The Long Journey to the Higgs Boson and Beyond with Howard
(and highlights from ATLAS)

Gordon Fest

BNL, 2nd October 2017

The plan:

A bit about the history of the LHC
A bit about the history of ATLAS
About the US and BNL in LHC and ATLAS
Examples of technical challenges
Comment on computing
Some physics highlights results
- *Standard Model*
- *Higgs (combination with CMS)*
- *Beyond the SM searches*

Outlook

And of course Howard's impact and role in all of that!

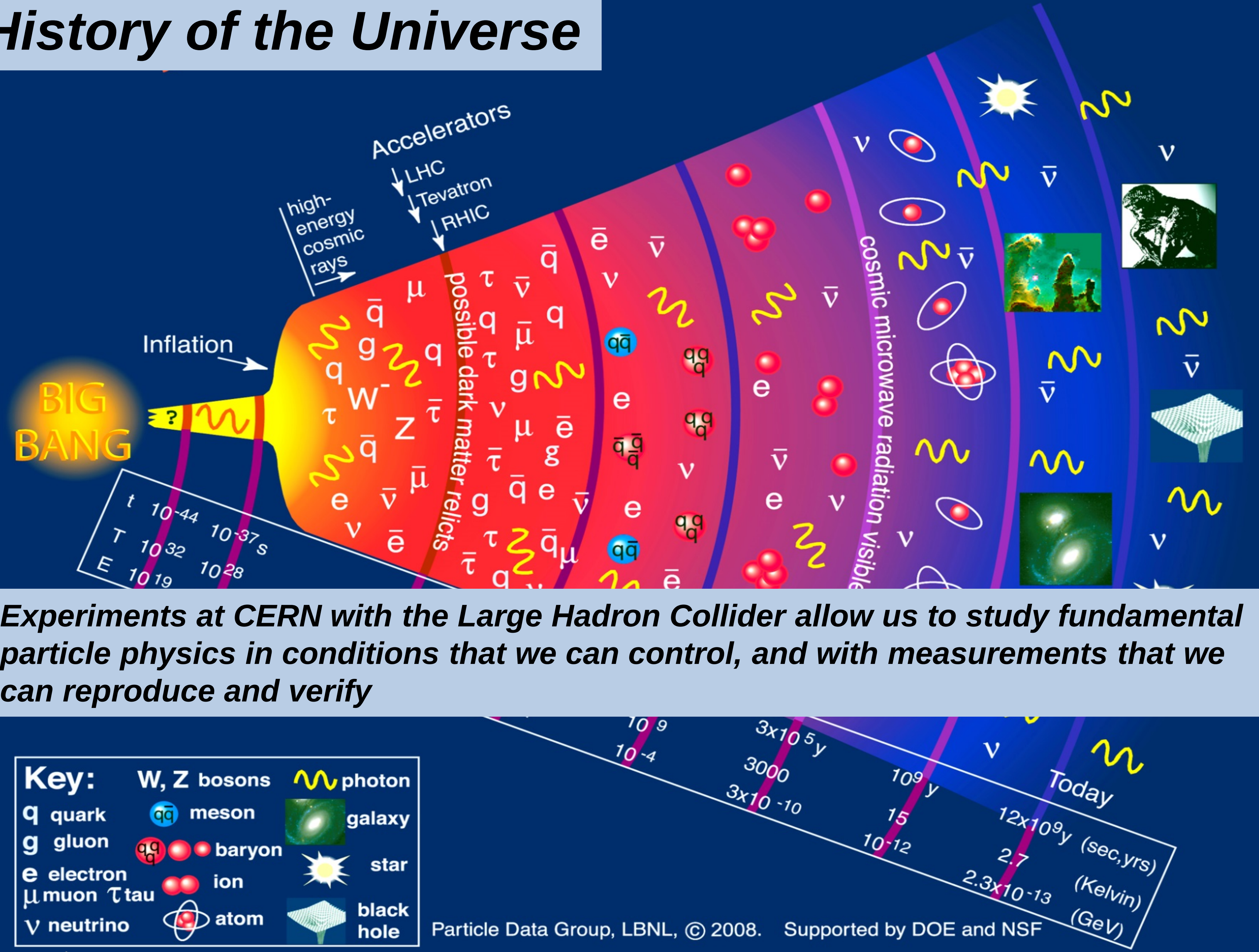
Drawing by Sergio Cittolin

Peter Jenni, Freiburg and CERN

The Large Hadron Collider project is a global scientific adventure, which was initiated more than 30 years ago, combining the accelerator, the experiments, a worldwide computing grid, and with lots of motivation from our theory colleagues

It is a great privilege and pleasure to talk now about physics results

History of the Universe



Experiments at CERN with the Large Hadron Collider allow us to study fundamental particle physics in conditions that we can control, and with measurements that we can reproduce and verify

How the LHC came to be …

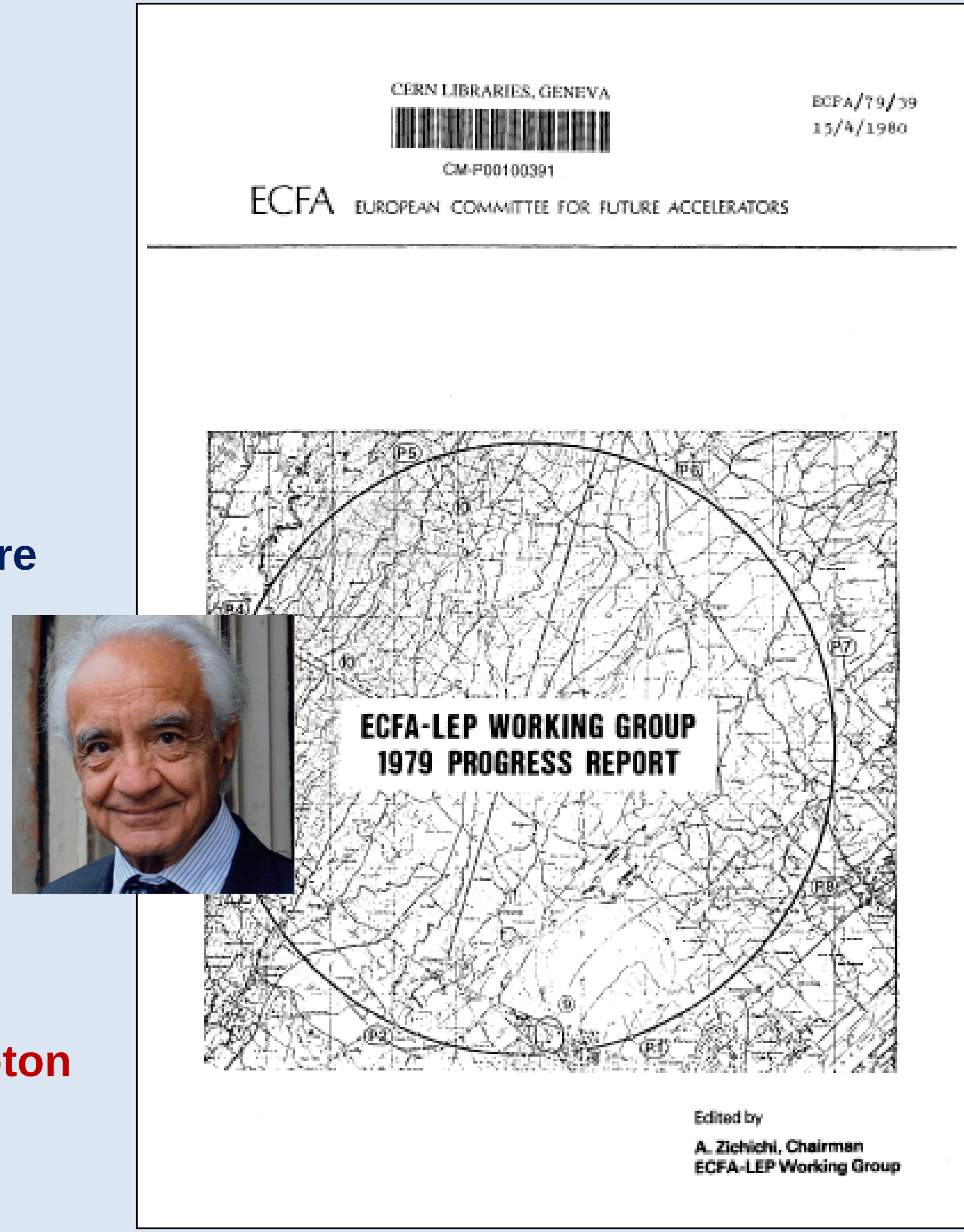
Some very early key dates

1977 The community talked about the LEP project, and it was already mentioned that a new tunnel could also house a hadron collider in the far future

1979 LEP White Book:

ECFA-LEP Working Group 1979 chaired by A Zichichi

‘Tunnel with 27 km circumference and a diameter of 5 m, with a view to the replacement of LEP at the end of its activities by a proton-proton Collider using cryogenic magnets’


CERN LIBRARIES, GENEVA
CM-P00100391
ECFA/79/39
15/4/1980

ECFA EUROPEAN COMMITTEE FOR FUTURE ACCELERATORS

ECFA-LEP WORKING GROUP
1979 PROGRESS REPORT

Edited by
A. Zichichi, Chairman
ECFA-LEP Working Group

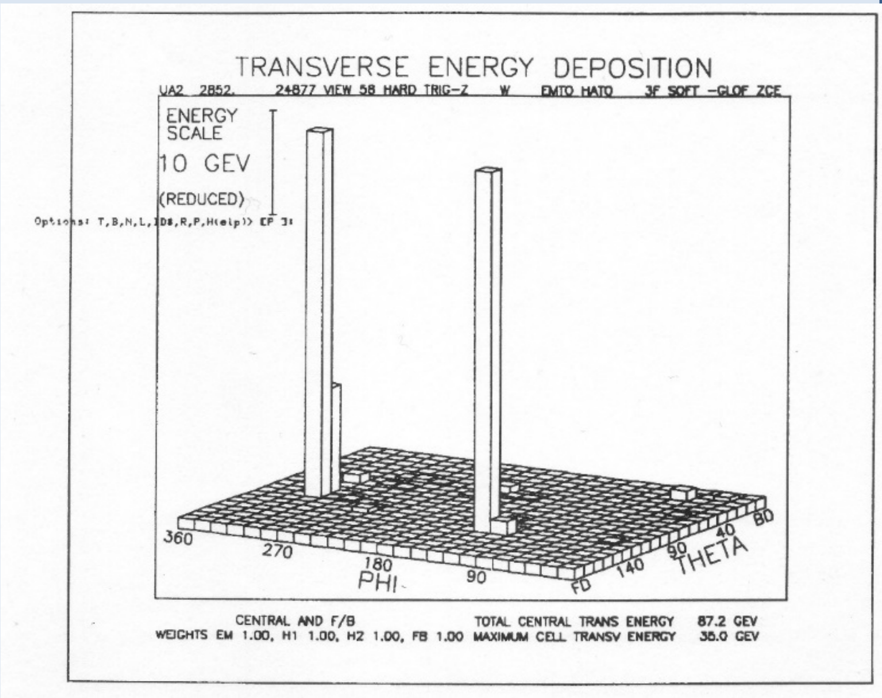
1981 LEP was approved with a large and long (27 km) ring tunnel

Herwig Schopper
CERN DG 1981 - 1988

1983 The early 1980s were crucial

The real belief that a 'dirty' hadron collider can actually do great discovery physics came from UA1 and UA2 with their W and Z boson discoveries at CERN

A very early Z → ee online display from one of the detectors (UA2)

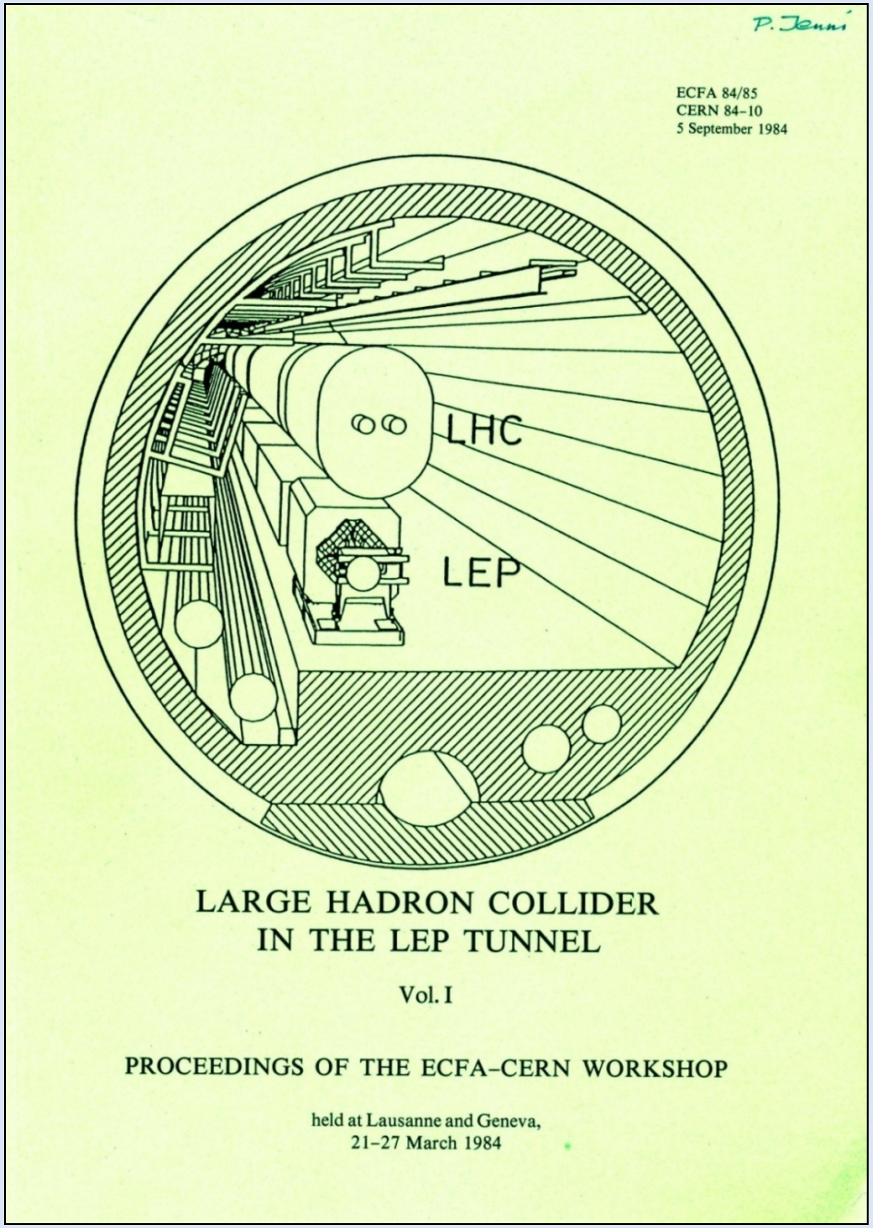


1984 For the community it all started with the CERN - ECFA Workshop in Lausanne on the feasibility of a hadron collider in the future LEP tunnel

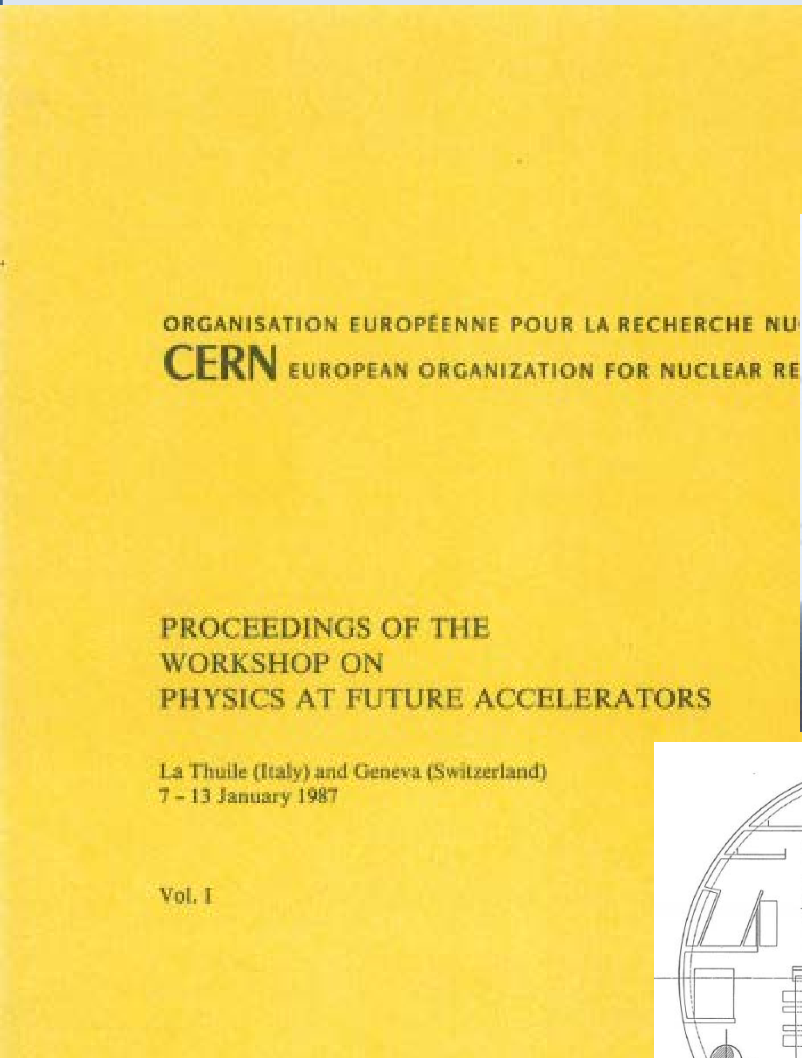
1986 LAA R&D on new detector technologies started, later followed by the DRDC

1987 La Thuile Workshop

Many LHC colleagues were already involved in this WS set up by Carlo Rubbia as part of the Long Range Planning Committee



Some history: 30 years ago …
La Thuile 7 – 13 January 1987
(Carlo Rubbia's Long Range Planning Committee)


CERN 87-07
Vol. I
4 June 1987

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NU
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RE

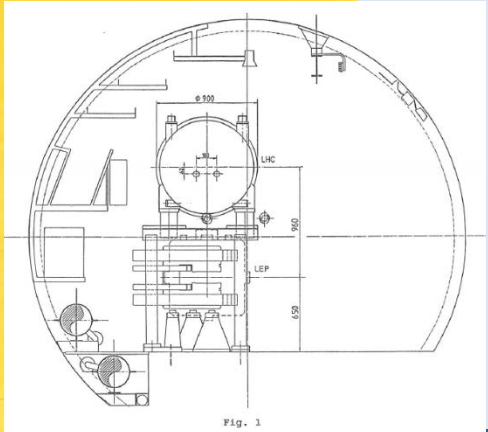
PROCEEDINGS OF THE
WORKSHOP ON
PHYSICS AT FUTURE ACCELERATORS

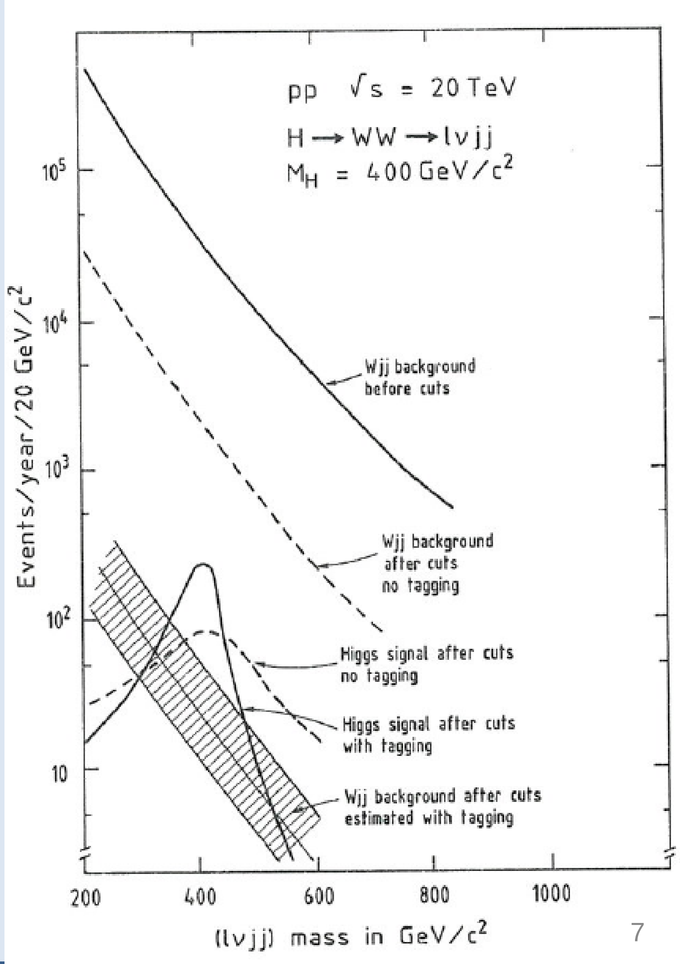
La Thuile (Italy) and Geneva (Switzerland)
7 - 13 January 1987

Vol. I

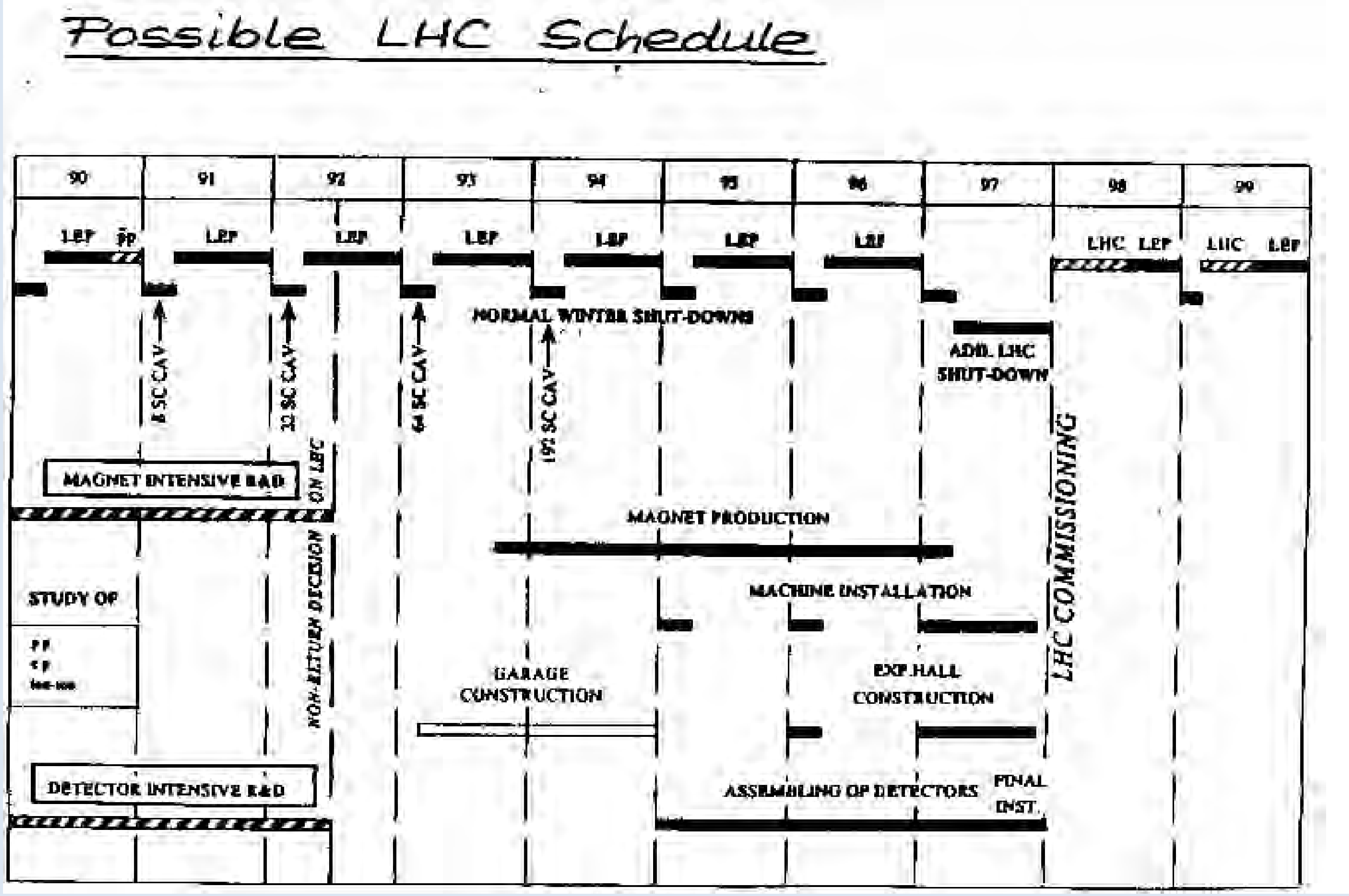
Collider parameters

Machine		$\sqrt{s}$ (TeV)	L ($cm^{-2}s^{-1}$)
LHC	pp	16	$10^{33} \rightarrow 10^{34}$
	ep	1.3	10^{32}
		1.8	10^{31}
CLIC	e^+e^-	2	$10^{33} \rightarrow 10^{34}$





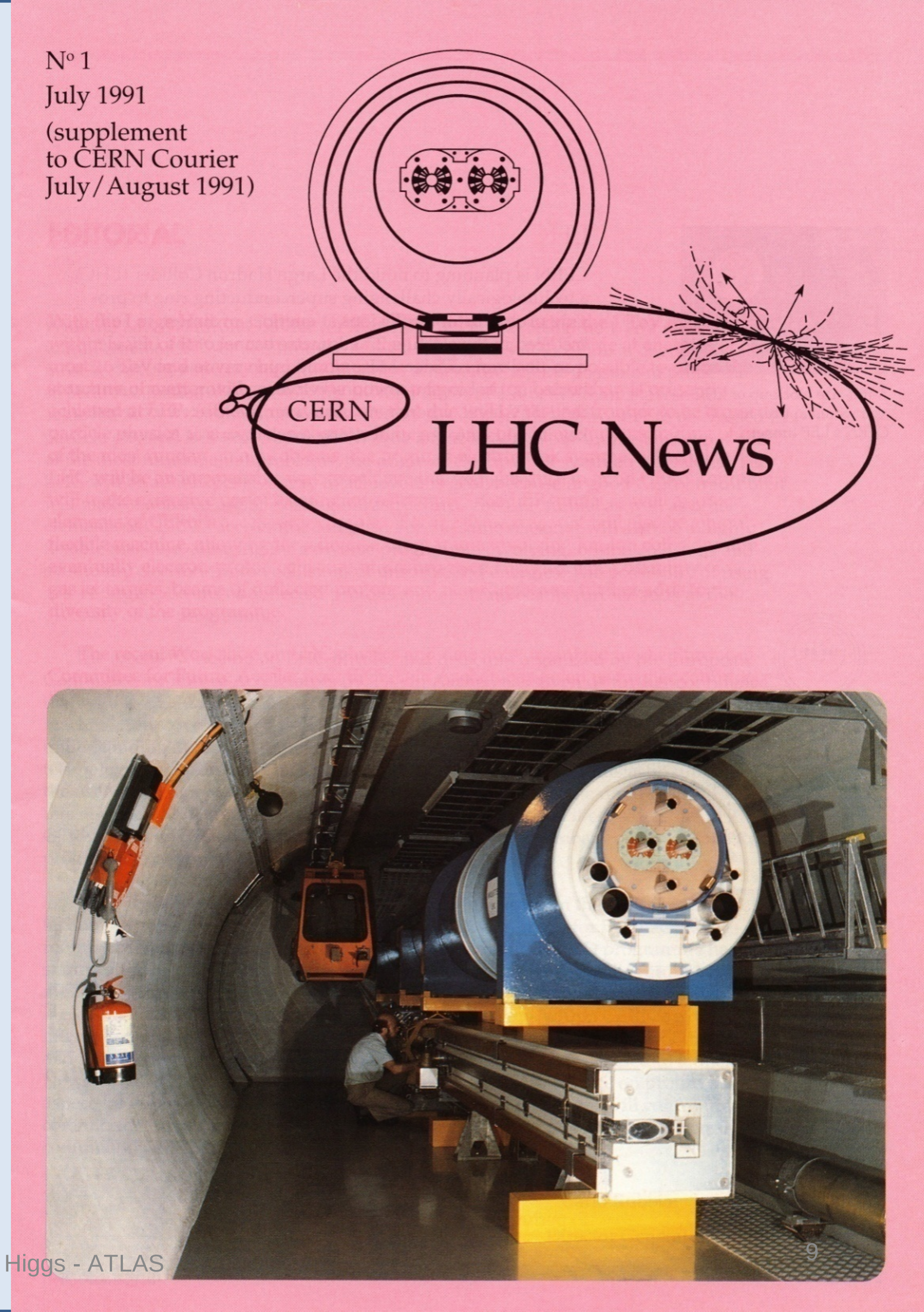
From a very early talk about the LHC, must have been around 1987 …



1991 December CERN Council: 'LHC is the right machine for advance of the subject and the future of CERN' (thanks to the great push by DG C Rubbia)

1993 December proposal of LHC with commissioning in 2002

Minister Boris Saltykov and DG Carlo Rubbia signing an updated Cooperation Agreement Russia and CERN (28 June 1993)



1991 December CERN Council: ‘LHC is the right machine for advance of the subject and the future of CERN’ (thanks to the great push by DG C Rubbia)

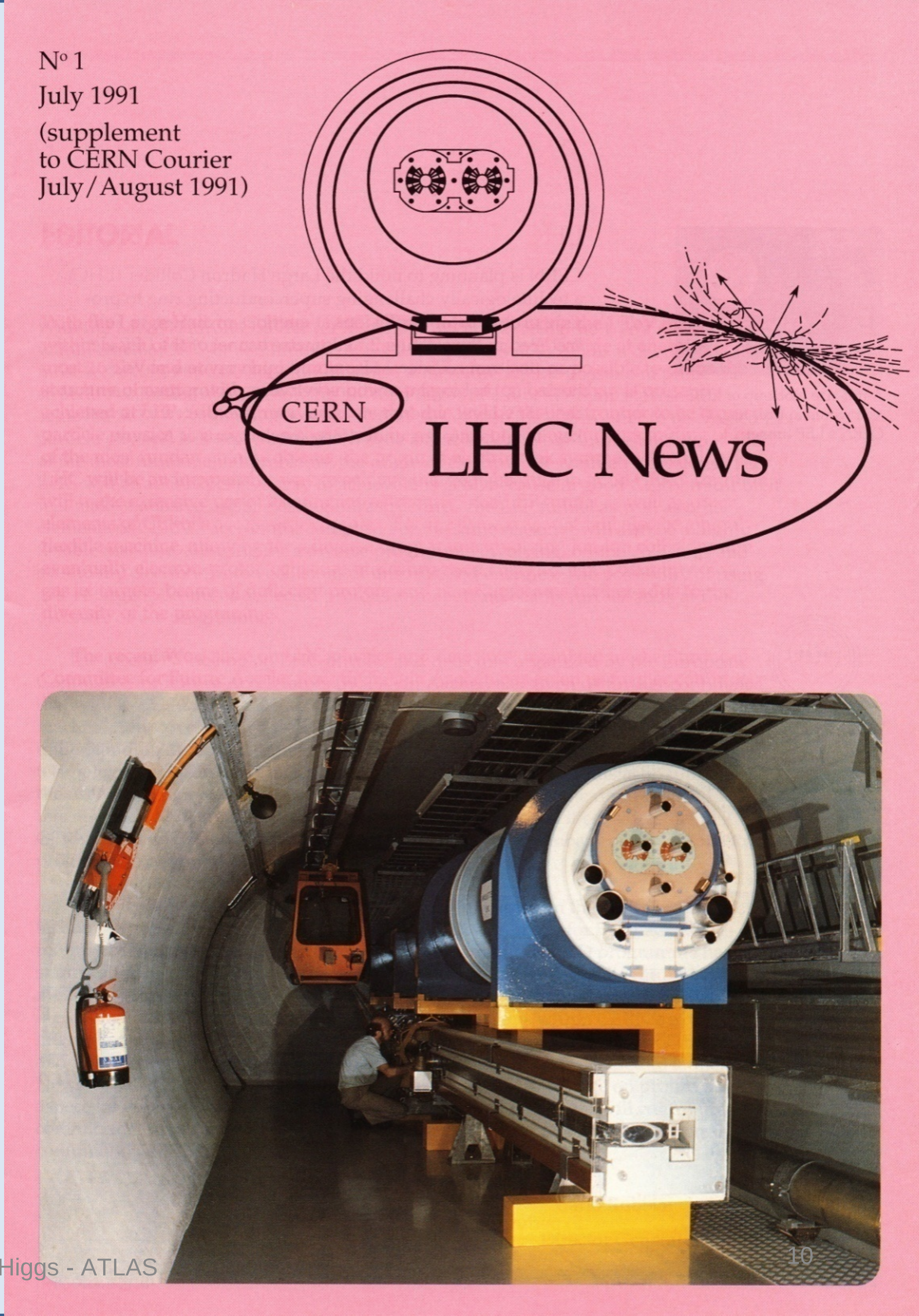
1993 December proposal of LHC with commissioning in 2002

1994 June Council:

Staged construction was proposed by DG Chris Llewellyn Smith, but some countries could not yet agree, so the Council session vote was suspended until

16 December 1994 Council:

(Two-stage) construction of LHC was approved



The two-stage approval of LHC was understood to be modified in case sufficient CERN non-member state contributions would become available

A lot of LHC campaigns and negotiations took place in the years 1995 - 1997, including also the experiments

Japan, Russia, JINR, India, Canada and the USA were agreeing in that phase to contribute to the LHC

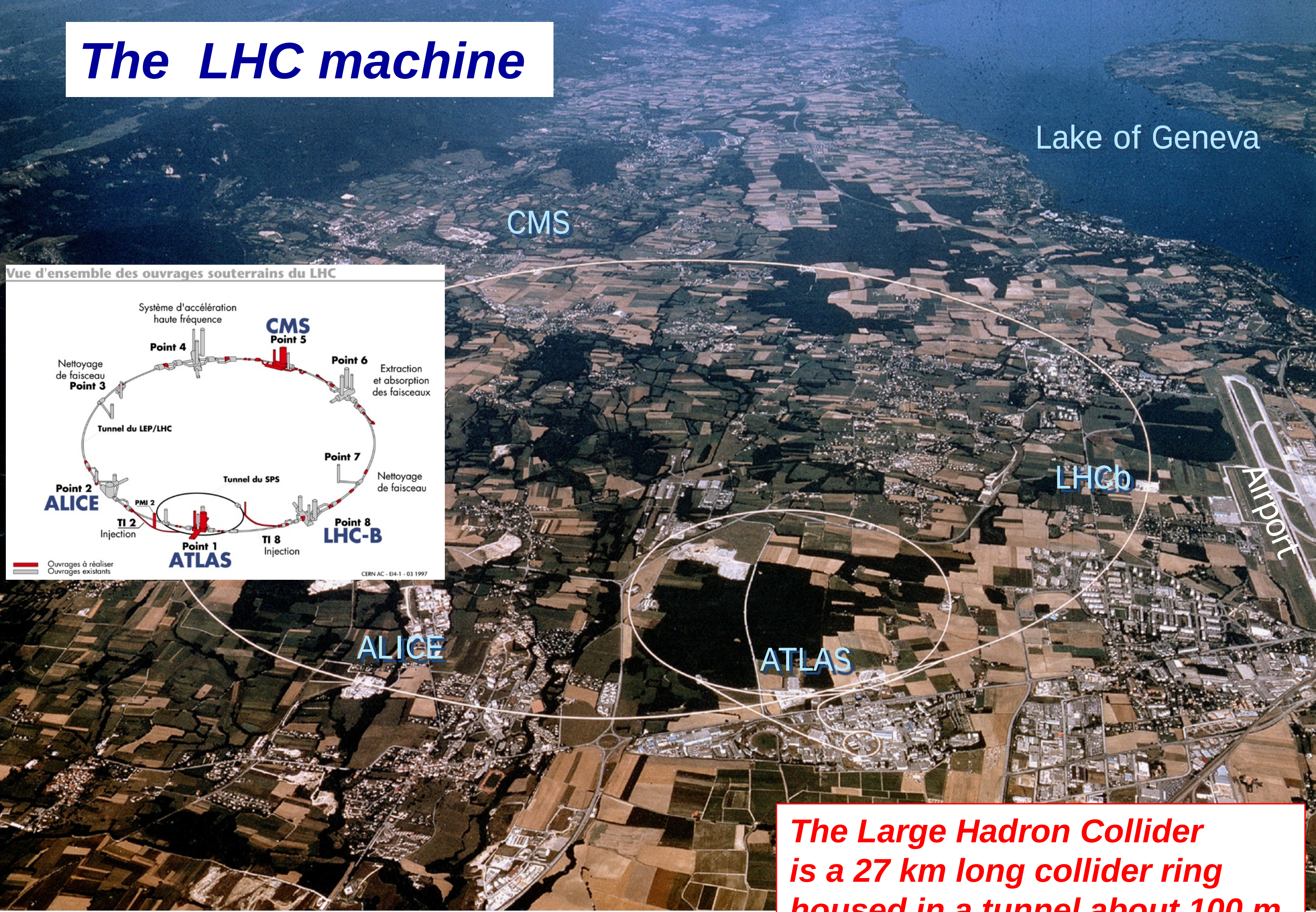
(Israel contributed all along to the full CERN programme and LHC)

1996

December Council approved finally the single-stage 14 TeV LHC for completion in 2005

Signature of the US-CERN agreement on 19th December 1997: R Eisenstein (NSF), C Llewellyn Smith (CERN DG), M Krebs (DOE)

The LHC machine

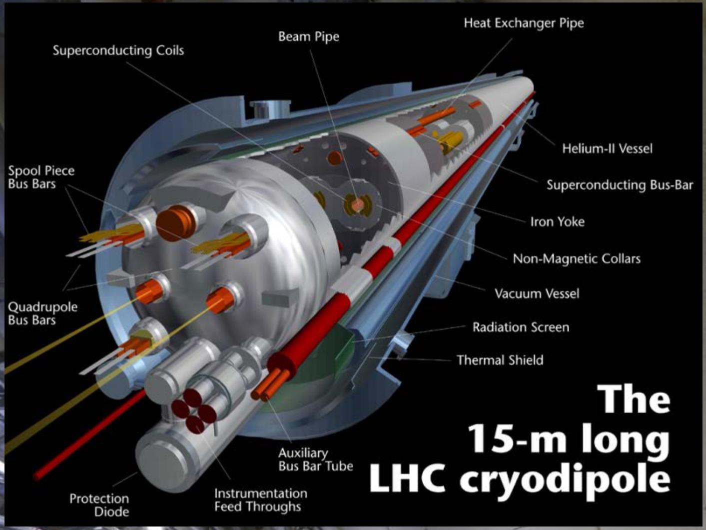


The Large Hadron Collider is a 27 km long collider ring housed in a tunnel about 100 m underground near Geneva

