

BLOCKKURS: SOFTWARE IN DER TEILCHENPHYSIK

Alexander Mann, Sascha Mehlhase

based on work from Johannes Elmsheuser and Gnter Duceck
Ludwig-Maximilians-Universität München

13 April 2015



① ORGANISATORISCHES

② LHC, ATLAS UND ANALYSE

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ORGANISATORISCHES

- Dozenten:
Alexander Mann, a.mann@physik.uni-muenchen.de
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Unterstützung: C. Bock, J. Heinrich, J. Lorenz, O. Schaile
Lehrstuhl Schaile, Experimentelle Teilchenphysik
- Übungen und Kursvorlesungen:
Mo-Fr 10:00-12:30 Uhr, 14-17:00 Uhr,
2.Stock, Zi. 219 Am Coulombwall 1, Garching
- Vorlesungswebseite:
www.etp.physik.uni-muenchen.de/kurs/comp15
- Klausur/Schein:
Am Ende des Semesters
Inhalt: Software-Kurs und Teilchenphysik Vorlesung

- Ein/Ausgabe von Daten
- Graphische Darstellung
- ATLAS ATLANTIS Event Display
- ROOT tuples und eine kleine Analyse
- Analyse von OPAL Z0 daten
- Fitten von Daten
- HistPresent

Für die Übungen wird das ROOT Programmpaket verwendet, das eine umfangreiche Klassen- und Funktionenbibliothek in C++ bereitstellt.

- Übungen zu Themen der Vorlesung an Hand vom konkreten Beispielen
- Programmierung von kleinen Beispielen in C/C++ (für Experten auch in Python)
- Verwendung von ROOT:
 - Object-Oriented Data Analysis Framework
 - Standard-Werkzeug in Teilchenphysik und darüber hinaus
 - <http://root.cern.ch/>
- Anleitungen zu C/C++:
 - u.a. Kurs: C++ für Physiker
<http://www.etp.physik.uni-muenchen.de/kurs/Computing/ckurs>

LITERATUR

- ATLAS Experiment: <http://www.iop.org/EJ/abstract/1748-0221/3/08/S08003/> bzw. http://www.iop.org/EJ/article/1748-0221/3/08/S08003/jinst8_08_s08003.pdf
- ATLAS Physik: <http://arxiv.org/abs/0901.0512> bzw. <http://arxiv.org/pdf/0901.0512v2>
- B.Blobel/E.Lohrmann, Statistische und numerische Methoden der Datenanalyse, Teubner, 1998
- W.-M. Yao et al., The Review of Particle Physics, Journal of Physics, G 33, 1 (2006), Anfangskapitel <http://pdg.lbl.gov/>

WEITERE VERANSTALTUNGEN

- Teilchenphysik an Hadron Collidern für Bachelor/Master Studenten
Vorlesung: Physik am Tevatron und LHC
Termin: Mo 10:00-12:30, Zi. 219
Otmar Biebel, Johannes Elmsheuser
- Seminar: Moderne Aspekte der Teilchenphysik
Termin: wahrscheinlich Fr 10-12
Sascha Mehlhase

BACHELORARBEIT

- Verbindlich: Abgabe der Bachelorarbeit in gebundener Form nach 10 Wochen
- \approx 10 Wochen: 20. April-3. Juli; Abgabe bis 3. Juli bei Frau Epp - 2 Exemplare in gebundener Form.
- Stil der Arbeit: max. 20-30 Seiten

- Arbeitsplatz im 3. Stock, Am Coulombwall 1, Garching
- Haus ist ab 8 Uhr offen, wer nach 16-16:30 (Fr. 13:00) noch mal rein möchte, braucht die Telefonnummer von jemand, der ihn reinlässt.
- Gruppenschlüssel vorhanden

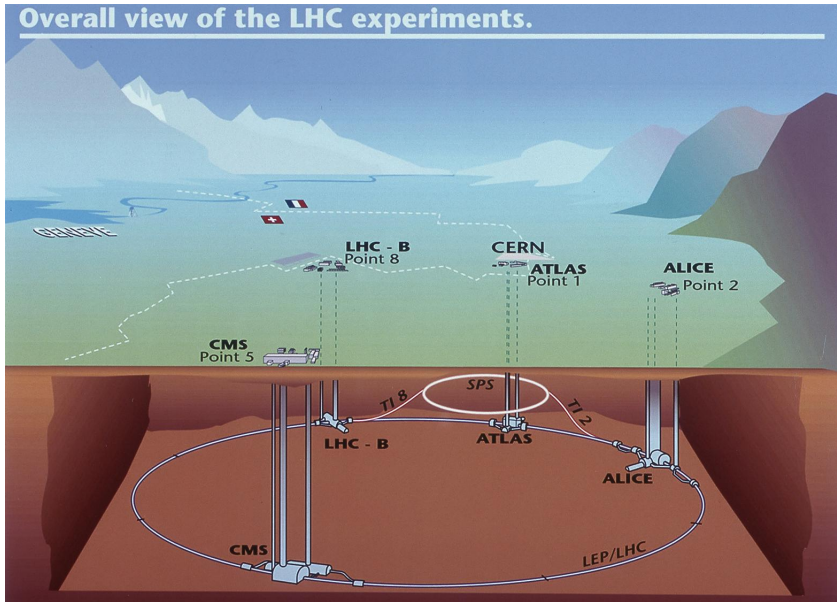
① ORGANISATORISCHES

② LHC, ATLAS UND ANALYSE

DER LHC UND DIE EXPERIMENTE I



DER LHC UND DIE EXPERIMENTE II



DAS ATLAS EXPERIMENT

Muon Spectrometer ($|\eta| < 2.7$): air-core toroids with gas-based muon chambers
 Muon trigger and measurement with momentum resolution $< 10\%$ up to $E_\mu \sim 1$ TeV

