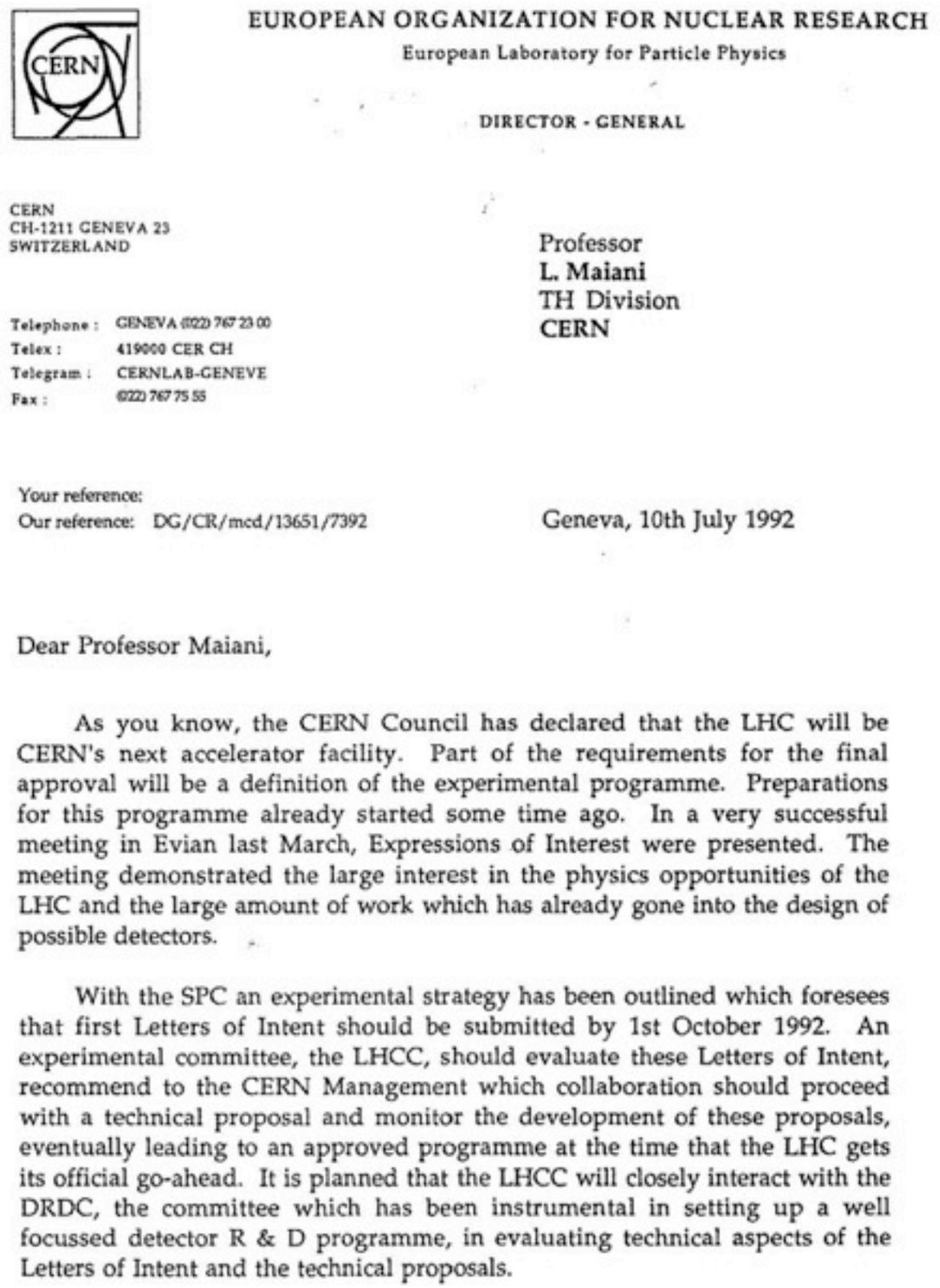
Luciano Maiani:
. Lezione Fermi 28
Esperimenti a LHC

1. La sfida dei rivelatori
2. Affollamento, fotoni, ermeticita’
3. Calcolo ad LHC
4. La scoperta del bosone di Higgs

1. La sfida dei rivelatori

- 1992.
- Marzo. Espressioni di interesse agli esperimenti con LHC presentati alla Conferenza di Evian
- Luglio. E' formata la LHC Committee, LHCC
- Ottobre. Lettere d'Intento sottoposte alla SPC
- Parte la ricerca sui rivelatori capaci di sopportare la luminosita' estrema di LHC
  - n. di collisioni = 1 Miliardo /sec
- di distinguere rapidamente i segnali interessanti (trigger)
- di misurare con precisione le caratteristiche delle migliaia di particelle che originano da ciascuna collisione
- inviare l'informazione prima dell'arrivo del prossimo pacchetto (distanziato di 25 ns)



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
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Professor
L. Maiani
TH Division
CERN

Your reference:
Our reference: DG/CR/mcd/13651/7392

Geneva, 10th July 1992

Dear Professor Maiani,

As you know, the CERN Council has declared that the LHC will be CERN's next accelerator facility. Part of the requirements for the final approval will be a definition of the experimental programme. Preparations for this programme already started some time ago. In a very successful meeting in Evian last March, Expressions of Interest were presented. The meeting demonstrated the large interest in the physics opportunities of the LHC and the large amount of work which has already gone into the design of possible detectors.

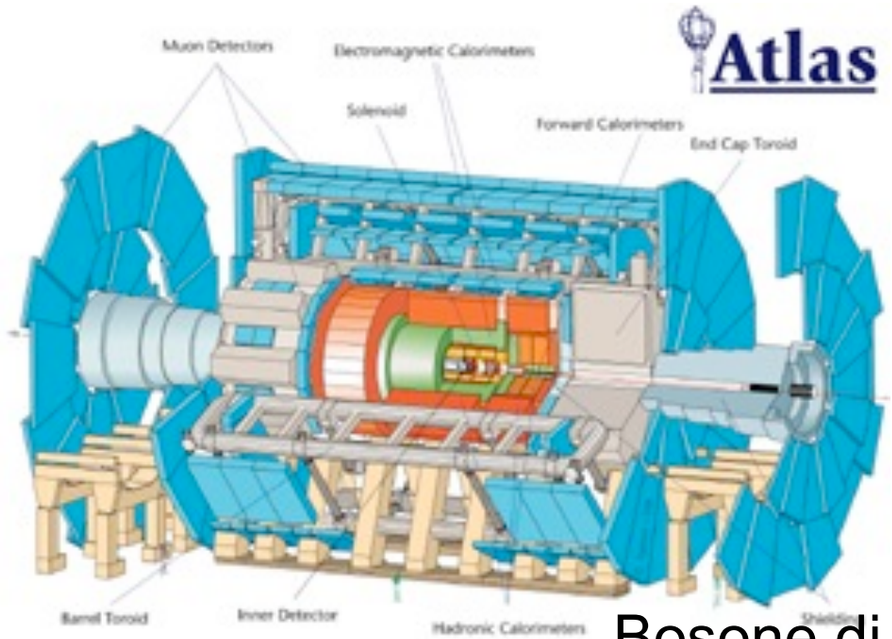
With the SPC an experimental strategy has been outlined which foresees that first Letters of Intent should be submitted by 1st October 1992. An experimental committee, the LHCC, should evaluate these Letters of Intent, recommend to the CERN Management which collaboration should proceed with a technical proposal and monitor the development of these proposals, eventually leading to an approved programme at the time that the LHC gets its official go-ahead. It is planned that the LHCC will closely interact with the DRDC, the committee which has been instrumental in setting up a well focussed detector R & D programme, in evaluating technical aspects of the Letters of Intent and the technical proposals.

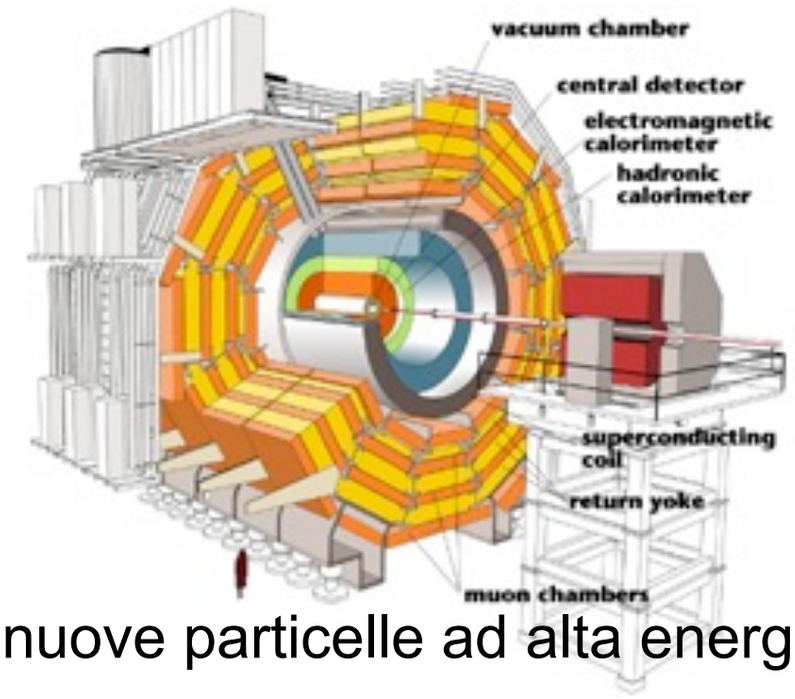
./.

sociologia

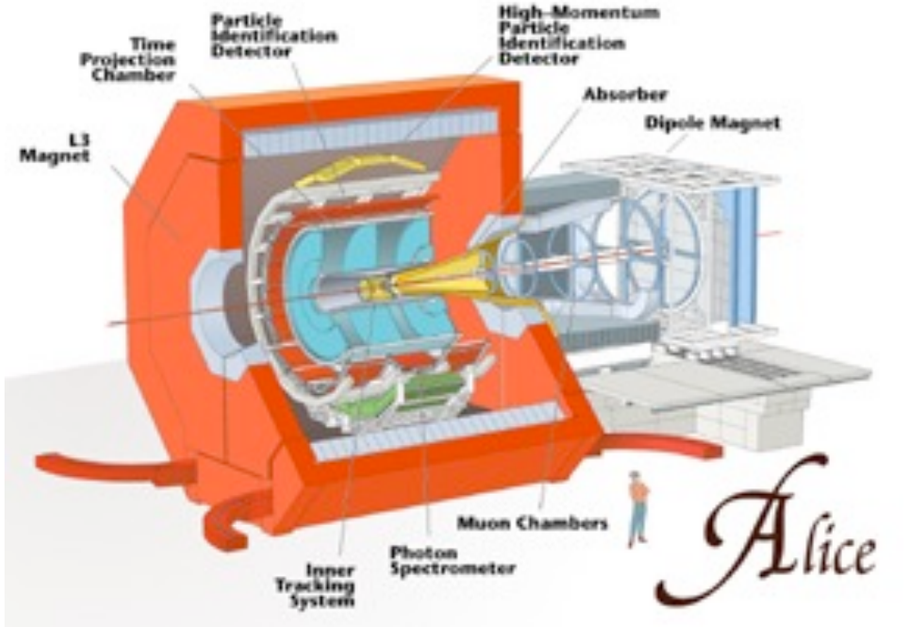
- Collaborazioni di migliaia di ricercatori e ingegneri che devono coordinarsi per la ricerca e per la costruzione delle diverse parti dei rivelatori
- ..che poi saranno integrati al CERN nel disegno complessivo: gigantesco pic-nic, Torre di Babele...you choose
- le collaborazioni includono India, Pakistan, Cina, Giapppone, Corea, Russia, Usa, Brasile, Argentina, ...

