Recent bounds on solar Hidden Photons obtained at CAST

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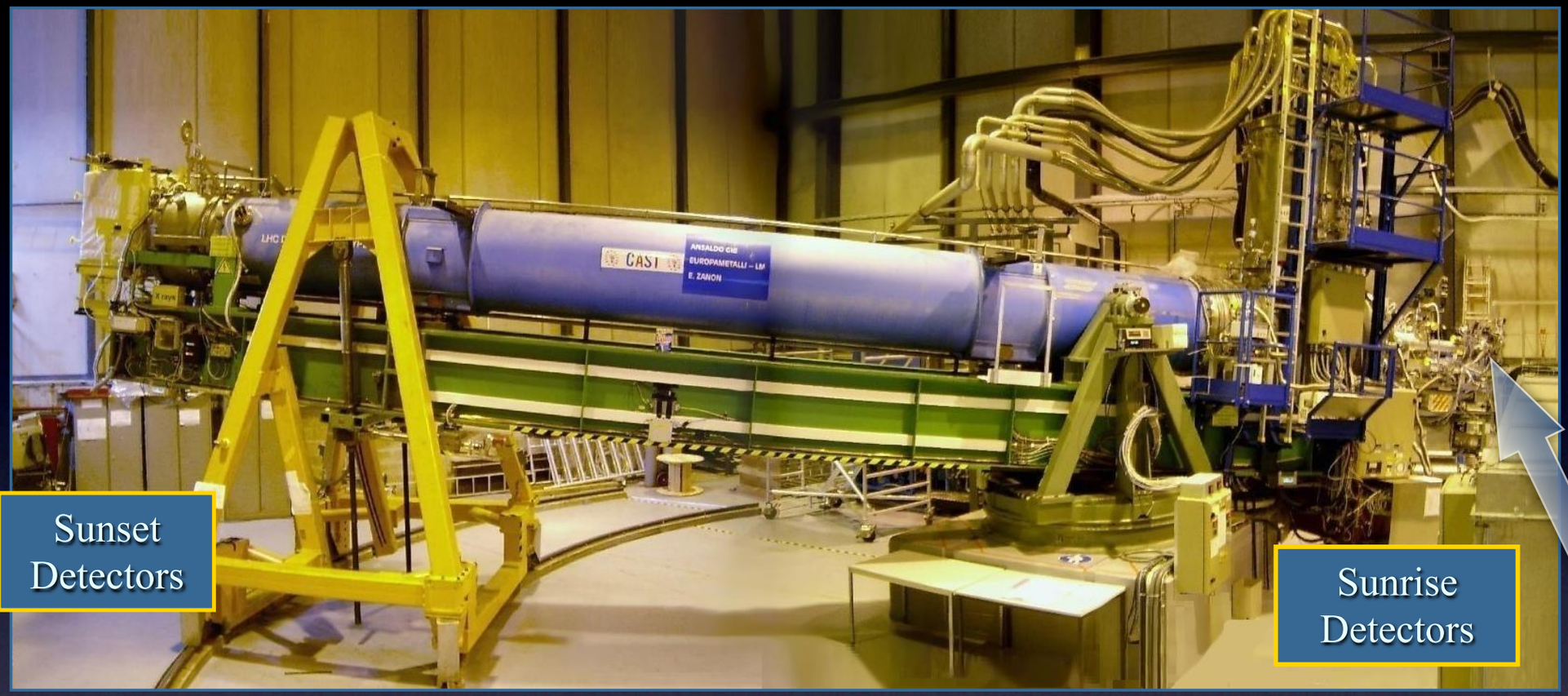
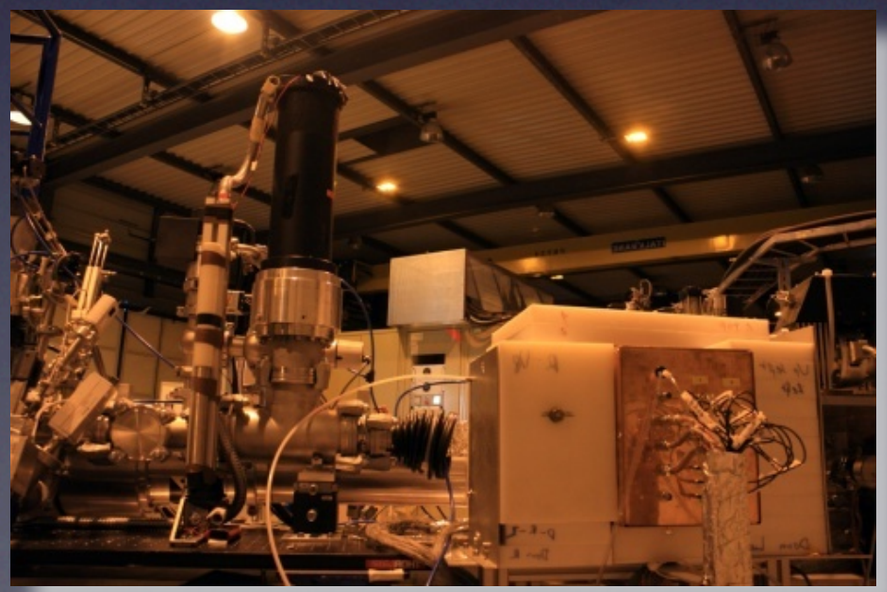
Summary

