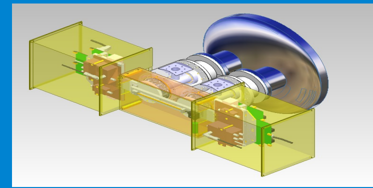
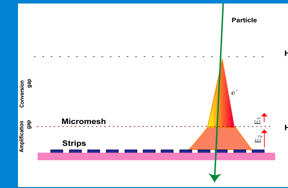
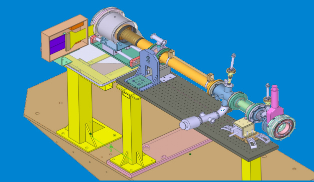
CAST Micromegas
Detector Performance







CAST Micromegas Detector Performance

S. Cenk Yıldız[1,2]

On behalf of the CAST Micromegas team

S. Aune[3], S.A. Cetin[2], T. Dafni[8], M. Davenport[7], G. Fanourakis4[4], E. Ferrer-Ribas[3], J.A. Garcia[8], J. Galan[3], A. Gardikiotis[5], T. Geralis[4], I. Giomataris[3], H. Gomez[8], J. Gracia[8], F.J. Iguaz[3], I.G. Irastorza[8], T. Papaevangelou[3], A. Rodriguez[8], J. Ruz[7,8], A. Tomas[8], *T Vafeiadis*[6,7] , K. Zioutas[5,7]

1 *Boğaziçi University, Istanbul, Turkey*
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5 *University of Patras, Greece*
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7 *CERN, European Organization for Particle Physics and Nuclear Research, Switzerland*
8 *Laboratorio de Física Nuclear y Astropartículas, Universidad de Zaragoza, Spain*

OUTLINE

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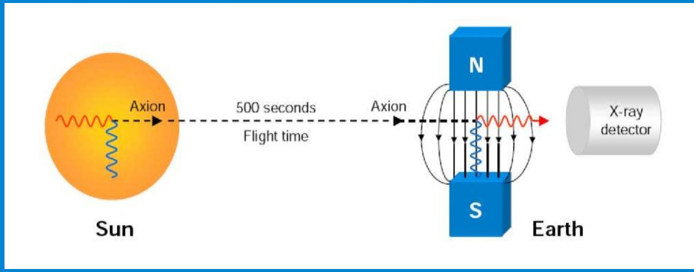
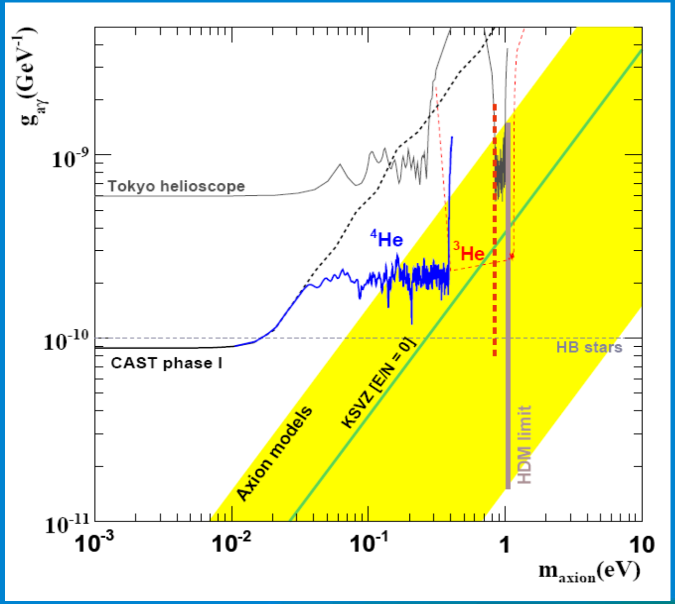
Cern Axion Solar Telescope (CAST) Experiment



- LCH Prototype Dipole Magnet

B = 9T T = 1.8K
L = 9.26m



- Axions coming from the sun are converted into x-rays in CAST magnet, and detected by x-ray detectors.
- Signal: Excess of x-rays in detectors during tracking.
- Tracks the sun 1.5 hours twice a day.
- 3 MicroMegas, 1 Charge Coupled(CCD) detectors are installed
- Discovery potential and upper limits on coupling constant depend on:
  - Magnetic Field
  - Exposure Time
  - Magnet Length
  - Background level and efficiency of detectors

FIXED (Magnetic Field, Exposure Time, Magnet Length)

Expected counts:
0.3 counts / hour for $g_{a\gamma\gamma}=10^{-10}GeV^{-1}$

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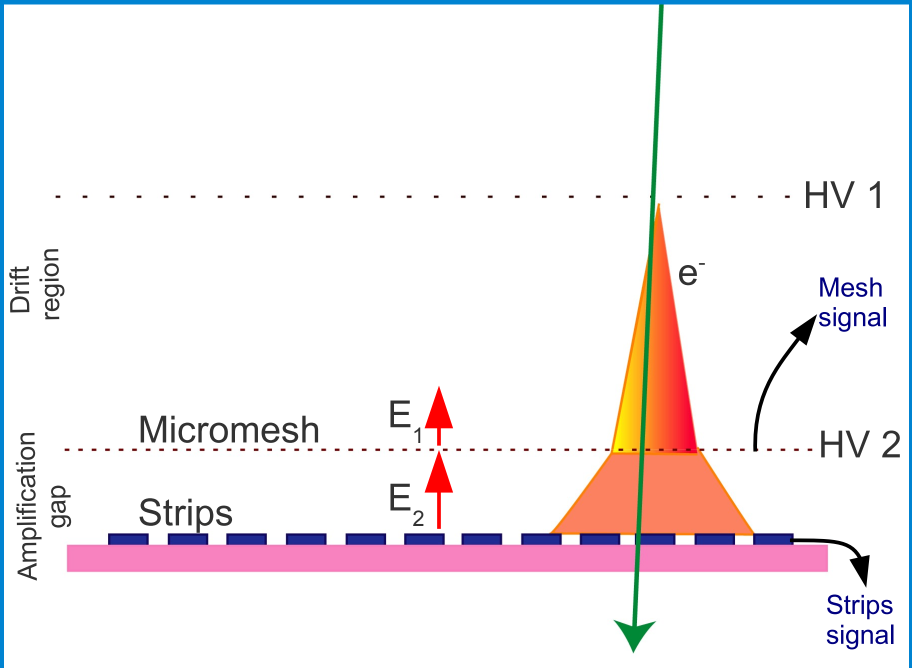
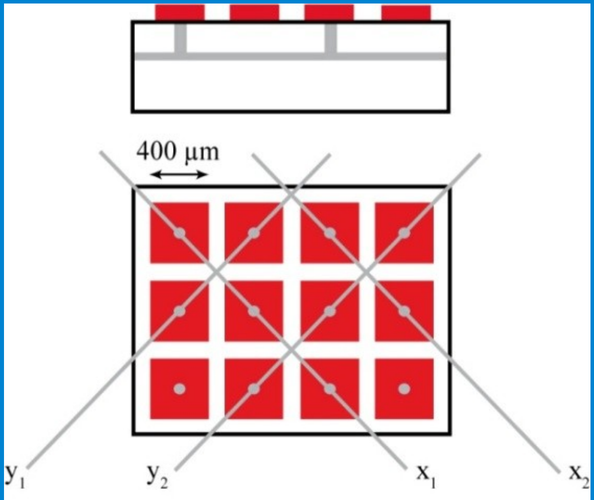
CAST Micromegas
Detector Performance

