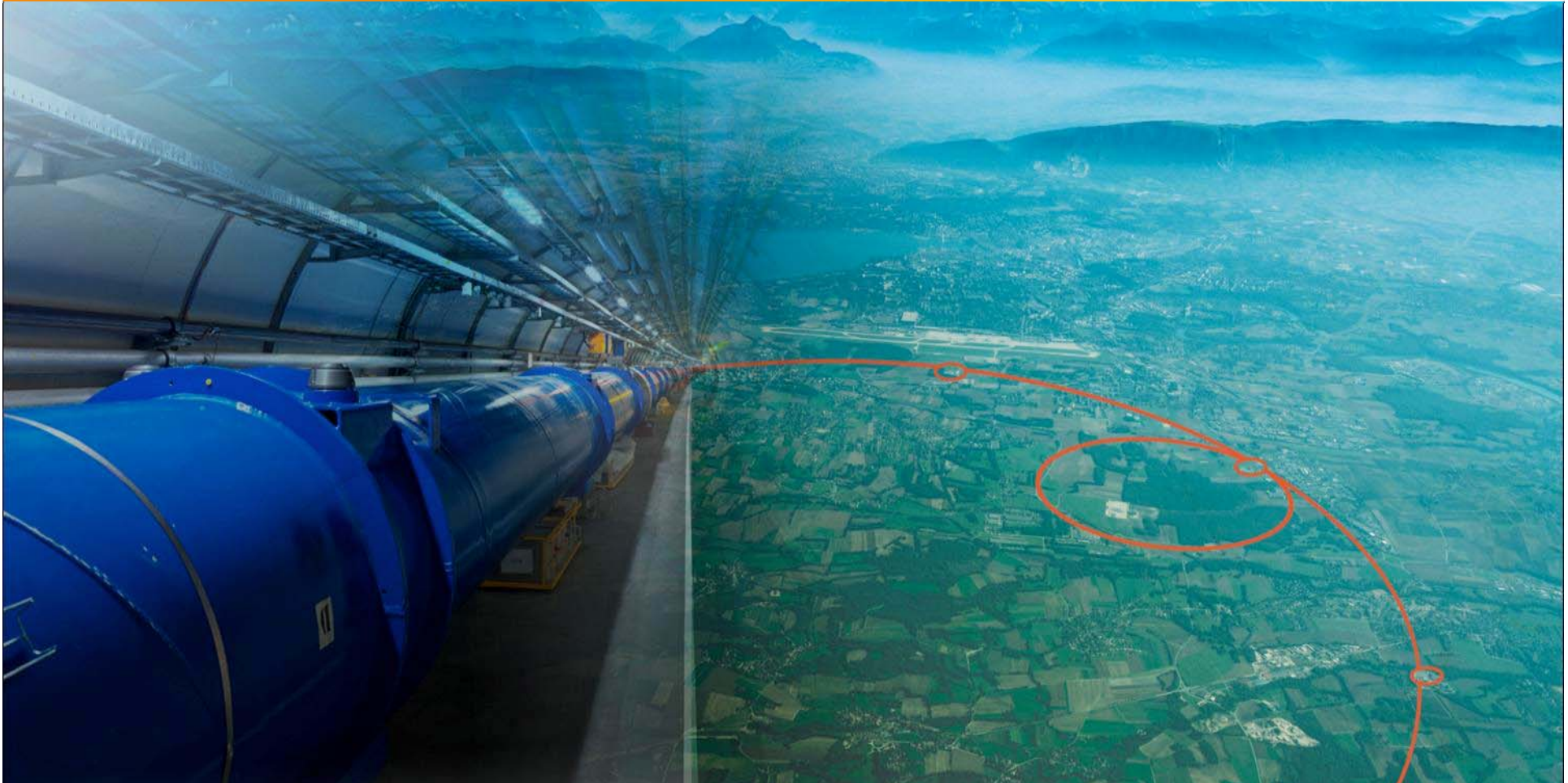


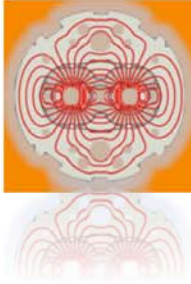
The Large Hadron Collider at CERN

Lyn Evans



LHC Symposium
Lisbon 29th November 2010

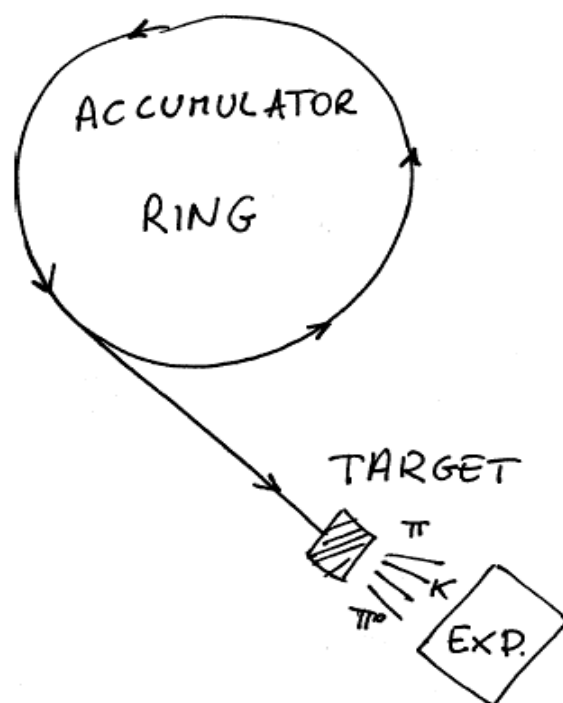




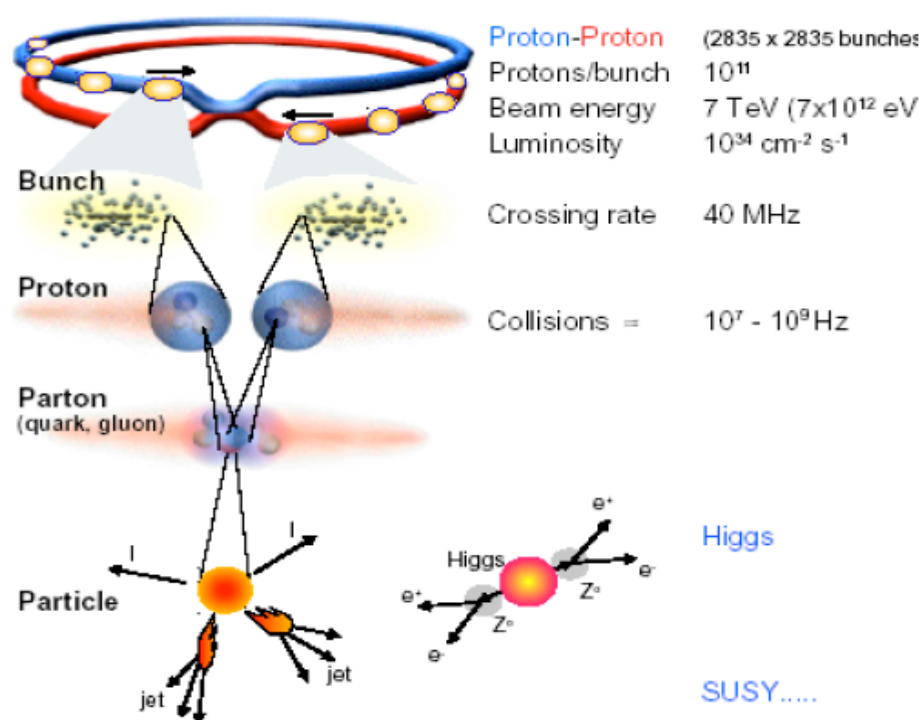
Different Approaches: fixed Target vs Collider



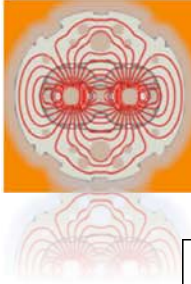
Fixed target



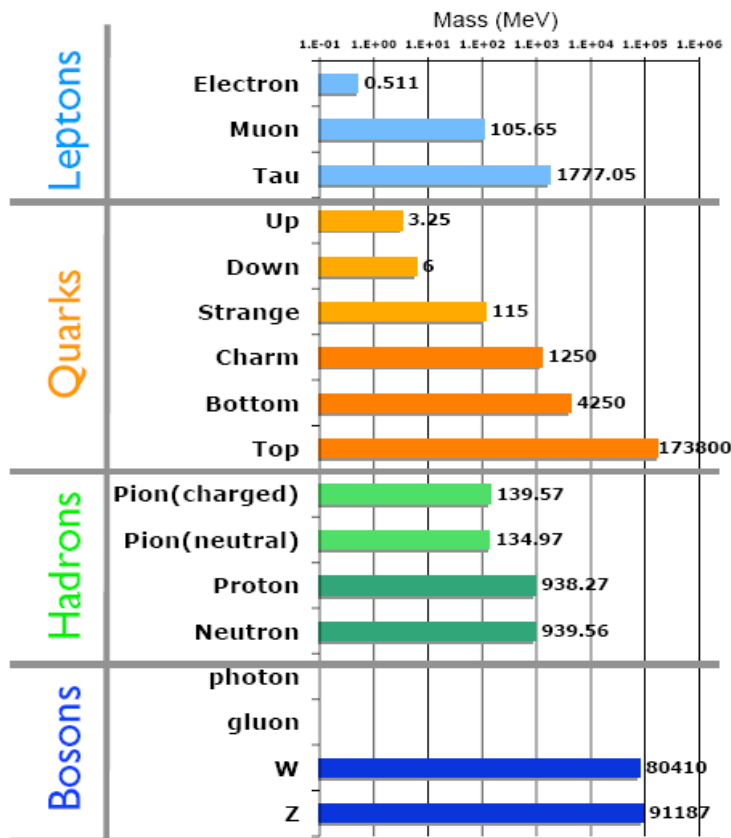
Storage ring/collider



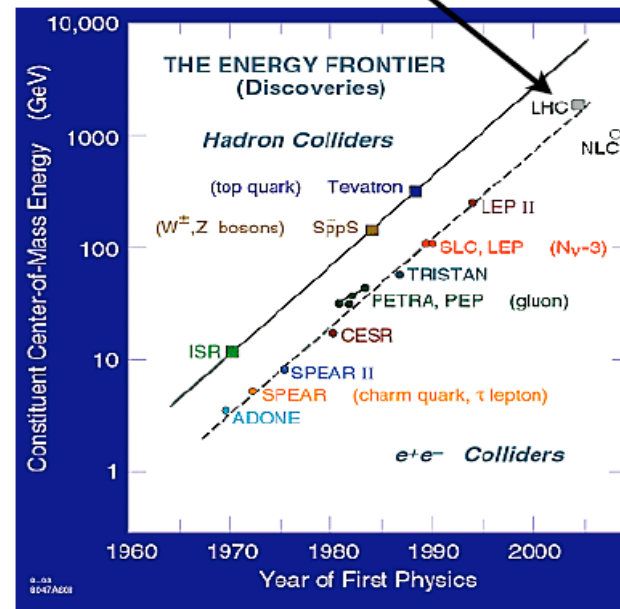
$$E_{CM} = \sqrt{2(E_{beam}mc^2 + m^2c^4)} \ll E_{CM} = 2(E_{beam} + mc^2)$$



