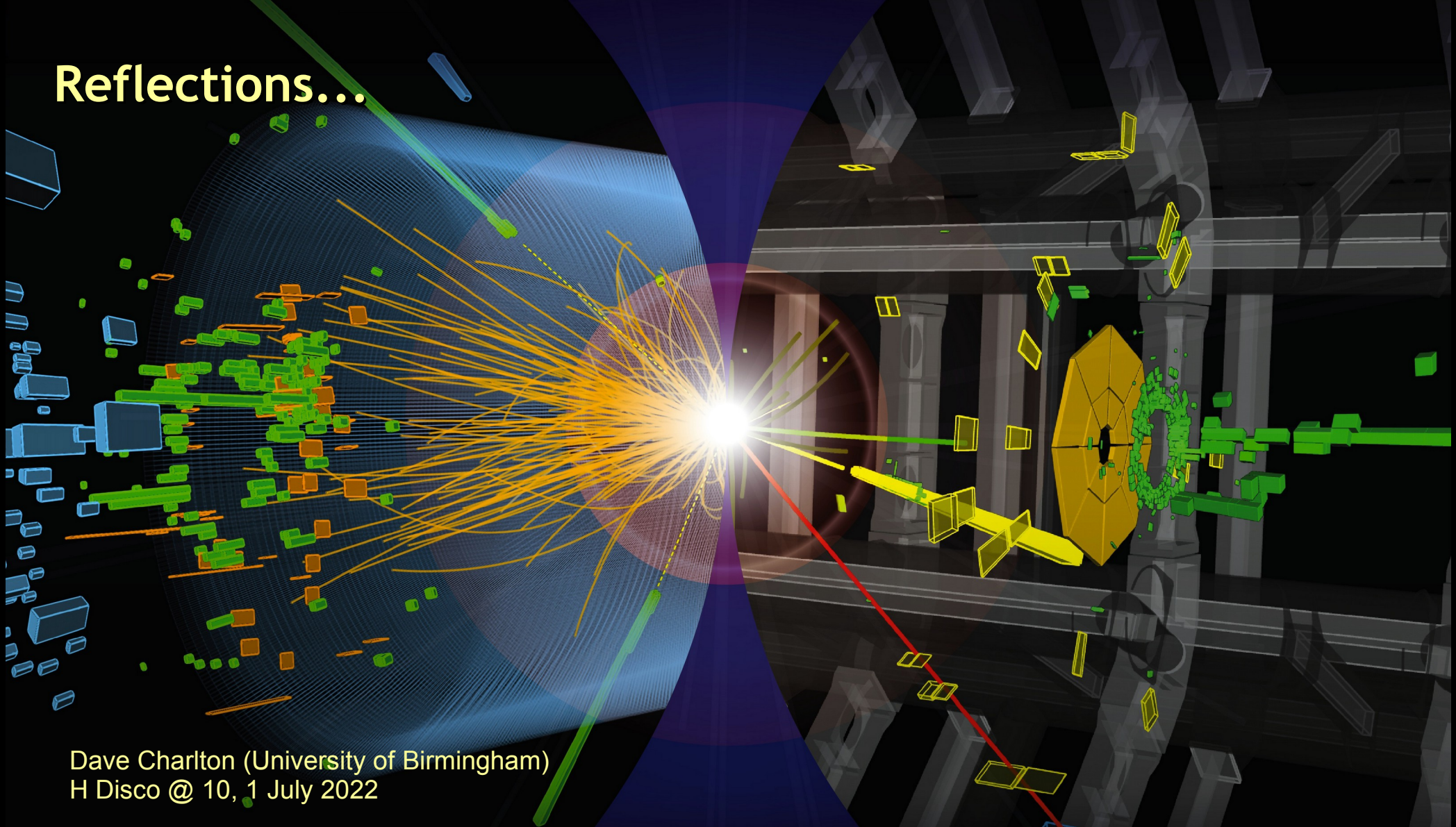
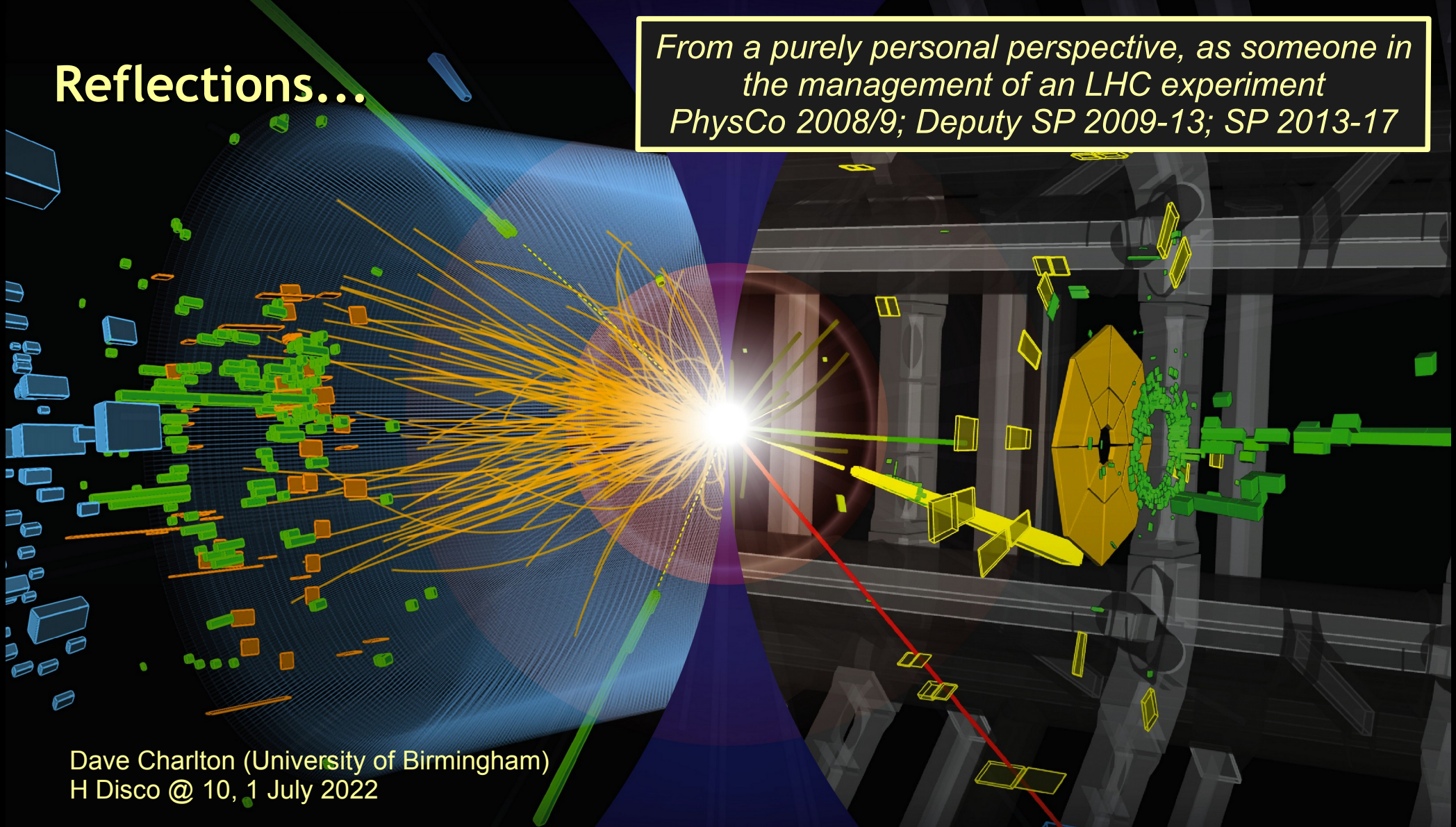
Reflections...



Dave Charlton (University of Birmingham)
H Disco @ 10, 1 July 2022

Reflections…

From a purely personal perspective, as someone in the management of an LHC experiment
PhysCo 2008/9; Deputy SP 2009-13; SP 2013-17



Dave Charlton (University of Birmingham)
H Disco @ 10, 1 July 2022

A Brief History

1992 Collaborations formed
1997 Construction of components started
2003 ATLAS Cavern available
2008 First beam ("Big-Bang Day")
2009 First collisions
2010+ Collisions and physics at high energy!

We expect to continue to ~~2035~~ 2040+

(2014)

Global collaborations

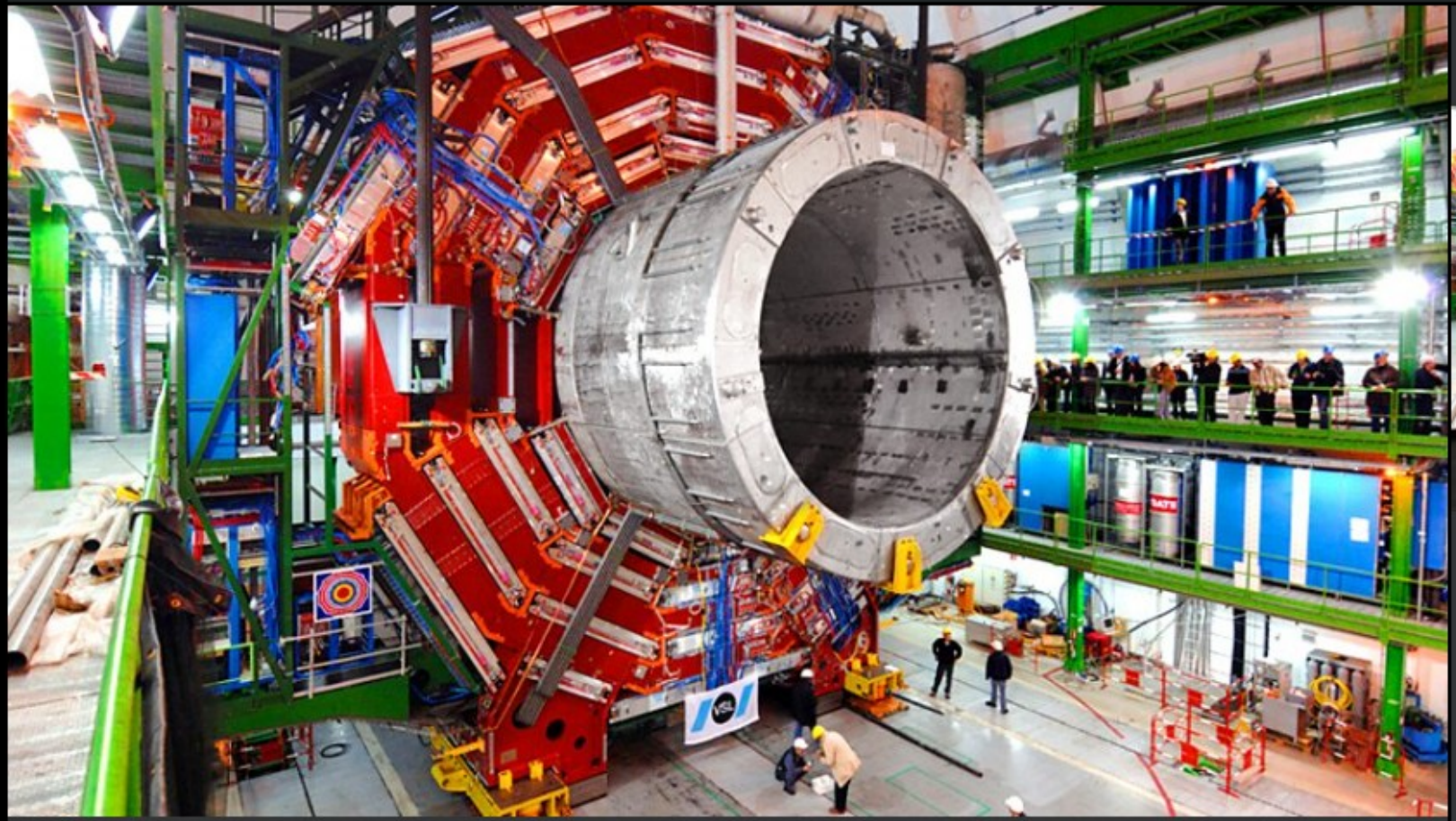
ATLAS: 178 institutions from 38 countries 2900 scientific authors, including 1000 students