- le dimensioni dei rivelatori sono dettate dalla necessita' di assorbire e misurare l'energia sviluppata nelle collisioni:
- 14 TeV, 40 volte quella di Sp pbarS (300 GeV)
- ferro in CMS=Torre Eiffel
- peso di ATLAS=7000 ton (una nave da guerra di stazza media)

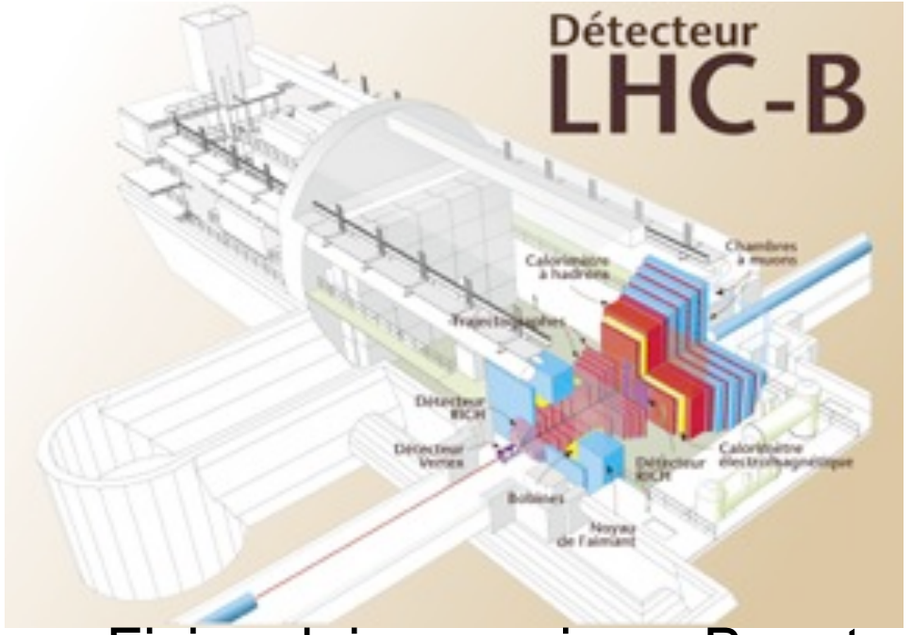




Bosone di HIggs, nuove particelle ad alta energia



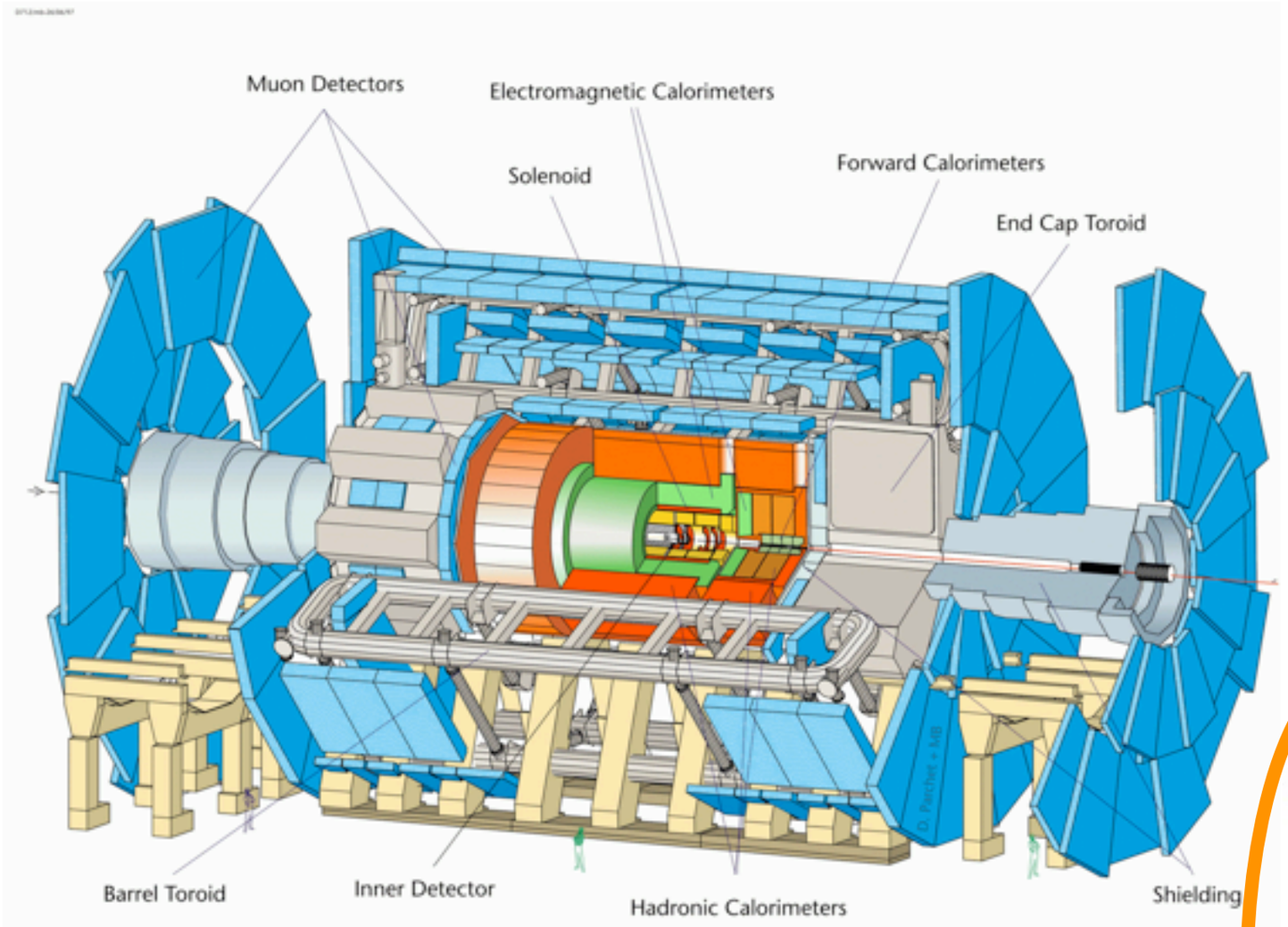
Collisioni tra ioni Pb



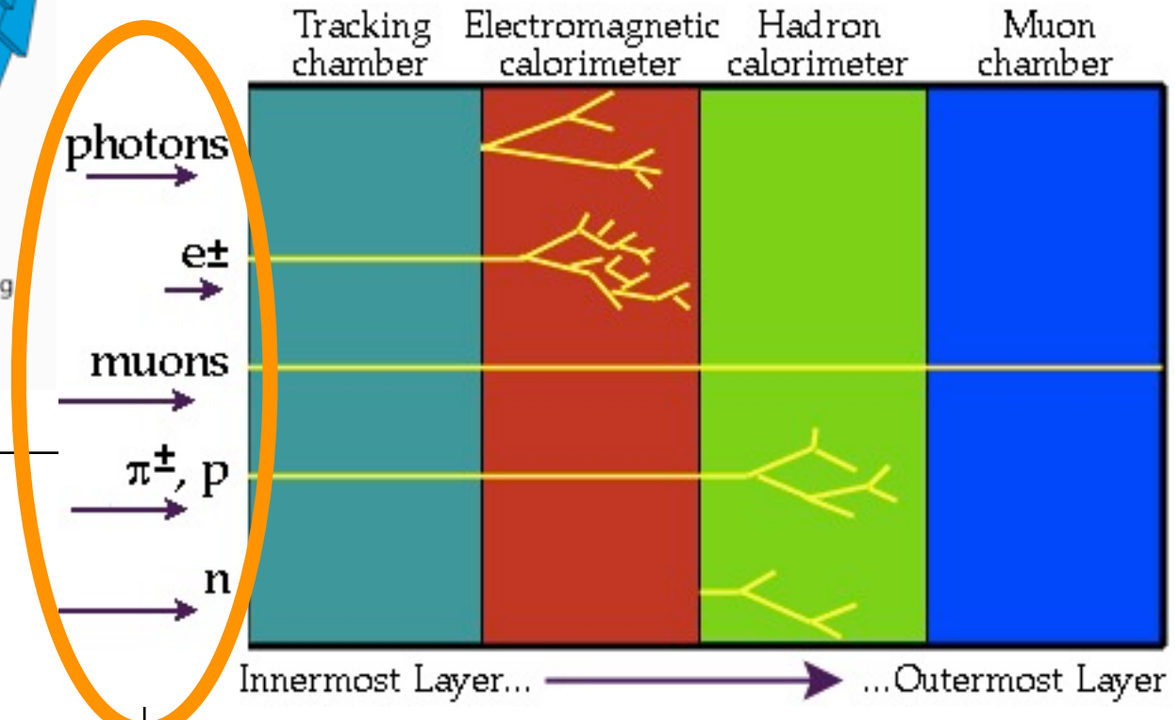
Fisica dei mesoni con Beauty

ATLAS

F. Gianotti, 2007



Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels
~ 3000 km of cables



- Inner Detector ($|\eta|<2.5$, B=2T) :
  - -- Si pixels and strips
  - -- Transition Radiation Detector (e/π separation)

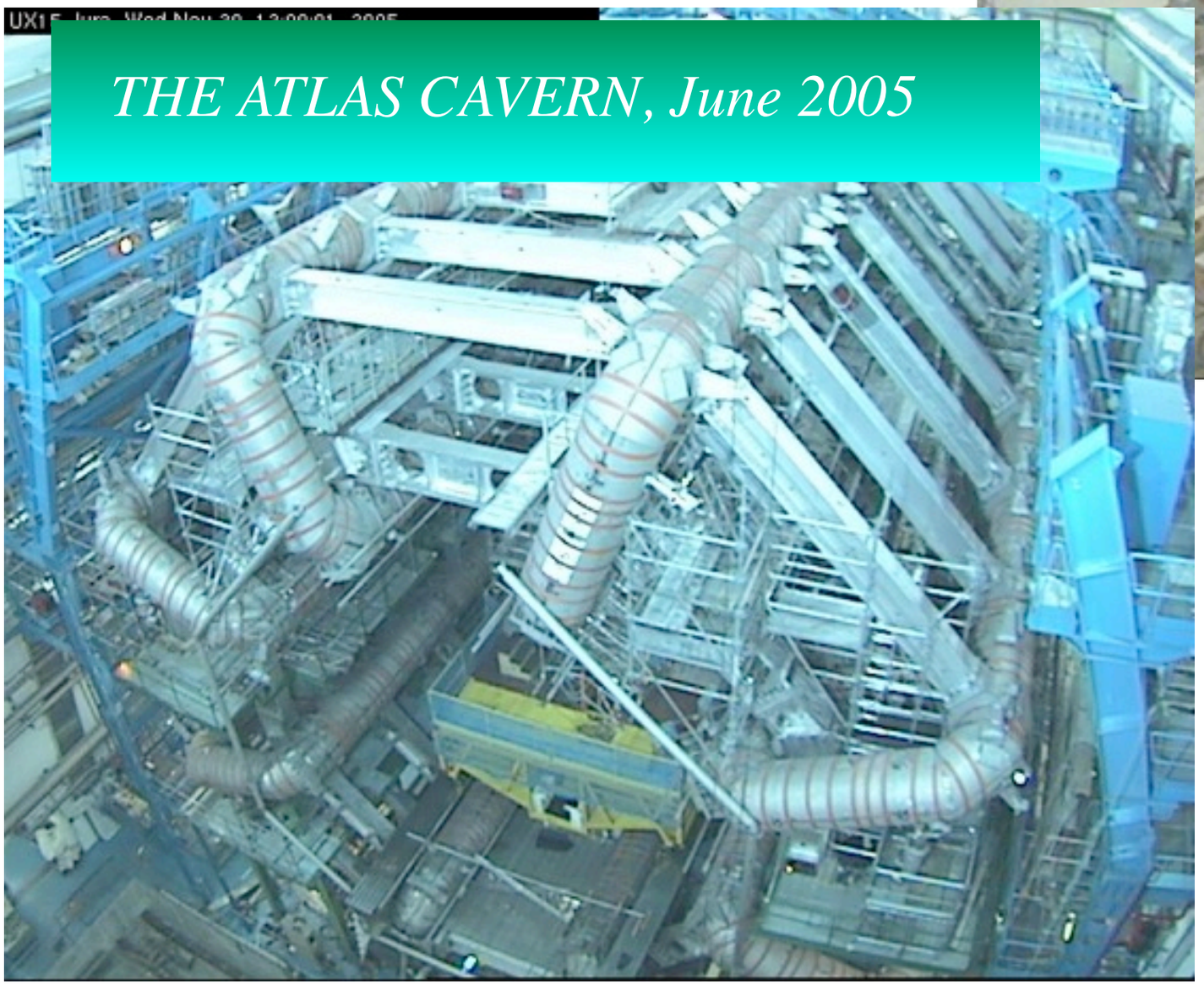
- Calorimetry ($|\eta|<5$) :
  - -- EM : Pb-LAr
  - -- HAD: Fe/scintillator (central), Cu/W-LAr (fwd)

