Search for Solar ALPs in the Low Energy Range at CAST

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- Introduction
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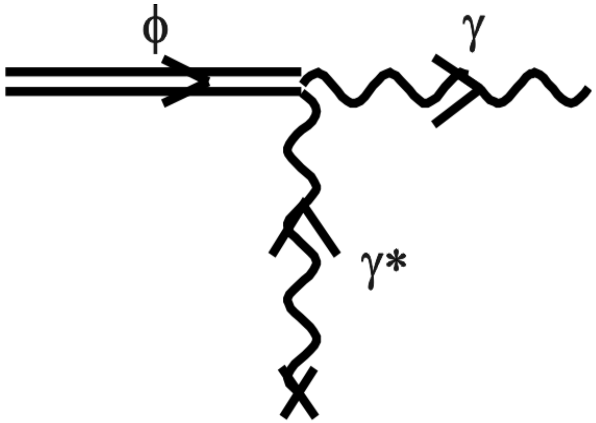
  - Sun
  - CAST
- BaRBE
- Experimental setup
- Results
- Summary

Introduction: ALPs

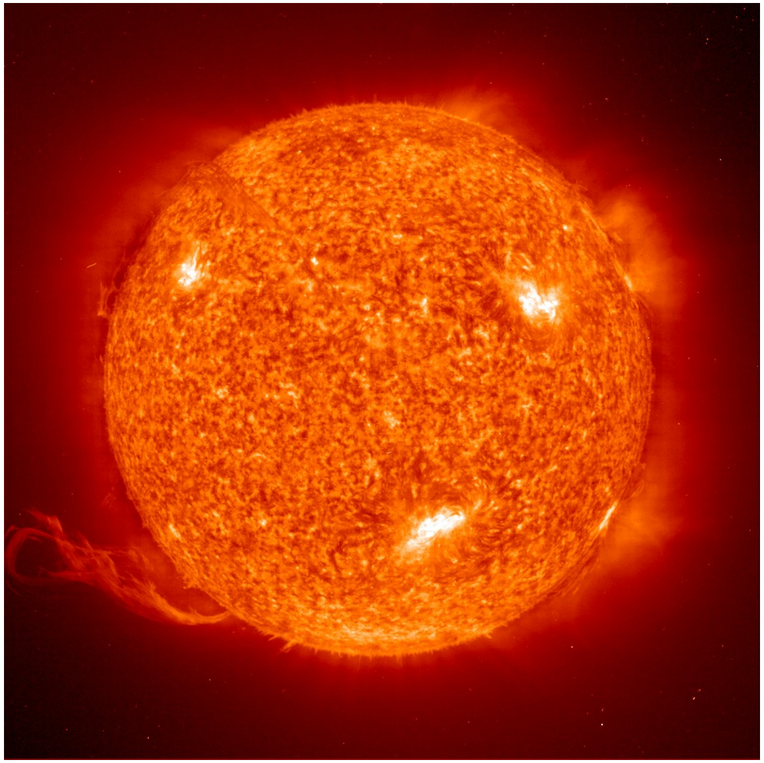


- couple to photons via Primakoff effect
- nearly massless
- weakly interacting

- The axion is a hypothetical elementary particle postulated by the Peccei-Quinn theory in 1977 to resolve the strong-CP problem.

- In particle physics, the strong CP problem is the puzzling question why quantum chromodynamics (QCD) does not seem to break the CP symmetry.

Introduction: Sun



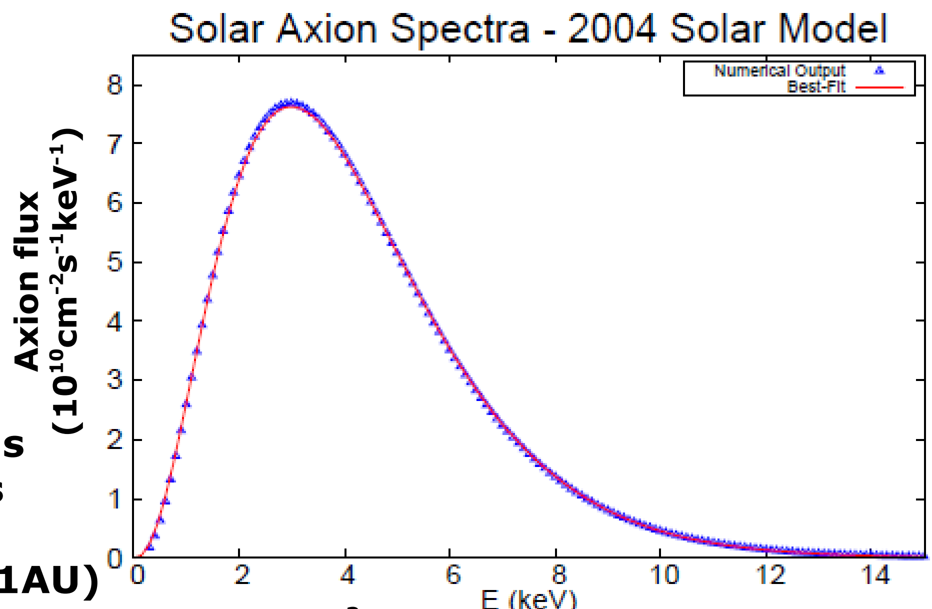
Integrating over a standard solar model, one finds an axion flux at Earth that is is well approximated by (E in keV)

$$\frac{d\Phi_a}{dE} = g_{10}^2\, 6.0 \times 10^{10}\,\mathrm{cm^{-2}\,s^{-1}\,keV^{-1}}\, E^{2.481}\, e^{-E/1.205}\,, \qquad (13)$$

where $g_{10} = g_{a\gamma\gamma}/(10^{-10}\,\mathrm{GeV^{-1}})$. The integrated flux parameters are

$$\Phi_a = g_{10}^2\, 3.75 \times 10^{11}\,\mathrm{cm^{-2}\,s^{-1}}\,,$$
$$L_a = g_{10}^2\, 1.85 \times 10^{-3} L_\odot\,. \qquad (14)$$

The maximum of the distribution is at 3.0 keV, the average energy is 4.2 keV.



