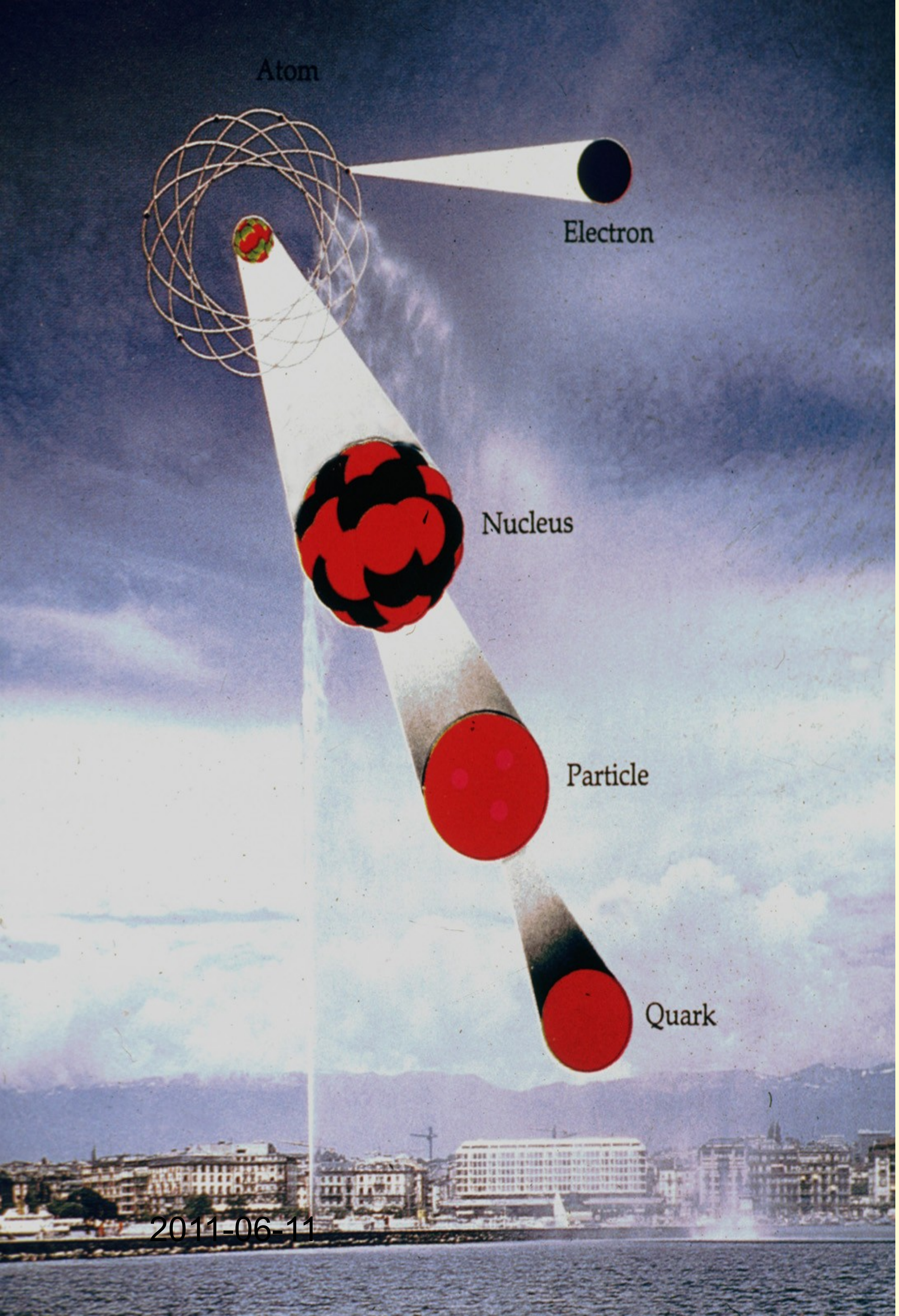
ATLAS for everybody

Celebrating Anna’s half century

2011-06-11



The structure of matter

Electron (-1)

1897 Thomson (Nobel prize 1906)

Atomic nucleus 1911 Rutherford (Nobel prize chemistry 1908!)

Proton +1 1919 Rutherford

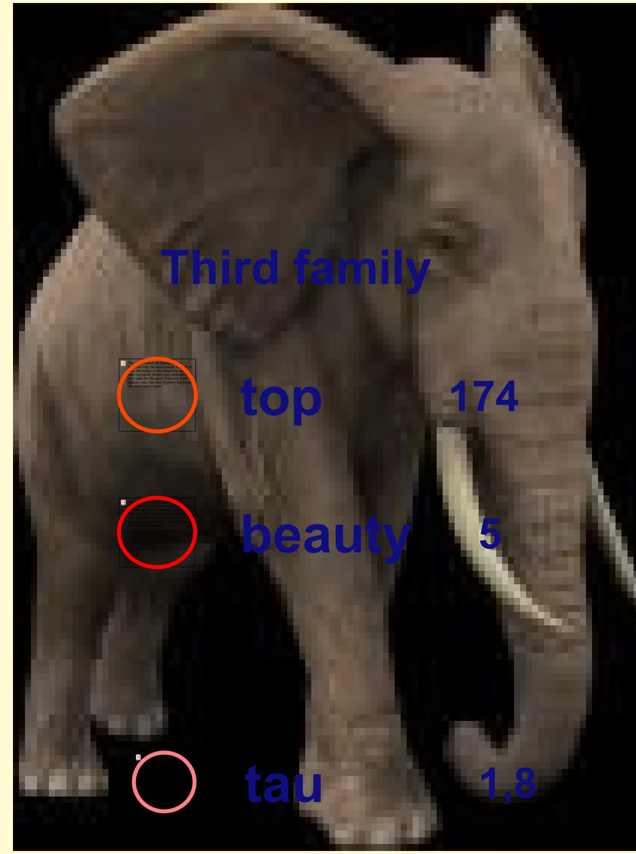
Neutron 0 1932 Chadwick (Nobel prize 1935)

”1964” Gell-Mann (prize 1969)

ca 1970 Friedman, Kendall, Taylor (Nobel prize 1990)

1974 Richter, Ting (prize 1976)

The smallest building blocks
à là Standard Model



	First family		Second family		Third family	
Quarks	**up**	**<1**	**charm**	**1,5**	**top**	**174**
	down	**<1**	**strange**	**<1**	**beauty**	**5**
Leptons	**electron**	**0.0005**	**muon**	**0.1**	**tau**	**1,8**
	e-neutrino		**m-neutrino**		**t-neutrino**	

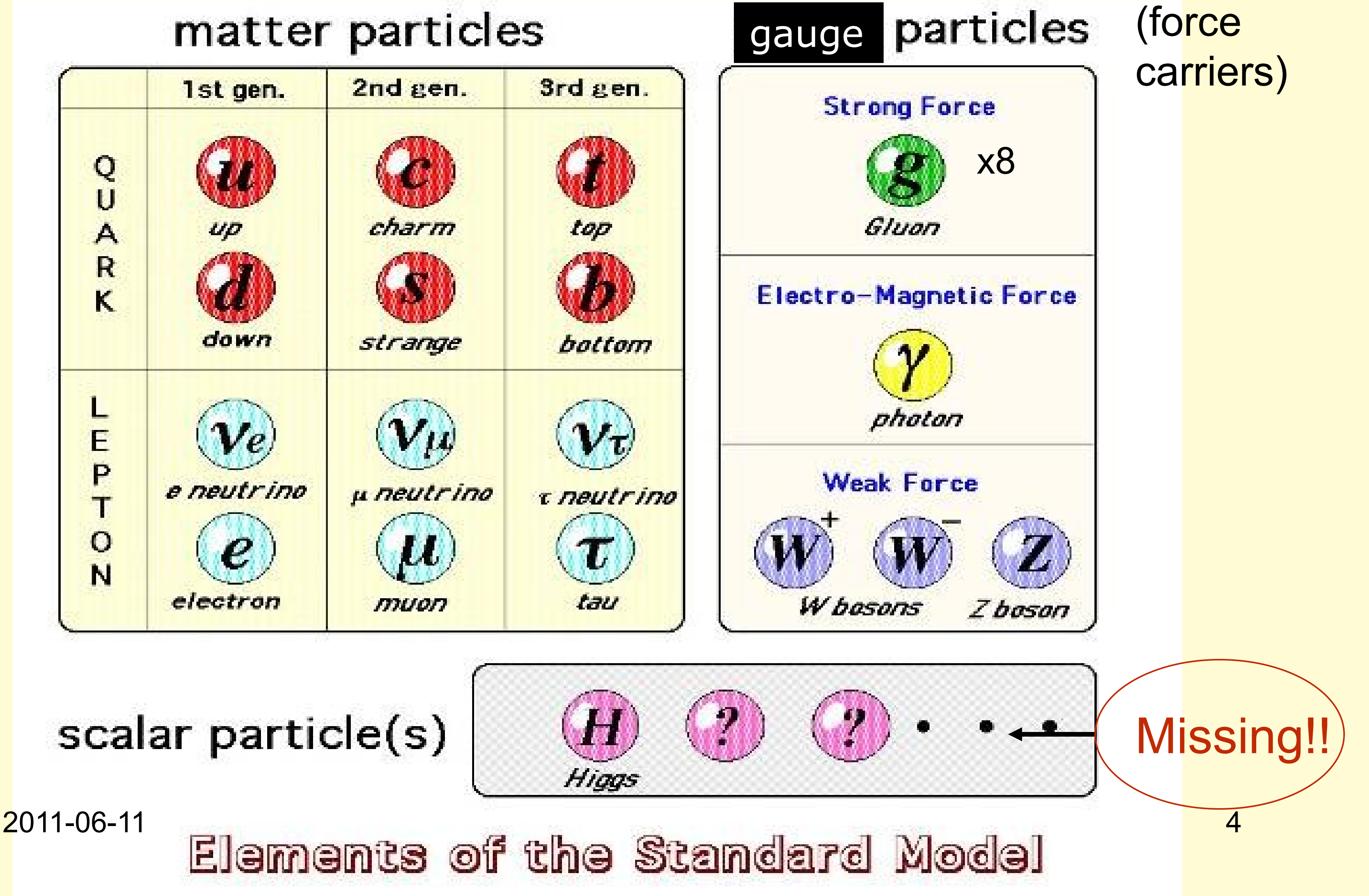
+ anti particles for all particles

The STANDARD MODEL

Spin 1/2

Spin 1

(force carriers)

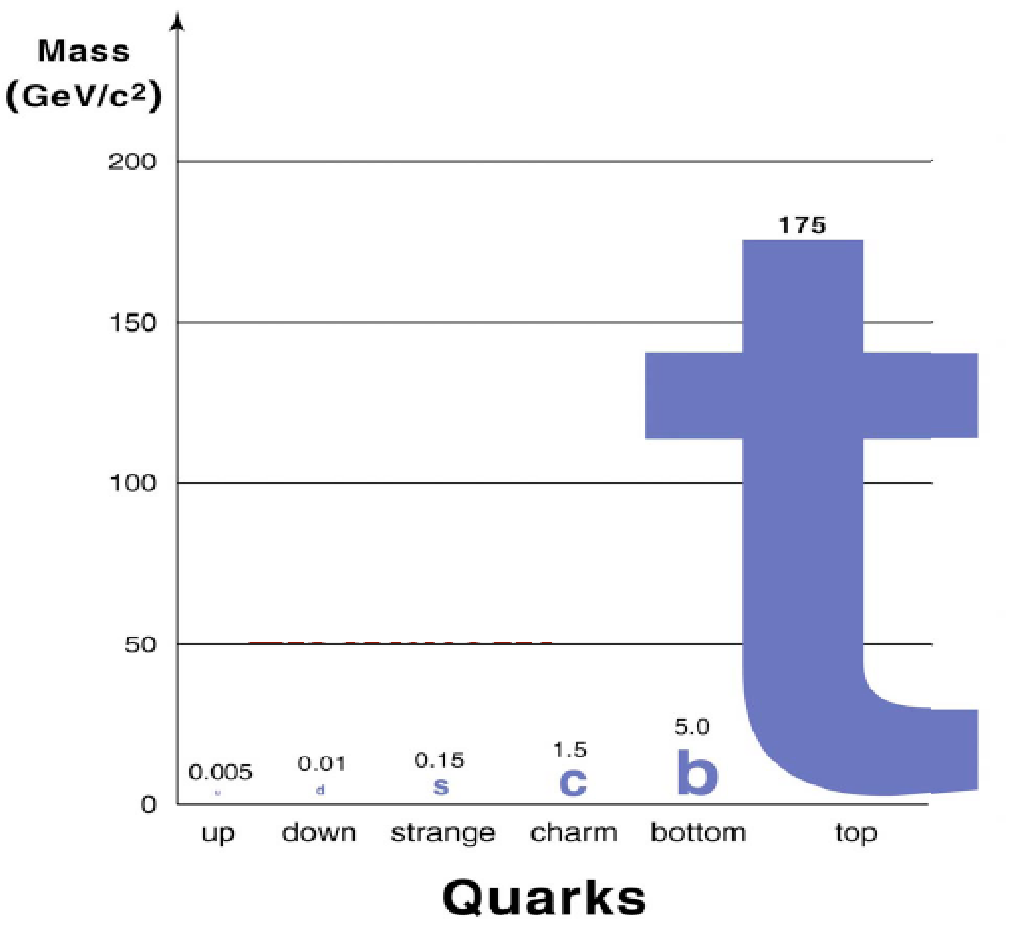


… and the need to go beyond - some of the fundamental questions yet to be answered

- Why do particles have mass? — Higgs?
- What is the dark matter of the Universe? — Can Supersymmetry be a solution?
- Gravity? Not included in the Standard Model. — What about string theory? Extra dimensions?
- Why is there only matter in the Universe? — Origin of matter – antimatter asymmetry?

A most basic question is why particles (and matter) have masses (and so different masses)

The mass mystery could be solved with the 'Higgs mechanism' which predicts the existence of a new elementary particle, the 'Higgs' particle (theory 1964, P. Higgs, R. Brout and F. Englert)



Peter Higgs

• The unification of the electromagnetic and weak forces in the Standard Model requires mathematically that the force carriers, the photon, the W and Z bosons are mass less.

• But we know that the masses of W and Z are around 80 and 90 GeV respectively!

• P Higgs, R Brout, F Englert proposed the Higgs mechanism.

•They proposed that all particles were massless just after the Big Bang.

