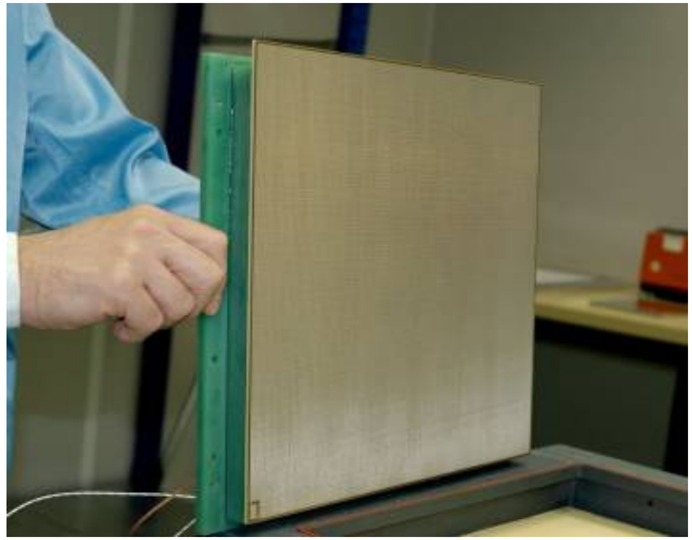
Highlights on recent detector and physics developments

I. Giomataris CEA-Saclay



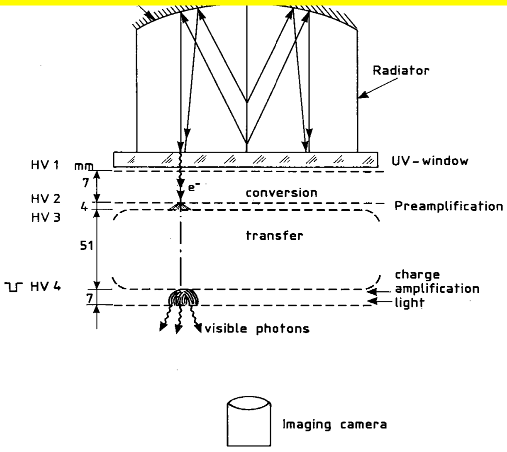
- **Micromegas detector**

- **Spherical Proportional counter**

- **My collaboration with J.D Vergados**

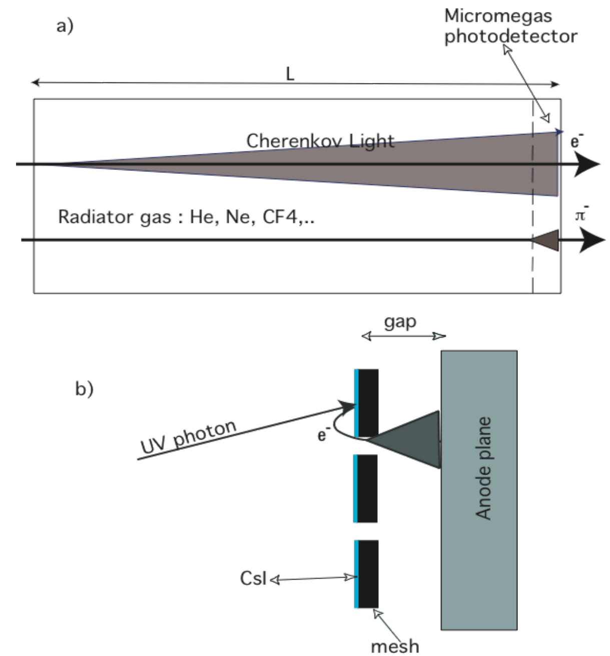
Previous developments

A high-energy gamma ray telescope
I. Giomataris; G. Charpak, CERN-EP-88-94

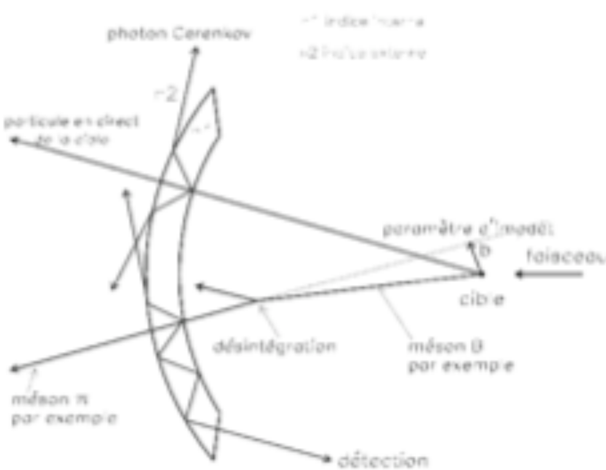


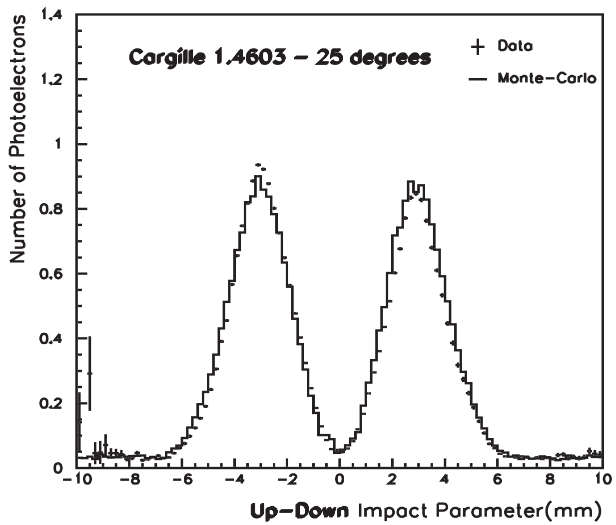
A single electron shower
G. Charpak, Y. Giomataris,, A. Gougas,NIM.A343:300,1994.

A Hadron Blind Detector (HBD)
I. Giomataris,G. Charpak, NIM A310(1991)589

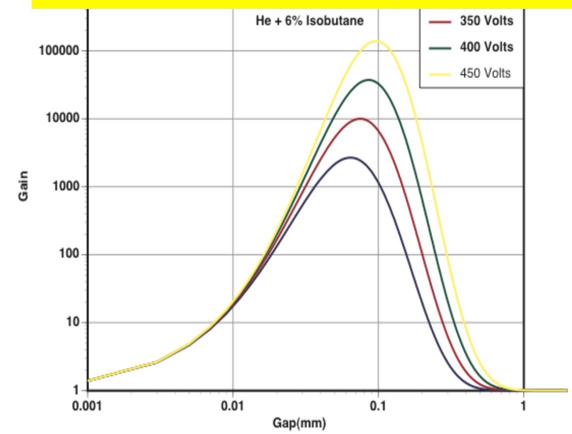


The trigger for Beauty
G. Charpak, I. Giomataris, L.Lederman, NIMA306(1991)439
Developed by Lausanne Uni, Saclay,CERN





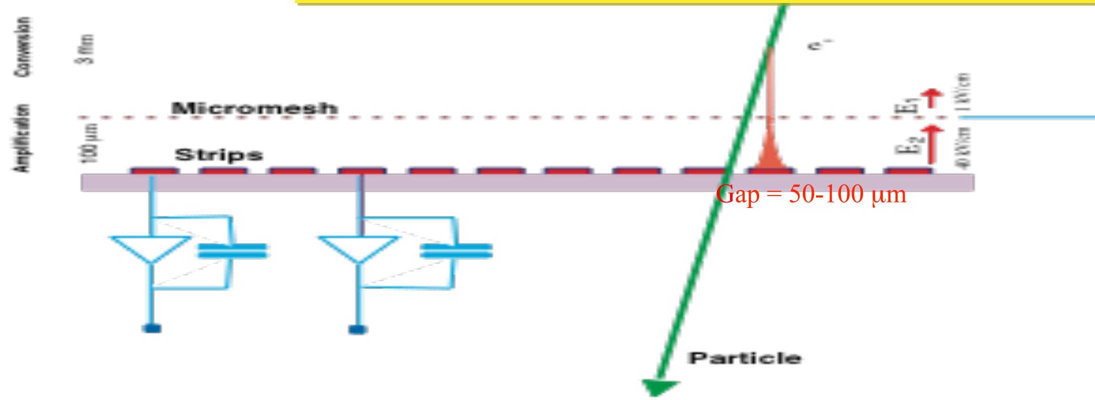
Virtue of the small gap
Y. Giomataris, NIM A419, p239 (1998)



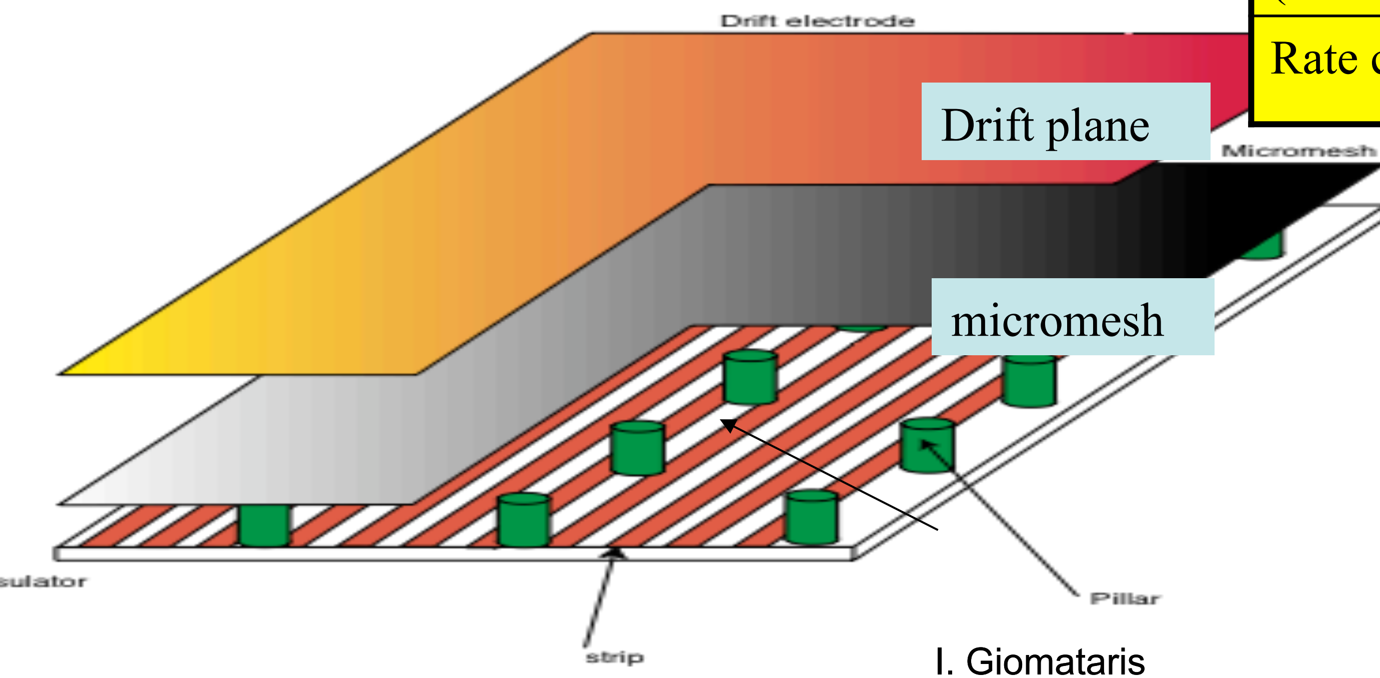
Optimum gap : 30 - 100 microns

MICROMEGAS

Y. Giomataris, Ph. Rebourgeard, J.P. Robert, Charpak, NIMA376(1996)29



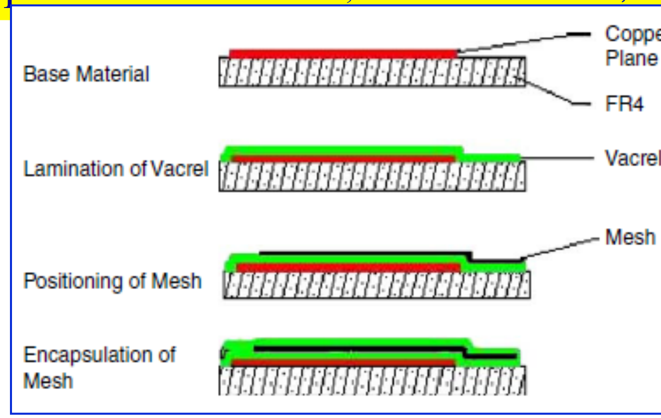
Spatial resolution	<12 µm
Time resolution	<1 ns
Energy resolution (FWHM)	11% (5.9keV)
Rate capability	> 10^6/mm^2/s

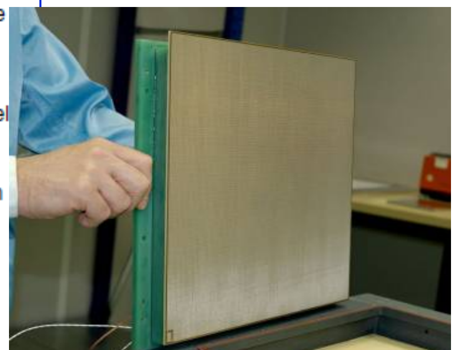


I. Giomataris

Micromegas fabrication technologies

Bulk micromegas : pre-stretched steel mesh laminated together with a PCB support and a photoresistive layer, later removed apart where pillars are formed, *I. Giomataris et al., NIMA 560 (2006) 405*

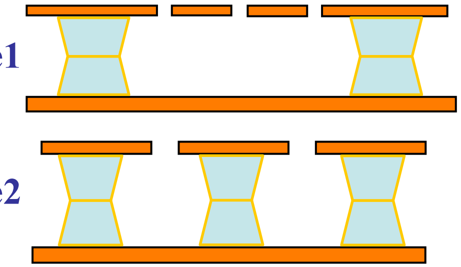




micro-Bulk,
50 µm, 25 and 12.5 µm gaps fabricated

Type1

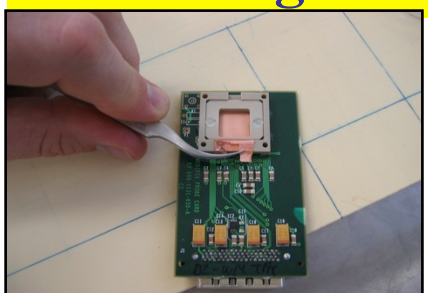
Type2

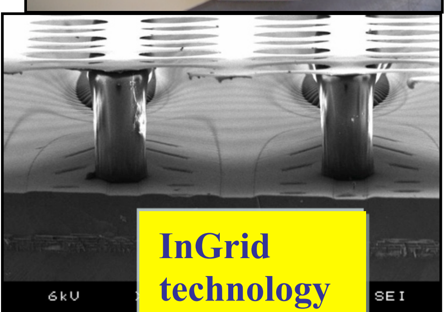


Very good energy resolution 11% at 5.9 keV
- Flexible structure (cylinder)
- Low material
- Low radioactivity

