Development of photon and phonon detectors for rare-event experiments

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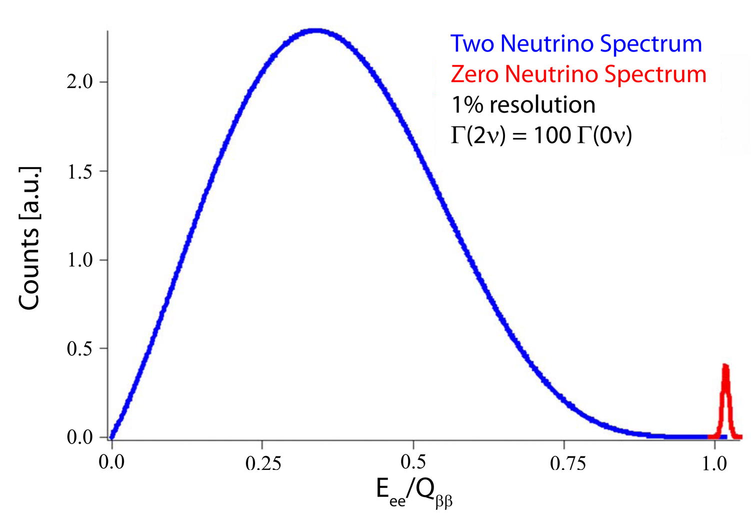
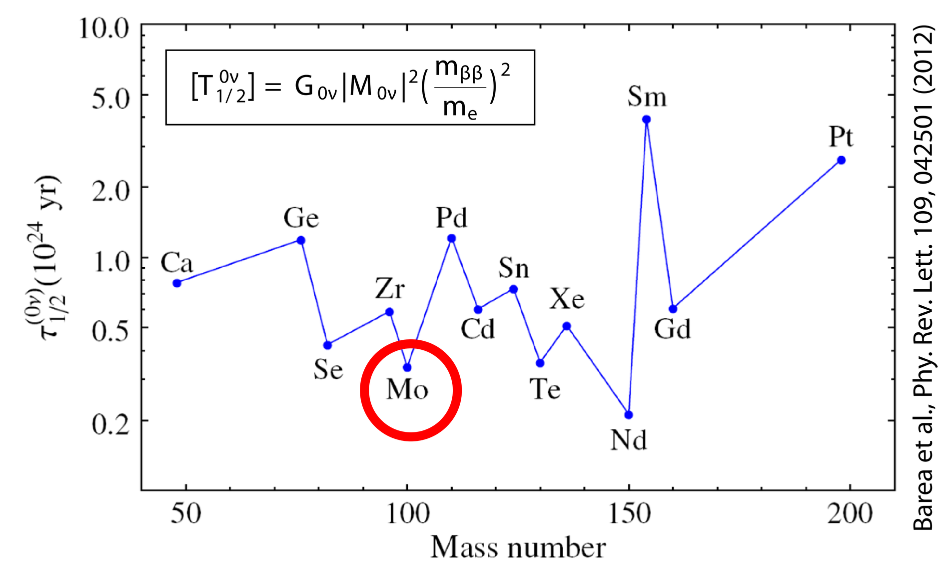
Neutrinoless double beta decay



