Testing the Particle Interpretation of the PVLAS Results

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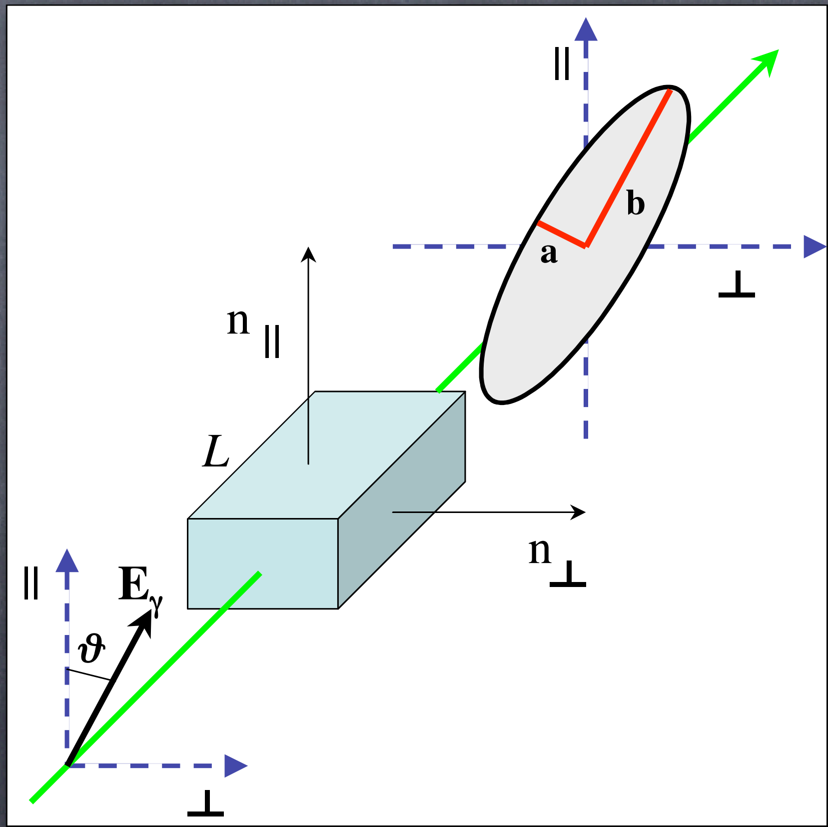
- PVLAS has a signal
- Many journals have written about our result commenting on its importance, if confirmed
- They all talk about a yet undetected particle
- This is a possible interpretation of our result which must be verified

Linear Birefringence

- A birefringent medium has $n_{||} \neq n_{\perp}$
- A linearly polarised light beam propagating through a birefringent medium will acquire an ellipticity Ψ

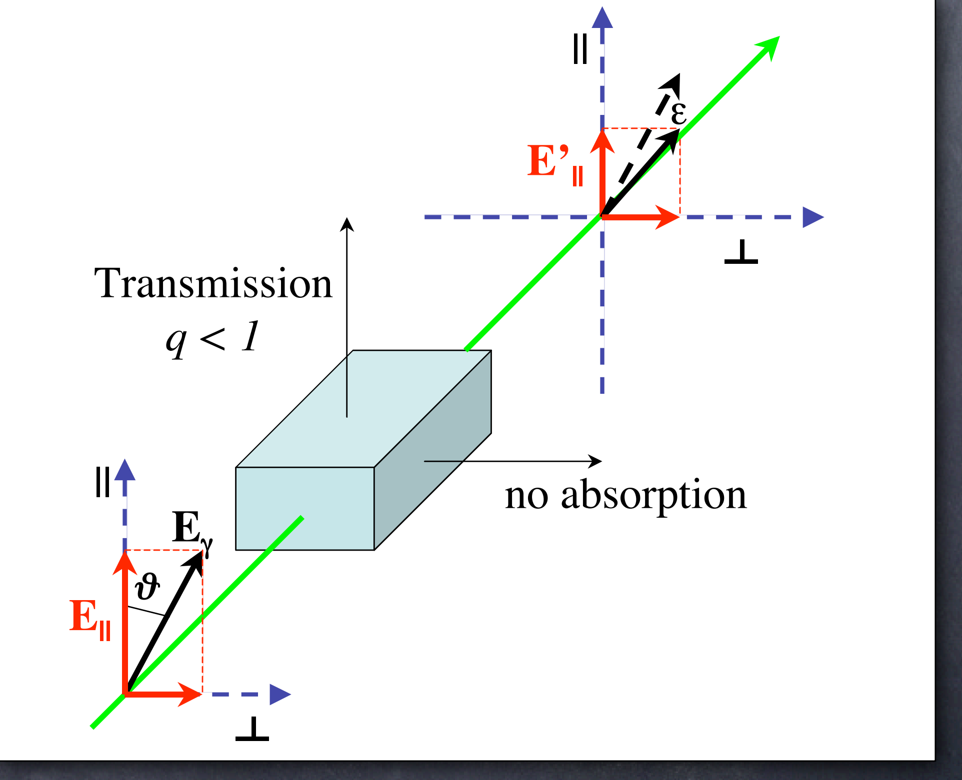
$$\psi = \frac{a}{b} = \frac{\pi L}{\lambda}\left(n_{\parallel} - n_{\perp}\right)\sin 2\vartheta$$



Linear Dichroism

- A dichroic medium has a selective absorption of one polarization component
- A linearly polarized light beam propagating through a dichroic medium will acquire a rotation ϵ

