The ATLAS Road Map for the Higgs Boson and Beyond

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KSETA Inauguration Symposium KIT Karlsruhe, 1st February 2013



Julius Wess Award lecture



Peter Jenni, CERN

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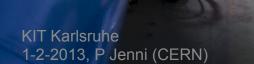


Drawing by Sergio Cittolin

alice

The Large Hadron Collider project is a global scientific adventure, combining the accelerator, a worldwide computing grid and the experiments, initiated more than 25 years ago

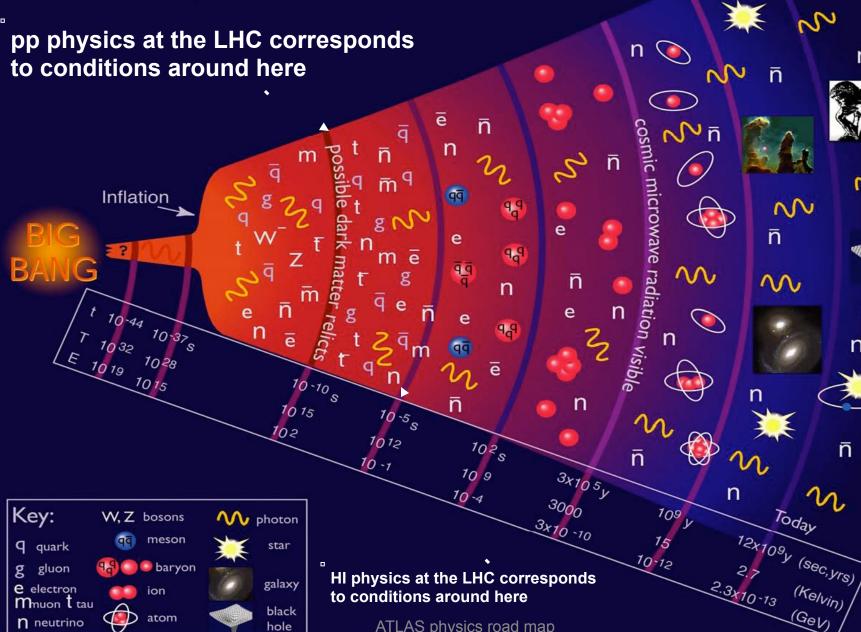
There is a fourth, essential element: the constant driving motivation from our theory colleagues, and Julius Wess and Bruno Zumino with SUSY have created such an essential one!



It is a great privilege and pleasure to present now first physics results

History of the **Universe**

hole



ATLAS physics road map Particle Data Group, LBNL, © 2000. Supported by DOE and NSF n

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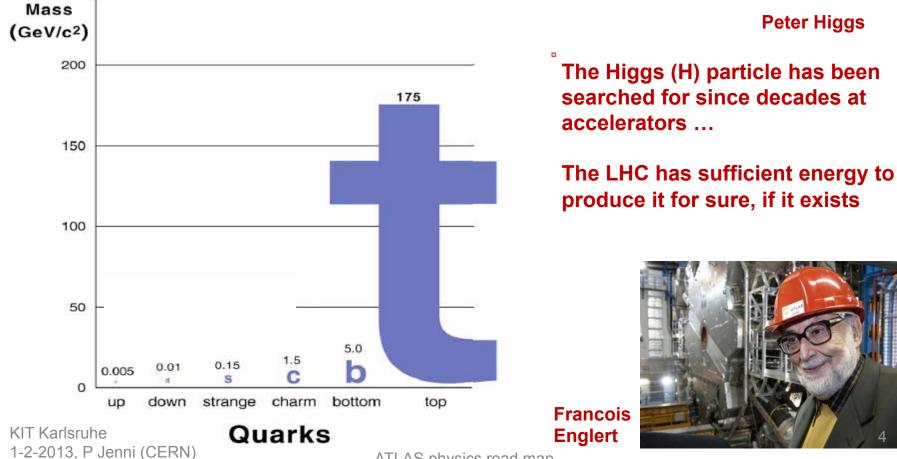
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A most basic question is why particles (and *matter) have masses (and so different masses)*

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







ATLAS physics road map

Supersymmetry (SUSY)

(Julius Wess and Bruno Zumino, 1974)

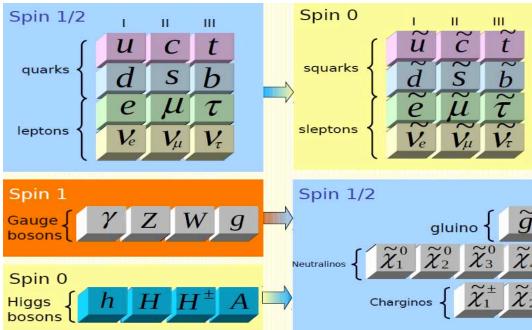
Establishes a symmetry between fermions (matter) and bosons (forces):

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

q (s=1/2) \rightarrow \tilde{q} (s=0) squark g (s=1) \rightarrow \tilde{g} (s=1/2) gluino

Maybe a new world?

Our known world...







Motivation:

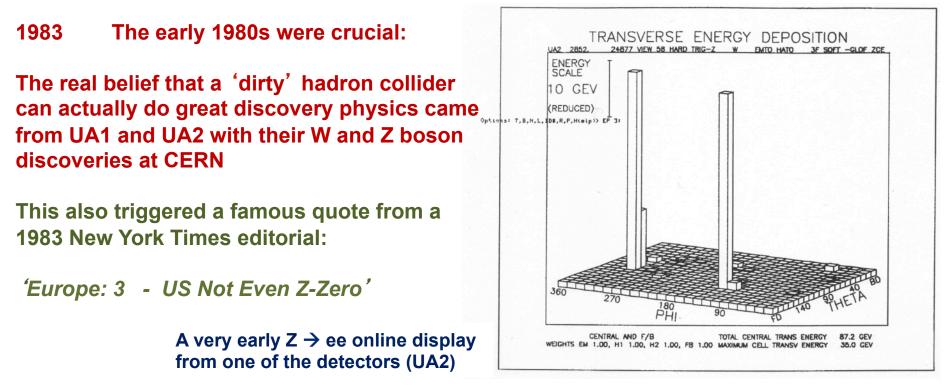
- Unification (fermions-bosons, matter-forces)
- Solves some deep problems of the Standard Model

How the LHC came to be ...

(see a nice article by Chris Llewellyn Smith in Nature 448, p281)

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





ATLAS and CMS were born with Letters of Intent (LoI), submitted on 1st October 1992, 20 years ago

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ATLAS physics road map

celebrating 20 years of ATLAS

on 1st October 2012

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:

Construction was formally proposed by DG Chris Llewellyn Smith, but few countries could not yet agree, so the Council session vote was suspended until

16 December 1994 Council:

(Two-stage) construction of LHC was approved



ATLAS physics road map

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, 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



Delivery of the last dipole for the LHC injection lines from Russia (15th June 2001), with DG L Maiani and A Skrinsky in the centre

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

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11/16/95 Peter, "Official Feak" The LHCC reconnends the approval of the ATLAS + CMS projects, logether with the plans, including milestone, leading to the subsystem Technical Derige Reposts

Mik second prize to get to build it.

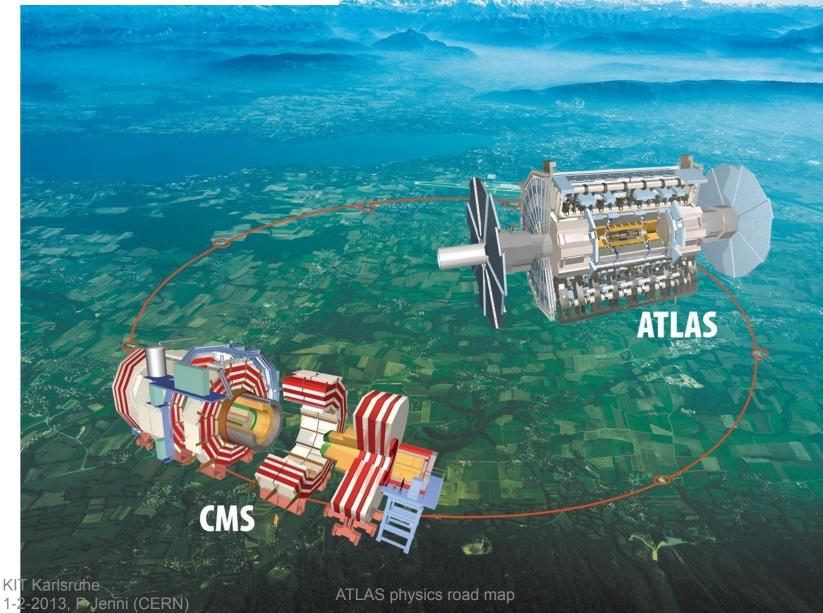
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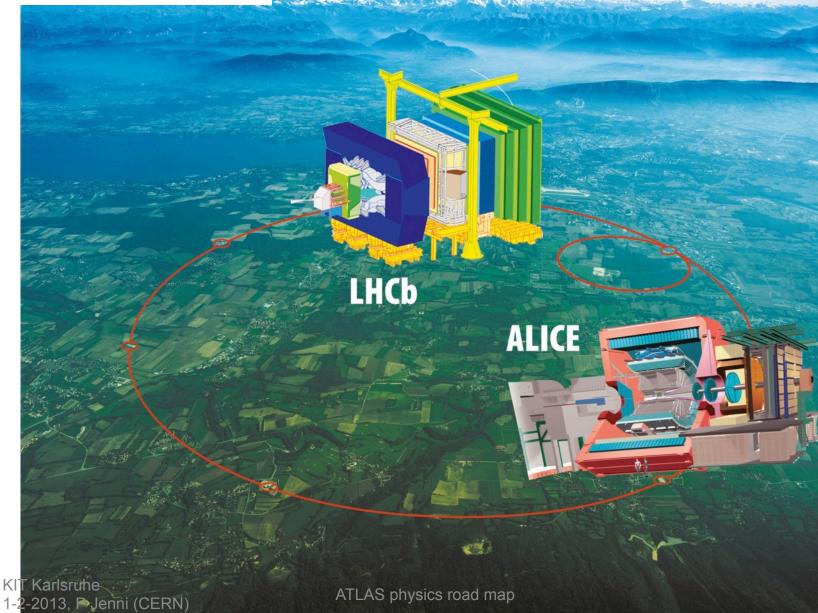
Bonne Chanc

