The Key to the Success of SuperCDMS:

Lessons from CDMS II Background Studies

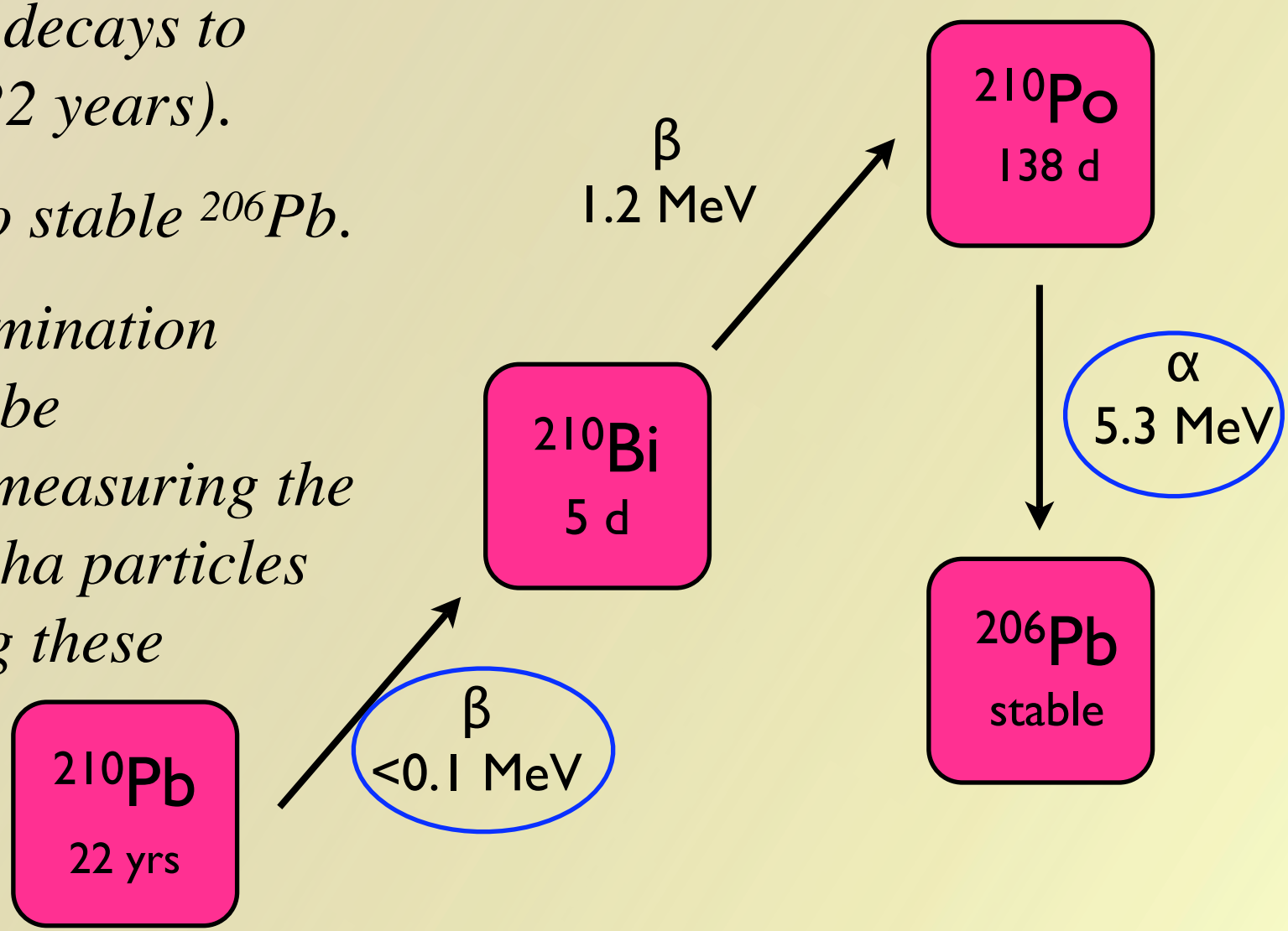
Jodi Cooley
Stanford University
for the CDMS Collaboration

Types of Backgrounds

- *Neutrons: Generated by muons from cosmic showers interacting in the shield or cavern rock.*
- *Electromagnetic:*
  - *Bulk: Primarily electrons emitted from radio-isotopes in the bulk of the detectors and from photons*
  - *Surface: Photons that interact in the first 35 μm of the detector surface and electrons ('betas') emitted by radioactive contaminants on the detectors or surfaces near the detectors.*

