Preface

In V. Razin talk it was suggested to develop large- area gaseous photomultipliers

Is it realistic to make them?

The aim of this talk is review what was done in this direction in order to answer this question

Photomultipliers based on micropattern gaseous detectors:

what was done

what could be done

PS. This picture shows gaseous PMs based on micropattern detectors developed by Hamamatsu Inc

So, what was done?

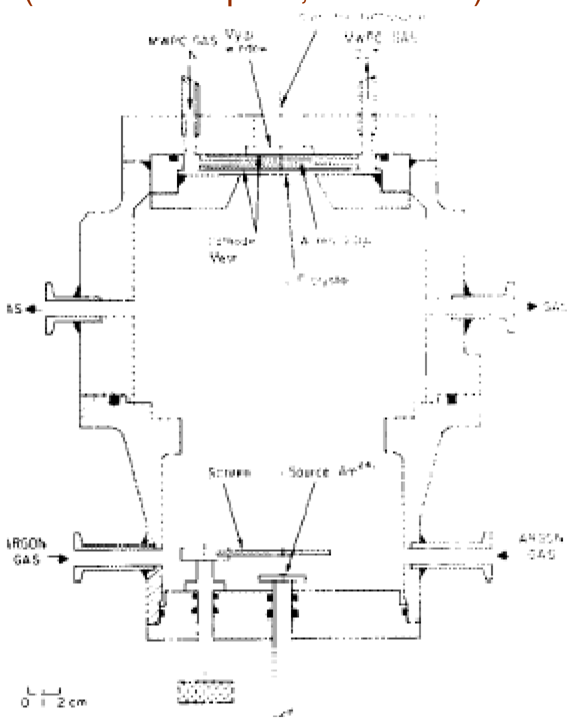
Historical background

Efforts to develop gaseous PMs started a at the end on 70's, they were triggered by an invention of MWPC

<u>The motivation was</u>
to develop:
large-area (no mechanical constrains on the window size),
cheap and
position- sensitive (at this time position sensitive vacuum or solid state PMs did not exist!) photodetectors

First photosensitive MWPC were developed at the same time by J. Seguinot, T Ypsilantis (*NIM 142,1977,377*) and G.Bogomolov, Yu. Dubrovski, V. Peskov (*Instr. Exp. Tech. 21,1978,779*)

Photosensitive MWPC for **RICH applications** (benzene vapors, λ<135nm)



(*Submitted in December 1976*)

Photosensitive MWPC for **plasma applications** (toluene vapors , λ<146nm)

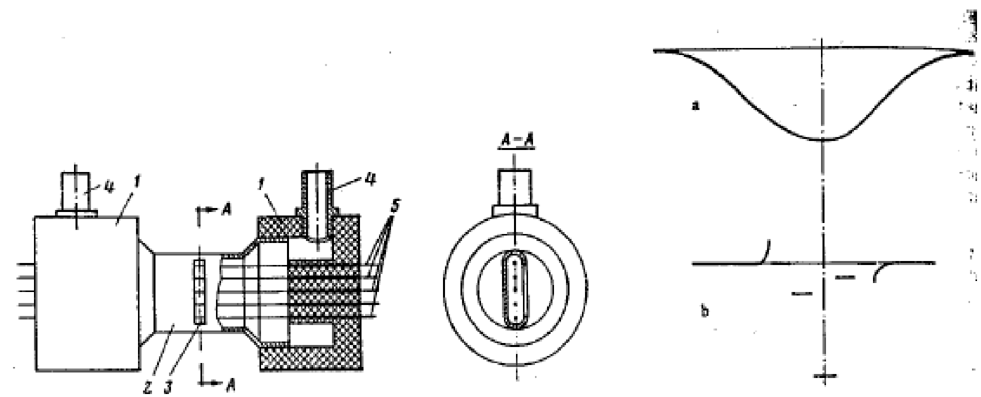


Fig. 1 Fig. 2

Fig. 1. Schematic sketch of a five-wire counter. 1) Plastic insulators; 2) copper anode; 3) window of the counter; 4) fitting for injection of working mixture; 5) anodes.

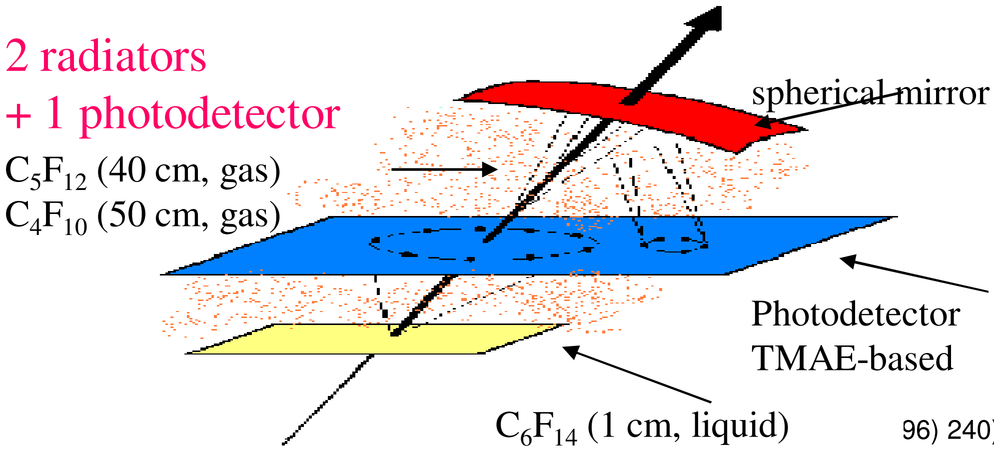
Fig. 2. Oscillograms of signals from the dissector (a) and counter (b).

(*Submitted January 1977*)

These two papers open new possibilities in experimental techniques and applications

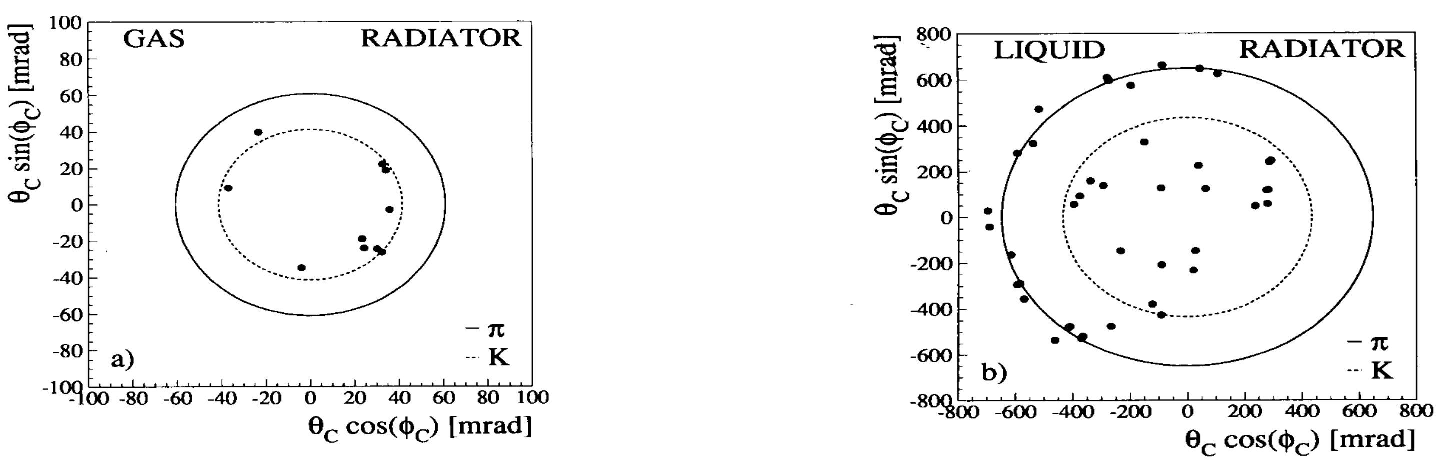
Cherenkov detectors

DELPHI RICH

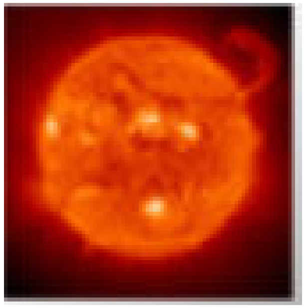


A RICH with two radiators to cover a large momentum range. π/K/p separation 0.7 - 45 GeV/c: DELPHI and SLD

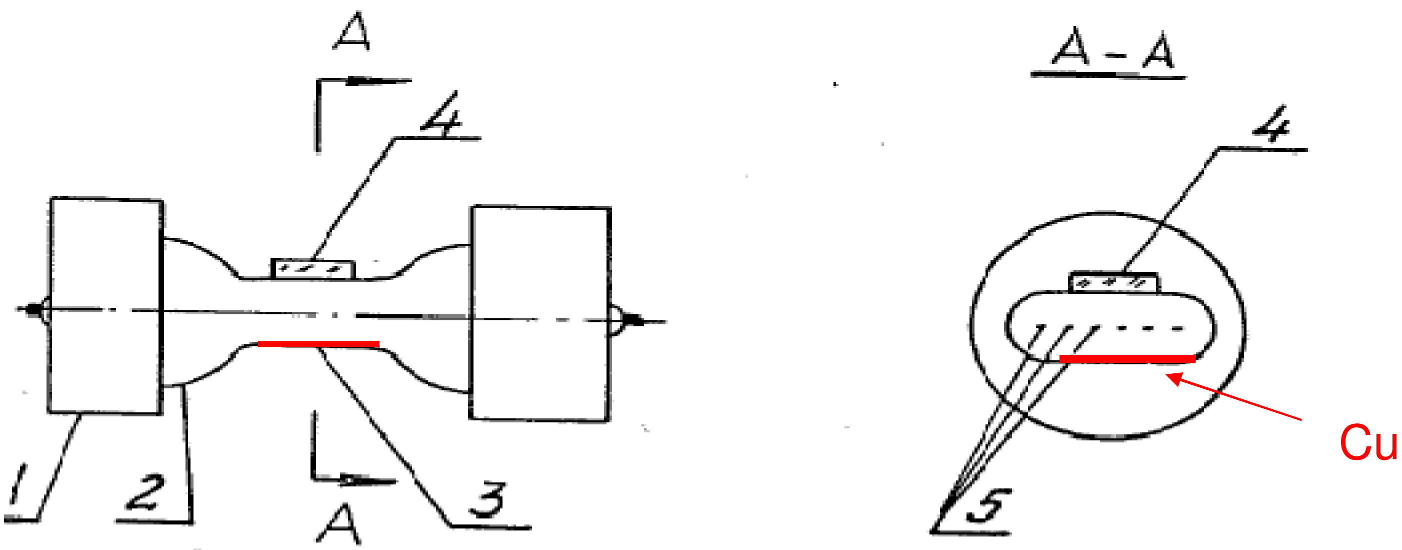
Two particles from a hadronic jet (Z-decay) in the DELPHI gas and liquid radiator + hypothesis for π and K



Next step: solid photcathodes



For example, MWPC with : CuI photocathodes
were used for **plasma diagnostics**



V. Peskov, Doctror of Sci. Thesis, 1981

Various solid photocathodes were investigated,

(see for example: *V. Peskov,NIM269.1988,149,V. Peskov, NIM 283,1989, 786,J. Séguinot et al, NIM 297,1990,133, G. Charpak et al., NIM 310,1991, 128, D. C. Imrie et al.,.,NIM 310,1991,122, V. Peskov, NIM 315,1992,77,D. C. Imrie et al., NIM317,1992,92,*

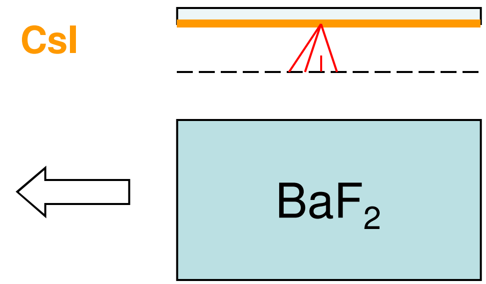
G. Malamud et al, NIM 348,1994,275 and reference there in)

however,

the greatest success was achieved with **CsI** photocathodes

Starting chain of works on CsI photocathodes:

G. Charapak, V Peskov and D. Scigocki,
Proc. Symp. on. Particle Identification
at High Luminosity Hadron Colliders,.
Fermilab. Batavia. 5-7 April 1989. p. 295

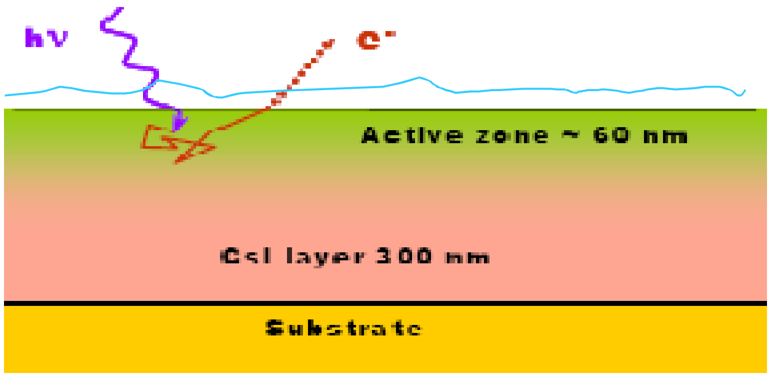


J. Seguinot et al., NIM, 1990

A. Breskin et al, NIM,1990

(see review paper A. Breskin, NIM 371,1996,116)

Advantages of CsI photocathodes: high quantum efficiency, tolerate a short contact with air, have potential for high time resolution



Absorbed layer

Two major effects:

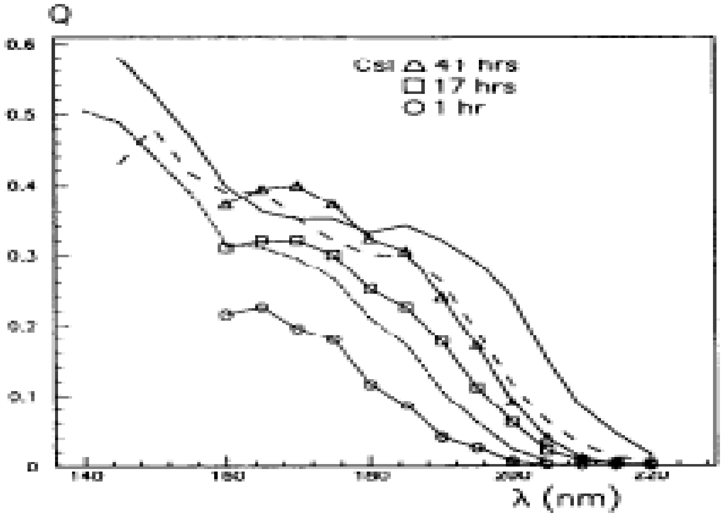


Fig. 5. The measured quantum yields versus the photon wavelength of a 500 nm thick CsI photocathode after 1, 17, and 41 h of methane gas-flow through the chamber. The solid line without data points is the TMAE gas-phase yield, and the dash-dotted line is the Carruthers vacuum photocathode yield [22].

