
Physics at the LHC 2010
opening talk
R.-D. Heuer, CERN
DESY-HH, June 7, 2010

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Past few decades

"Discovery" of Standard Model

through synergy of

hadron - hadron colliders (e.g. Tevatron)

lepton - hadron colliders (HERA)

lepton - lepton colliders (e.g. LEP, SLC)

Status of the SM Higgs fit

F. Canelli

Winter '09

Sensitive to log m_H

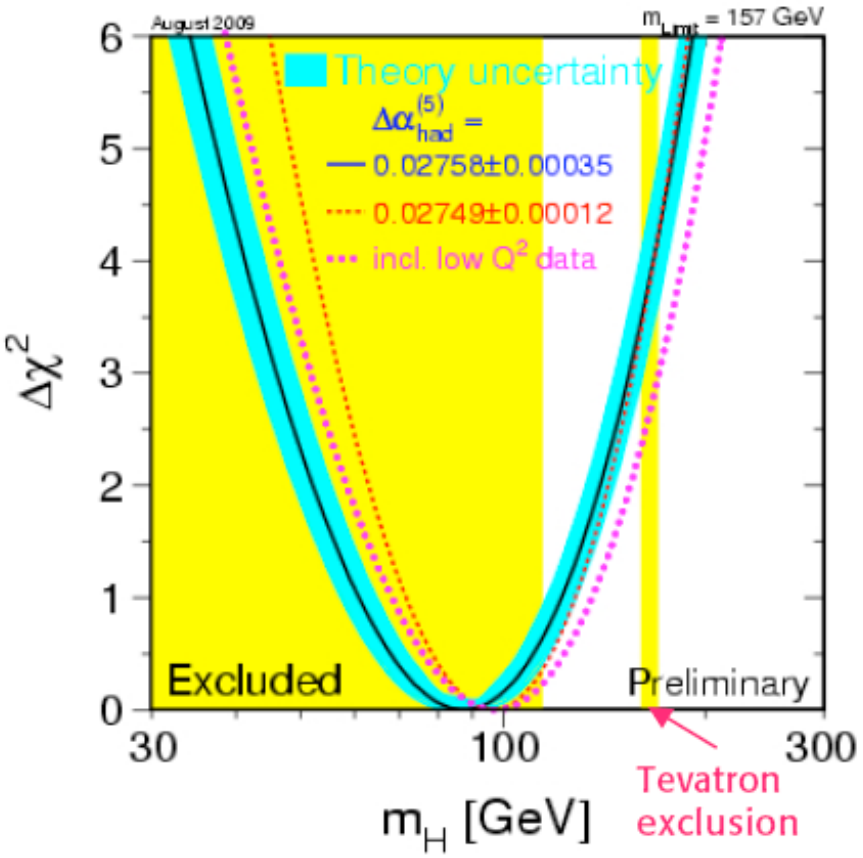
Rad Corr.s -> $\log_{10} m_H(\text{GeV}) = 1.94 \pm 0.15$

$m_H = 87^{+35}_{-26}$ GeV

This is a great triumph for the SM: ~right in the narrow allowed range $\log_{10} m_H$ ~2 - 3

Direct search: $m_H > 114.4$ GeV

Radiative corr's indicate a light H



At 95 % cl

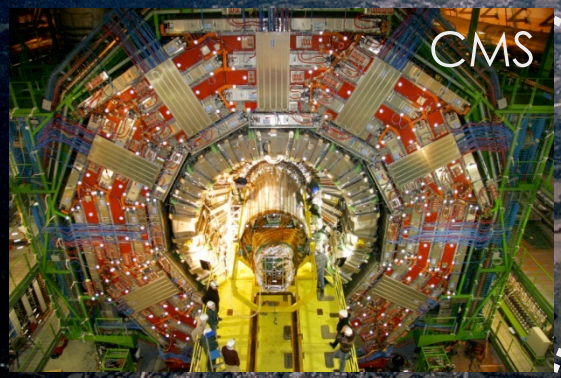
$m_H < 157$ GeV (rad corr.'s)

$m_H < 186$ GeV (incl. direct search bound)

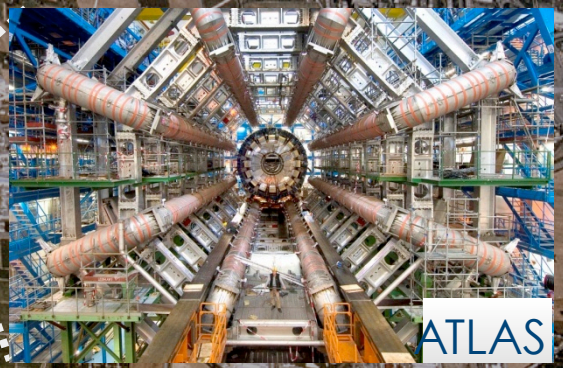
(G.Altarelli, LP09)

Enter a New Era in Fundamental Science

Start-up of the Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.



Exploration of a new energy frontier
Proton-proton collisions at E_{CM} = 14 TeV



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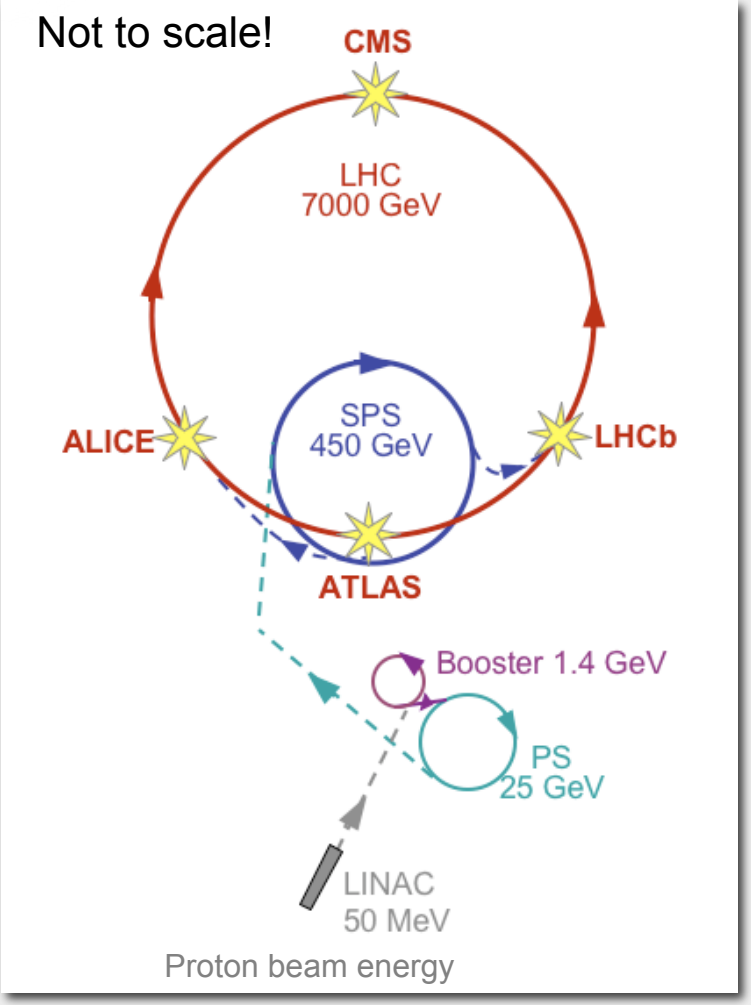
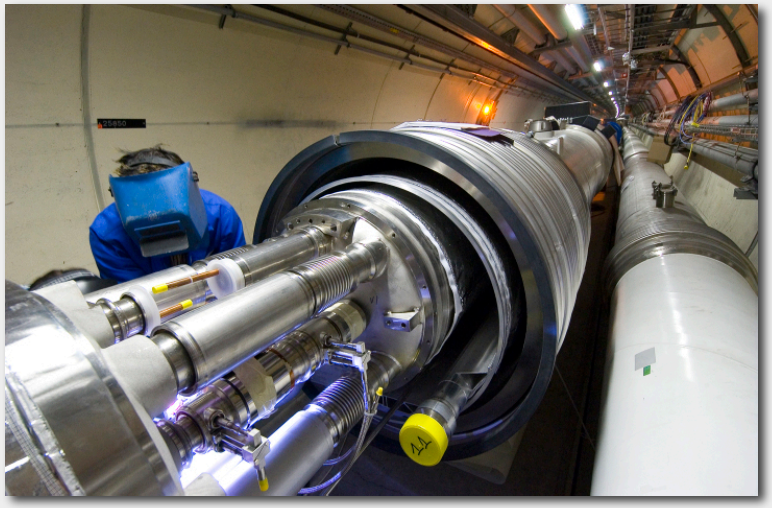
LHC operation in September 2008

