CAST micromegas detectors in the Canfranc Underground Laboratory

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on behalf of the CAST micromegas team:

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Outline

The CONTEXT

- The CERN Axion Solar Telescope (CAST).
- CAST *microbulk* micromegas detectors.
- The Canfranc Underground Laboratory (LSC).

The MERGING

- Canfranc's CAST-like set-up: Direct comparison.
- Going 'deeper' underground: To seize upon underground possibilities.

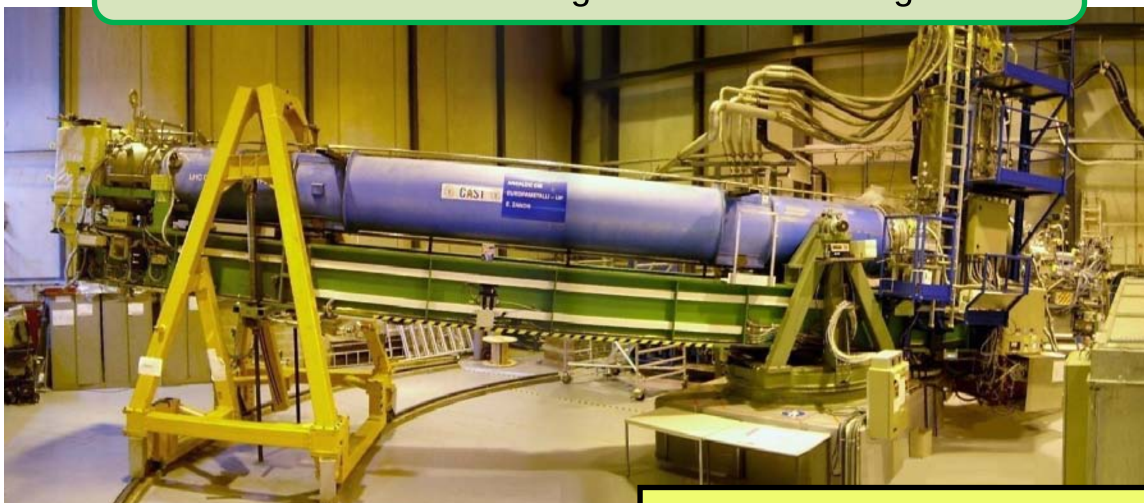
- Summary and Conclusions

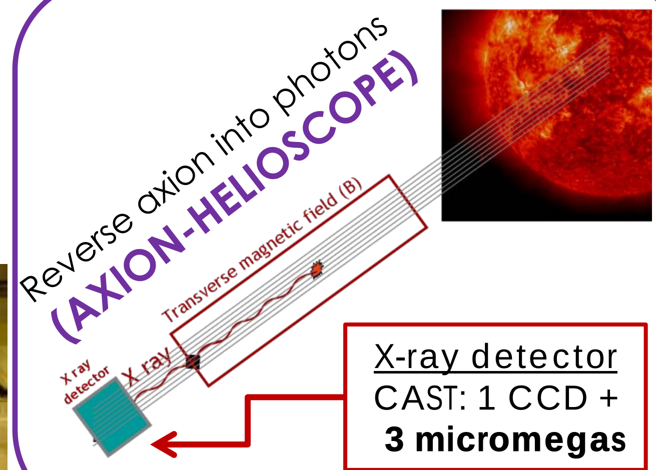
CAST (CERN Axion Solar Telescope). *Since 2002*

A helioscope from a LHC decommissioned prototype dipole:

9 T transversal along 9,26 m length (two bores)

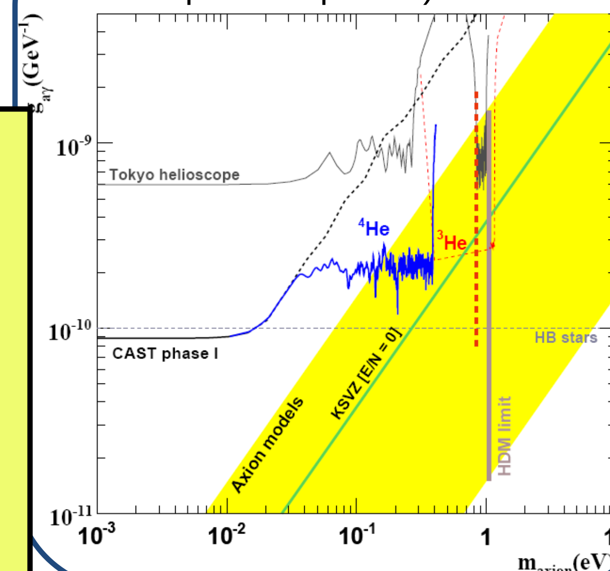
1.5 hours tracking the sun every sunrise and sunset.
Rest of the time defining detectors background





X-ray detector
CAST: 1 CCD +
3 micromegas

Exclusion plot (in red, expected for the present phase)



Each count in a tracking is significant!.

Conserving the magnet (fixing conversion probability), decreasing the background is the key way to improve the *discovery potential*.

***Rare Event Search*:**
CAST sensitivity's *requirement* on detector background:

To down to $g_{a\gamma\gamma} = 10^{-10}$ GeV^{-1}

~ ½ counts/tracking

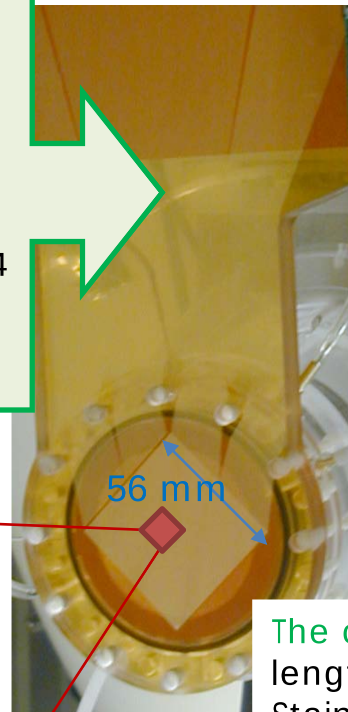
in 14.5 cm^2 in 2-7 keV

CAST *microbulk* micromegas. Low background strategies.

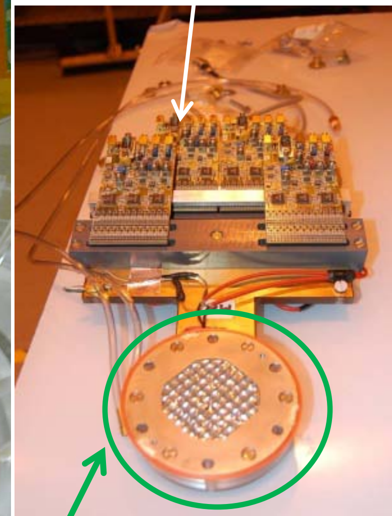
1. Low intrinsic radiopurity. Low mass readout (80 µm thickness).

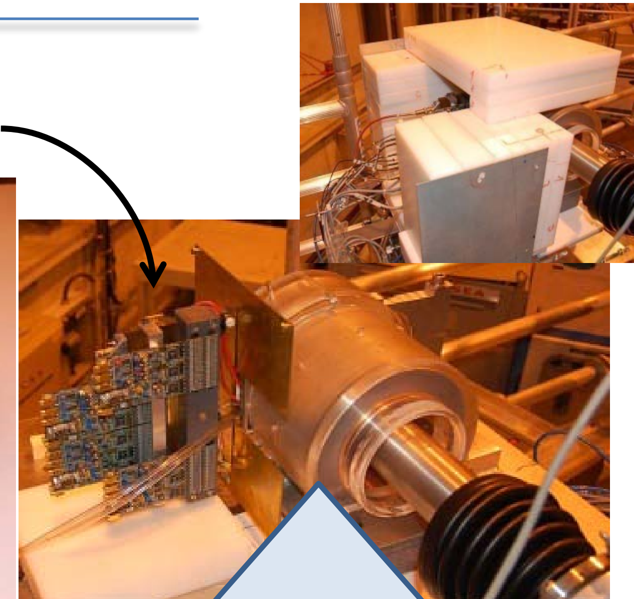
LSC measurement (HPGe): Astropart.Ph. **2011**, *34*, 354

Glued to a Plexiglas pedestal.