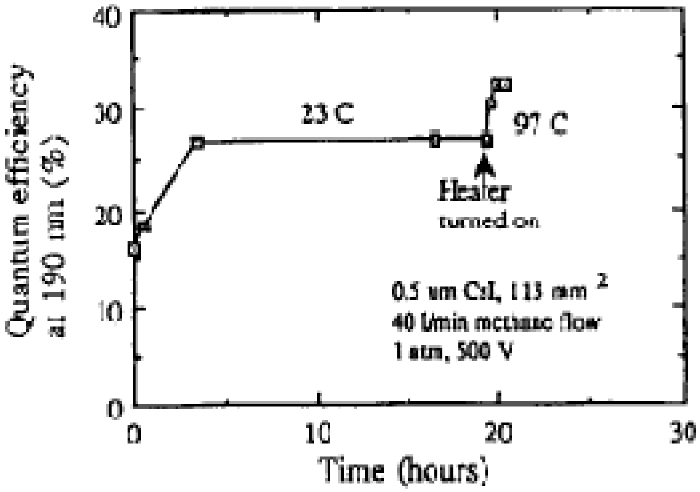


Fig. 6. QE as a function of time of a freshly deposited, 0.5 nm thick CsI photocathode, with a 40 l/min flow of methane. At 20 h the photocathode is heated to 97°C, resulting in the enhancement of the photoyield [38].

CsI RICH

Chain of proposals to the CERN committee

Development of a high-efficiency gaseous detector for the localization of photons from scintillators and Cherenkov radiators
Charpak, Georges; Giomataris, Yu; Peskov, V (et al.)
1991

Declined

↓

Development of a high-efficiency gaseous detector for the localization of photons from the Scintillator and a new generation of Cherenkov counters
A.Braem, André; Charpak, Georges; Peskov, V; et al
1992

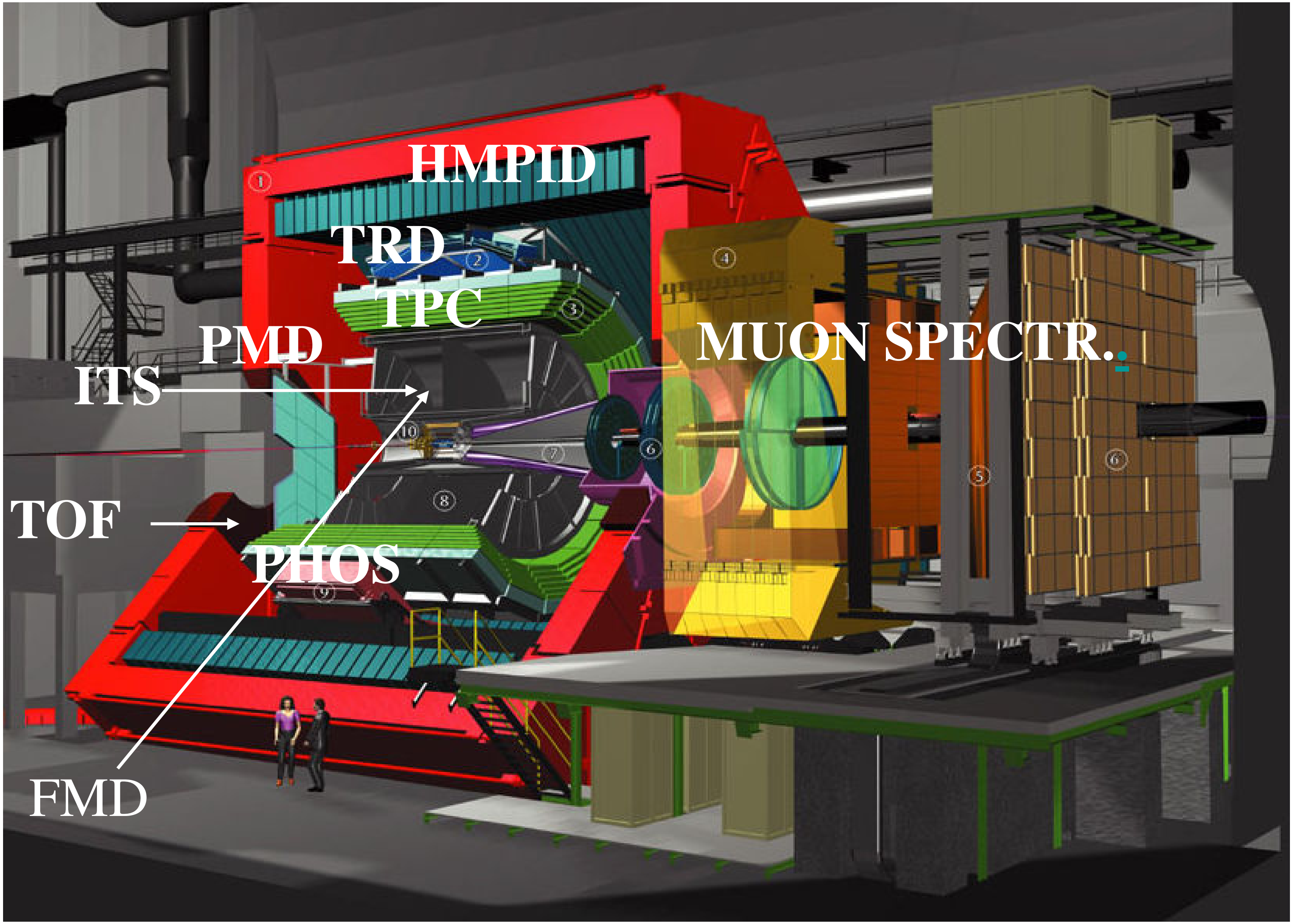
Declined

↓

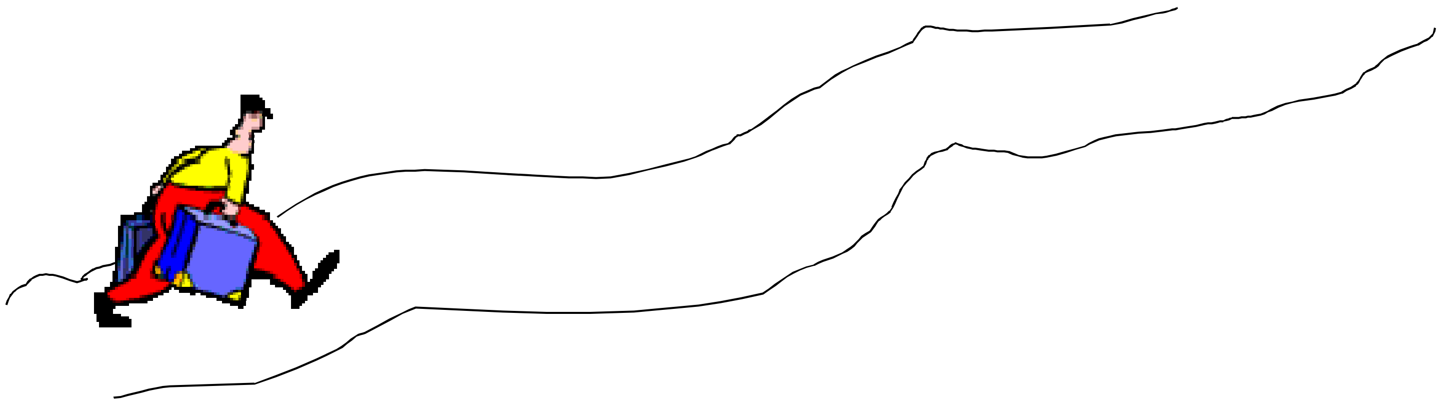
Development of a large area advanced fast rich detector for particle identification at the Large Hadron Collider operated with heavy ions
Nappi, E *et al.*
1992

Approved!

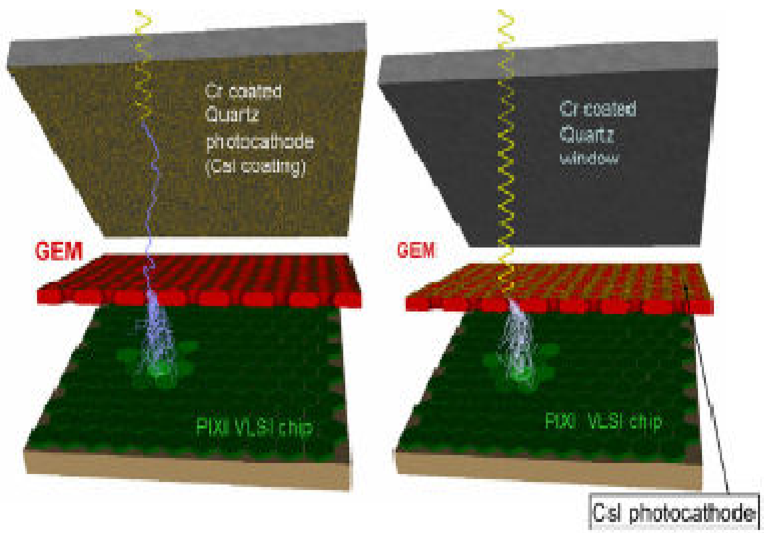
Now several experiments have CsI RICH: ALICE, HADES, COMPASS, STAR and others

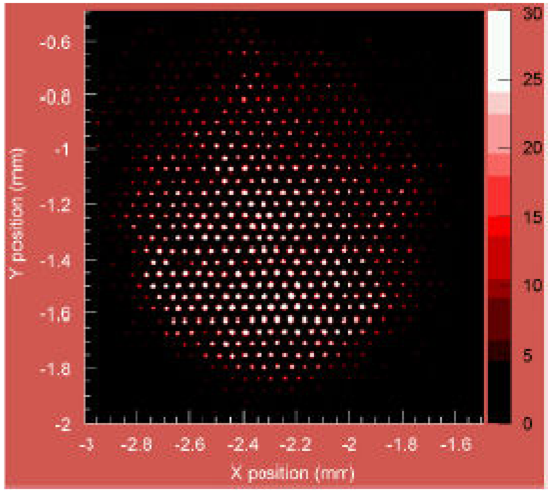


It was a long way from the first prototypes to the present state of art CsI-based detectors…



<u>Latest tendency</u> : micropatten gaseous detectors combined with CsI photocathode (for the exhausting review see *R. Chechik, et al., NIM A595,2008,116)*

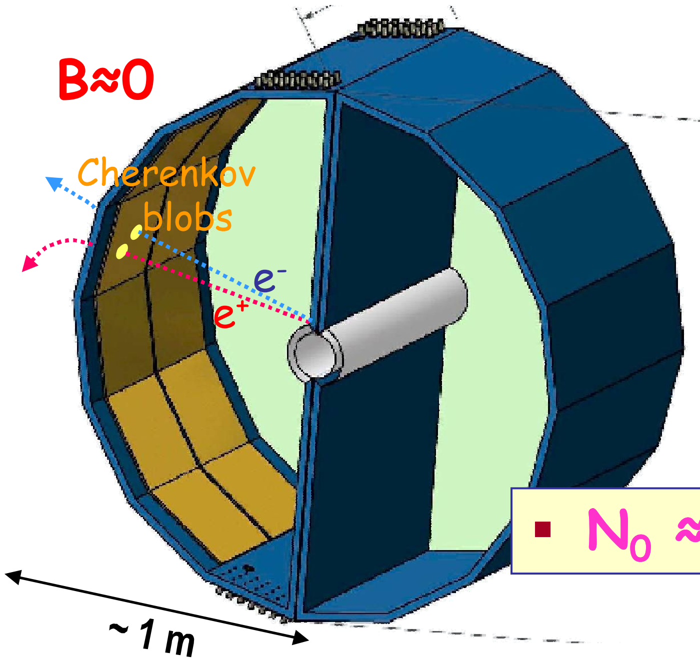




<u>Example:</u> an impressive work from *R.Bellazzini et al., , NIM A581,2007246*

