

Understanding the Higgs

Torino - 28 Novembre 2012



CERN, 4 Luglio 2012

Gli esperimenti **ATLAS** e **CMS** annunciano la scoperta di un **nuovo bosone**

È probabilmente il **bosone di Higgs** – da quasi 50 anni ritenuto il “tassello mancante” nella nostra comprensione del mondo sub-atomico




Una sfida durata mezzo secolo

- ◆ **1964:** Papers sul **campo di Higgs** (Brout & Englert; Higgs; Guralnik, Kibble & Hagen)
- ◆ **1967:** Weinberg, Glashow, Salam: **unificazione elettrodebole** con il campo di Higgs responsabile della massa delle particelle
- ◆ **1970:** 't Hooft and Veltman: il Modello Standard è rinormalizzabile
- ◆ **1970s:** Si inizia a pensare a come può essere prodotto ed osservato l'Higgs
- ◆ **1980s–90s:** Proposti il SSC (US, mai completato) e il Large Hadron Collider (**LHC**)
- ◆ **1990s–2000s:** Ricerche dirette e indirette a **LEP** e **Tevatron**: 0 – 115, 140 – 170 GeV
Costruzione di LHC e dei relativi esperimenti
- ◆ **2012:** LHC osserva un nuovo bosone consistente con l'Higgs a circa **125 GeV**

Eccezionale risonanza mediatica..

The New York Times
 Wednesday, July 4, 2012 Last Update: 4:00 AM ET
 DIGITAL SUBSCRIPTION: 4 WEEKS FOR...



New Particle Could Be Physics' Holy Grail
 By DENNIS OVERBYE 4 minutes ago
 If confirmed to be the elusive Higgs boson, a newly discovered particle named for the physicist Peter Higgs, above in Geneva, could explain the universe's origin.

Le Monde.fr
 Mercredi 4 juillet 2012 - Paris

INTERNATIONAL POLITIQUE SOCIÉTÉ ÉCONOMIE CULTURE

EN CIUDADES EUROPEAS EN CIUDADES ESPAÑOLAS

EN CE MOMENT Nicolas Sarkozy Mall. Boson de Higgs 1962 : l'indépendance

Le boson de Higgs découvert avec 99,9% de certitude



Voilà la confirmation tant attendue : une nouvelle particule a été découverte au Centre de recherche nucléaire (CERN), près de Genève.

Boson de Higgs : la fin de la traque

Le boson de Higgs : les raisons d'une

Le PAÍS
 Miércoles 4 de julio de 2012 - París

INTERNACIONAL POLÍTICA ECONOMÍA CULTURA

ESTÁ PASANDO Bosón Higgs Amnistía fiscal Código Calixtino Incendios Valencia Caso Barclays Caso Bette

Hallada "la más sólida evidencia" de la existencia del bosón de Higgs

Los científicos del CERN anuncian el descubrimiento de una partícula que podría ser Higgs. Si se confirma, explicaría un avance que, de confirmarse, supondría un paso esencial para explicar el origen de la materia.

El posible descubrimiento de la partícula es un paso esencial hacia la explicación del origen de la materia

"Puedo confirmar que se ha descubierto consistente con la teoría del bosón de Higgs. El descubrimiento de la partícula explicaría el origen de la masa. Los físicos del CERN celebran sus hallazgos

Diccionario para entender en qué consiste la "caza" del bosón de Higgs, por A. video Una explicación del bosón de Higgs. Sigue en directo la conferencia del CERN. FOTOGALERÍA Indicios hallados del bosón de Higgs. 'Hacia la partícula de Dios', por J. M.



Registro del CMS que pudiera ser la firma de la partícula de Higgs. / CERN

THE INDEPENDENT
 www.independent.co.uk

HOMOPHOBIA, HIP-HOP AND THE STAR WHO CAME OUT
 Trending, pages 26-27

THE L'OREAL FILES: COULD SARKOZY GO DOWN?
 News, page 35

MURRAY ONE MAN FROM THE FINAL
 Sport, pages 70-71

EUREKA!



