Search for heavy resonances with the ATLAS detector

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On behalf of the ATLAS collaboration

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Introduction

- **The Standard Model:** mission complete?
  - hierarchy problem? higher symmetries? compositeness? electroweak symmetry breaking? ...
- **New Physics beyond the SM**
  - extra dimensions: Randall-Sundrum model (RS G^*, bulk RS G^*)
  - new gauge bosons: E_6 GUT (Z'_ψ, Z'_χ), sequential model (Z', W')
  - compositeness: excited quarks and leptons (q^*, ℓ^*)
  - dynamic EWSB: technicolor (ρ_{T}, ...)
  - ...

- **Presented in this talk:**

signature	models	$\mathcal{L}$ @ 8 TeV	publication
$\ell^+\ell^-$	Z',G^*	20fb^{-1}	ATLAS-CONF-2013-017
jj	q^*	13fb^{-1}	ATLAS-CONF-2012-148
$\ell\bar{\ell}\gamma$	ℓ^*	13fb^{-1}	ATLAS-CONF-2012-146
$\ell\nu\ell\ell$	W',ρ_{T}	13fb^{-1}	ATLAS-CONF-2013-015
$\ell\ell jj$	G^*_{bulk}	7.2fb^{-1}	ATLAS-CONF-2012-150

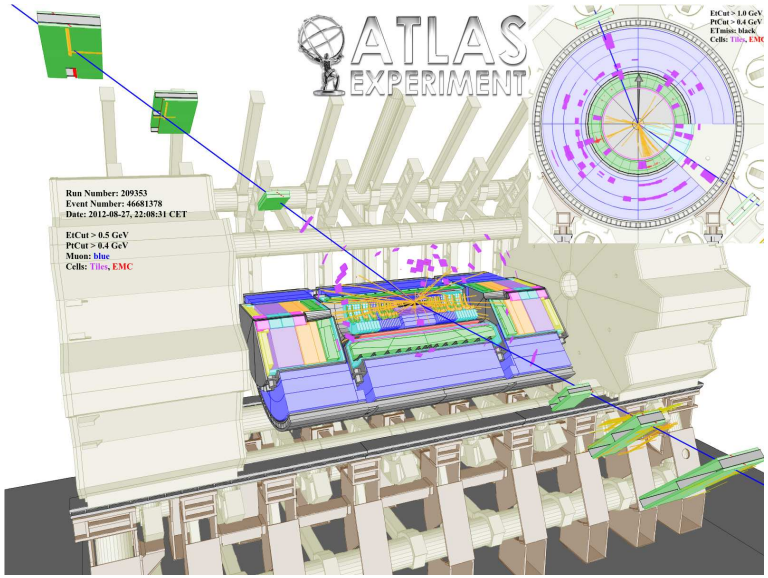
- **In other talks:**

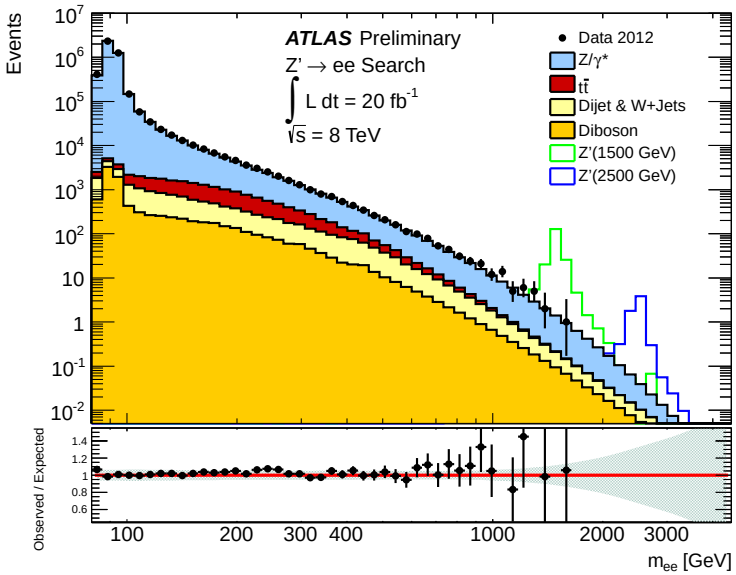
topic	speaker
Searches for monojets and monophotons	Jalal Abdallah (IFAE Barcelona (ES))
Searches for long-lived particles and lepton-jets	Daniela Salvatore (Universita della Calabria (IT))
Searches for fourth generation vector-like quarks and ttbar resonances	Snezana Nektarijevic (Universite de Geneve (CH))
Combining searches of Z' and W' bosons	Manuel Perez-Victoria (University of Granada)

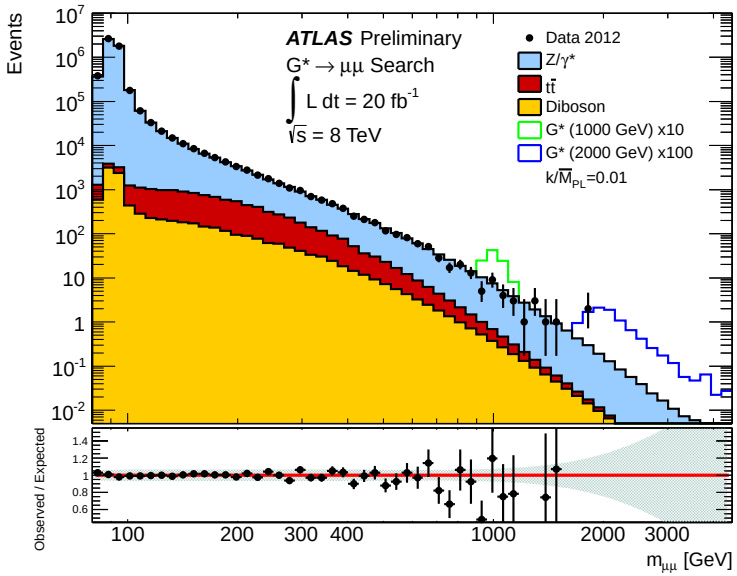
dilepton [1]

