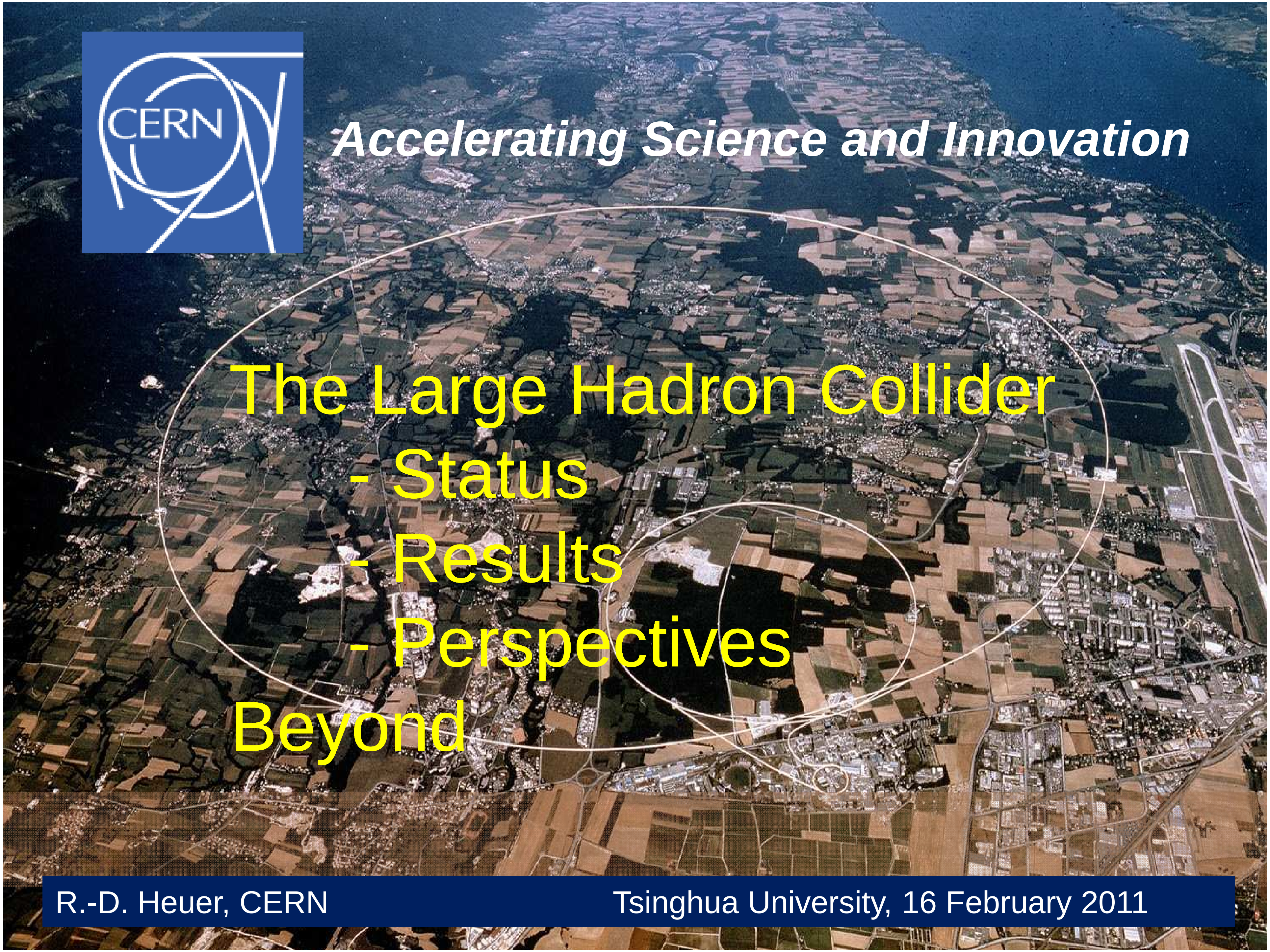


Accelerating Science and Innovation

The Large Hadron Collider
- Status
- Results
- Perspectives
Beyond

R.-D. Heuer, CERN

Tsinghua University, 16 February 2011

Past few decades

“Discovery” of Standard Model

through synergy of

hadron - hadron colliders (e.g. Tevatron)

lepton - hadron colliders (HERA)

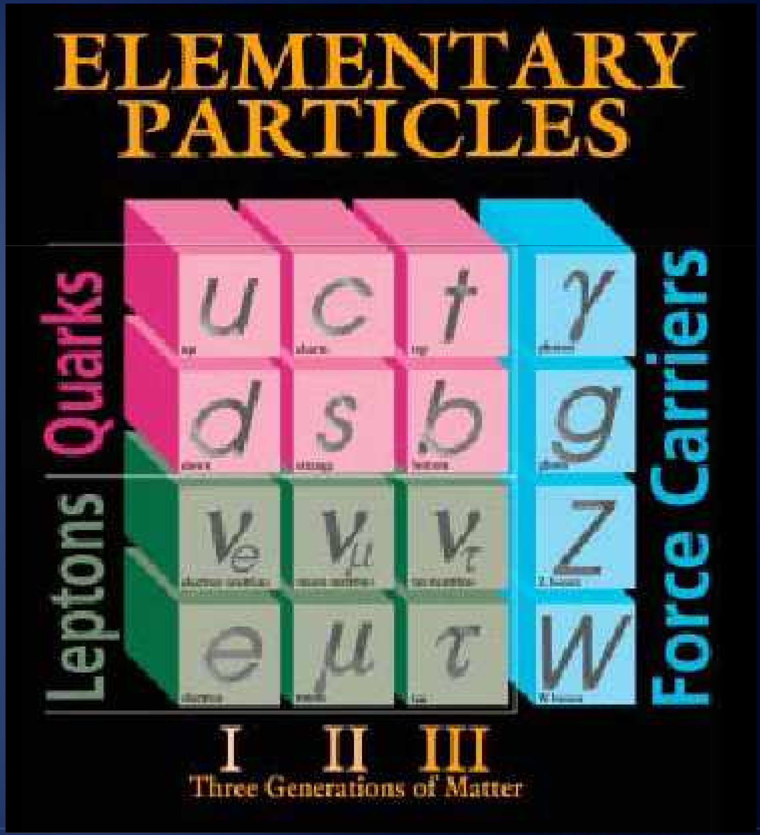
lepton - lepton colliders (e.g. LEP, SLC)

What have we learned the last 50 years
or
Status of the **Standard Model**

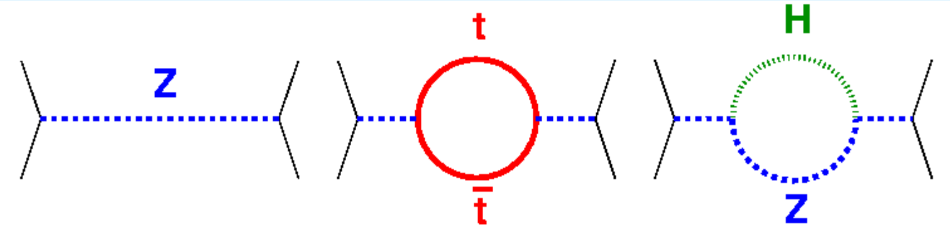
The physical world is composed of
Quarks and Leptons
(Fermions)

interacting via force carriers
(Gauge Bosons)

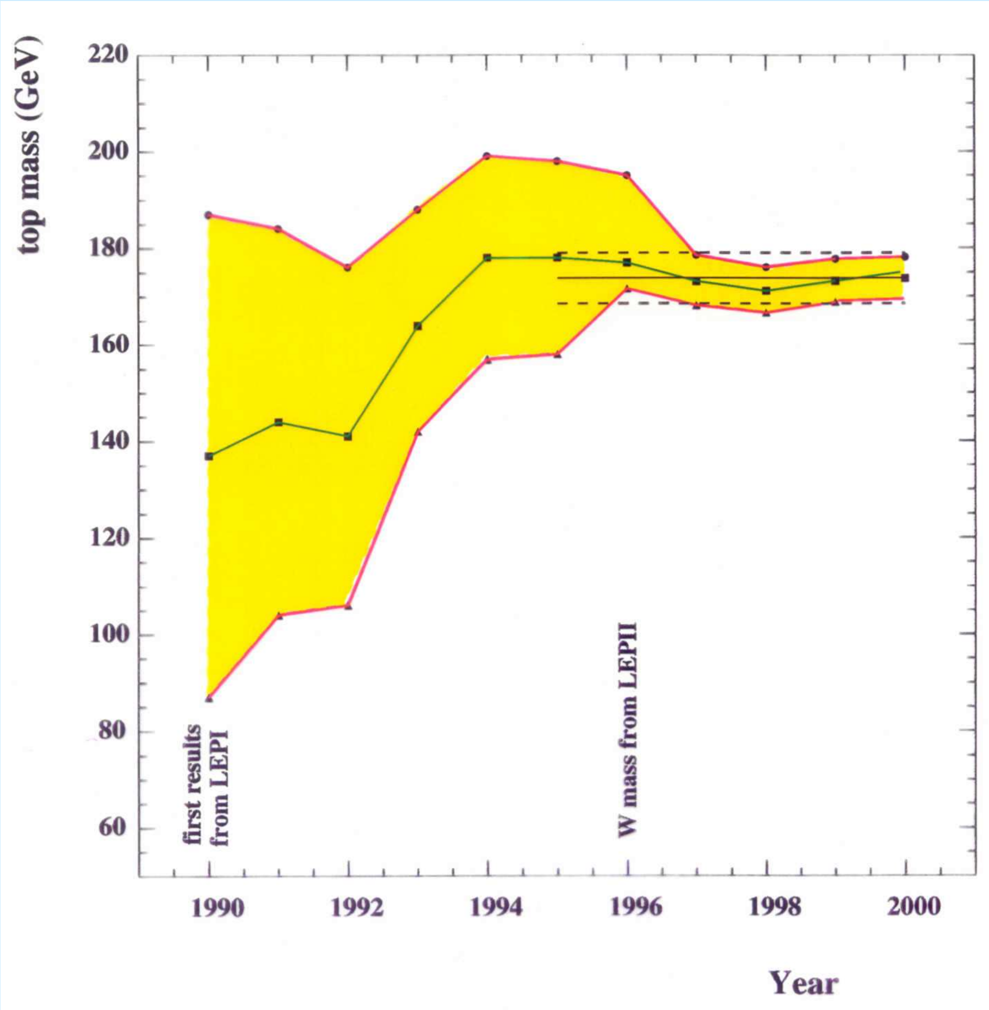
Last entries: top-quark 1995
tau-neutrino 2000



EXPERIMENT



Standard Model:
Testing Quantum Fluctuations



LEP(e^+e^- collider):

Indirect determination of the top mass

possible due to

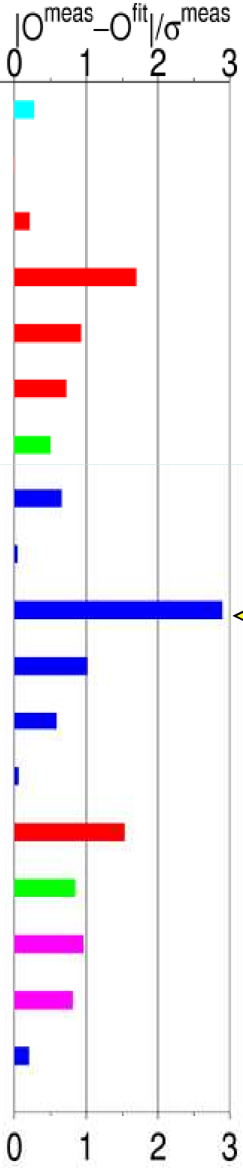
- precision measurements
- known higher order electroweak corrections

$$\propto \left(\frac{\boxed{M_t}}{M_W}\right)^2, \ln\left(\frac{\boxed{M_h}}{M_W}\right)$$

Status recent Summer Conferences

Standard Model Analysis

	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02758 ± 0.00035	0.02768
m_Z [GeV]	91.1875 ± 0.0021	91.1875
Γ_Z [GeV]	2.4952 ± 0.0023	2.4957
σ_{had}^0 [nb]	41.540 ± 0.037	41.477
R_l	20.767 ± 0.025	20.744
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01645
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1481
R_b	0.21629 ± 0.00066	0.21586
R_c	0.1721 ± 0.0030	0.1722
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1038
$A_{fb}^{0,c}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1481
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.398 ± 0.025	80.374
Γ_W [GeV]	2.140 ± 0.060	2.091
m_t [GeV]	170.9 ± 1.8	171.3



Fit to 17 high-Q^2 observables plus $\Delta\alpha_{had}$:

χ^2/ndof = 18.2/13 (15.1%)

Largest χ^2 contribution:
A_l(SLD) vs. $A_{fb}b$(LEP)

Decided in favour of leptons

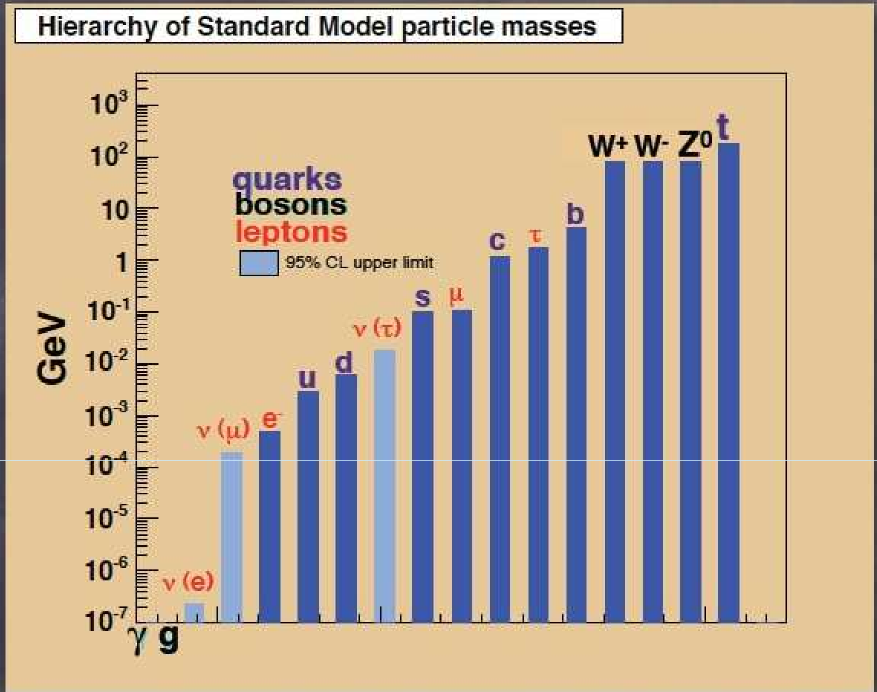
Without this point, the fit is *too* good!

Afb(b) has largest pull: 2.9σ!

however . . .

. . . one piece missing within Standard Model

How to generate mass & break electroweak symmetry ?

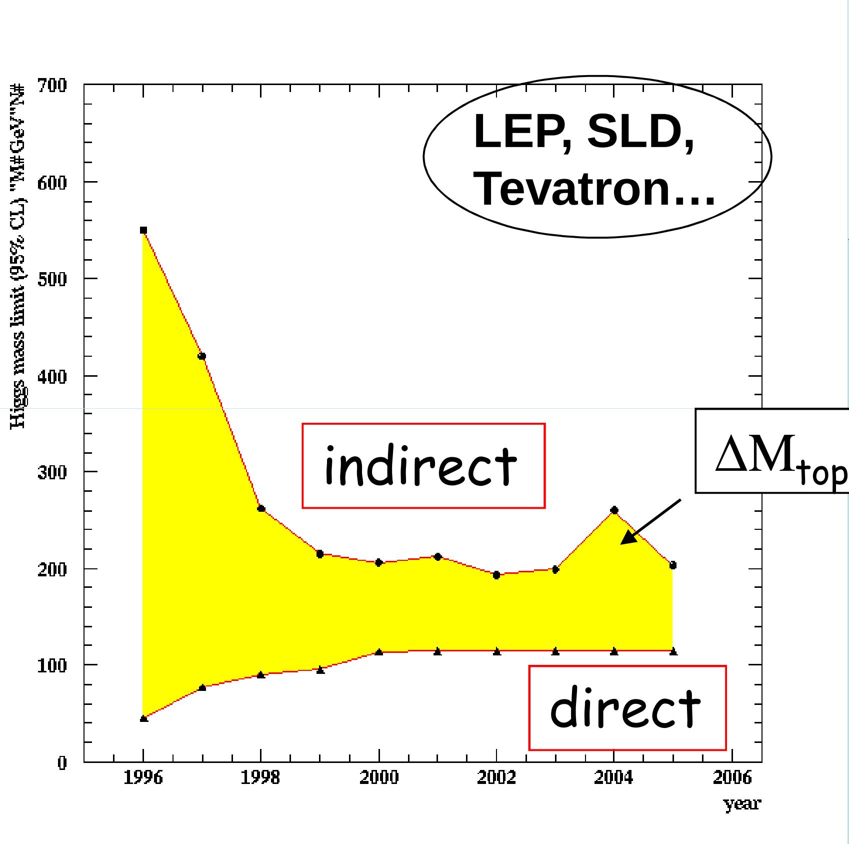


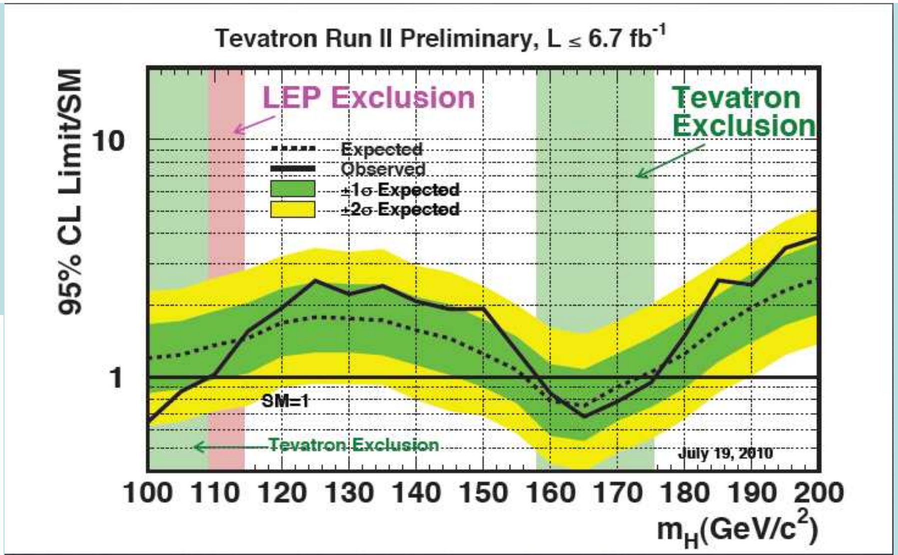
Higgs mechanism : Non-zero field permeating the universe generates mass

- W and Z bosons gain mass through degrees of freedom of Higgs field
- Fermions gain mass interacting with the Higgs field
- New particle Higgs boson predicted

- Finding the Higgs boson
  - Means Higgs field exists
    - Means we confirm our theory for the origin of mass

Time evolution of experimental limits on the Higgs boson mass





knowledge obtained only through combination of results from different accelerator types

in particular:
Lepton and Hadron Collider

Synergy of colliders

M_H between 114 and ~200 GeV,
window 158-175 GeV excluded by Tevatron

But What is Wrong with this Picture?

Cosmic problems……

Standard Model

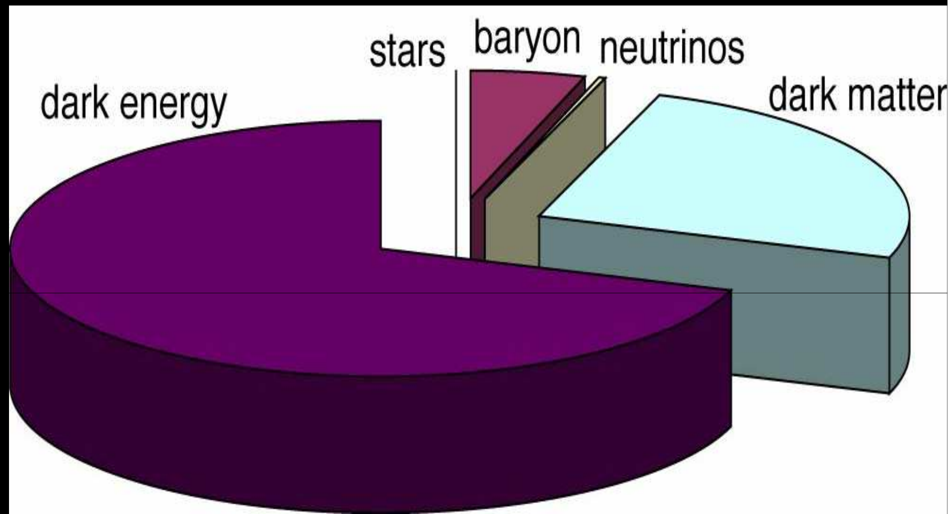
THE ENERGY DENSITY BUDGET

BARYONS

COLD DARK MATTER

NEUTRINOS

DARK ENERGY



→ with the Large Hadron Collider
at the Terascale now entering the 'Dark World'

Key Questions of Particle Physics

origin of mass/matter or
origin of electroweak symmetry breaking

unification of forces

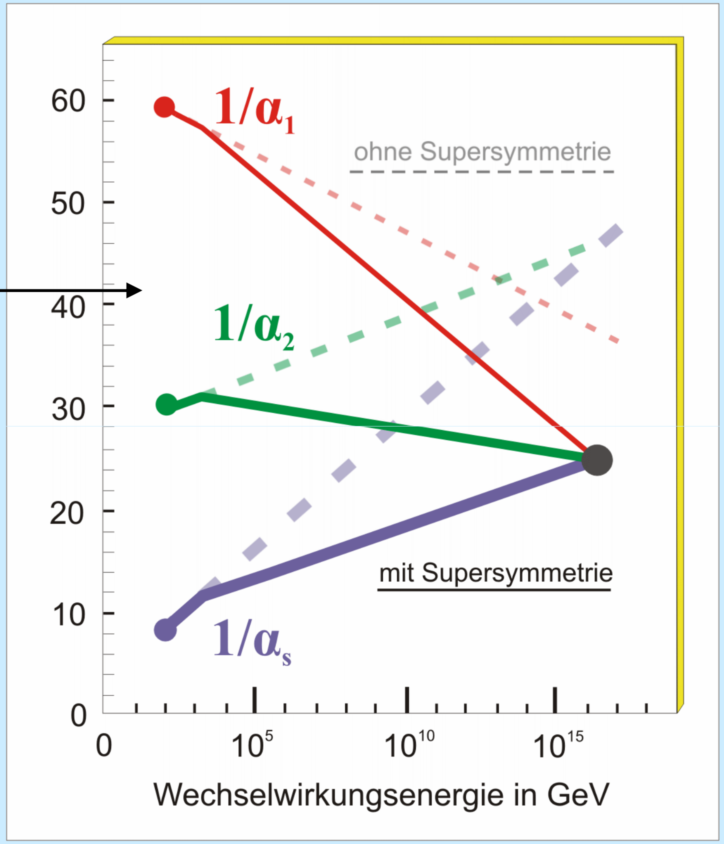
fundamental symmetry of forces and matter

unification of quantum physics and general relativity

number of space/time dimensions

what is dark matter

what is dark energy



Solutions?

Standard Model

For all proposed solutions:
new particles should appear
at the **TeV** scale or below

ccessful for ever ??

Selected NP
since 1957
Except P. Higgs

Technicolor

New (strong) interactions produce EWSB

Extensions of the SM gauge group :

Little Higgs / GUTs / ...