Good continue bion metil the final success ! - P. Go- Kenner

General purpose detectors







ATLAS Collaboration

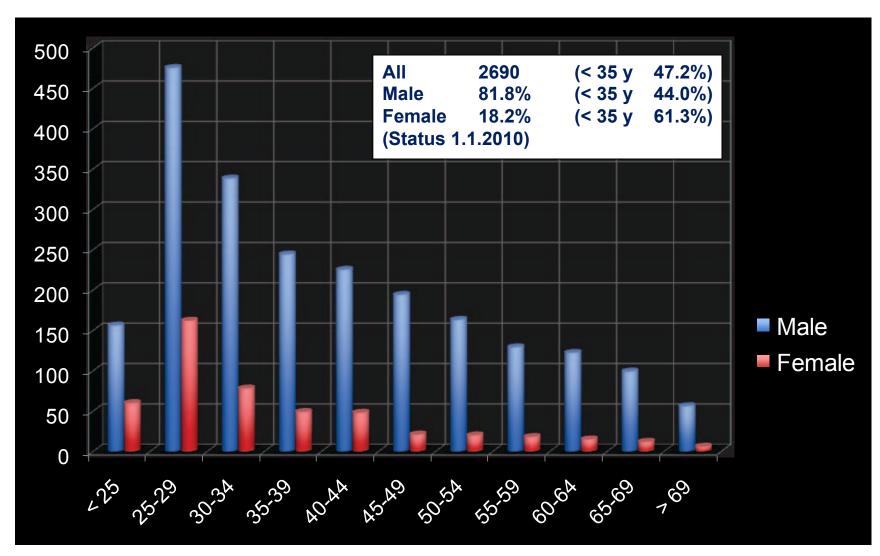
38 Countries 176 Institutions 3000 Scientific participants total (1000 Students)

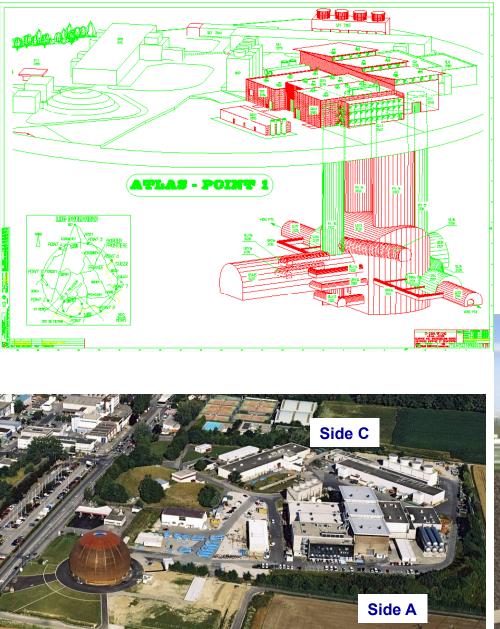
It is a pleasure to collaborate with 425 colleagues, senior and junior, from 13 Universities, DESY and MPI Munich from Germany



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, Brasil Cluster, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, SMU Dallas, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Edinburgh, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Iowa, UC Irvine, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Kyushu, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, LMU Munich, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, Northern Illinois, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, NPI Petersburg, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, South Africa, Stockholm, KTH Stockholm, Stony Brook, Sydney, Sussex, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Tokyo Tech, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, UI Urbana, Valencia, UBC Vancouver, Victoria, Warwick, Waseda, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

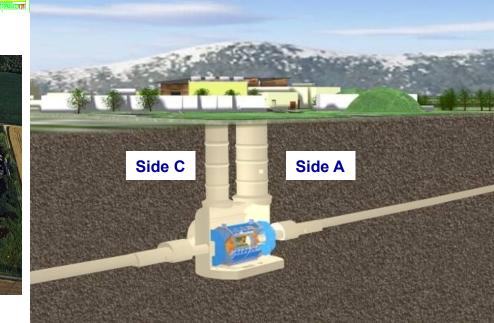
Age distribution of the ATLAS population

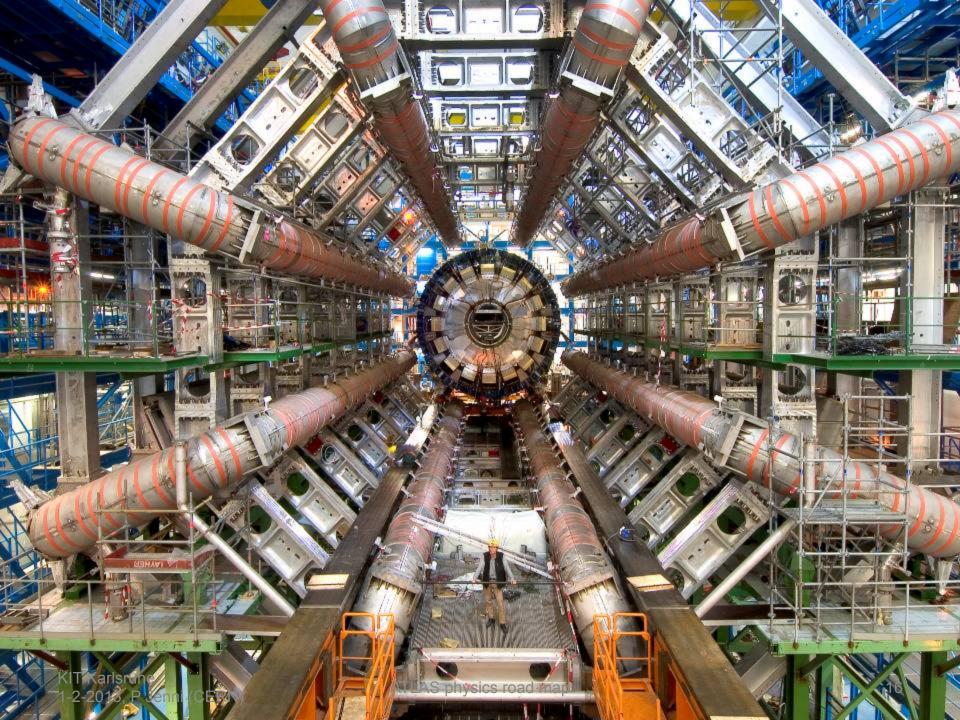


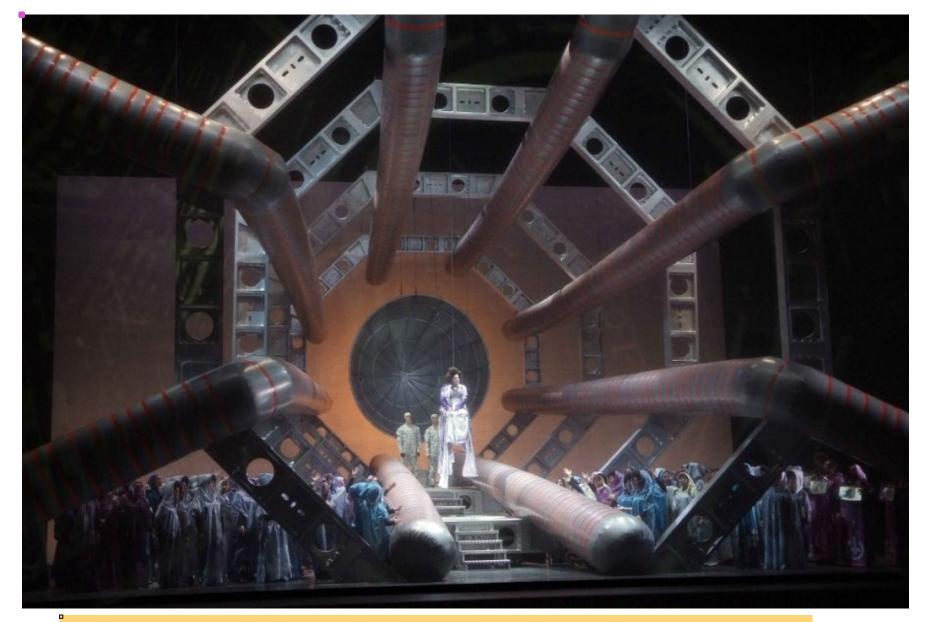


The Underground Cavern at Point-1 for the ATLAS Detector

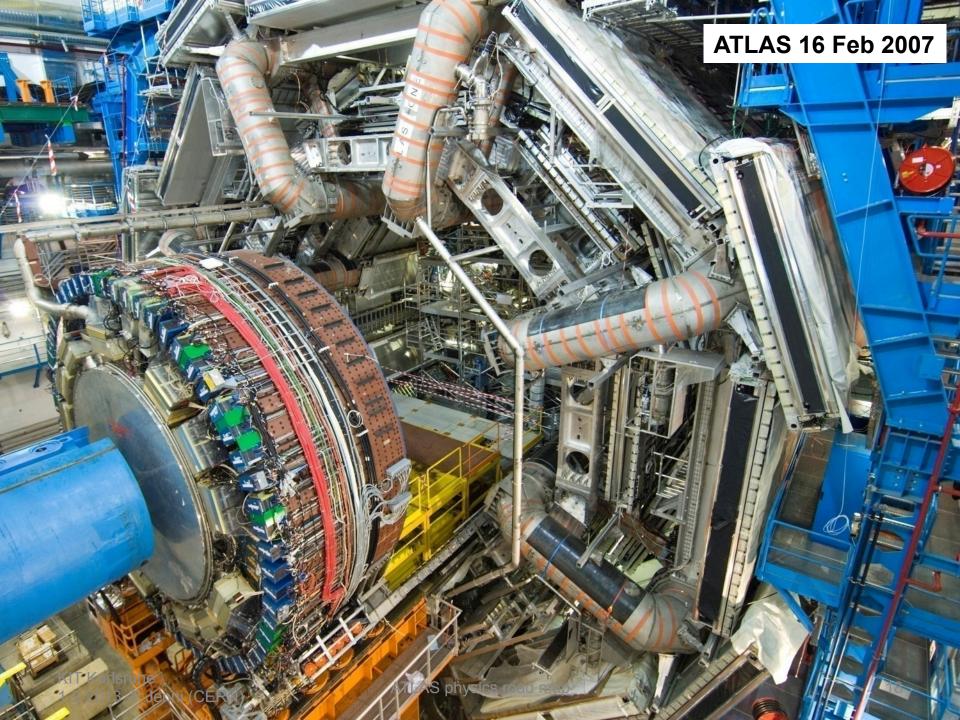
Length	= 55 m
Width	= 32 m
Height	= 35 m







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

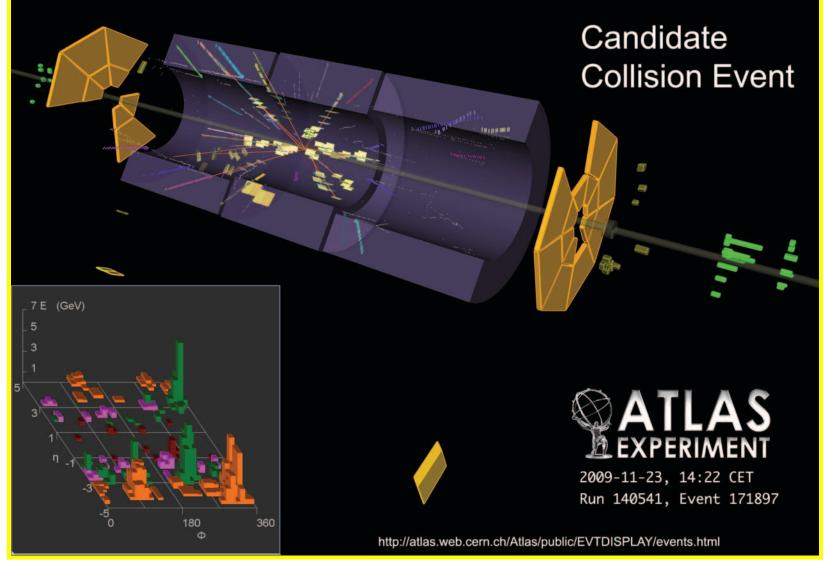


The joy in the ATLAS Control Room when the first LHC beam collided on November 23rd, 2009....

