

# The APE Experience

Nicola Cabibbo

Università di Roma "La Sapienza"  
INFN — Sezione di Roma

apeNEXT: Computational Challenges  
and First Physics Results



# Birth and early growth of LQCD

- K. Wilson 1974: Introduces LQCD.
- M. Creutz 1979: C. Rebbi 1980 First Monte-Carlo simulations.
- H. Hamber and G. Parisi 1981, D. Weingarten 1982: Quenched approximation.
- N. C., G. Martinelli, R. Petronzio 1983: Simulation of weak interactions.

The need for computer power!

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In the next Section we outline the method of computation. In
section 3 we describe the numerical results based on 14 link
configurations in a  $10^3 \times 20$  lattice, for which the Wilson quark
propagators were already available /6/. This analysis is
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# Cray vs. Dedicated Supercomputers

The top commercial machine was the Cray:  $\approx 1$  Gflops for  $\approx 20$  G\$. Available in Italy at CINECA ( $\approx 300$  KLire/hour), at CEA in Paris, etc. [Difficult or expensive access to University groups.](#)

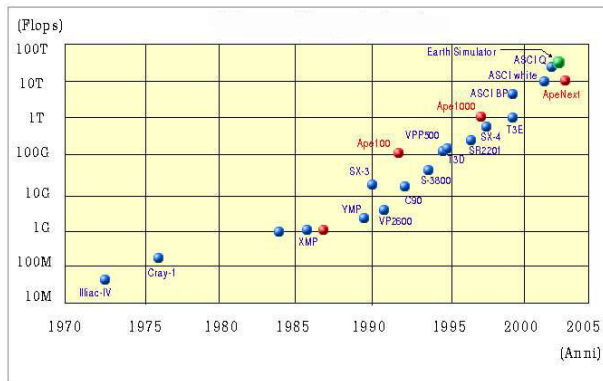
The alternative was offered by home-brew machines. The shining example was the [CERN/SLAC “3081/E Emulator”](#) project. Emulator farms were the forerunner of modern PC-Clusters, and were widely used, e.g. in LEP experiments.

APE was conceived in october 1984 with the aim to be as powerful as a contemporary Cray (1 Gflops) but at a fraction of the price.

The “3081/E Emulator” was a great inspiration for the inception of the APE project; parts of the Emulator machines — the integer board, the crates, etc. — were used in the first APE.



# APE over the years.



Other important projects of the 80's:

- Columbia University machine – N. H. Christ
- QCD-PACS in Japan
- GF11 at IBM – D. Weingarten



# Il team del primo APE

## P. Bacilieri

[INFN-CNAF](#), Bologna, Italy

## S. Cabasino, A. Frighi, F. Marzano, N. Matone, P. S. Paolucci, S. Petrarca, G. Salina

[INFN, Sezione di Roma](#), Italy

## N. Cabibbo, E. Marinari, G. Parisi

Dipartimento di Fisica, II Univerita' di Roma "Tor Vergata"; [INFN, Sezione di Roma](#), Italy

## F. Costantini, G. Fiorentini, S. Galeotti, D. Passuello, R. Tripiccione

[Dipartimento di Fisica, Univerita' di Pisa](#); [INFN, Sezione di Pisa](#), Italy

## A. Fucci, R. Petronzio, F. Rapuano

[CERN](#), Geneva, Switzerland

## D. Pascoli, P. Rossi

Dipartimento di Fisica, [Univerita' di Padova](#); [INFN, Sezione di Padova](#), Italy

## E. Remiddi

Dipartimento di Fisica, Univerita' di Bologna; [INFN-CNAF](#), Bologna, Italy; [INFN, Sezione di Bologna](#), Italy

## R. Rusack

[Rockefeller University](#), New York, U.S.A.