- Muon Spectrometer ($|\eta|<2.7$) :
  air-core toroids with muon chambers

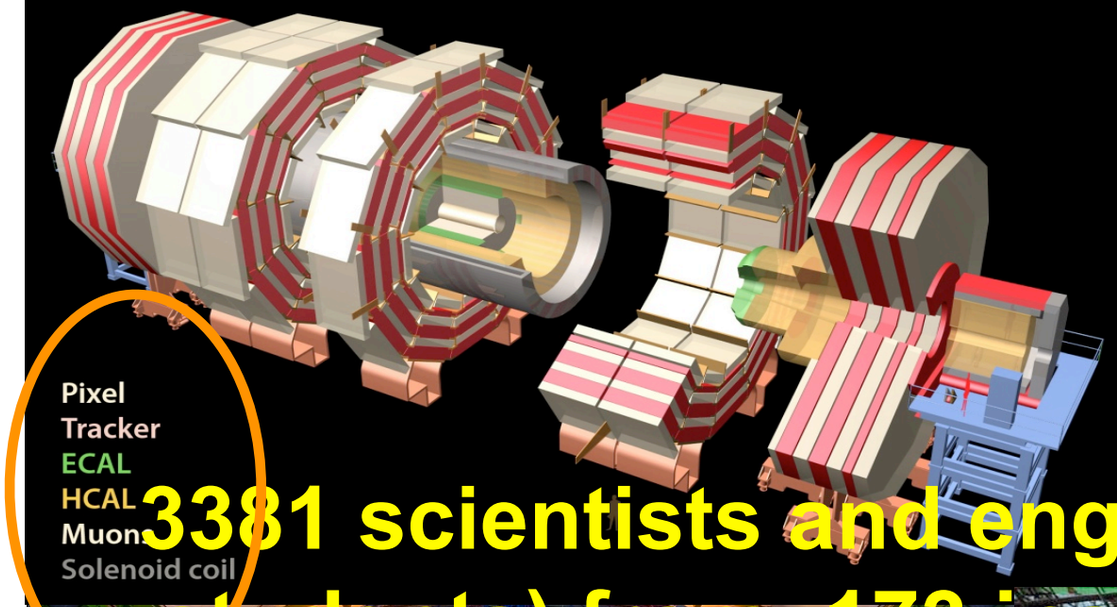
And …. 2000 physicists from
167 Institutions from 37 countries
from 5 continents

THE ATLAS CAVERN, June 2003

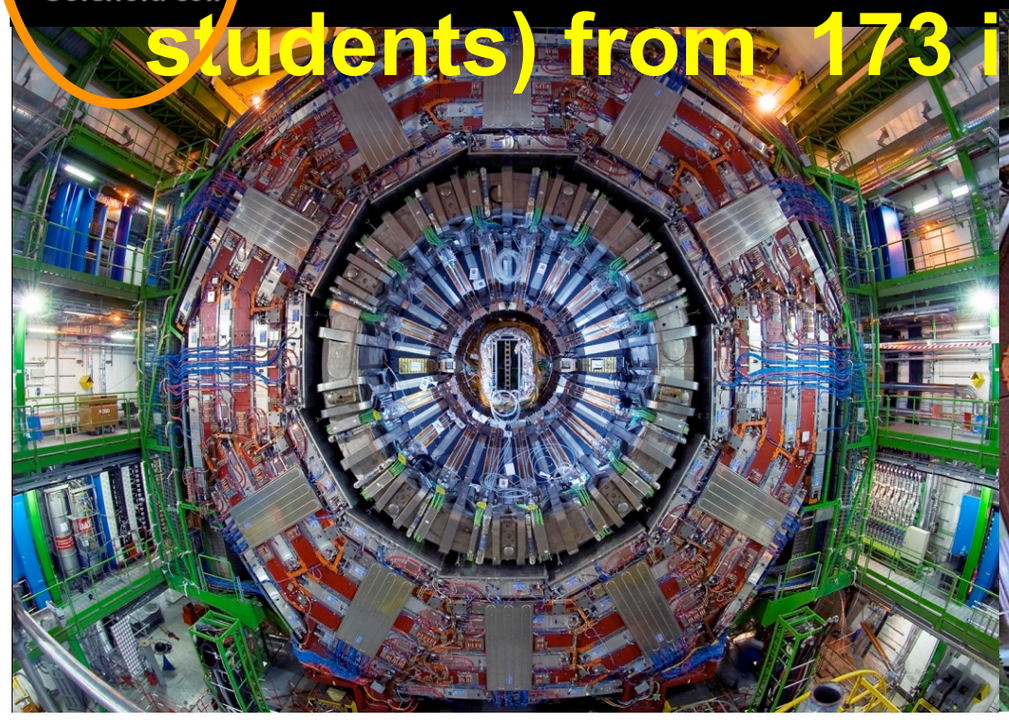
THE ATLAS CAVERN, June 2005

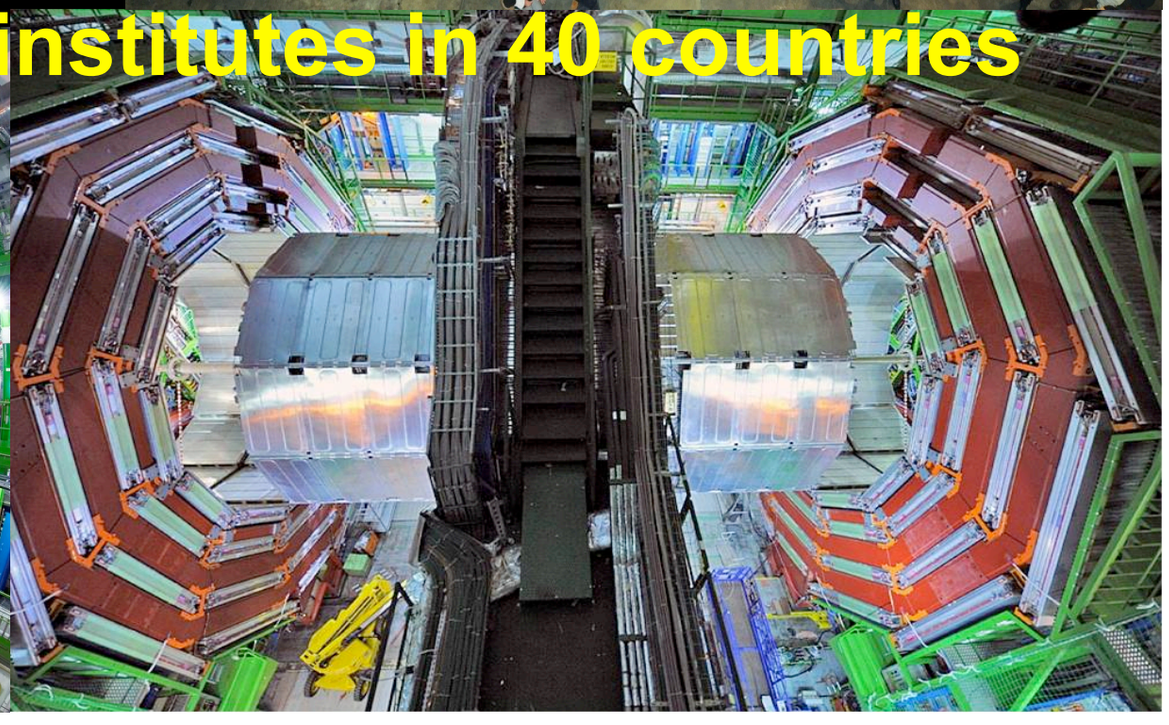


The CMS Collaboration



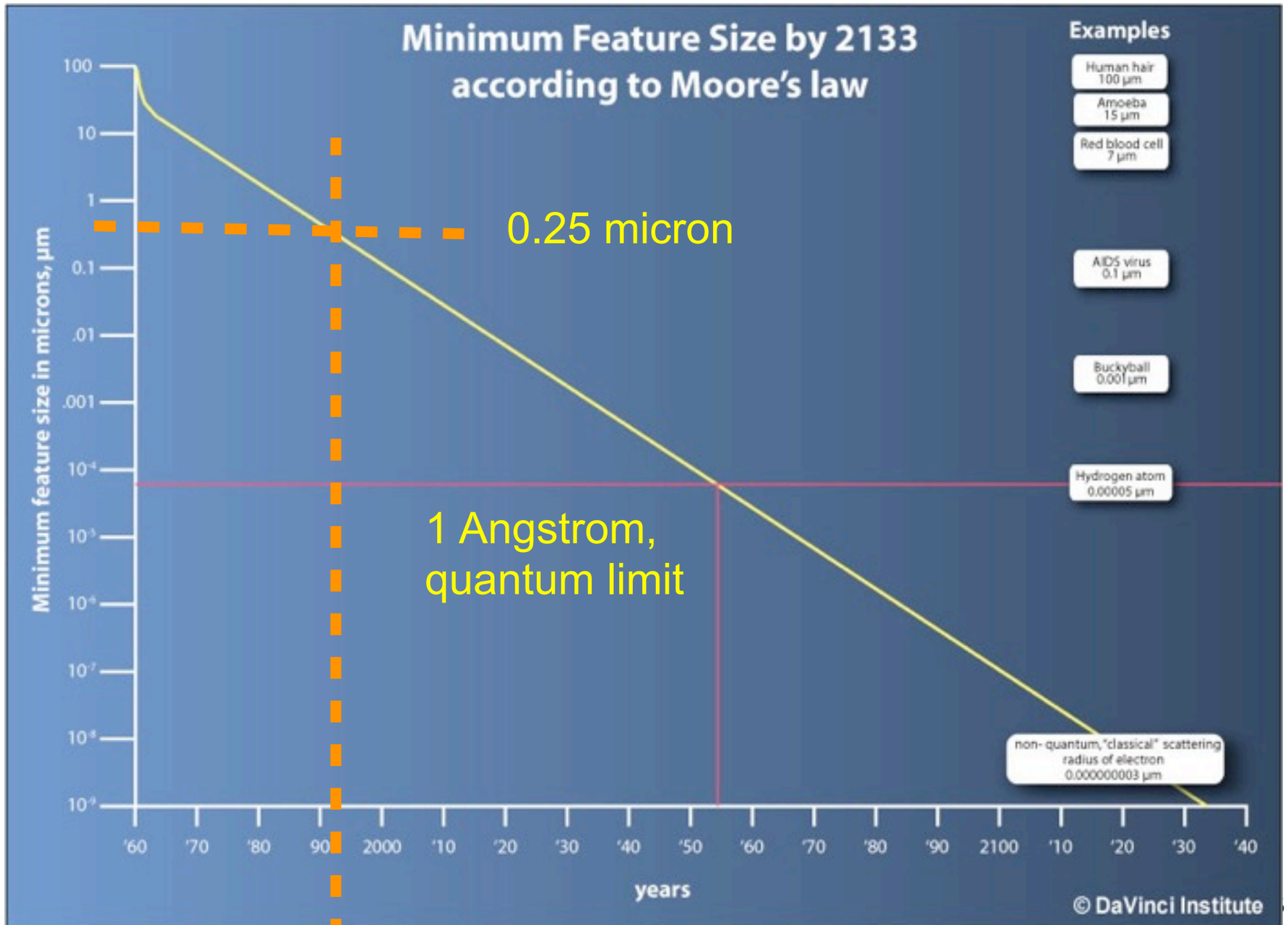
3381 scientists and engineers (including ~840 students) from 173 institutes in 40 countries





