

First Year PhD. Report
University College London High Energy Physics

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Summary

Here I present a short introduction to the experiment I am working on for my PhD, the Cryogenic Dark Matter Search (CDMS), and discuss its motivations from cosmology and particle physics perspectives. I outline the research I have conducted in my first year of working on the experiment, concentrating on the use of GEANT4 Monte Carlo simulations to model CDMS detector (BLIP and ZIP) responses to beta, gamma and neutron background fluxes. The aim of the work is to provide a better understanding of background identification and discrimination, when looking for the much rarer dark matter nuclear recoil events.

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1. Dark Matter

- Cosmology Introduction and Ω
- Role of cold dark matter (CDM)
- Particle physics

Cosmology Introduction

Omega is the quantity which measures the space-time geometry of the universe.

Defined as:

$$\Omega = \rho / \rho_c$$

Where ρ is the total energy density of the universe, and ρ_c is the critical energy density, the value required for a Euclidean (flat) universe. (Note that ρ and ρ_c both change with time as the universe expands.) Given the generally accepted assumption that space is isotropic, the universe has constant curvature (homogenizing energy density fluctuations caused by galaxies etc.).

$\Omega > 1 \Rightarrow$ the universe has positive curvature, e.g. a sphere.

$\Omega < 1 \Rightarrow$ the universe has negative curvature

$\Omega = 1 \Rightarrow$ the universe has zero curvature, i.e. is flat and obeys Euclidean geometry.

In a matter dominated (Einstein-de Sitter) universe, Ω tells us whether the universe is open, closed or flat.

Open:

$\Omega < 1$, the universe will continue to expand forever

Closed:

$\Omega > 1$, the expansion will slow and the universe will eventually contract into a 'big crunch'. The universe has a finite volume.

Flat:

$\Omega = 1$, the universe will expand forever asymptotically to a limit

From recent CMB observations, Ω looks like 1 ± 0.1 . These observations are based on measuring the peaks in the angular correlation spectrum that gives the size of causally connected areas of the sky at the time of last scattering. The size of this should look like $c \cdot t$ (time of last scattering) without gravitational lensing (assuming a flat geometry) and this is indeed what it looks like. Other methods in observational cosmology (including galaxy cluster gravitation lensing) yield a value of $\Omega_M=0.3$ for all matter. Indications that a lot of dark matter is extragalactic come from gravitational lensing observations at different scales. Looking at galactical clusters yields a higher Ω_M than that calculated from looking at individual galaxies. (This assumes a Hubble constant of $70 \text{ km s}^{-1} \text{ Mpc}^{-1}$. The error in which is small enough that for the sake of this description I will not put in h dependence explicitly.)

$\Omega_B = 0.05$ for baryons from nucleosynthesis calculations from big bang

$\Omega_L = 0.005$ observed for baryons from looking at luminous matter – stars and galaxies

So there are three main 'dark' problems:

- 1st Where is the non-luminous $\Omega=0.04$ contribution in baryons?
- 2nd Where is the non-baryonic component of Ω_M that has $\Omega=0.25$? This is the 2nd dark matter problem, and relevant to CDMS
- 3rd What is the remaining $\Omega=0.7$? Theories include 'dark energy' a quantum field with non-zero (but still finite and quite small) vacuum expectation, 'quintessence' and the famous cosmological constant Λ that Einstein introduced into his General Relativity field-equations to provide possibility for a static universe.

Cold Dark Matter

From observations of the CMB, it appears very smooth and homogeneous (fluctuations are in the order of $\sim 10\mu K$ in a 2.7 K blackbody spectrum). The fluctuations, which represents a snapshot of baryon distribution at around 150,000 years, that we do see aren't big enough to be the gravitational seed required to explain the form of the structure of the universe – matter clumping. So something has to explain why the universe matter clumped the way it did. Something must have provided a gravitation seed for matter that would have not affected the CMB fluctuations. Since the CMB fluctuations are seen from the time at which matter and radiation decoupled, anything responsible for larger mass distribution inhomogeneities would have to not couple to the electromagnetic force, but obviously would couple to gravity. A candidate would also have to be cold i.e. non-relativistic in order for large inhomogeneities to exist/persist.

Dark matter was first introduced to explain anomalies in spiral galaxy velocity curves, which implied a significant surrounding mass was present but unobserved.

Particle Physics

The idea behind supersymmetry (SUSY) is that for every half-integer spin fermion there exists an integer-spin boson, and vice versa. Interactions in this framework may conserve a quantity called R-parity, with $R=+1$ for particles and $R=-1$ for SUSY particles. In the standard model, Baryon number B and Lepton number L are conserved. In SUSY models the quantity is $R = -1^{(3B+L+2S)}$ may need to be conserved but not necessarily B or L . We have yet to see evidence of supersymmetry from particle physics experiments, and we can use this result to place a lower bound on mass limits of SUSY particles. Supersymmetry theories have been developed to explain the apparent broken symmetry of fermions and bosons, and attempt to explain the non-divergence of the Higgs mass. The presence of bosons loops cancel fermion loops in calculations that, with a symmetry breaking mechanism, lead to a finite Higgs mass.