History/Energy Line vs Discovery

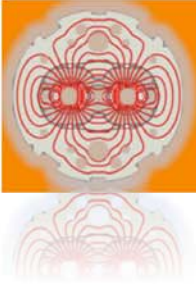


Higgs and super-symmetry ?
Or something else maybe

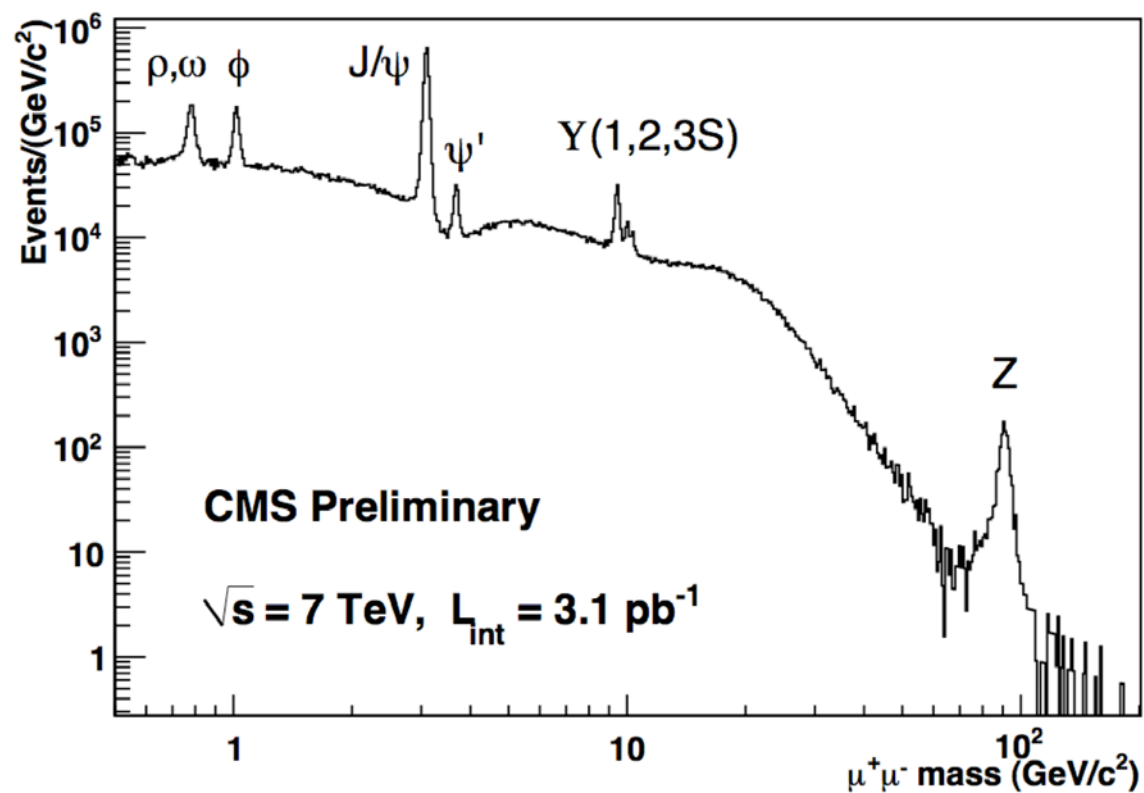


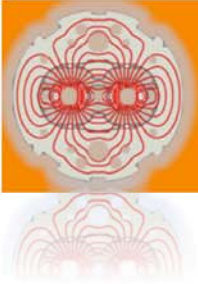
Behind the history plot is hidden the technological development required for each step

Obs: you can notice different particle species used in the different colliders
electron-positrons and hadron colliders (either \bar{p} -p as Tevatron, p-p as LHC)

