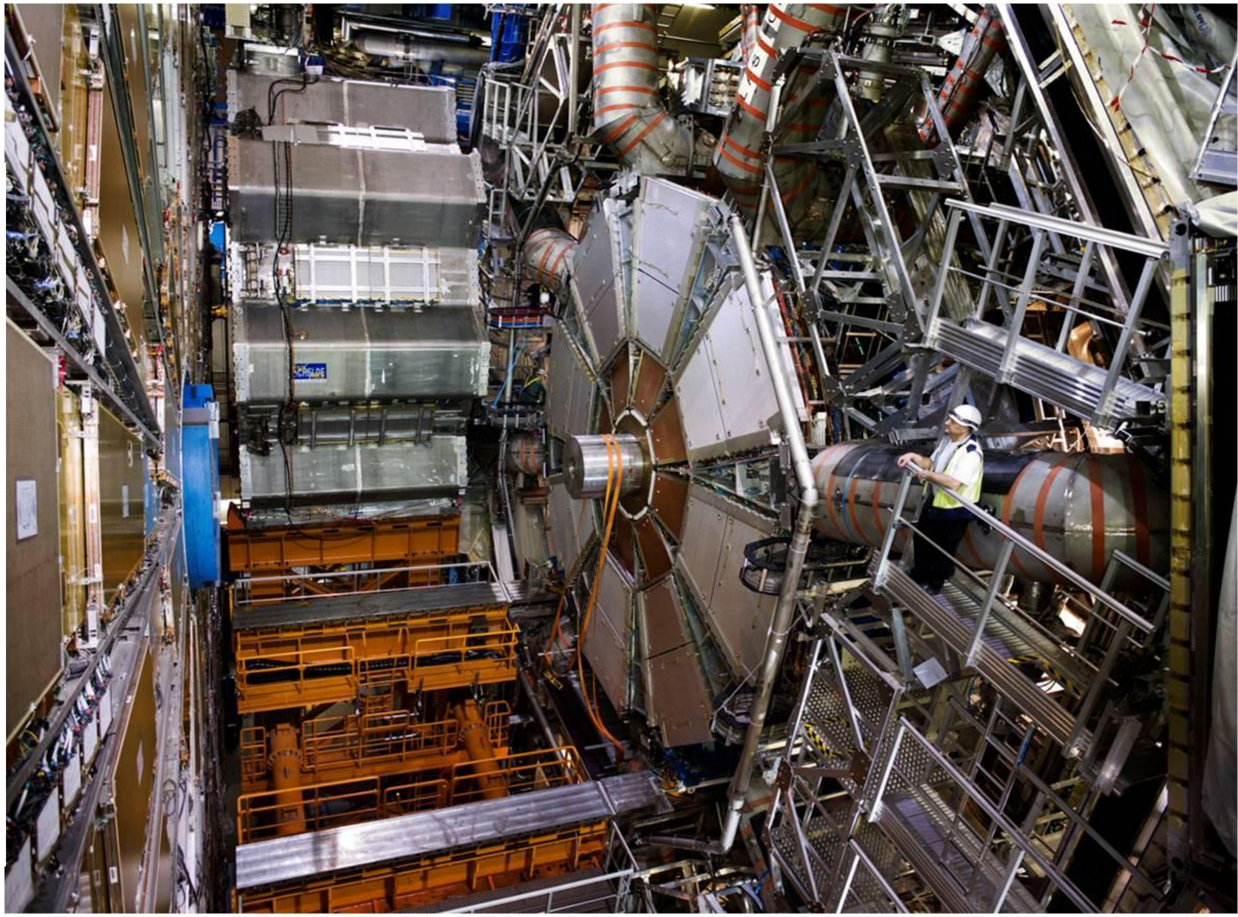
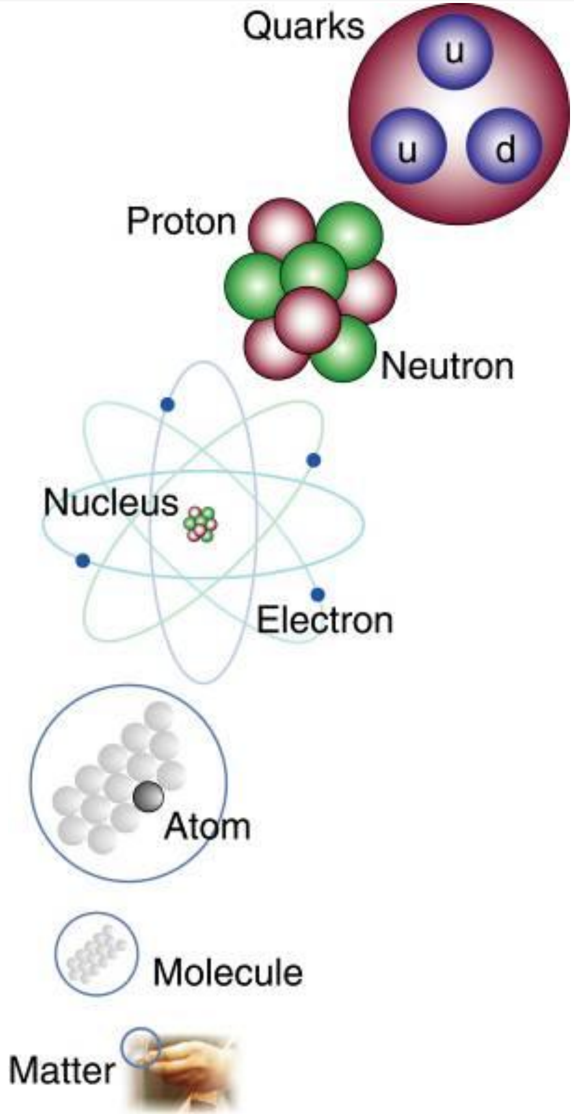
My detector is bigger than yours:
Big Science, Particle Physics and Women.

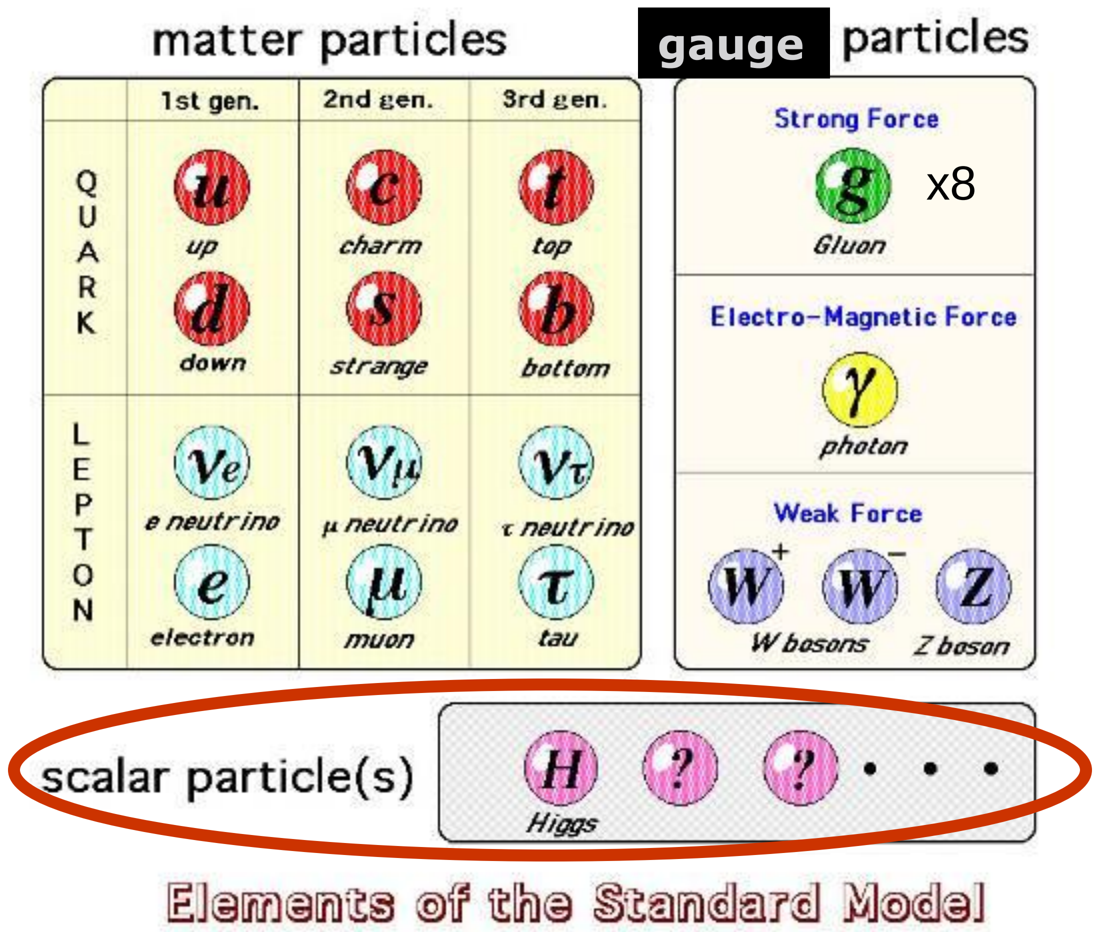
1. Introduction to particle physics
2. The Large Hadron Collider at CERN
3. The ATLAS detector
4. Physics with ATLAS
5. ATLAS collaboration
6. Women in ATLAS and particle physics



Pauline Gagnon, Indiana University and
ATLAS collaboration at CERN,

The study of elementary particles and their interactions





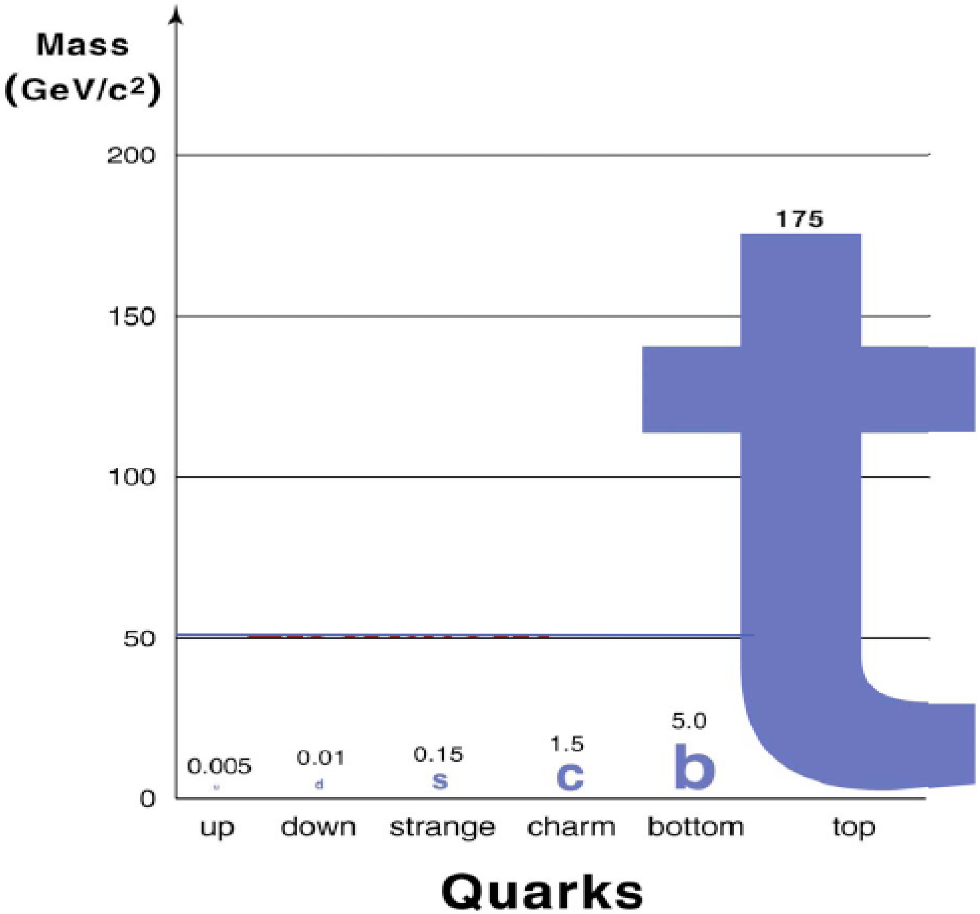
But how do these particles acquire a mass?

- The **"Standard Model"** is a theoretical model that describes *almost* everything we see.
- <u>One small problem</u>: all the particles coming out of the equations are **massless**, just like photons
- **But we know matter has a mass**: if atoms and molecules have a mass, their smallest constituents must also have a mass.

The Higgs mechanism in simple words

- In 1964, 3 theorists, Peter Higgs, Robert Brout and François Englert, proposed a mechanism to explain how particles could acquire mass
- They proposed a new field and a new particle to go with it, the Higgs boson
- This Higgs field would make the universe seem "viscous" and all massless particles moving within that viscous field would experience a drag force i.e. acquire resistance to motion
- In physics, the mass is "resistance to motion" so they would all gain mass

The mass mystery could be solved with the 'Higgs mechanism'

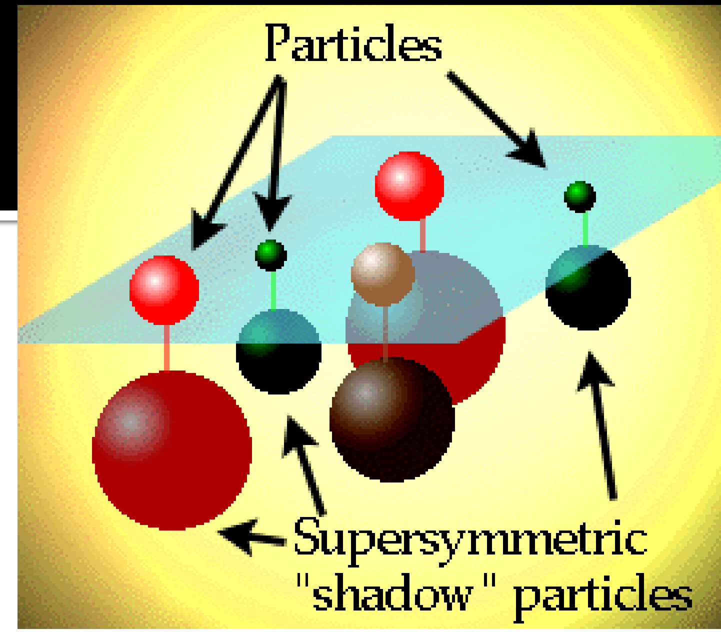


Not only the origin of mass is unknown but also why the quark and lepton masses span 5 orders of magnitude

People have been looking for the Higgs particle for decades at various accelerators, but it has not yet been found…

The new accelerator built near Geneva, the LHC, will have sufficient energy to produce it for sure if it exists

Supersymmetry (SUSY)



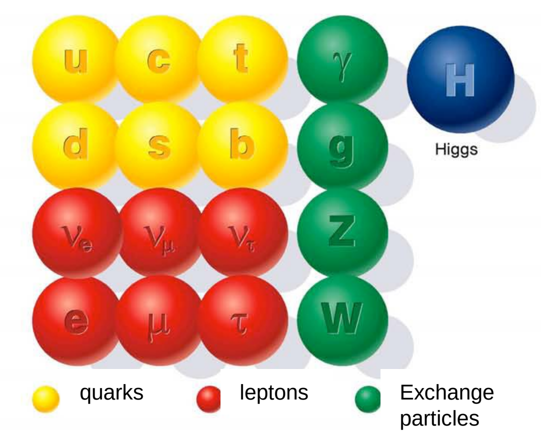
Establishes a symmetry between fermions (matter) and bosons (forces):

- Each particle p with spin s has a SUSY partner $\tilde{p}$ with spin s -1/2

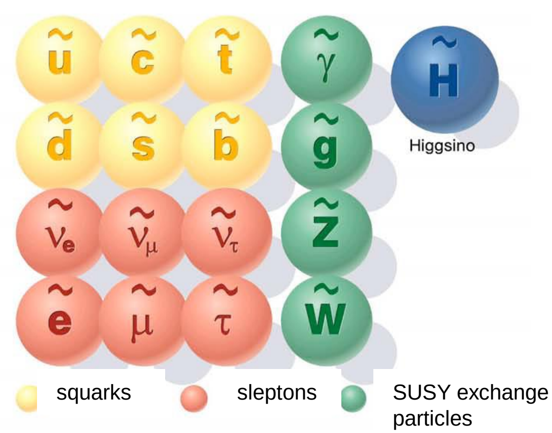
- Examples q (s=1/2) → $\tilde{q}$ (s=0) **squark**

g (s=1) → $\tilde{g}$ (s=1/2) **gluino**

Our known world with standard particles



Maybe a new world with SUSY particles?