Supersymmetry

New particles at ≈ TeV scale, light Higgs

Unification of forces

Higgs mass stabilized

No new interactions

Extra Dimensions

New dimensions introduced

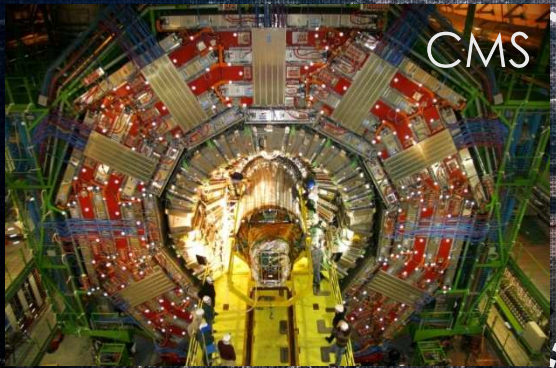
$m_{Gravity} \approx m_{elw}$ Hierarchy problem solved

New particles at ≈ TeV scale

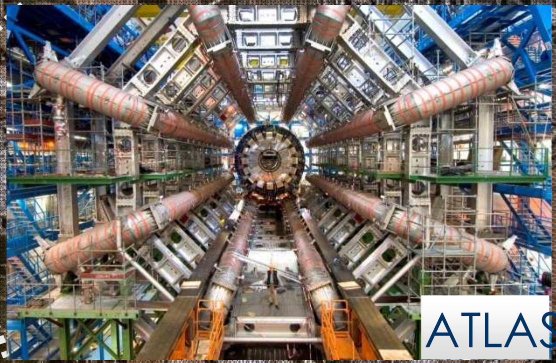
CERN

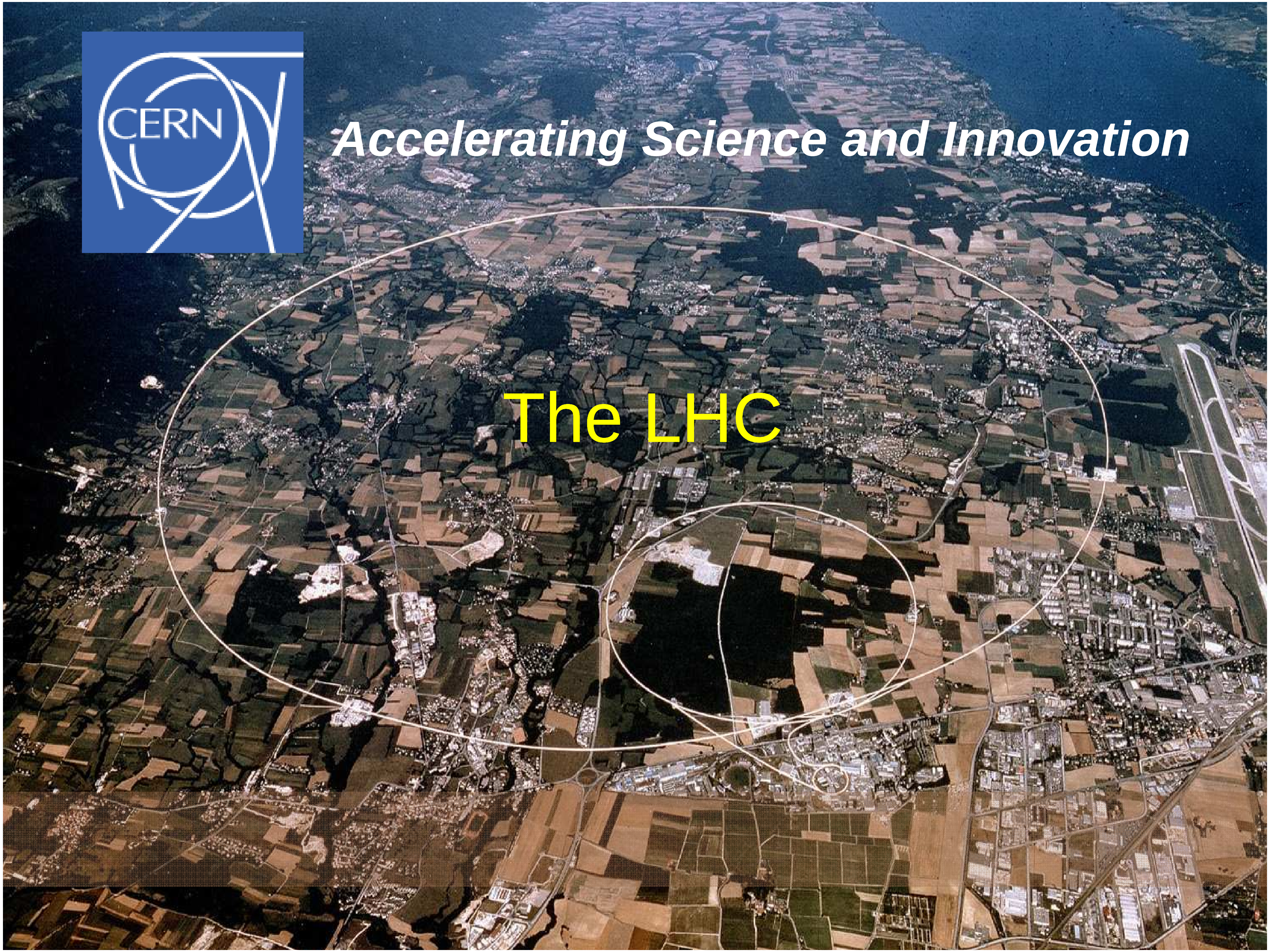
Enter a New Era in Fundamental Science

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.

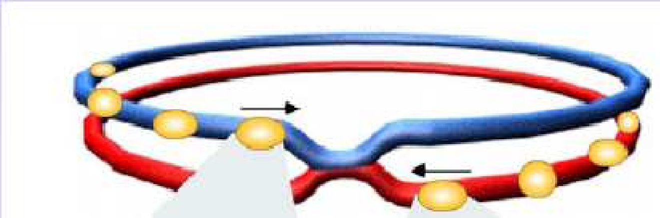


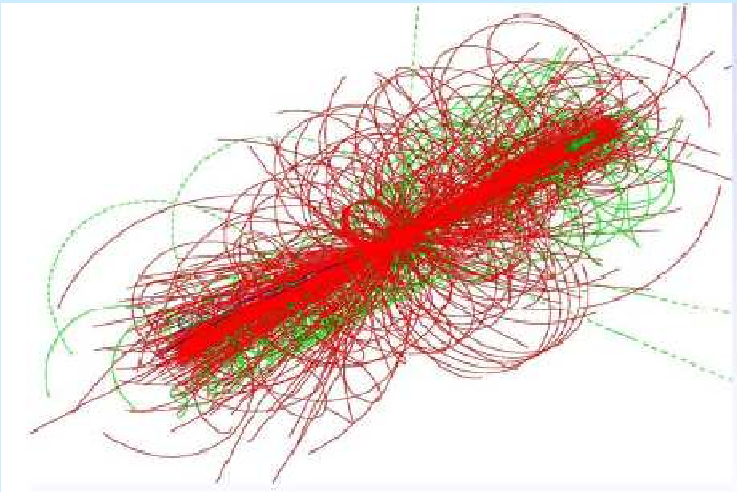
Exploration of a new energy frontier
Proton-proton collisions at E_{CM} up to 14 TeV




Accelerating Science and Innovation
The LHC

Proton-Proton Collisions at the LHC





- 2835 + 2835 proton bunches
  separated by 7.5 m

→ collisions every 25 ns
  = 40 MHz crossing rate

- 10^{11} protons per bunch

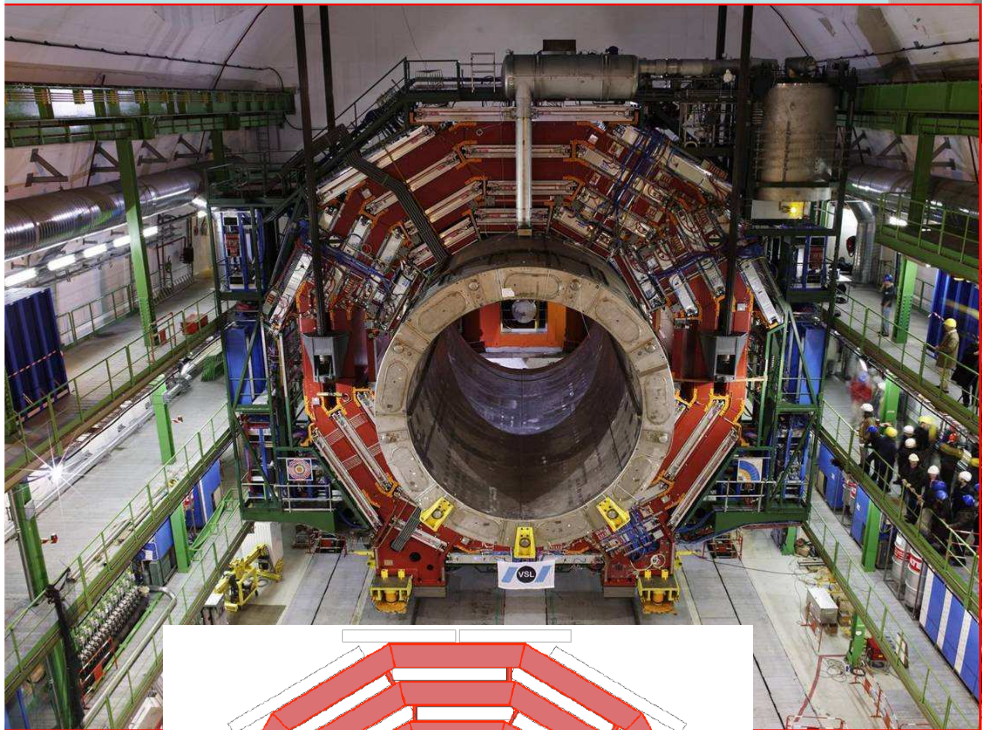
- at 10^{34}/cm^2/s
  ≈ 35 pp interactions per crossing
  pile-up

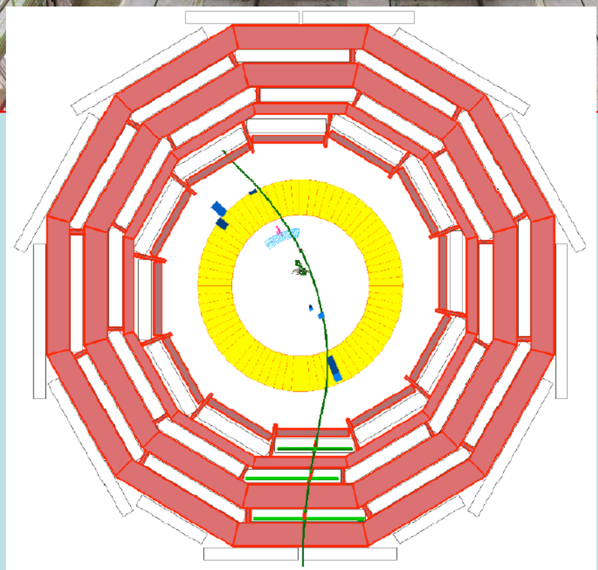
→ ≈ 10^9 pp interactions per second !!!

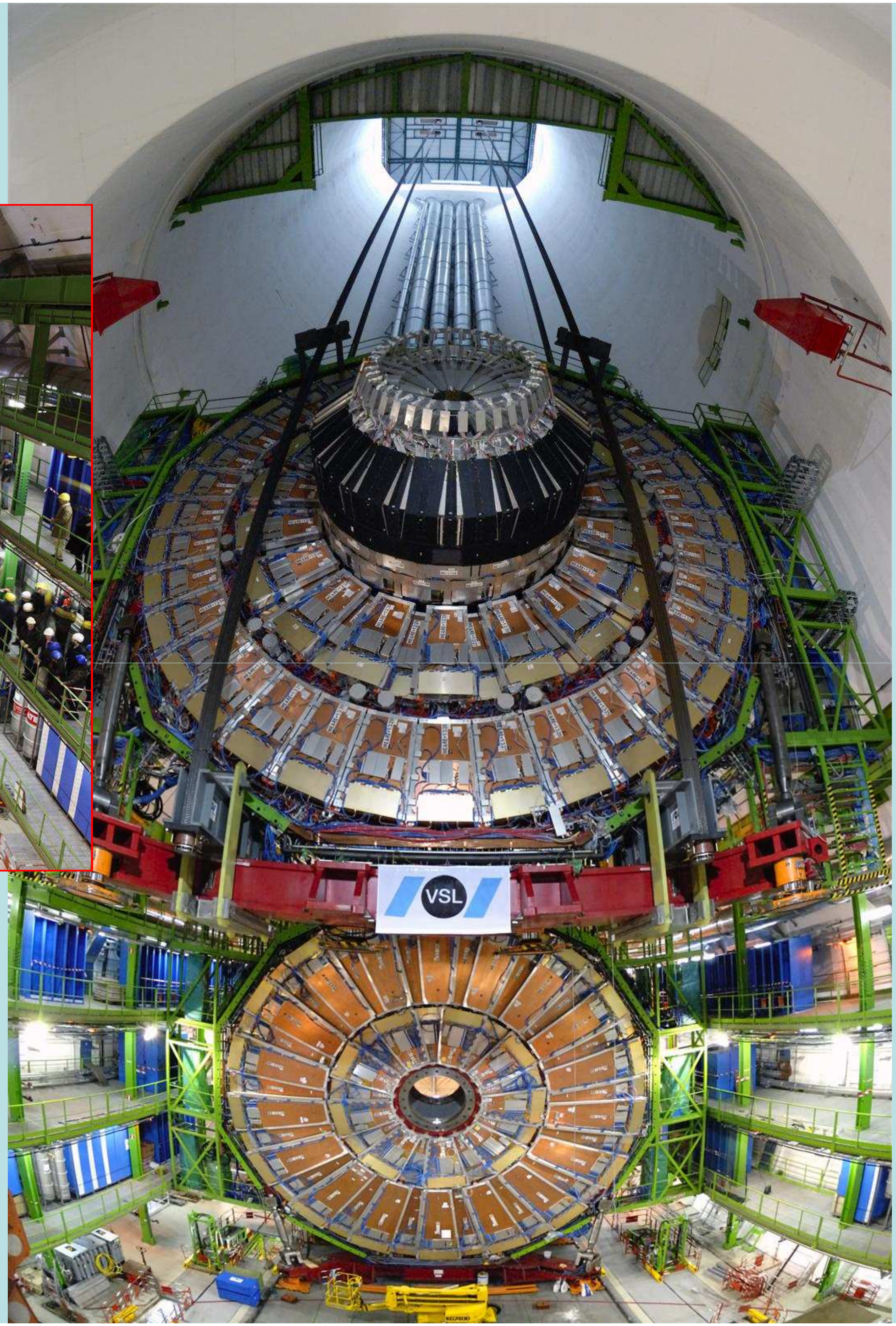
- in each collision
  ≈ 1600 charged particles produced

enormous challenge for the detectors
and for data collection/storage/analysis

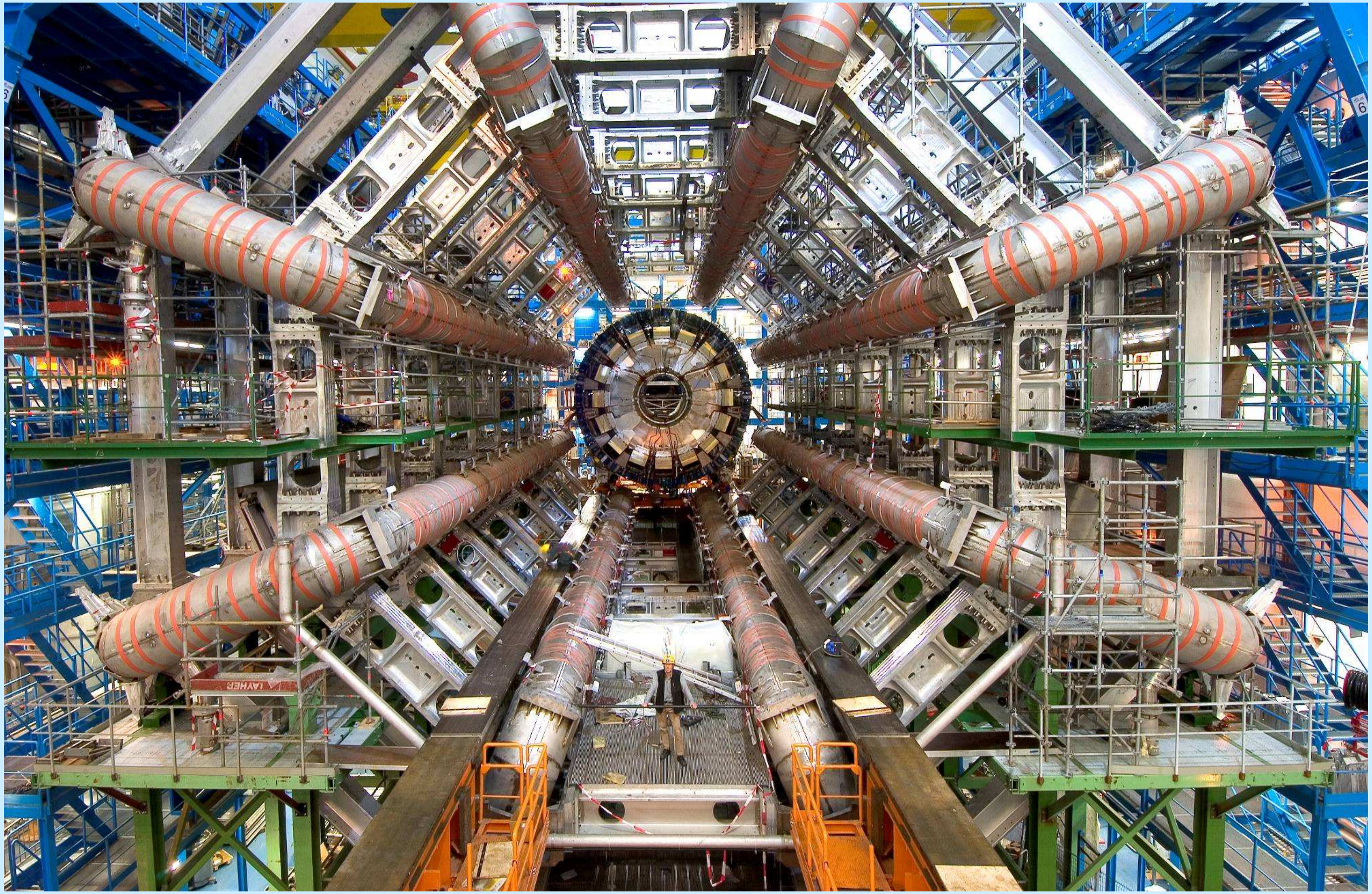
The CMS experiment







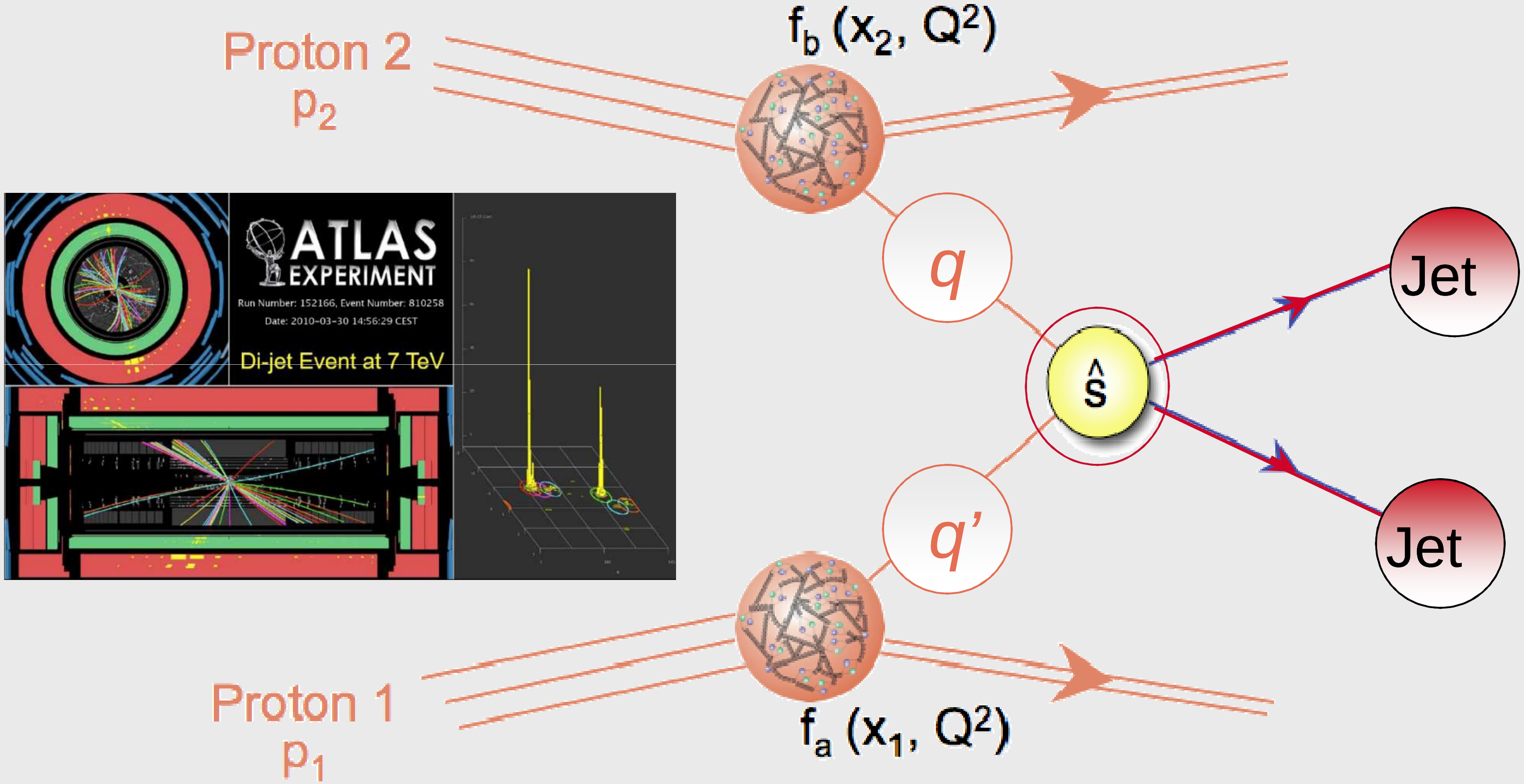
the largest and most complex detectors



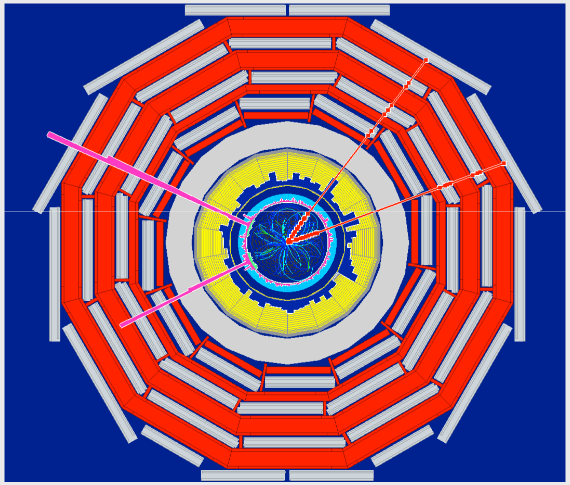
To select and record the signals from the 600 million proton collisions every second, huge detectors have been built to measure the particles traces to an extraordinary precision.