MicroMegas Detector

- MICRO MEsh GAseous Structure: Invented in 1996 by G. Charpak, I. Giomataris
- Position sensitive gaseous detector.
- 2 regions: drift, amplification
- Working principle:
  - Ionization of gas in the drift region by a charged particle or photon
  - Drift of electrons to transparent mesh, creation of mesh signal
  - Multiplication of electrons in the amplification gap, creation of signal in the readout strips





106 x 106 readout strips

- Stable operation
- Low background levels

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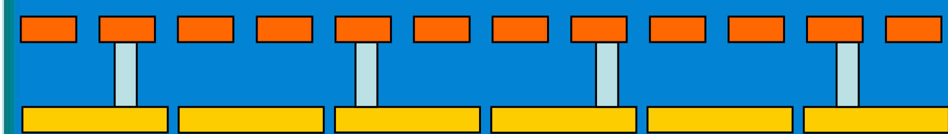
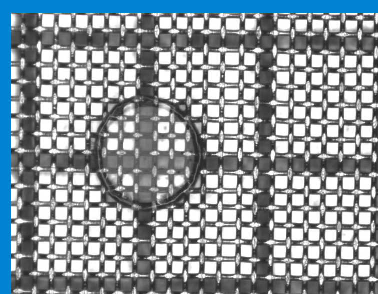
MicroMegas Technologies

Conventional Micromegas: Oldest technology. Mesh is attached to readout strips by mechanical means.

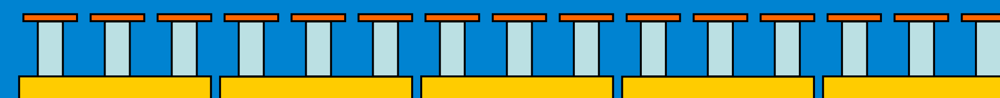
Bulk Micromegas





- 30μm inox mesh.
- 128μm amplification gap.
- Energy resolution: %18 FWHM at 5.96keV
- Pillars are attached to mesh and to strips by PCB technology.
- Robust and stable.

Microbulk Micromegas



- 5μm copper mesh.
- 50μm amplification gap.
- Energy resolution: %13 FWHM at 5.96keV
- Kapton pillars are created between mesh and strips by chemical processes.
- 36cm^2 active area.
- Better stability
- Lower background levels

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CAST Micromegas Detector Performance

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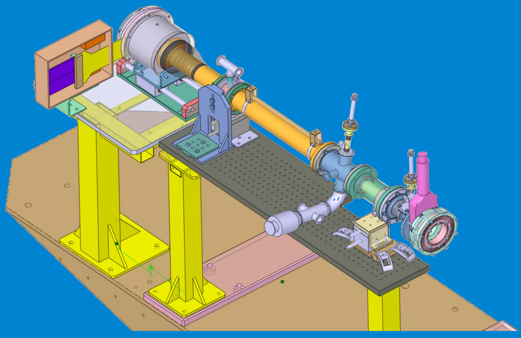
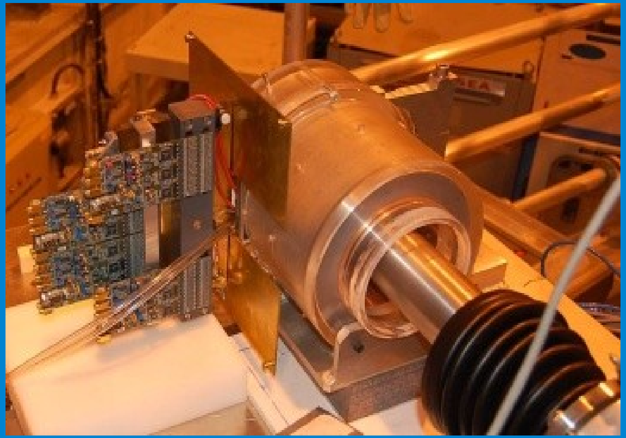
Micromegas Detectors in CAST

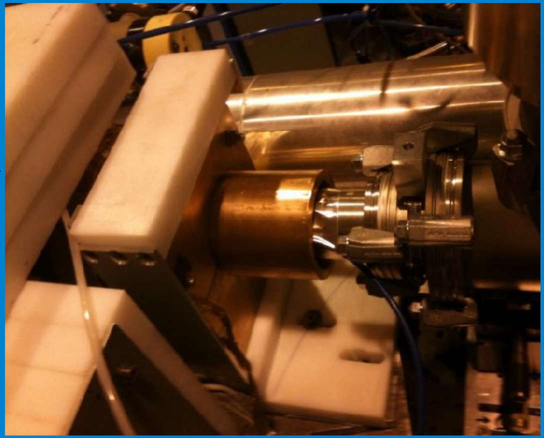
CAST is one of the first experiments to use MicroMegas.
CAST has been actively contributing the development of MicroMegas technology

Sunrise Line



- Operational since the start of CAST.
- All micromegas technologies were used.
- Currently a shielded microbulk detector is installed.
- Operating at 1.4bar with a mixture of Ar, 2.3% C_4H_{10}





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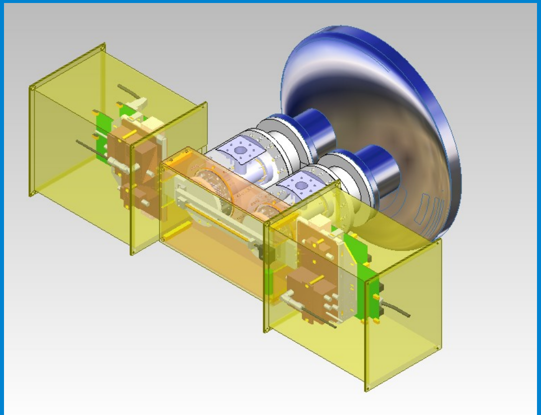
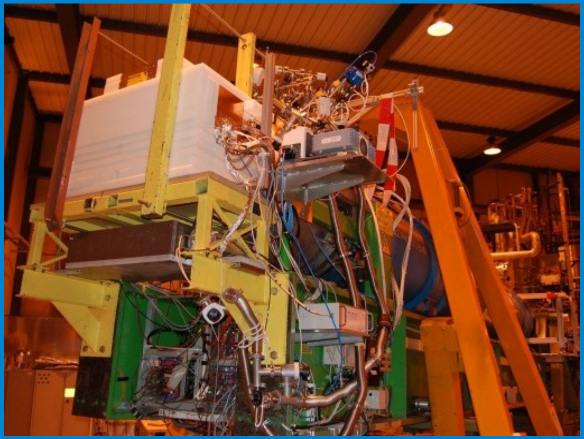
Sunset Line