Front-end electronics





The chamber, 3 cm drift length, made of Plexiglas. Stainless steel cathode. 4 µm mylar window.

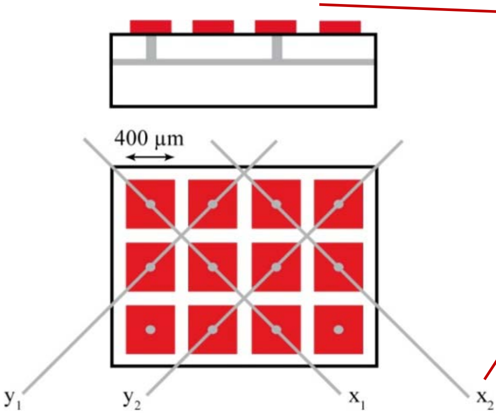
2. Shielding

Isolation from environmental radiation (natural gamma flux and no radiopure components)

✓Inner shielding: 0.5 cm Cu (radiopure).

✓External shielding: 2.5 cm Pb + Polyethylene.

✓Clean atmosphere (No Rn): constant N2 flux.



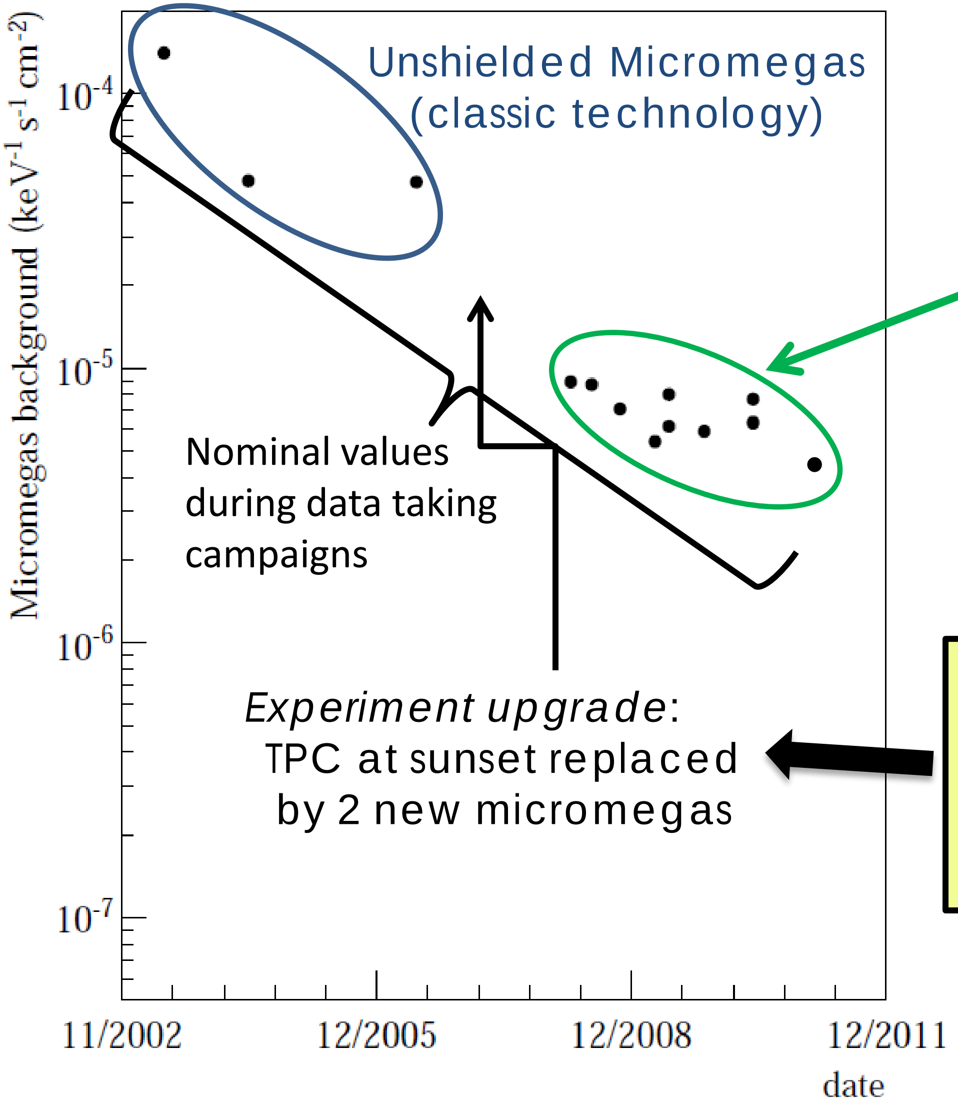
2d Spatial information
+
Time information
(pulse generated during amplification)

3. Offline discrimination.

Analysis based in evaluation of background events characteristics in contrast to X-rays signal description (actualized by daily calibrations).

Discussion: F.J. Iguaz's talk

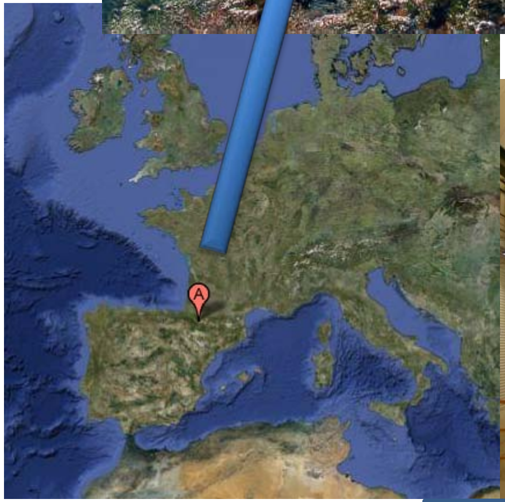
Background levels of micromegas detectors in CAST over the years



Long time operation: **reliability** and **stability**, the other CAST requirements for detectors.

During 5 years micromegas in the sunrise side proved to be **confident** and **competitive** as X-ray detectors.

The Canfranc Underground Laboratory. *Since 1985*



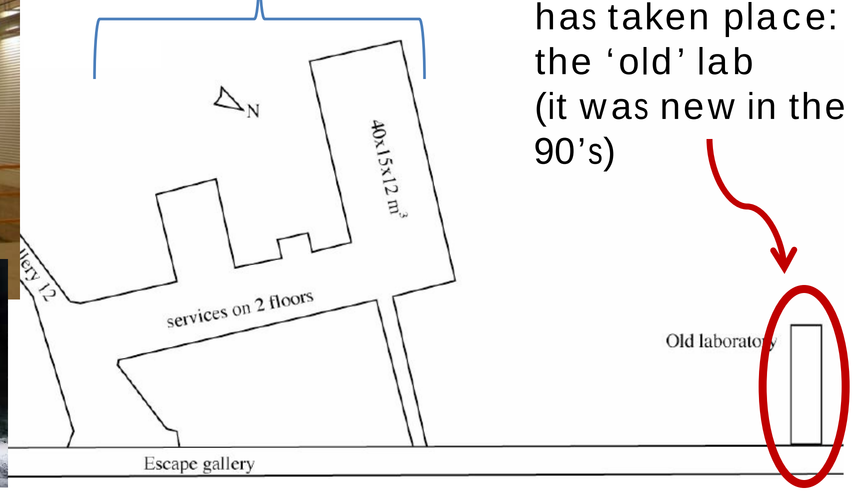
The Canfranc Underground Lab (**LSC**) situated inside an old train tunnel under the Tobazo mountain in the Spanish Pyrenees at the deep of **2500 m.w.e**. (meter of water equivalent).

Research at LSC was carried out by the High Energy Physics group of the **University of Zaragoza** since **1985**. Main subjects: *dark matter* and *double beta decay.*

Hall A (2006)

In 2006 it became an independent facility.

