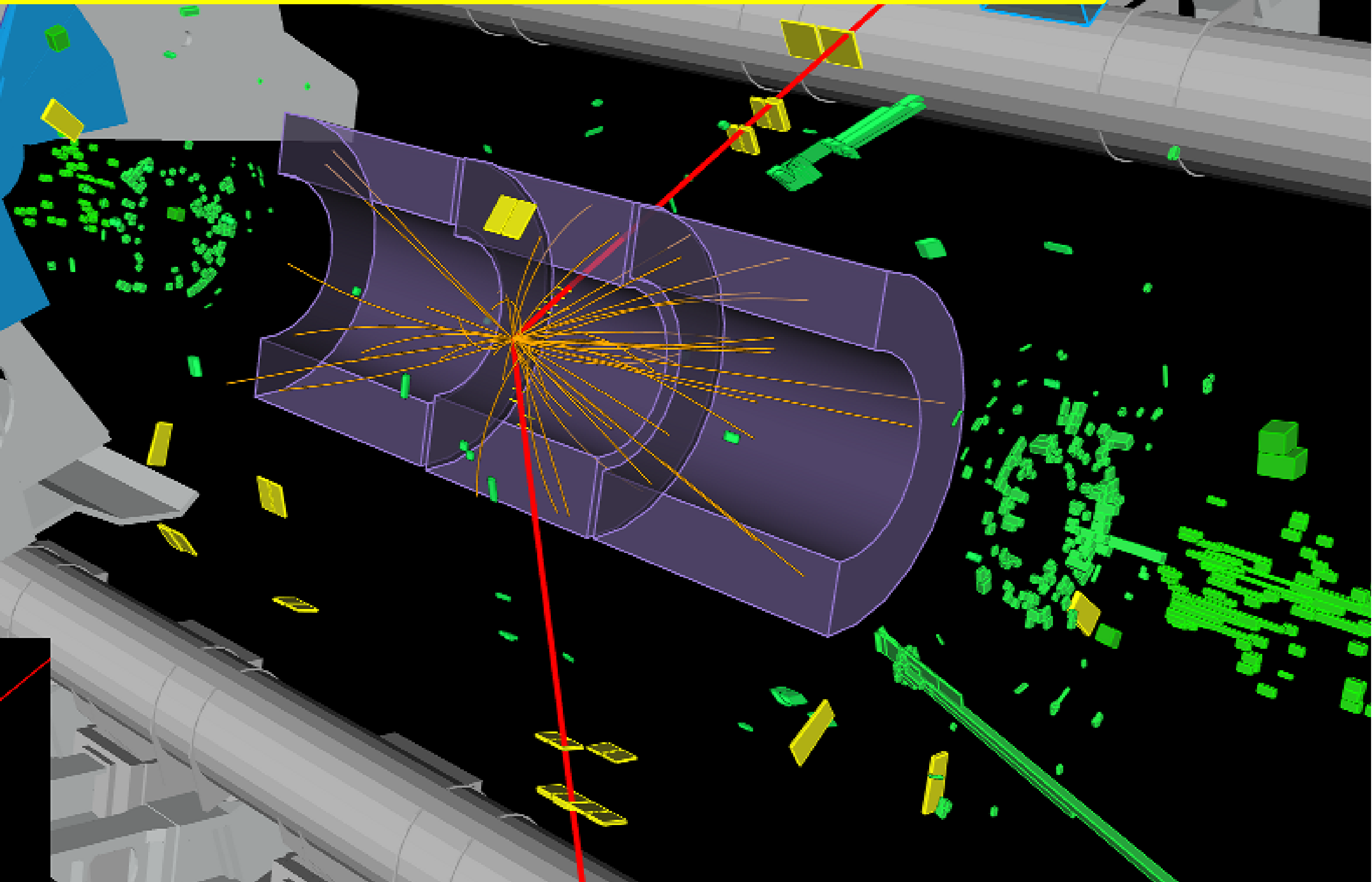
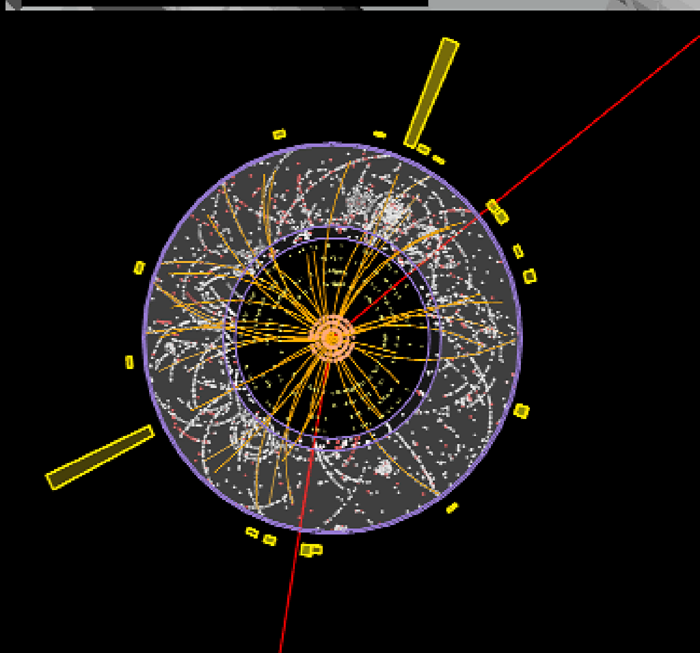
Highlights and Searches in ATLAS



ATLAS EXPERIMENT
http://atlas.ch



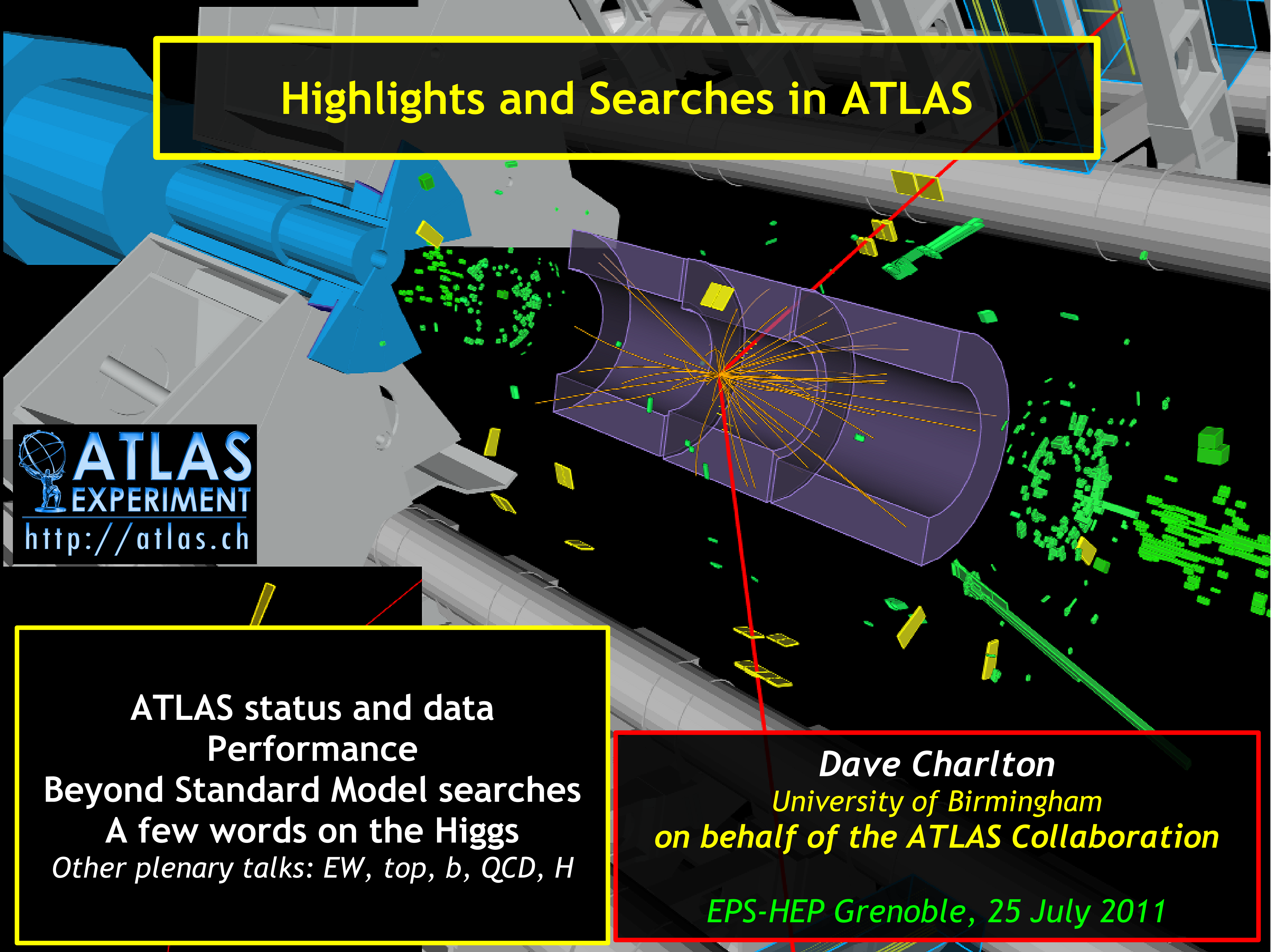
Dave Charlton

University of Birmingham

on behalf of the ATLAS Collaboration

EPS-HEP Grenoble, 25 July 2011

Highlights and Searches in ATLAS



ATLAS status and data
Performance
Beyond Standard Model searches
A few words on the Higgs
Other plenary talks: EW, top, b, QCD, H

Dave Charlton
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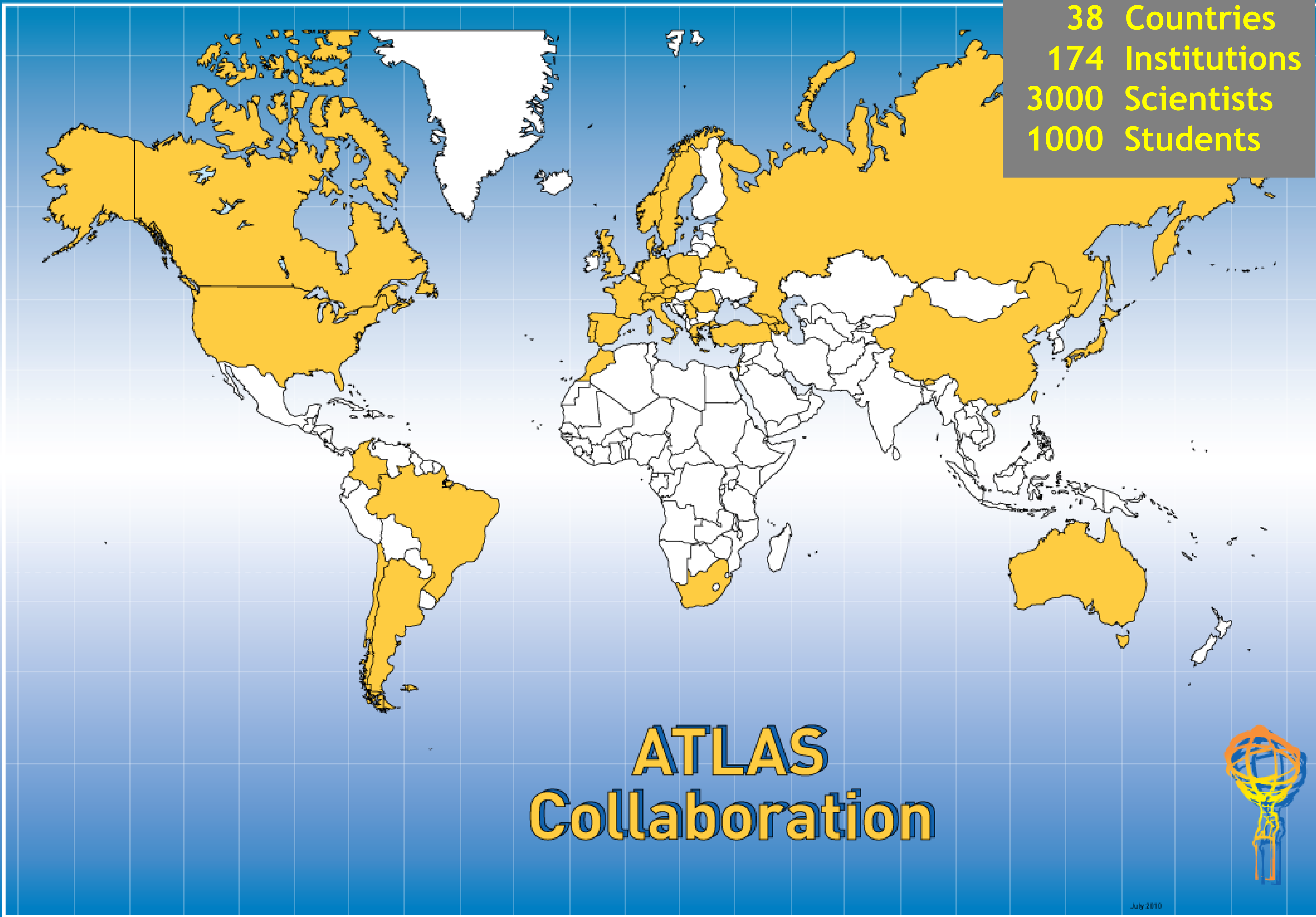
on behalf of the ATLAS Collaboration

EPS-HEP Grenoble, 25 July 2011

38 Countries
174 Institutions
3000 Scientists
1000 Students



38 Countries
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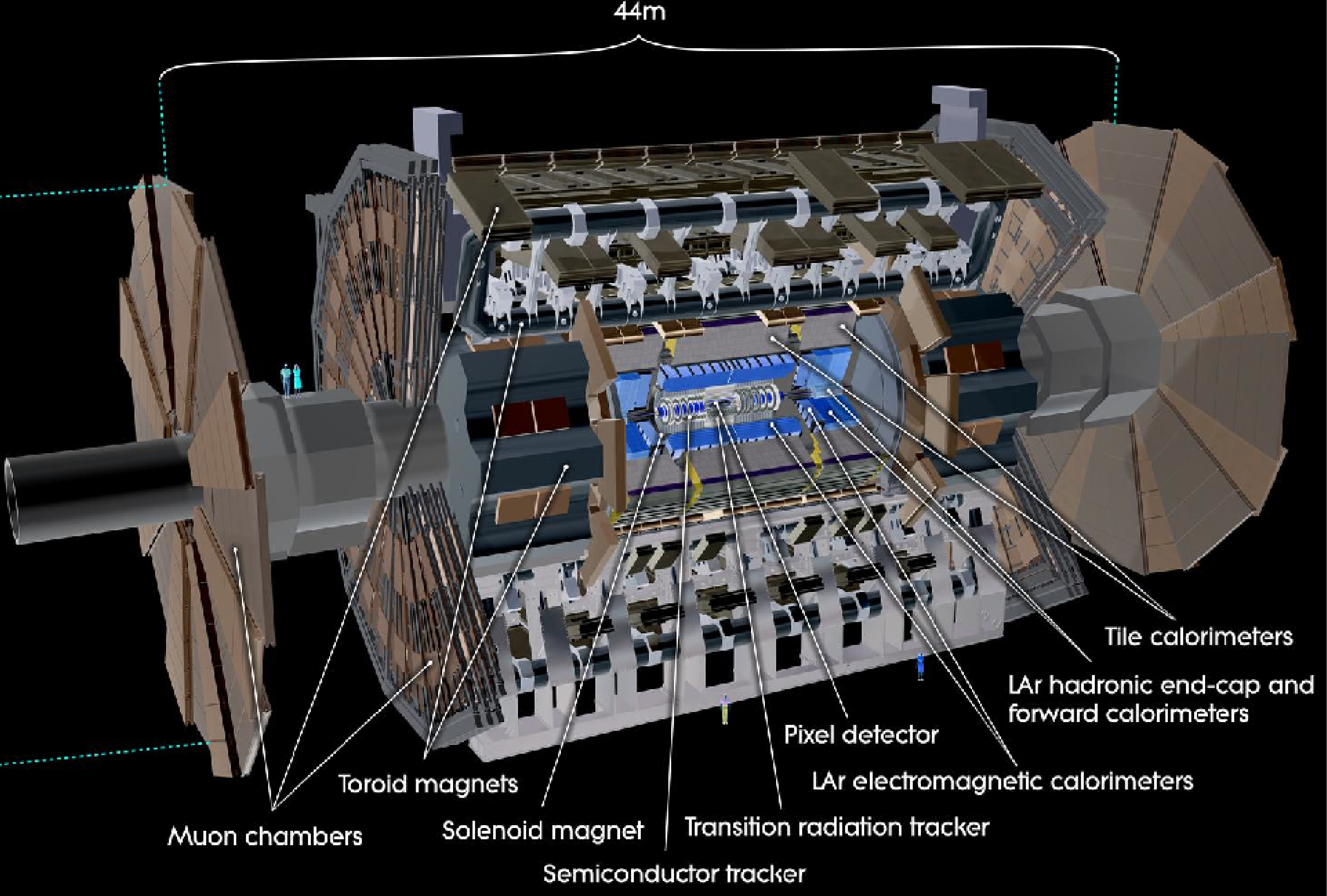
Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Brasil Cluster, Bratislava/SAS Kosice, Brookhaven NL, Buenos 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, 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, Regina, 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, Waseda, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

ATLAS Detector

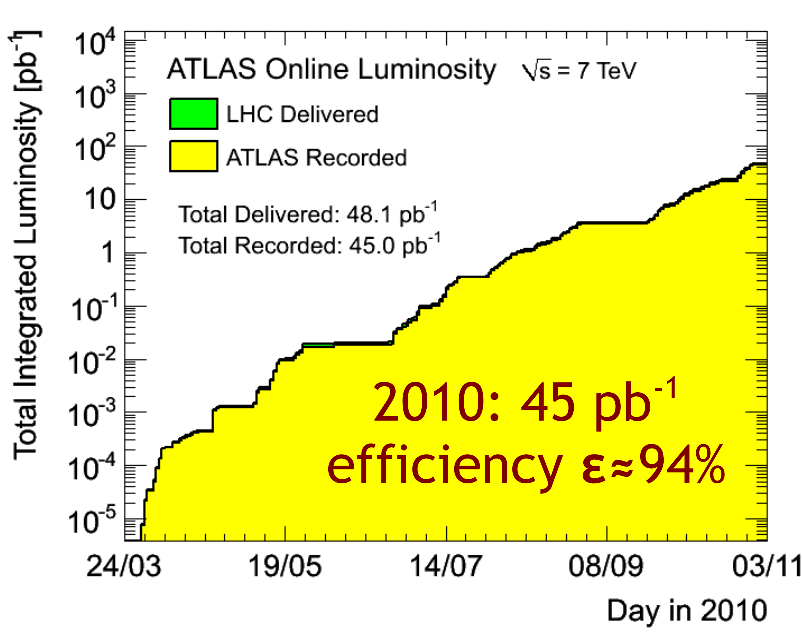
2T solenoid, toroid system ($\int Bdl$=1-7.5 Tm)
Tracking to |η|=2.5, calorimetry to |η|=4.9

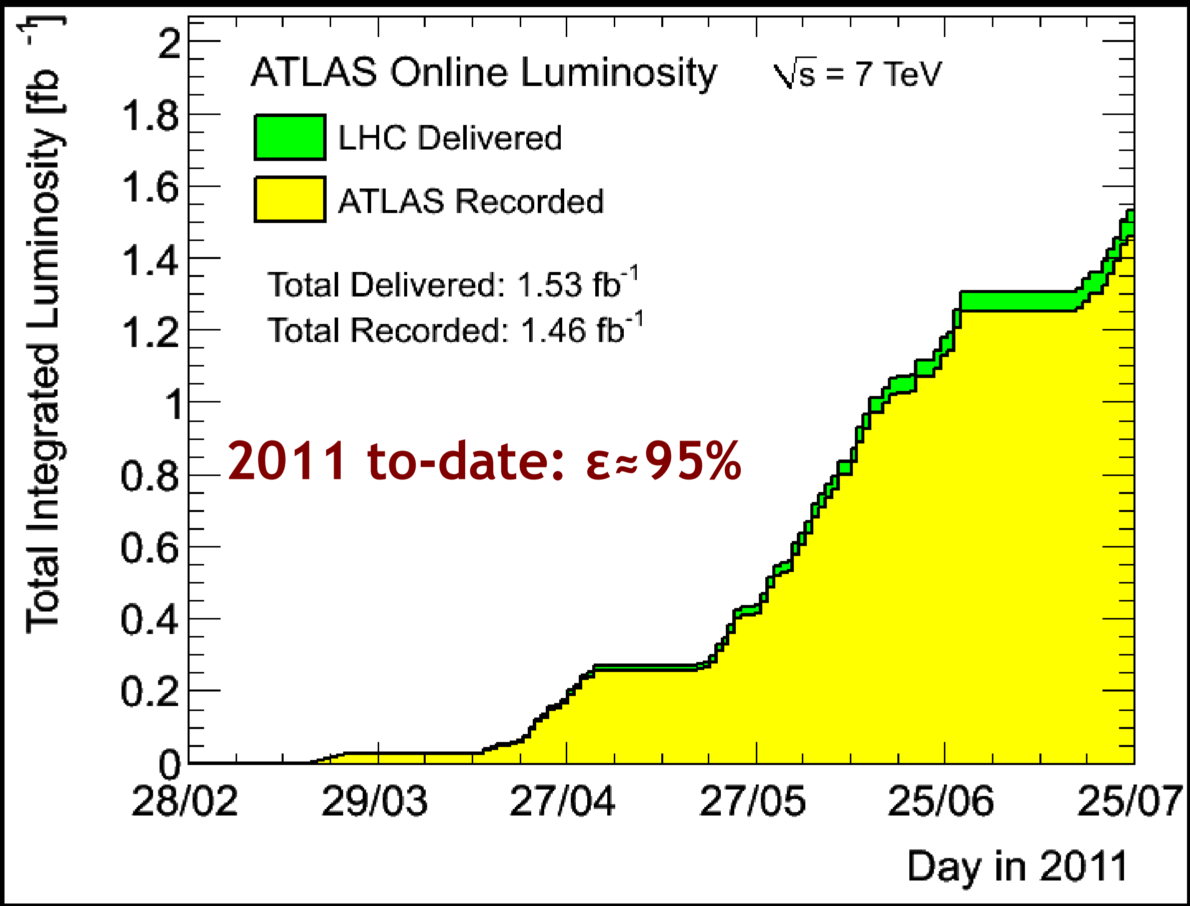


Data Collection

2010 operation: gradual (~exponential) ramp-up of instantaneous luminosity

2011 – sustained delivery of integrated luminosity





$1\ fb^{-1}$ of 2011 data recorded by 17 June

Peak luminosity ~~1.28~~ 1.75 x $10^{33}\ cm^{-2}s^{-1}$

Best in a day: $63\ pb^{-1}$

Results with up to $1.2\ fb^{-1}$

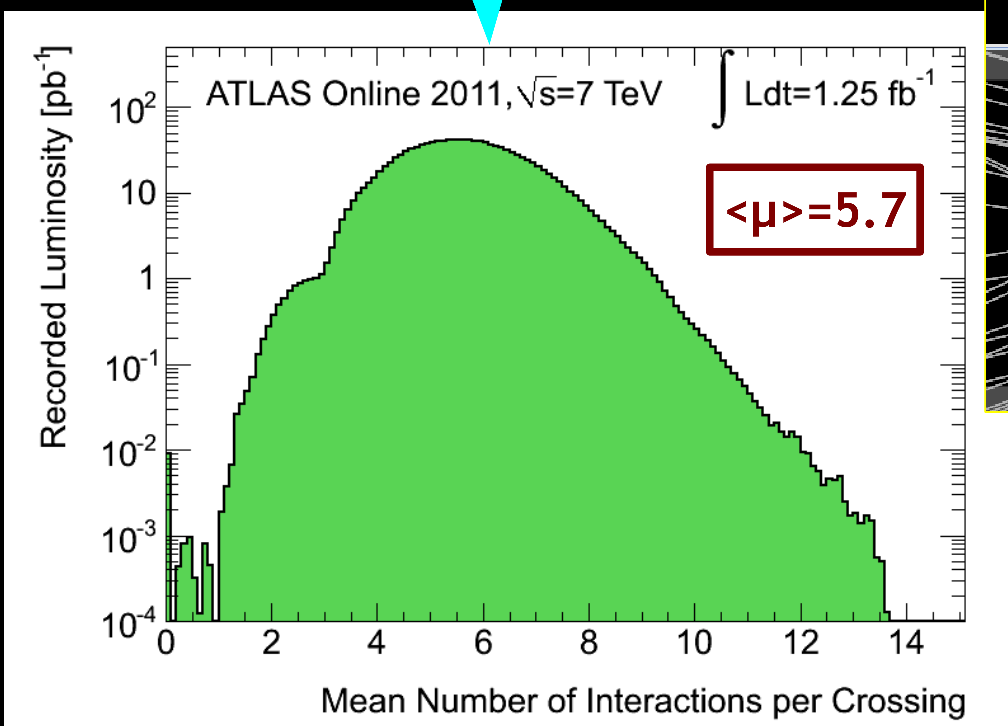
Pile-up Challenge

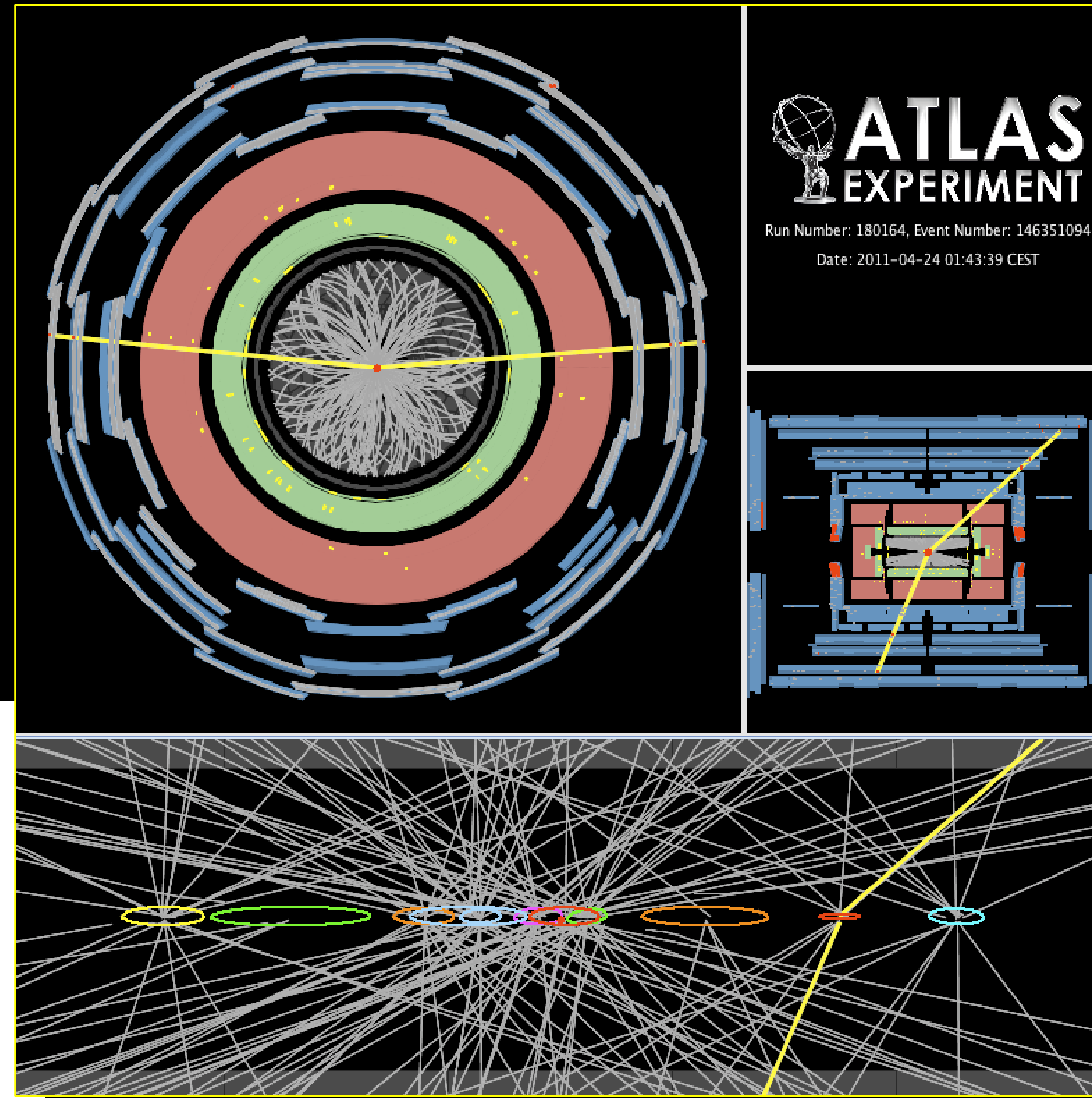
50 ns bunch trains for ~all 2011 data

Substantial in- and out-of-time pileup

- Much progress understanding impact on performance, with data & simulation
- Continuing detailed performance studies