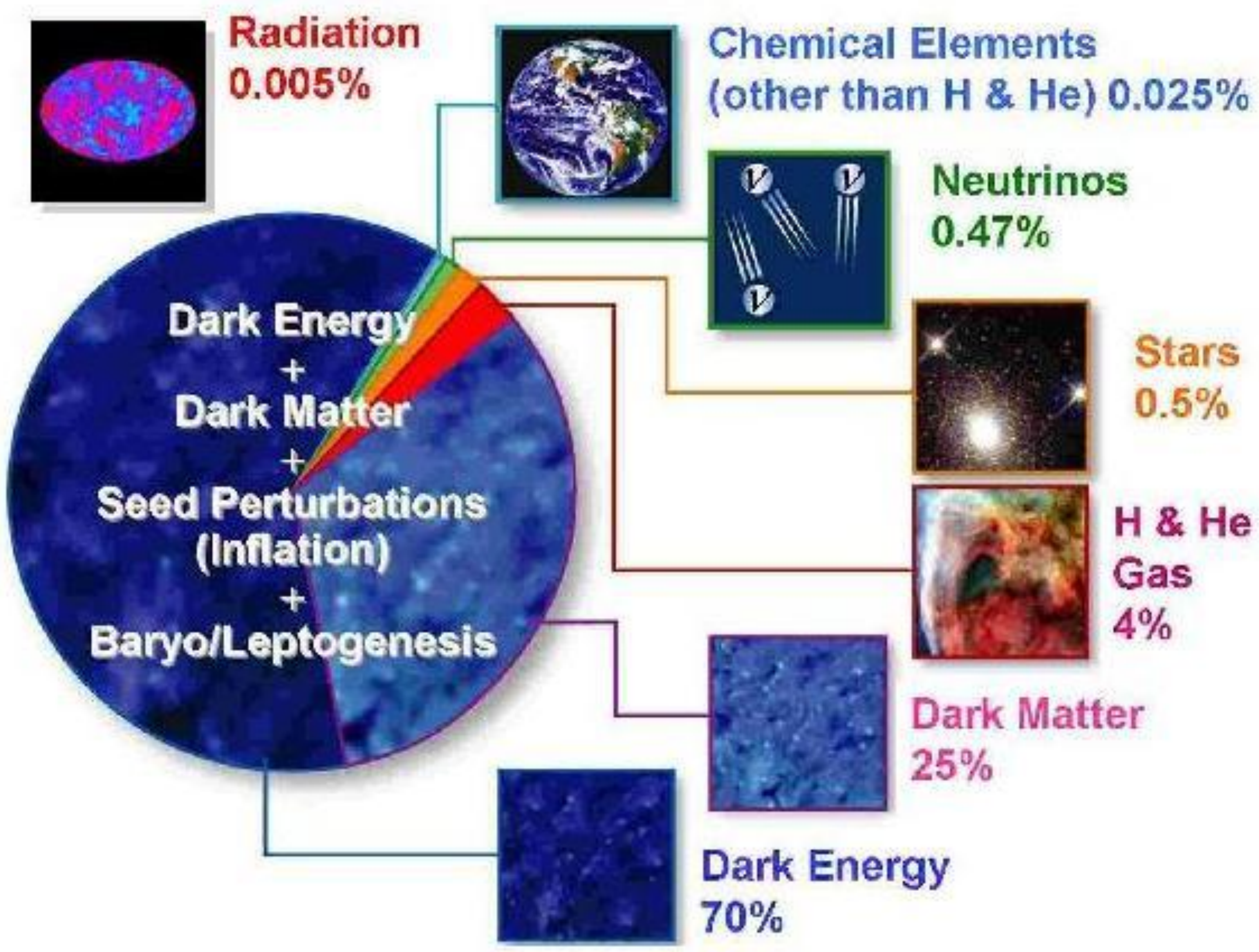


Motivation:

- Unify matter-forces (fermions-bosons)

- Solve some deep problems of the Standard Model

Dark matter and dark energy: what is our Universe made of?



From John Ellis's paper: Gauguin's questions in particle physics

Answering many such questions is the purpose of CERN

- **Centre Européen de la recherche nucléaire** (European Center for Particle Physics) is located near Geneva, on the French-Swiss border
- CERN employs ~ 1800 scientists
- Hosts ~10000 researchers from all over the world
- Subsidized by Member States (most European countries) plus observers such as USA, Canada, Japan, Israel, Turkey, India, Pakistan etc.

(Note: the WWW is from CERN…)

What do we do at CERN?

- The "accelerator "… accelerates protons in a gigantic ring at near the speed of light. Two proton beams circulate in opposite directions
- The beams collide at specific "collisions " points
- The energy of these collisions materializes and creates new particles: $E = mc^2$
- These particles are unstable and decay into smaller particles

  …. like mini firework
- The "detectors" act like giant microscopes

  …. They will allow us to "see" the new particles and their fragments

The accelerator:
The Large Hadron Collider (LHC)

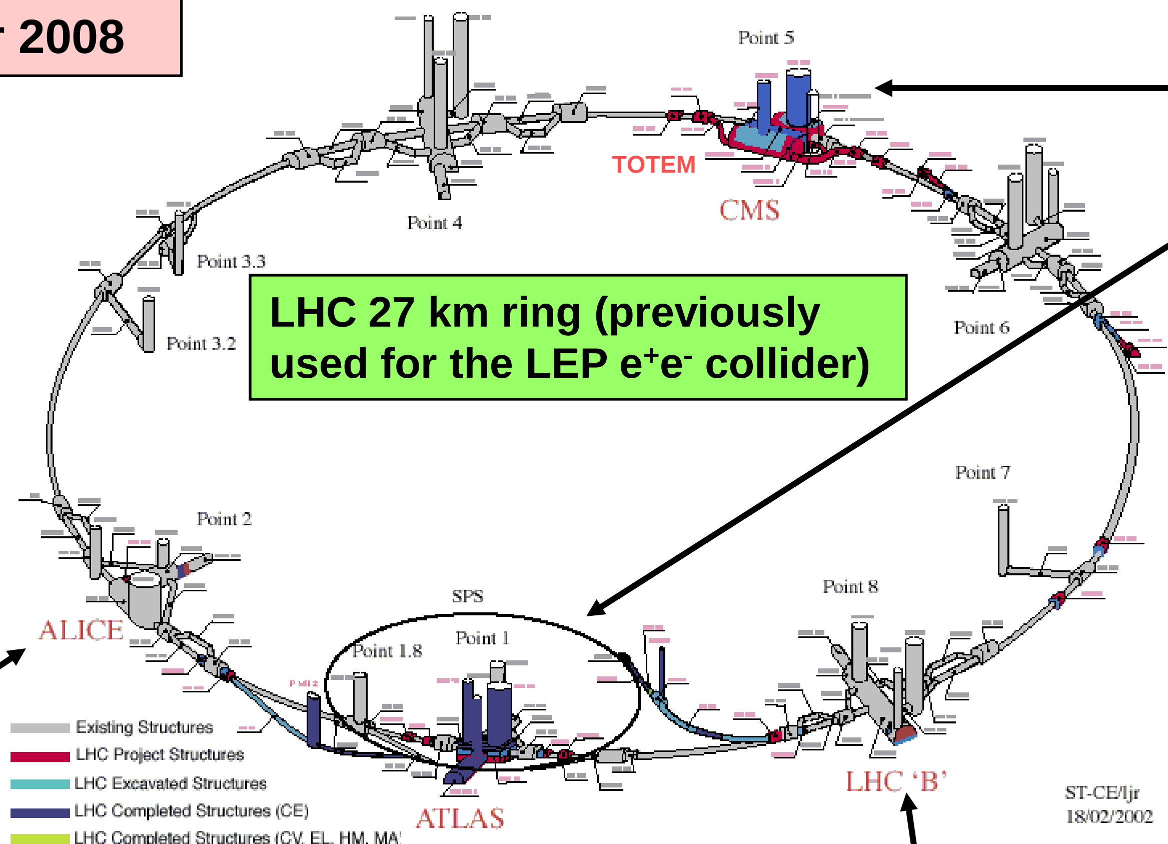
The LHC is a 27 km-long particle accelerator housed in a tunnel about 100 m underground near Geneva

One accelerator and 4 large detectors

First collisions: summer 2008

ATLAS and CMS : pp, general purpose

LHC 27 km ring (previously used for the LEP e^+e^- collider)



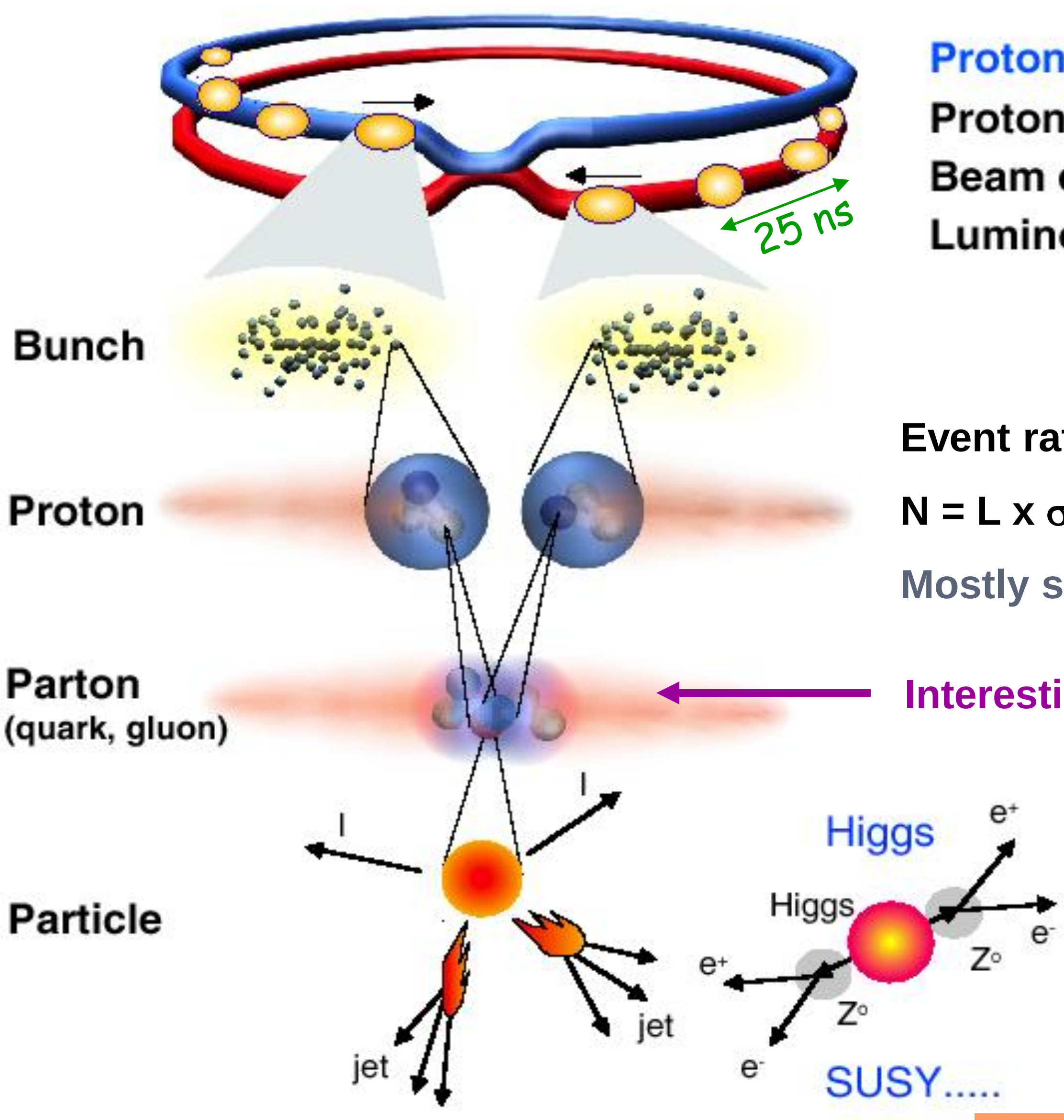
ALICE : ion-ion, p-ion

LHCb : pp, B-physics, CP-violation


Large dipole magnets
used to accelerate the
proton beams
The LHC accelerator
is fully installed and
almost ready to operate...

Special quadrupole magnets are focussing the particle beams to reach the highest densities at their interaction point in the centre of the detectors

Collisions at LHC



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

Event rate:

$N = L \times \sigma$ (pp) ≈ 10^9 interactions/s

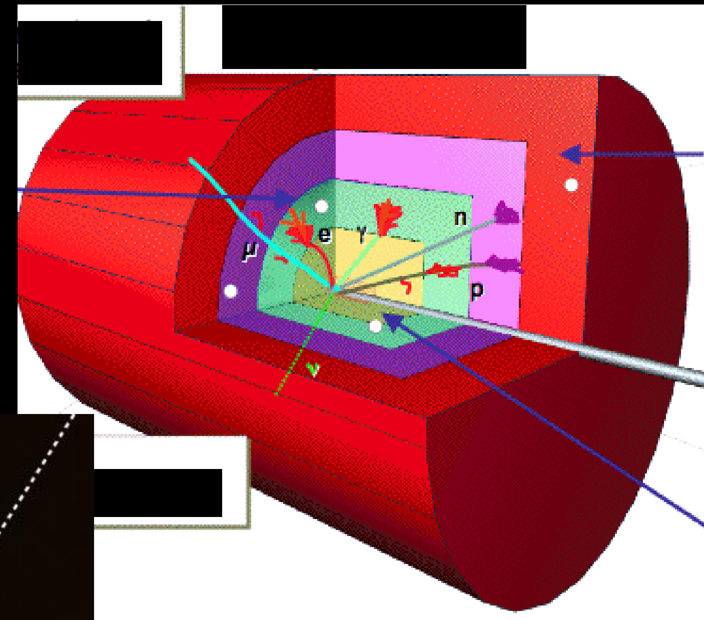
Mostly soft (low p_T) events

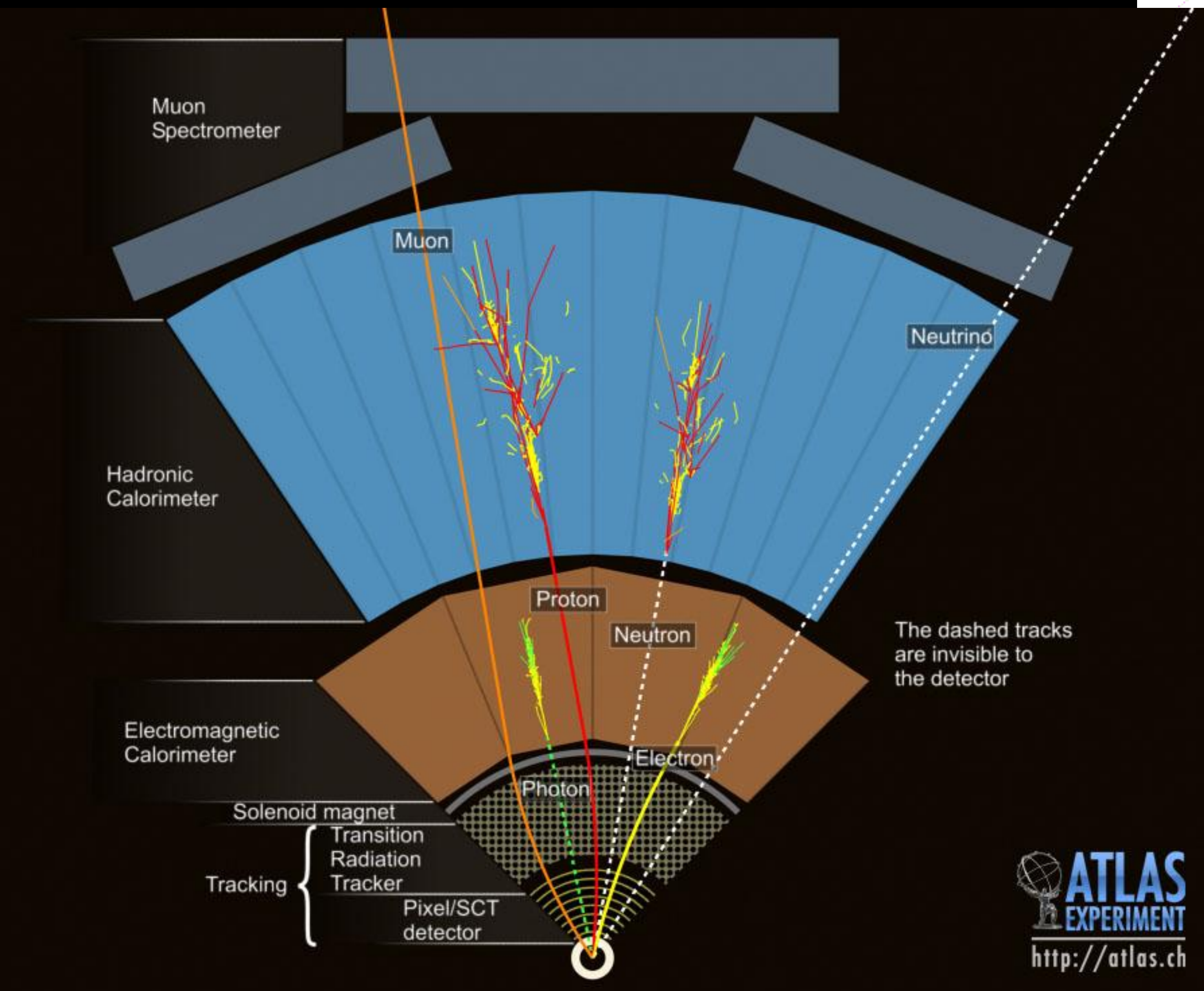
Interesting hard (high-p_T) events are rare

