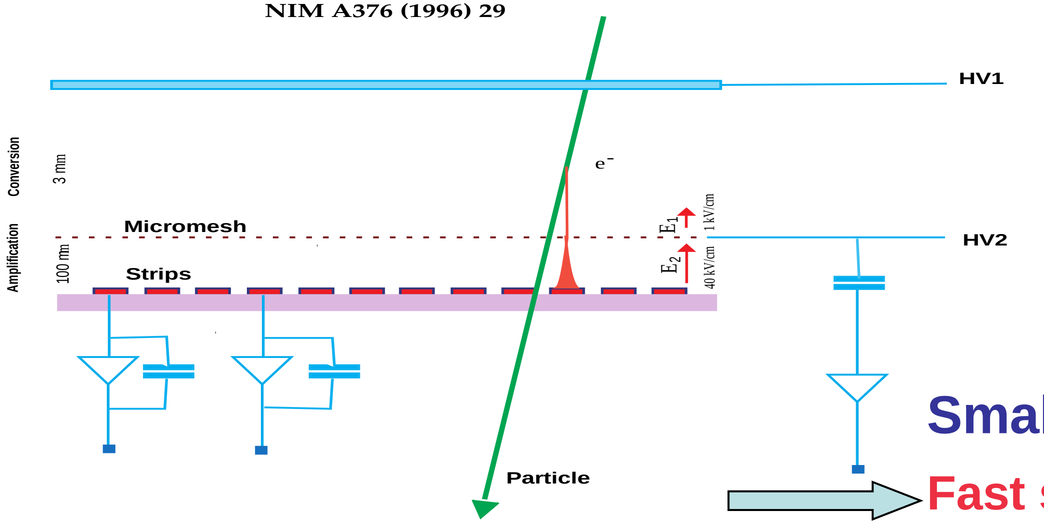
Micromegas detector for fast timing

Giomataris Ioannis, CEA-Saclay

- Micromegas technology and prospects
- Past experiments with sub-ns time resolution
- Photodetector and applications
- Towards ultimate time resolution
  in photodection mode
- Conclusions

MICROMEGAS

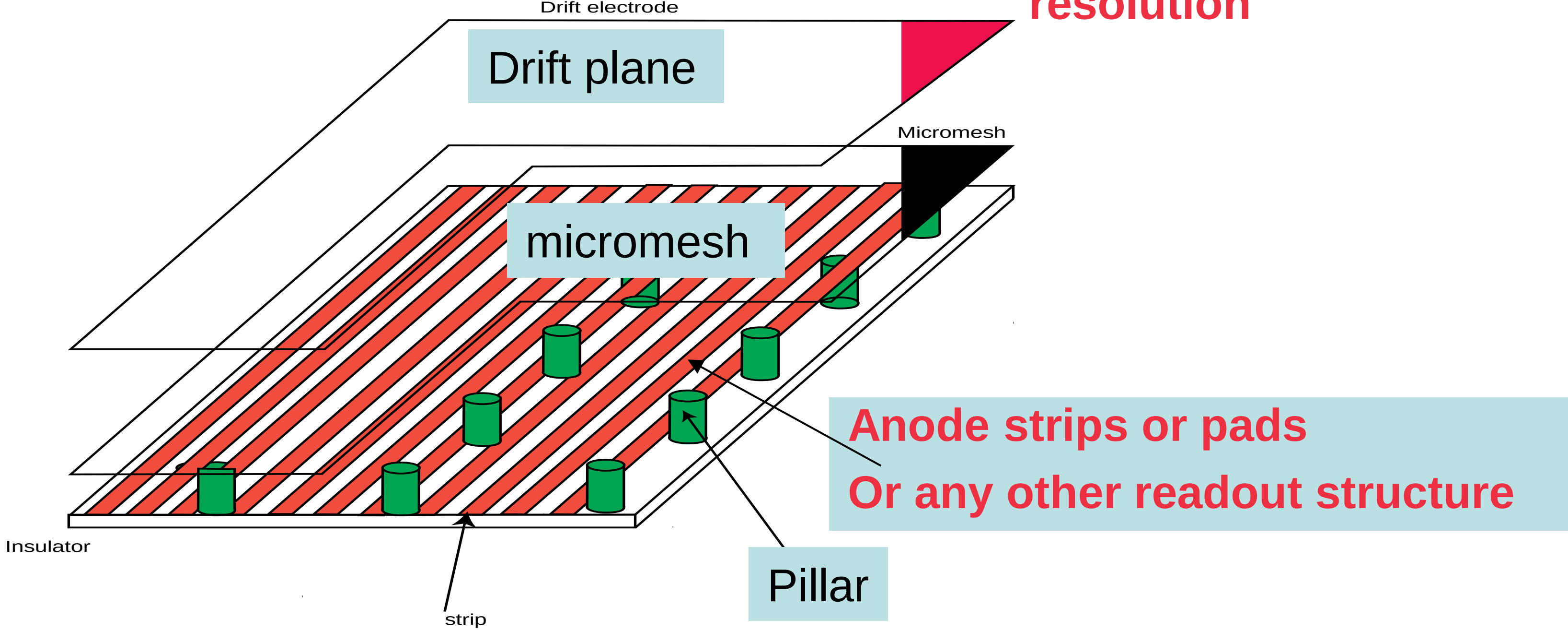
Y.Giomataris, Ph. Rebourgeard, J.P Robert and G. Charpak
NIM A376 (1996) 29



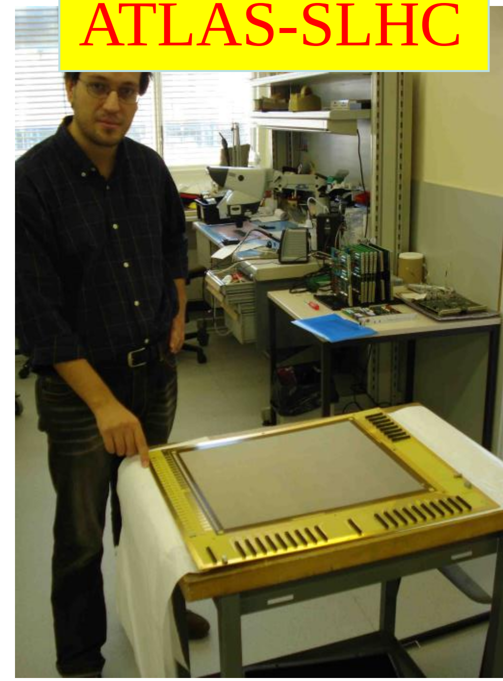
Small amplification gap

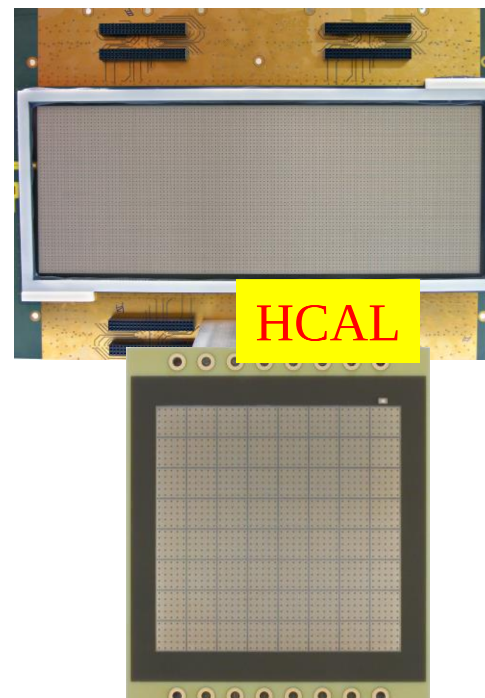
→ **Fast signals**

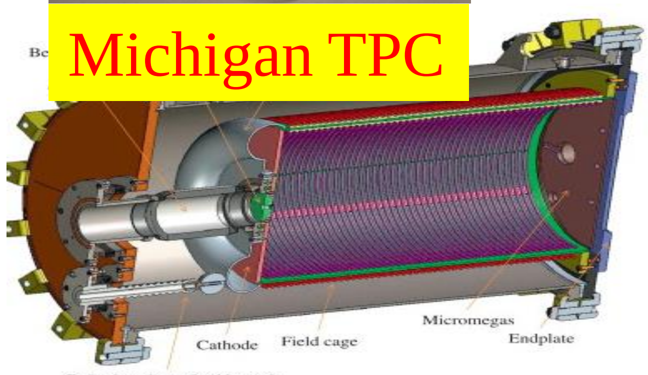
→ **Good time and space resolution**



Some experiments using **Bulk Micromegas**

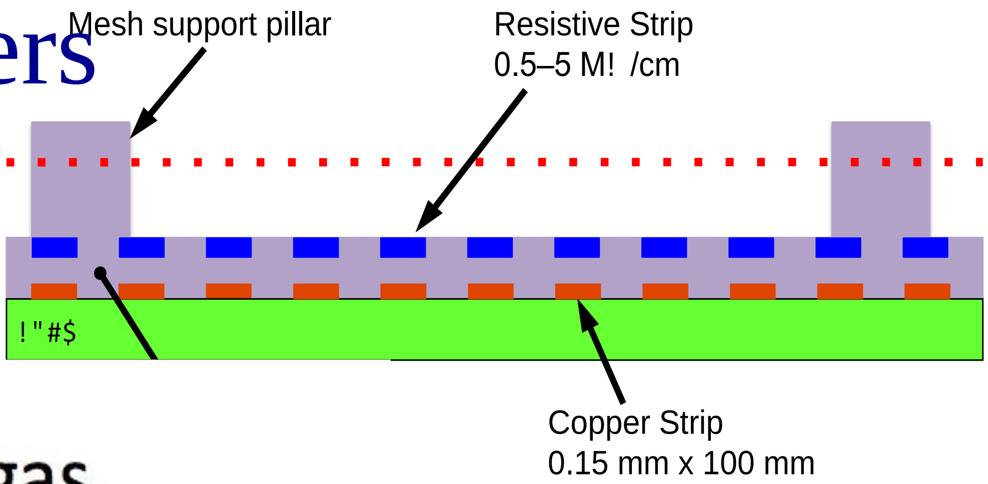






ATLAS large chambers

Resistive strip technology



1 x 1 m² micromegas

1 x 1 m² readout board composed of 2 boards of 0.5 x 1 m²
2048 strips of 1.06 m length with a pitch of 0.45 mm

