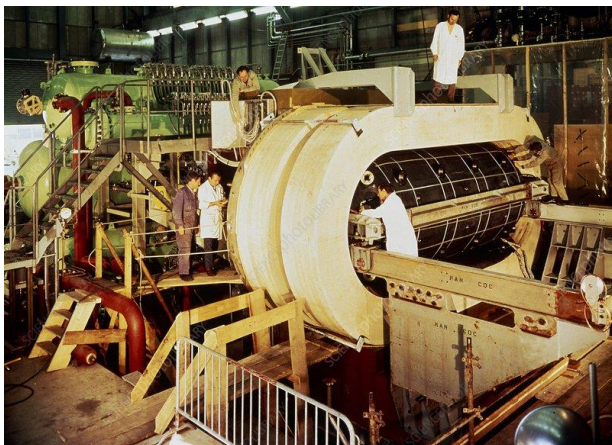




Front-end electronics for ATLAS calorimeter



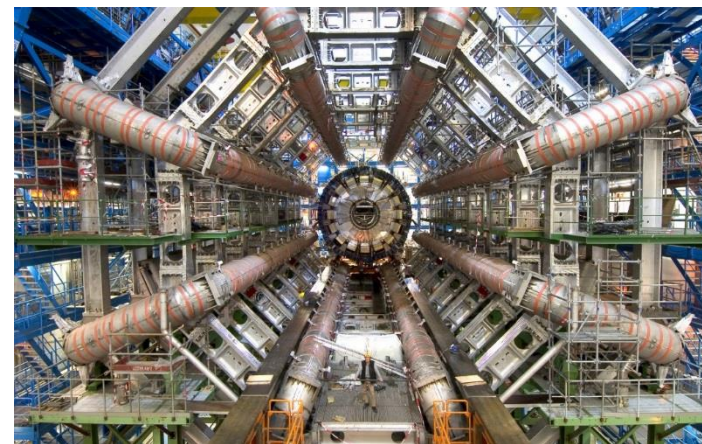
Christophe de LA TAILLE
9 sept 2022



Gargamelle 1970



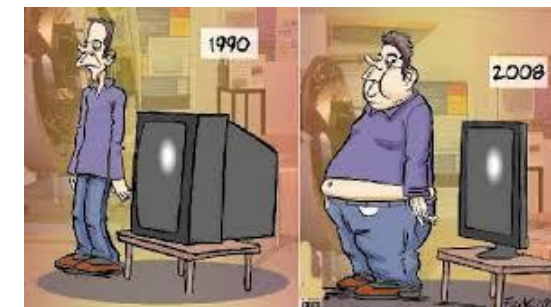
ALEPH 1990

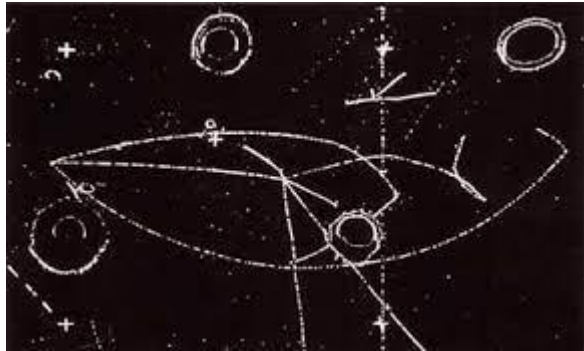


ATLAS 2010

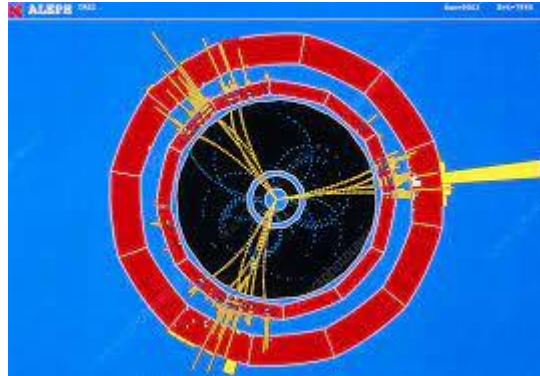


CMS upgrade 2030

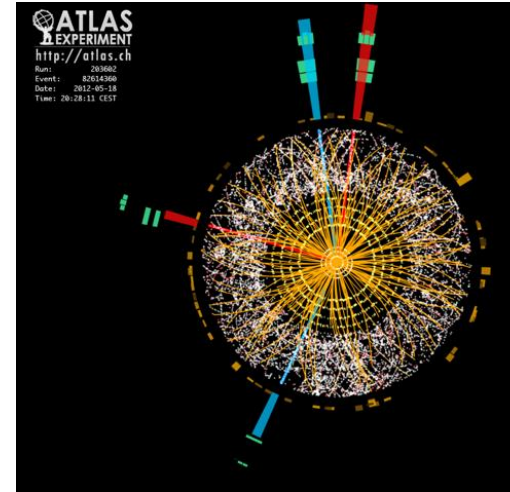




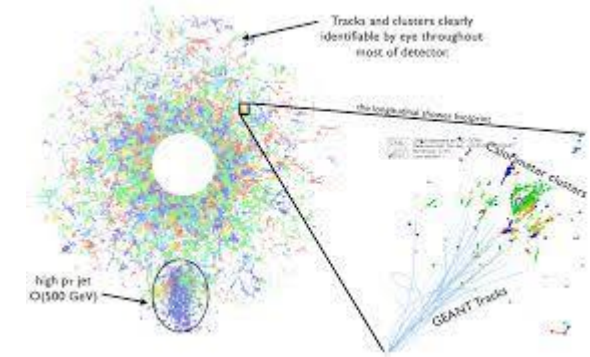
Gargamelle 1970



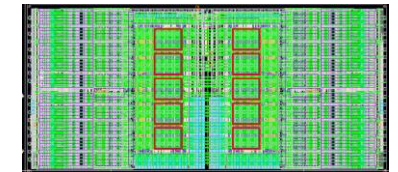
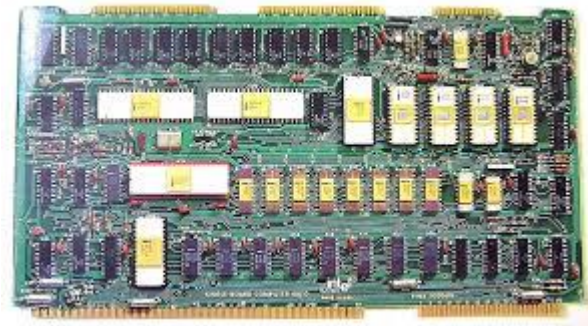
ALEPH 1990