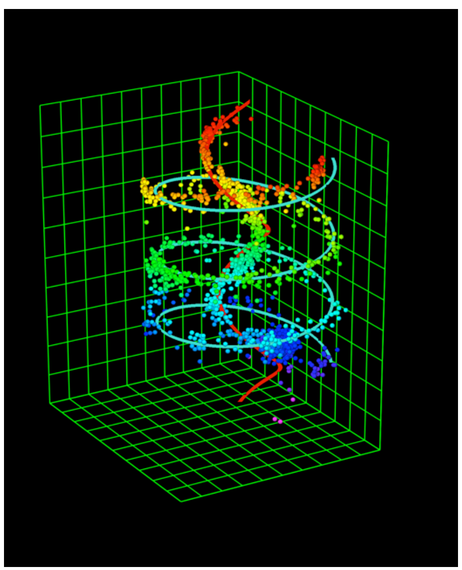
Piggy Back: read-out separated from the active volume

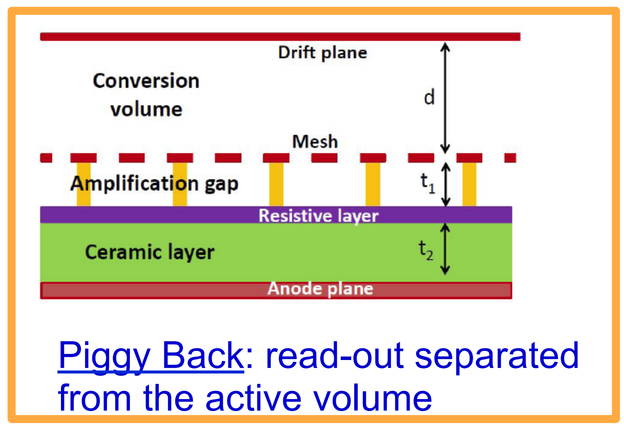
Micromegas + micro-pixels

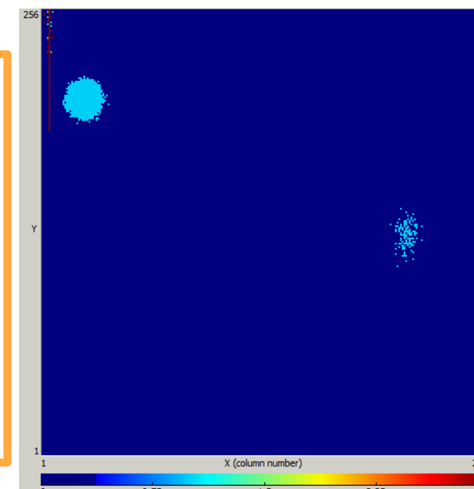




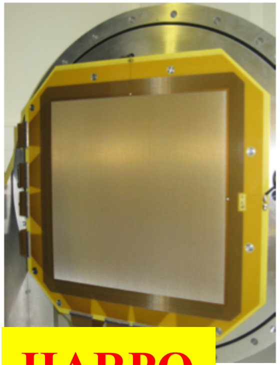
InGrid technology

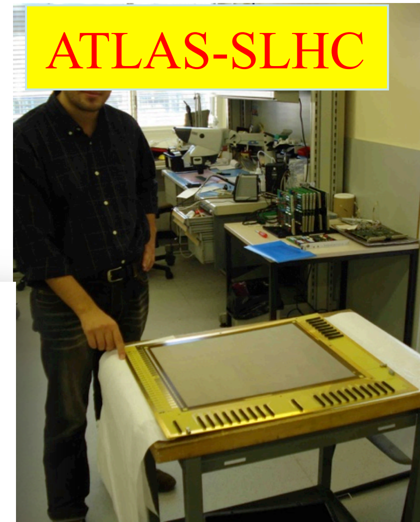


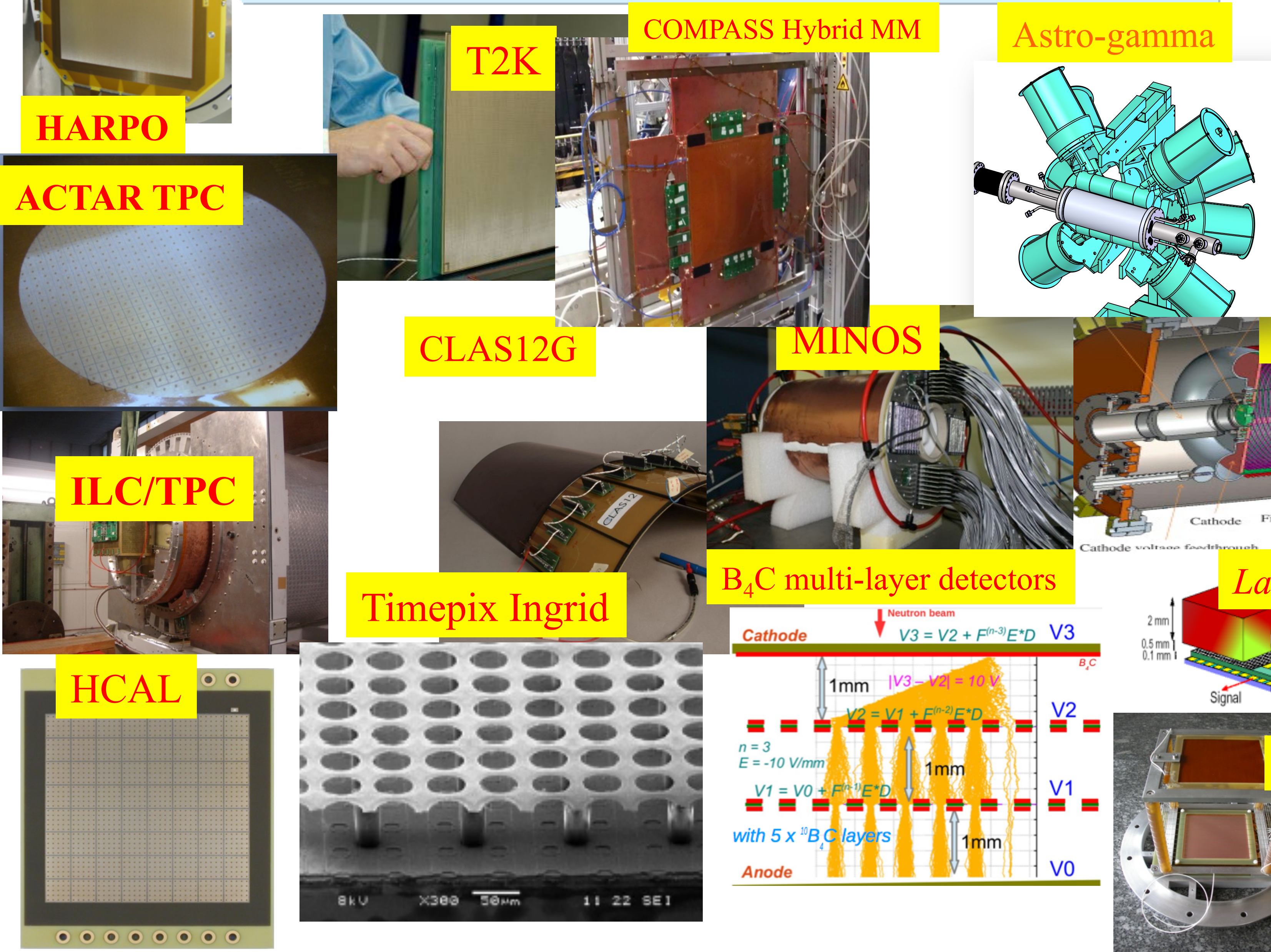


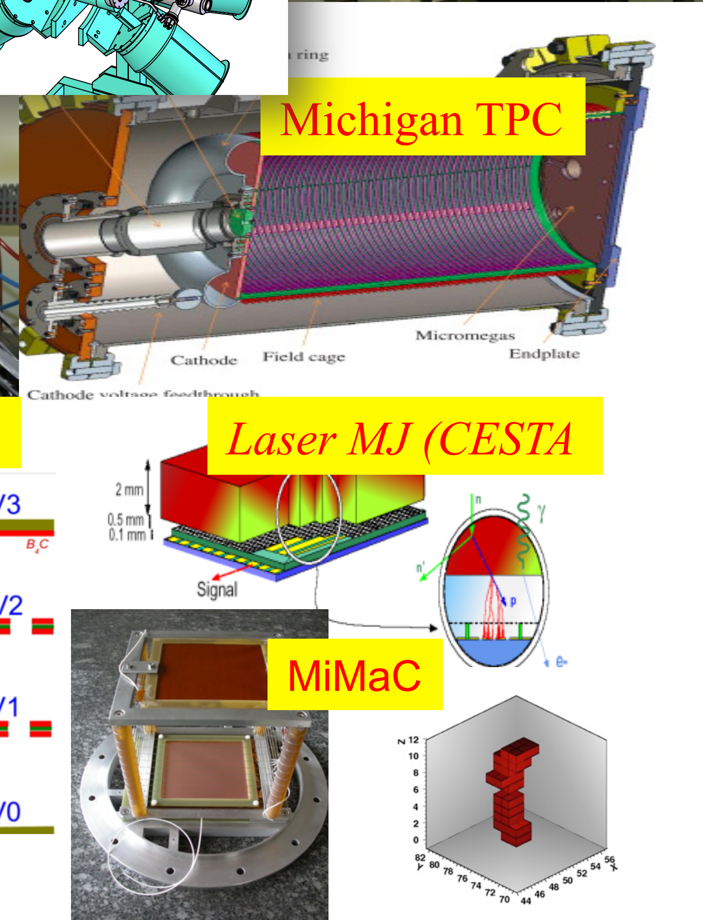


Some experiments using Micromegas read-out



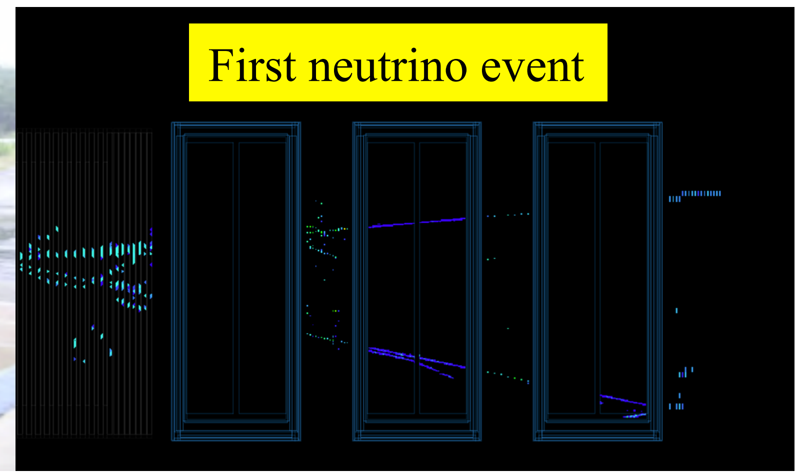


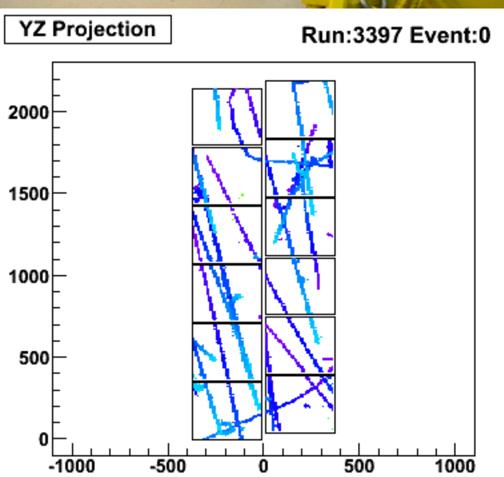




T2K Micromegas TPC – Bulk technology

3xTPCs, 6 end plates, 72 Micromegas





Next upgrade under under study:
A high pressure TPC

Construction of large chambers in ATLAS

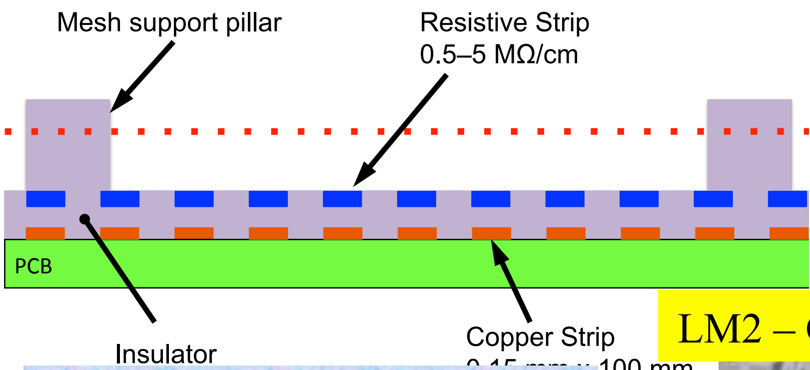
Goal : 1200 m2 total detector surface

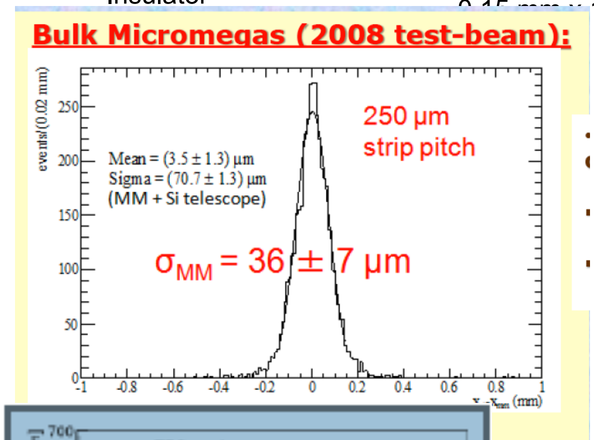
Industrialization is going on through ELVIA, ELTOS

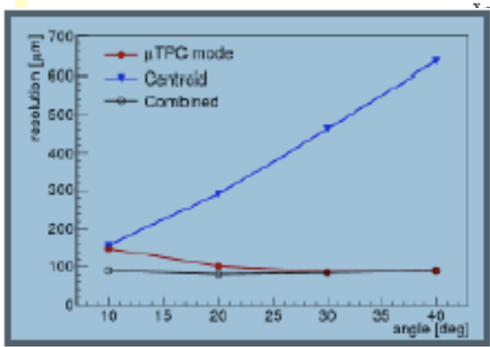
ATLAS Resistive strip technology

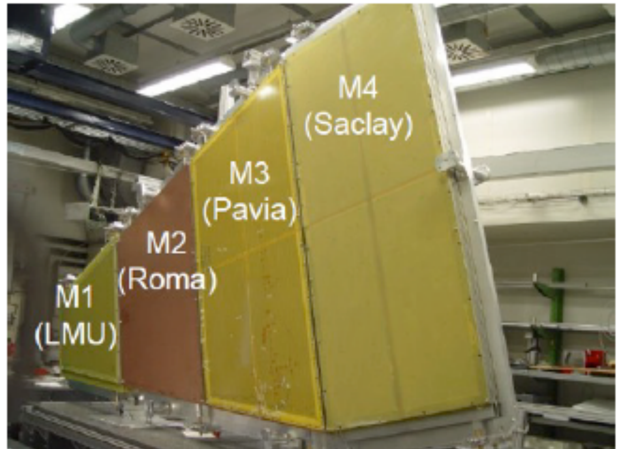
Joerg Wotschack, Mod.Phys.Lett. A28 (2013) 1340020

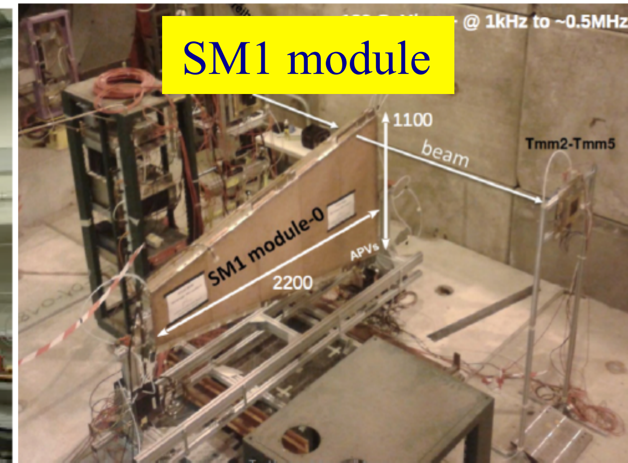
T. Alexopoulos, et al. Nucl. Instrum. Meth. A 640, 110-118, (2011).



