

Il rivelatore di vertici dell'esperimento ALEPH

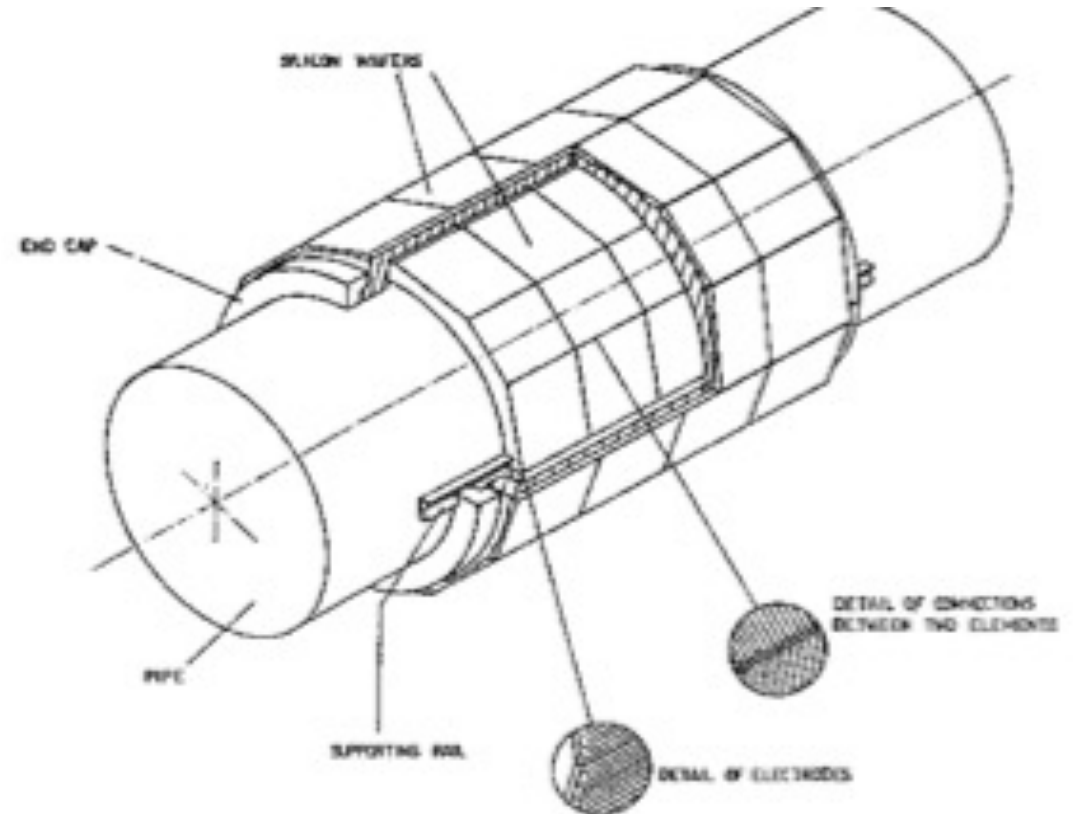
November 07, 2023

Francesco Forti,
INFN and University, Pisa



Silicon Detectors for vertex measurement

- Double-sided silicon strip detectors were 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

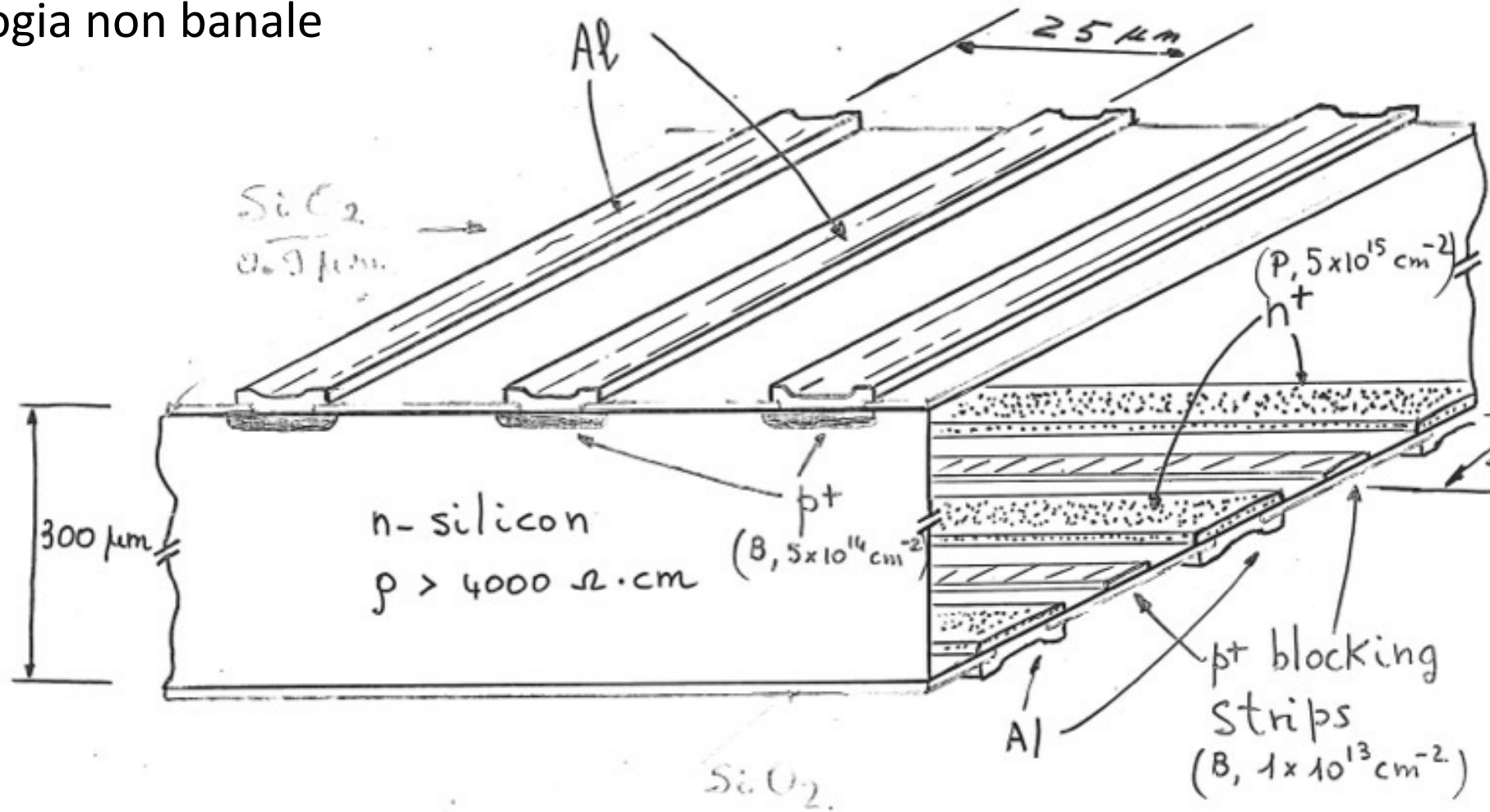
Prime prove di fabbricazione in casa

E.Focardi

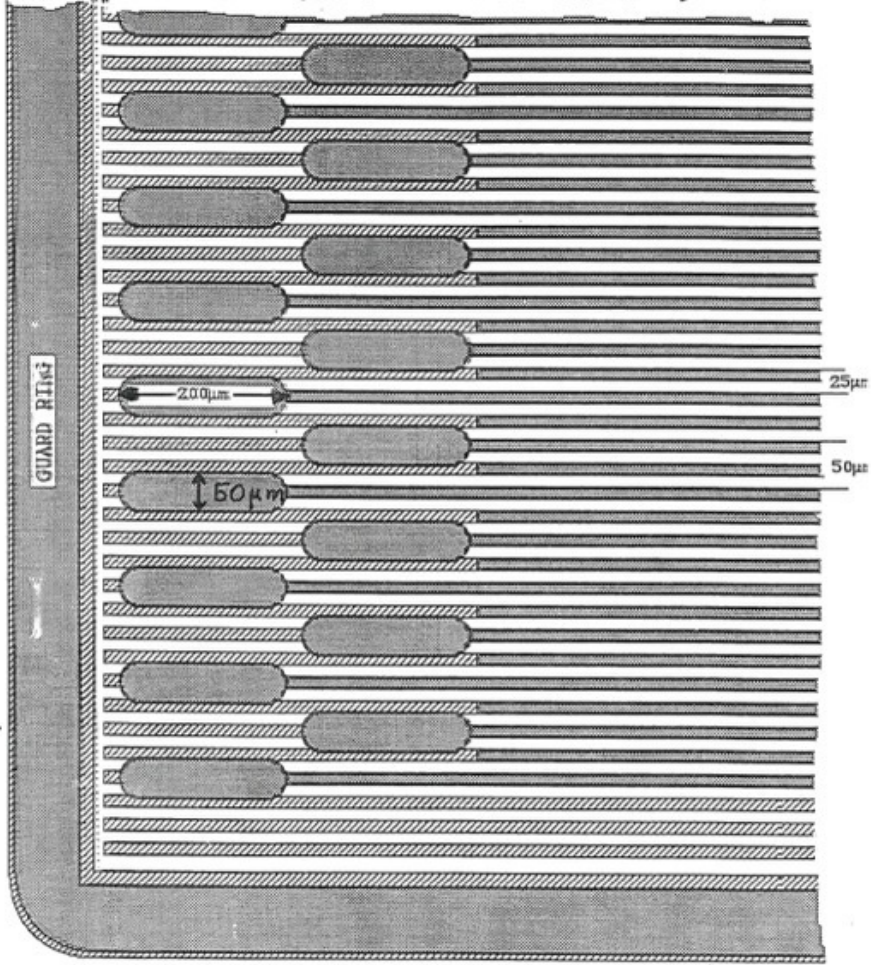


Double side readout detector

Tecnologia non banale

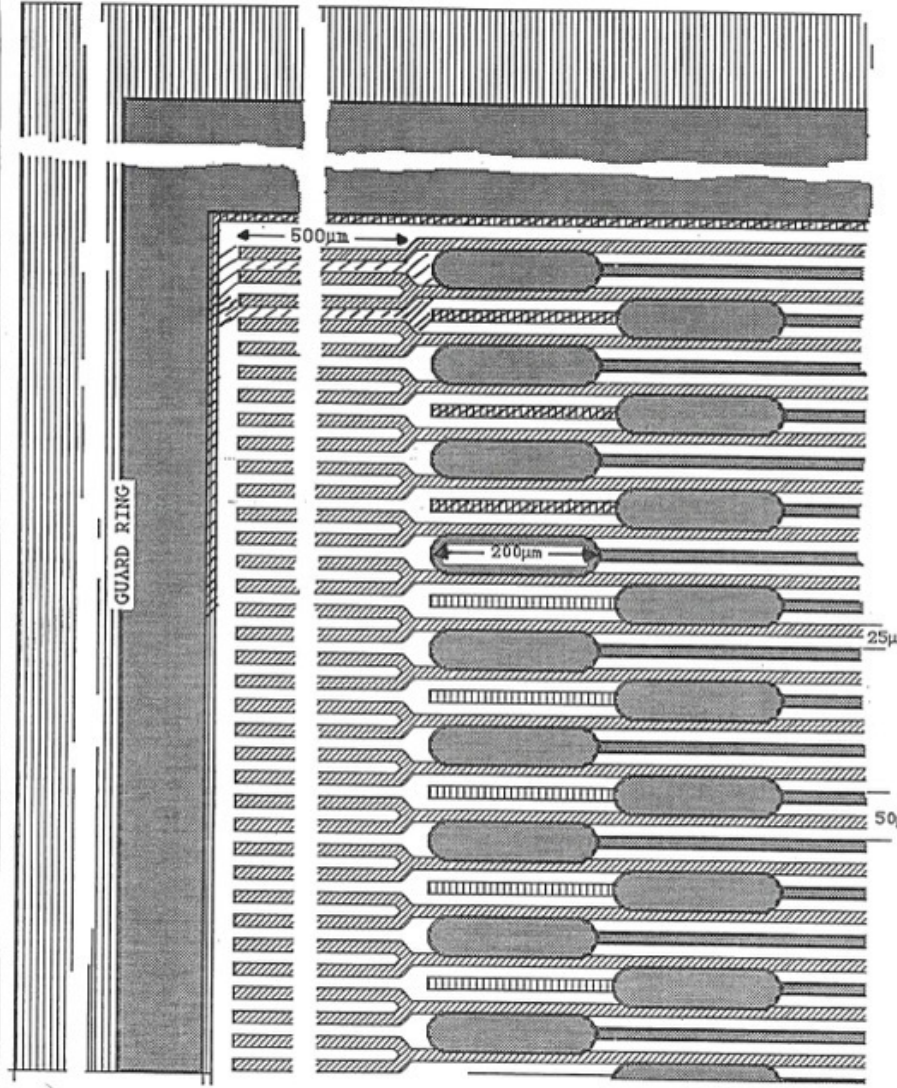


PUNCH-THROUGH GAP
 4 μm
 1 μm (5 μm)
 PISA DETECTOR : junction side
 P-SIDE
 implantation (B)
 metallization (Al/Si)
 (CONTACT NOT SHOWN)



1991 P^+ STRIPS { 25 μm PITCH
 12 μm WIDE
 13 μm GAP
 993 BONDING PADS 50 μm PITCH

PISA DETECTOR : ohmic side
 Accumulation layer
 metallization (Al/Si)
 implantation (P)