PHENIX Upgrade (PHENIX HBD)

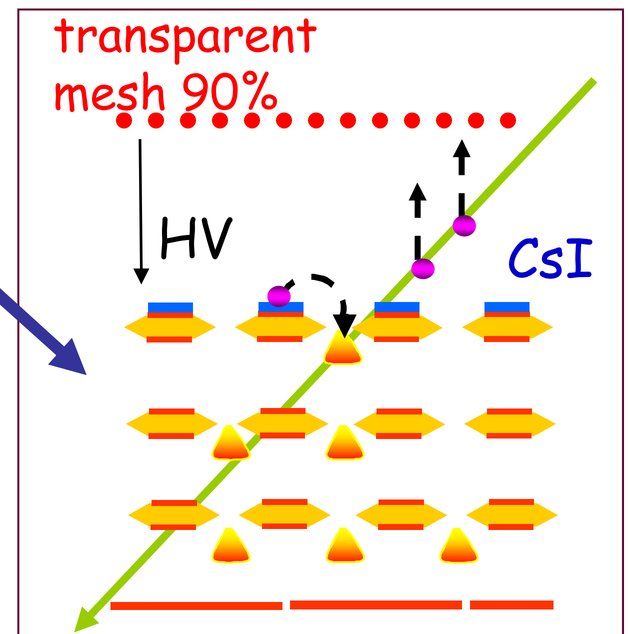
A. Milov et al.
J. Phys. G34, S701 2007



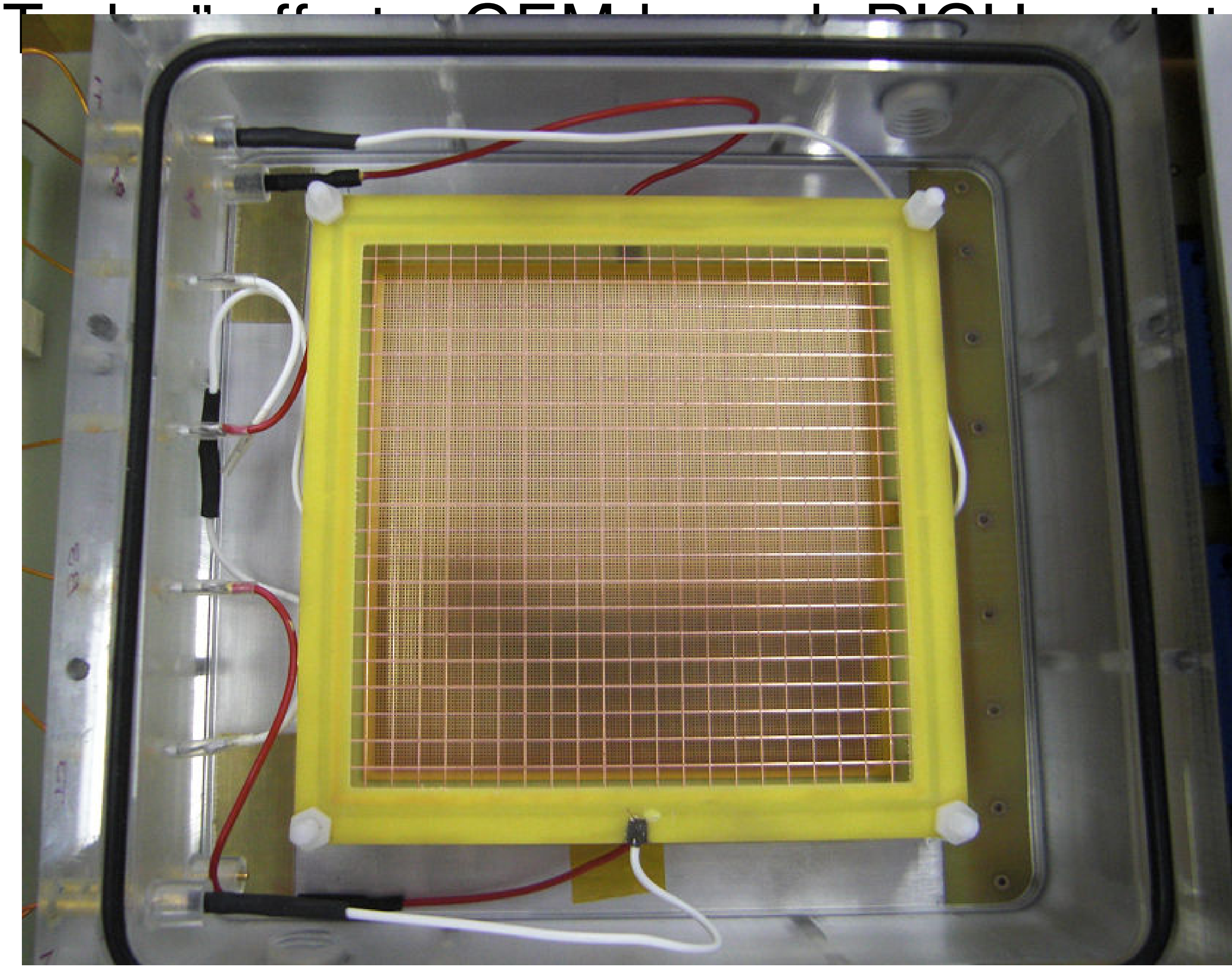
RICH added around the interaction region.
Goal: identify low-mass e^--pairs (π^0, γ) to reduce X300 combinatorial BG.
But: limited to 50 cm length.
Solution: Radiator gas = Working gas = CF_4.
Proximity=> Radiating particles produce blobs, diameter ~ 3.6 cm.

- $N_0 \approx 840\ cm^{-1}$ (x6 larger than any e/π RICH)

- The GPD of choice is a multi-GEM +REF PC
- Relies on CsI preparation knowledge and techniques from CERN:
  Gold-coated GEM,
  in-situ QE monitoring, QE enhancement,
  PC transport and storage.
- CsI QE match to CF_4

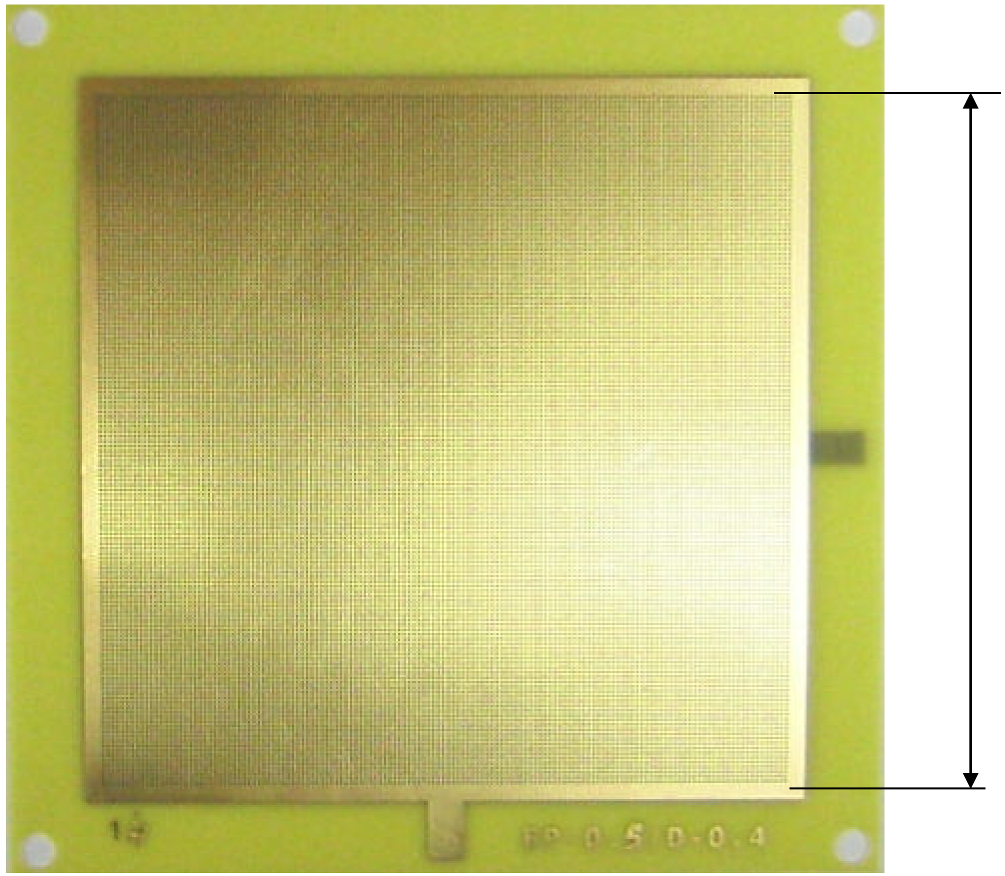


R. Chechik presentation ar RICH Conf



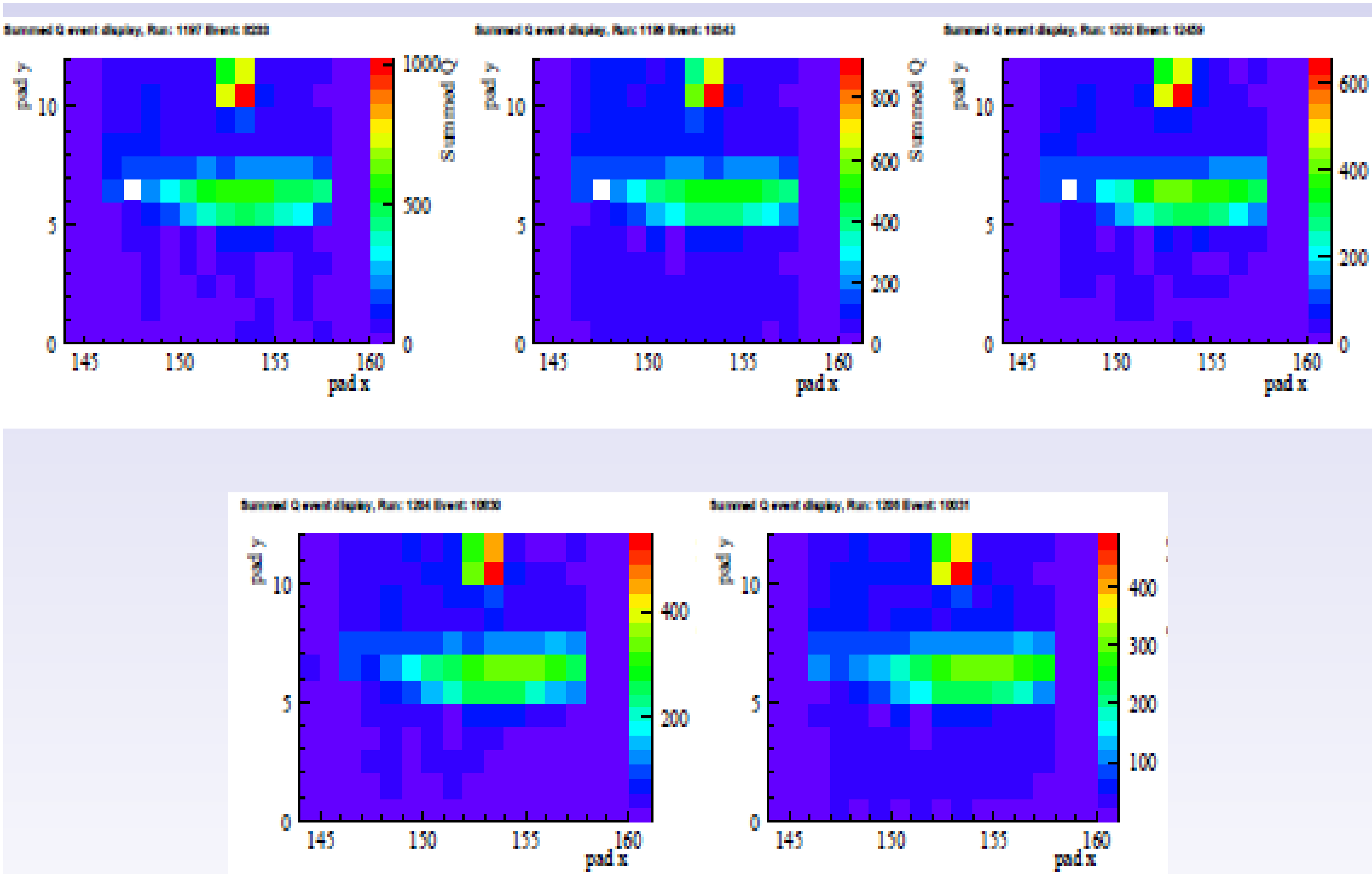
P. Martinengo presentation at this meeting

Photo CsI coated TGEMs



P. Martinengo presentation at this meeting

First images of the Cherenkov light



P. Matinego talk at this meeting

Those gaseous PMs were sensitive to UV light only (λ<220nm)

However, let's recall that at the time when vacuum and solid state position-sensitive detectors did not exist, gases PM were really unique:

they had efficiency to UV as the best PMT,

were position sensitive,

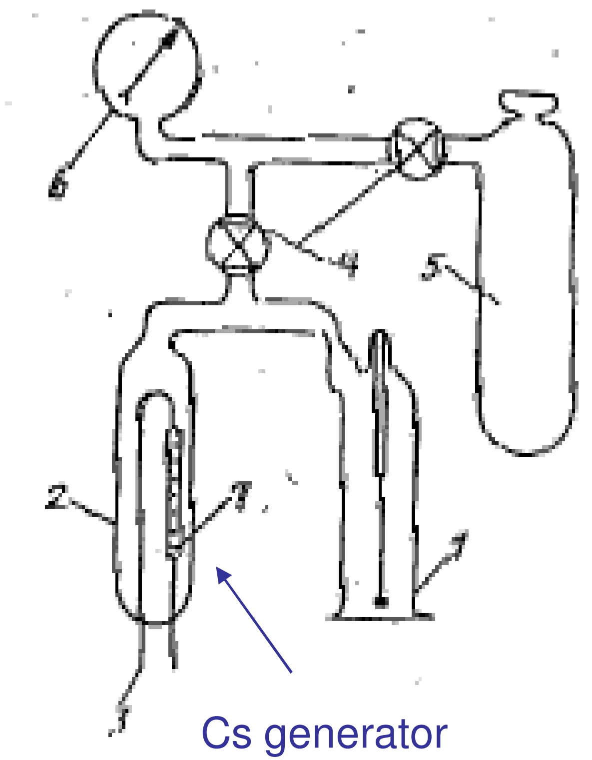
rather cheap and sensitive.