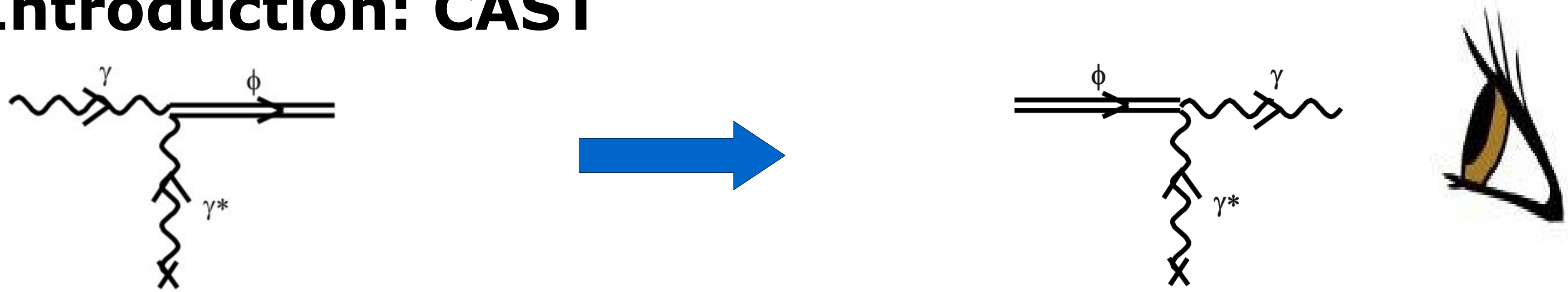
$$\times \left(\frac{g_{a\gamma\gamma}}{10^{-10}\,\mathrm{GeV^{-1}}}\right)^2$$

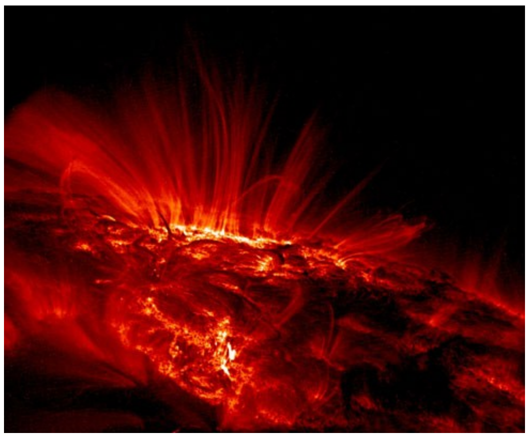
Volume: 1.412 x 10^{18} km^3 _ 1,300,000 Earth's
Mass : 1.989 x 10^{30} kg _ 332,900 x Earth's
Radius : 6.955 x 10^5 km _ 109 x Earth's
Mean Distance to Earth: 149.60 million km (1AU)
Solar Constant (Total Solar Irradiance): 1.365 - 1.369 kW/m^2
(at the mean distance of the earth from the Sun, about one AU)

- solar corona heating

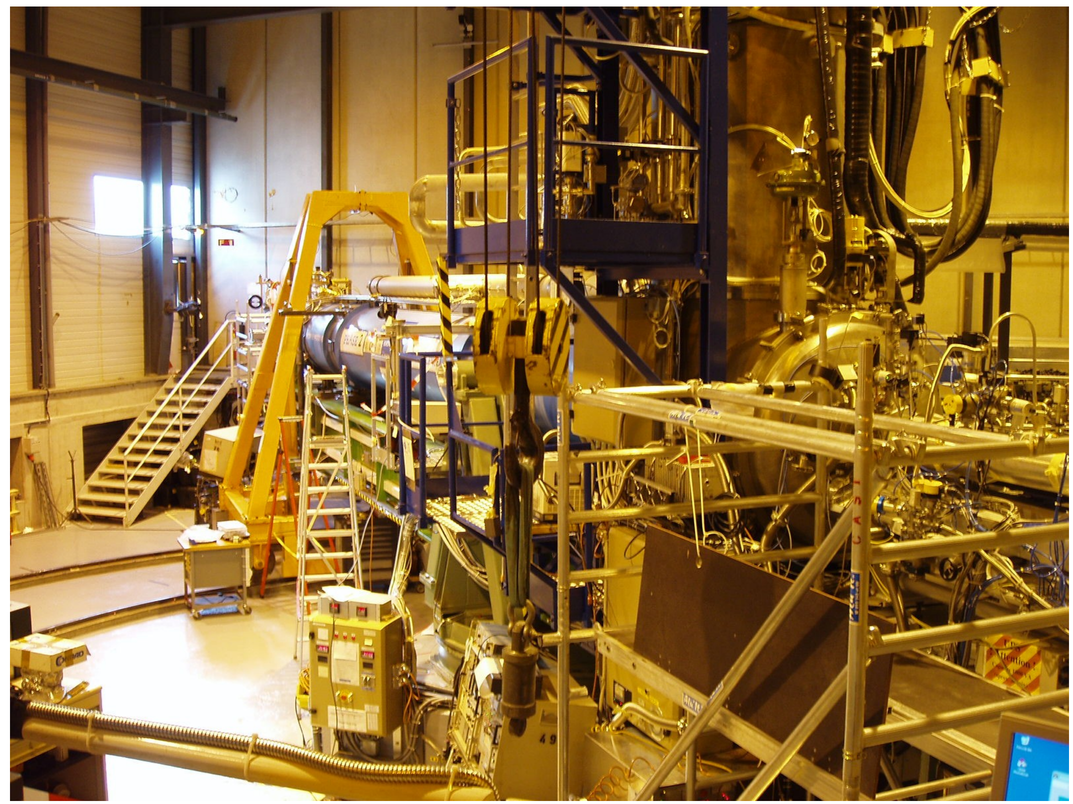
*AXIONS: RECENT SEARCHES AND NEW LIMITS,GEORG G. RAFFELT, arXiv:hep-ph/0504152 v2 2 May 2005