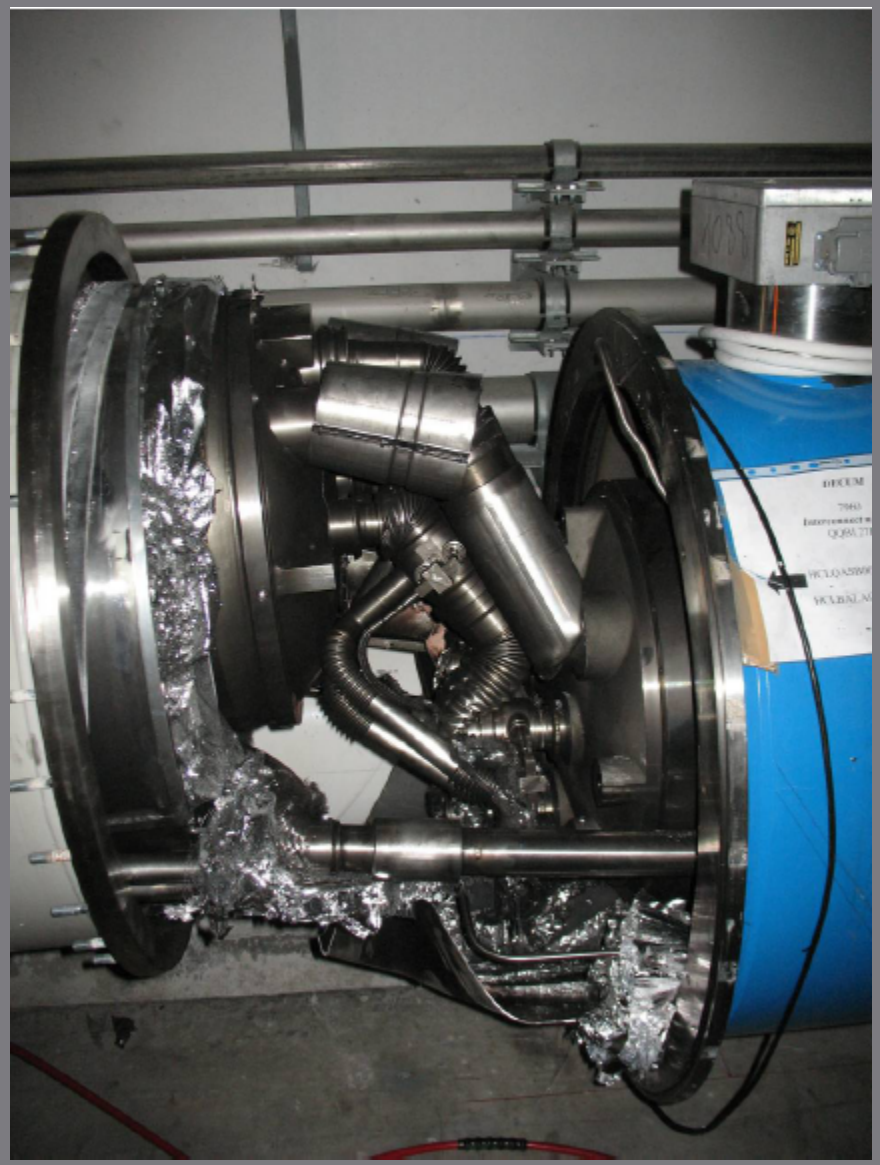
10 September 2008: first protons circulating in the LHC ring