$$\varepsilon = \left(\frac{1-q}{2}\right)\sin 2\vartheta$$

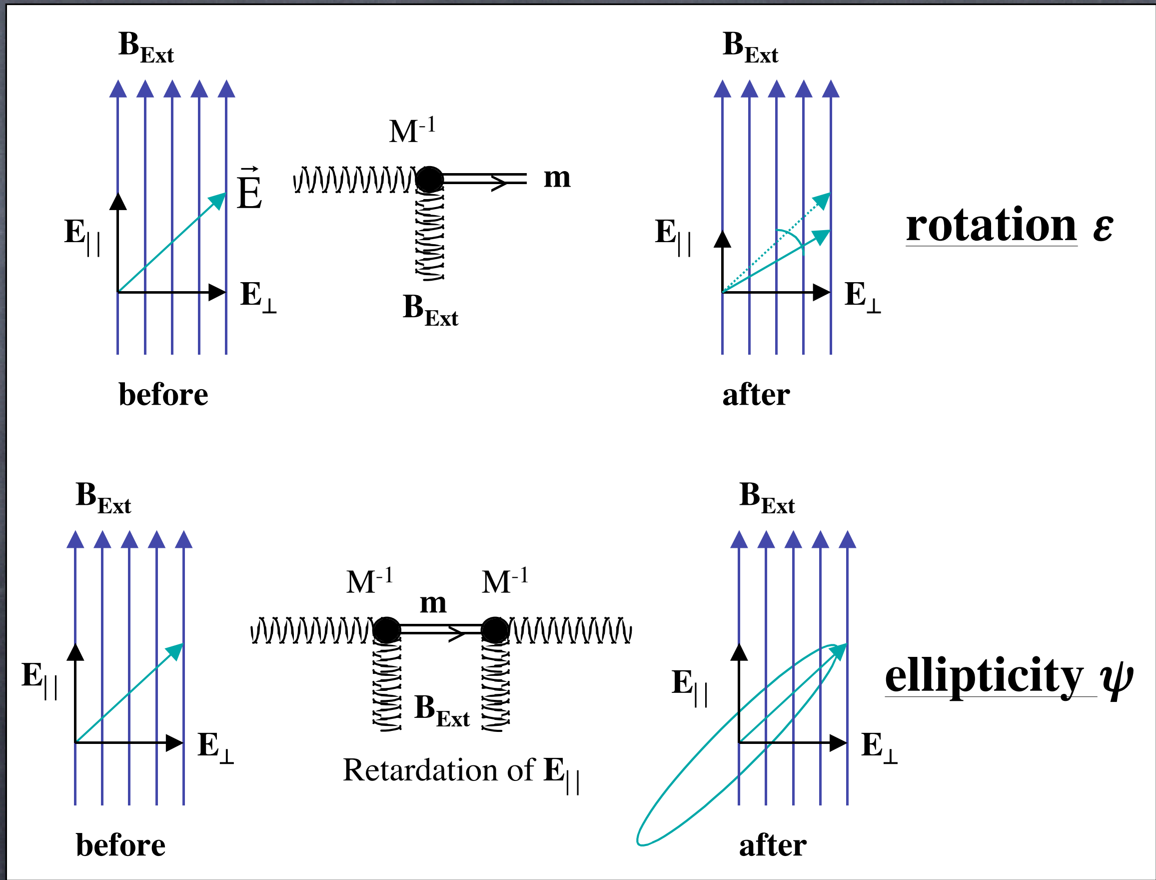


Particle induced dichroism and birefringence

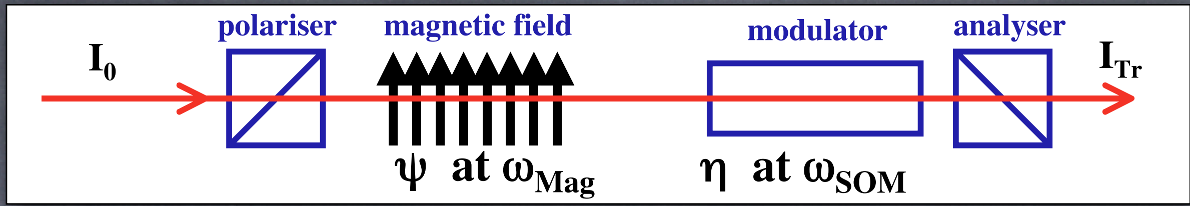
In this example there is an interaction $\propto \mathbf{B}_{Ext} \cdot \mathbf{E}$

Dichroism

Birefringence



Ellipticity measurement principle

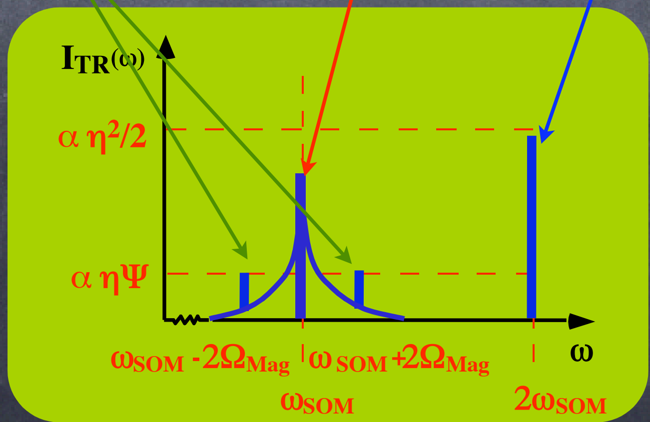


- Modulate the effect and add a carrier $\eta(t)$ to signal at ω_{SOM}
- Rotating the field at Ω_{Mag} produces an ellipticity at $2\Omega_{Mag}$

$$I_{Tr} = I_0\left[\sigma^2 + \left(\psi(t) + \eta(t) + \beta_s(t)\right)^2\right]$$

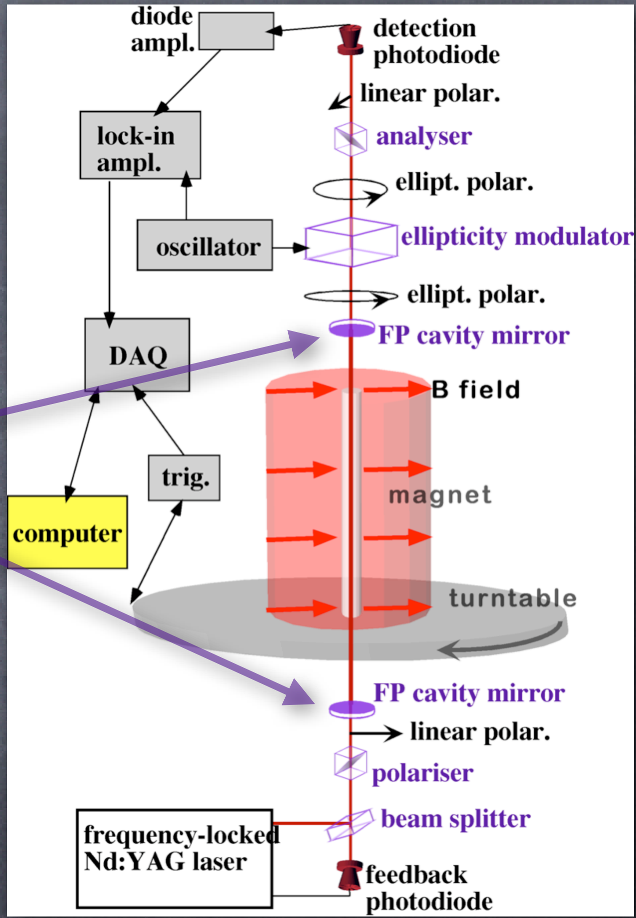
$$= I_0\left[\sigma^2 + \left(2\psi(t)\eta(t) + 2\beta_s(t)\eta(t) + \eta(t)^2 ...\right)\right]$$

Desired signal — Birefringence noise — Normalization



Particle production

- Main parameters of the apparatus
  - magnet
    - dipole, 6 T, temp. 4.2 K, 1 m field zone
  - cryostat
    - rotation frequency ~300 mHz, sliding contacts, warm bore to allow light propagation in the interaction zone
  - laser
    - 1064 nm, 100 mW, frequency-locked to the F.-P. cavity
  - Fabry-Perot optical cavity
    - 6.4 m length, finesse ~100000, optical path in the interaction region ~ 60 km
  - heterodyne ellipsometer
    - ellipticity modulator (SOM) and high extinction ($\sim 10^{-7}$) crossed polarisers + Quarter Wave Plate (QWP)
    - time-modulation of the effect
  - detection chain
    - photodiode with low-noise amplifier
  - DAQ
    - Slow: demodulated at low frequency and phase-locked to the magnetic field instantaneous direction
    - Fast: high sampling frequency direct acquisition