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

→ very powerful detectors needed

Detectors for particle physics

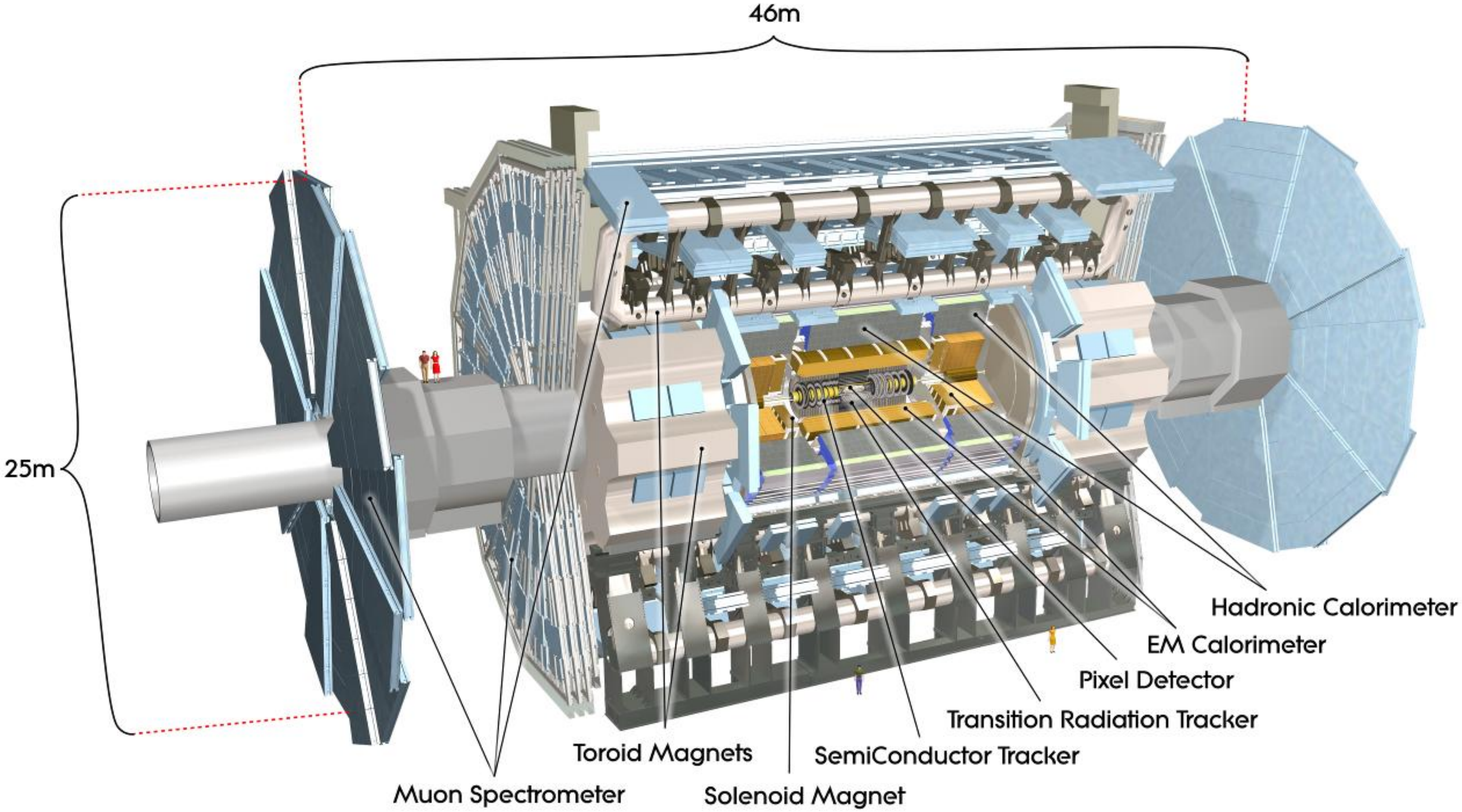




Cover the whole angular range around the collision point to detect all particles produced in the collision.

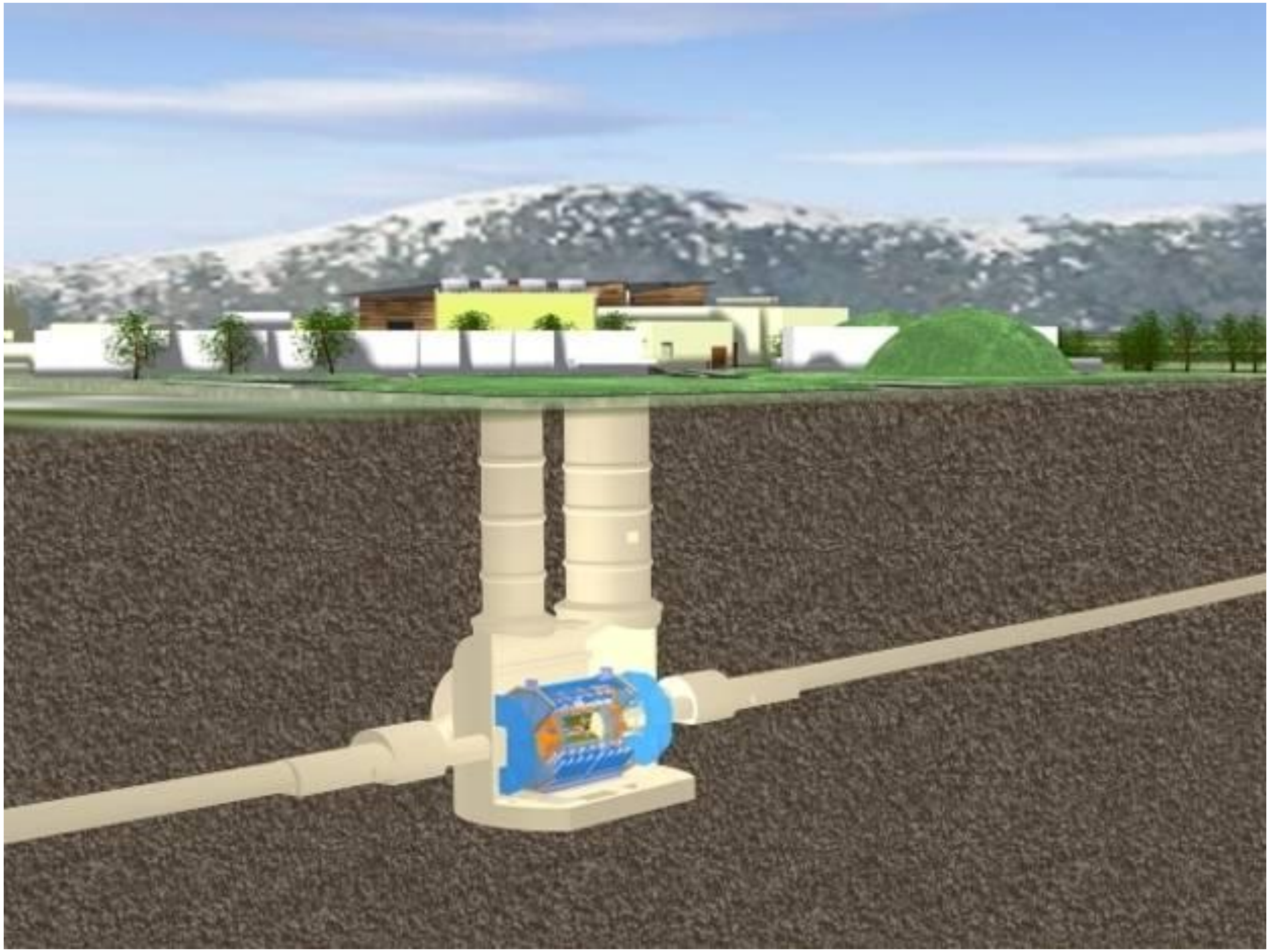
Nothing must escape

Schematic view of the ATLAS detector



Diameter	*25 m*
Barrel toroid length	*26 m*
End-cap end-wall chamber span	*46 m*
Overall weight	*7000 Tons*

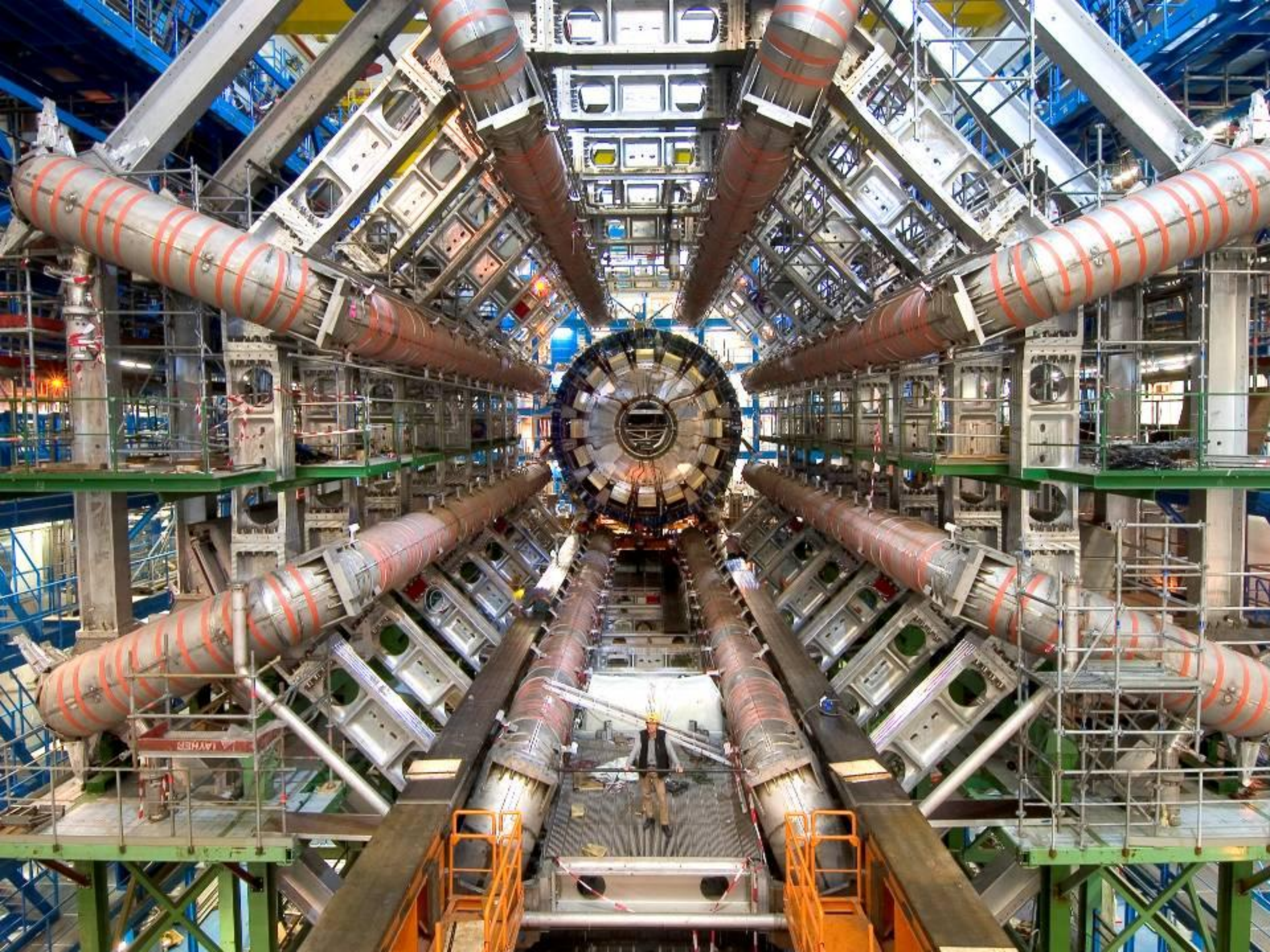
The ATLAS detector was built in an underground cavern like a ship in a bottle