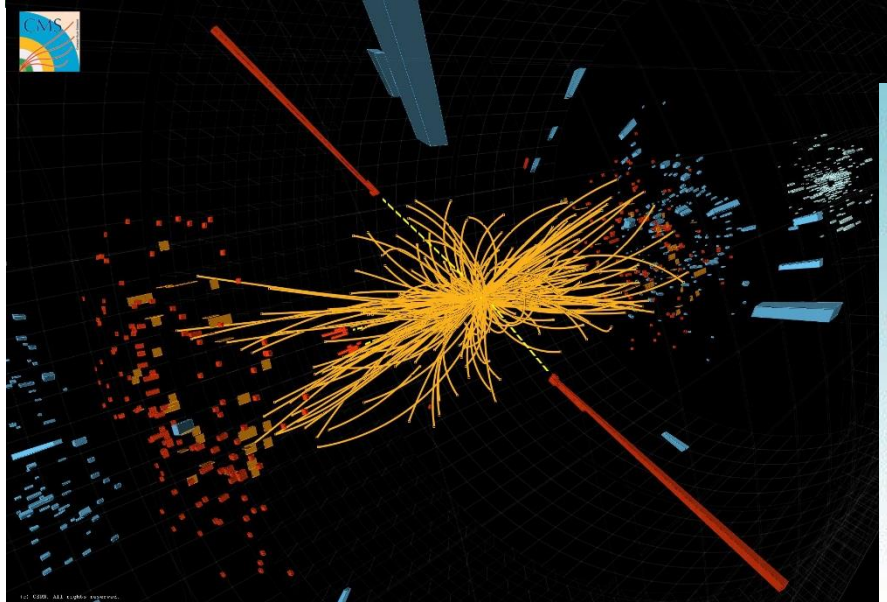
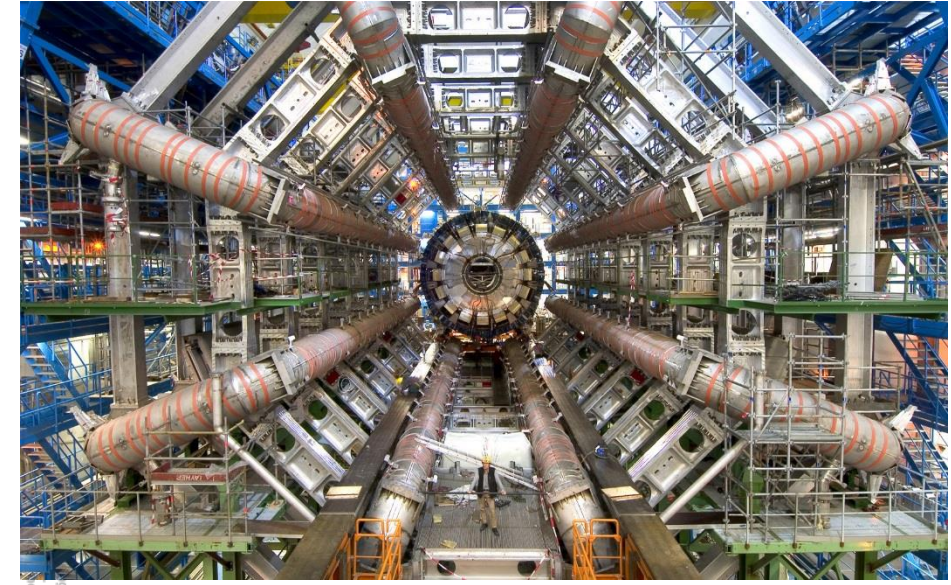
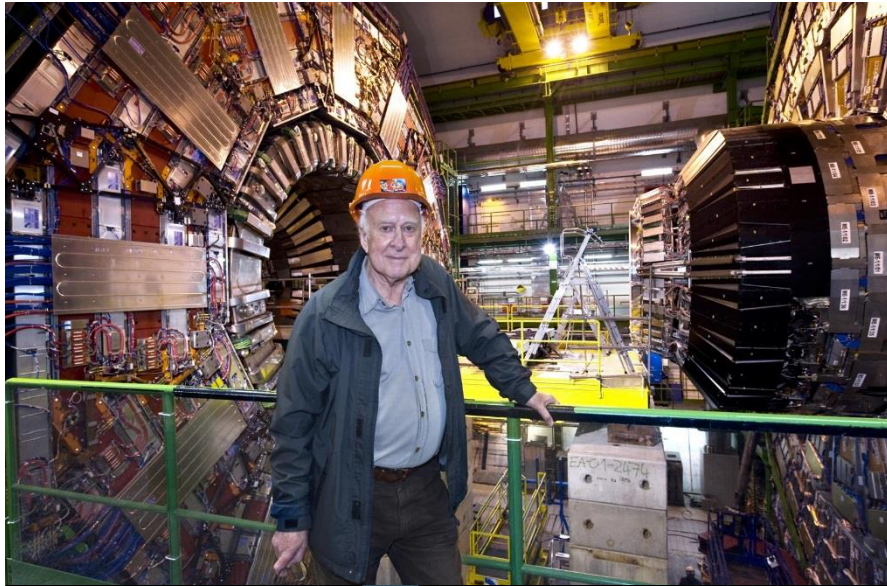
ATLAS 2010



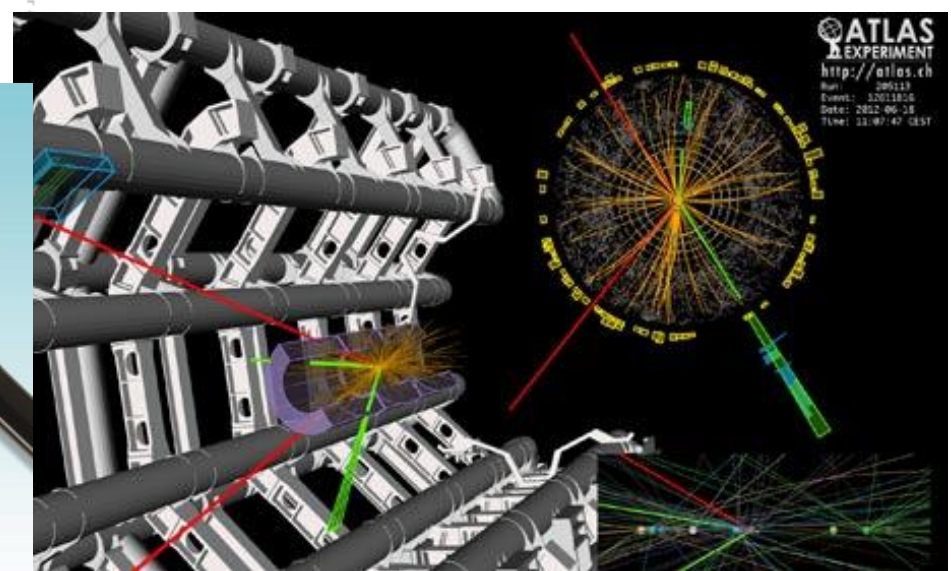
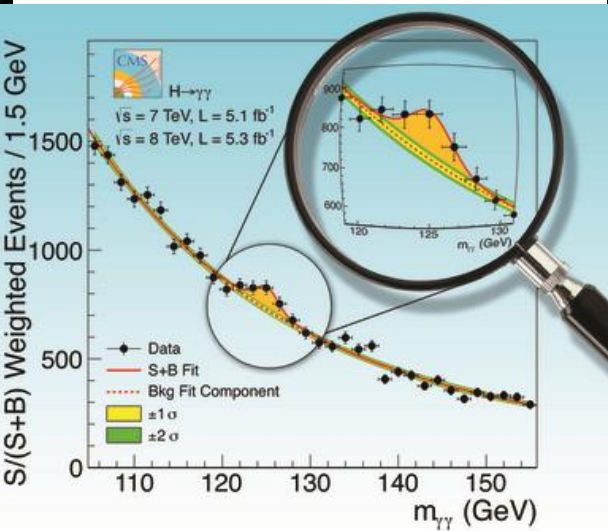
CMS 2030