2006 upgrade



Where this work has taken place: the ‘old’ lab (it was new in the 90’s)

Underground Possibilities.

What does staying under a mountain offer to Particle Physics?

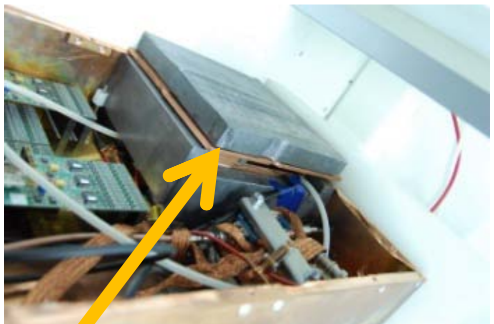
- 10^4 reduction factor in cosmic muons.
- Stable environmental conditions (T, P, humidity).
- Environmental gamma radiation well known.

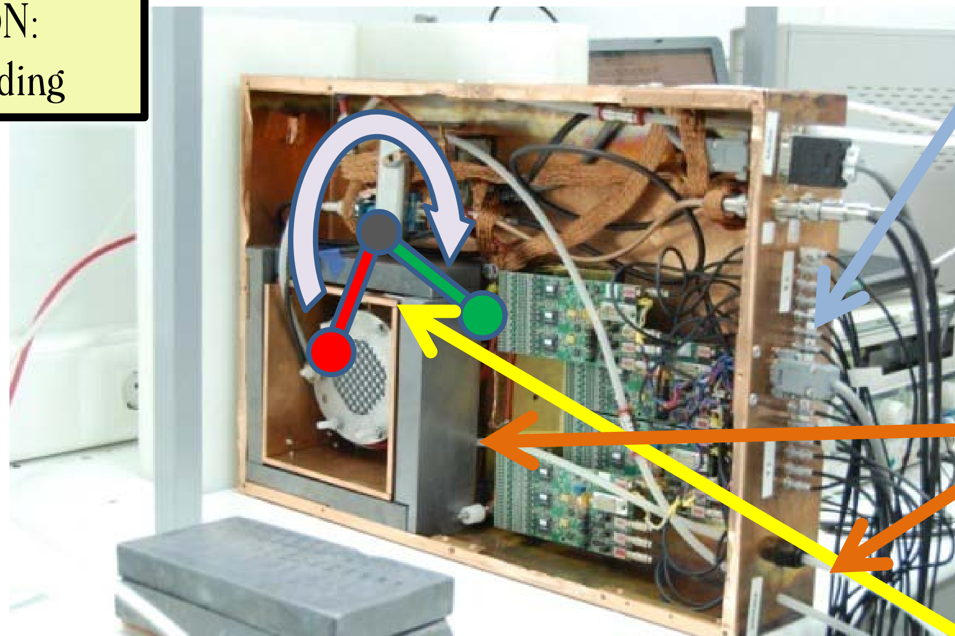
GOALS (Installation of a CAST microbulk micromegas detector at LSC)

- Study CAST background nature. Itemize different origin contributions:
  - cosmic rays.
  - external gamma flux (natural radioactivity).
  - internal contamination (detector/readout).
- Avoid systematic effects related with environment conditions.
- Estimate microbulk micromegas reliability for an ultra-low background experiment (underground).

Canfranc's CAST-like set-up.

INTIMATE CONFIGURATION:
front-end electronics and shielding





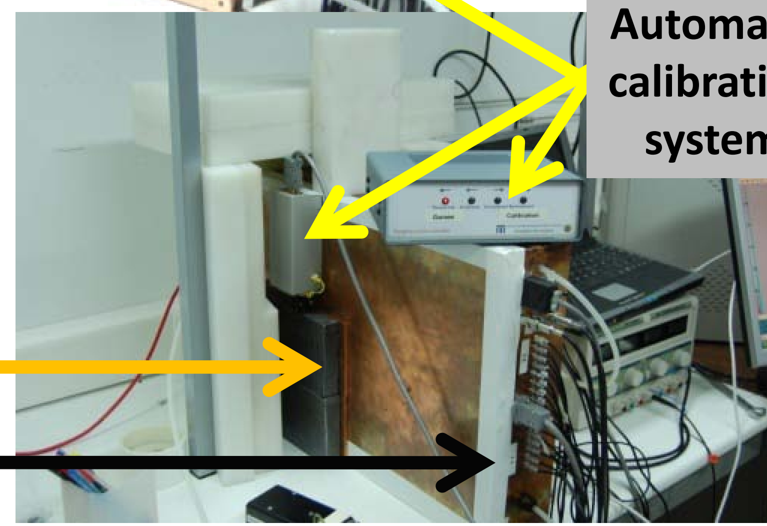
All the connections extracted via *feedthroughts*.

N2 flowing into the inner shielding

Automatic calibration system

4π inner shielding: 5 mm Cu + 25 mm Pb

(With exception of a minimum gap for the calibrator to introduce the source)



***Last touch*: close it leak-tight as possible to preserve nitrogen atmosphere.**

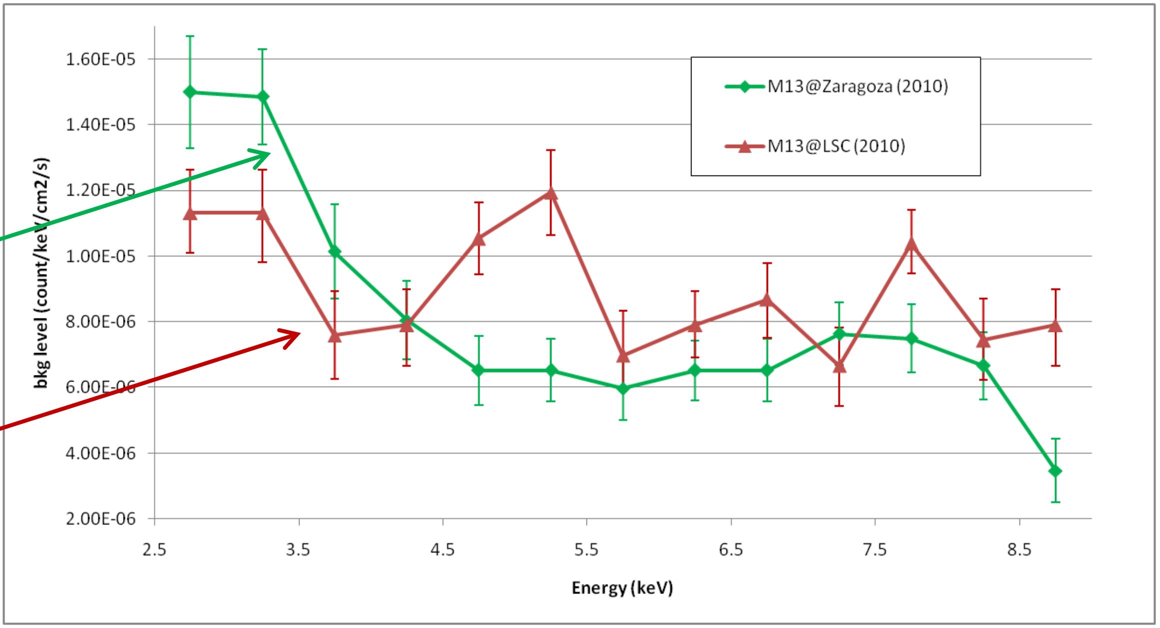
Canfranc's CAST-like set-up. *DIRECT COMPARISON (I).*

Final background
(after offline events selection)

M13 detector at surface (Zaragoza's lab)

M13 detector at Canfranc

Both measurements using the same set-up and configuration



The microbulk micromegas M13, CAST spare detector, when installed at surface, registered ~1 Hz trigger rate and performed a final background level of:

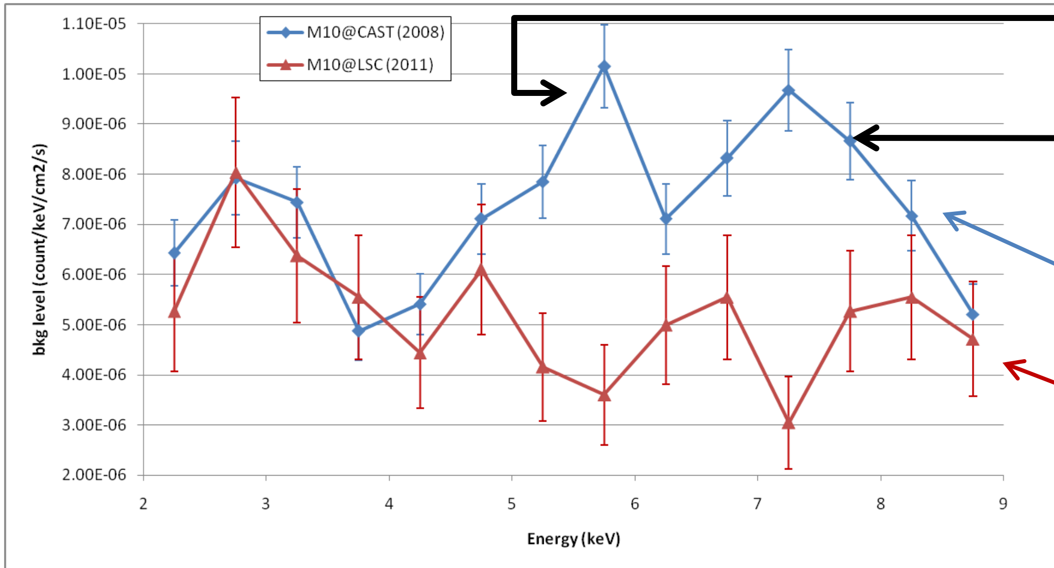
~$8 \cdot 10^{-6}$ counts keV^{-1} cm^{-2} s^{-1} (2-7 keV)

Independently on several amplifier settings and detector gain. Once underground trigger rate is only ~0.2 Hz and the background:

~$9 \cdot 10^{-6}$ counts keV^{-1} cm^{-2} s^{-1} (2-7 keV)

Cosmic rays dominate the trigger rate at surface, but had only a small effect in background after offline analysis, *cosmic events are easily discriminated.*

Canfranc's CAST-like set-up. *DIRECT COMPARISON (II).*



Fe (steel): cathode, pipe connection to CAST magnet bore.

Cu: micromegas mesh and pixels.

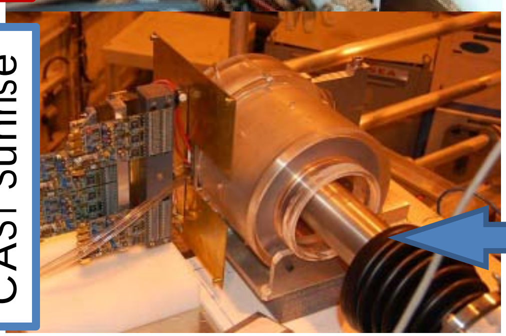
M10 detector at service in CAST (Sunrise side, 2008 campaign)

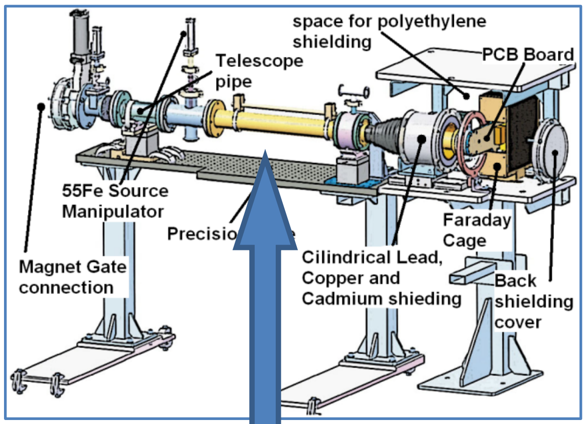
M10 detector at Canfranc

New front shielding recently installed in CAST sunrise !!

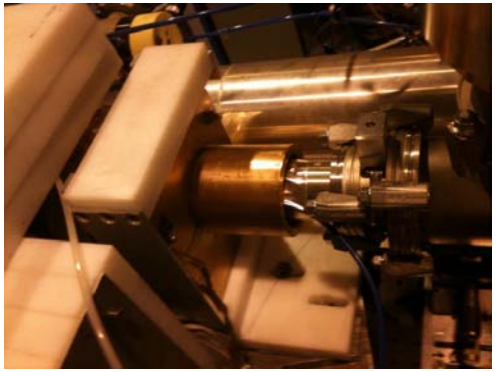
LSC set-up

CAST Sunrise

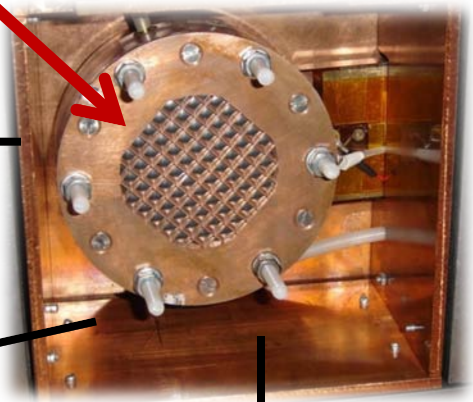




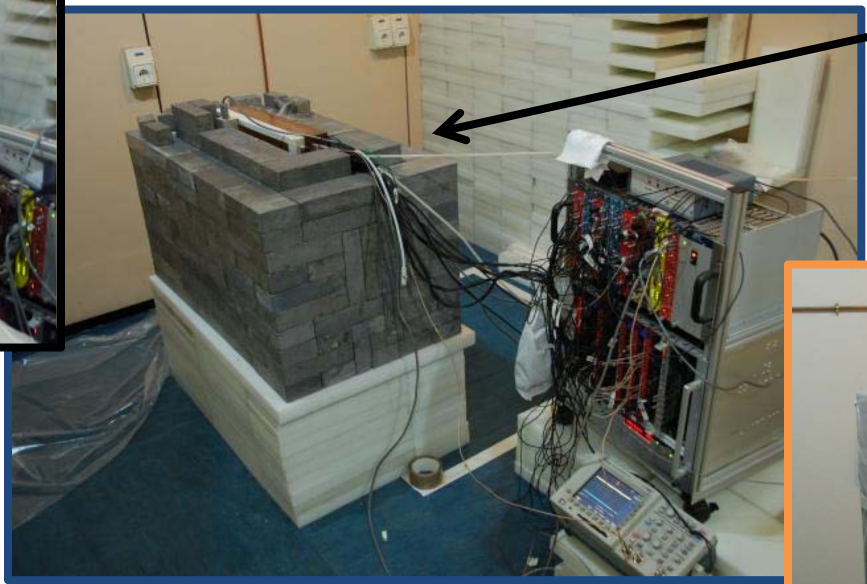
Pipe to magnet cold-bore



Shielding configurations (CAST microbulk with Cu cathode inside):