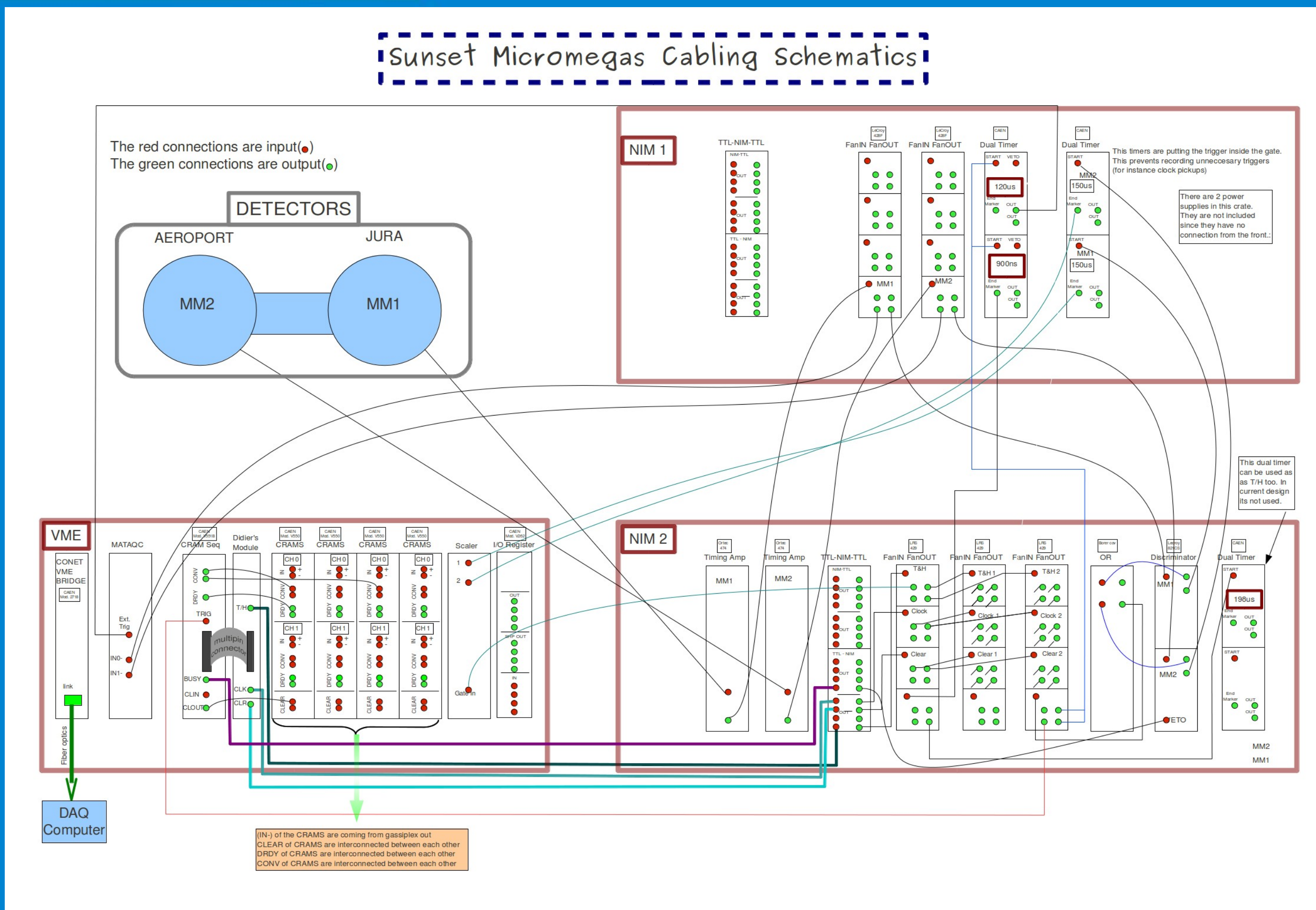
- Until 2007, a Time Projection Chamber(TPC) was operating.
- In 2007 TPC is replaced with 1 bulk, 1 microbulk micromegas. (Current status: 2 microbulk)
- Shielding improvements throughout the years decreased background levels.
- Electronics noise was mostly eliminated with grounding improvements.
- Operating at 1.4 bar with a mixture of Ar, 2% C_4H_{10}



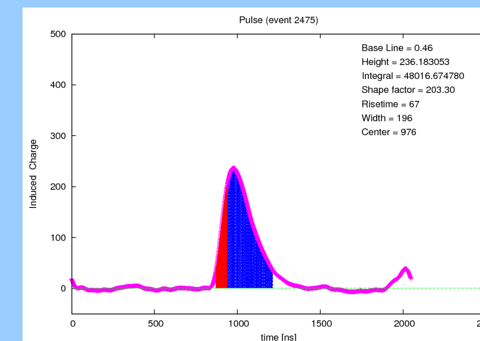


CAST Micromegas Detector Performance

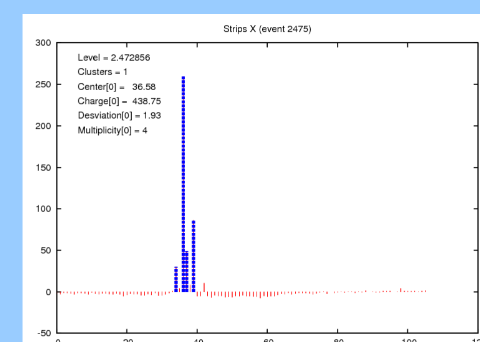
Data Acquisition System



Mesh Signal



Strip Charge



- Data acquisition software written in Labview.
- Mesh pulse triggers the DAQ chain.
- Time evolution of mesh pulse recorded through MATACQ card.
- Charge on each strip is integrated and recorded through gassiplex cards.

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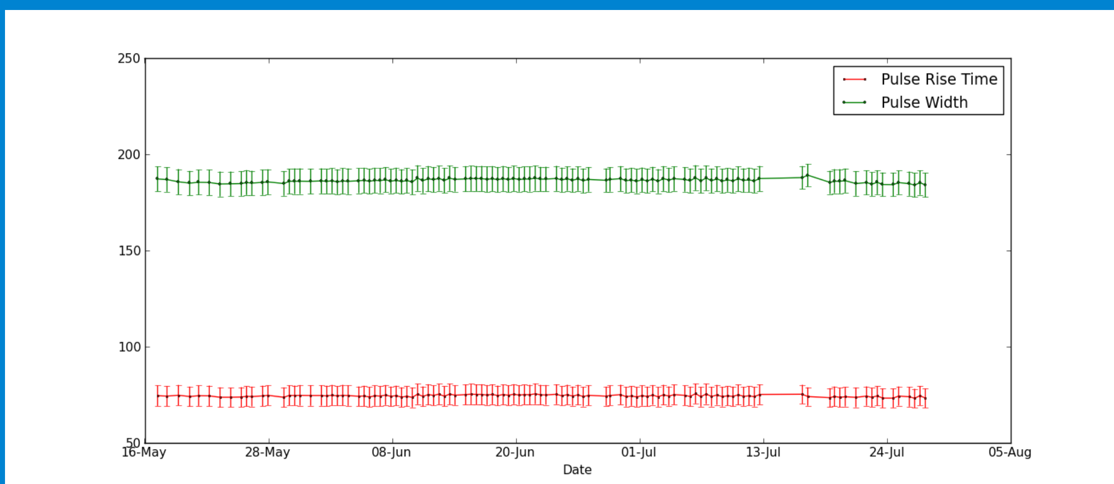
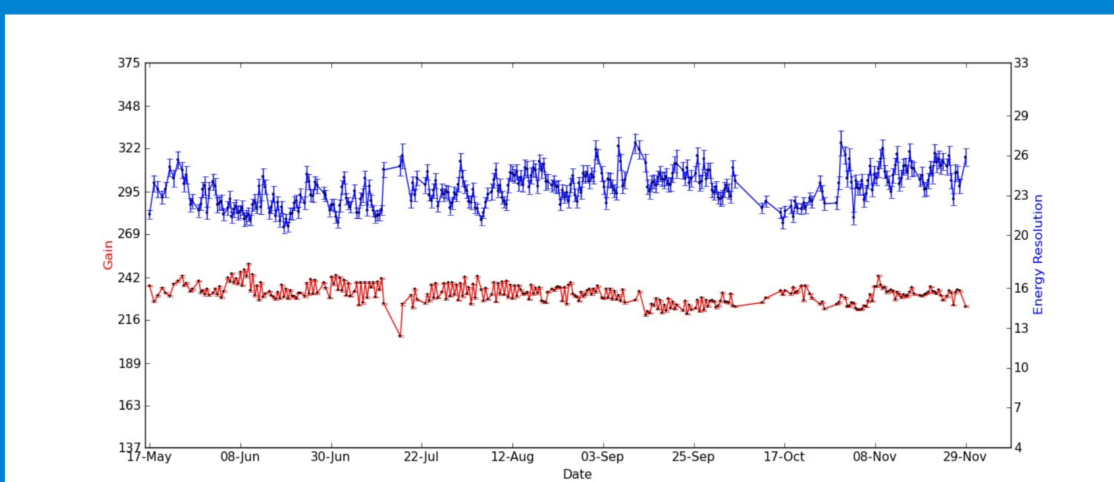
CAST Micromegas
Detector Performance