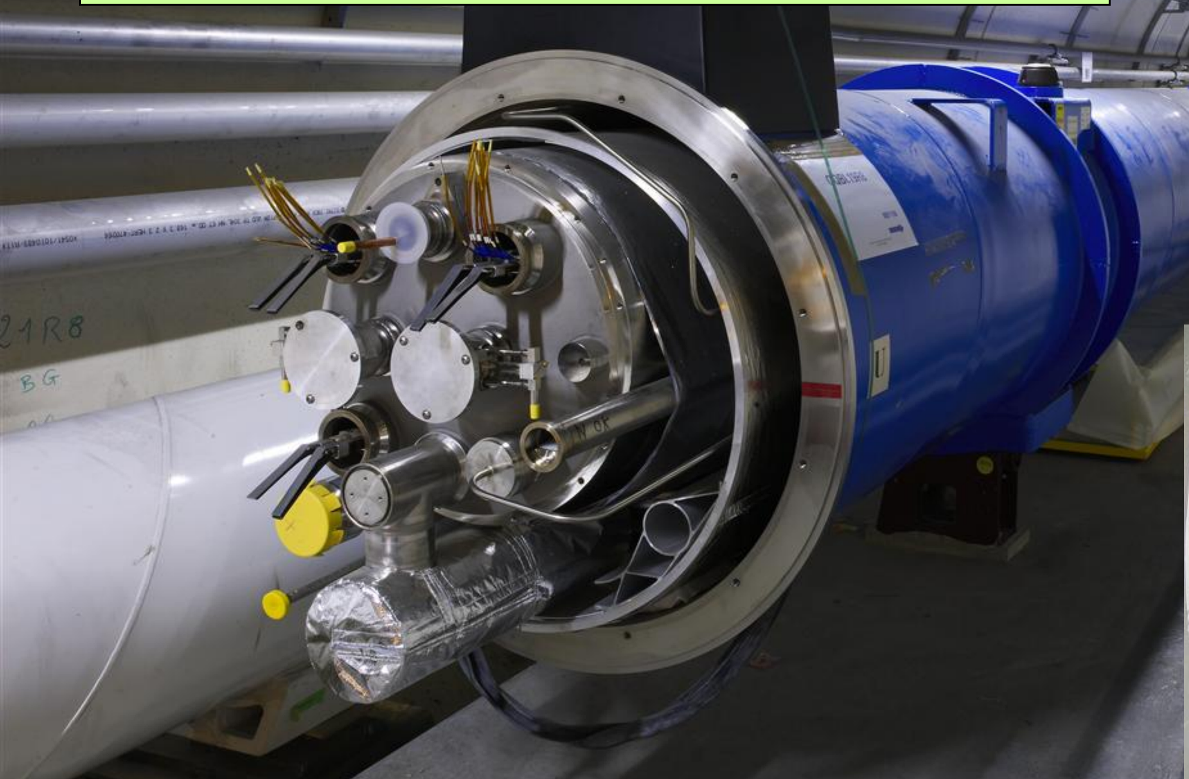
The most challenging components were the 1232 high-tech superconducting dipole magnets

Magnetic field:	**8.4 T**
Operation temperature:	**1.9 K**
(120 tons of superfluid Helium)	
Dipole current:	**11700 A**
Stored energy:	**7 MJ**
Dipole weight:	**34 tons**

7600 km of Nb-Ti superconducting cable



p(TeV) = 0.3 B(T) R(km)



LHC Construction Project Leader Lyndon Evans

BNL visit at CERN, 27th Oct 1999, with Howard and Lyn Evans are pictured: Director John Marburger, Ass. Director HEP Tom Kirk, DOE's John O'Fallon

The first of 20 special BNL interaction-region dipole leaving Brookhaven …

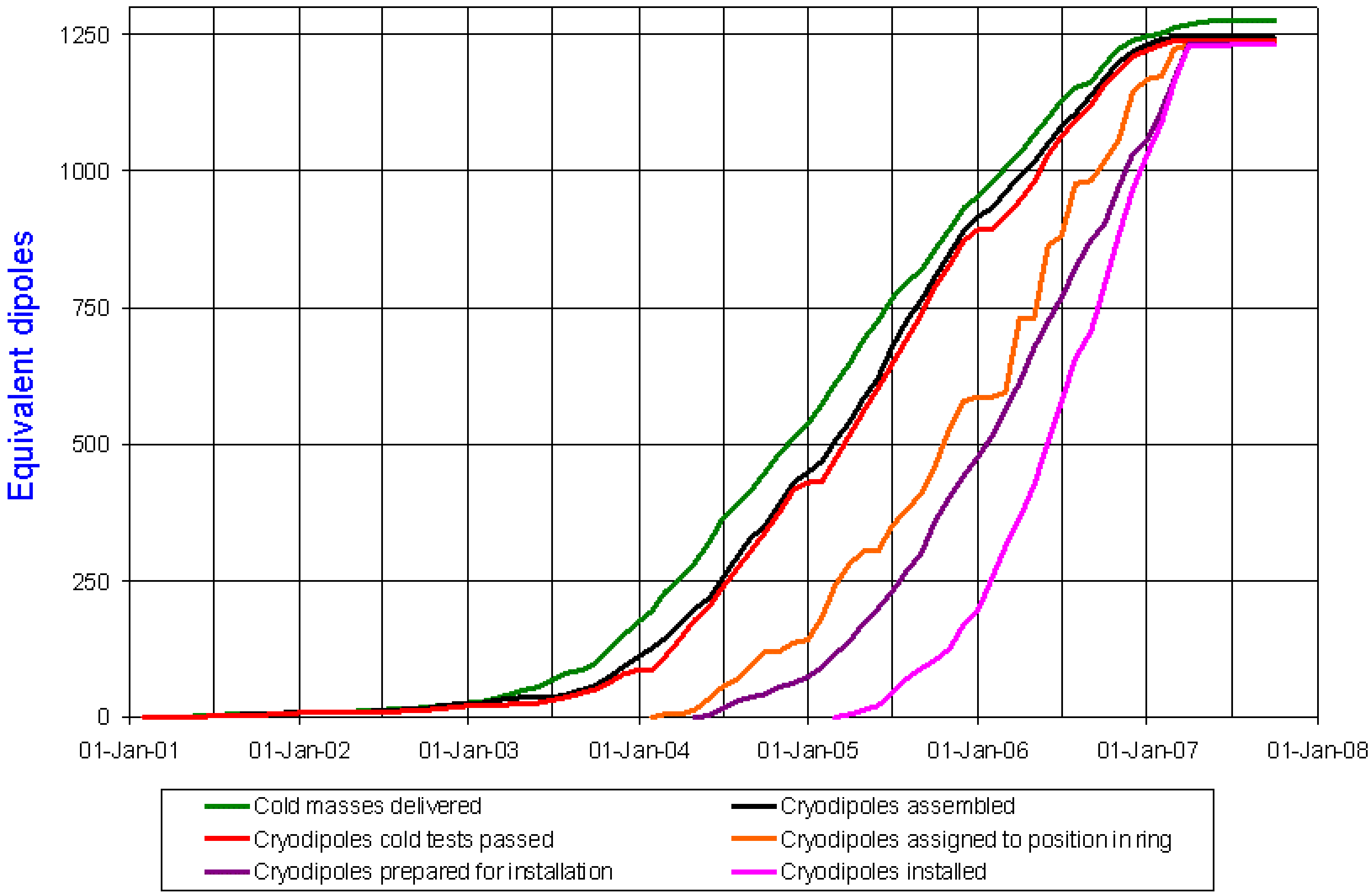
… and arriving at CERN (10th Feb 2003)

LHC Progress Dashboard

History of the dipole magnet construction and installation

Accelerator Technology Department

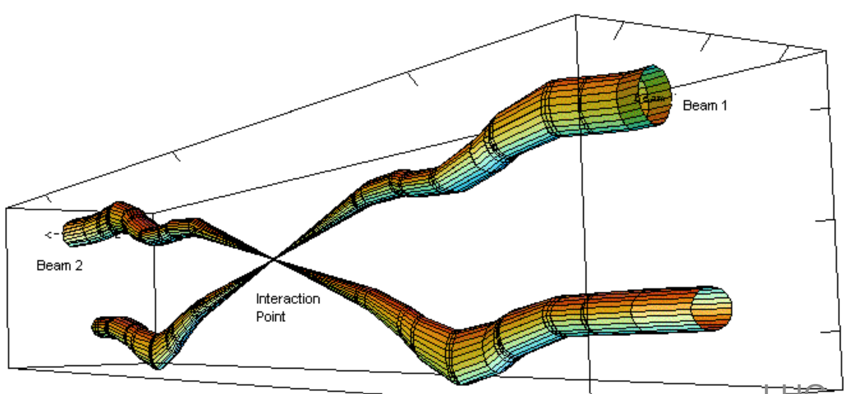
Cryodipole overview



Updated 30 September 2007

Data provided by D. Tommasini AT-MCS, L. Bottura AT-MTM

Special quadrupole magnets ('Inner Triplets') are focussing the particle beams to reach highest densities ('luminosity') at their interaction point in the centre of the experiments



Relative beam sizes around the collision point

Arguing after the mid-1980s of being ambitious and design a general purpose detector …

A very simplified summary:

detector signature		accessible physics process
$\mu^\pm$		$H \to ZZ \to 4\mu^\pm$ $Z' \to \mu^+\mu^-$ (σ_m ?)
$\mu^\pm$, jets, $\not{p}_T$	add:	$H \to ZZ \to \mu^+\mu^-\nu\bar{\nu}$ $W' \to \mu^\pm\nu$ compositeness $\tilde{q}, \tilde{g}$ (direct decays) jet spectroscopy
e, $\mu^\pm$, jets, $\not{p}_T$ (non-)magnetic central part (reduced tracking)	add:	4× rate $H \to ZZ \to 4e^\pm$ 2× rate $H \to ZZ \to e^+e^-\nu\bar{\nu}$ 2× rate Z', W' $\tilde{q}, \tilde{g}$ (also cascade decays) mass resolution $e\mu$ heavy Q, L $H \to \gamma\gamma$
$e^{\pm}$, $\mu^\pm$, $\tau^\pm$, jets, $\not{p}_T$ full momentum and tracking	add:	more redundancy and cross-checks on above, H^+, SUSY-H, heavy flavour tags

Lepton detection at LHC is crucial. Small rates are expected for many potential signals

⇒ detection of e and μ

Muons are relatively easy to identify but hard to measure well

(precise μ measurements may mean hundreds of MCHF)

Electrons are relatively easy to measure but hard to identify at 10^{34}

(radiation-hard inner detector)

Lepton isolation criteria are also important to reject backgrounds from heavy flavour decays

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1986 LAA R&D on new detector technologies started, later followed by the DRDC

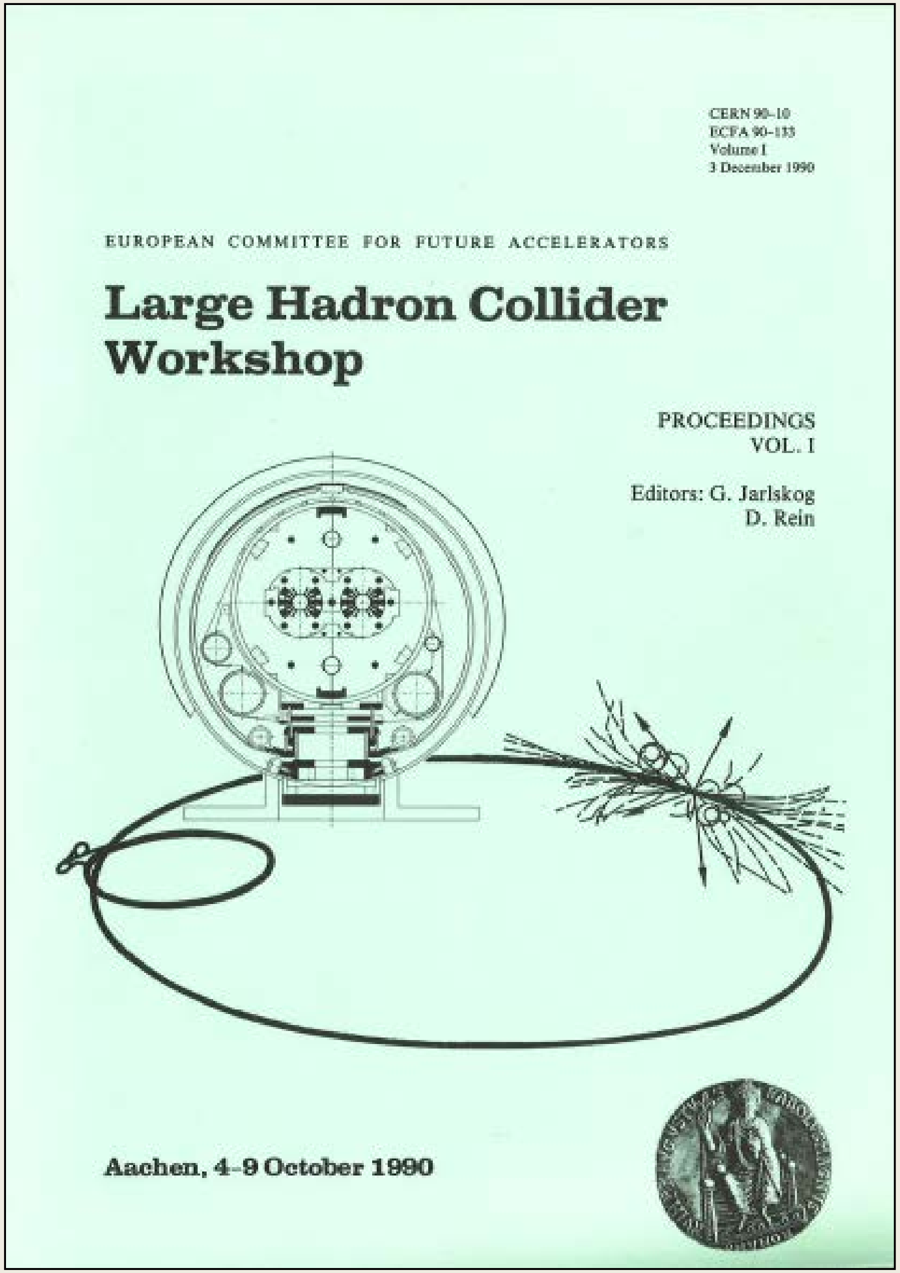
1987 La Thuile Workshop

Many LHC colleagues were already involved in this WS set up by Carlo Rubbia as part of the Long Range Planning Committee

1989 ECFA Study Week in Barcelona for LHC instrumentation

1990 Large Hadron Collider Workshop Aachen (CERN - ECFA)

1992 CERN – ECFA meeting 'Towards the LHC Experimental Programme' in Evian



The birth of ATLAS

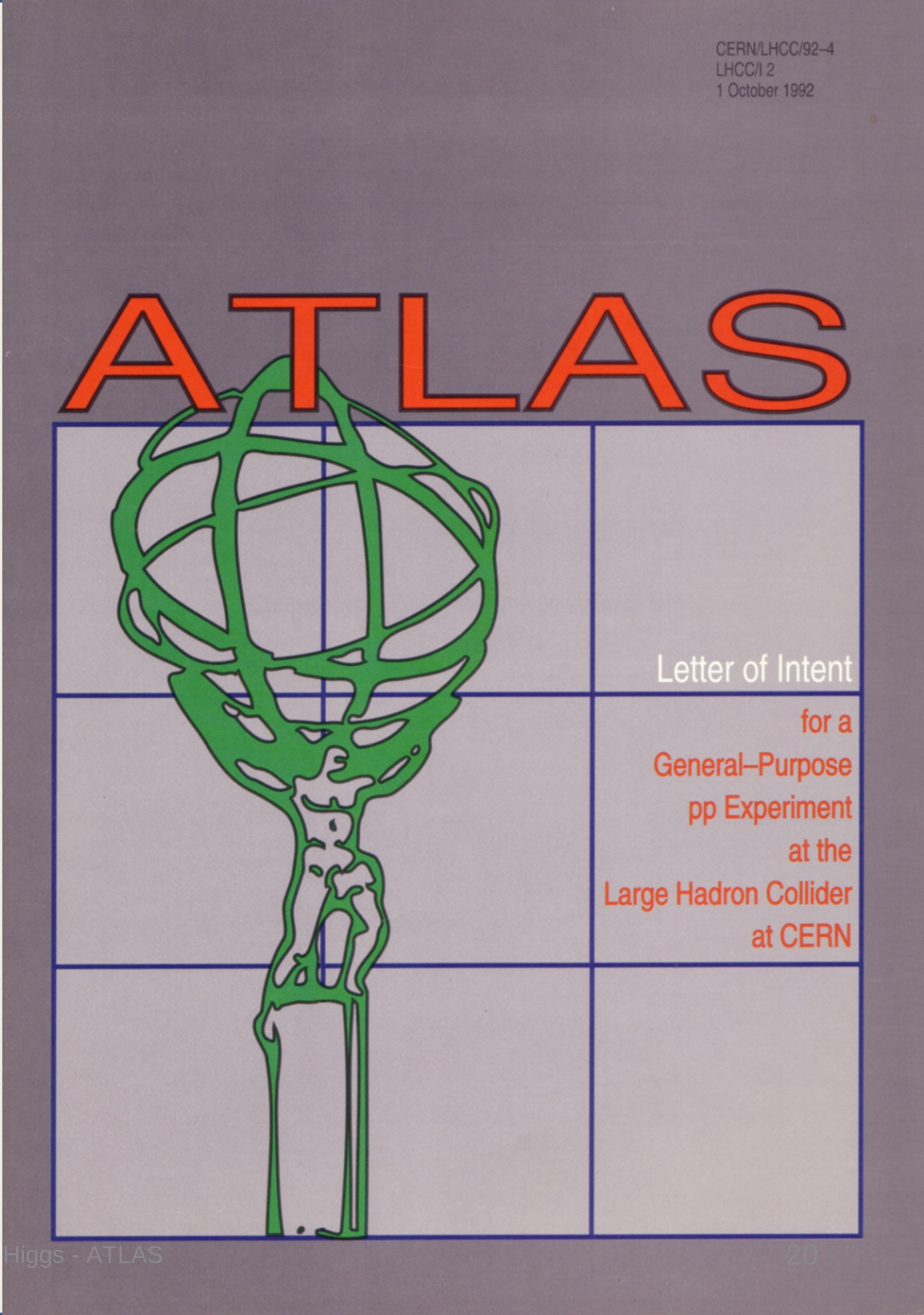
March 1992 – Summer 1992

Merging of EAGLE and ASCOT

September 1992: Decision on the name

October 1992:

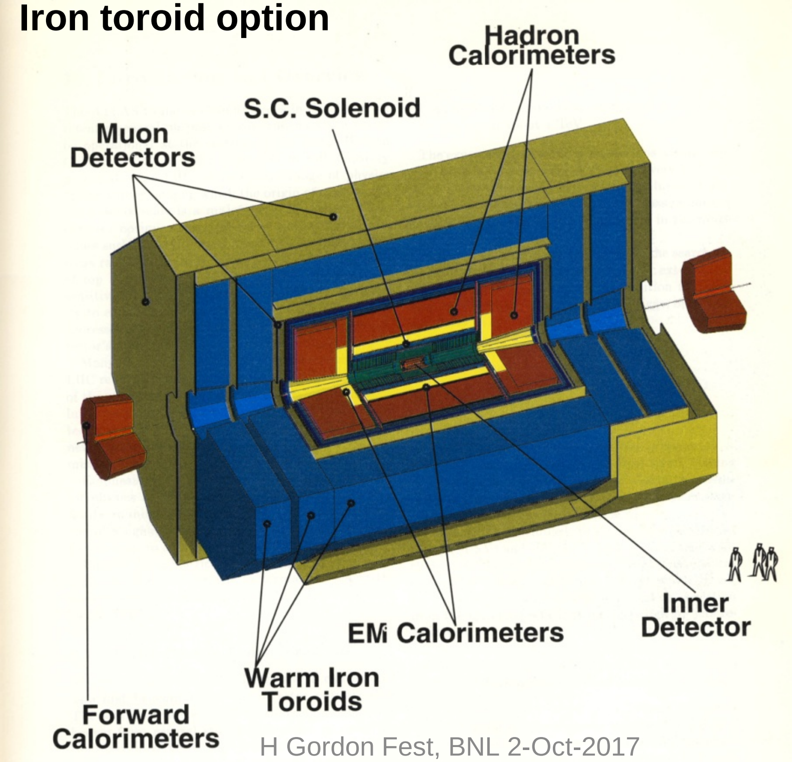
ATLAS LoI submitted to the LHCC (as well as the CMS LoI)

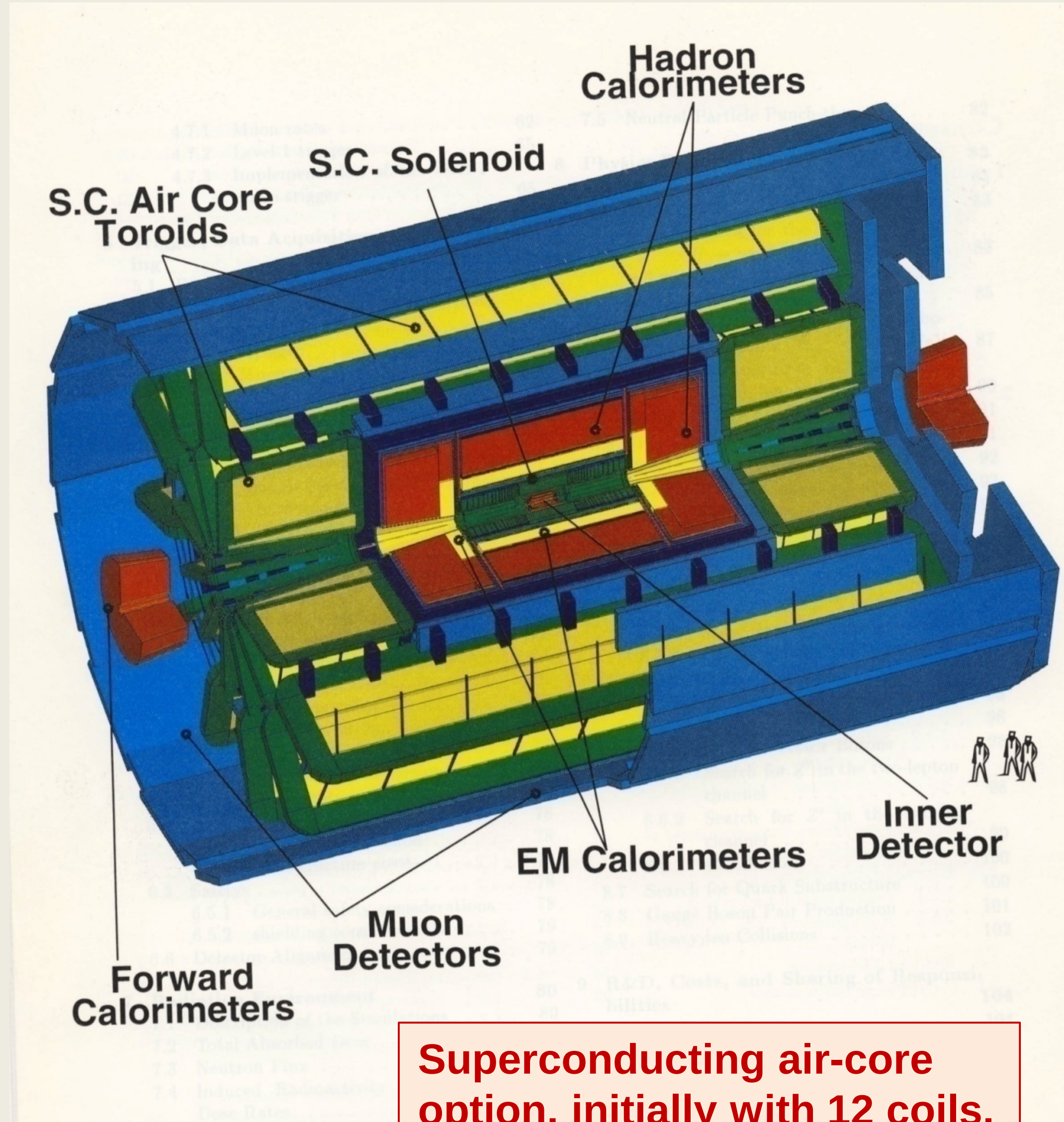


The LoI still had two *toroid* options, one iron and one superconducting air-core

Shortly after we decided for the superior air-core magnet

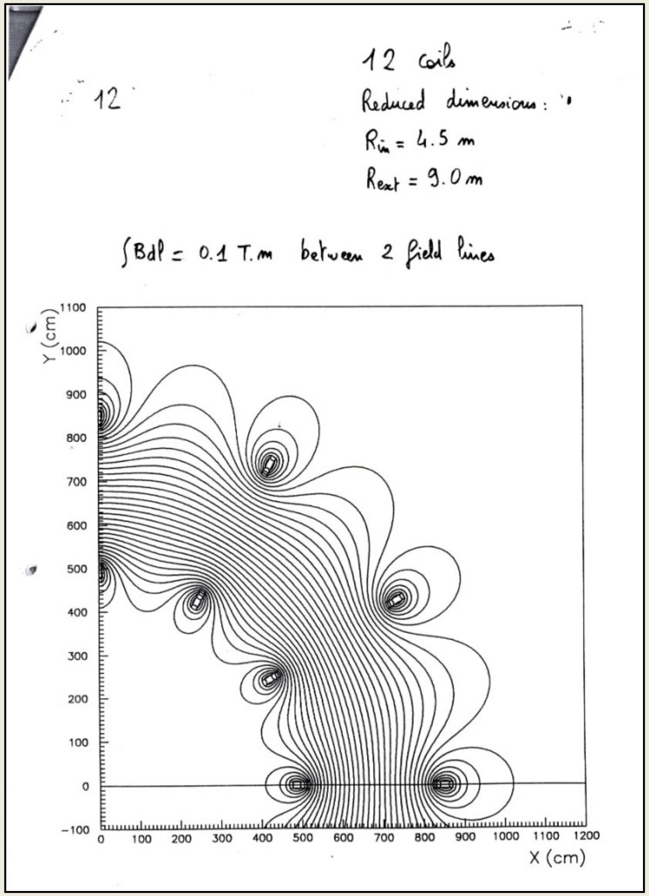
Iron toroid option

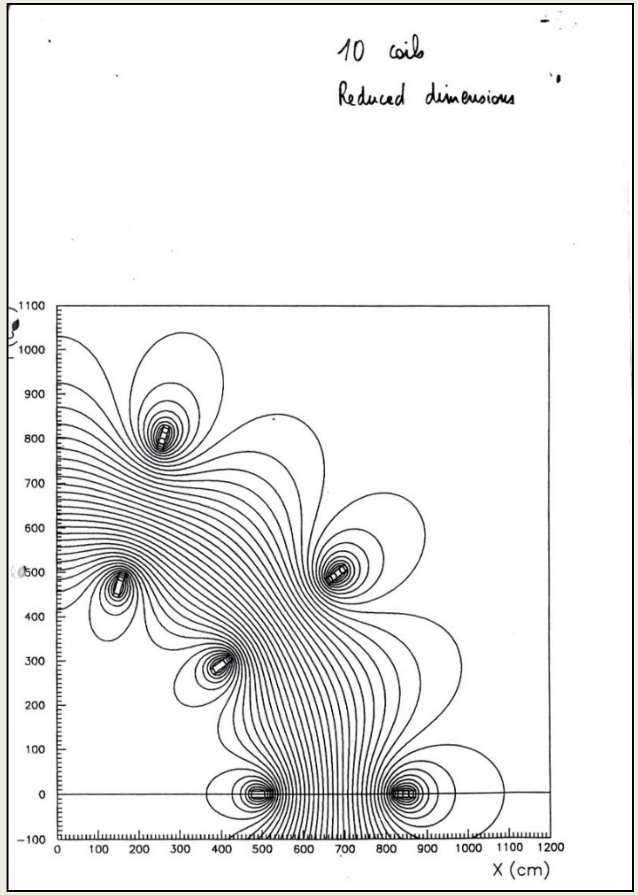


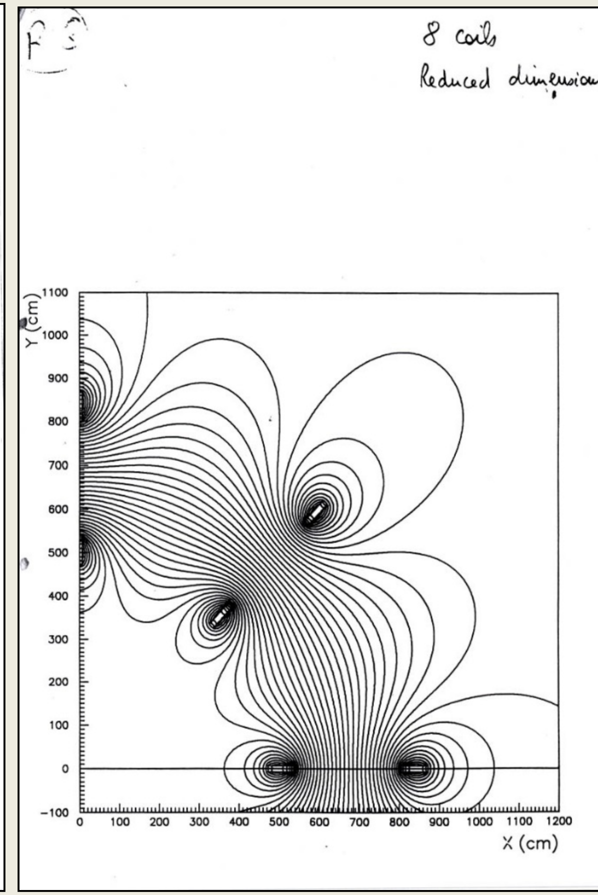


Superconducting air-core option, initially with 12 coils, then redesigned with 8 coils

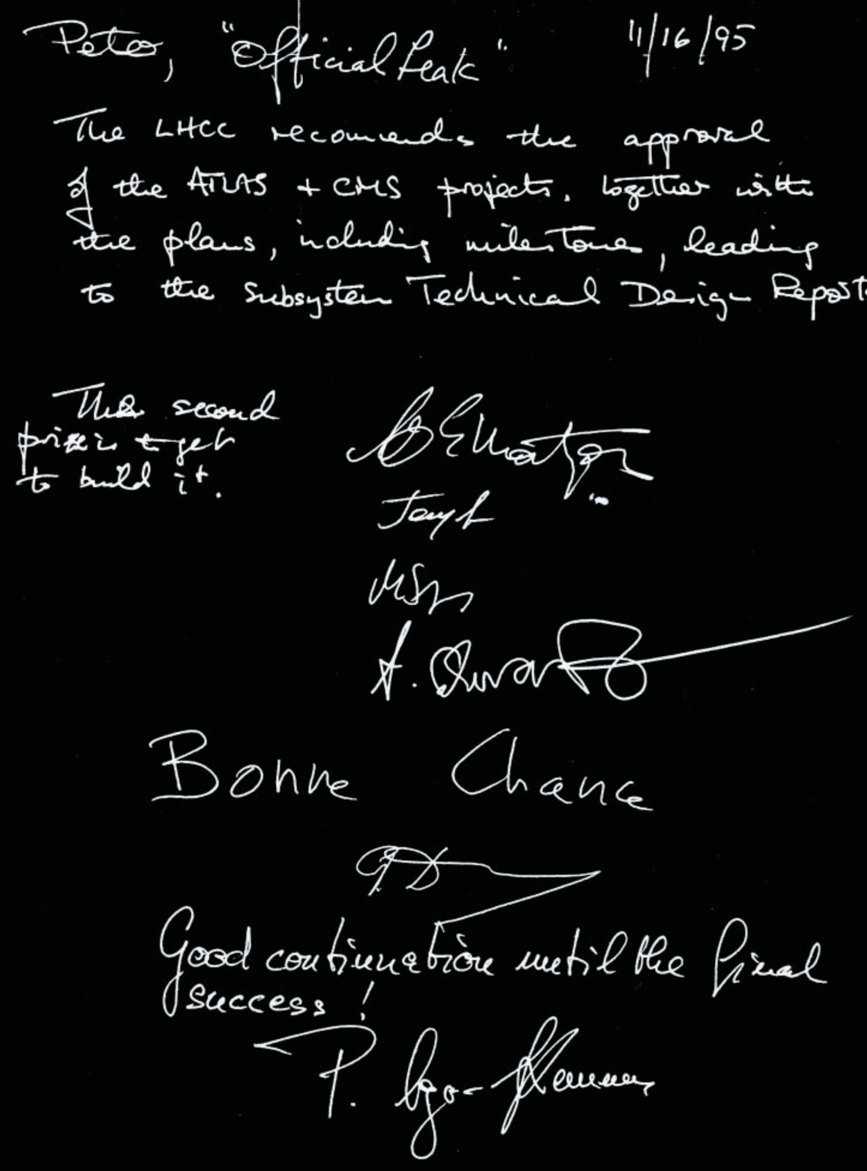
Coming back to the LoI in December 1992: It was well received, but a long saga started for ATLAS about money … this was the first act:







For the experiments it was a long way convincing the LHCC, but finally, on 16th November 1995, our referees were happy, and Hugh Montgomery, ATLAS main referee at that time, gave us the following 'official leak' from the committee…



The LHCC recommendations meant in particular that ATLAS and CMS could now proceed in developing their series of Technical Design Reports

In the meantime the ATLAS Collaboration had grown substantially, this is a snap-shot just after the Technical Proposal approval

The final scope of the experiment became possible with the strong intellectual and material resources brought in by our US colleagues after the termination of the SSC

Signature of the US-CERN agreement in December 1997

(R Eisenstein – NSF,
C Llewellyn-Smith – CERN DG,
M Krebs – DOE)

ATLAS
Collaboration

(Status: January 1996)

Albany, Alberta, Alma Ata, NIKHEF Amsterdam, LAPP Annecy, Argonne NL, Arizona, Arlington UT, Athens, NTU Athens, Baku, UA Barcelona, Bergen, Berkeley LBL and UC, Bern, Birmingham, Bochum, Bonn, Boston, Brandeis, Bratislava, Brookhaven NL, IAP Bucharest, Cambridge, Carleton/CRPP, CERN, Chicago, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, INP Cracow, FPNT Cracow, Dortmund, JINR Dubna, Duke, Edinburgh, Frascati, Freiburg, Fukui, Geneva, Genoa, Glasgow, ISN Grenoble, Technion Haifa, Hamburg, Harvard, Hawaii, Heidelberg, SEFT Helsinki, Hiroshima IT, Hiroshima, Indiana, Innsbruck, Irvine UC, Istanbul Bogazici, Jena, KEK, Kobe, Kosice, Kyoto UE, Lancaster, Lecce, Lisbon, Liverpool, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille, MIT, Melbourne, Michigan SU, Milano, Minsk, Montreal, ITEP Moscow, Lebedev Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Naples, Naruto UE, New Mexico, Nijmegen, Northern Illinois, BINP Novosibirsk, Oklahoma, LAL Orsay, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, COPPE Rio de Janeiro, Rochester, Rockefeller, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sao Paulo, Sheffield, Shinshu, Siegen, Southern Methodist, IFMO St. Petersburg, NPI St. Petersburg, Stockholm, KTH Stockholm, Sydney, Ansto Sydney, Tbilisi AS, Tbilisi SU, Tel-Aviv, Thessaloniki, Tokyo CU, Tokyo ICEPP, Tokyo MU, Tokyo AT, Toronto, TRIUMF, Tufts, Udine, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, Wisconsin, Wuppertal, Yerevan

(147 Institutions with about 1550 authors)

(The participation of Non-Member State groups is subject to the satisfactory conclusion of bilateral agreements between the Funding Agencies and CERN)

The negotiations were particularly intense with the US as largest non-member state participant → It is fair to say that the ATLAS negotiation team certainly contributed to get a bit more for the experiments (250 MUSD) than the machine (200 MUSD) when sharing the DOE money… (1996)

FIRST ANALYSIS OF PROPOSED US CONTRIBUTION

Accelerator contribution – $(225 ± 25)M
Assuming $112.5M in cash equivalent form (→ 135 MCHF value for CERN) and that $1M in kind is worth 0.7 MCHF for CERN
⇒ *(195–230)MCHF value for CERN with over half in cash equivalent*

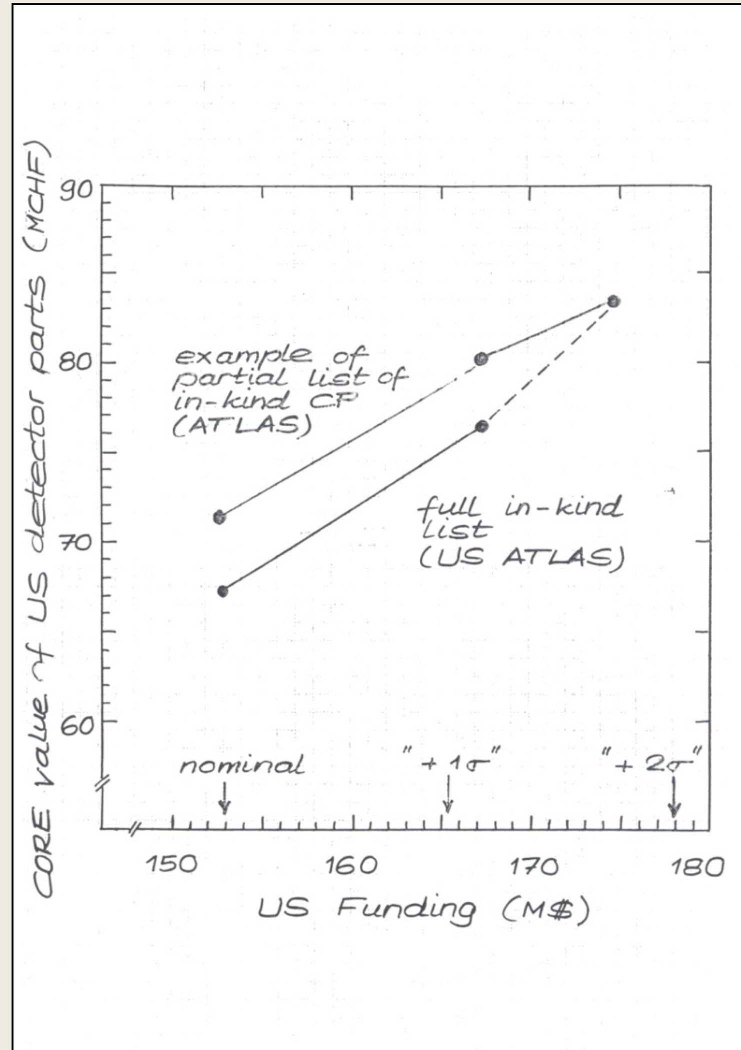
Detector contribution – $(225 ± 25)M from DOE + $78M from NSF

Requests

	MCHF CERN accounting	$M US accounting DOE	$M US accounting NSF				
ATLAS	102.9	125.0	+60.7	=185.7	= $356M	proposed →	$(303±25)M
CMS	113.2	153.0	+17.1	=170.1			

Note - reduced US input will constrain/cap the number of US participants

Committee of Council - March 1996



Anything worked out fine, and alltogether we produced an impressive series of TDRs…

The formal construction approval was then given with the approval of the first TDRs, namely for the calorimeters

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

Professor C H Llewellyn Smith
Director General
CH - 1211 Geneva 23, Switzerland
Telephone Direct: (41.22) 767 23 00
Secretary: (41.22) 767 35 96
Fax: (41.22) 767 89 95
E-mail: Christopher.Llewellyn.Smith@cern.ch