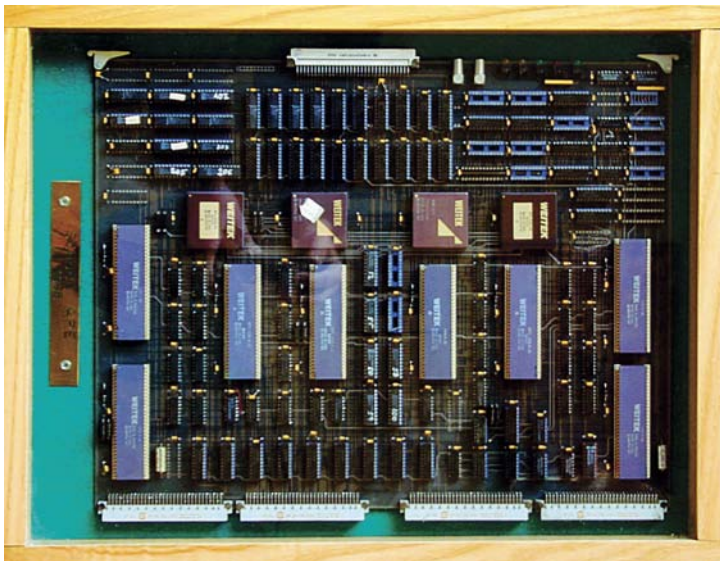
## B. Tirozzi

Dipartimento di Matematica - [Universita' "La Sapienza"](#) Roma, Italy

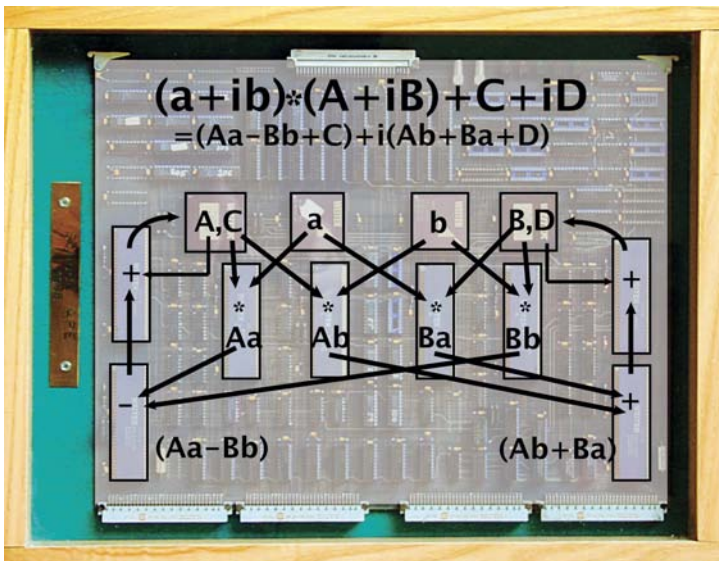
Many younger people joined the group over the years, often as thesis students, probably close to 100 by now.



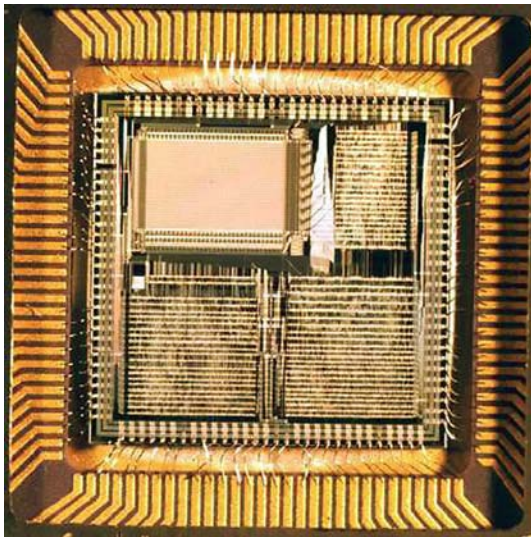
# The Processor of the first APE



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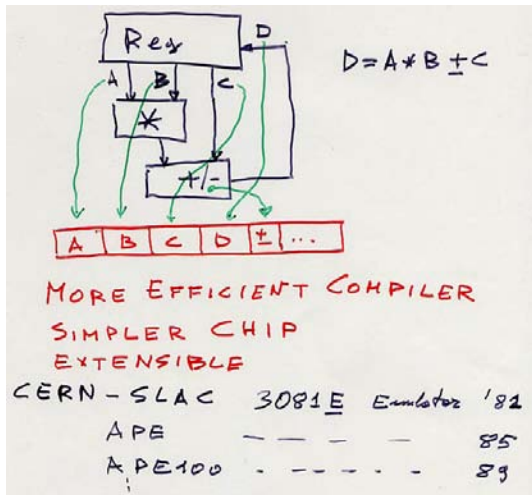