Characterise by μ - mean number of interactions per bunch-crossing





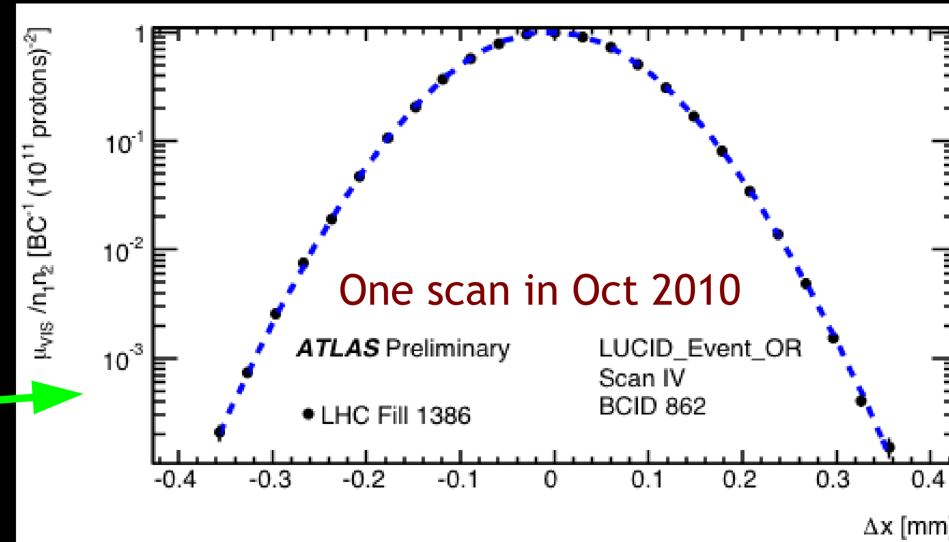
Z→μμ event with 11 primary vertices

Luminosity Measurement

Absolute luminosity calibration

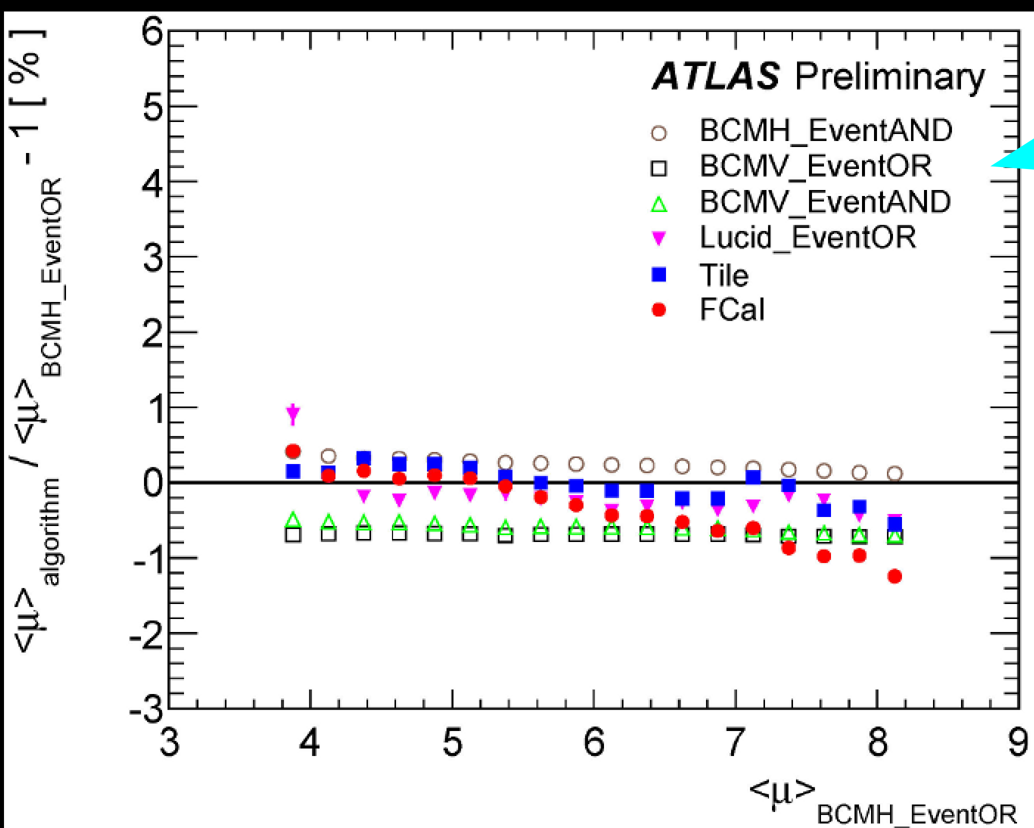
- beam-beam (van der Meer) scans
- both with special and physics beams

Quality of VdM scans was excellent



Several relative measures of instantaneous luminosity in physics

- Powerful cross-checks



Pileup dependence of different luminosity estimators
→ small additional uncertainty in 2011 relative to 2010

ΔL/L = **±3.4%** (2010, prel)
ΔL/L = **±3.7%** (2011, prel)

see also V Hedberg parallel talk, C Gabaldon poster

Trigger

Primary triggers are kept stable, e.g.

- Inclusive e p_T>20 GeV
- Inclusive μ p_T>18 GeV
- Inclusive jet p_T>180 GeV
- E_T^{miss} > 60 GeV
- Diphoton p_T > 20 GeV
- ...

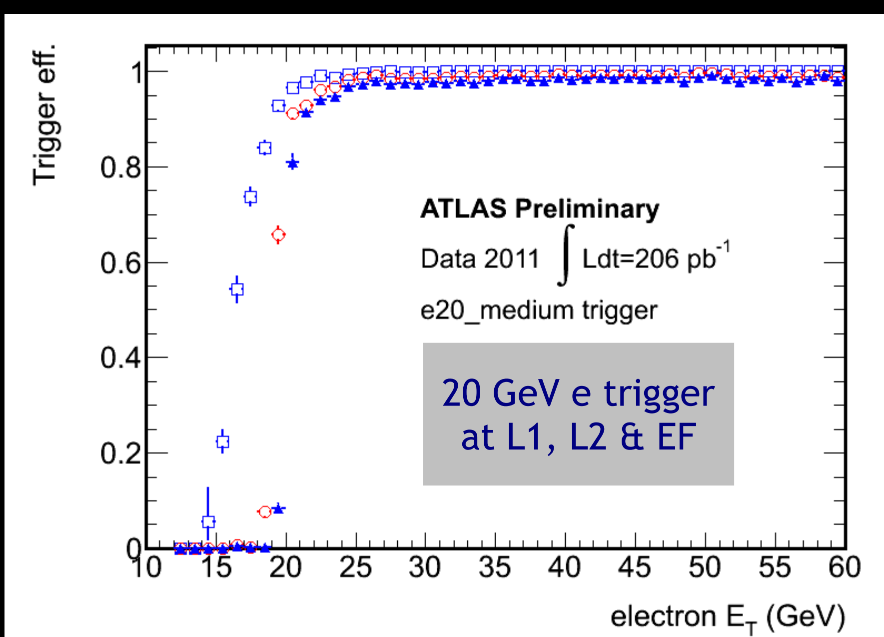
Such triggers are not prescaled

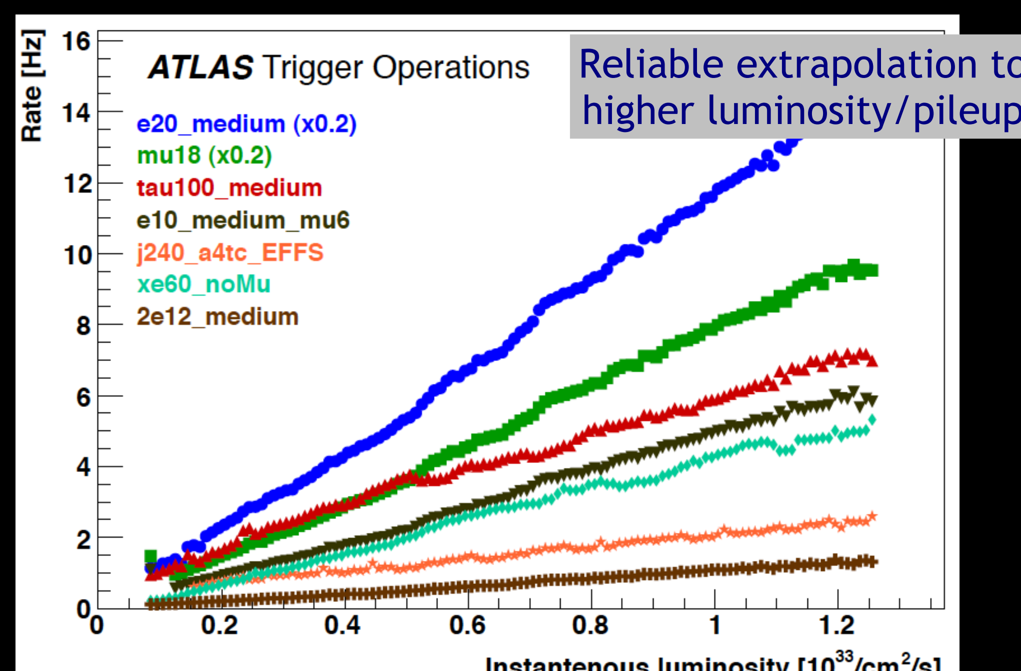
Supplemented by supporting & monitoring triggers

Sophisticated and flexible menus

trigger	L1 item	L1 Rate (Hz)	EF Rate (Hz)
e20_medium	EM14	8500	50
2e12_medium	2EM7	5700	1
g80_loose	EM30	700	3
2g20_loose	2EM14	750	2
mu18	MU10	5300	40
2mu10	2MU10	100	1
xe60	XE40	300	4
j180	J75	200	6
tau29medium_xe35	TAU11_XE20	3800	6
tau16_e15	TAU6_EM10	7500	6
j75_xe45	J50_XE20	500	10

Rates at $10^{33}cm^{-2}s^{-1}$





Detector Performance and Data Quality

Data-taking efficiency >95%

Operational fractions of detector also >~97%

Data for analyses depends on specific detector requirements

Of 1.24 fb^{-1} collected by end June, between **1.04 and 1.21 fb^{-1}** for most results presented

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	96.8%
SCT Silicon Strips	6.3 M	99.1%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.8%
Tile calorimeter	9800	97.5%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trigger	370 k	99.5%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	97.7%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	98.1%

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.8	100	89.0	92.4	94.2	99.7	99.8	99.7	99.8	99.7	99.3	99.0

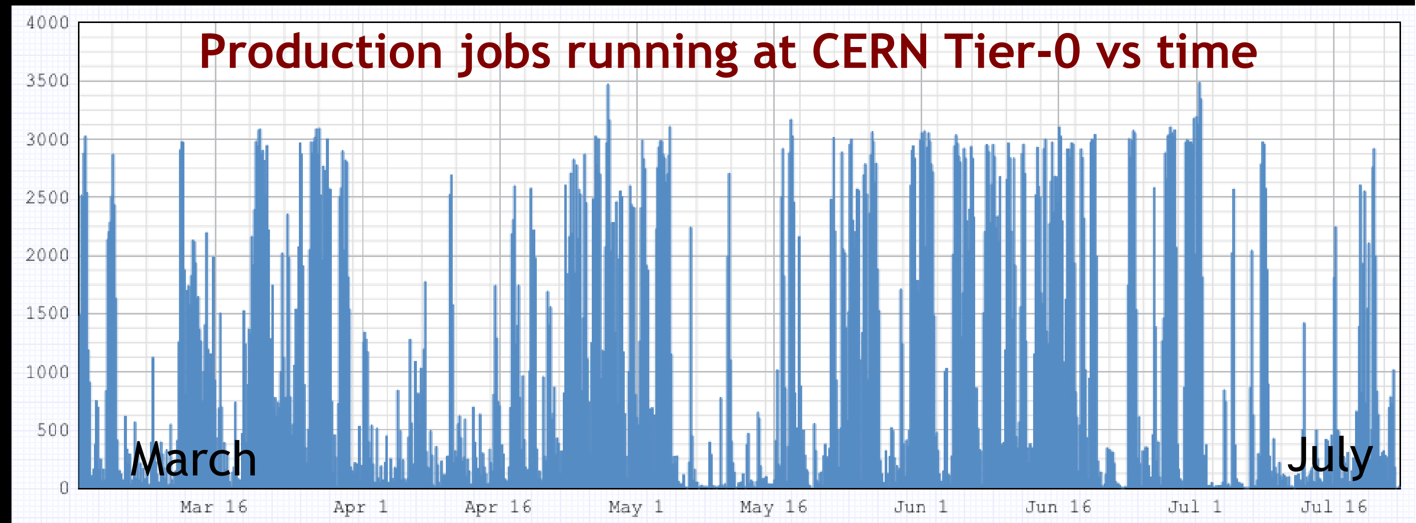
Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 13th and June 29th (in %). The inefficiencies in the LAr calorimeter will partially be recovered in the future. The magnets were not operational for a 3-day period at the start of the data taking.

"All good" fraction will increase by ~7% in reprocessing campaign starting now (fine-grained flagging of calo noise bursts)

Computing Grid Delivers Physics

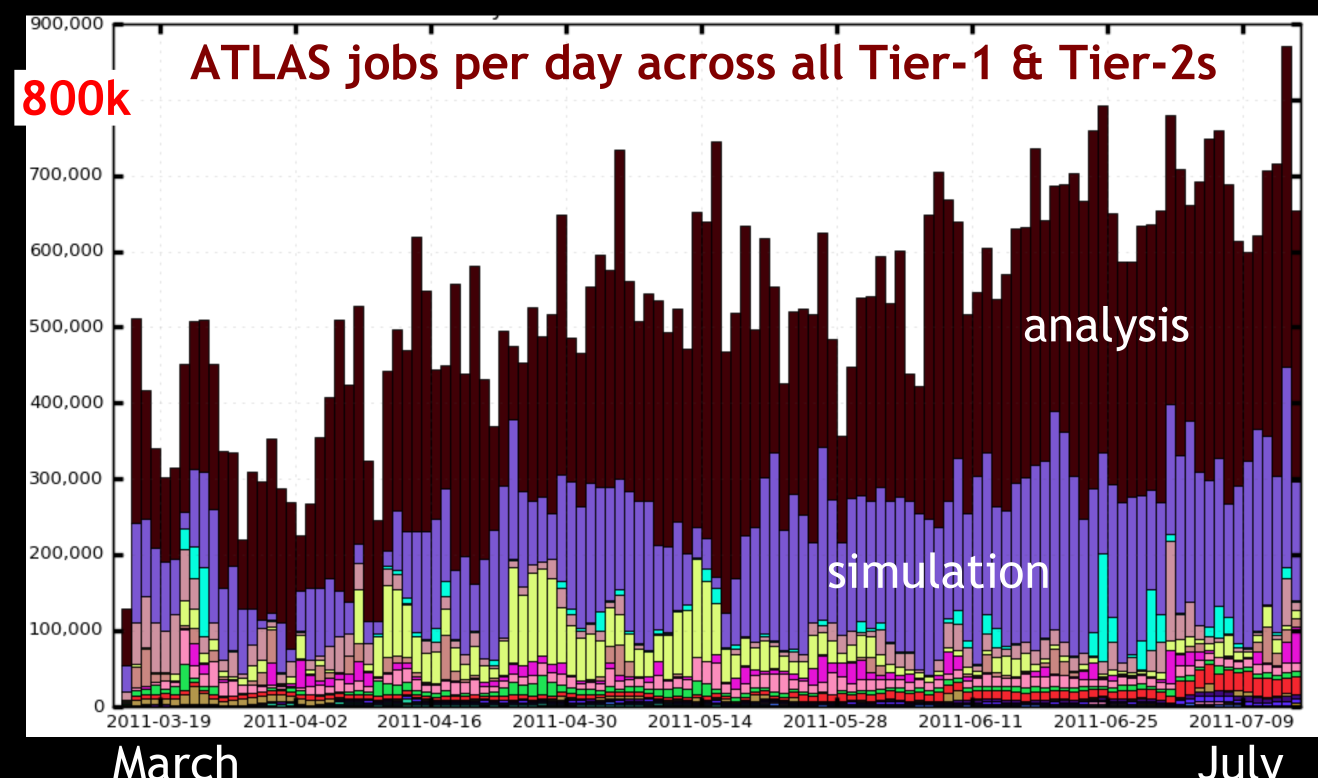
Data preparation:

- First-pass reco. at Tier-0 within ~2 days
- Calibration/DQ good for physics analysis
- Data analysable on Grid within ~1 week



Tier-1 and Tier-2's process ~⅔ M jobs per day

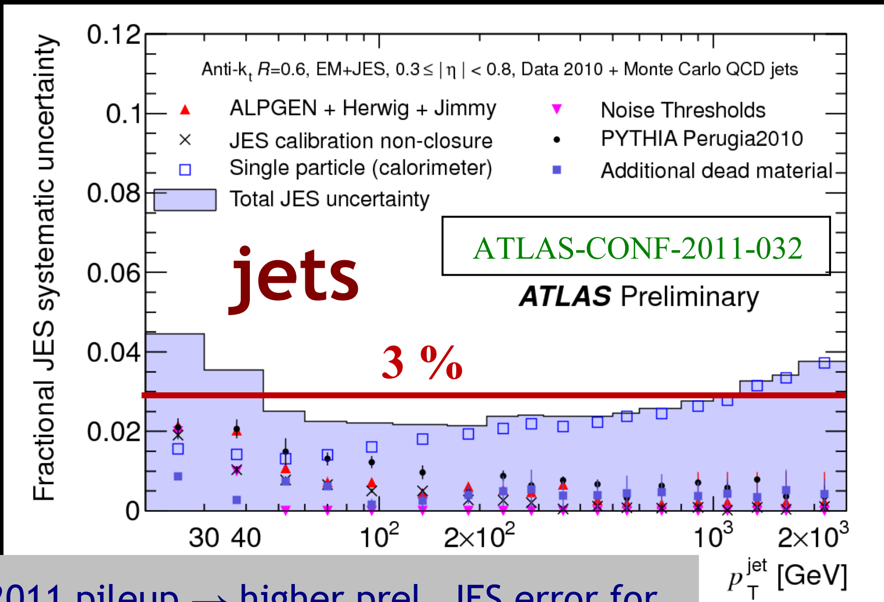
- simulation
- re-reconstruction (campaigns)
- group production (ntuples...)
- physics analysis



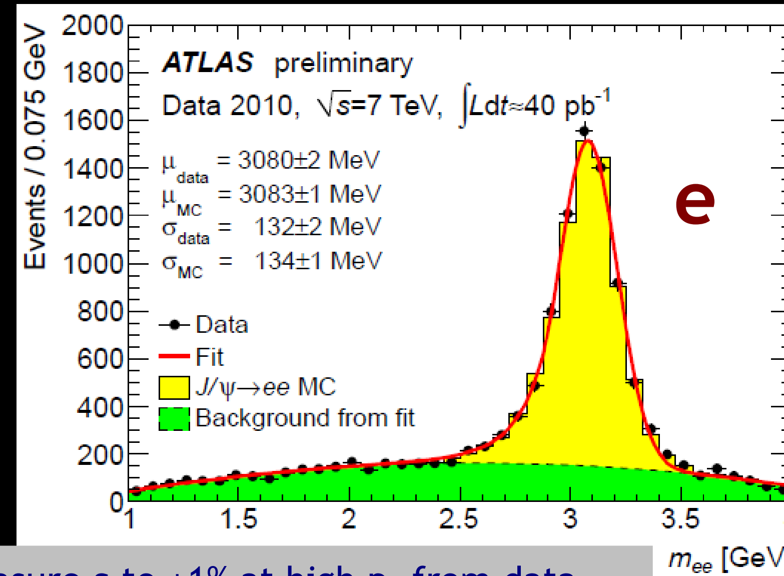
The high quality computing system allows us to show results on data taken until the end of June

Payback for the years of investment and hard work

Performance for Physics

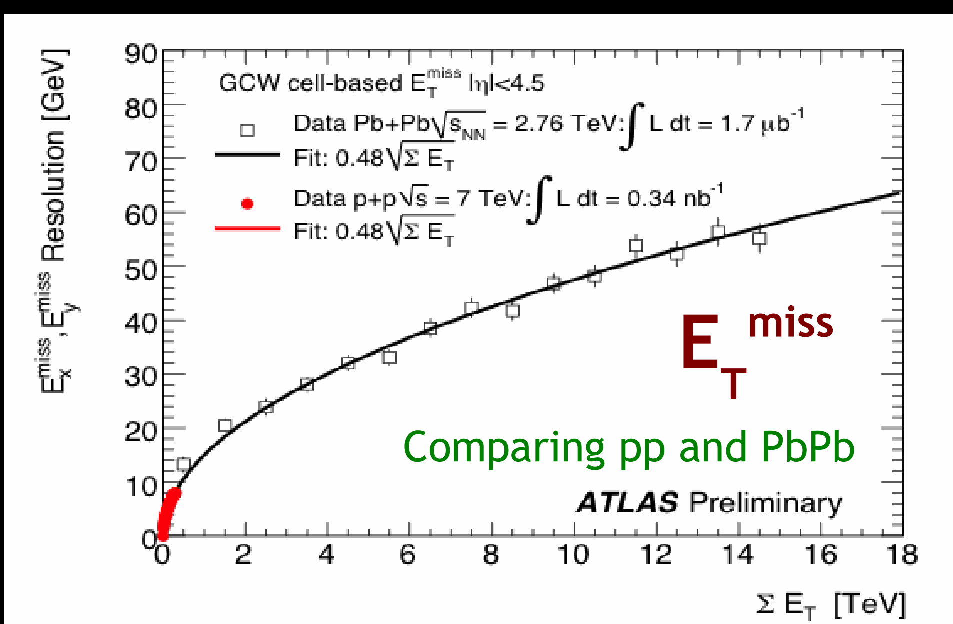


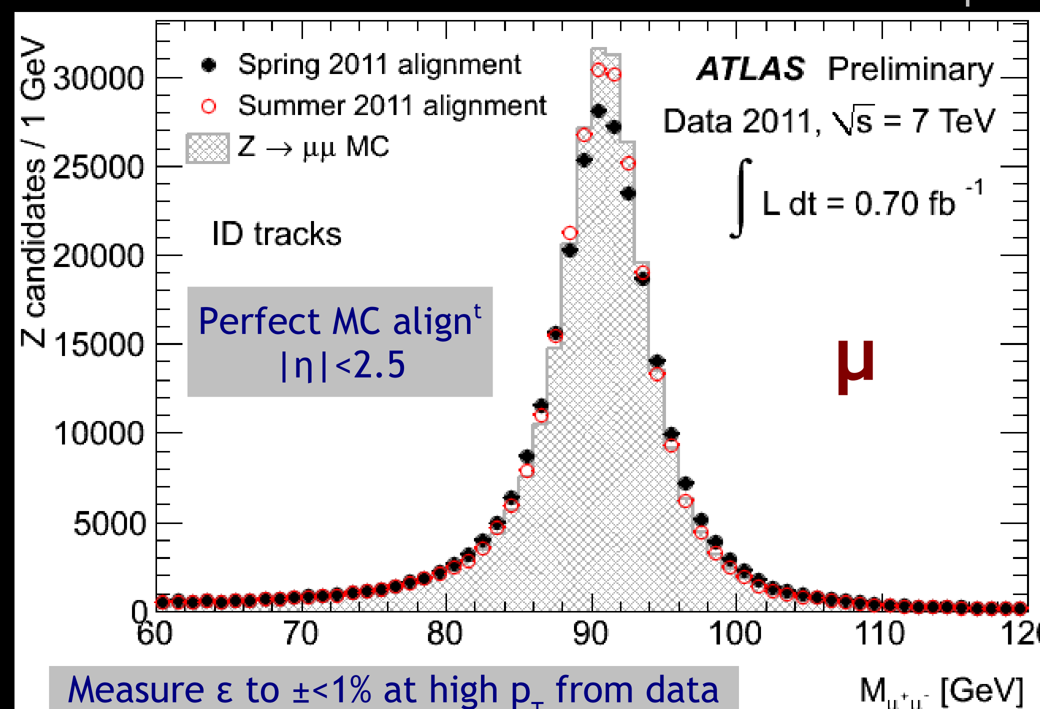
2011 pileup → higher prel. JES error for E_T<100 GeV jets (±2-5% for |η|<2.1)



