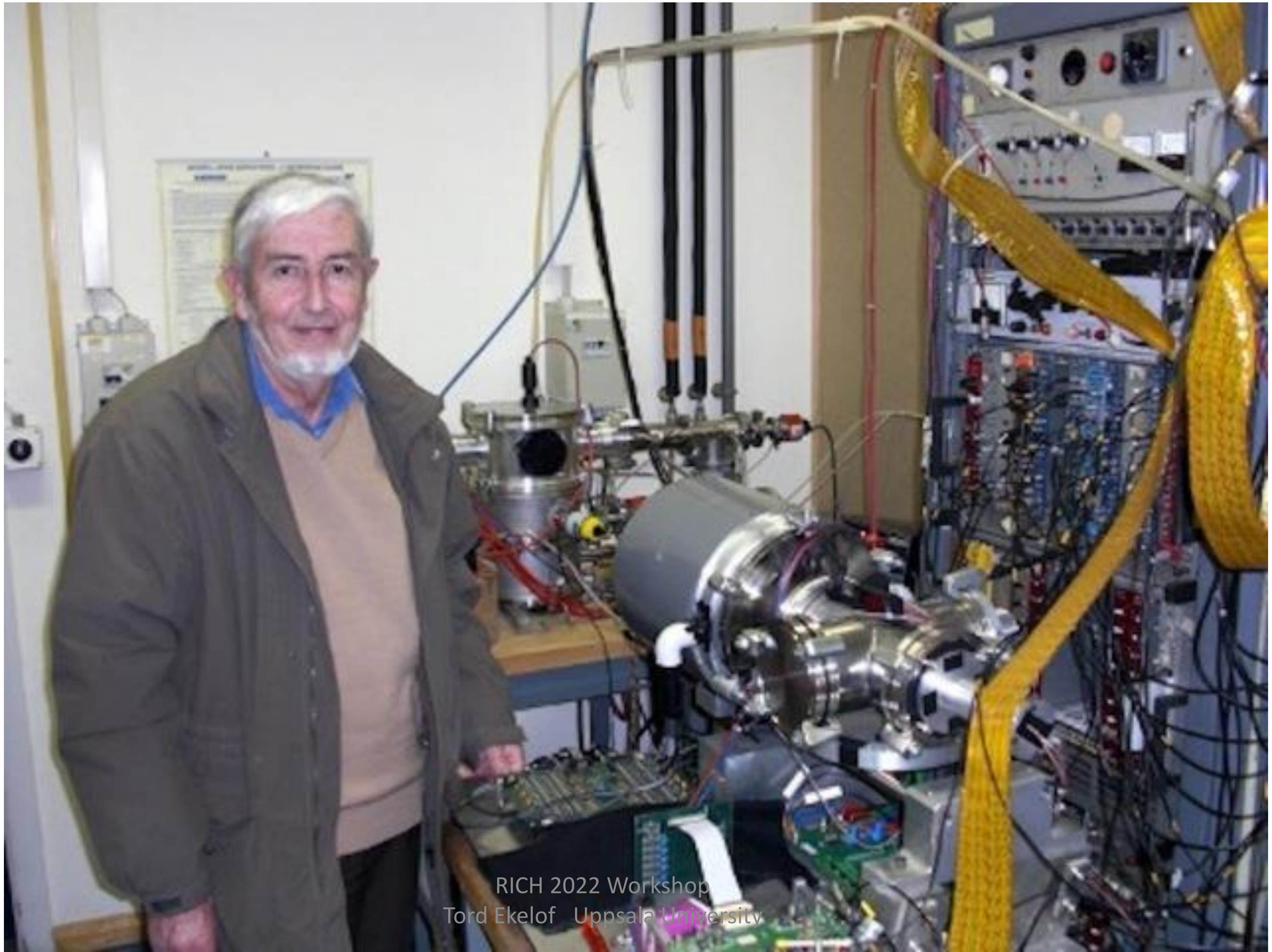
Homage to
Jacques Séguinot
1932-2020

RICH2022 Workshop in Edinburgh
12 September 2022

Tord Ekelof
Uppsala University

Jacques in his lab at CERN



Jacque’s 80th birthday at CERN 10 Feb 2012

I first met Jacques Séguinot at CERN in 1977. It was Tom Ypsilantis who introduced me to Jacque. Tom and I had met at an ECFA Study Week on e+e- storage rings beyond PETRA energies in February 1977 at which Tom presented Jacques' and his - as it would later turn out - historical paper on "Photo-ionization and Cherenkov ring imaging", which had been published as a CERN preprint already 18 November 1976. Toms presentation made a strong impression on me - I still have my notes from his talk in this notebook. After the ECFA Study Week I contacted Tom and Jacques at CERN and soon decided to join their Photo-Ionization Cherenkov, PIC, project as it was called, later re-baptised to RICH.

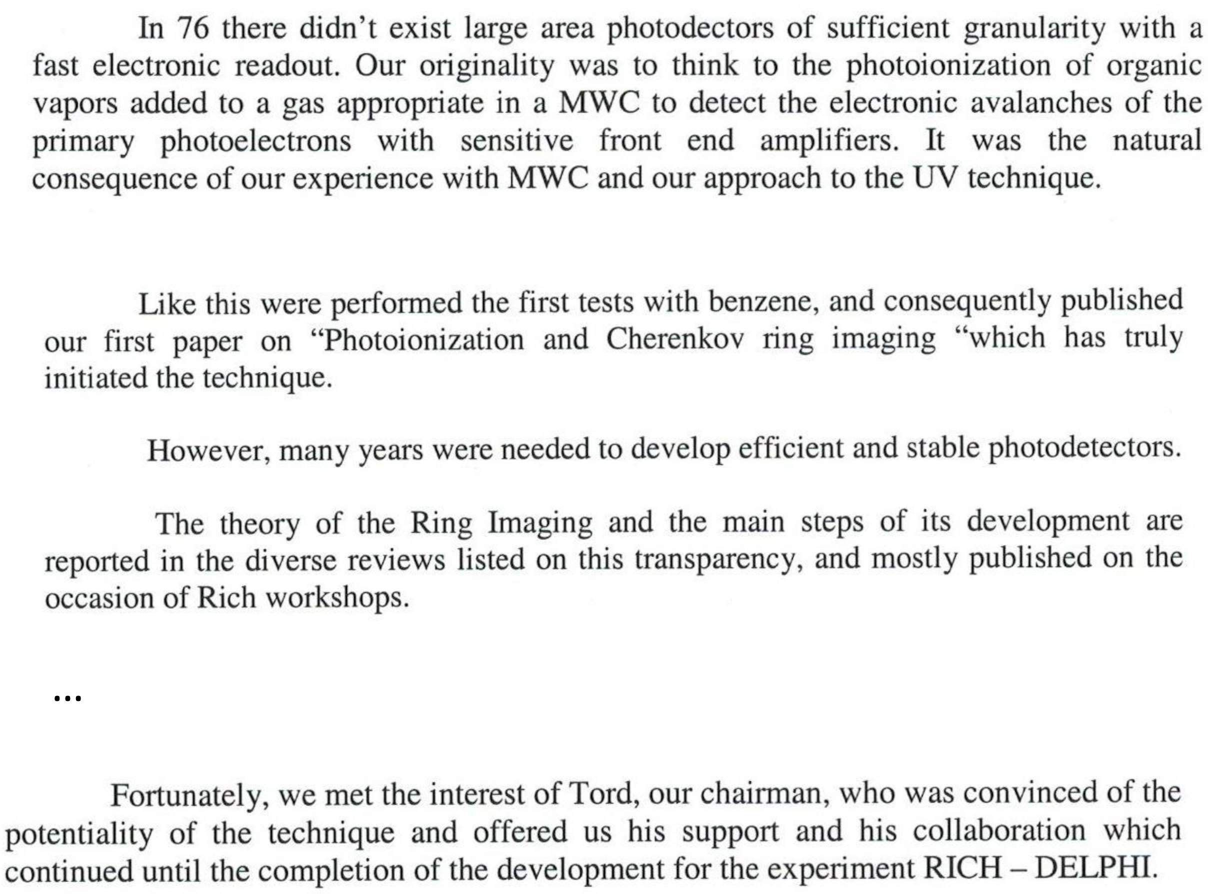
Jacques was an outstanding representative of the French science and engineering culture: brilliant, rigorous, tenacious, with a particular talent for invention, design, construction and tests of scientific instrumentation. Tom was, with Jacques own words, "original, creative but also pugnacious and an eternal optimist ahead of his time about possible experiments and techniques". Tom's creativity and optimism would probably have left little concrete results if there would not have been Jacques, who daringly designed, ordered the manufacture of, set up and tested the prototype detectors that they conceived together.

Abbreviated CV of Jacques’ up to completion of the DELPHI Barrel RICH

1932 Birth dans la Vendée in France
1950 Electromechanical engineering studies at the University of Caen
1954 PhD in physics
1955 Cosmic-ray experiments at Col du Midi followed by accelerator-based experiments at CEA Saclay
1964 Start of experiments at CERN’s Proton Synchrotron
1969 Start of collaboration with Tom Ypsilantis
1977 Historic publication “Photo-ionization and Cherenkov ring imaging”
1979 Start of work on DELPHI RICH
1980 Great year of many RICH innovations
1982 Directeur de recherche
1987 Completion of DELPH Barrel RICH prototype
1990 Official retirement
1992 Completion of DELPHI Barrel RICH
Work on RICH’s for CLEO, ALICE, COMPASS, AQUARICH… and on HPD, medical PET detector…
2020 Death

Jacques’ companion Tom Ypsilantis

Quotes from Jacques Homage talk for Tom Ypsilantis at the RICH 2002 Workshop at Pylos, Grece



In 76 there didn't exist large area photodectors of sufficient granularity with a fast electronic readout. Our originality was to think to the photoionization of organic vapors added to a gas appropriate in a MWC to detect the electronic avalanches of the primary photoelectrons with sensitive front end amplifiers. It was the natural consequence of our experience with MWC and our approach to the UV technique.

