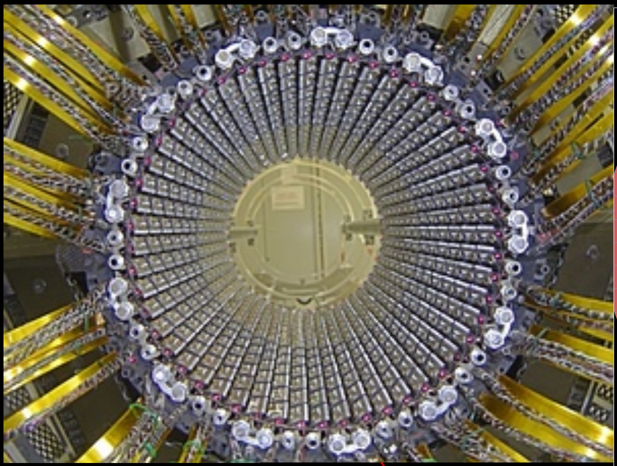
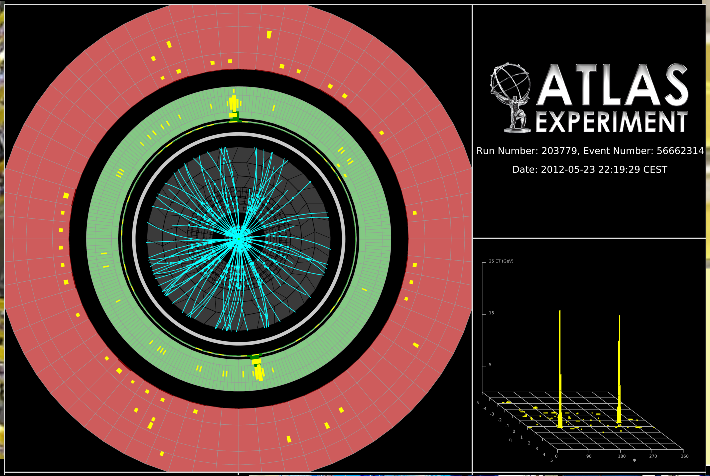
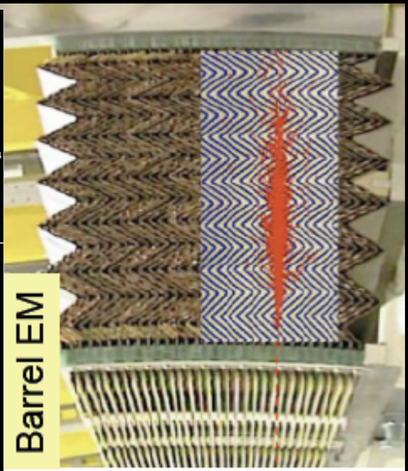
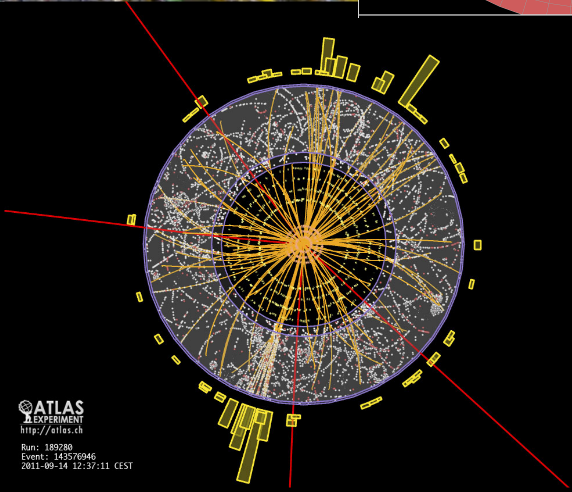
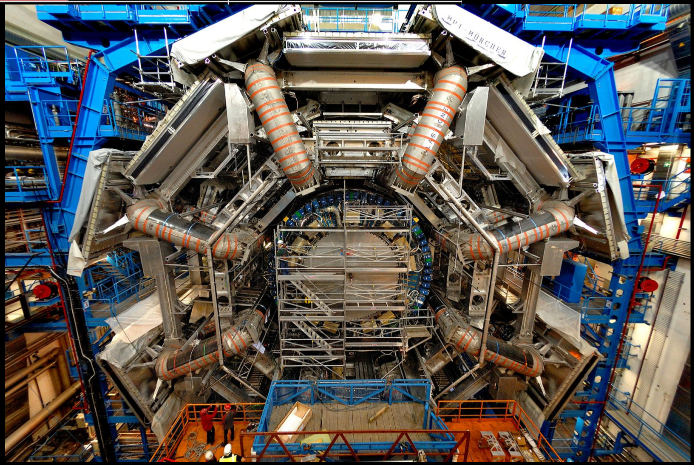
ATLAS Highlights and Outlook









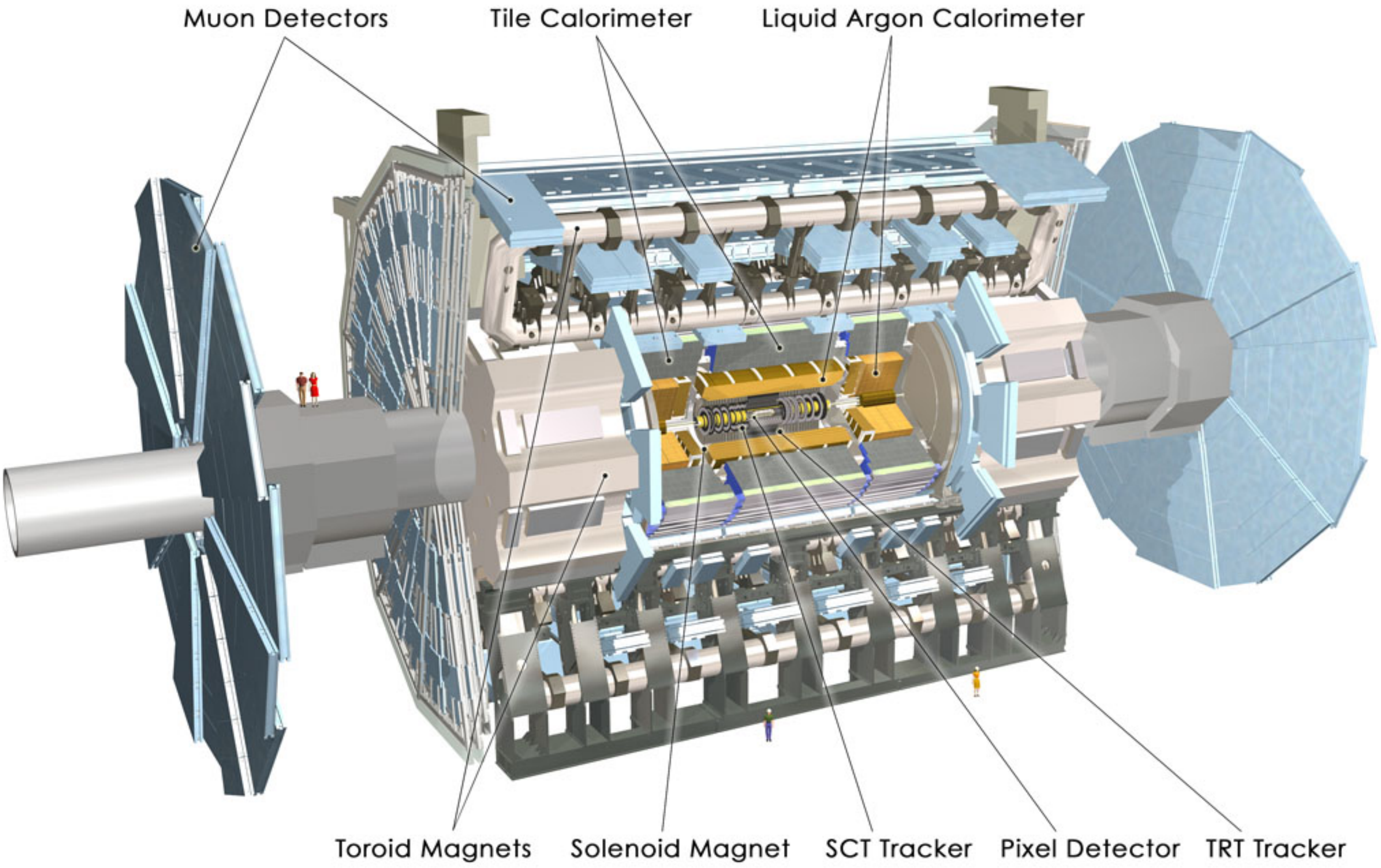


Beate Heinemann

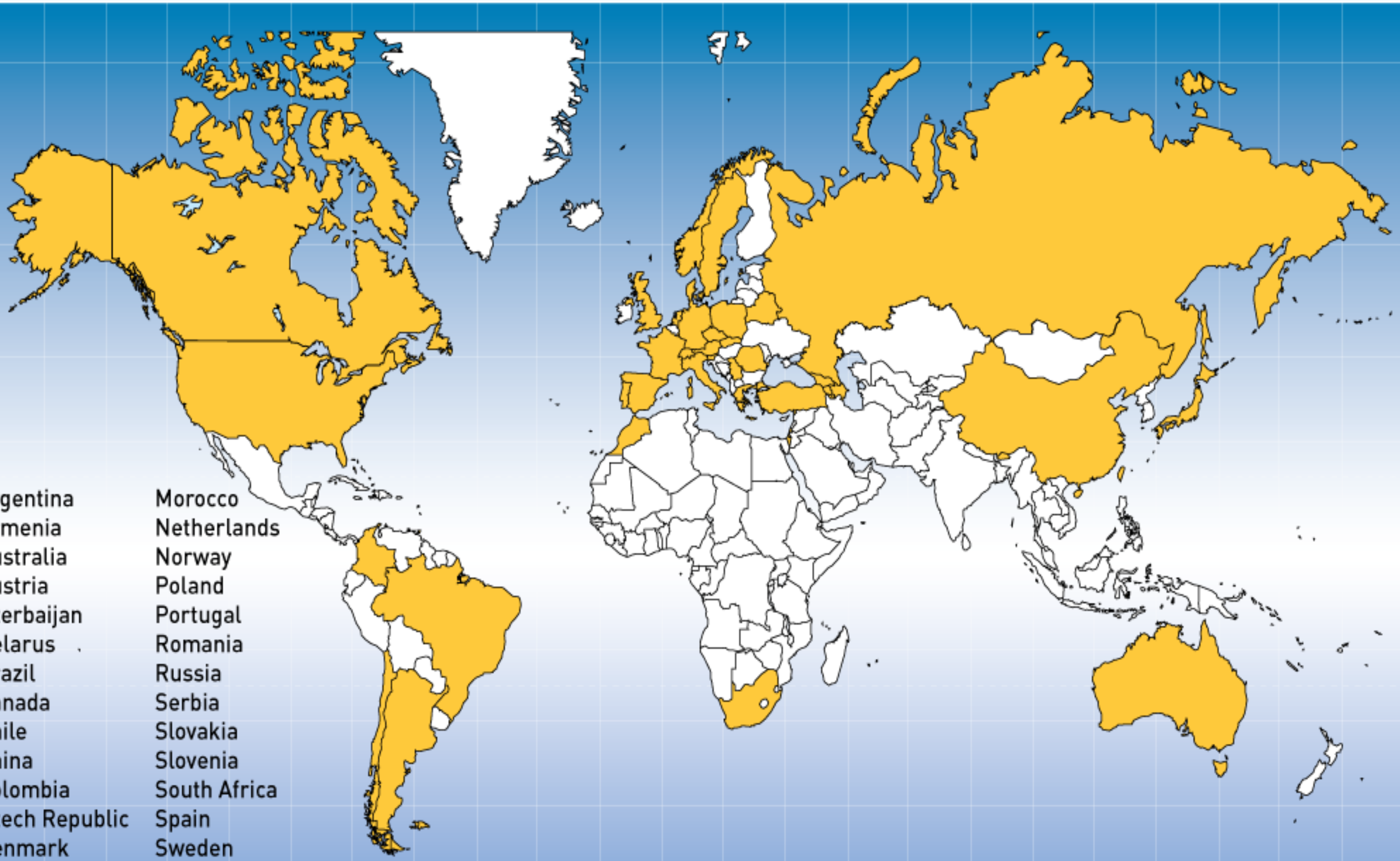
UC Berkeley and Lawrence Berkeley National Laboratory
on behalf of the ATLAS Collaboration

USLUO meeting, Madison/WI, Nov. 7th 2013

The ATLAS Detector



ATLAS Collaboration



- Argentina
- Armenia
- Australia
- Austria
- Azerbaijan
- Belarus
- Brazil
- Canada
- Chile
- China
- Colombia
- Czech Republic
- Denmark
- France
- Georgia
- Germany
- Greece
- Israel
- Italy
- Japan
- Morocco
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- Russia
- Serbia
- Slovakia
- Slovenia
- South Africa
- Spain
- Sweden
- Switzerland
- Taiwan
- Turkey
- UK
- USA
- CERN
- JINR

July 2010

Adelaide, Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brazil Cluster, 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, QM London, RH London, UC London, Louisiana Tech, 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, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, Northern Illinois University, BINP Novosibirsk, NPI Petersburg, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Rome I, Rome II, Rome III, RAL-STFC, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, South Africa Cluster, 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

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USA
CERN
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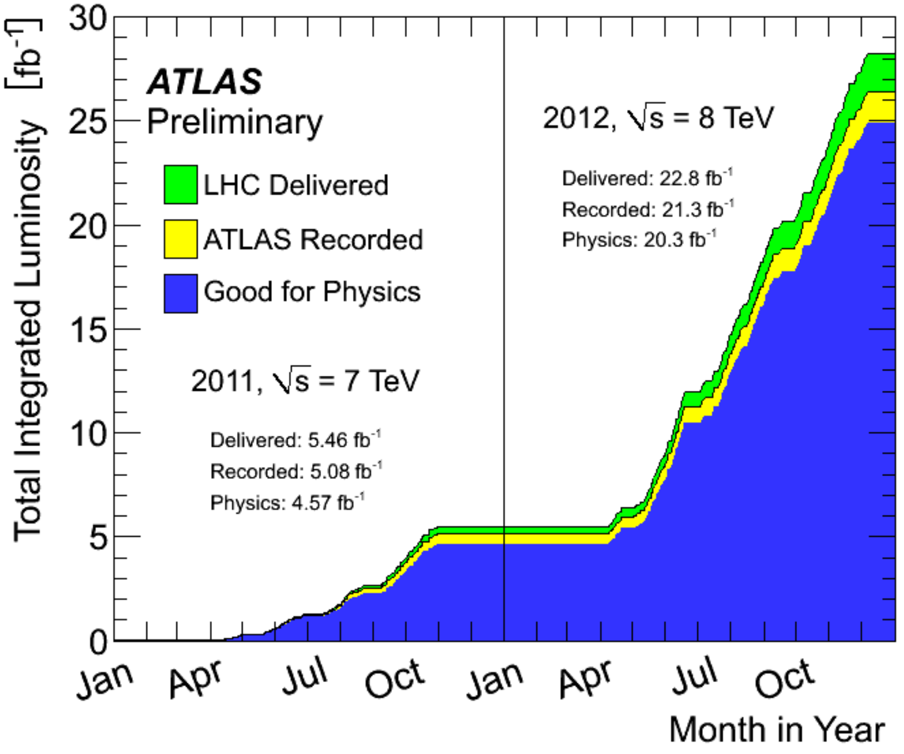
ATLAS Collaboration

July 2010

Summary of Run 1 Data Taking

- **Run-1 data taking completed in Feb. 2013**
- **>94% of recorded data used for physics analyses**

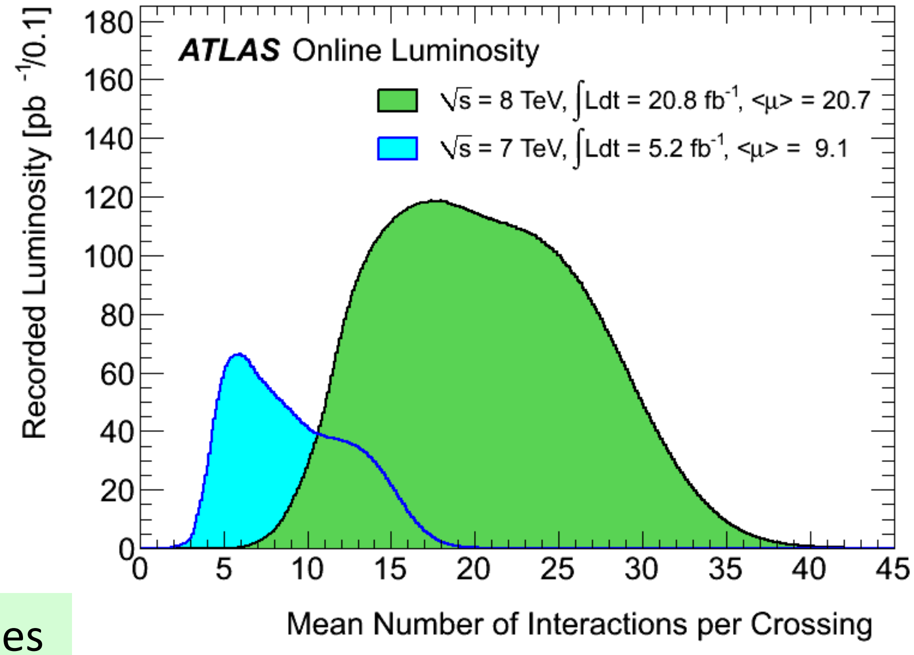
	√s [TeV]	years	Ldt (rec.)
pp	7	2010-11	5.1 fb^{-1}
pp	8	2012	21.3 fb^{-1}
Pb+Pb	2.76	2010-11	160 μb^{-1}
Pb+p	5	2013	30 nb^{-1}



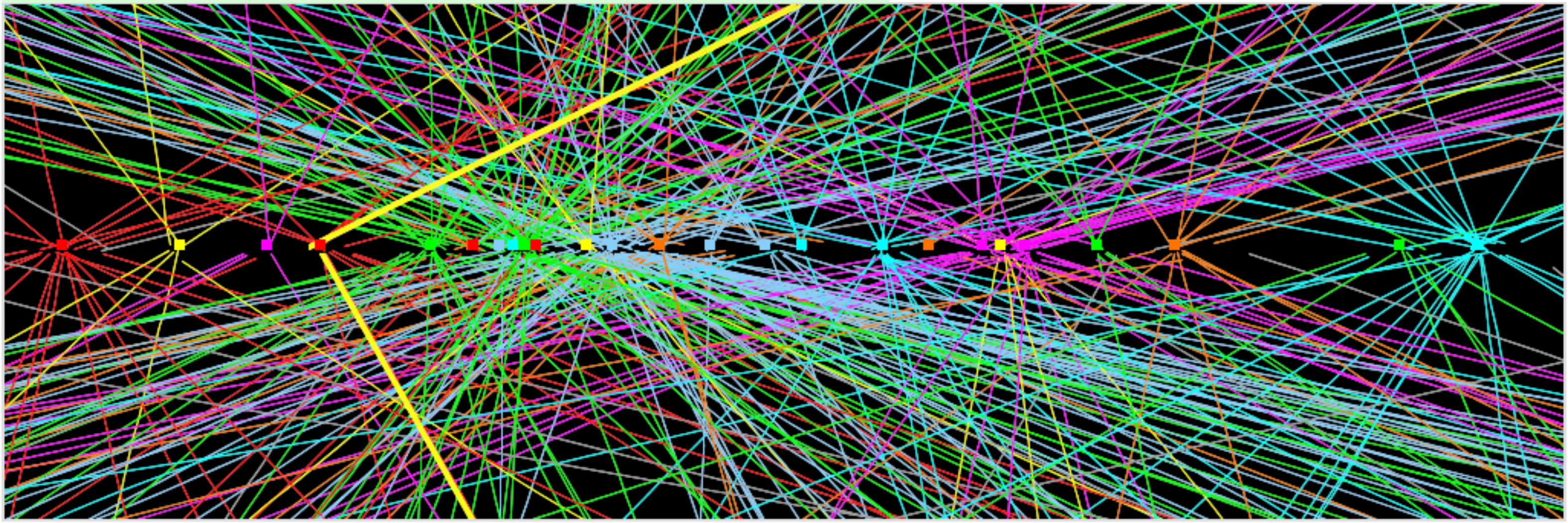
- **Outstanding performance of LHC machine and ATLAS detector!**

