Georges Charpak,

the man beyond science

Ioannis Giomataris, CEA - Saclay

The Nobel Prize in Physics 1992

The Royal Swedish Academy of Sciences awards the 1992 Nobel Prize in Physics to **Georges Charpak** for his invention and development of particle detectors, in particular the multiwire proportional chamber.

Georges Charpak
CERN, Geneva, Switzerland

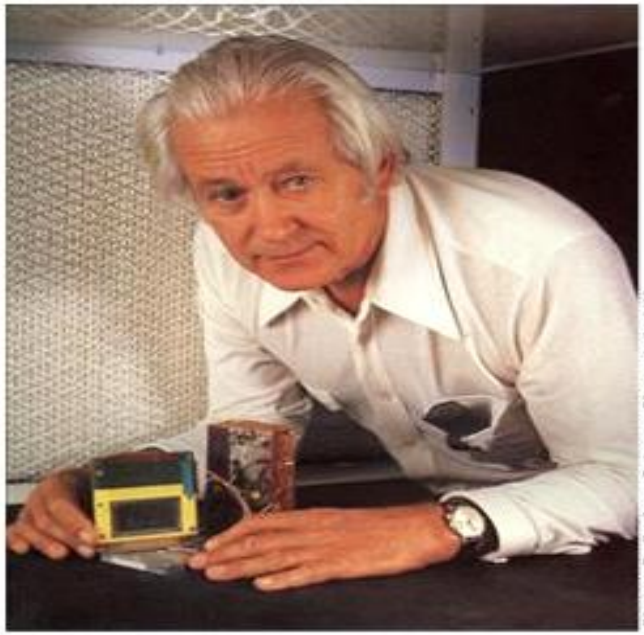
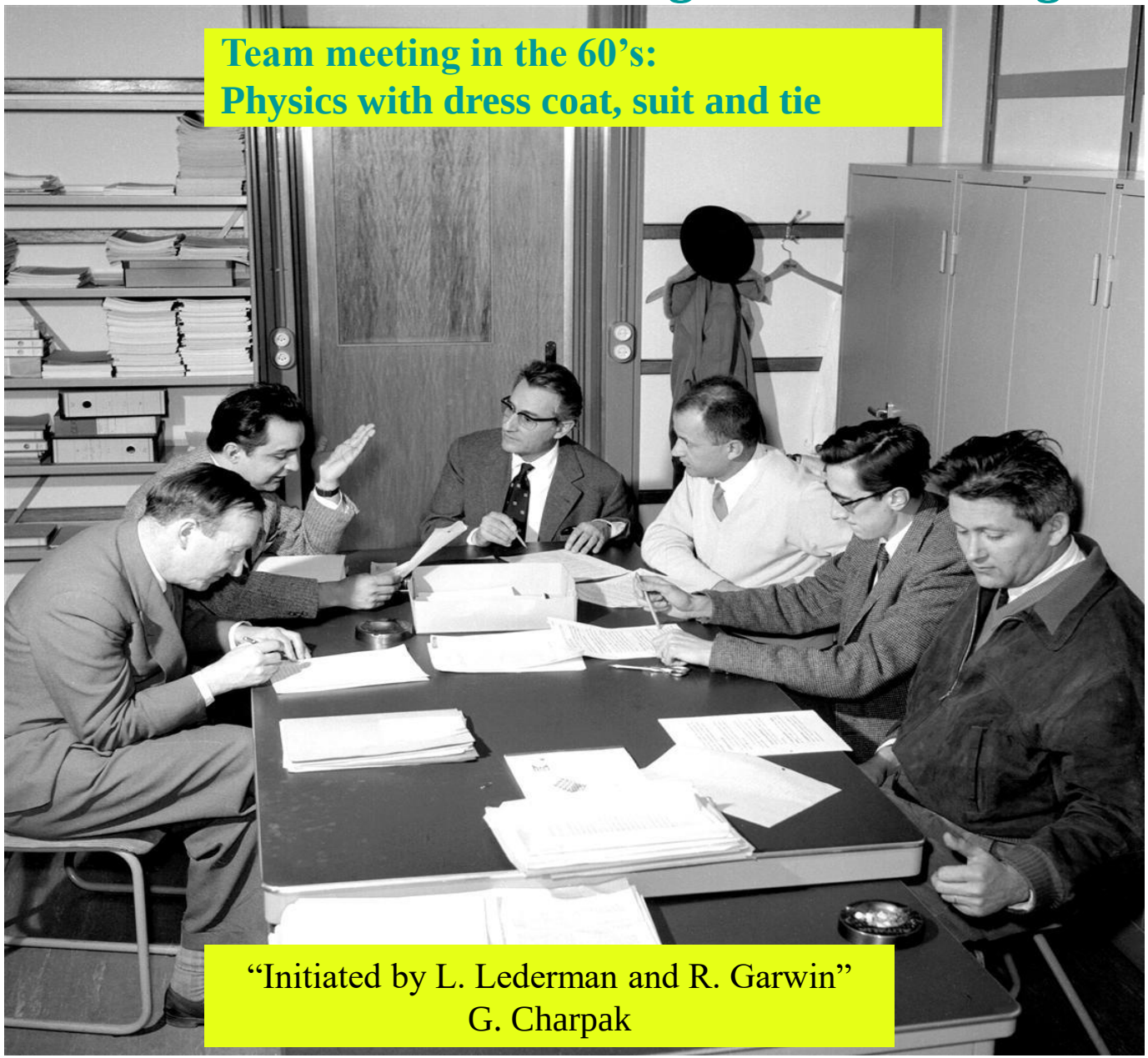


Photo: D. Parker, Science Photo Lab, UK

- Born in Dabrowica, Poland on 1924
- Moved from Poland to Paris on 1931
- During 2nd war served in resistance and imprisoned
- On 1944 he was deported to the Nazi concentration camp at Dachau
- On 1955, Phd from the College de France, Paris, under Frederic Joliot-Curie
- On 1985 member of the French Academy of Science
- Nobel Prize for Physics on 1992

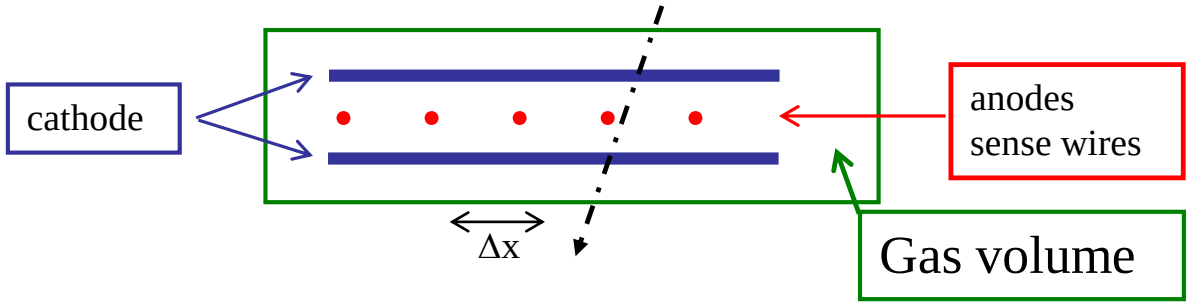
His first particle physics experiment
The muon anomalous magnetic moment: g-2



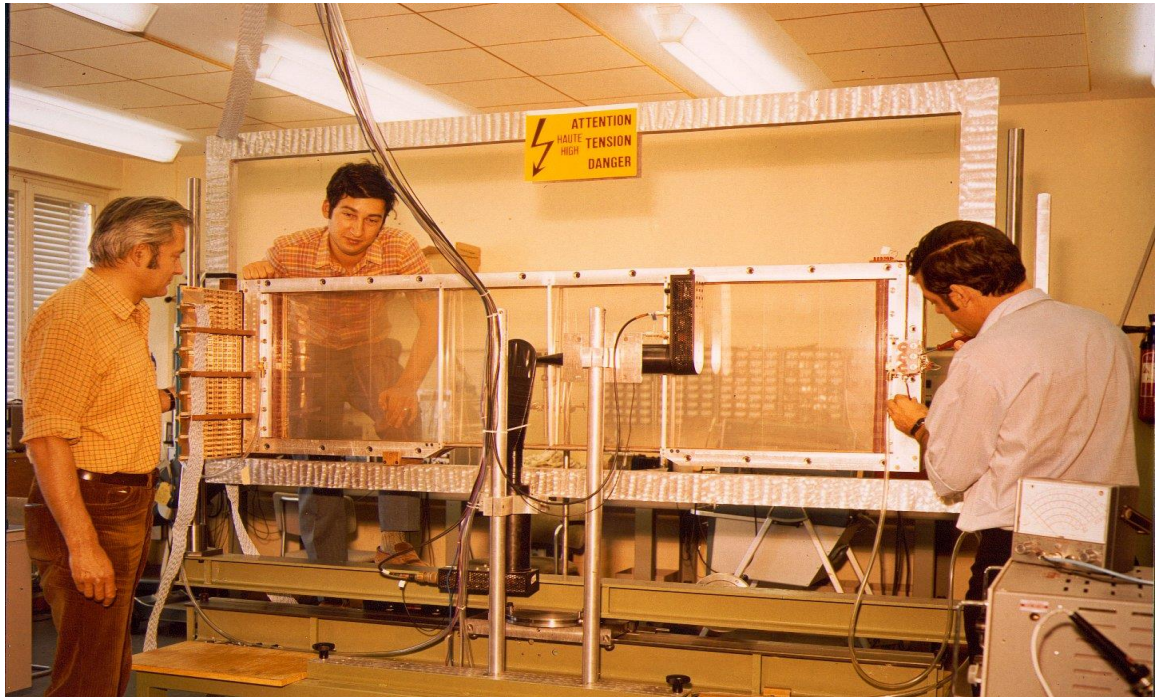
Multiwire Proportional Chamber (MWPC)

G. Charpak et al., Nucl.Instrum.Meth.62:262-268,1968
G. Charpak, D. Rahm, H. Steiner, NIM80:13-34,1970
G. Charpak, Ann.Rev.Nucl.Part.Sci.20:195-254,1970

His previous experience at College de France with a cylindrical counter 'was of paramount importance'



The first MPWC



Experiments used MPWC

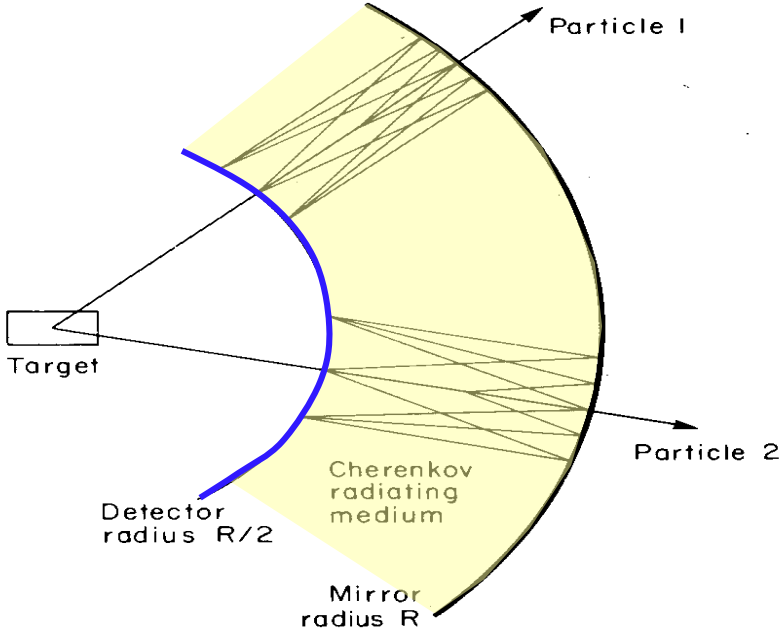
J- experiment at Brookhaven
Discovery of J/psi 1974
Headed by S. Ting

