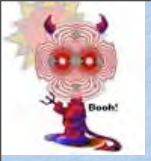
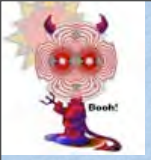
SEARCH FOR LOW ENERGY SOLAR AXIONS WITH CAST

G. Cantatore for the CAST Collaboration
Trieste Group - INFN BaRBE



SUMMARY

- Detector set-up and preparation
- Summary of data taking runs with preliminary results
- What next?

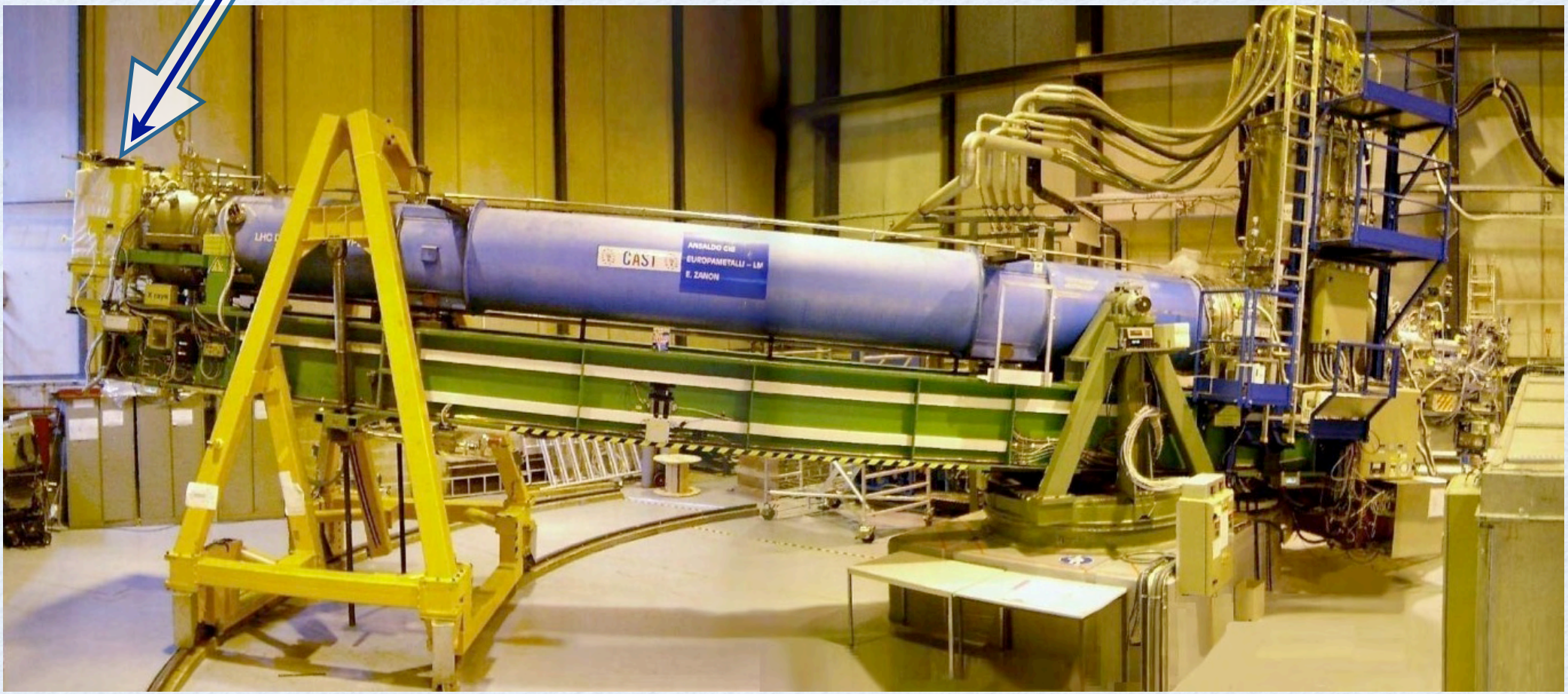


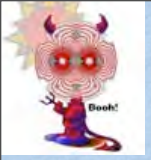
OBJECTIVES

- **Short term:** couple a detector system for **~eV photons** to a CAST magnet bore and **evaluate background**
- **Long term**: attemp to detect "low" energy (tens of eV's) photons generated in the CAST magnet by possible interactions of **low-energy solar axions**

CAST MAGNET

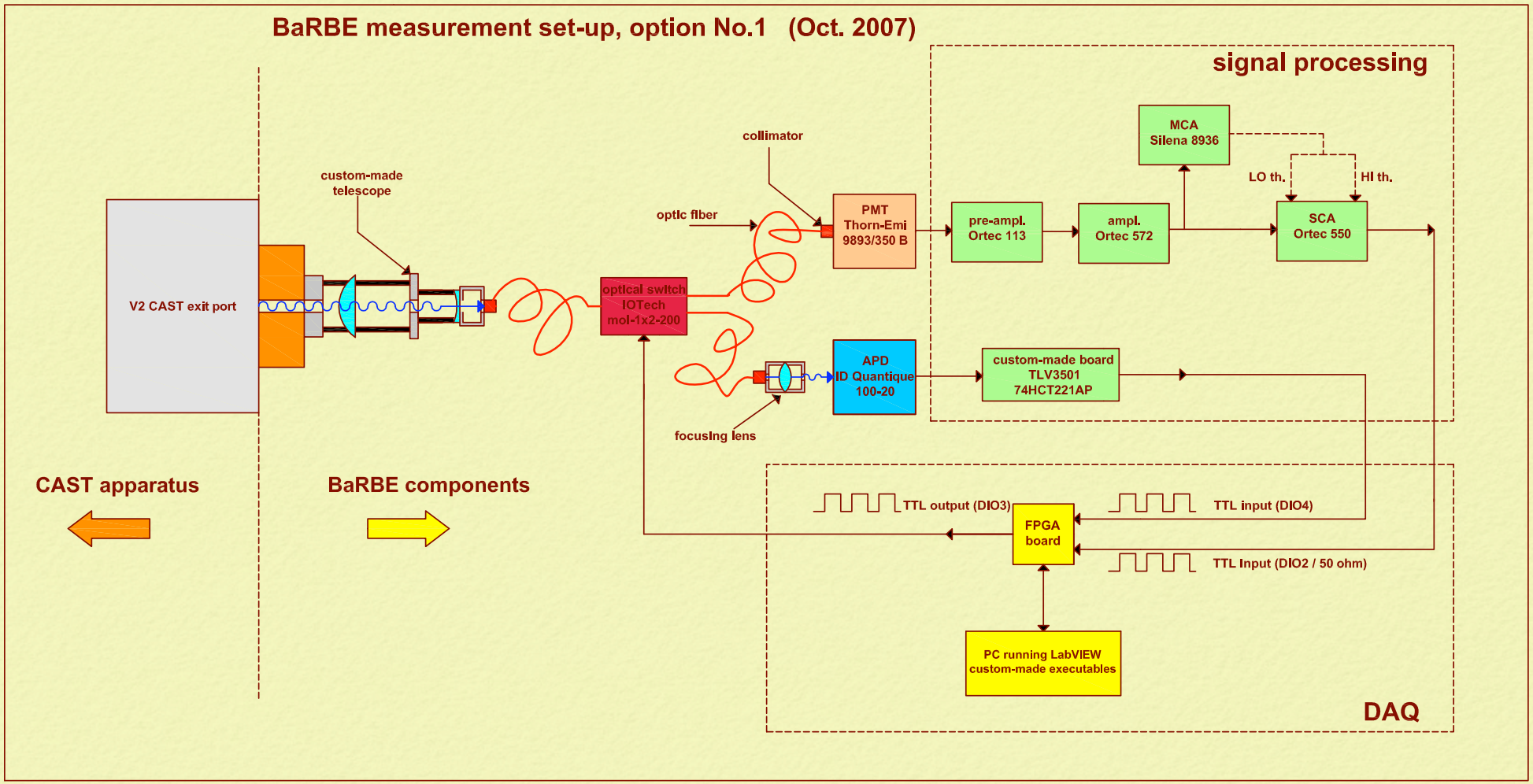
"Sunset side" -> visible detector position

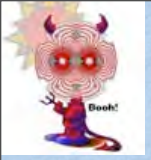




BASIC IDEA

- Start with readily available "visible" detectors: a PMT and an APD
- Optically couple the detector(s) to one of the CAST magnet ports
  - Galileian telescope
  - multimode optical fiber
  - optical switch
- Share fiber output between two detectors using an optical switch: each detector "sees" the "beam" for 50% of the time, leaving the rest for background


BaRBE measurement set-up, option No.1 (Oct. 2007)
signal processing
MCA
Silena 8936
LO th.
HI th.
collimator
custom-made
telescope
optic fiber
PMT
Thorn-Emi
9893/350 B
pre-ampl.
Ortec 113
ampl.
Ortec 572
SCA
Ortec 550
V2 CAST exit port
optical switch
IOTech
mol-1x2-200
APD
ID Quantique
100-20
custom-made board
TLV3501
74HCT221AP
focusing lens
CAST apparatus
BaRBE components
TTL output (DIO3)
FPGA
board
TTL input (DIO4)
TTL Input (DIO2 / 50 ohm)
PC running LabVIEW
custom-made executables
DAQ