Pileup

- **Luminosity came with harsh conditions**
  - Typically 21 interactions per bunch crossing in 2013
- **ATLAS developed techniques to cope**



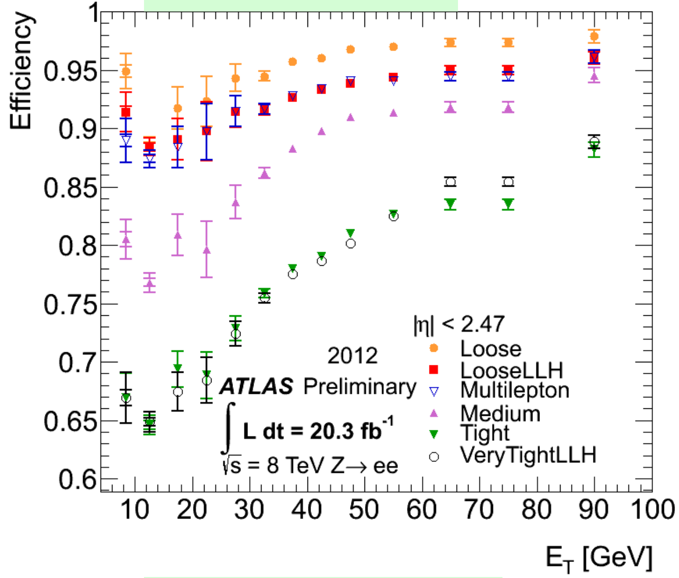
Z->μμ candidate with 20 additional vertices



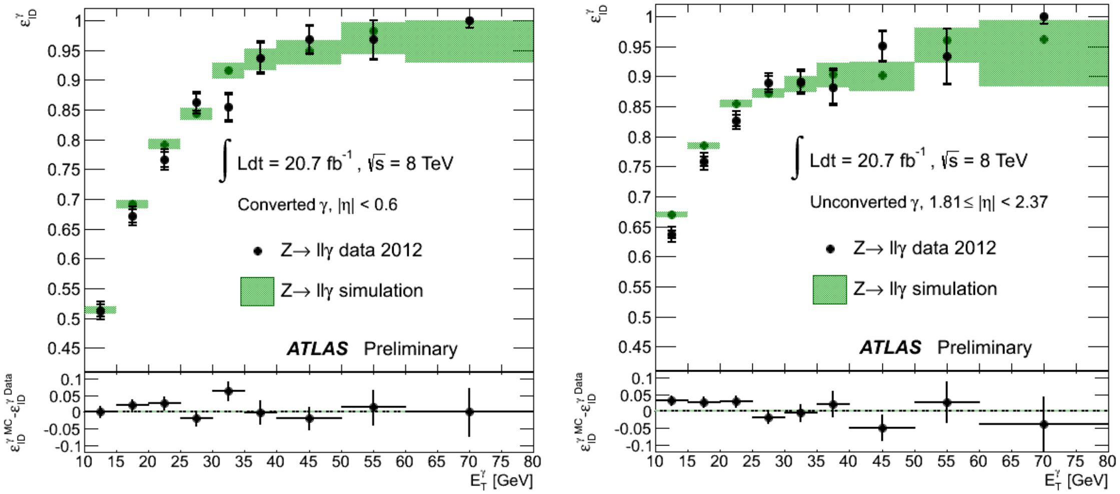
Performance

Electrons, Photons and Muons

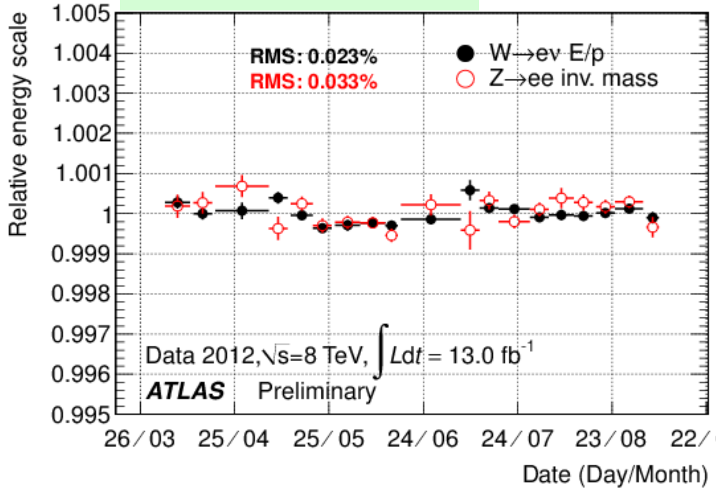
e ID efficiency



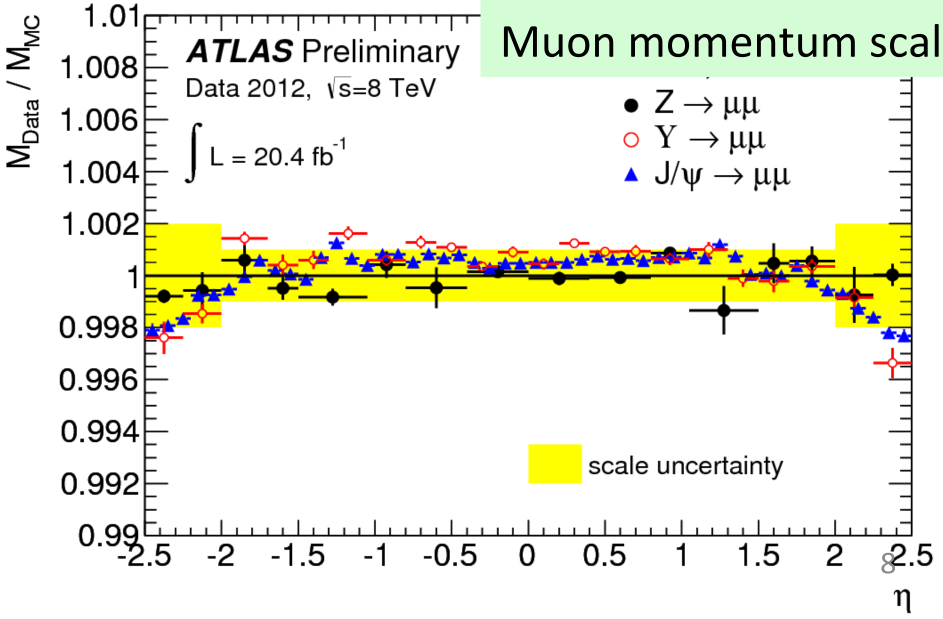
γ ID efficiency (for conv. and unconv. photons)



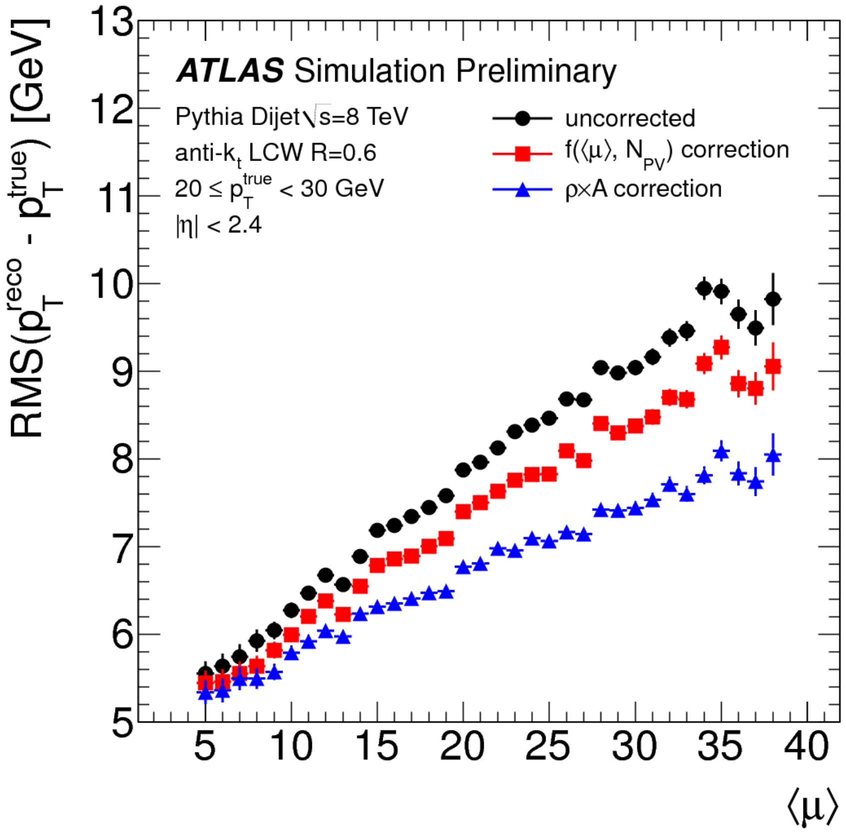
e/γ energy scale

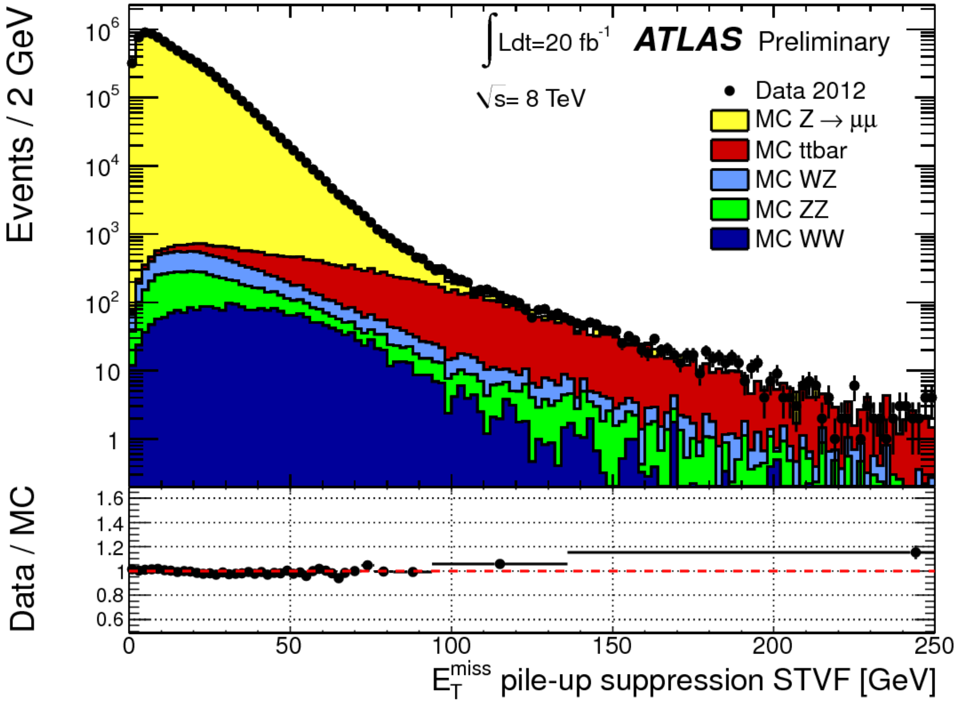


Muon momentum scale



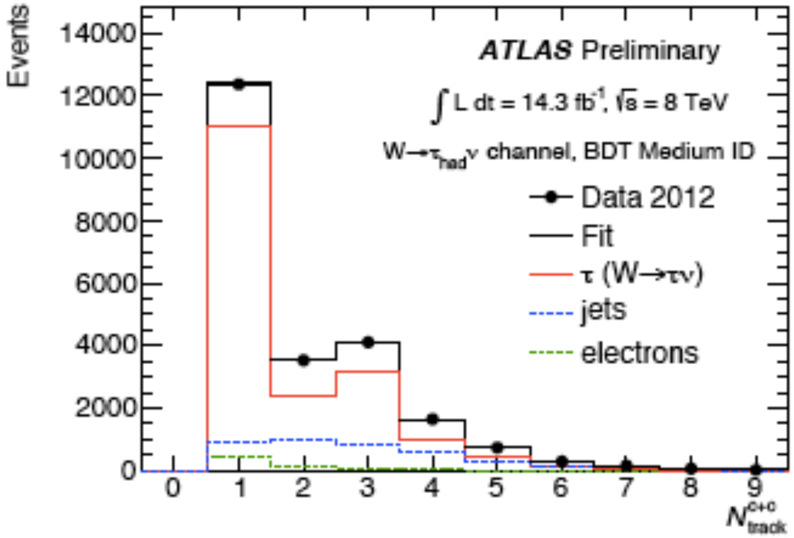
Jets and E_T^{miss}

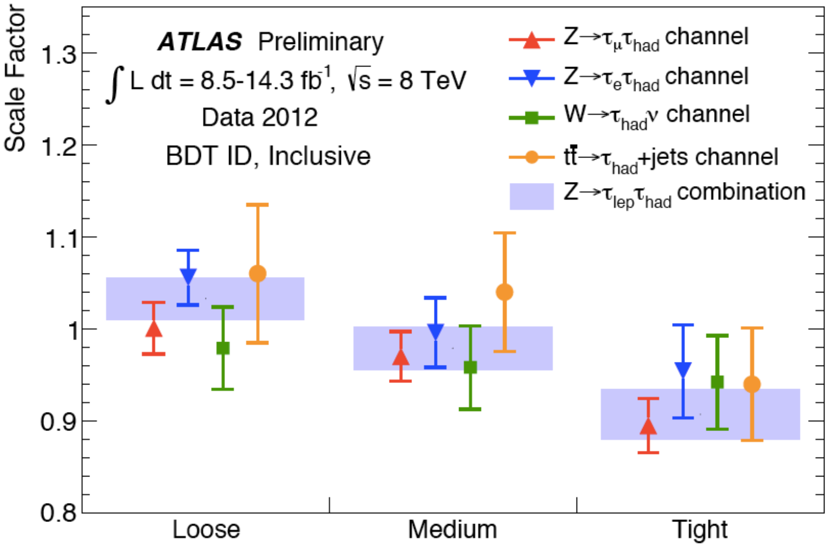


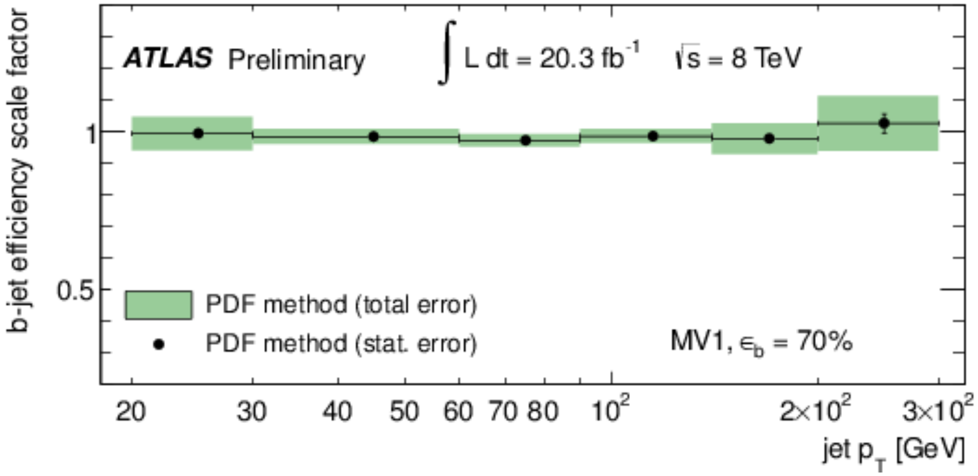


- **Jets and missing E_T well understood at high pileup**
  - Techniques developed to reduce resolution degradation at high pileup

Tau ID and B-tagging





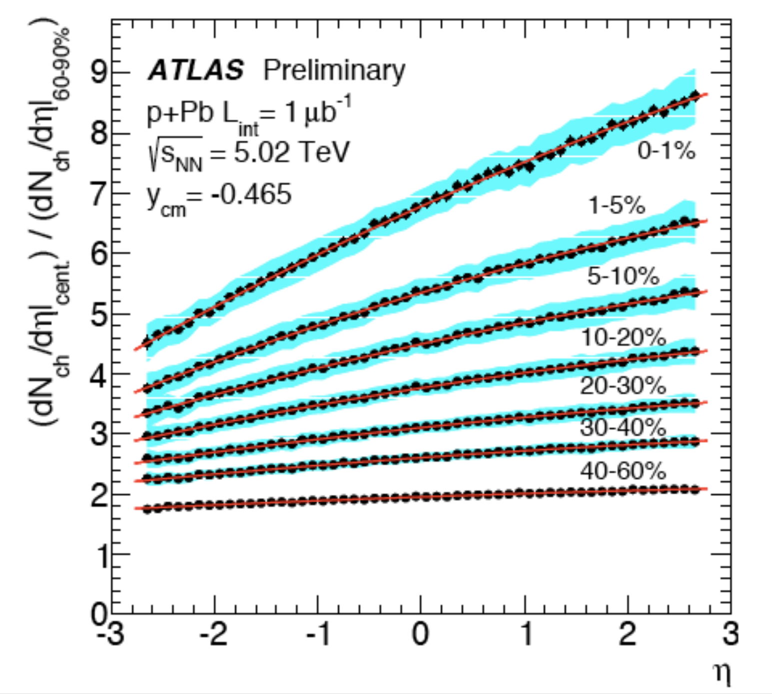


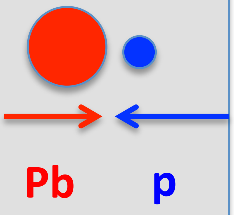
- **Tau ID and b-tag efficiencies measured with many methods**
  - Good agreement among those complementary methods

