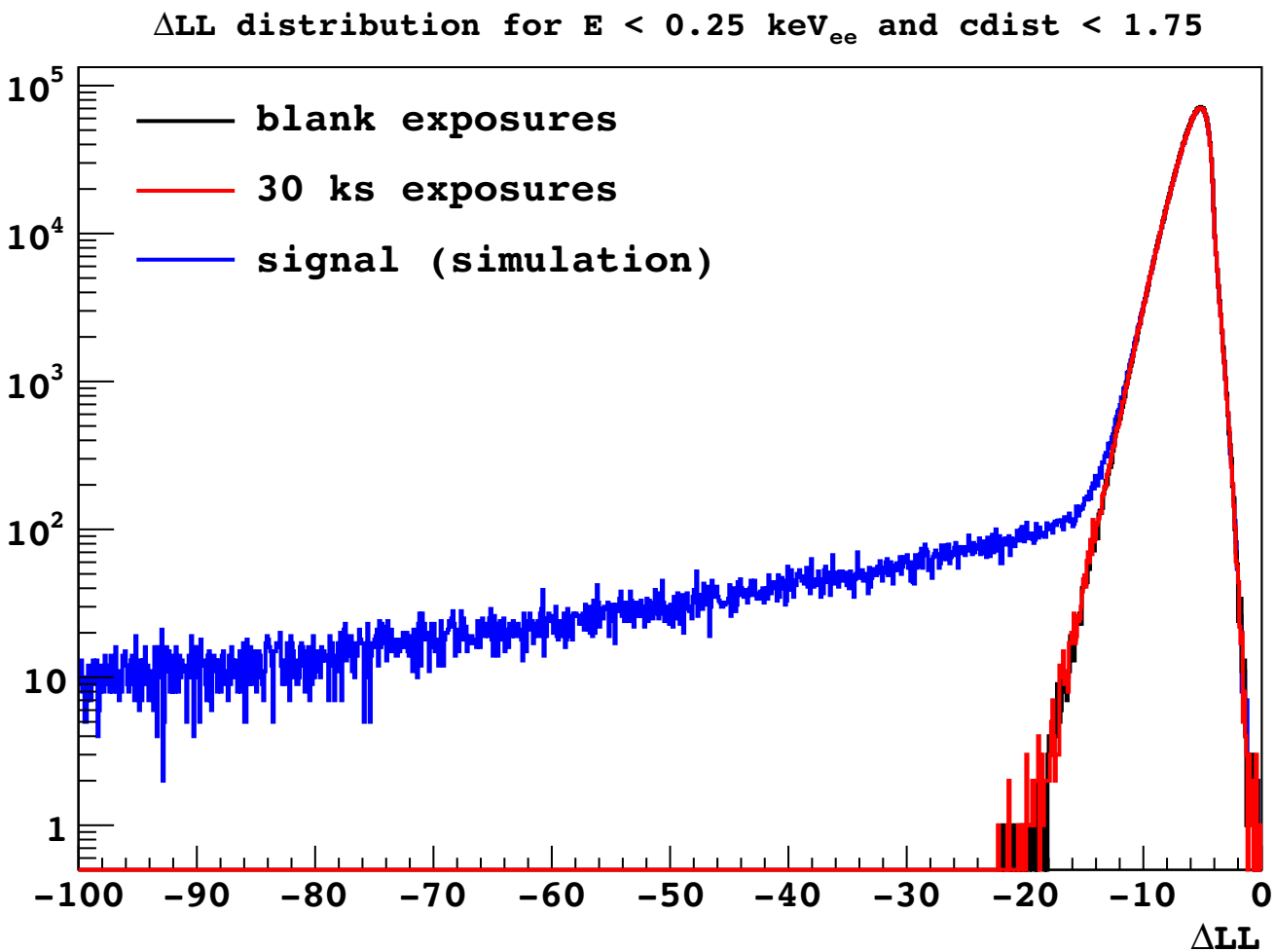
Data Analysis



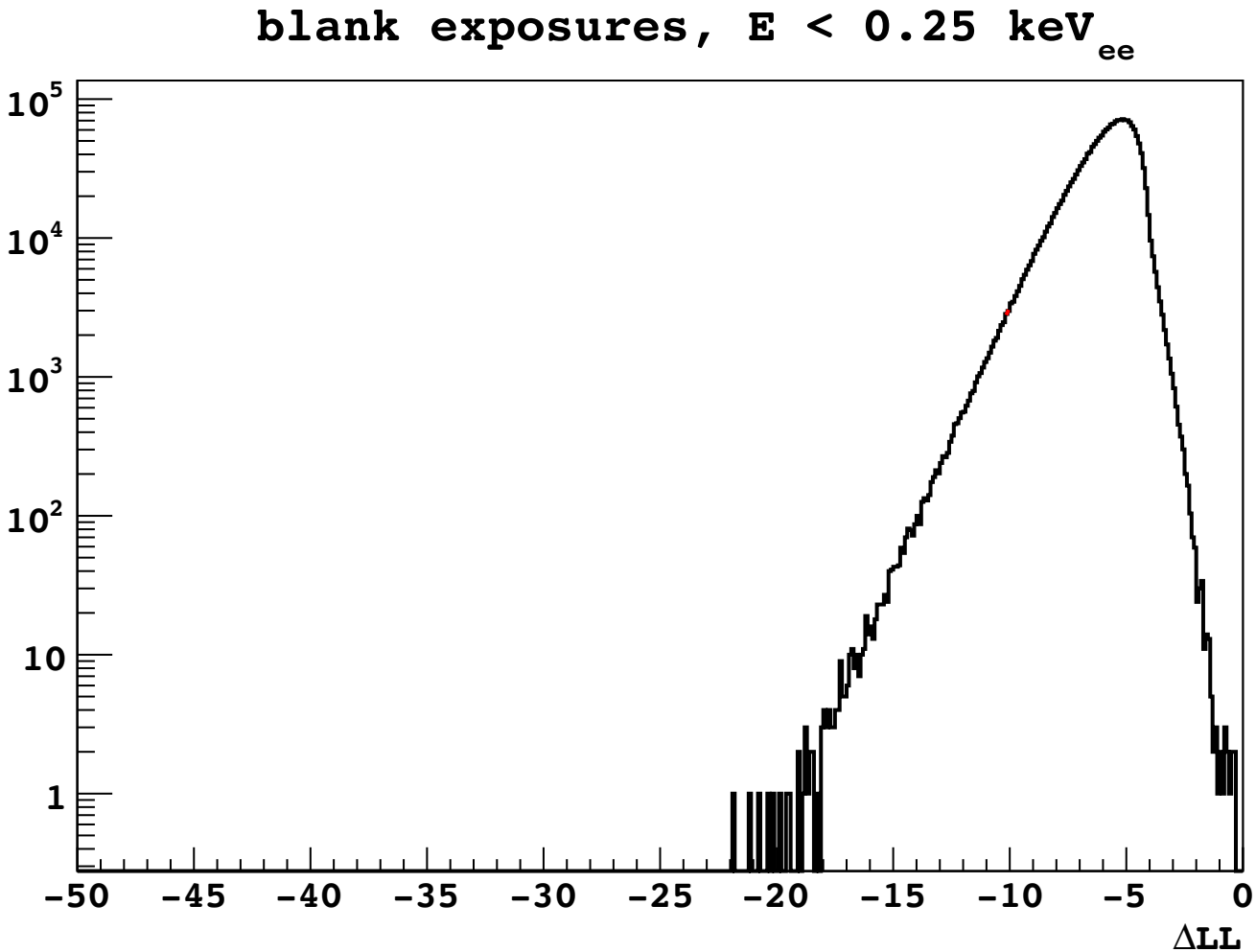
Data Analysis