- Barbe setup at CAST
- Paraphoton measurements
- Barbe results and exclusion plots
- Conclusions

BaRBE setup at CAST

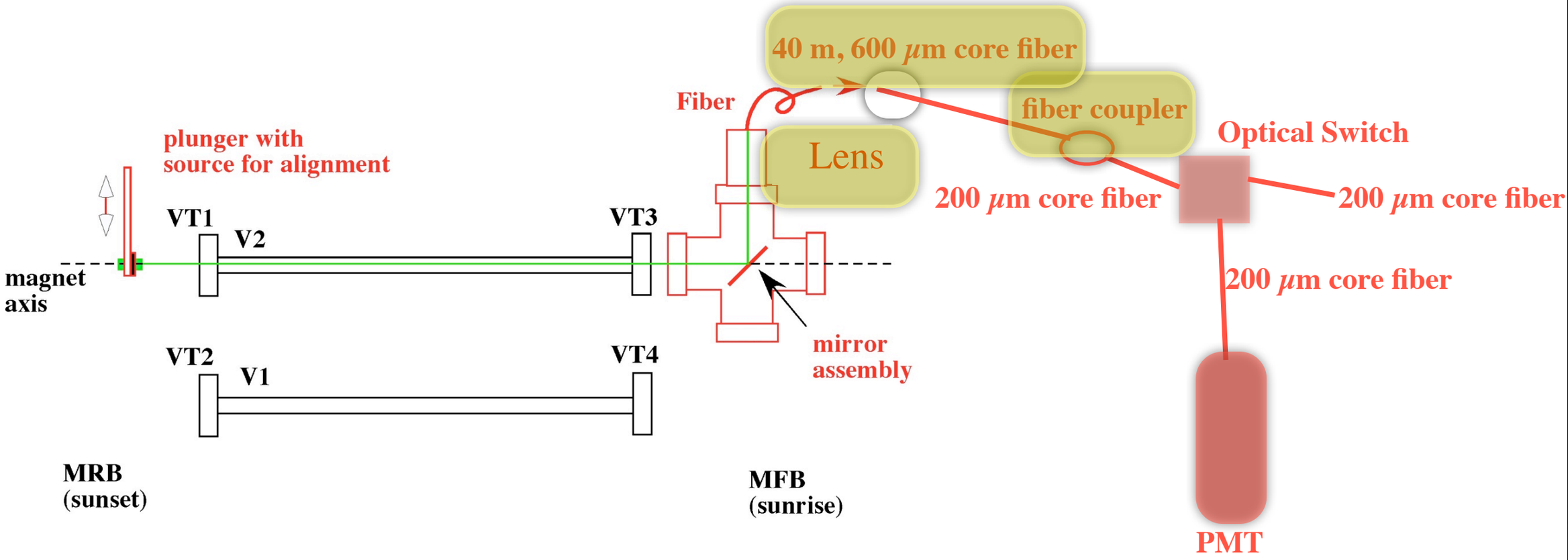


beam



Off-axis low energy BaRBE line on sunrise side

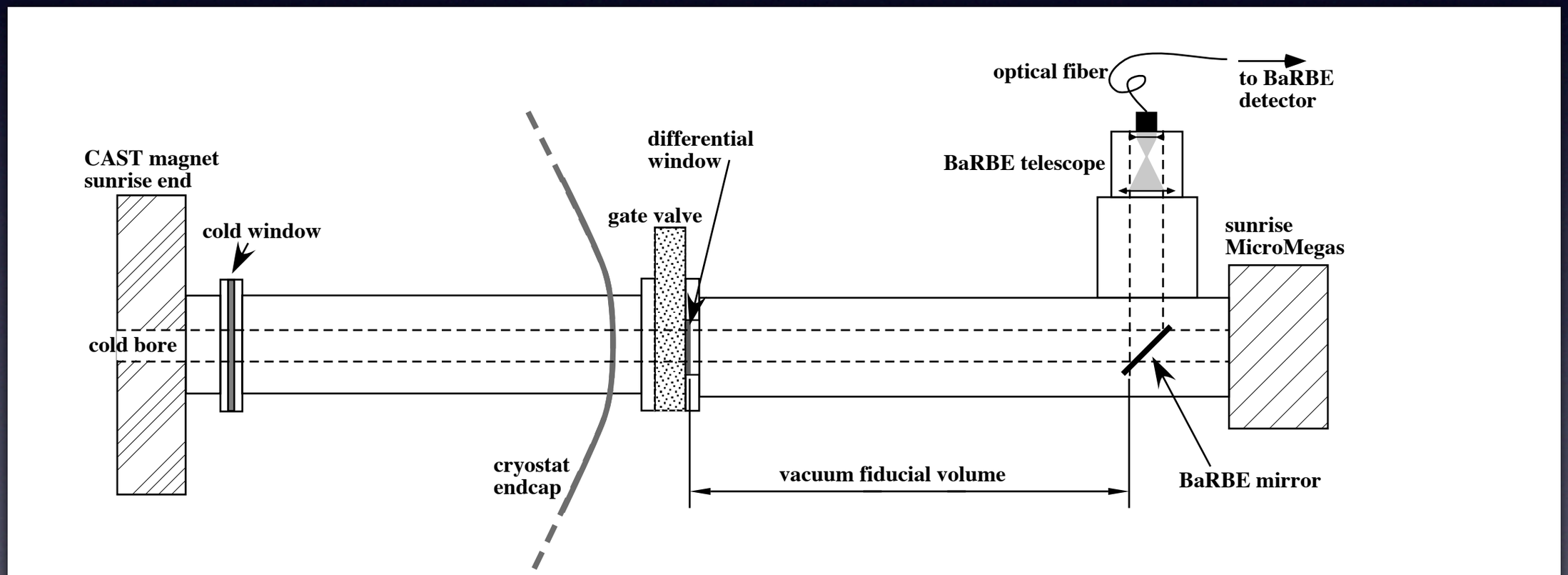
2012 BaRBE optics setup at CAST



- Main elements
  - Mirror assembly - 5 μm thick Polypropylene with 10 nm of Al metallization
  - Lens - 75 mm dia., 85 mm focal length
  - 600 μm core, 40 m length optical fiber - fiber coupler
  - optical switch with 200 μm core input/output fibers
  - PMT detector (3.5 eV peak sensitivity, overall detection efficiency 10%)

