Prospects for Searches for Narrow Resonances Decaying to Top Quark Pairs

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Introduction

- Search for Z' → ttbar as model for narrow resonance
- All-hadronic and l+jets channels
- Scenario : 14 TeV pp collider (300 fb^{-1}, 3000 fb^{-1})

- Model :
  - Leptophobic topcolor Z' [hep-ph/9911288]
  - 1.2% width
  - Cross-sections from [arXiv:1112.4928]

- All current limits < 2 TeV (using up to 14 fb^{-1} at 8 TeV [ATLAS-CONF-2013-052])

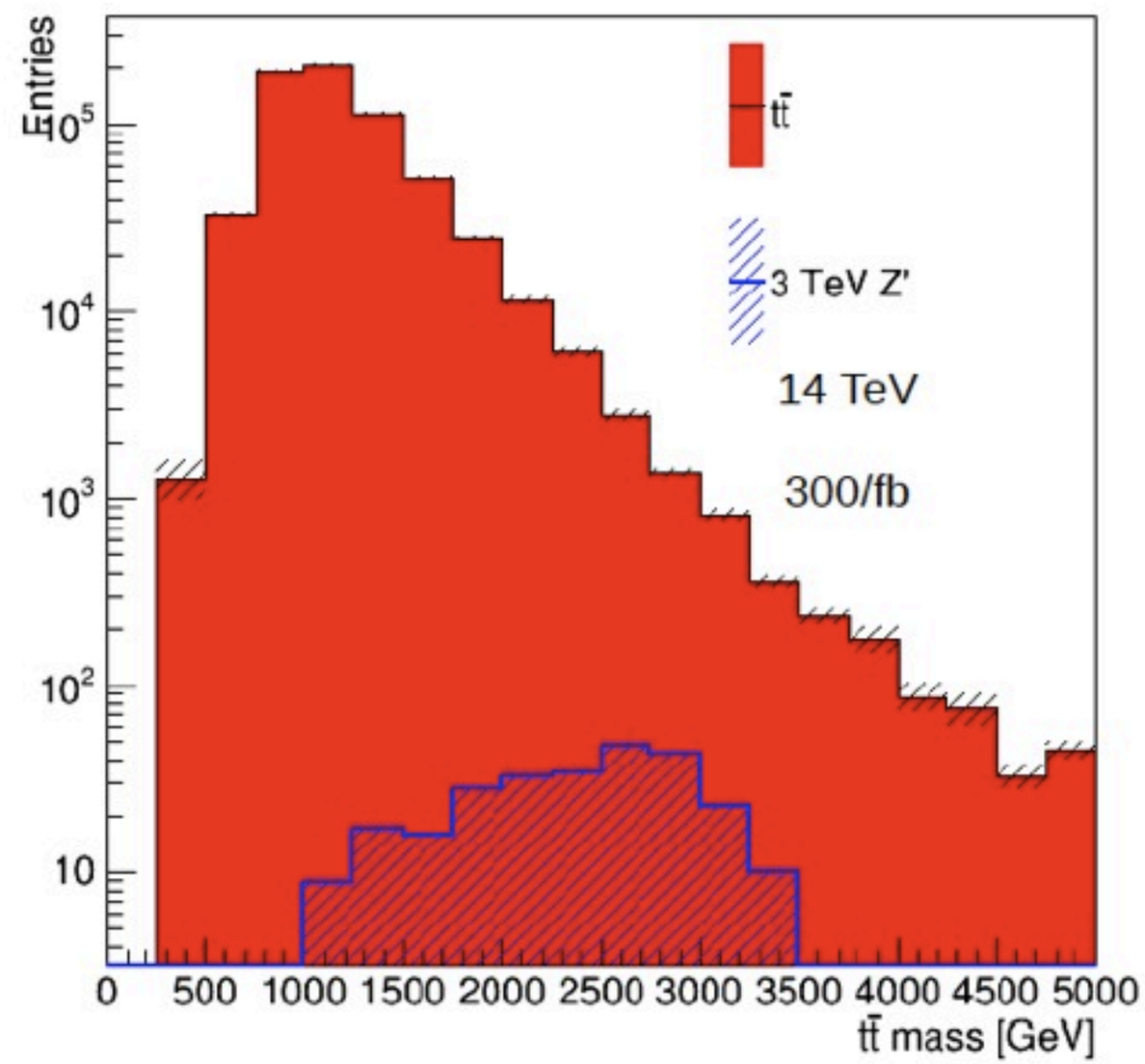
- Strategy :
  - all-hadronic : reduce QCD with substructure & b-tagging
  - l+jets : use substructure, b-tagging and lepton mini-isolation

l+jets analysis

- Boosted l+jets selection :
  - 1 fat jet (p_T > 600 GeV), top-tagged
  - 1 mini-isolated lepton, p_T > 25 GeV
  - E_T^{miss} > 50 GeV
  - 1 b-tagged skinny jet (anti-k_t 0.5)
  - ΔR (fat jet, lepton) > 1.0
  - ΔR (fat jet, skinny jet) > 1.0
  - ΔR (skinny jet, lepton) < 1.0