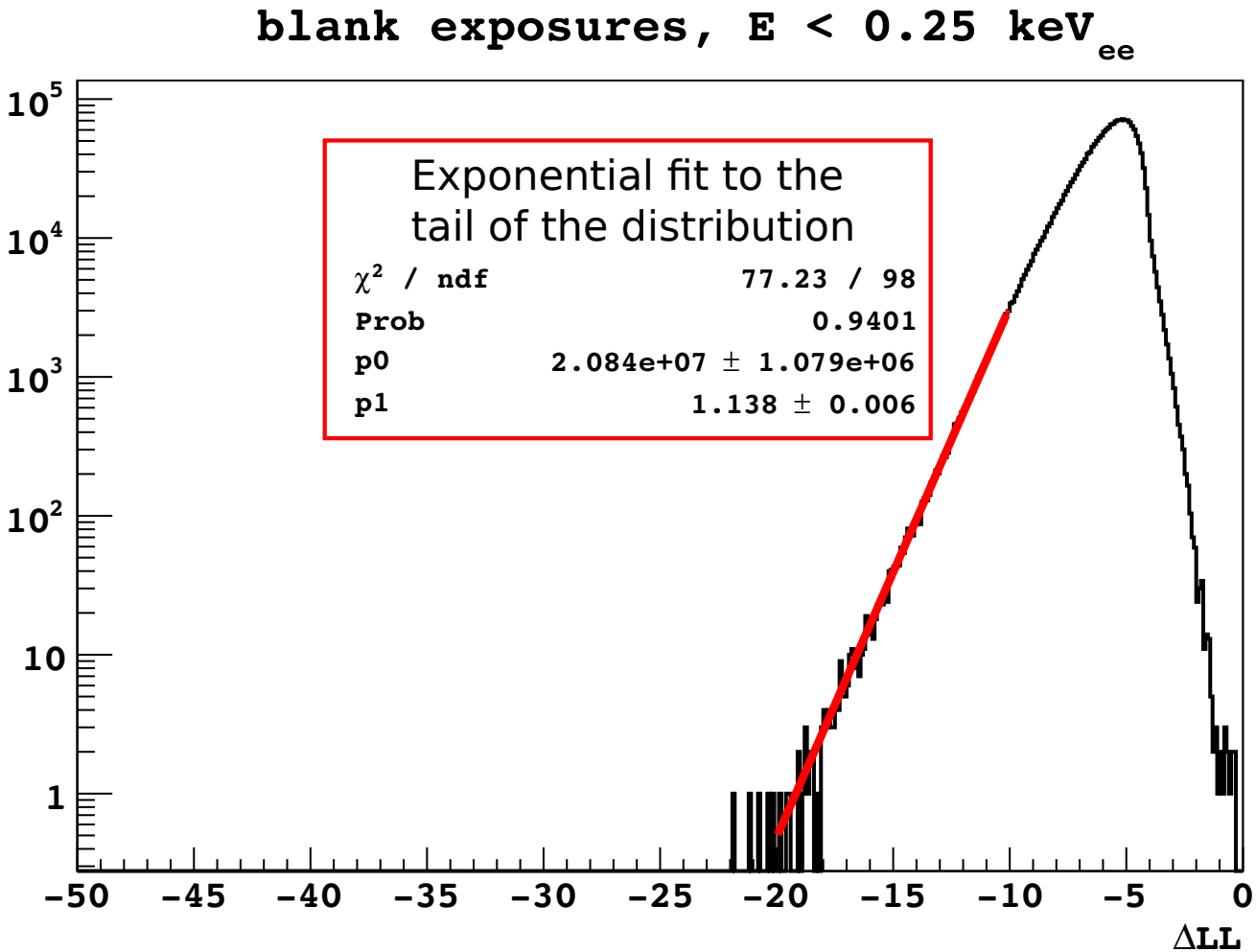
Data Analysis



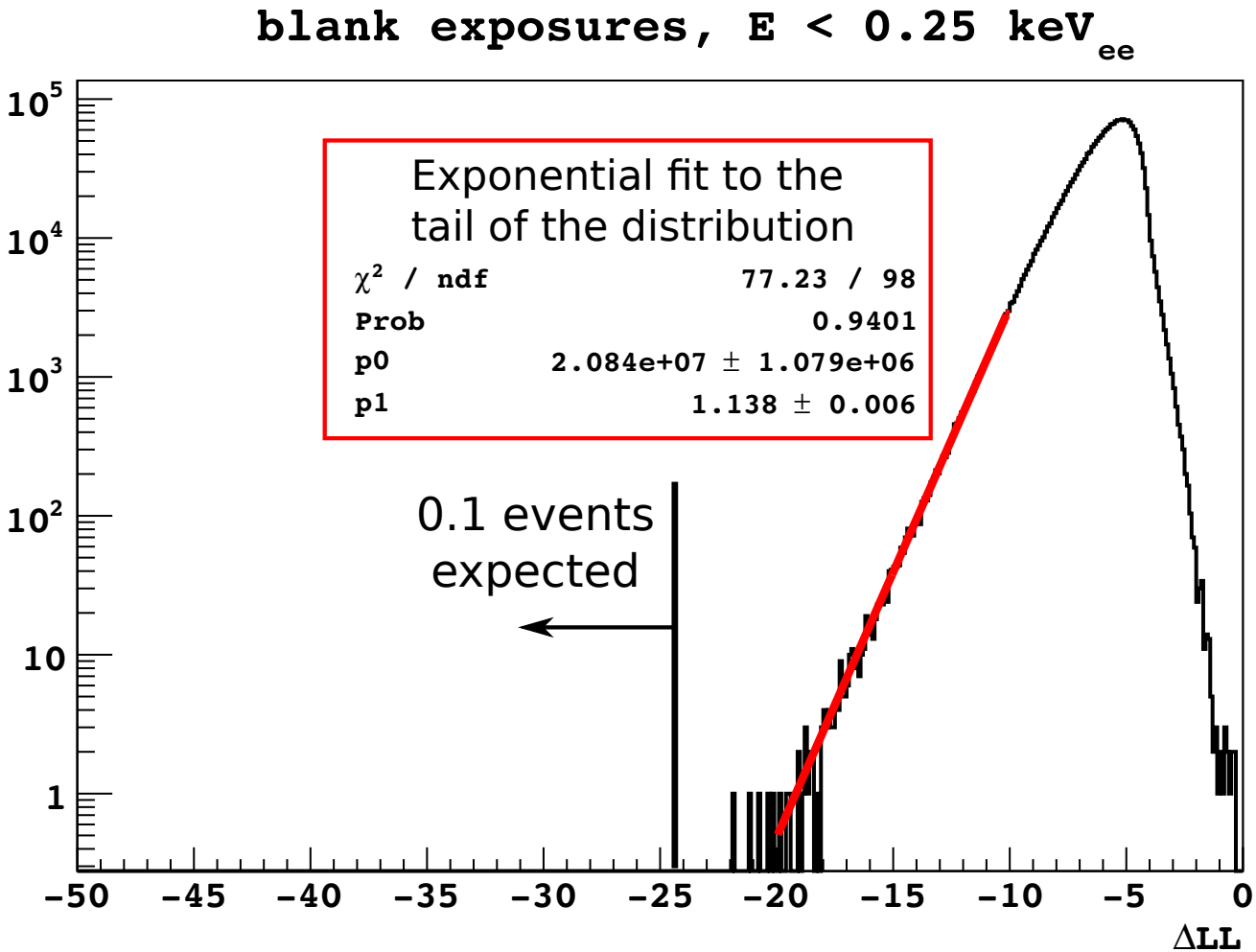
Data Analysis: events selection - quality cut