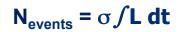
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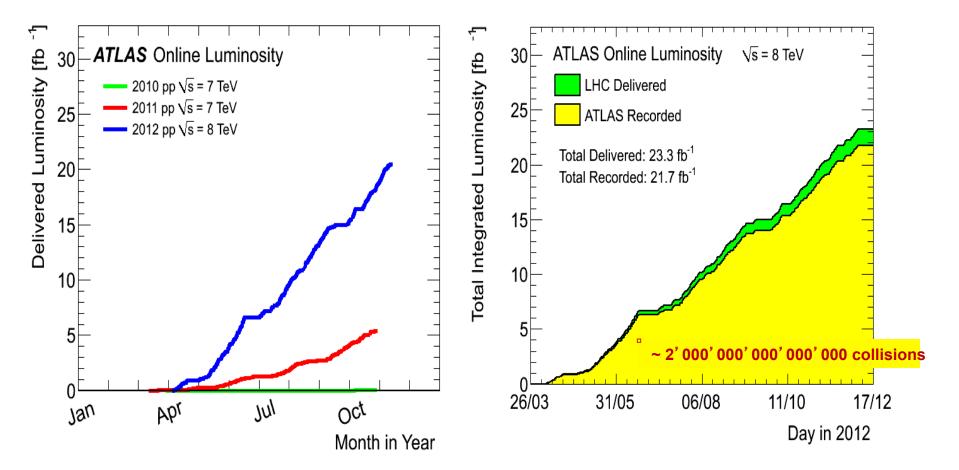
ATLAS physics road map

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



Total integrated luminosity



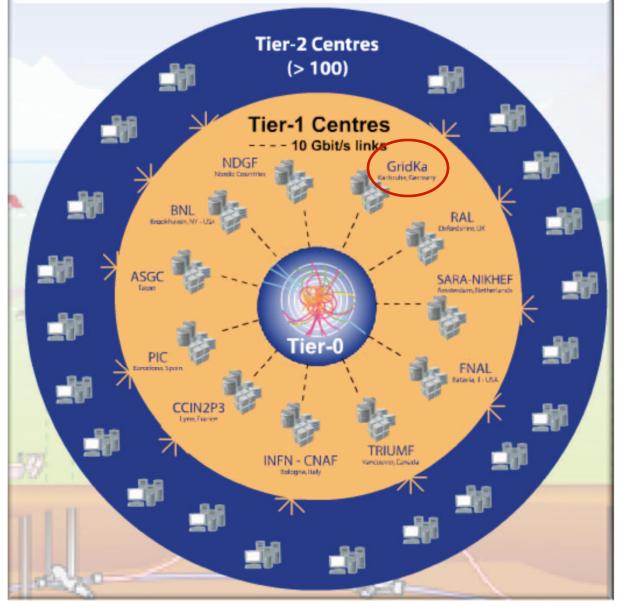


The experiment records typically 94% of the stably delivered luminosity, and uses up to 90% of the LHC luminosity in the final analyses!

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ATLAS physics road map

The Worldwide LHC Computing Grid (wLCG)





Tier-0 (CERN):
Data recording
Initial data reconstruction
Data distribution

Tier-1 (12 centres):

Permanent storage
Re-processing
Analysis
Simulation

Tier-2 (68 federations of >100 centres):

- Simulation
- End-user analysis

Physics Highlights:

General event properties

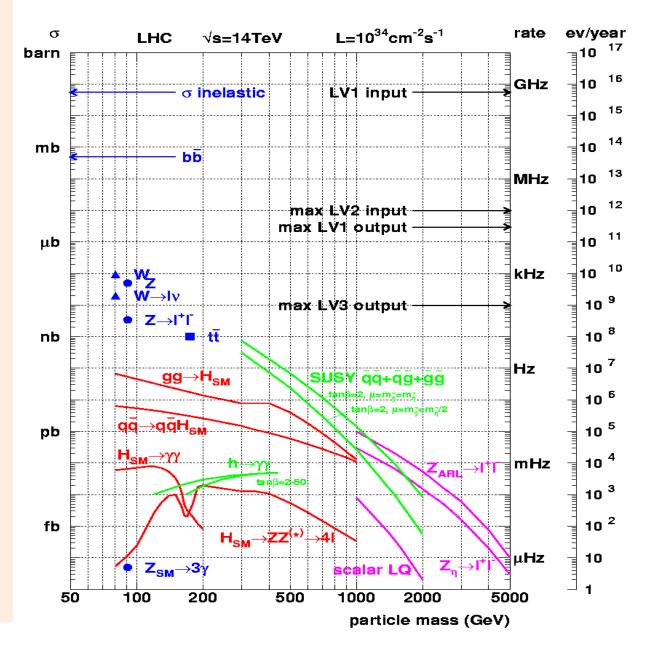
Heavy flavour physics

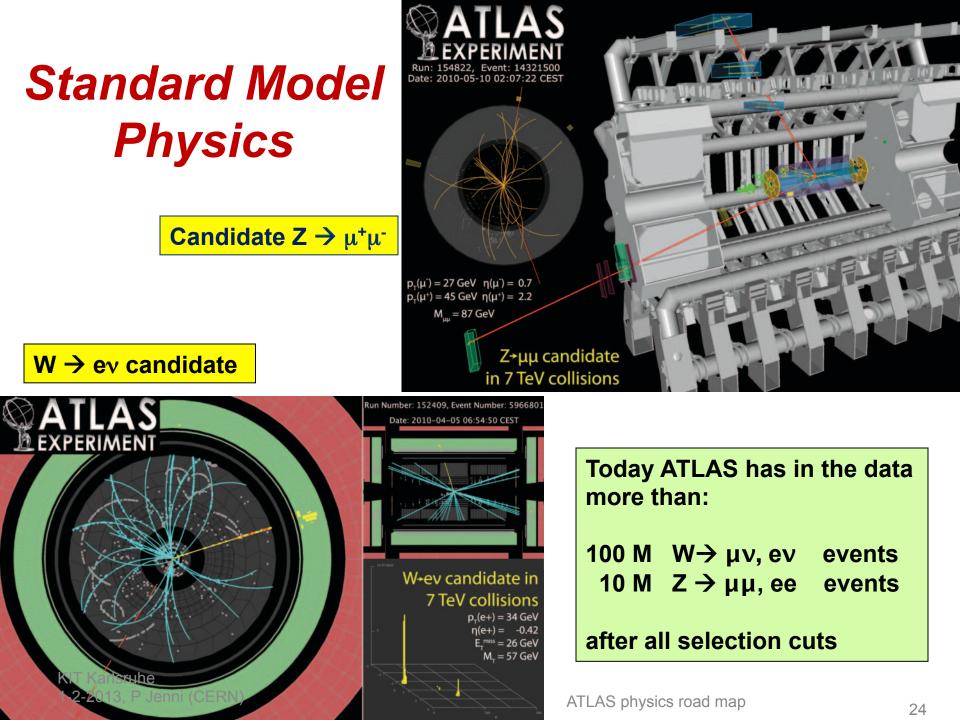
Standard Model physics including QCD jets

Higgs searches

Searches for SUSY

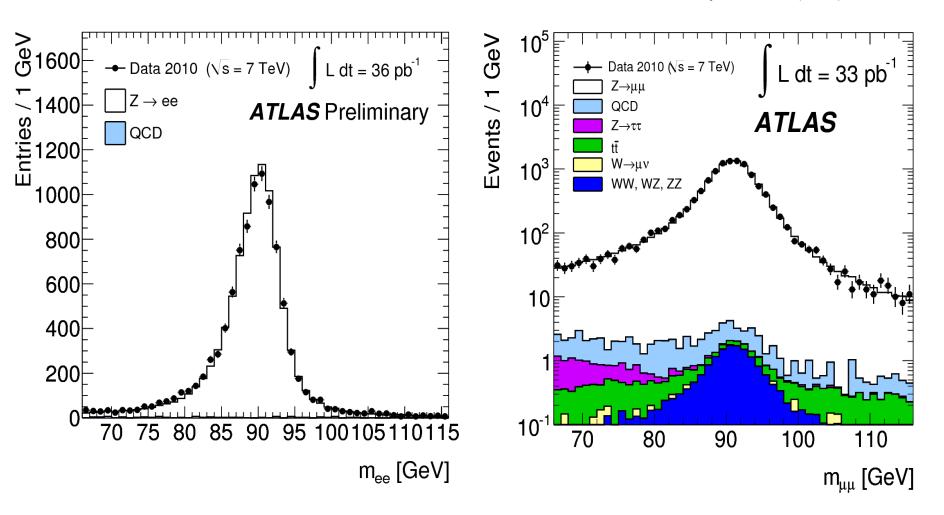
Examples of searches for 'exotic' new physics





Z and W production

Phys Rev D85 (2012) 072004



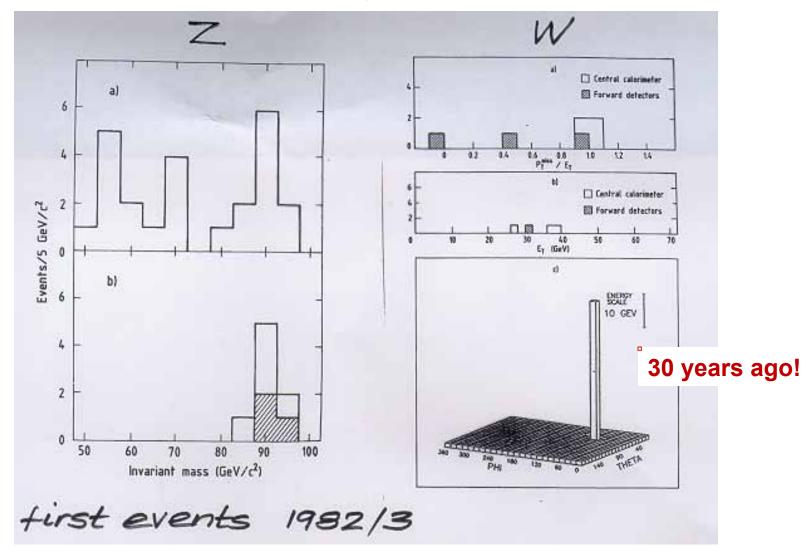
Z peak (di-lepton pair mass distributions, can be extracted essentially background-free)

$$m = \sqrt{(E_1 + E_2)^2 - (\vec{p_1} + \vec{p_2})^2}$$

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ATLAS physics road map

What a contrast to the Intermediate Vector Boson discovery distributions in 1982 and 1983 by UA1 and UA2 ...