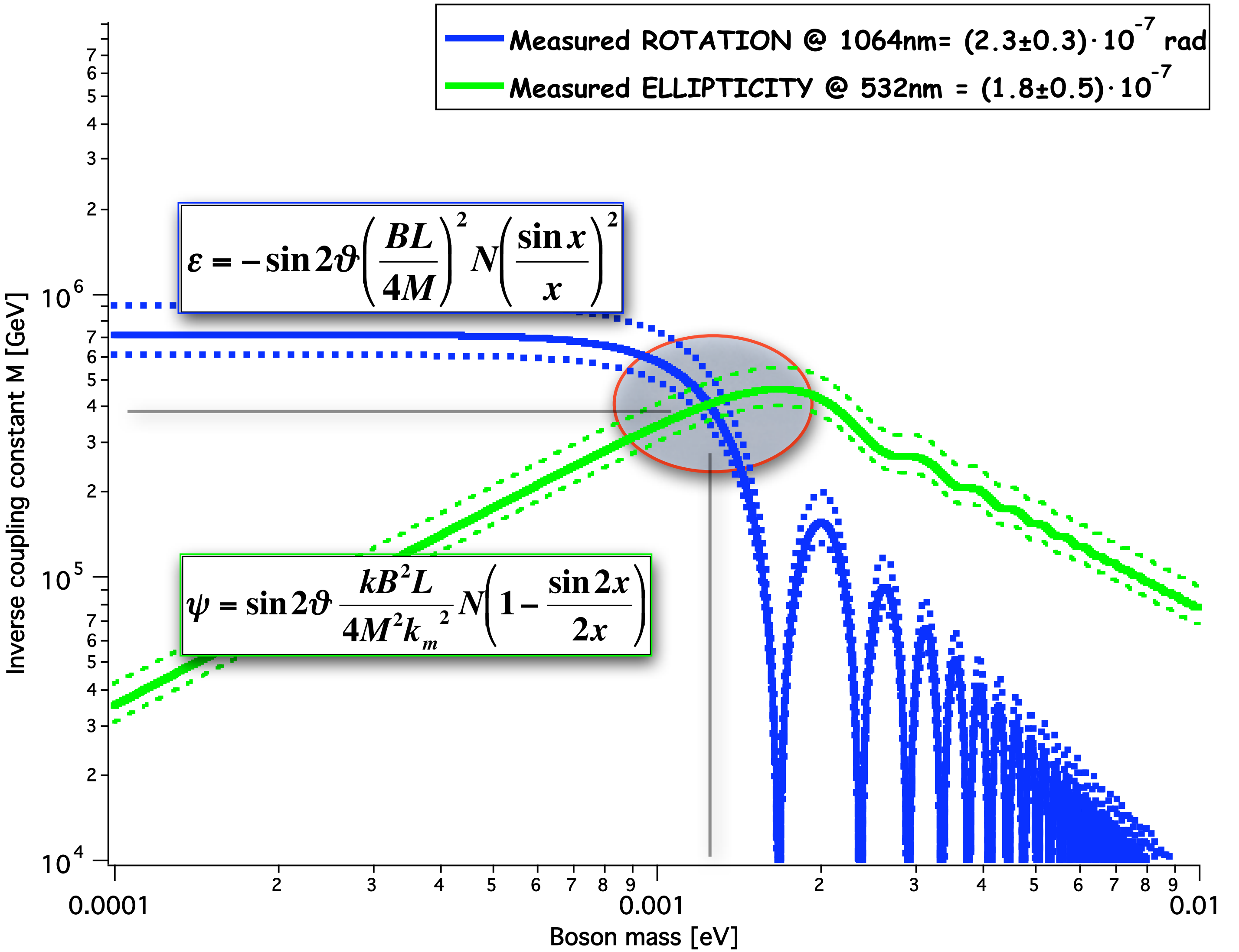


PVLAS results

$$x = \frac{L}{2}\left[\frac{k_m^2}{2k}\right]$$

$$k = \frac{2\pi}{\lambda}$$

$$k_m = \frac{mc}{\hbar}$$



$$\varepsilon = -\sin 2\vartheta\left(\frac{BL}{4M}\right)^2 N\left(\frac{\sin x}{x}\right)^2$$

$$\psi = \sin 2\vartheta\,\frac{kB^2L}{4M^2k_m^2}N\left(1-\frac{\sin 2x}{2x}\right)$$

Particle production

Rotation signal = (1-q)/2 = $2.3 \cdot 10^{-7}$

Outcoming power W from cavity ≈ 60 mWatt
Converted photons = $(W/E_{ph}) \cdot (1-q) = 1.5 \cdot 10^{11}$ photons/s