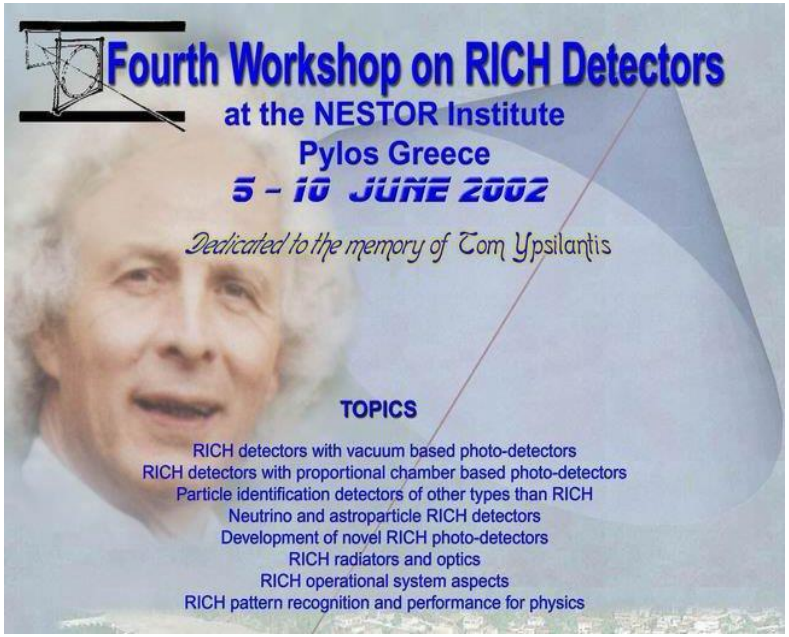
UA1 experiment at CERN
Discovery of W and Z,
Headed by C. Rubia

ATLAS and CMS at CERN
Discovery of Higgs boson 2012

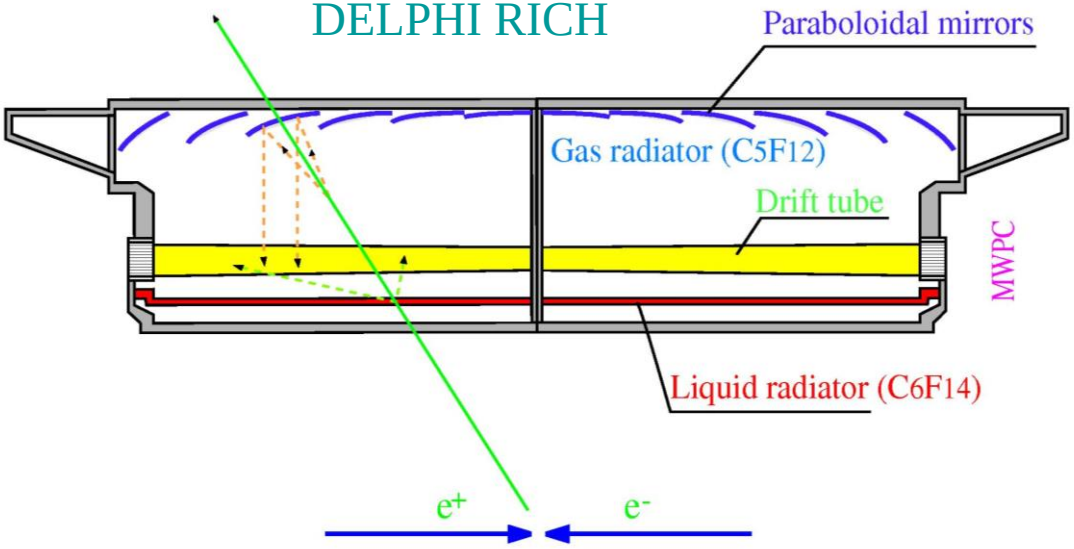
The Ring Imaging Cherenkov Counter (RICH)

J. Seguinot and T. Ypsilantis, Nucl. Instr. and Meth.142 (1977) 377

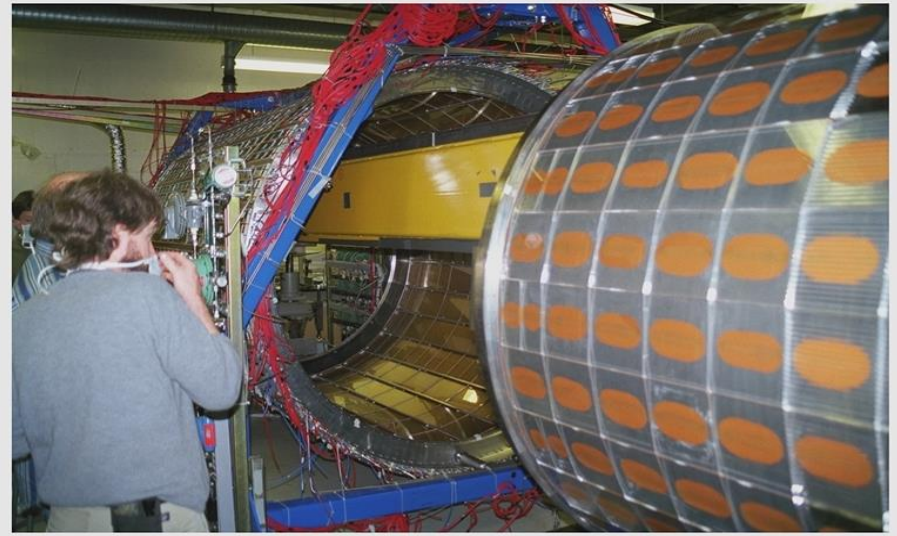




DELPHI RICH

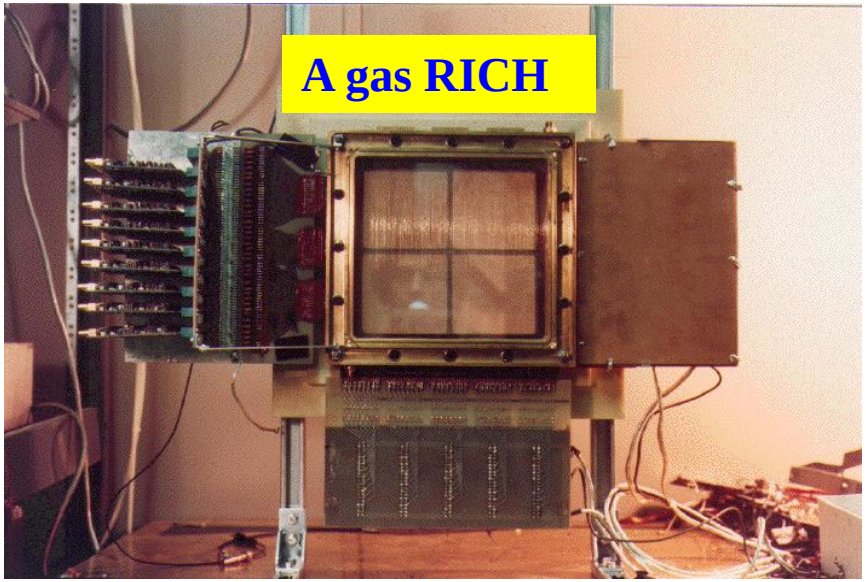


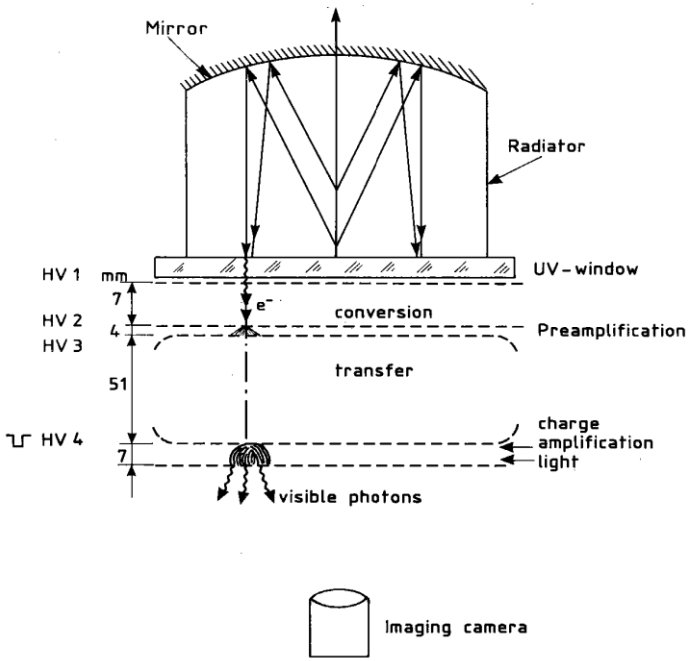
CLEO fast RICH

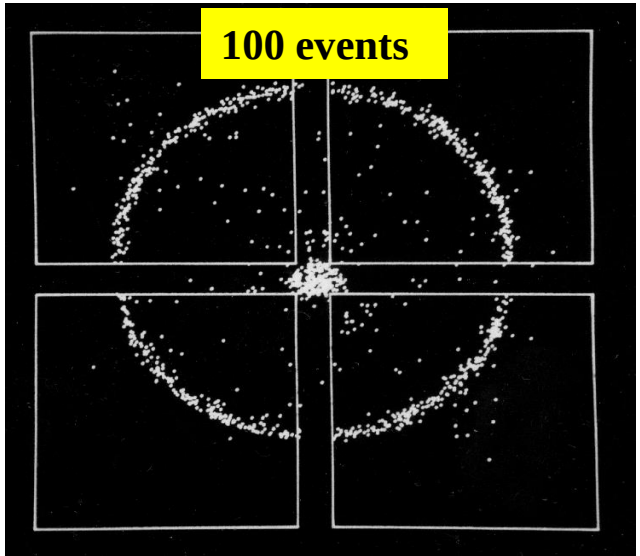


The imaging chamber

Georges Charpak, W. Dominik, J.P. Fabre, J. Gaudaen, V. Peskov, F. Sauli, M. Suzuki ,
A. Breskin, R. Chechik, D. Sauvage, IEEE Trans.Nucl.Sci.35:483-486,1988.
Y. Giomataris, A. Gougas, W. Dominik, Georges Charpak, F. SaulI, N. Zaganidis, NIMA279(1989)322