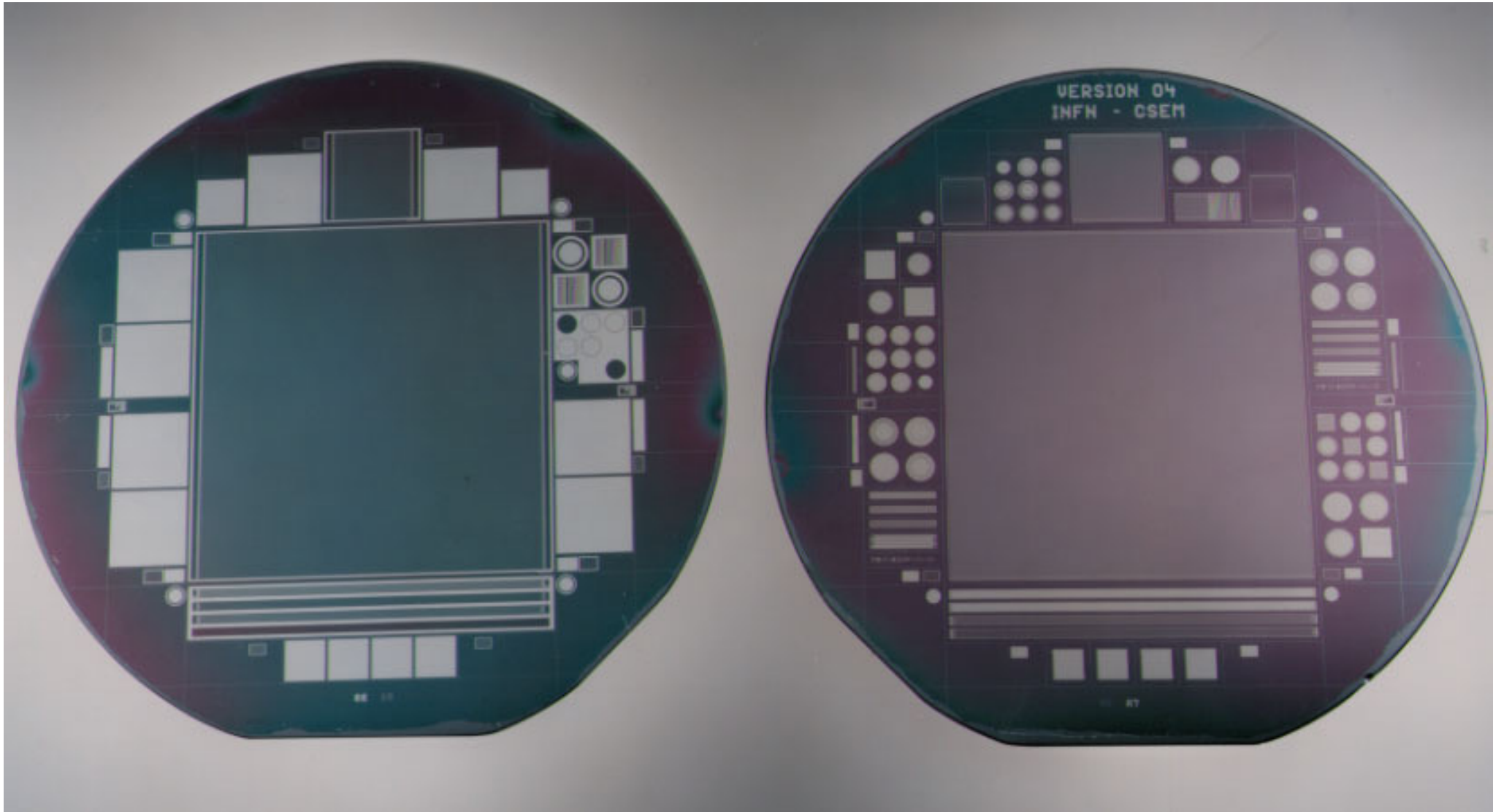


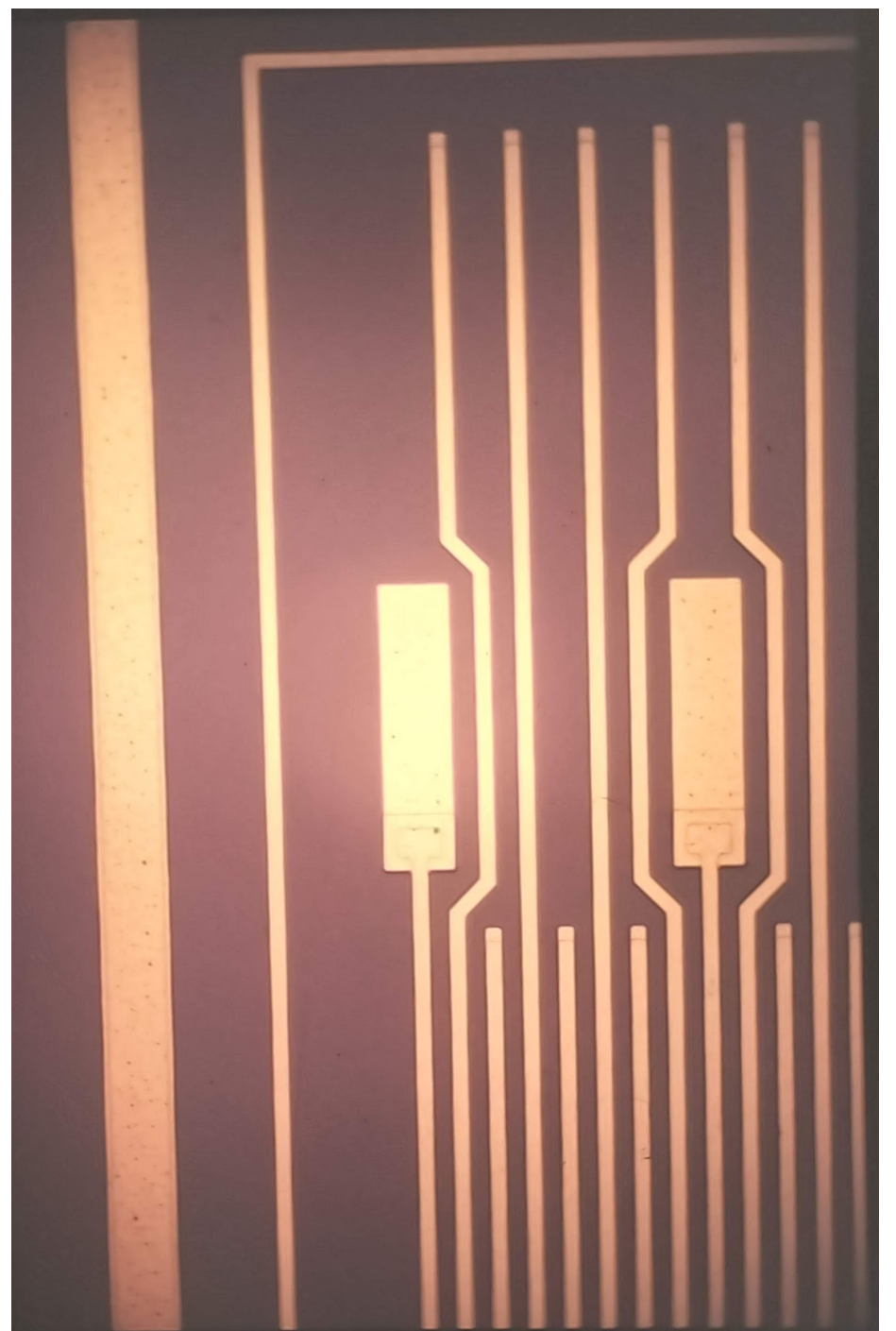
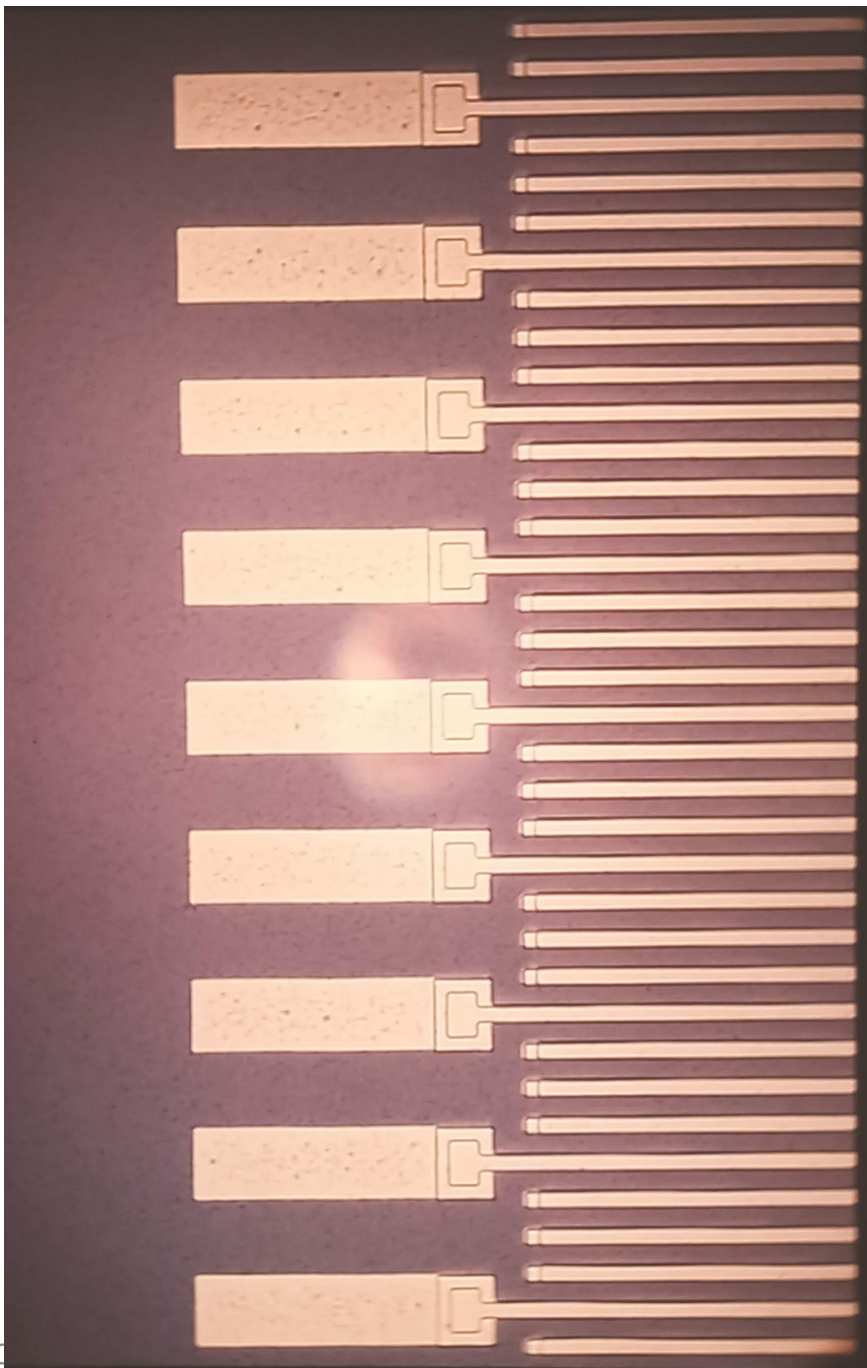
993 n^+ -STRIPS 50 μm PITCH
 12 μm WIDE
 38 μm GAP