Drift electrode and mesh panel (top) and
detail showing the O-ring as gas seal

Industrialization is going on Through CIREA, ELTOS, Triangle Labs (US)

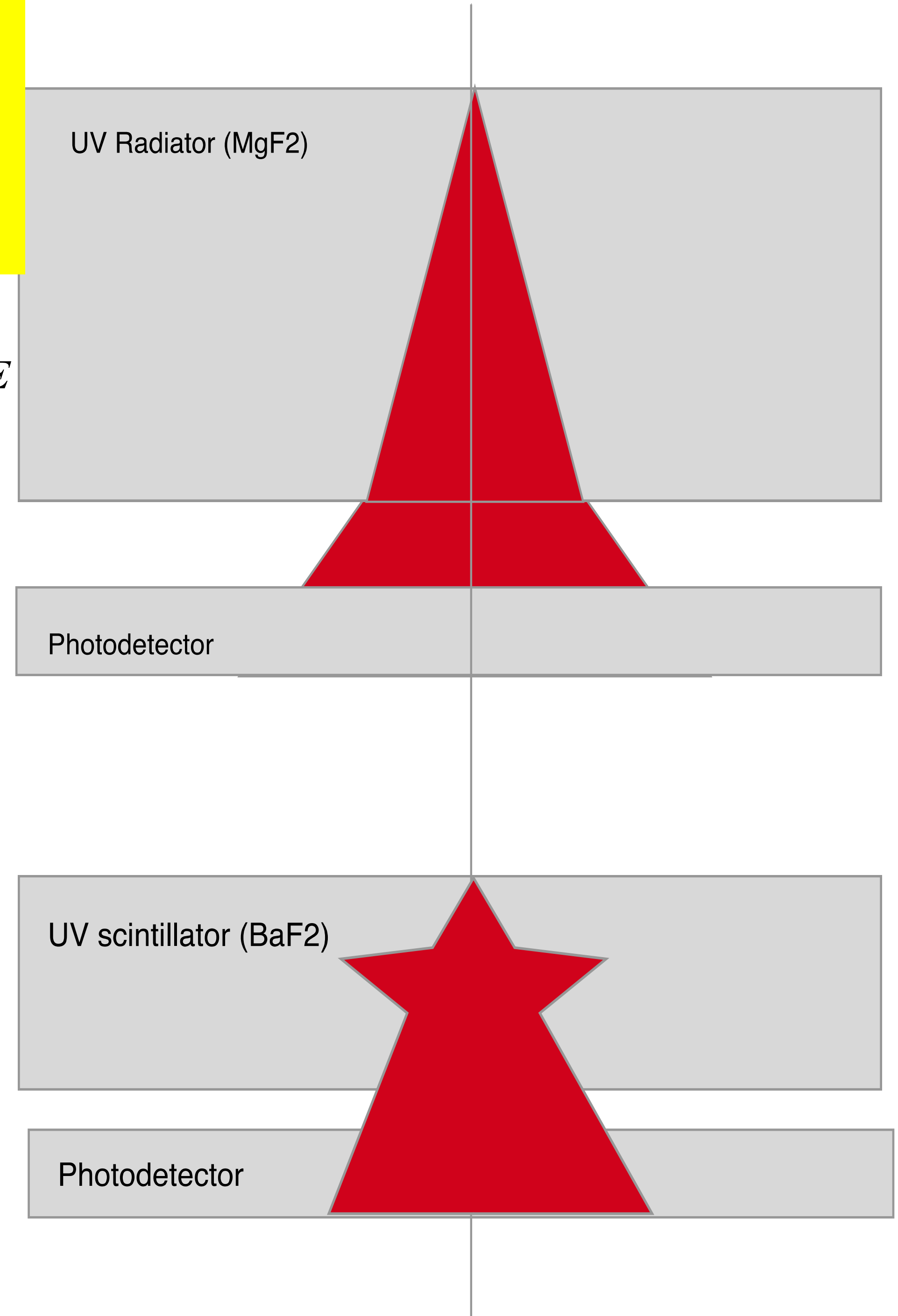
How to get fast signals?

- Cherenkov light detected
- by Micromegas photodetector
- Fast scintillation light

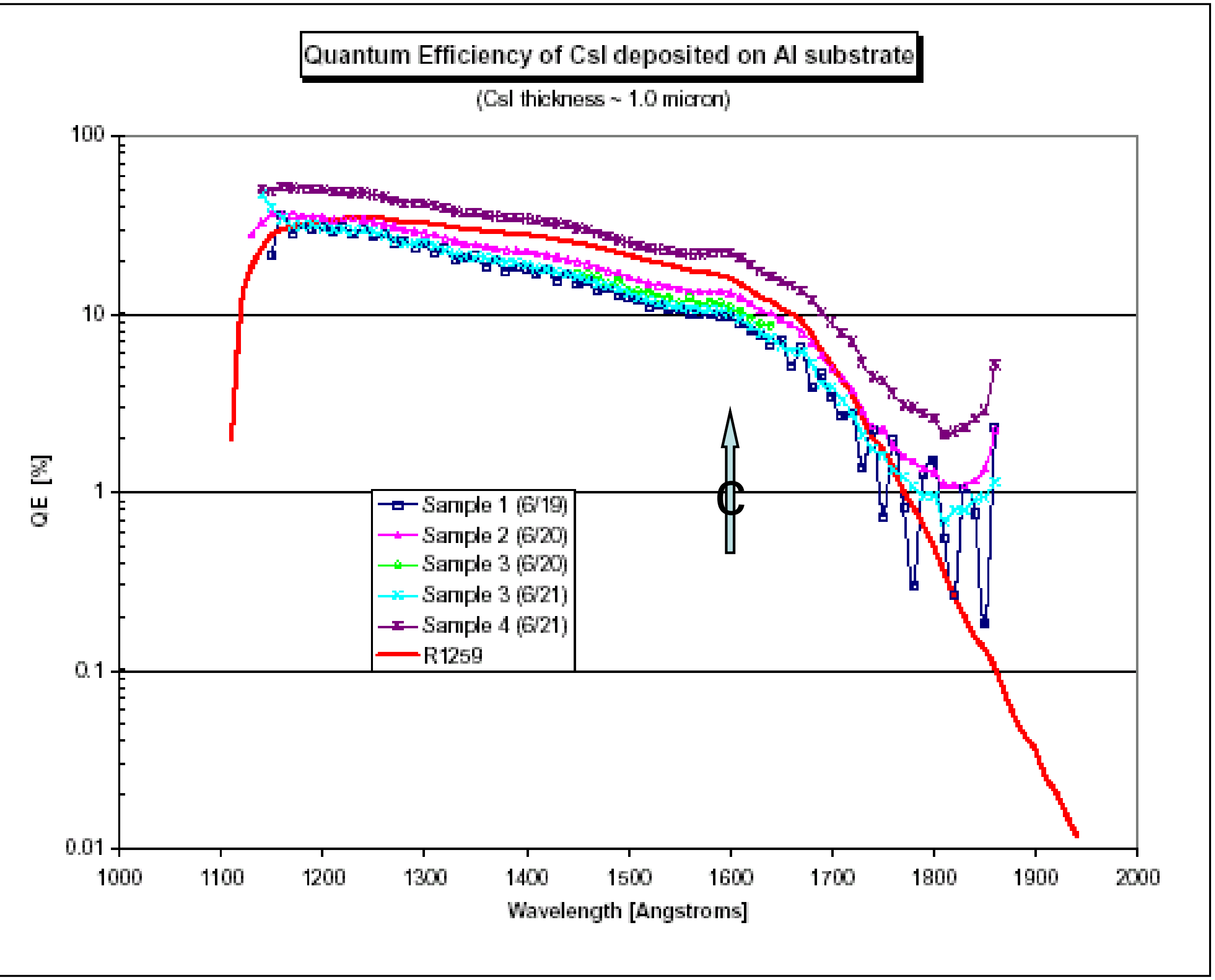
$$N_0 = \frac{\alpha^2}{r_e m_e c^2} \int \varepsilon_{coll}(E)\,\varepsilon_{\det}(E)\,Q(E)\,dE$$