It has taken nearly 50 years and cost £2.6bn. Now, at last, the Higgs boson particle has been found – and a new chapter in our understanding of the universe can begin

vk.nl
 de site van VKS

NIEUWS OPINIE CULTUUR SPORT ECONOMIE REIZEN

BINNENLAND POLITIEK BUITENLAND INTERNET & MEDIA WETENSCHAP & GEZONDHEID OPMERKEL

Higgs of niet, het is een spectaculaire ontdekking

Door: Pieter Sabel - 04/07/12, 11:29



VERWANT NIEUWS

- 'Trenen van geluk, Higgs' - 04/07/12
- Higgs-deeltje 'zeer nauw gevonden' - 04/07/12
- 'Maatschappij heeft nodig' - 04/07/12

MEER OVER

Natuurkunde Wetenschap

Deeltjesfysici wacht sp...

Nico

© EPA. Foto uit 2007 van de supergeleidende magneetkern van de deeltjesversneller van CERN in

the guardian

News Sport Comment Culture Business Money London 2012 Life & style Travel Environment Video

UK World Development US Politics Media Education Society Science Tech Law Data TV R

Breaking news: Weather not limitations end Mount McKinley climb - AP

Diamond set to come out of hiding as he faces MPs

Chief executive to reveal role of City watchdogs and Whitehall in Libor rate-fixing scandal

Key questions for MPs to ponder: How did the exchanges that led to Diamond's demise and Miliband clash over inquiry? Why is he likely to balk at vast severance deal? How do you interpret this as guidance to lower rate? What is the Bank Libor rate submissions 2005-08? How does the Libor rate-fixing scandal affect the coverage of the Libor rate-fixing scandal?

The definite particle? Higgs boson discovered? Live coverage



ends supply route dispute

...-month blockade follows apology from state for deaths of Pakistanis

© EPA

2012 3

Non senza un po' di confusione...

The New York Times
Wednesday, July 4, 2012 Last Update: 4:00 AM ET
DIGITAL SUBSCRIPTION: 4 WEEKS FOR



Le Monde.fr
Mise à jour à 19h02 - Paris

INTERNATIONAL POLITIQUE SOCIÉTÉ ÉCONOMIE CULTURE

EN CIUDADES EUROPEAS EN CIUDADES ESPAÑOLAS

EN CE MOMENT Nicolas Sarkozy Mall, Boson de Higgs 1962 - Fintopia

Le boson de Higgs découvert avec 99,9 certitude

EL PAÍS

INTERNACIONAL POLÍTICA ECONOMÍA CULTURA

ESTÁ PASANDO Bosón Higgs Amnistía fiscal Códice Calixtino Incendios Valencia Caso Barclays Caso Beteta

DIRECTO Los científicos del CERN anuncian el descubrimiento de una partícula que podría ser Higgs. Si explicando un avance que, de confirmarse, supondría un paso esencial de la física para explicar el origen de la materia

Hallada "la más sólida evidencia de la existencia del bosón de Higgs"

The INDEPENDENT
www.independent.co.uk SINCE 1986 NUMBER 60328

HOMOPHOBIA, HIP-HOP AND THE STAR WHO CAME OUT
Trending, pages 26-27

THE L'OREAL FILES: COULD SARKOZY GO DOWN?
News, page 35

MURRAY ONE MAT FROM THE FINAL
Sport, pages 70-71

THE AUSTRALIAN
WWW.THEAUSTRALIAN.COM.AU | THE HEART OF THE NATION

NEWS & PLUS

LOGIES BOYCOTT
Fossil spills with free-to-air (MELBA P12)

WALL STREET ON TRIAL
Goldman Sachs fraud claim (P21)

I'VE GIVEN UP ON OZ
Eddy Croves exclusive interview (P11)

Abbott to soften IR policy on unfair dismissal exemptions

The new Coalition plan is to restrict sackings immunity to firms of no more than five workers

micro-businesses of up to five full-time equivalent employees now under 'false' consideration for the federal approach.

In an attempt to meet the demand for a political signal, the Coalition will also reduce the number of workers covered by the law, proposing a cap on the number of workers in a business.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The Coalition's proposal is to restrict the exemption to firms of no more than five workers.