(2014)

10 Sep 2008 “Big Bang Day”

Big Bang Day: The Making of CERN

Home Episodes



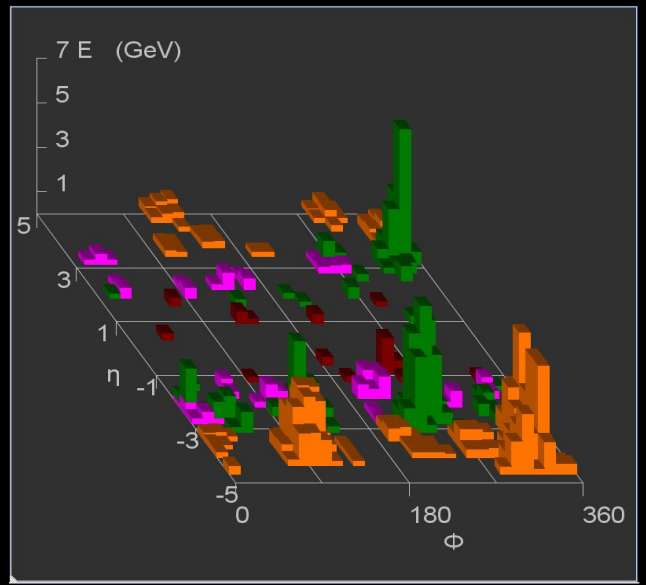
Available

Episode 2

Quentin Cooper explores the fifty-year history of CERN, the European particle physics laboratory in Switzerland