The supersymmetric partner to the electron is the selectron, and the partner to the quark is the squark. These partners are scalar particles with 0 spin. The fermion superpartners of the B W and H electroweak bosons are the Bino, Wino and two Higgsinos, which are force eigenstates. The mass eigenstates of these superpartners are the four Neutralinos, which are neutrally electromagnetically charged. Most SUSY models predict a neutralino to be the lowest energy supersymmetric partner, or LSP. The neutralino LSP (assuming R-Parity conservation) is the candidate SUSY particle for the WIMP.

There are other possible Cold Dark Matter candidates (such as Axions), however my own space and time constraints prevent any discussion here.

2. CDMS – The Cryogenic Dark Matter search

We have two experiments, one at the Stanford Underground Facility (SUF) in Stanford, California 10.6m underground , and phase 2 (CDMSII) at Soudan, Minnesota (~1000m underground). CDMS is looking for occasion nuclear recoil events caused by the hypothetical WIMP dark matter particle. The Weakly Interacting Massive Particles (WIMPs) which CDMS are searching for, are postulated to exist with masses of around 100 GeV. The mass limits for this supposed LSP are given from accelerator physics and cosmology.

Lower limit: $M_W > 50$ GeV from LEP II not seeing supersymmetry.

Upper limit: $M_W \sim 1$ TeV, since for a WIMP > 1 TeV cosmology predicts $\Omega_m \gg 1$, which would be inconsistent with cosmological observation.

For WIMPs gravitationally confined in the Milky Way with an average velocity $v \sim 230$ km/s $\sim 10^{-3} c$ means their kinetic energy is

$$\begin{aligned} KE &= \frac{1}{2} 100 \text{ GeV} (10^{-3}c)^2 \\ &= \frac{1}{2} M_W (10^{-3}c)^2 \\ &= 50 \text{ keV} \end{aligned}$$

So for a nuclear recoil event involving a WIMP, given these assumptions, the maximum recoil would be 50 keV, for an event involving a nucleus of 100 GeV. The recoil spectrum would be like a Compton event, with a flat distribution from 0-50 keV. In CDMS we use the semiconductor germanium, which has a nuclear mass of ~ 70 GeV (actually more like 0.93 GeV per nucleon). Given the very small predicted cross-section for such an event, we would expect to only see single recoils with this profile.

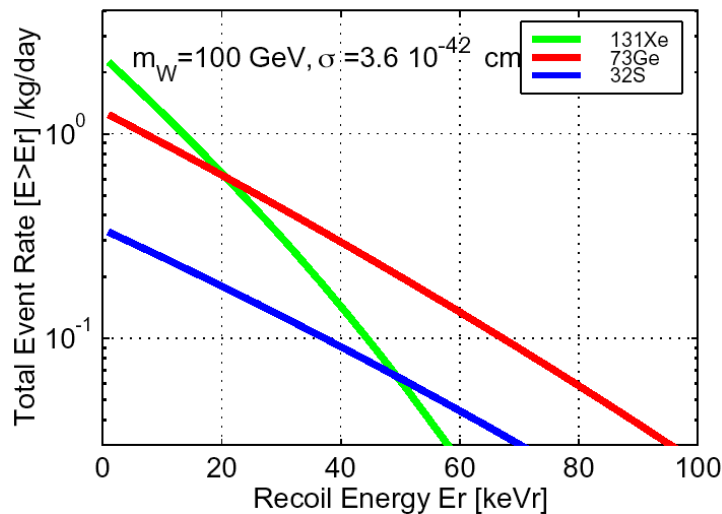


Figure 1: Plot of integral WIMP event rates against threshold recoil energy. Note that the S line (blue) is very similar to the event rate for Si (not plotted). Event rates are nucleus form-factor corrected, and apply for WIMP mass and WIMP-nucleon cross-section shown in plot.

CDMS is currently operating 6 ZIP detectors (see below) at the Stanford site. The ZIPs sit in a tower configuration within a copper housing. Surrounding this is an internal (low radioactivity) lead shield. Surrounding this is a copper cryostat, then a Polyethylene shield and then a final lead

outer shield. The cryostat (“icebox”) has layers that are cooled progressively from 4K to ~20mK at which temperature the ZIPs work at (also see below). On top of the approximately cubic 2m layered shielding sits an active-scintillator muon veto.