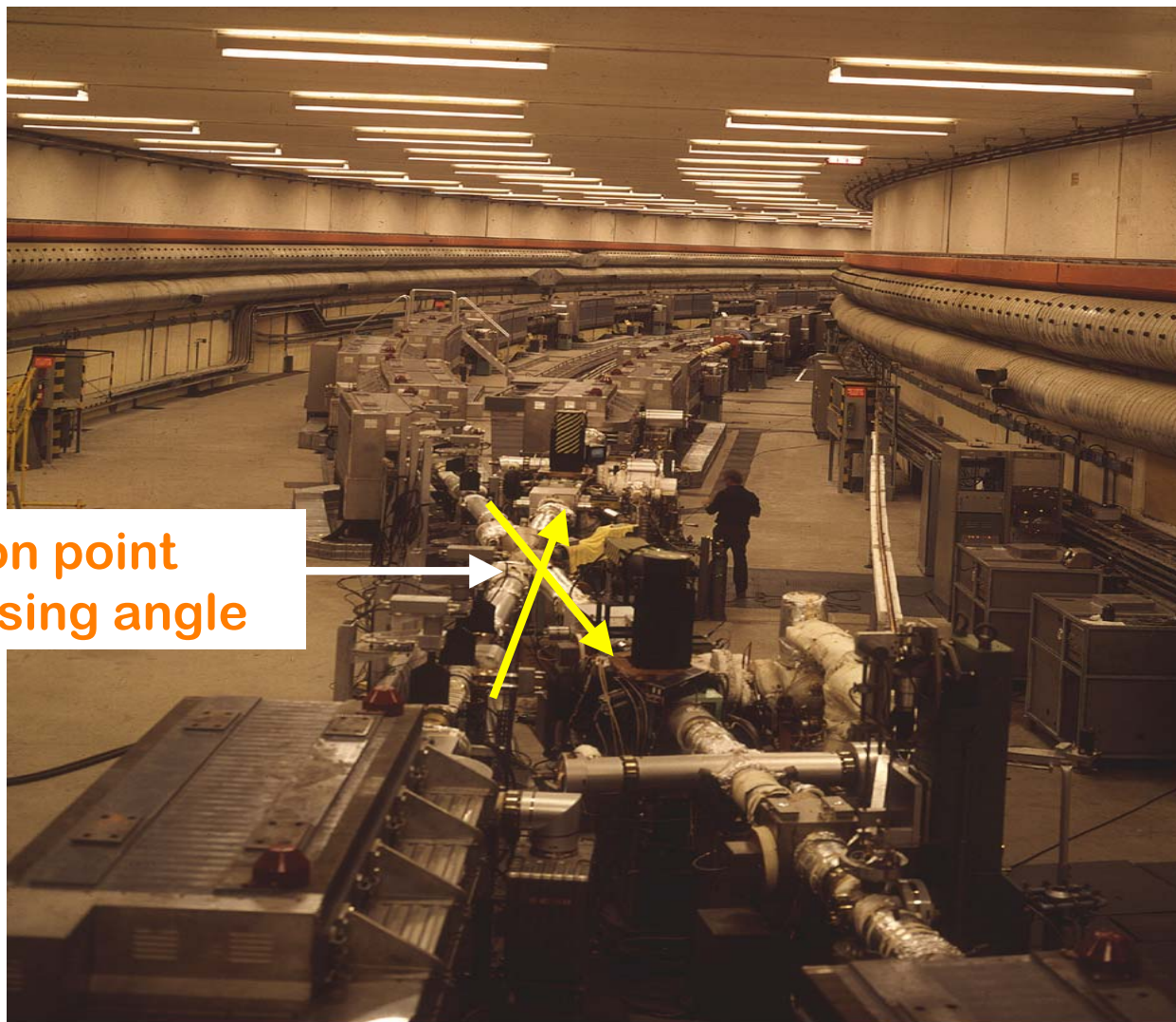


CMS Muon Pairs Mass

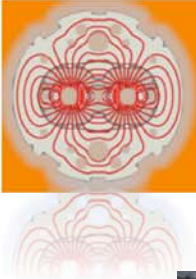




ISR

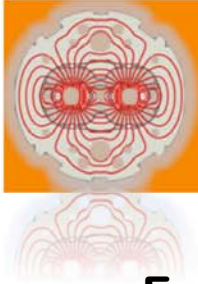


Interaction point
with crossing angle



23 Kms of superconducting Magnets

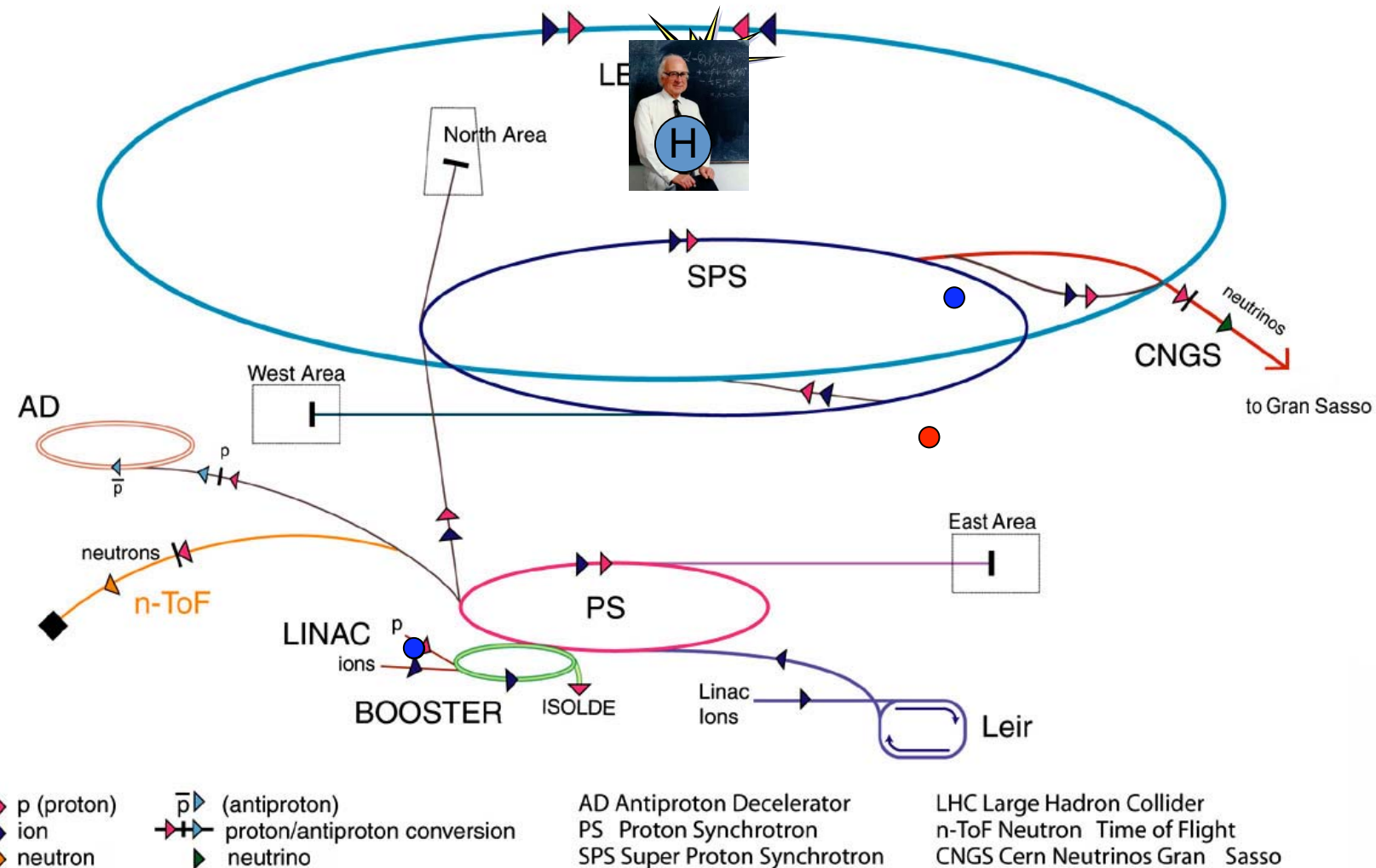


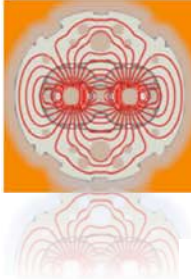


CERN's Particle Accelerator Chain

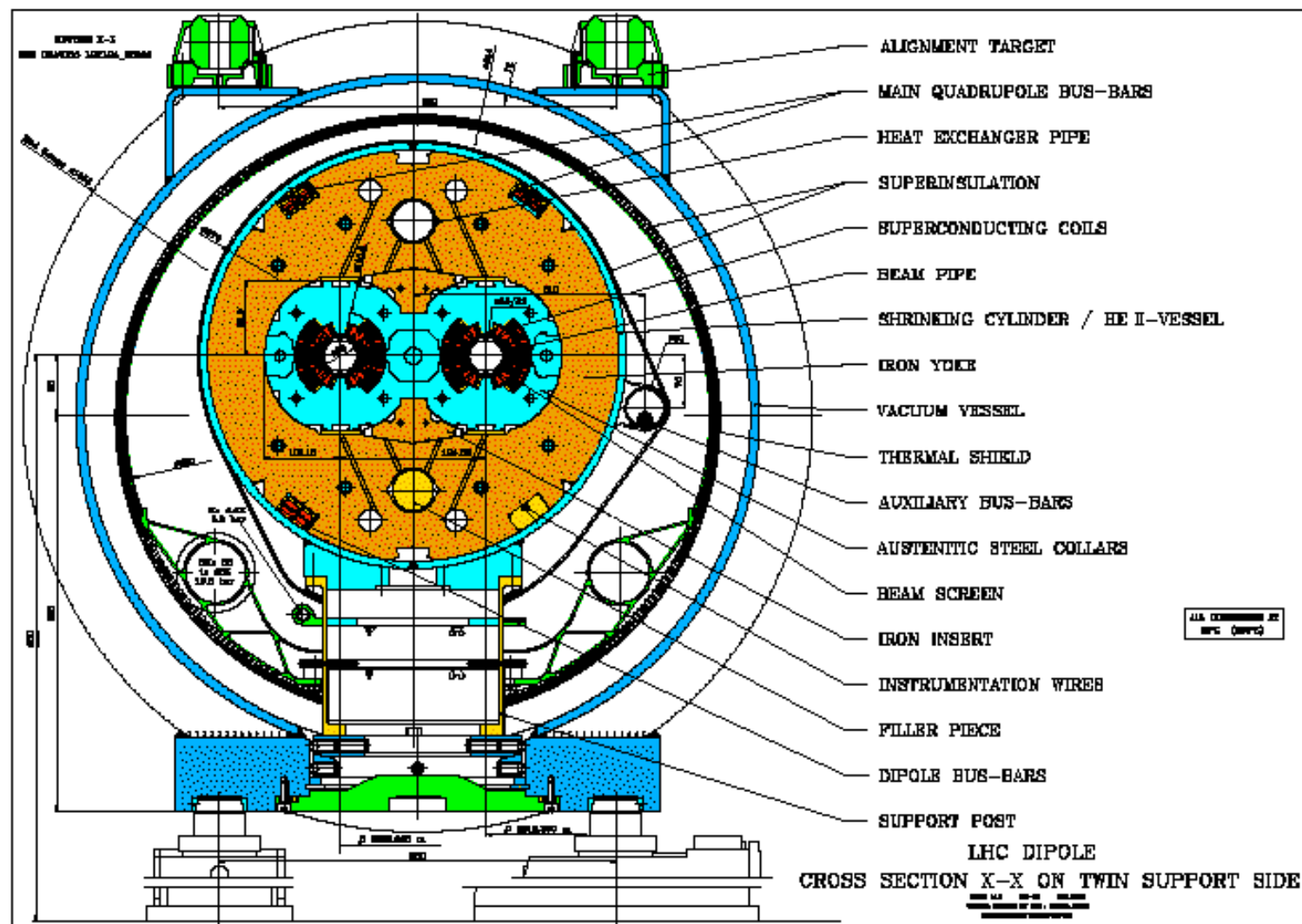


From LINAC to LHC...





Cryodipole Cross-Section



Rutherford Cables



Needs for 10-20 kA cable for protection

Needs very high packing factor: 90%
!!

Needs a system simple that keep strands

The strand are fully transposed

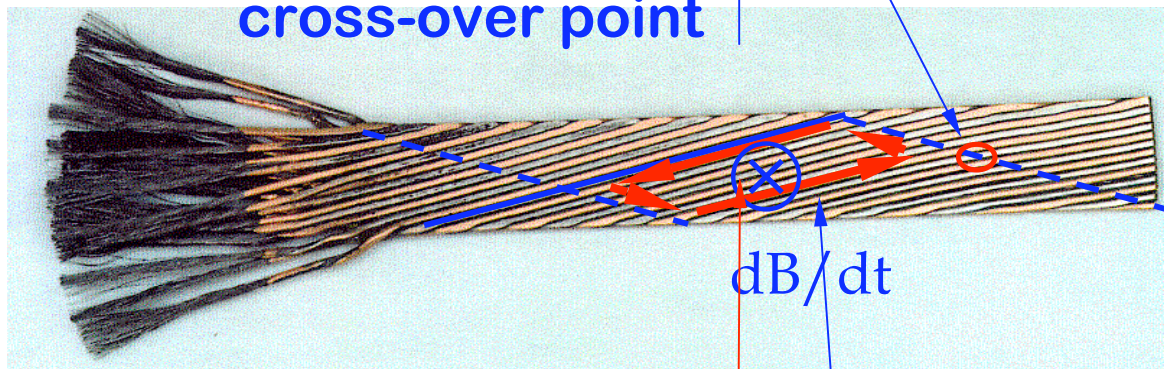
BUT field changes over a period !

Ends problems

Junctions

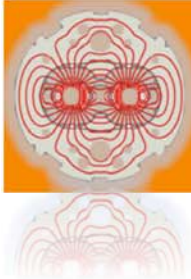
BICC

resistive contact R_c at cross-over point

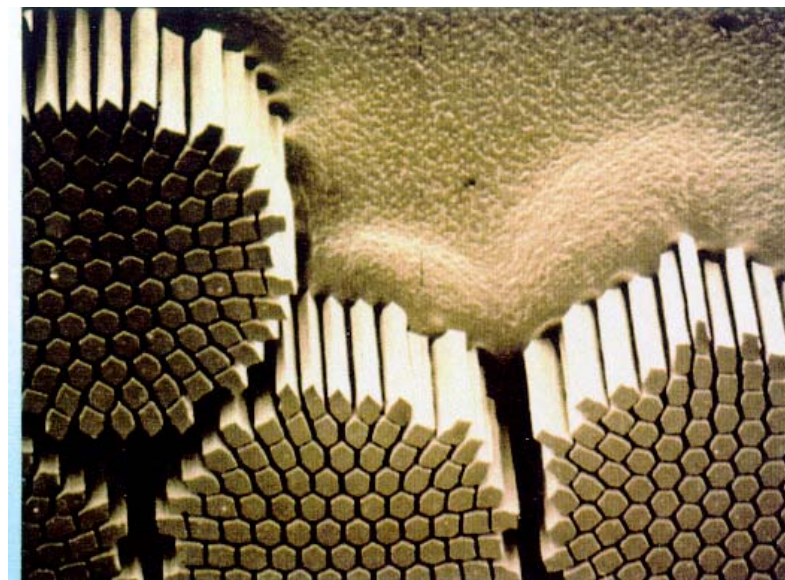
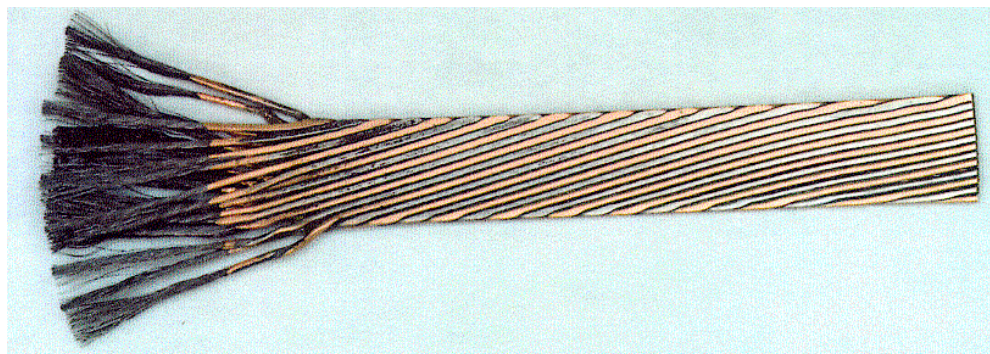