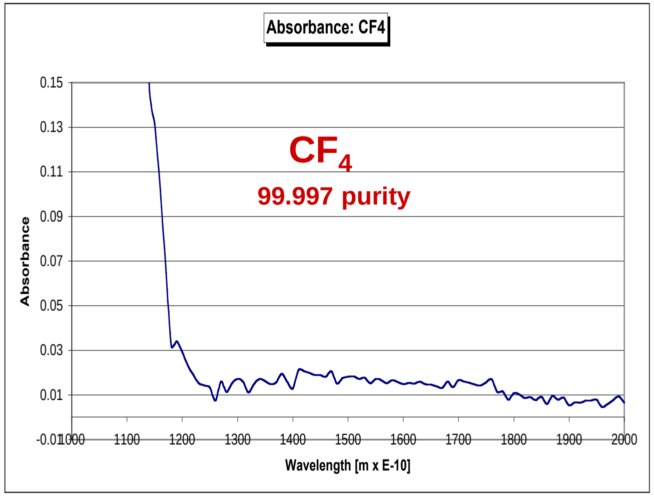
$$N_{pe} \approx N_0 L < \sin^2 \theta_c > \approx N_0 L 2(< n > - 1)$$

Assuming a N0 of 200
With MgF2 we expect
100 photoelectrons/cm



CsI + gaseous detector : J. Seguinot, Georges Charpak, Y. Giomataris, V. Peskov, J. Tischhauser, T. Ypsilantis, Nucl.Instrum.Meth.A297:133-147,1990





How to get the highest N_0

$$N_0 = \frac{\alpha^2}{r_e m_e c^2} \int \varepsilon_{coll}(E)\,\varepsilon_{\det}(E)\,Q(E)\,dE$$

$$N_{pe} \approx N_0 L < \sin^2 \theta_c > \approx N_0 L 2(< n > - 1)$$

Gas	<n>-1	γ_{th}	θ_{sat}	$\Delta\theta_{sat}$	$E_{cut\text{-}off}$	N_o
	10^{-6}		mrad	mrad	eV	cm^{-1}
CH_4	444	34	30	1.6	8.5	185
CF_4	620	28	36	1.8	11.5	936
He	35	120	8	1.6	24	5200
Ne	67	86	12	1.3	15	2664
Ar	42	42	24	3.3	12	1020

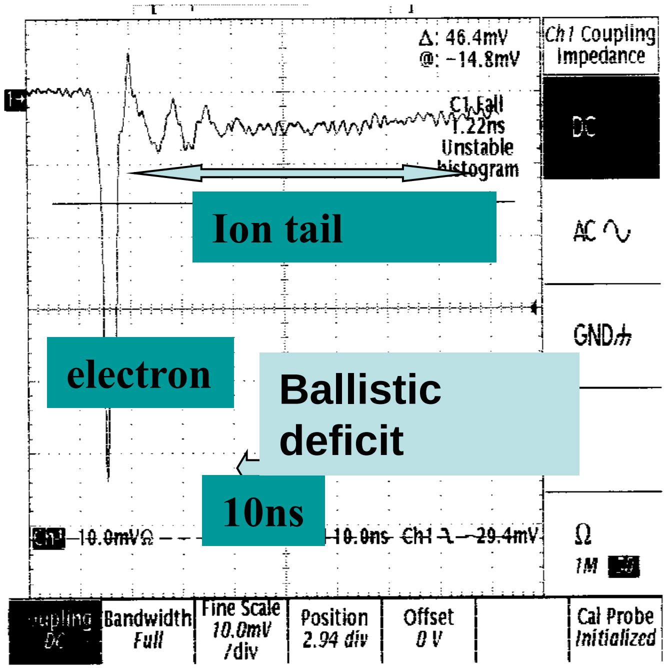
N_0 =500 measured in CF4

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

Similar is expected in MgF2 crystal

We will assume N0=200

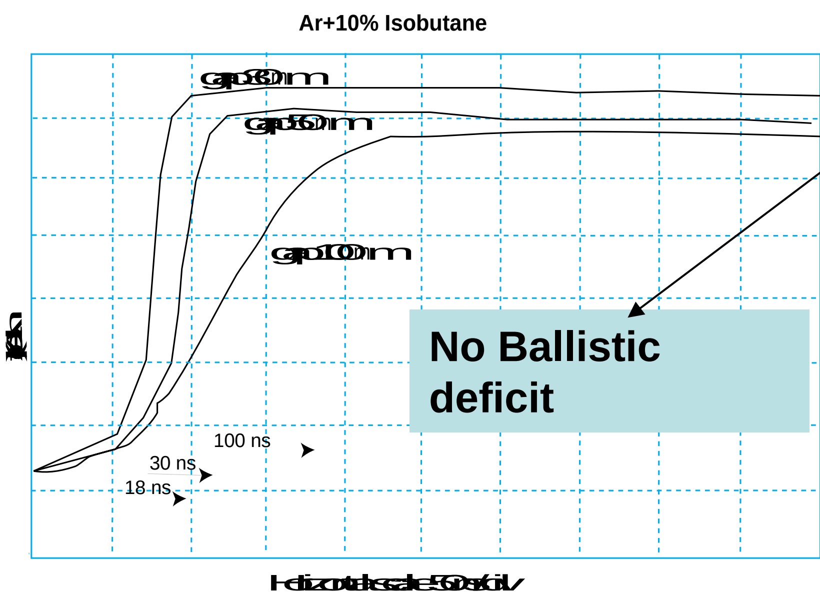
It will give 100 photoelectrons/cm



Small gap → fast signals

Very-fast current signal
1 ns rise time

12.5 µm Micromegas has been already developed
Ion collection time will be :
5 ns in Argon
2 ns in Neon
< 1 ns in Helium !!!!
Much faster than Si (x40)



Fast signal 20-100 ns
from charge preamplifier

MICROMEGAS PHOTODETECTOR
Reflective mode

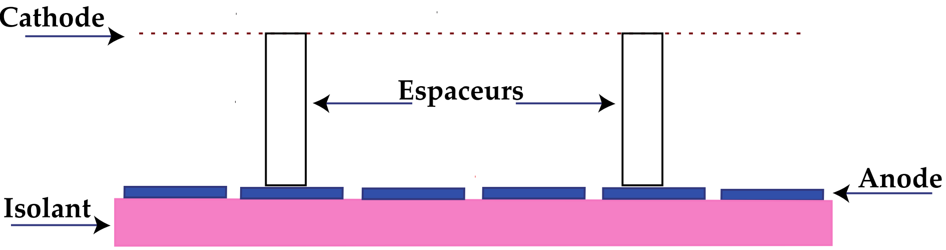
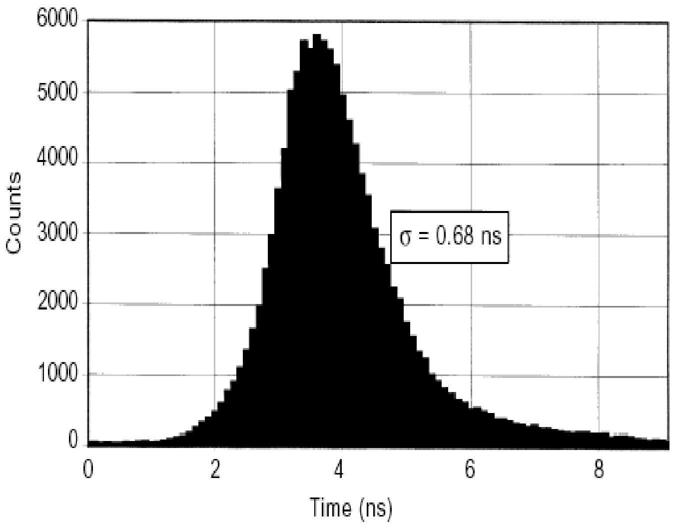