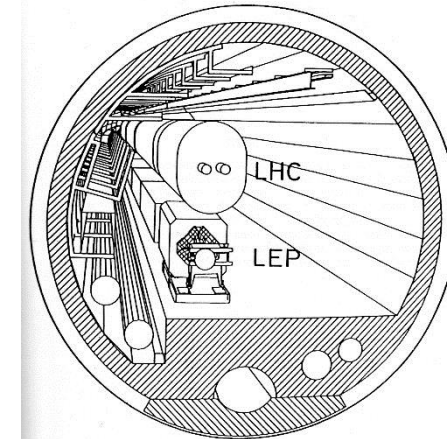
How to « see » the Higgs boson ?



"Take a look at this everyone - it just could be the signature we've been looking for!"

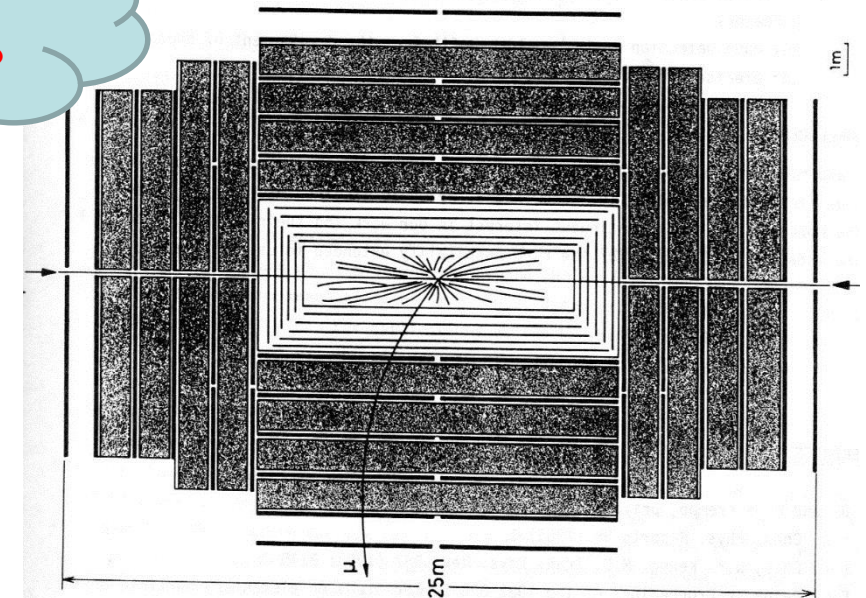
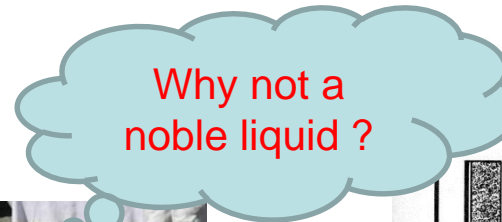


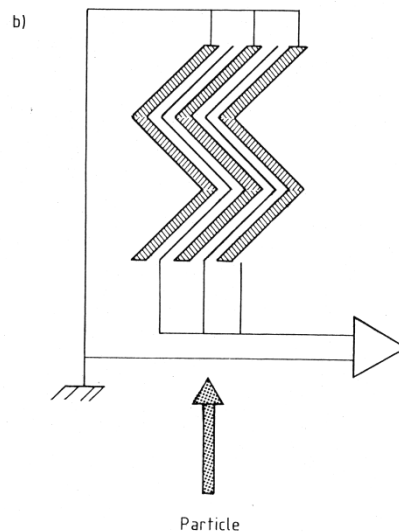
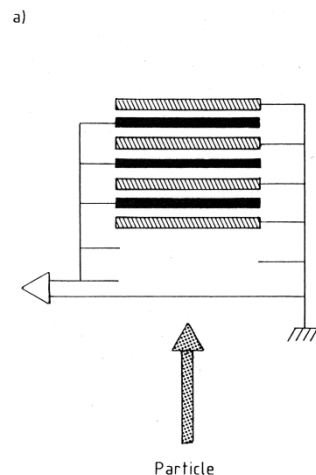
- Challenging LHC
 - High energy 14 TeV
 - High collision rate : 40 MHz
 - Small branching ratios...
- Challenging calorimetry
 - Good resolution
 - Small constant term (<1%)
 - Low dead material
- Challenging electronics
 - Large dynamic range (16 bits)
 - Low noise ($< 1\text{ nV}/\sqrt{\text{Hz}}$)
 - High speed (25 ns)
 - High radiation hardness (>Mrad)
- Challenging schedule
 - Be ready for 1999 !



LARGE HADRON COLLIDER
IN THE LEP TUNNEL

- 221 -





An approach to high granularity, fast Liq Ar calorimetry using an "accordion" structure

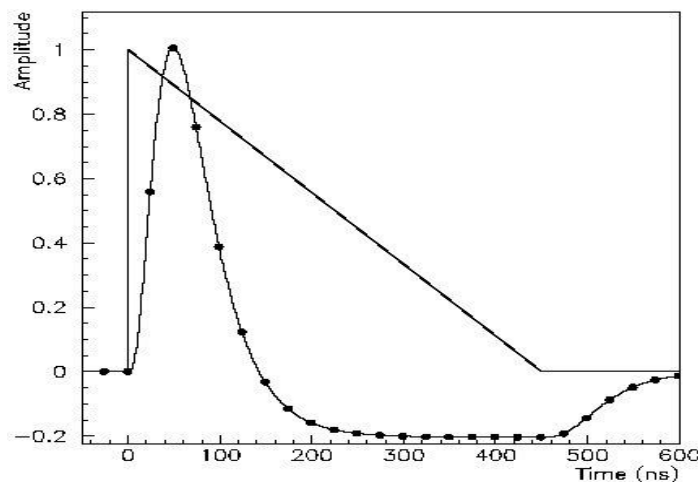
Slow because of parasitic inductance

Fast because behaves as transmission line

1) BASIC IDEA

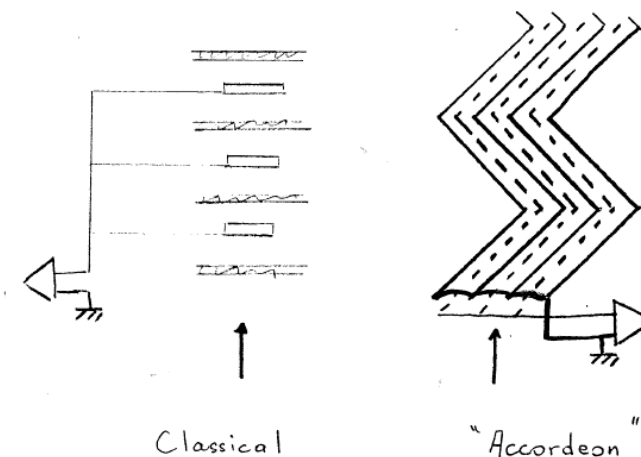
In the conventional approach of liquid argon calorimetry parallel electrodes are connected in parallel (or in serie in the ES transformer approach) to form a tower. Instead one consider here a scheme in which the converter plates and electrodes are at ± 45 degrees, thus making an "automatic" connection of the elements forming a tower.

