

Title: Dark Matter Search with CDMS and SuperCDMS

Date: Jun 12, 2009 10:20 AM

URL: <http://pirsa.org/09060041>

Abstract: The Cryogenic Dark Matter Search (CDMS) experiment employs cryogenic ionization detectors to search for nuclear recoils induced by Weakly Interacting massive dark matter particles (WIMPs). A fast readout of the thermal energy deposition and the simultaneous measurement of an ionization signal provide an excellent handle for rejection of electron recoil background events from environmental radiation. This unique technology together with passive and active shielding makes CDMS the only background free experiment in the field.

The recently published data based on the full complement of 30 individual detector modules operated in the Soudan Underground Laboratory in Minnesota give the best sensitivity for spin-independent WIMP-nucleon scattering for the most interesting mass range above about 40 GeV/c²; The experiment is in a transition to the next phase, SuperCDMS, with increased total target mass and larger individual detector modules with improved sensor technology. SuperCDMS plans to install a total of 100-200 kg of cryogenic germanium detectors in the new SNOLAB facility near Sudbury ON, which, as the deepest large underground laboratory, provides the best conditions for direct dark matter search experiments.

Overview

CDMS Detectors

CDMS results

Analysis in Progress

SuperCDMS

Conclusions

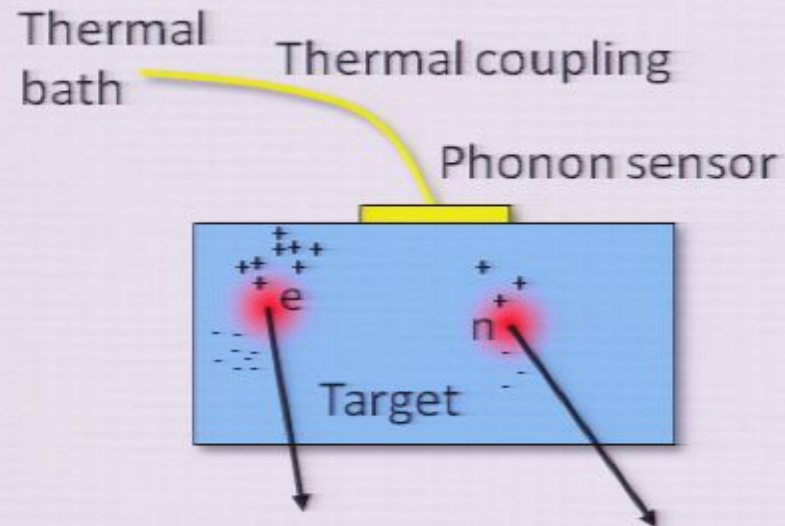
CDMS Detectors

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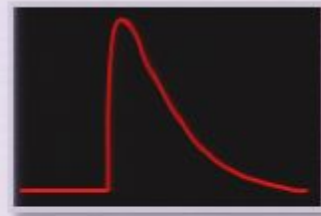
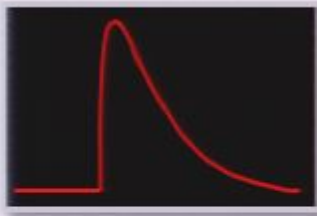
CDMS Detectors

- Measure energy deposit through thermal energy, requires low temperature

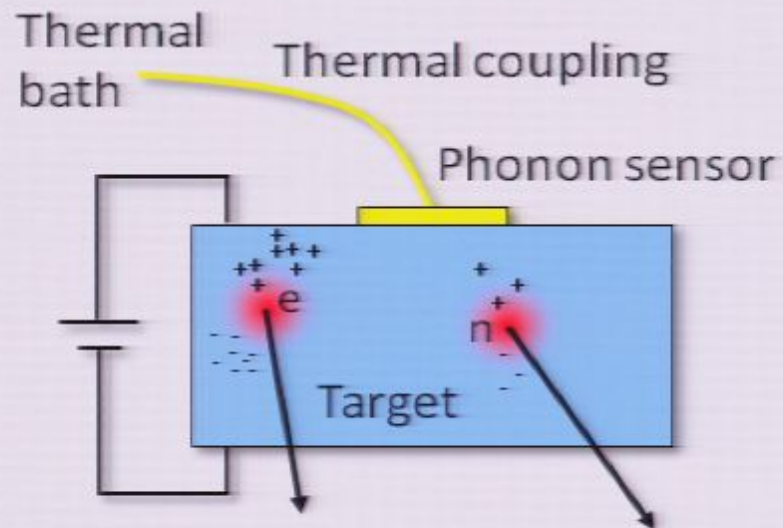
CDMS Detectors



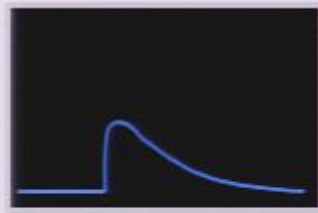
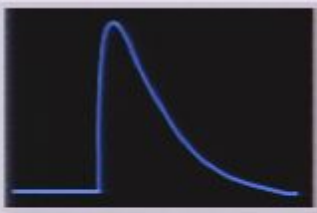
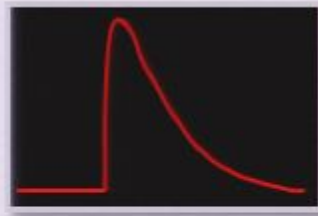
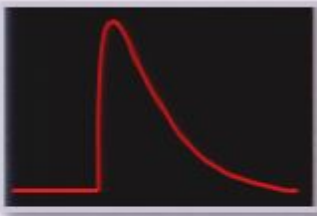
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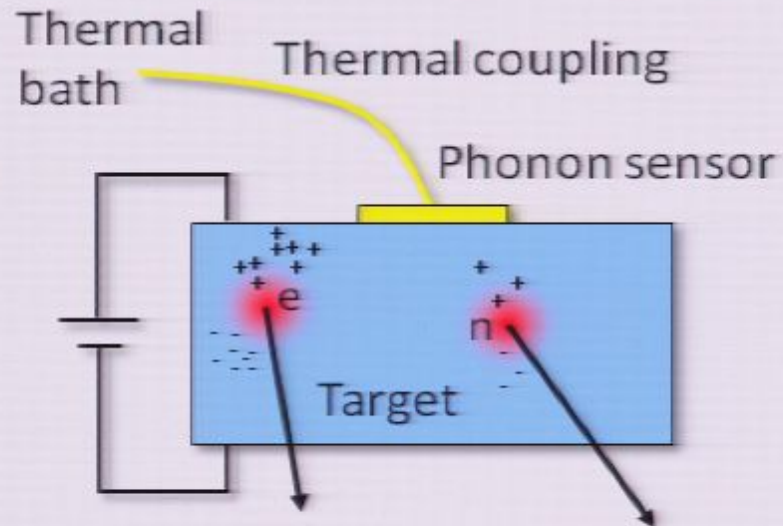
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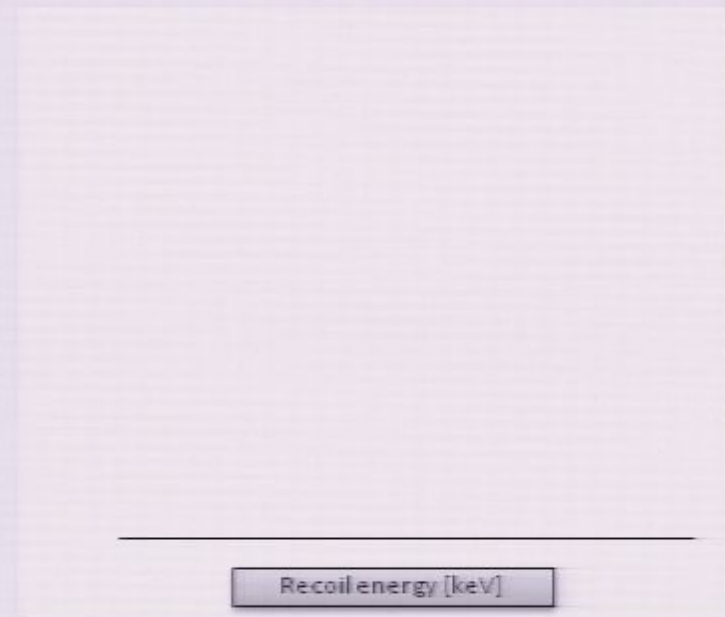
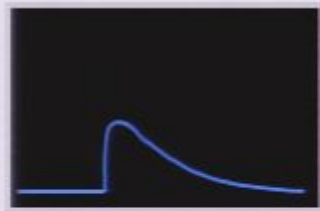
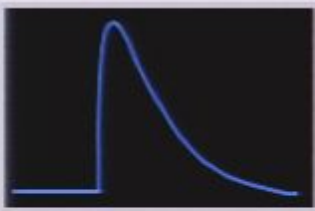
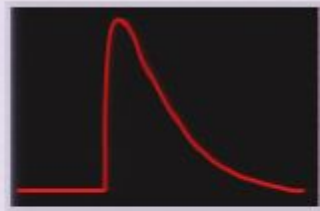
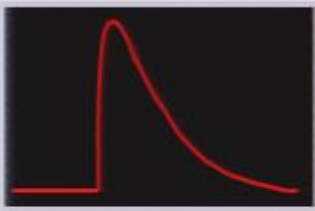
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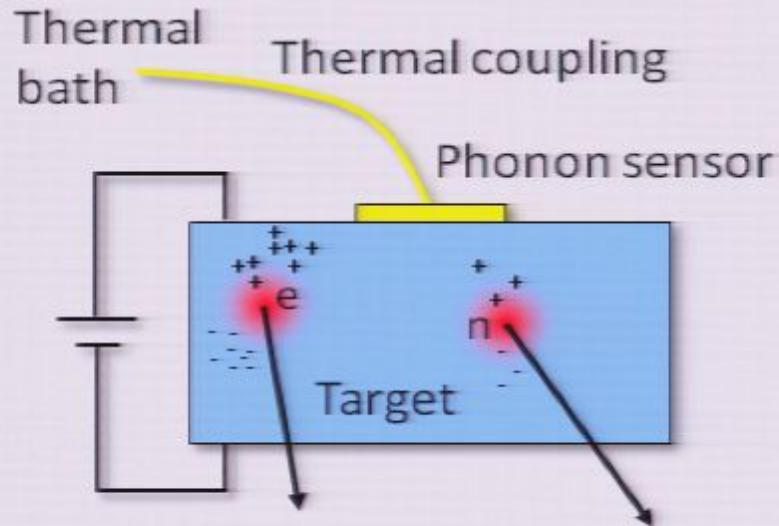
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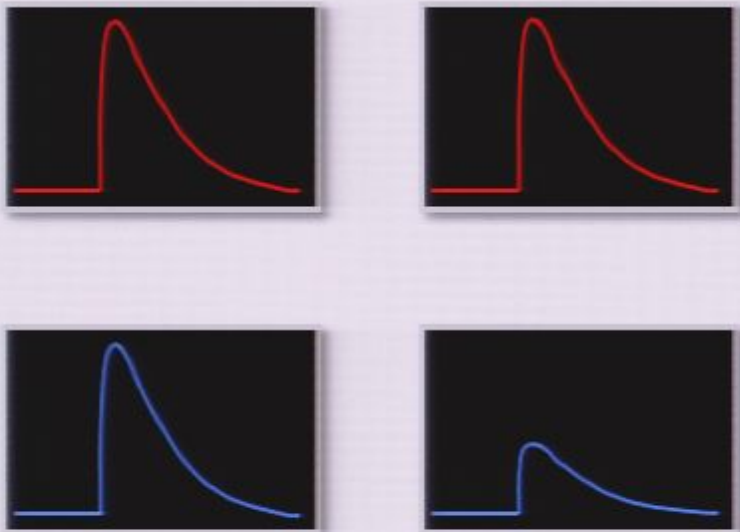
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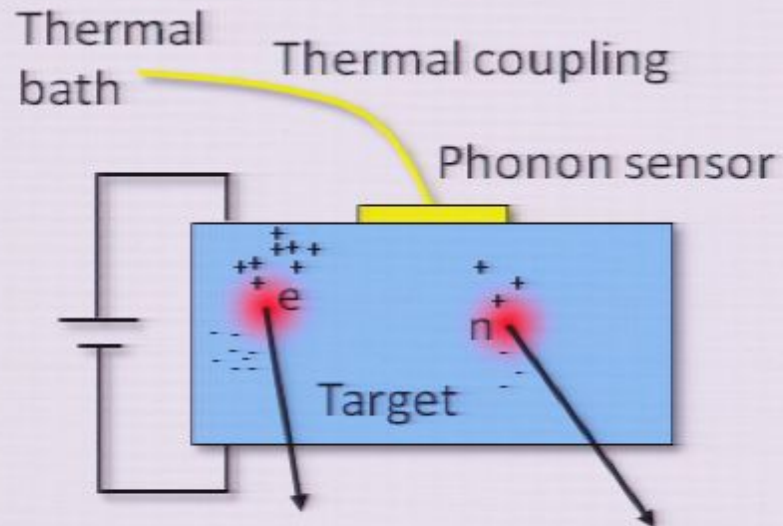
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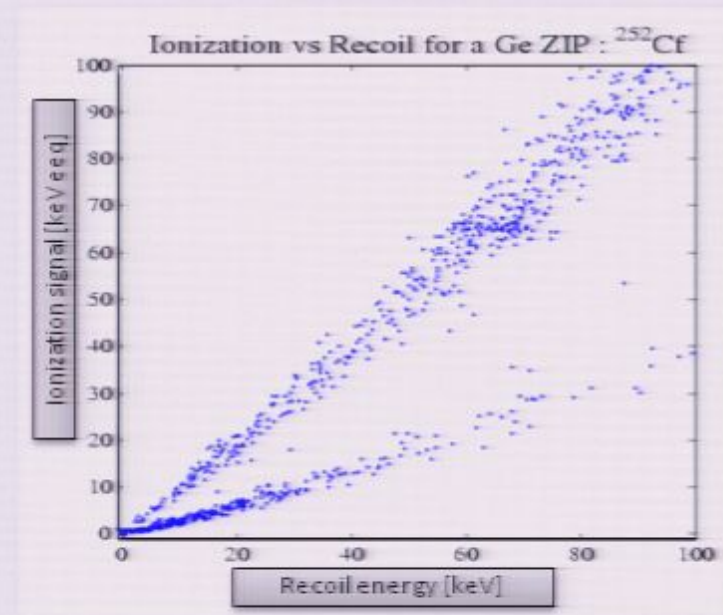
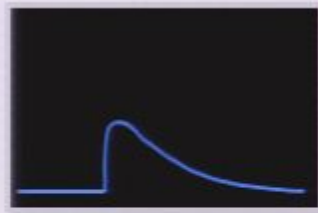
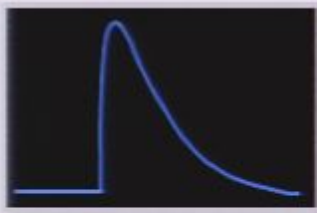
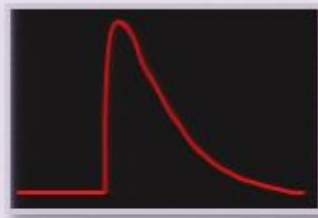
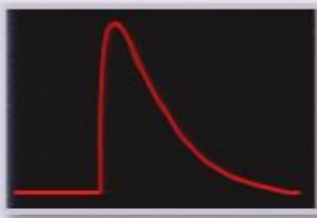
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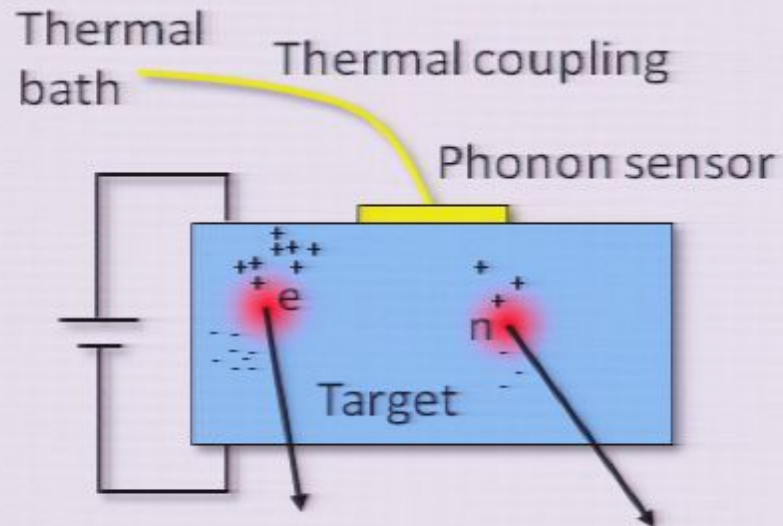
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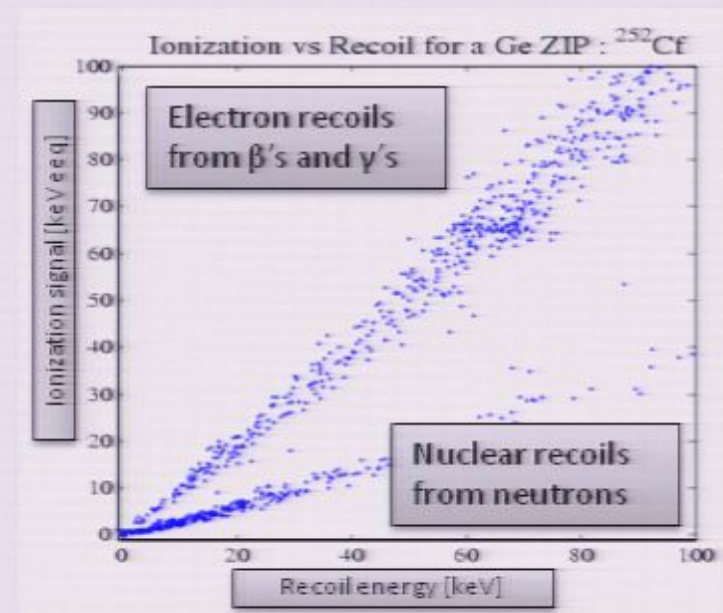
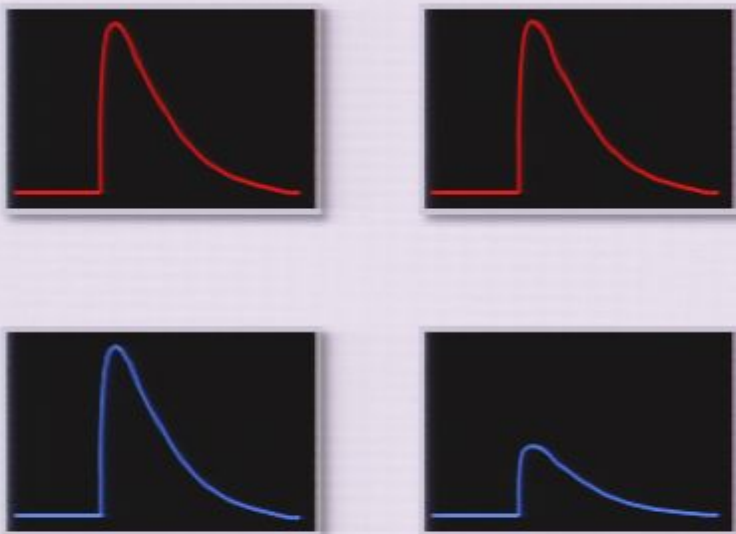
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CDMS Detectors

- Cryogenic ionization detectors, Ge (Si)
- $\varnothing = 7$ cm, $h = 1$ cm, $m = 250$ g (100 g)
- Thermal readout: superconducting phase transition sensor (TES)
- Transition temperature: 50 – 100 mK
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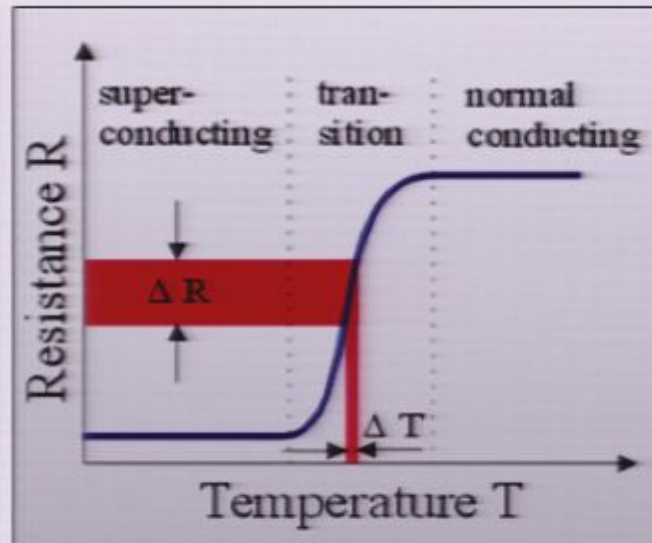
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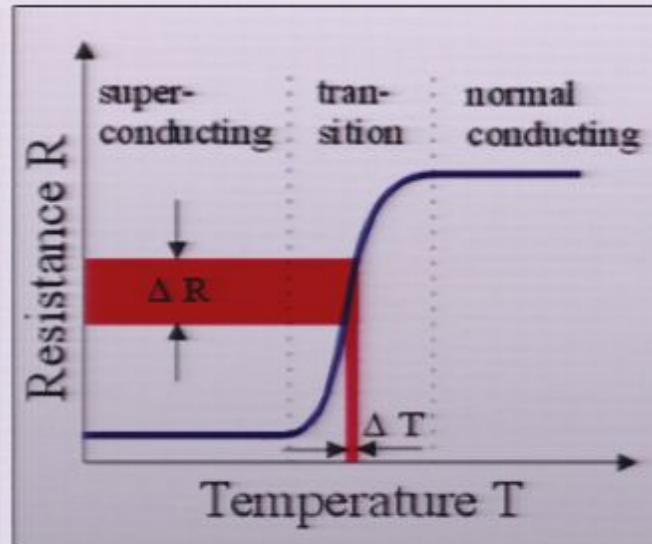
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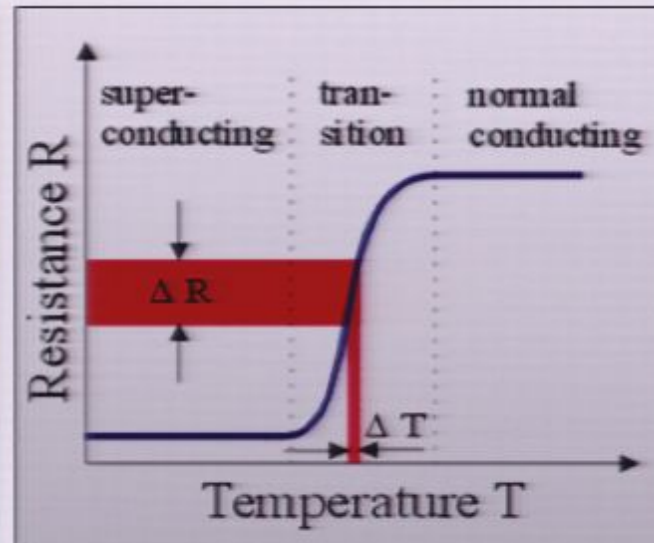
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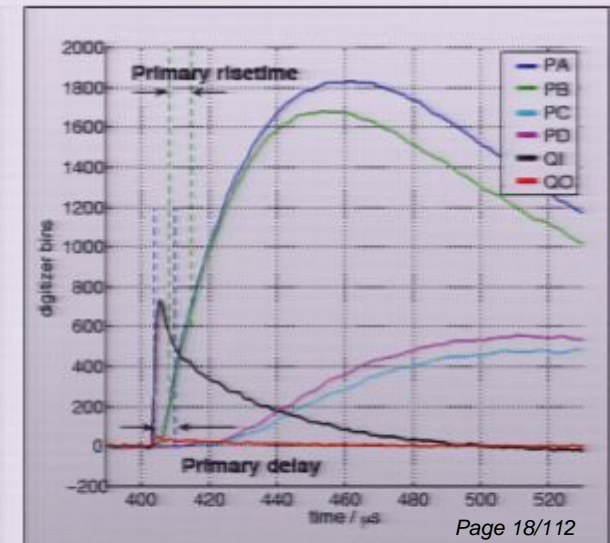
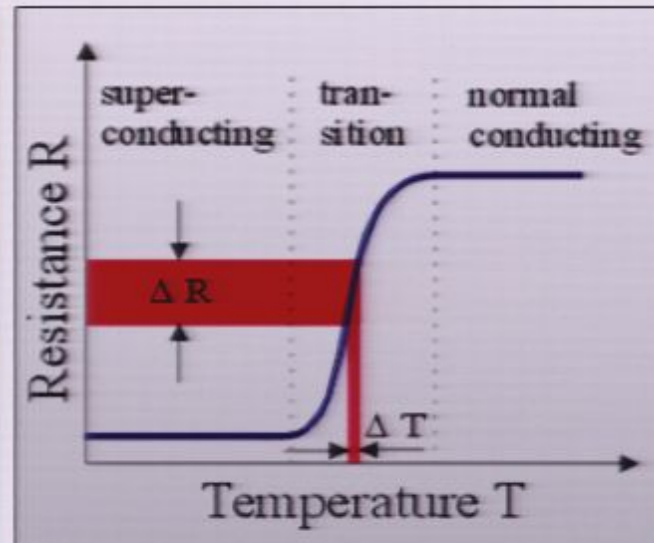
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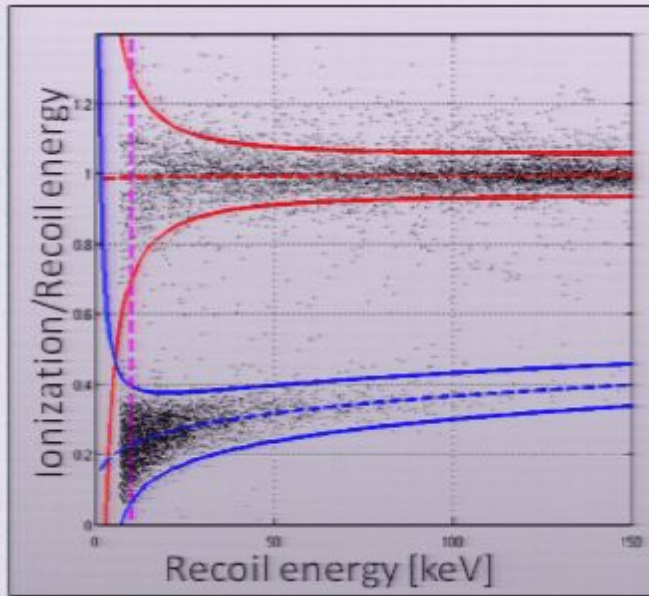
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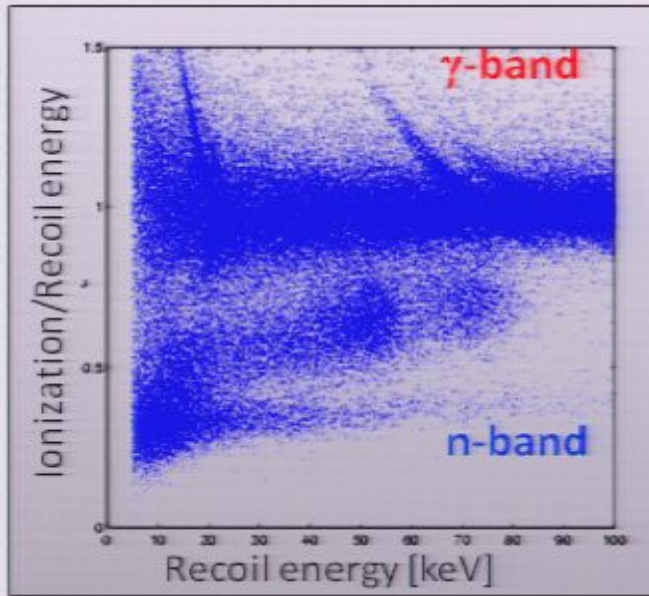
CDMS Detectors

