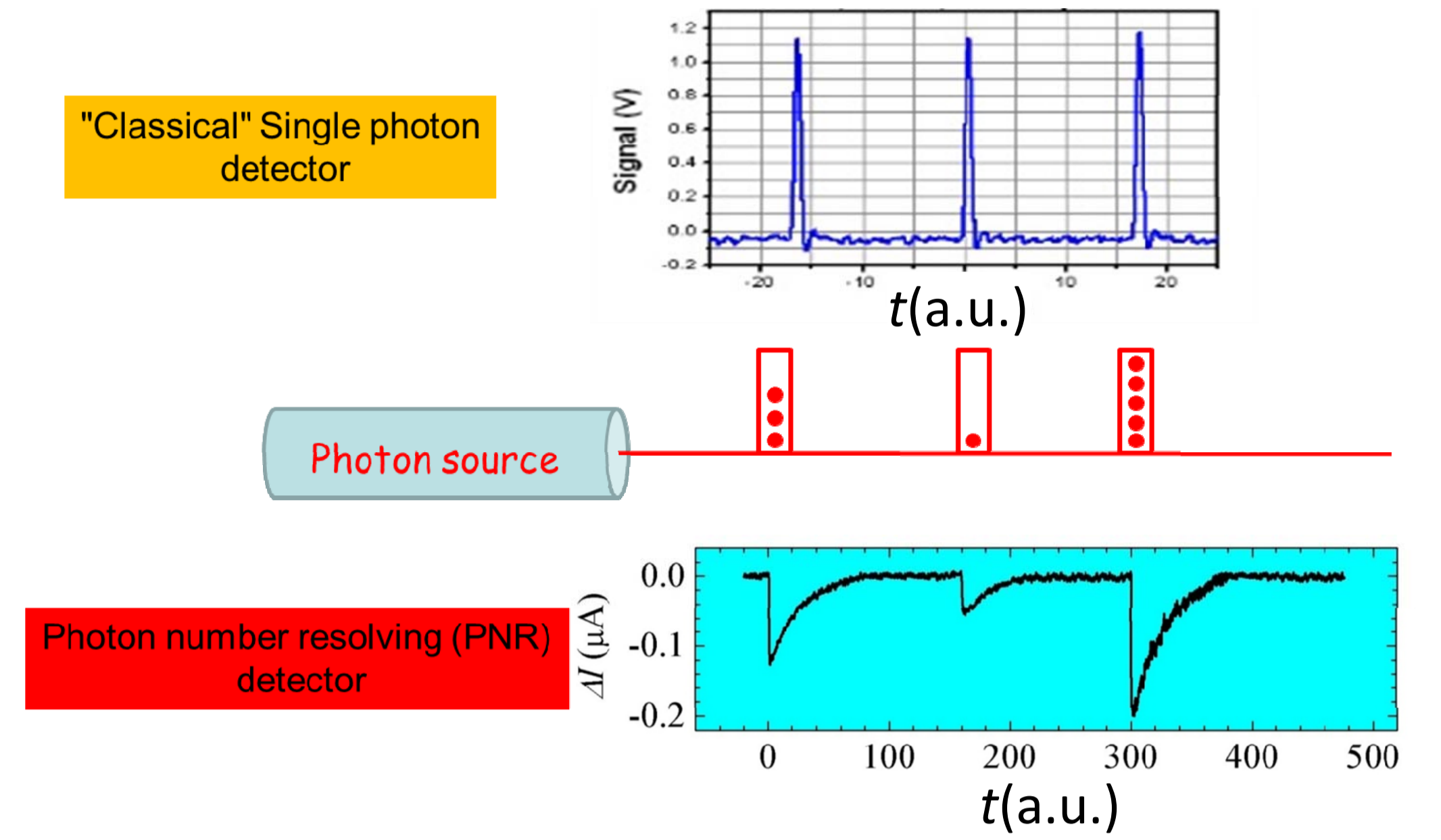


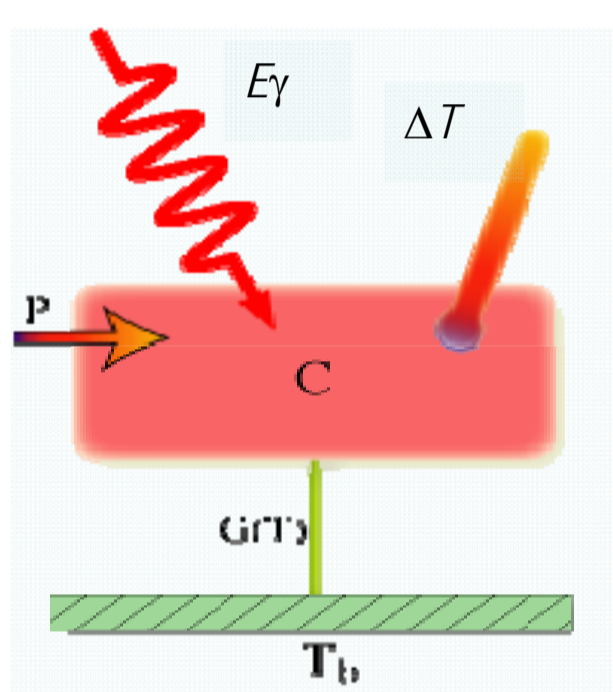
Introduction

- Photonics is becoming a key enabling technology for the 21st century
- To discriminate the number of photons in a light pulse is a fundamental tool for quantum metrology and quantum technologies
- One of the best photon number resolving (PNR) detector available nowadays is the **Transition-Edge Sensor (TES)**

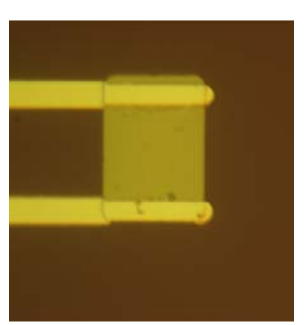
Photon Number Resolution (PNR)