In this situation the incident particle makes an angle of 45 degrees with the converter plates. To first order resolution similar to the standard case is recovered by choosing converter plates thinner by $\sqrt{2}$.



Long signal \Rightarrow Fast shaping

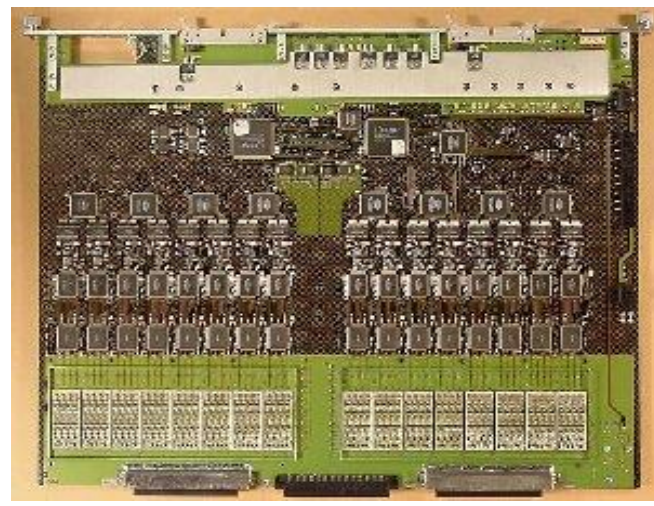
Charge sensitive \Rightarrow Current sensitive preamps



116 Calibration boards



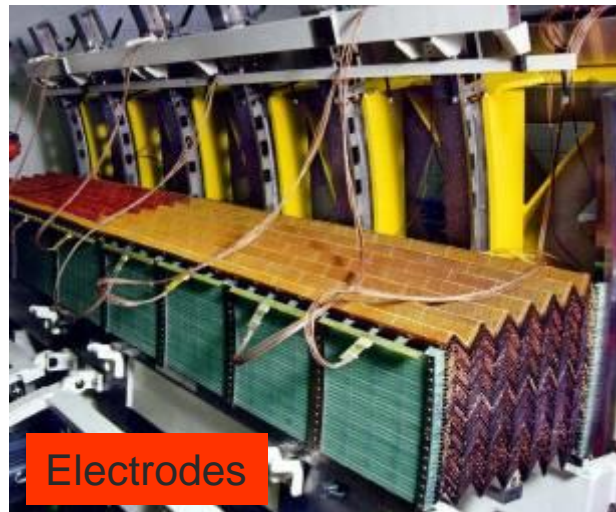
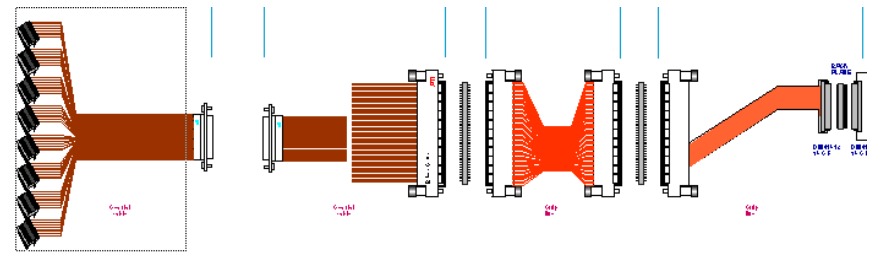
1524 Front End Board (FEB)



Readout and Calib. signals



Cold to warm Feedthroughs

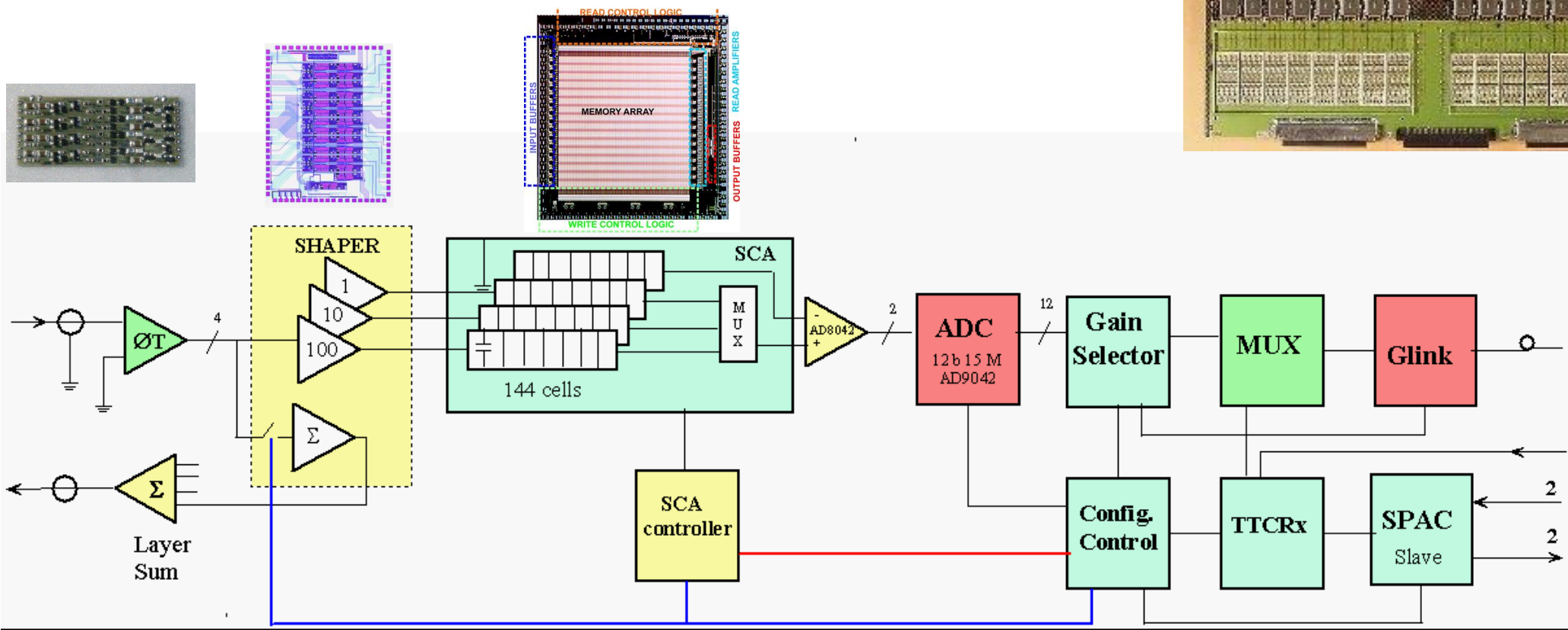
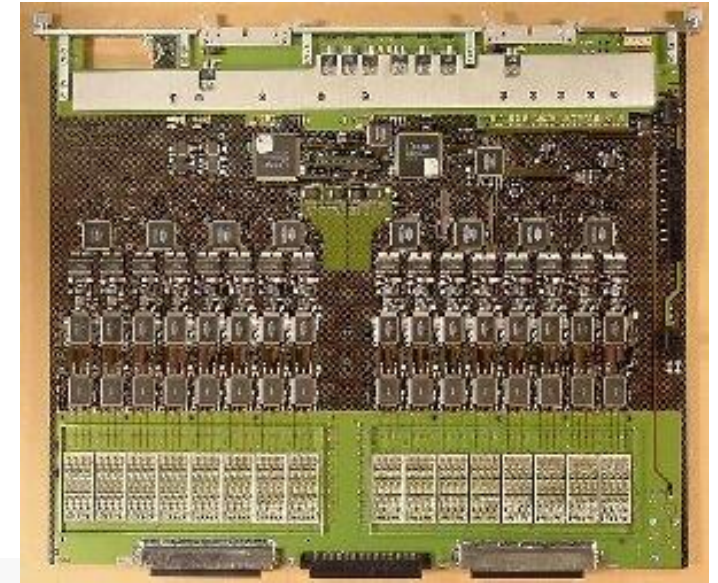


