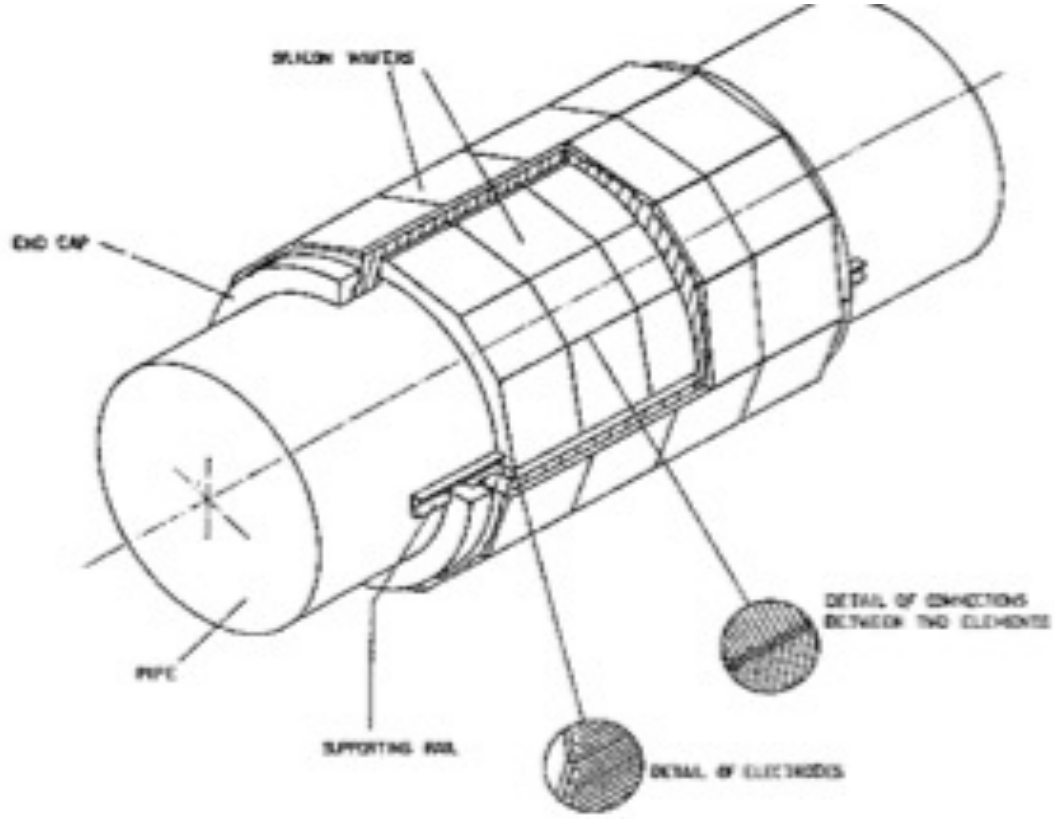
Il rivelatore di vertici dell'esperimento ALEPH

November 07, 2023

Francesco Forti,
INFN and University, Pisa

Silicon Detectors for vertex measurement

- Double-sided silicon strip detectors where on the bleeding edge of R&D at that time
- It was clear they would enable the measurement of secondary vertices and improve a large fraction of LEP physics