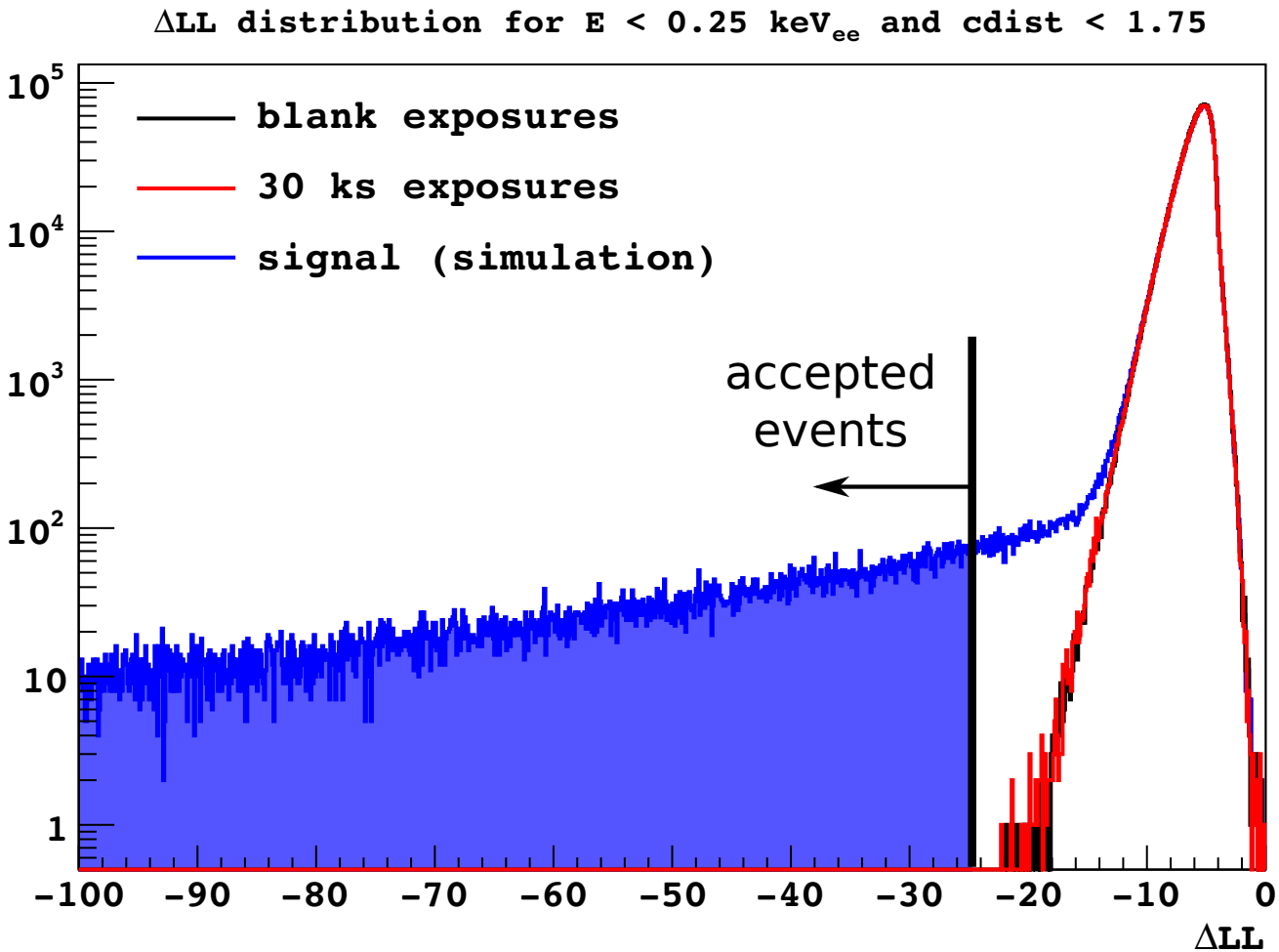
Data Analysis: events selection - quality cut



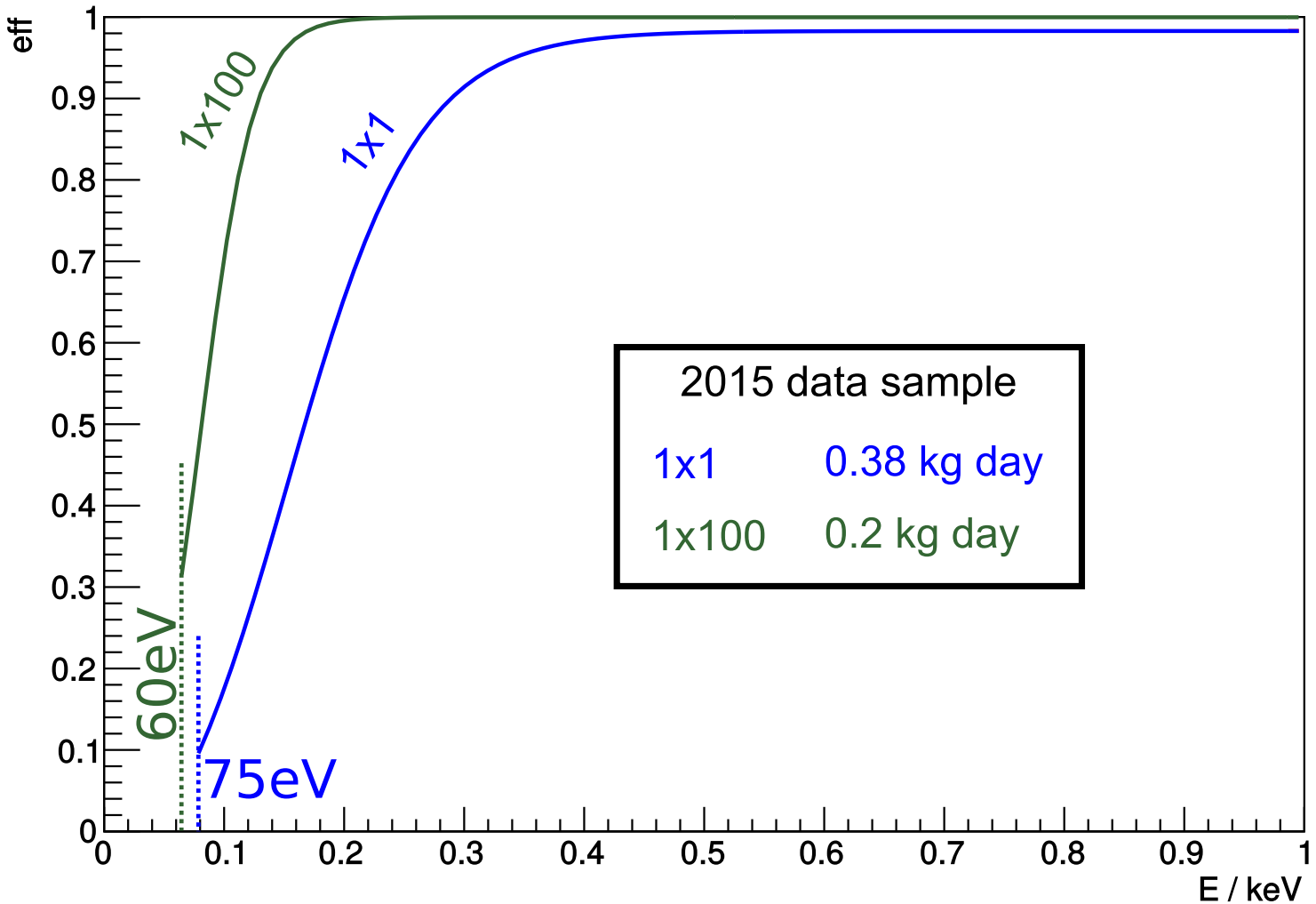
Data Analysis: events selection - quality cut