# APE100 — Processor on Chip





# VLIW — Very Long Instruction Word

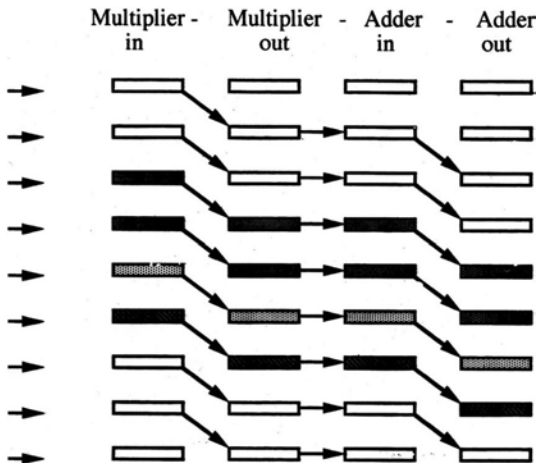


The Very Long Instruction Word structure was borrowed from the 3081/E design.

VLIW simplifies the processor structure — no (or minimal) instruction decoding — and significantly reduces power consumption.



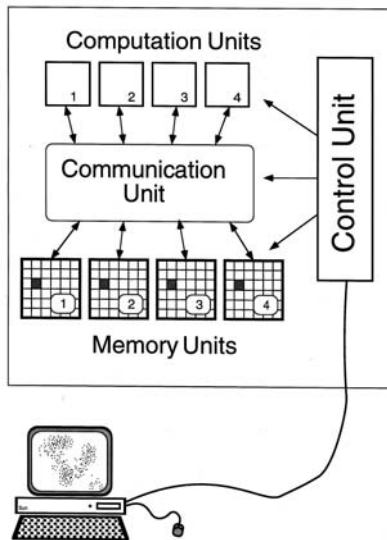
# The Pipeline and the Normal Operation



Not providing separate add and multiply instructions actually *improves* the processor efficiency, as it helps filling the pipeline.



# SIMD — Single Instruction Multiple Data



## J&T: Aritmetica

- Pipelined “normal” complessa

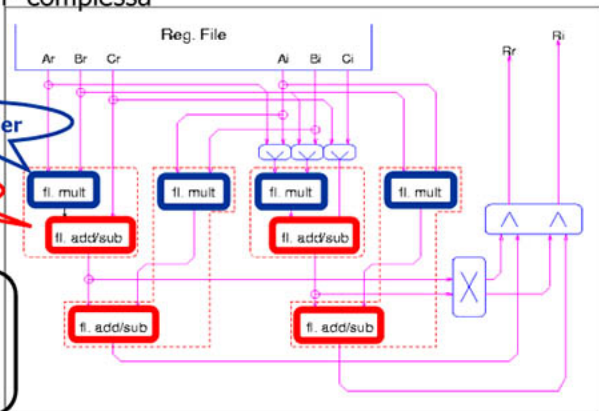
$a*b+c$  (8 flops)

per cycle

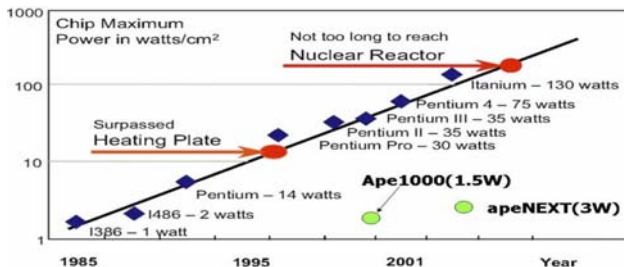
4 multiplier

4 adder/sub

**A 200 MHz  
(fully piped)  
= 1.6 GFlops**



# Saving Energy and Saving Space



Machine	RLX TM5600	RLX TM5800	Avalon	ASCI Red	ASCI White
Performance (Gflops)	21.4	3.3	17.6	600	2500
Power (kilowatts)	5.2	0.52	18.0	1200	2000
Perf/Power (Mflops/watt)	4.12	6.35	0.978	0.5	1.25

Table 4. Performance-Power Ratio for Five Parallel-Computing Systems

Machine	RLX TM5600	RLX TM5800	Avalon	ASCI Red	ASCI White
Performance (Gflops)	21.4	3.3	17.6	600	2500
Area (feet <sup>2</sup> )	6	6	120	1600	9920
Perf/Power (Mflops/feet <sup>2</sup> )	3500	550	150	375	252