20 Nov 2009

Candidate Collision Event

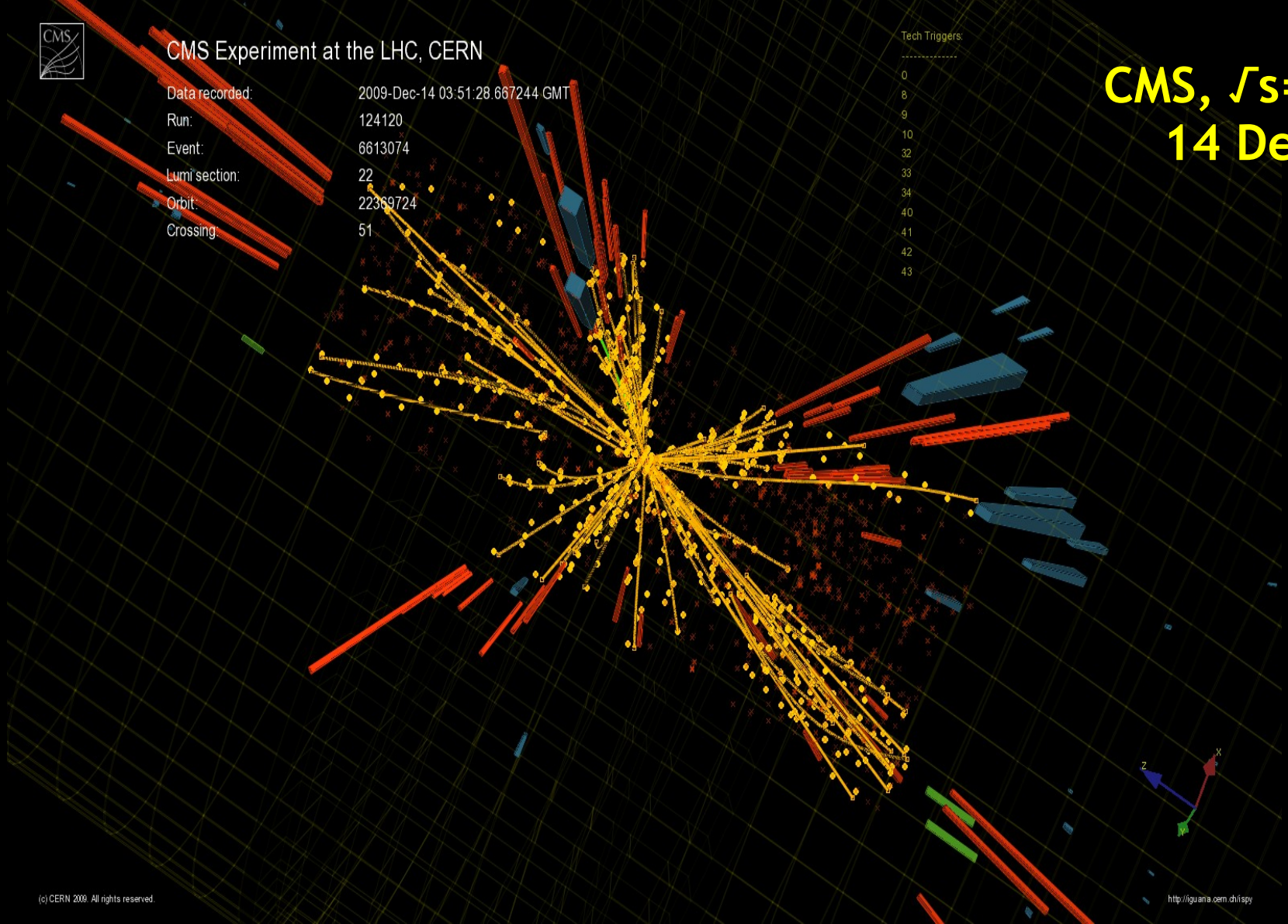


ATLAS EXPERIMENT

2009-11-23 14:22 CET

Run 140541, Event 171897

http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

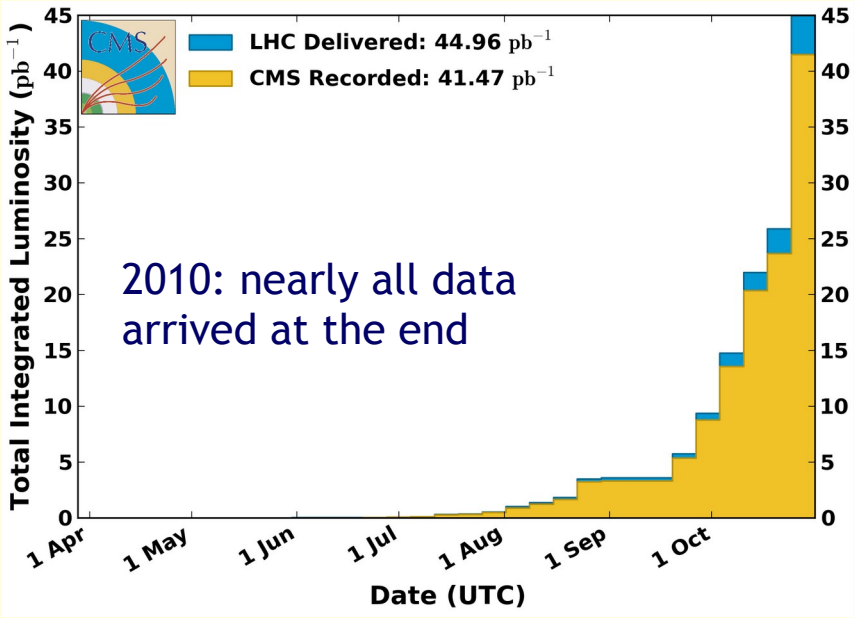


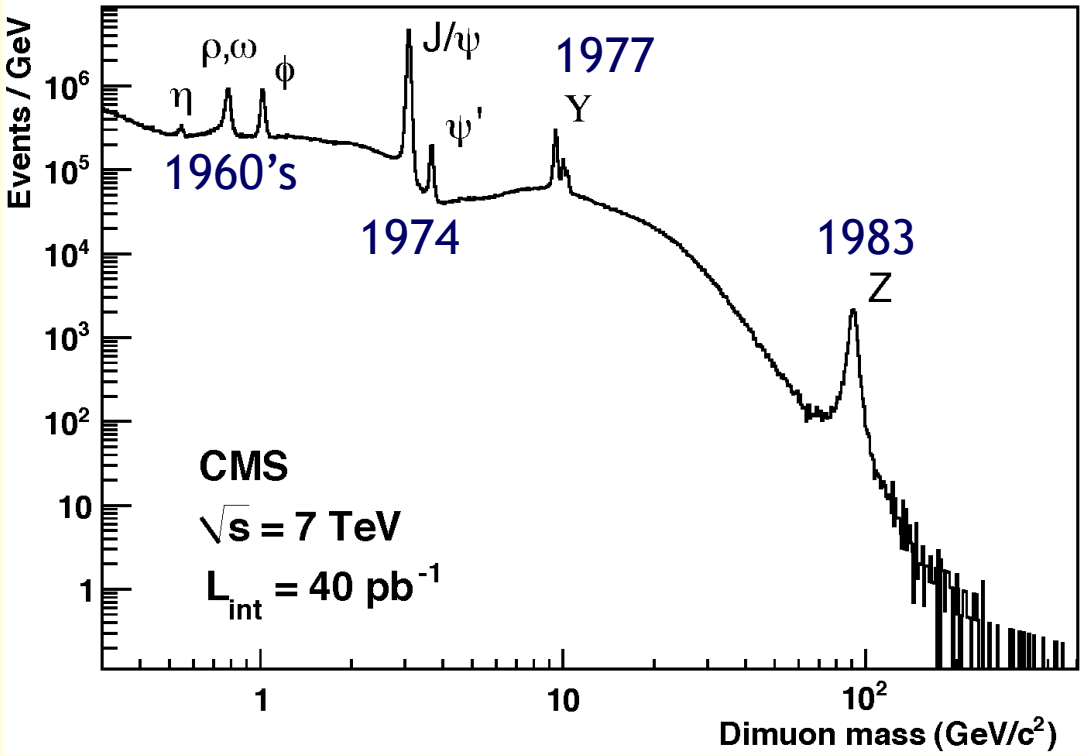
CMS, $\sqrt{s}$=2.36 TeV
14 Dec 2009

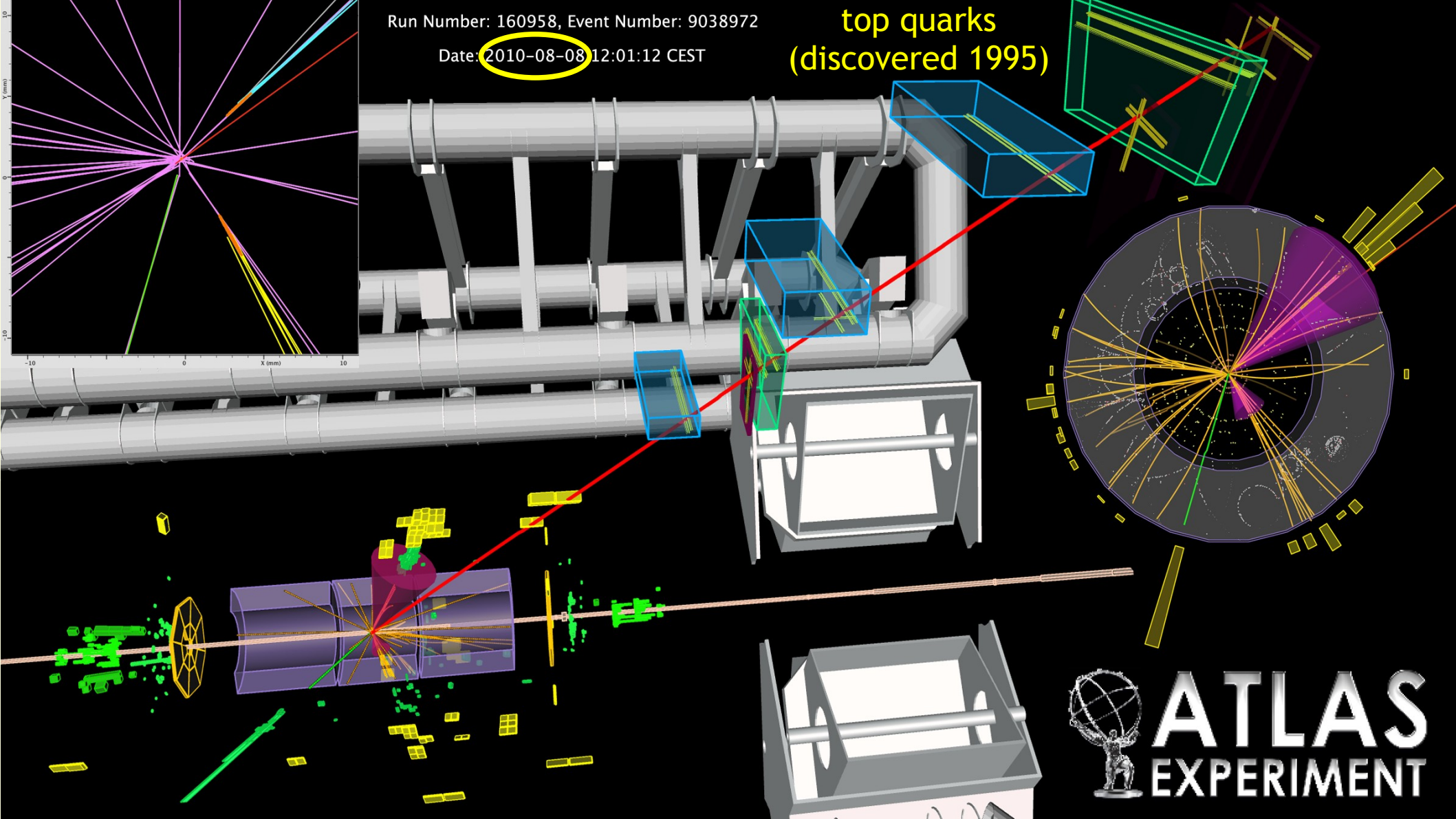
2010: Collisions at 7 TeV

Addressing the dual requirements

- Higher collision energy *("√s")*
- Greater number of collisions *(integrated luminosity)*






Run Number: 160958, Event Number: 9038972
Date: 2010-08-08 12:01:12 CEST
top quarks
(discovered 1995)
ATLAS
EXPERIMENT

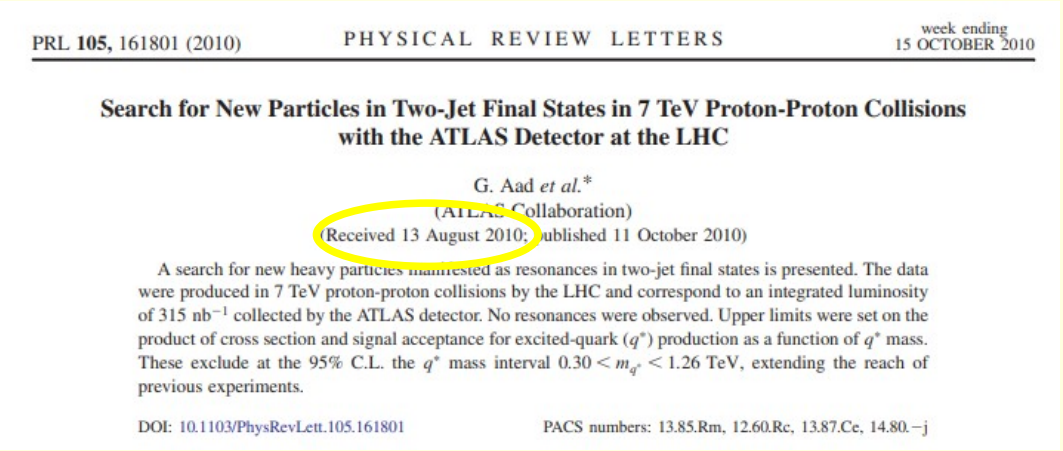
Searching for new processes

Particles or interactions which are too high mass, or too weakly coupled, to have been seen before

Every step in energy and luminosity gives us more reach

Broad types of search

- topological searches looking for new/anomalous event signatures
- model-driven searches (e.g. supersymmetry: SUSY)
- and many in-between (e.g. some dark matter searches)



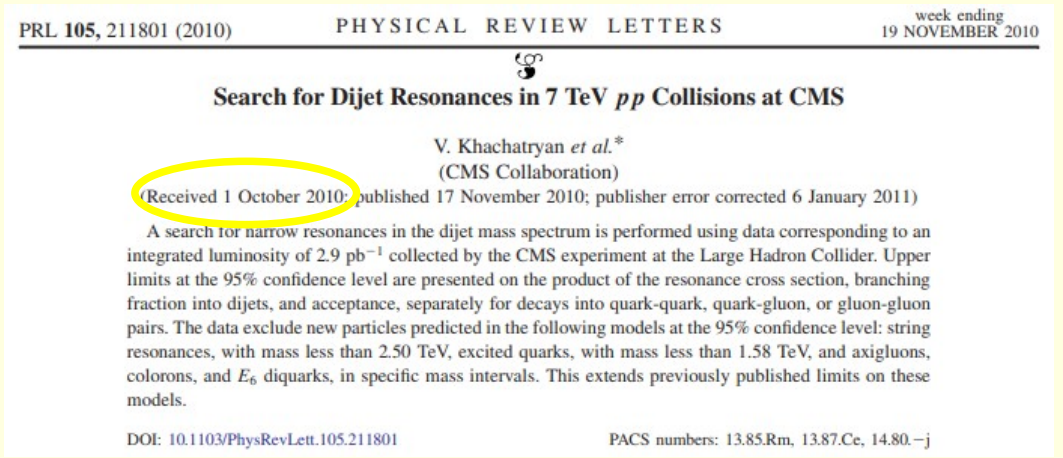
PRL 105, 161801 (2010) PHYSICAL REVIEW LETTERS week ending 15 OCTOBER 2010

Search for New Particles in Two-Jet Final States in 7 TeV Proton-Proton Collisions with the ATLAS Detector at the LHC

G. Aad *et al.**
(ATLAS Collaboration)
(Received 13 August 2010; published 11 October 2010)

A search for new heavy particles manifested as resonances in two-jet final states is presented. The data were produced in 7 TeV proton-proton collisions by the LHC and correspond to an integrated luminosity of 315 nb^{-1} collected by the ATLAS detector. No resonances were observed. Upper limits were set on the product of cross section and signal acceptance for excited-quark (q^*) production as a function of q^* mass. These exclude at the 95% C.L. the q^* mass interval $0.30 < m_{q^*} < 1.26$ TeV, extending the reach of previous experiments.

DOI: 10.1103/PhysRevLett.105.161801 PACS numbers: 13.85.Rm, 12.60.Rc, 13.87.Ce, 14.80.−j



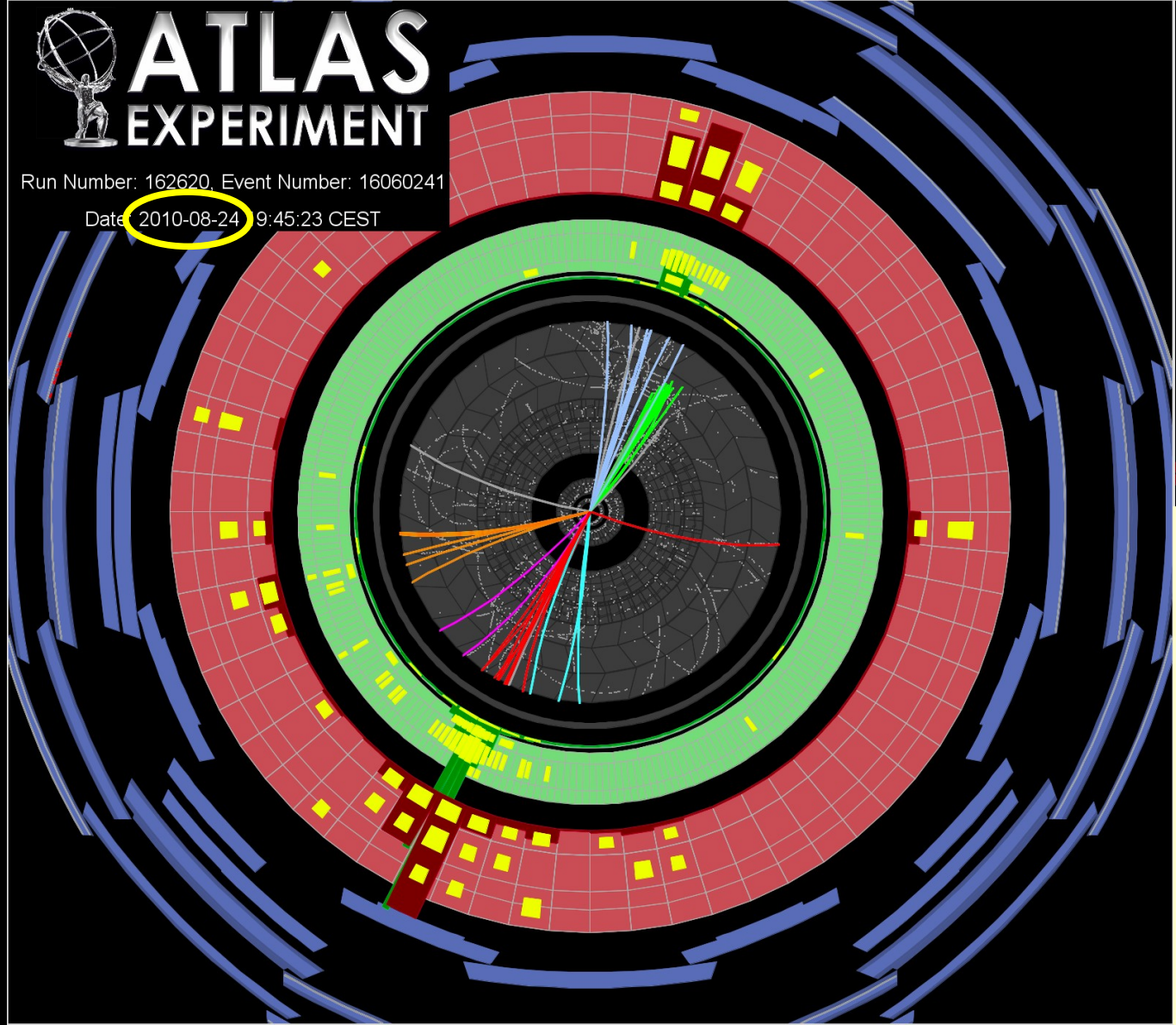
PRL 105, 211801 (2010) PHYSICAL REVIEW LETTERS week ending 19 NOVEMBER 2010

