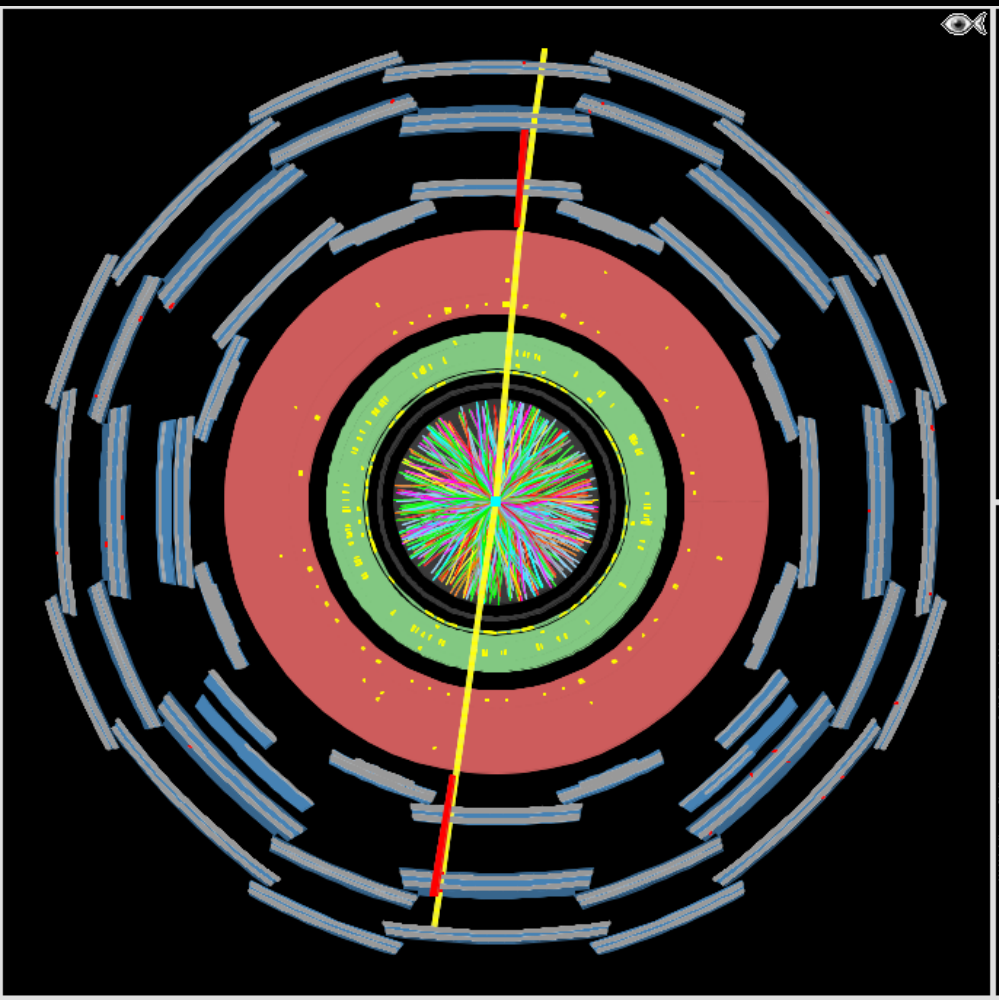
Latest news from the LHC

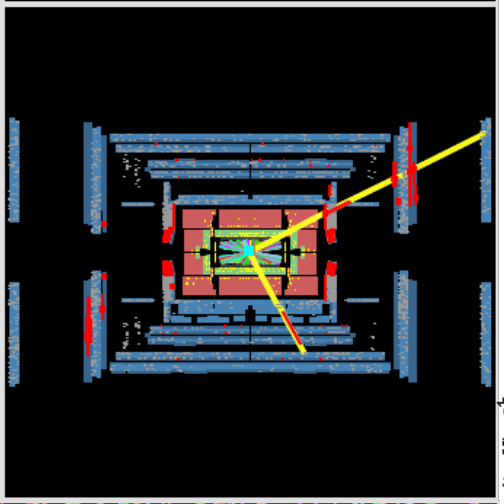
Jonathan Butterworth
University College London
On behalf of ATLAS & CMS

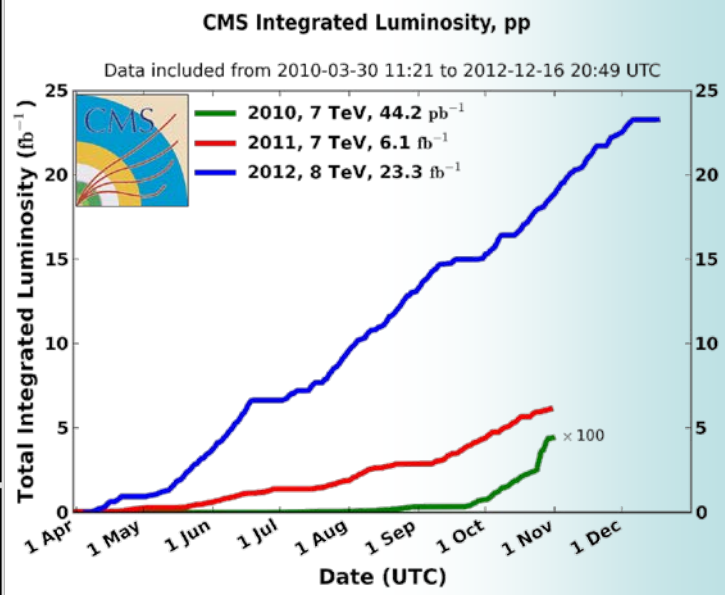
Planck 2013, Bonn 20/5/2013

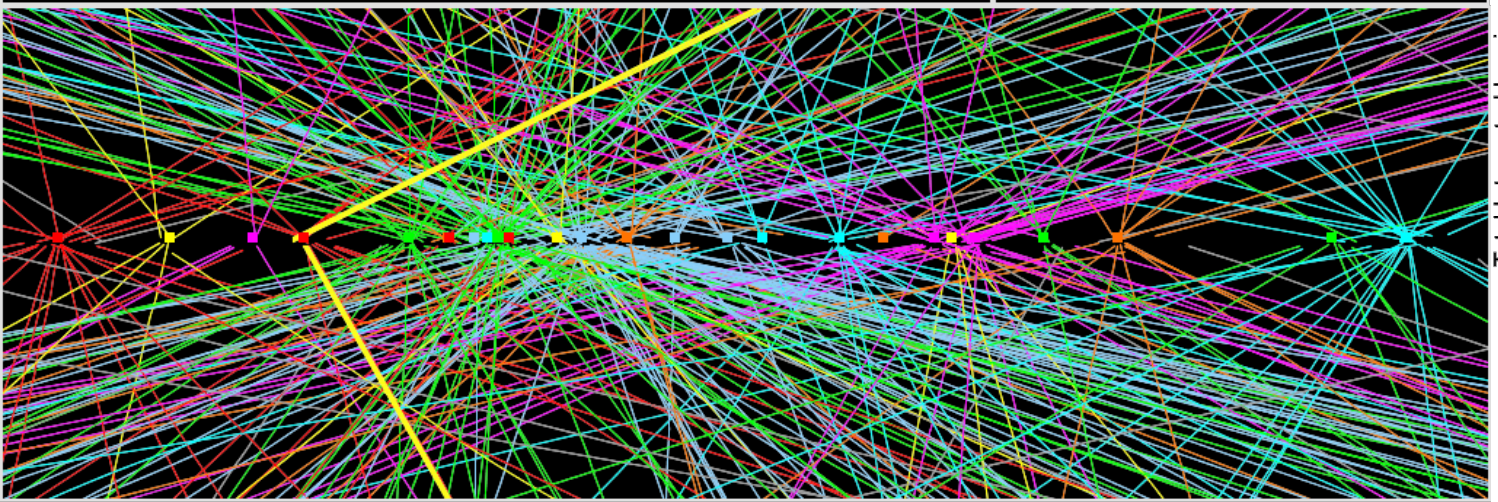

LHCb
ATLAS
CERN Meyrin
PS 628 m
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
ALICE
CMS
LHC 27 km

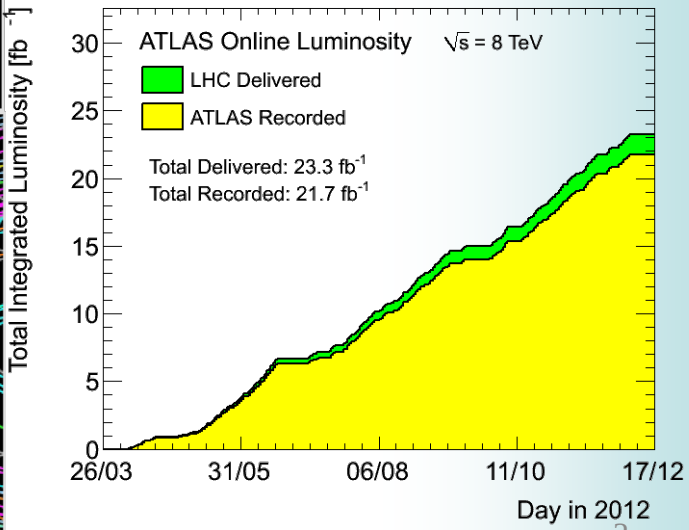


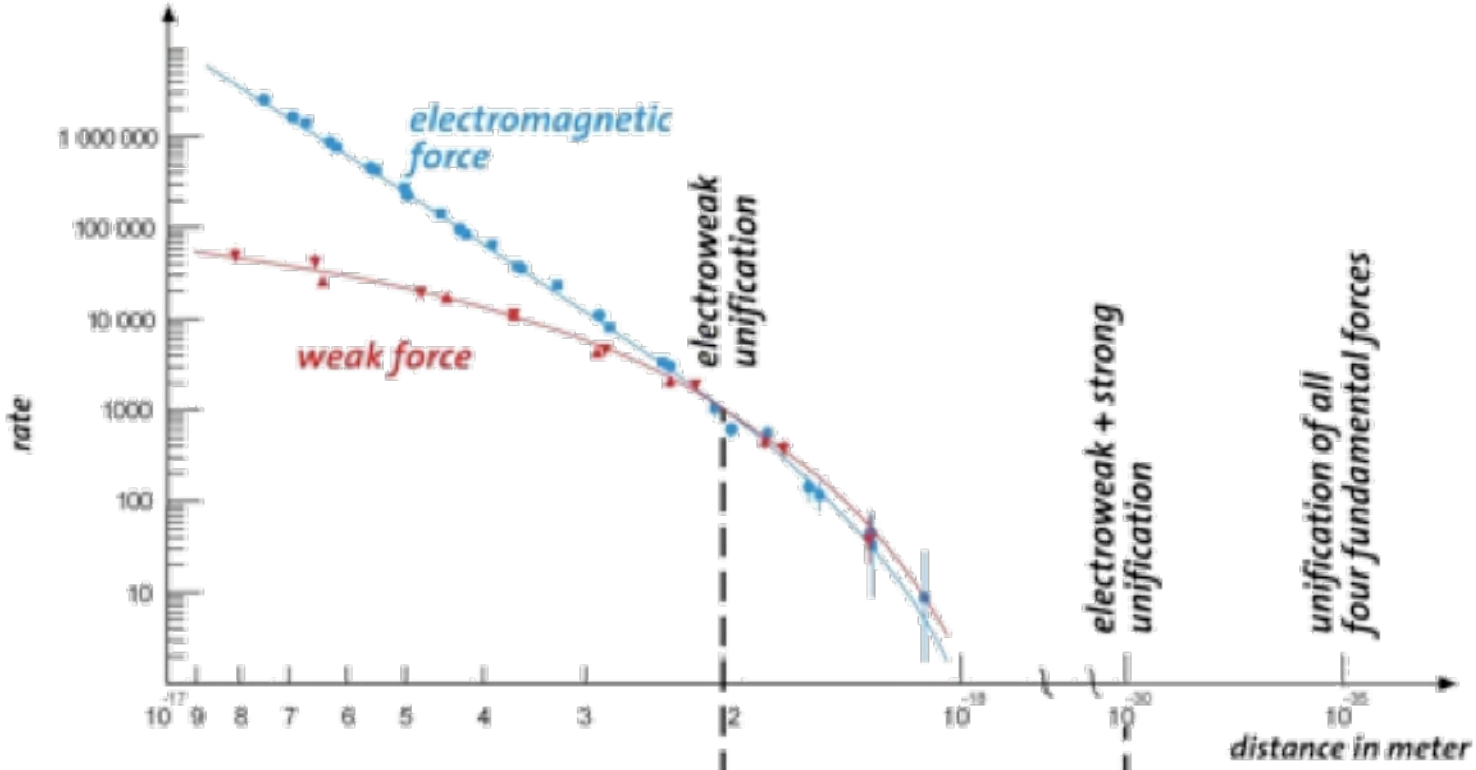

ATLAS
EXPERIMENT
Run Number: 201289, Event Number: 24151616
Date: 2012-04-15 16:52:58 CEST

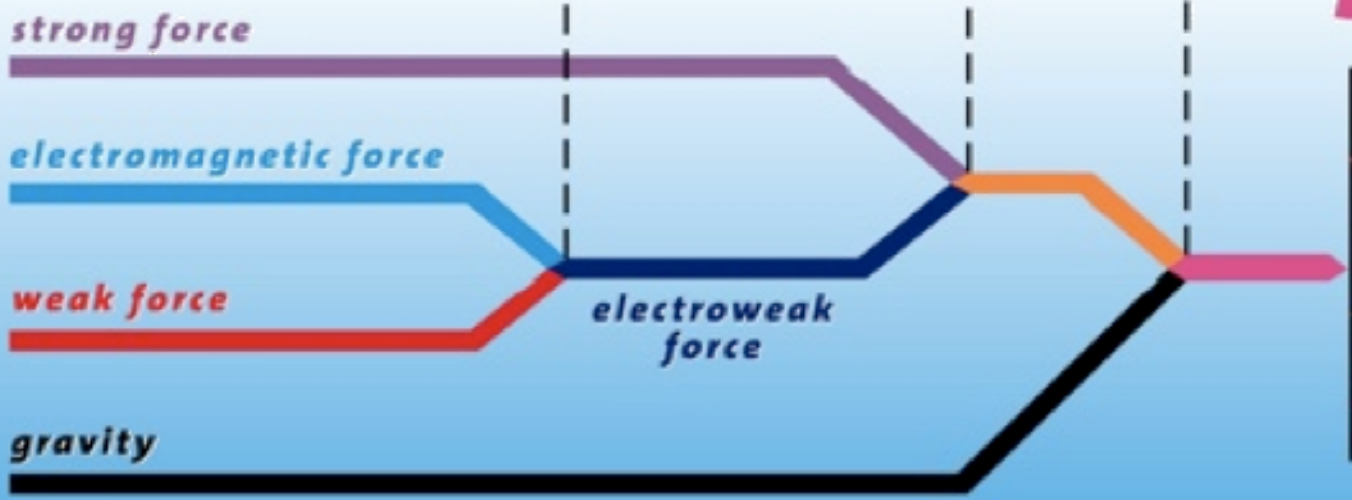



CMS Integrated Luminosity, pp
Data included from 2010-03-30 11:21 to 2012-12-16 20:49 UTC
2010, 7 TeV, 44.2 pb⁻¹
2011, 7 TeV, 6.1 fb⁻¹
2012, 8 TeV, 23.3 fb⁻¹
× 100
Total Integrated Luminosity (fb⁻¹)
1 Apr
1 May
1 Jun
1 Jul
1 Aug
1 Sep
1 Oct
1 Nov
1 Dec
Date (UTC)

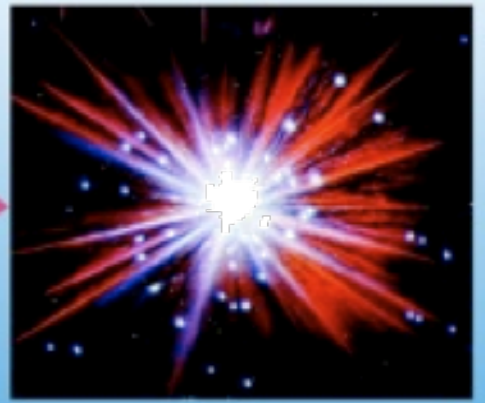



ATLAS Online Luminosity
√s = 8 TeV
LHC Delivered
ATLAS Recorded
Total Delivered: 23.3 fb⁻¹
Total Recorded: 21.7 fb⁻¹
Total Integrated Luminosity [fb⁻¹]
26/03
31/05
06/08
11/10
17/12
Day in 2012


electromagnetic force
weak force
rate
1 000 000
100 000
10 000
1000
100
10
electroweak unification
electroweak + strong unification
unification of all four fundamental forces
distance in meter