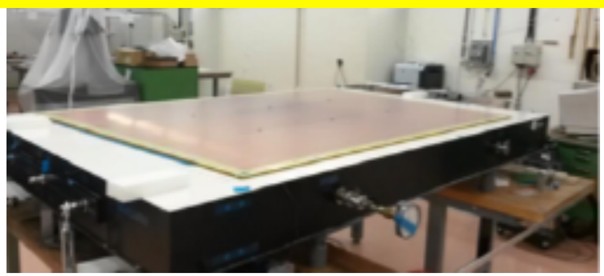








LM2 – CERN / Dubna -Thessaloniki

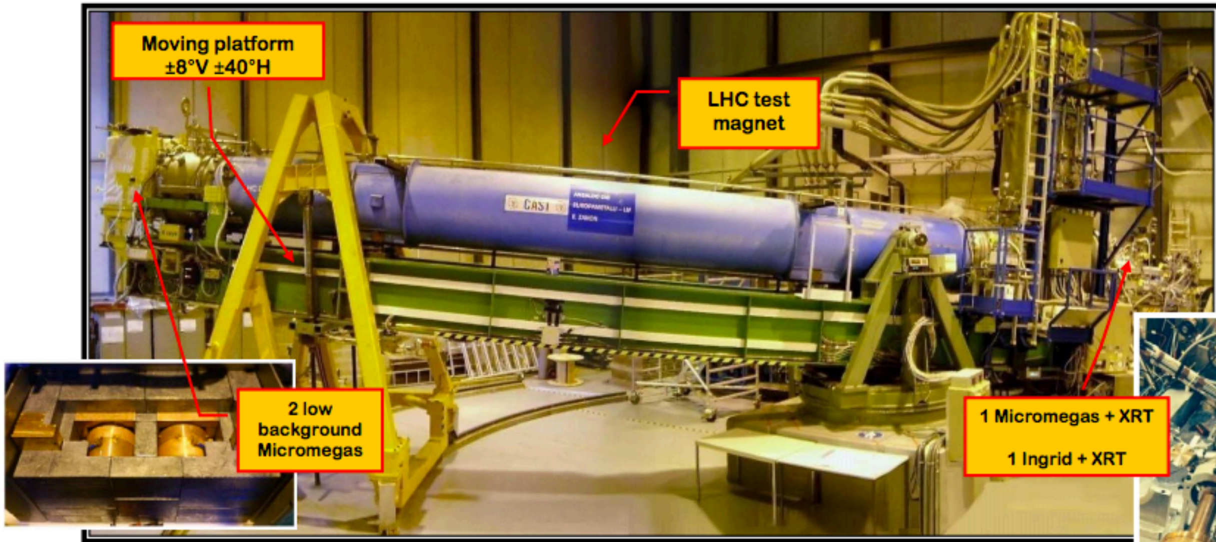


SM2 – Germany

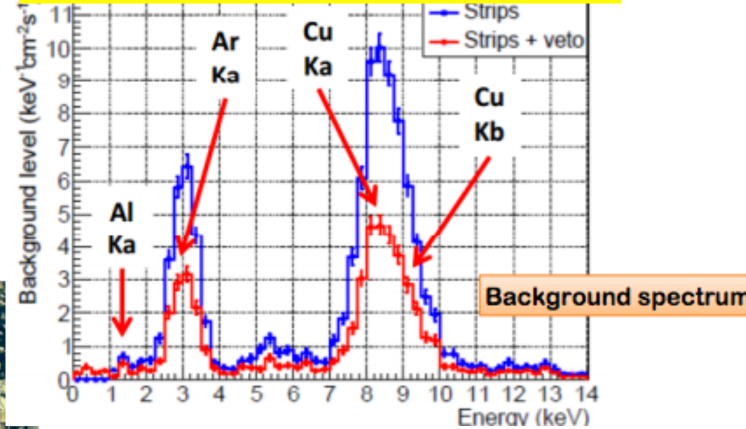
At Saclay the large clean room is ready and operational

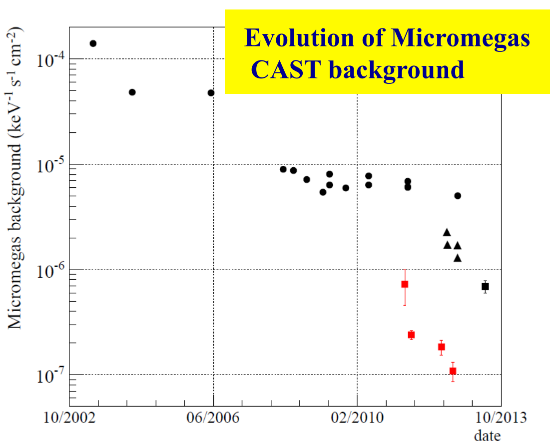
First M0 module is under construction and soon will be tested

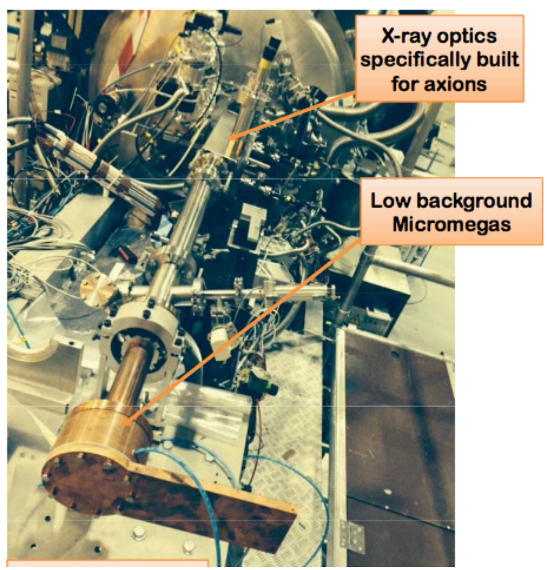
Micromegas micro-bulk in CAST



Lowest background than any other CAST detector

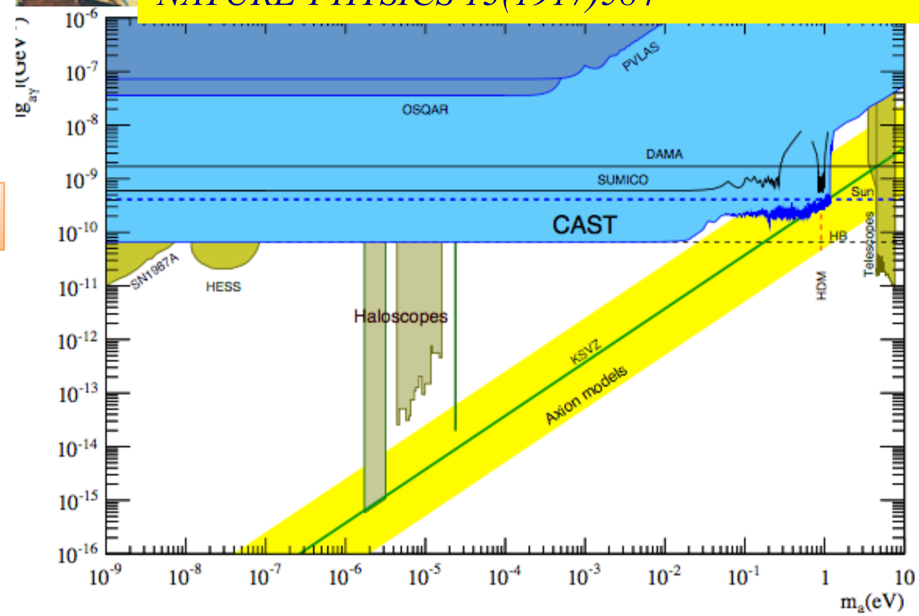






Axion search latest exclusion plots

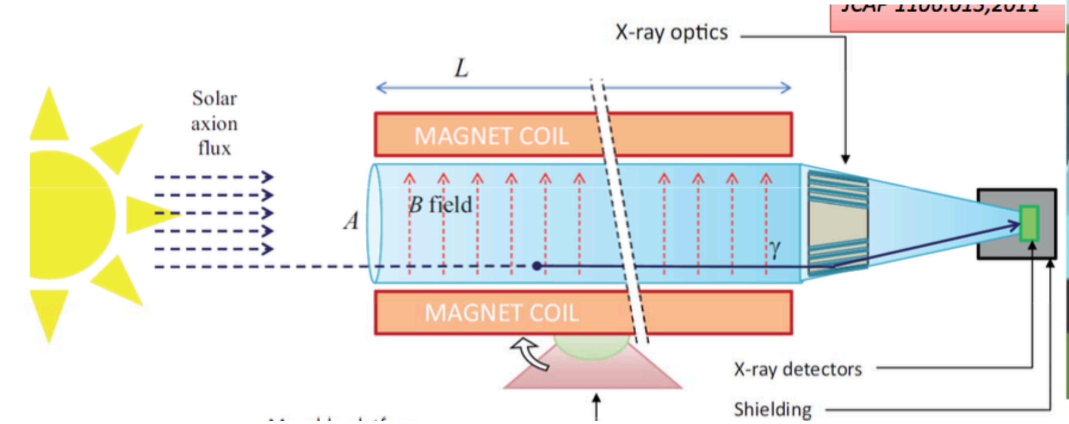
NATURE-PHYSICS 13(1917)584

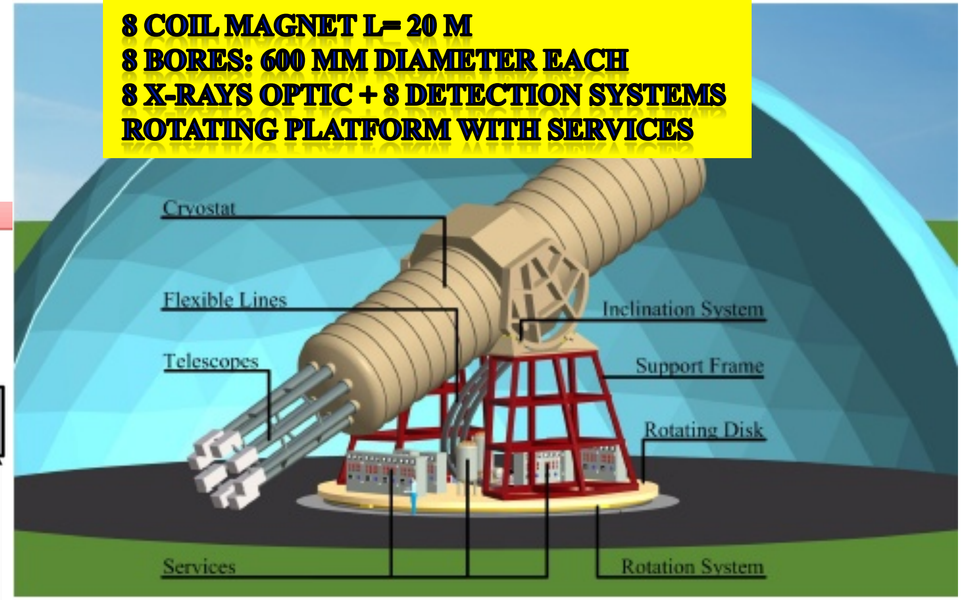


International Axion Observatory (IAXO)

A new proposed experiment

JCAP 1106:013,2011

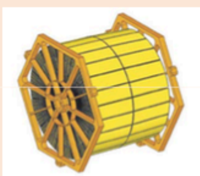




IAXO technologies – Baseline

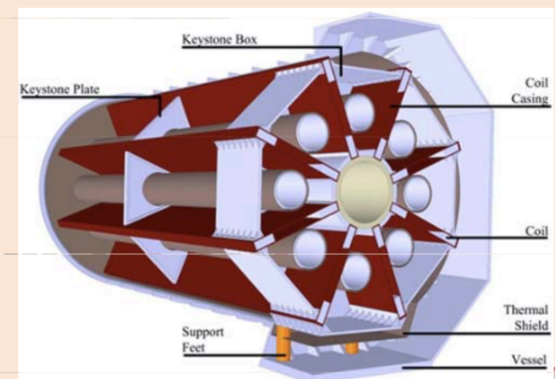
IAXO telescopes

- Slumped glass technology with multilayers
- Cost-effective to cover large areas
- Based on NuSTAR developments
- Focal length ~5 m
- 60-70% efficiency
- LLNL+UC+DTU+MIT expertise



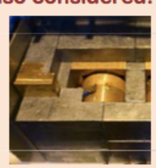
IAXO magnet

- Superconducting "detector" magnet.
- Toriodal geometry (8 coils)
- Based on ATLAS toroid technical solutions.
- CERN+CEA expertise
- 8 bores / 20 m long / 60 cm Ø per bore