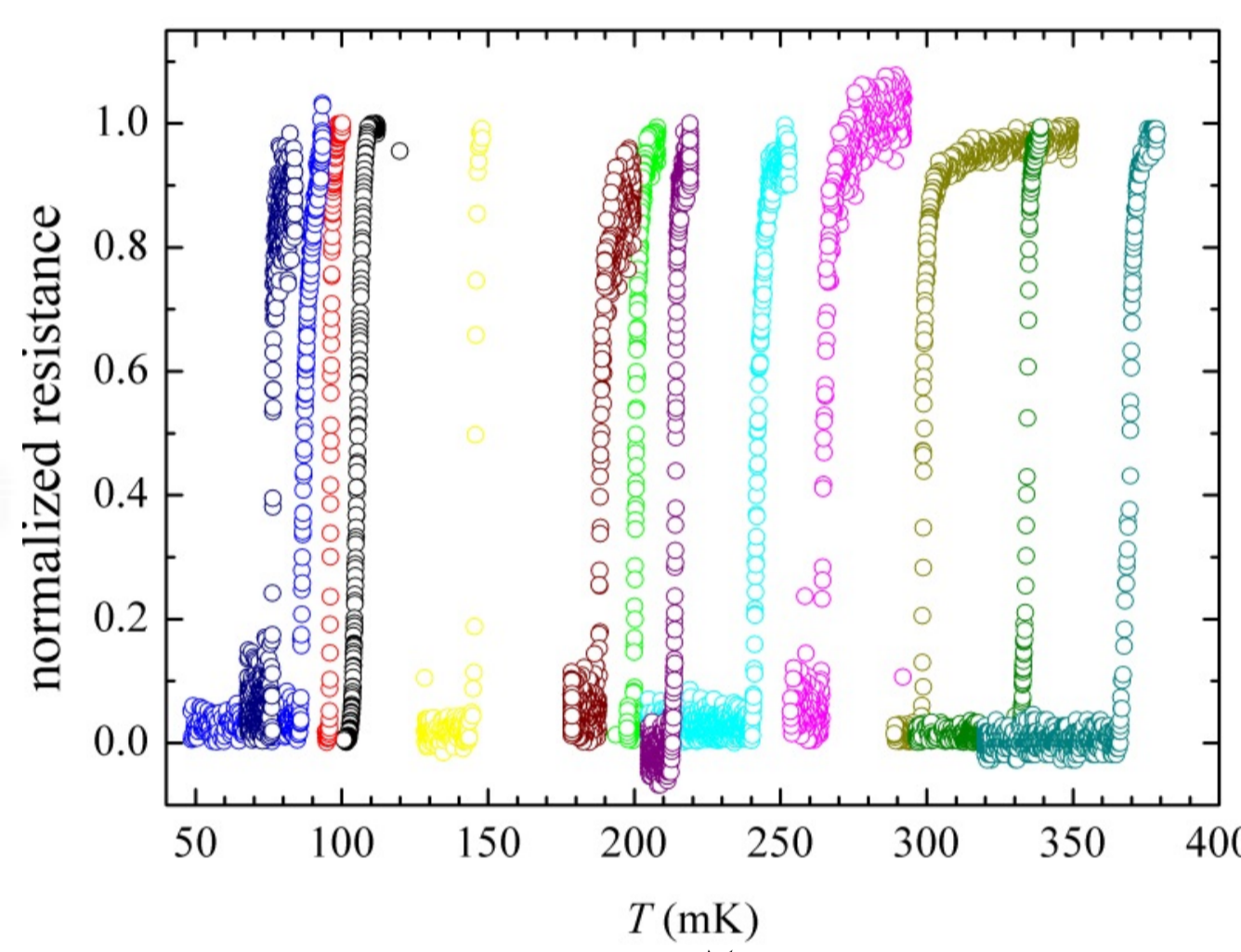