• When the Universe was cooled down a field was released, the Higgs field, with a corresponding particle, the Higgs boson.

• The field exists in the whole Universe and particles interacting with it get mass. Stronger interaction gives higher mass.

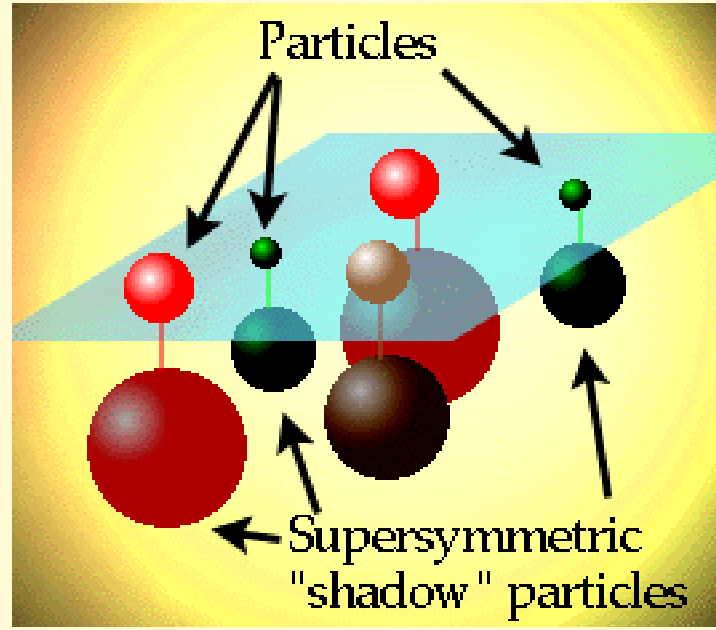
The Higgs particle has been looked for at several accelerators but up to now it has not been found…
LHC has enough energy to produce it if it exists…

Supersymmetry (SUSY)

Establishes a symmetry between
matter particles (fermions, quarks and leptons)
and force carriers (bosons):

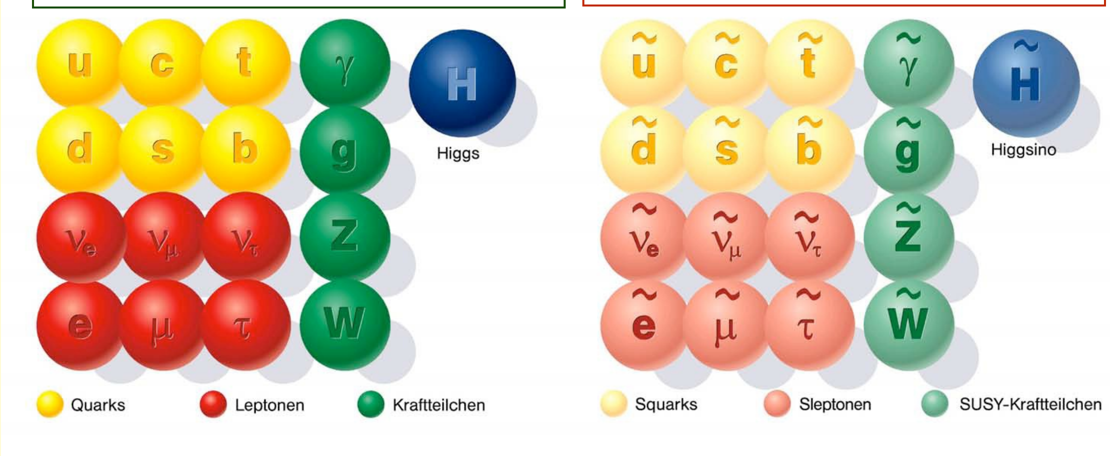
Examples:

quark q (s=1/2)	↔	$\tilde{q}$ (s=0)	squark
gluon g (s=1)	↔	$\tilde{g}$ (s=1/2)	gluino



Our known world with standard particles

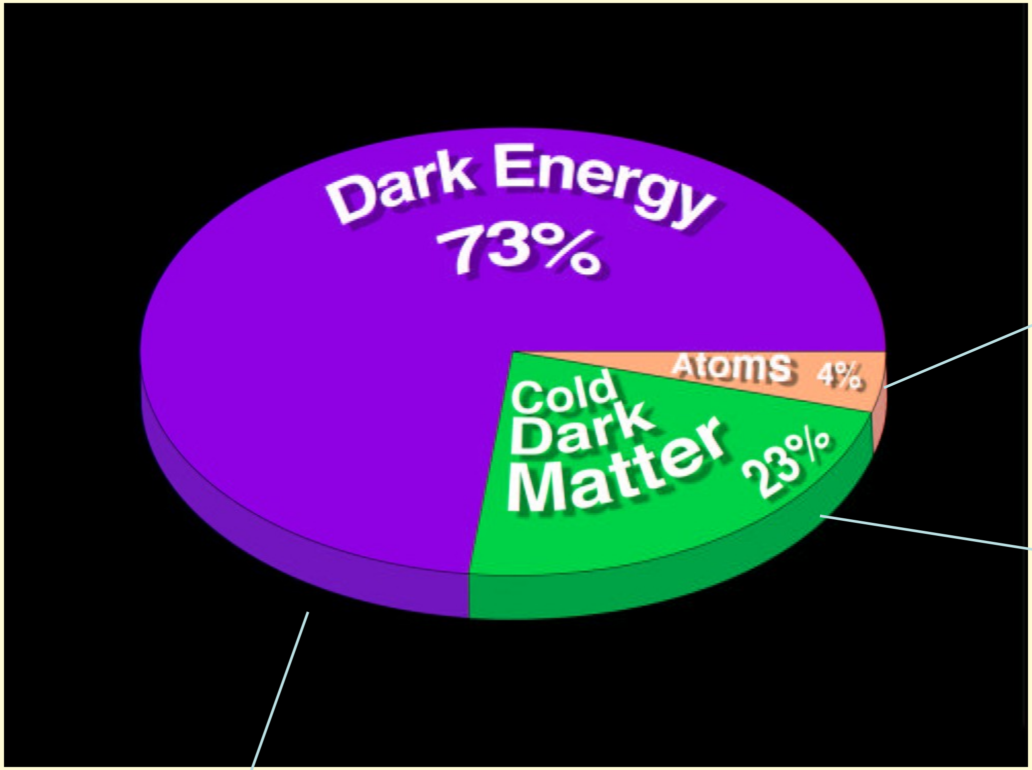
Maybe a new world with SUSY particles?

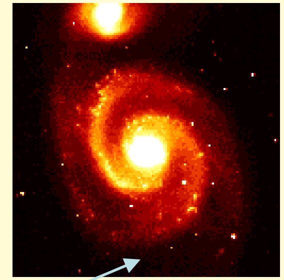


Motivation:

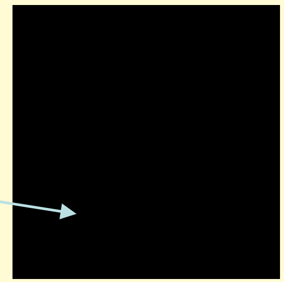
- Unification (fermions-bosons, matter-forces)
- Offers a candidate Dark Matter particle
- Solves some deep problems of the Standard Model

Today's picture of the Universe





• Atoms – "ordinary" matter - ca 4%. Described by the **Standard Model**.



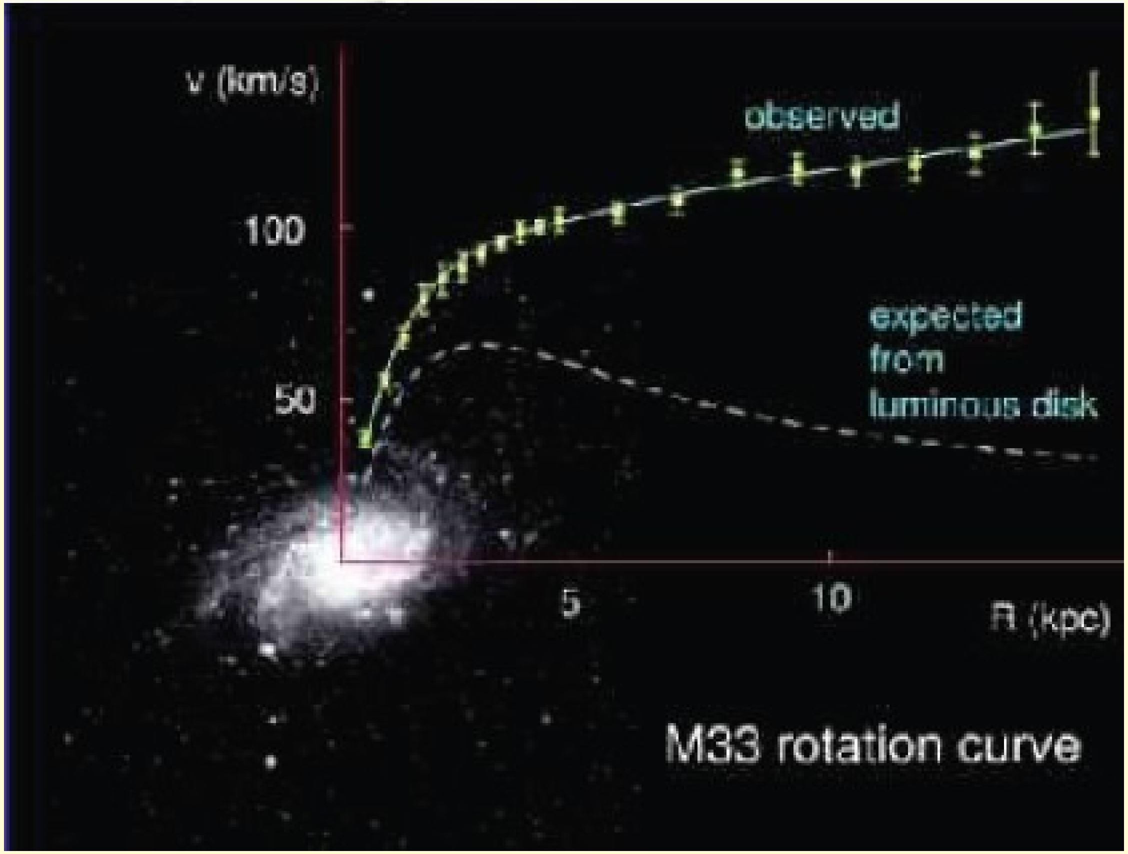
• **Dark Matter** - ca 23%. We don't know what it is!**Supersymmetry??**

• Dark Energy – Completely unknown form of energy which is responsible for the accelerating expansion of the Universe.

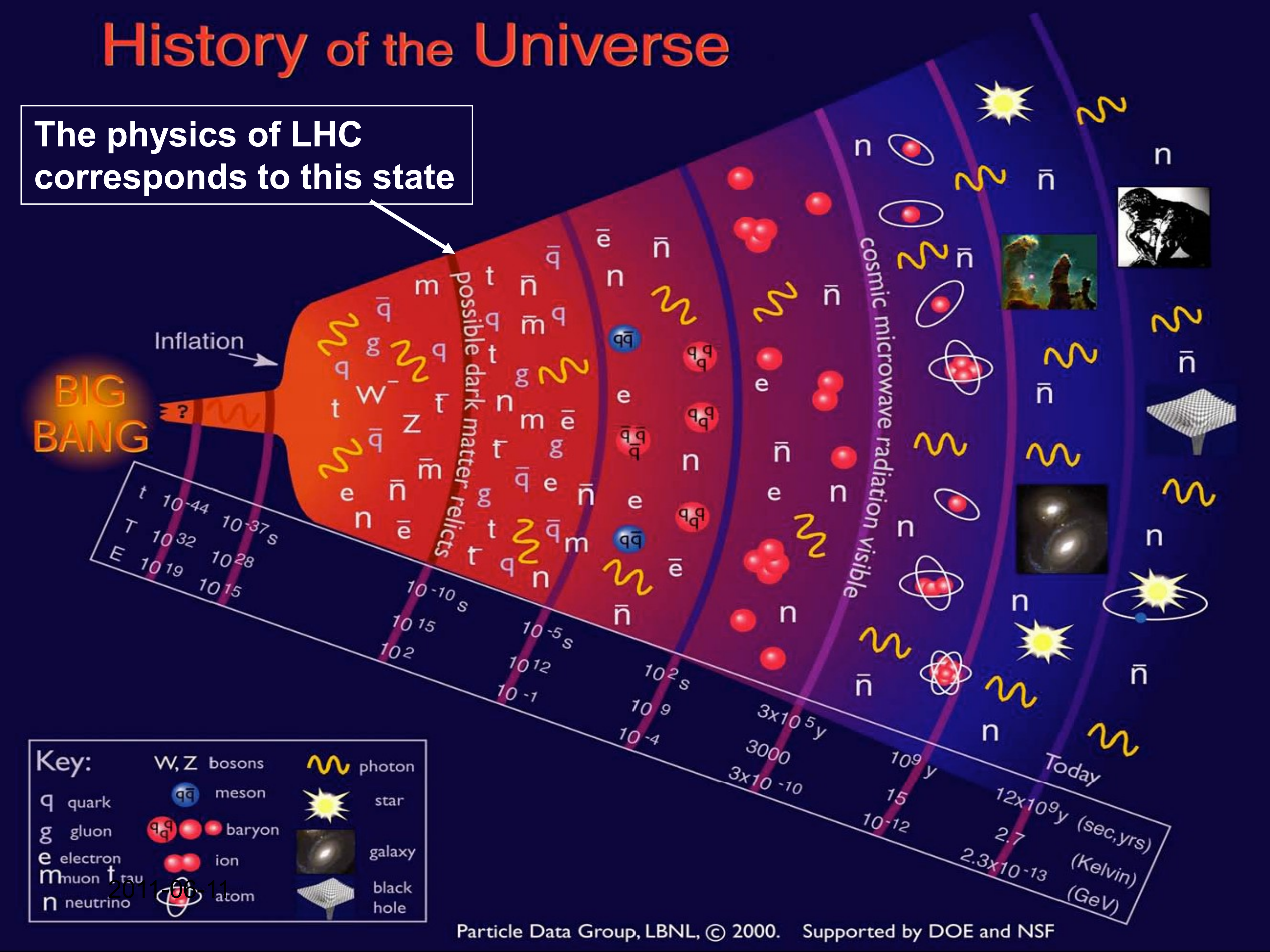
If **Supersymmetry** exists, the Lightest Supersymmetric Particle (rather heavy…) may be stable and be the **Dark Matter Particle**.
We look for it at the LHC!!