Detector Stability

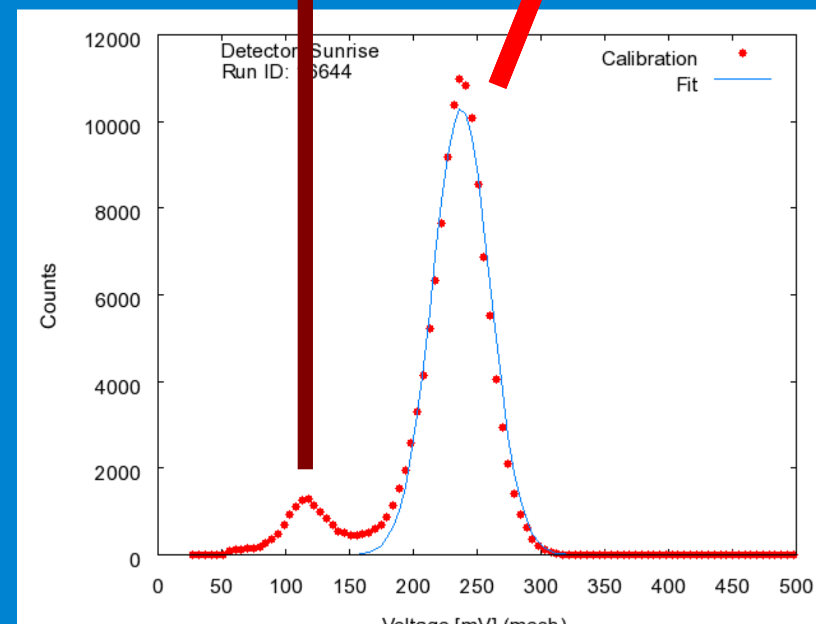
- Fe55 calibration done everyday at least once
- Gain, resolution and other characteristics of daily calibrations are stable.





Escape peak of Argon

Main peak of Fe55



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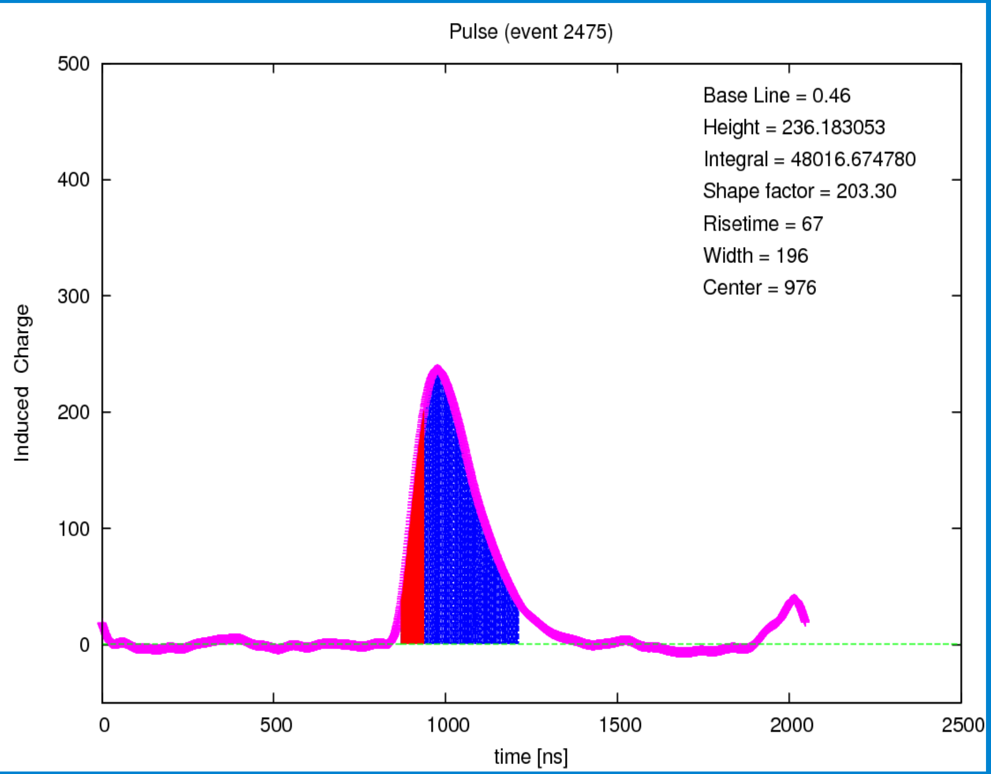
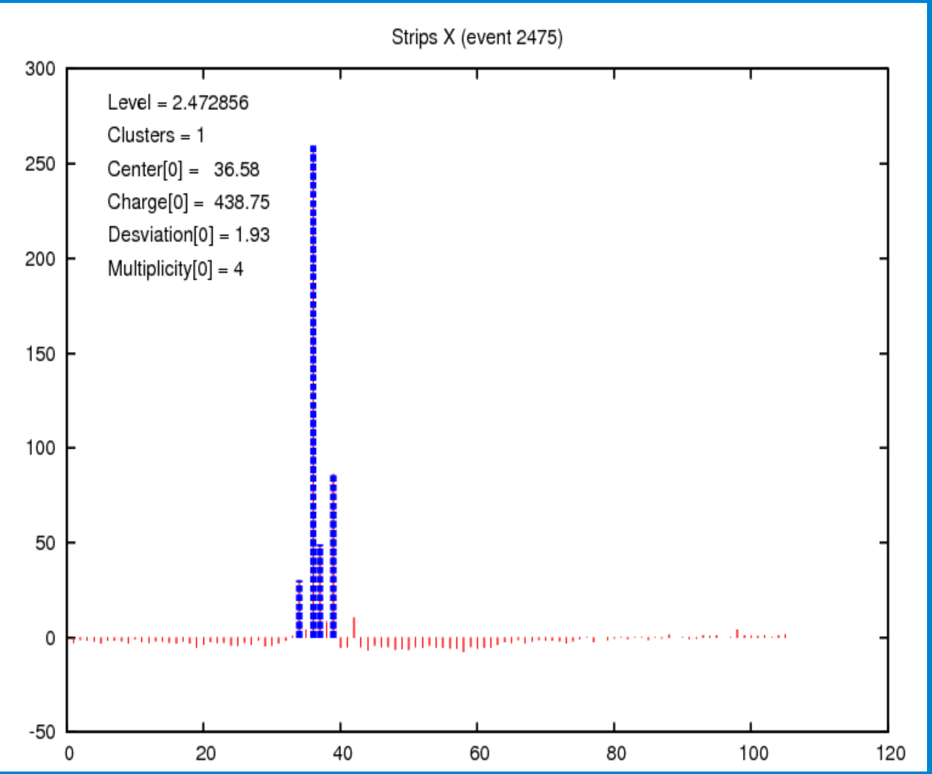
Background Discrimination 1