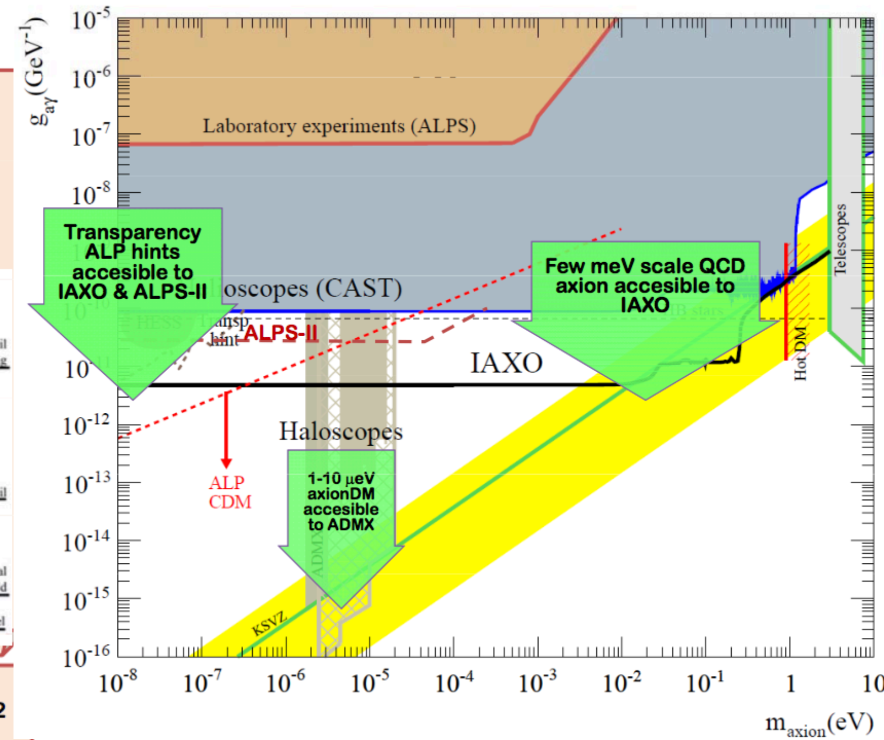


IAXO detectors

- Micromegas gaseous detectors
- Radiopure components + shielding
- Discrimination from event topology in gas
- Long trajectory in CAST
- Zaragoza + CEA (+ others) expertise
- Also considered: Ingrid, MMCs, CCDs



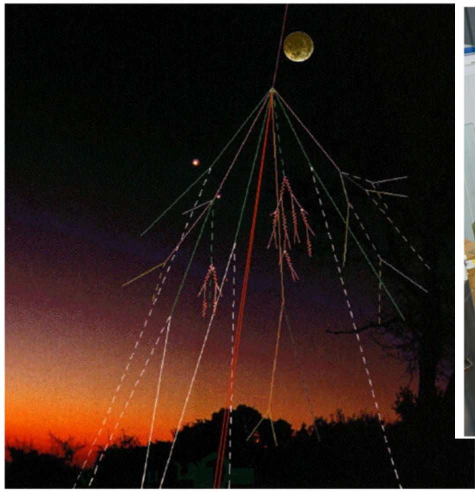
Baseline developed at:
IAXO Letter of Intent: CERN-SPSC-2013-022
IAXO Conceptual Design: JINST 9 (2014) T05002 (arXiv:1401.3233)

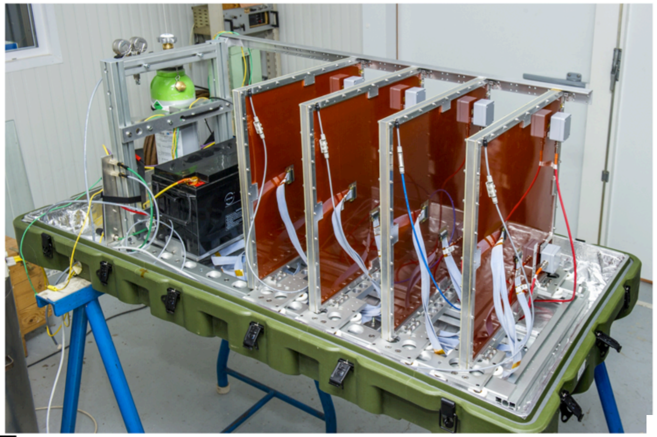


Muon tomography using Micromegas detector

D. Attie, S. Bouteille, S. Procureur et al.

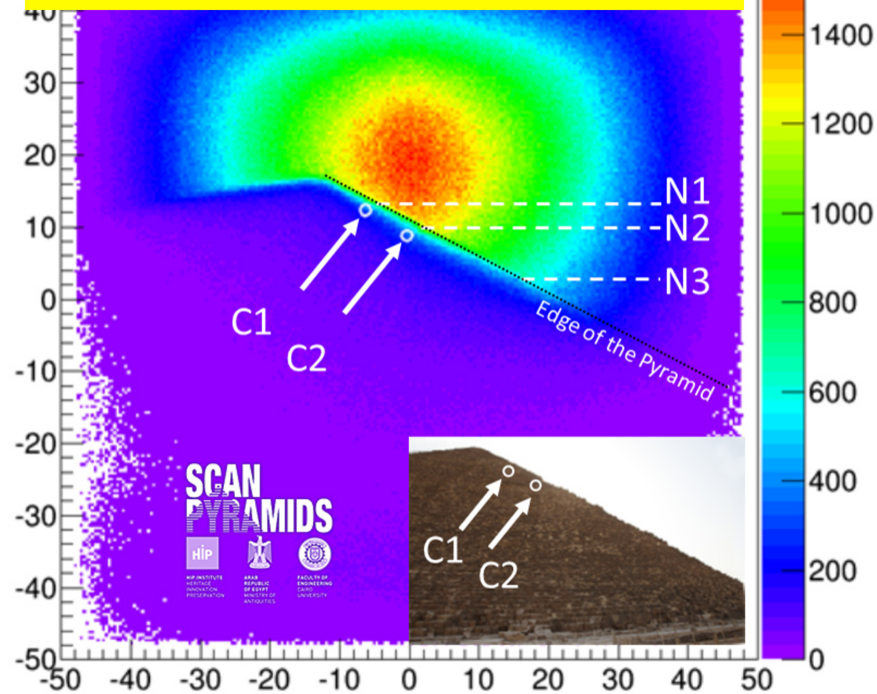
ScanPyramids Mission



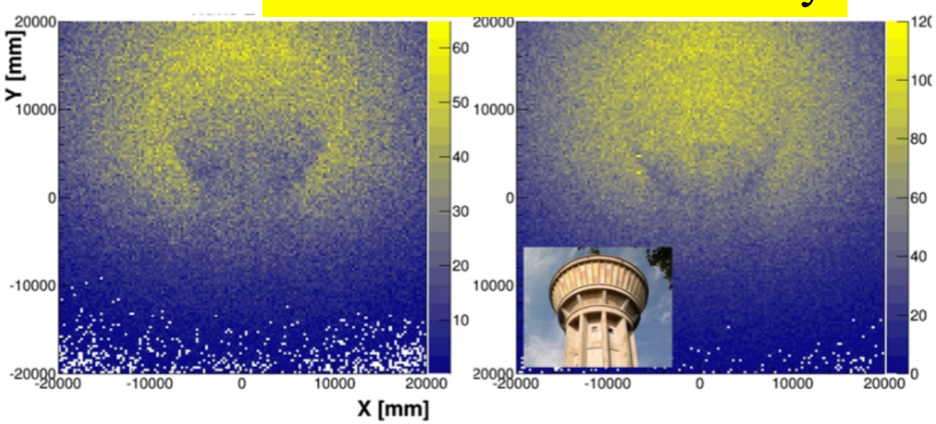


Cheops: Discovery of a new cavity

Press released: October 15th, 2016

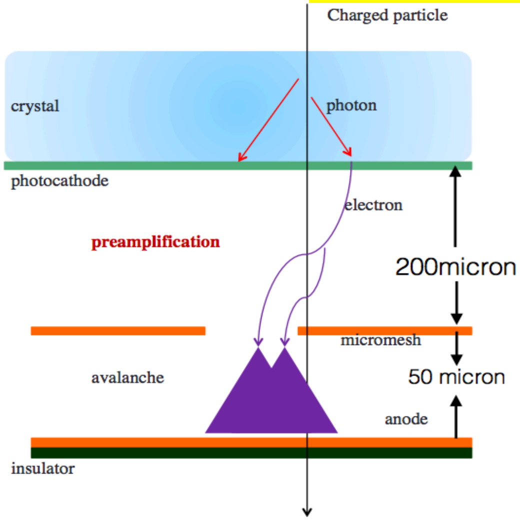


‘Chateau d’eau’ at Saclay



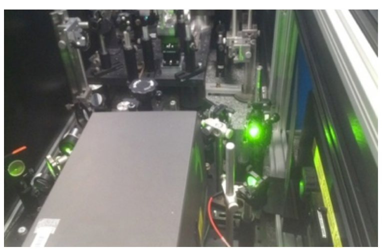
Fast timing Picosecond Micromegas

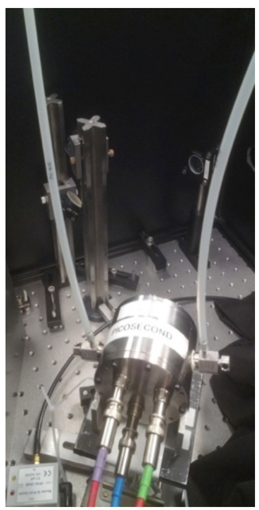
CEA-Saclay, CERN, Thessaloniki, Athens, Princeton, USTC, San Diego



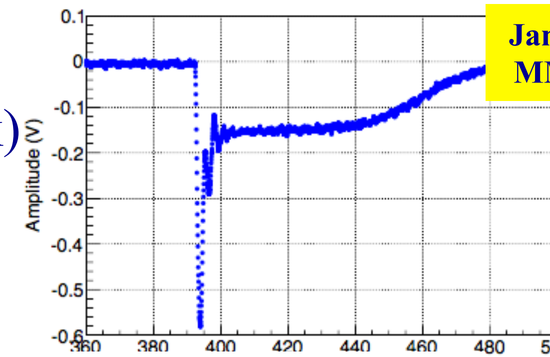
Test with UV fs laser @ IRAMIS-CEA

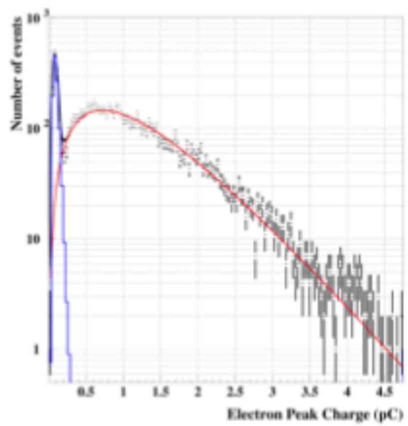
UV Photocathodes on MgF window:
CsI, Cr, Al, Diamond (10-50nm thick)

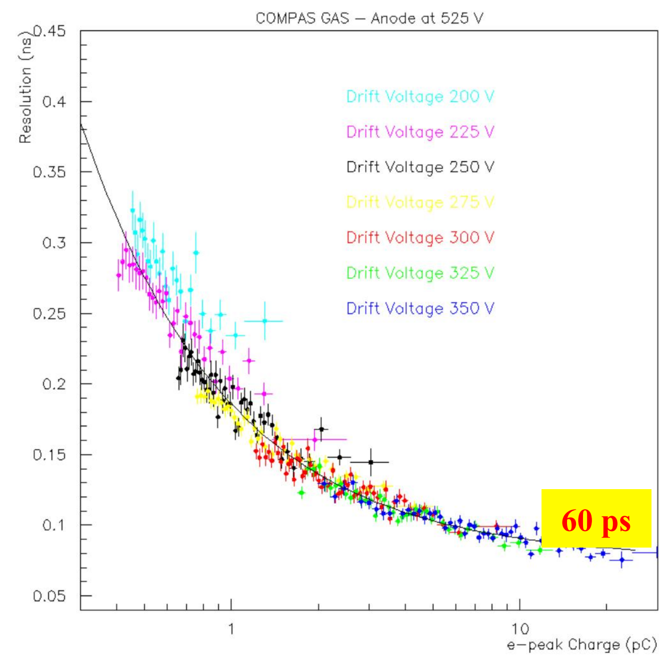




January 2017, Cr 18nm, single electrons/pulse
MM amplification 10^4, preamplification 10-50



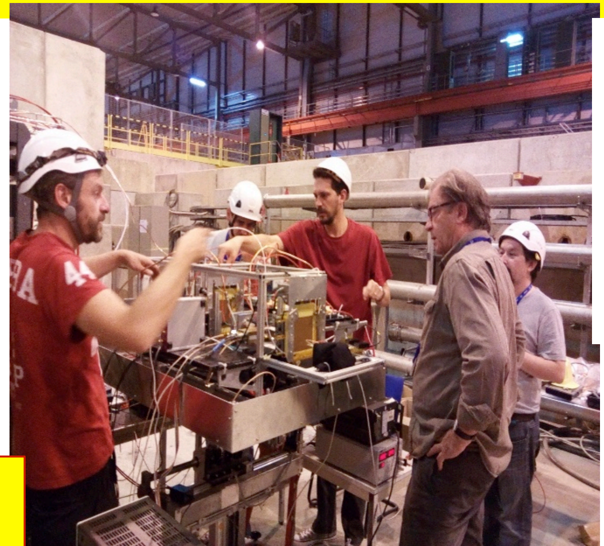


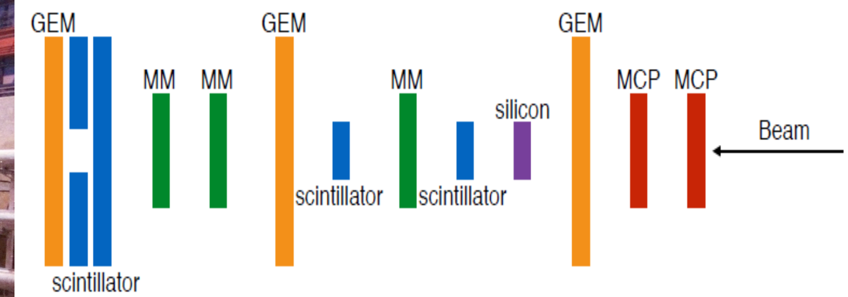


Beam tests with 150 GeV muons @ SPS H4

June 2016

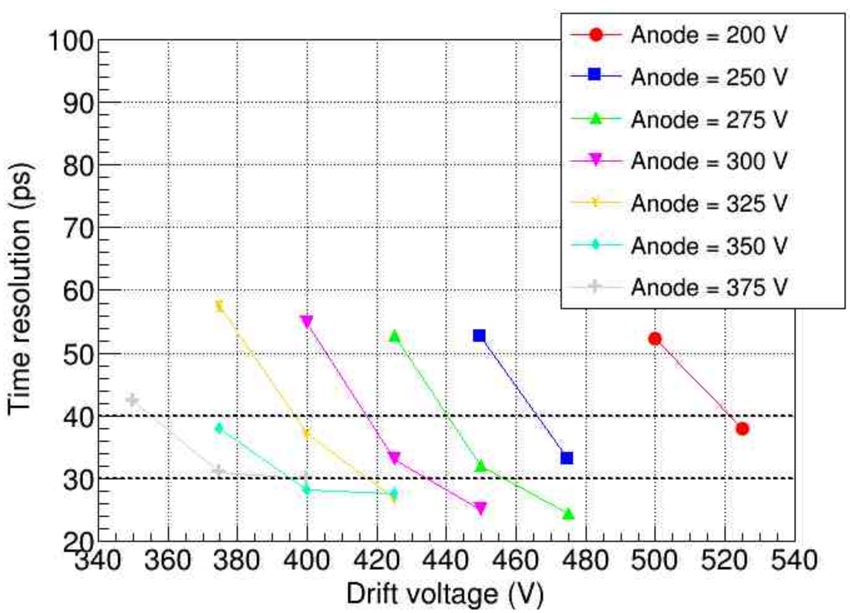
- **Sensors:** ***Standard bulk Micromegas***
- ***Photocathodes: 3,5mm*** **MgF_2**
  CsI photocathodes : CsI, Cr, Diamond
  + 6 nm Al + 10.5 nm CsI
- **Gas mixtures:**
  $Ne/C_2H_6/CF_4$ (80/10/10)
  Ne/CH_4 (95/5)
  CF4 / C_2H_6 (sealed mode)