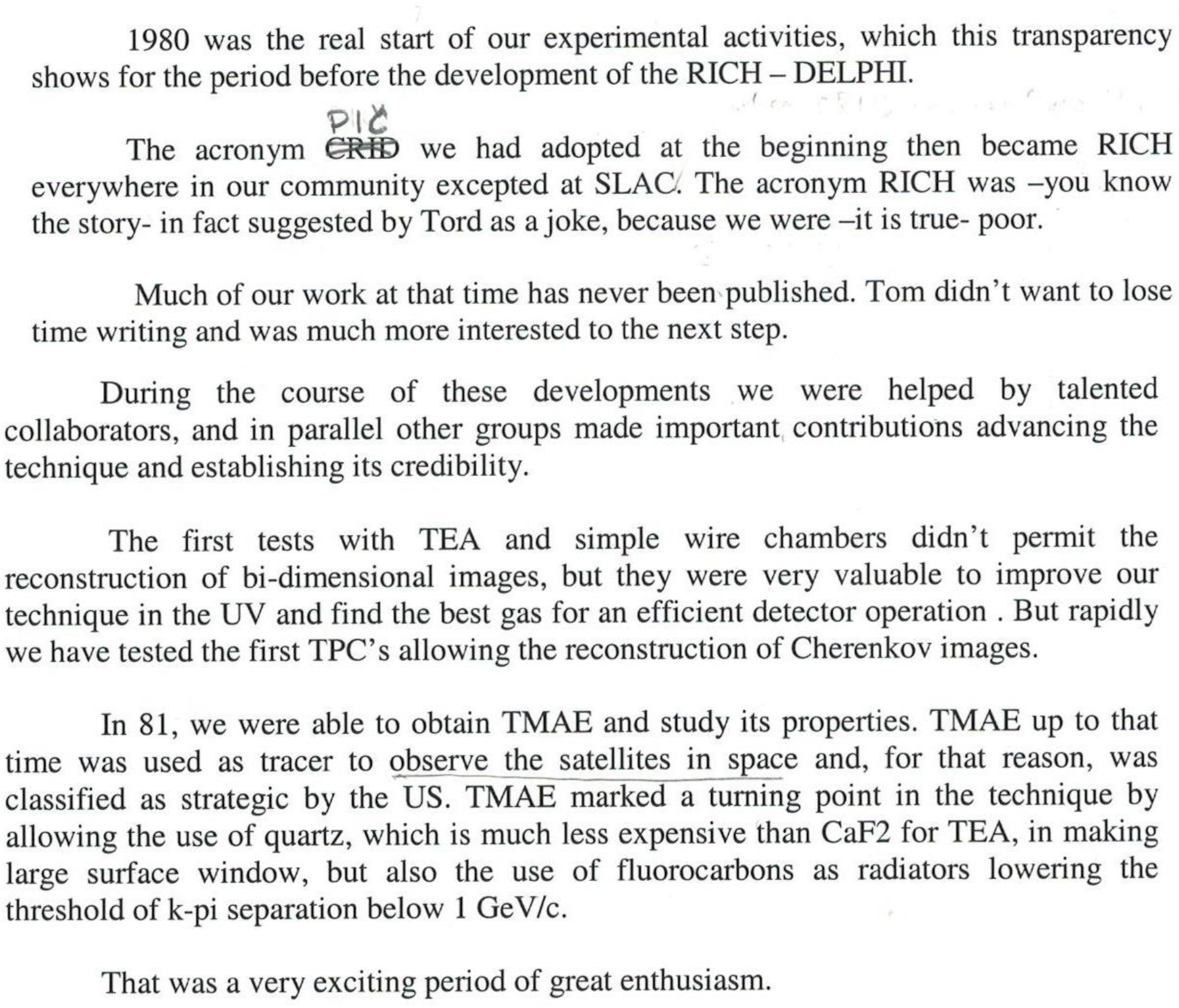
Like this were performed the first tests with benzene, and consequently published our first paper on "Photoionization and Cherenkov ring imaging "which has truly initiated the technique.

However, many years were needed to develop efficient and stable photodetectors.

The theory of the Ring Imaging and the main steps of its development are reported in the diverse reviews listed on this transparency, and mostly published on the occasion of Rich workshops.

…

Fortunately, we met the interest of Tord, our chairman, who was convinced of the potentiality of the technique and offered us his support and his collaboration which continued until the completion of the development for the experiment RICH – DELPHI.



1980 was the real start of our experimental activities, which this transparency shows for the period before the development of the RICH – DELPHI.

The acronym ~~CRID~~ PIC we had adopted at the beginning then became RICH everywhere in our community excepted at SLAC. The acronym RICH was –you know the story- in fact suggested by Tord as a joke, because we were –it is true- poor.

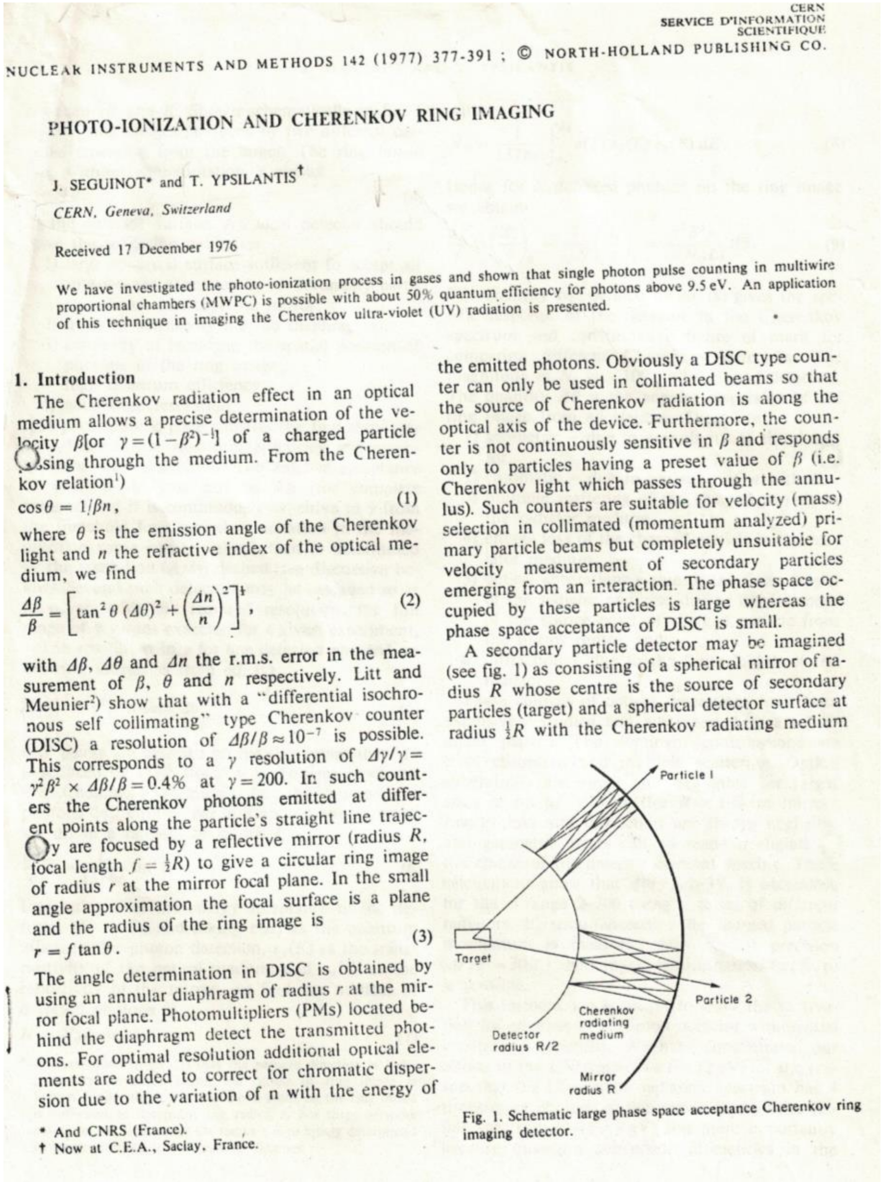
Much of our work at that time has never been published. Tom didn't want to lose time writing and was much more interested to the next step.

During the course of these developments we were helped by talented collaborators, and in parallel other groups made important contributions advancing the technique and establishing its credibility.

The first tests with TEA and simple wire chambers didn't permit the reconstruction of bi-dimensional images, but they were very valuable to improve our technique in the UV and find the best gas for an efficient detector operation . But rapidly we have tested the first TPC's allowing the reconstruction of Cherenkov images.

In 81, we were able to obtain TMAE and study its properties. TMAE up to that time was used as tracer to observe the satellites in space and, for that reason, was classified as strategic by the US. TMAE marked a turning point in the technique by allowing the use of quartz, which is much less expensive than CaF2 for TEA, in making large surface window, but also the use of fluorocarbons as radiators lowering the threshold of k-pi separation below 1 GeV/c.

That was a very exciting period of great enthusiasm.



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NUCLEAR INSTRUMENTS AND METHODS 142 (1977) 377-391 ; © NORTH-HOLLAND PUBLISHING CO.

PHOTO-IONIZATION AND CHERENKOV RING IMAGING

J. SEGUINOT* and T. YPSILANTIS†

CERN, Geneva, Switzerland

Received 17 December 1976

We have investigated the photo-ionization process in gases and shown that single photon pulse counting in multiwire proportional chambers (MWPC) is possible with about 50% quantum efficiency for photons above 9.5 eV. An application of this technique in imaging the Cherenkov ultra-violet (UV) radiation is presented.

1. Introduction

The Cherenkov radiation effect in an optical medium allows a precise determination of the velocity β[or $\gamma=(1-\beta^2)^{-\frac{1}{2}}$] of a charged particle passing through the medium. From the Cherenkov relation¹)

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

where θ is the emission angle of the Cherenkov light and n the refractive index of the optical medium, we find

$$\frac{\Delta\beta}{\beta} = \left[\tan^2\theta\,(\Delta\theta)^2 + \left(\frac{\Delta n}{n}\right)^2\right]^{\frac{1}{2}}, \qquad (2)$$

with $\Delta\beta$, $\Delta\theta$ and Δn the r.m.s. error in the measurement of β, θ and n respectively. Litt and Meunier²) show that with a "differential isochronous self collimating" type Cherenkov counter (DISC) a resolution of $\Delta\beta/\beta \approx 10^{-7}$ is possible. This corresponds to a γ resolution of $\Delta\gamma/\gamma = \gamma^2\beta^2 \times \Delta\beta/\beta = 0.4\%$ at $\gamma = 200$. In such counters the Cherenkov photons emitted at different points along the particle's straight line trajectory are focused by a reflective mirror (radius R, focal length $f=\frac{1}{2}R$) to give a circular ring image of radius r at the mirror focal plane. In the small angle approximation the focal surface is a plane and the radius of the ring image is

$$r = f\tan\theta. \qquad (3)$$

The angle determination in DISC is obtained by using an annular diaphragm of radius r at the mirror focal plane. Photomultipliers (PMs) located behind the diaphragm detect the transmitted photons. For optimal resolution additional optical elements are added to correct for chromatic dispersion due to the variation of n with the energy of the emitted photons. Obviously a DISC type counter can only be used in collimated beams so that the source of Cherenkov radiation is along the optical axis of the device. Furthermore, the counter is not continuously sensitive in β and responds only to particles having a preset value of β (i.e. Cherenkov light which passes through the annulus). Such counters are suitable for velocity (mass) selection in collimated (momentum analyzed) primary particle beams but completely unsuitable for velocity measurement of secondary particles emerging from an interaction. The phase space occupied by these particles is large whereas the phase space acceptance of DISC is small.