- There are 2 sets of observables:

Mesh: Pulse risetime, width, integral

Strips: multiplicity, cluster size, cluster sigma, charge balance





- Information extracted from calibrations about x-rays:
  - Localized (single cluster)
  - Narrow distributions

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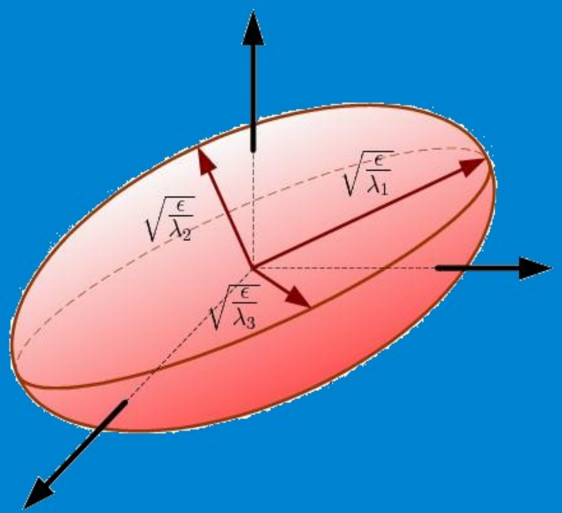
CAST Micromegas
Detector Performance

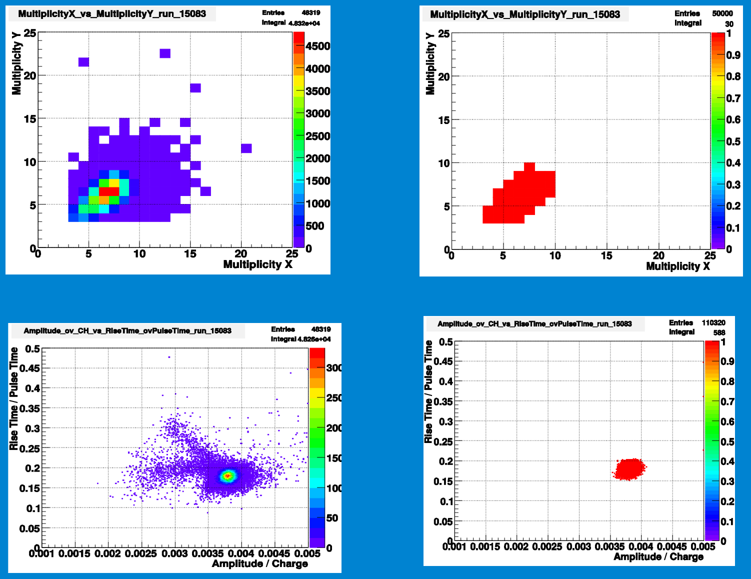
Background Discrimination 2

Multivariate Analysis



- Takes the correlations of observables into account.
- Defines a single parameter, that has the information of selected observables.
- Rejects the events that are out of the n-dimensional hyper-ellipsoid

Sequential Cuts



- 2D regions in parameter space, or intervals for single parameters are selected.
- Cuts are applied one after another

- With both methods, 99.9% of the events are rejected

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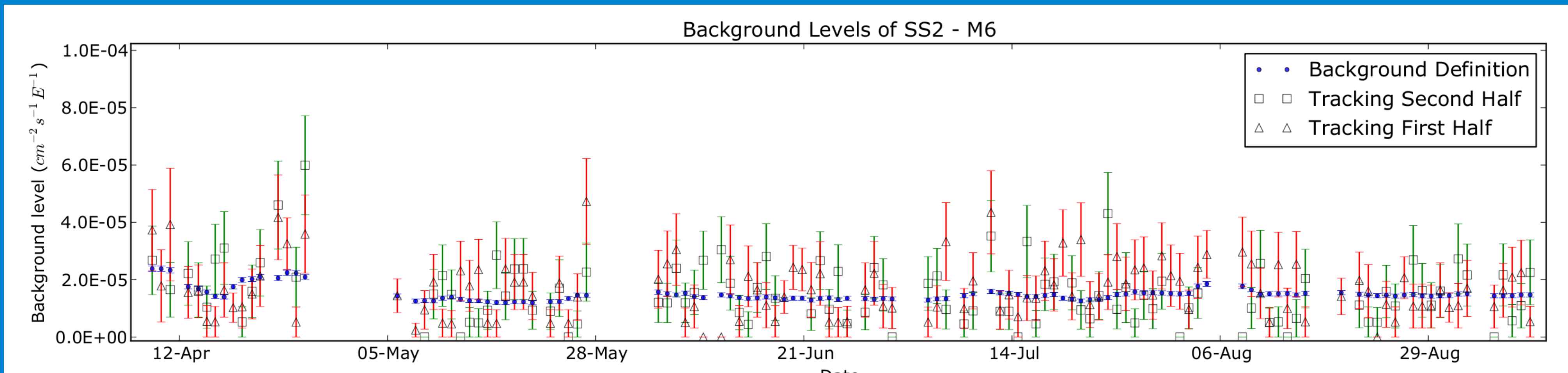
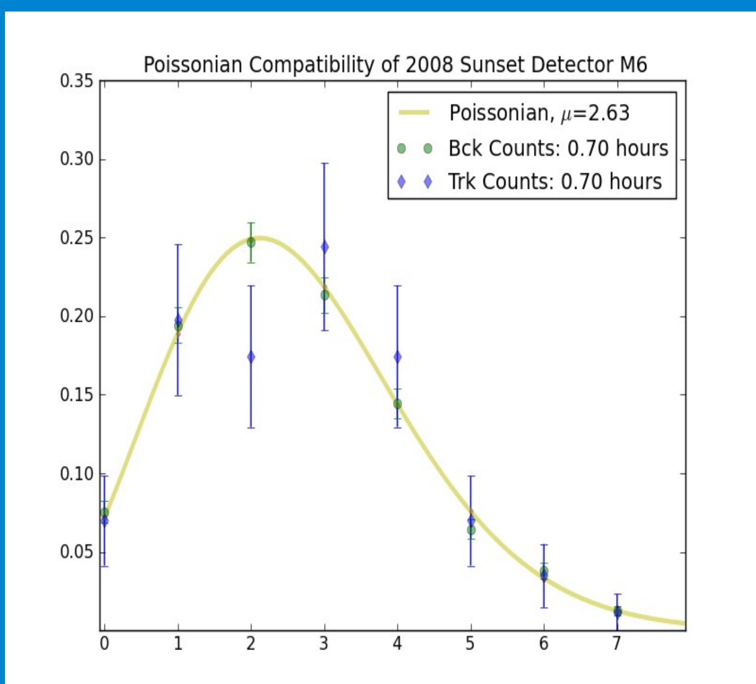
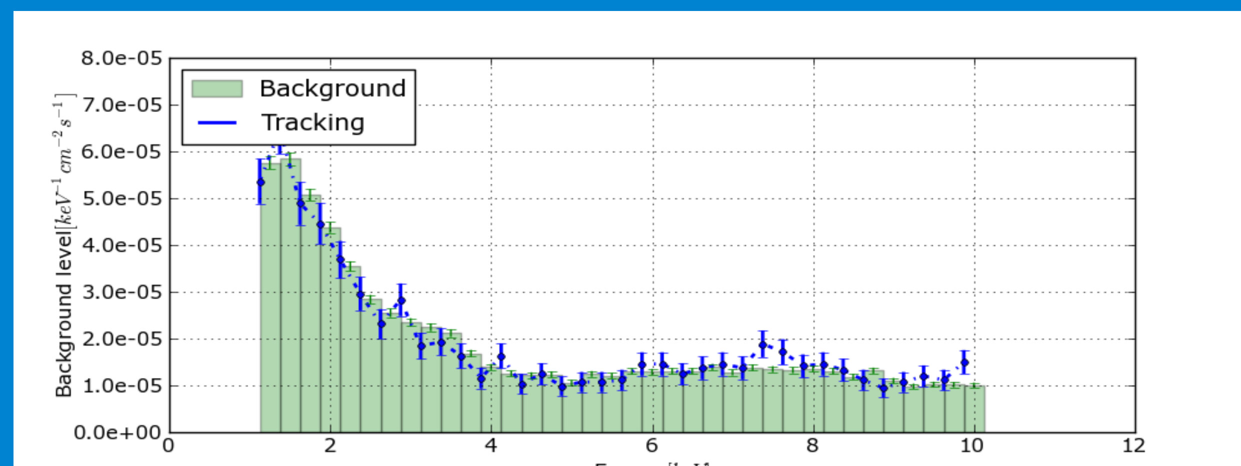
Background Discrimination 3