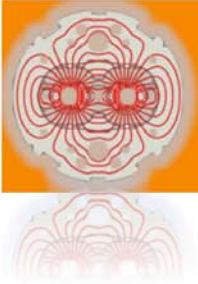
induced eddy currents in the loop $I \propto -dB/dt$
and $I \propto 1/R_c$

superconducting path in the strands

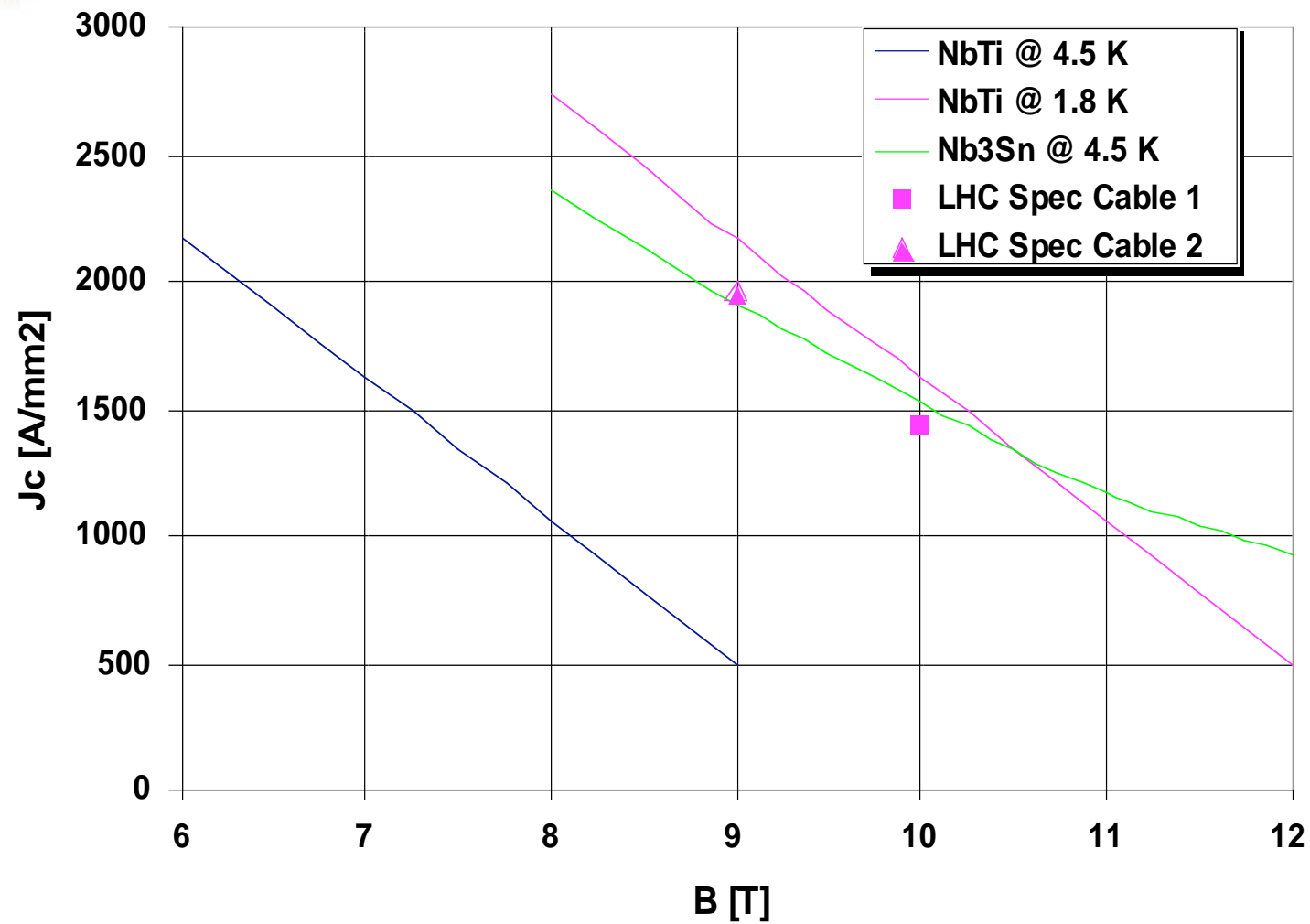


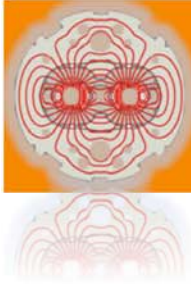
7000 Kms of superconducting Cable Nb-Ti





Critical current Density of technical Superconductors





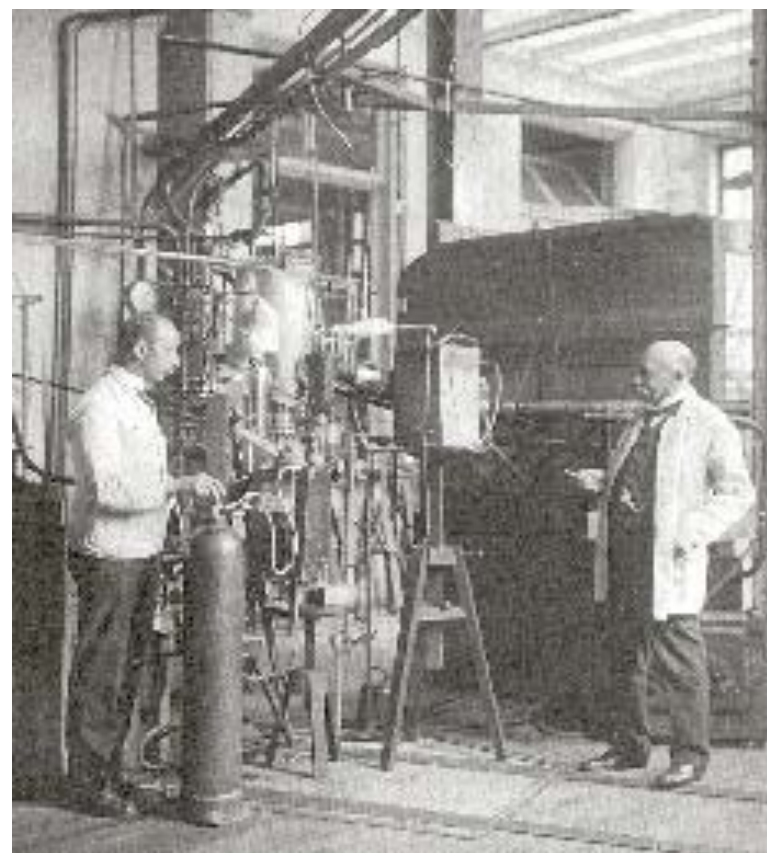
...at the Physics Laboratory of Leyden, Helium was first liquified

