New prospects for CAST from the new Microbulk performance

the limits of the helioscope technique

Thomas Papaevangelou
IRFU, CEA Saclay

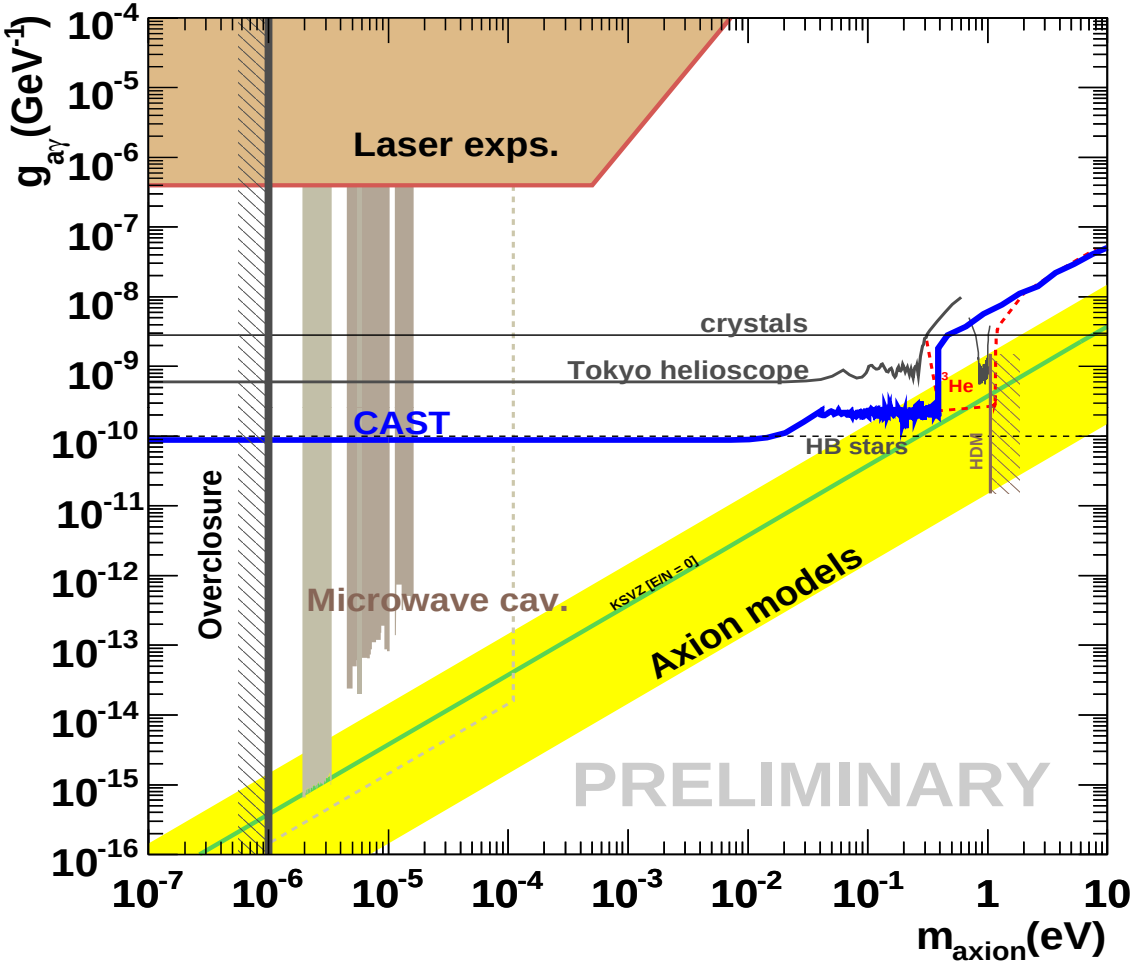
Outline

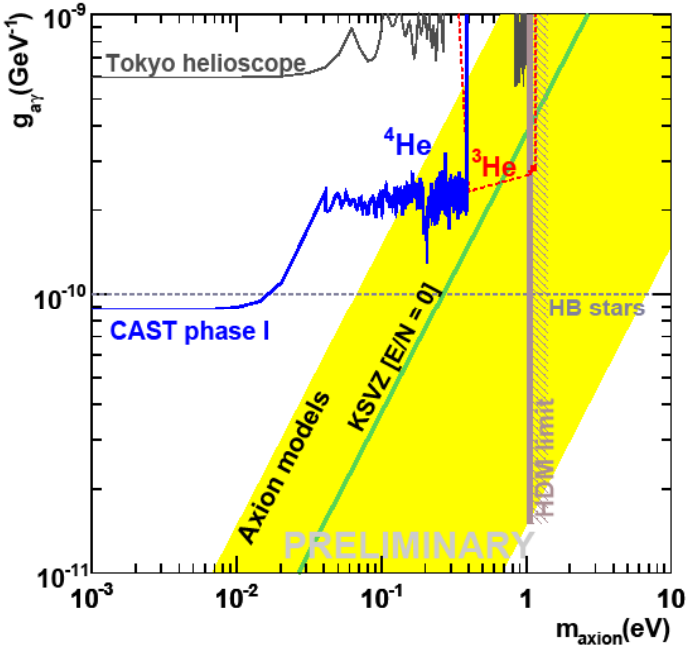
The new Micromegas performance in CAST

Limit estimations

Conclusions - Outlook

CAST Phase I & II-^{4}He result





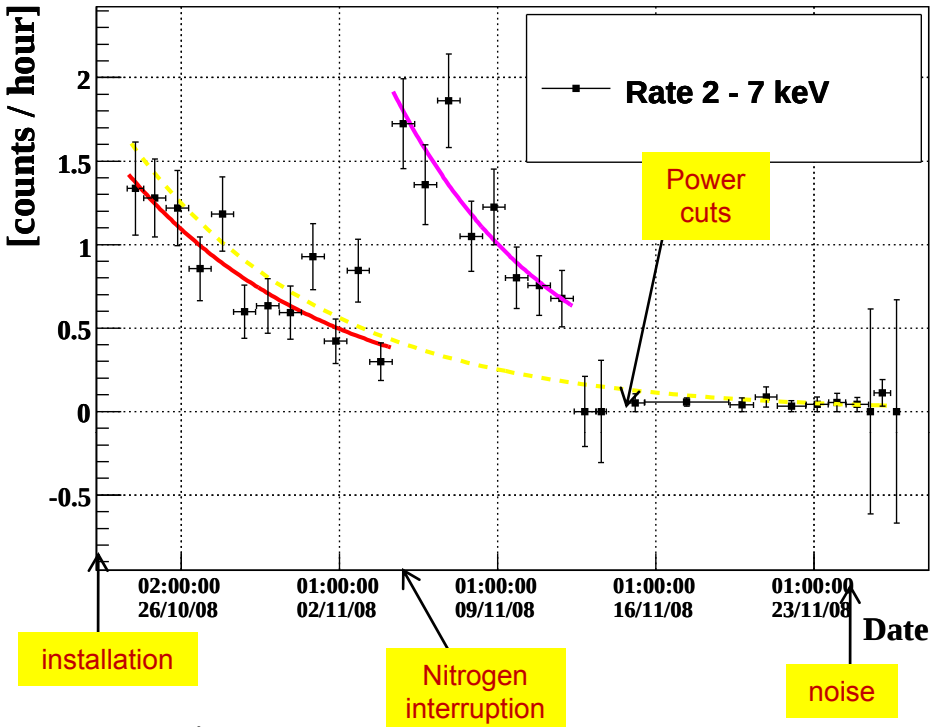
CAST has entered the theoretically favored axion model region!