Our Ref. DG/mnd/2540

Dr Peter Jenni
PPE Division
CERN

Geneva, 1st July 1997

Dear Peter,

Following the thorough discussion of the status of ATLAS and CMS by Council and its Committees two weeks ago, the way is now open for construction to begin. I am therefore pleased to inform you that I have decided to *i)* set the cost ceiling for ATLAS at 475 MCHF (1995 prices), and *ii)* approve the TDR of the ATLAS calorimeters on the following basis formulated by the LHCC and endorsed by the Research Board at its meeting on 12th June:

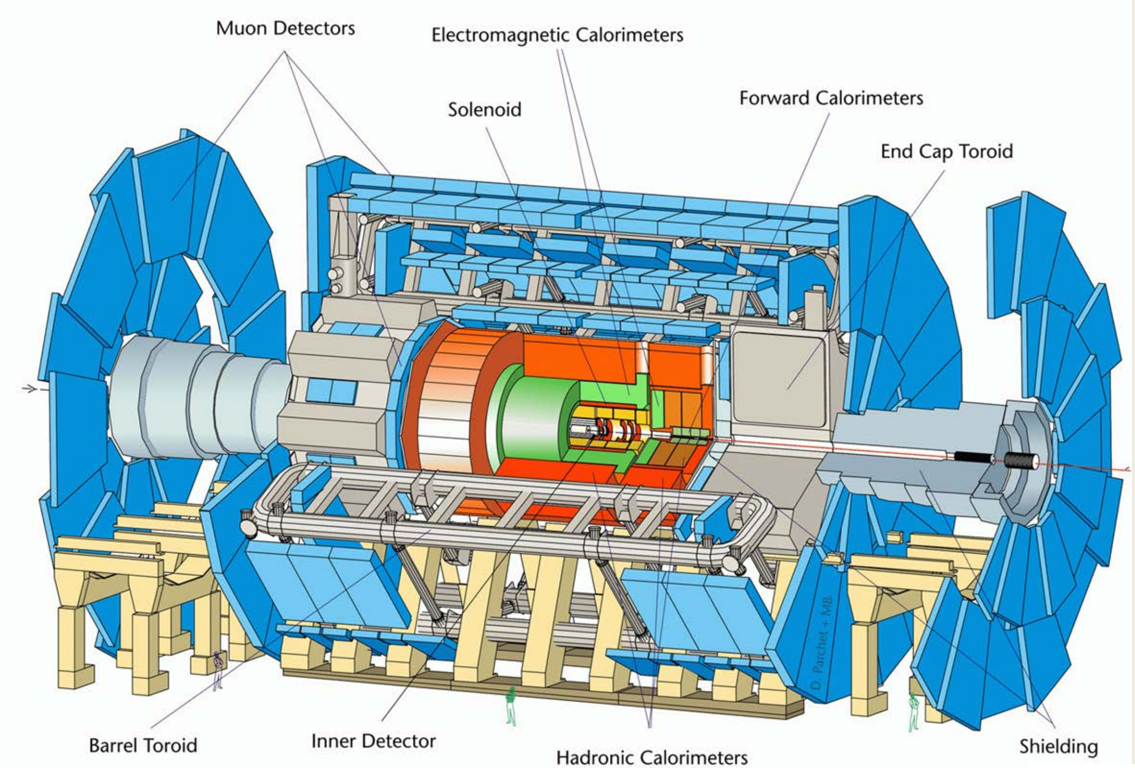
*"The LHCC **recommends general approval** of the ATLAS Calorimetry Technical Design Report describing design, performance, construction, and installation in 2004. The review **identified some concerns** in limited areas, which require resolution (LHCC 97–27). The LHCC considers that the schedules and milestones given in the TDR are reasonable, and these will be used by the committee to measure and regulate the future progress of the project."*

Yours sincerely,

Chris

Chris Llewellyn Smith

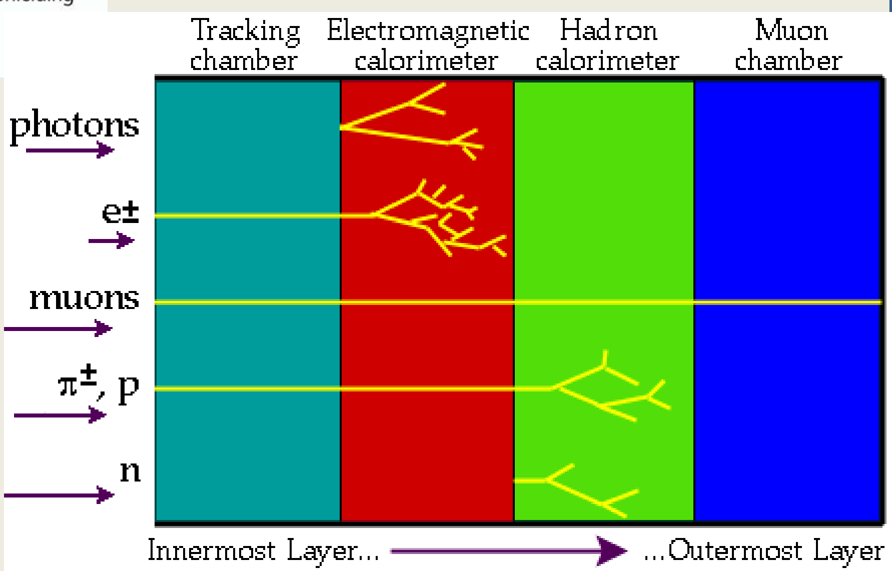
cc: L Foà
E Iarocci



ATLAS

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~ 10^8 electronic channels
~ 3000 km of cables

- **Tracking (|η|<2.5, B=2T) :**
  - -- Si pixels and strips
  - -- Transition Radiation Detector (e/π separation)
- **Calorimetry (|η|<5) :**
  - -- EM : Pb-LAr
  - -- HAD: Fe/scintillator (central), Cu/W-LAr (fwd)
- **Muon Spectrometer (|η|<2.7) :**
  - -- air-core toroids with muon chambers



One of our main concerns at the time:
(from my introduction to the Week)

Completion of the Initial Detector

A very major theme constraining all our activities are the resources required and available for building, installing and commissioning the initial ATLAS detector

It is very important to note that Funding Agencies are making large efforts on deliverables and in-kind contributions to cover an important part of the resources problems

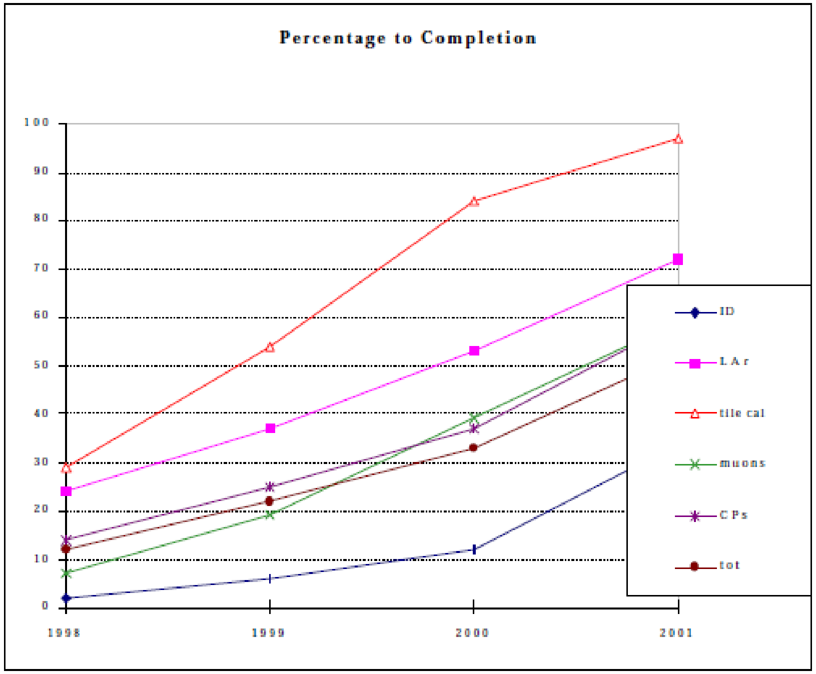
We all must gratefully acknowledge this!

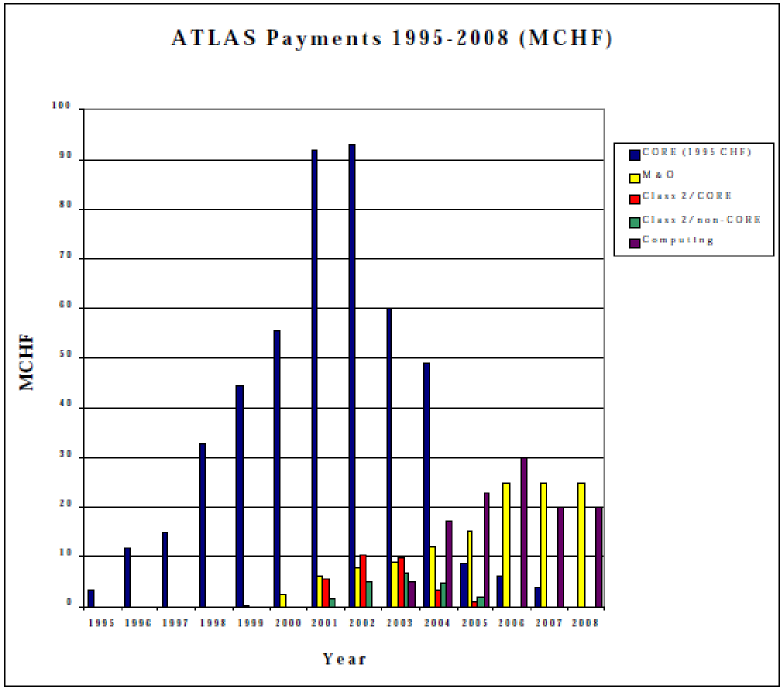
(from my introduction to the BNL ATLAS Week)

ATLAS Resources

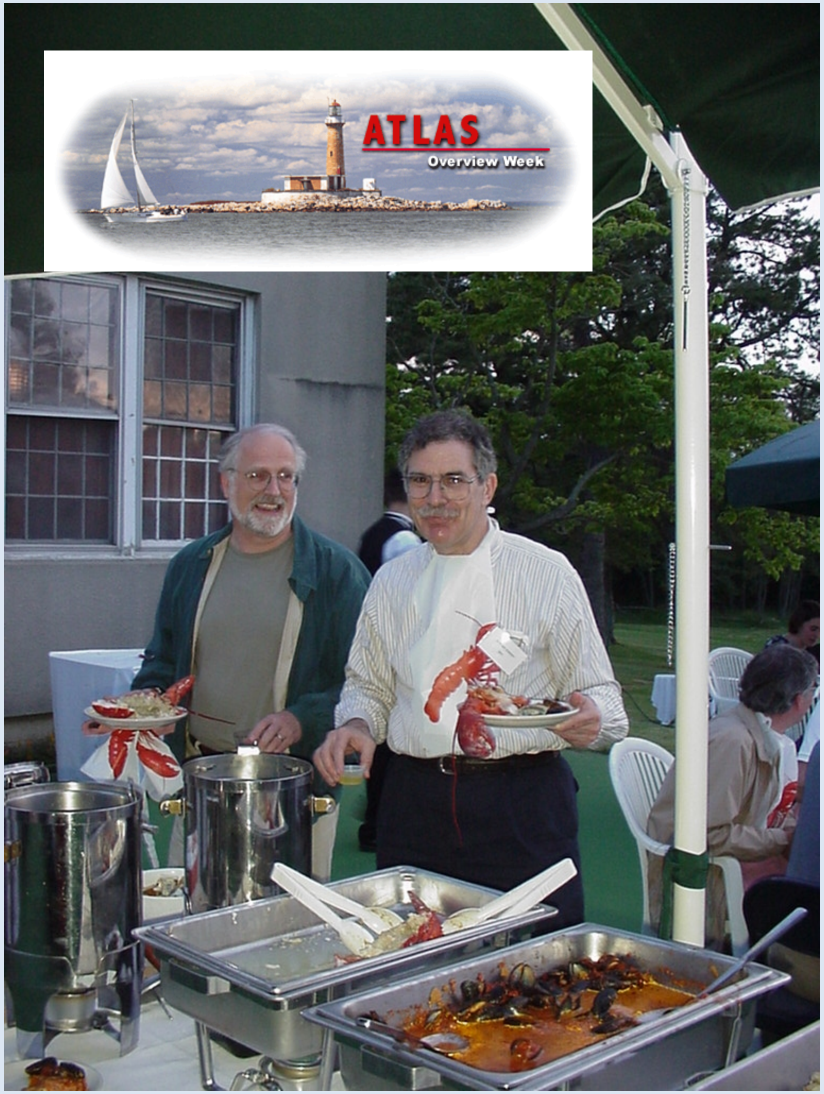
There are several resources issues requiring a setting of priorities for the completion of the initial detector

- Non – CORE costs are higher than initially expected (typically for common assembly infrastructures at CERN)
- Manpower needs at the construction sites and centrally at CERN are higher than initially planned
- Effects of purchasing power evolutions since 1995 (inflation and exchange rates)
- Cost increases in the construction of components
- Some technical difficulties with industry (requiring new contracts, usually more expensive)





But we had also plenty of fun !
(Clam Bake 4th June 2001)



Conclusions (part II)

We have enjoyed a great week here at Brookhaven!

The highly efficient and friendly organizing team has made our stay here a real pleasure in spite of the heavy meeting schedule

Our most warm thanks go to the secretariat with

- Jackie Mooney and Connie Potter for the coordination
- Vanessa Langhorn for the transport
- Linda Feierabend for the food management
- Kathy Einfeld

We appreciated greatly the warm hospitality of the Brookhaven National Lab

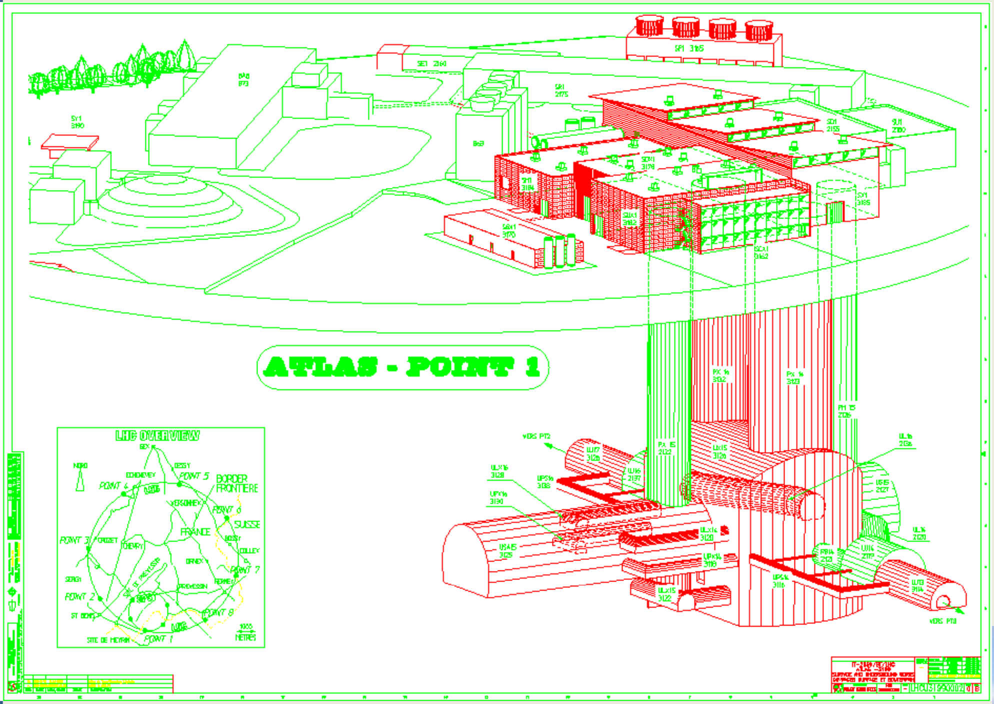
but

All this would not have been such a great event without our main host

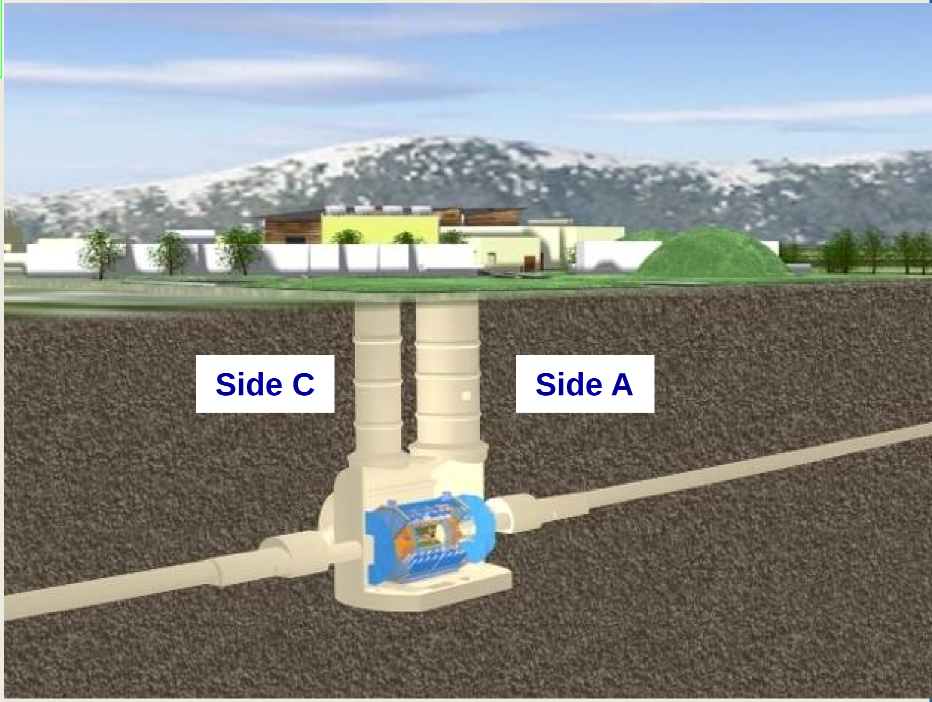
Howard Gordon

who has prepared and conducted all these days in a just outstanding way!

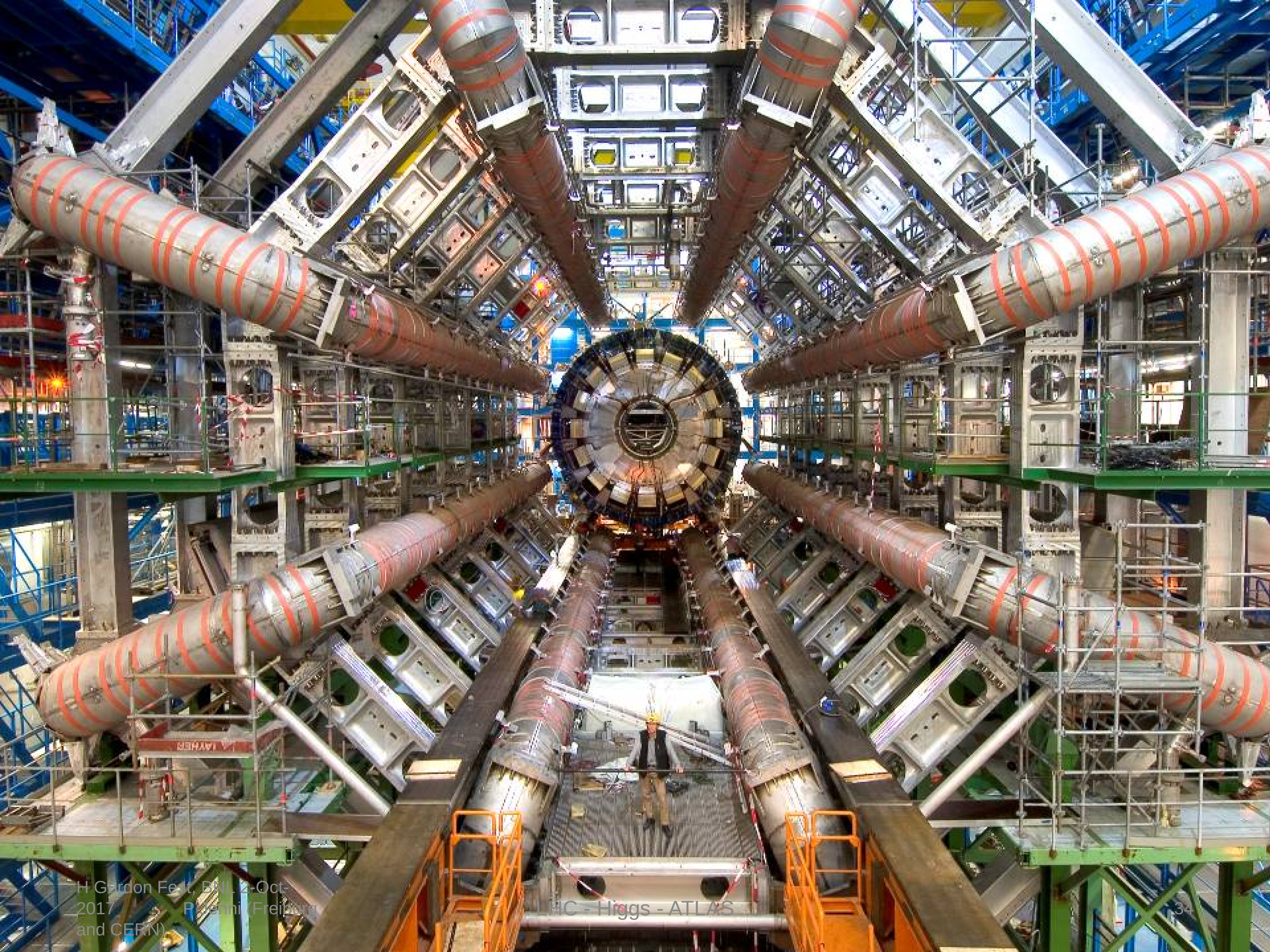
The Underground Cavern at Point-1 for the ATLAS Detector
(excavation started in 1998)



Length = 55 m
Width = 32 m
Height = 35 m



LHC Point 1 - UX 15 Cavern - Concrete walls 6th lift - 20-02-2003 - CERN ST-CE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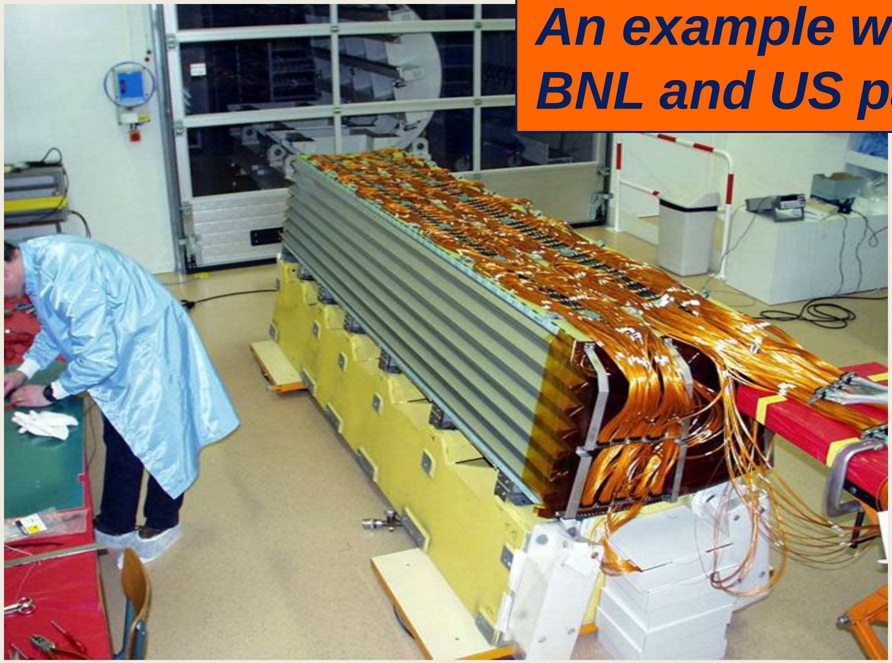
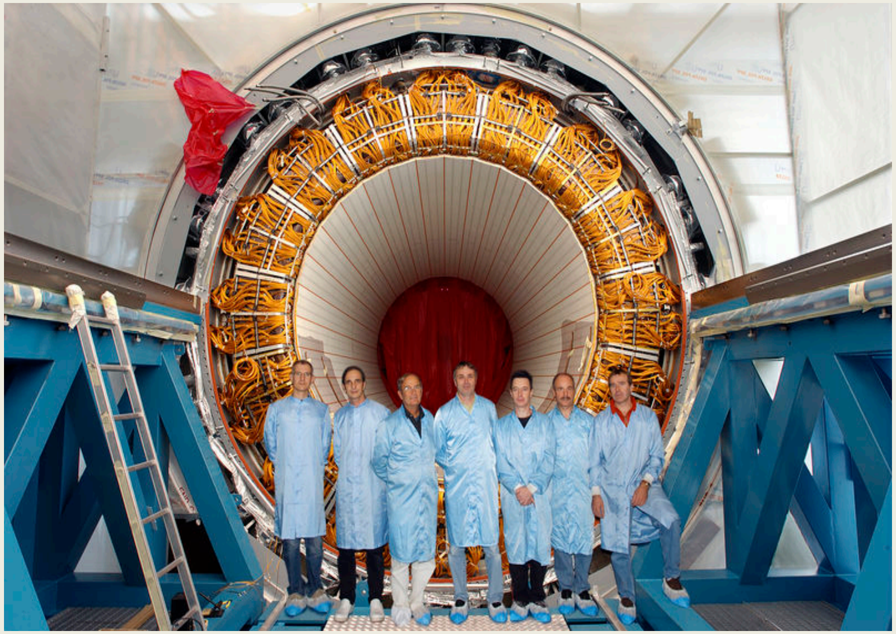
An example with strong BNL and US participation



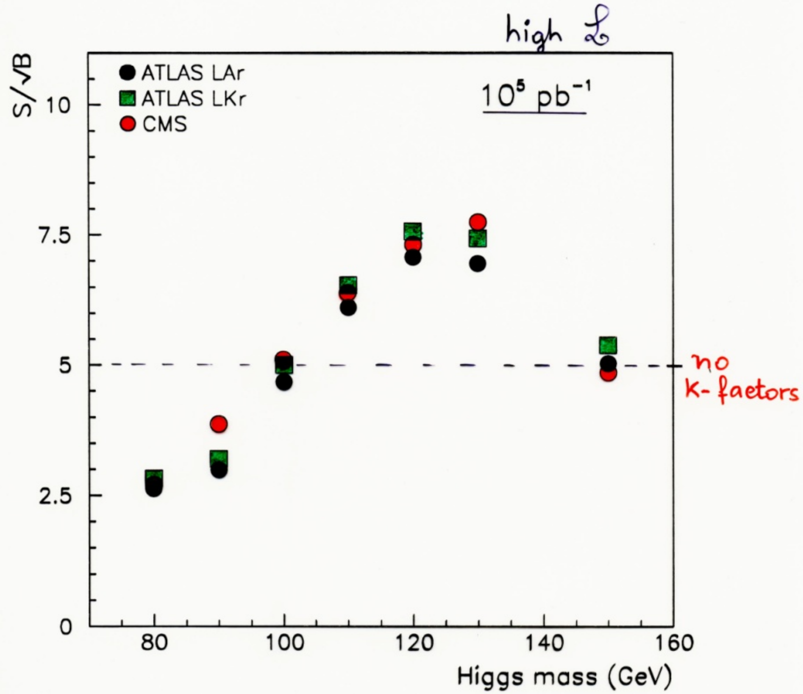


LAr EM Calorimeter 1999 - 2004

We also had quite some fights with the LHCC about performance issues, what is relevant and what not, here an example on the EM resolution…

H → γγ SIGNIFICANCE

LKr : ~ 7% better than LAr



CMS : à la ATLAS : no K-factors
jet bckgr. included
etc.

low $\mathcal{L}$: CMS ~ 20% better than ATLAS LAr
~ 12% LKr

H → γγ $m_H = 100$ GeV

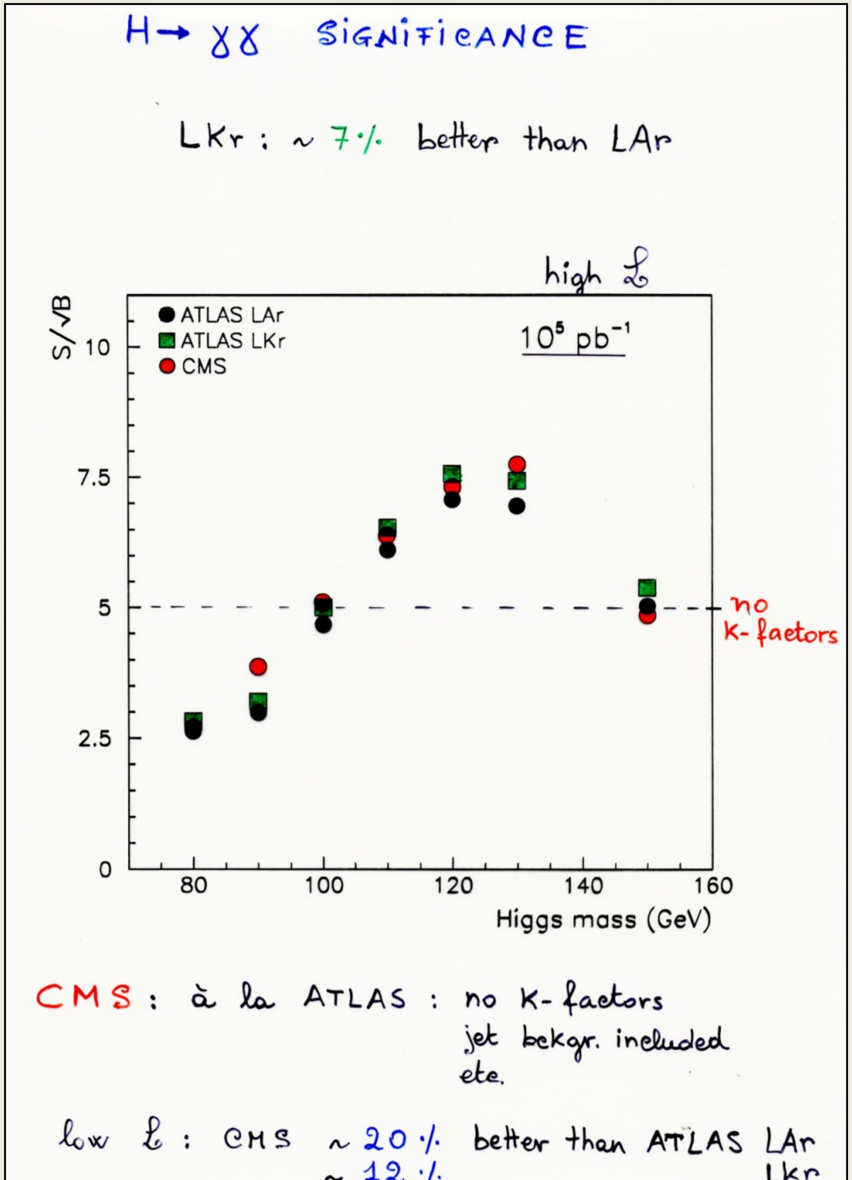
Contributions to σ_m

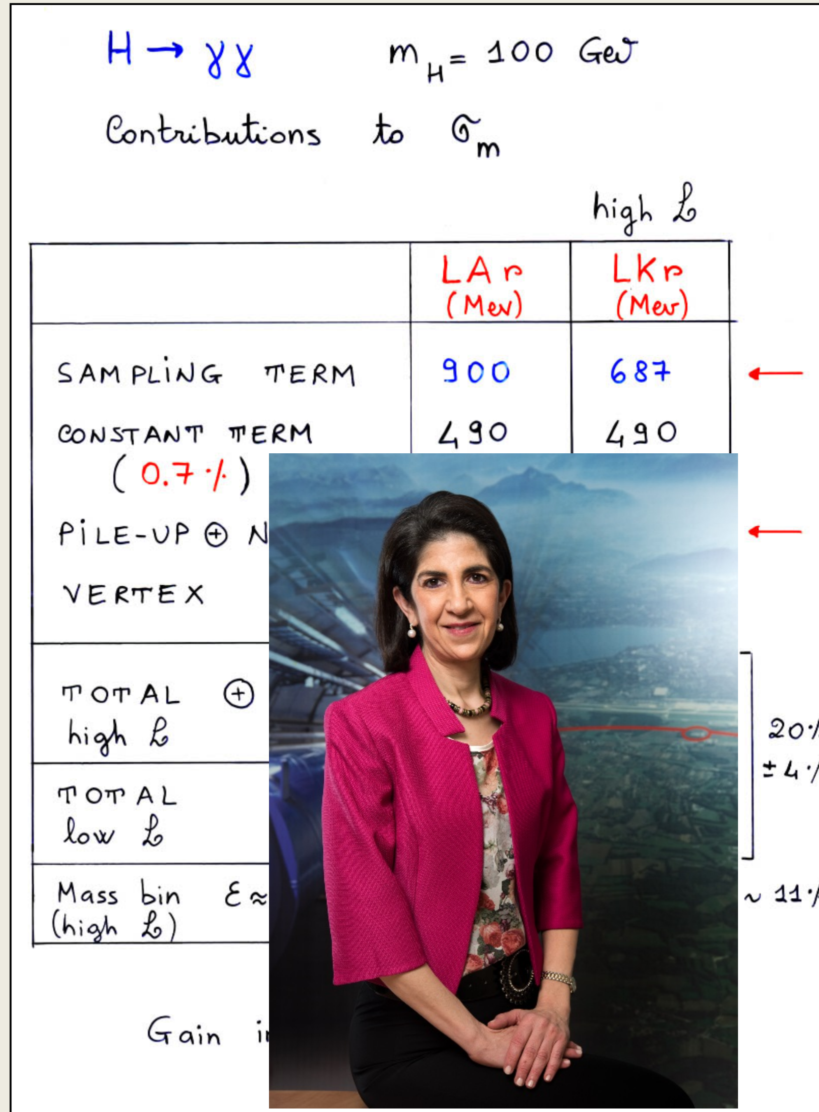
high $\mathcal{L}$

	LAr (MeV)	LKr (MeV)	
SAMPLING TERM	900	687	←
CONSTANT TERM (0.7 %)	490	490	
PILE-UP ⊕ NOISE	500	390	←
VERTEX	400	403	
TOTAL ⊕ high $\mathcal{L}$	1250 ± 30	1040 ± 30	20% ± 4%
TOTAL low $\mathcal{L}$	1050 ± 30	860 ± 30	
Mass bin $\varepsilon \approx 80$ % (high $\mathcal{L}$)	3430	3080	~ 11%

Gain in $S/\sqrt{B} \approx 7$ %

We also had quite some fights with the LHCC about performance issues, what is relevant and what not, here an example on the EM resolution…

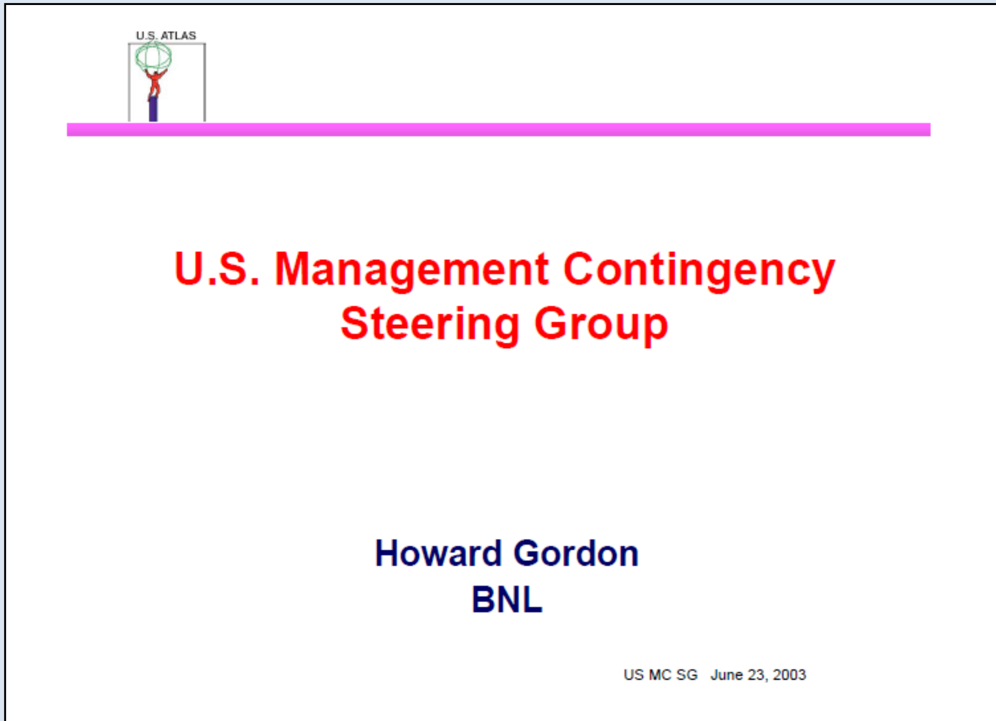




(You recognize Fabiola's handwriting!)