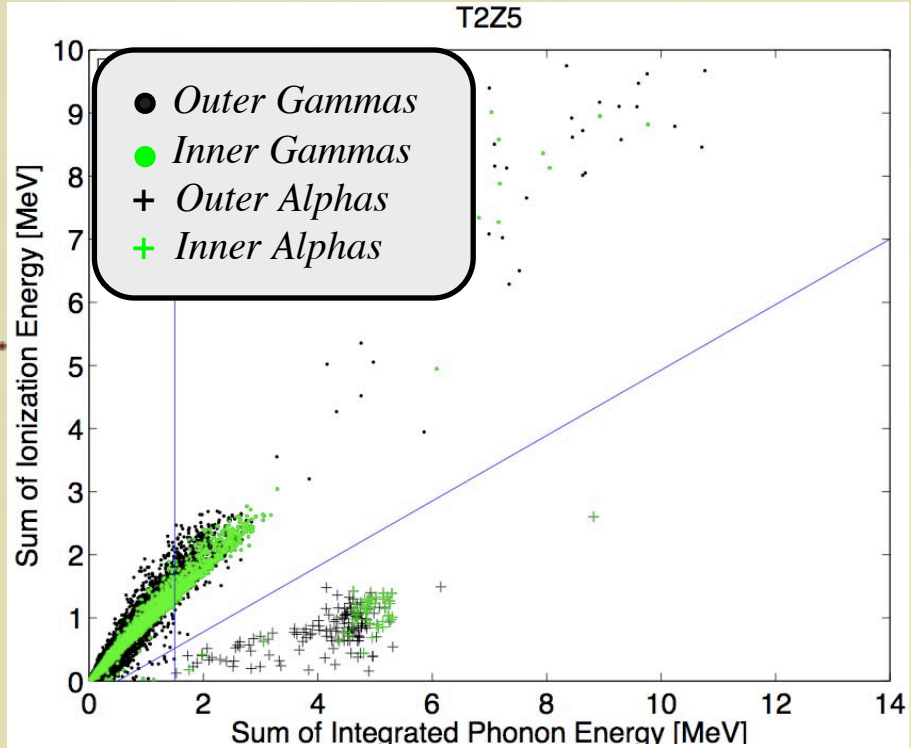
Surface Events: Radon Contamination

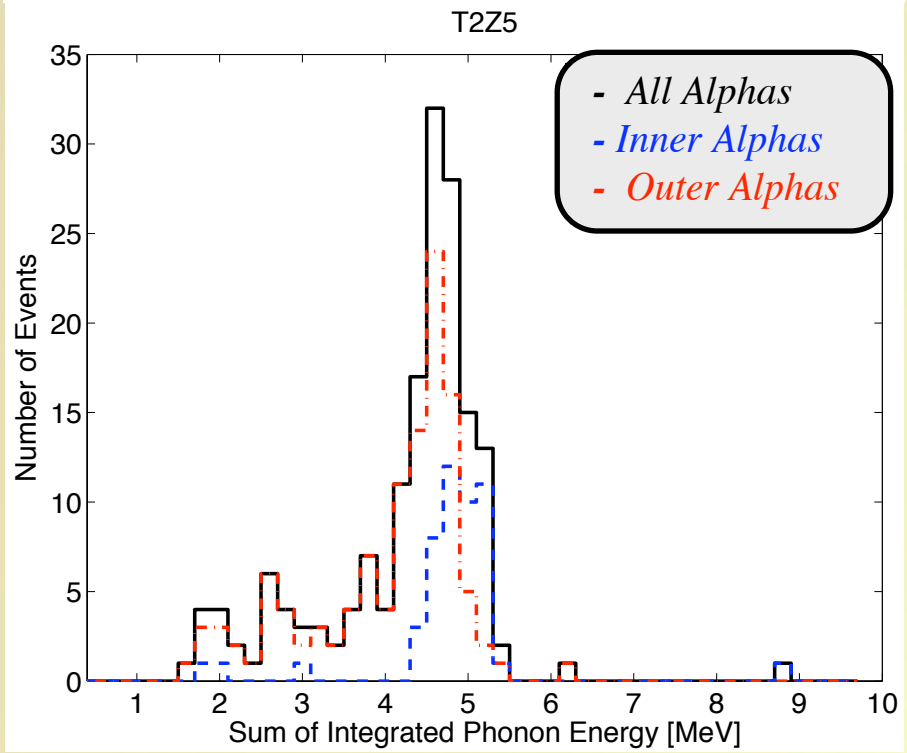
- *Airborne ^{222}Rn decays to ^{210}Pb (1/2 life 22 years).*
- *^{210}Pb decays to stable ^{206}Pb.*
- *Detector contamination from ^{222}Rn can be determined by measuring the beta and/or alpha particles given off during these decays.*