Measure ε to ±1% at high p_T from data, also down to 4 GeV, using J/ψ, W, Z
E scale to 0.3-1.6% over |η|<2.47 to 1 TeV

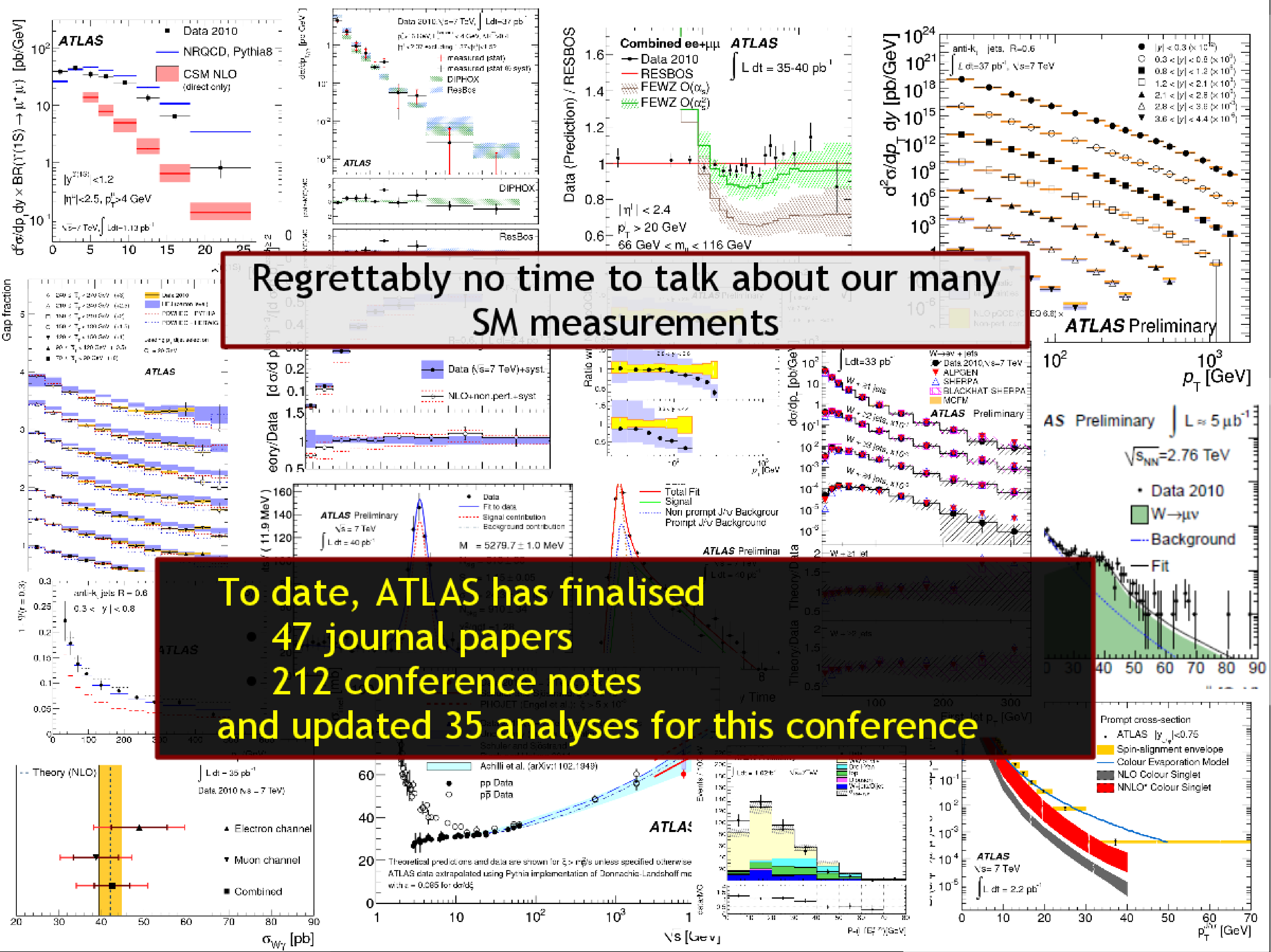
see also T Theveneaux-Pelzer poster





Perfect MC align^t
|η|<2.5

Measure ε to ±<1% at high p_T from data
$\Delta p_T/p_T$=13% at 1 TeV (barrel)



Regrettably no time to talk about our many SM measurements

To date, ATLAS has finalised

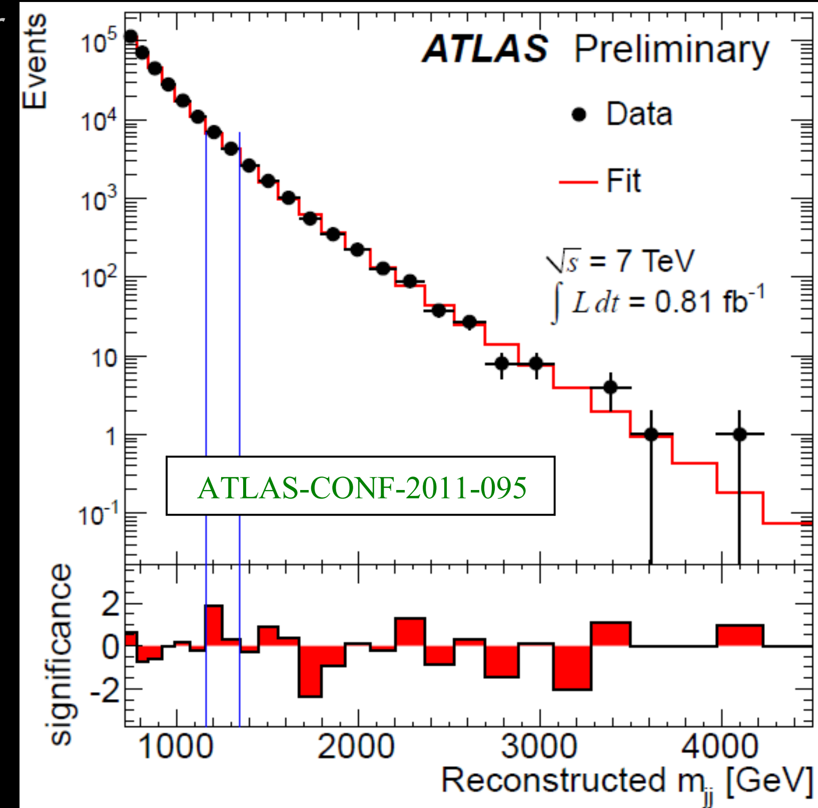
- 47 journal papers
- 212 conference notes

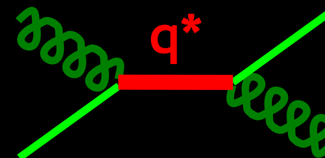
and updated 35 analyses for this conference see also A Gibson parallel talk,T Dietzsch poster

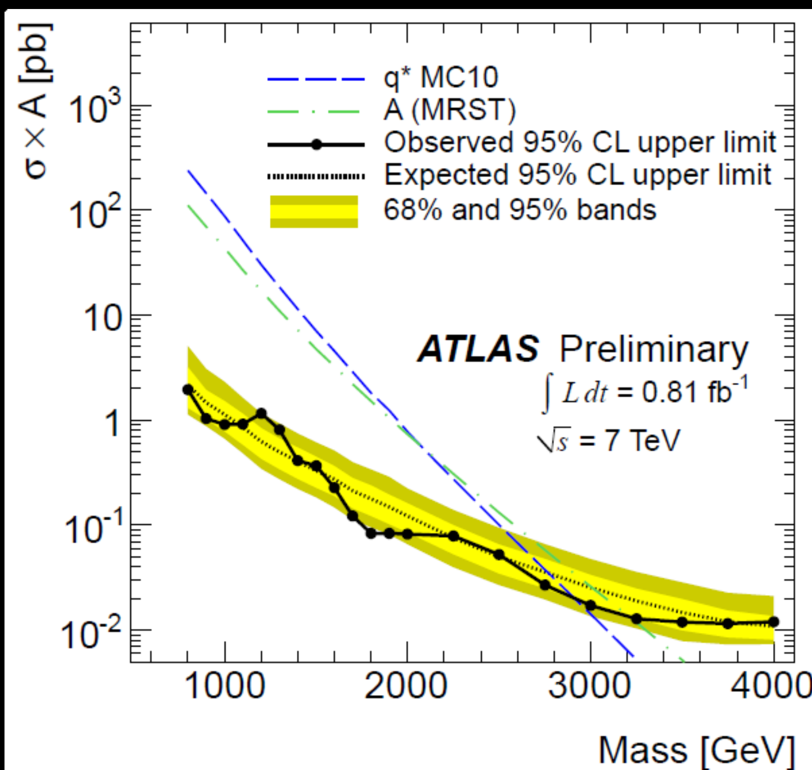
Dijet Resonance Search

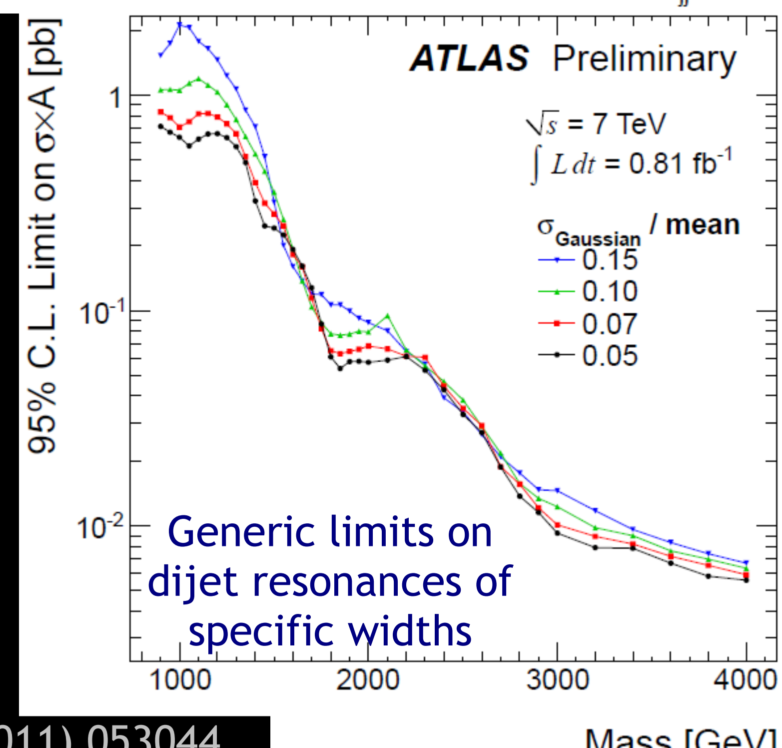
Search for peaks in the m_{jj} spectrum

Examples: q*, axigluon, colour-octet scalar models – also generic limits









Model	Expected limit	Observed limit	Obs. 2010
q*	2.77	**2.91**	2.15
axigluon	3.02	**3.21**	2.10
c.o.s (s8)	1.71	**1.91**	-

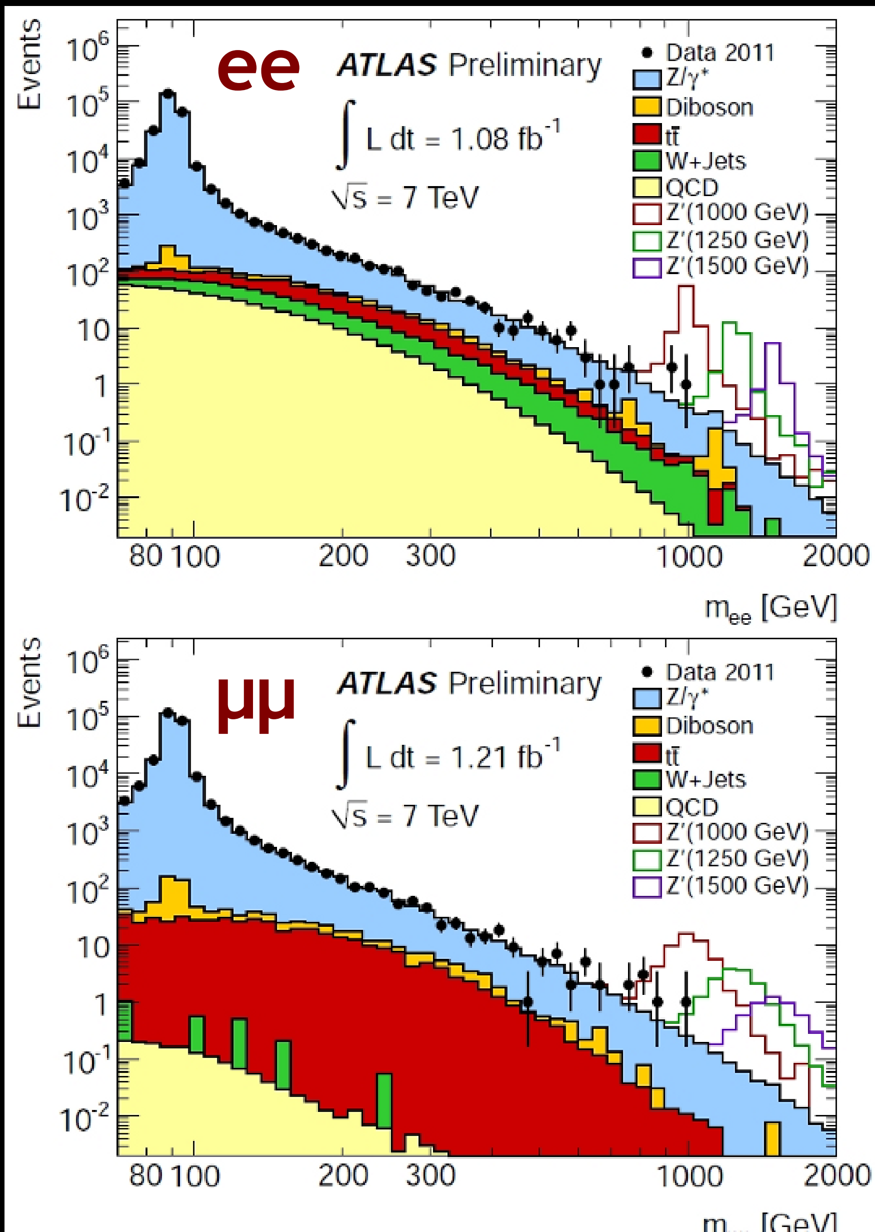
95% CL limits in TeV

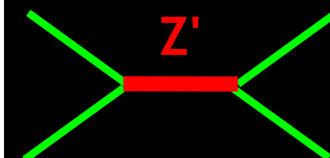
2010 analyses studying also angular distributions: New J Phys 13 (2011) 053044

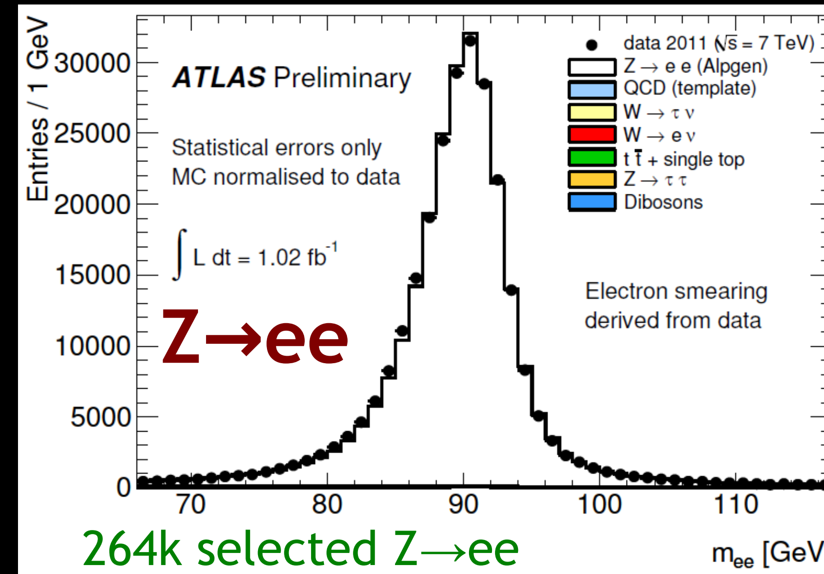
Dilepton Resonances

e^+e^- and $\mu^+\mu^-$ invariant mass distributions

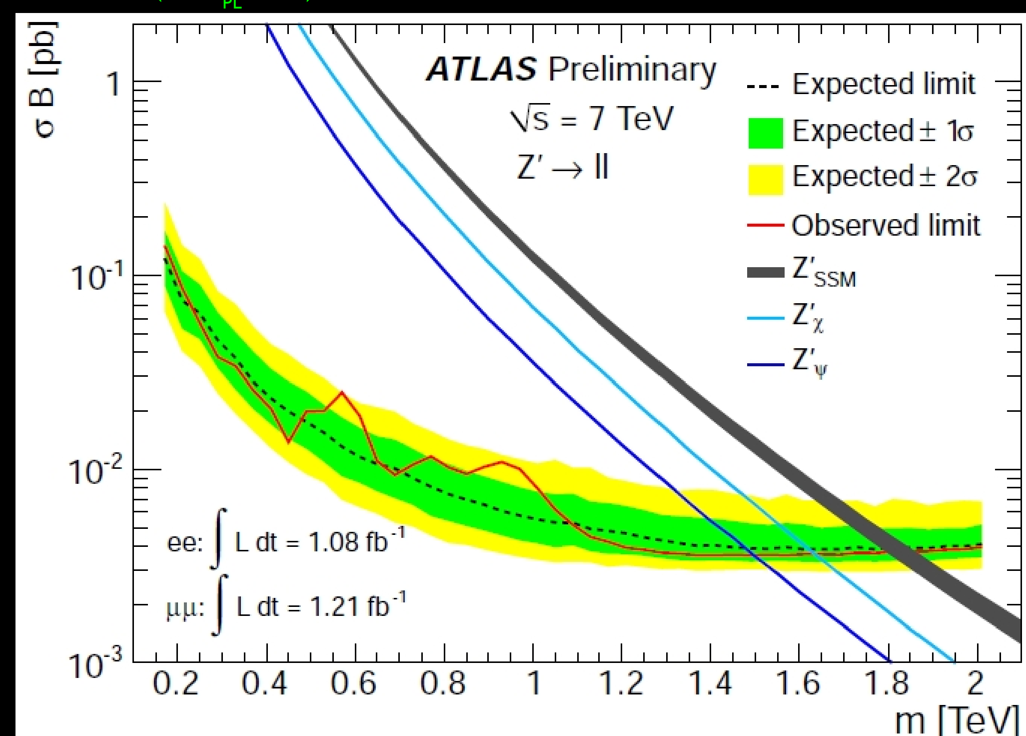
Look for Z' and RS graviton (G*) production







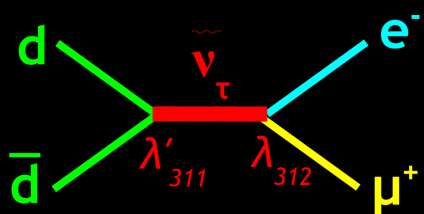
Model	Observed 95% CL limit	2010
Z' SSM	**1.83 TeV**	1.048 TeV
G* (k/m_{PL}=0.1)	**1.63 TeV**	-



see also T Hryn'ova parallel talk, S Heim, S Viel posters

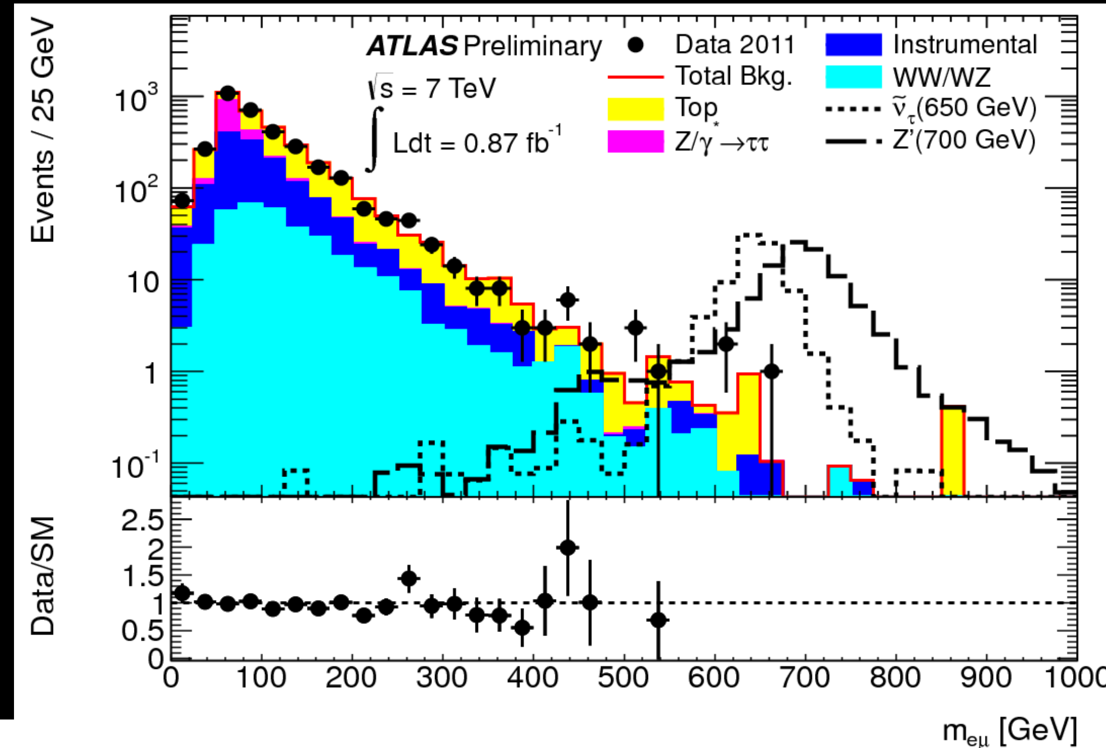
eμ Resonance Search

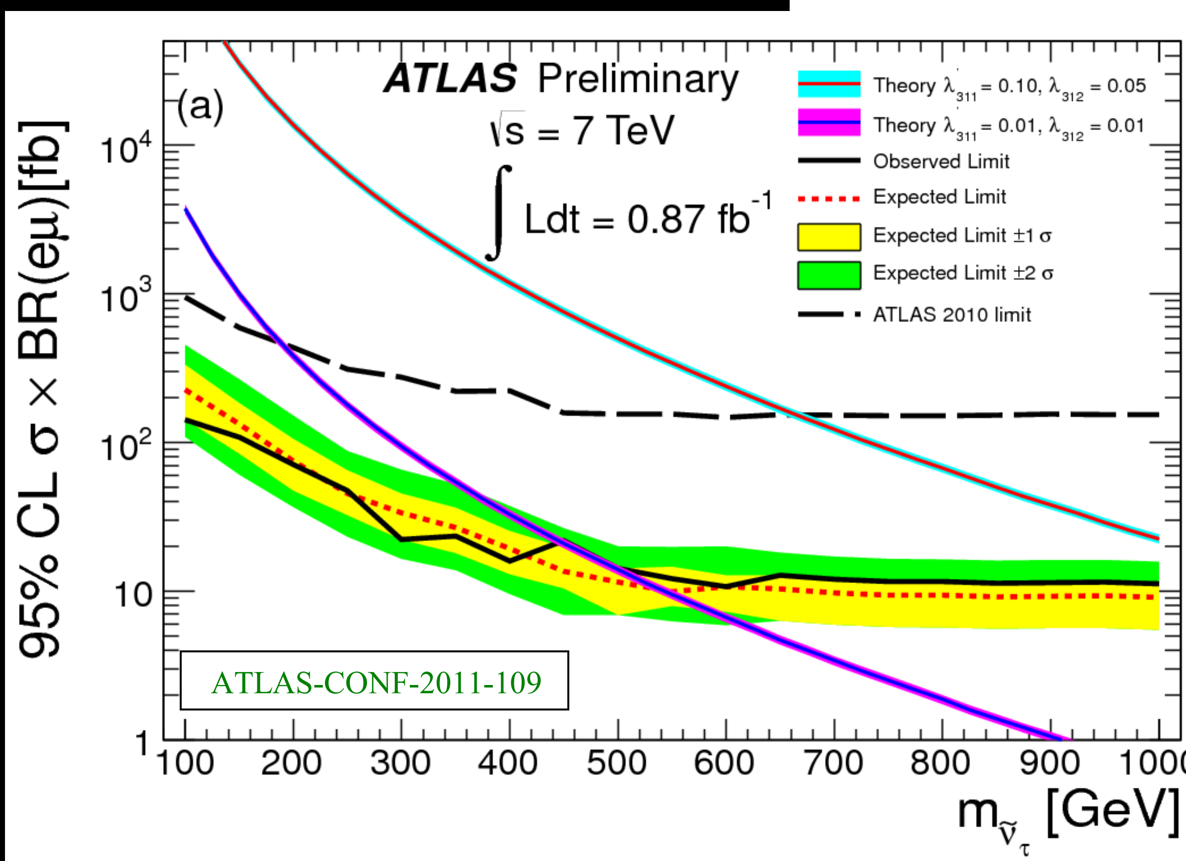
Search in s-channel for eμ resonances



Example straw-man models:

- $\tilde{\nu}_\tau$ in RPV SUSY, with only λ'_{311}, $\lambda_{312} \neq 0$
- SM-like Z' with non-diagonal couplings