Discrimination



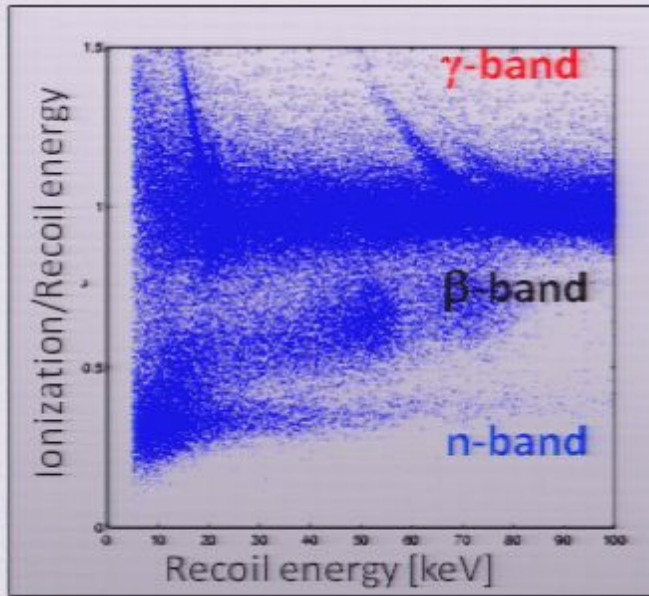
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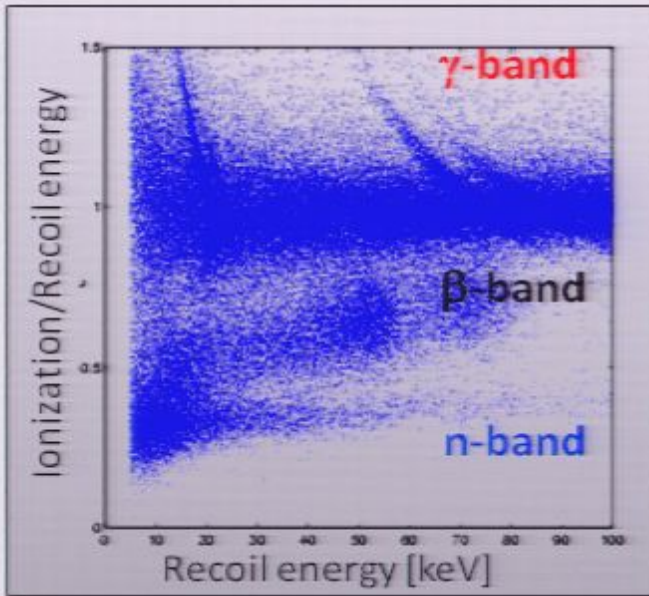
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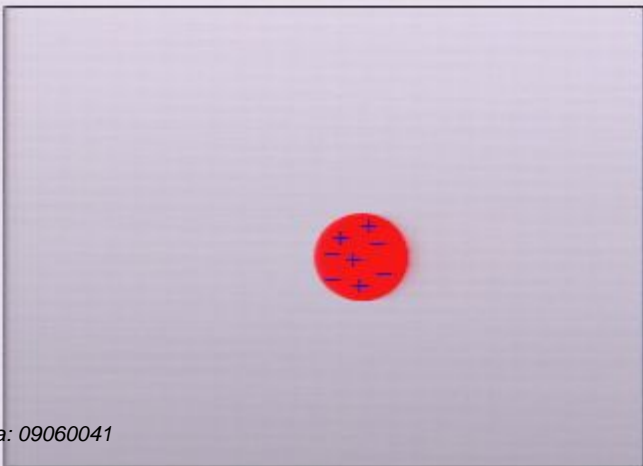
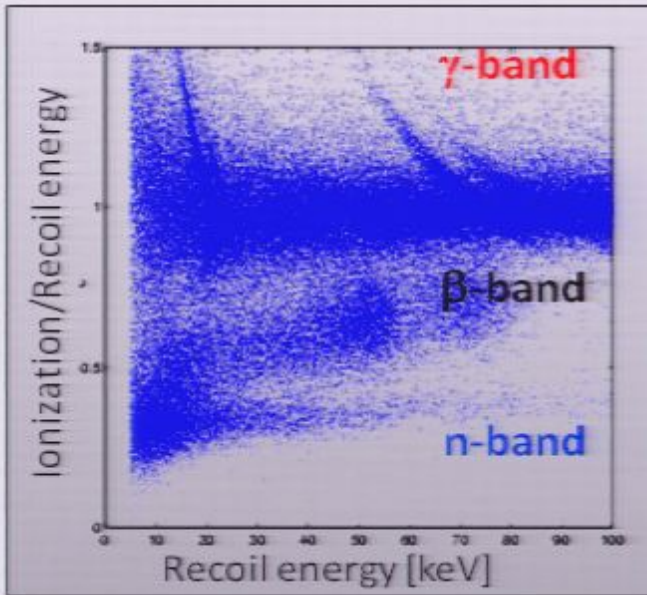
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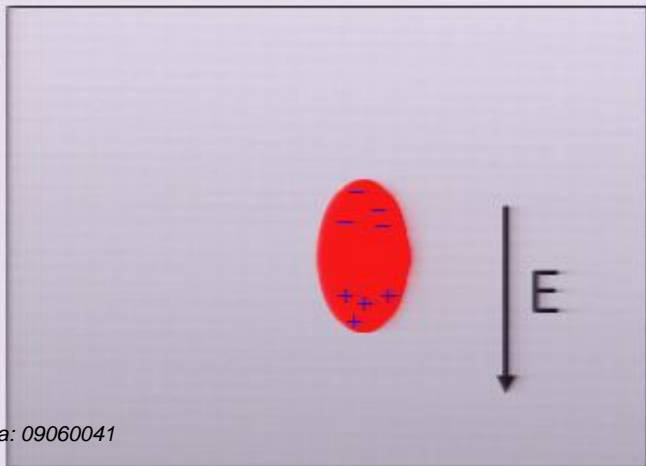
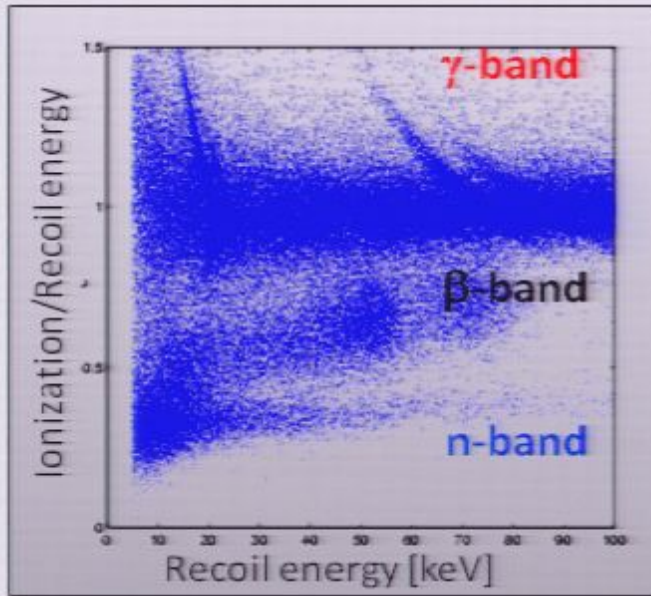
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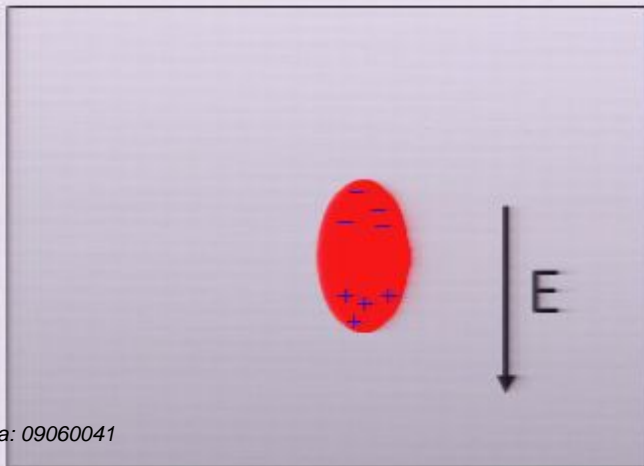
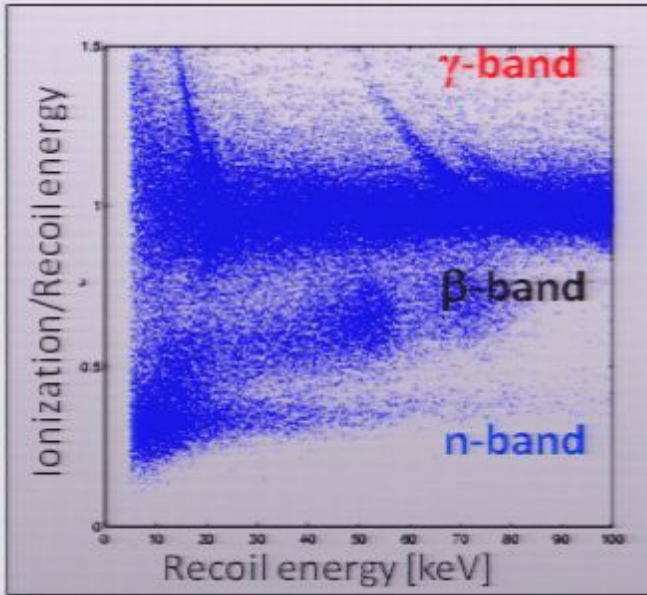
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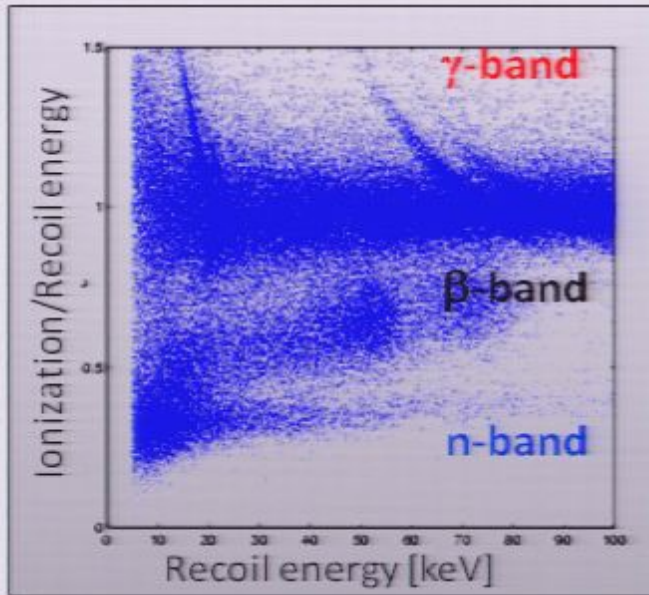
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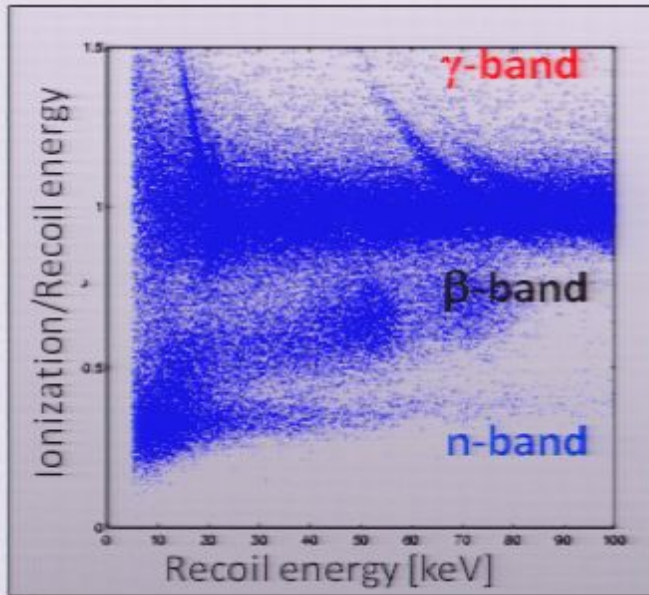


Surface effect



CDMS Detectors

Discrimination

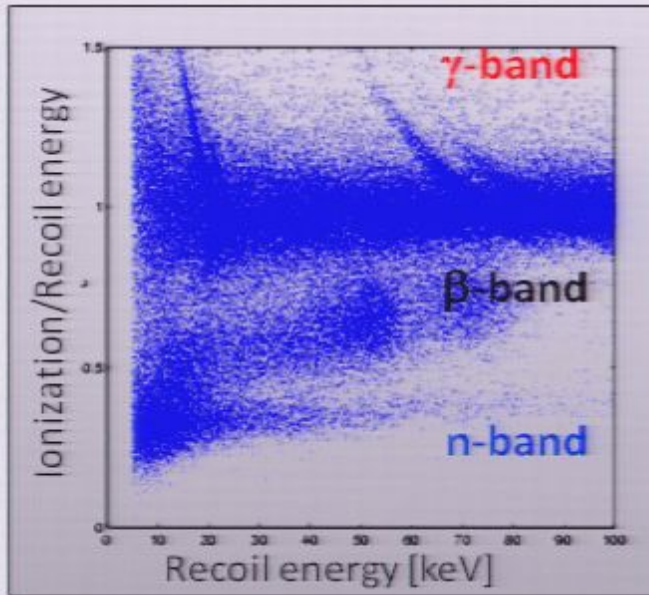


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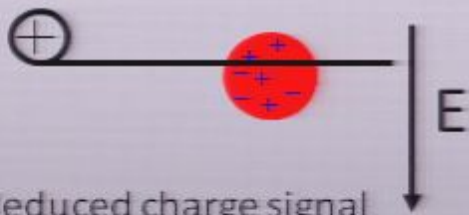


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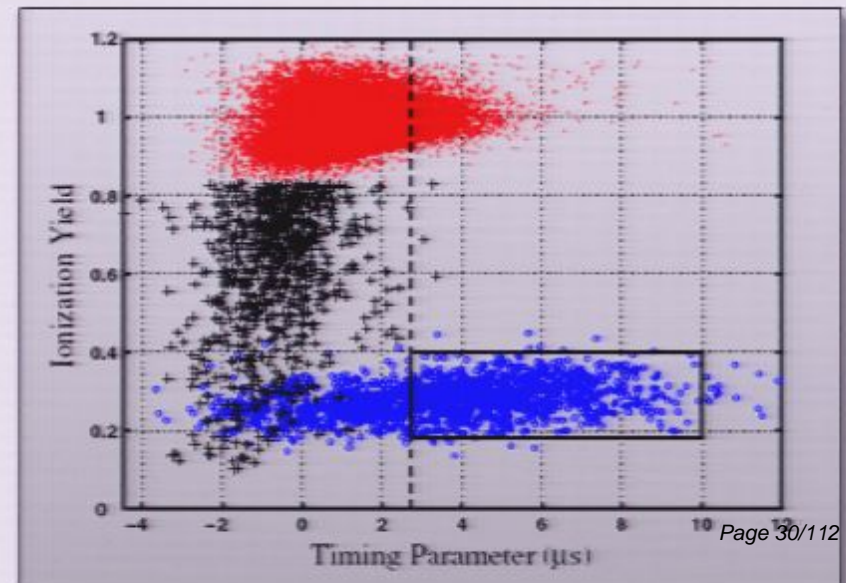
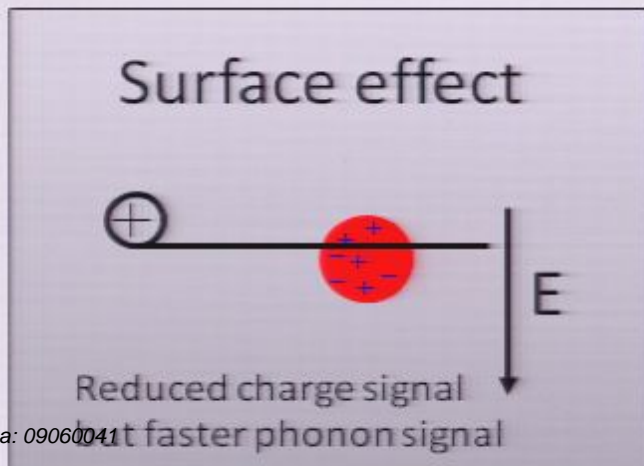
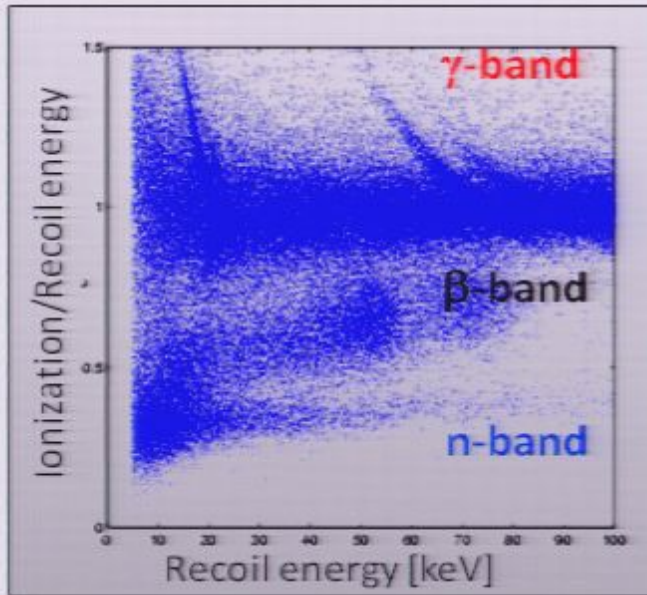
Surface effect



Reduced charge signal
but faster phonon signal

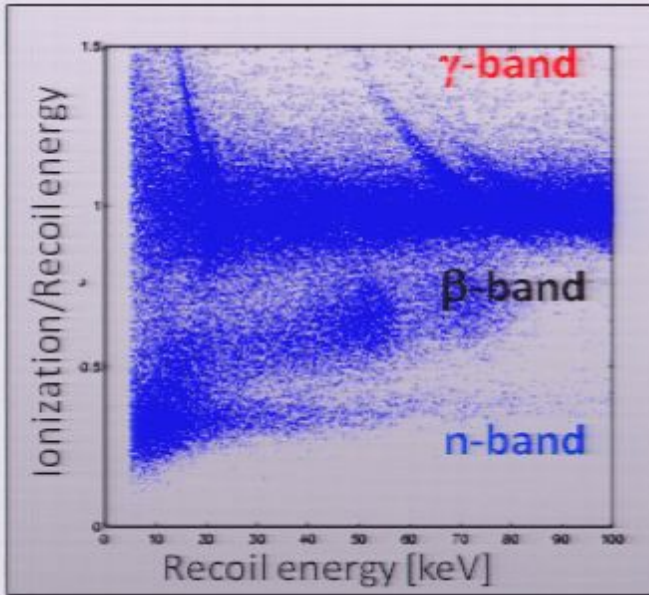
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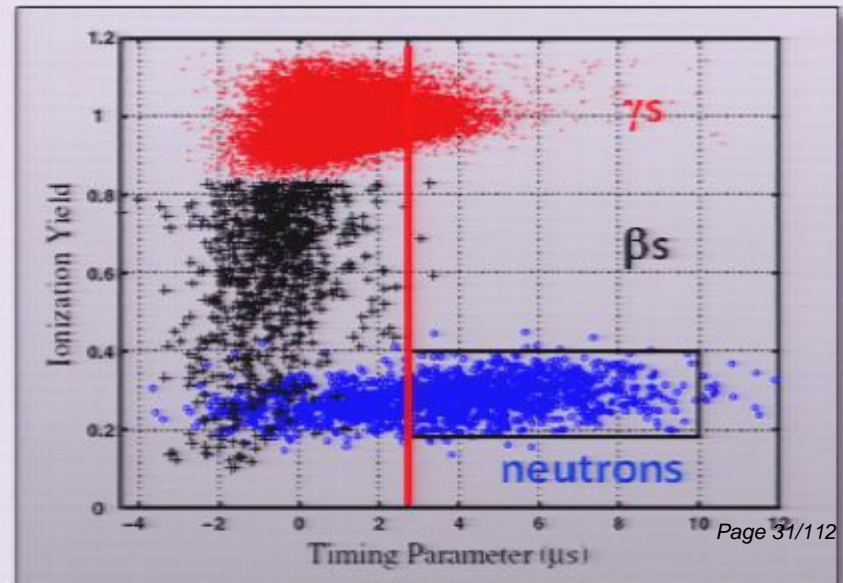
Discrimination



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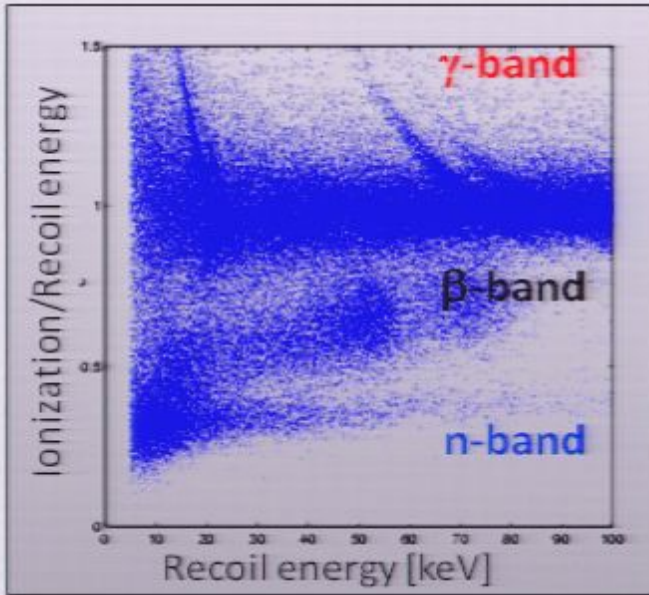


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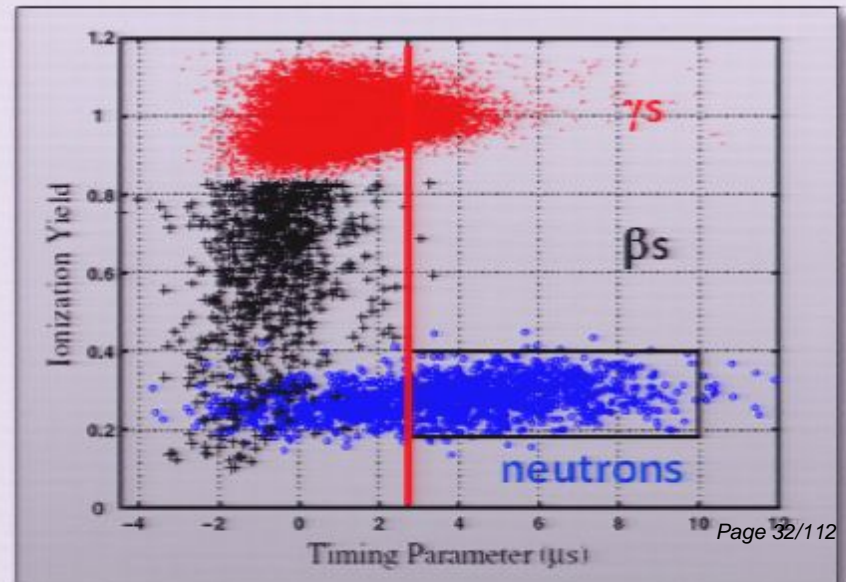


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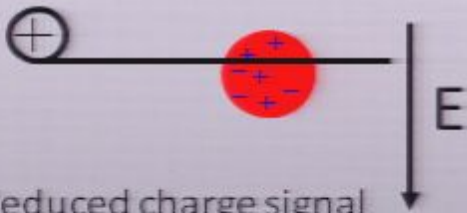
Discrimination



Position/Timing



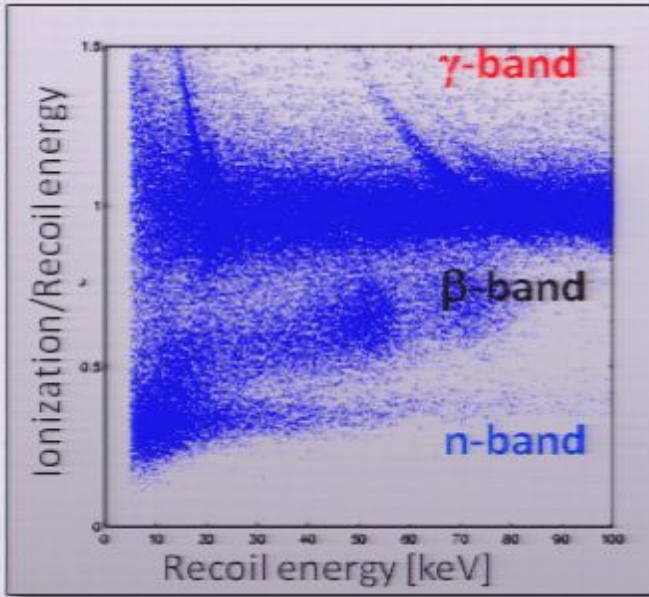
Surface effect



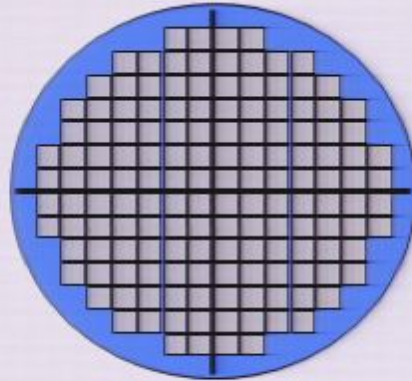
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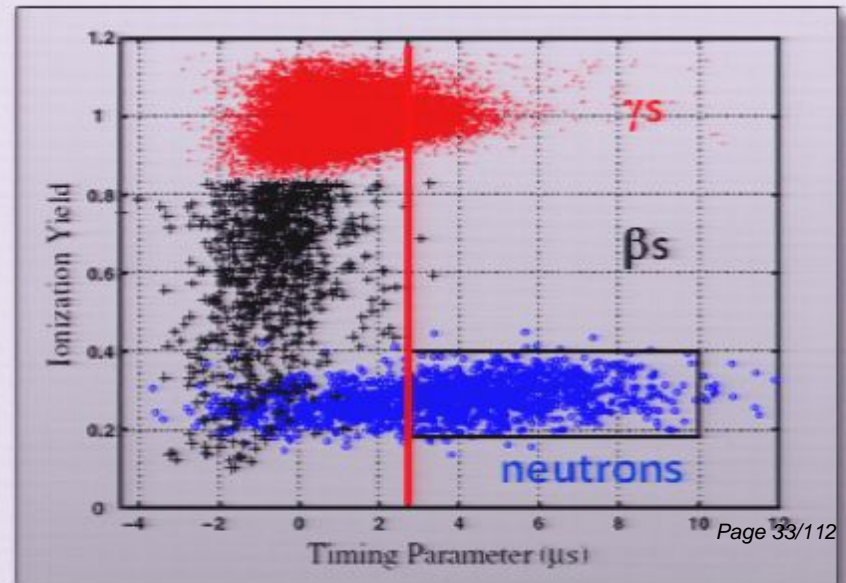
Discrimination



Detector



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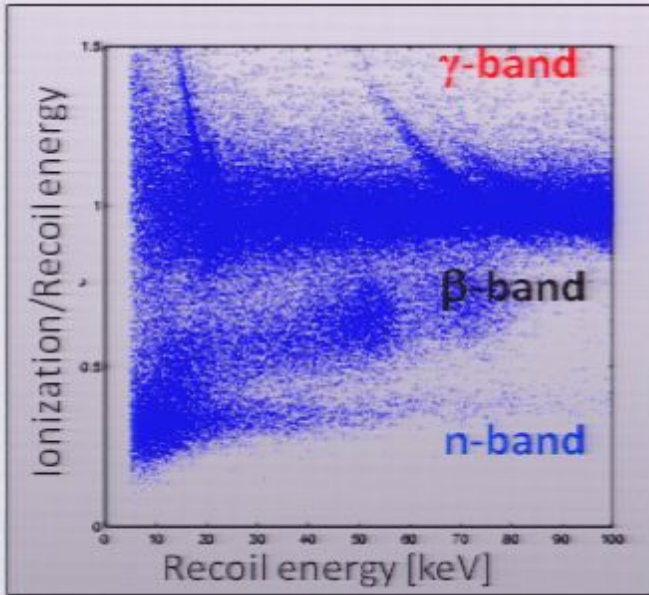
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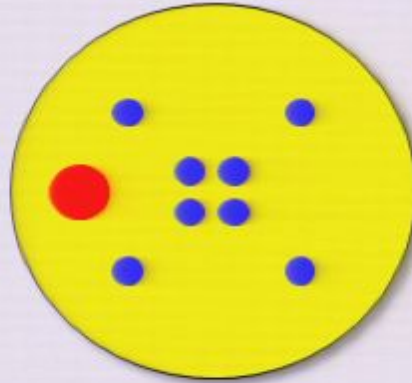
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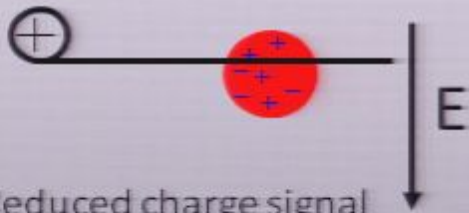


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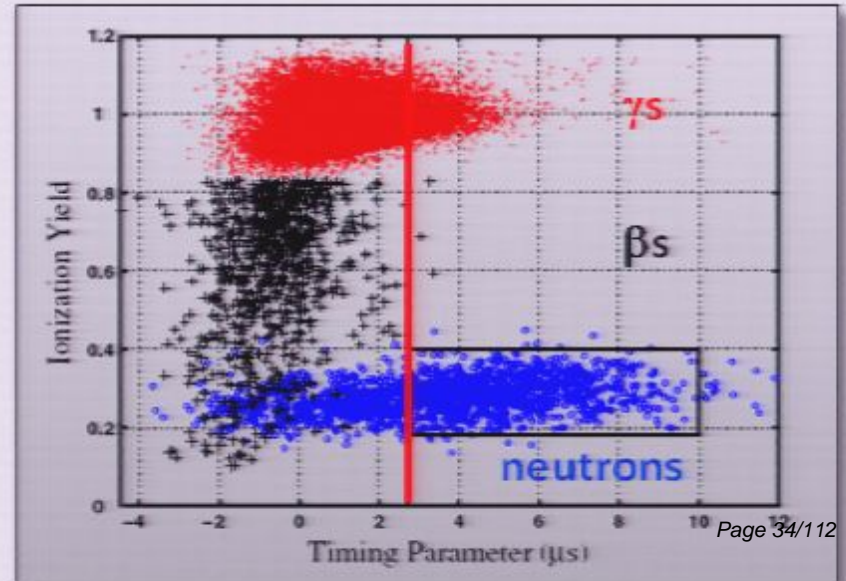
Collimator