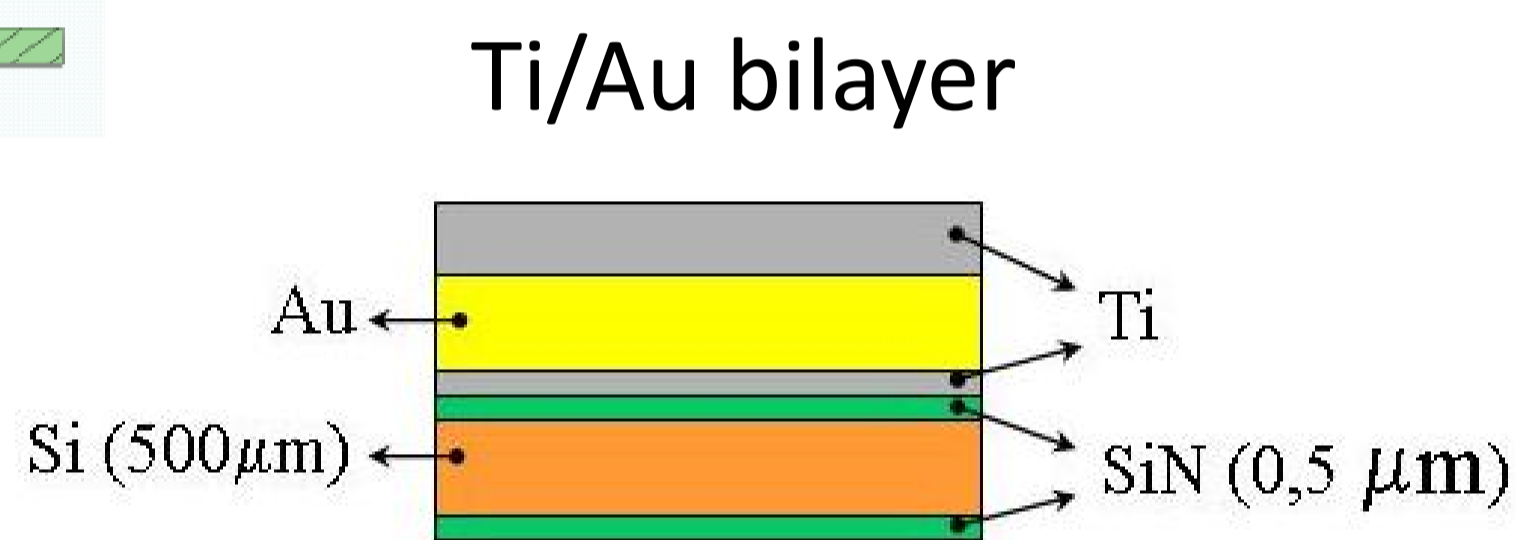
Transition Edge Sensor (TES)