Dark Matter in the Universe

Vera Rubin made the first systematic study of rotation curves of spiral galaxies in 1970



Surprising resultat:
Most of the matter of galaxies (90%) is dark, it doesn't emit light.


History of the Universe
The physics of LHC corresponds to this state
BIG BANG
Inflation
possible dark matter relicts
cosmic microwave radiation visible
t 10-44 10-37 s
T 1032 1028
E 1019 1015
10-10 s
1015
102
10-5 s
1012
10-1
102 s
109
10-4
3x105 y
3000
3x10-10
109 y
15
10-12
Today
12x109 y (sec,yrs)
2.7 (Kelvin)
2.3x10-13 (GeV)
Key:
q quark
g gluon
e electron
m muon
t tau
n neutrino
W, Z bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
Particle Data Group, LBNL, © 2000. Supported by DOE and NSF
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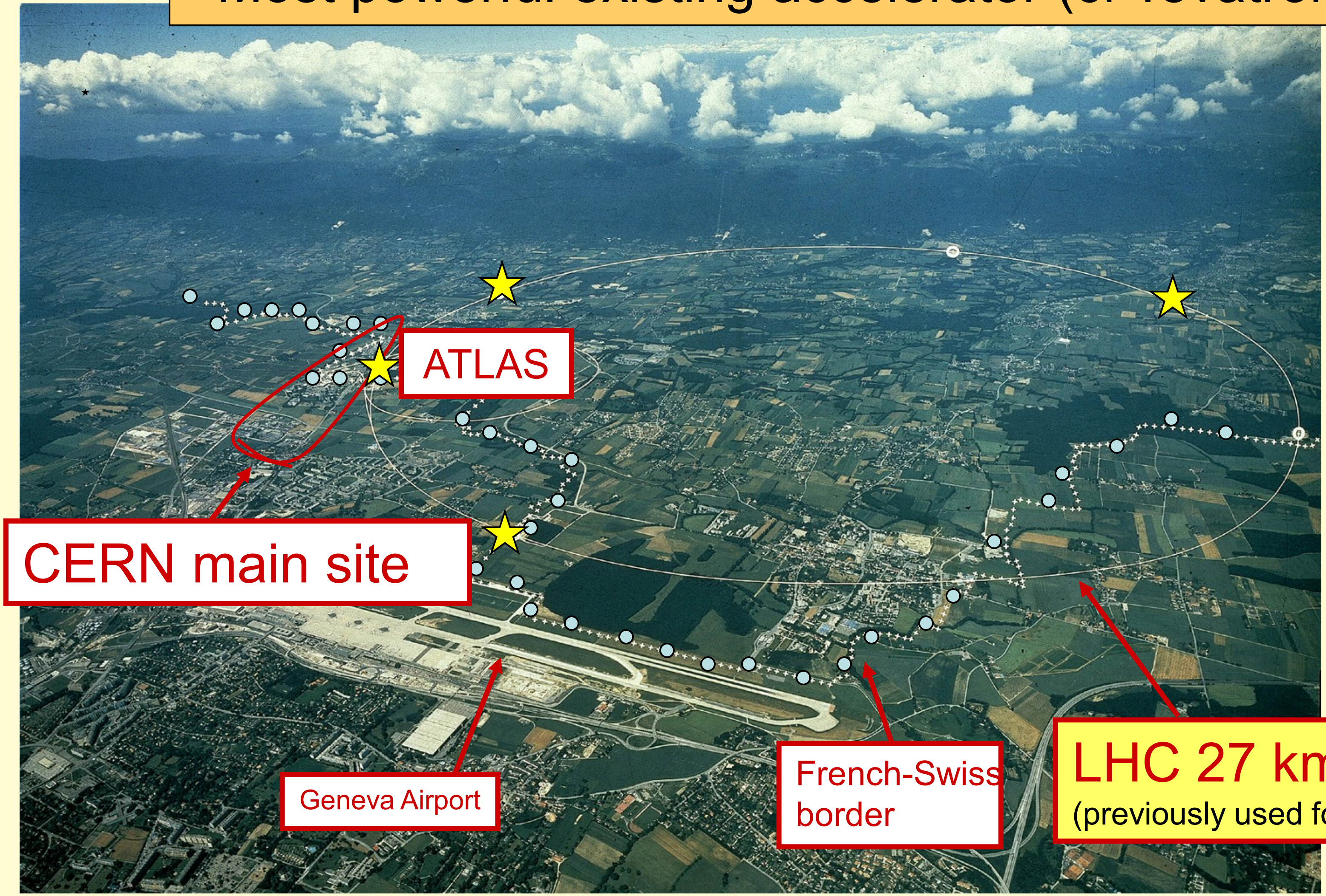
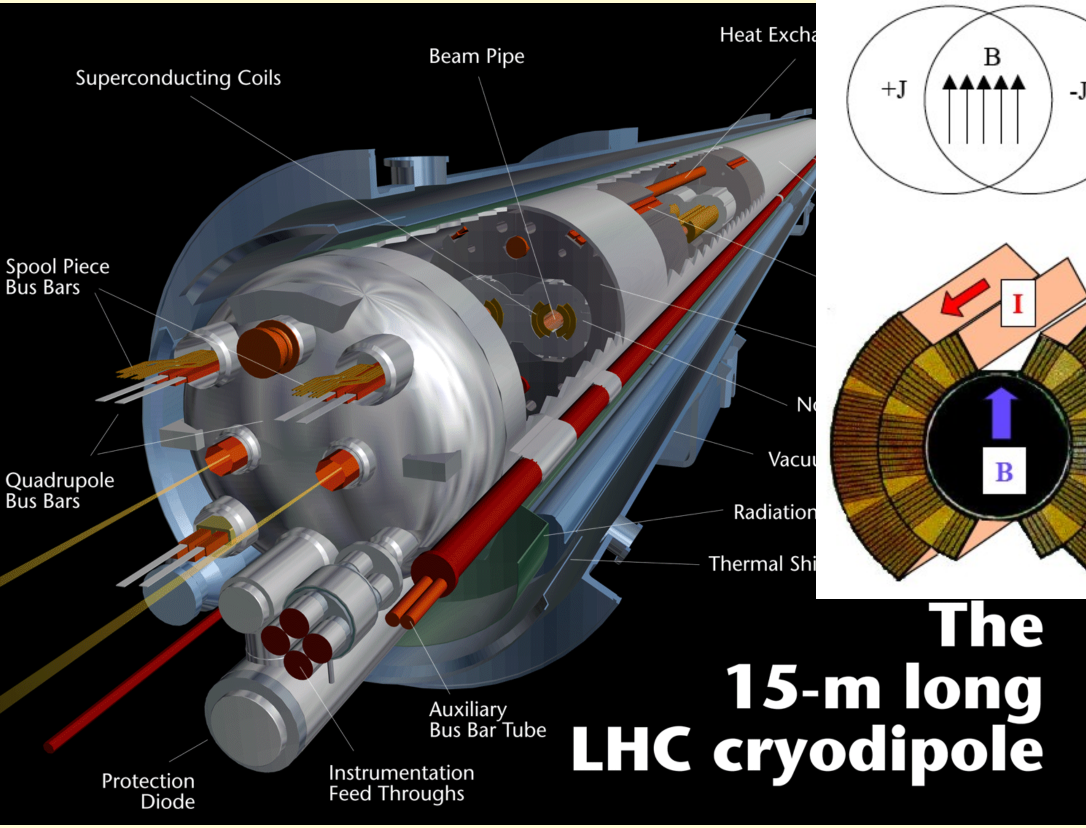
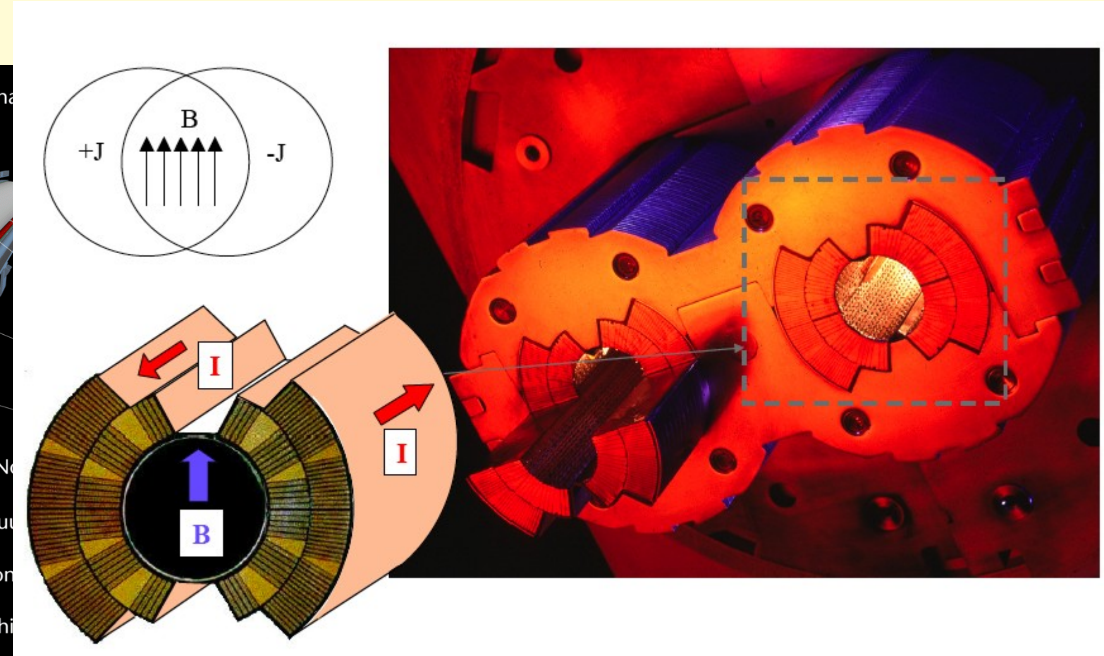
LHC

Proton – proton collisions at a centre-of-mass energy of
7 TeV (2010 – 2012)
14 TeV (2014 – 2030?)
Most powerful existing accelerator (cf Tevatron 2 TeV)



LHC Accelerator Challenge: Dipole Magnets





1232 dipol magnets
à 35 ton around LHC

Magnetic field needed to make the protons stay in their orbit: 8.4 Tesla

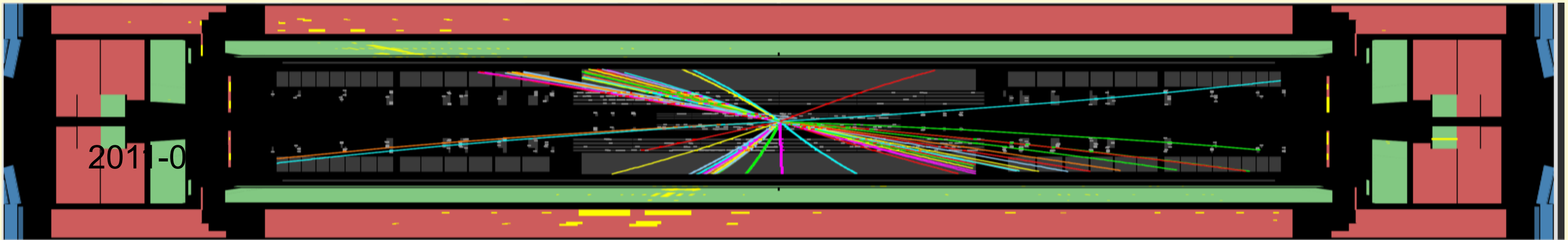
Current in the superconductive magnets: 12 kA

The LHC magnets are cooled with superfluid helium

Coolest Place in the Universe? 1,9 K ……

Proton beams in the LHC

- 10 September 2008: Proton beams circulated around LHC for the first time, in both directions!!
- 19 September 2008: LHC suffered from an incident. A faulty electrical connection between two magnets caused a catastrophic He-release that damaged several magnets. and had to be repaired
- 20 November 2009: LHC was running again and we had proton collisions at 900 GeV a few days later
- ***30 March 2010: The first collisions at the world record energy, 7 TeV***
- 2010 – 2012: Long run at 7 TeV. We get lots of collisions…
- 2013-14: Upgrade of the LHC energy to 14 TeV
- 2014 - … : Collision energy of 14 TeV
- LHC will most likely run for 20 years