Figure 1

Sub-nanosecond time resolution

With single electrons from a UV hydrogen flash lamp



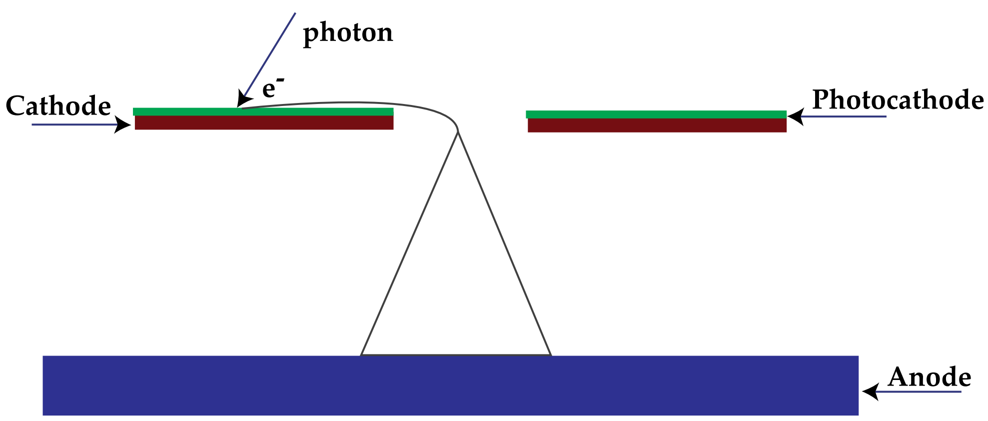


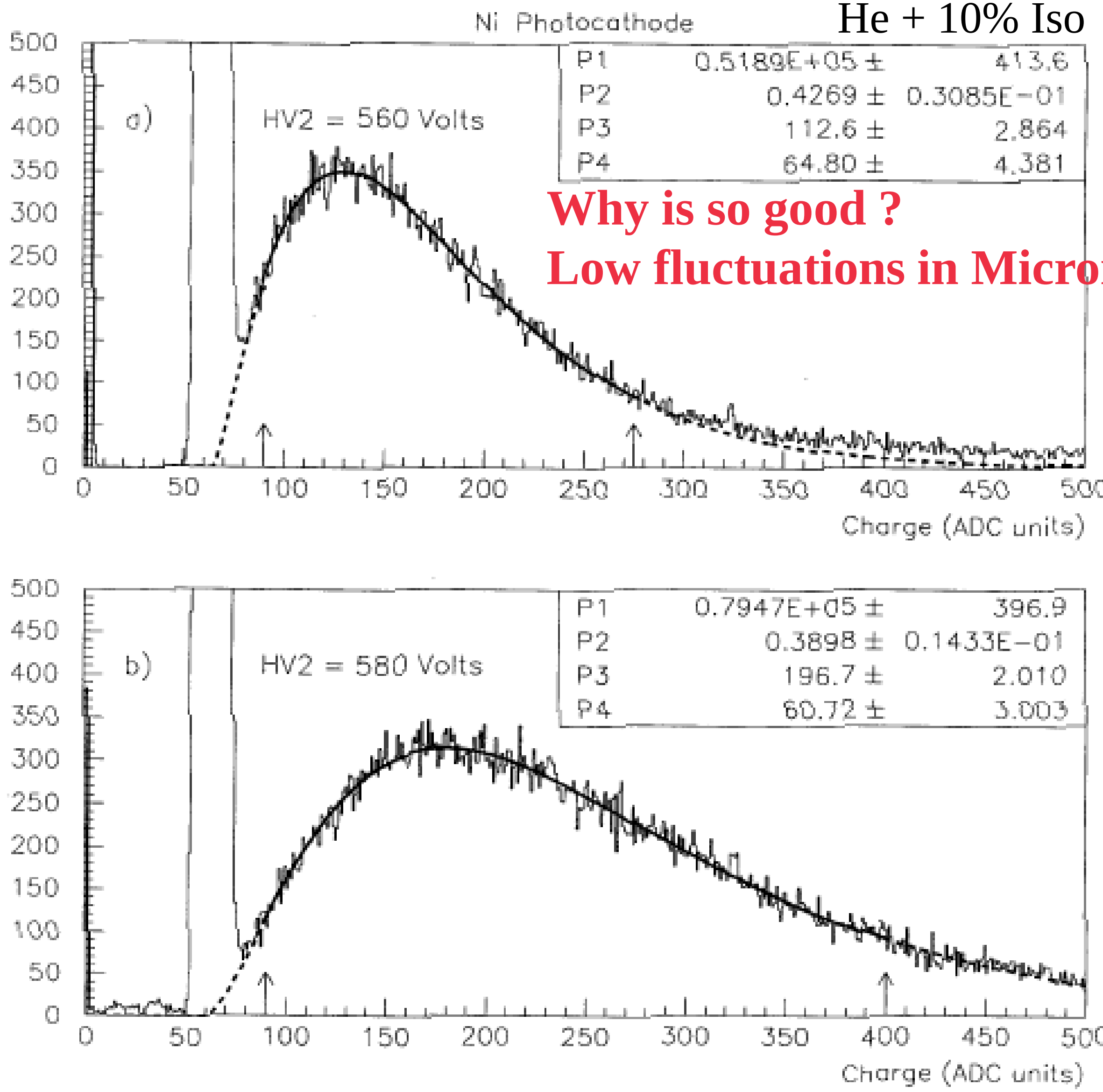
Figure 2

With N2 fast laser we got a better resolution of 400 ps with single electrons

Excellent single electron resolution

J. Derre, Y. Giomataris, P. Rebourgeard, H. Zaccone, J.P. Perroud, Georges Charpak
Nucl.Instrum.Meth.A449:314-321,2000

He + 10% Iso



Why is so good ?
Low fluctuations in Micromegas

Spatial and temporal resolution of Micromegas

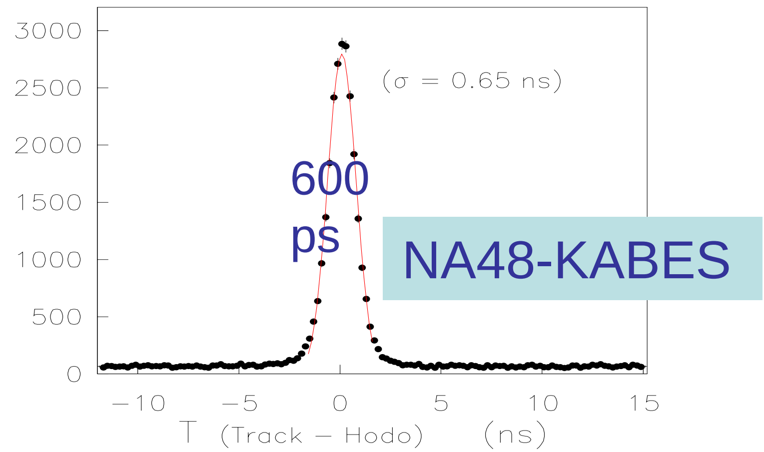
Ultimate limitation is the pitch of the mesh → < 10 μm, < 100 ps

Spatial resolution with MIPs

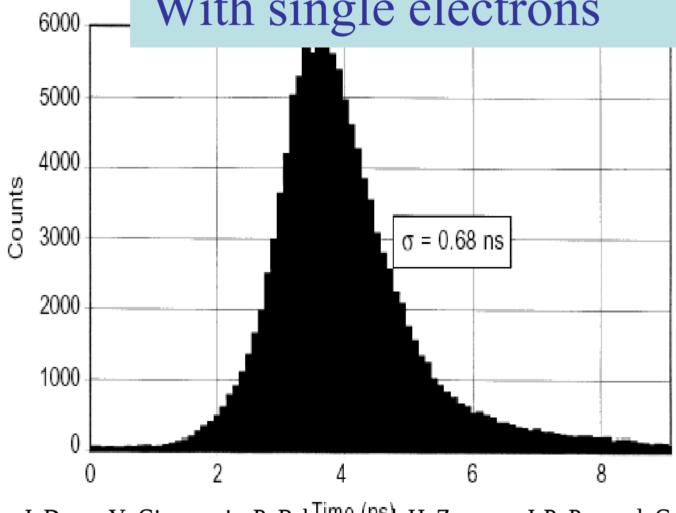
12	Pitch(μm)	Gas mixture	Institute
60	317	Ar + 10% DME	Saclay
45	200	Ar + 25% CO2	Subatech
50	200	Ne + 10% DME	Mulhouse
42	100	Ar + 10% Isobutane	Saclay
29	100	He+ 6% Isobutane + 10% CF_4	Saclay
25	50	He + 20% DME	Saclay
12	100	CF_4 + 20% Isobutane	Saclay