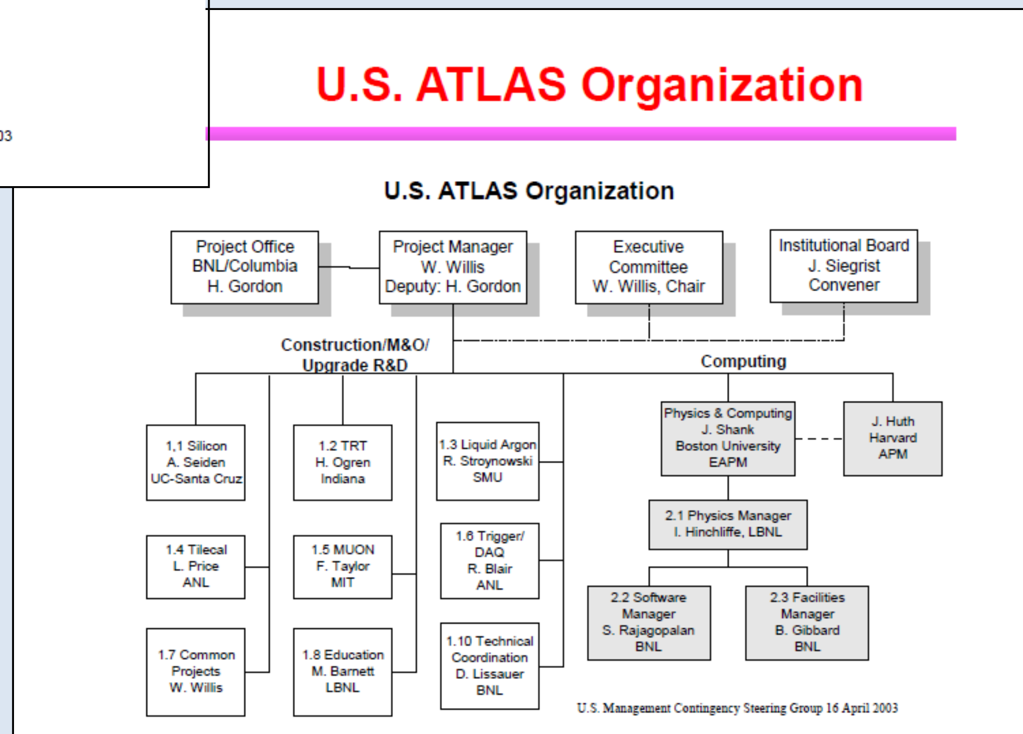
A picture which should include Howard… : LAr barrel cryostat 'ATLAS Supplier Award' for the device built, managed and contributed by BNL (for US ATLAS)

(2 Sep 2002)



A very major and serious activity Howard et al shared with the ATLAS management

Howard was really the main 'architect' with Bill Willis to make this effort a success



Over the years 2000 to 2007 we had more than 20 USMC meetings, optimizing together what could be made with the capped US ATLAS budget, all documented in formal minutes

A concise summary of BNL’s huge contributions to the construction

(borrowed from Hong Ma’s presentation to a BNL DOE review, 22 April 2002, shown in an USMC Steering Group meeting)

U.S. ATLAS

Summary

- ATLAS detector construction at BNL is well underway, and on schedule
  - Most LAr Calorimeter components are completed.
  - CSC construction will finish by end of ’03
- Major effort in system integration
  - LAr front-end crate system test
  - Installation and commissioning
- Technical Coordination
  - Playing a critical role in ATLAS Technical Coor.
- LHC upgrade:
  - Inner Tracker R & D

Hong Ma , BNL DOE Annual HEP Program Review, April 22, 2002

Close-out Report
Department of Energy/
National Science Foundation
Review Committee Report
on the
Technical, Cost, Schedule, and
Management Review
of the

U.S. LHC ATLAS DETECTOR PROJECT

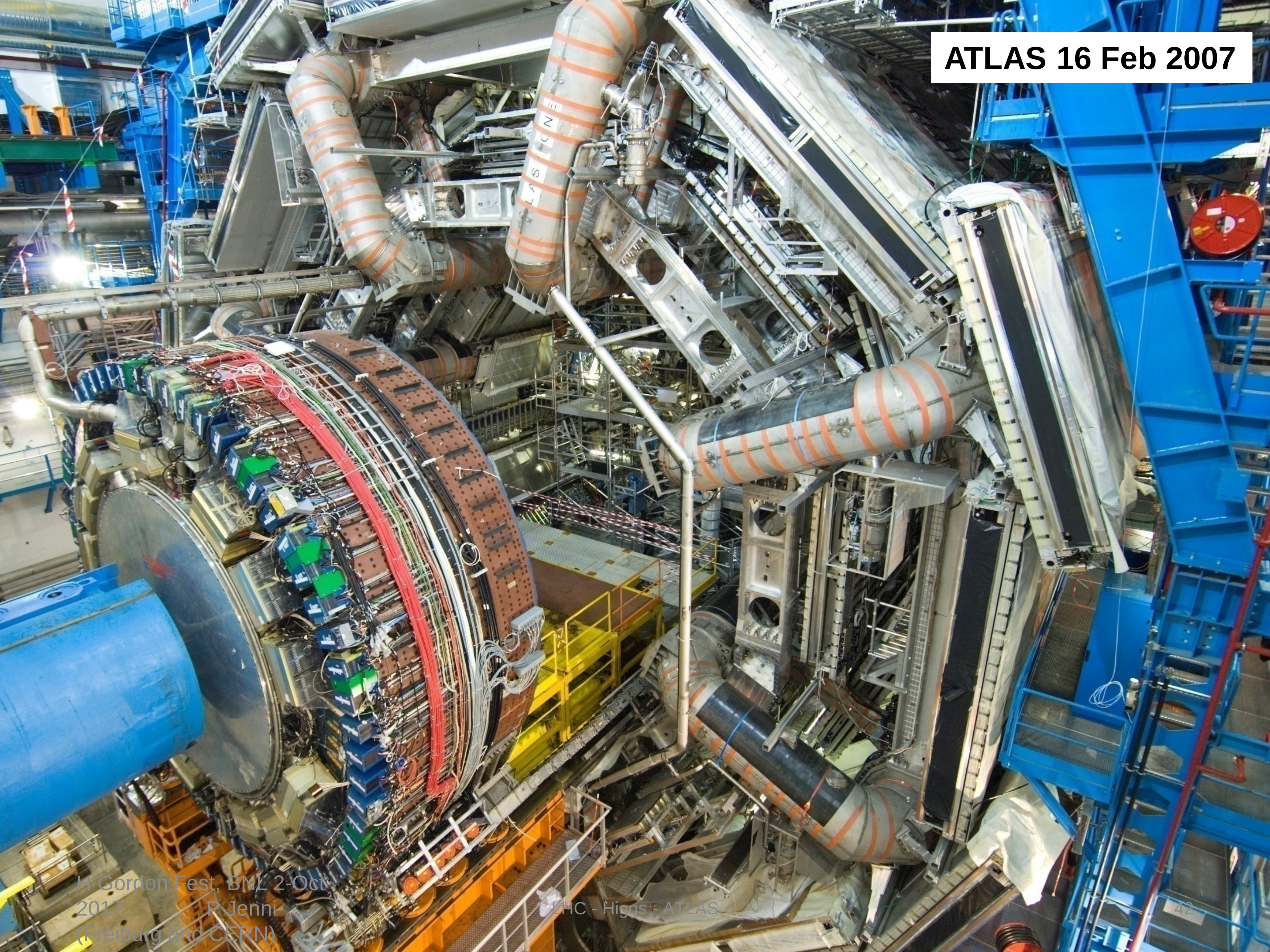
May 19, 2004

Here the conclusions from one of many DOE/NSF reviews

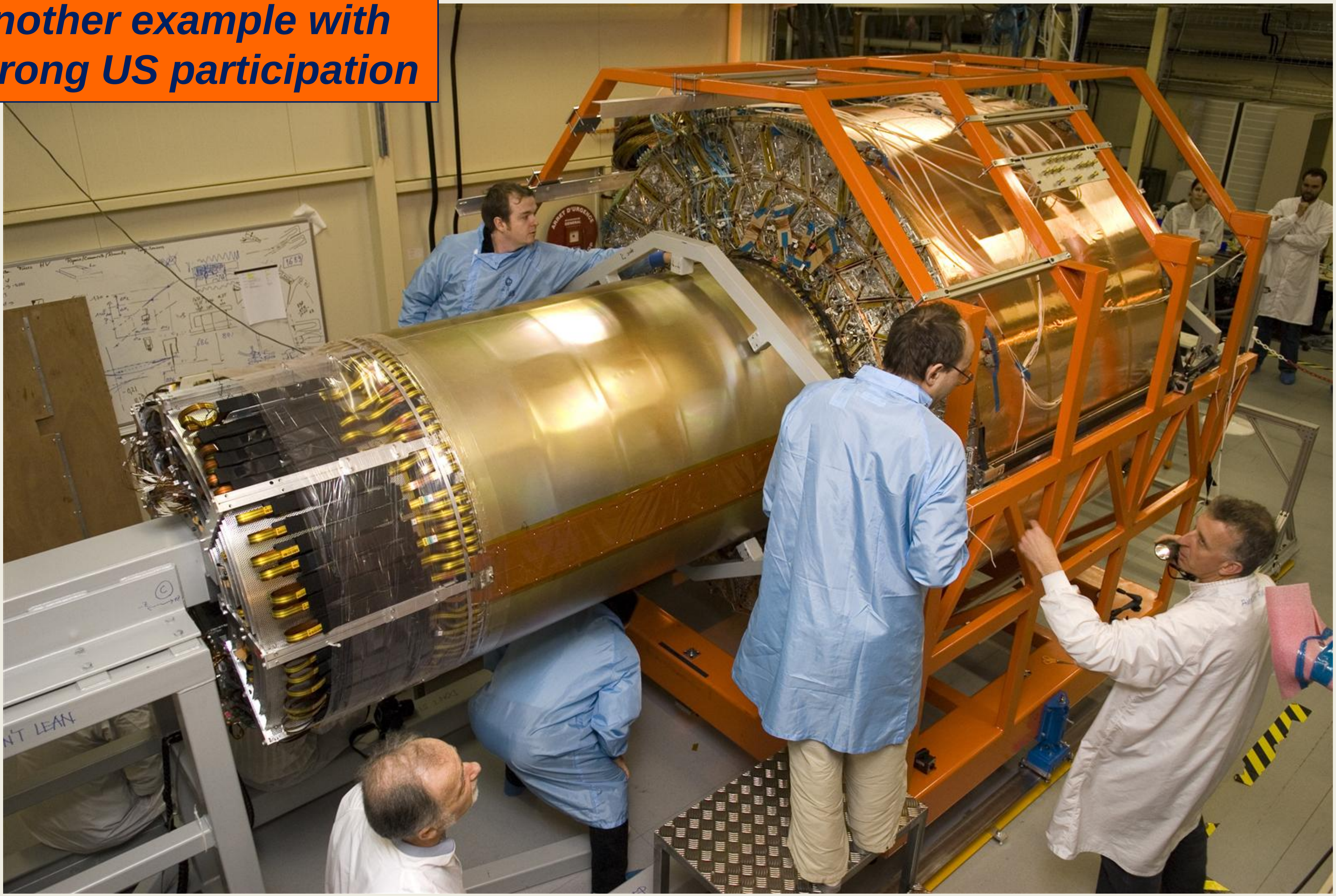
Howard was really the main 'architect' with Bill Willis to make this effort a success

- Management
  - U.S. ATLAS Management is working well with ATLAS management and is responding well to challenges presented.
  - Installation cost estimates for U.S. supplied components should be revisited in light of schedule delays that have forced a more rapid installation schedule.
  - U.S. Subsystem schedules should be examined to ensure that they reflect the latest ATLAS schedule information and assure adequate float .

ATLAS 16 Feb 2007



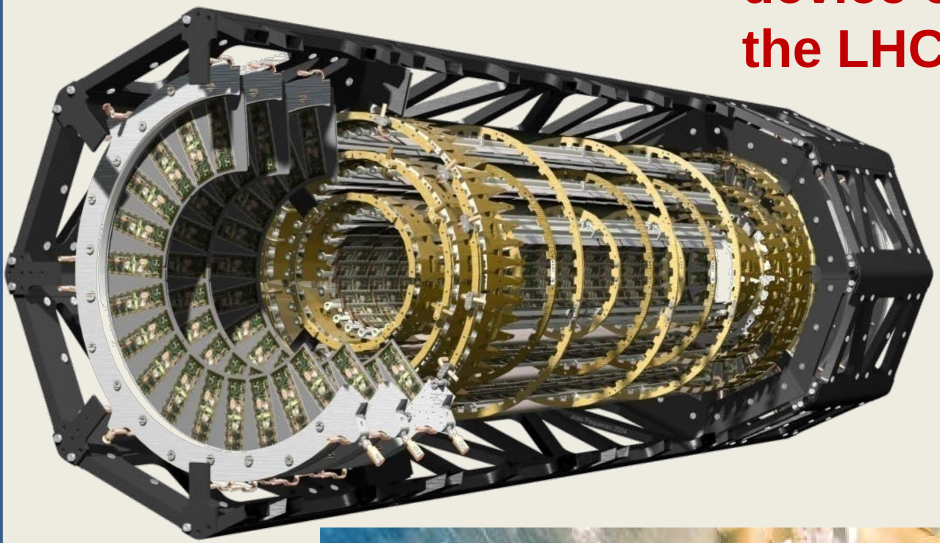
Another example with strong US participation

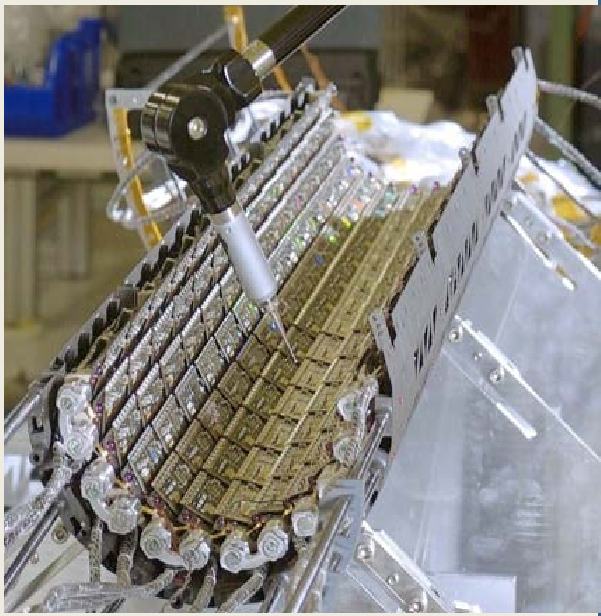


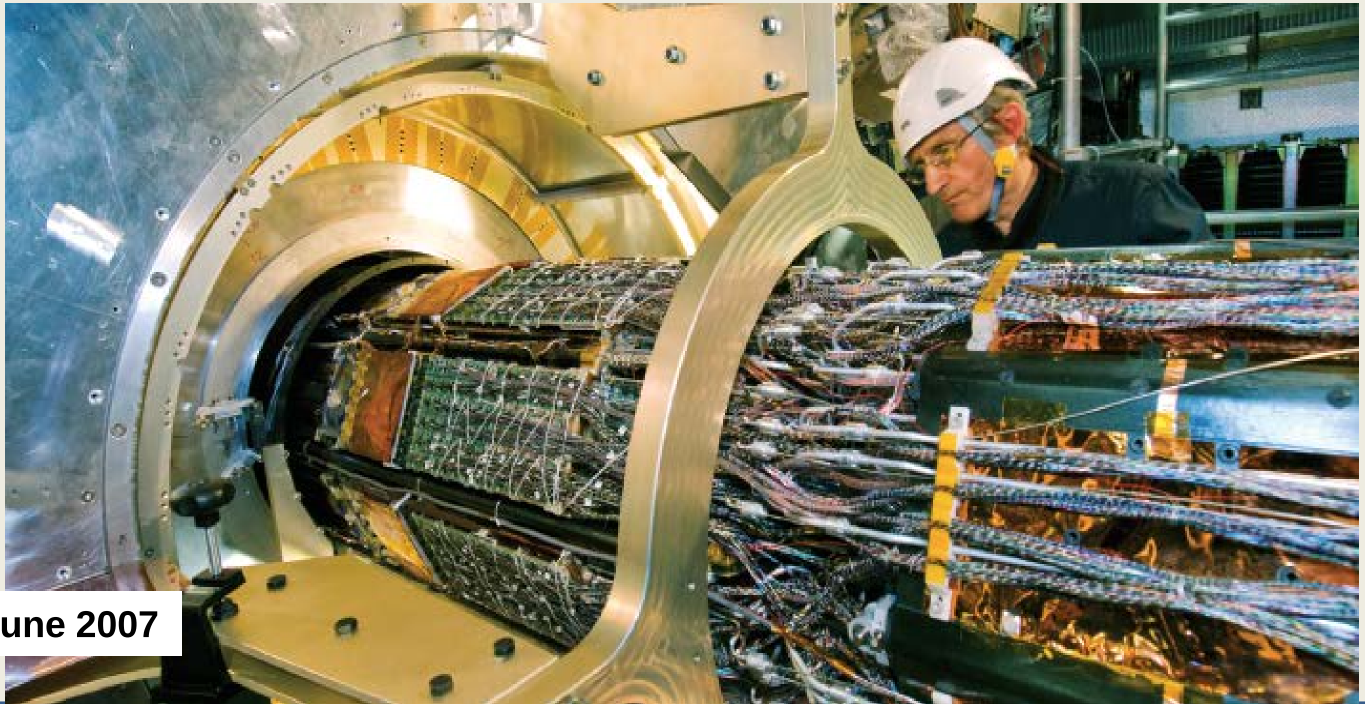
Barrel SCT insertion into TRT (17 Feb 2006)

Another example with strong US participation

The Pixel tracker is a particularly high-tech device close around the LHC beam pipe





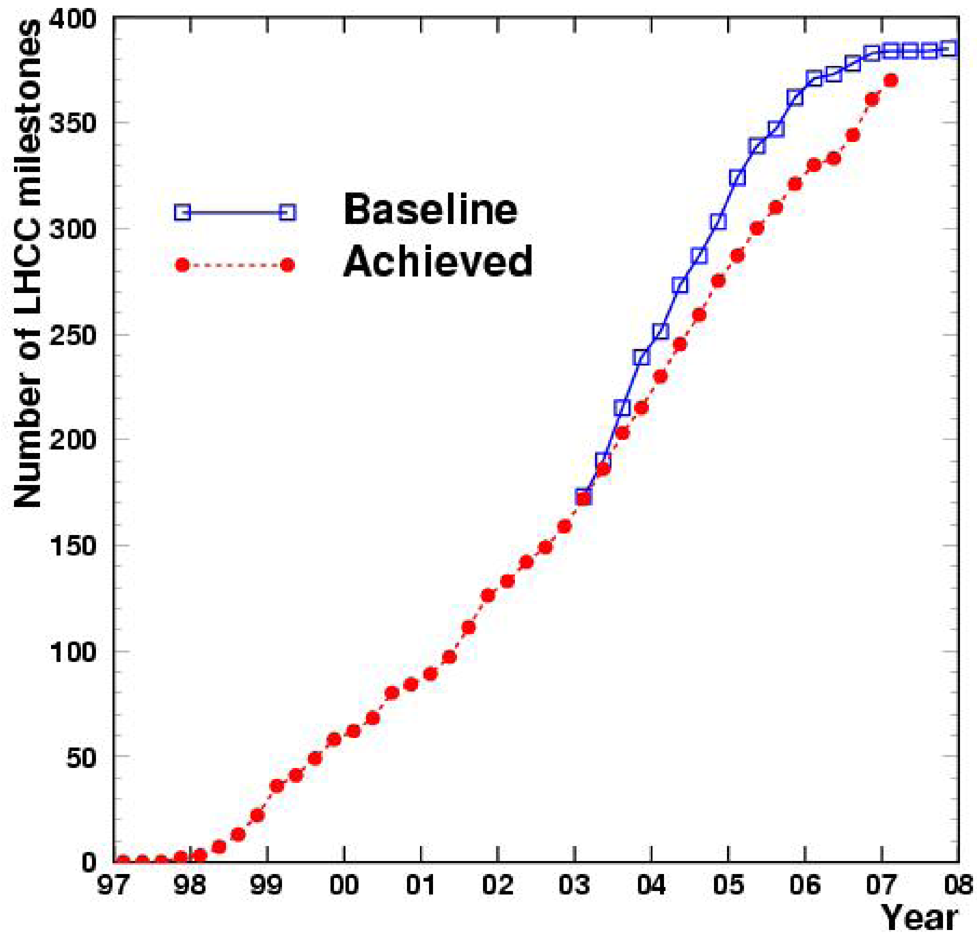


Insertion in June 2007

from a 2007 slide:

Construction follow-up: LHCC milestones evolution

The technical and scientific progress of the project was frequently (6x per year…) reviewed by an external expert committee ('LHCC') that reports to the CERN Directors

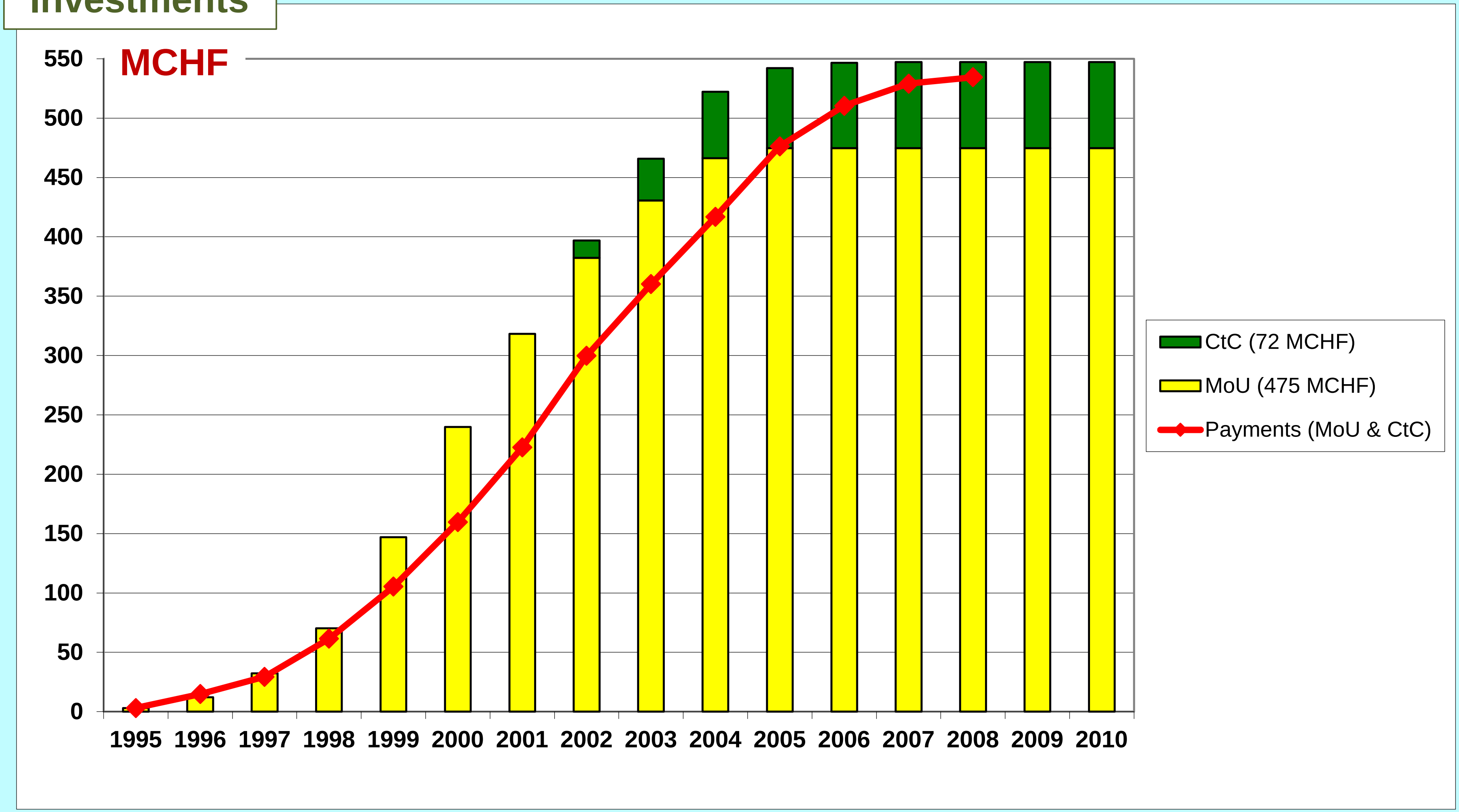


Construction issues and risks ('Top-Watch List'),
strong involvement of BNL Technical Coordination

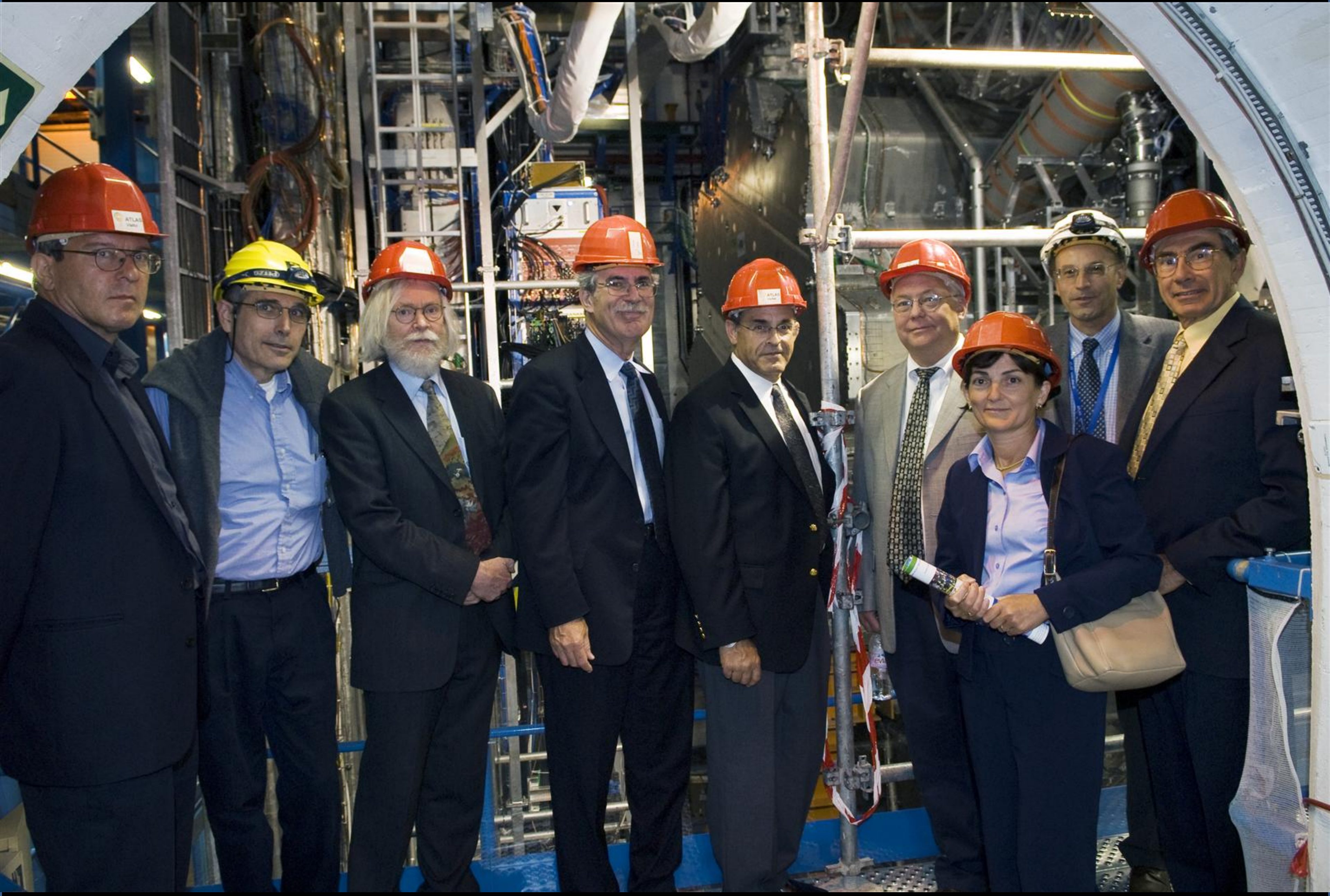
A list of these issues is monitored monthly by the TMB and EB, and it is publicly visible on the Web, including a description of the corrective actions undertaken

Overview of the integrated financial evolution of the 'CORE' costs of ATLAS (Construction MoU deliverables and Common Fund, Cost-to-Completion, in MCHF)

'Investments'



BNL Director Samuel Aronson visiting ATLAS and CERN, 24 Sep 2007



ATLAS 4 April 2008

Peter Higgs

LHC incident

Interconnections of two magnets

One (superconductor) joint failed on 19th September 2008, and it caused a catastrophic He-release that made serious collateral damage to sector 3-4 of the LHC machine (required a 15 months repair period)

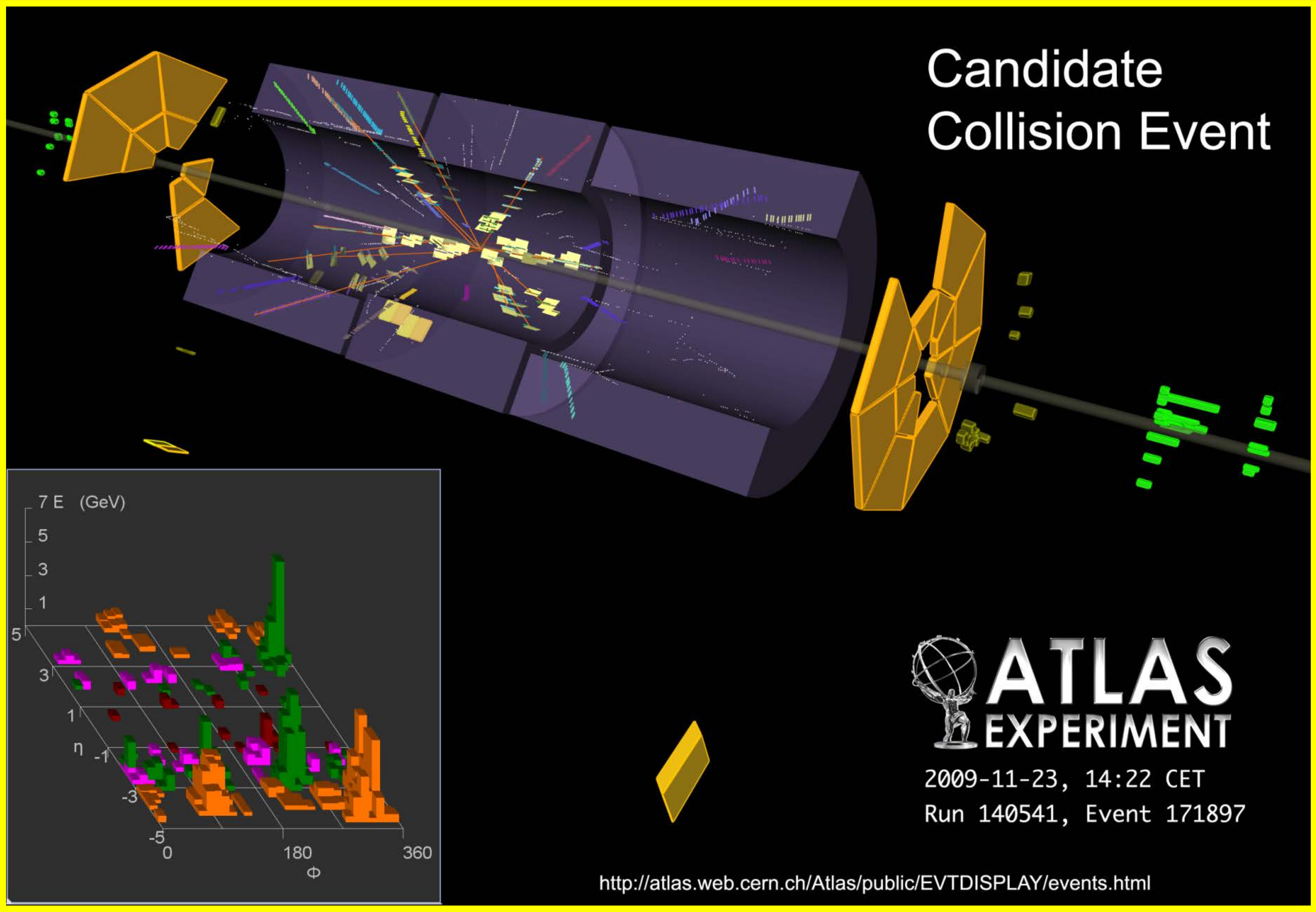
Nevertheless, ATLAS celebrated on 4th Oct 2008 the successful 15 years of design, construction and installation of the detector

… also with humour, Howard bringing the hottest news from the US

Expecting in the ATLAS Control Room the first LHC beam to collide on November 23rd, 2009....

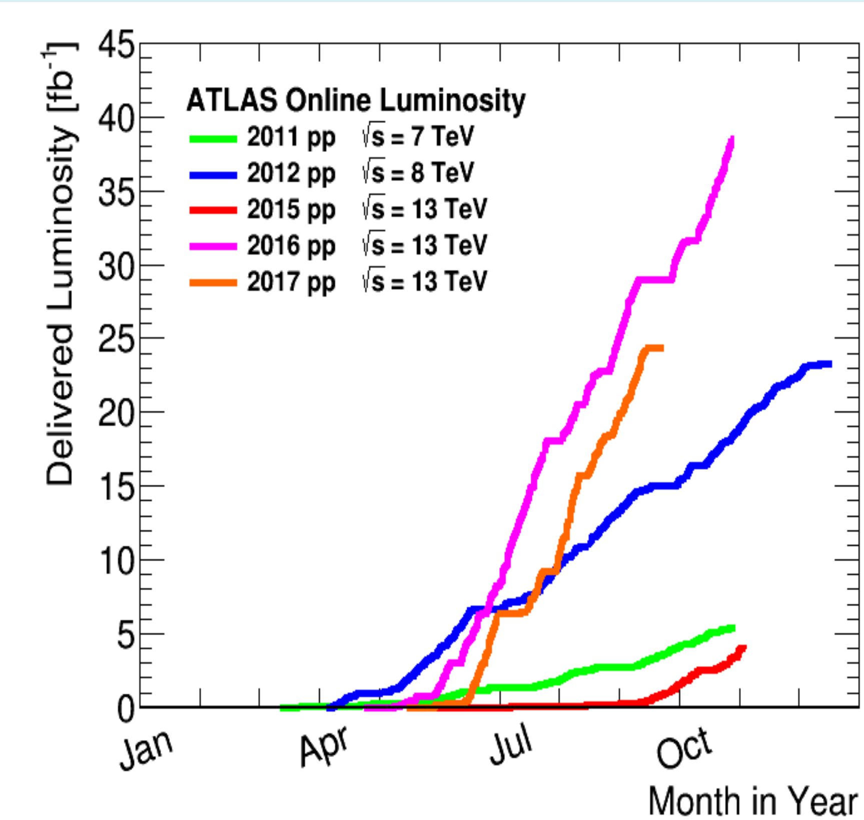
The joy in the ATLAS Control Room when the first LHC beam collided on November 23rd, 2009....

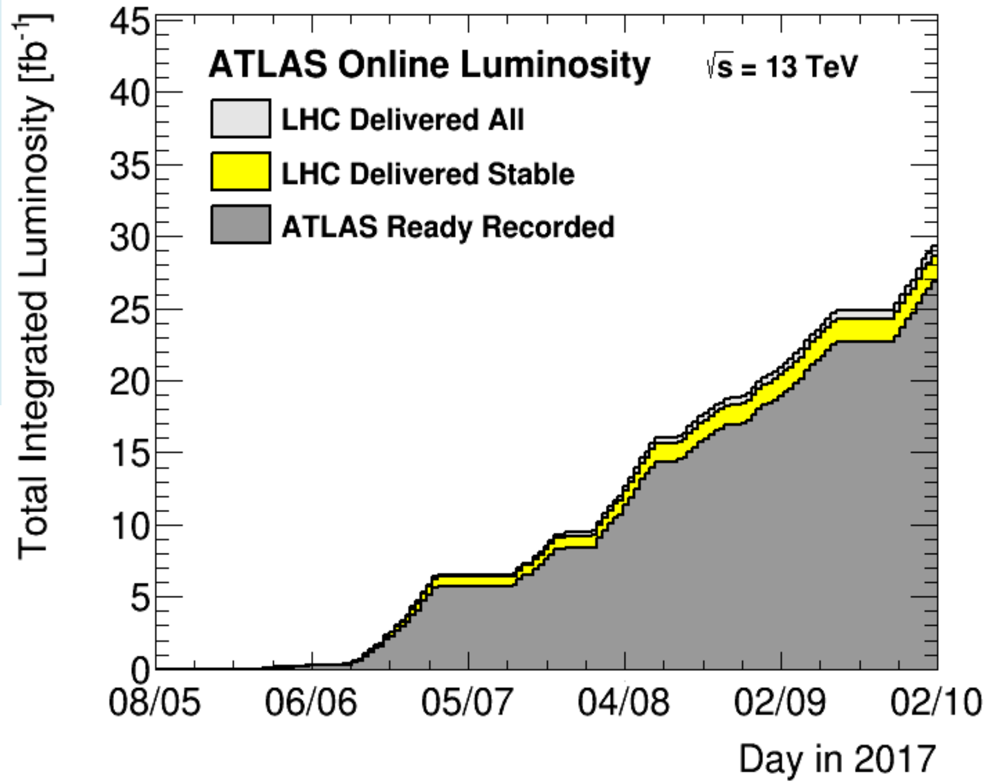
First collisions at the LHC end of November 2009 with beams at the injection energy of 450 GeV



The LHC and ATLAS performances for Run-2 (2015-2018) at 13 TeV

The machine worked outstandingly well and delivered in 2016 about 40 fb^{-1} data, and the same can be expected for 2017





ATLAS pp 25ns run: April-October 2016

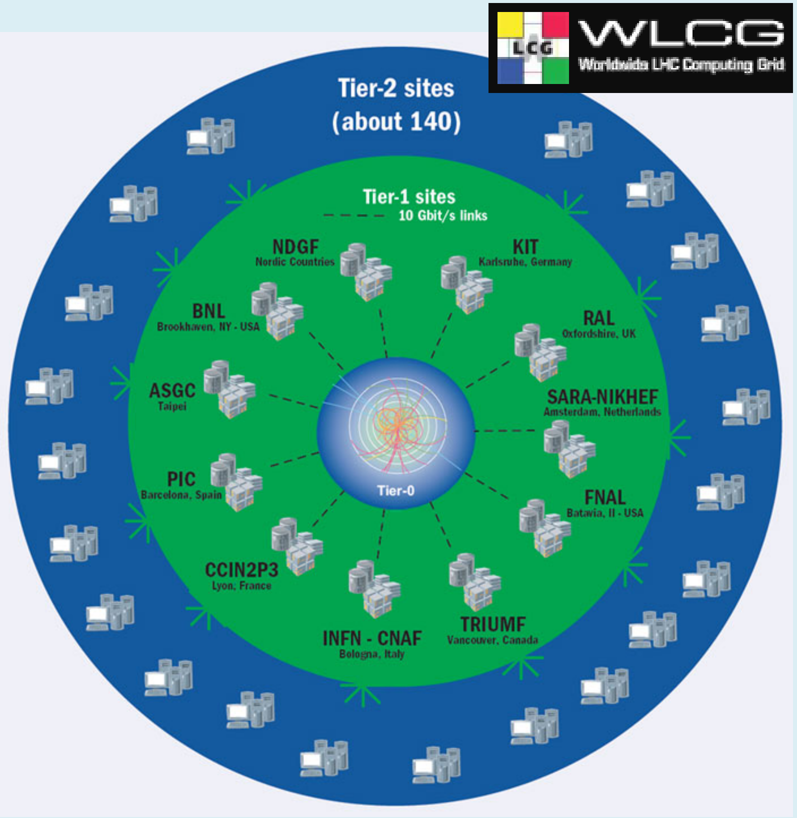
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets		Trigger
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid	L1
98.9	99.9	99.7	99.3	98.9	99.8	99.8	99.9	99.9	99.1	97.2	98.3

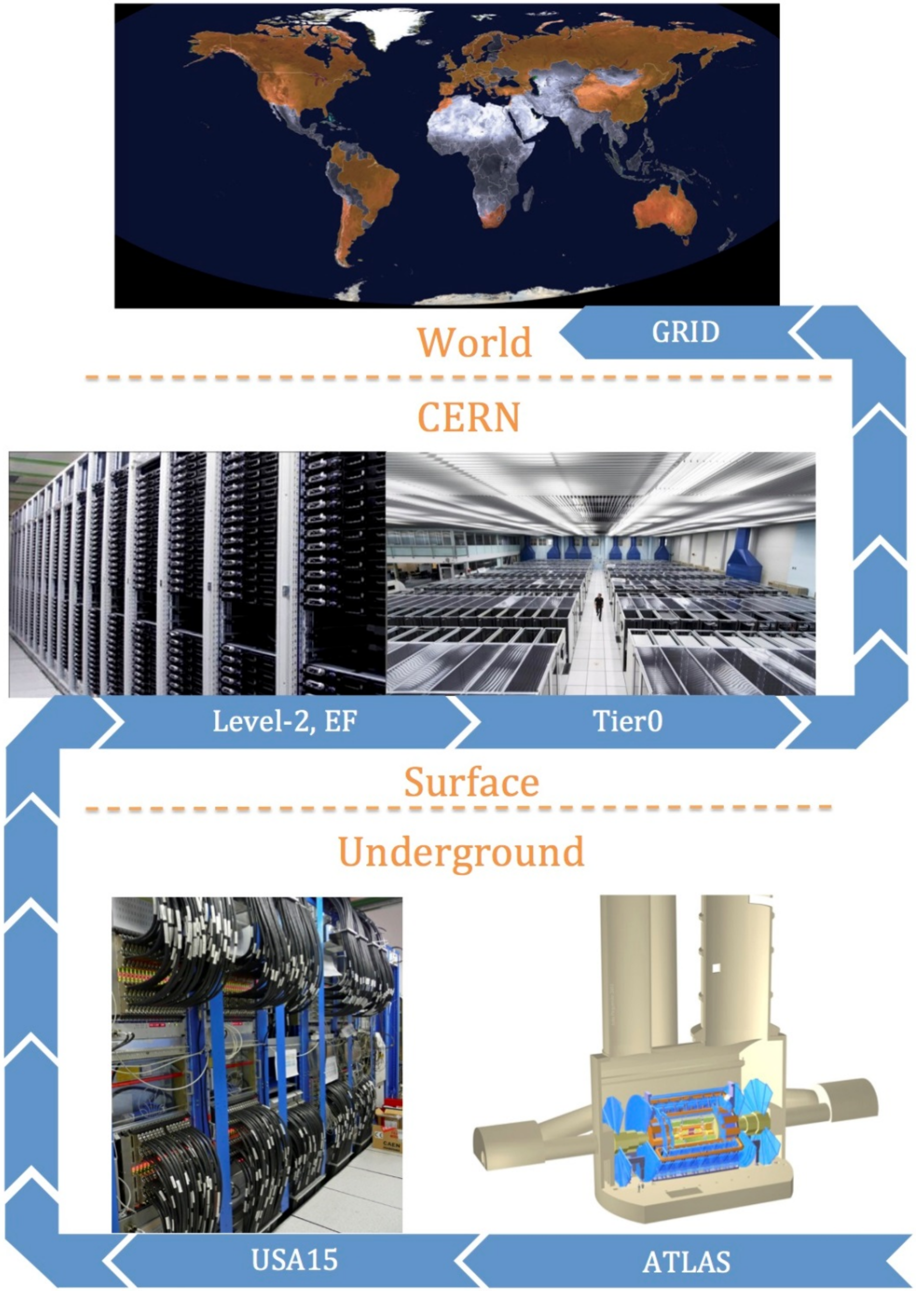
Good for physics: 93-95% (33.3-33.9 fb^{-1})

Luminosity weighted relative detector uptime and good data quality efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at √s=13 TeV between April-October 2016, corresponding to an integrated luminosity of 35.9 fb^{-1}. The toroid magnet was off for some runs, leading to a loss of 0.7 fb^{-1}. Analyses that don't require the toroid magnet can use that data.