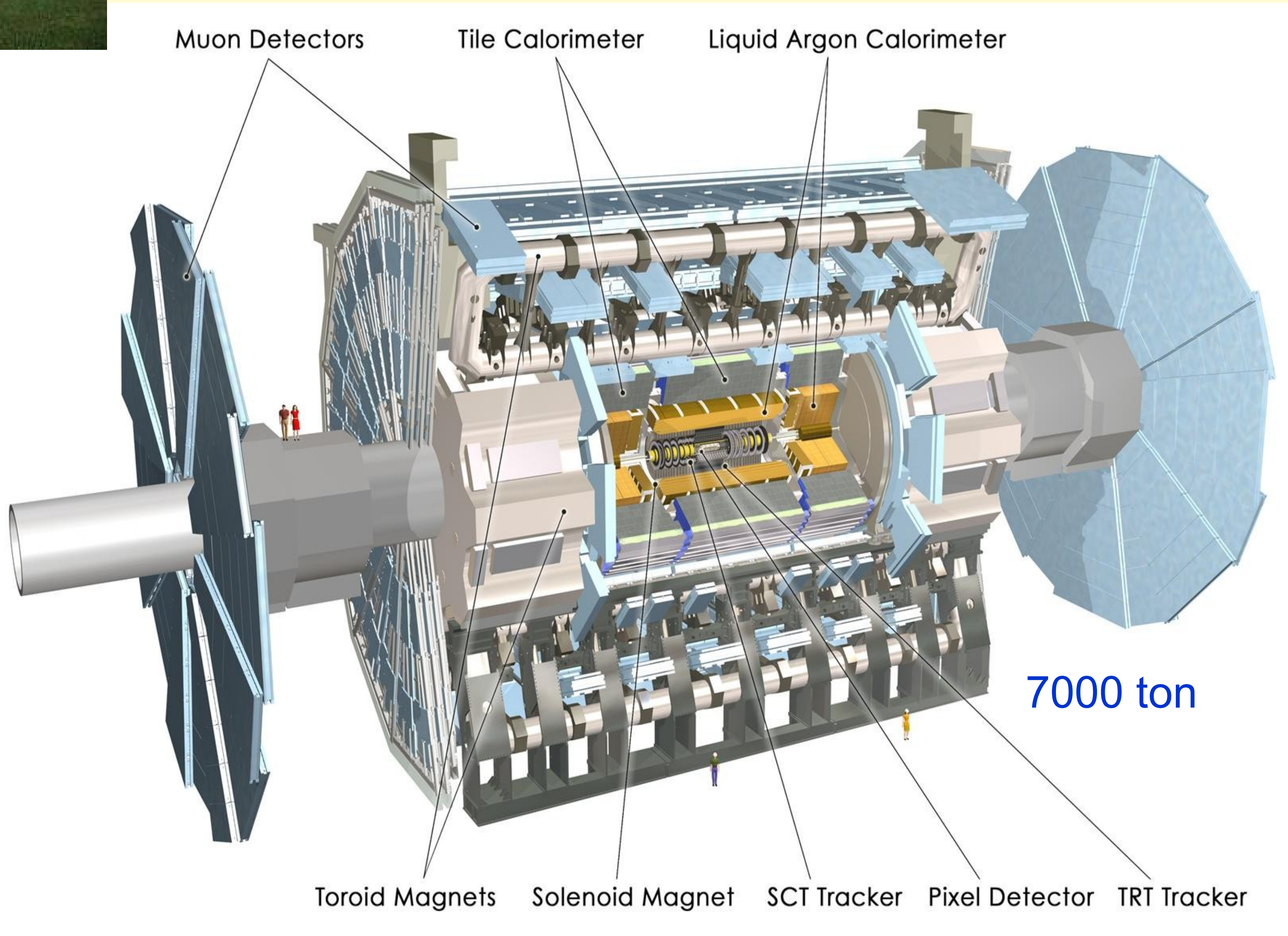


The ATLAS detector

ATLAS picture superimposed to a photo of building 40 at CERN

45 m

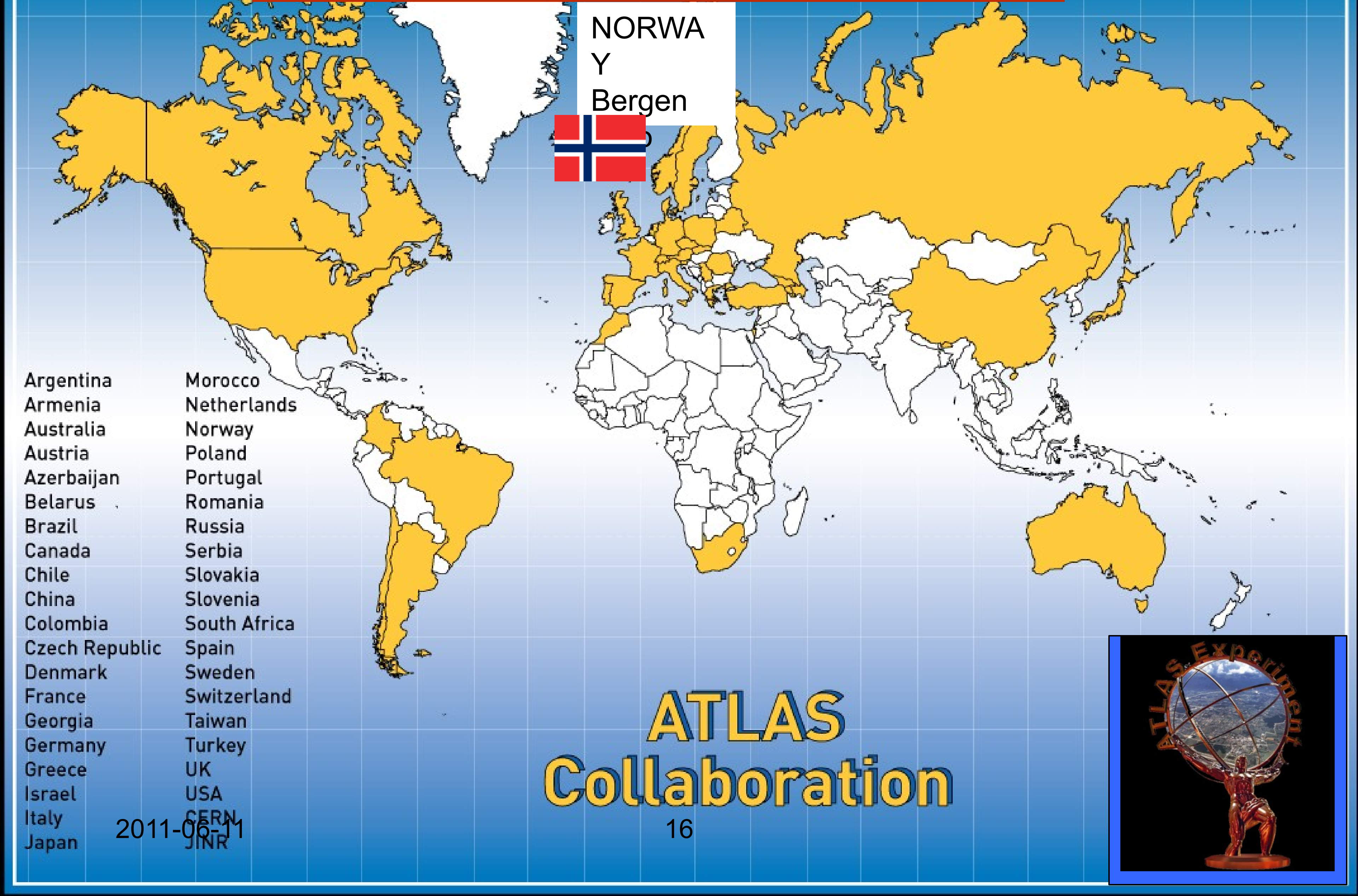
24 m

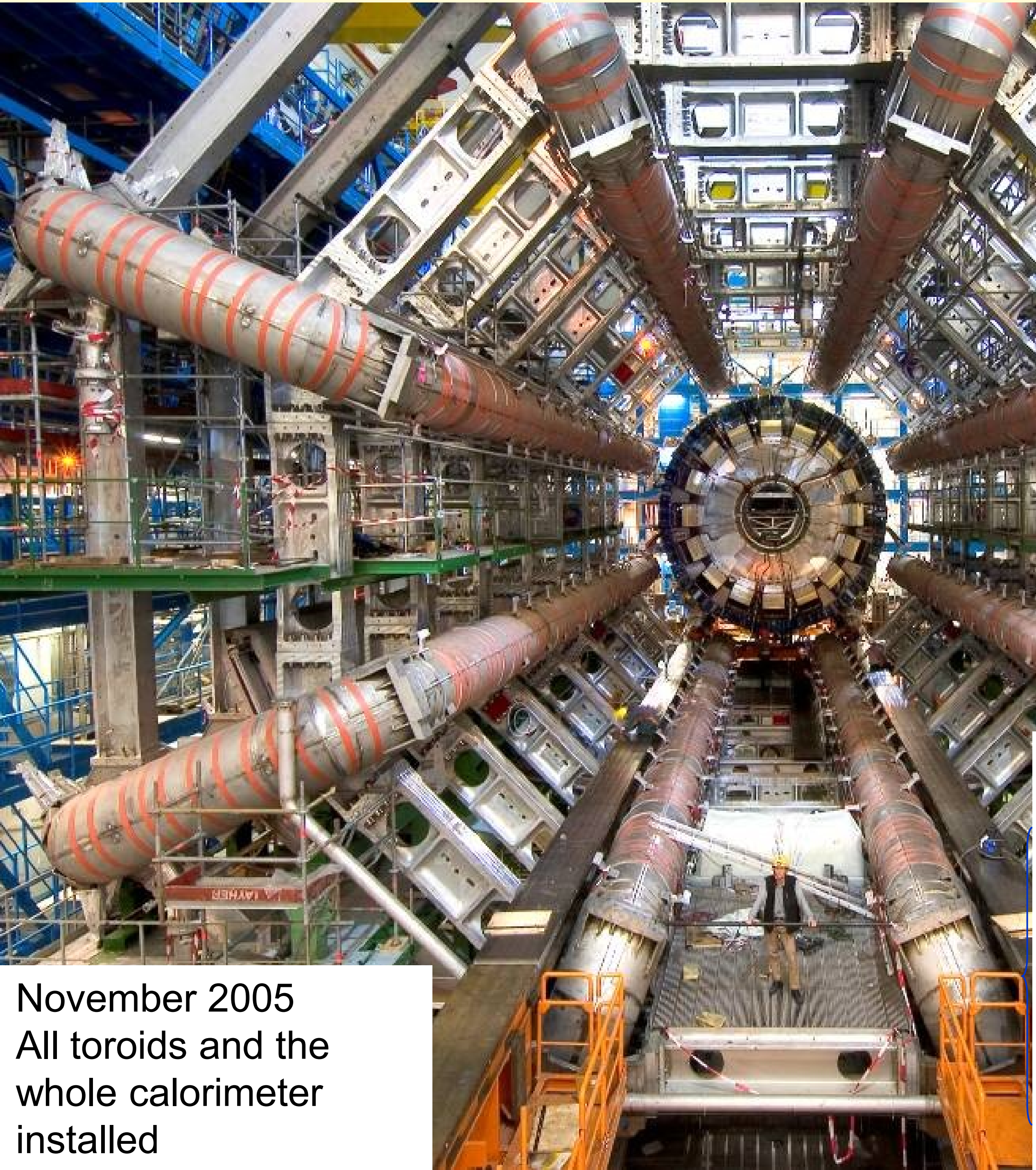


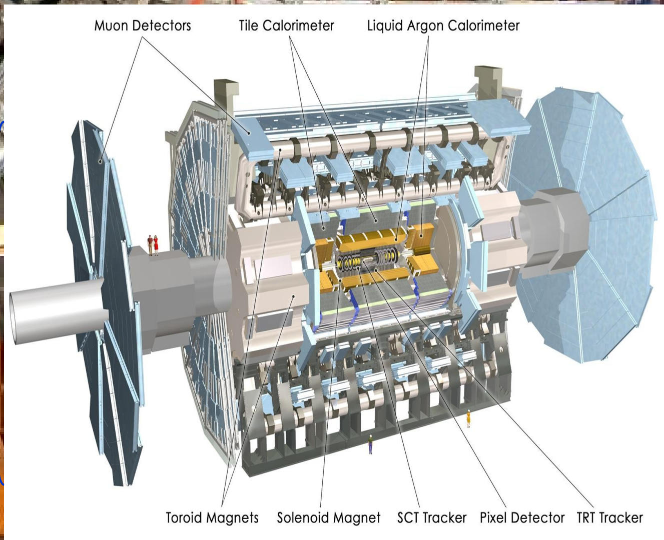
7000 ton

2011-06-11

~3000 scientists from 174 Institutions and 38 Countries



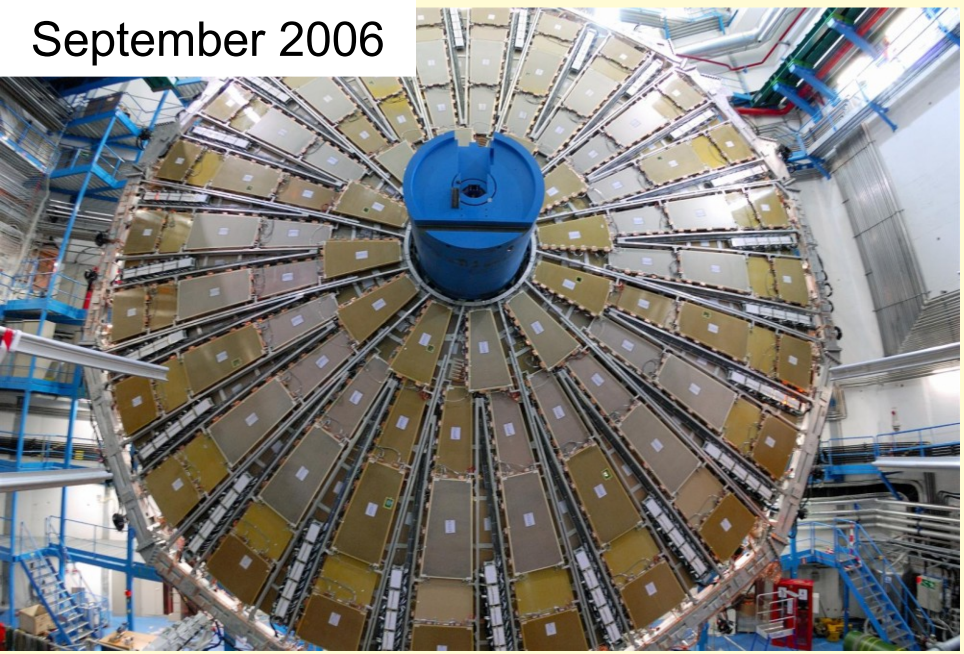




November 2005
All toroids and the whole calorimeter installed

Installation of the end cap muon chambers – the big and small wheels

September 2006

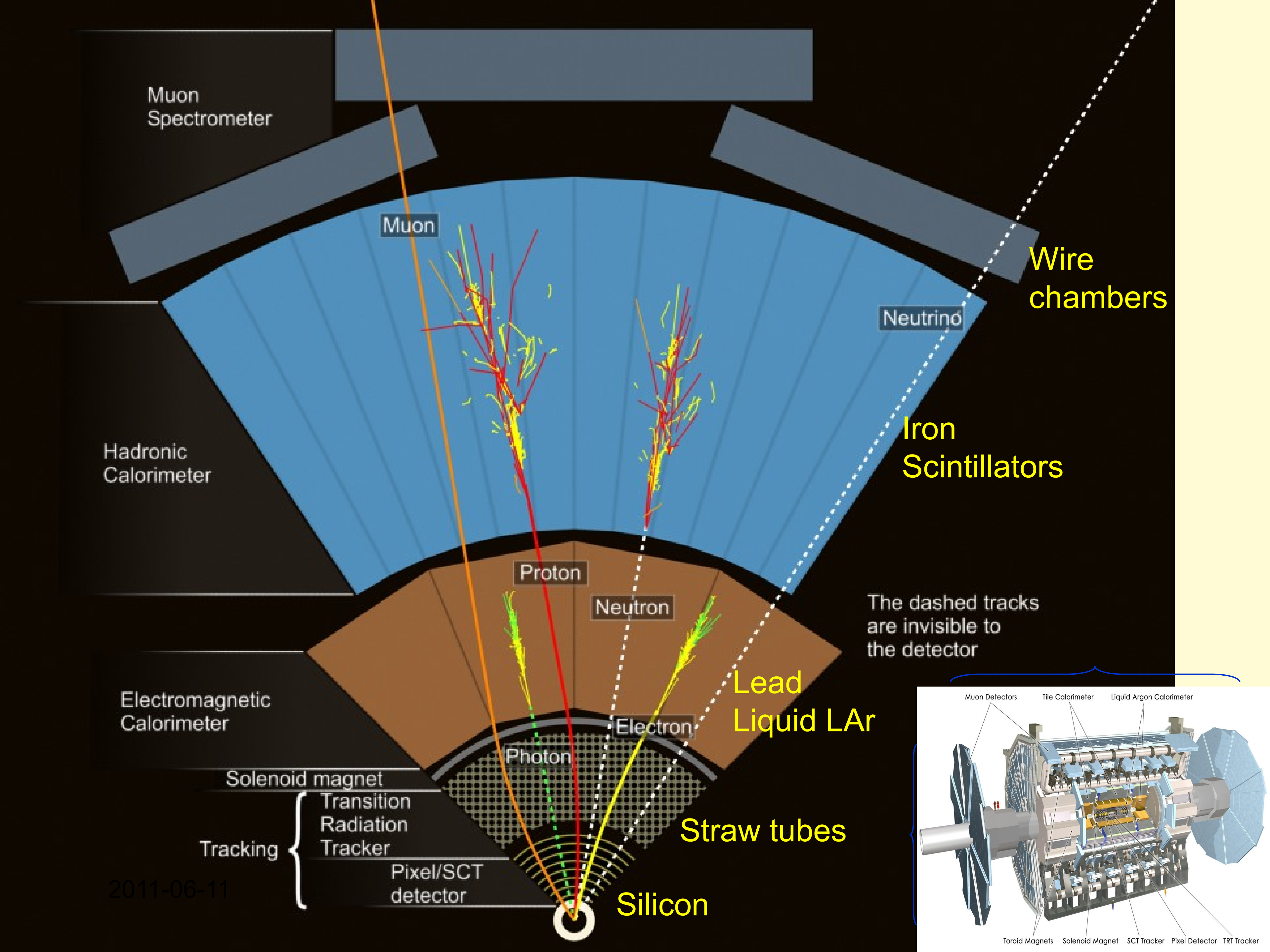


September 2007

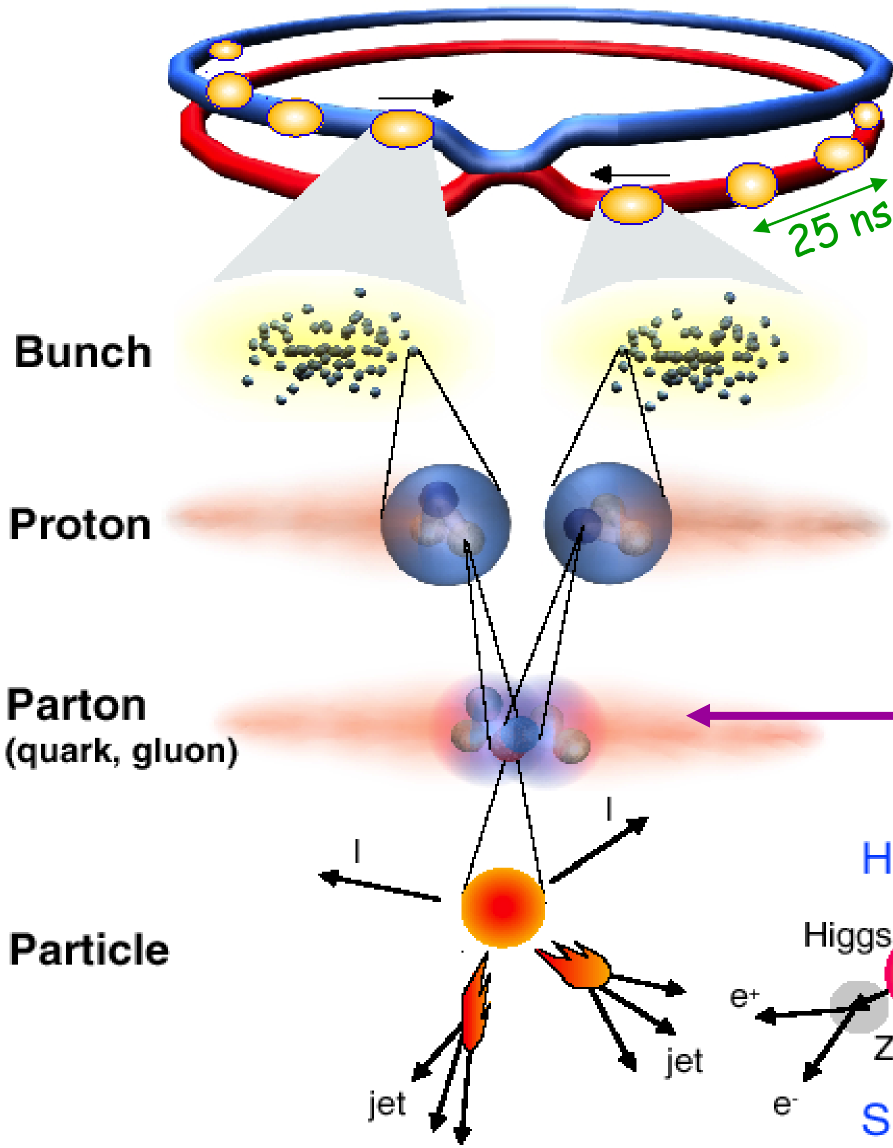
February 2008

A historical moment

Closure of the LHC beam pipe ring on 16th June 2008 (the last piece was the one shown here in ATLAS side A)


Muon Spectrometer
Hadronic Calorimeter
Electromagnetic Calorimeter
Solenoid magnet
Tracking
Transition Radiation Tracker
Pixel/SCT detector
Muon
Neutrino
Proton
Neutron
Electron
Photon
Wire chambers
Iron Scintillators
The dashed tracks are invisible to the detector