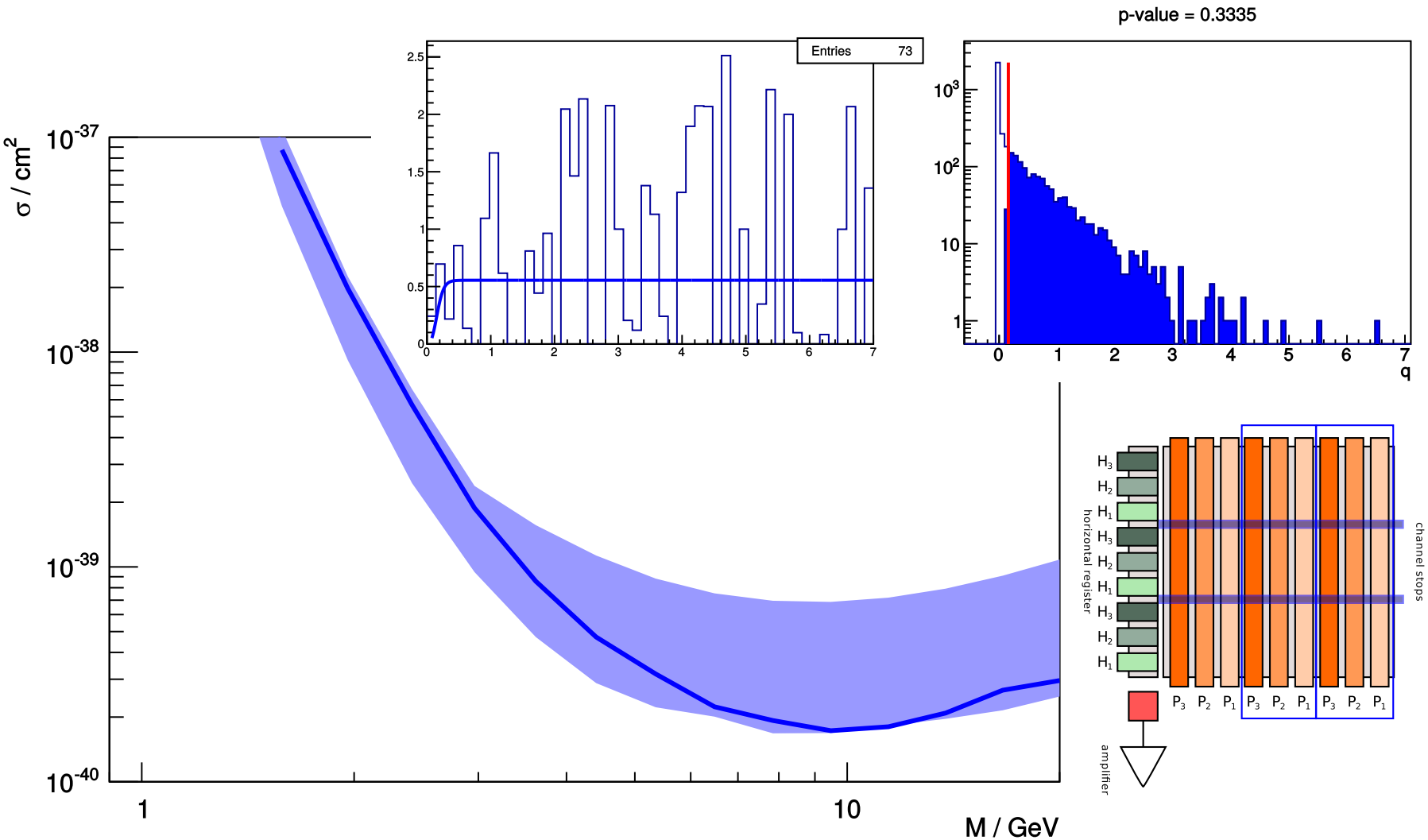
Data Analysis: events selection - quality cut