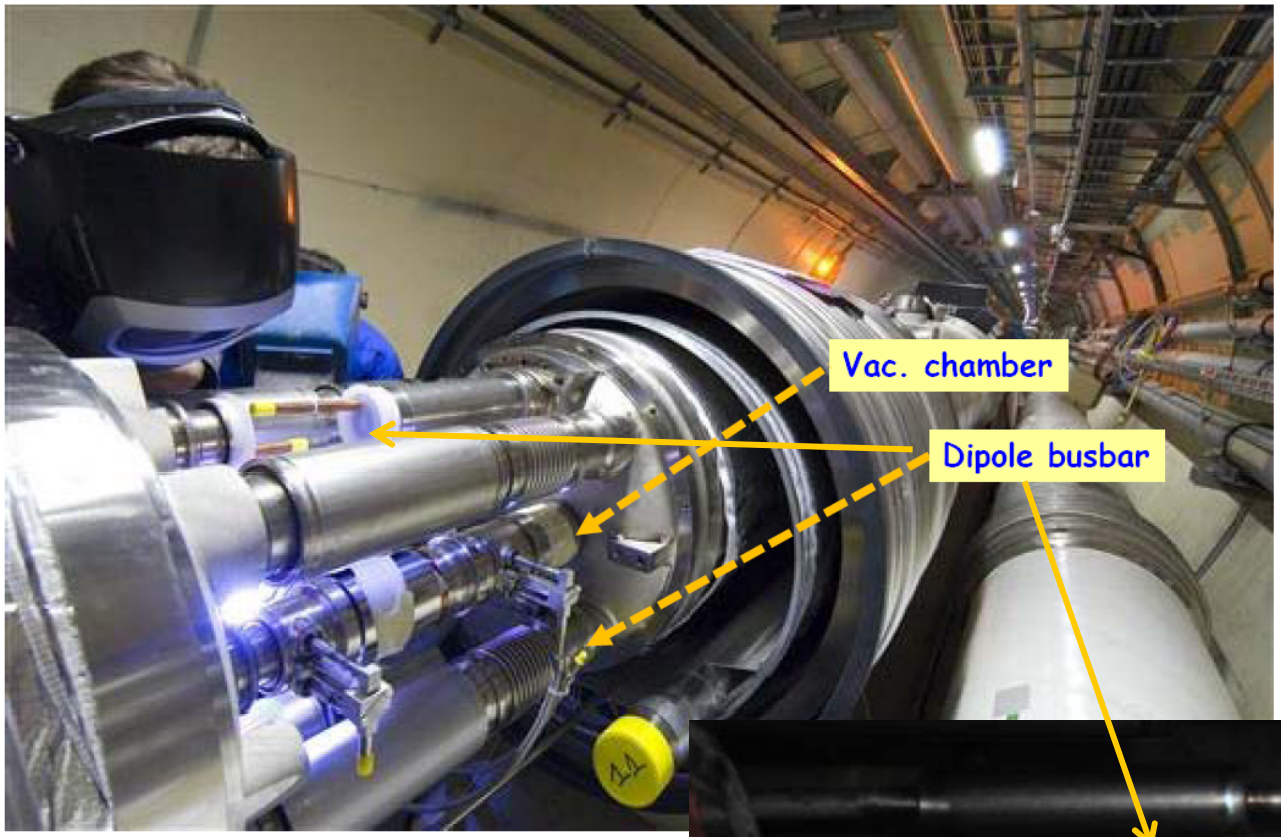


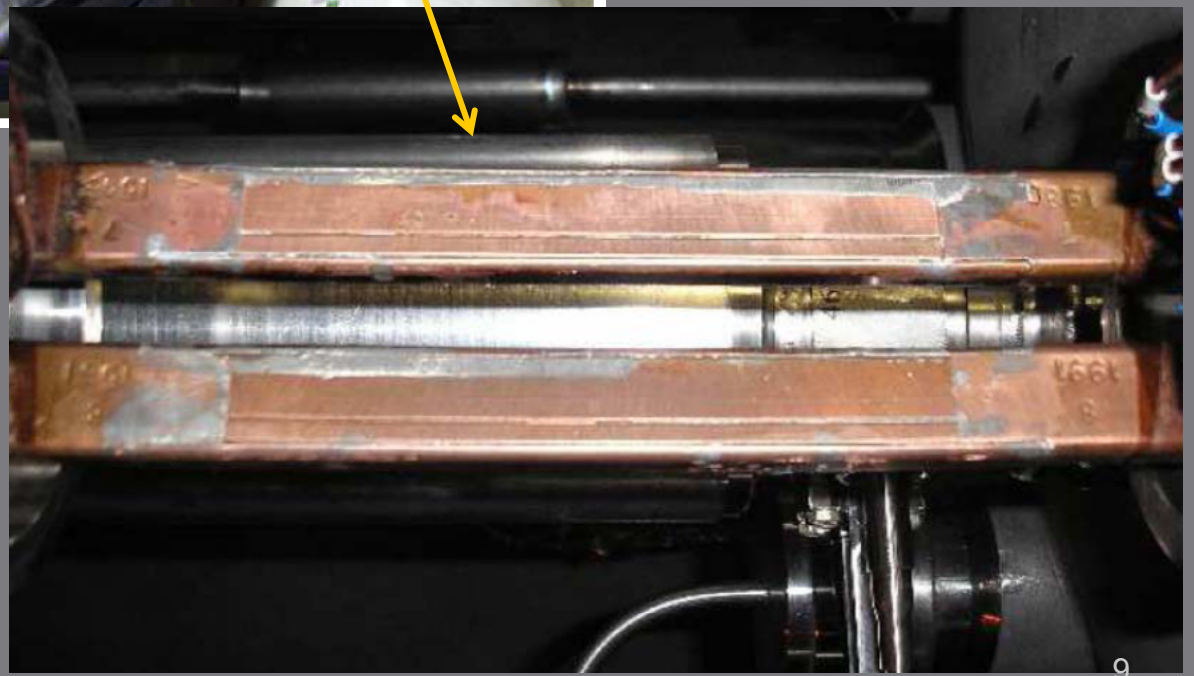
19 September: incident in sector 3-4



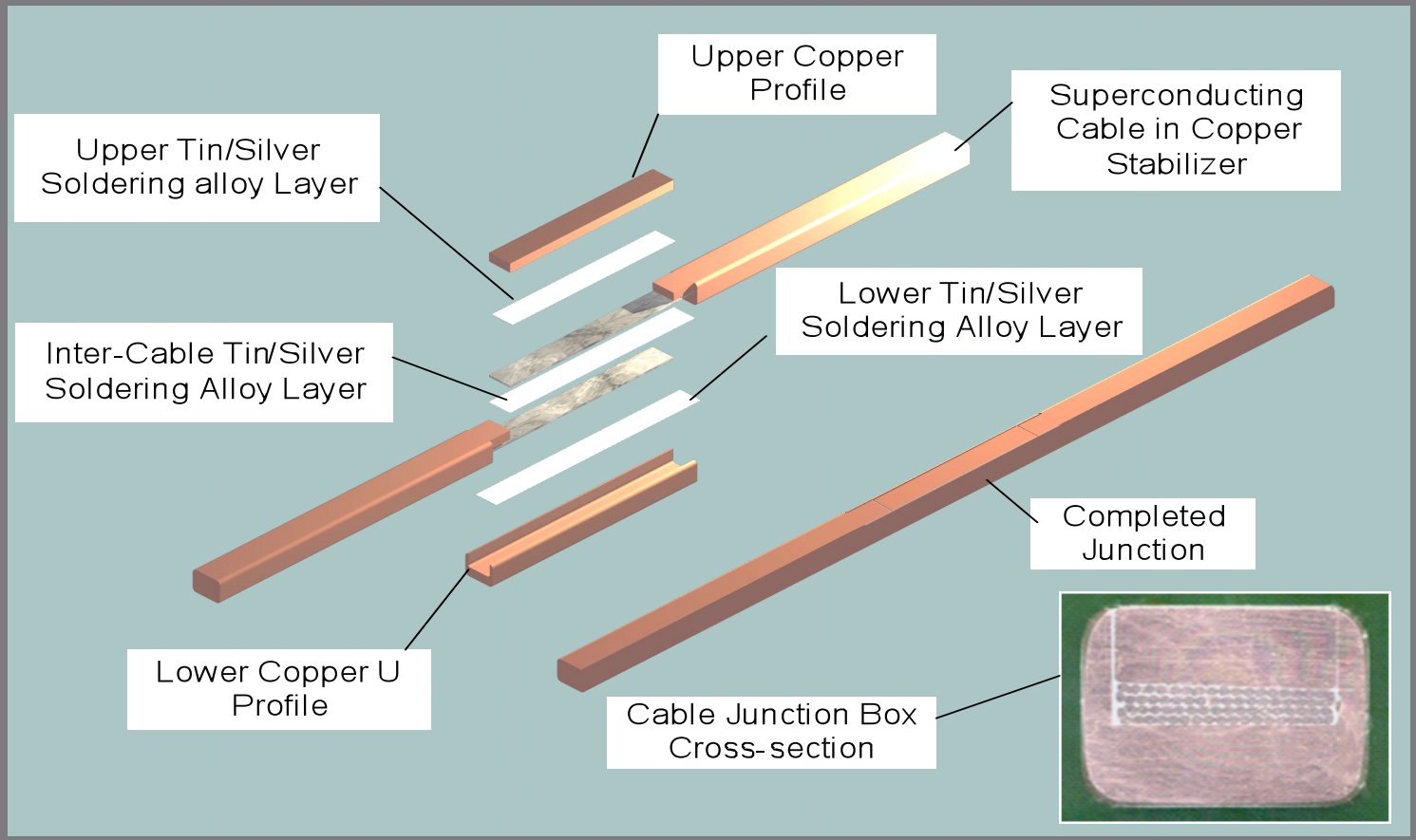
The incident was traced to a faulty electrical connection between segments of the LHC's superconducting cable
(busbars)
High impact was caused by collateral damage