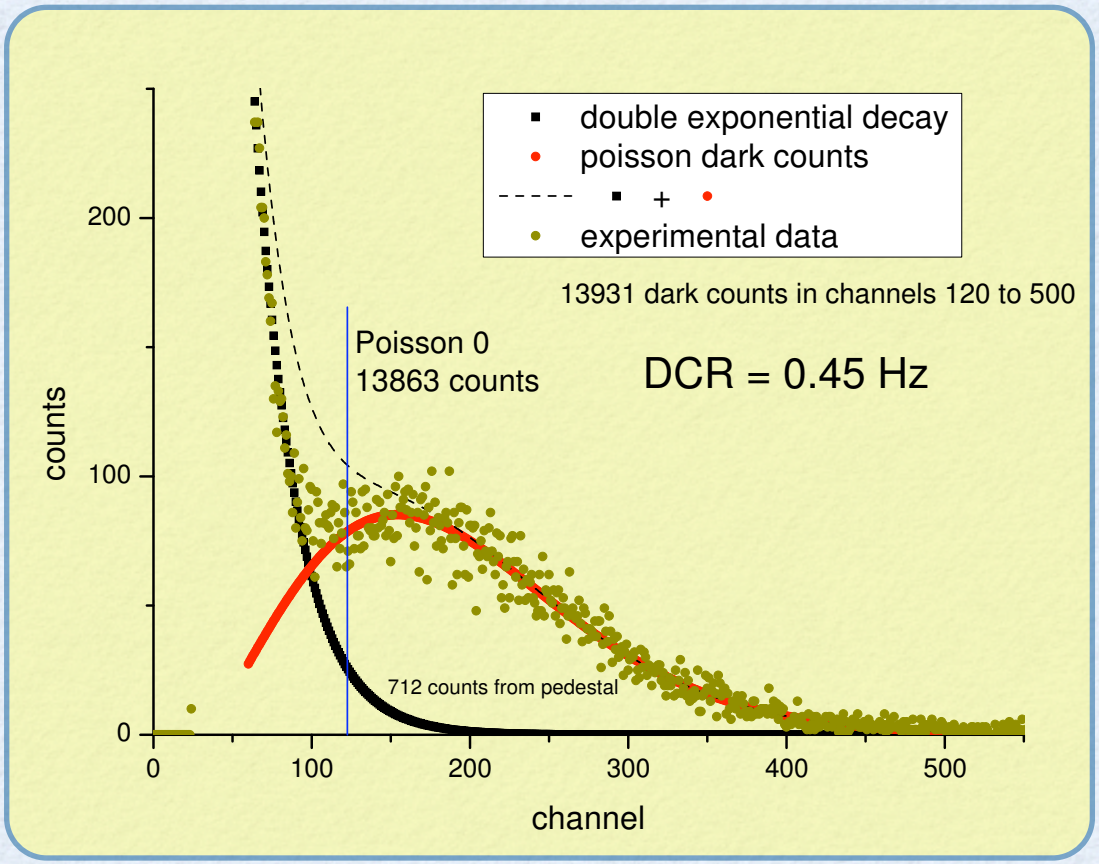


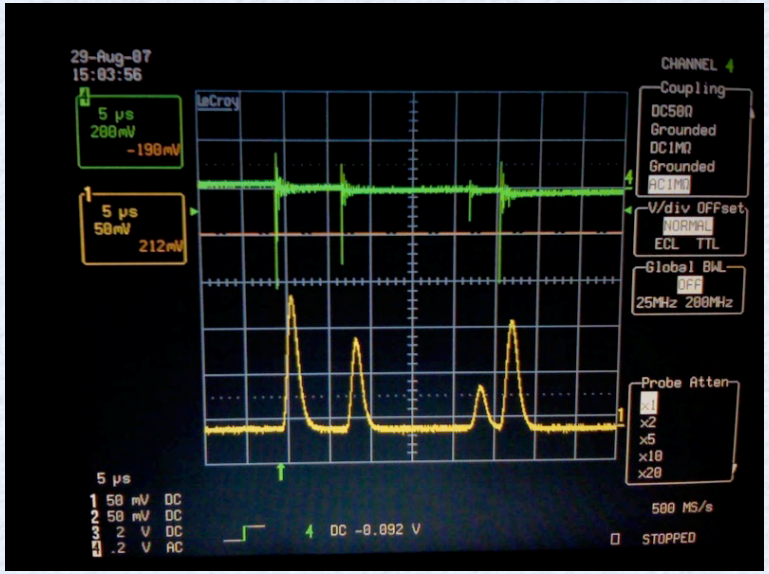
Executive summary: for those who can't wait for coffee...

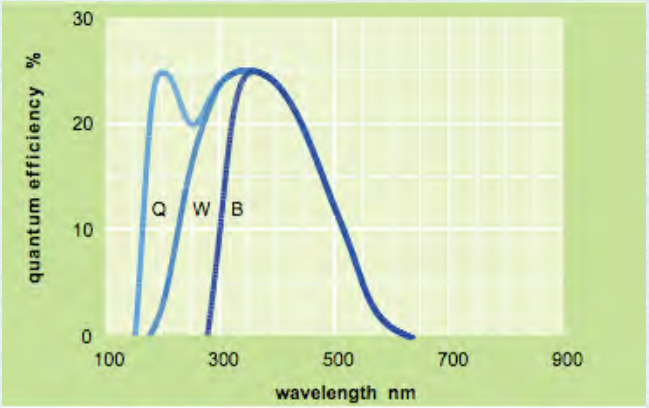
- **Concept actually works...**
- **Main facts (at this time)**
  - **Two "live" data taking runs: November 07 and March 08**
  - **Data taken with fiber-coupled PMT and APD (first run) or PMT only (second run)**
  - **DCR ~ 0.4 Hz (immune to environmental conditions)**
  - **No evidence of a signal above background**

PRE-TEST ON EMI THORN 9893/350B PMT

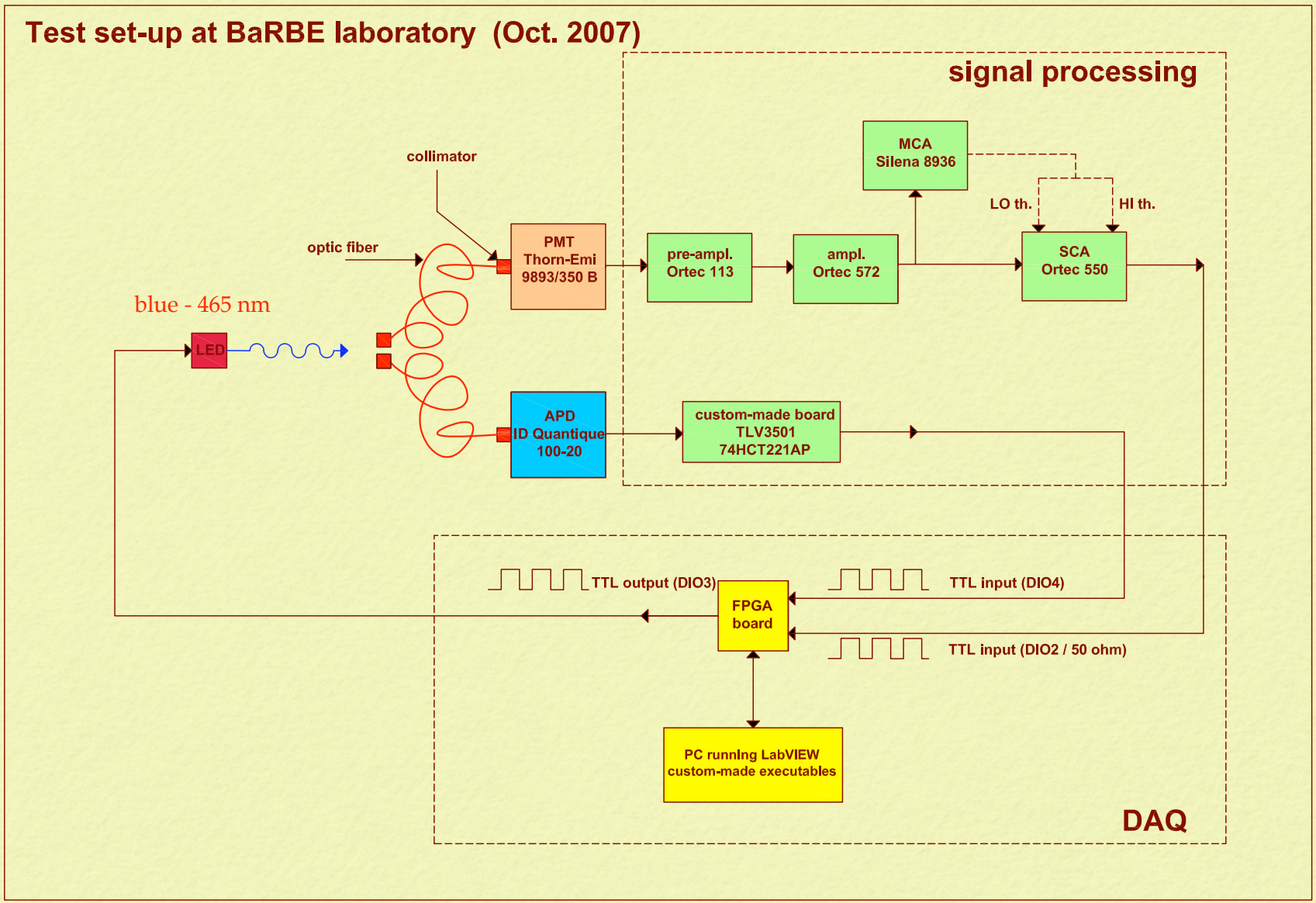
- PMT under test: EMI Thorn 9893/350B (spectral sensitivity 290-630 nm, peak at 350))
- Operation: 1950 V, cooled to -20 °C, window covered by black cardboard screen
- Total integration time 30000 s, count distribution fitted with a Poissonian curve with average m = 1
- **Dark Count Rate (DCR) = 0.45 Hz**