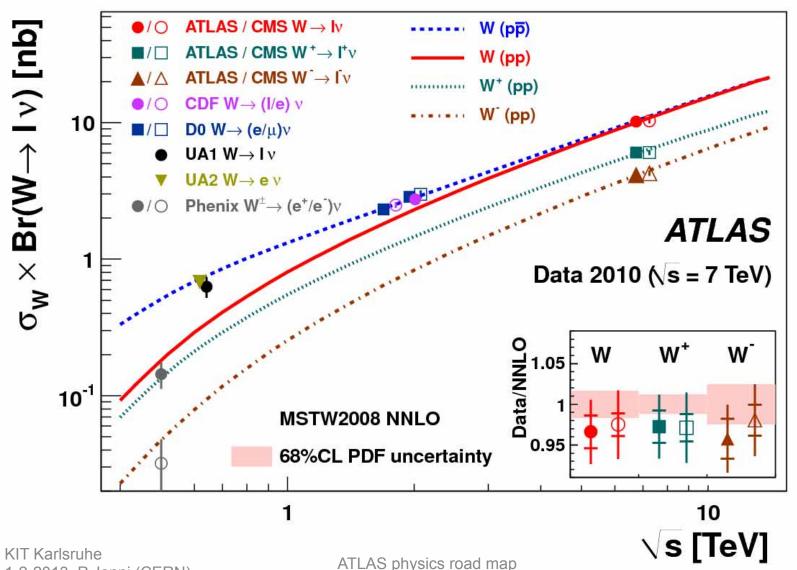
(here are shown the UA2 distributions)

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ATLAS physics road map

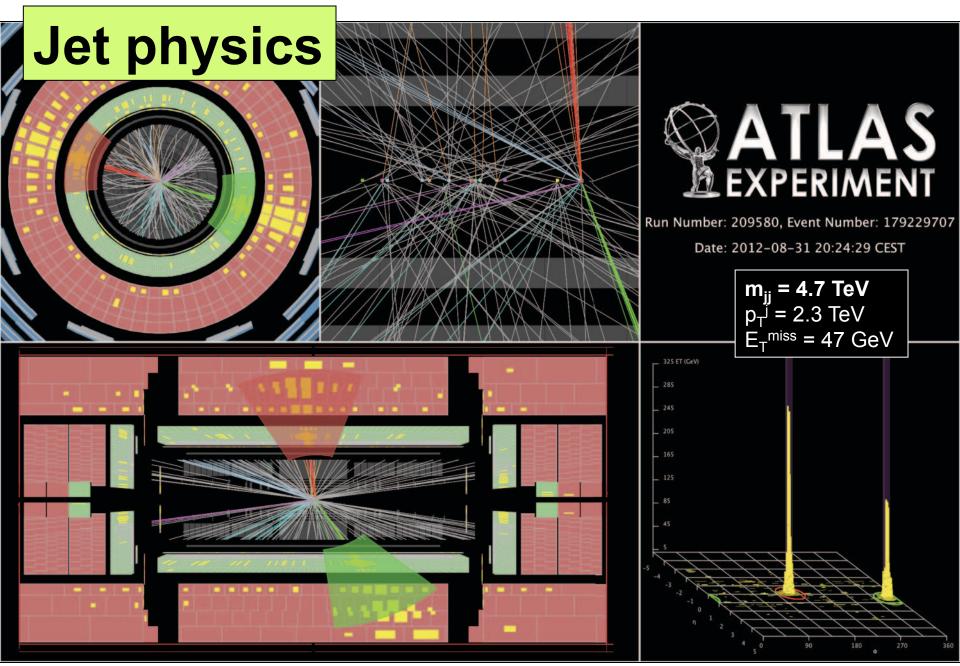
W cross section measurement with e and μ

Phys Rev D85 (2012) 072004

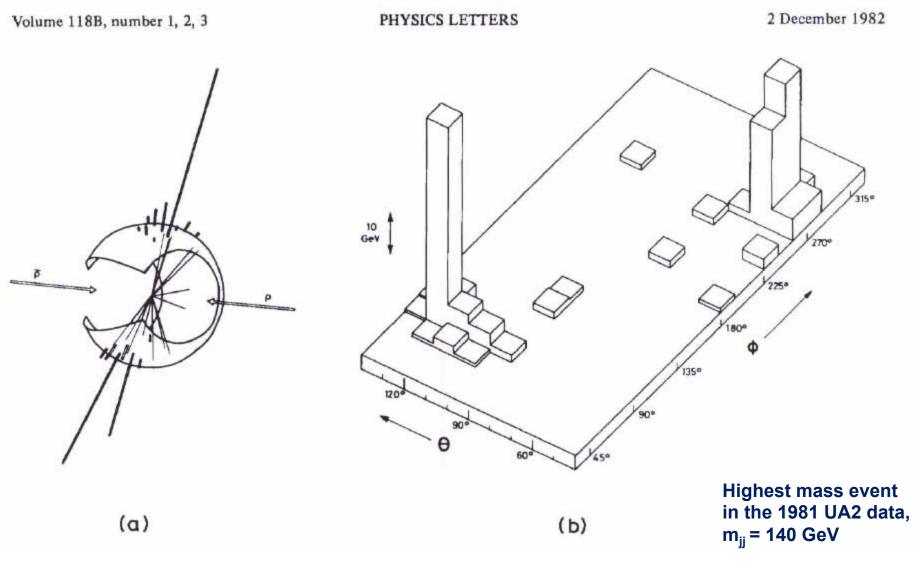


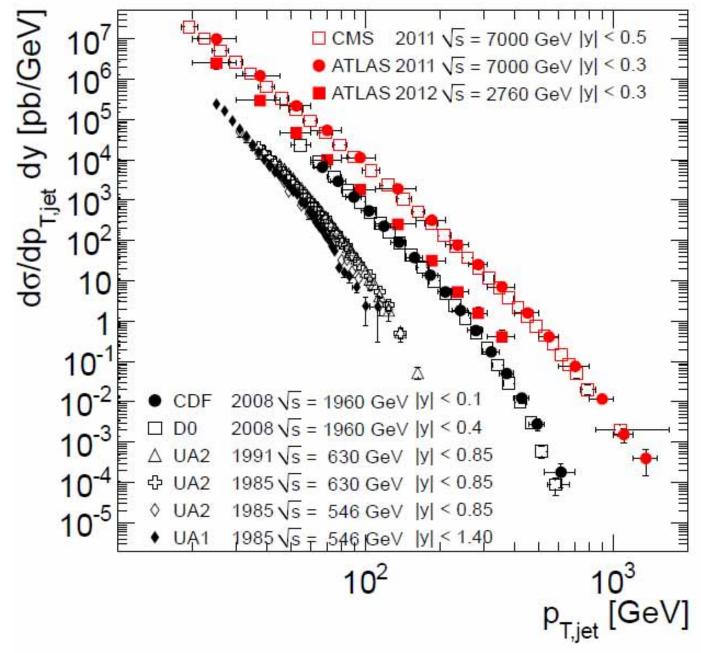
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Note also that the event displays have become more sophisticated since the first spectacular events, hand-drawn, at a hadron collider ...





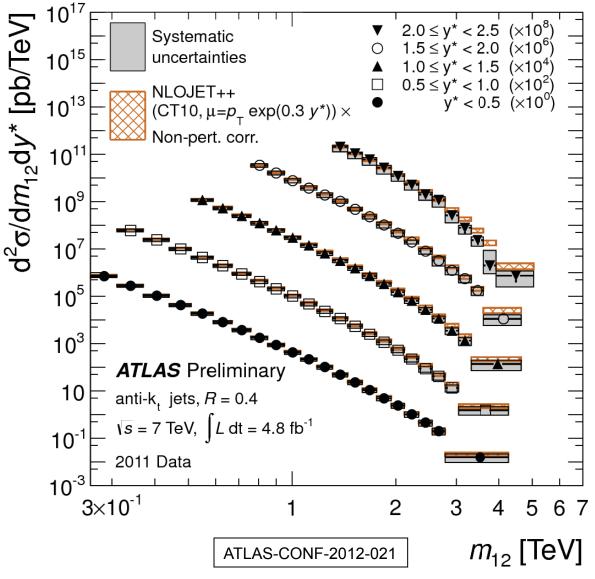
Very detailed jet measurements are now available from LHC that can be compared with QCD calculations ...