Surface Events: α Measurements

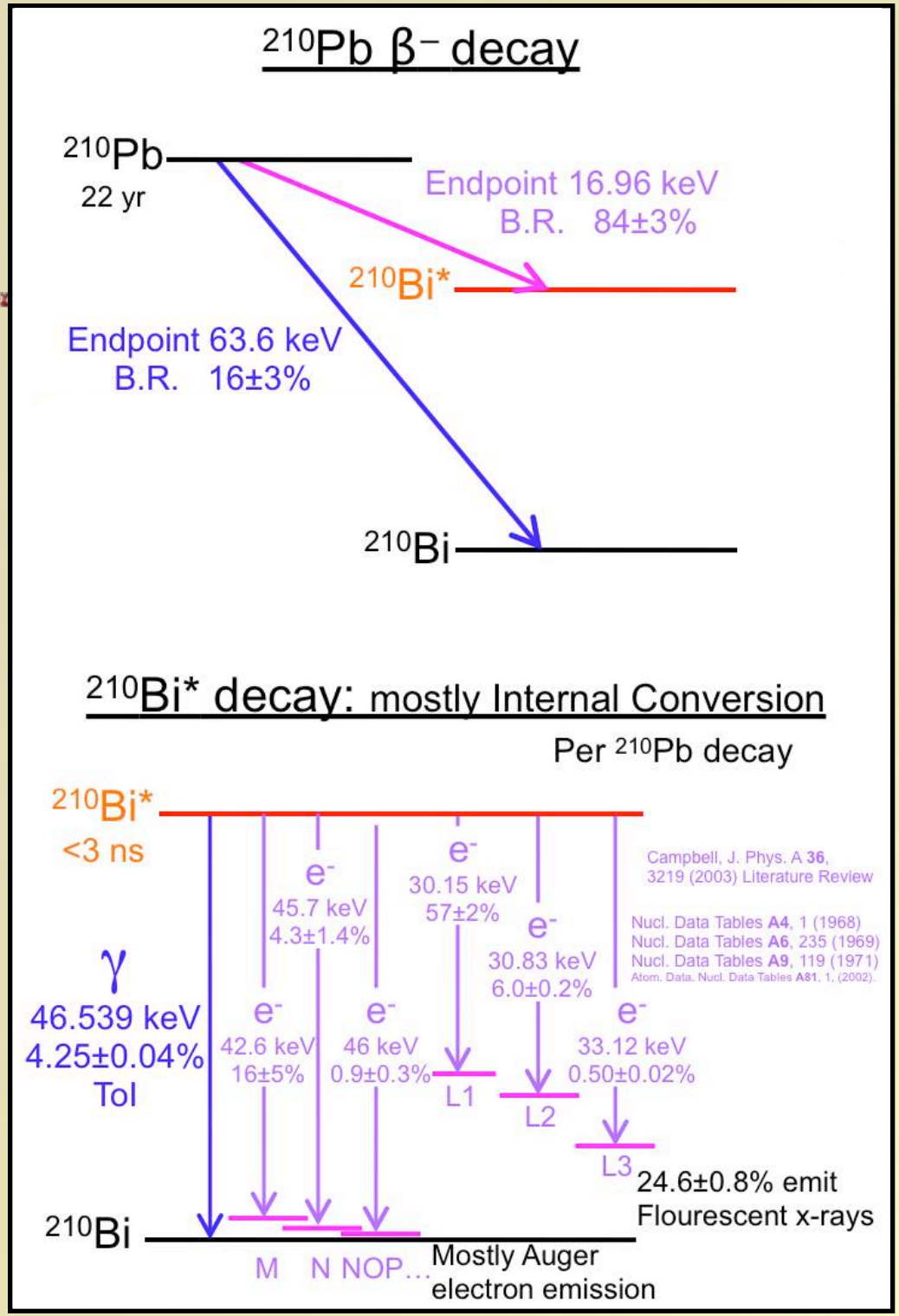
- *We identify alphas by reconstructing phonon and charge energy for events in the MeV energy range.*
- *Events contained in the inner electrode have energy consistent with ^{210}Po alpha at 5.3 MeV.*
- *Alphas are observed at a rate of ~ 0.4/detector/day.*