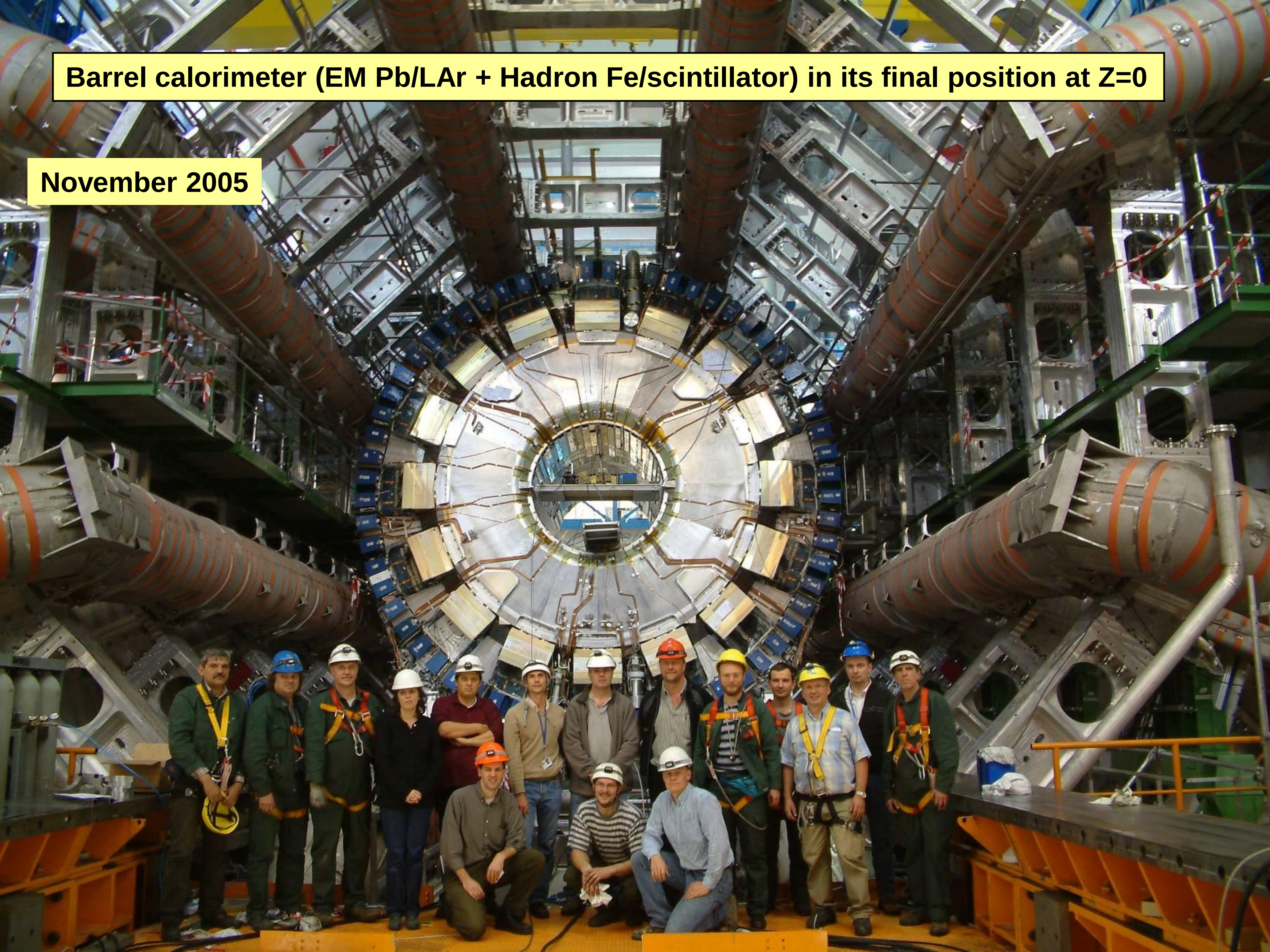


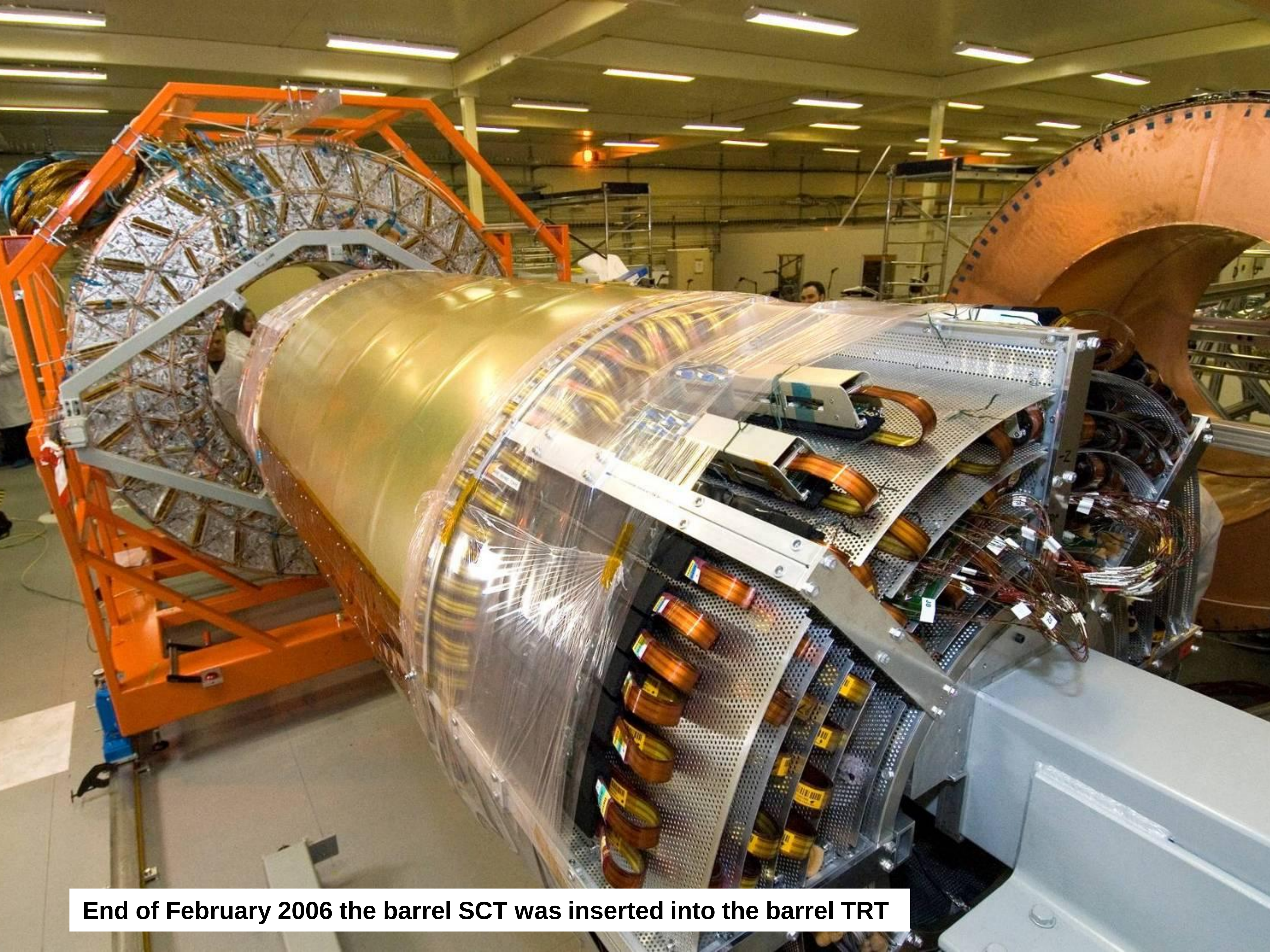
<u>Cavern:</u>

Length	**= 55 m**
Width	**= 32 m**
Height	**= 35 m**
Depth	**= 100 m**

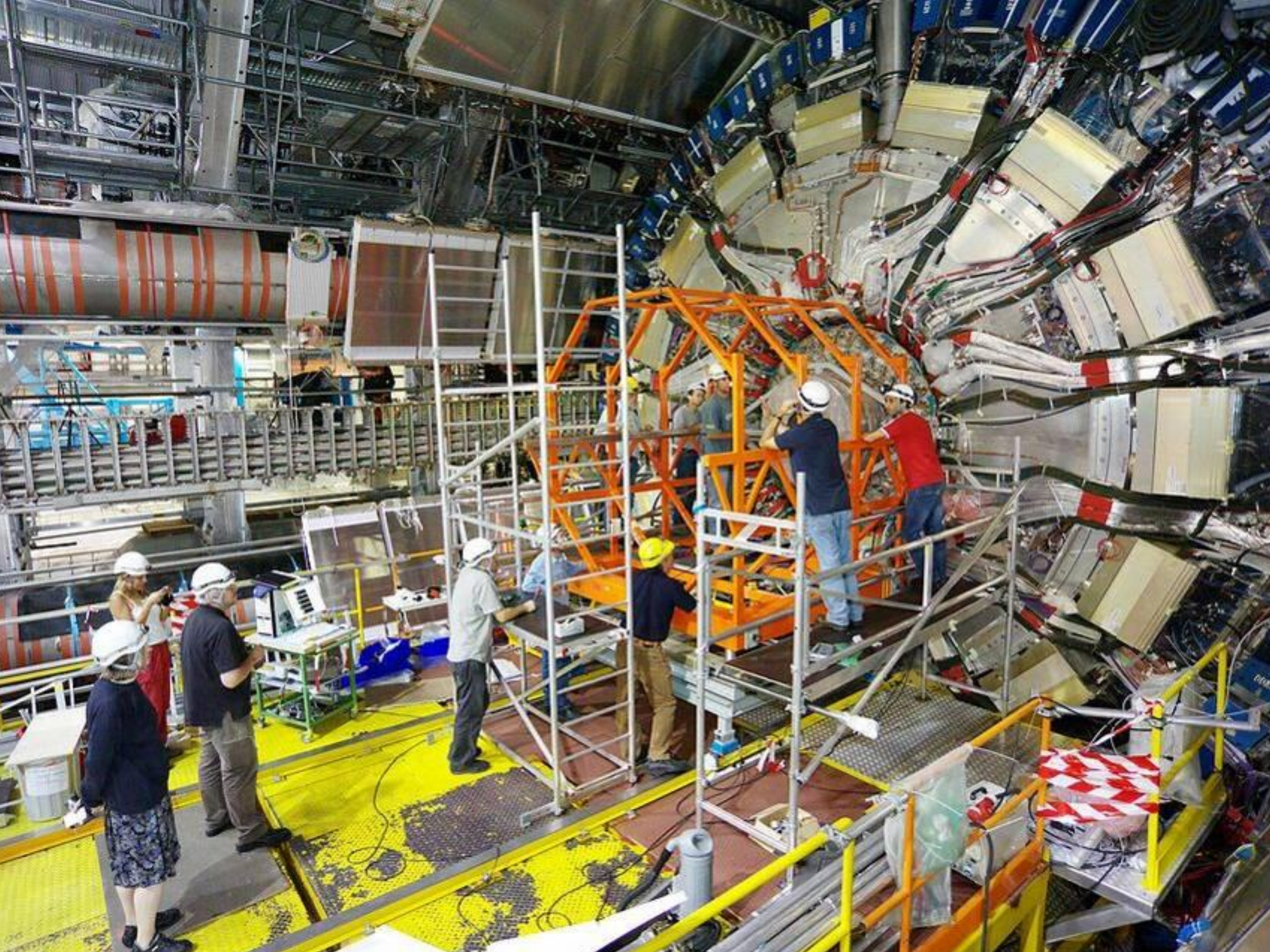
ATLAS Barrel Toroid coil transport and lowering into the underground cavern




Barrel calorimeter (EM Pb/LAr + Hadron Fe/scintillator) in its final position at Z=0
November 2005



End of February 2006 the barrel SCT was inserted into the barrel TRT

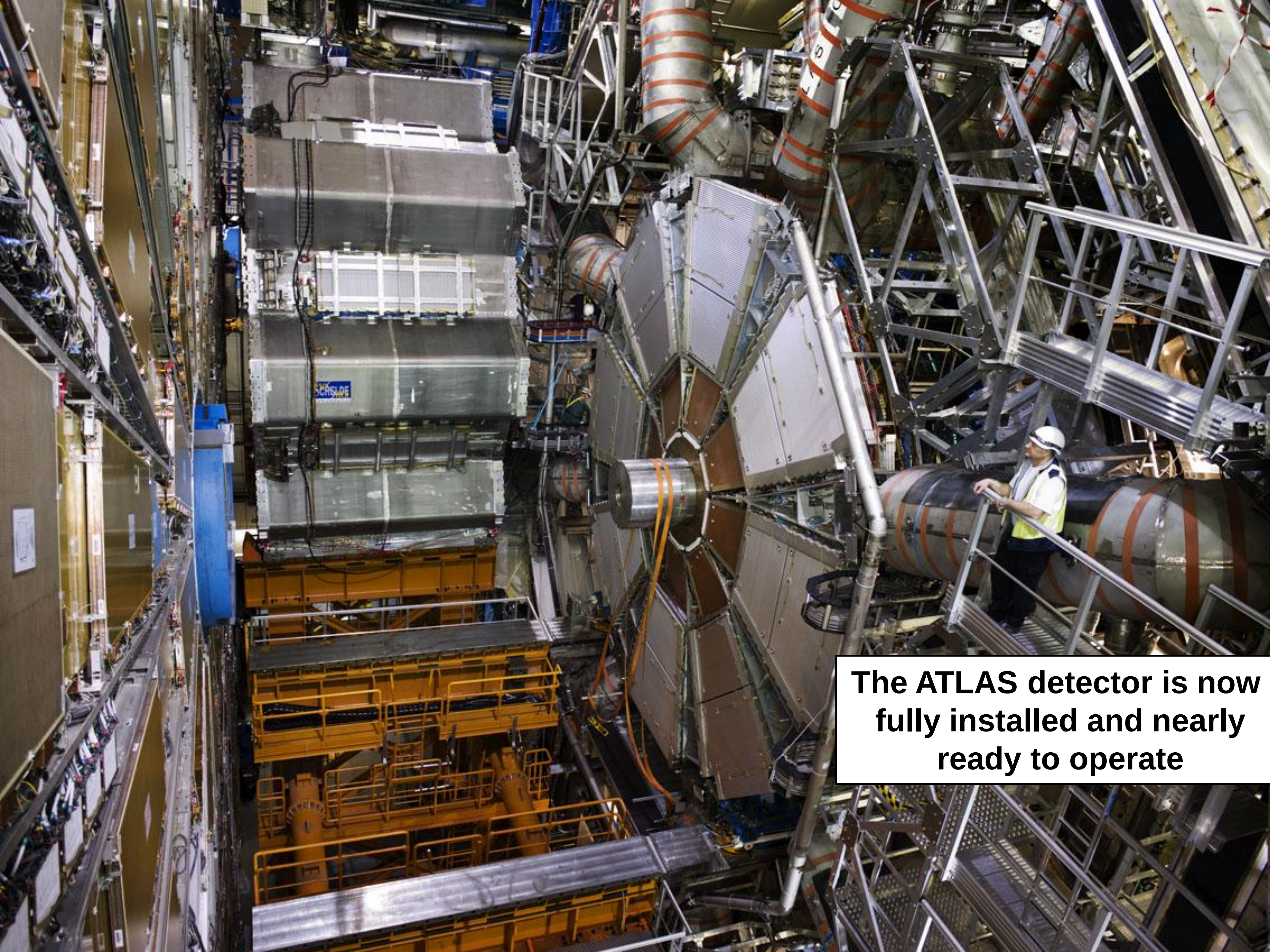


ATLAS End-Cap Toroid installation

Transport and installation done by specialized firms

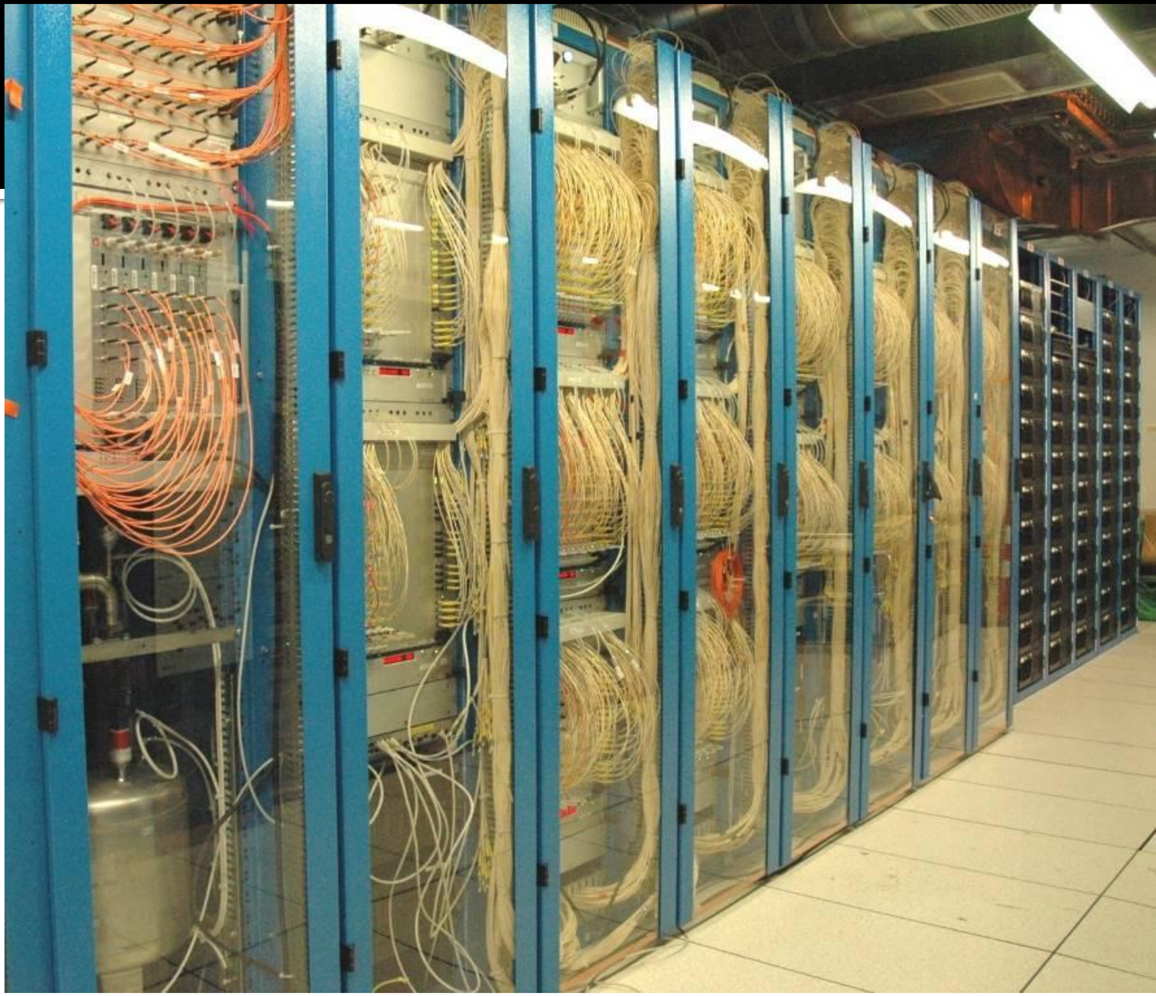
Each one is 250 tons, 15 m high, 5 m wide

Lowered in Summer 2007



The ATLAS detector is now fully installed and nearly ready to operate

Example of LAr calorimeter read-out electronics

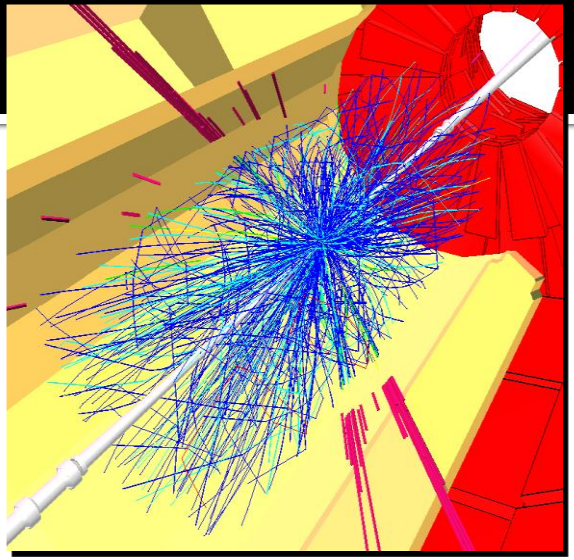


In total about 300 racks with electronics in the underground counting room
More than <u>4000 km of cables</u> and as many pipes to bring services and take data out