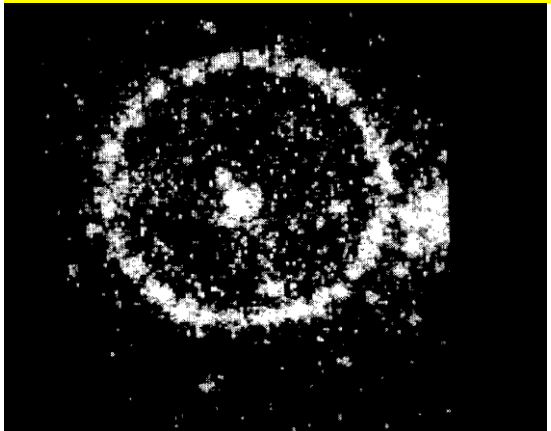






A single electron shower

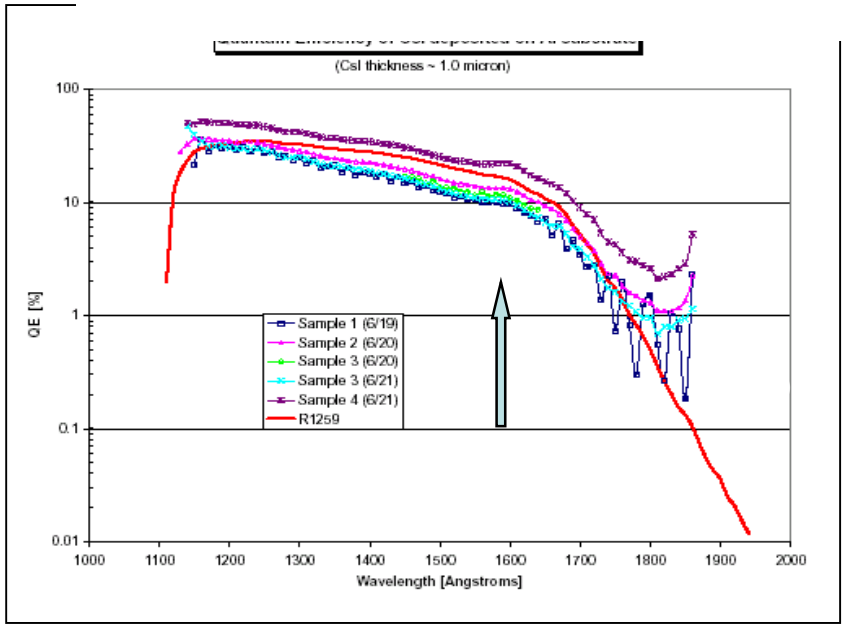
G. Charpak, Y. Giomataris,, A. Gougas,NIM.A343:300,1994.

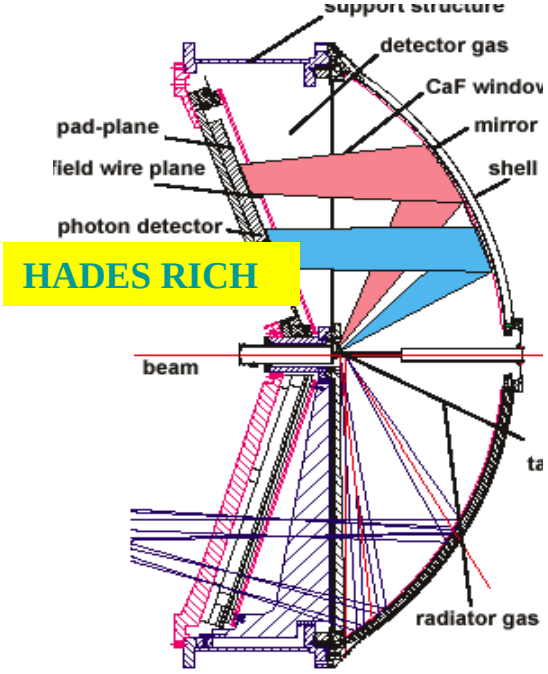


Solid photocathodes: CsI + gaseous detector

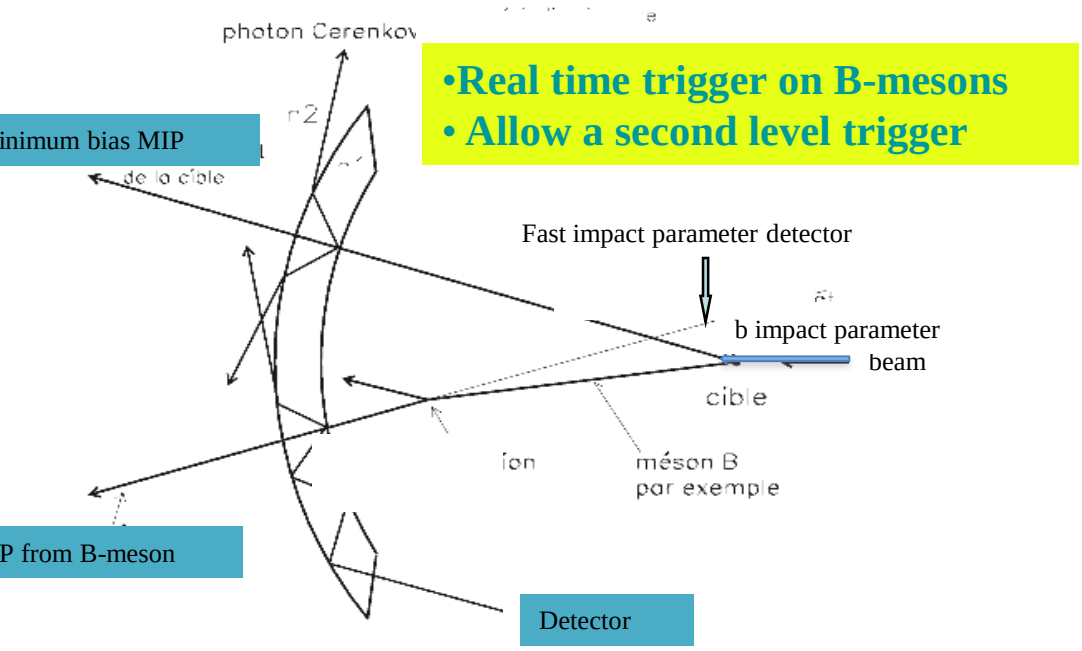
J. Seguinot, Georges Charpak, Y. Giomataris, V. Peskov, J. Tischhauser, T. Ypsilantis, NIM.A297:133-147,1990

A. Breskin, Nucl.Instrum.Meth.A371:116-136,1996.
F. Piuz et al.,Nucl.Instrum.Meth.A433:178-189,1999
D. Anderson, S. Kwan, V. Peskov, B. Hoeneisen,
Nucl.Instrum.Meth.A323:626-634,1992



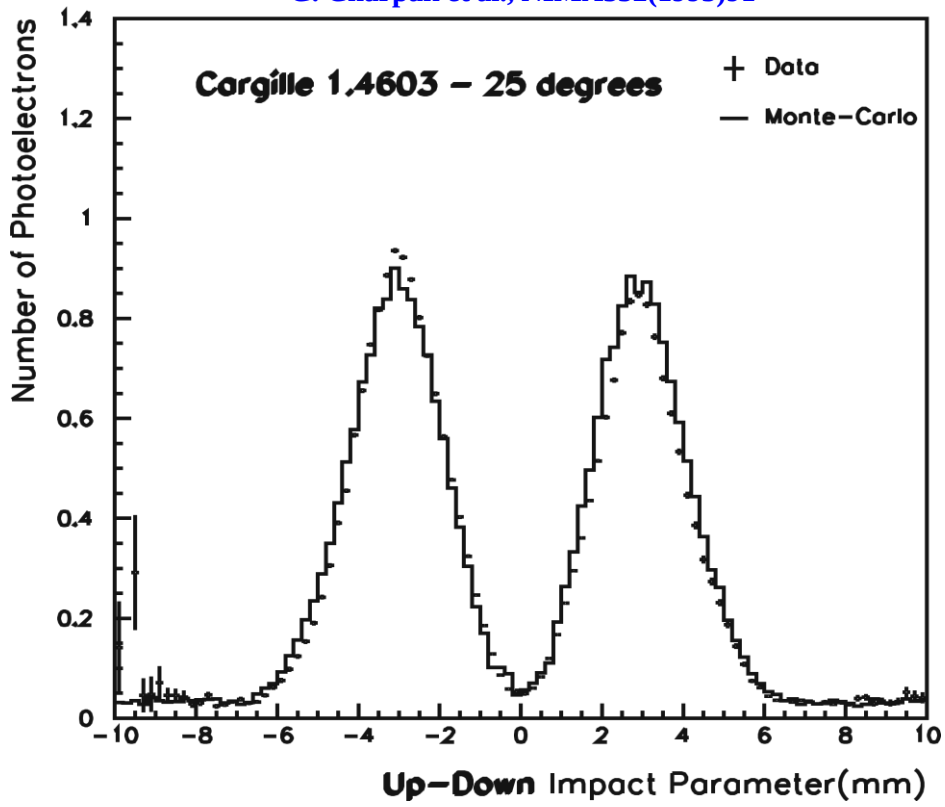


The trigger for Beauty *G. Charpak, I. Giomataris, L.Lederman, NIMA306(1991)439*
Developed by Lausanne Uni, Saclay,CERN