The taxpayer funded rort behind "new particle"

Higgs boson to wreck jobs and economy, says report



MON DIEU! HARPER COZIES UP TO THE FRENCH P.16

BANK SCANDALS TOO BIG TO BEHAVE WHY GLOBAL BANKS CAN'T BE TRUSTED P.34

SHOULD WE BAN FLIP-FLOPS? P.4

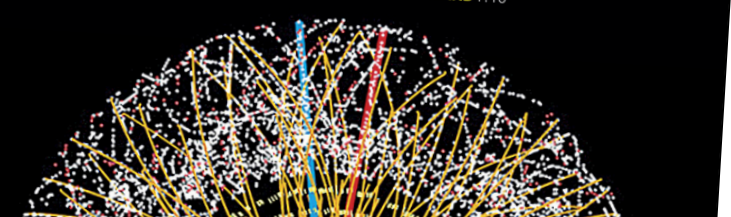
MACLEAN'S
CANADA'S NATIONAL MAGAZINE

July 23, 2012

Teleportation, phasers, alternate dimensions: the Higgs boson discovery does more than just explain the universe

THIS CHANGES EVERYTHING

A SPECIAL REPORT FROM SWITZERLAND P.40



Il seminario di oggi



Meeting place:
"Dipartimento di Fisica"
Aula Magna

Via Pietro Giuria 1, Torino

Understanding the HIGGS 28 Novembre 2012, Torino

The workshop will be focused on the discovery of the new boson at LHC and on the current theoretical implications.

A general presentation on the importance and the meaning of the last piece of the Standard Model will introduce the discovery.

This workshop intends to bring theorists and experimentalists together to make the point on the new data coming from 2012 LHC run and discuss the future perspectives.

- ◆ *Illustrare i recenti risultati e la loro rilevanza*
- ◆ *Mettere in evidenza il contributo diretto di Torino*
- ◆ *Spiegare in cosa consiste il nostro lavoro*