σ(Z') < 11 fb at 95% CL
for $m_{Z'}$ >700 GeV

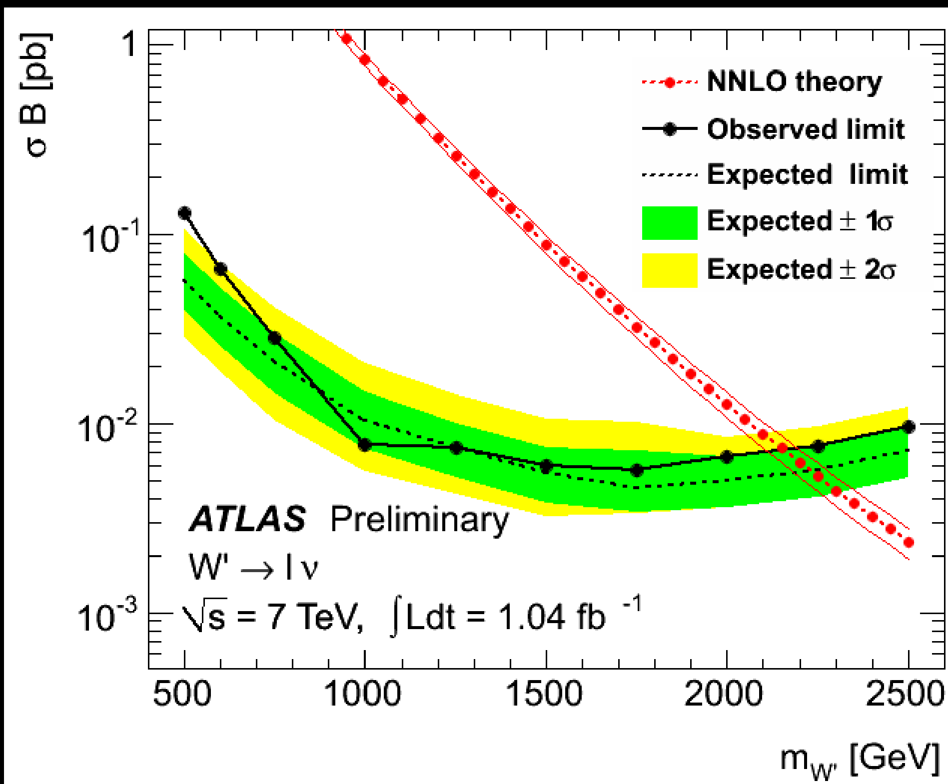
see also T Hryn'ova parallel talk

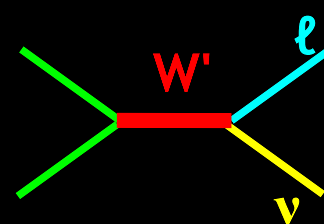
Lepton + E_T^{miss}

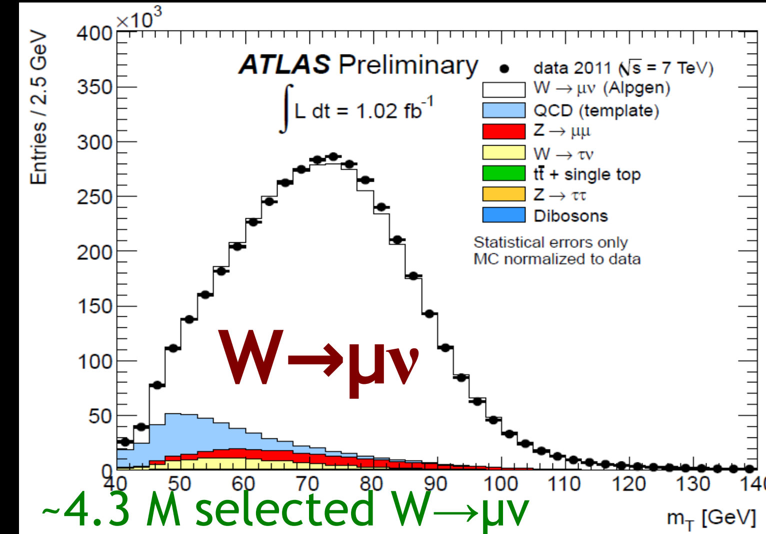
Search in transverse mass spectra for e/μ + E_T^{miss}

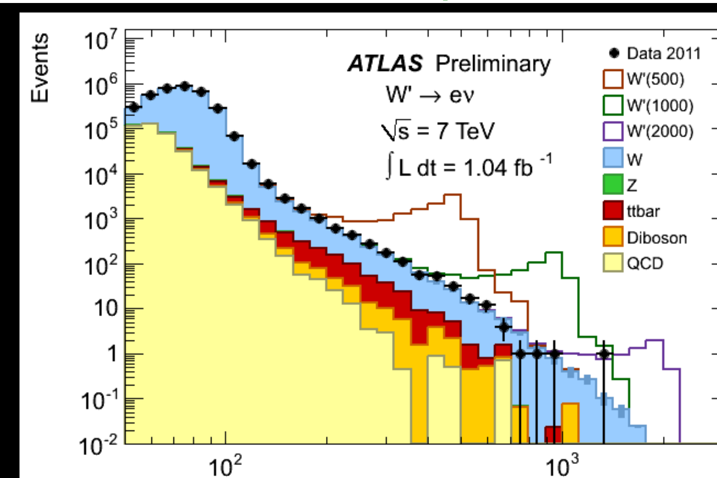
$$m_T = \sqrt{2 p_T^{\ell} p_T^{\nu} (1 - \cos(\phi^{\ell} - \phi^{\nu}))}$$

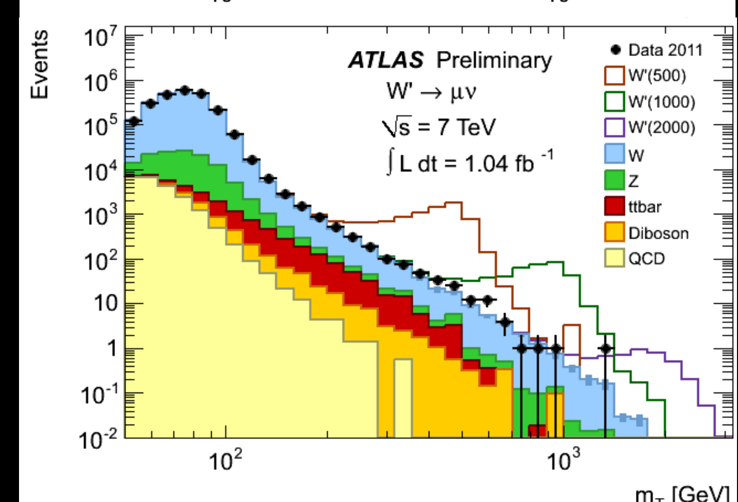
Constrains a sequential SM-like W'











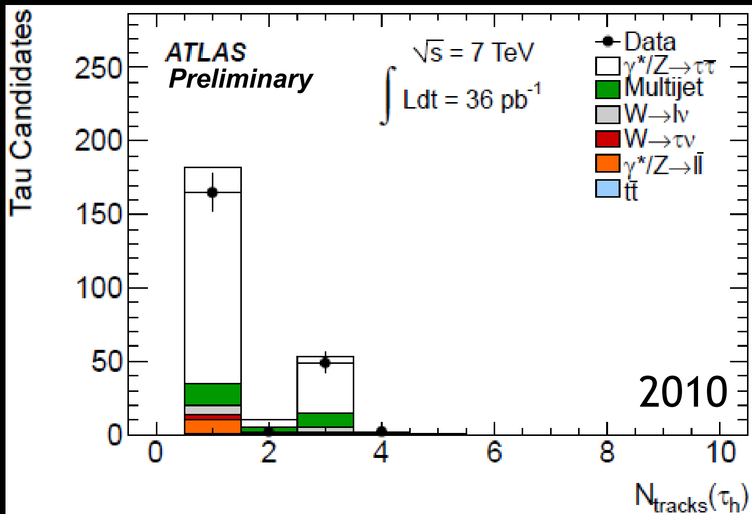
Channel	Expected limit	Observed limit	Obs. 2010
eν	2.17	**2.08**	1.37
μν	2.08	**1.98**	1.29
both	2.23	**2.15**	1.49

95% CL limits in TeV

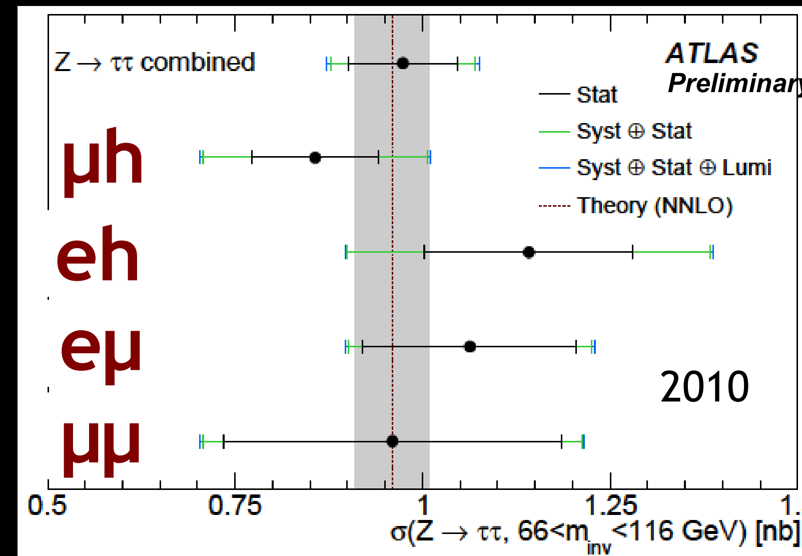
see also T Hryn'ova parallel talk

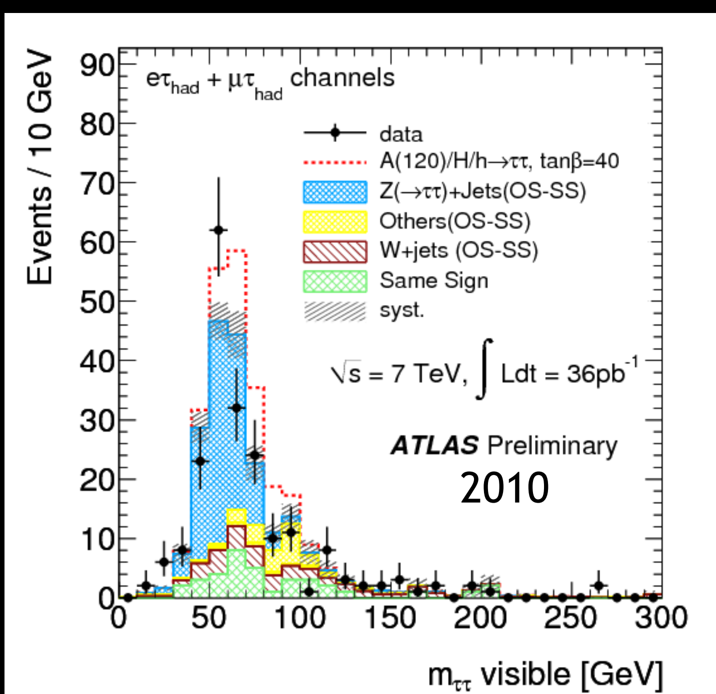
see also S Lai parallel talk, F Seifert poster

Physics with Taus



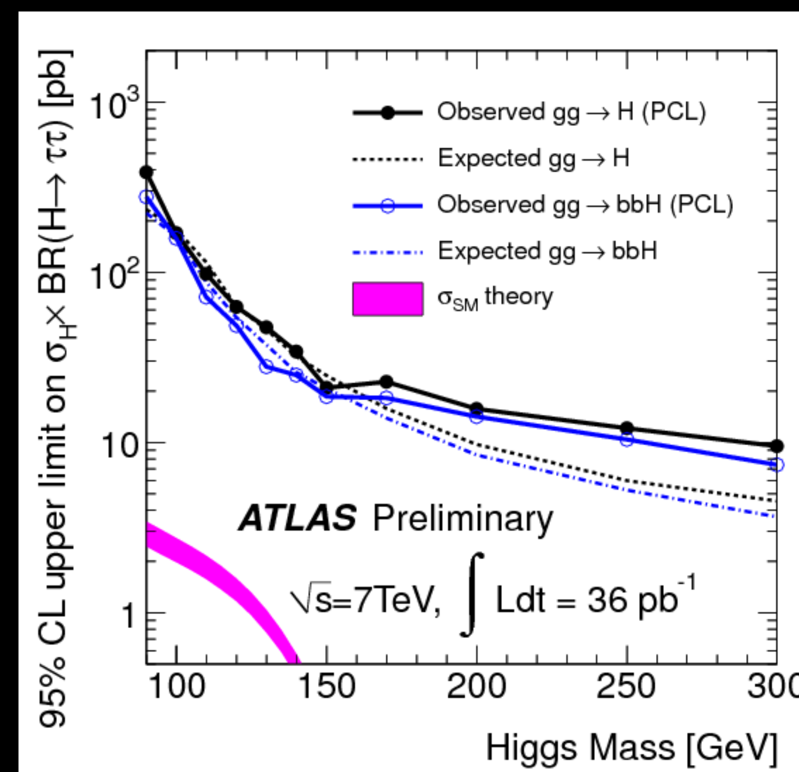
Z→ττ cross-section measurement





Constraints on A/H/h→ττ production in SUSY models

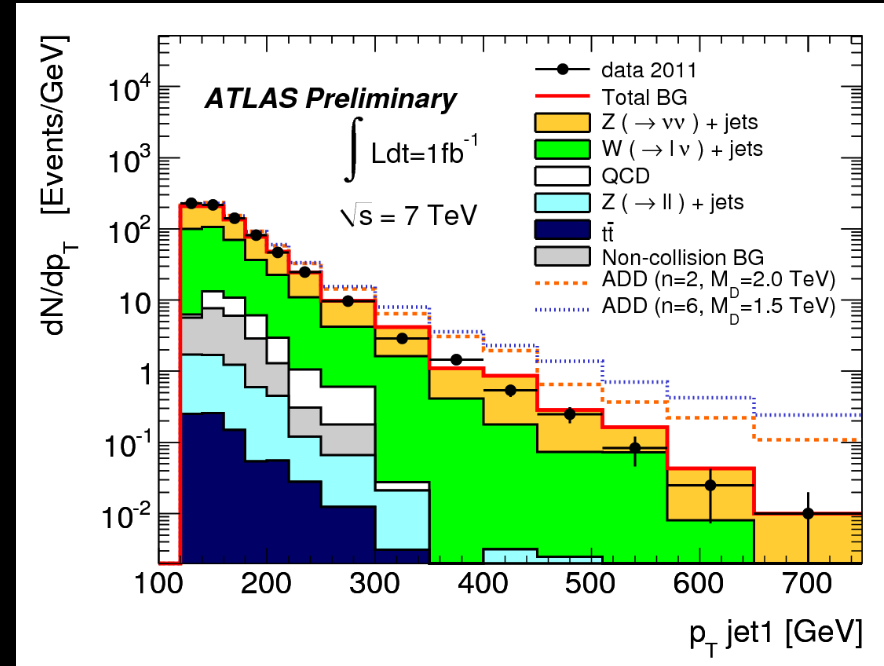
$e\mu 4\nu$, $e\tau_{had}3\nu$, $\mu\tau_{had}3\nu$ channels

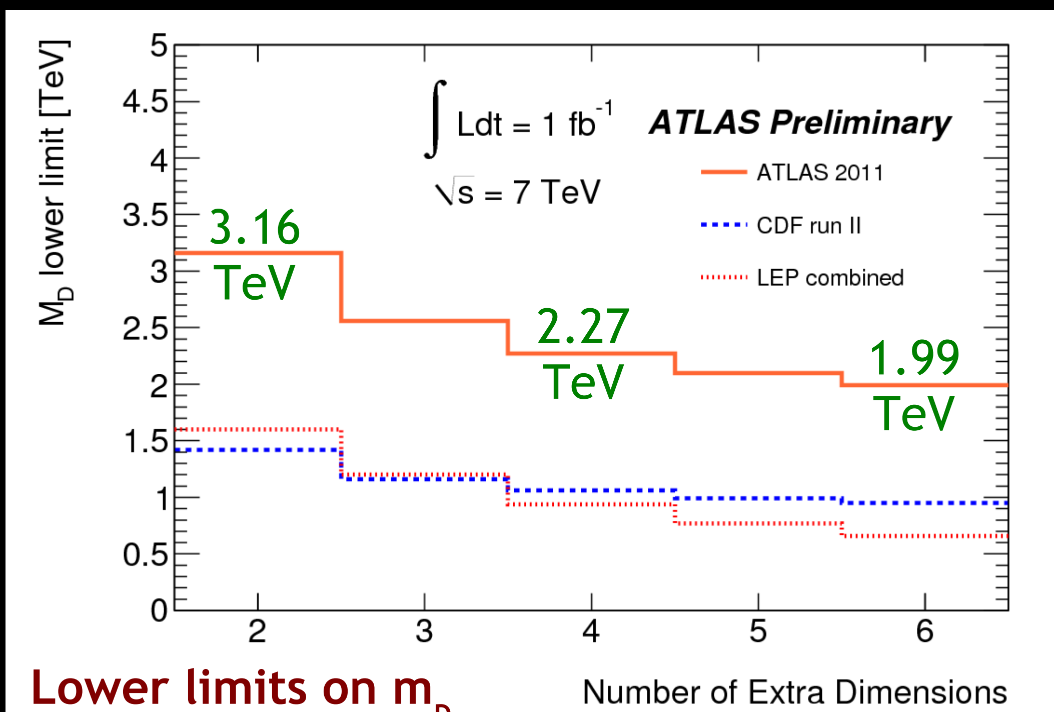


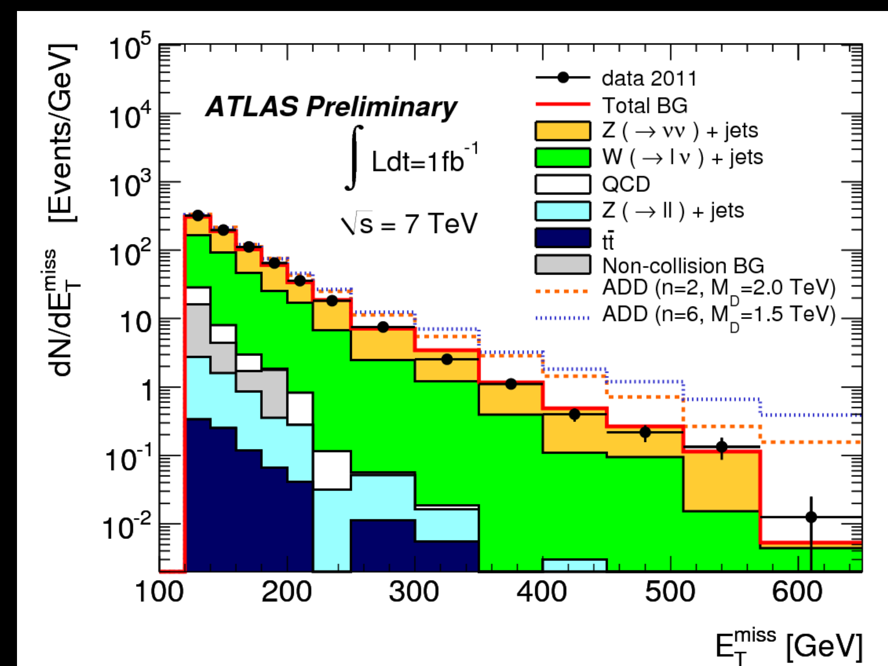
Monojet: Jet + E_T^{miss}

High-p_T jet opposite ~no activity

- Standard Model: $Z \to \nu\bar{\nu}$
- Large-extra dimensions with unobserved graviton
  4+n dimensions, 4+n-dimensional Planck scale M_D

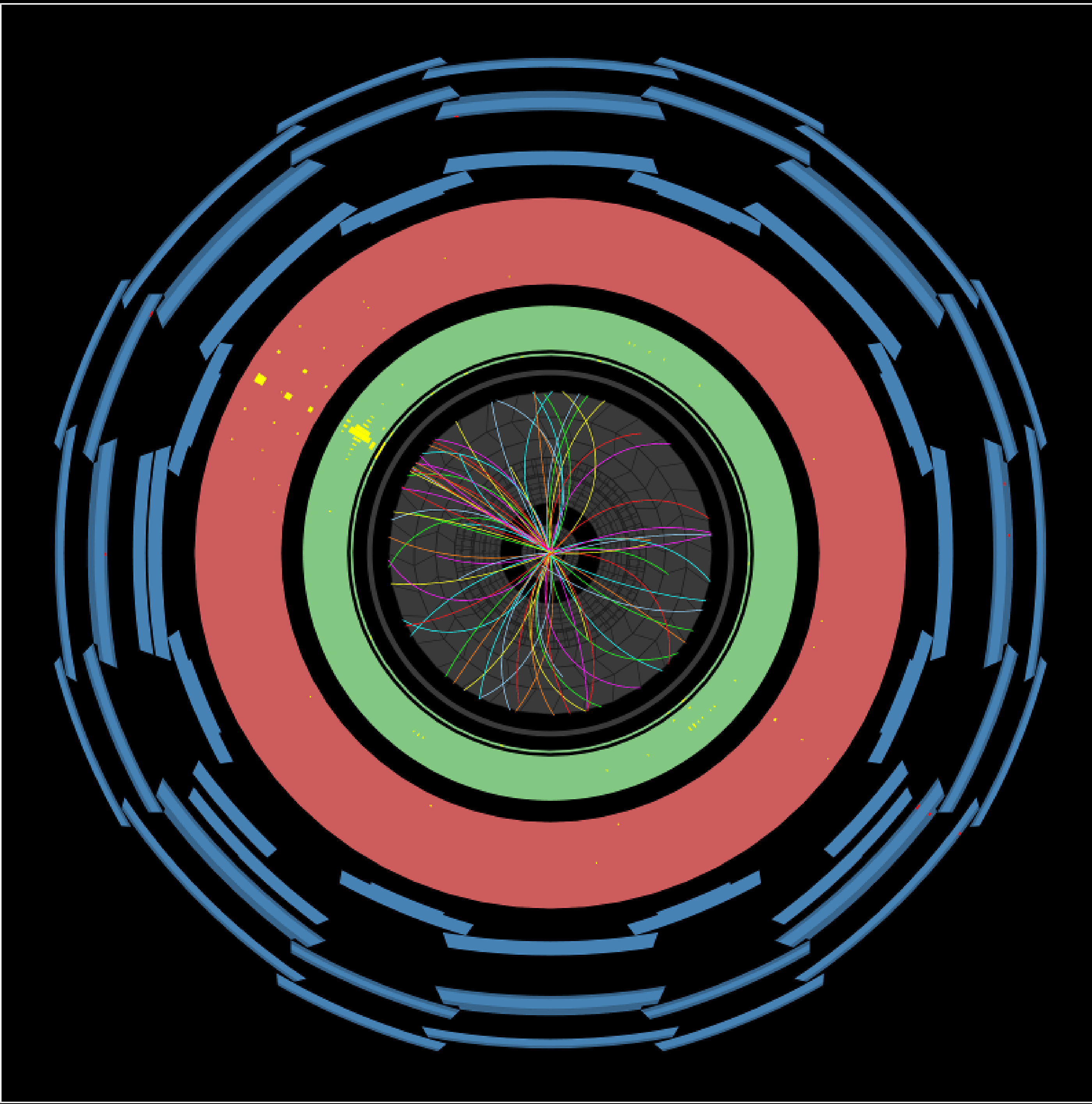


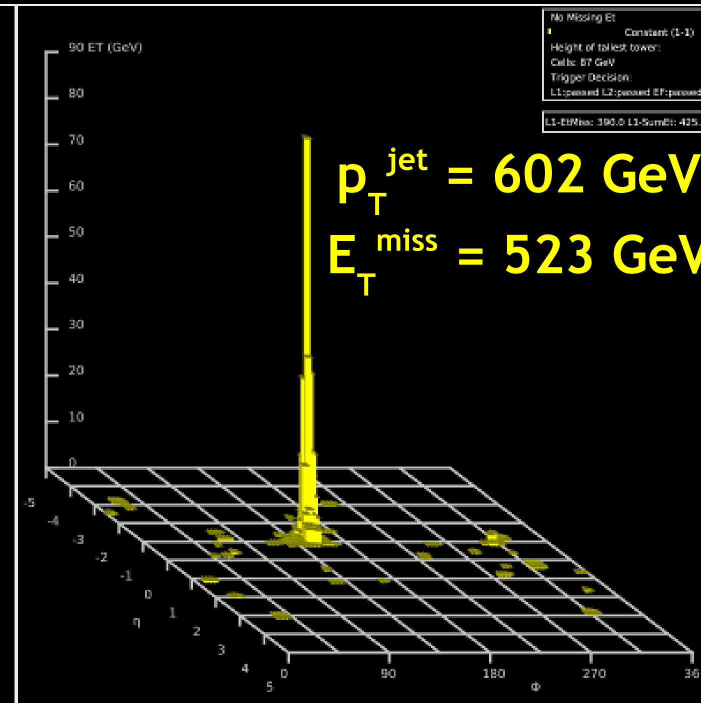




If we only consider $\hat{s} < m_D^2$, $m_D > 1.68$ TeV for n=6

see also A Gibson parallel talk, V Rossetti poster





ATLAS EXPERIMENT

Run Number: 180309, Event Number: 36060682

Date: 2011-04-27 02:33:15 CEST

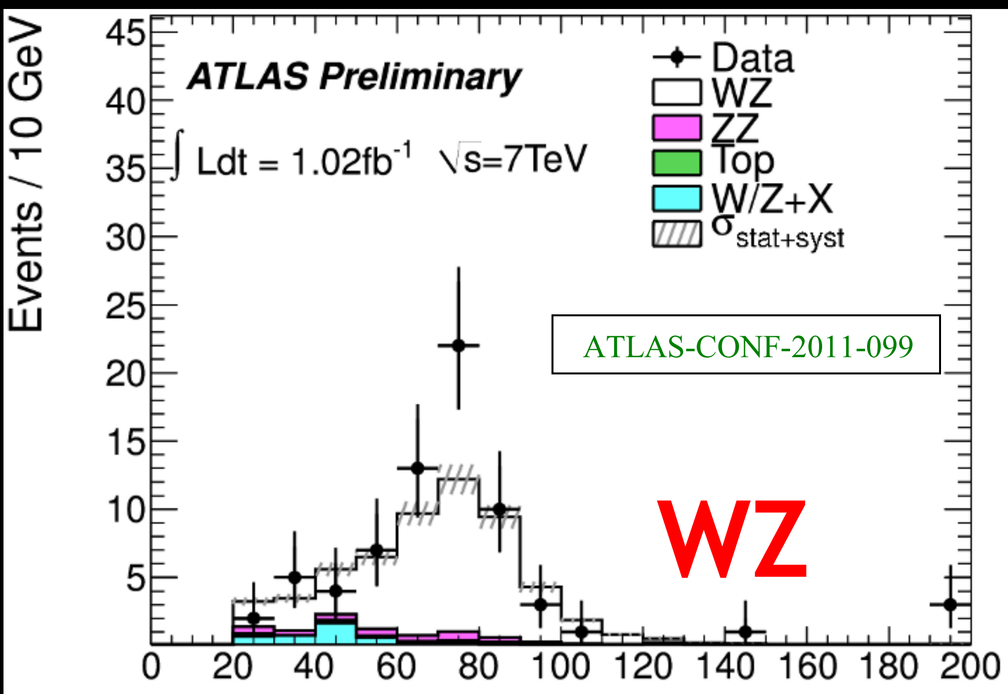
A high-p_T monojet event - SM interpretation $Z \to \nu\bar{\nu}$ + jet

