Project Update 1

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» Overview

* Introduction Si HV and Hybrid detector data analysis.
* Derivation of neutrino scattering rate at MINER

Detector and data analysis

* Introduction of detector
  - -Silicon High Voltage detector
  - -Silicon Hybrid detector
* MINER data
* Data Analysis
  - -Flowchart for Reading data
  - -Examples of raw pulses from Si HV and Hybrid detector.

» Si HV detector

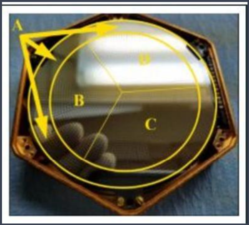


Figure: Si-HV detector with 4 phonon channels shown

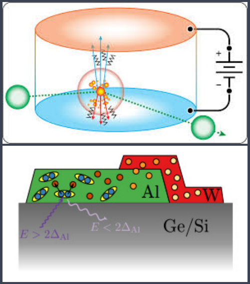
- Detector Material:^{28}Si
- Detector Dimmension: Diameter =7.6cm,Height = 1cm.
- Detector mass:100g
- Signal measured:Phonon
- No of Phonon channels:4(A,B,C,D)
- Phonon sensor madeup:Aluminium and Tungsten(Superconducting material)
- Operating temperature:40mK
- Bias voltage:125V

» Si Hybrid detector

Figure: Hybrid detector

- Detector Material: ^{28}Si
- Detector Dimmension: Diameter(bottom) =7.6cm, Diameter(top)=2.5cm, Height = 2.5cm. Side portion is at 45°.
- Detector mass: 112g
- Signal measured: Phonon
- No of Phonon channels: 5 {1 at top, 4(A,B,C,D) at bottom}
- Phonon sensor madeup: Aluminium and Tungsten(Superconducting material)
- Operating temperature: 40mK
- Bias voltage: 12V

» Working principle



1. WIMP elastically scatters of atomic nucleus creating a nuclear recoil.
2. The recoiling nucleus provide energy for the creation of $e^- h^+$ and phonons.
3. e^- move under applied electric field and release more phonons(NTL).
4. Phonons get collected at TES(Transition edge sensors).

Si HV	Hybrid
Can measure very low recoil energies	Discrimination in types of interaction

» MINER data(30 July)

Detector readout	No of events(nEvents)
Si HV(^{55}Fe)	6000
Si HV Noise	1008
Hybrid(^{241}Am)	6000
Hybrid Noise	1016

Source detail:
Si HV: ^{55}Fe(6KeV line) placed at center of B,C,D channel
Hybrid: ^{241}Am(18 KeV,14 KeV, 26.4 KeV and 60 KeV line) placed at center of top channel

» Flowchart for Reading data(Si HV)

(1) Start

(2) Read all .lvm file

(3) Read first line and obtain:
Sampling rate=col 8
No of samples(nSamples)=col 9

(4) Define 2D array pB,pC,pD
with size=nSamples$\times$nEvents

(5) Set time=[1,2,..,nSamples]
$\times$ Sampling rate

(6) Read first nSamples lines
and store: pB col 1=col 1,
pC col 1=col 2, pD col 1=col 3

(7) Draw Tgraphs(nSamples,nCh,time)

(8) Read nth nSamples lines(nth event)
and store: pB col n=col 1,
pC col n=col 2, pD col n=col 3

(9) Draw Tgraphs(nSamples,nCh,time)

(10) Repeat till all events have read.

(11) Save all tgraphs in a root file

(12) stop

» Flowchart for Reading data(Hybrid)

Repeat above process with small change in 3,4,6,8.