1985 - 1990

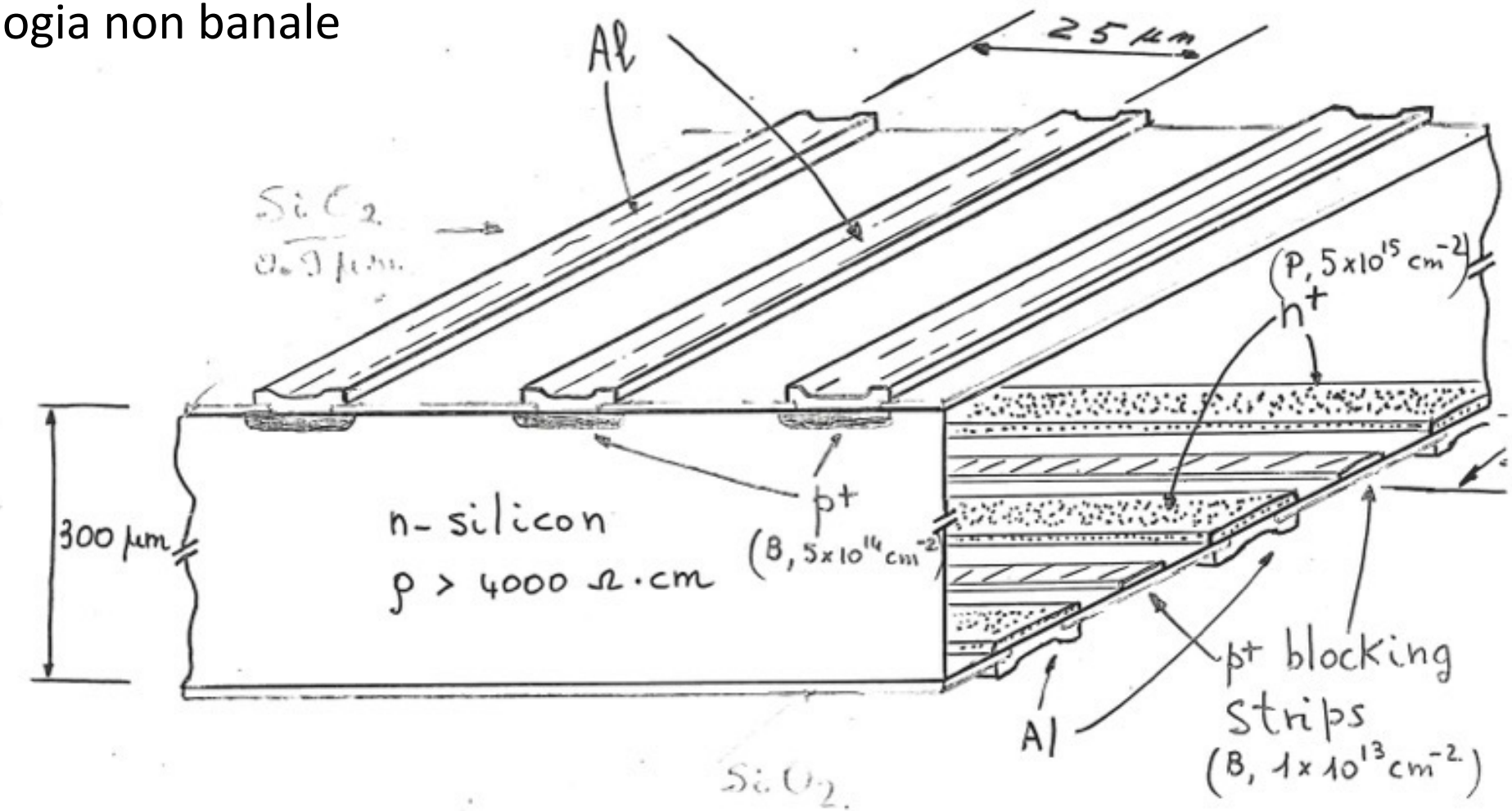
Prime prove di fabbricazione in casa

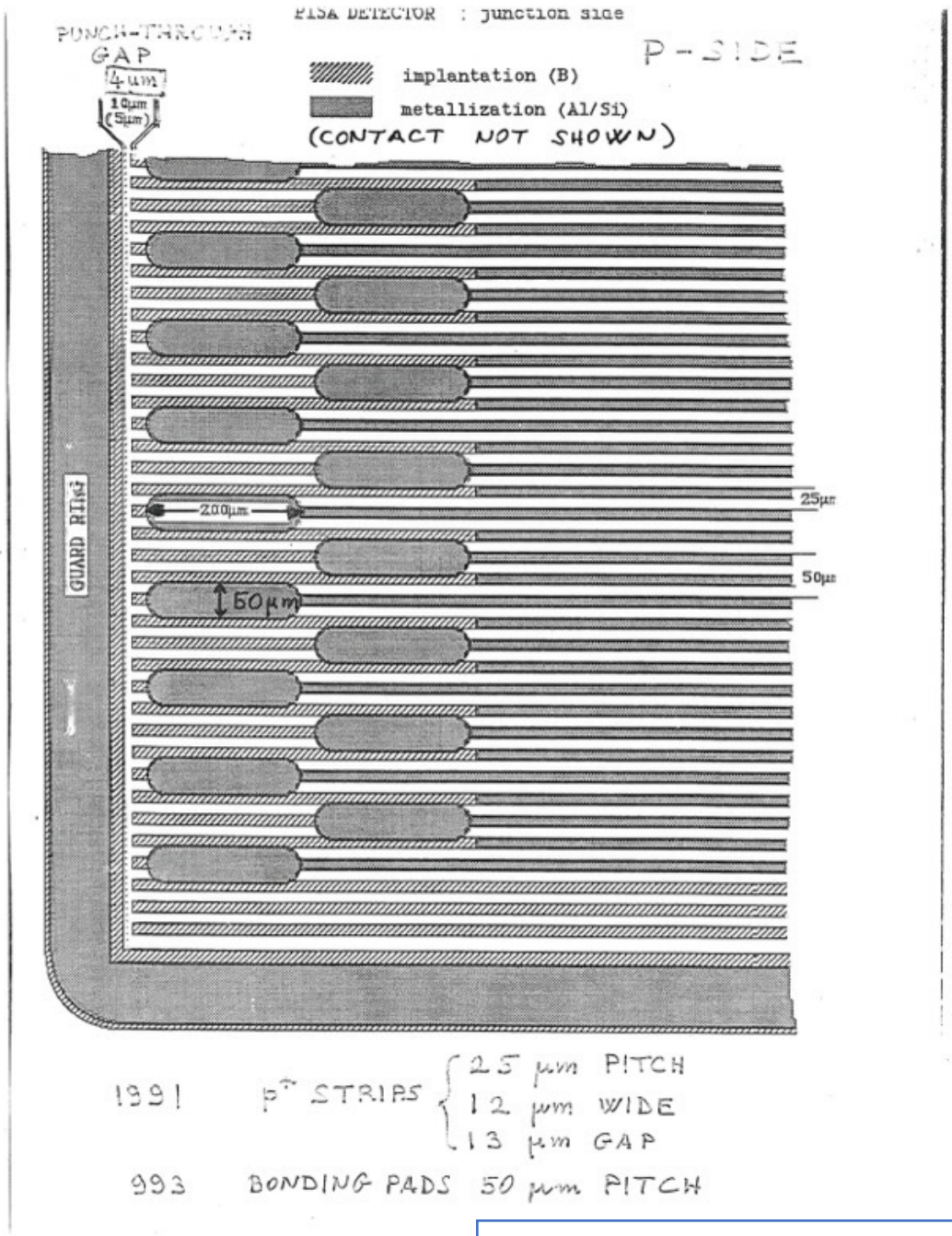
F.Forti

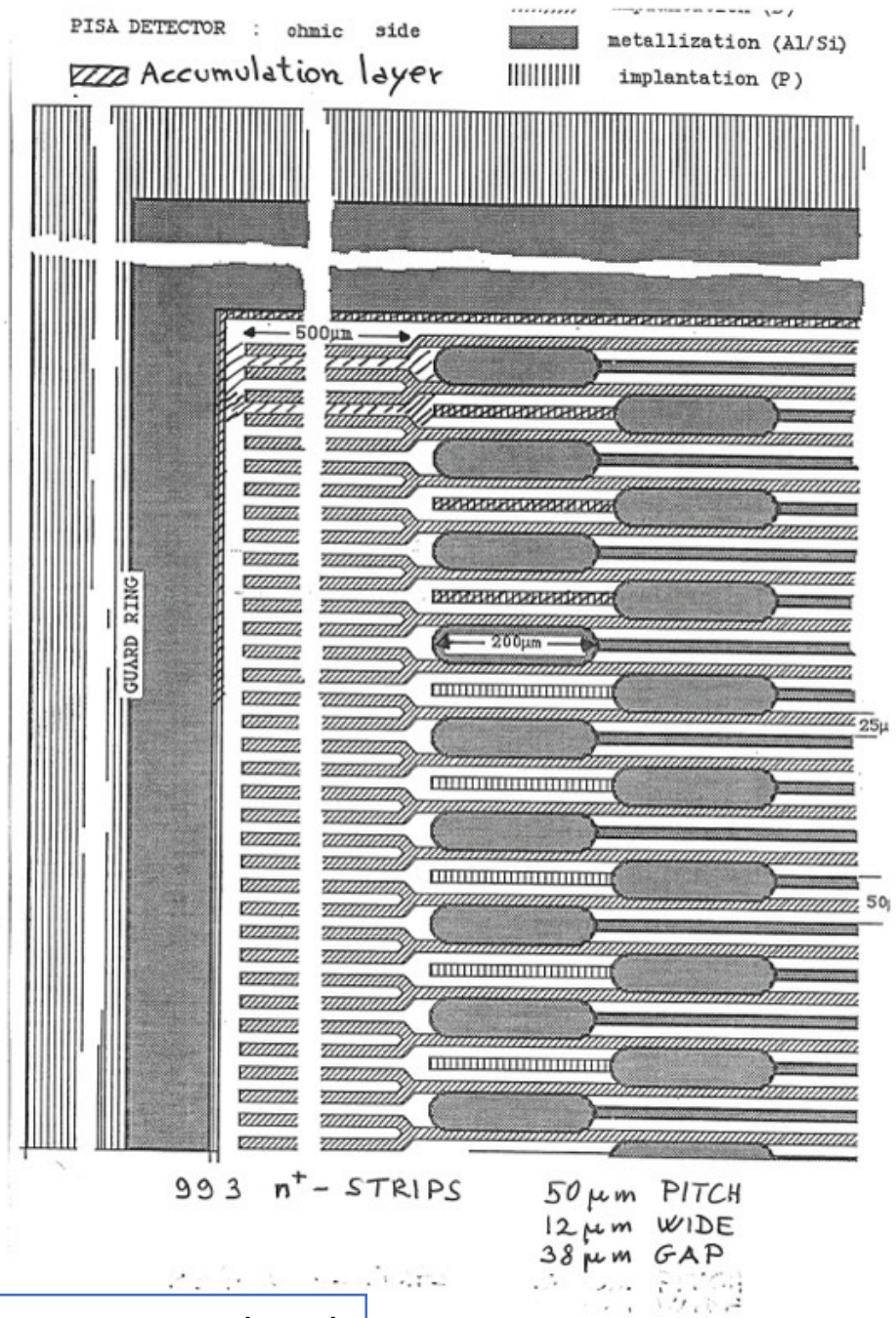
E.Focardi

Double side readout detector

Tecnologia non banale

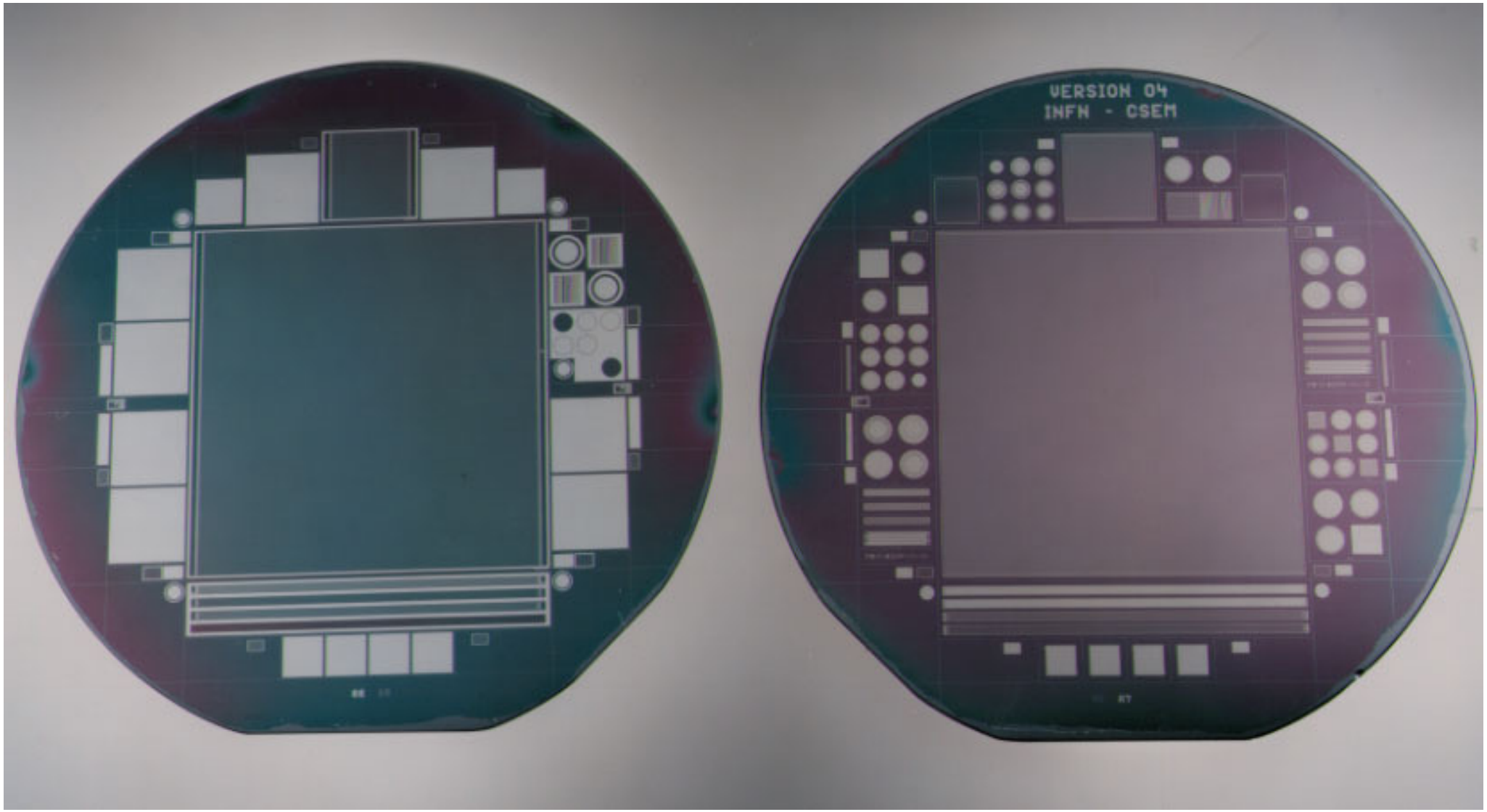


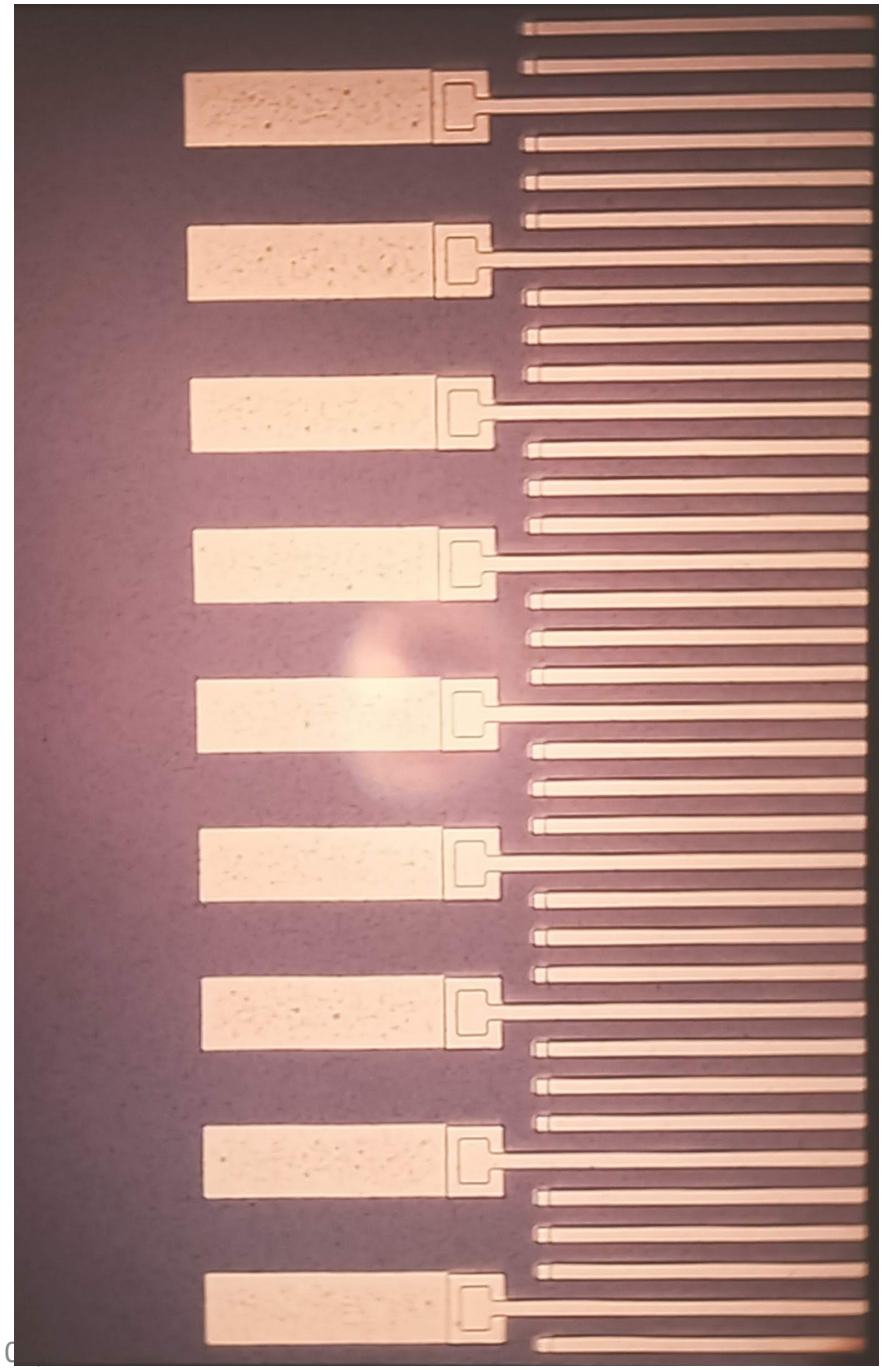


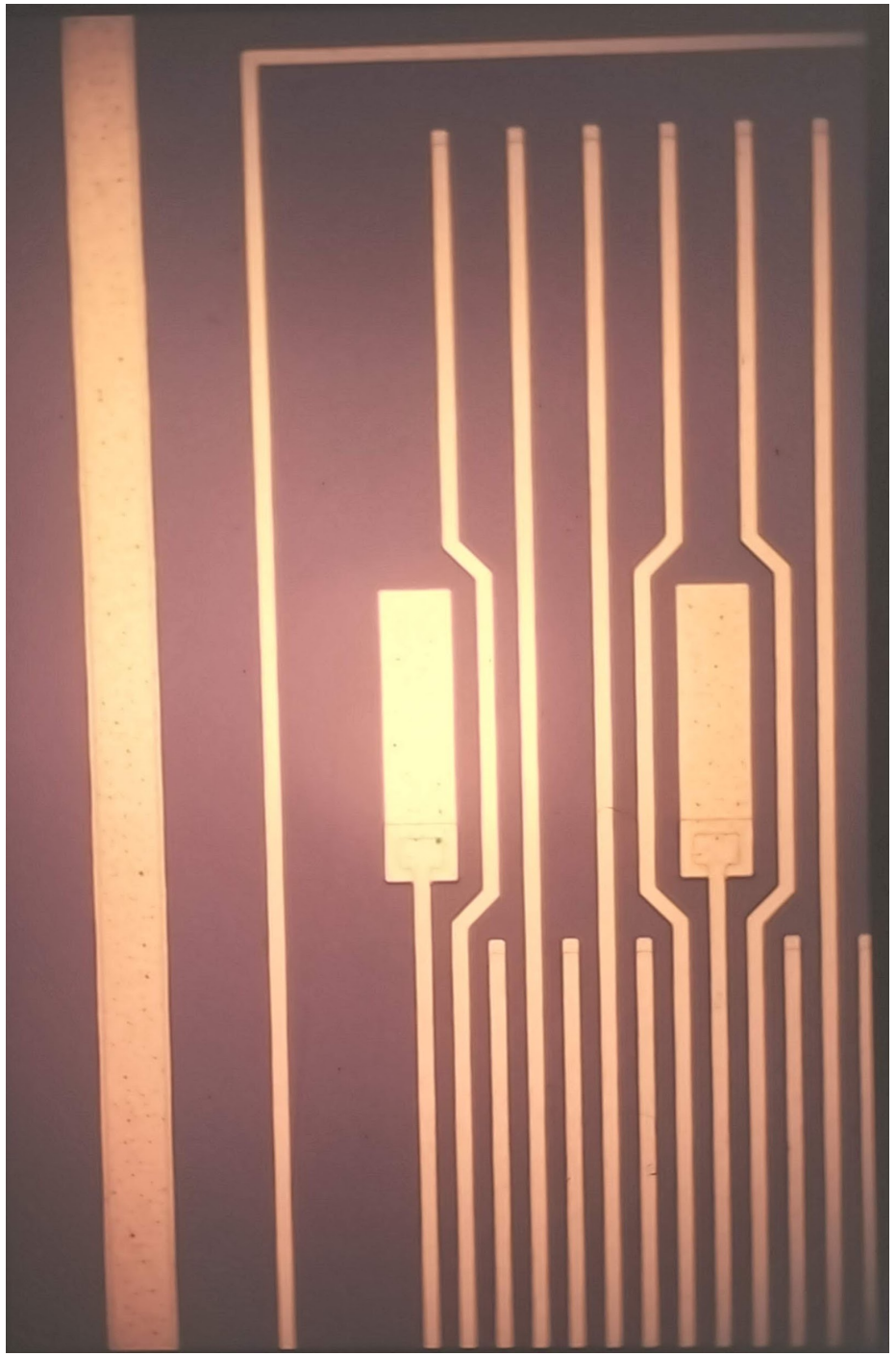


Technology developed with CSEM, Neuchatel

I wafer doppia faccia prodotti da CSEM

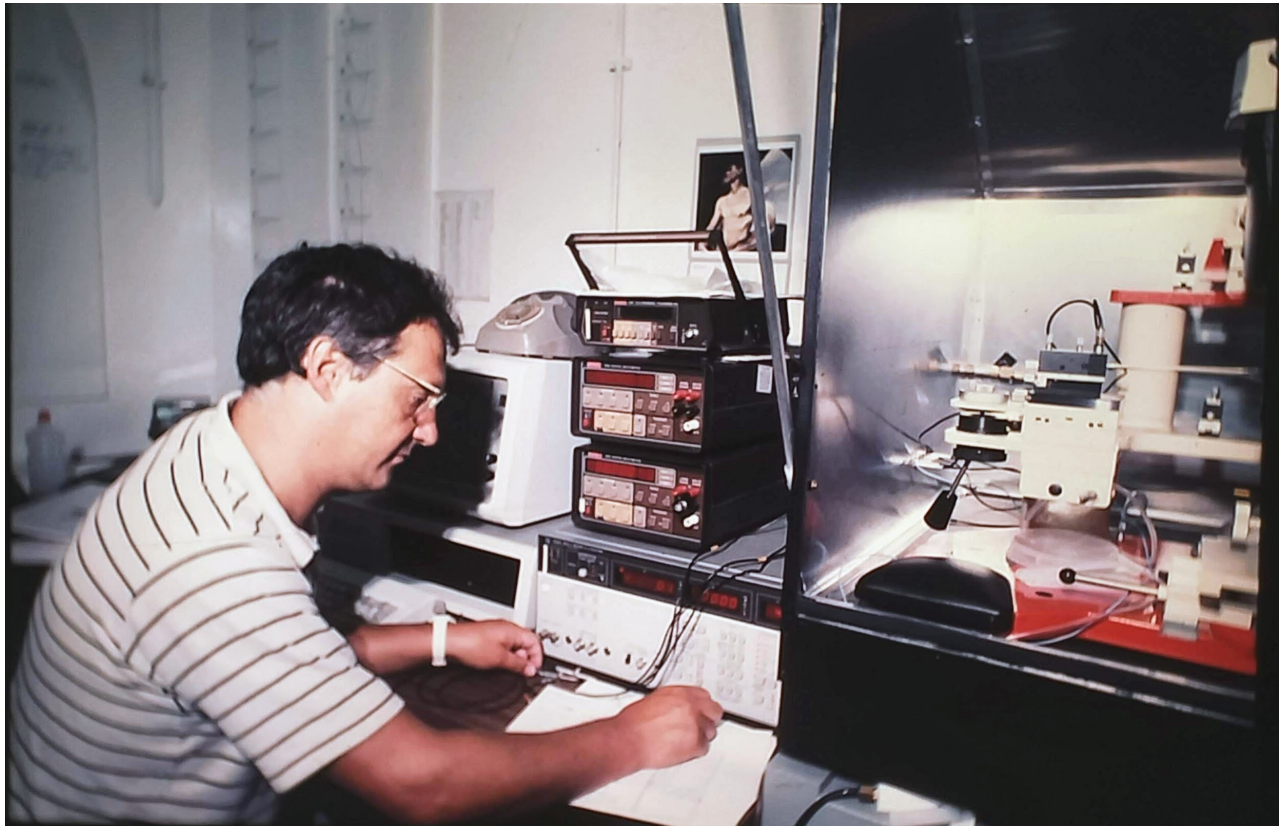






Misure e caratterizzazione

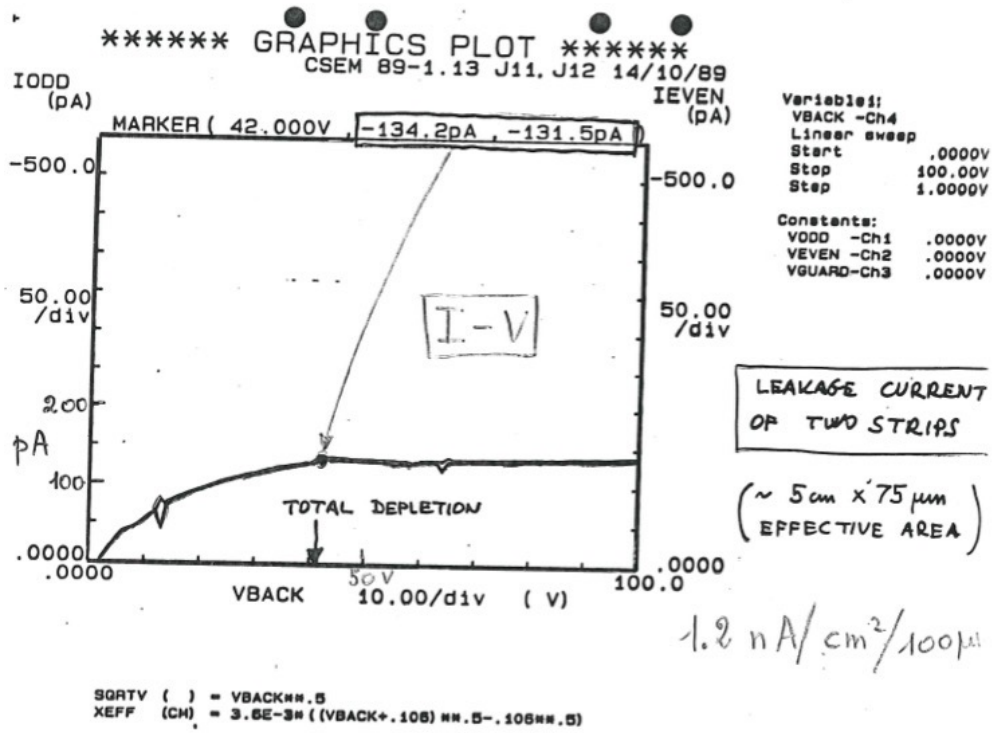
M.A.Giorgi

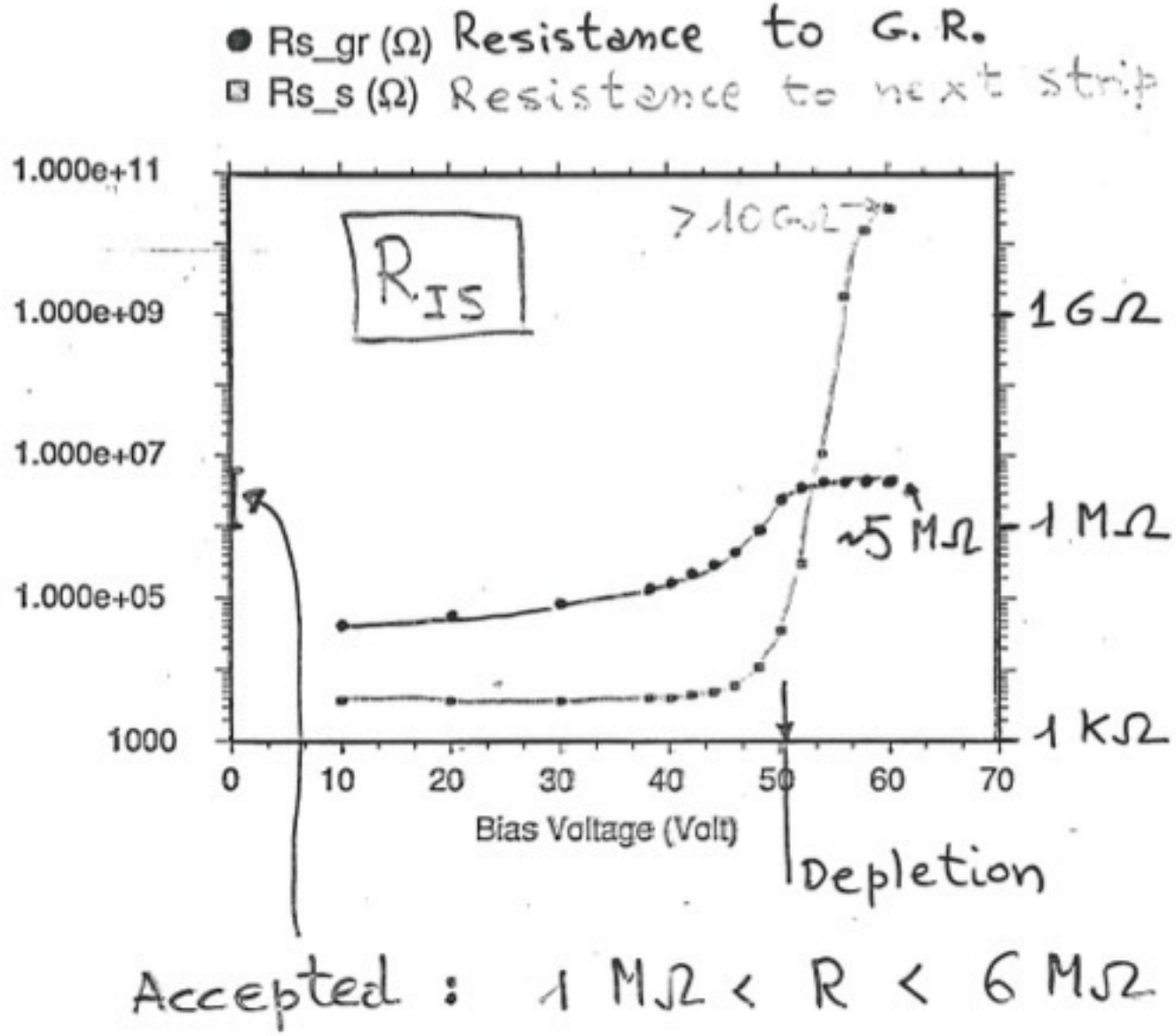


M.A.Giorgi F.Forti

Funziona !