Example: The inclusive di-jet cross sections as a function of the di-jet mass for various rapidity separations

The data are spanning jets over a large phase space:

- 20 GeV < p_T < 2 TeV - ΙηΙ < 4.4

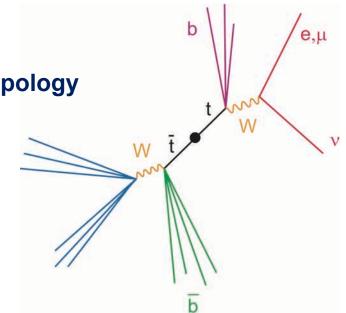
(y* = 0.5 lη₁ ⊡η₂l)



ATLAS physics road map

Top measurements

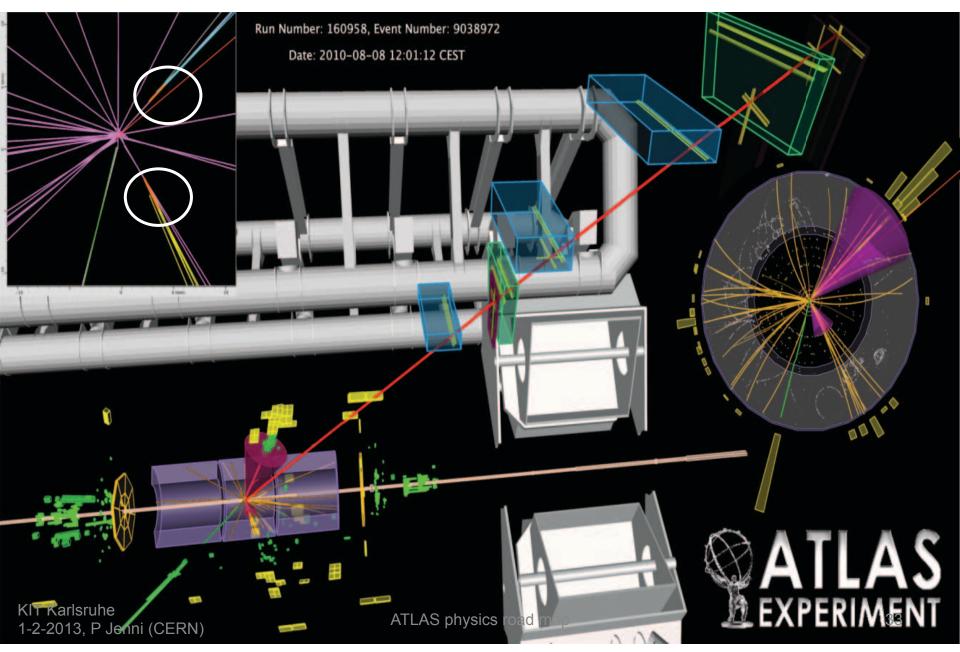
- Complete set of ingredients to investigate production of ttbar, which is the next step in verifying the SM at the LHC:
 - e, μ , E_T^{miss} , jets, b-tag
- Assume all tops decay to Wb: event topology then depends on the W decays:
 - one lepton (e or μ), E_T^{miss}, jjbb (37.9%)
 - di-lepton (ee, μμ or eμ), E_T^{miss}, bb (6.5%)



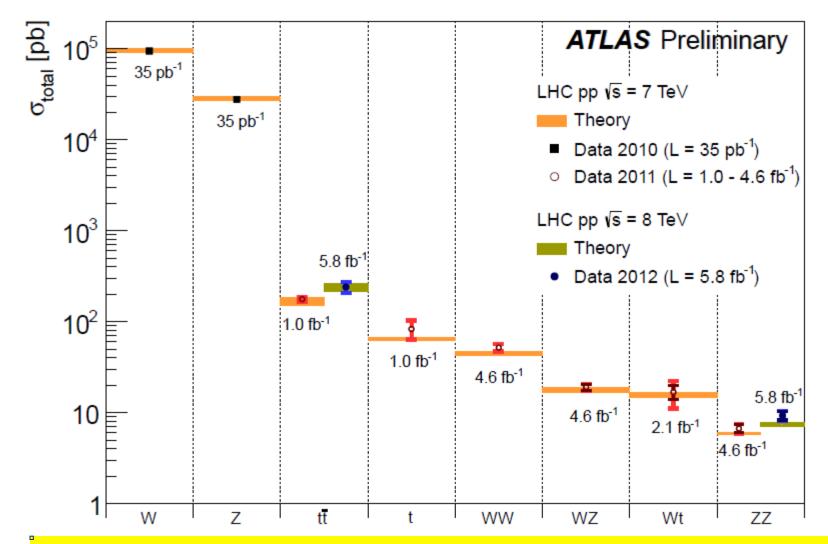
• Data-driven methods to control QCD and W+jets backgrounds

tt candidate event

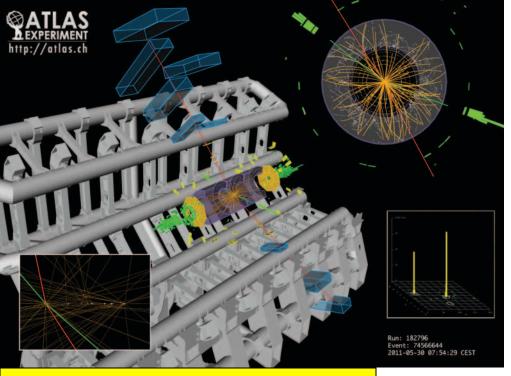
e + μ + 2 jets (b-tagged) +ETmiss



A summary of Standard Model measurements



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

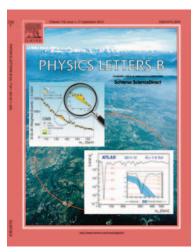


ATLAS and CMS have announced the discovery of a new boson together on 4th July 2012, published in a special issue of Physics Letter B

Phys. Lett. B 716 (2012) 1

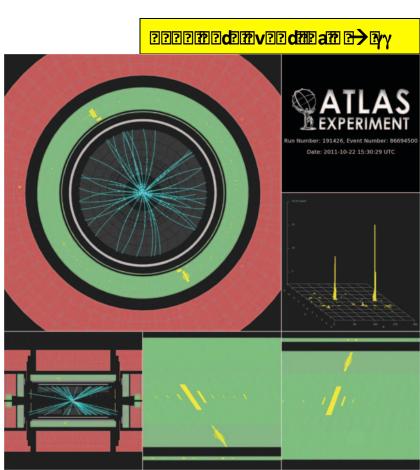
Phys. Lett. B 716 (2012) 30

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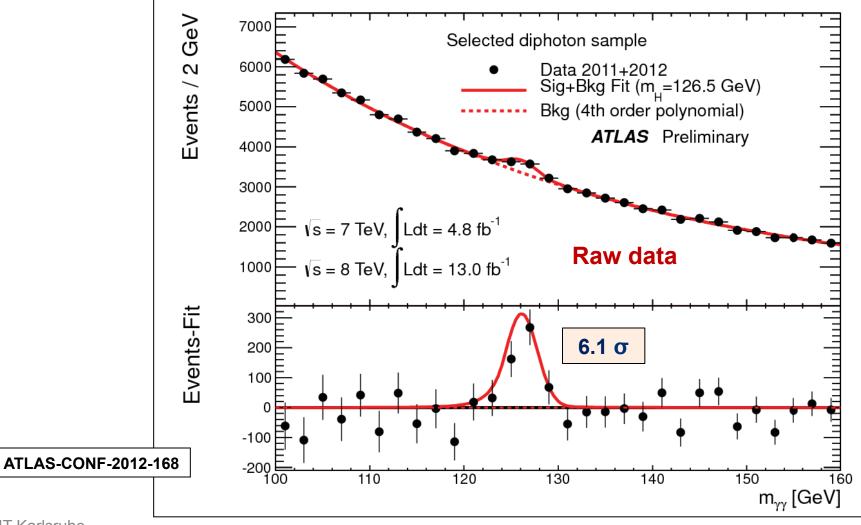
ATLAS physics road map

The Higgs(-like) boson





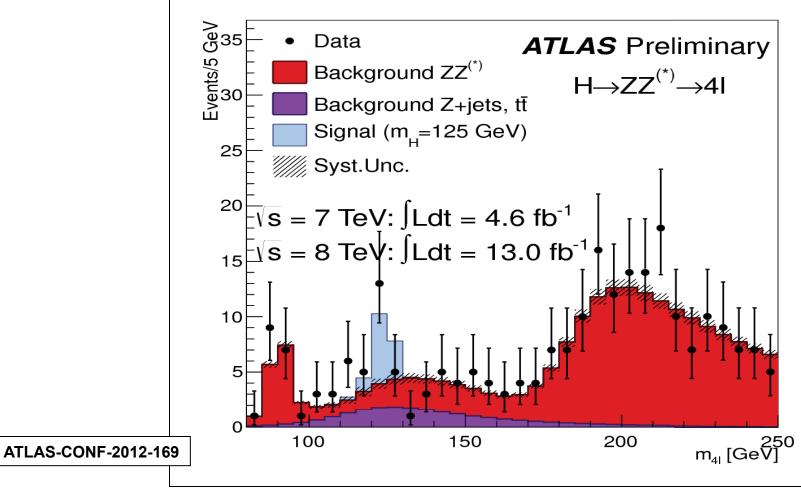
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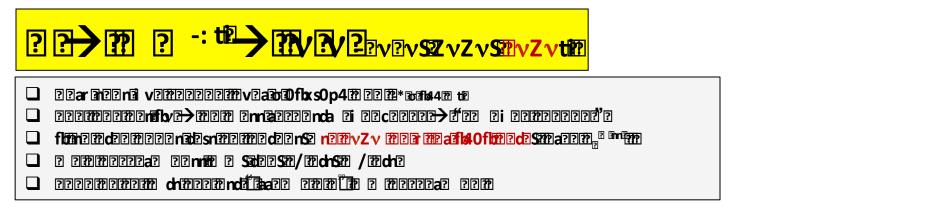


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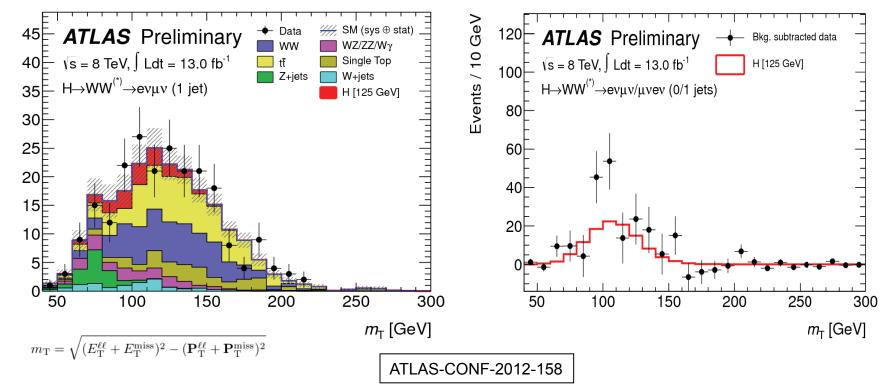




Events / 10 GeV

(Just as an example of several subsamples)

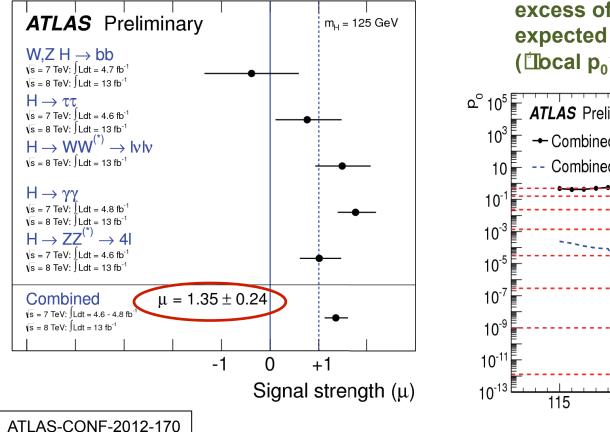
(All subsamples, background subtracted)