Surface effect

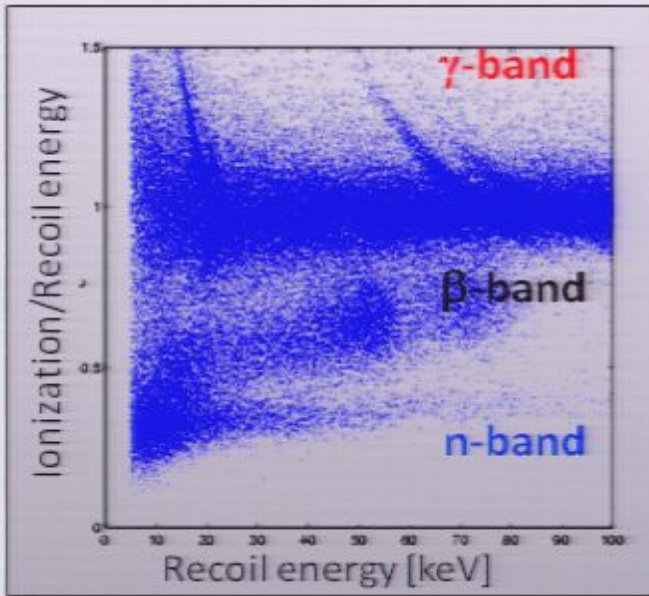


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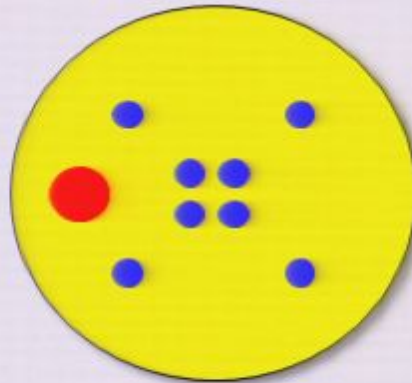


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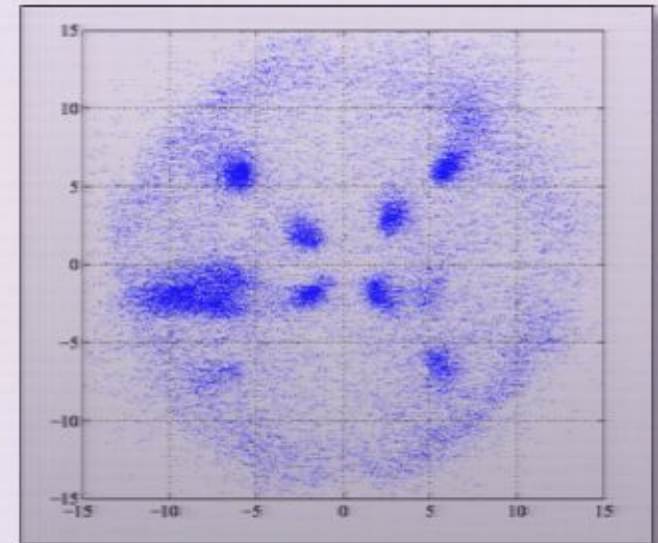
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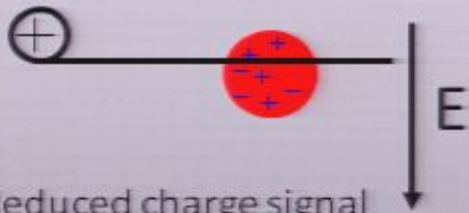
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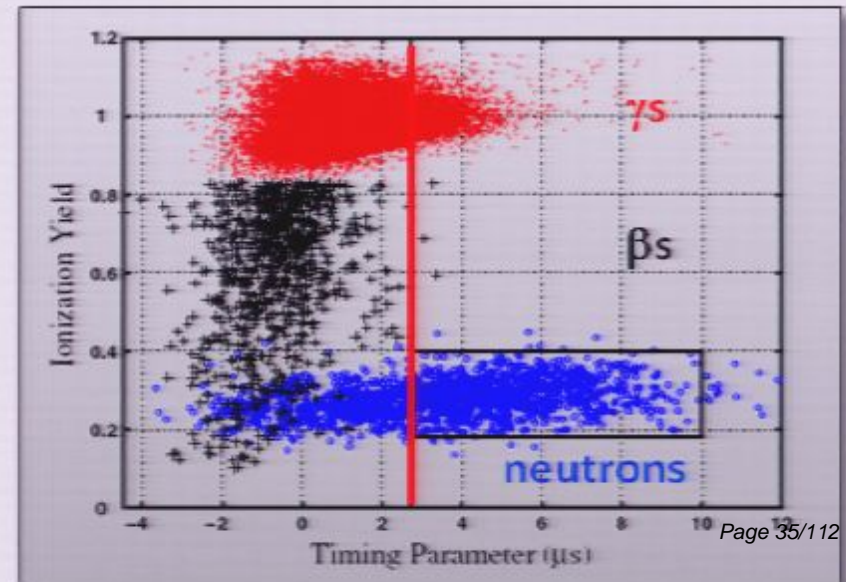
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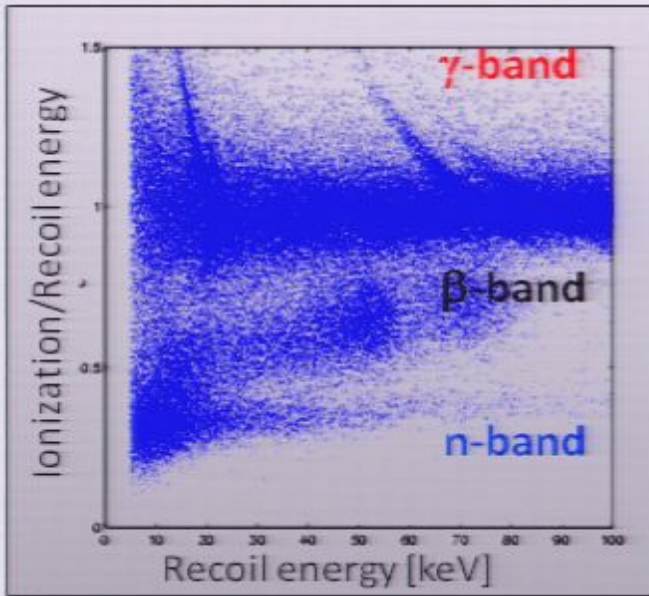


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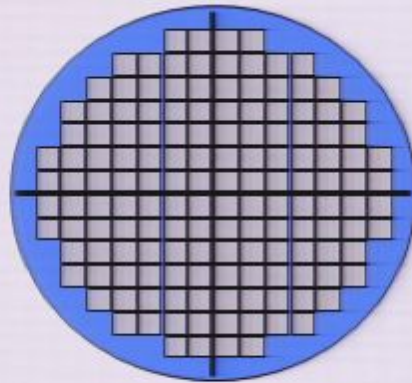


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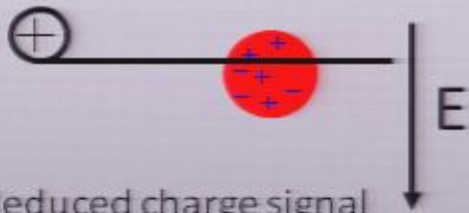
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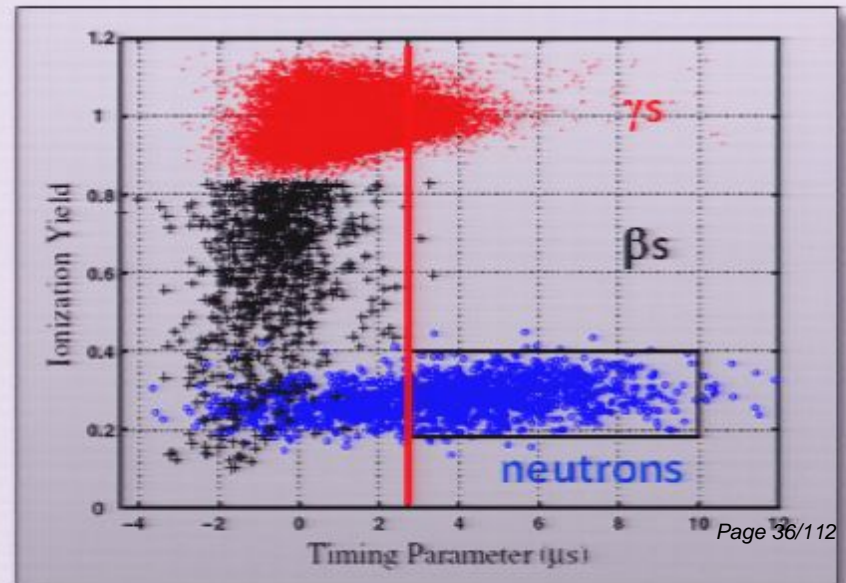
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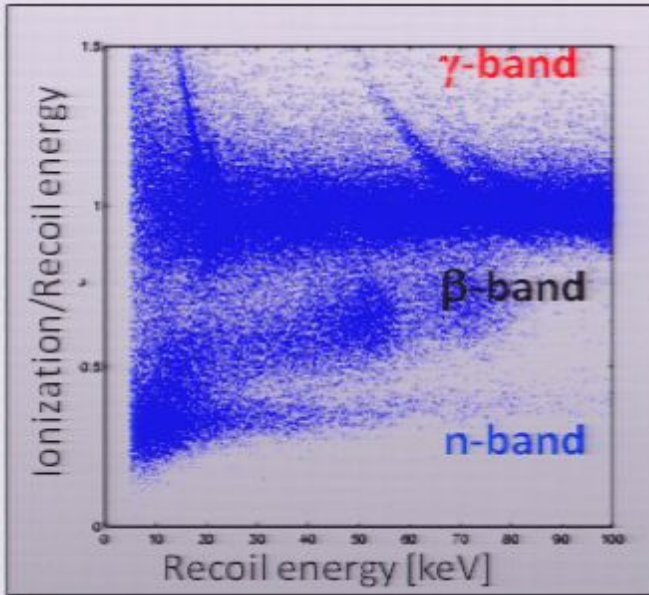


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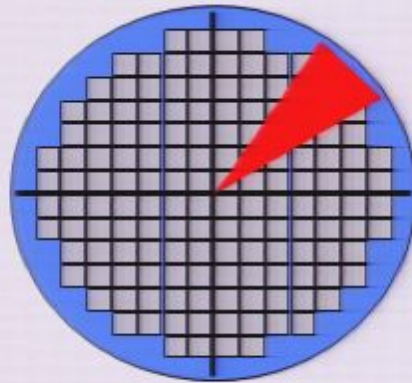


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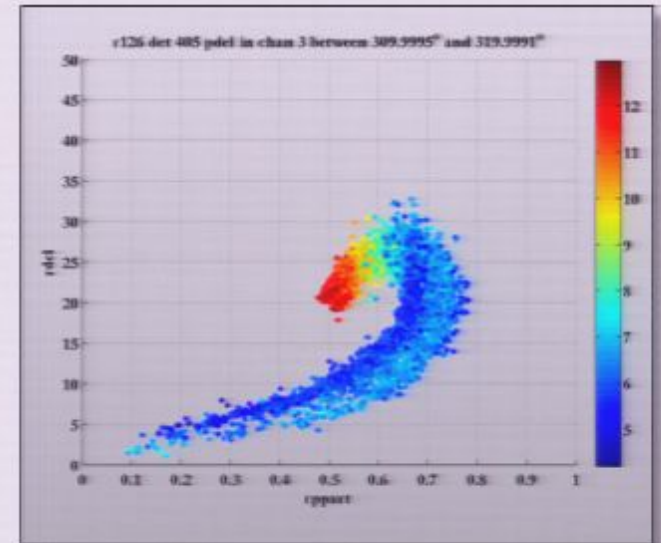
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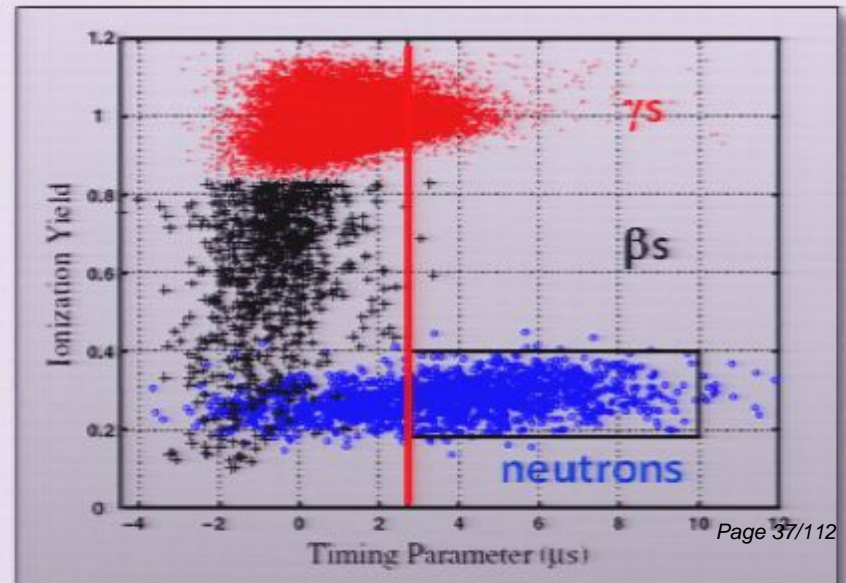
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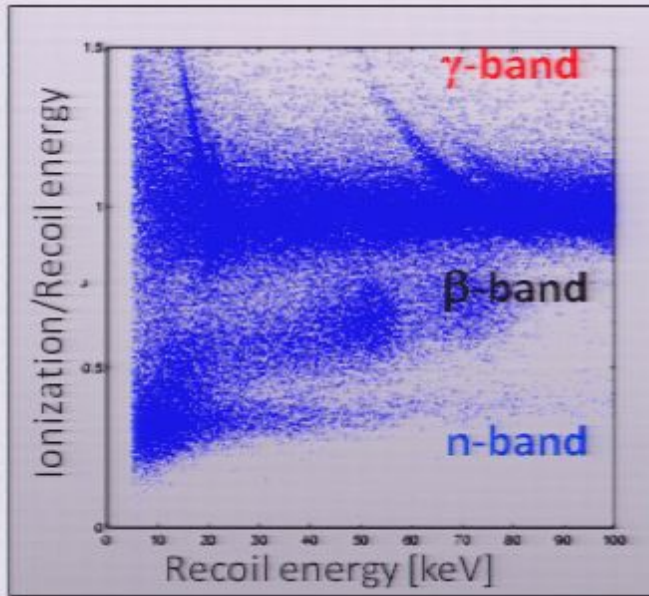


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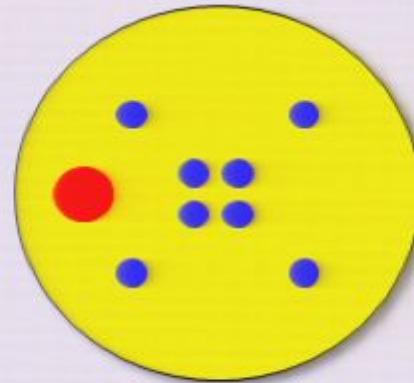


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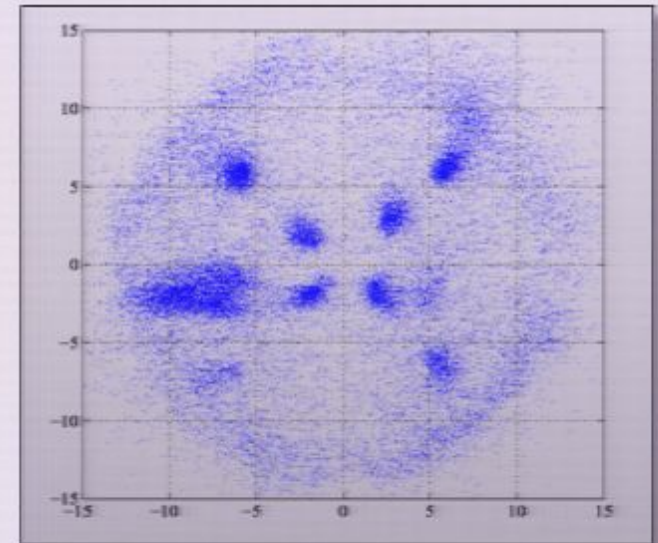
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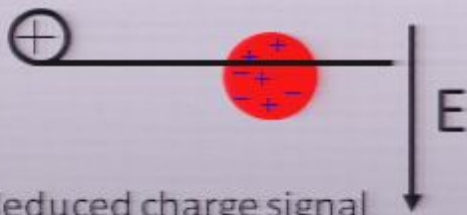
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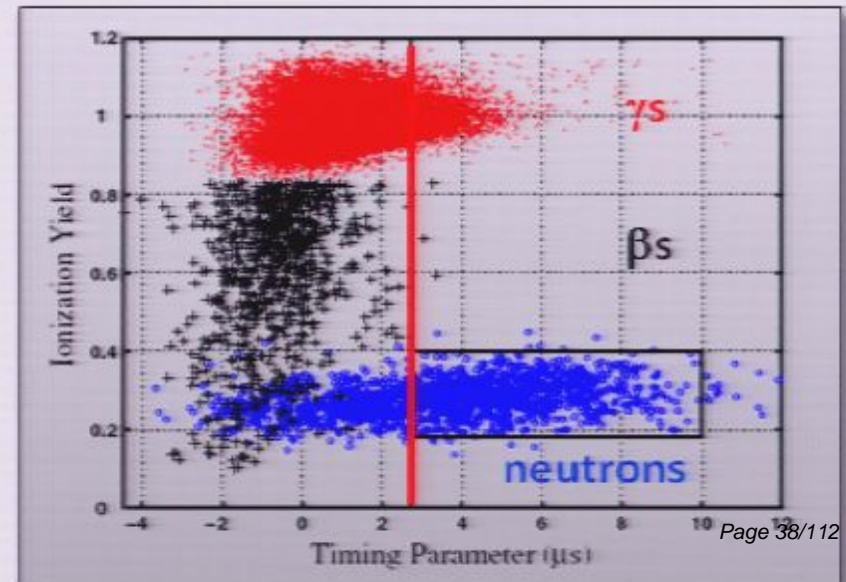
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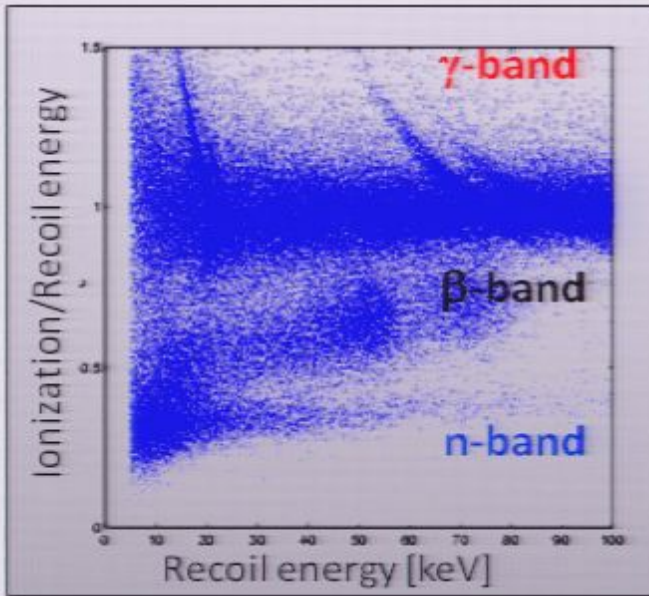


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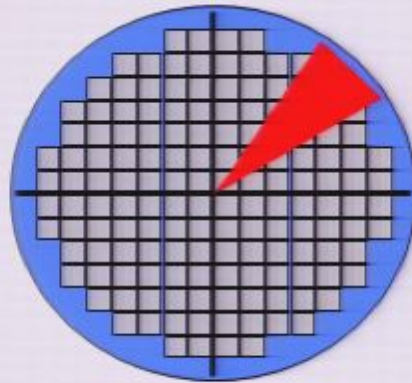


CDMS Detectors

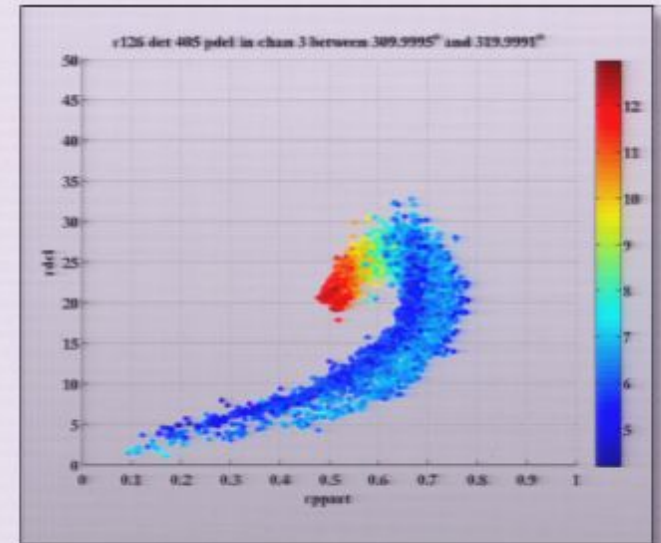
Discrimination



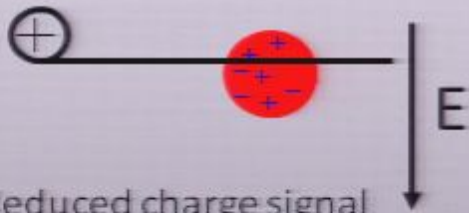
Detector



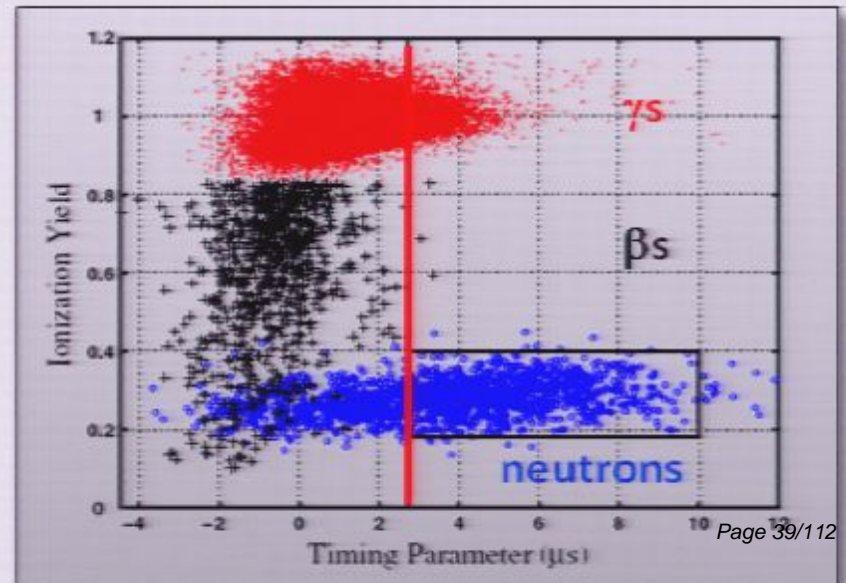
Position/Timing



Surface effect

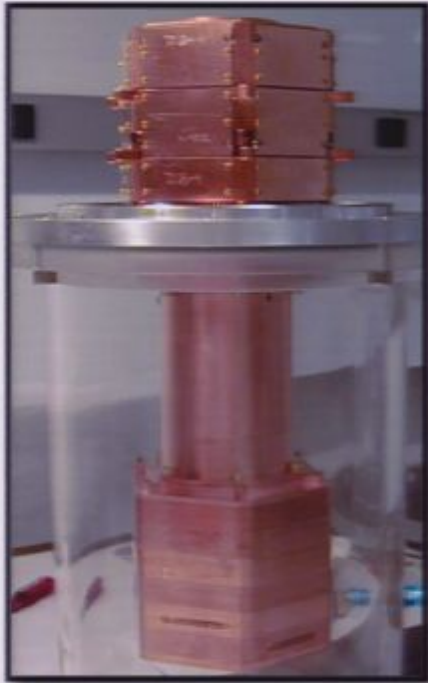


Reduced charge signal
but faster phonon signal

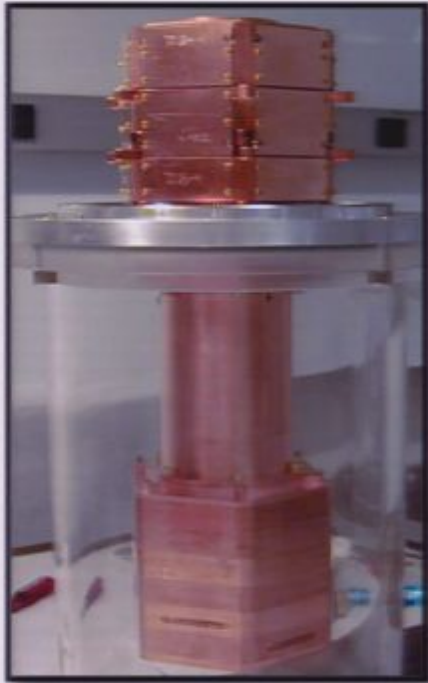


CDMS Detectors

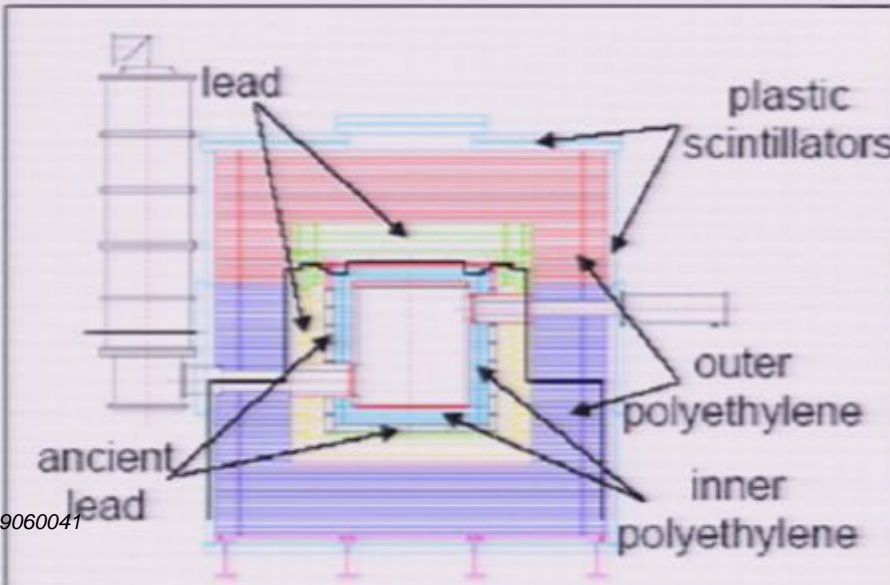
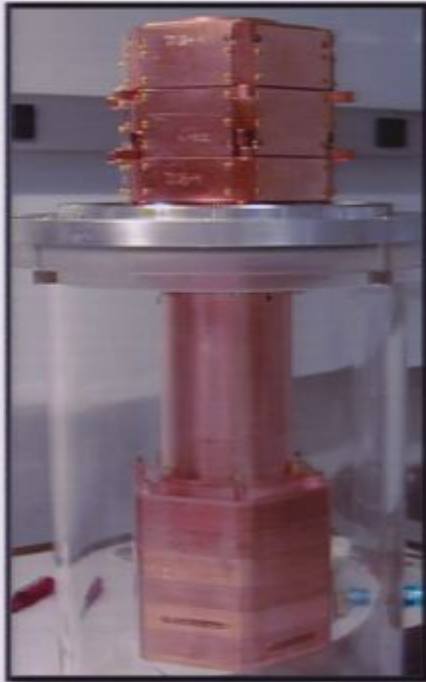
CDMS Detectors



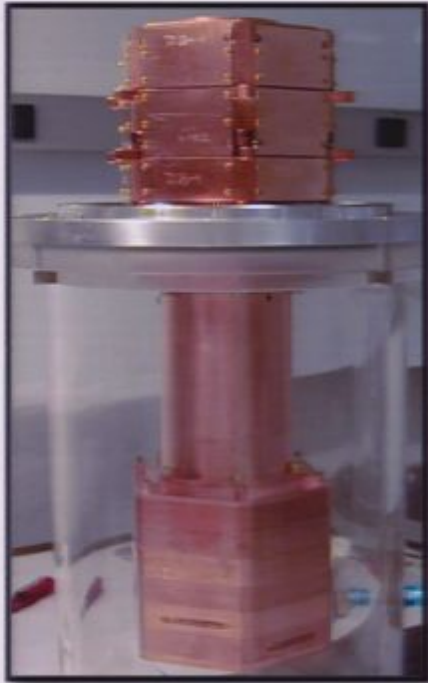
CDMS Detectors



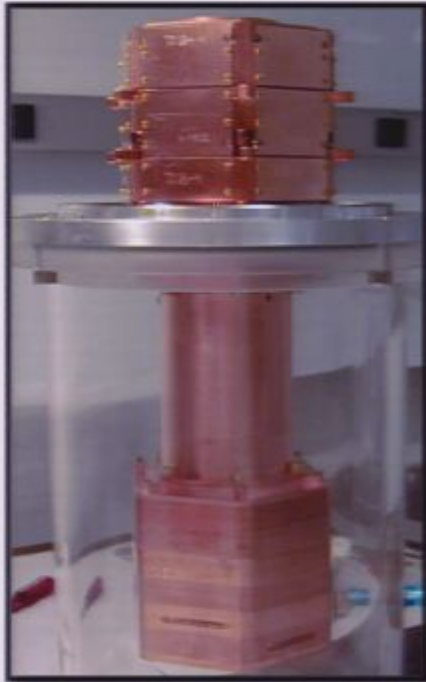
CDMS Detectors



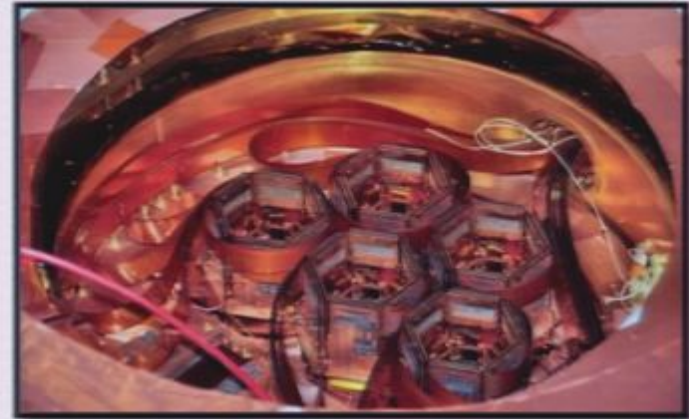
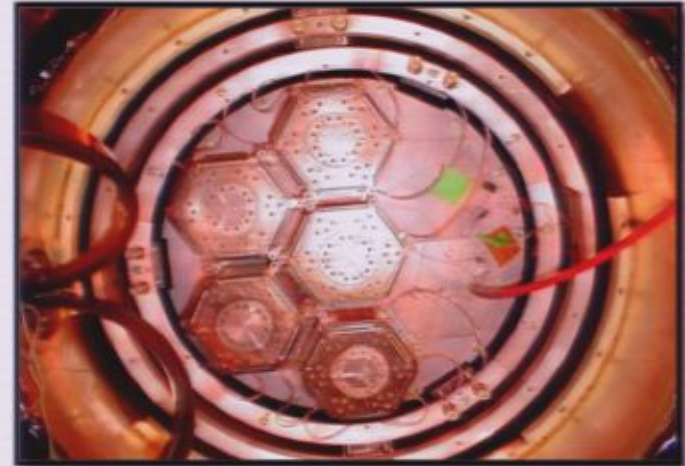
CDMS Detectors