Introduction: CAST



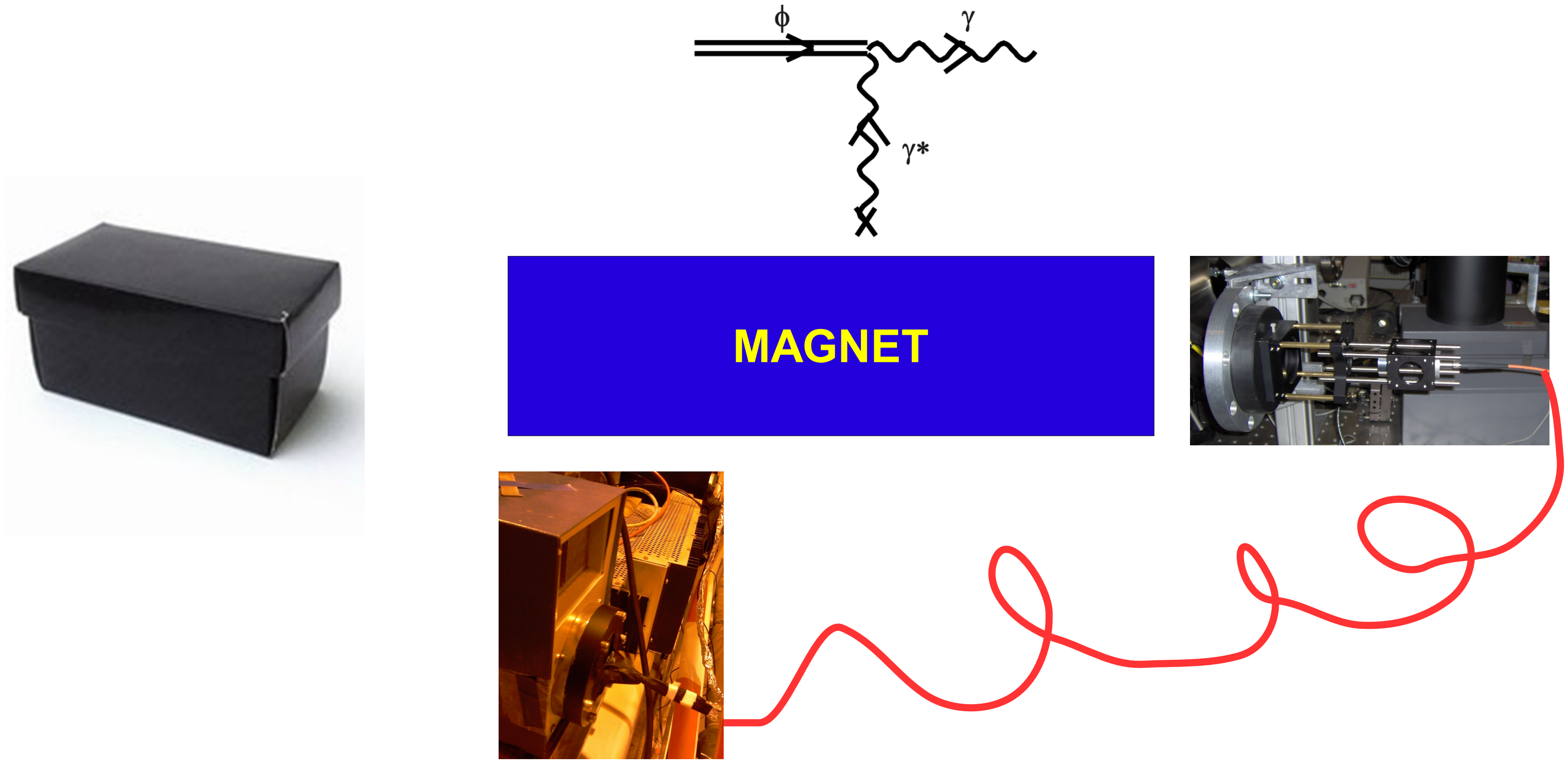


- reconverted photons peaked at 3.2 keV
- LHC dipole magnet L=9.3 m, B=9 T
  d=43 mm, A=14.5 cm^2 x2
- data taking 1.5 h at sunset & sunrise
- 3 MM & 1 CCD
- PMT to look for low energy reconverted photons