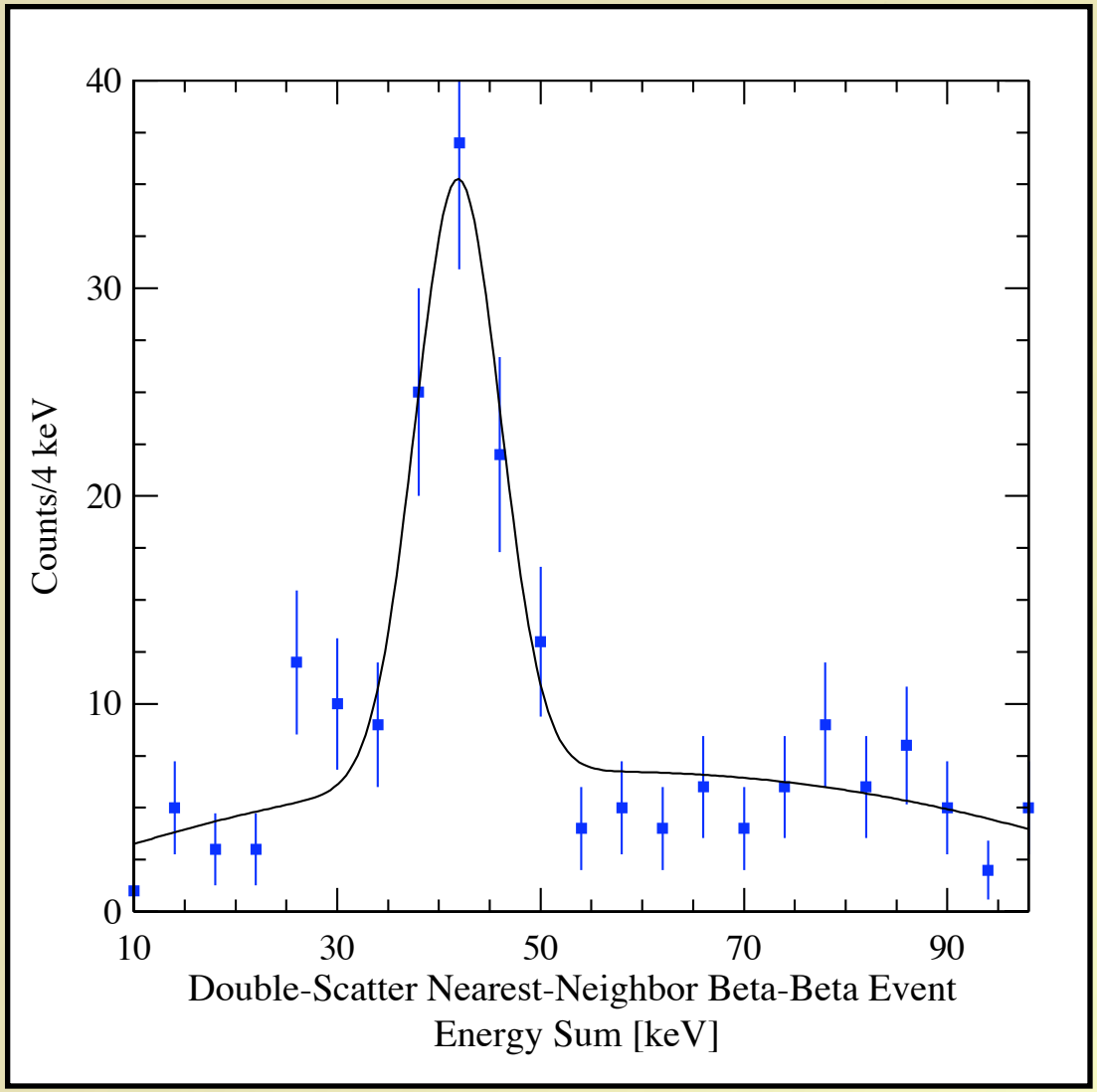
$^{210}Pb \rightarrow {}^{210}Bi$

- *^{210}Pb decays to $^{210}Bi^*$ with a branching fraction of ~84%*
- *$^{210}Bi^*$ decays directly by emitting a γ or via internal conversion electrons which have a combined energy of 45.6 keV*