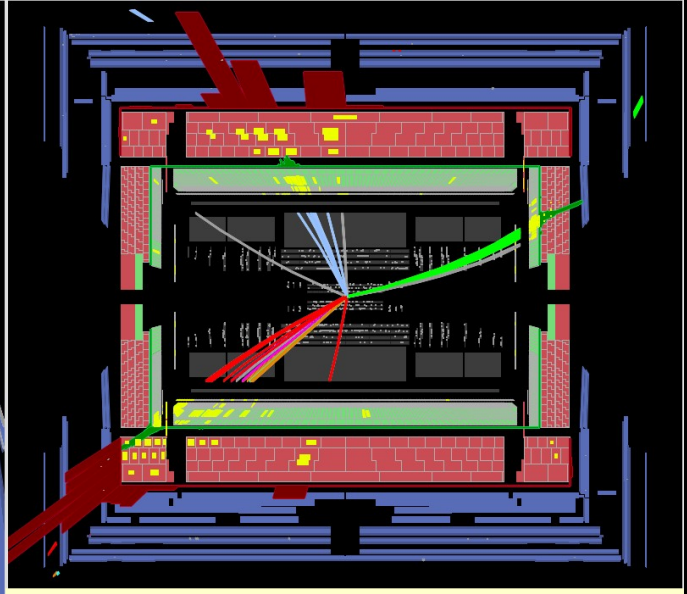
Search for Dijet Resonances in 7 TeV *pp* Collisions at CMS

V. Khachatryan *et al.**
(CMS Collaboration)
(Received 1 October 2010; published 17 November 2010; publisher error corrected 6 January 2011)

A search for narrow resonances in the dijet mass spectrum is performed using data corresponding to an integrated luminosity of 2.9 pb^{-1} collected by the CMS experiment at the Large Hadron Collider. Upper limits at the 95% confidence level are presented on the product of the resonance cross section, branching fraction into dijets, and acceptance, separately for decays into quark-quark, quark-gluon, or gluon-gluon pairs. The data exclude new particles predicted in the following models at the 95% confidence level: string resonances, with mass less than 2.50 TeV, excited quarks, with mass less than 1.58 TeV, and axigluons, colorons, and E_6 diquarks, in specific mass intervals. This extends previously published limits on these models.

DOI: 10.1103/PhysRevLett.105.211801 PACS numbers: 13.85.Rm, 13.87.Ce, 14.80.−j





Two very high energy jets of hadrons in this event, plus a third lower energy jet

The two jets together have a mass of 3.1 TeV

No previous collider could get close to these energies

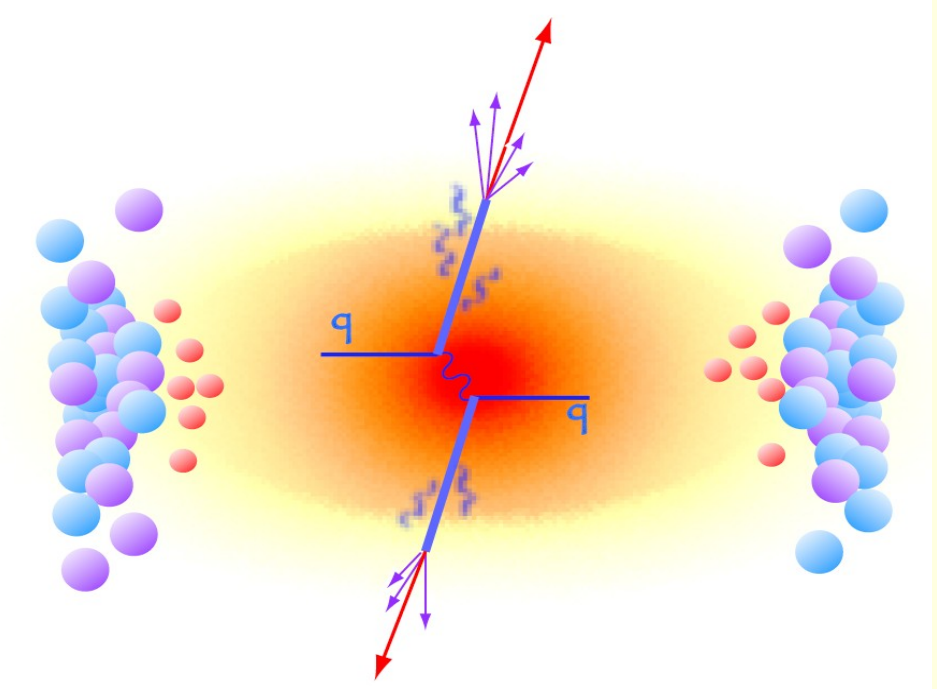
Observation of jet quenching

LHC also collides lead (Pb) nuclei

- Forms a region of hot dense matter – quark-gluon plasma

First LHC Pb+Pb collisions in 2010: saw immediately the new phenomenon of "jet quenching"

- High-energy quark or gluon travelling far through the hot dense matter loses energy
- "One-sided" jet events



While not "conventional" Beyond-the-Standard Model new physics, this was a new physical phenomenon

Observation of jet

LHC also collides lead (Pb) nuclei

- Forms a region of hot dense matter – quark-gluon plasma

First LHC Pb+Pb collisions in 2010: saw immediately the new phenomenon of “jet quenching”

- High-energy quark or gluon travelling far through the hot dense matter loses energy
- “One-sided” jet events

PRL 105, 252303 (2010) Selected for a Viewpoint in *Physics* PHYSICAL REVIEW LETTERS week ending 17 DECEMBER 2010

Observation of a Centrality-Dependent Dijet Asymmetry in Lead-Lead Collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ATLAS Detector at the LHC

G. Aad *et al.**
(ATLAS Collaboration)

(Received 25 November 2010; published 13 December 2010)

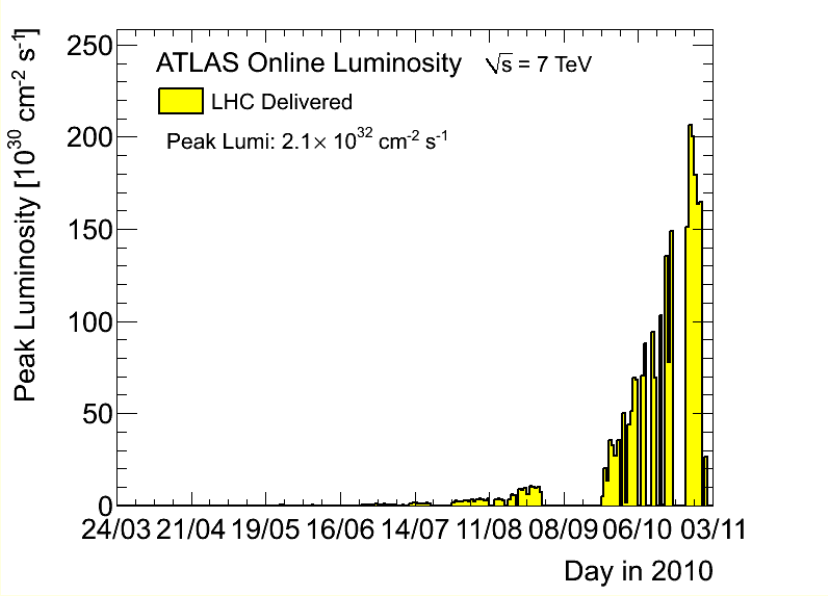
By using the ATLAS detector, observations have been made of a centrality-dependent dijet asymmetry in the collisions of lead ions at the Large Hadron Collider. In a sample of lead-lead events with a per-nucleon center of mass energy of 2.76 TeV, selected with a minimum bias trigger, jets are reconstructed in fine-grained, longitudinally segmented electromagnetic and hadronic calorimeters. The transverse energies of dijets in opposite hemispheres are observed to become systematically more unbalanced with increasing event centrality leading to a large number of events which contain highly asymmetric dijets. This is the first observation of an enhancement of events with such large dijet asymmetries, not observed in proton-proton collisions, which may point to an interpretation in terms of strong jet energy loss in a hot, dense medium.

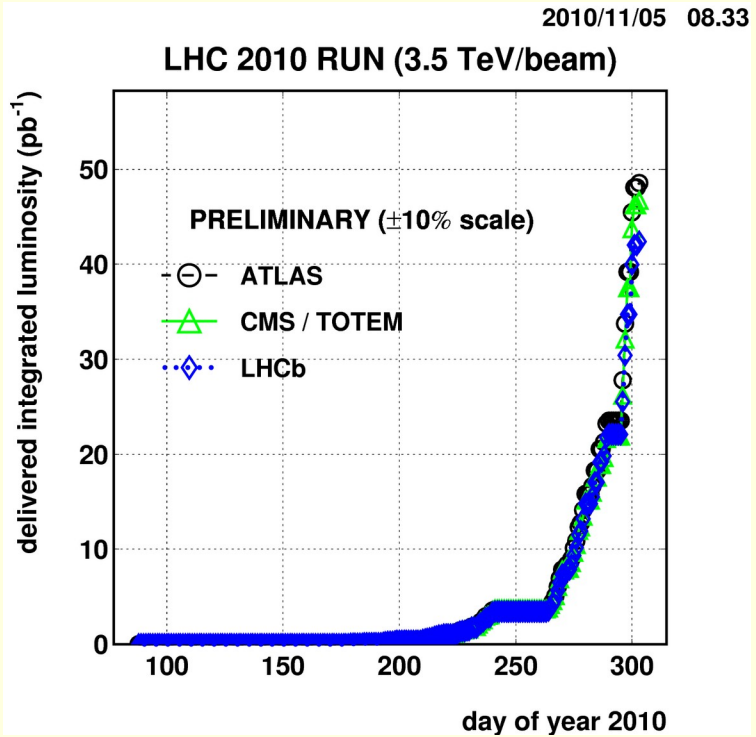
DOI: 10.1103/PhysRevLett.105.252303 PACS numbers: 25.75.Bh

Reschedule?