strong force
electromagnetic force
weak force
electroweak force
gravity

big bang



Measurements

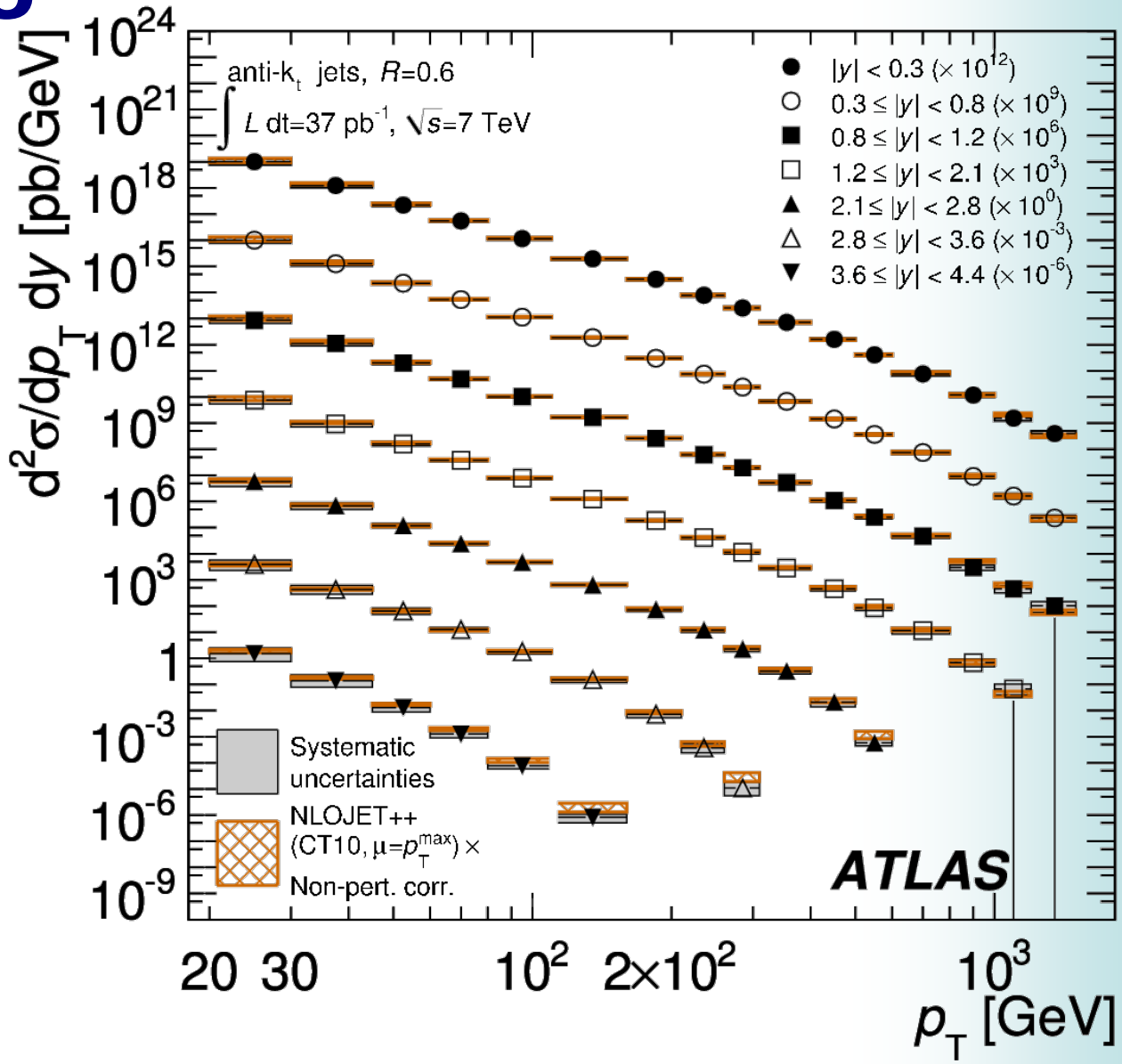
Discovery

Searches

Measurements

Jets at the highest scales

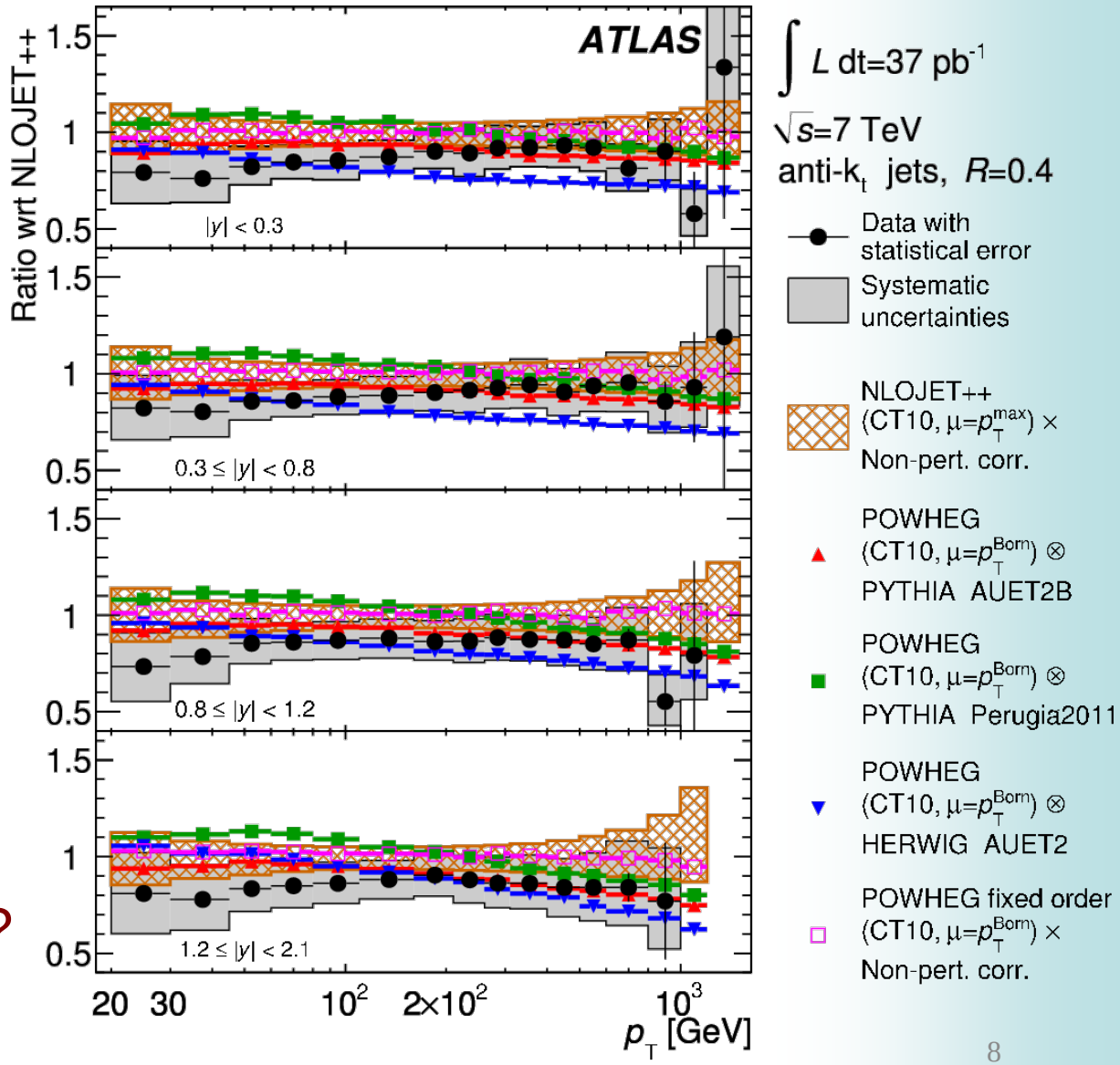
- Highest transverse momentum jets; at the TeV scale
  - *arXiv:1009.5908 (EPJC),arXiv:1112.6297 (PRD)*
  - *arXiv:1106.0208 (PRL)*



Jets at the highest scales

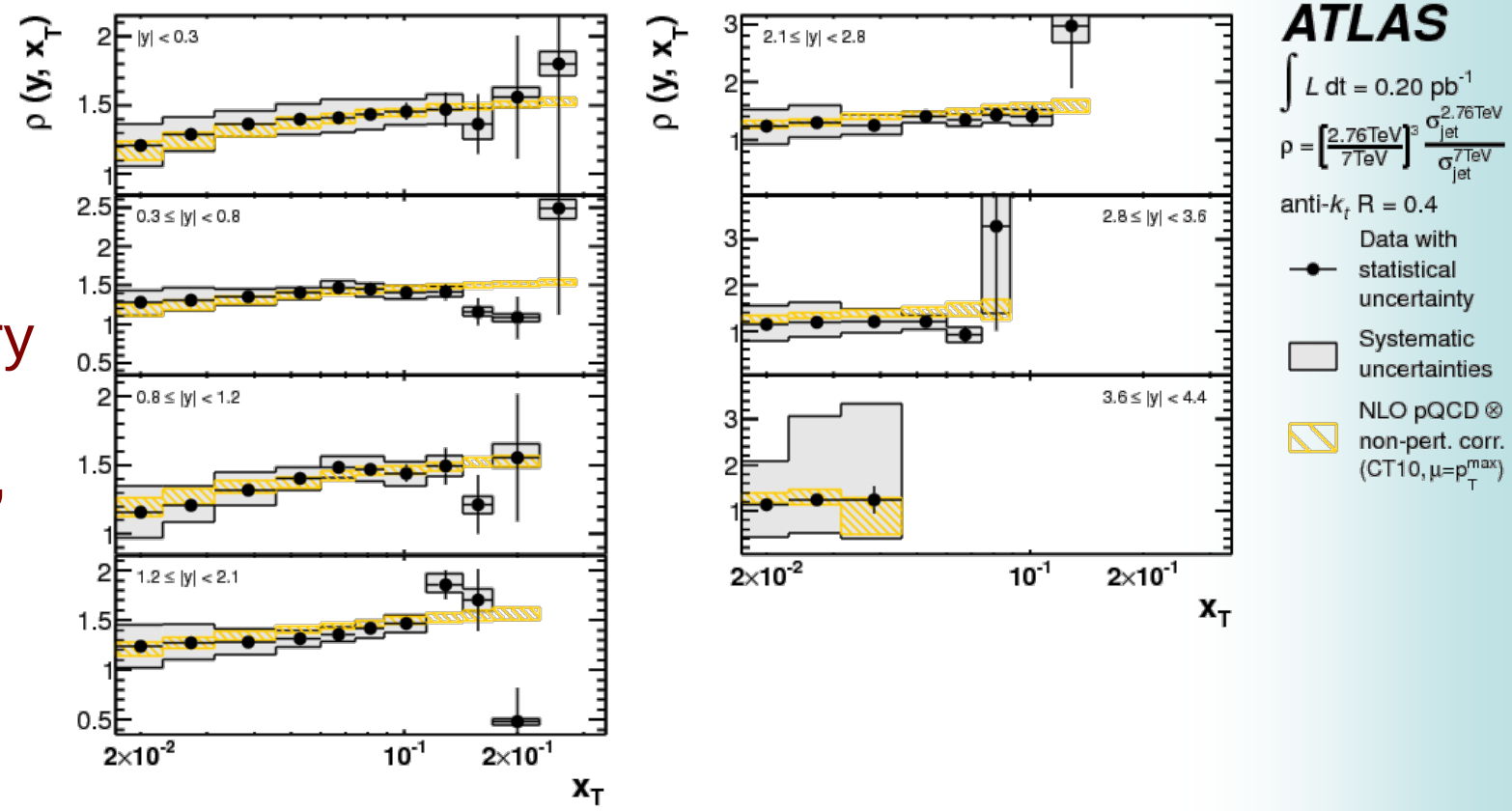
- Highest transverse momentum jets; at the TeV scale
  - *arXiv:1009.5908 (EPJC),arXiv:1112.6297 (PRD)*
  - *arXiv:1106.0208 (PRL)*
- General agreement with NLO QCD calculations (after soft corrections)

Significant spread in “NLO” predictions. ME/PS matching? MC tune (UE)? PDFs?



Jets as a probe of the proton

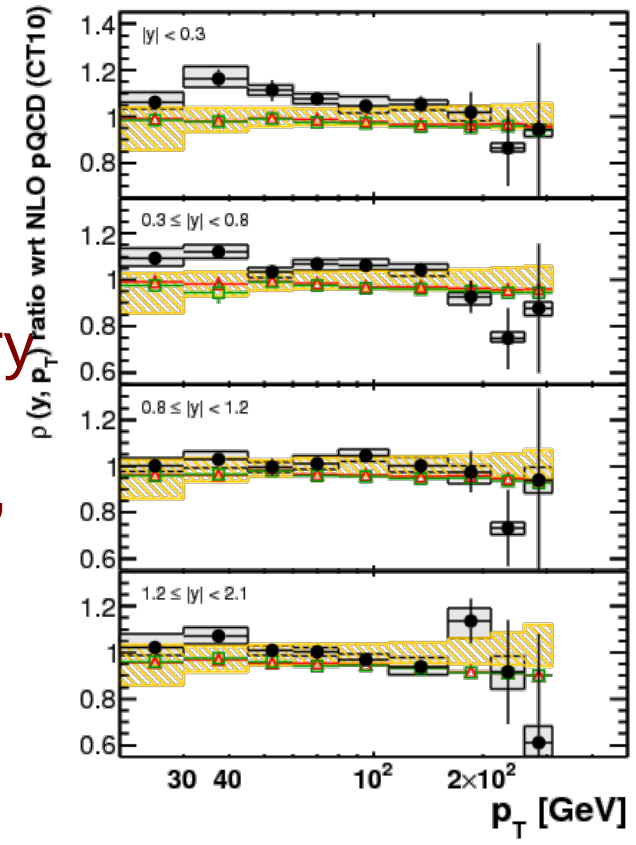
- Use 2.76 TeV CM data to measure cross sections.
- Ratios;
  - in x_T, many theory uncertainties ~cancel (same x, different Q^2)

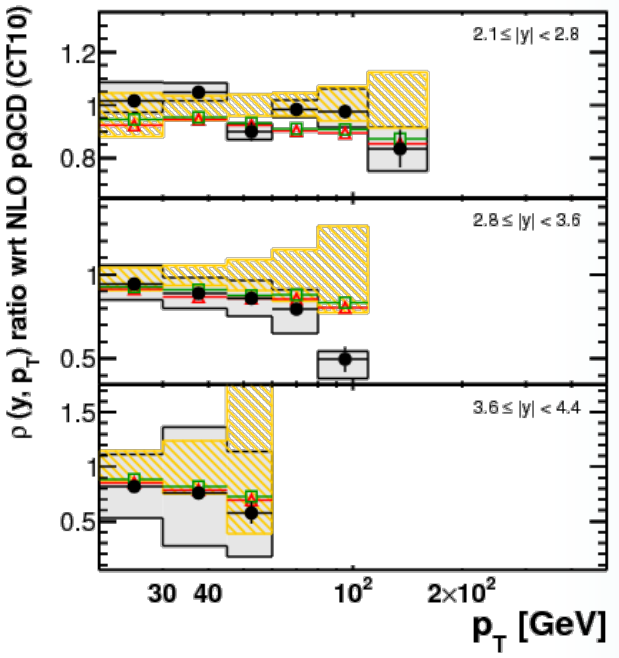


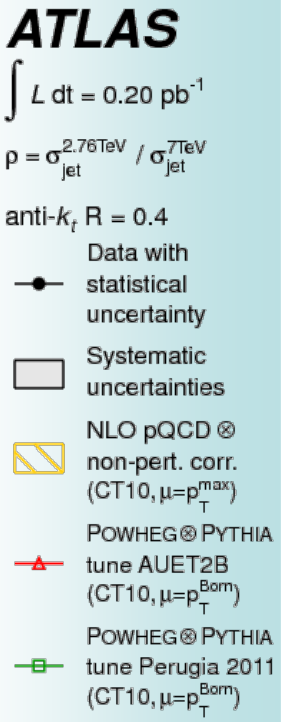
arXiv:1304.4739

Jets as a probe of the proton

- Use 2.76 TeV CM data to measure cross sections.
- Ratios;
  - in x_T, many theory uncertainties ~cancel (same x, different Q^2)
  - In p_T, jet energy scale ~cancels (dominant experimental uncertainty)



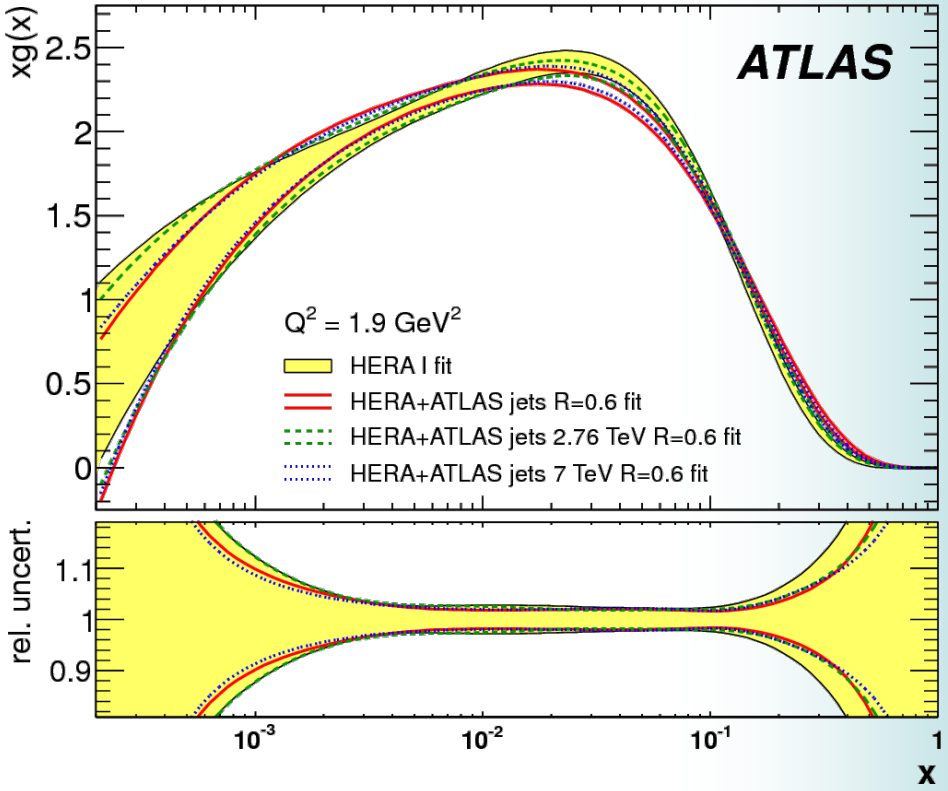




arXiv:1304.4739

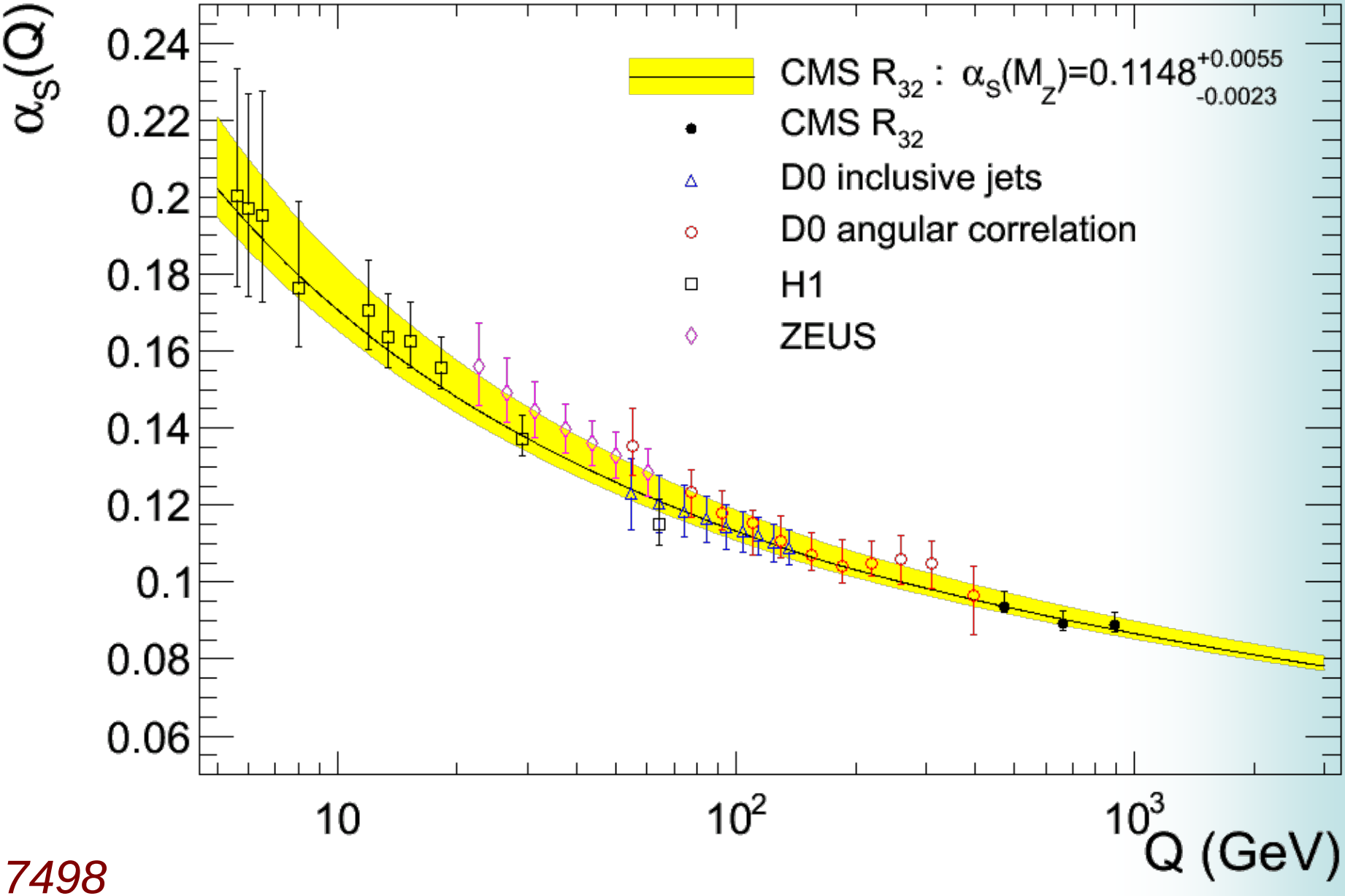
Jets as a probe of the proton

- Illustrative fit to HERA and ATLAS data
- Valence quarks heavily constrained by HERA
- High x gluon and sea quarks modified by addition of ATLAS data