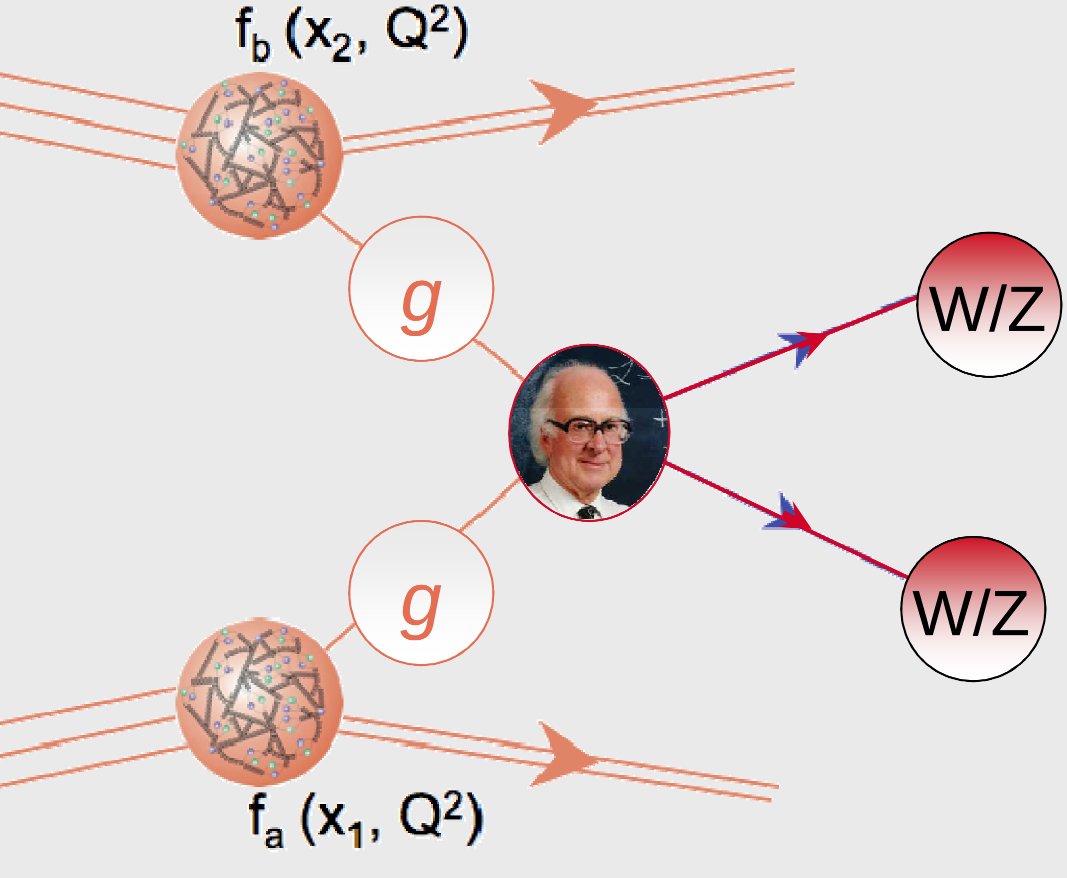
Hector Berlioz, “Les Troyens”, opera in five acts
Valencia, Palau de les Arts Reina Sofia, 31 October -12 November 2009

Basic processes at LHC

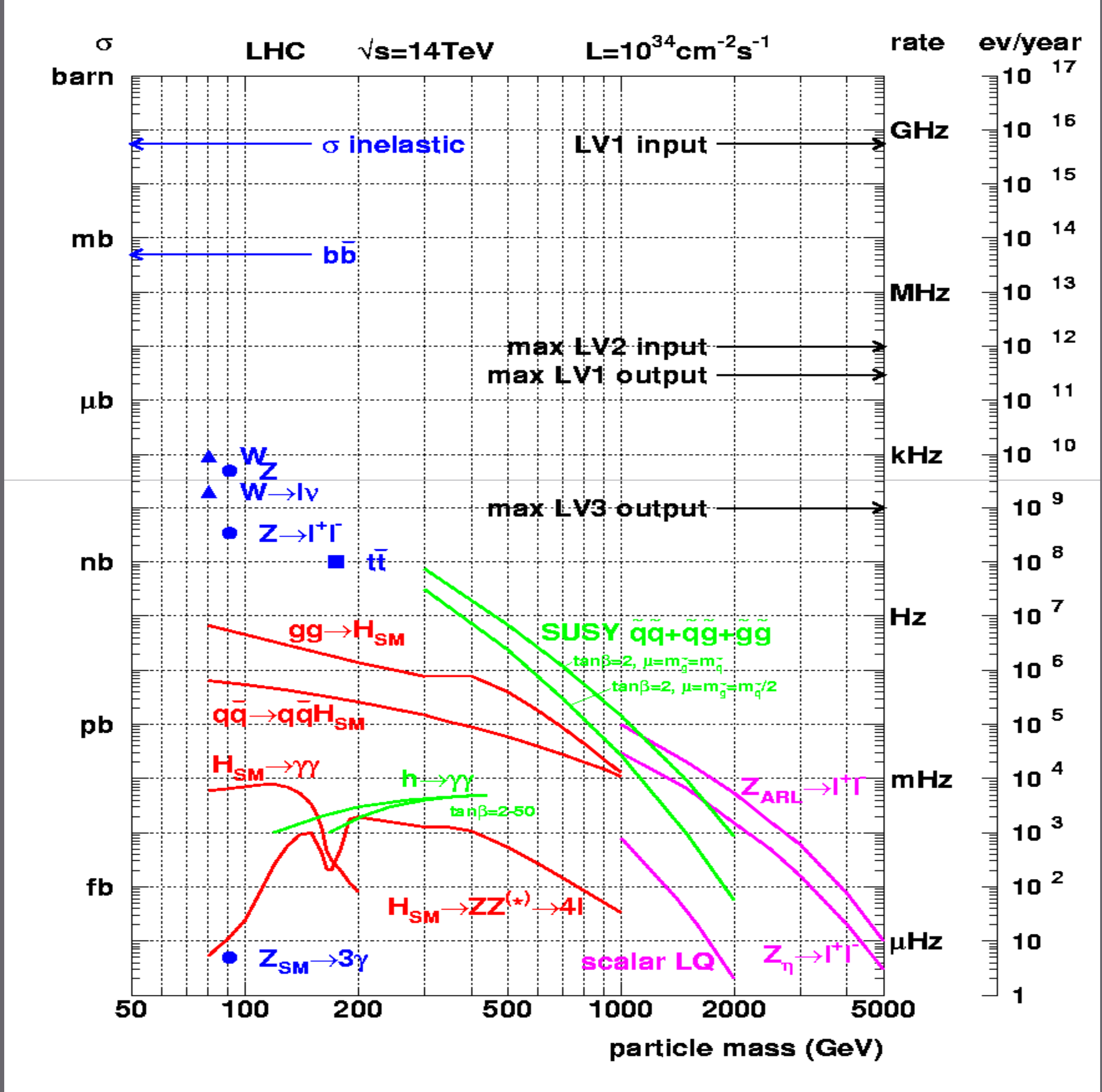


Basic processes at LHC





Cross sections at the LHC

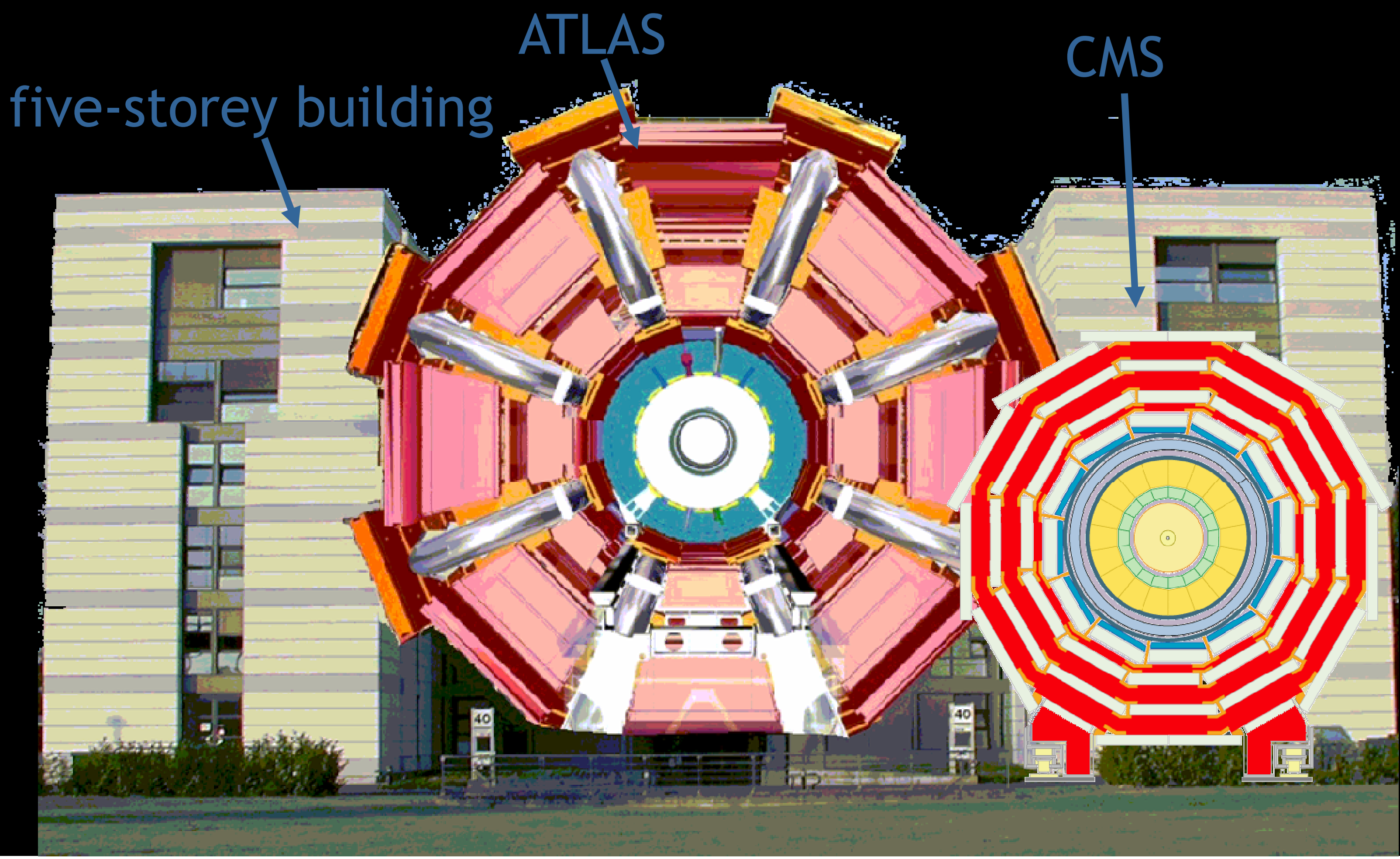


"Well known" processes. Don't need to keep all of them …

New Physics!!

We want to keep!!

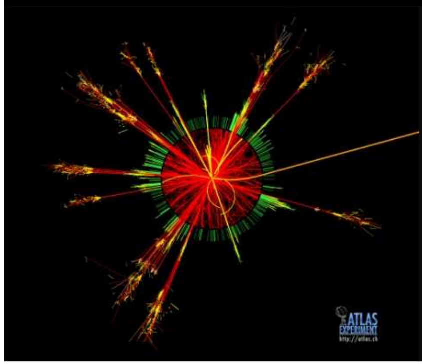
The LHC experiments:
about 100 million “sensors” each
[think your 6MP digital camera...
...taking 40 million pictures a second]

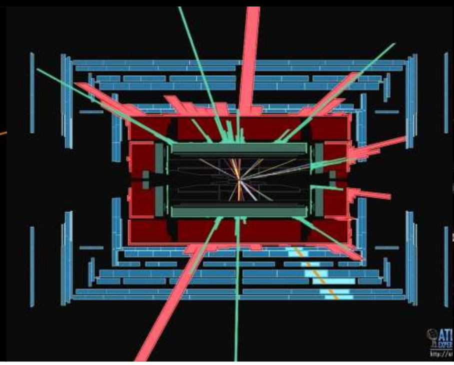


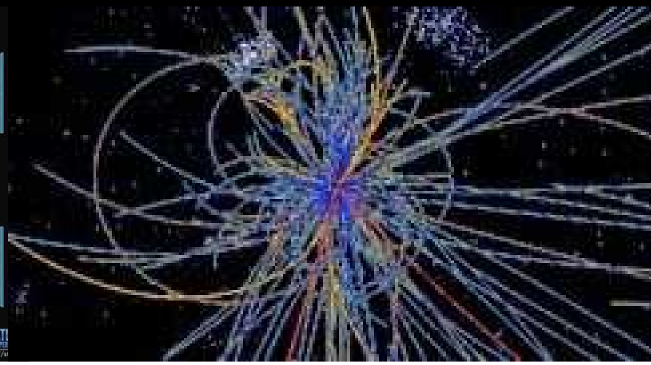
The LHC data

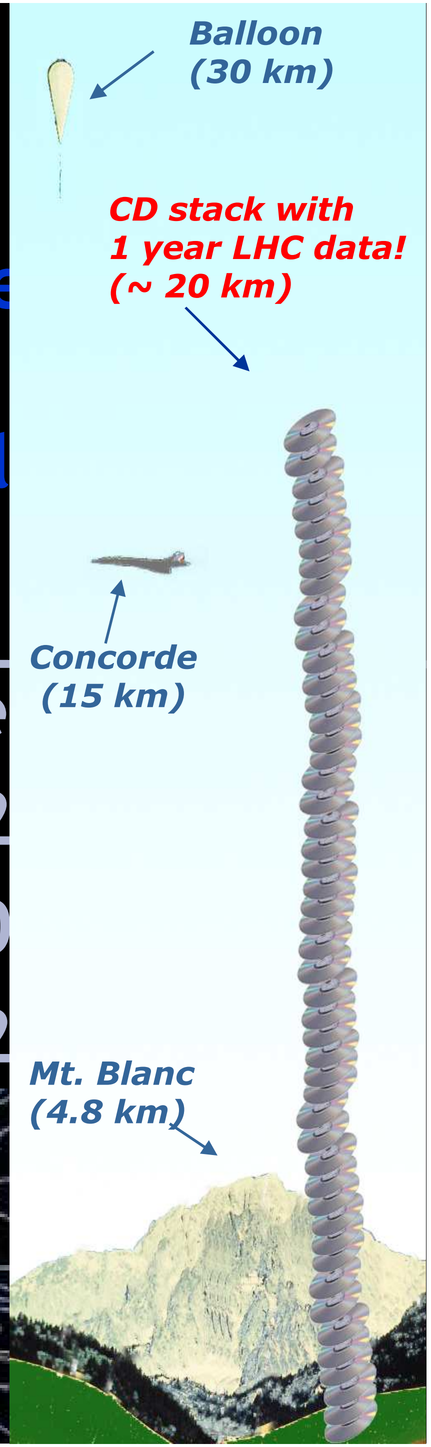
- 40 million events (pictures) per second
- Select (on the fly) the ~200 interesting e second to write on tape
- “Reconstruct” data and convert for anal “physics data” [→ the grid...]

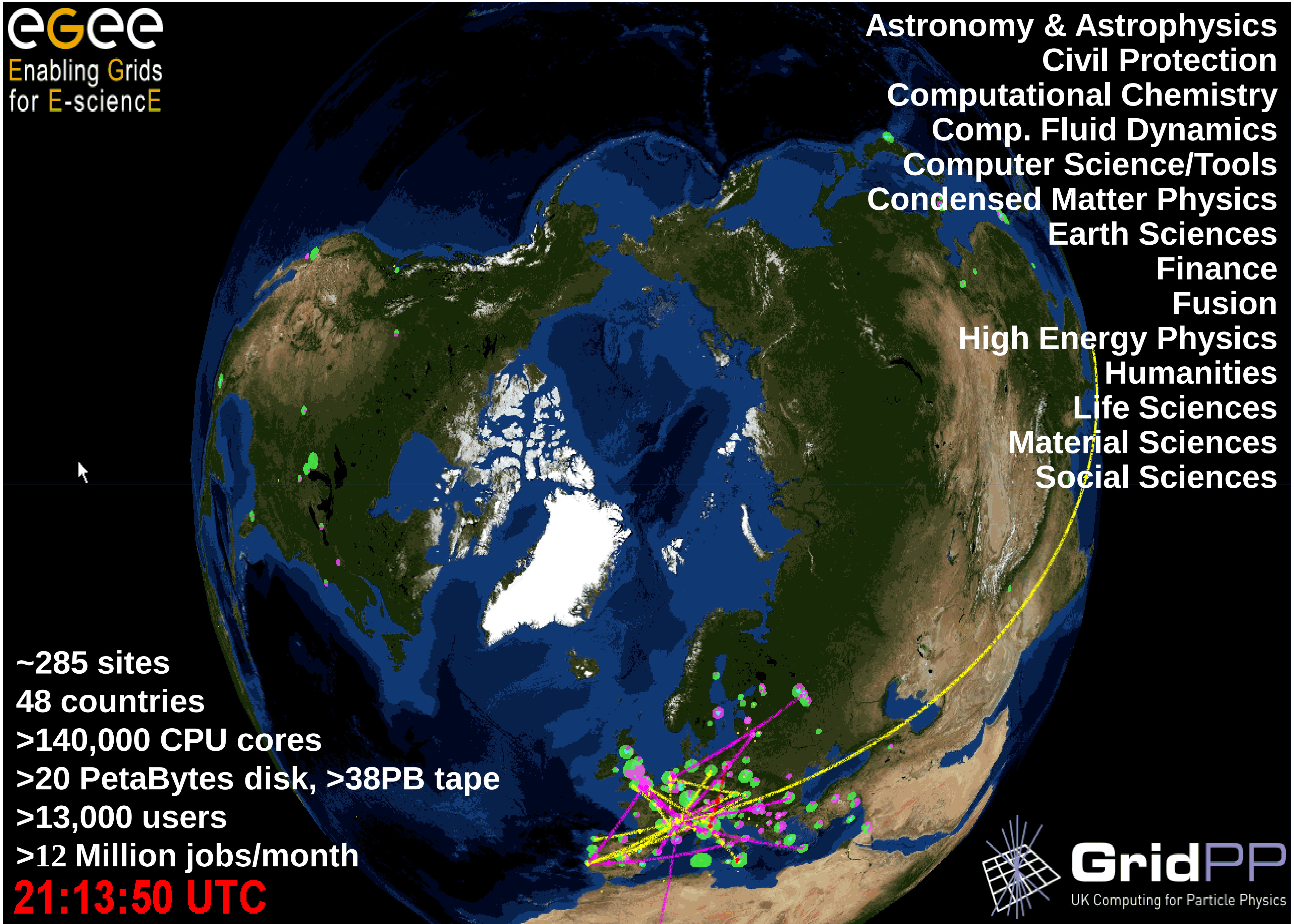
(x4 experiments x15 years)	Per event	Pe
Raw data	1.6 MB	32
Reconstructed data	1.0 MB	20
Physics data	0.1 MB	2



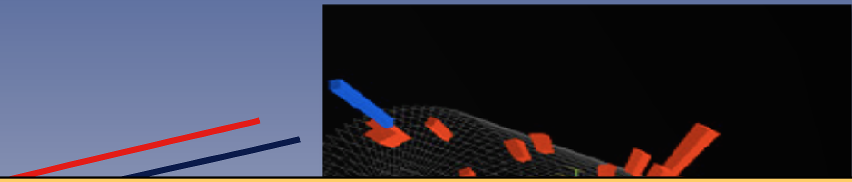







egee
Enabling Grids for E-sciencE
Astronomy & Astrophysics
Civil Protection
Computational Chemistry
Comp. Fluid Dynamics
Computer Science/Tools
Condensed Matter Physics
Earth Sciences
Finance
Fusion
High Energy Physics
Humanities
Life Sciences
Material Sciences
Social Sciences
~285 sites
48 countries
>140,000 CPU cores
>20 PetaBytes disk, >38PB tape
>13,000 users
>12 Million jobs/month
21:13:50 UTC
GridPP
UK Computing for Particle Physics

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



Chronology of a fantastic escalation of events:

2009

20 November: first beams circulating in the LHC
23 November: first collisions at $\sqrt{s}$ = 900 GeV
8, 14, 16 December: few hours of collisions at $\sqrt{s}$ = 2.36 TeV (the world record !)
16 December- 26 February: technical stop

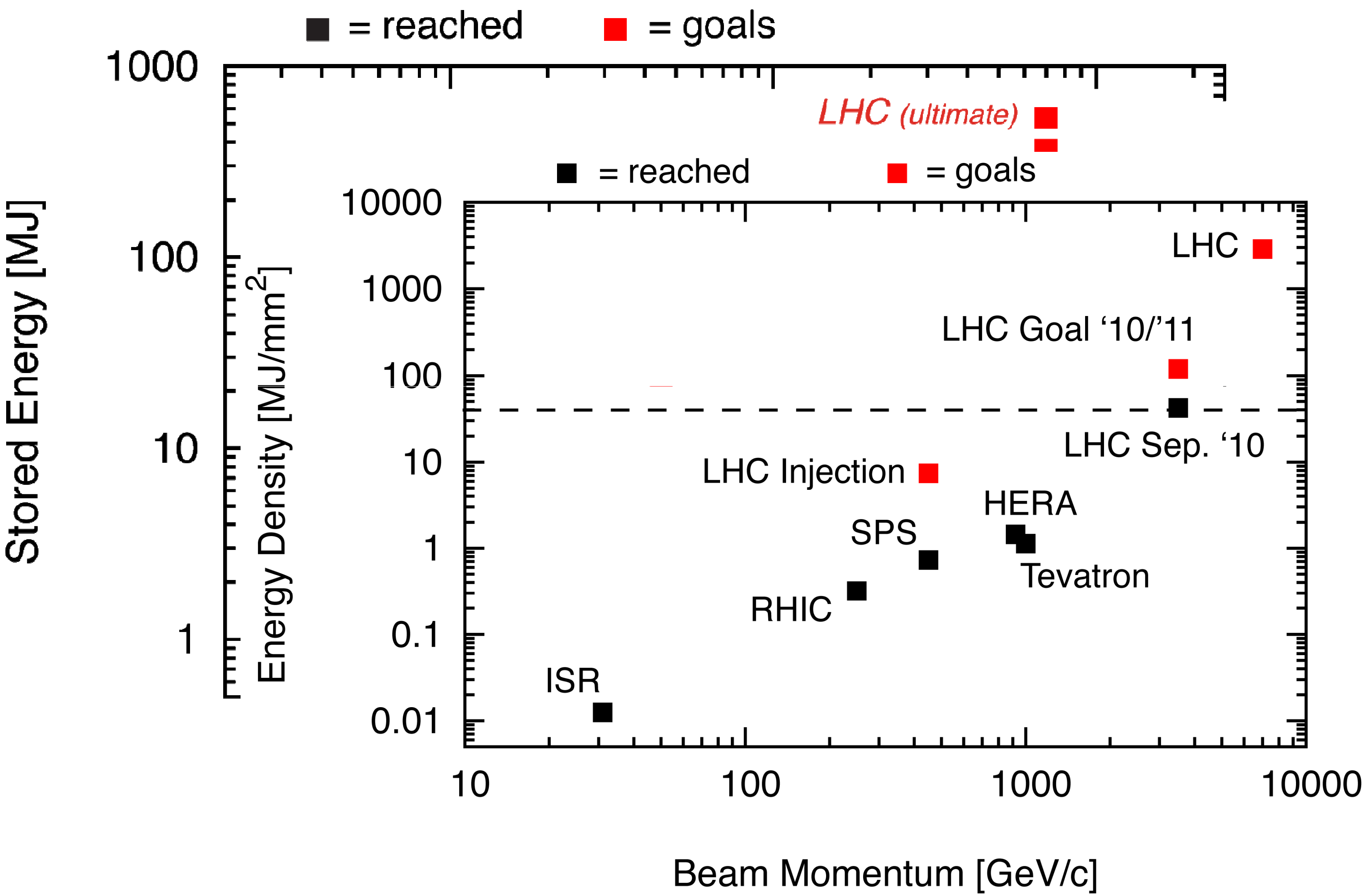
2010

27 February : machine operation started again
19 March   : first (single) beams ramped up to 3.5 TeV
30 March   : first collisions at 3.5+3.5 TeV

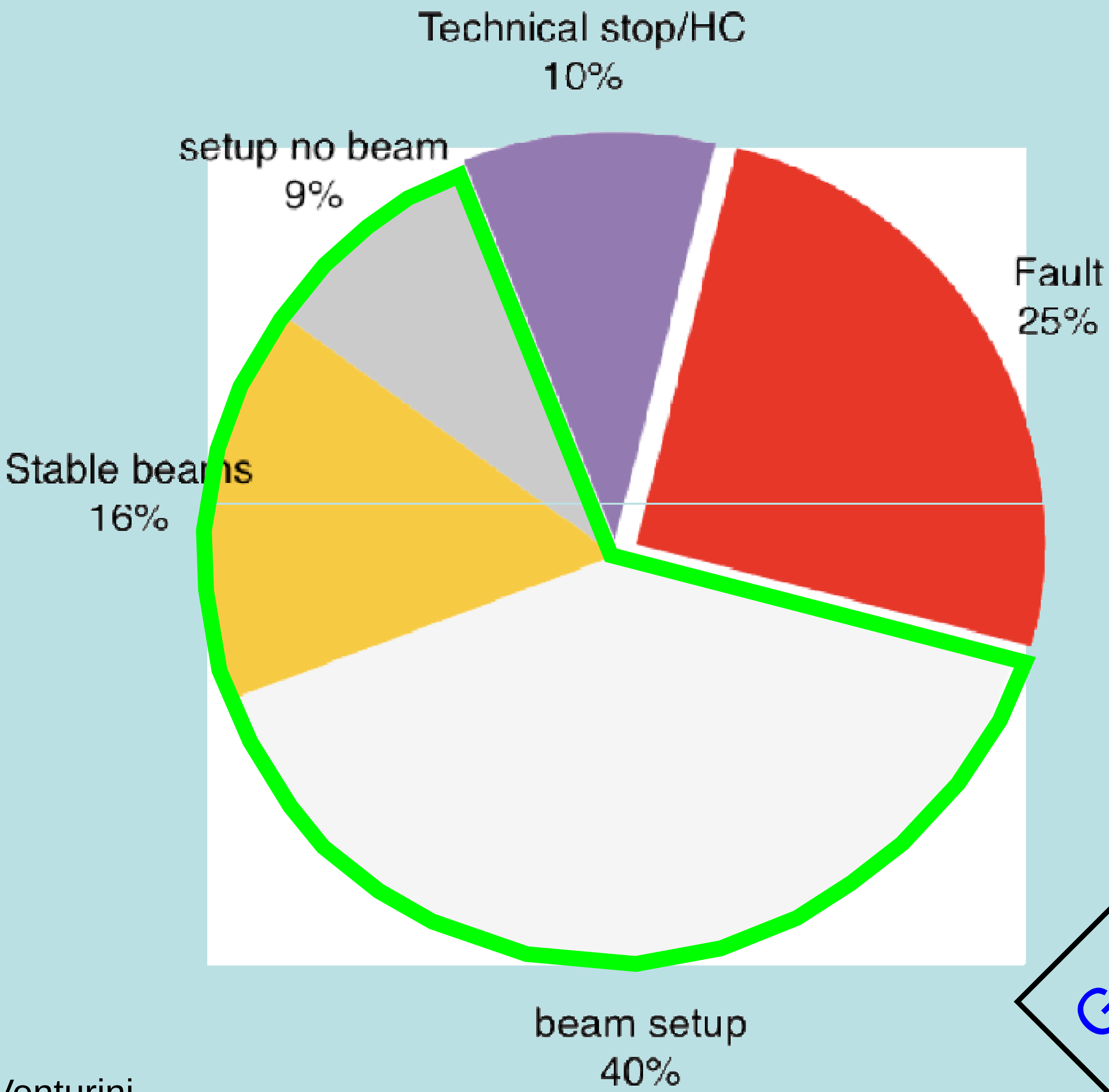
immediate data taking by all experiments with high efficiency
end July: first results presented at the international High Energy Conference
since then, more than tenfold statistics increase

… after more than a year of repairs and improvements

Stored Energy in the LHC



Overall LHC efficiency in 2010



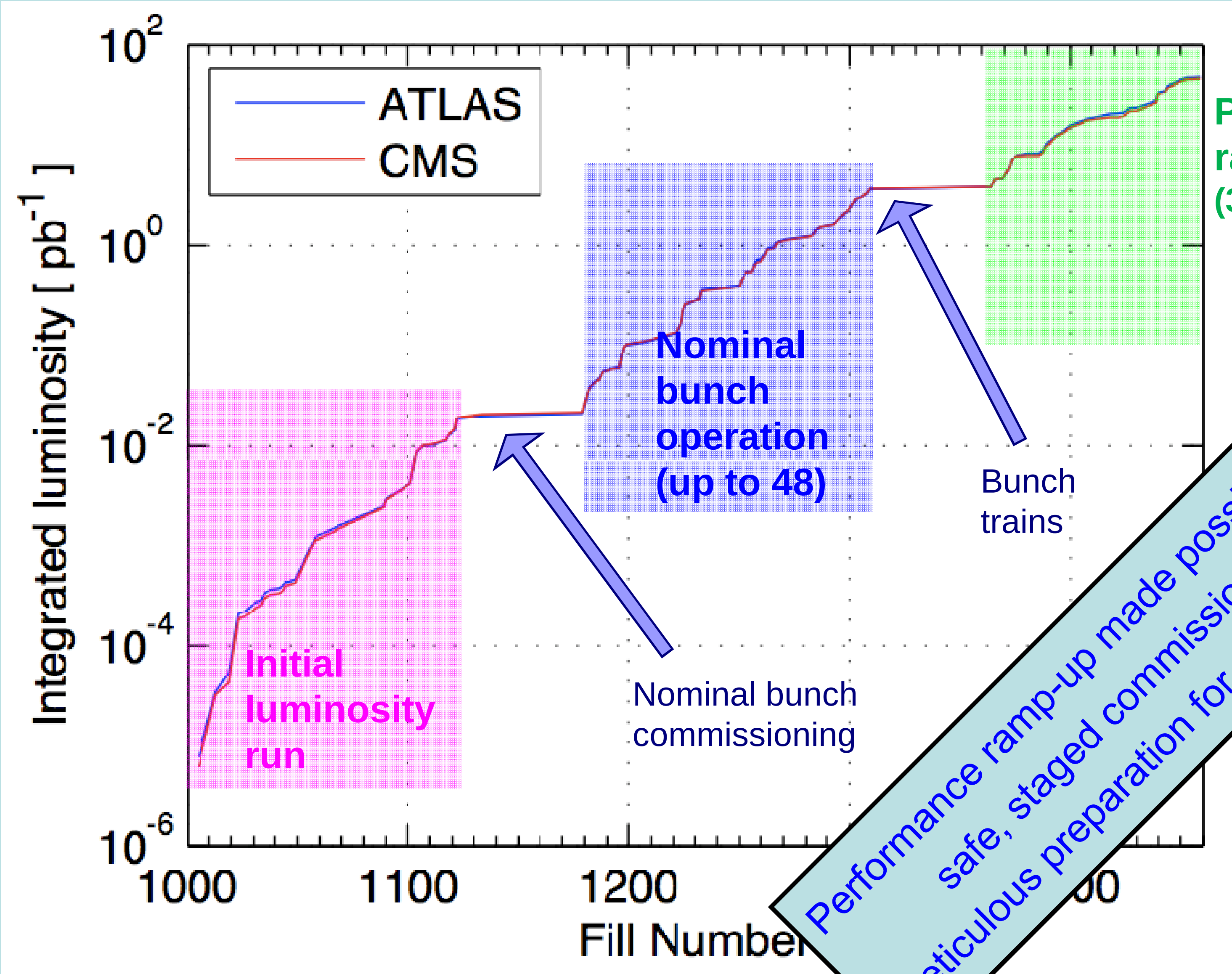
65% availability!