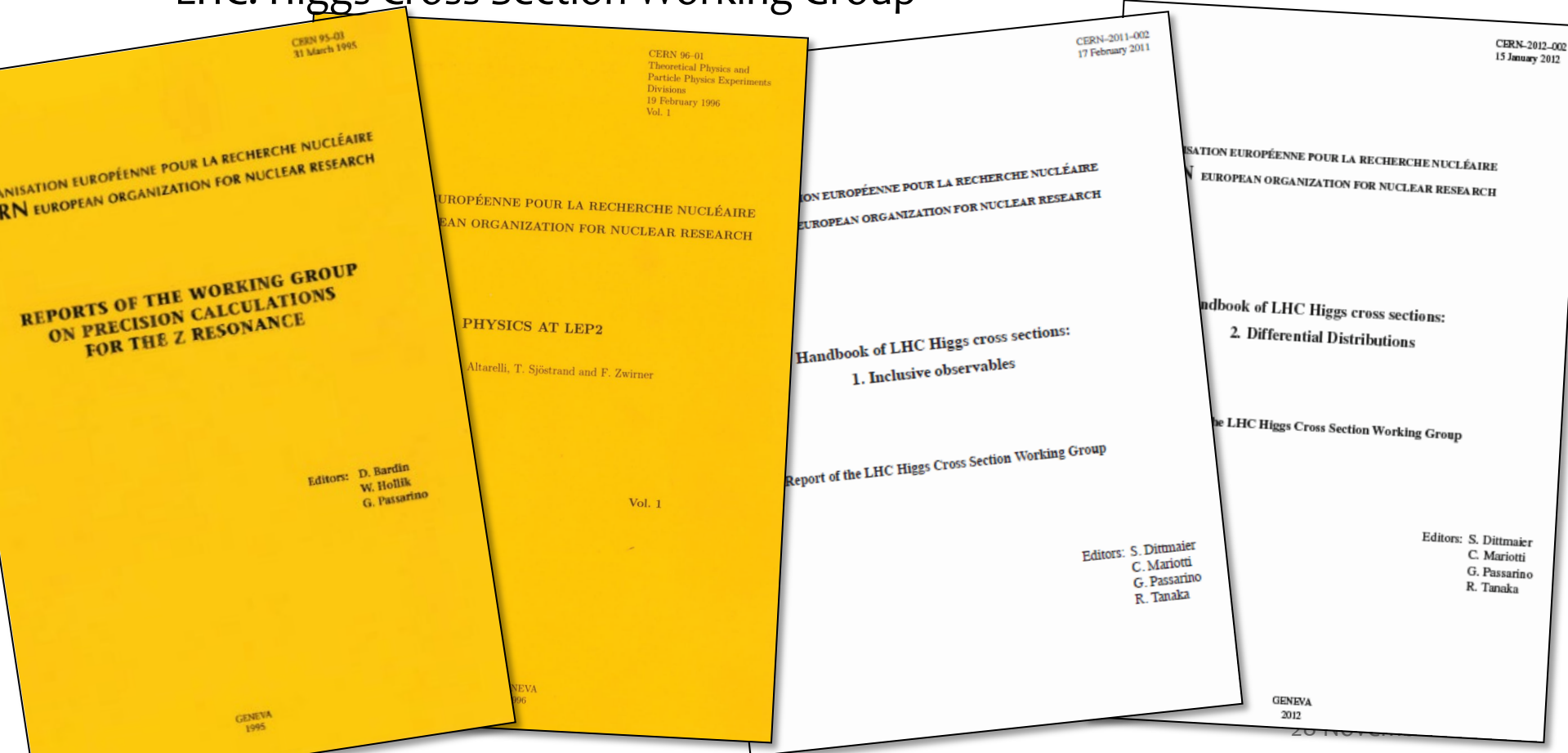


SM & Higgs @ Torino

- ◆ **Tradizione ultra-decennale** di ricerca nel campo della fisica dello **Standard Model** e dell'**Higgs** (e delle alte energie in generale)
 - Grazie alla **collaborazione fra Università e l'Istituto Nazionale di Fisica Nucleare** (INFN), che è fra gli istituti di ricerca che maggiormente ha contribuito a LHC ed al CERN a livello internazionale
 - Stretta **collaborazione fra comunità teorica e sperimentale**
- ◆ Contributi fondamentali su:
 - Teoria
 - Generatori Monte Carlo
 - Sviluppo, costruzione ed operazione dei rivelatori
 - Analisi dei dati

Da LEP a LHC: Paving the Road to Discovery

- ◆ Contributo ai lavori fondamentali che hanno portato alla scoperta
 - LEP1: Z line shape, electroweak precision measurements
 - LEP2: Single Boson and WW production; Higgs Physics
 - LHC: Higgs Cross Section Working Group



Costruzione di CMS: il contributo di TO

CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel (100x150 μm) $\sim 16\text{m}^2 \sim 66\text{M}$ channels
Microstrips (80x180 μm) $\sim 200\text{m}^2 \sim 9.6\text{M}$ channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying $\sim 18,000\text{A}$