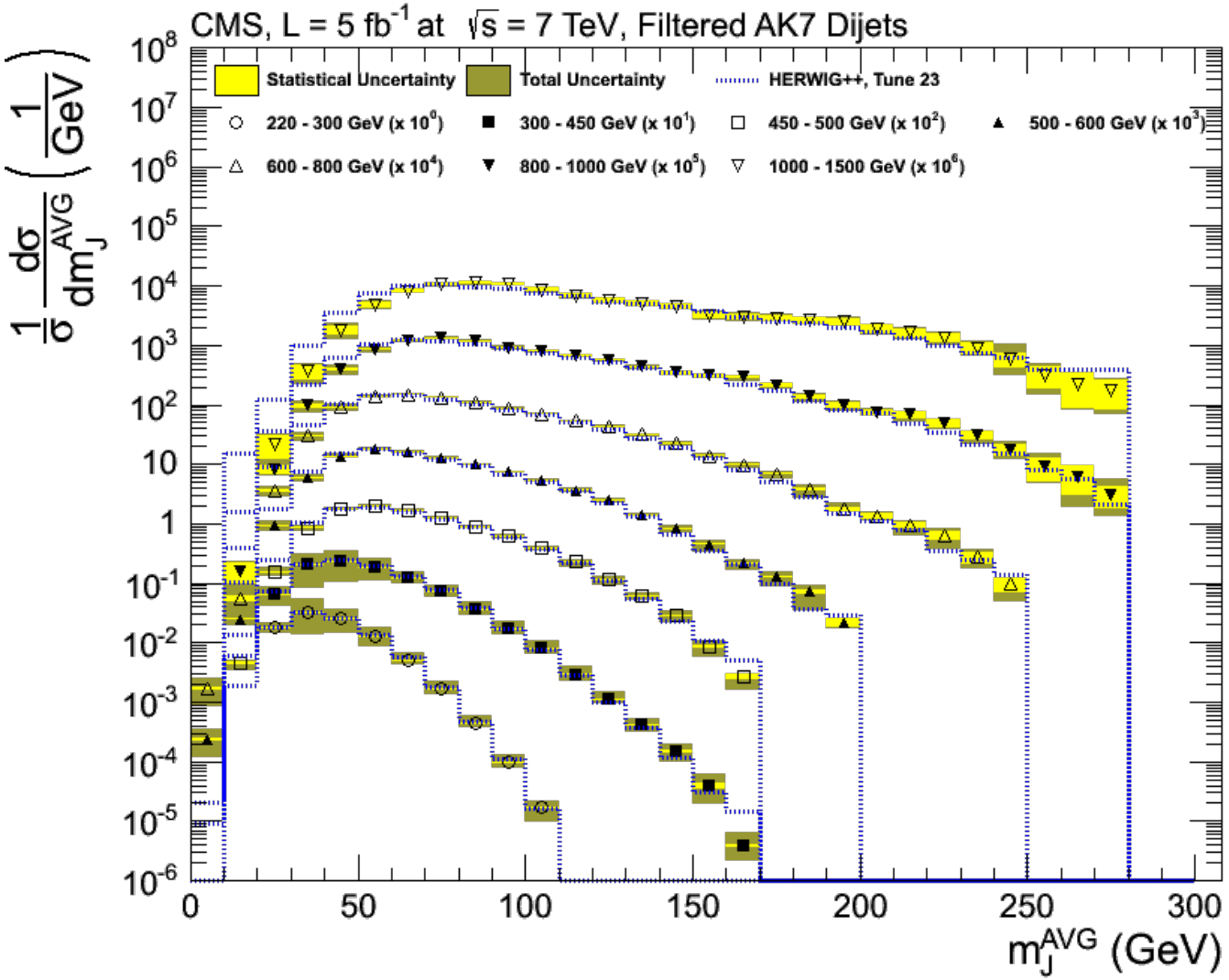
ATLAS-CONF-2012-128

Running of the strong coupling



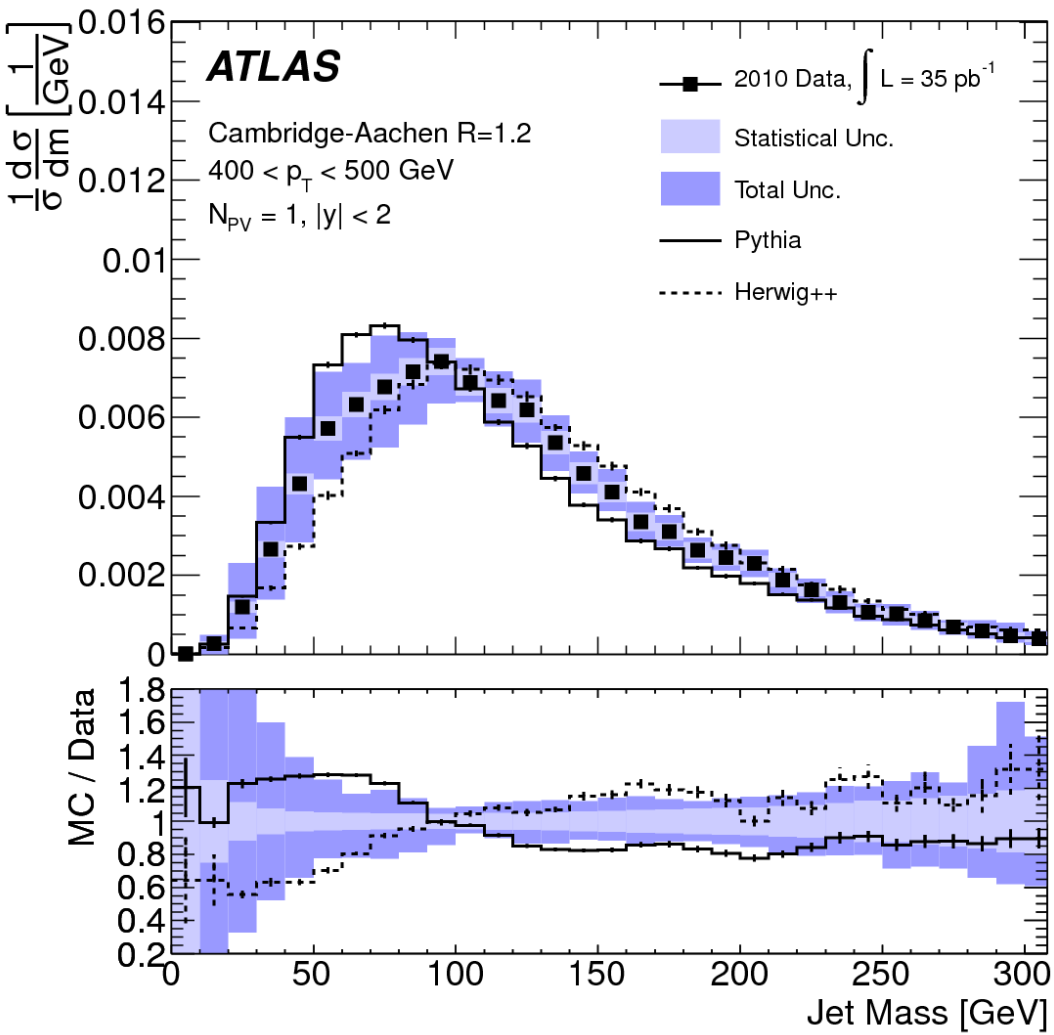
arXiv:1304.7498

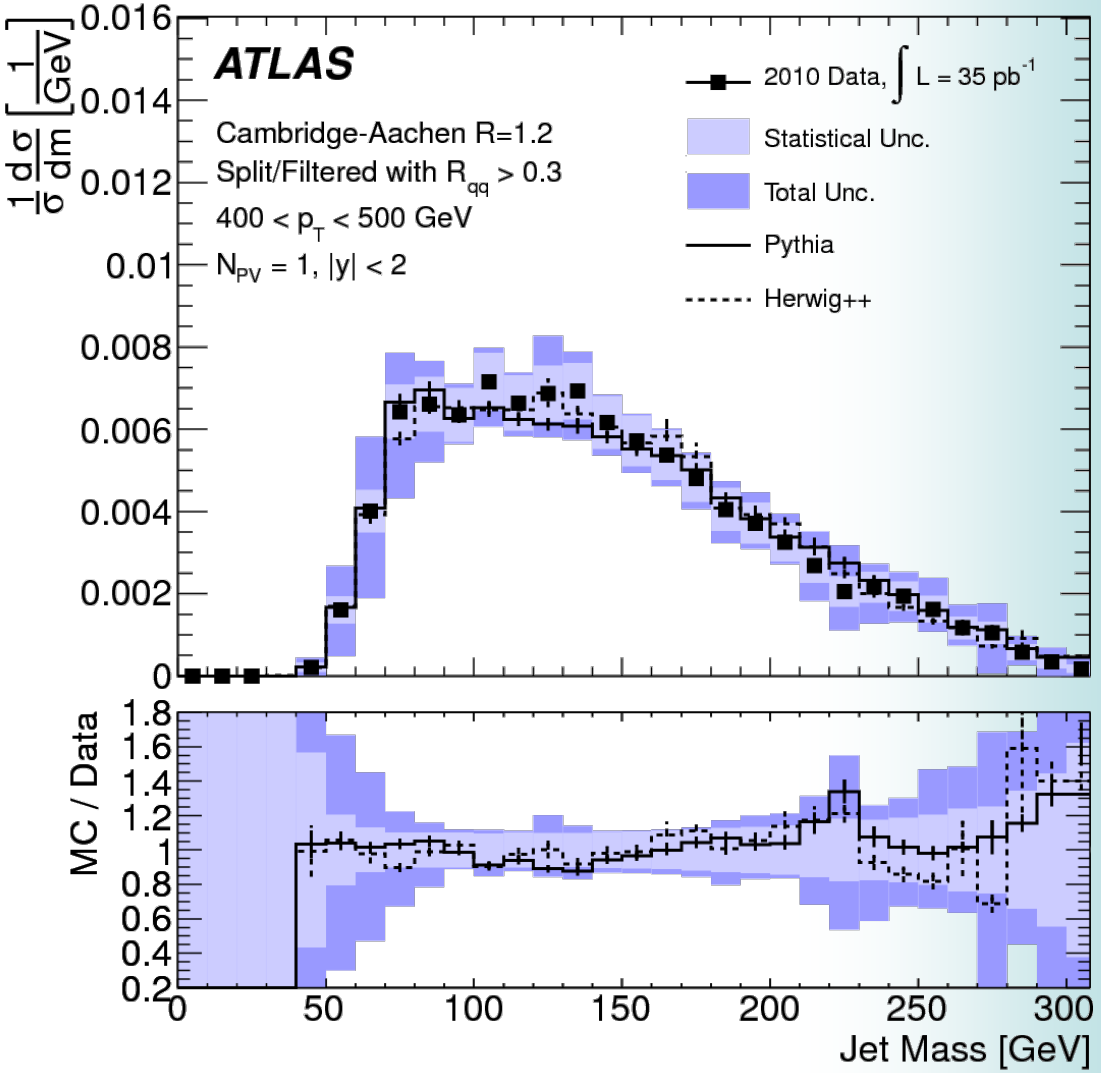
Jet grooming and subjets



arXiv:1303.4811

Jet grooming and subjets

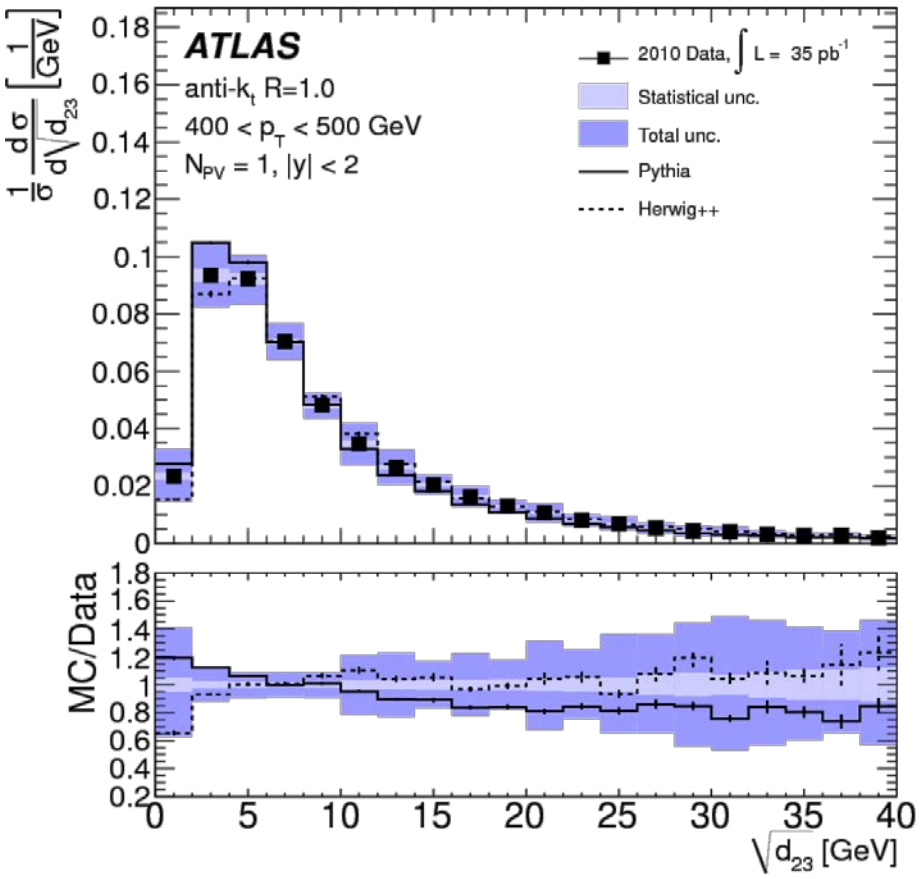


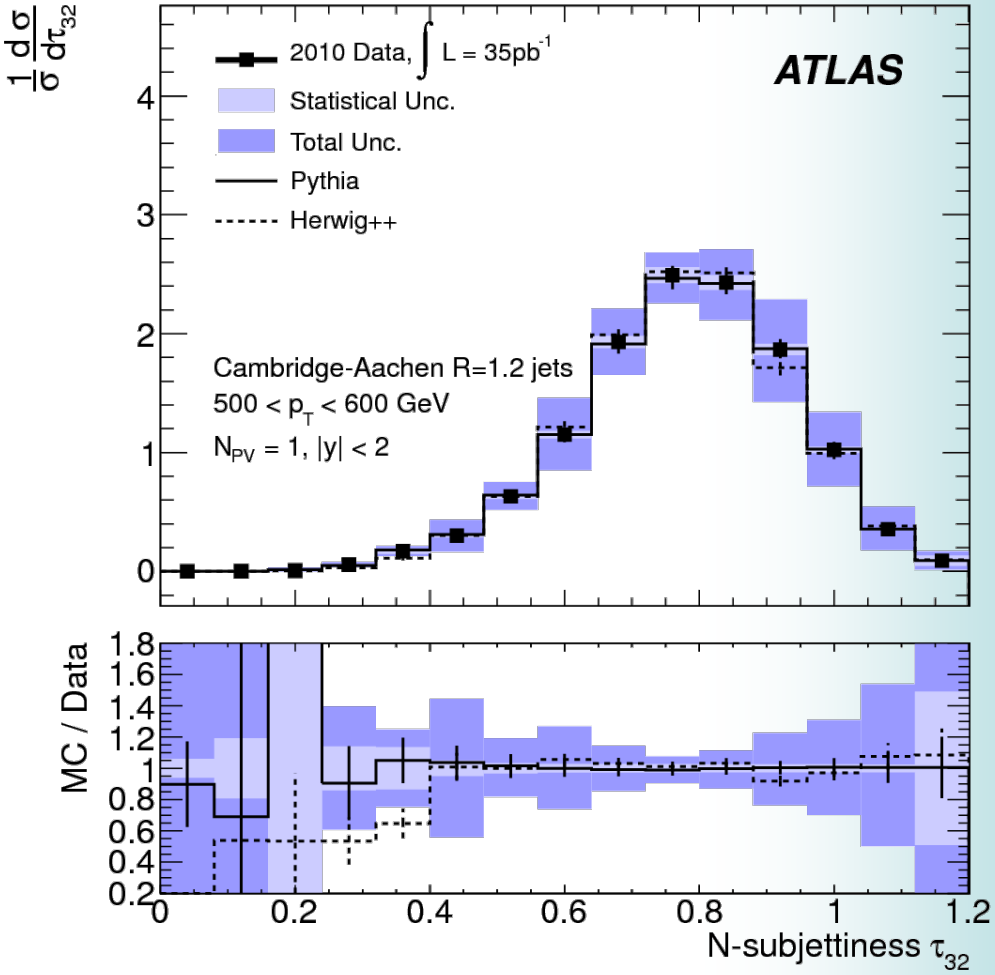


arXiv:1203.4606

Jet grooming and subjets

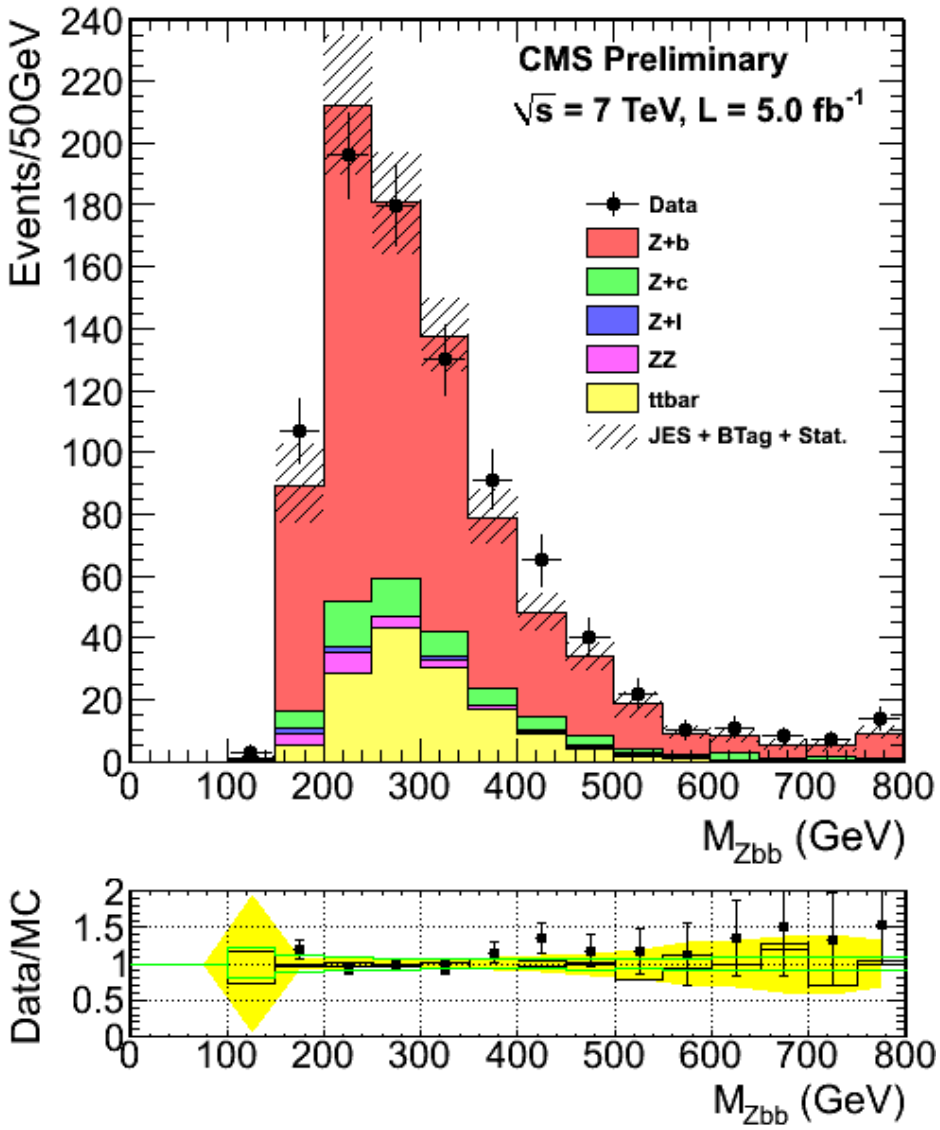
- k_T scale, N-subjettiness

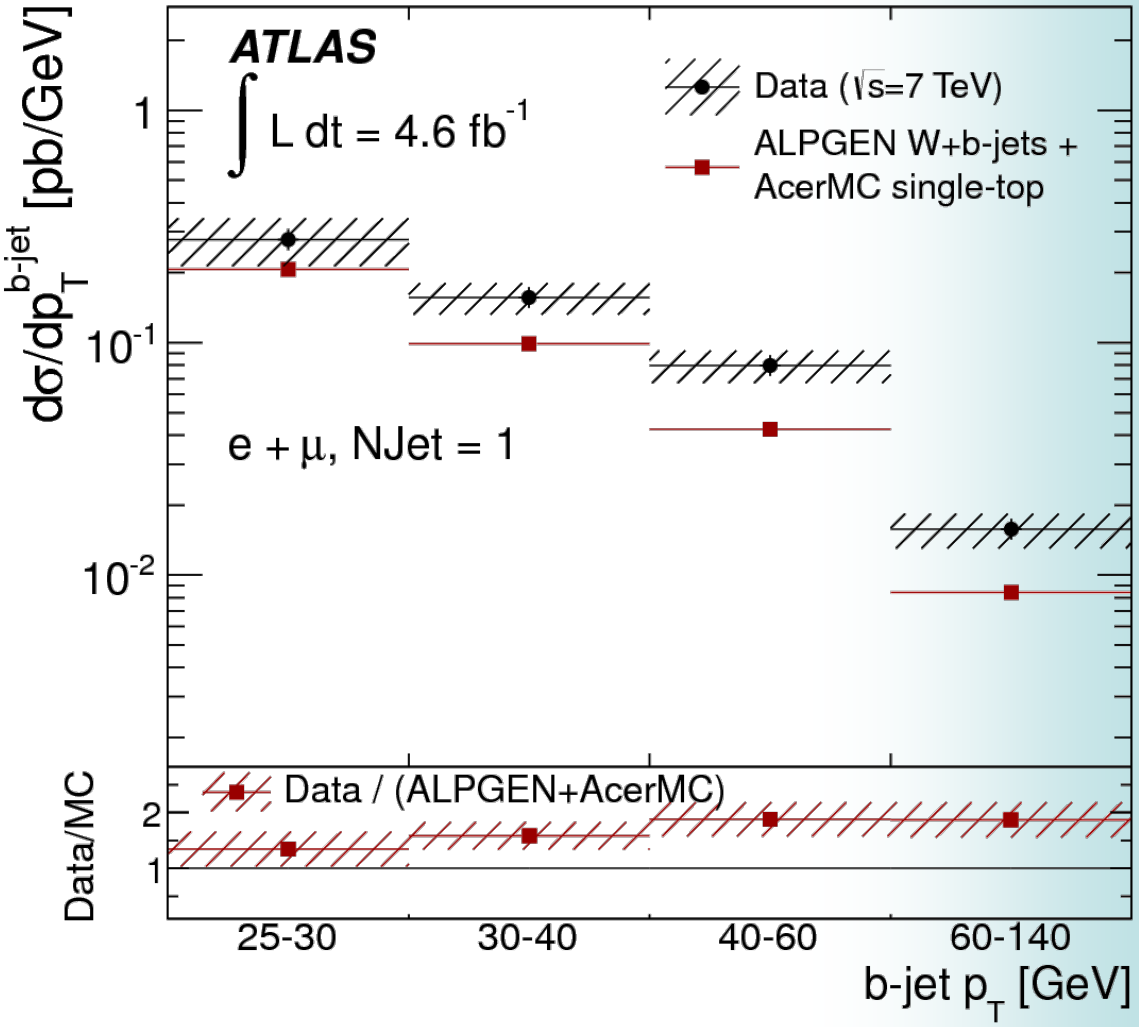




arXiv:1203.4606

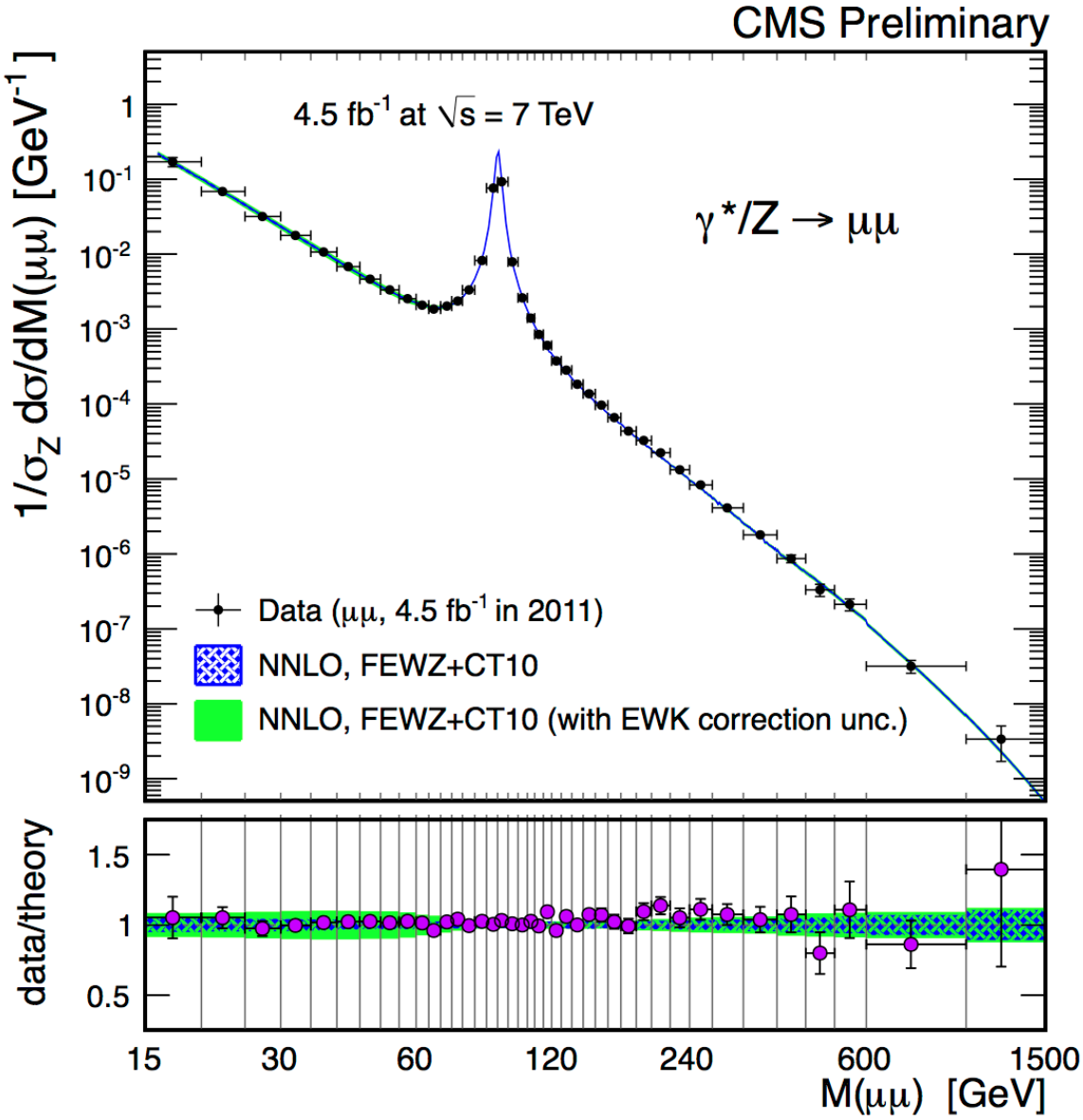
Vector bosons and (b) jets

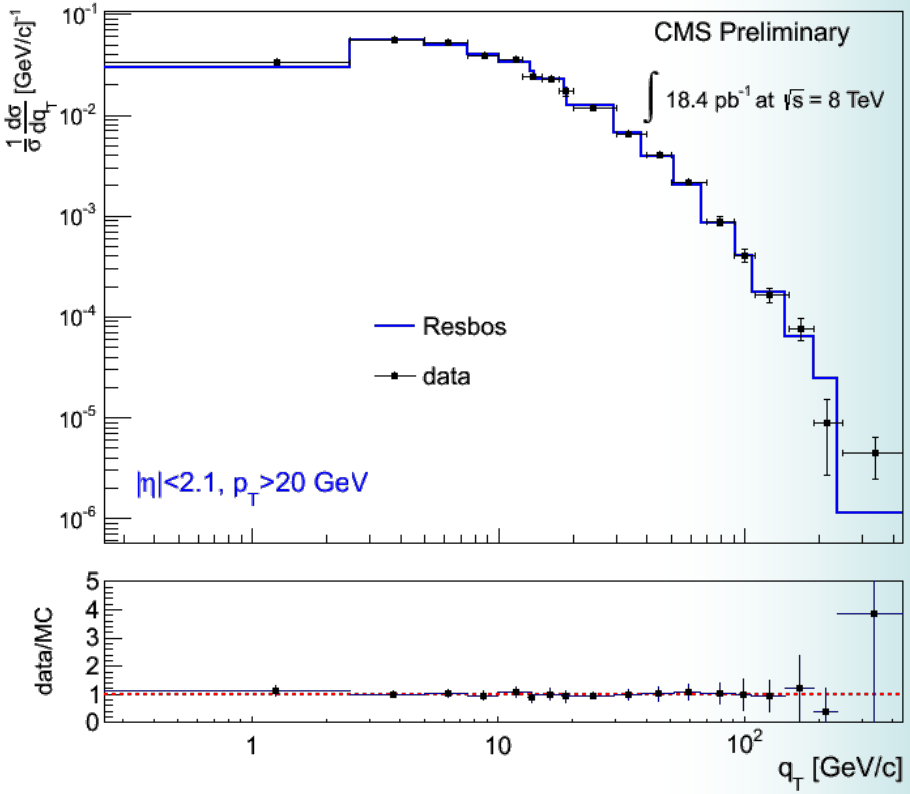




CMS PAS **SMP-13-004**
ATLAS **arxiv:1302:2929**

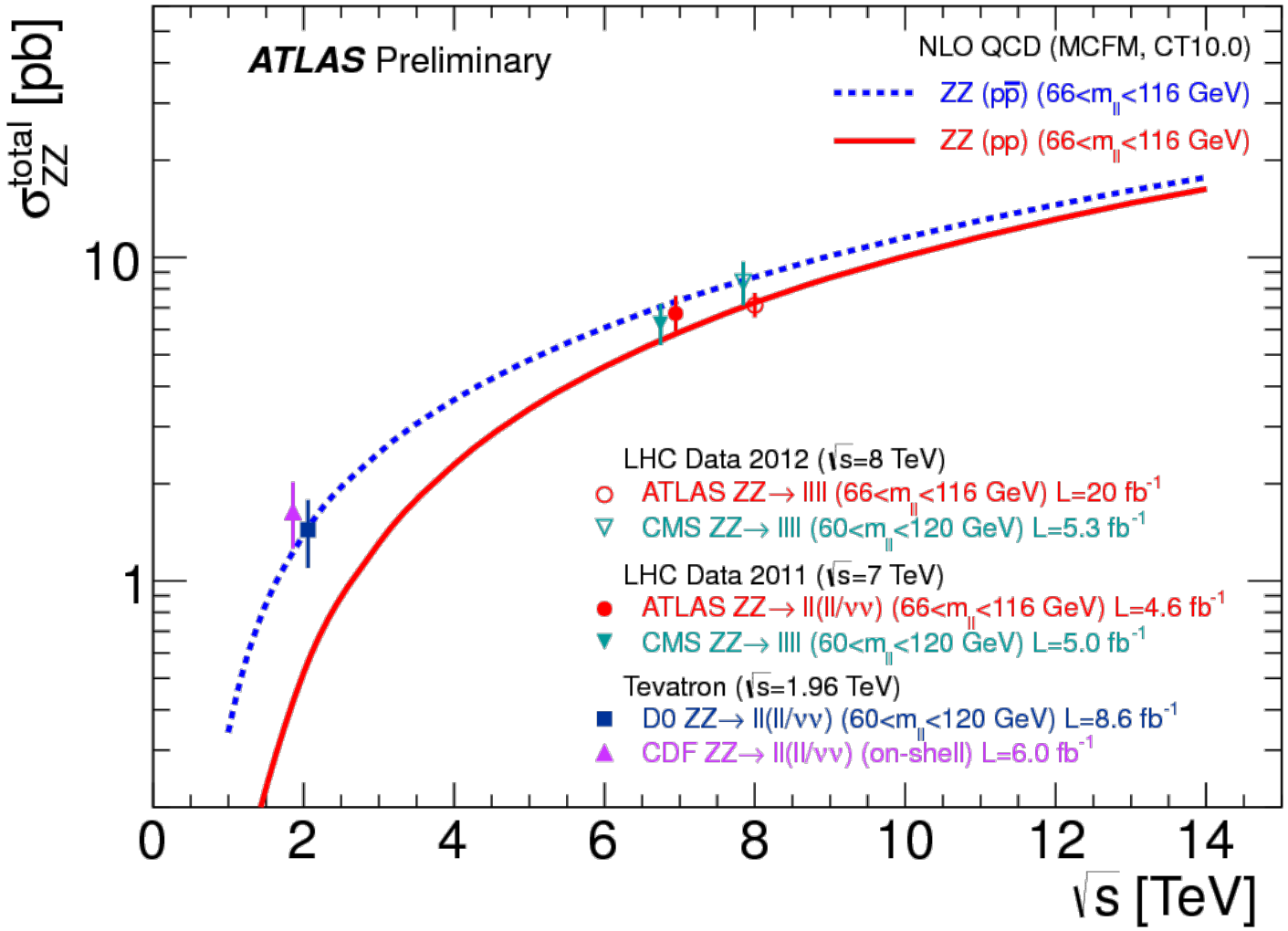
Lepton pairs

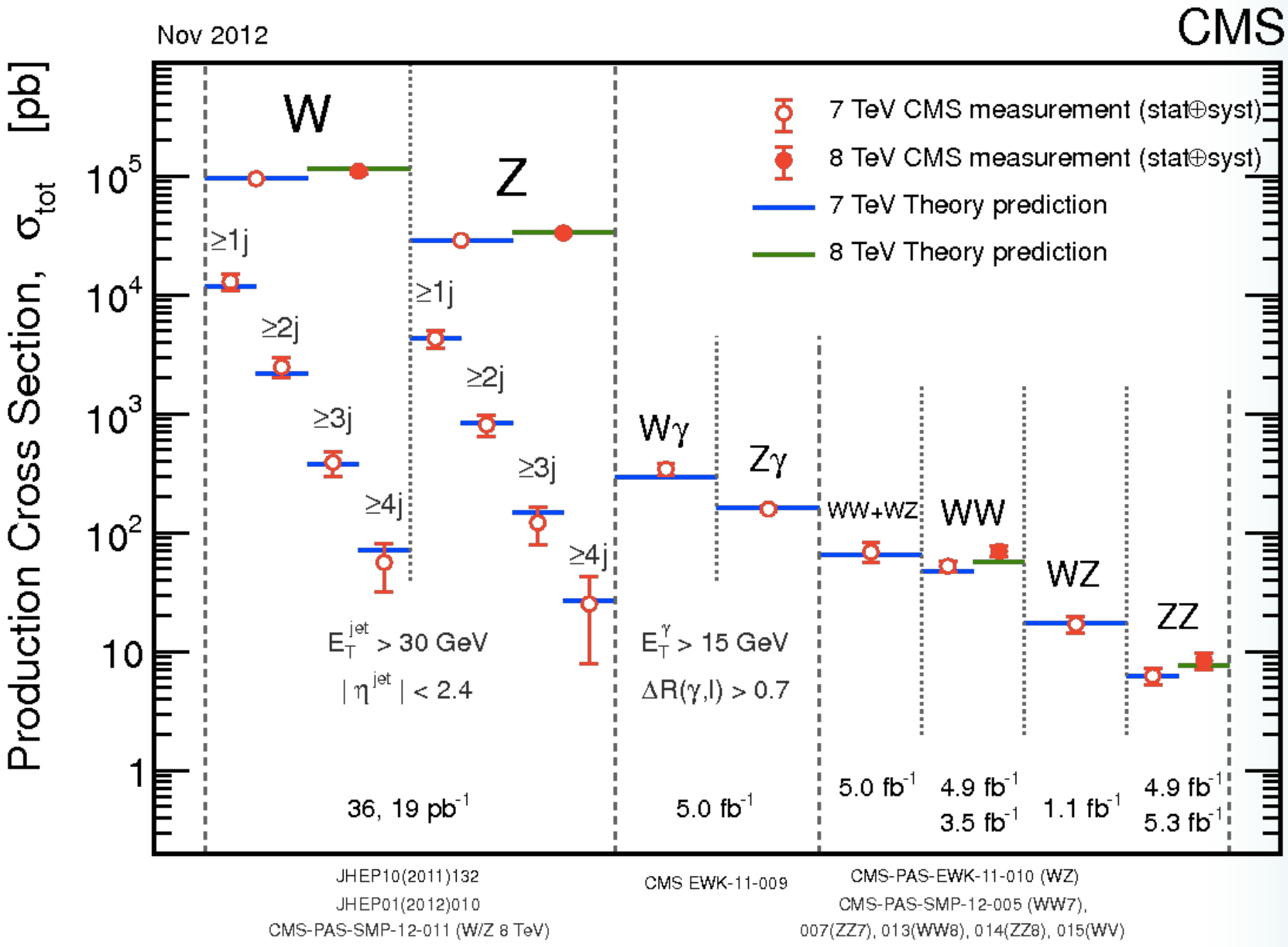


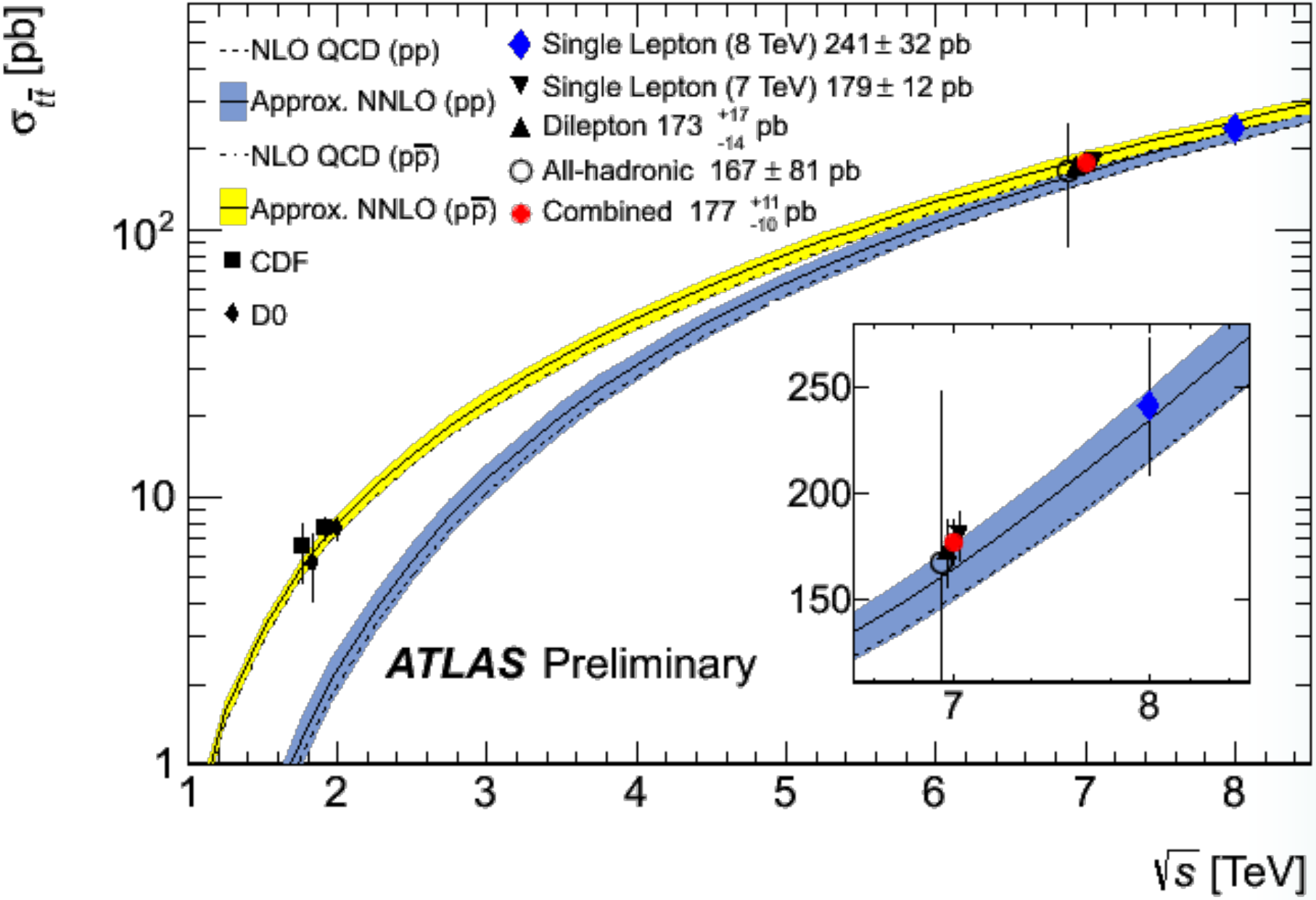


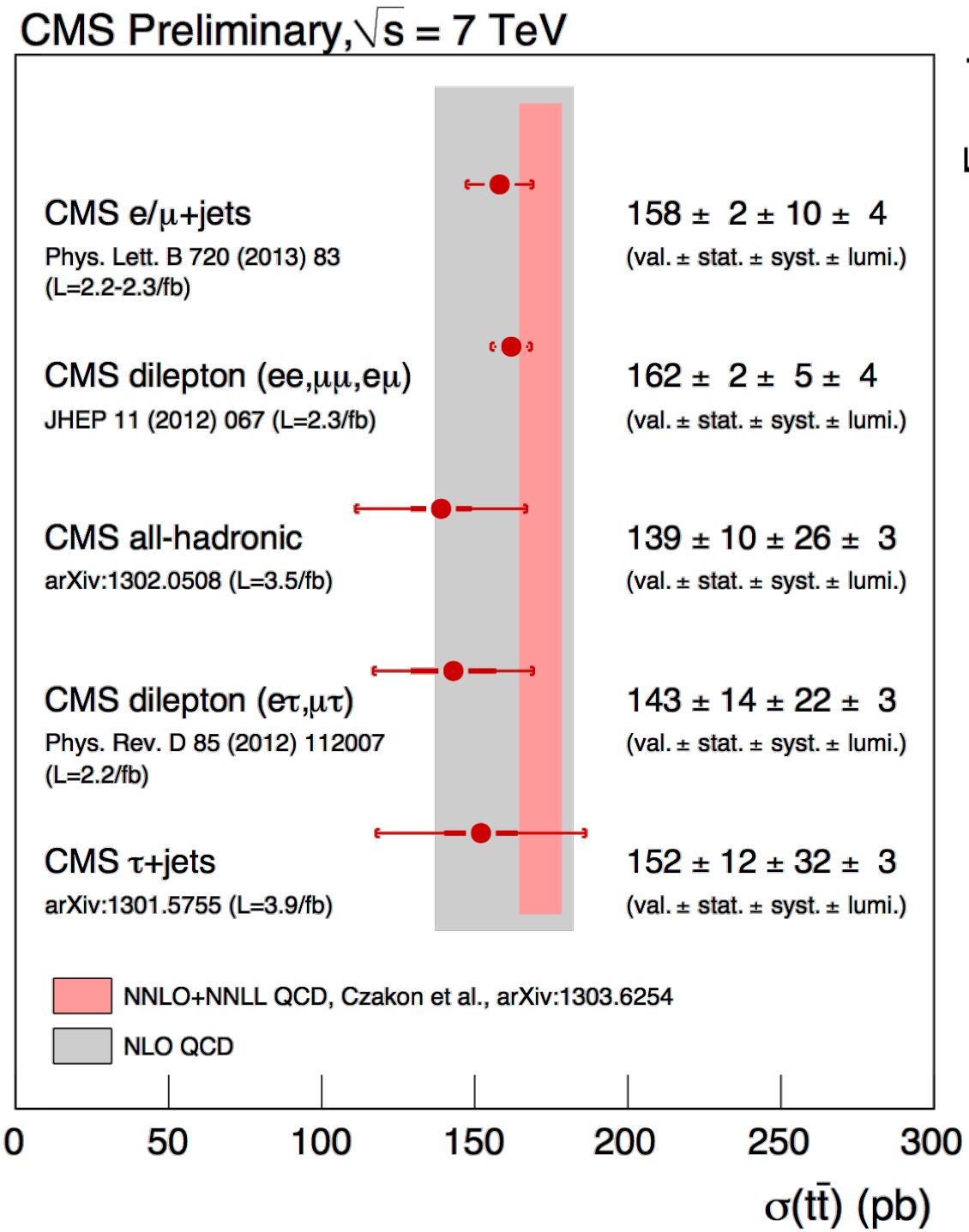
CMS PAS **SMP-12-025**

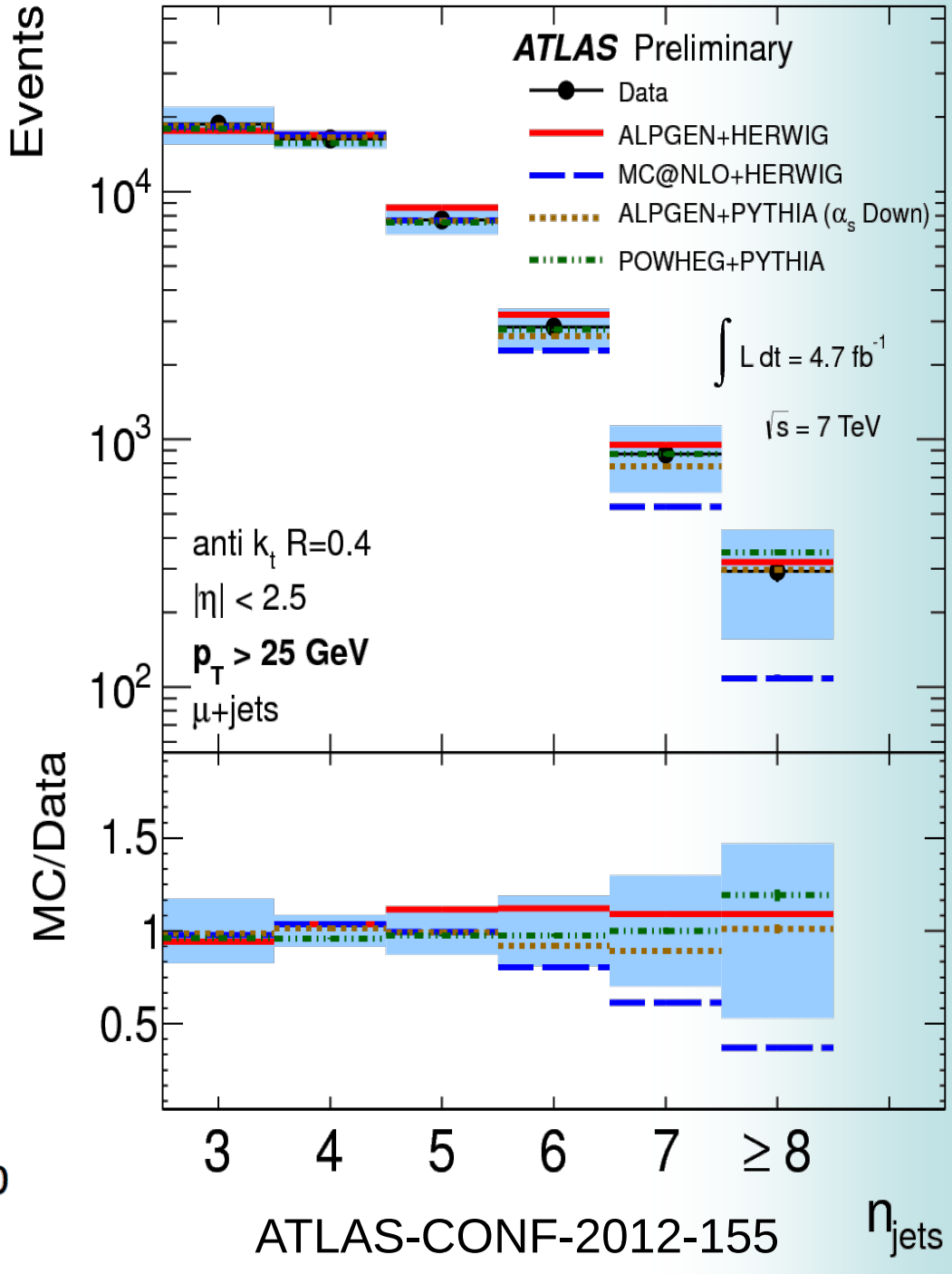
CMS PAS **SMP-13-003**


ATLAS Preliminary
NLO QCD (MCFM, CT10.0)
ZZ (pp̄) (66<m_ll<116 GeV)