The goal of the shielding is to minimize the rate of interactions arising from external particle sources that can mimic nuclear recoils in the cryogenic detectors. The outer and inner lead shielding is there to attenuate external photon flux. The inner lead shield is a special old lead with low amounts of the ^{210}Pb isotope to reduce the gamma background the detectors see. The polyethylene shield is very effective at moderating and attenuating neutrons, from material surrounding the experiment and from cosmic muon interactions with the outer lead shield.

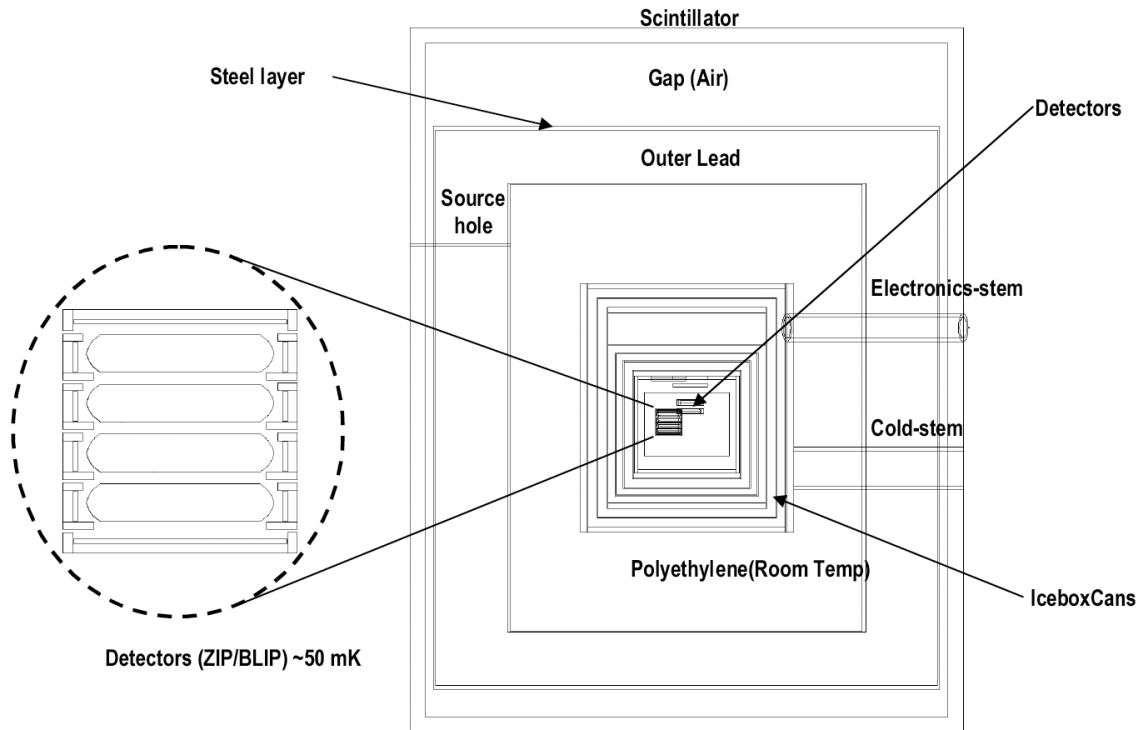


Figure 2: CDMS “icebox” Geometry.

The detectors work by measuring electron-hole pairs created from nuclear (neutron-nucleus WIMP-nucleus) or electron (electron-electron photon-electron) recoil events i.e. ionization energy, and by simultaneously determining phonon energy signals produced by particle interactions. The detectors need to be cryogenically cooled so that the phonons created are detectable above the ambient thermal phonon population.

Combining the ‘charge’ and ‘phonon’ data makes it possible to distinguish nuclear-recoil events from electron-recoil events because nuclear recoils dissipate a significantly smaller fraction of their energy into electron-hole pairs than do electron recoils. The ratio of charge to recoil energy is known as “ y ” and is normalized to 1 for electron recoil events, and ~0.3 for nuclear recoil.

The detector technology of CDMS has moved from what are known as BLIPs (Berkeley Large Ionization and Phonon) to ZIPs (Z ionization and phonons). ZIPs are 12 mm thick single crystal germanium or silicon cylinders with a diameter of 76mm.

Each of the two faces on the disc-shaped detector has an electrodes maintained at a different voltage to supply an electric field through which the electrons and holes drift. The charge-

measurement is made as the electrons and holes drift toward the electrodes. (As they drift they also produce an extra phonon population.)

The main difference between the older BLIPs and the newer ZIPs is the method by which the phonon signal is measured. Phonon production in BLIPs is determined by calorimetric temperature change measured with NTD Ge thermistors. In ZIPs, athermal phonons are collected by a complex grid pattern of phonon traps on the detector surface, used to determine both the phonon production and xy-position of the event.