Electrodes

200 000 kapton cables

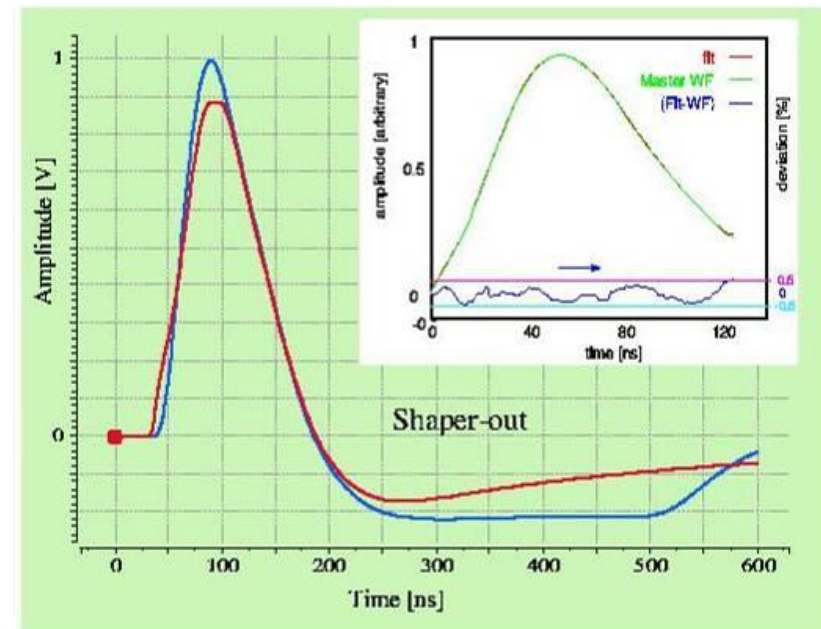
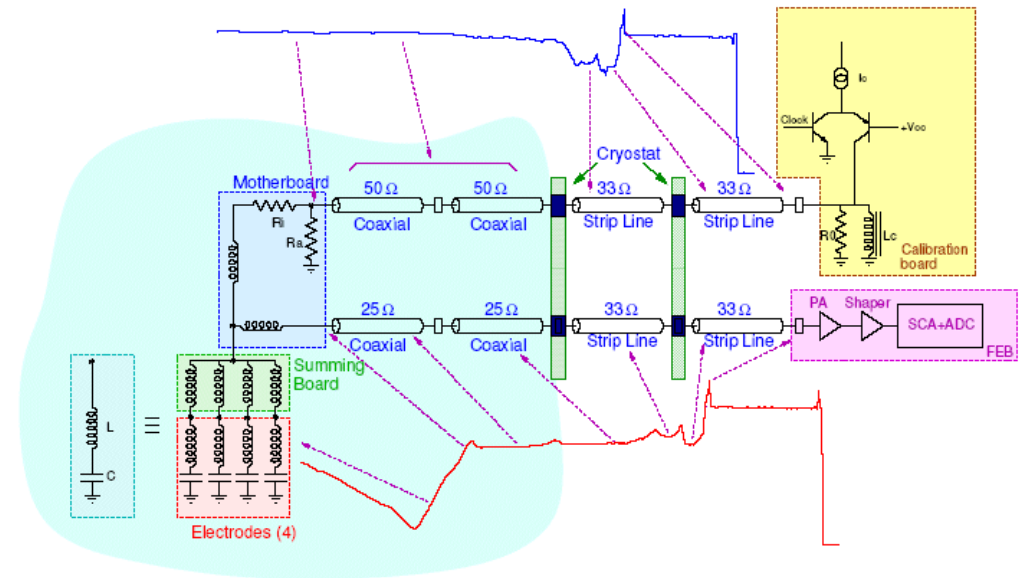
Cryostat

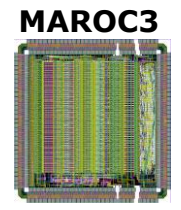
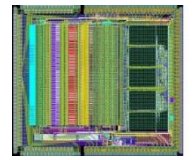
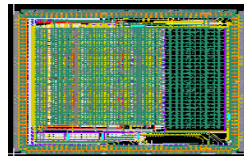
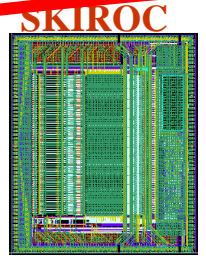
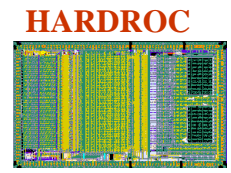
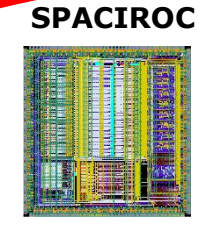
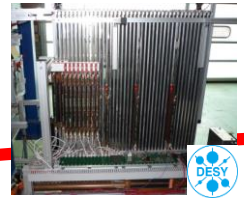
- Amplify, shape, store and digitize LAr signals
 - 16 bits dynamic range, ultra-low noise current preamps
 - Trigain (1-10-100) CRRC² shapers
 - 12 bits R/W analog memories
 - 10 different ASICs rad hard...



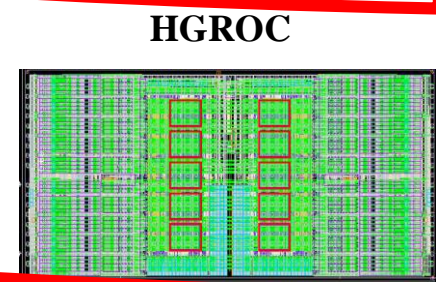
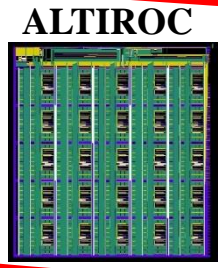
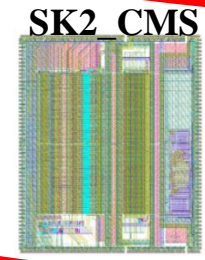
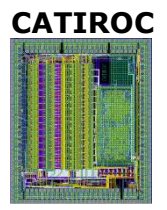
Why we do our chips instead of buying them ?