2. Affollamento

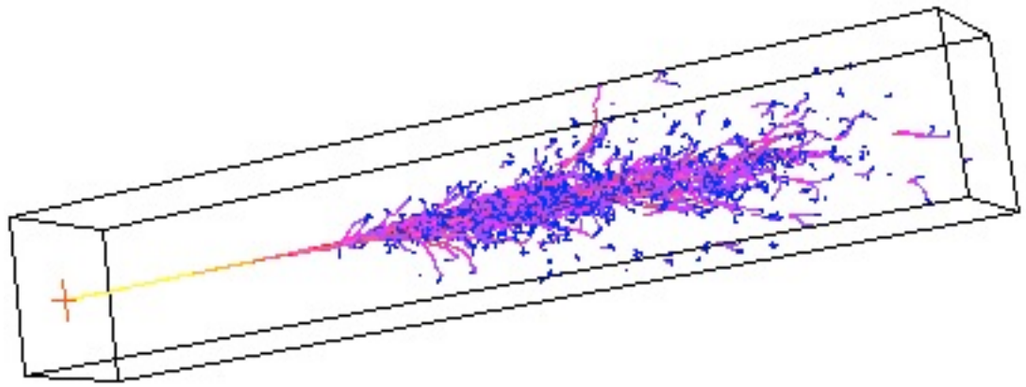
- un pixel attraversato da una particelle carica da' un segnale
- dai segnali si ricostruisce la traiettoria complessiva, ***se non ci sono piu' di una particella in ogni pixel***
- per eliminare l'affollamento bisogna ridurre la dimensione dei pixel
- la luminosita' si doma con la Legge di Moore
- LHC: 0.25 micron



- siamo ancora lontani dai limiti quantistici
- c'e' ancora spazio per il prossimo aumento di luminosita' (SLHC)

fotoni

- la ricerca del bosone di Higgs attraverso il decadimento H $\rightarrow \gamma\,\gamma$:
  - si cerca un picco nella distribuzione della massa di due fotoni
- richiede di misurare energia e momento dei fotoni con grandissima precisione, per distinguere il picco dal fondo enorme di fotoni scorrelati tra loro
- CMS: cristalli di tungstato di piombo
  - prodotti in Cina
  - montati in moduli e testati a Roma-Casaccia da un team guidato da Marcella Diemoz



The CMS electromagnetic calorimeter ("Ecal") consists of 75,848 tightly packed lead-tungstate crystals

- ATLAS: liquid argon Accordeon

Manufactured at the Orsay Laboratory near Paris.

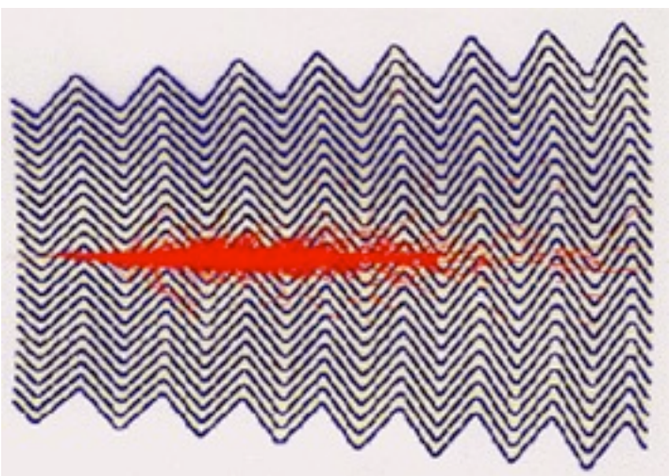
Electrodes built by Swiss firm Cicorel and folded in LAPP Laboratory, Annecy.

Forwarded to the LPNHE Laboratory in Paris or to the Milan University Physics Department to be fitted out.

Spacers, incompressible honeycomb structures like those used in the aeronautical industry, are being produced under the responsibility of Saclay.

All components brought back to CERN, Annecy or Saclay for assembly.

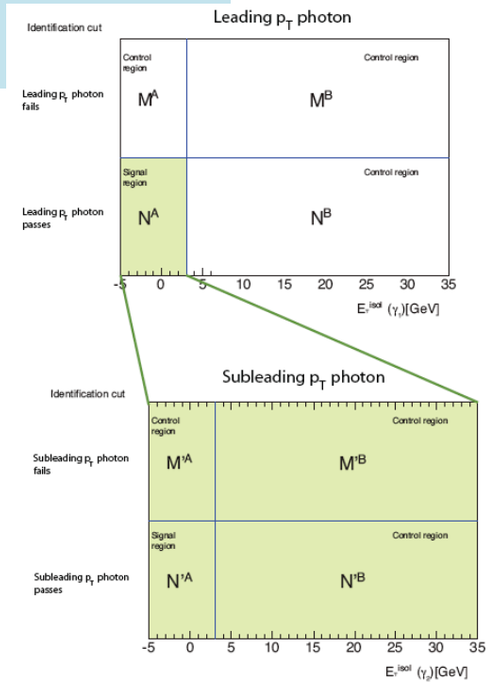
Precision required on the width of the gap between the electrode and the absorber is better than 0.1 mm over the entire 3,200-mm length of the module.

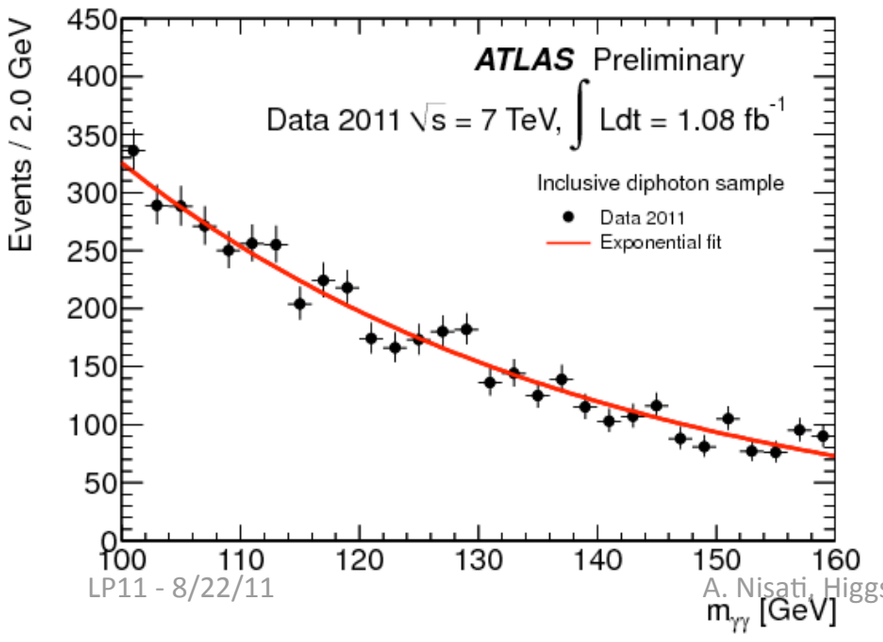


nel 2011 non si vedeva niente....

H→γγ – results

- Measure the SM background using control samples
  - analyze photon isolation and identification criteria (loose-tight) to extract the γγ, γj, and jj components
- Perform the analysis of the data classifying the events in 5 categories
  - these are based on the direction of the photons in η and on whether they are converted-unconverted



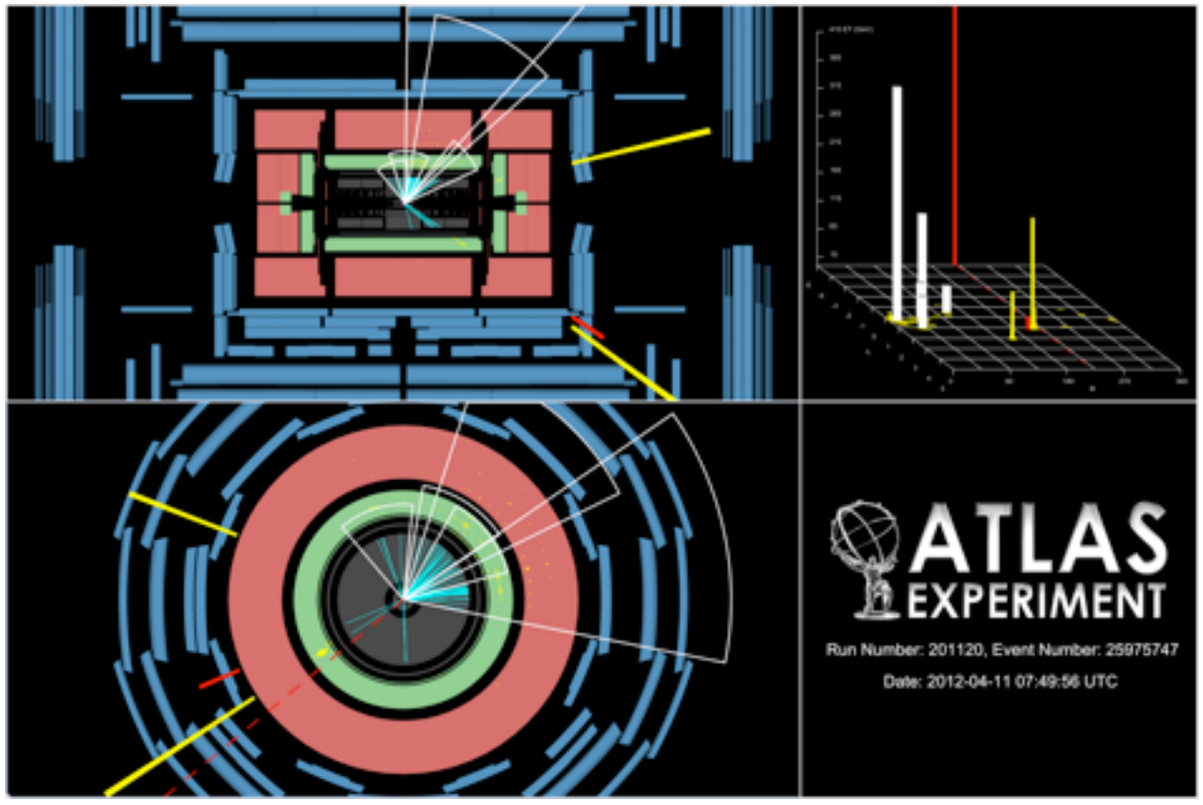


- Fit the data in each category with an exponential falling distribution plus a crystal-ball function to describe the signal
- No indication of a significant excess is found
- ➔ limits on SM Higgs production cross-section are set

ermeticita’

- particelle pesanti (bosone di Higgs, particelle SUSY, mini black holes) sono prodotte quasi in quiete e decadono emettendo particelle a grandi angoli
- questa zona deve essere coperta ermeticamente dai rivelatori, con misura dell’ energia e del momento di tute le particelle visibili
- eventi con sbilanciamento nel momento trasverso indicano la presenza di neutrini (ad esempio perche’ la particella decade in W, seguito da: $W \rightarrow \mu\, \nu$)

Event display for run 201120 event 25975747. This event was selected by the MIS and WP2 selections. Reconstructed tracks are displayed only if their transverse momentum is greater than 2.5 GeV.
The E_T of the two leading photons was measured to be 197 and 84 GeV, while E_T^miss was measured to be 478 GeV. The event has five reconstructed jets with p_T > 30 GeV.