TES: a microcalorimeter made by a superconducting film operated in the temperature region between the normal and the superconducting state



Active Area
10 μm × 10 μm

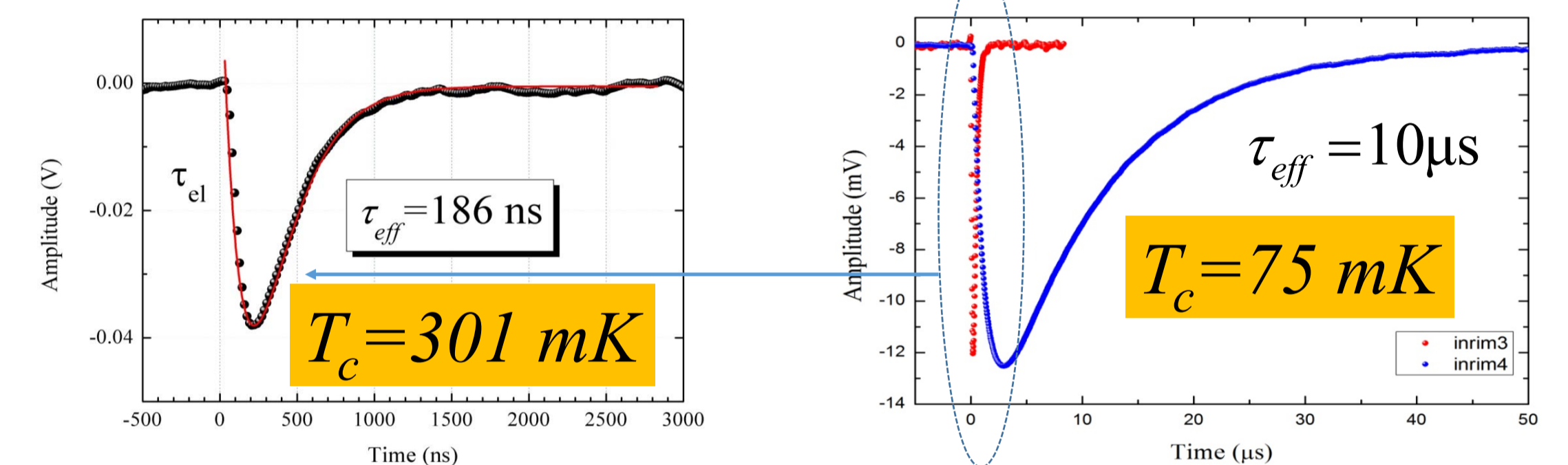


Single photon @ 1550 nm $\Rightarrow E_\gamma = 0.79$ eV
(1.27×10^{-19} J)

We need TESs with C of the order of: $C = E_\gamma / \Delta T \sim 1$ fJ/K $\Delta T \sim 0.1$ mK

Effective response time

$$\tau_{eff} = \tau_{th} \left\{ 1 + \frac{\alpha}{n} \left(1 - \frac{T_s}{T_c} \right) \right\}^{-1} \approx \frac{n}{\alpha} \tau_{th} \approx \frac{C}{G} \propto T_c^{-3}$$