J. Derre, Y. Giomataris, H. Zaccone, A. Bay, J.P. Perroud, F. Ronga, Nucl.Instrum.Meth.A459:523-531,2001

G. Charpak, J. Derre, Y. Giomataris, P. Rebourgeard, Nucl.Instrum.Meth.A478:26-36,2002



Sub-nanosecond time resolution
With single electrons



J. Derre, Y. Giomataris, P. Rebourgeard, H. Zaccone, J.P. Perroud, Georges Charpak
Nucl.Instrum.Meth.A449:314-321,2000

NA48/KABES : KAon BEam Spectrometer

↳ NA48 experiment

KABES Spectrometer

↳ 2 Kabes stations on the NA48 60 GeV/c charged kaon beam

↳ 30 Mhz beam in ~8 cm^2

- Measure of the momentum of individual tracks with $\Delta p/p < 1\%$

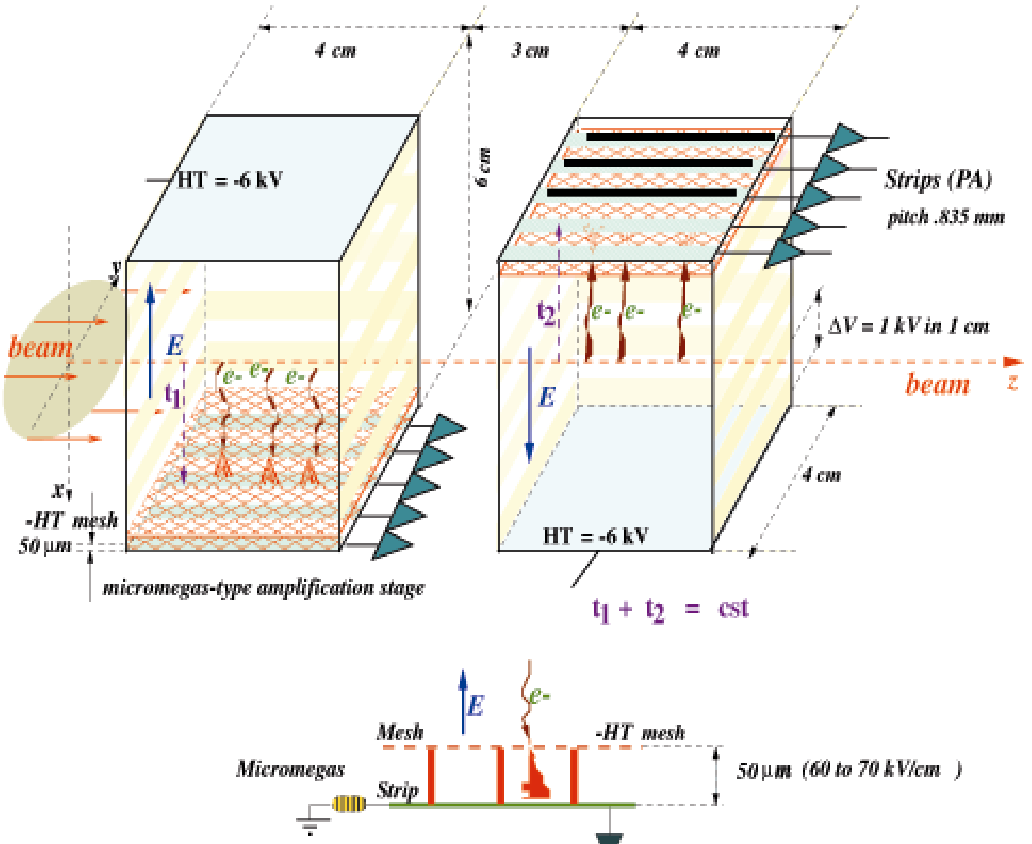
Performance

- Time resolution 600 ps
- spatial resolution 80 µm (60 µm along the drift)
- Highest strip rate 2 Mhz
- Efficiency > 95 %

Kabes Station

Gas : 79%Ne/11%C2H6/10%CF4

2 Micromegas-type projection chambers

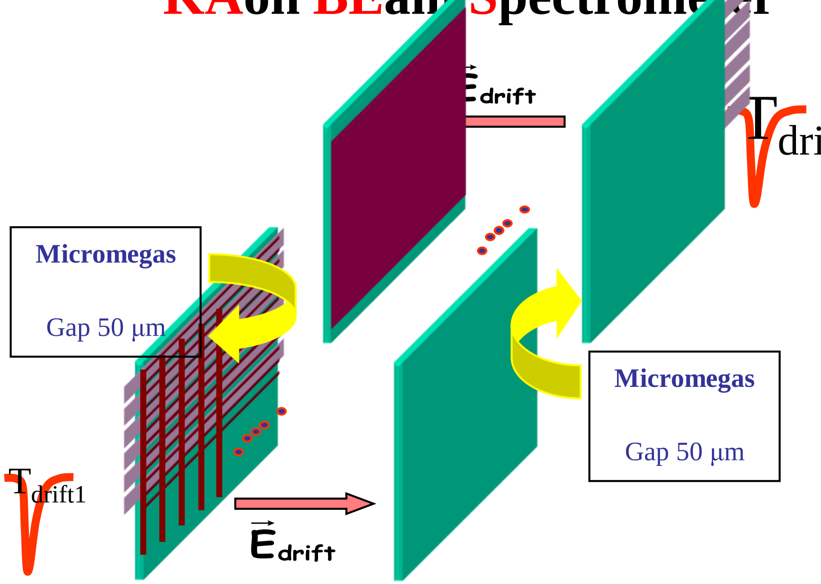


Kabes group (DAPNIA-Saclay/Dubna)

NA48/KABES

- **CP violation experiment in operation at CERN from summer 2003 to end of 2004. Flux $3x10^6/cm^2/s$**
- **Principle : TPC + micromegas**

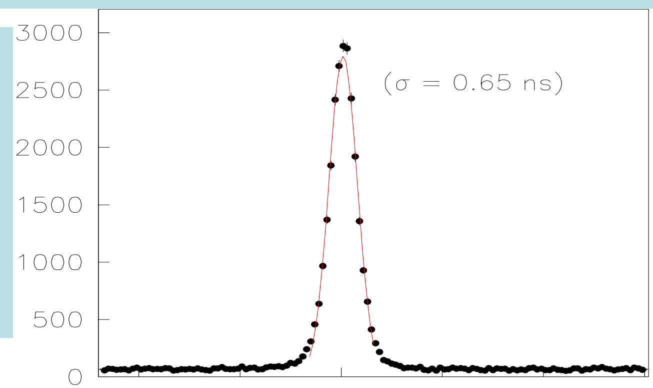
KAon BEam Spectrometer



KABES in K12 (K^++K^-) beam line

Time resolution: 0.6 ns

Space resolution from drift time measurement: 70 µm



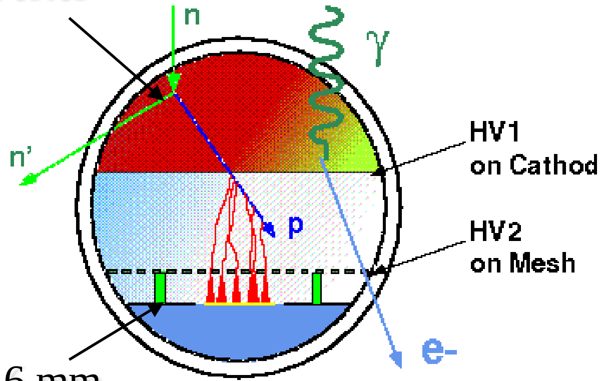
$(T_0)_{KABES}$- $(T_0)_{DCH\ Spectrometer}$ (ns)

Tagging with reconstructed $K^{\pm}$ □ □$^{\pm}$ □$^{+}$ □$^{-}$

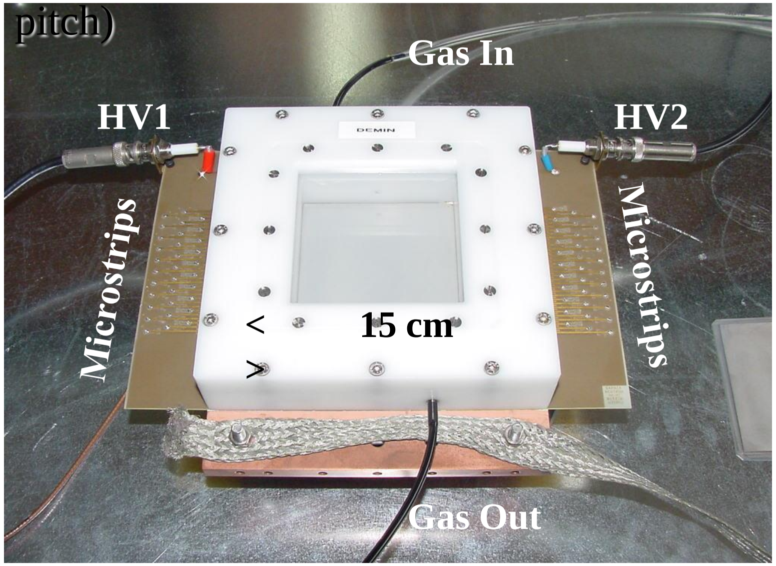
Micromégas Concept for Laser MégaJoule and ICF Facilities

The γ insensitivity of Micromégas applied to neutron spectroscopy on Inertial Confinement Fusion experiments

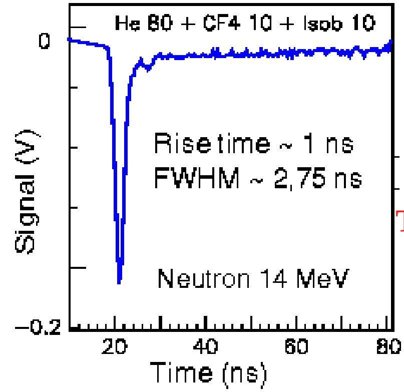
2mm CH_2 converter



65 strips (1.6 mm pitch)



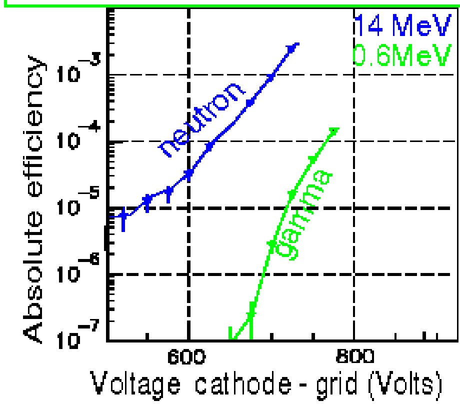
Neutron measurement by TOF in time windows of ~ 100 ns
-> Fast pulses



- Time of flight : δE/E~1%
- Low pile-up

Time response < 500 ps

Neutron measurement in a High γ Background
-> n/γ discrimination



Efficiency Ratio

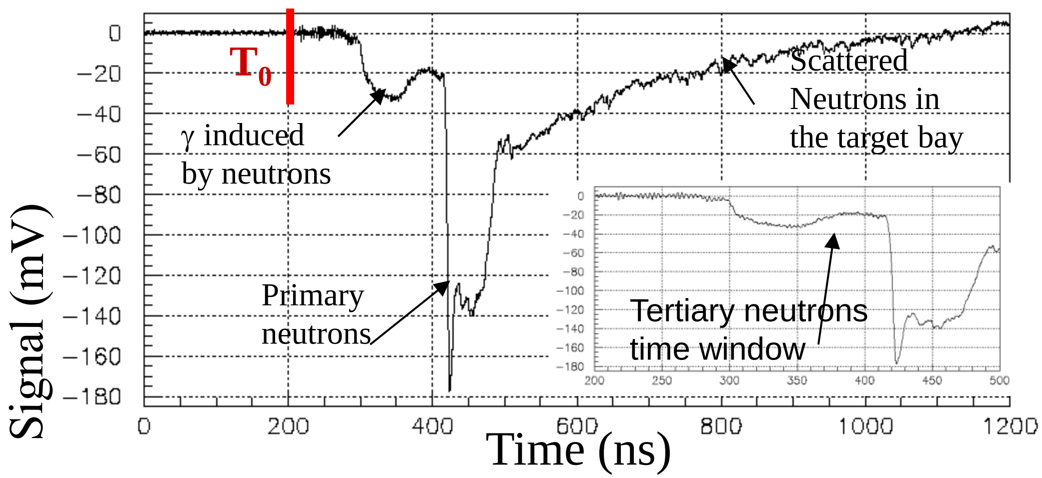
-> 10^3

Ref: CEA/DIF/DCRE/SDE M. Houry

DEMIN group (CEA/DIF/DCRE and DAPNIA)