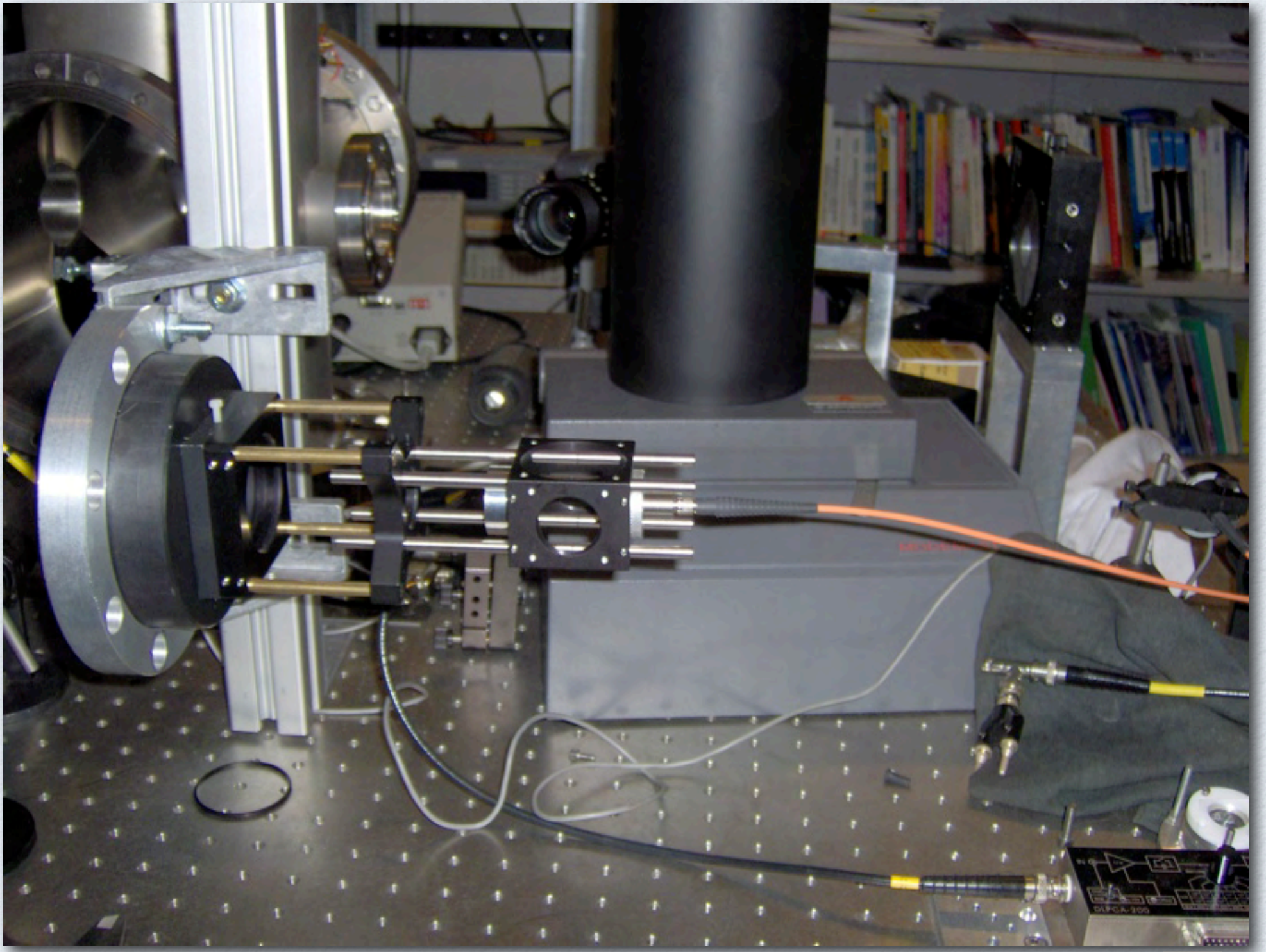


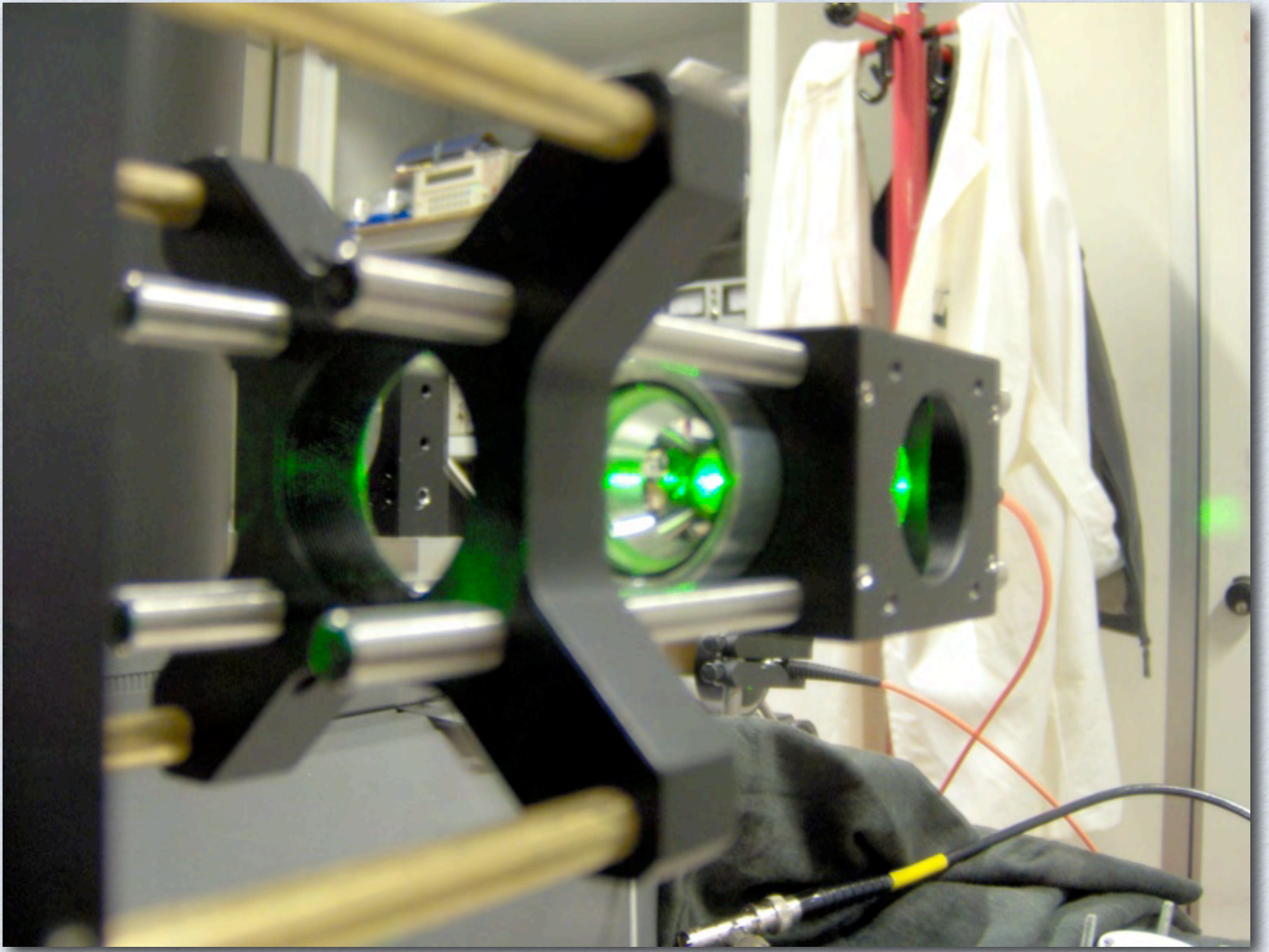
TEST SETUP AT TRIESTE LAB

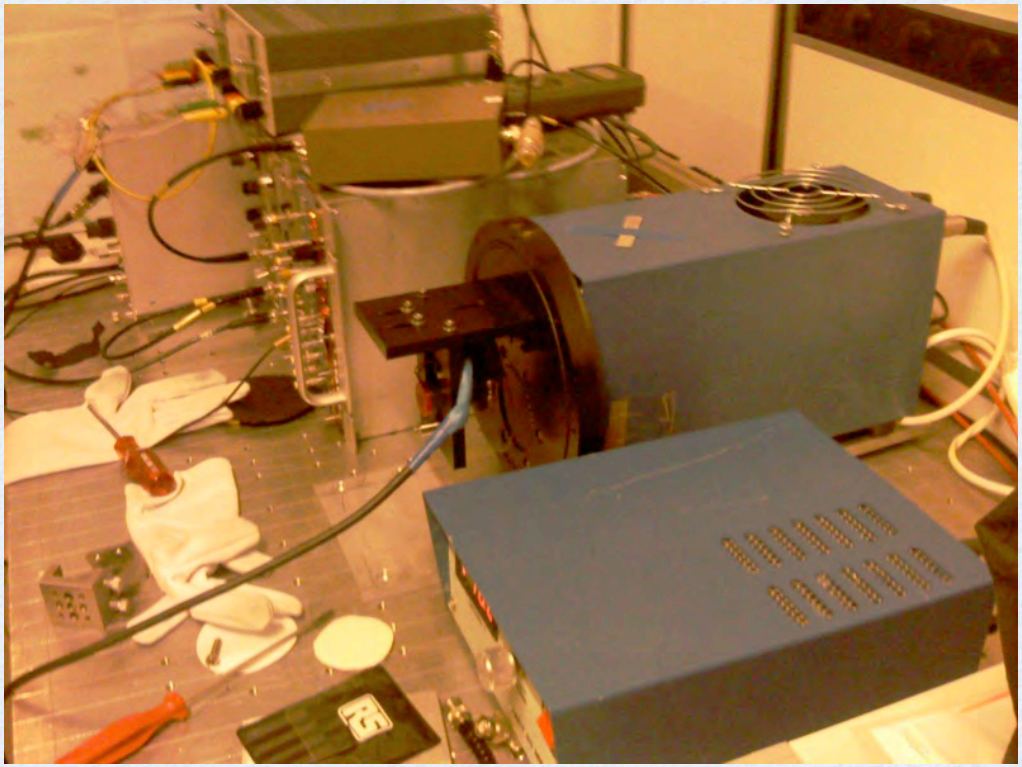


BENCHMARK TEST RESULTS

- Tests done with a blue LED source illuminating PMT and APD
- Single photon detection achieved with both detectors
- DCR for both detectors ~ 0.45 Hz
- Focussing problem with APD: efficiency much reduced (~ 1%) -> must address in the future