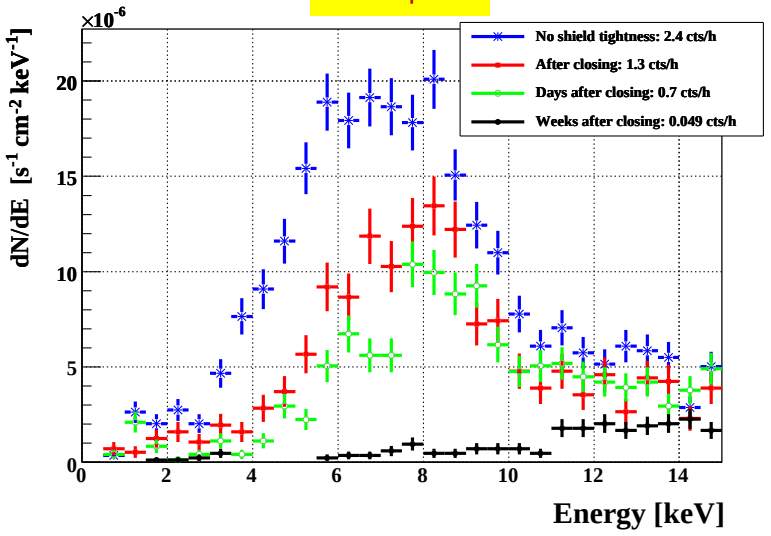
CAST <u>experimental</u> limit dominates in the most of the favored (cosmology/astrophysics) parameter space

CAN IT BE IMPROVED?

Background of the new Microbulks

- The background level of the new detector was initially ~1×10^{-5} s^{-1} keV^{-1} cm^{-2}
- The count rate appeared to drop with time
- Several days later the background reached an unexpected low level of **~2×10^{-7} s^{-1} keV^{-1} cm^{-2}** implying **~0.05 counts/hour** for the energy range 1-7 keV
- The intrinsic background level of the detector is minimal due to clean materials: only plexiglas, capton, copper for the detector and mylar, aluminum and stainless steel for the window
- Muons are efficiently rejected by the offline analysis
- External radiation is stopped by the shielding (4 cm **archeological lead**, **Cd**, 5mm **Copper**, **external polyethylene** + **Nitrogen flow** + **detector plexiglas**)
- Under these conditions the background is determined by the fluorescence lines (Copper, Iron and escape peaks) – the spectra during the different phases seem to be proportional
- These lines are mainly excited by radon radioactivity ➔ **extremely important to eliminate it from inside the shielding** (tightness is achieved using aluminum tape!!!)
- More details on Collaboration meeting talk (Thursday)





Prospects with new background

- Reduce the exposure time for each step in ^{3}He-Phase phase in order to achieve desired sensitivity

  (reduced tracking times → more steps per tracking?)

- New prospects for vacuum phase → Phase I limit

  →Fit measured background

  →Produce simulation-expected spectra for background & fixed exposure times

  →Assume (new) experimental conditions

  ➢Calculate limits

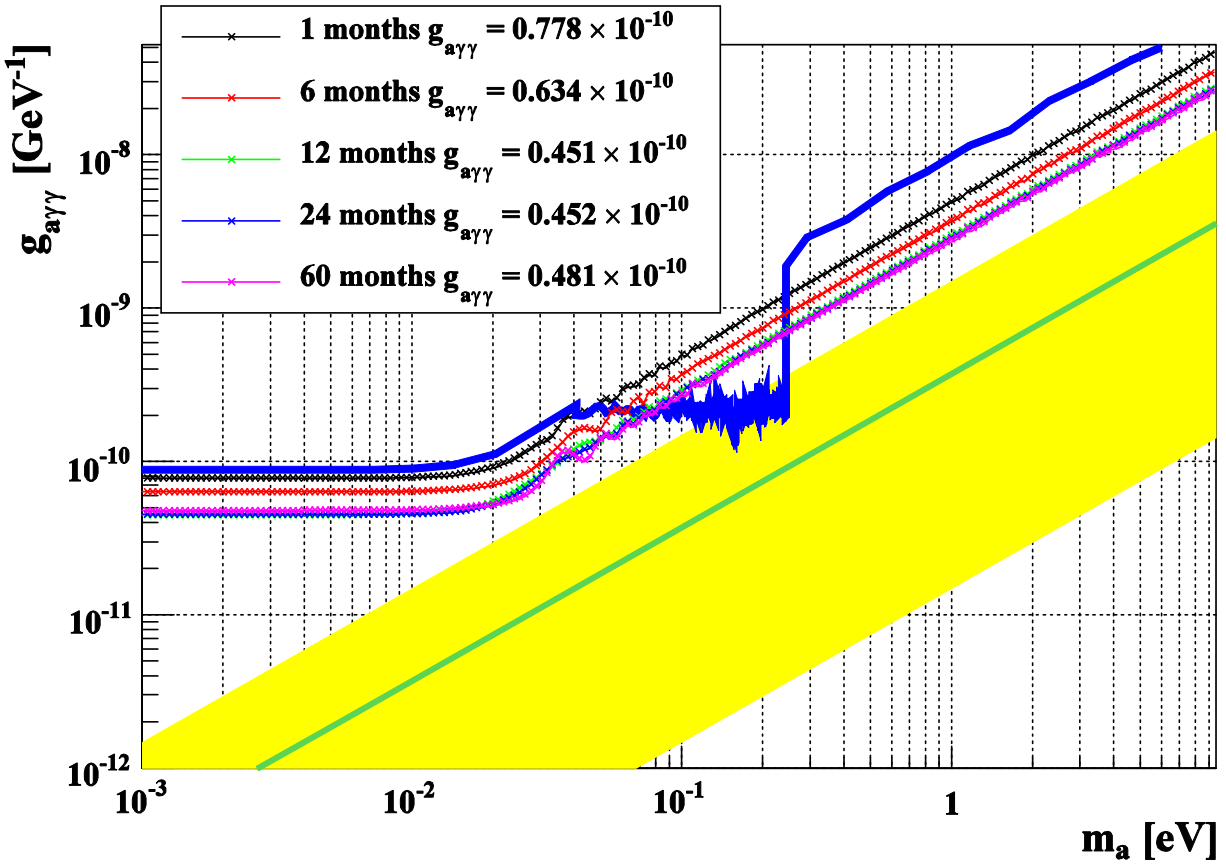
Current conditions *(very cheep solution!!!)*