Paraphoton measurements

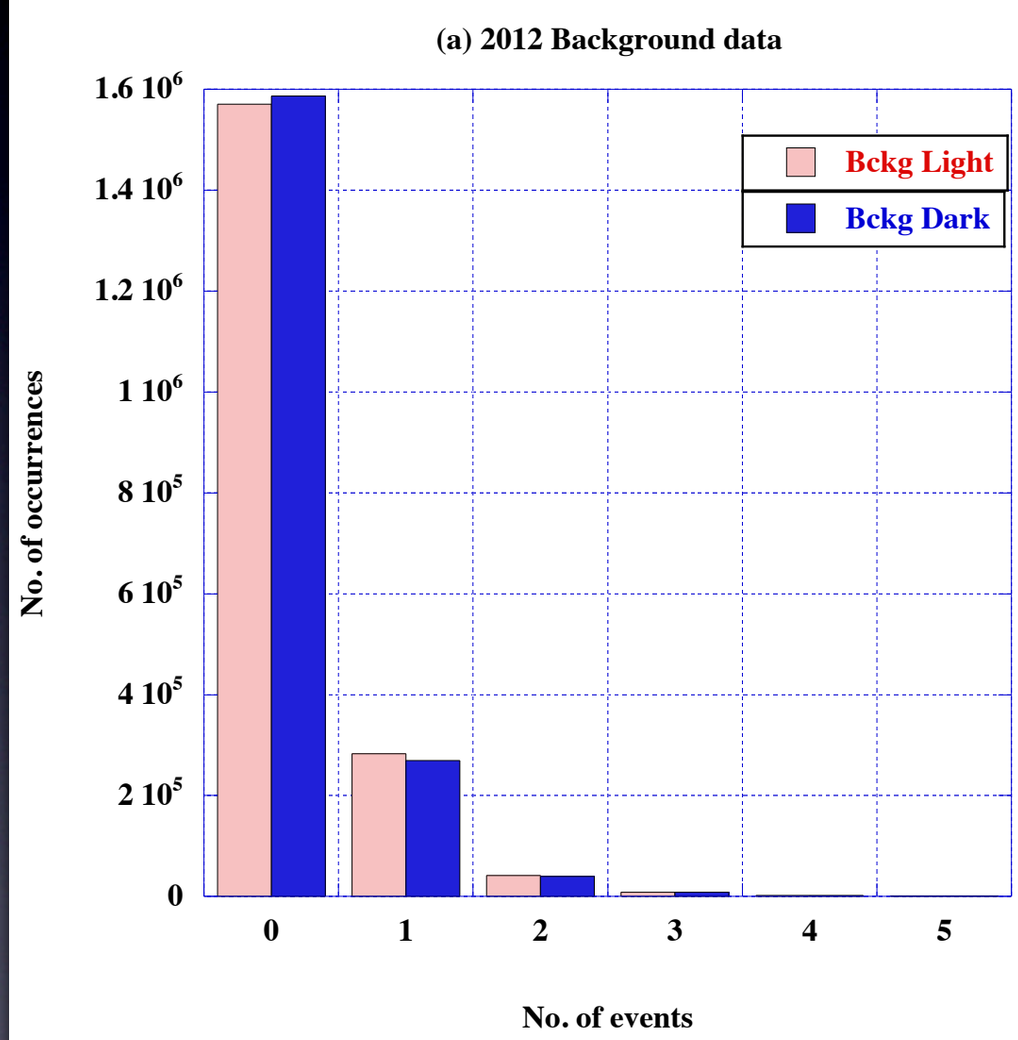
- Thanks to the optical switch concept, the detector looks for half the time at the fiducial volume ("Light" state) and for another half at a shutter ("Dark" state)
- Since switching occurs at a frequency of 1 Hz, it is safe to assume that the "light" and "dark" states share a common background which can then be subtracted
- The unrestricted vacuum fiducial volume has a length of 70 cm
- The measured dark count rate when sun tracking is translated into a paraphoton exclusion plot based on an estimated solar flux