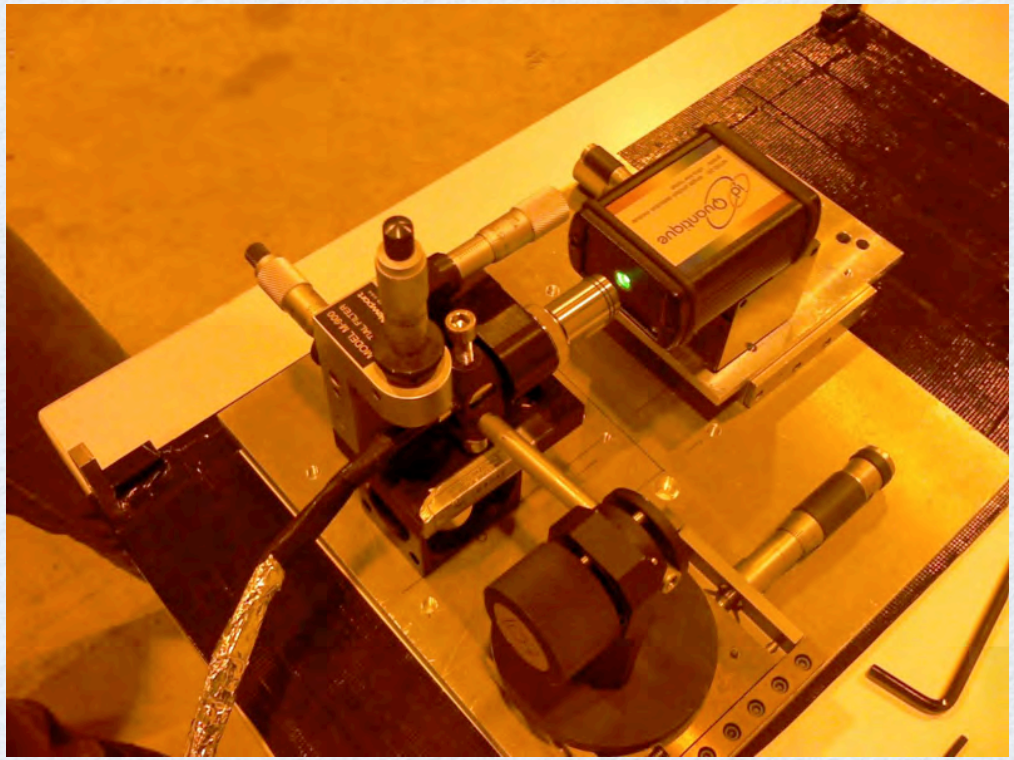






EMI Thorn cooled PMT

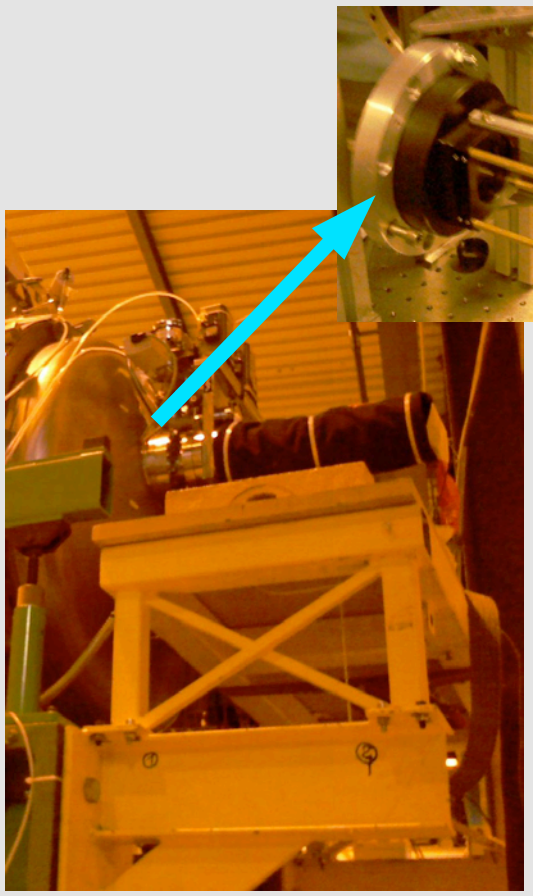
idQuantique APD detector

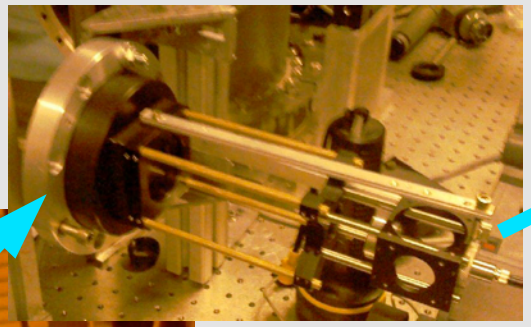


ACTUAL SET-UP AT CAST

- each detector takes data 50 % of acquisition time, remaining 50 % is background

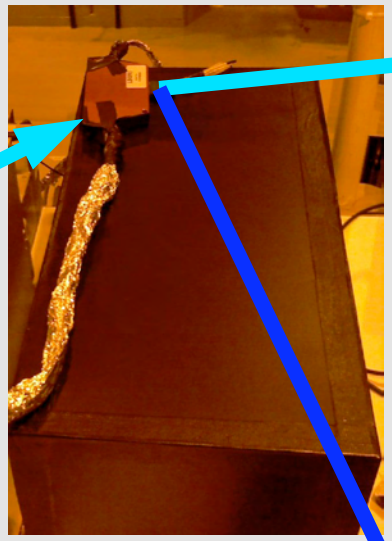
- PMT
- APD
-switch (1 Hz)

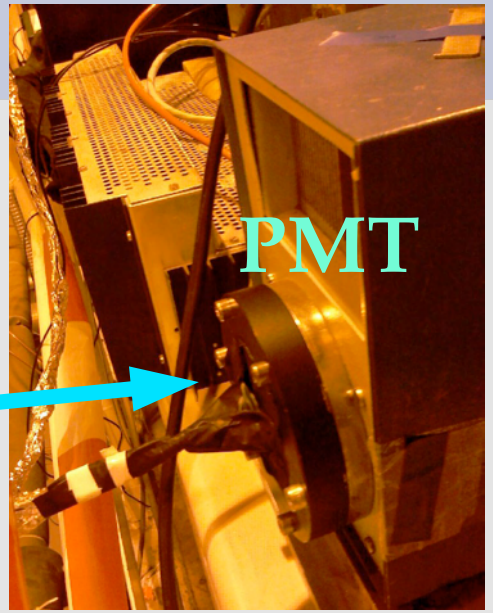




telescope

optical switch

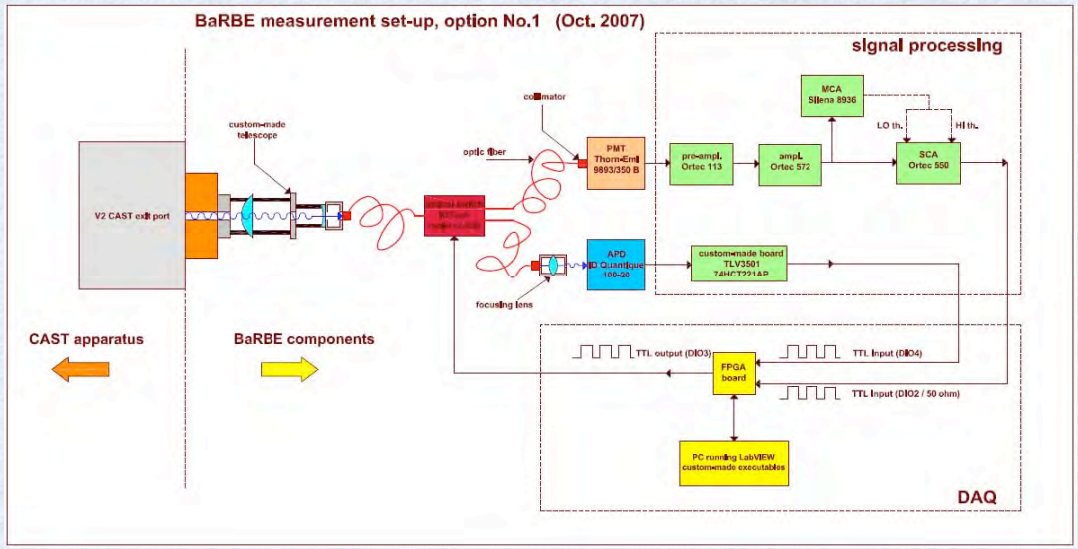


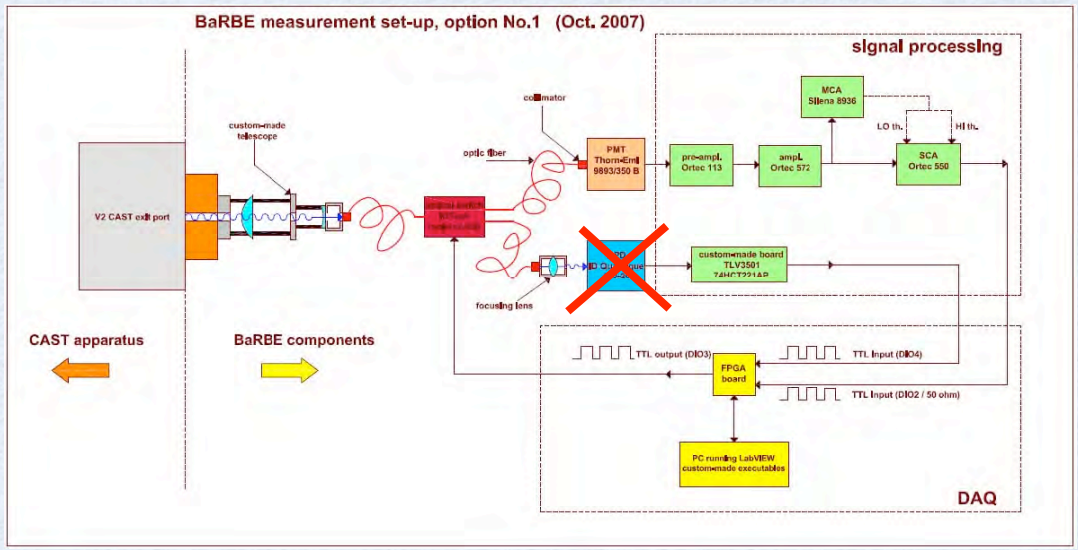


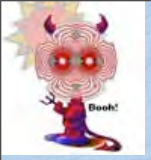
40 m optical fiber

DETECTOR CONFIGURATION

- **November 2007 run**
  - telescope on CAST V2 port coupled via 40 m optical fiber to switch -> PMT (50%) and APD (50%)
- **March 2008 run**
  - telescope on CAST V1 port -> 40 m optical fiber -> PMT (50% “light” - 50% “dark”)







TELESCOPE ALIGNMENT

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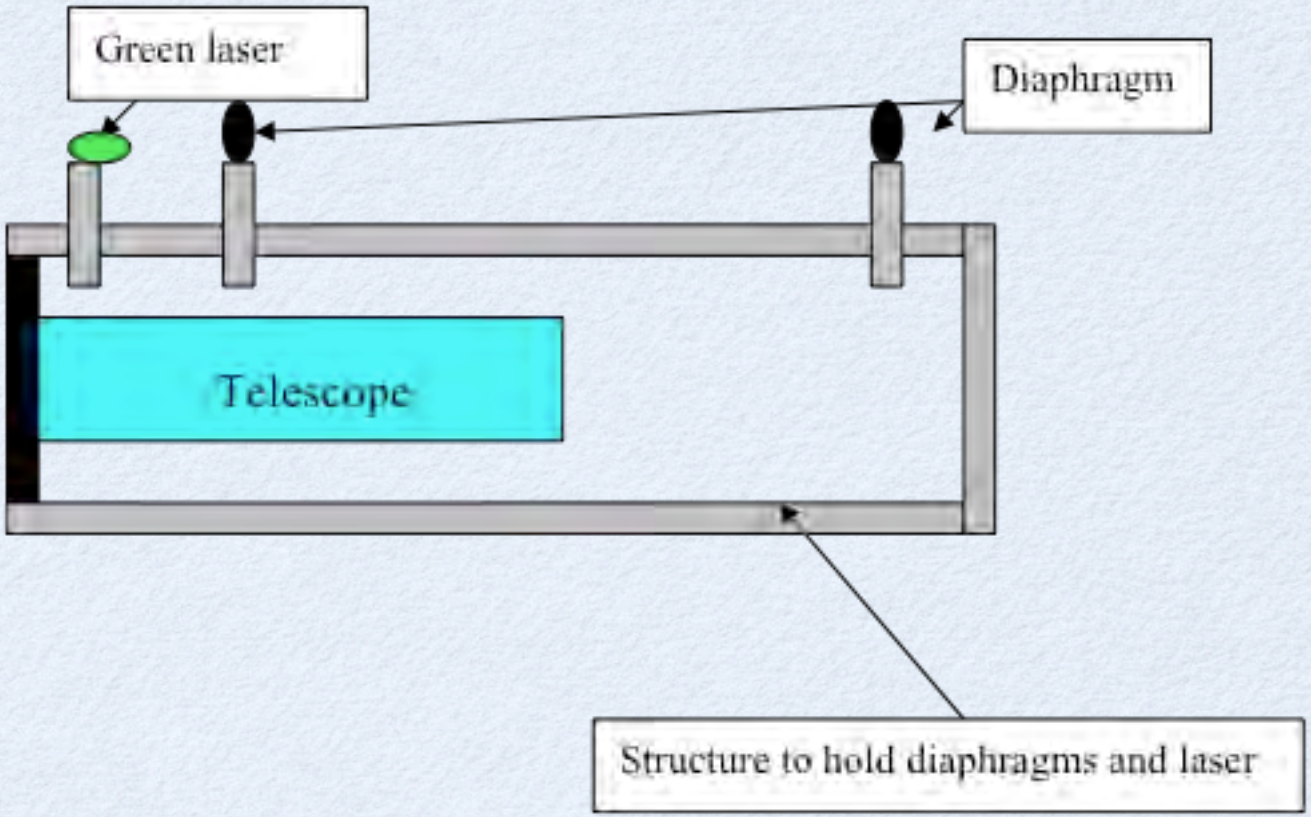
- **Alignment procedure**

  i. mark reference axis on telescope (TL) assembly and record its position with respect to the optical axis of the TL



