

Low Temperature Single photon detectors for Quantum Information Applications

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Basics of Quantum Information Science

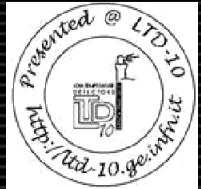


- Use of information encoded in quantum mechanical states
- Manipulation and measurement of quantum states

Easy to generate quantum states
with photons

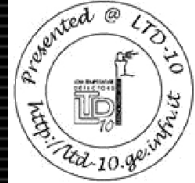
Quantum Information Examples

- Quantum Cryptography
 - Quantum Key Distribution
 - Quantum Coin Tossing
- Quantum Measurement and Optics
 - Single Photon Sources, SPDC, SPT
 - Bell State Analysis, Quantum Teleportation
- Quantum Computing
 - Efficient linear optical quantum computing



Optical photon detector needs in Quantum Information

- High Quantum Efficiency
 - As high as possible
- Low Dark Count rate
 - No false counts
- Speed
- Energy Resolving / Photon Number Resolving

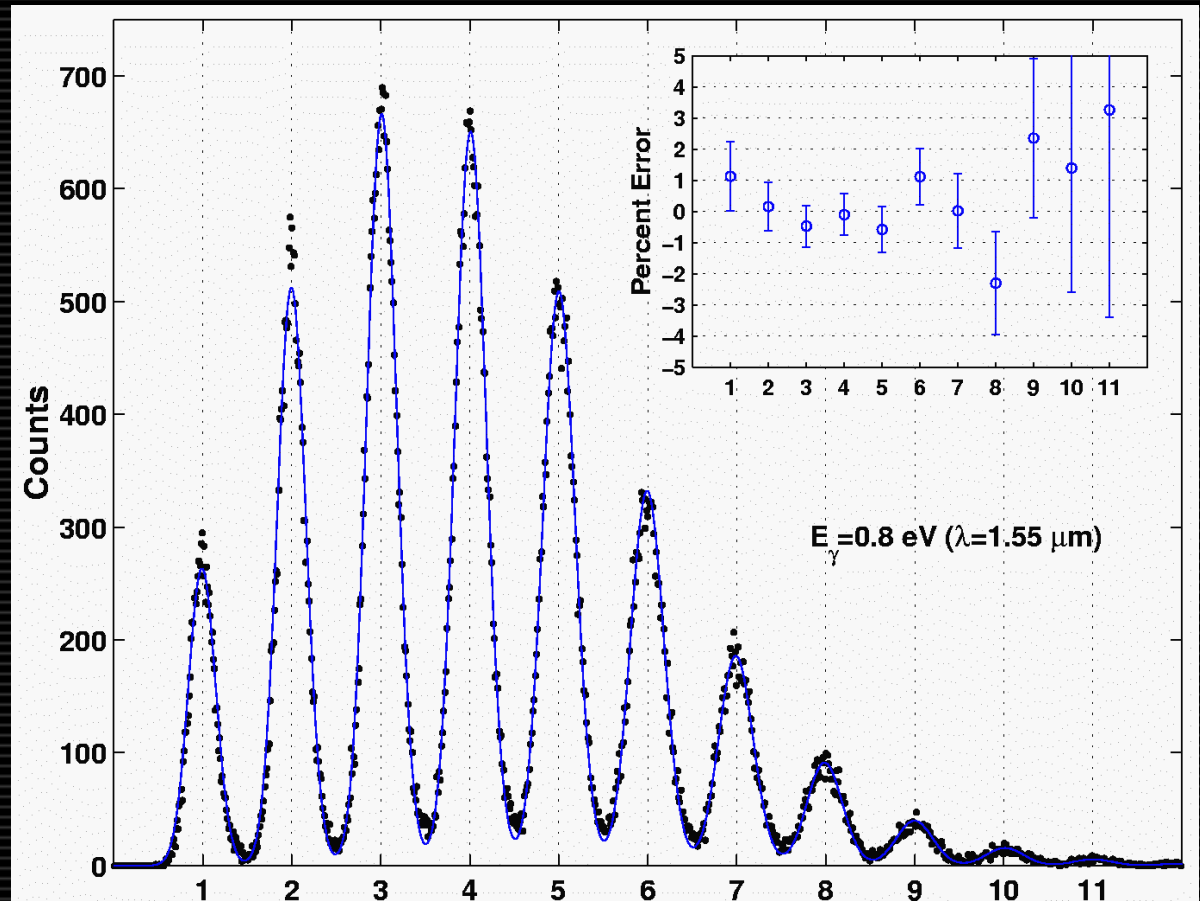
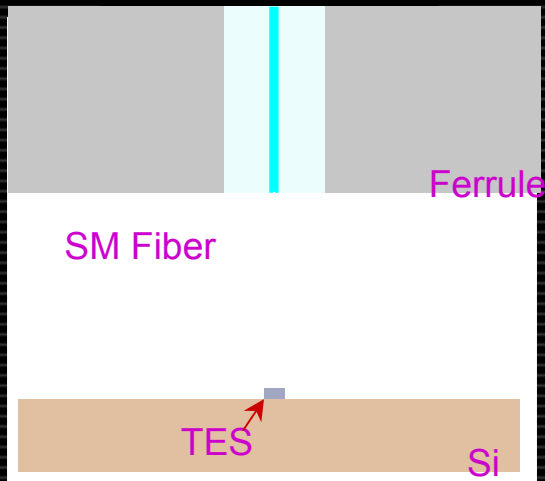
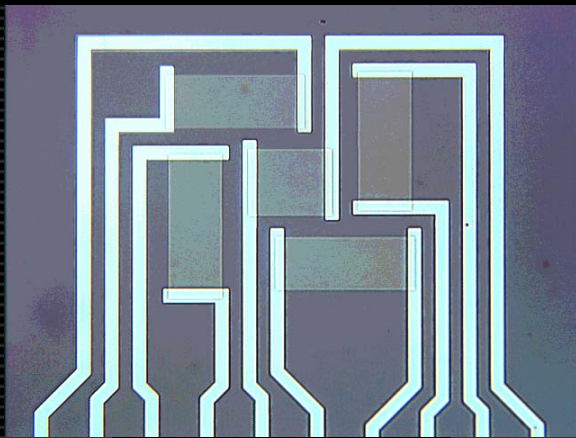