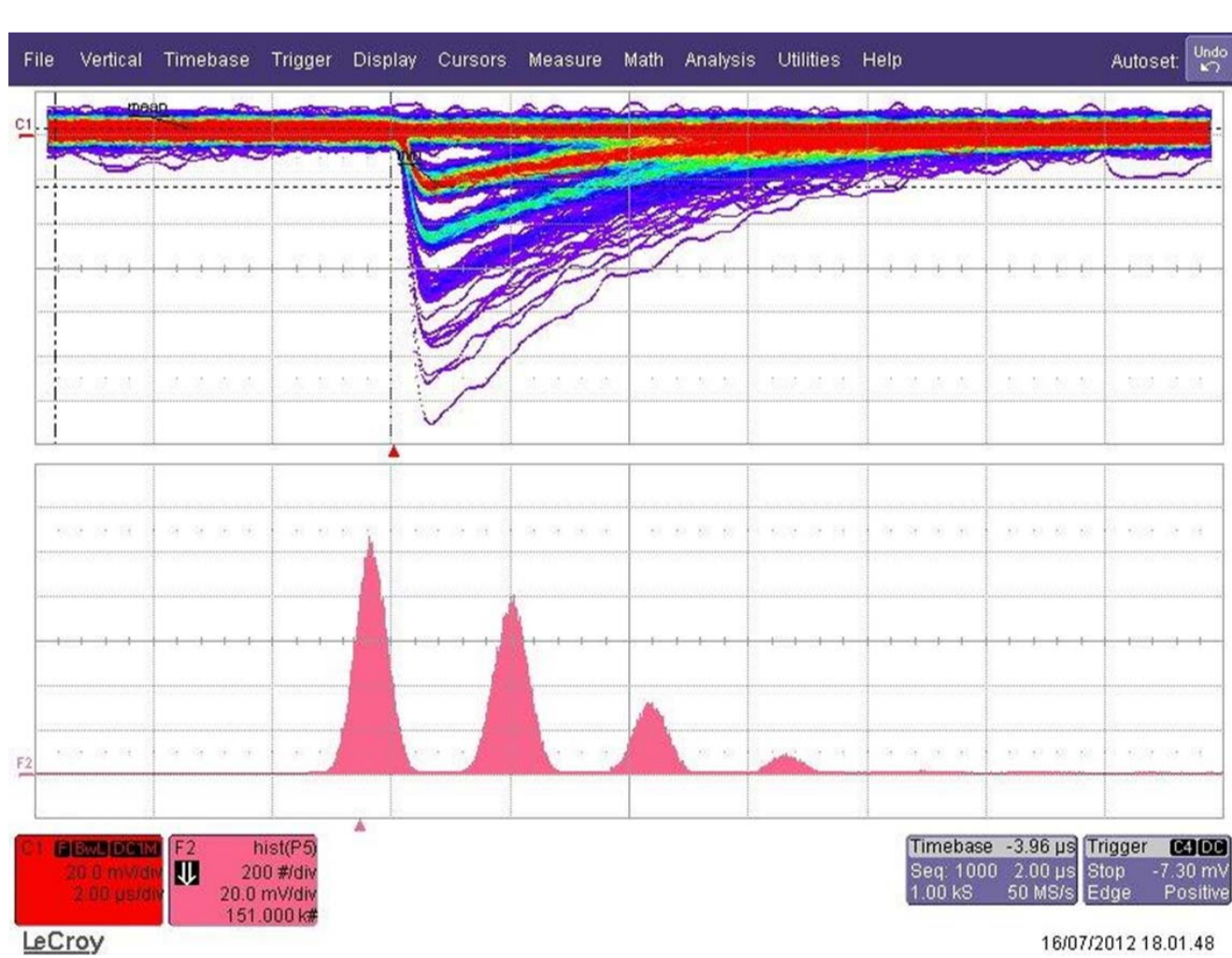
Energy resolution

$$\Delta E_{FWHM} \approx 2.36 \sqrt{4kT_0^2 \frac{C_e}{\alpha} \sqrt{n/2}} \propto T_c^{3/2}$$