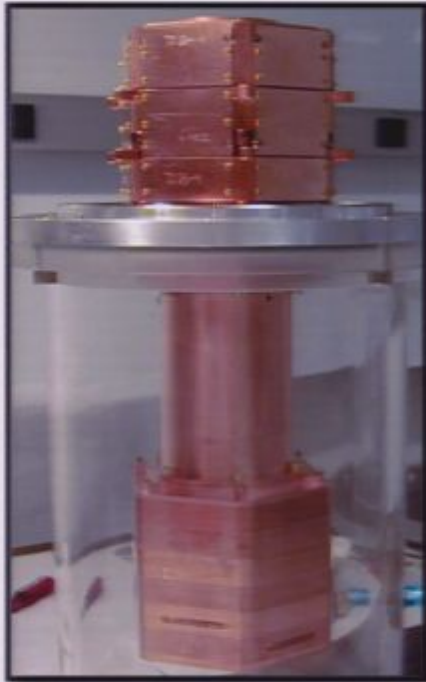
CDMS Detectors



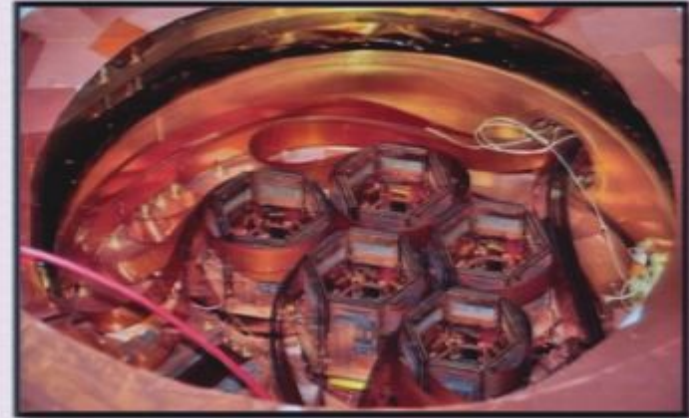
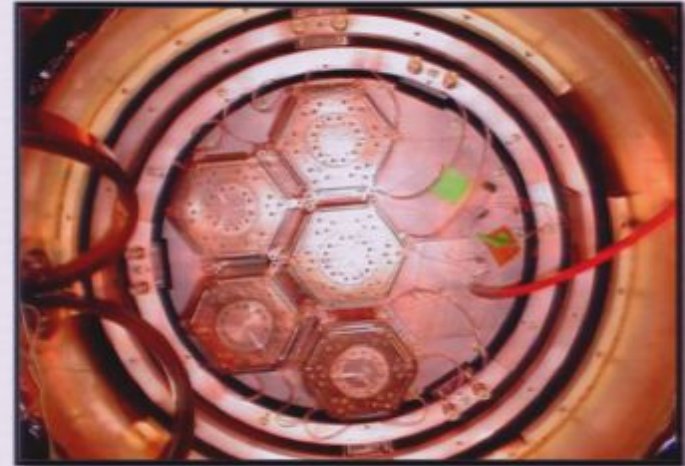
5 "Towers" á 6 detectors
~5 kg Ge, 1 kg Si



CDMS Detectors



5 "Towers" á 6 detectors
~5 kg Ge, 1 kg Si



Operated in Soudan Lab
(Minnesota) 2006 – 2009

Results

Results

- Data from Oct. 2006 – June 2007

Results

- Data from Oct. 2006 – June 2007
- Raw exposure: ~ 400 kg days

Results

- Data from Oct. 2006 – June 2007
- Raw exposure: ~ 400 kg days
- Analysis threshold: 10 keV
- Main analysis steps:

Results

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Results

- Data from Oct. 2006 – June 2007
- Raw exposure: ~ 400 kg days
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- Main analysis steps:
 - Determine position dependent calibration and timing performance

Results

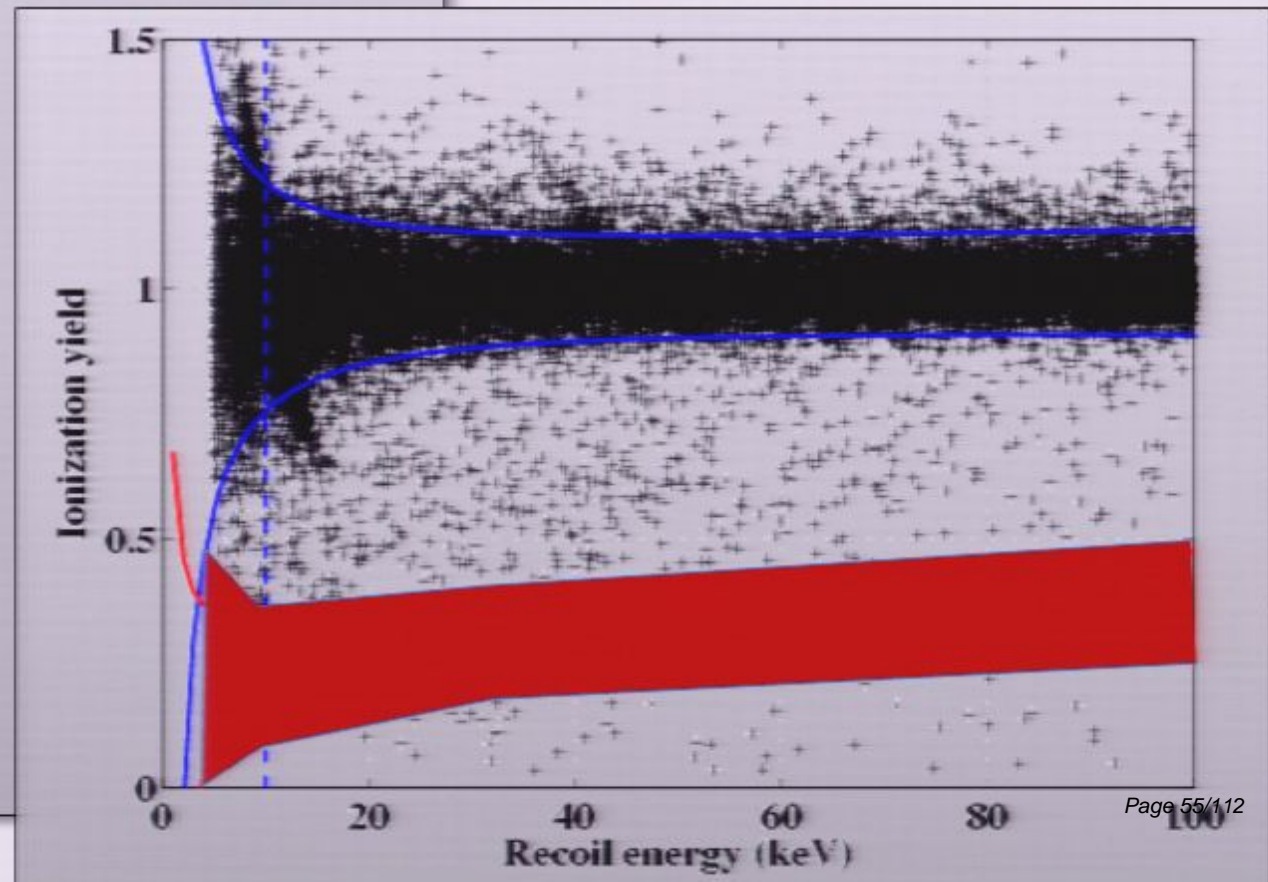
- Data from Oct. 2006 – June 2007
- Raw exposure: ~ 400 kg days
- Analysis threshold: 10 keV
- Main analysis steps:
 - Determine position dependent calibration and timing performance
 - Remove periods with bad detector performance

Results

- Data from Oct. 2006 – June 2007
- Raw exposure: ~ 400 kg days
- Analysis threshold: 10 keV
- Main analysis steps:
 - Determine position dependent calibration and timing performance
 - Remove periods with bad detector performance
 - Remove multiple scatter & muon veto events

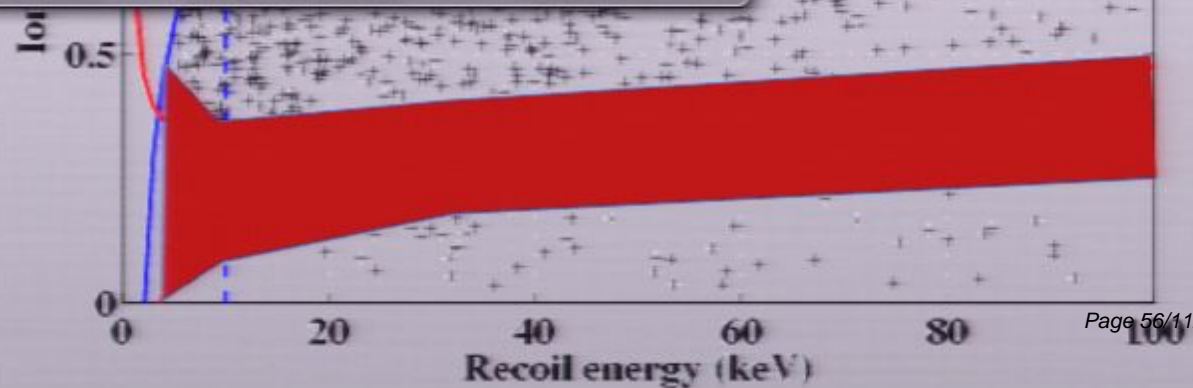
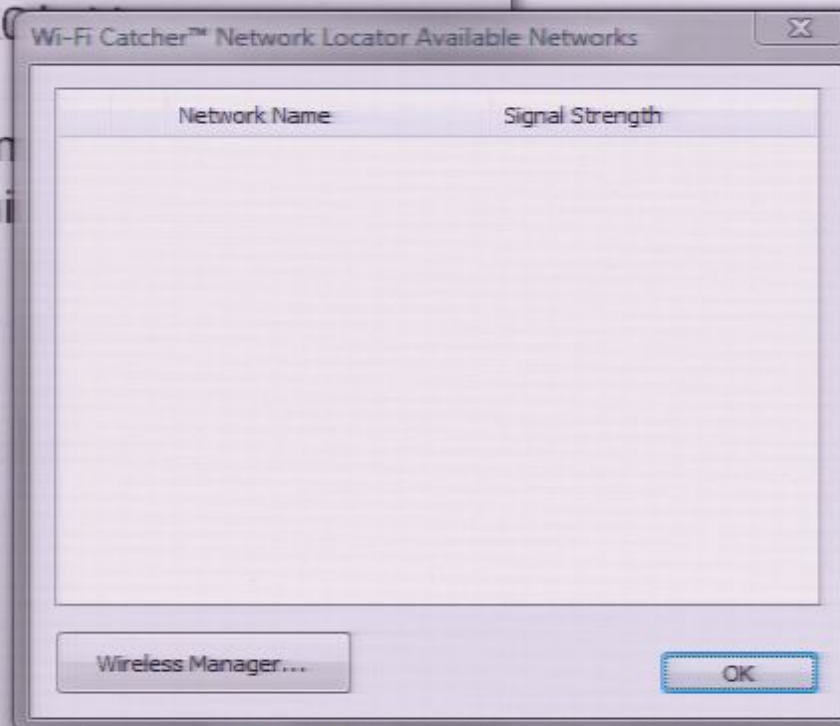
Results

- Data from Oct. 2006 – June 2007
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 - Determine position dependent calibration and timing performance
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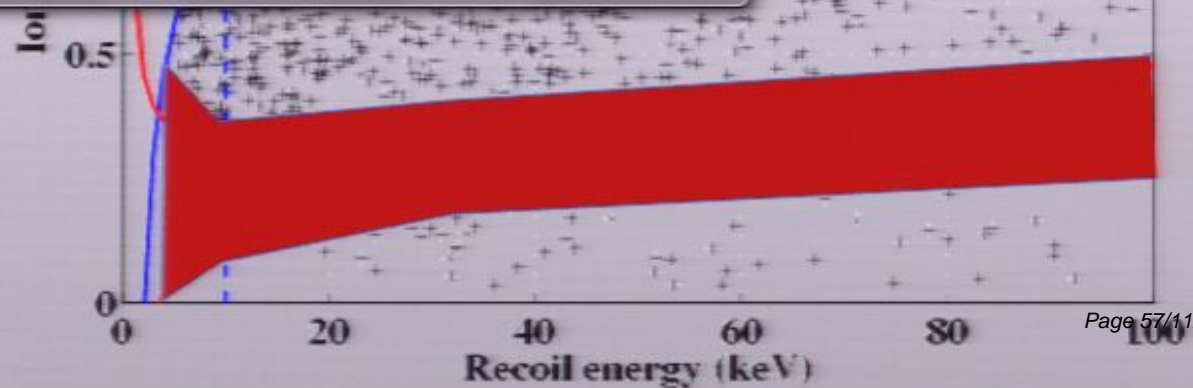
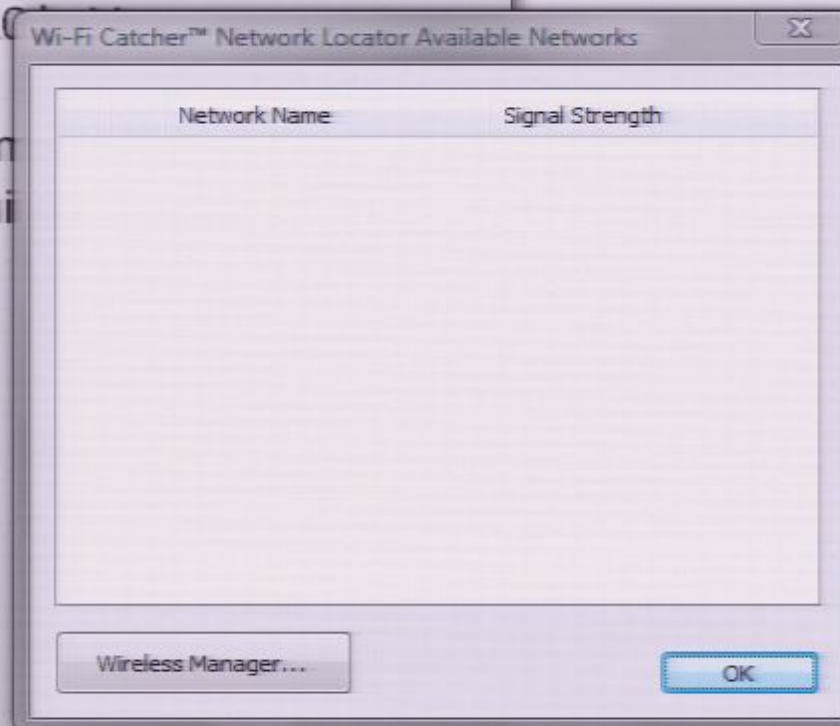
Results

- Data from Oct. 2006 – June 2007
- Raw exposure: ~ 400 kg days
- Analysis threshold: 10^{-5}
- Main analysis steps:
 - Determine position calibration and timing
 - Remove periods with bad detector performance
 - Remove multiple scatter & muon veto events



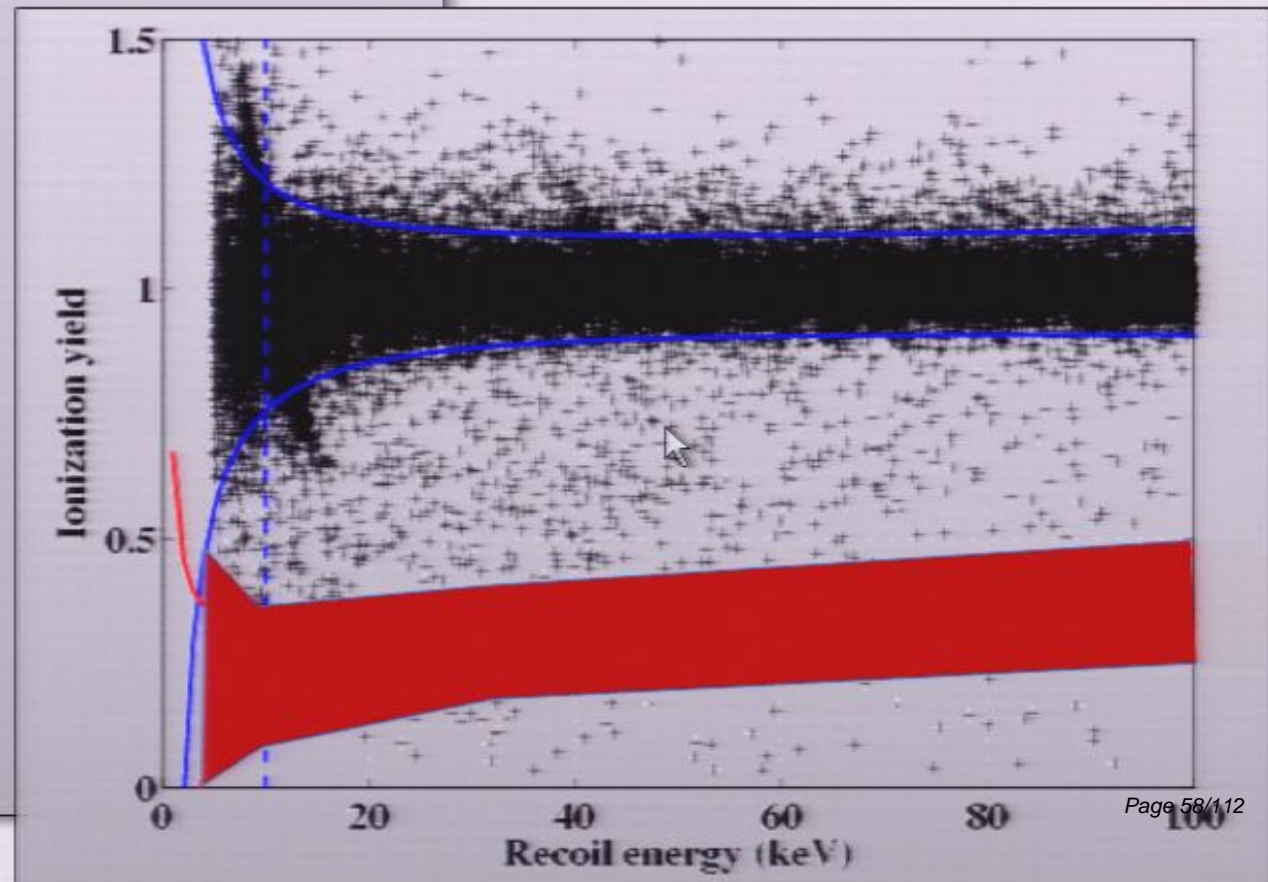
Results

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- Raw exposure: ~ 400 kg days
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 - Determine position calibration and timing
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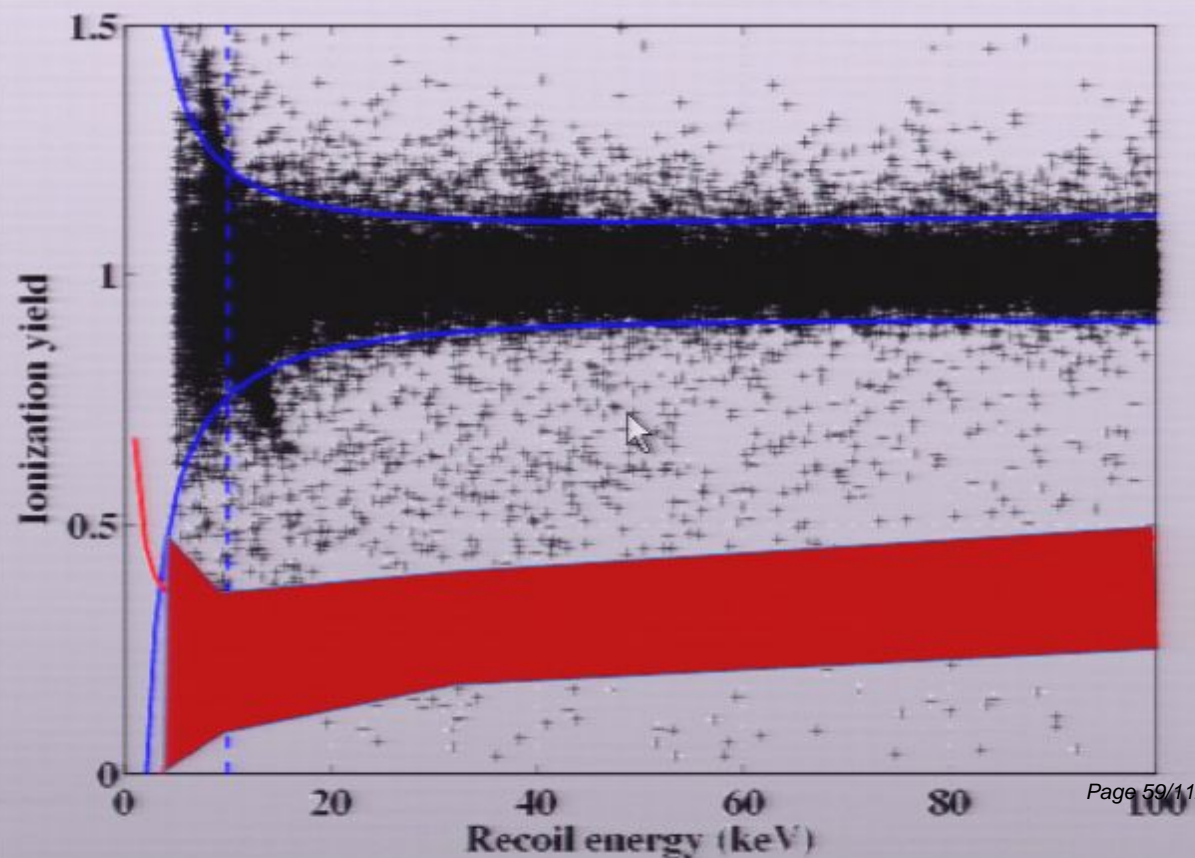
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- Raw exposure: ~ 400 kg days
- Analysis threshold: 10 keV
- Main analysis steps:
 - Determine position dependent calibration and timing performance
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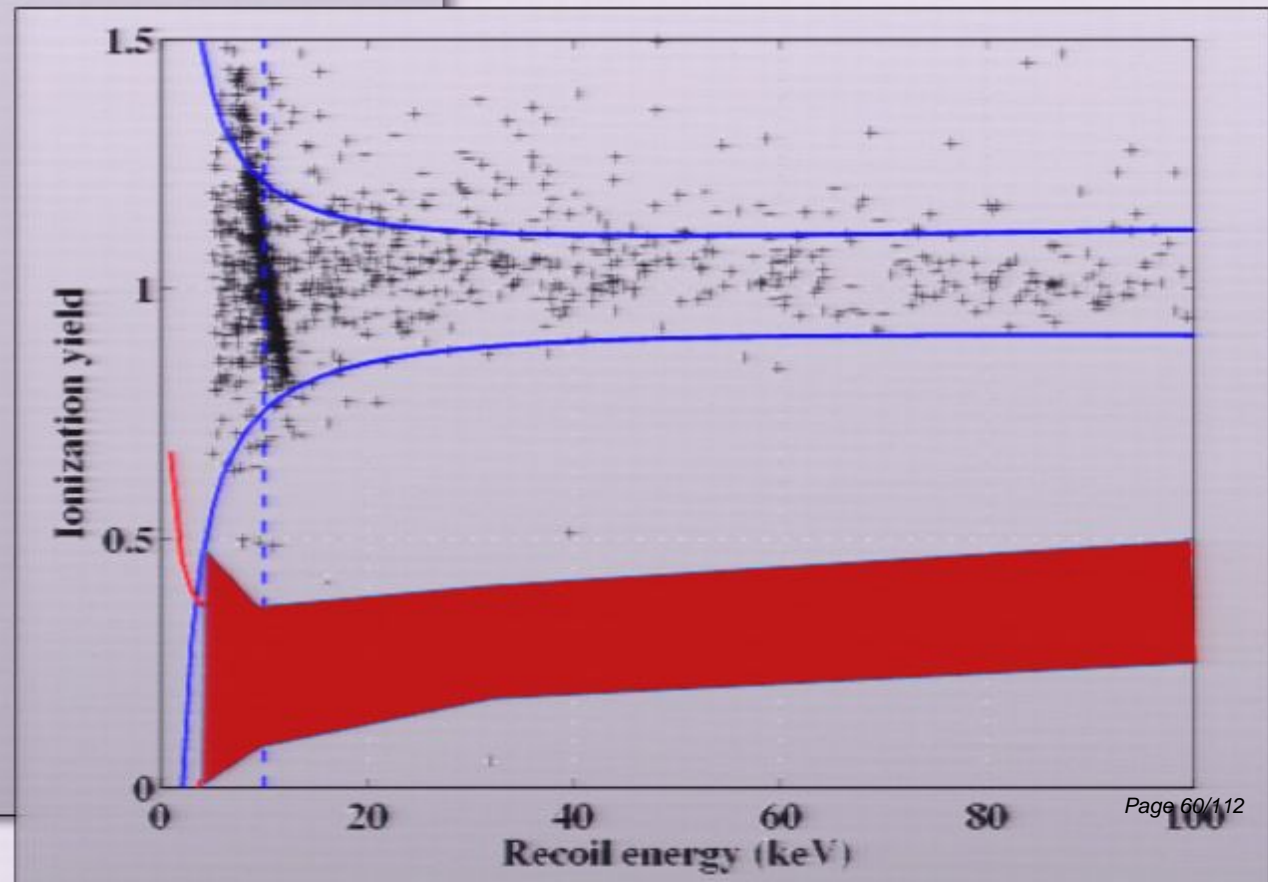
Results

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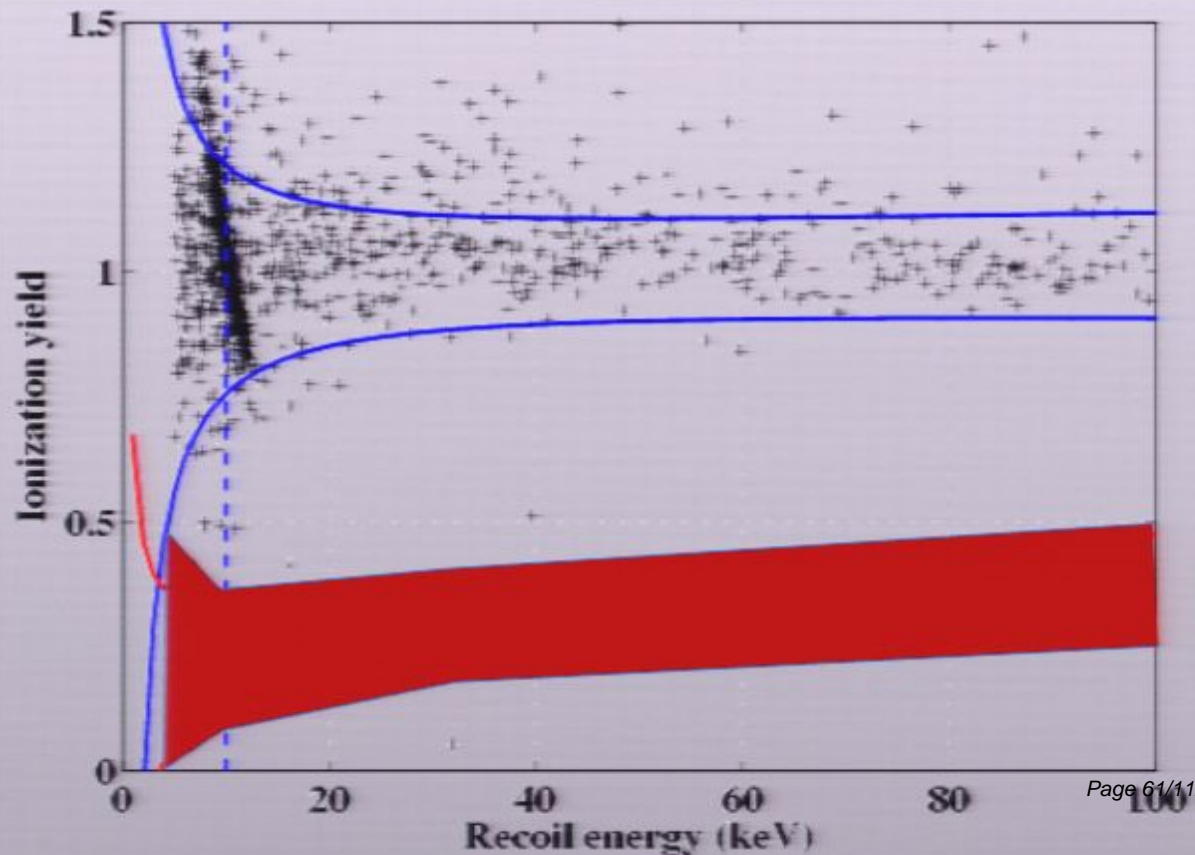
Results