Transition-edge sensor performance



- Photon Number Resolution
- Low Noise
 - NEP < 10^{-19} W/ $\sqrt{\text{Hz}}$ (limited by stray light)
 - No Dark Counts
- High QE at telecommunication wavelengths
 - $\sim 20\%$ end-to-end measured
 - AR coatings give no limit, in principle
 - Target of $>80\%$ at 1550 nm

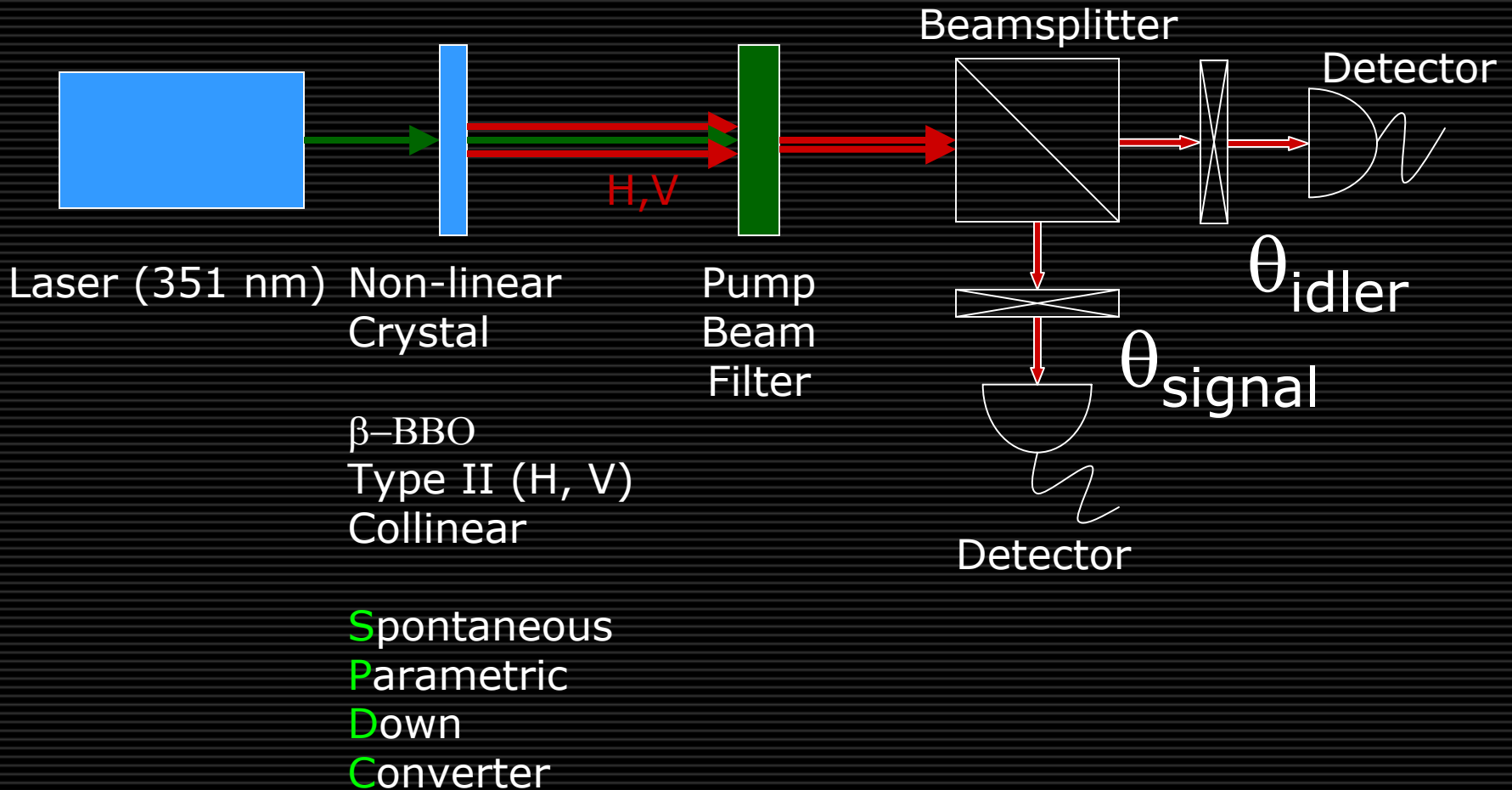