Recent physics results

New Heavy Ion Results: pPb and PbPb

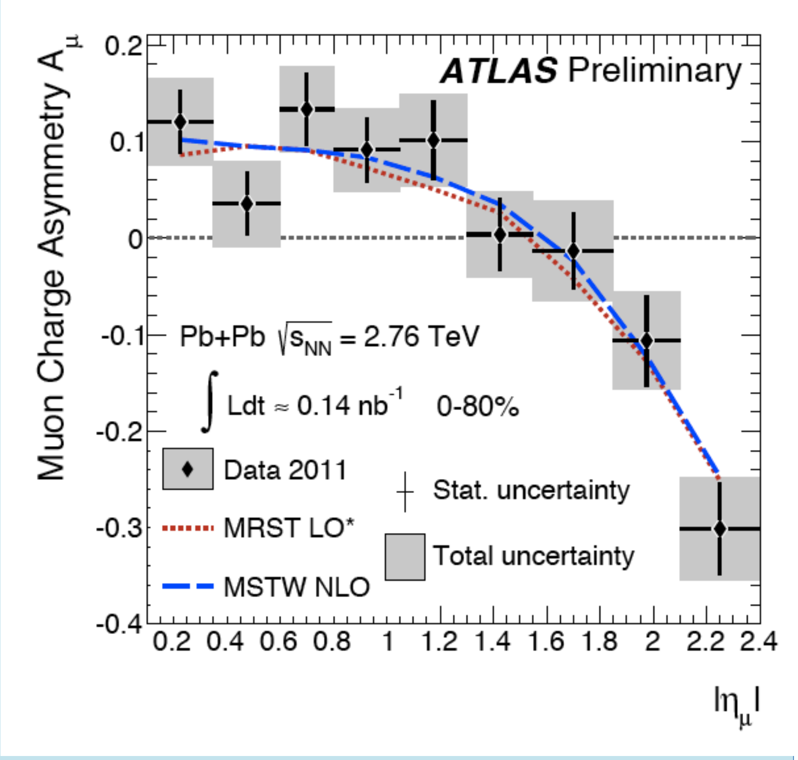
Charged particle multiplicity relative to peripheral collisions





- **Particle multiplicity strongly dependent on centrality of pPb collision**
  - Increase nearly linear with η

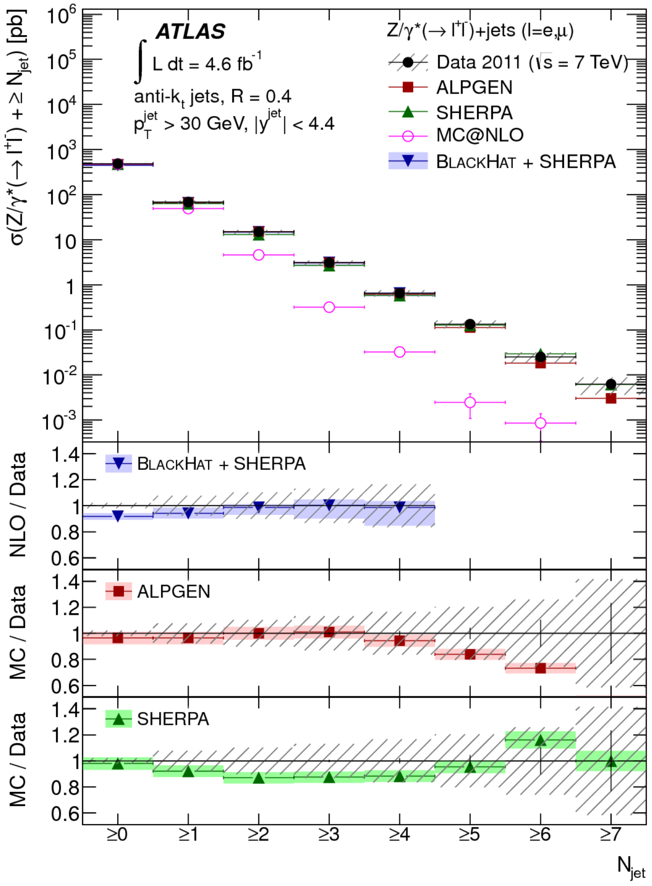
W charge asymmetry in PbPb data



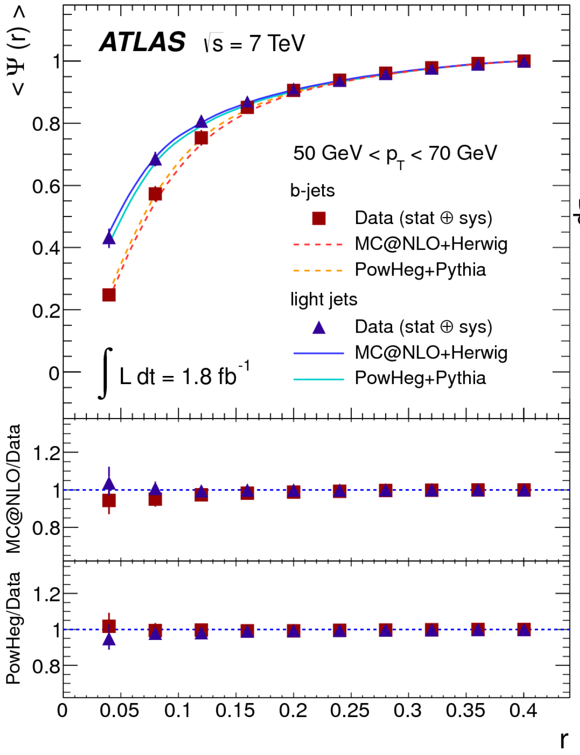
- **W charge asymmetry in PbPb data in good agreement with PDFs to within precision of ~5%**

Highlights of Standard Model Measurements

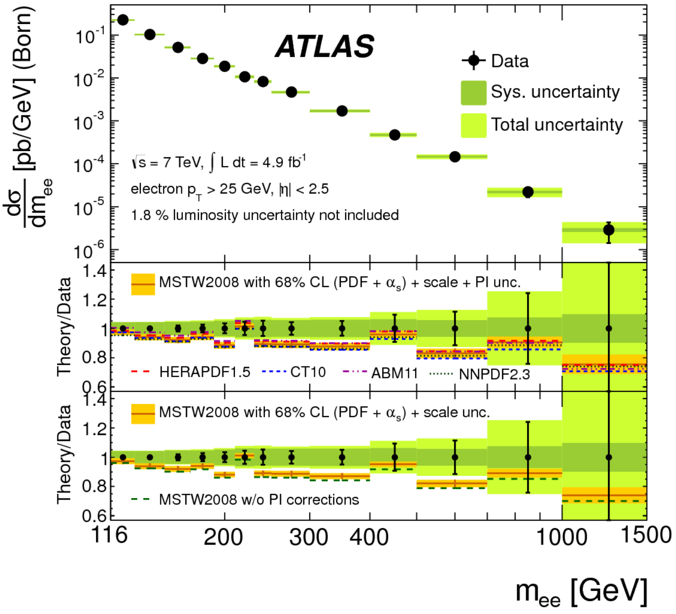
Z+jets cross section



Jet shapes



Drell-Yan cross section

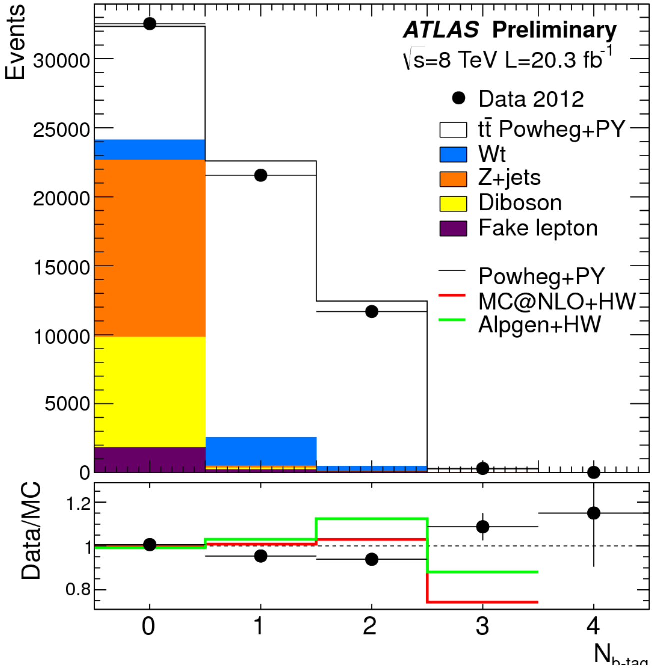


- **Many precision measurements of SM processes**
  - Understand if MC models adequately describe data
  - Provide data to further improve MC modeling
  - Constrain parton distribution functions

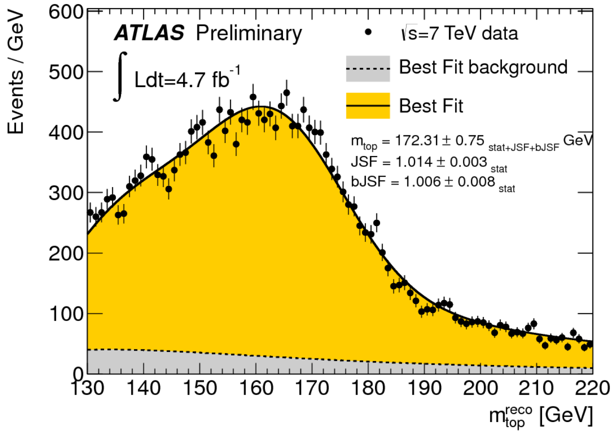
Top Quark: cross section and mass

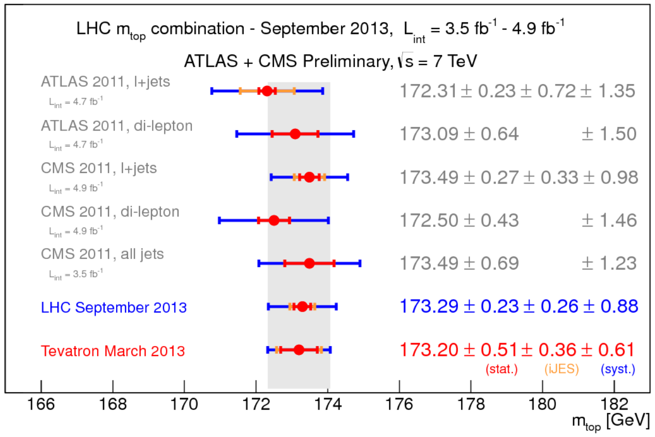
- **Cross section**
  - Precision measurement using eμ dilepton candidates
  - Events with 1 and 2 b-tagged jets
  - Uncertainty: 4.8%
  - Good agreement with theor. Prediction

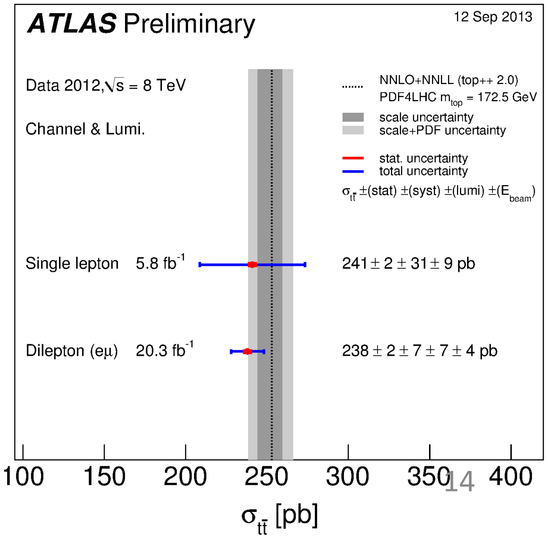
$$\sigma_{t\bar{t}} = 237.7 \pm 1.7\ (\text{stat}) \pm 7.4\ (\text{syst}) \pm 7.4\ (\text{lumi}) \pm 4.0\ (\text{beam energy})\ \text{pb}$$



- **Mass**
  - Precision measurements in l+jets and dilepton channels
    - lepton+jets channel uses novel 3D fit to constrain b-jet energy scale *in situ*
  - Combined with CMS



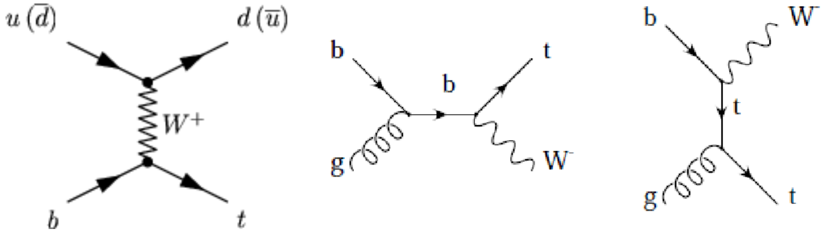


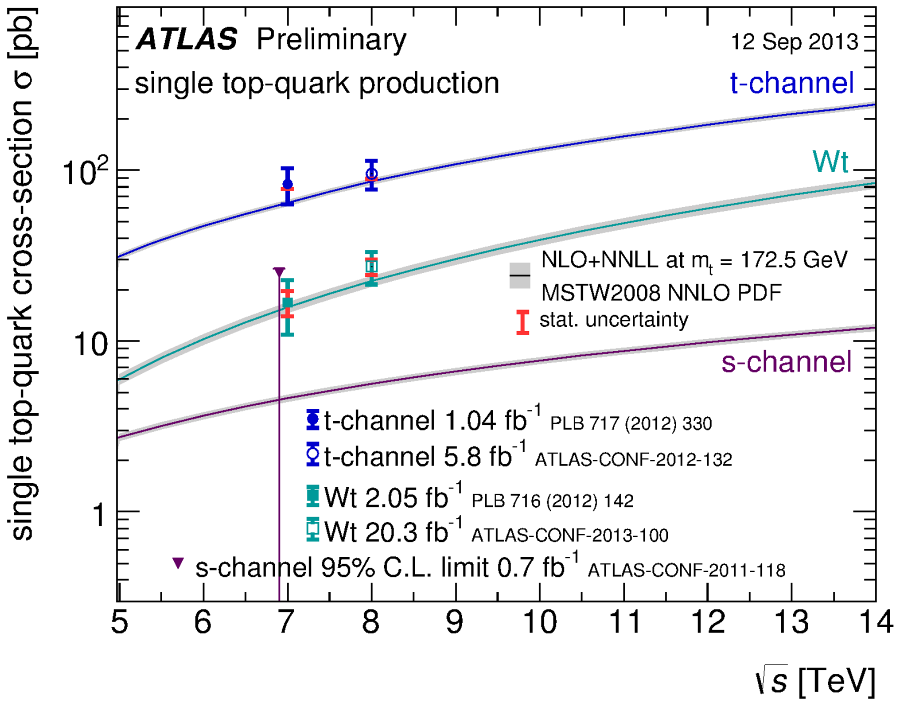


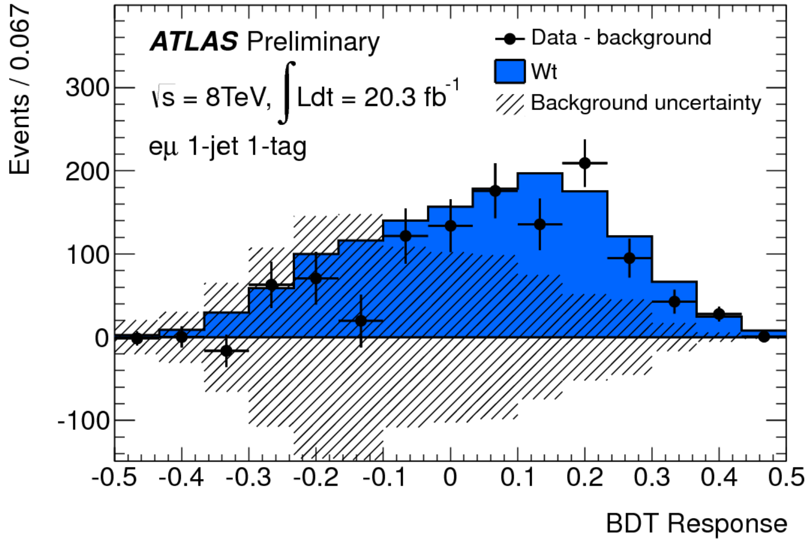
Single Top Quark Production

- **Single top production via different diagrams:**
  - t-channel
  - s-channel
  - Wt
- **Wt measurement using boosted decision tree**

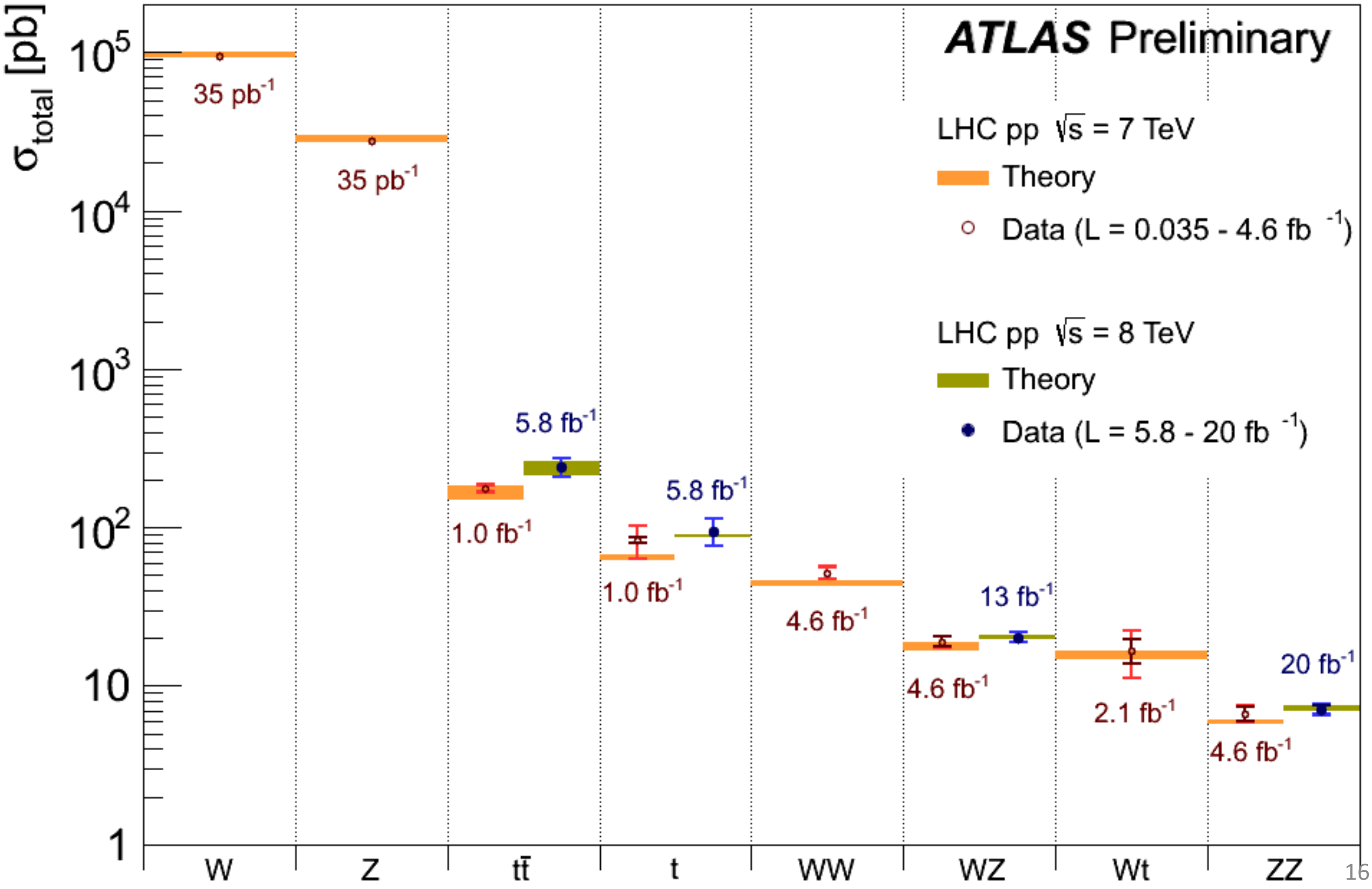
$$\sigma(pp \to Wt + X) = 27.2 \pm 2.8\ (\text{stat}) \pm 5.4\ (\text{syst})\ \text{pb}$$