4. Calcolo ad LHC

- quantita' enorme di dati da analizzare
- storing facility al CERN: sarebbe un gigantesco ingorgo informatico

Computing and communication perspectives at the LHC

- The data volume transmitted during **ONE SECOND** of LHC running, through the readout network, is equivalent to:
  - the amount of information exchanged by **WORLD TELECOM** (≈ 100 million phone calls) …. or,
  - the data exchanged by the **WORLD WIDE WEB** in Jan 2000.

… However in Jan 2001 it will be only 1/10 of WWW traffic

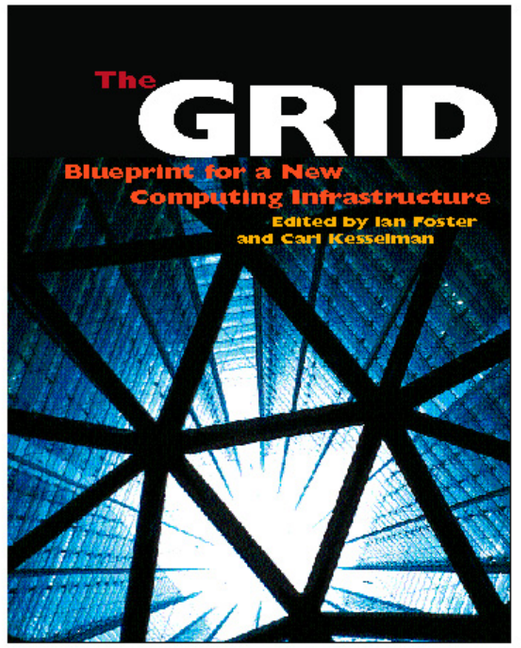
13/09/2000 Luciano MAIANI.CERN 19

DATA GRID

- LHC Data Grid: un concetto rivoluzionario
  - dati distribuiti in centri (Tier 1) in diversi paesi
  - la rete, LHC Grid, li distribuisce a richiesta agli utenti sparsi nel globo, come fa la rete dell' energia elettrica
  - l'utente NON possiede i dati e NON possiede i programmi di calcolo
  - e' stato necessario eleborare l'informatica per rendere disponibili dati e programmi di calcolo agli utenti (Progetto EGEE)

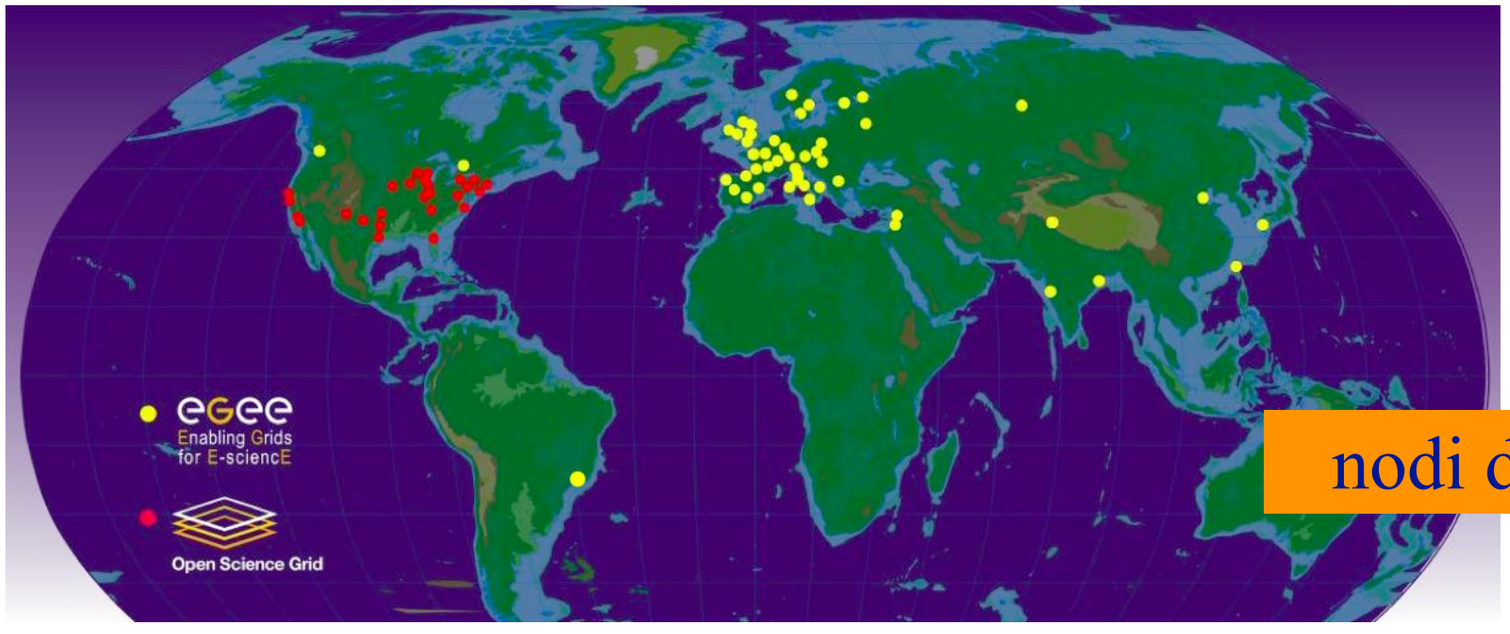
Five Emerging Models of Networked Computing From *The Grid*

- Distributed Computing
  - // synchronous processing
- High-Throughput Computing
  - // asynchronous processing
- On-Demand Computing
  - // dynamic resources
- Data-Intensive Computing
  - // databases
- Collaborative Computing
  - // scientists



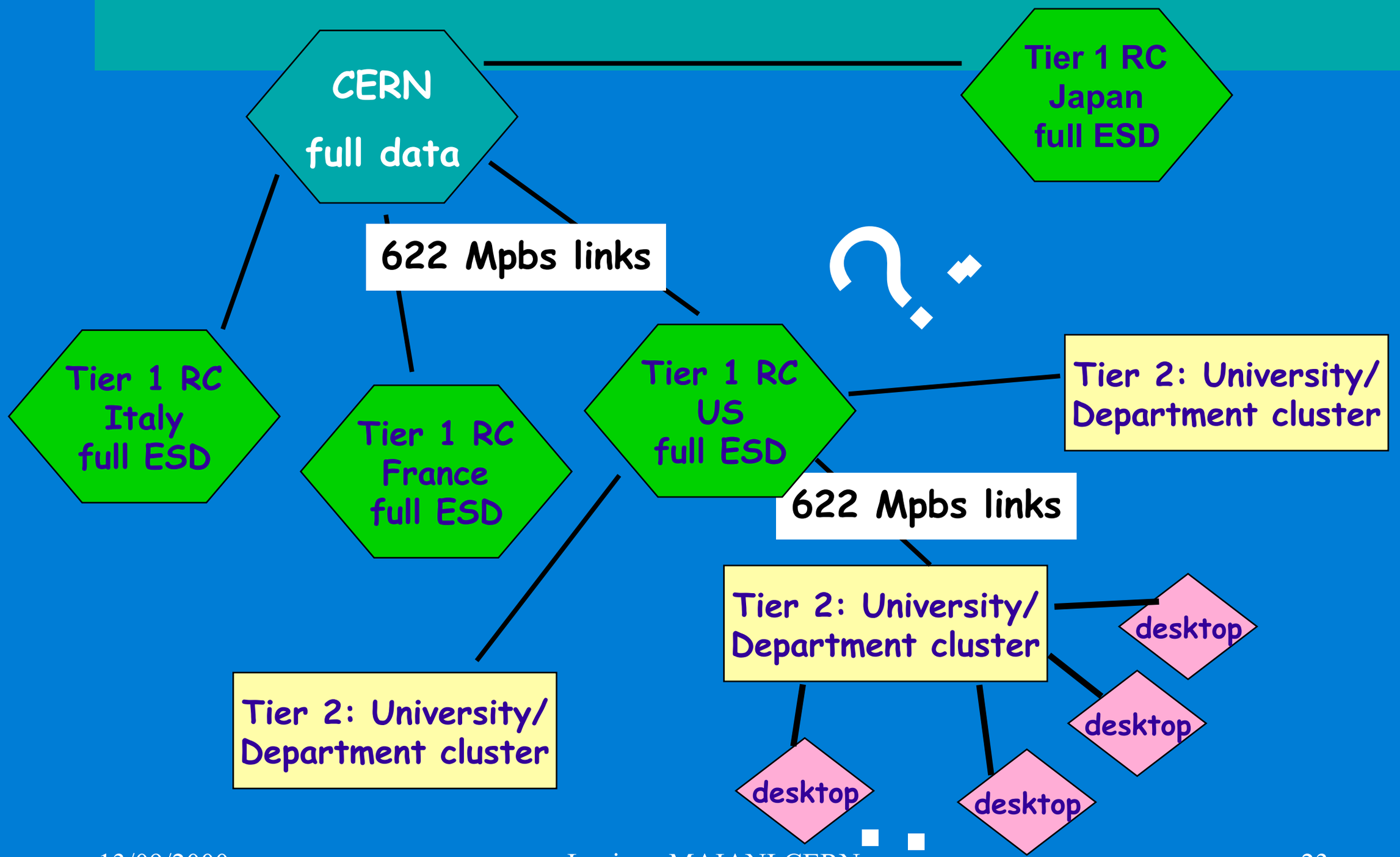
Ian Foster and Carl Kesselman, editors, "The Grid: Blueprint for a New Computing Infrastructure," Morgan Kaufmann, 1999, http://www.mkp.com/grids

13/09/2000 Luciano MAIANI.CERN 22



nodi di LHC Grid

CERN offline computing
Regional Centres - a Multi-Tier Model



CERN
openlab for DataGrid Applications

You make it,
we break it.

CERN COURIER

Apr 27, 2012

The openlab adventure continues to thrive

As the CERN openlab enters its second decade, François Fluckiger offers a personal account and some of his own recollections of how this bold initiative began and went on to thrive.

Résumé

L'aventure CERN openlab continue

Au printemps 2001, Manuel Delfino, Chef de la Division IT, convoque François Fluckiger et lui présente une idée absolument novatrice, et pourtant limpide : un modèle ambitieux de partenariats nouveaux, de longue durée, utilisant tous un cadre commun, avec les géants industriels de l'informatique. Il lui demande de s'en occuper. Manuel écrit directement aux présidents des entreprises, leur donnant six semaines pour devenir membres fondateurs. Et cela fonctionne. L'openlab est né ! Dans cet article, François Fluckiger, qui a quitté le projet en ce début d'année, apporte un témoignage sur la naissance étonnante et les étapes majeures de cette entreprise unique.