Tungsten TES



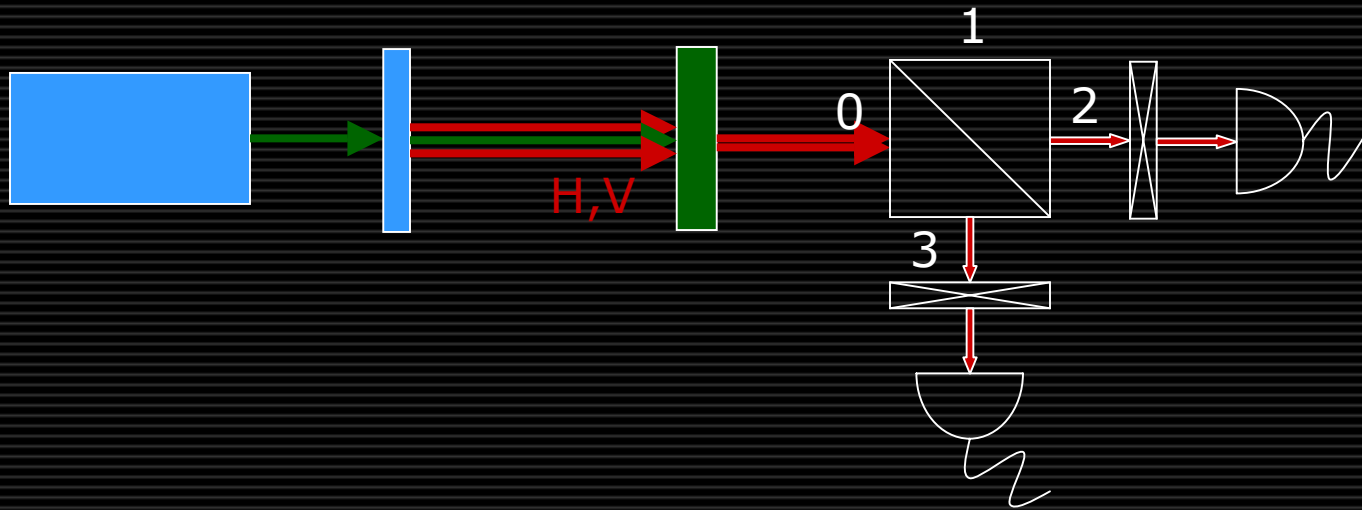
TES compared to APD

	TES	APD
Quantum Efficiency	~20% (->100%) AR coatings	~15% - 70% intrinsic limit
Wavelengths	10 μm - 100 nm	Gap dependent
Count Rate	<50 kHz thermal recovery	~100 kHz afterpulsing
Dark Count Rate	None, Stray light	~10-30 kHz Bias Gating
# Resolving	YES	Difficult