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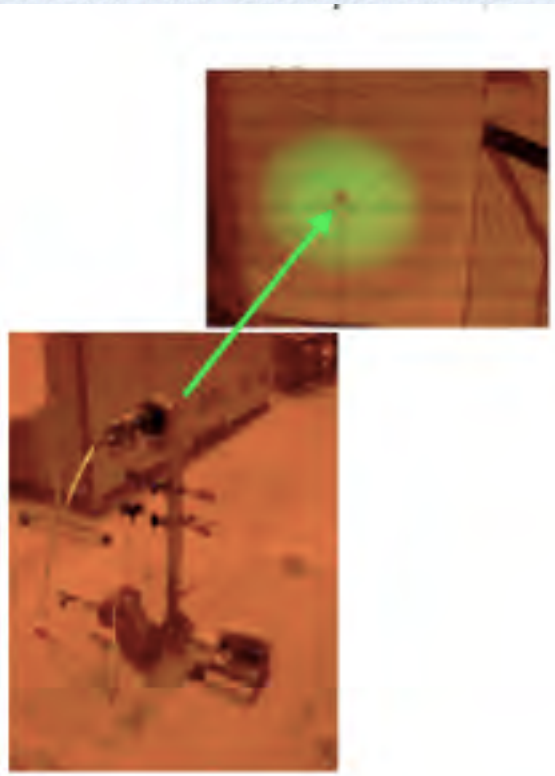

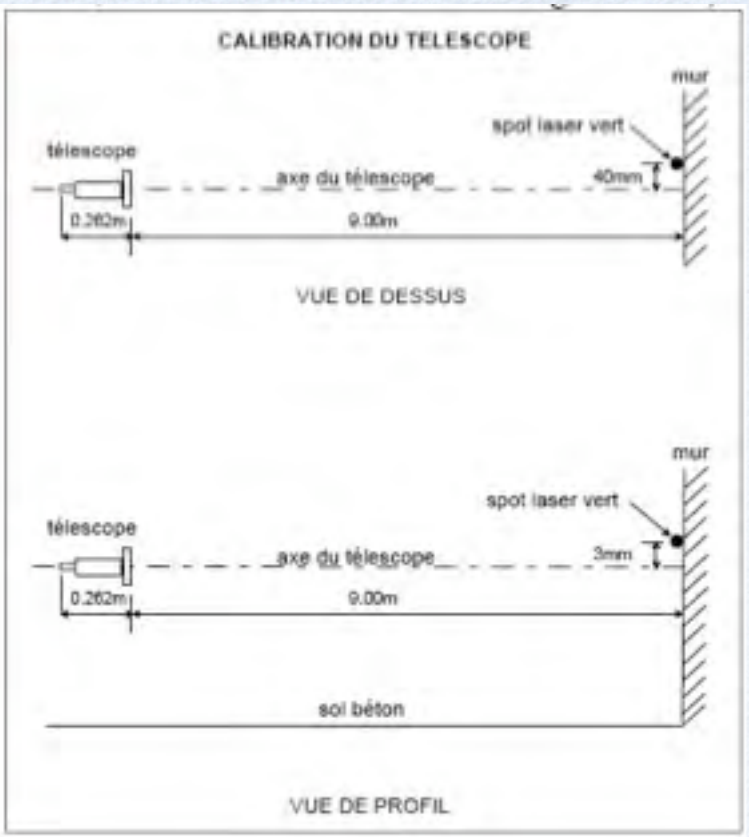

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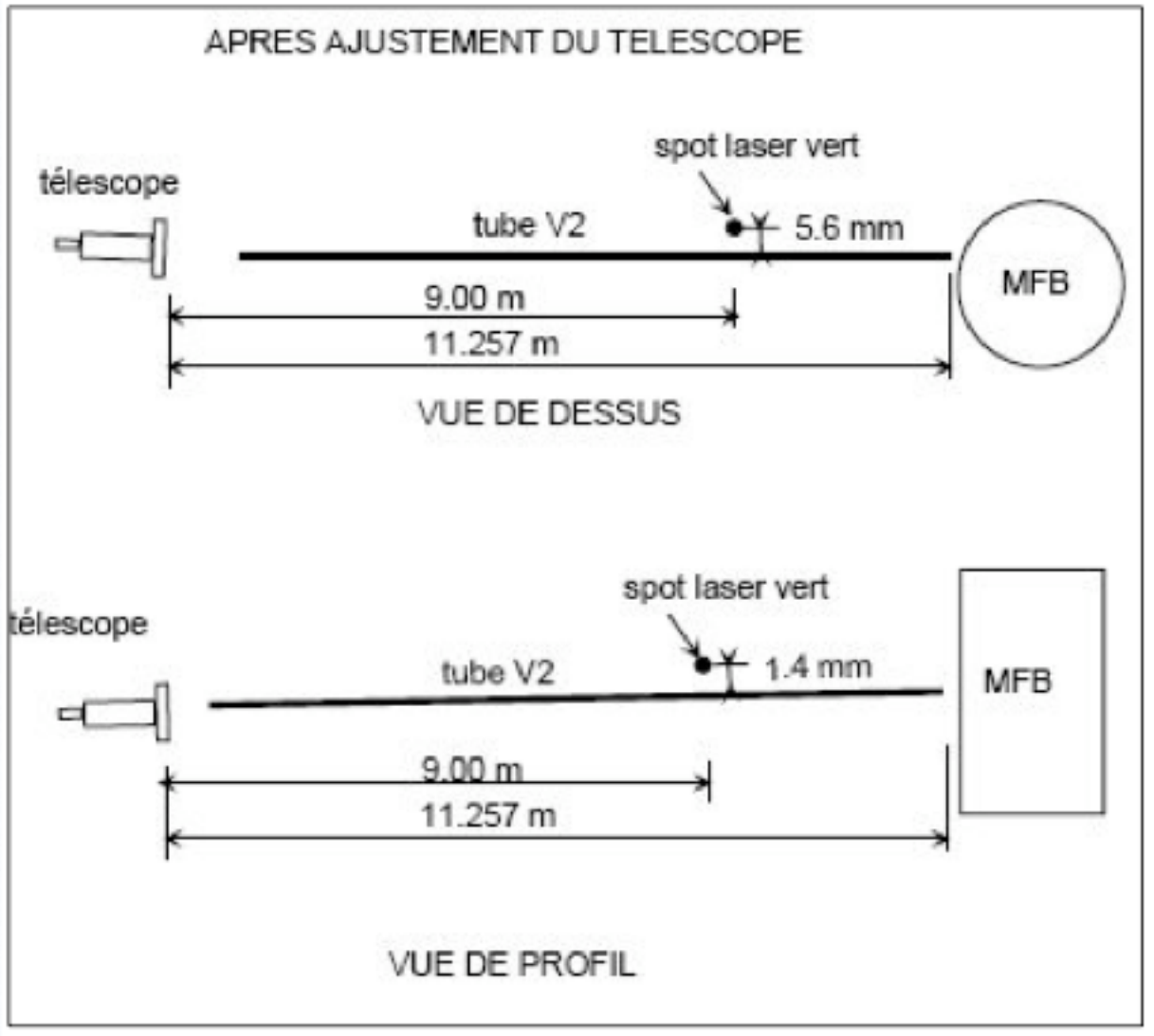
  ii. surveyor -> align the reference axis -> optical axis || to magnet axis



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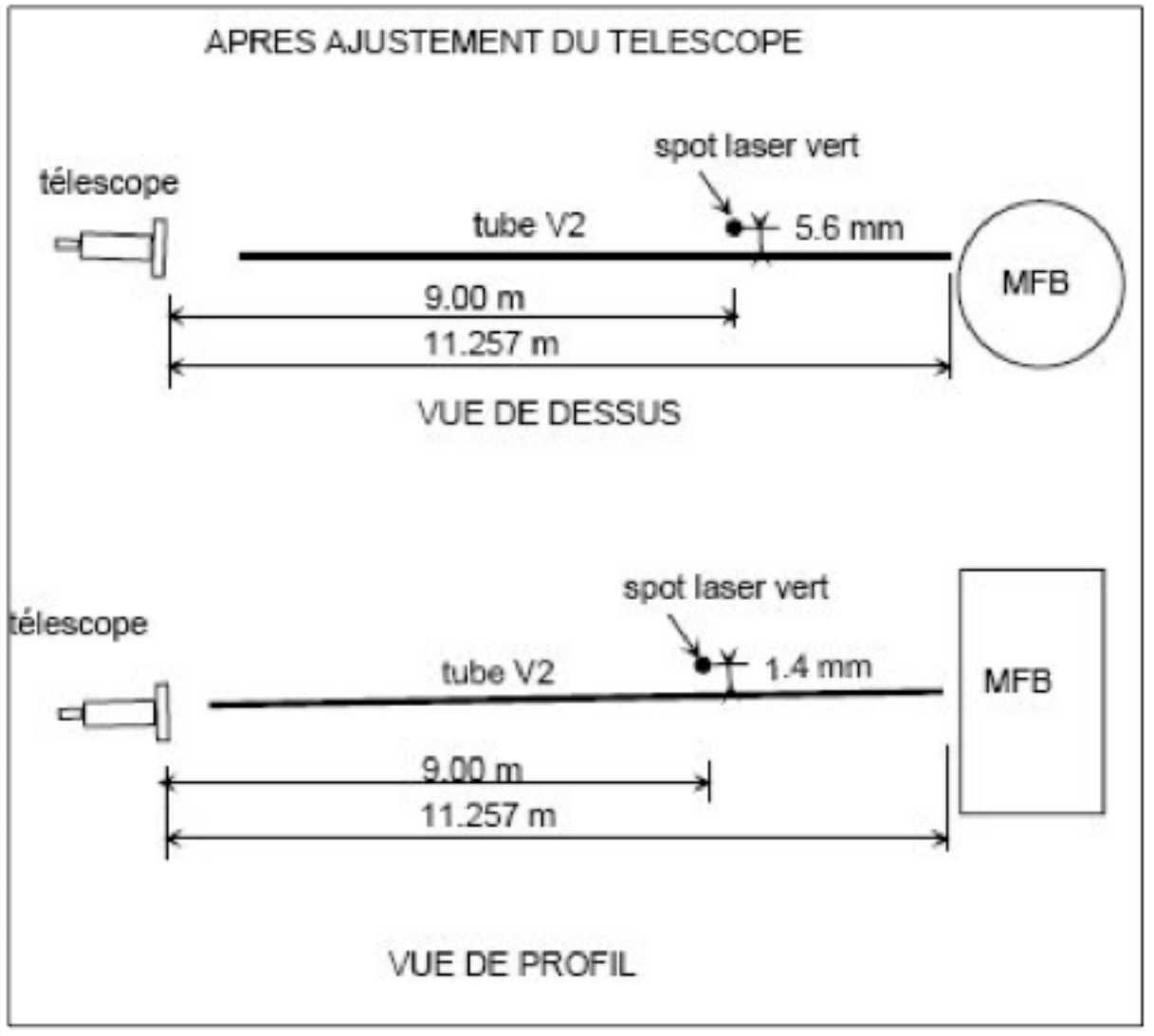
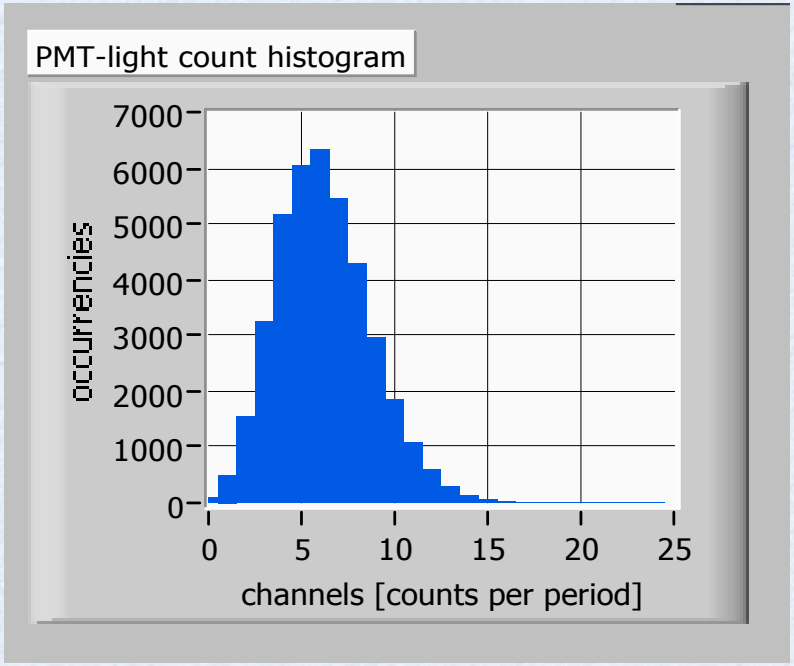
iii. final alignment offset: 1.2 mm horiz. and 1.6 mm vert. -> satisfactory given the 0.03 rad TL input acceptance.