Great achievement for the first year of operation!

W. Venturini

Luminosity: 3 running periods

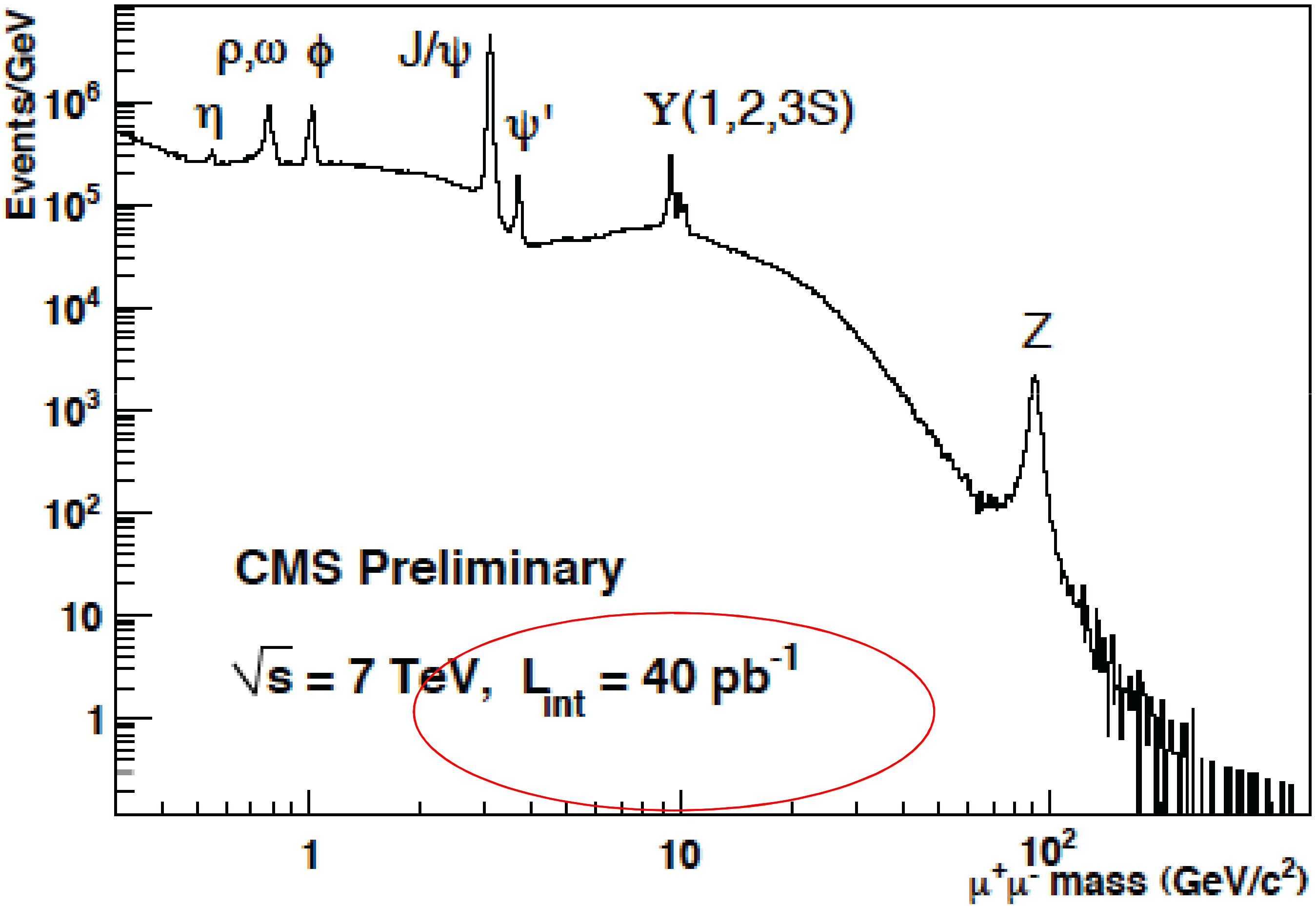
2010

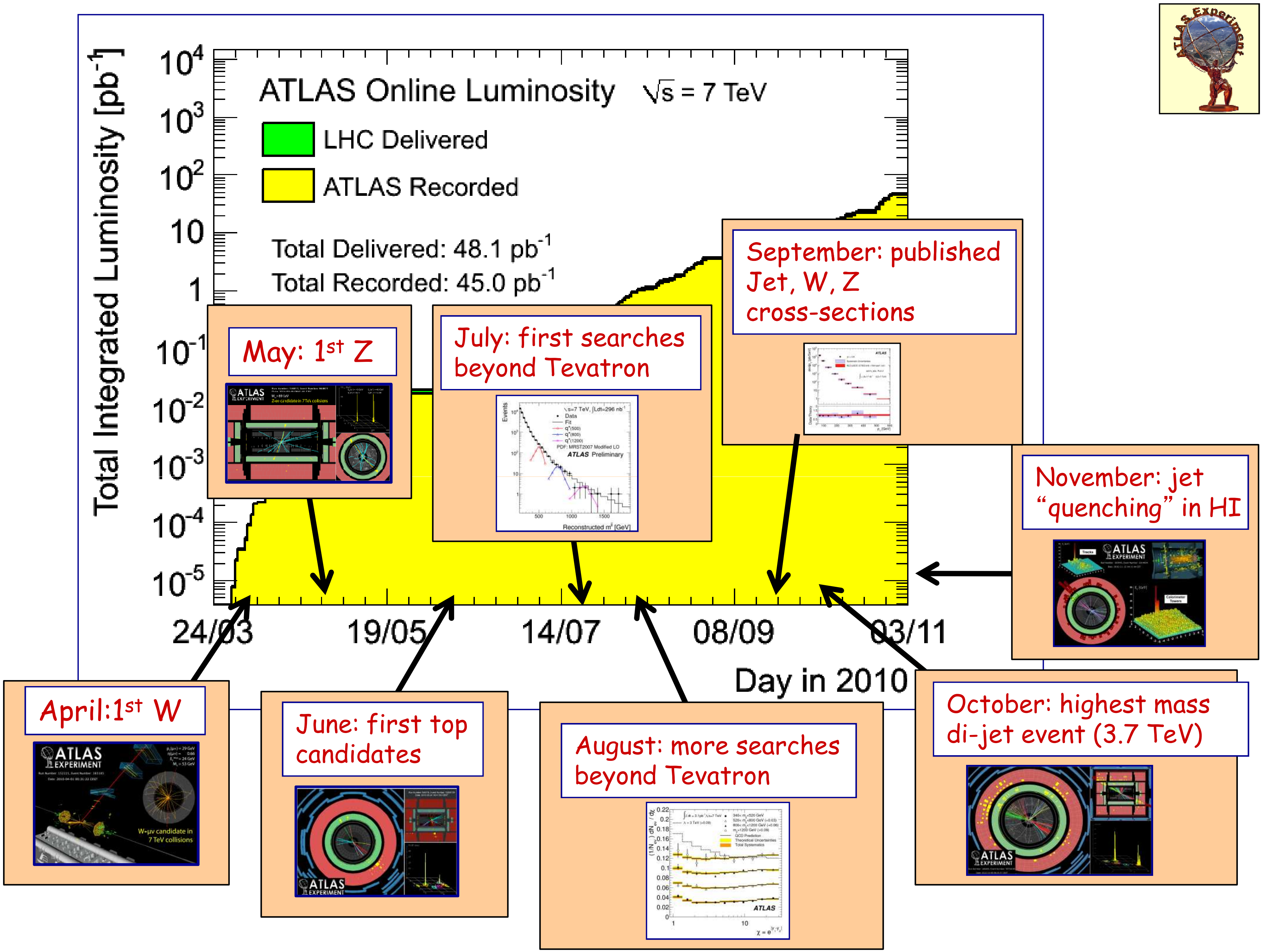


Performance ramp-up (368 bunches)

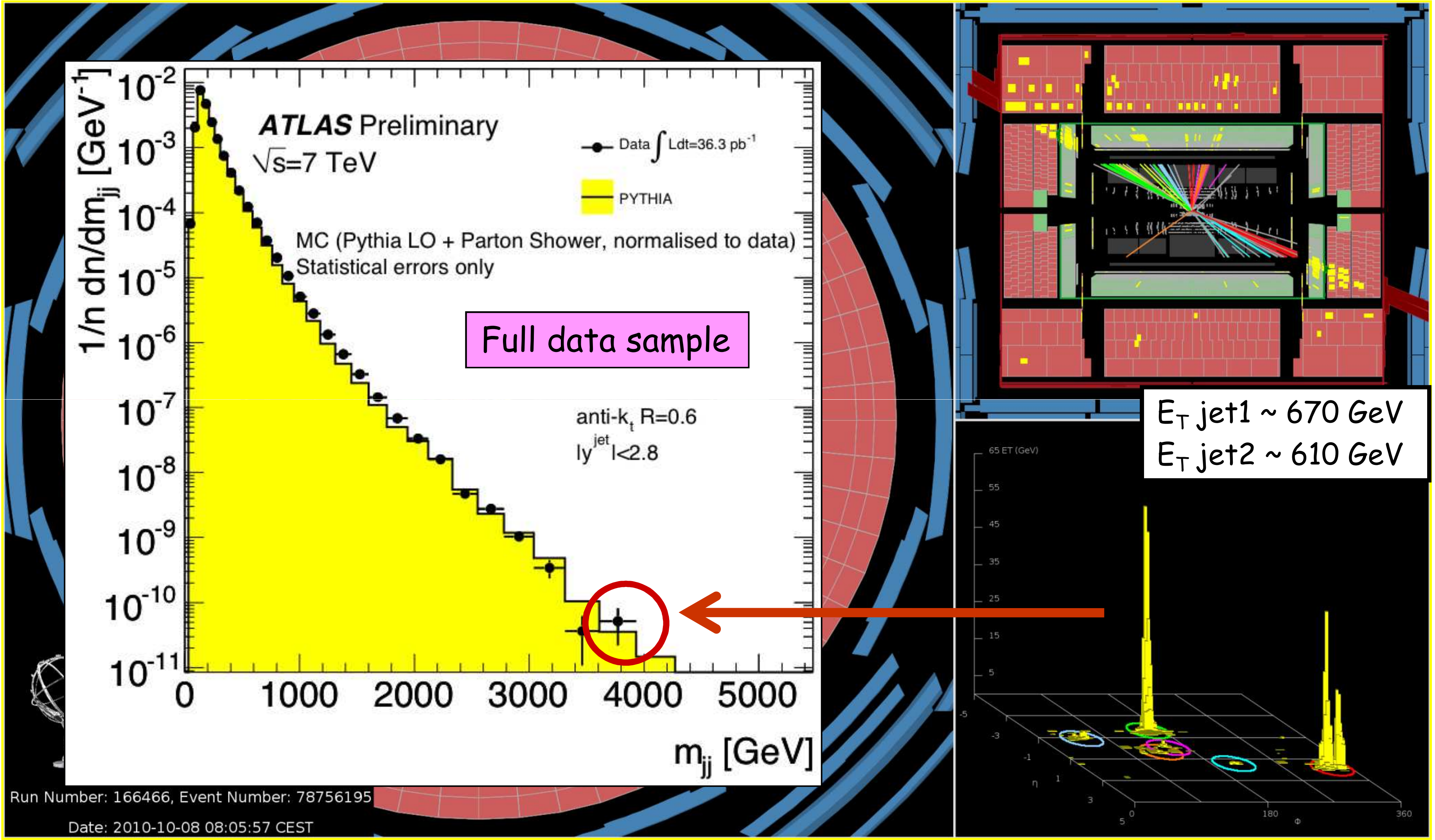
Performance ramp-up made possible by a safe, staged commissioning.
Meticulous preparation for unsafe beams!

Re-discovered the Standard Model at 7TeV

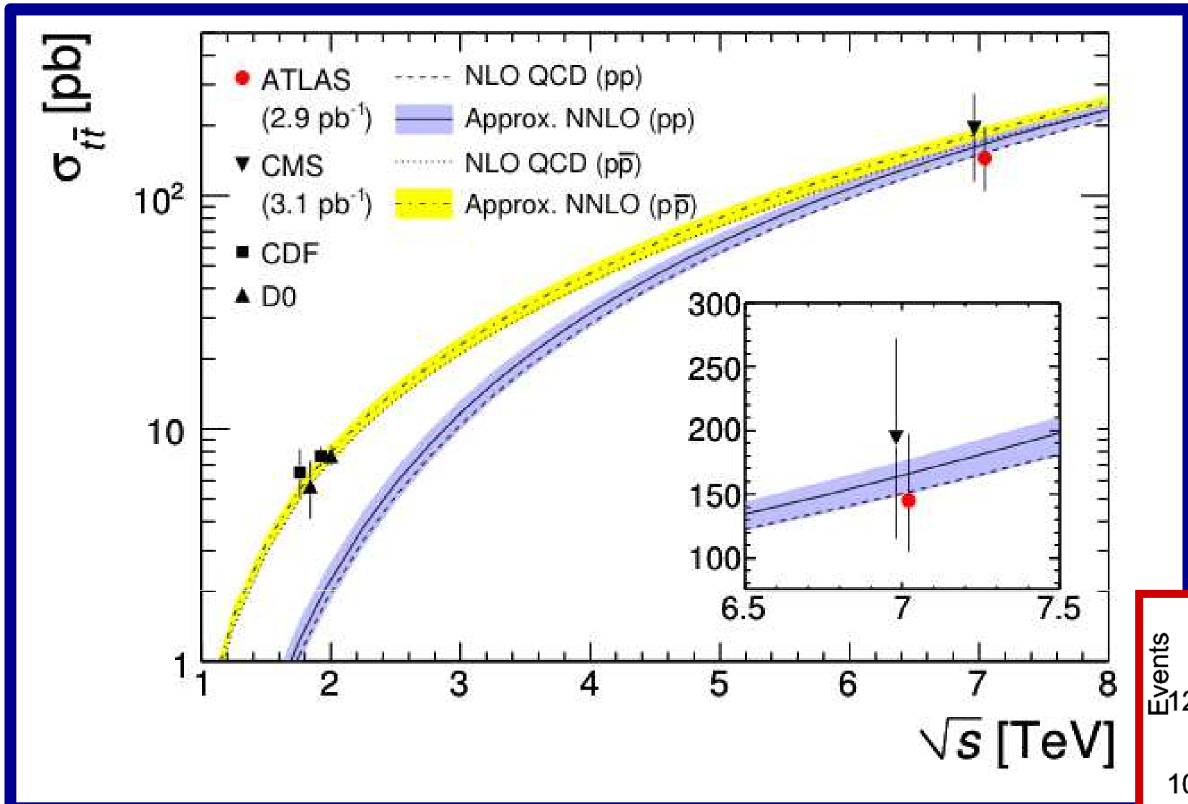


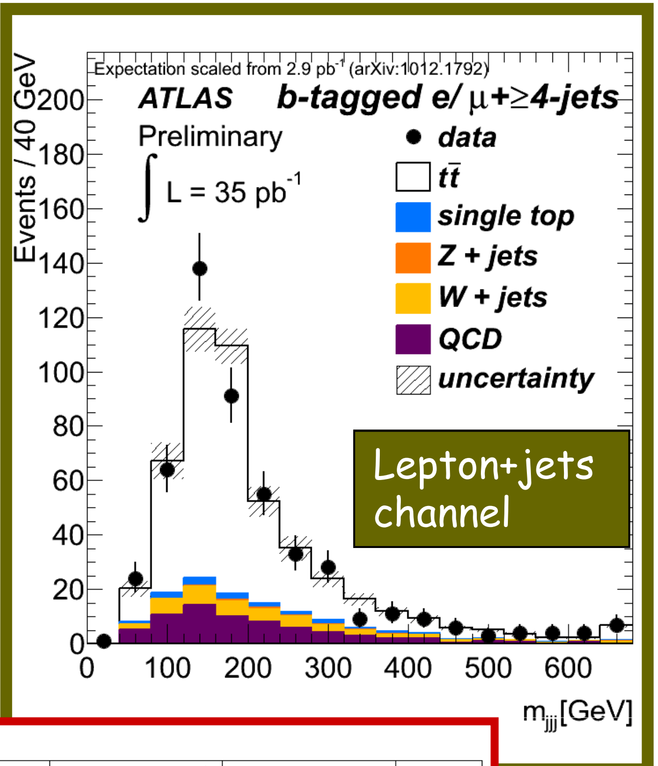

ATLAS Online Luminosity √s = 7 TeV
LHC Delivered
ATLAS Recorded
Total Delivered: 48.1 pb⁻¹
Total Recorded: 45.0 pb⁻¹
Total Integrated Luminosity [pb⁻¹]
Day in 2010
24/03
19/05
14/07
08/09
03/11
April: 1st W
May: 1st Z
June: first top candidates
July: first searches beyond Tevatron
August: more searches beyond Tevatron
September: published Jet, W, Z cross-sections
October: highest mass di-jet event (3.7 TeV)
November: jet "quenching" in HI

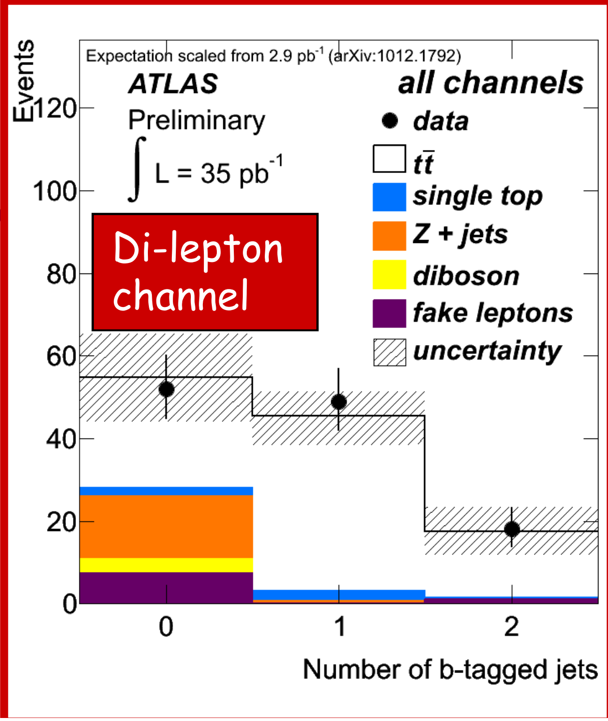
Highest mass dijet event recorded by ATLAS: M_{jj} =3.7 TeV



First top measurements at $\sqrt{s}$ = 7 TeV





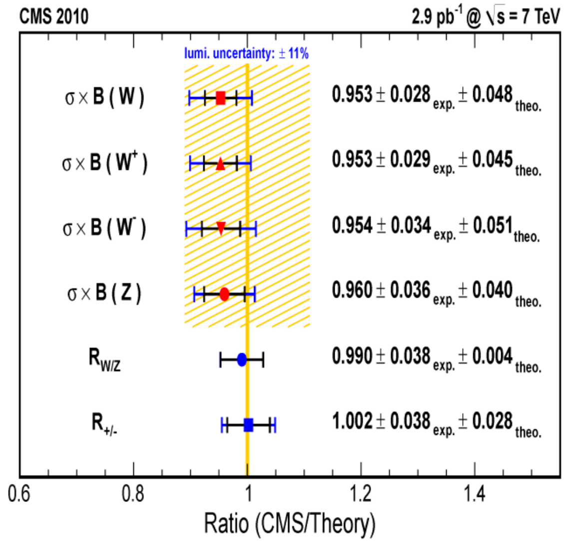


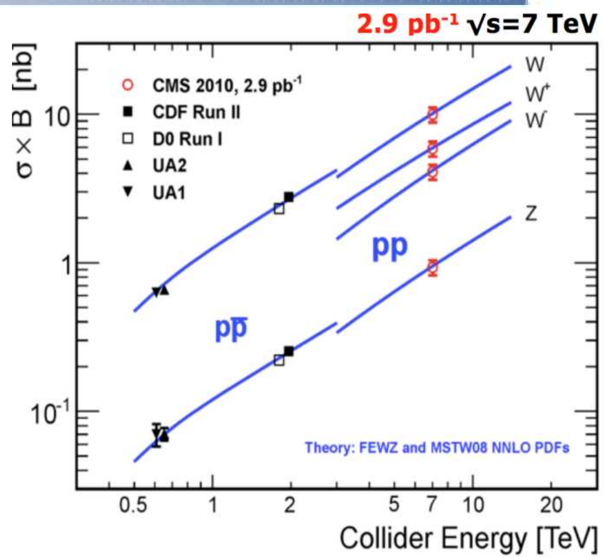
In the full data sample recorded so far, ATLAS has ~ 700 top-antitop events → only ~ 8 times less than CDF or D0

W, Z, top production cross sections

Measurements of Inclusive W and Z Cross Sections

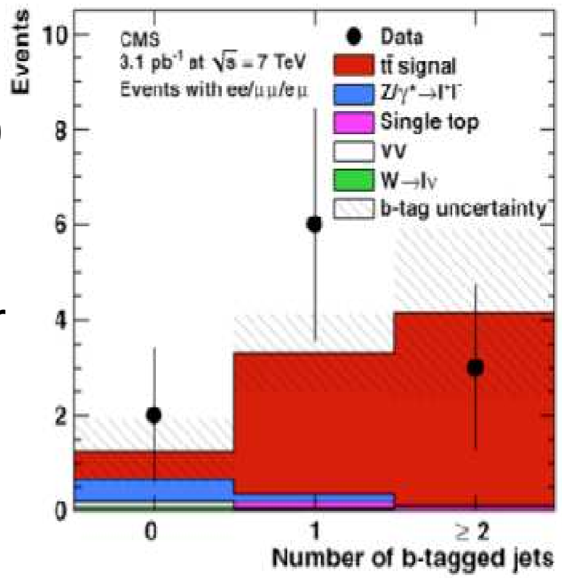
arXiv:1012.2466 ; *J. High Energy Phys.* 01 (2011) 080

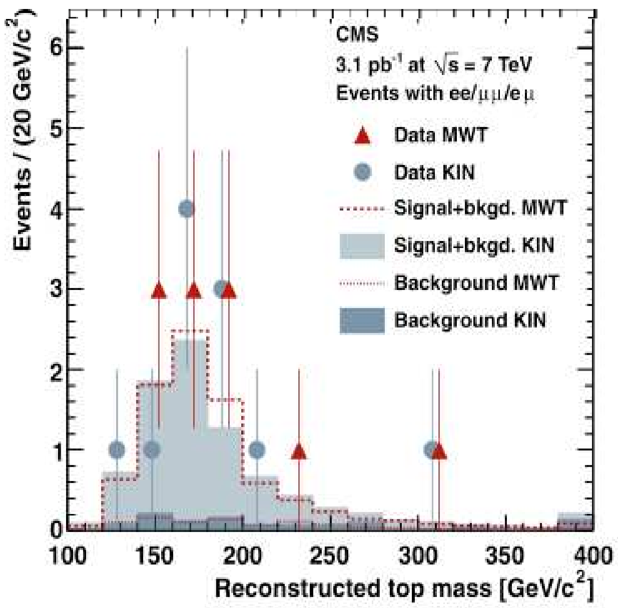




First Measurement of the Top Cross Section at LHC.