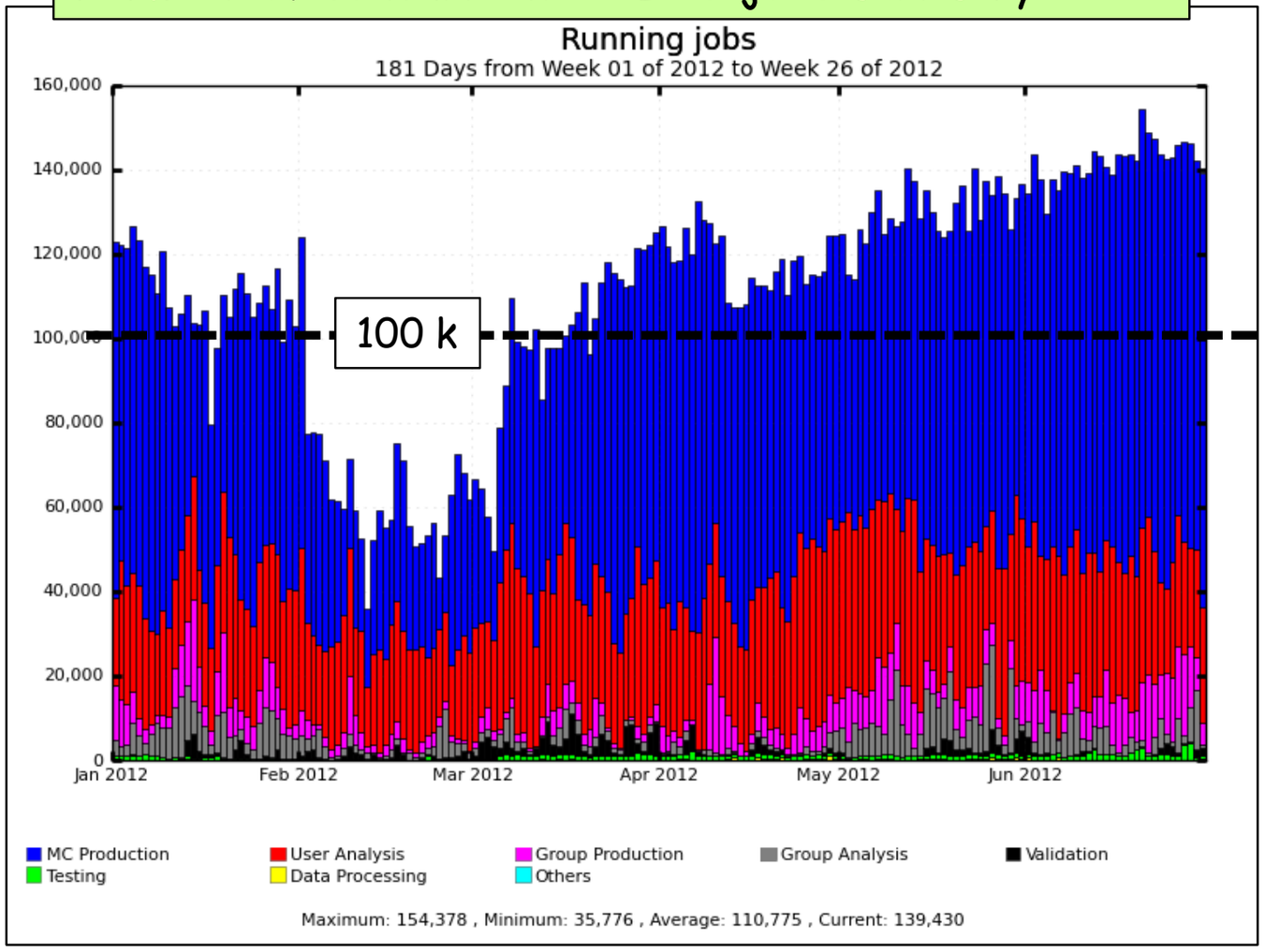
Accordo CERN-Intel

Delfino, Maiani (http://images.iop.org/objects/ccr/cern/52/4/21/CCope2_04_12.jpg)

GRID al lavoro

It would have been impossible to release physics results so quickly without the outstanding performance of the Grid (including the CERN Tier-0)

Number of concurrent ATLAS jobs Jan-July 2012



Includes MC production, user and group analysis at CERN, 10 Tier1-s, ~ 70 Tier-2 federations → > 80 sites

> 1500 distinct ATLAS users do analysis on the GRID

- Available resources fully used/stressed (beyond pledges in some cases)
- Massive production of 8 TeV Monte Carlo samples
- Very effective and flexible Computing Model and Operation team → accommodate high trigger rates and pile-up, intense MC simulation, analysis demands from worldwide users (through e.g. dynamic data placement)

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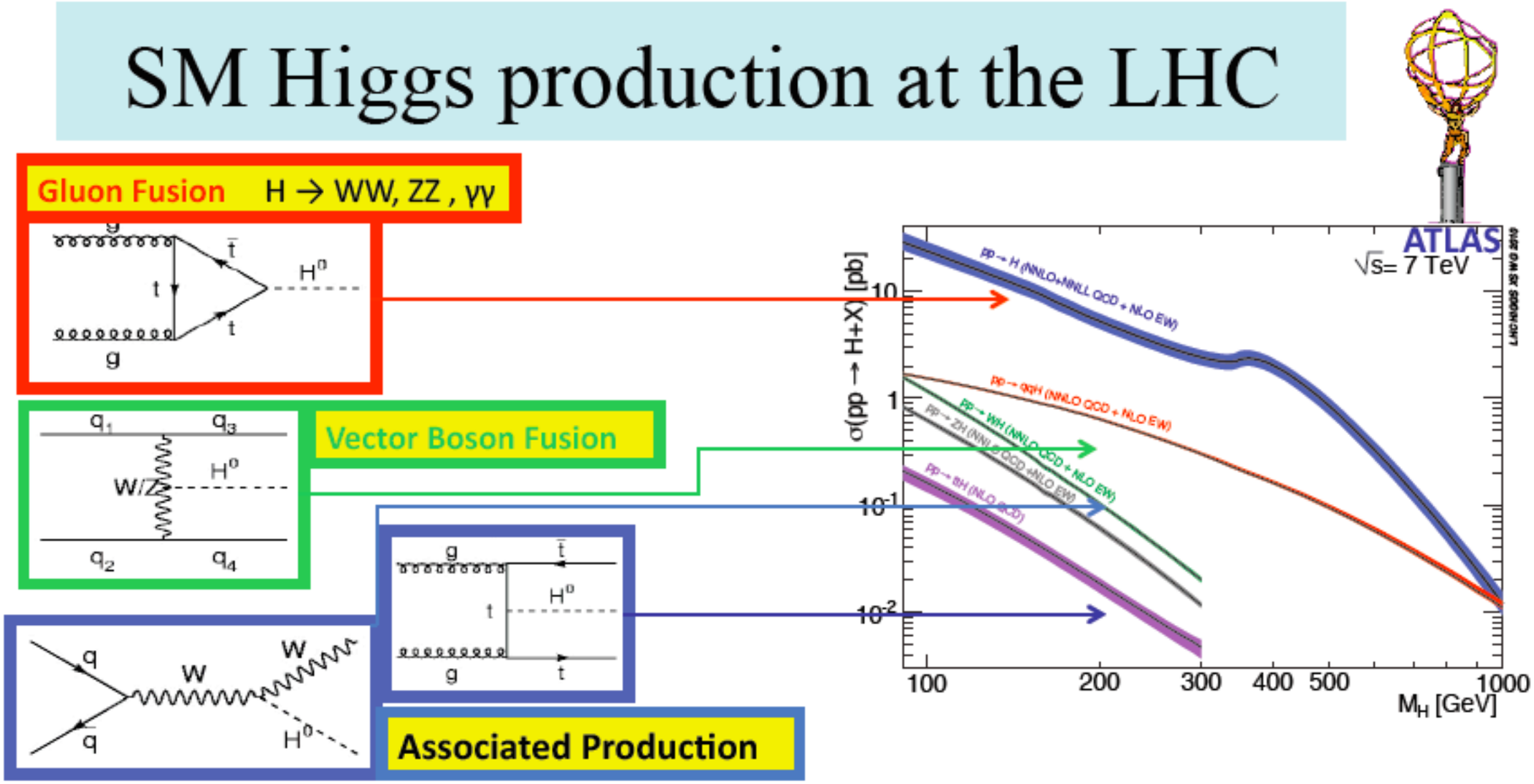
5. la scoperta del bosone di Higgs

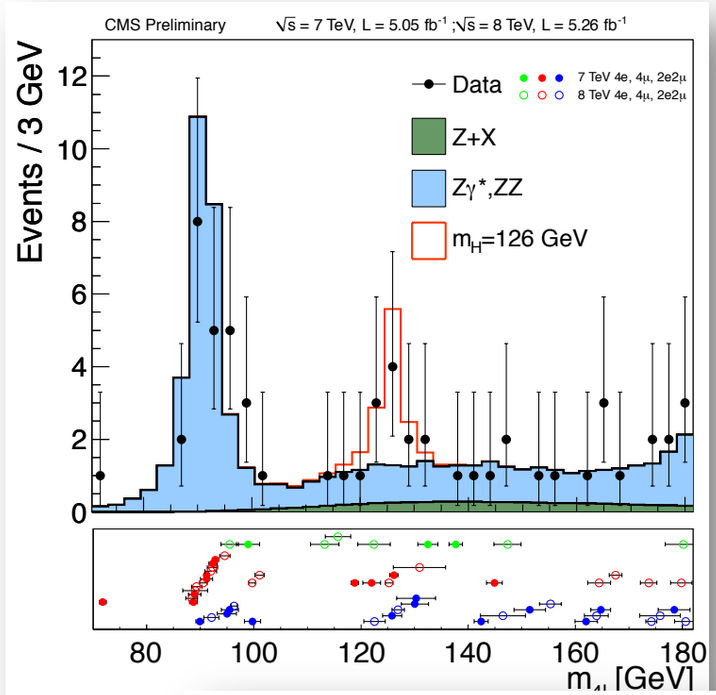
SM Higgs production at the LHC

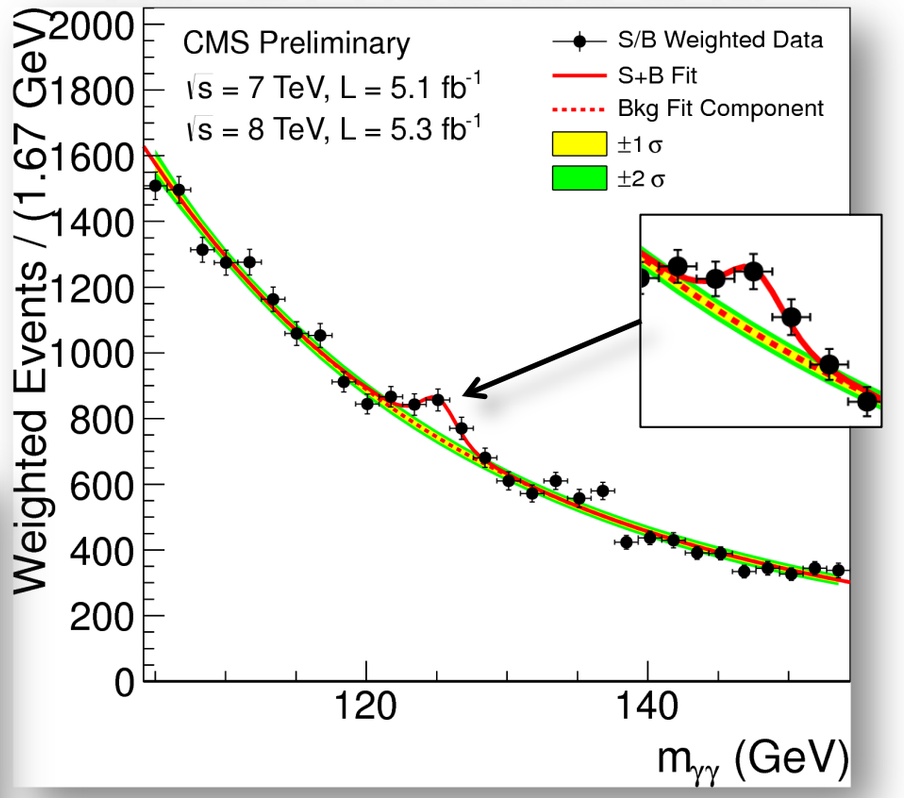


- Gluon fusion is the dominant mechanism for Higgs production at present hadron colliders
  - At LHC this is x10 higher than at Tevatron!
- Associated production is also important: qqH, VH, ttH