A secondary particle detector may be imagined (see fig. 1) as consisting of a spherical mirror of radius R whose centre is the source of secondary particles (target) and a spherical detector surface at radius $\frac{1}{2}R$ with the Cherenkov radiating medium

Fig. 1. Schematic large phase space acceptance Cherenkov ring imaging detector.

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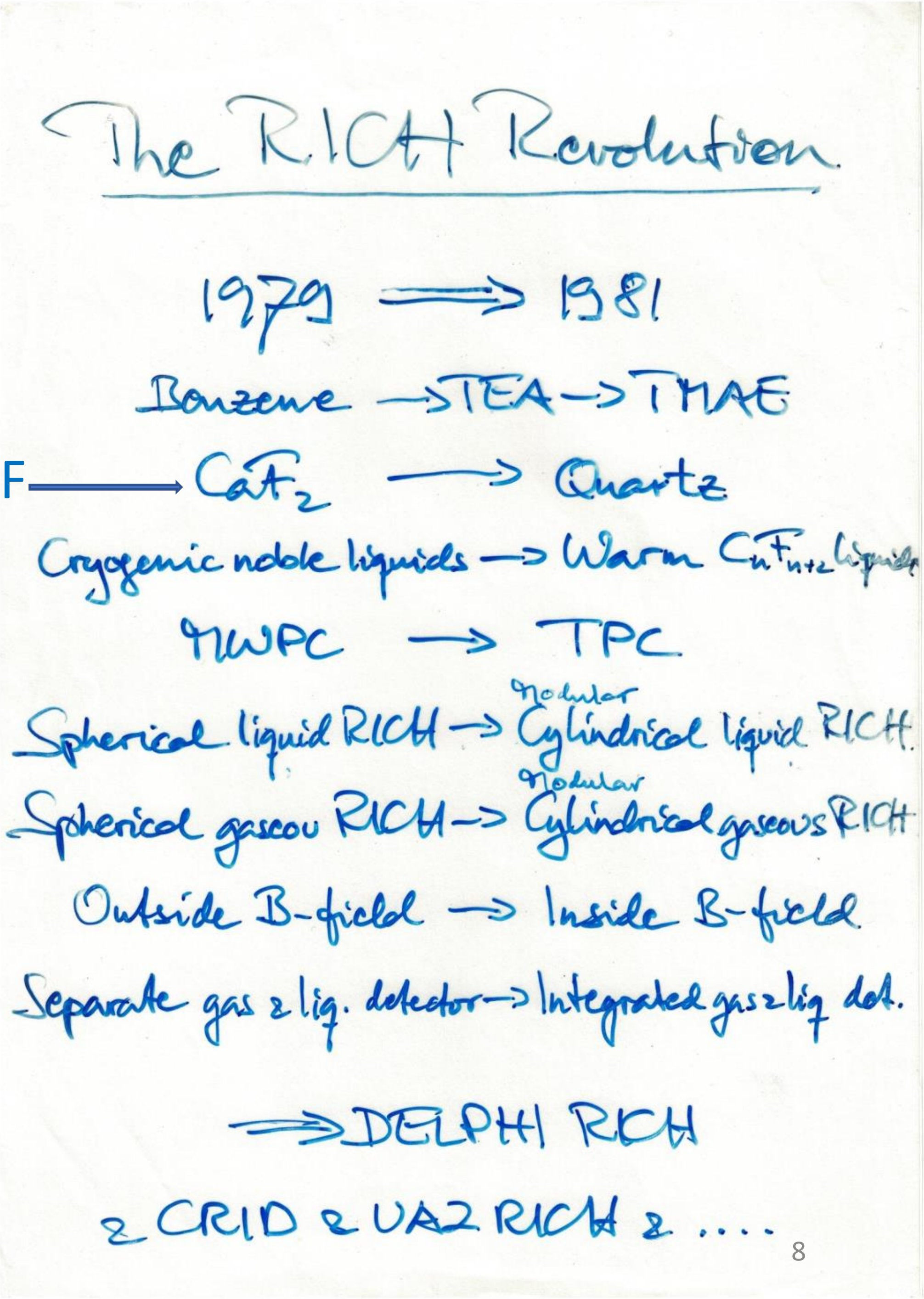
* And CNRS (France).

† Now at C.E.A., Saclay, France.



The RICH Revolution

1979 ⟹ 1981

Benzene → TEA → TMAE

LiF ⟶ CaF_2 → Quartz

Cryogenic noble liquids → Warm C_nF_{n+2} liquids

MWPC → TPC

Spherical liquid RICH → Modular Cylindrical liquid RICH.

Spherical gascou RICH → Modular Cylindrical gaseous RICH

Outside B-field → Inside B-field

Separate gas & liq. detector → Integrated gas & liq det.

⟹ DELPHI RICH

& CRID & UA2 RICH & ....

PIC TELLUS 1m radius

1979

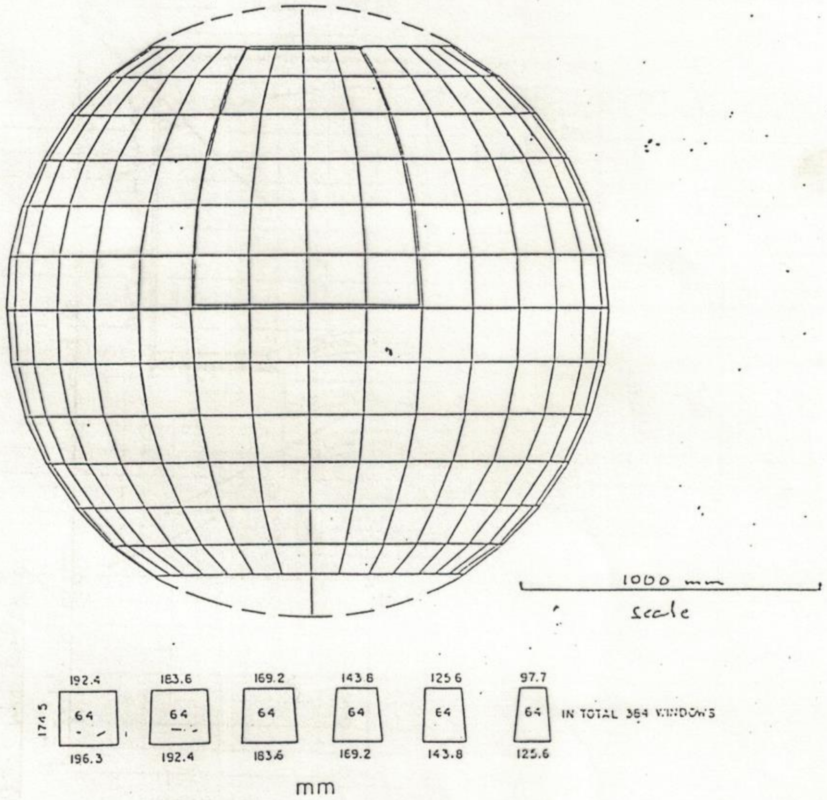
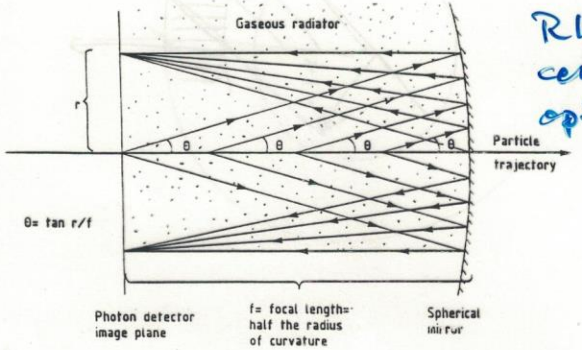


Fig 4

Modular
Gaseous Cupola RICH

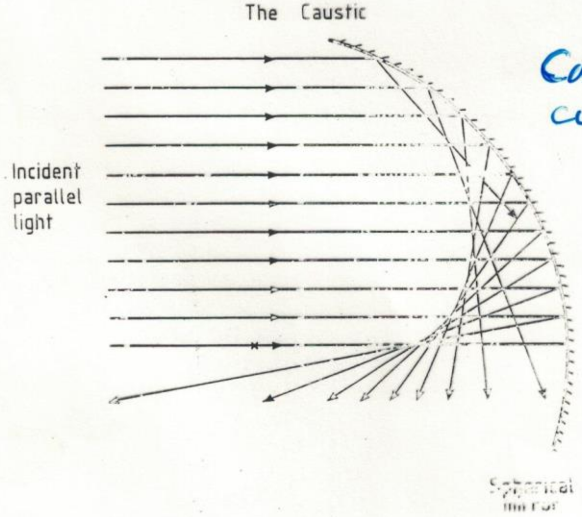
FOCUSSING WITH SPHERICAL MIRROR



RICH
central
optics

Fig. 3 Determination of the Cherenkov angle by letting the light emitted in a gaseous radiator be focalized by a spherical mirror onto a photon-detector surface.

The Caustic



Caustic
curve

Fig. 4 The so-called caustic curve which shows how the position of the focus for parallel light reflected by a sperical mirror depends on the impact parameter of the light. The center of curvature of the mirror is indicated with a cross. (The caustic can be straightforwardly observed in sunlight, e.g. inside a wedding-ring placed on a flat surface or in a filled coffee cup).