- Benchmark models: Z', G^*
- Clean signature: ee or $\mu^+\mu^-$
- Backgrounds:
  - MC estimation: Z/γ^*, $t\bar{t}$, diboson
  - data-driven estimation: multijet, W+jets
- The pair with the highest p_{T} scalar sum is selected; Sum of backgrounds is normalized to data in 80-110 GeV region

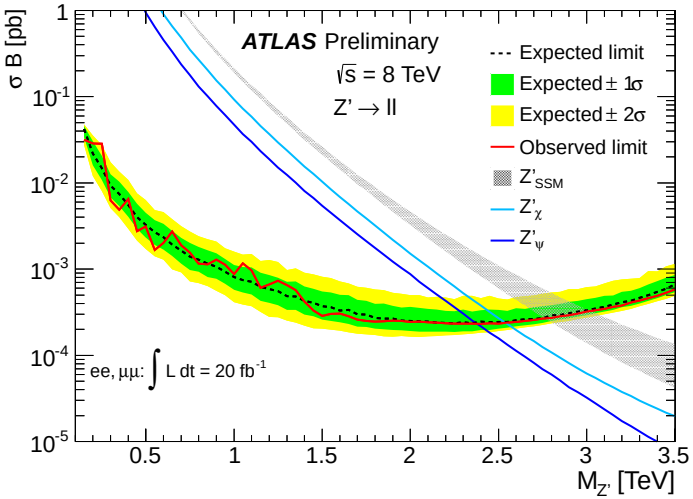
$p_{\mathrm{T}}^{\mu 1}$ =653 GeV, $p_{\mathrm{T}}^{\mu 2}$ =646 GeV, $m_{\mu\mu}$ =1844 GeV

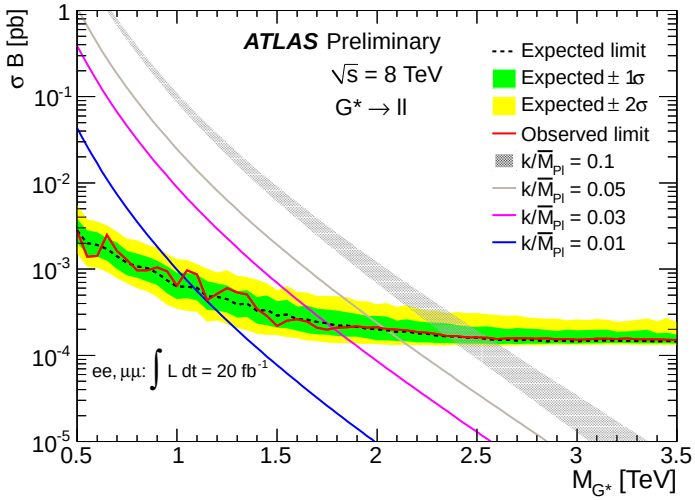






- 95% C.L. limits on signal σB





- 95% C.L. mass limits with 20 fb^{-1} @ 8 TeV [1]

model	Z'_{SSM}	Z'_{ψ}	Z'_{N}	Z'_{η}	Z'_{I}	Z'_{S}	Z'_{χ}	G^* $(k/\bar{M}_{\mathrm{Pl}}=0.1)$
Observed mass limit [TeV]	2.86	2.38	2.39	2.44	2.42	2.47	2.54	2.47
Expected mass limit [TeV]	2.85	2.37	2.38	2.43	2.40	2.46	2.53	2.47

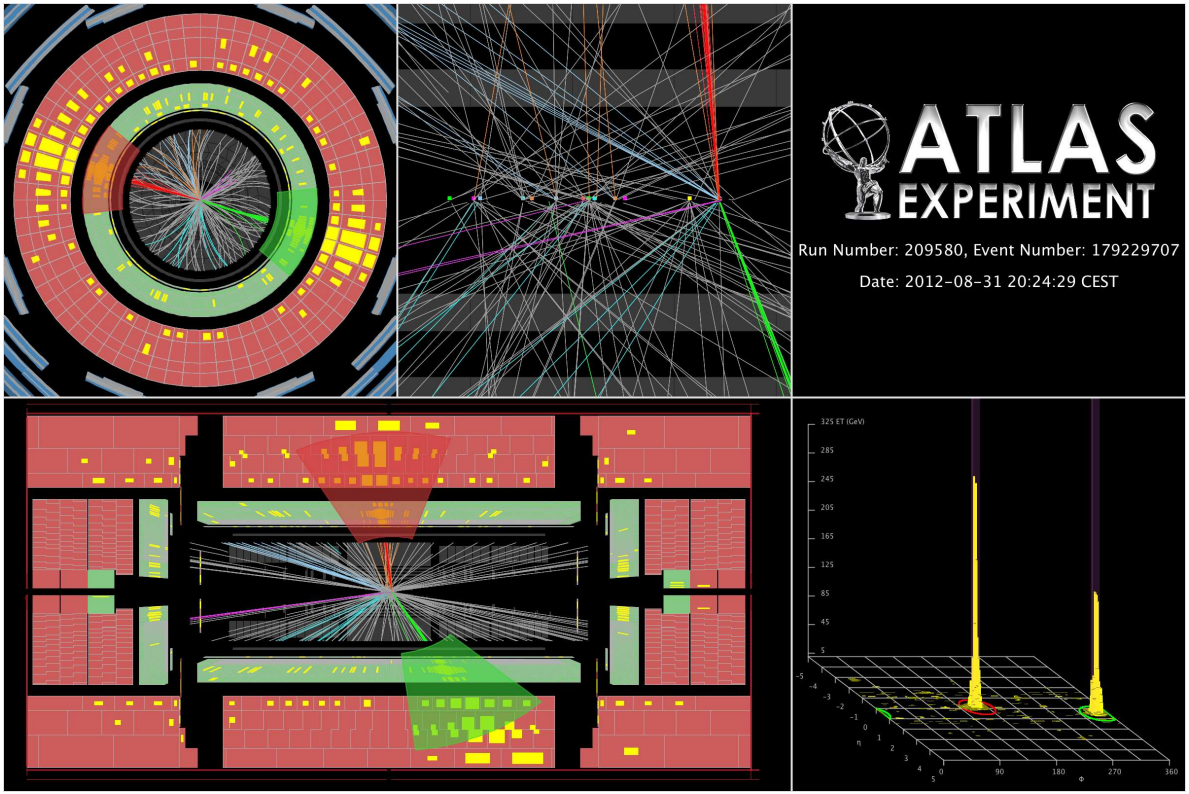
- 95% C.L. mass limits with 5 fb^{-1} @ 7 TeV [2]

model	Z'_{SSM}	Z'_{ψ}	Z'_{N}	Z'_{η}	Z'_{I}	Z'_{S}	Z'_{χ}	G^* $(k/\bar{M}_{\mathrm{Pl}}=0.1)$
Observed mass limit [TeV]	2.22	1.79	1.79	1.87	1.86	1.91	1.97	2.16
Expected mass limit [TeV]	2.25	1.87	1.87	1.92	1.91	1.95	2.00	2.17