- ASIC = Application **Specific** Integrated Circuit
- Innovation and technological progress allow new/better detectors
- Complex readout path
- Directly impact physics performance
- Close collaboration physicists/designers
- No chip => no detector => no experiment...





2006



2021

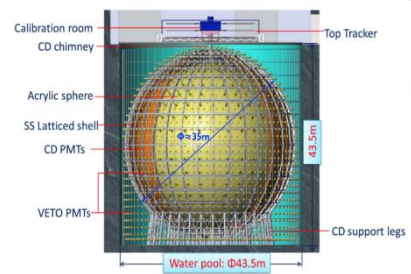
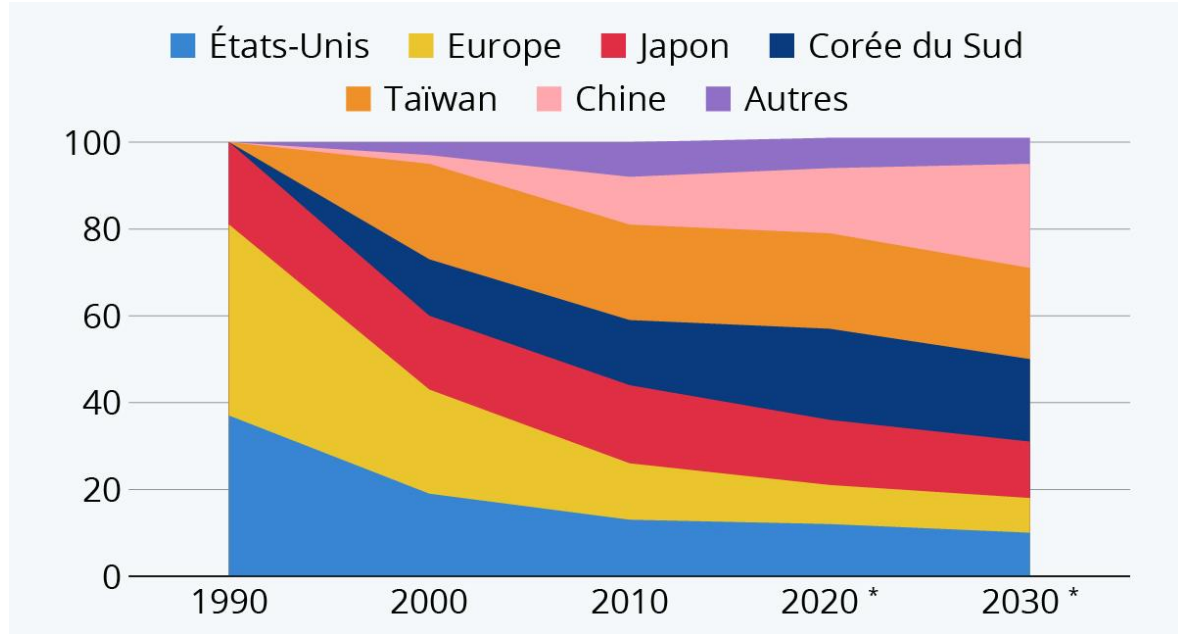
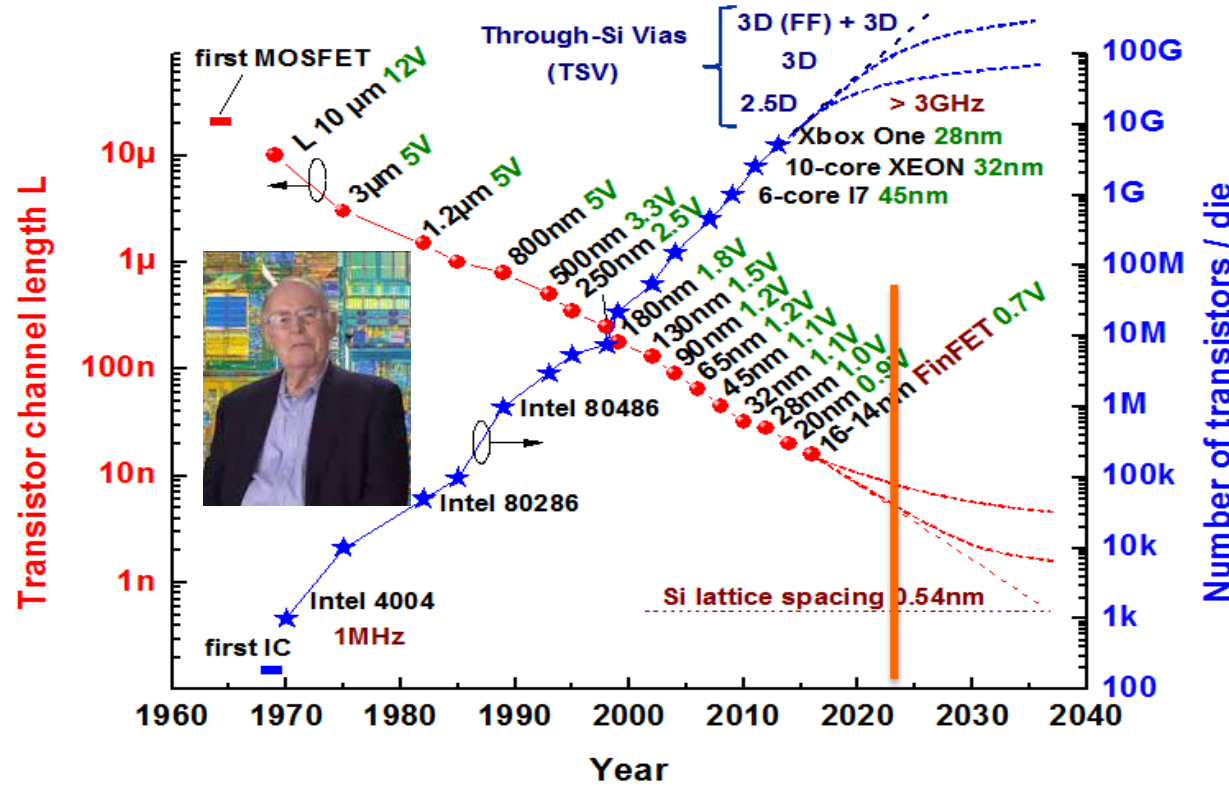


Figure 8.13: Seven 0" silicon ASIC modules, equipped with SKIROC/CMS ASIC, mounted on a copper support (existing phase during the 2017 observant campaigns).