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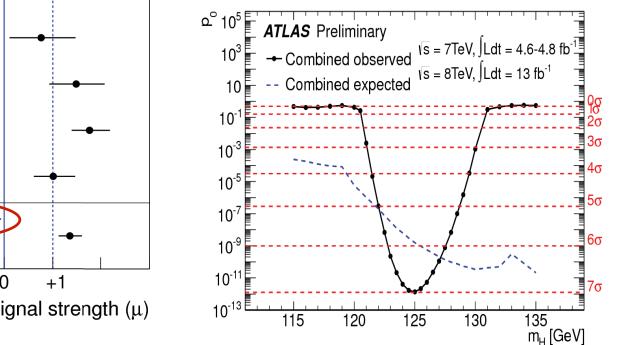
Summary and combination

background only hypothesis **μ = 0** SM Higgs hypothesis u = 1



m = 125.2 ± 0.3 (stat) ± 0.6 (syst) GeV

Observed data compared to the probability that the background fluctuates to fake the observed excess of events, and what is expected from a SM Higgs $(\square ocal p_0 \square)$



(First analyses and fits for the Higgs couplings and spin have been made as well which are still very much limited by statistics, albeit well compatible with the Standard Model)

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

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Dark Matter in the Universe

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

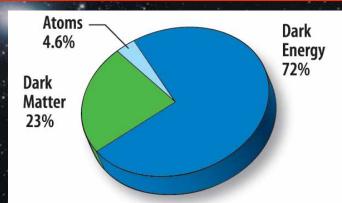
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Vera Rubin ~ 1970

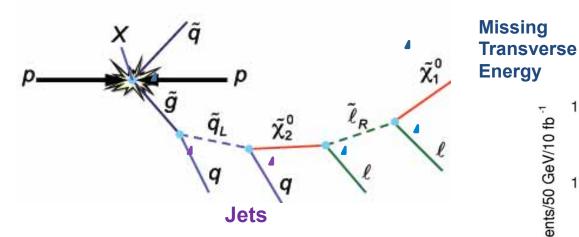
Supersymmetric particles ?





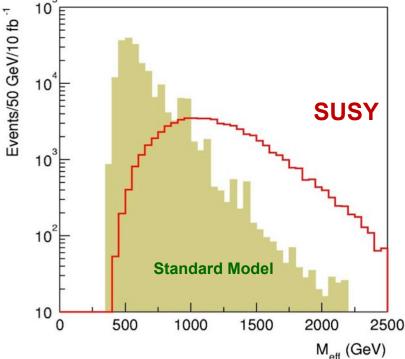
In practice SUSY searches at LHC are rather complicated

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
 - Photons: typically for models with the gravitino as LSP

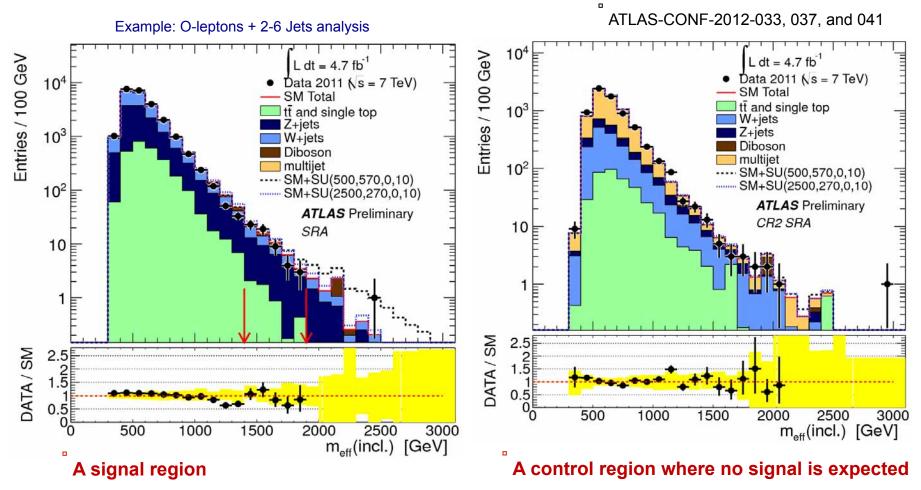
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Meff = Etmiss + Σ pT(jets)

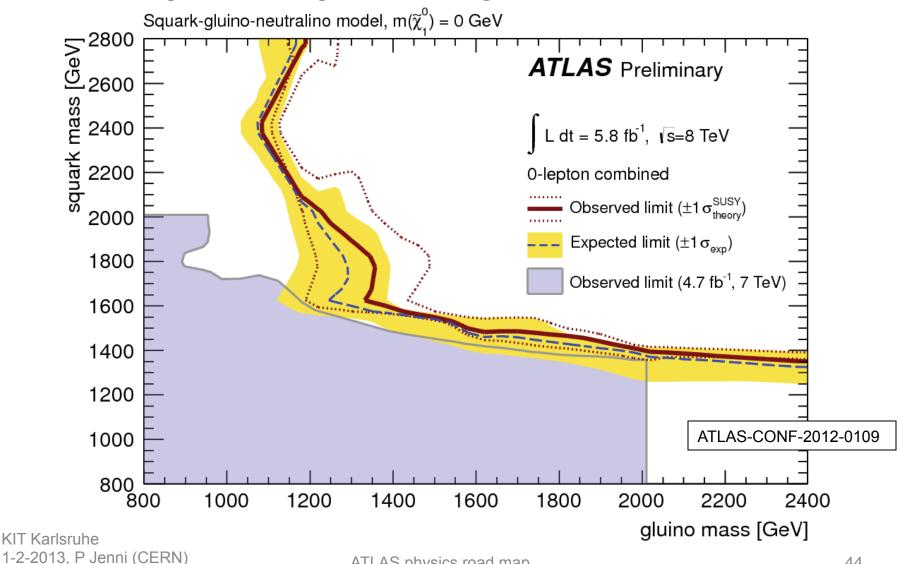
Analyses re-optimized and updated with full 2011 Luminosity

- 0-lepton + 2-6 jets + high MET (based on Et-miss+jet triggers)
- 0-lepton + 6-9 (multi-)jets + MET (based on multi-jet triggers)
- 1-lepton + 3,4 jets + high MET (based on lepton triggers)



Interpretation of the results

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



ATLAS physics road map

SUSY limits

ATLAS SUSY Searches* - 95% CL Lower Limits (Status: HCP 2012)