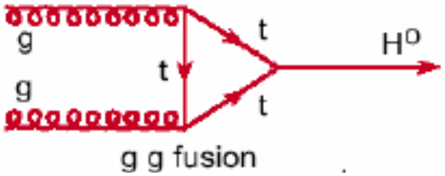


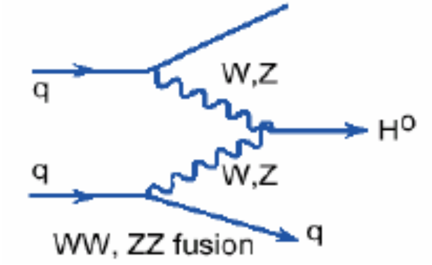
Summary of SM Measurements

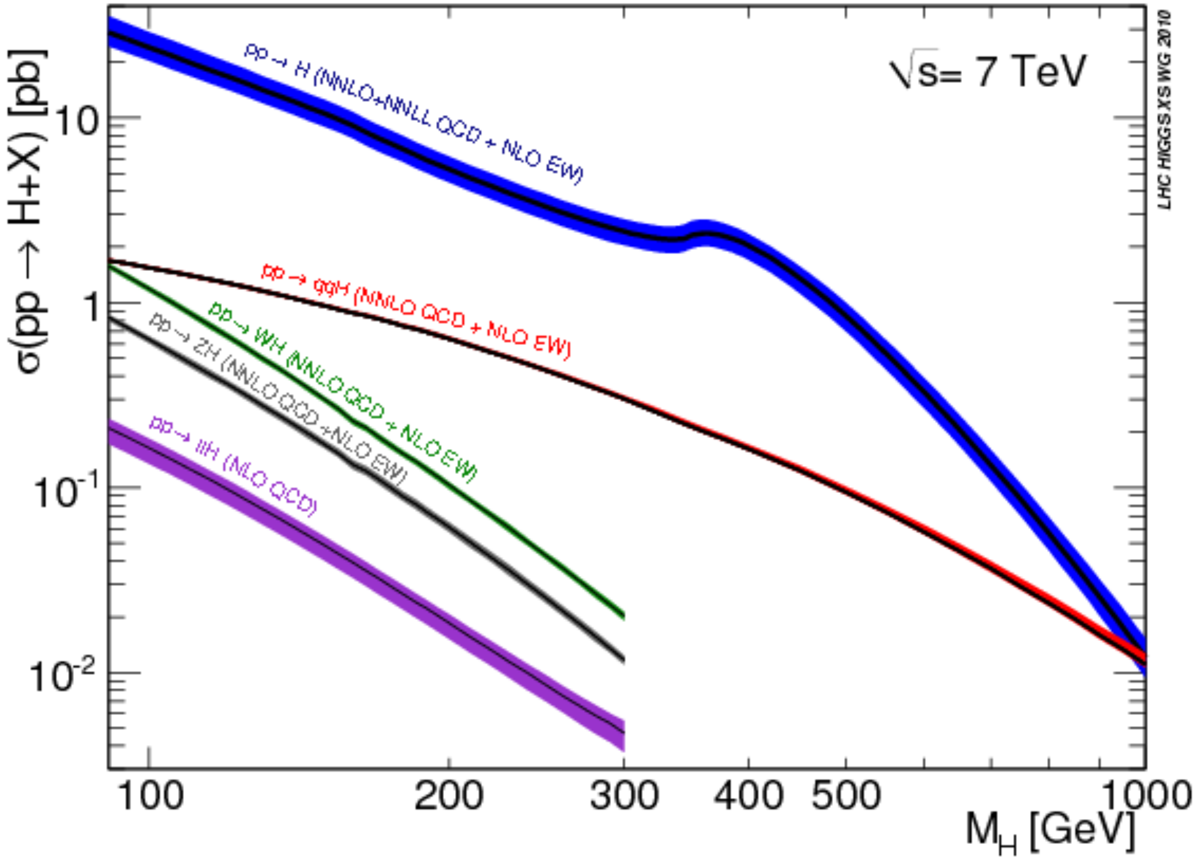


Higgs Boson Physics

Higgs Boson Production

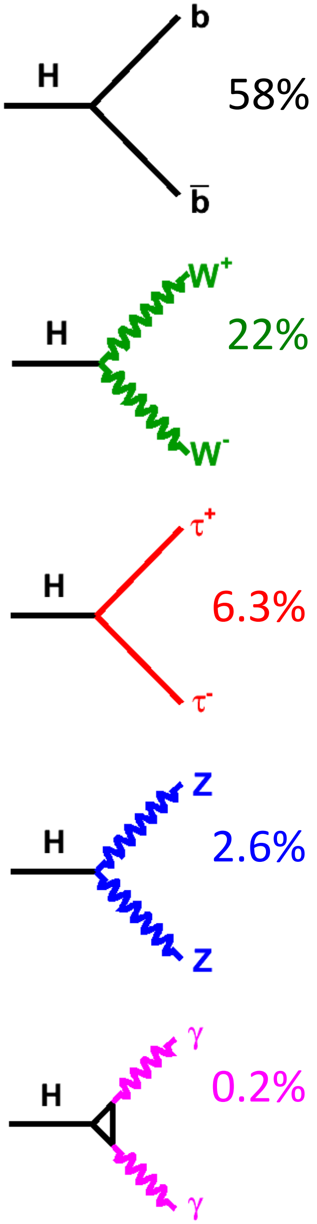


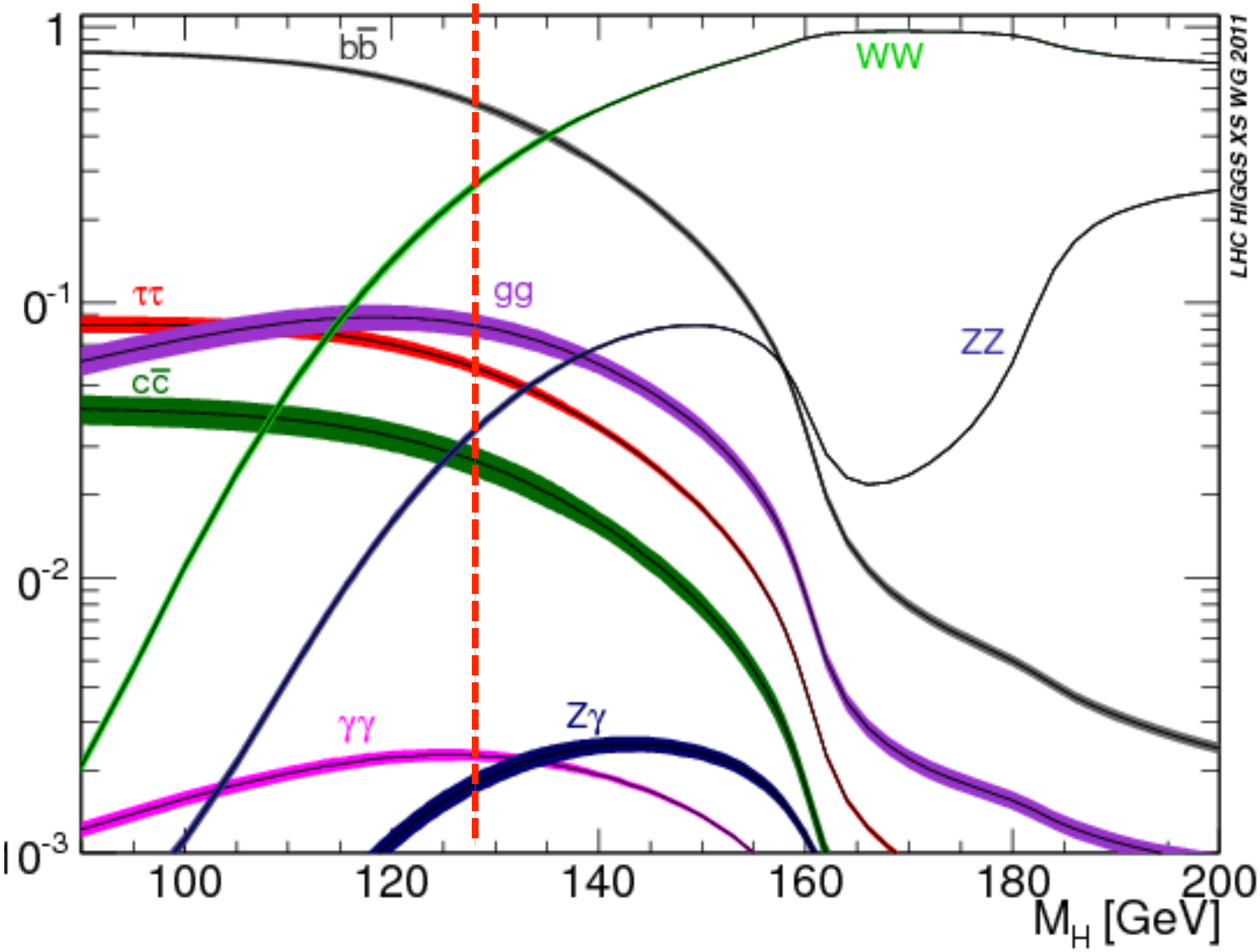




- **Production rate know to 2-10%**
  - Various production mechanisms sensitive to different Higgs couplings (top quark versus W boson)

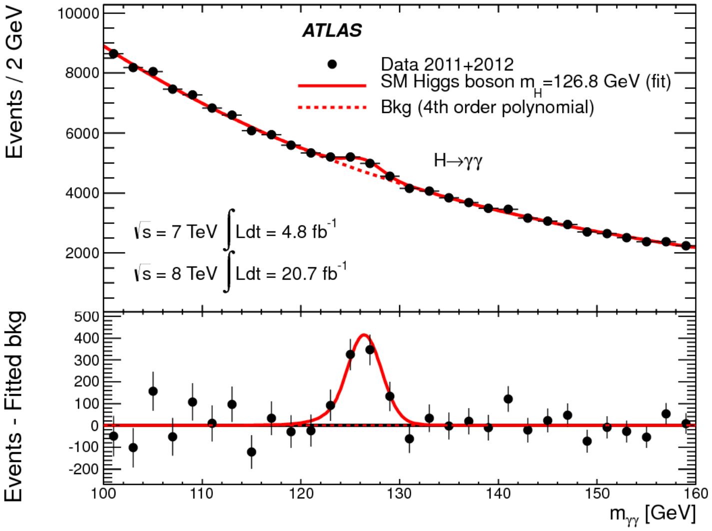
Higgs Boson Decay



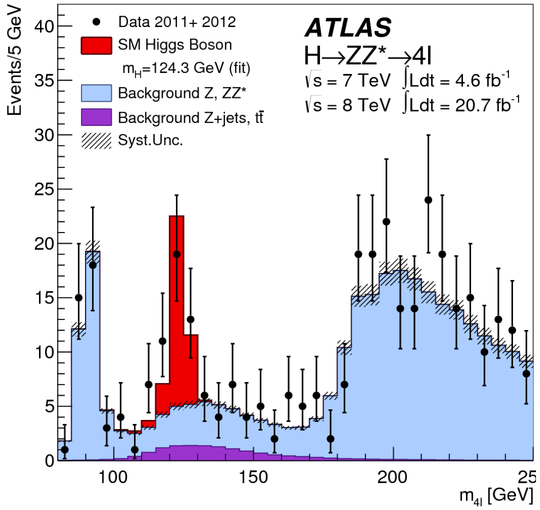


Higgs Boson Signals

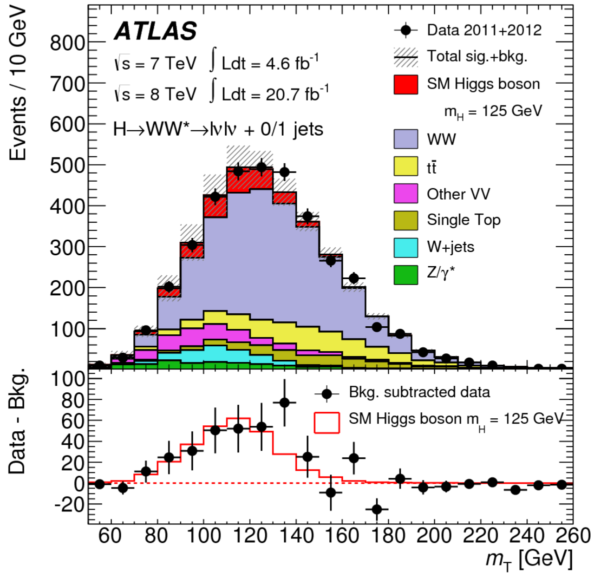
γγ



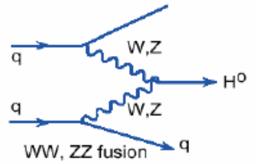
ZZ

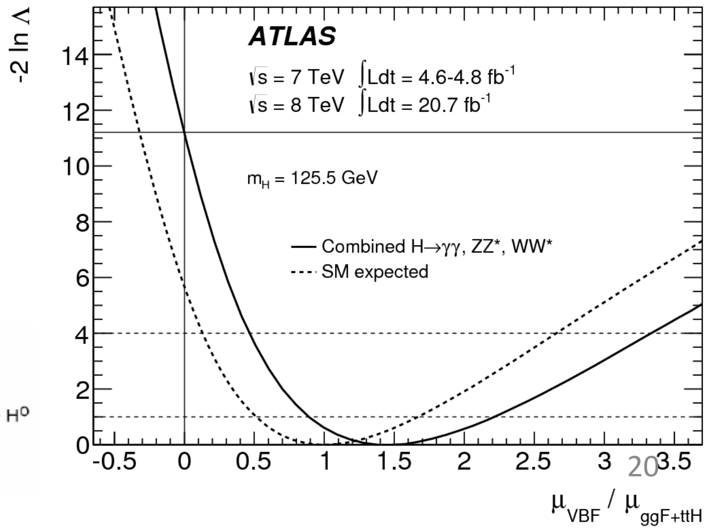


WW

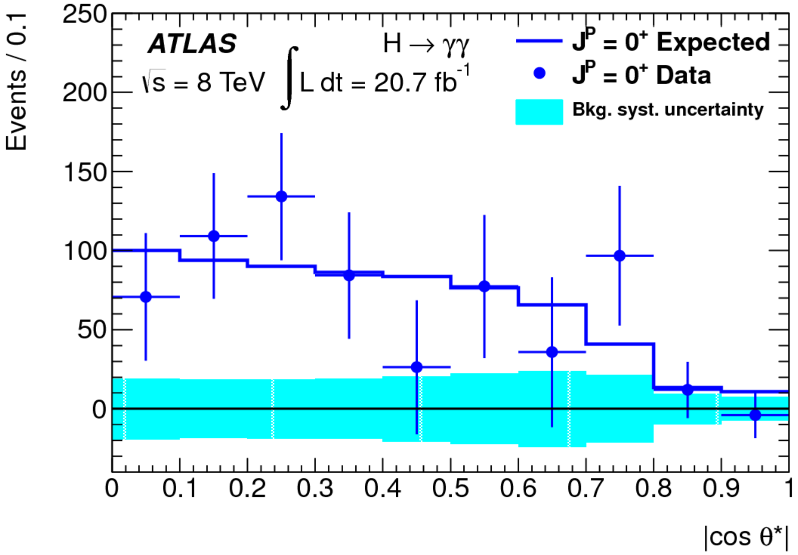


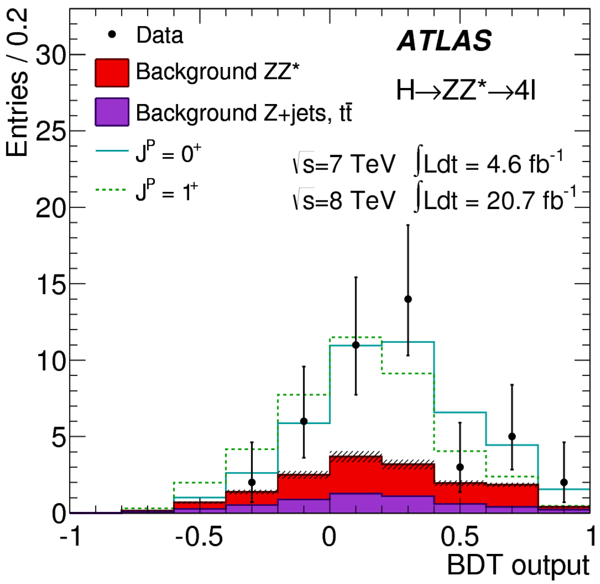
- **Signal established in bosonic decay modes**
  - $\mu=\sigma/\sigma_{SM}=1.33^{+0.21}_{-0.18}$
  - Evidence for VBF: 3.3σ

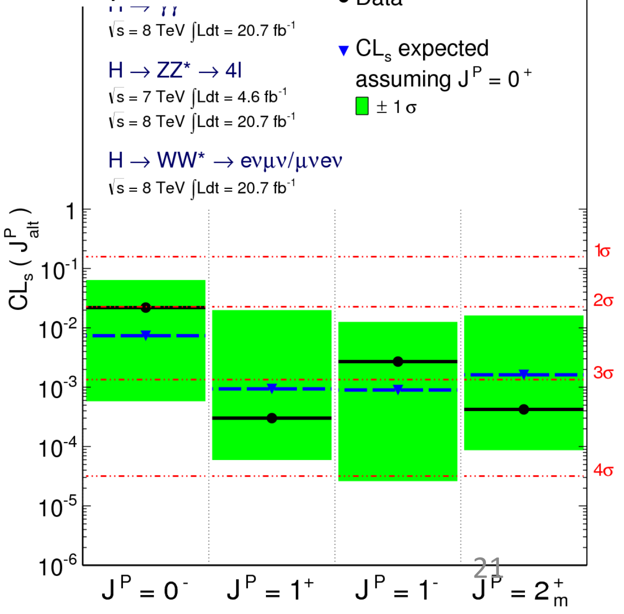




Spin Determination



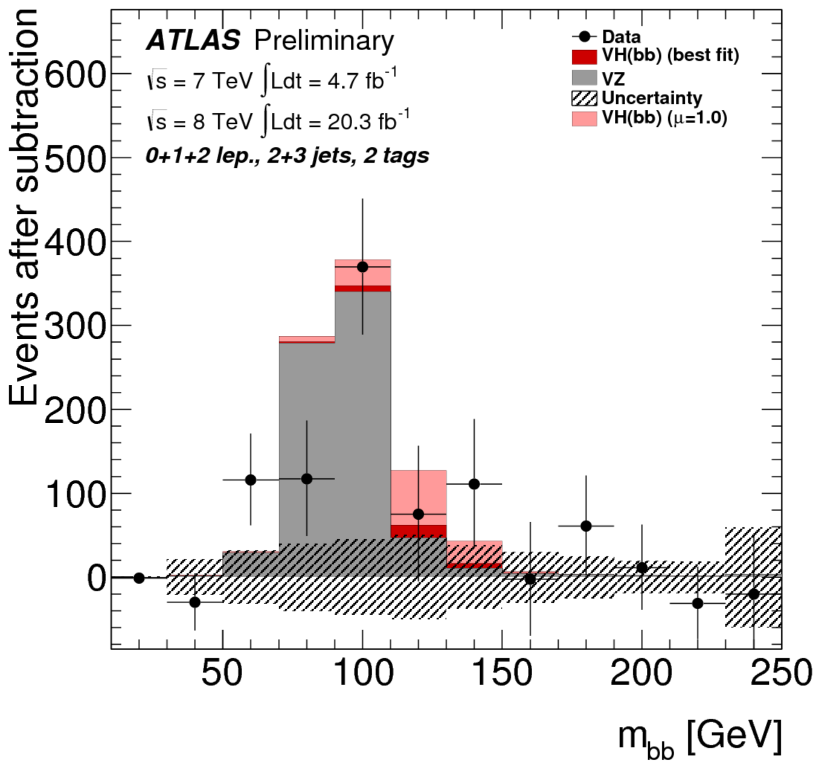




- **Based on angular distributions in bosonic modes**
  - Rule out other spin hypotheses (≠0) with >99% CL
  - Rule out odd parity with 97.8% CL