Figure 3: Photograph of CDMS ZIP detectors.

Backgrounds in CDMS Detectors

There are three main competing backgrounds that give rise to a signal in CDMS that have to be discriminated against, or rejected. These are:

Gamma
Beta
Neutron

My recent research has been concentrating on understanding the surface dead layer problem that affects charge measurements, and how it influences gamma and beta rejection.

1. Gamma

One of the competing backgrounds are gammas from ^{238}U / ^{232}Th decay chains and from ^{40}Kr . An example, to give a better idea of how background goals are arrived at:

~1.0 dru (differential rate unit) in the range we are looking for WIMP interactions within: energies 5-35 keV. (1 dru is 1 event per keV per kg per day.) $1 \text{ year} * 0.25 \text{ kg} (\sim \text{mass of a ZIP}) * 1 \text{ evt/kev/kg/day} \sim 100 \text{ evts/kev}$.

This means that in a histogram of events in energy, we would see ~100 events in each 1 keV energy bin, for each detector per year.

A rejection efficiency goal for the original CDMSII experiment was 99.5%, and would give a background gamma rate of 0.5 evt/kev/year/detector. In a 30 keV range, the approximate range over we look for WIMP events (5-35 keV), the gamma background is about 15 events per year per detector. In fact, current detectors do a factor of at least 25 times better rejection than this at 99.98%, and the background at Soudan will be ~0.25 dru. This will give a background signal of less than 1 event per year. The rejection is done using the ionization potential parameter y .

The gamma rejection is limited by what is called the 'dead layer' at the surface of the detectors. In the bulk of the detector crystals, y may be accurately determined, but closer to the surface, the detectors do not have complete charge collection, which in turn reduces the calculated quantity $y = E_q/E_r$ and thus gives rise to the possibility of event misidentification.

2. Beta

Another main background is Beta electrons. There are no definite lower levels for this background as yet, and the potential sources are being studied and eliminated.

We achieve approximately 95% rejection. The dead layer poses a bigger problem in beta rejection, since the beta particles do not typically penetrate very deep into the crystal.

The new ZIP phonon detection technology helps here. Since the phonon detection is very fast (of the order of a few microseconds) information can be extracted from pulse shapes and the pulse risetime can be used to help identify beta events. Monte-Carlo simulations are also an invaluable tool for tracking down the source.

3. Neutron

At the shallow Stanford site, a significant unvetoes neutron background is expected due to neutrons produced outside the muon veto by high energy photonuclear and hadronic shower processes induced by cosmic ray muons. This limits the ultimate dark matter search performance at the shallow site. However, at Soudan current Monte Carlo simulations indicate the unvetoes neutron signal will be less than 1 event per year per (250 g Ge) detector. (0.01 events per kg per day.) All other sources of low energy neutrons are moderated by the polyethylene shielding.

I have conducted neutron modeling of source calibration signals, which is discussed in the next section.

3. Monte-Carlo and GEANT4

Why are we using MC?

Monte Carlo simulations provide an invaluable tool for detailed understanding of backgrounds in the experiment, and can be used to test hypotheses of detector and electronics response. However, in order to trust software for this kind of work, detailed validation of the simulation also needs to be conducted.

GEANT4

GEANT4 is a new object oriented Monte Carlo library package written using c++ (rather than FORTRAN that was used for GEANT3) made by CERN. It has numerous advantages over competing software (for example GEANT3, EGS and MCNC), although it is still in development at this time. Amongst the advantages relevant to non-accelerator based experiments such as CDMS are its ability to simulate low energy electromagnetic physics. It can do this accurately down to 250 eV with processes such as Compton scattering and photoelectric events, and accurate treatment of electron cascade x-ray production. Also very relevant for CDMS is GEANT4's accurate neutron physics – with, for example, inclusion of anisotropic elastic scattering cross sections, that packages such as GEANT3 don't have as standard.

Aside from the more complete physics, it has a very flexible C++ OO code structure that enables GEANT4 to be easily integrated into other code frameworks, such as integration with analysis and data representation software such as Root.

Another important tool included with GEANT4 is a module called the General Radioactive Decay Manager, that provides a radioactive source confined to volumes within the simulation, accurately simulating radioactive decay chains and their products. This will be invaluable for isolating gamma sources, and for future simulation work involving background studies and contamination.

Simulation Work

I have added numerous code improvements and customizations, such as the introduction of particle and volume dependent energy cuts for fine tuning the simulation accuracy, random number generation, batch/command line modes and integration with analysis and visualization software.

Validation Work

Since GEANT4 is a relatively new Monte Carlo, and hasn't been used in the CDMS collaboration before, significant validation of its models relevant to the low-energy physics of CDMS have been required. GEANT4 is a significant practical evolution of Monte Carlo simulations. It has been developed specifically to be used for low-energy physics and medical applications, in addition to high-energy accelerator physics.