Inclusive searches	$\begin{array}{l} MSUGRA/CMSSM: 0 \ lep + j's + E_{T,miss} \\ MSUGRA/CMSSM: 1 \ lep + j's + E_{T,miss} \\ Pheno \ model: 0 \ lep + j's + E_{T,miss} \\ Pheno \ model: 0 \ lep + j's + E_{T,miss} \\ Gluino \ med, \widetilde{\chi}^{\pm} (\widetilde{g} {\rightarrow} q \overline{q} \widetilde{\chi}^{\pm}): 1 \ lep + j's + E_{T,miss} \\ GMSB \ (I \ NLSP): 2 \ lep \ (OS) + j's + E_{T,miss} \\ GMSB \ (\bar{\tau} \ NLSP): 1{-}2 \ \tau + 0{-}1 \ lep + j's + E_{T,miss} \\ GGM \ (bino \ NLSP): \gamma \gamma + E_{T,miss} \\ GGM \ (bino \ NLSP): \gamma + lep + E_{T,miss}^{T,miss} \\ GGM \ (higgsino-bino \ NLSP): \gamma + b + E_{T,miss}^{T,miss} \\ GGM \ (higgsino \ NLSP): \gamma + b + E_{T,miss} \\ GGM \ (higgsino \ NLSP): Z + jets + E_{T,miss} \\ GGM \ (higgsino \ NLSP): Z + jets + E_{T,miss} \\ GFavitino \ LSP: 'monojet' + E_{T,miss} \\ \end{array}$	L=4.8 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-144] 619 GeV g mass $(m(\tilde{\chi}_1^0) > 220 \text{ GeV})$ L=4.8 fb ⁻¹ , 7 TeV [1211.1167] 900 GeV \tilde{g} mass $(m(\tilde{\chi}_1^0) > 220 \text{ GeV})$ L=5.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-152] 690 GeV \tilde{g} mass $(m(\tilde{H}) > 200 \text{ GeV})$ L=10.5 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-147] 645 GeV $F^{1/2}$ scale $(m(\tilde{G}) > 10^4 \text{ eV})$	ATLAS Preliminary iii) <i>t</i> = (2.1 - 13.0) fb ⁻¹ i s = 7, 8 TeV
3rd gen. sq. gluino med.	$ \begin{array}{l} \widetilde{g} \rightarrow b \overline{b} \overline{\chi}^{o} (\text{virtual } \overline{b}) : 0 \text{ lep } + 3 \text{ b-j's } + E_{T,\text{miss}} \\ \widetilde{g} \rightarrow t \overline{t} \overline{\chi}^{o}_{+} (\text{virtual } \overline{t}) : 2 \text{ lep } (SS) + \text{j's } + E_{T,\text{miss}} \\ \widetilde{g} \rightarrow t \overline{t} \overline{\chi}^{o}_{+} (\text{virtual } \overline{t}) : 3 \text{ lep } + \text{j's } + E_{T,\text{miss}} \\ \widetilde{g} \rightarrow t \overline{t} \overline{\chi}^{o}_{+} (\text{virtual } \overline{t}) : 0 \text{ lep } + \text{multi-j's } + E_{T,\text{miss}} \\ \widetilde{g} \rightarrow t \overline{t} \overline{\chi}^{o}_{+} (\text{virtual } \overline{t}) : 0 \text{ lep } + 3 \text{ b-j's } + E_{T,\text{miss}} \\ \end{array} $	L=12.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-145] 1.24 TeV \widetilde{g} mass $(m(\overline{\chi}_1^0) < 200 \text{ GeV})$ L=5.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-105] 850 GeV \widetilde{g} mass $(m(\overline{\chi}_1^0) < 300 \text{ GeV})$ L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-151] 860 GeV \widetilde{g} mass $(m(\overline{\chi}_1^0) < 300 \text{ GeV})$ L=5.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-103] 1.00 TeV \widetilde{g} mass $(m(\overline{\chi}_1^0) < 300 \text{ GeV})$ L=12.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-145] 1.15 TeV \widetilde{g} mass $(m(\overline{\chi}_1^0) < 200 \text{ GeV})$	8 TeV results 7 TeV results
3rd gen. squarks direct production	bb, b ₁ \rightarrow b $\overline{\chi}_{1}^{-}$: 0 lep + 2-b-jets + $E_{T,miss}$ bb, b ₁ \rightarrow t $\overline{\chi}_{1}^{\pm}$: 3 lep + j's + $E_{T,miss}$ tt (very light), t \rightarrow b $\overline{\chi}_{1}^{\pm}$: 2 lep + $E_{T,miss}$ tt (light), t \rightarrow b $\overline{\chi}_{1}^{\pm}$: 1/2 lep + b-jet + $E_{T,miss}$ tt (medium), t \rightarrow t $\overline{\chi}_{0}^{-}$: 2 lep + b-jet + $E_{T,miss}$ tt (heavy), t \rightarrow t $\overline{\chi}_{0}^{-}$: 1 lep + b-jet + $E_{T,miss}$ tt (heavy), t \rightarrow t $\overline{\chi}_{1}^{-}$: 0 lep + b-jet + $E_{T,miss}$ tt (natural GMSB) Z_{1}^{+} Z(\rightarrow II) + b-jet + $E_{T,miss}^{-}$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-106] 480 GeV b mass $(m(\overline{\chi}_{1}^{0}) < 150 \text{ GeV})$ L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-151] 405 GeV b mass $(m(\overline{\chi}_{1}^{0}) = 2m(\overline{\chi}_{1}^{0}))$ L=4.7 fb ⁻¹ , 7 TeV [1208.4305] 130 GeV t mass $(m(\overline{\chi}_{1}^{0}) < 70 \text{ GeV})$ L=4.7 fb ⁻¹ , 7 TeV [1209.2102] 123-167 GeV t mass $(m(\overline{\chi}_{1}^{0}) = 55 \text{ GeV})$ L=4.7 fb ⁻¹ , 7 TeV [1209.4186] 298-305 GeV t mass $(m(\overline{\chi}_{1}^{0}) = 0)$ L=4.7 fb ⁻¹ , 7 TeV [1208.2590] 230-440 GeV t mass $(m(\overline{\chi}_{1}^{0}) = 0)$ L=4.7 fb ⁻¹ , 7 TeV [1208.1447] 370-465 GeV t mass $(m(\overline{\chi}_{1}^{0}) = 0)$ L=2.1 fb ⁻¹ , 7 TeV [1204.6736] 310 GeV t mass $(115 < m(\overline{\chi}_{1}^{0}) < 230 \text{ GeV})$	
EW direct	$ \begin{array}{c} \downarrow_{L}, \rightarrow \overline{\chi}_{0}^{*}: 2 \text{ lep } + E_{T,\text{miss}} \\ \tilde{\chi}_{1}^{+}\overline{\chi}_{1}^{-}, \tilde{\chi}_{1}^{+} \rightarrow \overline{Iv}(\overline{Iv}) \rightarrow \overline{Iv}\overline{\chi}_{1}^{*}: 2 \text{ lep } + E_{T,\text{miss}} \\ \tilde{\chi}_{1}^{+}\overline{\chi}_{2}^{-} \rightarrow \overline{Iv}_{1}^{+}U_{1}^{+}[(\overline{vv}), \overline{Iv}]_{1}(\overline{vv}): 3 \text{ lep } + E_{T,\text{miss}} \\ \tilde{\chi}_{1}^{\pm}\overline{\chi}_{2}^{-} \rightarrow W^{+}\overline{\chi}_{2}^{-}\overline{\chi}_{2}^{-}(*)\overline{\chi}_{1}^{*}: 3 \text{ lep } + E_{T,\text{miss}} \end{array} $	L=4.7 fb ⁻¹ , 7 TeV [1208.2884] 85-195 GeV I mass I mass $(m(\overline{\chi}_1^0) = 0)$ I I mass $(m(\overline{\chi}_1^0) < 10 \text{ GeV}, m(\overline{\chi}_1^0) < 10 \text{ GeV}, m(\overline{\chi}_1^0) = \frac{1}{2}(m(\overline{\chi}_1^0) + m(\overline{\chi}_1^0)))$ L=4.7 fb ⁻¹ , 7 TeV [1208.2884] 110-340 GeV I mass $(m(\overline{\chi}_1^0) < 10 \text{ GeV}, m(\overline{\chi}_1^0) < 10 \text{ GeV}, m(\overline{\chi}_1^0) = \frac{1}{2}(m(\overline{\chi}_1^0) + m(\overline{\chi}_1^0)))$ L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-154] 580 GeV I 40-295 GeV $=^{\pm}$ $\overline{\chi}_1^{\pm}$ mass $(m(\overline{\chi}_1^0) = m(\overline{\chi}_2^0), m(\overline{\chi}_1^0) = 0, \text{ sleptons decoupled})$	
Long-lived particles	Direct $\overline{\chi}_{1}^{e_{1}}$ påir prod. (AMSB) : long-lived $\overline{\chi}_{1}^{e_{1}}$ Stable \widetilde{g} R-hadrons : low β , $\beta\gamma$ (full detector) Stable t R-hadrons : low β , $\beta\gamma$ (full detector) GMSB : stable $\overline{\tau}$ $\overline{\chi}_{*}^{0} \rightarrow qq\mu$ (RPV) : μ + heavy displaced vertex	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	ĝ decoupled)
RPV	LFV : pp $\rightarrow \overline{v}_{\tau} + X$, $\overline{v}_{\tau} \rightarrow e + \mu$ resonance LFV : pp $\rightarrow \overline{v}_{\tau} + X$, $\overline{v}_{\tau} \rightarrow e(\mu) + \tau$ resonance Bilinear RPV CMSSM : 1 lep + 7 j's + $E_{\tau,miss}$ $\overline{\chi}_{1}^{+} \overline{\chi}_{\tau}^{-} \overline{\chi}_{1}^{+} \rightarrow W \overline{\chi}_{0}^{0}, \overline{\chi}_{0}^{0} \rightarrow eev_{\mu}, e\mu v_{e}$: 4 lep + $E_{\tau,miss}$ $ L _{L}, L_{\mu} \rightarrow \overline{\chi}_{1}, \overline{\chi}_{1} \rightarrow eev_{\mu}, e\mu v_{e}$: 4 lep + $E_{\tau,miss}$ $\overline{g} \rightarrow qqq$: 3-jet resonance pair	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	
WIM	Scalar gluon : 2-jet resonance pair P interaction (D5, Dirac χ) : 'monojet' + $E_{T,miss}$	L=4.6 fb ⁻¹ , 7 TeV [1210.4826] 100-287 GeV Sgluon mass (incl. limit from 1110.2693) L=10.5 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-147] 704 GeV M* \$Cale (m_{\chi} < 80 GeV, limit of < 687 GeV for D8)	
		10 ⁻¹ 1 10	

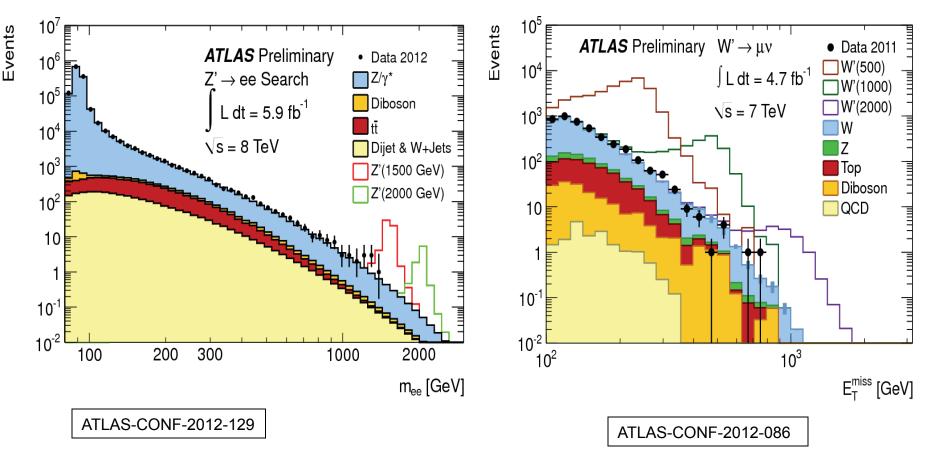
*Only a selection of the available mass limits on new states or phenomena shown. All limits quoted are observed minus 1 σ theoretical signal cross section uncertainty. Mass scale [TeV]

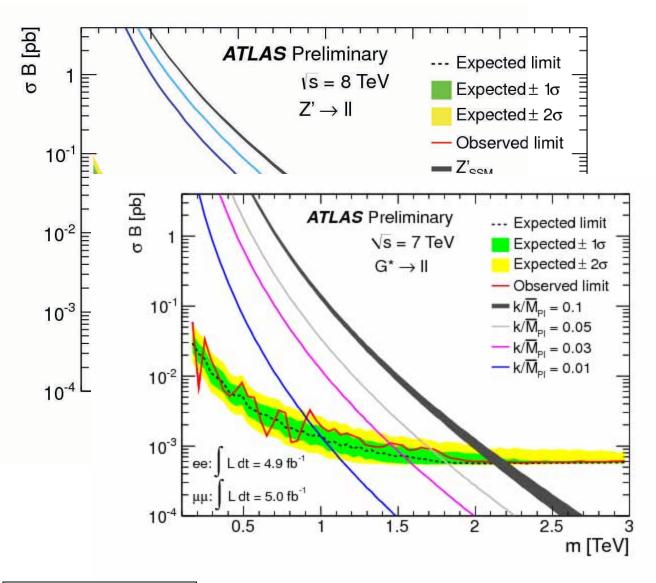
Searches for heavy W and Z like particles

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

Z^[] Di-lepton pairs

W^L Lepton + ETmiss







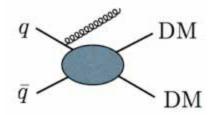
R Sundrum L Randall F Gianotti

ATLAS-CONF-2012-129

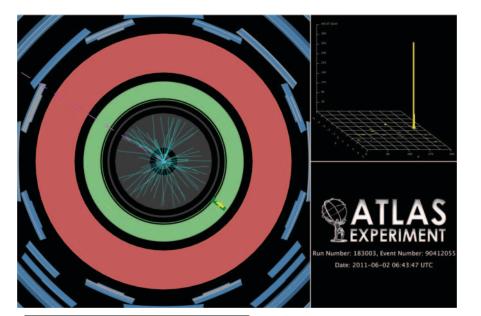
Randall-Sundrum Graviton

ATLAS-CONF-2012-007

Search for direct Dark Matter (DM) particles in pair-production

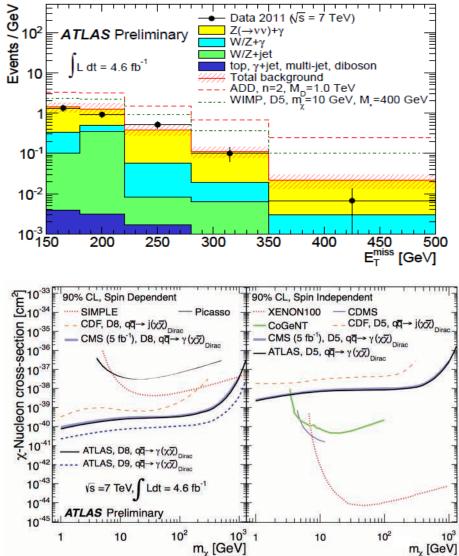


A single photon (150 GeV) or jet plus ETmiss



ATLAS-CONF-2012-085 arXiv:1210.4491v1[hep-ex]