H→ bb Search

- **Associated production:**
  - WH->lvbb
  - ZH->llbb or vvbb
- **Difficult backgrounds**
  - W/Z+jets, top, single top
- **Control channels**
  - WZ->lvbb
  - ZZ->llbb or vvbb



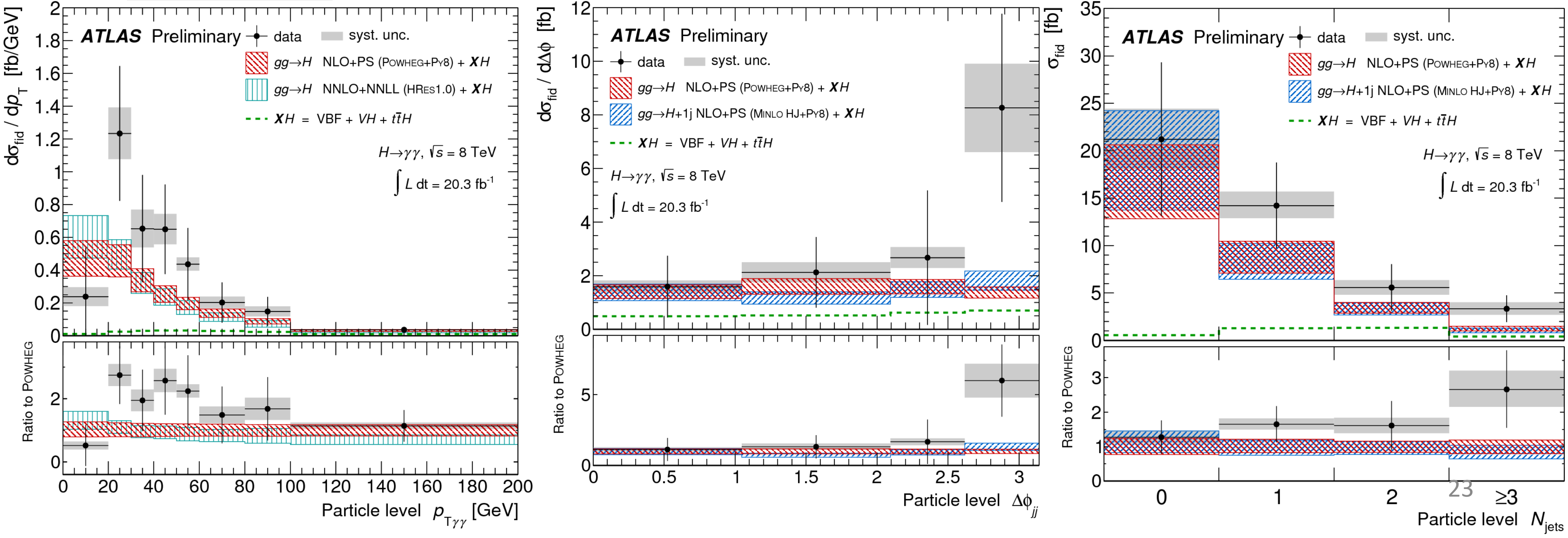
$\mu_{VZ,Z->bb}$ = 0.9±0.2 (SM=1)

$\mu_{VH,H->bb}$ = 0.2±0.5(stat)±0.4(syst)
(consistent with both μ=0 and μ=1)

Higgs: differential cross-section measurements

- **First differential cross section measurements of Higgs production**
  - $p_T(\gamma\gamma)$,$|y_{\gamma\gamma}|$, $|\cos\theta^*|$, $p_T(j1)$, N(jets), $\Delta\varphi(jj)$, $p_T(\gamma\gamma jj)$
  - In fiducial region
- **Will help understand accuracy of MC models and QCD calculations**
  - Critical for precision measurements!
- **Measurements consistent with current state-of-the-art predictions**
  - PowHeg, MINLO, HRes1.0

ATLAS-CONF-2013-072



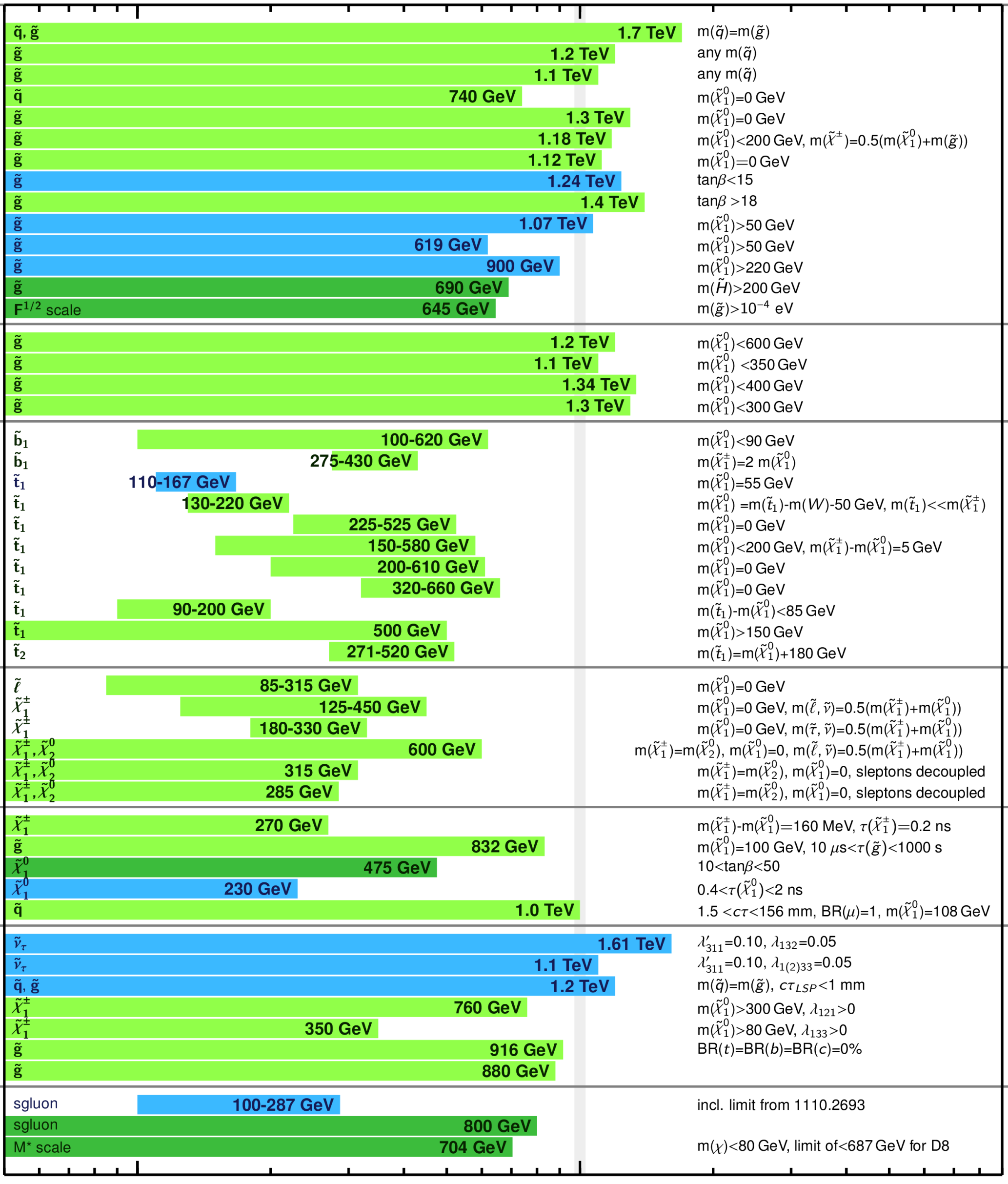
New Physics Searches

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

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

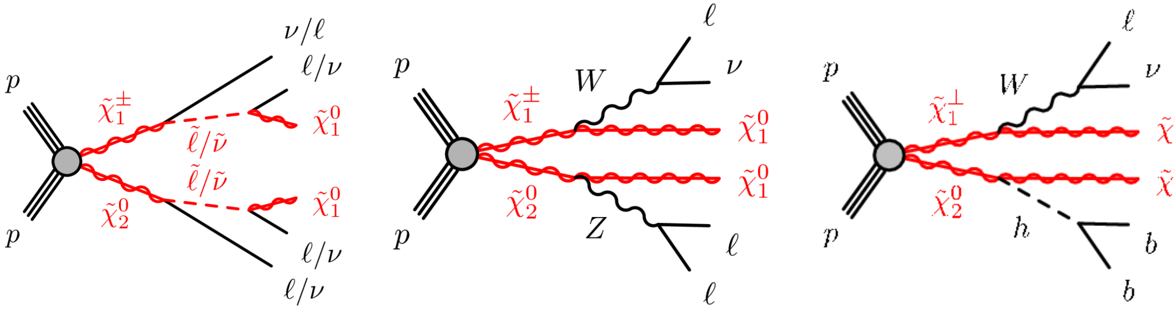


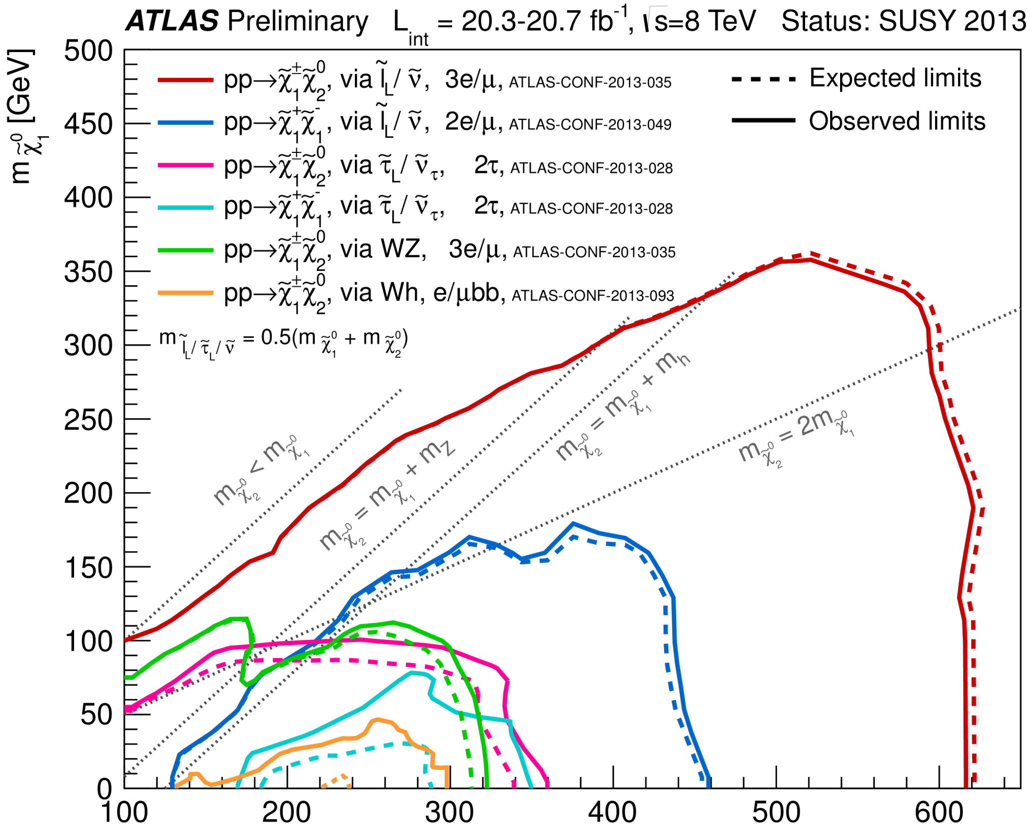
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit			Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	tanβ<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	tanβ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	F$^{1/2}$ scale	645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 GeV	$m(\tilde{\chi}_1^\pm)=2\ m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-220 GeV	$m(\tilde{\chi}_1^0)$ =$m(\tilde{t}_1)$-$m(W)$-50 GeV, $m(\tilde{t}_1)$<<$m(\tilde{\chi}_1^\pm)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$	225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^\pm)$-$m(\tilde{\chi}_1^0)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	$m(\tilde{t}_1)$-$m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	271-520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}_1^0)$+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$	85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	285 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$	270 GeV	$m(\tilde{\chi}_1^\pm)$-$m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e+\mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\tilde{\nu}_\mu$, $e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e$, $e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1t$, $\tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e, μ (SS)	1 b	Yes	14.3	sgluon	800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

🟦	🟩	🟩
$\sqrt{s}$ = 7 TeV full data	$\sqrt{s}$ = 8 TeV partial data	$\sqrt{s}$ = 8 TeV full data

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

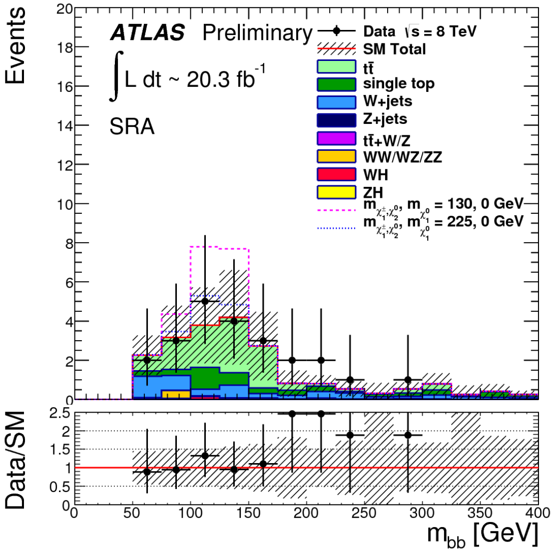
Direct chargino/neutralino production





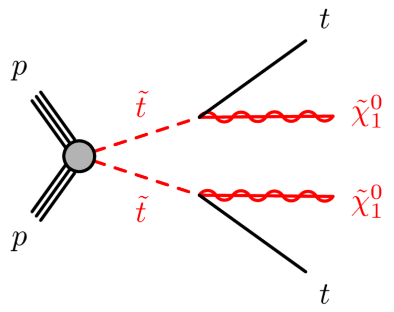
Sensitive to $\chi^{\pm}$, χ^0 decays to sleptons, W, Z, Higgs

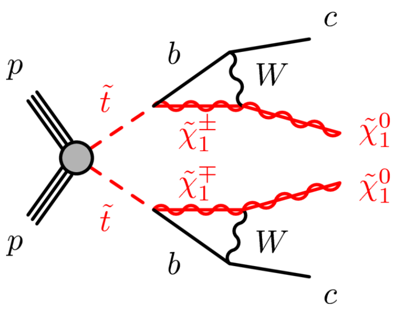
ATLAS-CONF-2013-093



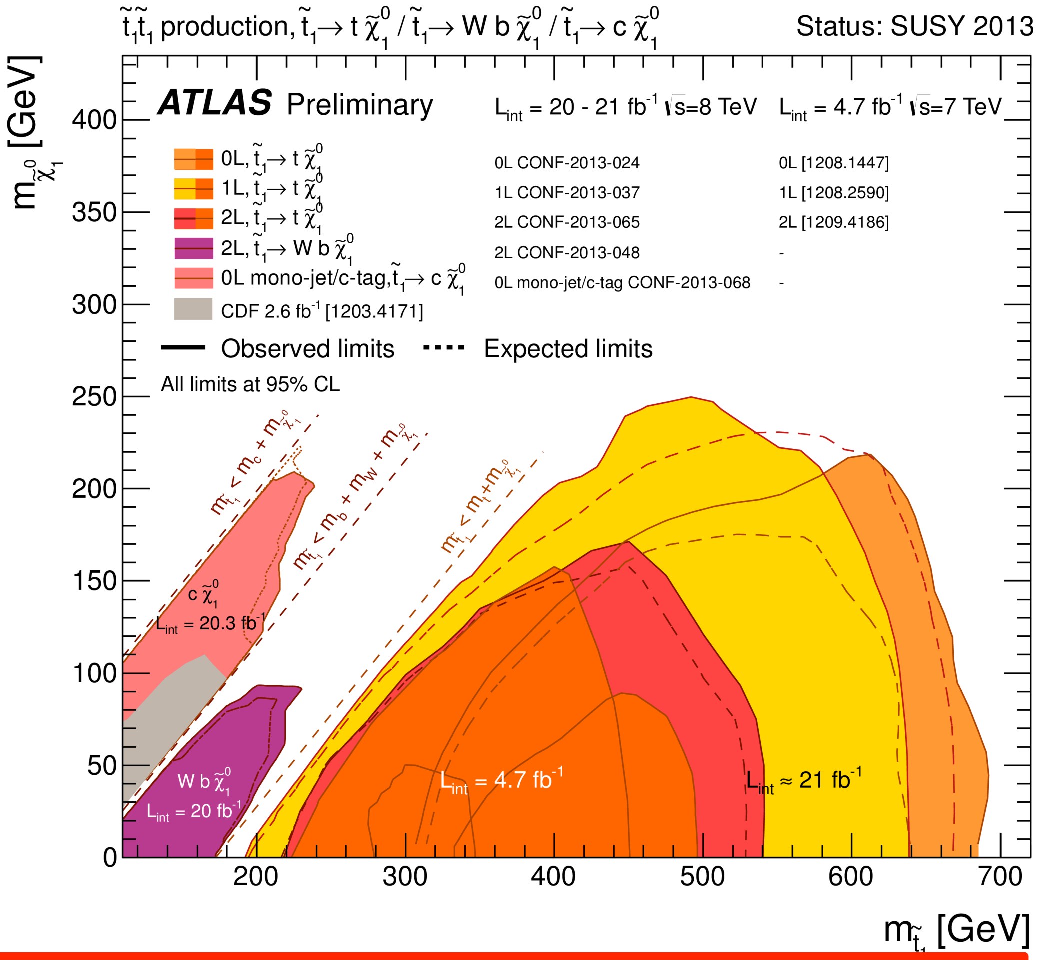
- **Dominant decay mode depends on details of SUSY model**
  - Use simplified models to assess broad range of possibilities
  - Recently first analysis with Higgs in decay chain (difficult!!)
  - Probing up LSP masses between 0 and 300 GeV depending on SUSY parameters

