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Colloquia: The Legacy of Bruno Pontecorvo

Bruno Pontecorvo's legacy: Radiochemical solar neutrino detection and neutrino oscillations

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Summary. — This talk is a rather subjective personal reminiscence on how my own work in neutrino physics was influenced by the ground-breaking ideas and anticipations of Bruno Pontecorvo.

1. – Inverse beta decay

"The experimental observation of an inverse beta process produced by neutrinos is not out of the question with the modern experimental facilities."

"The radioactivity of the produced nucleus (in: $\nu_e + Z \rightarrow (Z+1) + \beta^-$) may be looked for as proof of the inverse process.

"The nucleus produced in inverse β transformations must be radioactive with a period of at least one day, because of the long time involved in the separation."

"The experiment with Chlorine, for example, would consist in irradiating with neutrinos a large volume of Chlorine or Carbon Tetrachloride, for a time of the order of one month, and extracting the radioactive Ar^{37}."

These statements [B. Pontecorvo 1946 (Chalk River Report PD-205)] contain already all the basic elements for the later successful story of the radiochemical solar neutrino detection method that earned Ray Davis the Physics Nobel Prize in 2002. They stem from 1946!

2. – Solar neutrinos

The Homestake Chlorine Solar Neutrino Experiment of R. Davis detected only at a level of $\sim 1/3$ of what was expected from the Standard Solar Model (SSM) *viz*, the 'Solar Neutrino Problem' (SNP).

The deficit could be caused by deviations due to an incomplete or false description of the solar interior by the SSM ('astrophysical solution of the SNP') or by non-standard neutrino properties: 'particle physics solution of the SNP' like, *e.g.* non-zero neutrino mass at the root of neutrino flavor oscillations.

For *pp*-neutrinos, the astrophysical solution can be ruled out since their flux at origin is directly fixed to the solar luminosity which is well known; *pp*-neutrinos are by far the most abundant solar neutrinos, yet their energy is very low (< 420 keV). This demands a detection reaction with very low threshold. The only practical option is $Ga^{71}(\nu, e^-)$ Ge^{71}.

The Gallex experiment, a big technological challenge, was the solution.

After 12 years of GALLEX and GNO data taking, the combined result became 69.3 ± 5.5 Solar Neutrino Units (SNU) [*Physics Letters B*, **616** (2005) 174-190] compared with a SSM expectation of 125 ± 8 SNU.

A suppression of *pp*-neutrinos due to neutrino mass is an inescapable consequence.

Together with the results from the Homestake and Kamiokande experiments, mixing parameters can be deduced quantitatively.

3. – ν-flavour oscillations

Also the concept of neutrino oscillations as a consequence of neutrino mass goes back to B. Pontecorvo. If masses are very small, oscillation lengths become astronomical. This is unique for solar neutrinos (high flux from great distance).

Results from solar neutrinos together with results from high energy atmospheric neutrinos (Superkamiokande experiment) led to a rather clear determination of neutrino masses and mixing angles.

In 1968 Bruno Pontecorvo suggested to search for evidence of non-zero neutrino masses via the experimental detection of Double Beta Decay of tellurium isotopes (Te^{130}, Te^{128}) decaying to (Xe^{130}, Xe^{128}) without neutrino emission (Majorana Decay).