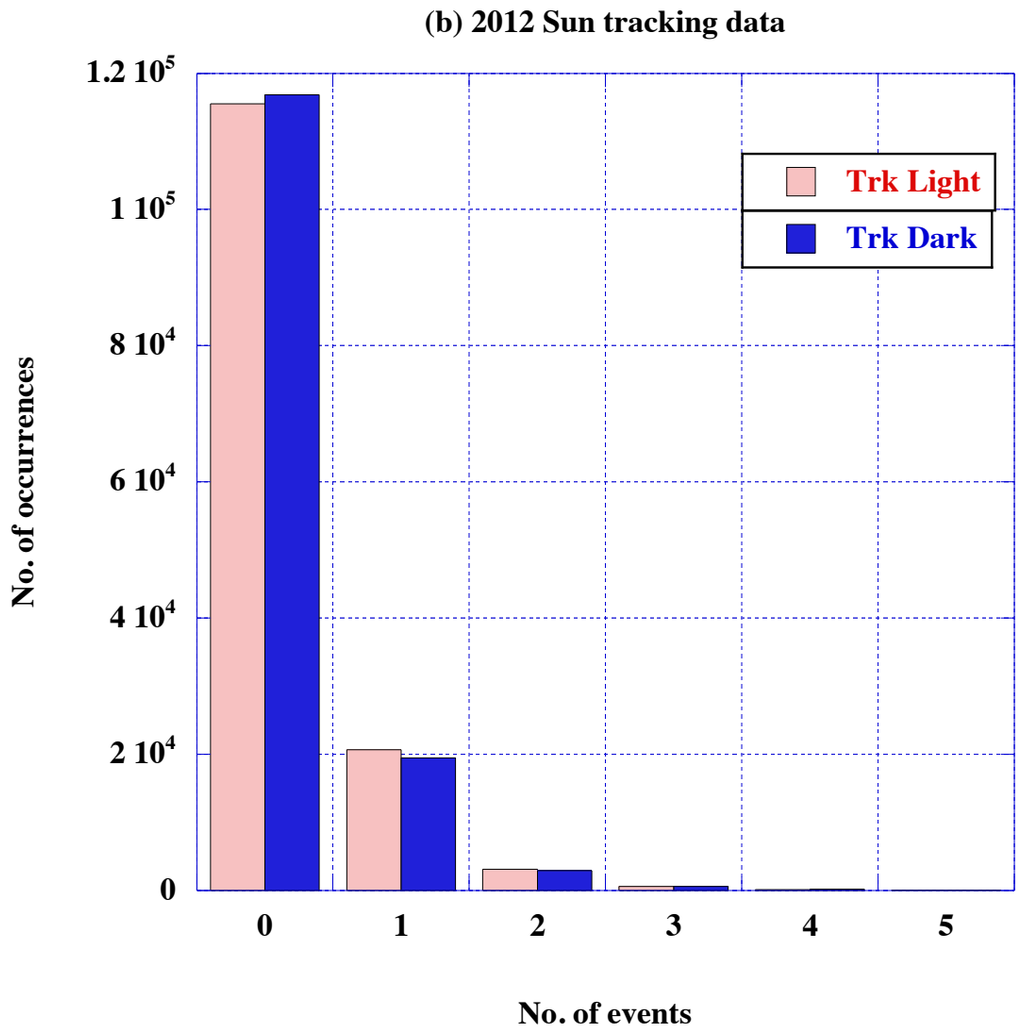


BaRBE results - DAQ

- Data taking periods
  - 2010-2011 (FOV 1 mrad)
    - $8.7 \cdot 10^5$ s sun-tracking, $1.17 \cdot 10^7$ s background
  - 2012 (FOV 7.5 mrad)
    - $1.5 \cdot 10^5$ s sun-tracking, $1.9 \cdot 10^6$ s background
- Data acquisition strategy
  - data are acquired each day during CAST suntracking runs for 5500 s, followed by 72000 s of background data wih the magnet in parking position
  - daily runs are summarized in histograms where the bins correspond to the number of events observed within a pre-set time window (0.5 s since the optical switch frequency is 1 Hz); thus bin "zero" would give the numer of times no events have been observed in the time window
  - daily histograms are then summed over homogeneous data sets to obtain summary histograms