Spectra and Count Rates







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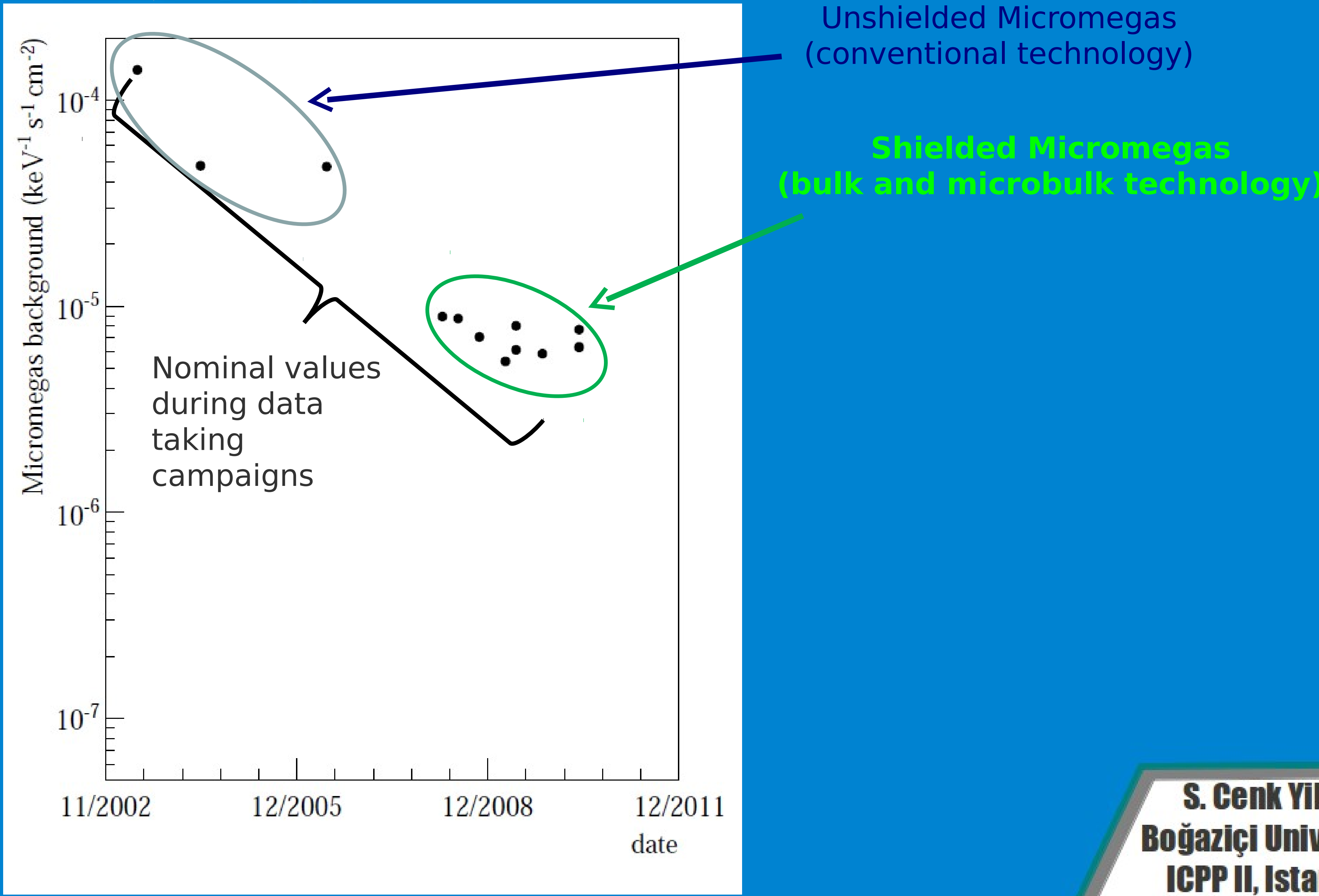
CAST Micromegas
Detector Performance

Evolution of CAST Micromegas



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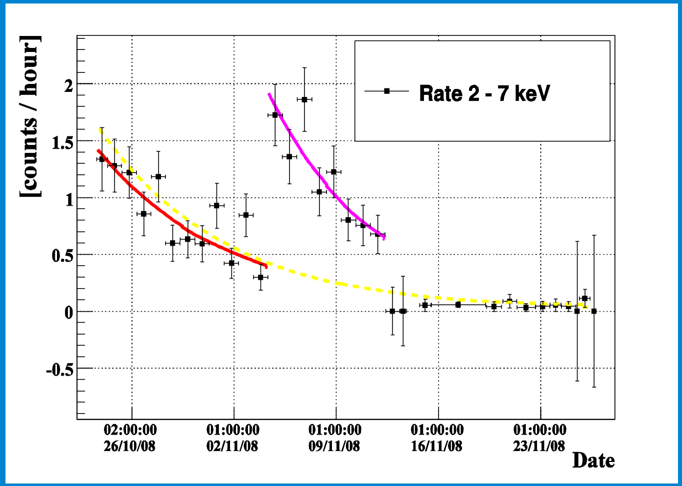
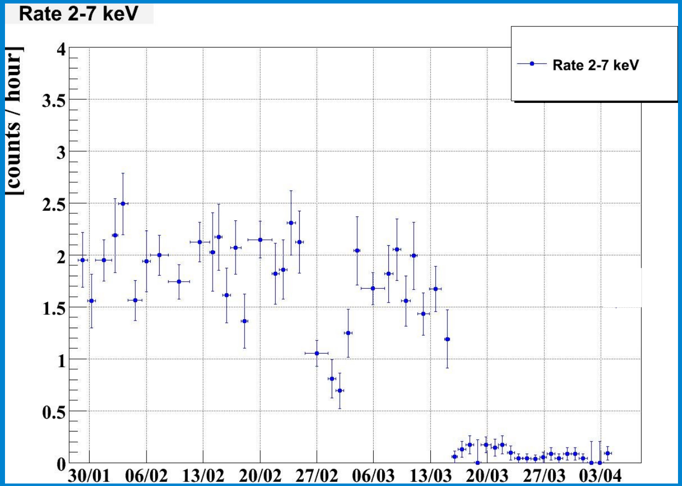
Ultra Low Background