LHC in 2010 had ramped up peak luminosity quite gradually

But at the end of the year it was running very well





Meanwhile, the Tevatron was running well… competition focussed minds

Should we shut LHC down for a year in 2012, as then planned?

Reschedule?

Many factors went into decision

- LHC performance
- Tevatron competition for H
- Work programme in LS1 (to go to ~14 TeV)
- LS1 experiment programmes

This was a critical decision point

Reschedule!

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CERN announces LHC to run in 2012

31 JANUARY, 2011

Geneva, 31 January 2011. CERN[1] today announced that the LHC will run through to the end of 2012 with a short technical stop at the end of 2011. The beam energy for 2011 will be 3.5 TeV. This decision, taken by CERN management following the annual planning workshop held in Chamonix last week and a report delivered today by the laboratory's machine advisory committee, gives the LHC's experiments a good chance of finding new physics in the next two years, before the LHC goes into a long shutdown to prepare for higher energy running starting 2014.

"If LHC continues to improve in 2011 as it did in 2010, we've got a very exciting year ahead of us," said CERN's Director for Accelerators and Technology, Steve Myers. *"The signs are that we should be able to increase the data collection rate by at least a factor of three over the course of this year."*

The LHC was previously scheduled to run to the end 2011 before going into a long technical stop necessary to prepare it for running at its full design energy of 7 TeV per beam. However, the machine's excellent performance in its first full year of operation forced a rethink. Expected performance improvements in 2011 should increase the rate that the experiments can collect data by at least a factor of three compared to 2010. That would lead to enough data being collected this year to bring tantalising hints of new physics, if there is new physics currently within reach of the LHC operating at its current energy. However, to turn those hints into a discovery would require more data than can be delivered in one year, hence the decision to postpone the long shutdown. If there is no new physics in the energy range currently being explored by the LHC, running through 2012 will give the LHC experiments the data needed to fully explore this energy range before moving up to higher energy.

"With the LHC running so well in 2010, and further improvements in performance expected, there's a real chance that exciting new physics may be within our sights by the end of the year," Said CERN's Research Director, Sergio Bertolucci. *"For example, if nature is kind to us and the lightest supersymmetric particle, or the Higgs boson, is within reach of the LHC's current energy, the data we expect to collect by the end of 2012 will put them within our grasp."*

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- Tevatron competition for H
- Work programme in LS1 (to go to ~14 TeV)
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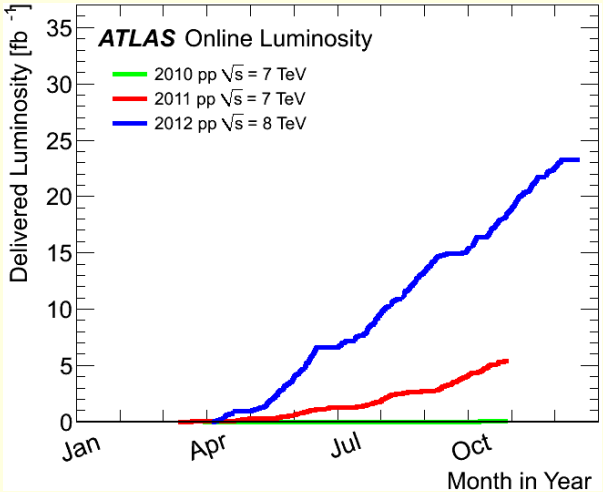

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End 2011: the first new particle at the LHC!

A new excited particle state of bottomonium, the $\chi_b(3P)$, was found via a distinctive decay mode – a new hadron state

PRL 108, 152001 (2012) PHYSICAL REVIEW LETTERS week ending 13 APRIL 2012

Observation of a New χ_b State in Radiative Transitions to $\Upsilon(1S)$ and $\Upsilon(2S)$ at ATLAS

G. Aad *et al.**
(ATLAS Collaboration)

(Received 21 December 2011; revised manuscript received 18 February 2012; published 9 April 2012)

The $\chi_b(nP)$ quarkonium states are produced in proton-proton collisions at the Large Hadron Collider at $\sqrt{s} = 7$ TeV and recorded by the ATLAS detector. Using a data sample corresponding to an integrated luminosity of 4.4 fb^{-1}, these states are reconstructed through their radiative decays to $\Upsilon(1S, 2S)$ with $\Upsilon \to \mu^+\mu^-$. In addition to the mass peaks corresponding to the decay modes $\chi_b(1P, 2P) \to \Upsilon(1S)\gamma$, a new structure centered at a mass of $10.530 \pm 0.005(\text{stat}) \pm 0.009(\text{syst})$ GeV is also observed, in both the $\Upsilon(1S)\gamma$ and $\Upsilon(2S)\gamma$ decay modes. This structure is interpreted as the $\chi_b(3P)$ system.

DOI: 10.1103/PhysRevLett.108.152001 PACS numbers: 14.40.Pq, 12.38.−t, 13.20.Gd, 14.65.Fy

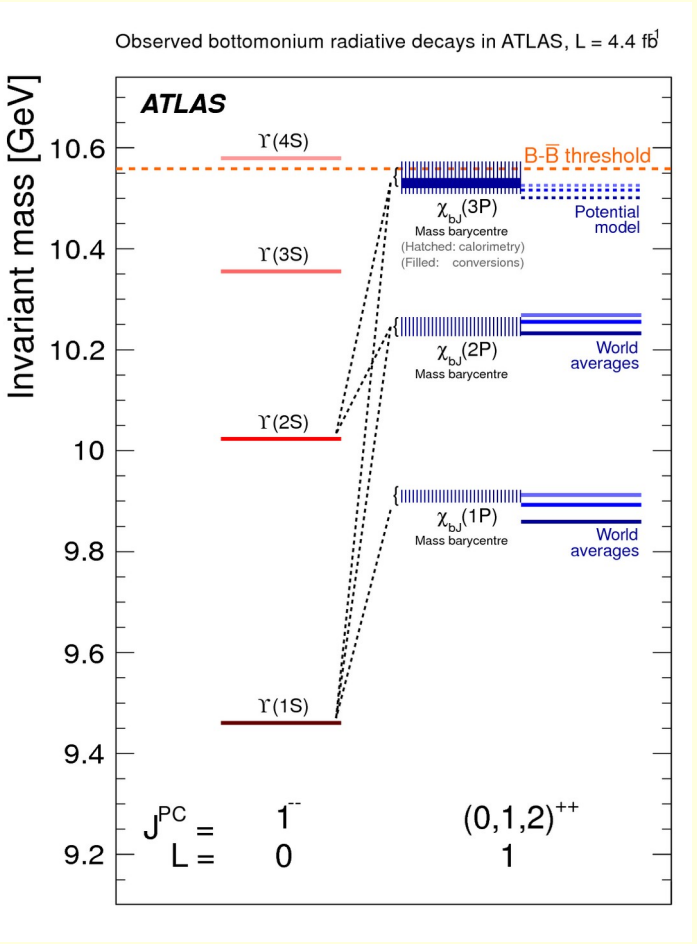
Measurements of the properties of heavy quark-antiquark bound states, or quarkonia, provide a unique insight into the

liquid-argon calorimeters for both electromagnetic and hadronic measurements. The muon spectrometer surrounds

LHC reports discovery of its first new particle

By Jonathan Amos
Science correspondent, BBC News

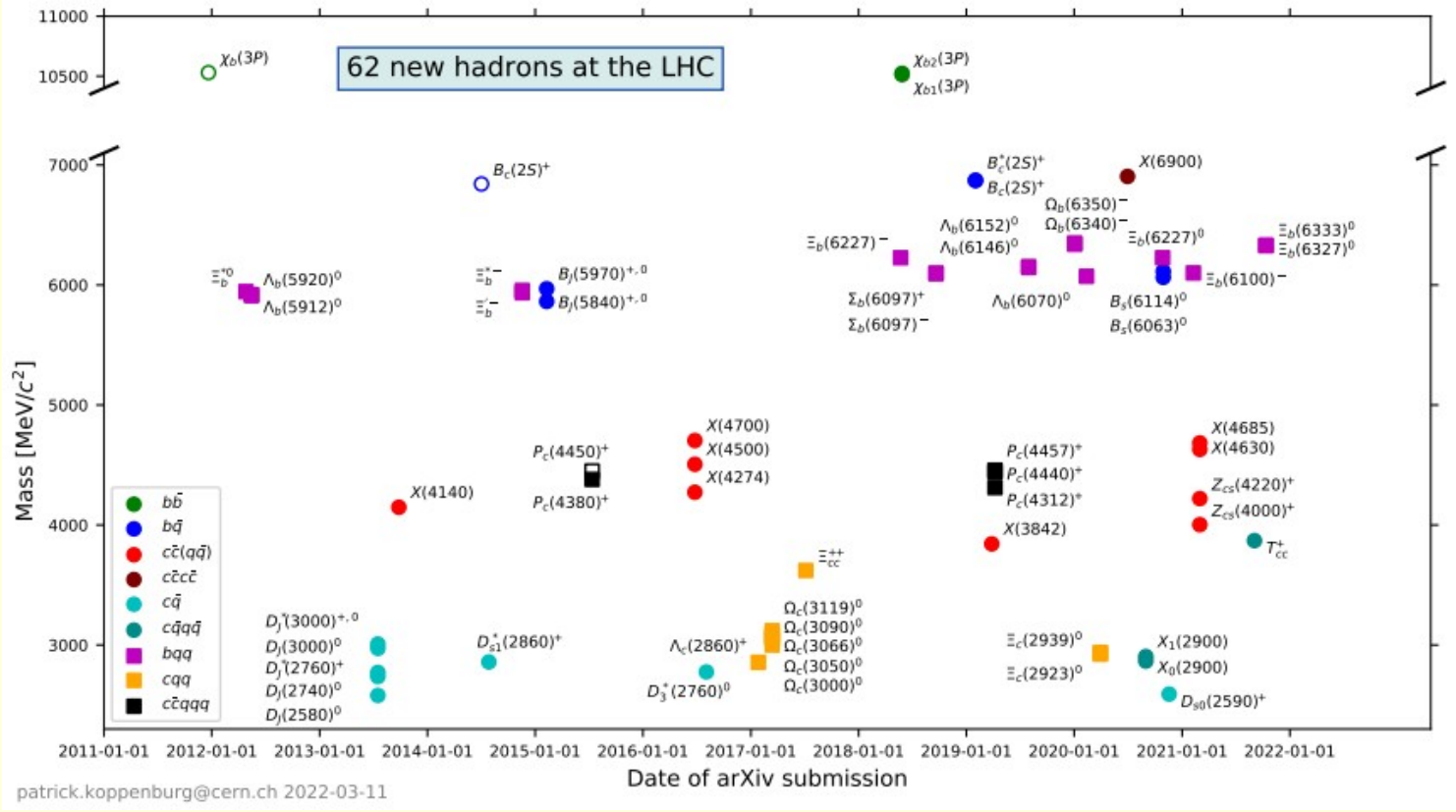
22 December 2011



End 2011: the first new particle of many

Many more *new hadrons* discovered since then – a speciality particularly of LHCb