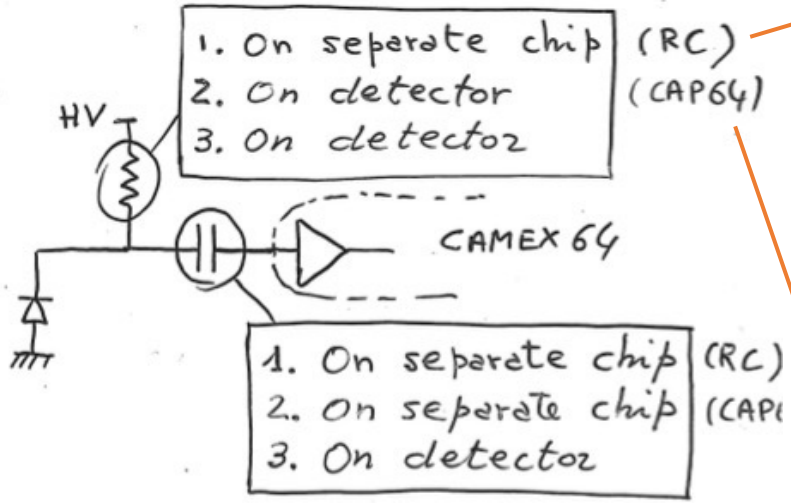
Bassa corrente





Isolamento delle strip lato ohmico

Detectors design summary



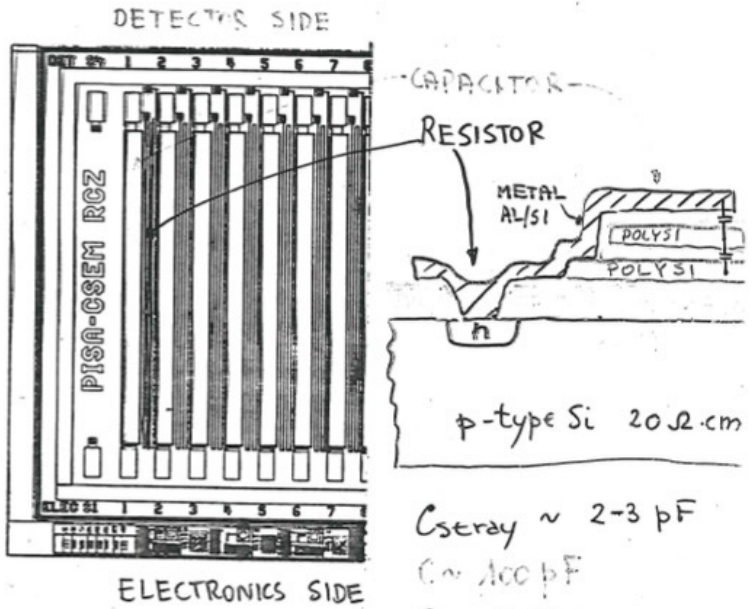
1. Pisa old fashioned } Processed at CSEM, C
2. Pisa latest

3. M.P.I. Processed by MBB, D

	1.	2.	3.
	- 2x μbonds	- 2x μbonds	+ Less μbonds
	- So-so bias	+ Good bias	+ Good bias
	+ Good yield	+ Good yield	- yield problem
	+ Passive R	- accumul. layer	- accumulation la
pitch ⊥	100	100	100 μm
pitch //	200	100	100 μm

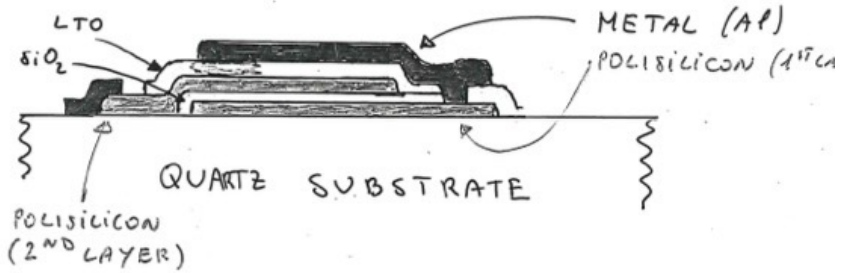
historical reasons

R-C



C-only CAP64

CAPACITOR CROSS SECTION

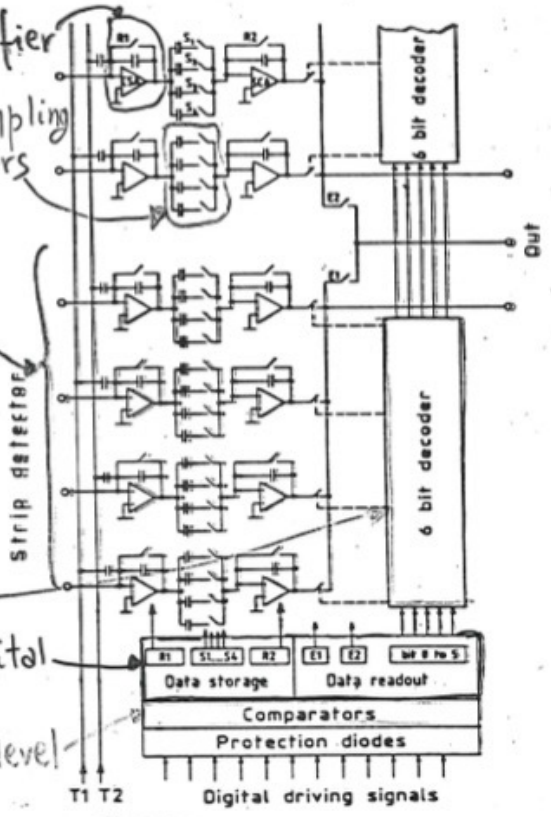


CAPACITOR VALUE	210 pF
STRAY CAPACITANCE	0.3 pF
PARASITIC RESISTANCE	> 10 GΩ
VOLTAGE TOLERANCE	≳ 20 V.

Varie soluzioni e competizione

CAMEX CHIP (MPI)

- Charge sensitive amplifier
- Multi-correlated sampling and switched capacitors
- 64 input channels 100 μm pitch
- Random access with address decoder (6-bits)
- Regeneration of digital signals
- Comparators → low level signals possible



Complete chip

- Gain : 15 mV/FC
- Power : adjustable, switchable ≲ 2 mW/chan
- Noise : ENC = 335 e⁻ + 30 e/pF · C_{IN}

Radiation damage
- Unpowered : @ 200 kRad S/N → 1/2
- Powered : @ 18 kRad Noise increase

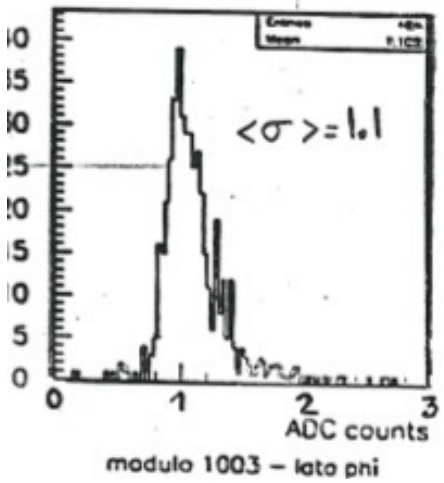
7

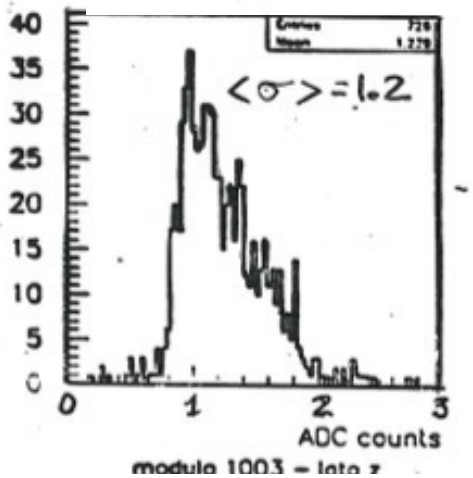
Signal to noise ratio

junction side S/N = 12:1

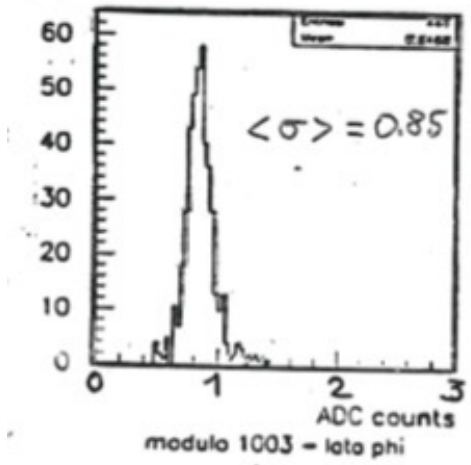
ohmic side S/N = 11:1

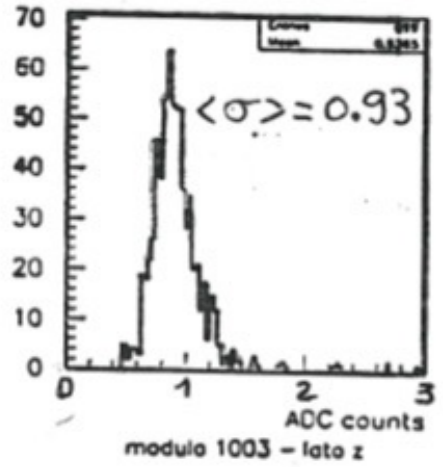
'Nature'