The Worldwide LHC Computing Grid

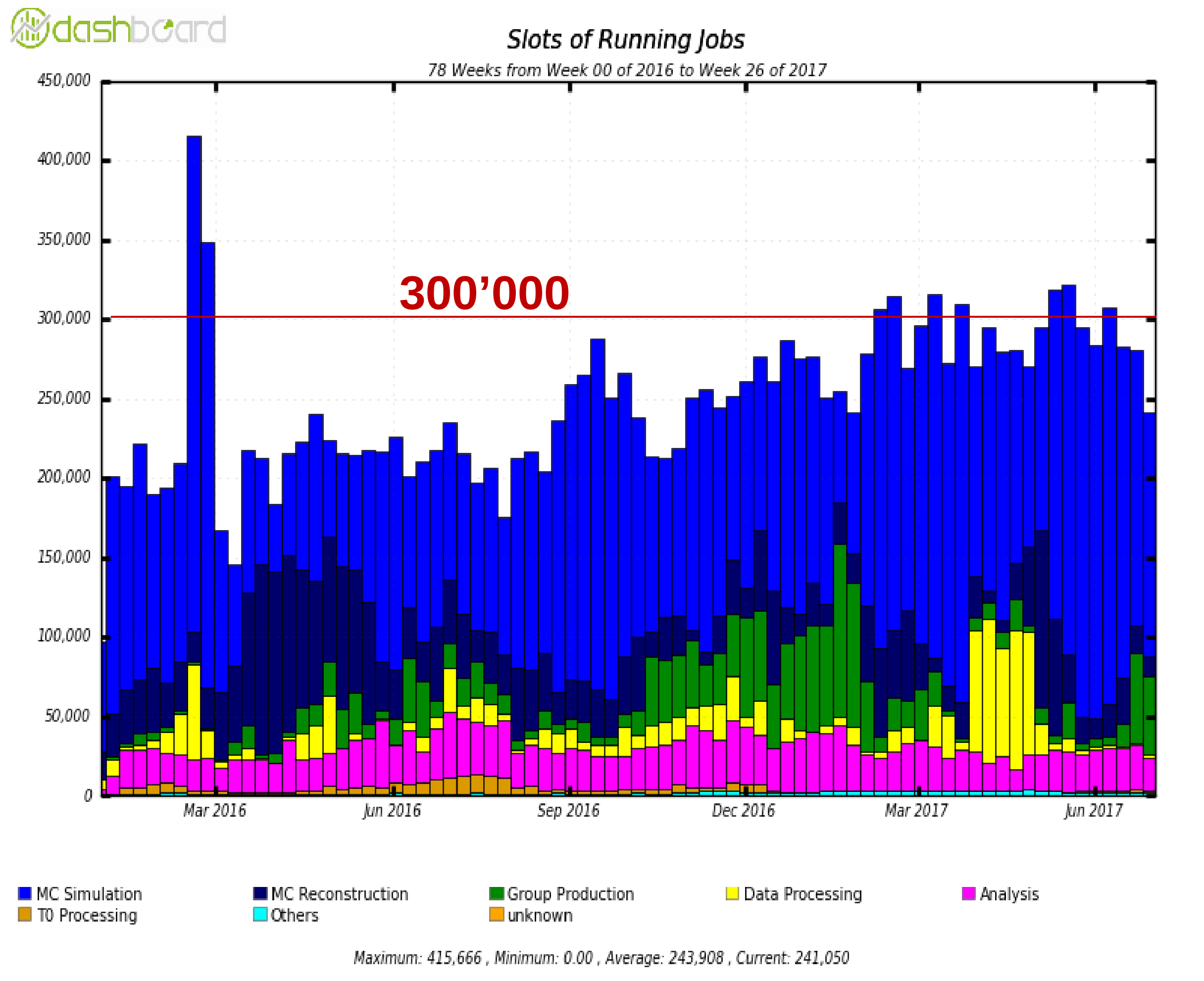
GRID computing was developed to solve problem of data storage and analysis (tens of Petabytes)



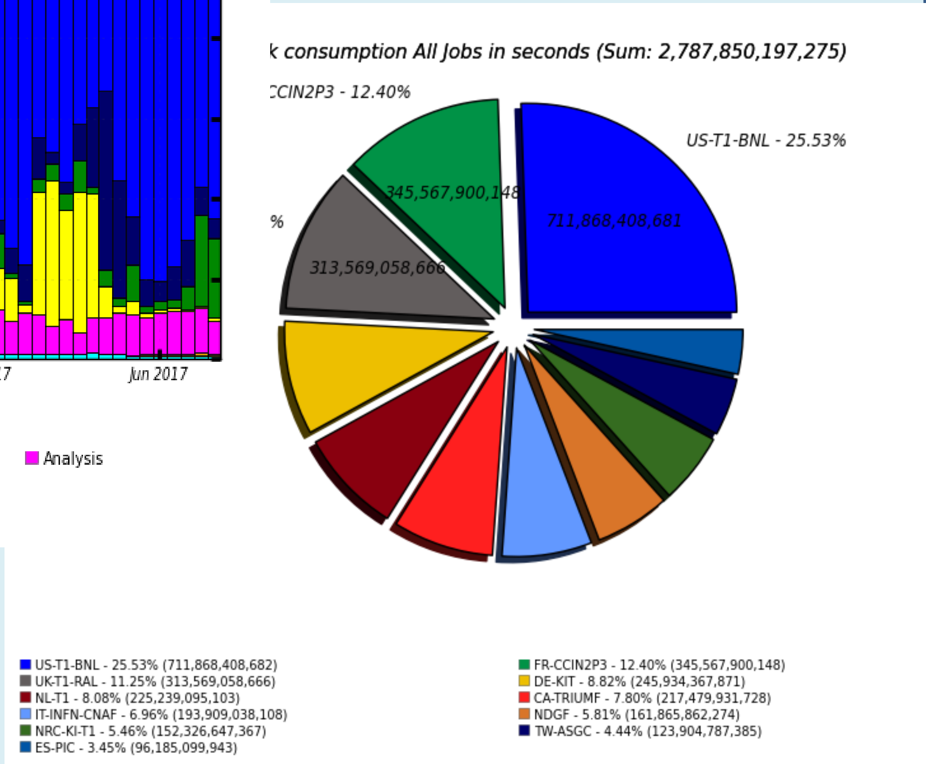


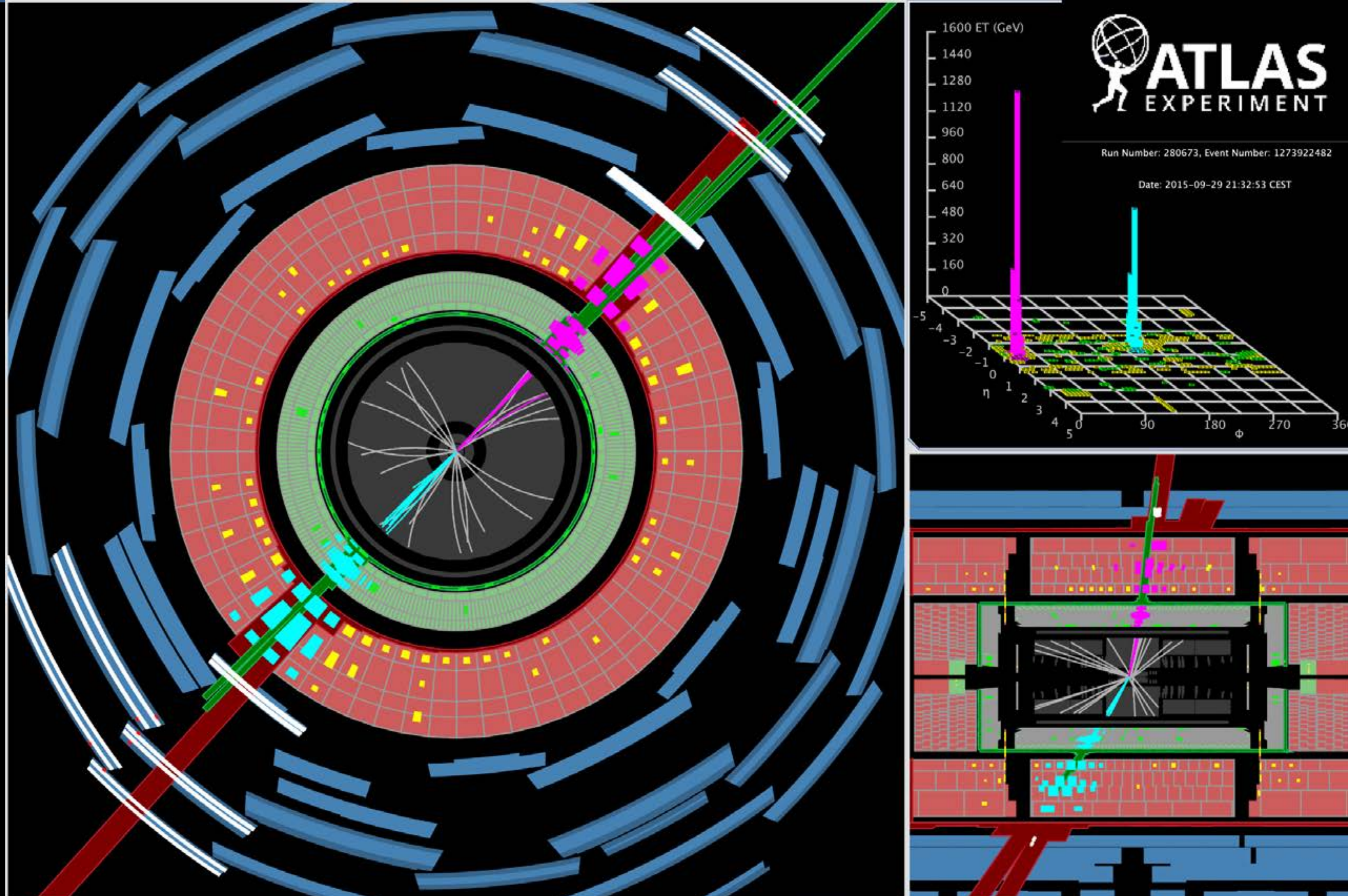
Data flow

Weekly averages of cores running for ATLAS



Wall clock consumption for all jobs in the 11 Tier-1s



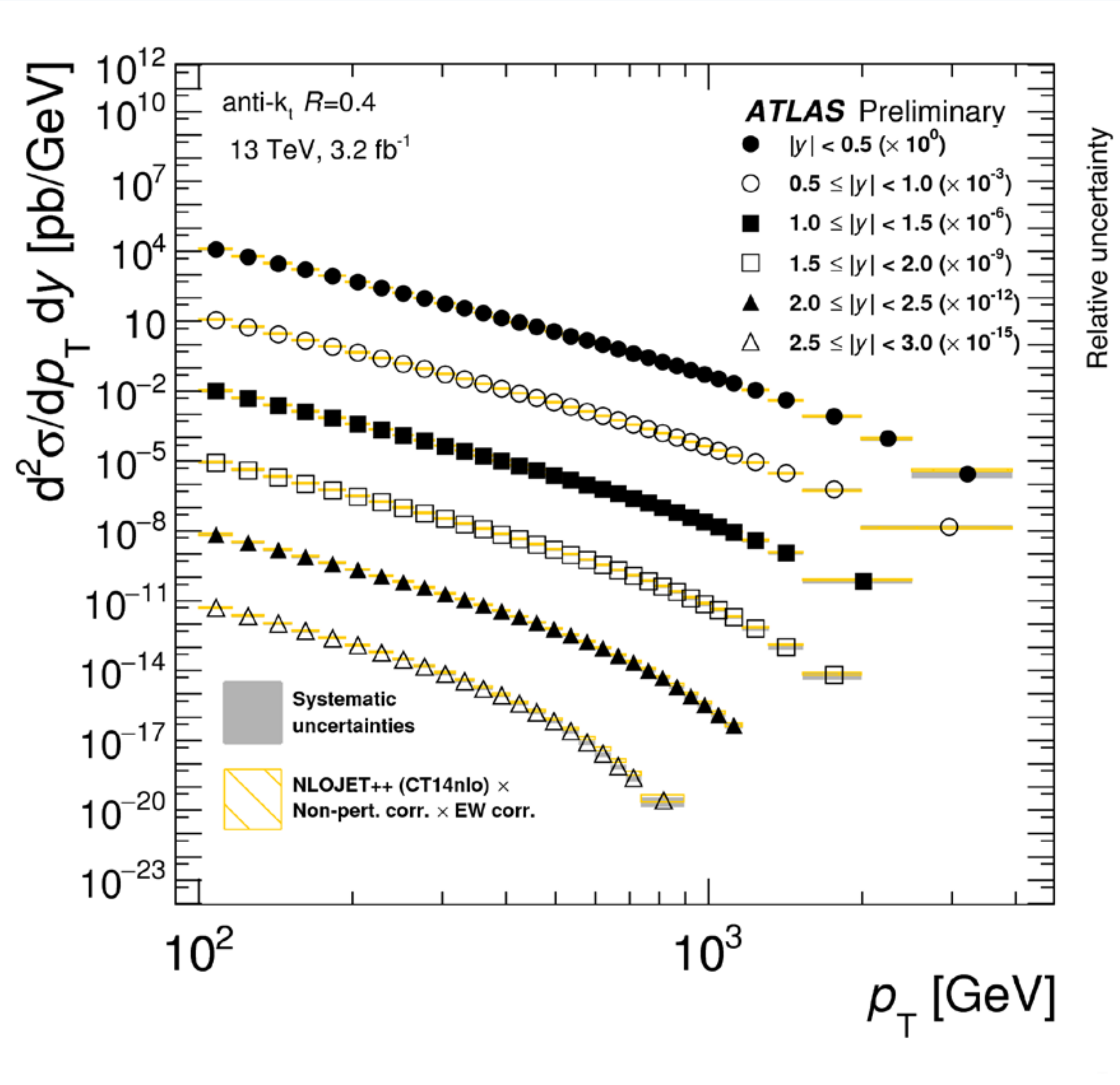


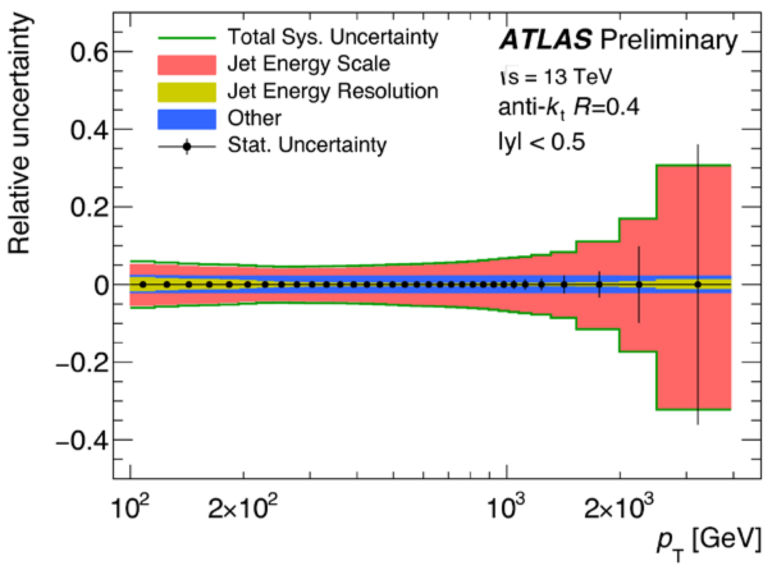
Di-jet events

Highest mass central di-jet event 2015

$p_{T1} = p_{T2} = 3.2$ TeV $m_{JJ} = 6.9$ TeV $ET_{miss} = 46$ GeV

A recent example of a QCD analysis: Inclusive jet cross-section at 13 TeV





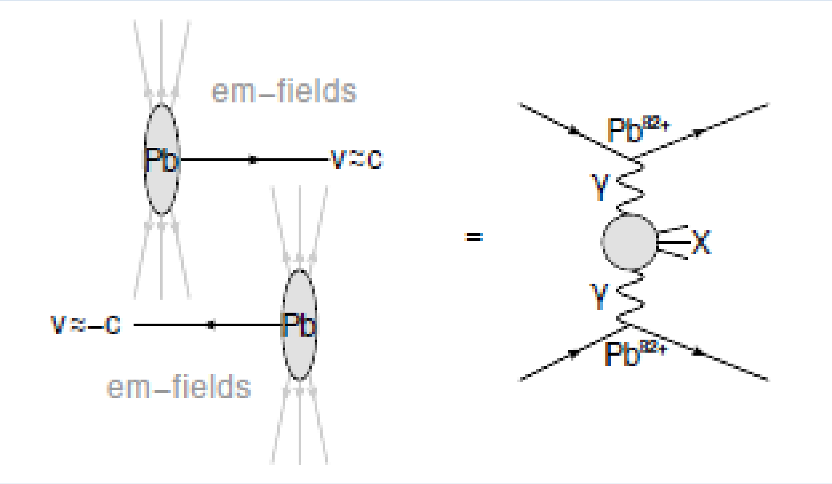
Jet energy scale (JES) and jet energy resolution (JER) uncertainties

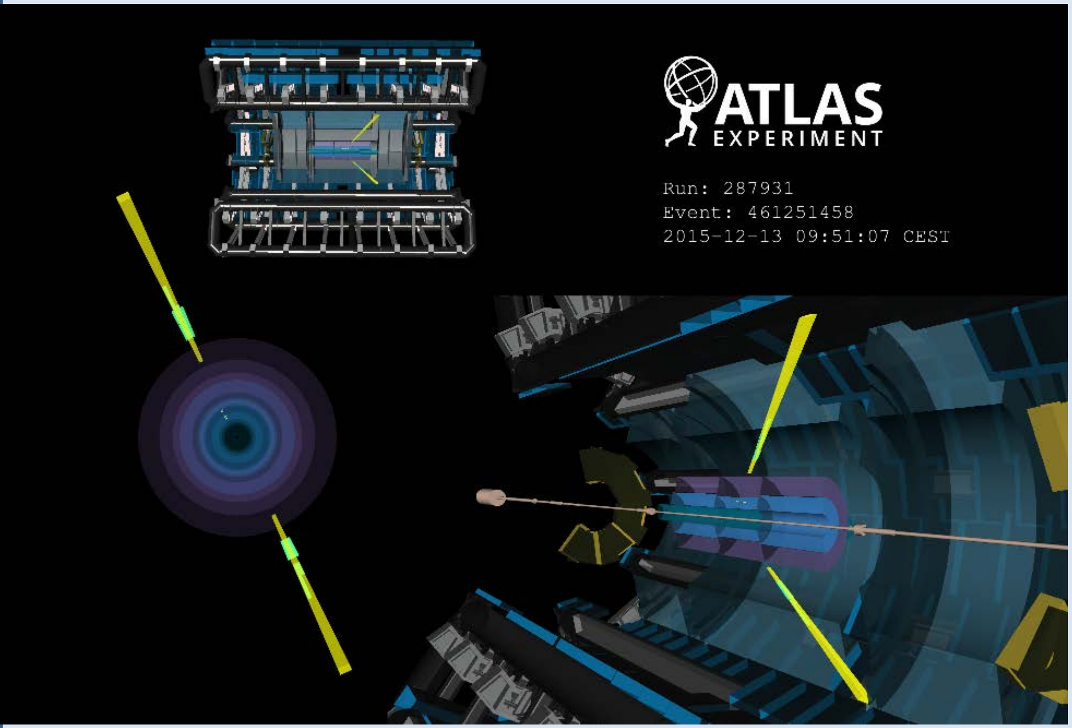
ATLAS-CONF-2017-048

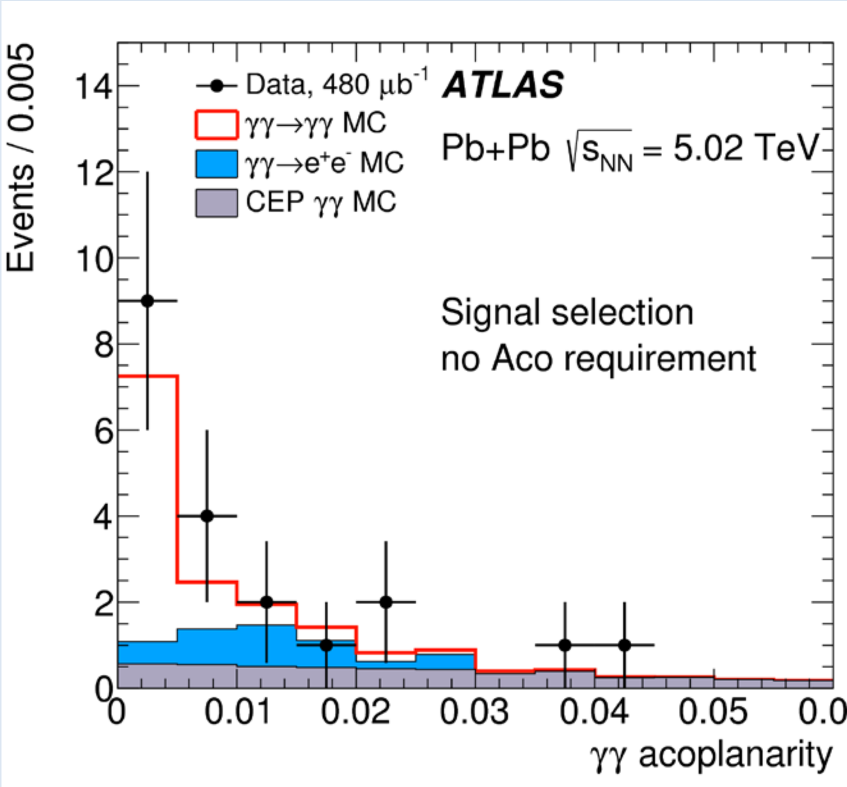
An example of physics that was certainly not anticipated at the time of the conception of ATLAS:

Evidence of light-by-light scattering in heavy ion collisions

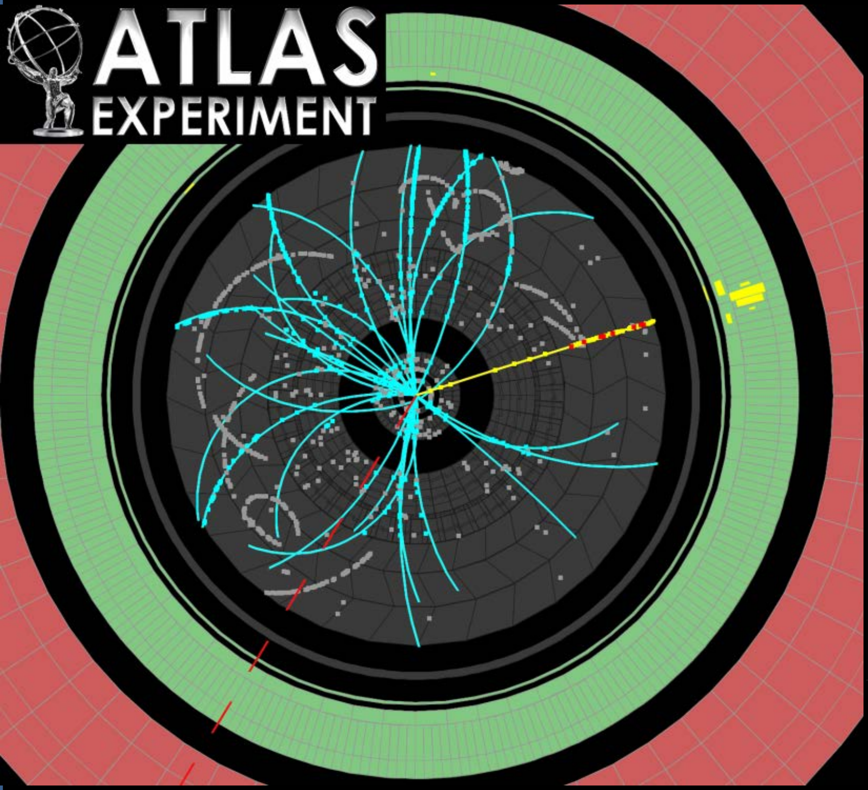
arXiv:1702.01625[hep-exp] accepted by Nature Physics

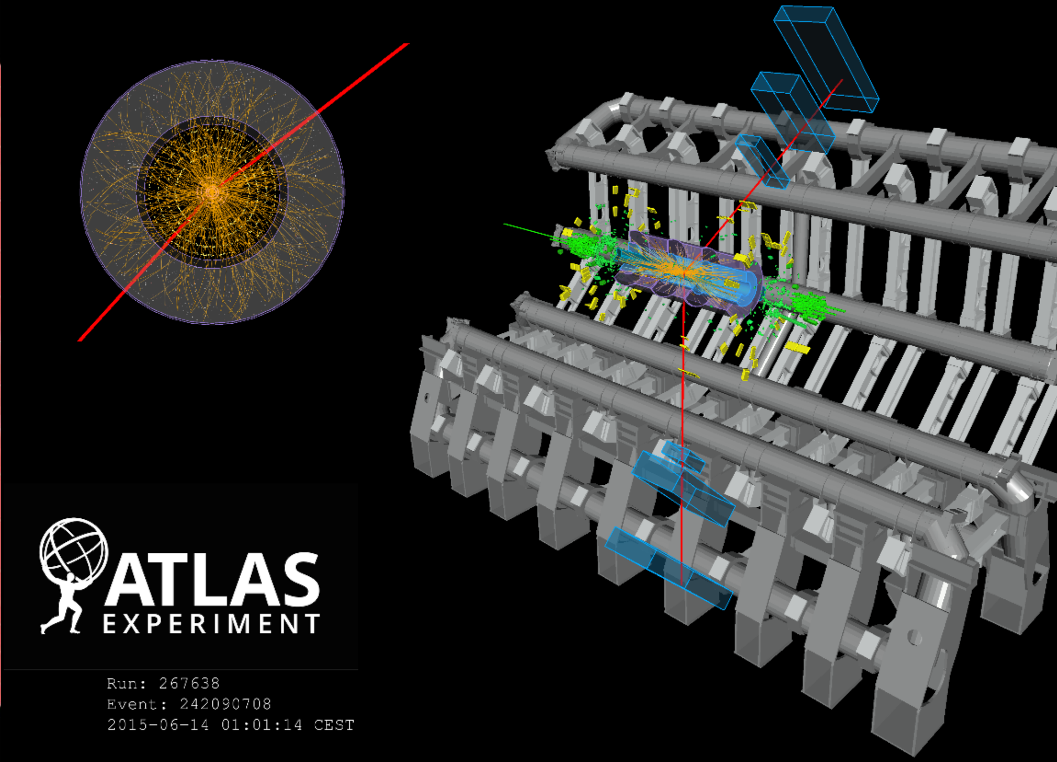






‘Standard Candles’ for the LHC physics: W and Z bosons

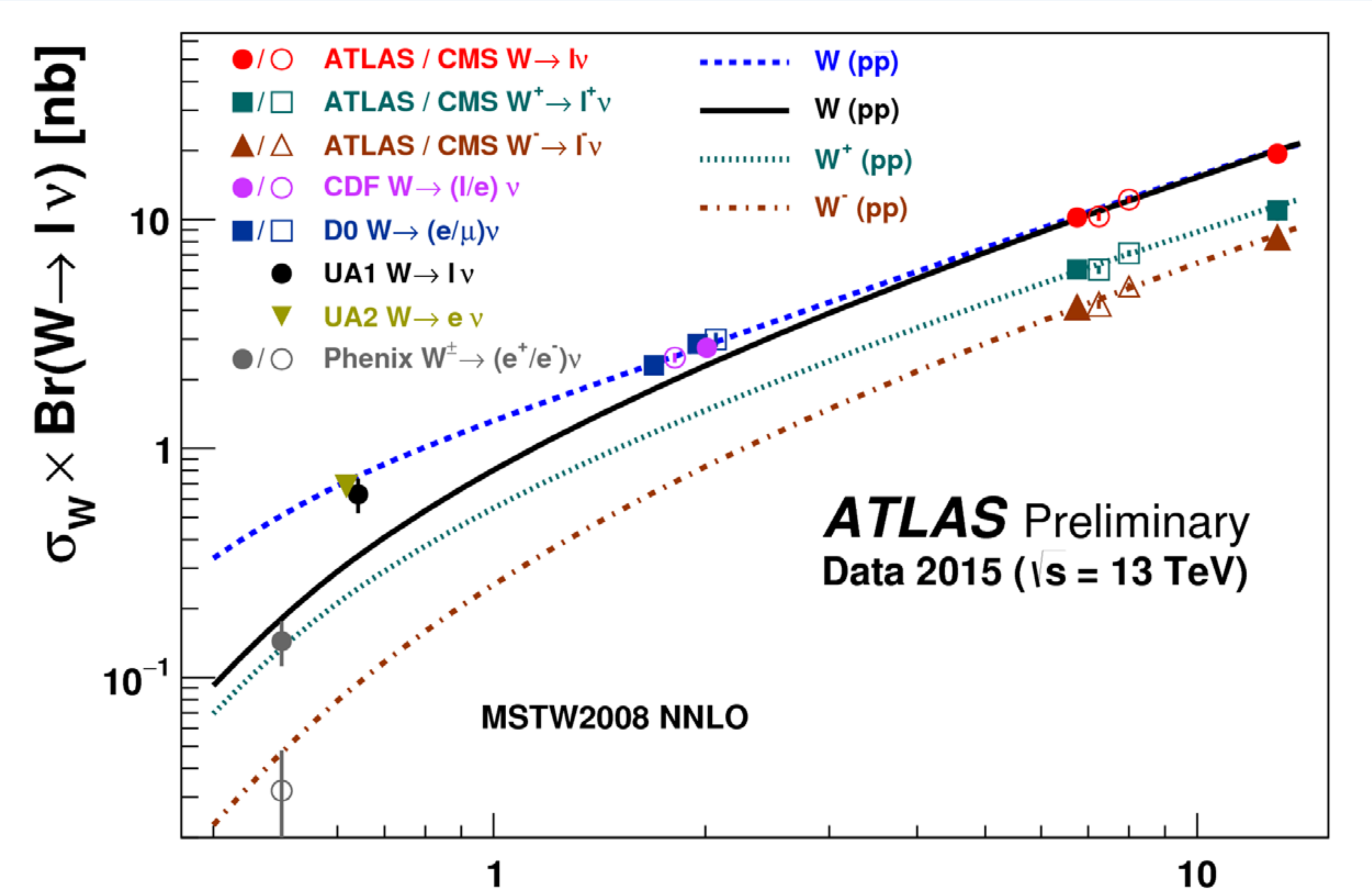




W → eν candidate

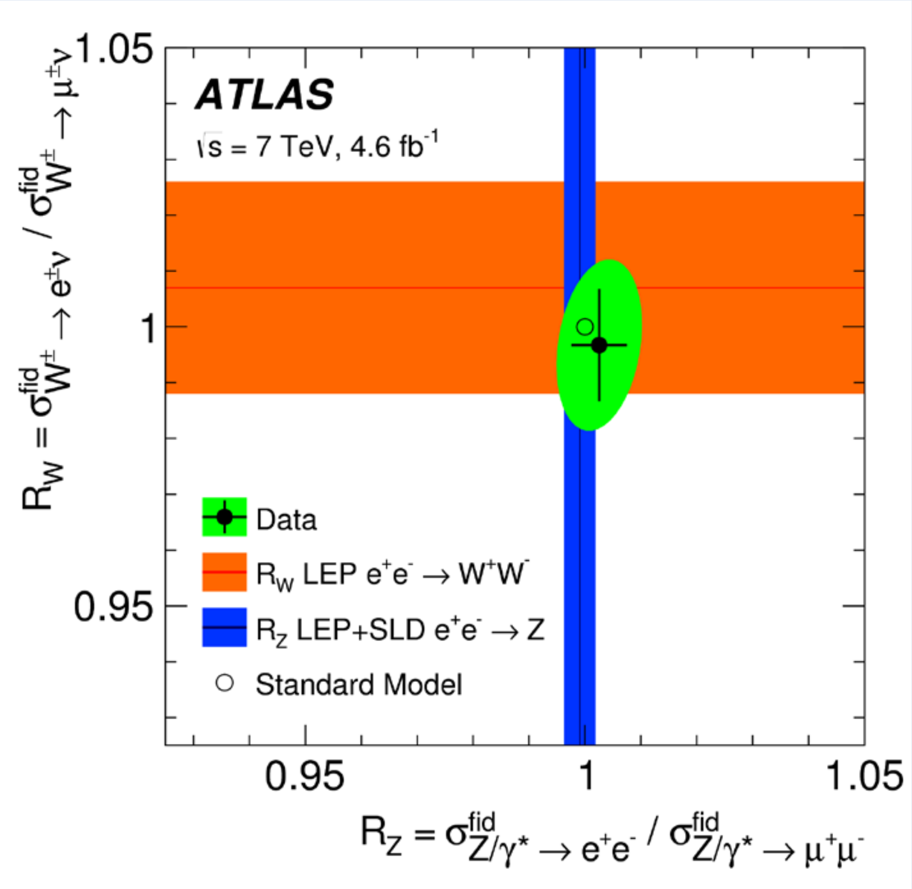
Candidate Z → $\mu^+\mu^-$

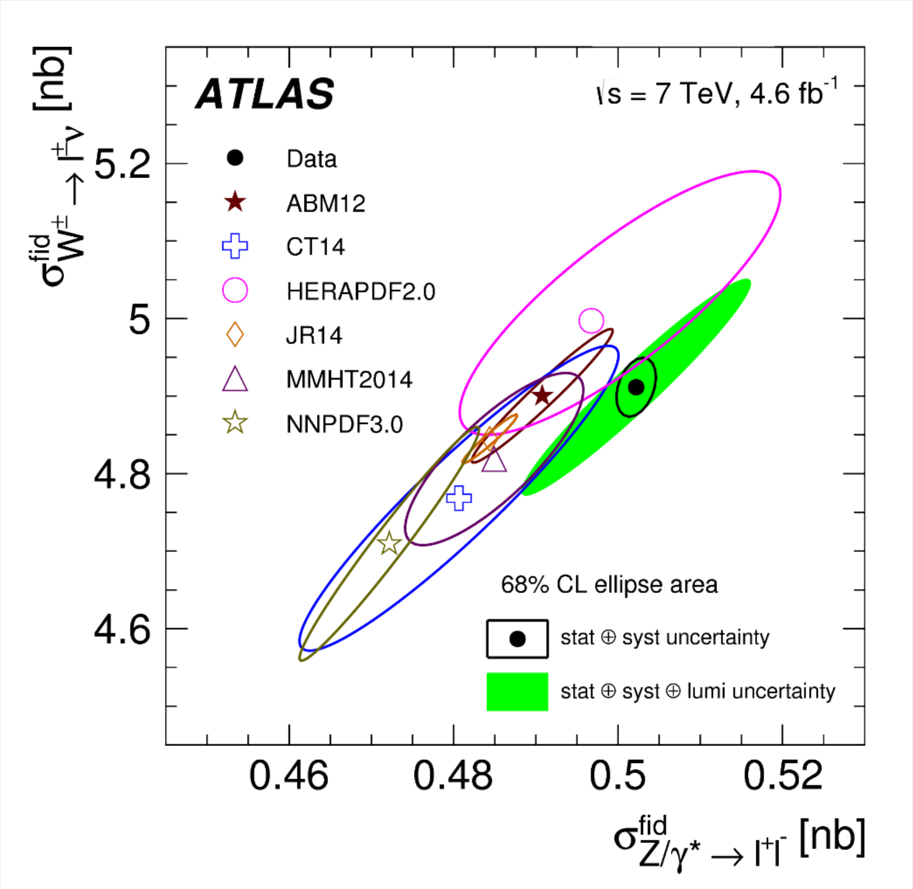
W cross section measurements in pp collisions