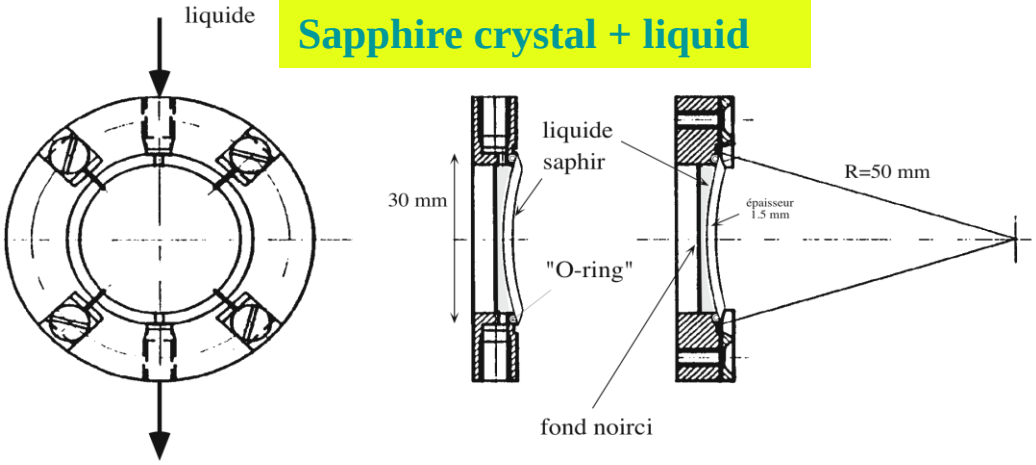


- **Real time trigger on B-mesons**
- **Allow a second level trigger**

G. Charpak et al., NIMA332(1993)91-



Sapphire crystal + liquid



Designed for a fixed target experiment GAJET
Not approved

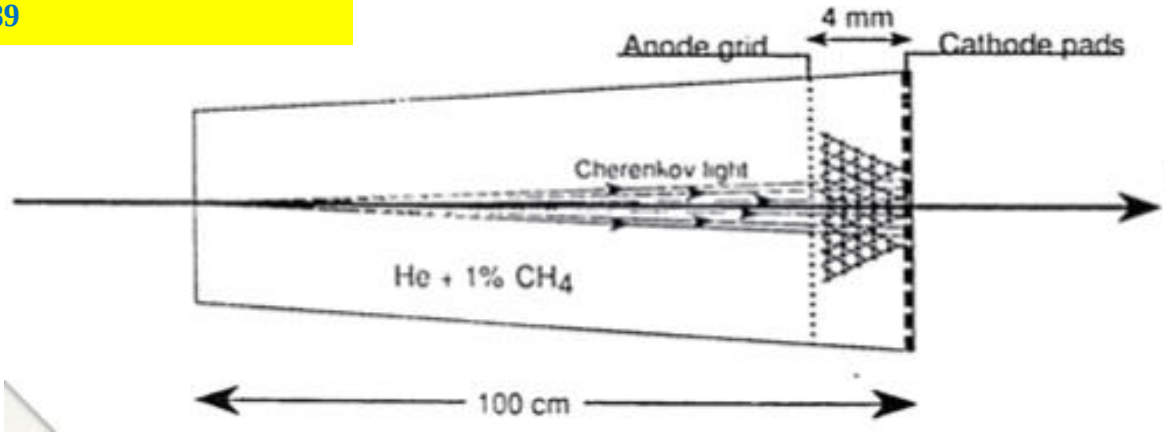
The Hadron Blind Detector

I. Giomataris,G. Charpak, NIM A310(1991)589

No windows Large bandwidth

CF_4 provides the largest bandwidth

Y. Giomataris, G. Charpak, V. Peskov and F. Sauli, Nucl.Instrum.Meth.A323:431,1992



1992 First succesfull test at the SPS - CERN

MIT, CERN, Lausanne, ITEP,

M. Chen et al., NIM A346(1994)120

N_0 =500 measured,,good electron efficiency with a hadron rejection factor of > 30

Main background:

- Ionisation produced in the PPL plate gap 4mm
- Micromegas is an ideal detector gap .1mm

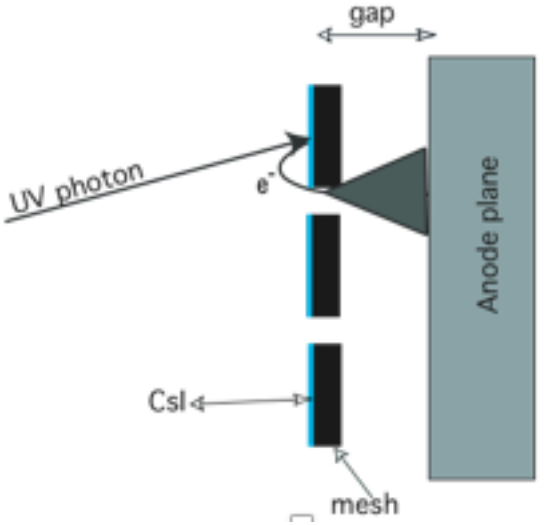
1992 Proof of principle

First succesfull test at the SPS - CERN

Collabotion MIT, CERN, Lausanne, ITEP,

M. Chen et al., NIM A346(1994)120

N_0 =500 measured,,good electron efficiency with a hadron rejection factor of > 30



HBD concept verified by R.P. Pisani et al.,

Nucl.Instrum.Meth.A400:243-254,1997

Some new ideas

Neutrino Exploration Of The Earth.

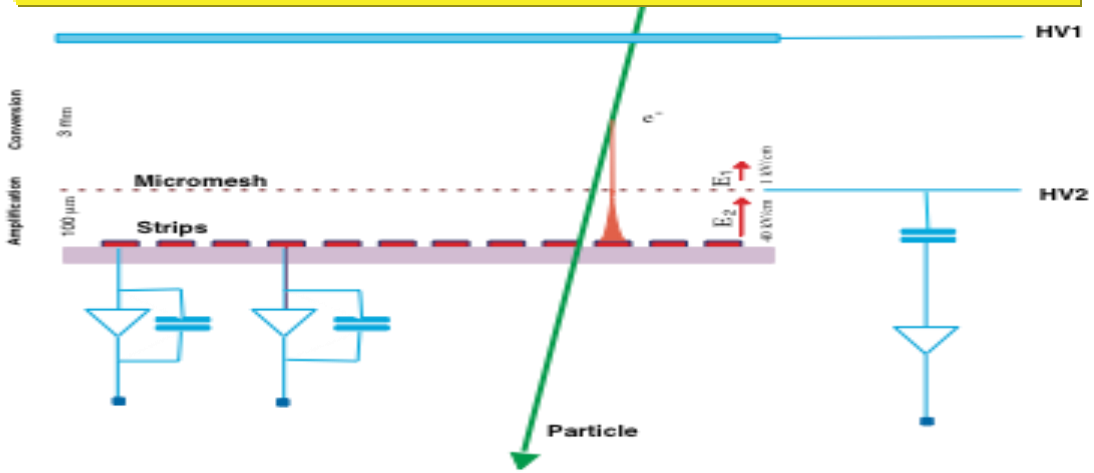
A. De Rujula, S.L. Glashow, Robert Rathbun Wilson, Georges Charpak, Phys.Rept.99:341,1983.

Laboratory party

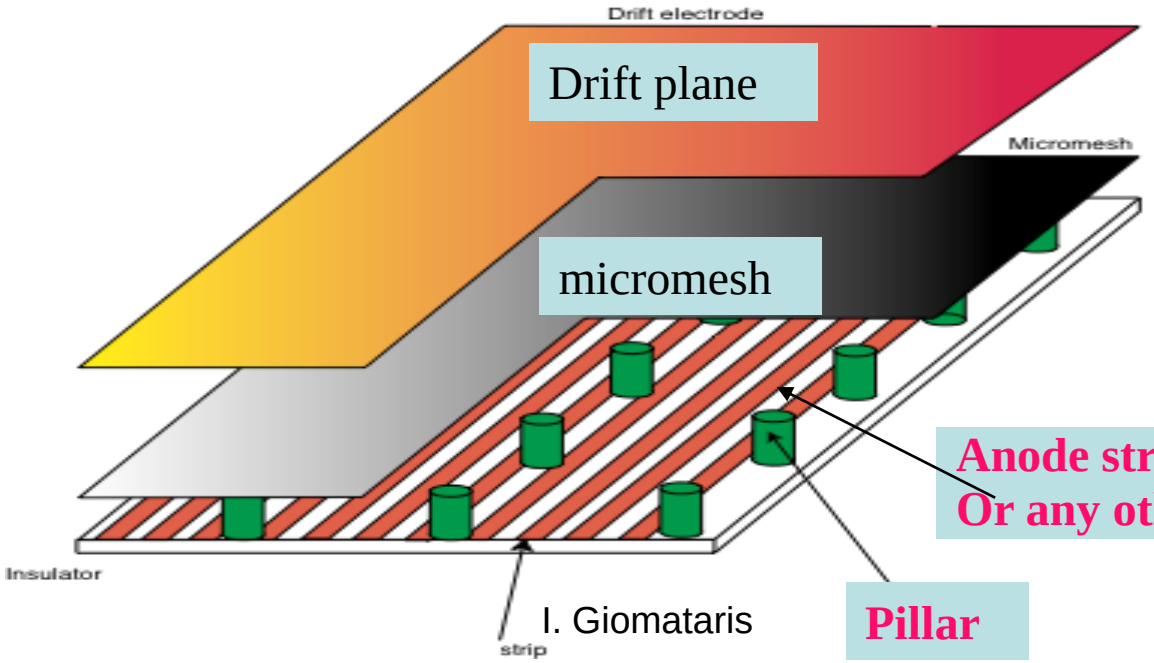
Is it possible to discuss physics in Corsica?

MICROMEGAS

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



In 1st Micromegas
Fishing line spacers have been used



Virtue of the small gap

Y. Giomataris, NIM A419, p239 (1998)

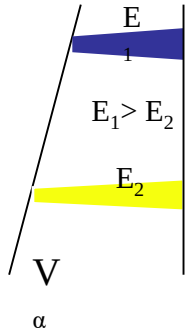
Parallel plate detector gain: $G = e^{\alpha d}$

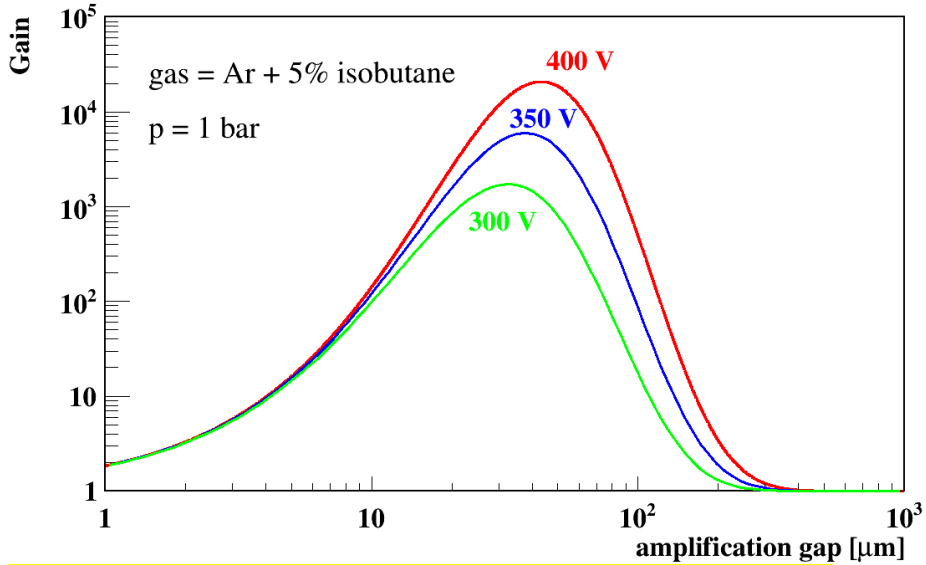
Townsend α: $a = \frac{p}{\lambda} e^{-\frac{I_e}{\lambda}\frac{pd}{V_a}}$

$$\frac{\delta G}{G} = G\left(1 - \frac{I_e}{\lambda}\frac{pd}{V_a}\right)\frac{\delta d}{d}$$