ZZ (pp) (66<m_ll<116 GeV)
LHC Data 2012 (√s=8 TeV)
ATLAS ZZ→ llll (66<m_ll<116 GeV) L=20 fb^-1
CMS ZZ→ llll (60<m_ll<120 GeV) L=5.3 fb^-1
LHC Data 2011 (√s=7 TeV)
ATLAS ZZ→ ll(ll/νν) (66<m_ll<116 GeV) L=4.6 fb^-1
CMS ZZ→ llll (60<m_ll<120 GeV) L=5.0 fb^-1
Tevatron (√s=1.96 TeV)
D0 ZZ→ ll(ll/νν) (60<m_ll<120 GeV) L=8.6 fb^-1
CDF ZZ→ ll(ll/νν) (on-shell) L=6.0 fb^-1
σ^total_ZZ [pb]
10
1
0
2
4
6
8
10
12
14
√s [TeV]

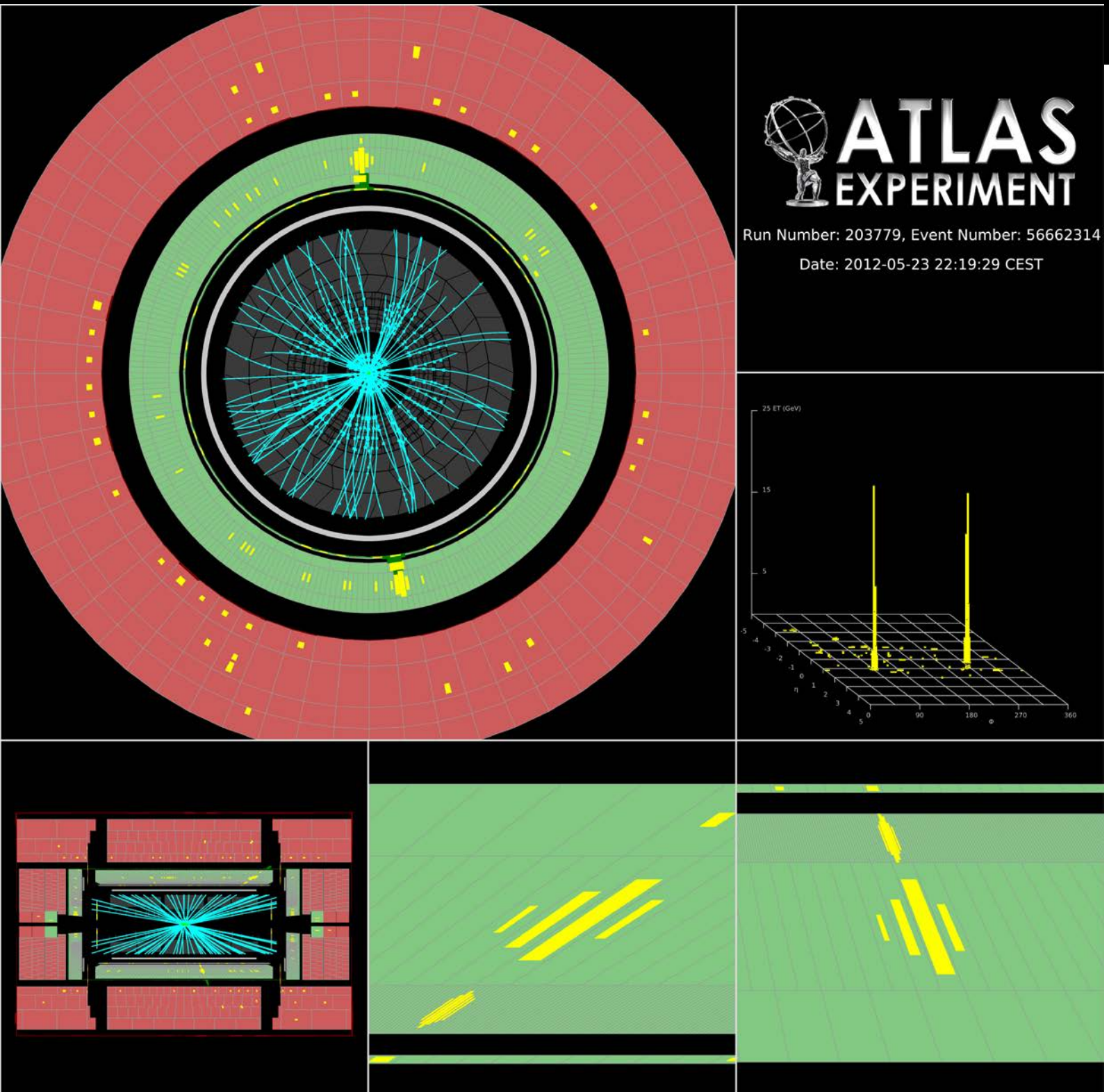

CMS
Nov 2012
Production Cross Section, σ_{tot} [pb]
10^5
10^4
10^3
10^2
10
1
W
Z
≥1j
≥2j
≥3j
≥4j
≥1j
≥2j
≥3j
≥4j
Wγ
Zγ
WW+WZ
WW
WZ
ZZ
7 TeV CMS measurement (stat⊕syst)
8 TeV CMS measurement (stat⊕syst)
7 TeV Theory prediction
8 TeV Theory prediction
E_T^{jet} > 30 GeV
$|\eta^{jet}|$ < 2.4
E_T^{γ} > 15 GeV
ΔR(γ,l) > 0.7
36, 19 pb^{-1}
5.0 fb^{-1}
5.0 fb^{-1}
4.9 fb^{-1}
3.5 fb^{-1}
1.1 fb^{-1}
4.9 fb^{-1}
5.3 fb^{-1}
JHEP10(2011)132
JHEP01(2012)010
CMS-PAS-SMP-12-011 (W/Z 8 TeV)
CMS EWK-11-009
CMS-PAS-EWK-11-010 (WZ)
CMS-PAS-SMP-12-005 (WW7),
007(ZZ7), 013(WW8), 014(ZZ8), 015(WV)