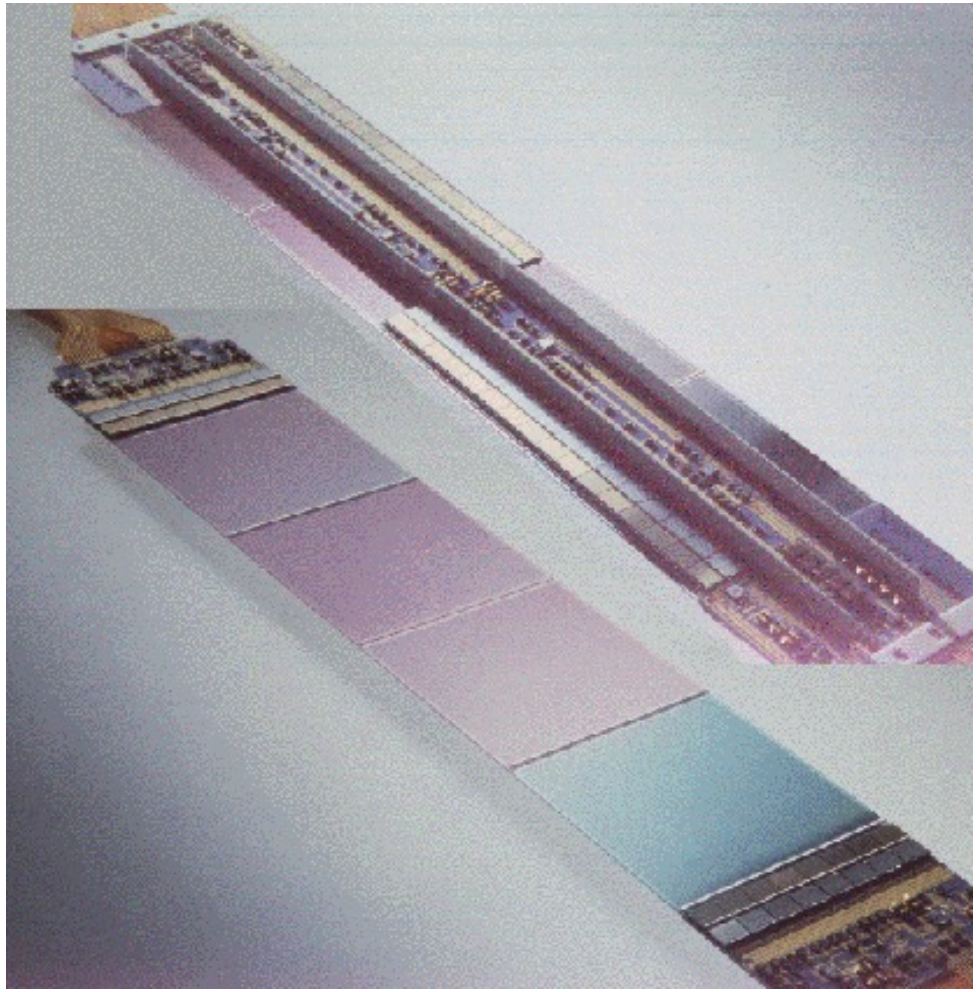
Common mode subtracted

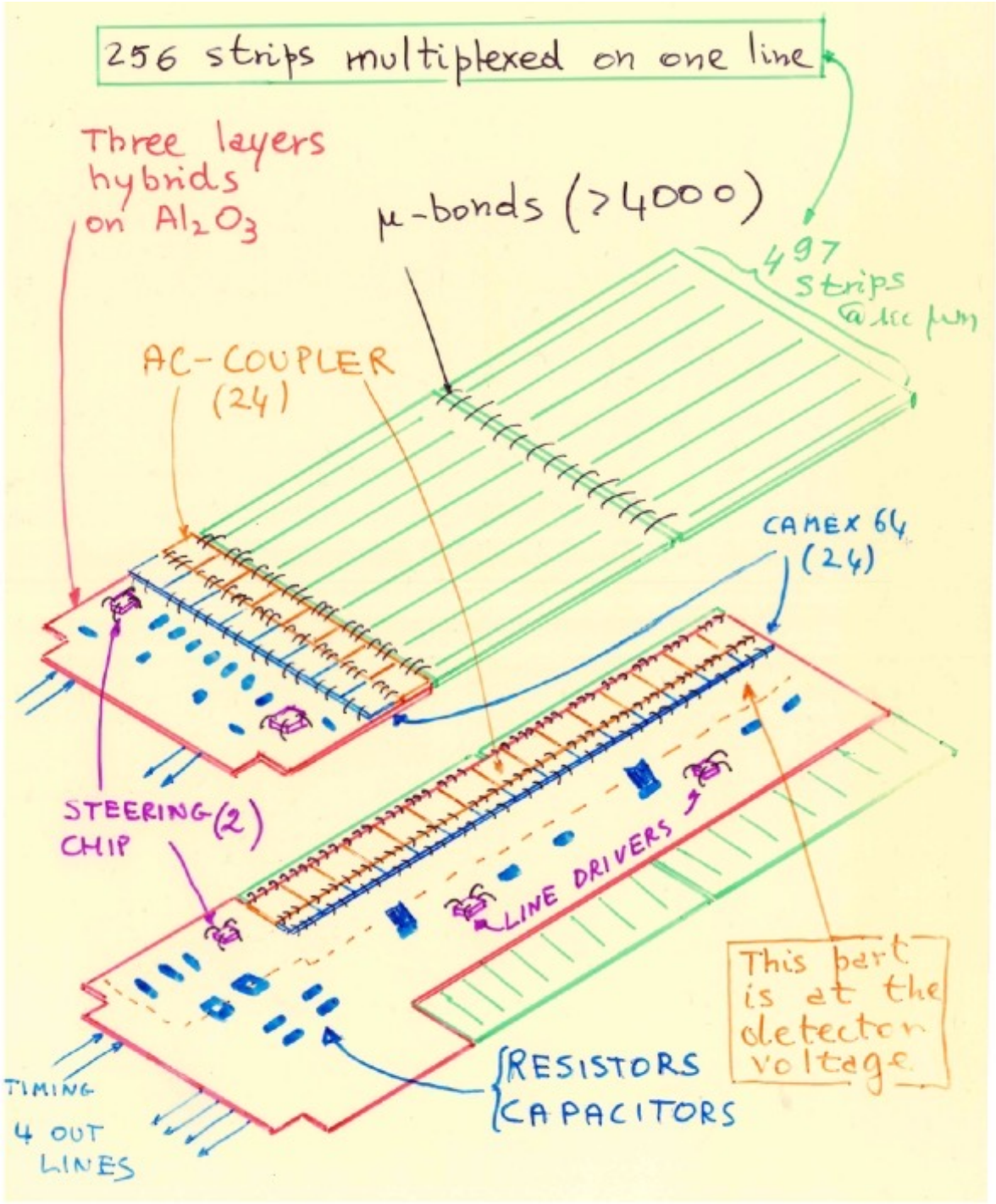




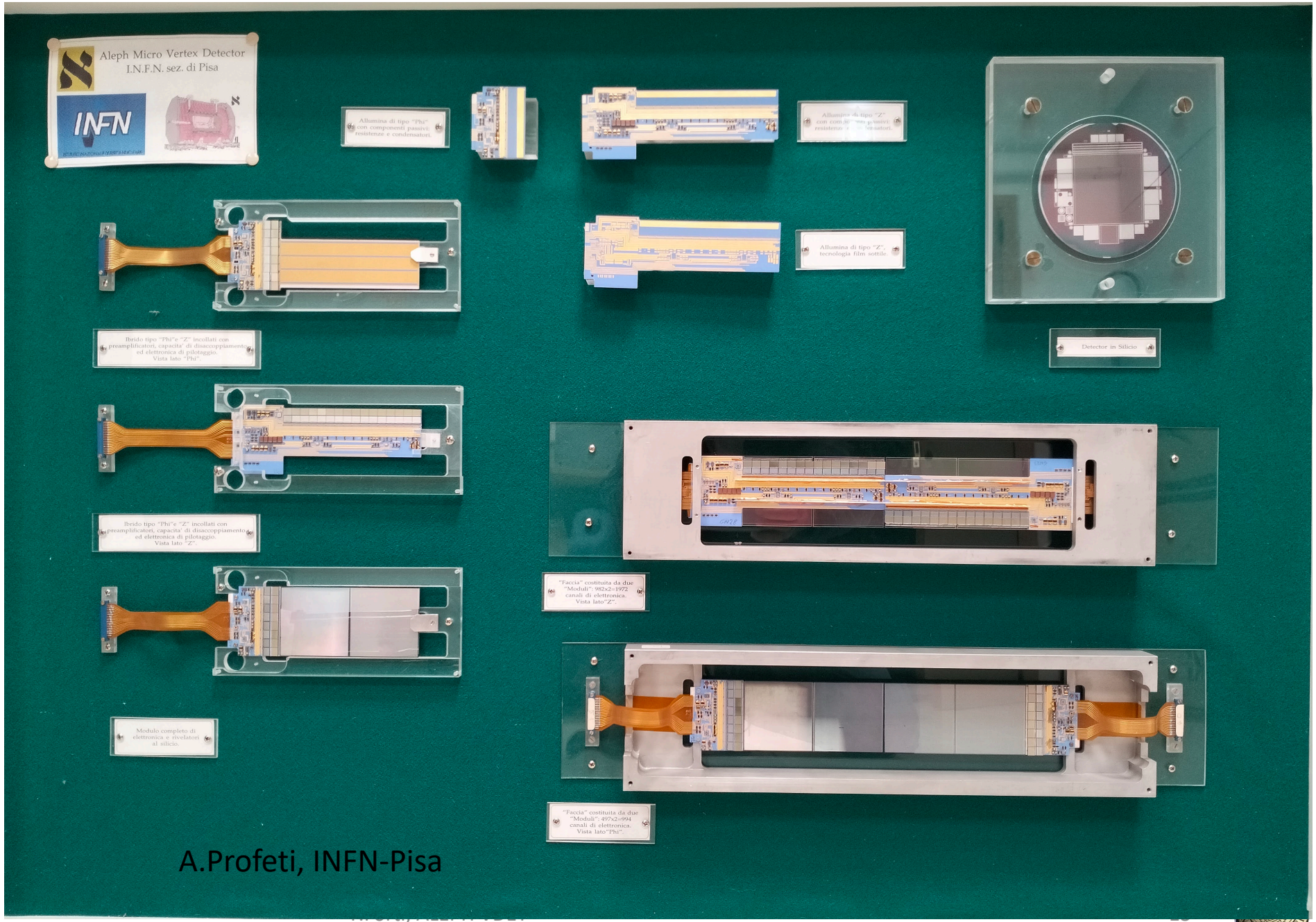
Elettronica di lettura

Module layout

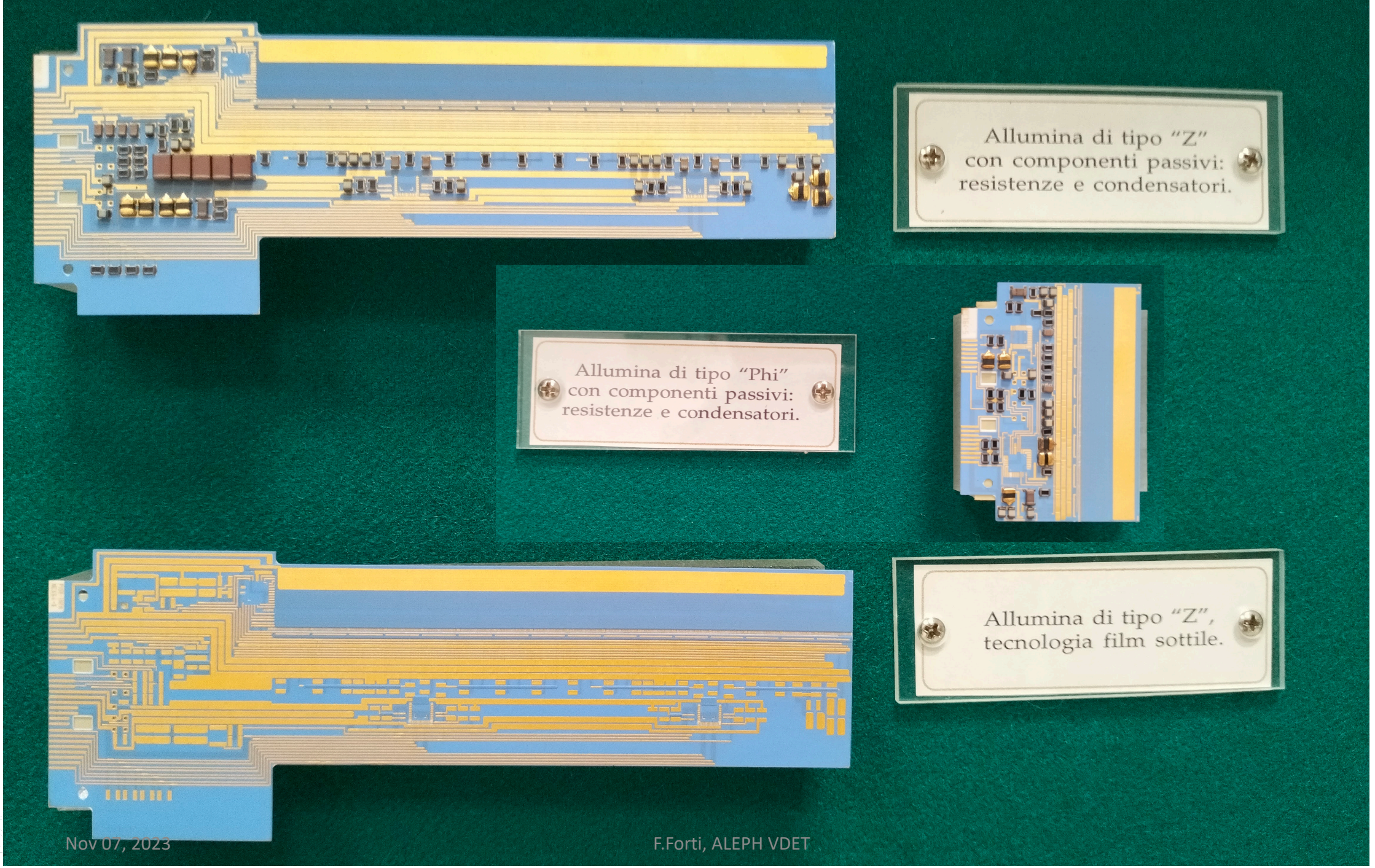




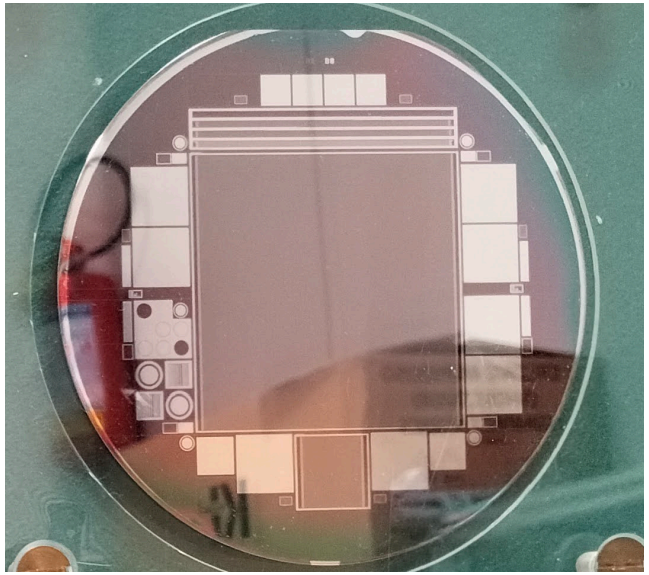
Assemblaggio complesso

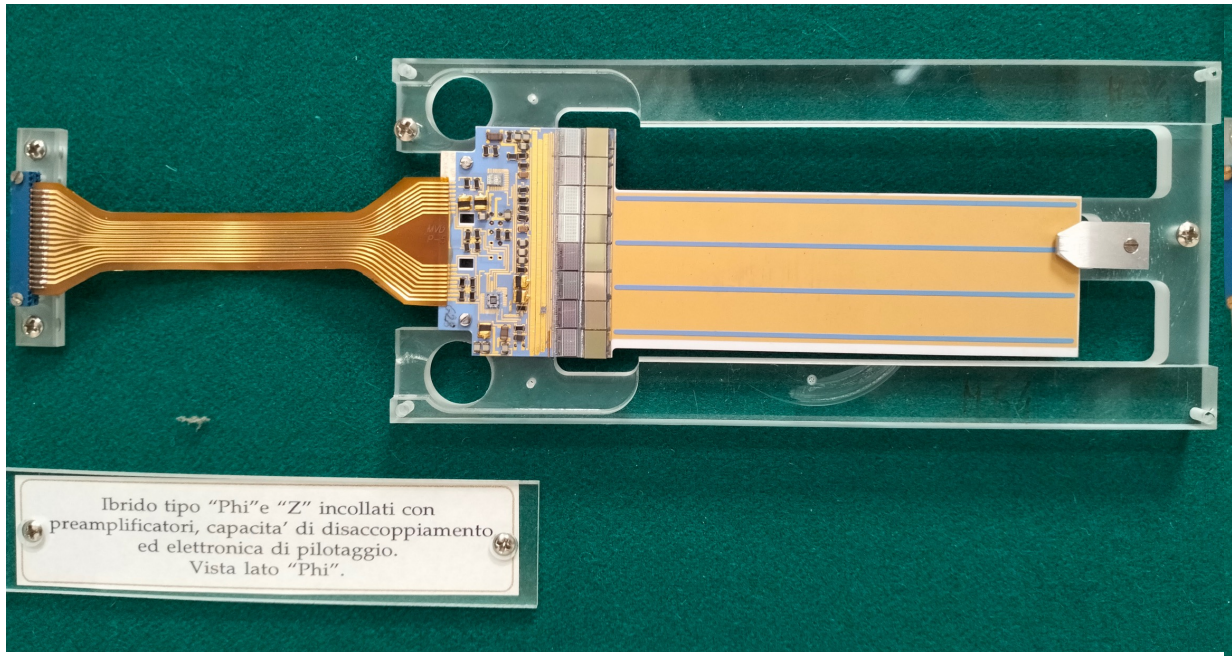


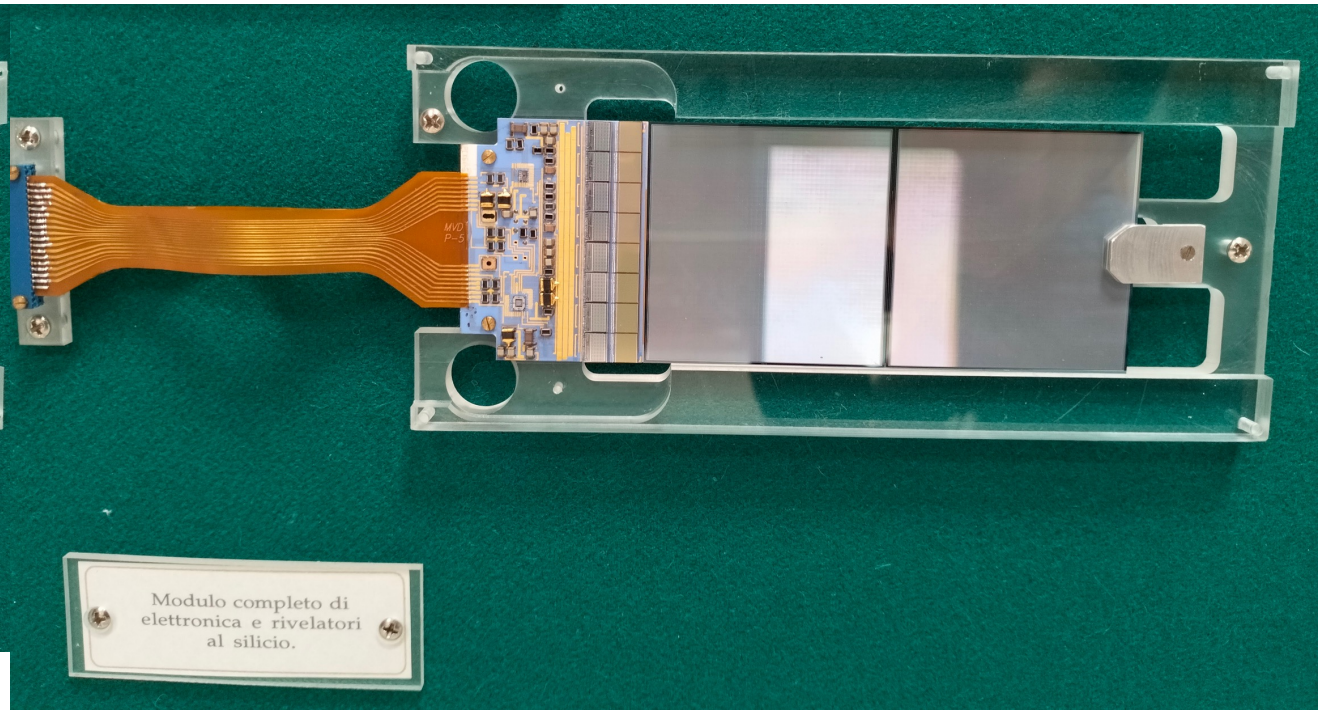
A.Profeti, INFN-Pisa


Allumina di tipo "Z"
con componenti passivi:
resistenze e condensatori.
Allumina di tipo "Phi"
con componenti passivi:
resistenze e condensatori.
Allumina di tipo "Z",
tecnologia film sottile.