Table 5. Performance-Space Ratio for Five Parallel-Computing Systems

apeNEXT

3670

80

46

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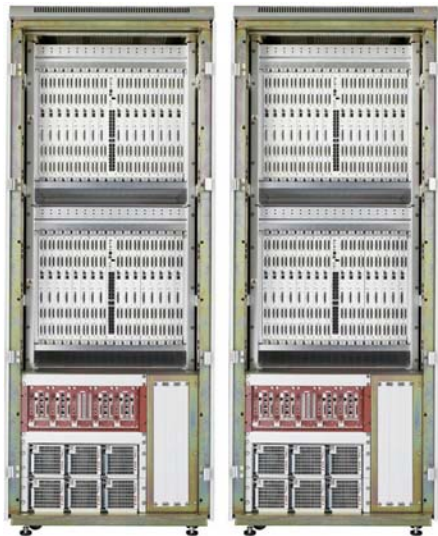
3670

72

50972



# APE in Numbers



## Apemille (2000):

Italy	1365 GF
Germany	650 GF
UK	65 GF
France	16 GF

**Total** 2 TF

## apeNEXT (2005):

Development costs = 2000 kEuro

1100 kEuro VLSI NRE

250 kEuro non-VLSI NRE

650 kEuro prototype procurement

Manpower = 20 man/year

Mass production cost ~ 0.5 Euro/Mflops

Installations:

Italy	10.6 TF
Germany	8.0 TF
France	1.6 TF

**Total** 20.2 TF



# A Future for APE?

The question should be turned around:

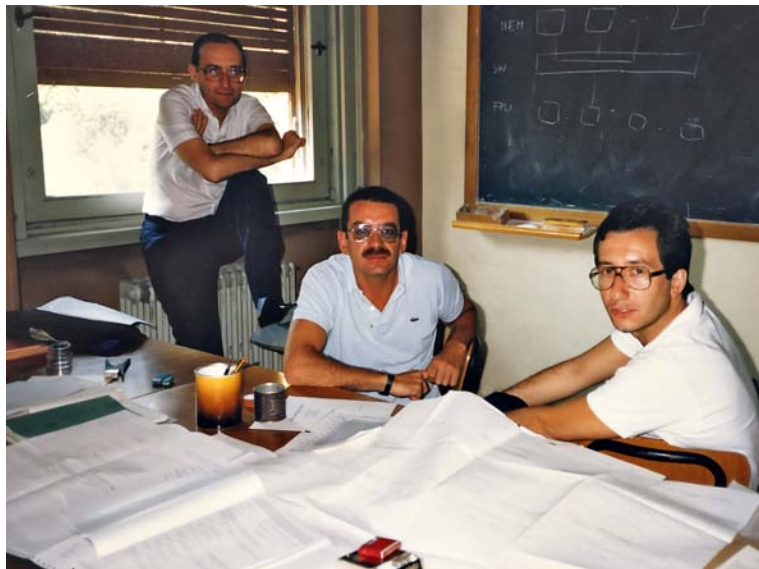
Is there a physics problem which is worth pursuing  
and requires 10 or 100 times the computational power of apeNEXT?

If the answer is yes, the APE way is probably  
still today the best way to do it.

The question is still open,  
but in the mean time, let us get the best of apeNEXT.

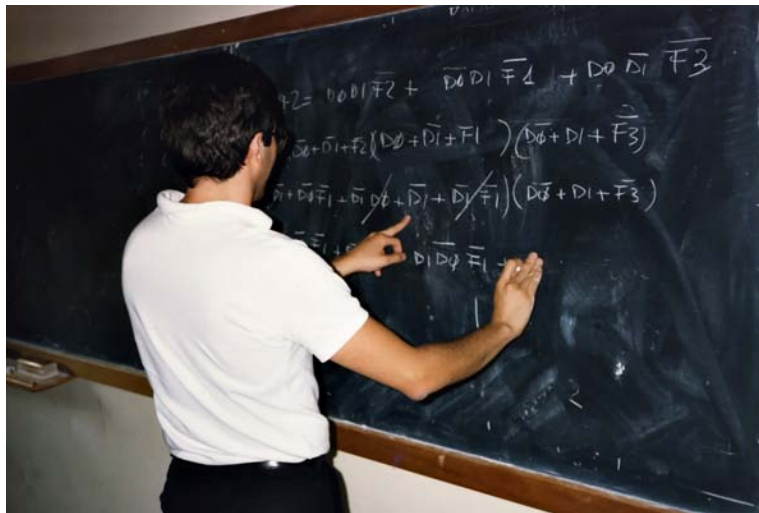


# Designing APE





# Getting it Right



# Building APE



# Proud of the first APE



# The four processor APE



The End