DATA ANALYSIS

- **Analysis principle: eliminate the effect of PMT afterpulses**

- Start from the **raw data histogram** and solve the Poisson distribution equation for the **mean rate of counts m with x = 0** since **occurrences in channel 0 are not affected by afterpulses**



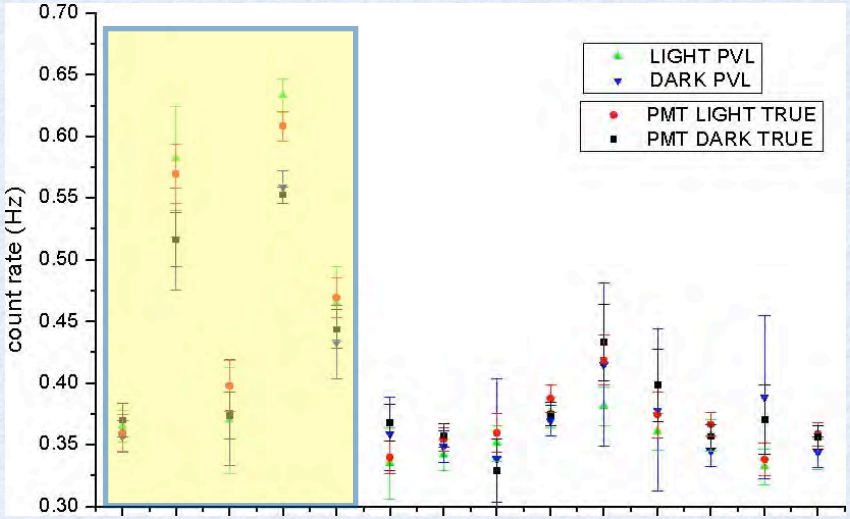
$$N_x = A\frac{e^{-m}m^x}{x!}$$

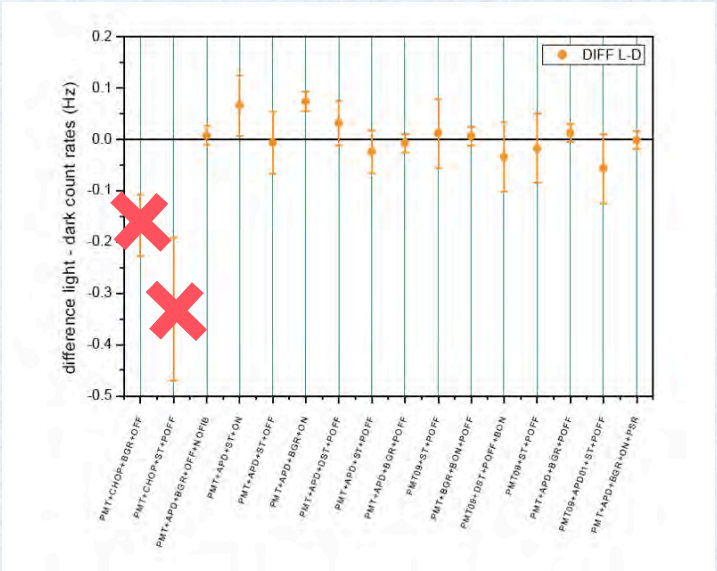
A = total no. of occurrences in all channels

N_x = no. of occurrences in the x-th channel

RUN SUMMARY I

- **Summary of November 2007 run**
  - detector chain attached to the CAST VT1 gate valve port
  - environmental checks
  - background measurements in different magnet positions and with the field on and off
  - **about 10000 s of Dummy Sun Tracking data**
  - **about 35000 s of actual Sun Tracking data**





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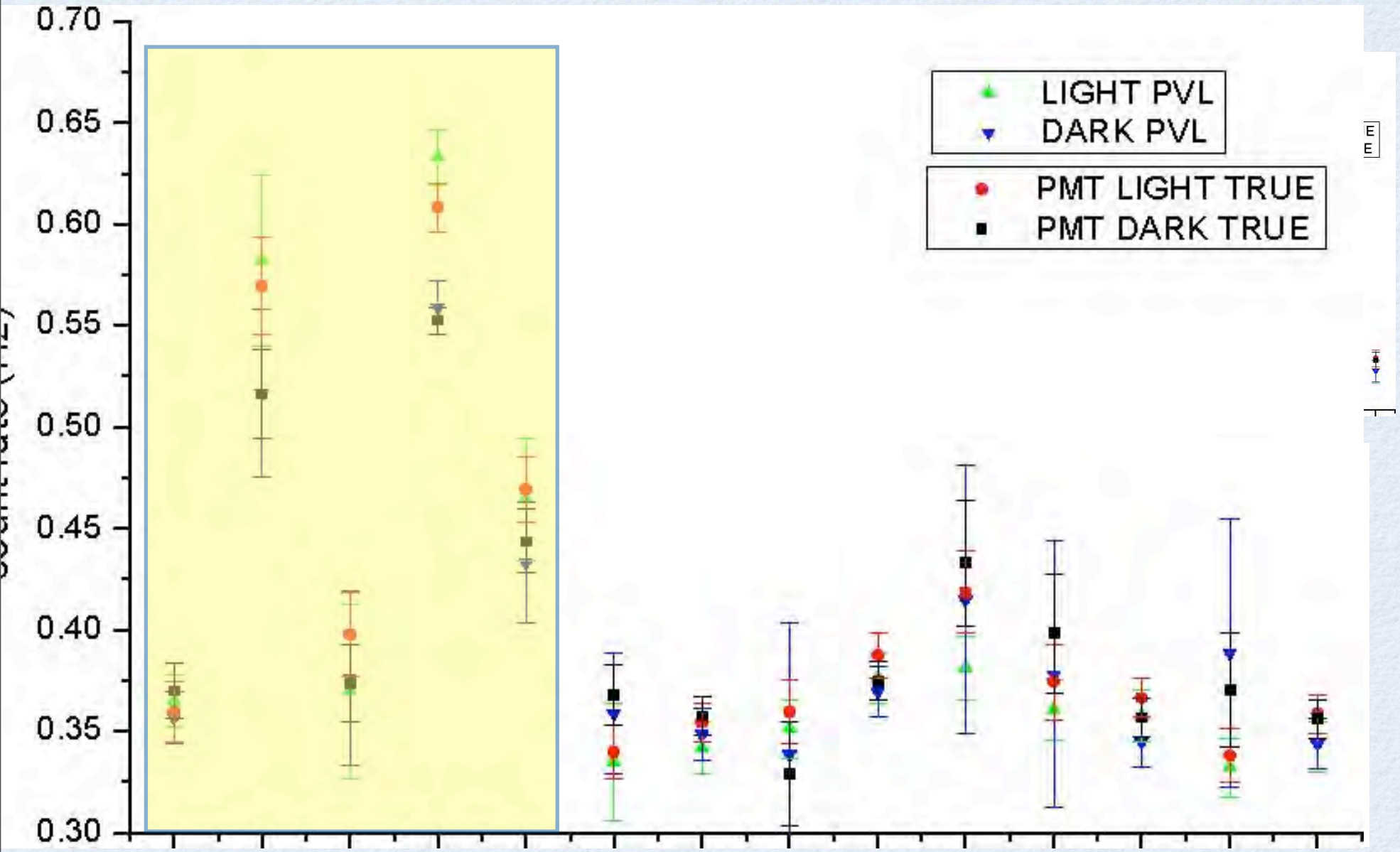

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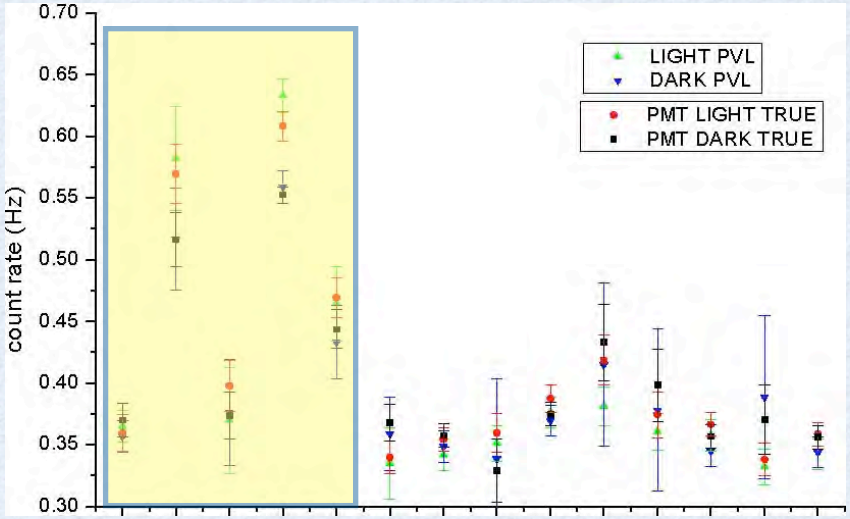