Lead Liquid LAr
Straw tubes
Silicon
2011-06-11
Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

Collisions at LHC



Proton-Proton

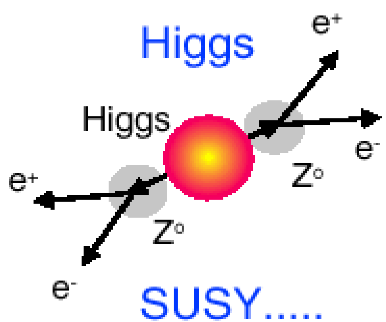
Protons/bunch	**10^{11}**
Beam energy	**7 TeV ($7x10^{12}$ eV)**
Luminosity	**10^{34} cm^{-2} s^{-1}**

Event rate:

N = L x σ (pp) ≈ 10^9 interactions/s

Mostly soft (low p_T) events

Interesting hard (high-p_T) events are rare

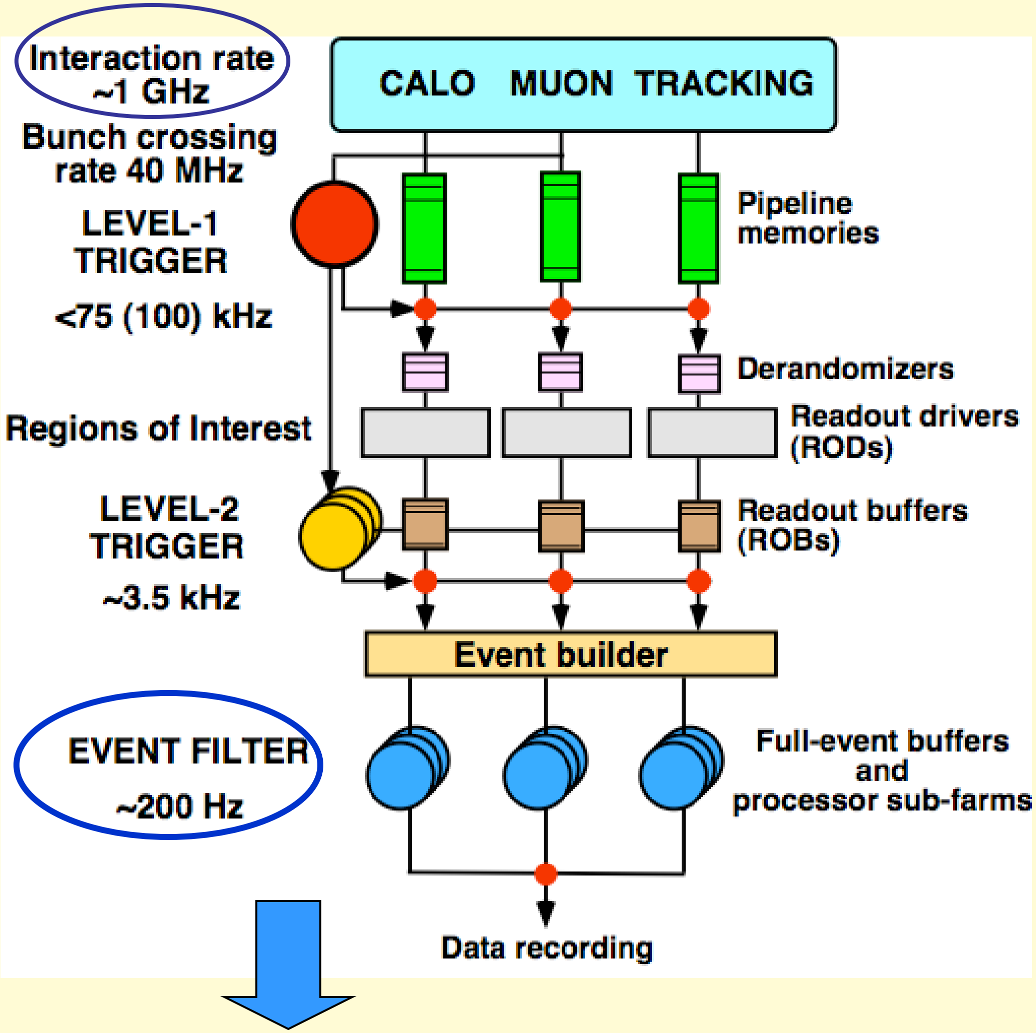


Selection of 1 in 10,000,000,000,000

⇒ very powerful detectors needed

The trigger selects interesting collisions

Around 1 billion collisions per sec



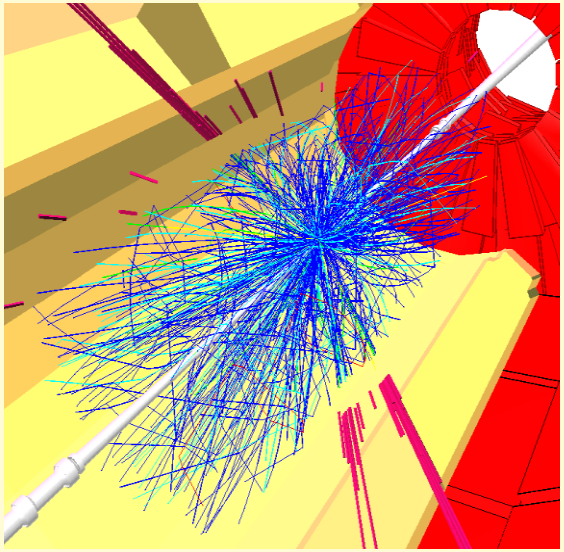
Data from ca 200 collisions per sec written to disk

1 collision of 5 millions is selected!

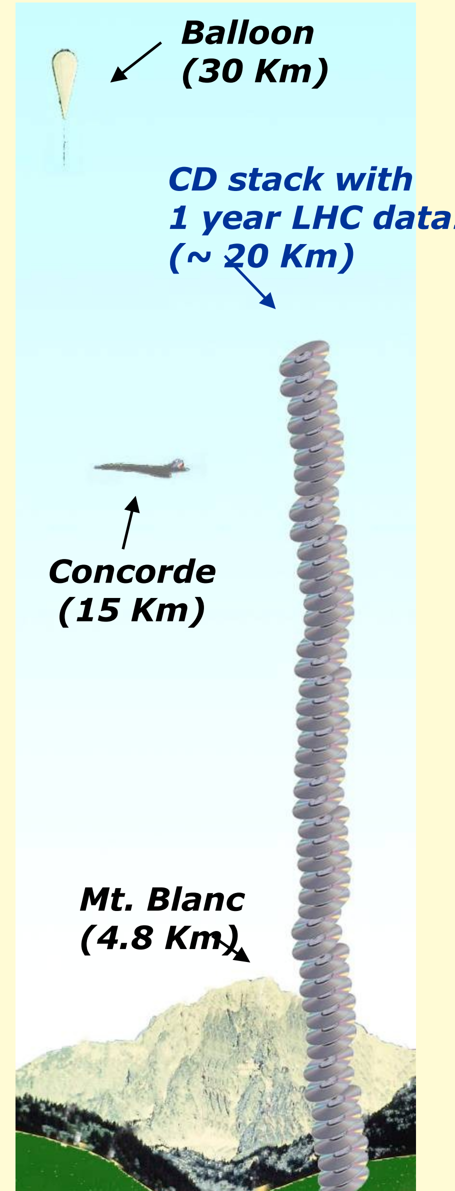
300 MByte/s

to Computer Center ... Pbytes stored / year

Worldwide LHC Computing Grid (WLCG)



WLCG is a worldwide collaborative effort on an unprecedented scale in terms of storage and CPU requirements, as well as the software project's size