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- Analysis threshold: 10 keV
- Main analysis steps:
 - Determine position dependent calibration and timing performance
 - Remove periods with bad detector performance
 - Remove multiple scatter & muon veto events
 - Remove surface events (timing)



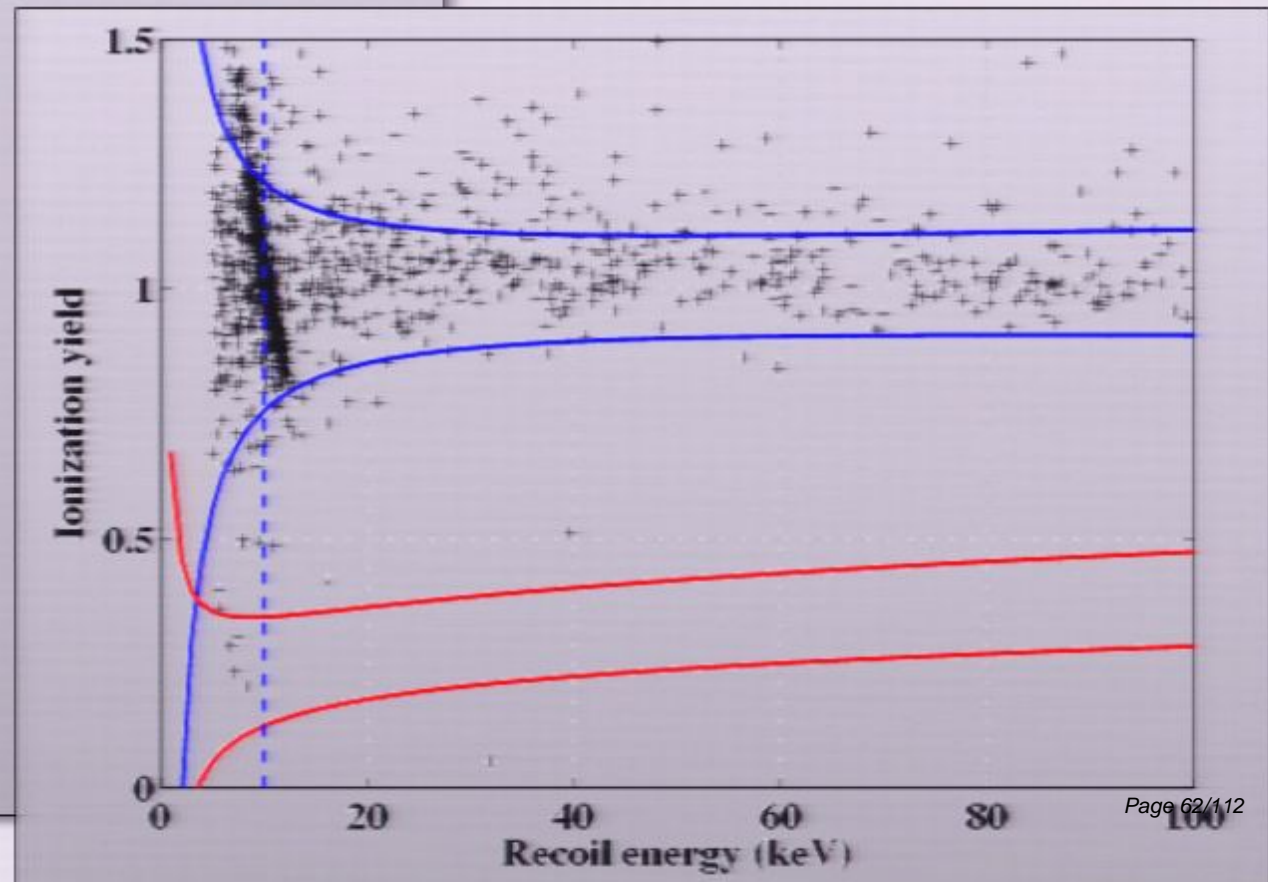
Results

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- Raw exposure: ~ 400 kg days
- Analysis threshold: 10 keV
- Main analysis steps:
 - Determine position dependent calibration and timing performance
 - Remove periods with bad detector performance
 - Remove multiple scatter & muon veto events
 - Remove surface events (timing)
 - Calculate expected background: 0.6 ± 0.5 events
- 120 kg days after cuts



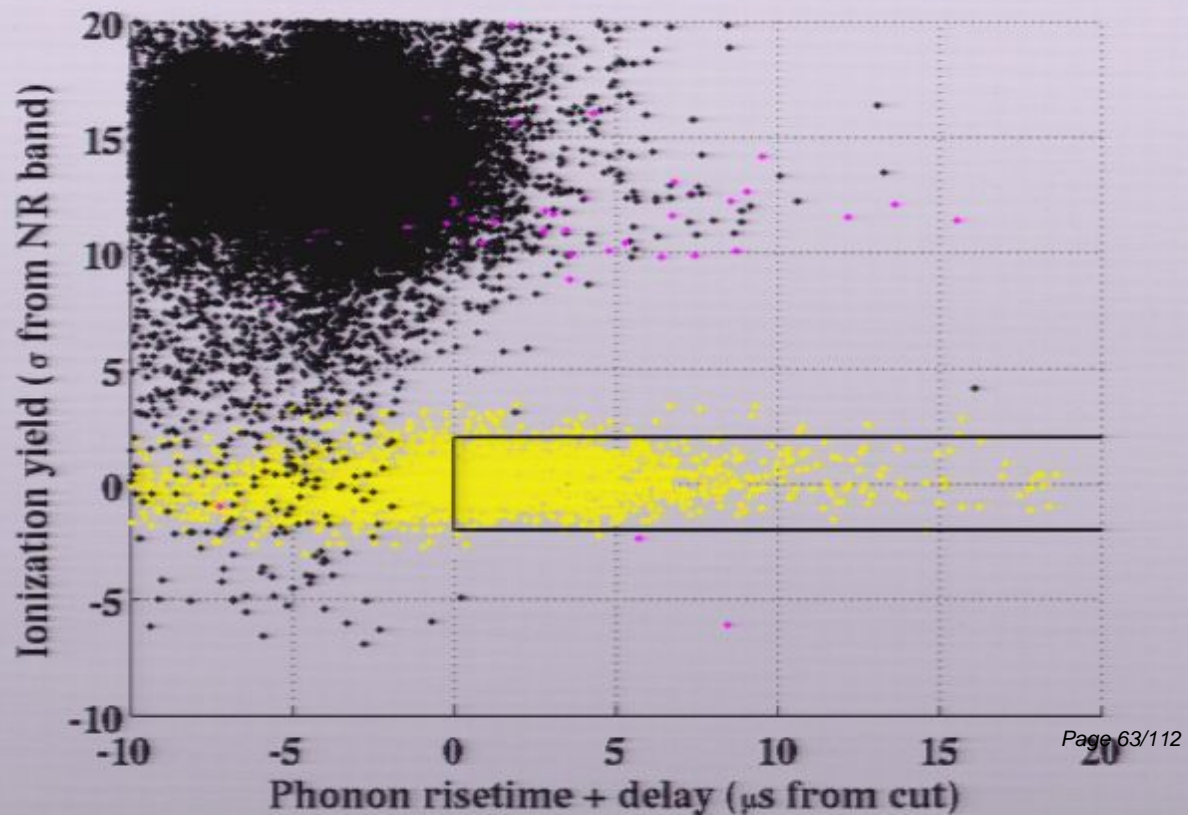
Results

- Data from Oct. 2006 – June 2007
- Raw exposure: ~ 400 kg days
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- Main analysis steps:
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 - Remove periods with bad detector performance
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 - Remove surface events (timing)
 - Calculate expected background: 0.6 ± 0.5 events
- 120 kg days after cuts
- NO events observed!

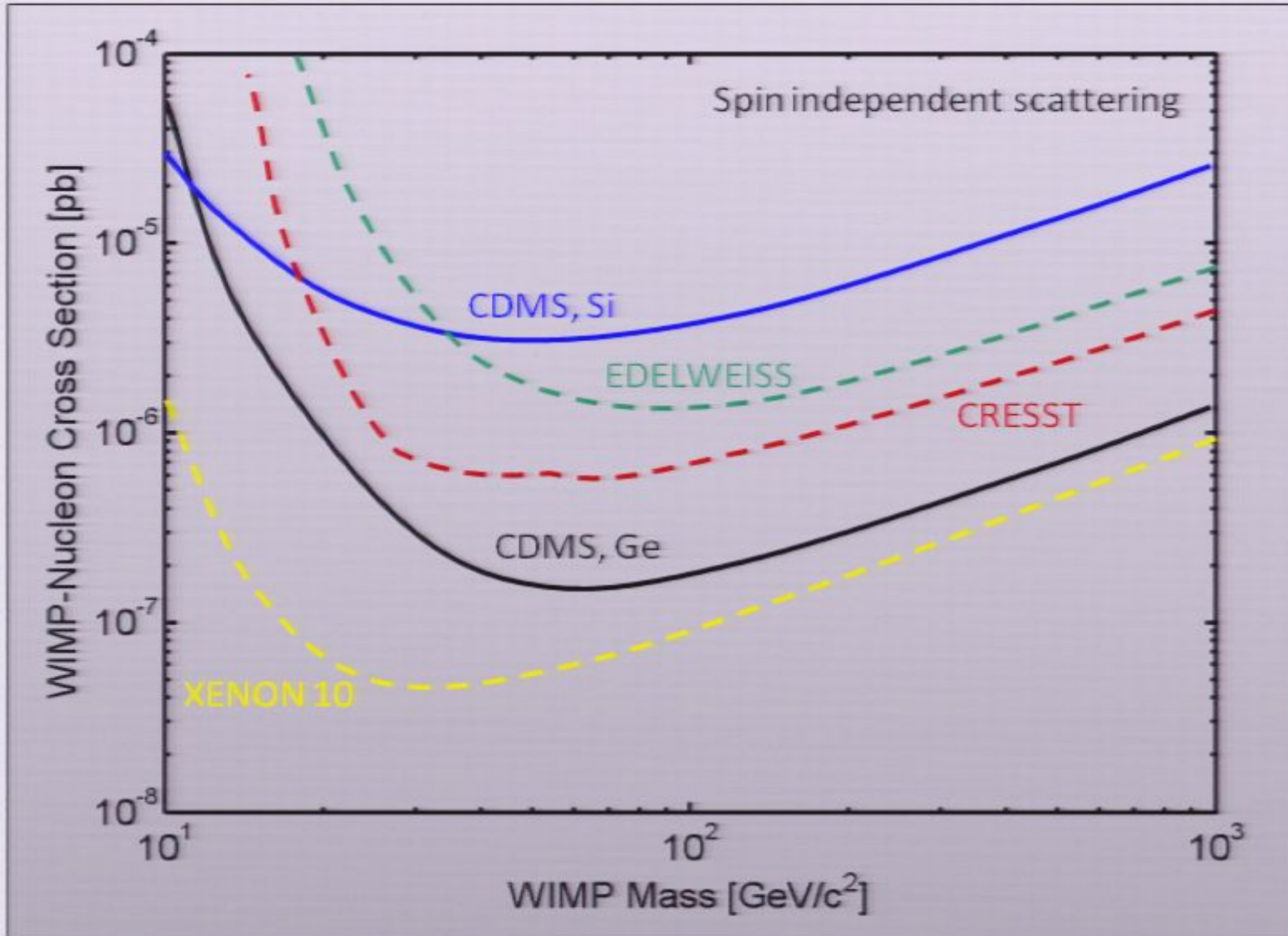


Results

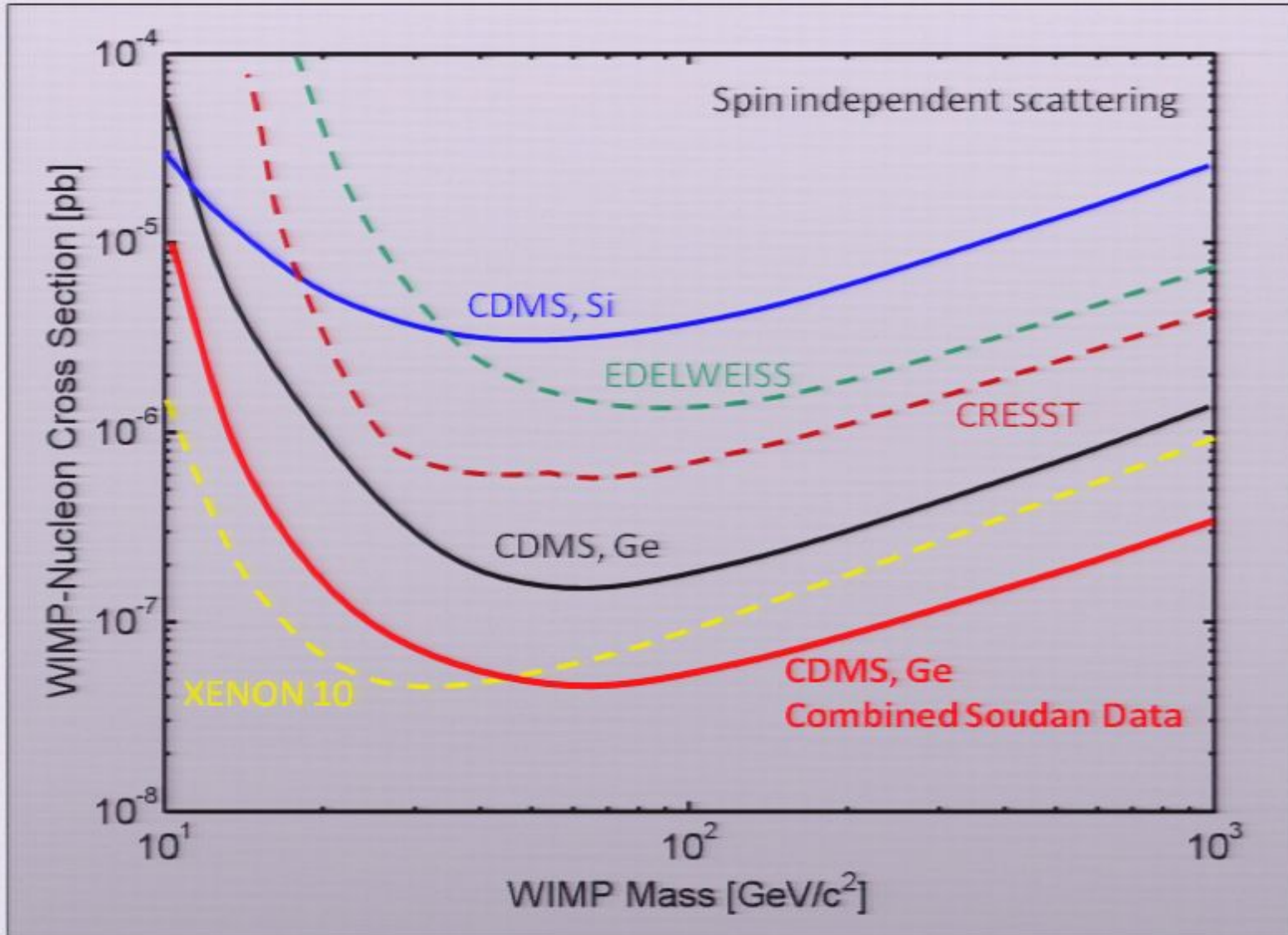
- Data from Oct. 2006 – June 2007
- Raw exposure: ~ 400 kg days
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- Main analysis steps:
 - Determine position dependent calibration and timing performance
 - Remove periods with bad detector performance
 - Remove multiple scatter & muon veto events
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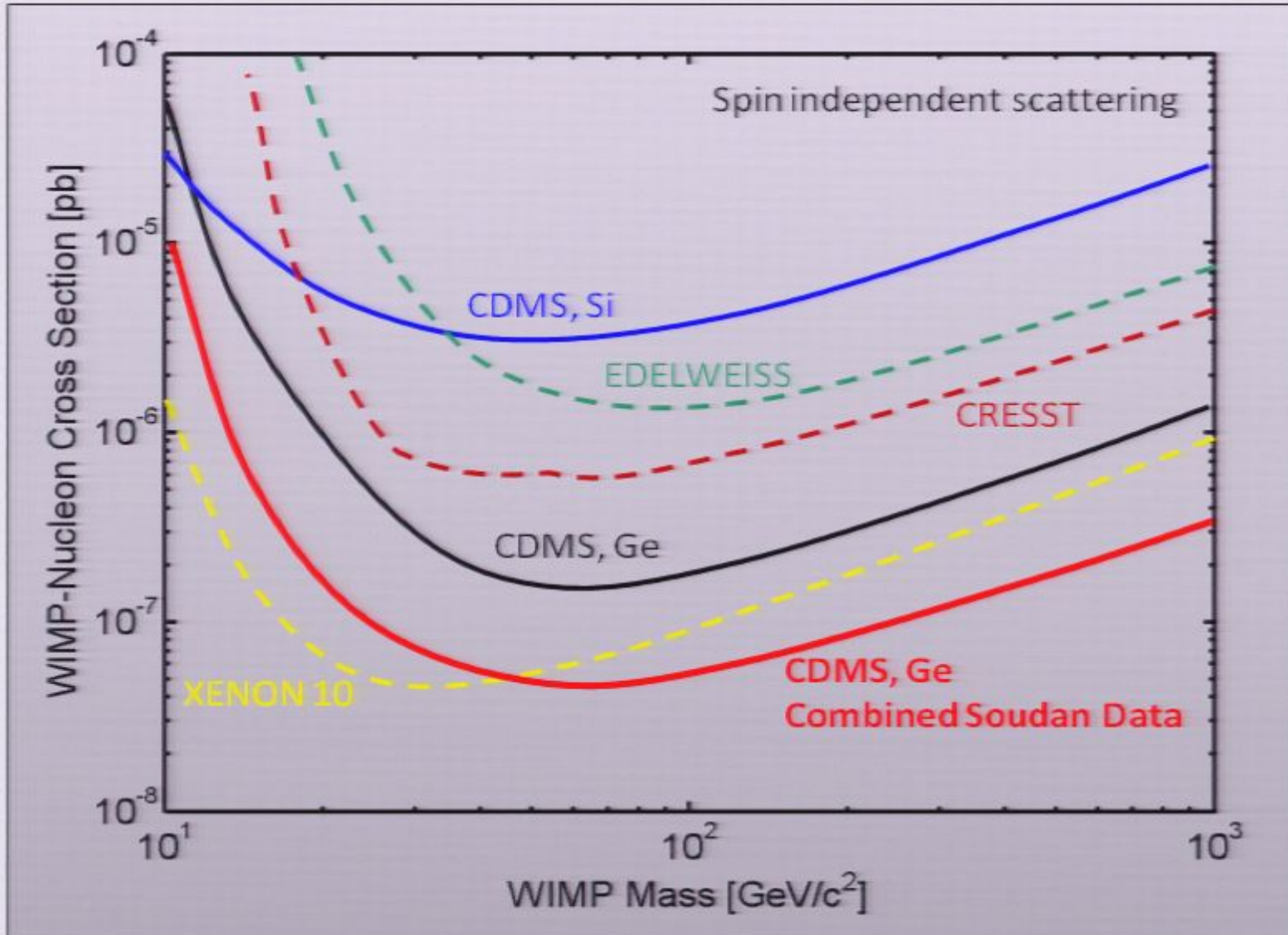
Results



Results



Results



Spin dependent (σ) : minimum at 2×10^{-2} pb

Results

Results

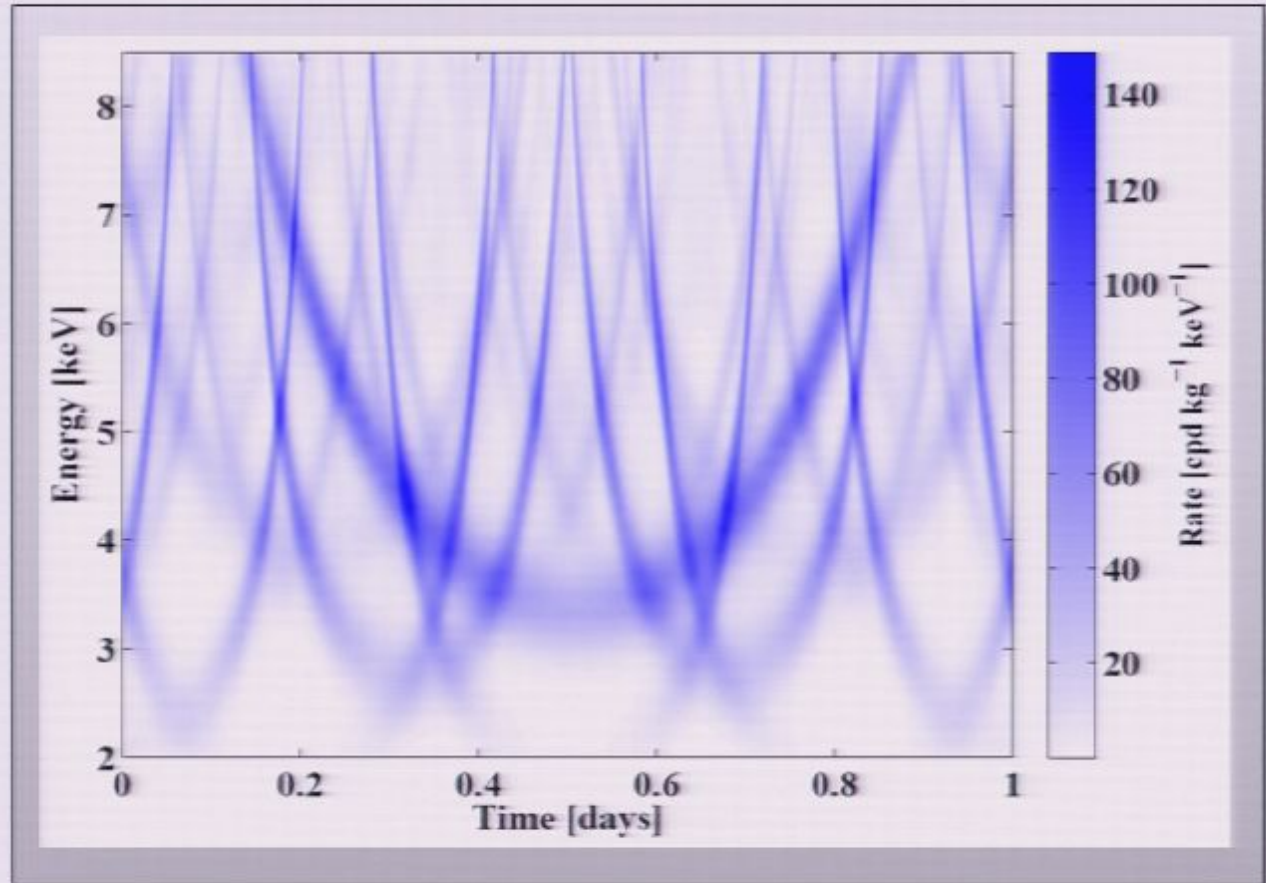
Solar Axions

- Convert in nuclear electric field to $\gamma\gamma$
- “Bragg” condition enhances x-section

Results

Solar Axions

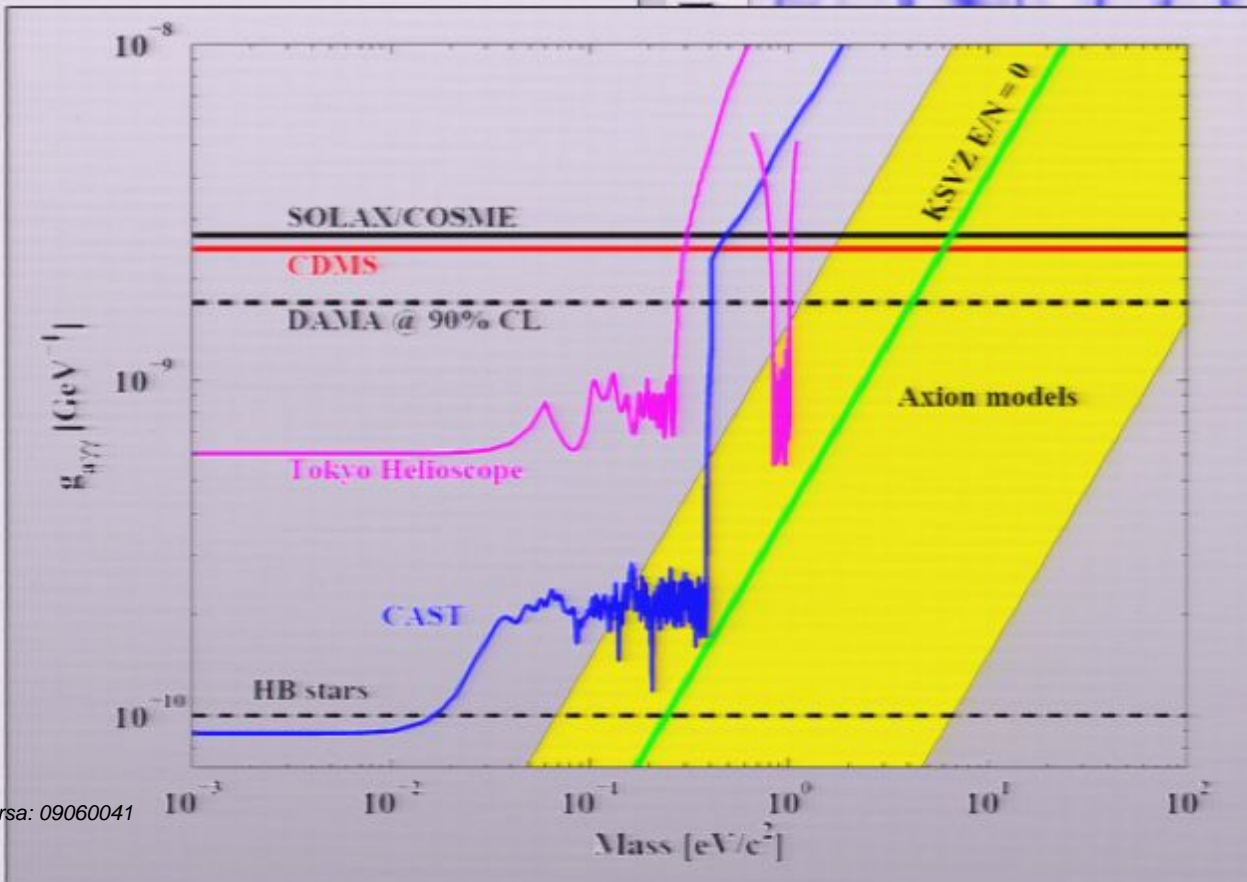
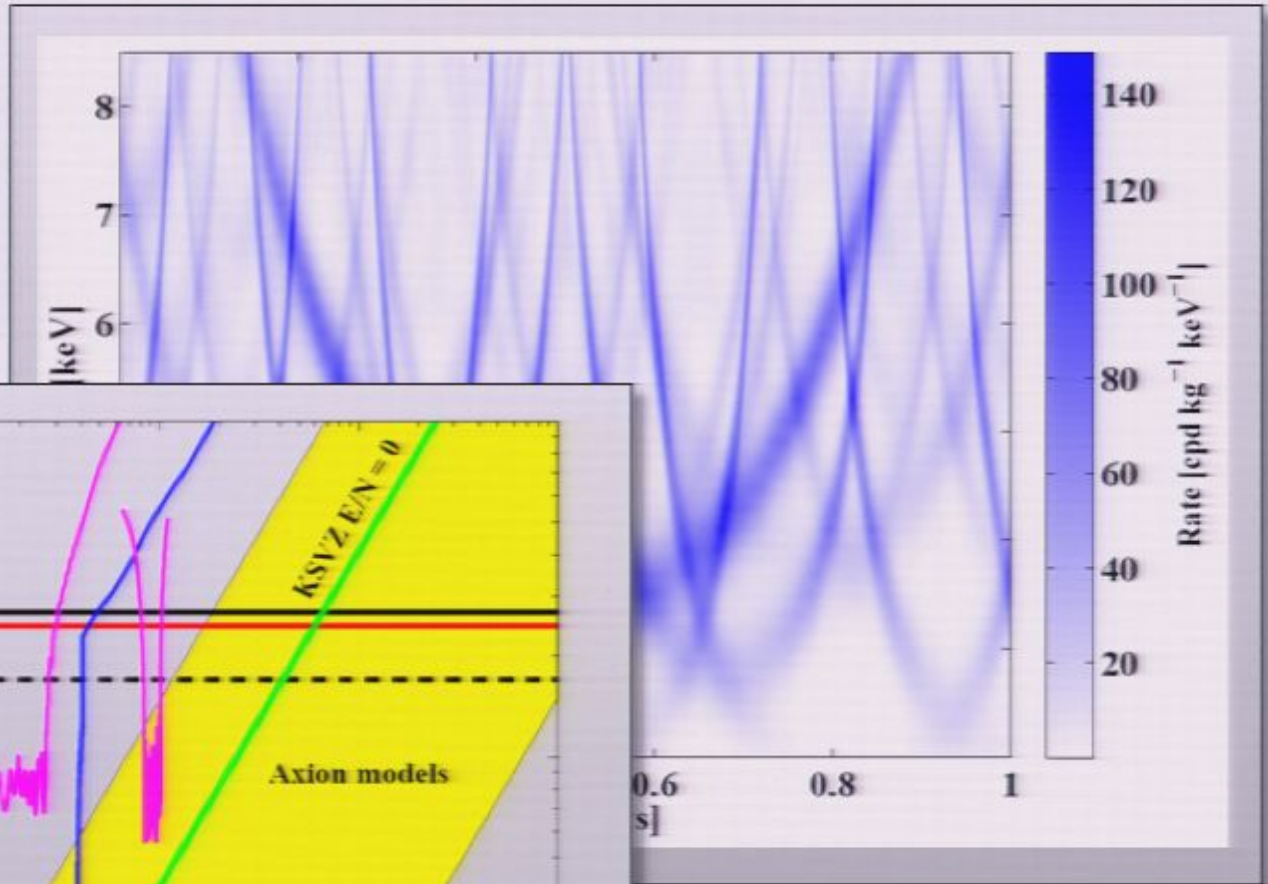
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Results