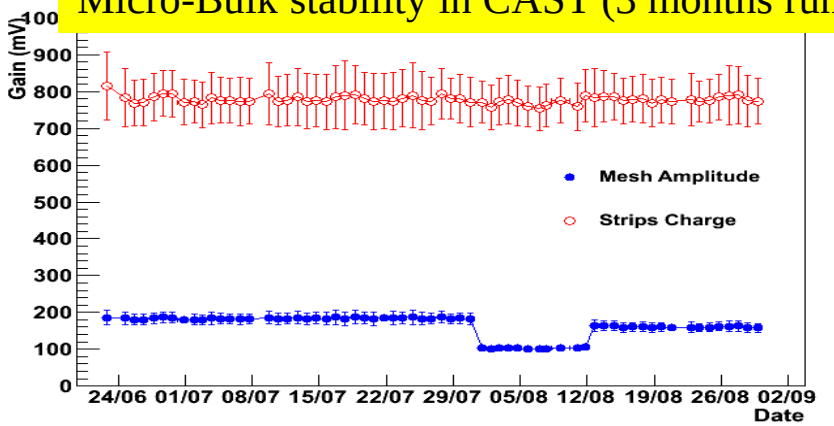
The gain variation is reaching a minimum for :

$$d = \frac{V_a}{p}\frac{\lambda}{I_e}$$





Micro-Bulk stability in CAST (3 months run)



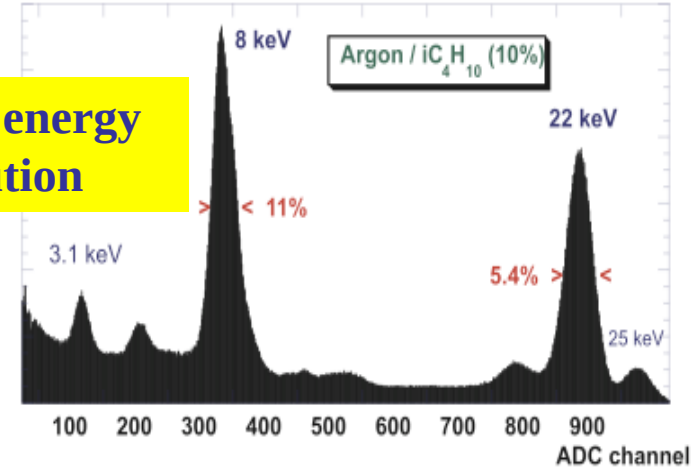
Stable gain and low sensitivity to flatness defects or temperature and pressure variation, good energy resolution

Micromegas performance

High radiation resistance : > 30 mC/mm2 > 25 LHC years

G. Puill, et al., IEEE Trans. Nucl. Sci. NS-46 (6) (1999)1894.

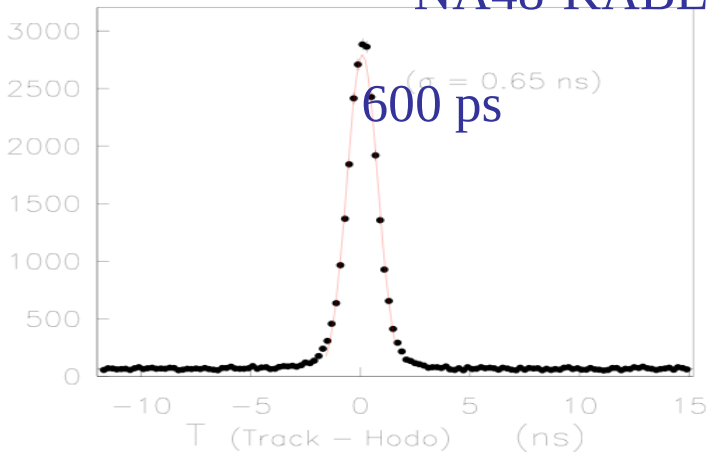
Good energy resolution



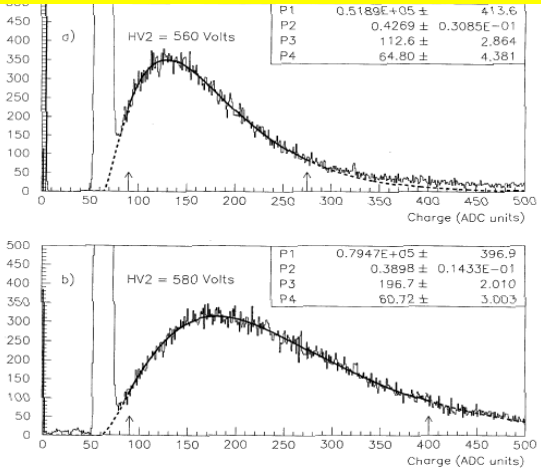
A. Delbart, ***Nucl.Instrum.Meth.A461:84-87,2001***

Sub-nanosecond time resolution

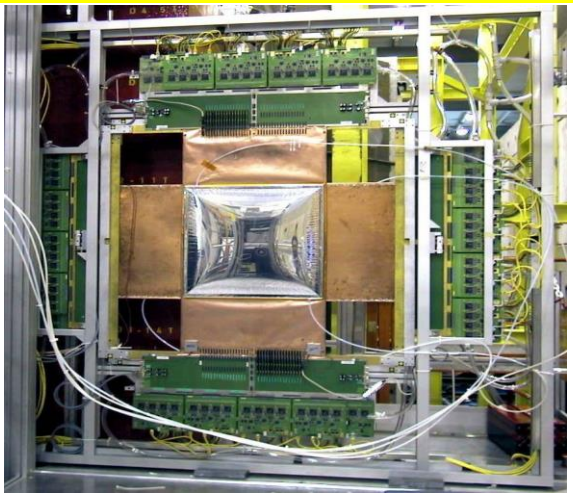
NA48-KABES



Excellent single electron resolution

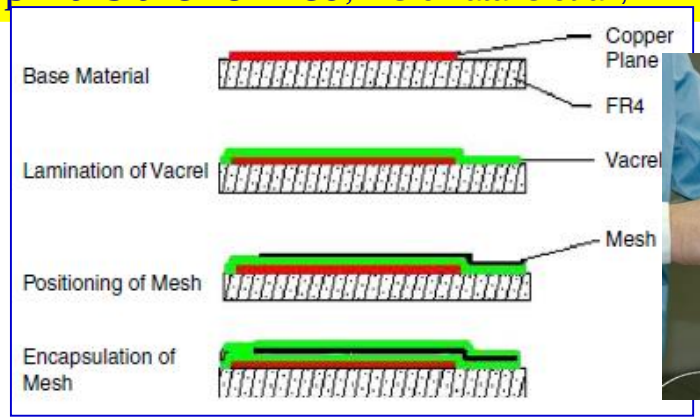


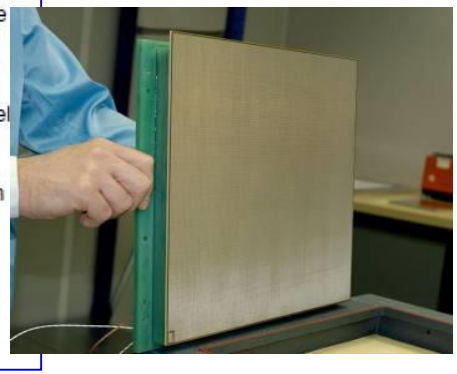
COMPASS: large 40x40 detectors



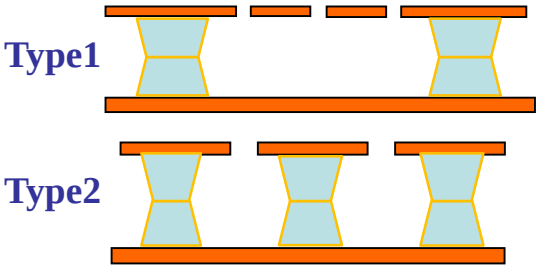
Micromegas fabrication technologies

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*





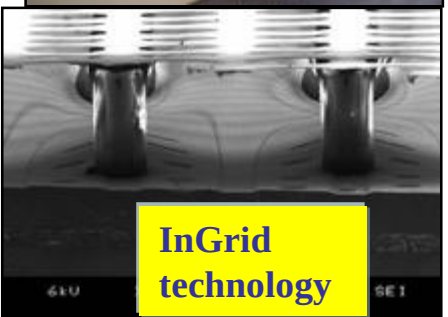
micro-Bulk,
50 μm, 25 and 12.5 μm gaps fabricated



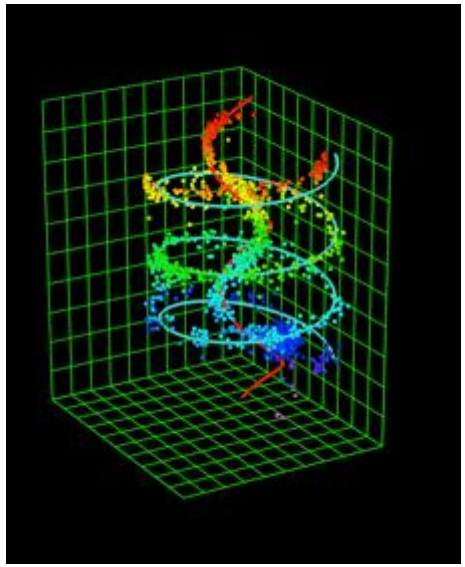
Very good energy resolution 11% at 5.9 keV
- **Flexible structure (cylinder)**
- **Low material**
- **Low radioactivity**

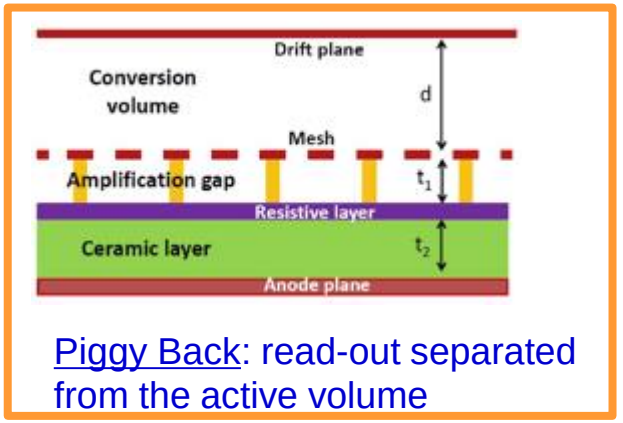
Piggy Back: read-out separated from the active volume