BaRBE results - 2012 summary histograms





BaRBE results - data analysis I

- Two ways to obtain a Dark Count Rate (DCR) from the summary histogram data (assuming they are distributed according to a Poissonian)
- **Afterpulse rejection**
  - the PMT is affected by a measured rate of afterpulses around 11%
  - bin "zero" is not affect by afterpulses (by definition), then the average number of events m occuring in the 0.5 s time window determined by the switching frequency is found from the equation $N_0 = A\frac{e^{-m}m^0}{0!}$ and **DCR [afterpulse] = m/(0.5 s)**
- **<u>Standard analysis</u>**
- The total number of events is considered as the total numer of detected photons, therefore
- **DCR [standard] = total number of events/total acquisition time**
- When using afterpulse rejection the uncertainty on m is minimum when the total number of occurrences A is equal to the total number of events N. In our case A = 4N, therefore the uncertainty on m is overestimated by 40%, and **the choice falls on standard analysis**

BaRBE results - data analysis II

- Background rejection
  - due to the switching, the detector looks for 0.5 s to the fiducial volume ("Light" state) and for 0.5 s to a closed shutter ("Dark" state)
  - exploiting this fact the background is eliminated by subtracting the "Dark" count rate from the "Light" count rate

- Common mode rejection
  - after background subtaction a non-zero residual rate is present
  - this residual rate is however the same, within uncertainties, both for sun-tracking runs and for background runs
  - we attribute this to an undisclosed light leak in the optical system and assume as the final dark counting rate the uncertainty of the Light-Dark difference

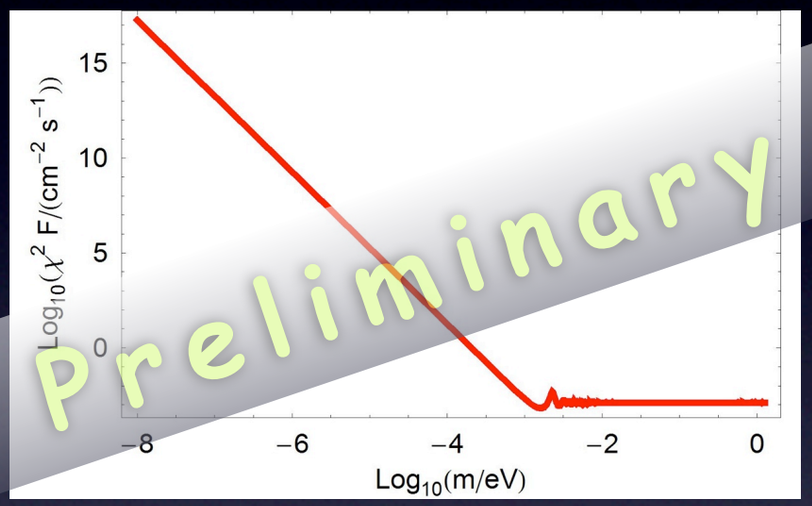
BaRBE results - DCRs

	2010-2011 data			
	Afterpulse rejection		Standard analysis	
	Diff DCR(L-D) [Hz]	SigmaDiff [Hz]	Diff DCR(L-D) [Hz]	SigmaDiff [Hz]
Background ($8.7 \cdot 10^5$ s)	0.0207	0.0009	0.0205	0.0004
Tracking ($1.17 \cdot 10^7$ s)	0.0188	0.0033	0.0196	**0.0014**
	2012 data			
	Afterpulse rejection		Standard analysis	
	Diff DCR(L-D) [Hz]	SigmaDiff [Hz]	Diff DCR(L-D) [Hz]	SigmaDiff [Hz]
Background ($1.5 \cdot 10^5$ s)	0.0207	0.0023	0.0210	0.0009
Tracking ($1.9 \cdot 10^6$ s)	0.0227	0.0083	0.0182	**0.0035**