Solar Axions

- Convert in nuclear electric field to $\gamma\gamma$
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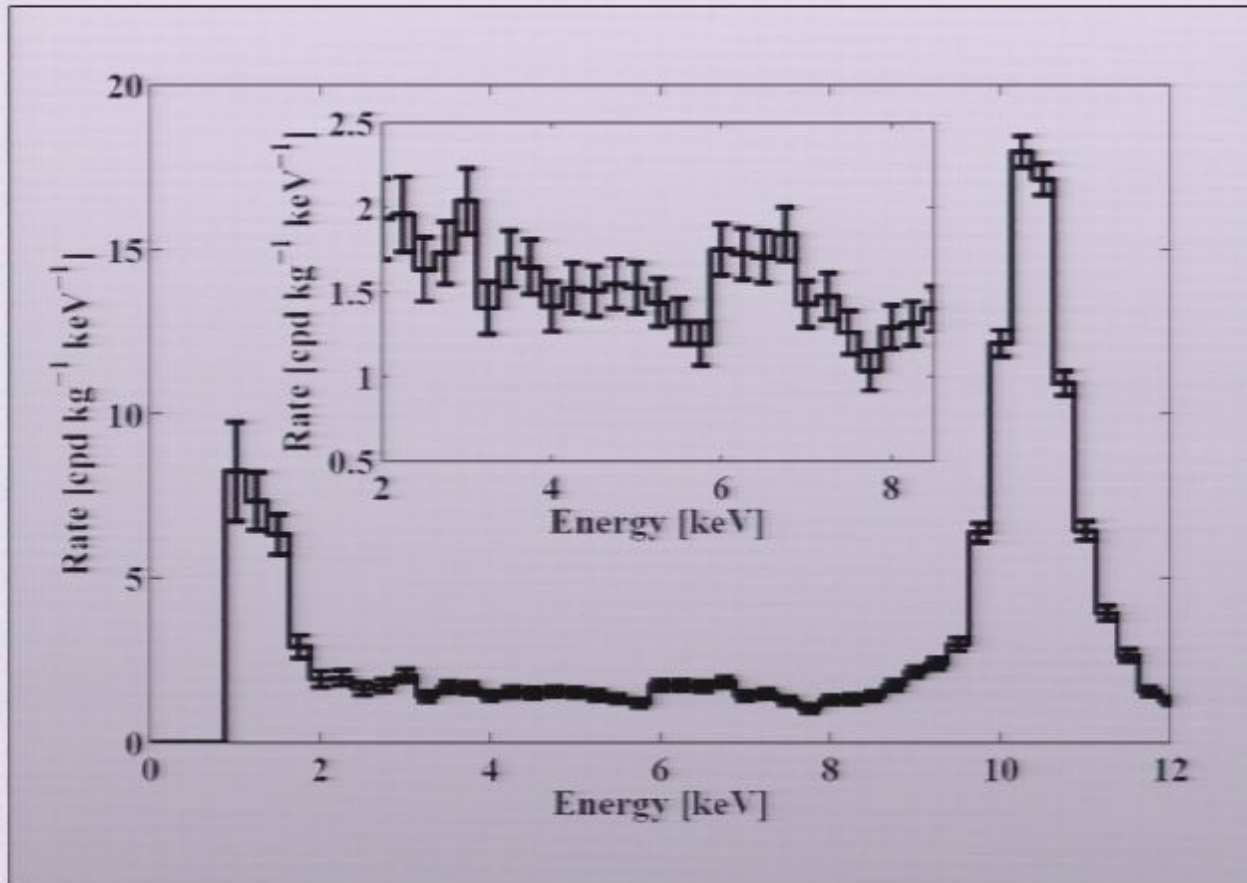


Results

Relic Axions

- No preferred direction
- Consider all electron recoil events

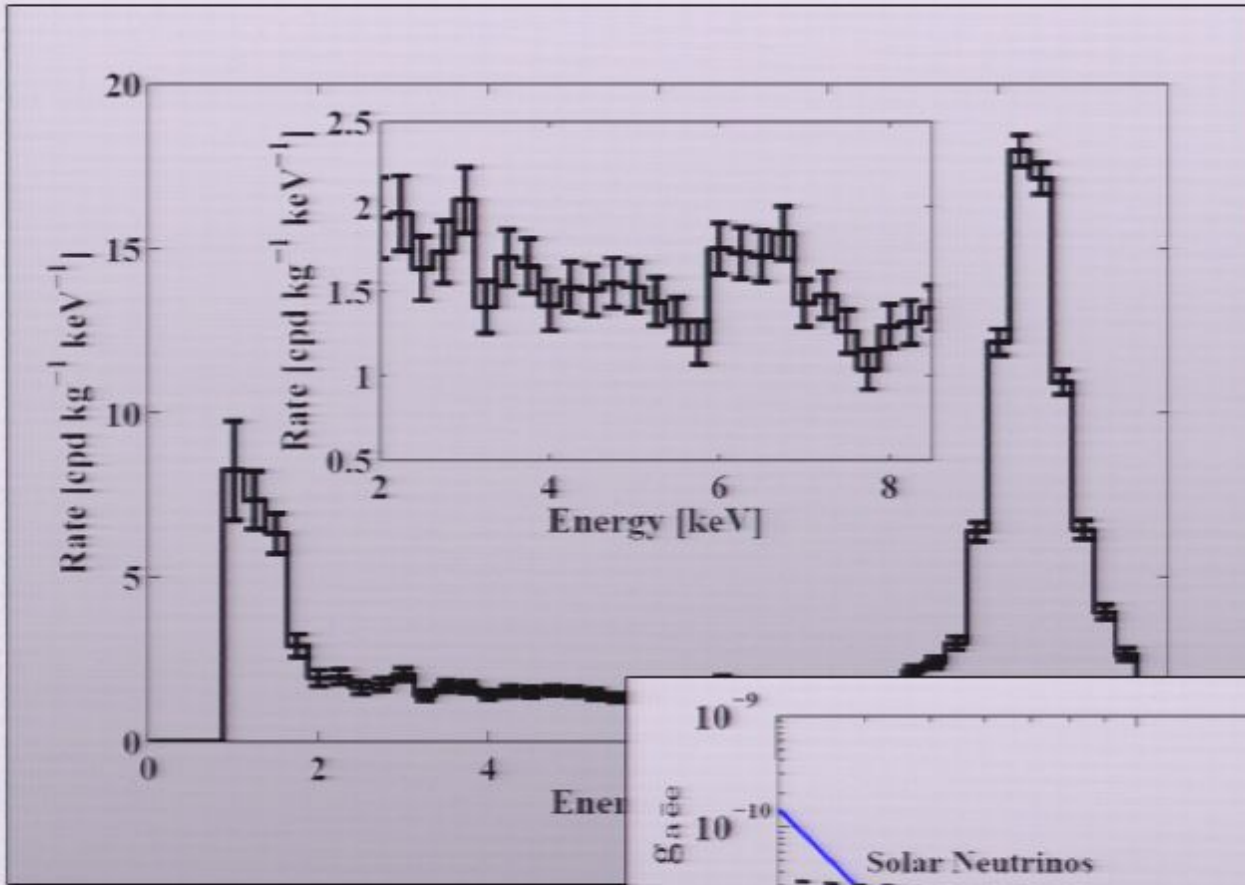
Results



Relic Axions

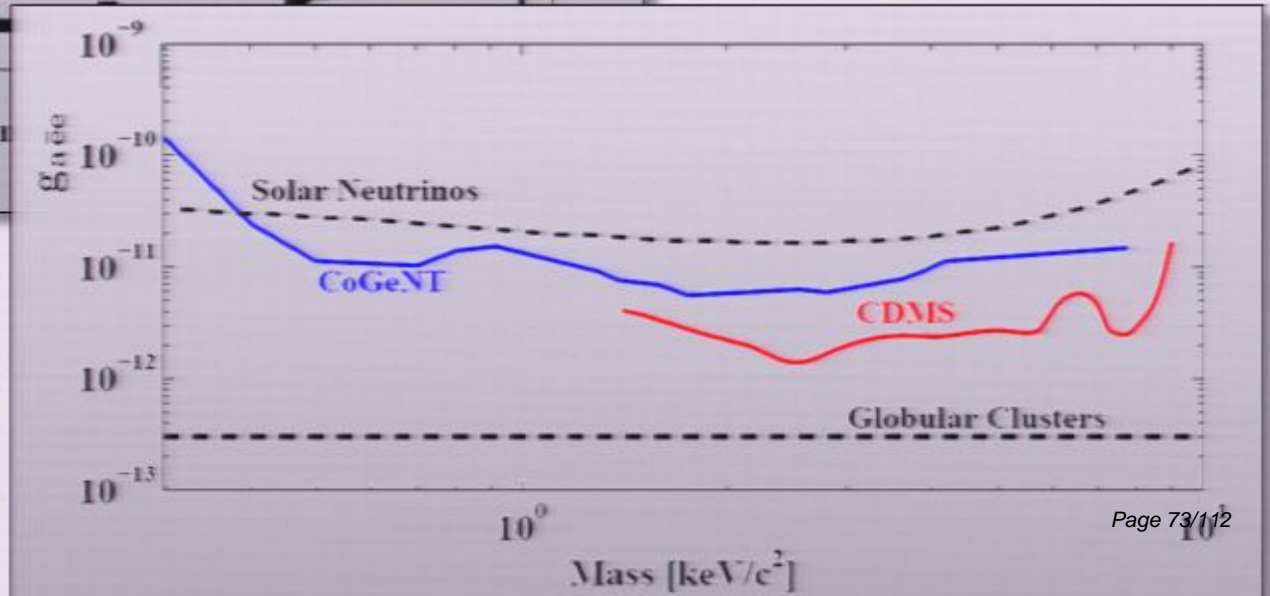
- No preferred direction
- Consider all electron recoil events

Results



Relic Axions

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- Consider all electron recoil events

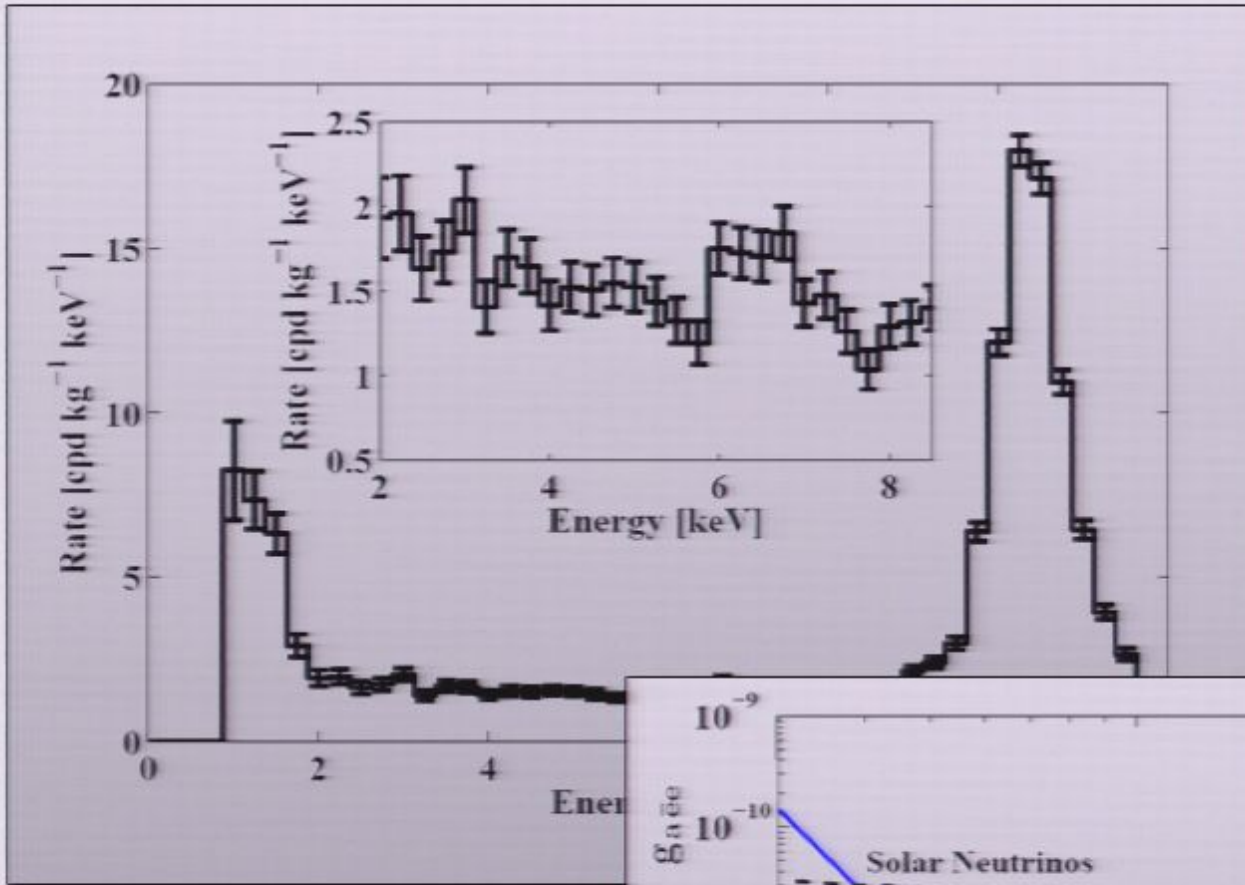


Analysis in Progress

- Data from July 2007 – fall 2008

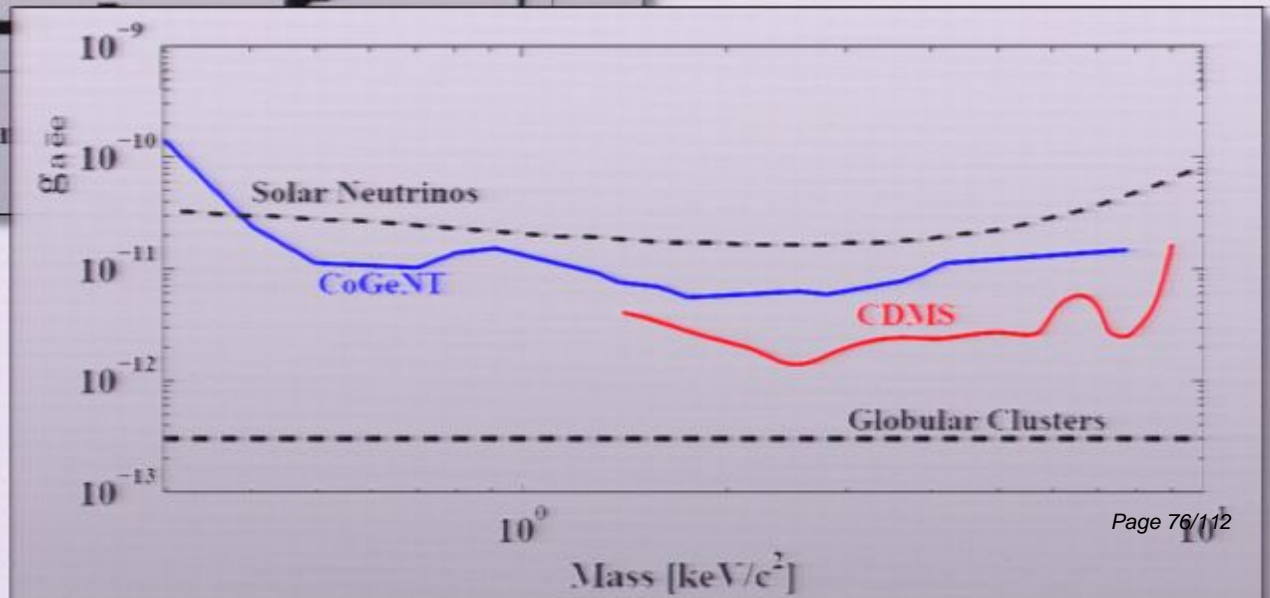
Analysis in Progress

Results



Relic Axions

- No preferred direction
- Consider all electron recoil events



Analysis in Progress

- Data from July 2007 – fall 2008

Analysis in Progress

- Data from July 2007 – fall 2008
- Increase of total exposure by a factor of ~3

Analysis in Progress

- Data from July 2007 – fall 2008
- Increase of total exposure by a factor of ~ 3
- Improvements in data analysis:
 - Data quality cuts
 - Better algorithm to account for position dependence
 - Would need to tighten surface event cuts (timing) to keep expected background to < 1 event
 - Test new approaches for timing analysis

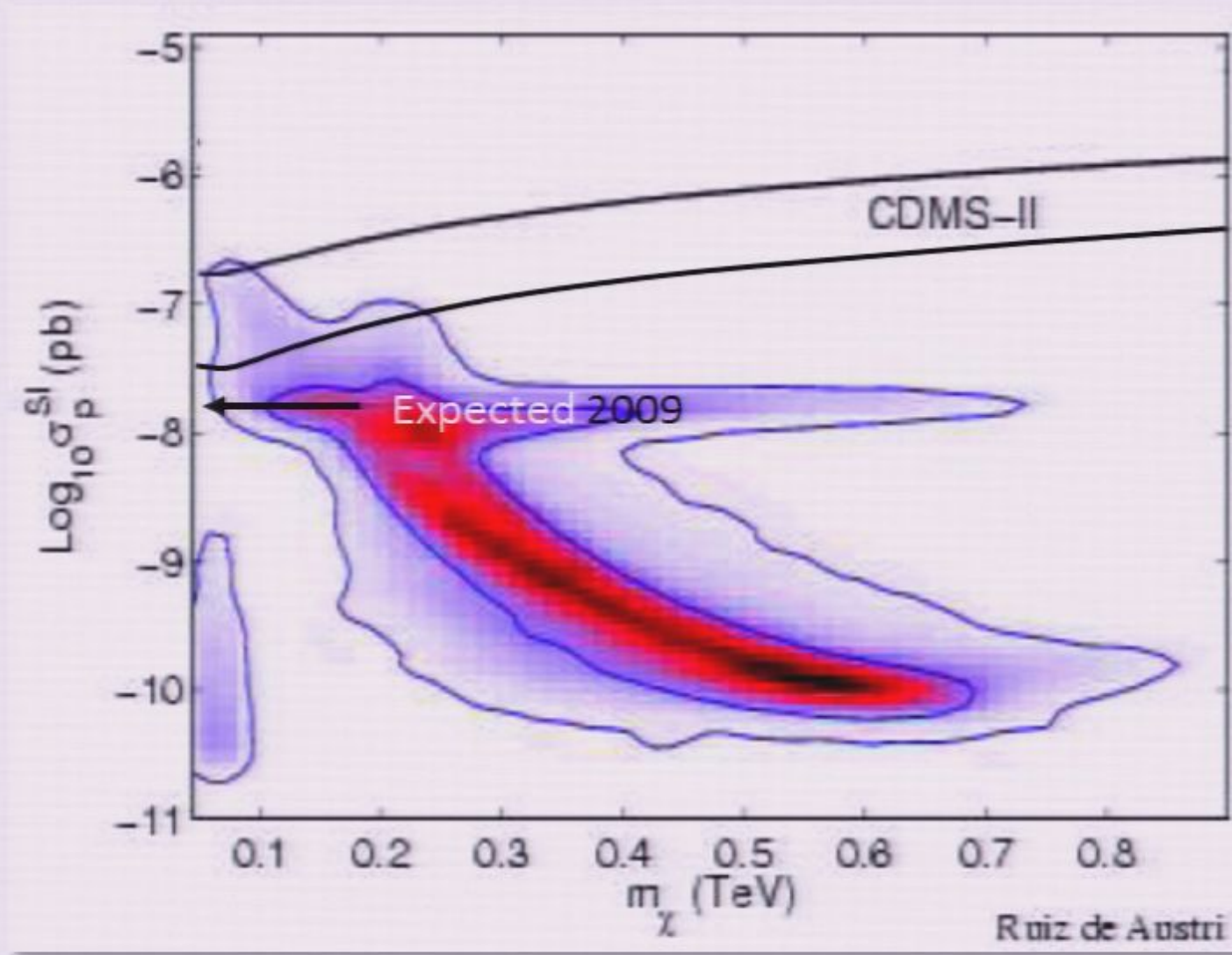
Analysis in Progress

- Data from July 2007 – fall 2008
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- Timeline: announce results later this summer

Analysis in Progress

- Data from July 2007 – fall 2008
- Increase of total exposure by a factor of ~ 3
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 - Data quality cuts
 - Better algorithm to account for position dependence
 - Would need to tighten surface event cuts (timing) to keep expected background to < 1 event
 - Test new approaches for timing analysis
- Timeline: announce results later this summer
- Expected improvement in sensitivity: factor 2-3 (similar to increase in exposure)

Analysis in Progress



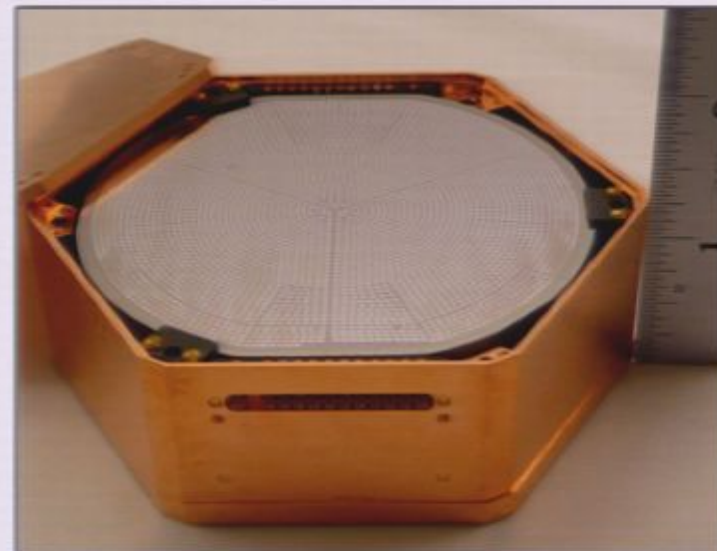
SuperCDMS

SuperCDMS



SuperCDMS

Larger detectors
(250 g → 630 g)



SuperCDMS



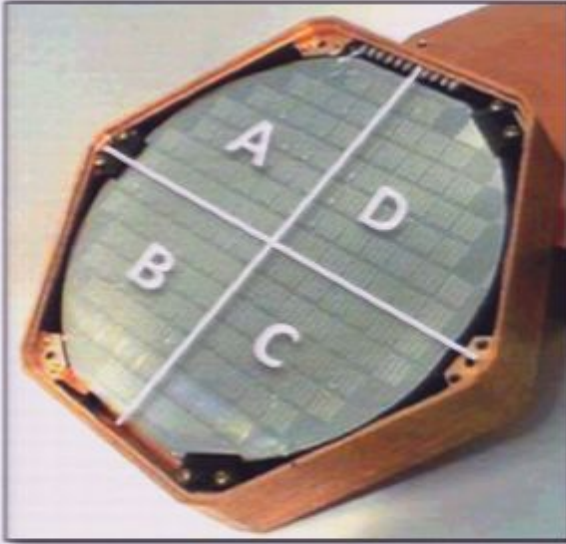
Larger detectors
(250 g \rightarrow 630 g)



Improved sensor
design



SuperCDMS



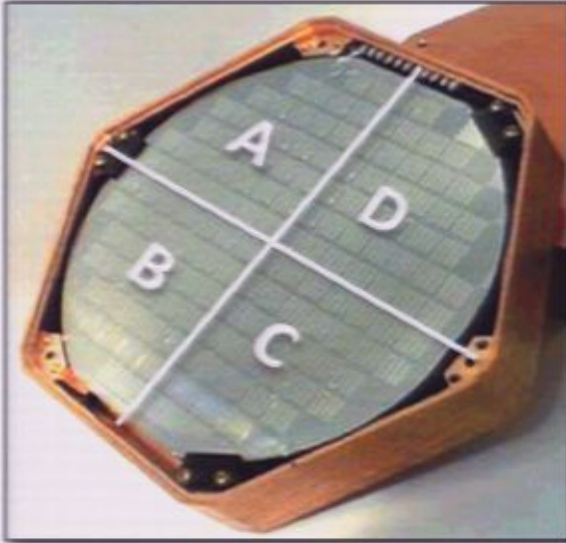
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SuperCDMS



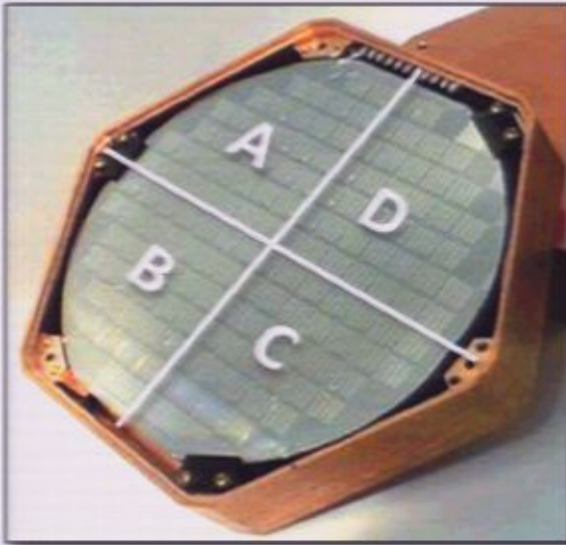
Larger detectors
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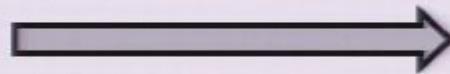
Improved sensor
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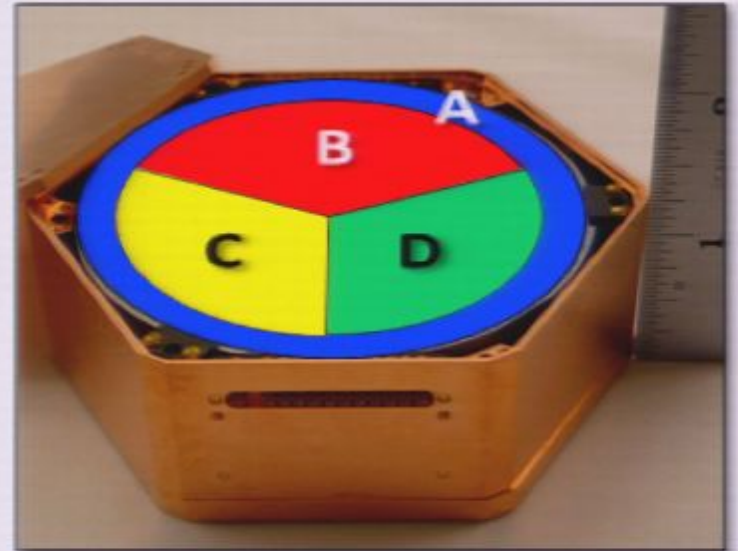
SuperCDMS



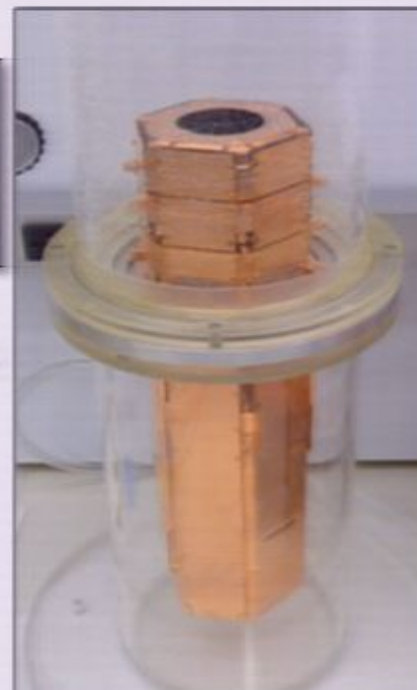
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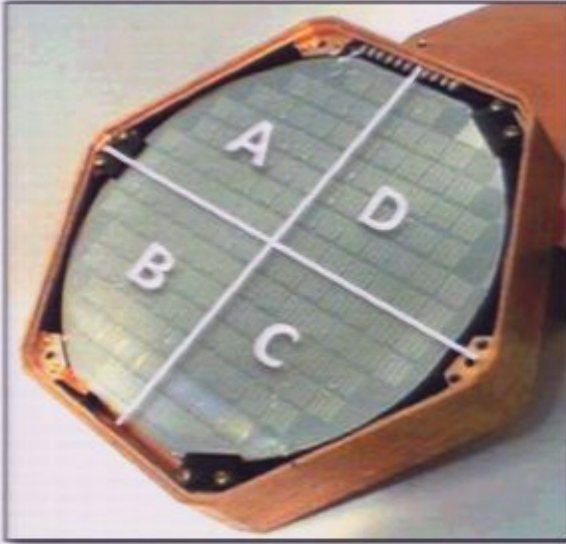
Improved sensor
design