Technology developed with CSEM, Neuchatel



I wafer doppia faccia prodotti da CSEM

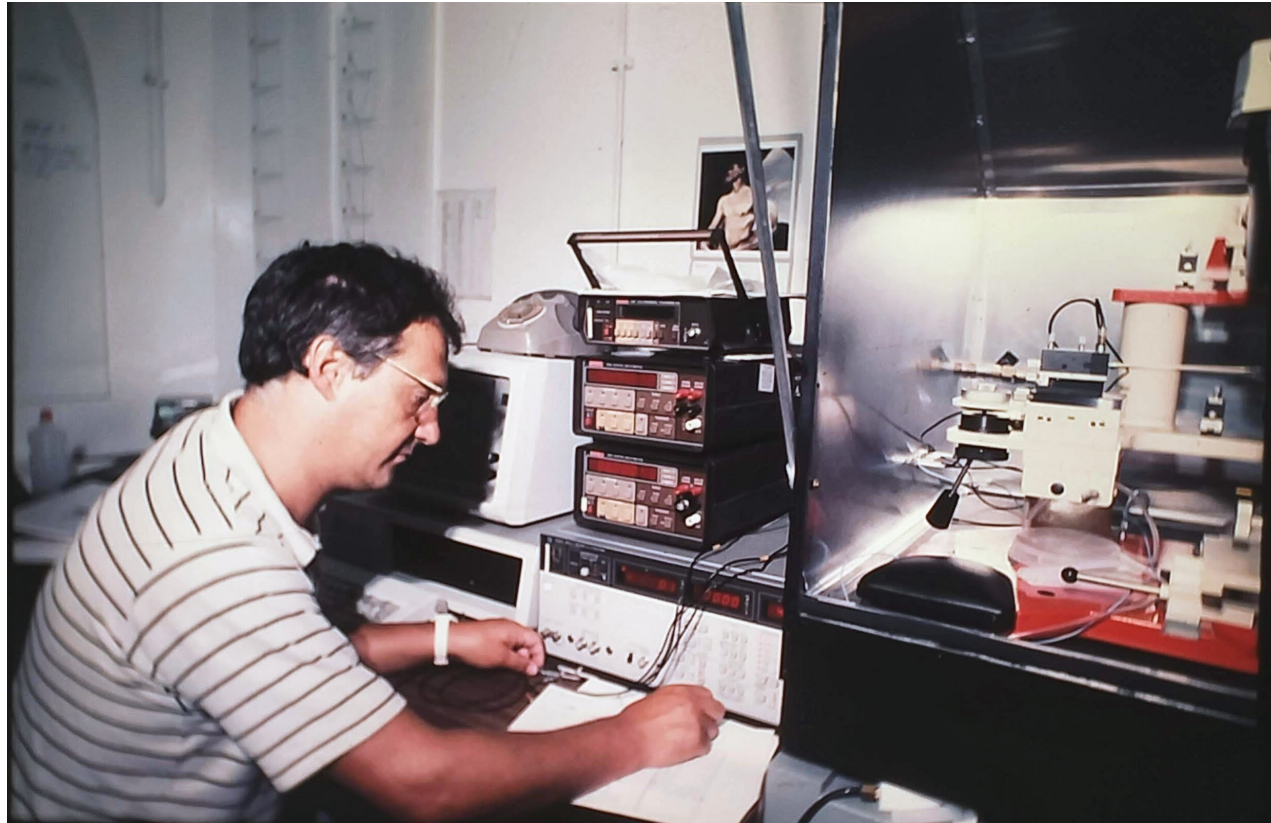




F.Forti, ALEPH VDET

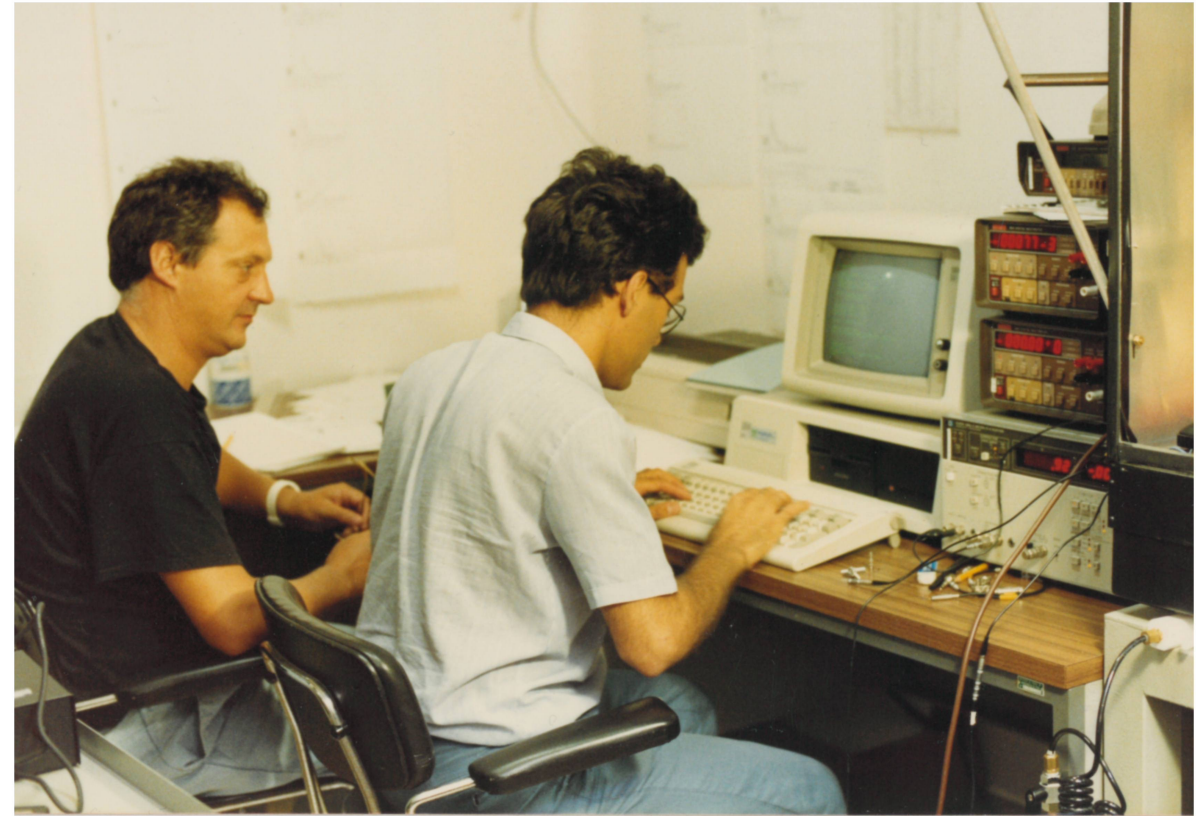
Misure e caratterizzazione

M.A.Giorgi



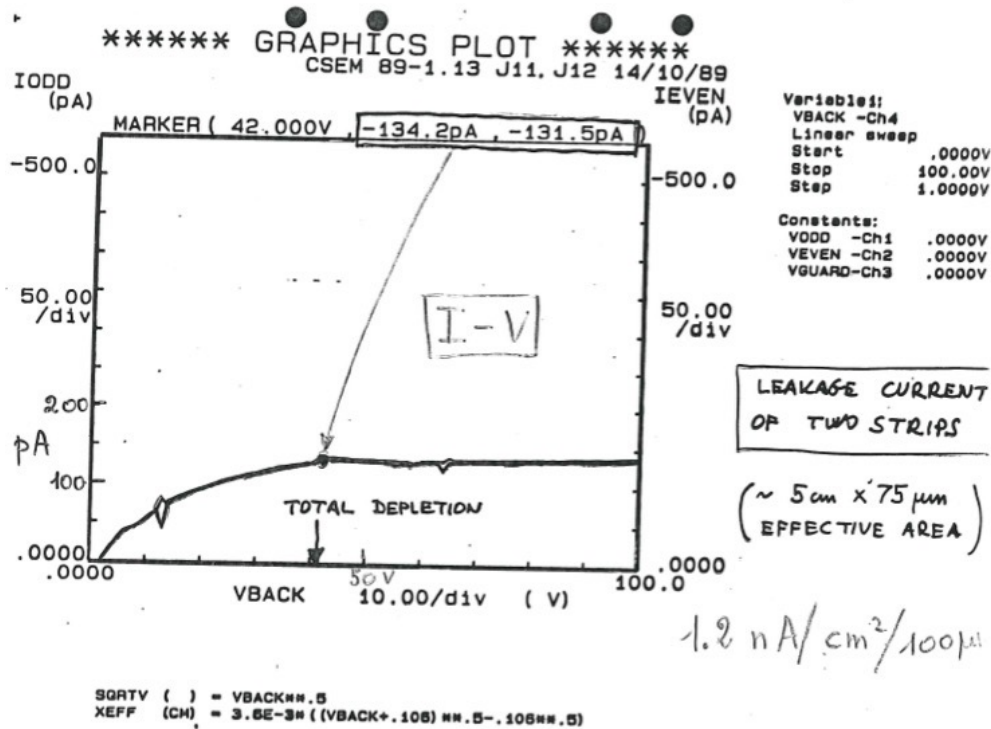
M.A.Giorgi

F.Forti

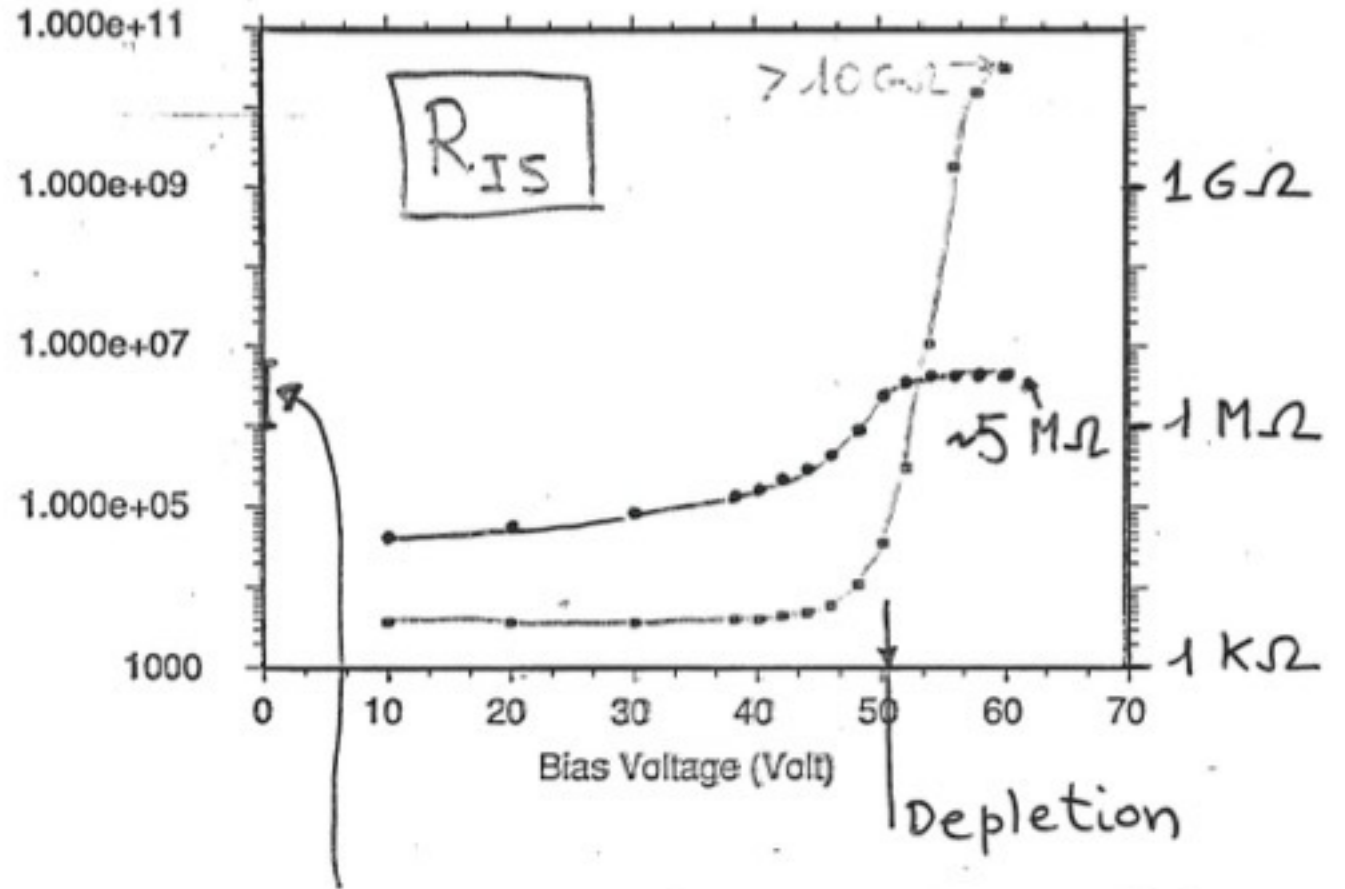


Funziona !

Bassa corrente



- $R_{s_gr} (\Omega)$ Resistance to G. R.
- $R_{s_s} (\Omega)$ Resistance to next strip

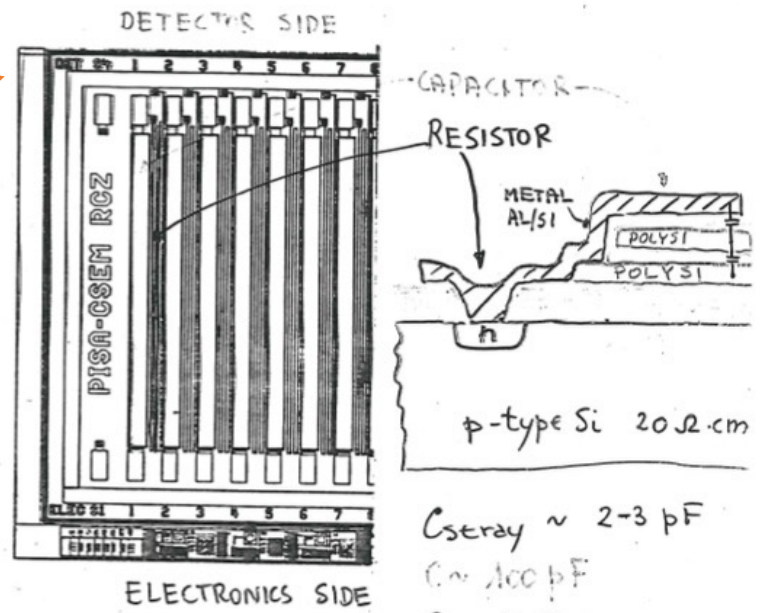
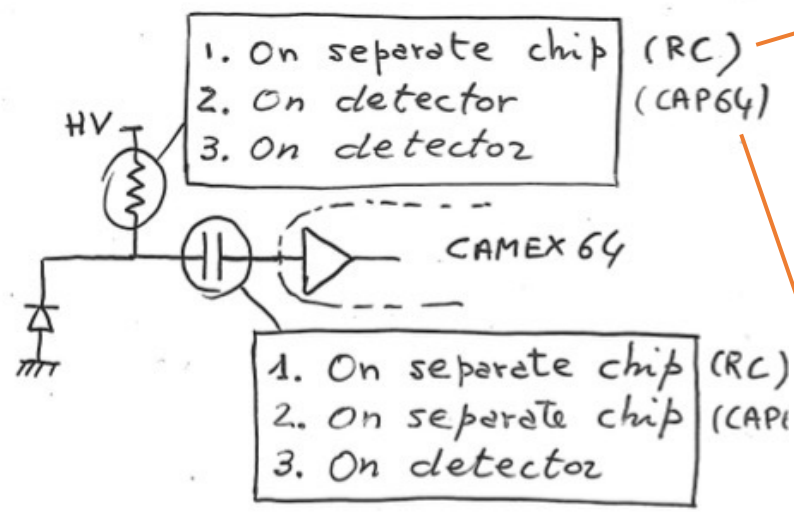


Accepted : $1 M\Omega < R < 6 M\Omega$

Isolamento delle strip lato ohmico

Detectors design summary

R-C

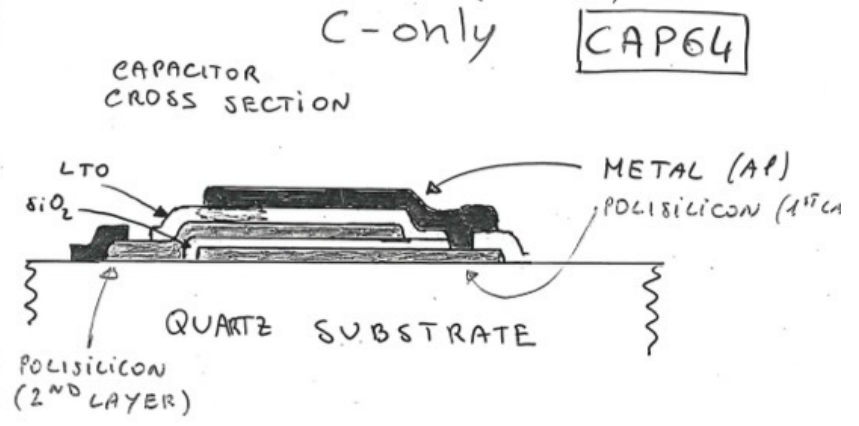


- 1. Pisa old fashioned } Processed at CSEM, C
- 2. Pisa latest }

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

	1.	2.	3.
- 2x μbonds	- 2x μbonds	+ Less μbonds	
- 50-50 bias	+ Good bias	+ Good bias	
+ Good yield	+ Good yield	- yield problem	
+ Passive R	- accumul. layer	- accumulation lay	
pitch j	100	100	100 μm
pitch Ω	200	100	100 μm

historical reasons



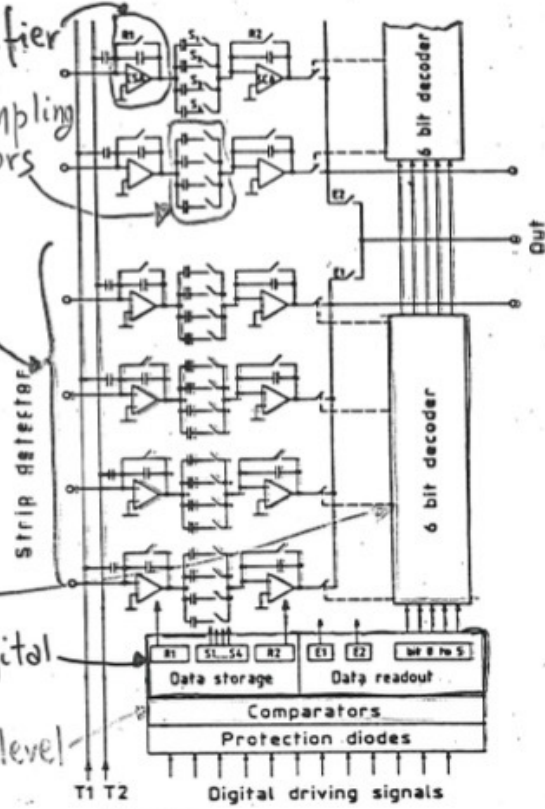
CAPACITOR VALUE	210 pF
STRAY CAPACITANCE	0.3 pF
PARASITIC RESISTANCE	> 10 GΩ
VOLTAGE TOLERANCE	≥ 80 V

Varie soluzioni e competizione



LAMEX 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 \rightarrow low level signals possible



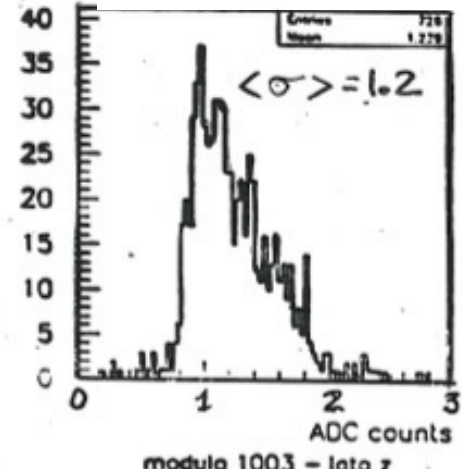
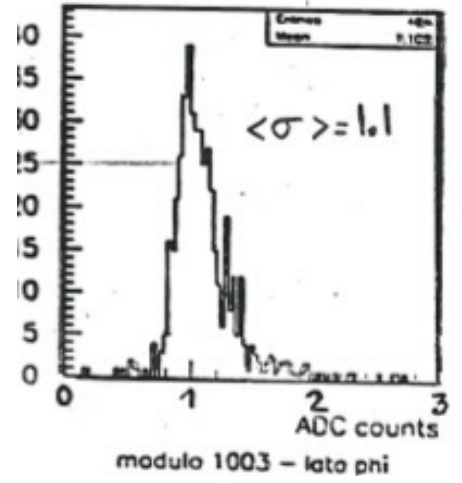
Complete chip

- Gain : 15 mV/FC
- Power : adjustable, switchable \lesssim 2 mW/channel
- Noise : $\text{ENC} = 335 e^- + 30 e^-/\text{pF} \cdot C_{\text{IN}}$
- Radiation damage
- Unpowered : @ 200 kRad S/N \rightarrow 1/2
- Powered : @ 18 kRad Noise increase

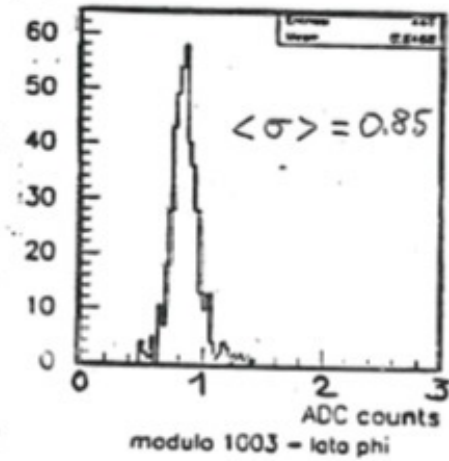
Signal to noise ratio

junction side S/N = 12:1
ohmic side S/N = 11:1

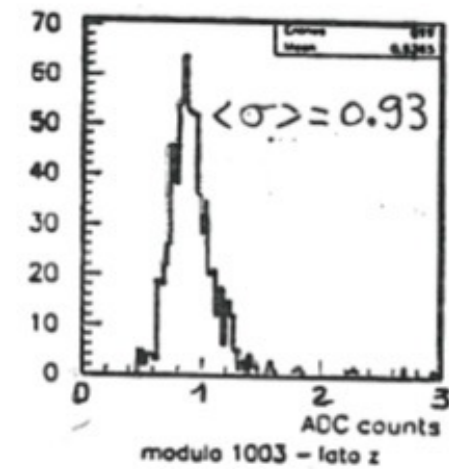
'Nature'



Common mode



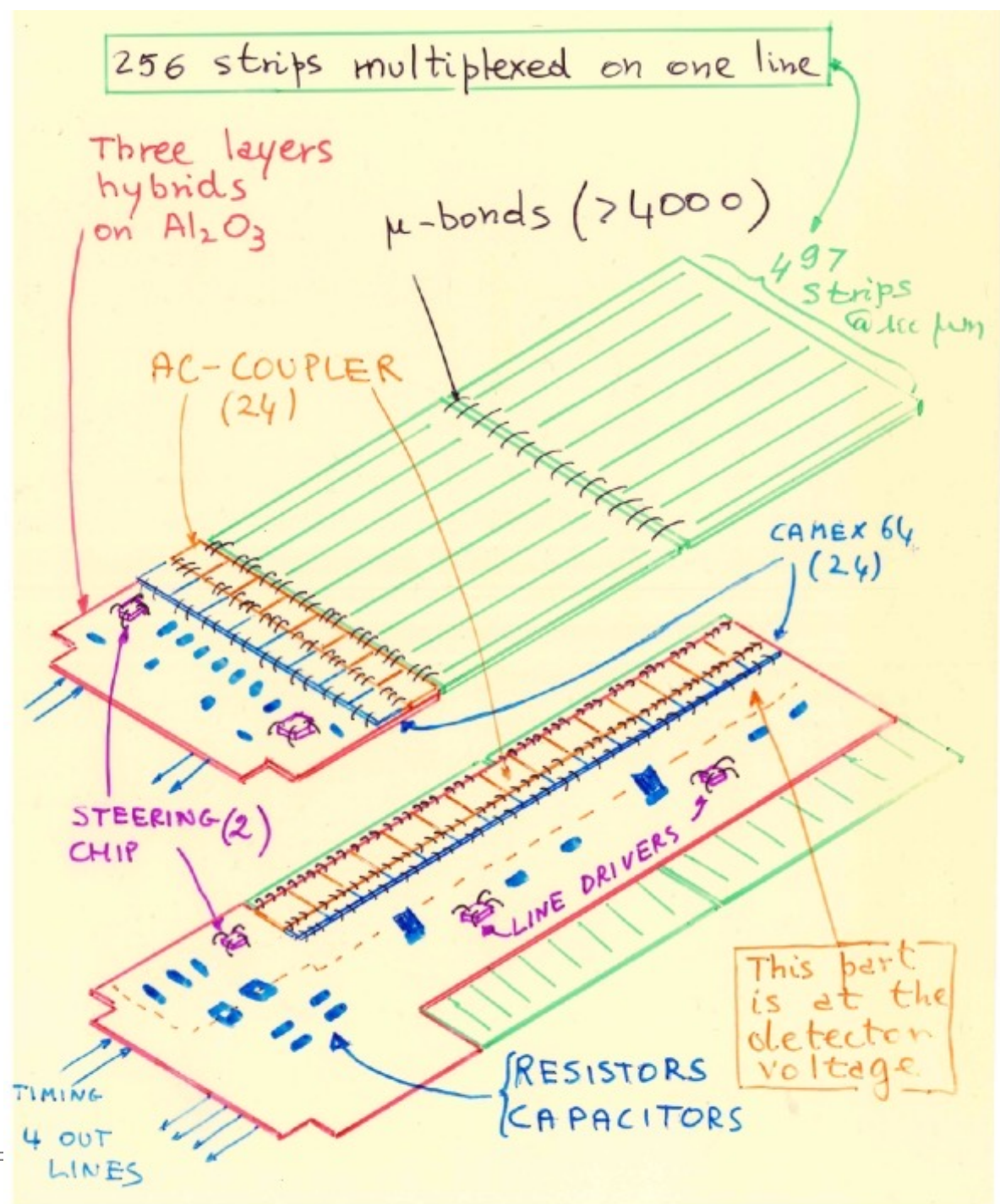
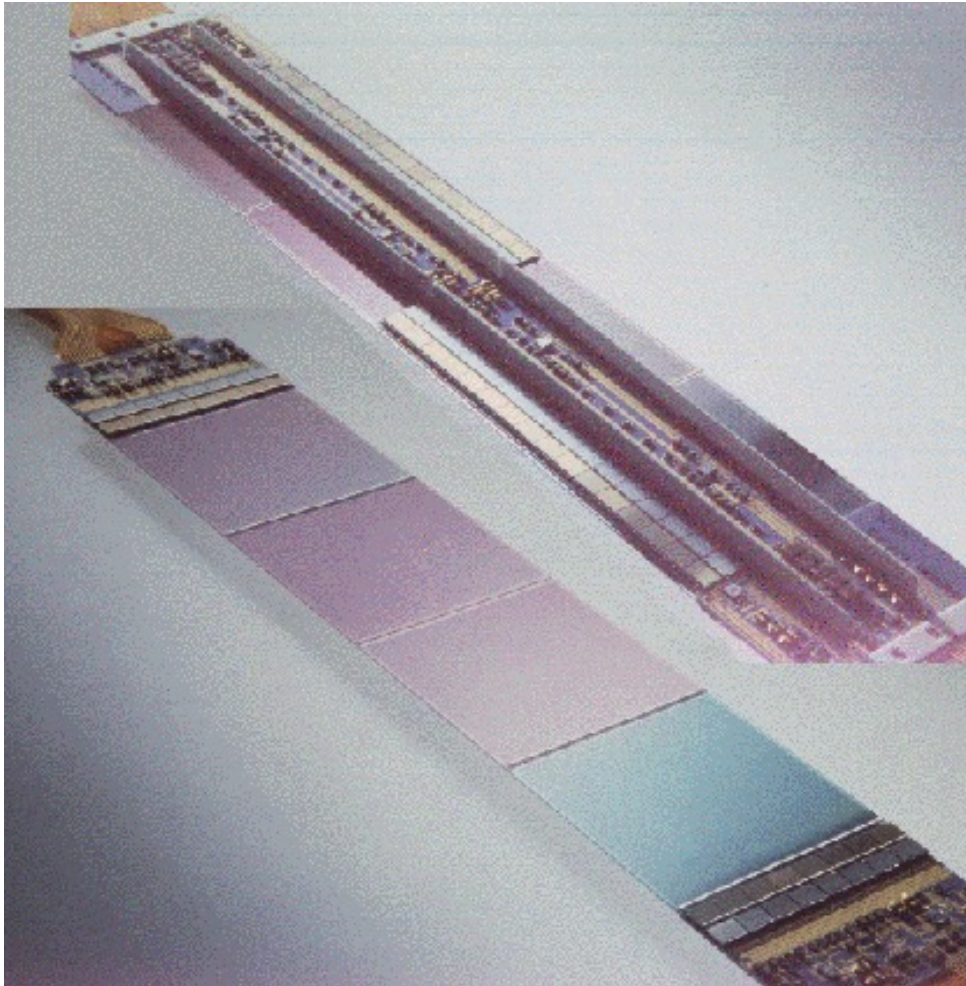
subtracted