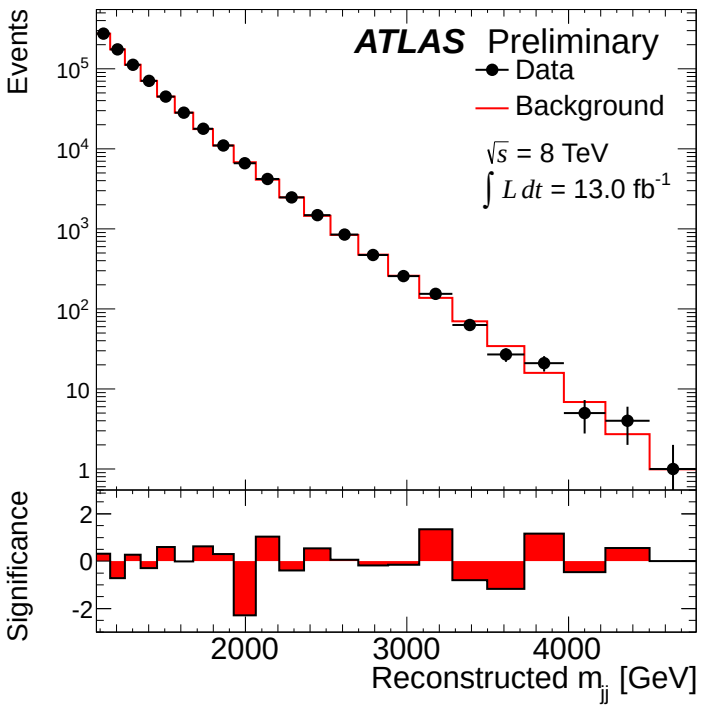
dijet [3]

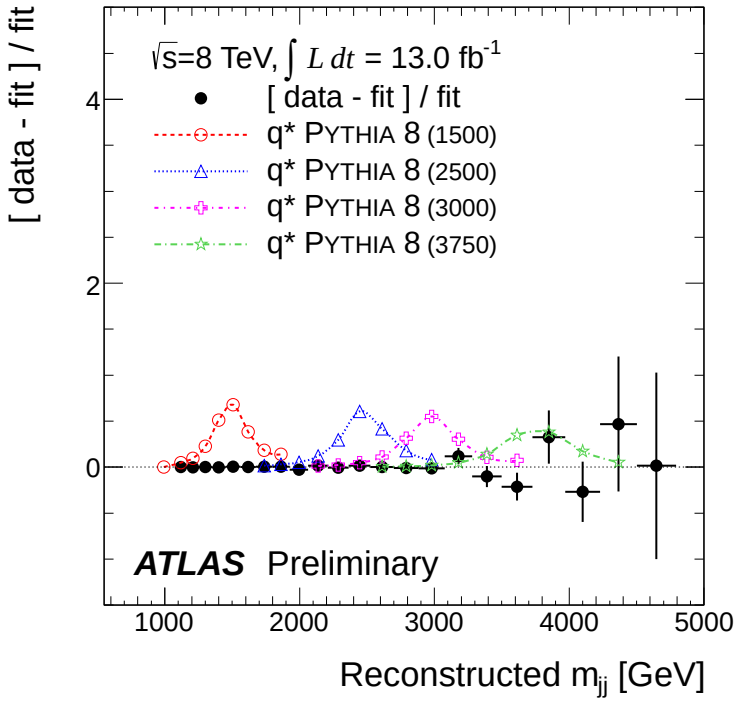
- Benchmark model: excited quark q^*
- Selection:
  - triggered by an OR of two high-energy single jet triggers (350/360 GeV)
  - two highest-p_{T} jets with $|y_{1,2}| < 2.8$, $|y_1 - y_2|/2 < 0.6$, $m_{jj} > 1$ TeV
- Candidate event:

$p_{\mathrm{T}}^{j_1} = 2.29$ TeV, $p_{\mathrm{T}}^{j_2} = 2.19$ TeV, $m_{jj} = 4.69$ TeV

