Norton Nabs a ν: On the occasion of the 100th birthday of Dr Seuss

Canto I: Golly, golly, Dr Pauli *(ca. 1927)*

Some scientists working on nuclear breakup
Saw something that gave all their theories a shake-up.
"These beta-producers defy explanation!
They're showing us energy non-conservation!"

Another researcher, a theorist named Pauli
Remarked, "I have solved it! Eureka, by golly!
You think these decays to be just bifurcation –
But trios are really the split situation!
The nucleus doesn't just spit out a beta,
A 'ghost' comes out, too – this will fix up your data!
'But where's the third piece?' I can hear you protesting,
'We've looked, we saw nothing!' Here's what I'm suggesting:
A new sort of beastie – aloof and elusive,
Both chargeless and massless, it's downright reclusive!
It zips through detectors; your catchers all miss it!
It carries the leftover energy with it!"

So people agreed to accept this new thingy,
Though extra ghost particles seemed a bit ding-y.
Quipped Fermi, "How should we denote this bambino?
It's little! It's neutral! Let's call it neutrino!"

Canto II: Norton Nabs a ν *(ca. 1956)*

For thirty-odd years, that was status neutrino:
No hits and no runs – they remained quite unseen-o.
Fred Reines and colleague Clyde Cowan decided
To search for these particles, as yet unsighted.
Two things were required to catch sight of these specters:
A copious source and a large-scale detector.

So Cowan and Reines concocted a plan which
Used stacked photon-catchers – a strange sort of sandwich.
To glimpse a clear footprint that all would believe,
They needed a hallmark that only ν's leave.

Neutrinos that chance to collide with a proton,
Will alter, by putting a positive coat on,
Becoming an anti-electron, then turning
The proton to neutron. Quite simple? You're learning…

So how can you tell if a hit really happened?
The signal's distinctive – here's how you can tap in:
The anti-electron's a time-bomb unfailing --
E-plus plus e-minus makes photons go sailing.
The neutron will wander, then find a new home,
And out some additional photons will come.
These light-bursts together – a marker so clear:
It's as if the neutrino had yelled out, "I'm here!"

The source of neutrinos: a new and quite nifty
Reactor (recall this took place in the Fifties!).
For nuclear plants would appear to shine bright
If your eyes saw neutrinos instead of just light.

They built their detector beneath the reactor
And looked for a year, and cross-checked all the factors.
At last they announced it: no smoke and no mirr-ahs:
Neutrinos no longer were Pauli's chimeras.

Canto III: One neutrino, two neutrino, e neutrino, μ neutrino, I *(ca. 1960)*

Consider the curious puzzler, the muon:
It undergoes beta decay, not to two-ons
But three: one electron, and two tiny zipster
Neutrinos, and here's the anomaly, hipsters:
You start with a μ ; it decays to an e,
Which means you've two diff'rent neutrinos, you see:
Paired up with the e, you get one ANTI-ν
Another neutrino is left from the μ.

Oh, my! Here's a ν with an anti! You say:
Why don't they make photons and vanish away?
But wait: we don't get this! No muons we see
Have ever decayed into γ plus e.

We solve it, by seeing what does and what doesn't:
We say: these aren't opposites – just, sort of, cousins…

For Nature, constructing the particle zoo,
Built separate compartments for e and for μ.
The muon decays to an anti- ν_e
And standard ν_μ, and electron, you see.
Neutrinos, type μ, simply will not combine
With antineutrinos that come in e kind.

The kind of neutrinos we shoot at detectors
Determines the stuff that collects in collectors.
Electron neutrinos react to make e's
And muon neutrinos make μ's, Q.E.D.

Canto IV: One neutrino, two neutrino, e neutrino, μ neutrino, II *(ca. 1998)*

Our theory of how the world worked said, "ν_e's
Should stay as ν_e's, and ν_μ's, if you please,
Should stay as ν_μ's" -- which sounds simple and stable,
But Nature puts something quite else on the table.
Neutrinos aren't massless, as once we had thought.
"Just how do you know that?" (We get that a lot.)
To "weigh" a neutrino requires application
Of something quite strange that's been dubbed "oscillation."

A stream of neutrinos – ν_μ's, let us say
Starts out on a trip from point I to point J
If asked at point I, all neutrinos would chime:
"We're muon neutrinos at this point in time;
But as from point I to point J we go zappin',
A quirky and quantum effect might just happen.
By quantum mechanical rules, we behave:
A particle sometimes can act like a wave!"
How far does the wave stretch? The length, crest to crest,
Is set by the particle's mass, when at rest.
And waves interfere as they travel through space,
They add and subtract if they get out of phase.
Neutrinos do, too, if you get what I mean --
They're made of components, they're not quite pristine.
Let's say that the thing that we've named as ν_μ
Is made of two pieces: ν_1 and ν_2.
(I know what it sounds like – you don't smell a rat!
This isn't just cadged from *The Cat in the Hat*!)

They started their travels, ν_1 and ν_2,
Combined to comprise each initial ν_μ.
Remember, however, these two pieces' masses
Are not quite the same, so as travel time passes
The waves, as they're waving, wave one and wave two,
Move out of the pattern that made a ν_μ!
But after a few ups and downings have darted
The waves will wave back to the way that they started.

So what does this mean? This combined undulation
Explains the phenomenon called oscillation.
You start with ν_μ's at initial point I,
Off zipping they go; if you stop to say, "Hi"
Downstream at point J, where you placed your detector,
Some distance away from the ν_μ projector,
You'll find, if you ask, "Hey, neutrinos! Are you
Neutrinos type e? Or neutrinos type μ?'
A tiny percentage have altered their stripe –
They were of type μ, but are now of e type!
The way that this sort of effect comes to pass
Can "weigh" a neutrino, determine its mass.

Coda

Neutrinos have come a long way since Herr Pauli
Set physicists off on this particle trolley.
Neutrinos illumine how nuclei work,
How suns start to shine, what odd mysteries lurk
Inside neutron stars, and much other fun stuff –
It seems that they just cannot teach us enough!

Stay tuned! There are puzzles unsolved yet remaining,
More knots for untying, results for obtaining.
And thanks for perusing these verses abstruse:
Where Mr Neutrino has met Dr Seuss!