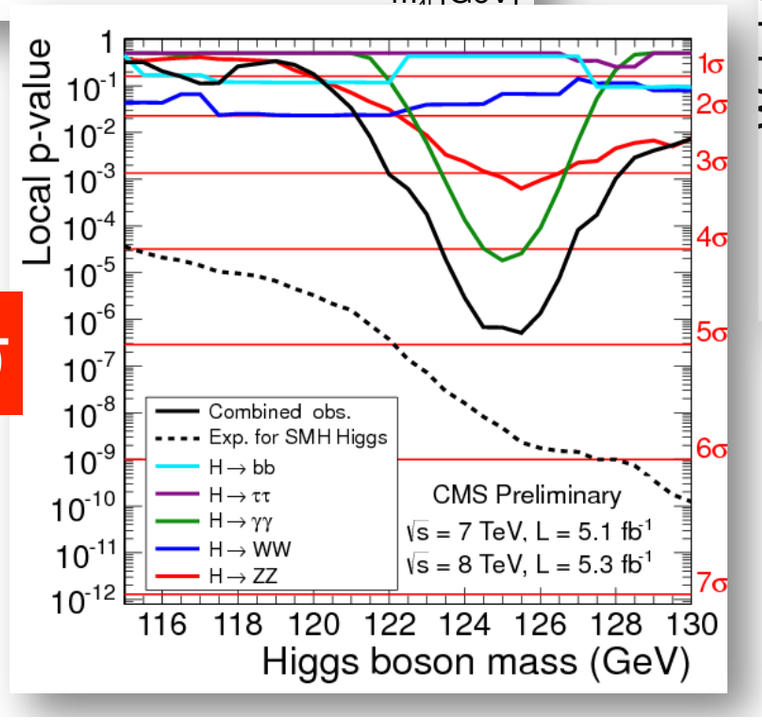
CERN-4 luglio 2012

In summary



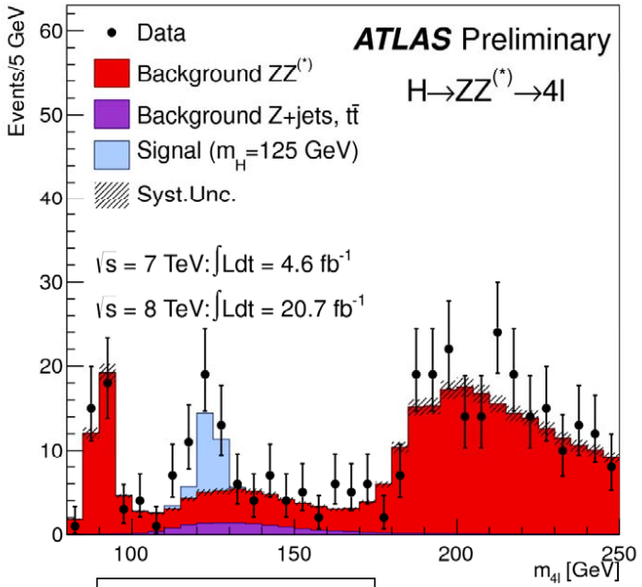


5σ



$H \rightarrow ZZ^{(*)} \rightarrow 4l$ (4e, 4μ, 2e2μ)

- Rare process, small cross section: σ ~ 2-5 fb
- However: pure: S/B ~ 1
- 4 leptons:
- Main background: $ZZ^{(*)}$ (irreducible)
  In addition: Zbb, Z+jets, tt with two leptons from b-quarks or jets



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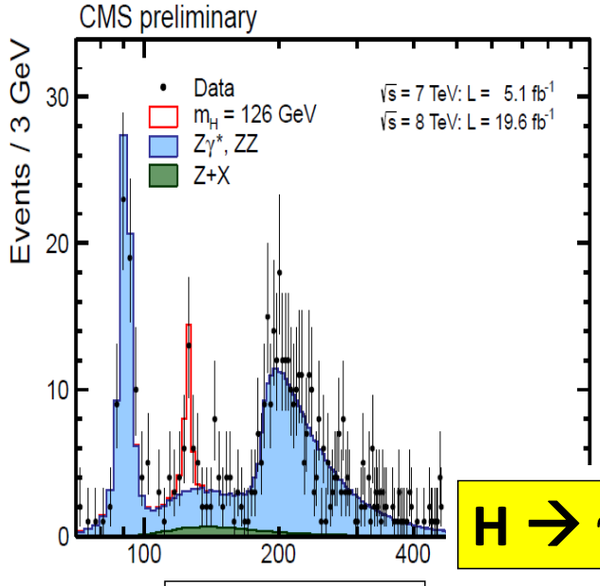
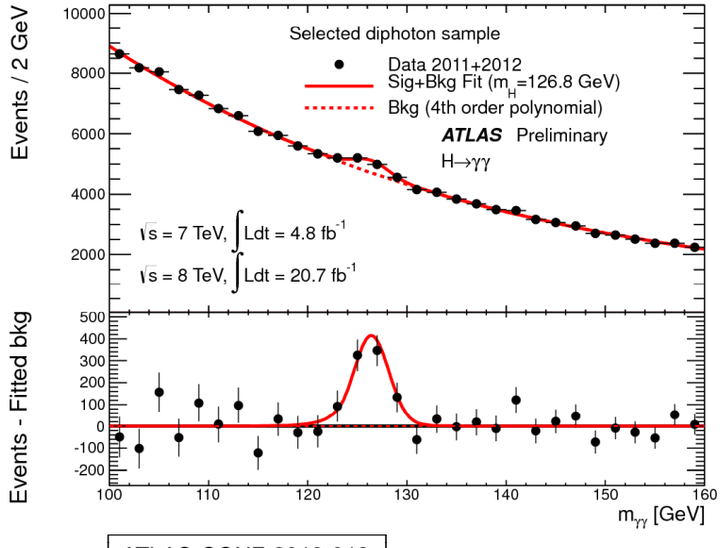


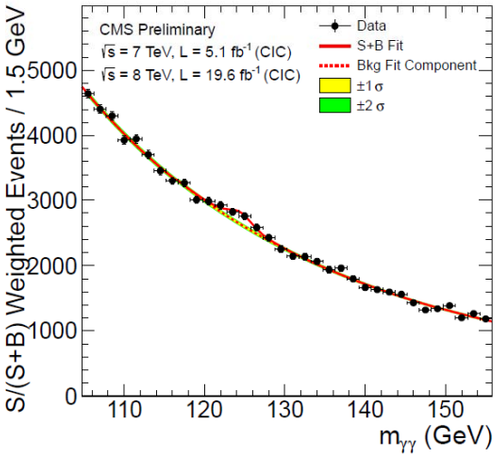
CMS-PAS-HIG-13-002

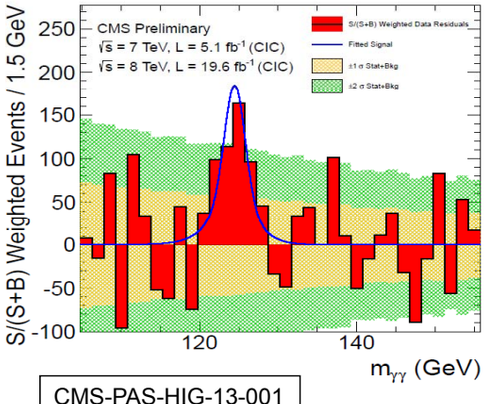
$H \rightarrow \gamma\gamma$

- Small cross-section: σ ~ 40 fb
- Expected S/B ~ 0.02
- Simple final state: two high-p_T isolated photons
- Main background: γγ continuum (irreducible)
  and fake γ from γj and jj events (reducible)



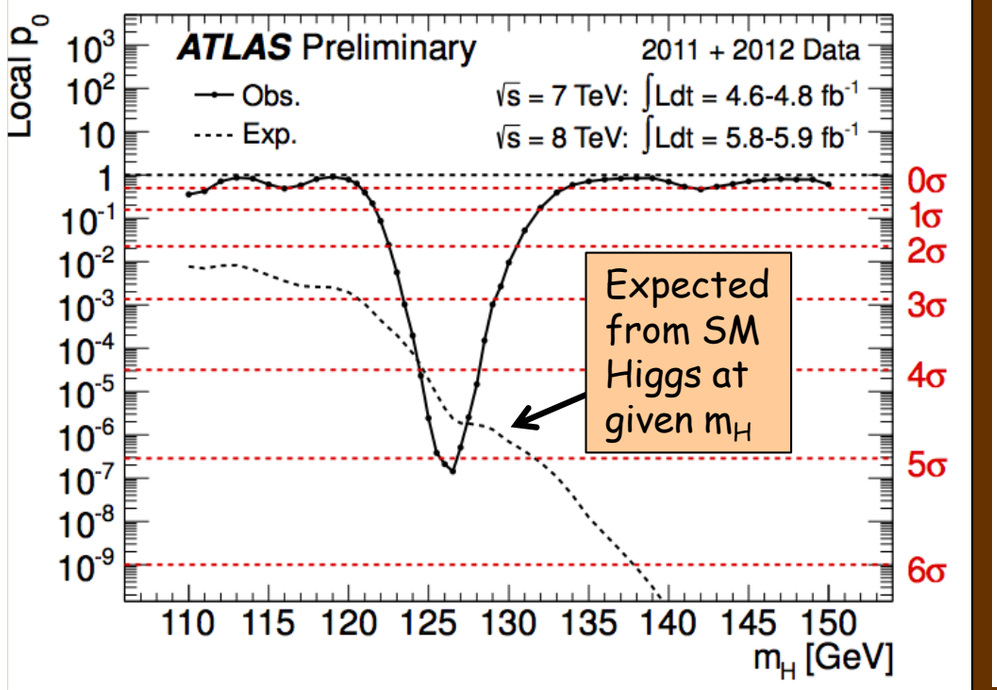
ATLAS-CONF-2013-012

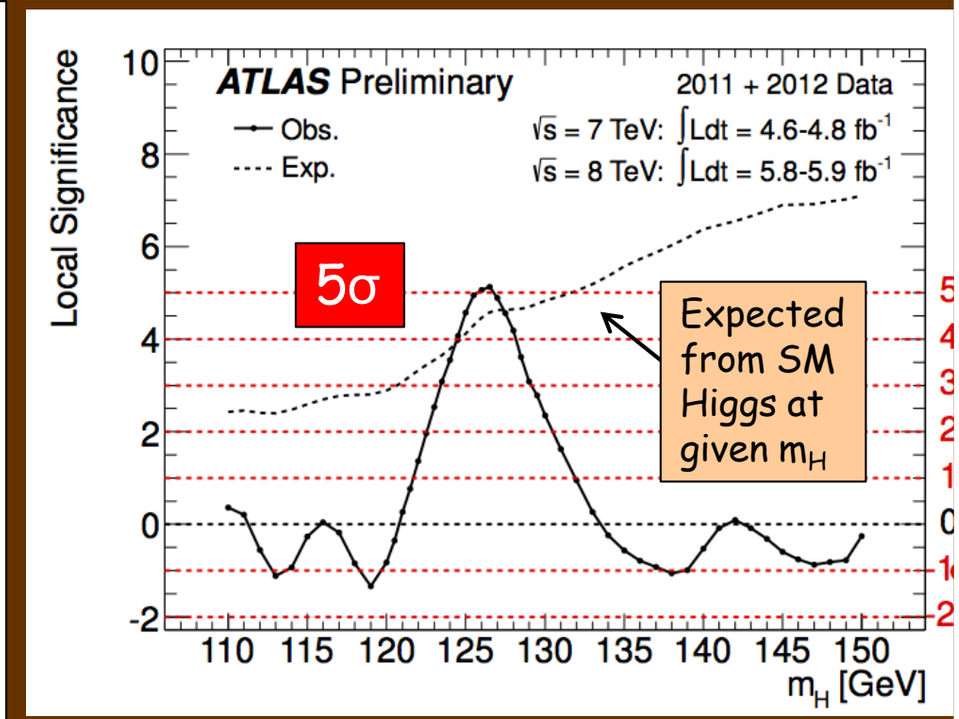




CMS-PAS-HIG-13-001

Combined results: the excess





Maximum excess observed at	m_H = 126.5 GeV
Local significance (including energy-scale systematics)	5.0 σ
Probability of background up-fluctuation	3 x 10^{-7}
Expected from SM Higgs m_H=126.5	4.6 σ

