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

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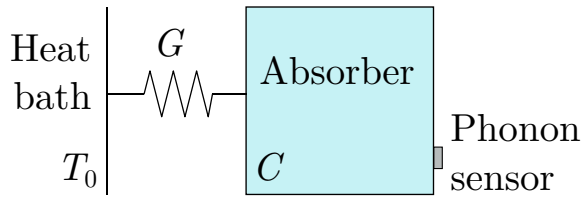
Pile-up in cryogenic bolometers

- 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}Mo with $Li_2{}^{100}MoO_4$ crystals
  - mass: 450 kg / bkg: 10^{-4} c keV^{-1} kg^{-1} yr^{-1} / $T_{1/2} > 10^{27}$ yr

see Giuliani's talk

- 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


arXiv:1907.09376 [physics.ins-det]

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_2MoO_4 crystals inside an 8-crystal array to study the performance of CUPID-like crystals

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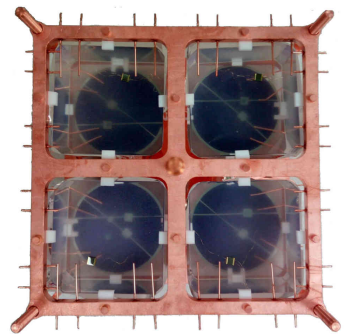
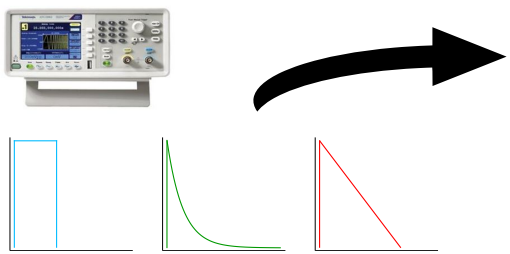
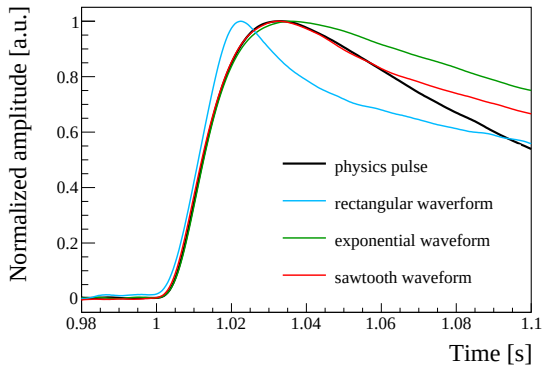


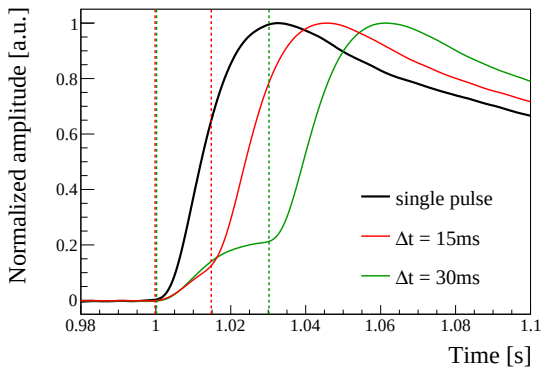
see Ressa's talk

Measurement

- Identification of waveform reproducing physics pulses on detectors
  - detector pulses do NOT resemble original waveform



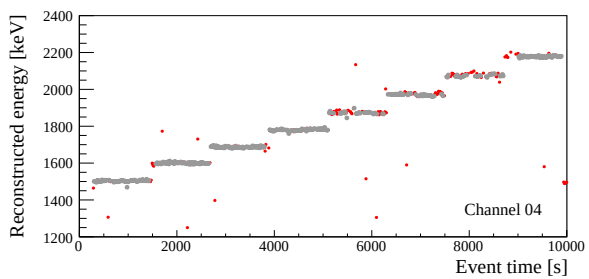




  - Δt between pulses is maintained

- Multiple combinations of Δt / amplitude-ratio (α) between pulses
  - extract pulse parameters (rise/decay time, amplitude, . . .)
  - compute average values

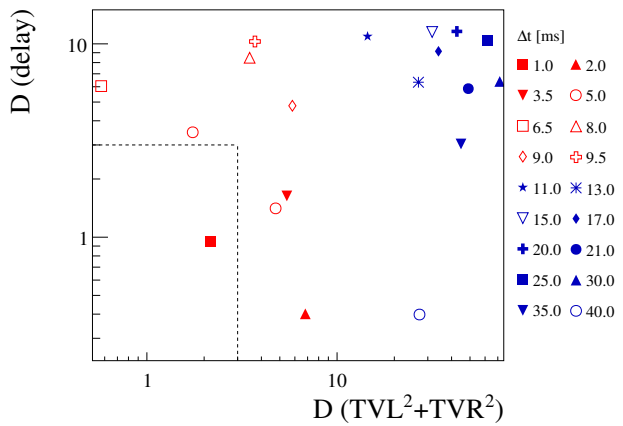
    for each configuration



Pile-up identification & rejection

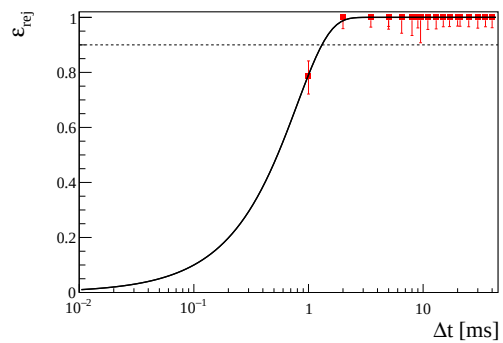
Discrimination power

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



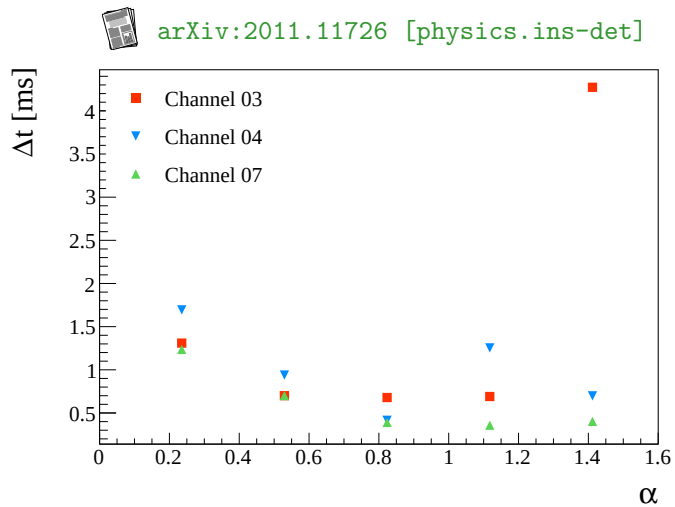
Rejection efficiency

- Ratio of excluded events over total
  - $\epsilon_{rej} = n_{rejected} \,/\, n_{total}$
  - combined shape parameters
    - TVL^2+TVR^2 & Delay
  - 3σ-cut on reference non-pile-up distribution
  - fit distribution with *erf* for each α configuration



Results & Outlook

- We obtain a $\epsilon_{rej} = 90\%$ for Δt 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 Δt 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

Thank you!