Verifying A Positive Signal in Direct Detection

As our background suppression gets ever and ever more heroic....
(already practically unbelievable).

Any detector–at some level– will have *some* "unexplained" events.

Background....Noise,....Spirits...Alcoholic Spirits...
Wishful Thinking??

Desperate search for as yet unsuspected backgounds will ensue.

Will probably find some.

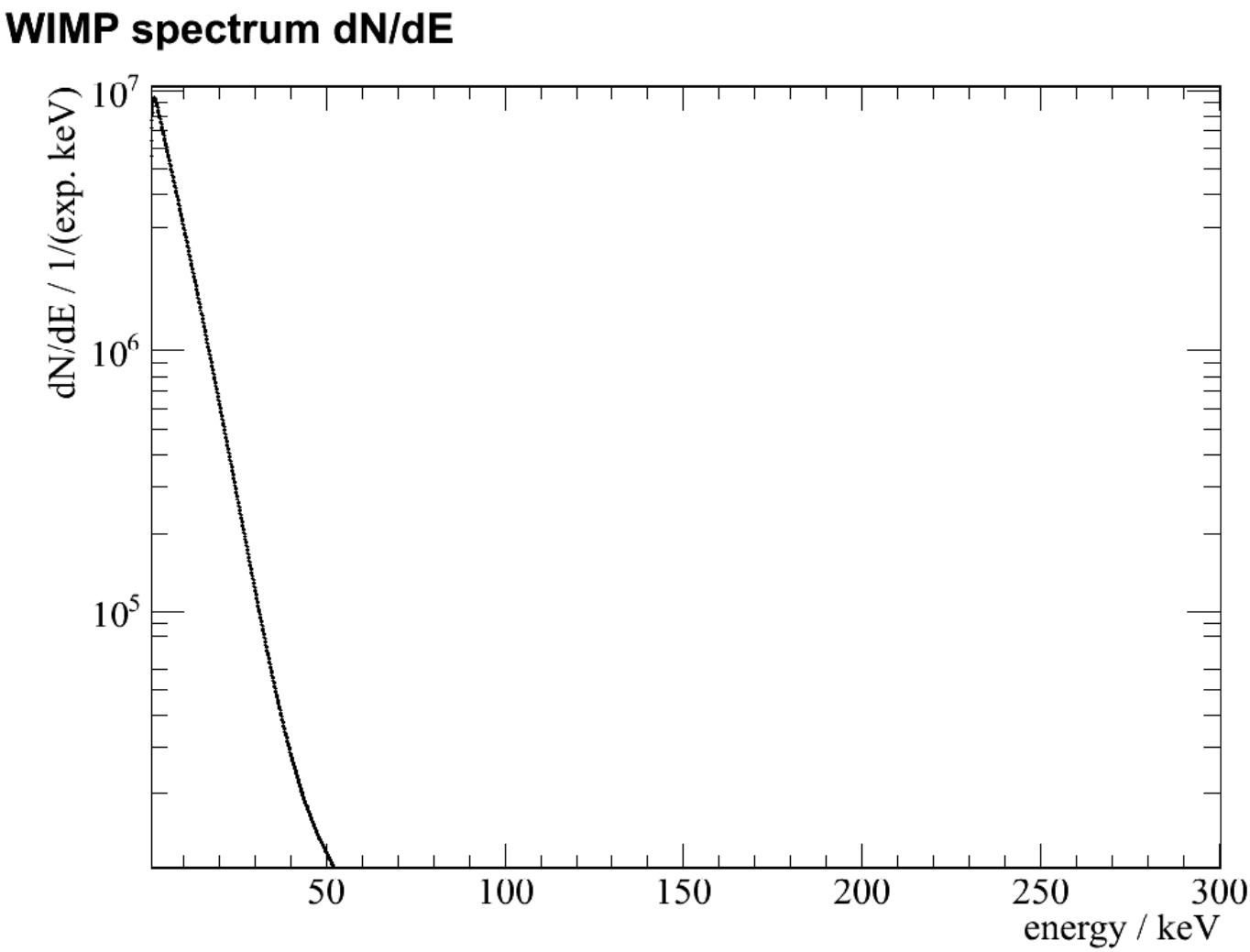
Or MAYBE indeed it is a WIMP!!!??

Would be VERY good to have some characteristic feature(s) of a WIMP signal

- Not also present for some background

- Not involving some a poriori assumptions like A^2,... details of WIMP spectrum,...