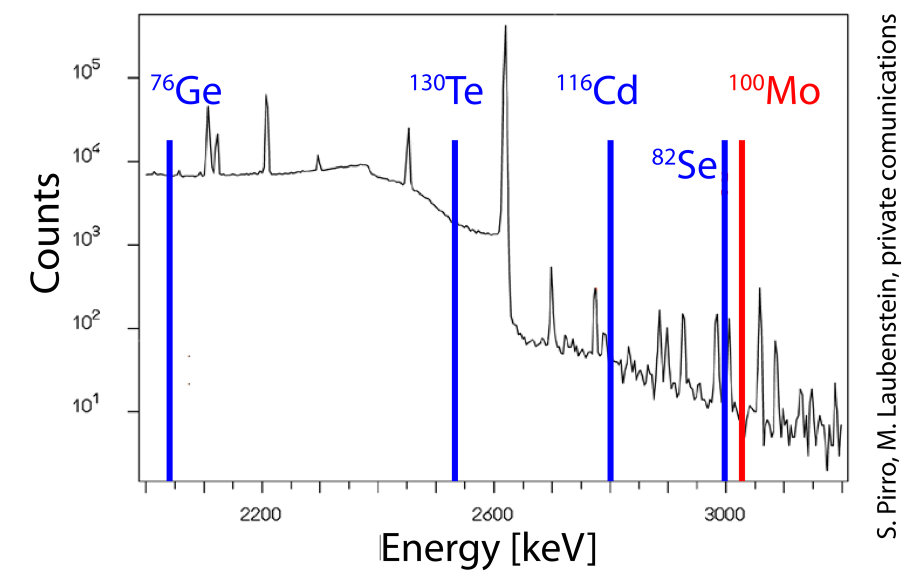
$2\nu\beta\beta$: $(A,Z) \longrightarrow (A, Z+2) + 2e^- + 2\bar{\nu}_e$
$0\nu\beta\beta$: $(A,Z) \longrightarrow (A, Z+2) + 2e^-$

Candidate	Q (MeV)	Abund. (%)
^{48}Ca	4.271	0.2
^{76}Ge	2.040	7.8
^{82}Se	2.995	8.7
^{100}Mo	3.034	9.7
^{116}Cd	2.802	7.5
^{124}Sn	2.228	5.8
^{130}Te	2.533	34.1
^{136}Xe	2.479	8.9
^{150}Nd	3.367	5.6

High natural abundance of ^{100}Mo



Relatively short half life ($0\nu\beta\beta$) of ^{100}Mo



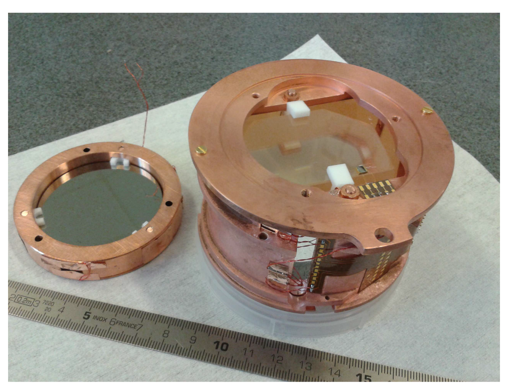
Q-value of ^{100}Mo above natural γ radioactivity