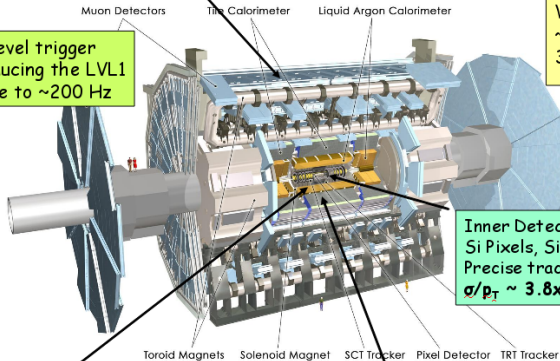
Length : ~ 46 m
 Radius : ~ 12 m
 Weight : ~ 7000 tons
 $\sim 10^8$ electronic channels
 3000 km of cables

3-level trigger
 reducing the LVL1
 rate to ~ 200 Hz

Inner Detector ($|\eta| < 2.5$, $B=2T$):
 Si Pixels, Si strips, TRT
 Precise tracking and vertexing,
 $\sigma/p_T \sim 3.8 \times 10^{-4}$ p_T (GeV) $\oplus 0.015$

EM calorimeter: Pb-LAr Accordion
 e/ γ trigger, identification and measurement
 E-resolution: $\sigma/E \sim 10\%/ \sqrt{E} \oplus 0.007$
 granularity : $.025 \times .025 \oplus$ strips

HAD calorimetry ($|\eta| < 3$): segmentation 0.1×0.1
 Fe/scintillator Tiles (central), Cu/W-LAr (fwd)
 E-resolution: $\sigma/E \sim 50\%/ \sqrt{E} \oplus 0.03$
 FWD calorimetry: W/LAr $\sigma/E \sim 90\%/ \sqrt{E} \oplus 0.07$

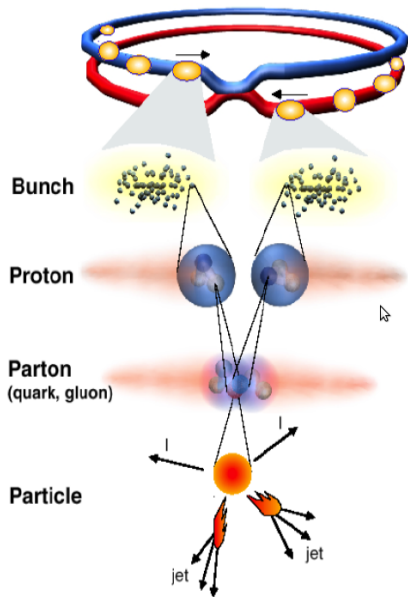


DAS ATLAS EXPERIMENT

~3000 scientists from 174 Institutions and 38 Countries



KOLLISIONEN IM LHC



Proton-Proton-Kollisionen
2835 Teilchenbündel (Bunch)

10^{11} Protonen / Bunch
Kollisionsrate 40 MHz (25 ns)

Schwerpunktsenergie 14 TeV
(= 7400 x Ruheenergie der kollidierenden Teilchen)

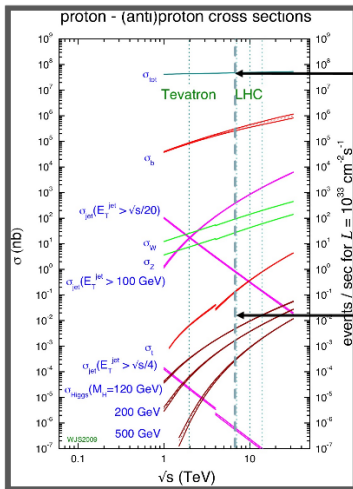
Schwerpunktsenergie der kollidierenden Quarks und Gluonen bis einige TeV

~25 pp-Kollisionen pro Bunch-Kollision

Interessante Ereignisse: 10^{-9} – 10^{-11} unterdrückt!

WIRKUNGSQUERSCHNITTE I

Number of events in 45pb^{-1}



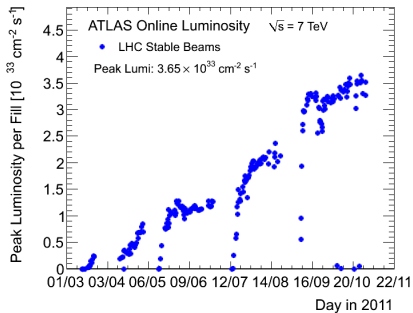
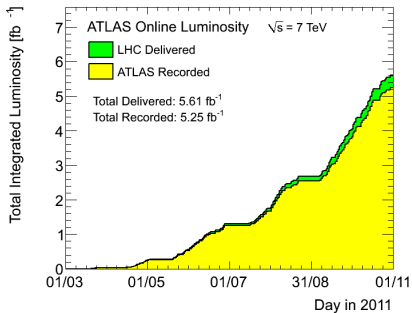
70 billion (10^9) $\text{pb} \rightarrow$ 3 trillion (10^{12}) events! *

* N.B. only a very small fraction saved!