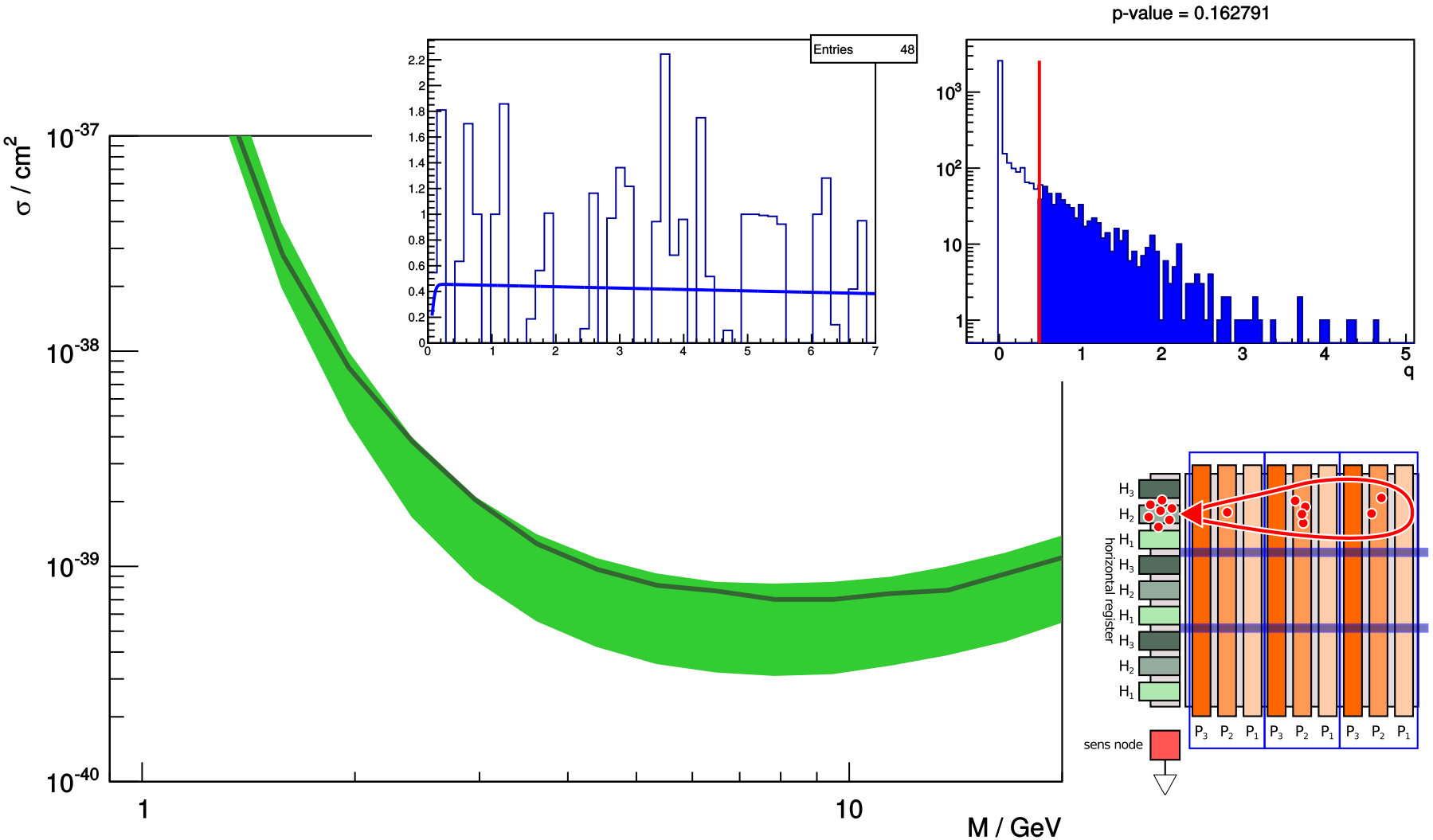
Efficiency


eff
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1x100
1x1
60eV
75eV
2015 data sample
1x1 0.38 kg day
1x100 0.2 kg day
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
E / keV

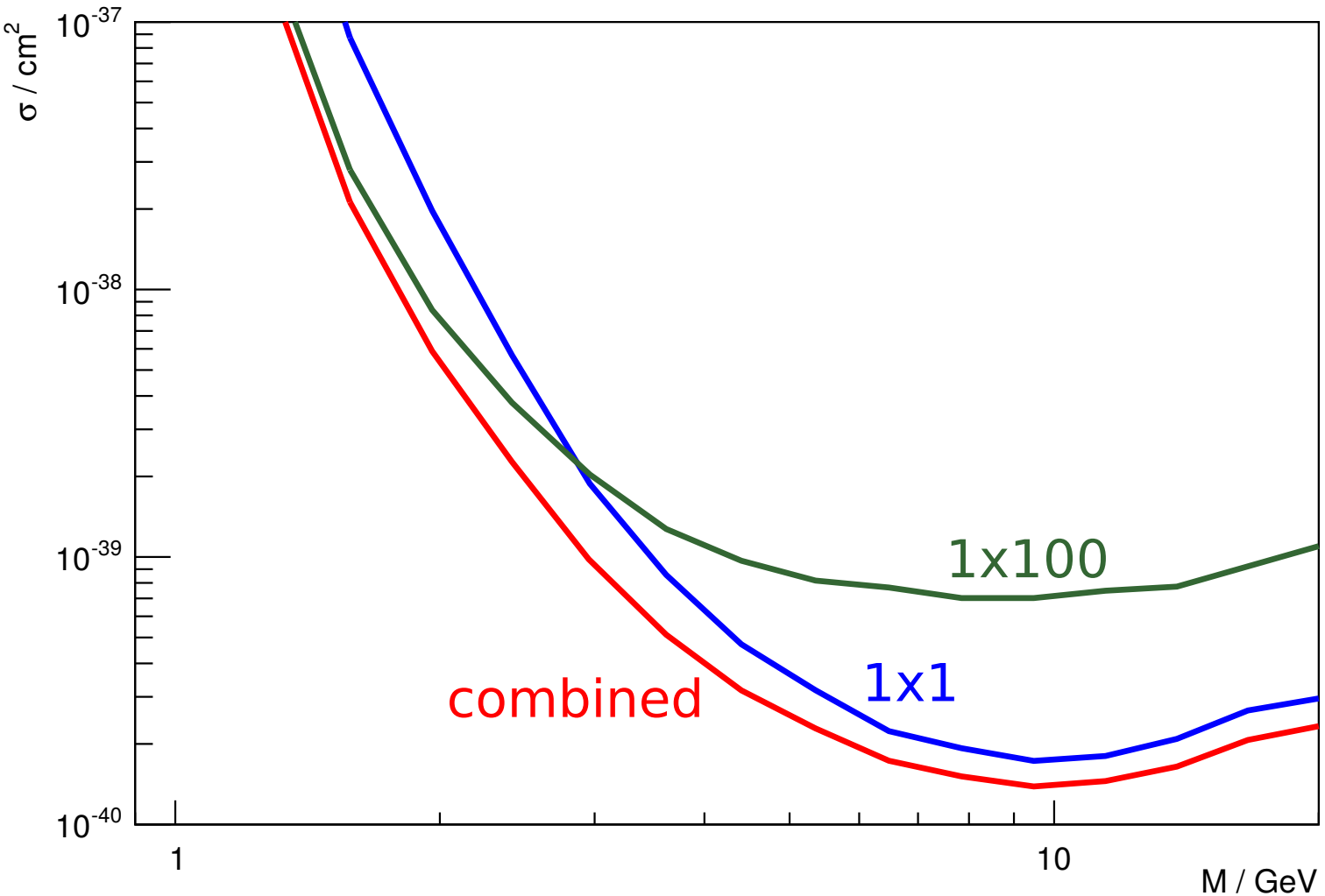
1x1


σ / cm²
10^-37
10^-38
10^-39
10^-40
1
10
M / GeV
Entries 73
p-value = 0.3335
q
horizontal register
channel stops
amplifier
H3
H2
H1
P3
P2
P1