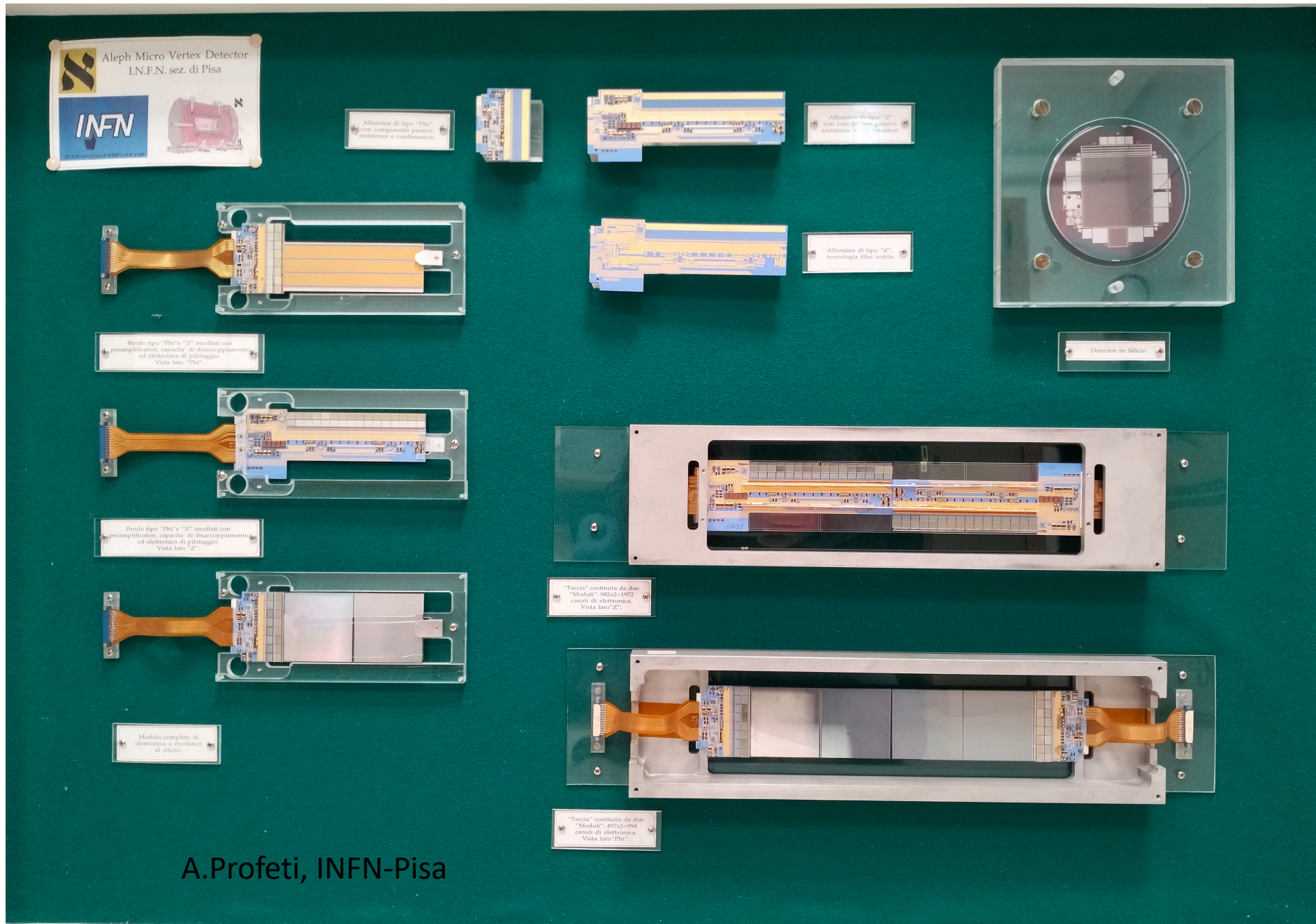
Elettronica di lettura



Module layout



Assemblaggio complesso

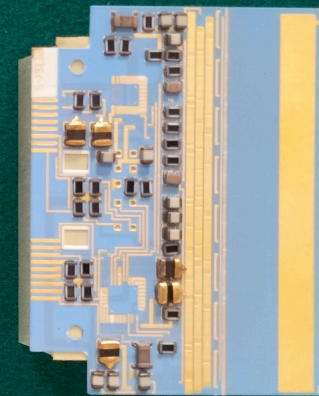


A.Profeti, INFN-Pisa

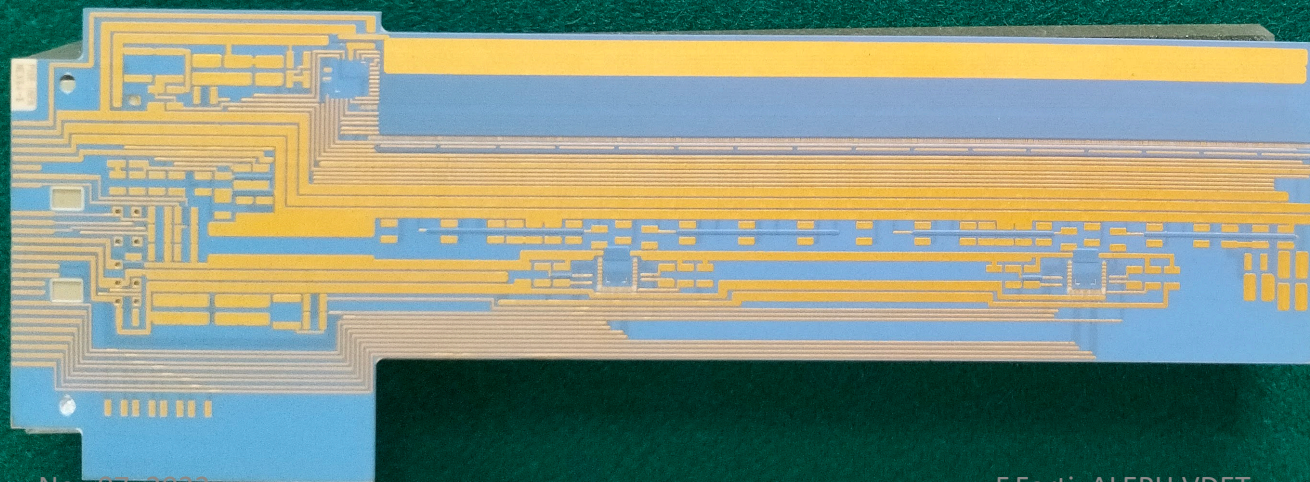


Allumina di tipo "Z"
con componenti passivi:
resistenze e condensatori.

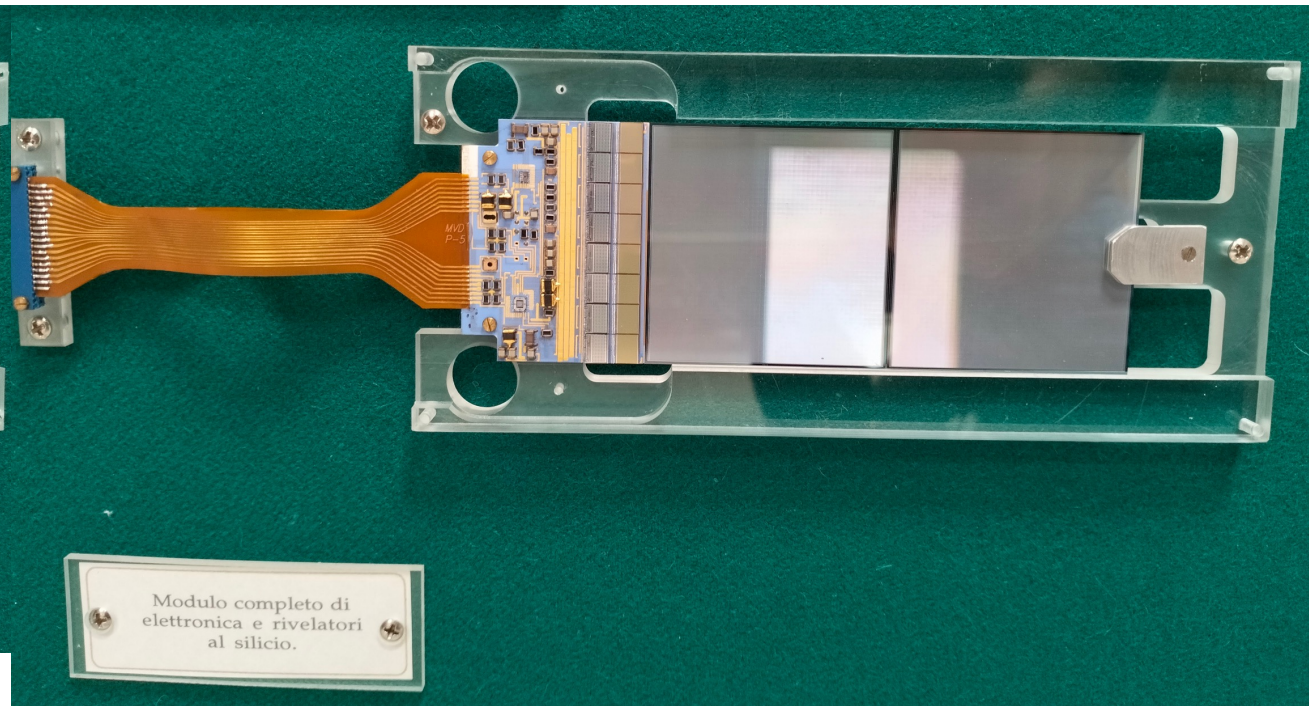
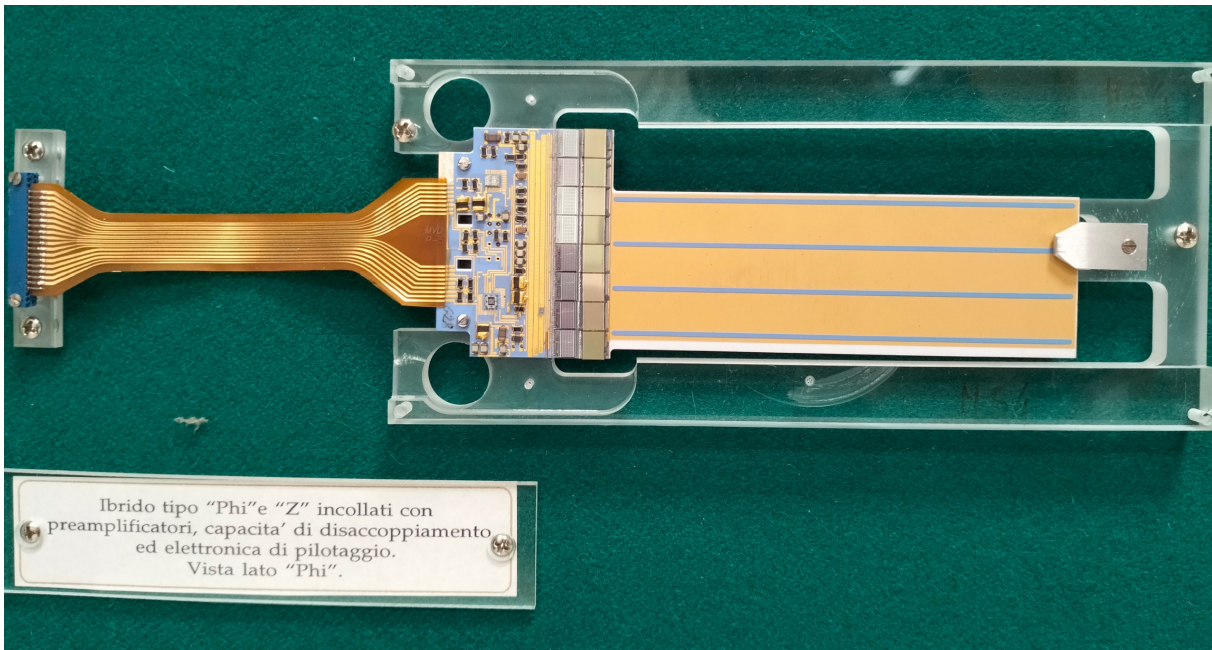
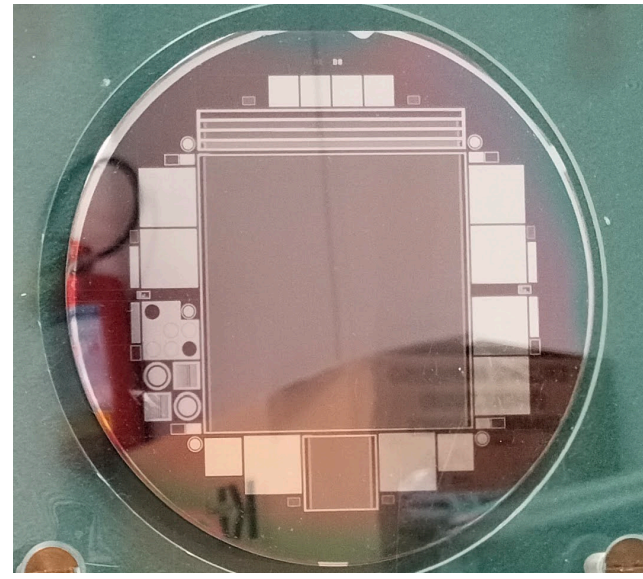
Allumina di tipo "Phi"
con componenti passivi:
resistenze e condensatori.



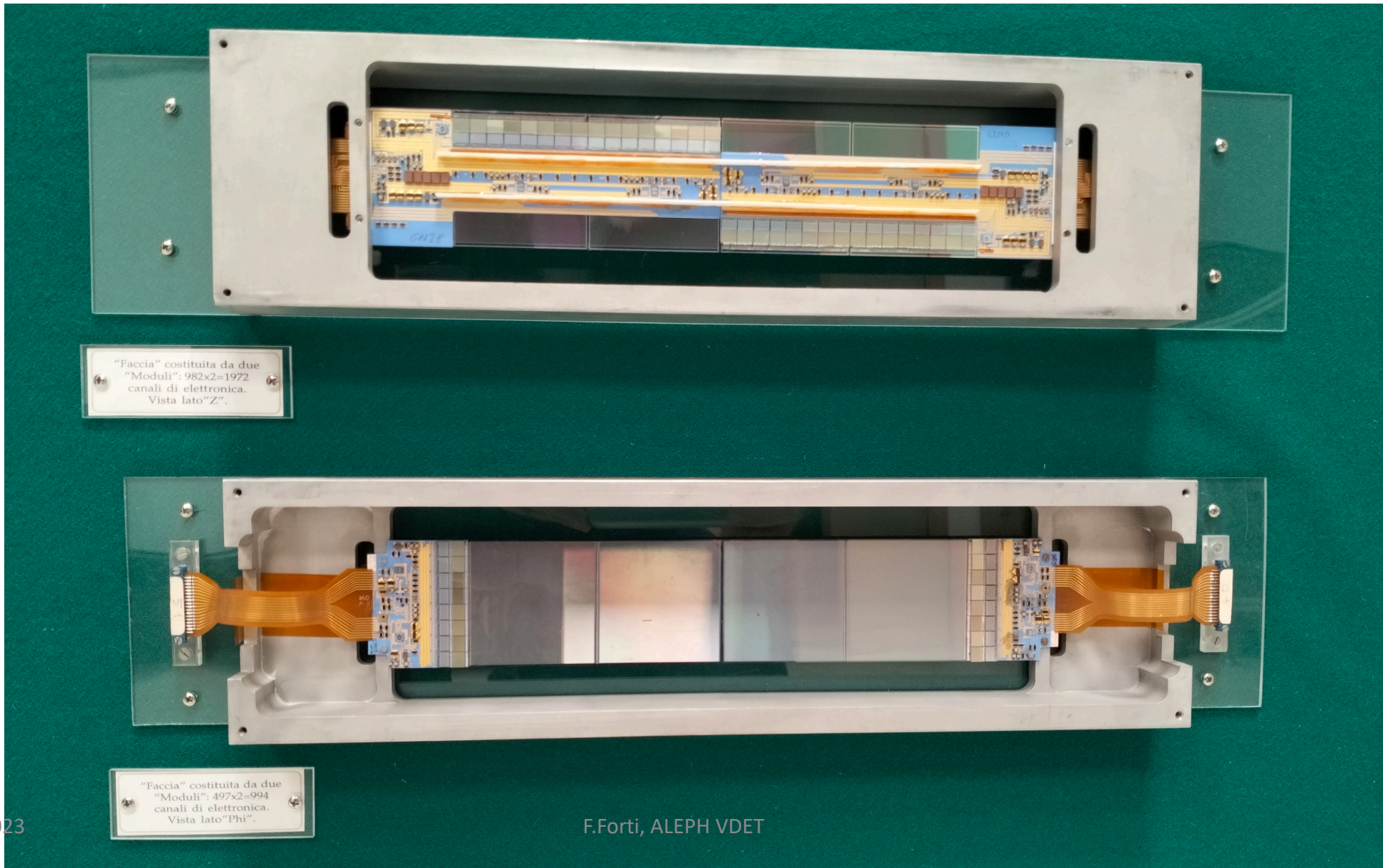
Allumina di tipo "Z",
tecnologia film sottile.