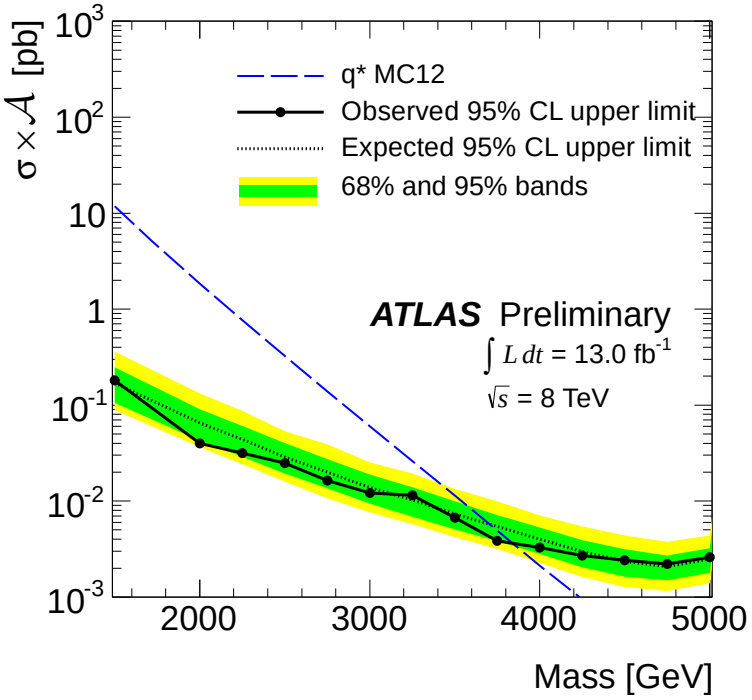


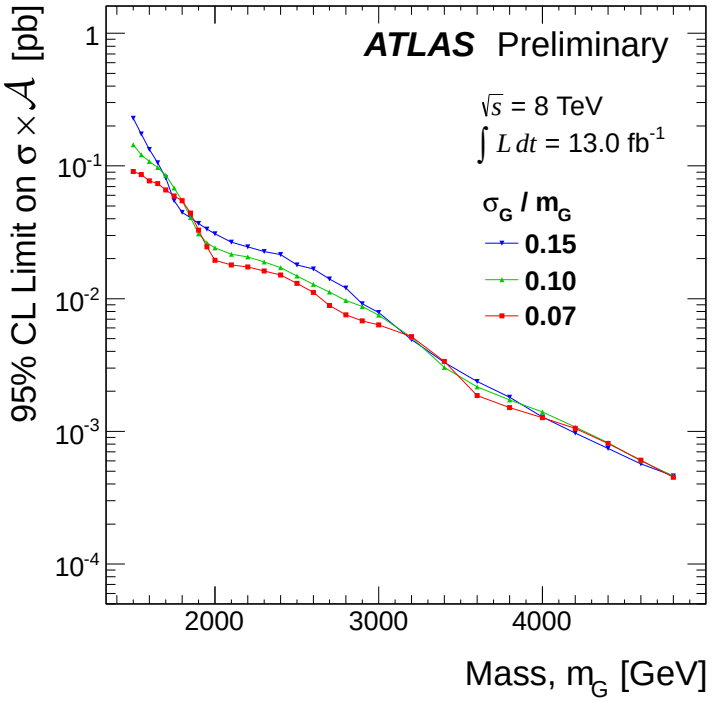
- Backgrounds: data-driven estimation by fitting the observed m_{jj} spectrum with a smooth function; the analysis is only searching for a localized resonant structure





- 95% C.L. limits on $\sigma \times \mathcal{A}$ for q^* and Gaussian resonance
  - Gaussian resonances: model-independent Gaussian-shaped hypothetical resonances; easy to compare with other theoretical predictions



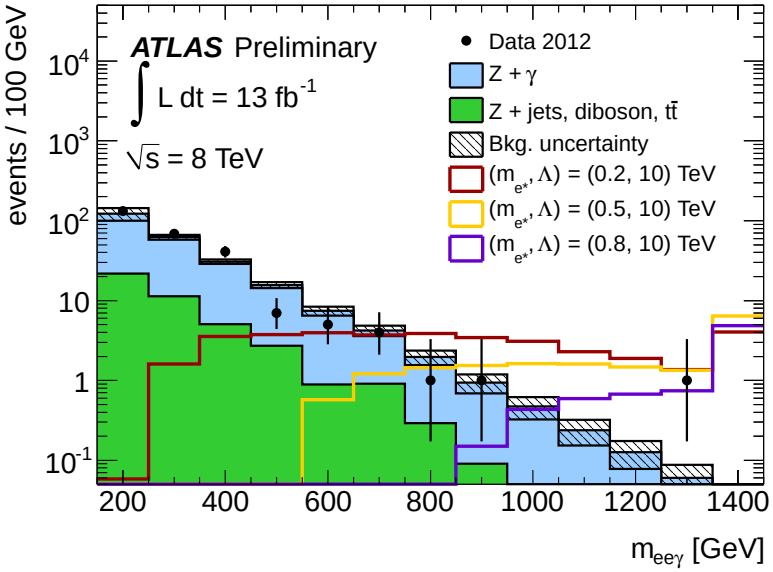


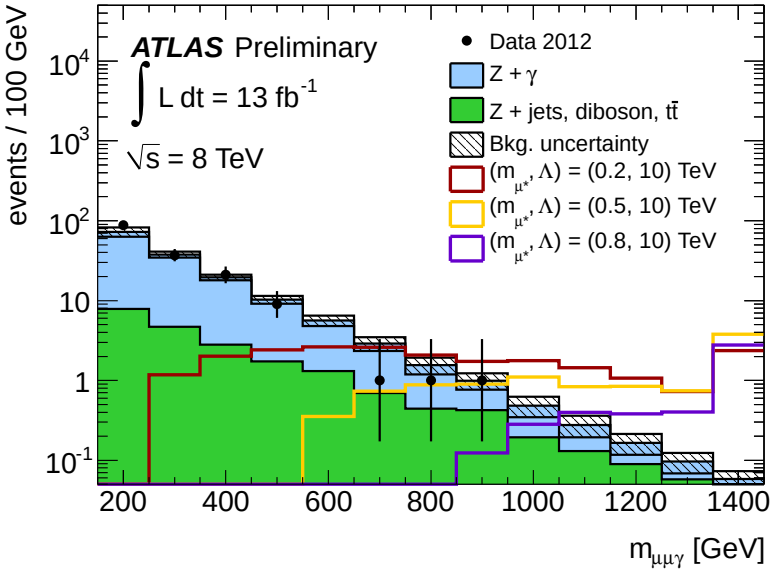
- 95% C.L. mass limits on q^*

model	q^*	
$\mathcal{L}@\sqrt{s}$	13 fb^{-1} @ 8 TeV [3]	4.8 fb^{-1} @ 7 TeV [4]
Observed mass limit [TeV]	3.84	2.83
Expected mass limit [TeV]	3.70	2.94

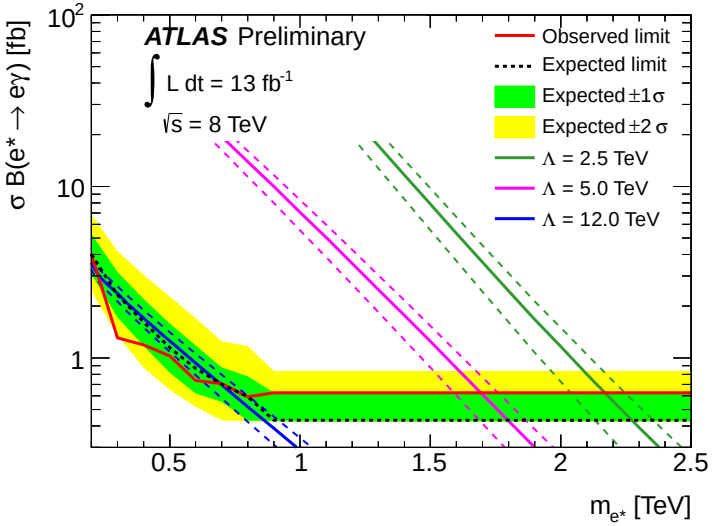
$\ell\bar{\ell}\gamma$ [5]