$\sigma(pp \rightarrow t\bar{t}+X) = 194 \pm 72(\text{stat.}) \pm 24(\text{syst.}) \pm 21(\text{lumi.})$ pb. Consistent with NLO prediction of 158(±24)pb for a top quark mass of $m_t = 172.5 GeV/c^2$

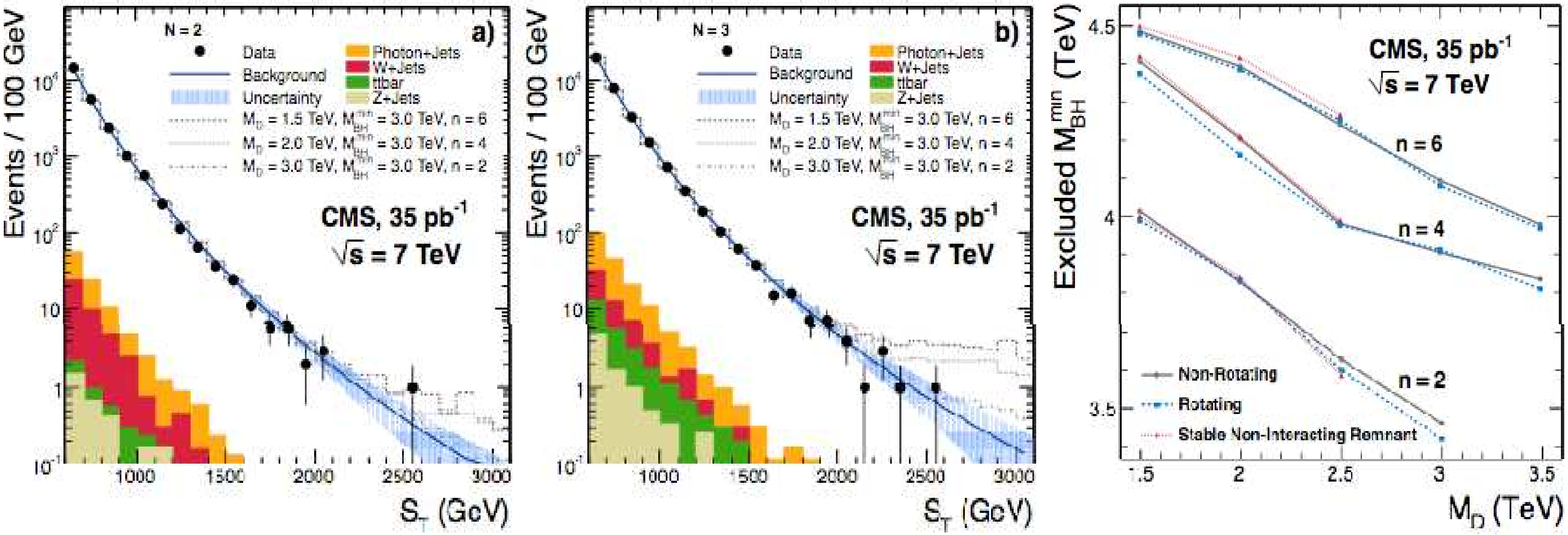




arXiv:1010.5994 Phys. Lett. B 695 (2011) 424-443

Search for microscopic black holes signatures

Events with large total transverse energy are analyzed for the presence of multiple high-energy jets, leptons, and photons, typical of a signal expected from a microscopic black hole.



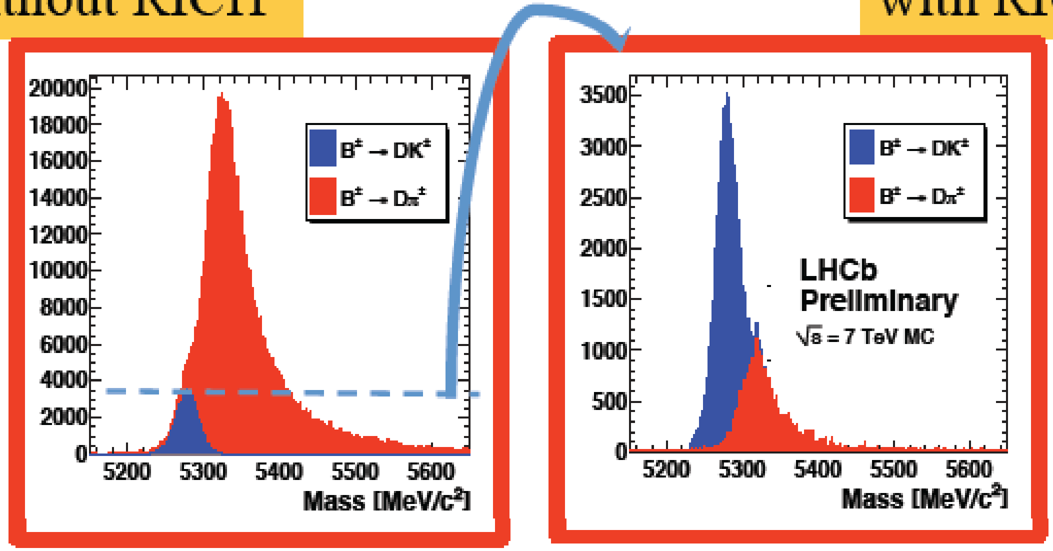
Good agreement with the expected standard model backgrounds, dominated by QCD multijet production, is observed for various final-state multiplicities. Limits on the minimum black hole mass are set, in the range **3.5–4.5 TeV**, for a variety of parameters in a model with large extra dimensions. **First direct search of BH at a particle collider.** **arXiv:1012.3375**; CMS-EXO-10-017; CERN-PH-EP-2010-073. Accepted by PLB.

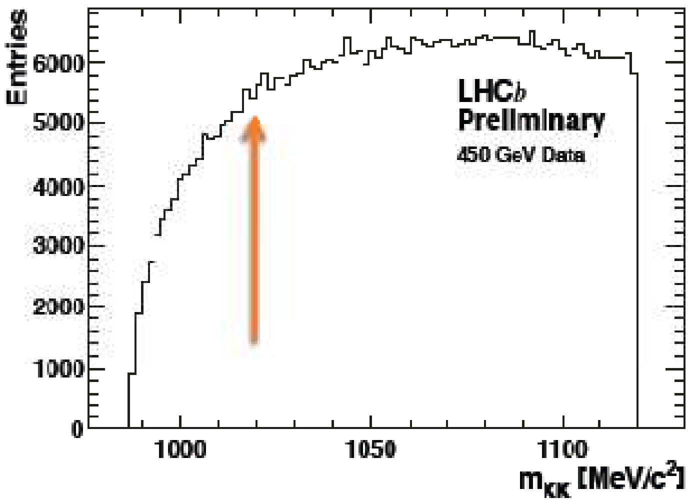
PID with RICH

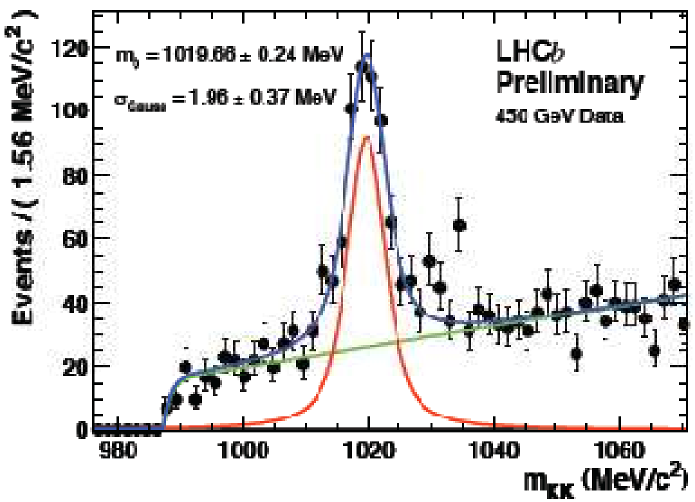
LHCb

without RICH

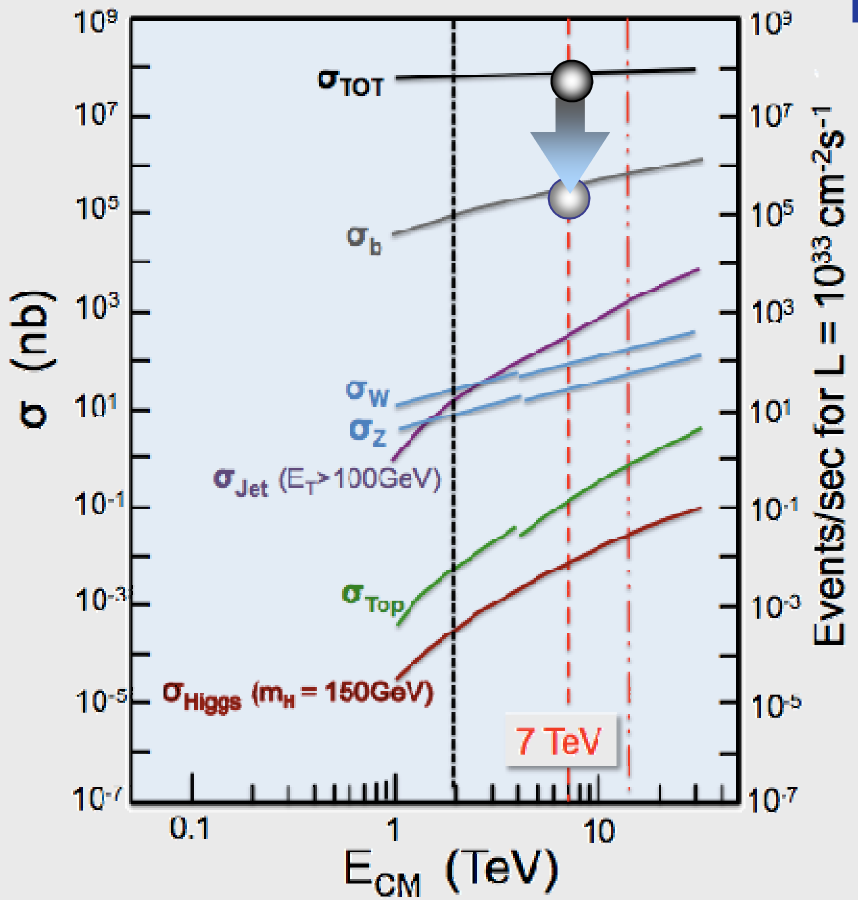
with RICH

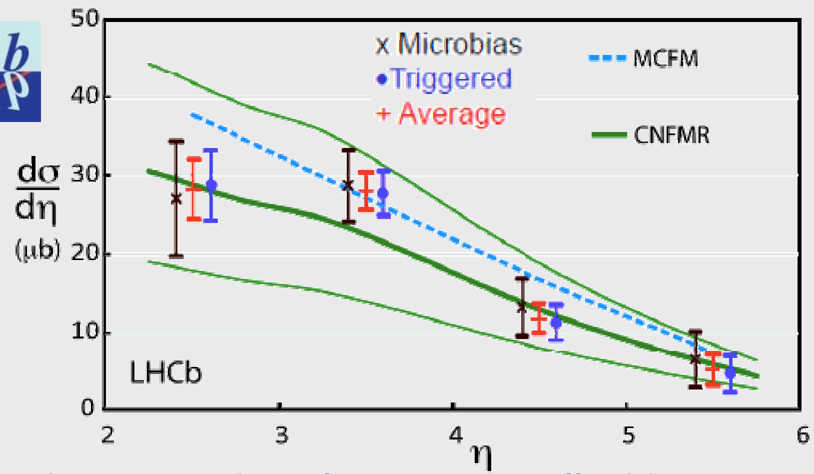




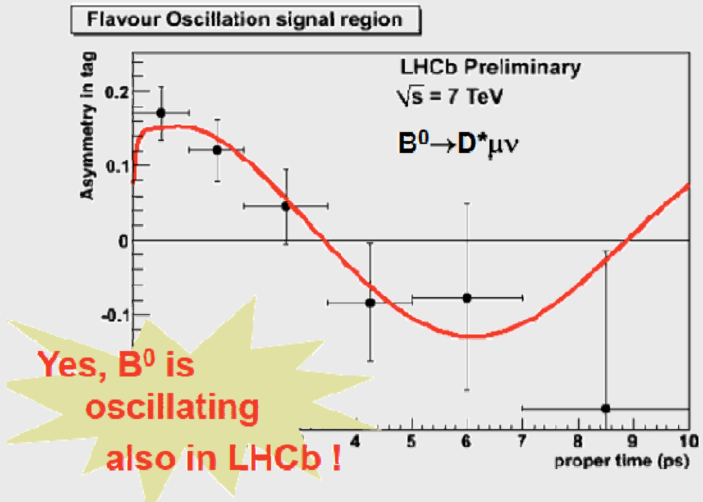


B-quark production at 7 TeV



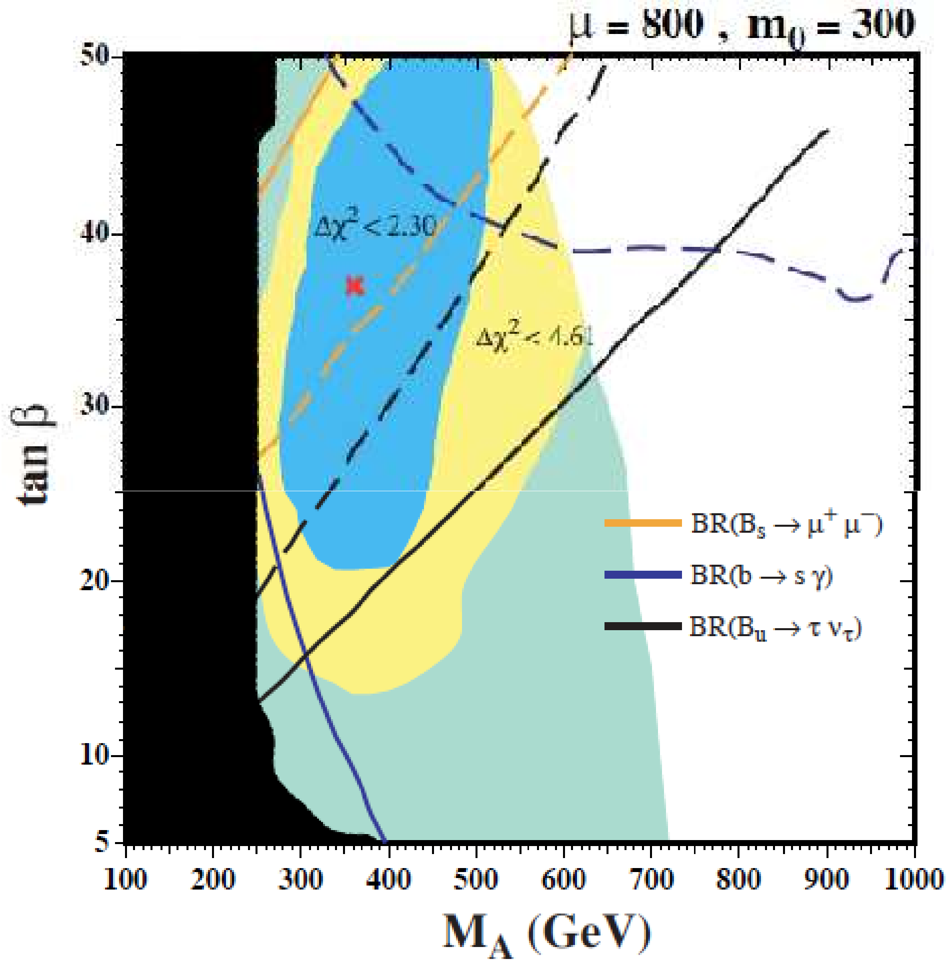


Shapes and scales agree well with expectation.
Validates QCD prediction at LHC energies.



First signal of flavour oscillation

Strongest constraints on MSSM Higgs come not from direct searches but from $B_s \rightarrow \mu\mu$, $b \rightarrow s\gamma$ and $b \rightarrow \tau\nu$

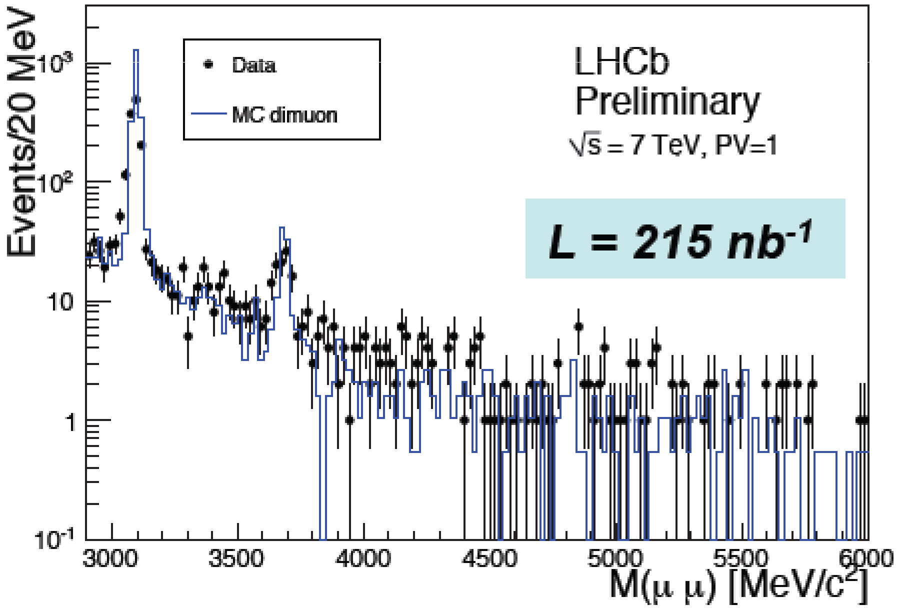


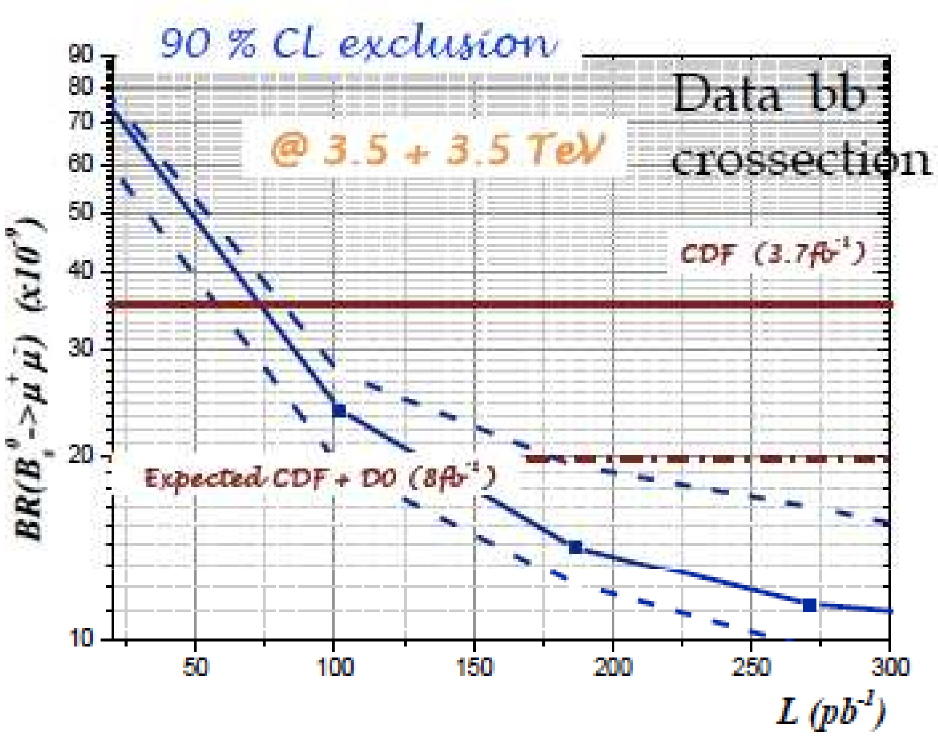
By measuring BR($B_s \rightarrow \mu\mu$) LHCb will probe the entire best-fit region of parameters with 2011 data. Direct searches would require several years running at nominal L to achieve this goal

Prospects for $B_s \rightarrow \mu\mu$

For the SM prediction LHCb expects 10 signal events in 1 fb^{-1}

Background expected from MC is in good agreement with data

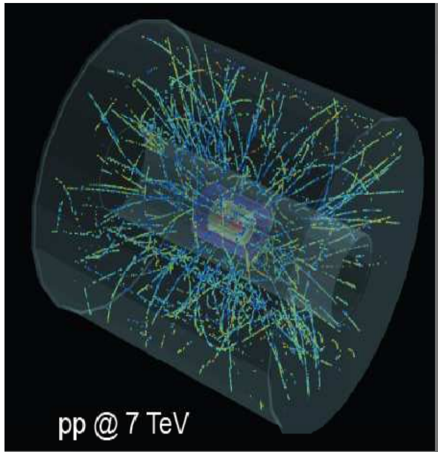


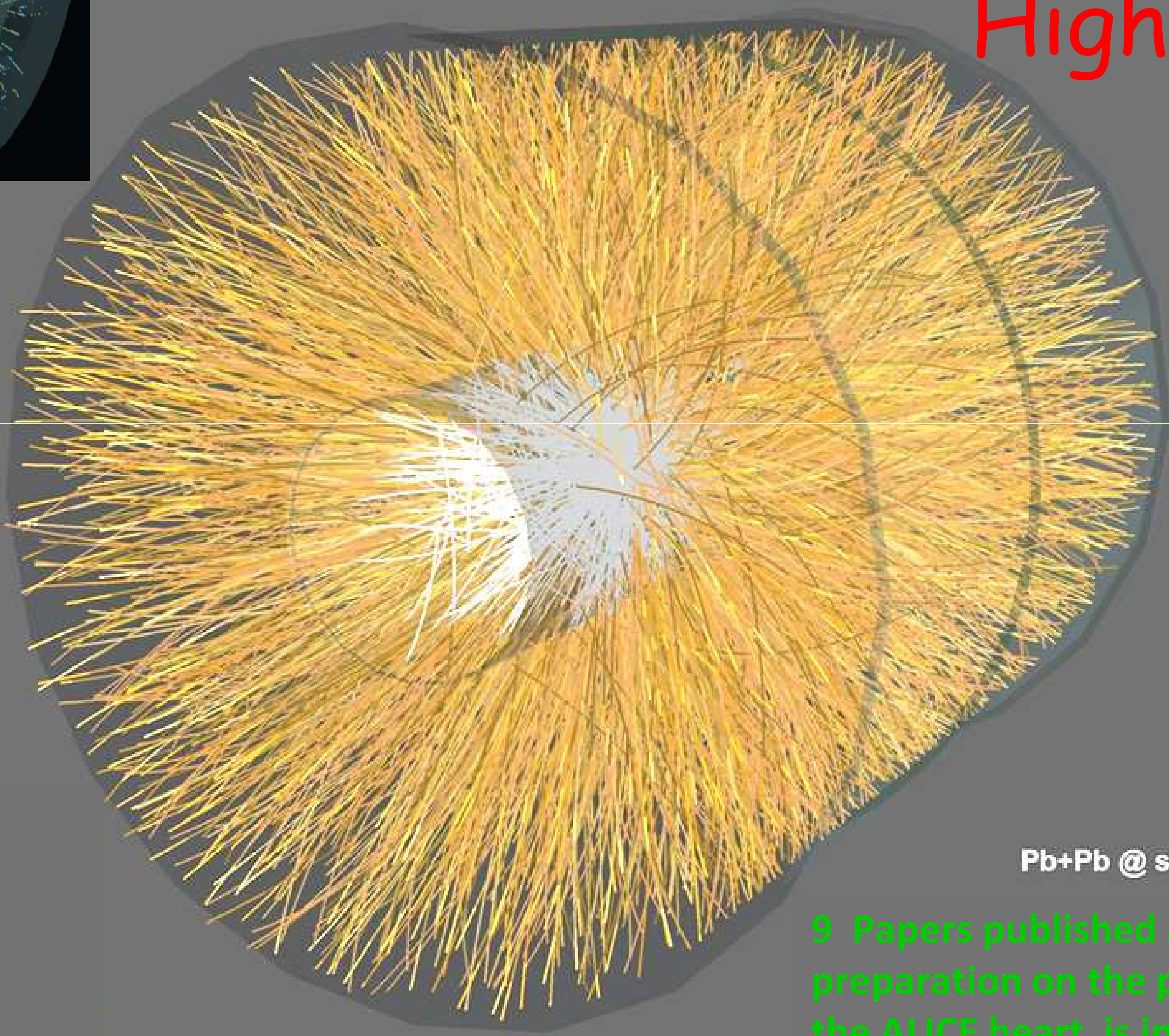


With 2010 data** (37pb^{-1} collected in only two weeks running at ~2$\times$10^{32} cm^{-2} s^{-1}) **LHCb reaches TEVATRON sensitivity !!!