DEMIN : FIRST EXPERIMENT IN OMEGA

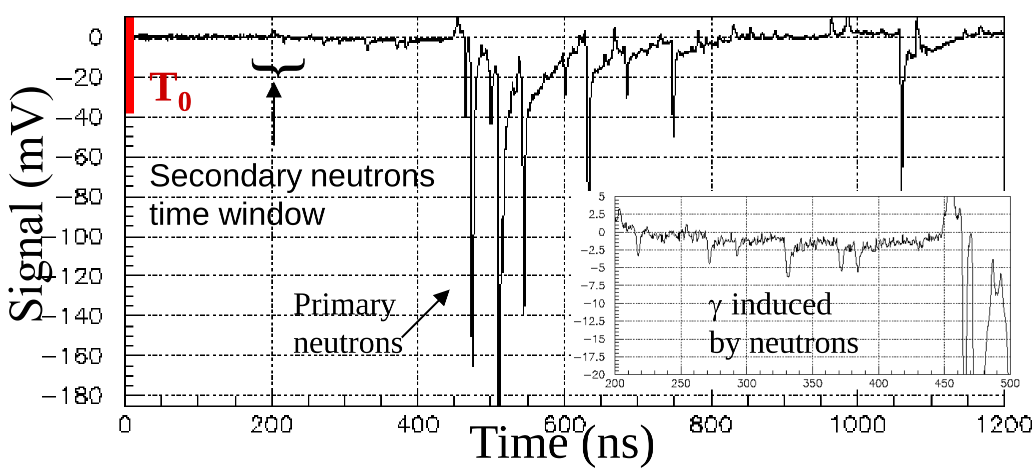
DT SHOT, 31769; 4.10^{13} n_{14MeV}



- Saturation effects for the primary neutrons pulse (capacitif coupling).
- γ background induces low signal
- Signal for expected tertiary neutrons should be higher than γ signal.

Signal on strip # 16

DD SHOT, 31777; 2.10^{11} $n_{2.45MeV}$



- Detection efficiency of 2.45 MeV neutrons is low due to the convertor which is designed for 14 MeV neutrons.
- γ background signal is low; < 5 mV
- Each secondary neutron will induce up to several hundred of mV.

Two operation modes

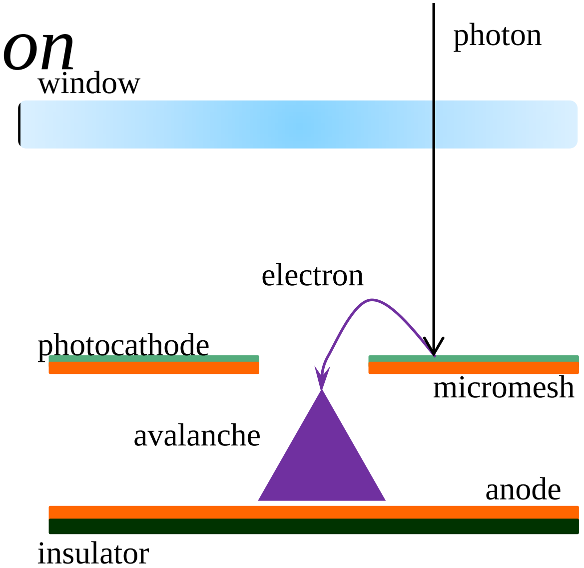
for UV photon detection

- Reflective photocathode:

  Photosensitive material is deposited on the top surface of the micromesh.

  Photoelectrons extracted by photons will follow the field lines to the amplification region

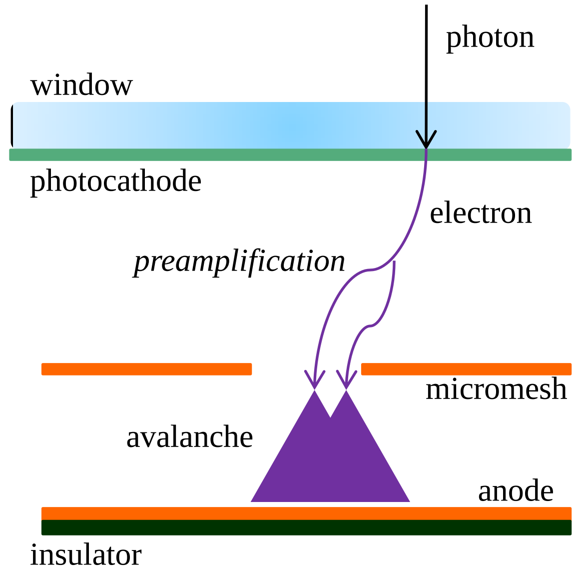
  - ✓ The photocathode does not see the avalanche ➔ *no ion feedback effect* ➔ *higher gain (up to 10^6)*
  - ✓ High electron extraction & collection efficiency
  - ✓ Field on photocathode 10^4 V/cm



- Semi-transparent photocathode:

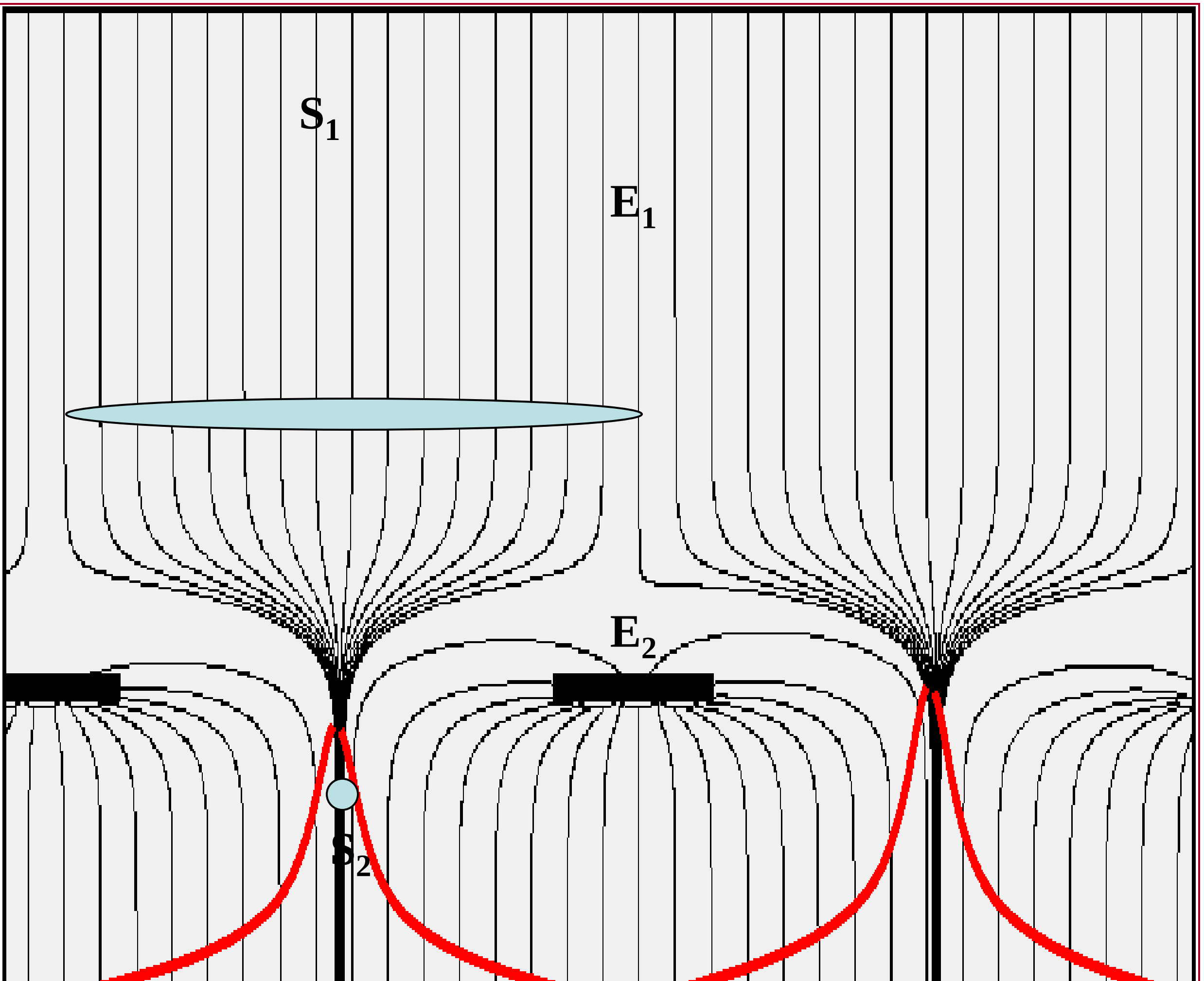
  Photosensitive material is deposited on an aluminized quartz window (drift electrode)