7

Cupola RICH

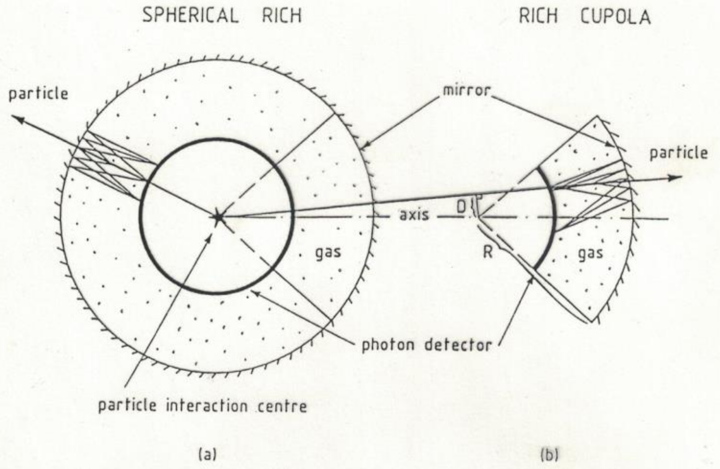
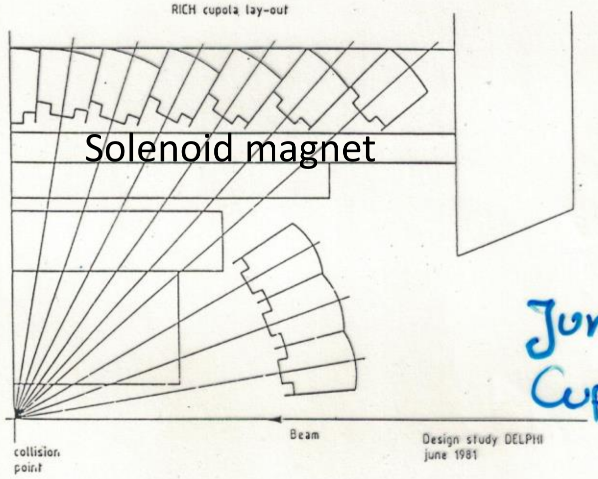


Fig. 8. The optics of the originally proposed spherical RICH counter [6] and that of a so-called 'cupola' RICH counter [7].



June 1981
Cupola RICH

Fig. 9. Early working-drawing of a spherical-mirror cupola-array from the discussions that led to the conception of the DELPHI RICH counters.

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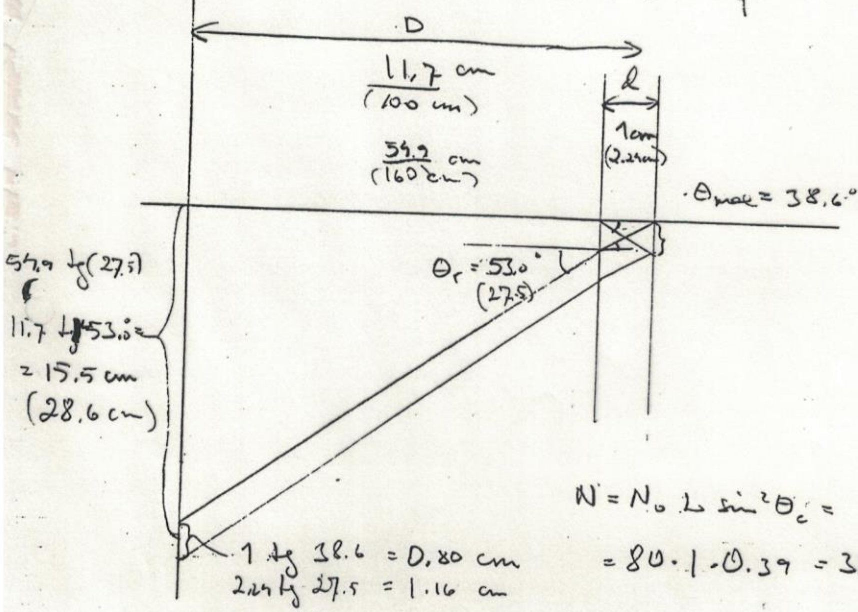
Planar proximity focussing detector liq Ar
(Values in paranthesis valid for liq Ne)



$N = N_0 L \sin^2\theta_c =$

$= 80 \cdot 1 \cdot 0.39 = 31$

$\frac{\Delta R}{R} = \frac{0.80}{15.5} = 5.2\%\ (4.08\%)$

$\left(\frac{\Delta\theta}{\theta}\right)_{chrom} = \frac{10.9\ \text{mr}}{673\ \text{mr}} = 1.62\%$

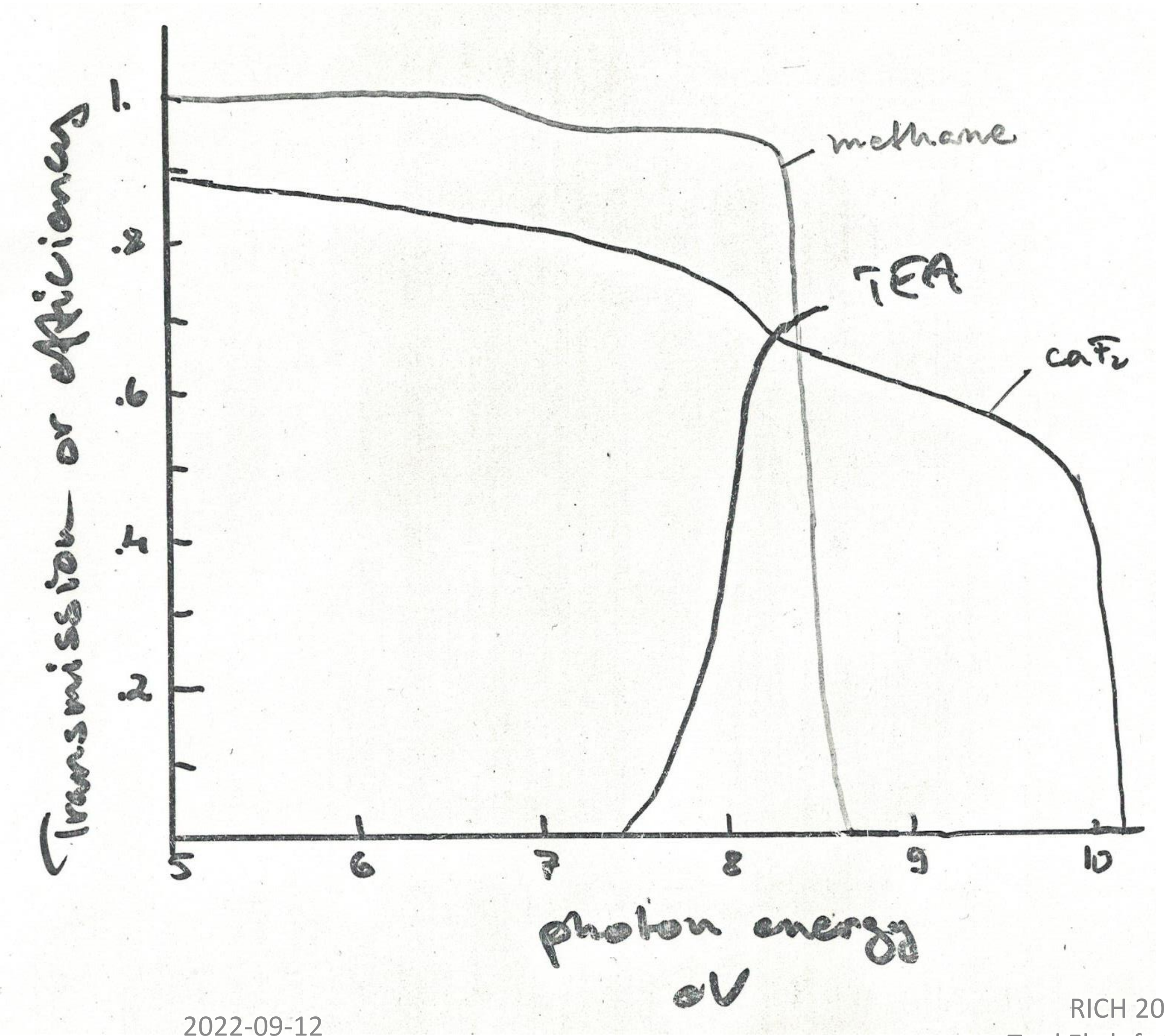
March 1981
Proximity
focussing

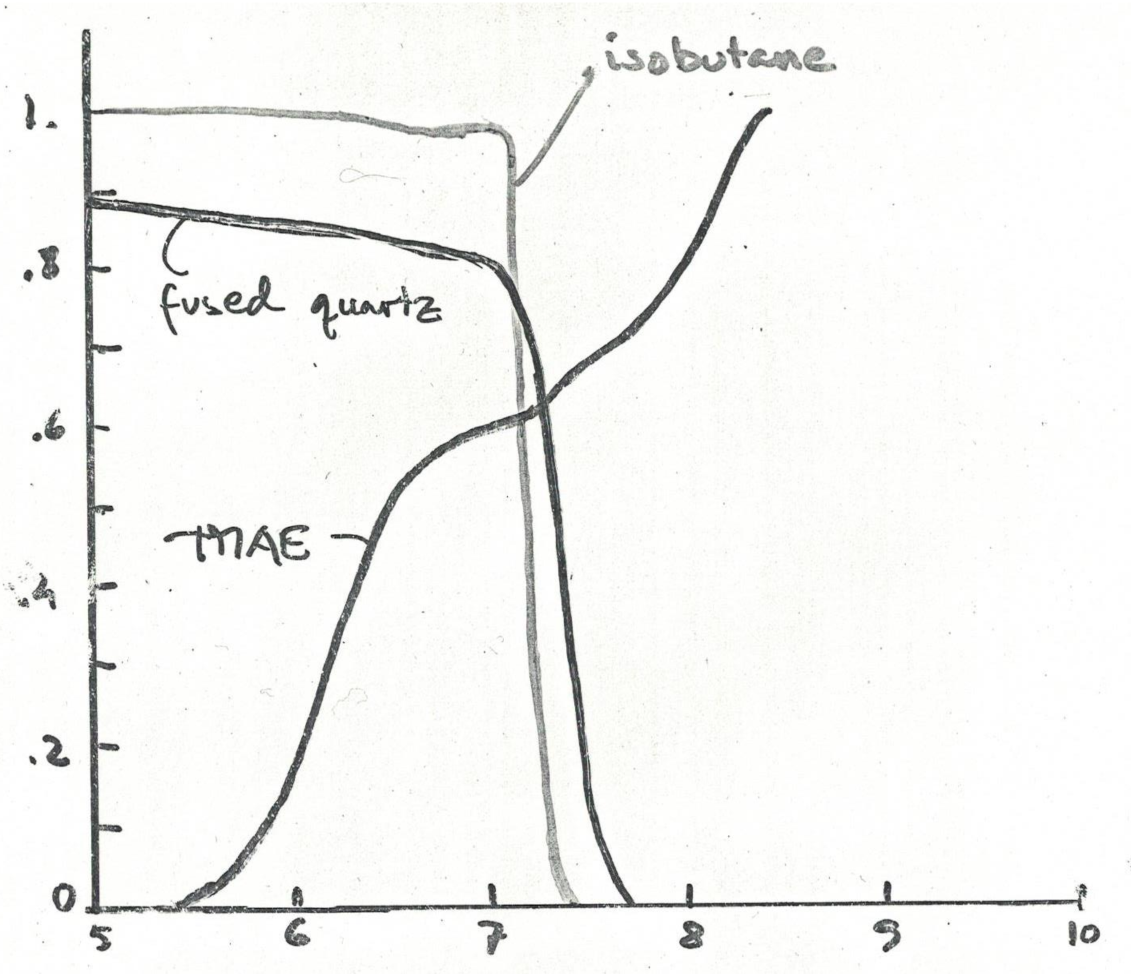
$\left(\frac{\Delta\theta}{\theta}\right)_{geom} = \frac{1}{\sqrt{N}} \cdot \frac{1}{\sqrt{12}} \cdot 5.2\% = 0.24\%$