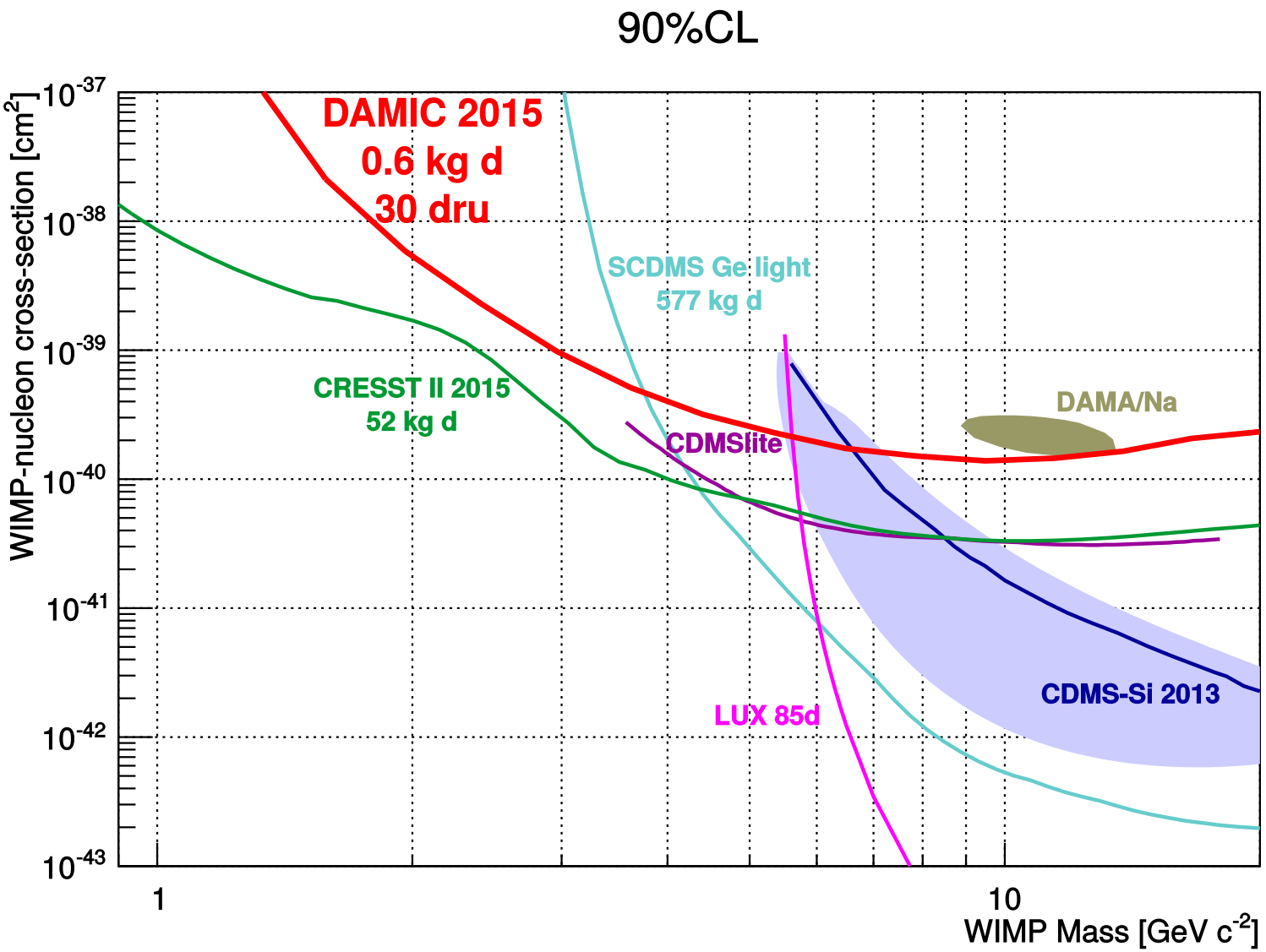
1x100 hardware binning



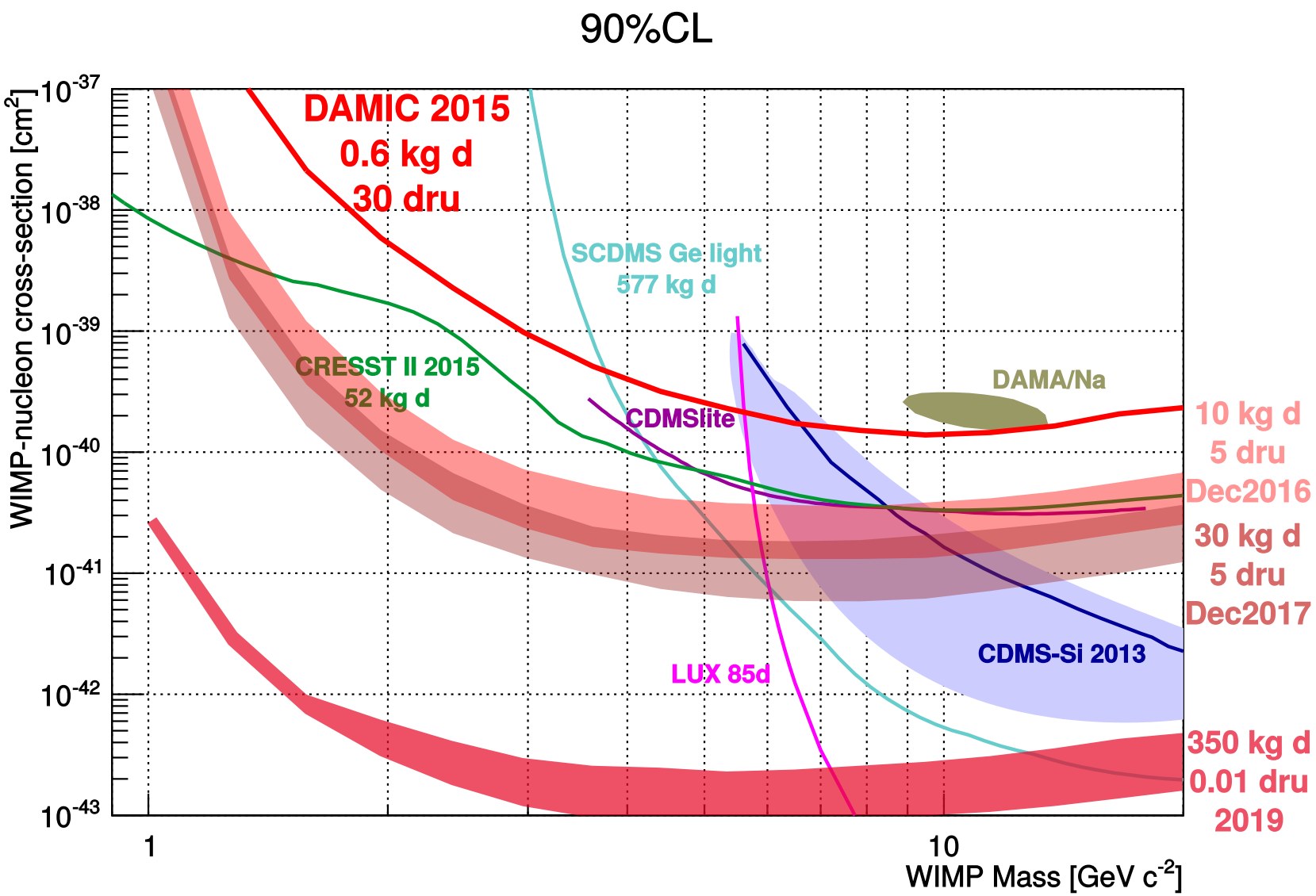
Limits



Limit


90%CL
DAMIC 2015
0.6 kg d
30 dru
SCDMS Ge light
577 kg d
CRESST II 2015
52 kg d
CDMSlite
DAMA/Na
LUX 85d
CDMS-Si 2013
WIMP-nucleon cross-section [cm^2]
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
1
10
WIMP Mass [GeV c^{-2}]