GRID computing developed to solve problem of data storage and analysis

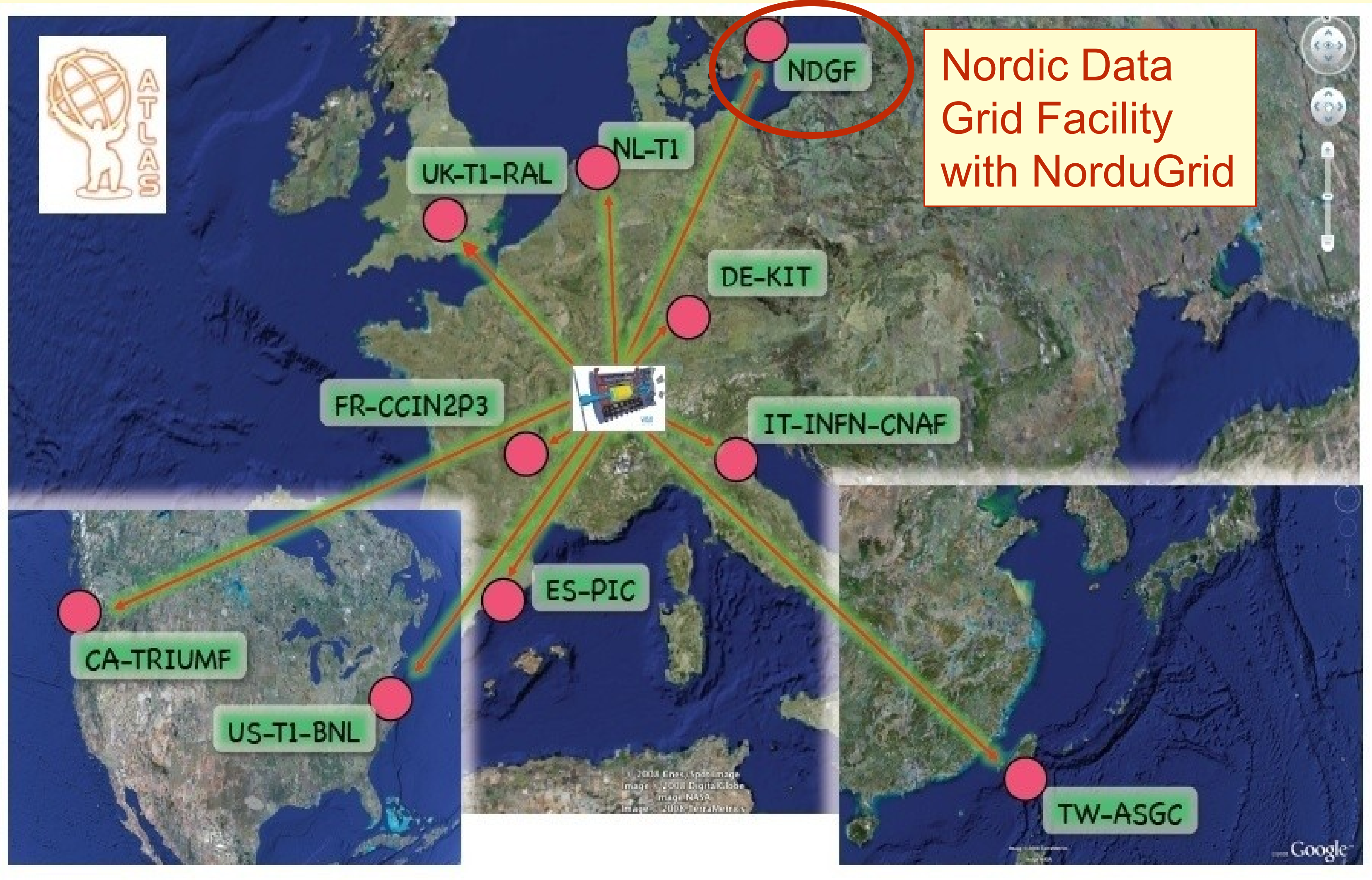
LHC data volume per year: 10-15 Petabytes

One CD has ~ 600 Megabytes
1 Petabyte = 10^9 MB = 10^{15} Byte

(Note: the WWW is from CERN...)

wLCG Grid

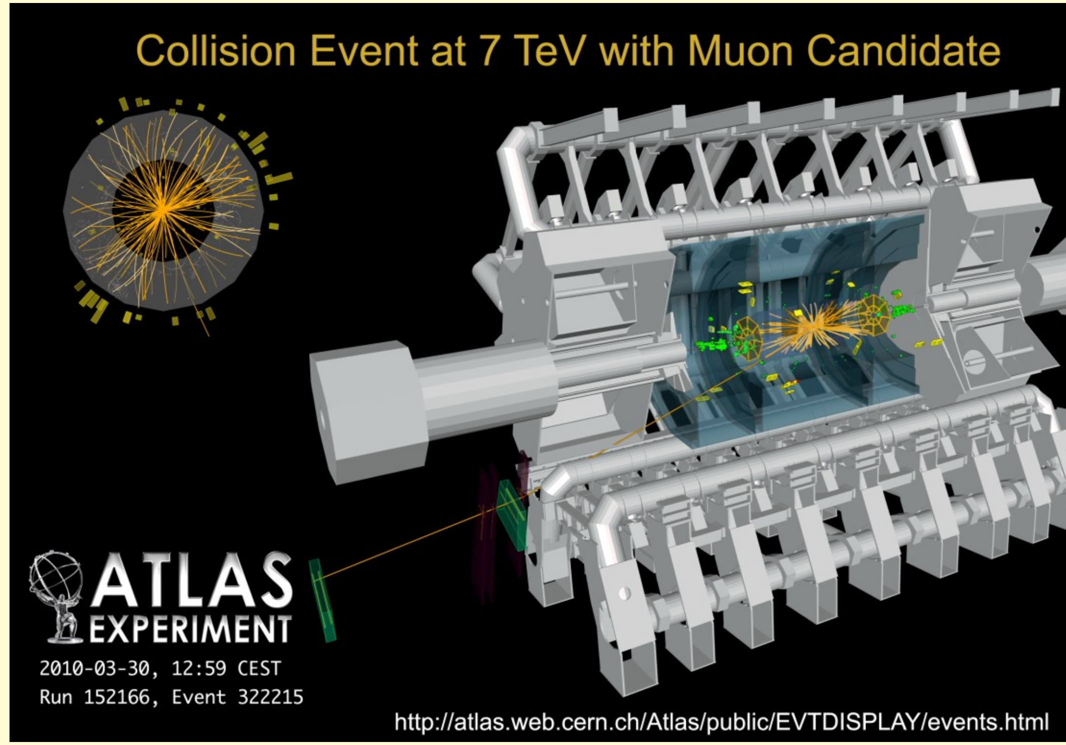
The computing centre at CERN and the 10 largest ATLAS computing centers in the world



Nordic Data Grid Facility with NorduGrid

First high energy collisions detected in ATLAS 30 March 2010!

7 TeV



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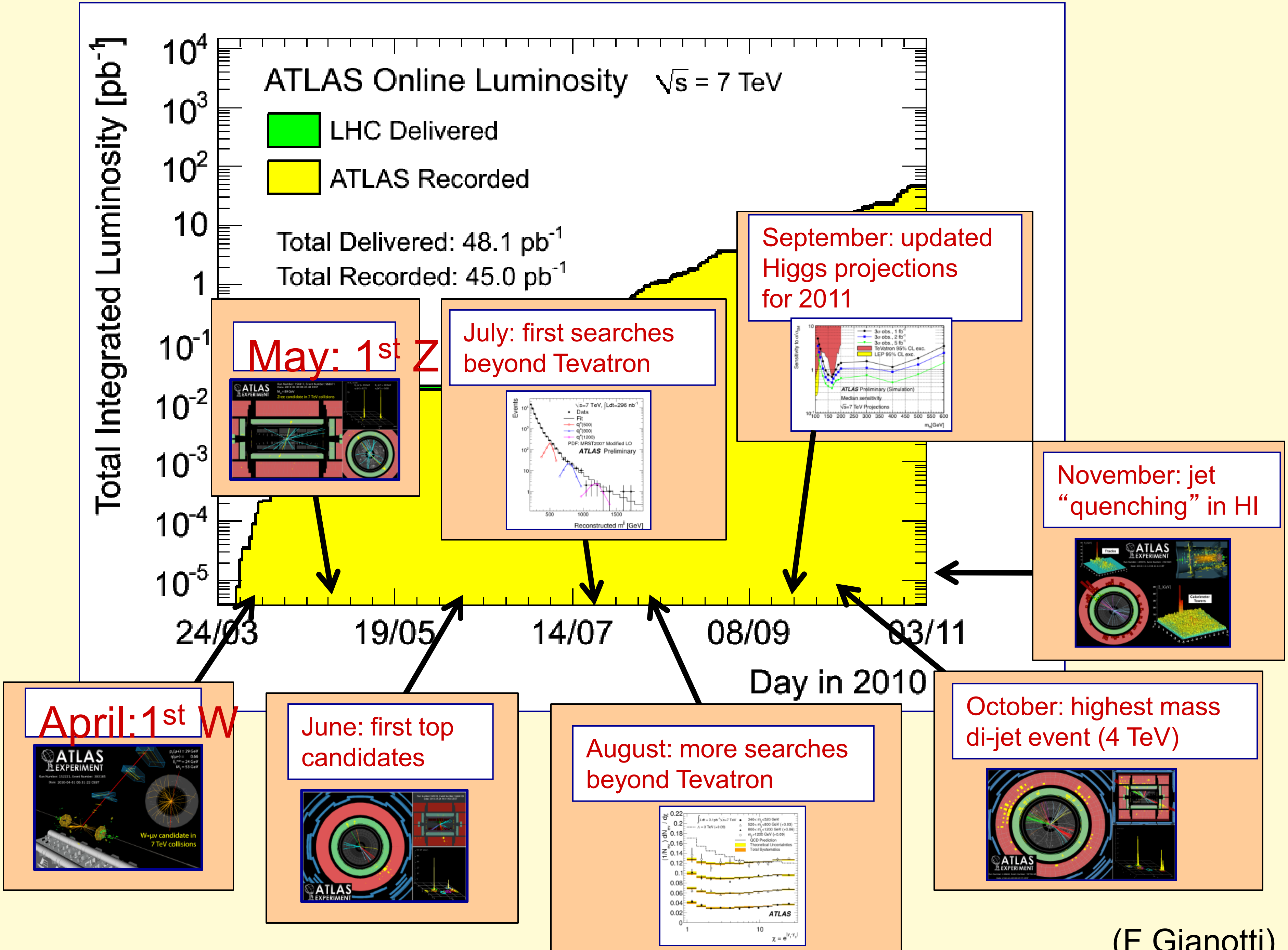
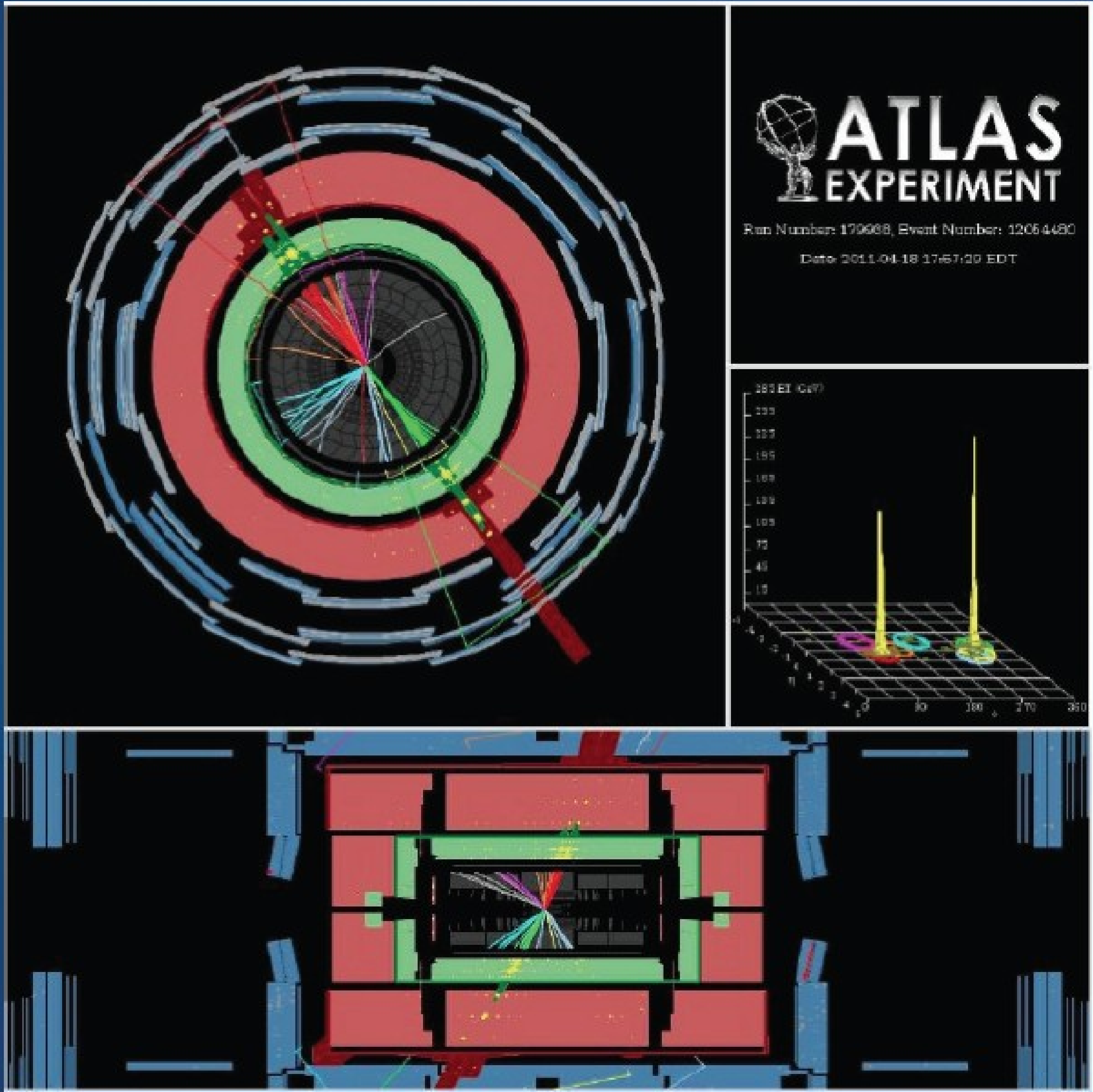
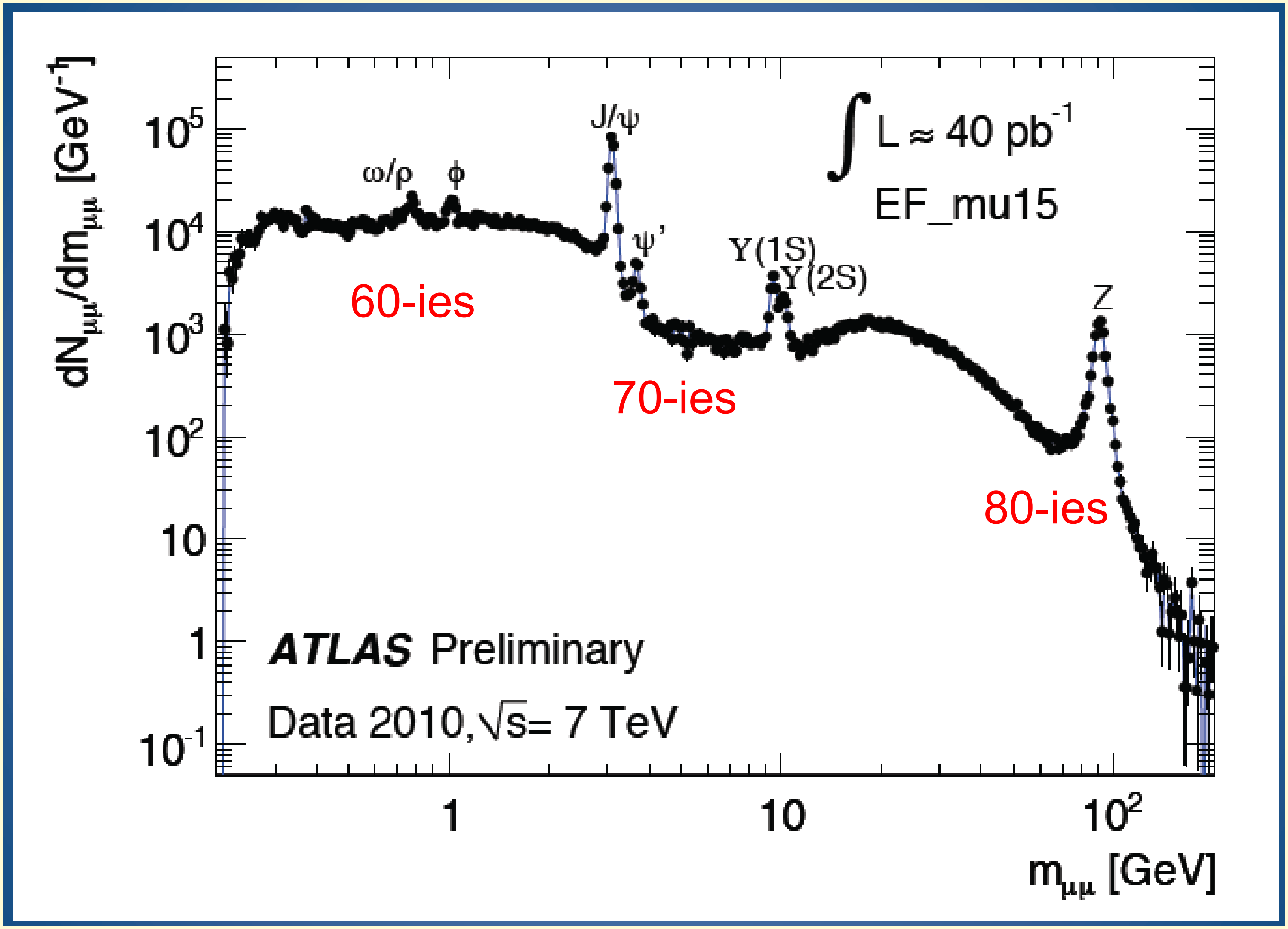