Example in Quantum Optics



Counting *ALL* the photons

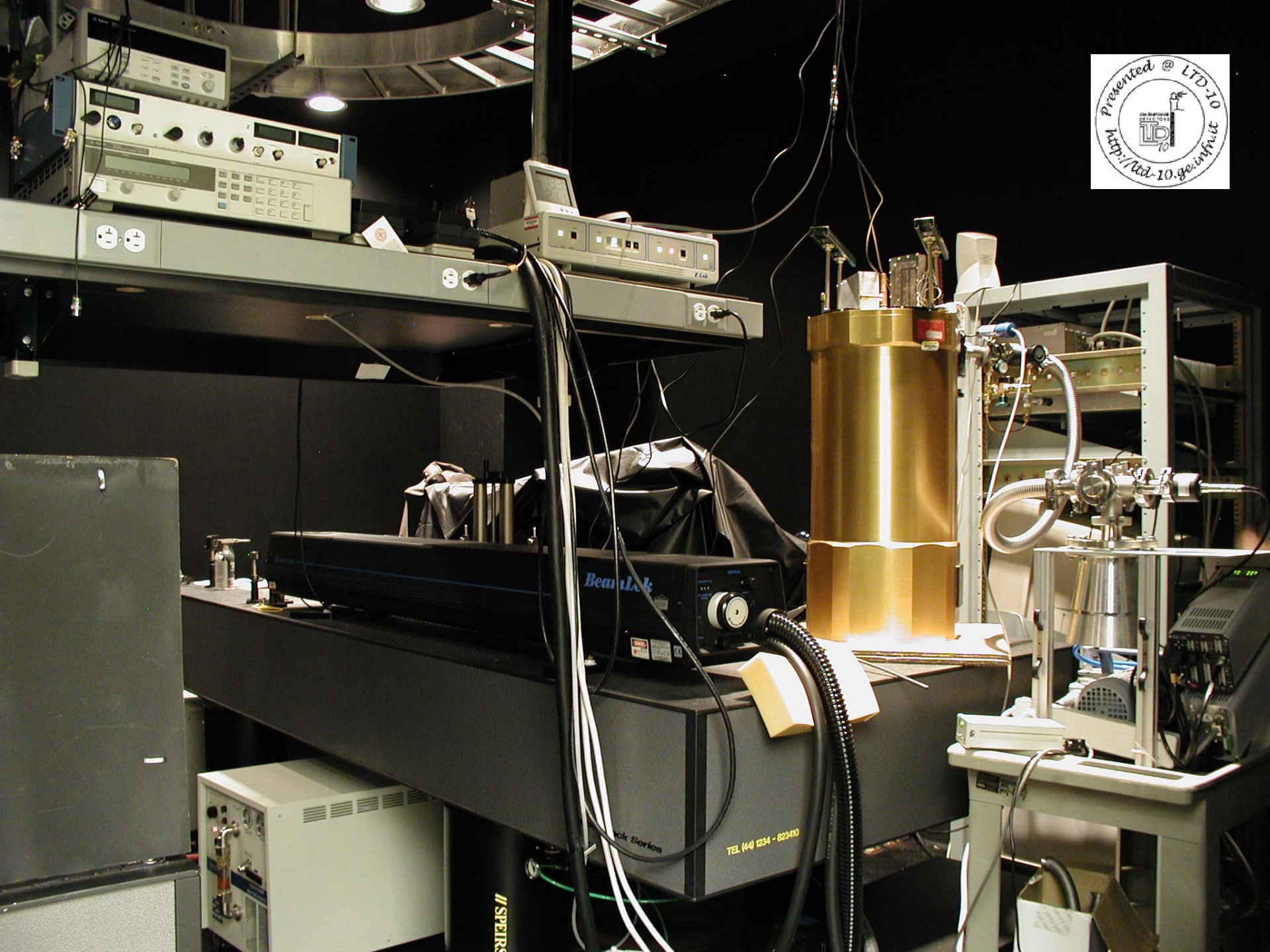
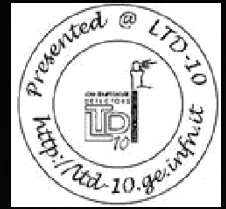


- What is the rate of “coincident” events?
- What is the rate of “doubles” events?