Particle production = $1.5 \cdot 10^{11}$ per second

Ellipticity curve ∩ Dichroism curve

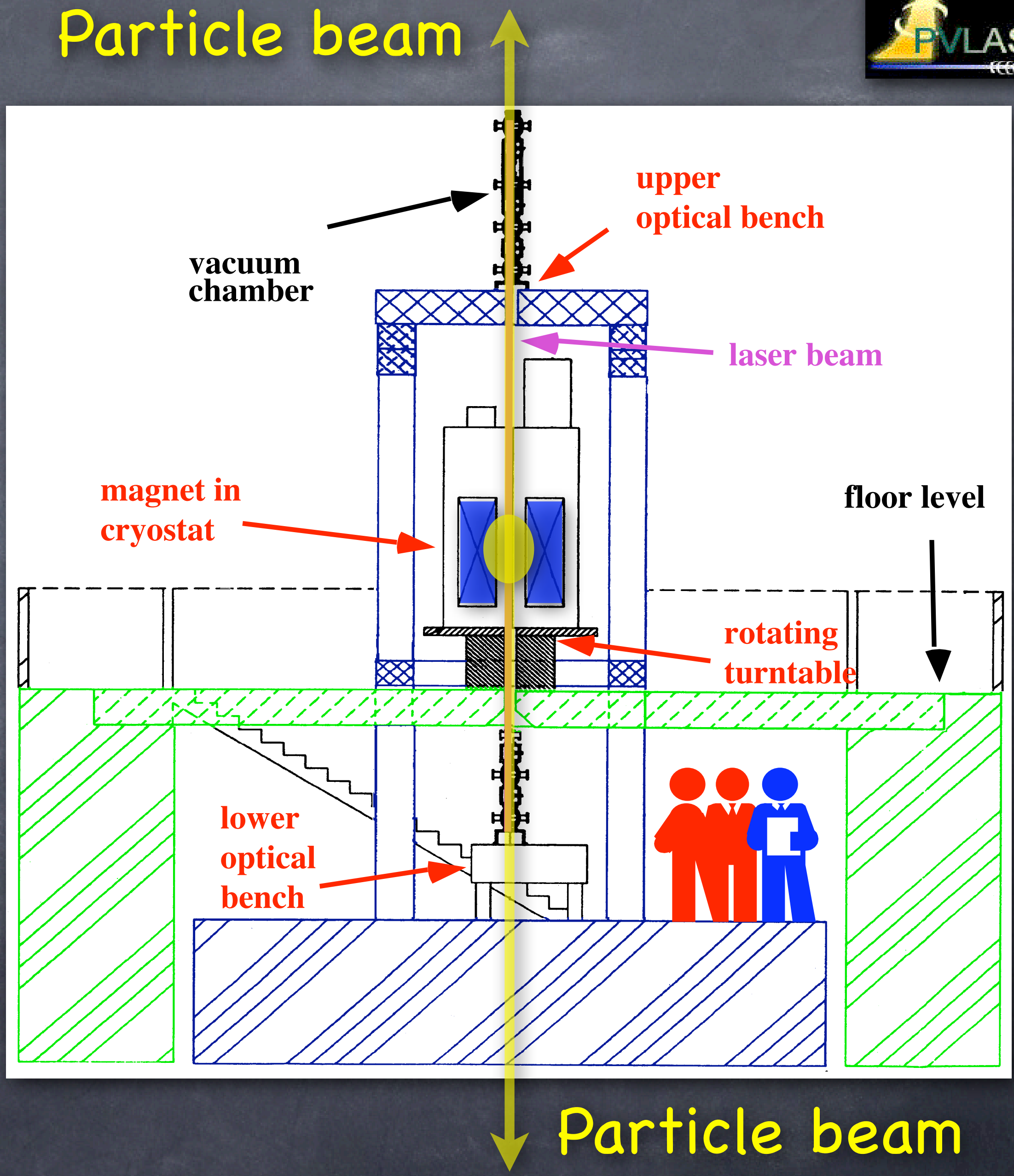
Mass m = 0.001 eV; M = $3.8 \cdot 10^{5}$ GeV

Small mass compared to photon energy

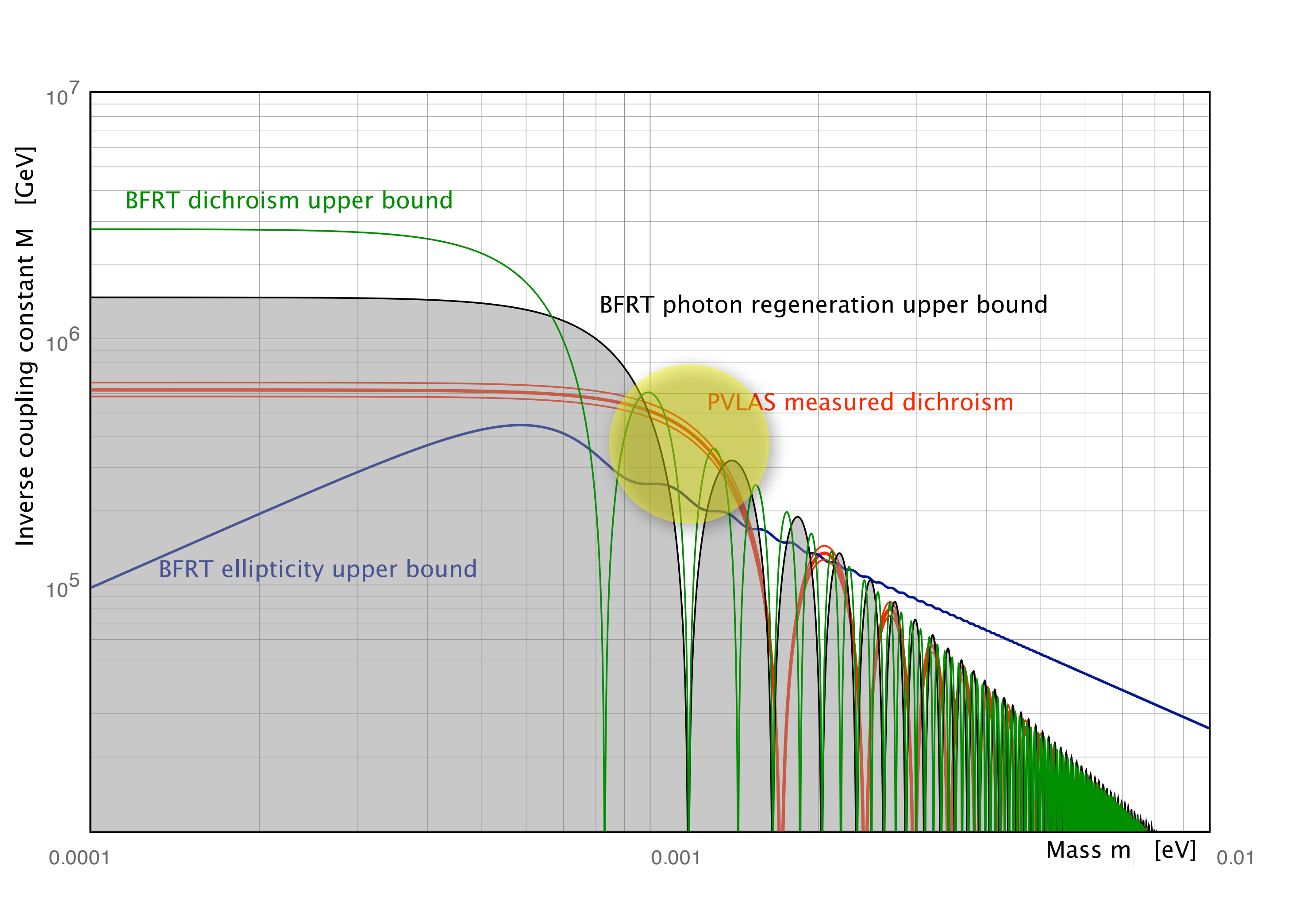
0.001 eV << 1.17 eV

Particles are collinear to laser beam:

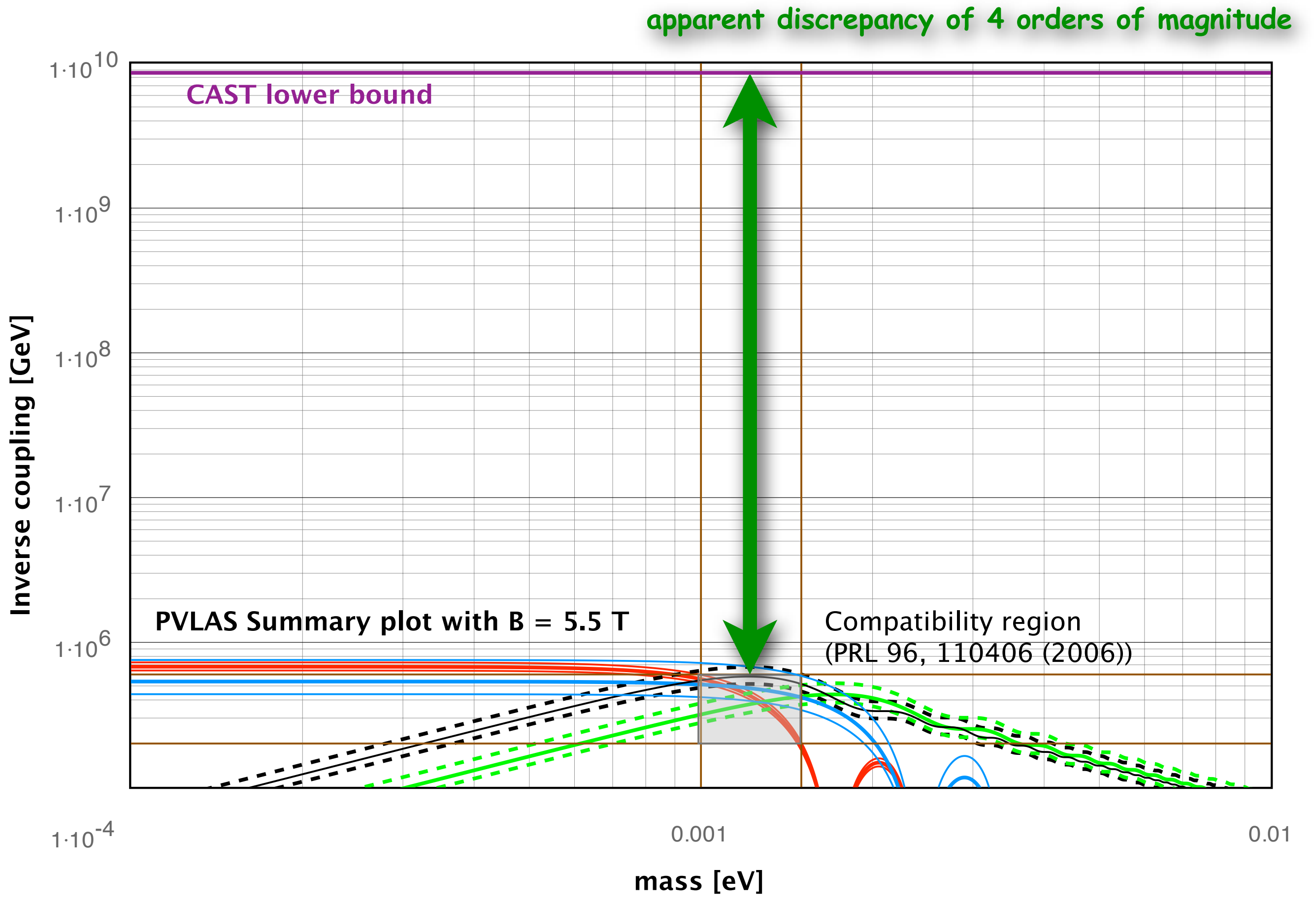
$7 \cdot 10^{10}$ s^{-1} up going and $7 \cdot 10^{10}$ s^{-1} down going particles



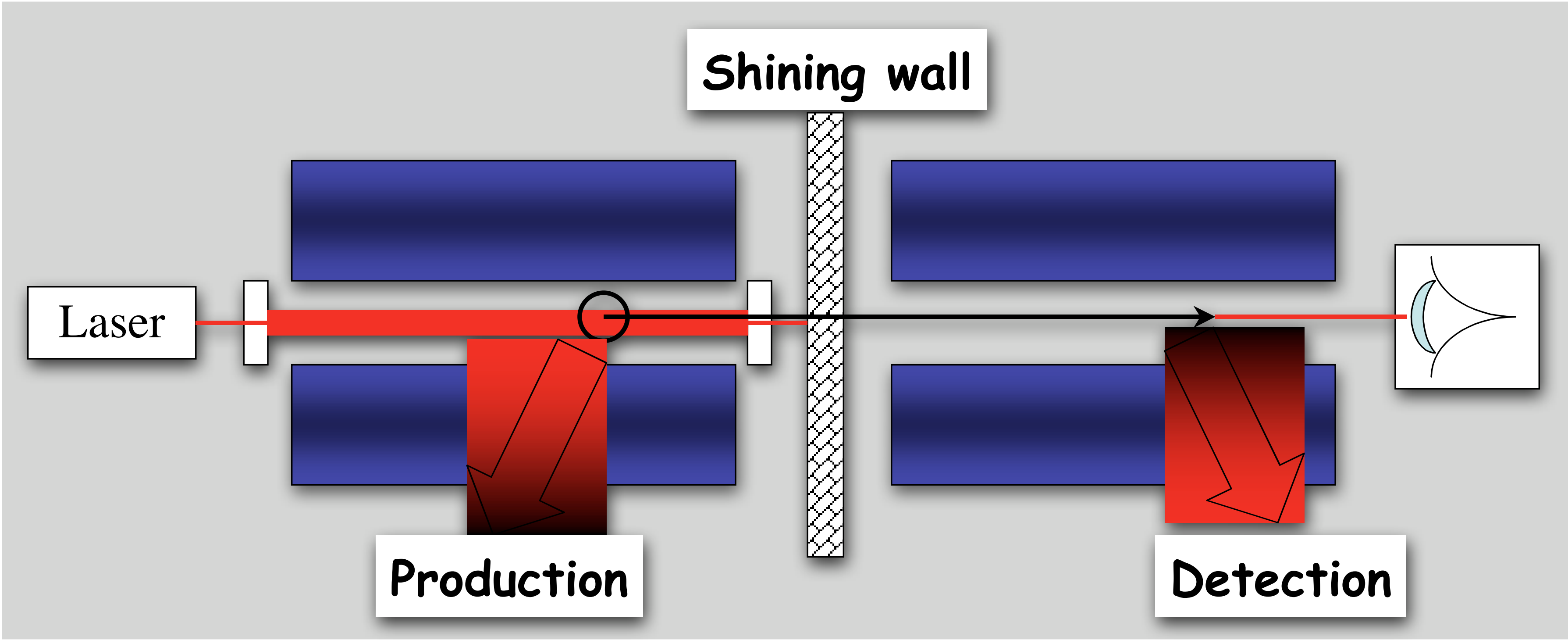
Comparison with BFRT

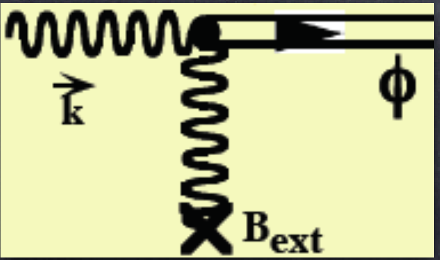


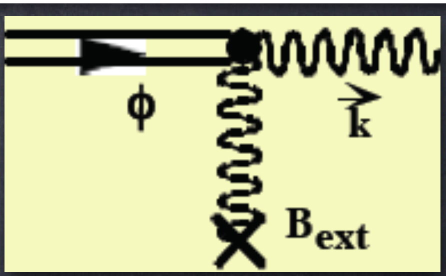
Comparison with CAST



Regeneration







Photon regeneration plans:

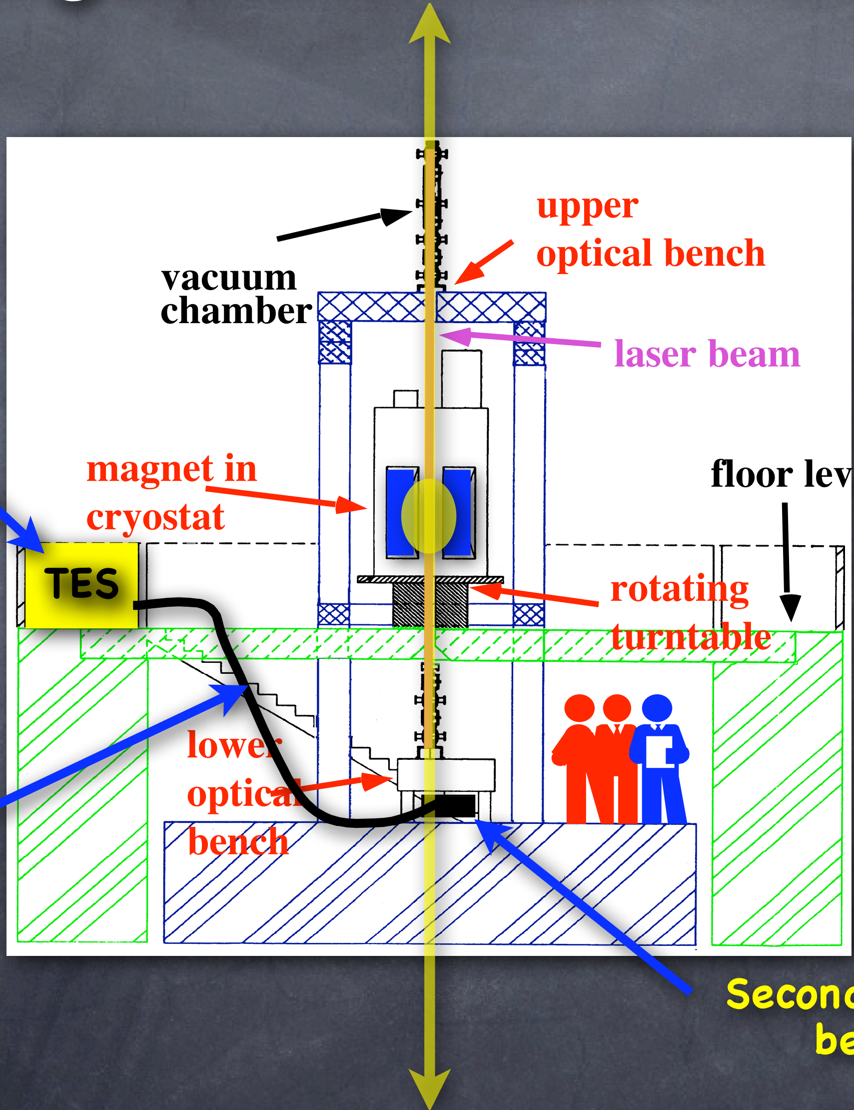
Name	Place	Laser	Flux of initial γ's	Magnets	$P_{\gamma\phi\gamma}\vert_{(g,m_\phi)\mathrm{PVLAS}}$
PVLAS	Legnaro/I	$\lambda = 1064$ nm, $\omega = 1.17$ eV $P = 20 - 800$ mW, cw $N_r = 5 \times 10^5$	3×10^{22}/s - 1×10^{24}/s	$B_1 = 5$ T $l_1 = 1$ m $B_2 = 2.2$ T $l_2 = 0.5$ m	$\sim 10^{-23}$
LIPSS	Jlab/USA	$\lambda = 900$ nm, $\omega = 1.38$ eV $P = 3 - 10$ kW, cw $N_r = 0$	1×10^{22}/s - 5×10^{22}/s	$B = 1.7$ T $l = 1$ m	$\sim 10^{-23.5}$
ALPS	DESY/D	$\lambda = 1064$ nm, $\omega = 1.17$ eV $P = 1$ kW, cw $N_r = 0$ **Test di PVLAS inizio 2007**	1×10^{22}/s	$B = 5$ T $l = 4.21$ m	$\sim 10^{-19}$
BMV	LULI/F	$\lambda = 1053$ nm, $\omega = 1.18$ eV 4 pulses of 1500 J/day $N_r = 0$ **Primi dati fine 2006** **Test di PVLAS Marzo 2007**	8×10^{21}/pulse	$B = 11$ T $l = 0.25$ m	$\sim 10^{-21}$
APFEL	DESY/D	$\lambda = 32$ nm, $\omega = 38.7$ eV 8×10^3 pulses of 50μJ/sec $N_r = 0$	8×10^{12}/pulse	$B = 2.24$ T $l = 6$ m	$\sim 10^{-19.5}$
????	CERN/CH	$\lambda = 1064$ nm, $\omega = 1.17$ eV $P = 1$ kW, cw $N_r = 0$	1×10^{22}/s	$B = 9.6$ T $l = 7$ m	$\sim 10^{-17}$