  - ✓ Extra preamplification stage ➔ better long-term stability
  - × Lower photon extraction efficiency (factor 2)
  - × Fragility to sparks
  - × Ion feedback ➔ gain limitation

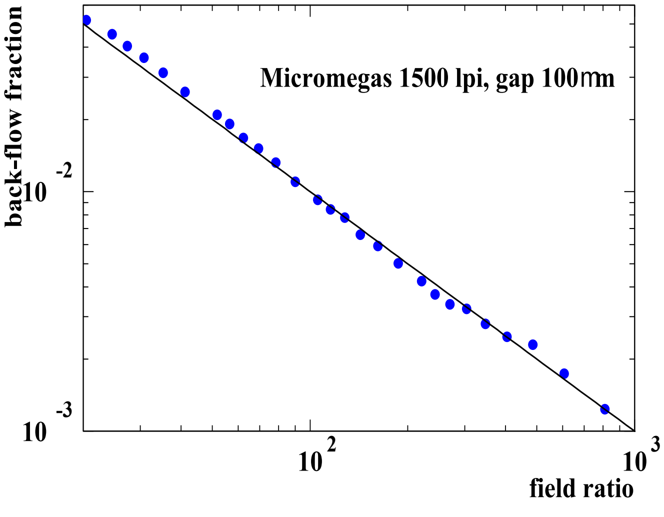


Rob Veenhov preliminary simulation show a jitter of

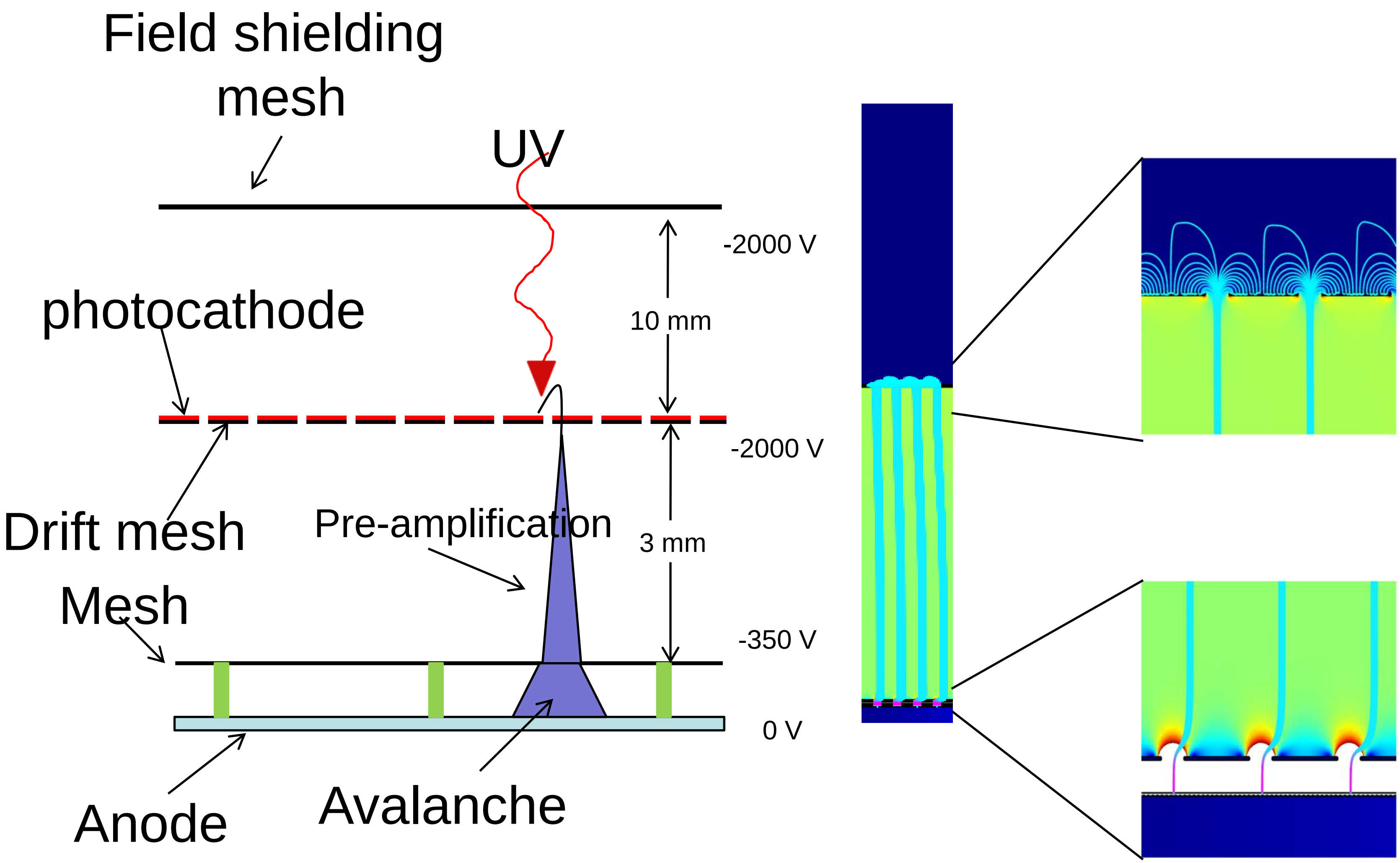
In reflective mode time jitter is dominated by drift time fluctuations of different electron paths.
In a standard mesh (500 LPI) this is about 50 ps at the average
In 2000 LPI much lower time jitter is expected



$S_2/S_1 = E_2/E_1 > 100$



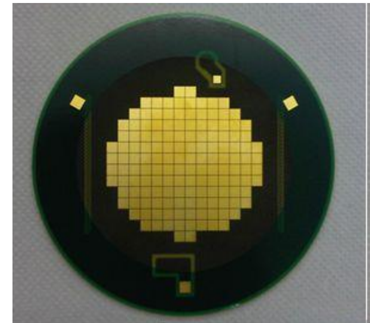
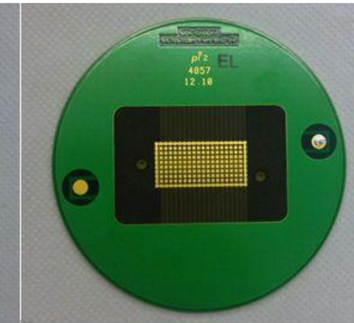
photodetector prototype developed in Saclay

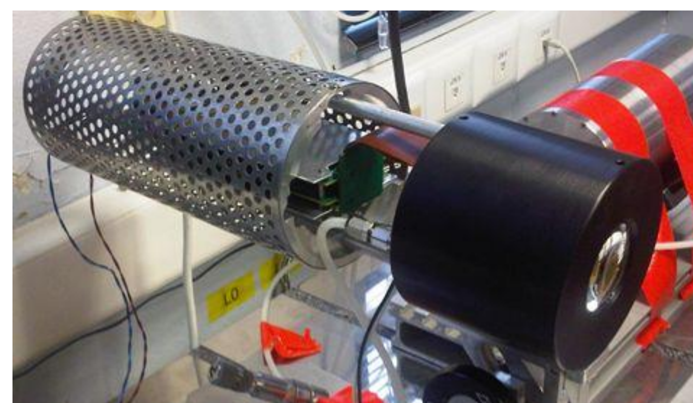


The Micromegas prototype

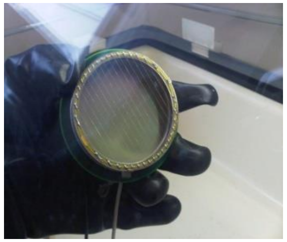
V4 model is available since end of January 2011 - Modifications for:

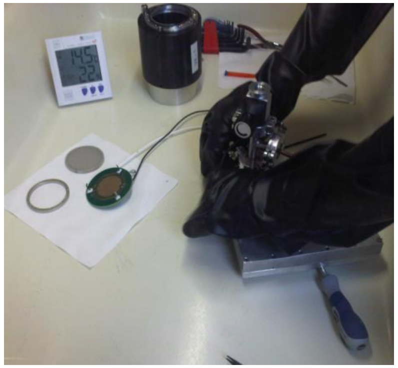
- *Simplify mass production*
    - ✓ 144 Pixel detector
    - ✓ Mechanical problems of previous detectors solved
    - ✓ New photocathode supports
    - ✓ External high voltage connectors
    - ✓ High gain
    - ✓ High pre-amplification capabilities