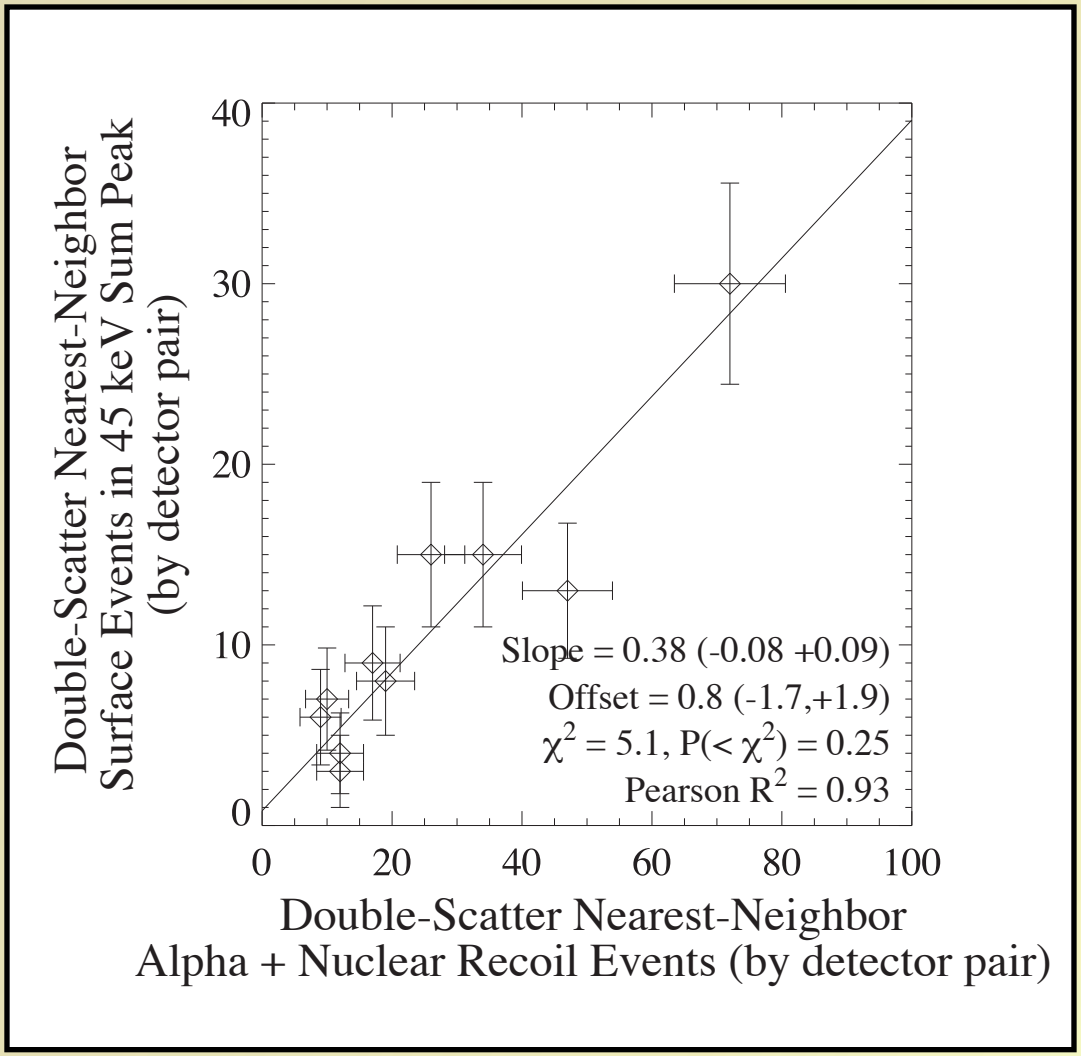
Surface Events: β Measurements

- *Betas from ^{210}Pb decays are identified by looking for double coincident beta events in neighboring detectors*
- *This class of events produce a broad spectrum 45 keV peak of 'beta-beta' events, consistent with predictions from ^{210}Pb.*