Mezzo modulo



Modulo completo



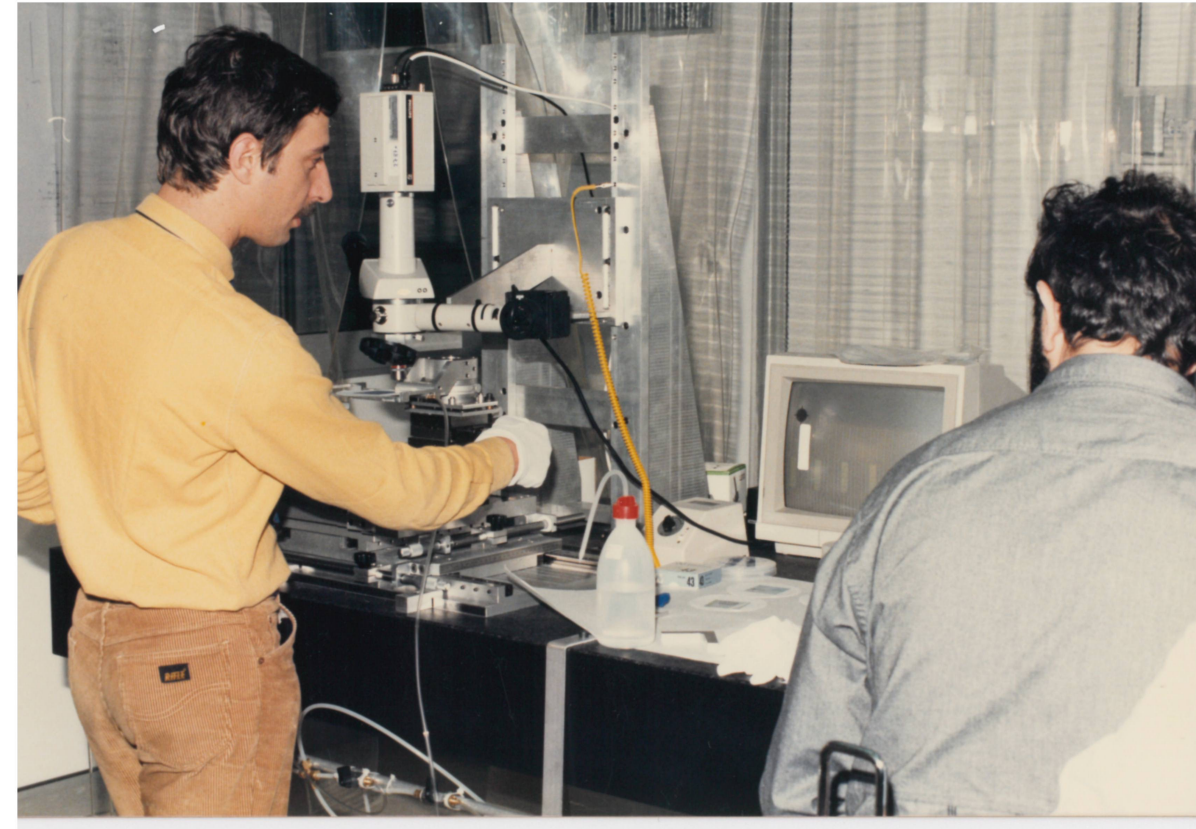
"Faccia" costituita da due "Moduli": 982x2=1972 canali di elettronica. Vista lato "Z".

"Faccia" costituita da due "Moduli": 497x2=994 canali di elettronica. Vista lato "Phi".

Incollaggi e allineamenti



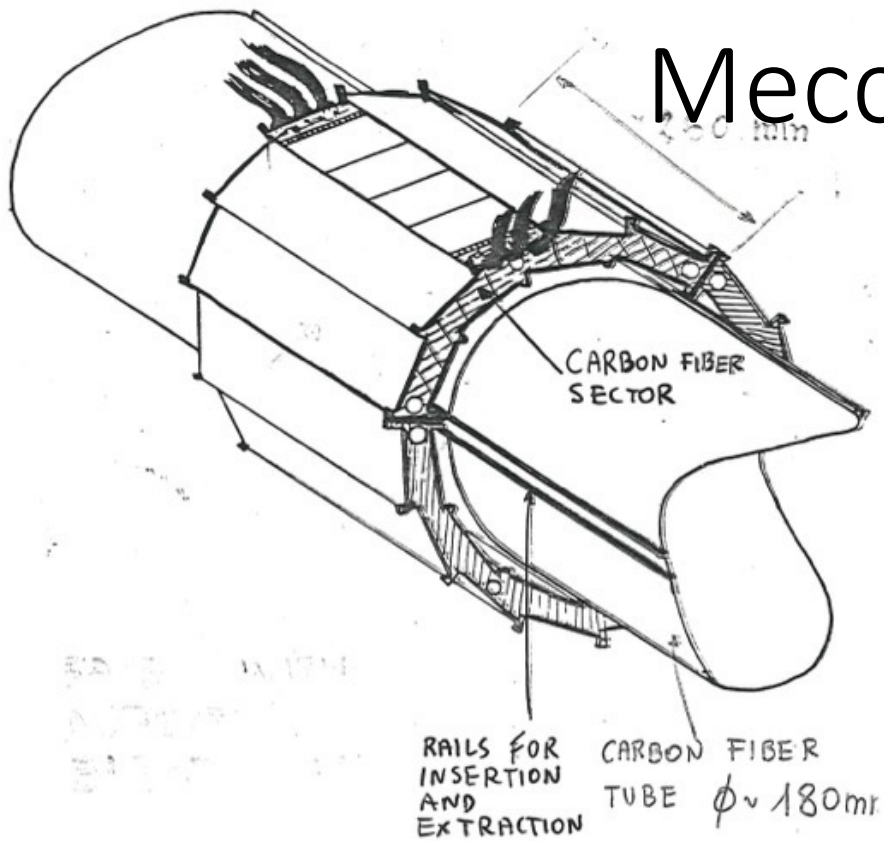
G.Tonelli



G.Batignani

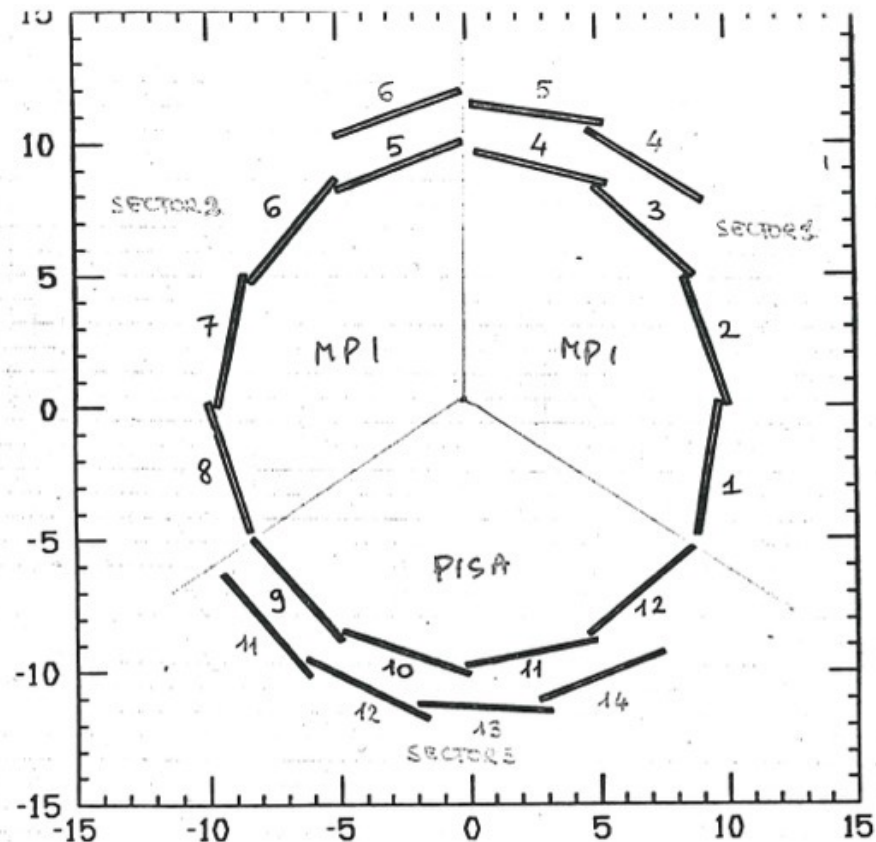
G.Tonelli

OVERALL VIEW



Meccanica

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



THE WHOLE INNER LAYER : 12 FACES $\langle r \rangle \sim 9.1$
 $\sim 1/2$ OUTER LAYER : 7 FACES $\langle r \rangle \sim 11$

 19 FACES

EACH FACE : 2 MODULES x 2 DETECTORS/MODULE =
 76 SILICON DETECTORS
 ($5 \times 5 \text{ cm}^2$)

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

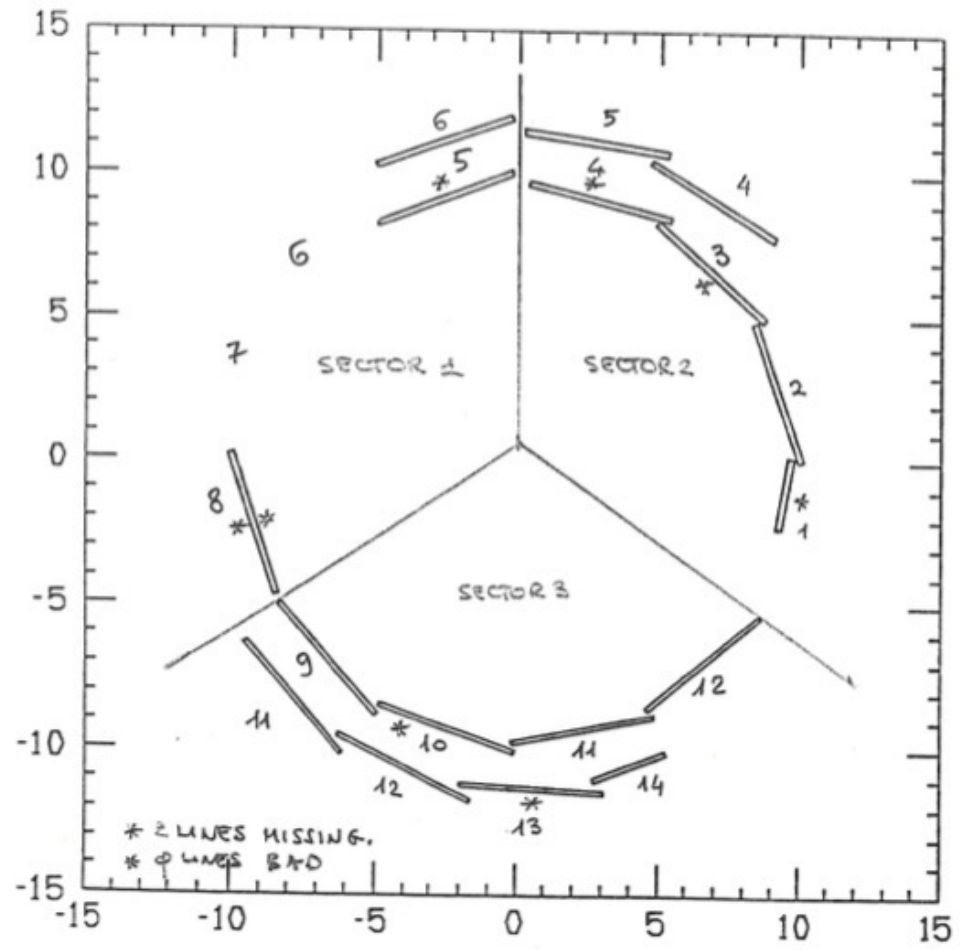


	1986	1987												1988				
	O N D	F	M	A	M	J	J	A	S	O	N	D	F	M	A	M	J	
MECHANICAL PROTOTYPE TEST AND INNER DET. TRIAL ASSEMBLY	■																	
FULL SIZE PROTOTYPE DET. MASKS		■																
FULL SIZE PROTOTYPE DET.			■															
NEW ELECTRONIC CHIP PROD.			■															
NEW CHIP TEST				■														
DETECTORS + ELECTRONICS TEST IN LAB.					■													
BEAM TESTS						■												
DETECTORS + ELECTRONICS FINAL MASKS							■											
ELECTRONICS PROD.								■										
DETECTORS PRODUCT. AND TEST									■									
FINAL ASSEMBLY										■								
MECHANICS											■							

Initial schedule a bit optimistic

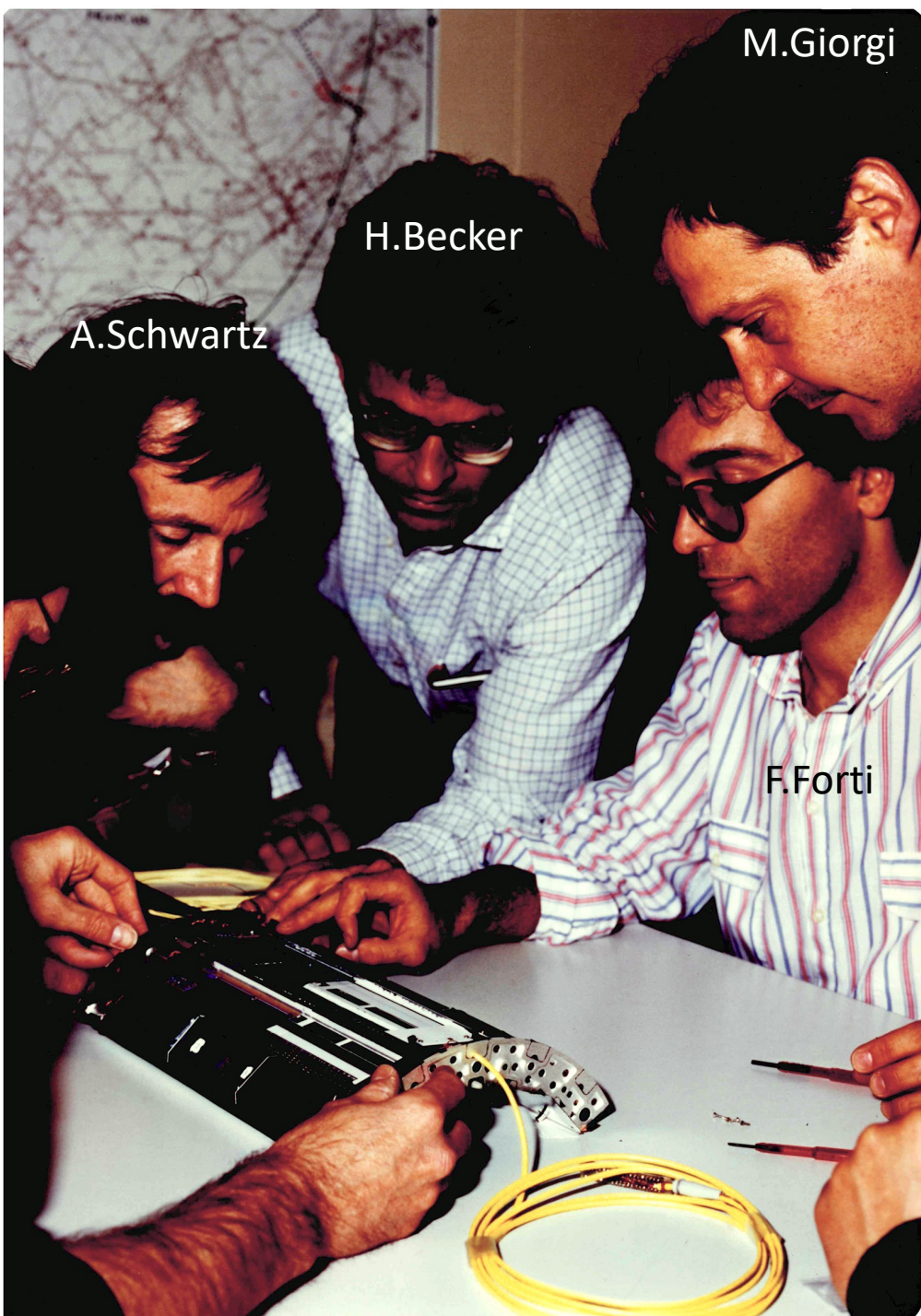
1990

VDET STATUS (June 1990)