"Half" closed:
5/6· 4π 20 cm extra Pb



CAST-like:
No extra Pb

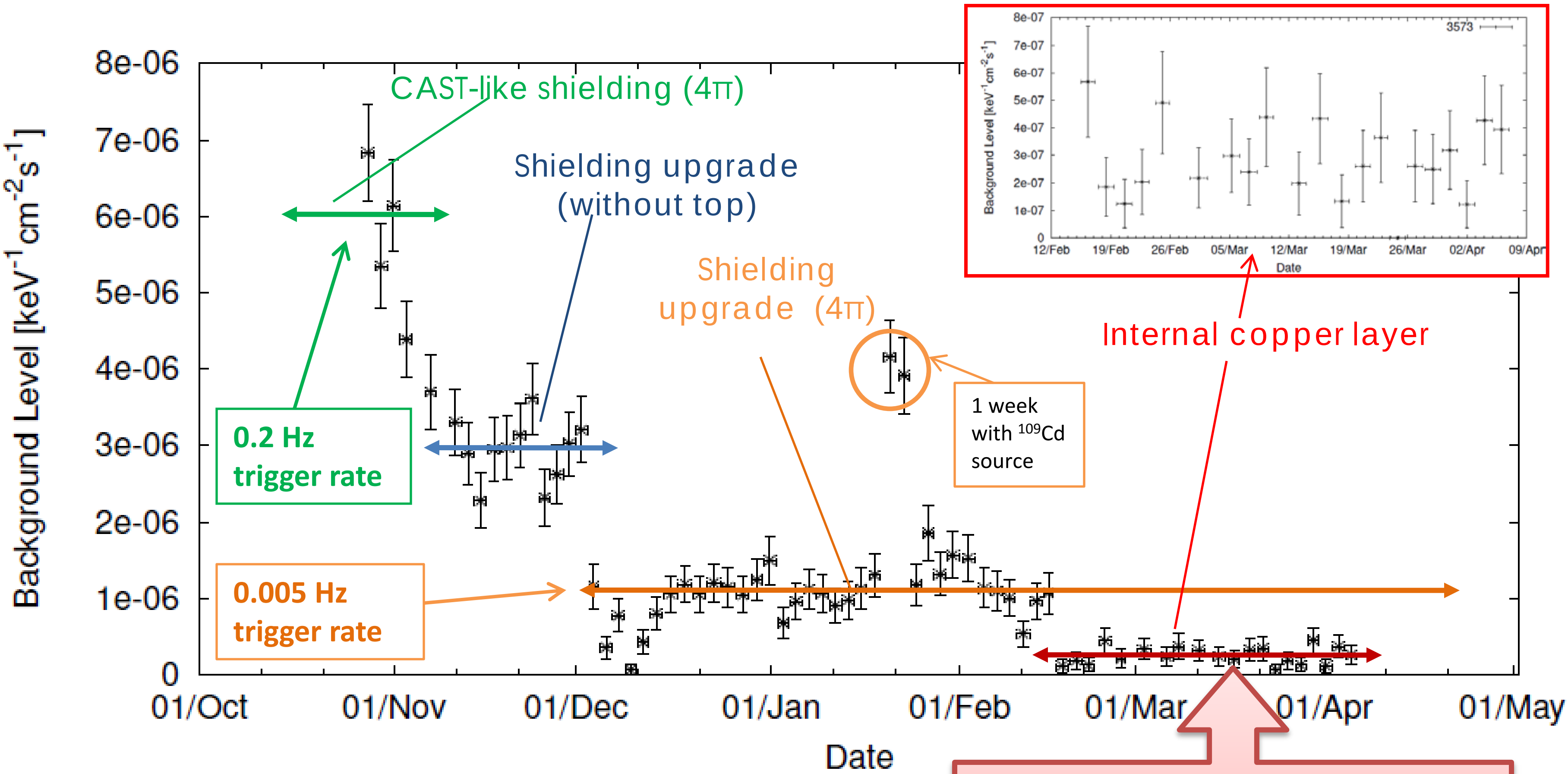
"Complete":
20 cm extra of Pb

All configurations with internal 4π shielding:

0,5 cm Cu + 2,5 cm Pb

+ Nitrogen flux against Rn

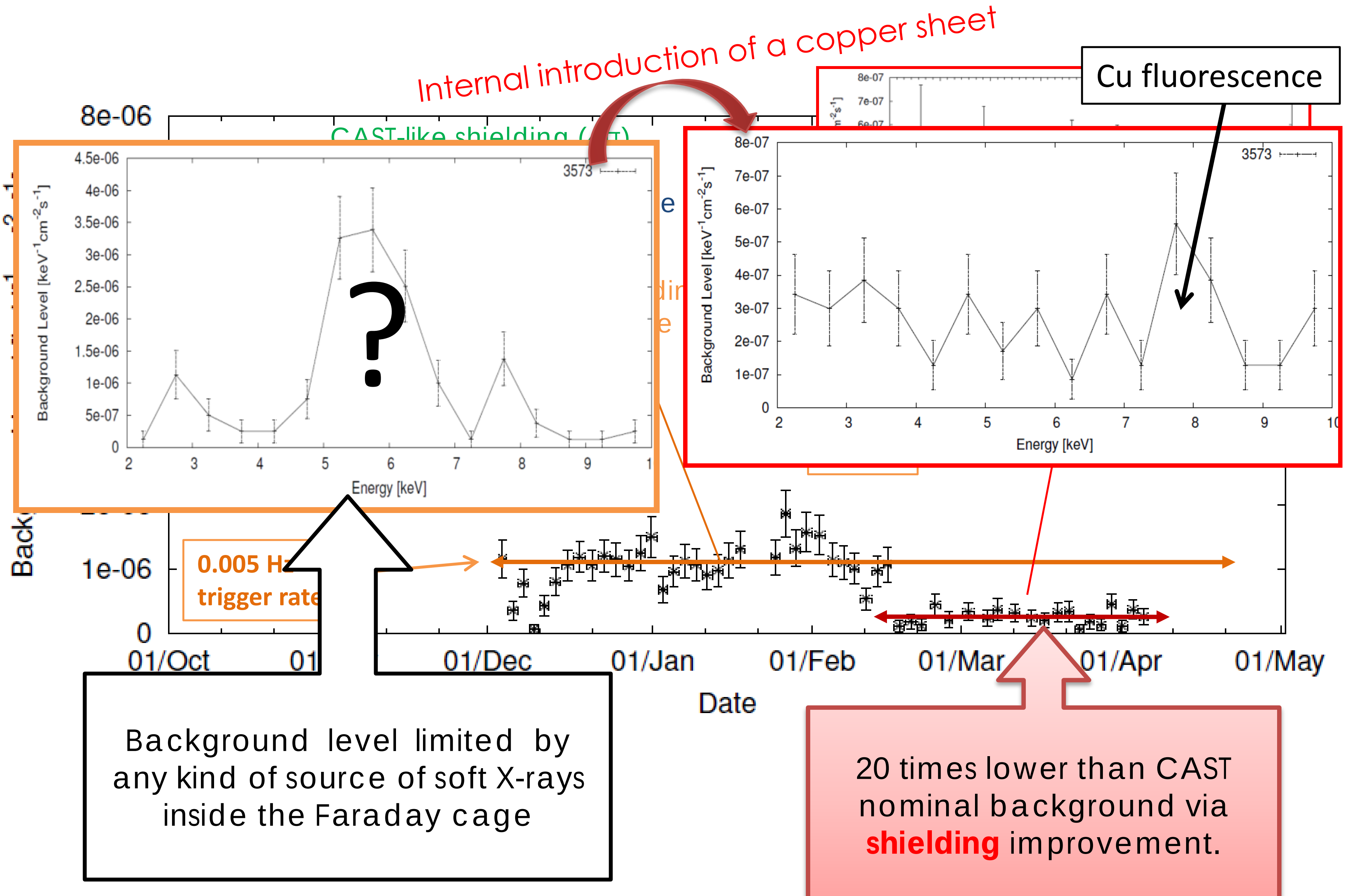
M10 at LSC. Background evolution.



Energy range: 2-9 keV

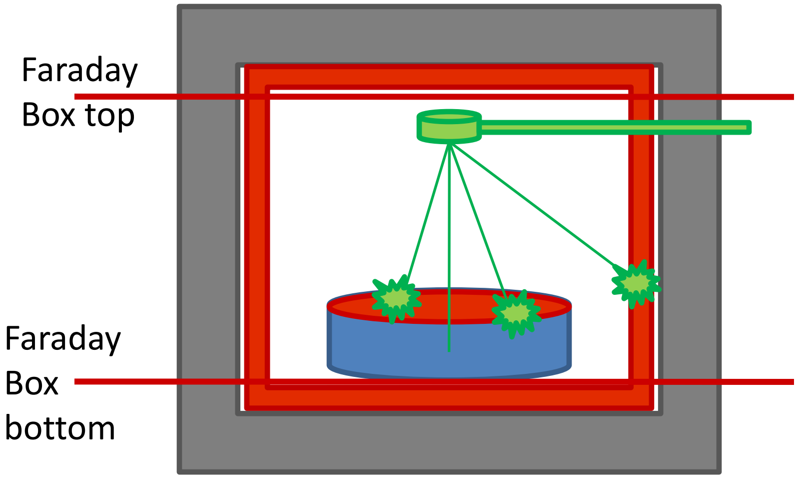
20 times lower than CAST nominal background via **shielding** improvement.