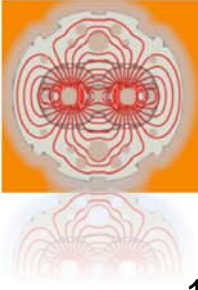


Heike Kamerlingh Onnes

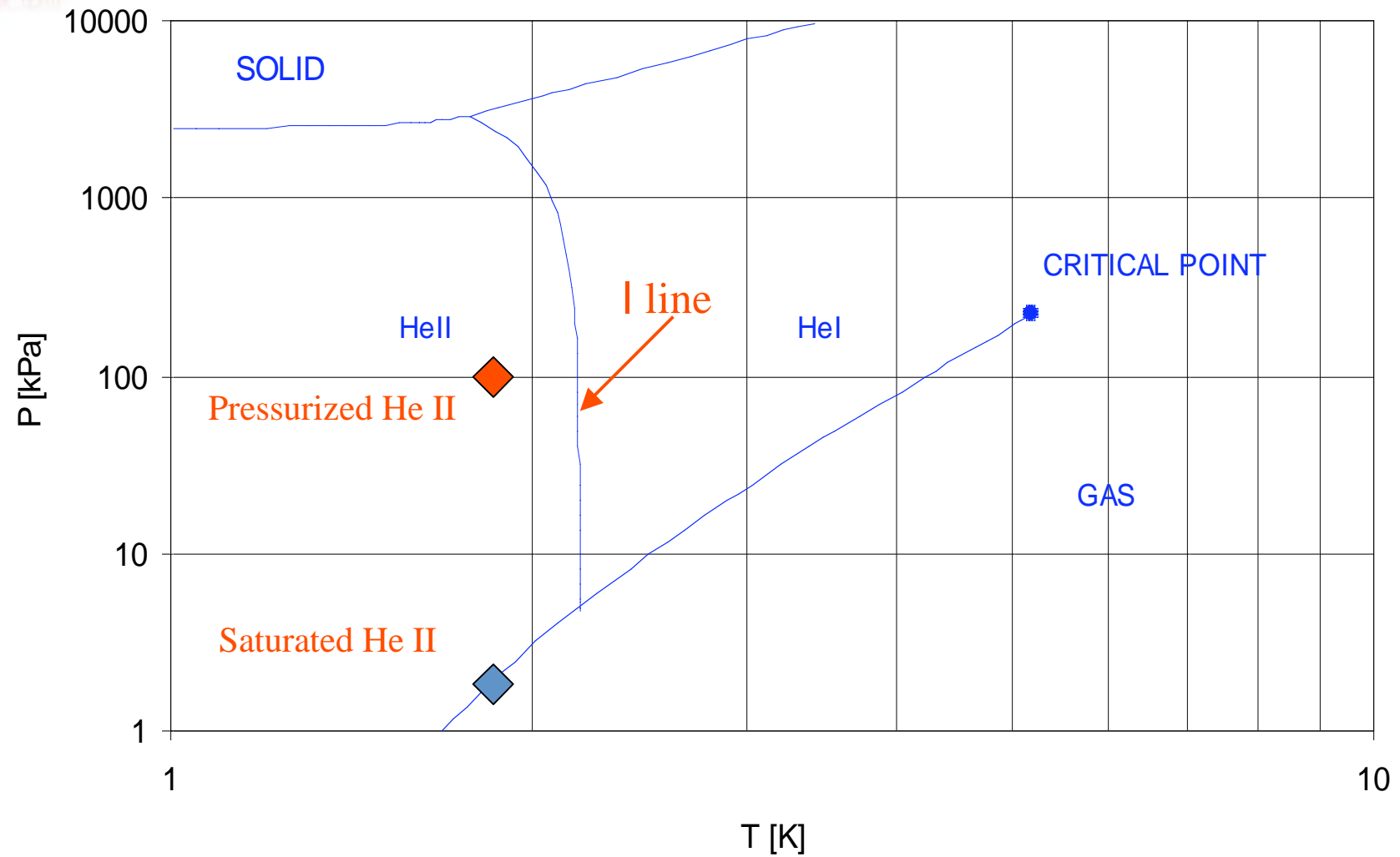


**“Door meten tot weten”
To knowledge through measurement**

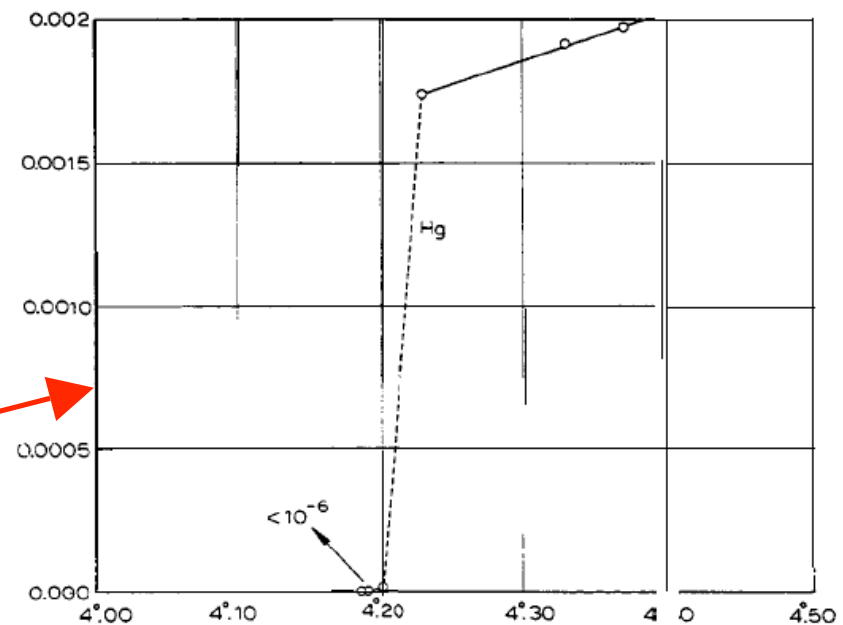
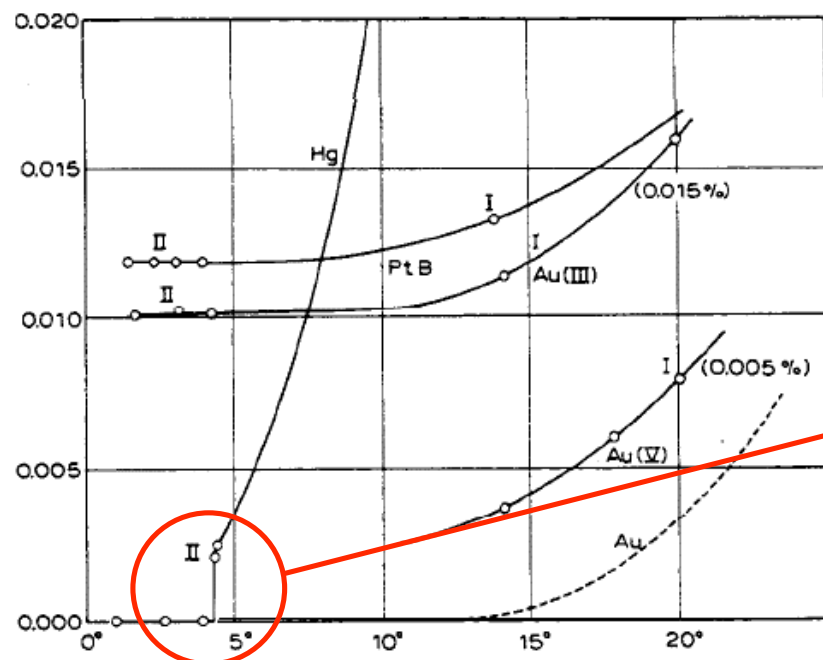




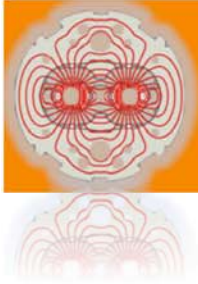
Phase Diagram of Helium



Discovery of Superconductivity (1911)



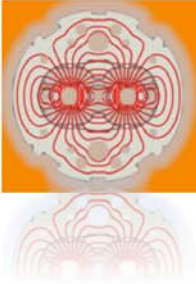
Thus the mercury at 4.2°K has entered a new state, which, owing to its particular electrical properties, can be called the state of superconductivity.



Hint of a quantum Effect...?



It is very noticeable that the experiments indicate that the density of the helium, which at first quickly drops with the temperature, reaches a maximum at 2.2°K approximately, and if one goes down further even drops again. Such an extreme could possibly be connected with the quantum theory.

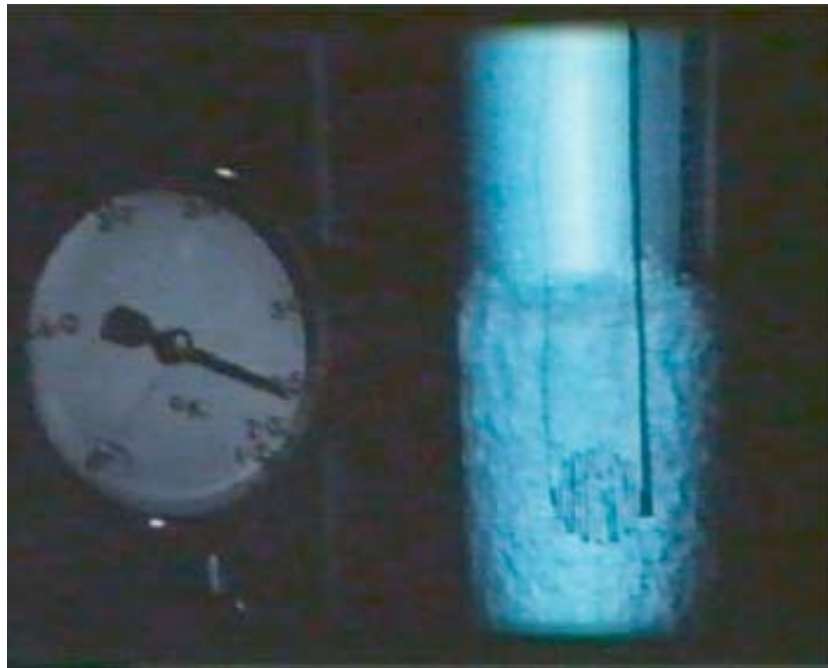


Discovery of Superfluidity in He II (1938)

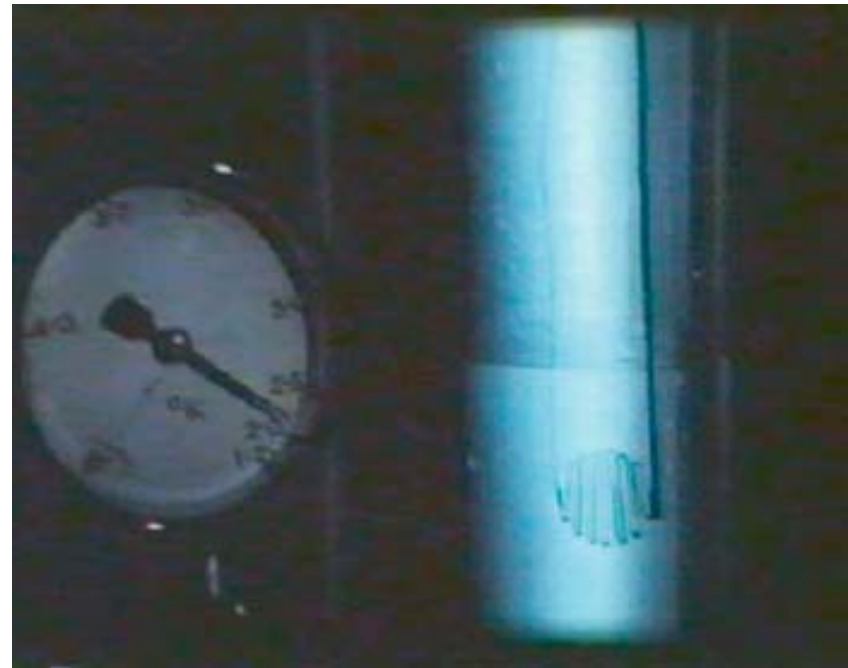


J.F. Allen & A.D. Misener (Cambridge)
P.L. Kapitsa (Moscow)

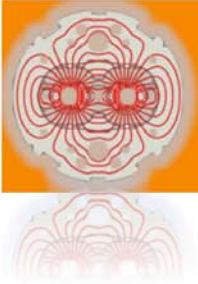
Vaporization of liquid helium



He I ($T=2.4$ K)



He II ($T=2.1$ K)