Massive Di-Bosons

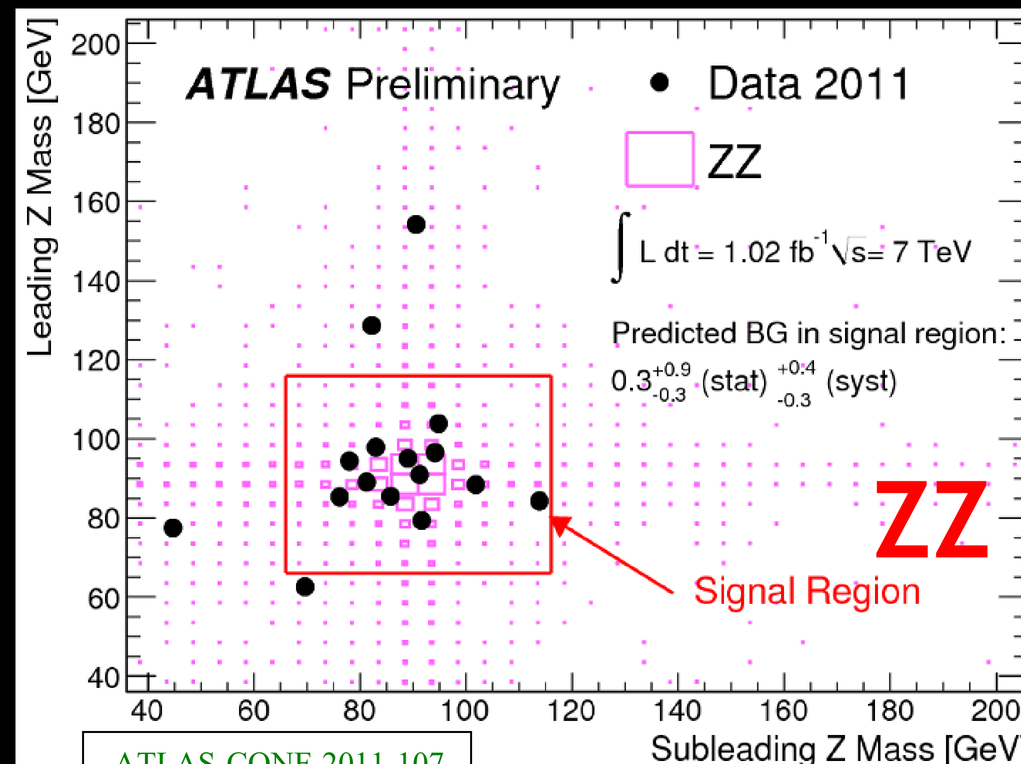
Low cross-sections: observation is a step towards searching with these final states

$\sigma^{tot}(WZ)=21.1\pm^{3.1}_{2.8}\pm1.2\pm0.9$ pb
SM NLO: 17 pb

$\sigma^{tot}(ZZ)=8.4\pm^{2.7}_{2.3}\pm^{0.4}_{0.7}\pm0.3$ pb
SM NLO: 6.5 pb



$M_T(W\rightarrow\ell\nu)$ in events with a $Z\rightarrow\ell\ell$ candidate

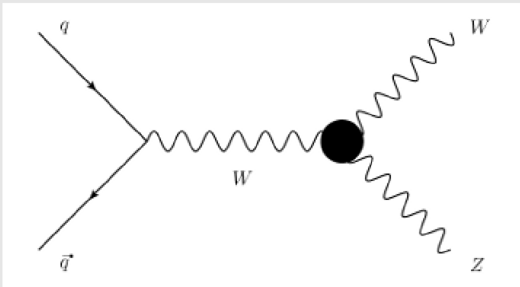


WW, WZ and ZZ diboson signals established in double leptonic decay channels

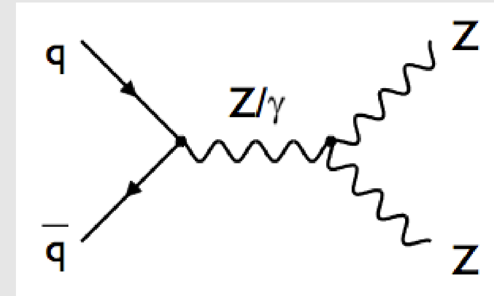
WW: ATLAS-CONF-2011-110

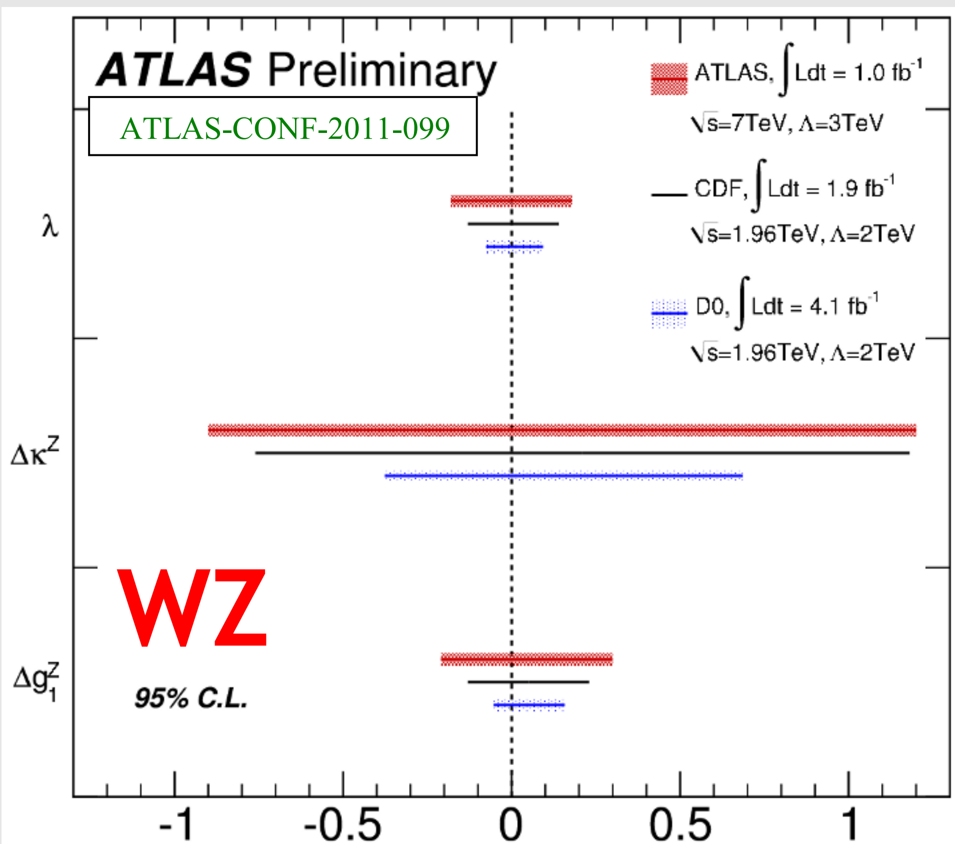
see also A Oh parallel talk

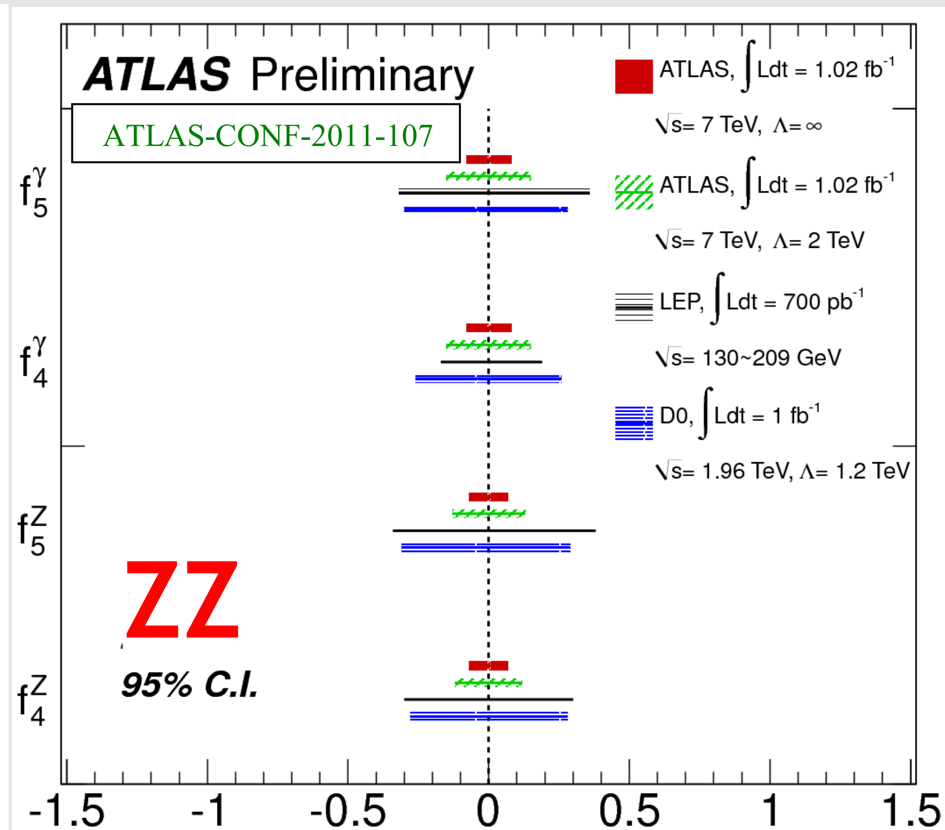
Massive Di-Bosons

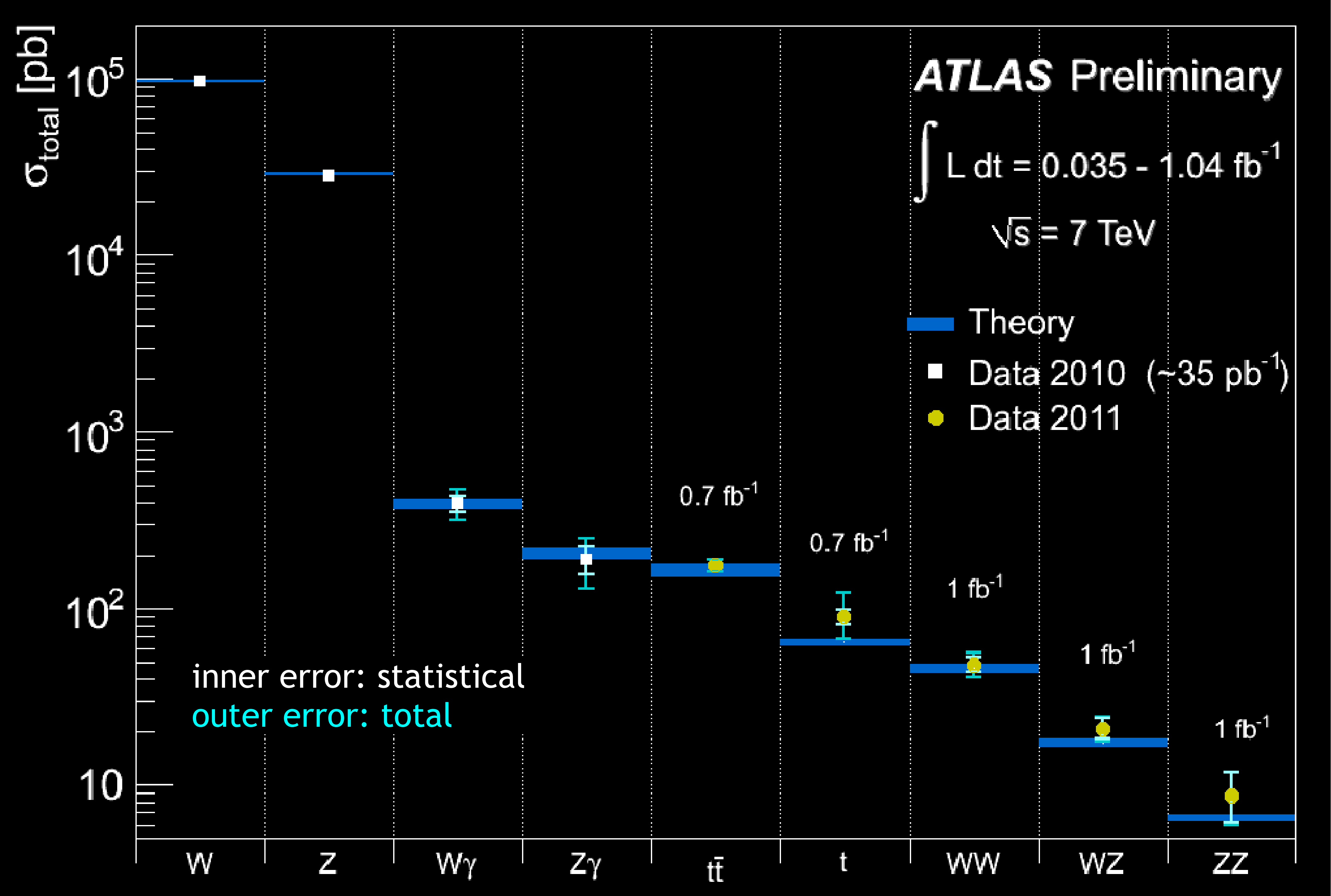


First ATLAS constraints on anomalous triple gauge couplings







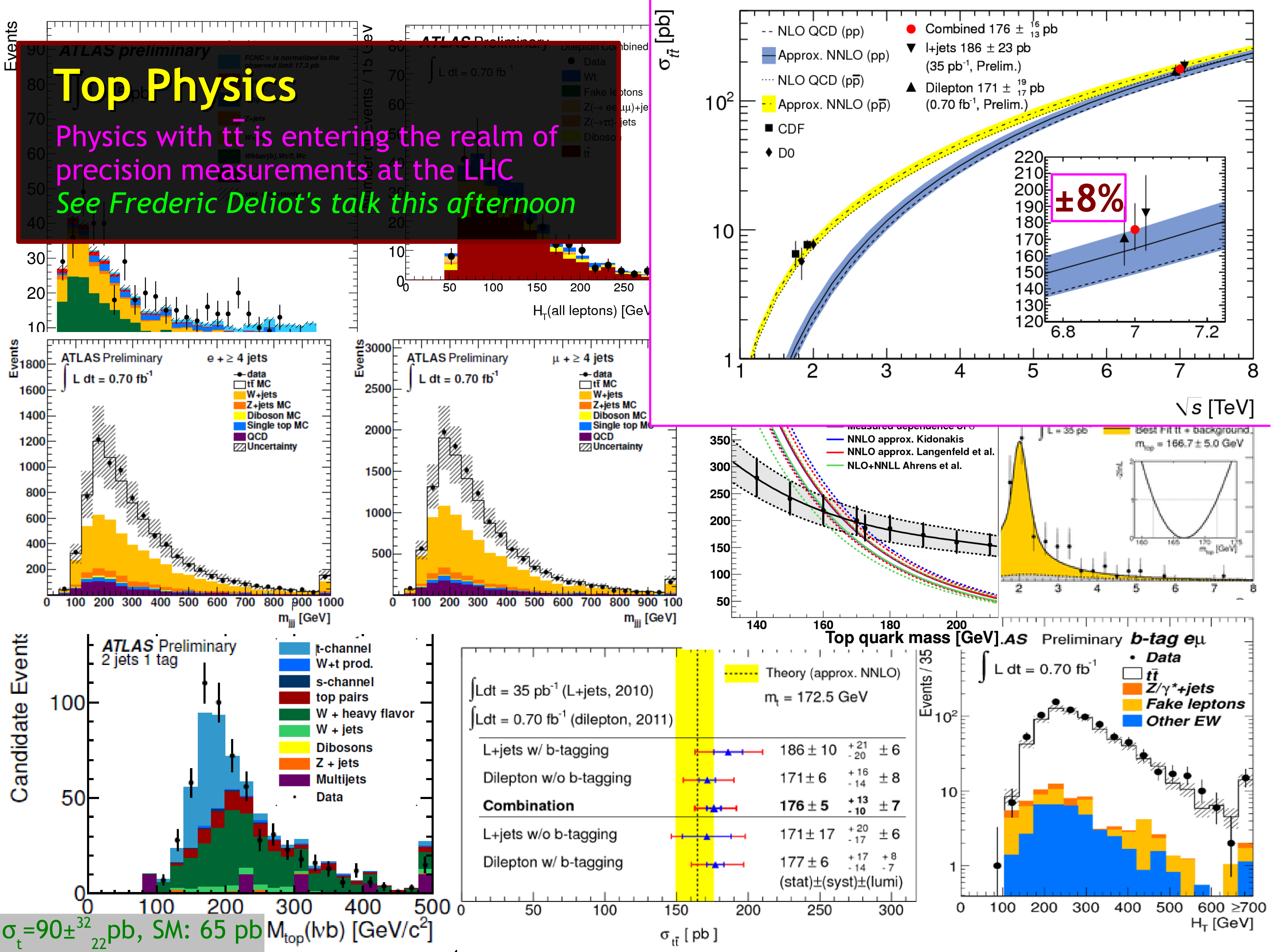


ATLAS Preliminary
∫ L dt = 0.035 - 1.04 fb-1
√s = 7 TeV
Theory
Data 2010 (~35 pb-1)
Data 2011
0.7 fb-1
0.7 fb-1
1 fb-1
1 fb-1
1 fb-1
inner error: statistical
outer error: total
σtotal [pb]
10^5
10^4
10^3
10^2
10
W
Z
Wγ
Zγ
tt̄
t
WW
WZ
ZZ

Top Physics

Physics with $t\bar{t}$ is entering the realm of precision measurements at the LHC

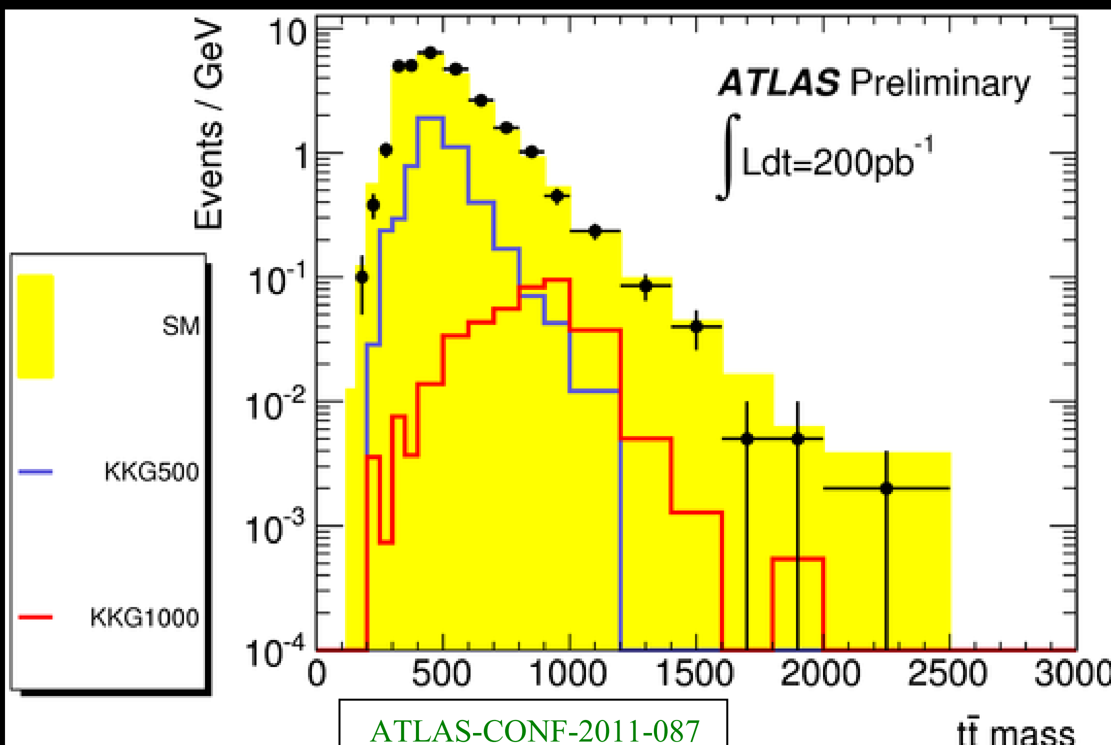
See Frederic Deliot's talk this afternoon

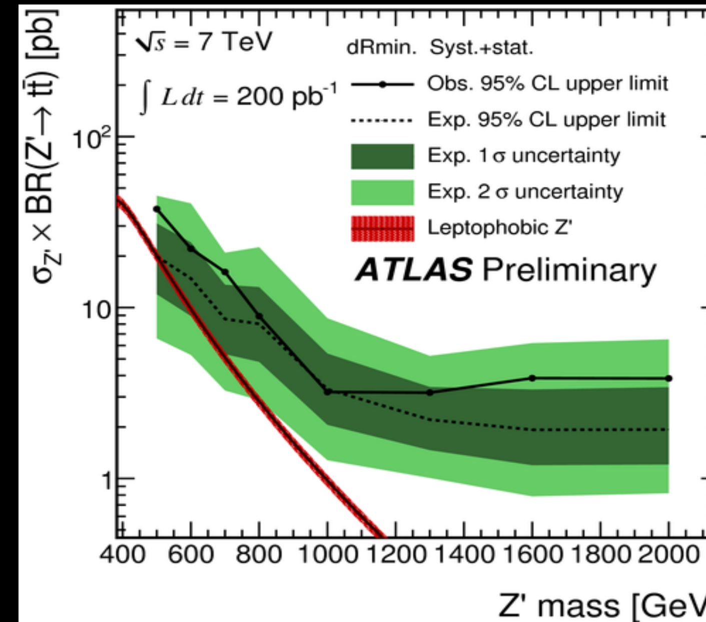


$\sigma_t = 90 \pm^{32}_{22}$ pb, SM: 65 pb

$t\bar{t}$ Resonance Search

Reconstruct semileptonic $t\bar{t}$ events, examine $m(t\bar{t})$ distribution for possible resonances

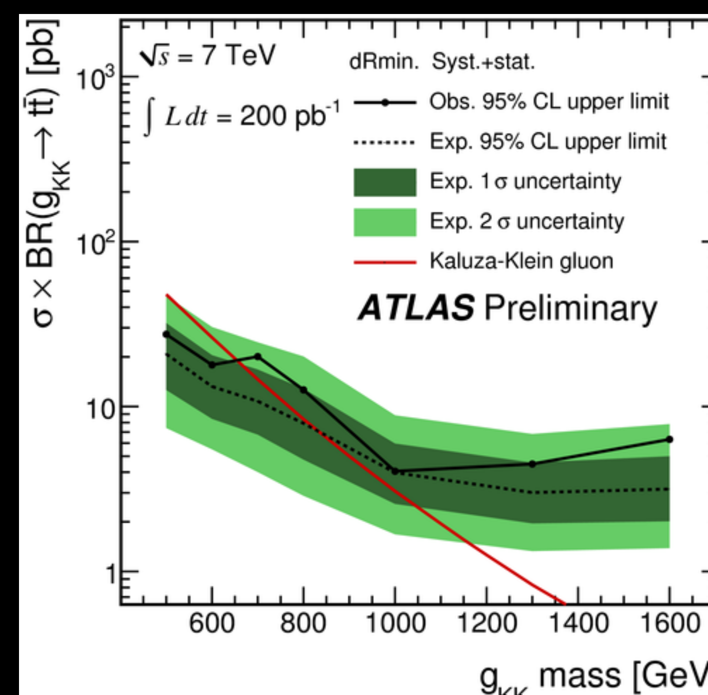




Limits on

- narrow resonance: topcolour $Z' \rightarrow t\bar{t}$ in a leptophobic scenario
- wide resonance (RS model) $g_{KK} \rightarrow t\bar{t}$

Limits on σ.B in few pb range for m_{tt} ~ 1 TeV

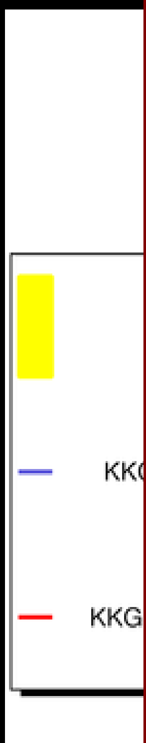


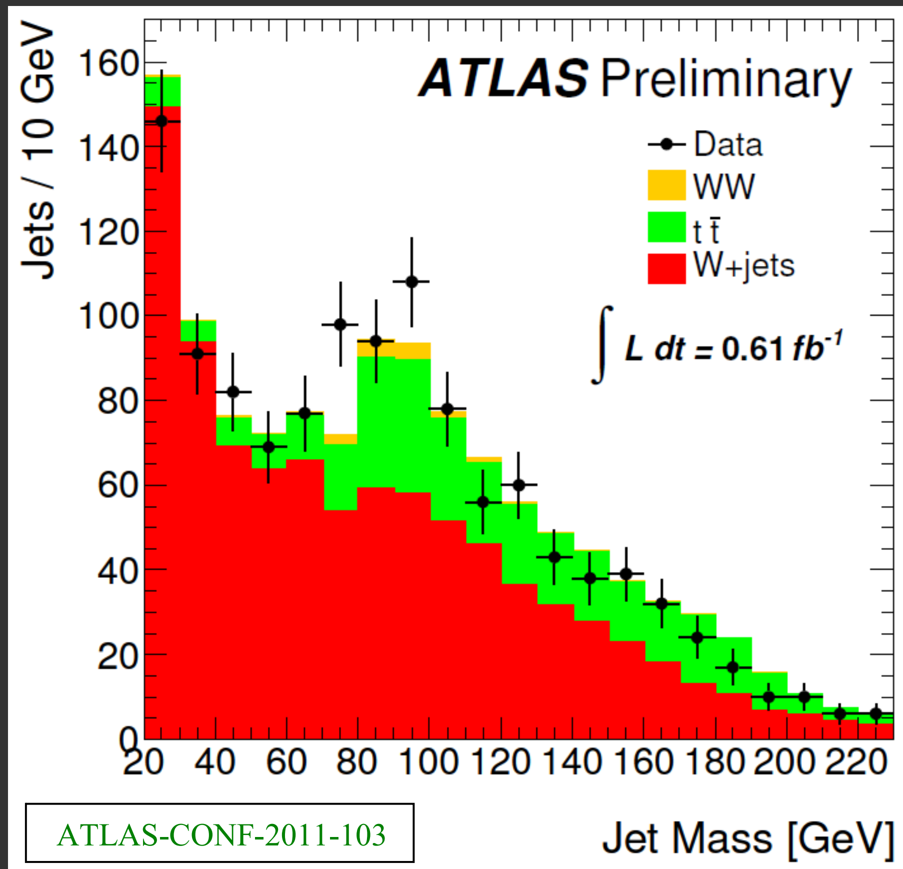
see also T Kuhl parallel talk, R Camacho Toro poster

$t\bar{t}$ R...