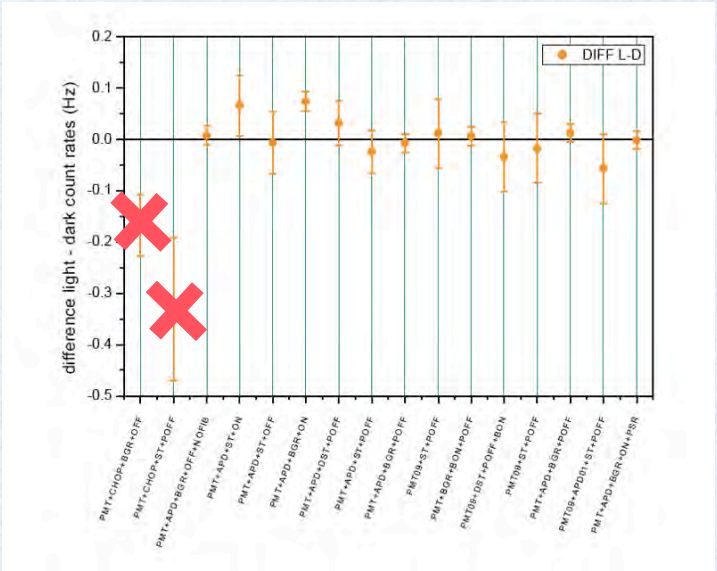

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  - background m
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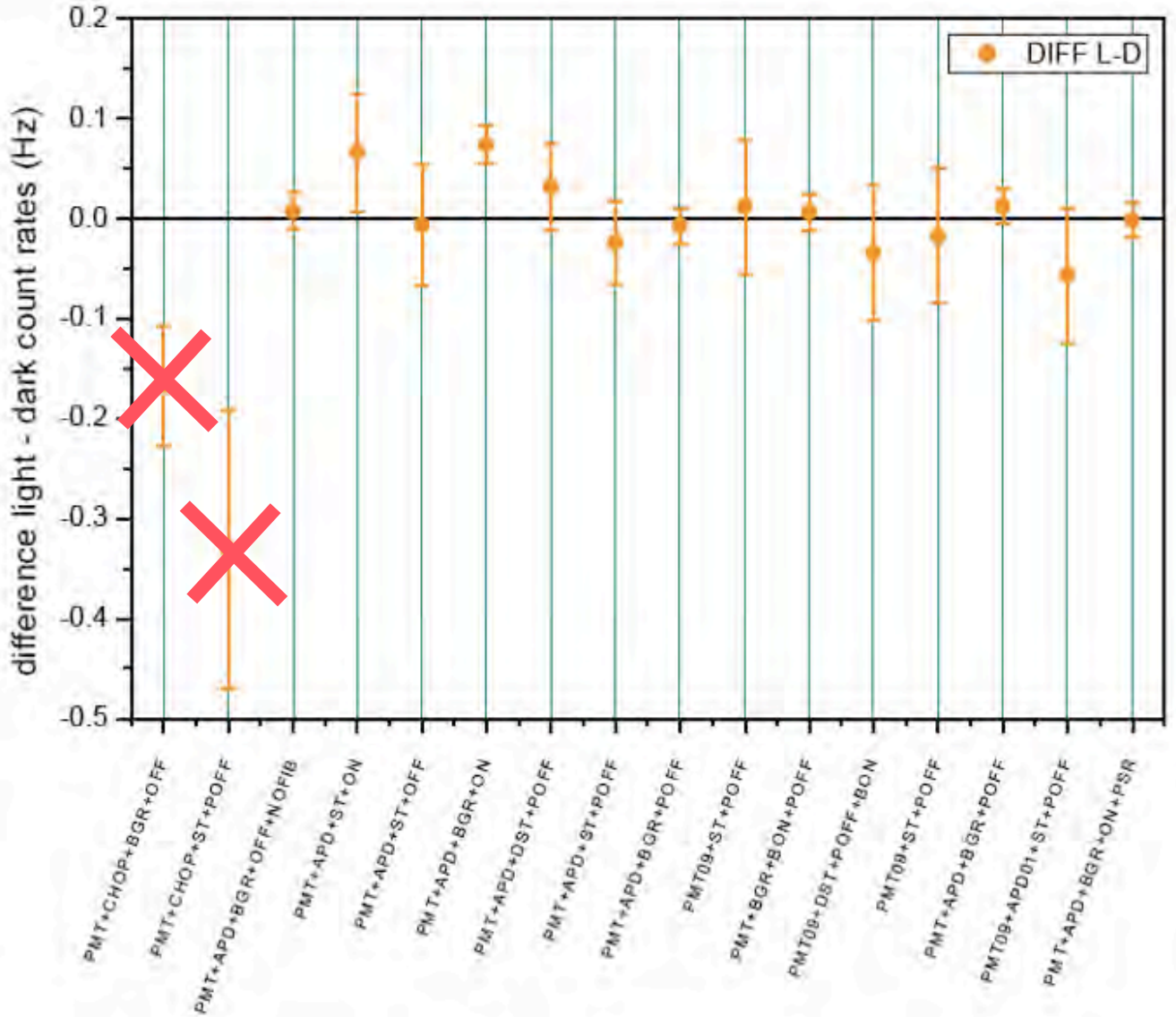

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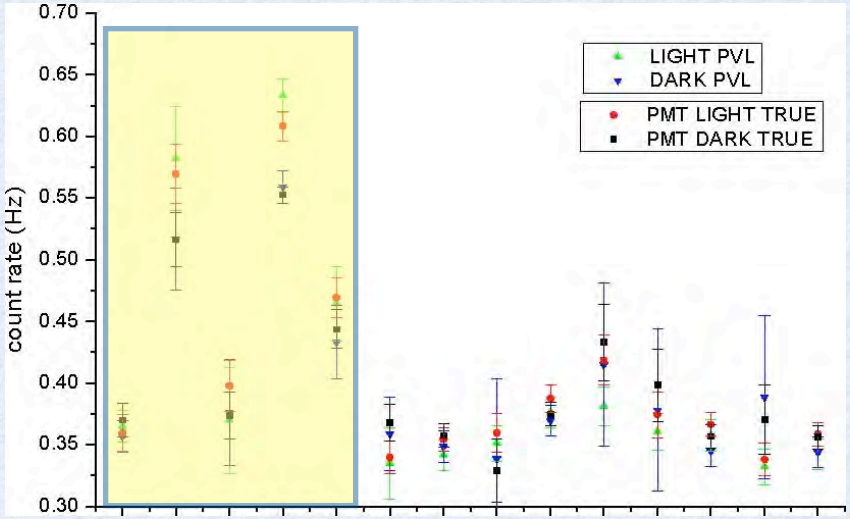

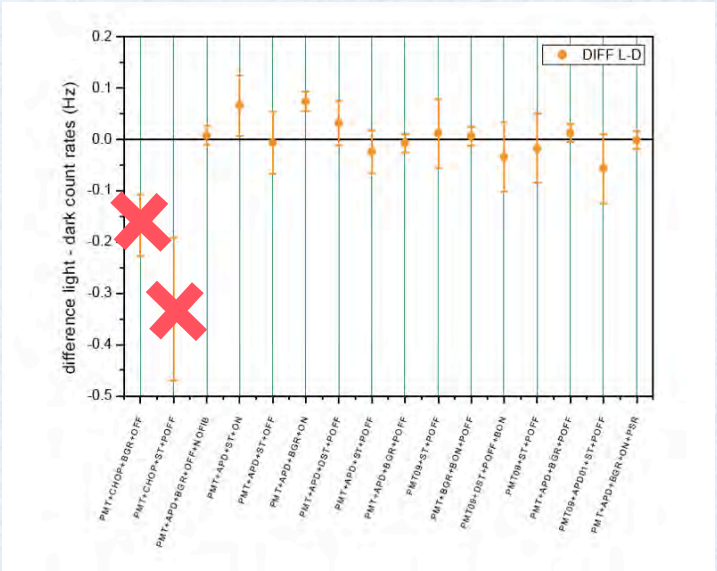

RUN SUMMARY II

- **Summary of February/March 2008 run**
  - detector chain attached to the CAST VT2 gate valve port
  - background measurements in the two magnet parking positions and with the field on and off
  - **about 5000 s of DST data**
  - **about 40000 s of actual ST data**; 20000 s were taken with the magnet pointing off-center of the sun, half 0.25° to the right and half 0.25° to the left.

RUN SUMMARY II

- **Summary**
  - detector
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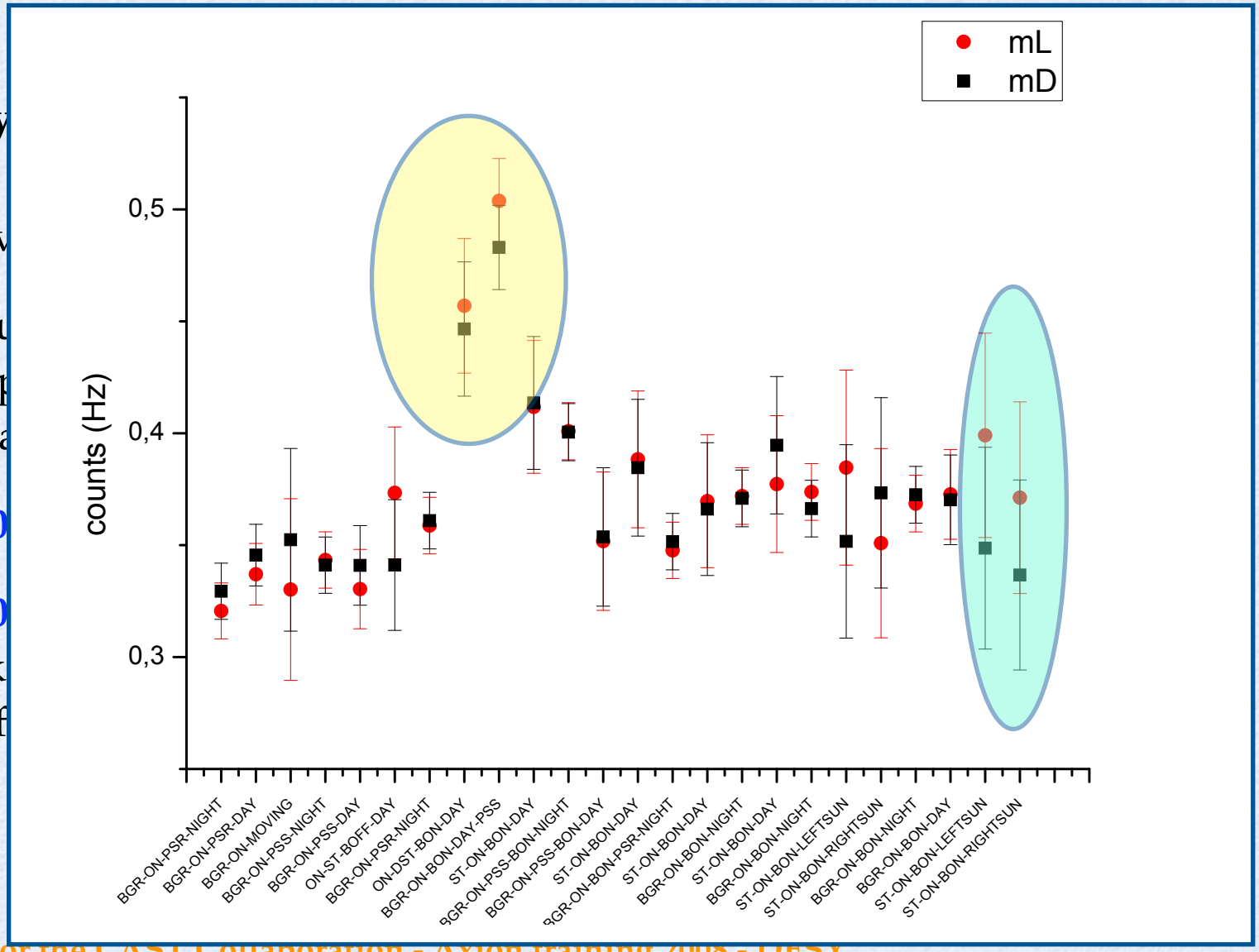