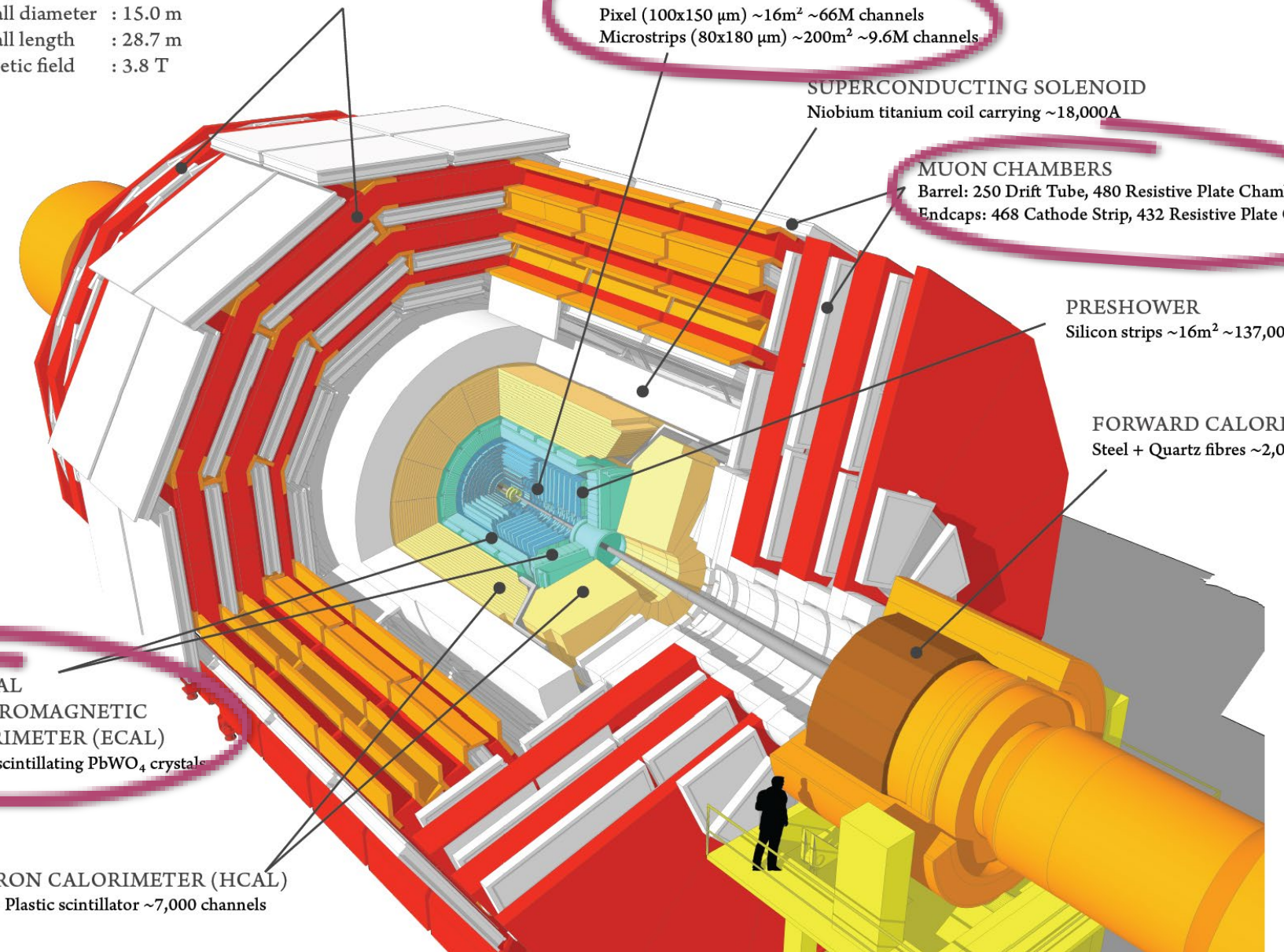
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

PRESHOWER
Silicon strips $\sim 16\text{m}^2 \sim 137,000$ channels

FORWARD CALORIMETER
Steel + Quartz fibres $\sim 2,000$ Channels

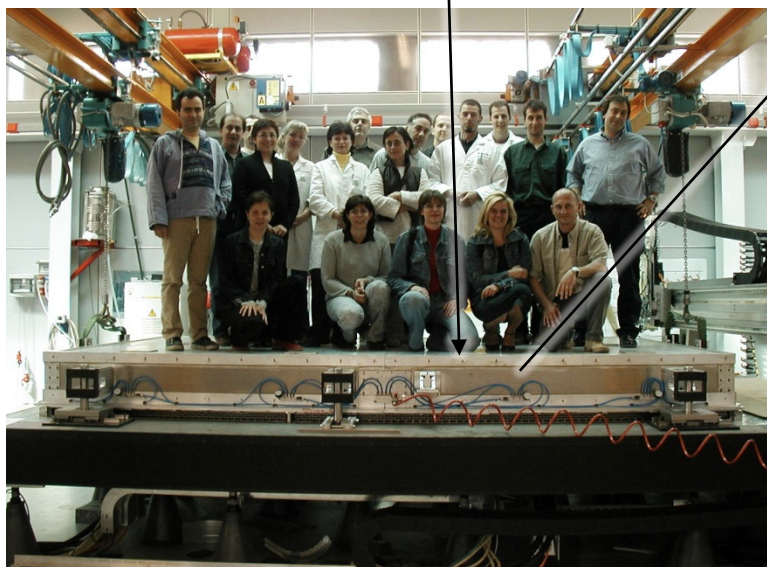
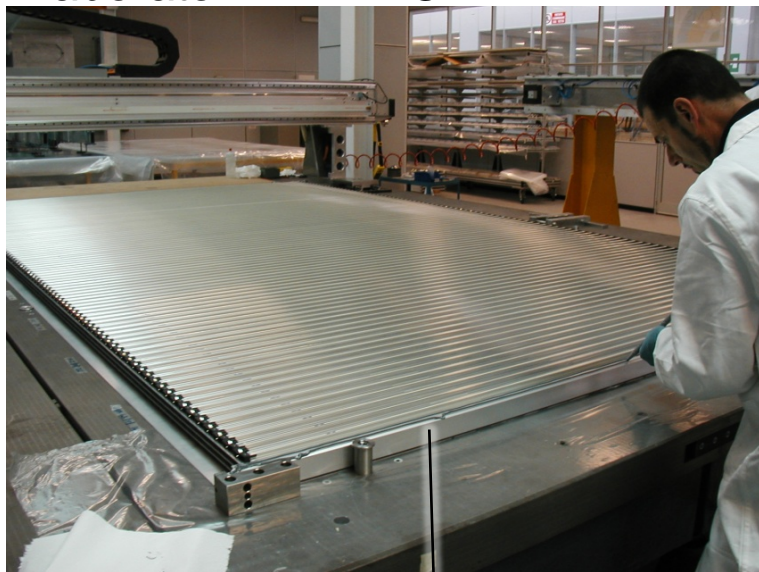
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
 $\sim 76,000$ scintillating PbWO_4 crystals

HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator $\sim 7,000$ channels



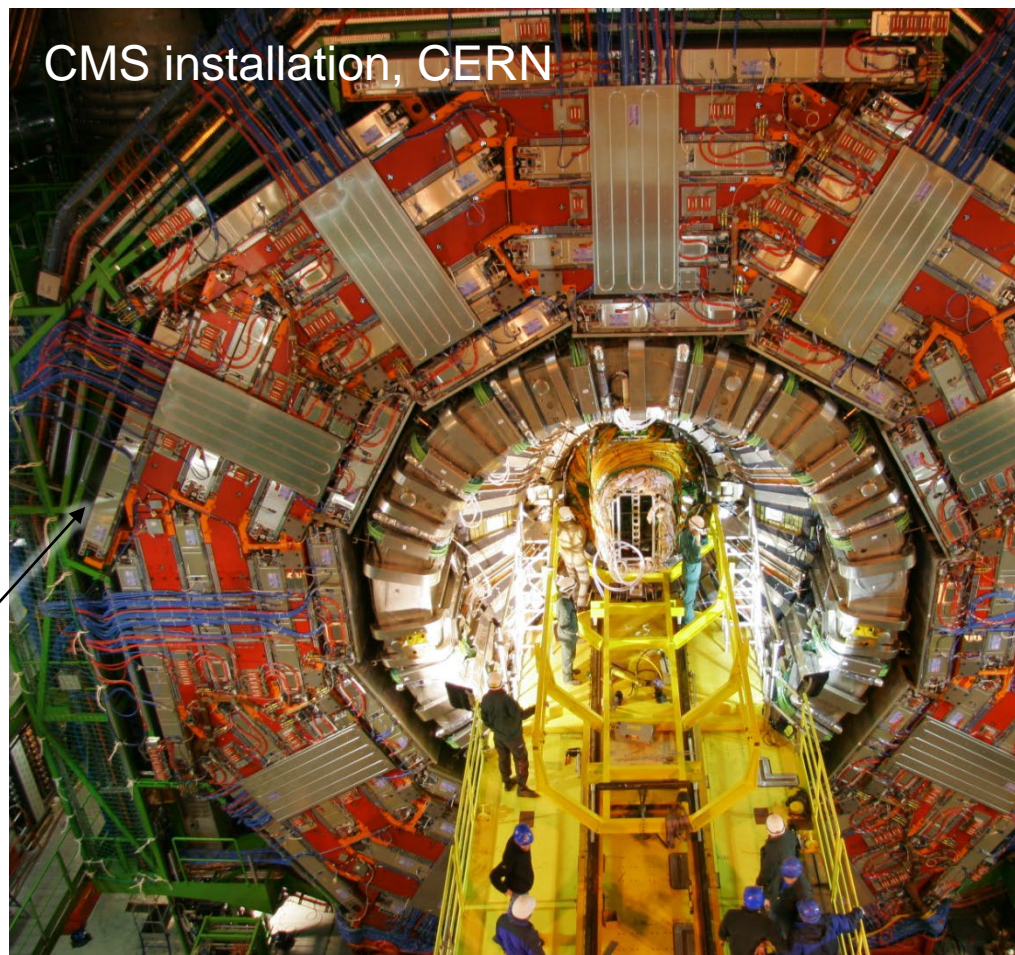
Costruzione di CMS: il contributo di TO

Laboratori INFN TO



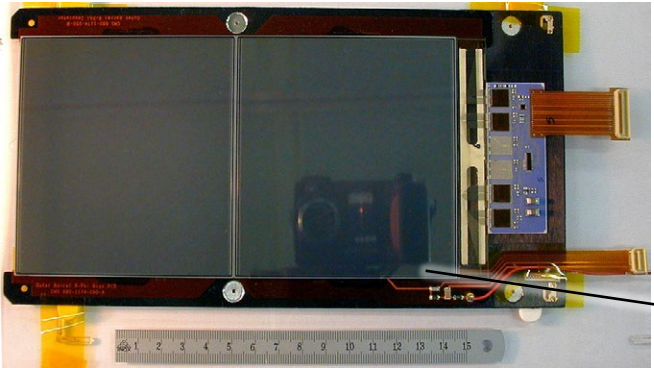
Nicola Amapane

CMS installation, CERN

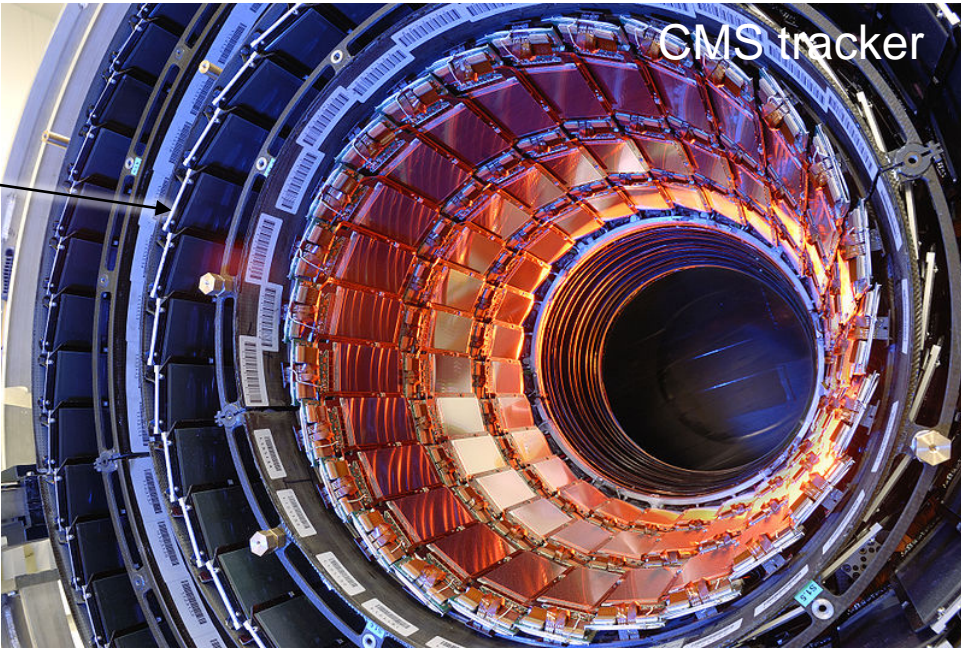