Micromegas + micro-pixels

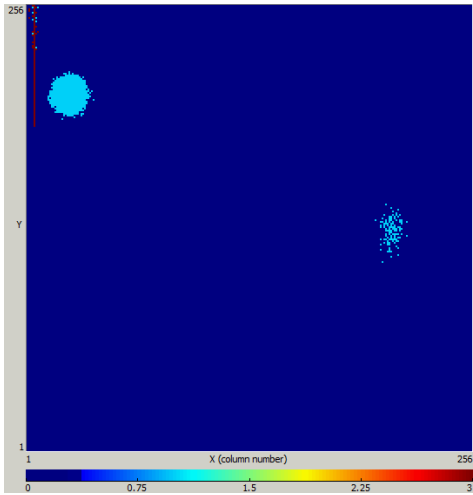


InGrid technology



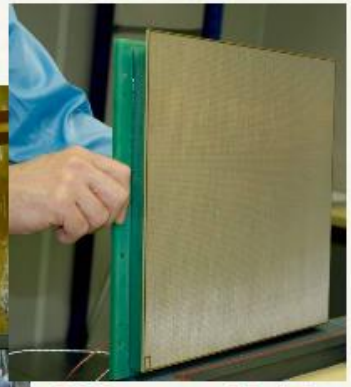


Piggy Back: read-out separated from the active volume



MM-bulk first application: T2K

Operational in 2009

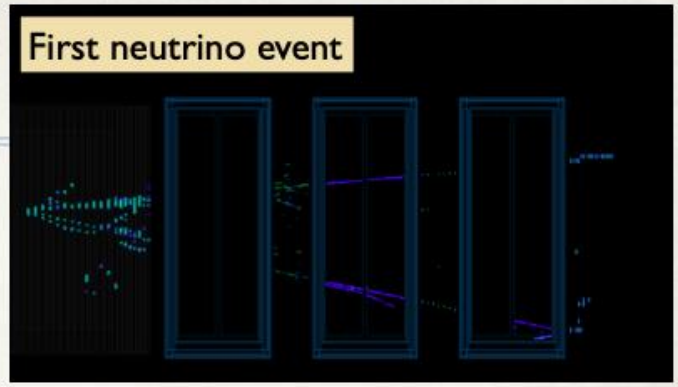


1 Micromegas Module
=
34 x 36 cm²
1726 pixels (10x7 mm²)

3 TPCs → 72 modules → 9 m²

125000 channels

1700 chips AFTER
400 FEC boards
72 FEM boards



High-Angle TPC (2018-) for ND280 upgrade

ND280 @ JPARC

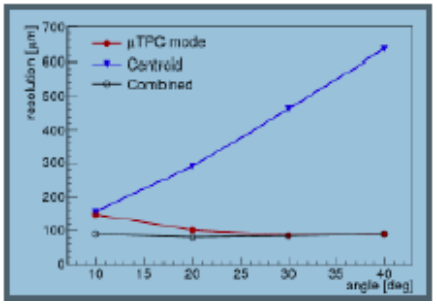
Towards Larger Micromegas

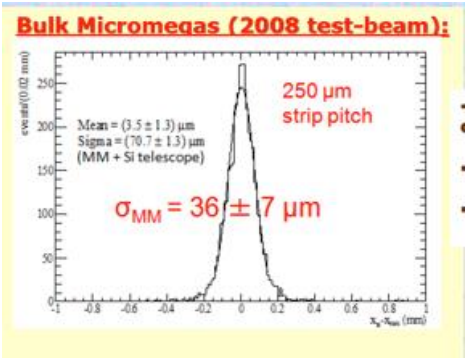
1st prototype
45x35 cm^2

ATLAS-MAMMA muon system,

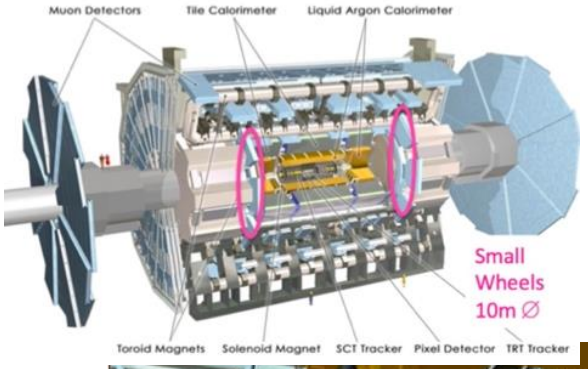
Joerg Wotschack, Mod.Phys.Lett. A28 (2013) 1340020

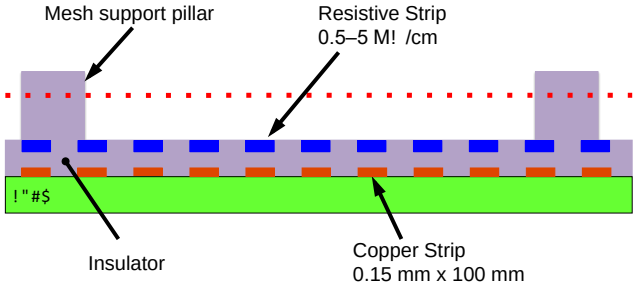
T. Alexopoulos, et al. NIM. A 640, 110-118, (2011).



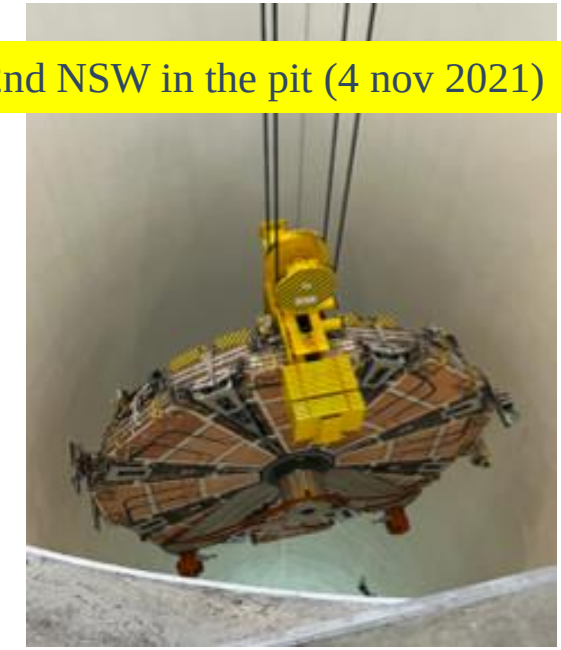


The Atlas New small wheels Upgrade

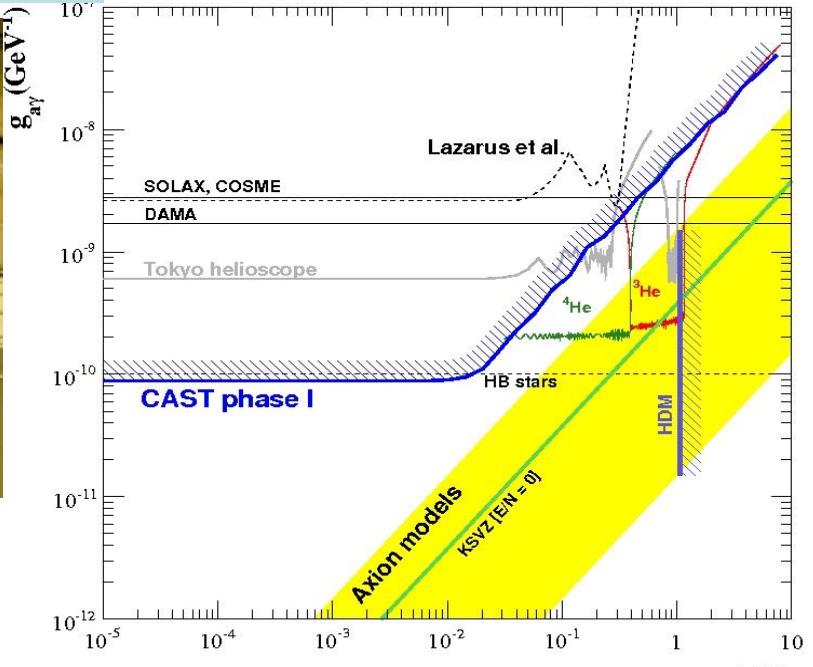




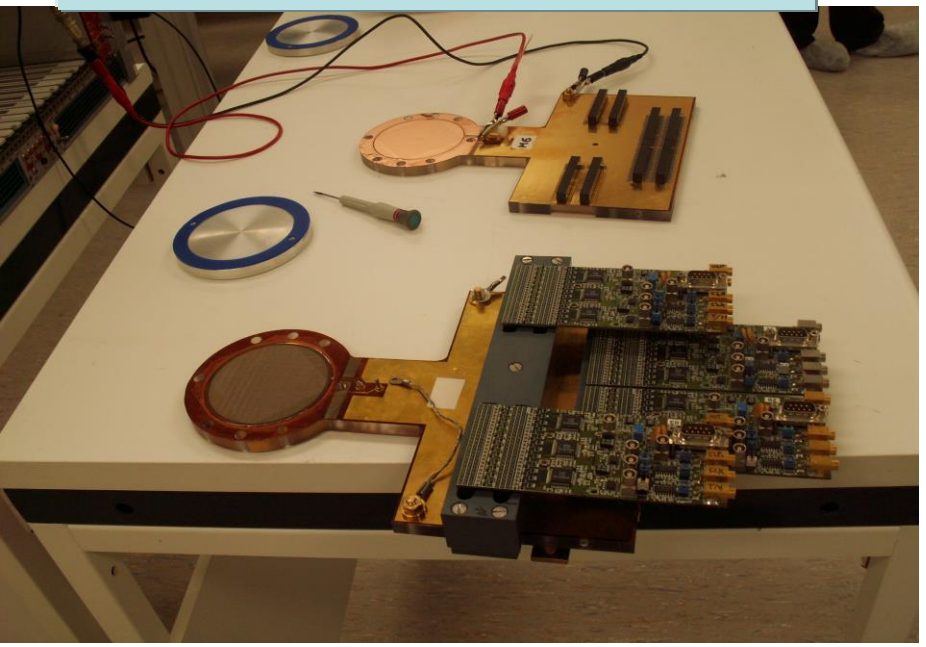
2nd NSW in the pit (4 nov 2021)