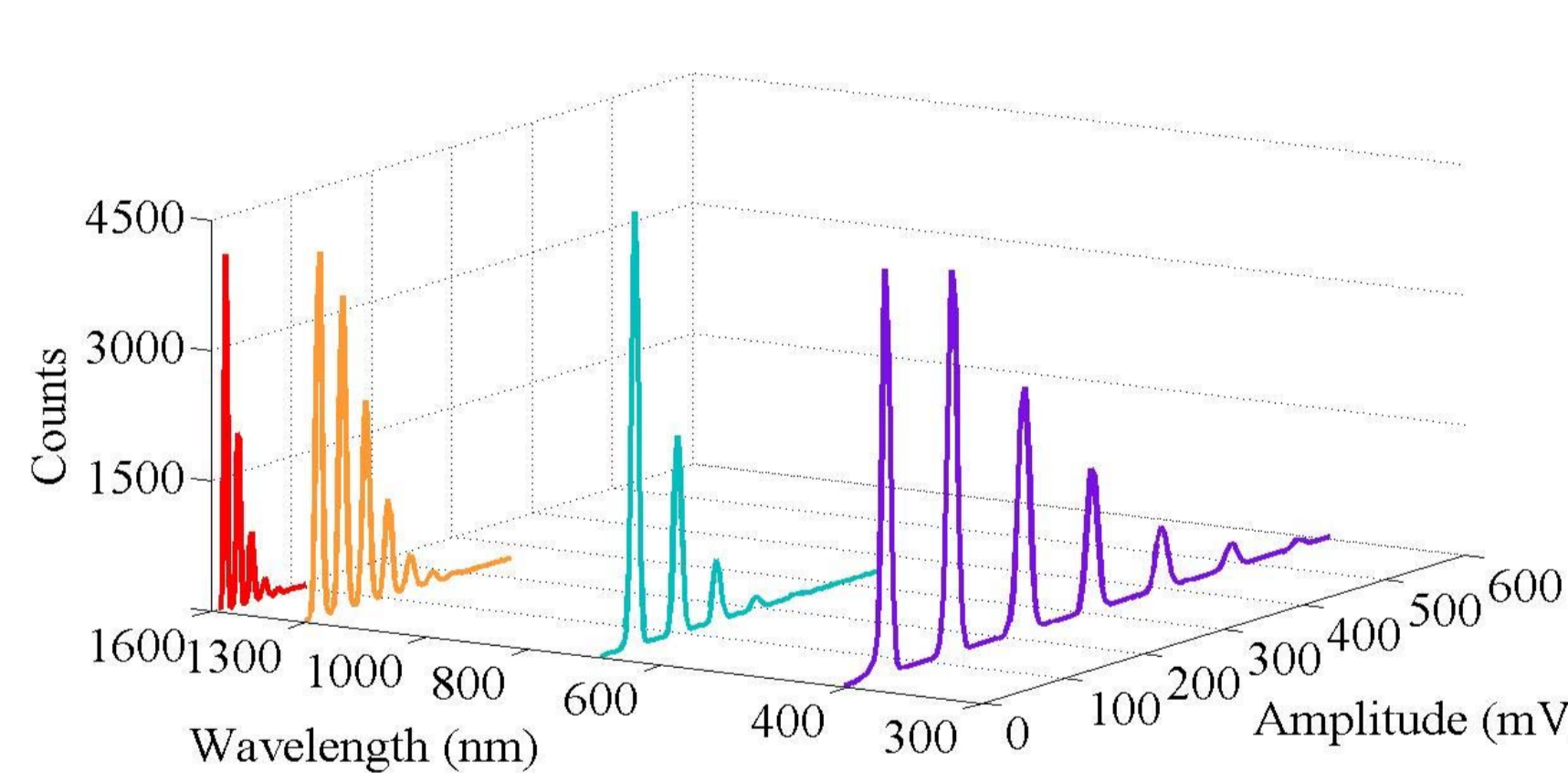
Trade-off between response time and energy resolution

