Neutrino

Coherent Scattering:

Astrophysics

νTechnology

Fantasy

Elementary prediction of the Electro-weak Standard Model: Coulomb or Rutherford scattering with 'weak charges'

But after 40 years still not observed in the lab.

Coherence: Add amplitudes before squaring

Find $f^A \sim N - Z(1 - 4sin^2\theta_W)$.
So with $sin^2\theta_W \approx 1/4$

Nuclear elastic scattering amplitude $f^A \sim N$

$$\sigma^{elastic} \sim N^2$$

Astrophysics

Core collapse Super Novas
'de-leptonization' $e^- p \to n\nu$

ν trapping in collapse phase:

ν's do not stream out immediately
Big cross section of $\nu + Fe \to \nu + Fe$ leads to formation of 'neutrinosphere '.

Energetics, time scale, of SN 1987a in terms of observed neutrinos at earth seems to be roughly OK

Would be quite different if ν's escaped immediately

Flavor independence

Coherent scattering is via Z^o exchange and the weak doublets $(e, \nu_e), (\mu, \nu_\mu), (\tau, \nu_\tau)$ all look the same to the Z^o

Expect $\sigma(\nu_e), \sigma(\nu_\mu), \sigma(\nu_\tau)$ 1:1:1 for coherent scattering. Would be quite interesting if strongly violated.

Interesting for theory and for

ν oscillation effects in matter

MSW, earth oscillations, depend on flavor dependence of the ν index of refraction $n(\nu_e) - n(\nu_{mu}), ...$ At present this variation is believed to be only due to the electrons in matter (W exchange possible).

$n = 1 + \rho \frac{2\pi}{p^2} f^o$

Presently believed coherence means

$f^o_A \sim N$, same for all ν flavors. So cancels in oscillation effects. But if a significant flavor dependence of coherent f^o_A, would be important for ν oscillation effects in matter.

Tests of flavor independence interesting

Of course expect

Small, –percent level– radiative corrections in SM, flavor independence no longer true.

$\sigma(v_e) : \sigma(v_\mu) : \sigma(\nu_\tau); 1 : 1.04 : 1.06$ (for Z=N nuclei), see (1). In any case would be interesting to see, Too small to measure in direct expts?

And for radiative corrections to index of refraction see (2)

Unexplored corner of the Standard Model–window on new physics?

Neutrino Technology

The promise of a light-weight, perhaps mobile, ν detector

TABLE IX. As in Tables VII and VIII, some sample configurations for a reactor experiment, with a flux of 10^{13} cm^2/sec, and the ILL spectrum.

T (mK)	Material	R (μm)	E_{TH} (eV)	Rate 1 [(kg day)$^{-1}$]	Rate 2 [(kg day)$^{-1}$]
50	Ge(Ga)	4.5	20	160	150
50	Ge(Ga)	10	100	77	56
50	Sn	4.1	100	84	50
50	Pb	2.1	20	380	320
50	Pb	3.6	100	75	42
400	Ge(Ga)	3.5	100	77	56
400	Pb	1.7	100	75	42

From (3)

Inspired our patent application of 1982 (EP 0 102 398 B1)

30. The use of a neutrino detector in accordance with one of the preceding claims 28 or 29 wherein the total mass of the detecting material is at least one hundred kilograms and wherein the measured flux of neutrinos is used for dynamic analysis of reactor performance.

31. The use of a neutrino detector in accordance with any one of the preceding claims 28 to 30 wherein the total mass of the detecting materials is larger than 1000 kgs and wherein the detector is either divided into several modules or is arranged for movement around the reactor core for tomographic reconstruction of the location of fission products inside the reactor core.

32. The use of a neutrino detector operating in accordance with the method of one of the preceding claims 1 to 11 or a neutrino detector in accordance with one of the preceding claims 12 to 27 for monitoring installations for the storage and/or processing of radioactive materials.

33. The use of a neutrino detector operating in accordance with the method of claims 1 to 11 or a neutrino detector in accordance with claims 12 to 27, for studying the geological structure of the earth through the neutrino signature of radioactive elements.

34. The use of a neutrino detector in accordance with claim 33 for at least one of the following purposes: for detecting raw material deposits in the earth, for detecting deposits of one or more of the naturally radioactive elements, in particular K 40, U 238, U 235 and thorium, for detecting raw material resources which are found in association with one or more radioactive elements, for detecting deposits of materials with lower than average neutrino activity, in particular oil, gas and coal deposits, and for finding additional deposits of raw materials in existing mines from the neutrino signature of these deposits; wherein the neutrino detector is arranged for movement in mine shafts and tunnels, said neutrino detector being preferably either mounted, towed or suspended for geological prospecting beneath the oceans, seas or lakes or appropriately shielded and transported by a movable vehicle for above ground prospecting.

Revendications

1. Procédé pour la détection de neutrinos comprenant les étapes consistant à: exposer un détecteur à un environnement afin de permettre à tout neutrino présent de diffuser sur les noyaux du détecteur, et à analyser les signaux fournis par le détecteur pour distinguer entre le recul d'un seul noyau et les autres interactions dans lesquelles une pluralité d'électrons et/ou de noyaux reculent, et d'accepter le signal comme compte-neutrino seulement s'il y avait recul d'un seul noyau .

2. Procédé selon la revendication 1 caractérisé en ce que les signaux d'une pluralité de volumes du détecteur sont analysés et en ce que ledit compte-neutrino n'est augmenté que s'il y a recul d'un seul noyau dans l'un desdits volumes.