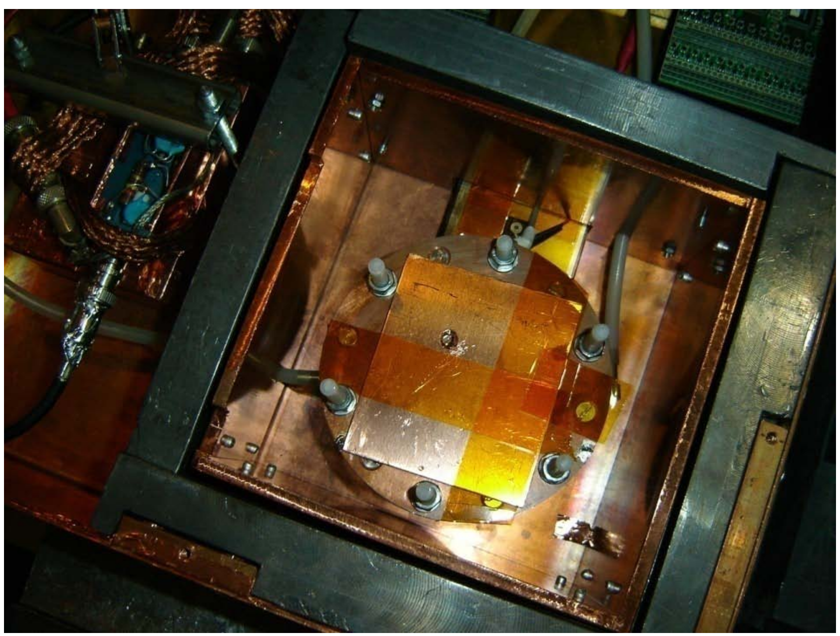
M10 at LSC. Background evolution.



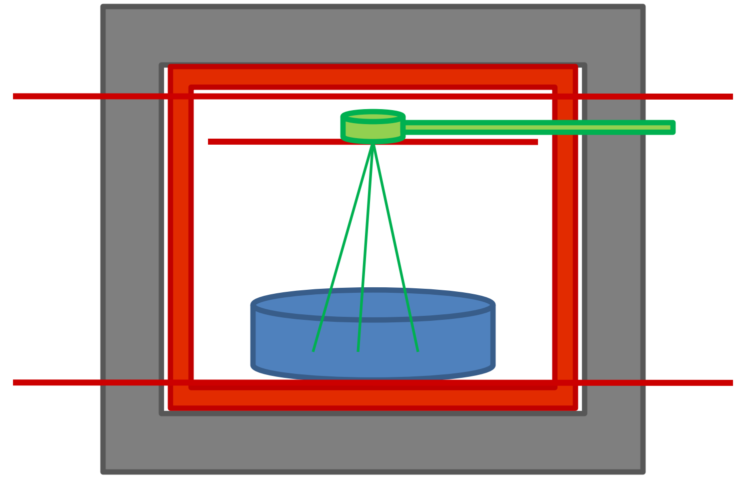
M10 at LSC. Internal configurations for Ultra-low background

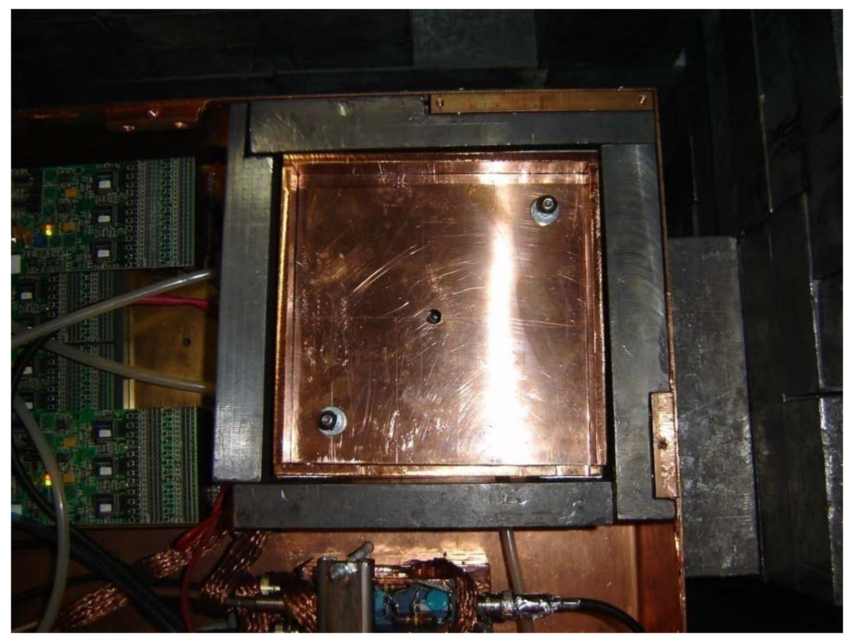
Cu layer on STRONGBACK





Cu layer on TOP



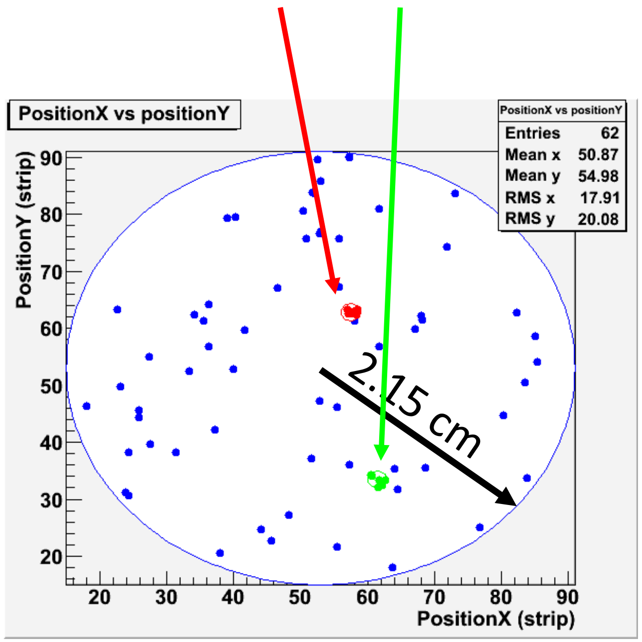


M10 at LSC. 40 days of Ultra-low background.

2 *Hotspots* are found in the background hitmap during these days.

So concentrated events are thought to be *micro-sparks*.