Recor...

$m(t\bar{t})$...





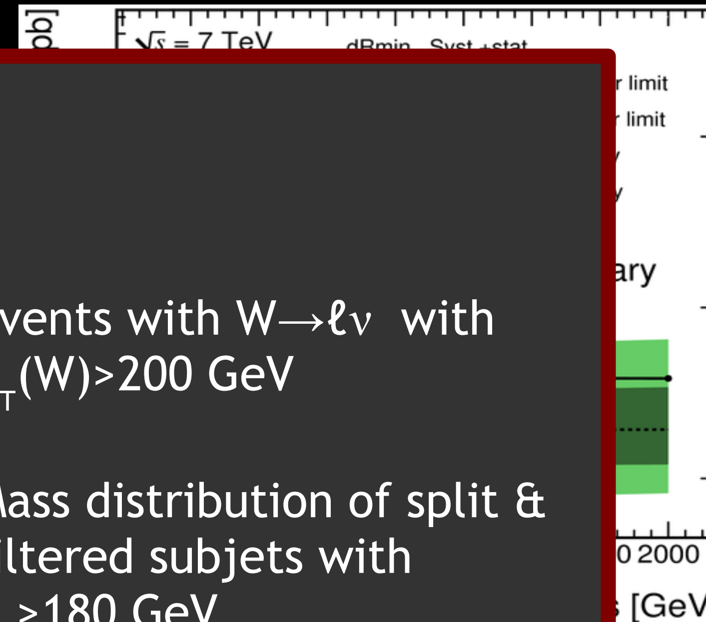
Events with $W\rightarrow\ell\nu$ with $p_T(W)$>200 GeV

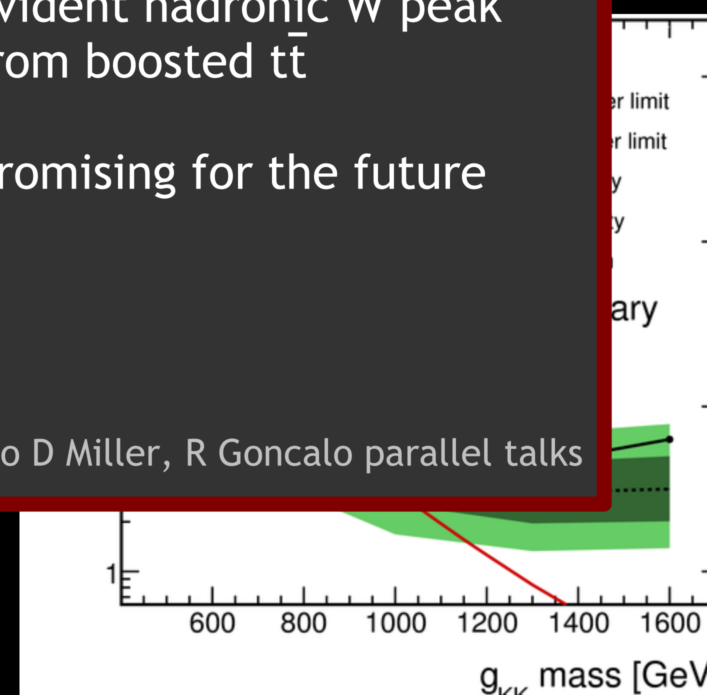
Mass distribution of split & filtered subjets with p_T>180 GeV

Evident hadronic W peak from boosted $t\bar{t}$

Promising for the future

see also D Miller, R Goncalo parallel talks

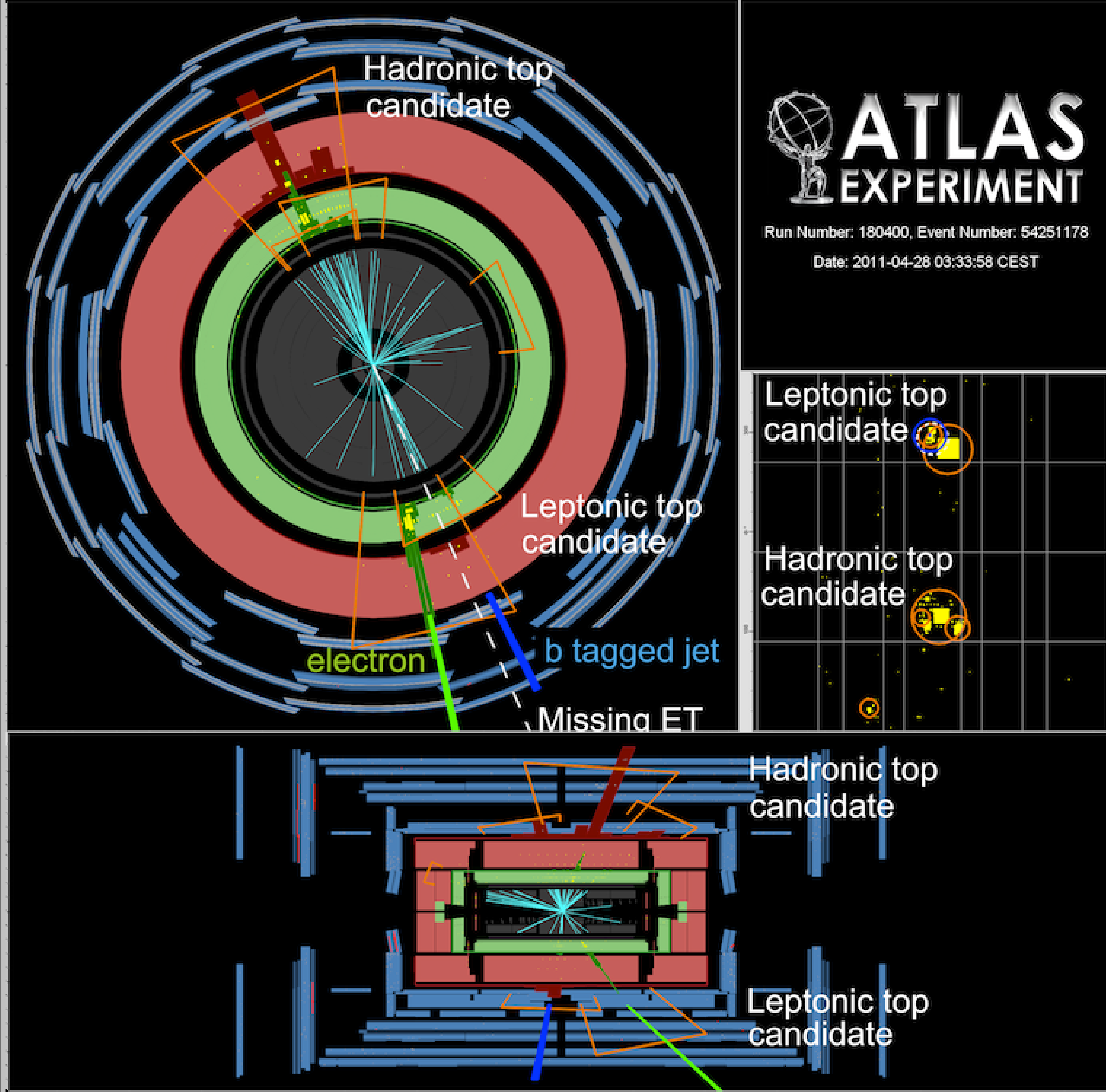




Limi...

- ... leptophobic scenario
- wide resonance (RS model) $g_{KK}\rightarrow t\bar{t}$

Limits on σ.B in few pb range for m_{tt} ~ 1 TeV



Candidate highly-boosted $t\bar{t}$ event

$m(t\bar{t}) \approx 1.6$ TeV

Wealth of searches in ATLAS look for SUSY signatures in various topologies

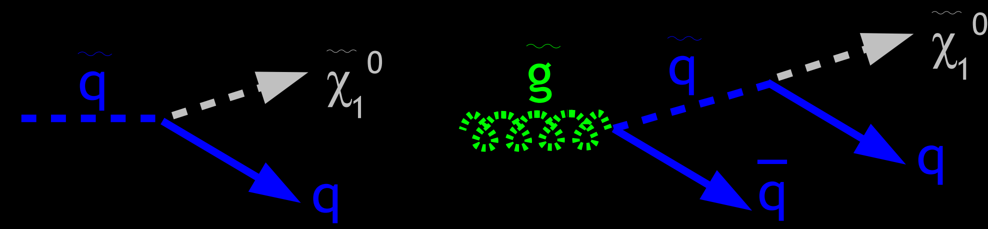
ATLAS has results from:

- Zero leptons, jets and E_T^{miss}
- Zero leptons, b-jets and E_T^{miss}
- One lepton, jets and E_T^{miss}
- Lepton pairs and E_T^{miss} – like flavour/like sign/opposite sign
- Multileptons, jets and E_T^{miss}
- $\gamma\gamma$ and E_T^{miss}
- RPV $\tilde{\nu}_\tau \rightarrow e\mu$ (earlier)
- R-hadrons in inner tracker and calorimeter
- Stable $\tilde{\tau}$ or gluino R-hadrons, via muon system

see also H Hayward, P Jackson, A Taffard, I Vivarelli parallel talks, J Lorenz poster

SUSY in 0-lepton channel

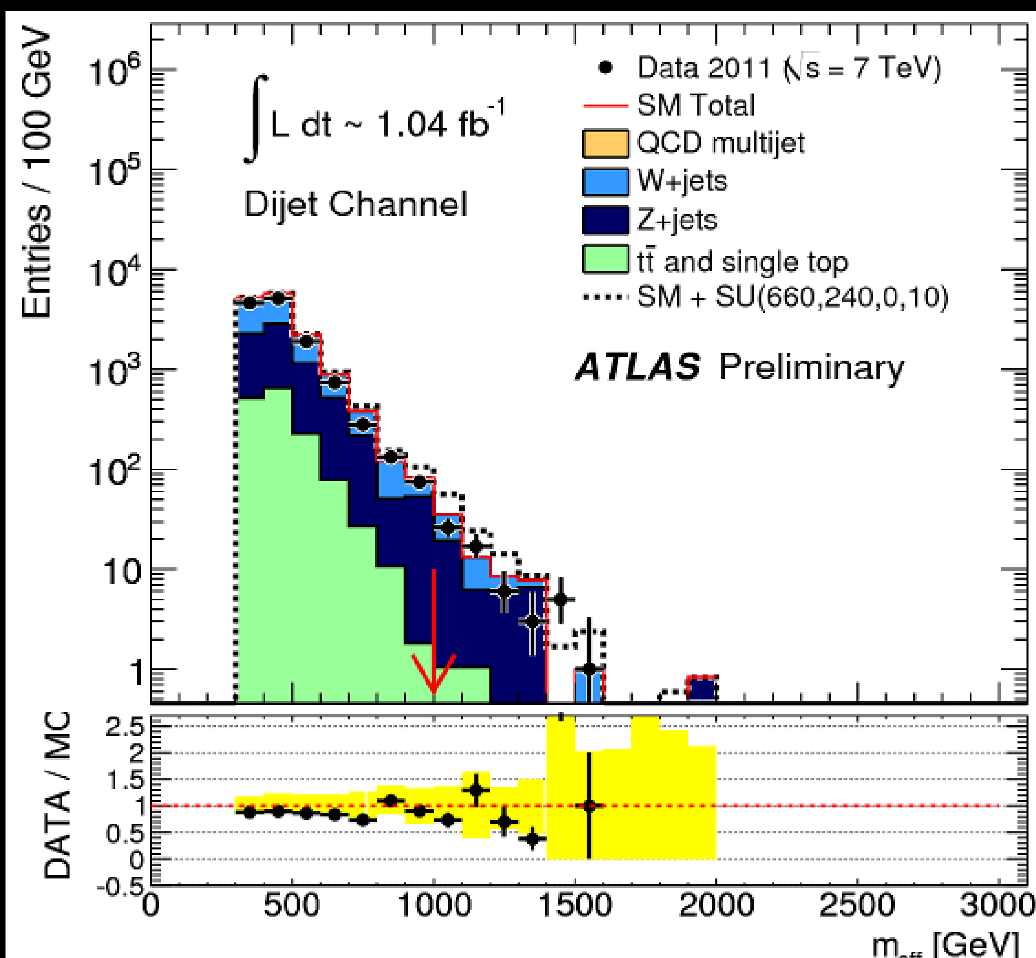
Strong production: $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, $\tilde{q}\tilde{q}$

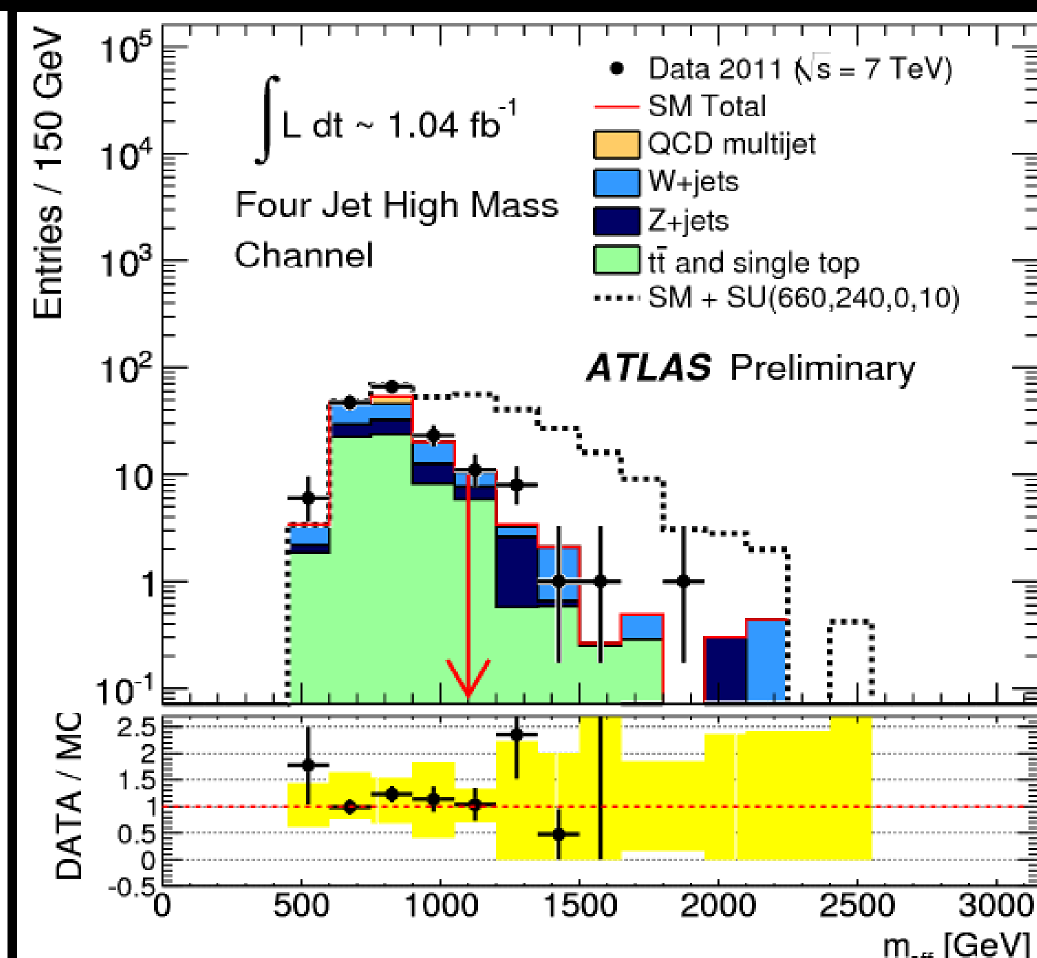


Multi-jet plus E_T^{miss}, e/μ veto

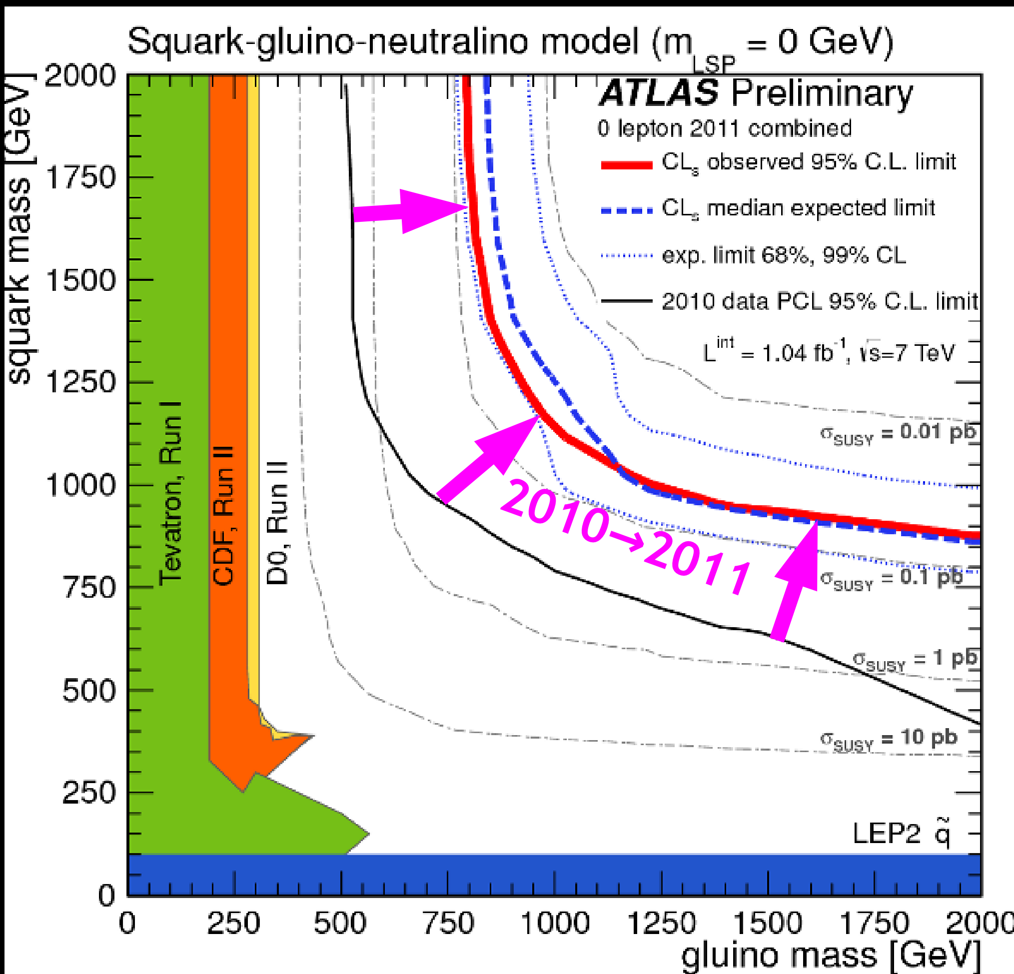
Analysis includes ≥4 jet event category

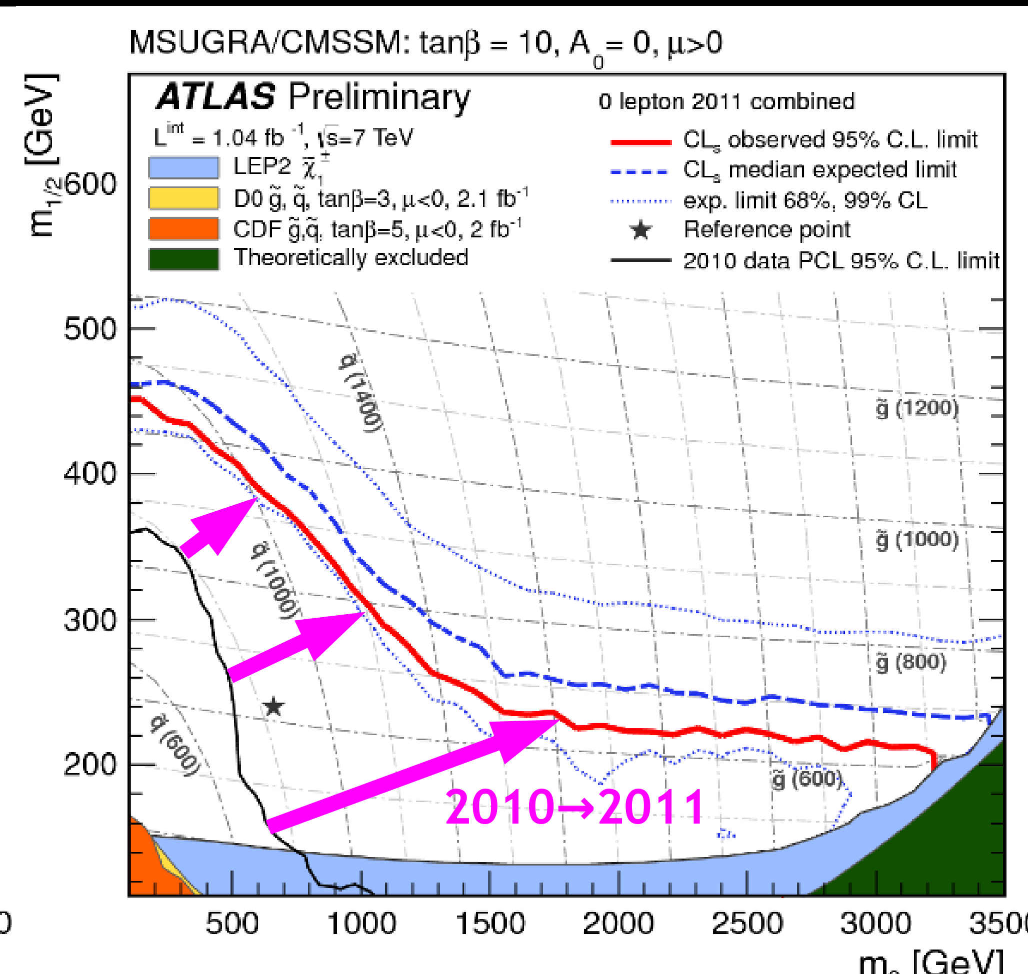
$$m_{eff} = E_T^{miss} + \sum_1^n p_T^{jet}$$





SUSY in 0-lepton channel





Simplified model with two $\tilde{q}$ generations, $m(\tilde{\chi}_1^0)$~0

$m_{\tilde{g}}$>800 GeV $m_{\tilde{q}}$>850 GeV

Equal mass case: $m_{\tilde{g}}=m_{\tilde{q}}$>1.075 TeV

MSUGRA/CMSSM: tanβ=10, A_0=0, μ>0

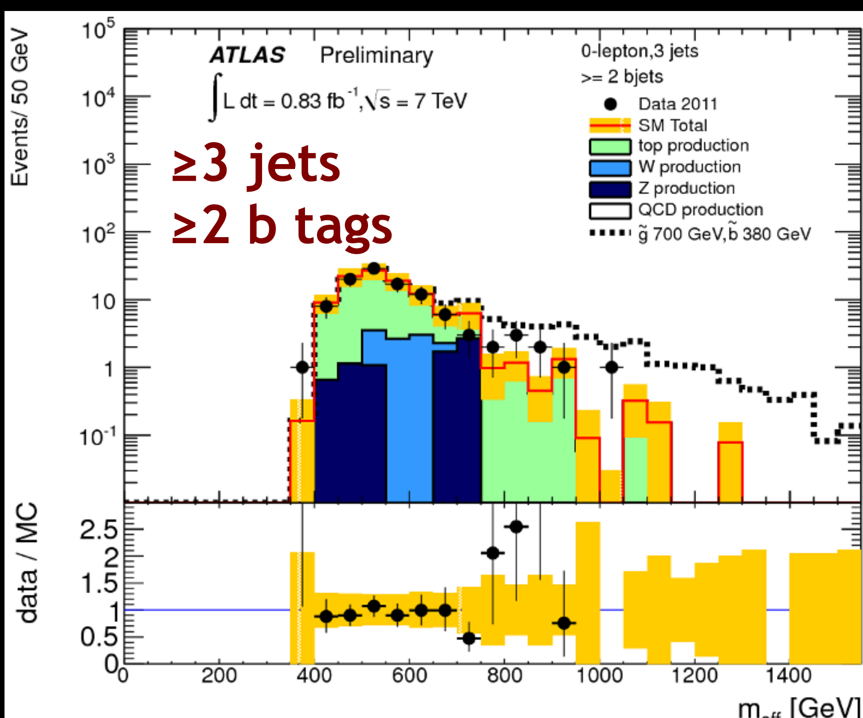
Equal mass case: $m_{\tilde{q}}=m_{\tilde{g}}$ > 980 GeV

SUSY in 0ℓ+b-jets channel

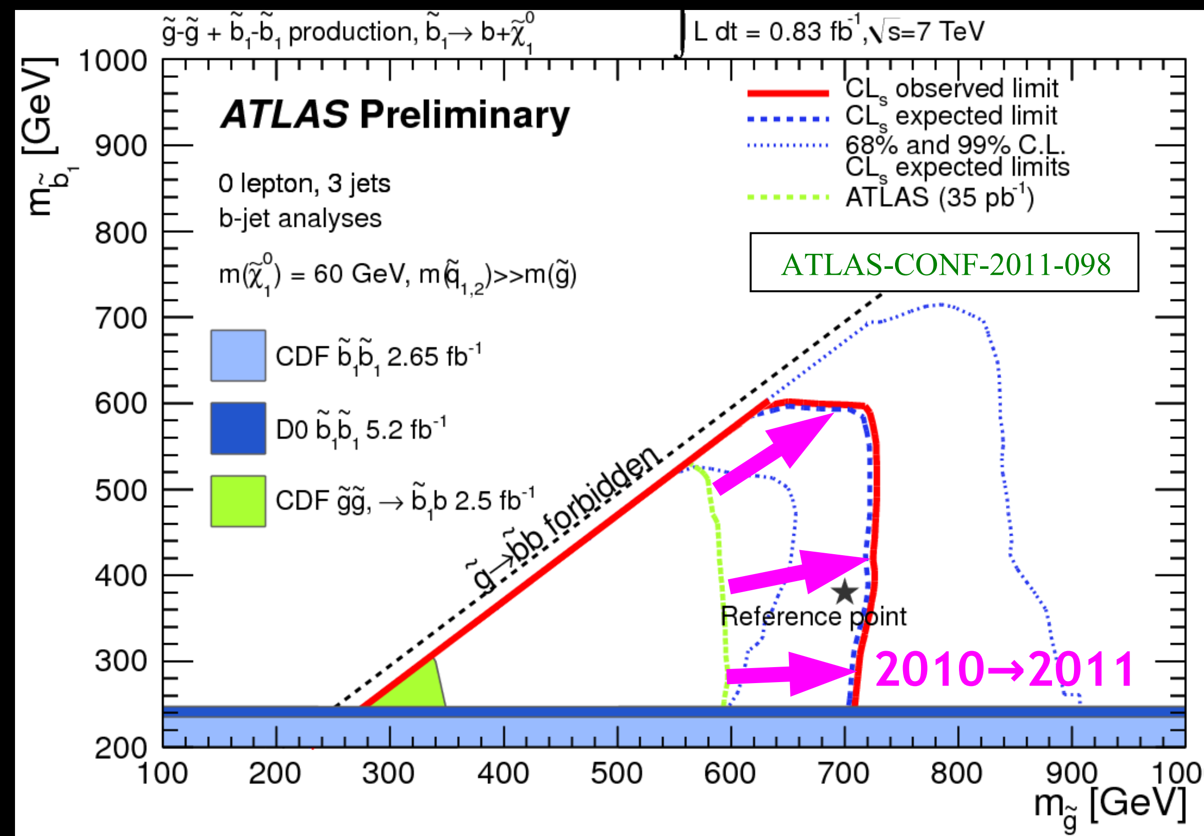
Models in which $\tilde{b}_1$ or $\tilde{t}_1$ is lightest squark