In the course of validating the GEANT4 physics accuracy for CDMS, a number of problems were discovered by me and reported back to the GEANT4 collaboration. Amongst the more serious of those problems were:

1. Energy non-conservation in low energy electromagnetic processes with very low 'max step' values. The max step simulation parameter allows you to control the precision by specifying a maximum length of step.
2. Low energy electron back-scattering rates, overdependence on step sizes
3. Hadronic nuclear recoil elastic cross-section tables incorrect.

These problems been corrected in later versions and updates/bug patched.

Other validation simulations include multi-gamma radioactive decay and numerous low energy beta and gamma and neutron physics.

Physics Simulations Conducted in 1st Year

The physics work I have done with GEANT4 breaks into three main sections:

1. 252Cf Neutron calibration
2. 60Co Gamma Calibration
3. C14 Beta source simulation

252Cf Neutron Calibration

We performed GEANT4 based simulations of neutron source calibration runs at Stanford, firstly, to compare GEANT4 versus GEANT3 simulation of identical geometry and look for improvements in the simulation. Secondly, to study neutron background behavior in preparation for Soudan.

In order to study WIMP nuclear recoil events, a 252Cf fission source (0-6 MeV neutrons) was placed ~1m from the detectors outside the experiments shielding, on the top face of the scintillator veto. In order for the neutrons to penetrate to the detector, given the low energy of such neutrons, the top layers of polyethylene were removed. With the source and shielding in this configuration, the data set is neutron dominated, making the total event rate 3 times higher than that of low-background data-taking. The cut-efficiency is reduced because of significant event pile-up, because of the higher event rate.

This neutron calibration was done as Run19 of CDMSI at SUF with BLIP detectors. A GEANT3 simulation of the neutron calibration was carried out by others in the CDMS Monte Carlo working group, a further simulation with GEANT4 was conducted by me on the belief that GEANT4 would produce a more accurate data set. Good agreement between the Monte Carlo and real data sets is an important step in understanding the physical processes involved with CDMS that give the results we see. The full geometry of the CDMS icebox; detectors and shielding were coded into a GEANT4 simulation, and all the relevant physical processes included. The energy spectrum of the 252Cf fission source was input to GEANT4 as a source-energy histogram. The source type was set to be isotropic and confined to 2π (inward) solid angle to speed up the simulation.

Comparisons were made to the GEANT3 simulations, and significant disagreements were primarily due the lack of inclusion of angular cross-section variation in GEANT3, as was highlighted in earlier work that directly compared the neutron physics of both simulation packages. The GEANT4 data-set was normalized to the real data-set, with a source strength of 2.92×10^4 neutrons per second, and ~0.1 liveday exposure. The GEANT4 data-set was also adjusted to show only Qi events (see below), and adjusted to account for energy dependent ionization potential for nuclear recoil events). Qi (Q-inner) events are those events which only deposit significant energy within 85% of the radius of the detector. This is called the inner fiducial cut. A veto is made on events with > 2 keV deposited in the Q-outer region, that outside of the fiducial region. Electromagnetic tracking was ignored within the simulation for all volumes not 'active' volumes, i.e. everything but the BLIP detectors; the PB Poly and Cu shielding. This was done to speed-up the simulation, and preliminary analysis showed the contributions to be negligible. Useful code developed by myself for GEANT4 was used here. The code enables the ability to impose volume-dependent energy tracking-constraints for different particles. This enables a simulation to have a control of volume and particle dependent simulation accuracy not existing within the standard GEANT4 code base.

The absolute agreement between the simulation and experimental data is very good (better than 10% in the main region of interest: 0-50 keV recoil energy). However, a factor of ~ 2 disagreement between the simulations and the real data sets exists for nuclear recoil events > 50 keV. This is not understood, and may be an effect of low statistics for the real data-set. We are continuing to study this.

Within the code written to store information on events and hits (a hit is an individual energy deposition, an event is those hits corresponding to the same initial particle fired by the simulation source) using Root, code was written to store along with hit energy, the energy of the mother particle, which enabled analysis of the neutron flux entering the BLIP detectors. Preliminary analysis indicated a change in exponential slope of the neutron flux energy.

We need to carry out further neutron calibration simulations, for current runs at Stanford and future run geometry at Soudan.

60Co Gamma Calibration

The goal of this simulation is to understand more about the dead layer profile on the ZIP surface and aims to produce data that can be compared to 60Co calibration data from Run21.

A photon calibration was performed on CDMS by inserting a 60Co source through a small pluggable hole in the lead shield. 60Co emits two high energy photons at 1173 keV and 1332 keV. These photons Compton scatter in the material surrounding the detectors, resulting in a secondary photon spectrum similar to the radioactive backgrounds.