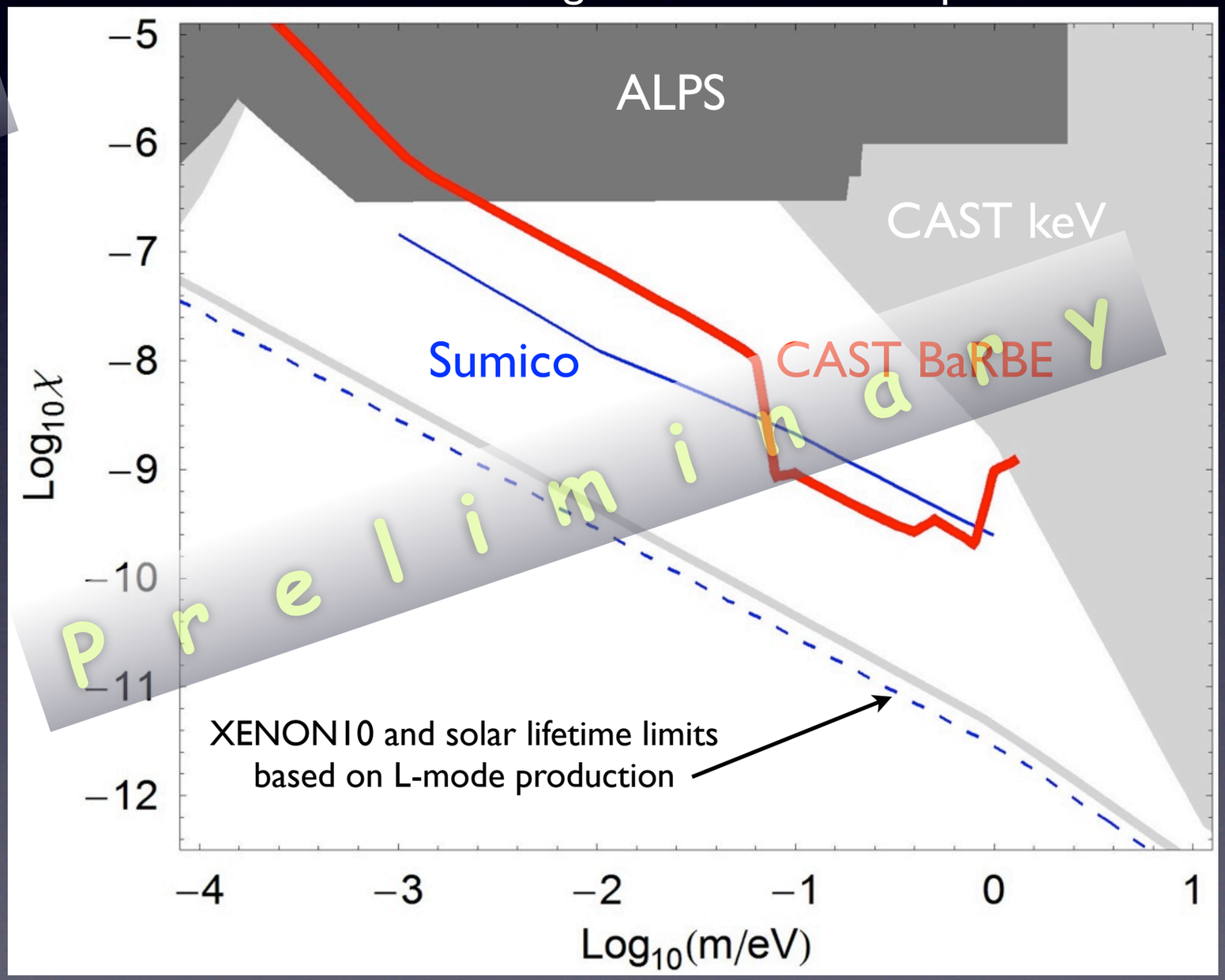
Preliminary exclusion plots

- Plots calculated and produced by S. Troitsky based on BaRBE results

flux vs. mass plot



kinetic mixing vs. mass exclusion plot



Conclusions

- The BaRBE low energy photon detector setup has been taking data on a CAST beamline until 2012 during normal sun tracking runs
- Differential Dark Count Rates of 1-3 mHz have been achieved
- Preliminary exclusion region in the HP kinetic mixing vs. mass plane
- Upcoming paper