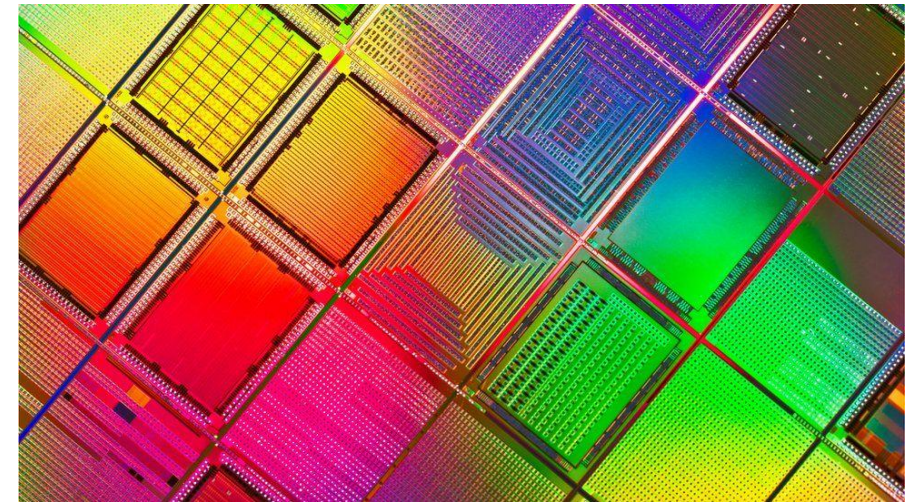
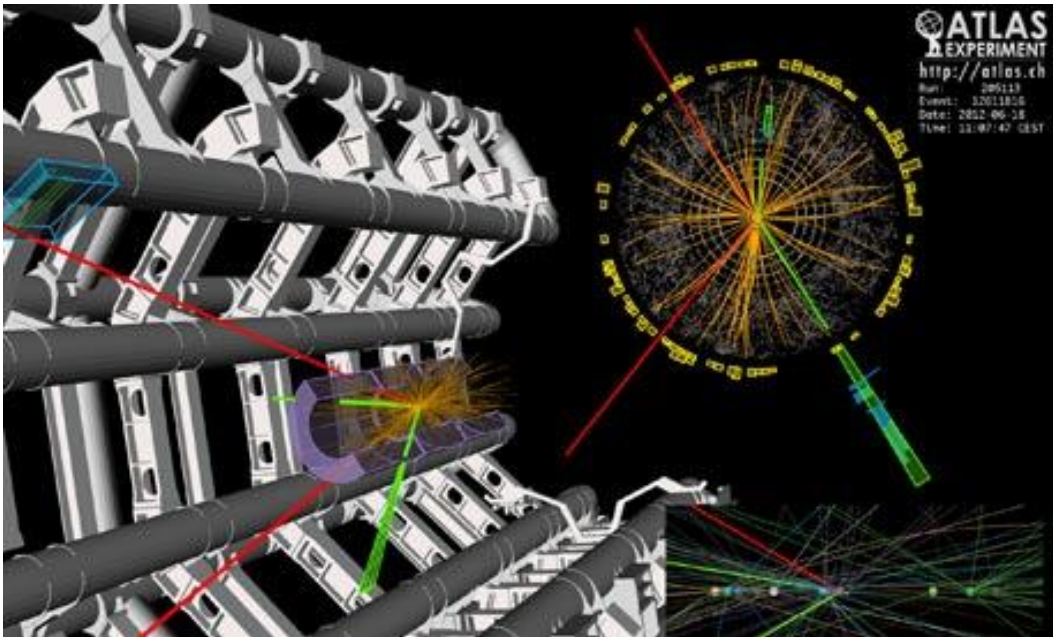


Evolution of technologies

- Evolution of technologies more and more complex and expensive: Moore's law
- Allow high integration => « system on chip » (SoC)



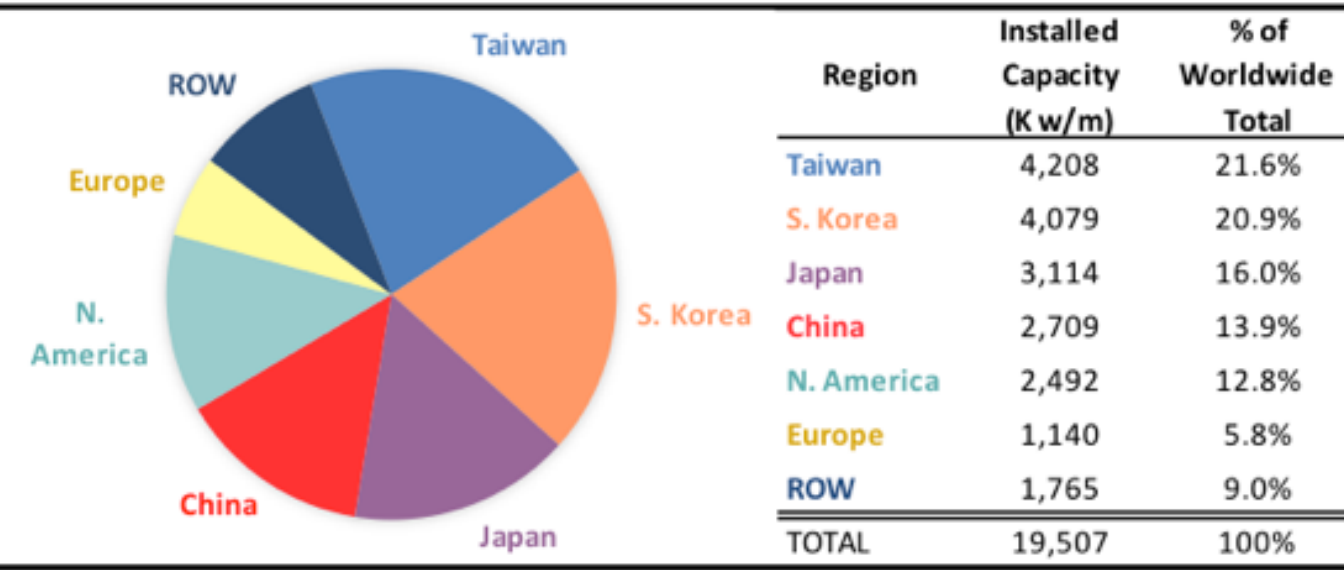
- Excellent performance of ATLAS readout electronics crucial for Higgs discovery
 - Importance of detectors and readout electronics for physics performance : a real research area
- Large international collaborations : electronics is a strategic issue