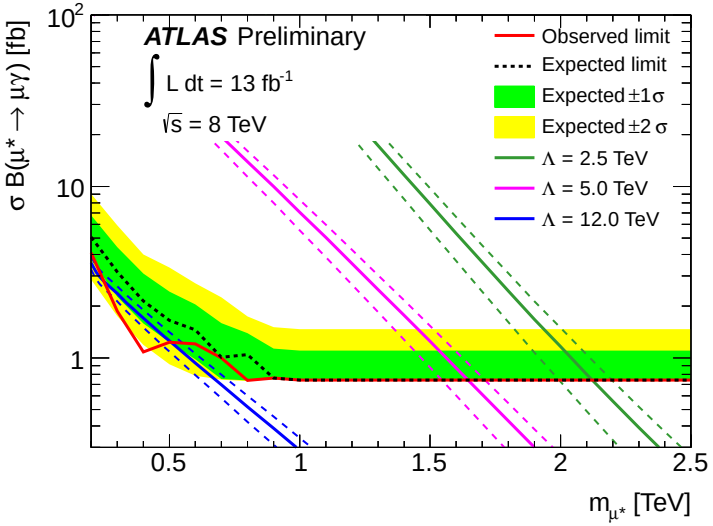
- Benchmark model: excited lepton ℓ^* ($q\bar{q} \to \ell^*\bar{\ell} \to \ell\gamma\bar{\ell}$)
- Signature: two same-flavor leptons (ee or $\mu^+\mu^-$) + a photon
- Backgrounds: $Z+\gamma$, Z+jets, diboson, $t\bar{t}$
- Z+jets is scaled to fit the 70< $m_{\ell\ell}$ <110 GeV region; $Z+\gamma$ and Z+jets extrapolated into high mass region using fitting
- When more than one pair of leptons, the one with largest invariant-mass is selected



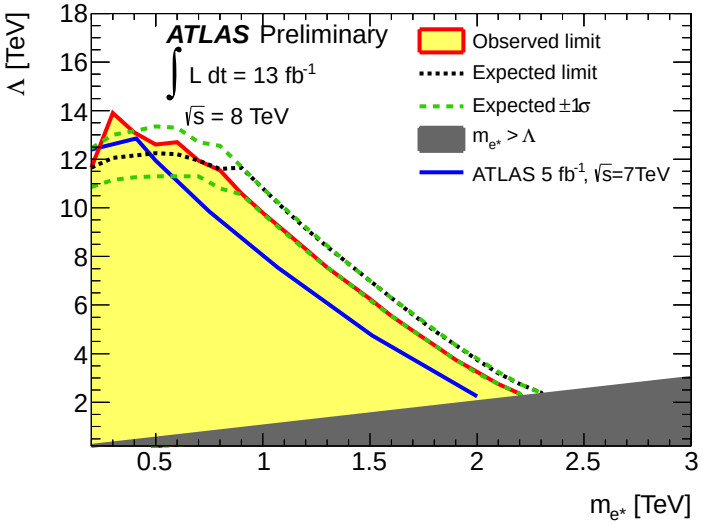


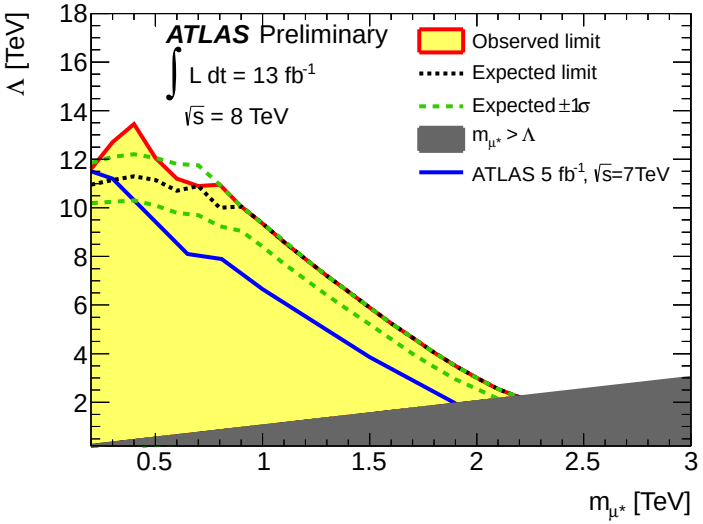
- 95% C.L. limits on $\sigma \times \mathcal{B}(\ell^* \to \ell\gamma)$