→ $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, $\tilde{q}\tilde{q}$ production/decay gives final-states with b-quarks and E_T^{miss}

Jets and E_T^{miss} topology, at least one b-tagged



$$m_{eff}=E_T^{miss}+p_T^{j1}+p_T^{j2}+p_T^{j3}$$



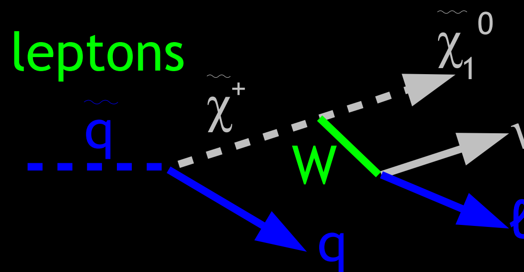
Hypothesis: $\tilde{g}\tilde{g}$ and $\tilde{b}_1\tilde{b}_1$ production,

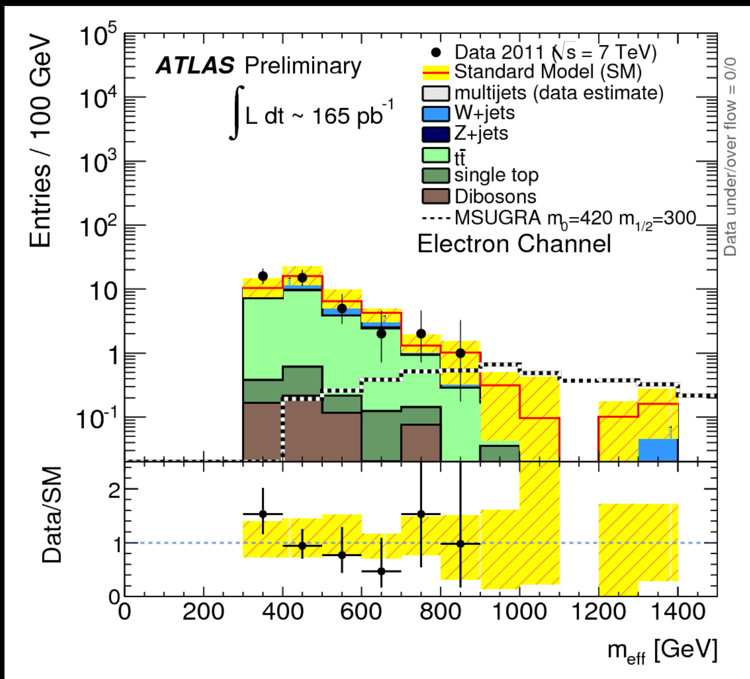
$m(\tilde{\chi}_1^0)$=60 GeV, $\tilde{b}_1 \rightarrow b\tilde{g}$ 100% BR

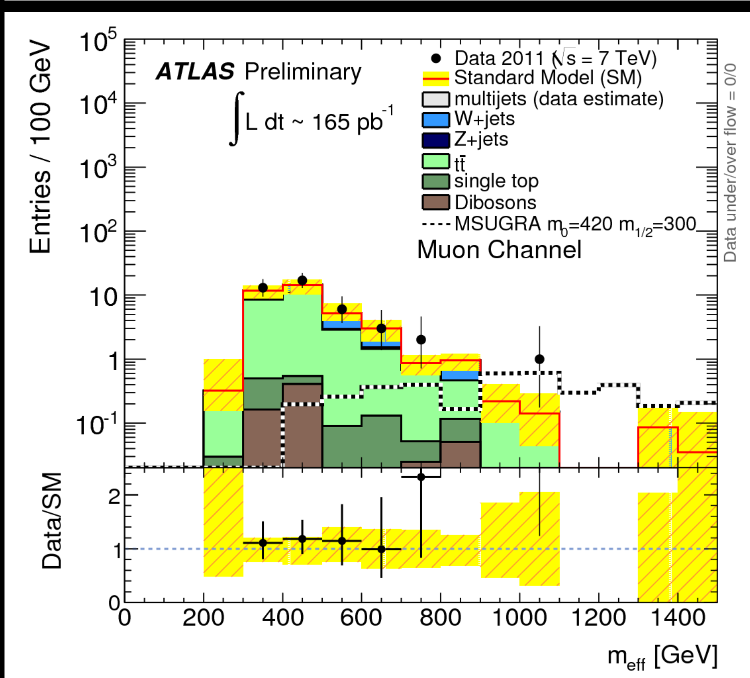
SUSY in 1-lepton channel

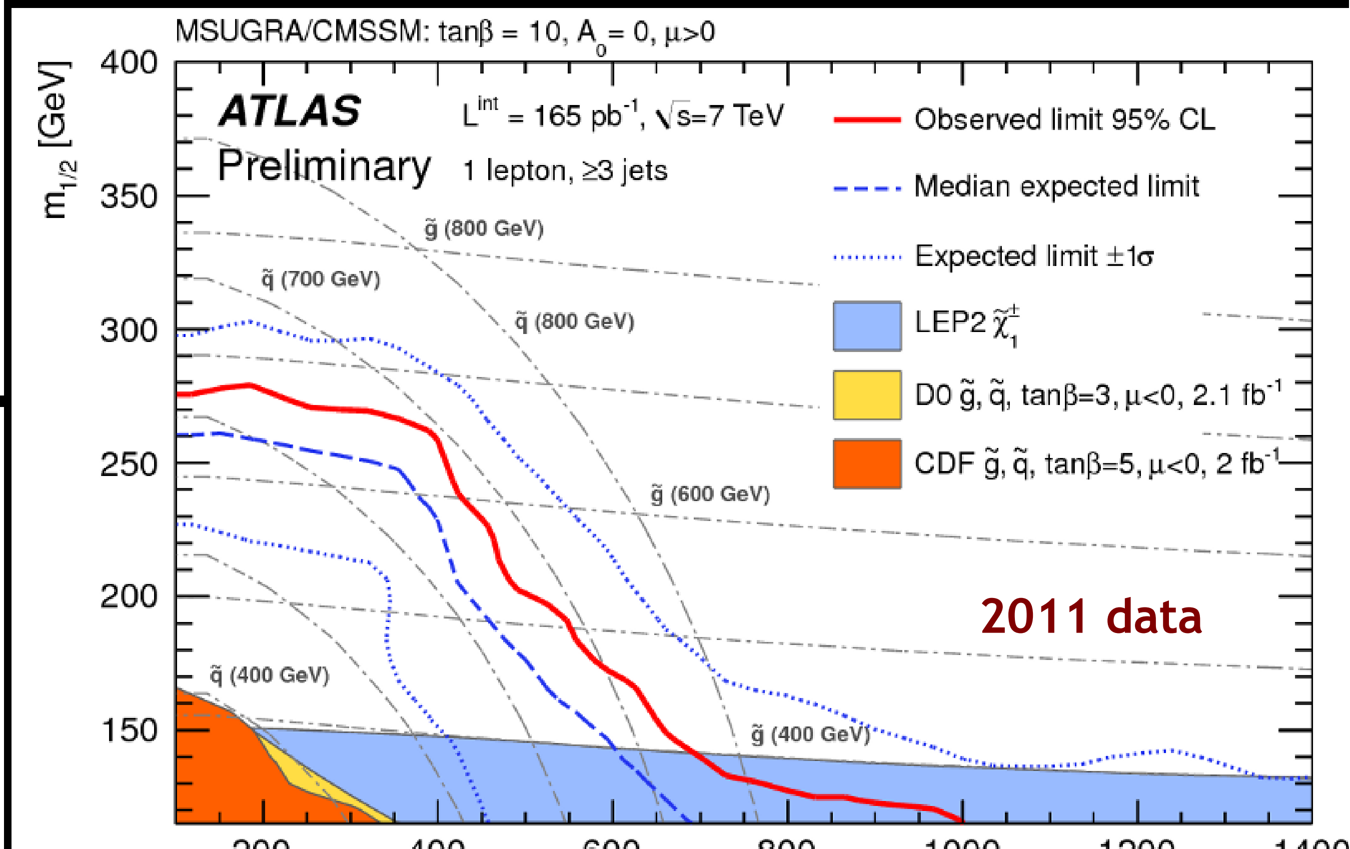
$\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, $\tilde{q}\tilde{q}$ may give isolated leptons

Single e/μ, jets, E_T^{miss}









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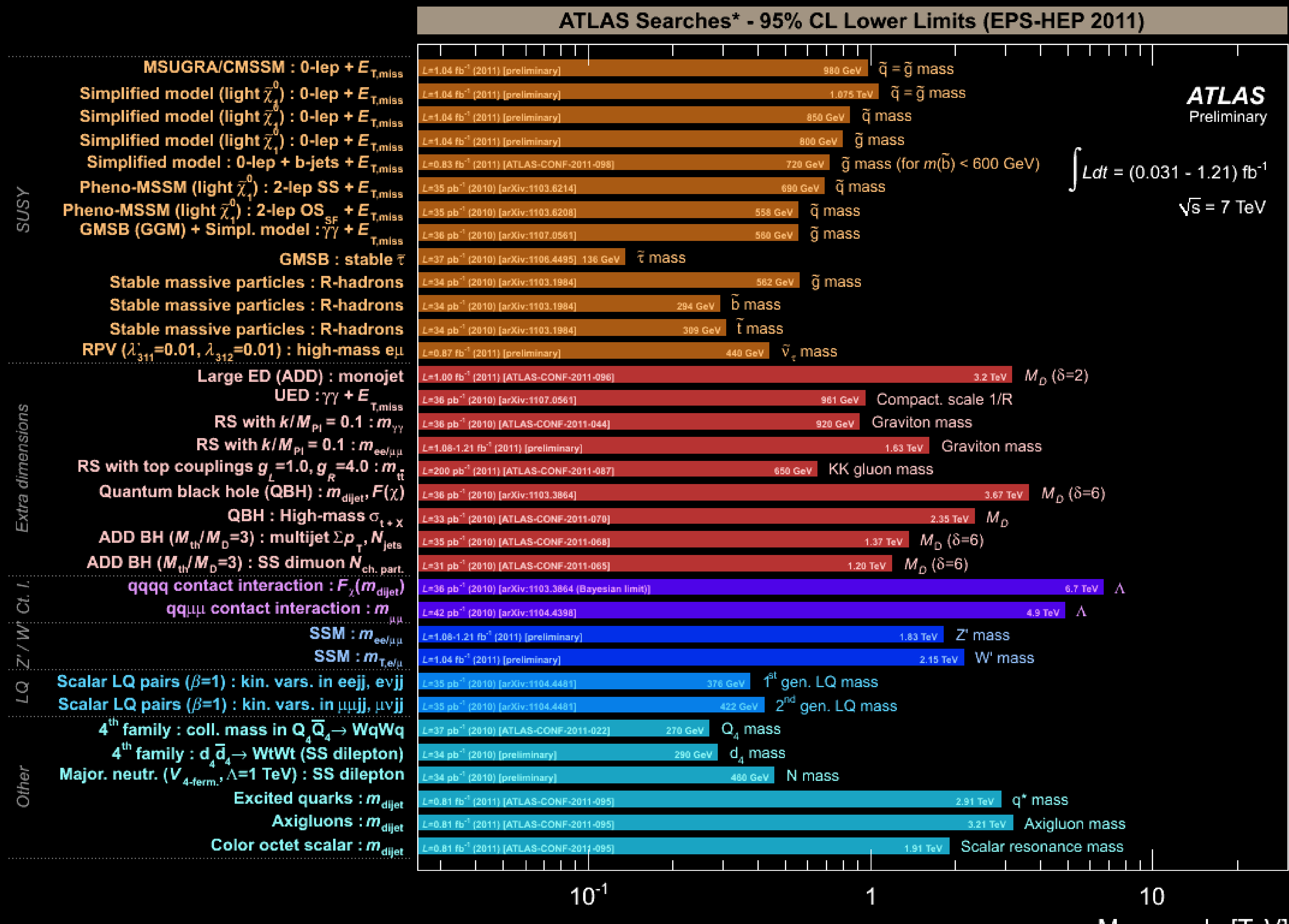


*Only a selection of the available results shown

LHC Higgs results will be discussed by Bill Murray on Wednesday afternoon

Here I show just a few Higgs highlights from ATLAS data

ATLAS has results **with >1 fb^{-1}** on:

- $H \rightarrow \gamma\gamma$
- $H \rightarrow ZZ^{(*)} \rightarrow \ell\ell\ell\ell$
- $H \rightarrow ZZ \rightarrow \ell\ell\nu\nu$
- $H \rightarrow ZZ \rightarrow \ell\ell qq$
- $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$
- $H \rightarrow WW \rightarrow \ell\nu qq$
- $WH \rightarrow \ell\nu bb$
- $ZH \rightarrow \ell\ell bb$
- Combined limits

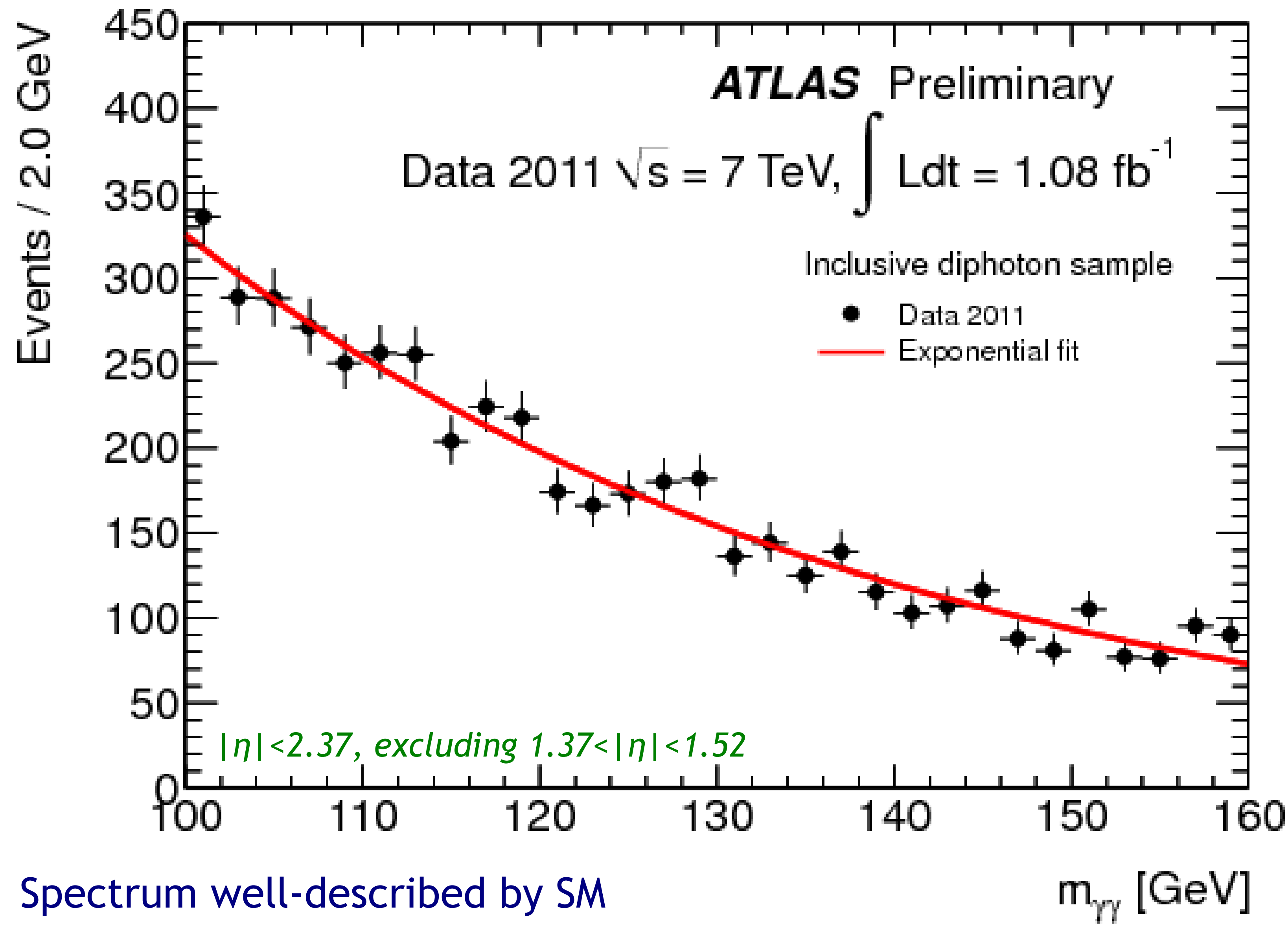
Cut-based analyses preferred at this stage

All Higgs results shown use cut-based techniques

see also M Kado, K Nikolopoulos, J Strandberg, R Goncalo, K Cranmer parallel talks, X Ruan, P Conde Muino posters

$H \rightarrow \gamma\gamma$

Mass resolution σ for 120 GeV H is ~1.7 GeV (2010 calibration)



Spectrum well-described by SM

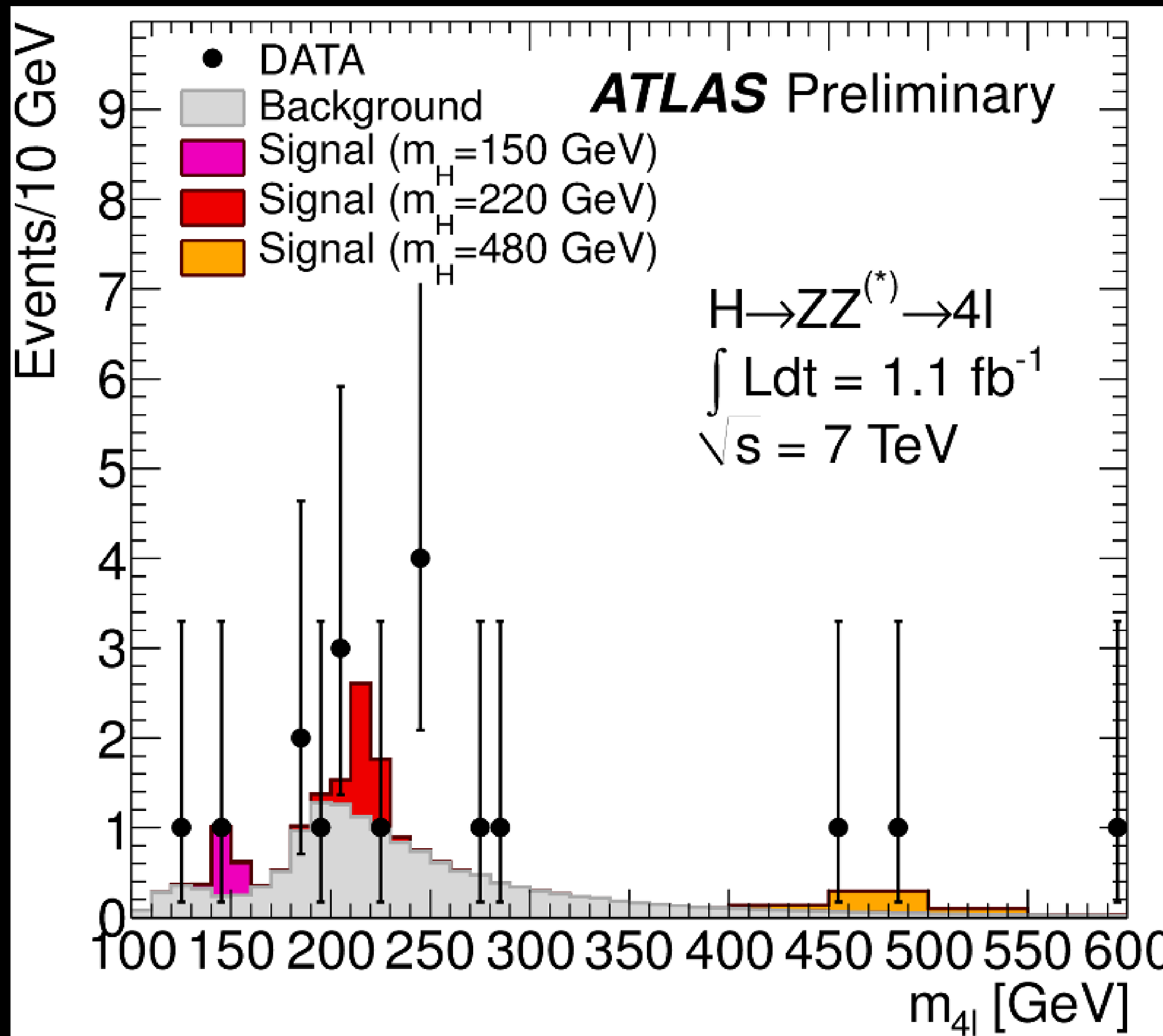
$H \rightarrow ZZ^{(*)} \rightarrow 4\ell$

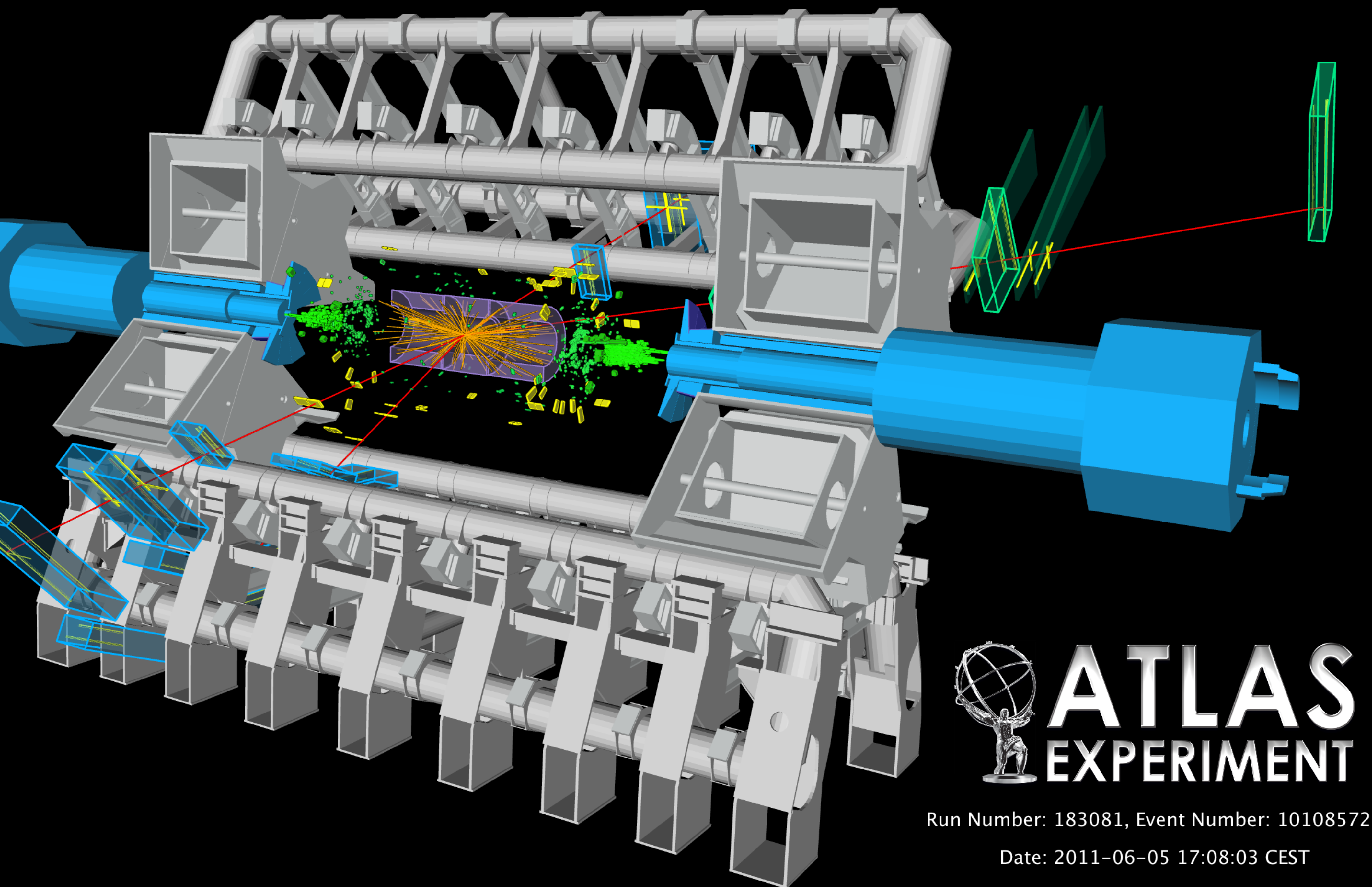
Excellent mass resolution and signal/background

Low product branching ratio

Useful below ZZ threshold

- Leptons 3 and 4 down to 7 GeV
- Low and high-mass selections - divide at 180 GeV