Background:

measured one, for 3 similar microbulks

Asume:

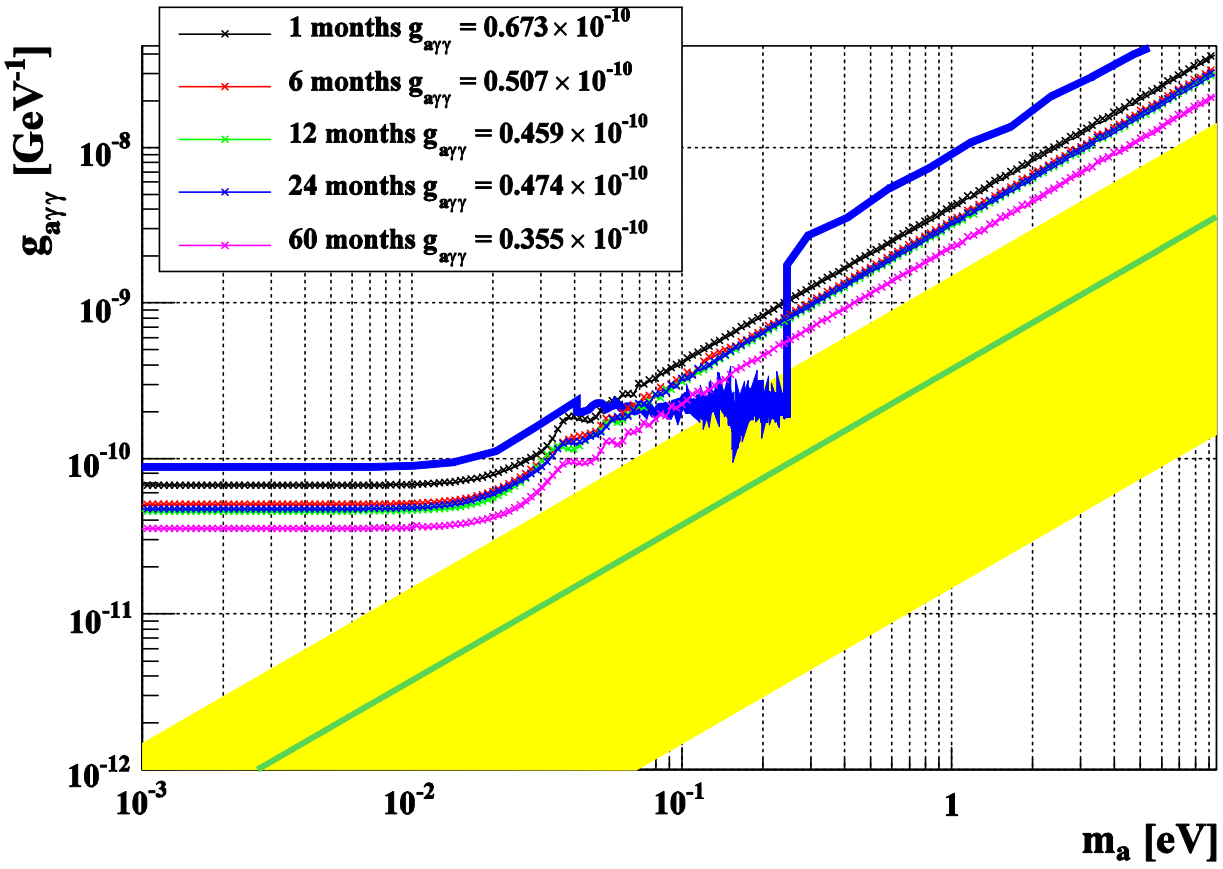
- Existing magnet
- Phase I conditions (*Vacuum, no cold windows*)
- Three microbulk detectors performing like sunrise one



Taking into account higher energies…

1-10 keV

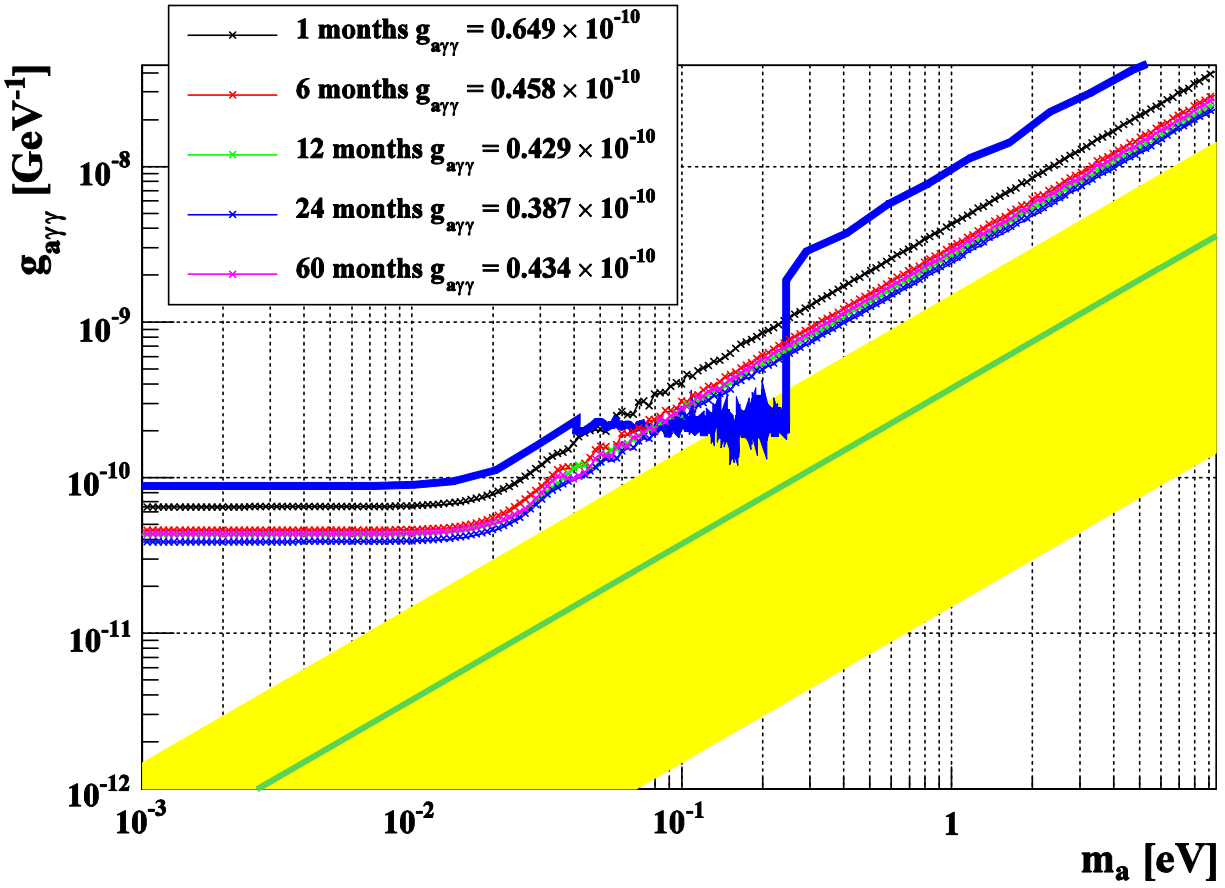
Simulation statistics!!!