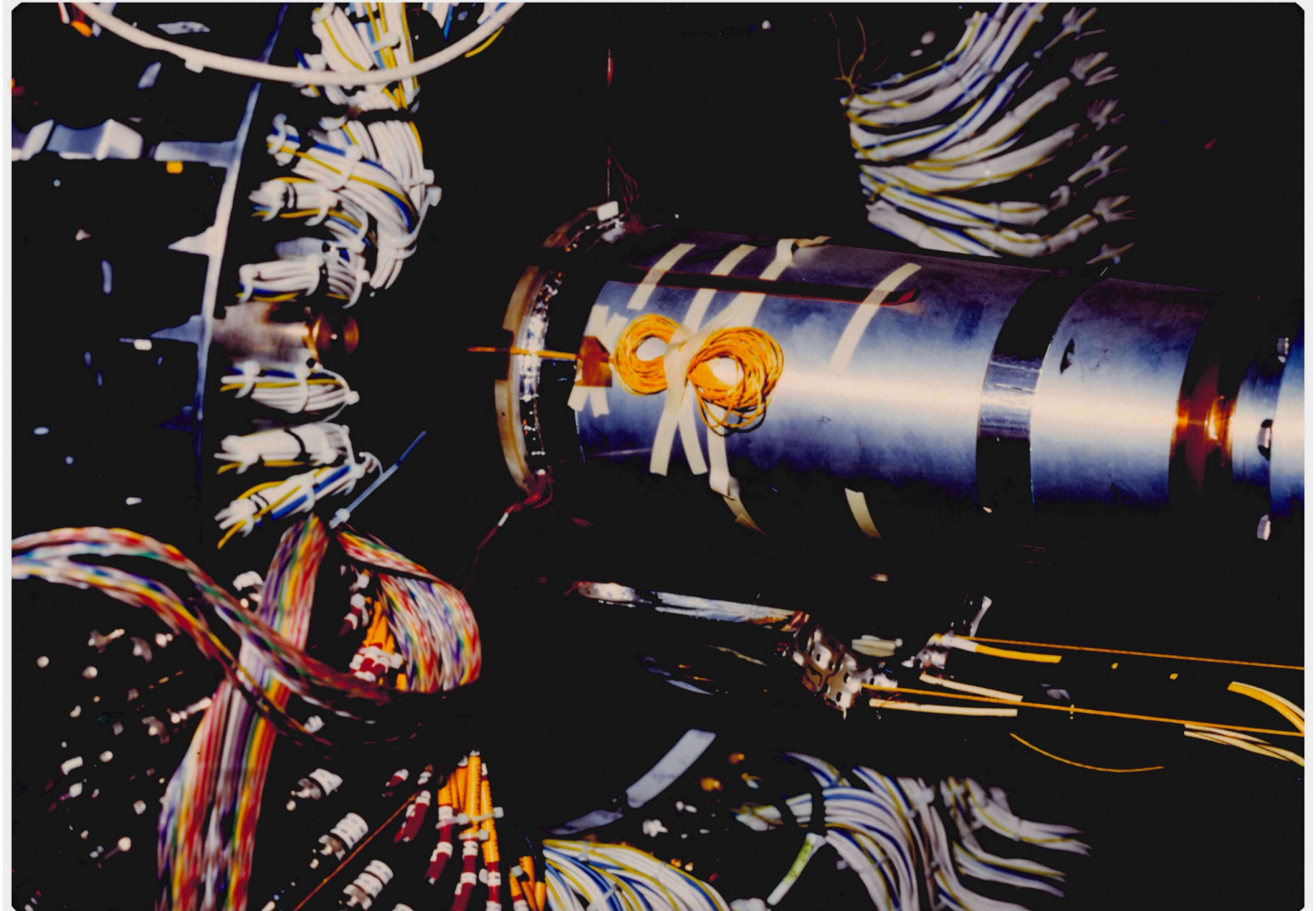


66 TPD LINES OFF/VETOED ~ 28% OF ALL READ-OUT LINES
 $\leq \frac{1}{5}$ ϕ COVERAGE OFF.





Installazione



F.Forti, ALEPH VDET

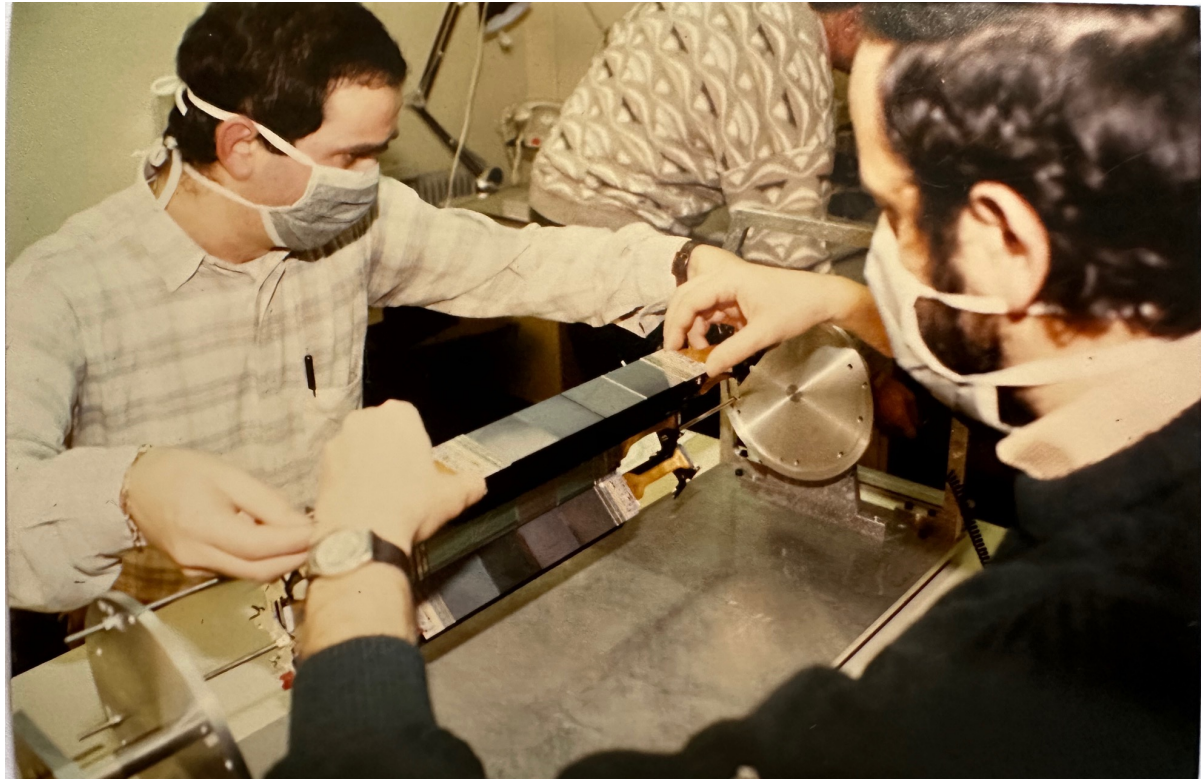


VDET 1991

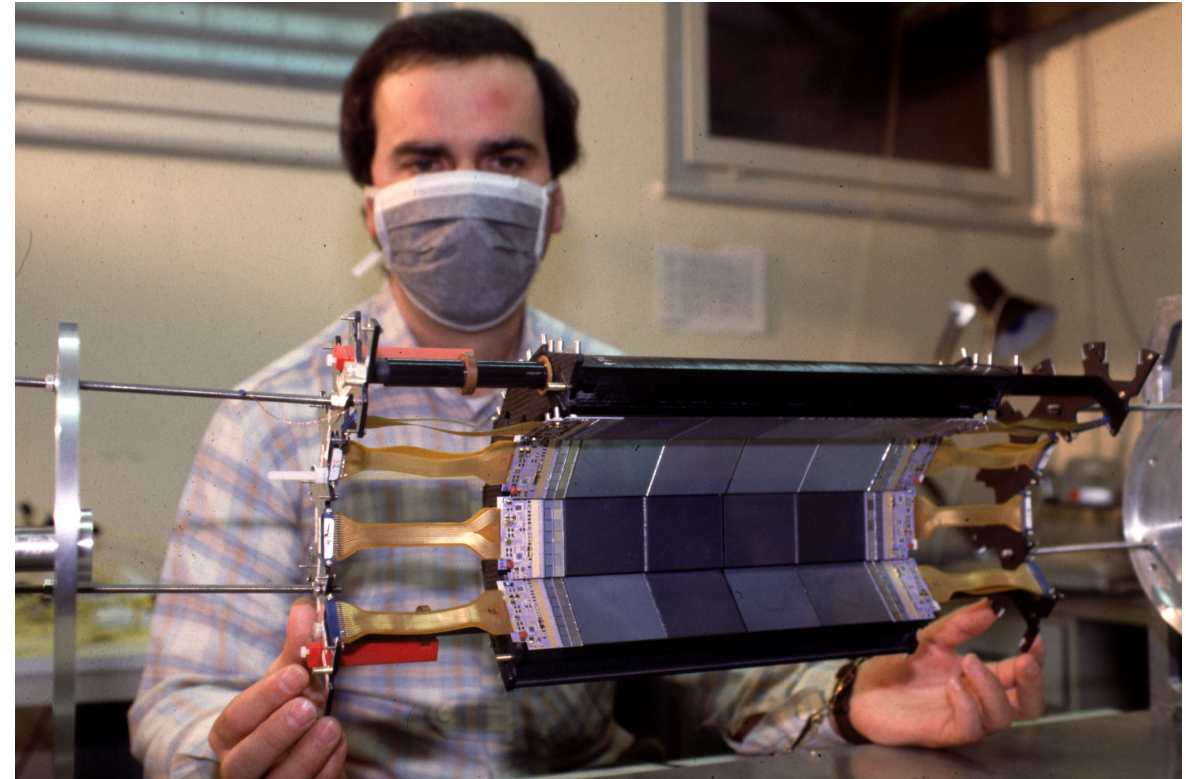
Better mechanics. Complete coverage

E.Focardi

G.Tonelli

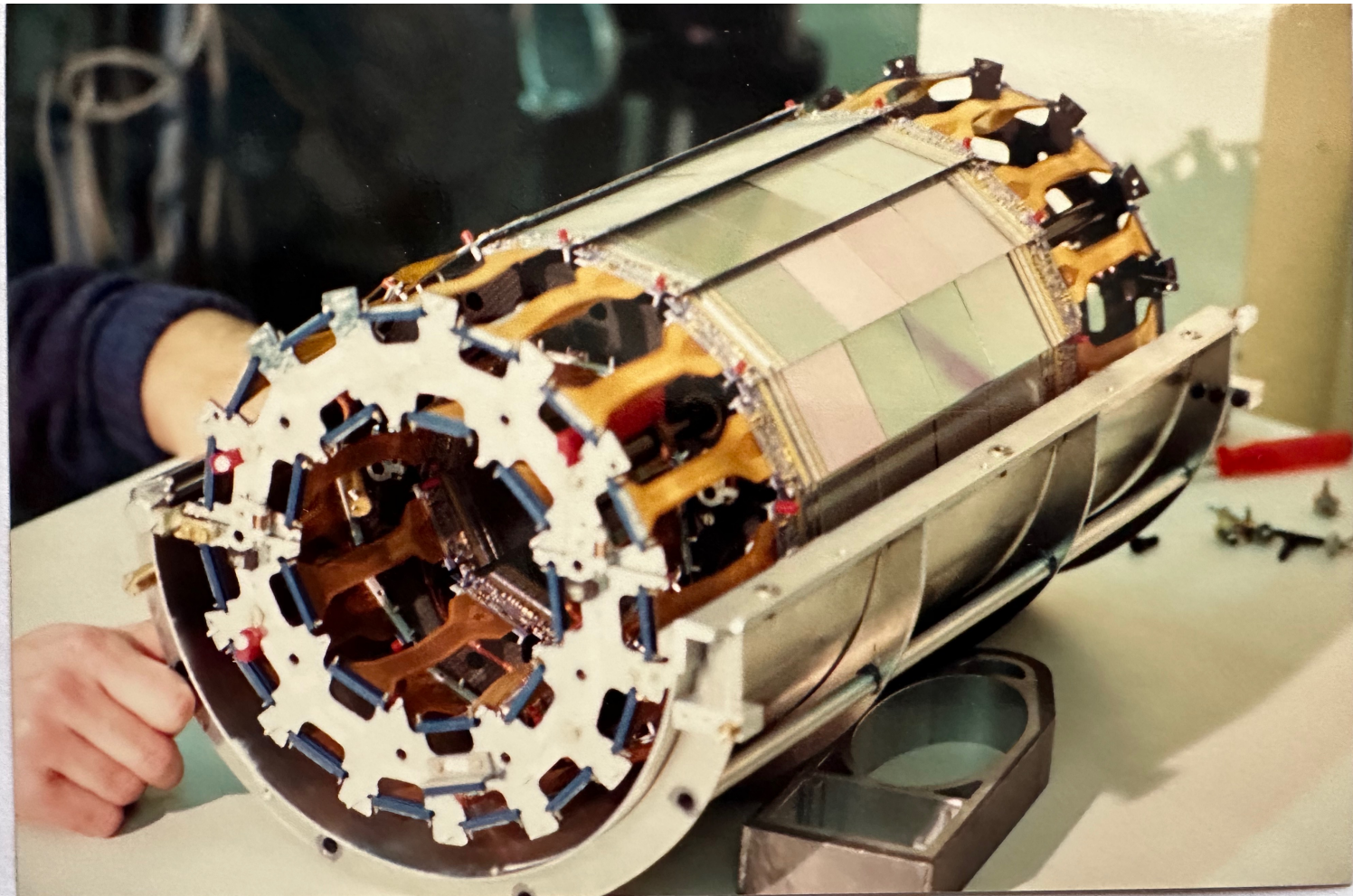


E.Focardi



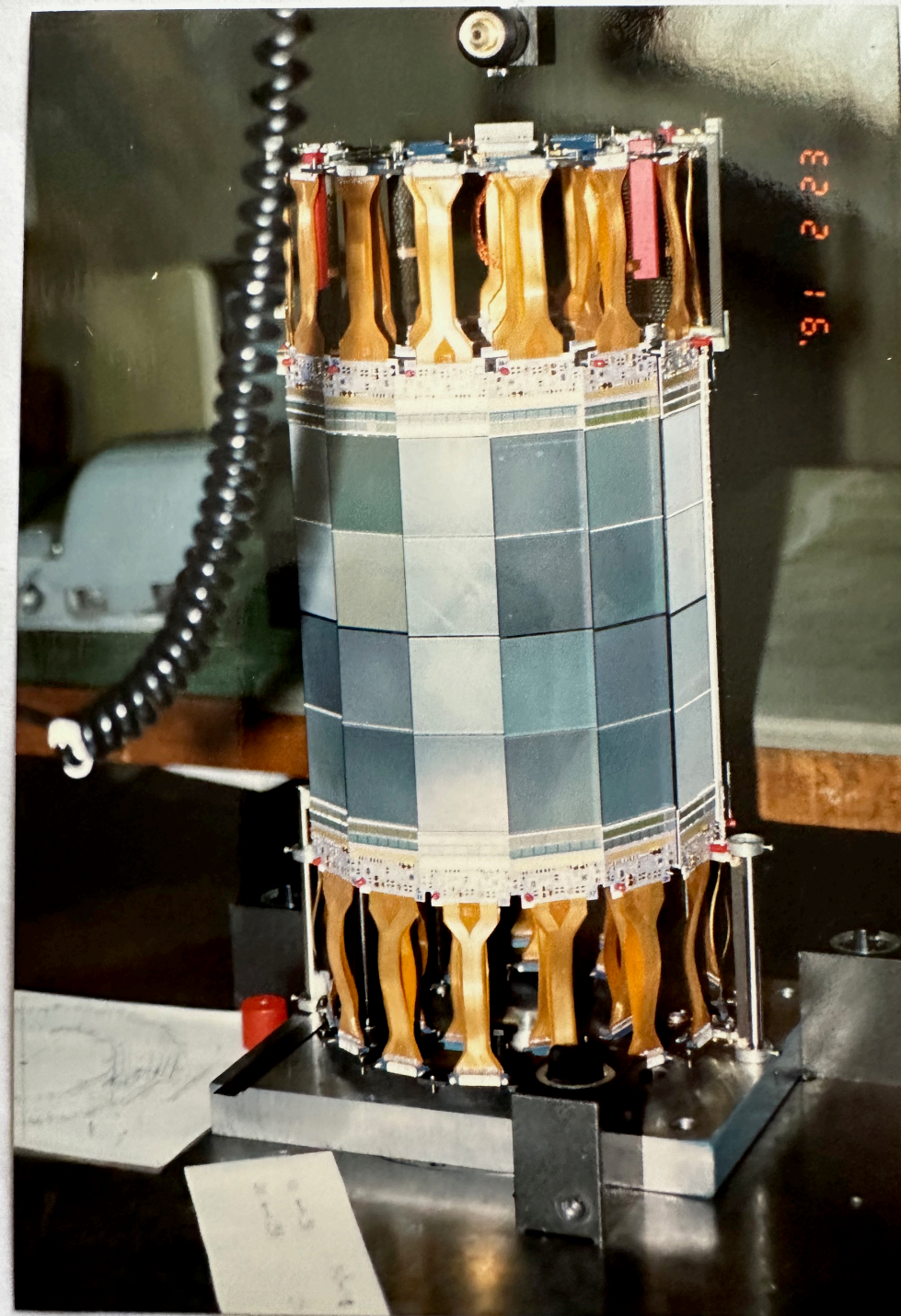