Third Generation Squarks



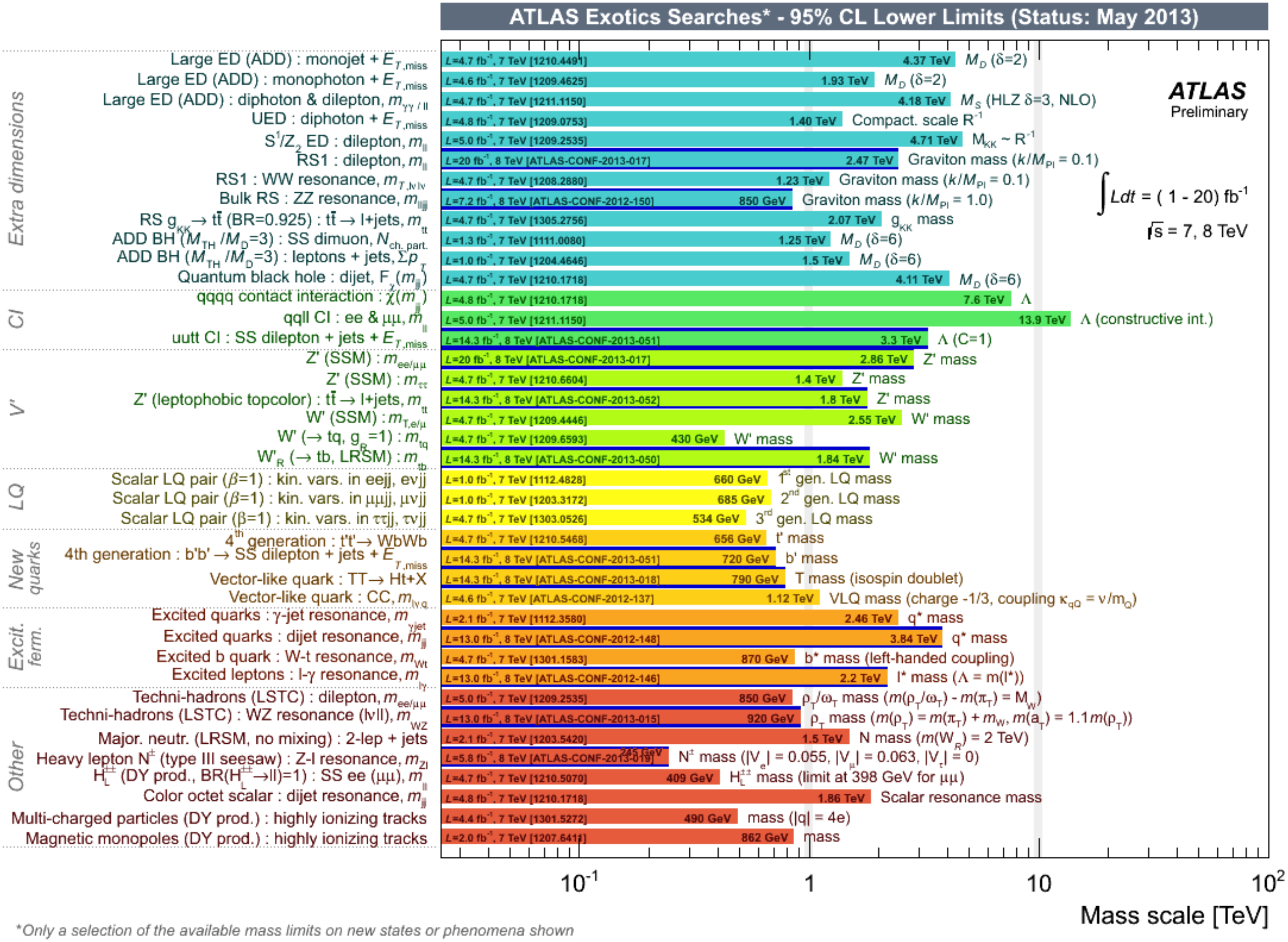


- **Third generation SUSY searches directly related to hierarchy problem**
  - Does the stop protect the Higgs?
- **Very active area of searches**
  - Many decay modes possible depending of mass hierarchies of involved sparticles
- **Most recent search**
  - Top decay to charm+LSP
    - First search with c-tagging at LHC



Probing stop masses up to ~700 GeV and LSP masses up to 250 GeV

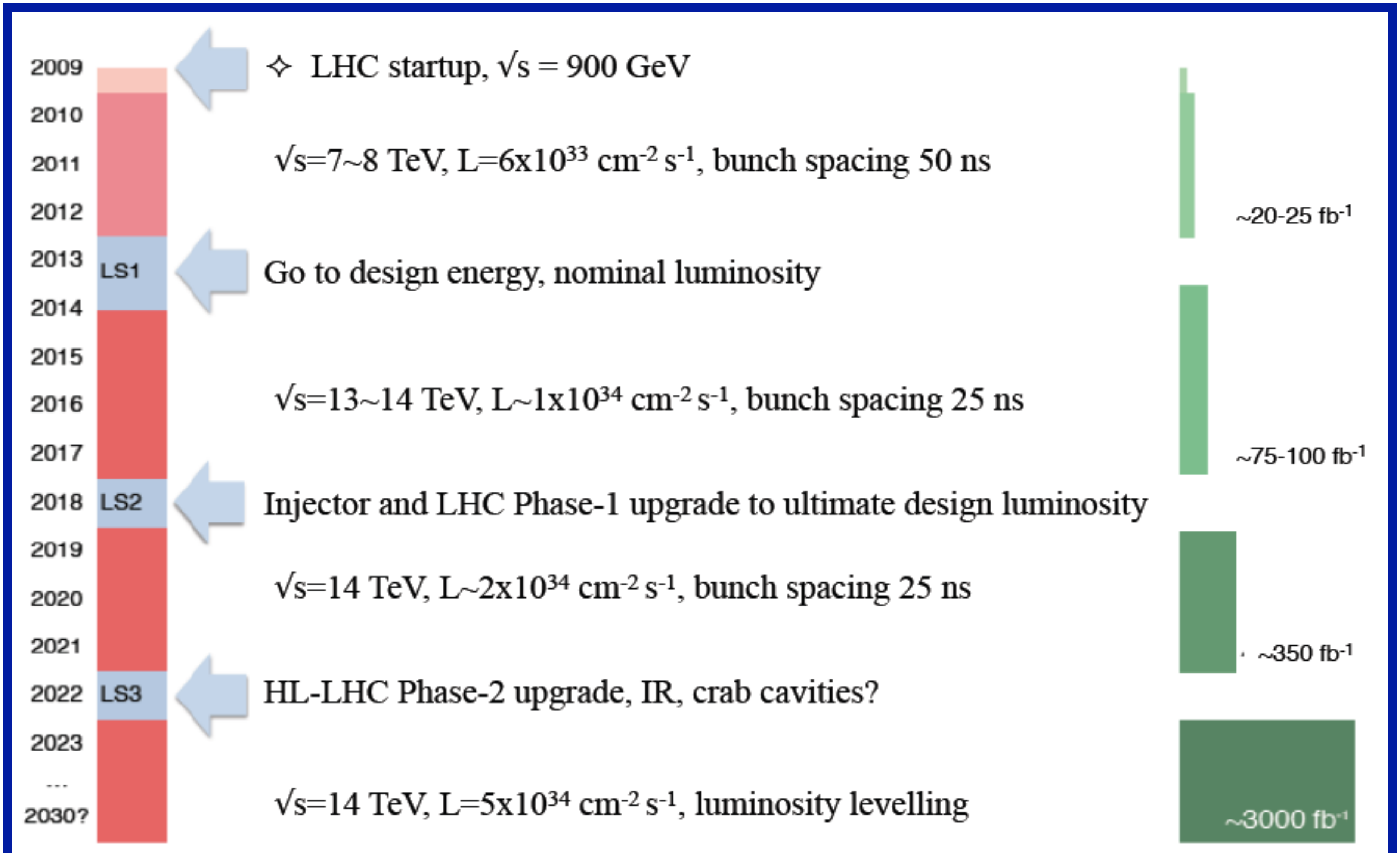
Exotica Searches Summary



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

Future

The LHC roadmap



✧ LHC startup, $\sqrt{s}$ = 900 GeV

$\sqrt{s}$=7~8 TeV, L=6x10^{33} cm^{-2} s^{-1}, bunch spacing 50 ns

Go to design energy, nominal luminosity

$\sqrt{s}$=13~14 TeV, L~1x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

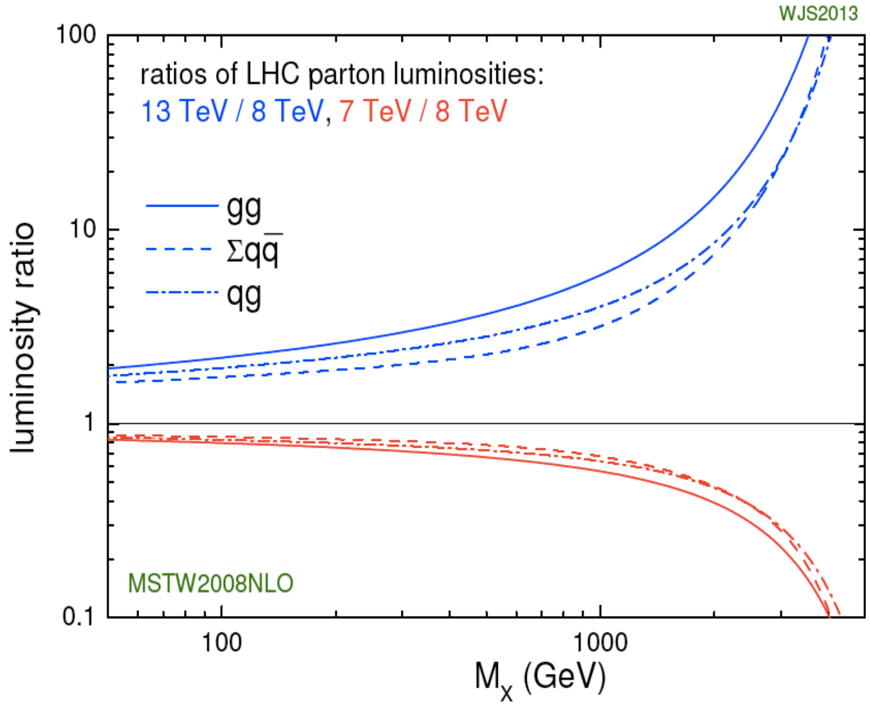
Injector and LHC Phase-1 upgrade to ultimate design luminosity

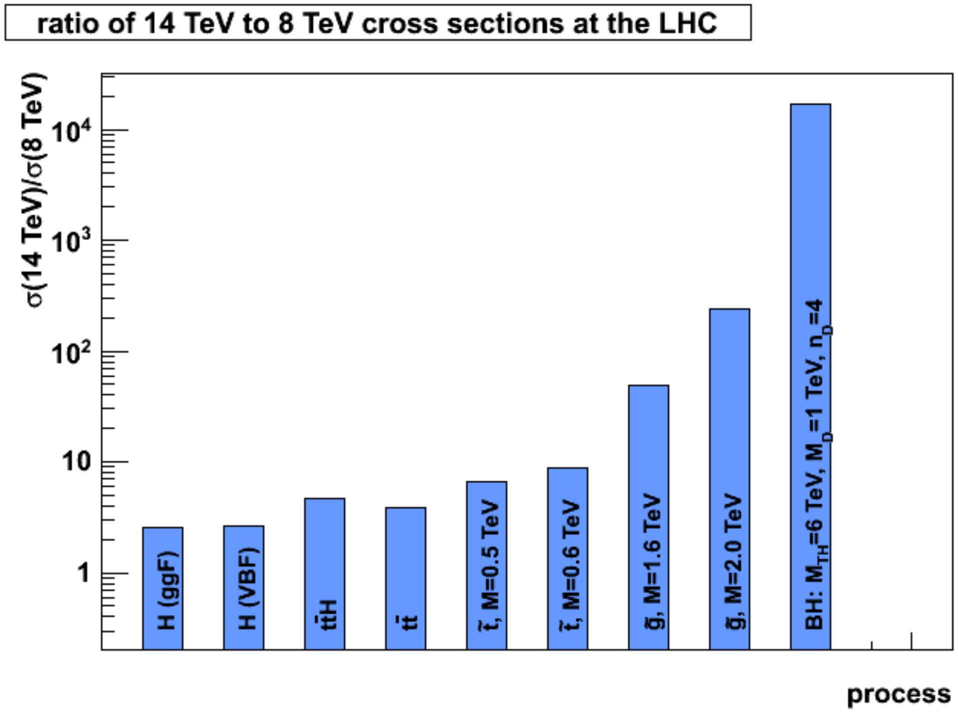
$\sqrt{s}$=14 TeV, L~2x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

HL-LHC Phase-2 upgrade, IR, crab cavities?

$\sqrt{s}$=14 TeV, L=5x10^{34} cm^{-2} s^{-1}, luminosity levelling

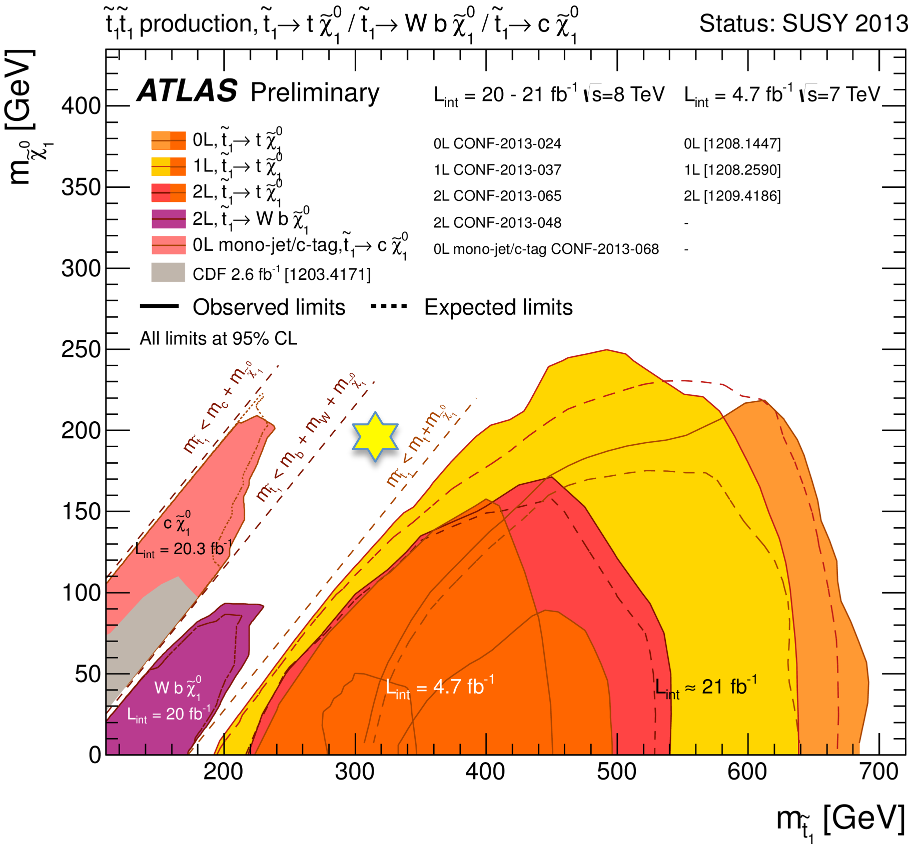
Run-2 Physics Cross Sections

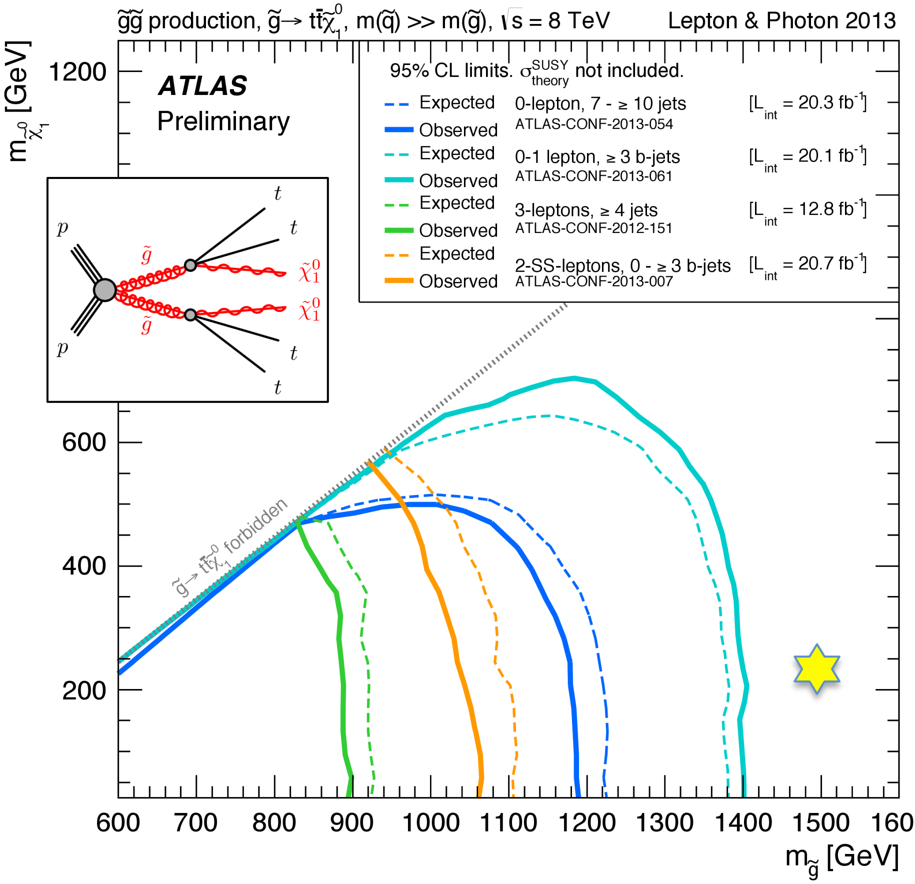




- **Run-2 will most likely see pp collisions at √s=13 TeV**
- **Large increase in cross section**
  - Increase ~5 for M=1 TeV and ~10 for M=2 TeV
- **Discovery potential beyond Run-1 with a few fb^{-1}**

Constraints on top squarks



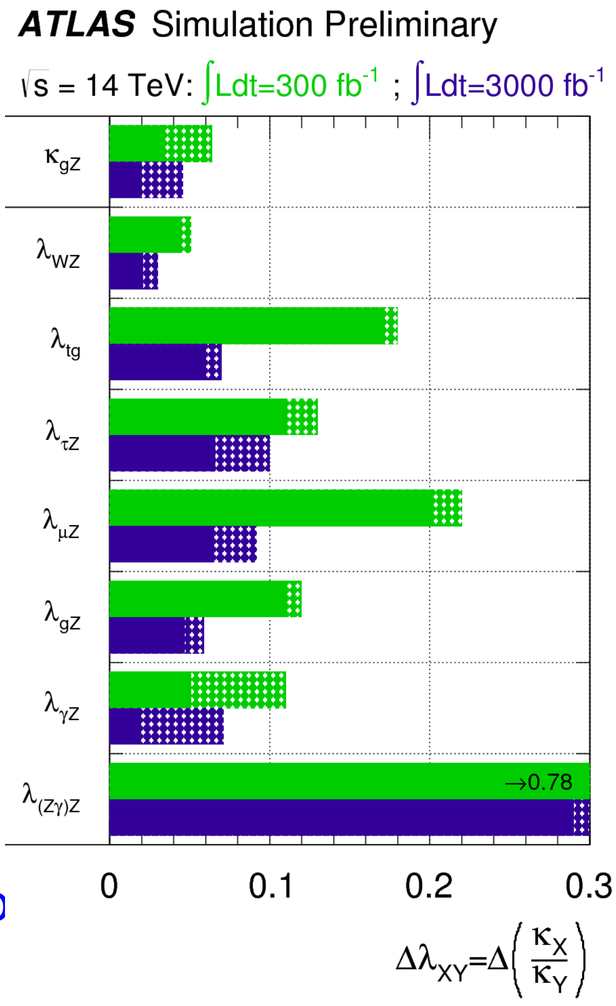


- **Constraints ever improving from both ATLAS and CMS**
- **However, pretty natural scenarios still allowed, e.g**
  - M(gluino)=1.5 TeV, m(stop)=300 GeV, m(LSP)=200 GeV
- **LHC (and HL-LHC) will be able to discover such scenarios**

What can H(125) tell us about new physics?