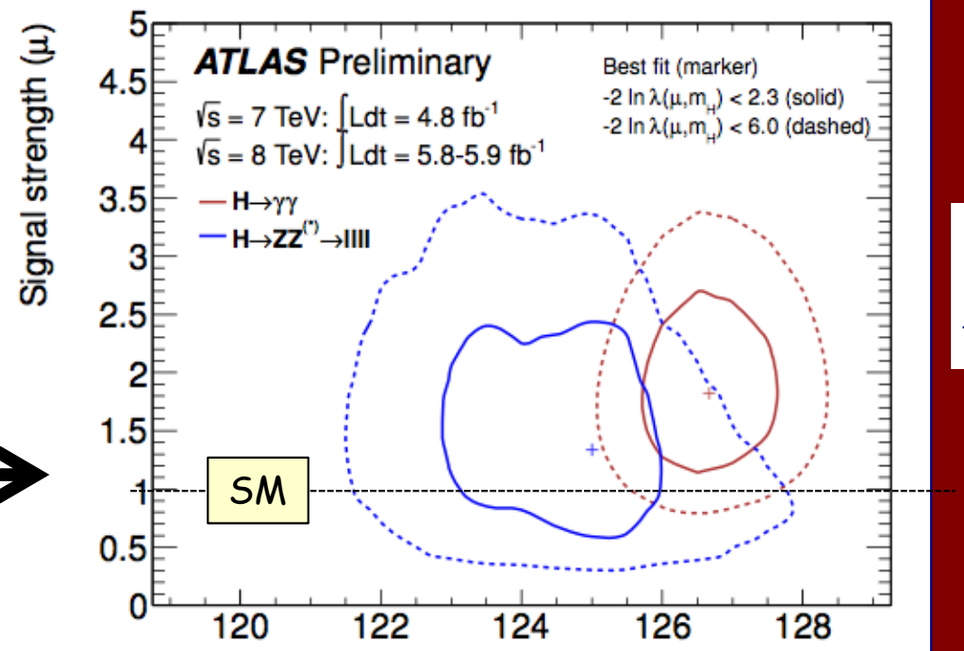
Global significance: 4.1-4.3 σ (for LEE over 110-600 or 110-150 GeV)

The mass of the new particle

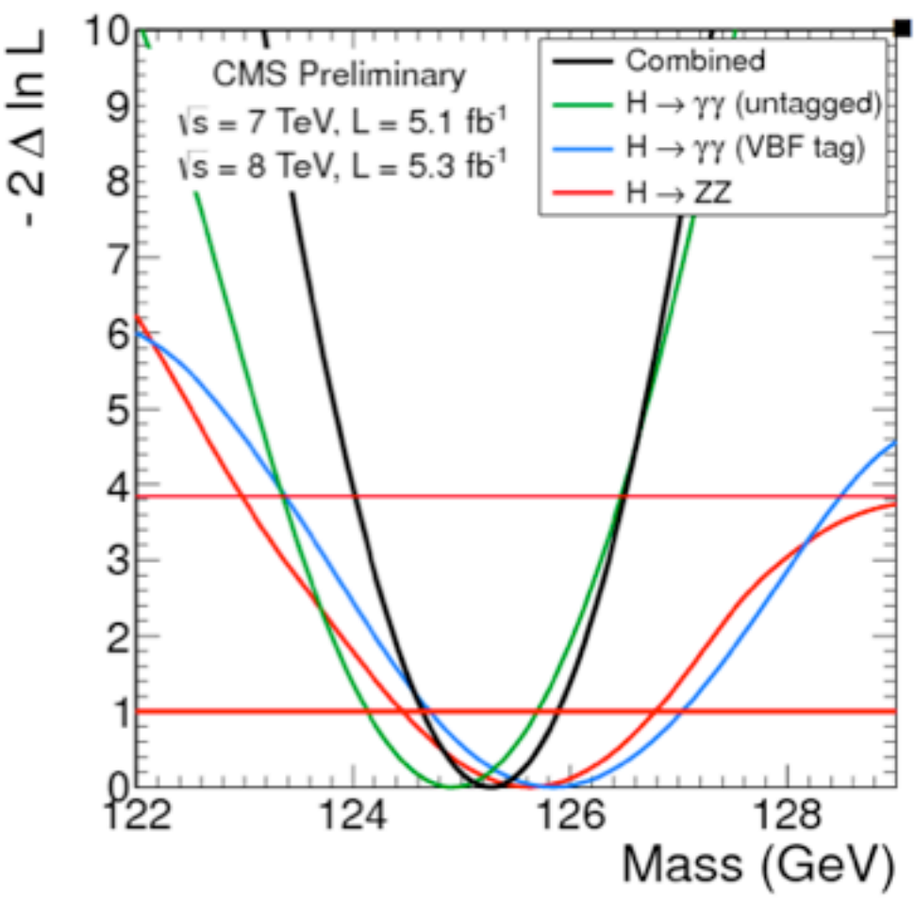
Combined results: consistency of the global picture

Are the 4l and γγ observations consistent ?

From 2-dim likelihood fit to signal mass and strength →curves show approximate 68% (full) and 95% (dashed) CL contours



ATLAS



To reduce model dependence, allow for free cross sections in three channels and fit for the common mass:

$m_X = 125.3 \pm 0.6$ GeV

to the nnels,

CMS

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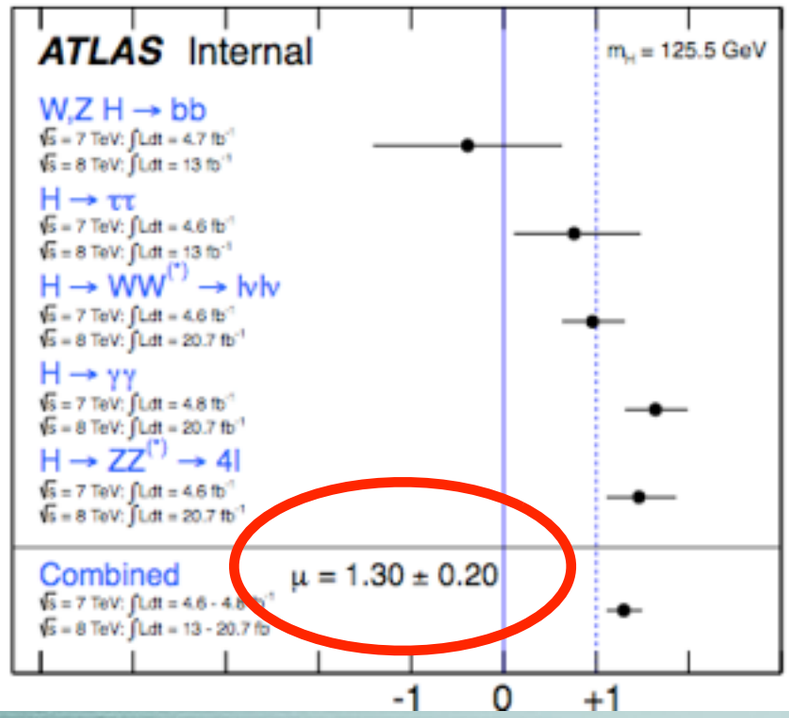
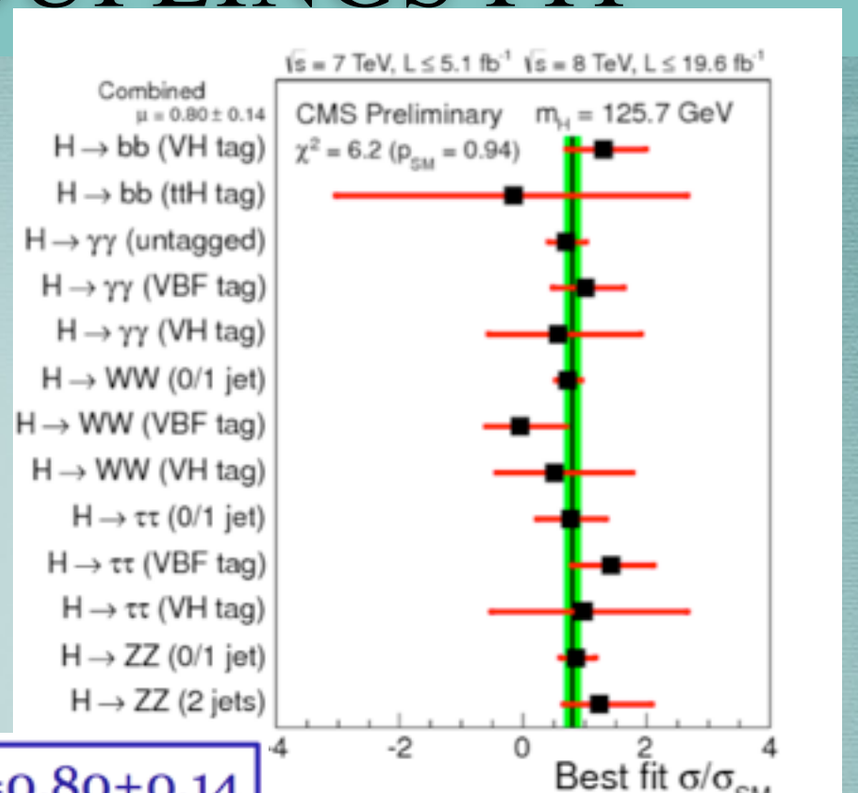
DATA AND THREE-COUPLINGS FIT



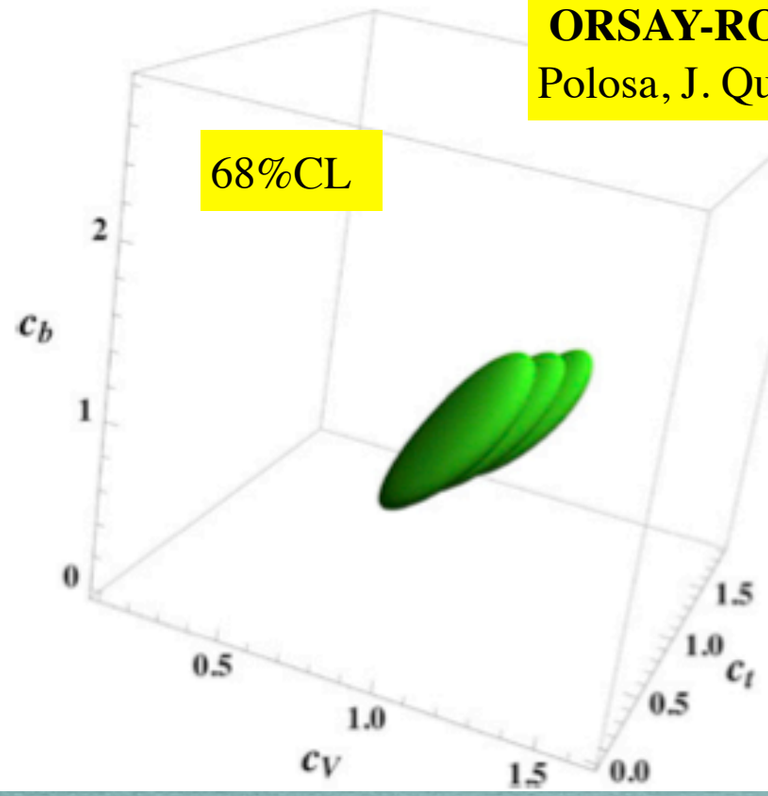


μ=0.80±0.14

Fig. 4 Best-fit regions at 68 % CL (*green*, *left*) and 99 % CL (*light gray*, *right*) for the Higgs signal strengths in the three-dimensional space $[c_t, c_b, c_V]$. The three overlapped regions are associated to central and two extreme choices of the theoretical prediction for the Higgs rates

ORSAY-ROMA Collab.: A. Djouadi, L. Maiani, G. Moreau, A. Polosa, J. Quevillon1 , V. Riquer, EPJ C in press, arXiv: 1307.5205

68%CL



99%CL