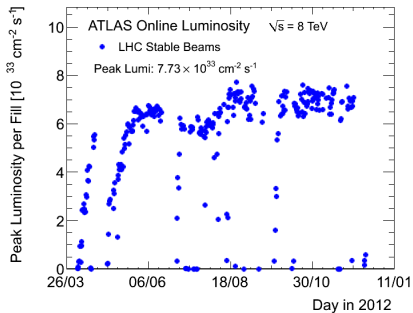
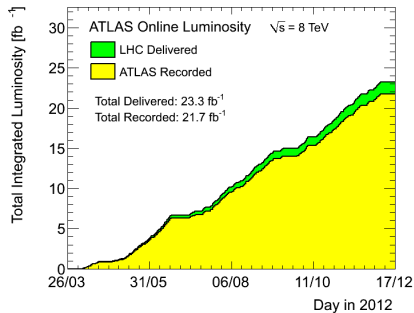
Higgs ($m_H=120$): 17 $\text{pb} \rightarrow$ 750 events

e.g. potentially ~ 1 Higgs in every 300 billion interactions!

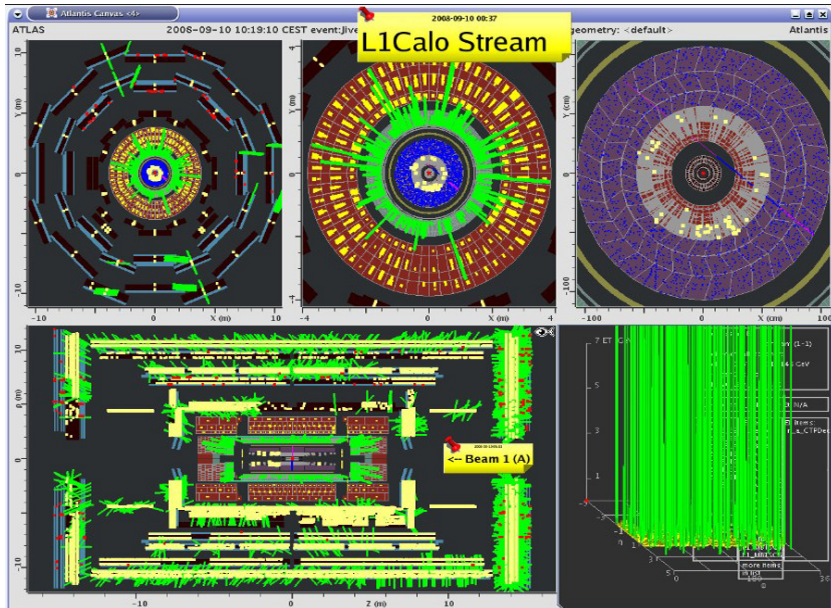
ATLAS STATUS 2011



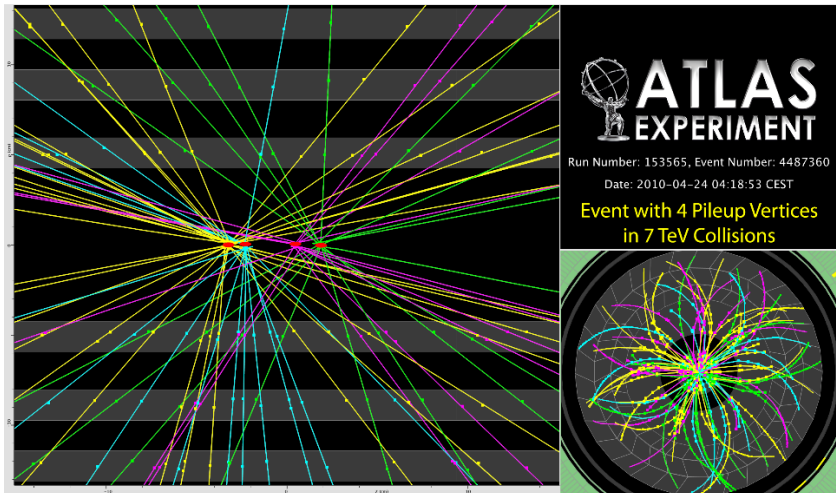
ATLAS STATUS 2012



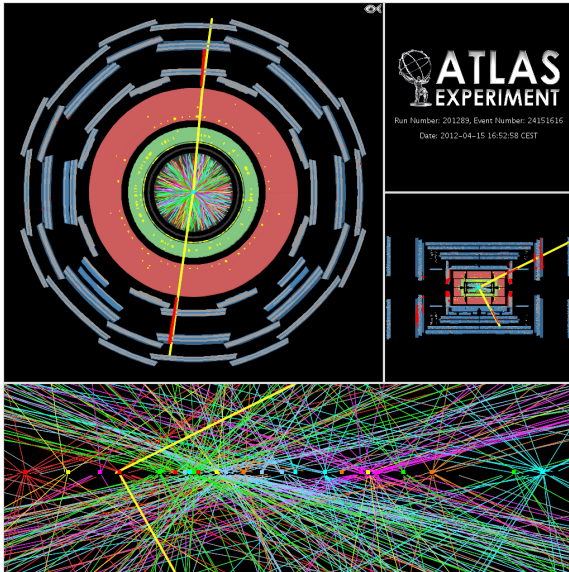
EIN ERSTES LIVE-EREIGNIS 2009



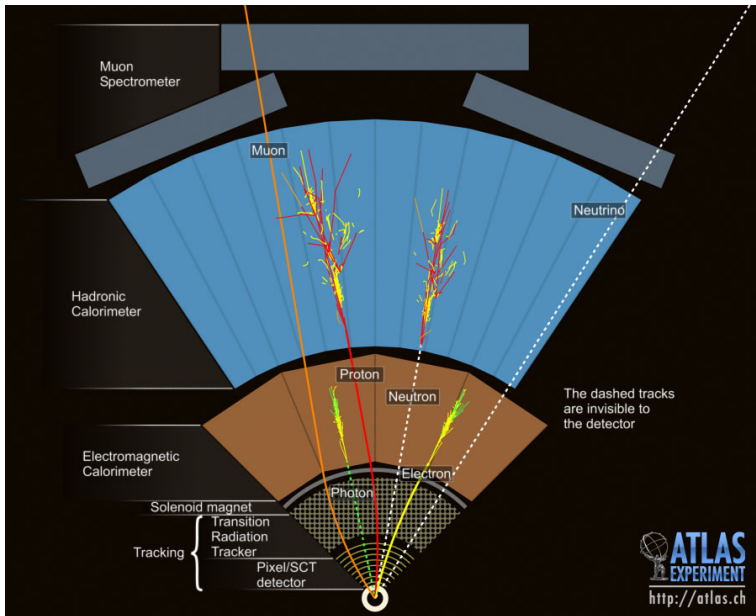
Event with 4 pileup vertices in same pp-collision



REKONSTRUKTION: $Z \rightarrow \mu^+ \mu^-$ UND PILE-UP


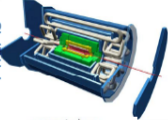
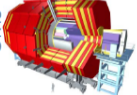
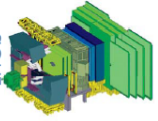