Current conditions *(detector gas change)*

Assuming 20 % Xenon

background?

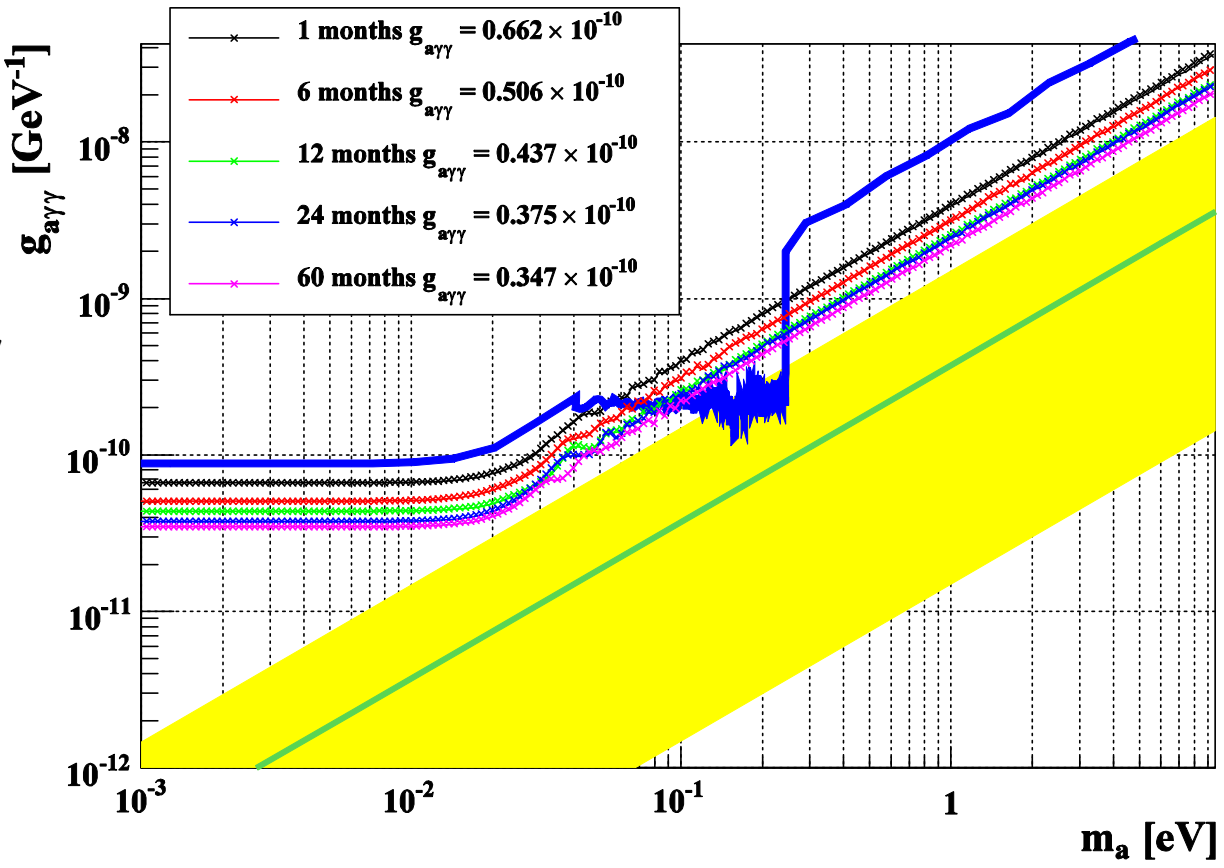


Current conditions *(1 new telescope)*

Background:
measured one, for 3 similar microbulks

Assume:

- Phase I conditions (*Vacuum, no cold windows*)
- Two microbulk detectors (performing like sunrise one)
- **One microbulk with telescope**



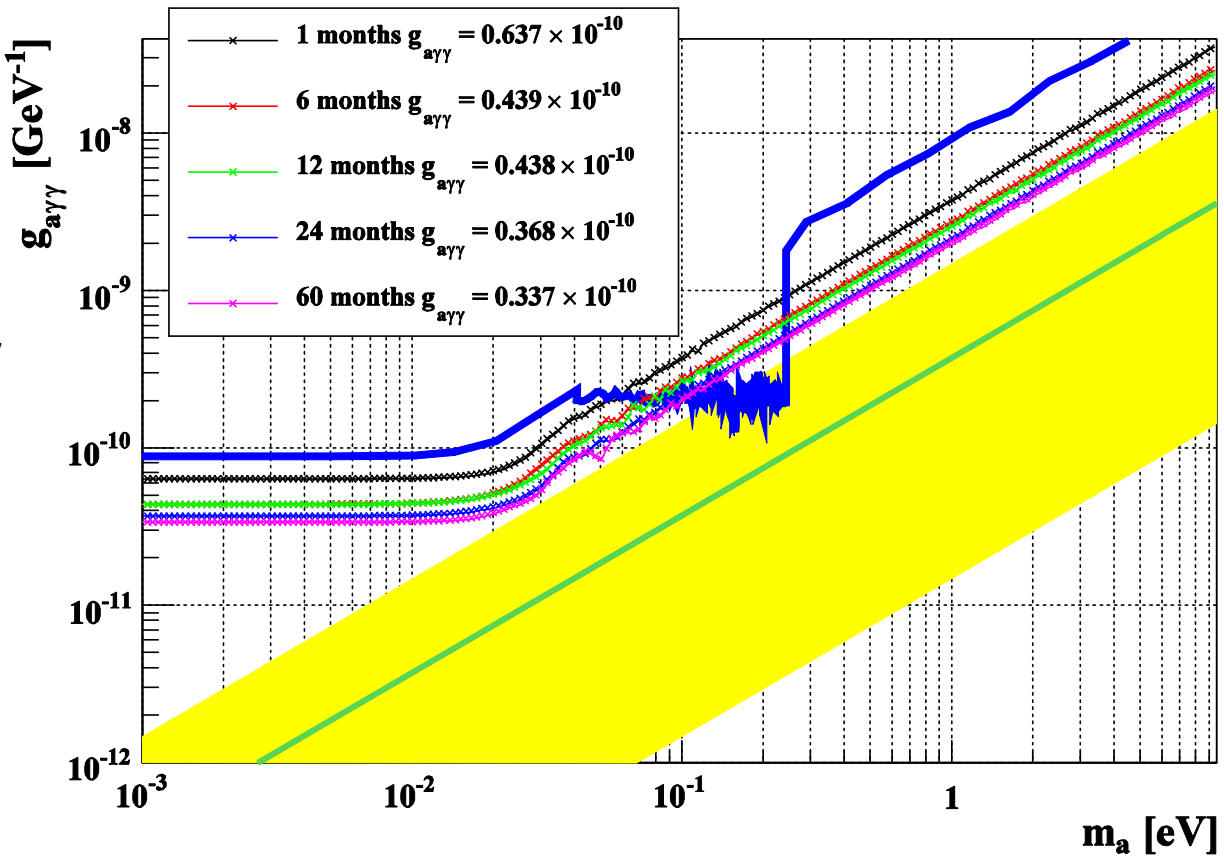
Using 2 telescopes - *The limit of CAST…*