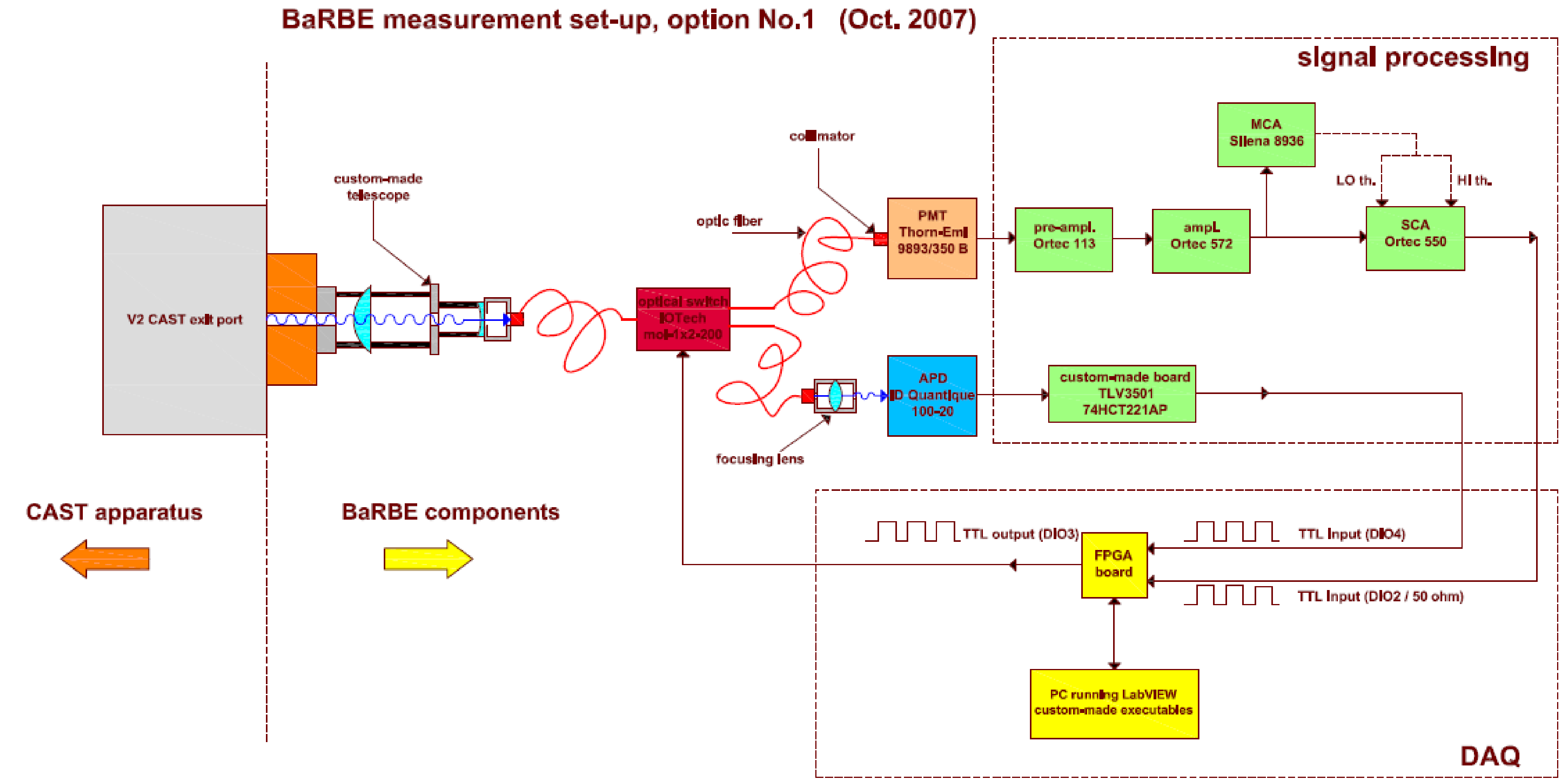
- view from BaRBE counting room

BaRBE
Low Rate – Low Energy



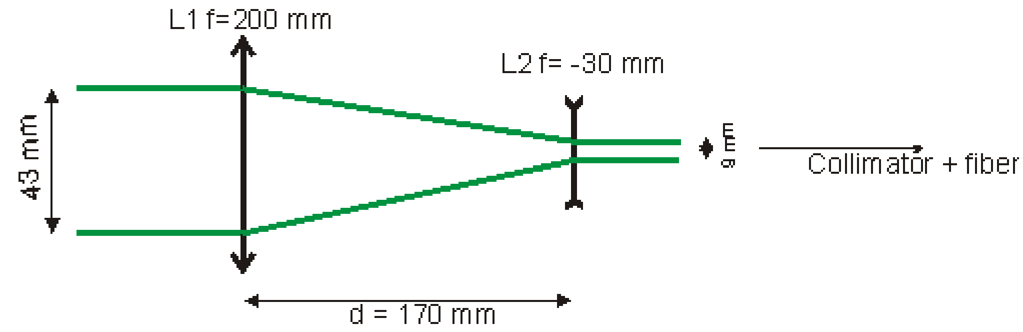
- limited experimental effort financed by INFN
- study various types of detectors with low background
- check coupling with the reconversion magnet with an optical fibre
- look for low energy photons in the magnet bore
- first tests with PMT with an ALPs beam