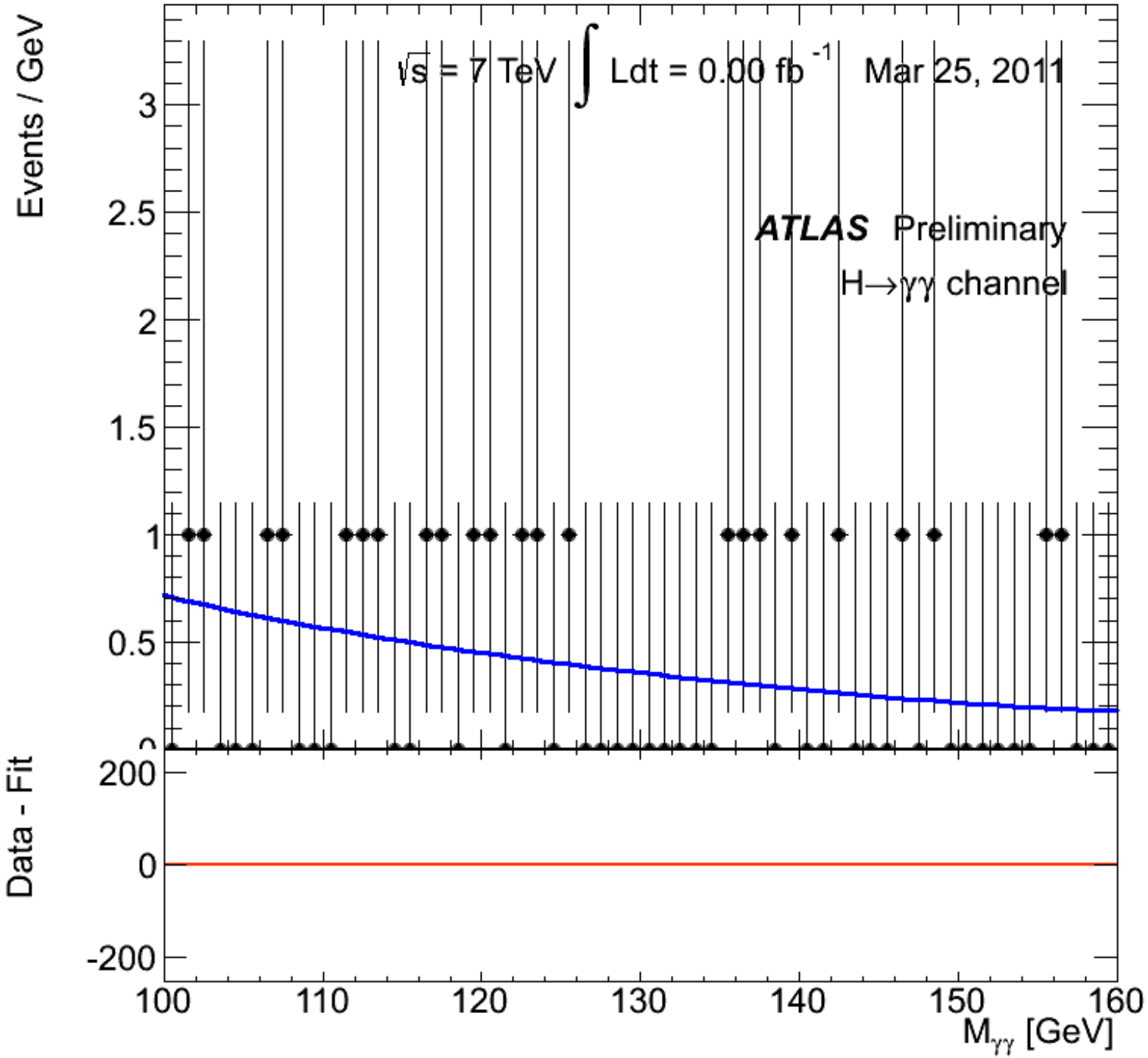

$\sigma_{t\bar{t}}$ [pb]
NLO QCD (pp)
Approx. NNLO (pp)
NLO QCD ($p\bar{p}$)
Approx. NNLO ($p\bar{p}$)
CDF
D0
Single Lepton (8 TeV) 241 ± 32 pb
Single Lepton (7 TeV) 179 ± 12 pb
Dilepton 173 $^{+17}_{-14}$ pb
All-hadronic 167 ± 81 pb
Combined 177 $^{+11}_{-10}$ pb
ATLAS Preliminary
$\sqrt{s}$ [TeV]

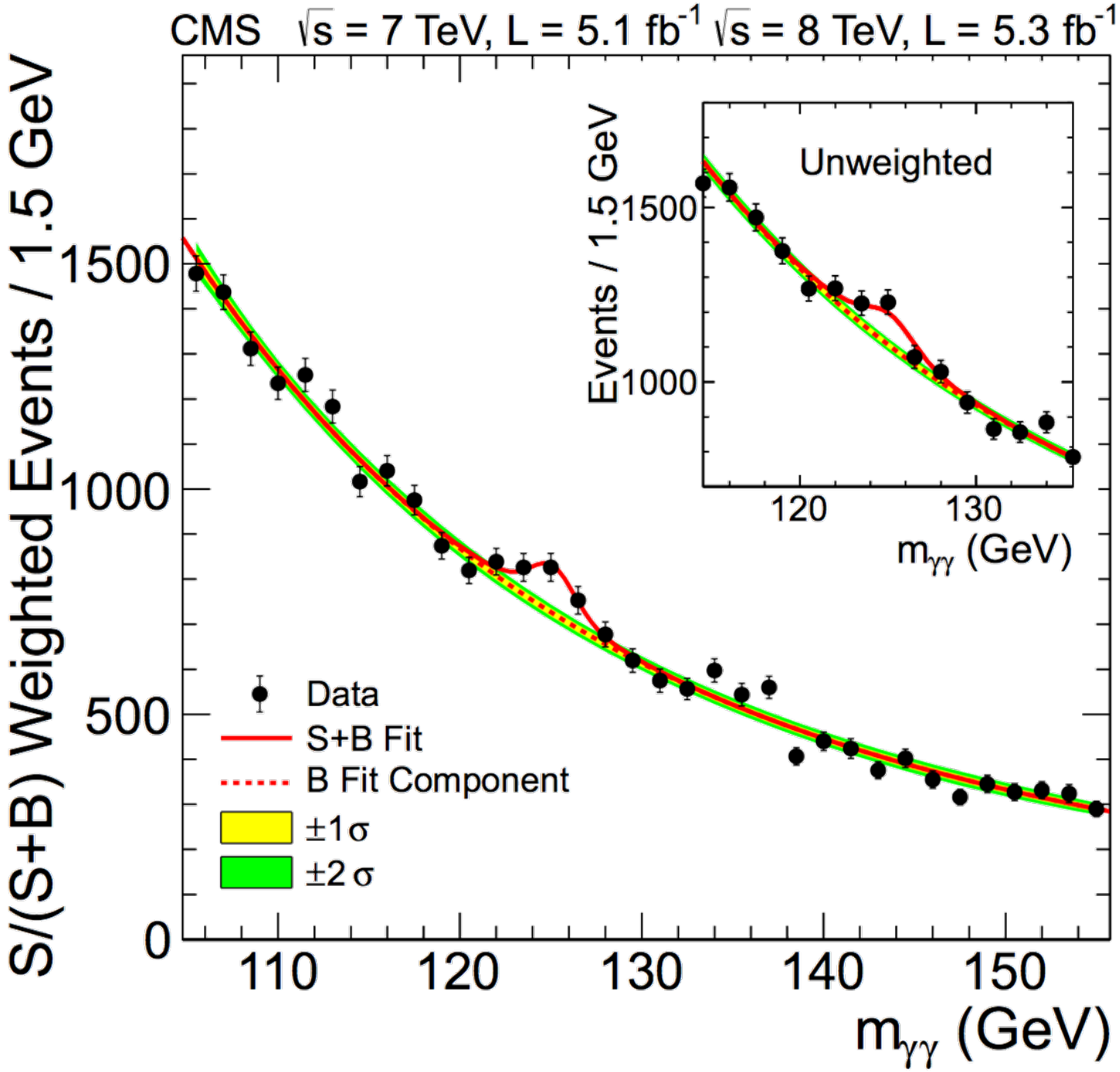

CMS Preliminary, $\sqrt{s}$ = 7 TeV
CMS e/μ+jets
Phys. Lett. B 720 (2013) 83
(L=2.2-2.3/fb)
158 ± 2 ± 10 ± 4
(val. ± stat. ± syst. ± lumi.)
CMS dilepton (ee,μμ,eμ)
JHEP 11 (2012) 067 (L=2.3/fb)
162 ± 2 ± 5 ± 4
(val. ± stat. ± syst. ± lumi.)
CMS all-hadronic
arXiv:1302.0508 (L=3.5/fb)
139 ± 10 ± 26 ± 3
(val. ± stat. ± syst. ± lumi.)
CMS dilepton (eτ,μτ)
Phys. Rev. D 85 (2012) 112007
(L=2.2/fb)
143 ± 14 ± 22 ± 3
(val. ± stat. ± syst. ± lumi.)
CMS τ+jets
arXiv:1301.5755 (L=3.9/fb)
152 ± 12 ± 32 ± 3
(val. ± stat. ± syst. ± lumi.)
NNLO+NNLL QCD, Czakon et al., arXiv:1303.6254
NLO QCD
0
50
100
150
200
250
300
σ(tt̄) (pb)


