A novel technique for the study of pile-up events in cryogenic bolometers

Stefano Dell’Oro, on behalf of the CUPID Collaboration

Dipartimento di Fisica G. Occhialini, Università di Milano-Bicocca
INFN, Sezione di Milano-Bicocca

XIX International Workshop on Neutrino Telescopes
February 18 – 26, 2021 (online)
Pile-up in cryogenic bolometers

- **Bolometers** are calorimetric particle detectors
  - operating $T \sim$ tens of mK
  - energy release in the absorber
  - conversion to phonons
  - measurement of temperature variation

- Bolometers are playing and will continue to play a major role in the future searches for neutrinoless double-beta decay ($0\nu\beta\beta$)
  - **CUPID**: search for $0\nu\beta\beta$ of $^{100}\text{Mo}$ with $\text{Li}_2^{100}\text{MoO}_4$ crystals
    - mass: 450 kg / bkg: $10^{-4}$ c keV$^{-1}$ kg$^{-1}$ yr$^{-1}$ / $T_{1/2} > 10^{27}$ yr

- The slow time response (rise-time in the range of ms) can cause accidental pile-up of $2\nu\beta\beta$ and/or bkg events in the signal region
  - a resolving time $\lesssim 1$ ms is required to comply with background target

See Giuliani’s talk

---

S. Dell’Oro - NeuTel 2021
Pile-up study with pulser

- Assessment of pile-up rejection capability of CUPID-like bolometers
- Produce controlled sets pile-up events
  - use of a *programmable waveform generator*
  - reliable and reproducible control of time separation and relative energy of individual components
- Inject signals into resistances coupled to crystals
  - Joule heating $\rightarrow$ thermal signal
  - readout via NTD sensor
- Benchmark test-run performed @ LNGS (Italy)
  - 3 Li$_2$MoO$_4$ crystals inside an 8-crystal array to study the performance of CUPID-like crystals
Measurement

- Identification of waveform reproducing physics pulses on detectors
  - detector pulses do NOT resemble original waveform
  - $\Delta t$ between pulses is maintained

- Multiple combinations of $\Delta t$ / amplitude-ratio ($\alpha$) between pulses
  - extract pulse parameters (rise/decay time, amplitude, ...)
  - compute average values for each configuration
Pile-up identification & rejection

**Discrimination power**

- Distance of distributions individual vs. pile-up events
  - \( D \equiv \left| M_{x,i} - M_{x,R} \right| / \sqrt{\sigma_{x,i}^2 + \sigma_{x,R}^2} \)
  - computed for each \( \Delta t/\alpha \) configuration
  - benefit from using multiple variables

**Rejection efficiency**

- Ratio of excluded events over total
  - \( \epsilon_{\text{rej}} = n_{\text{rejected}} / n_{\text{total}} \)
  - combined shape parameters
    - \( \text{TVL}^2 + \text{TVR}^2 \) & Delay
    - 3\( \sigma \)-cut on reference non-pile-up distribution
    - fit distribution with \( \text{erf} \) for each \( \alpha \) configuration
Results & Outlook

- We obtain a $\epsilon_{rej} = 90\%$ for $\Delta t$ of about 2 ms ($t_{rise} \sim 15$ ms)
- The measurement did not allow to push this method to its limits
  - sub-optimal noise condition due to cryostat instabilities
  - sampling frequency limited minimum resolution to $\Delta t$ close to 1 ms
- There is room for improvement
  - improved analysis & measurement
  - support by simulations
- New run is already scheduled
  - higher sampling frequency
  - improved noise conditions
- Final goal: assess the impact of pile-up on CUPID

[Graph showing data points for different channels and time delays]
Thank you!