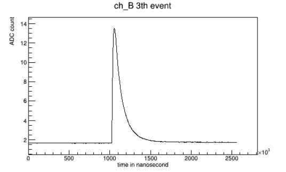
(3) Read first line and obtain:
Sampling rate=col 10
No of samples(nSamples)=col 11

(4) Define 2D array ptop,pA,pB,pC,pD
with size=nSamples$\times$nEvents

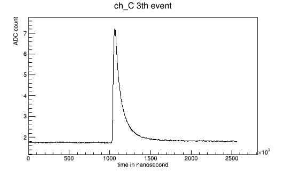
(6) Read first nSamples lines
and store: ptop col 1= col 1, pA col 1= col 2
pB col 1=col 3, pC col 1=col 4, pD col 1=col 5

(8) Read nth nSamples lines(nth event)
and store:ptop col n= col 1, pA col n= col 2
pB col n=col 1, pC col n=col 2, pD col n=col 3

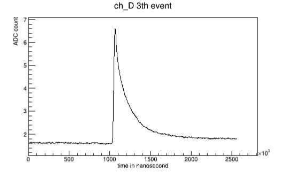
» Raw pulses in Si HV-Fe^{55}



(a) pulse in ch_B for Silicon HV

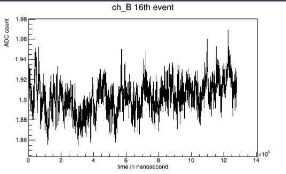


(b) pulse in ch_C for Silicon Hv

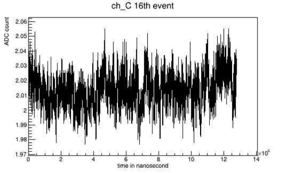


(c) pulse in ch_D for Silicon HV

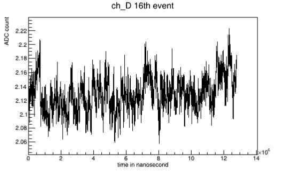
» Si HV noise



(a) pulse in ch_B for Silicon HV noise



(b) pulse in ch_C for Silicon HV noise



(c) pulse in ch_D for Silicon HV noise

» Hybrid Am^{241}

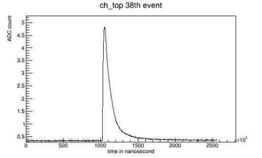


Figure: pulse in Hybrid detector at channel top

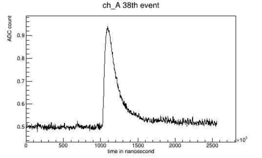


Figure: pulse in Hybrid detector at channel A

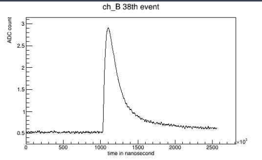


Figure: pulse in Hybrid detector at channel B

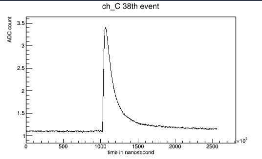


Figure: pulse in Hybrid detector at channel C

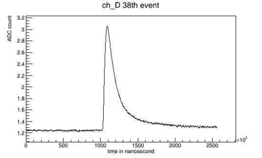


Figure: pulse in Hybrid detector at channel D

» Hybrid noise

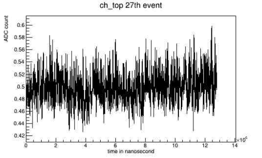


Figure: Noise in Hybrid detector at channel top

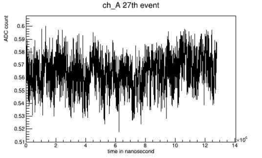


Figure: Noise in Hybrid detector at channel A

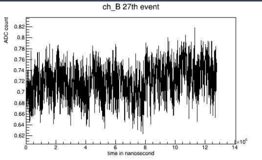


Figure: Noise in Hybrid detector at channel B

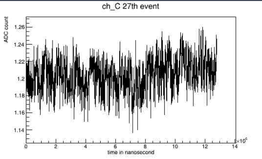


Figure: Noise in Hybrid detector at channel C

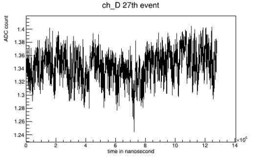
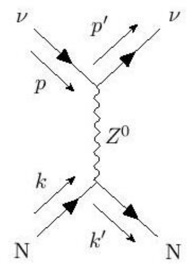


Figure: Noise in Hybrid detector at channel D

» Scattering energy and recoil energy



Find the Scattered neutrino energy in terms of incident neutrino energy(E_ν), Mass of target nucleii(M) and scattering angle(ϕ) in a coherent elastic neutrino nucleus scattering? Also find the nuclear recoil energy in this scattering?