TEILCHENNACHWEIS

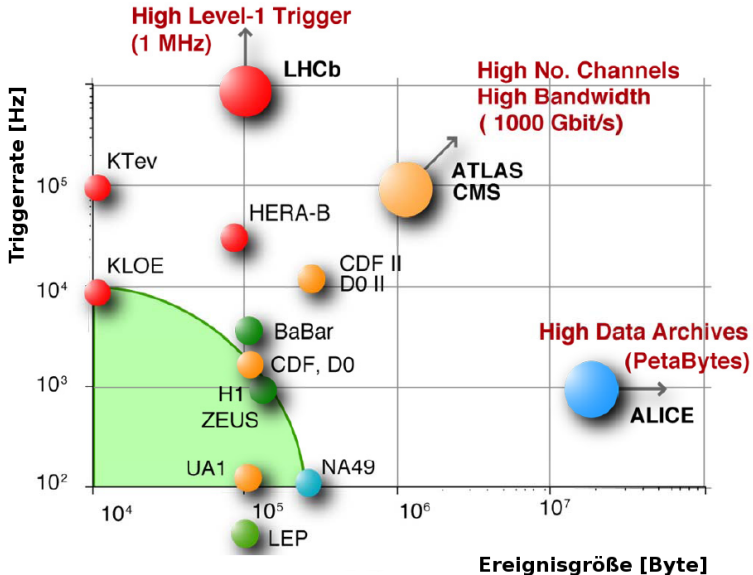




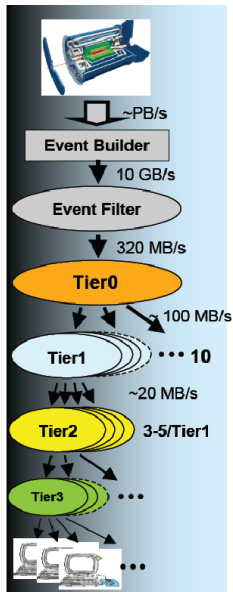
Trigger/DAQ parameters

	No.Levels Trigger	Level-0,1,2 Rate (Hz)	Event Size (Byte)	Readout Bandw.(GB/s)	HLT Out MB/s (Event/s)
ALICE 	4	Pb-Pb 500 p-p 10^3	5×10^7 2×10^6	25	1250 (10^2) 200 (10^2)
ATLAS 	3	LV-1 10^5 LV-2 3×10^3	1.5×10^6	4.5	300 (2×10^2)
CMS 	2	LV-1 10^5	10^6	100	~ 1000 (10^2)
LHCb 	2	LV-0 10^6	3.5×10^4	35	70 (2×10^3)

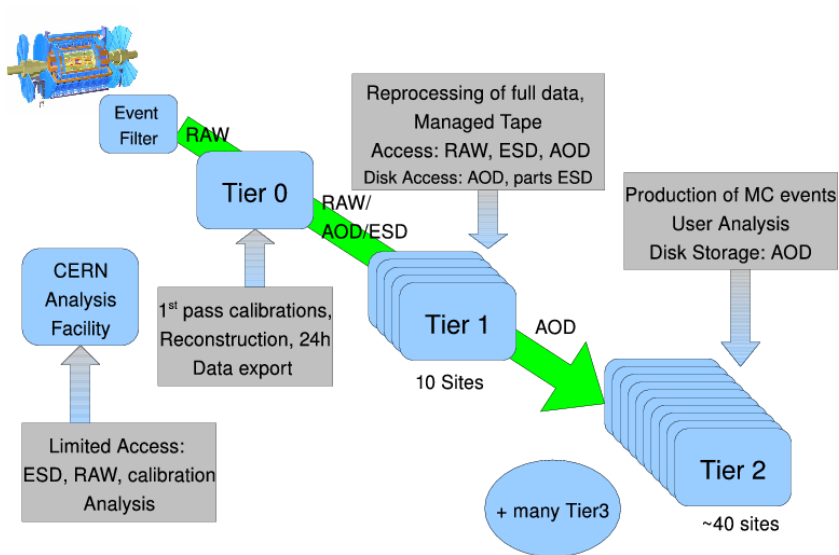
TRIGGER UND EREIGNIS-GRÖSSE



RECHENZENTREN- UND GRIDKA-ORGANISATION



DATEN VERTEILUNG: ATLAS



Analysis ingredients in a nutshell

Cross section measurement:

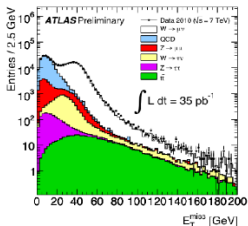
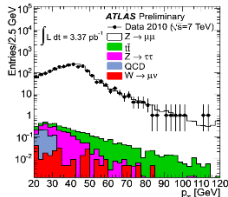
$$\sigma = \frac{N_{\text{Observed}} - N_{\text{BG}}}{\epsilon_{\text{Total}} * L}$$

N_{Observed} : number of observed events

N_{BG} : Number of background events

ϵ_{total} : Overall detection efficiency

L : Luminosity provided by collider



Select interesting events based signal event characteristics:

- e.g. leptons, jets, E_T^{Miss} , angular correlations etc.

Example: $Z \rightarrow \mu\mu$:

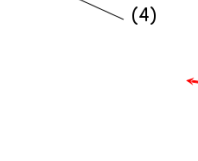
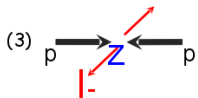
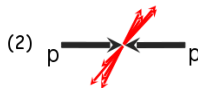
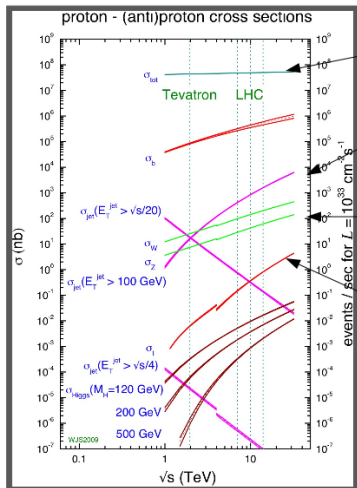
- .2 isolated μ -tracks, back-to-back, low E_T^{Miss} , high transverse momentum, low jet activity

Determine N_{BG} or Signal prediction from Monte Carlo or data driven methods

ϵ_{total} : Combination of Efficiencies:

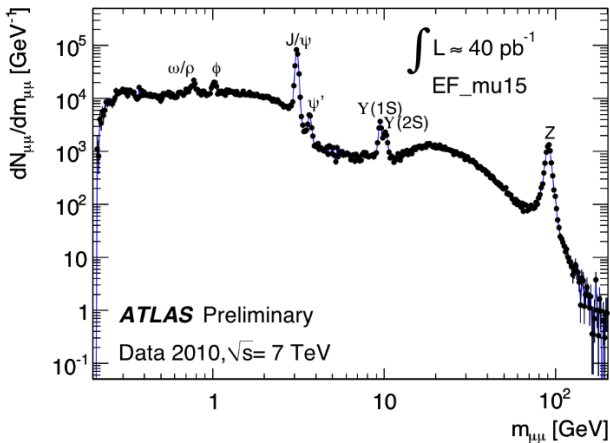
- Trigger, Reconstruction, Acceptance, Cuts etc.

Different Analysis



Di-muon invariant mass

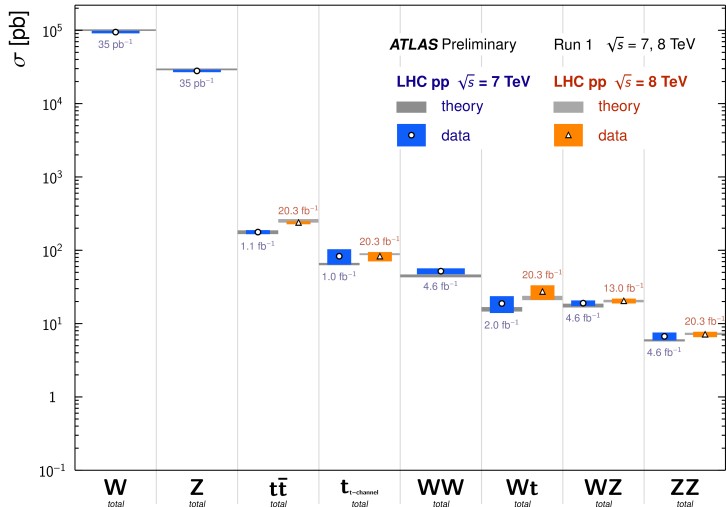
Leading muon, $p_T > 15$ GeV, second muon, $p_T > 2.5$ GeV