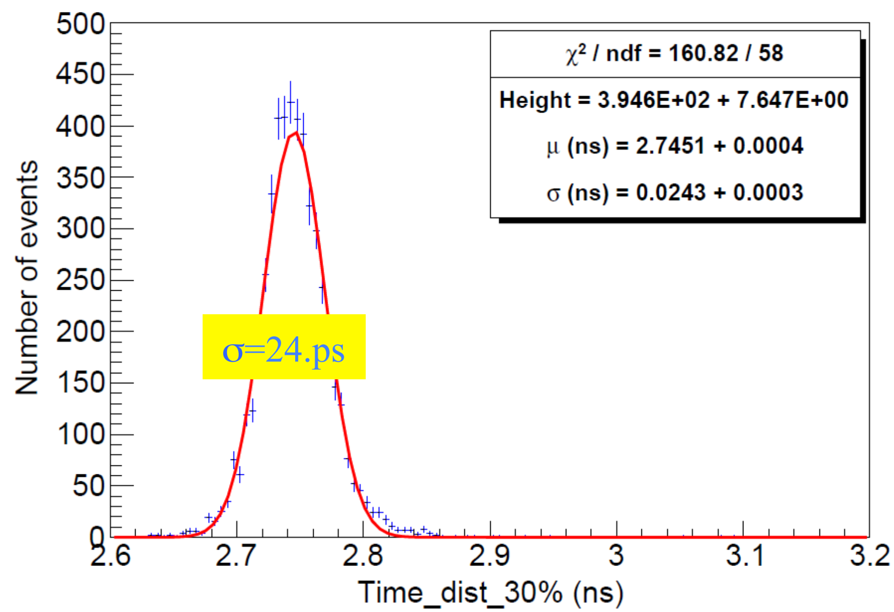




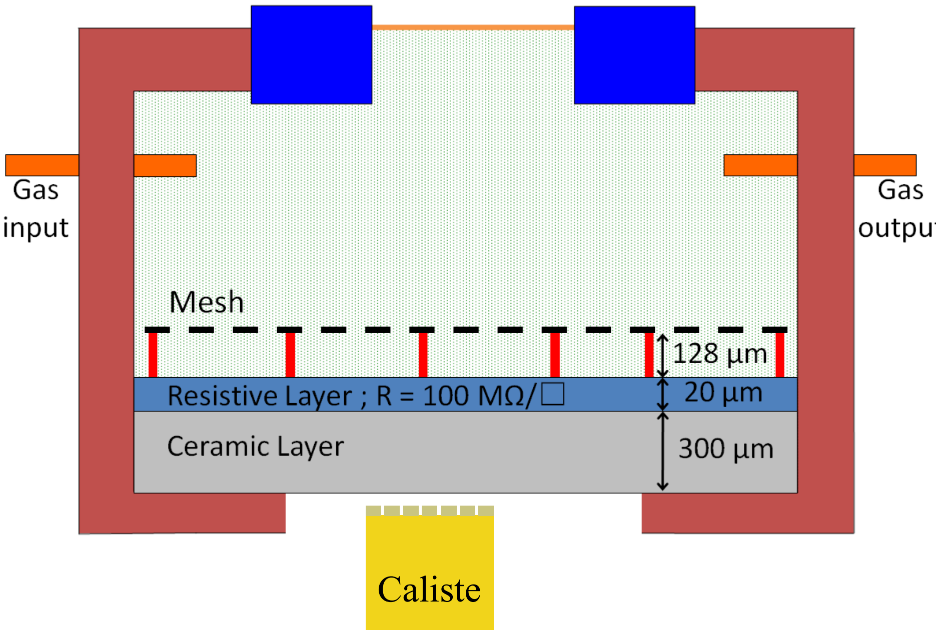
Data analysis in progress. Data from different detector configurations to be analyzed. Results for:

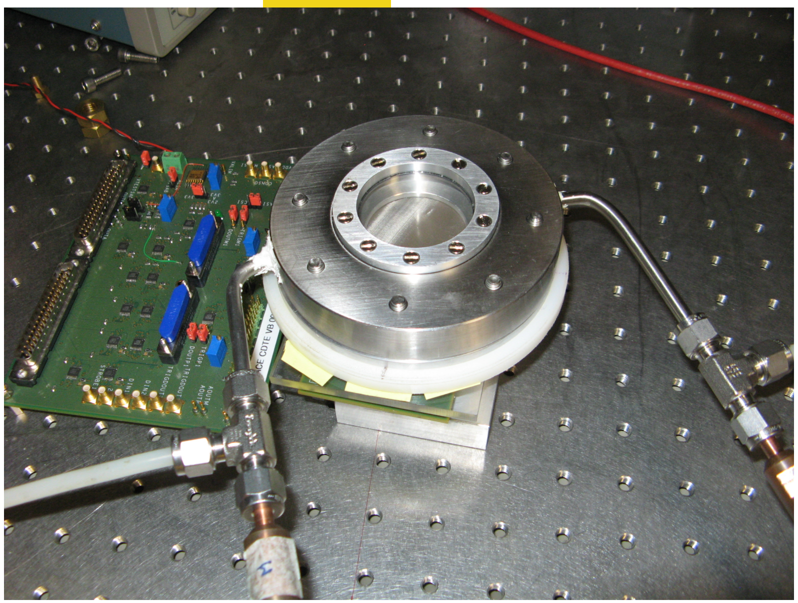
➢ **$\sigma_t \approx 24$ ps, $\langle N_{p.e.} \rangle \approx 13$**



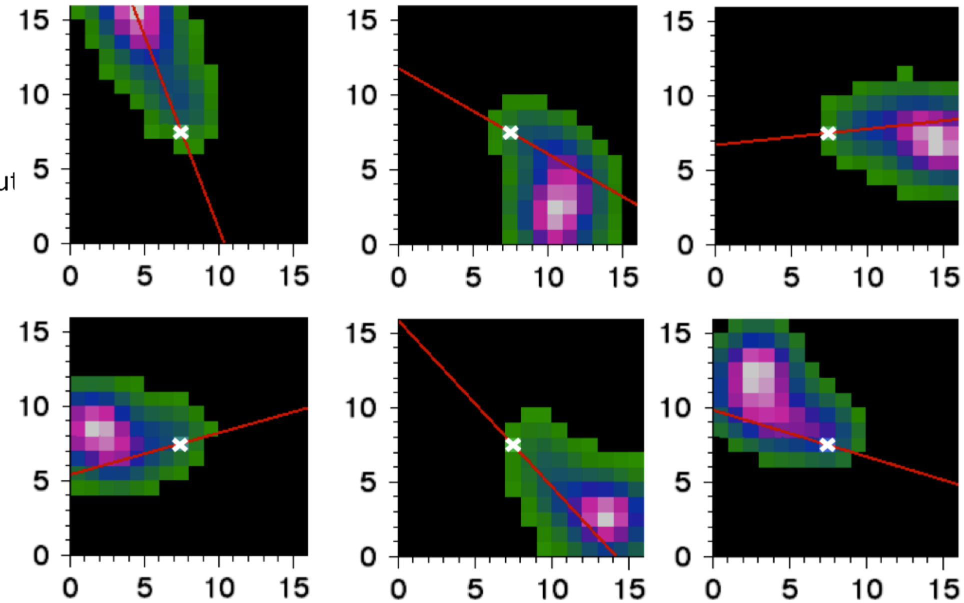


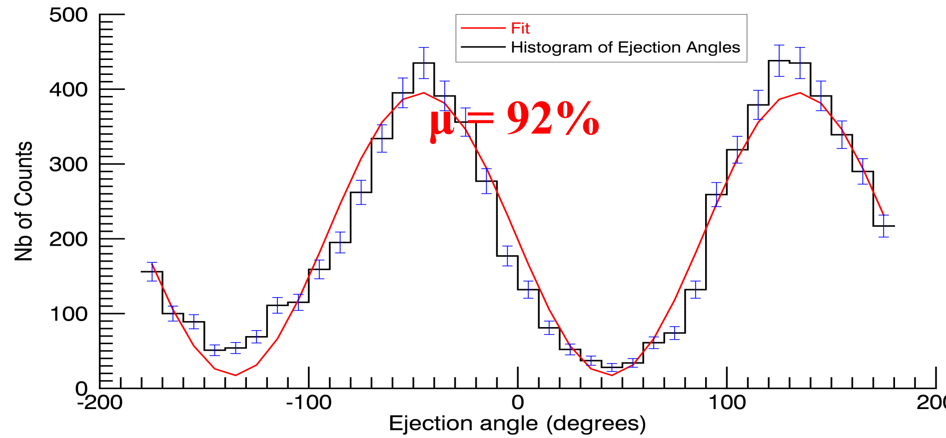
Soft X-ray polarimetry with ‘Piggy back’ Micromegas





Recorded events with 8 keV linerarly polarized in helium-isobutane





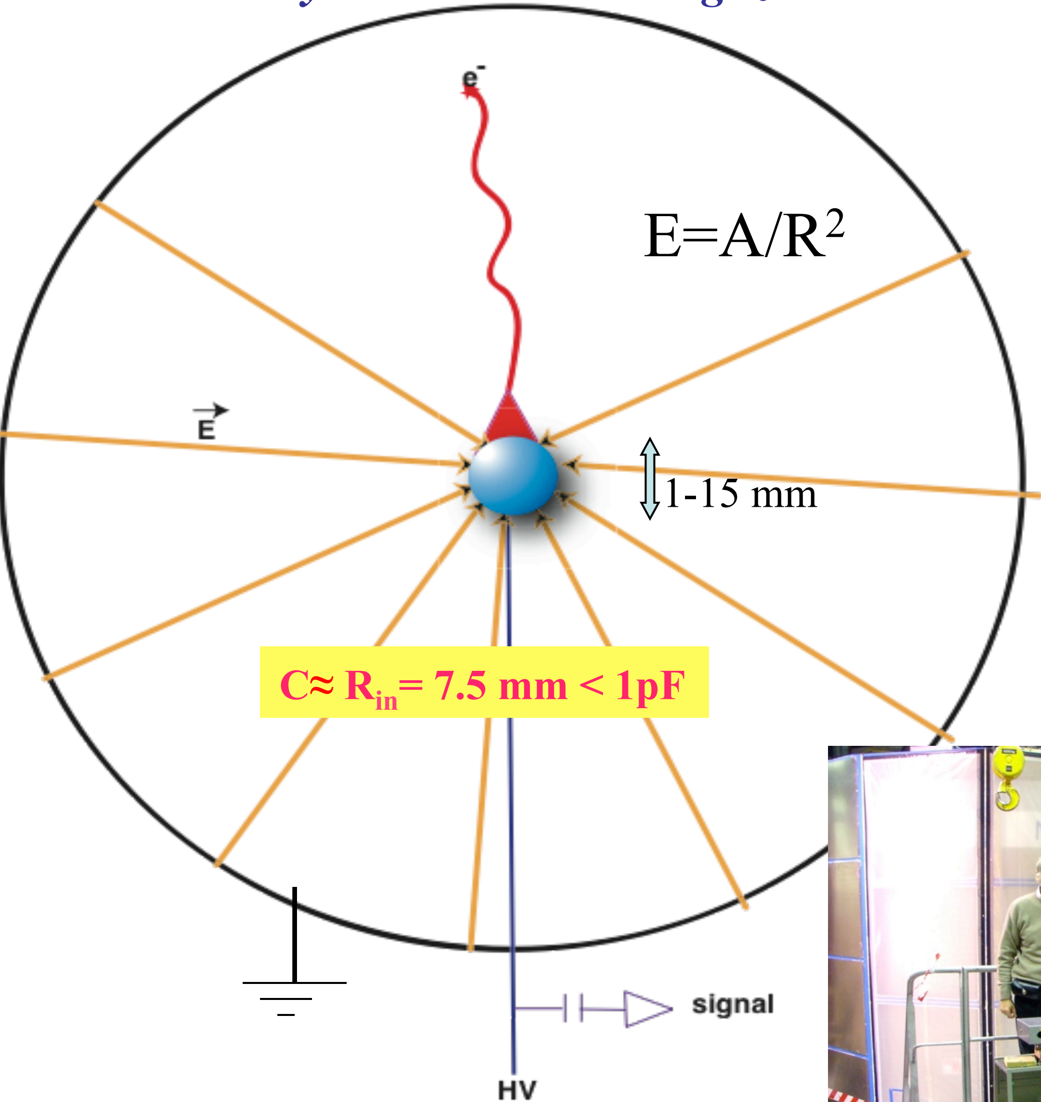
Second part

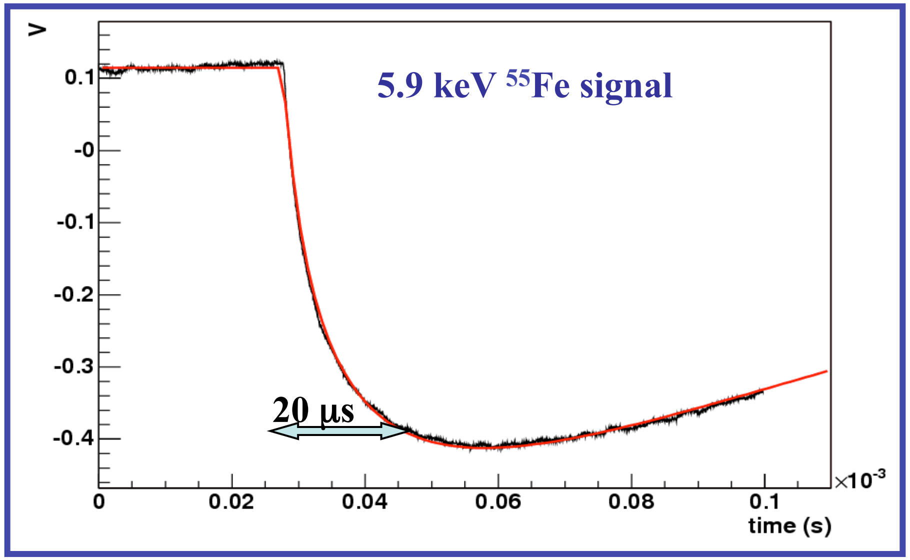
Spherical detector
Light-dark matter search
and low-energy neutrino physics