Calculations

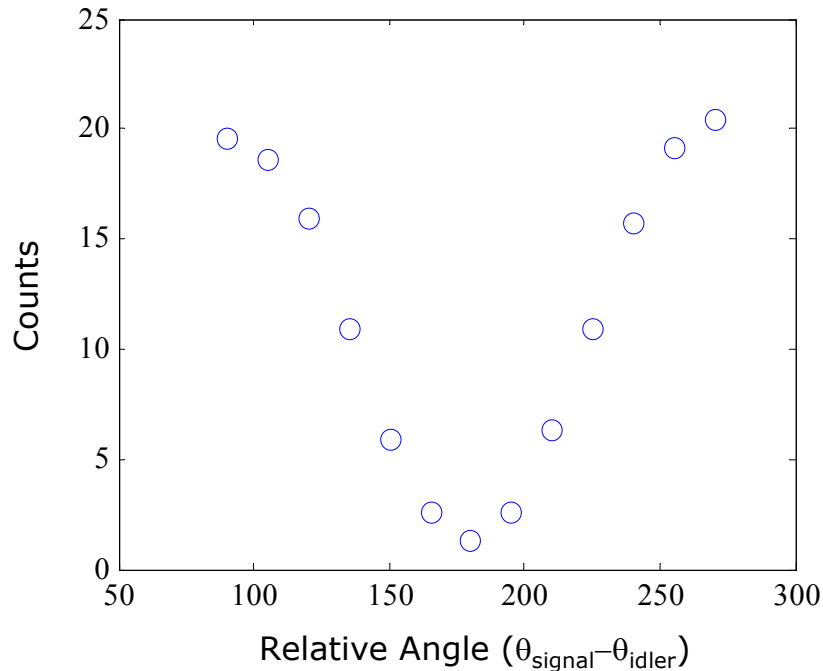
$$\begin{aligned}
 |H_0V_0\rangle &\rightarrow i|H_3V_2\rangle - i|V_3H_2\rangle + \\
 &\quad |H_2V_2\rangle - |H_3V_3\rangle \\
 &\rightarrow (\cos(\theta_3)\sin(\theta_2) \\
 &\quad - \sin(\theta_3)\cos(\theta_2)) |D1 D2\rangle \\
 &\quad + \sin(\theta_2)\cos(\theta_2) |D1 D1\rangle \\
 &\quad + \sin(\theta_3)\cos(\theta_3) |D2 D2\rangle
 \end{aligned}$$

Probability : $\sin^2(\theta_3 - \theta_2)$ Coincident
 $\sin^2(2\theta_2), \sin^2(2\theta_3)$ Doubles

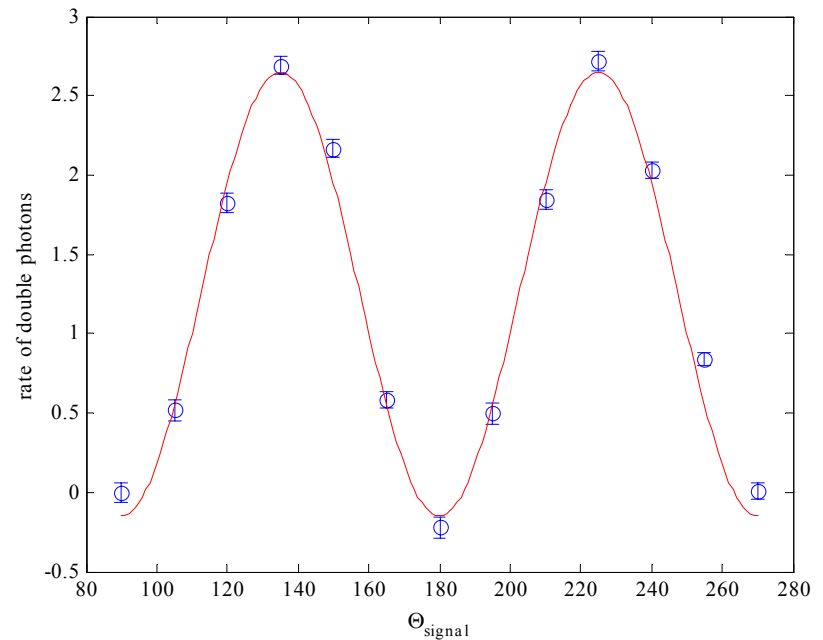


Data with a TES

Coincident



Doubles



Conclusions

- Many opportunities in quantum information
 - Basic tests of quantum mechanics
 - First applications using W-TES
- LTDs are advantageous to use
 - PNR, Dark count rate, QE
- Room for improvement
 - Light leaks, QE