More collaboration, less competition

Completed



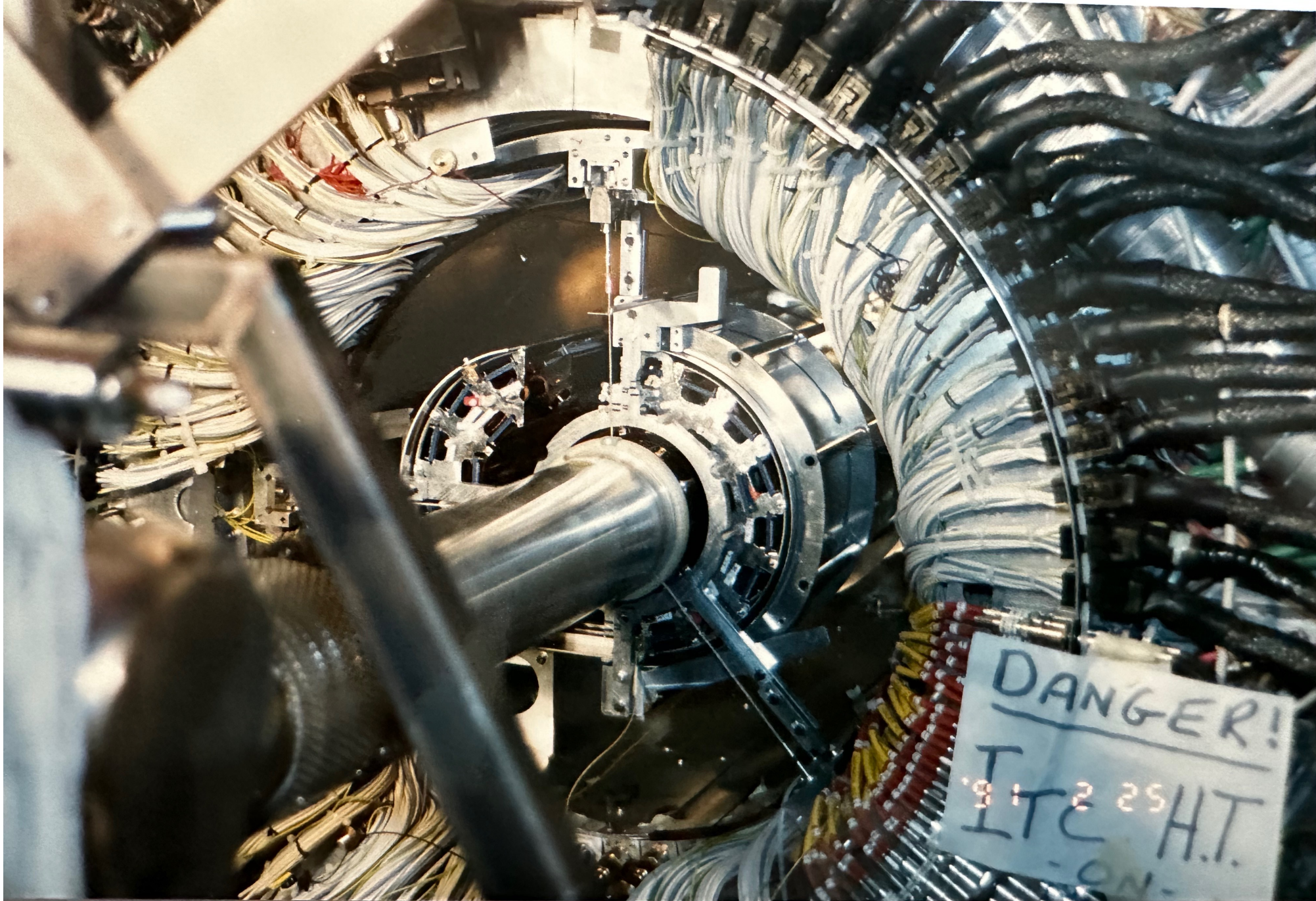
NOV 07, 2025

F.FORU, ALFFH VDET



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

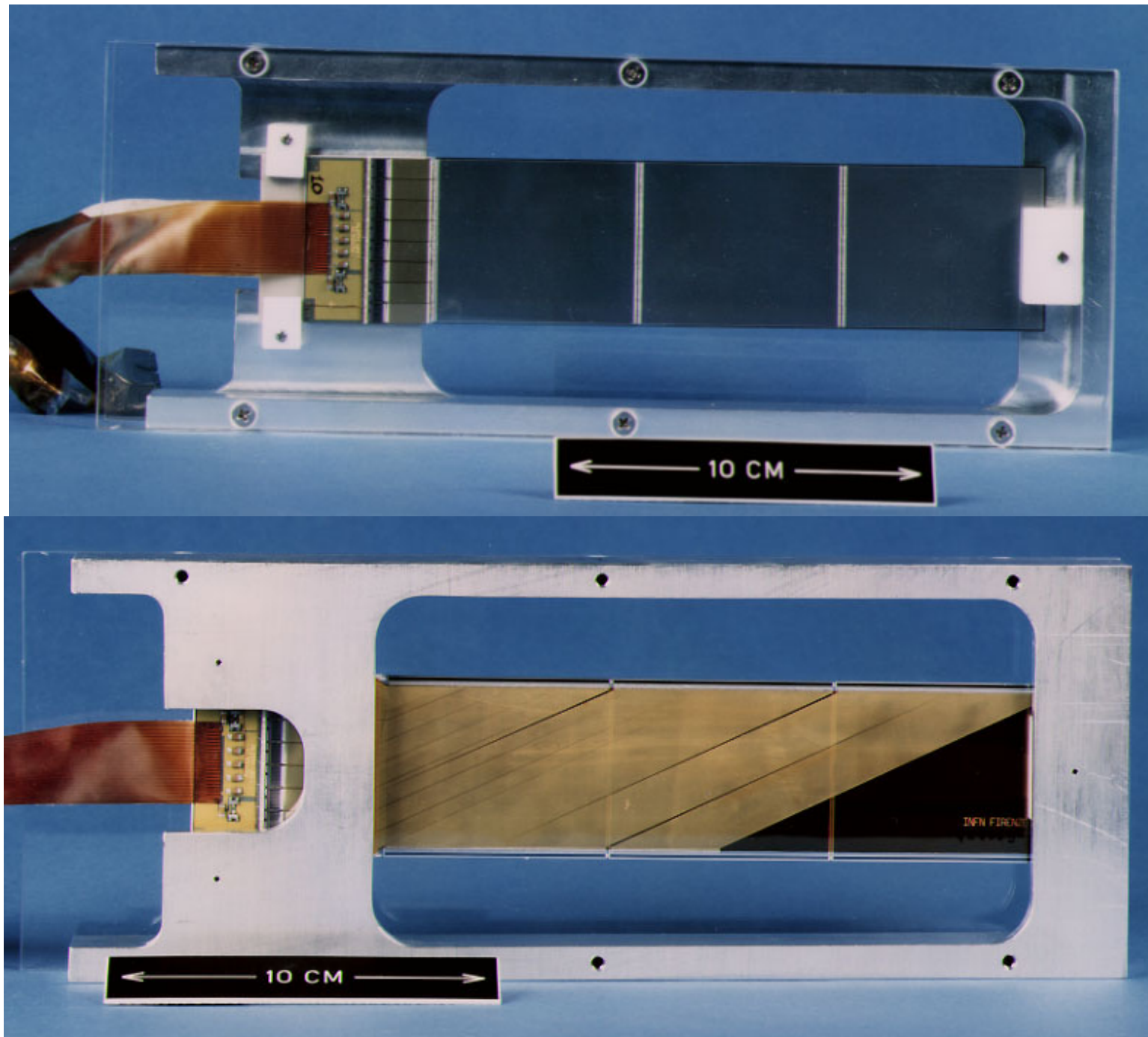


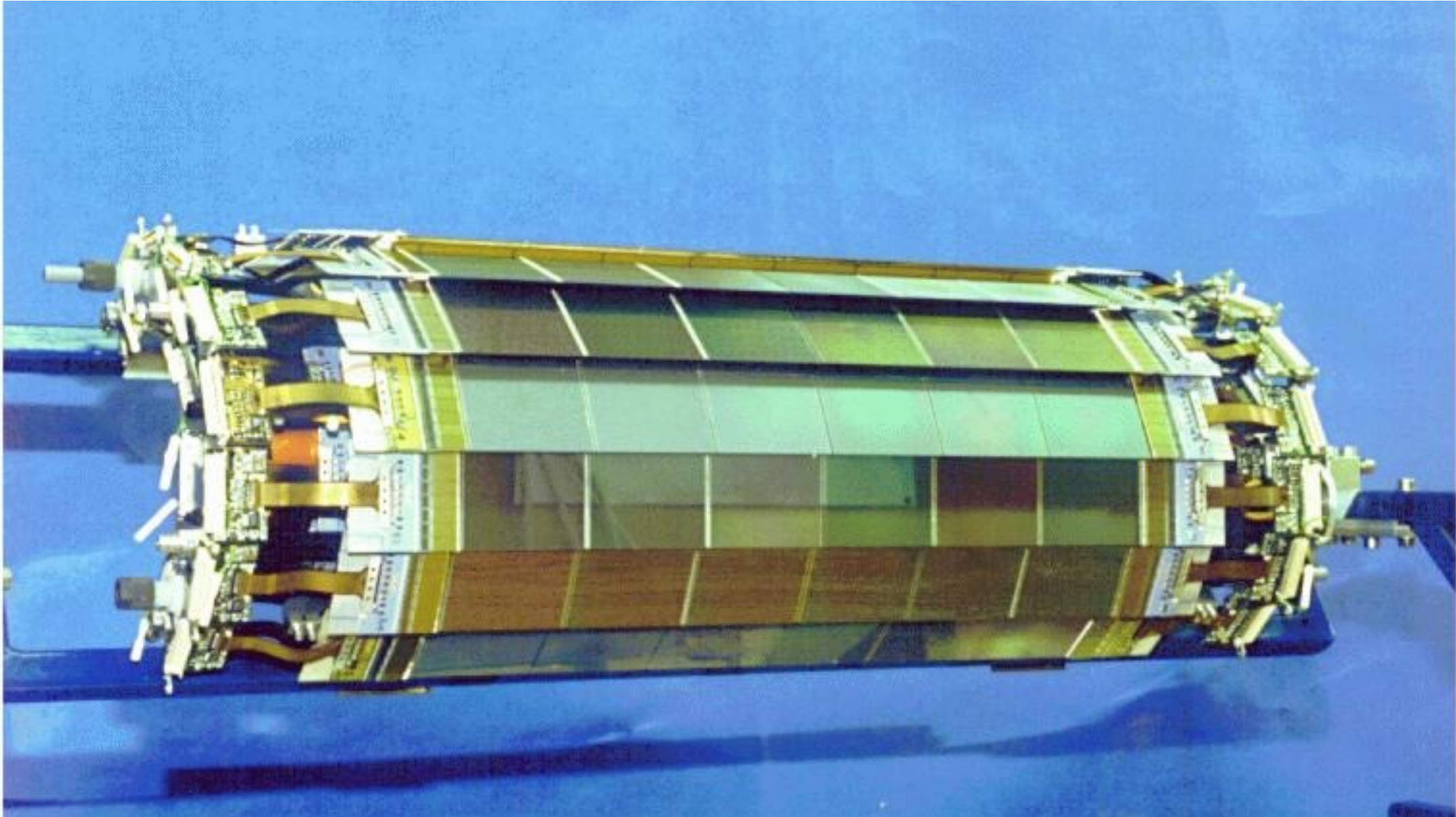


DANGER!
ITC 225 H.T.
-ON-

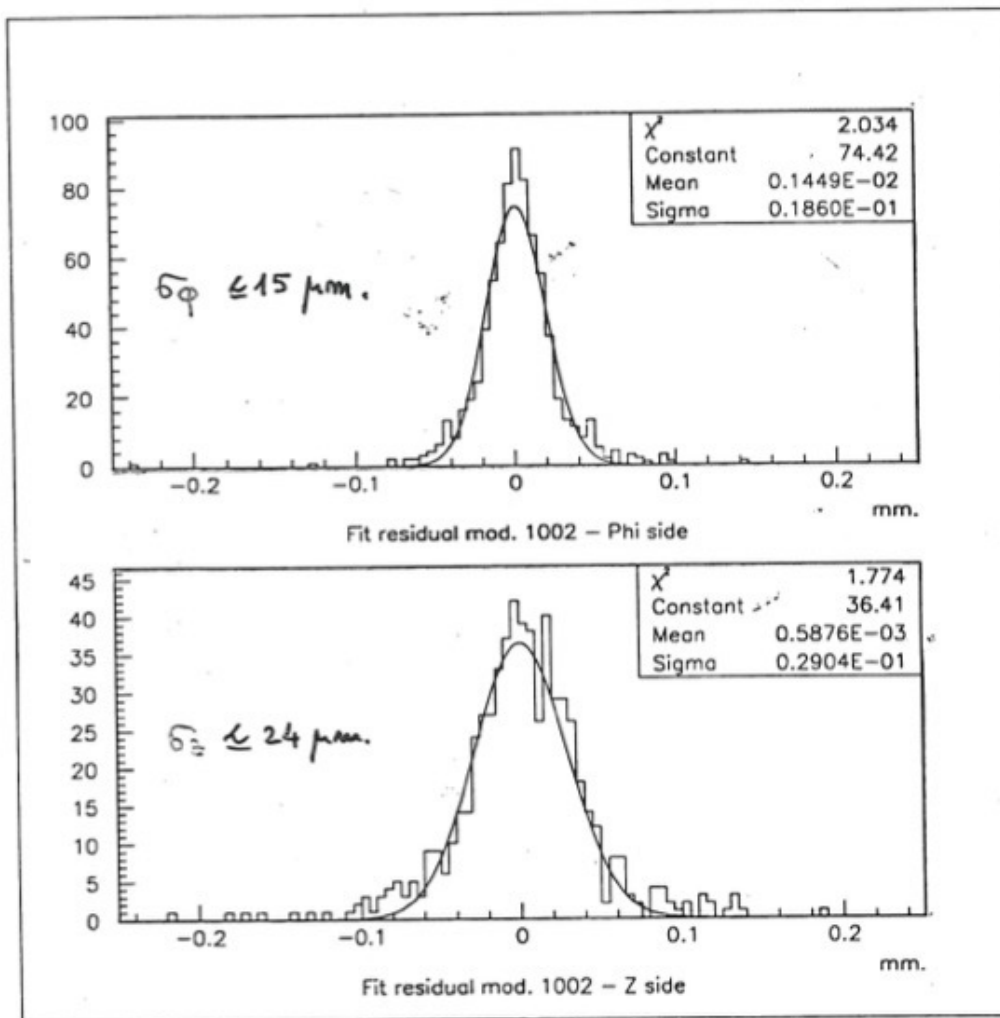
VDET200 (1995)

- 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.