- 95% C.L. exclusion limits in the m_{ℓ^*} - Λ plane

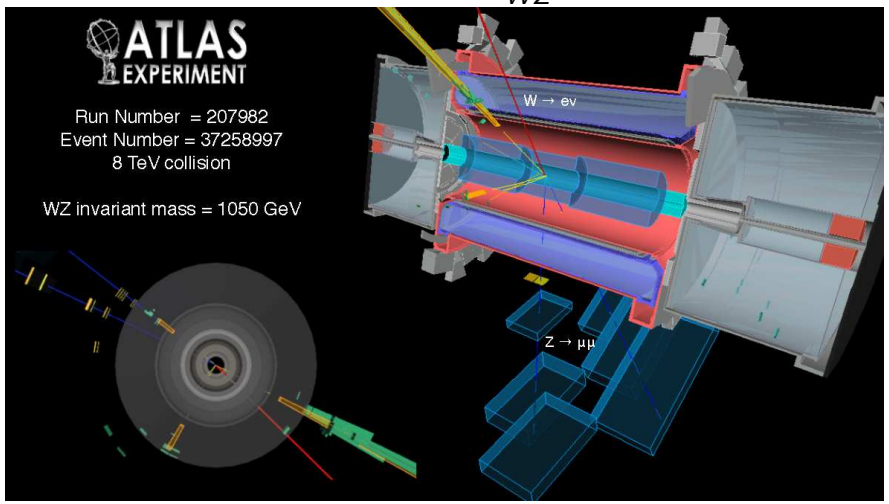


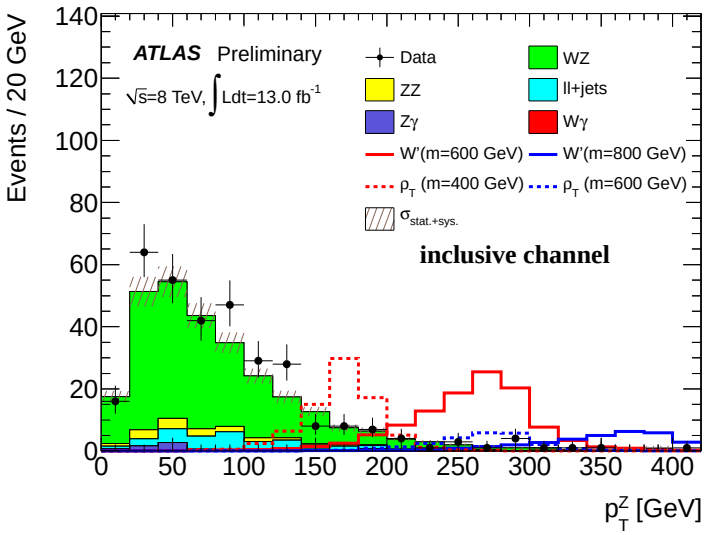


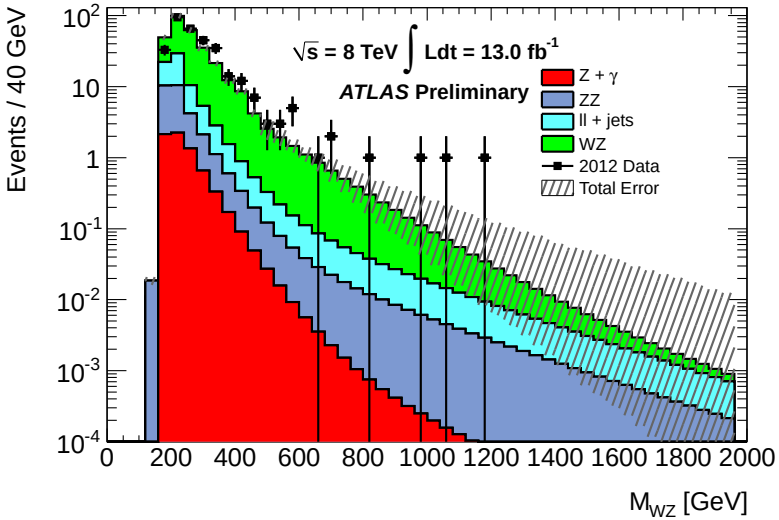
$WZ \to \ell\nu\ell\ell$ [6]

- Benchmark model: W', ρ_{T}
- Selection: exactly three leptons to reconstruct a pair of $W(\ell^{\pm}\nu)$ and $Z(\ell^{+}\ell^{-})$
- Backgrounds: WZ, ZZ, Z+jets, $t\bar{t}$, $Z\gamma$
- data-driven estimation for Z+jets and $t\bar{t}$
- W mass constraint for solving the p_z^{ν}
- $\Delta y(W,Z)$ <1.8, $\Delta\phi(W,Z)$ >2.6
- Fitting for extrapolation into high mass region

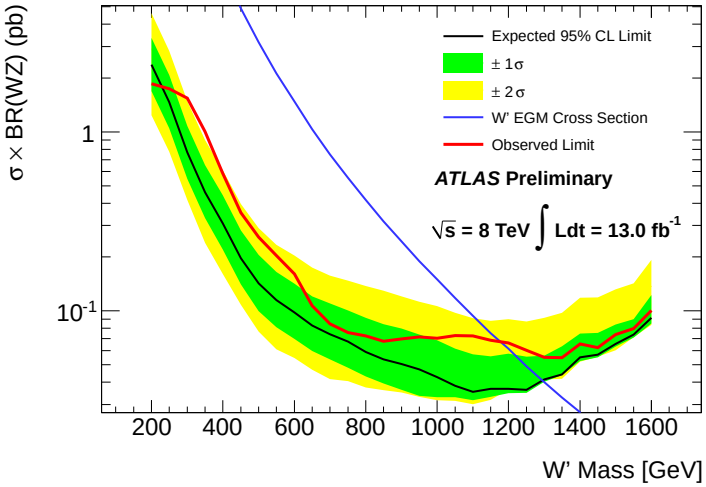
$e\nu\mu\mu$ candidate event, m_{WZ} =1050 GeV

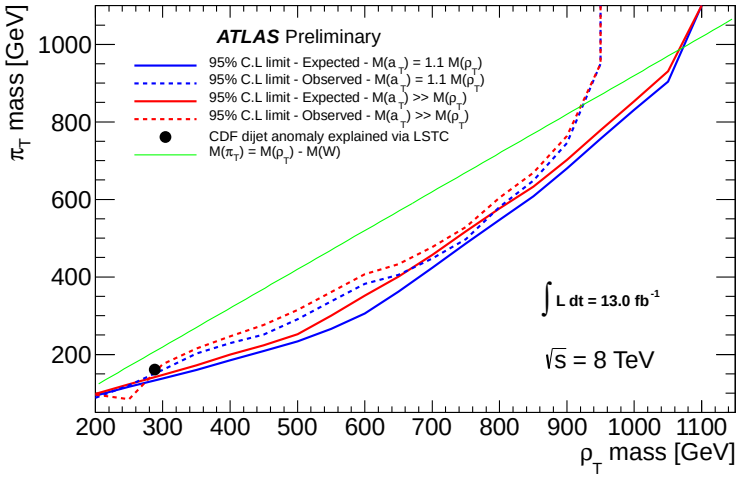






- 95% C.L. limits on $\sigma \times \mathcal{B}(W' \to WZ)$ and exclusion limits on $(\pi_{\mathrm{T}}, \rho_{\mathrm{T}})$ mass plane