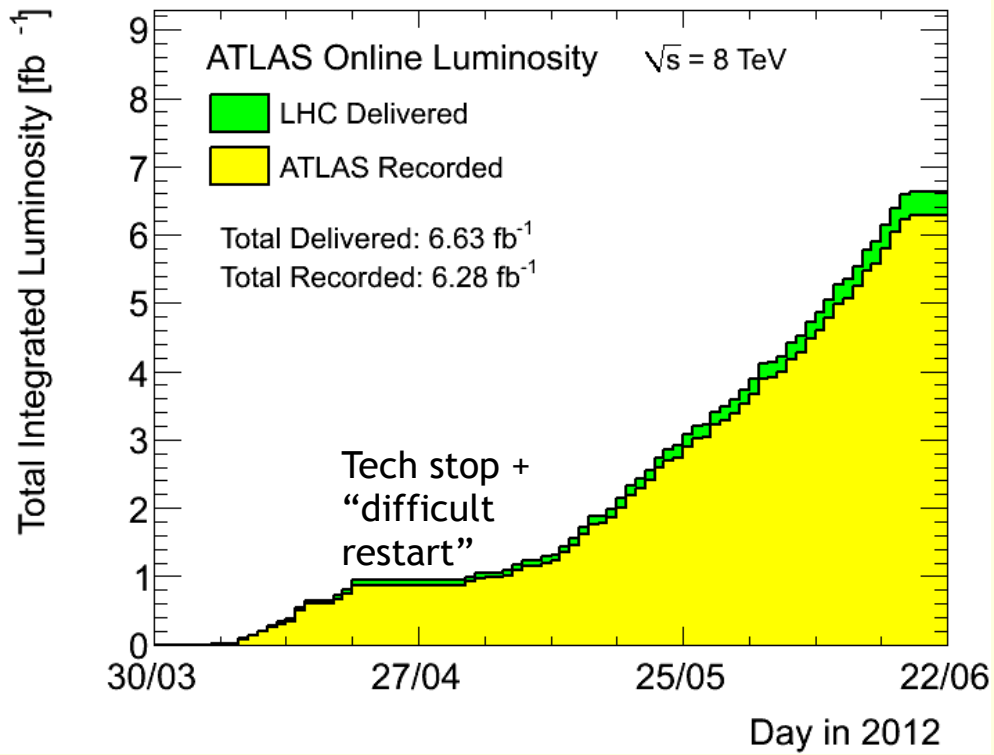
LHCb measures a vast range of properties of hadrons containing b and c quarks



2012

Evident at the end-of-2011 Jamboree that “an update” would have to be made by ICHEP

Much discussion in May/June about the nature of this – “stronger hints” / “very preliminary” seemed most likely



Four weeks in summer 2012

	MON	TUE	WED	THU	FRI	SAT	SUN
25	18 Jun Final ICHEP data	19	20 DG,SP meeting	21 CERN Council	22 CERN Council	23	24
26	25	26	27	28	29	30	1 Jul
27	2	3	4	5	6	7	8
28	9	10	11	12	13	14	15

The lead-up to 4 July 2012...

20 June (Weds)

Meeting of CERN Director-General, Director of Research and Computing, and ATLAS and CMS Spokespersons, to discuss the preparations for the Higgs search update for ICHEP

21 June (Thu)

CERN Council meeting (21 and 22 June)
Press offices alerted to the likelihood of an “update seminar” in early July

22 June (Fri)

Collaborations informed that tentatively the update seminar would be in the morning of 4 July at CERN, as requested by Council

Four weeks in summer 2012

	MON	TUE	WED	THU	FRI	SAT	SUN
25	18 Jun	19	20 DG,SP meeting	21 CERN Council	22 CERN Council	23	24
26	25	26	27	28	29	30	1 Jul
27	2	3	4 Seminar: 9am CERN, 5pm Melbourne	5	6	7	8
28	9	10	11	12	13	14	15

The crazy days continued...

Thursday 28 June

Final approvals (in ATLAS), with full data-sample available

Earlier than for some other summer conferences - for results to be checked, checked, checked, talks to be updated and polished, and even for some of us to fly to Melbourne

Monday 2 July

Fermilab submitted their final H search results to the arXiv, held a seminar, and issued a press release

Tevatron

Tevatron scientists announce their final results on the Higgs particle

July 2, 2012

Share Tweet Email

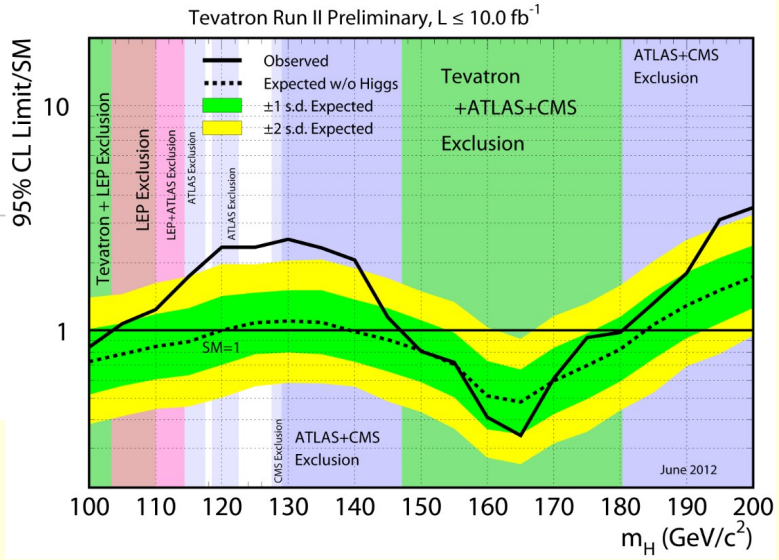
Science contact

- Gregorio Bernardi, co-spokesperson, DZero Experiment, Fermilab, gregorio@fnal.gov, 773-744-8259
- Dmitri Denisov, co-spokesperson, DZero Experiment, Fermilab, denisovd@fnal.gov, 630-531-0413
- Luciano Ristori, co-spokesperson, CDF Experiment, Fermilab, luciano@fnal.gov, 630-840-8612
- Rob Roser, Physicist, Fermilab, roser@fnal.gov, + 1 630-399-2609

Media contact

- Kurt Riesselmann, Fermilab Office of Communication, media@fnal.gov, 630-840-3351

After more than 10 years of gathering and analyzing data produced by the U.S. Department of Energy's Tevatron collider, scientists from the CDF and DZero collaborations have found their strongest indication to date for the long-sought Higgs particle. Squeezing the last bit of information out of 500 trillion collisions produced by the Tevatron for each experiment since March 2001, the final analysis of the data does not settle the question of whether the Higgs particle exists, but gets closer to an answer. The Tevatron scientists unveiled their latest results on July 2, two days before the highly anticipated announcement of the latest Higgs-search results from the Large Hadron Collider in Europe.