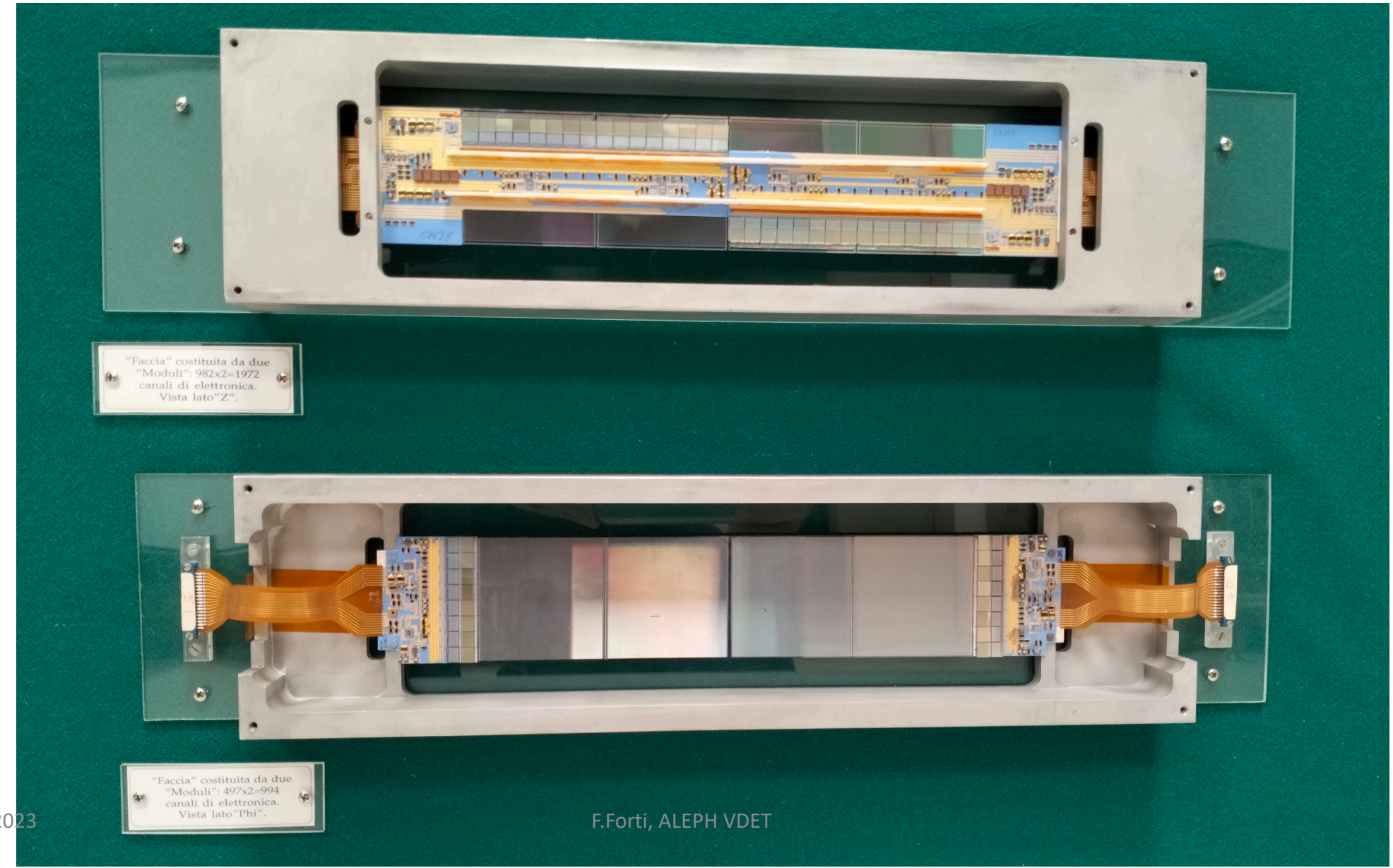
Mezzo modulo



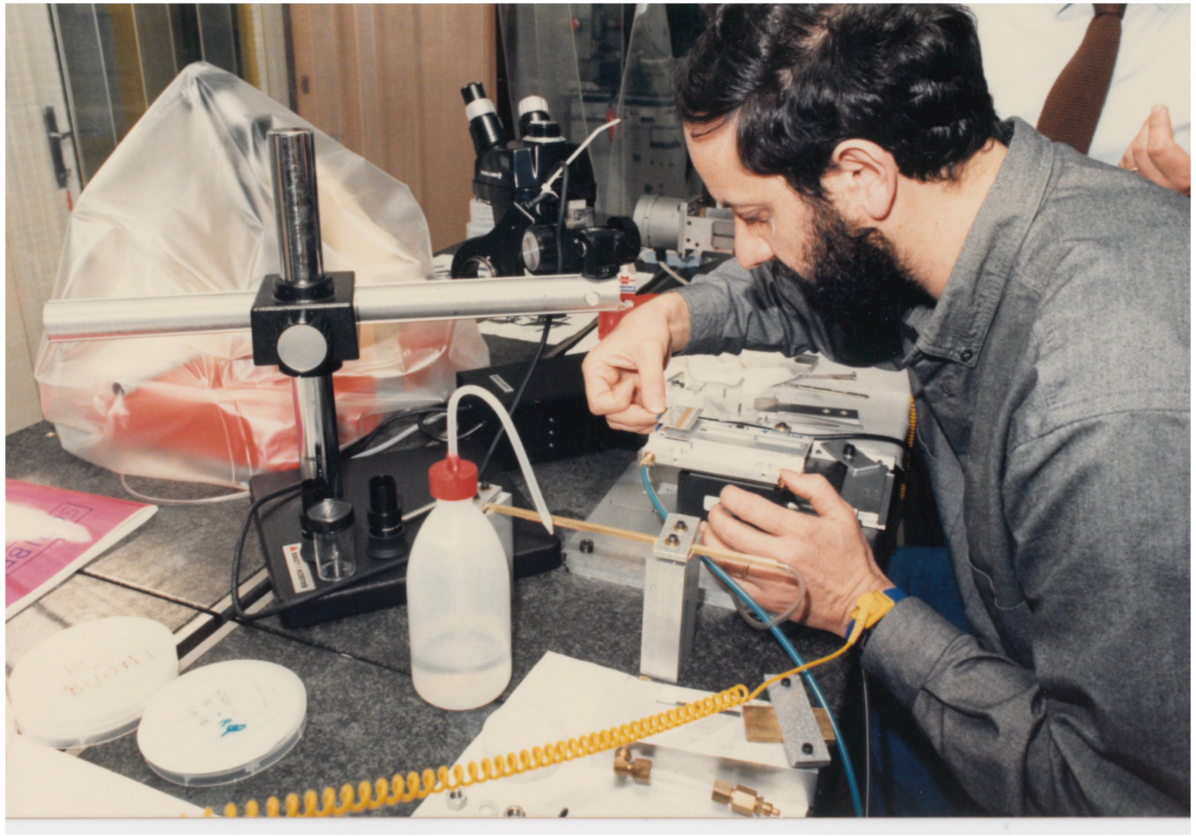




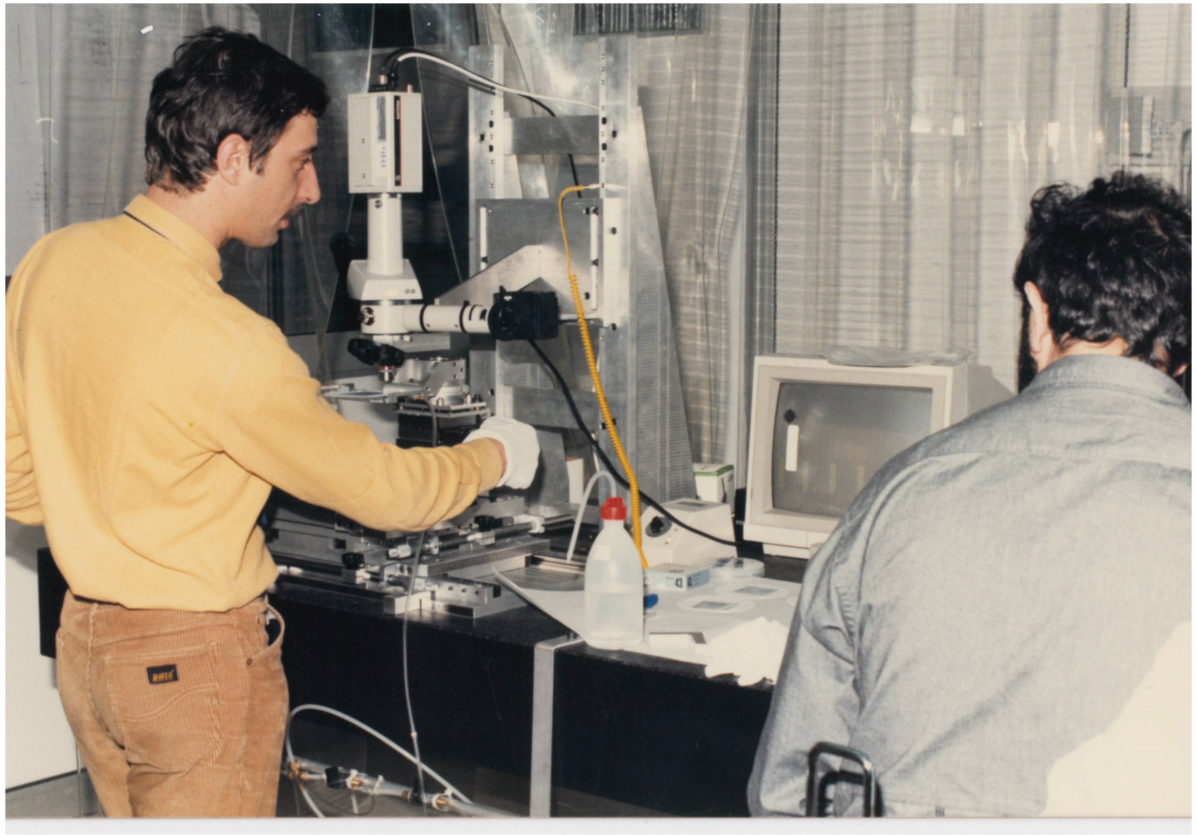
Modulo completo



Incollaggi e allineamenti



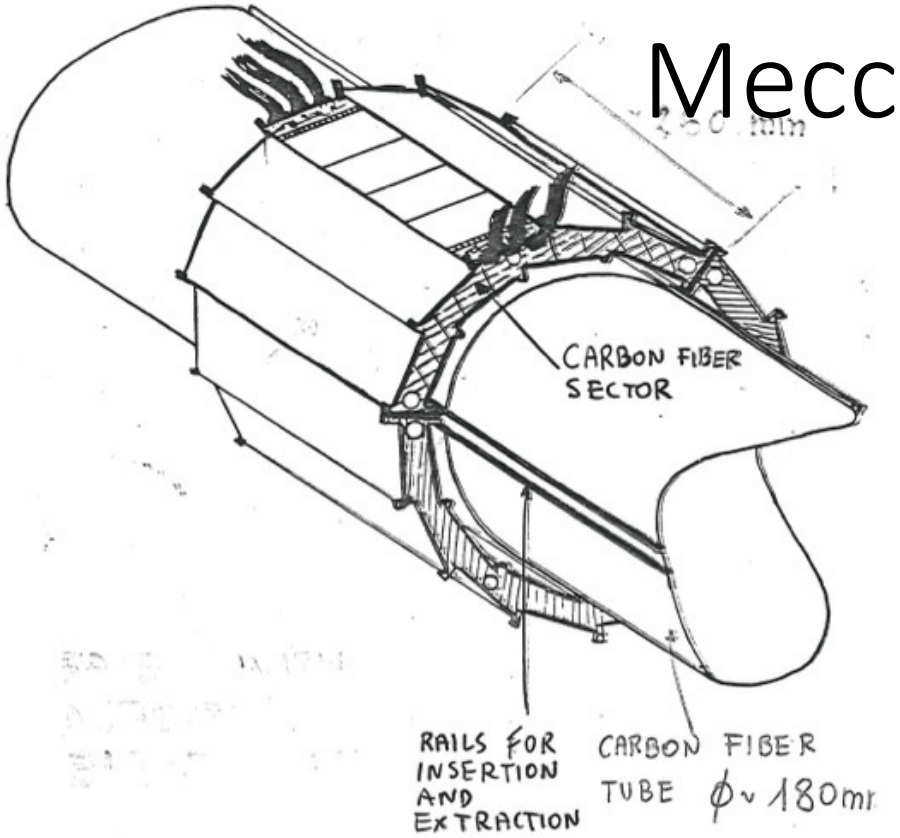
G.Tonelli



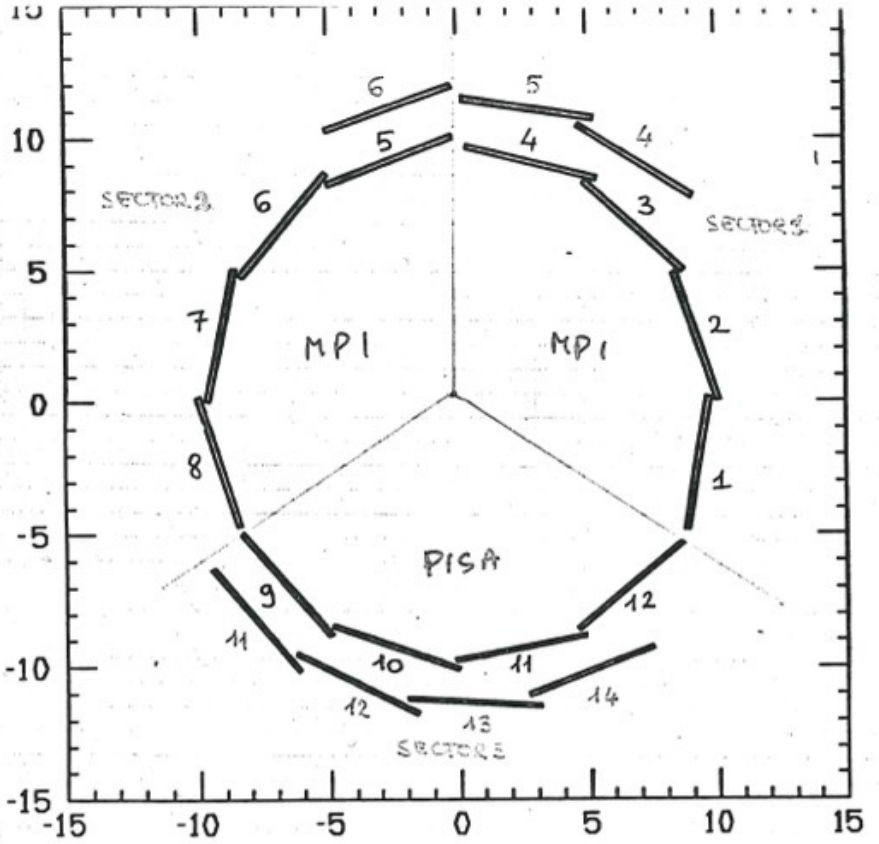
G.Batignani

G.Tonelli

Meccanica



- 3 Sectors with 4 internal faces
  5 external faces
- each sector is indipendent of the other



THE WHOLE INNER LAYER : 12 FACES <r> ~ 9.
~ ½ OUTER LAYER : 7 FACES <r> ~ 11.

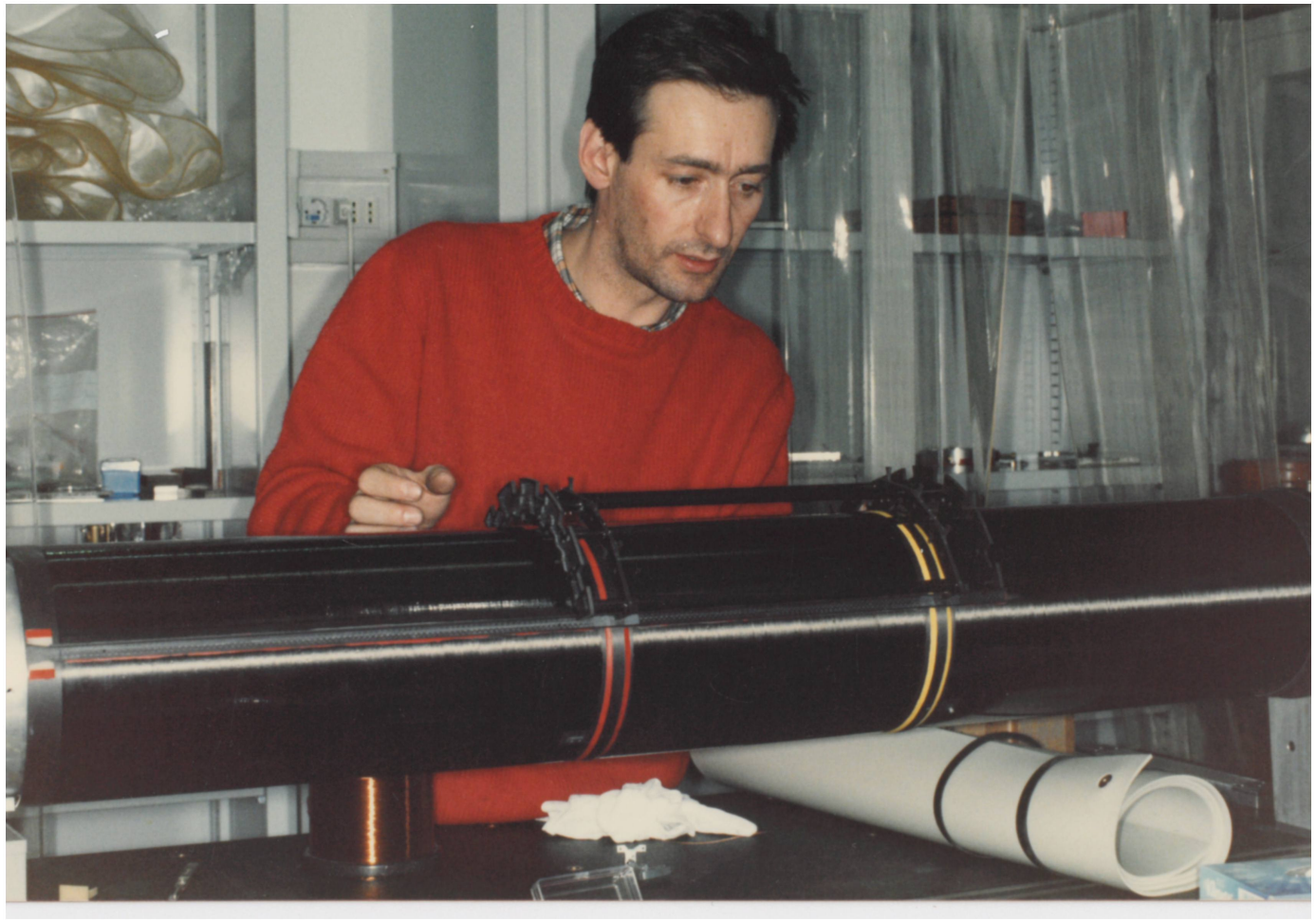
19 FACES

EACH FACE : 2 MODULES x 2 DETECTORS/MODULE =
76 SILICON DETECTORS
(5x5 cm²)