With L ~ 1 fb^{-1} exclusion of SM enhancement up to BR($B_s \rightarrow \mu\mu$) ~ 7$\times$10^{-9}

ALICE Highlights



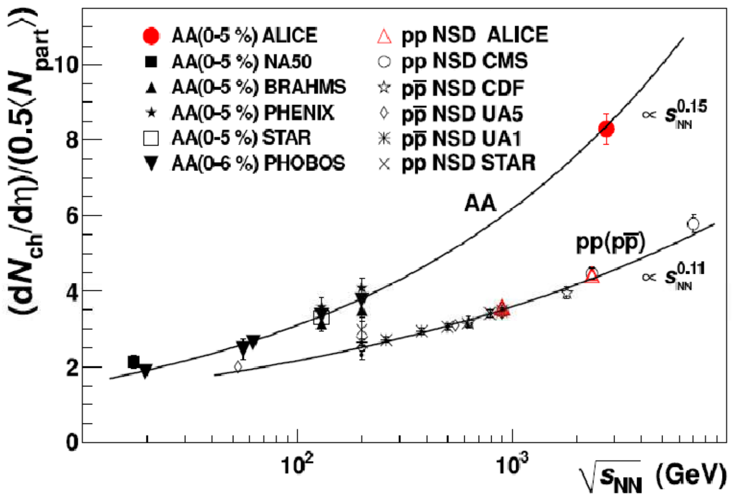


Pb+Pb @ sqrt(s) = 2.76 ATeV

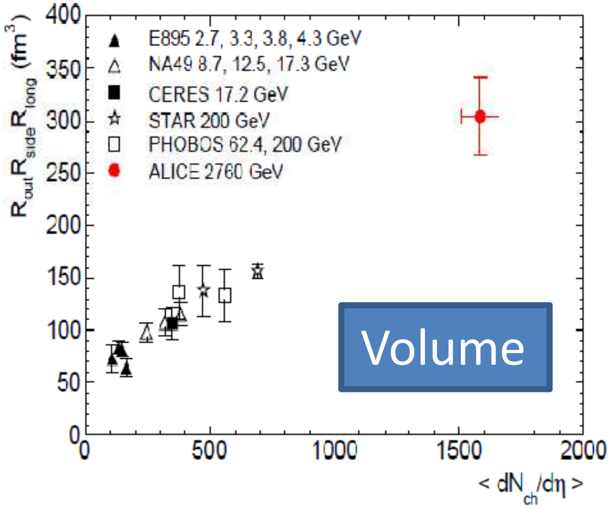
9 Papers published and lots in preparation on the pp data ... but the ALICE heart is in Heavy Ions

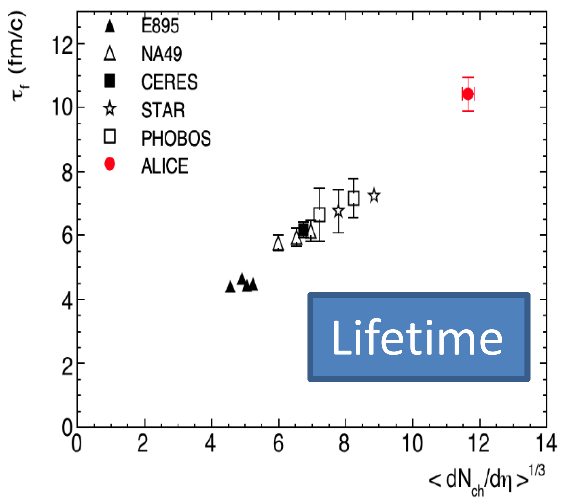
Characteristics of Central Pb+Pb Collisions at 2.76 TeV

- **Energy density from $dN_{ch}/d\eta$**
  - $dN_{ch}/d\eta = 1599 \pm 4$ (stat.) ± 80 (syst.)
  - constrains / rules out models
  - 100 times cold nuclear matter density
  - 3 times the density reached at RHIC ($\varepsilon \approx 15$ GeV/fm^3)



- **Volume and lifetime from HBT interferometry**



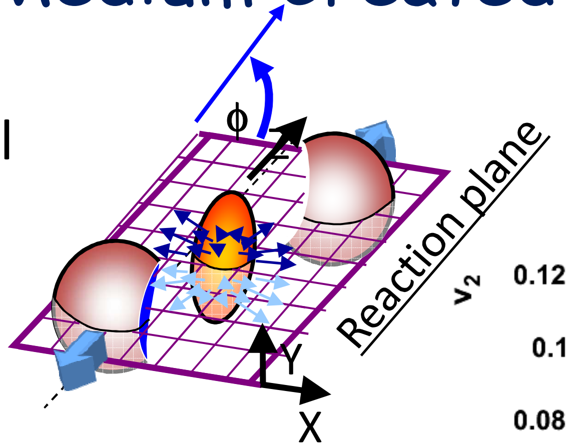


- Freeze-out volume 300 fm^3
- 2 times the volume measured at RHIC (AuAu@200 GeV)
- Lifetime until freeze-out 10 fm/c

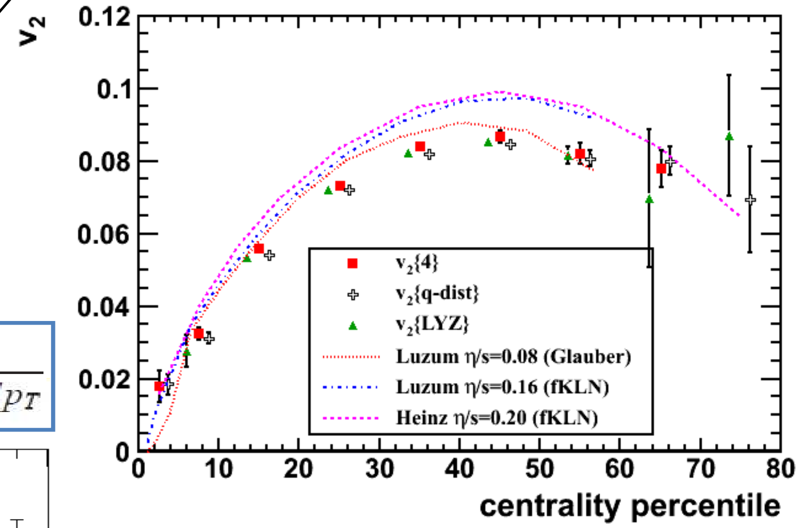
Properties of the Medium Created in Pb+Pb Collisions

The LHC QGP, much hotter than the RHIC QGP, has still the properties of a ~perfect fluid (elliptic flow measurement)

$\eta/s \approx 1/4\pi$ (conjectured quantum bound)

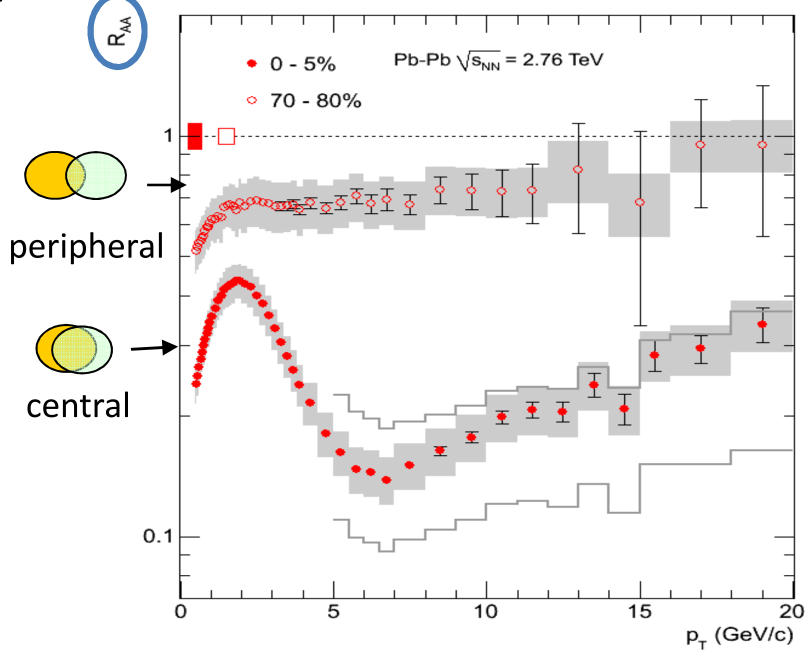


Most extreme state of matter ever created in the lab …

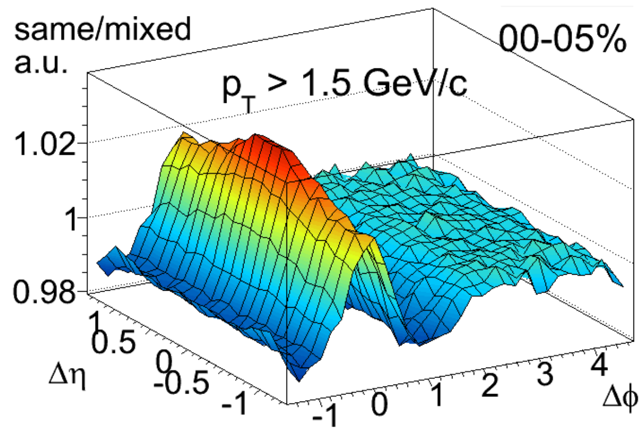


- Strong energy loss of particles in hot and dense medium
- Quantified by nuclear suppression factor R_{AA}
- Maximum suppression R_{AA} ~ 1.5 – 2 x stronger than at RHIC

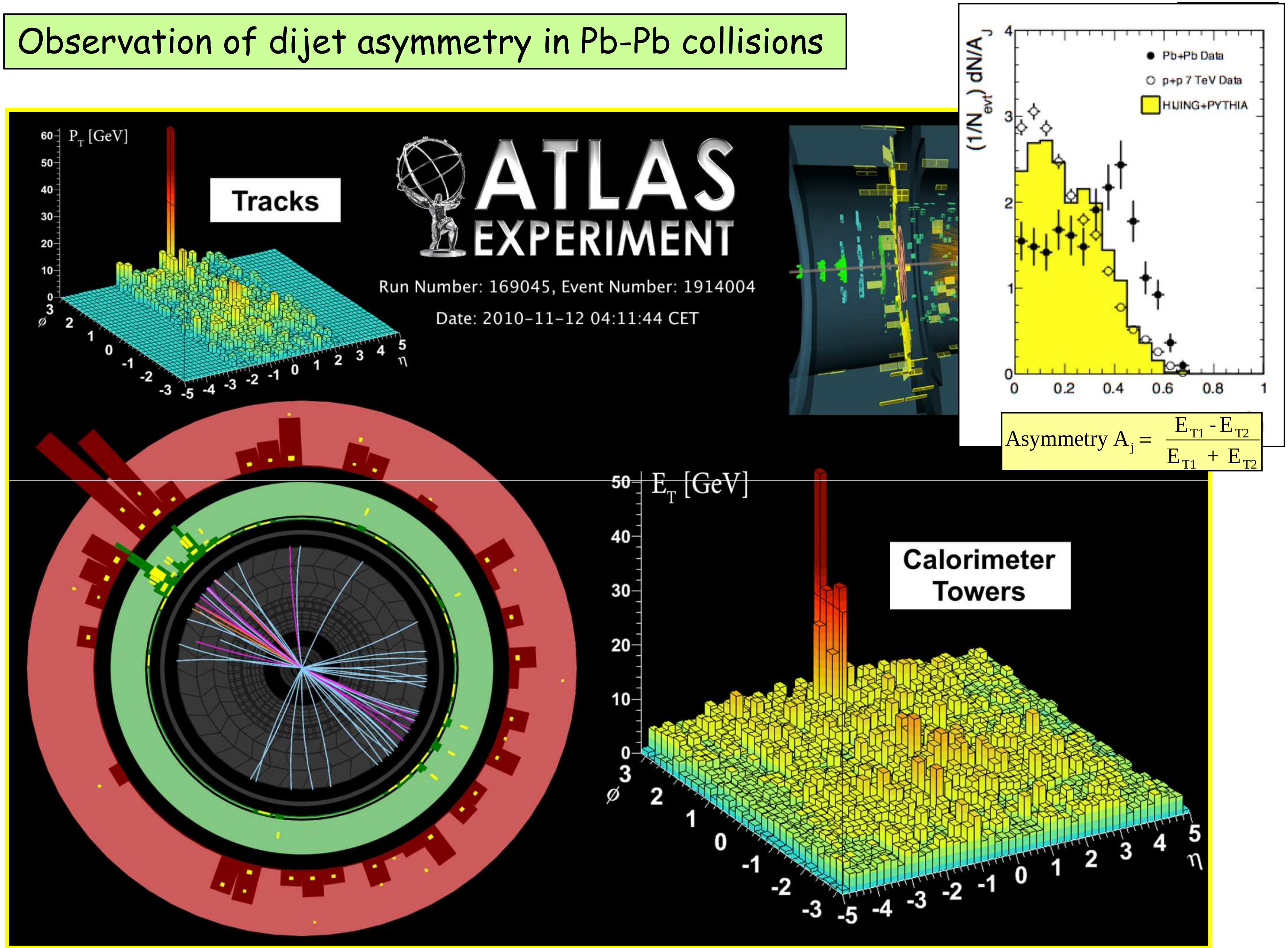
$$R_{AA}(p_T) = \frac{(1/N^{AA}_{evt})\, d^2N^{AA}_{ch}/d\eta dp_T}{\langle N_{coll}\rangle\,(1/N^{pp}_{evt})\, d^2N^{pp}_{ch}/d\eta dp_T}$$



- now addressing features of the medium via correlations



Observation of dijet asymmetry in Pb-Pb collisions



$$\text{Asymmetry } A_j = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}$$

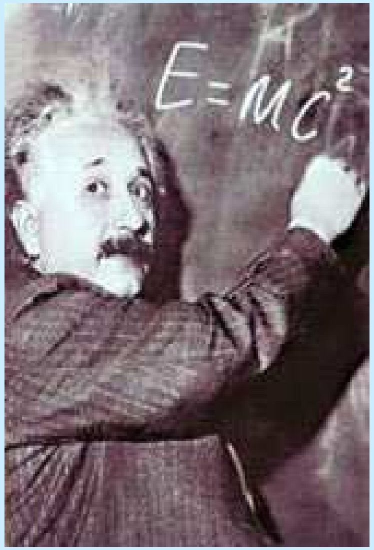
Summary as of today

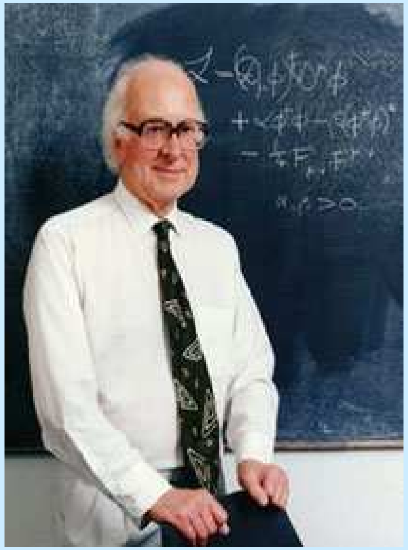
- Experiments enthusiastically following the exceptional machine progression
- Standard Model particle zoo completed with the observation of the “european” top quark
- WLCG keeping the pace smoothly
- A steady flow of physics results streaming out
- Ready for more and the first unexpected results are around the corner. . . !

The Science

We are now ready to tackle

some of the most profound questions in physics:





"Newton's" unfinished business… what is mass?

Nature's favouritism… why is there no more antimatter?

The secrets of the Big Bang… what was matter like within the first second of the Universe's life?

Science's little embarrassment… what is 96% of the Universe made of?

ready to enter the
Dark Universe

Dark Matter

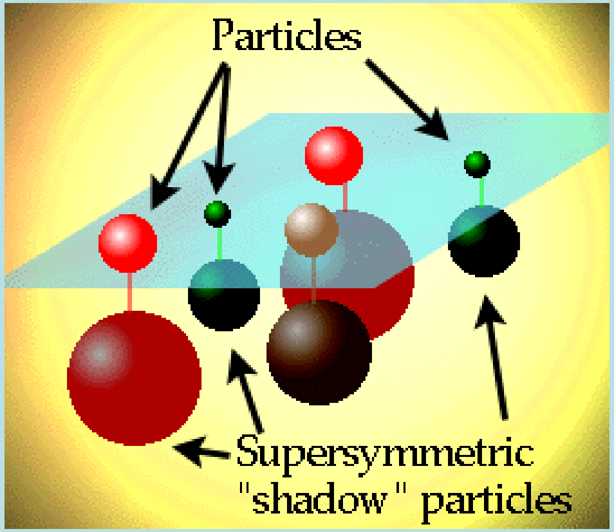
Astronomers & astrophysicists over the next two decades using powerful new telescopes will tell us how dark matter has shaped the stars and galaxies we see in the night sky.

Only particle accelerators can produce dark matter in the laboratory and understand exactly what it is.

Composed of a single kind of particle
or
more rich and varied (as the visible world)?

LHC may be the perfect machine to study dark matter.

Supersymmetry



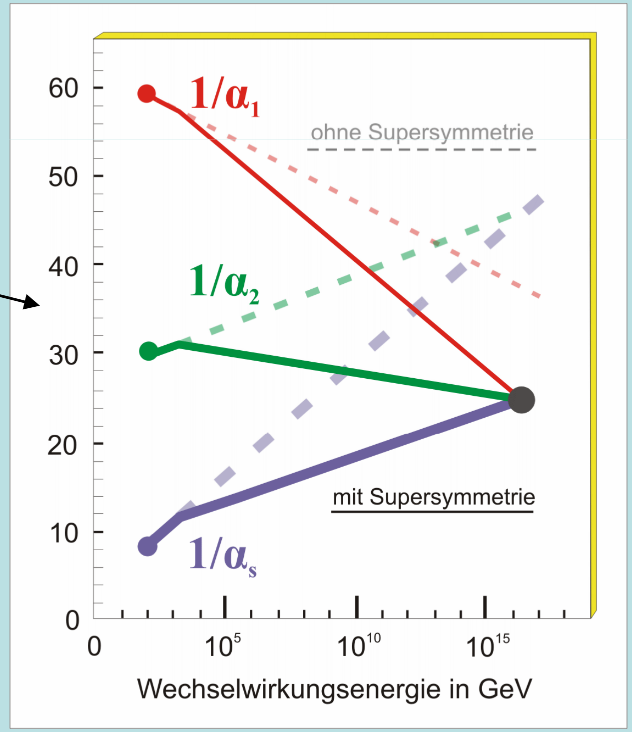
- unifies matter with forces

  for each particle a supersymmetric partner (*sparticle*) of opposite statistics is introduced

- allows to unify strong and electroweak forces

  $\sin^2\theta_W^{SUSY} = 0.2335(17)$

  $\sin^2\theta_W^{exp} = 0.2315(2)$

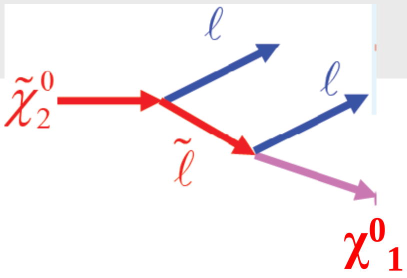


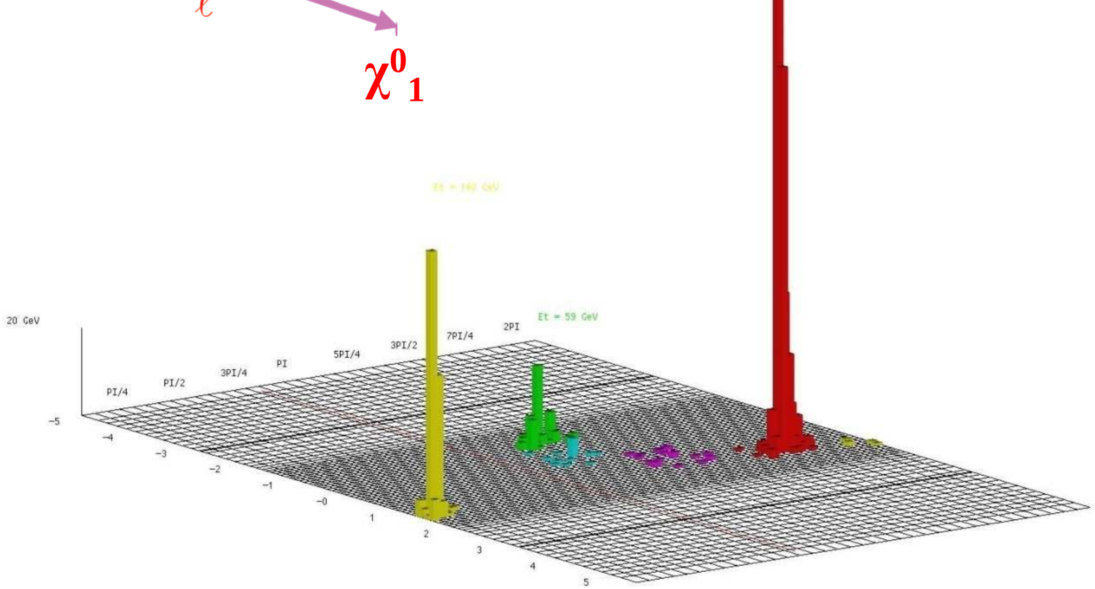
- provides link to string theories

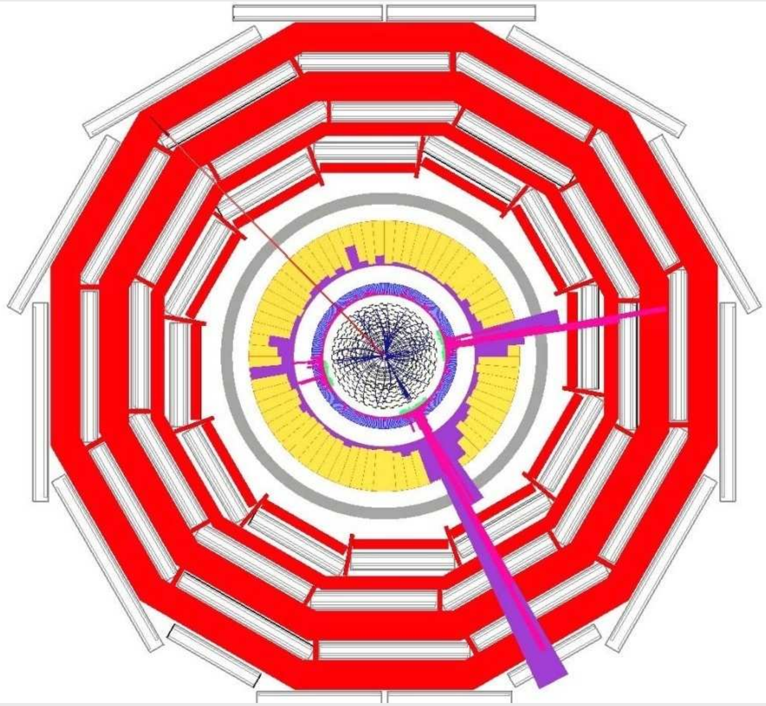
- provides Dark Matter candidate

  (stable Lightest Supersymmetric Particle)

Looking for Dark Matter



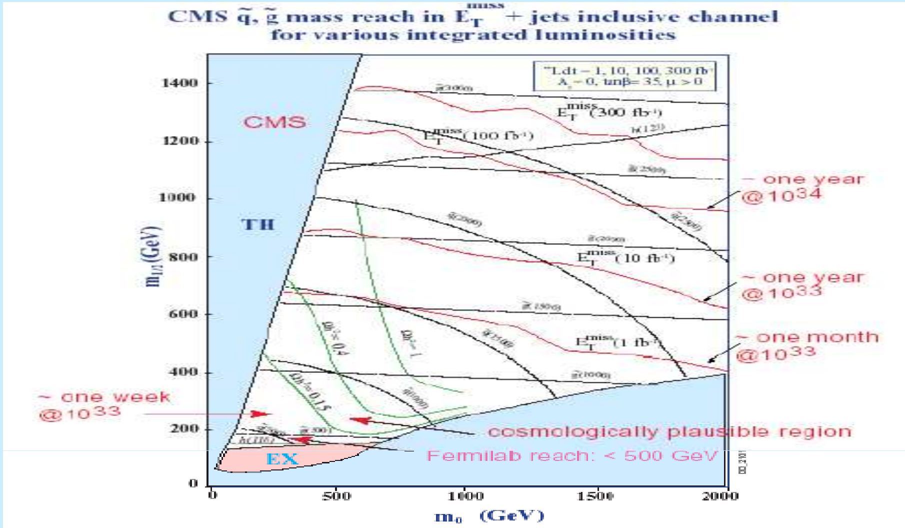


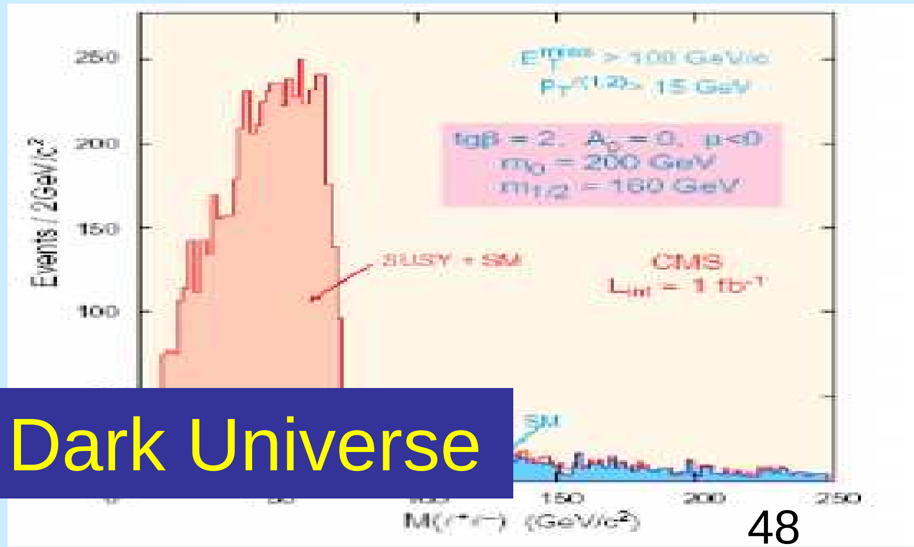


Missing energy
taken away by dark matter particles

Search for SUSY at LHC Start-up

- Due to their high production cross-sections, squarks and gluinos can be produced in large numbers even at modest luminosities.
- Potential for discovery of SUSY is sizeable even at LHC start-up.