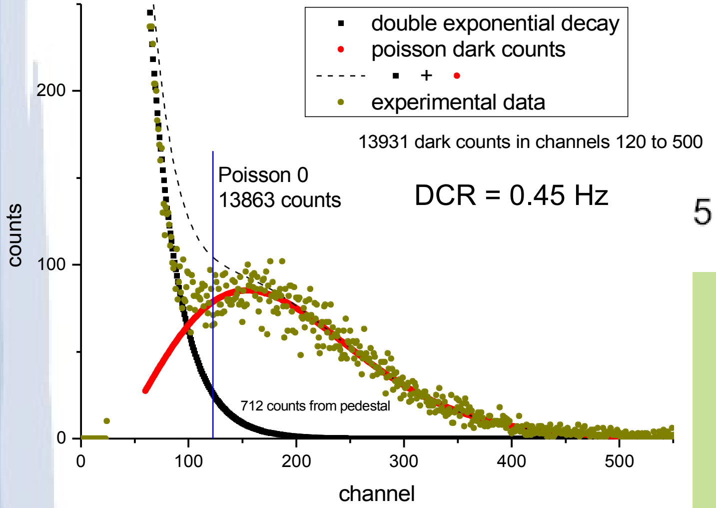
Experimental setup

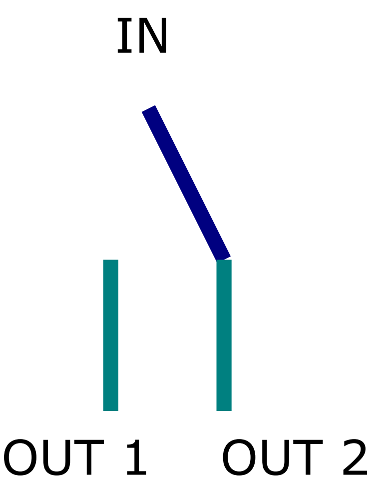


- main idea: divide beam time between two detectors
  use an optical switch
  simultaneous background/live data taking