ATLAS-CONF-2015-039

Testing in detail the predictions of the Standard Model



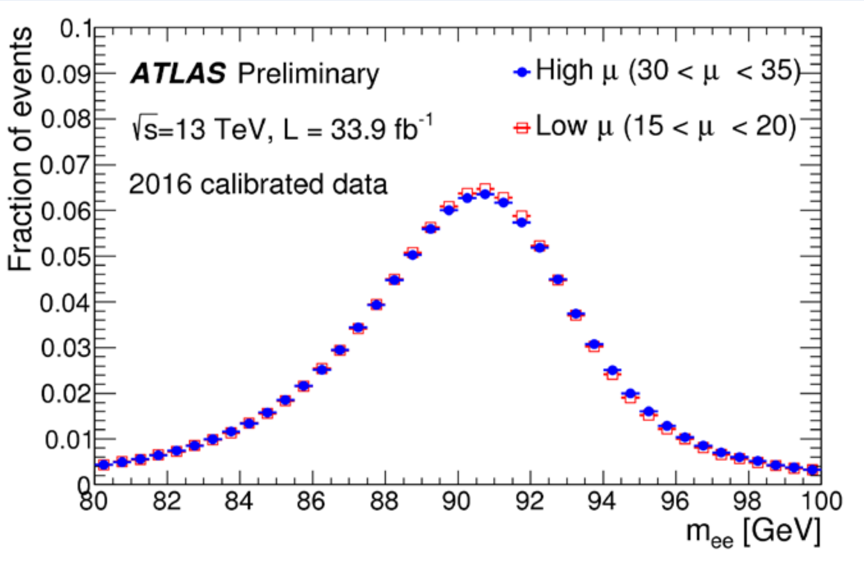


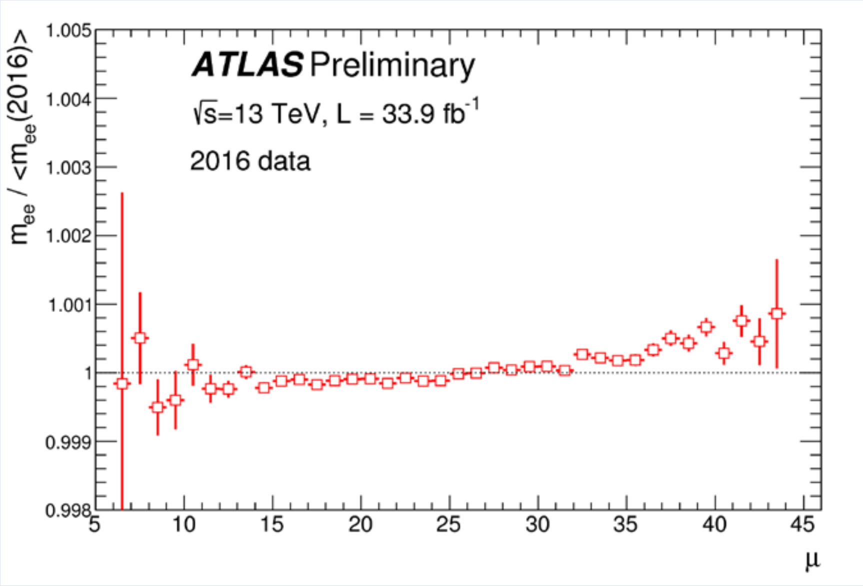
Lepton Universality

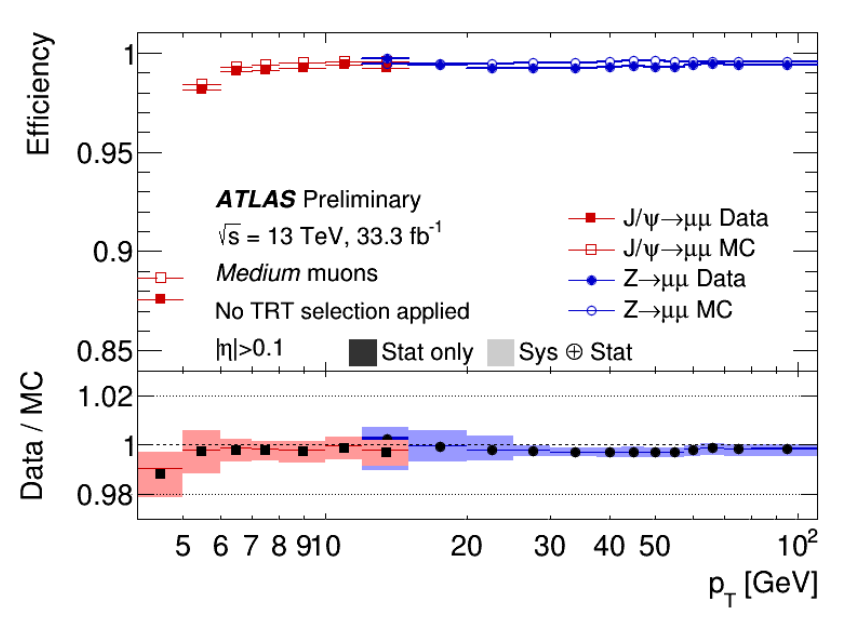
Cross-section predictions for different parton distributions

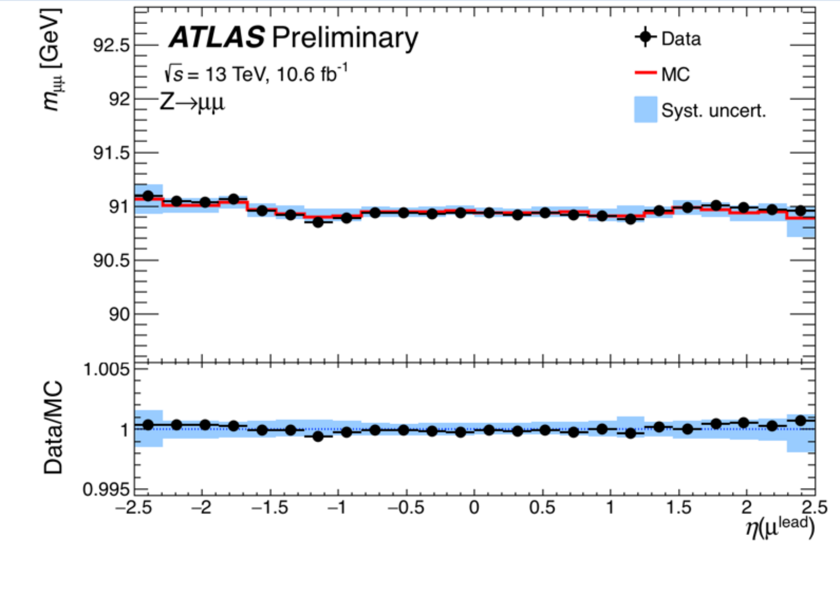
Eur. Phys. J. C77(2017)367

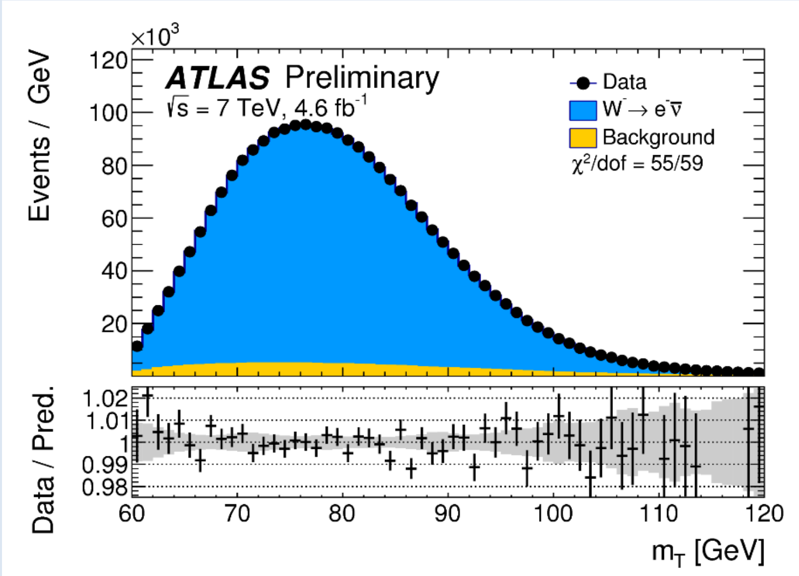
Detailed performance studies for electrons and muons (mass scales, efficiencies, dependence on pile-up …) are most important for precision measurements

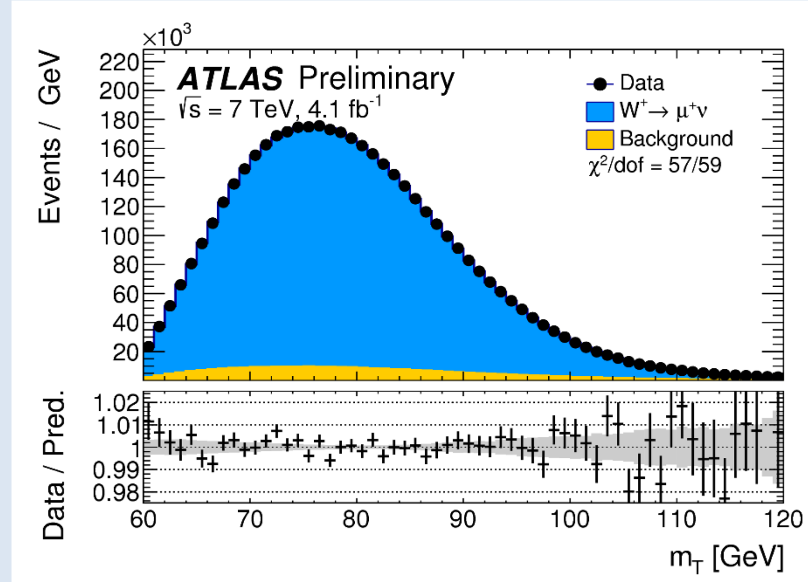










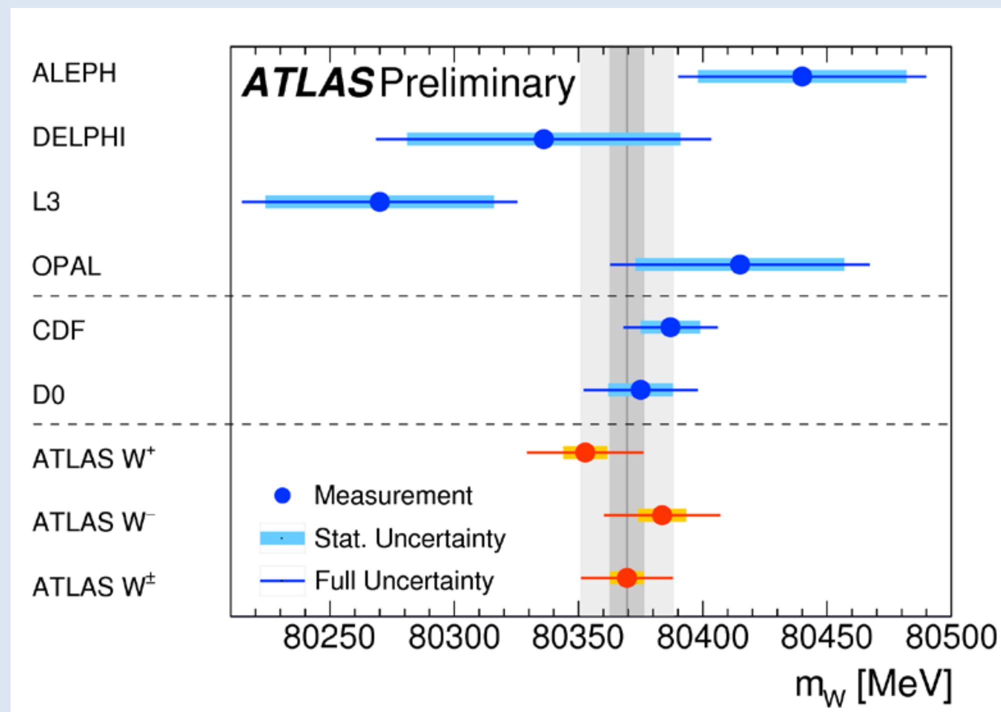


$$m_{\mathrm{T}} = \sqrt{2 p_{\mathrm{T}}^{\ell} p_{\mathrm{T}}^{\nu} (1 - \cos(\phi^{\ell} - \phi^{\nu}))}$$

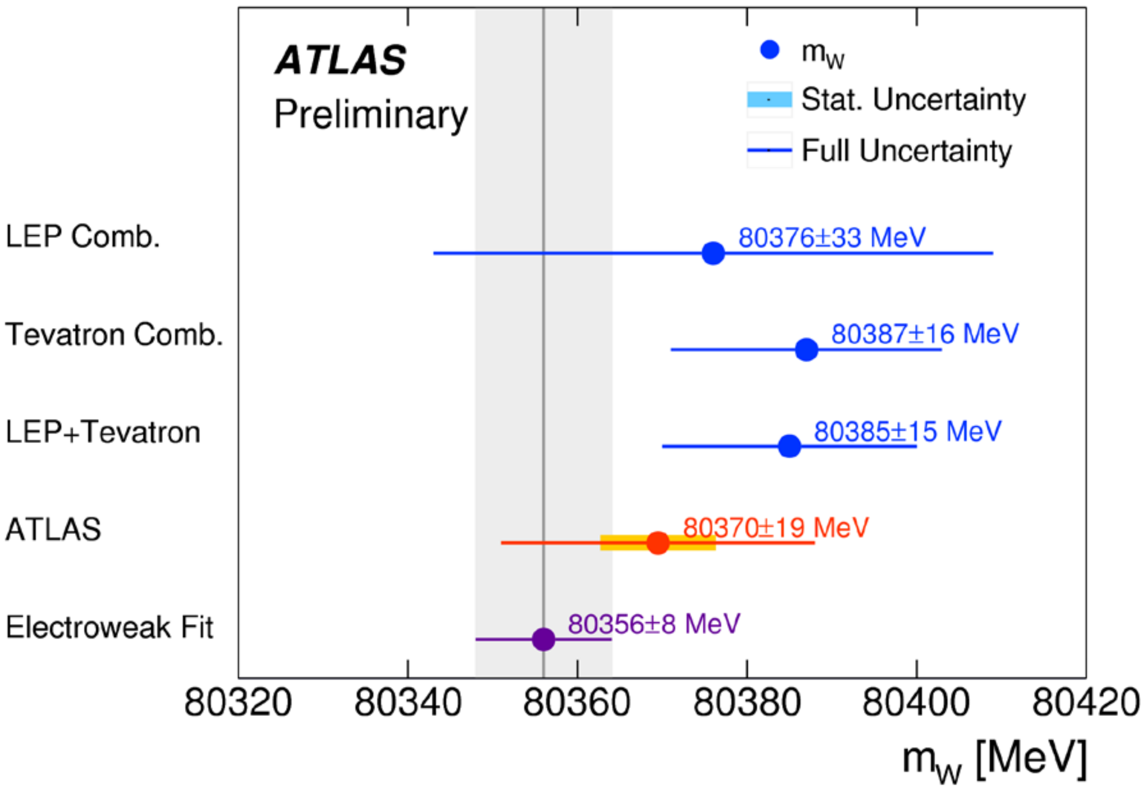
Precision measurement of the W mass recently released by ATLAS

m_W = 80.370 ± 0.019 GeV

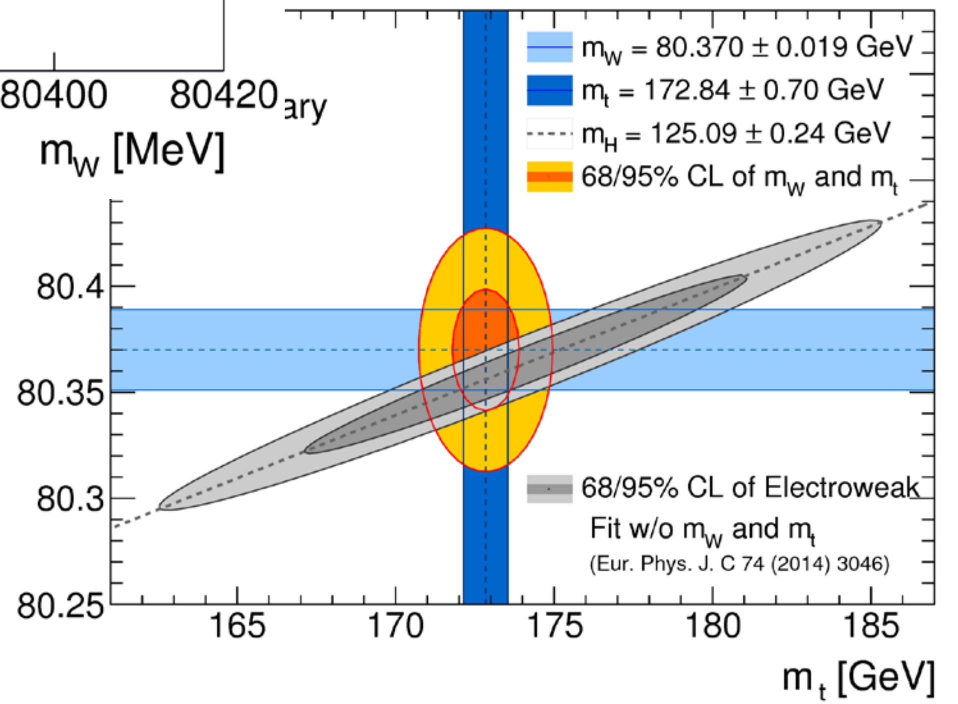
arXiv:1701.07240[hep-exp], submitted to EPJC



Standard Model consistency



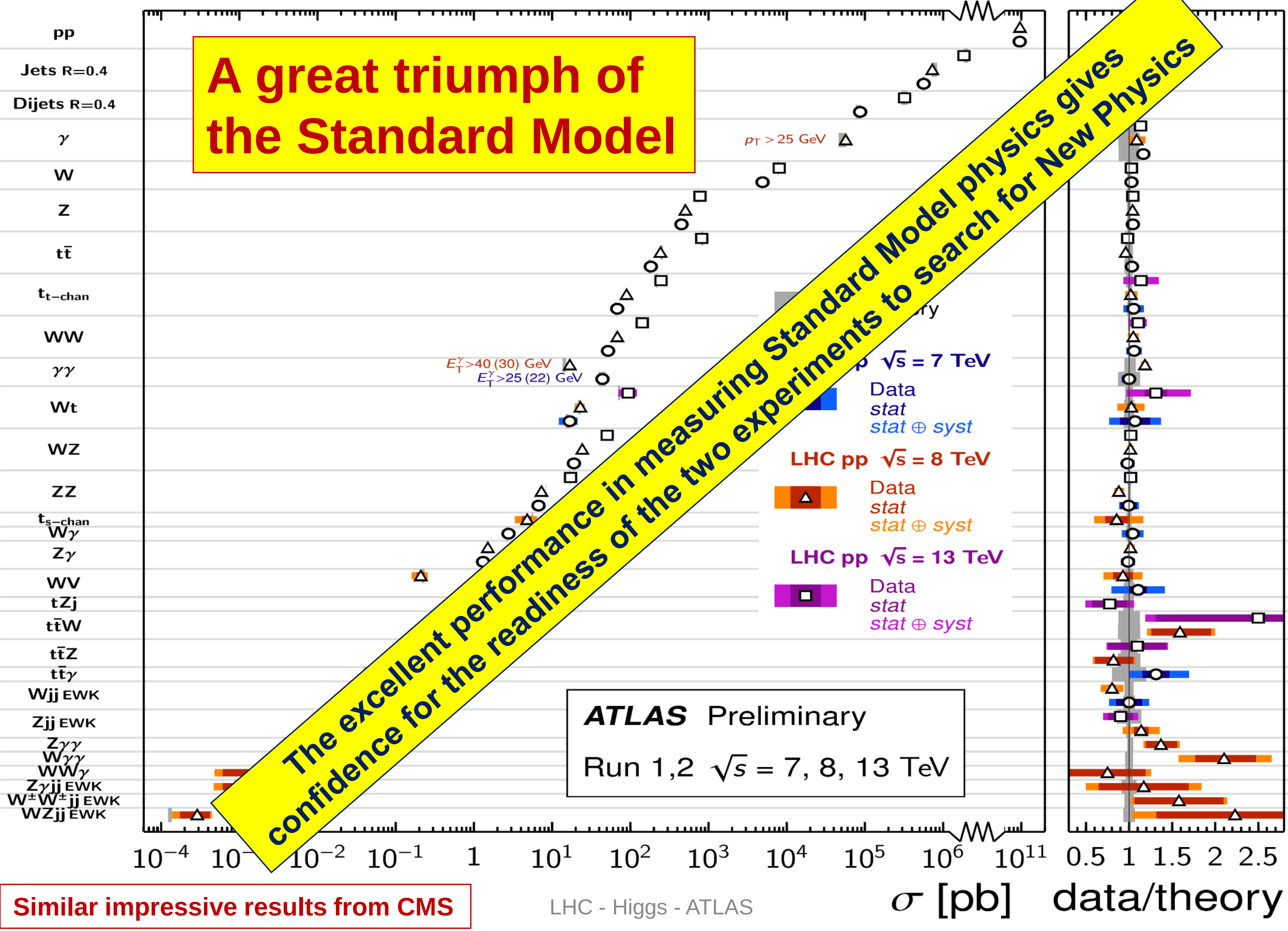
arXiv:1701.07240[hep-exp], submitted to EPJC



(SM prediction for m_W is assuming:
m_H = 125.09 ± 0.24 GeV
m_t = 172.84 ± 0.70 GeV)

Standard Model Production Cross Section Measurements

Status: July 2017



A great triumph of the Standard Model

The excellent performance in measuring Standard Model physics gives confidence for the readiness of the two experiments to search for New Physics

Similar impressive results from CMS

Happy faces after the announcement of the discovery on 4th July 2012 at CERN and at ICHEP Melbourne

Back to Howard and ATLAS: Collaboration Board Chair

The ATLAS Collaboration Board is the highest body in the Collaboration, with the delegates from all (today 178) Institutions setting the overall policies and electing the ATLAS management, as well as the CB Chairperson

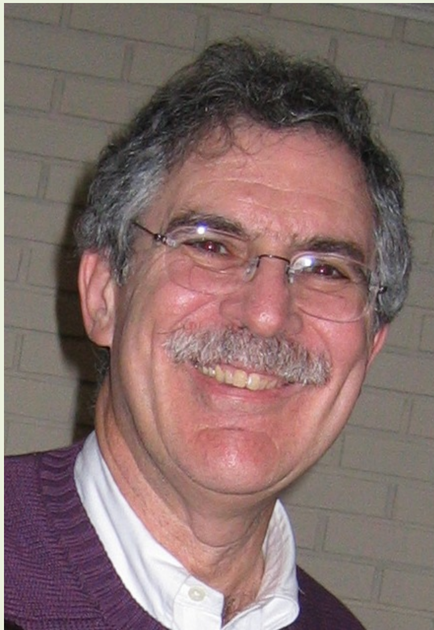
Howard's term of office: Deputy Chairperson 2013 and 2016
Chairperson 2014 and 2015
(also in the EB ex-officio during this time, #170 to #204)

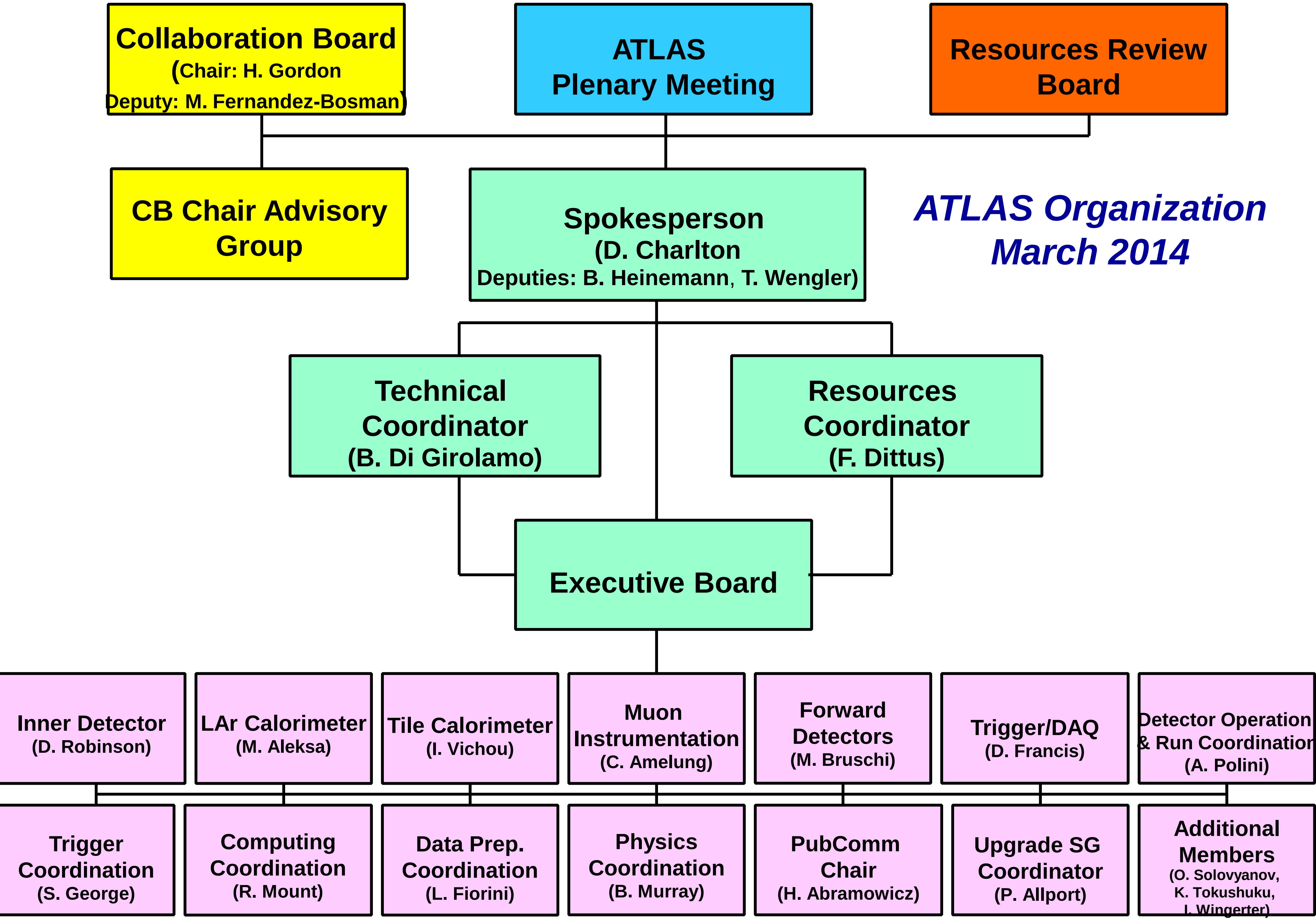
The years 2013 to 2016 were very important, and decisions from that time have a strong influence of how ATLAS operates now and prepares the future

A few specific examples as documented in the CB minutes #74 to #85 besides the long list of 'standard businesses' and elections:

- **Many matters related to the upgrades, several Phase-I TDRs and the general Phase-II LoI, initial cost discussions, scoping document**
- **Data preservation policy, open access to data policy**
- **Spokesperson elections (Dave Charlton 2nd term, Karl Jakobs)**

- **Setting up a Diversity Group to shape policy for 'all ATLAS members should have equal opportunities', resulting now ATLAS having**
  - **Diversity contact group**
  - **Early Career Scientist Board**




Collaboration Board
(Chair: H. Gordon
Deputy: M. Fernandez-Bosman)
ATLAS
Plenary Meeting
Resources Review
Board
CB Chair Advisory
Group
Spokesperson
(D. Charlton
Deputies: B. Heinemann, T. Wengler)
ATLAS Organization
March 2014
Technical
Coordinator
(B. Di Girolamo)
Resources
Coordinator
(F. Dittus)
Executive Board
Inner Detector
(D. Robinson)
LAr Calorimeter
(M. Aleksa)
Tile Calorimeter
(I. Vichou)
Muon
Instrumentation
(C. Amelung)
Forward
Detectors
(M. Bruschi)
Trigger/DAQ
(D. Francis)
Detector Operation
& Run Coordination
(A. Polini)
Trigger
Coordination
(S. George)
Computing
Coordination
(R. Mount)
Data Prep.
Coordination
(L. Fiorini)
Physics
Coordination
(B. Murray)
PubComm
Chair
(H. Abramowicz)
Upgrade SG
Coordinator
(P. Allport)
Additional
Members
(O. Solovyanov,
K. Tokushuku,
I. Wingerter)

Howard's first ATLAS Overview Week as CB (Deputy-) Chair Marrakech, 6-11 Oct 2013

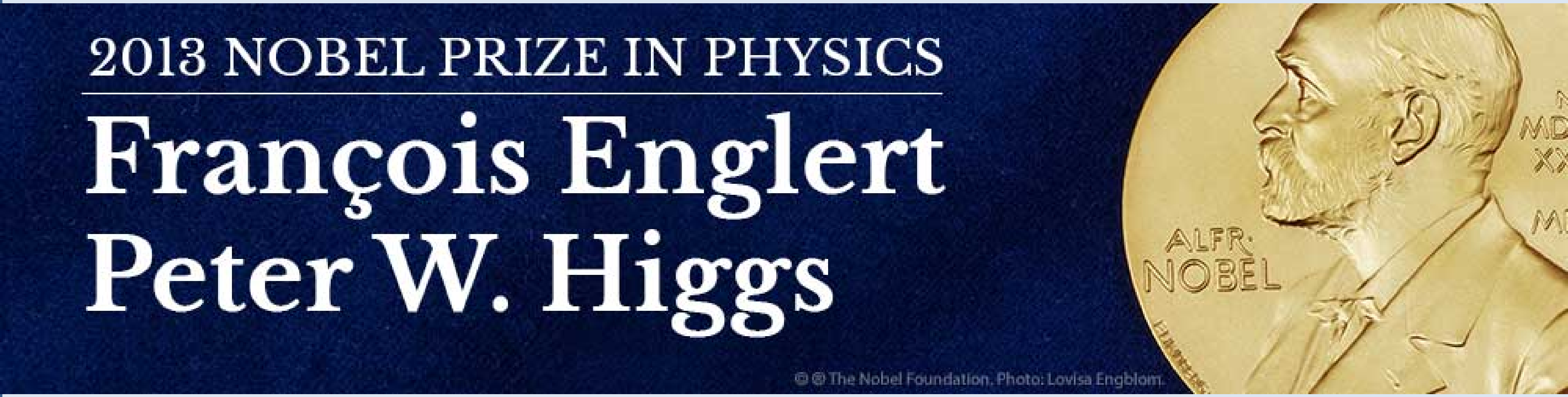
Howard’s first ATLAS Overview Week as CB (Deputy-) Chair Marrakech, 6-11 Oct 2013

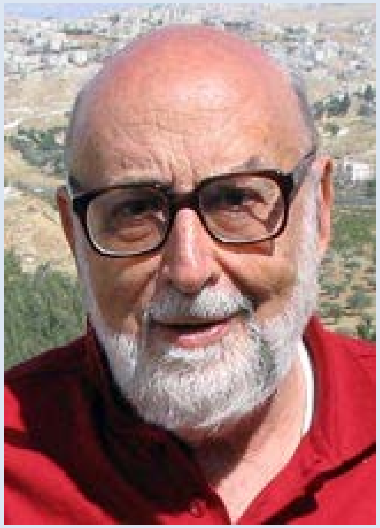
Waiting for news from Stockholm, 8^{th} October

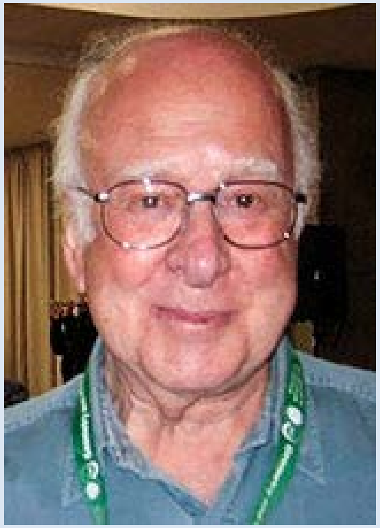
Howard's first ATLAS Overview Week as CB (Deputy-) Chair Marrakech, 6-11 Oct 2013


Finally getting the happy news !

Announced on 8th October, celebrated on 10th December 2013

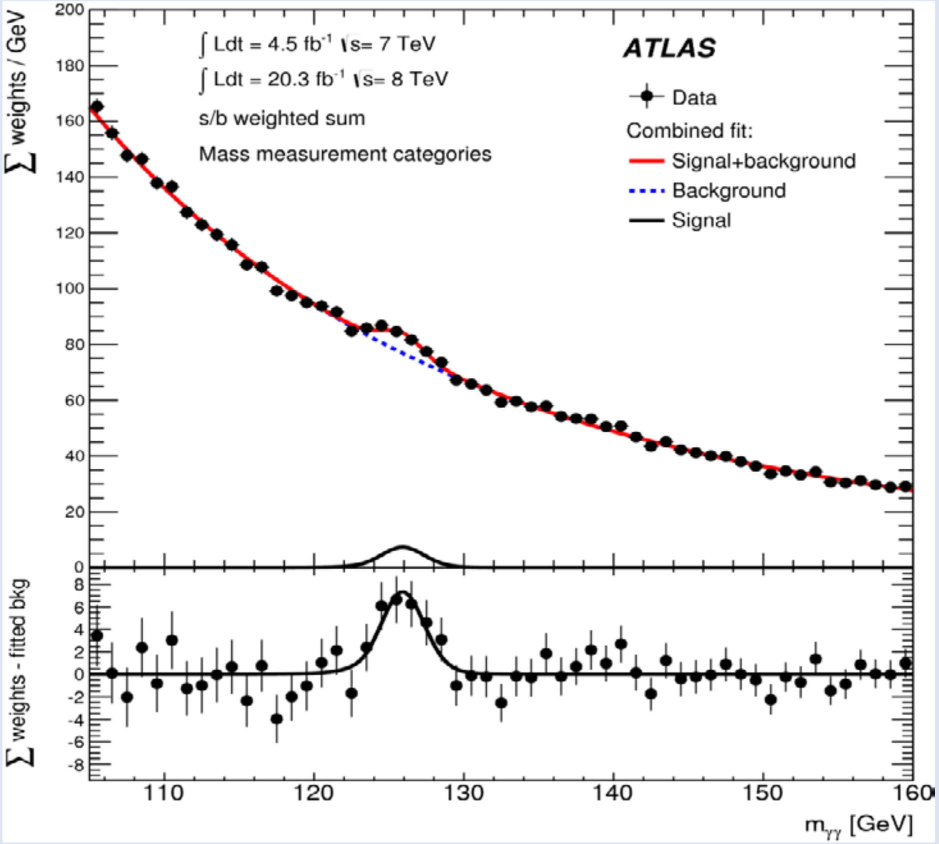


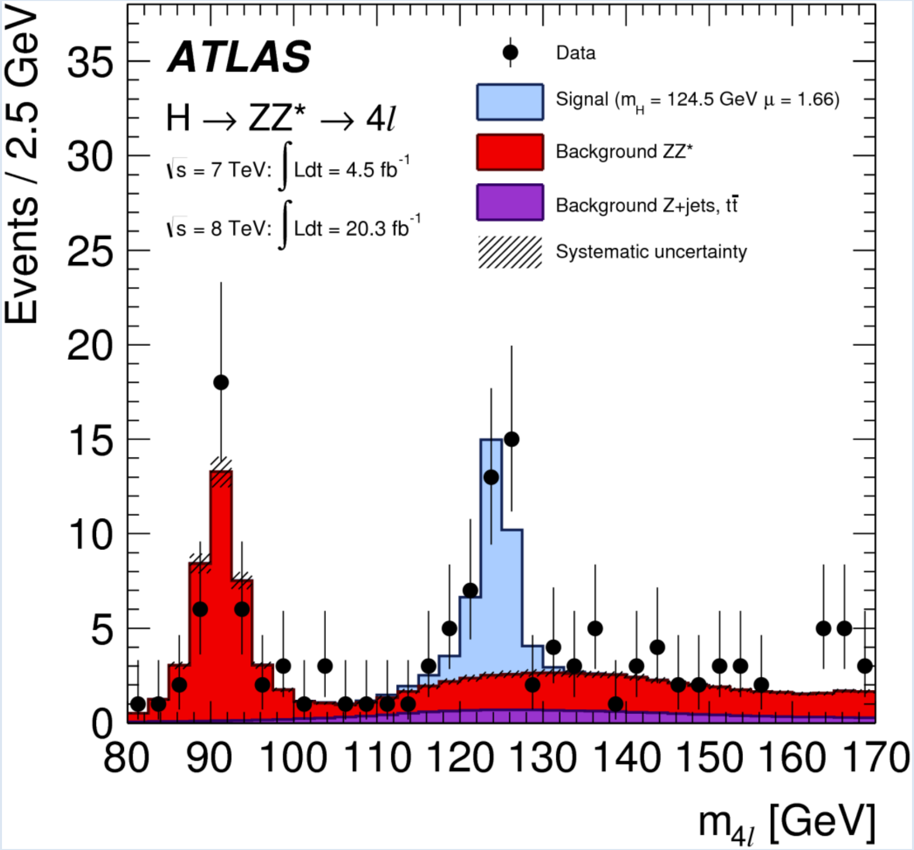




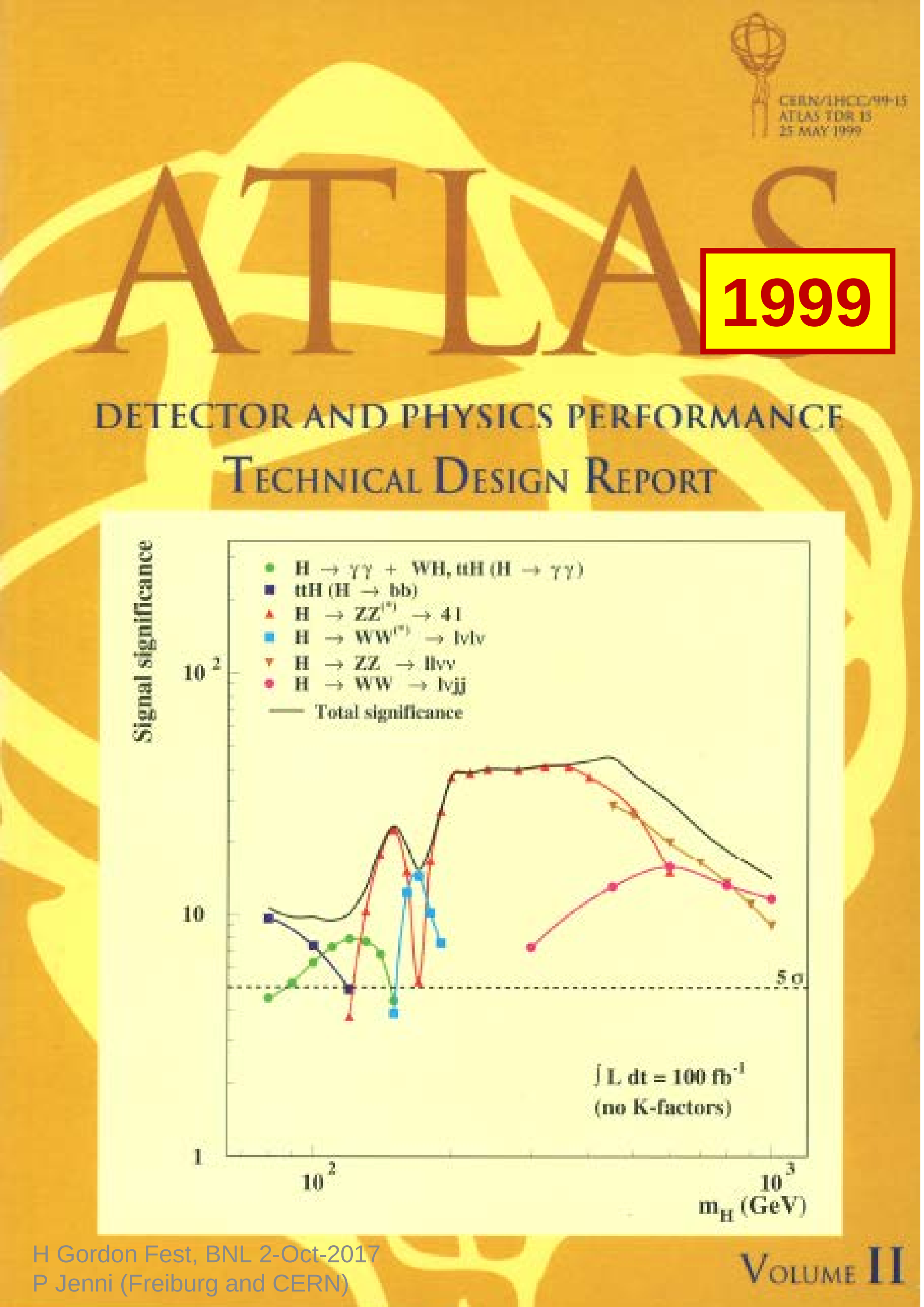
"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"