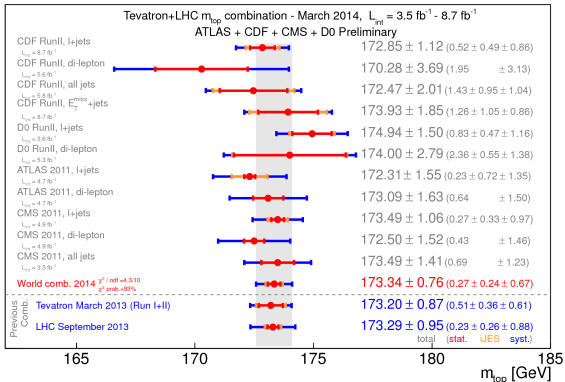
ATLAS RESULTS I

Standard Model Total Production Cross Section Measurements

Status: March 2014



ATLAS RESULTS II



ATLAS RESULTS III

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Moriond 2014

ATLAS Preliminary

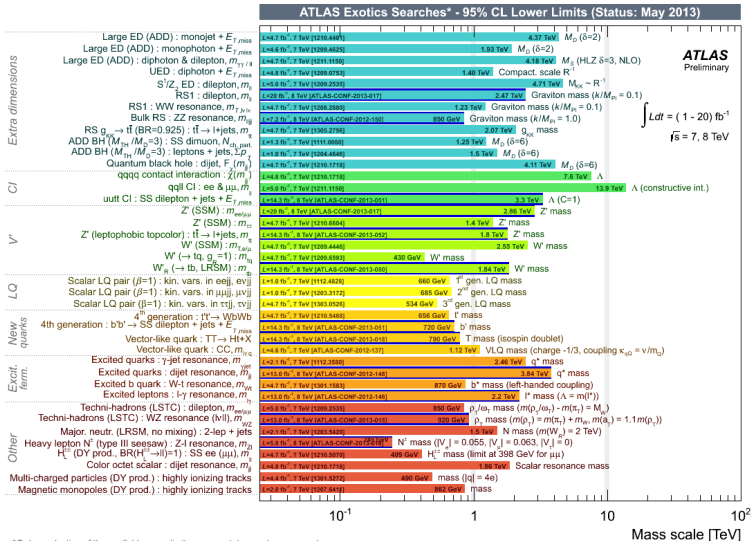
$$\int \mathcal{L} dt = (4.6 - 22.9) \text{ fb}^{-1} \quad \sqrt{s} = 7, 8 \text{ TeV}$$