INRiM TES at work

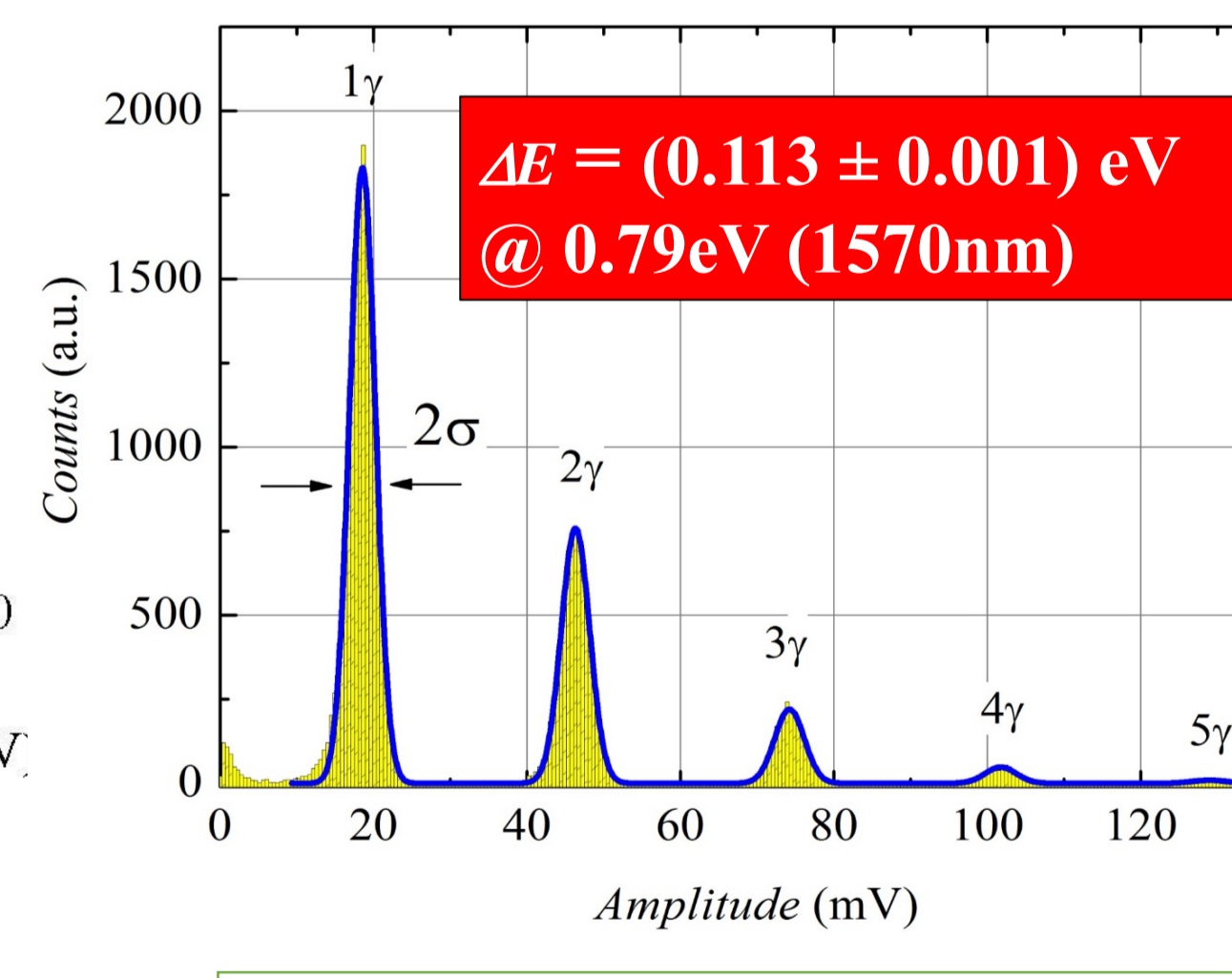
Real time PNR



UV-NIR range

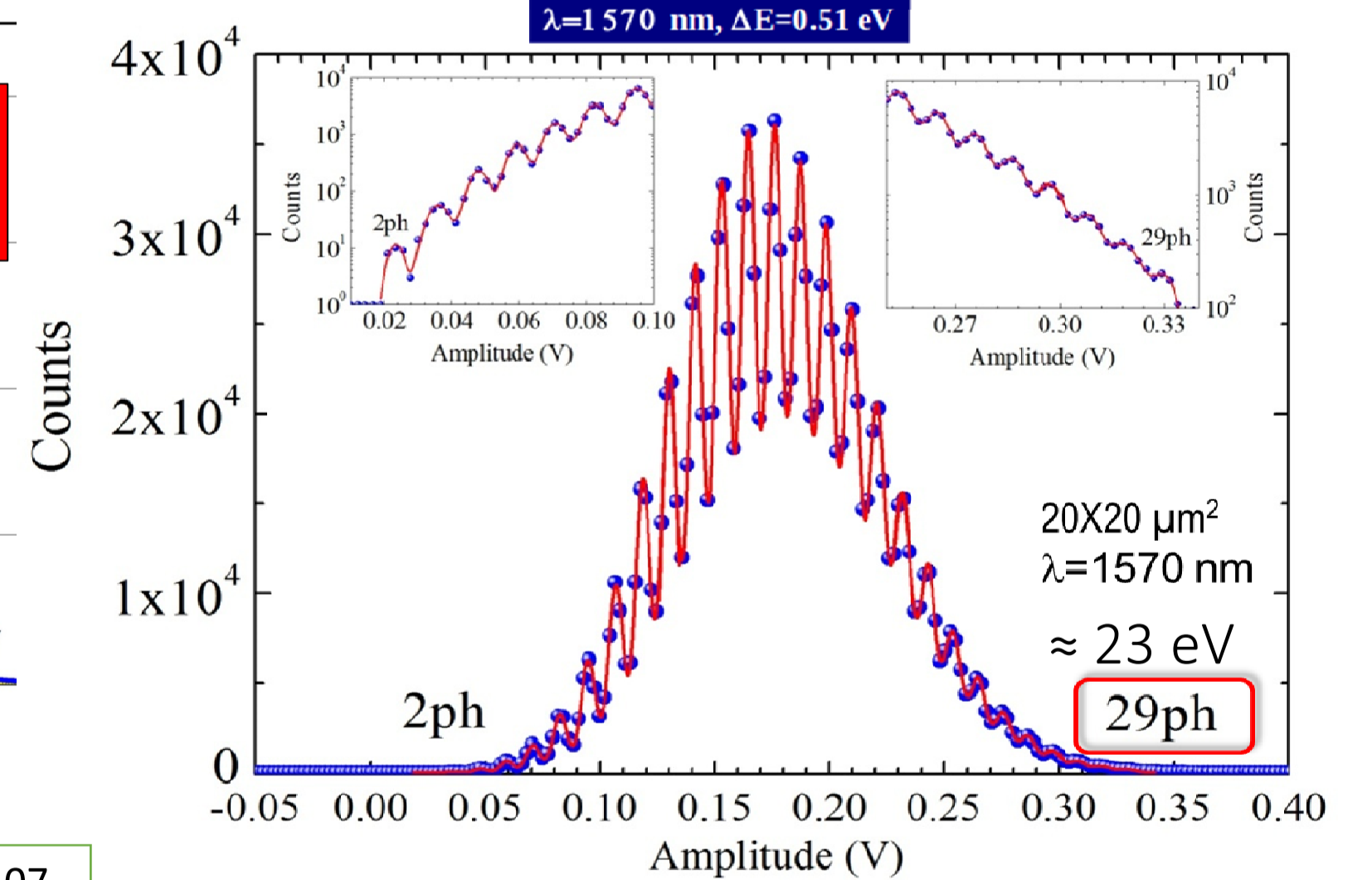


High Energy Resolution



L. Lolli et al., *App. Phys. Lett.*, 103, (2013) 041107

High Dynamic range



L. Lolli et al., *J. Low Temp. Phys.*, 167, (2012) 803

Summary

- TESs are among the best single photon detectors:
- ✓ High quantum efficiency: up to 98% (in literature)
 - ✓ Low dark counts: few mHz
 - ✓ Photon Number Resolving capability (0.1 - 0.2 eV FWHM)
 - ✓ Wavelength tunability (VIS-NIR)
 - ✓ Count rate up to 1 MHz
 - ✓ Time jitter 5 ns

Acknowledgment

This results have been obtained thanks to the support of EURAMET projects *qu-candela* and *MetNEMS*.
We would like to thanks L.Lolli, E. Taralli, and C. Portesi for their collaboration.