From Higgs Snowmass Report (arXiv:1310.8361)

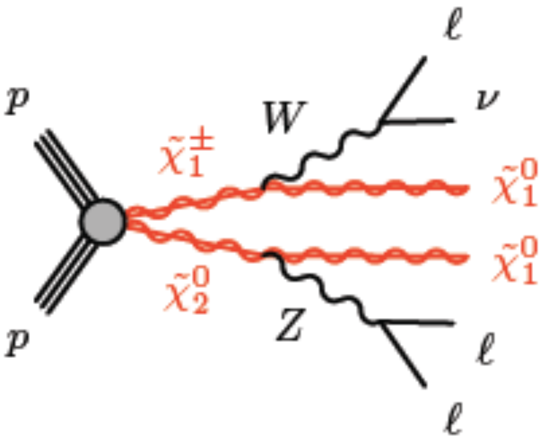
Model	κ_V	κ_b	κ_γ
Singlet mixing	~ 6%	~ 6%	~ 6%
2HDM	~ 1%	~ 10%	~ 1%
Decoupling MSSM	~-0.0013%	~ 1.6%	~ -0.4%
Composite	~ -3%	~ -(3-9)%	~ -9%
Top Partner	~ -2%	~ -2%	~ +1%

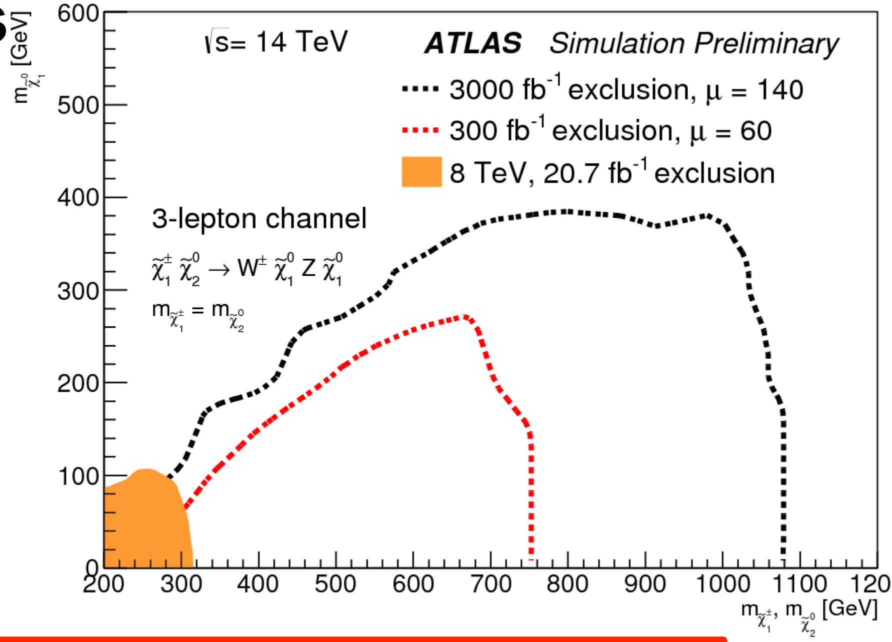


- **Run-1 probes couplings with ~30% accuracy**
  - No serious challenge for BSM models
- **Run-2+Run-3: precision ~10-20%**
- **HL-LHC required to get ~2-5% precision**
  - Will challenge models predicting subtle deviatio
  - Some rare decays (Zγ, μμ,…) become only accessible with HL-LHC
- **170M Higgs bosons produced at HL-LHC**
  - About 3M useful for precision measurements

New physics at the weak scale

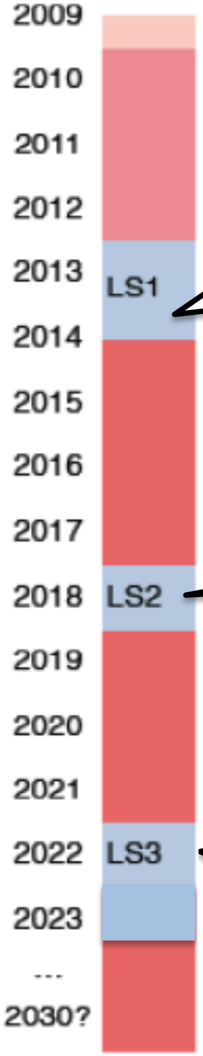
- **Even if Nature is finetuned and stop is heavy we have other reasons for new physics at weak scale**
  - Unification of couplings, Dark Matter, …
- **E.g. in “split-SUSY” other scalars are all heavy but gauginos are at ~low mass**





Dramatic improvement in reach by HL-LHC: probing ~1 TeV charginos!

ATLAS Upgrade Plans



Phase-0

New inner pixel layer

Detector consolidation

Construction ongoing

Phase-1

Improve L1 Trigger capabilities to cope with higher rates

4 Technical Design Reports

Phase-2 (HL-LHC)

Prepare for <μ>=200

Replace Inner Tracker

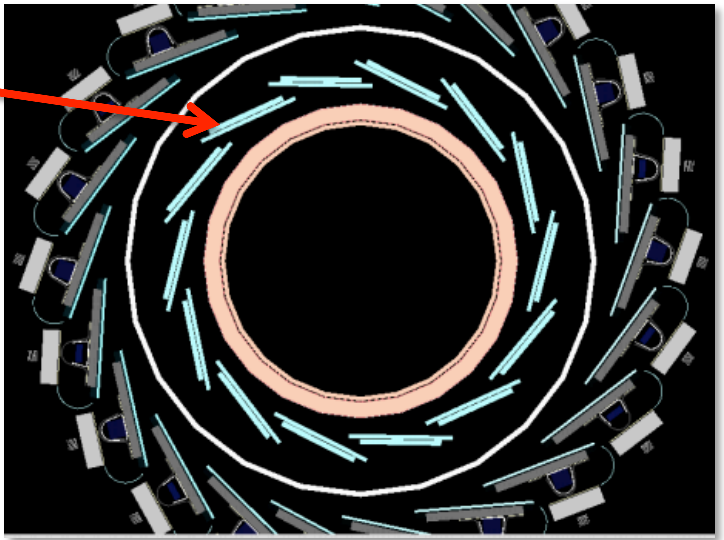
New L0/L1 trigger scheme

Upgrade muon/calorimeter electronics

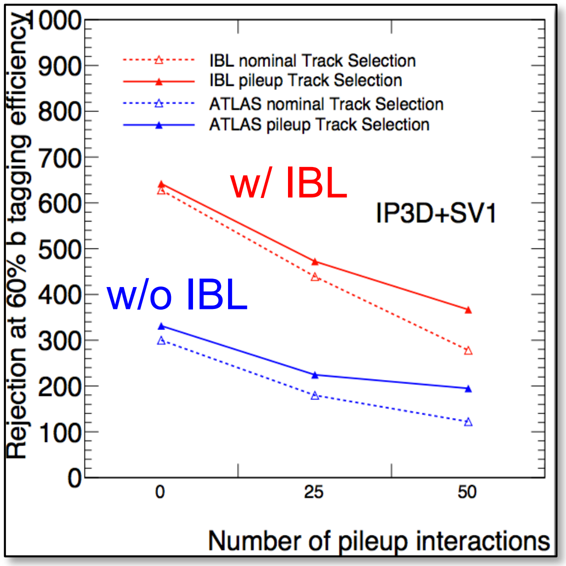
Letter of Intent

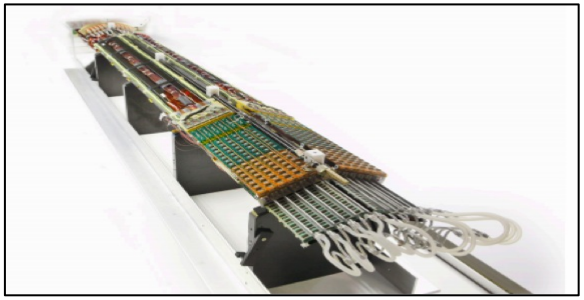
Ongoing: Phase-0 upgrades (LS-1)

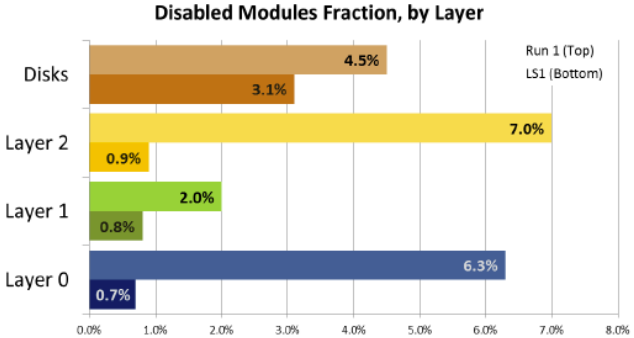
- **Insertable B-Layer**
  - Production/Integration ongoing
  - Installation of IBL in the pixel detector, in the pit: May 2014
  - Important ingredient for low mass, rad-hard construction: 2 cm x 2 cm FE-I4 Pixel Chip, 130 nm CMOS process
  - Will stay until Phase-II



b-tagging rejection vs pile-up



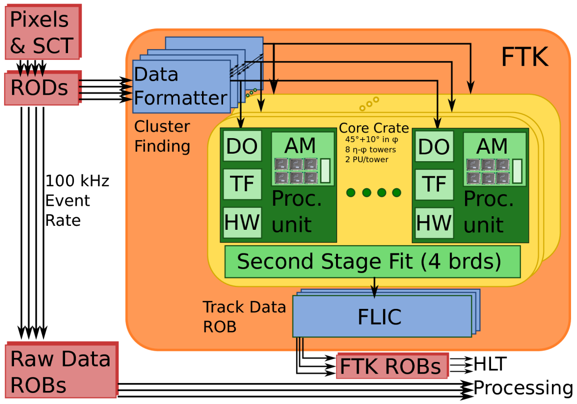


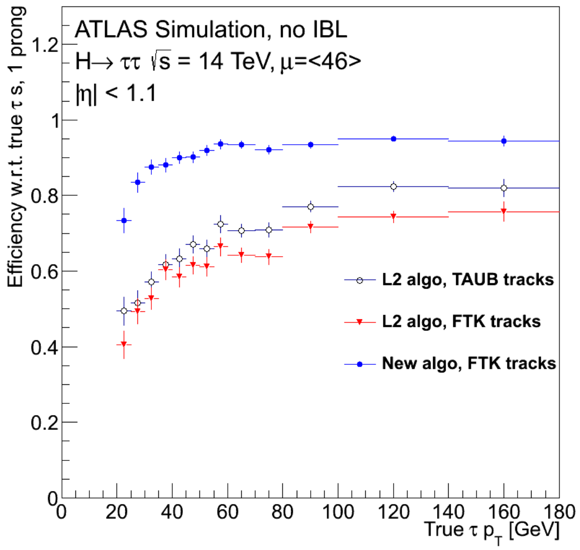


- **New service quarter panels**
  - At end of run-1 5% of Pixel modules were not working
  - New SQPs recovered majority of dead channels: live fraction 95.2% => 98.9%

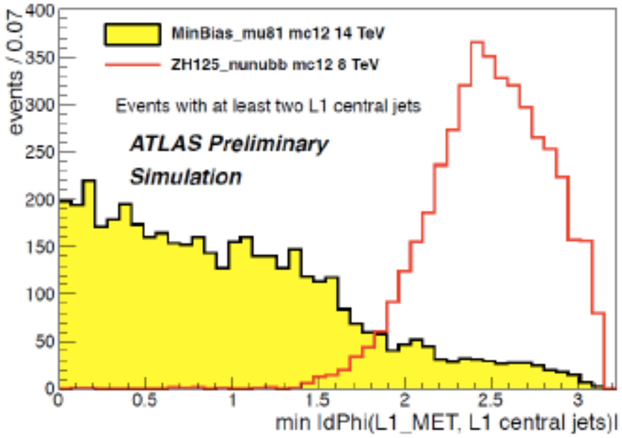
Phase-1 Upgrades: FTK and L1Topo

- **Fast TracKer (FTK)**
  - Dedicated, hardware-based track finder
  - Runs after L1, on duplicated Si-detector read-out links
  - Provides tracking input for L2 for the full event
  - Finds and fits tracks (~ 25 μs) in the ID silicon layers at an "offline precision"





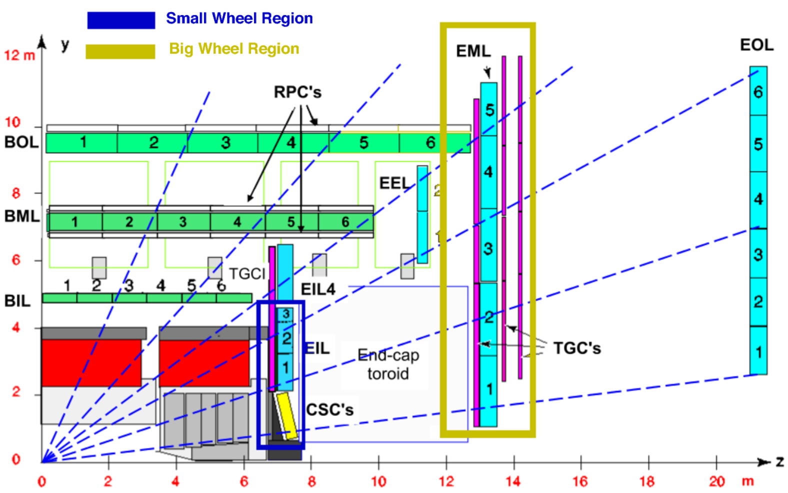
- **L1Topo**
  - Topological L1 trigger
  - Correlate L1 objects with each other
  - E.g. deltaphi(MEt, jet) for ZH→vvbb



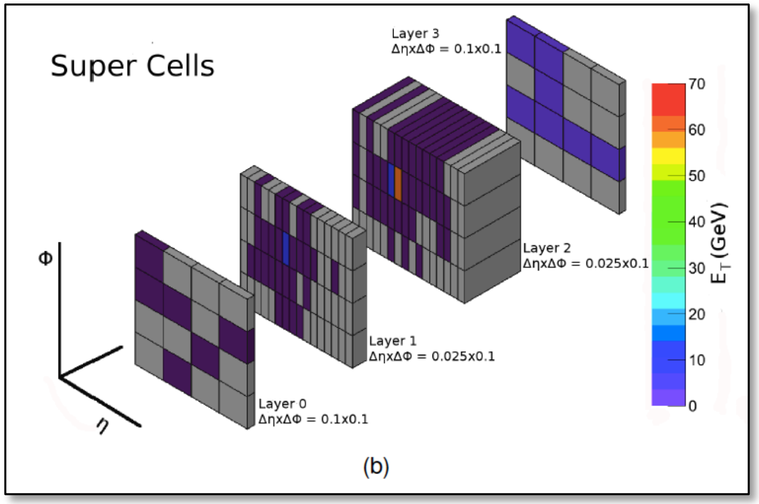
- **Installation for Run-2**
  - L1Topo expected to be ready for 2015
  - FTK: partial system in 2015, full system in 2016

Phase-1 Upgrades: NSW and LAr

New Small Wheel



LAr calorimeter



(b)

- **New Muon Small Wheels**
  - improved tracking and trigger capabilities
  - position resolution < 100 μm
  - Meets Phase-II requirements
    - compatible with $<\mu>=200$, up to $L \sim 7 \times 10^{34}$ $cm^{-2}s^{-1}$
  - Technology: MicroMegas and sTGCs
  - Reduce muon trigger thresholds

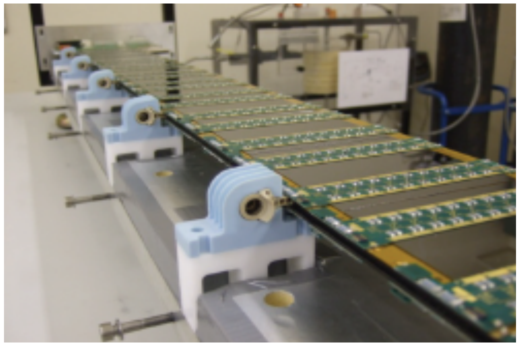
- **LAr Calorimeter readout**
  - Use higher granularity in trigger
    - In space and in energy resolution
  - Use shower shape variables
  - Improve energy resolution
  - Reduce electron, photon, tau, jet and missing ET trigger thresholds

Installation of both during LS2

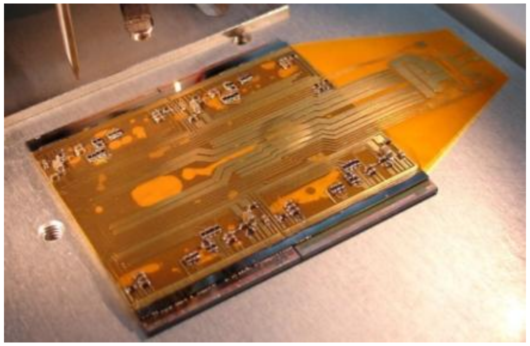
Phase-2 Upgrade: New Inner TracKer (ITK)

- **Current Inner Detector (ID)**
  - Designed to operate for 10 years at L=1x10^{34} cm^{-2}s^{-1} with <μ>=23, @25ns, L1=100kHz
- **Limiting factors at HL-LHC**
  - Bandwidth saturation (Pixels, SCT)
  - Too high occupancies (TRT, SCT)
  - Radiation damage: Pixels (SCT) designed for 400 (700) fb^{-1}