KIT Karlsruhe 1-2-2013, P Jenni (CERN)

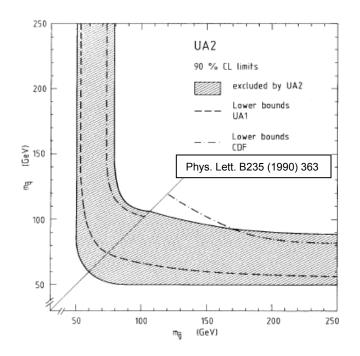


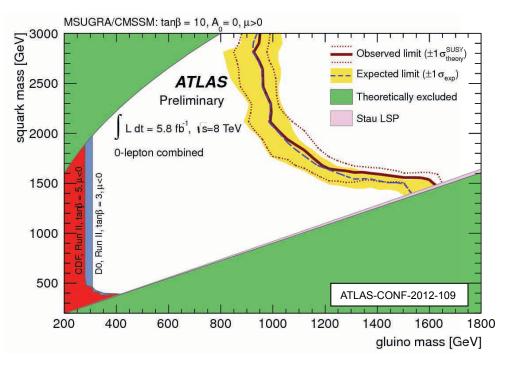
ATLAS BSM searches

ATLAS Exotics Searches* - 95% CL Lower Limits (Status: HCP 2012)

1,000000,000000,000000	Large ED (ADD) : monojet + E _{T.miss}	(-4.7.0) ² 7 ToV (1210 4491)	4.37 TeV M _D (δ=2)			
	Large ED (ADD) : monophoton + $E_{T,miss}$	1 - 4 C ft. 7 Tay (1200 4225)	1.93 TeV M _D (δ=2)	545, 2526) - 2555A		
\$	Large ED (ADD) : diphoton & dilepton, $m_{yy/II}$	L=4.6 fb , 7 feV (1213,4625)	4.18 TeV M _S (HLZ (S=3 NLO) ATLAS		
UC	UED : diphoton + $E_{T,miss}$		1.41 TeV Compact, scale R ⁻¹	Preliminary		
Sit		L=4.8 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-072]	4.71 TeV MKK ~ R	310 2538 (CHAP STO 25		
GU	S^{1}/Z_{2} ED : dilepton, m_{\parallel}	L=4.9-5.0 ID 7 1eV [1209.2005]				
Extra dimensions	RS1 : diphotoň & dilepton, m					
qi	RS1: ZZ resonance, m	L=1.0 fb", 7 TeV [1203.0718]	845 GeV Graviton mass $(k/M_{\rm Pl} = 0.1)$	$1 dt = (1.0 - 13.0) \text{ fb}^{-1}$		
20	RS1: WW resonance, m _{T,NW}	L=4.7 fb ⁻ , 7 TeV [1208.2880]	1.23 TeV Graviton mass (k/M _{PI} = 0.1)	$\int Ldt = (1.0 - 13.0) \text{fb}^{-1}$		
xt	RS $g_{KK} \rightarrow tt$ (BR=0.925) : $tt \rightarrow l+jets, m_{t,NN}$	L=4.7 fb ⁻ , 7 TeV [ATLAS-CONF-2012-136]	1.9 TeV g _{KK} mass	s = 7, 8 TeV		
Ш	ADD BH $(M_{TH}/M_0=3)$; 55 dimuon, $N_{ch, nart}$	L=1.3 fb ⁻ , 7 TeV [1111.0080]	1.25 TeV M _D (δ=6)	19 11 0 101		
	ADD BH $(M_{TH}/M_{D}=3)$: leptons + jets, Σp_{T}	L=1.0 fb ^{-*} , 7 TeV.[1204.4646]	1.5 TeV M _D (δ=6)			
	Quantum black hole : dijet, $F_{\chi}(m_{j})$	L=4.7 fb ^{-*} , 7 TeV [1210.1718]	4.11 TeV M _D (δ=6)			
- 2011 - 10 - 11 - 11 - 11 - 11 - 11 - 1	qqqq contact interaction : χ(m)	L=4.8 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-038]	7.8 TeV	Δ		
G	qqll Cl : ee & μμ, m	L=4.9-5.0 fb ⁻⁷ . 7 TeV [1211.1150]	4:	3.9 TeV A (constructive int.)		
	uutt CI : SS dilepton + jets + E _{7,miss}	L=1.0 fb ⁻¹ , 7 TeV [1202.5520]	1.7 TeV Λ			
	Z' (SSM) : m _{ee/µµ}	L=5.9-6.1 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-129]	2.49 TeV Z' mass			
	Z' (SSM) : m _{st}	L=4.7 fb ⁻¹ , 7 TeV [1210.6604]	1.4 TeV Z' mass			
	W' (SSM) : m _{T.e/u}	L=4.7 fb ⁻¹ , 7 TeV [1209.4446]	2.55 TeV W' mass			
2	W' $(\rightarrow tq, q = 1)$: m_{in}	L=4.7 fb ⁻¹ , 7 TeV [1209.6593]	430 GeV W' mass			
	W'_{R} (\rightarrow tb, SSM) : m_{R}	L=1.0 fb ⁻¹ , 7 TeV [1205.1016]	1.13 TeV W' mass			
	W*: m _{T.e/µ}	L=4.7 fb ⁻¹ , 7 TeV [1209.4446]	2,42 TeV W* mass			
	Scalar LQ pair (β =1) : kin. vars. in eejj, evjj	L=1.0 fb ⁻¹ , 7 TeV [1112.4828]	660 GeV 1 ²¹ gen. LQ mass			
C O	Scalar LQ pair (β=1) : kin. vars. in μμjj, μvjj	£=1.0 fb ⁻¹ , 7 TeV [1203.3172]	685 Gev 2 nd gen. LQ mass			
1	Scalar LQ pair (β=1) : kin. vars. in ττjj, τvjj	£=4.7 fb ⁻¹ , 7 TeV [Preliminary]	538 GeV 3 rd gen. LQ mass			
\$	4 th generation : t't'→ WbWb	L=4.7 fb ⁻¹ , 7 TeV [1210.5070]	656 GeV t' mass			
ž	4 th generation : b'b'(T _{5/3} T _{5/3})→ WtWt	L=4.7 (b", 7 TeV [ATLAS-CONF-2012-130]	670 GeV b' (T _{5/3}) mass			
en	New quark b' : b'b' \rightarrow Zb+X, m		00 GeV b' mass			
ferm. New quarks	Top partner : $TT \rightarrow tt + A_0A_0$ (dilepton, M_{T2}^{2b})	L=4.7 fb ⁻¹ , 7 TeV [1209.4186]	483 GeV T mass (m(A) < 100 GeV)			
No.	Vector-like quark : CC, miya	L=4.6 fb", 7 TeV IATLAS-CONF-2012-1371	1.12 TeV VLQ mass (charge -1/3, coup	pling $\kappa_{-2} = \gamma/m_{e}$		
Ne	Vector-like quark : NC, mig	L=4.6 fb ⁻¹ , 7 TeV IATLAS-CONF-2012-1371	1.08 TeV VLQ mass (charge 2/3, coupl			
	Excited quarks : y-jet resonance, m	L=2.1 fb ⁻¹ 7 TeV 11112.35801	2.46 TeV q* mass	9 40 TTTO/		
in m	Excited quarks : dijet resonance, m	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-148]	3.84 TeV q* mass			
fe	Excited lepton : I-y resonance, m	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-146]	2.2 TeV I* mass (A = m(I*))			
There there is a second second	Techni-hadrons (LSTC) : dilepton, m.,	L=4.9-5.0 fb ⁻¹ , 7 TeV [1209.2535]	850 GeV $ρ_{\tau}/ω_{\tau}$ mass $(m(ρ_{\tau}/ω_{\tau}) - m(\pi_{\tau}) = M$	×		
Techn	i-hadrons (LSTC) : WZ resonance (vIII), $m_{T,WZ}$	Land da 7 Tay 14204 46401	483 GeV ρ_{T} mass $(m(\rho_{T}) = m(\pi_{T}) + m_{W}, m(a_{T}) = 1.1$			
	Major. neutr. (LRSM, no mixing) : 2-lep + jets	L=2.1 (b 7 TeV [1203.5420]	1.5 TeV N mass $(m(W_p) = 2 \text{ TeV})$			
Other	W_{R} (LRSM, no mixing) : 2-lep + jets	L-2.110	2.4 TeV W _R mass (m(N) <			
HC DH	H_{L}^{\pm} (DY prod., BR($H_{L}^{\pm} \rightarrow II$)=1): SS ee (µµ), m	L=2.110 , 7 16V (1203.0420)	H ^{±±} mass (limit at 398 GeV for μμ)	14 164)		
C	H_{i}^{\pm} (DY prod., BR($H_{i}^{\pm} \rightarrow e\mu$)=1): SS ee ($\mu\mu$), m_{i}^{\pm} H_{i}^{\pm} (DY prod., BR($H_{i}^{\pm} \rightarrow e\mu$)=1): SS e μ , m_{i}^{\pm}		5 GeV Η ^{±±} mass			
	Color octet scalar : dijet resonance, $m_{e_{\mu}}$	And the state of t				
	Color octet scalar , dijet resonance, m	L=4.8 fb", 7 TeV [1210.1718]	1.86 TeV Scalar resonance ma	ss i i i i i i i i i i i i i i i i i i		
OFO/			· · · · · · · · · · · · · · · · · · ·			
95%	CL limits	10 ⁻¹	1	10 10 ²		
ATLAS physics road map Mass scale ¶TeV]						

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





On a personal note:

The search for SUSY has been a motivation for me for 30 years, and in spite of exclusion limits only so far I have not given up yet!

I am therefore particularly happy and grateful to be honoured with the Julius Wess Award



The journey with LHC into new physics territory has only just begun, and for sure, further exciting times are ahead of us!

Thank you for your attention

MAR

Further reading:

The Higgs Boson

ARTICLE

Journey in the Search for the Higgs Boson: The ATLAS and CMS Experiments at the Large Hadron Collider

M. Della Negra,¹ P. Jenni,² T. S. Virdee¹*

The search for the standard model Higgs boson at the Large Hadron Collider (LHC) started more than two decades ago. Much innovation was required and diverse challenges had to be overcome during the conception and construction of the LHC and its experiments. The ATLAS and CMS Collaboration experiments at the LHC have discovered a heavy boson that could complete the standard model of particle physics.





Journey in the Search for the Higgs Boson: The ATLAS and CMS Experiments at the Large Hadron Collider

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http://www.sciencemag.org/content/338/6114/1560.full.html