DAMIC100 reach

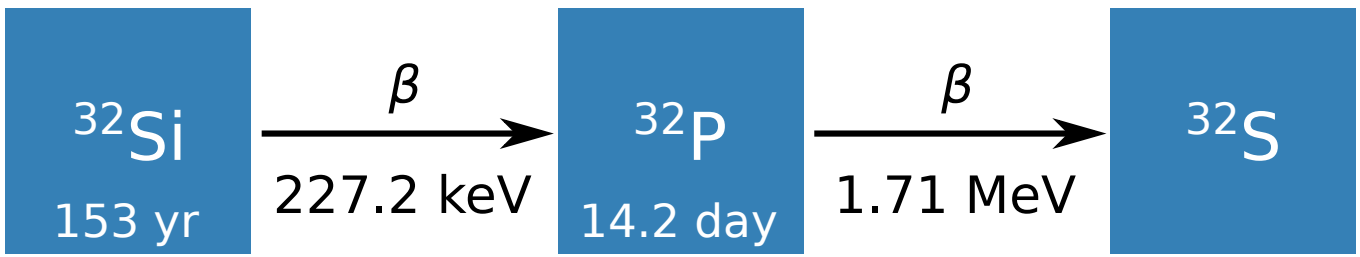


- CCDs are an excellent candidate for detecting low energy DM events. The lack of mass is compensated by the low threshold.
- Nuclear recoil energy calibrated down to threshold
  - **deviation from Lindhard at low energy**
- DAMIC operations at Snolab very reliable and consistent ($\sim$ 95% uptime)
- DAMIC100 in production mode. 10 sensors already packaged ad tested.
- **DAMIC100 commissioning in April 2016**

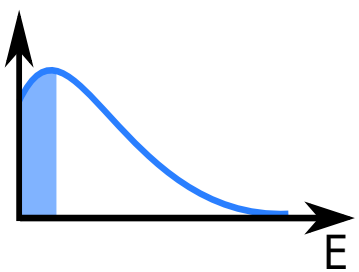
BACK UP SLIDES

Background from Silicon: could be a limiting factor

There is a long lived radioactive silicon isotope that is cosmogenically produced in the interaction of cosmic rays with atmospheric argon and other elements

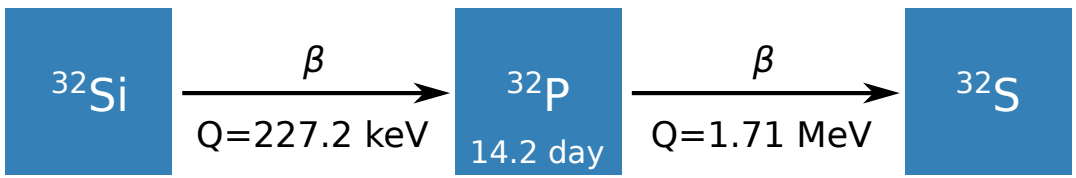


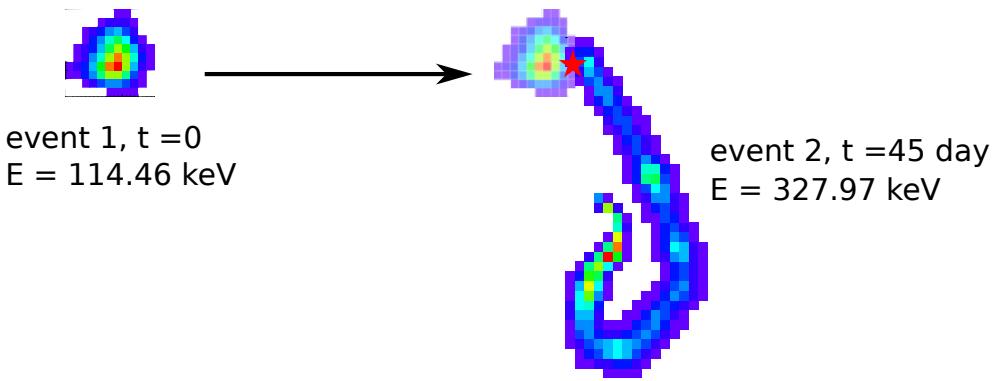
Low energy electrons from β decays could be a significant background in silicon



Background from Silicon: candidate ^{32}Si event

The precise position reconstruction in the CCD allows the study of spatial coincidences to measure and veto ^{32}Si events in the CCD