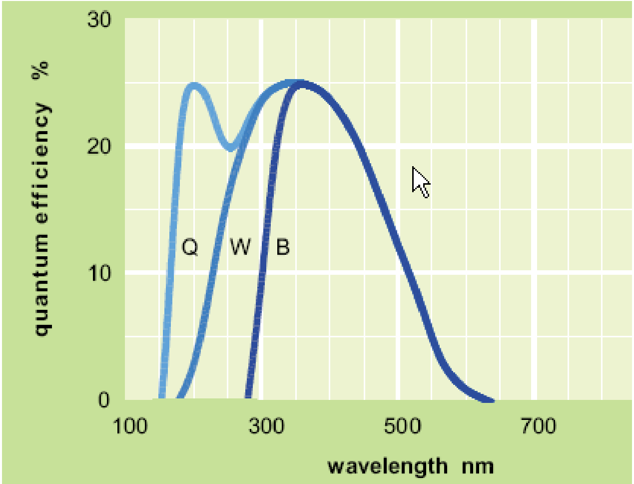
Experimental setup

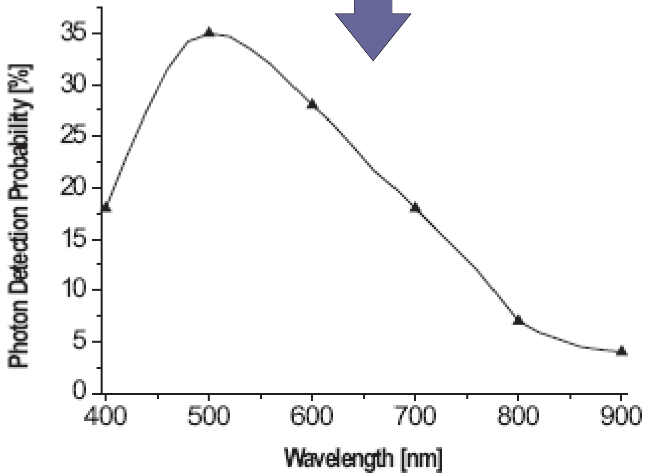






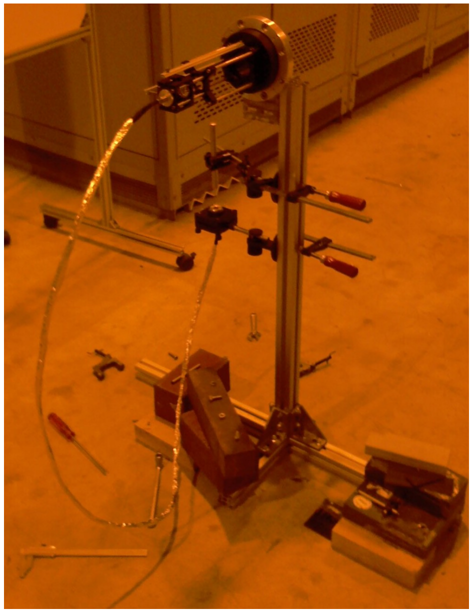
5 typical spectral response curve



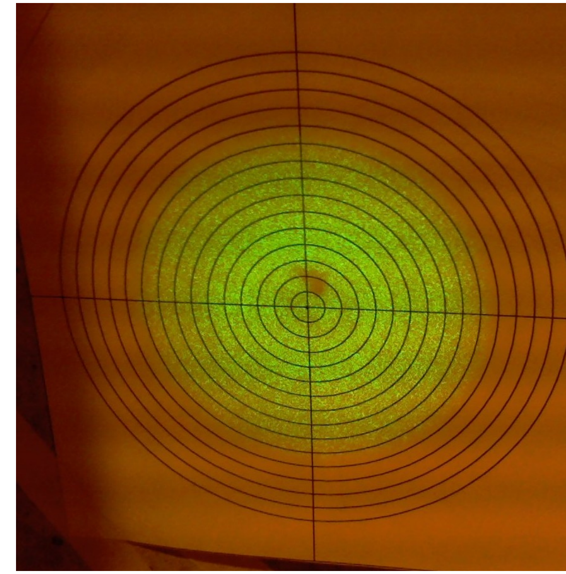


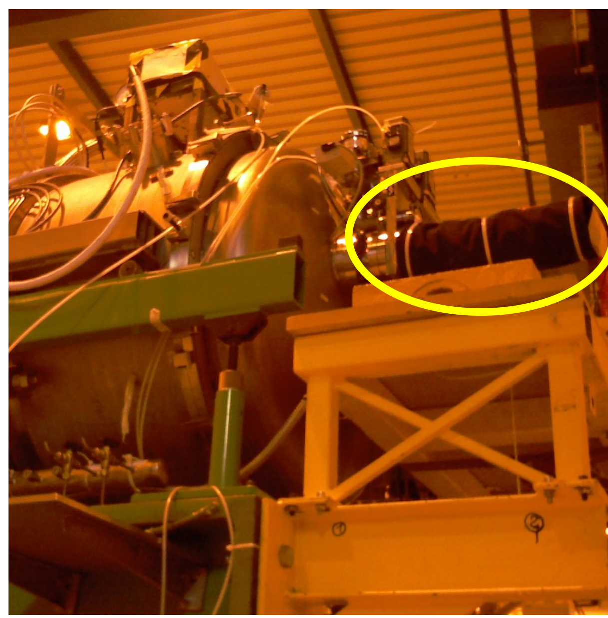
- PMT Thorn EMI 9893/350B, measured dark count rate 0.4 Hz
- APD idQuantique model id100-20, 0.4 Hz DCR, 20 micron diameter

Experimental setup: Alignment



9 m





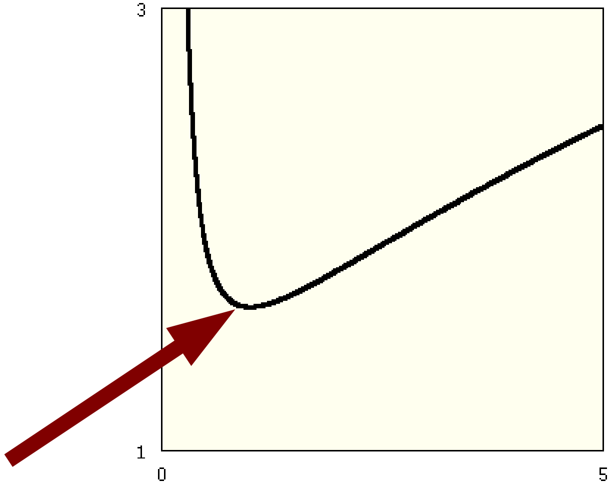
Telescope on CAST magnet

- blind alignment, with surveyors help
- take reference points on the telescope with respect to the beam, align the reference points with the magnet axis

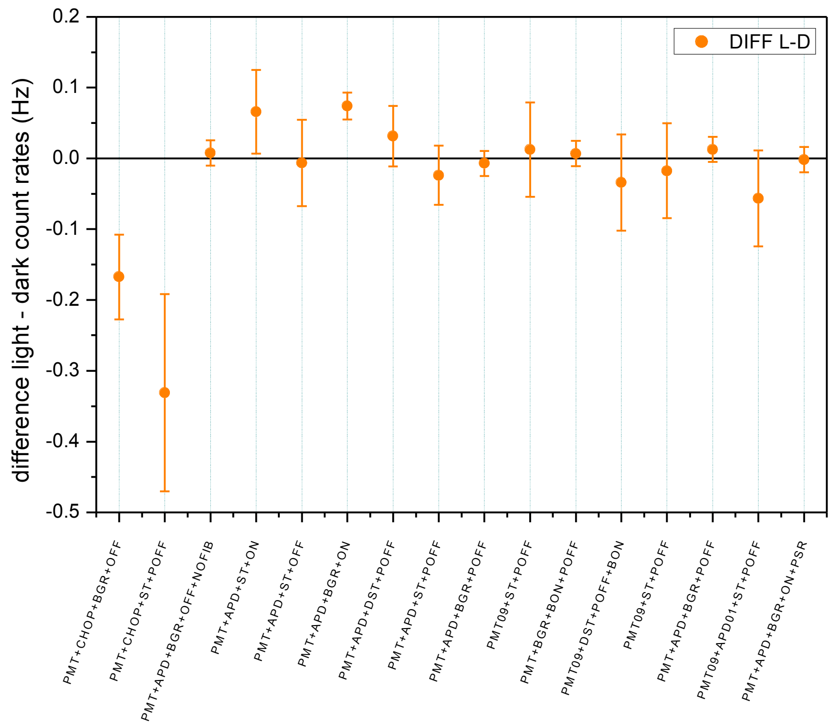
Analysis

Since the data follow a Poisson distribution, another way to calculate the mean rate of counts (light and dark) is to solve the following equation (for x = 0): $N_x = A \cdot e^{(-m)} m^x / x!$ where x is the channel number, A is the total number of occurrences in all channels, N_x is the number of occurrences in the x - th channel measured experimentally. The advantage of this method is that occurrences in the channel 0 are not affected by the afterpulses so the obtained value does not have to be corrected for.