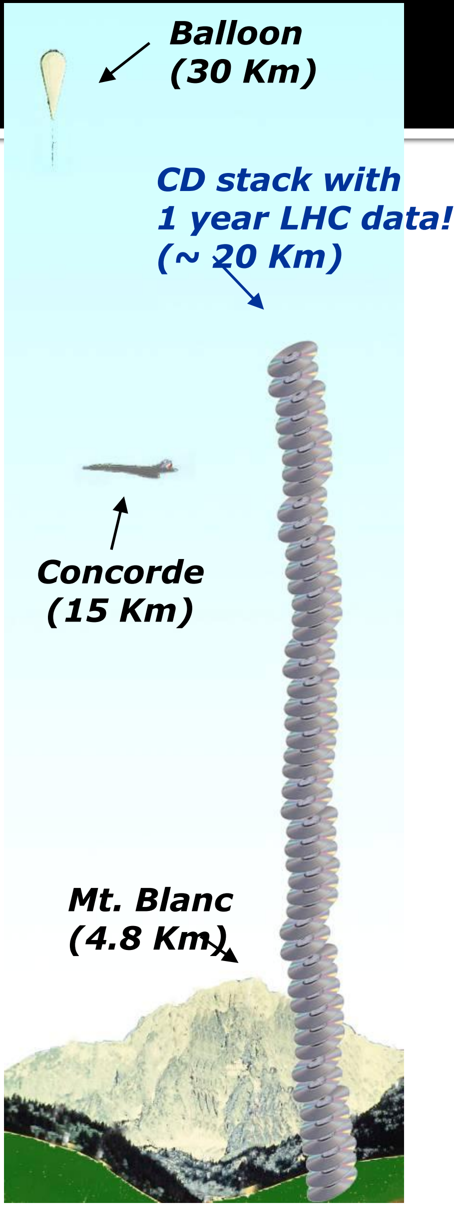
Example of Level-1 Trigger electronics

There is a lot of activity in the ATLAS Control Room with commissioning runs including data taking with cosmic rays, which are distributed over the Grid to all ATLAS institutions

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

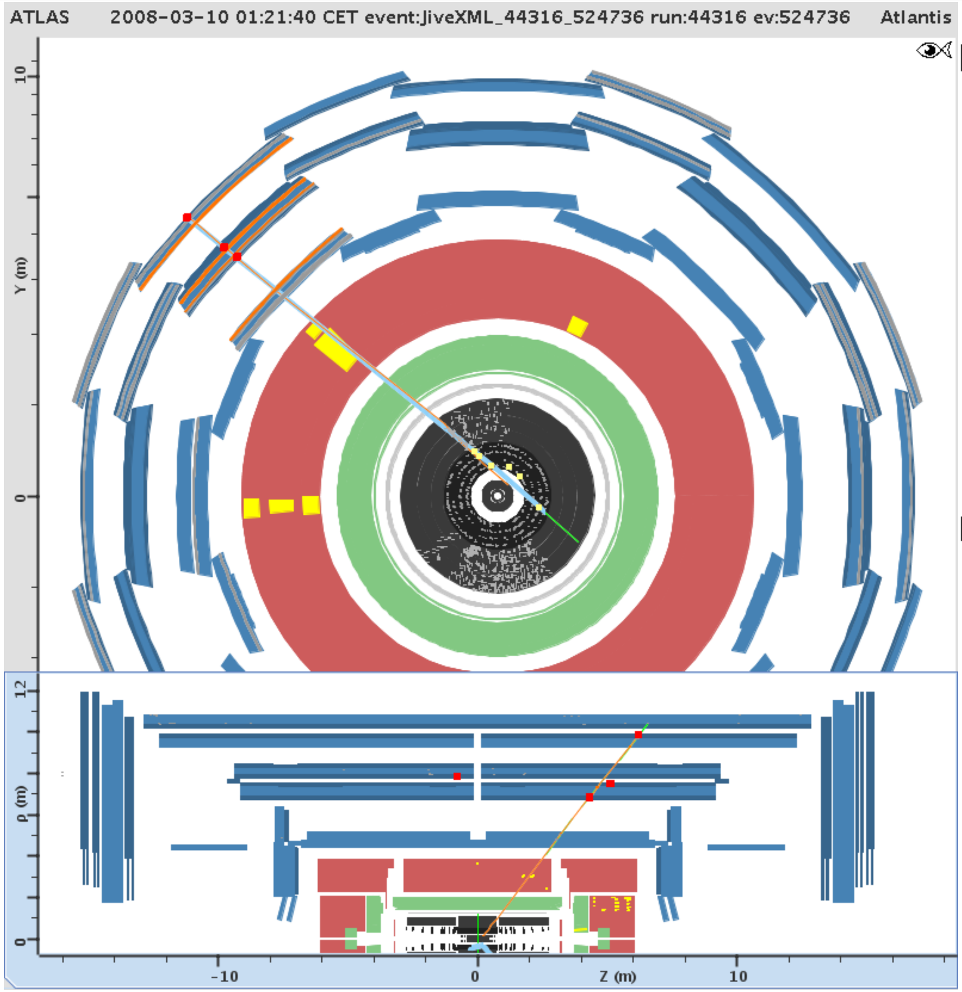


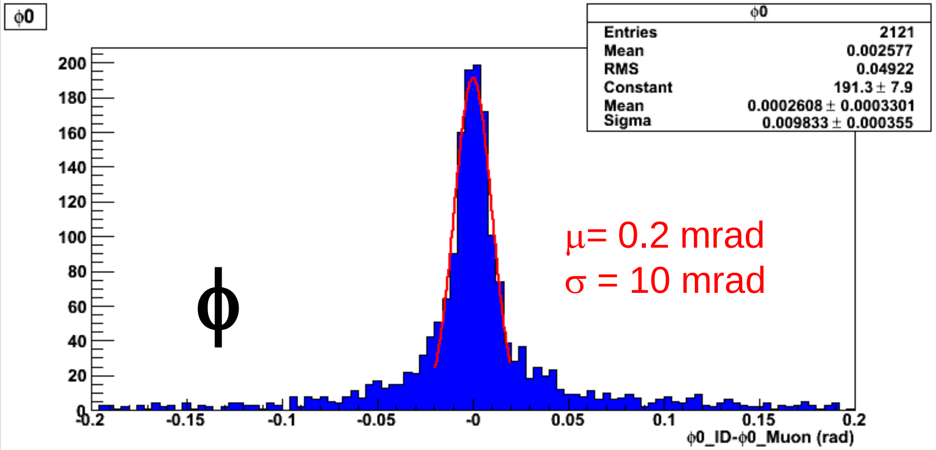
GRID computing developed to solve problem of data storage and analysis

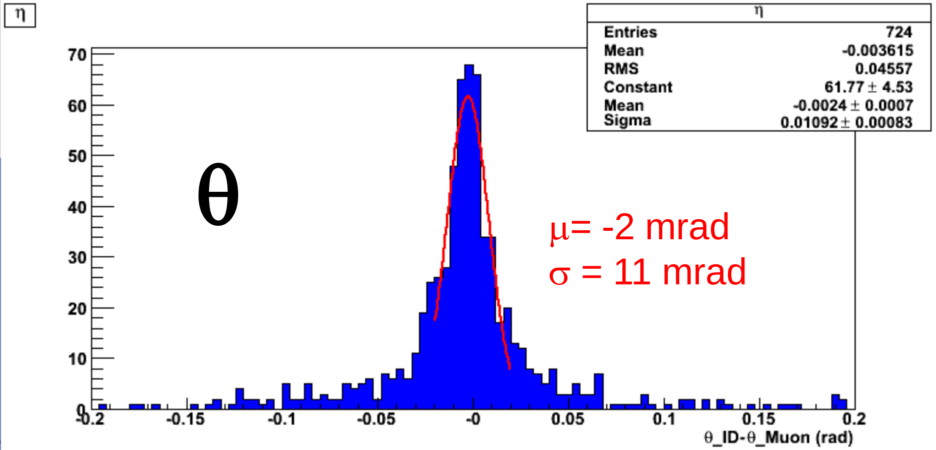
LHC data volume per year:
10-15 Petabytes = 17 million CD

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

Tracking cosmic rays through Muon System and Inner Detector

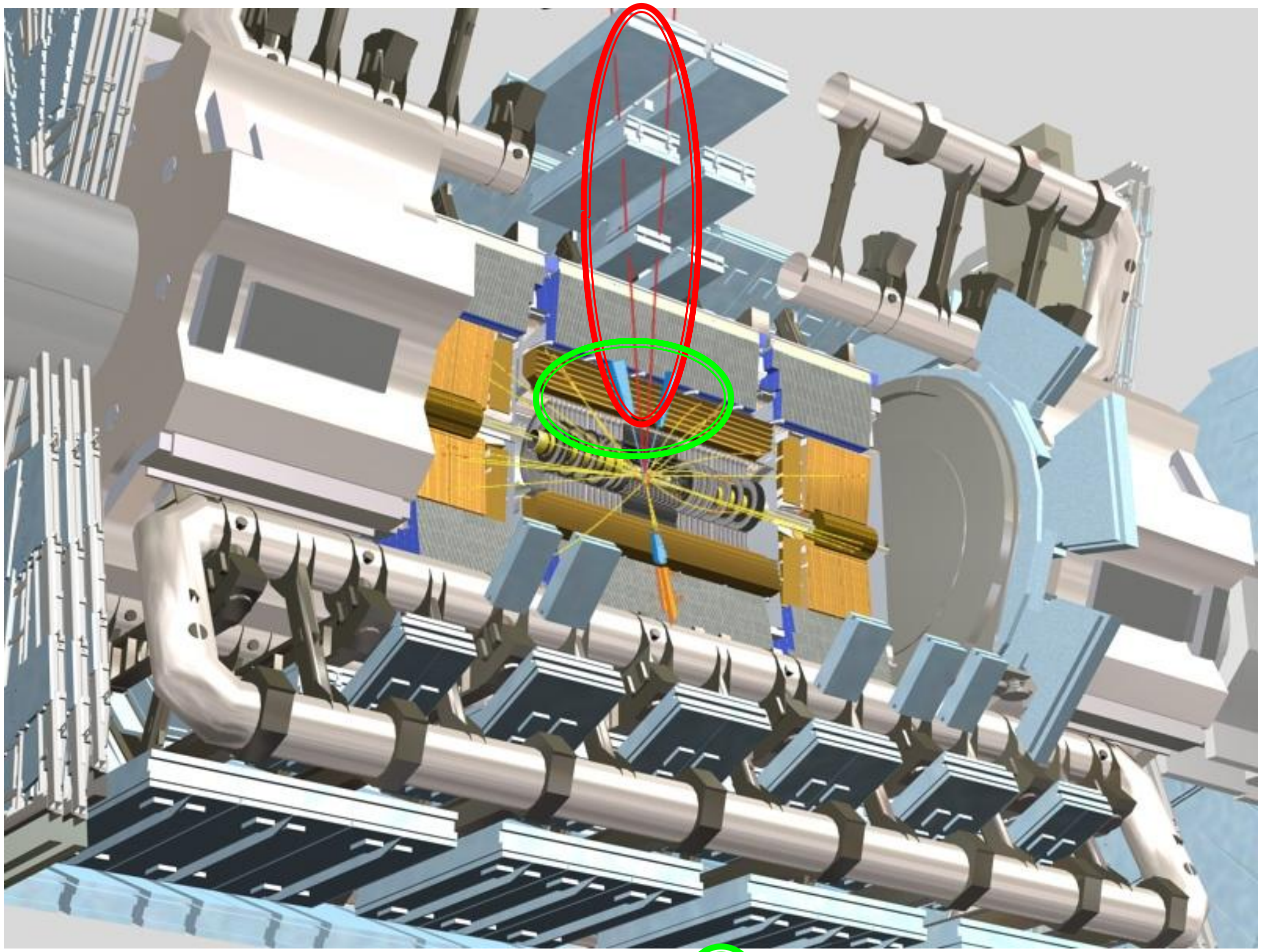






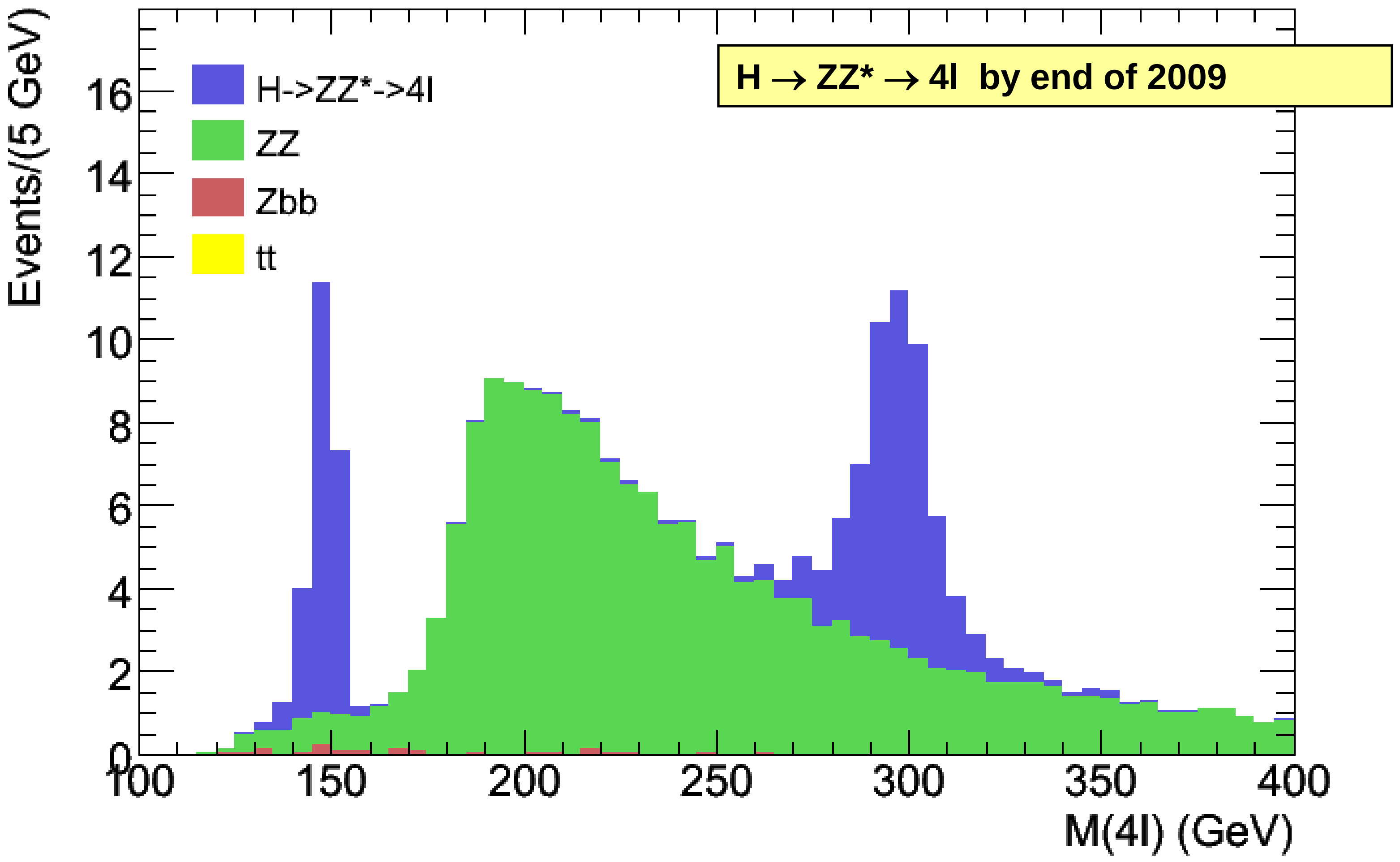
Matching between muon and inner detector tracks