Even nowadays they can compete with other detectors in many applications

Gaseous PMs with Cs-based photocathodes sensitive to UV and visible light

These attempts also have a long history…

Cesiates Cu photocathode



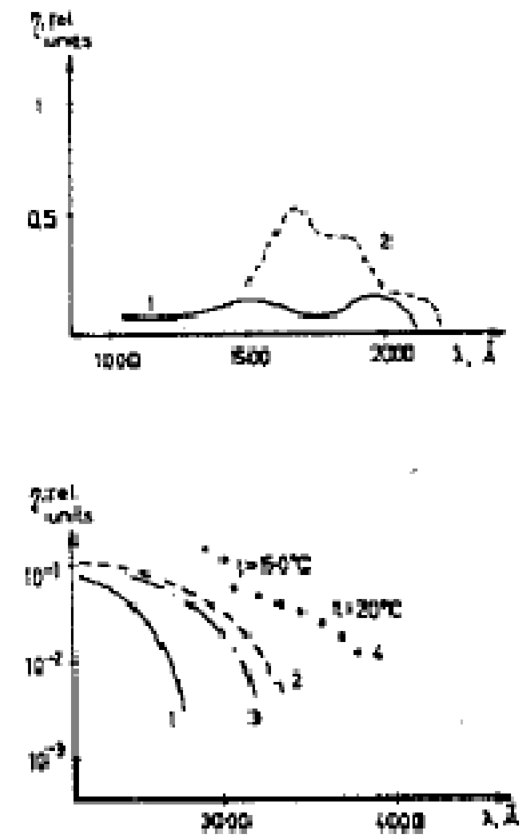
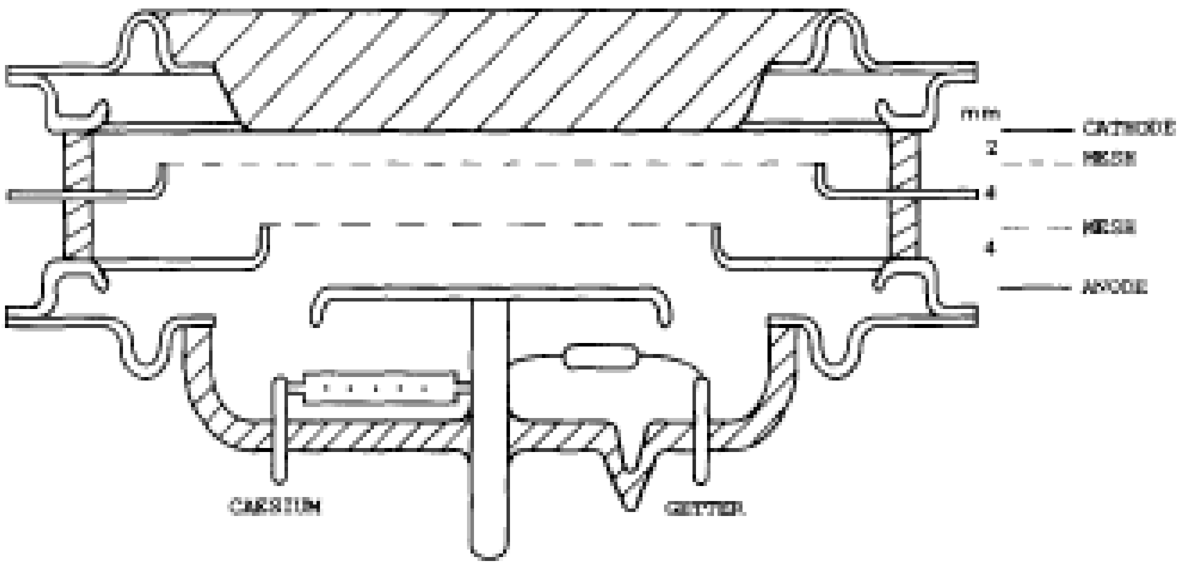


Fig. 2. Efficiencies, φ, of radiation from copper-cathode counters filled with ethyl-ferrocene (1) and TMAE (2). Efficiencies measured for CuI (3) and Cs (4) photocathodes are also given.

V. Peskov , Jour Spectr, 48, 1988,316

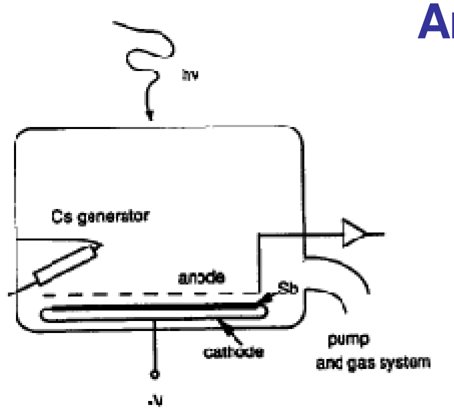
V. Peskov, NIM, 252,1986, 465

Cesiates Sb photocathode



J.S Edmens NIM A 273, 1988, 145 (in cooperation with a photonic company)

Another cesiated photocathdes



<u>Three main difficulties</u>:
Feedback
QE,
Cleanness

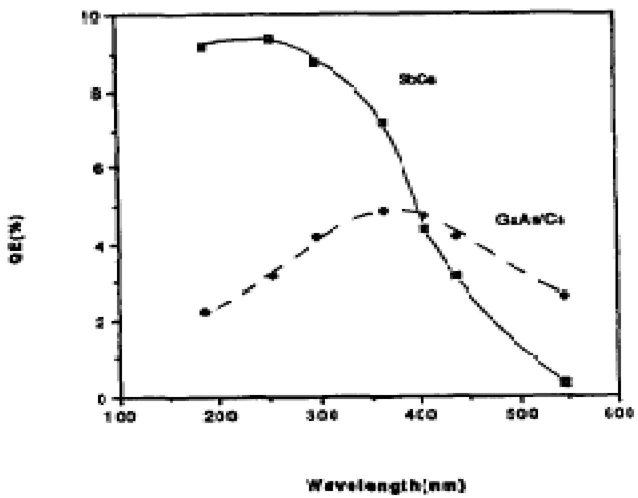


Fig. 2. Typical QE of SbCs and GaAs/Cs photocathodes fabricated inside the glass chamber.

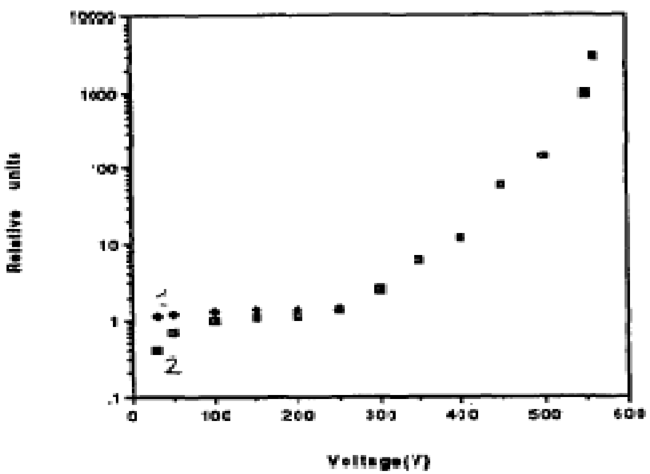


Fig. 3. Photocurrent in relative units versus voltage for the SbCs photocathode fabricated inside the stainless steel chamber. 1 – results in vacuum, 2 – results in CH_4 at 80 Torr.

G. Charpak et al, NIM 323, 1992,445, A. Borovick-Romanov et al, NIM348,1994,269, V. Peskov, NIM 353, 1994, 184, V. Peskov, NIM 367,1995, 347

Photocathode protection

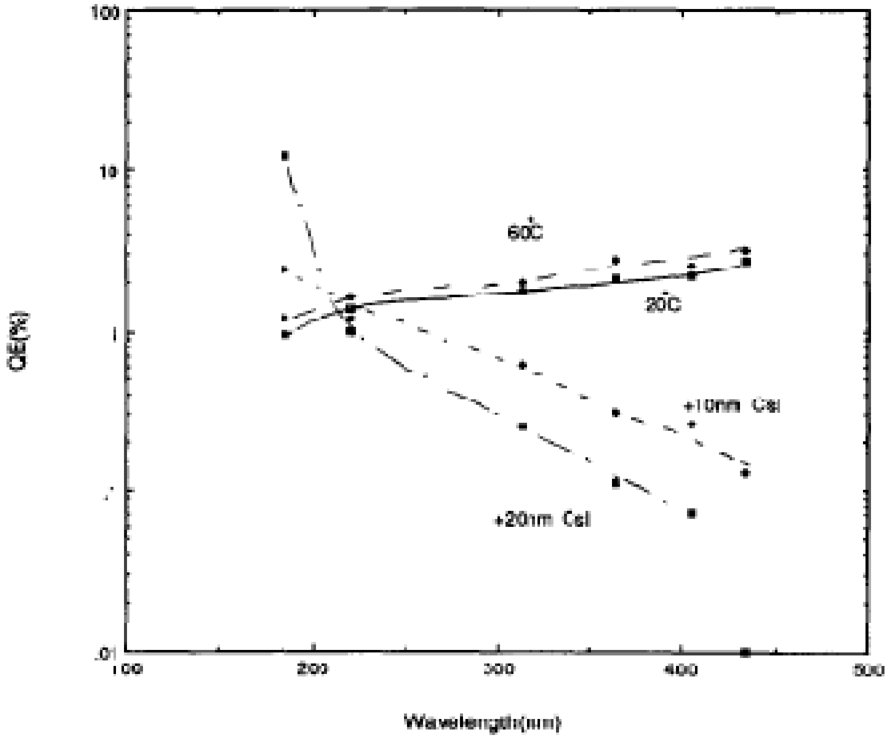
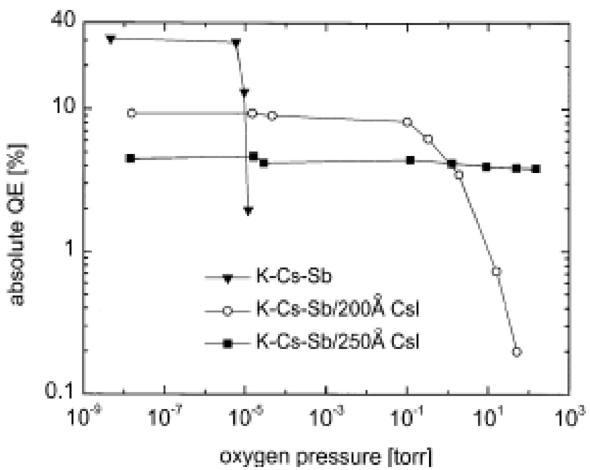


Fig. 2. The QE of the SbCs photocathodes vs the wavelength under different conditions: room temperature (20°C), 60°C and without and with CsI protective layers. One can see that heating to 60°C helped to increase the QE. A similar effect was observed earlier in the case of a CsI photocathode [30].