ATLAS Online Luminosity √s = 7 TeV
LHC Delivered
ATLAS Recorded
Total Delivered: 48.1 pb⁻¹
Total Recorded: 45.0 pb⁻¹
Total Integrated Luminosity [pb⁻¹]
Day in 2010
24/03
19/05
14/07
08/09
03/11
April: 1st W
May: 1st Z
June: first top candidates
July: first searches beyond Tevatron
August: more searches beyond Tevatron
September: updated Higgs projections for 2011
October: highest mass di-jet event (4 TeV)
November: jet "quenching" in HI

(F Gianotti)



Highest Di-Jet mass in central Region:
M_{jj} = 4 TeV

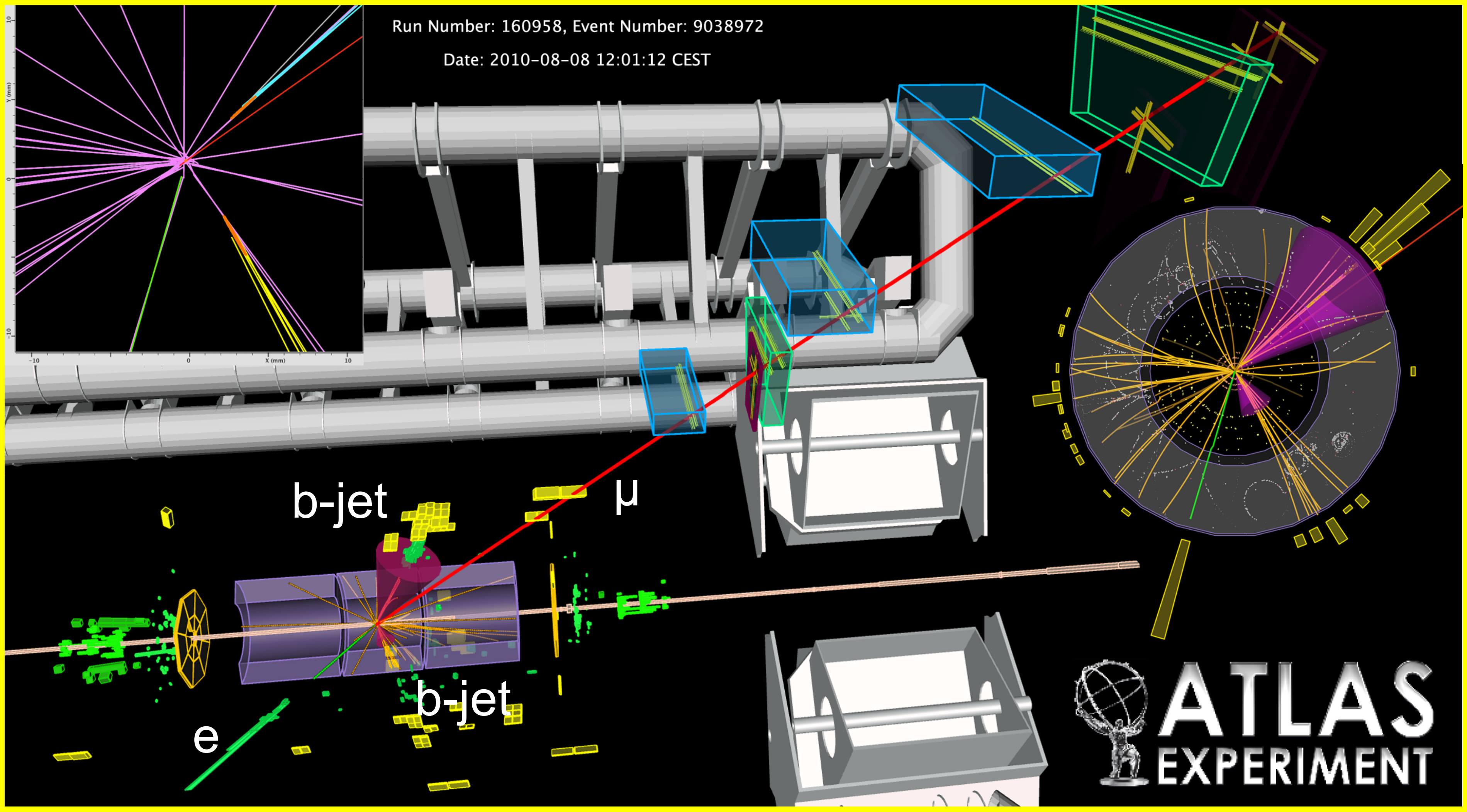
Calibrating the detector with Nobel Prize physics



This event display is most likely a top quark decay

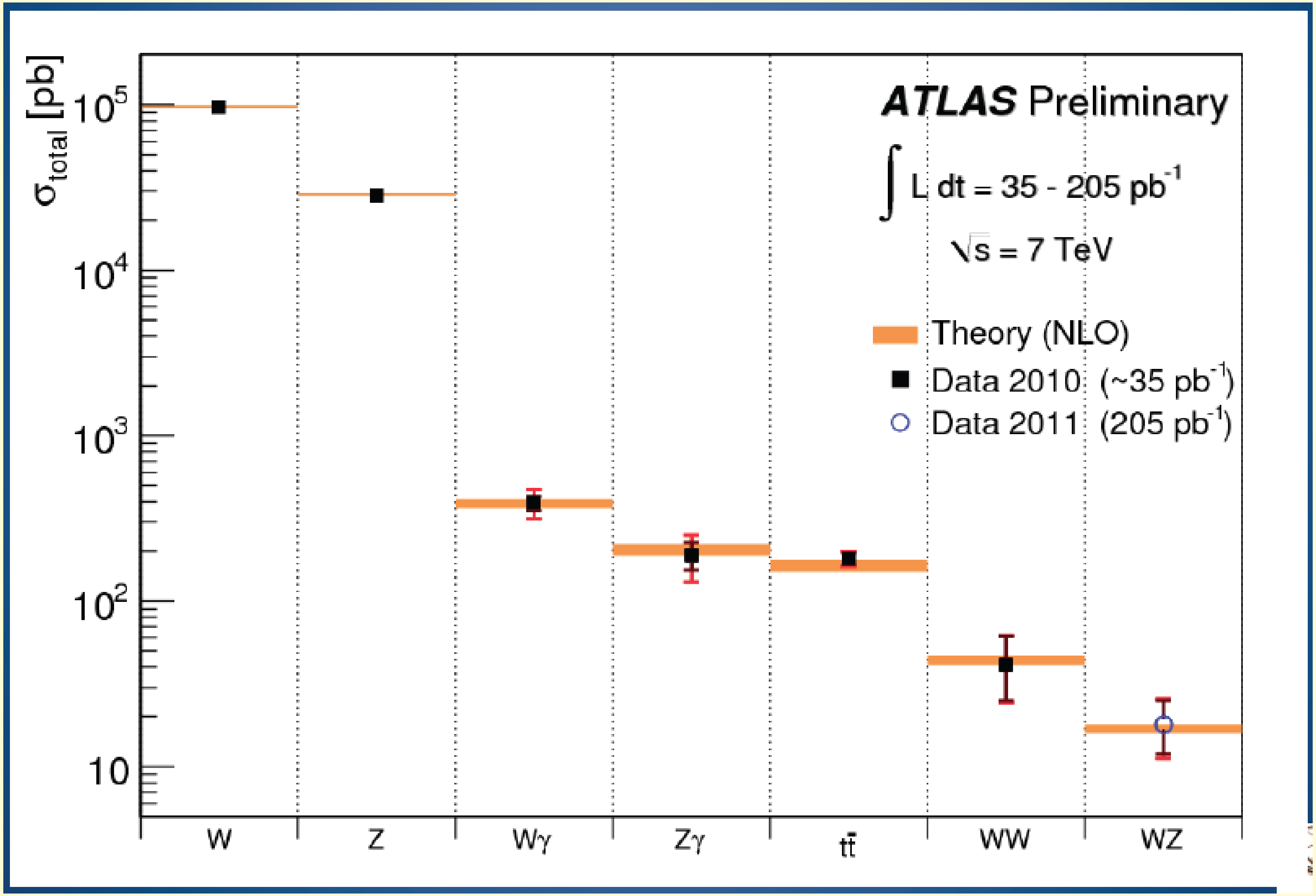
tt → bev bμv

LHC is now doing physics of the top quark – the heaviest known particle



Main ATLAS Standard Model measurements compared to theory

The Standard Model agrees beautifully with the data!



top quark

Summary of current searches for Higgs…
(from a recent conference)

- No evidence for a Standard Model Higgs boson yet!
- At the end of next year we should be able to tell whether it exists in a wide mass range

Summary Prospects

❖ ATLAS detector performs very well.
ATLAS has measured most possible SM channels : $H \to \gamma\gamma$, H->WW->lvlv/lvqq, H->ZZ->4l,llvv/llqq.

Dominant background contributions determined with data-driven methods.

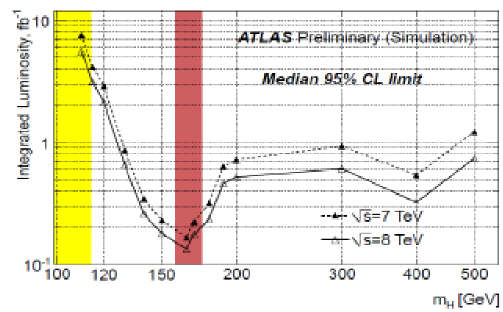
No evidence for SM Higgs boson yet!

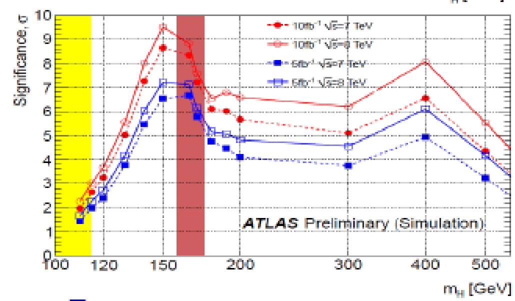
❖ 95% C.L. exclusion limit
$H \to \gamma\gamma$ search excludes 6~7X σ_{SM}.

H->WW->lvlv search excludes a 160 GeV SM Higgs with $2.4\times\sigma_{SM}$ (exp)

Limit is expected to be improved with more than 1fb^{-1} data by the end of 2011!