$\left(\frac{\Delta\theta}{\theta}\right)_{chro} = \frac{1}{\sqrt{N}} \cdot \frac{1}{\sqrt{12}} \cdot 1.62\% = 0.08\%$

$\left(\frac{\Delta\theta}{\theta}\right)_{tot} = 0.25\%$ (0.21%)

$\theta_{max} = 38.6°\ (24.6°) \Rightarrow \Delta\theta = 0.097°\ (0.052°) = 1.68$ mrad


Transmission or efficiency
1.
.8
.6
.4
.2
5
6
7
8
9
10
photon energy
eV
methane
TEA
CaF₂


isobutane
1.
.8
.6
.4
.2
0
5
6
7
8
9
10
fused quartz
TMAE

TPC foton detektor

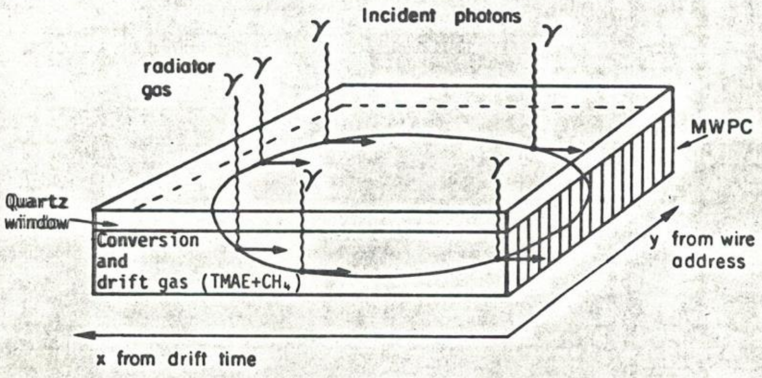
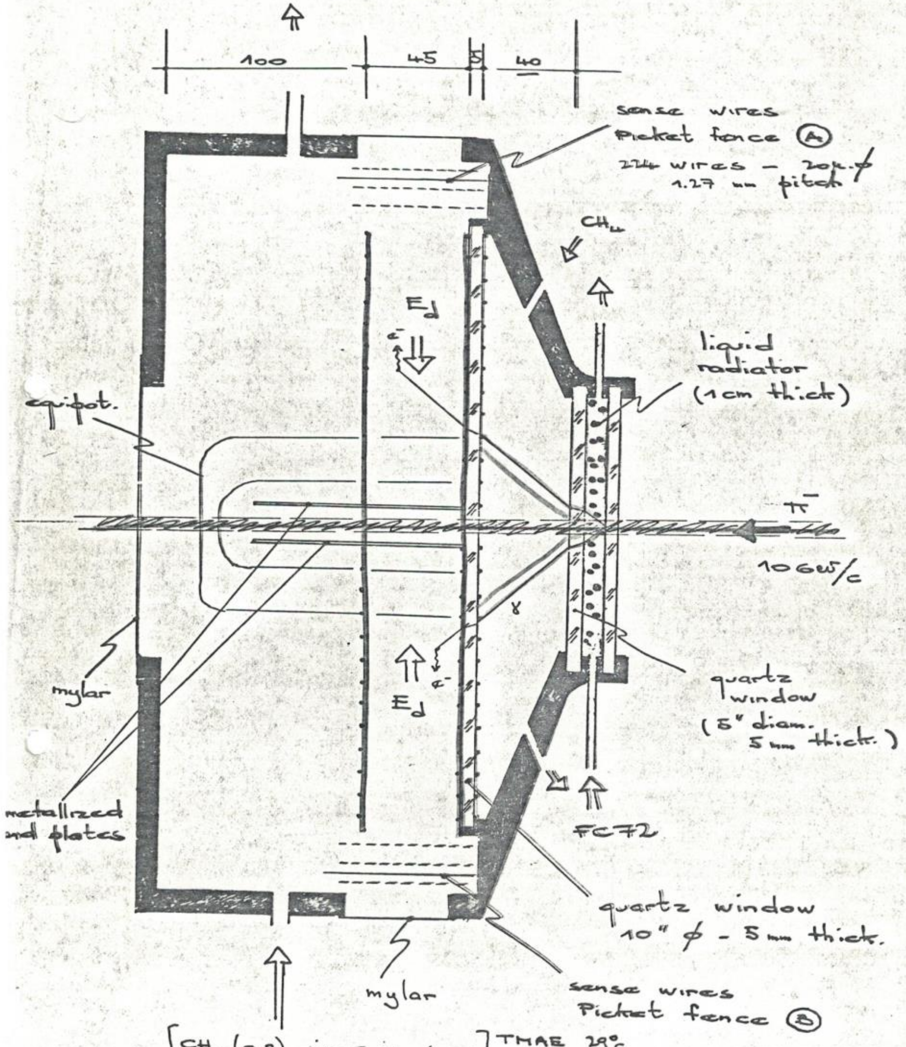


Fig. 6 Schematic view of the single-photon drift detector

'PICNEON' DETECTOR



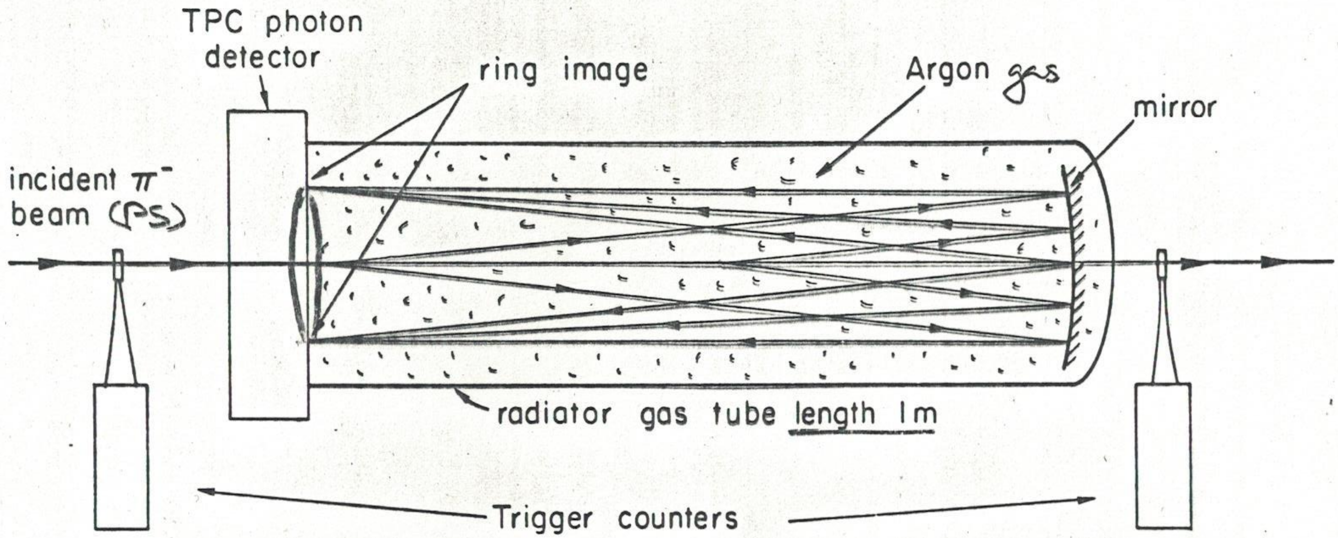
$\left[CH_4(0,8) - iso\ C_4H_{10}(0,2)\right]^{TMAE\ 28°C}$

Detector at 35°C

$E_d = 1\ kV/cm$

$v_d = 6{,}49\ cm/\mu s$

all gas and liquid FC72 flow through oxisorb


TPC photon detector
ring image
Argon gas
mirror
incident π^- beam (PS)
radiator gas tube length 1m
Trigger counters

(Historical)

21 Feb 81

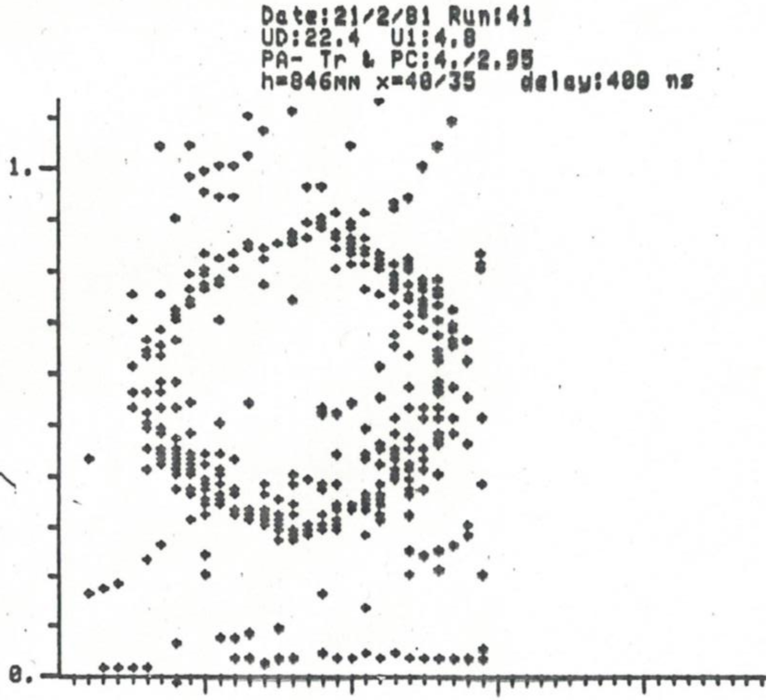
First twodimentional ring image with TPC (Time Projection Chamber) photoelectron detection