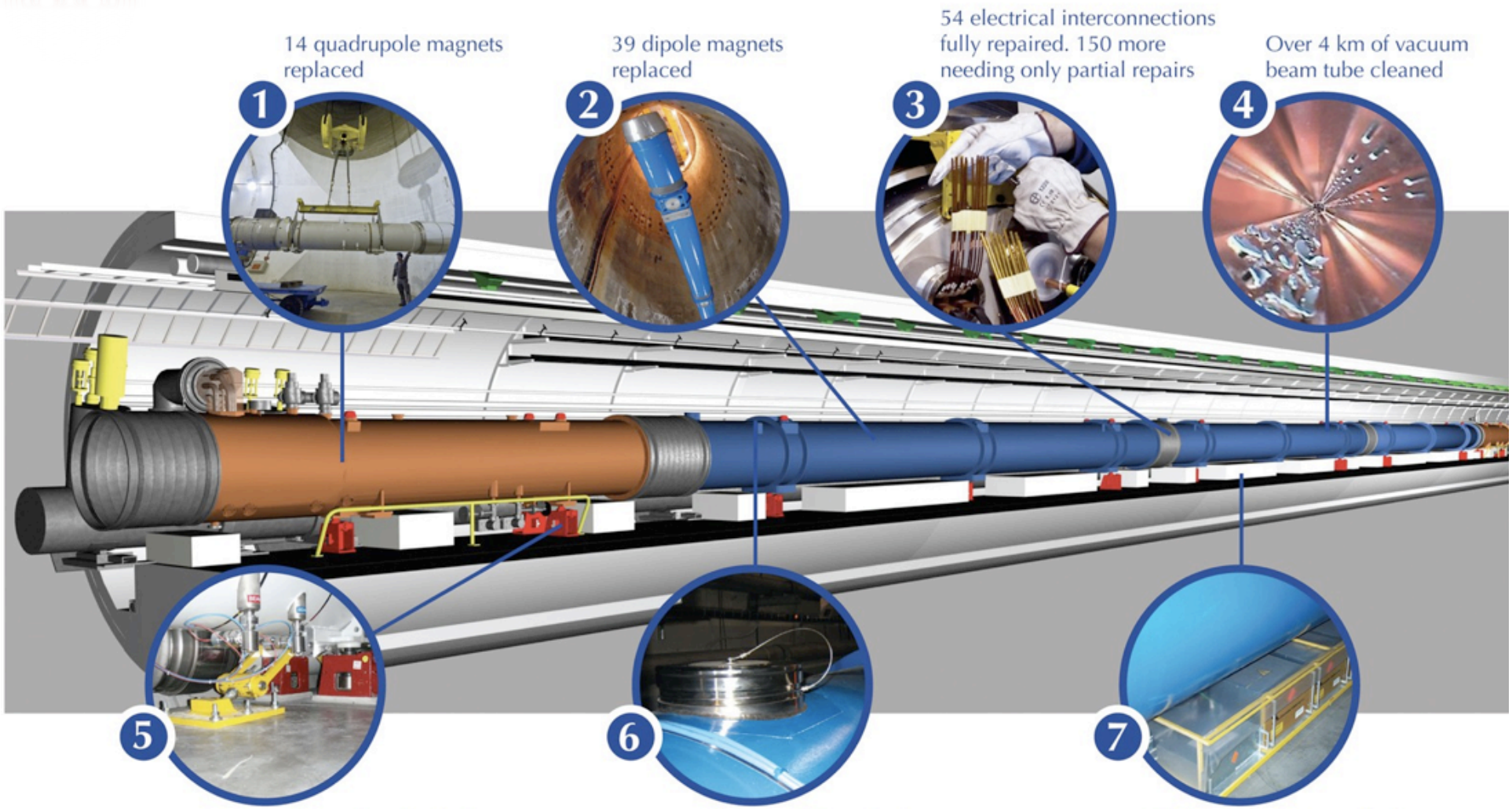

Vac. chamber
Dipole busbar



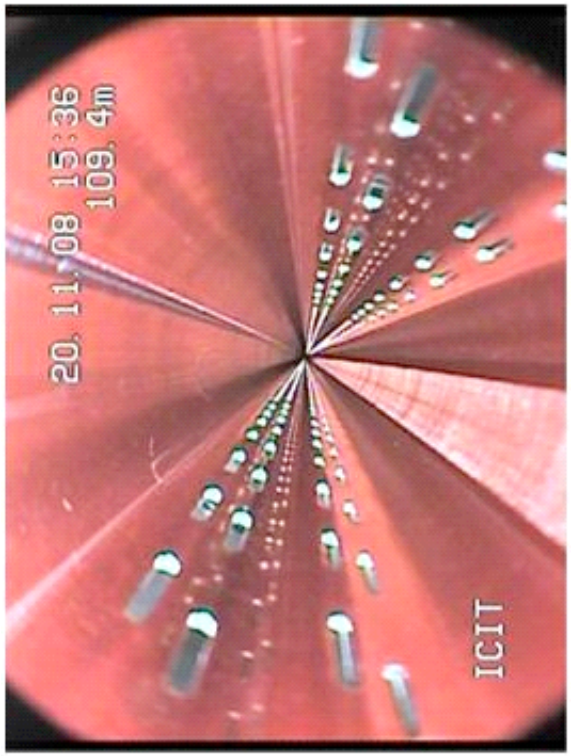
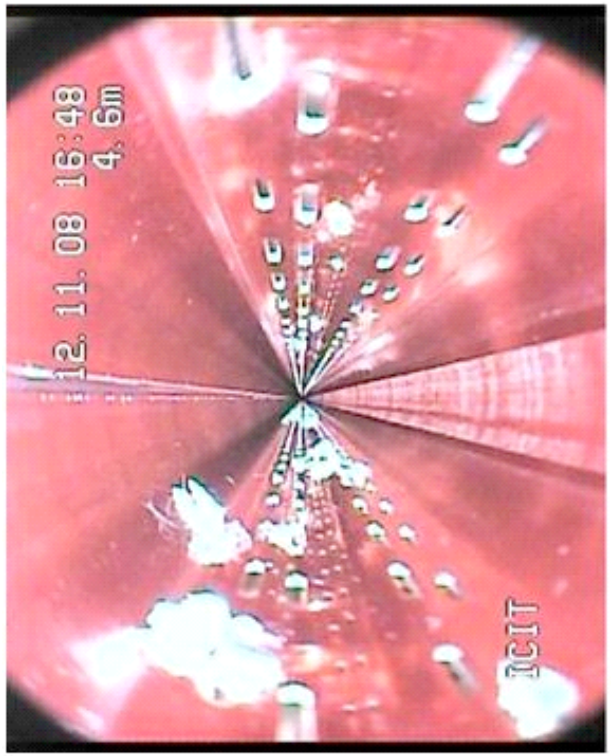
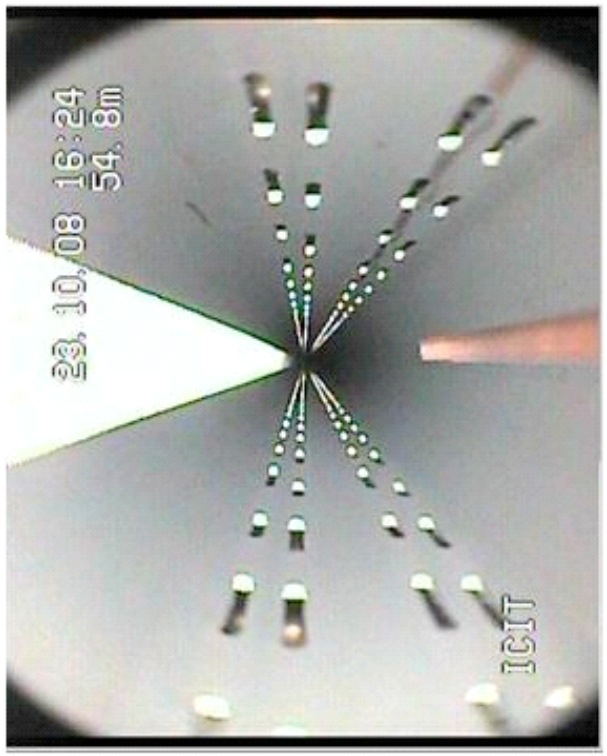
The magnet interconnects (busbars)



The LHC repairs in detail

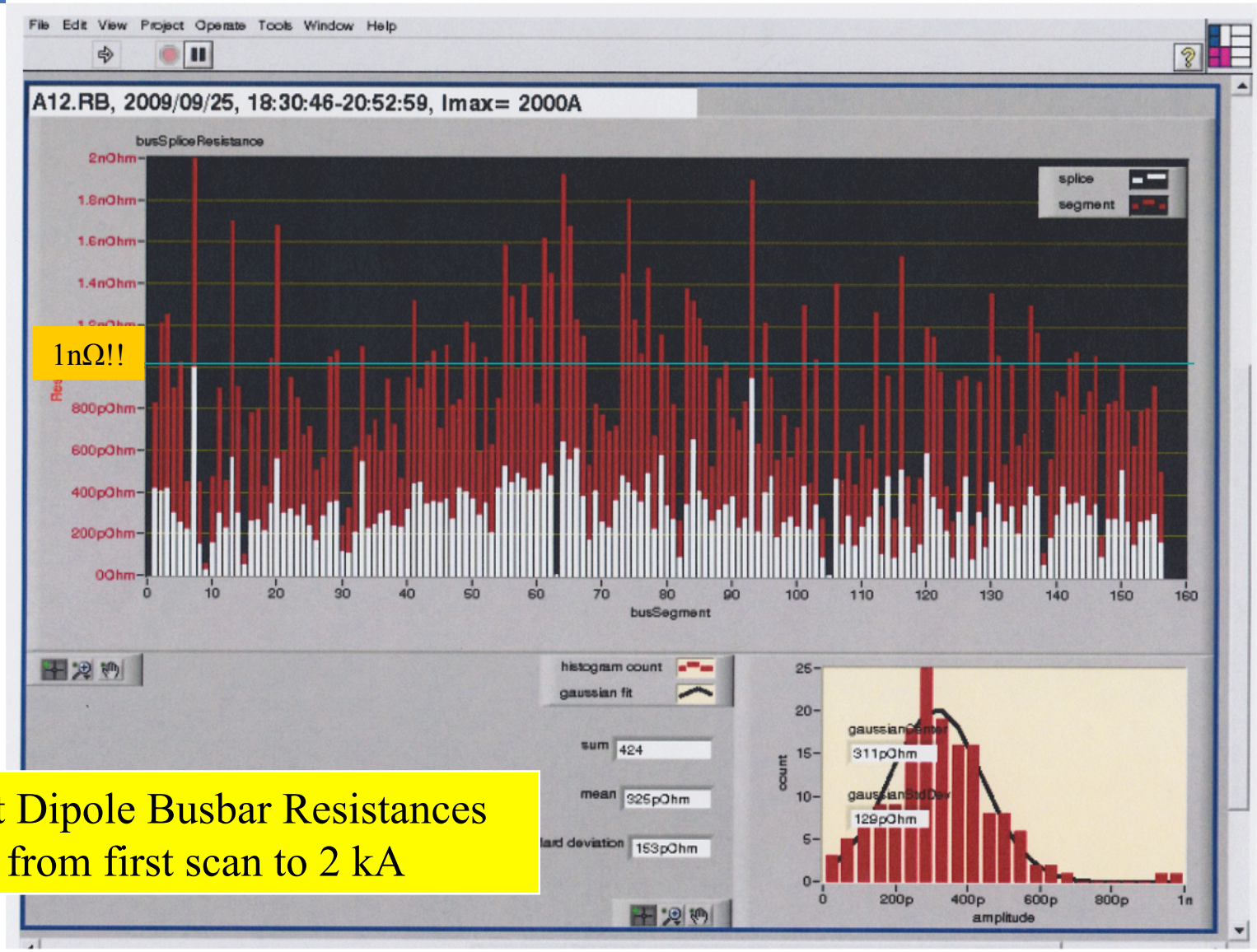


Beam vacuum recovery in sector 3-4
Beam Vacuum Contamination

Beam Screen (BS) : The red color is characteristic of a clean copper surface	BS with some contamination by super-isolation (MLI multi layer insulation)	BS with soot contamination. The grey color varies depending on the thickness of the soot, from grey to dark.
		