ATLAS Preliminary
Data
ALPGEN+HERWIG
MC@NLO+HERWIG
ALPGEN+PYTHIA (α_s Down)
POWHEG+PYTHIA
$\int$ L dt = 4.7 fb^{-1}
$\sqrt{s}$ = 7 TeV
anti k_t R=0.4
$|\eta| < 2.5$
p_T > 25 GeV
μ+jets
Events
MC/Data
10^4
10^3
10^2
1.5
1
0.5
3
4
5
6
7
≥ 8
n_{jets}
ATLAS-CONF-2012-155

Discovery


ATLAS
EXPERIMENT
Run Number: 203779, Event Number: 56662314
Date: 2012-05-23 22:19:29 CEST
25 ET (GeV)
15
5
-5
-4
-3
-2
-1
0
1
2
3
4
5
η
0
90
180
270
360
φ


√s = 7 TeV ∫ Ldt = 0.00 fb-1 Mar 25, 2011
ATLAS Preliminary
H→γγ channel
Events / GeV
Data - Fit
Mγγ [GeV]

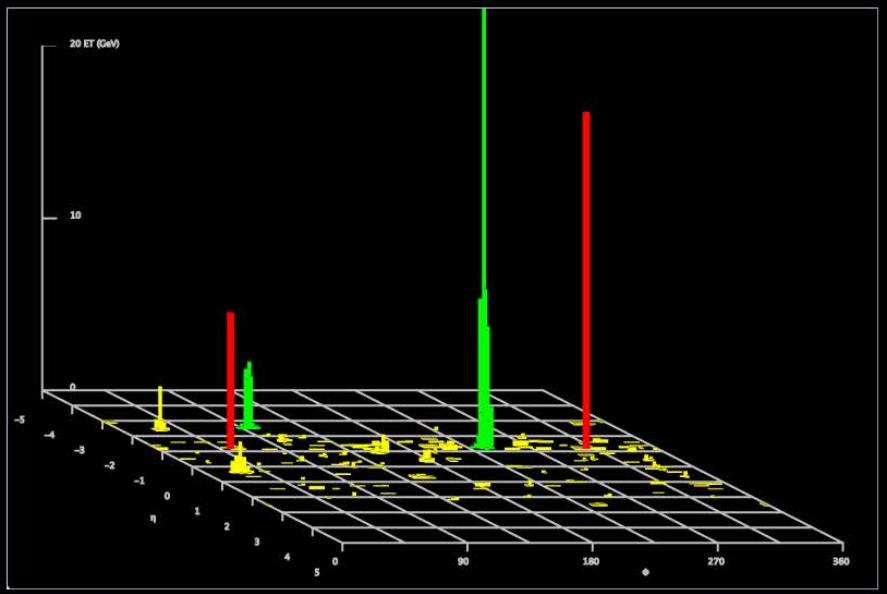

CMS √s = 7 TeV, L = 5.1 fb-1 √s = 8 TeV, L = 5.3 fb-1
S/(S+B) Weighted Events / 1.5 GeV
0
500
1000
1500
110
120
130
140
150
mγγ (GeV)
Data
S+B Fit
B Fit Component
±1σ
±2 σ
Unweighted
Events / 1.5 GeV
1000
1500
120
130
mγγ (GeV)

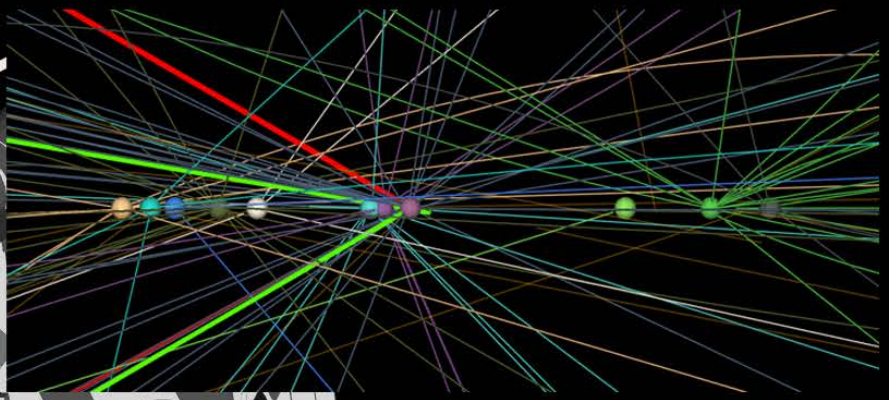
UCL

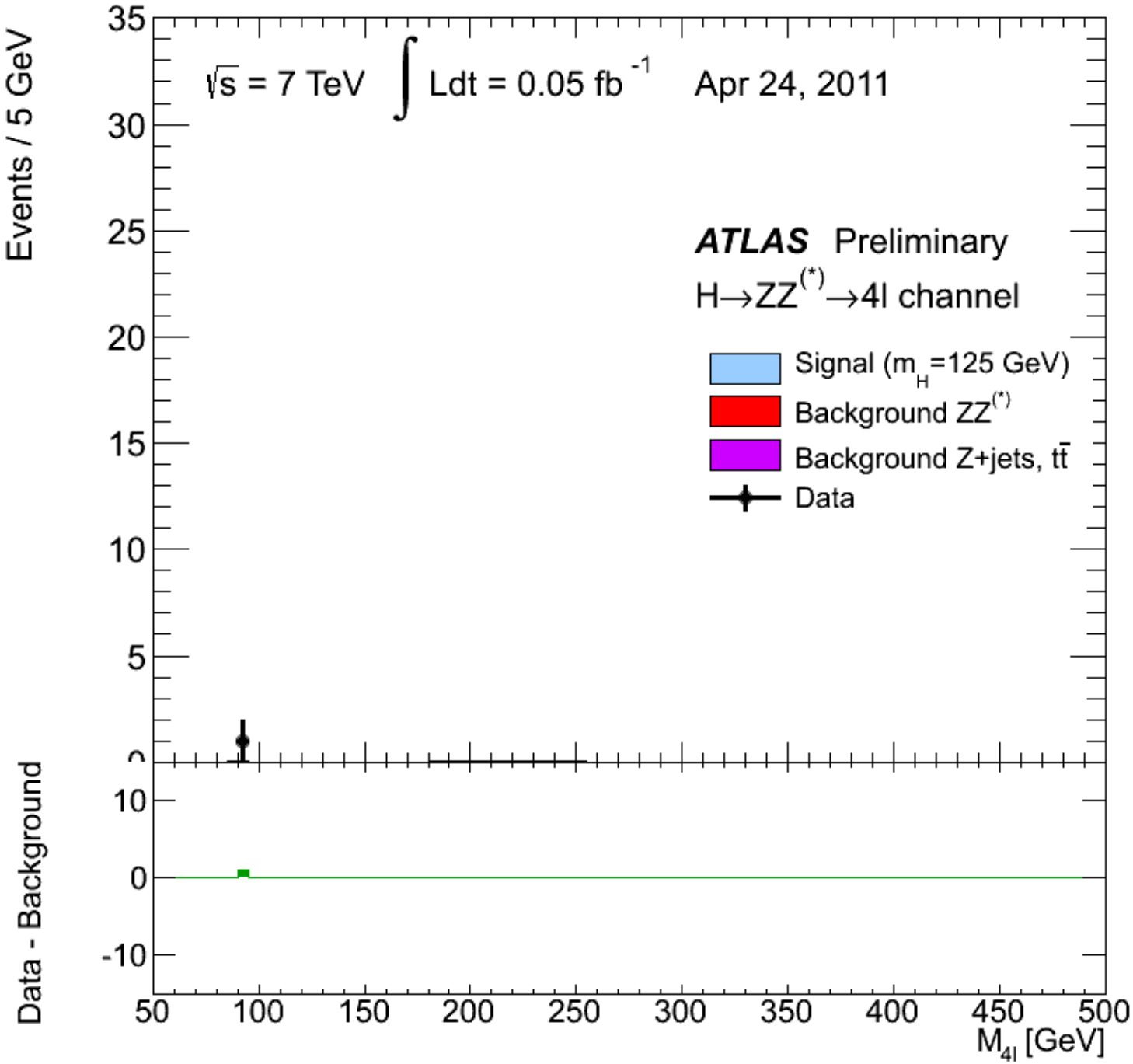
ATLAS EXPERIMENT

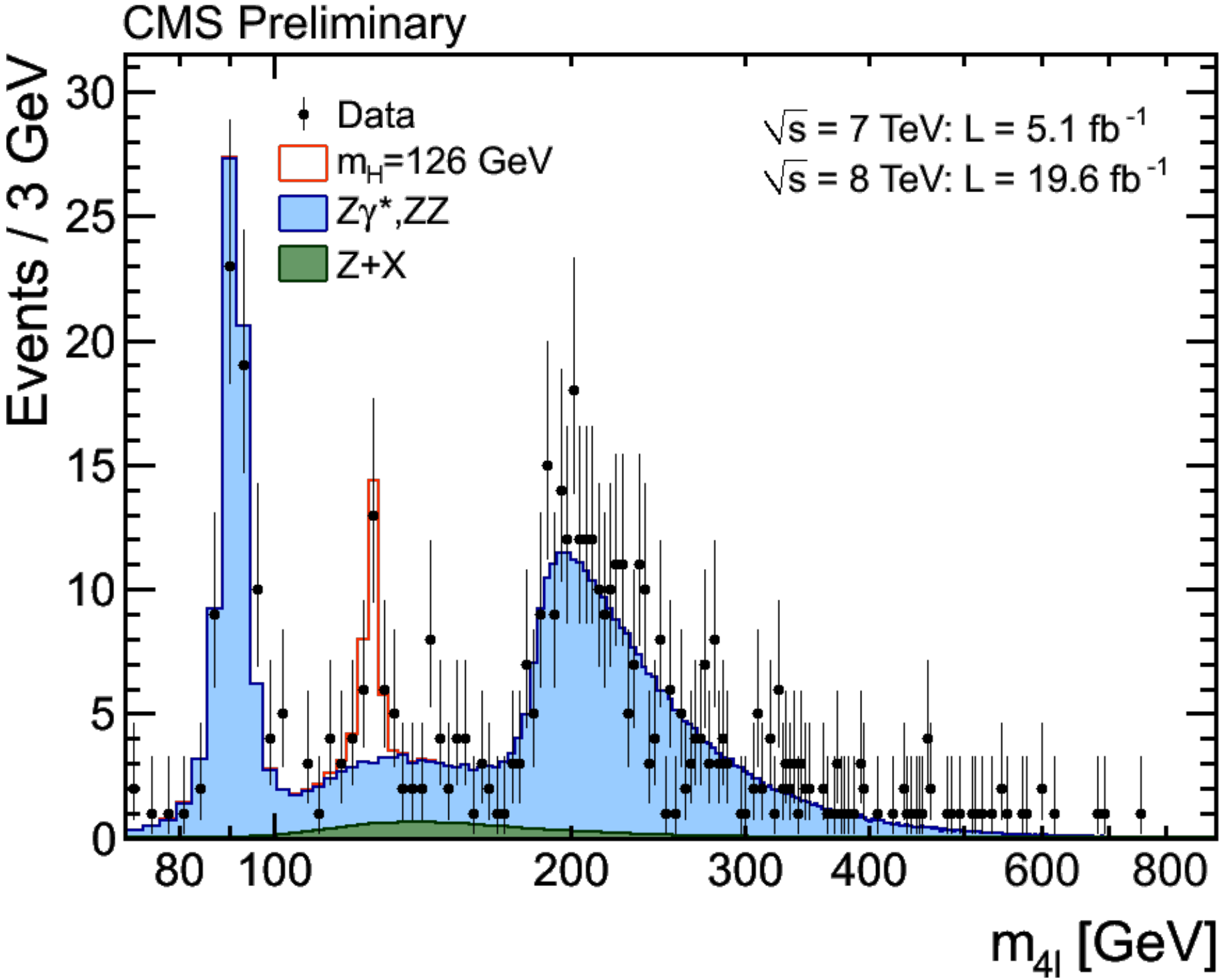
http://atlas.ch

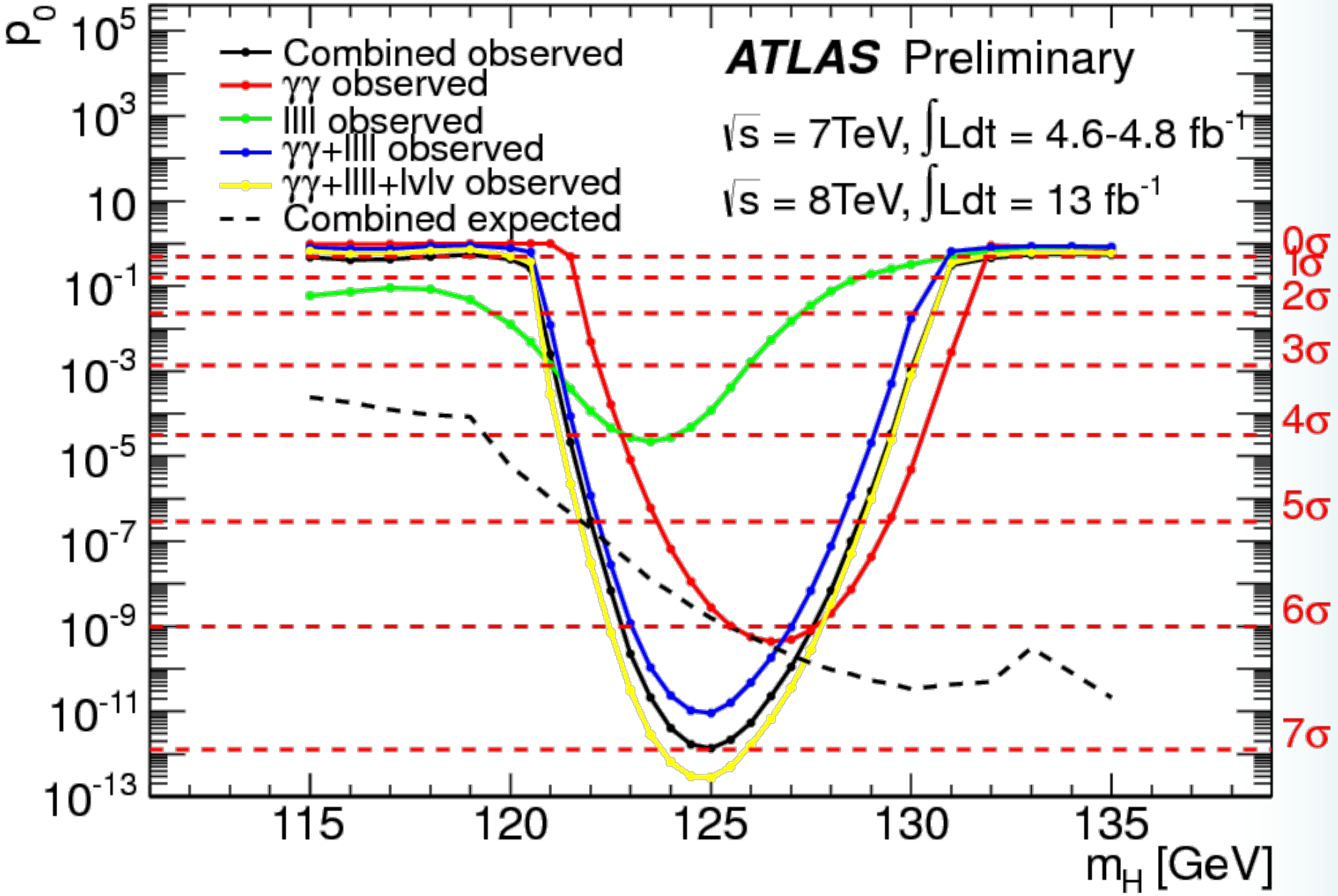
Run: 205113
Event: 12611816
Date: 2012-06-18
Time: 11:07:47 CEST