- ◆ Costruzione camere a drift per l'identificazione dei muoni presso i laboratori INFN

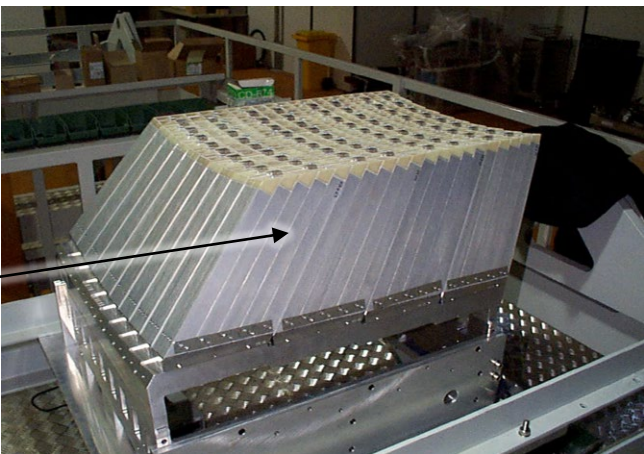
Costruzione di CMS: il contributo di TO



Produzione di 500 dei 4000 moduli che compongono la parte interna del Tracker



Test e installazione di parte dell'elettronica di read-out del calorimetro elettromagnetico