V. Peskov et al. NIM A353,1994,184

A great progress in this direction was achieved when **Breskin group** joined to these developments

This group learn how to manufacture high efficient photocathodes and made a lot of studies on photocathode protection



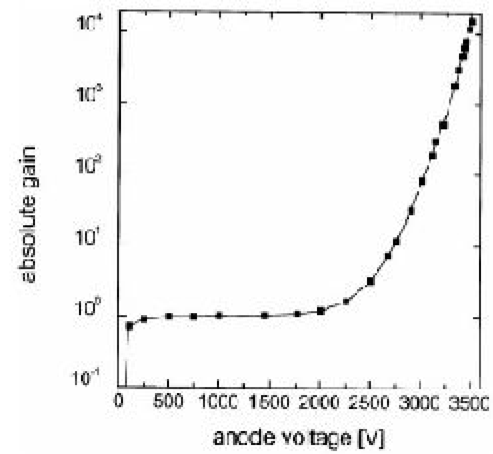
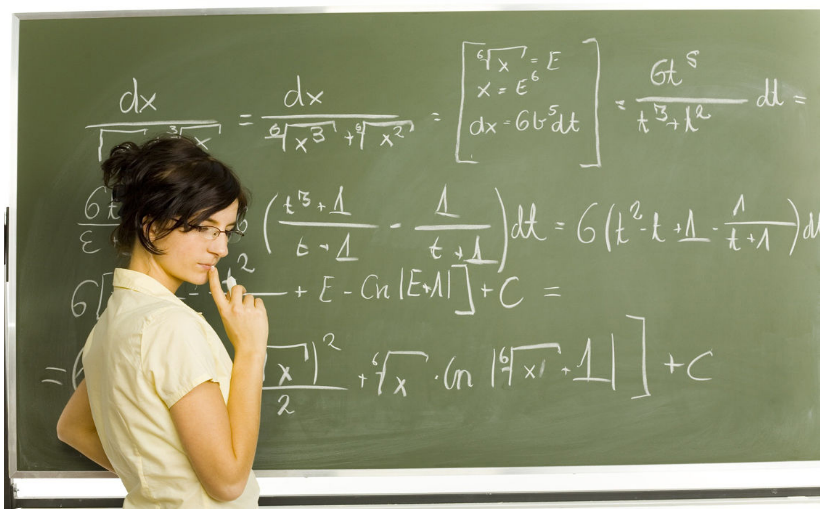


Fig. 3. Absolute gain as a function of anode voltage of a 1 mm gap parallel plate electron multiplier coupled to a semitransparent K–Cs–Sb photocathode coated with 300 Å thick CsBr film, at 1 atm of methane

However, the maximum reachable gains were<10^3 with high efficient photocathodes

See for example: *NIMA3871997,176,E. Shefer et al., NIMA411,1998,383, E. Sheferet al.,A433,1999502*

What limit the gain?



$$A\gamma_{ph}=1$$

or ,

$$A\gamma_{+}=1 \, ,$$

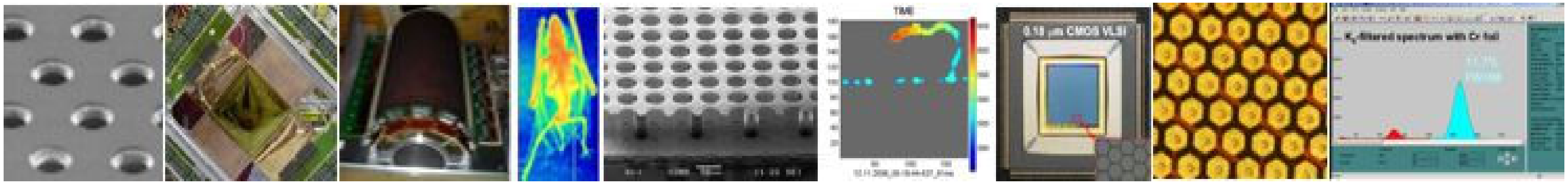
where

$$\gamma_{ph}=\int Q(V, E_{\nu})S(V,E_{\nu})dE_{\nu},$$

$$\gamma_{+}=k_{g}(V)\ (E_{i}-2\varphi)$$

Conclusion: with “open geometry (PPAC) we reached the limit

<u>New breakthrough</u>: photomultipliers based on **micropattern gaseous detectors**



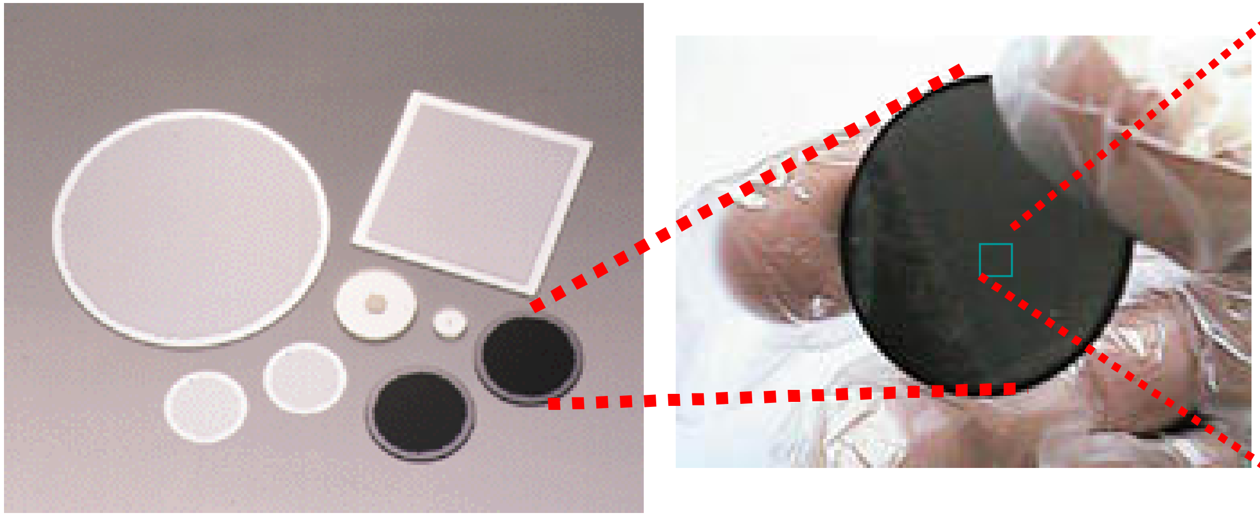
MPGDs open new possibilities in feedback suppression:

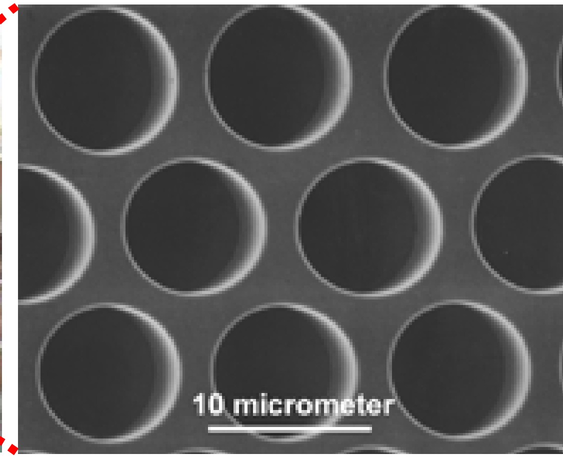
$$A b \gamma_{ph} = 1 \quad b << 1$$

or

$$A c \gamma_{+} = 1 \quad c < 1$$

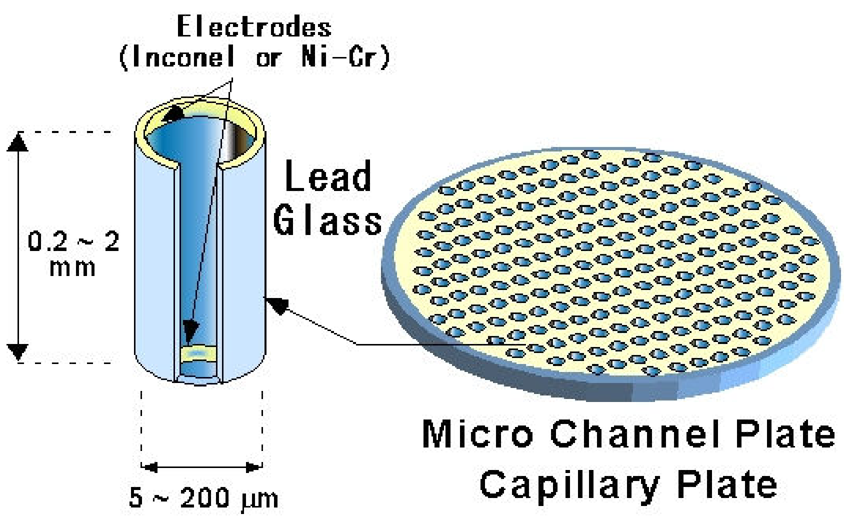
Micro Channel Plate / Capillary Plate





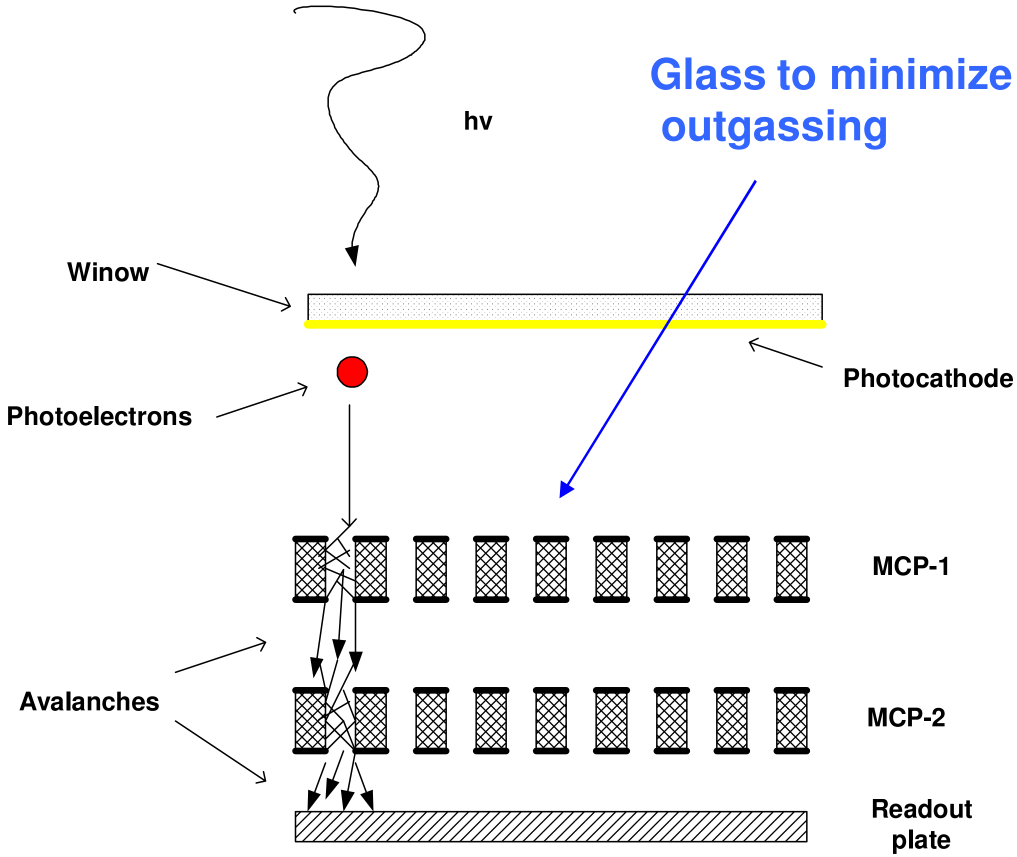
Physical Parameter of MCP and CP

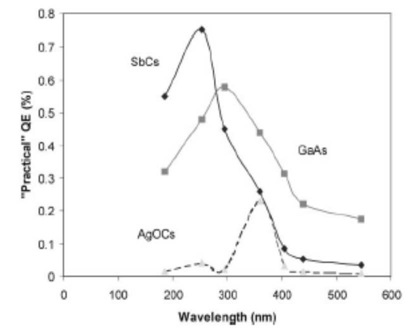
Material	Lead Glass
Outer Diameter (mm)	10~100
Package Density (cm^{-2})	~10^6
Thickness (mm)	0.2~2
Channel Diameter (μm)	5~200
Electrode Material	Inconel or Ni-Cr
Resistivity (Ω)	10^6~10^{10} : 10^{15}
Bias Angle (degree)	5~15 : 0

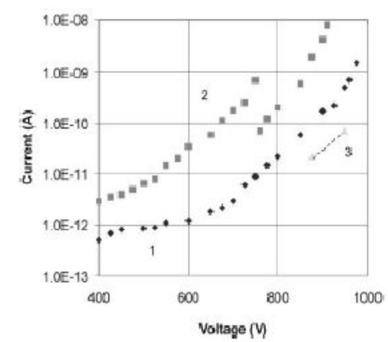


H. Sakurai et al., NIM A374, 1996,341

A schematic view of two capillary plates operating in cascade mode



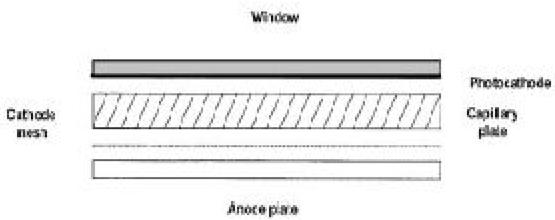




Gains $>10^4$ were possible to achieve

See: *Peskov et al, NIM A433,1999,492*

Several other designs :