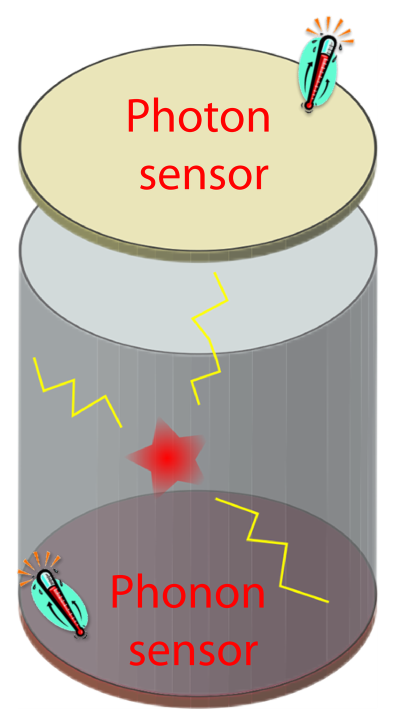
Scintillating Crystal and ^{100}Mo

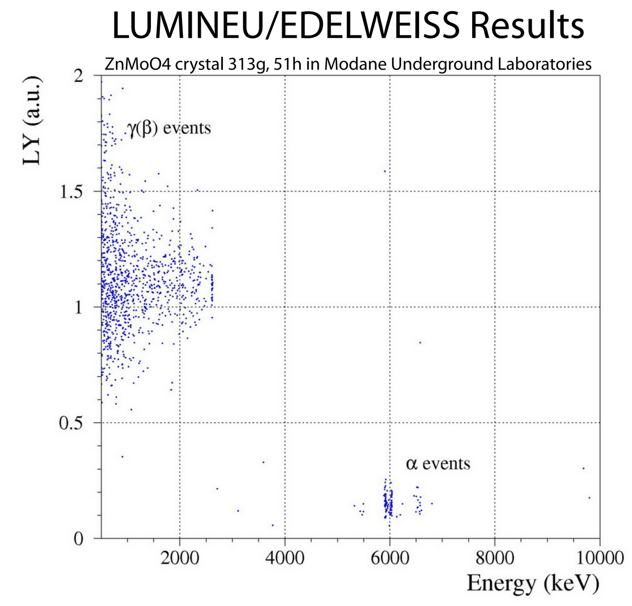
The energy of an interacting particle is converted into:

→ Heat
→ Light

- Light fraction depends on particle type
- Both fractions of energy are measured





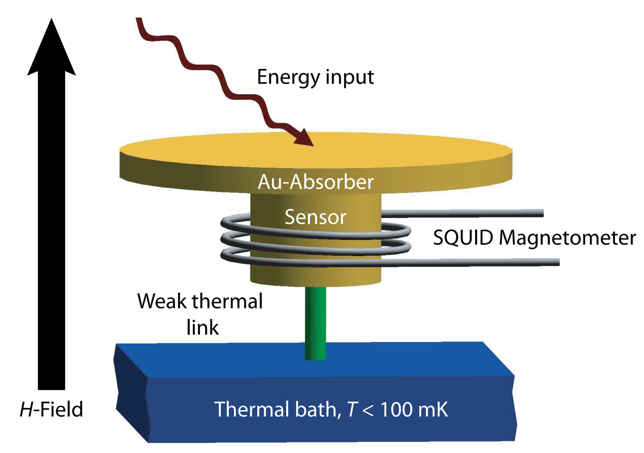


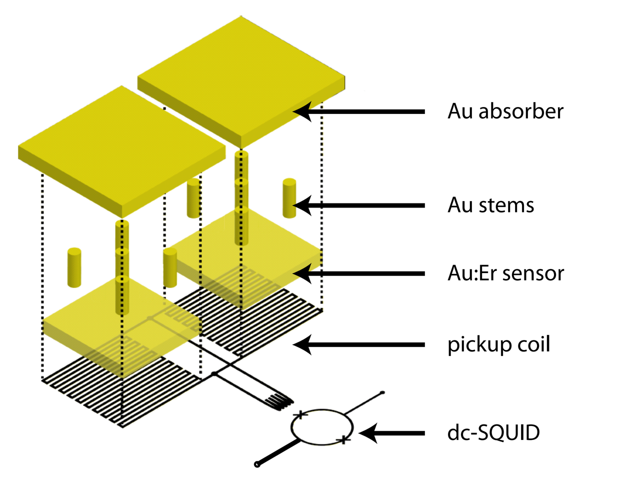
→ β/α discrimination
→ rejection of background events

AMoRE
(Advanced Mo-based Rare process Experiment)
Scintillating crystal: ^{48}Ca^{100}MoO$_4$

LUMINEU
(Luminescent Underground Molybdenum Investigation for Neutrino mass and nature)
Scintillating crystal: Zn^{100}MoO$_4$

Metallic magnetic calorimeters (MMCs)