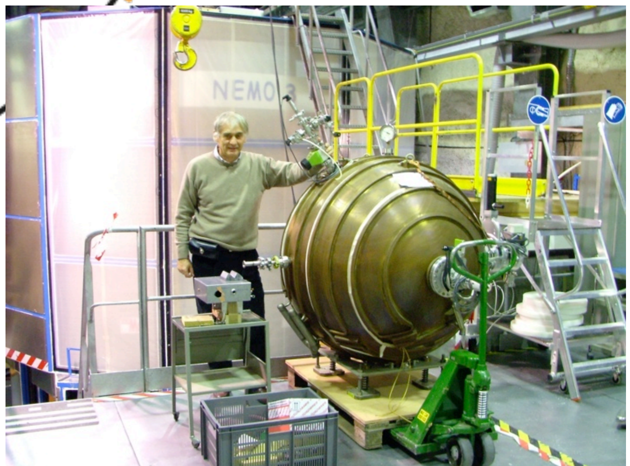
Radial TPC with spherical proportional counter read-out

Saclay-Thessaloniki-Saragoza

A Novel large-volume Spherical Detector with Proportional Amplification read-out, I. Giomataris *et al.*, JINST 3:P09007,2008





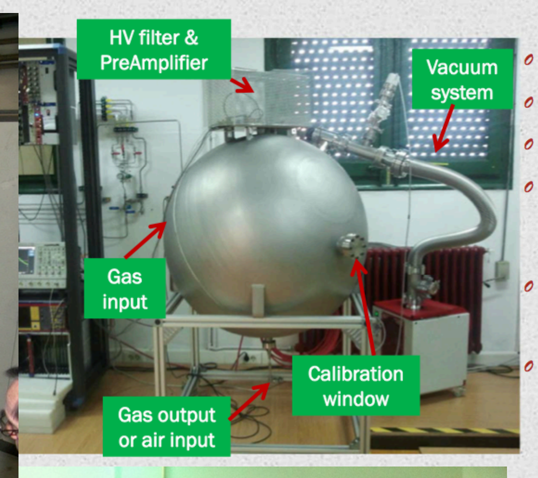


- Simple and cheap
- Large volume
- single read-out
- Robustness
- Good energy resolution
- Low energy threshold
- Efficient fiducial cut
- Low background capability

Low background detector d=60 cm p=10 bar

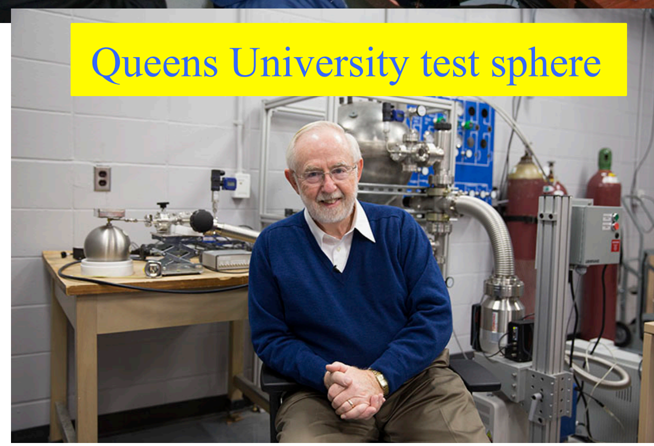
Basic R@D detector in Saclay

University of Saragoza detector



University of Thessaloniki detector

Queens University test sphere



University of Tsinghua - HEP detector

Bibliography

I Giomataris et al., JINST 3:P09007,2008.,

I Giomataris and J.D. Vergados, Nucl.Instrum.Meth.A530:330-358,2004,

I. Giomataris and J.D. Vergados, Phys.Lett.B634:23-29,2006.

I. Giomataris et al. Nucl.Phys.Proc.Suppl.150:208-213,2006.,

S. Aune et al., AIP Conf.Proc.785:110-118,2005.

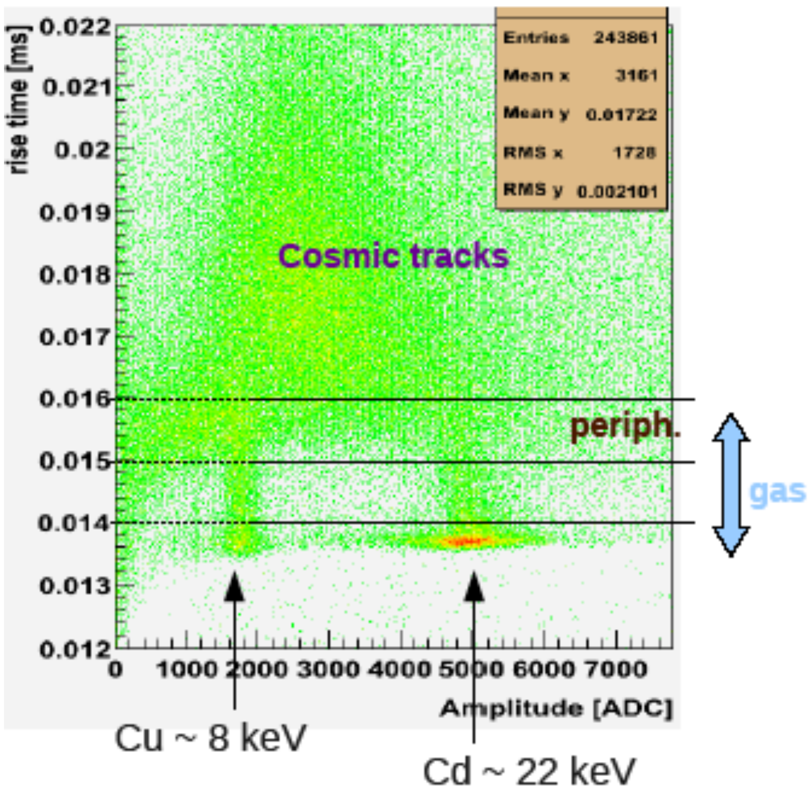
J. D. Vergados et al., Phys.Rev.D79:113001,2009.,

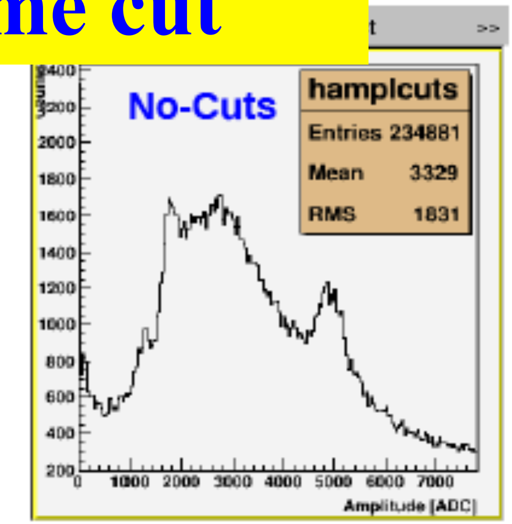
E Bougamont et al. arXiv:1010.4132 [physics.ins-det], 2010

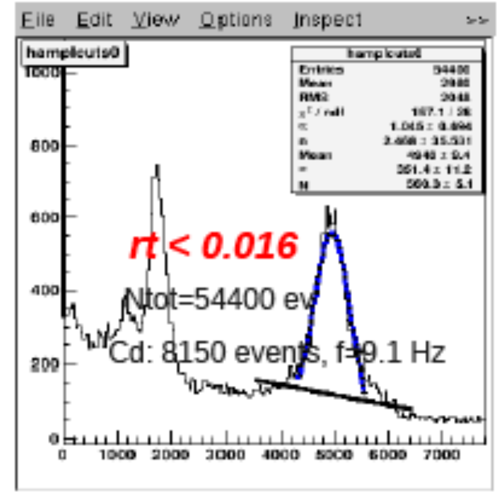
G. Gerbier et al.,arXiv:1401.790v1

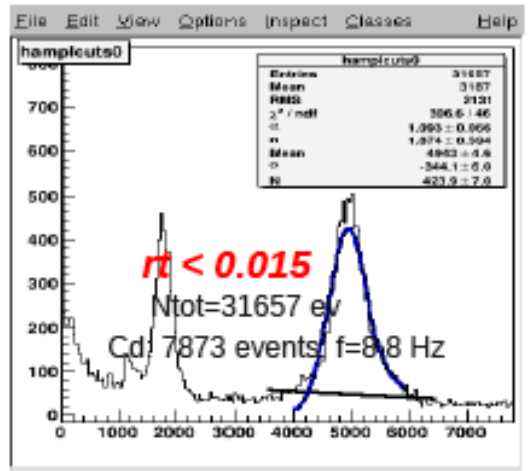
Rejection power
Rise time cut

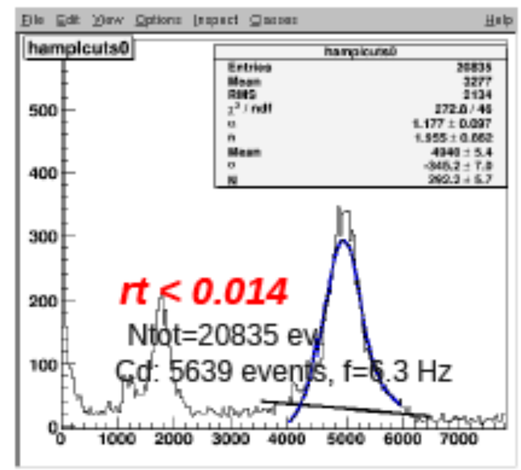
Using Cd-109 source – December 2009
Irradiate gas through 200µm Al window
P = 100 mb, Ar-CH_4 (2%)











If rt ~ 0.0155 ms ==> R = 65 cm
0.014 ms ==> ~70% of signal

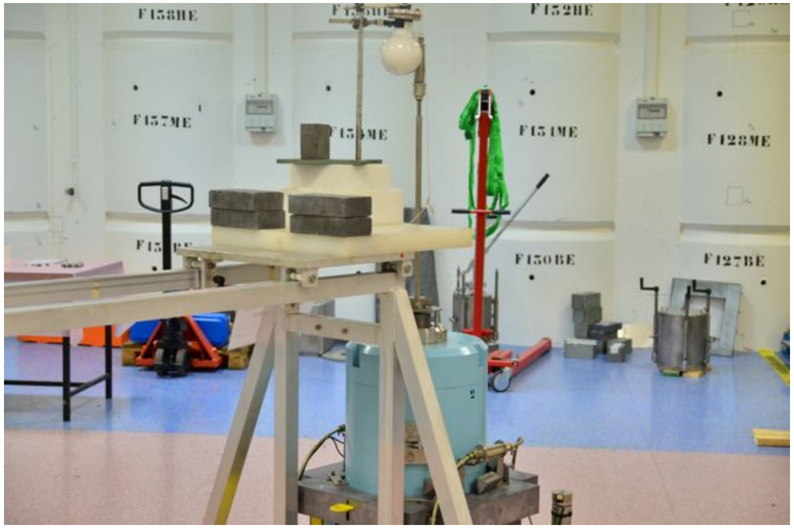
Efficiency of the cut in rt ==> ~ 70% signal (Cd peak)

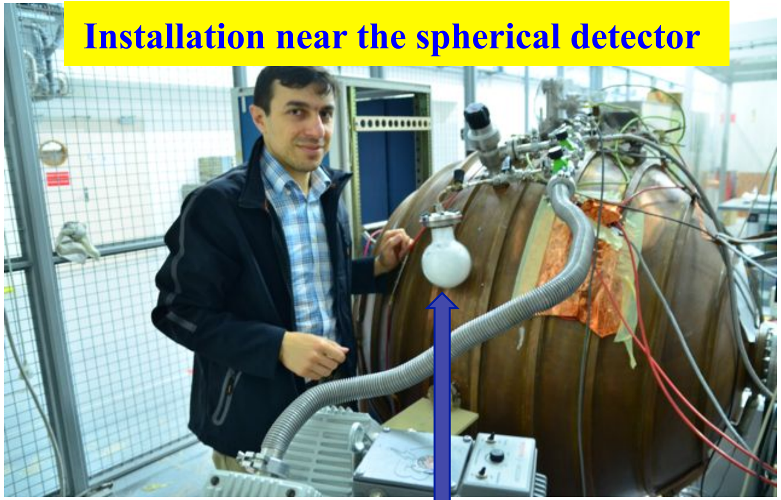
Severe background reduction

Energy resolution ~ 6 % and 9 % for Cu and Cd

Low-energy calibration source *Argon-37*

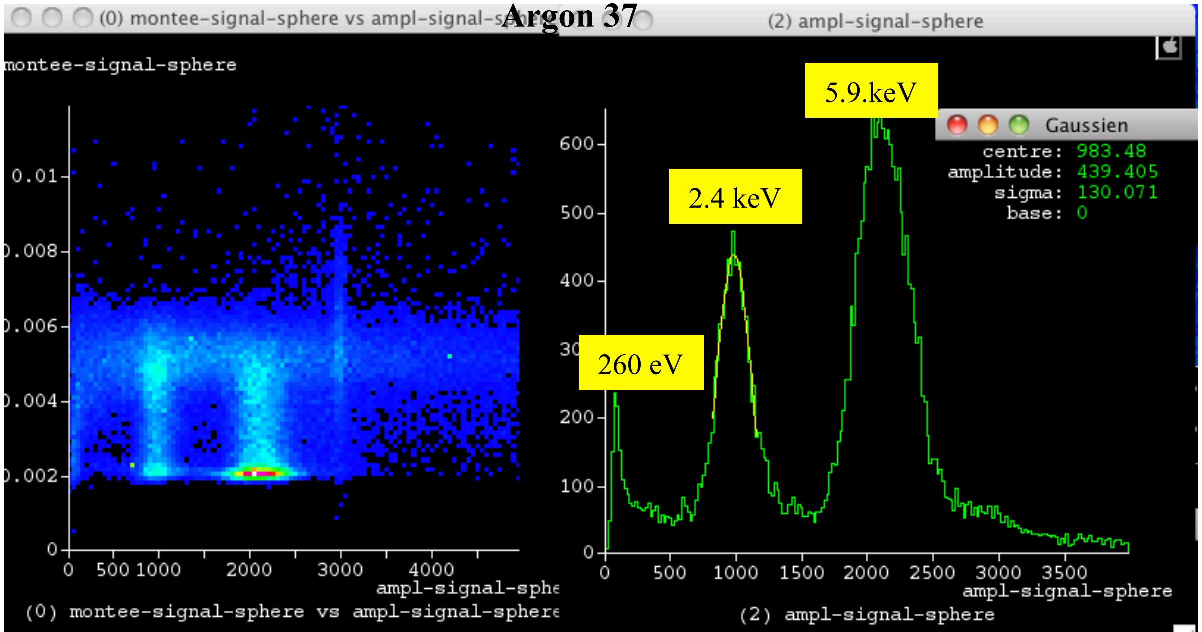
Home made Ar-37 source: irradiating Ca-40 powder with fast neutrons 7×10^{6} neutrons/s
Irradiation time 14 days. Ar-37 emits K(2.6 keV) and L(260 eV) X-rays (35 d decay time)