A total of 21 events from 62 concentrated in 2 spots of 2.2mm^2 !: 9 and 12 events

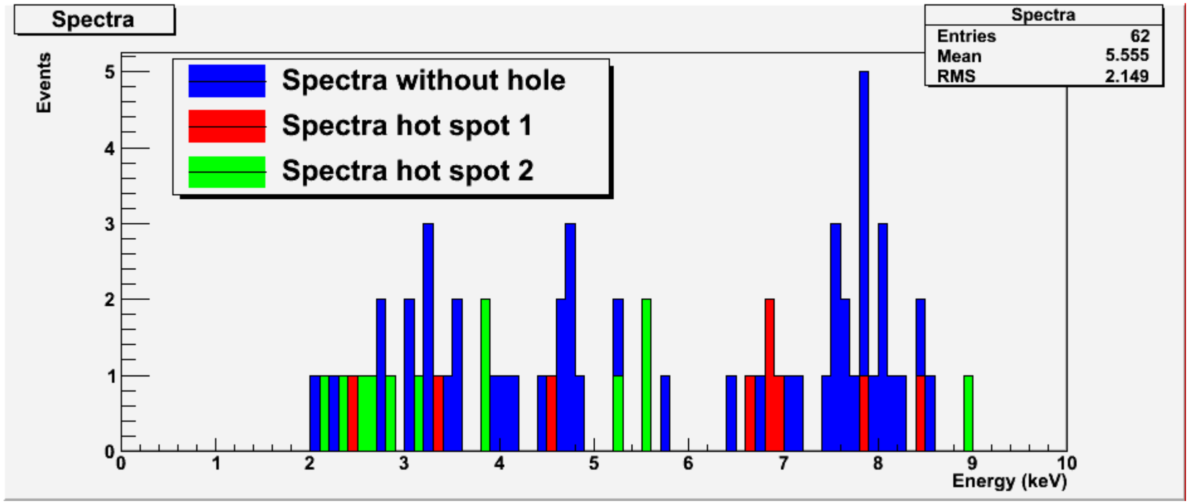


Removing the hotspots from the data we obtain the following:

Effective exposure time 993.83 hours

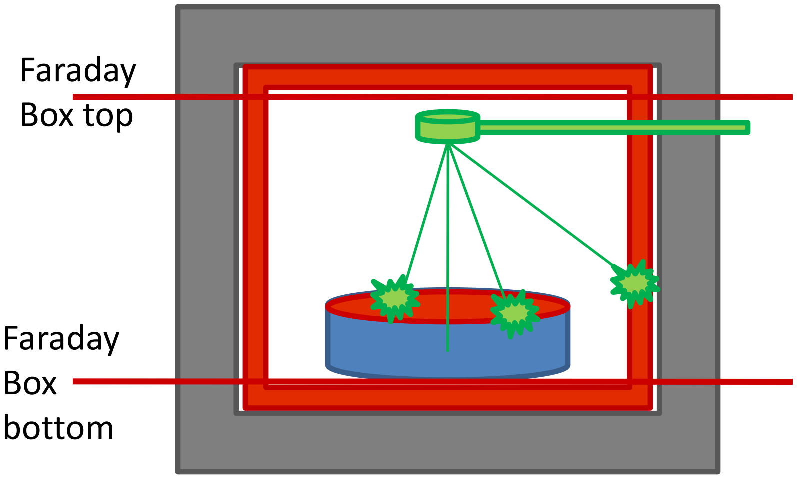
Rate (2-7keV)	$(1.5 \pm 0.6)\cdot10^{-7}$ keV^{-1} cm^{-2} s^{-1}
Rate (2-9 keV)	$(1.7 \pm 0.3)\cdot10^{-7}$ keV^{-1} cm^{-2} s^{-1}

- Clear Cu fluorescence peak
- Only small differences between both internal configurations.

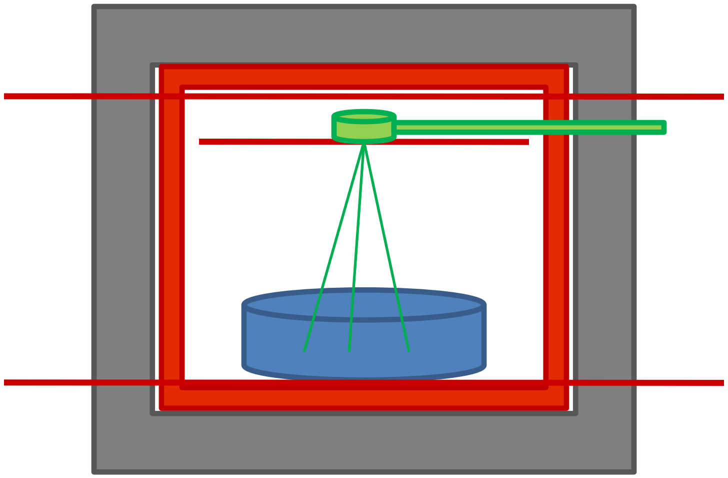


M10 at LSC. 40 days of Ultra-low background.

Cu layer on STRONGBACK



Cu layer on TOP



✓No external X-Rays can enter into the chamber (No window).
✓ More Copper surface exposed almost directly to the gas.
➢ **Suppression of environmental soft radiation**.

✓X-Rays cannot come from Faraday box top nor from calibrator gap.
✓ X-Rays from closest environment contribute.
➢ Real **internally shielded** configuration for a **CAST detector** (with window, of course).

Effective exposure time 534.84 hours

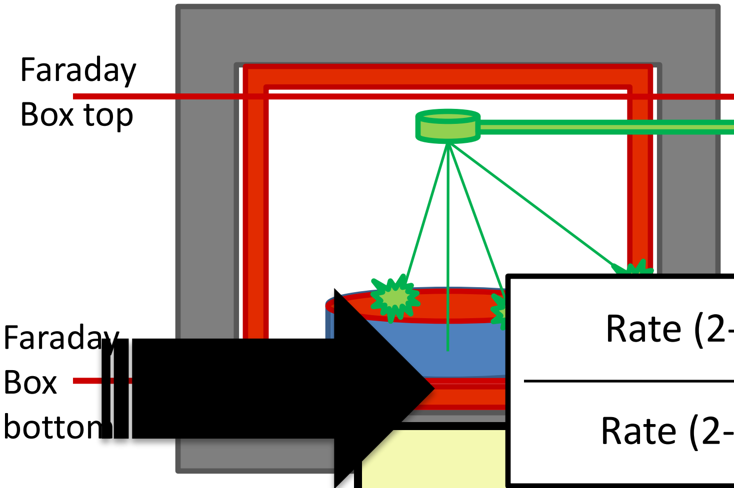
Rate (2-7keV)	$(1.5 \pm 0.9)\cdot 10^{-7}$ keV^{-1} cm^{-2} s^{-1}
Rate (2-9 keV)	$(1.8 \pm 0.8)\cdot 10^{-7}$ keV^{-1} cm^{-2} s^{-1}

Effective exposure time 469.83 hours

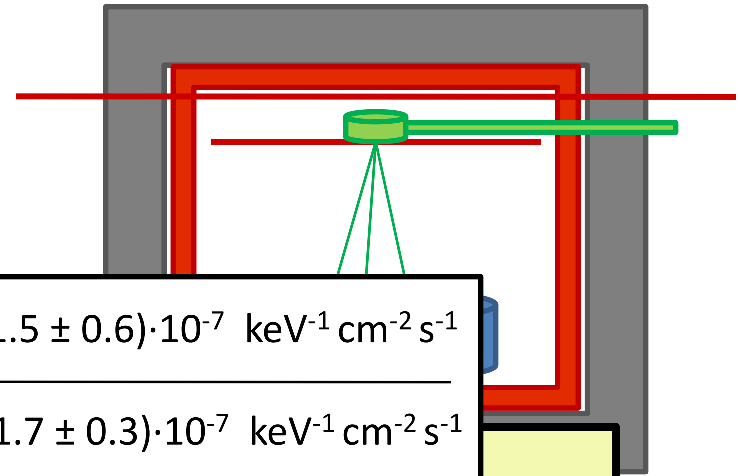
Rate (2-7keV)	$(1.6\pm 0.9)\cdot 10^{-7}$ keV^{-1} cm^{-2} s^{-1}
Rate (2-9 keV)	$(1.7 \pm 0.8)\cdot 10^{-7}$ keV^{-1} cm^{-2} s^{-1}

M10 at LSC. 40 days of Ultra-low background.

Cu layer on STRONGBACK



Cu layer on TOP



Rate (2-7keV)	$(1.5 \pm 0.6)\cdot10^{-7}$ $keV^{-1}\,cm^{-2}\,s^{-1}$
Rate (2-9 keV)	$(1.7 \pm 0.3)\cdot10^{-7}$ $keV^{-1}\,cm^{-2}\,s^{-1}$

It could be considered as the first *upper* boundary to the contribution to the background by the DETECTOR (*microbulk* + plexiglass structure + Cu cathode) INTRINSIC RADIOPURITY.