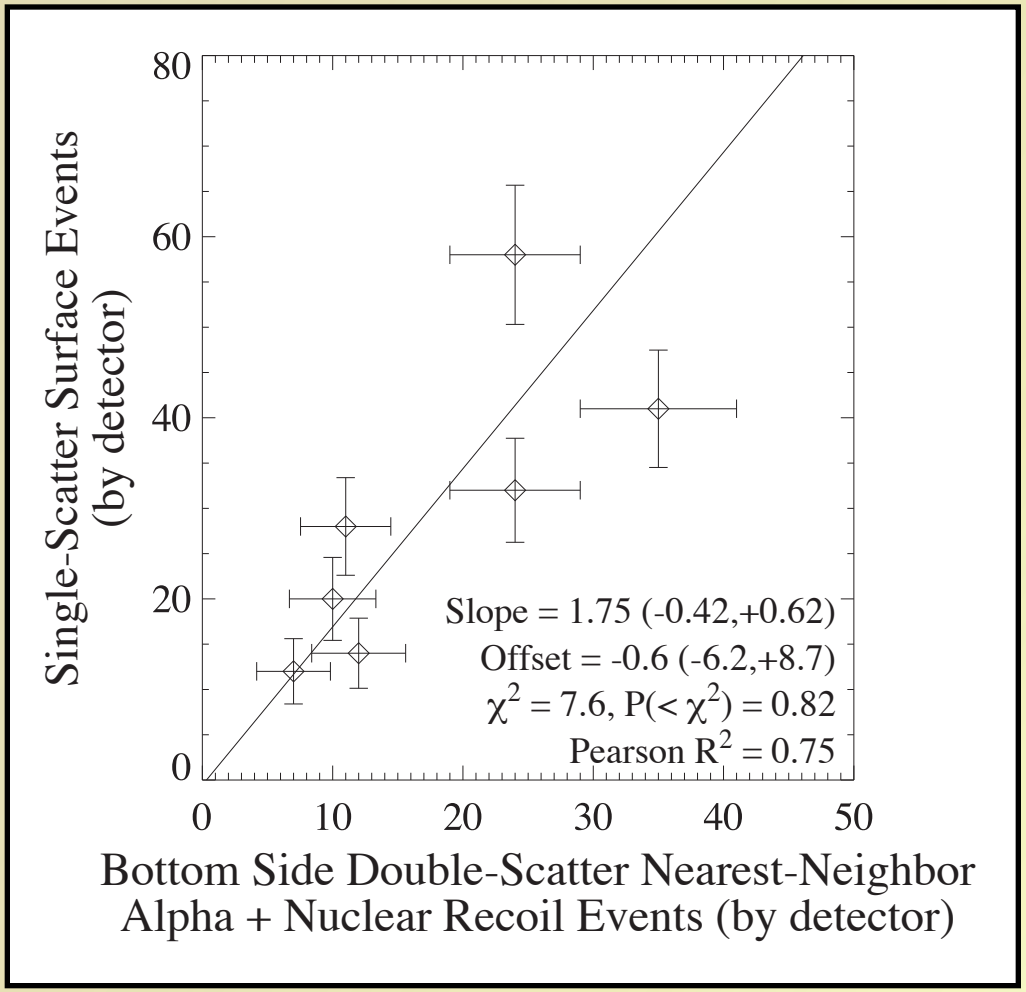
Alpha-Beta Correlation Analysis

- *Correlation between events identified in the 45 keV beta-beta peak and alpha analyses is strong, corroborating the identification of the peak with ^{210}Pb.*



Alpha-Beta Correlation Analysis (cont.)

- *A correlation also exists between single scatter surface events and events where an alpha is seen on the detector bottom and a ^{206}Pb recoil on a neighboring detector.*
- *Using the slope-intercept we establish a mean non-^{210}Pb count of 0.035/detector/day at a Bayesian 68% CL.*



Alpha-Betas: Putting it Together

The mean single-scatter rate in 'low-rate' detectors is 0.14/detector/day

+

Intercept analysis indicates 0.035/detector/day due to unrelated source(s)

=

This leaves ~75% attributed to ^{210}Pb

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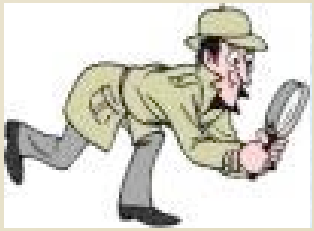
Uncertainties on both analyses are large: ^{210}Pb and photon-induced fractions have 1 σ ranges of (45% - 85%) and (0% - 40%)



Other Possible Surface Contaminants

- *^{40}K: Natural ^{40}K may be deposited though human contact.*
  - *Rutherford backscattering (RBS) and particle-induced x-ray emission (PIXE) analyses on test wafers produced at intermediate and final stages of processing give a preliminary upper limit on natural K of 1-2 x 10^{14} atoms/cm^2.*
  - *Simulations indicated that the resulting number of single scatters is in the range of 0.02-0.04 events/detector/day.*
- *^{14}C: Produced by cosmic ray induced reactions and could be introduced during processing.*
  - *Auger and RBS analysis indicate that 2-3 monolayers of carbon exist, consistent with exposure to air yielding 0.3 betas/day/detector with 156 keV endpoint energy indicating the single-scatter rate in the 10-40 keV region is small.*