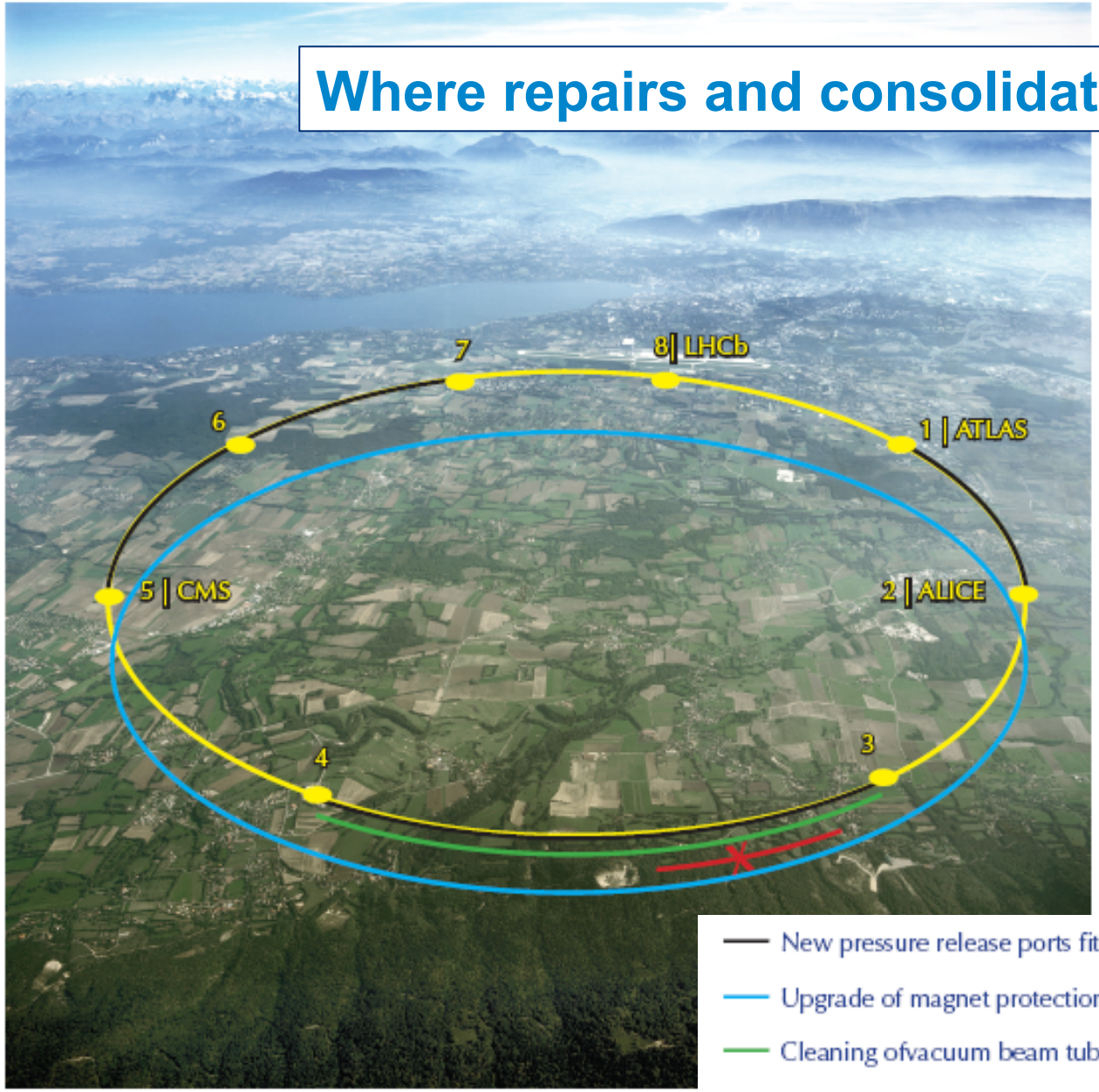
Splice Mapping of Dipoles

QPS team



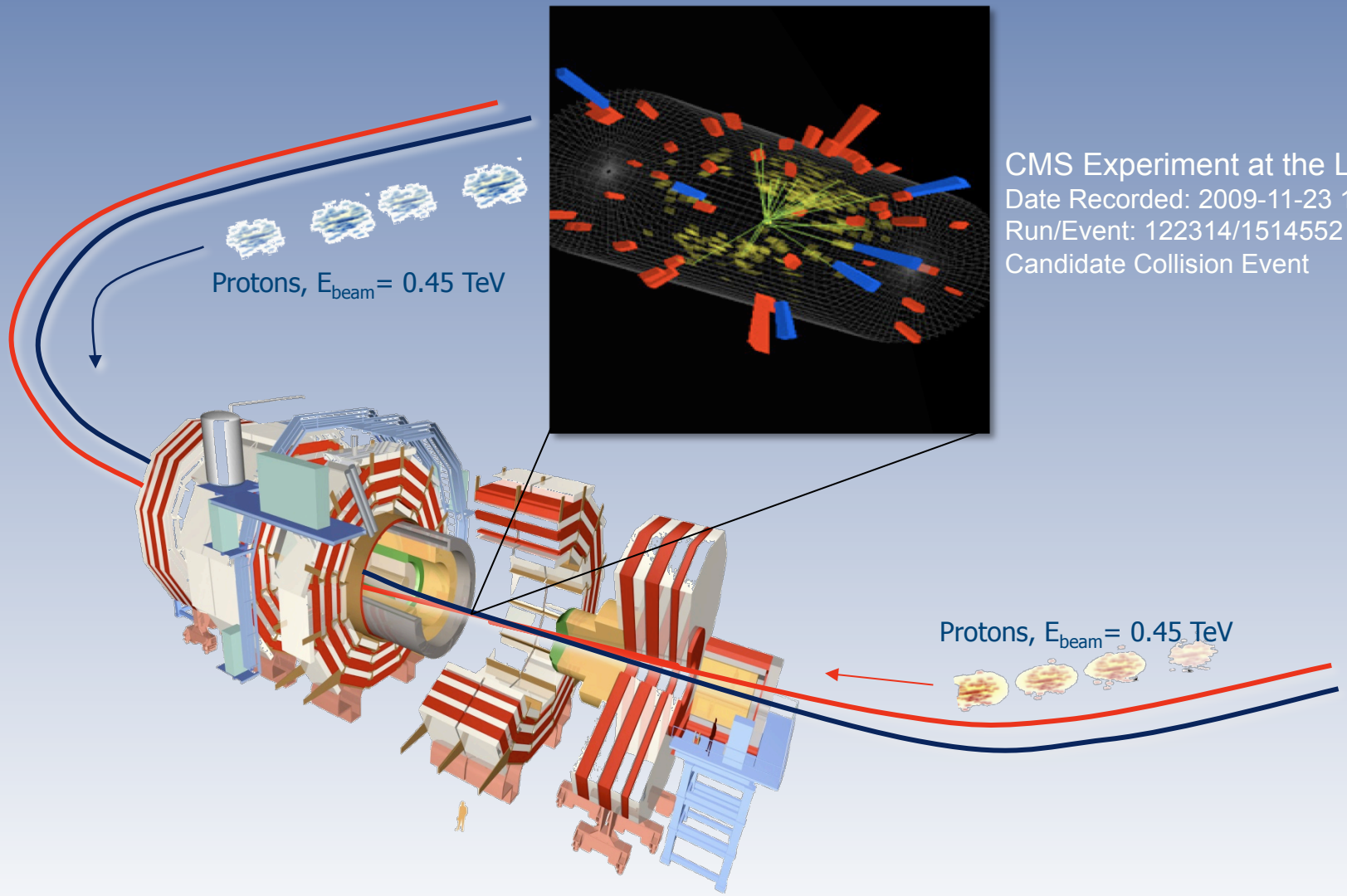
First Dipole Busbar Resistances
from first scan to 2 kA