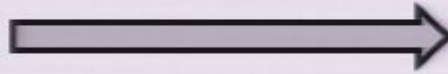
Tower → SuperTower



SuperCDMS



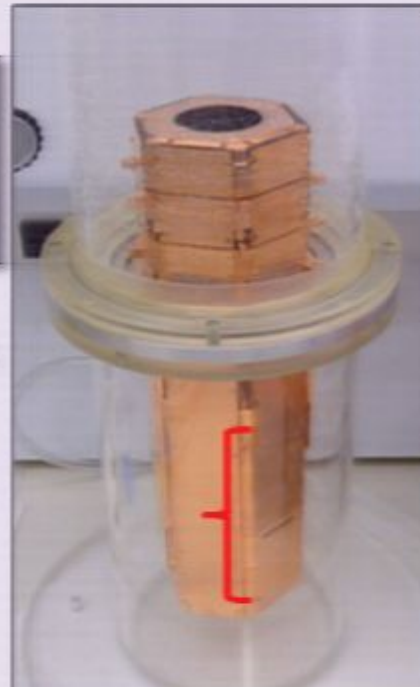
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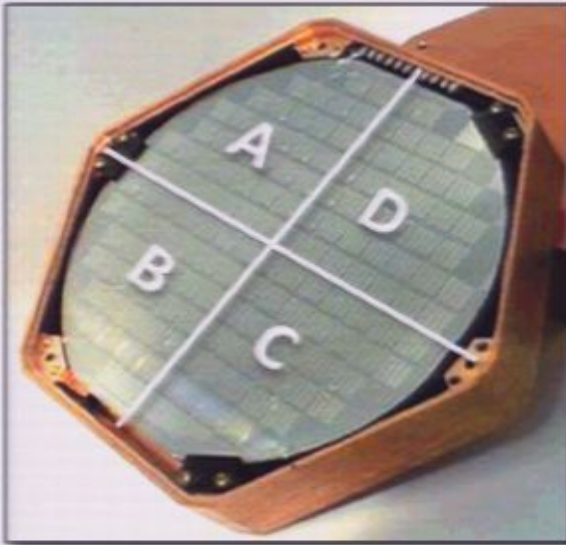
Improved sensor
design



Tower → SuperTower
More active detectors
per tower:



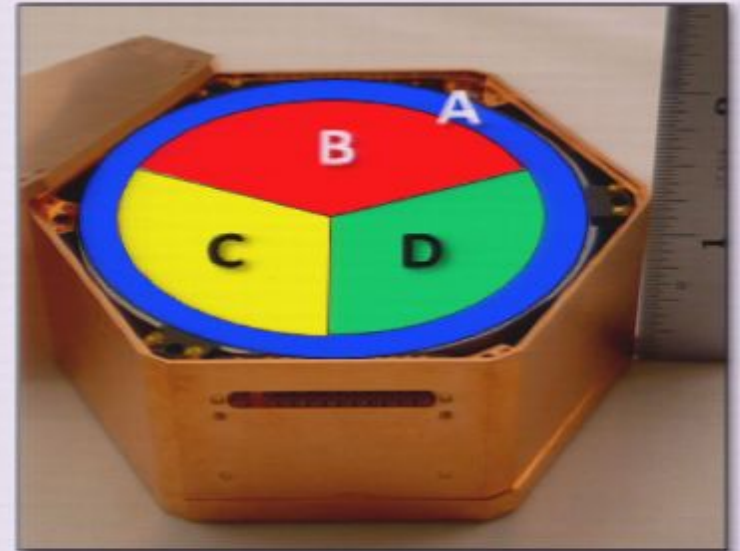
SuperCDMS



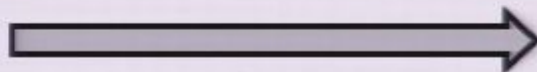
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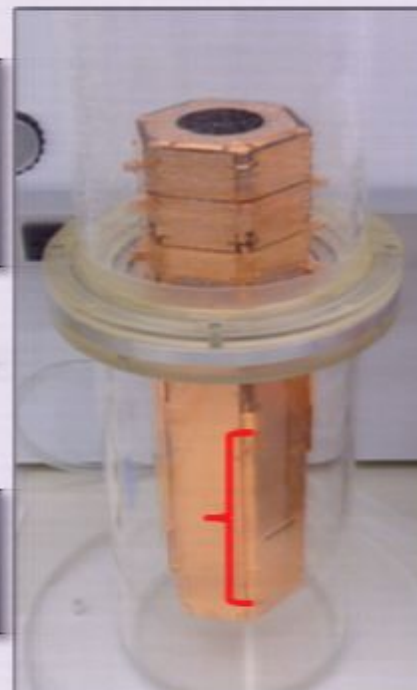
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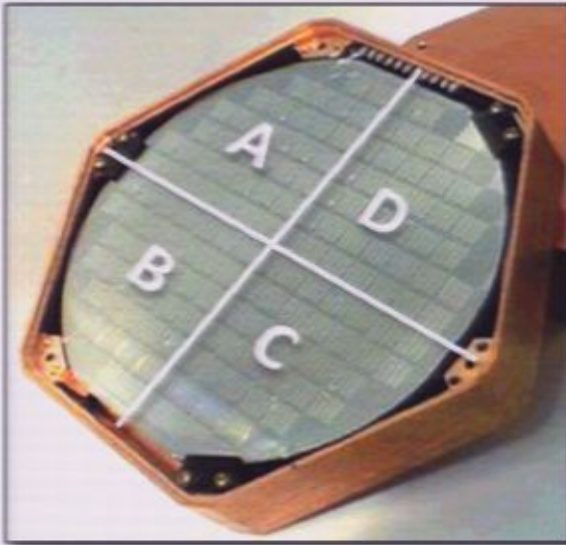
Tower → SuperTower
More active detectors
per tower:



4 out of 6 → 5 out of 7
(~ 1 kg → 3 kg)



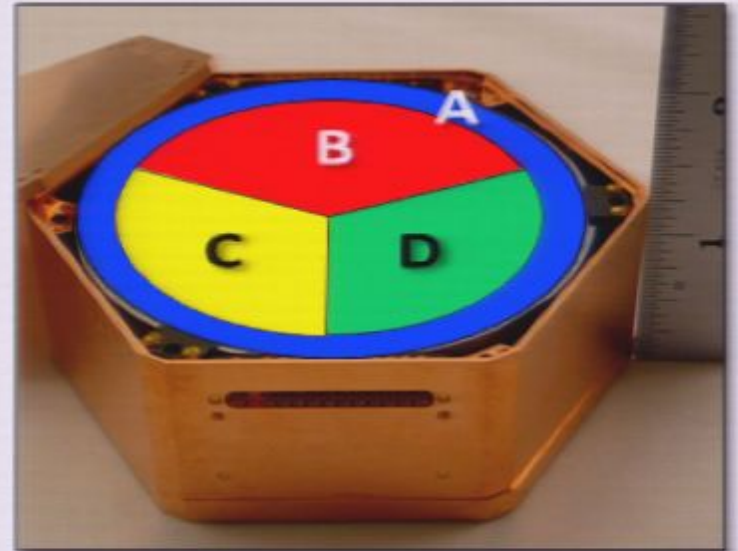
SuperCDMS



Larger detectors
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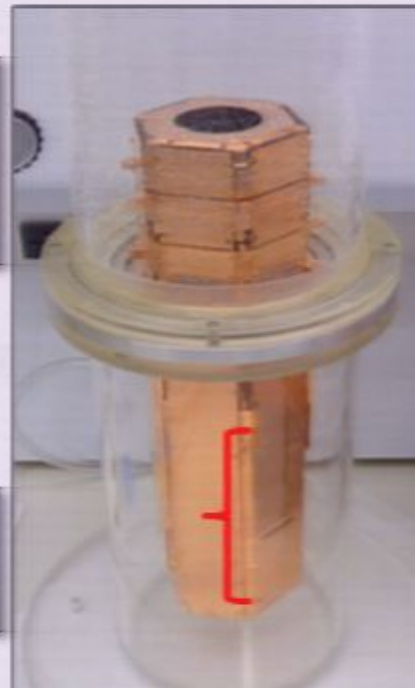
Improved sensor
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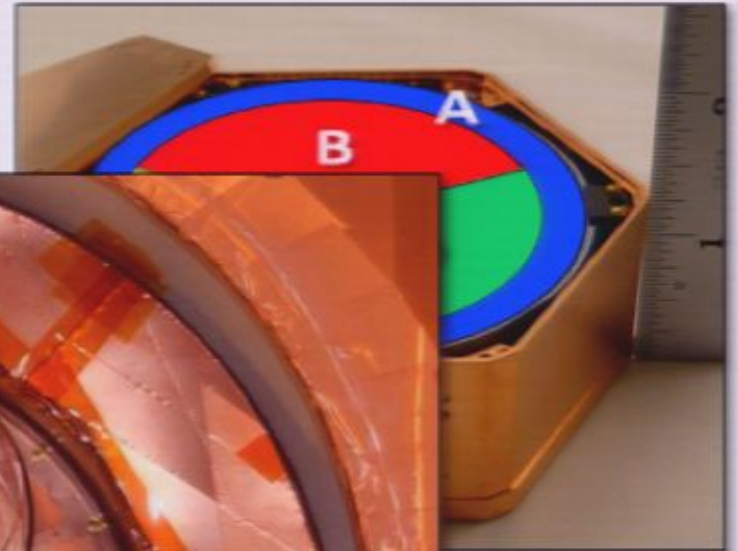
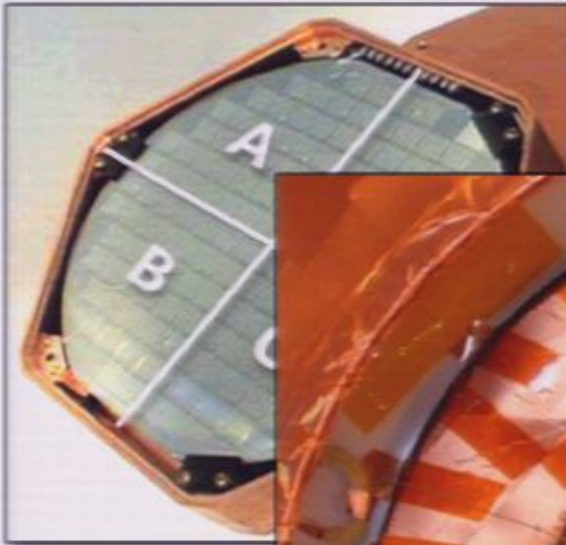
4 out of 6 → 5 out of 7
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Short term goal:
Build and install 5
SuperTowers (15 kg)
(first installed/cold)

SuperCDMS

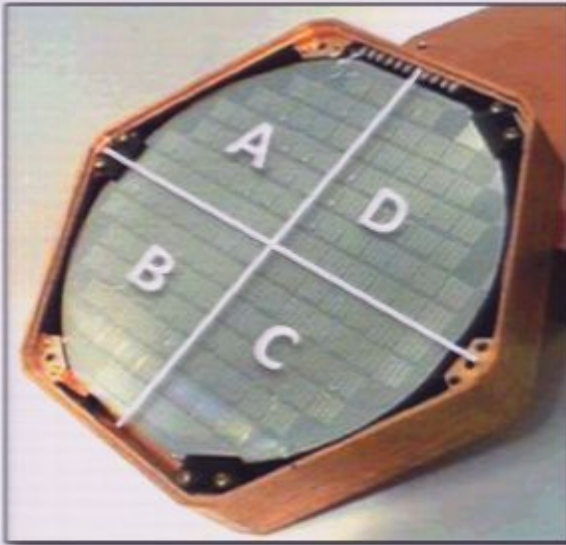
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SuperCDMS



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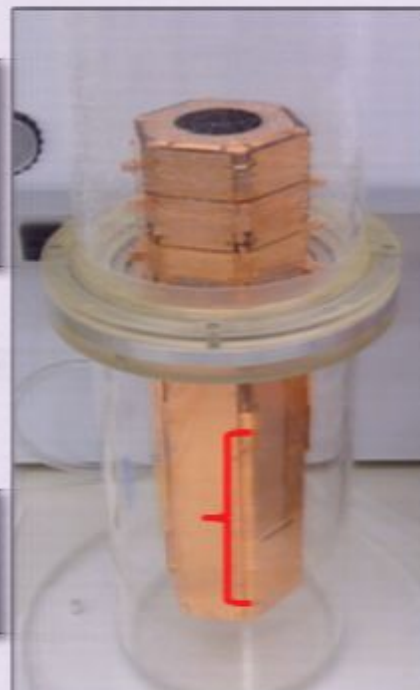
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More active detectors
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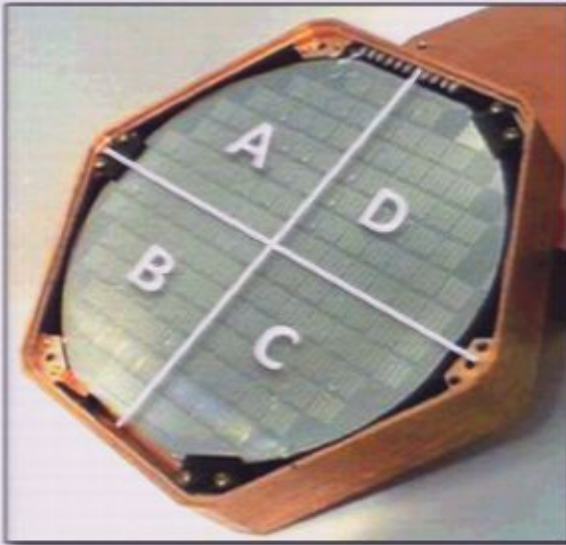


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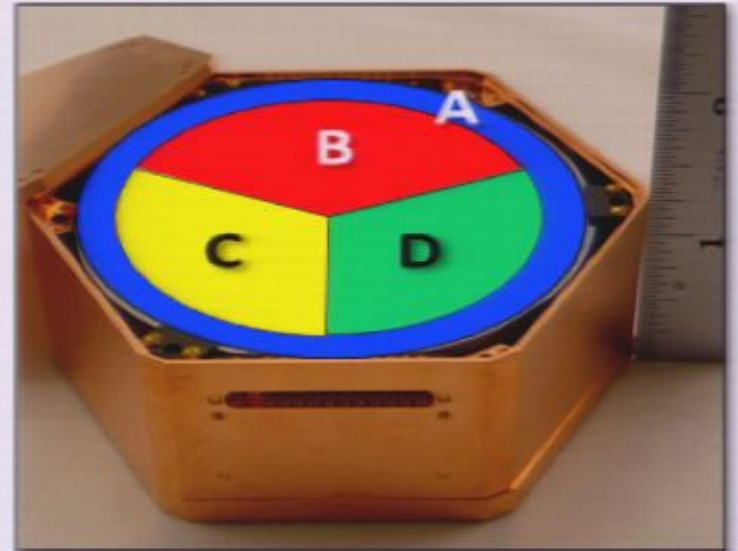
SuperCDMS



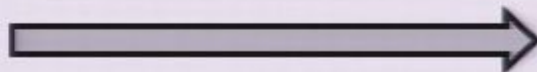
Larger detectors
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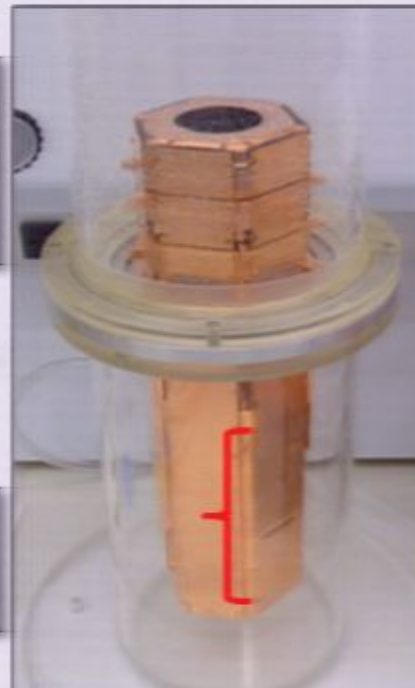
Improved sensor
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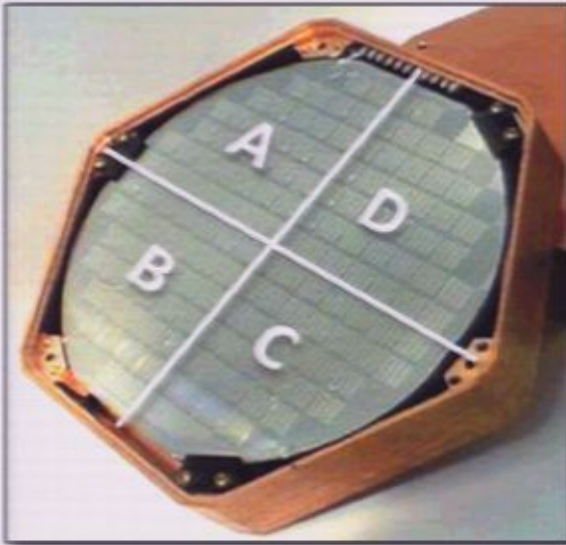
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Short term goal:
Build and install 5
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Medium term goal:
Further increase
mass/module; build
100-200 kg
experiment

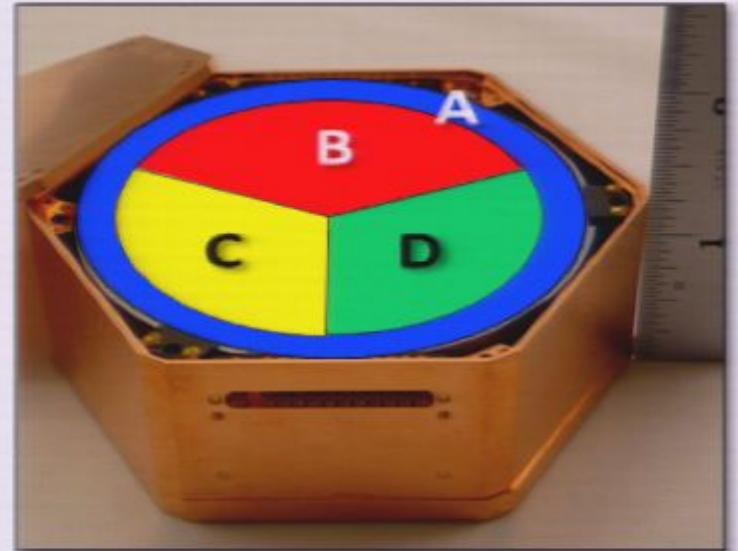
SuperCDMS



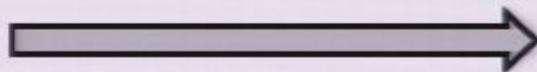
Larger detectors
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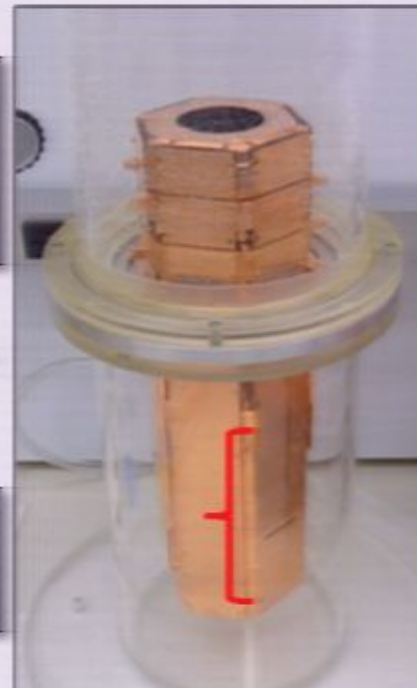
Improved sensor
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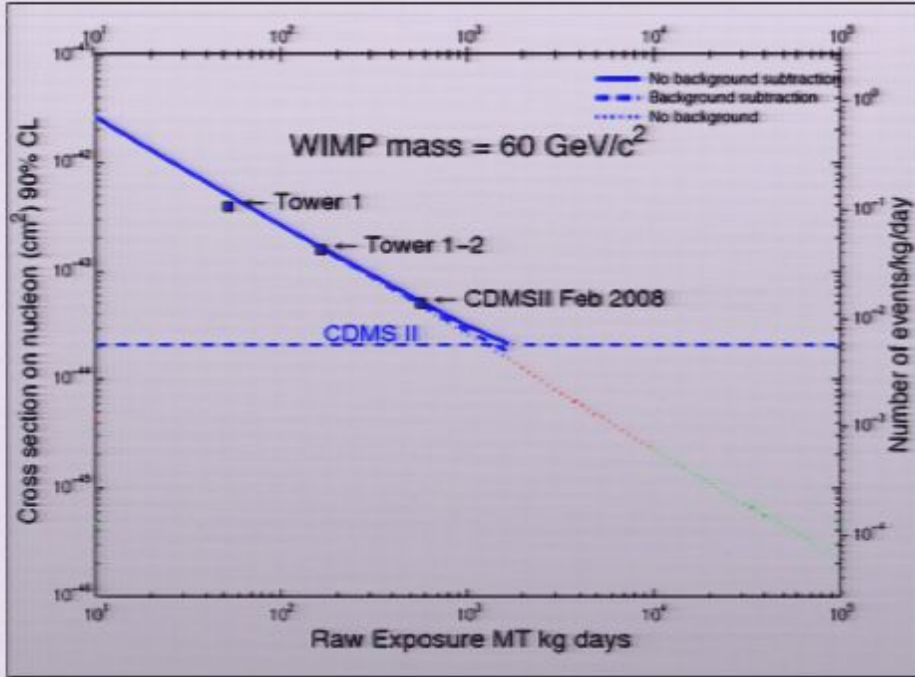
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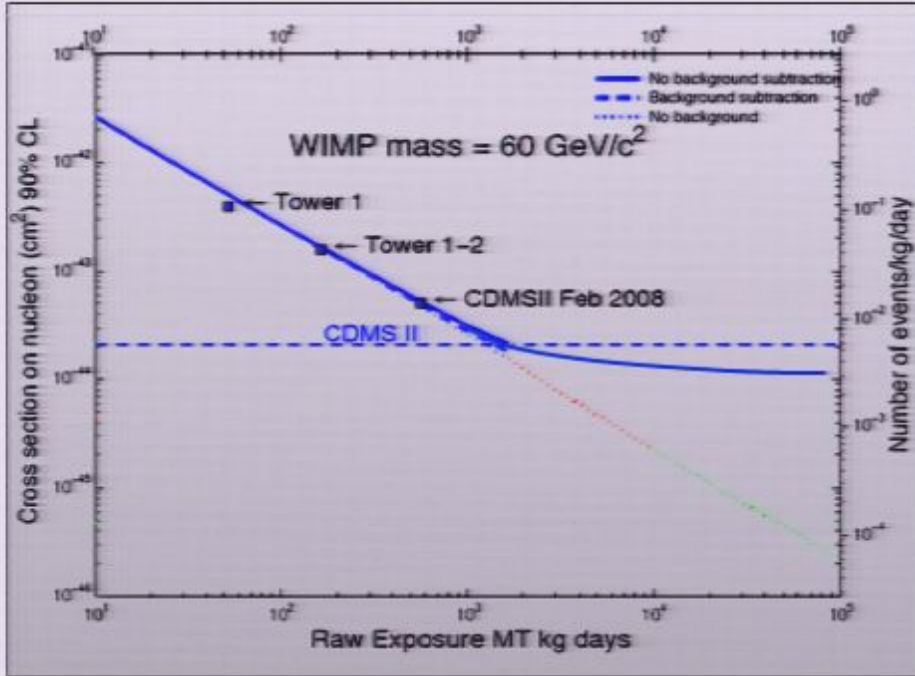
Long term: ~ 1 ton

SuperCDMS

SuperCDMS

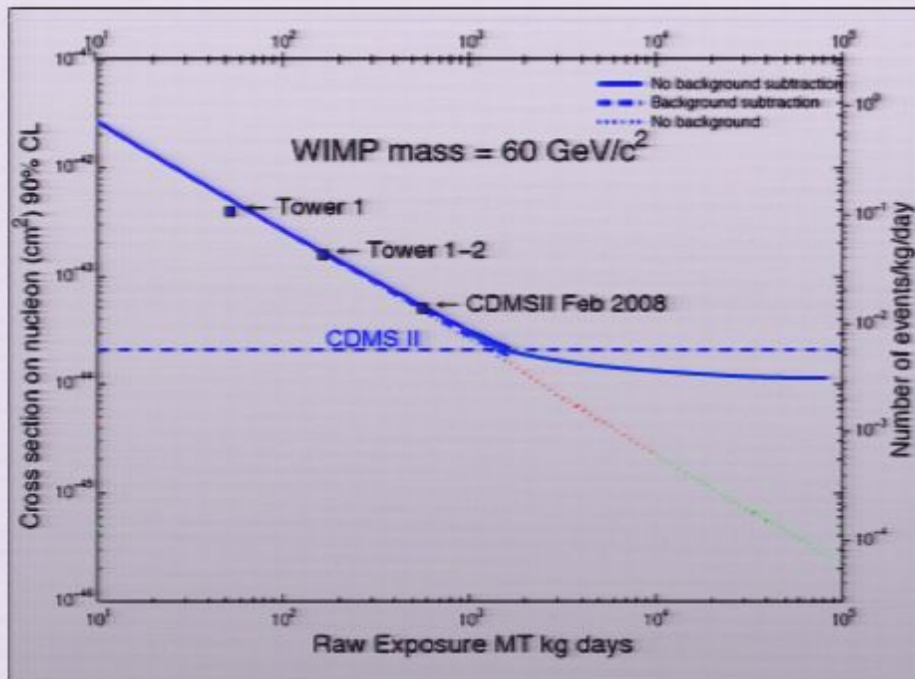


SuperCDMS



Need to reduce background!