✓No external X-Rays ca
(No window).
✓ More Copper surfac
directly to the gas.
➢ **Supression of enviro**

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Effective exposur

hours

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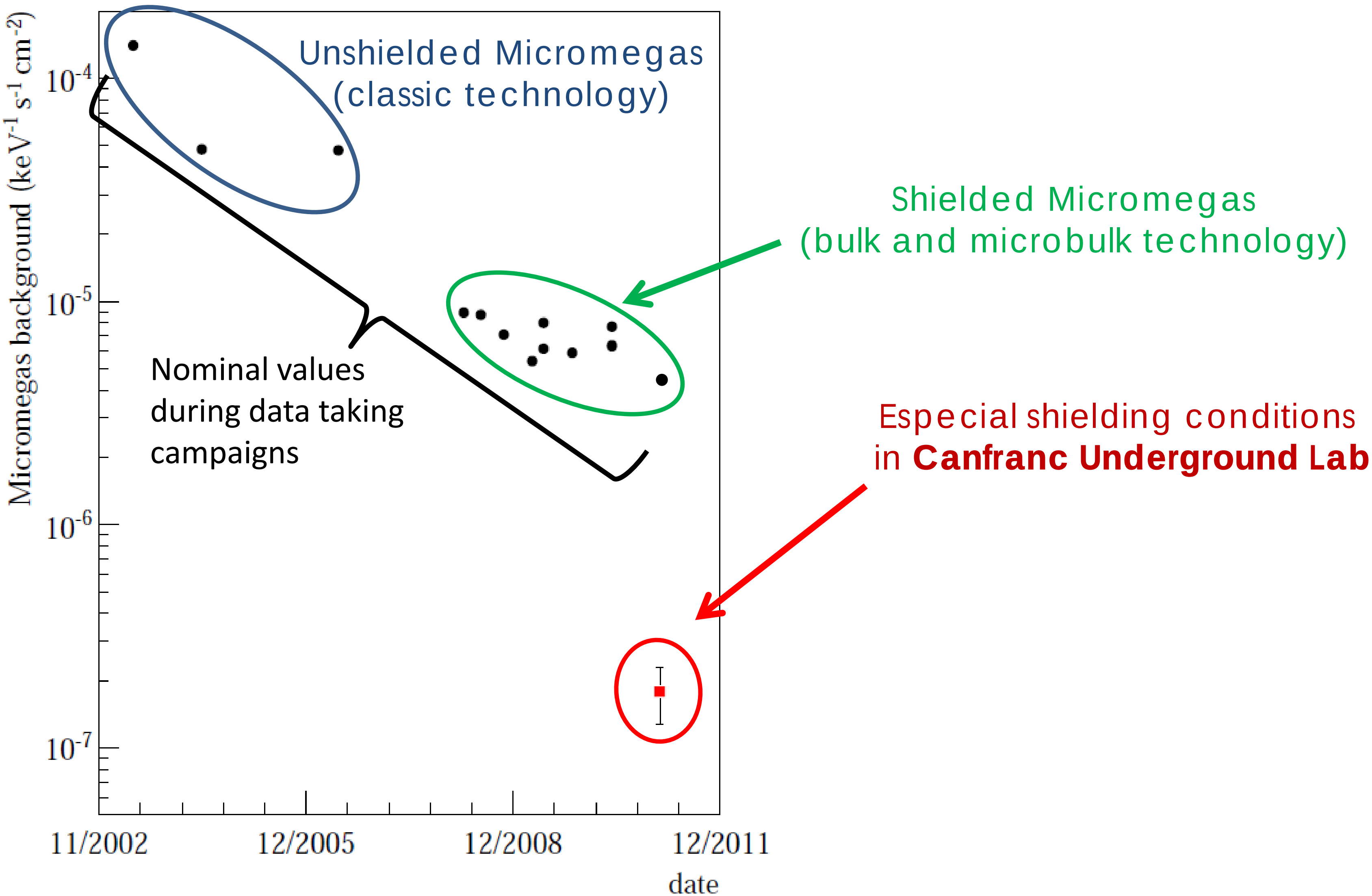
Background levels of CAST micromegas detectors over the years



Summary and Conclusions

- CAST micromegas experimented a continuous improvement in their performance by means of different strategies combining shielding, material selection and analysis.

- LSC is a useful test bench for CAST detectors.

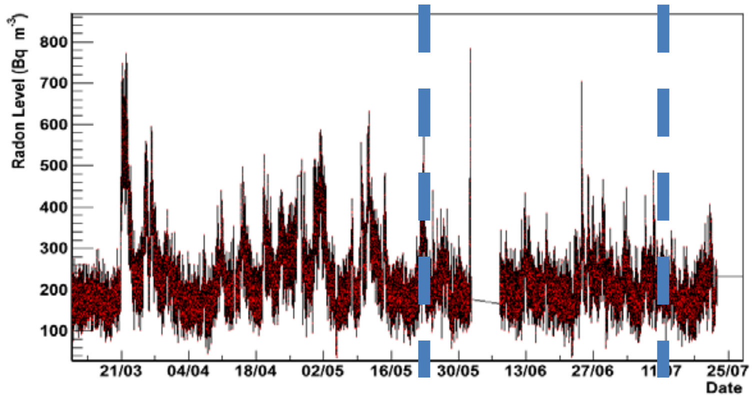
- CAST detectors have very similar background at surface as at LSC.
  - Little effect of cosmic rays thanks to a very efficient discrimination.

- Differences between CAST detectors mounted in CAST magnet line and in Canfranc's (4π closed) are concentrated in fluorescence peaks.
  - Their manifest the importance of pipe to cold-bore role in CAST background. Improvements in pipe shielding are giving the first results in CAST's micromegas which are currently taking data.

- Shielding upgrade at LSC led to a factor 30/40 of reduction in background/trigger rate.
  - CAST detectos background with CAST-like light shielding, is dominated by external gamma flux contribution.
  - Microbulk readout (and whole detector's chamber with copper cathode) is radiopure enough to drop background down to **$<2\cdot10^{-7}$ keV^{-1} cm^{-2}** s^{-1} in an underground lab.

Back-up slides

About Radon. Is everything stable in the underground lab?



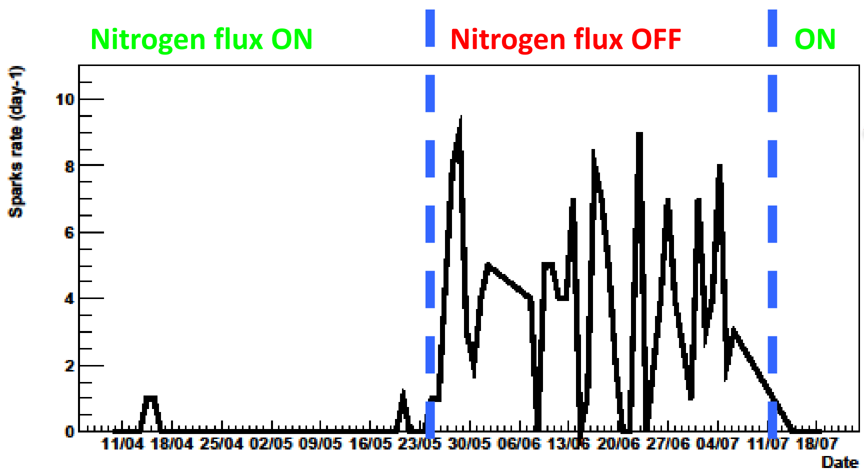
Rn activities registered in micromegas room at LSC

Typical surface level: 5-50 Bq/m^3

Good opportunity to study **effects on Rn concentration on background**. Until now:

- ✓ No correlation between Rn concentration in the room and final backgroun levels.
- ✓ No correlation between background levels and interventions in the set-up (which includes opening the Faraday box letting environmental Rn come inside).

However:



Spark rate measured by the power supply current temporary increase.

Since the sparks were not observed on surface, they are probably due to the higher Rn abundance underground (4.8 MeV αs).

Conclusions (2):

- Rn concentration at LSC is huge, compared with surface, and highly varying. No influence detected on micromegas background (but it is on micromegas sparks rate).