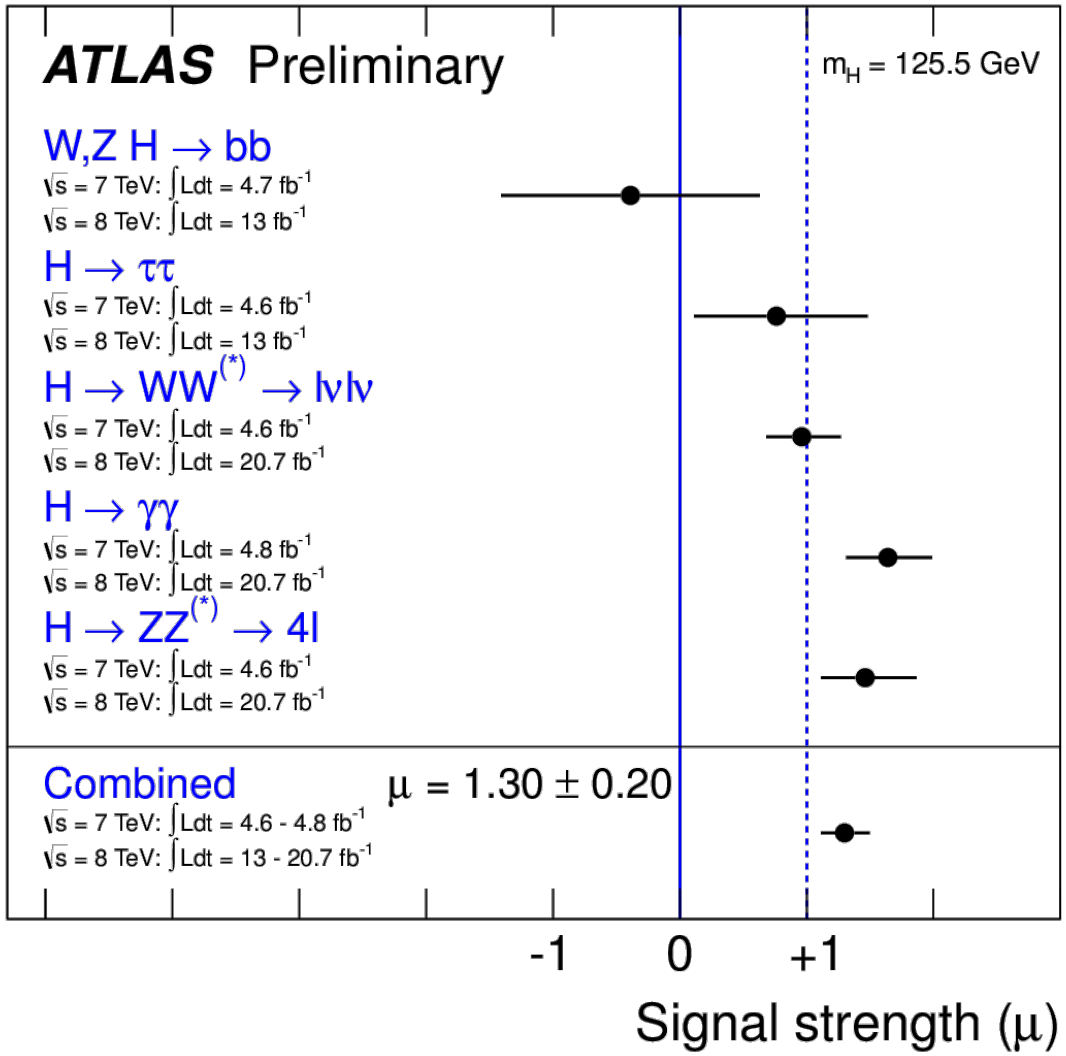


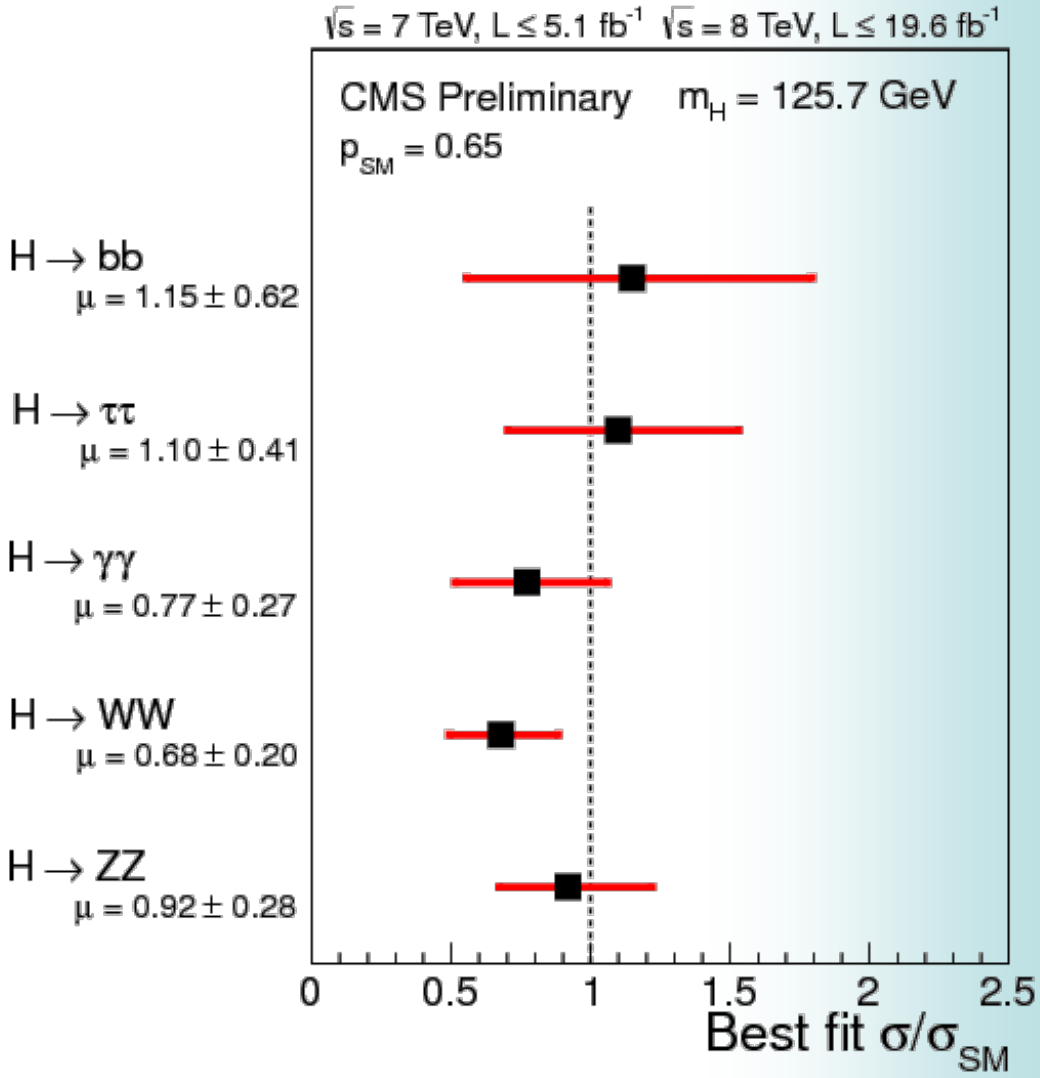


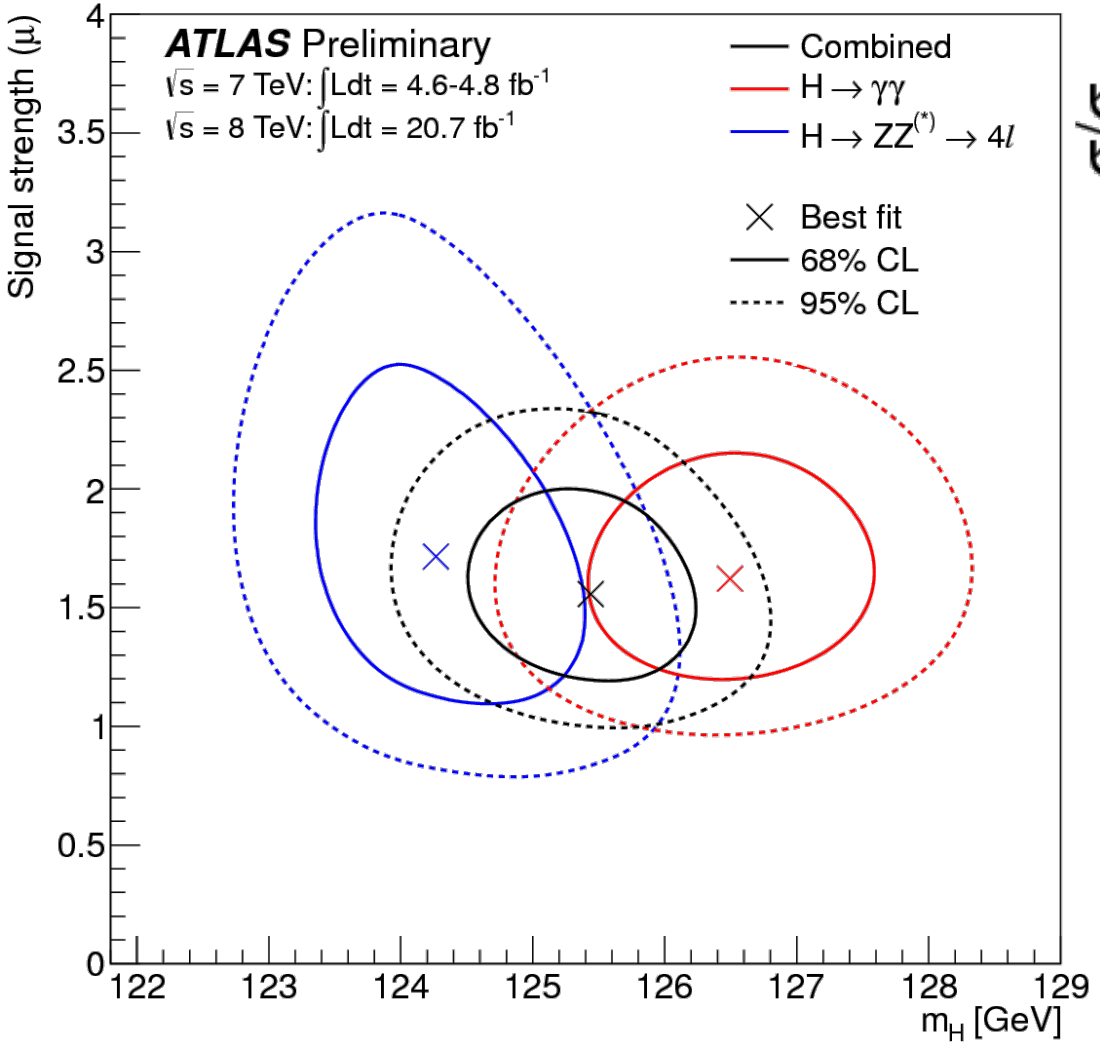

√s = 7 TeV ∫ Ldt = 0.05 fb-1 Apr 24, 2011
ATLAS Preliminary
H→ZZ(*)→4l channel
Signal (mH=125 GeV)
Background ZZ(*)
Background Z+jets, tt̄
Data
Events / 5 GeV
Data - Background
M4l [GeV]

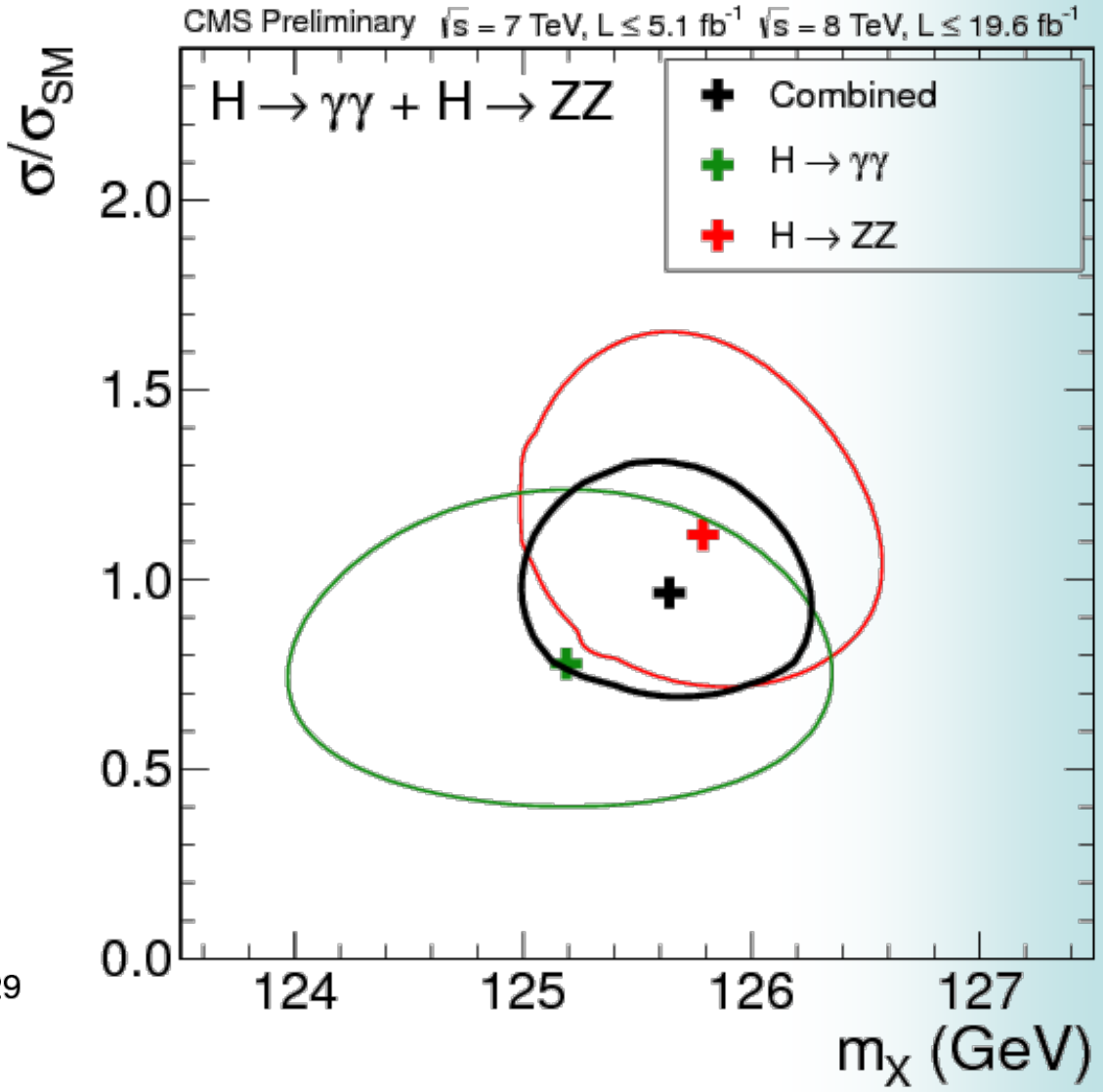

CMS Preliminary
Data
m_H=126 GeV
Zγ*,ZZ
Z+X
$\sqrt{s}$ = 7 TeV: L = 5.1 fb^{-1}
$\sqrt{s}$ = 8 TeV: L = 19.6 fb^{-1}
Events / 3 GeV
0
5
10
15
20
25
30
80
100
200
300
400
600
800
m_{4l} [GeV]

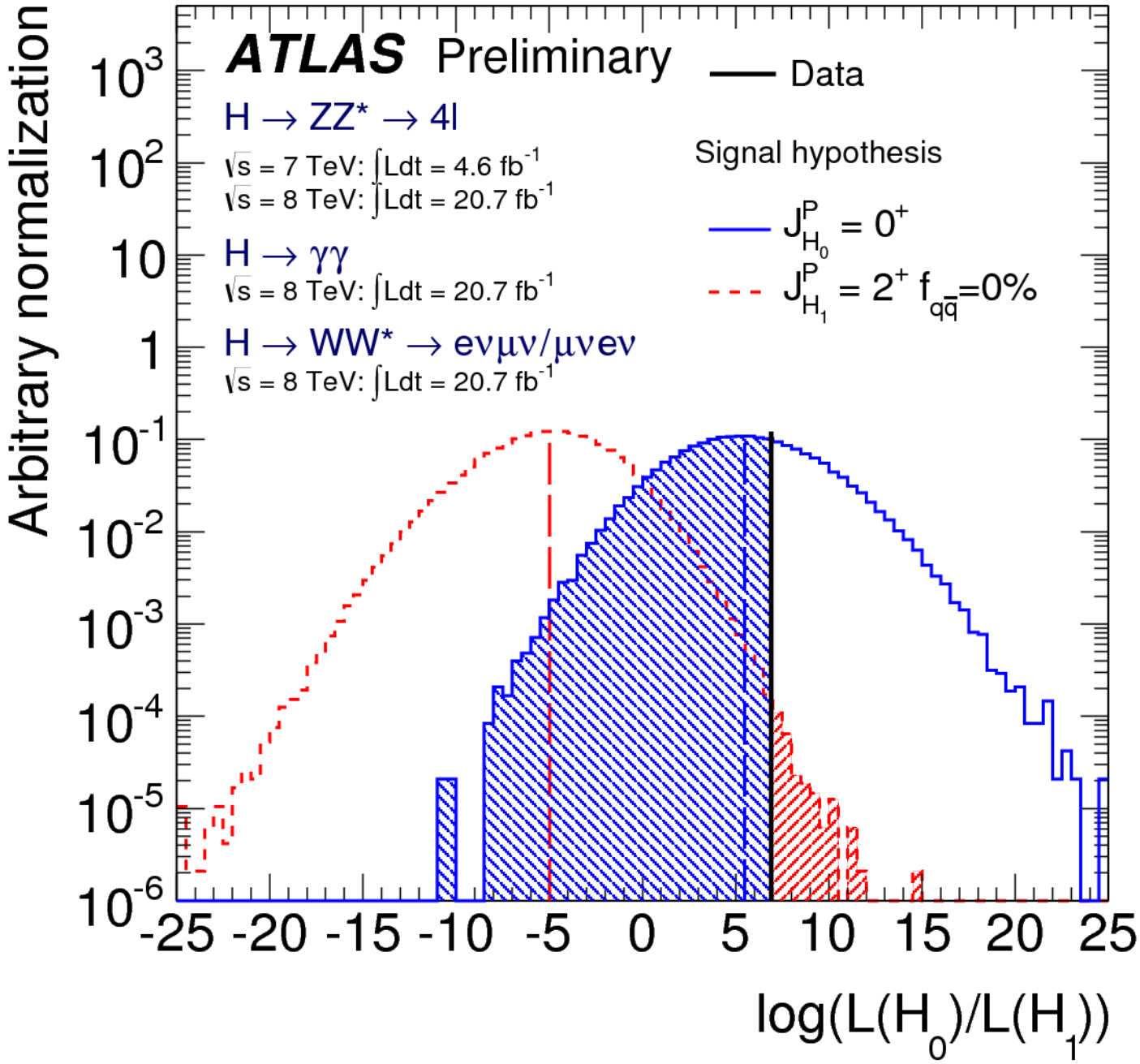

p0
10^5
10^3
10
10^-1
10^-3
10^-5
10^-7
10^-9
10^-11
10^-13
Combined observed
γγ observed
llll observed
γγ+llll observed
γγ+llll+lvlv observed
Combined expected
ATLAS Preliminary
√s = 7TeV, ∫Ldt = 4.6-4.8 fb-1
√s = 8TeV, ∫Ldt = 13 fb-1
0σ
1σ
2σ
3σ
4σ
5σ
6σ
7σ
115
120
125
130
135
mH [GeV]


ATLAS Preliminary
m_H = 125.5 GeV
W,Z H → bb
√s = 7 TeV: ∫Ldt = 4.7 fb^{-1}
√s = 8 TeV: ∫Ldt = 13 fb^{-1}
H → ττ
√s = 7 TeV: ∫Ldt = 4.6 fb^{-1}
√s = 8 TeV: ∫Ldt = 13 fb^{-1}
H → WW$^{(*)}$ → lνlν
√s = 7 TeV: ∫Ldt = 4.6 fb^{-1}
√s = 8 TeV: ∫Ldt = 20.7 fb^{-1}
H → γγ
√s = 7 TeV: ∫Ldt = 4.8 fb^{-1}
√s = 8 TeV: ∫Ldt = 20.7 fb^{-1}
H → ZZ$^{(*)}$ → 4l
√s = 7 TeV: ∫Ldt = 4.6 fb^{-1}
√s = 8 TeV: ∫Ldt = 20.7 fb^{-1}
Combined
μ = 1.30 ± 0.20
√s = 7 TeV: ∫Ldt = 4.6 - 4.8 fb^{-1}
√s = 8 TeV: ∫Ldt = 13 - 20.7 fb^{-1}
-1
0
+1
Signal strength (μ)


√s = 7 TeV, L ≤ 5.1 fb^{-1} √s = 8 TeV, L ≤ 19.6 fb^{-1}
CMS Preliminary m_H = 125.7 GeV
p_{SM} = 0.65
H → bb
μ = 1.15 ± 0.62
H → ττ
μ = 1.10 ± 0.41
H → γγ
μ = 0.77 ± 0.27
H → WW
μ = 0.68 ± 0.20
H → ZZ
μ = 0.92 ± 0.28
0
0.5
1
1.5
2
2.5
Best fit σ/σ$_{SM}$


ATLAS Preliminary
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb-1
√s = 8 TeV: ∫Ldt = 20.7 fb-1
Combined
H → γγ
H → ZZ(*) → 4l
Best fit
68% CL
95% CL
Signal strength (μ)
mH [GeV]