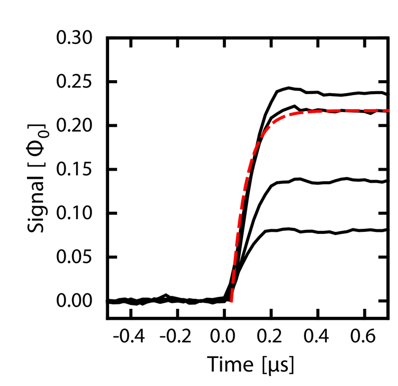
Detection Principle

Energy deposition → Temperature change → Change of magnetization → Change of magnetic flux

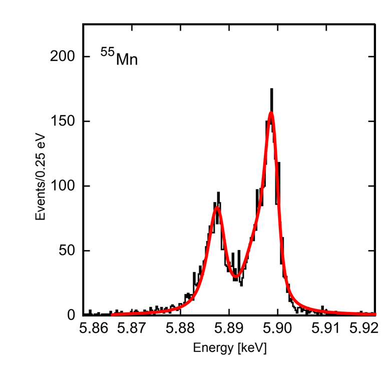
$$\delta E \rightarrow \delta T = \frac{\delta E}{C_{tot}} \rightarrow \delta M = \frac{\partial M}{\partial T}\frac{\delta E}{C_{tot}} \rightarrow \delta\Phi \sim \delta M \sim \delta E$$

