Metal-beta-diketone Scintillators for Neutrino Experiments
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Metal loaded scintillators in neutrino physics

Solar neutrinos
Reaction: $\nu_e + X \rightarrow e^- + e^+ + X$
Specs: low Q-value, metastable final state
Candidates: In, Yb, Gd, Mo

Neutrinomolecular double beta decay (DBB)
Reaction: $e^- + X \rightarrow e^- + e^+ + X$
Specs: High Q-value, nat. ab., radiopurity
Candidates: Ta, Nd, Cd, Xe

Reactor neutrinos
Reaction: $\nu_e + p \rightarrow n + e^+$
Specs: High cross-section n-capture, signature
Candidates: as reactor experiments

Geo neutrinos
Reaction: $\nu_e + p \rightarrow n + e^+$
Specs: as reactor experiments
Candidates: as reactor experiments

Liquid scintillator (LS) requirements

Solubility
(metal loading 0.1 – 10 %)

Transparency
(> detector dimensions)

High light yield

Radiopurity
(K, U, Th...)

Safety
(Flash point, toxicity)

Stability
(several years)

Scintillator composition

Solvent: aromatic organic liquid (e.g. LAB, PC, PXE)
- Compatibility with detector materials (e.g. acrylics)
- Multiple solvents allow tuning of scintillator properties

Wavelength shifters:
- Primary fluor (e.g. PPO, p-tp, few g/liter)
- Secondary fluor (e.g. bis-MSB, ~10 mg/liter)

Metal beta-diketone
- Stable molecule
- Purification by sublimation

Light yield model
- Describes energy transfer in LS including a quenching component
- Prediction of light yield for given liquid composition
- Light yield measurements:
  - Compton backscattering
  - Single electron energy (fixed angle of 180°)

Quenching curve for Target (left) and Gamma Catcher (right) Double Chooz LS.

Light yield measurements:
- Compton scattered photons detected in Ge spectrometer (select electron energy)
- Extract Birks parameter $k_B$ (critical input for MC simulations)

Pulse shape discrimination of the STEREO LS using AmBe source

Pulse shape studies (PSD)

- Scintillation time profiles different for gamma/electrons and proton recoils or alphas
- The pulse tail charge to pulse total charge ratio is used to discriminate electron (left peak) and proton recoils (right peak) in the STEREO detector with a FoM of 0.71
- PSD boosted by the addition of D2N in the LS.

Time stability of the Gd capture fraction using neutrons from the deployment of a 252Cf source in the Double Chooz detector

Stability

Low energy electrons and heavy particles (Birks Law)
- Quenching effect important for correct energy reconstruction
- Compton scattered photons detected in Ge spectrometer (select electron energy)
- Extract Birks parameter $k_B$ (critical input for MC simulations)

Liquid Handling

Energy resolution time dependence from neutron captures on Gd in Double Chooz

Geo neutrinos

Reaction: $n + p \rightarrow d + n$
Specs: High cross-section n-capture, signature
Candidates: as reactor experiments

Solar neutrinos

Reaction: $\nu_e + X \rightarrow e^- + e^+ + X$
Specs: Low Q-value, metastable final state
Candidates: In, Yb, Gd, Mo

References