Model	$\epsilon, \mu, \tau, \gamma$	Jets	E_{miss}^T	$\int \mathcal{L} dt (\text{fb}^{-1})$	Mass limit	Reference			
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{g}, \tilde{u}, \tilde{t}$	m(\tilde{g}), m(\tilde{t})	ATLAS CONF-2013-047	
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	\tilde{g}	1.2 TeV	any m(\tilde{g})	ATLAS CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	\tilde{g}	1.1 TeV	any m(\tilde{g})	1306.1841
	GMSB (f NLSP)	0	2-6 jets	Yes	20.3	\tilde{g}	740 GeV	m(\tilde{g})=0 GeV	ATLAS CONF-2013-047
	$\tilde{g}\tilde{g} \rightarrow \text{qqg} + \tilde{g}$	0	2-6 jets	Yes	20.3	\tilde{g}	1.3 TeV	m(\tilde{g})=0 GeV	ATLAS CONF-2013-047
	$\tilde{g}\tilde{g} \rightarrow \text{qqg}(f) \rightarrow \text{qq}W^{+}Z^0$	1 e, μ	3-6 jets	Yes	20.3	\tilde{g}	1.18 TeV	m(\tilde{g})=200 GeV, m(\tilde{t})=0.5m(\tilde{g}), m(\tilde{g})	ATLAS CONF-2013-062
	$\tilde{g}\tilde{g} \rightarrow \text{qqg}(f)(f') \rightarrow \text{qq}W^{+}Z^0$	2 e, μ	0-3 jets	Yes	20.3	\tilde{g}	1.12 TeV	m(\tilde{g})=0 GeV	ATLAS CONF-2013-089
	GMSB (f NLSP)	2 e, μ	2-4 jets	Yes	4.7	\tilde{g}	1.24 TeV	m(\tilde{g})=200 GeV	1208.4688
	GMSB (f' NLSP)	1, 2 e, μ	0-2 jets	Yes	20.7	\tilde{g}	1.4 TeV	tan β =18	ATLAS CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	20.3	\tilde{g}	1.28 TeV	m(\tilde{g})=50 GeV	ATLAS CONF-2014-001
3 rd gen. s _{quarks} direct production	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}$	0	2 b	Yes	20.1	\tilde{b}_1	100-620 GeV	m(\tilde{g})=0 GeV	ATLAS CONF-2013-061
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}\tilde{Z}^0$	0	7-10 jets	Yes	20.3	\tilde{b}_1	1.2 TeV	m(\tilde{g})=600 GeV	ATLAS CONF-2013-047
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}\tilde{H}_1^0$	0-1 e, μ	3 b	Yes	20.1	\tilde{b}_1	1.3 TeV	m(\tilde{g})=400 GeV	1306.1841
	$\tilde{b}_1\tilde{b}_1 \rightarrow b\bar{b}\tilde{H}_1^+$	0-1 e, μ	3 b	Yes	20.1	\tilde{b}_1	1.3 TeV	m(\tilde{g})=300 GeV	ATLAS CONF-2013-061
	$\tilde{b}_1\tilde{b}_1, \tilde{t}_1\tilde{t}_1 \rightarrow b\bar{b}\tilde{Z}^0$	0	2 b	Yes	20.1	\tilde{b}_1, \tilde{t}_1	100-620 GeV	m(\tilde{g})=0 GeV	1306.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{t}_1\tilde{t}_1 \rightarrow b\bar{b}\tilde{H}_1^0$	2 e, μ (SS)	0-3 b	Yes	20.7	\tilde{b}_1, \tilde{t}_1	275-430 GeV	m(\tilde{g})=2 m(\tilde{t})	ATLAS CONF-2013-007
	$\tilde{b}_1\tilde{b}_1(\text{light}), \tilde{t}_1\tilde{t}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1$	1, 2 e, μ	1-2 b	Yes	4.7	\tilde{b}_1, \tilde{t}_1	110-167 GeV	m(\tilde{g})=50 GeV	1208.4055, 1209.2102
	$\tilde{b}_1\tilde{b}_1(\text{medium}), \tilde{t}_1\tilde{t}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1$	2 e, μ	0-2 jets	Yes	20.3	\tilde{b}_1, \tilde{t}_1	130-210 GeV	m(\tilde{g})=m(\tilde{t}), m(\tilde{b})=50 GeV, m(\tilde{g}), m(\tilde{b}) < m(\tilde{t})	1403.4853
	$\tilde{b}_1\tilde{b}_1(\text{medium}), \tilde{t}_1\tilde{t}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1$	2 e, μ	2 jets	Yes	20.3	\tilde{b}_1, \tilde{t}_1	215-530 GeV	m(\tilde{g})=1 GeV	1403.4853
	$\tilde{b}_1\tilde{b}_1(\text{medium}), \tilde{t}_1\tilde{t}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1$	0	2 b	Yes	20.1	\tilde{b}_1, \tilde{t}_1	150-580 GeV	m(\tilde{g})=200 GeV, m(\tilde{t})=m(\tilde{g})+6 GeV	1306.2631
EW direct	$\tilde{b}_1\tilde{b}_1(\text{heavy}), \tilde{t}_1\tilde{t}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1$	1 e, μ	1 b	Yes	20.7	\tilde{b}_1, \tilde{t}_1	300-610 GeV	m(\tilde{g})=0 GeV	ATLAS CONF-2013-037
	$\tilde{b}_1\tilde{b}_1(\text{heavy}), \tilde{t}_1\tilde{t}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1$	0	2 b	Yes	20.5	\tilde{b}_1, \tilde{t}_1	300-460 GeV	m(\tilde{g})=0 GeV	ATLAS CONF-2013-024
	$\tilde{b}_1\tilde{b}_1, \tilde{t}_1\tilde{t}_1 \rightarrow b\bar{b}$	0	mono-jet+tag	Yes	20.3	\tilde{b}_1, \tilde{t}_1	90-200 GeV	m(\tilde{g})=0 GeV	ATLAS CONF-2013-068
	$\tilde{b}_1\tilde{b}_1(\text{natural GMSB})$	2 e, μ (Z)	1 b	Yes	20.3	\tilde{b}_1, \tilde{t}_1	150-580 GeV	m(\tilde{g})=150 GeV	1403.5222
	$\tilde{b}_1\tilde{b}_1, \tilde{t}_1\tilde{t}_1 \rightarrow Z$	3 e, μ (Z)	1 b	Yes	20.3	\tilde{b}_1, \tilde{t}_1	290-600 GeV	m(\tilde{g})=200 GeV	1403.5222
	$\tilde{t}_1\tilde{t}_1, \tilde{b}_1\tilde{b}_1, \tilde{t}_1\tilde{t}_1 \rightarrow \text{qq}$	2 e, μ	0	Yes	20.3	\tilde{t}_1, \tilde{b}_1	90-325 GeV	m(\tilde{g})=0 GeV	1403.5294