Detector Performance

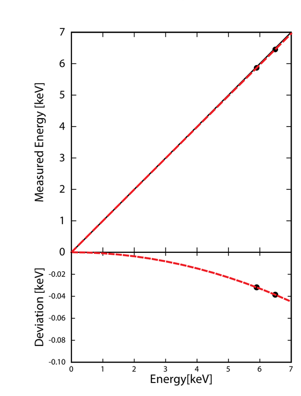
Signal rise time: 90ns



Energy resolution: 2 eV @ 6 keV



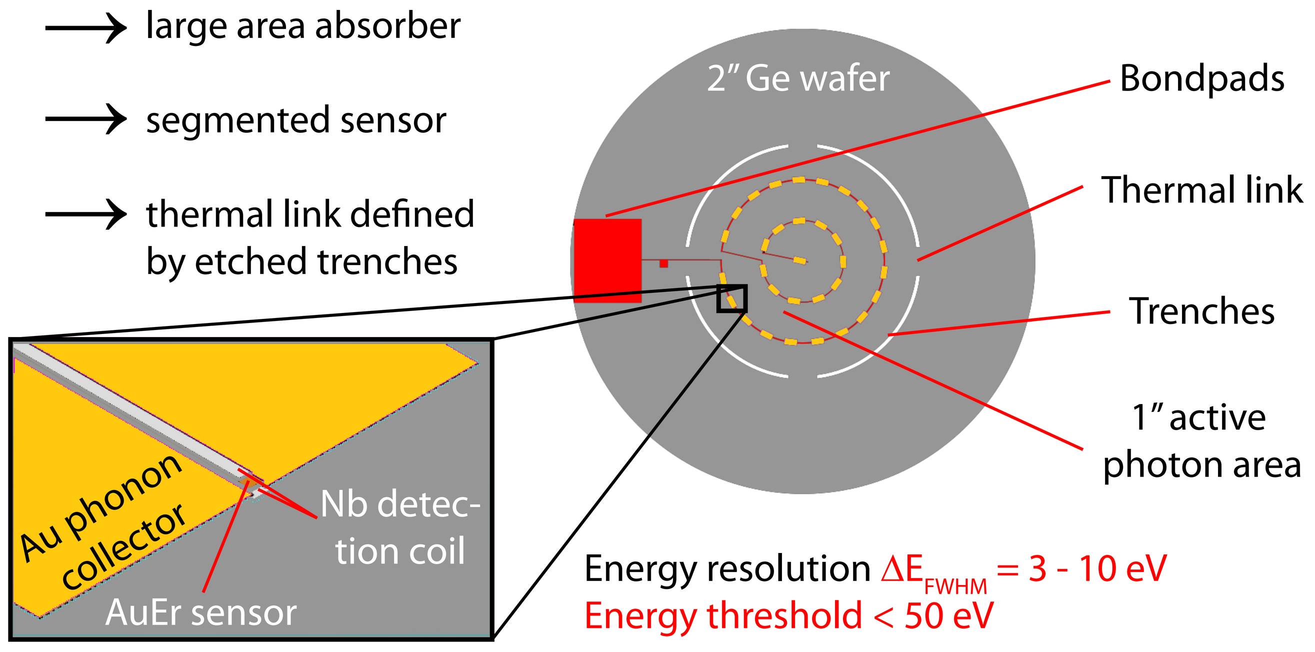
Non-linearity: < 1% @ 6 keV

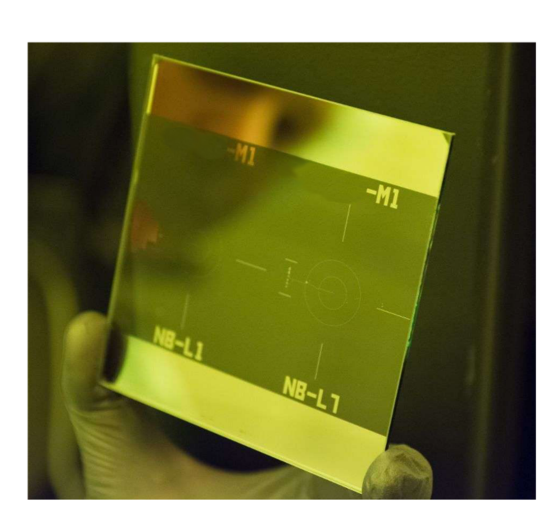


Detectors for rare-event experiments

Photon Detector

→ large area absorber
→ segmented sensor
→ thermal link defined by etched trenches