LHC Run-1 Higgs peaks

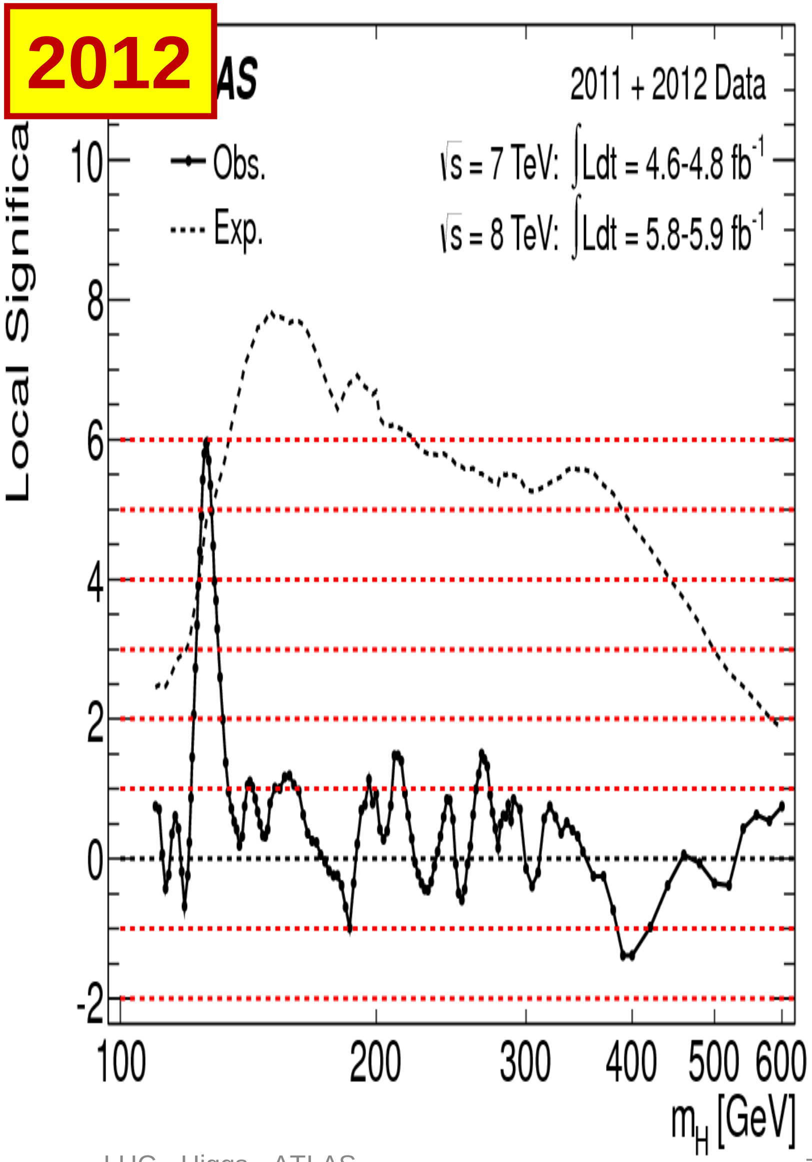




Phys. Rev. D 90 (2014) 052004

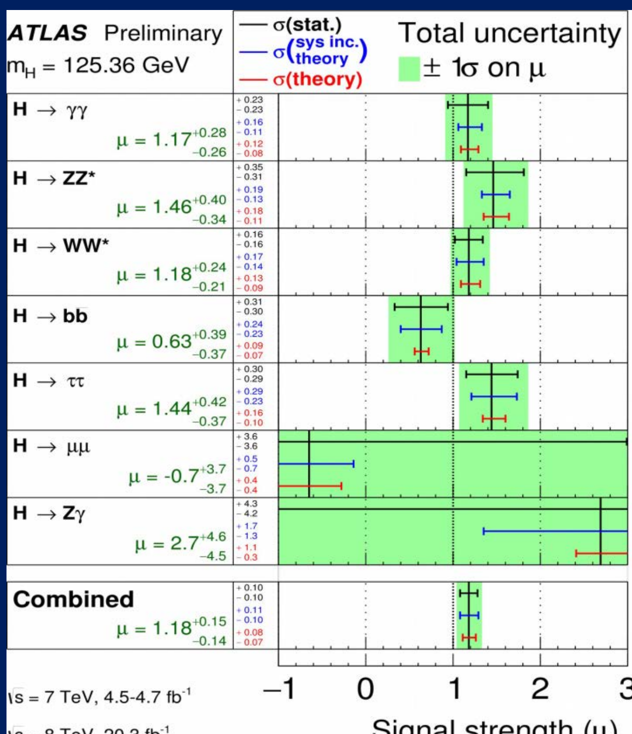


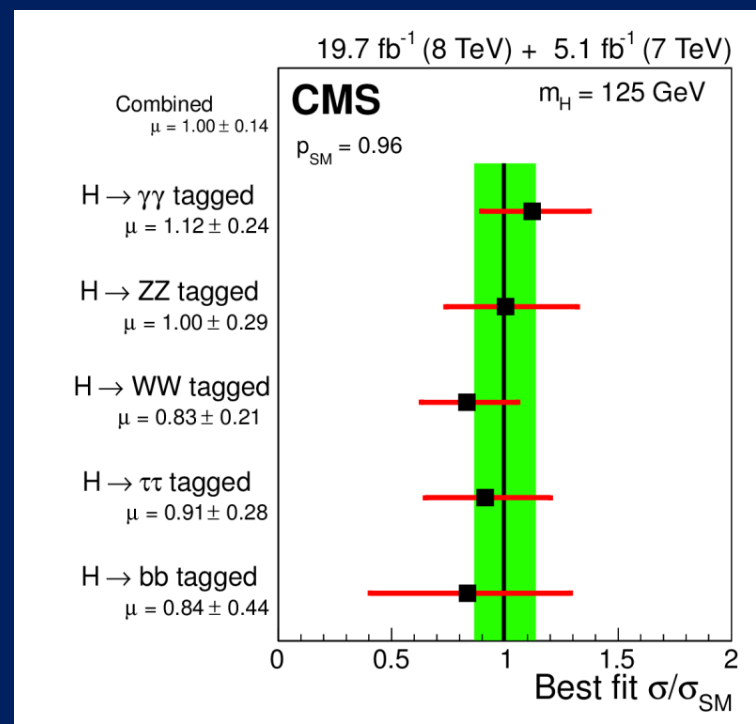
A dream becoming true much faster than anticipated long ago



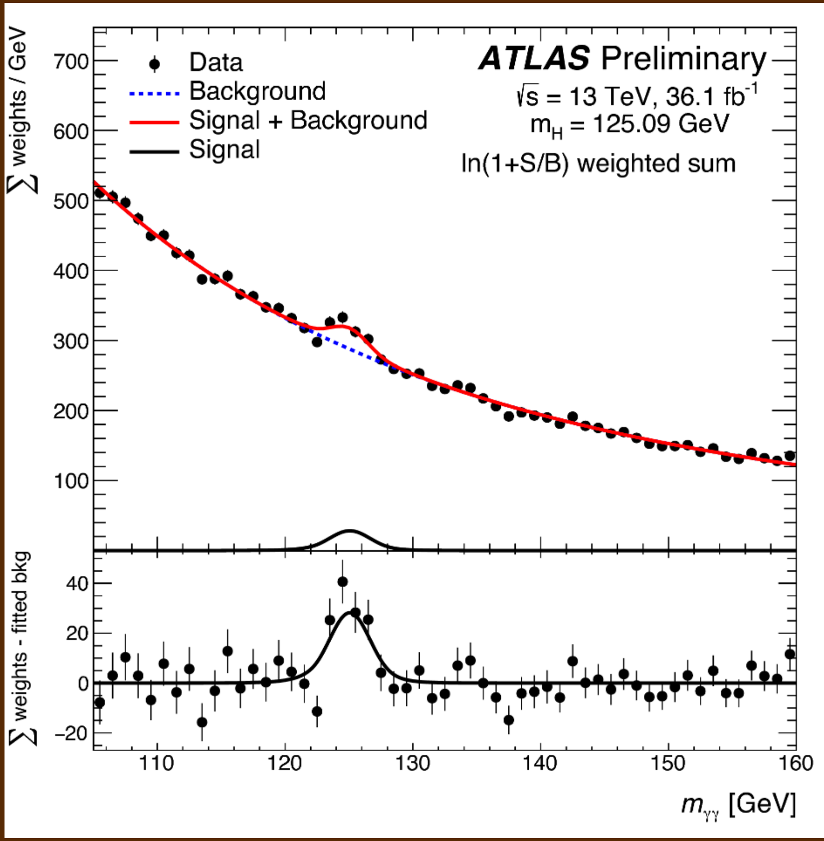
Complementary technologies provided comparable performances in term of significance of the signals (Run-1) !

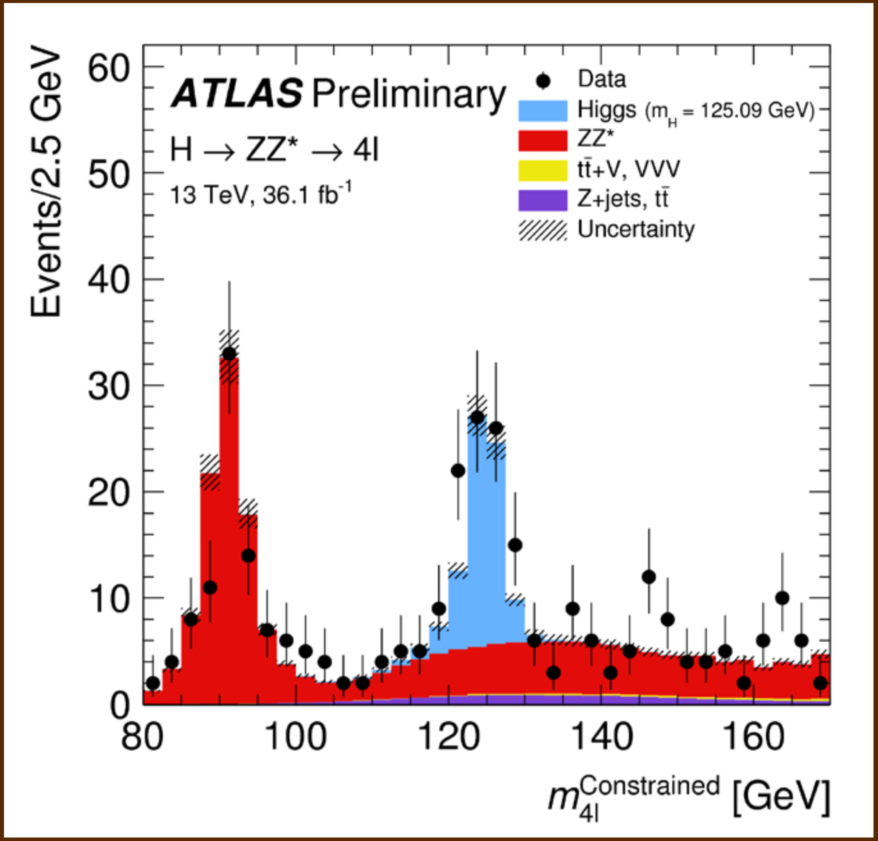
Experiment	ATLAS		CMS	
Decay mode/combination	Expected (σ)	Observed (σ)	Expected (σ)	Observed (σ)
γγ	4.6	5.2	5.3	5.6
ZZ	6.2	8.1	6.3	6.5
WW	5.8	6.1	5.4	4.7
bb	2.6	1.4	2.6	2.0
ττ	3.4	4.5	3.9	3.8





Higgs boson signals from Run-2 (2016) at 13 TeV

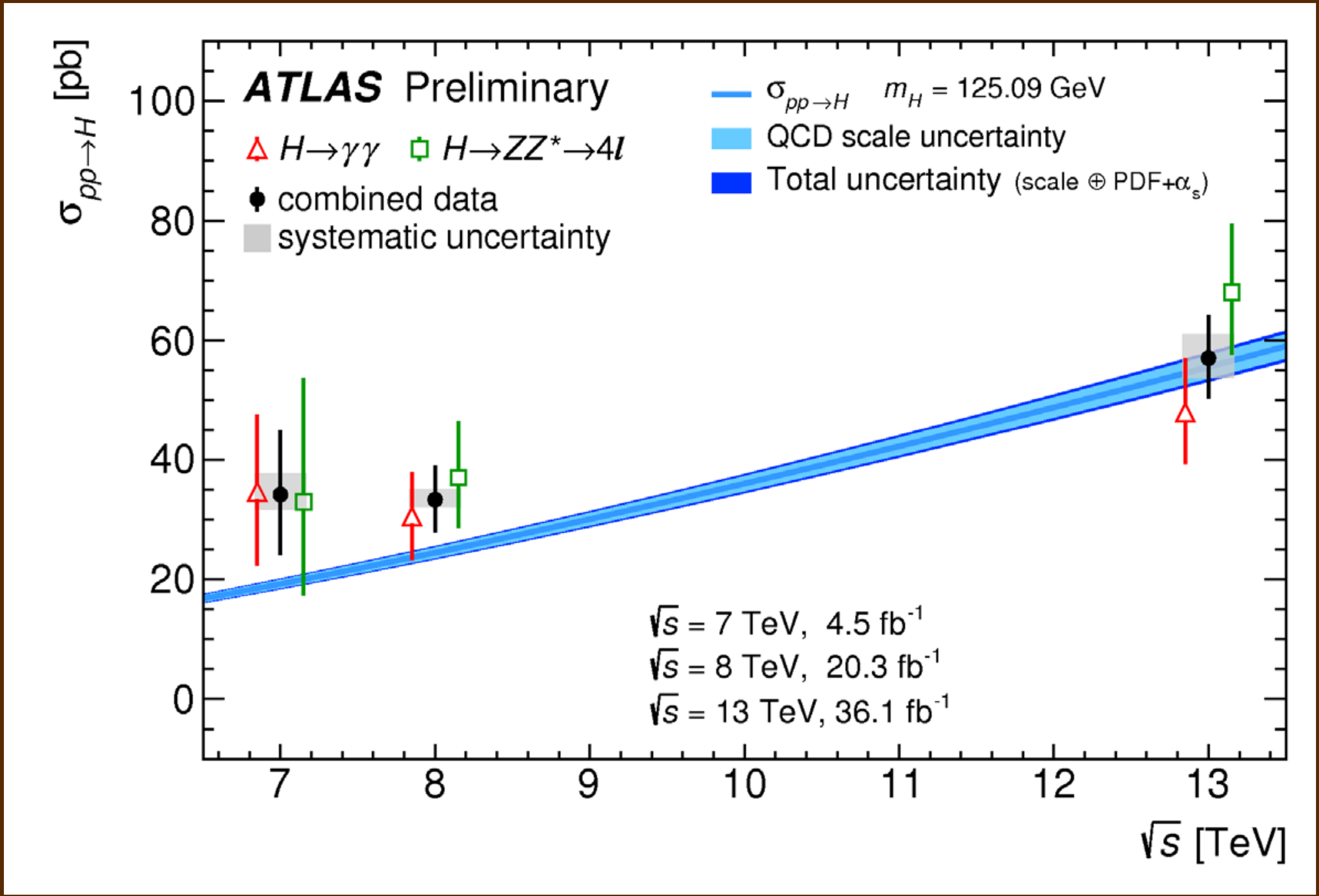




ATLAS-CONF-2017-045

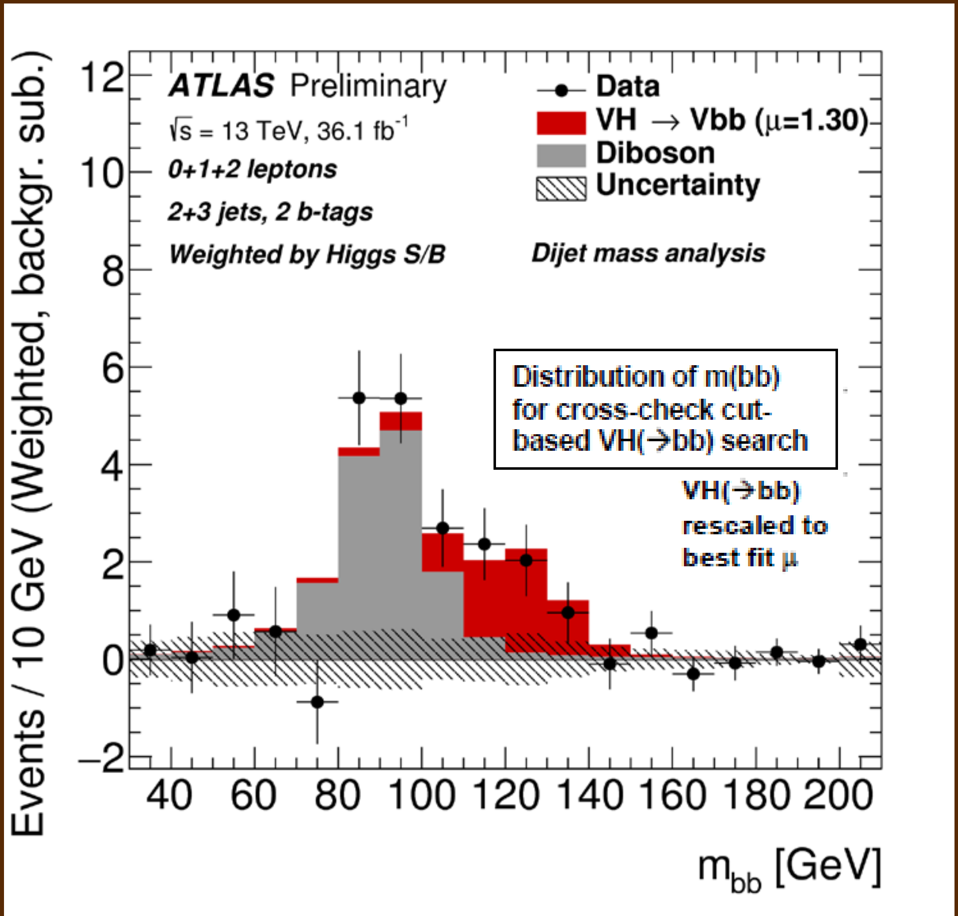
ATLAS-CONF-2017-043

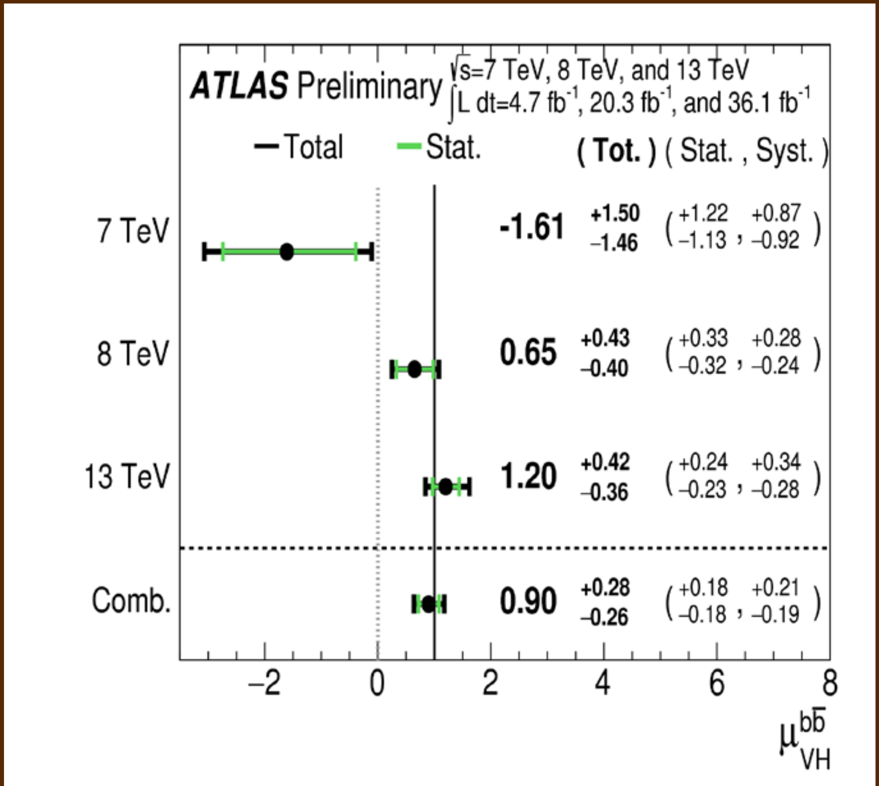
Higgs boson SM cross-sections Run-1 and Run-2 (2016)



ATLAS-CONF-2017-047

First evidence for H → bb decay consistent with SM in combined Run-1 and Run-2 (2016) data



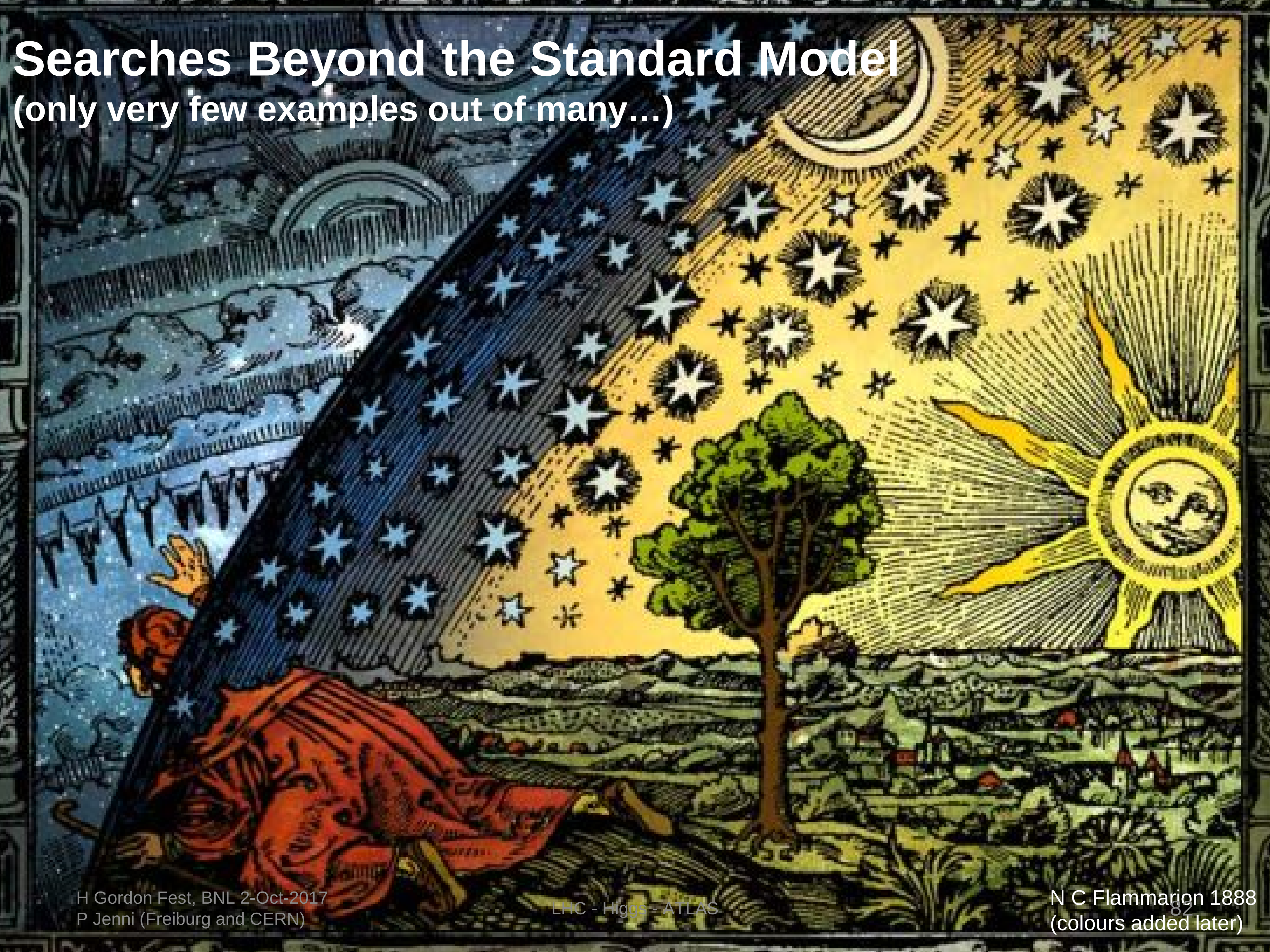


Significance from the MVA analysis: 3.6 σ observed (4.0 σ expected)

arXiv:1708.03299[hep-exp] sub. to JHEP

Note that CMS presented recently also new H → ττ and H → bb observations

Searches Beyond the Standard Model
(only very few examples out of many…)

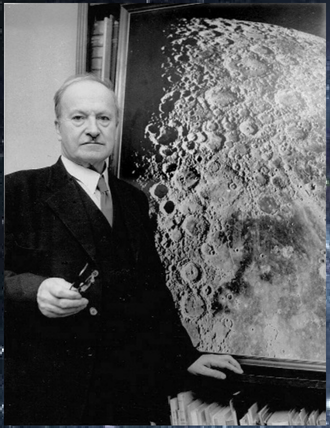


N C Flammarion 1888
(colours added later)

Dark Matter in the Universe

Astronomers found that most of the matter in the Universe must be invisible Dark Matter

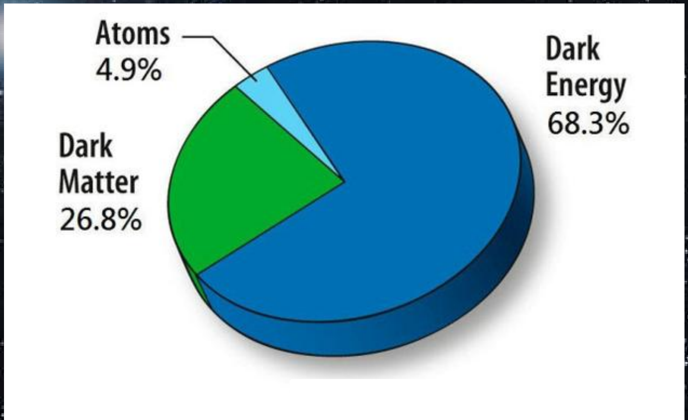
Vera Rubin ~ 1970



K. Lundmark 1889-1958

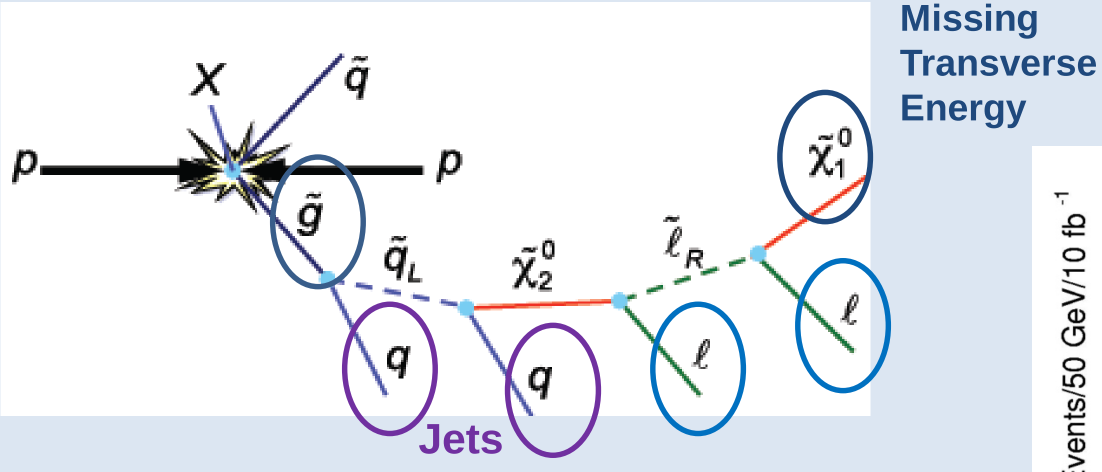
F. Zwicky 1898-1974

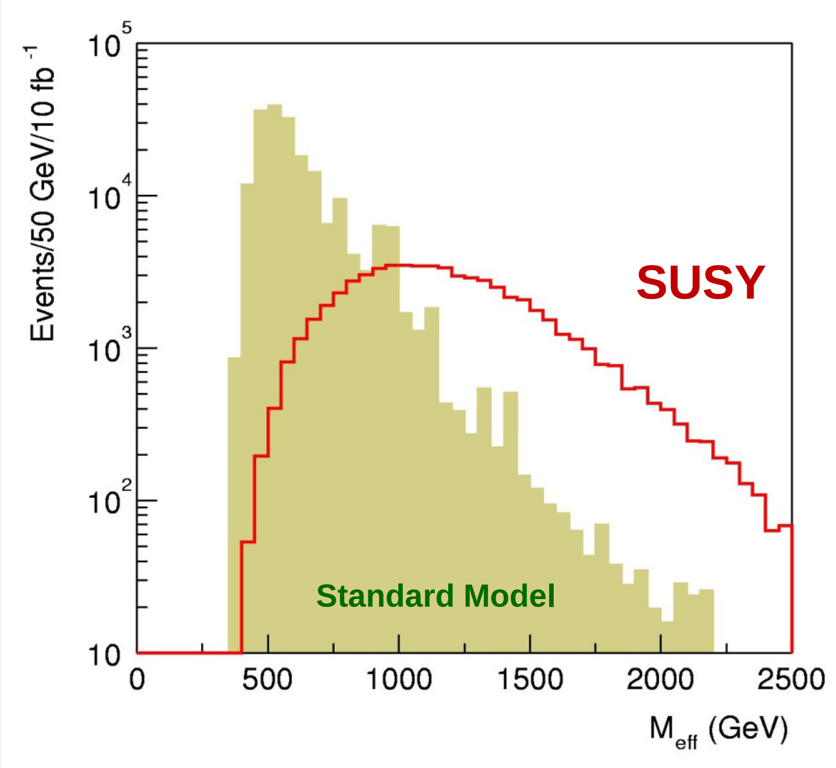
'Supersymmetric' particles ?



In practice SUSY searches at LHC are rather complicated

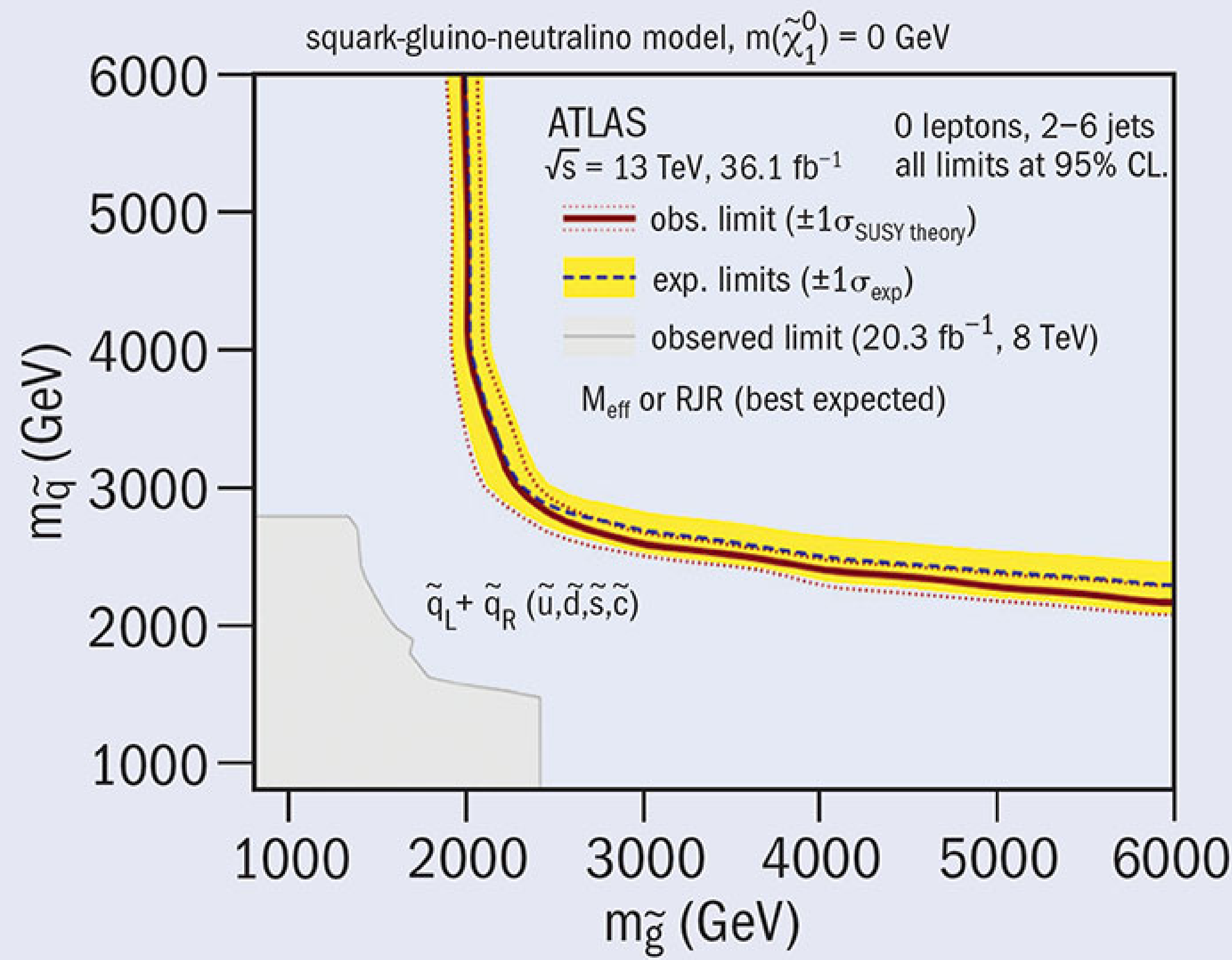
- **Complex (and model-dependent): example squark/gluino cascades**





Meff = Etmiss + Σ pT(jets)

- **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**
  - **Photons: typically for models with the gravitino as LSP**



squark-gluino-neutralino model, m($\tilde{\chi}_1^0$) = 0 GeV
ATLAS
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
0 leptons, 2–6 jets
all limits at 95% CL.
obs. limit ($\pm 1\sigma_{\text{SUSY theory}}$)
exp. limits ($\pm 1\sigma_{\text{exp}}$)
observed limit (20.3 fb^{-1}, 8 TeV)
M_{eff} or RJR (best expected)
$\tilde{q}_L + \tilde{q}_R$ ($\tilde{u},\tilde{d},\tilde{s},\tilde{c}$)
$m_{\tilde{q}}$ (GeV)
$m_{\tilde{g}}$ (GeV)
1000
2000
3000
4000
5000
6000