Argon 37

First measurement
with Ar-37 source
Total rate 40 hz
in 250 mbar gas, 8 mm ball
240 eV peak clearly seen
A key result for light dark matter search



NEWS collaboration

Queen’s University Kingston, IRFU/Saclay , LSM, Thessaloniki University, LPSC Grenoble, Birmingham, TU Munich, PNNLTRIUM

Tessaloniki 2012

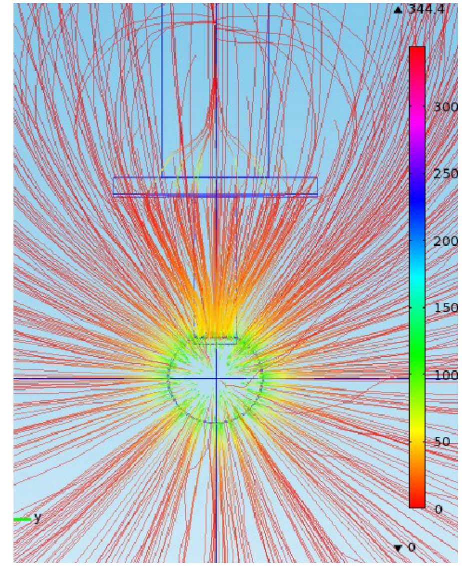
Collaboration meeting at LSM april 2016

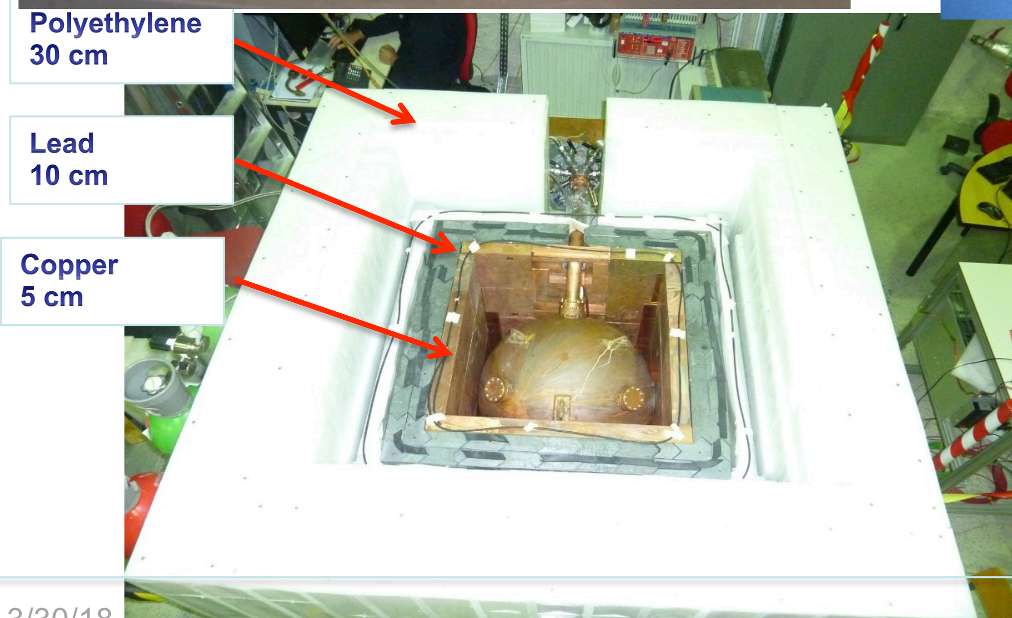
Collaboration meeting at Kingston 2017

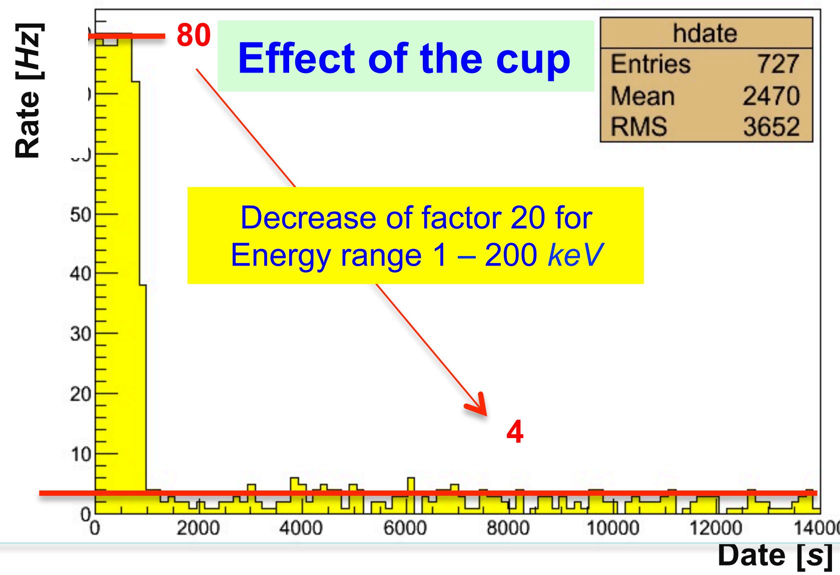
NEWS-LSM: Exploration of light dark matter search at LSM

Detector installed at LSM end 2012: 60 cm, Pressure = up to 10 bar

Gas targets: Ne, He, CH4





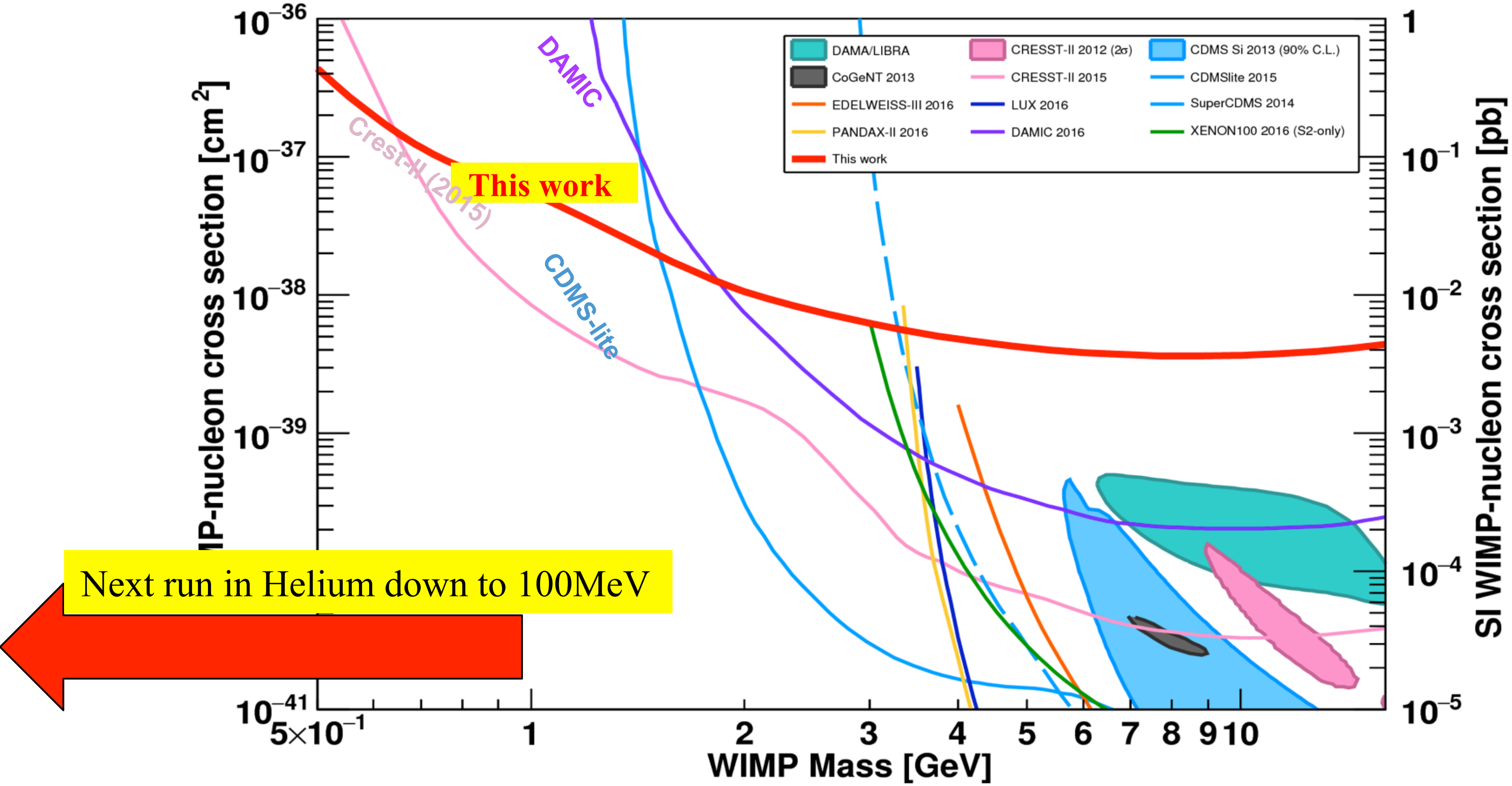


First results of NEWS-G with LSM SEDINE detector

[NEWS-G collaboration, Astropart. Phys. 97, 54 (2018)](#)

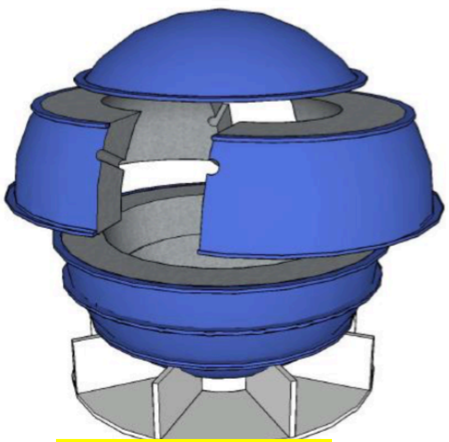
Exclusion at 90% confidence level (C.L.) of cross-sections above 4.4 · 10^{-37} cm^2 for a 0.5 GeV/c^2 WIMP

Current sensitivity with Neon at 3 bar
Data 40.5 days, threshold 30 eV

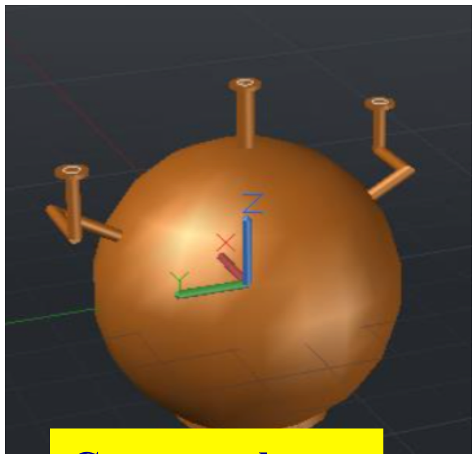


NEWS-G-SNO with compact shield : implementation at SNOLAB by fall 2017
Funded mainly by Canadian grant of excellence and ANR-France

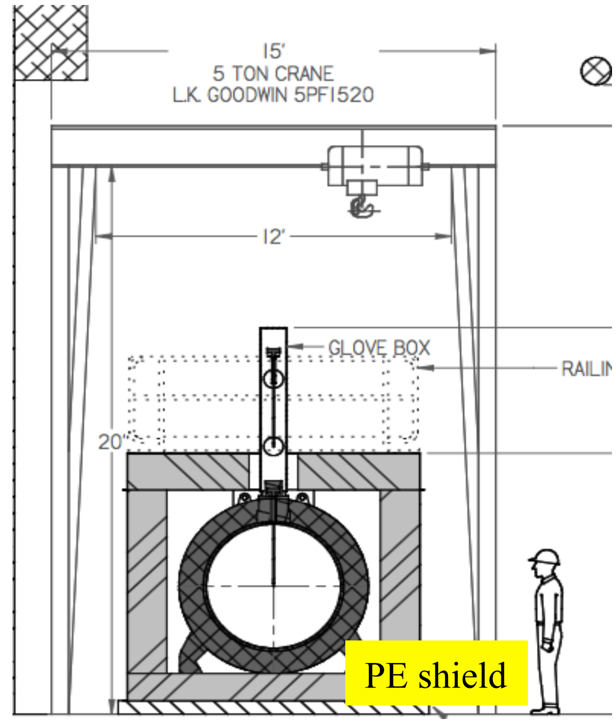
140 cm Ø detector, 10 bars, Ne, He, CH_4
Copper 1 mBq/kg
Compact lead –ancient- & PE shield solution