	$\tilde{t}_1\tilde{t}_1, \tilde{b}_1\tilde{b}_1 \rightarrow \text{qq}(f)\text{qq}(f')$	2 e, μ	0	Yes	20.3	\tilde{t}_1, \tilde{b}_1	140-265 GeV	m(\tilde{g})=0 GeV, m(\tilde{b})=0.5m(\tilde{g}), m(\tilde{g}) < m(\tilde{t})	1403.5294
	$\tilde{t}_1\tilde{t}_1, \tilde{b}_1\tilde{b}_1 \rightarrow \text{qq}(f)\text{qq}(f')$	2 e, μ	-	Yes	20.7	\tilde{t}_1, \tilde{b}_1	180-330 GeV	m(\tilde{g})=0 GeV, m(\tilde{b})=0.5m(\tilde{g}), m(\tilde{g}) < m(\tilde{t})	ATLAS CONF-2013-028
	$\tilde{t}_1\tilde{t}_1, \tilde{b}_1\tilde{b}_1 \rightarrow \text{qq}(f)\text{qq}(f')$	2 e, μ	0	Yes	20.3	\tilde{t}_1, \tilde{b}_1	700 GeV	m(\tilde{g})=m(\tilde{t}), m(\tilde{b})=0, m(\tilde{g})=0.5m(\tilde{t}), m(\tilde{g}) < m(\tilde{t})	1402.7029
	$\tilde{t}_1\tilde{t}_1, \tilde{b}_1\tilde{b}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1, Z^0$	2, 3 e, μ	0	Yes	20.3	\tilde{t}_1, \tilde{b}_1	420 GeV	m(\tilde{g})=m(\tilde{t}), m(\tilde{b})=0, stopquarks decoupled	1403.5294, 1402.7029
$\tilde{t}_1\tilde{t}_1, \tilde{b}_1\tilde{b}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1, Z^0$	1 e, μ	2 b	Yes	20.3	\tilde{t}_1, \tilde{b}_1	285 GeV	m(\tilde{g})=m(\tilde{t}), m(\tilde{b})=0, stopquarks decoupled	ATLAS CONF-2013-093	
Long-lived particles	Direct $\tilde{t}_1\tilde{t}_1$ prod., long-lived \tilde{t}_1	Disapp. trk	1 jet	Yes	20.3	\tilde{t}_1	270 GeV	m(\tilde{g})=m(\tilde{t})=180 MeV, $\tau(\tilde{t}_1)=0.2$ ns	ATLAS CONF-2013-069
	Stable, stopped \tilde{t}_1 -R-hadron	0	1-5 jets	Yes	22.9	\tilde{t}_1	832 GeV	m(\tilde{g})=0 GeV, 10 μs < $\tau(\tilde{t}_1)$ < 1000 s	ATLAS CONF-2013-057
	GMSB, stable $\tilde{t}_1 \rightarrow \text{qq}(f)\text{qq}(f')$	2 e, μ	-	Yes	15.9	\tilde{t}_1	475 GeV	10 μs < $\tau(\tilde{t}_1)$ < 100	ATLAS CONF-2013-058
	GMSB, $\tilde{t}_1 \rightarrow \text{gg}$, long-lived \tilde{t}_1	2 γ	-	Yes	4.7	\tilde{t}_1	230 GeV	0.4 < $\tau(\tilde{t}_1)$ < 2 ns	1304.6310
	$\tilde{g}\tilde{g}, \tilde{t}_1\tilde{t}_1 \rightarrow \text{qqg}(f)\text{qqg}(f')$ (RPV)	1 $\mu, \text{d, spl. vtx.}$	-	Not	20.3	\tilde{g}	1.0 TeV	1.5 < $\tau(\tilde{g})$ < 16 mm, BR(\tilde{g})=1, m(\tilde{g})=108 GeV	ATLAS CONF-2013-092
	LFV $\tilde{p}\tilde{p} \rightarrow \tau, X, \nu_i \rightarrow \nu + \mu$	2 e, μ	-	4.6	\tilde{p}	1.61 TeV	$\tilde{X}_{1,2} \rightarrow 0.10, \tilde{X}_{3,4} \rightarrow 0.05$	1212.1272	
	LFV $\tilde{p}\tilde{p} \rightarrow \tau, X, \nu_i \rightarrow \nu(\mu) + \tau$	1 $e, \mu + \tau$	-	4.6	\tilde{p}	1.1 TeV	$\tilde{X}_{1,2} \rightarrow 0.10, \tilde{X}_{3,4} \rightarrow 0.05$	1212.1272	
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	\tilde{g}	1.3 TeV	m(\tilde{g})=m(\tilde{t}), $\tau_{\tilde{g}} > 1$ mm	ATLAS CONF-2012-140
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\tilde{t}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1, Z^0 \rightarrow \text{qq}(f)\text{qq}(f')$	4 e, μ	-	Yes	20.7	\tilde{t}_1	760 GeV	m(\tilde{g})=300 GeV, $\tau_{\tilde{t}_1} > 0$	ATLAS CONF-2013-086
	$\tilde{t}_1\tilde{t}_1, \tilde{b}_1\tilde{b}_1 \rightarrow W^{+}\tilde{b}_1\tilde{t}_1, Z^0 \rightarrow \text{qq}(f)\text{qq}(f')$	3 $e, \mu + \tau$	-	Yes	4.7	\tilde{t}_1	350 GeV	m(\tilde{g})=80 GeV, $\tau_{\tilde{t}_1} > 0$	ATLAS CONF-2013-036
$\tilde{b}_1\tilde{b}_1 \rightarrow \text{qq}$	0	6-7 jets	Not	20.3	\tilde{b}_1	916 GeV	BR($\tilde{b}_1 \rightarrow \text{BR}(\tilde{g})$)=BR(\tilde{b}_1)=0%	ATLAS CONF-2013-091	
$\tilde{b}_1\tilde{b}_1, \tilde{t}_1\tilde{t}_1 \rightarrow b\bar{b}$	2 e, μ (SS)	0-3 b	Yes	20.7	\tilde{b}_1	880 GeV	m(\tilde{g})=0 GeV, BR(\tilde{b}_1)=0.07 GeV for DR	ATLAS CONF-2013-007	
Other	Scalar gluon pair, sgluon $\rightarrow \text{gg}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2603	1210.4826
	Scalar gluon pair, sgluon $\rightarrow \text{tt}$	2 e, μ (SS)	2 b	Yes	14.3	sgluon	350-609 GeV	m(\tilde{g})=0 GeV, BR(\tilde{g})=0.07 GeV for DR	ATLAS CONF-2013-051
	WIMP interaction (DS, Dirac χ)	0	mono-jet	Yes	10.5	sgluon	783 GeV	m(\tilde{g})=30 GeV, BR(\tilde{g})=0.07 GeV for DR	ATLAS CONF-2012-147

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

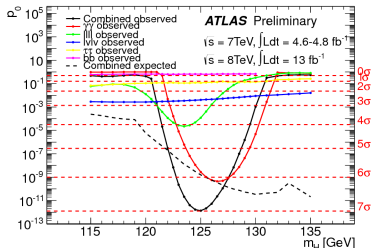
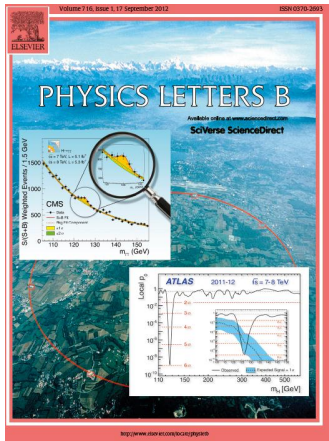
Mass scale [TeV]

ATLAS RESULTS III



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

ENTDECKUNG EINES SKALAREN BOSONS



Die lokale Wahrscheinlichkeit p_0 für ein untergrund-artiges Experiment mehr signal-artig zu sein als die tatsächliche Beobachtung als Funktion von m_H für verschiedene individuelle Kanäle

$H \rightarrow \gamma\gamma$ UND $H \rightarrow ZZ$