10 GeV π^-

Argon radiator 1m length

~1 photon/event

many events superimposed



```
Date:21/2/81 Run:41
UD:22.4  U1:4.8
PA- Tr & PC:4./2.95
h=846MM x=40/35   delay:400 ns
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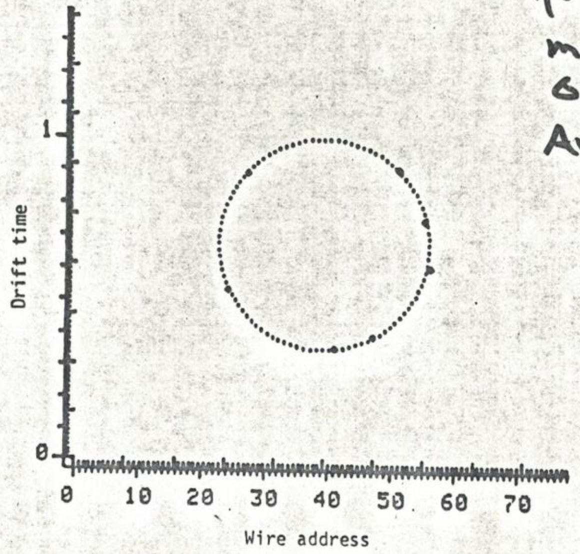
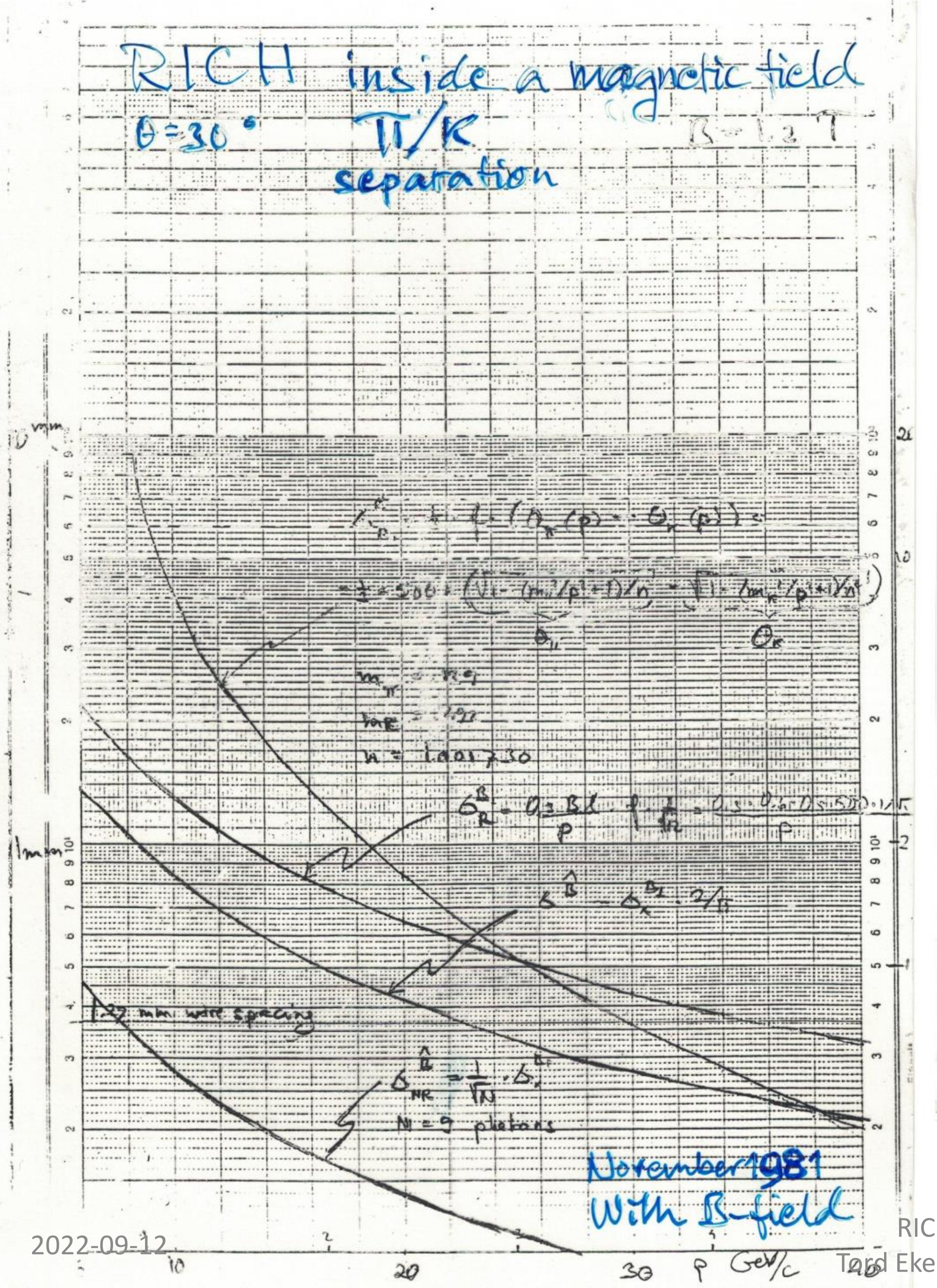
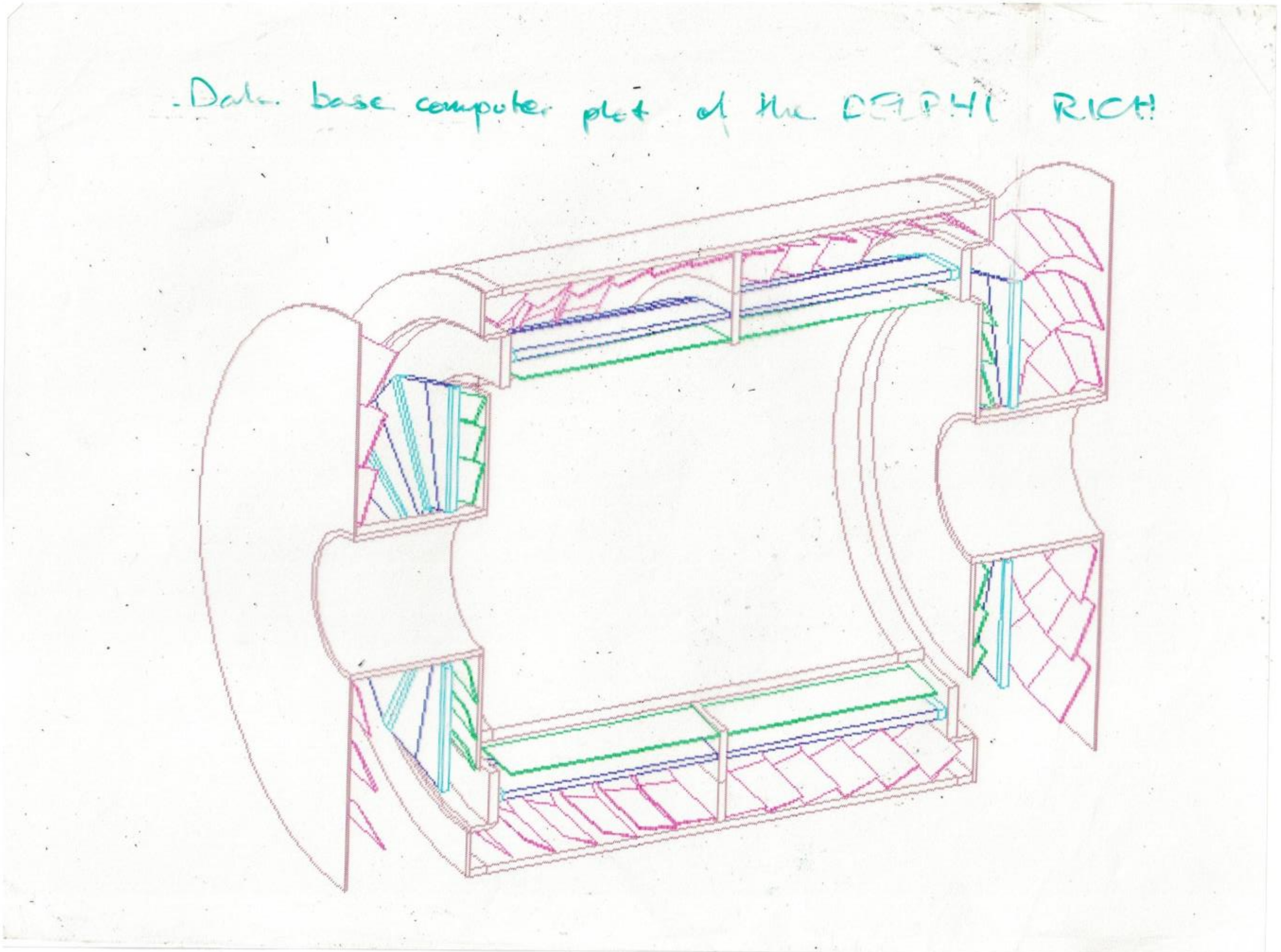
Prototype detector in PS beam
On-line data



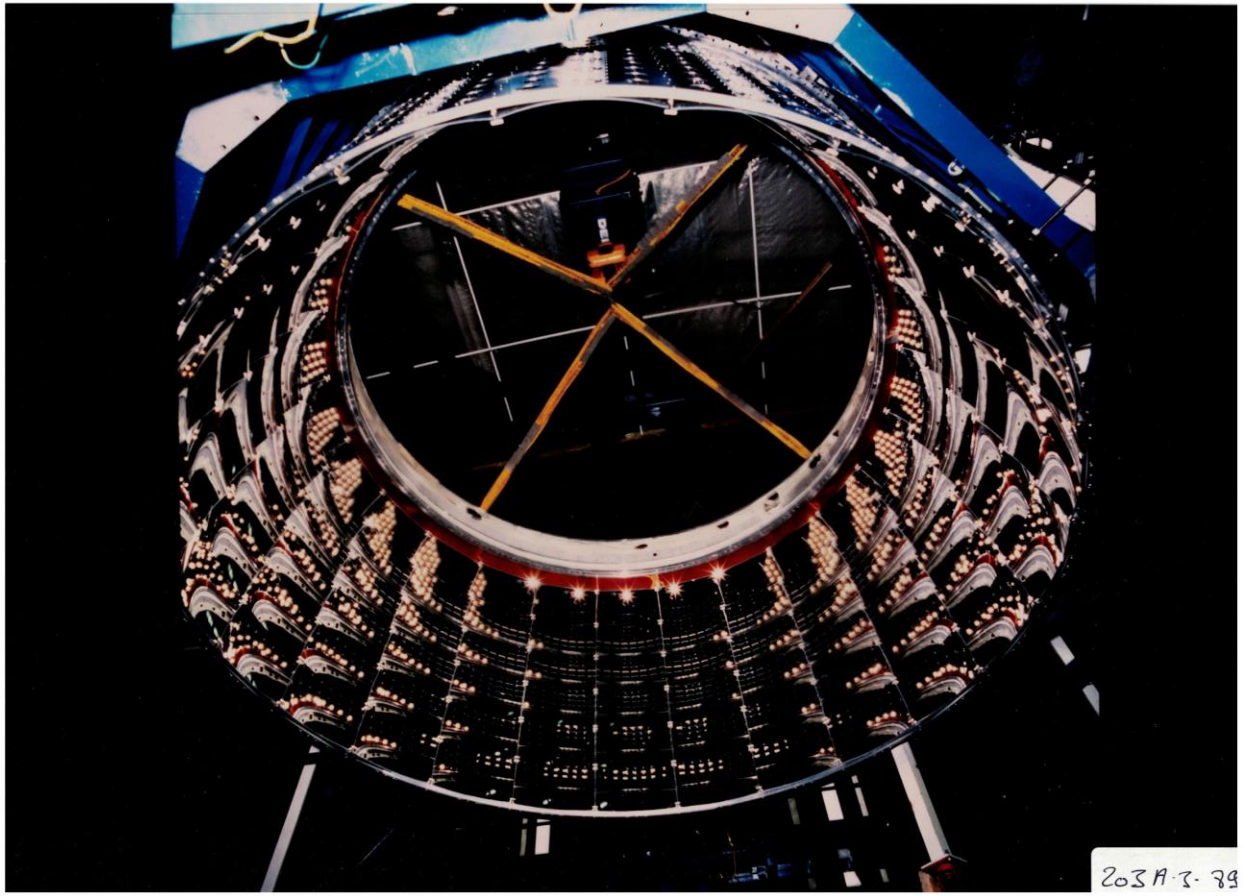
Isobutan
45 cm 1 bar equiv.
focal length 500 mm
measured radius 57 mrad
σ = 2 mrad
Average no of photons 8

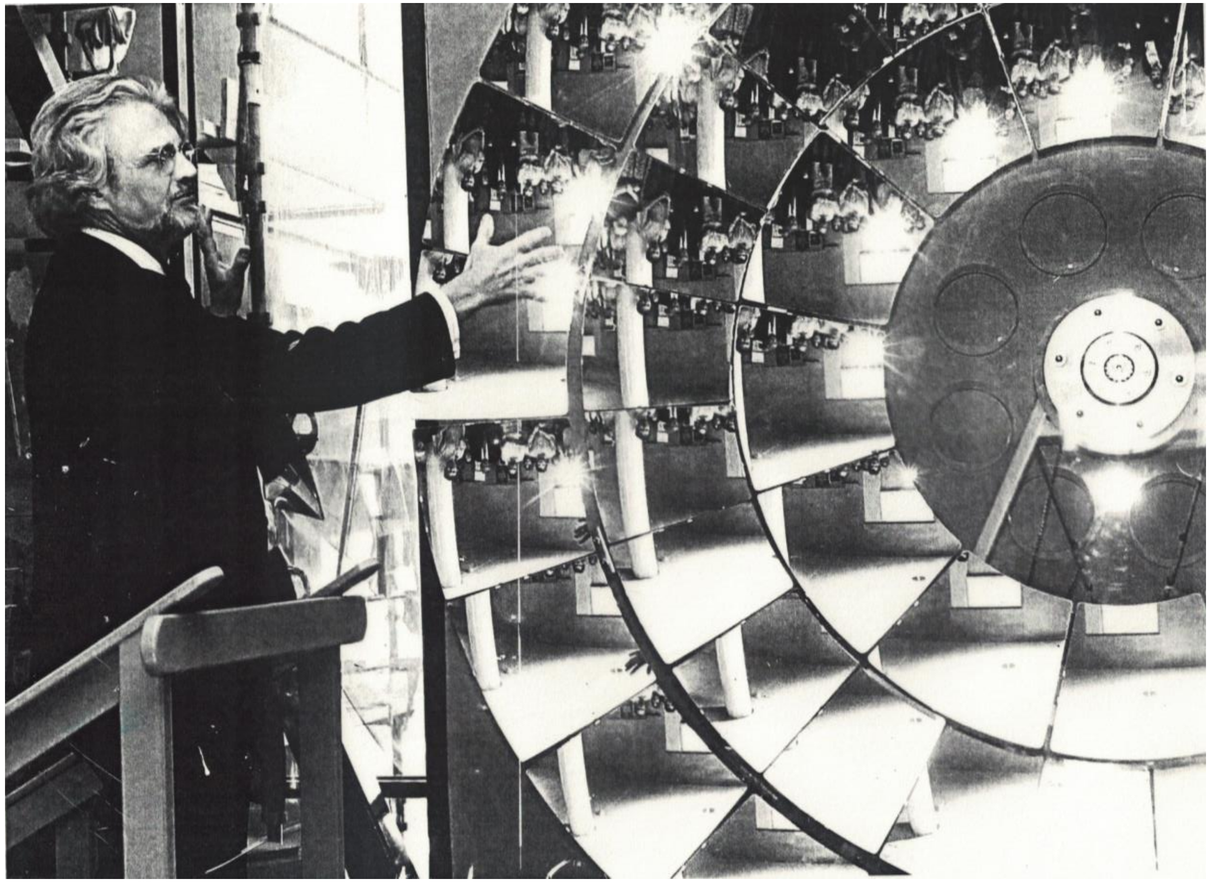


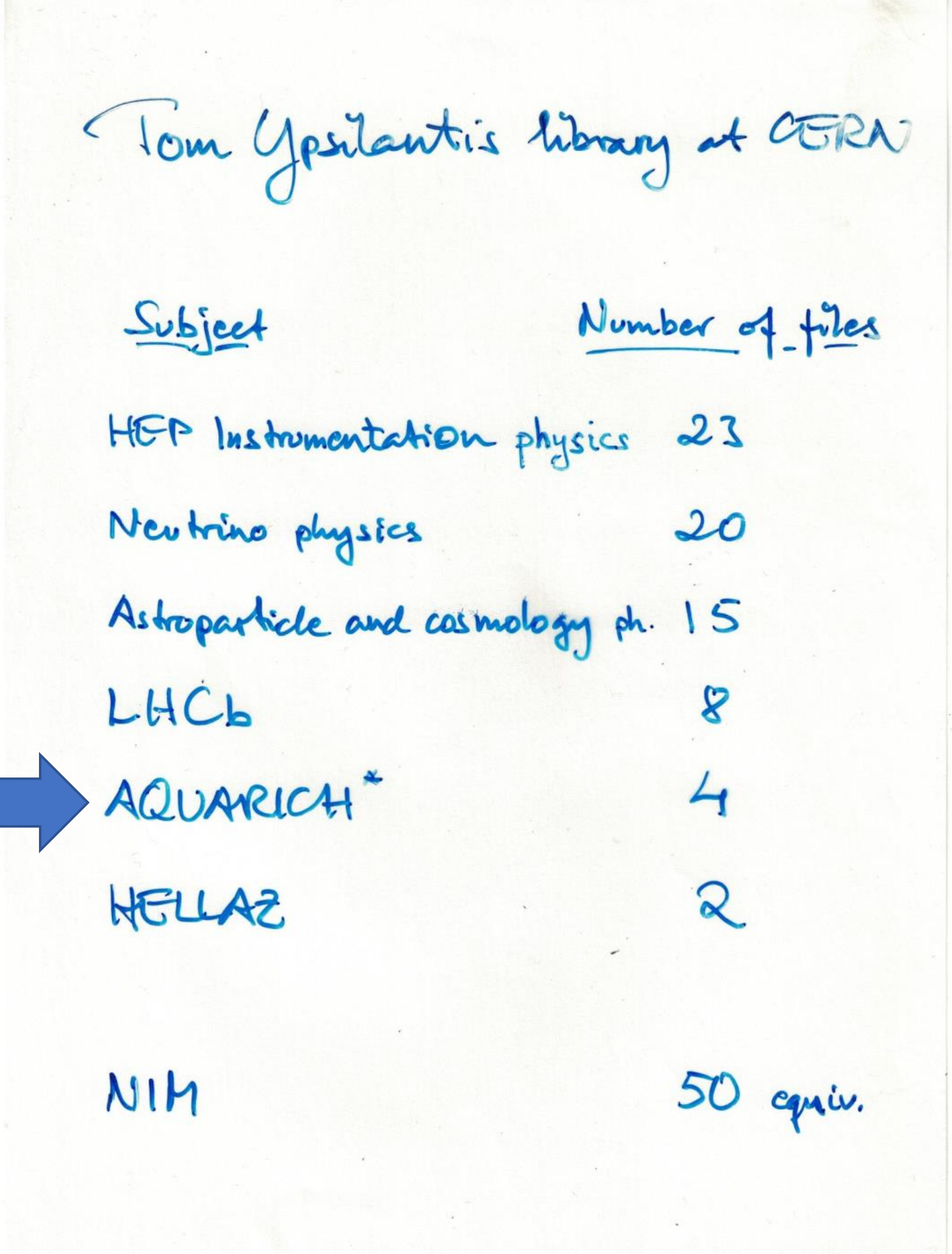
November 1981
With B-field



Data base computer plot of the DELPHI RICH

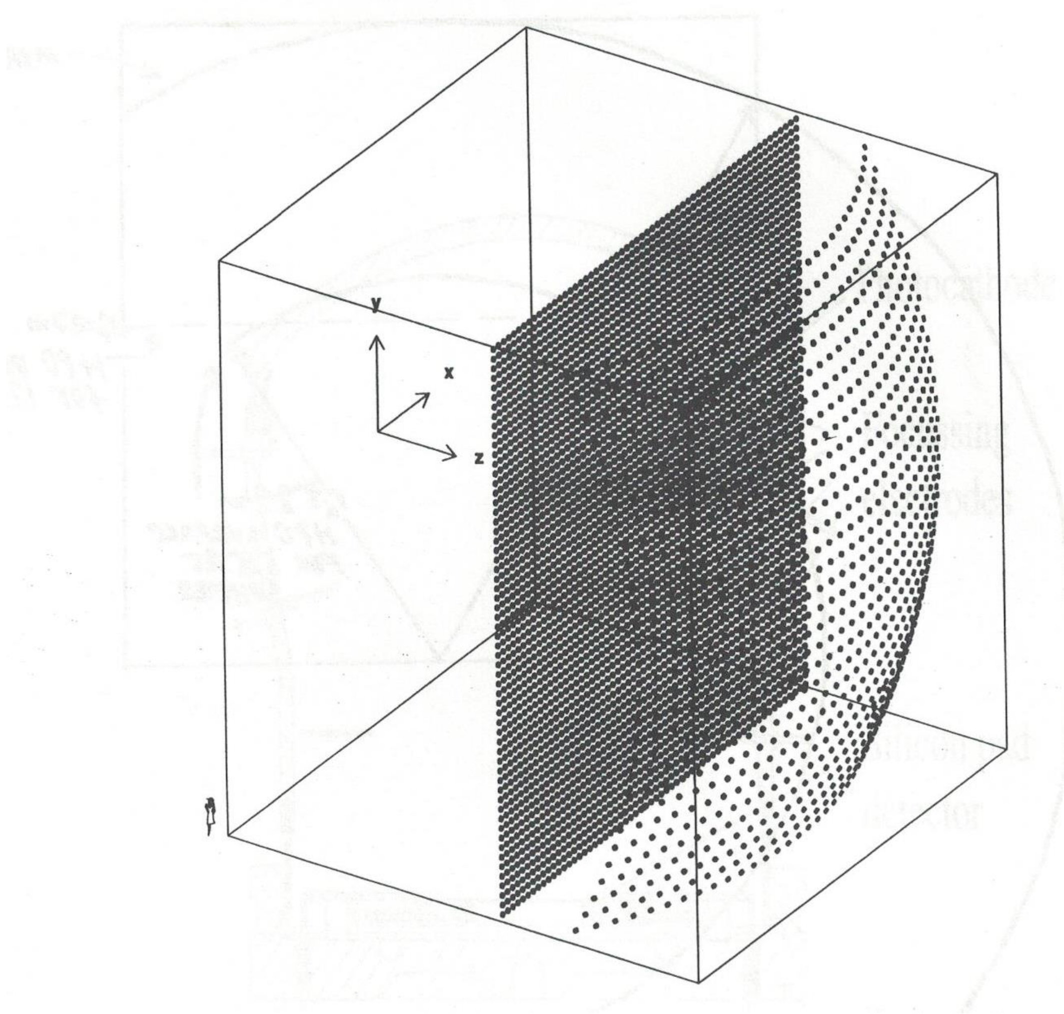

203A·3·89

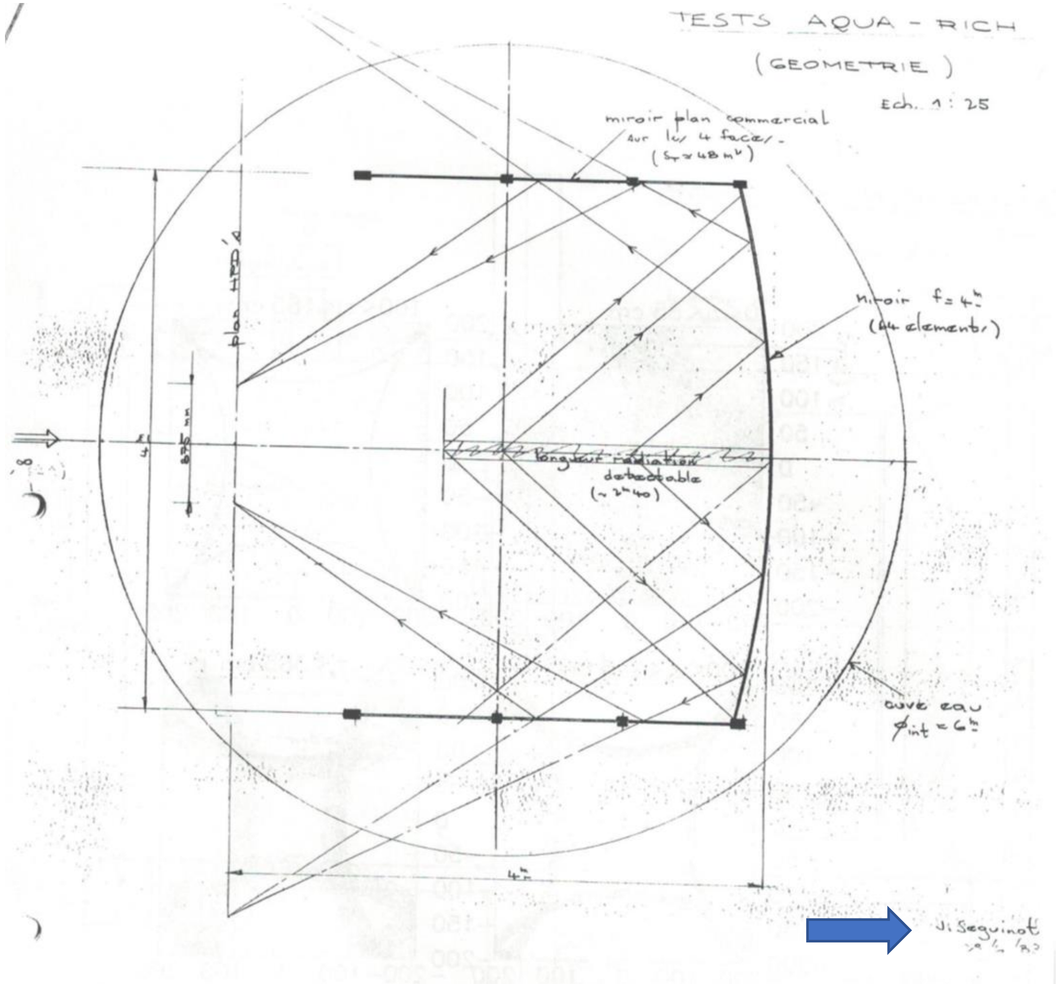




Tom Ypsilantis library at CERN

Subject	Number of files
HEP Instrumentation physics	23
Neutrino physics	20
Astroparticle and cosmology ph.	15
LHCb	8
AQUARICH*	4
HELLAZ	2
NIM	50 equiv.





J. Seguinot

Hybrid Photo Diode
HPD for AQUA-RICH

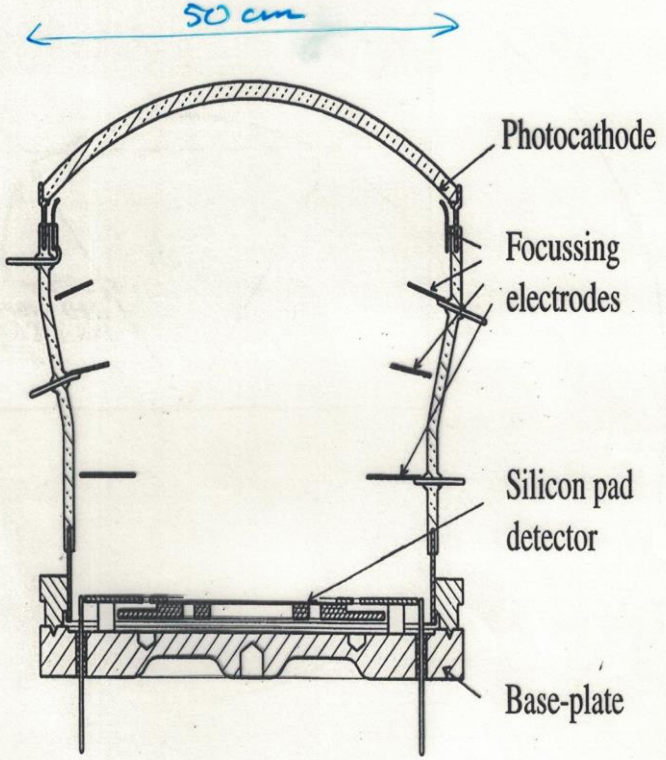


Fig. 2. The 10" HPD design with 85 silicon pad feedthroughs. The 20" design is similar.

Thank you

Jacques Séguinot, a founding father of the ring-imaging Cherenkov detector, passed away on 12 October 2020.

Born in 1932 in a small village in Vendée, Jacques studied electromechanical engineering at the University of Caen and received his PhD in physics in 1954. His solid engineering base was visible in every experiment that Jacques designed and built throughout his long career, which followed a classic French academic path – from a *stagiaire de recherche* in 1954 to a *directeur de recherche* in 1981, which he held until his official retirement in 1990.