SUSY limits

ATLAS SUSY Searches* - 95% CL Lower Limits

May 2017

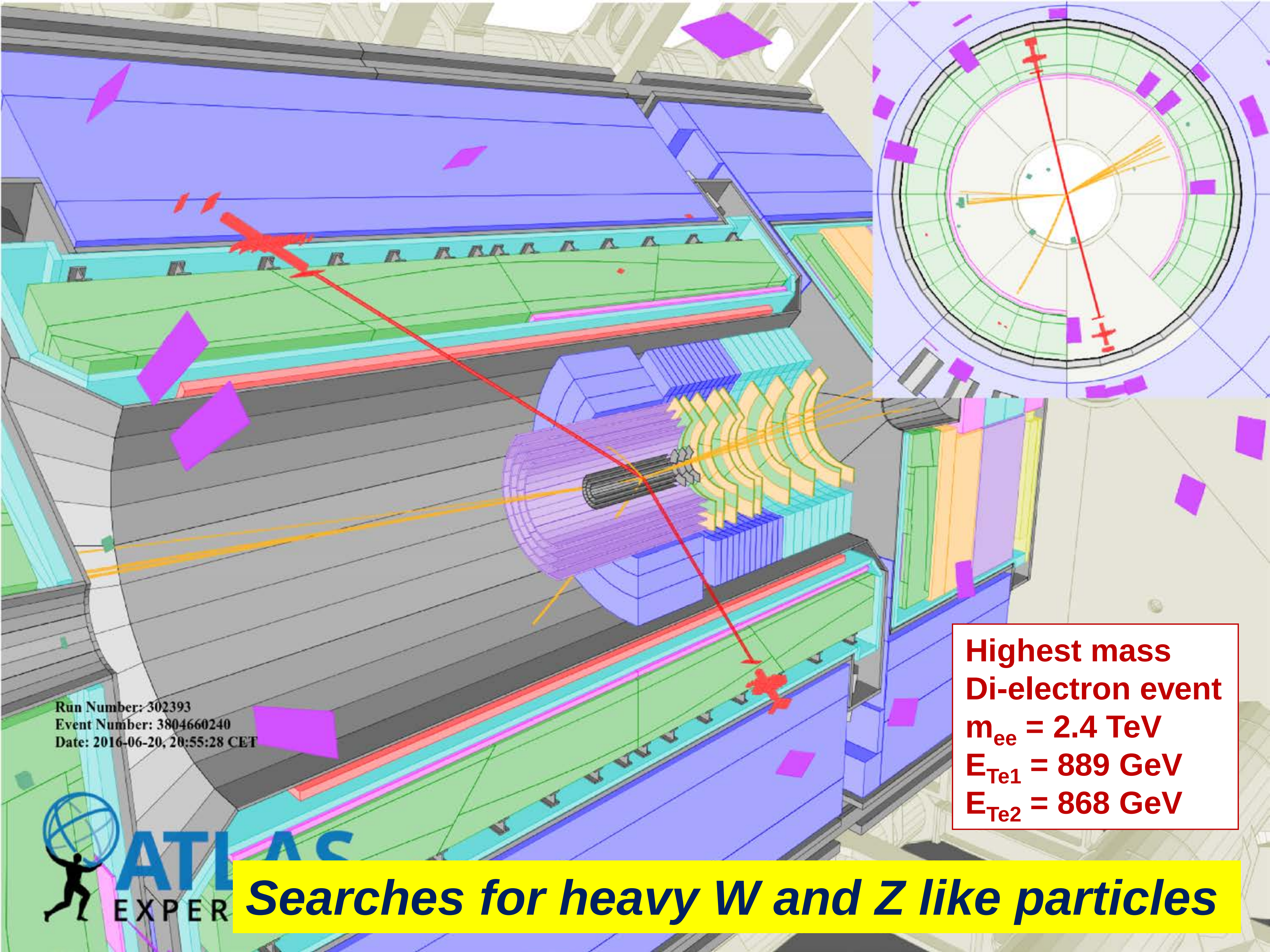
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit	
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.85 TeV	$m(\tilde{q})=m(\tilde{g})$
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	$\tilde{q}$ 1.57 TeV	$m(\tilde{\chi}^0_1)$<200 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$ 608 GeV	$m(\tilde{q})$-$m(\tilde{\chi}^0_1)$<5 GeV
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	$\tilde{g}$ 2.02 TeV	$m(\tilde{\chi}^0_1)$<200 GeV
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^{\pm}_1\to qqW^{\pm}\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	$\tilde{g}$ 2.01 TeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^{\pm})$=0.5($m(\tilde{\chi}^0_1)$+$m(\tilde{g})$)
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\nu\nu)\tilde{\chi}^0_1$	3 e,μ	4 jets	-	36.1	$\tilde{g}$ 1.825 TeV	$m(\tilde{\chi}^0_1)$<400 GeV
	$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}^0_1$	0	7-11 jets	Yes	36.1	$\tilde{g}$ 1.8 TeV	$m(\tilde{\chi}^0_1)$ <400 GeV
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	$\tilde{g}$ 2.0 TeV	
	GGM (bino NLSP)	2 γ	-	Yes	3.2	$\tilde{g}$ 1.65 TeV	$c\tau$(NLSP)<0.1 mm
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}^0_1)$<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	13.3	$\tilde{g}$ 1.8 TeV	$m(\tilde{\chi}^0_1)$>680 GeV, $c\tau$(NLSP)<0.1 mm, μ>0
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde{g}$ 900 GeV	m(NLSP)>430 GeV
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})$=1.5 TeV
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}^0_1$	0	3 b	Yes	36.1	$\tilde{g}$ 1.92 TeV	$m(\tilde{\chi}^0_1)$<600 GeV
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0-1 e,μ	3 b	Yes	36.1	$\tilde{g}$ 1.97 TeV	$m(\tilde{\chi}^0_1)$<200 GeV
	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}^+_1$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}^0_1)$<300 GeV
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}^0_1$	0	2 b	Yes	36.1	$\tilde{b}_1$ 950 GeV	$m(\tilde{\chi}^0_1)$<420 GeV
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}^{\pm}_1$	2 e,μ (SS)	1 b	Yes	36.1	$\tilde{b}_1$ 275-700 GeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^{\pm}_1)$= $m(\tilde{\chi}^0_1)$+100 GeV
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}^{\pm}_1$	0-2 e,μ	1-2 b	Yes	4.7/13.3	$\tilde{t}_1$ 117-170 GeV, 200-720 GeV	$m(\tilde{\chi}^{\pm}_1)$ = 2$m(\tilde{\chi}^0_1)$, $m(\tilde{\chi}^0_1)$=55 GeV
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}^0_1$ or $t\tilde{\chi}^0_1$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3/36.1	$\tilde{t}_1$ 90-198 GeV, 205-950 GeV	$m(\tilde{\chi}^0_1)$=1 GeV
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}^0_1$	0	mono-jet	Yes	3.2	$\tilde{t}_1$ 90-323 GeV	$m(\tilde{t}_1)$-$m(\tilde{\chi}^0_1)$=5 GeV
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-600 GeV	$m(\tilde{\chi}^0_1)$>150 GeV
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e,μ (Z)	1 b	Yes	36.1	$\tilde{t}_2$ 290-790 GeV	$m(\tilde{\chi}^0_1)$=0 GeV
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + h$	1-2 e,μ	4 b	Yes	36.1	$\tilde{t}_2$ 320-880 GeV	$m(\tilde{\chi}^0_1)$=0 GeV
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}^0_1$	2 e,μ	0	Yes	36.1	$\tilde{\ell}$ 90-440 GeV	$m(\tilde{\chi}^0_1)$=0
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	36.1	$\tilde{\chi}^{\pm}_1$ 710 GeV	$m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}^{\pm}_1)$+$m(\tilde{\chi}^0_1)$)
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^{\mp}_1/\tilde{\chi}^0_2, \tilde{\chi}^+_1\to\tilde{\tau}\nu(\tau\tilde{\nu}), \tilde{\chi}^0_2\to\tilde{\tau}\tau(\nu\tilde{\nu})$	2 τ	-	Yes	36.1	$\tilde{\chi}^{\pm}_1$ 760 GeV	$m(\tilde{\chi}^0_1)$=0, $m(\tilde{\tau},\tilde{\nu})$=0.5($m(\tilde{\chi}^{\pm}_1)$+$m(\tilde{\chi}^0_1)$)
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	36.1	$\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 1.16 TeV	$m(\tilde{\chi}^{\pm}_1)$=$m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}^{\pm}_1)$+$m(\tilde{\chi}^0_1)$)
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 Z\tilde{\chi}^0_1$	2-3 e,μ	0-2 jets	Yes	36.1	$\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 580 GeV	$m(\tilde{\chi}^{\pm}_1)$=$m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $\tilde{\ell}$ decoupled
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 h\tilde{\chi}^0_1, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 270 GeV	$m(\tilde{\chi}^{\pm}_1)$=$m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $\tilde{\ell}$ decoupled
	$\tilde{\chi}^0_2\tilde{\chi}^0_3, \tilde{\chi}^0_{2,3}\to\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}^0_{2,3}$ 635 GeV	$m(\tilde{\chi}^0_2)$=$m(\tilde{\chi}^0_3)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}^0_2)$+$m(\tilde{\chi}^0_1)$)
	GGM (wino NLSP) weak prod., $\tilde{\chi}^0_1\to\gamma\tilde{G}$	1 e,μ + γ	-	Yes	20.3	$\tilde{W}$ 115-370 GeV	$c\tau$<1 mm
	GGM (bino NLSP) weak prod., $\tilde{\chi}^0_1\to\gamma\tilde{G}$	2 γ	-	Yes	20.3	$\tilde{W}$ 590 GeV	$c\tau$<1 mm
Long-lived particles	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^{\pm}_1$	Disapp. trk	1 jet	Yes	36.1	$\tilde{\chi}^{\pm}_1$ 430 GeV	$m(\tilde{\chi}^{\pm}_1)$-$m(\tilde{\chi}^0_1)$~160 MeV, $\tau(\tilde{\chi}^{\pm}_1)$=0.2 ns
	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^{\pm}_1$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}^{\pm}_1$ 495 GeV	$m(\tilde{\chi}^{\pm}_1)$-$m(\tilde{\chi}^0_1)$~160 MeV, $\tau(\tilde{\chi}^{\pm}_1)$<15 ns
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 850 GeV	$m(\tilde{\chi}^0_1)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s
	Stable $\tilde{g}$ R-hadron	trk	-	-	3.2	$\tilde{g}$ 1.58 TeV	
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	$\tilde{g}$ 1.57 TeV	$m(\tilde{\chi}^0_1)$=100 GeV, τ>10 ns
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}^0_1\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}^0_1$ 537 GeV	10<tanβ<50
	GMSB, $\tilde{\chi}^0_1\to\gamma\tilde{G}$, long-lived $\tilde{\chi}^0_1$	2 γ	-	Yes	20.3	$\tilde{\chi}^0_1$ 440 GeV	1<$\tau(\tilde{\chi}^0_1)$<3 ns, SPS8 model
	$\tilde{g}\tilde{g}, \tilde{\chi}^0_1\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}^0_1$ 1.0 TeV	7 <$c\tau(\tilde{\chi}^0_1)$< 740 mm, $m(\tilde{g})$=1.3 TeV
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}^0_1\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}^0_1$ 1.0 TeV	6 <$c\tau(\tilde{\chi}^0_1)$< 480 mm, $m(\tilde{g})$=1.1 TeV
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	3.2	$\tilde{\nu}_\tau$ 1.9 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.45 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to ee\nu, e\mu\nu, \mu\mu\nu$	4 e,μ	-	Yes	13.3	$\tilde{\chi}^{\pm}_1$ 1.14 TeV	$m(\tilde{\chi}^0_1)$>400GeV, $\lambda_{12k}\neq0$ (k = 1, 2)
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to\tau\tau\nu_e, e\tau\nu_\tau$	3 e,μ + τ	-	Yes	20.3	$\tilde{\chi}^{\pm}_1$ 450 GeV	$m(\tilde{\chi}^0_1)$>0.2×$m(\tilde{\chi}^{\pm}_1)$, $\lambda_{133}\neq0$
	$\tilde{g}\tilde{g}, \tilde{g}\to qqq$	0	4-5 large-R jets	-	14.8	$\tilde{g}$ 1.08 TeV	BR(t)=BR(b)=BR(c)=0%
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^0_1, \tilde{\chi}^0_1\to qqq$	0	4-5 large-R jets	-	14.8	$\tilde{g}$ 1.55 TeV	$m(\tilde{\chi}^0_1)$=800 GeV
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}^0_1, \tilde{\chi}^0_1\to qqq$	1 e,μ	8-10 jets/0-4 b	-	36.1	$\tilde{g}$ 2.1 TeV	$m(\tilde{\chi}^0_1)$= 1 TeV, $\lambda_{112}\neq0$
	$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	1 e,μ	8-10 jets/0-4 b	-	36.1	$\tilde{g}$ 1.65 TeV	$m(\tilde{t}_1)$= 1 TeV, $\lambda_{323}\neq0$
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	15.4	$\tilde{t}_1$ 410 GeV, 450-510 GeV	
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e,μ	2 b	-	36.1	$\tilde{t}_1$ 0.4-1.45 TeV	BR($\tilde{t}_1\to be/\mu$)>20%
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}^0_1$	0	2 c	Yes	20.3	$\tilde{c}$ 510 GeV	$m(\tilde{\chi}^0_1)$<200 GeV

$\sqrt{s}$ = 7, 8 TeV $\sqrt{s}$ = 13 TeV

10^{-1} 1   Mass scale [TeV]

Similar limits come from CMS

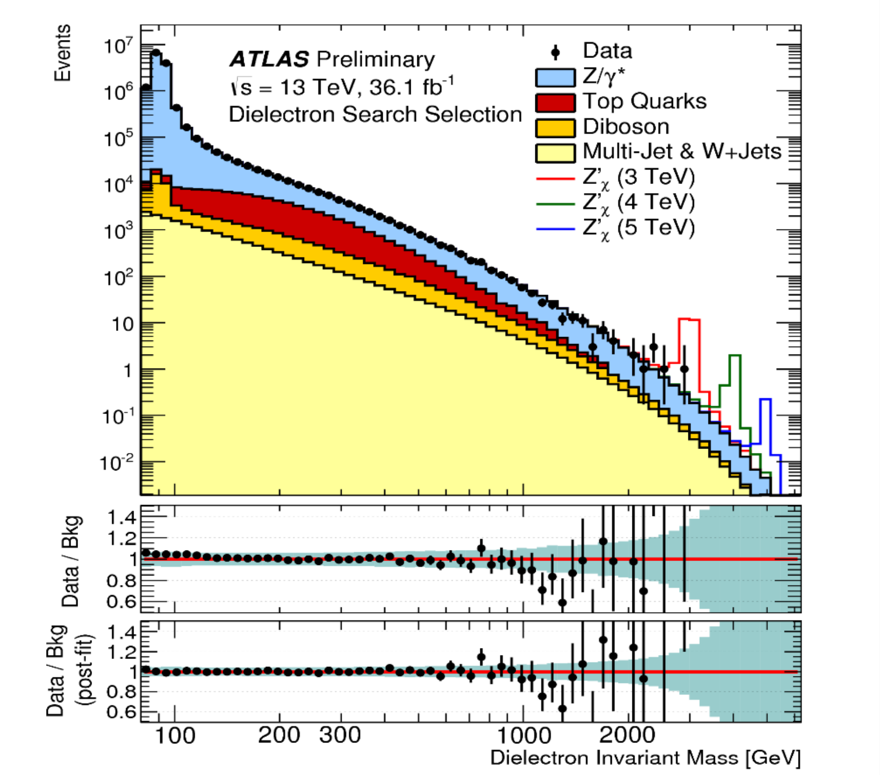
Searches for heavy W and Z like particles



Searches for heavy W and Z like particles

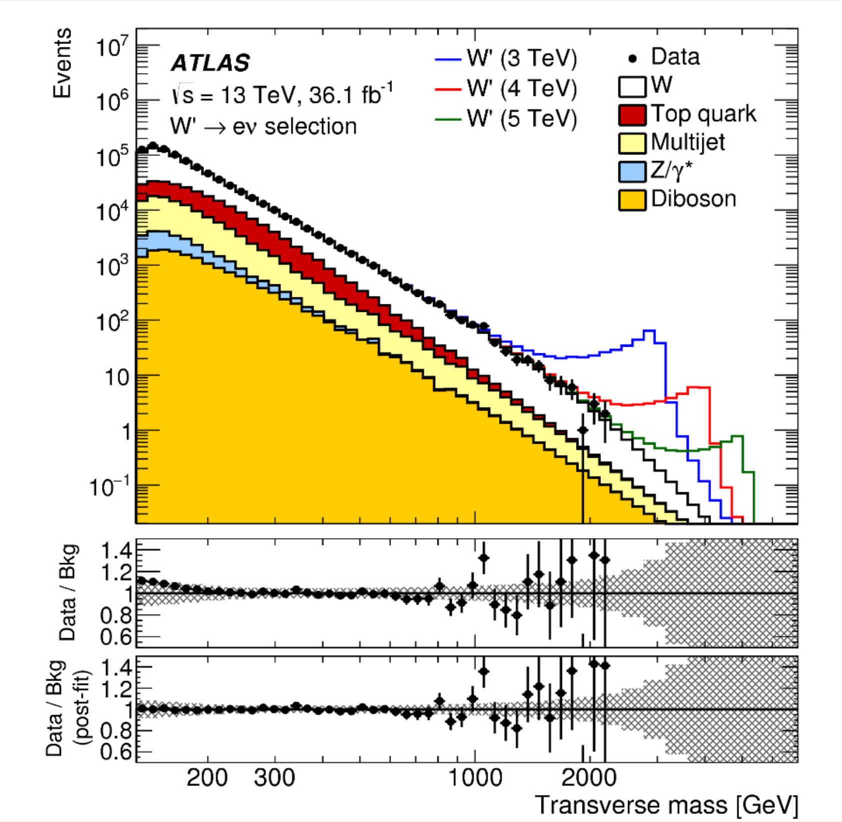
These searches are quite straight-forward, following basically the same analyses as for the familiar W and Z bosons

Z': Di-lepton pairs



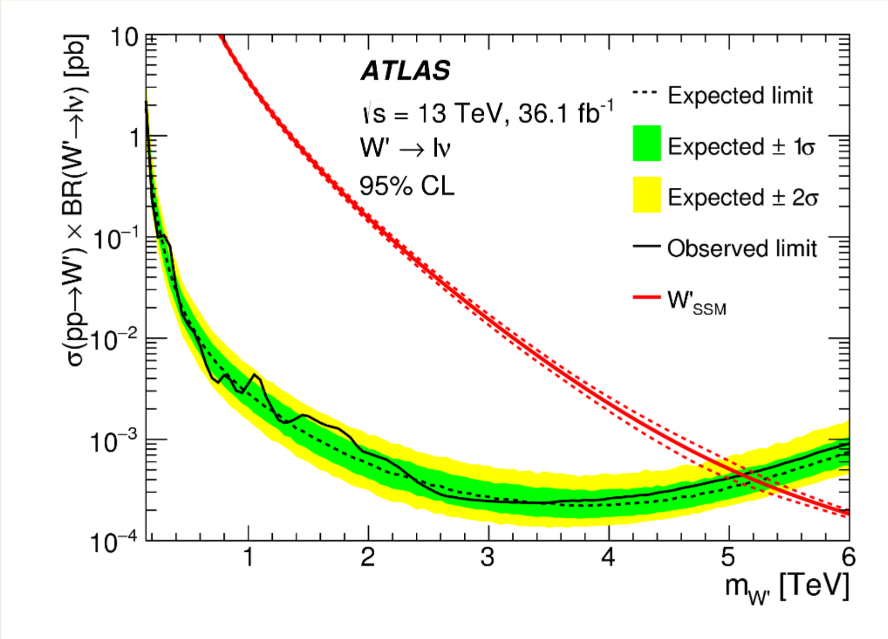
ATLAS-CONF-2017-027

W': Lepton + ETmiss

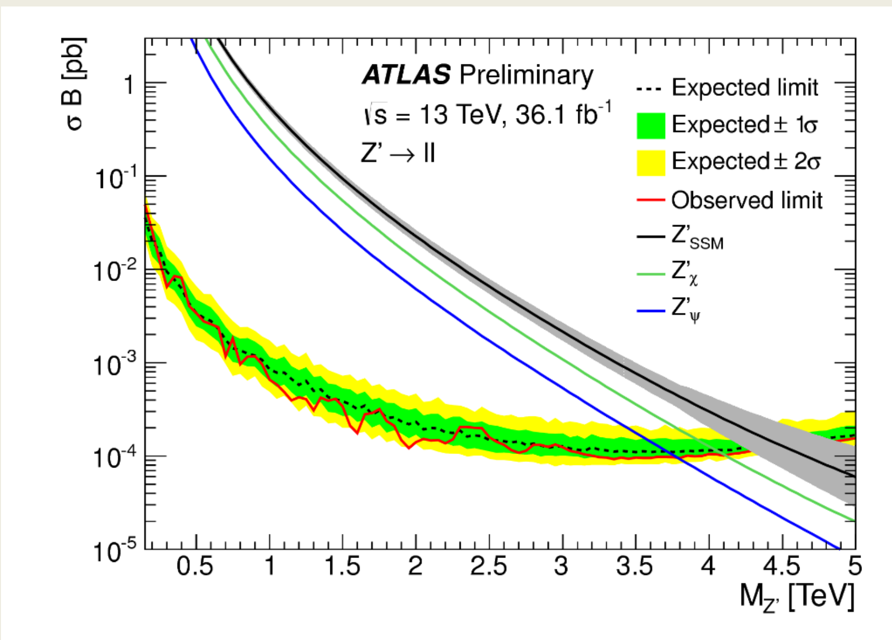


arXiv:1706.04786[hep-exp] subm. to EPJC

W' and Z' lower mass limits, at 95% CL



arXiv:1706.04786
subm. to EPJC

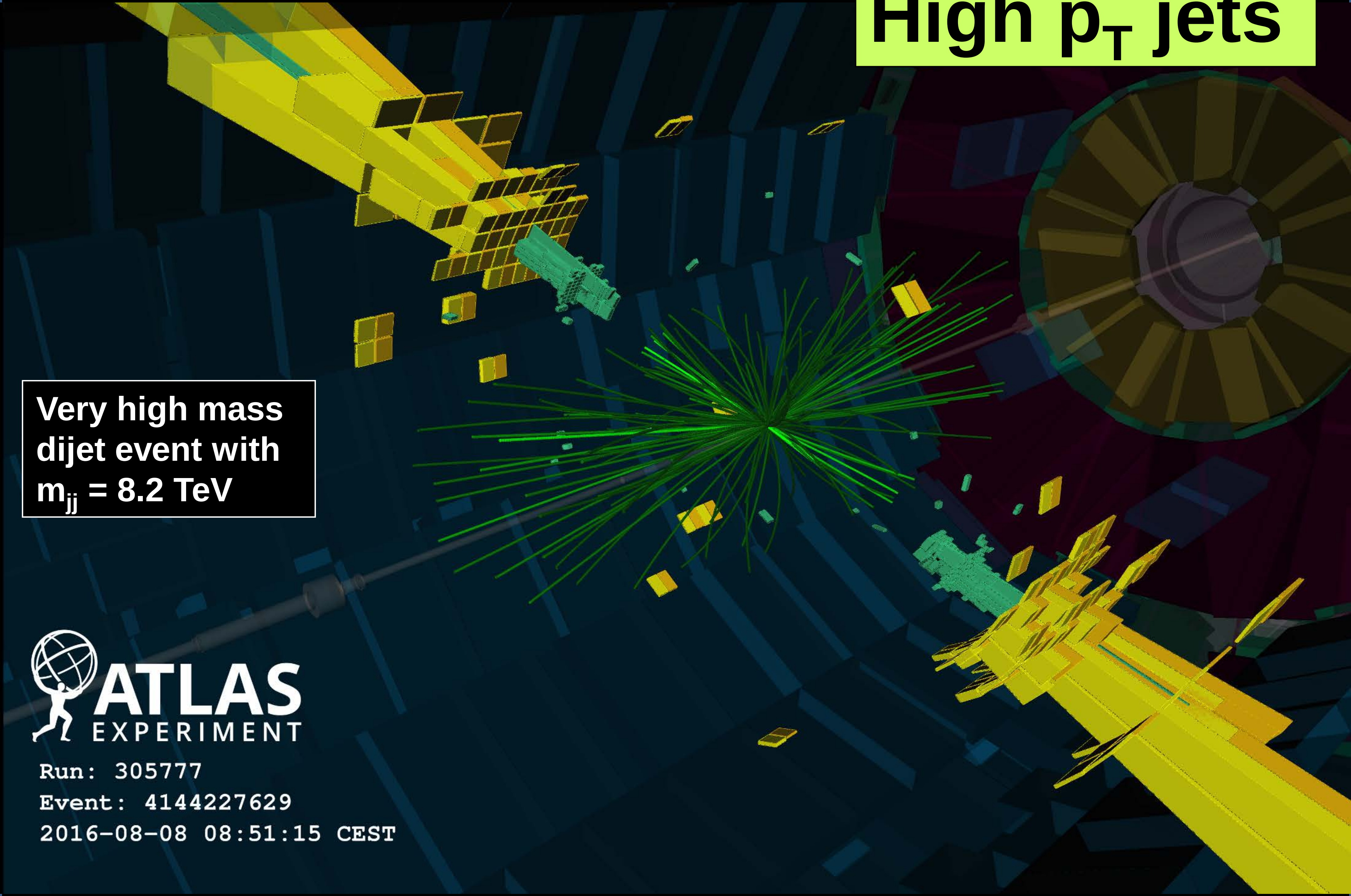


ATLAS-CONF-2017-027

Similar limits for Sundrum-Randall gravitons

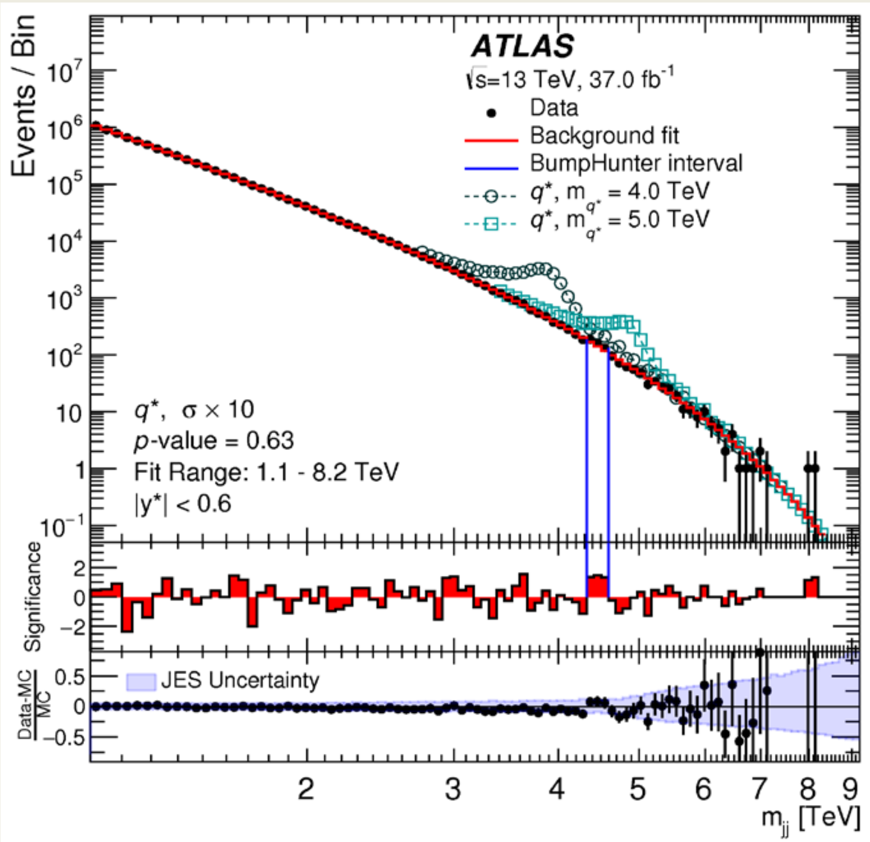
R Sundrum
L Randall
F Gianotti

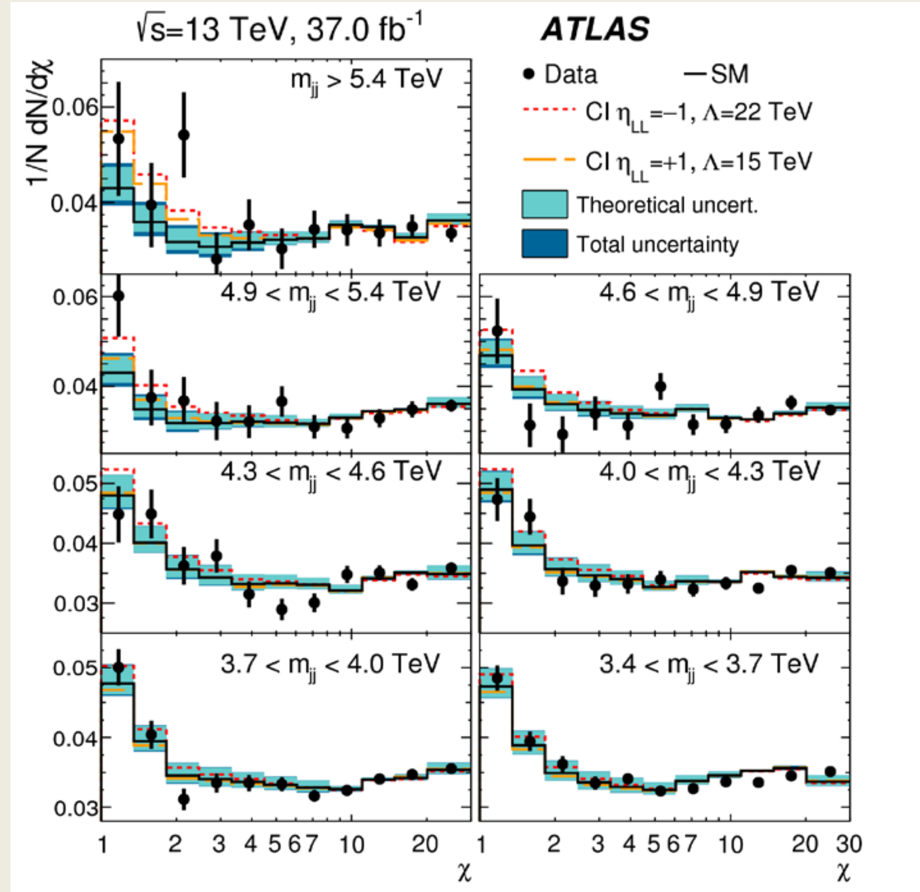
High p_T jets

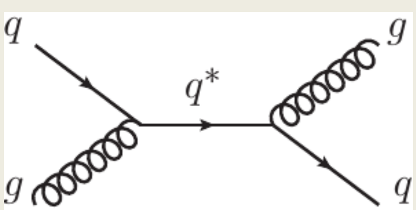


Very high mass dijet event with m_{jj} = 8.2 TeV

Searching for deviations from QCD
(Excited quarks, Black Holes, Compositeness…)







At 95% CL:
m(q*) > 6.0 TeV
Λ > 13 / 21 TeV

$$\chi = \exp(|y_1 - y_2|) = \frac{1 + \cos\vartheta^*}{1 - \cos\vartheta^*}$$

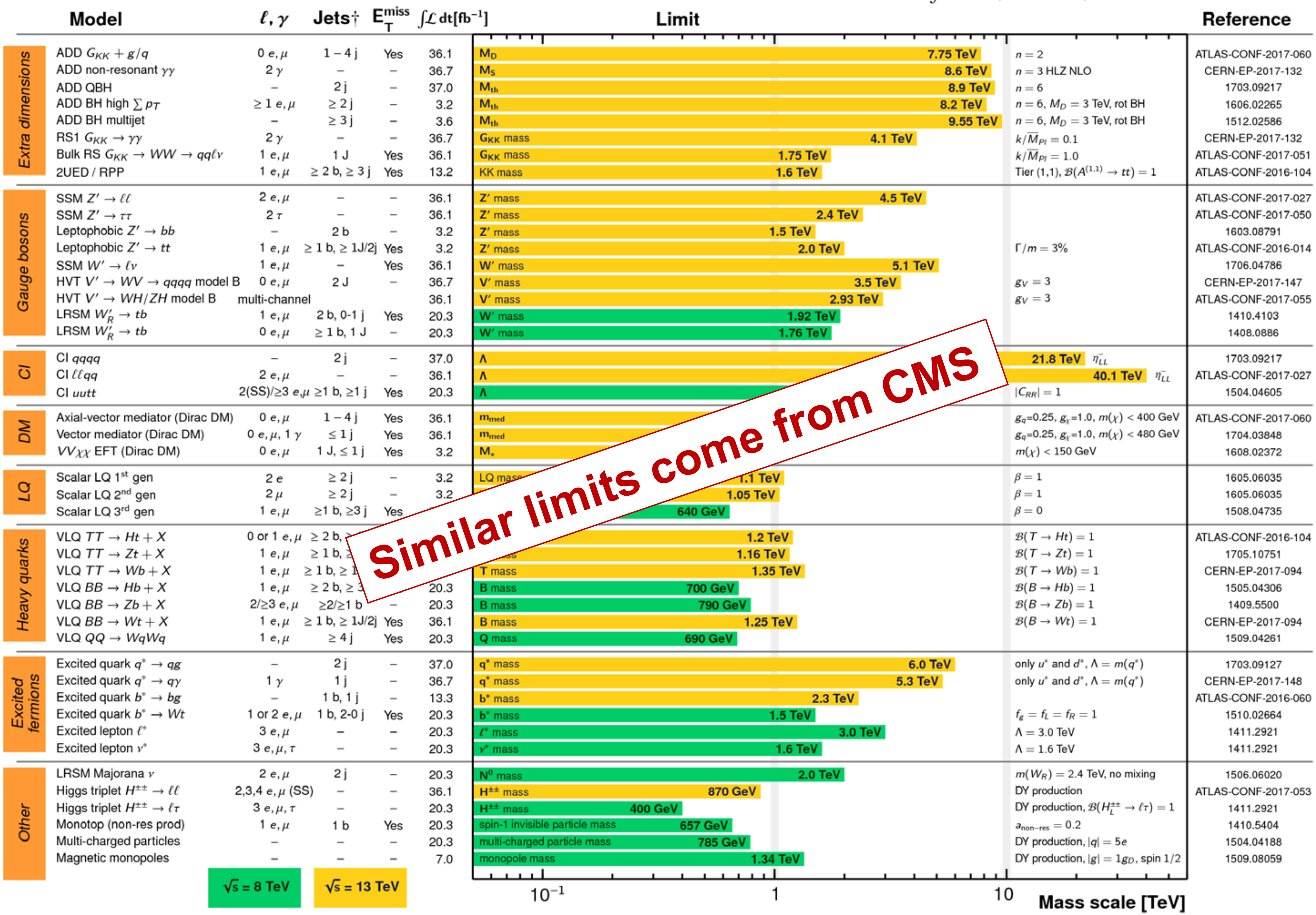
arXiv: 1703.09127 submitted to Phys. Rev. D (2017)

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: July 2017

ATLAS Preliminary

$\int\mathcal{L}\,dt = (3.2 - 37.0)\ \text{fb}^{-1}$ $\sqrt{s} = 8, 13$ TeV

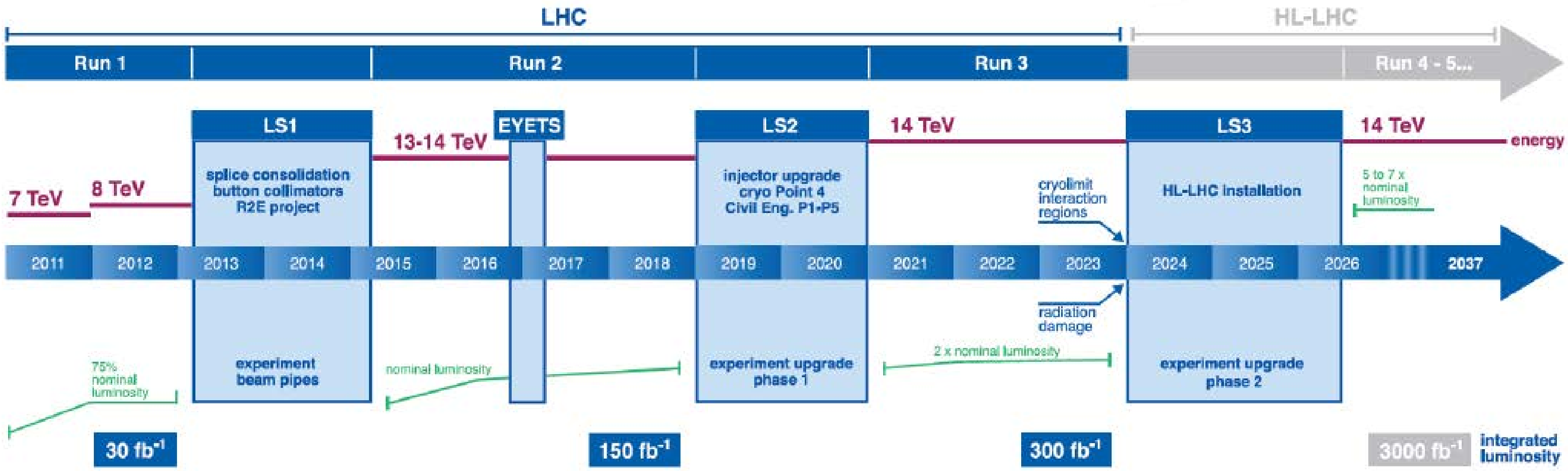


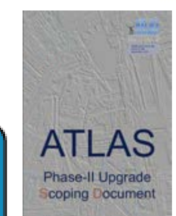
*Only a selection of the available mass limits on new states or phenomena is shown.

†Small-radius (large-radius) jets are denoted by the letter j (J).

LHC / HL-LHC Plan

High Luminosity LHC





ATLAS Phase-0

New inner pixel layer
Detector consolidation
2015: FTK deployment

ATLAS Phase-1

Improve L1 Trigger, NSW and LAr electronics to cope with higher rates

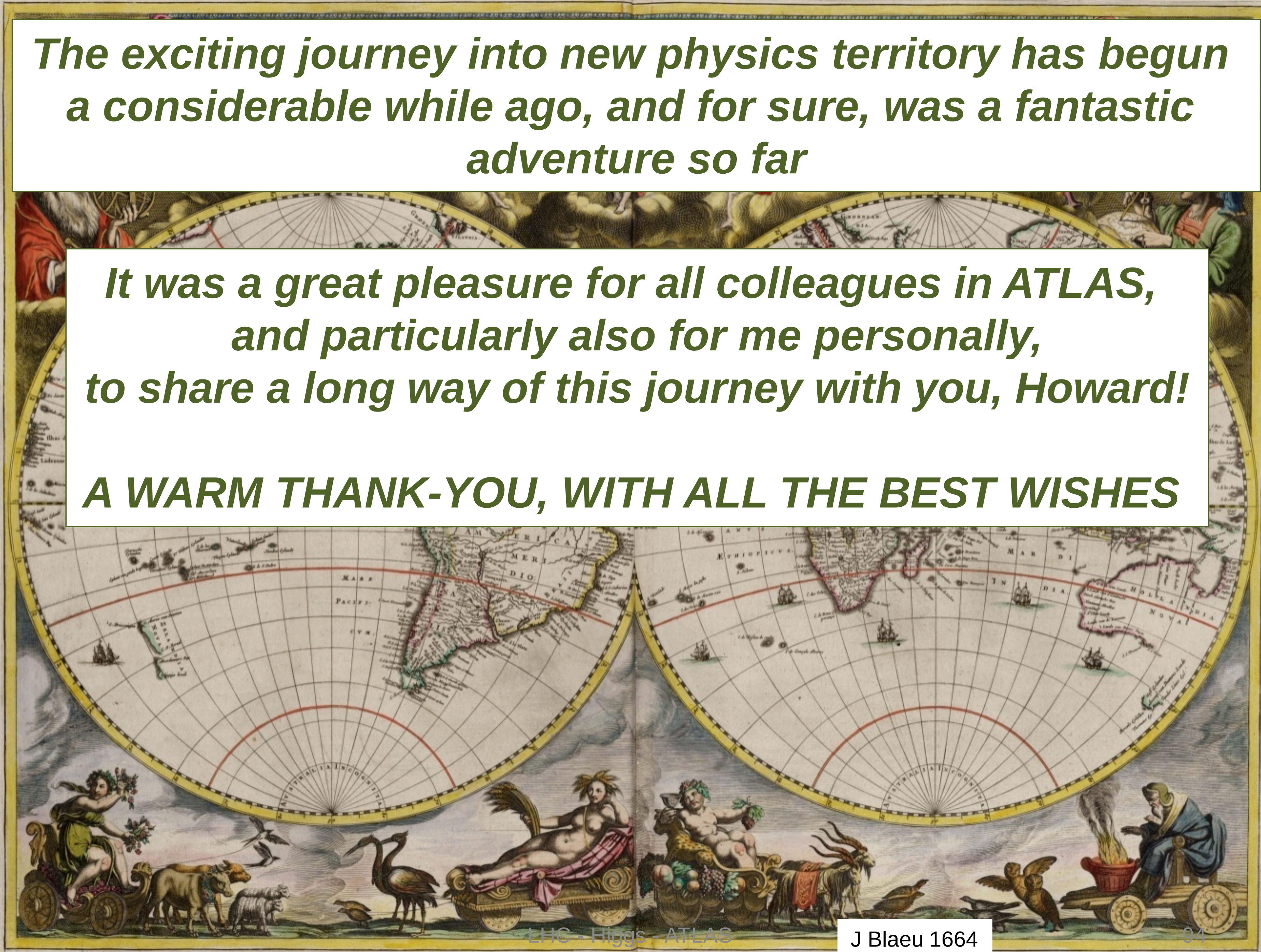
ATLAS Phase-2

Prepare for 140-200 pile-up events
Replace Inner Tracker
New L0/L1 trigger scheme
Upgrade muon/calorimeter electronics
Upgrade of DAQ detector readout

The exciting journey into new physics territory has begun a considerable while ago, and for sure, was a fantastic adventure so far

It was a great pleasure for all colleagues in ATLAS, and particularly also for me personally, to share a long way of this journey with you, Howard!

A WARM THANK-YOU, WITH ALL THE BEST WISHES



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