A. Ringwald (DESY) IDM 2006, Rhodes, Greece

Regeneration at PVLAS

Transition Edge Sensor (TES) for photon detection

Optical fiber

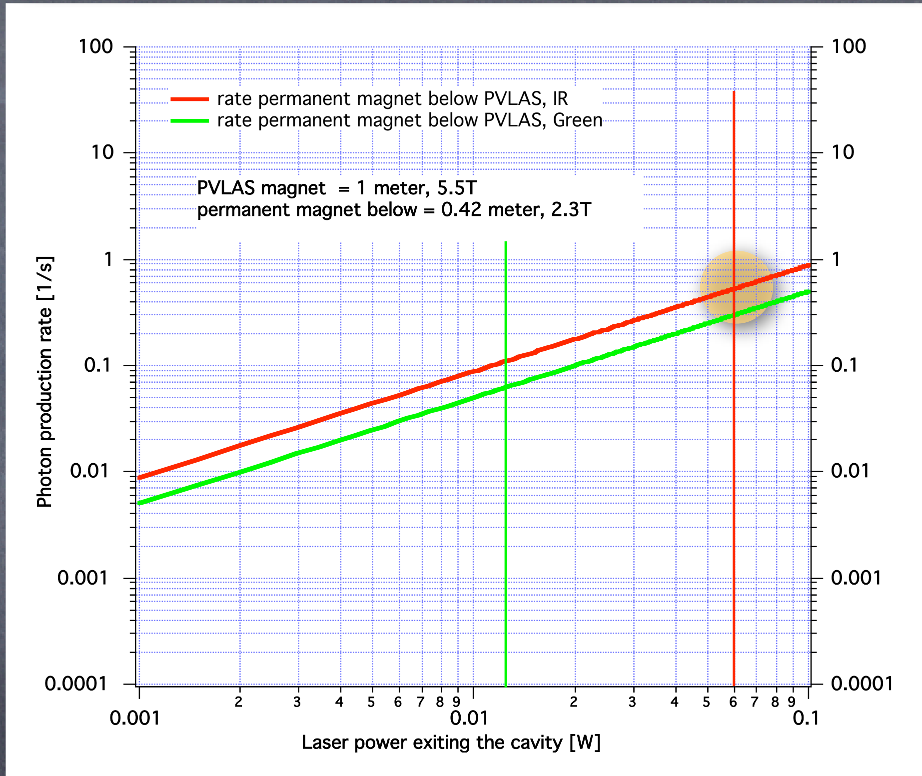


Second regeneration magnet below optical bench
L = 50 cm
B = 2.2 T

Rates and measurement times

- Scenario
  - 1064 nm laser, ~60 mW at FP output
  - 1 m, 5.5 T superconducting magnet for production
  - 42 cm, 2.3 T permanent magnet for regeneration
  - particle parameters
    - M = 3.8·105 GeV
    - m = 1.1 meV

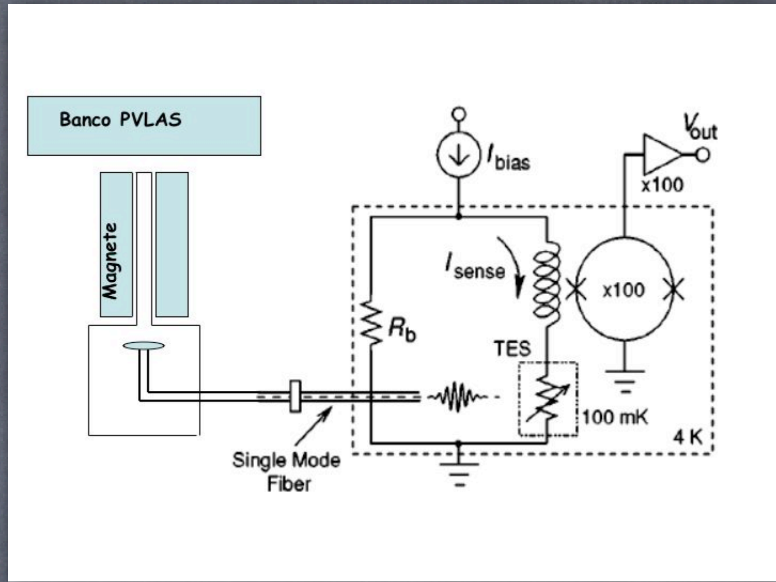
$$R = \frac{W}{E_{ph}}\frac{N}{2}\left(P_{\gamma\leftrightarrow a}\right)^2 = \frac{1}{16}\frac{W}{E_{ph}}\frac{N}{2}\left(\frac{B_0 L}{M}\right)^4\left(\frac{\sin x}{x}\right)^4$$

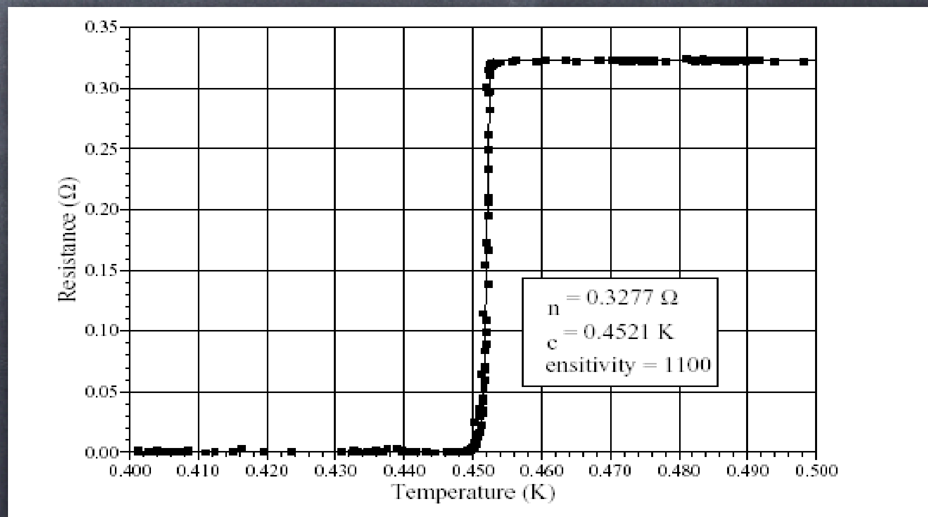


regeneration rate ~ 0.33 ph/s
assume: 0.01 Hz background, 0.3 efficiency
Measuring time with TES to have SNR = 1: ~ 10 s

TES detector

- Transition Edge Sensor
  - works as a bolometer
  - cryogenic temperatures (~100 mK)
  - potentially no background
  - spectroscopic ability
- Photon transport
  - fiber optic
  - 1064 nm interferential filter
- TES developed and provided by Genova INFN group led by F. Gatti