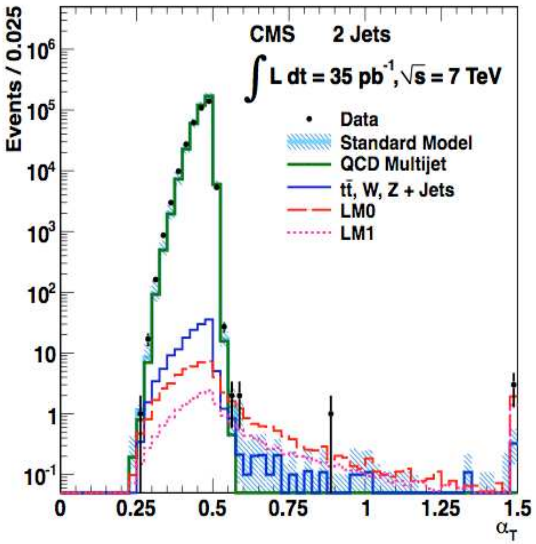


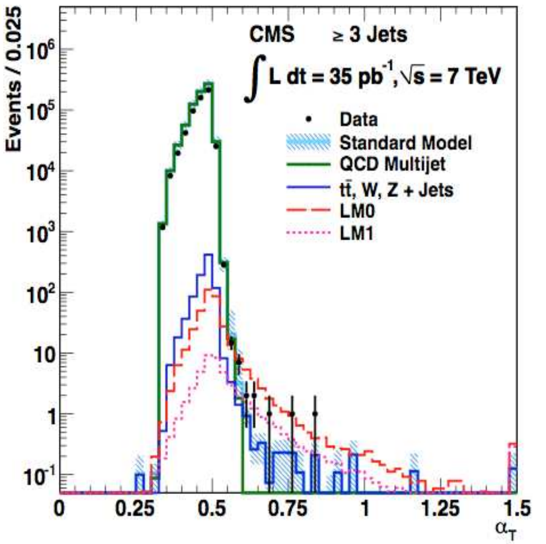


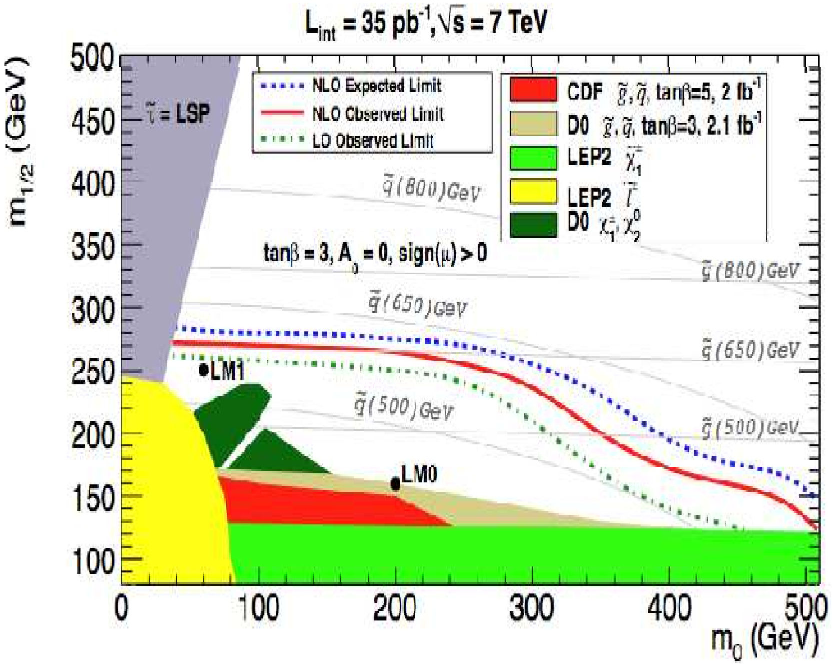
→ First light in the Dark Universe

First SUSY result from LHC

Using very clean signatures for early SUSY signals (α_T, di-photon+MET, multi-leptons etc) we are already exceeding limits on SUSY set by the Tevatron experiments.





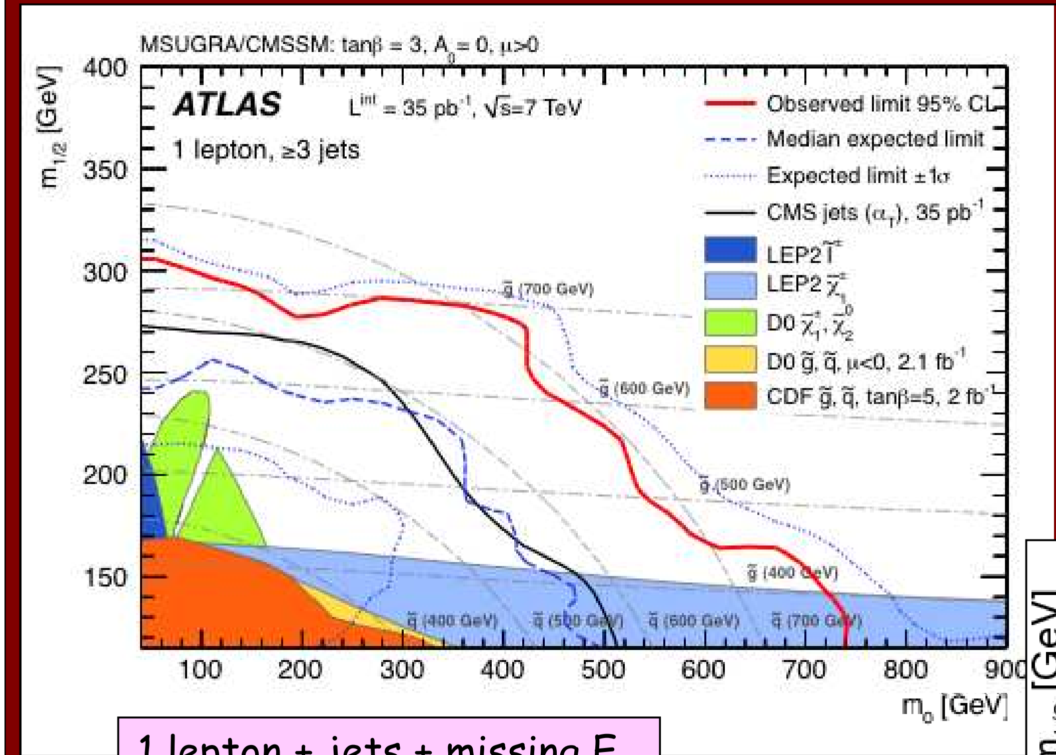


In a few months the exclusion range established in the last 20 years expanded by ~factor two.

arXiv:1101.1628 ; CMS-SUS-10-003 ; CERN-PH-EP-2010-084. – 2011 Submitted to Physics Letters B

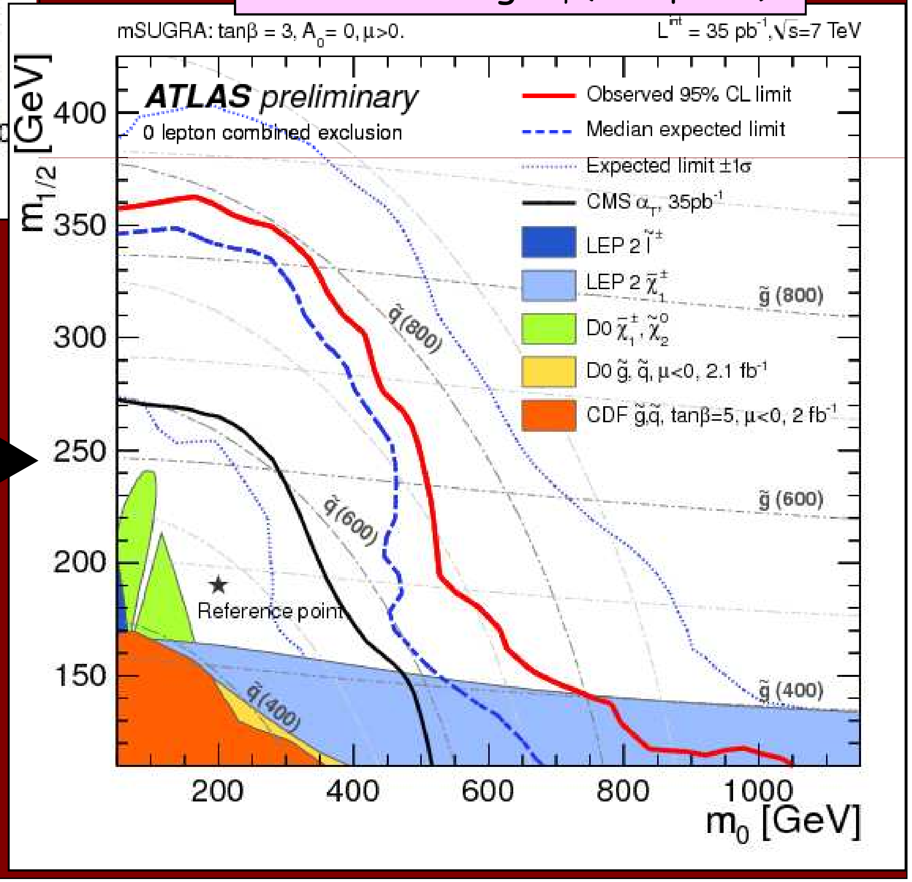
Prospects for 2011-12: discover squarks and gluinos (if SUSY is a symmetry of nature) above 1TeV.

Searches for Supersymmetry



1 lepton + jets + missing E_T

Jets + missing E_T (no leptons)



$m(\tilde{g}) > 775$ GeV for $m(\tilde{g}) = m(\tilde{q})$

Most stringent limits to date

LHC results should allow,
together with dedicated dark matter searches,
first discoveries in the dark universe

around 73% of the Universe is in some mysterious "dark energy". It is evenly spread, as if it were an intrinsic property of space.

Challenge:
get first hints about the world of dark energy in the laboratory

The Higgs is Different!

All the matter particles are spin-1/2 fermions.
All the force carriers are spin-1 bosons.

Higgs particles are spin-0 bosons (scalars).
The Higgs is neither matter nor force.
The Higgs is just different.
This would be the first fundamental scalar ever discovered.

The Higgs field is thought to fill the entire universe.
Could it give some handle of dark energy (scalar field)?

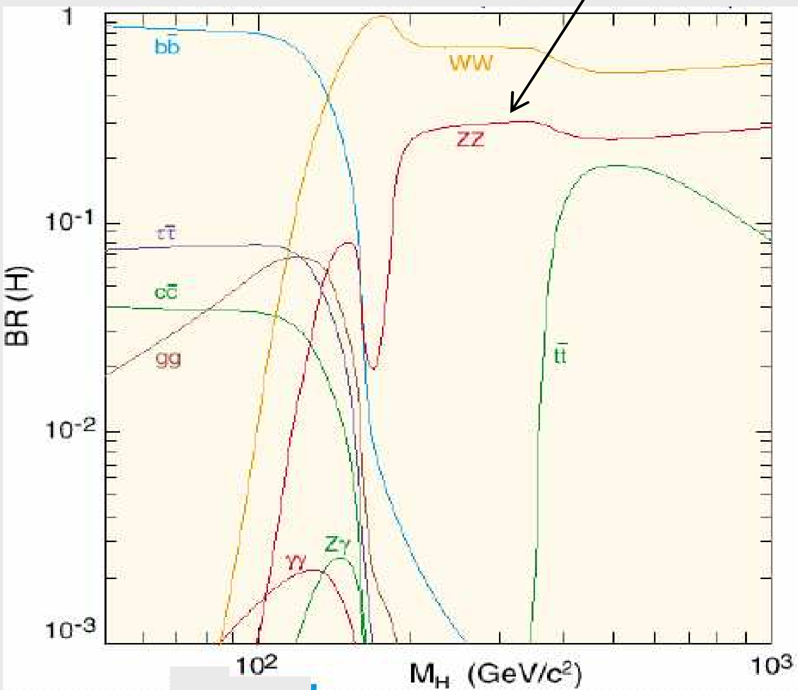
Many modern theories predict other scalar particles like the Higgs.
Why, after all, should the Higgs be the only one of its kind?

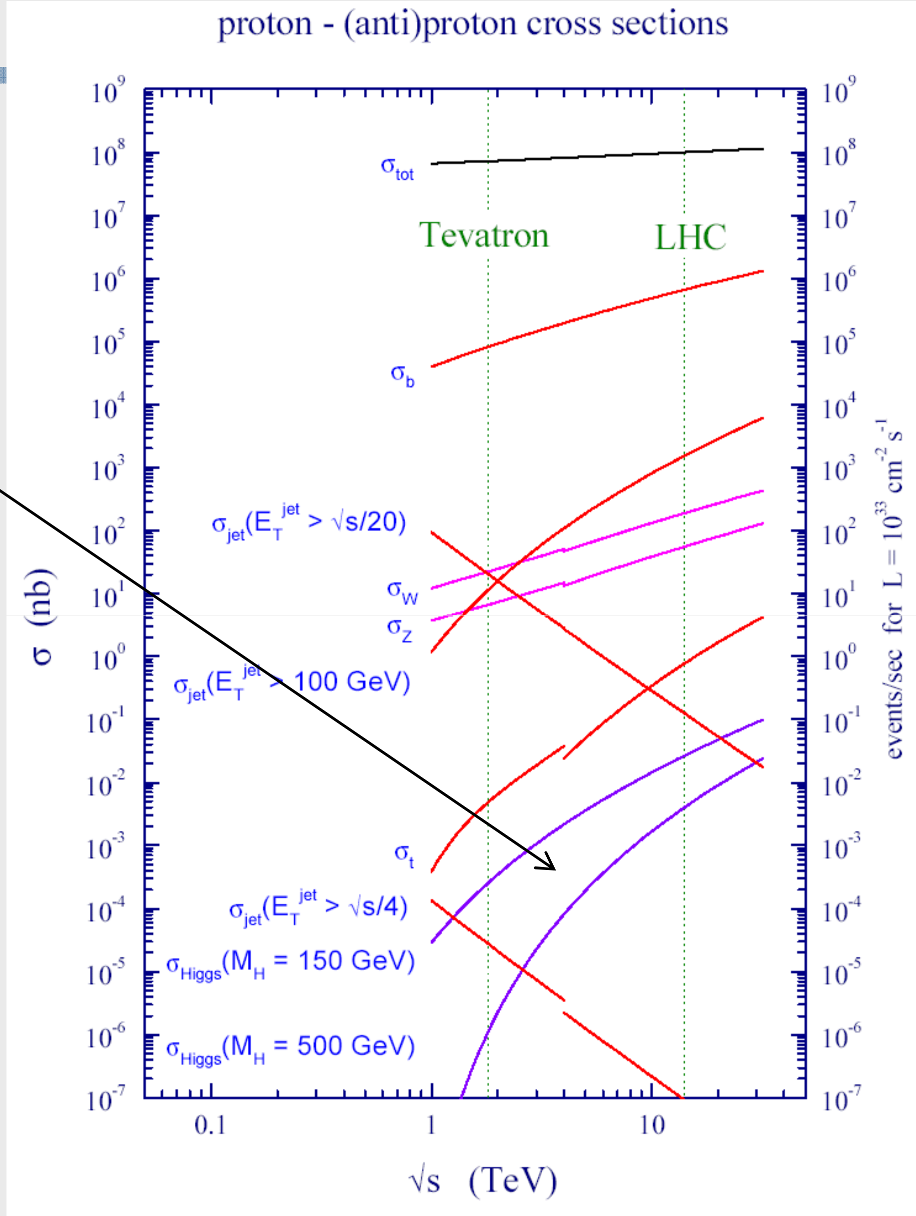
LHC can search for and study new scalars with precision.

Search for the Higgs-Boson at the LHC

Production rate
of the Higgs-Bosons
depends on its mass

as well as its decay possibilities
("Signature (or picture)"
as seen in the detector)





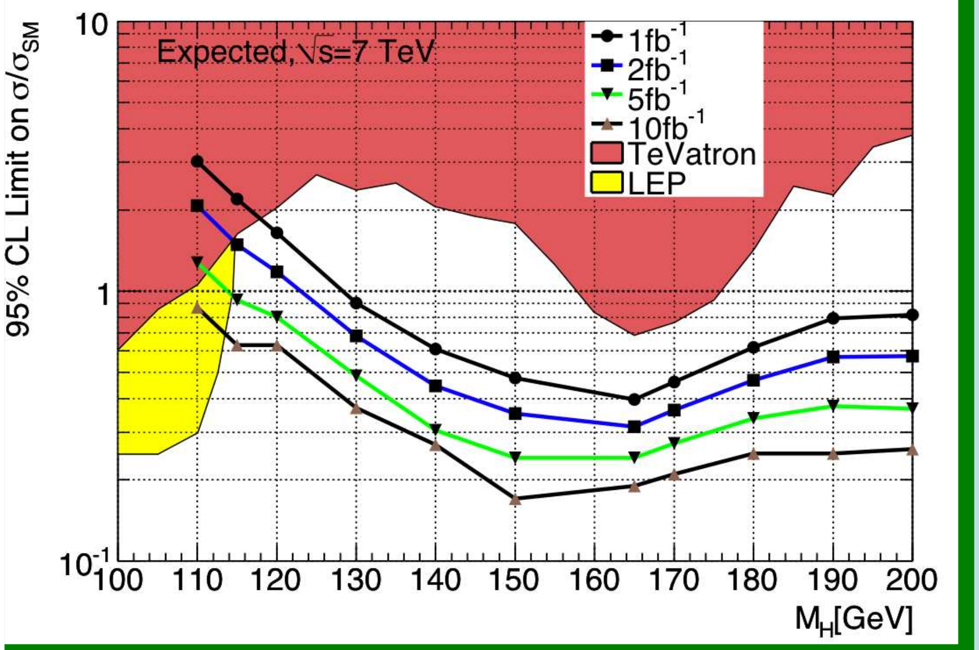
Higgs 2011/2012

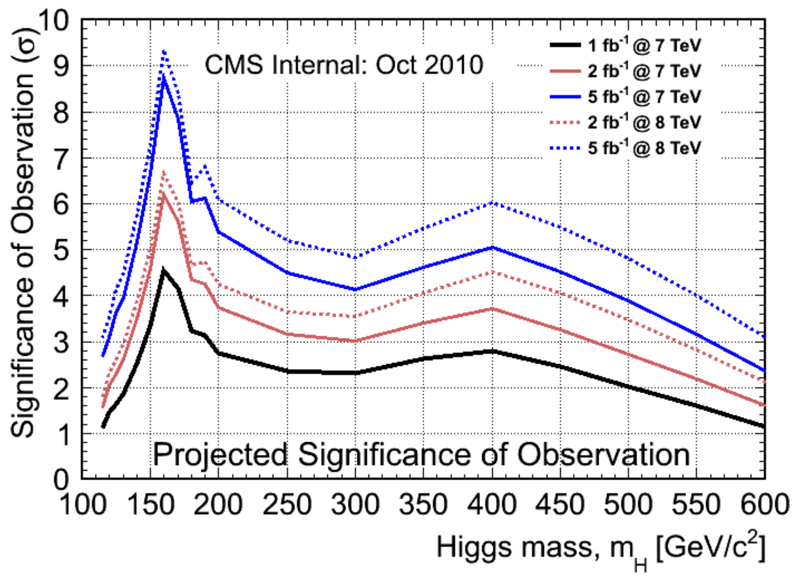
What do we know today ?

- Theory: m_H < 1 TeV
- Present experimental exclusion: m_H > 114.4 GeV (LEP),
  158 < m_H < 175 GeV (Tevatron)
- Favoured region (electroweak data → consistency of Standard Model):
  m_H < 158 GeV

→ 114.4-158 GeV is the "hottest" region (although higher masses cannot be excluded)

ATLAS and CMS internal and very preliminary





Higgs 2011/2012

If the Higgs is not there →
LHC needs **~2.5 fb^{-1} for exclusion** down to lowest masses

If the Higgs exists:

- Need **~5 fb^{-1} for 3σ evidence** around m_H ~ 115 GeV, but enough sensitivity at higher masses (above ~ 120 GeV) already with 1-3 fb^{-1}
- Discovery (5σ) over full allowed mass region requires ≤ 10 fb^{-1} at 8 TeV

LHC means ATLAS and CMS combined
(very preliminary)

Note on 8 TeV vs 7 TeV:
-- same reach with ~20% less luminosity
-- for same luminosity, extend low-mass reach down by ~ 3 GeV

LHC potential performance range

Goal: 1 fb^{-1}

- **Energy: 3.5 TeV to 4 TeV**
  To be discussed at the Chamonix workshop in Jan. 2011.
- **Bunch intensity**
  Baseline 1.2×10^{11} protons, higher possible from injectors.
- **Number of bunches**
  450 to 930 bunches (75 ns spacing): potential **factor 2**.
- **Colliding beam sizes**
  Maintain excellent beams from injectors: **50% smaller** than nominal
  Possible to “squeeze” beams further: another **50% gain**!
- **Peak luminosities in the range of 6 to 16 x 10^{32} cm^{-2}s^{-1} could be possible.**
  At least 3 times more than what we have seen in 2010!
- **Integrated luminosity between <u>1 and 3 fb^{-1}</u> would appear feasible.**

Higgs 2011/2012

- Accelerator Chain performed very well in 2010

- Detectors performed very well in 2010

- Headroom in accelerator performance

- Headroom in analysis performance

- Excellent prospects for Higgs-Boson Discovery or Exclusion in 2011/2012

Exciting Prospects: LHC running in 2011 and 2012
at $\sqrt{s}$ = 7 TeV (2011)

LHC results will allow
to study the Higgs mechanism in detail and
to reveal the character of the Higgs boson

This would be the first investigation
of a scalar field

This could be the very first step to
understanding Dark Energy


beyond LHC ?

Next decades

Road beyond Standard Model

through synergy of

hadron - hadr... (LHC, HL/HE-LHC?)

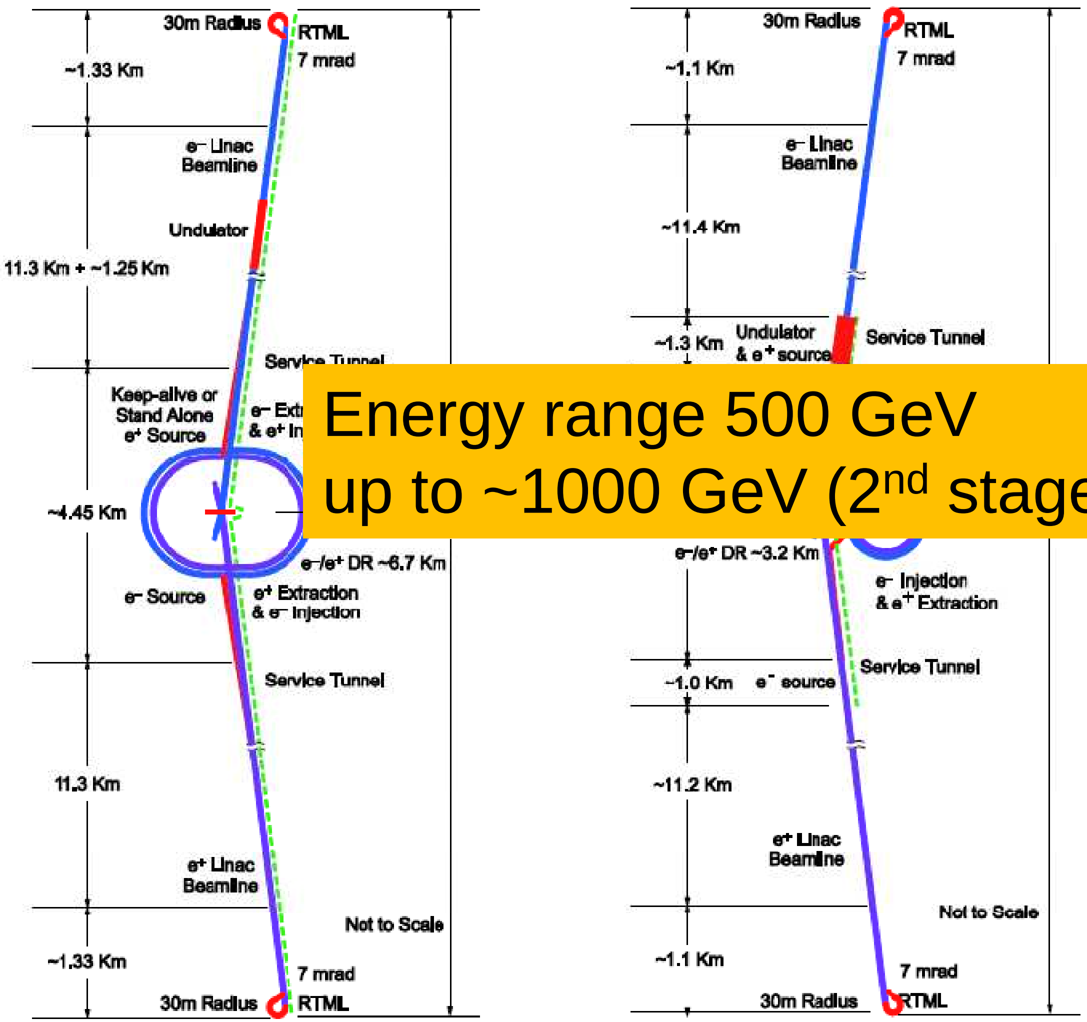
...**adron** **colliders** (LHeC ??)

lepton - lepton **colliders** (LC (ILC or CLIC) ?)