IMPACT PARAMETER RESOLUTION
 r- ϕ PLANE FOR $p > p_0$

FWHM
 [mm]

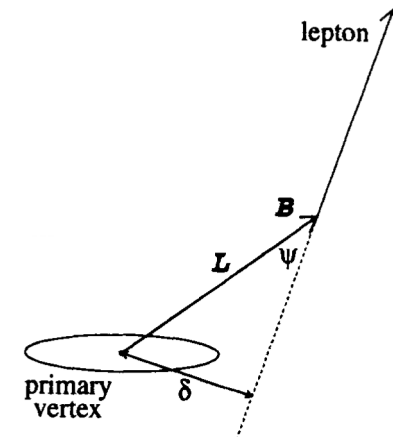
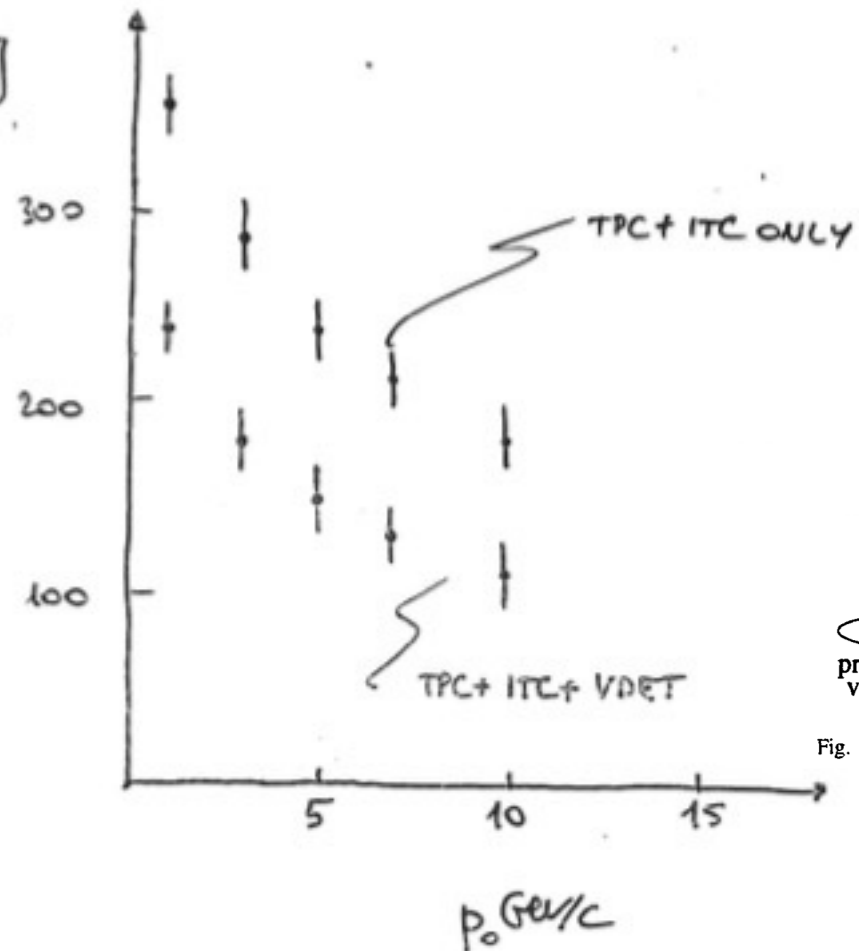
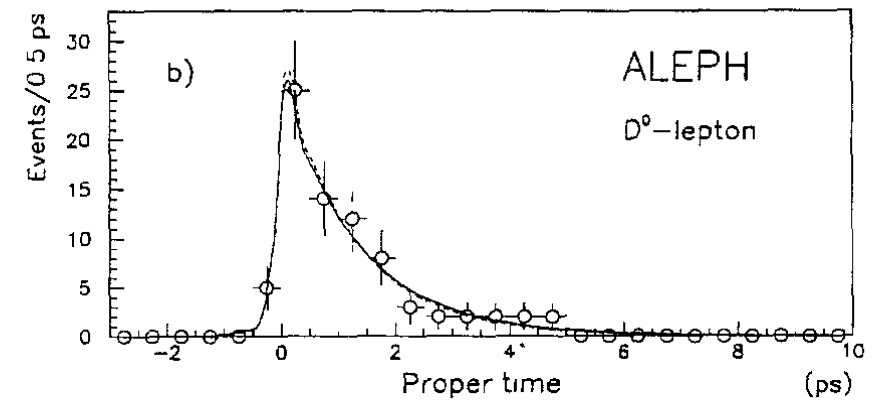
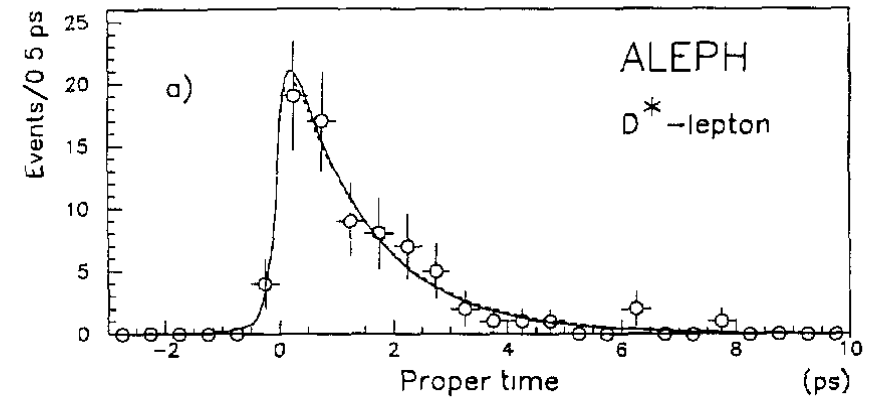
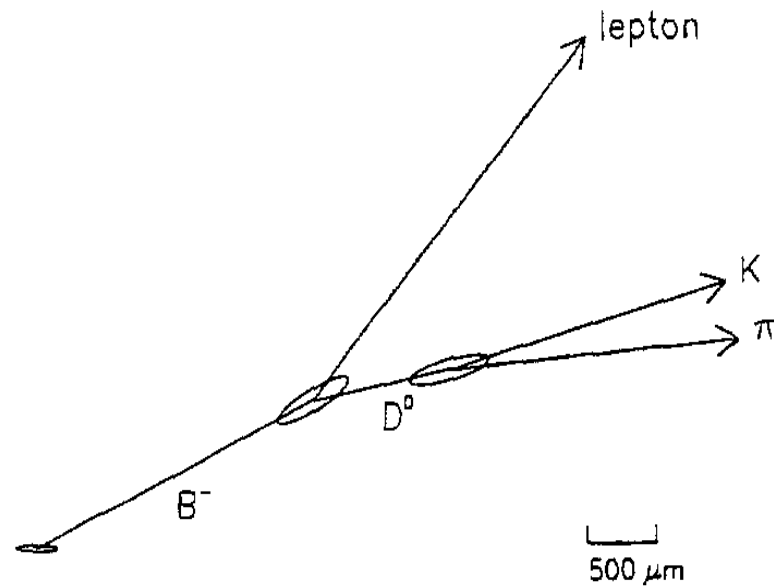
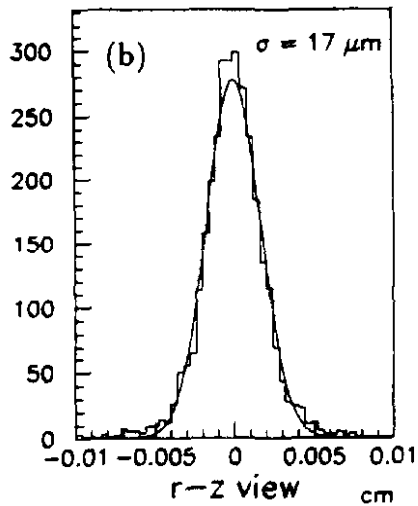
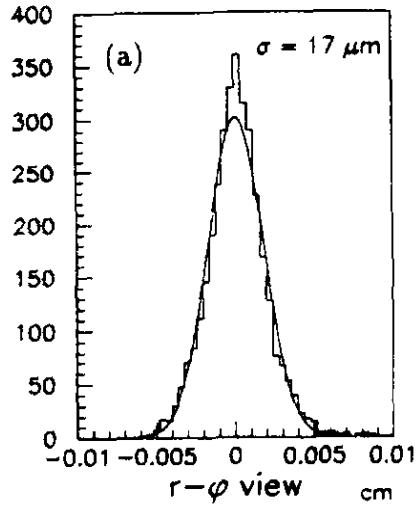


Fig. 1. Definition of the impact parameter.



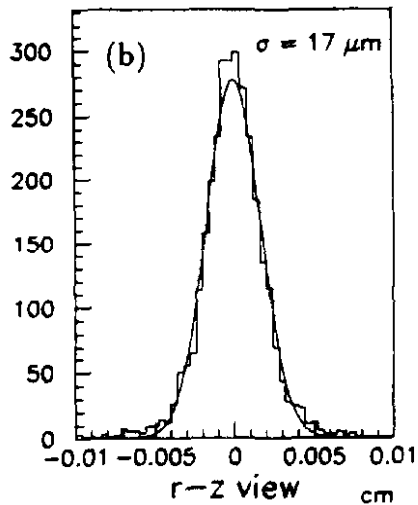
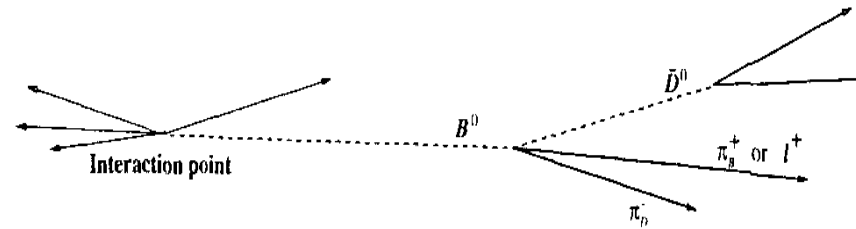
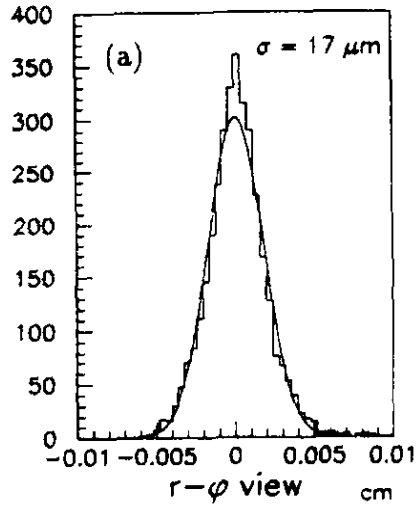
Example of measurement: B hadron lifetime

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

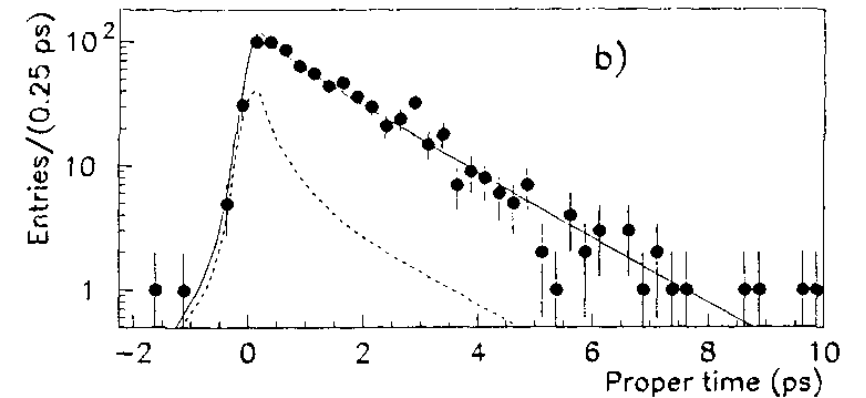
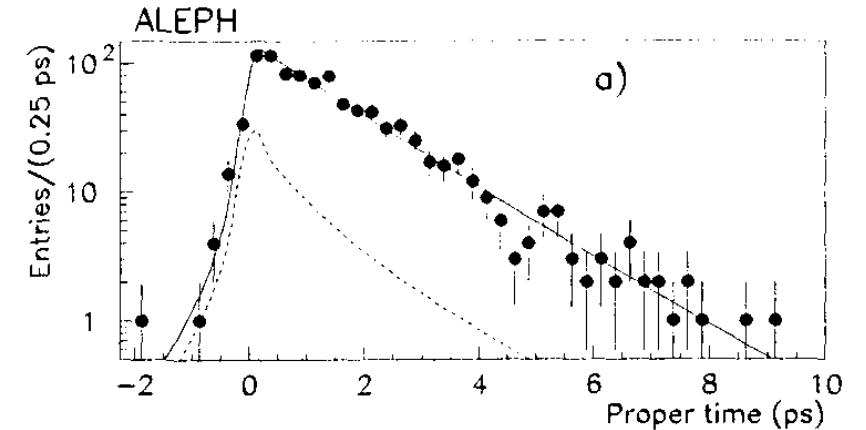


Example of measurement: B hadron lifetime

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



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



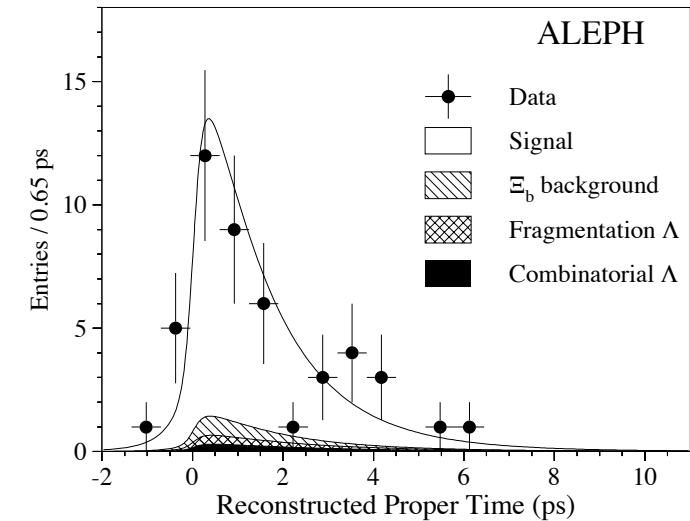
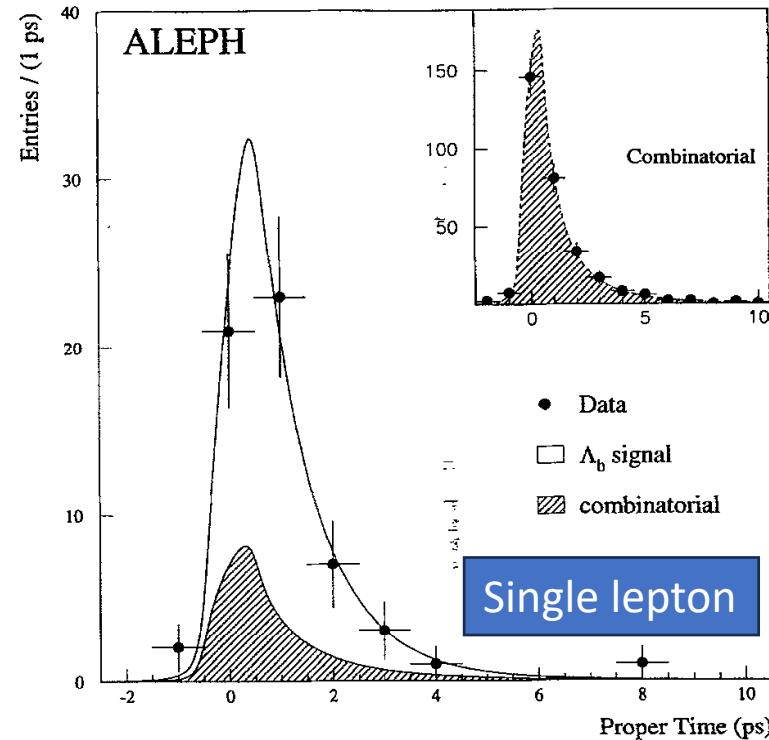
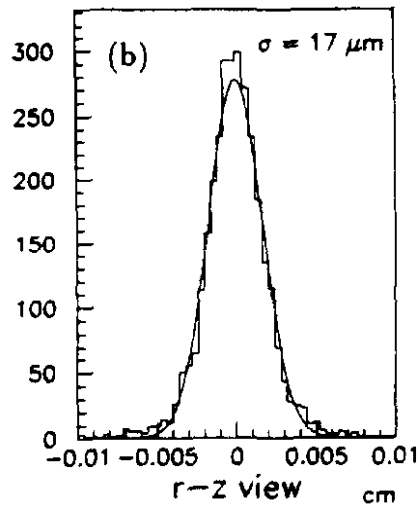
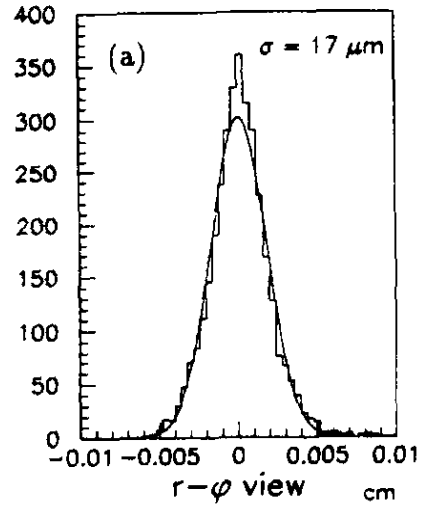
Example of measurement: b baryon lifetime

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

$$\Lambda_b \longrightarrow \Lambda_c^+ \ell_1^- \bar{\nu} X$$

$$\longmapsto \Lambda \ell_2^+ \nu X$$

Double lepton $\longmapsto p\pi^-$



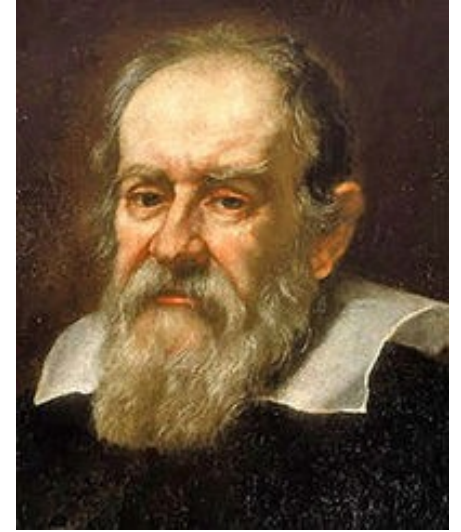
Point resolution in the two detector views

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

Measurements and discoveries

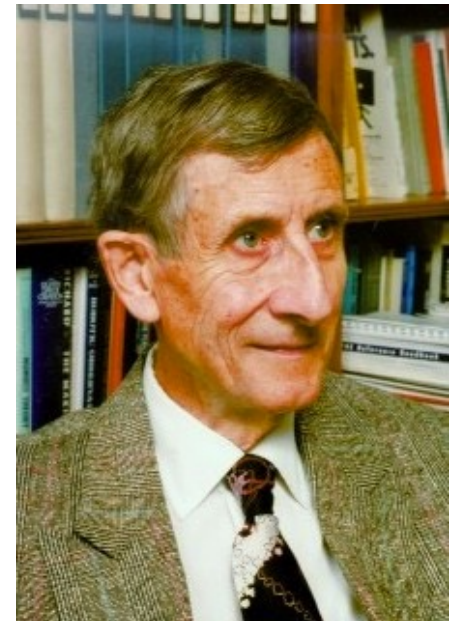
Galileo Galilei

- 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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F.Forti, G.Batignani



ALEPH VDET: one of the first vertex detectors