Search for the Higgs boson in ATLAS

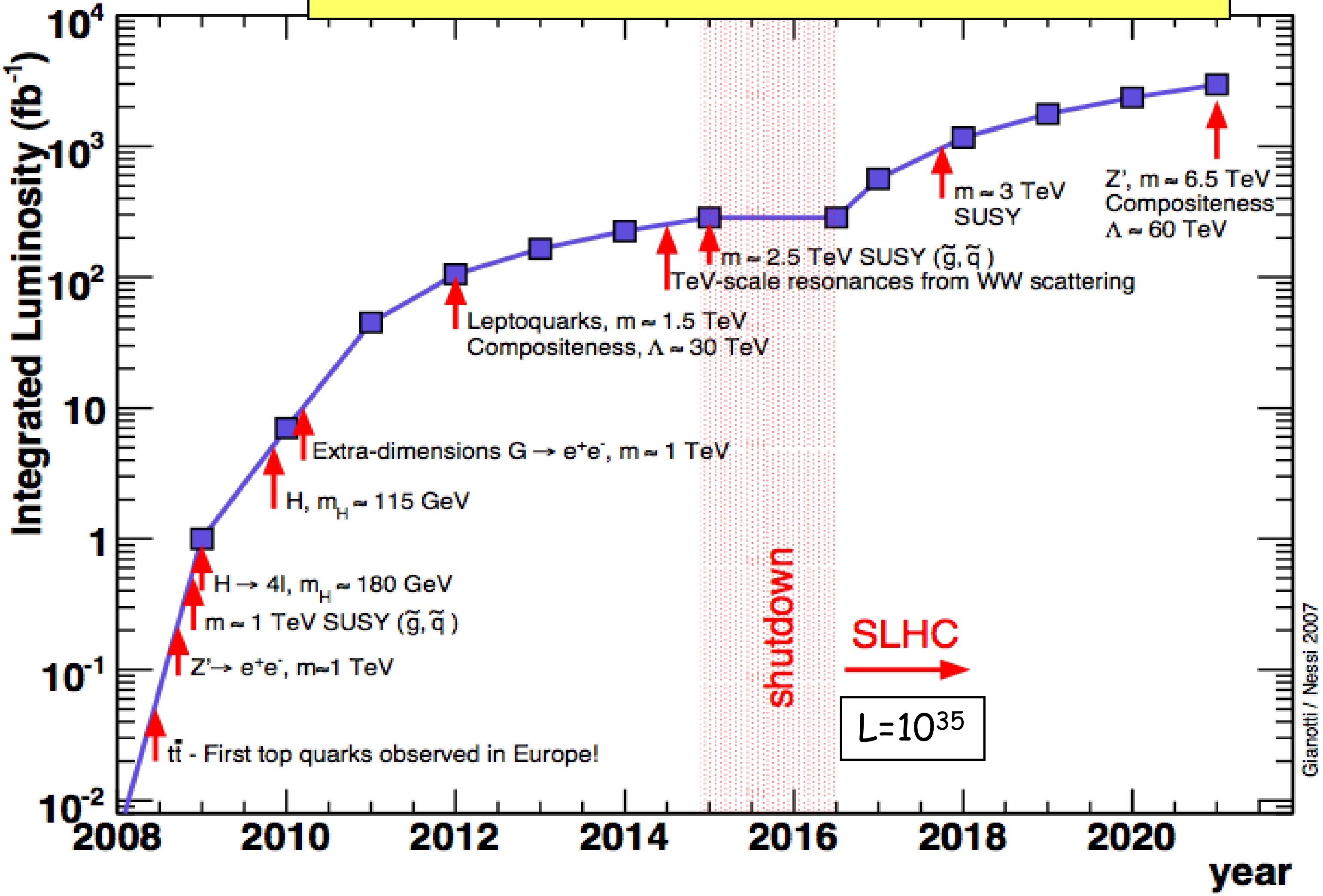


Simulation of a H → μμ ee event in ATLAS

How can we tell we have a Higgs?



LHC discoveries vs time: we can dream !



The coming decade will be exciting for fundamental physics and will shape our understanding of Nature; it is a great privilege to be part of this exploratory adventure

ATLAS Collaboration

(Status May 2008)

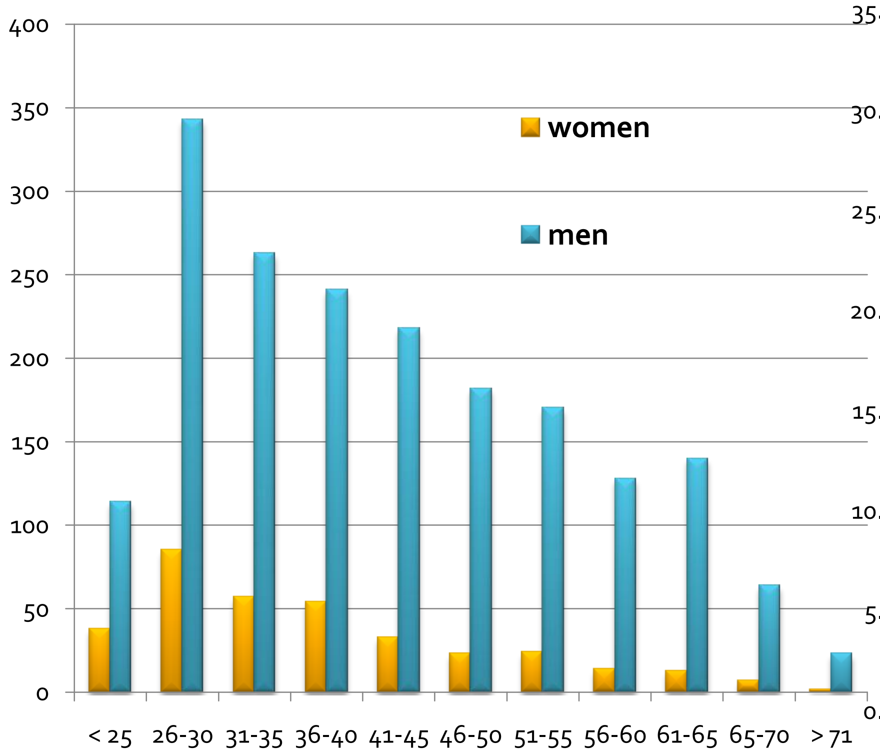
37 Countries
167 Institutions
2235 Scientific authors:

- **349 women**
- **15.6% women**

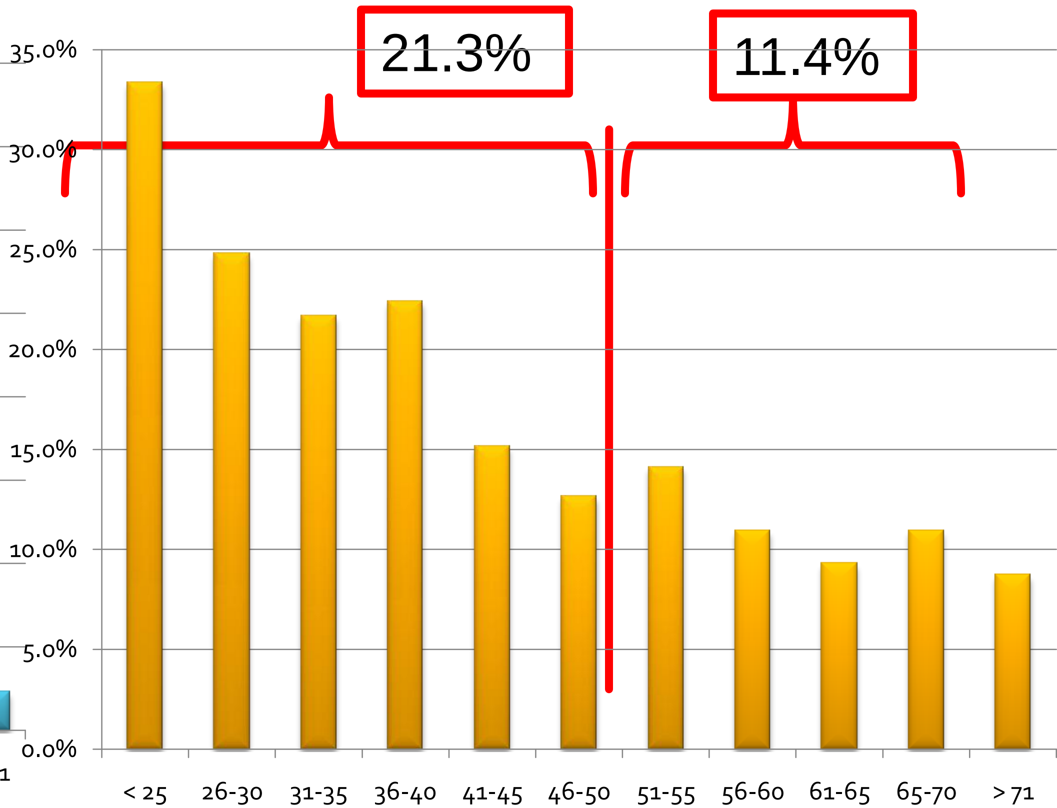
Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Ritsumeikan, UFRJ Rio de Janeiro, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Yale, Yerevan

Age distribution on ATLAS - Women account for 15.6% of all people

Gender per age group



% of women per age group



% of women per country of institute and nationality (only countries with large statistical samples)

Country	women	men	total	% women at institute	% women nationality
Grand Total	341	1825	2166	15.7%	15.7%
Italy	47	151	198	23.7%	24.1%
France	27	113	140	19.3%	18.0%
UK	35	170	205	17.1%	15.3%
Germany	37	222	259	14.3%	11.2%
Canada	12	74	86	14.0%	17.9%
USA	56	385	441	12.7%	10.2%
CERN	15	105	120	12.5%	-
Czech Republic	5	58	63	7.9%	8.5%
Switzerland	2	25	27	7.4%	4.3%
Japan	4	78	82	4.9%	5.7%
Russia	5	105	110	4.5%	6.7%

country educating more women physicists than hiring

country hiring more than educating women in physics

PhD in Physics to women in the world: ATLAS collaboration follows same trend

Best on ATLAS	PhD's	In ATLAS		Worse on ATLAS	PhD's	In ATLAS
Country	%	%		Country	%	%
France	27	18		China-Taipei	13	8
Poland	23	35		United States	13	10
Norway	23	15		Sweden	13	12
Ukraine	23	-		Canada	12	18
Australia	22	20		Mexico	10	---
Turkey	21	40		Germany	9	11
India	20	-		Switzerland	9	4
Denmark	17	14		The Netherlands	9	7
Lithuania	17	-		South Korea	8	-
United Kingdom	16	15		Japan	8	6

Data from 1996-2001   Source: Statistical Research Center, International Study of Women in Physics.

% of women per country of institute: ATLAS average is 15.6%

Country	women	men	% women	error on %	Country	women	men	% women	error on %
Georgia	3	0	100.0%	0.0%	Nederland	6	36	14.3%	5.4%
Colombia	1	1	50.0%	35.4%	Germany	37	222	14.3%	2.2%
Romania	9	9	50.0%	11.8%	Canada	12	74	14.0%	3.7%
Serbia	3	5	37.5%	17.1%	USA	56	385	12.7%	1.6%
Poland	7	14	33.3%	10.3%	CERN	15	105	12.5%	3.0%
Spain	23	50	31.5%	5.4%	Austria	1	9	10.0%	9.5%
Turkey	4	9	30.8%	12.8%	Portugal	2	21	8.7%	5.9%
Argentina	2	5	28.6%	17.1%	Czech Republic	5	58	7.9%	3.4%
Greece	9	24	27.3%	7.8%	Taiwan	1	12	7.7%	7.4%
Denmark	3	9	25.0%	12.5%	Switzerland	2	25	7.4%	5.0%
Italy	47	151	23.7%	3.0%	Japan	4	75	5.1%	2.5%
Brazil	2	7	22.2%	13.9%	Russia	5	105	4.5%	2.0%
Australia	3	11	21.4%	11.0%	Armenia	0	1	0.0%	0.0%
Sweden	7	27	20.6%	6.9%	Azerbaijan	0	3	0.0%	0.0%
Slovenia	2	8	20.0%	12.6%	Belarus	0	4	0.0%	0.0%
France	27	113	19.3%	3.3%	Chile	0	5	0.0%	0.0%
UK	35	170	17.1%	2.6%	China	0	14	0.0%	0.0%
Norway	3	16	15.8%	8.4%	Morrocco	0	3	0.0%	0.0%
Israel	5	27	15.6%	6.4%	Slovakia	0	12	0.0%	0.0%

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Is the large fraction of women in a country related to the salary level?

High % of women

- In Georgia, Romania, Greece, Turkey
  - **No male Georgian physicist works in Georgia**
  - **11 male and 1 female Georgians outside Georgia**
- Also high fractions of women in France, Italy and UK

Physicists salaries are low or modest in all these countries

Very low % of women

- In Japan, USA, CERN and Switzerland, salaries are high

Also very low % of women
in Russia or Czech Republic but salaries are not high there

I am not a statistician but one wonders….

ATLAS women in their institutes

		# people in institute	
# women per institute	# institutes	Average # people	Range of people
0	58	6.4	1-41
1	28	9.0	2-46
2	27	11.4	4-29
3	21	11.8	3-33
4	12	15.2	9-36
> 4	21	22.7	10-120
total 341	167	11.0	1-120

- On average, each institute has 9 men and 2.0 women
- Half the institutes still have only one or no women

Women are generally fairly isolated

Women at big national laboratories

ATLAS Institutes	Country	women	men	% women
Argonne	USA	1	18	5.3%
Brookhaven	USA	0	41	0.0%
SLAC	USA	1	16	5.9%
DESY	Germany	8	20	28.6%
JINR	Russia	1	45	2.2%
RAL	UK	2	21	9.5%
Saclay	France	7	20	25.9%
CERN	CERN	15	105	12.5%

In general, big national laboratories are not setting an example for their countries, except for DESY and Saclay which are above the national average

ATLAS organization

ATLAS management:
spokesperson
2 deputy spokesperson
resource coordinator
technical coordinator.

Collaboration Board:
chair
deputy chair

Project leaders:
SCT
Pixels
TRT
Inner Detector
LAr
TileCal
Muons

Executive Board

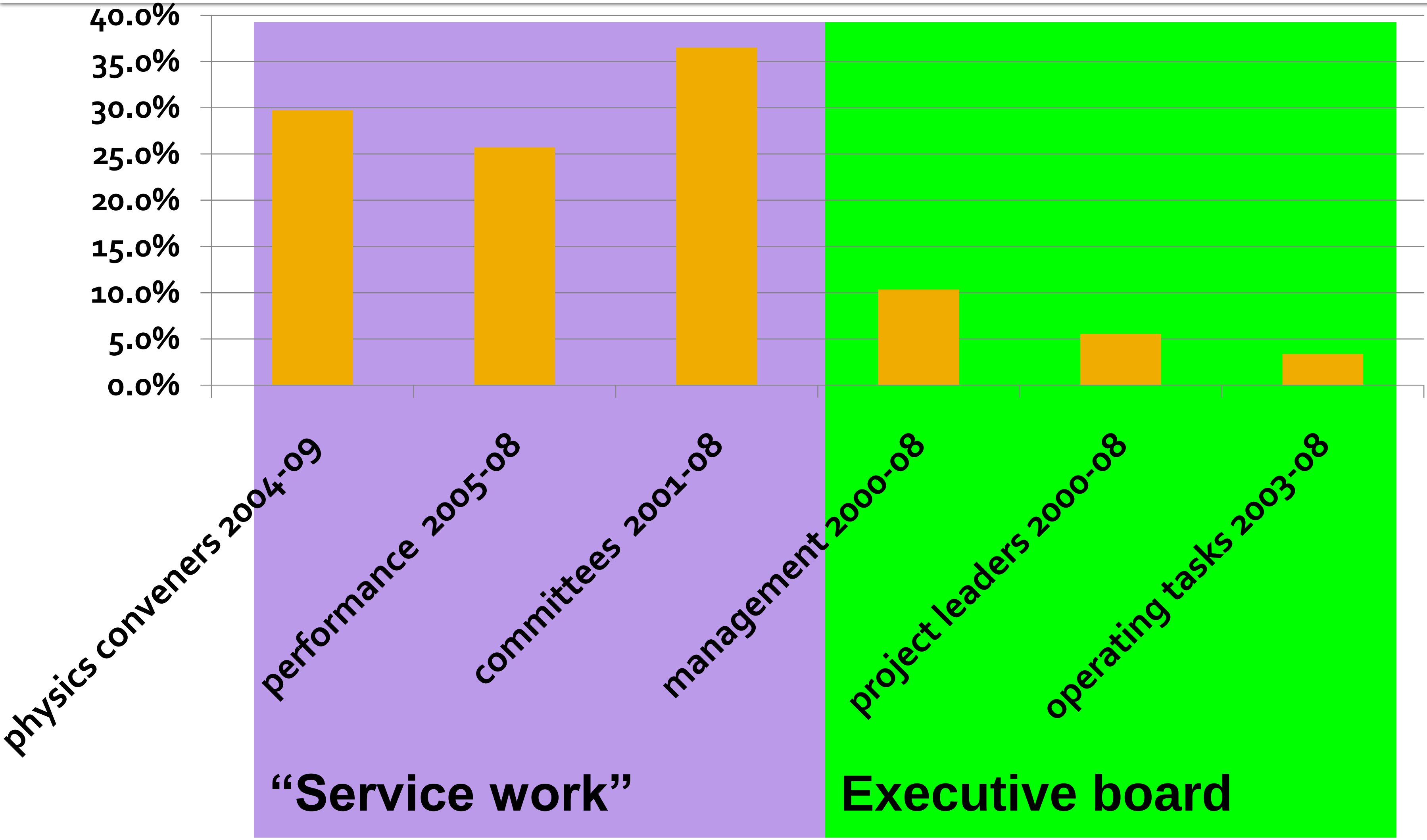
Committees:
publication committee,
authorship committee
speakers committee

Operation tasks:
run coordinator
trigger coordinator
computing coordinator
data preparation coordinator
physics coordinator

Performance groups:
e/gamma
Muon
B-tagging
Jets/Etmiss
tau

Physics groups:
Standard Model
Higgs
SUSY
Exotics
Top
b physics

Responsibilities by gender in ATLAS (2000-09) % of women per cumulative person year



Responsibilities by gender in ATLAS (2000-09) % of women per year

Female spokesperson elected last Friday

• Fabiola Gianotti was elected last Friday as next spokesperson for the ATLAS collaboration

• This is the first time a woman is elected as head of such a large collaboration

• A smaller experiment (CDF at Fermilab) had Young-Kee Kim as co-spokersperson

Fabiola Gianotti

• Young-Kee Kim is now Fermilab deputy lab director and Persis Drell is SLAC director. These are 2 of the leading High Energy Physics laboratories.