OVERALL WEIGHT 1.5 kg 20 cm LONG

Mock-up della beam pipe per testare la struttura meccanica

F.Bosi

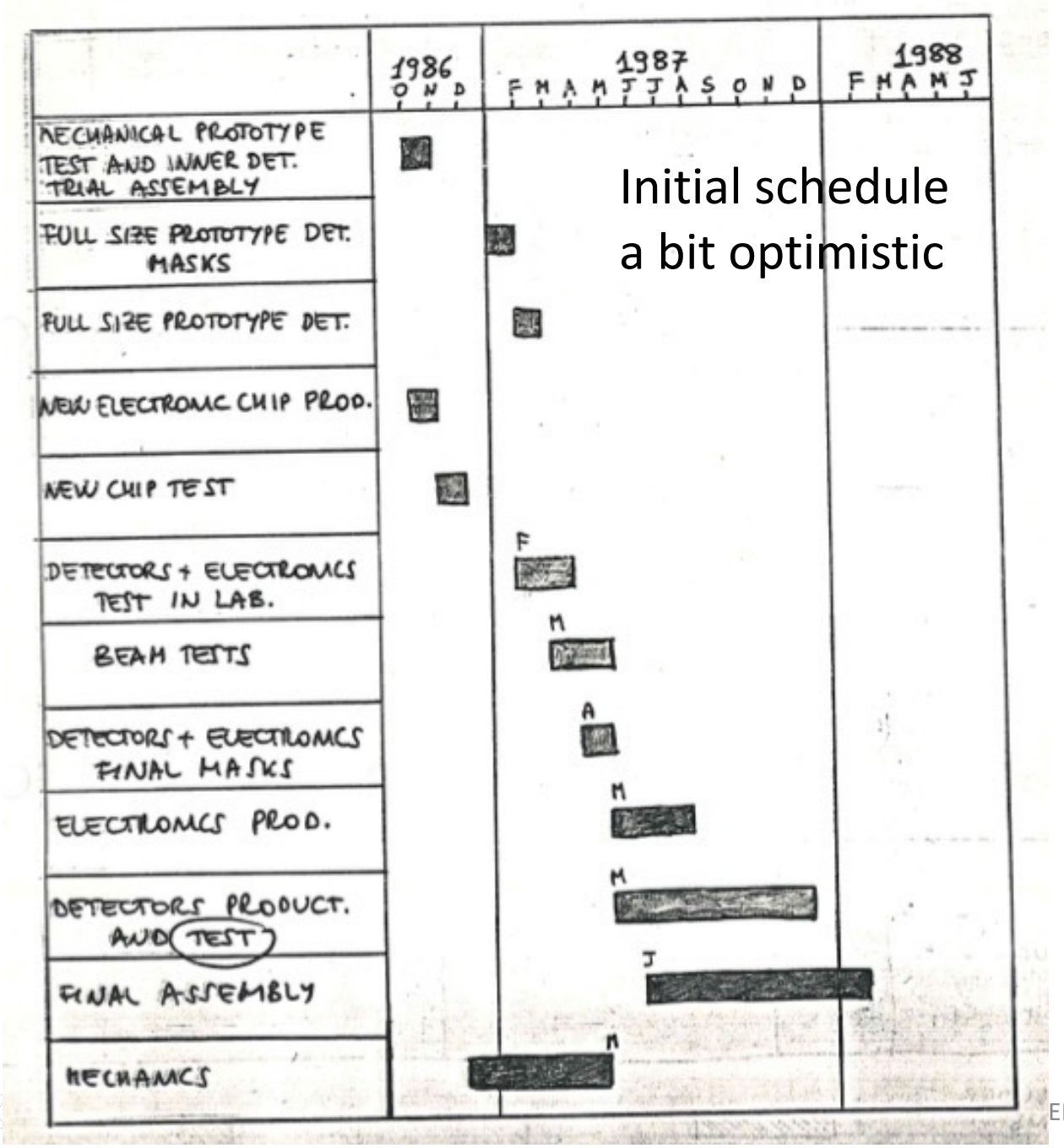


G.Tonelli F.Bosi

Aggiustaggi

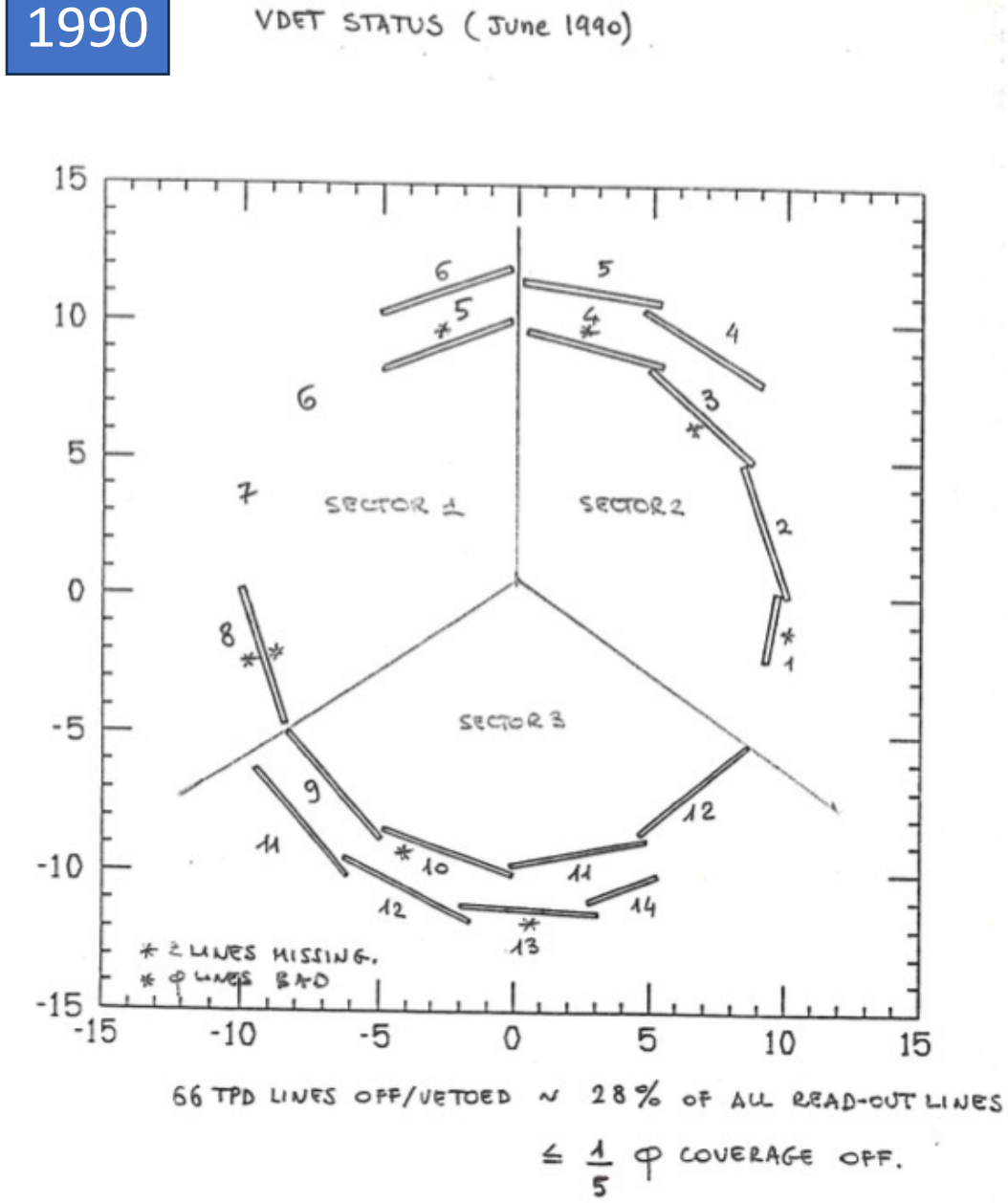
… a volte ci vuole anche la fresa

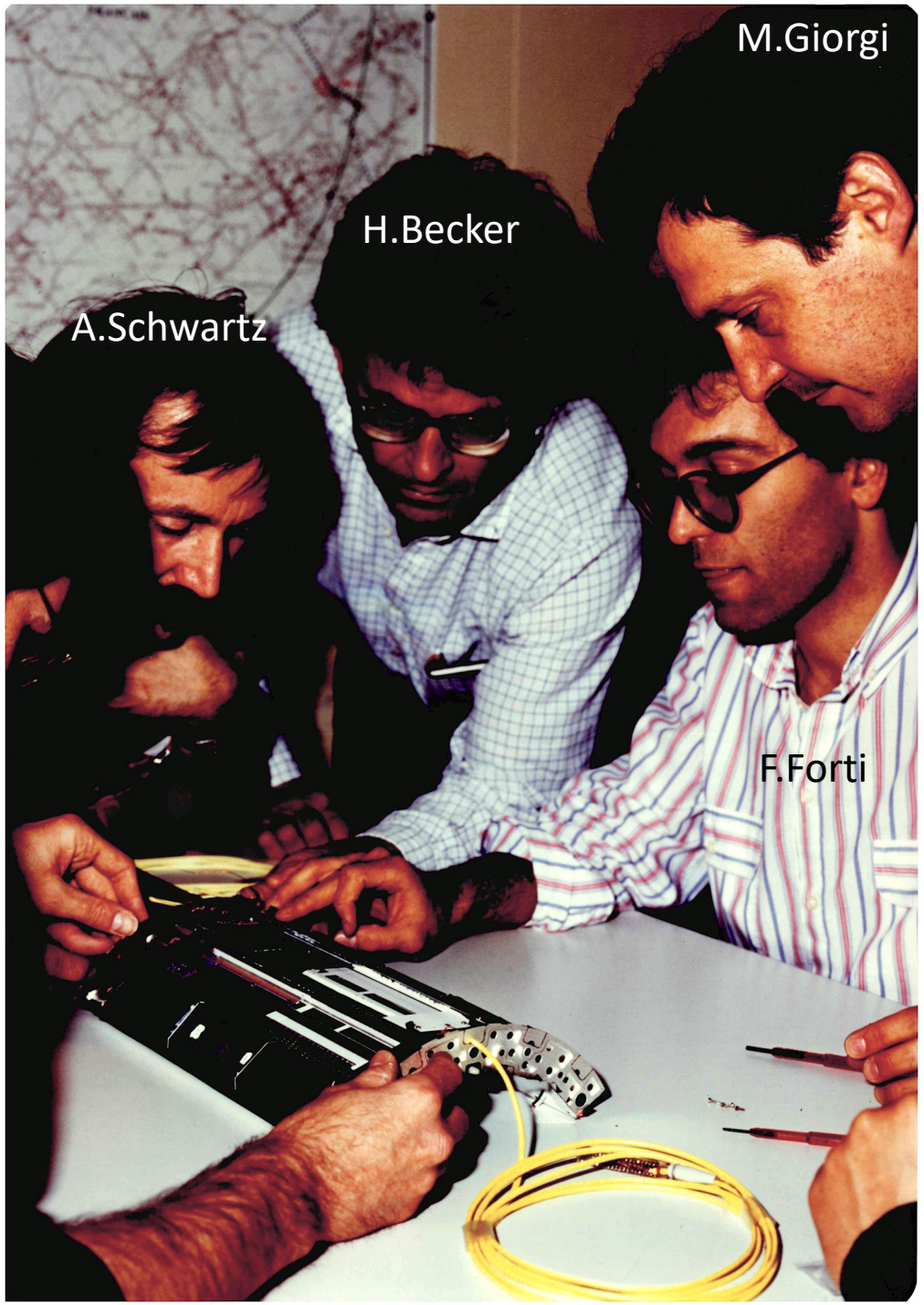
G.Triggiani



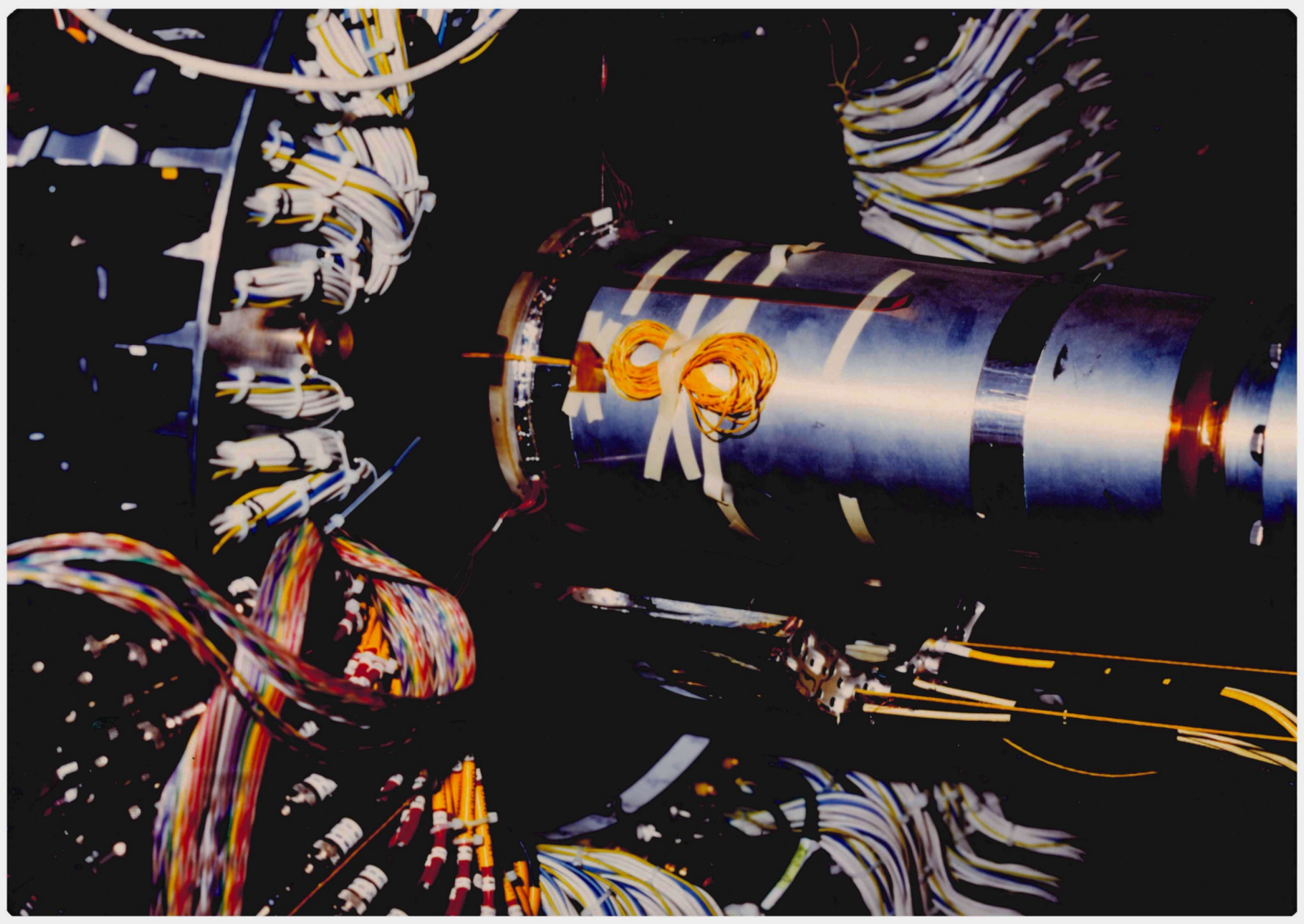
Initial schedule
a bit optimistic

1990





Installazione

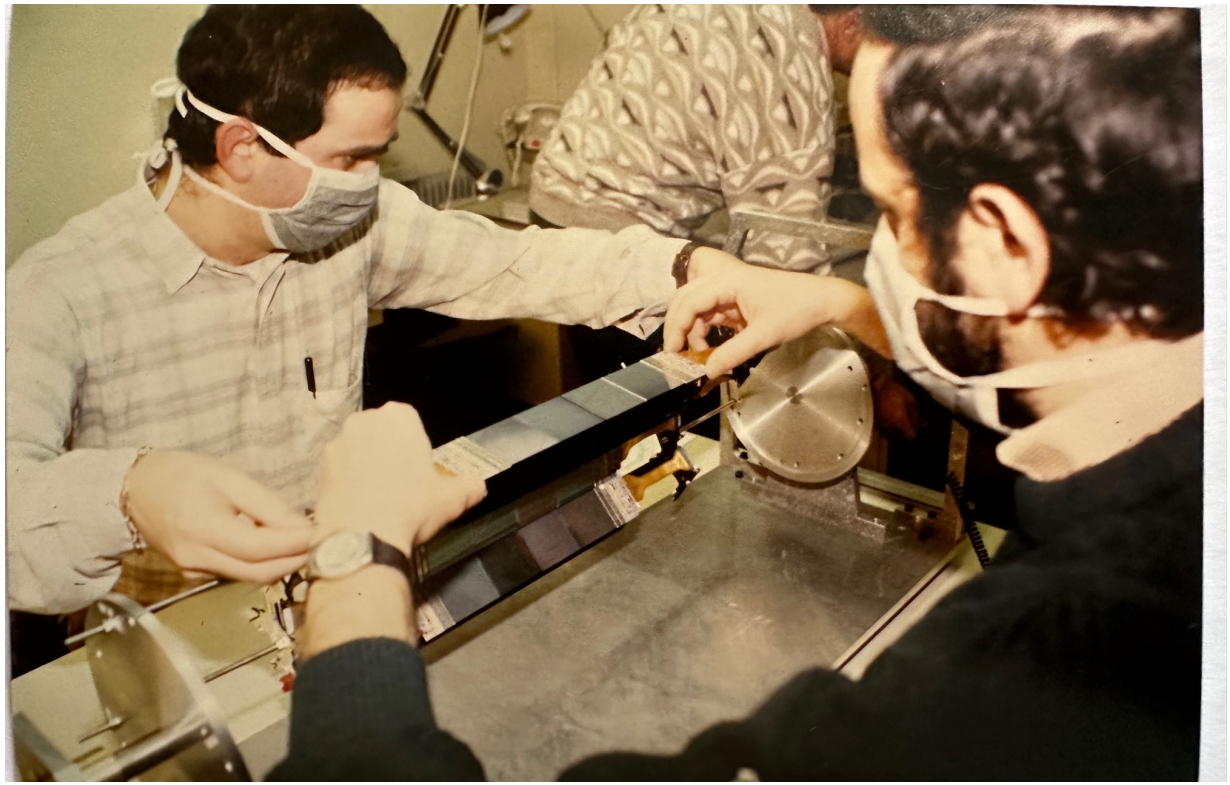


VDET 1991

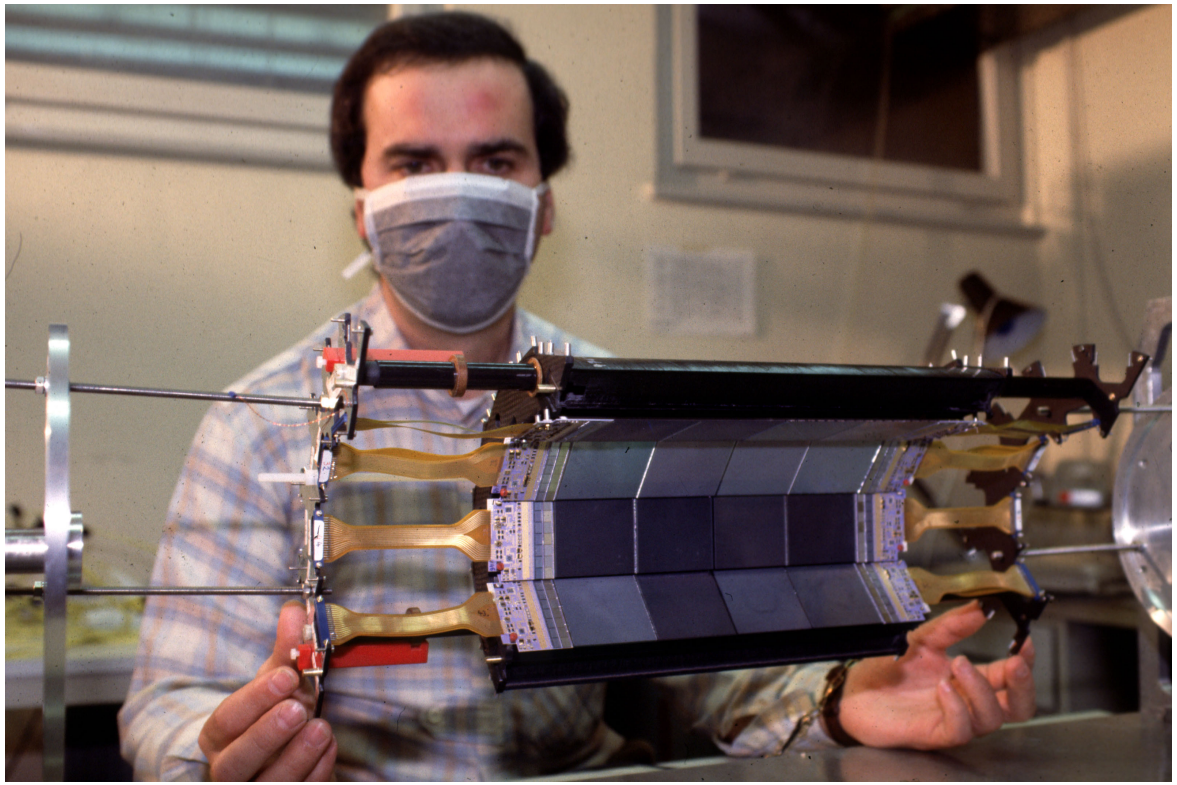
Better mechanics. Complete coverage

E.Focardi

G.Tonelli

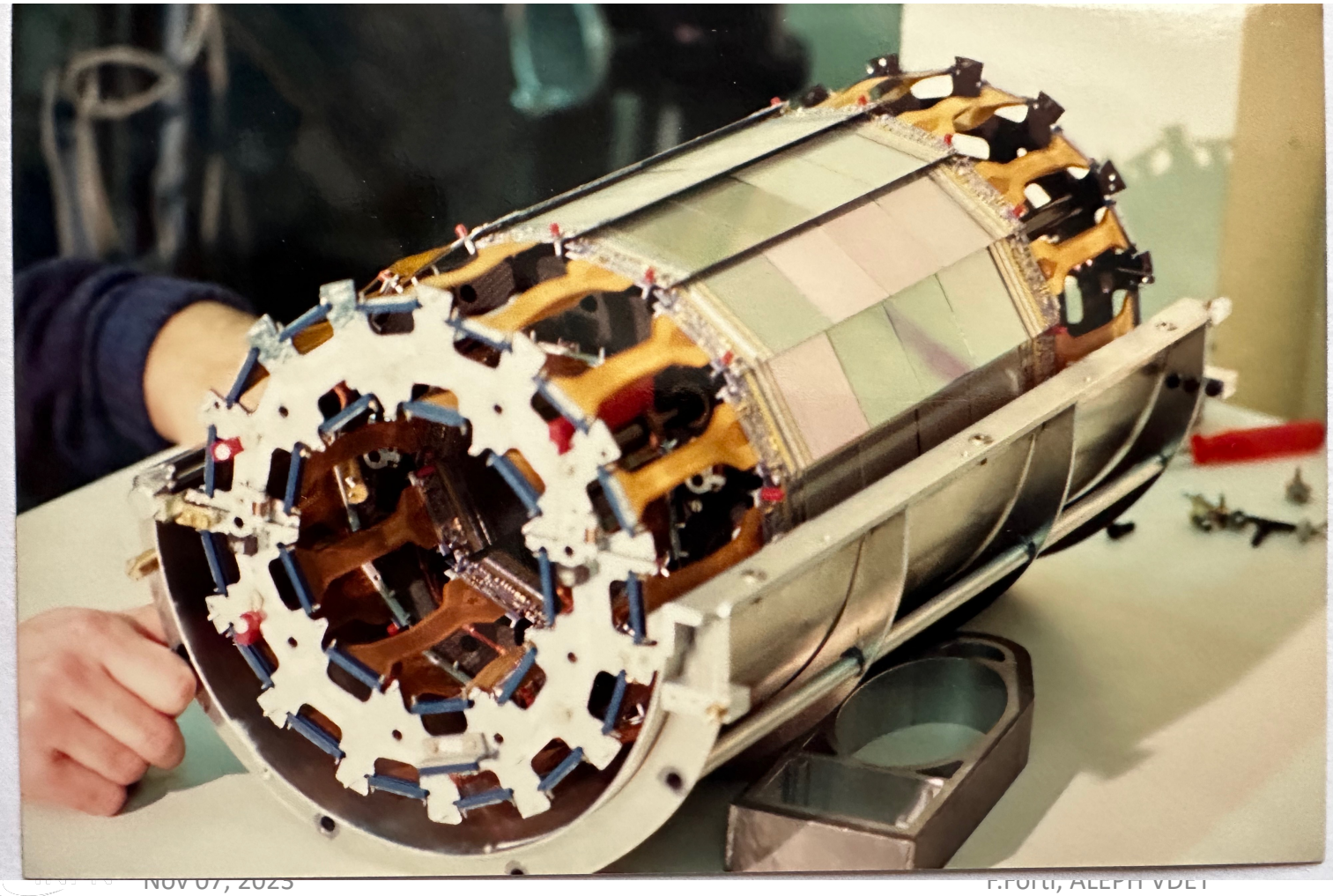