Background:

measured one, for 4 similar microbulks

Asume:

- Phase I conditions (*Vacuum, no cold windows*)
- Two microbulk detectors (performing like sunrise one)
- **Two microbulk with telescope**



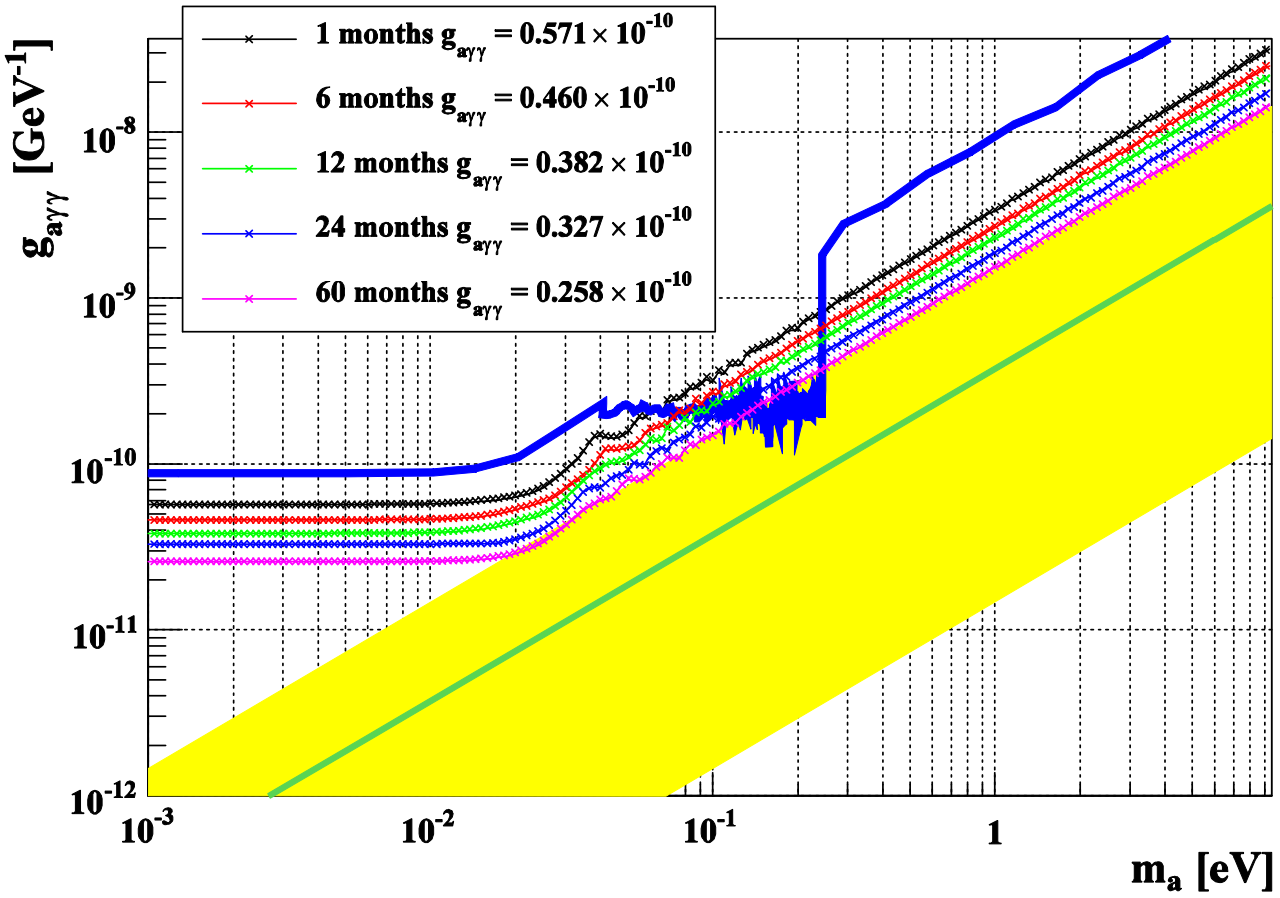
New Magnet *(15 T, 9.26 m long, 4.3 cm ∅)*

Background:

measured one, for 3 similar microbulks

Asume:

- Two microbulk detectors (performing like sunrise one)
- **One microbulk with telescope**