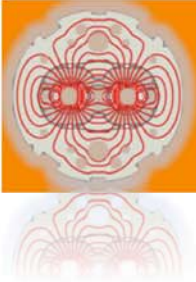


J. F. Allen

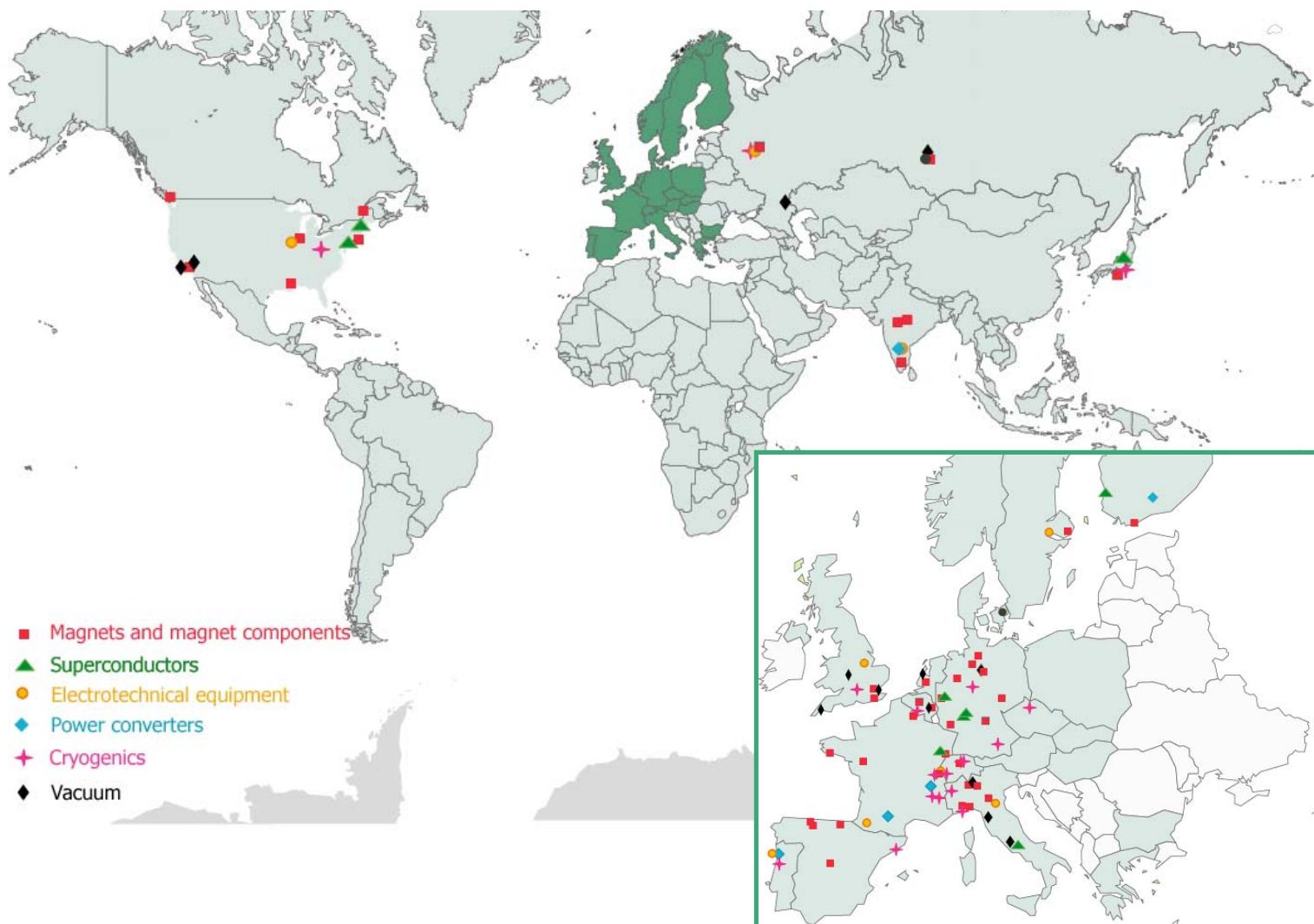


« In my PhD work in Toronto on superconductivity, I had often seen the sudden cessation of boiling at the lambda temperature T_λ but had paid it no particular attention. It never occurred to me that it was of fundamental significance. »

J. Allen, Physics World, November 1988, p 29.

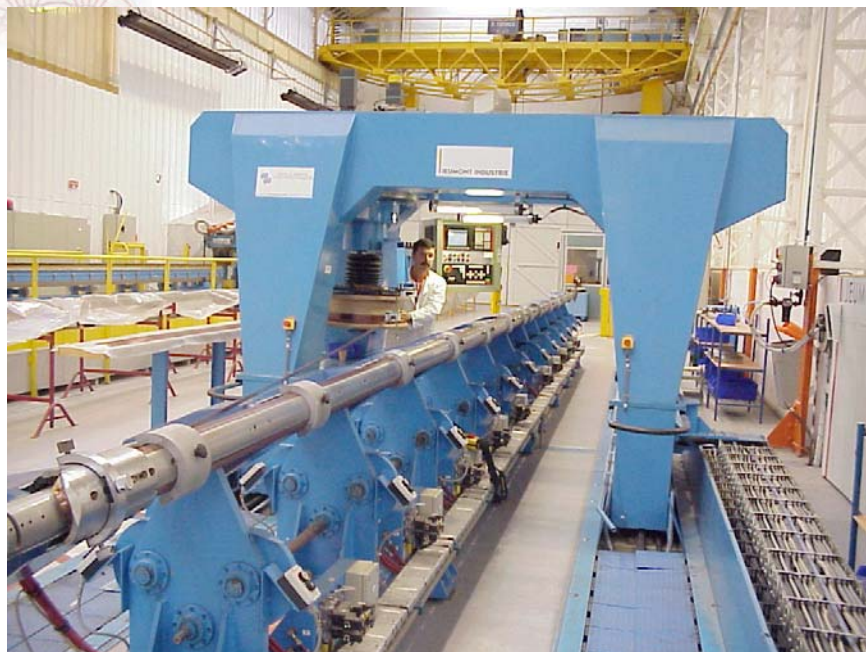


90 main industrial Contracts in the World





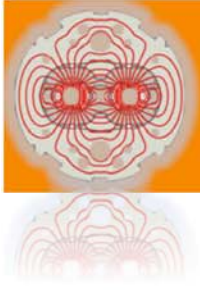
Manufacturing of superconducting Coils





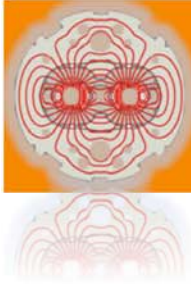
Assembly of dipole cold Masses



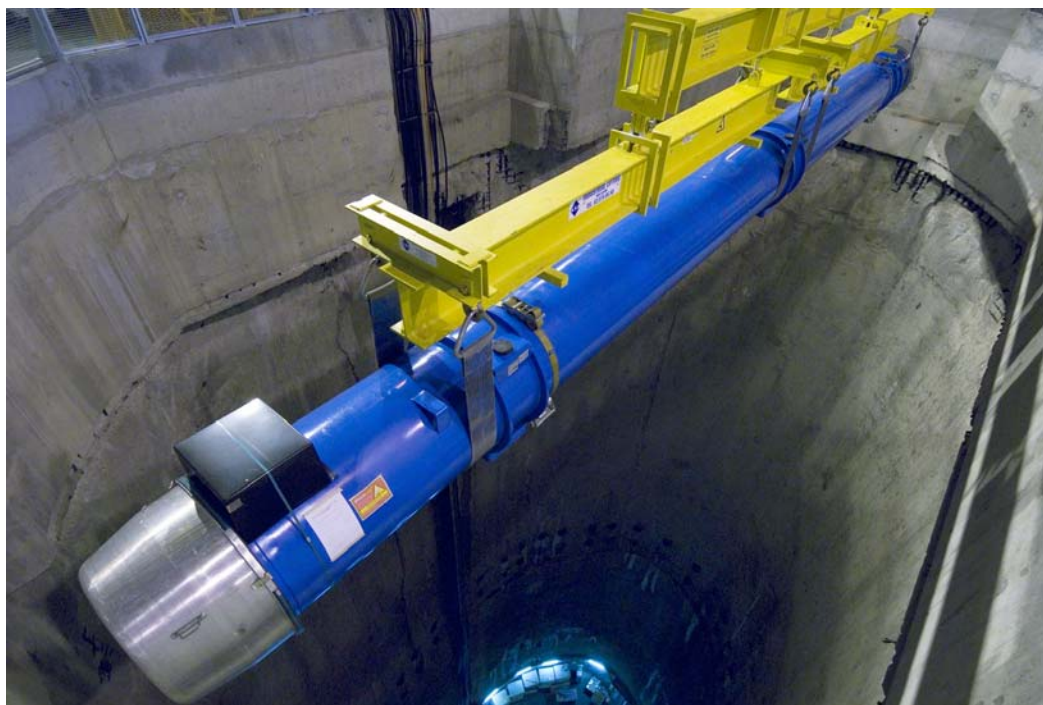


Cryogenic Test Benches





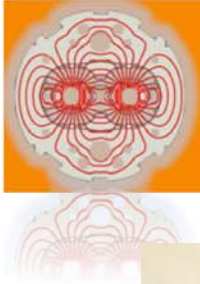
Magnet Descent into the Tunnel





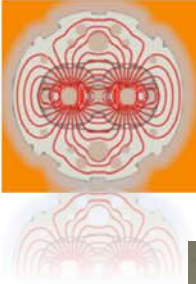
Transport in the Tunnel with an optical guided Vehicle