LHC results will guide the way at the energy frontier

Proposed Design changes for TDR

RDR **SB2009**



Energy range 500 GeV
up to ~1000 GeV (2nd stage)

- **Single Tunnel for main linac**
- **Move positron source to end of linac *****
- **Reduce number of ...ches factor of two ...er power) ****
- **Reduce size of damping rings (3.2km)**
- **Integrate central region**
- **Single stage bunch compressor**

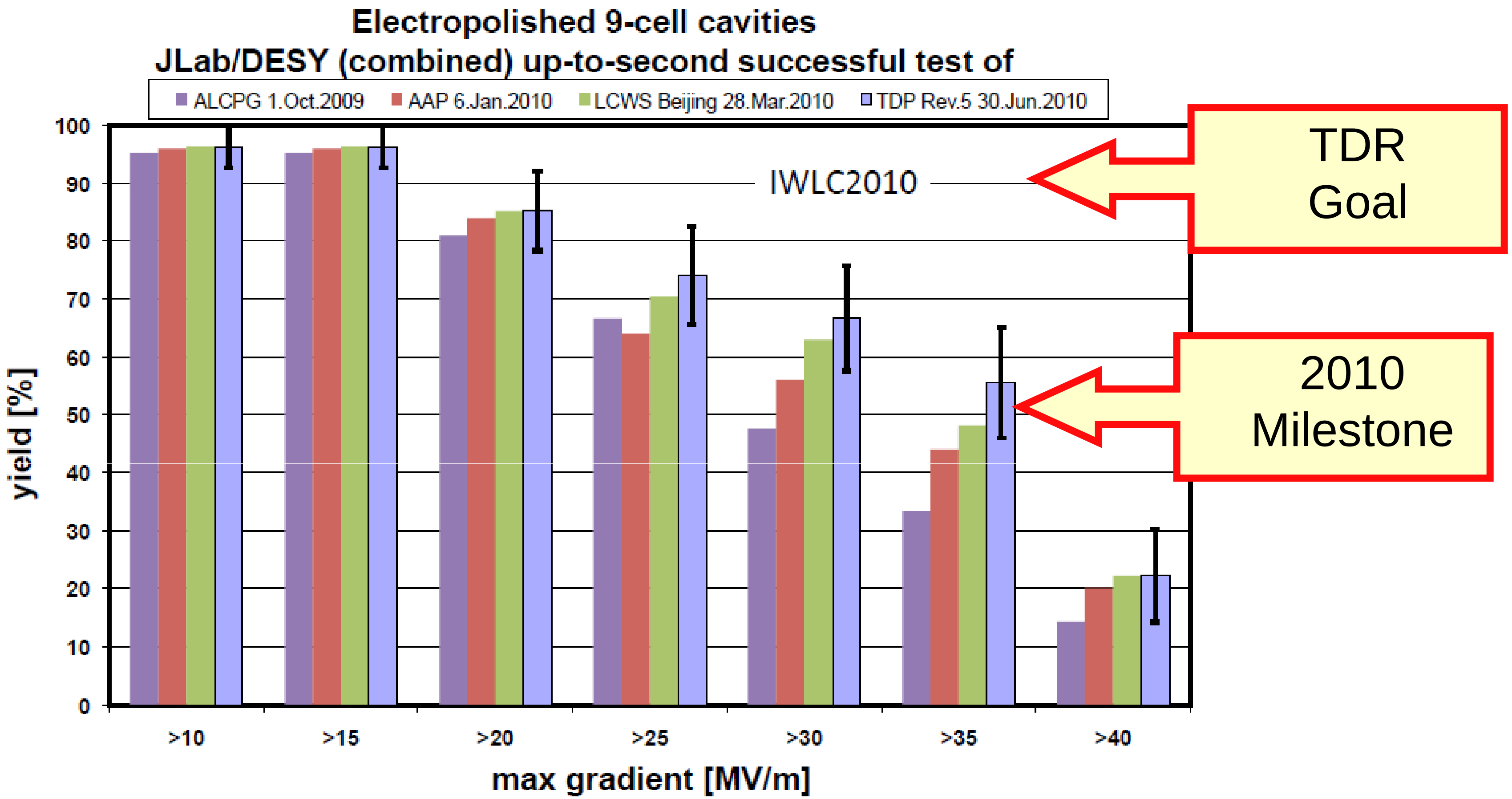
The ILC SCRF Cavity

Figure 1.2-1: A TESLA nine-cell 1.3 GHz superconducting niobium cavity.

- Achieve high gradient (35MV/m); develop multiple vendors; make cost effective, etc

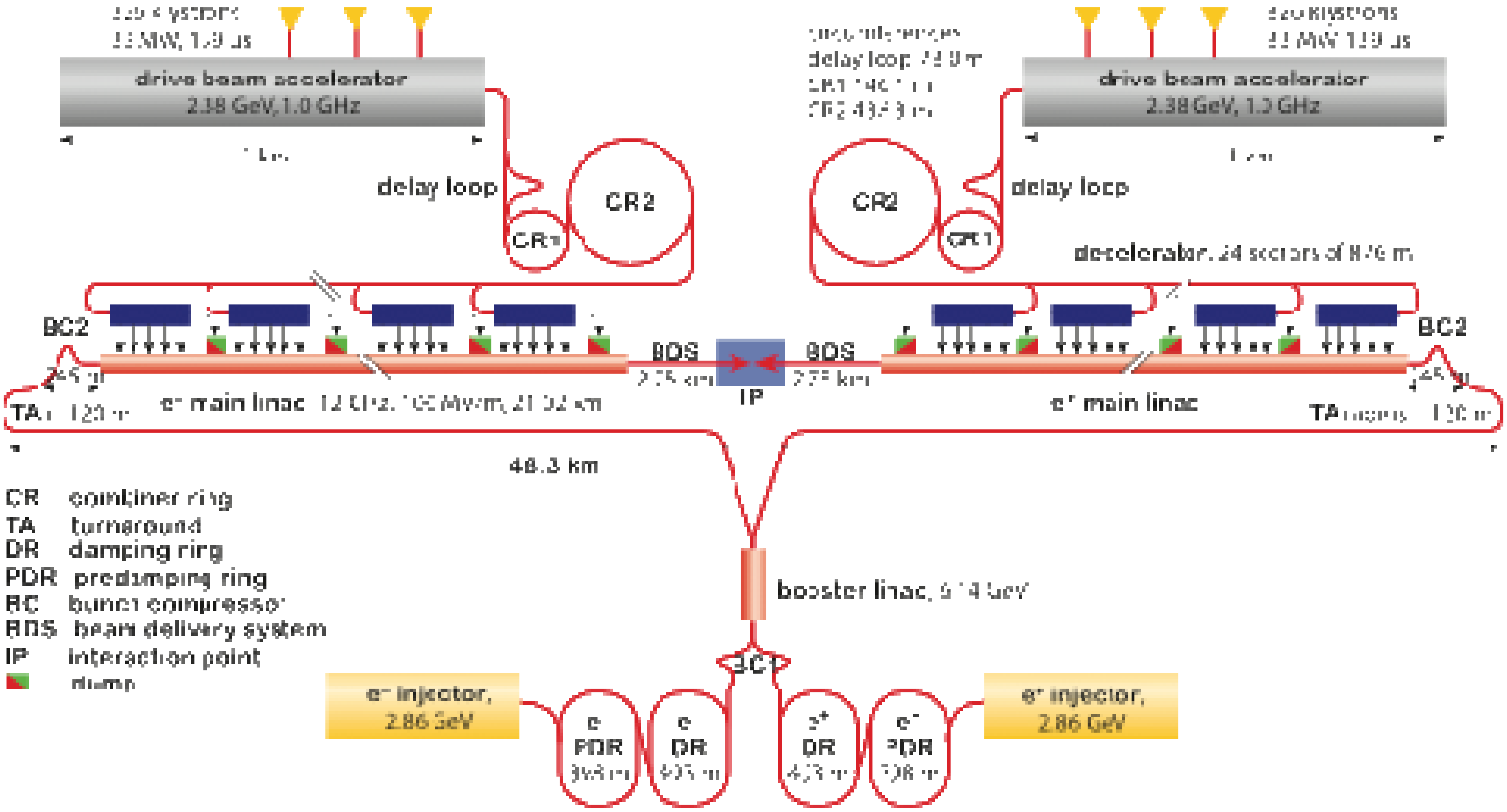
- Focus is on high gradient; production yields; cryogenic losses; radiation; system performance

Cavity Gradient Milestone Achieved

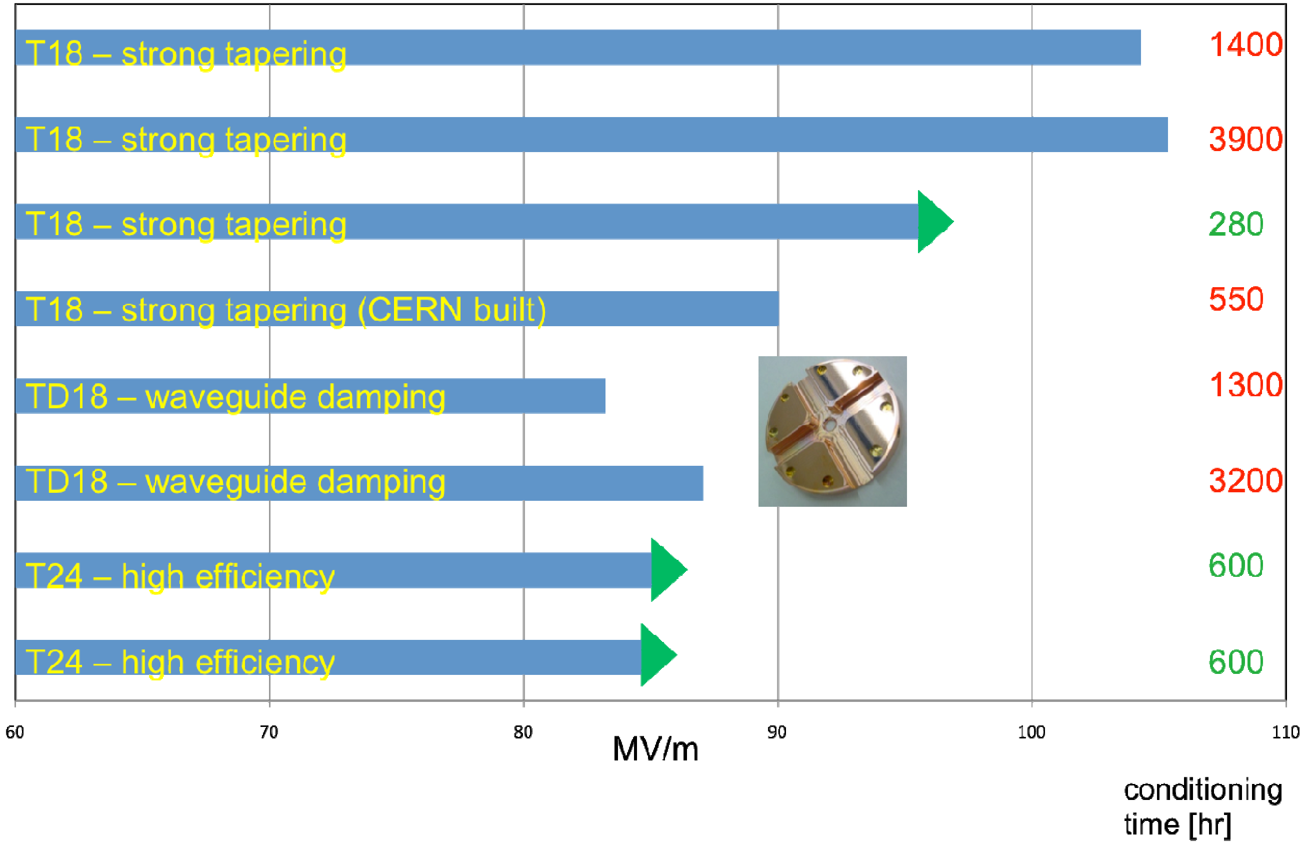


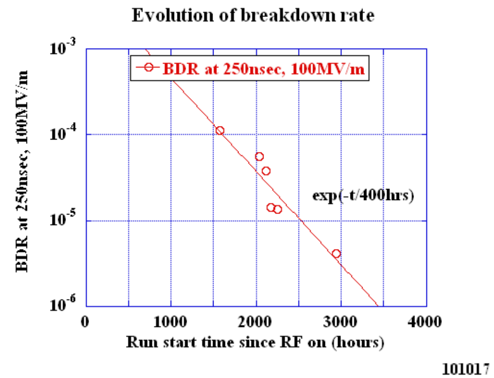
The CLIC Layout

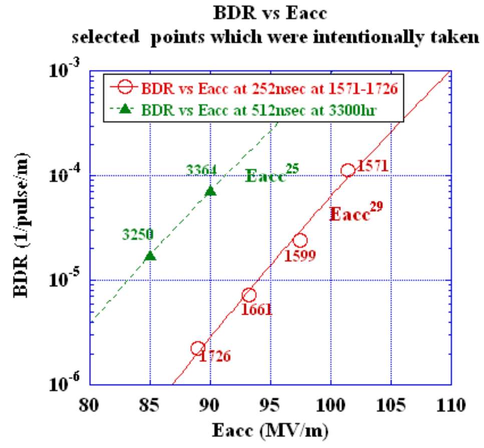
Energy range up to 3 TeV



Gradient at CLIC 4*10^{-7} BDR and 180 ns pulse length

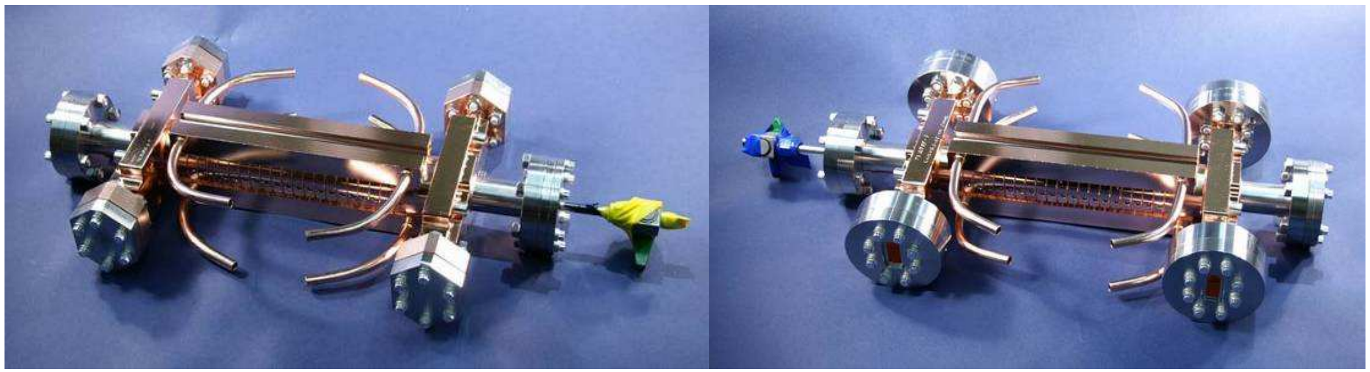




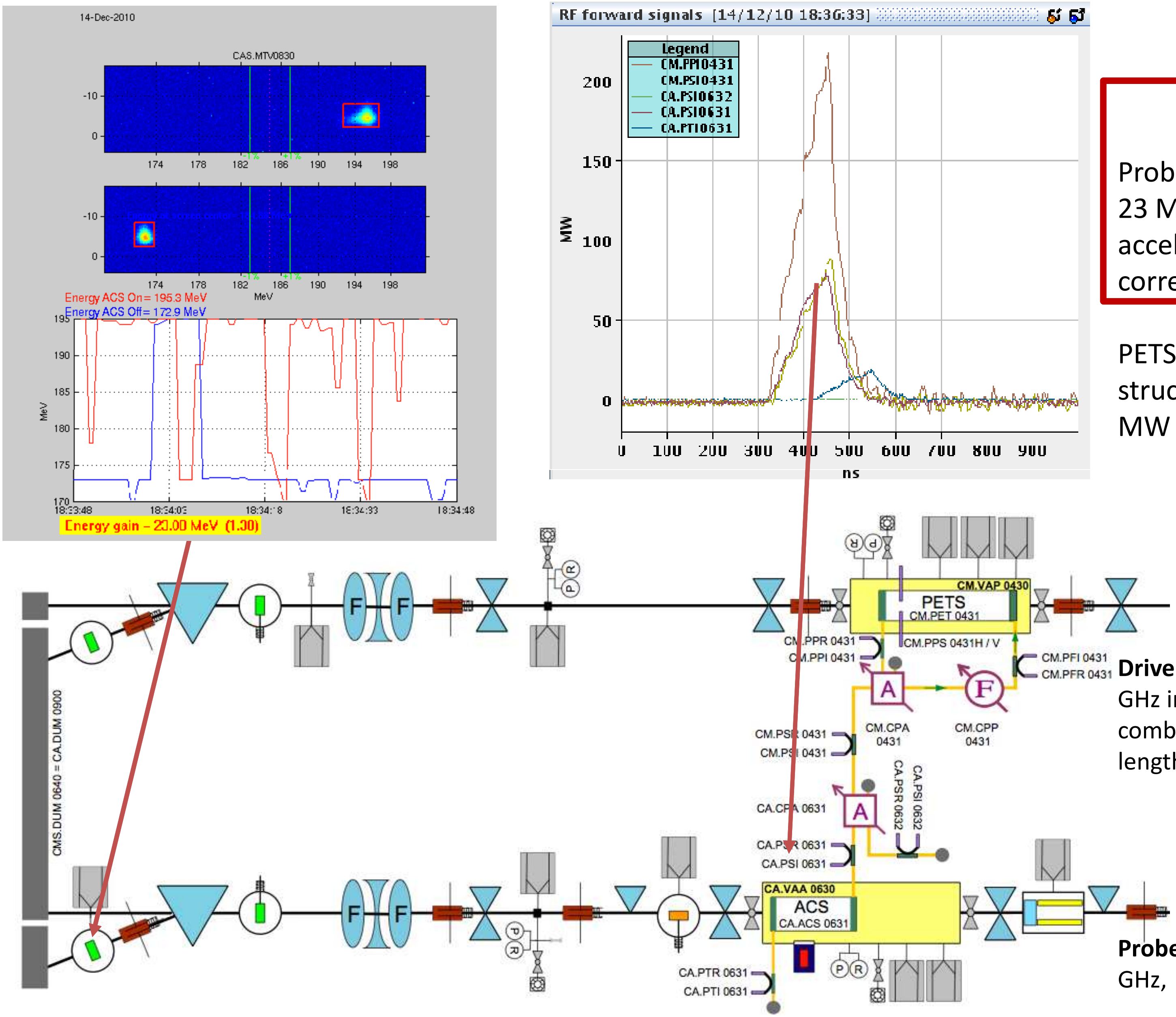


T18 and TD18 built and tested at SLAC and KEK

- real prototypes with improved design are T24 and TD24
- measurements in plot for TD18 at KEK



Two-beam acceleration with a gradient of 106 MV/m



December 14, 2010:

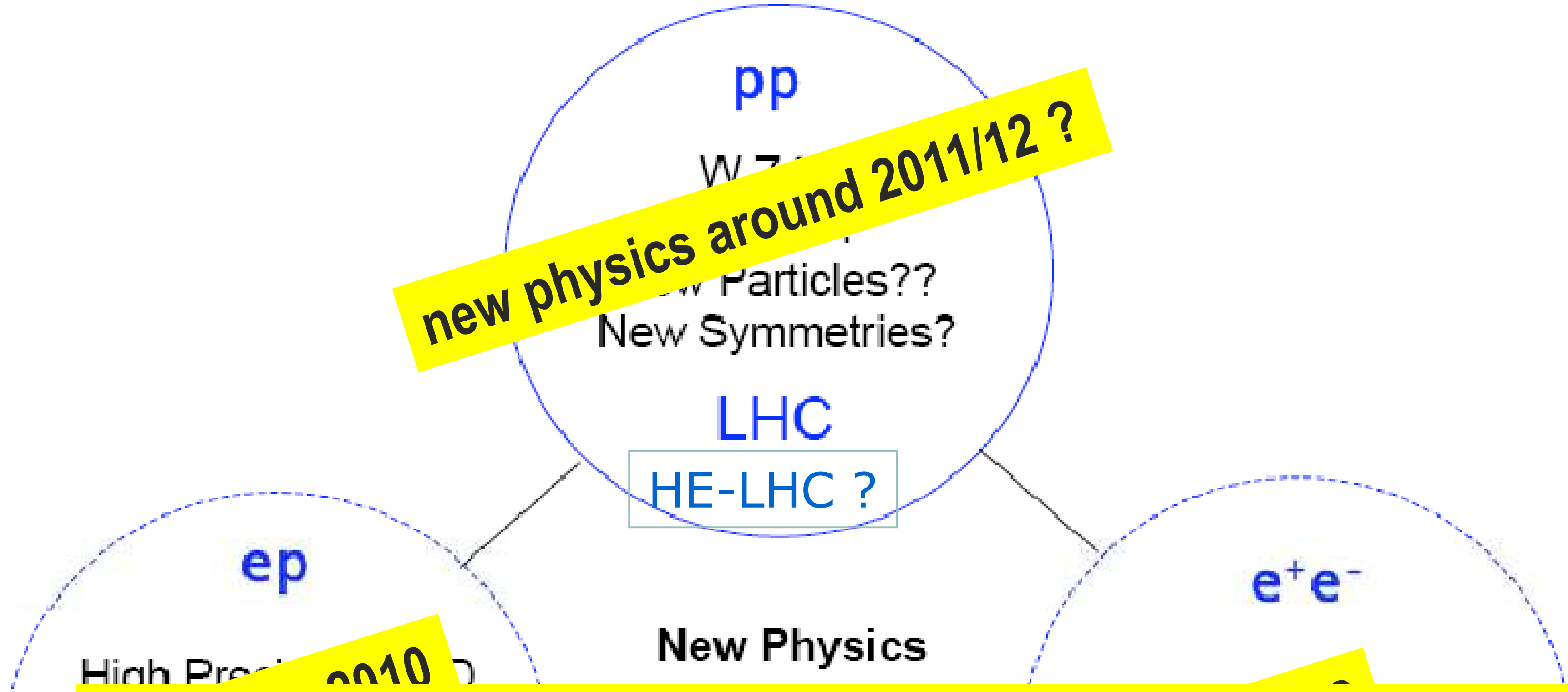
Probe beam accelerated by 23 MV in a TD24 accelerating structure, corresponding to 106 MV/m

PETS power input to structure ~ 80 MW (~200 MW in the resonant loop)

Drive beam: 12.5 A, 113 MV, 12 GHz in CLEX (1.5 GHz beam combined factor 8), 140 ns pulse length

Probe beam: 0.08 A, 173 MV, 1.5 GHz, 8 ns pulse length

The TeV Scale (far) beyond 2010



Great opportunities ahead at the TeV scale

first window of opportunity for enabling decision on the way forward around 2012 (?)

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)

→ more coordination and more collaboration required

Opening the door… 2010

Council opened the door to greater integration in particle physics when it unanimously adopted the recommendations to examine the role of CERN in the light of increasing globalization in particle physics.

The key points agreed by Council include:

- *All states shall be eligible for Membership, irrespective of their geographical location;*
- *A new Associate Membership status has been introduced to allow non-Member States to establish or intensify their institutional links with CERN;*
- *Participation of CERN in global projects wherever sited.*

Romania **is Candidate for Accession to Membership since 2010.**

Negotiations with ***Cyprus, Israel, Serbia, Slovenia and Turkey*** **applying for Membership are starting.**

Brazil **is applying for Associate Membership.**

We need to define the most appropriate organizational form for global projects 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