The obtained rate is afterwards normalized to 1 s period and is given in Hz.
The error is affected by the choice of A (function of switching frequency and acquisition time) and is given by $dm_n = \sqrt{(A)} \cdot e^{(N/2A)} / T_D$ This function has a minimum for A = N, i.e. the error is minimized when the number of counting periods is equal to the number of photons N counted during the acquisition time T_D as shown in the following graph (A = N = 1).



Results



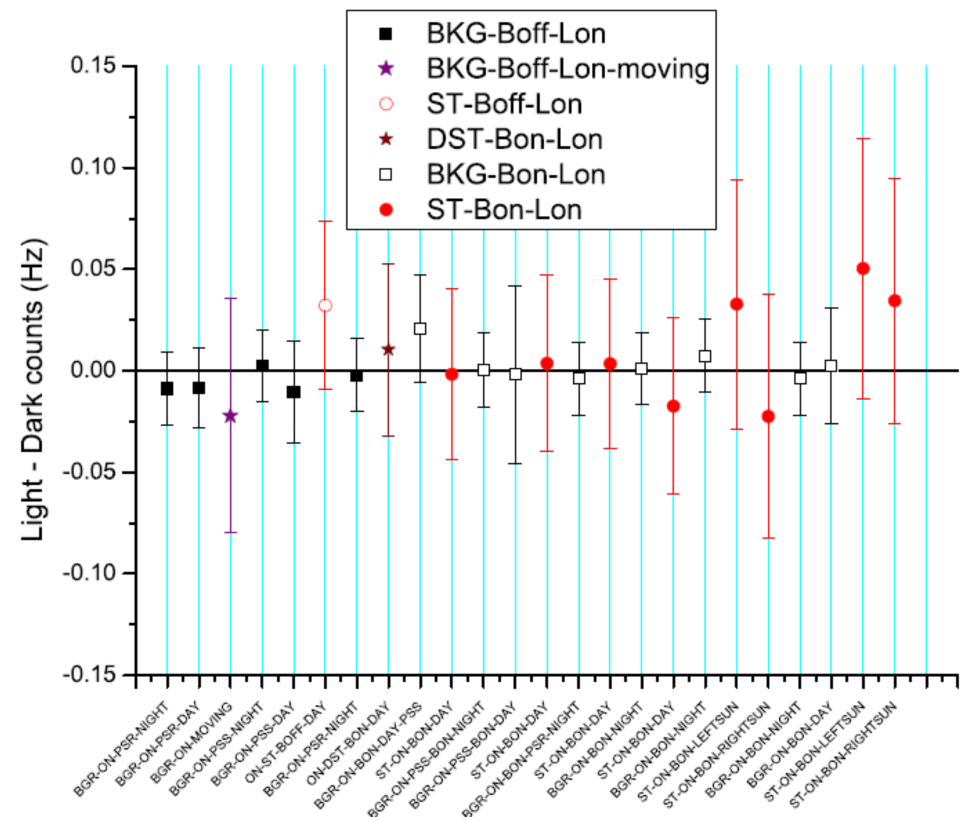
November 2007

τ = 50000 s

g $_{a\gamma\gamma}$ ~ 10^{-6} GeV^{-1}

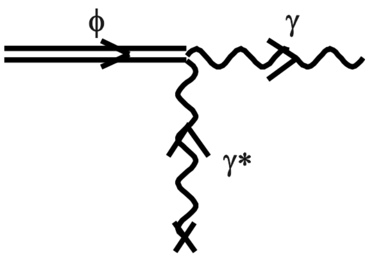
DCR = 0.35 Hz ± 0.02 Hz

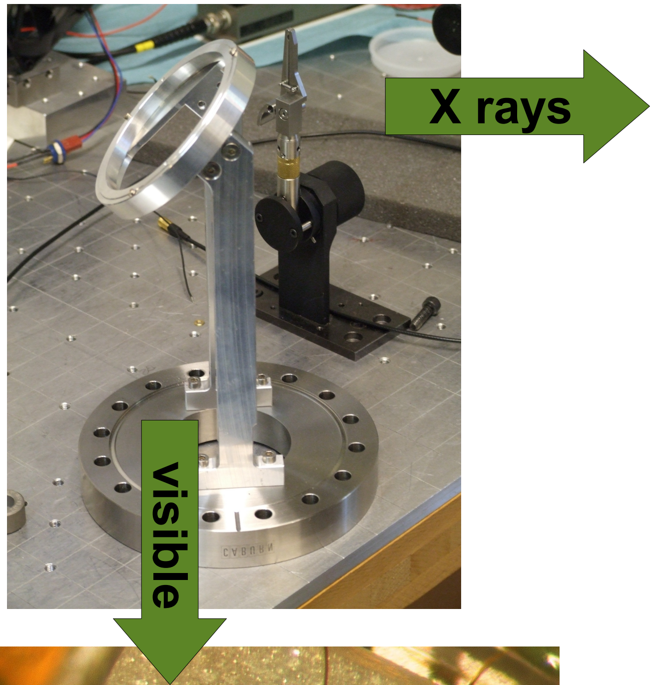
March 2008



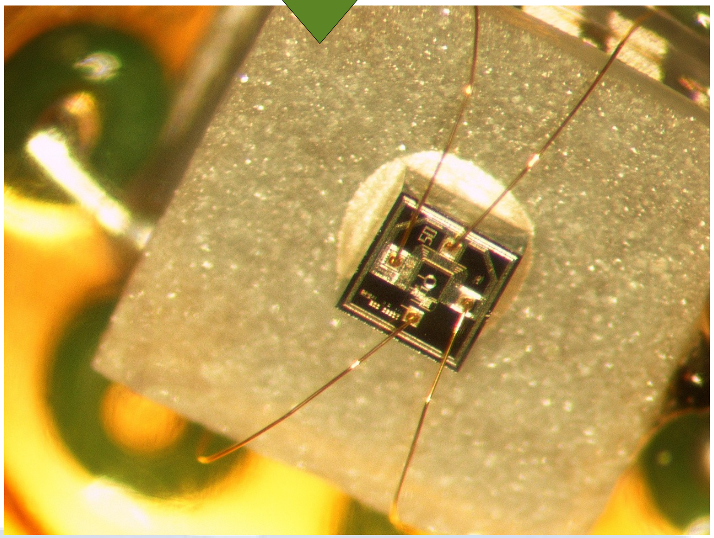