Transfer on Jacks





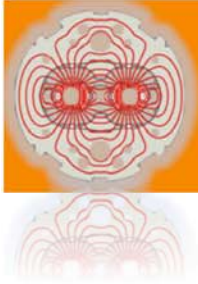
Dipole dipole Interconnect





Electrical Splice



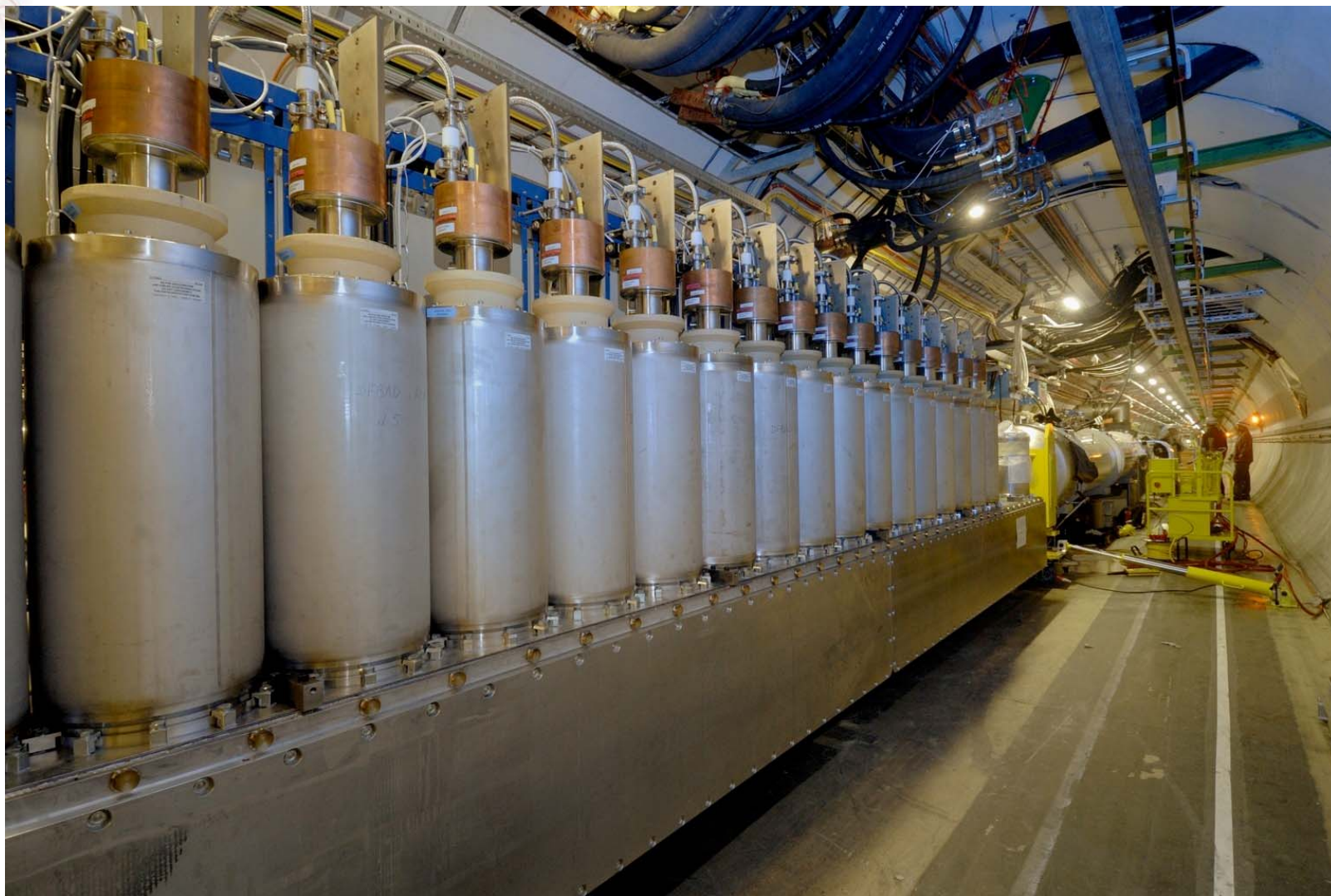


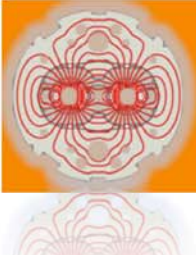
Electrical Quality Assurance in the Tunnel





DFBAO in Sector 7-8





Current Leads using HT Superconductor



	Resistive (WFL)	HTS (4 to 50 K) Resistive (> 50 K)
Heat inleak to liquid helium	1.1 W/kA	0.1 W/kA
Exergy loss	430 W/kA	150 W/kA
Electrical power of refrigerator	1430 W/kA	500 W/kA

Sum of currents into LHC ~ 1.7 MA, i.e. need current leads for 3.4 MA total rating (in and out)

Economy ~ 3400 W in liquid helium ~ 5000 l/h liquid helium

⇒ *capital: save extra cryoplant*

⇒ *operation: save ~ 3.2 MW*

13 kA HTS current lead for LHC

BSCCO
2223
tapes

Nb-Ti
wires



Luminosity Evolution 2010

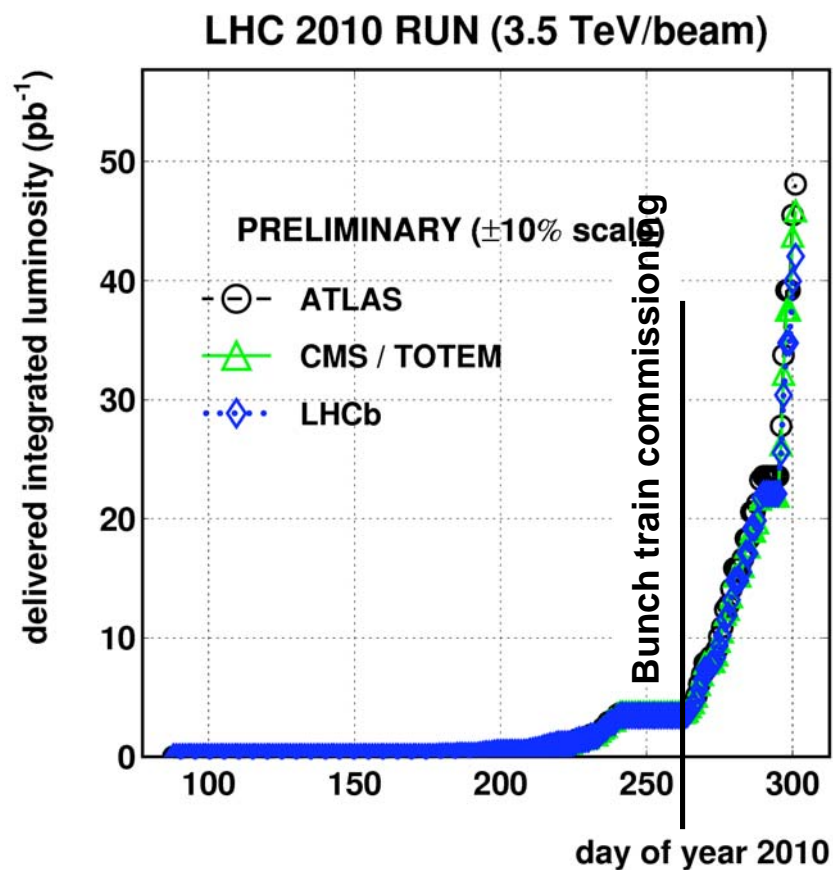
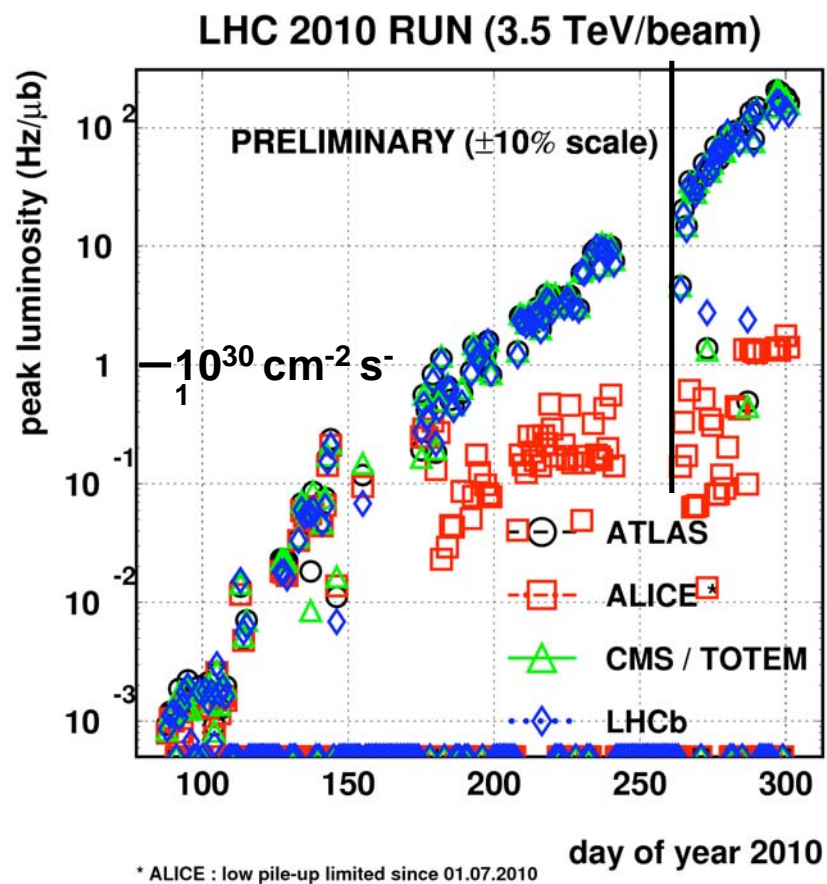


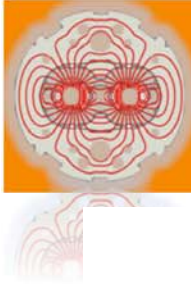
5 orders of magnitude in ~200 days

~50 pb⁻¹ delivered, half of it in the last week !