Ideally we would like to see



$M_{wimp} = 50$ GeV, $CaWO_4$

But In this beautiful curve we have

1)no bkgnd

2) perfect energy resolution

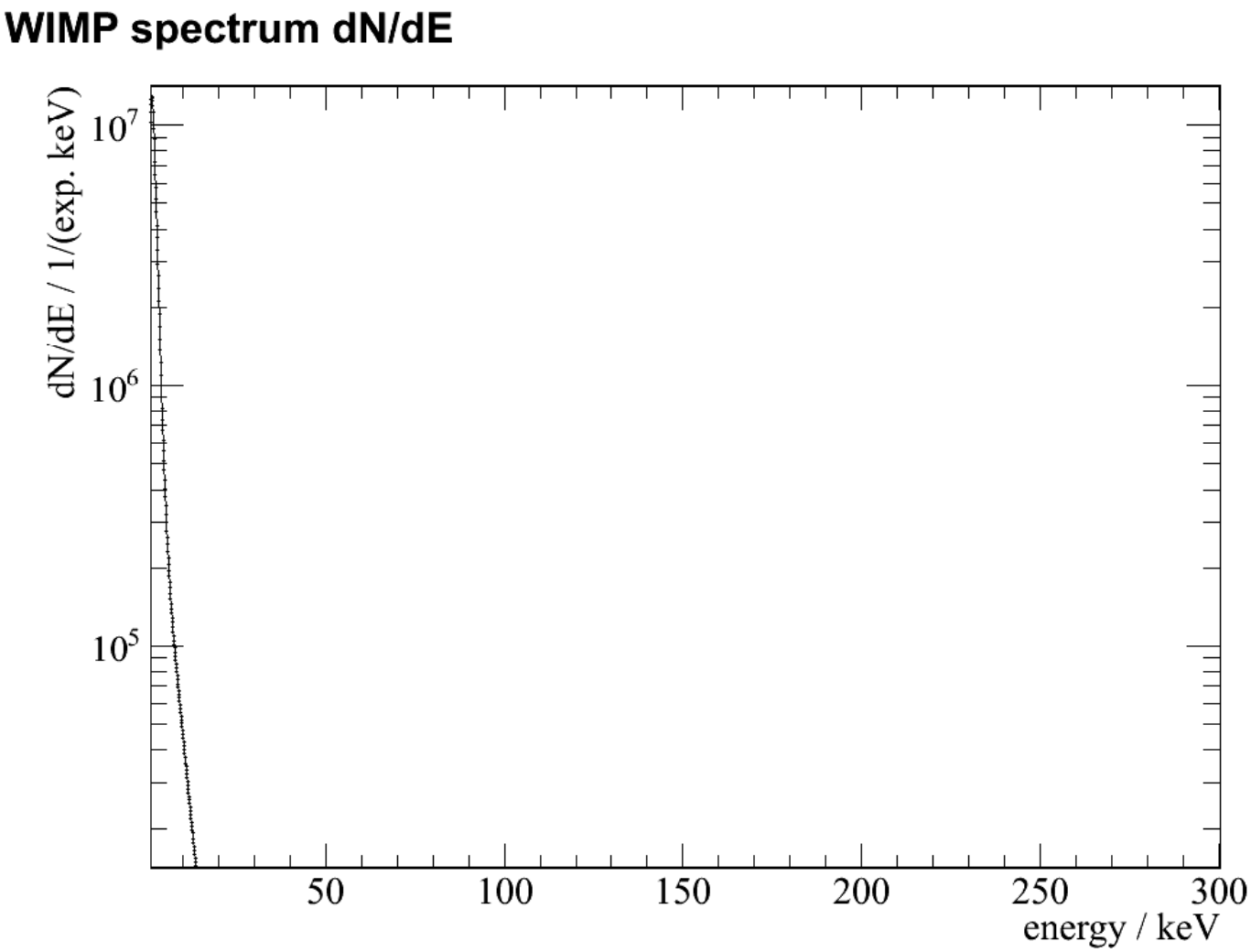
3) no (very low) energy threshold

(Note: almost all events below $\sim 20keV$)

4) more than a few events

Can we come even close to these requirements?

Energy threshold and energy resolution
more difficult with lighter WIMPs



$M_{wimp} = 10$ GeV, $CaWO_4$

(almost all events below $\sim 5keV$)

Low energy for WIMP because in the galaxy we talk about *velocity* (not energy).

$M_{wimp} = 10$ GeV, $v = 2 \times 10^{-3}$,

$E_{wimp} = \frac{1}{2} m v^2 \approx 20\, keV$

A further worry....