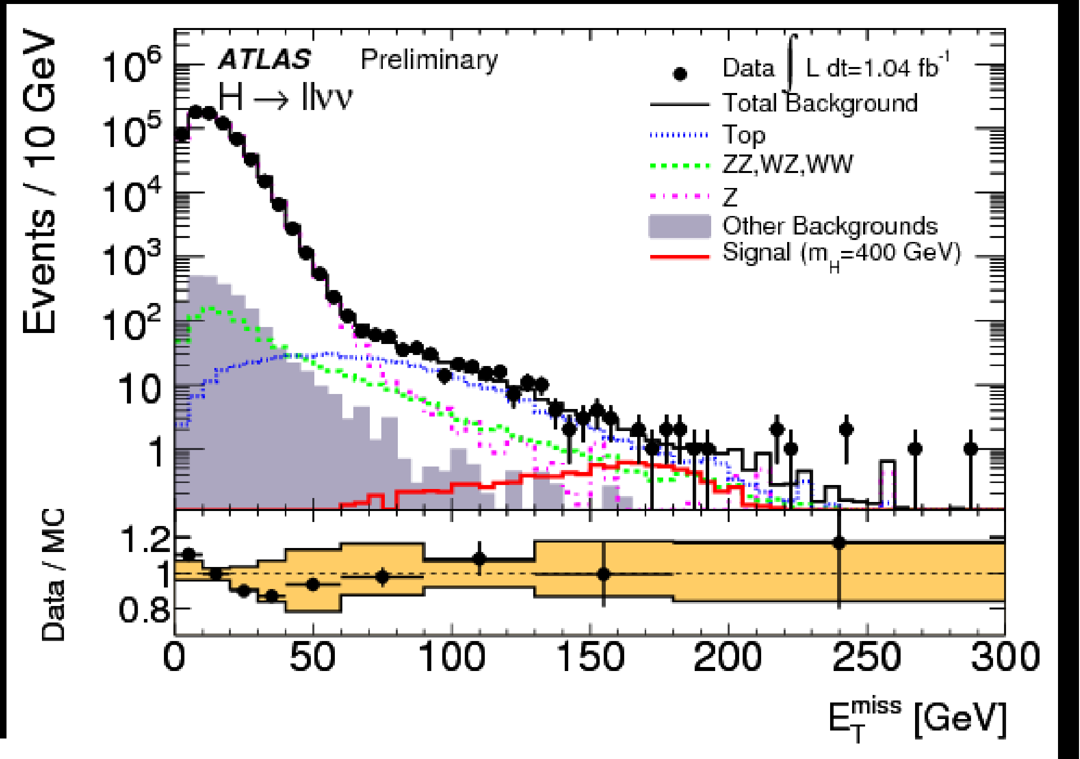


A $ZZ^* \rightarrow 4\mu$ candidate $m_{Z,1}$=90.6 GeV, $m_{Z^*,2}$=47.4 GeV, $m_{4\mu}$=143.5 GeV

$H \to ZZ \to \ell\ell\nu\nu$

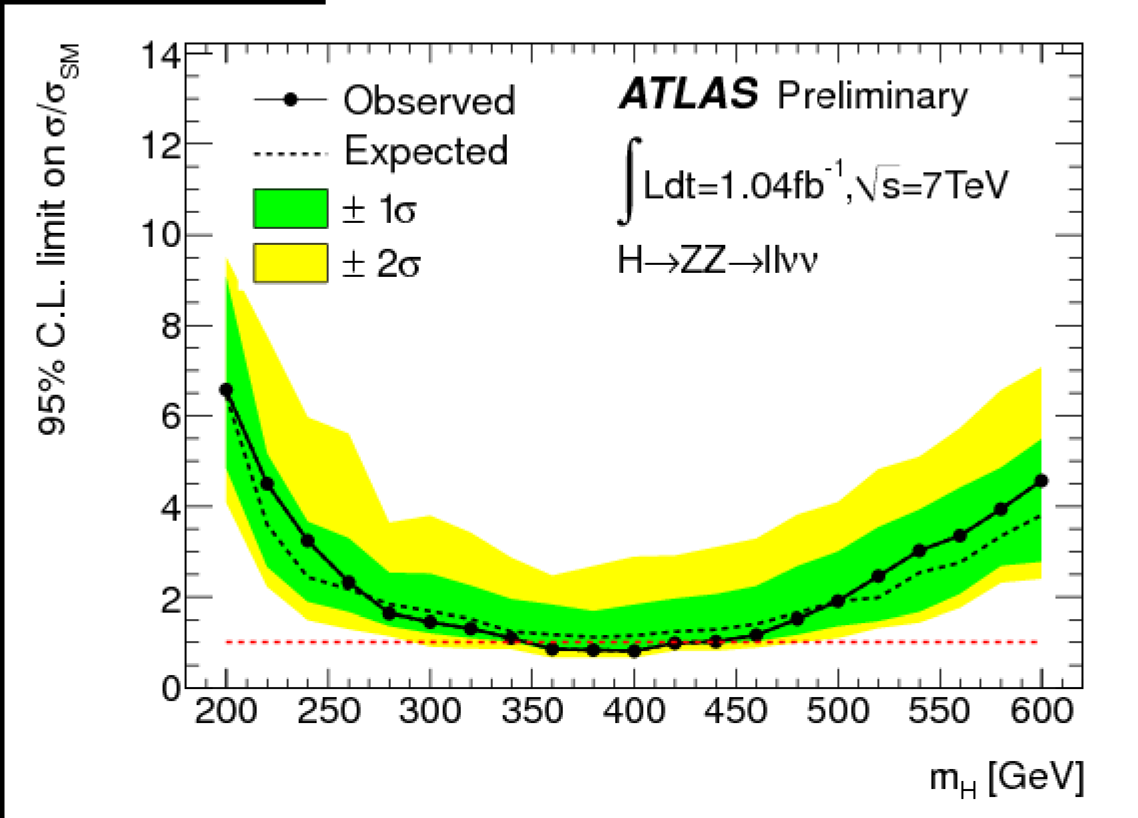
Powerful channel at high mass (BR vs S:B)

Select $Z \to \ell\ell$, angle cuts, veto b-jets, require high E_t^{miss}



Exclude at 95% CL $360 < m_H < 420$ GeV

Single channel high mass SM Higgs exclusion



H → WW → ℓνℓν

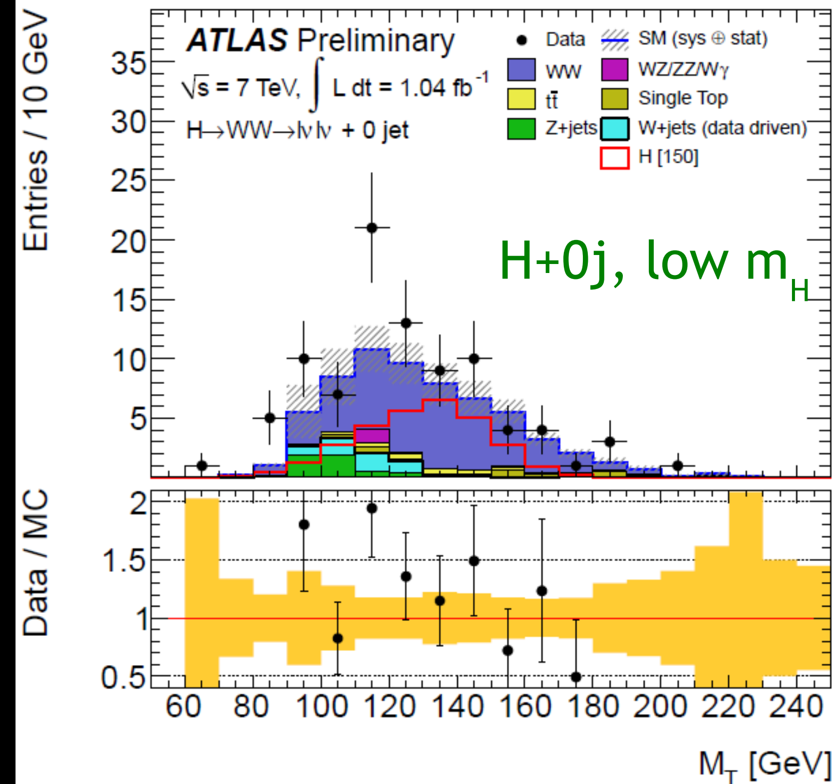
Two isolated high-p_T leptons

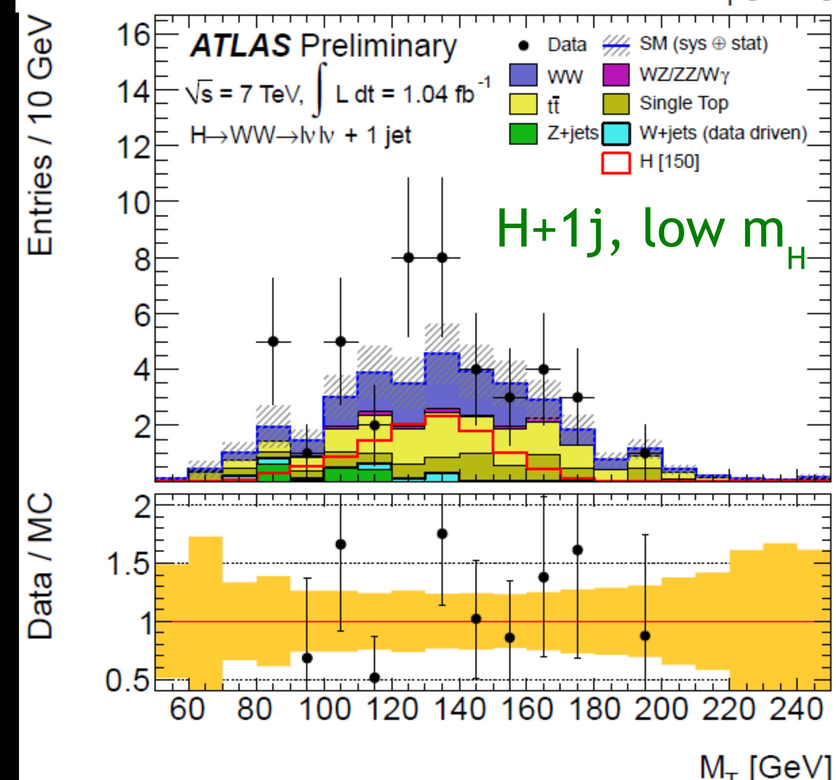
- Cuts to suppress Drell-Yan background
- Significant E_T^{miss}
- Use expectation for scalar H: leptons not well separated
- Divide into 0 and 1-jet categories
- Slice transverse mass distribution:

$$0.75m_H < m_T < m_H$$

Selected events for m_H=150 GeV mass hypothesis

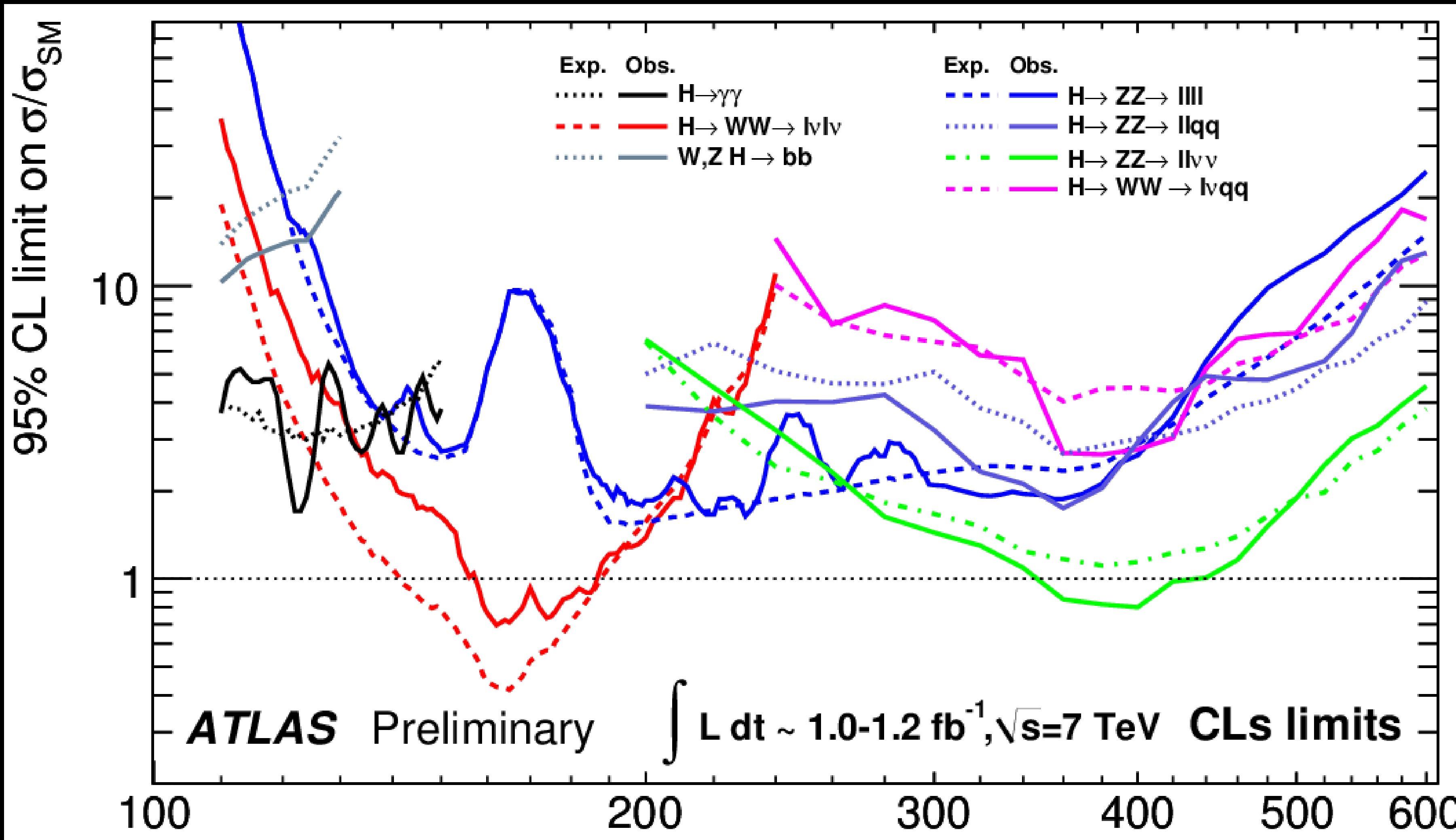
	total bkgd	data	signal expectn
0-jet			
ee	4.7±1.2	7	3.1±0.7
eμ	17±2	21	11±2
μμ	11±3	21	6.9±0.5
ℓℓ	**33±5**	**49**	**21±4**
1-jet			
ee	2.0±1.2	4	0.9±0.3
eμ	8.8±1.9	8	4.0±0.9
μμ	3.9±1.7	9	2.3±0.5
ℓℓ	**15±3**	**21**	**7.2±1.6**





Comparing Constraints

All analysed channels



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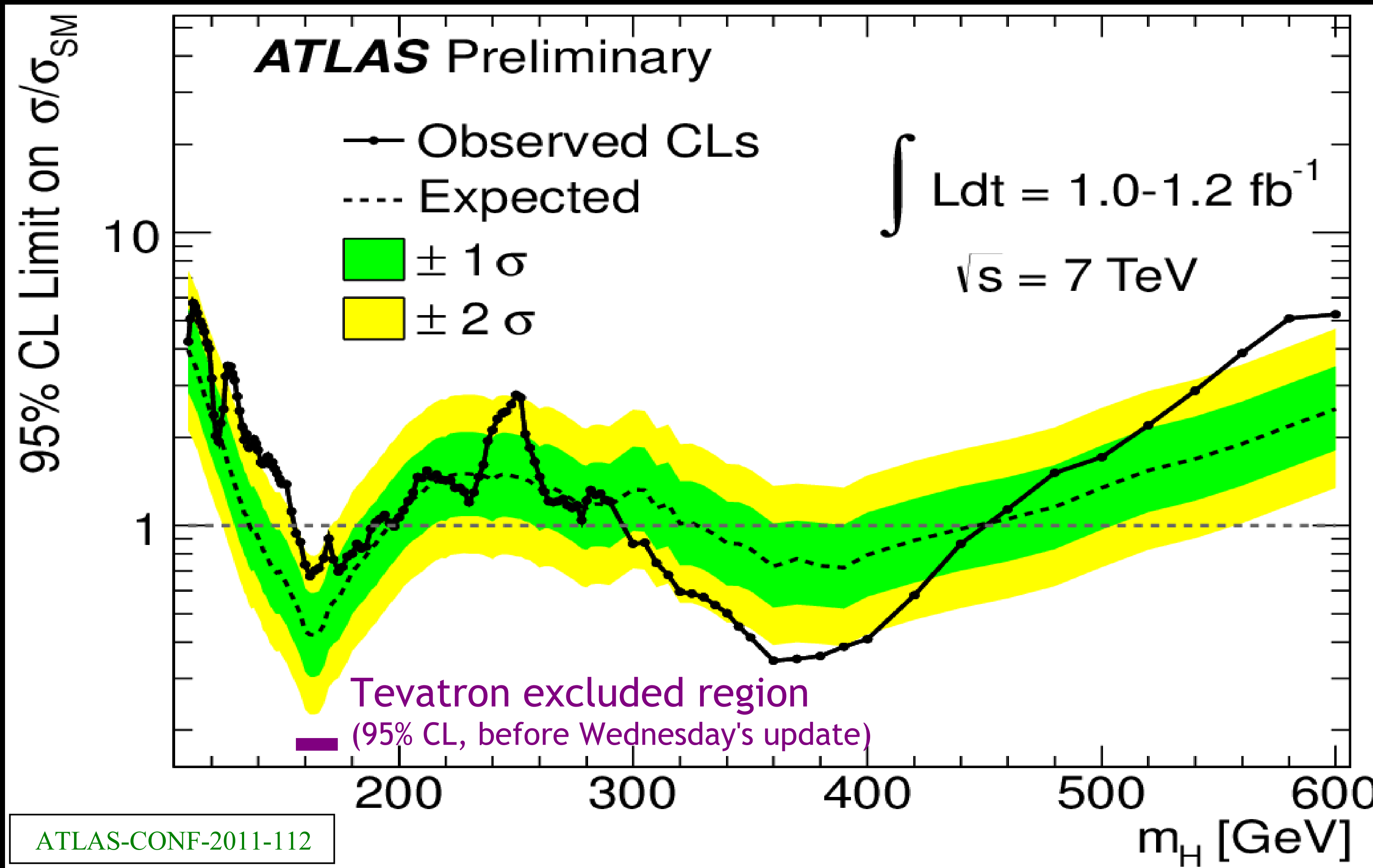
Combined Constraints

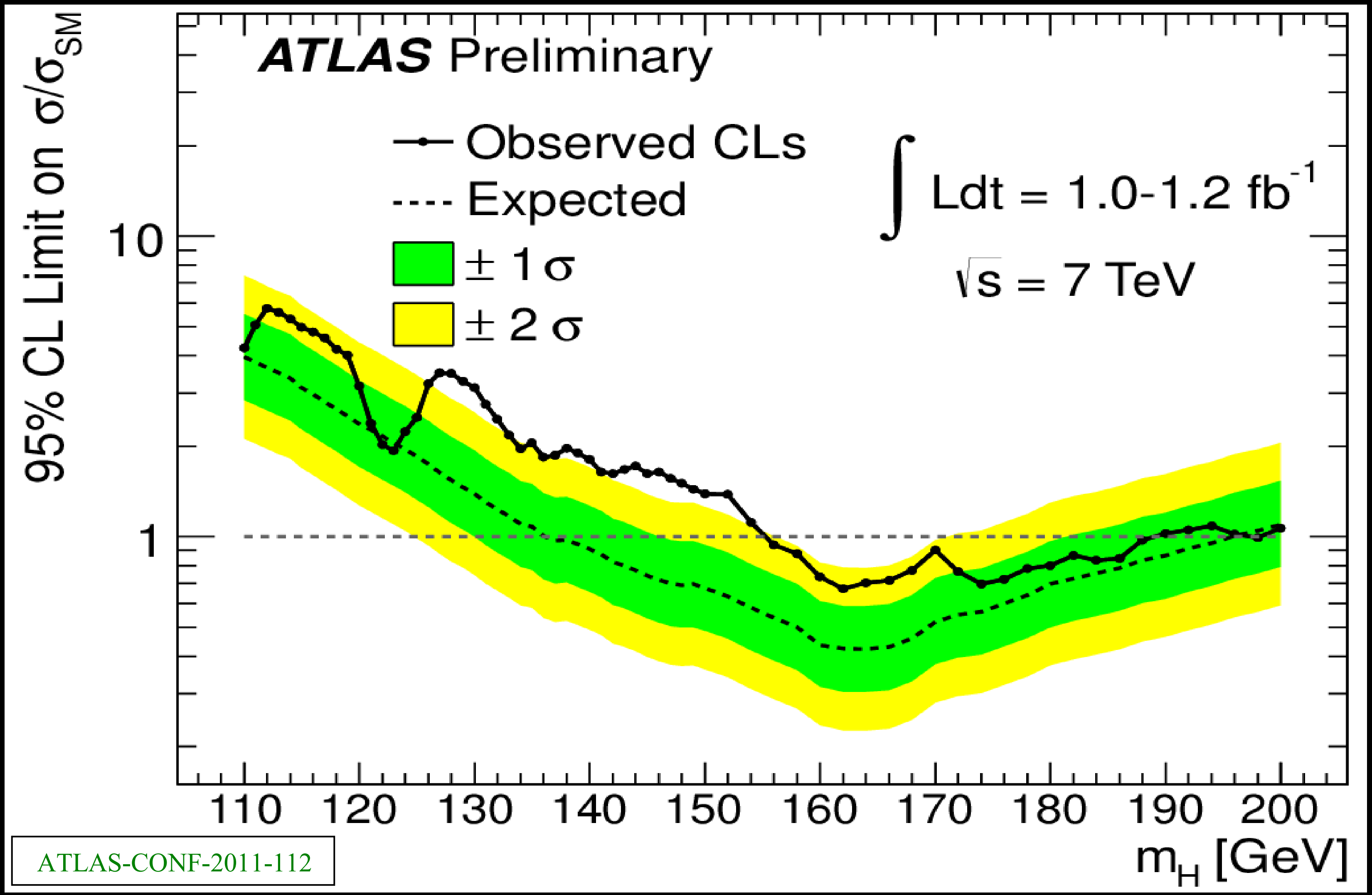
Combining all analysed channels



ATLAS excludes 155 < m_H < 190 GeV and 295 < m_H < 450 GeV at 95% CL

LHC provides first direct exclusion above 200 GeV, and helps widen the excluded range below 200 GeV

The Low Mass Region Is there more to say yet?

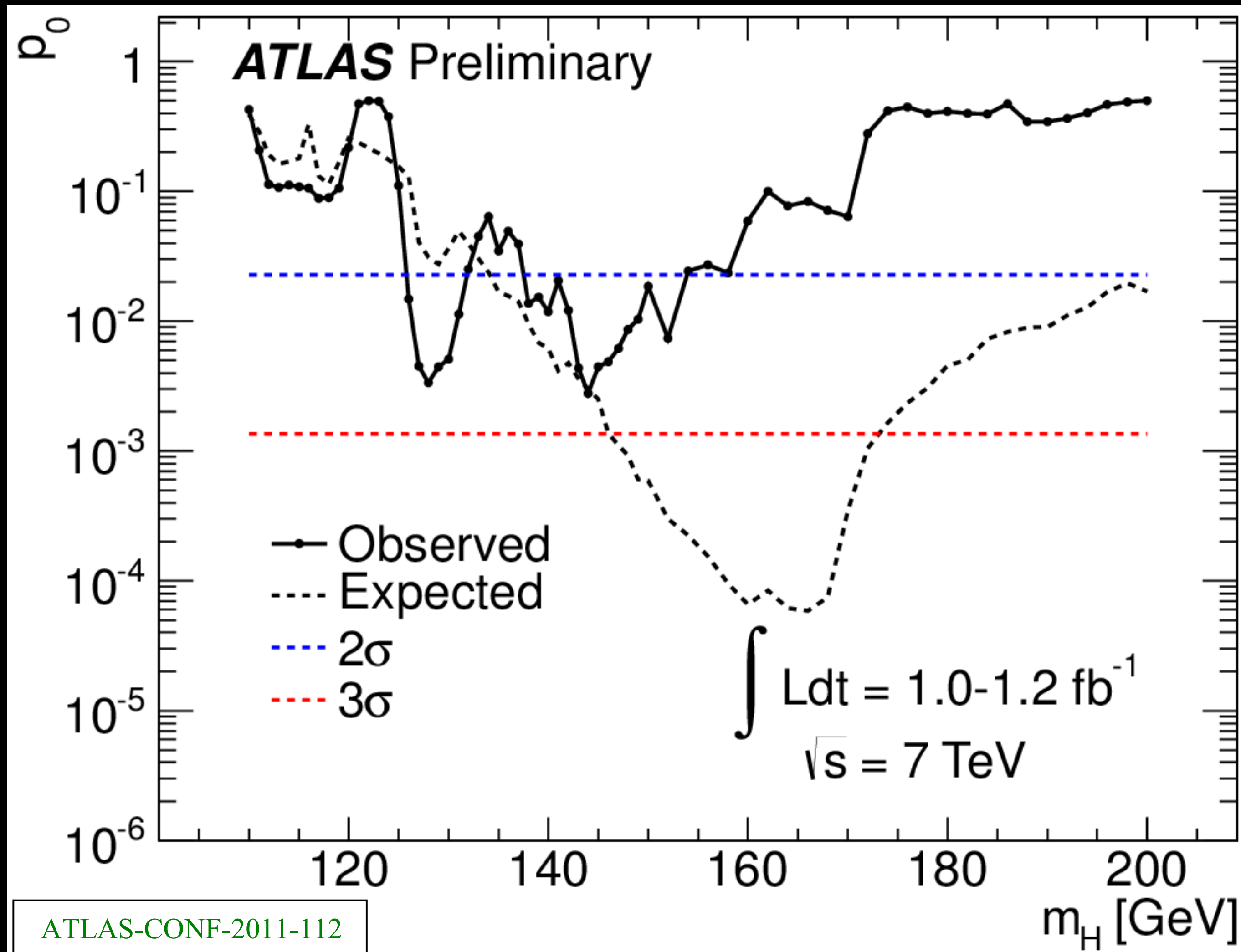


Limit on σ/σ_{SM} from data is generally rather poorer than median expectation if no Higgs

Is it a fluctuation, or a background, or something else?

The Low Mass Region

Consistency with background-only hypothesis



Least consistent point has a p-value corresponding to ~2.8σ
But the look-elsewhere effect can be large

The LHC and ATLAS are working very well

Many many thanks to our LHC colleagues for the superb performance of the collider

An abundance of important measurements now available at $\sqrt{s}$ = 7 TeV

Now pushing deep into unexplored regions of phase-space with both simple and complex search topologies

Major increase in sensitivity with 1 fb^{-1} of 2011 data

As yet, no significant/conclusive evidence of Higgs production: ATLAS excludes, at 95% CL, production of a Standard Model Higgs boson over 155-190 GeV and 295-450 GeV

https://twiki.cern.ch/twiki/bin/view/AtlasPublic