What can be drawn from this?

On the bright side:

- The fraction of women is increasing in ATLAS: many young women in the pipeline
- 25-30% of physics conveners and committee members are women, and this trend is increasing
- These women are gaining visibility and experience, and will be prime candidates for higher positions

On the not so bright side

- We still have a "leaky pipe"
- Women only account for 5% of the executive board
- Women are predominantly in "service" jobs, not decision making positions
- Many women are still isolated in their home institutes
- Most national labs have less women than universities

Recent study on gender bias

- Sherry Towers, formerly a physics post-doc on another collaboration similar to ATLAS published a study showing gender bias for post-docs **(see http://arxiv.org/abs/0804.2026)**
- She uses internal papers to assess individual productivity since journal publications are signed by >800 collaborators!
- Using that criterion, she shows that female were on average more productive than male post-docs but were allocated 1/3 the amount of conference presentations male peers received
- She argues that giving conference presentations is a key factor to predict future outcome, that is, who would get a job. Men and women obeyed different models

The ATLAS Women's Network

- A handful of women decided to start a network for women working on the ATLAS experiments in the Fall of 2005
- We first created a mailing list and a website:

https://twiki.cern.ch/twiki/bin/view/Atlas/AtlasWomenPage

- We meet during large collaboration meetings and weekly for lunch for informal discussion
- About 80-100 women have participated at least once in one of our activities

Our achievements

- We have created an effective network of women
  - Support each other and break the isolation
  - Facilitate the dissemination of information among women
  - Provide an opportunity for women from outside institutes to meet other women when visiting CERN
- We successfully supported a woman at the second highest management position in ATLAS
- We started many initiatives at CERN:
  - Ombudsperson inititiave
  - Childcare initiative

How can we grow bigger and better?

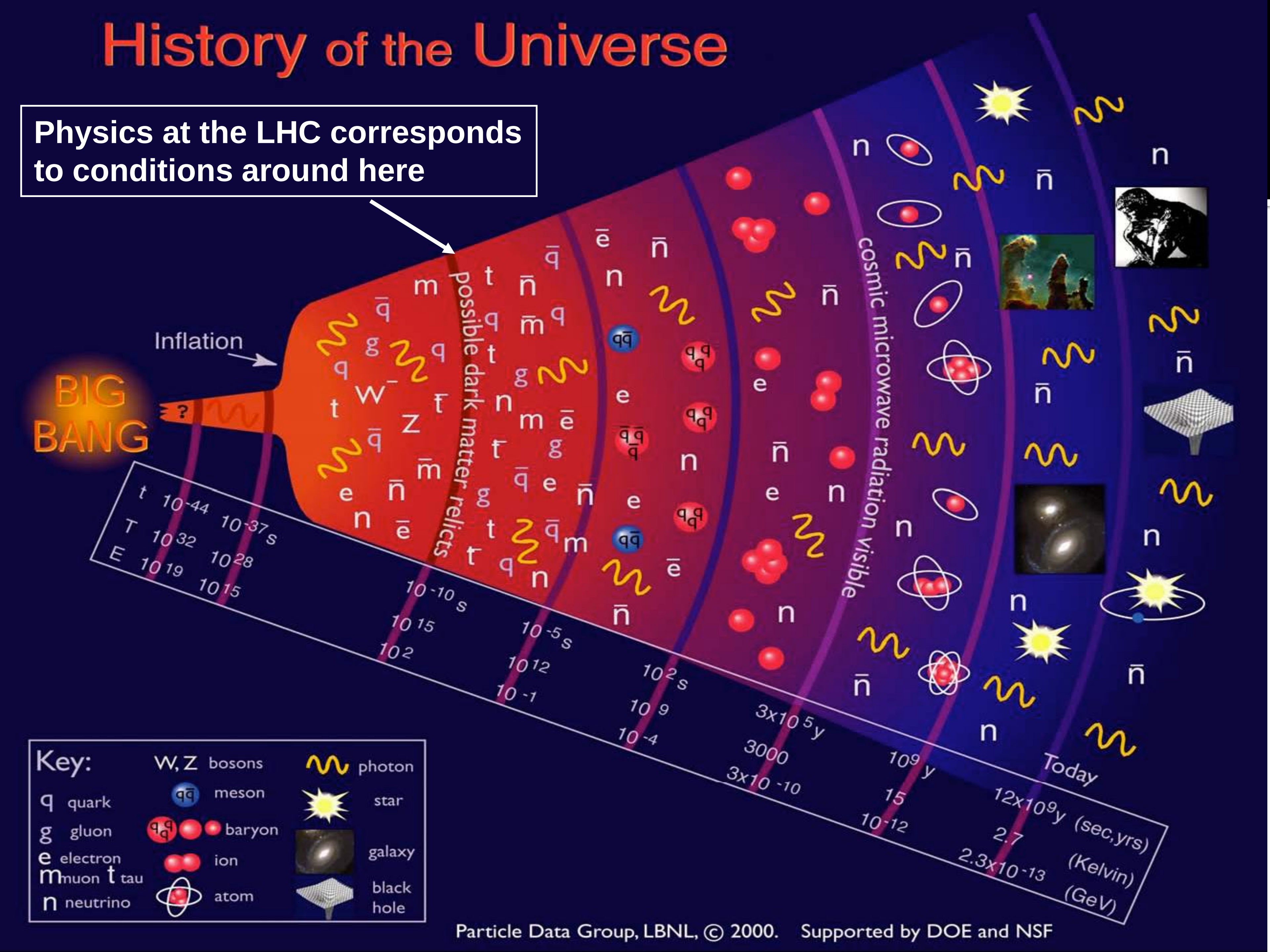
- We are still facing lots of reluctance from many female colleagues
  - Fear of being seen as a feminist
  - Nobody wants to be part of a discriminated group
  - Many women do not think there is discrimination
- Many cultural differences

Replace the way a typical ATLAS meeting looks like…

… by good food and good company!

Back-up slides

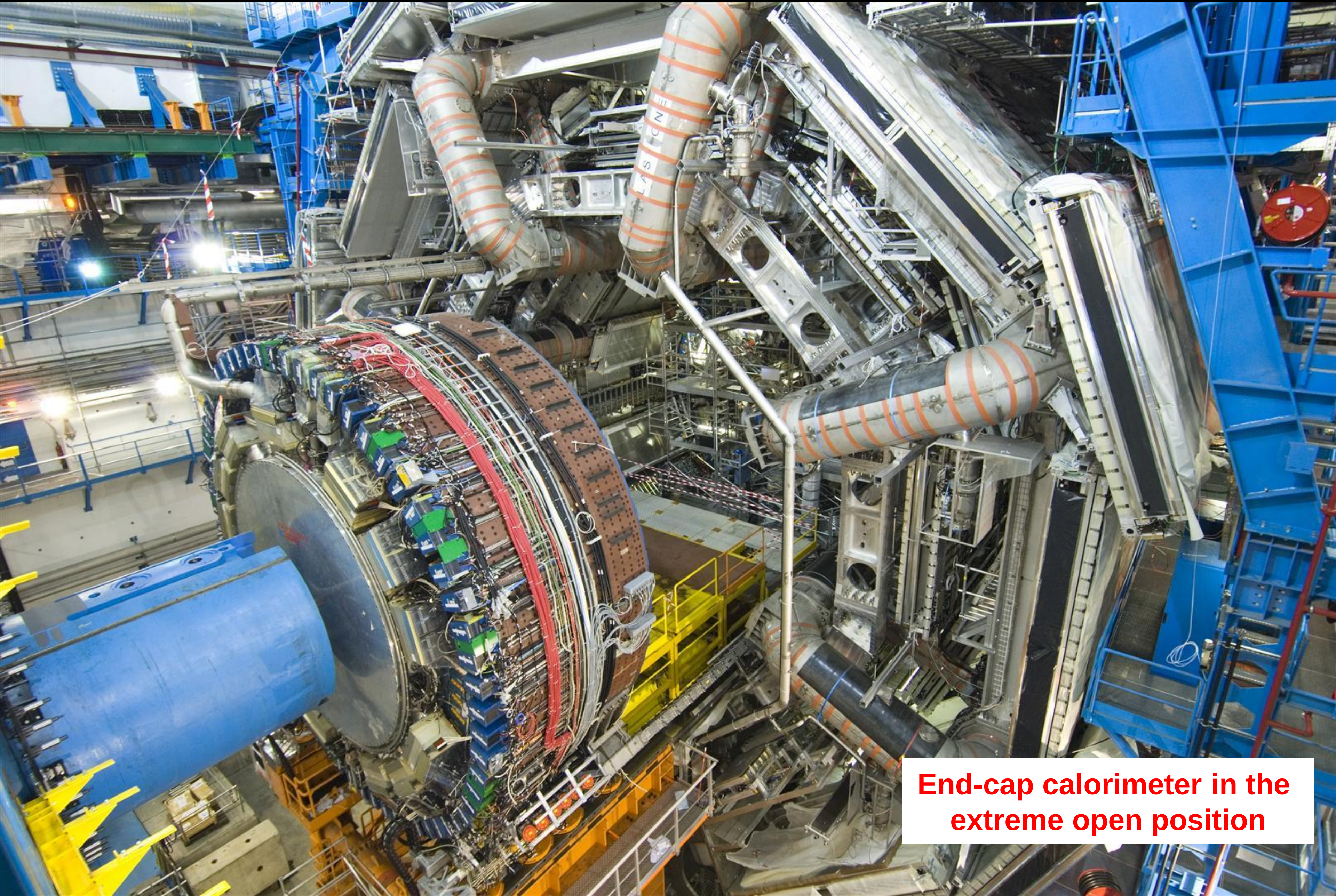
Physics at the LHC corresponds to conditions around here



Descent of the last dipole magnet, 26 April 2007

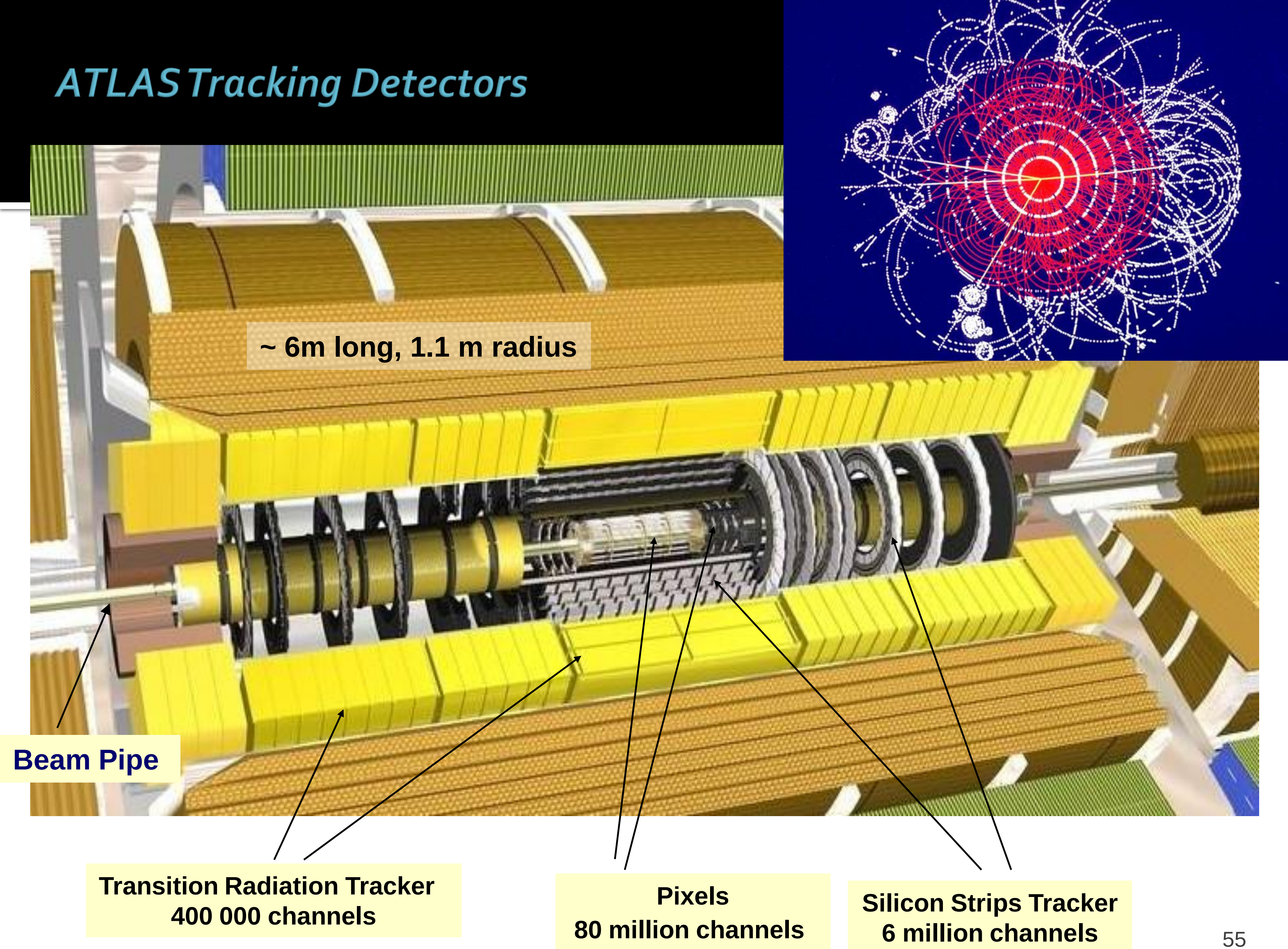
30’000 km underground transports at a speed of 2 km/h!