- there is no signal in both data taking runs
- the background is the same as in laboratory conditions

But ...

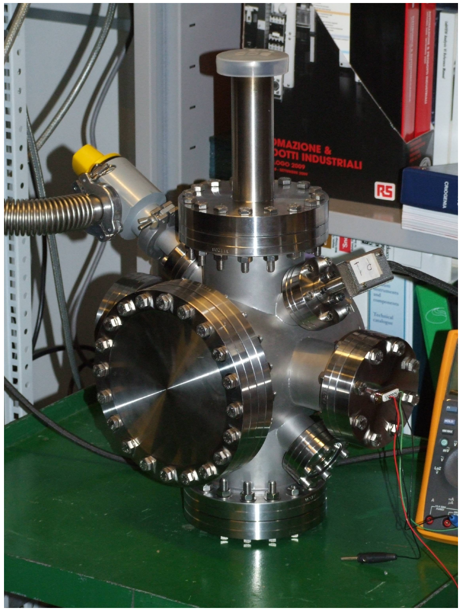


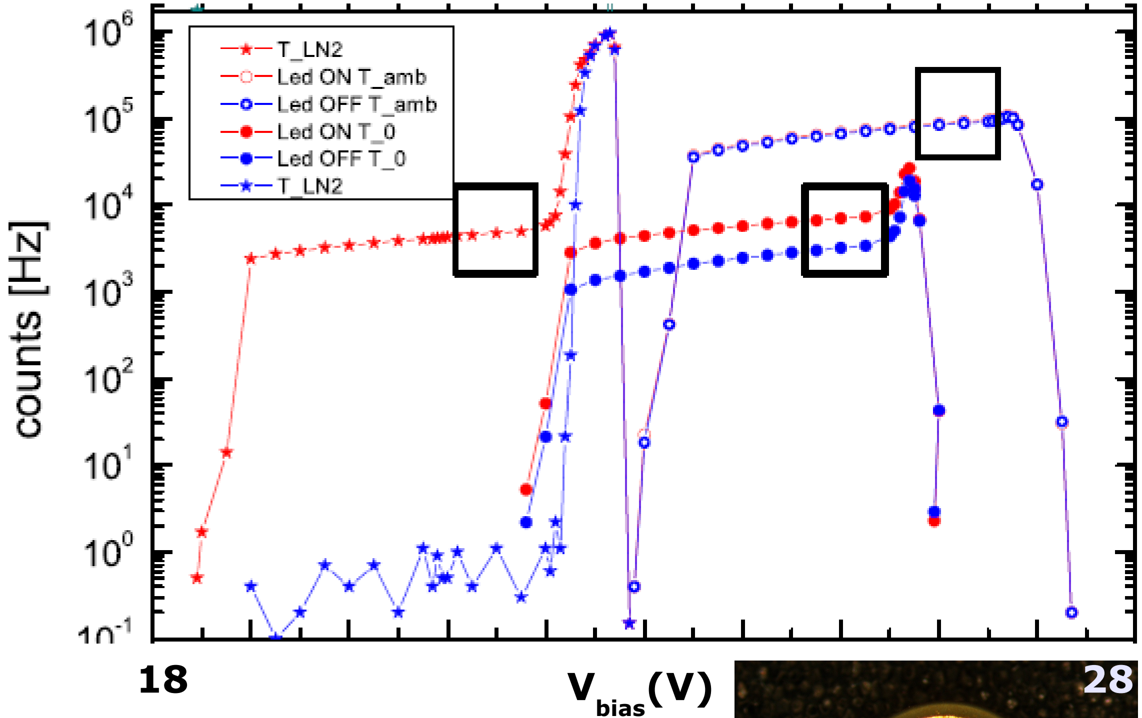


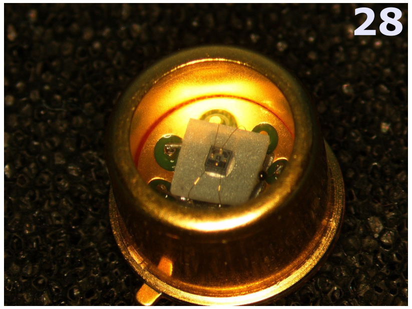
- ALPs source – black box
- semitransparent mirror
- continue to take data
- lower DCR --> detector choice



Poor (wise) man's choice: Cooled APD







- 10^4 background reduction
- no efficiency loss
- works for “bad” APDs
- will it work for “good” ones (starting DCR 1 Hz) ?

Summary

- 10^4 background reduction with cooled APD
- experimental setup is working
- with semitransparent mirror it is possible to continue taking data at CAST
- resonant regeneration
- a surprise can exit from the ALPs black box