This calibration was performed in Run21 of CDMSI at SUF with ZIP detectors. A full simulation of this calibration, including all electromagnetic physics and the whole 'icebox' would be very processor intensive, it would have taken a very long time to build up significant data set for the statistical fluctuations to be made trustingly small. It was therefore decided that a number of simplifications would be made.

Previous work with GEANT3 had included a full simulation of the insertion of a 60Co source. It was decided that a simplified "inner" geometry of 3 ZIPs and a single layer of copper shielding would be sufficient for detailed studies of detector surface response.

The tower of ZIPs in CDMS has 4 Ge ZIPs and 2 Si ZIPs (the silicon forms a way of cross checking and improving confidence in candidate WIMP signals). It was decided that Z5 (ZIP 5) was to be studied, which is sandwiched between the two silicon ZIPs.

To mimic the secondary internal photon spectrum produced by the 60Co source near the detectors, as seen inside the lead and poly shielding, the previous 60Co GEANT3 work was used. Data from this previous simulation provided a gamma energy histogram that was used to set up an isotropic flux outside the copper shield of the new GEANT4 simulation. This secondary spectrum (and even the primary spectrum) isn't quite isotropic, but again, sufficient for preliminary studies. A number of simulation-specific code improvements were introduced to improve the speed and the information/data-storage ratio, due to the large amount of data that was required to be produced.

Very little simulation work on the dead-layer problem had previously been done in CDMS, and it was a challenge to present the data meaningfully in order to better understand how the efficiency profile of the surface was composed and to compare the results with the Run21 data-set.

The first method devised for initial visualization was as follows:

Each hit is characterized by an energy and depth. For optimal portrayal of energy distribution, given a large number of events, the hit data has been binned in 2D (E, Z) as follows:

For every hit:

- E = total energy for the event that hit belongs to
- Z = depth of hit in ZIP
- n = fraction of E deposited at Z by the hit

Where n is the increment of the bin corresponding to (E, Z)

This allowed first impressions of the data to be visualized and basic expectations to be checked, such as general trends and spikes, and big surprises made obvious.

However, a more useful interpretation had to be devised. Since the goal was to study the poorly understood dead-layer problem, a visual method independent of any assumed dead-layer profile was the goal.

Previous experimental work by members of CDMS on this problem had been carried out on a simplified level that gave useful results. Amongst the work that provided a method to increase the dead-layer efficiency, profiles had been calculated that showed by 30 μ m into the crystal, the dead-layer problem ceased to be much of a problem.

The following method was devised:

To parameterize the output from G4 MC we are using a revised parameter $\langle z^* \rangle$ which characterizes the average depth of energy deposition (hit contributions are energy weighted) for an event. The individual z^* values for hits are constrained to be between 0 and 30 μ m (if $z > 30\mu$ m). Data from both top and bottom surfaces are combined in the analysis.

The use of $\langle z^* \rangle$ to characterize the events allows a more natural mapping into an effective y-efficiency depth for that event. We know from the previous surface layer studies that charge collection efficiency is ~100% for events deeper than 30 μ m. To first approximation y and z^* are then linear ($< 30\mu$ m) in all but the very surface layers (few μ m). [In a final analysis one can go back and reanalyze the MC data using a specific $z(\text{hit}) \rightarrow y(\text{hit})$ function, but for the time being this approximation allows for much more rapid data analysis.]

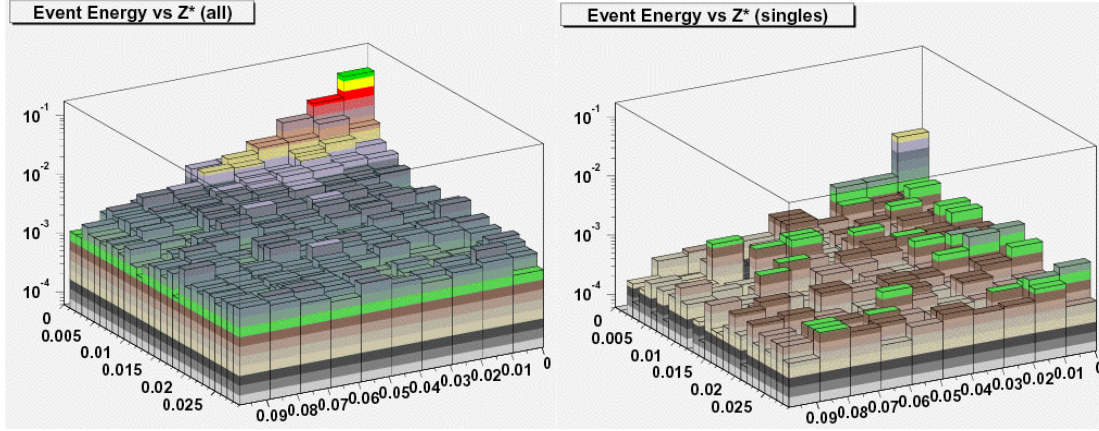


Figure 4: 2D histogram plots of $\langle z^* \rangle$ (0-29 μ m) versus event energy (0-100 keV) for multiple scatter events and single scatter events.