Una Scuola di alto livello

- ◆ Un'occasione per i nostri studenti per entrare nel mondo della ricerca di alto livello, collaborando ad istituzioni di livello internazionale
- ◆ “Esportiamo” postdoc in tutto il mondo
 - In questo momento presso: CERN, Johns Hopkins University, University of California Santa Barbara, Université Catholique de Louvain, Université de Lyon, Northeastern University, ...
 - Ruoli di rilievo nel coordinamento di gruppi internazionali in CMS, già durante il post-doc a Torino
- ◆ Torino è stato nodo di due Research and Training Networks, “*Physics at Collider*” ed “*HEPTools*”, nell'ambito dei quali abbiamo avuto 4 Graduate Schools

Progetto di Ateneo



“Innovative **M**ethods for **P**hysics at the **T**erascale”

- ◆ Catalizzare expertise teorica, sperimentale ed informatica esistente a TO su scoperta dell'Higgs, misura delle sue proprietà, e ricerca di nuova fisica
 - Partner: dip. di Fisica, dip. Informatica, INFN
 - Sviluppi teorici e metodologie sperimentali necessari all'osservazione e caratterizzazione dell'Higgs
 - Ricerca di soluzioni innovative per il problema computazionale nel calcolo teorico
- ◆ Tutti gli articoli sperimentali di CMS sulla scoperta del nuovo bosone e gli articoli teorici che vi fanno riferimento portano il nome del progetto

Phys. Lett. B 716 30-61

Physics Letters B 716 (2012) 30–61

Contents lists available at SciVerse ScienceDirect

 **Physics Letters B** 

www.elsevier.com/locate/physletb

Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC[☆]

CMS Collaboration^{*}

CERN, Switzerland

This paper is dedicated to the memory of our colleagues who worked on CMS but have since passed away. In recognition of their many contributions to the achievement of this observation.

ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received 31 July 2012 Received in revised form 9 August 2012 Accepted 11 August 2012 Available online 18 August 2012 Editor: W.-D. Schlatter</p> <p><i>Keywords:</i> CMS Physics Higgs</p>	<p>Results are presented from searches for the standard model Higgs boson in proton–proton collisions at $\sqrt{s} = 7$ and 8 TeV in the Compact Muon Solenoid experiment at the LHC, using data samples corresponding to integrated luminosities of up to 5.1 fb^{-1} at 7 TeV and 5.3 fb^{-1} at 8 TeV. The search is performed in five decay modes: $\gamma\gamma$, ZZ, W^+W^-, $\tau^+\tau^-$, and $b\bar{b}$. An excess of events is observed above the expected background, with a local significance of 5.0 standard deviations, at a mass near 125 GeV, signalling the production of a new particle. The expected significance for a standard model Higgs boson of that mass is 5.8 standard deviations. The excess is most significant in the two decay modes with the best mass resolution, $\gamma\gamma$ and ZZ; a fit to these signals gives a mass of $125.3 \pm 0.4(\text{stat.}) \pm 0.5(\text{syst.})$ GeV. The decay to two photons indicates that the new particle is a boson with spin different from one.</p> <p>© 2012 CERN. Published by Elsevier B.V. All rights reserved.</p>

Contributo diretto nell'analisi dello stato finale $H \rightarrow ZZ \rightarrow 4 \ell$

357 citazioni da Agosto ad oggi
(fonte: inSPIRE)

Nicola Amapane

Acknowledgements

wetenschap en technologie (IWT-Belgium), the Council of Science and Industrial Research, India; the Compagnia di San Paolo (Torino); and the HOMING PLUS programme of Foundation for Polish Science, cofinanced from European Union, Regional Development

Agenda

- ◆ **Higgs Hunting: the Adventure of Particle Physics** C. Mariotti
- ◆ **New Revelations From Particle Colliders.
Past, Present & Future : a theoretical perspective** G. Passarino
- *Coffee Break* –
- ◆ **The Experimental Challenge** N. Amapane
- ◆ **Data Analysis: Anatomy of a Discovery** M. Pelliccioni
- ◆ **The Theoretical challenge** S. Uccirati