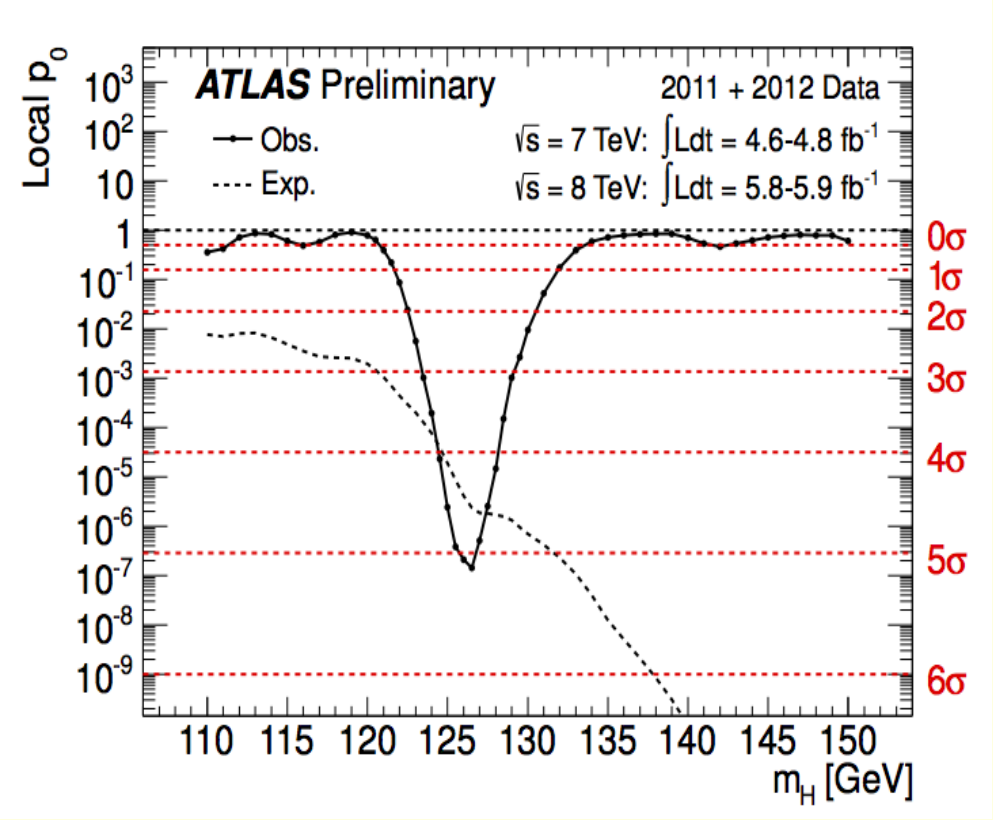
Four weeks in summer 2012

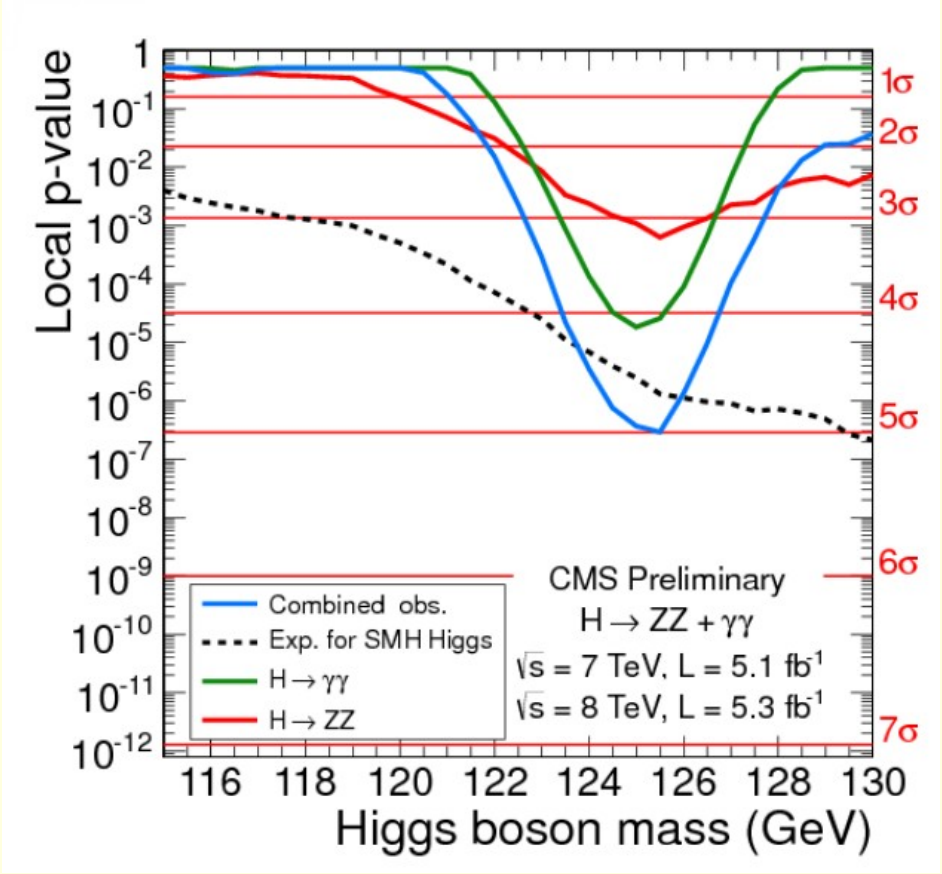
	MON	TUE	WED	THU	FRI	SAT	SUN
25	18 Jun Final data	19	20 DG,SP meeting	21 CERN Council	22 CERN Council	23	24
26	25	26	27	28 Approvals (A)	29	30	1 Jul
27	2 *(DGC: Geneva to Melbourne, 6pm Mon - 6am Wed)*	3	4 Seminar: 9am CERN, 5pm Melbourne	5	6	7	8
28	9	10	11	12	13	14	15

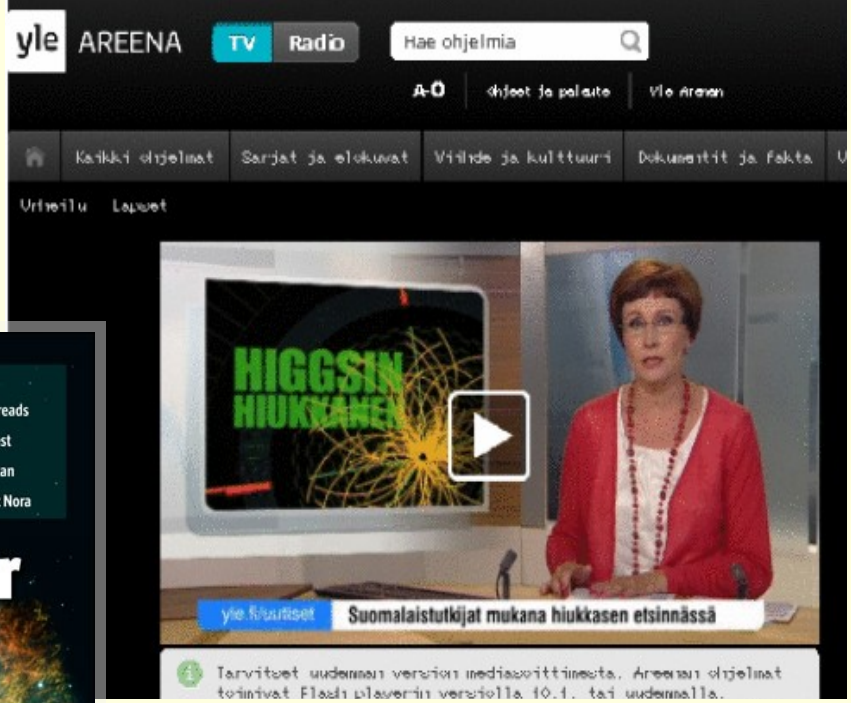

Combined results: the excess
Preliminary
Obs.
Exp.
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb⁻¹
2011 + 2012 Data
Expected from SM Higgs at given m_H
m_H [GeV]
ATLAS Preliminary
Local Significance
5σ
Maximum excess observed at
Local significance (including energy-scale systematics)
Probability of background up-fluctuation
Expected from SM Higgs m_H=126.5
m_H = 126.5 GeV
5.0 σ
3 x 10⁻⁷
4.6 σ
Global significance: 4.1-4.3 σ (for LEE over 110-600 or 110-150 GeV)


CHEP2012
MELBOURNE
THE UNIVERSITY OF MELBOURNE
CoEPP
CERN Main Amphitheatre
ansto
Australian Synchrotron
ACAS
CERN COURIER
DELL
RESERVED

The opened boxes on 4 July





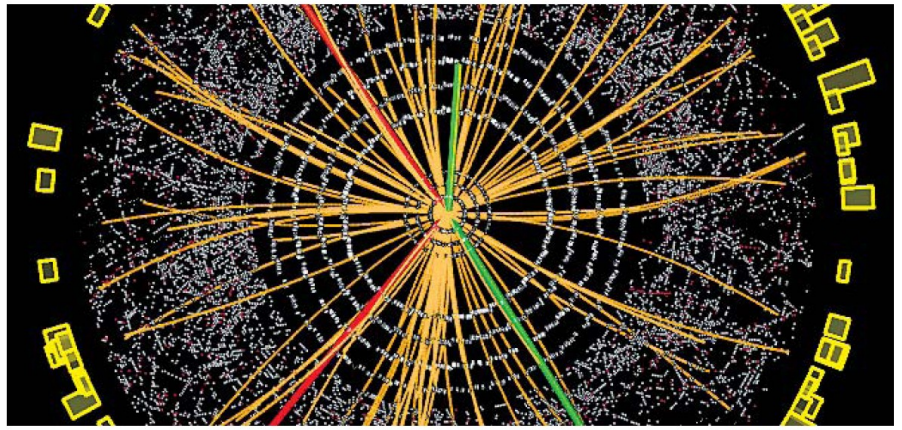


More than a billion people saw the news on TV, on five thousand broadcasts on a thousand TV stations

Ten thousand news articles in a hundred countries

Melbourne newspaper
“The Age” 5 July

Higgs was right Picture that changes the way we see the universe for ever



Ian Sample Geneva


1

New results indicate that particle discovered at CERN is a Higgs boson

14 MARCH, 2013

Geneva, 14 March 2013. At the Moriond Conference today, the ATLAS and CMS collaborations at CERN[1]'s Large Hadron Collider (LHC) presented preliminary new results that further elucidate the particle discovered last year. Having analysed two and a half times more data than was available for the discovery announcement in July, they find that the new particle is looking more and more like a Higgs boson, the particle linked to the mechanism that gives mass to elementary particles. It remains an open question, however, whether this is the Higgs boson of the Standard Model of particle physics, or possibly the lightest of several bosons predicted in some theories that go beyond the Standard Model. Finding the answer to this question will take time.

Whether or not it is a Higgs boson is demonstrated by how it interacts with other particles, and its quantum properties. For example, a Higgs boson is postulated to have spin 0, and in the Standard Model its parity – a measure of how its mirror image behaves – should be positive. CMS and ATLAS have compared a number of options for the spin-parity of this particle, and these all prefer no spin and positive parity. This, coupled with the measured interactions of the new particle with other particles, strongly indicates that it is a Higgs boson.

"*The preliminary results with the full 2012 data set are magnificent and to me it is clear that we are dealing with a Higgs boson though we still have a long way to go to know what kind of Higgs boson it is.*" *said CMS spokesperson Joe Incandela.*

"The beautiful new results represent a huge effort by many dedicated people. They point to the new particle having the spin-parity of a Higgs boson as in the Standard Model. We are now well started on the measurement programme in the Higgs sector," said ATLAS spokesperson Dave Charlton.

From the new boson to a Higgs boson

By March 2013, we were pretty sure it was spin-0 not spin-2

Judged it was time to start admitting we had a Higgs boson!

But, then and now, *not* "the Standard Model Higgs boson"

New results indicate that particle discovered at CERN is a Higgs boson

14 MARCH, 2013

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"The beautiful new results spin-parity of a Higgs boso Higgs sector," said ATLAS s

To determine if this is the Standard Model Higgs boson, the collaborations have, for example, to measure precisely the rate at which the boson decays into other particles and compare the results to the predictions. The detection of the boson is a very rare event - it takes around 1 trillion (10^{12}) proton-proton collisions for each observed event. To characterize all of the decay modes will require much more data from the LHC.

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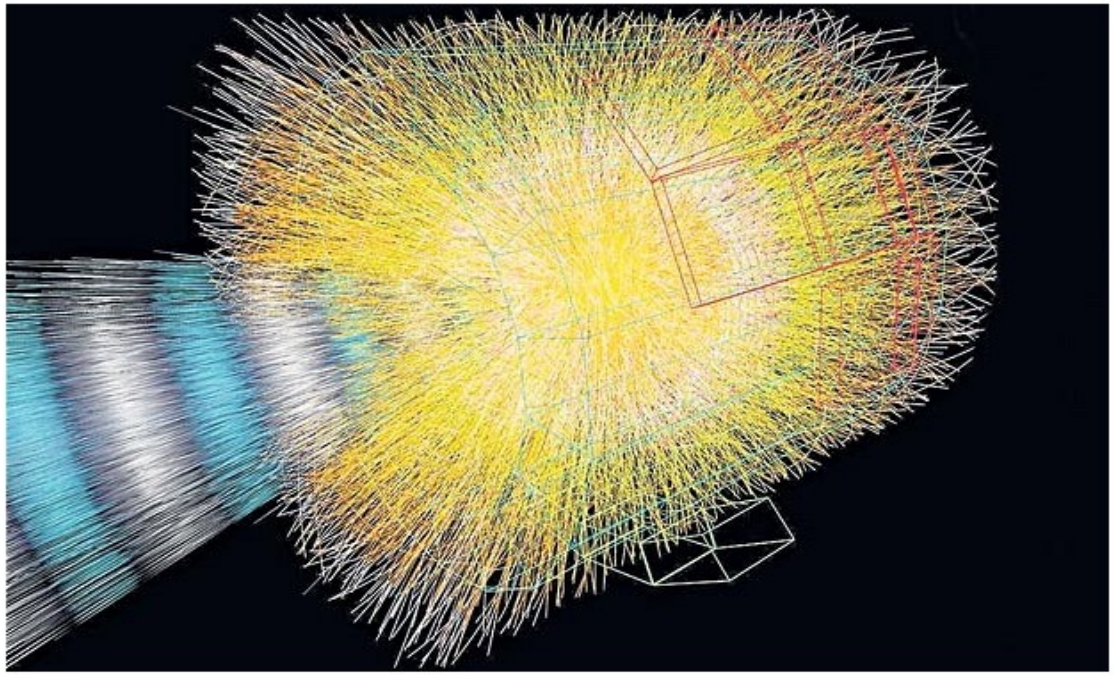
The Telegraph

Higgs boson: scientists confident they have discovered the 'God particle'

Scientists are confident that they have discovered the long sought after Higgs boson, known as the "God particle", which holds the physical fabric of the universe together.