- A phenomena observed for some short periods at CAST in Sunrise Micromegas.
- In 2011, longer ULB period was observed after installation of a new shielding.
- A real drop in background rate? Radon contamination? An artifact or systematic that we miss?
- Controlled laboratory studies are ongoing.

	counts $keV^{-1}\,cm^{-1}\,s^{-1}$	counts / hour
Nominal CAST MM Background	8×10^{-6}	2.1
Ultra Low Background	$\mathbf{1\times10^{-7}}$	**0.025**

If indeed it is real, it may lead us to develop ultra low background micromagas detector, that will increase our sensitivity significantly.





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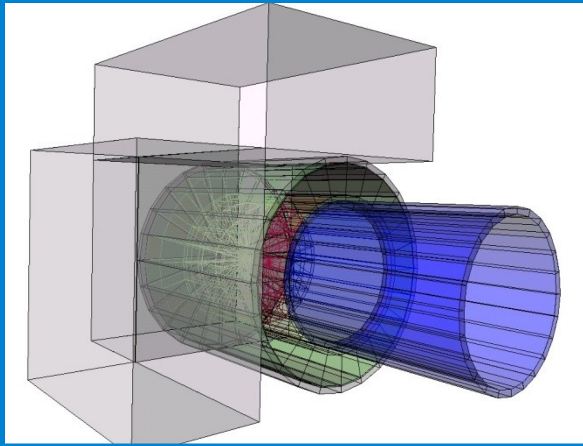
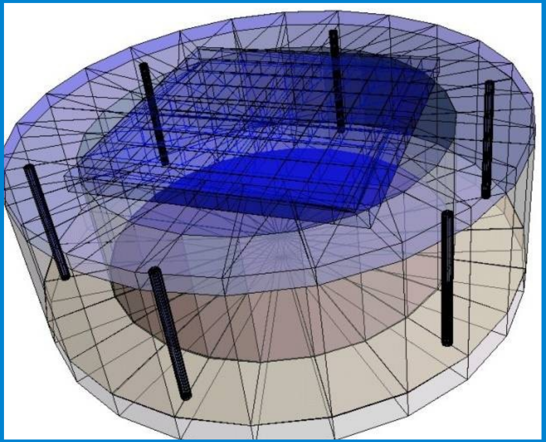
Background Simulations 1

To answer basic questions about Micromegas Detectors

- What is the nature of CAST background?
  - Cosmic rays, external gammas?
  - Internal radioactivity of detectors?
  - Radon contamination?



Detector geometry and shielding implemented in GEANT4



- The simulation data and real data are compatible
- Simulations shows that most of the micromegas background is coming from interaction of external gamma's with the material close to detector.

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Background Tests 1

A CAST type microbulk Micromegas detector is being tested at the Canfranc Underground Laboratory at deep of 2500 m.w.e (meter of water equivalent) in Zaragoza / Spain.

Why underground?

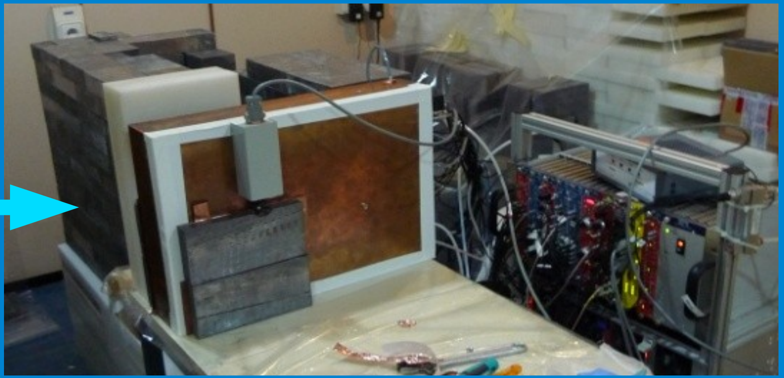
- Reduction of cosmic muon rate by 4 orders of magnitude
- Stable environment
- Well known environmental gamma radiation.

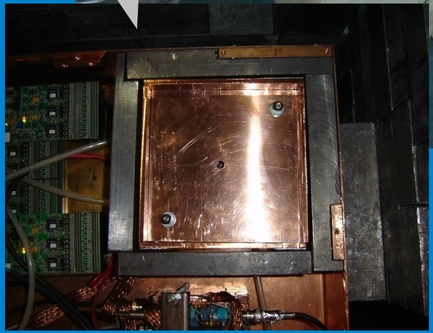
What is the aim?

- Understanding the nature of background.
- Investigating the effect on different shielding setups on background levels
- Find the limit of internal radioactivity of CAST micromegas detectors.

Background Tests 2

- The detector took data in several shielding conditions
  - ➔ CAST-like shielding
  - ➔ 5/6 · 4π lead shielding (20 cm thick)
  - ➔ 4π shielding (20 cm thick)
  - ➔ 4π shielding + copper layer