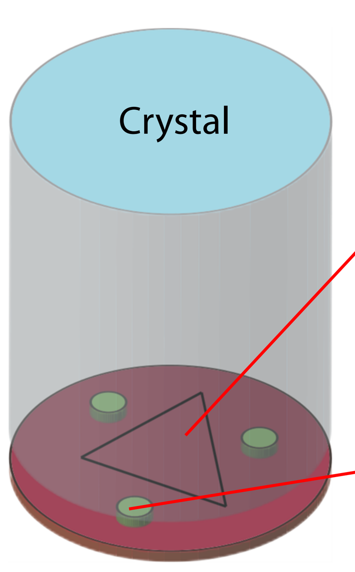


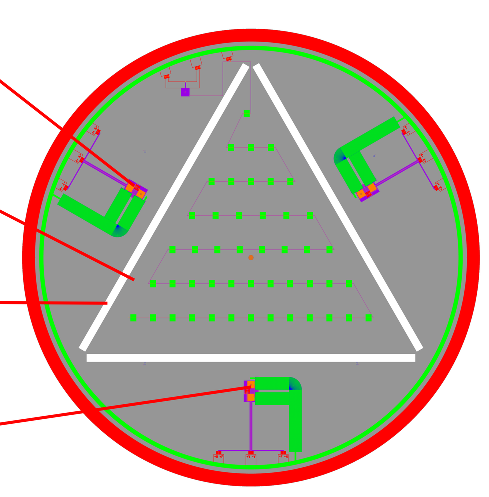


Energy resolution ΔE_{FWHM} = 3 - 10 eV
Energy threshold < 50 eV

Signal rise time τ_R < 50 µs
Pulse pair resolving time < 100 µs

Combined Phonon/Photon Detector





Crystal is positioned on gold cone by its own weight

→ Easy to mount a large crystal number
→ No other contact to crystal holder

Phonon Detector

Energy resolution ΔE_{FWHM} = 50 - 100 eV
Energy threshold < 500 eV

Signal rise time τ_R < 200 µs
Pulse pair resolving time < 500 µs

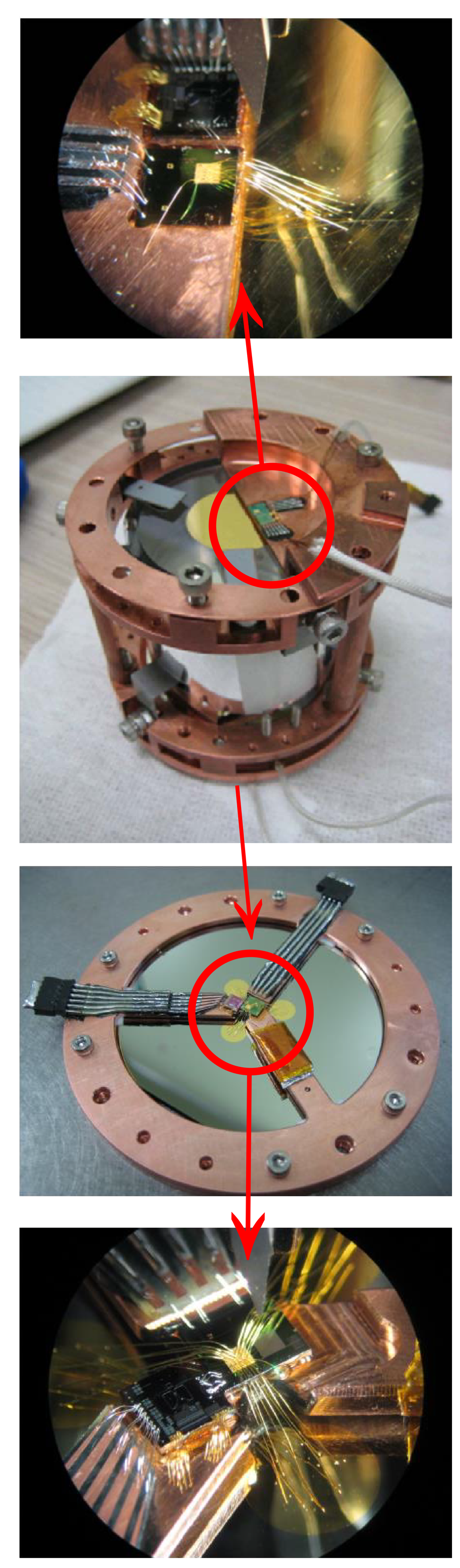
Photon Detector

Energy resolution ΔE_{FWHM} = 3 - 10 eV
Energy threshold < 50 eV

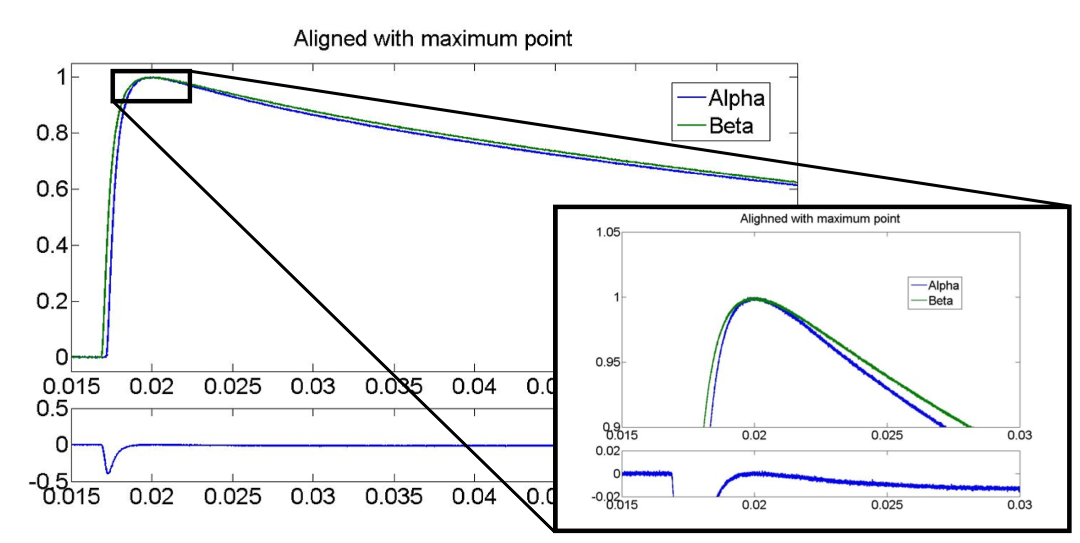
Signal rise time τ_R < 50 µs
Pulse pair resolving time < 100 µs