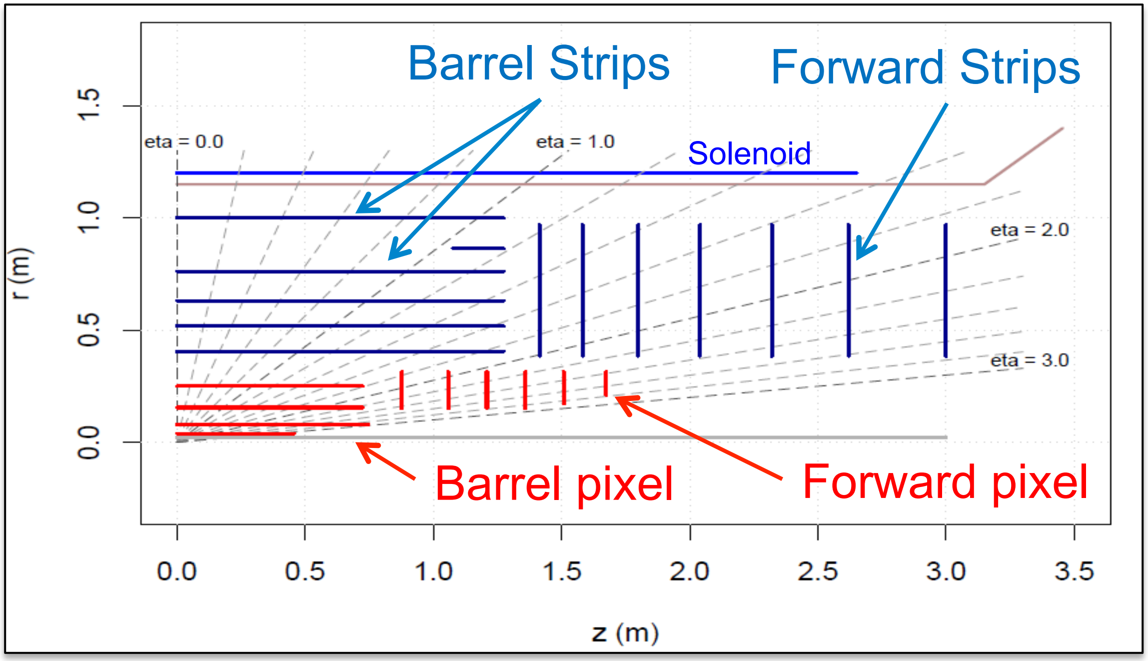
Microstrip Stave Prototype



Quad Pixel Module Prototype



LoI layout new (all Si) ATLAS Inner Tracker for HL-LHC



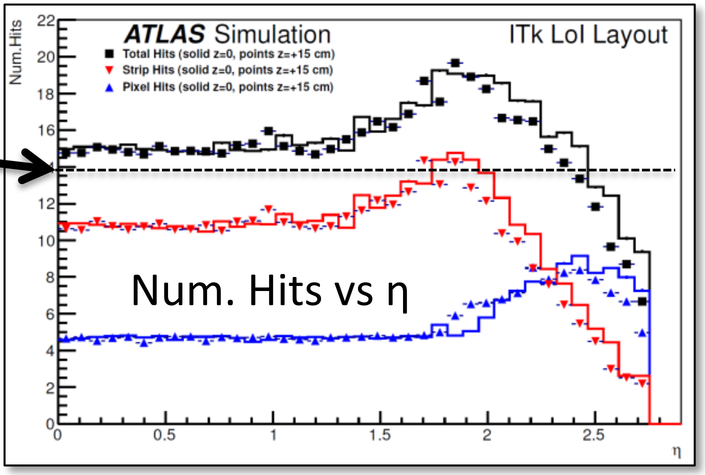
New 130nm prototype strip ASICs in production

- incorporates L0/L1 logic

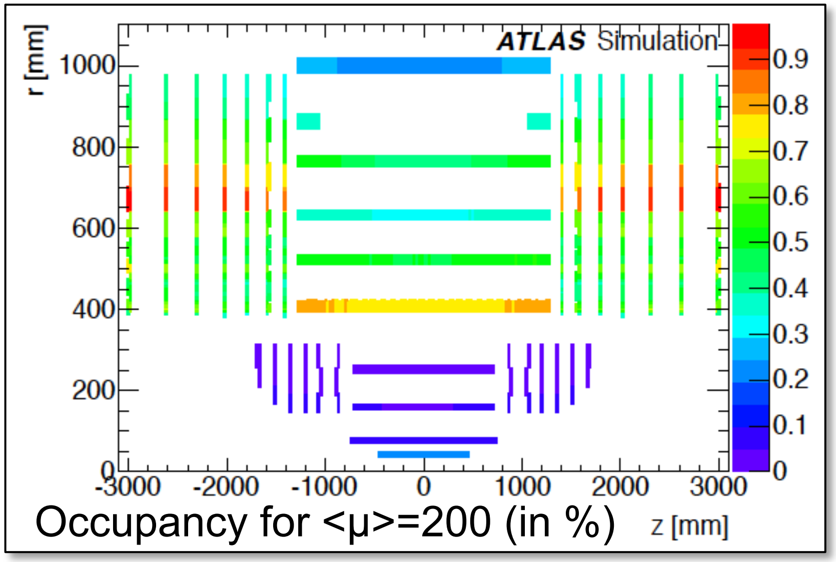
Sensors compatible with 256 channel ASIC being delivered

New Tracking detector cont.

- **Studies with LOI layout**
  - Robust tracking (14 layers)
  - Occupancy <1% for <μ>=200
  - Reduced material w.r.t. current ID
  - Better tracking performance at <μ>=200 than current ID at <μ>=0
- **Prototypes tested to 2x HL-LHC flux**
- **Solid baseline design**
  - Working on further optimisation, e.g. tracking up to |η|=4.0 for tagging vertex of forward jets in VBF processes?

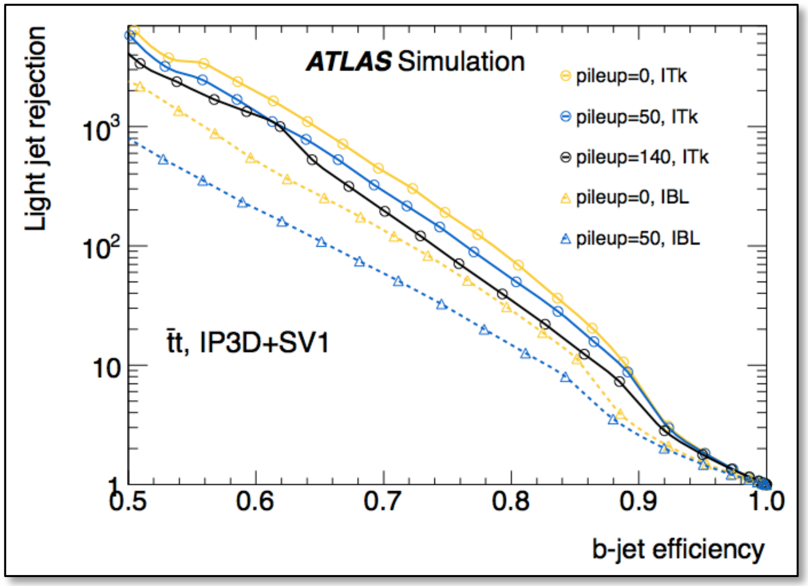


Num. Hits vs η



Occupancy for <μ>=200 (in %)

Light jet rejection, ID (w/IBL) and ITk



Conclusions and Outlook

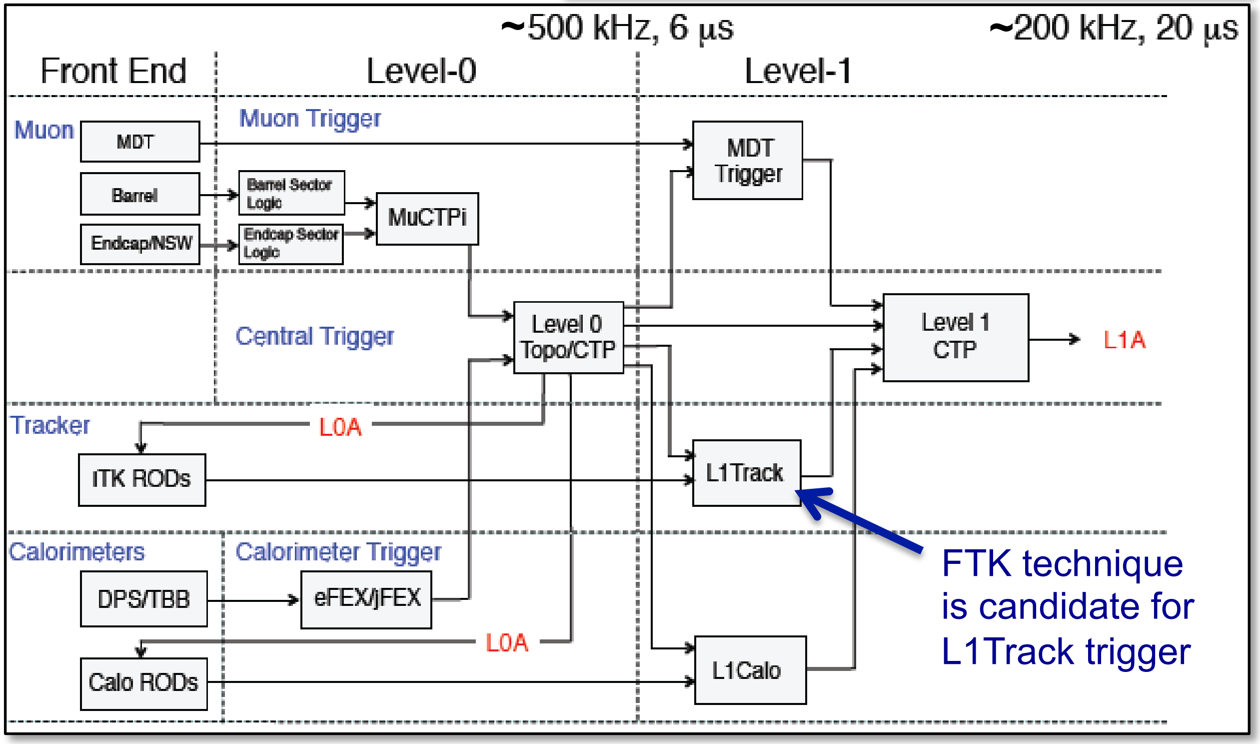
- **LHC has delivered large datasets and ATLAS has operated very efficiently**
  - Thanks to machine team for outstanding performance!
- **267 publications on collision data submitted by ATLAS**
  - Higgs boson discovered at M~125 GeV
    - looks rather SM-like at first glance but higher precision needed
  - Many searches for new physics
    - Severely constrains many models
  - Many precision measurements
    - Improve understanding of theoretical models and tools
- **Exciting future prospects**
  - Run-2 probes new territory with a few fb^{-1} of 13 TeV data
    - And probe Higgs boson more deeply
  - HL-LHC will do precision Higgs physics (~2-5% precision on couplings)
    - HL-LHC is Higgs factory: 170M Higgs bosons produced! (3M “useful”)
  - HL-LHC will significantly extend reach for many searches
    - Or provide data to explore any new discovery made earlier!!
- **Significant upgrades are required to fully explore the future LHC runs**
  - Strong technical expertise required from world-wide collaborators

Backup Slides

Trigger system architecture

- **New design for Phase II**
  - 2-level system, Phase-I L1 becomes Phase-II L0, new L1 includes tracking
  - Make use of improvements made in Phase 1 (NSW, L1Calo) in L0
  - Introduce precision muon and inner tracking information in L1
    - Better muon pT resolution
    - Track matching for electrons,…
  - Requires changes to detector FE electronics feeding trigger system

Will also have new timing/control links and LHC interface system



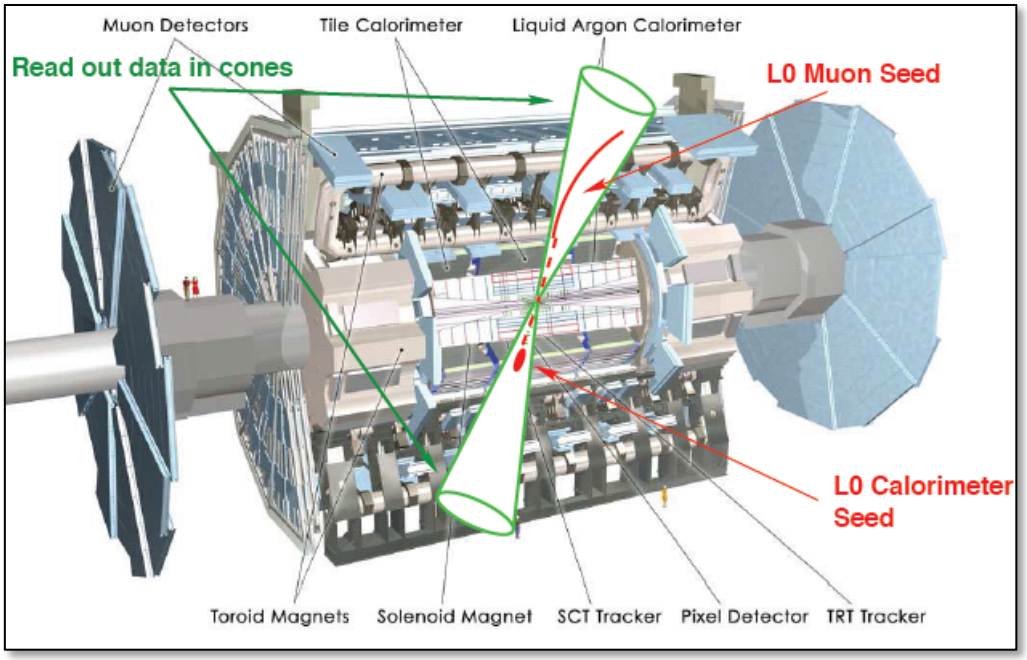
FTK technique is candidate for L1Track trigger

Level-0
Rate ~ 500 kHz, Lat. ~6 μs
Muon + Calo
Level-1
Rate ~200 kHz, Lat. ~20 μs
Muon + Calo + Tracks

L1Track Trigger

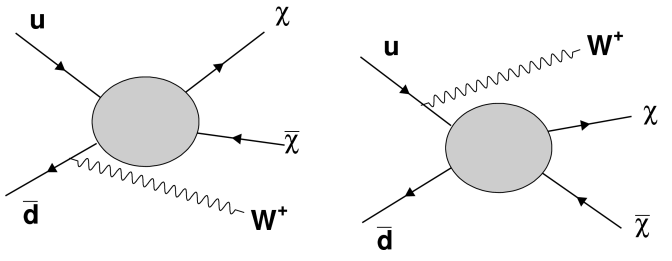
- **Adding tracking information at Level-1 (L1)**
  - Move part of High Level Trigger (HLT) reconstruction into L1
  - Goal: keep thresholds on p_T of triggering leptons and L1 trigger rates low

- **Triggering sequence**
  - L0 trigger (Calo/Muon) reduces rate within 6 μs to $\gtrsim$ 500 kHz and defines RoIs
  - L1 track trigger extracts tracking info inside RoIs from detector FEs



- **Challenge**
  - Finish processing within the latency constraints

Direct dark matter searches



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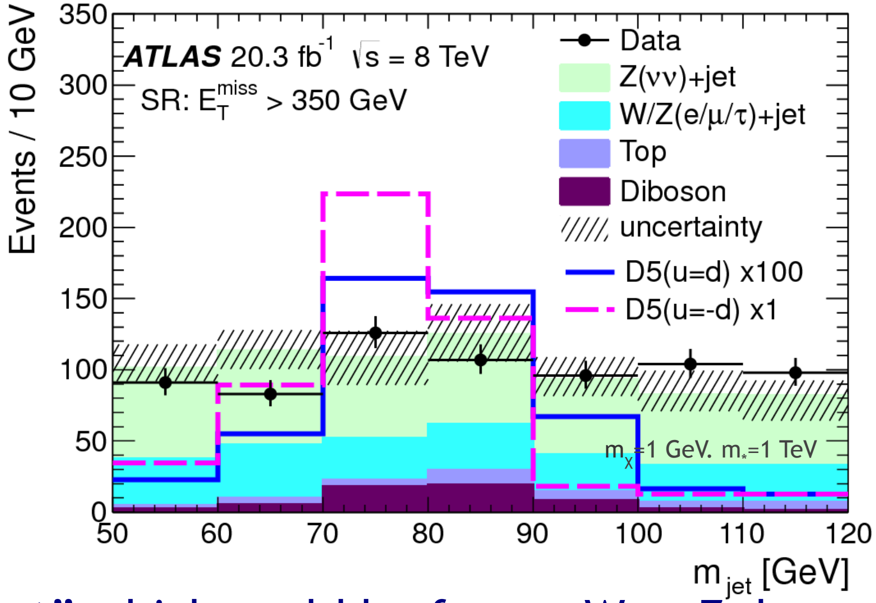
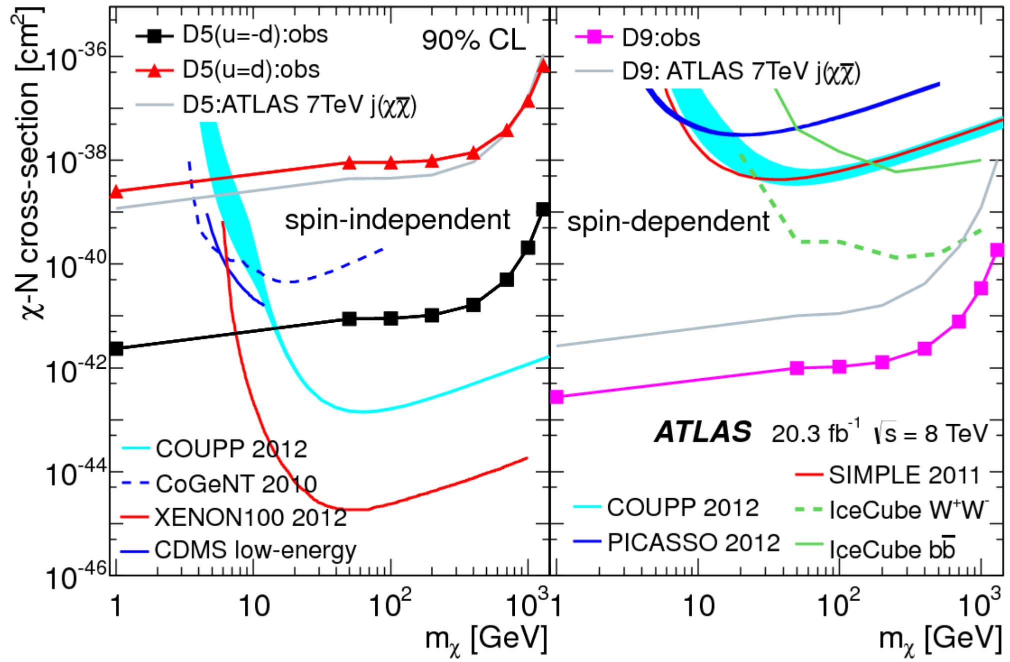


New result from monojet signature with a "fat jet" which could be from a W or Z decay

Complements earlier "inclusive monojet" searches



Search is for WIMP (χ) pair-production
→ missing-E_T signature

Limits placed in context of effective theories of DM interactions with SM particles: spin-independent (D5) and spin-dependent(D9) with C(u)=±C(d) (− sign enhances Wχχ)

arXiv:1309.4017