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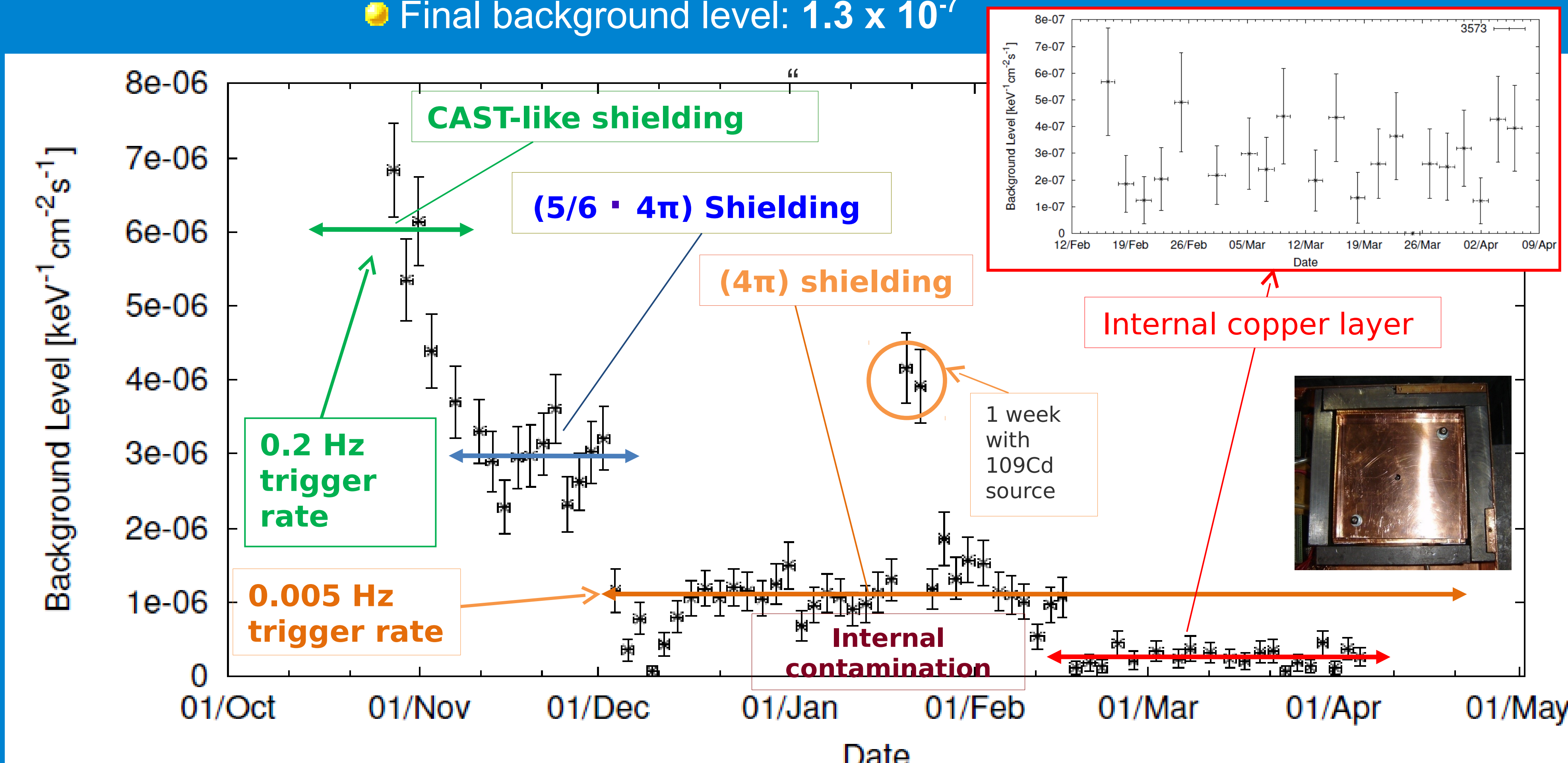
Background Tests 3

- With CAST Like shielding:
  - ➡ Decrease in trigger rate: 2 order of magnitude
  - ➡ Decrease in background level: None!,
- Final background level: **1.3 x 10^{-7}**



- Most of the background is coming from external gammas
- Intrinsic radioactivity of CAST detectors are low enough.

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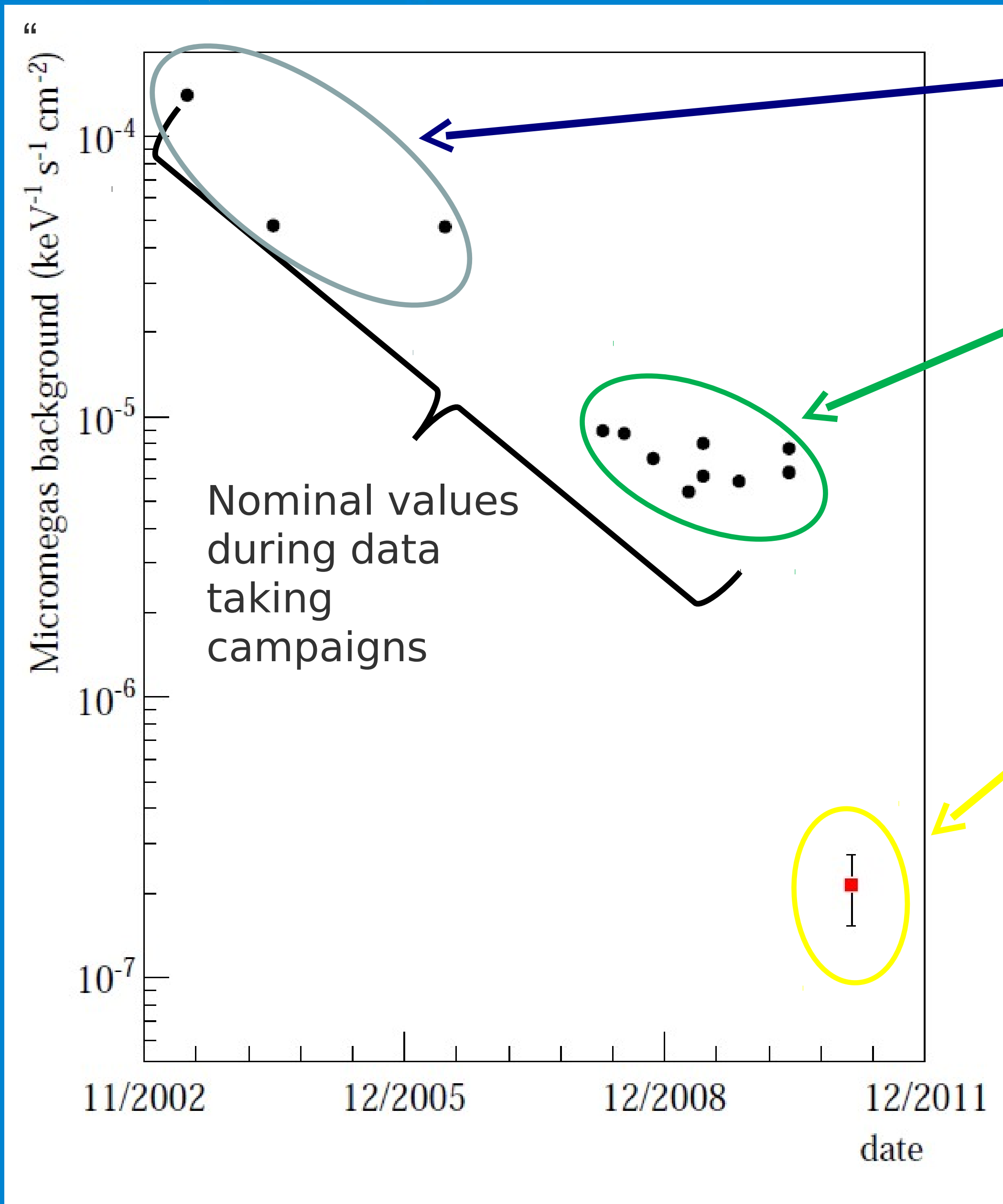
CAST Micromegas
Detector Performance

Evolution of CAST Micromegas



Unshielded Micromegas (conventional technology)

Shielded Micromegas (bulk and microbulk technology)

Full Shielding at Canfranc Underground Lab

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CONCLUSIONS

- In CAST, we need low background levels for increasing sensitivity.
- Micromegas detector has been used in CAST since the beginning.
- They show good stability and low background levels, with increasing performance year by year.
- Ultra low background phenomena was observed in several periods at CAST.
- Simulations and laboratory tests are ongoing to understand the nature and limits of background levels and help us develop ultra low background detector.
- A detector lab for CAST is being established at CERN for further tests.

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~SON~