Answer:

p=$\{E_\nu, \vec{p}\}$, where $E_\nu = |\vec{p}|$

p'=$\{E_\nu', \vec{p'}\}$, where $E_\nu = |\vec{p'}|$

k=$\{$M,0$\}$

k'=$\{E_N, \vec{k'}\}$

From four momentum conservation , we have

$$p + k = p' + k' \tag{1}$$

» Scattering energy and recoil energy

From eq-1 we get

$$E_\nu + M = E'_\nu + E_N$$
$$E_N^2 = E_\nu^2 + M^2 + E'^2_\nu + 2E_\nu M - 2E_\nu E'_\nu - 2E'_\nu M$$

and

$$\vec{p} = \vec{p'} + \vec{k'}$$
$$\Rightarrow (\vec{p} - \vec{p'})^2 = \vec{k'}^2$$
$$\Rightarrow \vec{p}^2 + \vec{p'}^2 - 2\vec{p}\cdot\vec{p'} = \vec{k'}^2$$
$$\Rightarrow E_\nu^2 + E'^2_\nu - 2E_\nu E'_\nu \cos\phi = E_N^2 - M^2$$

$$\Rightarrow \boxed{E'_\nu = \frac{E_\nu M}{M + E_\nu(1-\cos\phi)}} \quad (2)$$

Now going for Nucleus recoil energy

$$E_N = E_\nu + M - E'_\nu \quad (3)$$

Where $E_N = M + E_R$, E_R is recoil energy. Putting this value in equation-3

$$E_R = E_\nu - E'_\nu$$
$$= E_\nu - \frac{E_\nu M}{M + E_\nu(1-\cos\phi)}$$

$$\Rightarrow \boxed{E_R = \frac{E_\nu^2(1-\cos\phi)}{M + E_\nu(1-\cos\phi)}} \quad (4)$$

» Neutrino flux in detector

Find number of neutrino in detector per unit area per sec? Also find the number of neutrino nucleus elastic scattering inside the detector?
Power of the reactor is $1MW$.
Average energy released per fission 200 MeV.
Number of fission per sec is $1MW/200MeV = \frac{1}{3.2} \times 10^{17}$.
Neutrino released per fission is 6[2],
So total number of neutrino released per sec$= \frac{1}{3.2} \times 10^{17} \times 6 = 1.875 \times 10^{17}$.

Assuming neutrinos are released isotropically,
number of neutrino per unit area per sec at 2 meter from reactor center is $1.875 \times 10^{17}/4\pi r^2 = \boxed{3.73 \times 10^{11} \text{neutrinos}/cm^2/sec}$

» No of $CE\nu NS$ in detector

Scattering cross section of silicon is $7.4 \times 10^{-42} cm^2$[1]
No of silicon atom in $100g$ detector
$= 100/28 \times 6.023 \times 10^{23} = 2.15 \times 10^{24}$.
Total cross-sectional area for $100g$ detector
$= 2.15 \times 10^{24} \times 7.4 \times 10^{-42} cm^2 = 15.95 \times 10^{-18} cm^2$
Number of neutrino striking in this cross-section
$= 3.73 \times 10^{11} \times 15.95 \times 10^{-18}/sec = 5.95 \times 10^{-6}/sec = \boxed{0.488/day}$

» References

1. "Toward Single electron resolution, large mass detector for DM,CENNS",by"Nader Mirabolfathi",Page-6.
2. "Physics with reactor neutrinos", by "Xin qian", "Jen-Cheih peng", Page-5