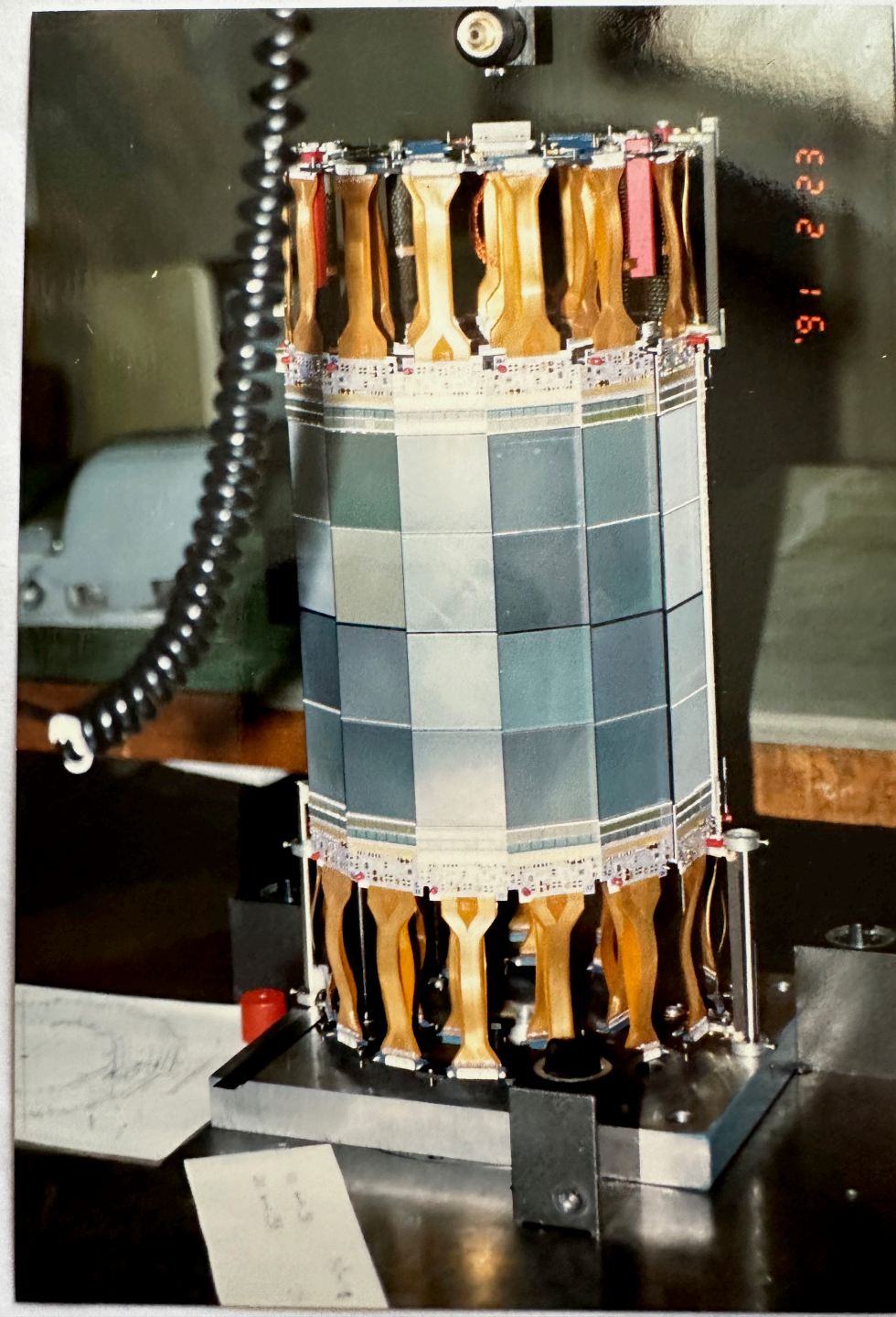
E.Focardi



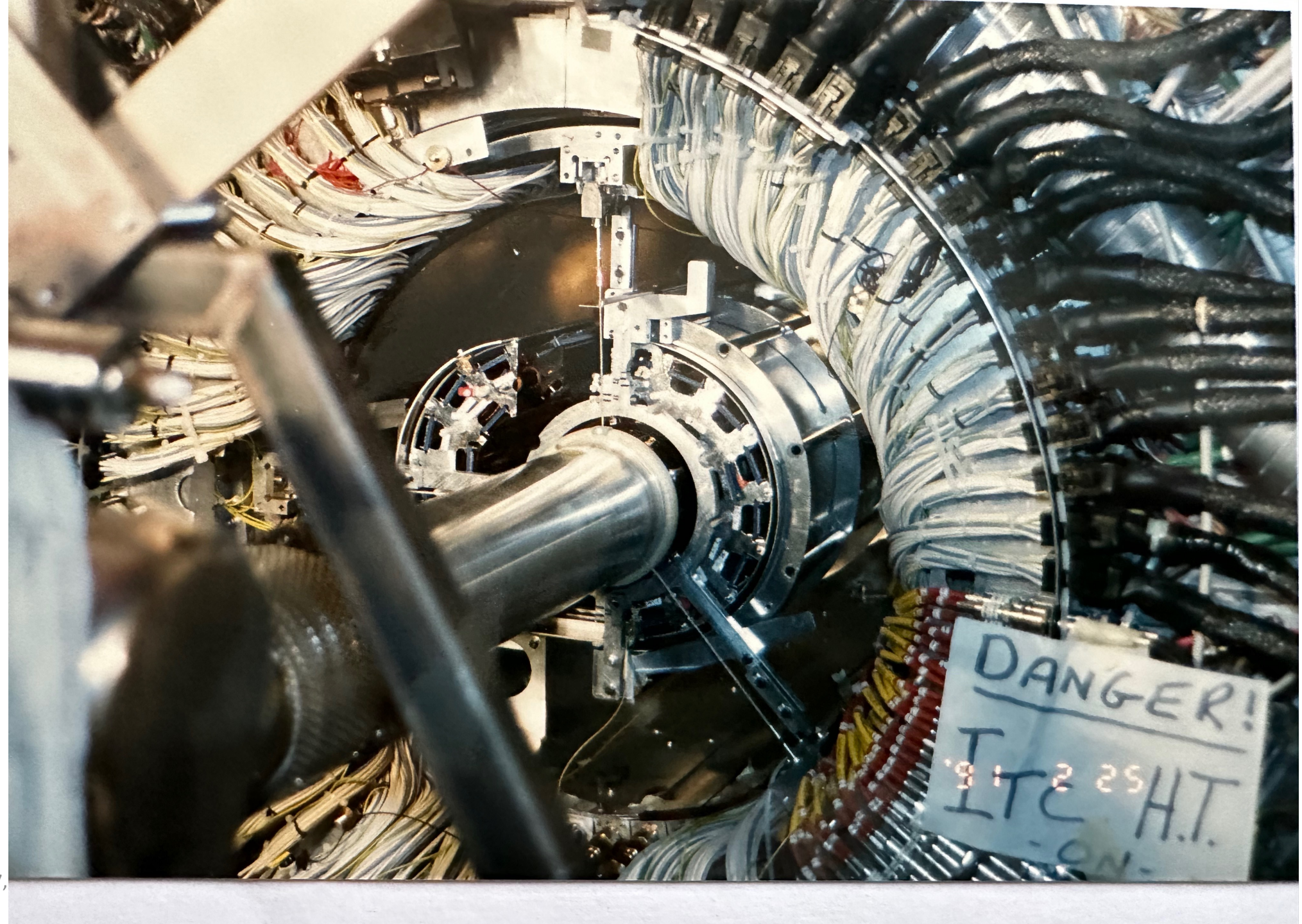
More collaboration, less competition

Completed



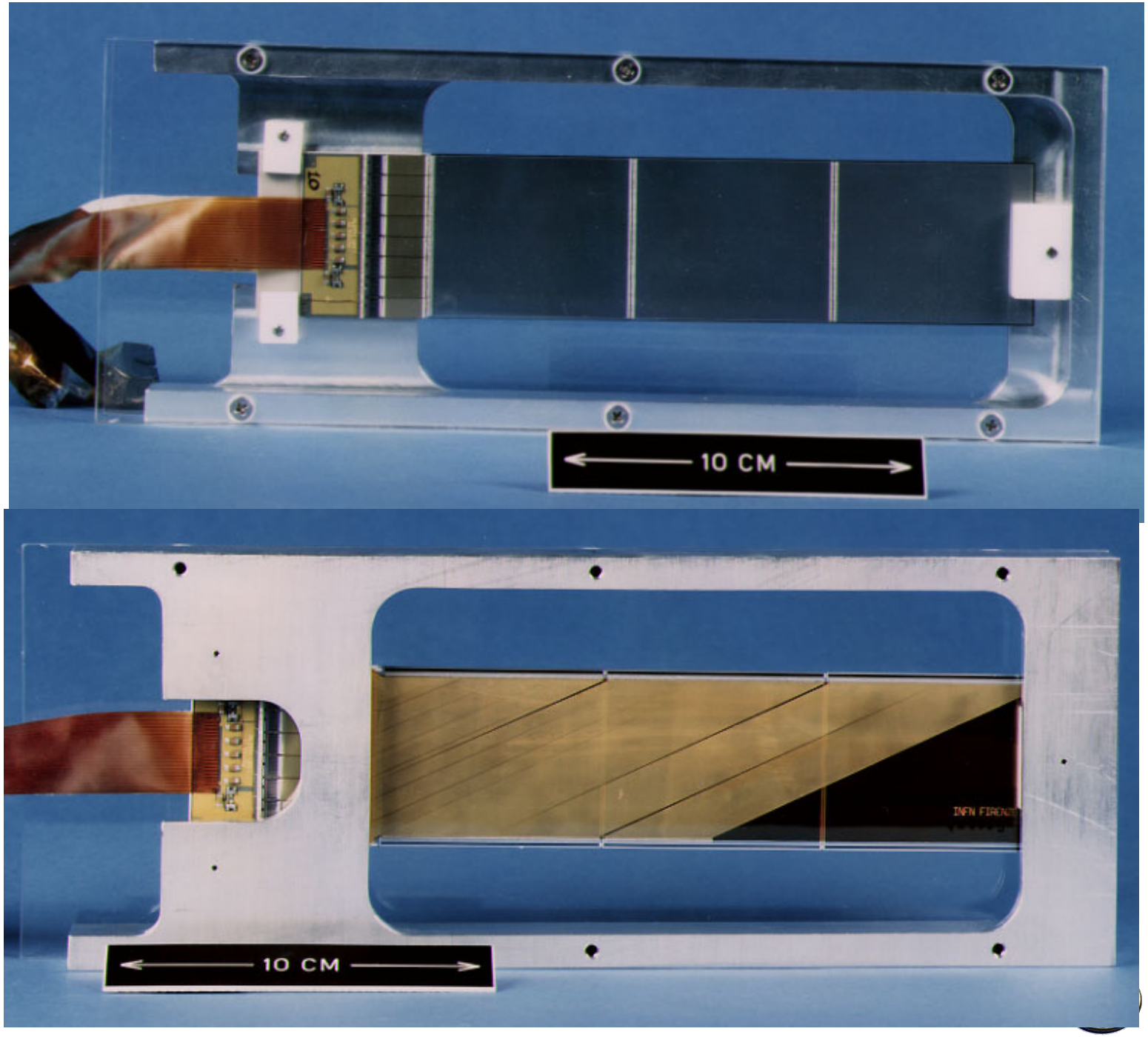


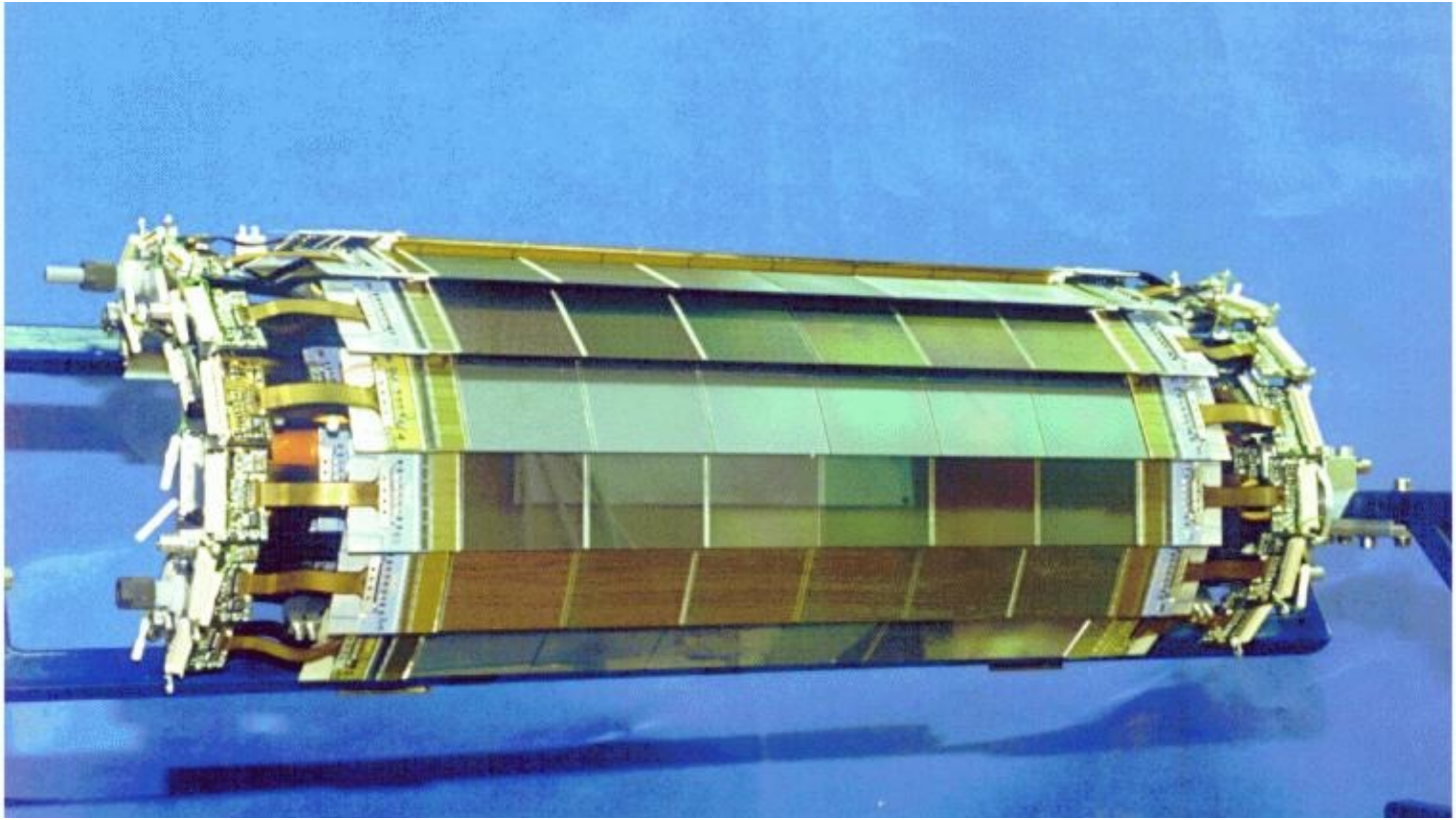

G.Tonelli, M.Favati. M.A.Giorgi, A.Profeti, E.Focardi, G.Triggiani, F.Bosi


DANGER!
ITC H.T.
-ON-

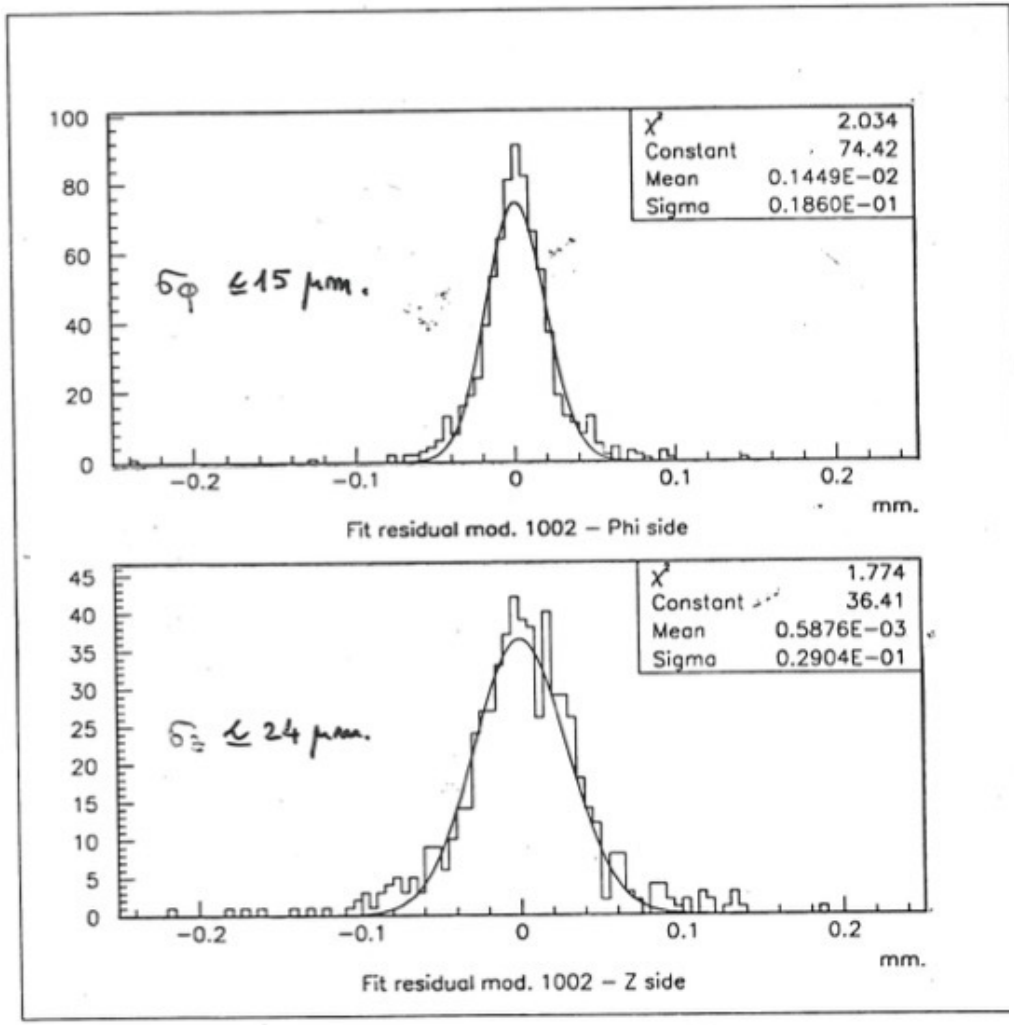
VDET200 (1995)

- Improve angular acceptance, reduce material
- Use fanout circuits to read z side



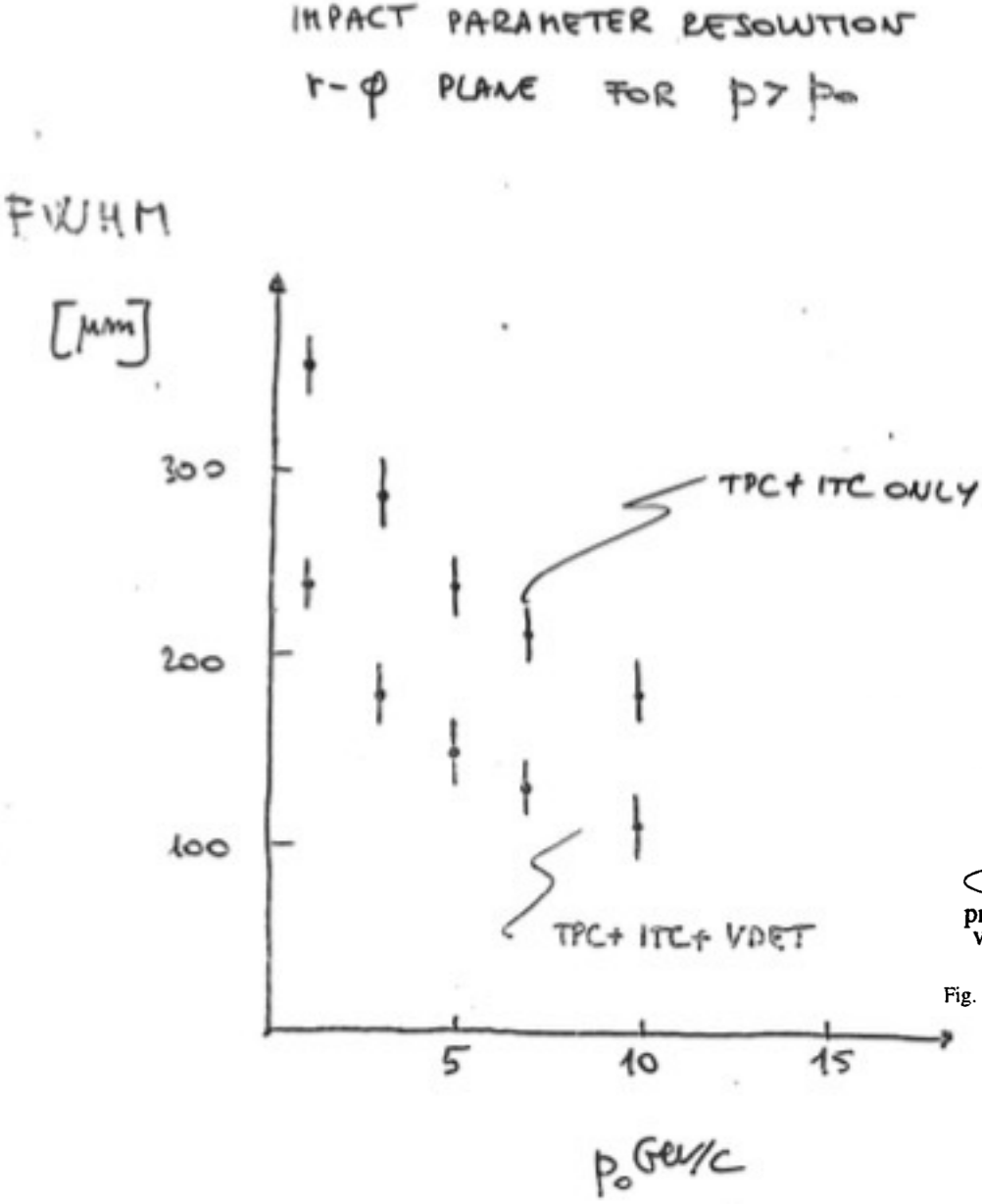


Performance



FROM TEST BEAM DATA [DEC. 1989]

- PERPENDICULAR TRACKS.
- SOME OF THE DETECTORS INSTALLED IN ALEPH.