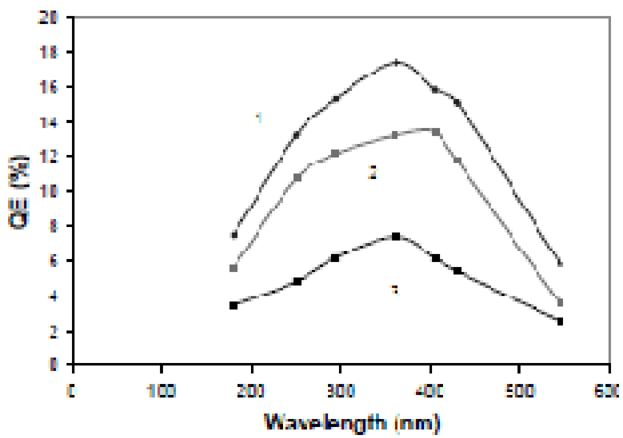
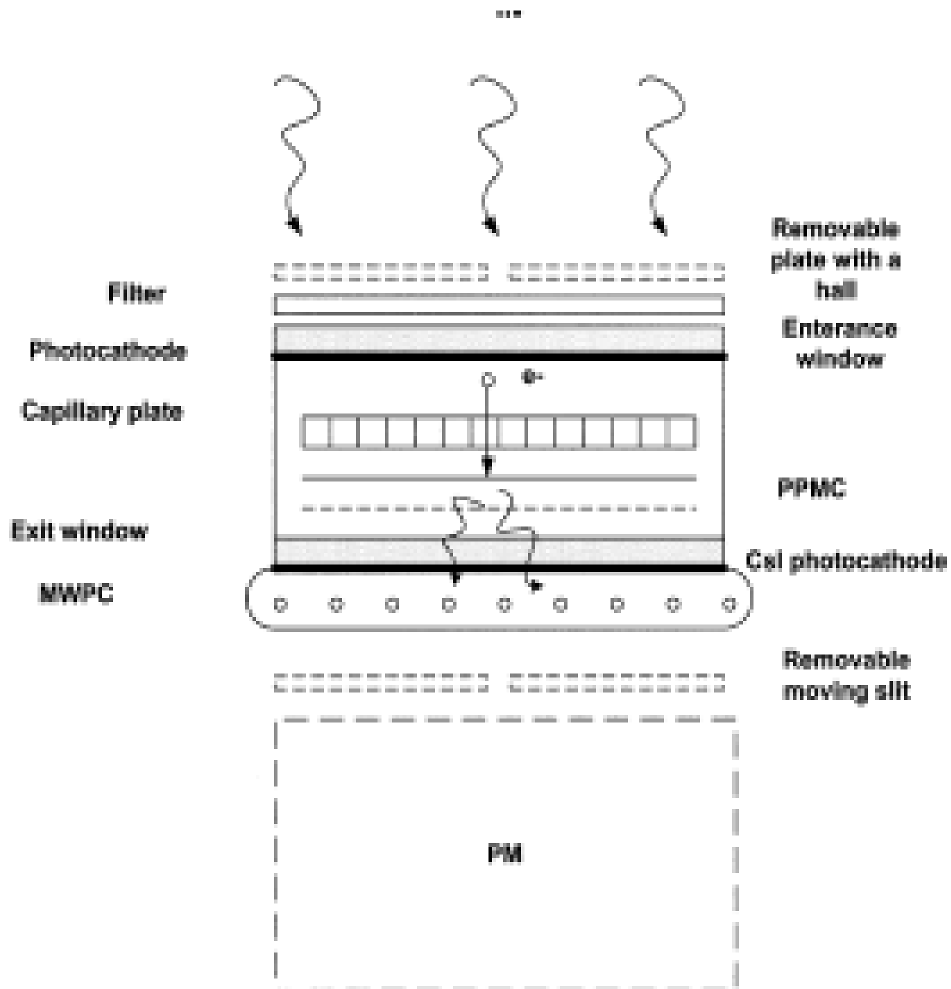


Fig. 1. QE efficiency of a bialkali photocathode, measured i vacuum (1), and in Ar + 5% CH_4 (2) in collection mode; (3 "practical" [11] QE measured in amplification mode.



S. Guinji et al, NIMA477,2002,8
V. Biteman et al., NIMA471,2001,205

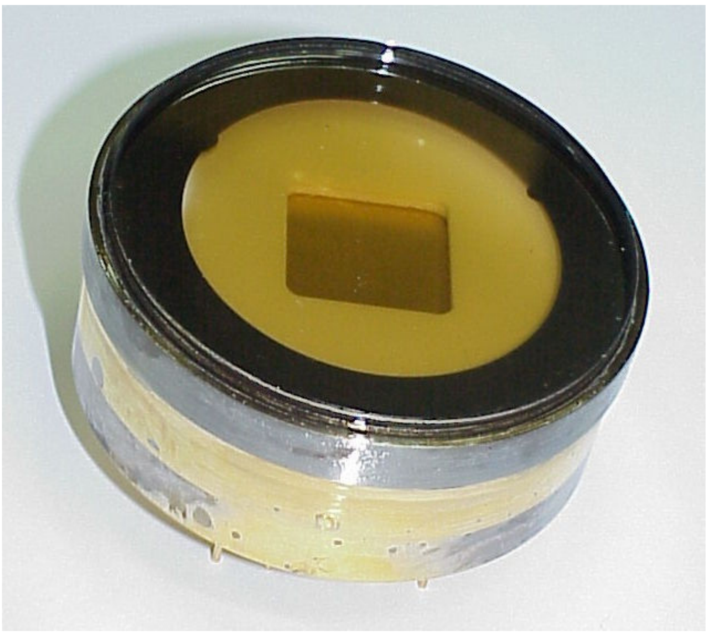
I. Rodionov et al., NIMA478,2002,384

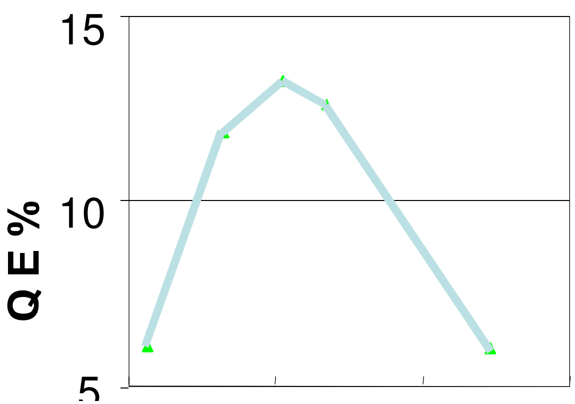
Later very impressive results in this direction were obtained by Breskin group

Sealed detector package

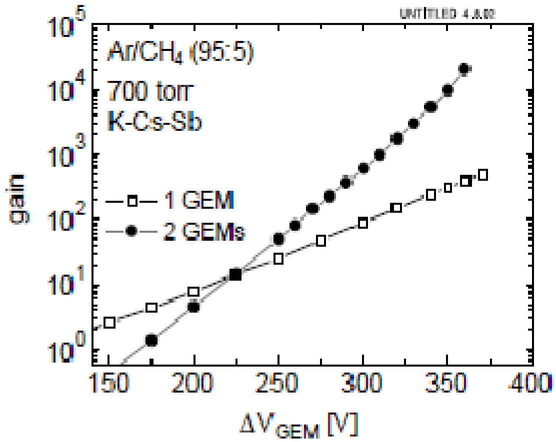
Sealing of 3 Kapton-GEMs + K-Cs-Sb photocathode

(Instead of capillaries)





13% = best QE measured after sealing.



Gain about 10^4

Sealing technique in gas: In/Sn; 130-150^{0}C

R. Chechik et al., NIMA502,2003,195

Beside Breskin team several other groups tried to develop PMs based on MPGDs:, Tokanai, Va'vara, Gorodecki-Giomataris

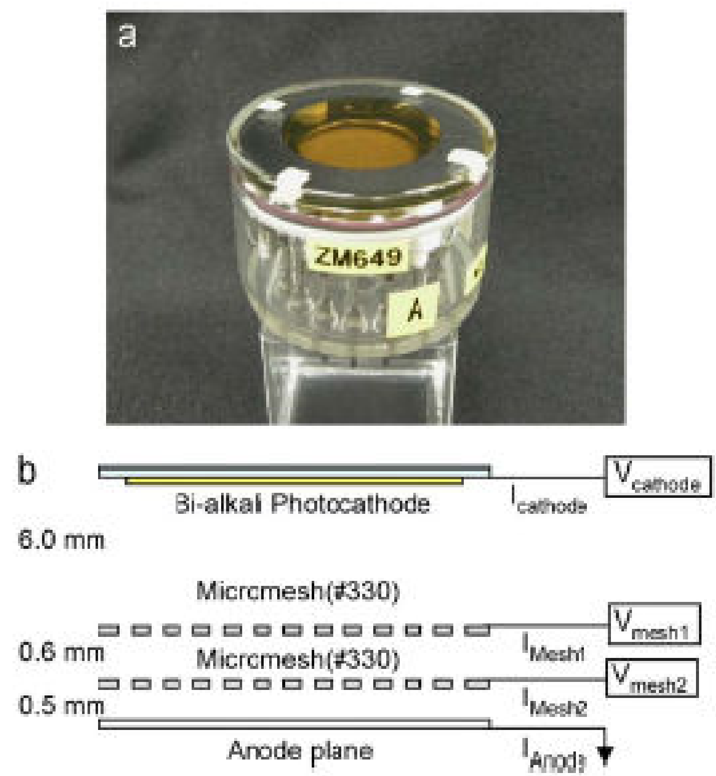
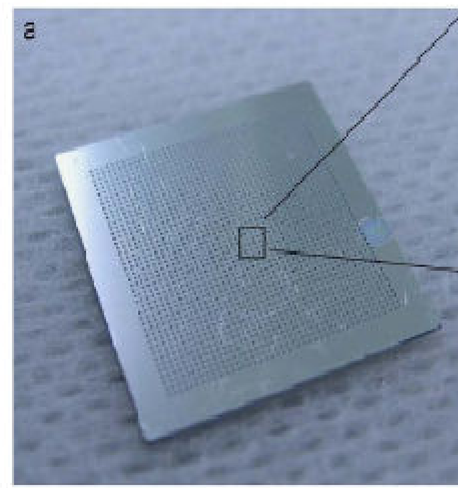
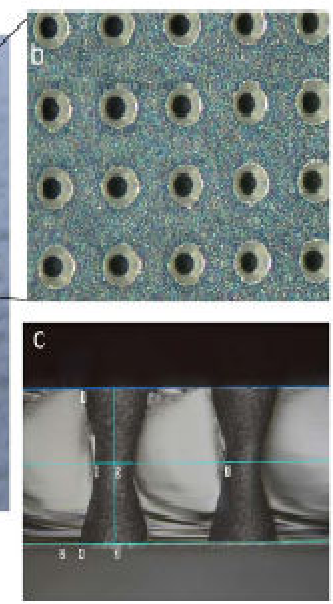


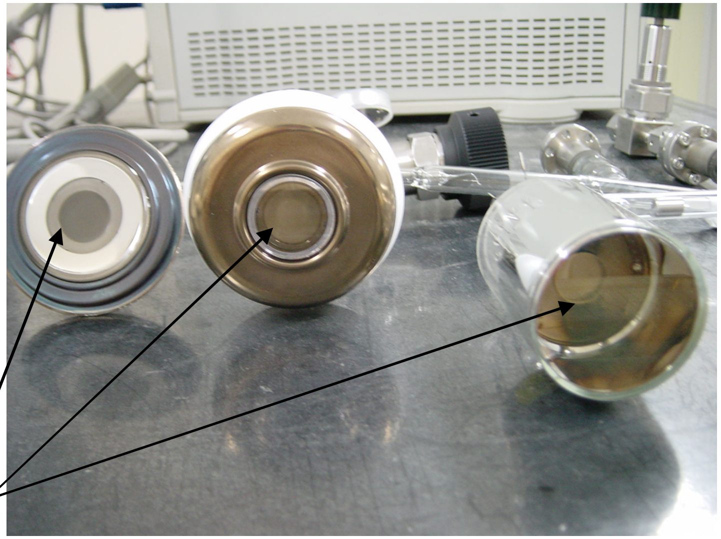
Fig. 1. Photograph (a) and schematic view (b) of the sealed gaseous PMT with a bialkali photocathode and double Micromegas detector.