His first studies saw him spend several months at the French cosmic-ray laboratory on the Col du Midi near Mont Blanc, after which he worked on accelerator-based experiments: first at Saturne (CEA Saclay), and from 1964 onwards at CERN's Proton Synchrotron studying strong interactions with pion and kaon beams. At the end of the 1960s, Jacques began a long and fruitful collaboration with Tom Ypsilantis, leading to a seminal 1977 paper establishing a new particle identification technology that became known as the RICH (Ring Imaging Cherenkov Counter).

The idea was to use the recently introduced multiwire proportional chamber, filled with a photosensitive gas, to detect and localise ultraviolet photons emitted by fast charged particles in a radiating medium, and to use a suitable optical arrangement to create a ring pattern whose radius depends on the particle speed. Combined with magnetic analysis, the RICH made it possible to identify a particle's mass in a wide range of energies. In further work, Séguinot and Ypsilantis developed algorithms to optimise the momentum resolution of the detectors, as well as adapting radiators to cover different momentum ranges where other technologies were ineffective.

The early RICH devices were successfully deployed at the fixed-target experiments OMEGA at CERN and E605 at Fermilab. The ability of the detector to extend over most of the solid angle around the target or colliding-beam intersections also made it particularly relevant for experiments at the newly commissioned LEP and SLD accelerators. The RICH detector at LEP's DELPHI experiment came close to the original design, with nearly 4π angular coverage, and Jacques' contribution to this detector was key.
In view of the growing interest in meson factories, Jacques and Tom worked on faster RICH devices with shorter photo-conversion lengths, and also on CsI solid photo-converters. This led to applications in the RICH for CLEO at the CESR storage ring, the CsI-based RICH detectors in CERN's ALICE, COMPASS and other experiments. Another very ambitious R&D programme, which started in the mid-1990s, aimed at developing highly segmented photodetectors sensitive to visible light. Jacques saw the potential of such hybrid photo detectors (HPD) for applications in medical imaging, and proposed an innovative PET device in which matrices of long scintillation crystals are read from both sides by HPDs. In the meantime, SiPM photodetectors had become available, with a number of practical advantages over HPDs. In the AX–PET collaboration, Jacques and several others built a fully operational axial PET with SiPM readout.
The high-energy physics community has lost an excellent detector physicist with an extraordinary sense of engineering. His groundbreaking ideas live on, including in the most recent detectors such as Belle II in Japan. But we will also remember Jacques' fine personality, patience and decency.

by Christian Joram and Fabio Sauli CERN.

Text and pictures are taken from [CERN courier obituary]