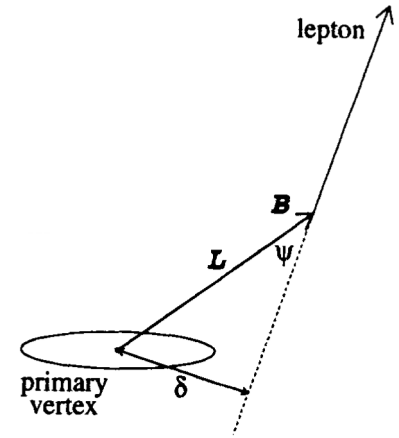
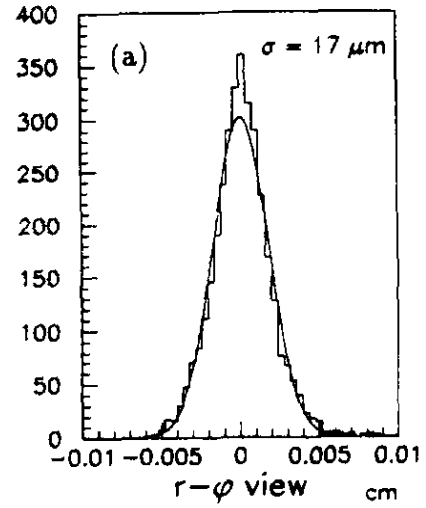
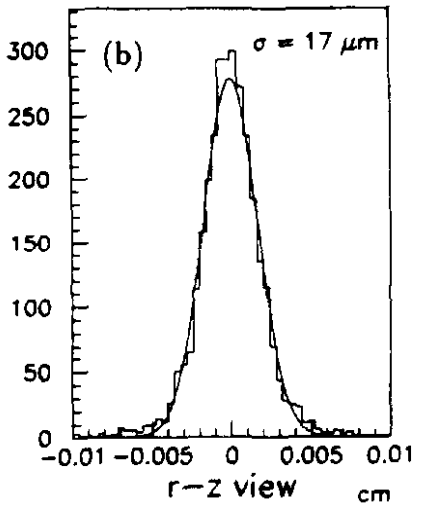


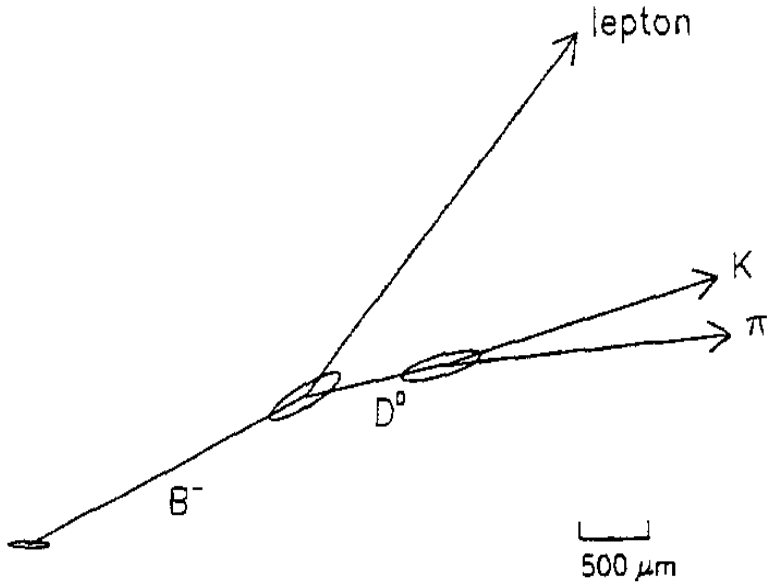
Fig. 1. Definition of the impact parameter.

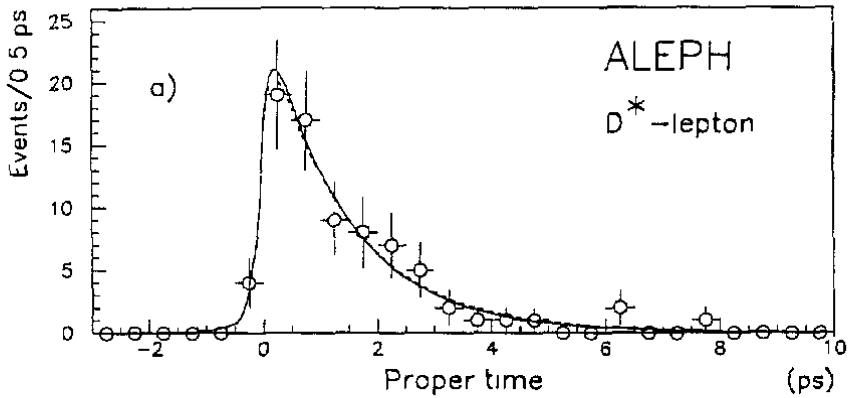
Example of measurement: B hadron lifetime

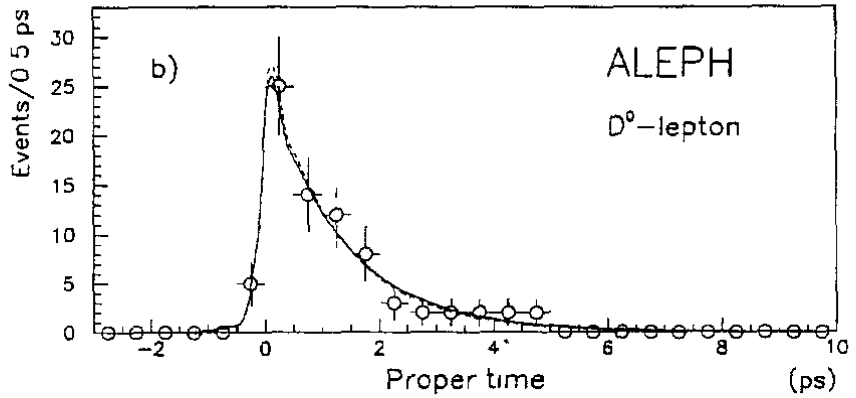




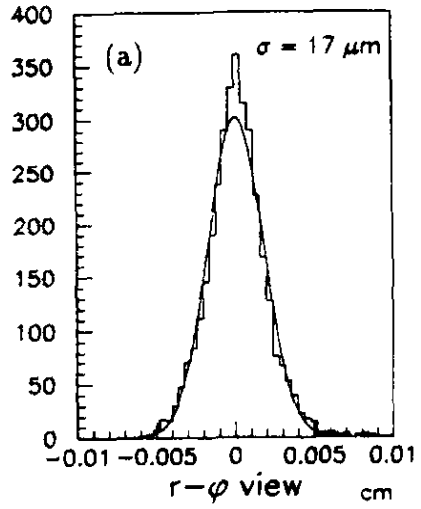
- One of the first measurement involving secondary vertices: 1993 → 1996

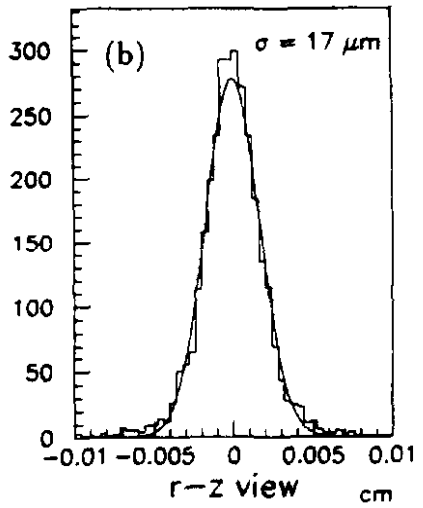






Example of measurement: B hadron lifetime





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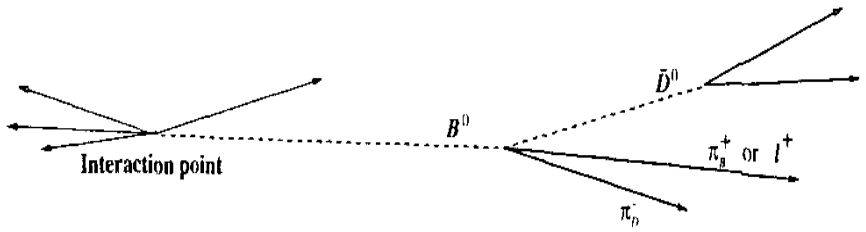
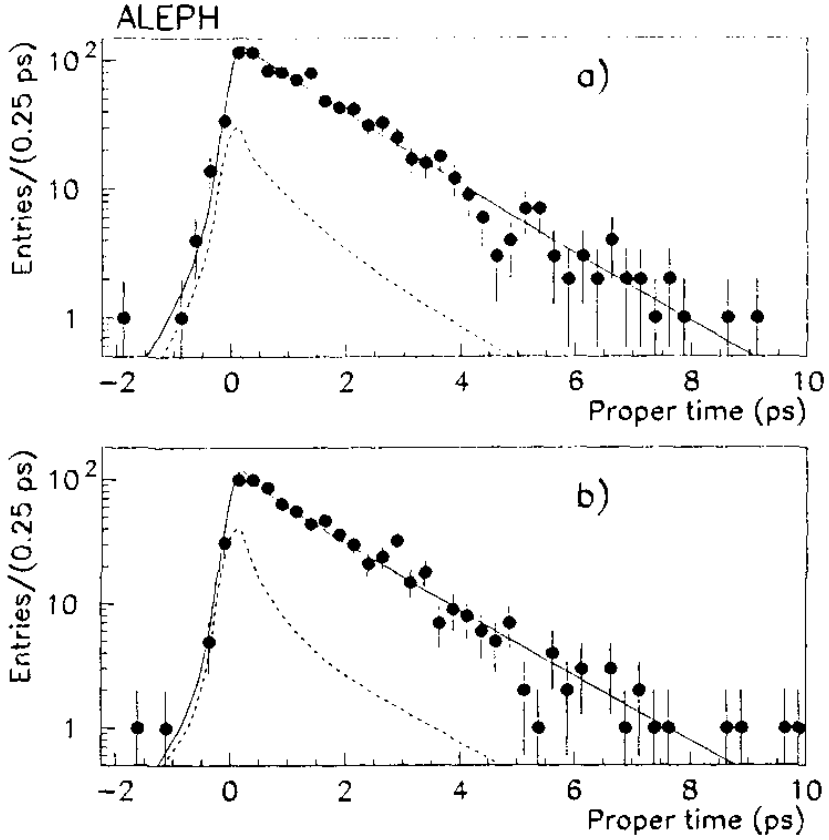
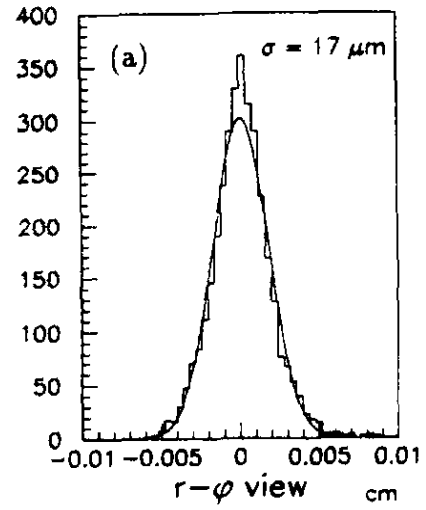
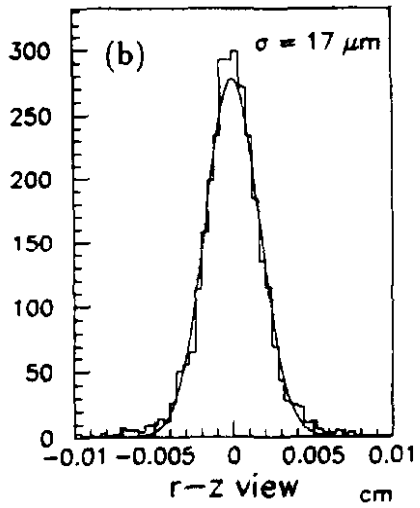


$$\tau_0 = 1.55 \pm 0.06 \pm 0.03 \text{ ps},$$
$$\tau_+ = 1.58 \pm 0.09 \pm 0.03 \text{ ps},$$
$$\frac{\tau_+}{\tau_0} = 1.03 \pm 0.08 \pm 0.02.$$



Example of measurement: b baryon lifetime

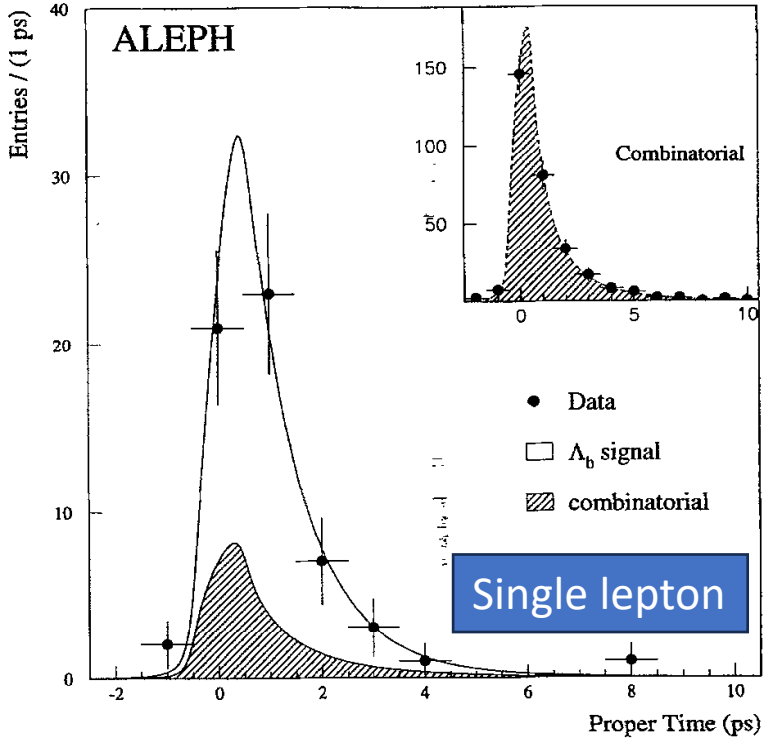




- One of the first measurement involving secondary vertices: 1995 → 1998 $\tau(\text{b baryon}) = 1.21 \pm 0.08$ ps.

$$\Lambda_b \longrightarrow \Lambda_c^+ \ell_1^- \overline{\nu} X$$
$$\hookrightarrow \Lambda \ell_2^+ \nu X$$
$$\hookrightarrow p\pi^-$$

Double lepton



Single lepton

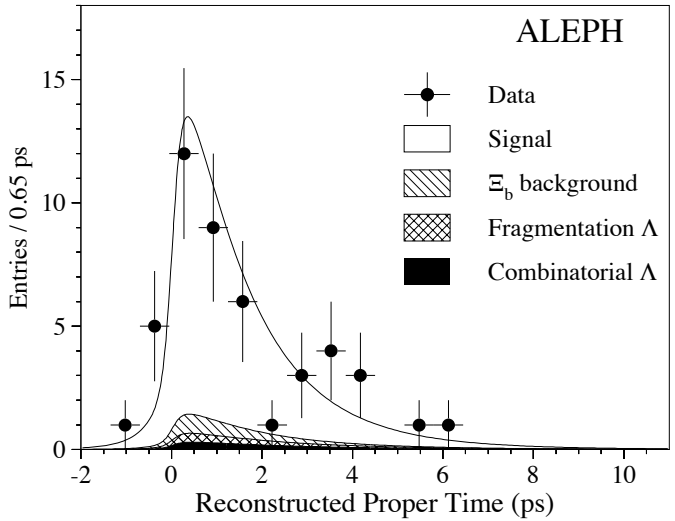
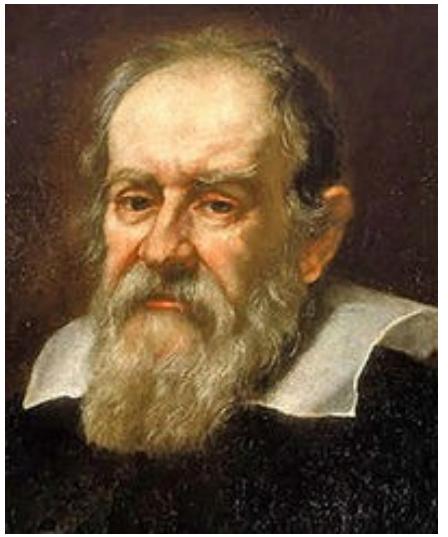


Fig. 8. Fit to the proper time distribution of the 46 candidates reconstructed in the $\Lambda\ell^+\ell^-$ decay mode

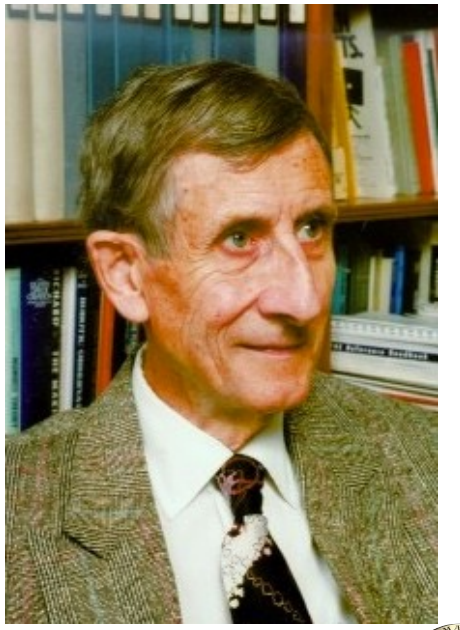
Point resolution in the two detector views

Measurements and discoveries



Galileo Galilei

- Measure what can be measured and make measurable what cannot be measured.



Freeman Dyson

- The effect of a concept-driven revolution is to explain old things in new ways.
- The effect of a tool-driven revolution is to discover new things that have to be explained.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ALEPH VDET: one of the first vertex detectors