3. Procédé selon l'une des revendications précedentes 1 et 2 caractérisé en ce que lesdits noyaux sont présents comme les noyaux d'une pluralité d'éléments métalliques supraconducteurs, par exemple sous forme de grains, de fils ou de couches minces, et en ce que l'étape de la détection du recul du noyau est effectuée par la détection de l'échauffement et du changement d'état y faisant suite de l'un des éléments métalliques supraconducteurs.

4. Procédé selon la revendication 3 caractérisé en ce que lesdits éléments métalliques supraconducteurs ne sont pas dans l'état surchauffé et comprenant de plus les étapes consistant á observer le temps nécessaire pour que ledit élément métallique supraconducteur revienne à l'état supraconducteur à comparer ce temps avec une plage de temps caractéristiques et d'accepter le compte-neutrino seulement quand ledit temps tombe dans ladite plage de temps.

5. Procédé selon l'une des revendications 3 ou 4 caractérisé en ce que lesdits éléments métalliques supraconducteurs sont chacun très petits dans au moins une dimension et sont distribués dans une pluralité de volumes, et en ce que au moins un corps supraconducteur relativement massif est présent dans chaque volume, le procédé de plus comprenant les étapes consistant à détecter les changements d'état desdits corps supraconducteurs relativement massifs comme mesure de l'instabilité de la température locale dans les volumes associés et à rejeter d'autres signaux provenant du volume

- Reactor monitoring
- Geological exploration

Mobility would allow tomography of reactor accident sites, oil bearing formations...

Difficulties:

- Not at a reactor–rates lower than in table

- Backgrounds:

Solar ν's (since Coh. Scat. sees ν,$\bar{\nu}$ equally)
Whole earth $\bar{\nu}$'s. But perhaps local variations detectable

Need studies of possible ν signal of interesting geological formations.

Fantasy

Extragalactic Neutrino Burst Detector (see 4)

Consider SN rates from different distances

Milky Way	Starburst Galaxies	Virgo Cluster
10 kpc	4 Mpc	10 Mpc
1/100 yrs	1/1 yr	1/wk

Defining a ‘ good event’ as 100 scatters in one sec, with coherent scattering one needs

10 kpc	4 Mpc	10 Mpc
10 Tons	1.6 MT	10MT

Not unthinkable

Main problem:

Background: 100 evts in 1 sec quite possible with MT's of ordinary material

For only one false SN per year need high purity:

4 Mpc	12 Mpc
1.6 MT	10 MT
10^{-2}kg/day	10^{-3}kg/day

So need MT's of purified material...prohibitive?

BUT

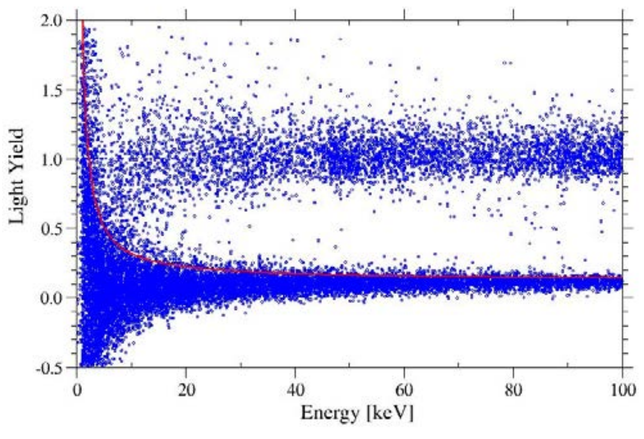
Two-channel readout

A new development in last decade with Dark Matter detectors.

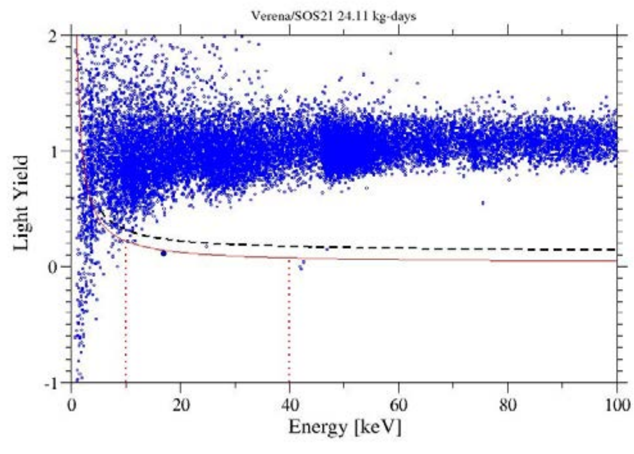
One is looking for nuclear recoils, main backgrounds are e, γ's

But e, γ's can be distinguished: e.g. by high light or ionization output, pulse shape, timing ...

In CRESST we use scintillation light



With neutron source



Without neutron source

From (5)

This and similiar 2-channel separations are working down to $E_{recoil} \sim few\, keV$. Can this or others work down to 10's or 100's of eV?.

But note: SN ν (30 MeV) lead to recoils(3) like that in present DM work

If so great benefits :

- Purity requirements for Extragalactic Detector greatly reduced

- For mobile detector applications, intrinsic background rejection reduces shielding needed

For any of these real or fantasy ideas,

Verification and study of Coherent Scattering is needed.

If possible with internal background rejection, as with the 2-channel method.

Good LUCK

References

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