More results with SM/non-SM Higgs , see Marc Escalier's plenary talk: "*Recent Higgs results from ATLAS*"





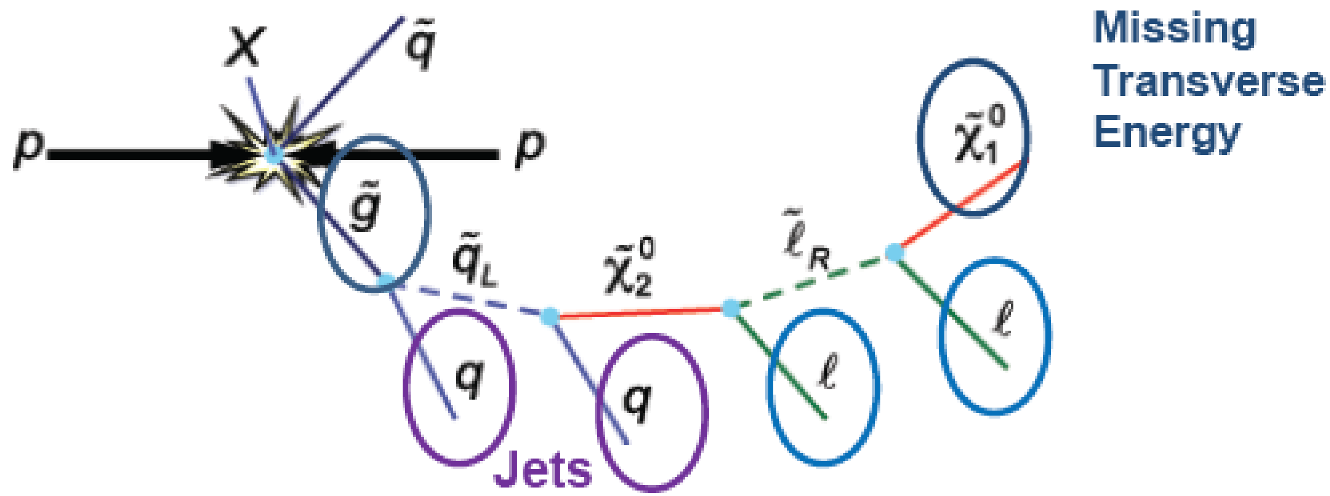
❖ **ATLAS Prospects:**
- with 1 fb^{-1} @ 7TeV, expects to exclude a SM Higgs in $130<m_H<460$ GeV.
- with 5-10 fb^{-1} @ 8TeV: 3σ evidence or 5σ discovery is expected in $120<m_H<500$ GeV

15

(Yingchun Zhu)

searches are complicated and we are eagerly searching …

Complex (and model-dependent) squark/gluino cascades



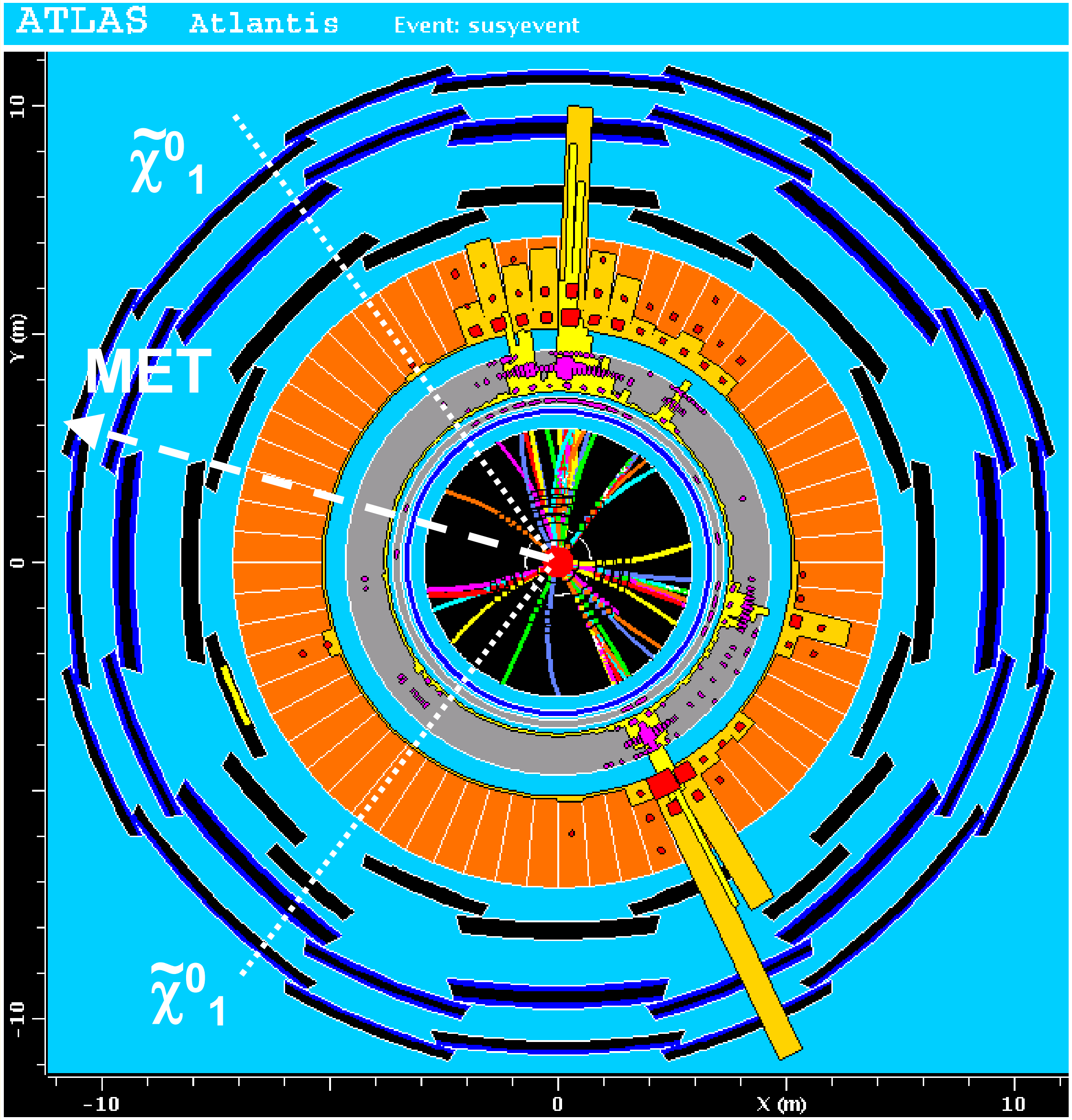
Focus on signatures covering large classes of models while strongly rejecting SM background

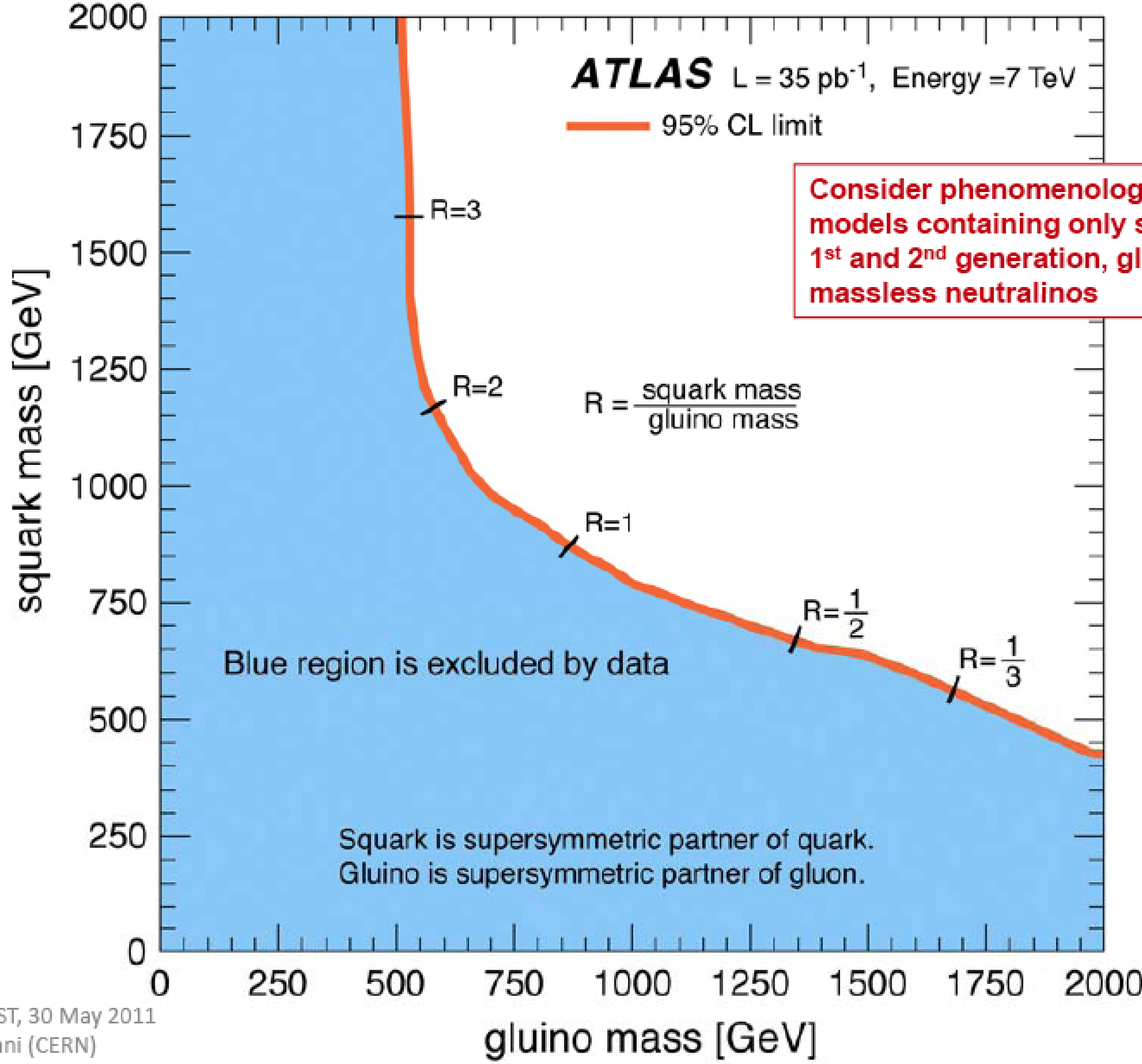
- large missing E_T
- High transverse momentum jets
- Leptons
  - Perform separate analyses with and without lepton veto (0-lepton / 1-lepton / 2-leptons)
- B-jets: to enhance sensitivity to third generation squarks

Dark Matter at LHC, simulated event

- Characteristic signature for Dark Matter production at ATLAS: Missing Transverse Energy ('MET')
- Valid for any DM candidate (not just SUSY)
- Observation of MET signal *necessary* but not *sufficient* to prove DM signal (DM particle could decay outside detector)

Combine LHC and Astroparticle physics data in order to proof that the neutralino hopefully observed at LHC would be the DM particle…





Consider phenomenological MSSM models containing only squarks of 1st and 2nd generation, gluino and massless neutralinos

Summary

- ATLAS works excellently
- Standard Model physics "rediscovered"
- Precision measurements will challenge the theory
- No sign of Higgs yet, but the future is exciting
- Limits for new physics being pushed but…

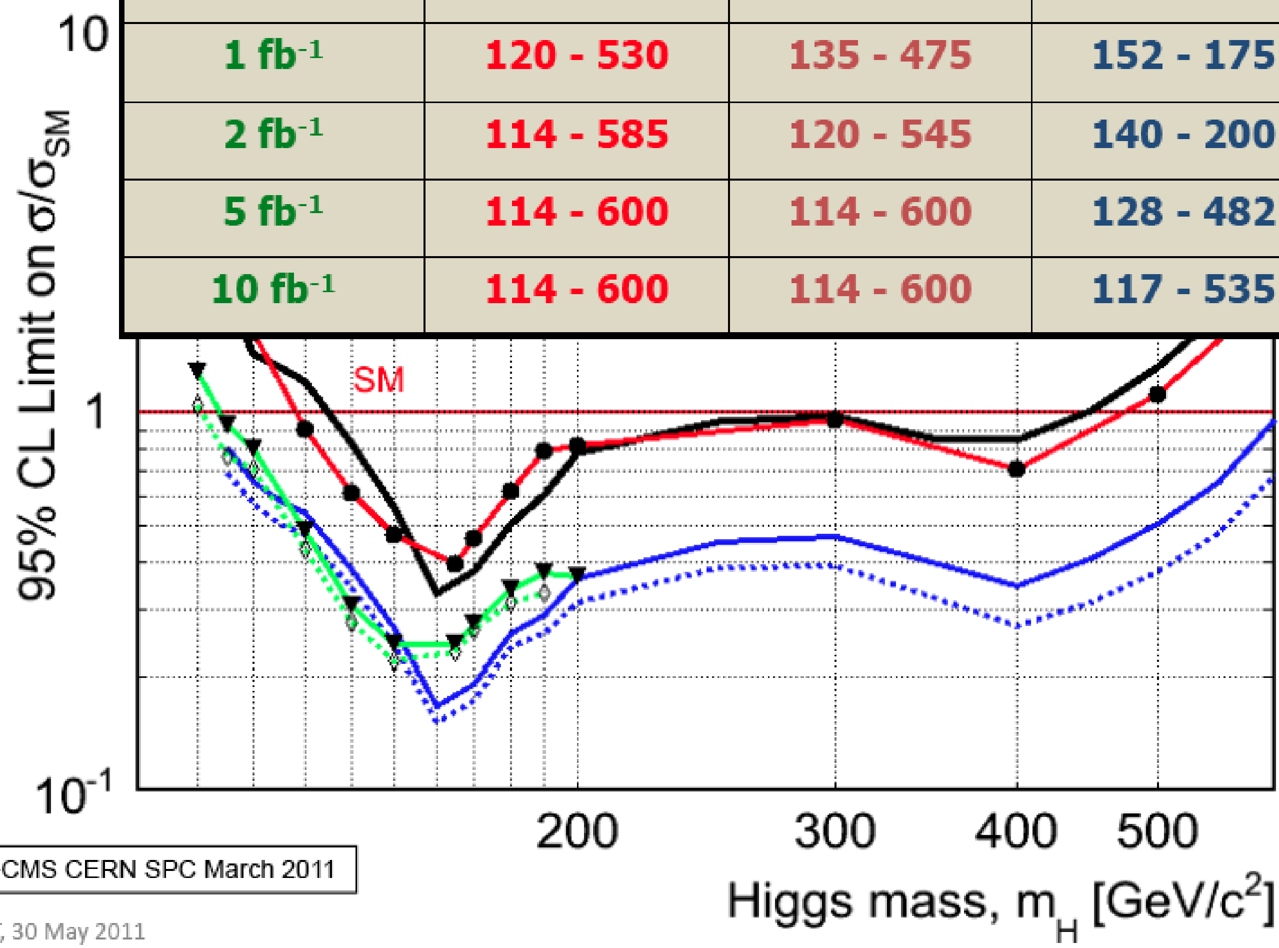
No New Physics (yet…)

Much more data is coming very fast and we will eagerly keep searching ready to harvest whatever Nature will provide us…

Happy Birthday Anna!

No sign of Higgs yet, but the future is bright.
By end of next year we will be able to tell whether it exists.

ATLAS+CMS 7 TeV	95% CL exclusion	3σ sensitivity	5σ sensitivity
1 fb^{-1}	120 - 530	135 - 475	152 - 175
2 fb^{-1}	114 - 585	120 - 545	140 - 200
5 fb^{-1}	114 - 600	114 - 600	128 - 482
10 fb^{-1}	114 - 600	114 - 600	117 - 535



ATLAS+CMS CERN SPC March 2011