Where repairs and consolidation works happened



- New pressure release ports fitted
- Upgrade of magnet protection system
- Cleaning ofvacuum beam tube
- Dipole and quadrupole magnets replaced and electrical interconnections
- LHC ring
- X Incident

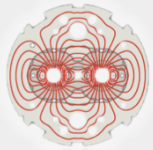
First Collisions at LHC on 23 November 2009 at E_{CM} = 900 GeV



CMS Experiment at the LHC
Date Recorded: 2009-11-23 19:21 CET
Run/Event: 122314/1514552
Candidate Collision Event

… after more than a year of repairs and improvements

First collision data: summary



- Excellent performance of Collider:
  Highest p-p collisions ever produced

- Excellent readiness of experiments:
  High data taking efficiency, fast turn-around for results

- Impressive information already provided at the 18 December 2009 meeting at CERN
  (LHC stopped on 16 Dec for technical stop)

- Collaborations already publishing results from first collisions observed at $\sqrt{s}$ = 0.9, 2.36, and 7 TeV

R.-D. Heuer, CERN

DESY-HH, June 7, 2010

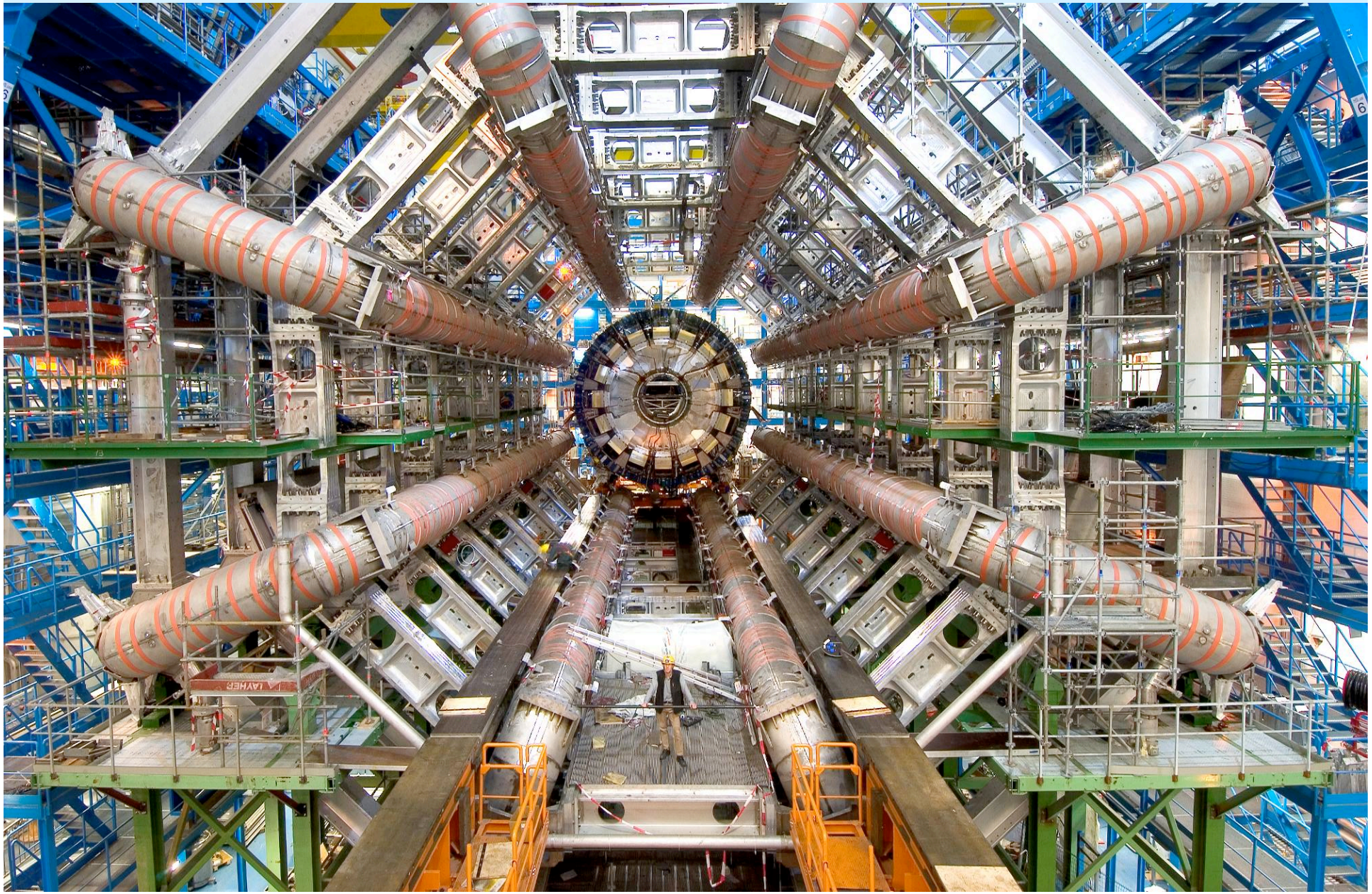
Fascinating Science

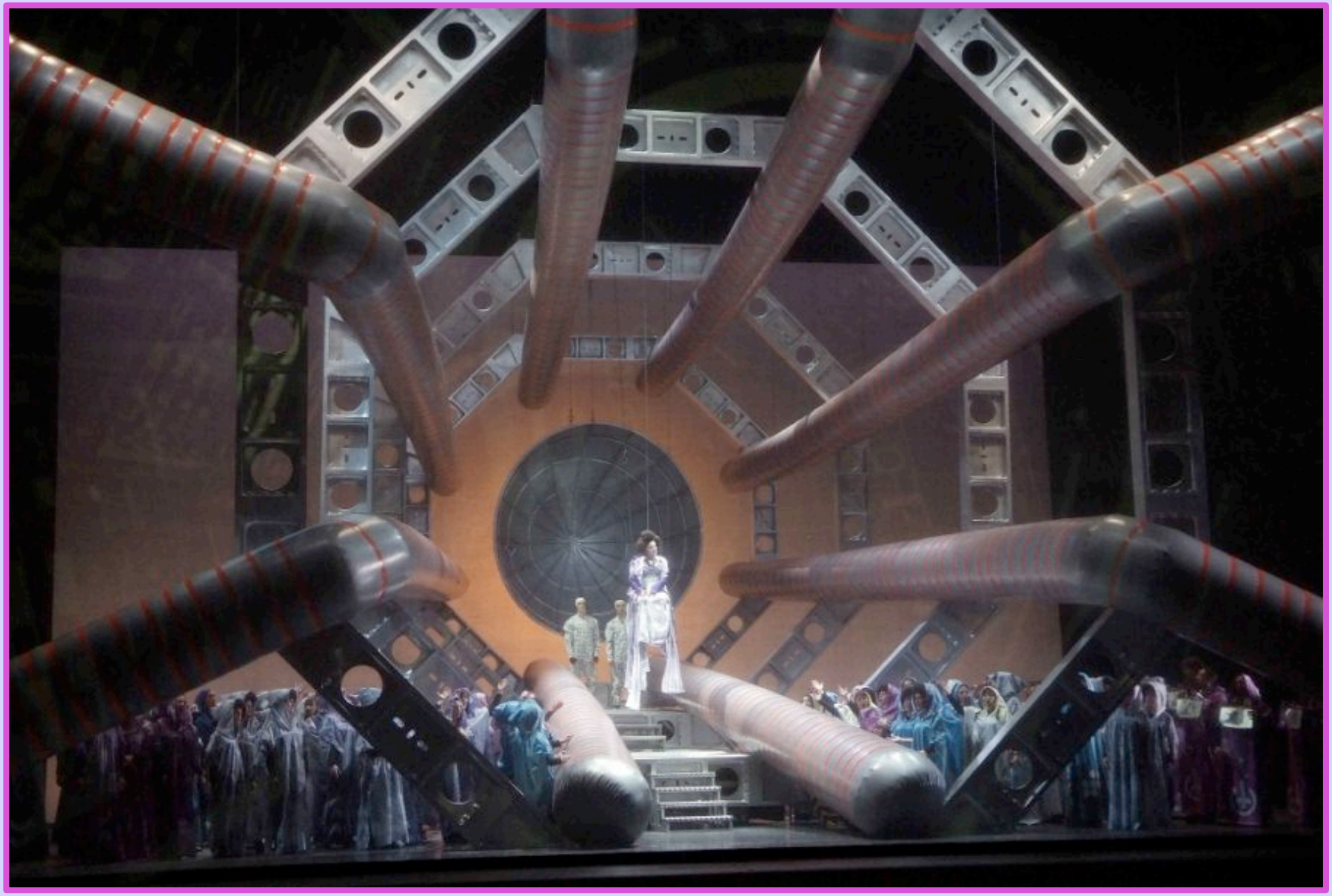
Today the LHC is attracting immense attention,
it is possibly THE most watched science project
→ the LHC is in the spotlight of the general public,
the journalists, . . .