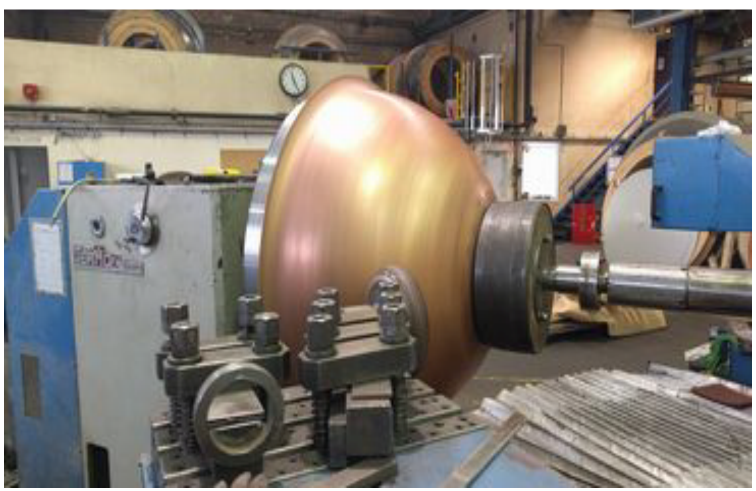
Lead shield

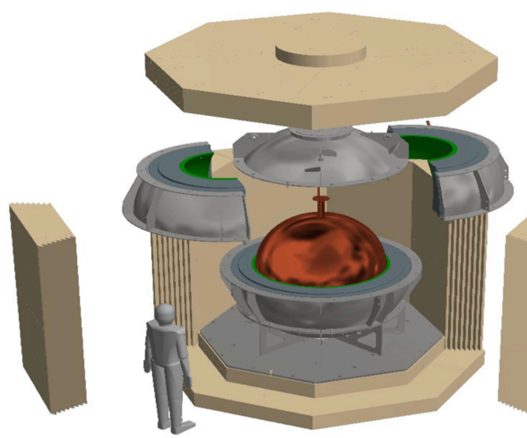


Copper sphere



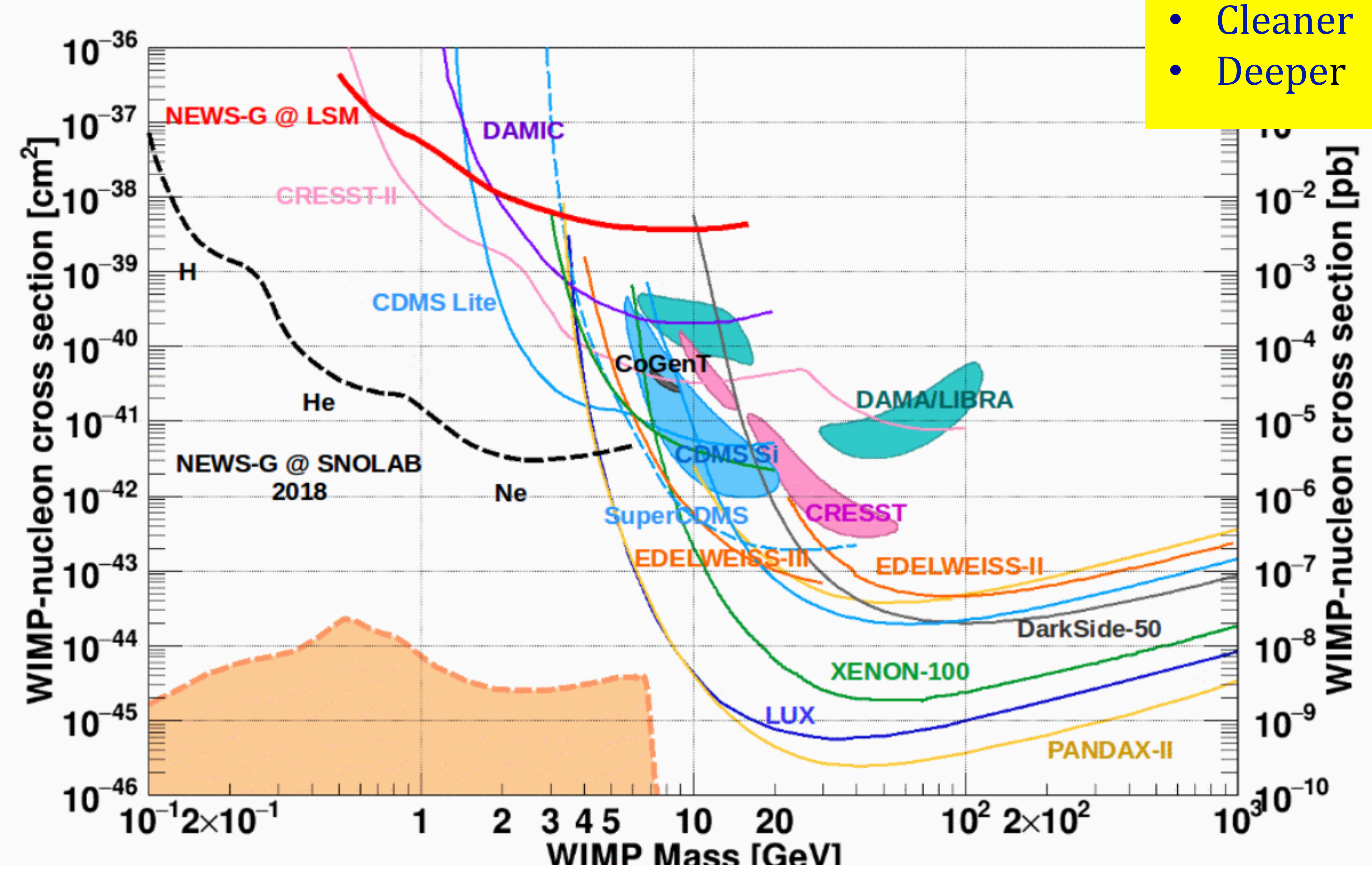
PE shield





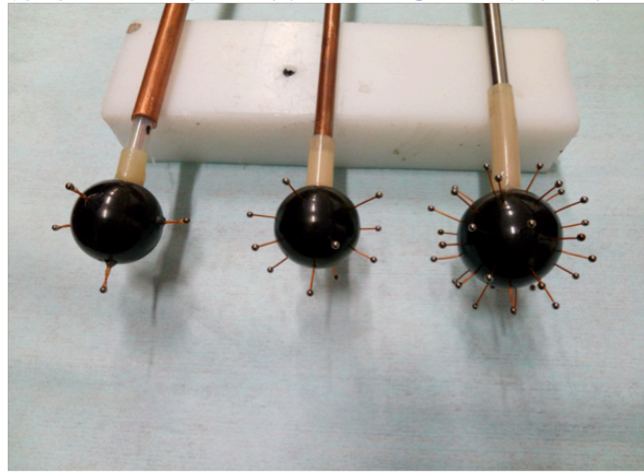
NEWS-SNOLAB project sensitivity

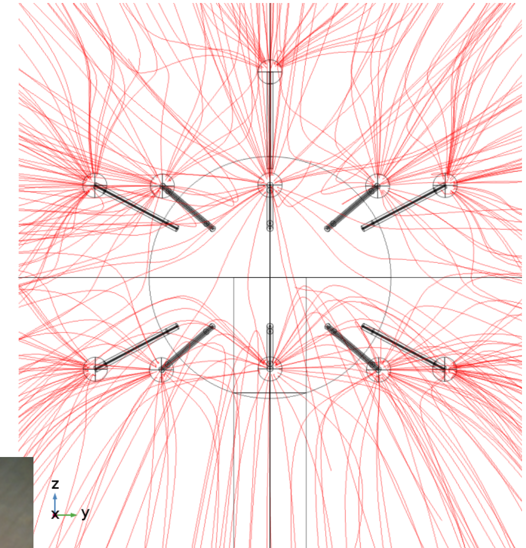
- Bigger
- Cleaner
- Deeper



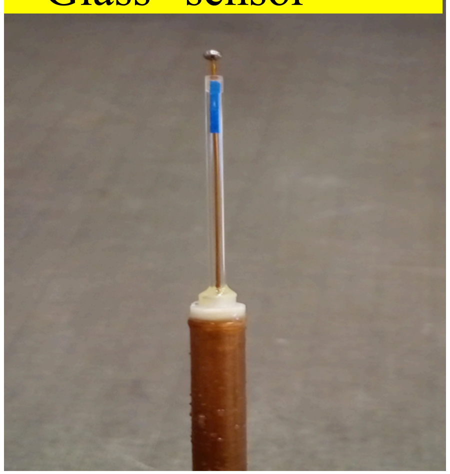
From single sensor ball to multi-ball 'ACHINOS' structure
Developed in Saclay in collaboration with University of Thessaloniki

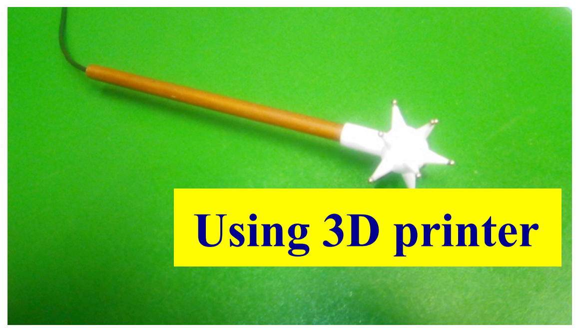
"Bakelite" sensor





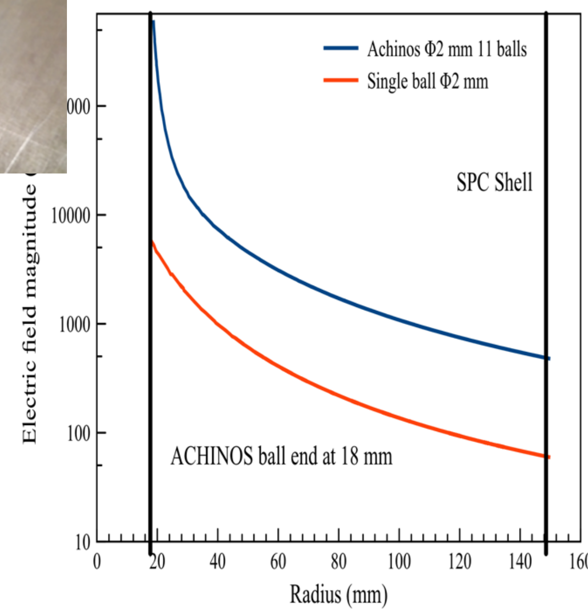
"Glass" sensor





Using 3D printer

Advantages
- Amplification tuned by the ball size: 1mm diameter for high pressure
-Volume electric field tuned by the size of the ACHINOS structure
- Detector segmentation: 3D TPC like



Additional physics

Competitive double beta decay experiment with Xe-136 at 50bar

CNBG, CPPM , SACLAY

The goal is to reach a record low background level << 10^{-4}/keV/Kg/y and an energy resolution of .3%

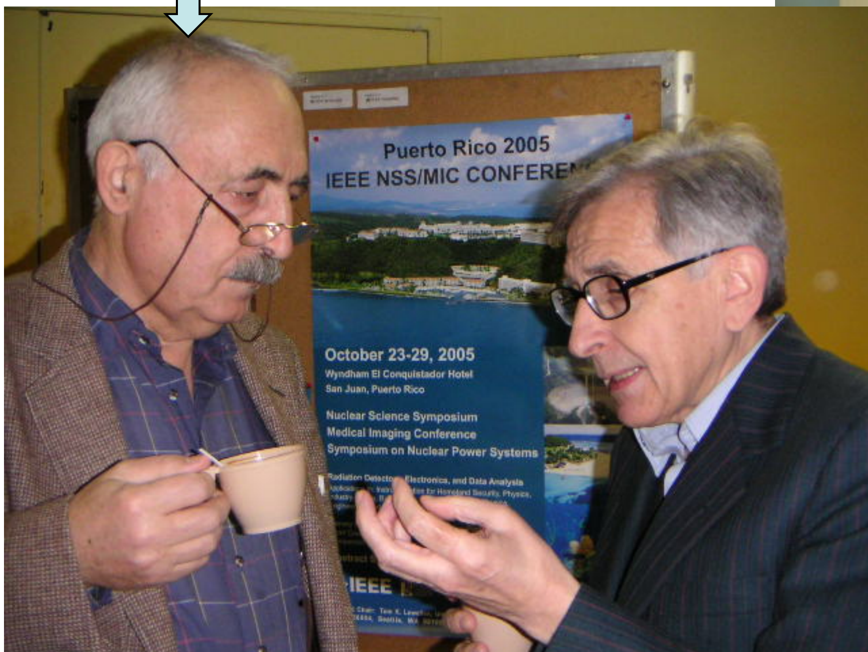
- Xenon is relatively safe and easy to enrich
- Natural abundance of ^{136}Xe is ~ 8%
- EXO and NEXT have 200 kg highly enriched in ^{136}Xe
- Low cost
- Pressure variation

High density is desirable to contain event
But there is an upper limit! $\rho < 0.55$ g/cm^3
Beyond this density, $\delta E/E$ deteriorates rapidly!

Additional rejection could be achieved through Cherenkov light detection:
Background free double beta decay experiment,

I. Giomataris, arXiv:1012.4289

Collaboration with J.D Vergados



TPC Paris conference 2004

TPC Paris conference 2010

Some common publications (out of 27)

Room size Neutrino oscillations using a strong tritium source

I. Giomataris, J.D. Vergados, Nucl.Instrum.Meth.A530:330-358,2004,

Neutrinos oscillate inside detector volume L_{23}=13 m

Additional physics: neutrino magnetic moment, weak interaction at low energy

A novel large-volume spherical detector with proportional amplification read-out

I Giomataris (Vergados) et al., JINST 3:P09007,2008.

With mono-energetic neutrino

Y. Giomataris, Y. Novikov, J.D. Vergados, J.Phys.Conf.Ser. 259 (2010) 012100

Some candidates are:

A=157 (Tb), $T_{1/2}$ = 70 y, E_ν=9.8 keV, L_0=4.9 m

A=163 (Ho), $T_{1/2}$ =4500, E_ν =0.5-2.6 keV, L_0=0.3-1.6 m

A=193 (Pt), $T_{1/2}$ =56.8y, E_ν =43.8 keV, L_0=21 m

A=178 (W), $T_{1/2}$=21.6d, E_ν =24 keV, L_0=12 m

A=194 (Hg), $T_{1/2}$ =440y, E_ν =55 keV, L_0=27 m

Nuclide	$T_{1/2}$ (d)	E_ν (keV)	L_{14} (m)	N_ν (s^{-1})
^{37}Ar	35	811	1.4	1.8×10^{16}
^{51}Cr	27.7	747	1.2	4.1×10^{17}
^{65}Zn	244	1343	2.2	3.0×10^{16}
^{59}Ni	2.8×10^7	1065	1.8	1.1×10^{14}
^{113}Sn	116	617	1.0	3.7×10^{16}
^{32}P	14.3	continuum	≈ 2.5	5.0×10^{16}

Sterile Neutrino Oscillations

J.D. Vergados,Y. Giomataris, Y. Novikov, Nucl.Phys. B854 (2012) 54-66 , Phys.Rev. D85 (2012) 033003

Secluded dark matter

A. Dedes, I. Giomataris, K. Suxho, J.D Verdados, Nucl.Phys. B826(2010)148.

Coherent neutrino at a spallation source

J. D. Vergados, F. Avignone, I. Giomataris Phys.Rev. D 79(2009)113001

A dedicated Supernova detector

Y. Giomataris, J. D. Vergados, Phys.Lett.B634:23-29,2006

A dedicated Supernova detector

Simple and cost effective - Life time >> 1 century

Through neutrino-nucleus coherent elastic scattering

Y. Giomataris, J. D. Vergados, Phys.Lett.B634:23-29,2006

Destruction of massive star initiated by

the Fe core collapse

- 10^{53} ergs of energy released
- 99% carried by neutrinos
- A few happen every century in our Galaxy, but the last one observed was over 300 years ago

Sensitivity for galactic explosion

For p=10 Atm, R=2m, D=10 kpc, U_ν =0.5x10^{53} ergs

 # Number of events (no quenching, zero threshold)

He	Ne	Ar	Kr	Xe	Xe (with Nuc. F.F)
.16	3.95	19.1	76.8	235	179

 # Number of events (after quenching, E_{th} =0.25 keV)

He	Ne	Ar	Kr	Xe	Xe (with Nuc. F.F)
0.08	1.5	6.7	23.8	68.1	**51.8**

Idea : A world wide network of several (tenths or hundreds) of such dedicated Supernova detectors robust, low cost, simple (one channel)

To be managed by an international scientific consortium and operated by students

THANK YOU