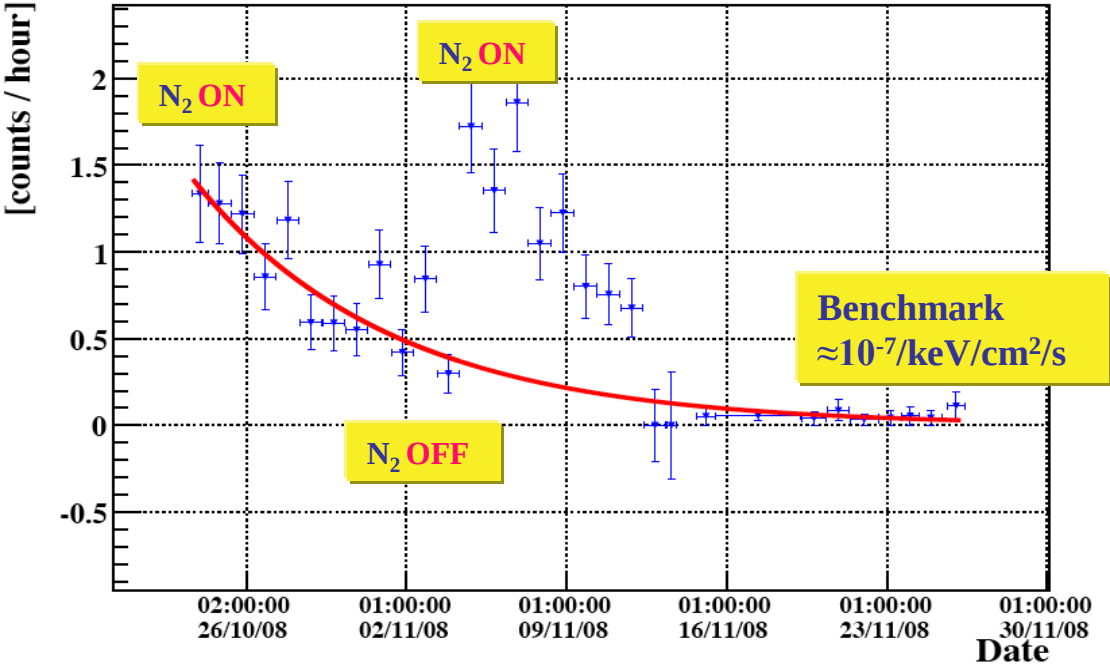


Micro-bulk in CAST - high performance



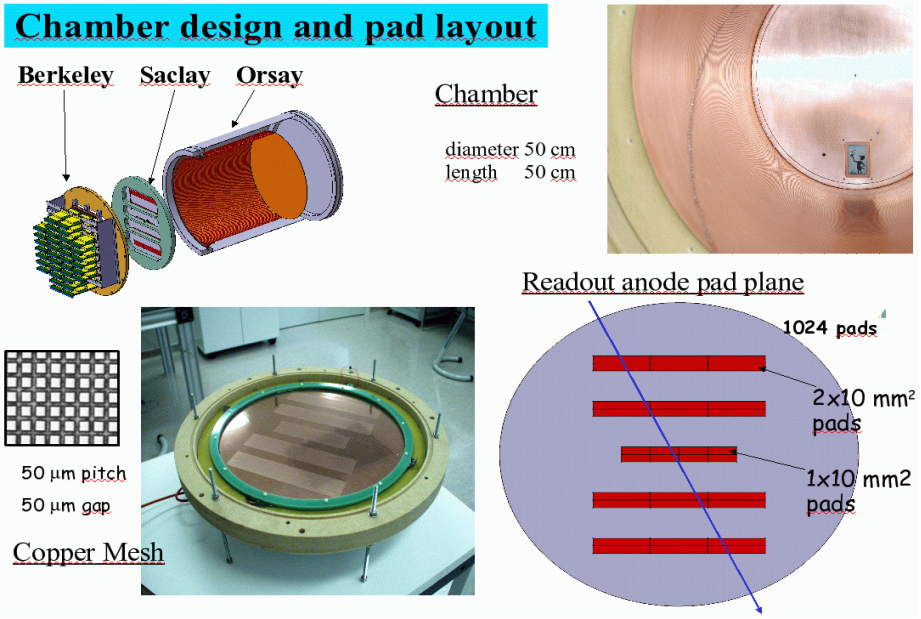
On low radioactivity support

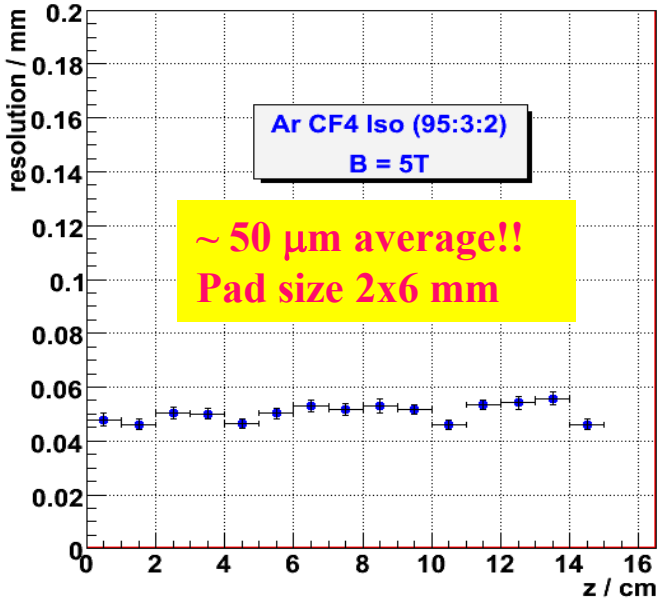




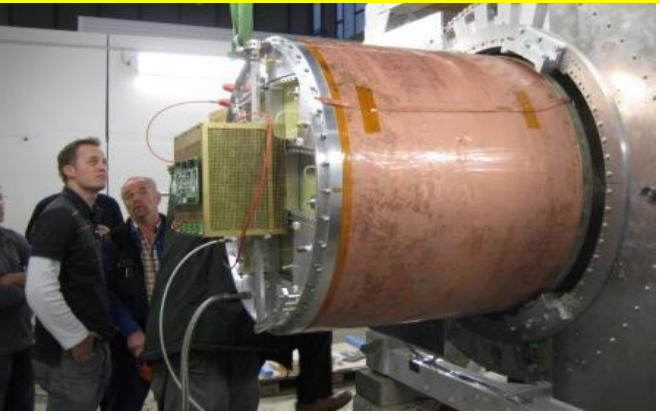
ILC TPC project

Large International collaboration

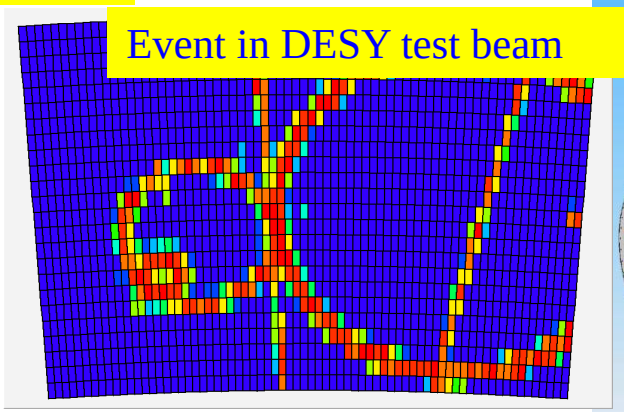




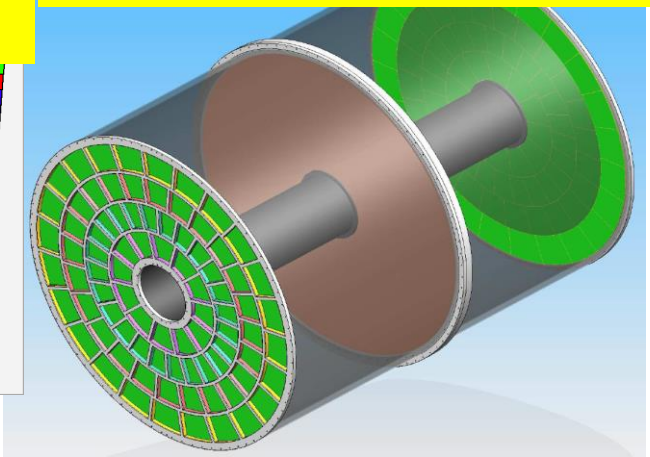
ILC TPC prototype with Micromegas



Event in DESY test beam



ILC TPC with Micromegas



Active participation in ‘Paris TPC Conference on rare event detection’

1st Workshop on December 2002

3rd Symposium on December 2006

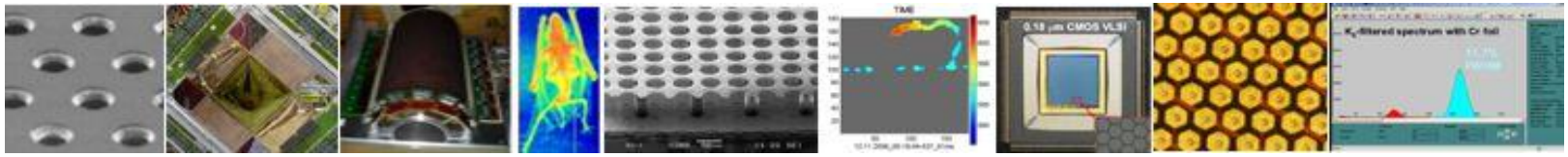
4th Symposium on December 2008

5th Symposium on December 2010

On 2004 RD51 Collaboration

~ 50 institutes declared interest

in the MPGD R & D Collaboration



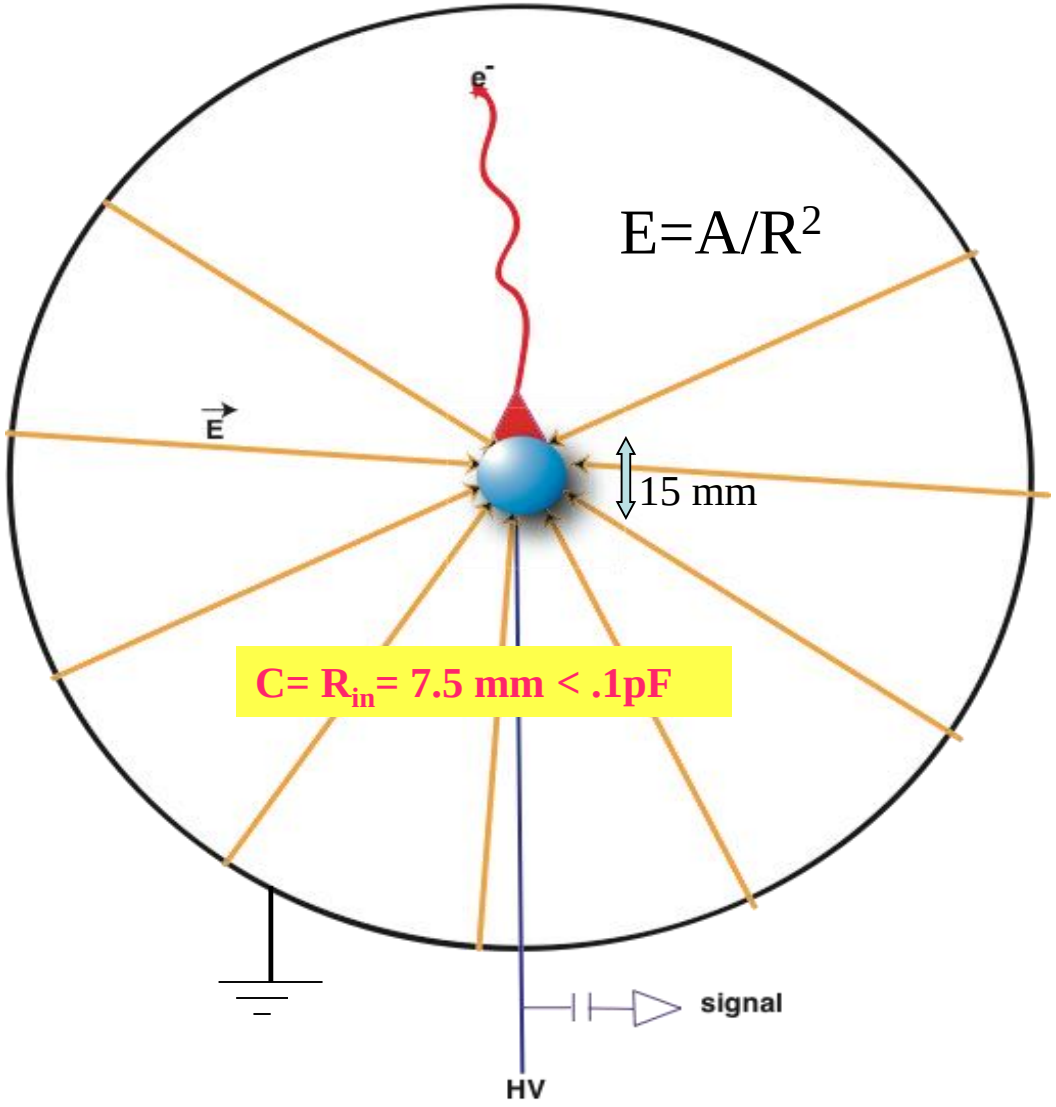
Current Trends in Micro-Pattern Gas Detectors (Technologies)