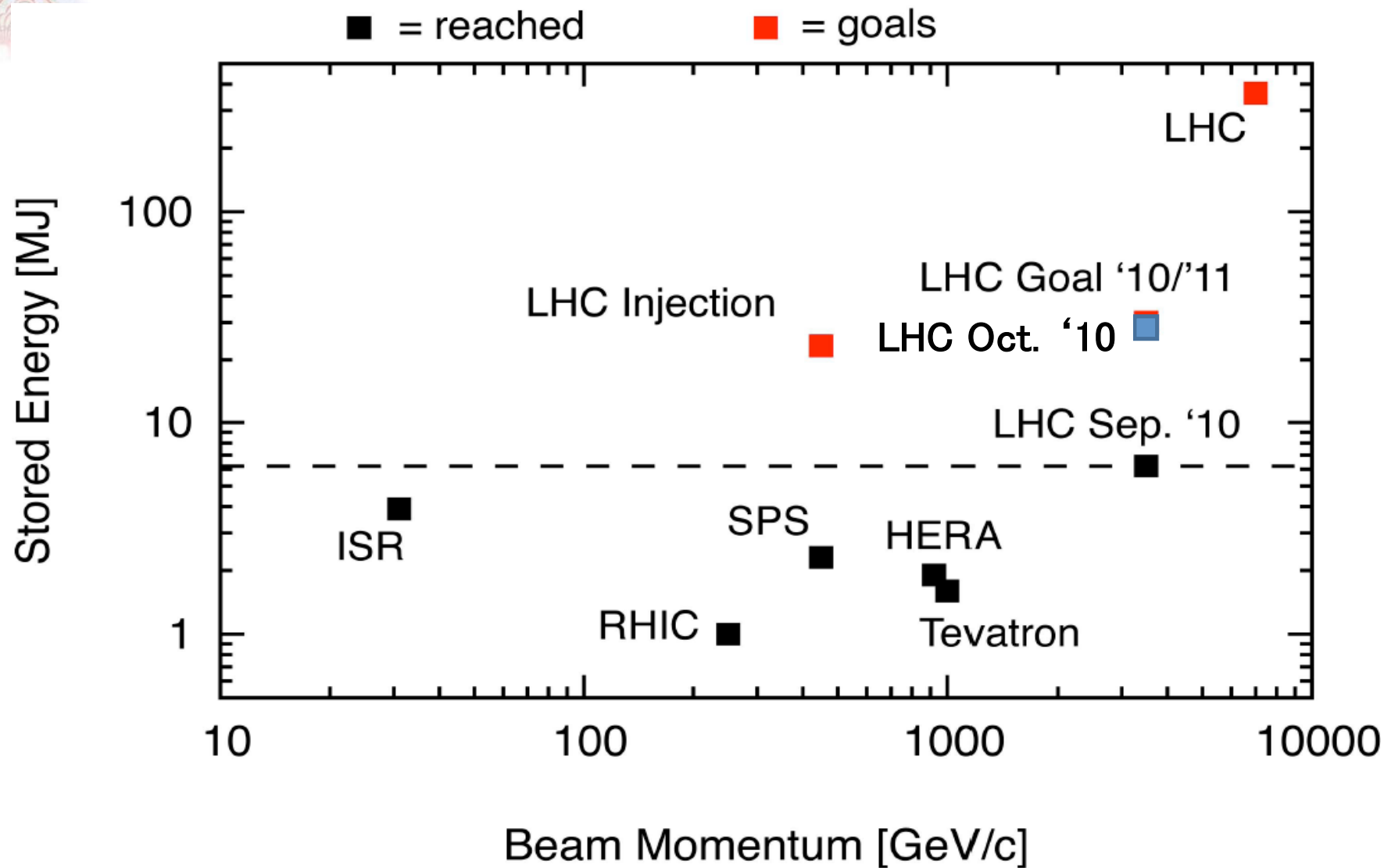
2010/10/29 15.18

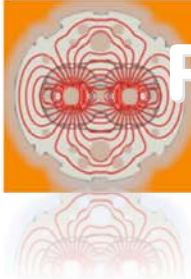
2010/10/29 15.16



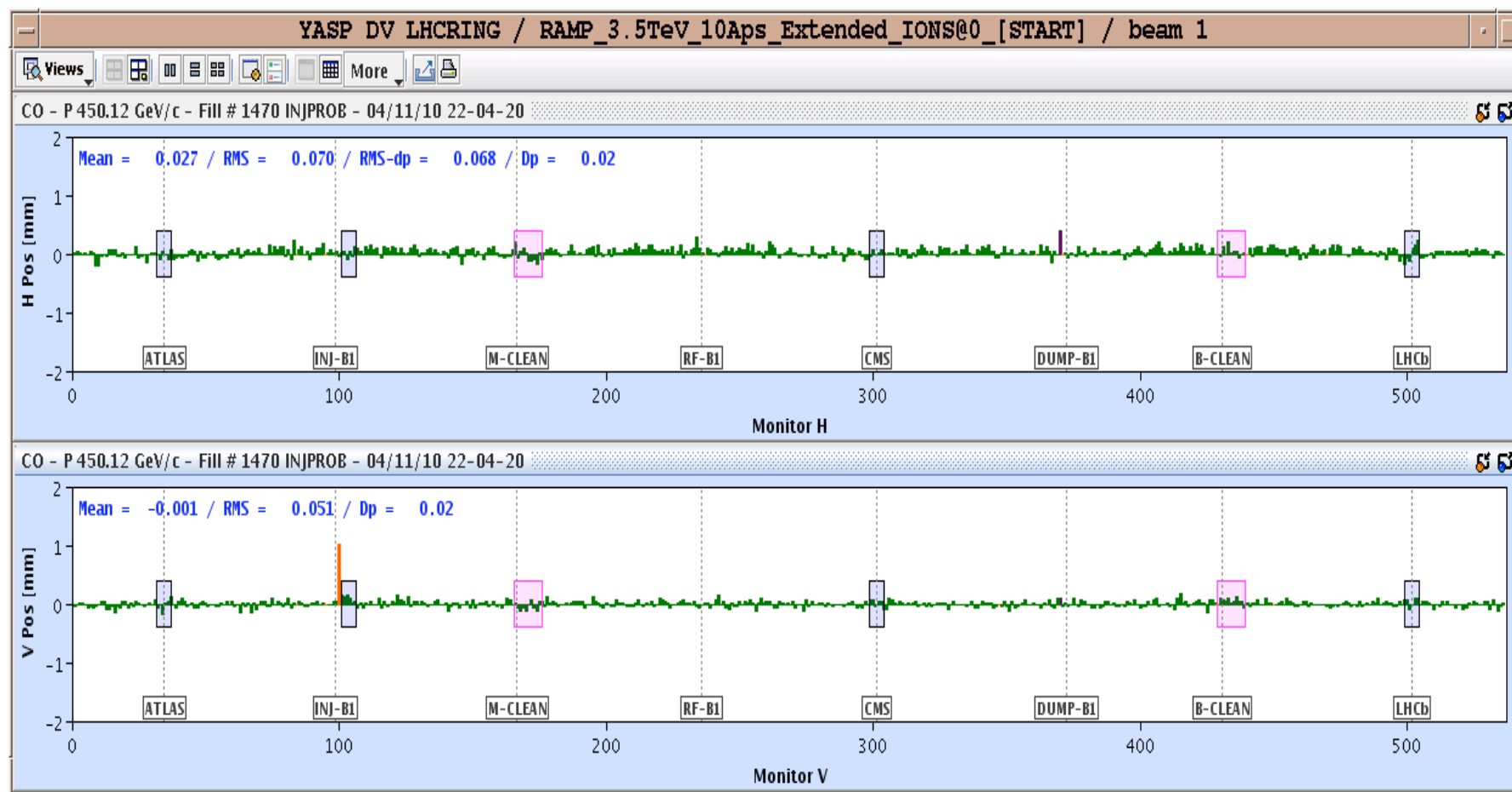


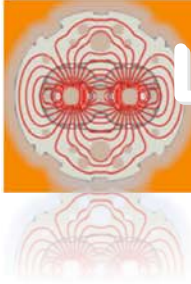
LHC now on its own in Terms of stored Energy





Pb Orbit compared to p Orbit – No Steering !



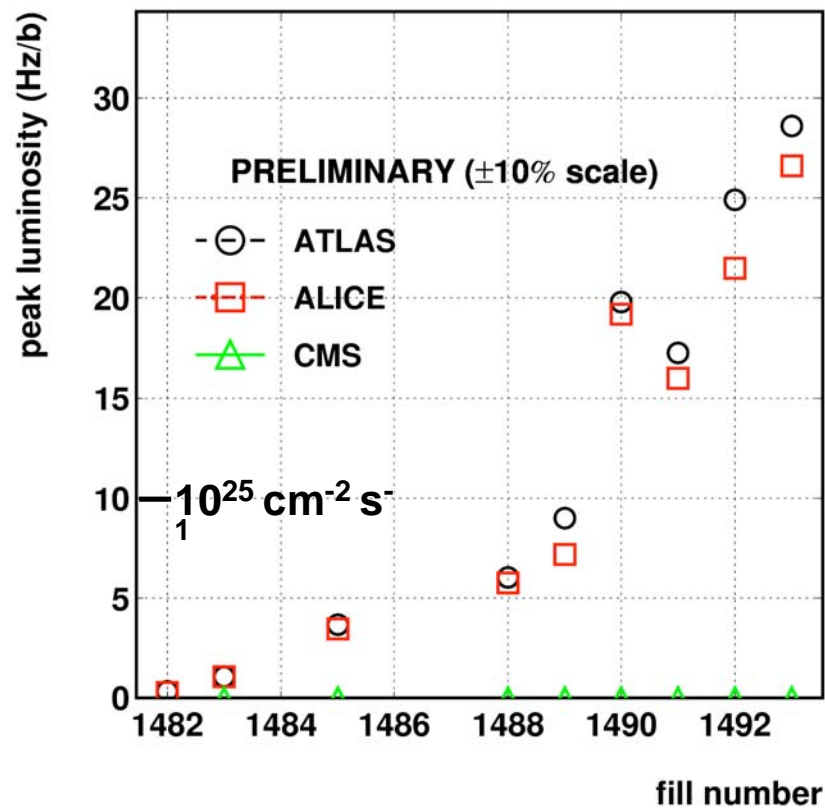


Luminosity Evolution (not quite up-to-date)



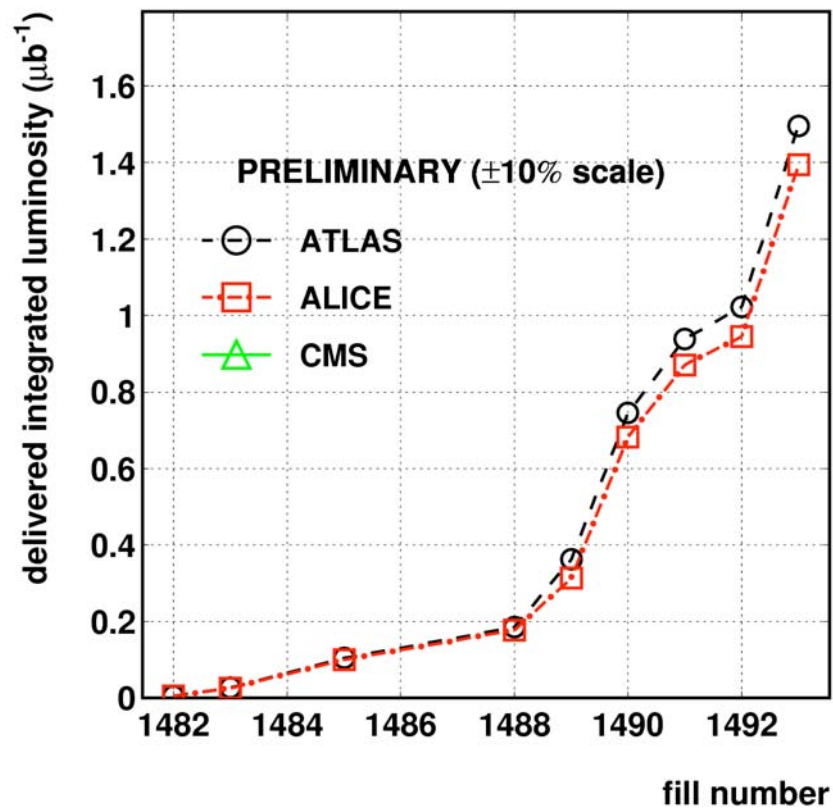
2010/11/16 08.15

LHC 2010 HI RUN (3.5 Z TeV/beam)



2010/11/16 08.15

LHC 2010 HI RUN (3.5 Z TeV/beam)





2011: “Reasonable” Numbers



- 4 TeV
- 936 bunches (75 ns)
- 3 micron emittance
- 1.2×10^{11} protons/bunch
- $\beta^* = 2.5$ m, nominal crossing angle

Peak luminosity	6.4×10^{32}
Integrated per day	11 pb ⁻¹
200 days	2.2 fb ⁻¹
Stored energy	72 MJ

Usual warnings apply – see problems, problems above