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- **Summa**
  - detecto
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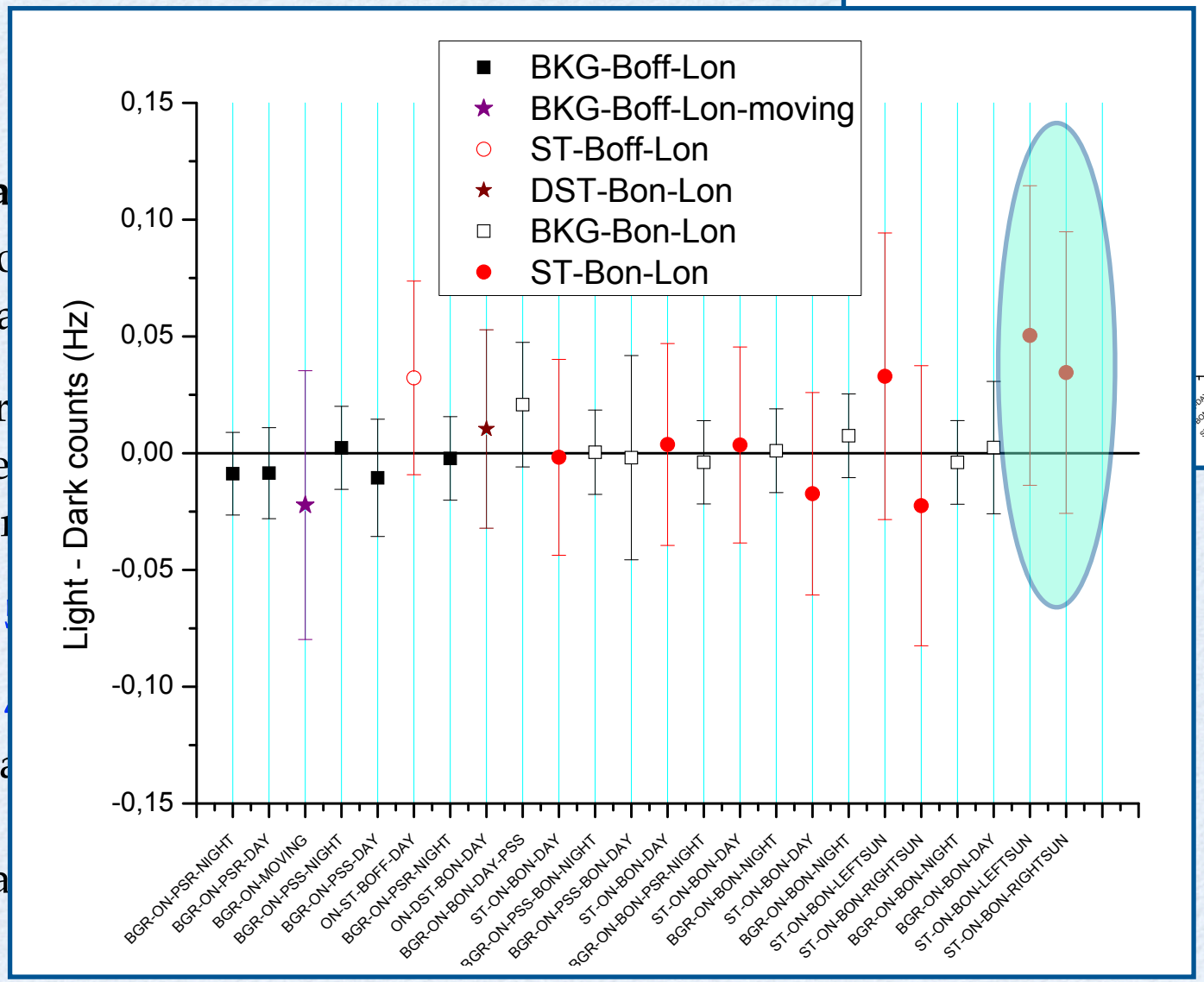

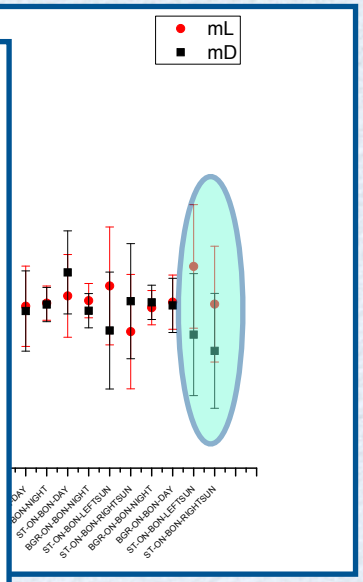

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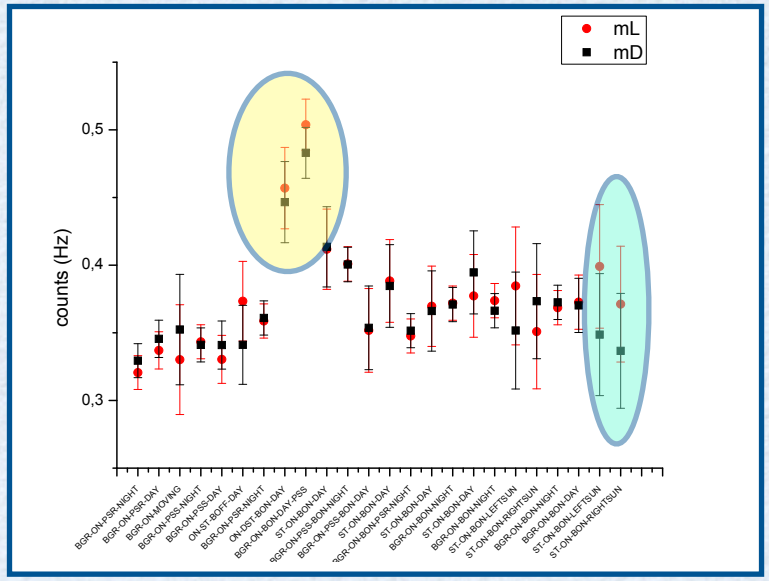

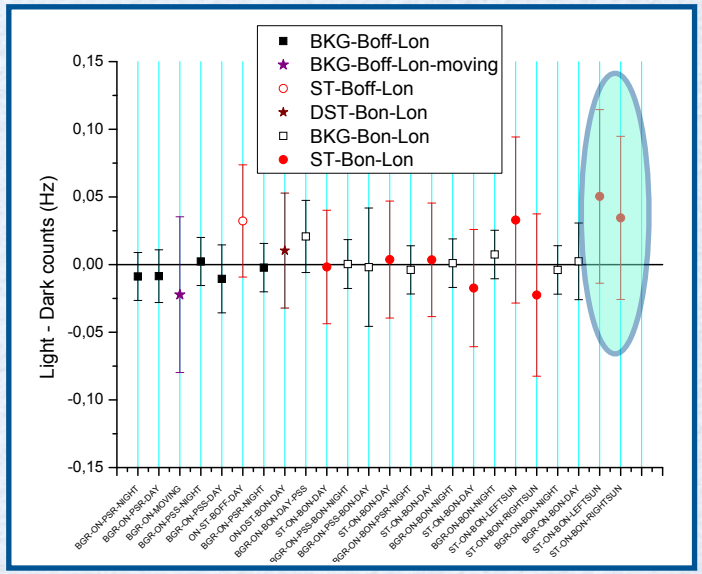

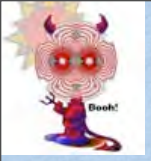

CONCLUSIONS

- It possible to **couple a "visible" detector** to the CAST magnet bore(s) **via an optical fiber** without introducing additional background sources (telescope efficiency 50%)
- Background rate measured at CAST for **3-4 eV photons** is **DCR = 0.35 Hz ± 0.02 Hz for 75000 s** of solar tracking data taking.
- In 12 data sets taken during solar tracking (2 sets taken pointing 0.25° degree off-center to the left of the sun and 2 pointing to the right) **no significative excess counts over background were observed**.

WHAT NEXT?

- **Two possible ways to improve the detection capability in the "visible":**
  i. a detector with lower DCR (short time scale -> maybe a year or less)
  ii. a resonant cavity inside the magnet bore in order to enhance the axion to photon conversion probability (longer time scale, need to anticipate/solve compatibility problems with the rest of the CAST apparatus)

DETECTOR DEVELOPMENT IDEAS

	TES	DEPFET	cooled APD
pro's	• VERY low background • spectroscopic capability • sensitive from IR up to tens of eV's	• low background in RNDR mode • spectroscopic capability (for higher energies) • sensitive from eV up to keV's (with gaps!)	• low background (?) (must accept afterpulsing) • relatively easy operation • already available (needs LN2 cryostat)
con's	• cryogenic operation (100 mK) • small area (100x100 microns) • difficult to use	• dedicated electronics • no "in house" expertise (yet!) • small detector area (array possible, no problem at eV's)	• small detector area (25x25 microns) • sensitive only in the visible

TRIESTE BARBE GROUP

- **BaRBE** INFN collaboration
  - INFN Trieste
    - G. Cantatore
    - M. Karuza
    - V. Lozza
    - G. Raiteri
  - INFN Frascati
    - R. Cimino

People doing the actual work ....