Surface Event Contributions

Source	*origin*	*rate (#/day)*	*% of singles*
photon-induced	*photon bkgrd*	*0.044*	*0 - 40 % clean det.*
^{210}Pb	*airborne radon*	*0.045 - 0.085 clean det.*	*45 - 85 % clean det.*
^{40}K	*natural potassium*	*< 0.02 - 0.04*	*< 15 - 30 %*
^{14}C	*natural carbon*	*<< 0.3*	*small*

Concluding Remark

- *If we stabilize the ^{210}Pb rates at the 0.10 single-scatter events/detector/day which was obtained for the cleanest detectors in CDMS II and meet detector design goals (see Mahapatra, this session), the SuperCDMS 25kg experiment can meet its "zero background" design goal.*

Backup Slides

Surface Events

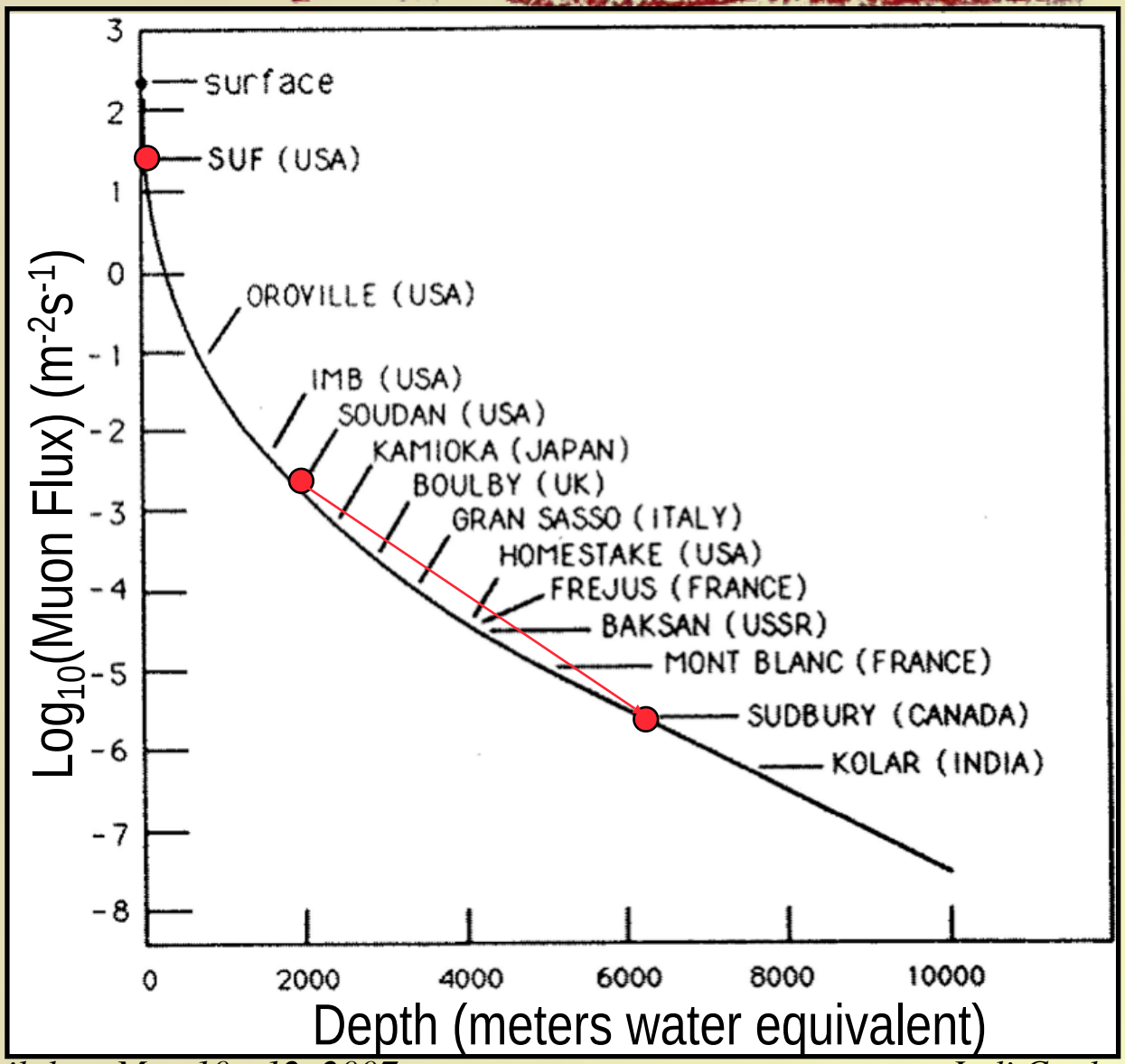
- *The dominant background in CDMS II is electrons from radioactive contaminants on the detector surfaces.*
- *These events are refered to as 'betas' reflecting the likelihood these events result from beta decay.*
- *Total rate of surface events in the energy range 10 - 40 keV is 1.7/detector/day of which 0.21/detector/day are single scatter.*