Many,– most– backgrounds peak at low energy

Look like WIMPs

Fast Neutrons

Elastic scattering diffraction peak
(nuclear optical model)

$\Delta R \sim 1$, so $E_{recoil} = \Delta^2/2M_A \approx (1/R)^2/2M_A$

Low recoil energy peak at energy

$E_R^o = \frac{1}{R^2} \times \frac{1}{2M_A} \approx \frac{10}{A^{5/3}} MeV$

Ranges 100 keV (oxygen) to 1.7 keV (tungsten)...right in the region of WIMP-induced recoils

$Element$	A	R(fermi)	$E_R^o(keV)$
O	16	3.5	98
F	19	3.7	74
Na	23	4.0	54
Si	28	4.2	39
Ar	40	4.8	21
Ca	40	4.8	21
Ge	74	5.9	7.7
I	127	7.0	3.1
Xe	132	7.1	2.9
W	184	7.9	1.7

But there is a way

Correct behavior when varying target nucleus

We can change the target but the 'beam' is the same

$\rightarrow$ simple behavior wrt nucleus

A general background unlikely to behave this way.

NOTE:

Not absolute rate—this can vary w WIMP Q nos.

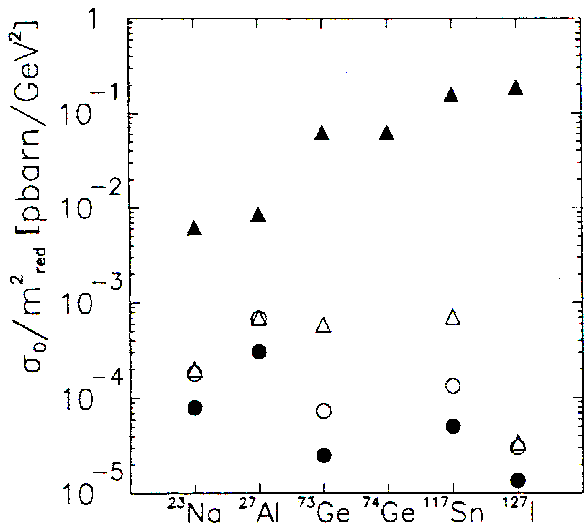


Figure 24: Cross section σ_0 (SI+SD) normalized to the reduced mass squared for different materials and neutralino compositions. Solid triangles: zino-higgsino mixture with 40% zino composition. Open triangles: pure higgsino. Solid circles: pure bino. Open circles: pure photino. The cross sections are calculated for set B with $\tan\beta$=2, M_A=50 GeV and $\alpha = -1.24$. As can be seen in Fig. 4, zino-higgsino mixtures and pure higgsinos are cosmologically relevant above ~20 GeV, while binos and photinos are cosmologically relevant above ~2 GeV (without grand unification constraints).

(Gabutti, et al. Astropart. Phys. **6**, 1,(1996))

(Indeed is a way of finding WIMP Q nos.)

Rather, *recoil spectrum*

Should see correct radius of nucleus.

Remark on coherent scattering:

Even with coherent $\sim A^2$ interaction, Rate is not $\sim A^2$.

Forward peak shrinks with inreasing radius:
form factor $F((\Delta R)^2)$

Integral over peak $A^2 \int F d\Delta^2 = A^2/R^2 \sim A^{4/3}$

Would need to see $\Delta \approx 0$ for A^2 behavior
(very good energy resolution)

Furthermore

For E_{wimp} not large but rather comparable to E_{recoil} there will be a cutoff in recoil spectrum towards E_{wimp} .

Thus for light WIMPs higher recoils come from hi velocity tail of the spectrum.