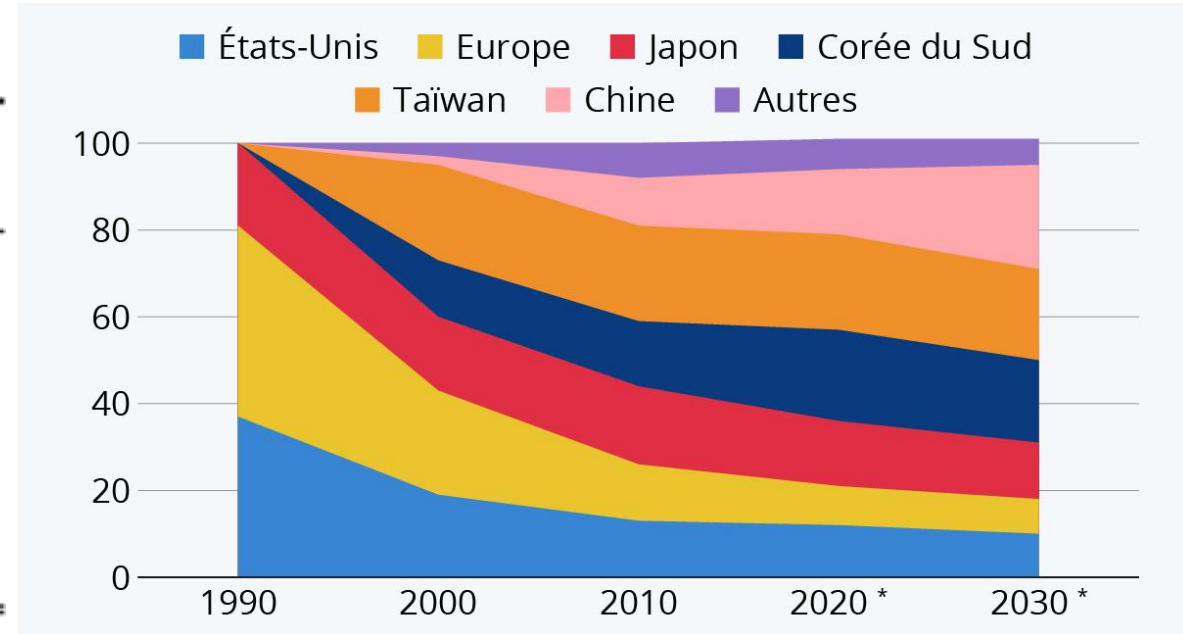
Fabricants de semiconducteurs (fonderies)

- Fabrication au $\frac{3}{4}$ en Asie

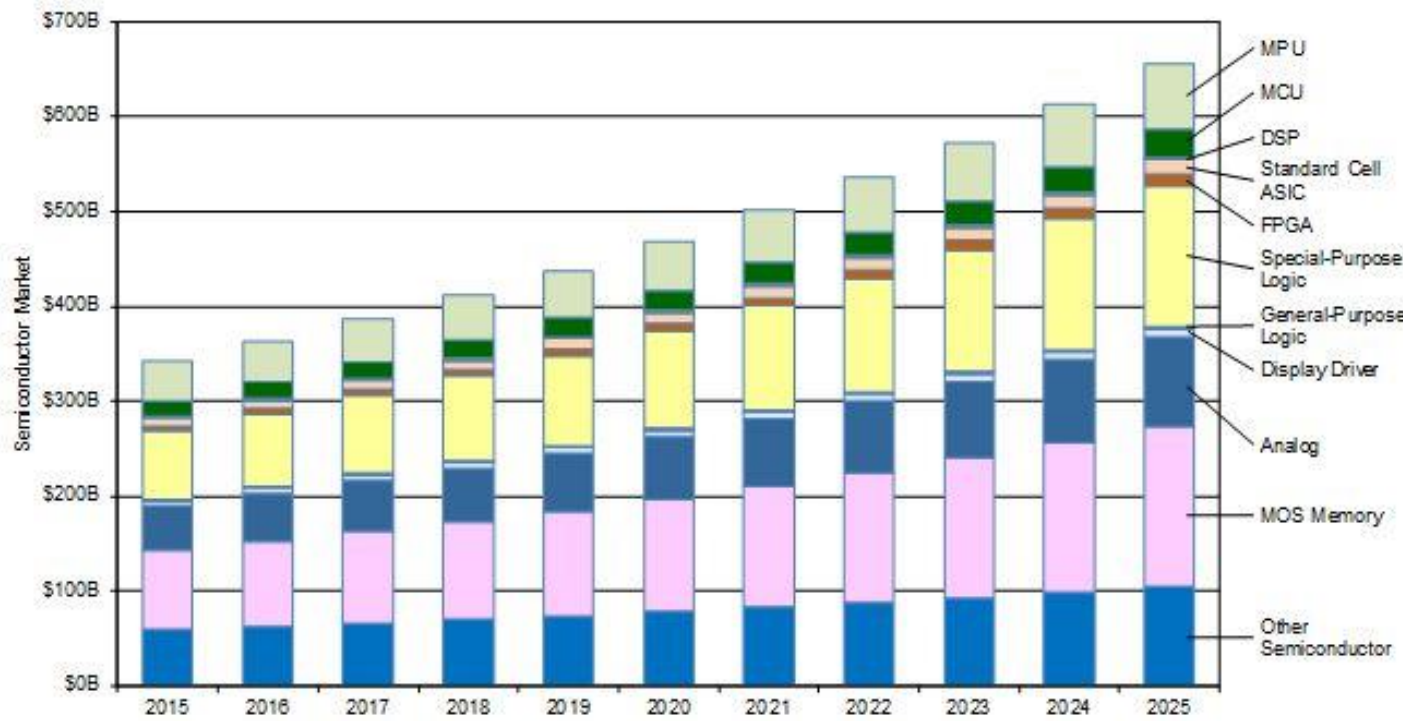
Wafer Capacity at Dec-2019 – by Geographic Region
(Monthly Installed Capacity in 200mm-equivalents)



Source: IC Insights

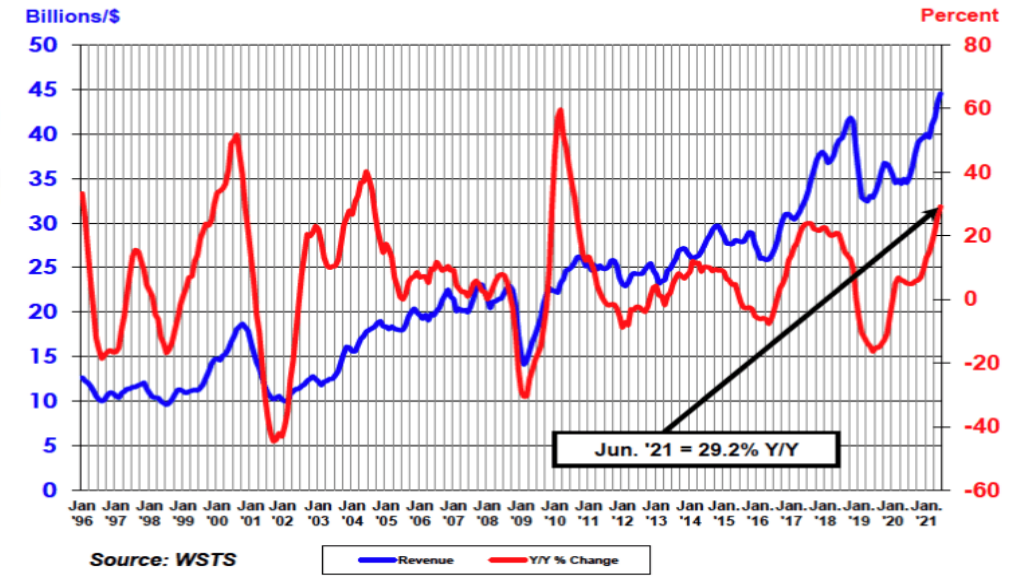


- Une activité cyclique, maintenant en forte tension



Worldwide Semiconductor Revenues

Year-to-Year Percent Change



Source: WSTS

Revenue Y/Y % Change