Gamma Rejection

- *Sources:*
- *Easy to reject when they occur in the bulk*

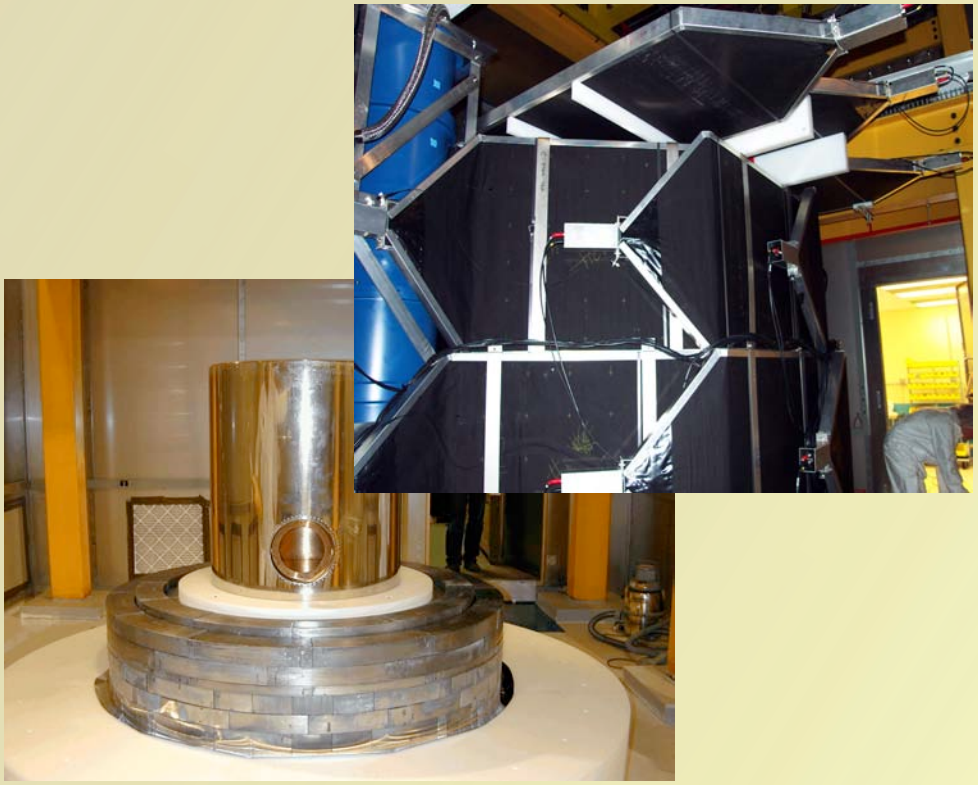
Neutrons: Shielding

- *At SUF*
  - *17 mwe*
  - *0.5 n/d/kg*
- *At Soudan*
  - *2090 mwe*
  - *0.05 n/y/kg*
- *At SNOLab*
  - *6600 mwe*
  - *0.2 n/y/ton*



Neutron Sources for CDMS II

- *Radioactivity*
- *U/Th in rock and shield*
  - *through α,n reactions*
  - *though spontaneous fission of ^{238}U*
- *Muon induced*
  - *muon interactions in shield*
  - *muon-induced high energy neutrons (>60 MeV) inteacting in shielding*



We use passive and active shielding to reduce neutron induced nuclear recoil rates to a negligible level.

Neutrons: Simulations

Event Type	Fluka/MCNPX	GEANT4	Description
Live time simulated	14 years	5 years	normalized using ~1 muon/min on veto
nuclear recoils	7.6/kg/yr	2.4/kg/yr	nuclear recoils in the 10-100 keV range per muon
vetoed by scintillator	7.1/kg/yr	2.3/kg/yr	by muon veto
vetoed by scintillator & zips	7.55/kg/yr	2.39/kg/yr	by muon veto & zips (multiples, etc)
total unvetoed scin. & zips	0.05 +/- 0.001(stat) /kg/yr	0.01 to 0.10 /kg/yr (68% CL)	unvetoed by the muon veto & zips
singles (with em) / singles	0.37	0.39	em = singles in coincidence with energy deposition from charged particles