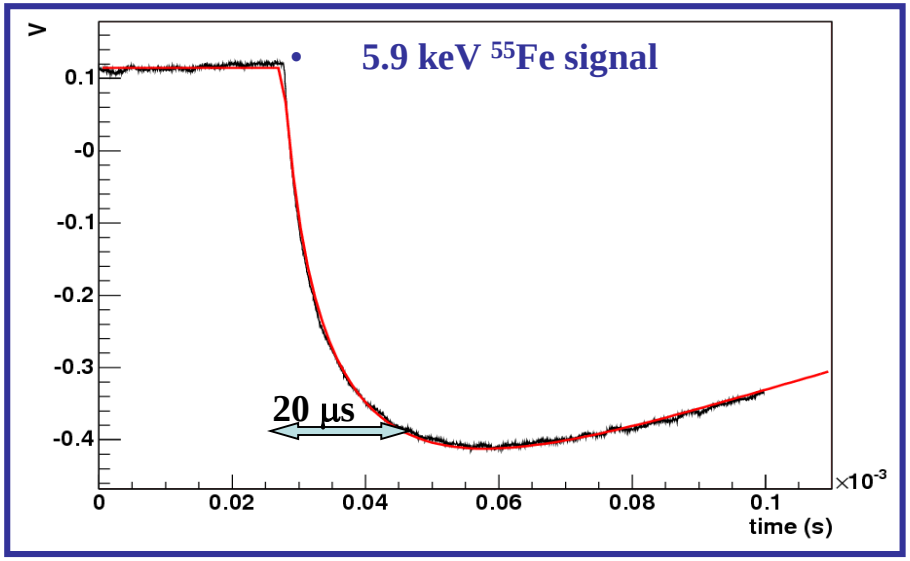
- Micromegas
- GEM
- Thick Thick-Hole GEM and RETGEM
- MPDG with pixel ASICs
- Ingrid Technology

2009 Kolympari, Crete, Greece
2011 Kobe, Japan
2013 Zaragoza, Spain
2015 Trieste, Italy
2017 Philadelphia, US
2019 La Rochelle, France
2022 Rehovot, Israël
2024 Hefei, China

Radial TPC with spherical proportional counter read-out

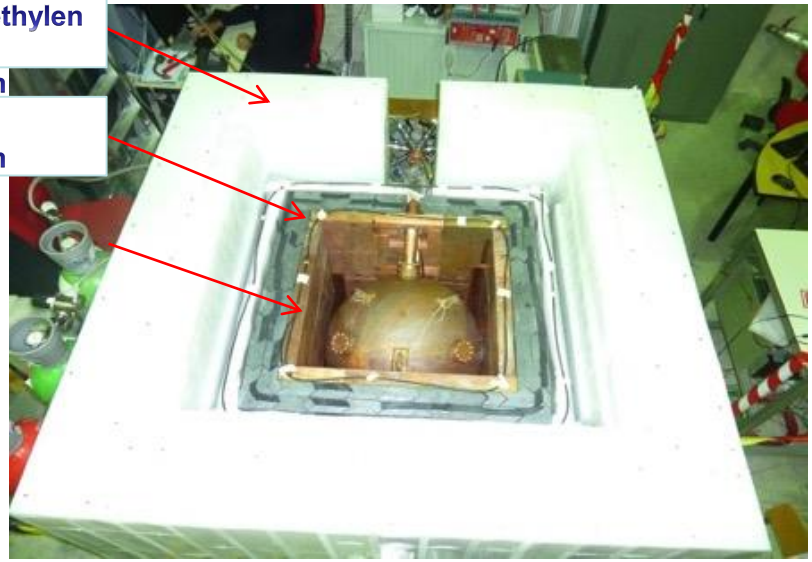
A Novel large-volume Spherical Detector with Proportional Amplification read-out, I. Giomataris *et al.*, JINST 3:P09007,2008



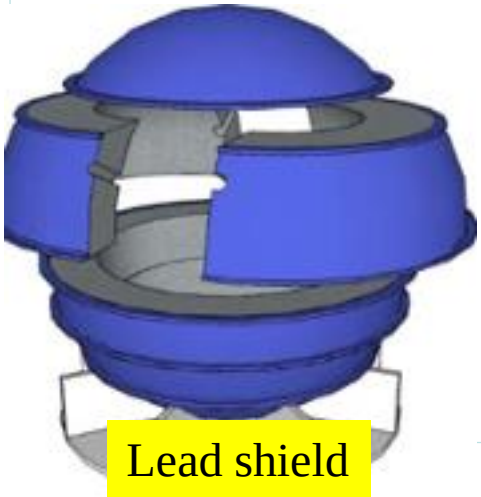


Multiball raed-out structure with DLC layer (from USTC)

NEWS-LSM: Exploration of light dark matter search at LSM
Gas targets: Ne, He, CH4 up to 10 bar



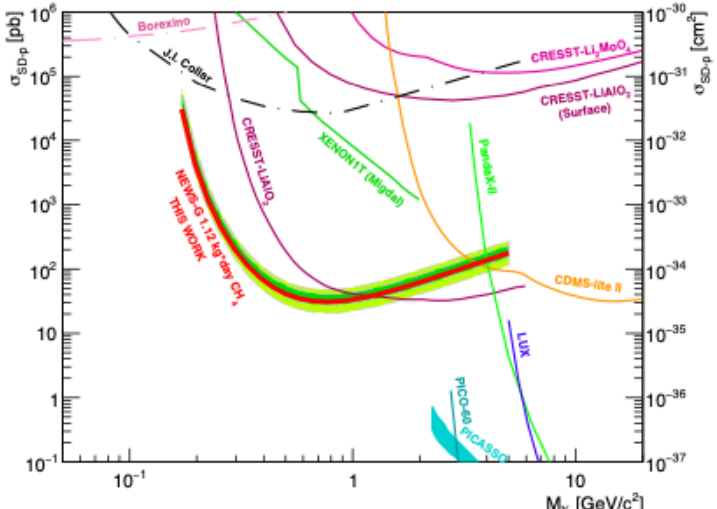
NEWS-G at SNOLAB with compact shield



Lead shield

Great low-mass WIMP sensitivity

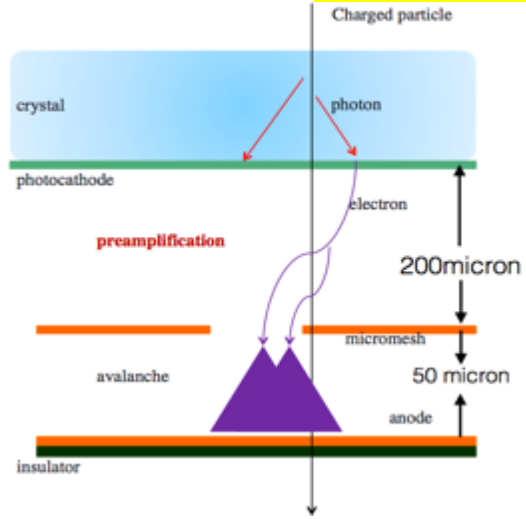
M. M. Arora et al., arXiv:2407.12769 **[hep-ex]**



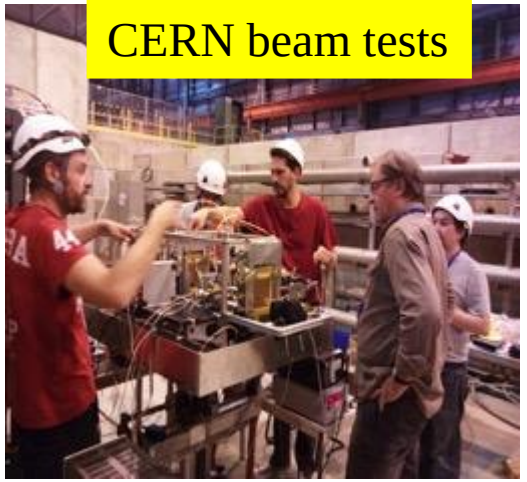
Georges last visit to our laboratory on 2009

Fast timing PICOSEC Micromegas project

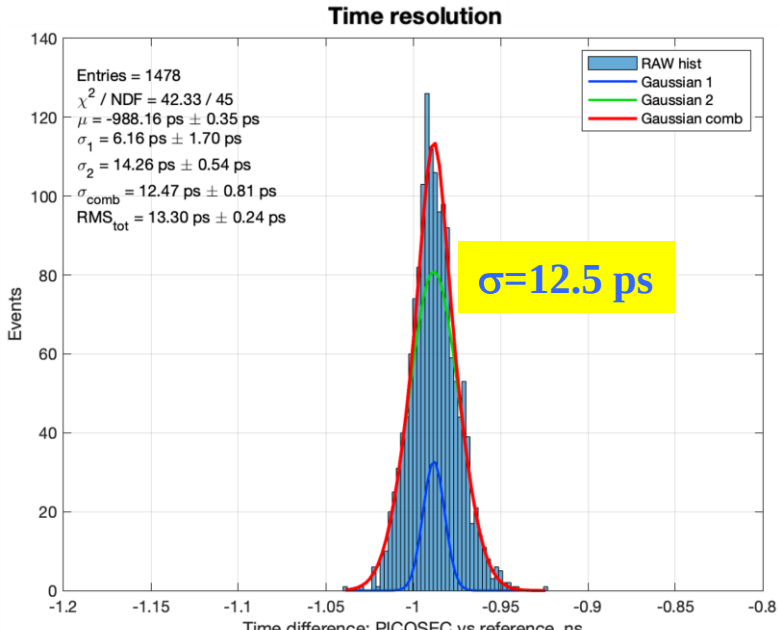
CEA-Saclay, CERN, Thessaloniki, Athens, Princeton, USTC, San Diego



Test with UV fs laser @ IRAMIS-CEA



UV Photocathodes on MgF window:
CsI, Cr, Al, Diamond, DLC, B4C…..



Major result in the SPS CERN beam

with CsI photocathode

- σ_t ~ **12.5 ps** , with single anode (∅=1cm)
- σ_t < **24 ps** **10 × 10 cm²** , prototypes (100 channels)

with **robust B_4C or DLC** photocathode,

- σ_t ~ **30–35 ps** , **10 × 10 cm²**

Creator of "La Main a la Pâte,"
Education in primary through science in France
an idea first initiated in Chicago by his friend Leon Lederman.

MUSIC AND EDUCATION

Stamp 2016

Thank you Georges
For your unforgettable heritage