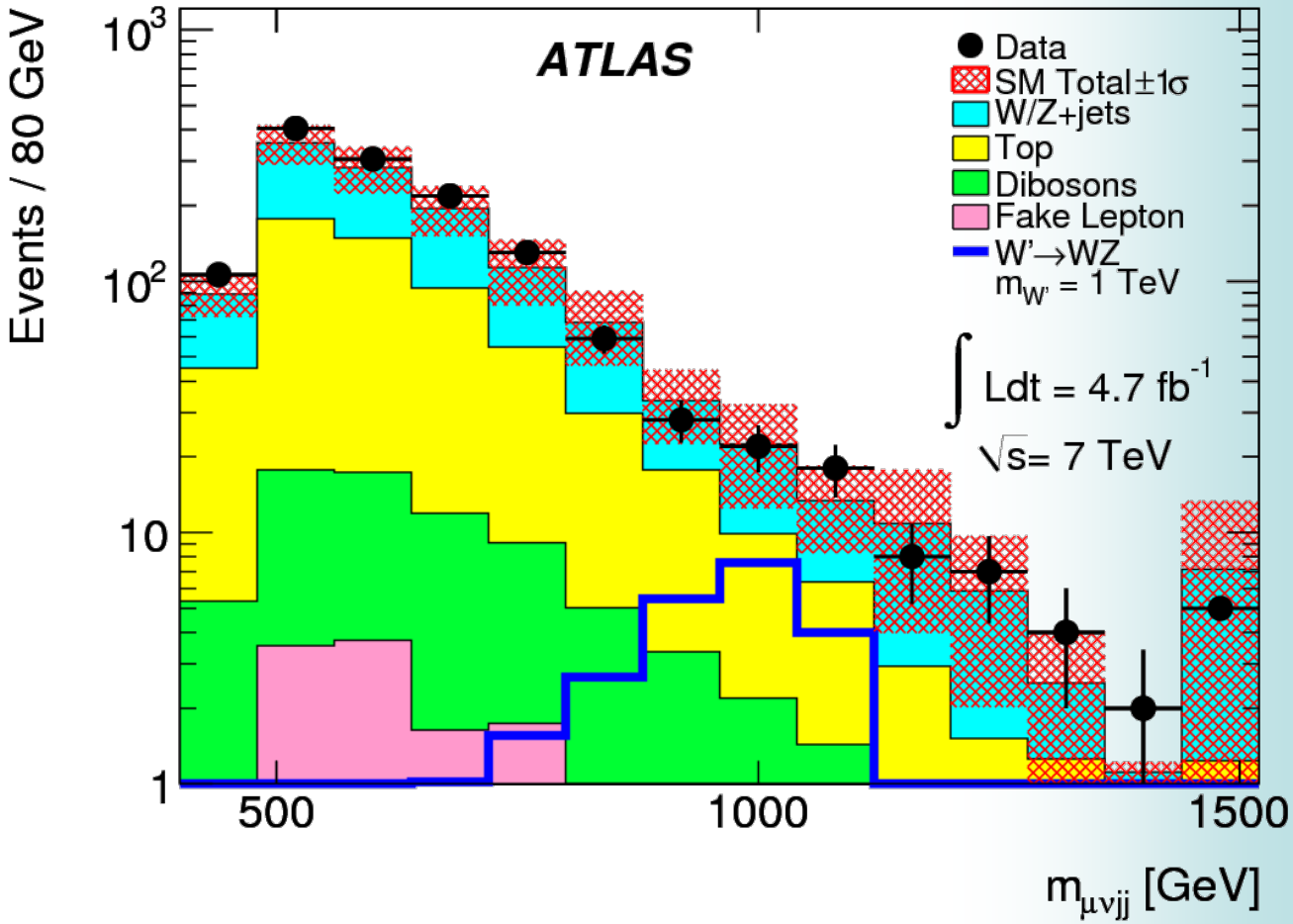

CMS Preliminary √s = 7 TeV, L ≤ 5.1 fb-1 √s = 8 TeV, L ≤ 19.6 fb-1
H → γγ + H → ZZ
Combined
H → γγ
H → ZZ
σ/σSM
mX (GeV)



Pure spin 2 excluded at > 99.9%

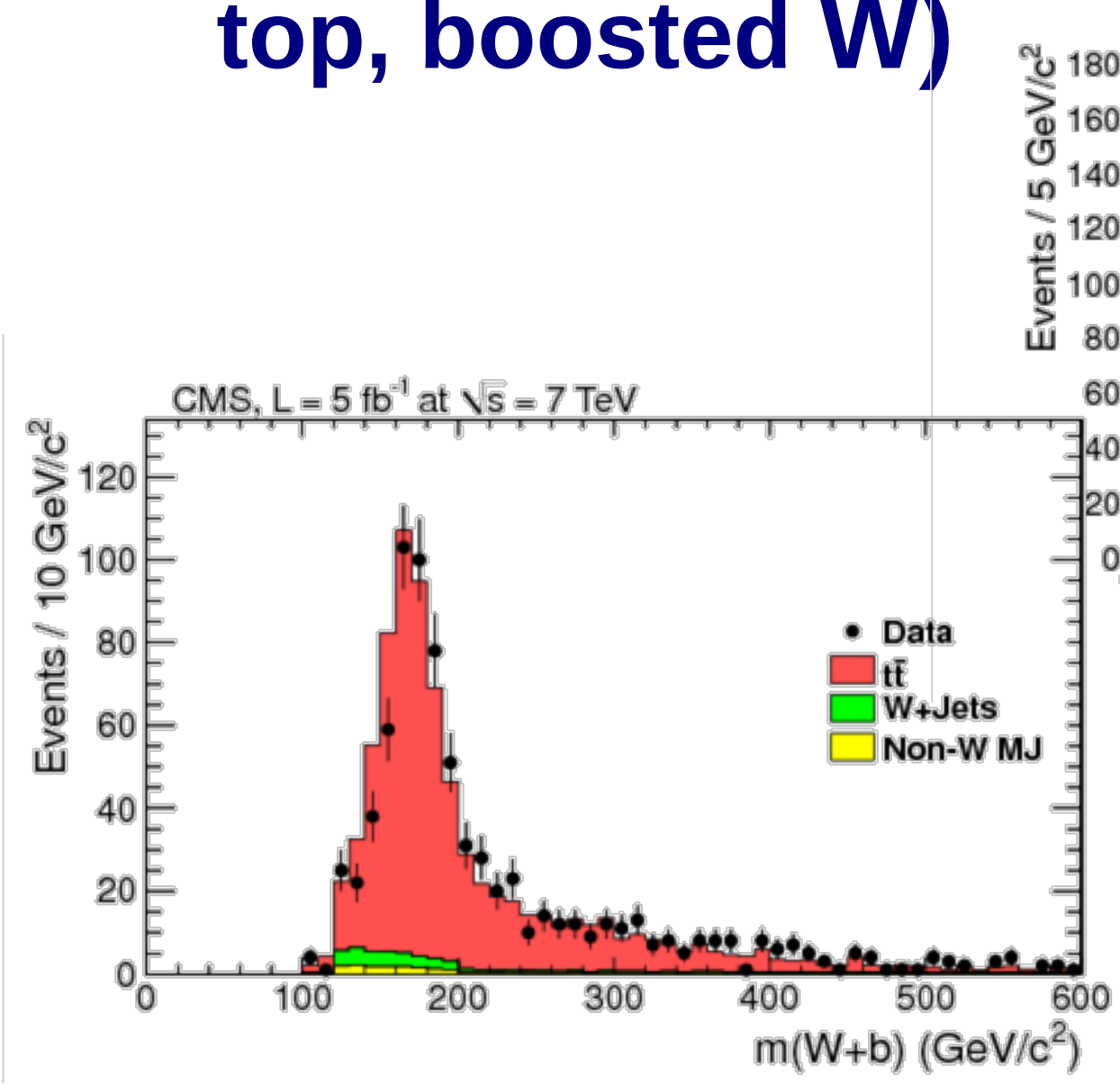
Searches

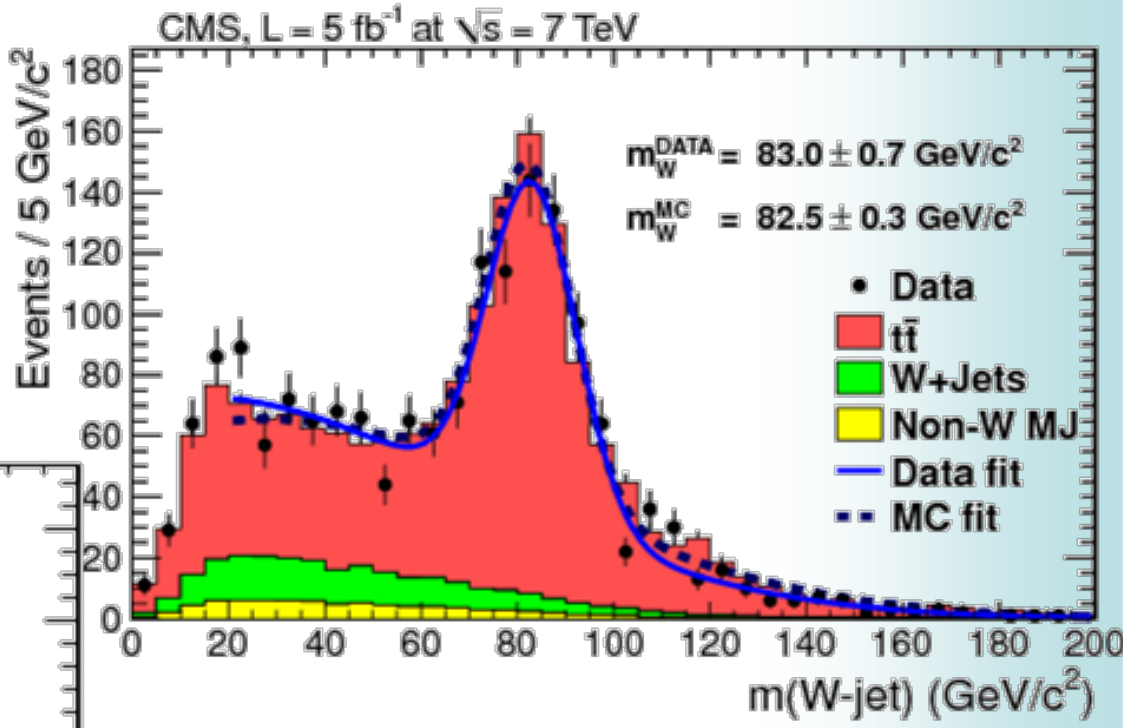
WZ/WW resonances

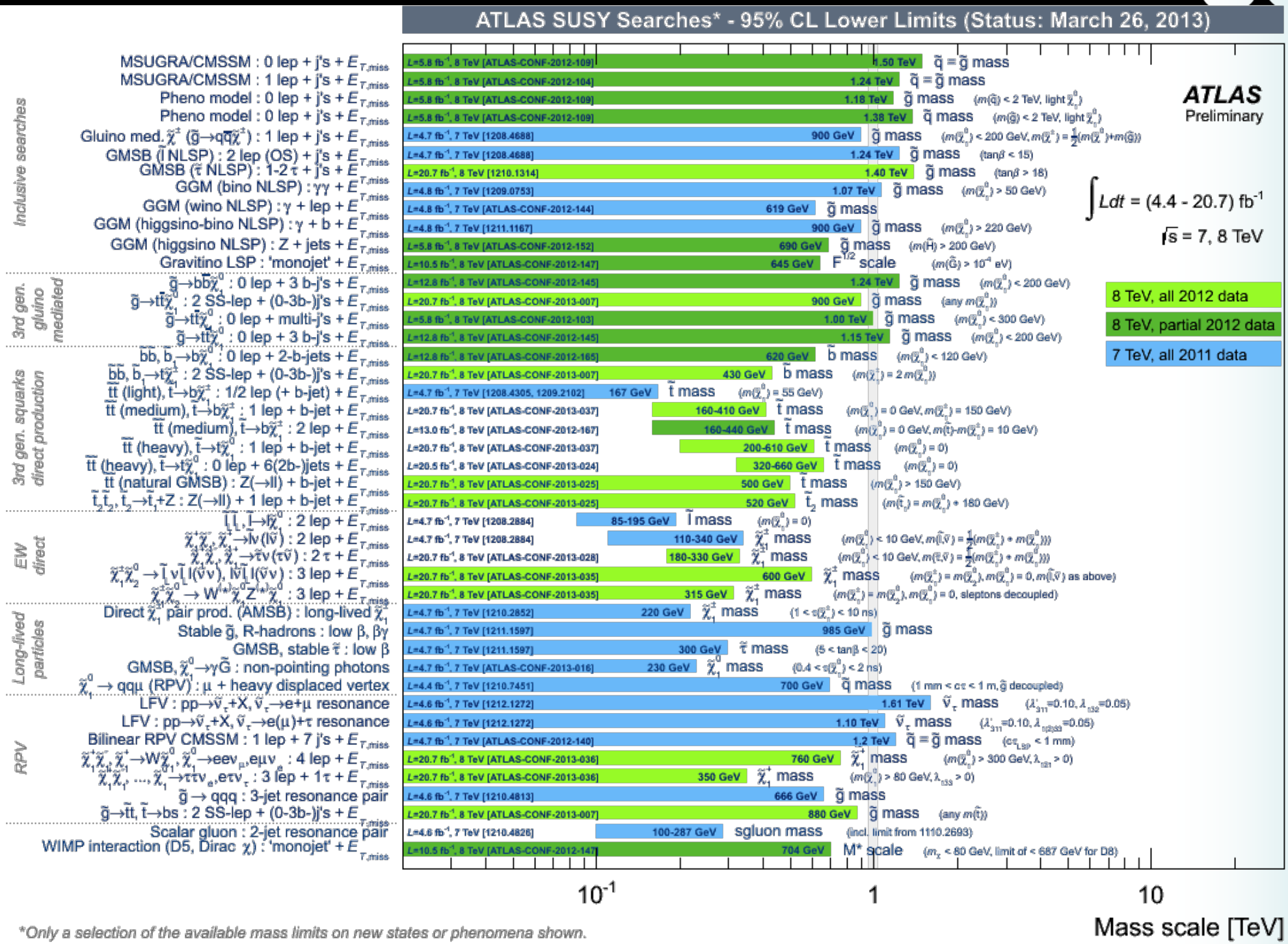


arXiv:1305.0125

Substructure in searches (boosted top, boosted W)

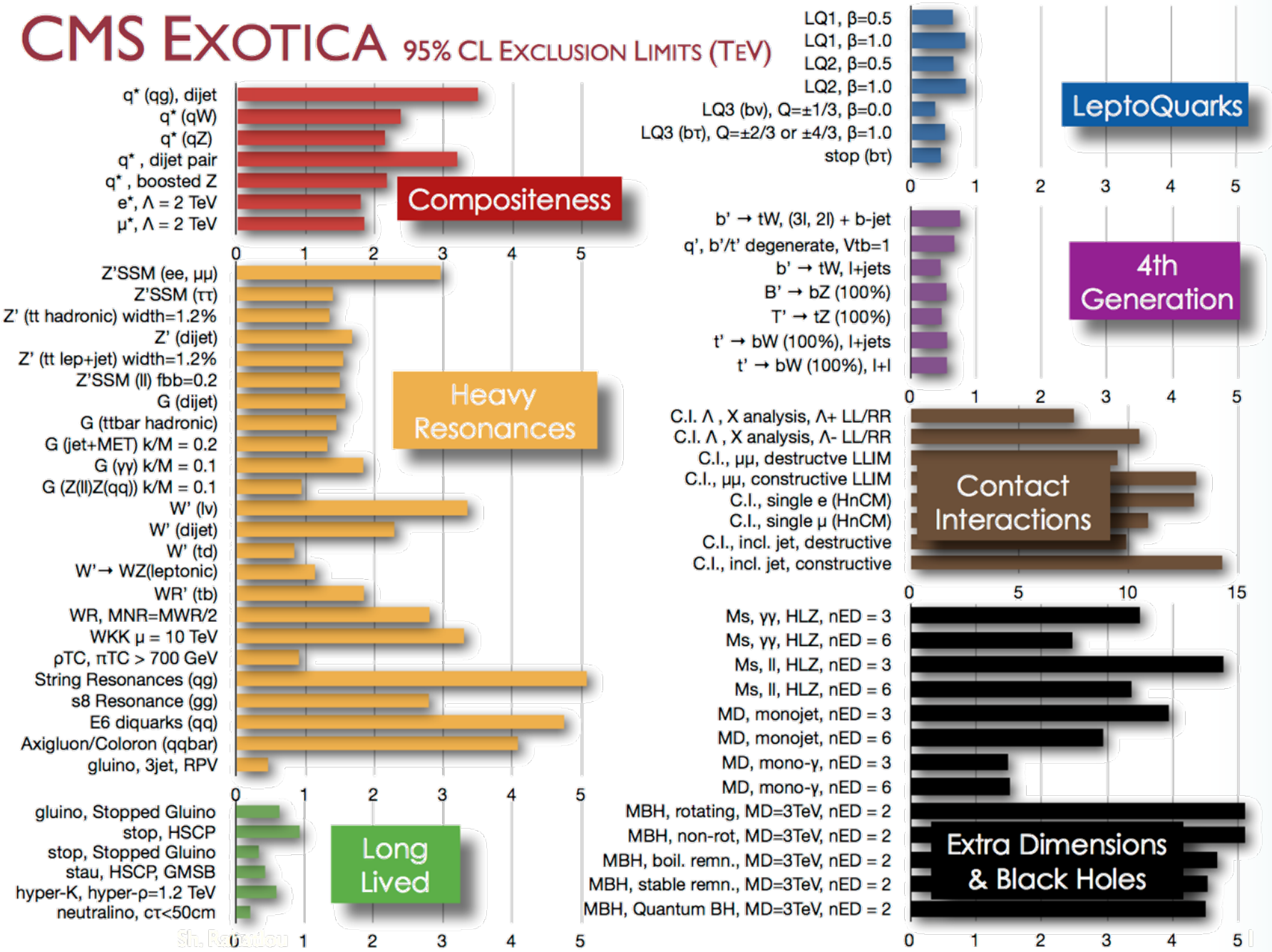


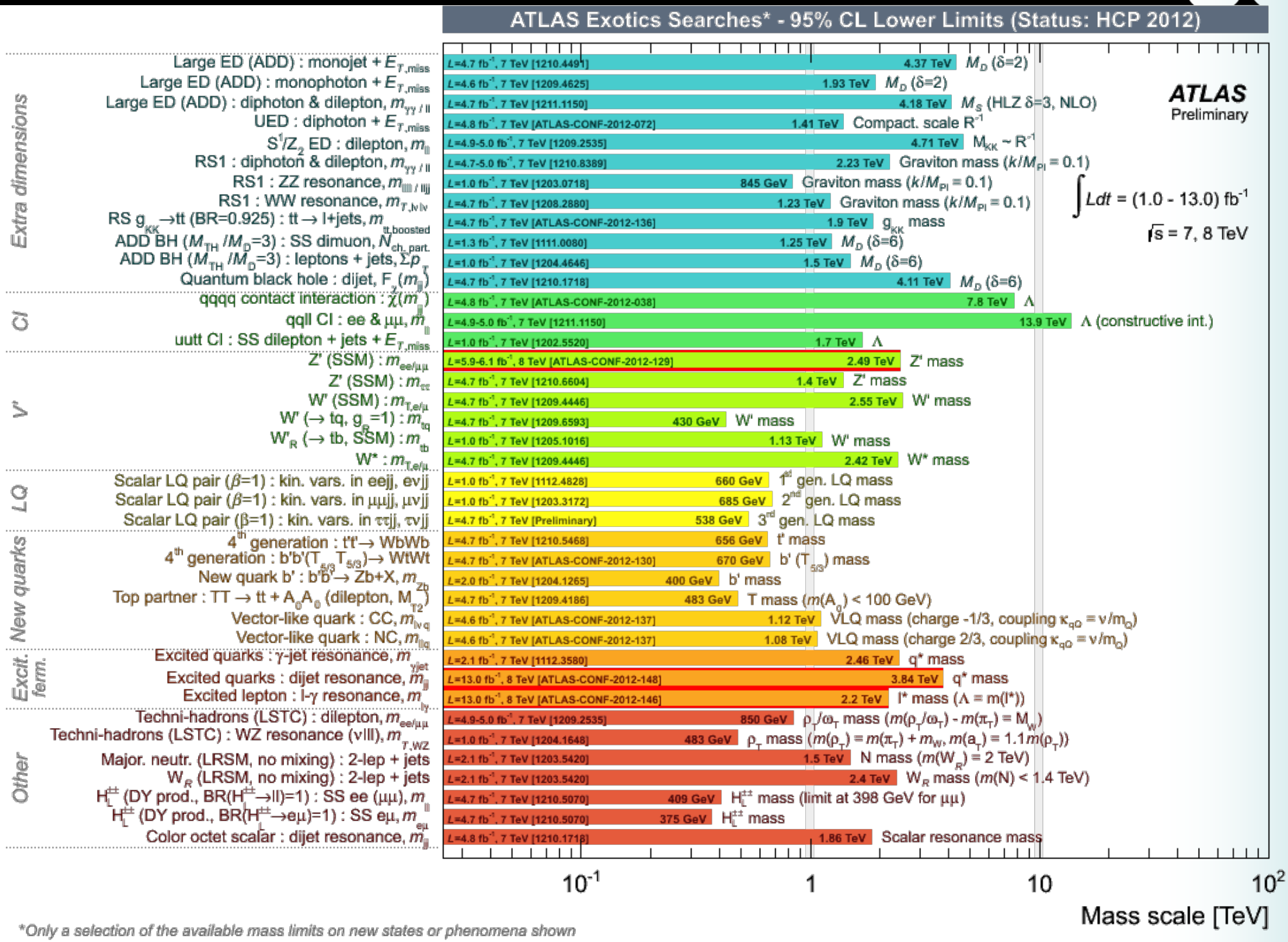




*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

CMS EXOTICA 95% CL EXCLUSION LIMITS (TEV)





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

The beginning of physics above the Electroweak Symmetry Breaking scale