A larger percentage of events were being deposited preferentially at the surface than a quick calculation of a uniform gamma flux would have suggested. This is interesting and affects the problem of the dead-layer significantly.

In order to compare the simulation results with those of the real Run21 data analysis, a method was devised for creating a 'fake' y-plot. y-plots had been generated from the real data – histograms for y in narrow energy ranges. For a broad cross-section I chose to compare the three energy ranges 5-20 keV, 20-40 keV and 100-150 keV. The energy dependence on the y-efficiency profile is also poorly known. The method involved taking the $\langle z^* \rangle$ simulation data and applying a depth $\rightarrow$ y transfer function (the efficiency profile, shown on the RHS plot of Figure 5), and applying a noise model. Preliminary results show a surprisingly good agreement between real and simulated data-sets.

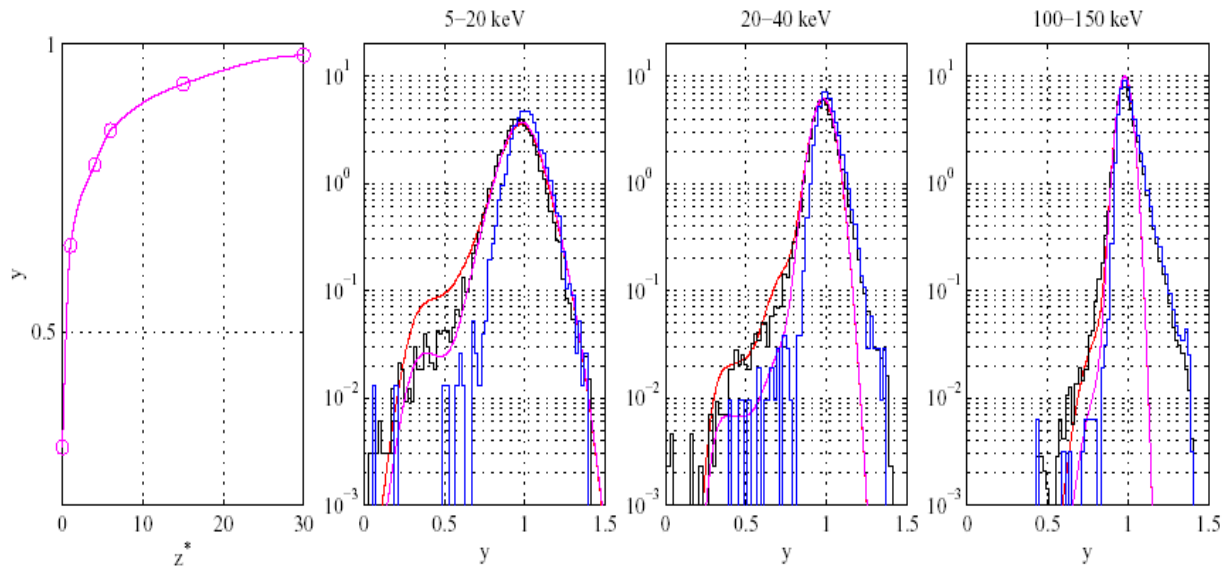


Figure 5: Histograms of simulated (red and magenta) and real (black and blue) y data-sets at three energy ranges: 5-20 keV; 20-40 keV and 100-150 keV. Single scatter events (upper lines, red and black) and multiple scatter events (lower lines, magenta and blue). Plot on far left shows $\langle z^* \rangle \rightarrow y$ transfer function.

Further simulations with higher statistics, and a reduced minimum scale size of $0.1\mu\text{m}$ (from $1\mu\text{m}$) are currently being conducted.

C14 Beta Source Simulation

We want to model expected spectra for local radioactive contaminants that emit betas. Possible local beta sources include ^3H , ^{14}C , ^{210}Bi , ^{40}K and perhaps cosmogenic Cu isotopes. CDMS Beta rejection is at least a factor of 10 worse than gamma rejection. In order to test GEANT4 reliability we simulated ^{14}C ZIP-surface contamination.

It transpired in Run 20 (at Stanford) that some of the detectors were badly contaminated with the ^{14}C radioisotope. This data provides an excellent test set to compare against Monte Carlo.