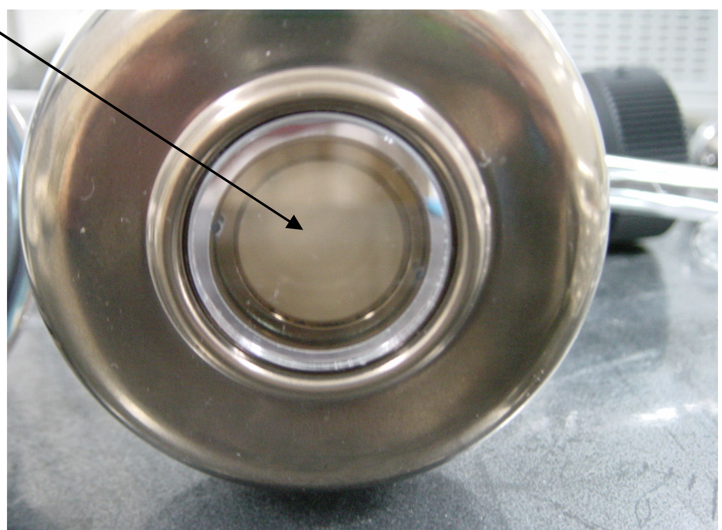
Capillary based gaseous PM

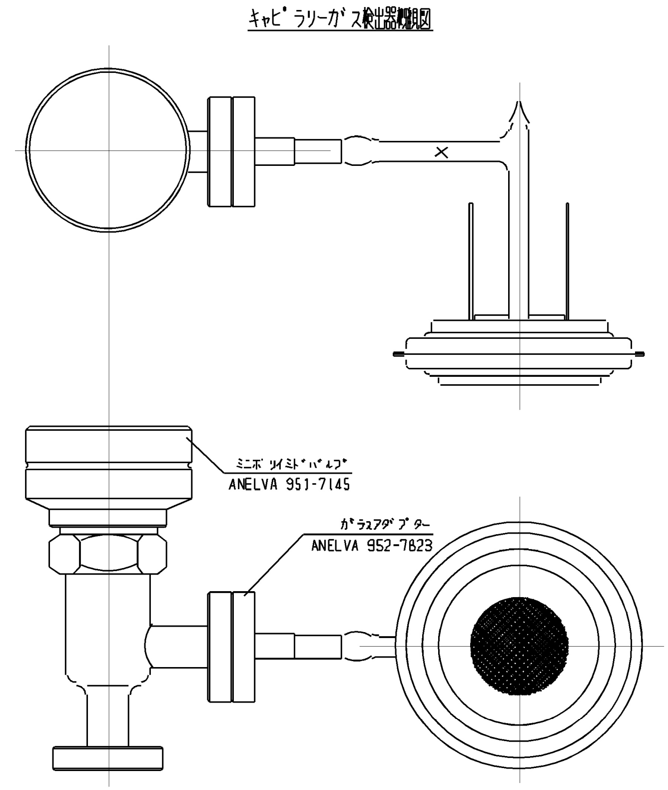
F. Tokanai et al, NIM A610,2009,164

H. Sakurai et al., Gas Photo-Multipliers. Made by Hamamatsu



Capillary plates





Presented at the Imaging Conf 2003

Capillary+MICROMEGAS

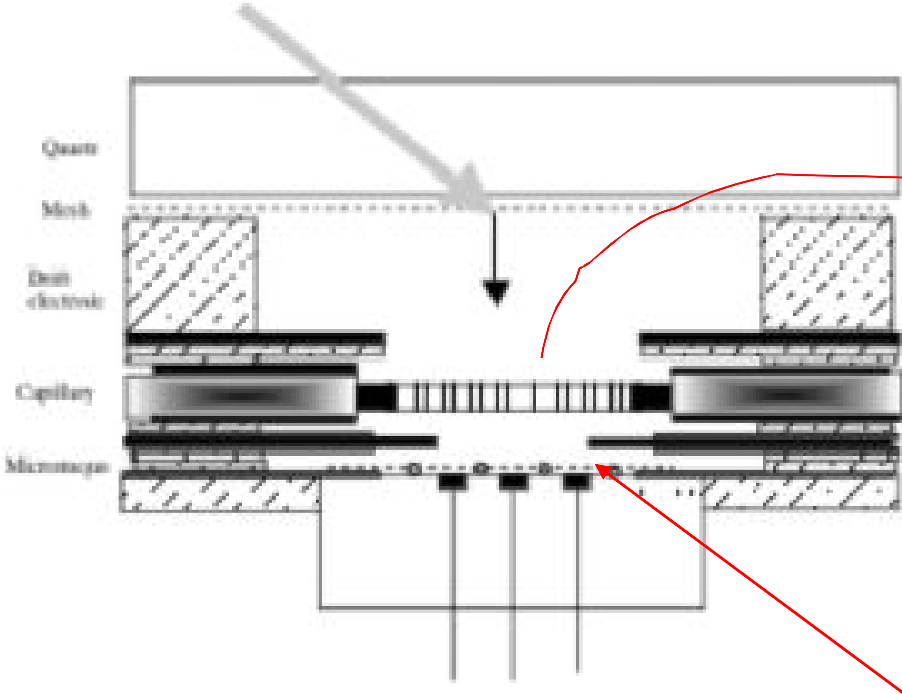
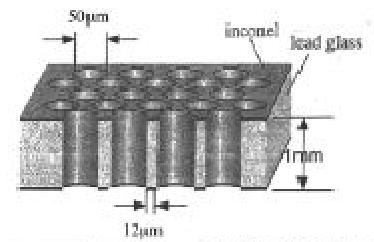
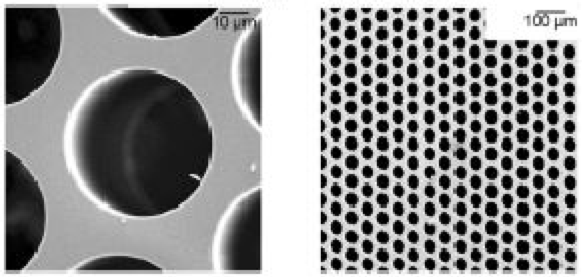


Fig. 2. Our detector is made by a combination of a single MCP and a single Micromegas. The Micromegas has a 100-μm gap, and the capillary has a 50-μm hole diameter. The Micromegas gap is held by 100-μm-diameter nylon lines in this particular test. Single electrons are produced by a UV light striking a dense s.s. mesh located at the entrance of the drift region.

Capillary plate





MICROMEGAS

J. Va'vra et al IEEE trans. Nucl. Sci,51,2004,2262

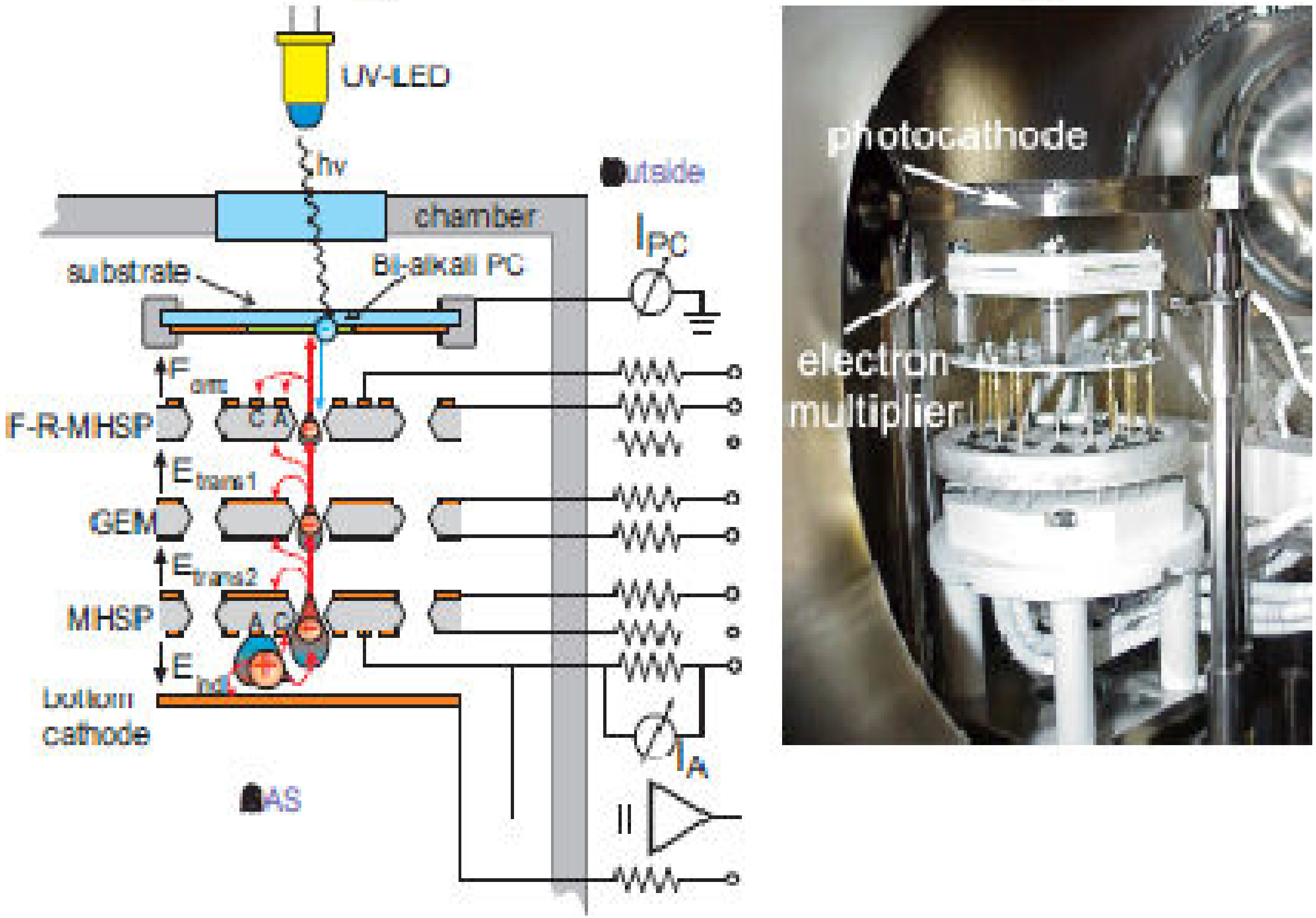
Each group has its oven technology

…some were generous enough to publish it

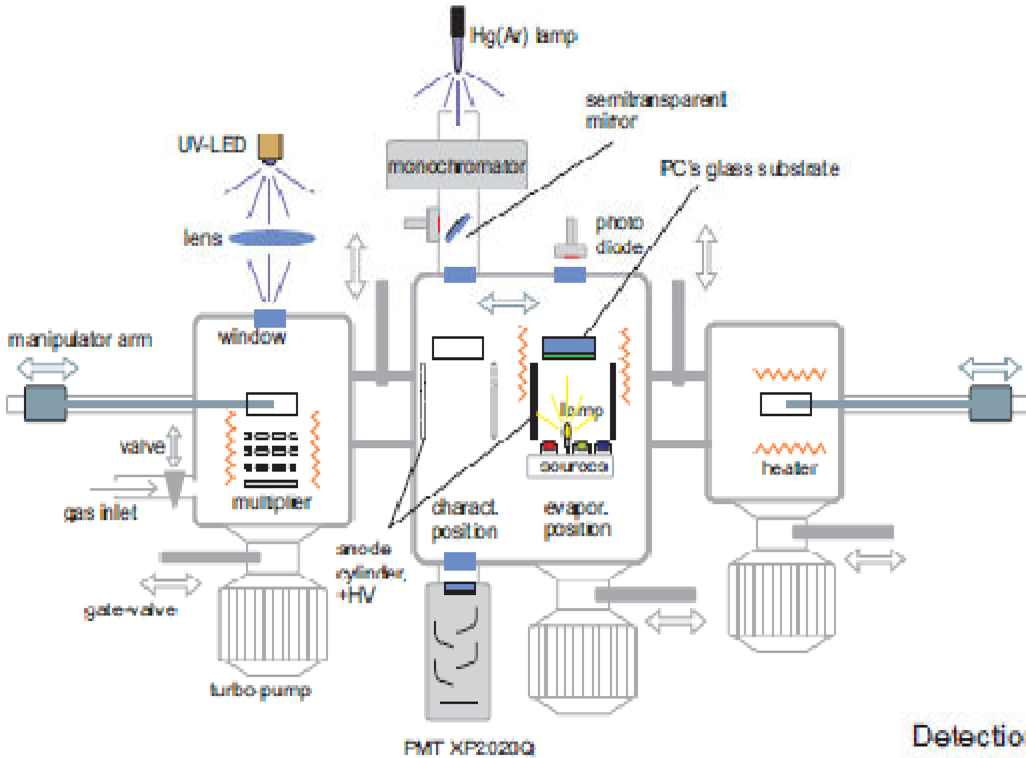
However, in spite of important contributions from various groups there is no doubt that the leader in these developments **today** is A. Breskin and his team

State of art gaseous PMT based on MPGDs

(a) (b)



A. Lyashenko et al., JINST 4 P07005, 2009

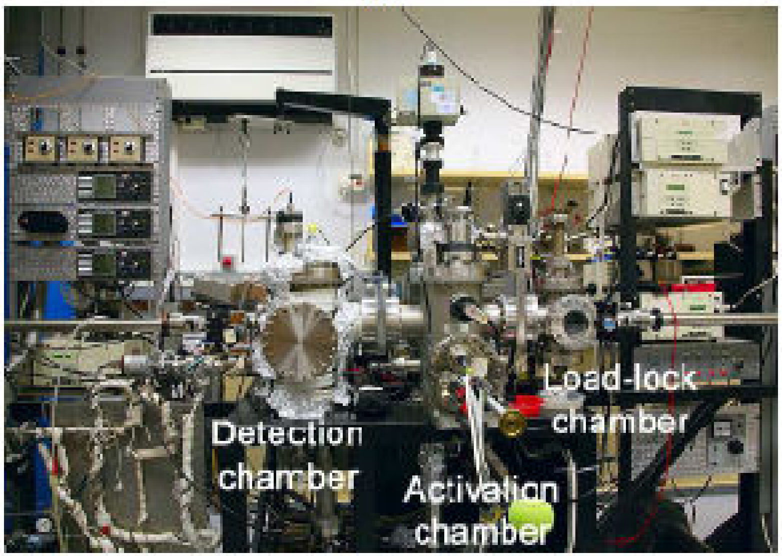


The set up is complicated and expensive

Detection chamber

Activation chamber

Load-lock chamber



A. Lyashenko et al., JINST 4 P07005, 2009

Detailed information about gaseous PMs can be found in recent review: *R. Chechik, et al., NIM A595,2008,116*

What could be done?