Atom-smashing: scientists are confident that the collisions within the £2.6 billion particle collider at CERN revealed the elusive Higgs boson Photo: CERN

By Hayley Dixon
11:04AM GMT 14 Mar 2013

381 Comments

CERN, the European Organisation for Nuclear Research, announced today that after extensive testing it was "looking more and more" like the particle which they discovered last year was the Higgs boson.

Finding the Higgs plugs a gaping hole in the Standard Model of physics, the theory that describes all the particles, forces and interactions that make up the universe.

Today the collaborating scientists from ATLAS and CMS announced their results at the Moriond Conference, in La Thuile, Italy, further confirming the "magnificent" discovery.

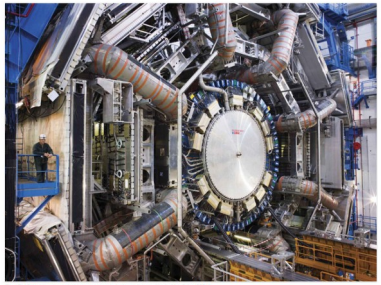
Yukawa couplings

A further fundamental discovery in the scalar sector

ATLAS sees Higgs boson decay to fermions

The ATLAS experiment at CERN has found evidence for the Higgs boson decaying to two tau particles

27 NOVEMBER, 2013 | By Abha Eli Phoboo & Sylvie Brunet

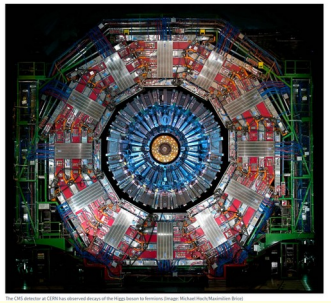


The ATLAS experiment at CERN has released preliminary results that show evidence that the Higgs boson decays to two tau particles. Taus belong to a group of subatomic particles called the fermions, which make up matter. This result – measured at 4.1 sigma on the 5-point scale particle physicists use to determine the certainty of a result – is the first evidence for a Higgs decay to fermions.

CMS presents evidence for Higgs decays to fermions

The CMS collaboration have measured the decay of the Higgs boson to pairs of bottom quarks and to pairs of tau leptons

3 DECEMBER, 2013 | By Achintya Rao



At a seminar at CERN this morning, the CMS collaboration presented several measurements of the properties of the Higgs boson. CMS showed strong evidence for the decay of Higgs bosons into fermions, corroborating CMS results shown earlier this year. CMS physicists have now measured the decay of the Higgs to pairs of bottom (b) quarks and pairs of tau leptons, with a combined significance of 4 sigma on the 5-point scale that particle physicists use to measure the certainty of a result. This significance means that the probability of a false positive is estimated to be only about one in 16,000.

Somehow we didn't manage to get this one onto the front pages of newspapers!

A host of prizes

Paris Sphicas, chair of the international organizing committee, centre, with the winners of the 2013 EPS-HEPP prize, left to right, Peter Jenni, Tejinder Virdee, Dave Charlto
Image credit: Abha Eli Phoboo.

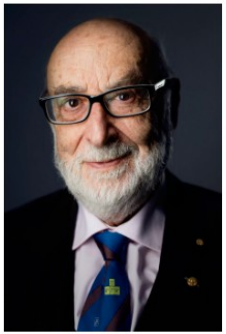
Fundación Princesa de Asturias

PRINCESS OF ASTURIAS AWARDS | LAUREATES

PETER HIGGS, FRANÇOIS ENGLERT AND EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH CERN

PRINCE OF ASTURIAS AWARD FOR TECHNICAL & SCIENTIFIC RESEARCH 2013

The Nobel Prize in Physics 2013



© Nobel Media AB. Photo: A. Mahmoud
François Englert
Prize share: 1/2

© Nobel Media AB. Photo: A. Mahmoud
Peter W. Higgs
Prize share: 1/2

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider."

Re-evaluating priorities

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Action to be taken		*Voting Procedure*
For Approval	**EUROPEAN STRATEGY SESSION OF COUNCIL** 16th Session - 30 May 2013 **European Commission** **Berlaymont Building - Brussels**	Simple Majority of Member States represented and voting

The European Strategy for Particle Physics
Update 2013

Having finalised its text by consensus at its Session of 22 March 2013, the Council is now invited to formally adopt the Update of the European Strategy for Particle Physics set out in this document.

Preamble

Since the adoption of the European Strategy for Particle Physics in 2006, the field has made impressive progress in the pursuit of its core mission, elucidating the laws of nature at the most fundamental level. A giant leap, the discovery of the Higgs boson, has been accompanied by many experimental results confirming the Standard Model beyond the previously explored energy scales. These results raise further questions on the origin of elementary particle masses and on the role of the Higgs boson in the more fundamental theory underlying the Standard Model, which may involve additional particles to be discovered around the TeV scale. Significant progress is being made towards solving long-standing puzzles such as the matter-antimatter asymmetry of the Universe and the nature of the mysterious dark matter. The observation of a new type of neutrino oscillation has opened the way for future investigations of matter-antimatter asymmetry in the neutrino sector. Intriguing prospects are emerging for experiments at the overlap with astroparticle physics and cosmology. Against the backdrop of dramatic developments in our understanding of the science landscape, Europe is updating its Strategy for Particle Physics in order to define the community's direction for the coming years and to prepare for the long-term future of the field.

Re-evaluating priorities

Also from the
Update of the European Strategy for Particle Physics 2013

c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

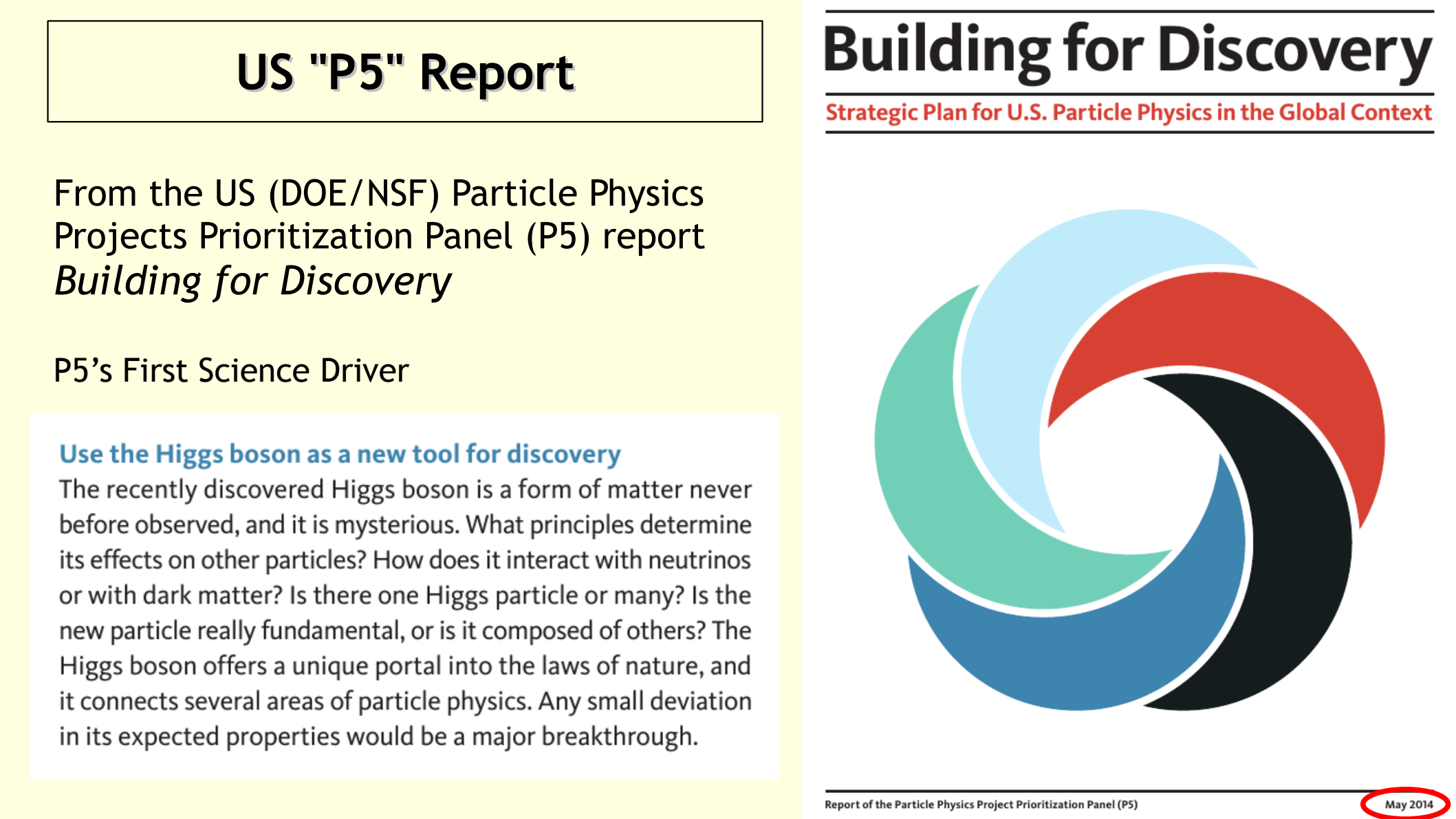
US "P5" Report

From the US (DOE/NSF) Particle Physics Projects Prioritization Panel (P5) report *Building for Discovery*

P5's First Science Driver

Use the Higgs boson as a new tool for discovery

The recently discovered Higgs boson is a form of matter never before observed, and it is mysterious. What principles determine its effects on other particles? How does it interact with neutrinos or with dark matter? Is there one Higgs particle or many? Is the new particle really fundamental, or is it composed of others? The Higgs boson offers a unique portal into the laws of nature, and it connects several areas of particle physics. Any small deviation in its expected properties would be a major breakthrough.



US "P5" Report

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Recommendation 10 : Complete the LHC phase-1 upgrades and continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS). The LHC upgrades constitute our highest-priority near-term large project.

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

Report of the Particle Physics Project Prioritization Panel (P5) May 2014

Much wider cultural impacts

Much wider cultural impacts and political

Reflections...

The impact of the discovery was immense

It is not every day that one
- Discovers a completely new type of particle
- Makes a step change in understanding of physical reality (well, the vacuum!)

It was hugely gratifying that the wider world shared in the excitement, and the feeling of progress for the knowledge of humanity

Even though it is ten years, the exploration of the scalar sector only just begun…

…and it was a wonderful privilege to be with many of you at the centre of it