Results from this simulation gave positive results. Firstly, that the GEANT4 code is able to simulate the transport of low energy electrons to below 1 keV, including the modeling of electron back scattering. Secondly, the agreement between the Monte Carlo and data on relative rates, spectra shapes and back scatter distributions seems very good.

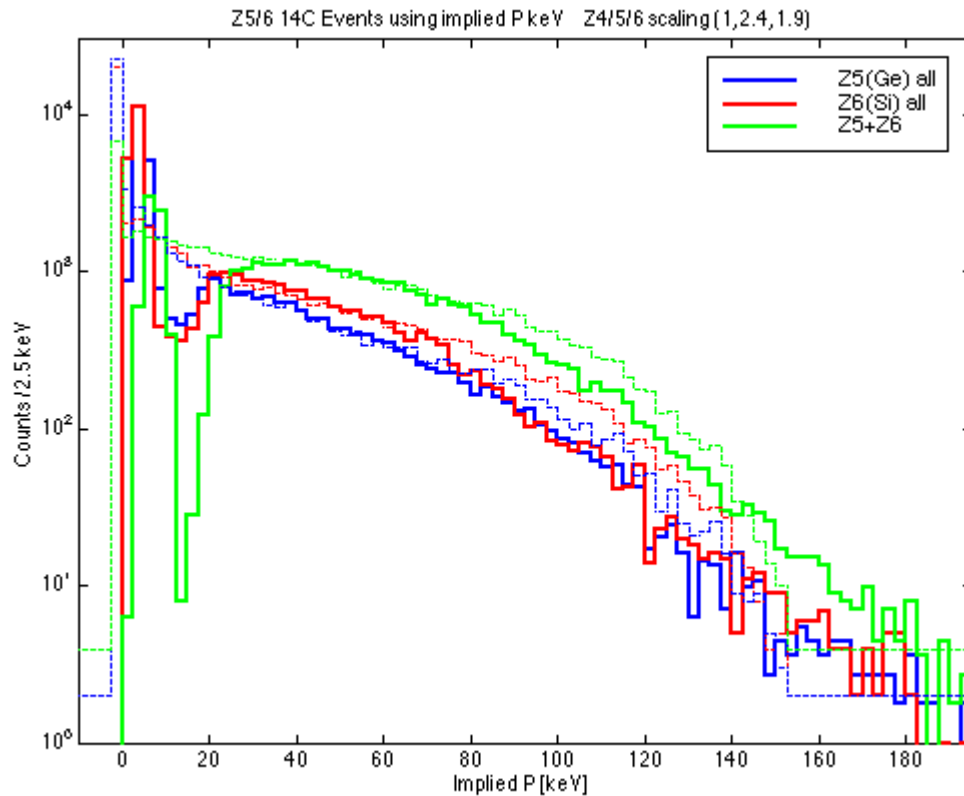


Figure 6: Histograms (solid thick lines) of ZIP5 (blue), ZIP6 (red) and ZIP5+ZIP6 (green) events in Run 20 (muon anticoincident) using implied phonon signal (after correction from original charge sum values). The data is dominated by the ^{14}C rate and so the distortion due to additional gamma rate is small. The GEANT4 simulated histograms for ^{14}C are also shown (thin dashed lines). We have not included a simulation of the charge trigger threshold in the Monte Carlo. There is slight discrepancy in the data and Monte Carlo at higher energies.

4. Future

I'll be leading the GEANT4 simulation work for the CDMSII experiment at Soudan. We will continue to focus on modeling gamma, beta and neutron backgrounds in the deep site, as well as source calibration runs. The number of detectors will grow 6 in the current experimental package to 42 in the full load.

I will address specific questions on how CDMSII at Soudan will compare to CDMSI at SUF:

1. A different cosmogenic activation environment
2. New icebox construction
3. Improved detector handling. Does it give rise to cleaner operational environment?

As mentioned in the CDMS section, we don't know where the limiting beta background sources will be located. Monte-Carlo simulations will be an invaluable tool for interpreting experimental low background data.

We also need to understand where the primary gamma (from the U/Th decay chain) sources are located in the CDMSII icebox.

The recent dead layer work is still in progress. We need to understand how the dead layer problem will affect CDMSII in Soudan when it will be operational, and see whether we can use this work to determine whether or not the rejection performance differs between detectors. The goal is for a complete model of detector response to gammas and betas. This requires Monte Carlo simulations since the detector surface response to radiation is so dependent on the source location, the source energy spectrum and type of particle.

Future plans include continued work at the Soudan site for CDMSII. This will involve practical and experimental aspects of phase II in CDMS, such as learning and applying knowledge of detector electronics and dilution fridge cryogenics to operations.

Other analysis work will involve pulse analysis of CDMS data that will be used in improving electron background event discrimination. This will be carried out on a new processor 'farm' that is being built and installed at Brown University.