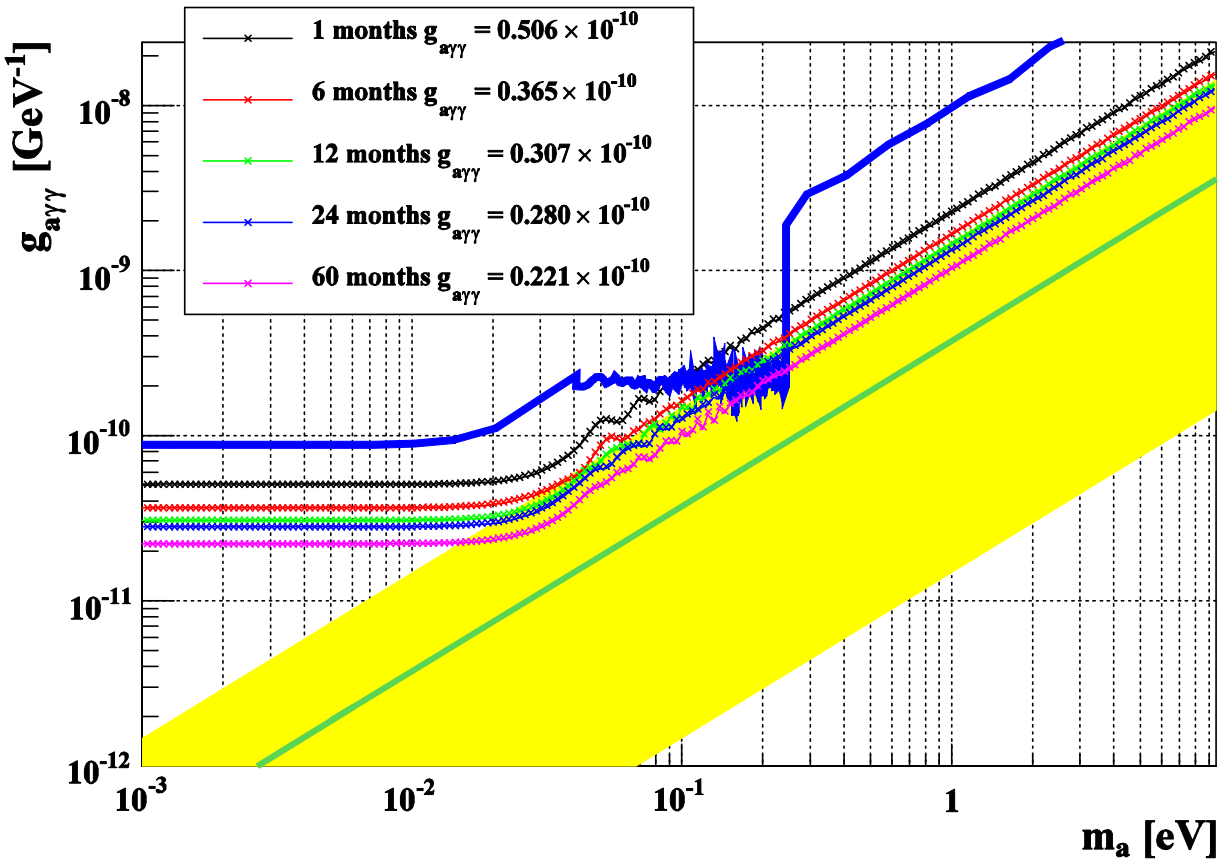
New Magnet *(15 T, 5 m long, x4 tracking time, 6 cm ∅)*

Background:

measured one, for 3 similar microbulks

Asume:

- Two microbulk detectors (performing like sunrise one)
- **One microbulk with telescope**

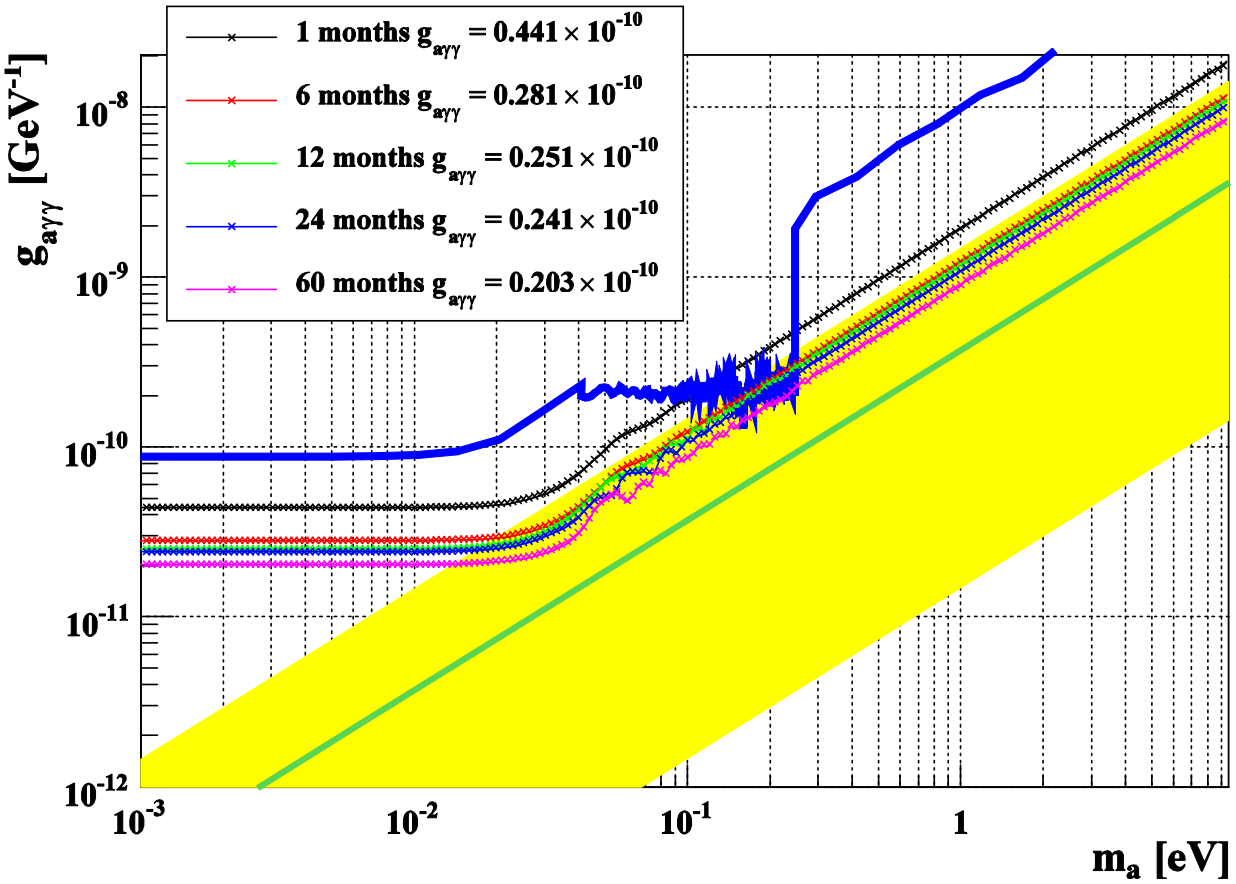


New Magnet *(15 T, 5 m long, x4 tracking time, 6 cm ∅, 2 telescopes)*

Background:
measured one, for 4 similar microbulks

Asume:

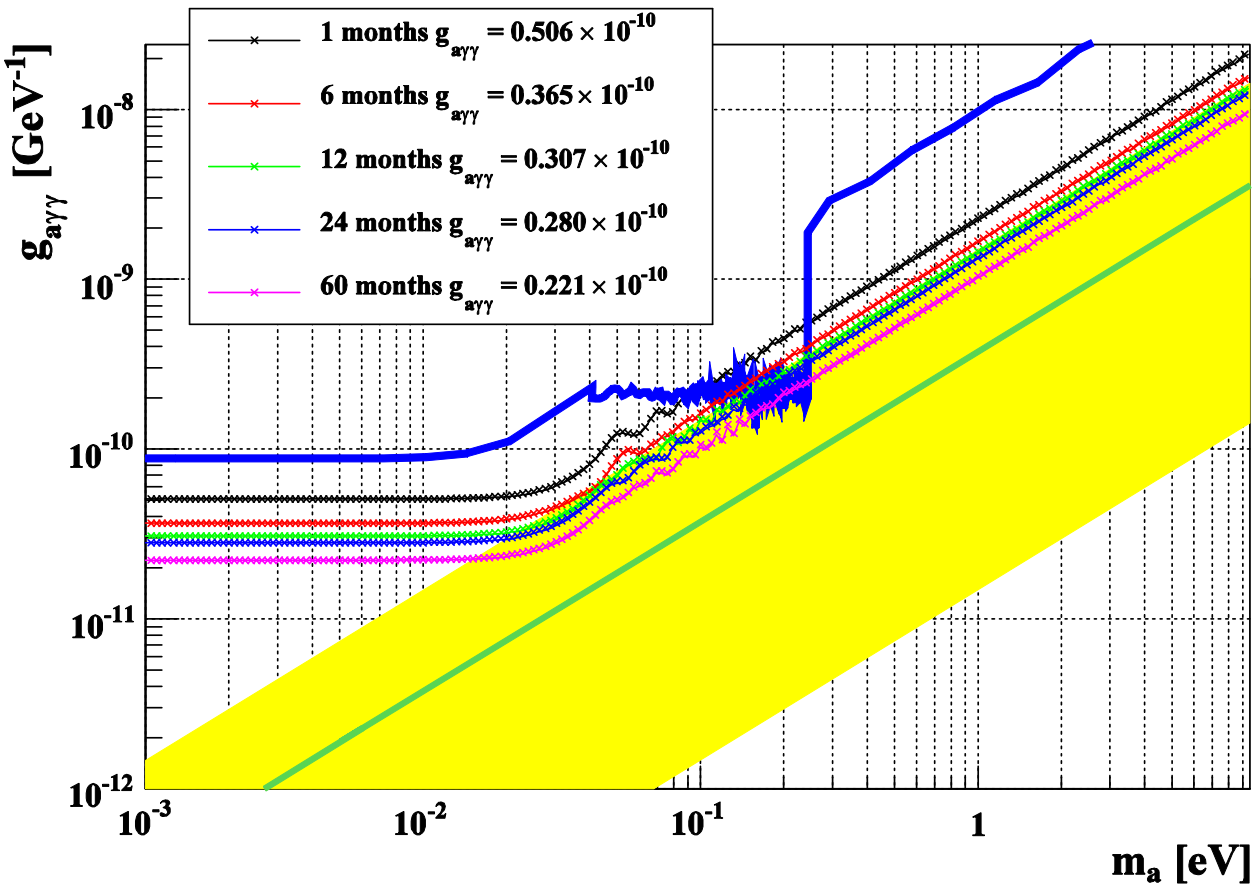
- Two microbulk detectors (performing like sunrise one)
- **two microbulk with telescope**



New Magnet *(15 T, 5 m long, x4 tracking time, 6 cm ∅, "Super-telescope")*

Background:
measured one,
for 1 microbulk

- **One telescope 60% efficiency, covering 2 bores**



CONCLUSIONS

The ultra-low-background level of the new microbulk detectors brings up new possibilities:

- Improve ^{3}He Phase limit – **higher discovery potential**
  → ***speed up "stepping" procedure?***
- Returning to phase I conditions for ~1 year would lead to a coupling constant limit
  $g_{a\gamma\gamma} \approx 4\times10^{-11}$ **GeV^{-1}**

✓ The implementation of an x-ray optics focusing device

- could push limit down to $g_{a\gamma\gamma} < 4\times10^{-11}$ **GeV^{-1}** and
- any single count could be interpreted as a **potential signal**!!! (0.15 expected counts in 6 months)

✓ A new technology magnet is necessary to push the limit **inside the model favored region**. (use of telescope important!)