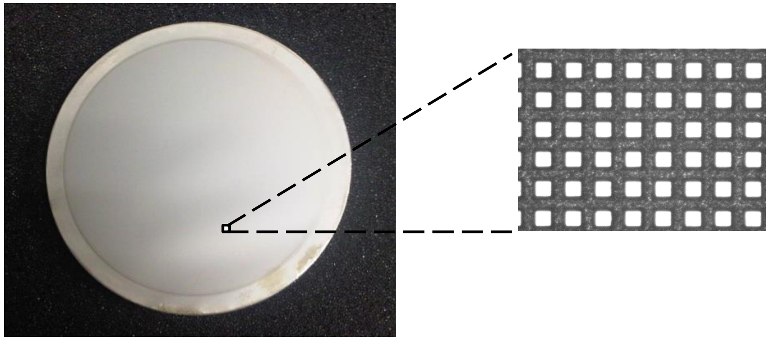



Photocathode Evaporation of CsI facility at CEA-Saclay

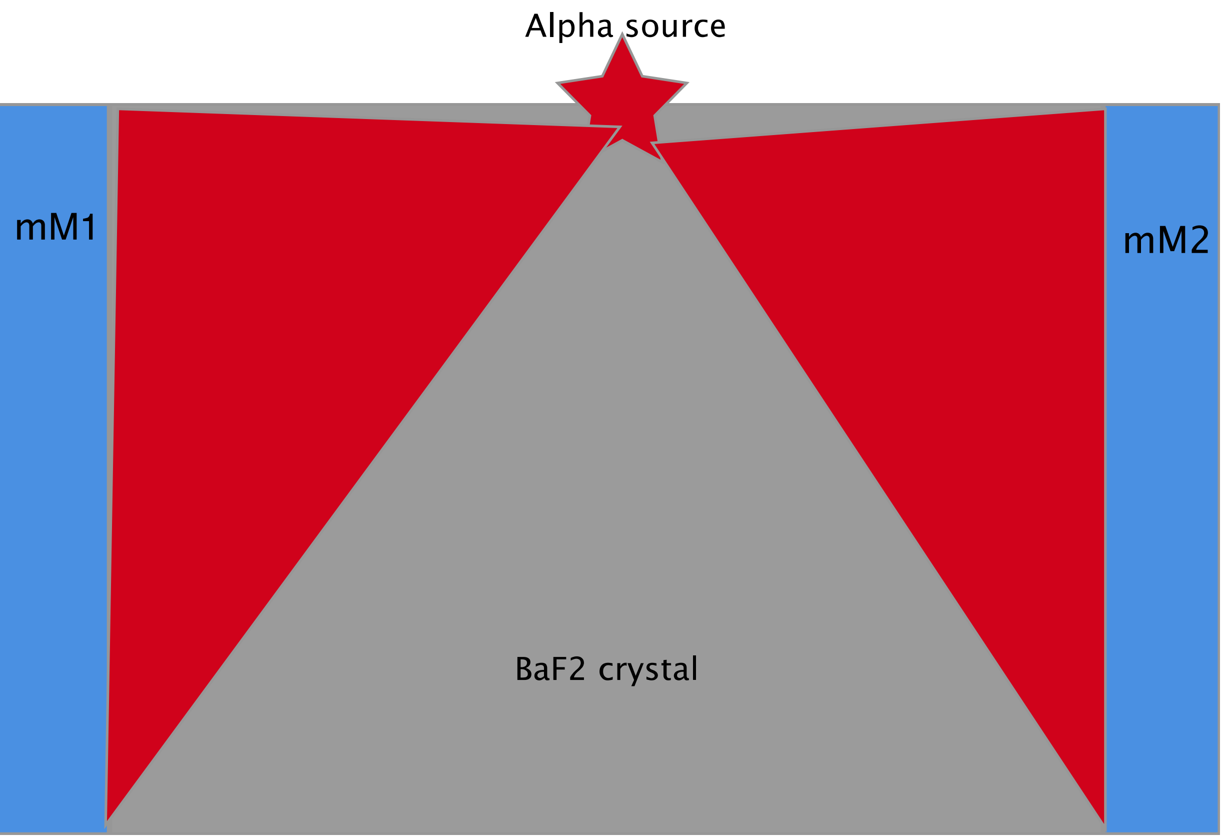






Next steps

1) Measure time resolution in BaF_2 (700ps decay time) with two mM CsI detectors



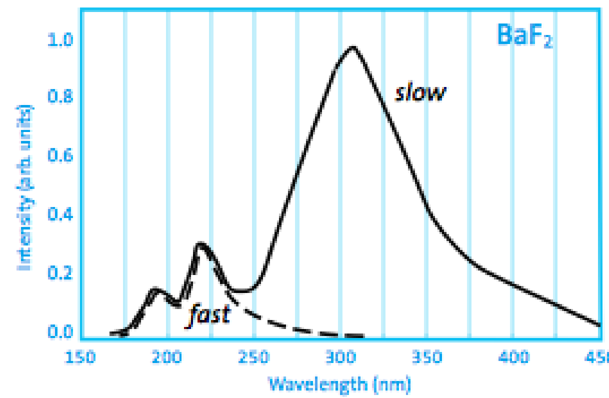
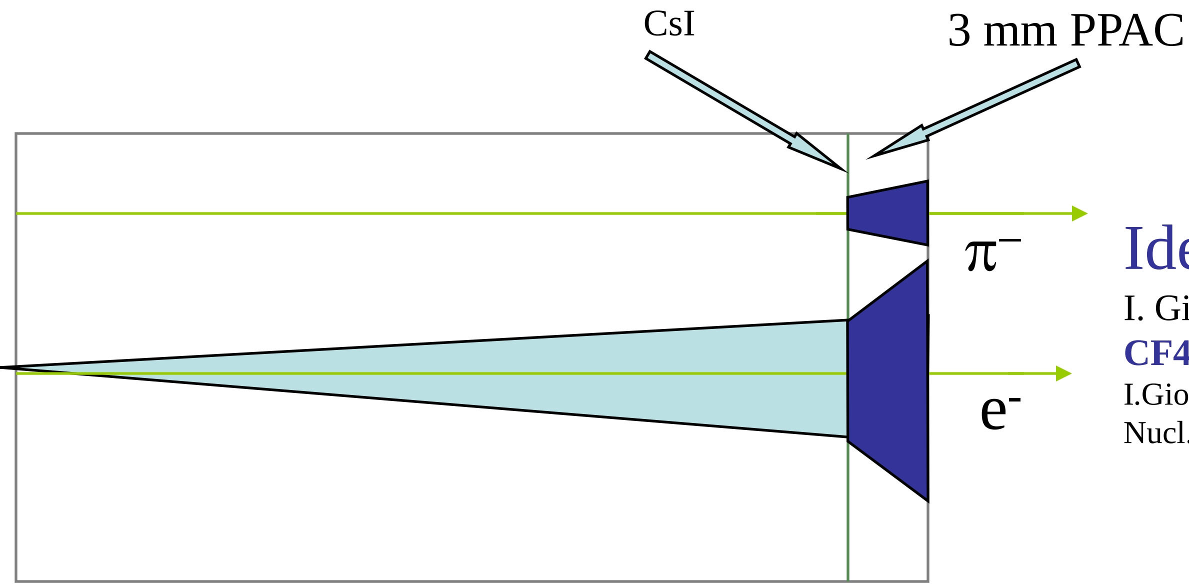


Figure 1. Scintillation emission spectrum of BaF_2

2) Test with a UV ps laser

3) Simulate and design a full detector system for beam tests

Hadron Blind Detector(HBD) → Micromegas



Idea

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

CF4 magic HBD gas

I.Giomataris,G.Charpak,V.Peskov,F.Sauli
Nucl.Instrum.Meth.A323:431-438,1992

HBD great result on 1992: N_0=500 and good signal to background ratio

M. Chen et al., Nucl.Instrum.Meth.A346:120-126,1994

HBD improvements

Very small PPAC gap:

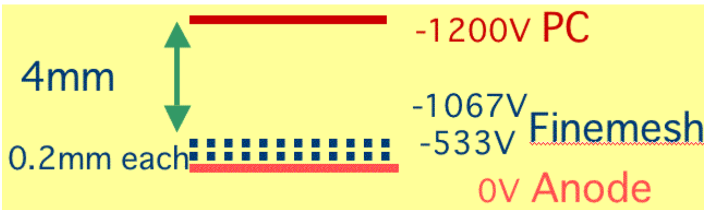
1 mm gap sucessfully tested but no uniform gain

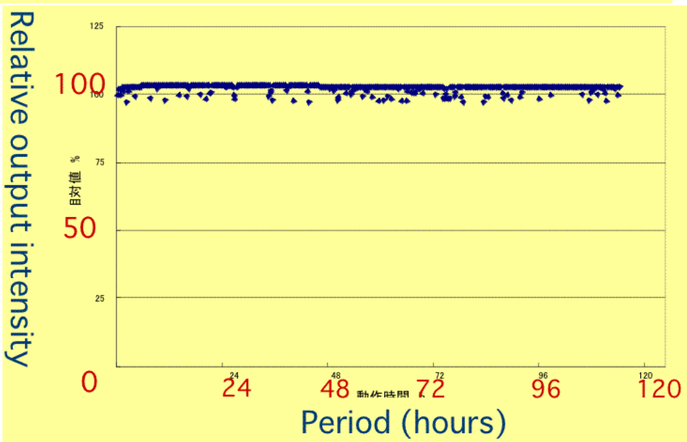
Micromegas is an ideal detector for HBD

I. Giomataris

Hamamatsu Bialkali Gas-PMT R&D work

Hamamatsu & Sumiyoshi, Tokanai, Va’vra





- Hamamatsu built a double-mesh Micromegas structure w bialkali pc.
- Works both in 90%Ar+10%CH_4 or 90%Ar+10%CF_4.
- No detorioration of the photocathode observed within 5 days
- Gain of ~$6x10^3$, limited by secondary effects. Not sufficient for single-photon detection.
- **Work with MCP & Bialkali photocathode is in progress.**