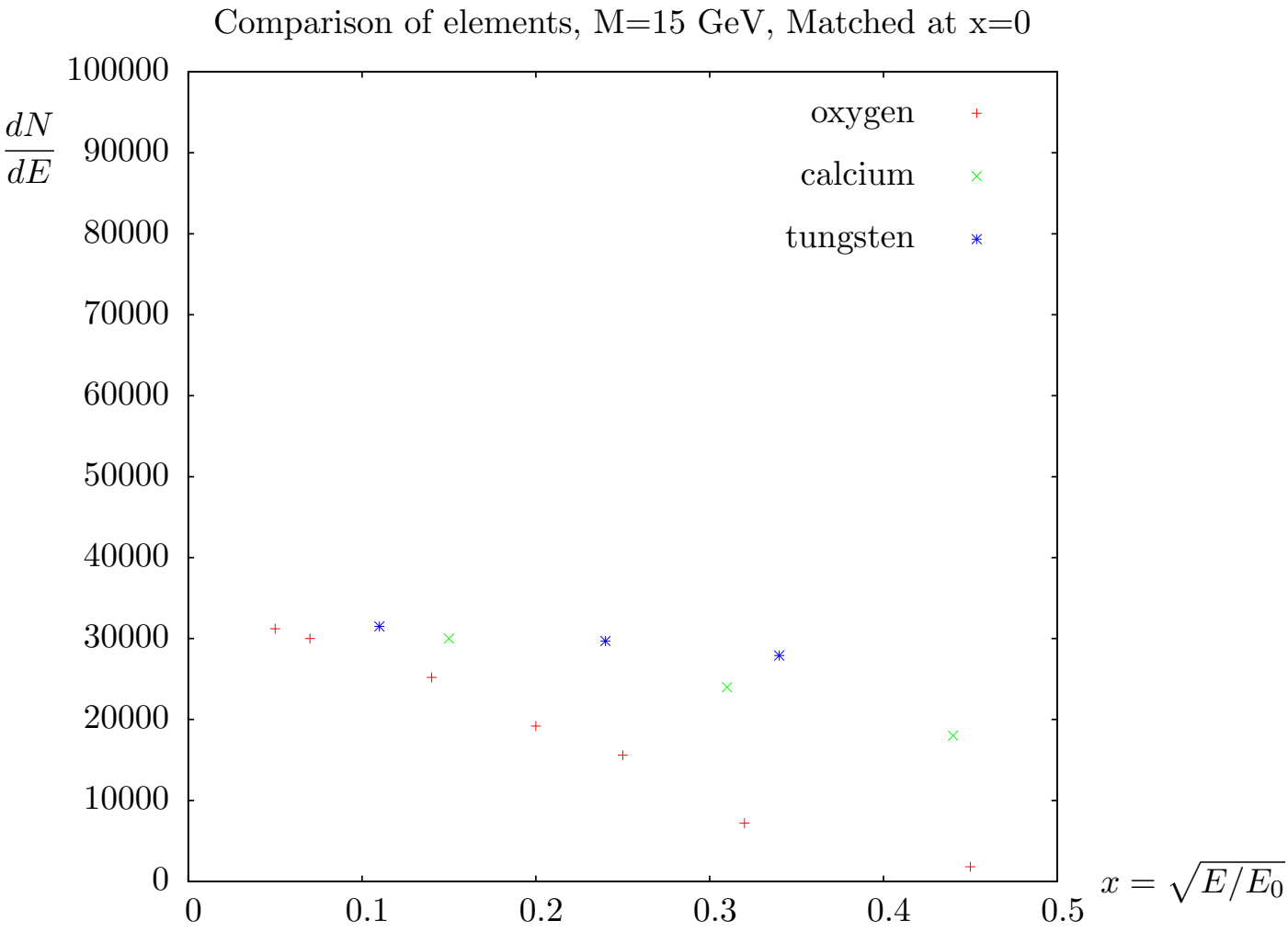
For light WIMPs shape of recoil spectrum also reflects velocity spectrum of WIMPs.

This effect becomes negligible if

$E_{recoil} << \frac{1}{2} M_{wimp} v^2$

In this case expect universal shape of recoil spectrum when plotted vs ΔR

All this illustrated in plot:



Variable $\sqrt{E/E_o}$ is ΔR
(E_o from table above)

Ca and W universal, Oxygen nucleus is light and so high recoil energy, comparable to WIMP energy

A data plot like this would be rather convincing

Also for neutron background

Diffraction scattering has characteristic A behavior
Different from WIMPs

Element	*A*	neutron E_R =20 keV	neutron E_R =30 keV	WIMP M=10 GeV	WIMP M=50 GeV
O	16	1	1	1	1
F	19	1.5	1.5	1.3	1.8
Na	23	2.2	2.2	1.6	3.3
Si	28	3.4	3.3	1.8	6.7
Ar	40	7.0	6.4	1.1	19
Ca	40	7.0	6.4	1.1	19
Ge	74	19	13	~ 0	93
I	127	20	5.1	~ 0	200
Xe	132	18	3.9	~ 0	240
W	184	2.6	1.6	~ 0	230

Table 3: Variation of the differential scattering rate per unit energy over various nuclei in the 'black disc' limit, Eq 11, at E_R =20 keV and E_R =30 keV. For comparison the same rate for a coherently scattering WIMP at $E_R = 20\,keV$ for masses 10 and 50 GeV is also shown. One notes different patterns of A behavior for neutrons and WIMPs. All values are per nucleus and normalized to that for oxygen.

(Leo, Astropart. Phys **35** 114 (2011))

Another reason to compare different nuclei

Convincing signal in direct detection

- Peaks at low recoil energy,

- Recoil spectrum varies correctly with nucleus

Additionally, nice if

- Varies with season correctly
(southern hemisphere detector?)

- Correct directional behavior
(if such detectors practical)

Some side comments

on Indirect Detection

Photons from space:

Circular polarization would show origin in weak interactions. Interesting expt'l problem.

Hi E neutrinos from Sun, Earth, would be very suggestive

Accelerators can suggest but not find DM