Why?

- Fascinating science
- Addresses long standing questions of mankind
- Forefront science
- Forefront technologies
- Sociological experiment

the largest and most complex detectors





Hector Berlioz, "Die Troyaner", Oper in fünf Akten
Valencia, Palau de les Arts Reina Sofia, 31 Oktober -12 November 2009

LHC fills lecture halls because it . . .

- addresses fundamental science questions
- stimulates general interest
- fascinates and inspires
- stimulates fantasy
- increases knowledge
- educates
- trains scientists and engineers for tomorrow
- drives innovation and technology
- and, and, and

→ use this interest to promote
our field and basic science in general

R.-D. Heuer, CERN

DESY-HH, June 7, 2010

LHC Strategy (I)

Full exploitation of the LHC physics potential
→ maximize integrated luminosity useful for physics

- Longer running periods (~ two years)
- Longer shutdowns in between, coordinated activities between experiments and experiments/machine

- Physics Run 2010/11 @ 7 TeV
- decide about slightly higher energy later in the run

- Shutdown 2012 to prepare LHC towards 14 TeV (copper stabilizer consolidation, He-release valves, . . .)

- Physics Run 2013/14 @ ~ 14 TeV

LHC @ 7 TeV: new territory in particle physics

Run plan 2010-2011:

- 2010:

L = ~10^{27} –>10^{32} cm^{-2} s^{-1} –> total of 100-200 pb^{-1}

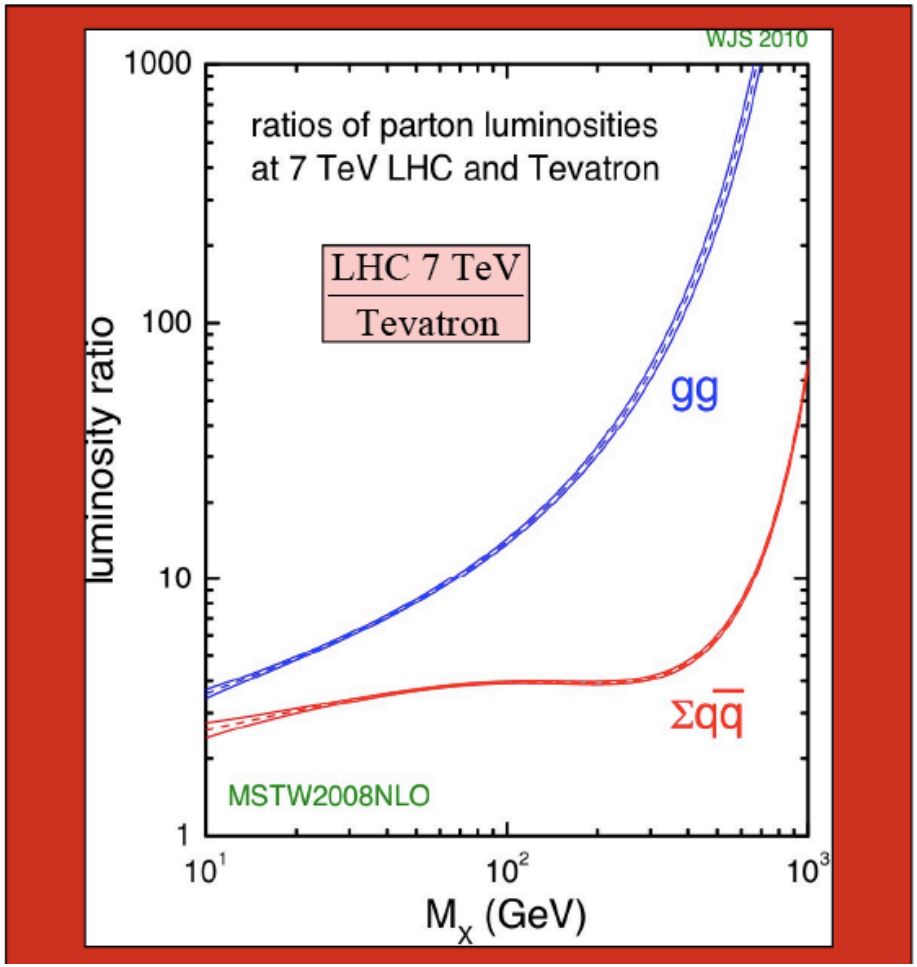
- 2011:

L = 1 –> few 10^{32} cm^{-2} s^{-1} –> collect ≥ 100 pb^{-1}/month

–> total of ~ 1 fb^{-1}

- Two heavy ions runs at the end of 2010 and 2011

LHC is a gluon collider



Cross-section	Tevatron	LHC@7TeV/Tevatron	LHC@14TeV/Tevatron
W/Z → lν, ll	2.5/0.25 nb per family	~ 5	~ 10
tt production	7.2 pb	~ 20	~ 100

New Physics reach

New Physics : approximate LHC reach (one experiment) for some benchmark scenarios ($\sqrt{s}$ = 7 TeV, unless otherwise stated)

Z' (SSM): Tevatron limit ~ 1 TeV (95% C.L)

50 pb^{-1} : exclusion up to ~ 1 TeV (95% C.L.)
500 pb^{-1} : discovery up to ~ 1.3 TeV
exclusion up to ~ 1.5 TeV
1 fb^{-1} : discovery up to ~ 1.5 TeV

W' : Tevatron limit ~ 1 TeV (95% C.L)

10 pb^{-1} : exclusion up to 1 TeV
100 pb^{-1} : discovery up to ~ 1.3 TeV
1 fb^{-1} : discovery up to ~ 1.9 TeV
exclusion up to ~ 2.2 TeV

SUSY ($\tilde{q}, \tilde{g}$) : Tevatron limit ~ 400 GeV (95% C.L)

100 pb^{-1} : discovery up to ~ 400 GeV
1 fb^{-1} : discovery up to ~ 800 GeV

Higgs boson

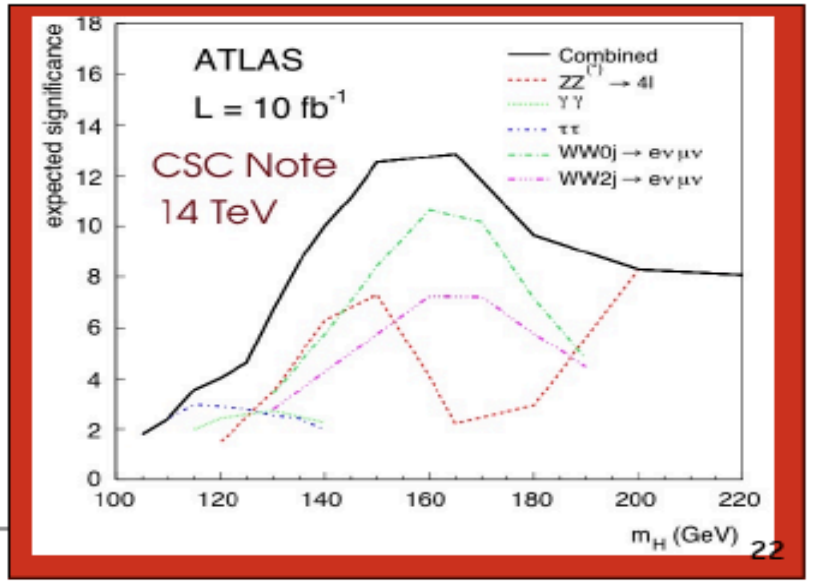
Very preliminary estimates

Higgs $\sqrt{s}$=7 TeV: H → WW, m_H ~ 160 GeV (Tevatron exclusion: 163-166 GeV)