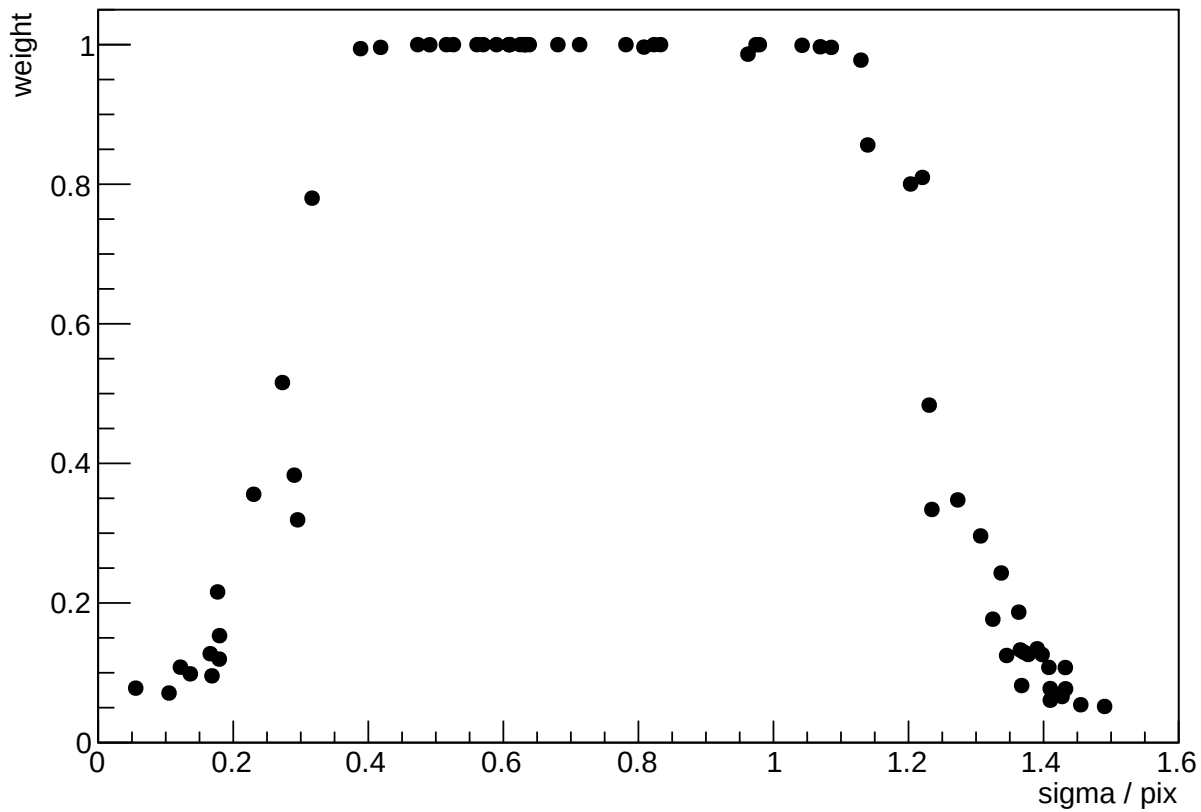


We observe 13 coincidences

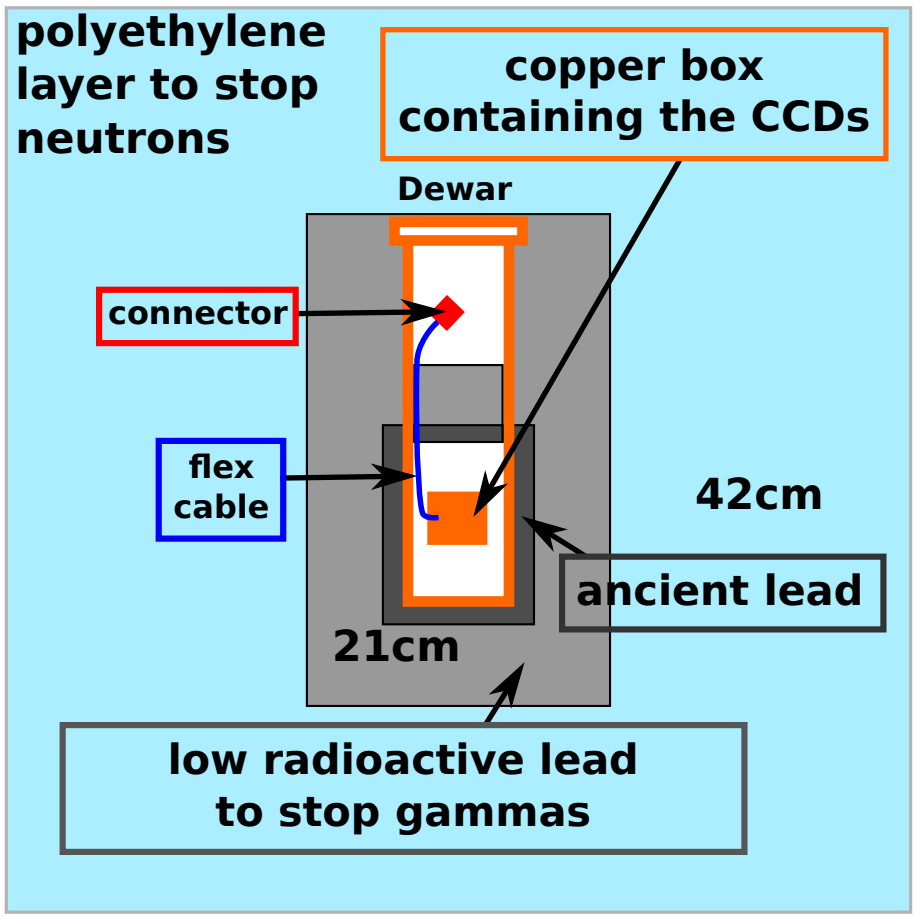
Expected from random chance: 6

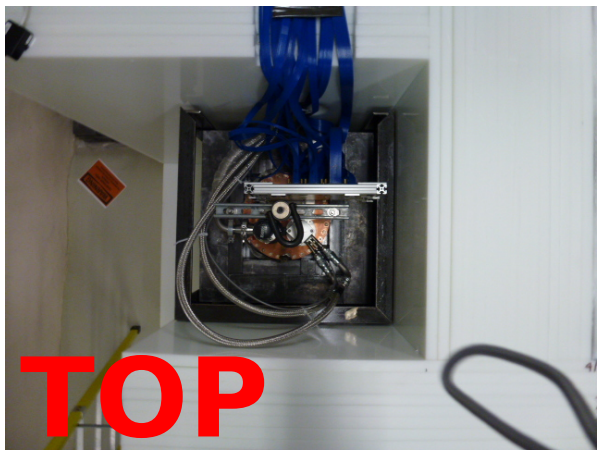
^{32}Si decay rate: 110^{+150}_{-90} Kg^{-1}d^{-1} 90% CL

Weights

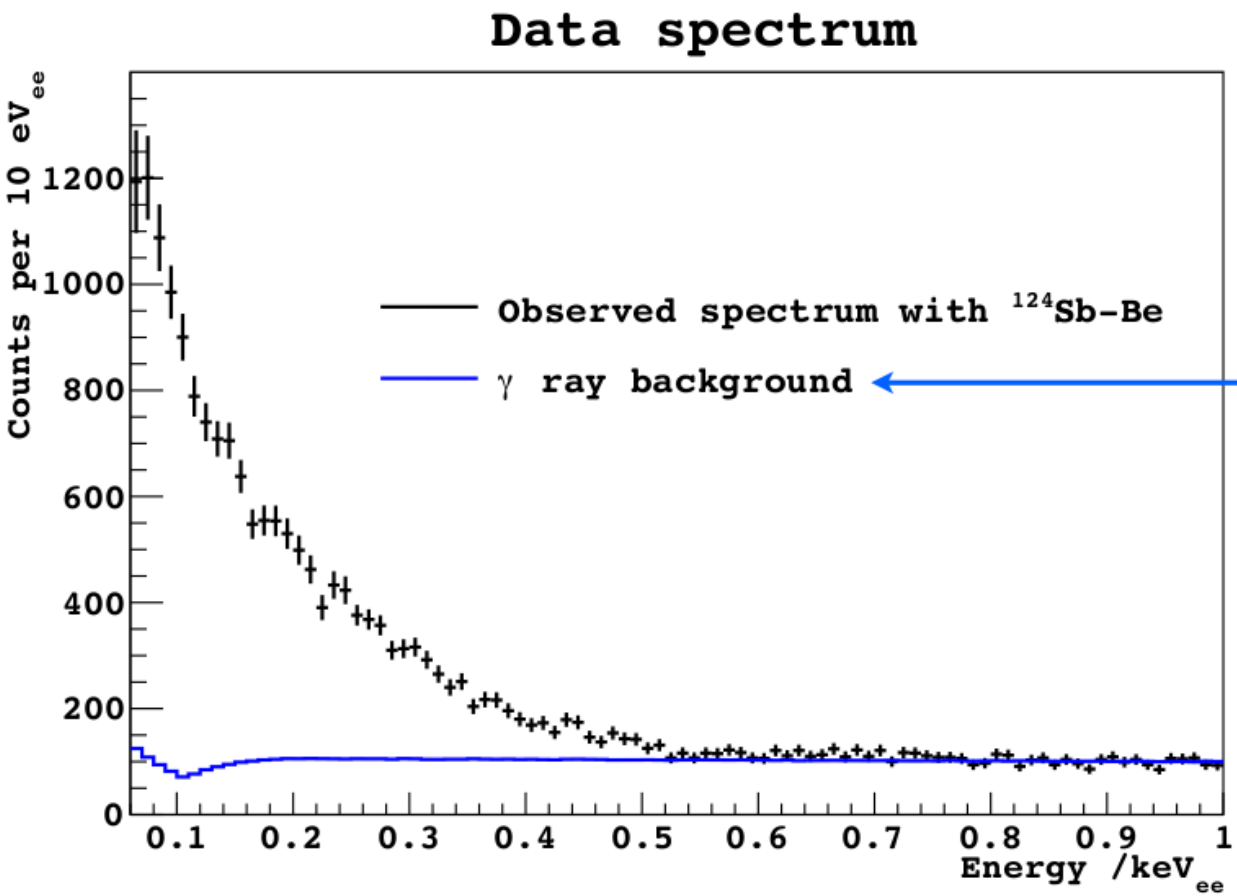


DAMIC detector: shielding





Nuclear recoil calibration



Normalized to count rate 2-5 keV$_{ee}$.

Uncertainty propagated in analysis.