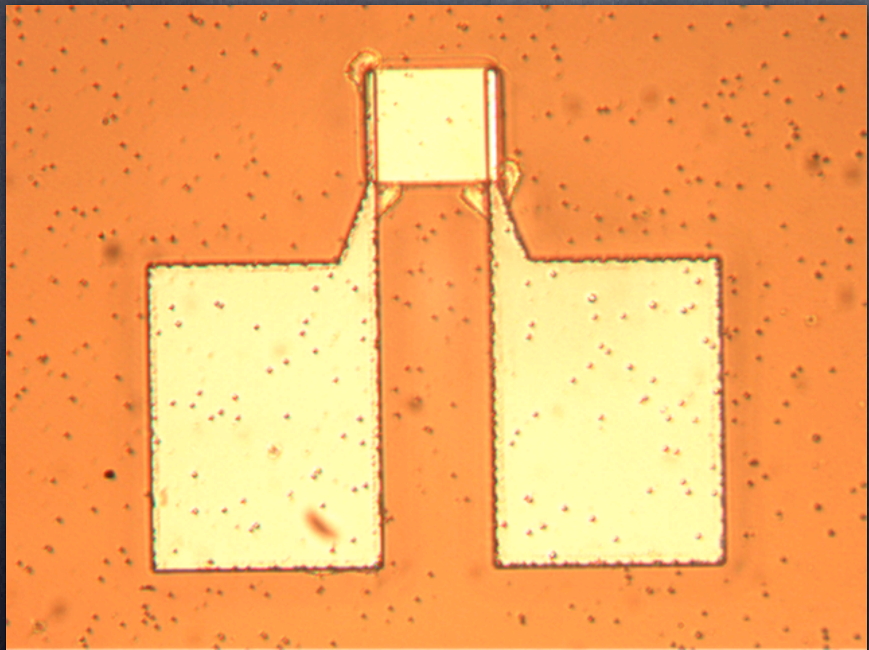


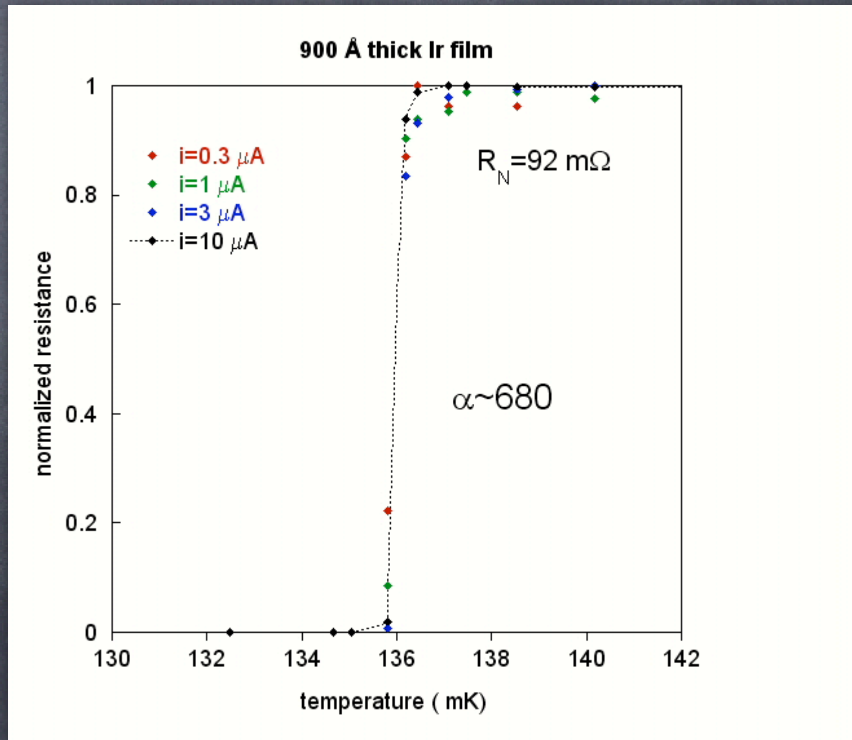


Rivelatore TES per PVLAS

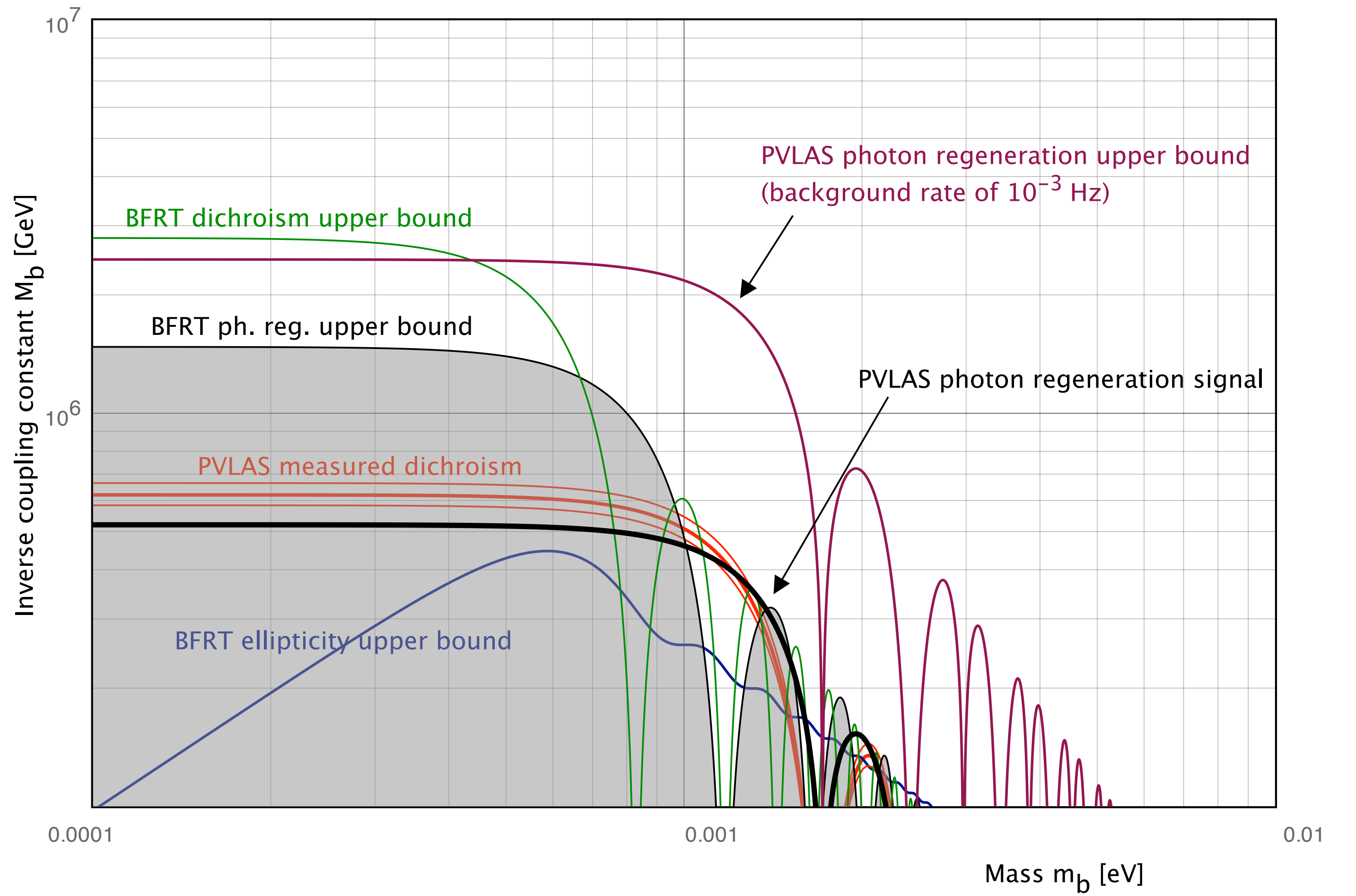
(gruppo di Ge - F. Gatti)

- mattonelle da (25 μmx25 μm)
- caratterizzate a freddo
- prossimamente (ottobre) -> test con fotoni





Regeneration: if No signal



Conclusion

- We will try do give a clear answer to one question: Are we generating an unknown particle?
- A regeneration measurement is an APPEARANCE measurement
- Appearance measurements are intrinsically less prone to systematics