- 95% C.L. mass limits with 13 fb^{-1} @ 8 TeV [6]

model	W'	ρ_{T} ($m_{\rho_{\mathrm{T}}} = m_{\pi_{\mathrm{T}}} + m_W$, $m_{a_{\mathrm{T}}} = 1.1 \times m_{\rho_{\mathrm{T}}}$, $sin\chi = 1/3$)
Observed mass limit [TeV]	1.18	0.92
Expected mass limit [TeV]	1.30	1.07

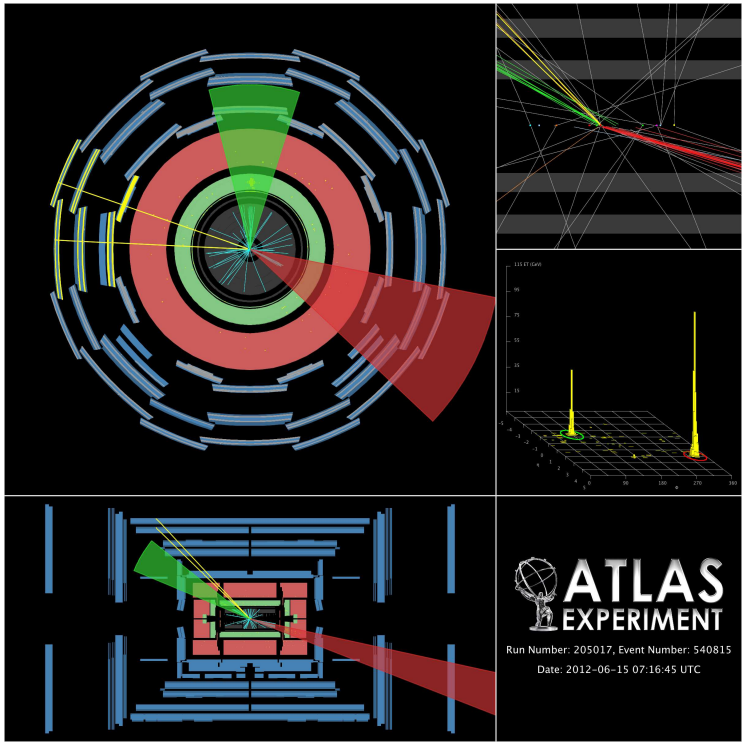
- 95% C.L. mass limits with 1 fb^{-1} @ 7 TeV [7]

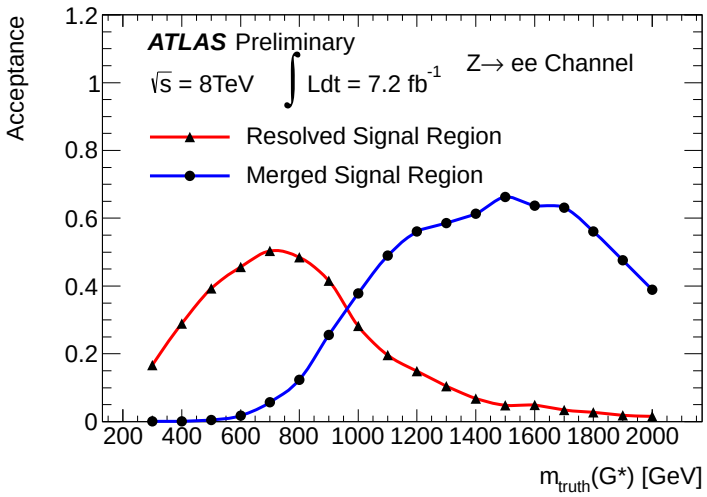
model	W'	ρ_{T} ($m_{\rho_{\mathrm{T}}} = m_{\pi_{\mathrm{T}}} + m_W$, $m_{a_{\mathrm{T}}} = 1.1 \times m_{\rho_{\mathrm{T}}}$, $sin\chi = 1/3$)
Observed mass limit [TeV]	0.76	0.48
Expected mass limit [TeV]	0.78	0.55

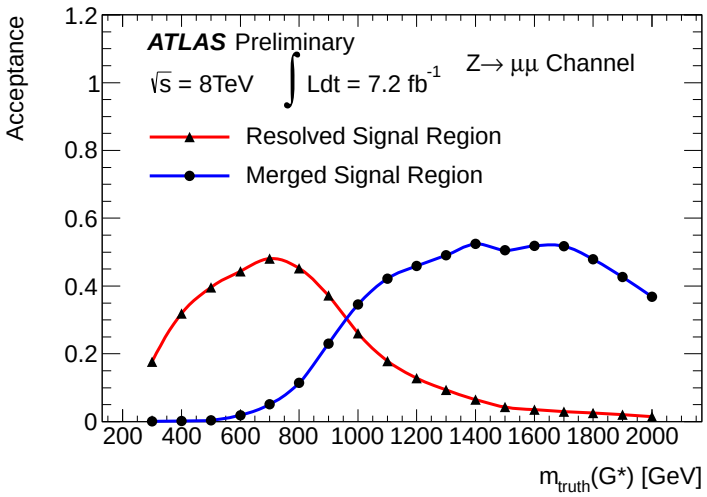
$ZZ \to \ell\ell qq$ [8]

- Benchmark model: bulk RS G^*
- exactly two leptons (ee or $\mu^+\mu^-$) with 66 $< m_{\ell\ell} <$ 116 GeV and high-p_{T} jets
- "resolved" SR: $p_{\mathrm{T}}^{\ell\ell}$ >50 GeV, $\Delta\phi(jj)$ <1.6, 65< m_{jj} <115 GeV
- "merged" SR: $p_{\mathrm{T}}^{\ell\ell}$ >200 GeV, p_{T}^{j} >200 GeV, m_j >40 GeV
- Backgrounds: Z+jets, diboson, $t\bar{t}$
- Signal acceptance in two signal regions:

$\mu\mu j$ candidate event, $m(\mu\mu j) = 2.9$ TeV

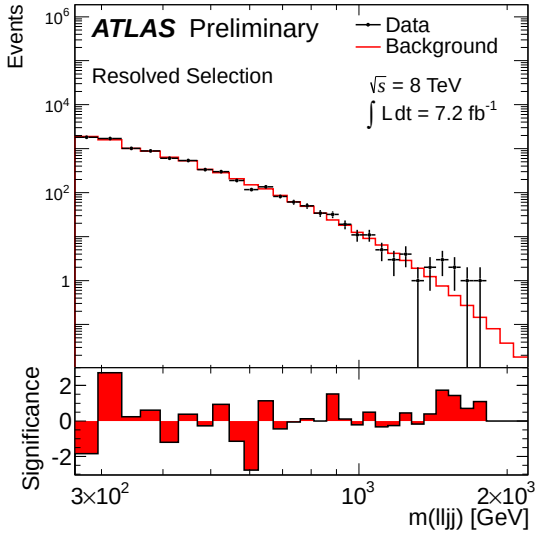


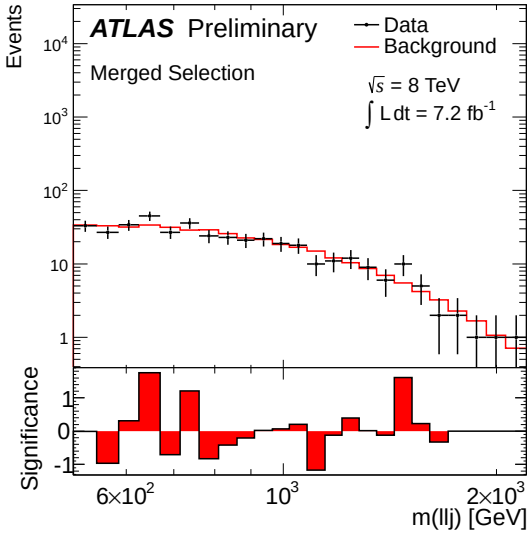




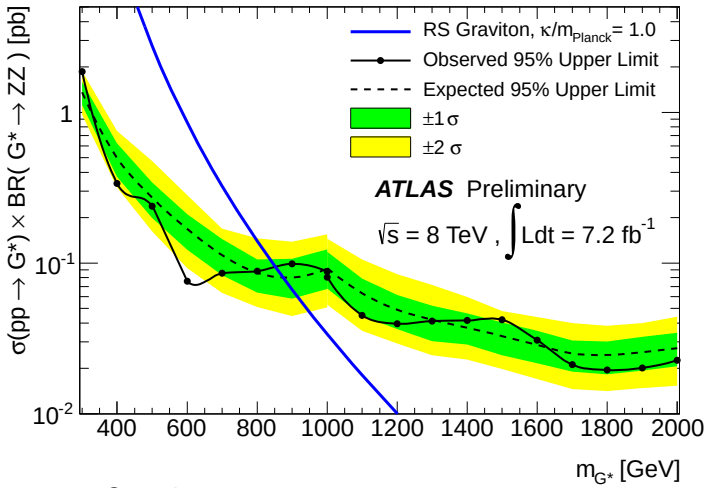
$ZZ \to \ell\ell qq$

- $m(\ell\ell jj)$,$m(\ell\ell j)$ distributions in the signal regions; The background is estimated by fitting the data





- 95% C.L. limits on $\sigma \times \mathcal{B}(G^* \to ZZ)$ [8]



model	bulk $G^*(k/M_{\rm Pl}$ =1.0)
Observed mass limit [TeV]	0.85
Expected mass limit [TeV]	0.87

Summary

- 5 ATLAS searches with 8 TeV data presented
- New tighter constraints on 7 different BSM models obtained
- Updates with larger data samples coming soon!
- Stay tuned ...

References I

[1] ATLAS Collaboration, ATLAS-CONF-2013-017.

[2] ATLAS Collaboration, arXiv:1209.2535.

[3] ATLAS Collaboration, ATLAS-CONF-2012-148.

[4] ATLAS Collaboration, arXiv:1210.1718.

[5] ATLAS Collaboration, ATLAS-CONF-2012-146.

[6] ATLAS Collaboration, ATLAS-CONF-2013-015.

[7] ATLAS Collaboration, arXiv:1204.1648v1.

[8] ATLAS Collaboration, ATLAS-CONF-2012-150.

[9] P. Langacker, Rev. Mod. Phys. **81** (2009) 1199-1228.

[10] D. London and J. L. Rosner, Phys. Rev. **D34** (1986) 1530.

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[12] U. Baur, I. Hinchliffe and D. Zeppenfeld, Int. J. Mod. Phys. **A2** (1987) 1285.

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[14] G. Altarelli, B. Mele and M. Ruiz-Altaba, Z. Phys. **C45** (1989) 109.

[15] E. Eichten and K. Lane, Phys. Lett. **B669** (2008) 235-238.

[16] E. Eichten, K. Lane, A. Martin and E. Pilon, `arXiv:1206.0186 [hep-ph]`.

[17] K. Agashe et al., Phys. Rev. **D76** (2007) 036006.

Backup Slides

Models I

- Sequential Standard Model [9]: the Z'_{SSM} has the same couplings to fermions as the Standard Model (SM) Z boson
- E_6 Grand Unification Model [10]: six different Z' states
- Randall-Sundrum Model [11]: solves the hierarchy problem with a warped extra dimension, predicts excited Kaluza-Klein modes of the graviton
- Excited quark and leptons [12, 13]: compositeness for solving hierarchy problem
- New vector bosons [14]: suppressed coupling $g_{W'WZ} = g_{WWZ}(m_W m_Z / m_{W'}^2)$
- Low-scale technicolor [15, 16]
- Bulk Randall-Sundrum Model [17]: enhanced branching fractions to heavy particles

Fit functions for the background extrapolation or estimation

- dilepton: $ax^b x^{c\ln x}$
- dijet: $p_1(1-x)^{p_2} x^{p_3+p_4\ln x}$
- $\ell\bar{\ell}\gamma$: $exp(P_0 + P_1 \times m_{\ell\ell\gamma})$
- $\ell\nu\ell\ell$: $c_1 e^{k_1 x} + c_2 e^{k_2 x}$
- $\ell\ell qq$: $p_0 \times \frac{(1-x)^{p_1}}{x^{p_2+p_3\ln x}}$