Preliminary AMoRE results

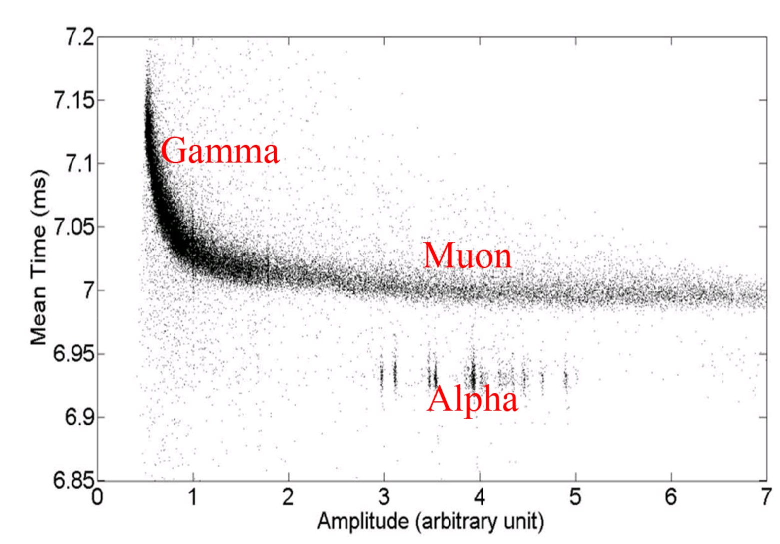
MMC phonon detector

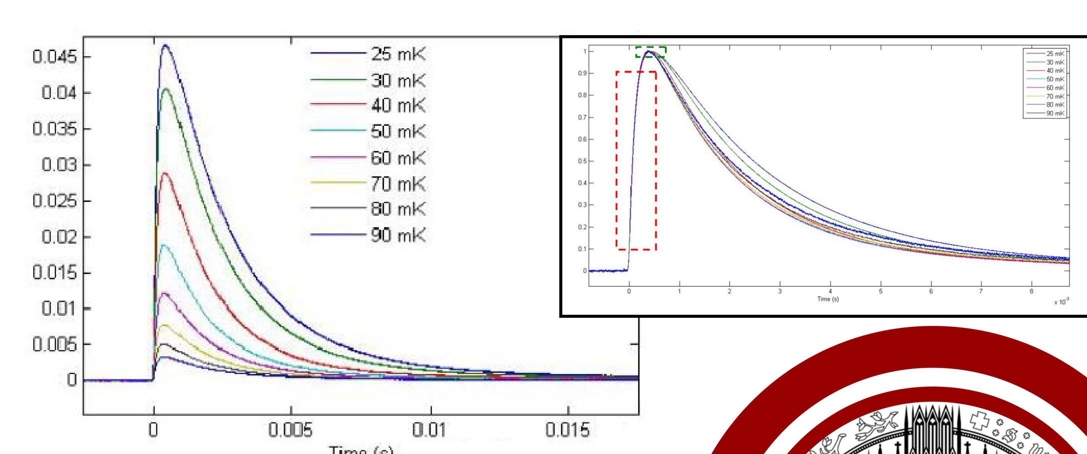


MMC photon detector



β/α discrimination in the phonon channel





Pulse shapes of photon detector