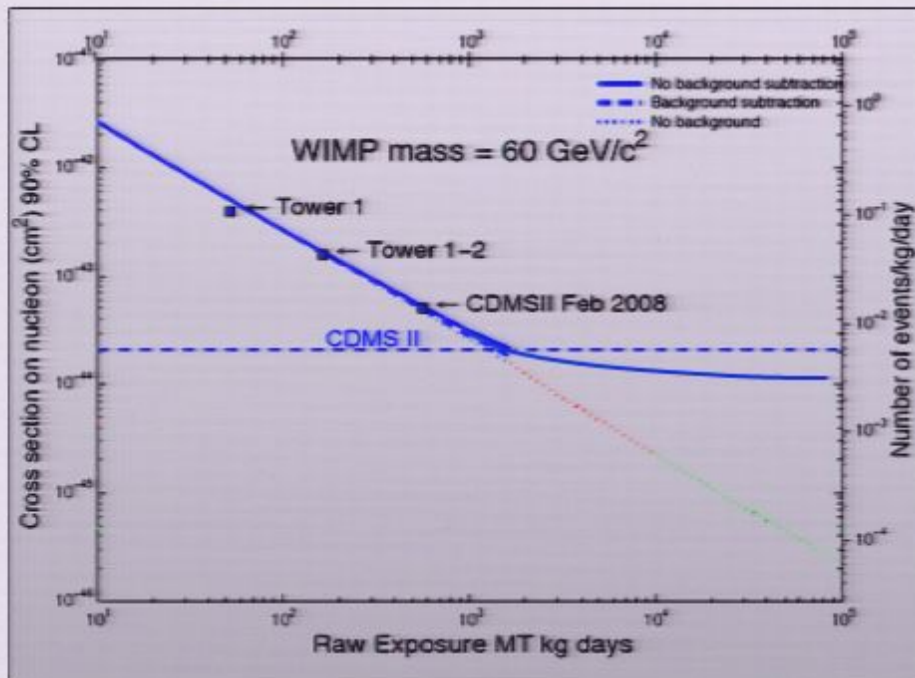
SuperCDMS



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- Reduce surface contamination (Rn, volume/surface ratio)

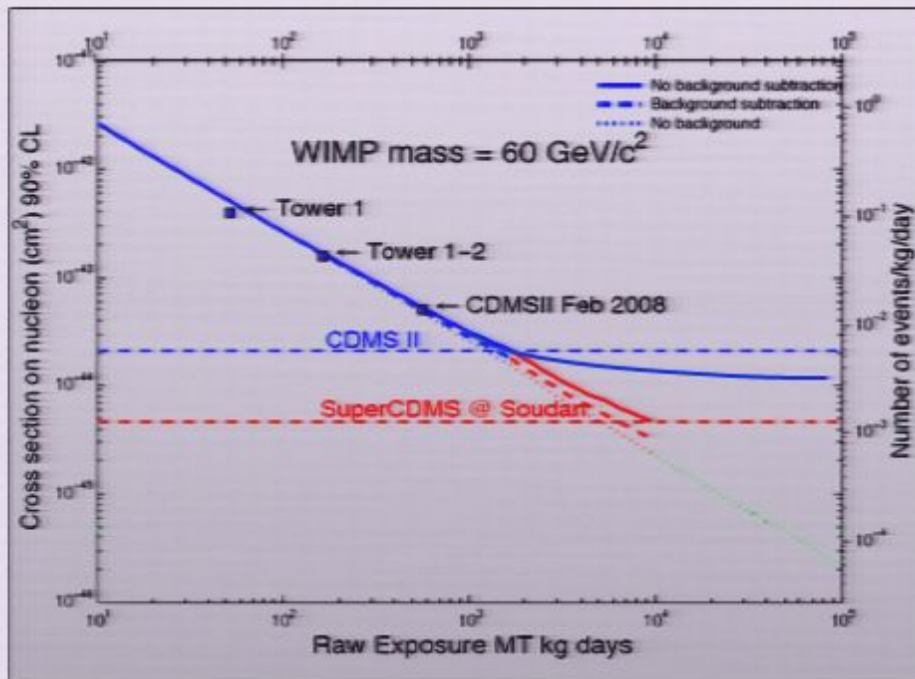
SuperCDMS



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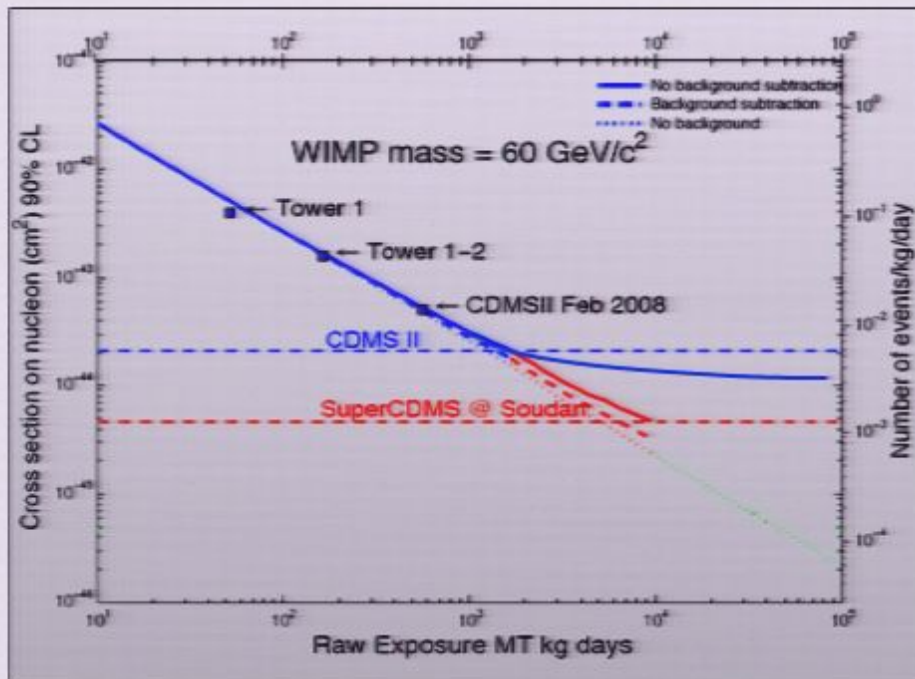
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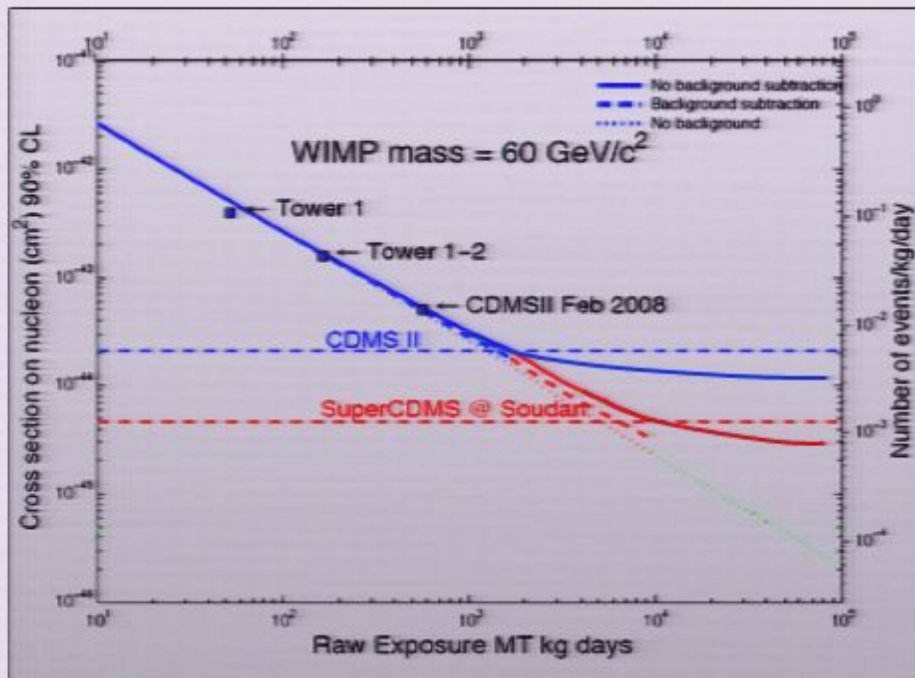
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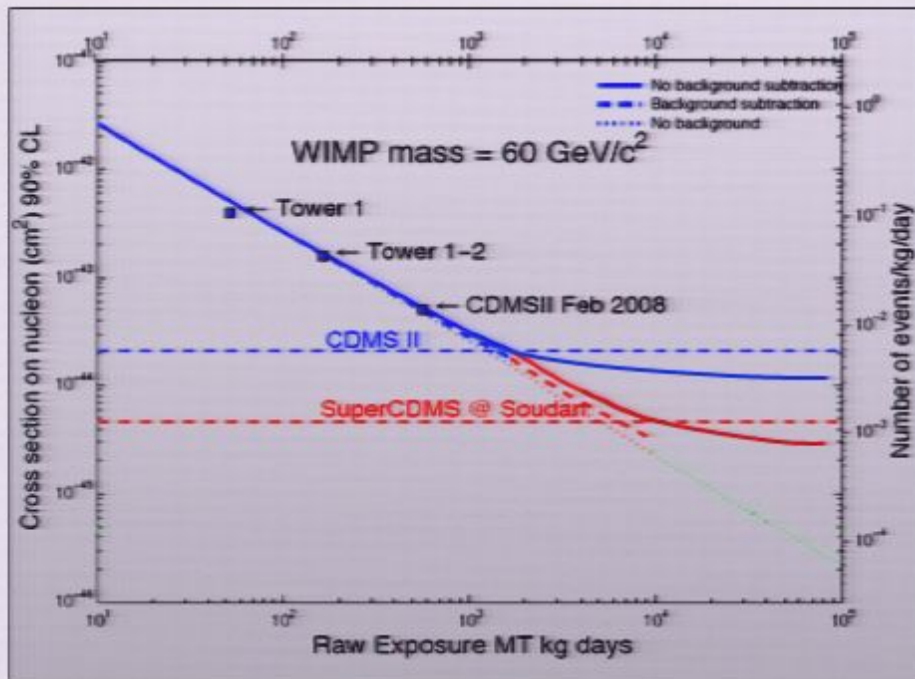
SuperCDMS



Need to reduce background!

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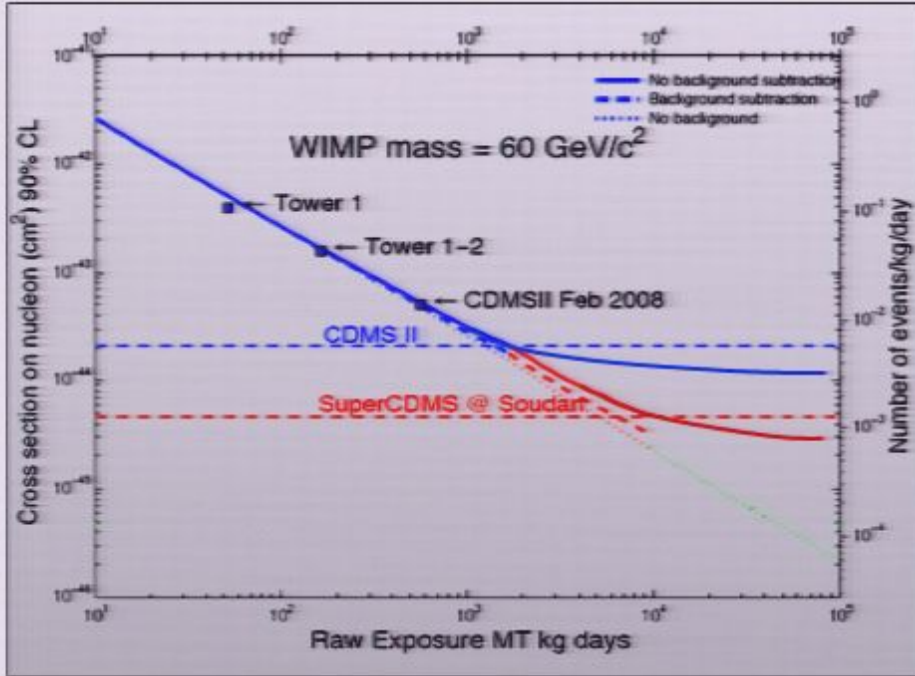


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⇒ **Move to SNOLAB**

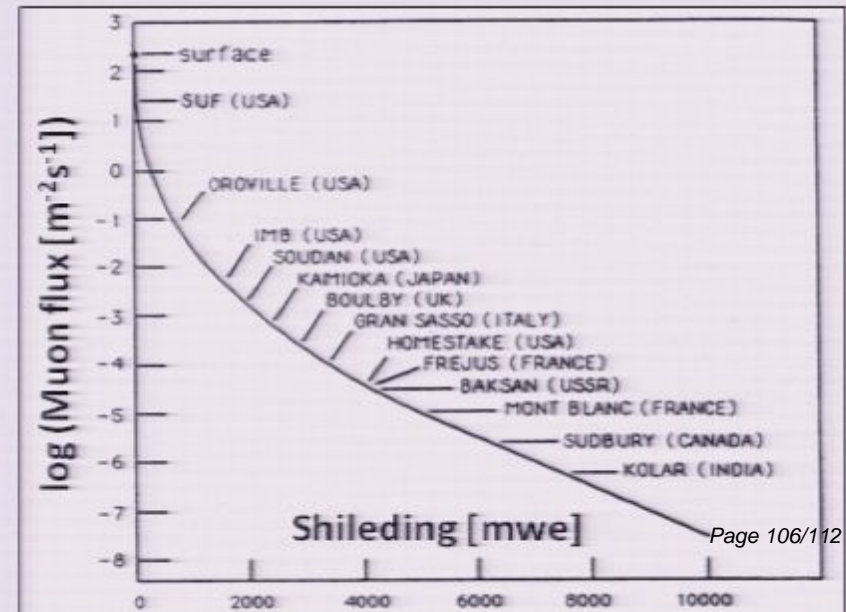
SuperCDMS



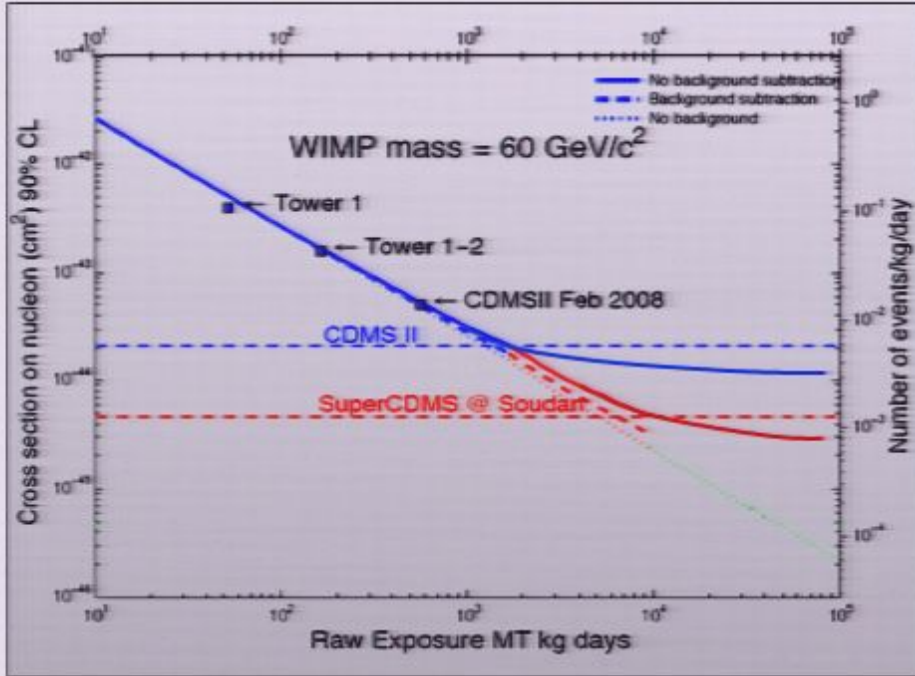
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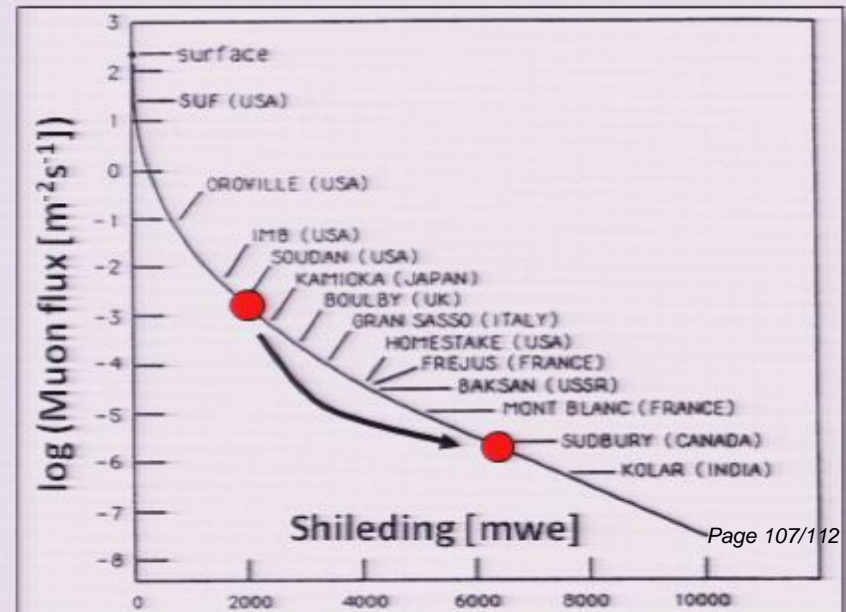
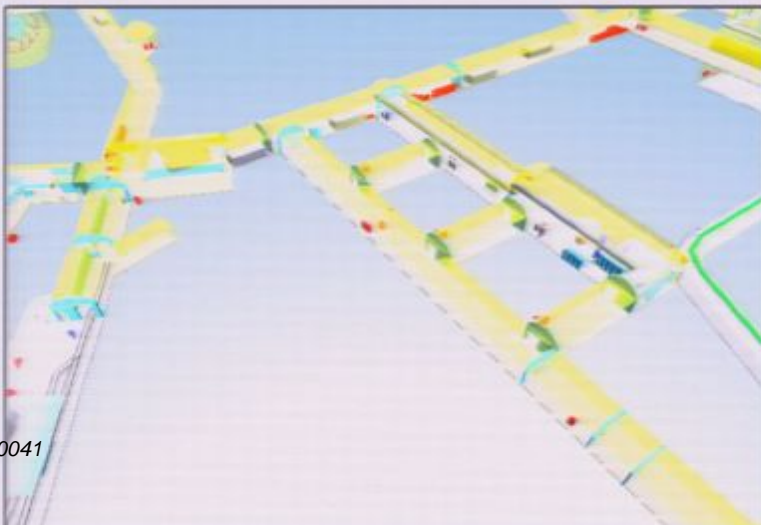
SuperCDMS



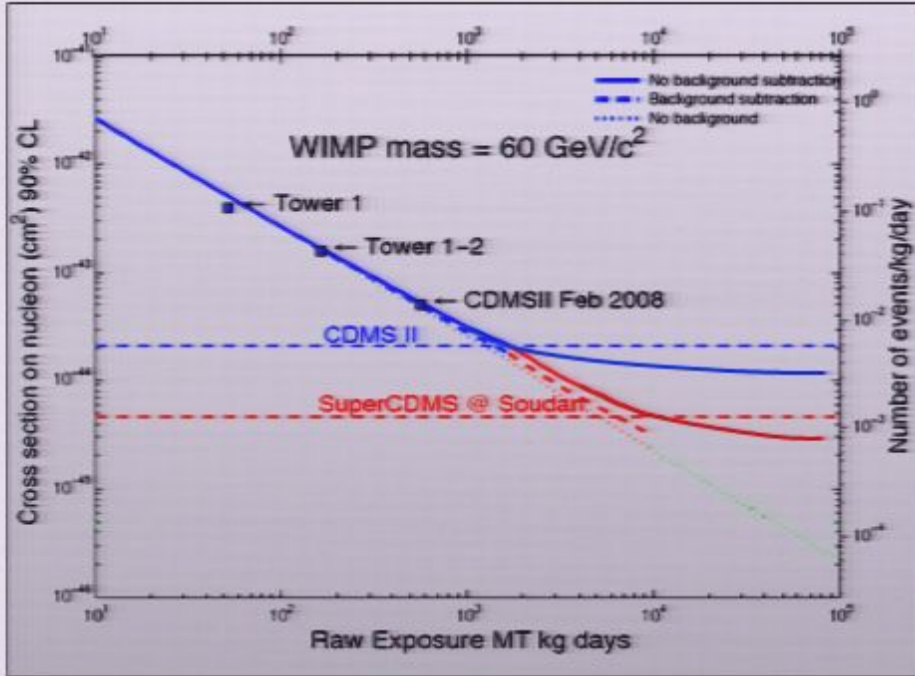
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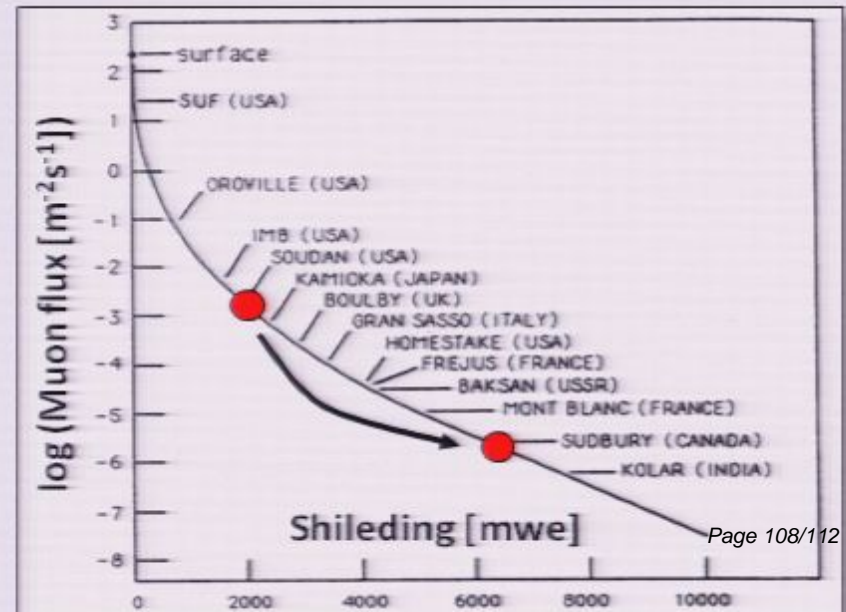
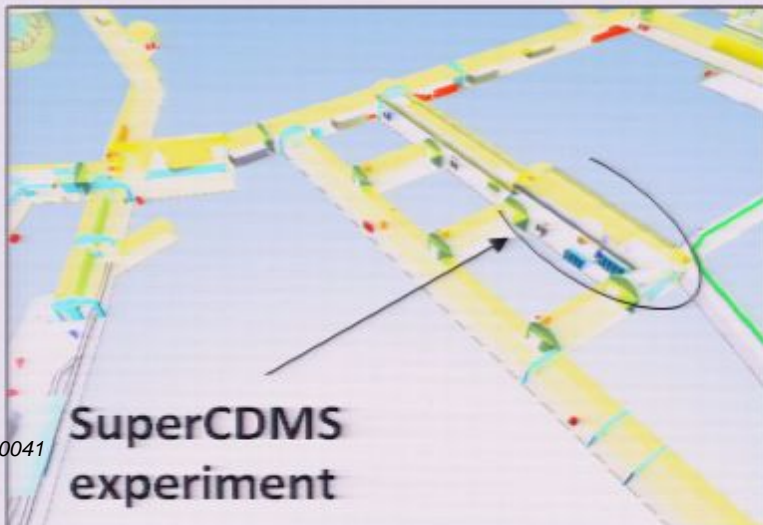


SuperCDMS

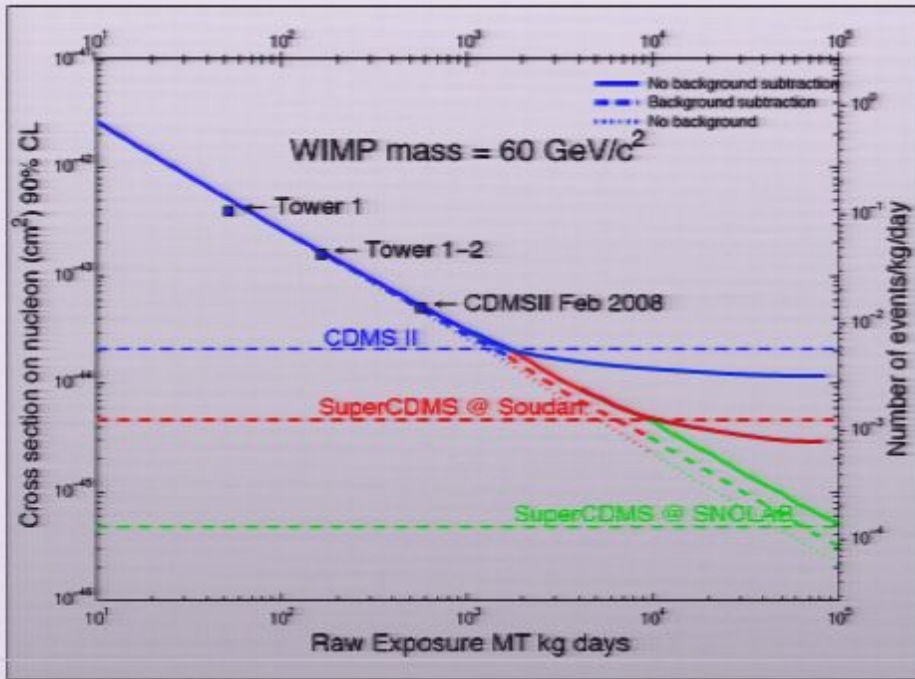


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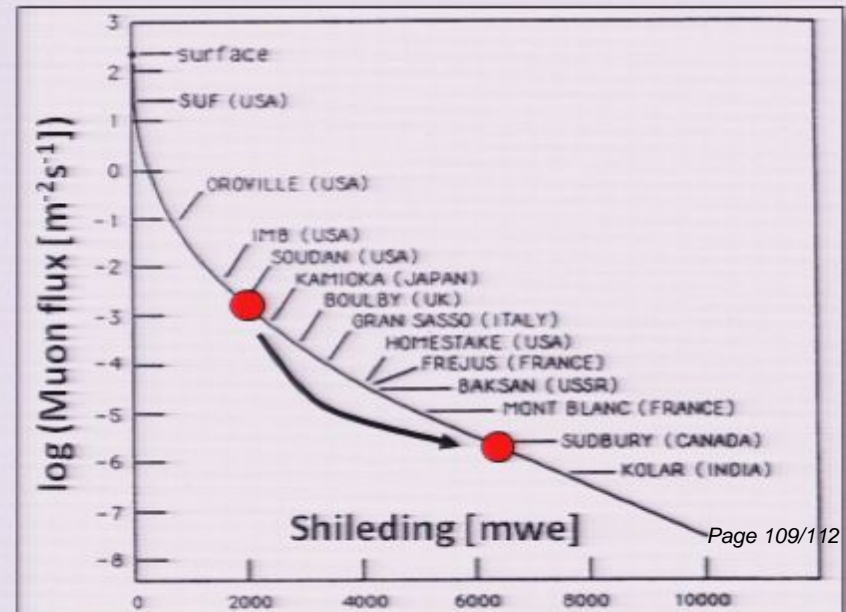
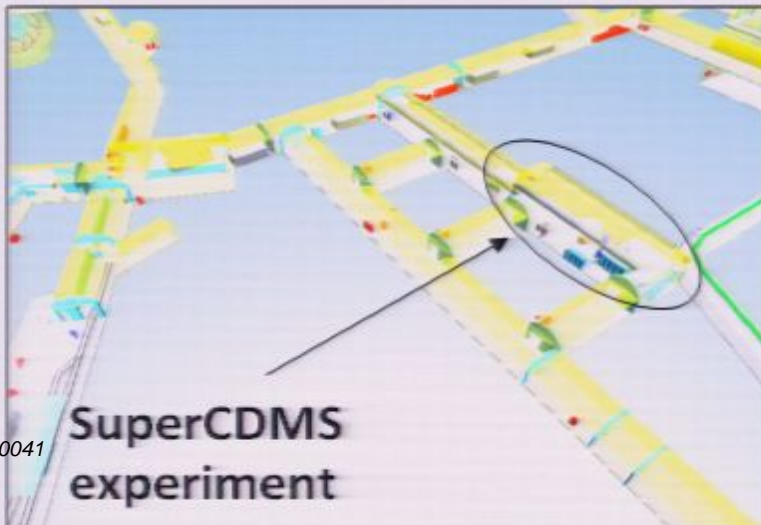


SuperCDMS

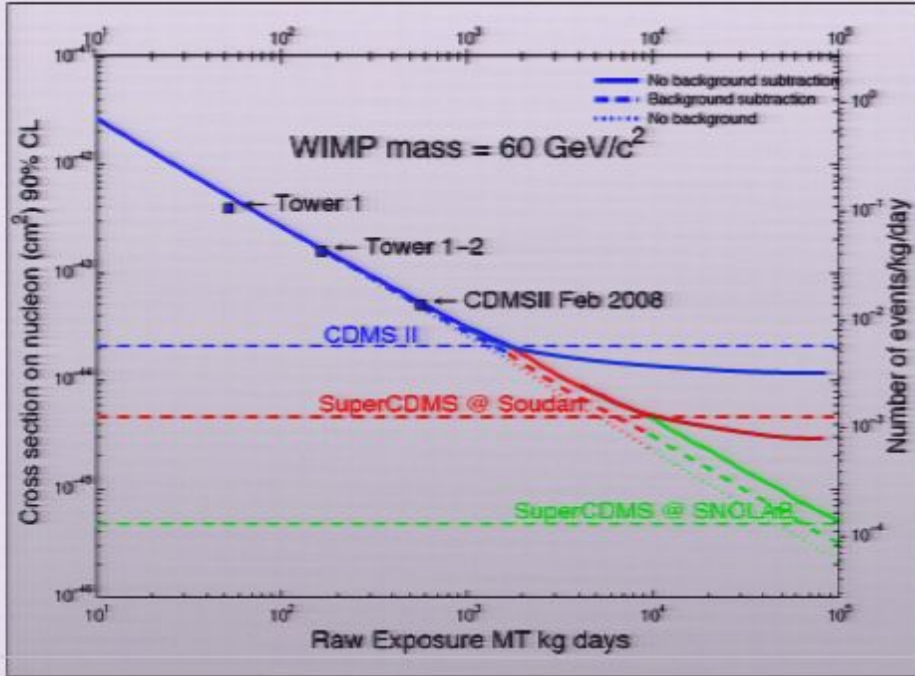


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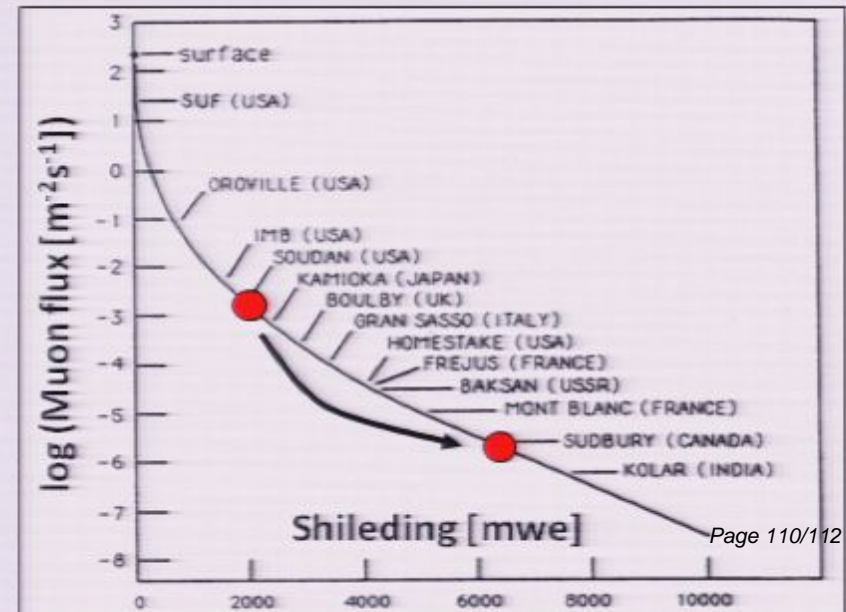
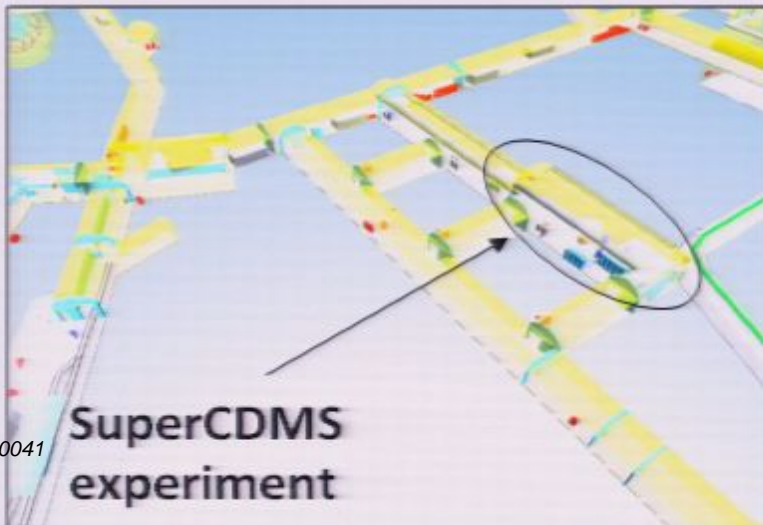
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Conclusion

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