✓ *Low energy axion searches*

END

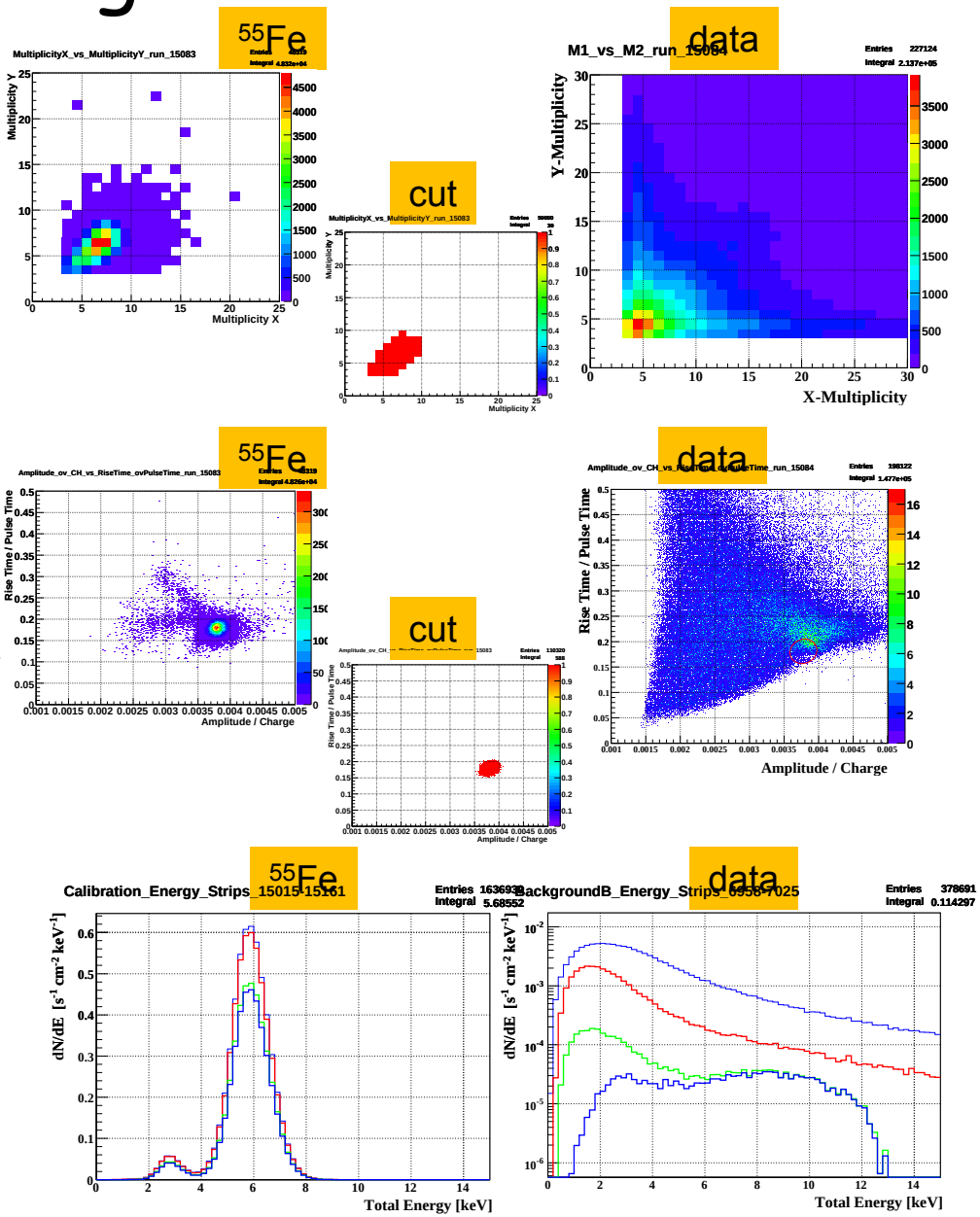
The new micromegas in CAST

- The bulk detectors were build on 400 μm of PCB for technical reasons
  - ➔ **Possibly increased intrinsic background**
- The bulk detectors, due to the bigger amplification gap, have potentially **reduced rejection efficiency**
- The first microbulks up to M8 had shown several defects, since the technique was still under development
  - ➔ **Possibly reduced rejection efficiency**
- A new series of defect free microbulk detectors was constructed
  - ➢ The new detectors were installed in CAST around October 24th, 2008

Pattern recognition algorithm

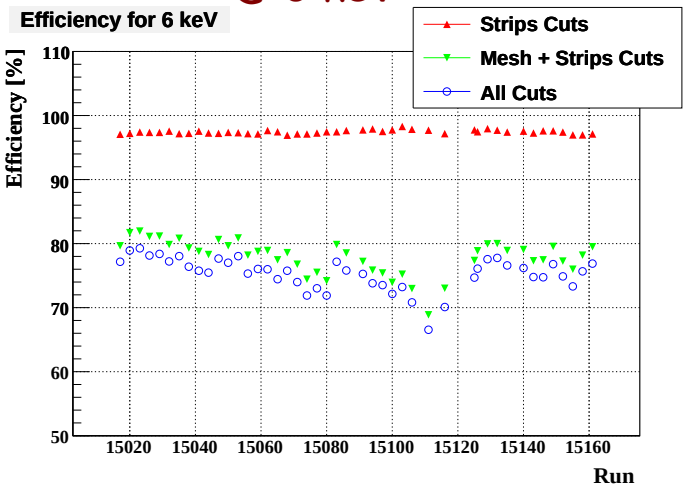
- Define signal characteristics for ^{55}Fe X-Rays (daily calibration runs)
  - Strips: multiplicity, width, topology of clusters
  - Mesh: risetime, width, amplitude, integral of signals
- Examine distributions
- Define cuts from bins with content above a relative value
- Apply cuts in data runs
  - Sequential
  - Multivariate analysis
  - Neural networks
- Optimize between efficiency and rejection

Data reduction >10^3

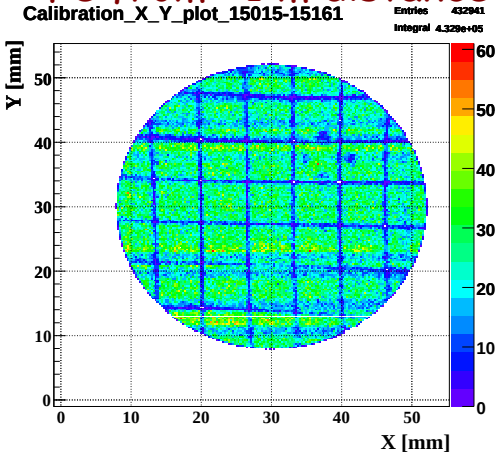


New Detector Performance

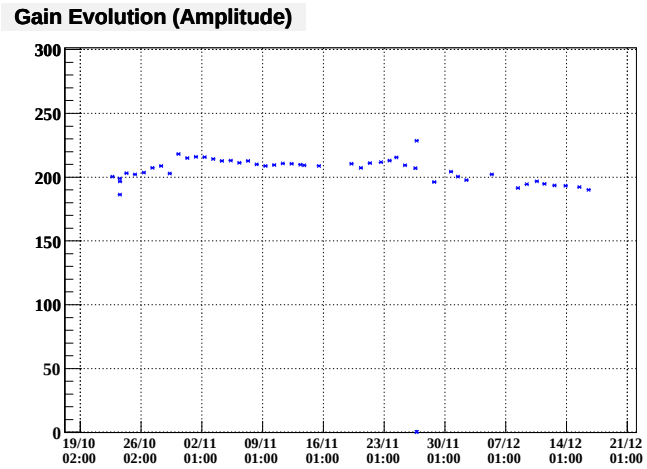
Software efficiency @ 6 keV



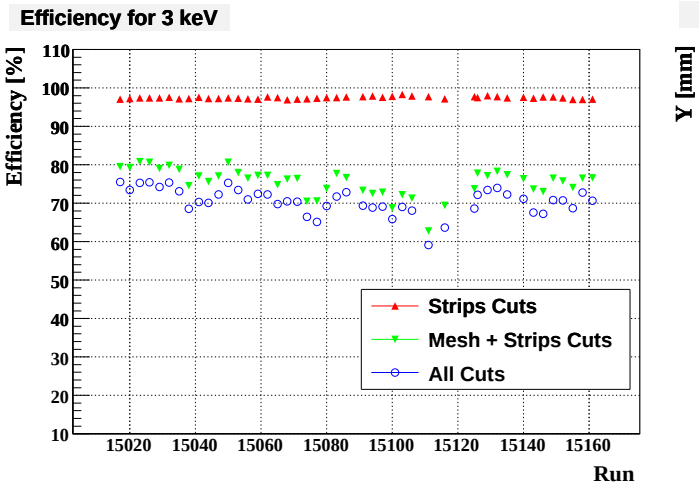
Calibration @ CAST with ^{55}Fe from ~1 m distance



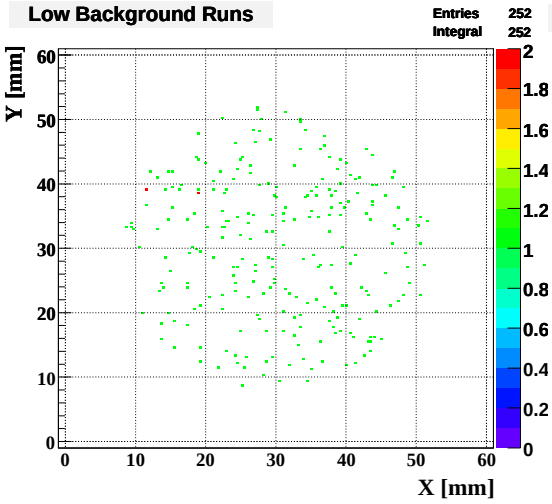
Long term stability of gain



Software efficiency @ 3 keV



Background count distribution



Resolution stability