All calorimeters are installed, and the three LAr cryostats are cold and filled with LAr

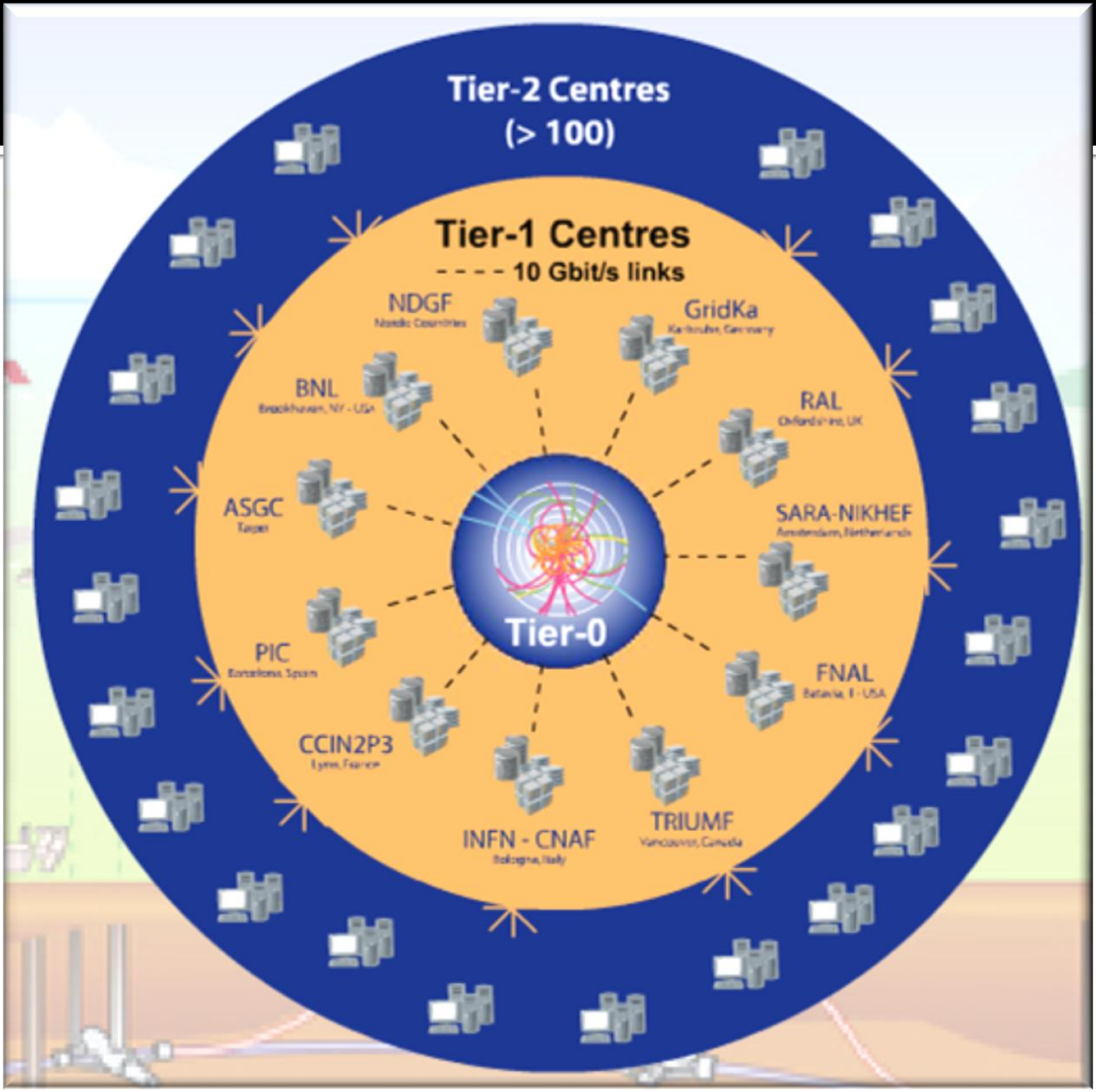


End-cap calorimeter in the extreme open position

ATLAS Tracking Detectors



WLCG Grid



Tier-0 (CERN):

- Data recording
- First-pass reconstruction
- Data distribution

Tier-1 (11 centres):

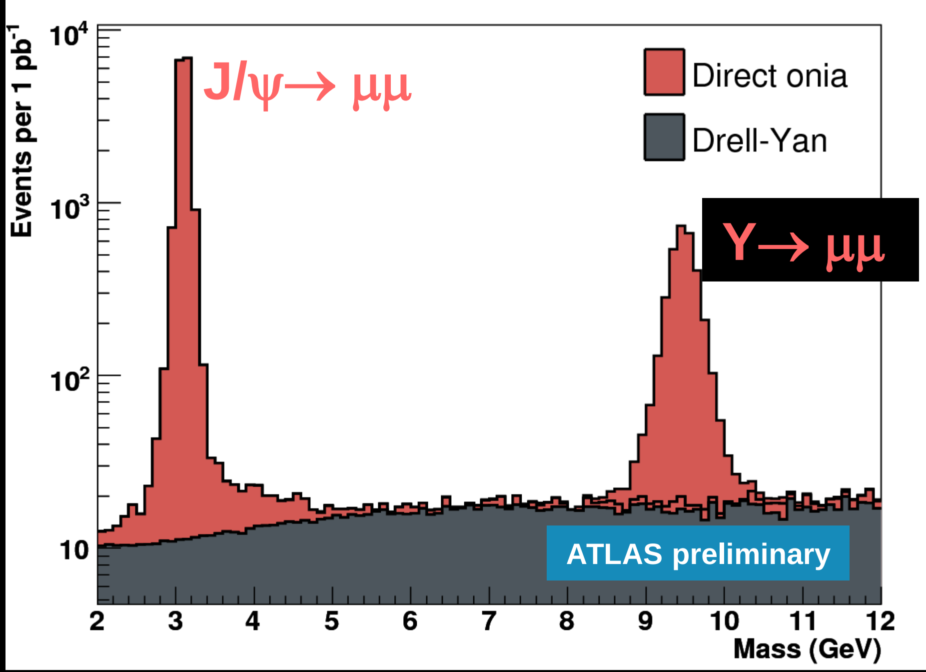
- Permanent storage
- Re-processing
- Analysis

Tier-2 (>200 centres):

- Simulation
- End-user analysis

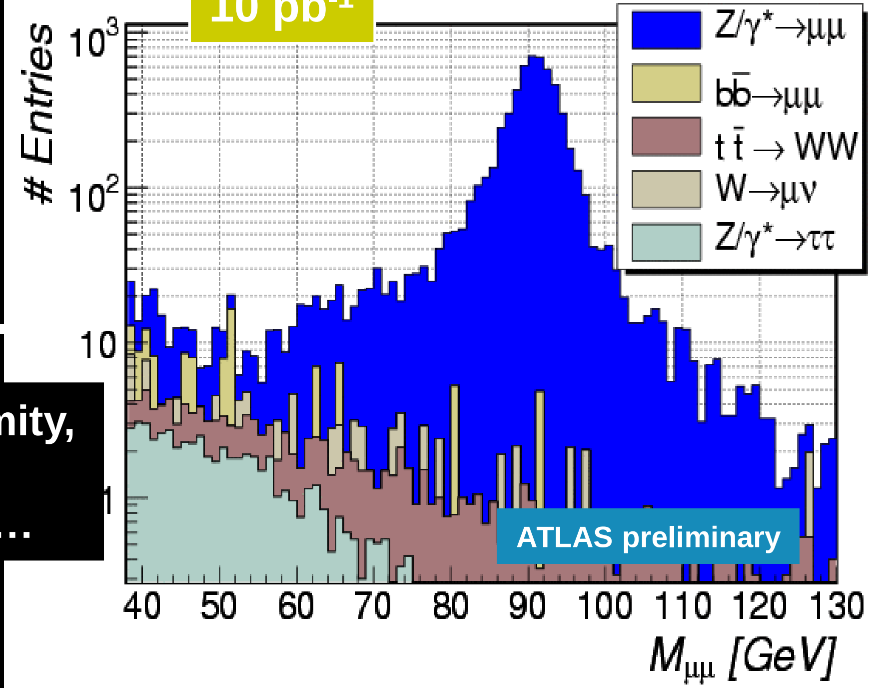
The first checks: reproduce known physics to prove that the detector works well

1 pb^{-1} ≡ 3 days at 10^{31} at 30% efficiency



→ tracker momentum scale, trigger performance, detector efficiency, sanity checks, …

10 pb^{-1}

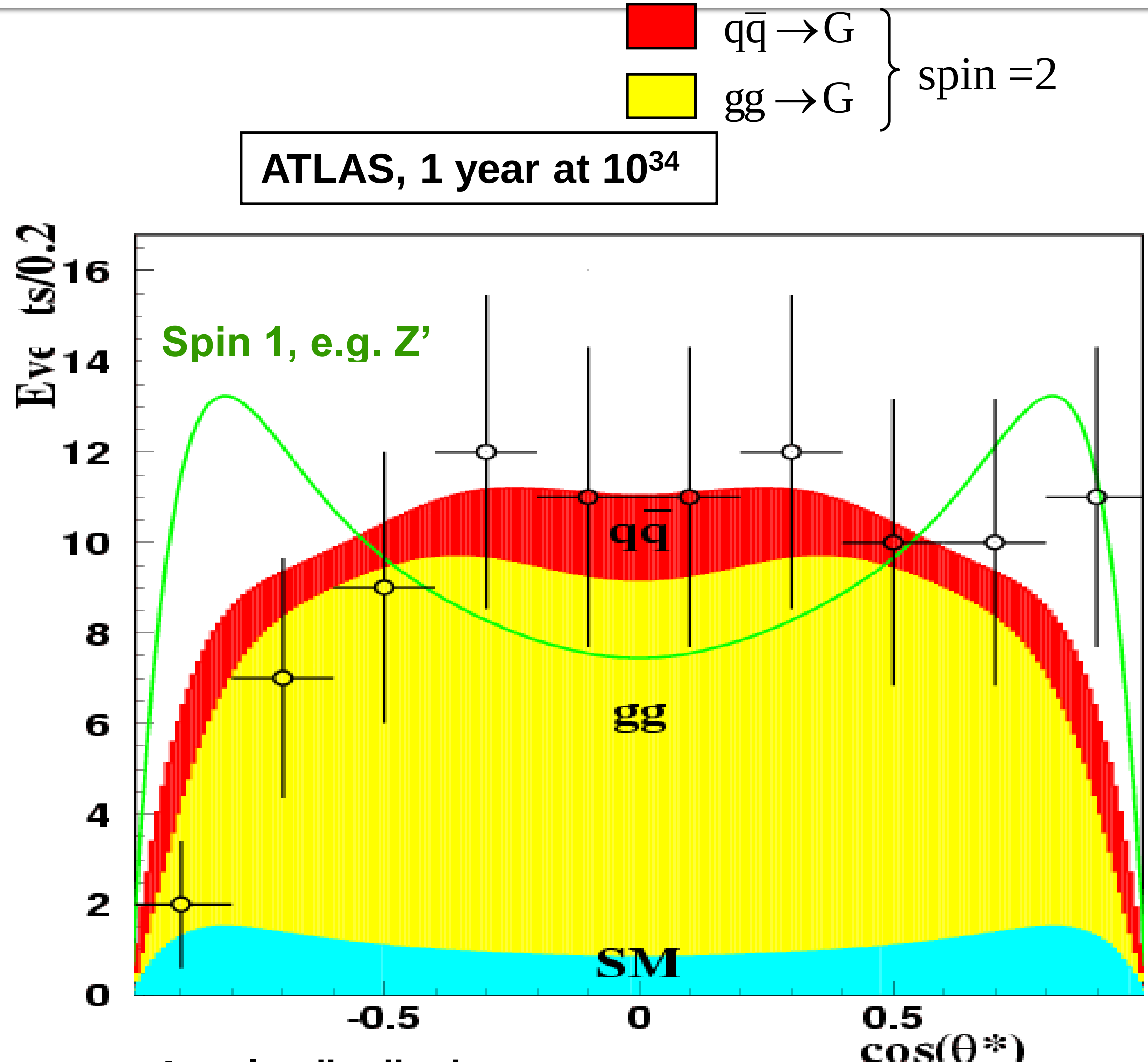


→ Muon Spectrometer alignment, ECAL uniformity, energy/momentum scale of full detector, lepton trigger and reconstruction efficiency, …

Warped Extra-Dimensions (Randall-Sundrum models): production of narrow Graviton resonances

Best discovery channel : $qq, gg \rightarrow G \rightarrow e^+e^-$

Lisa Randall visiting ATLAS



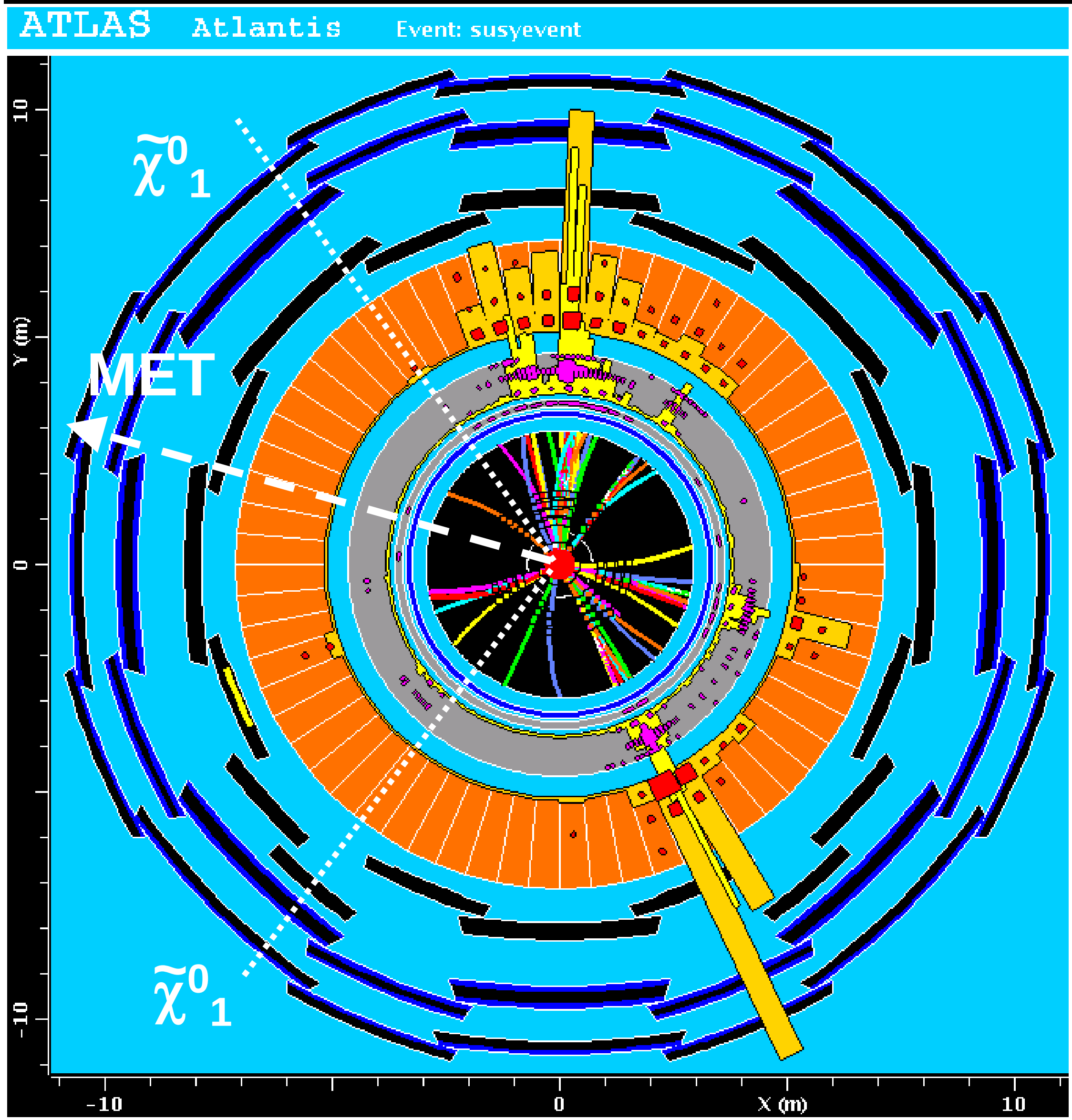
Angular distribution

Dark Matter at LHC

- Characteristic signature for Dark Matter production at ATLAS: Missing Transverse Energy ('MET')

- Valid for any Dark Matter candidate (not just SUSY)

Combine LHC and Astroparticle physics data in order to prove that a SUSY particle observed at LHC would be the Dark Matter particle…



Women on ATLAS per nationality above ATLAS average

Nationality	# women	# men	total	% women	% error
Romanian	11	16	27	40.7%	9.5%
Turkish	8	12	20	40.0%	11.0%
Polish	12	22	34	35.3%	8.2%
Greek	17	34	51	33.3%	6.6%
Spanish	23	59	82	28.0%	5.0%
Italian	66	217	283	23.3%	2.5%
Israeli	7	26	33	21.2%	7.1%
French	28	132	160	17.5%	3.0%
Canadian	12	59	71	16.9%	4.4%
ATLAS average	**349**	**1886**	**2235**	**15.6%**	0.8%

Women on ATLAS per nationality above ATLAS average

Nationality	# women	# men	total	% women	% error
British	28	153	181	15.5%	2.7%
Norwegian	3	17	20	15.0%	8.0%
Swedish	4	30	34	11.8%	5.5%
German	31	247	278	11.2%	1.9%
American	26	223	249	10.4%	1.9%
Czech	6	67	73	8.2%	3.2%
Chinese	4	49	53	7.5%	3.6%
Dutch	3	41	44	6.8%	3.8%
Portuguese	2	29	31	6.5%	4.4%
Russian	9	132	141	6.4%	2.1%
Japanese	5	86	91	5.5%	2.4%
Austrian	1	20	21	4.8%	4.6%
Swiss	1	22	23	4.3%	4.3%

Most significant countries (< 3% error)

Nationality	# women	# men	total	% women	% error
Italian	66	217	283	23.3%	2.5%
French	28	132	160	17.5%	3.0%
British	28	153	181	15.5%	2.7%
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ATLAS average	**350**	**1887**	**2237**	**15.6%**	0.8%

Responsibilities by gender in ATLAS (2000-09) % of women per cumulative person year