300 pb^{-1} per experiment : ~ 3σ sensitivity combining ATLAS and CMS (similar to Tevatron)
1 fb^{-1} per experiment : could exclude 145 < m_H < 180 GeV
~ 4.5 σ combining ATLAS and CMS

- Exclusion of the full mass range down to m_H~115 GeV requires ~1.5 fb^{-1} per experiment at 14 TeV
- Discovery for m_H ~ 115 GeV requires ~ 10 fb^{-1} per experiment at 14 TeV

A long way to go if the Higgs is just above the LEP2 limit.
Note: Tevatron and LHC are complementary for m_H~ 115 GeV:
-- main channels at the Tevatron:
WH, ZH with H→ bb
-- main channels at LHC: H →γγ, qqH → ττ



F.Gianotti, La Thuile, 3-3-2010

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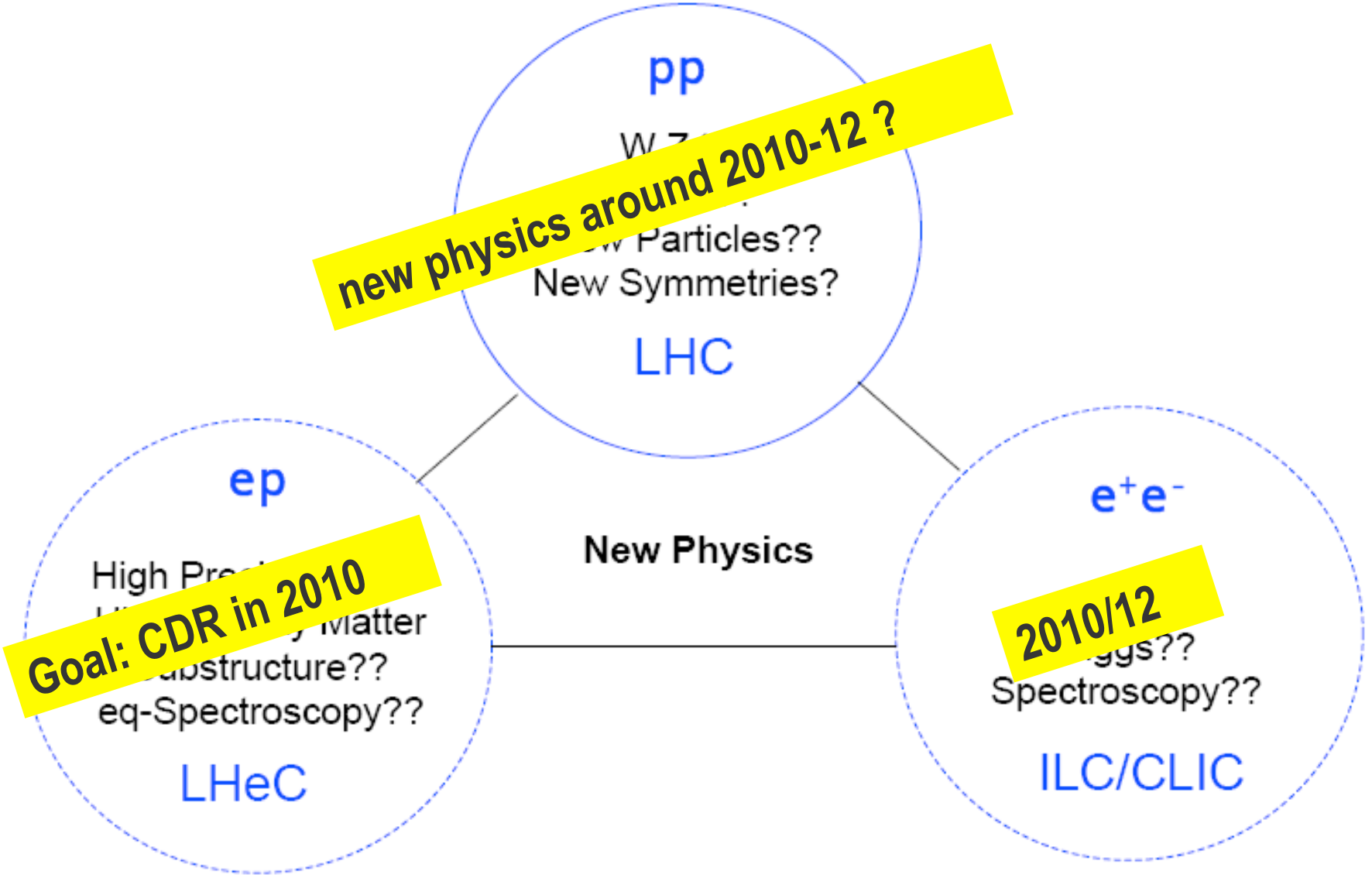
2010-2013: decisive years

Experimental data will take the floor to drive the field to the next steps:

- LHC results
- θ_{13} (T2K, DChooz, etc..)
- ν masses (Cuore, Gerda, Nemo…)
- Dark Matter searches
- …….

The TeV Scale beyond 2010



Particle Physics Strategy (short term)

European Strategy for Particle Physics
first established 2006
update planned for 2012

Input from LHC mandatory

→ Need to have interpretation of LHC results ready

→ Need close collaboration exp/theo
LHC and LC

LHC Strategy (II)

Full exploitation of the LHC physics potential
→ maximize integrated luminosity useful for physics

- LHC operation until around 2030, aim at $\int L dt \approx 3000/fb$

- Between 2010 and ~2020: design luminosity $10^{34}/cm^2/s$
  connection of LINAC4 earliest 2015
  detector modifications to optimize data collection

- High Luminosity LHC (HL-LHC) from ~2020 to ~2030
  luminosity around $5x10^{34}/cm^2/s$, luminosity leveling
  new Inner Triplet around 2020 (combine both phases)
  detector upgrades around 2020

Results from LHC will guide the way

Expect

- period for decision enabling on next steps earliest 2012 (at least) concerning energy frontier
- (similar situation concerning neutrino sector Θ_{13})

We are NOW in a new exciting era of accelerator

planning-design-construction-running

and need

- intensified efforts on R&D and technical design work to enable these decisions
- global collaboration and stability on long time scales (don‘t forget: first workshop on LHC was 1984)

Key Messages

- Need to clear the cloud of TeV-scale physics to obtain clear views
- Synergy of colliders
- LHC and HL-LHC with prospects towards 2030
- ILC could be constructed now
- CLIC more R&D needed
- Converge towards one LC project
- Detector R&D mandatory for all projects
- LHC results decisive

Great opportunities ahead at the TeV scale

Window of opportunity for enabling decision on the way forward around 2011/2012 (?)

…facts today

facilities for HEP (and other sciences) becoming larger and expensive

funding not increasing

fewer facilities realisable

time scales becoming longer

laboratories are changing missions

→ more coordination and more collaboration required

Outlook: Enhancing World Collaboration

Key message

Future major facilities in Europe and elsewhere require collaborations on a global scale; *Council, drawing on the European experience in the successful construction and operation of large-scale facilities, will prepare a framework for Europe to engage with the other regions of the world with the goal of optimizing the particle physics output through the best shared use of resources while maintaining European capabilities.*

from CERN Council Strategy Document

We need

- to maintain expertise in all regions
  national – regional – global projects
- long term stability and support in all three regions

- to engage all countries with HEP communities

- to integrate HEP emerging countries (regions)

- a global forum for funding agencies

- a closer link among particle and astroparticle physics

We need to define the most appropriate organizational form
NOW and need to be open and inventive
(scientists, funding agencies, politicians. . .)

Mandatory to have accelerator laboratories in all regions
as partners in accelerator development / construction /
commissiong / exploitation

Planning and execution of HEP projects today need
global partnership for *global, regional and national* projects
in other words: for the whole program

Use the exciting times ahead to establish such a partnership

Particle Physics can and should play its role as

spearhead in innovations as in the past

now and in future