A. Bream high technology team

Braem laboratory posses all necessary technology of photocathode's production

Impressive developments made in Braem Lab

The TOM 10-inch HPD with Integrated Electronics

8-inch X-HPD

Conclusions

● Experience of several groups show that gaseous PMs based on MPGDs and sensitive to visible light can be done, although it is **not an easy task**

●Development PMs based on micropattern detectors could be an excellent RD51 scientific and technological project

● A. Braem Lab has all know-how and all necessary equipment, so CERN could be **the best place to implement this project**

● What is needed to implement this project: some modes funds and a few enthusiasts ready to work full time on this project

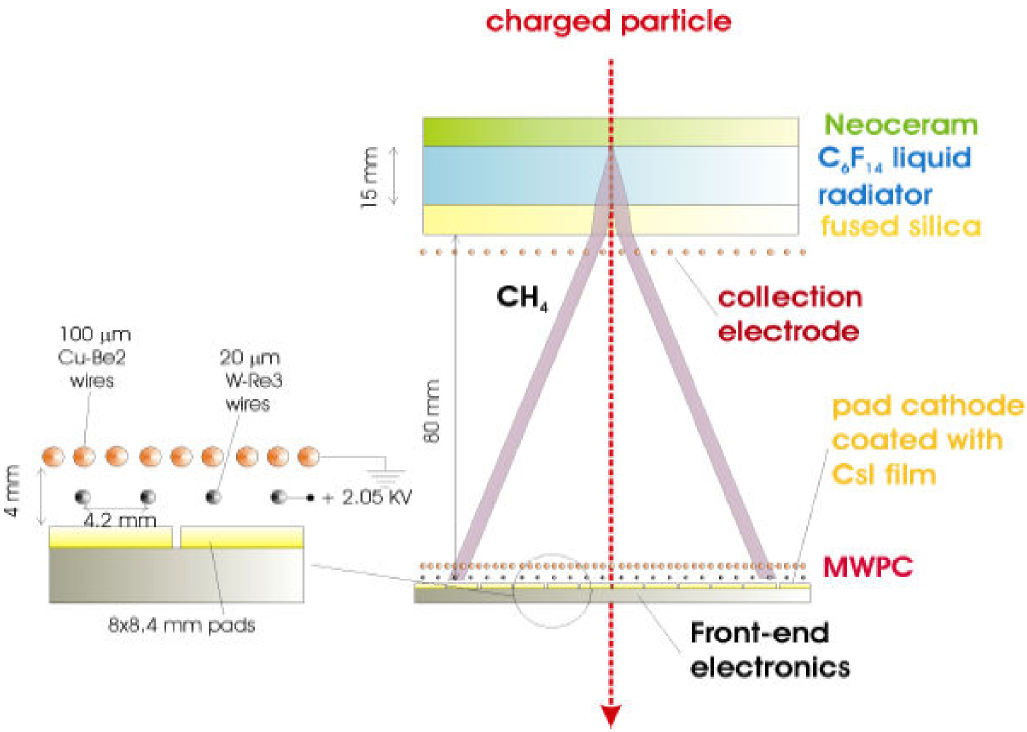
+

= **Success**

Together we can do this!

Spare slides

The ALICE/HMPID Detector



$\beta > 1/n$

$\cos\theta = 1/(n\,\beta)$

$N_{ph}[cm^{-1}eV^{-1}] = 370Z^2(1-1/n^2)$

Concept: proximity focussing CsI RICH

- liquid C_6F_{14} radiator
- MWPC
- cathode pads coated with CsI
- 3840 pads (8x8 mm^2) per PC with individual analogue readout

- 7 modules: total area 11 m^2 largest application so far
- 42 PCs (64 cm x 40 cm) in total (6 per module)

The STAR-RICH detector

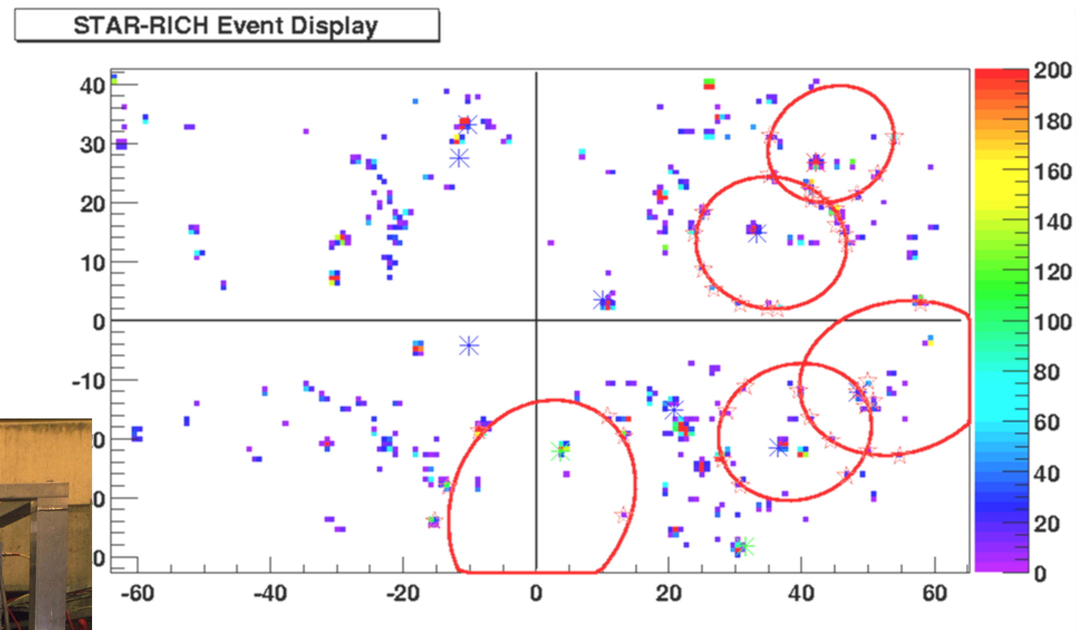
•**Charged particles multiplicity: 10 m^{-2}**

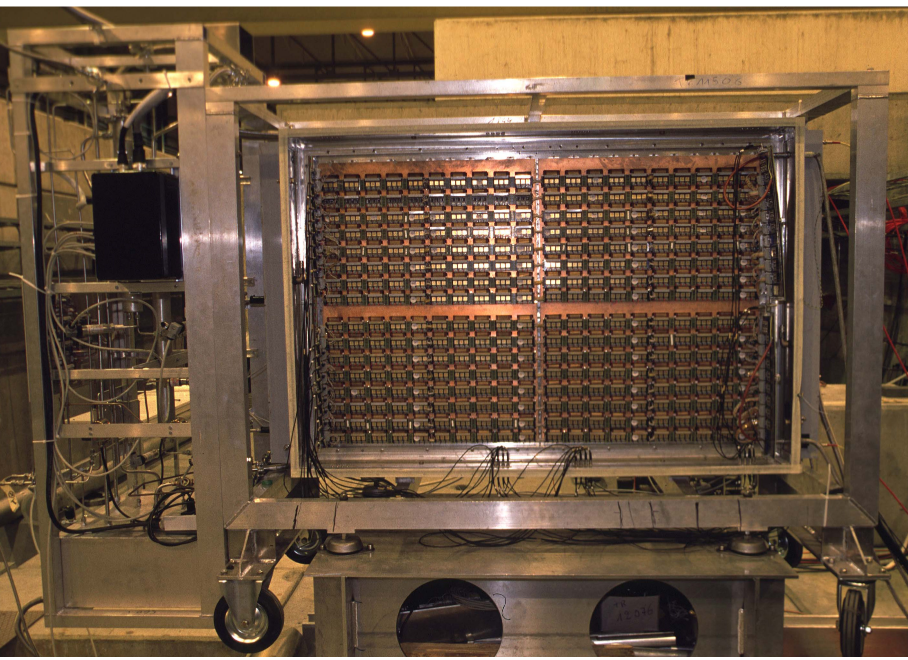
• **Interaction rate: 10^4**

• **PID:**

$1 < p < 3$ GeV/c π K

$2 < p < 5$ GeV/c p



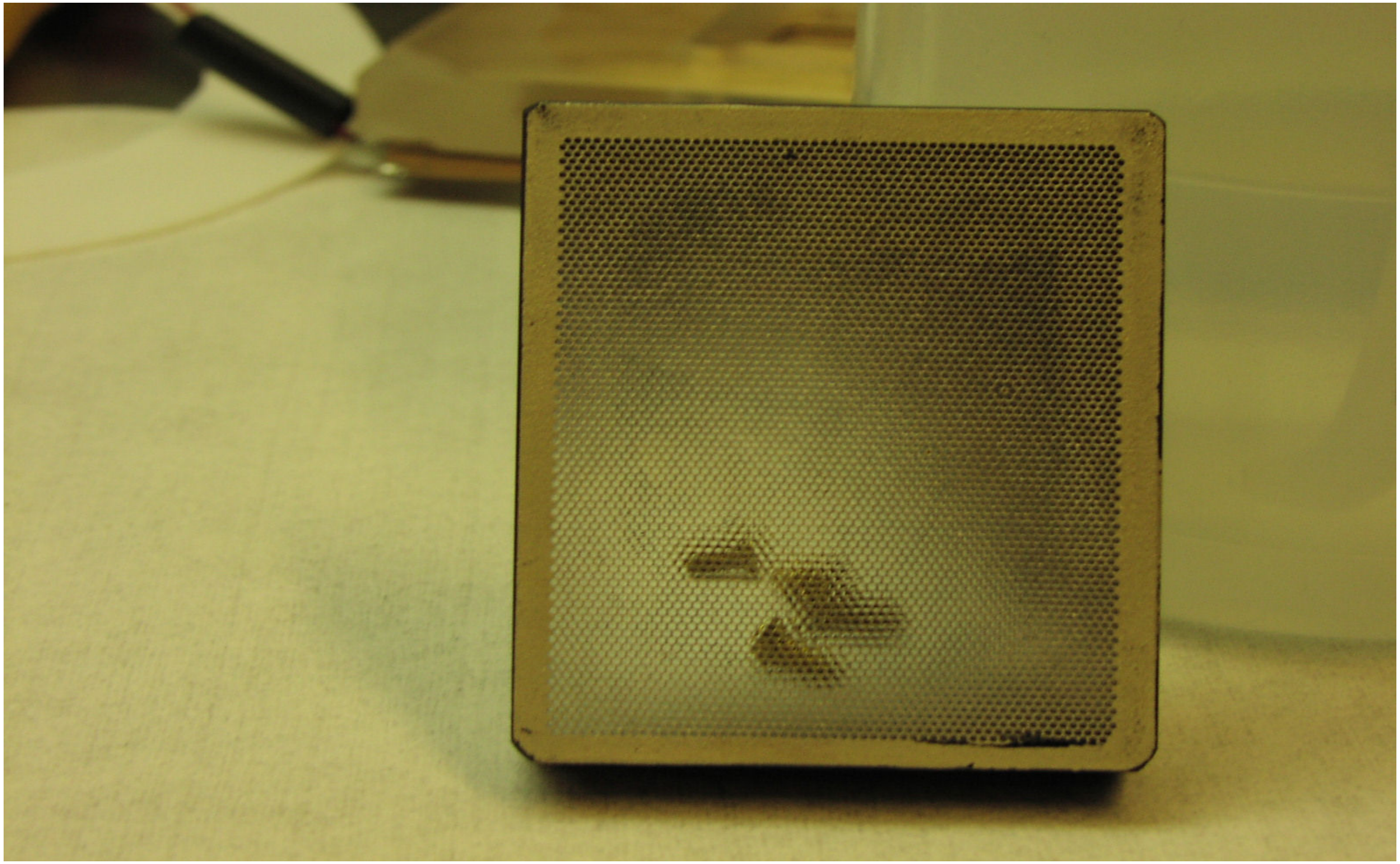


• **ALICE HMPID proto-2 (1 m^2 active area): proximity focusing (80 mm gap), 10 mm C_6F_{14} radiator, 4 CsI PC of 60x40 cm^2**

• **FEE: Gassiplex 1.5 μ, noise 1000 e^-**

New: First use of a CsI RICH detector in a collider experiment

Photo of a glass capillary plate



A. Del Guerra et al., NIM A257,1987, 609