- Analysis close to be finalized

- *Showing only all-hadronic results here*



Modeling

- Z' :
  - 100k events with Pythia8
  - m = 2 TeV, 3 TeV, 4 TeV, 5 TeV

- ttbar :
  - 1M events with Herwig++
  - p_T > 650 GeV

- QCD :
  - 1M events with Herwig++
  - p_T > 650 GeV

sample	cross section
Z' (2 TeV)	$214 \cdot 10^{-3}$ pb
Z' (3 TeV)	$23.2 \cdot 10^{-3}$ pb
Z' (4 TeV)	$3.24 \cdot 10^{-3}$ pb
Z' (5 TeV)	$0.553 \cdot 10^{-3}$ pb
$t\bar{t}$ ($p_T > 650$ GeV)	1.28 pb
QCD multijet ($p_T > 650$ GeV)	170 pb

- For ttbar and QCD : using Herwig++ cross section
- For Z' : additional k-factor 1.3

- Delphes 3.0.9 (private version by Jim Dolen including substructure variables)
- μ = 0, 50, 140

Selection

- 2 C/A R=0.8 jets with
  - p_T > 750 GeV
  - $|\eta| < 2.0$
  - top-tag : Q_W > 70 GeV $m_{trimmed}$ > 80 GeV
  - b-tag : $\varepsilon = 0.83 \cdot \exp(-0.7 \cdot pT[TeV])$

    $f = 1 / (80 \cdot \exp(-0.9 \cdot pT[TeV]))$

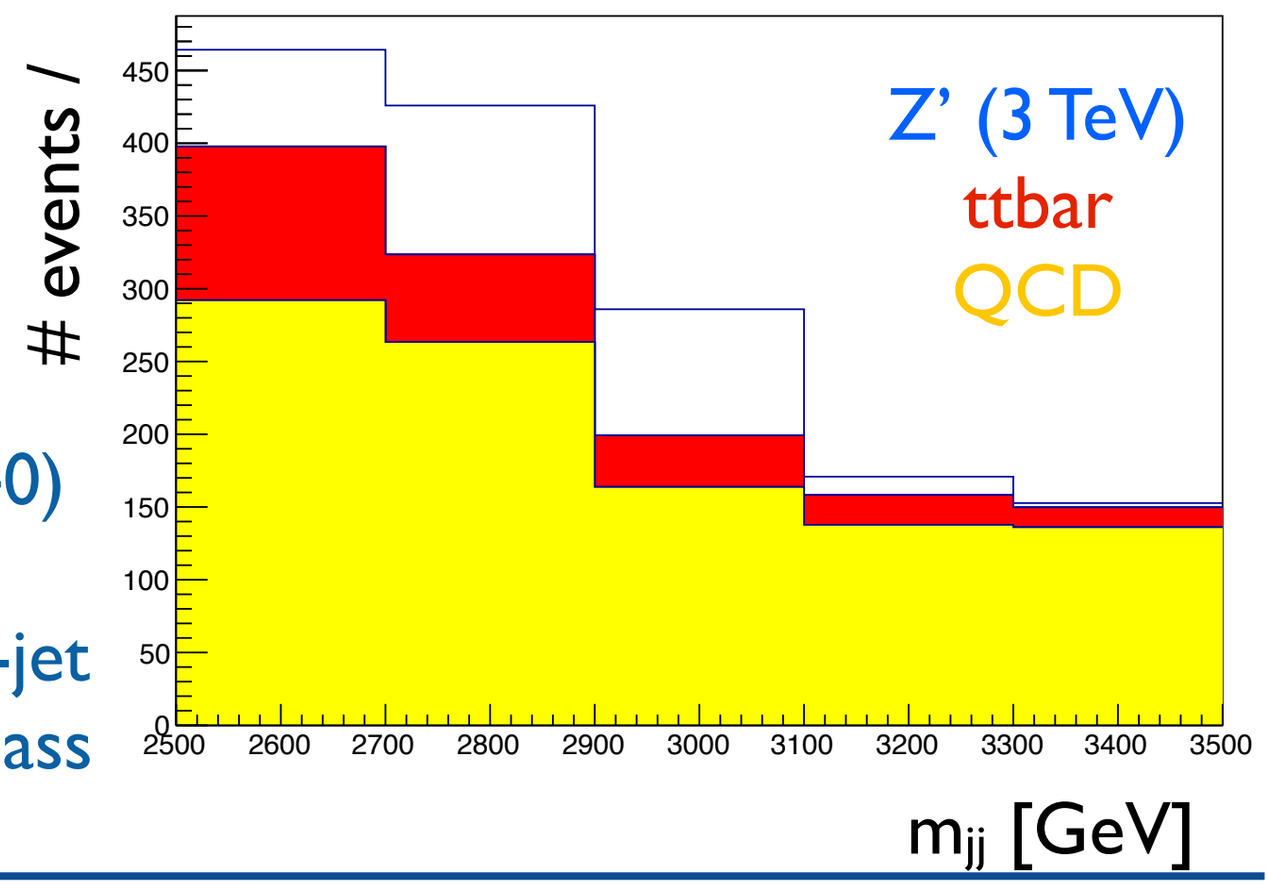
- top-tagging optimized using $S/\sqrt{B}$:

  $Q_W, \sqrt{d_{12}}, \sqrt{d_{23}}, \tau_{32}, \tau_{21}$, Nsubjets, $m_{trimmed}$

- b-tagging :
  - ε = 50% (30%) @ 0.75 (1.5) TeV
  - f = 2.5% (5%) @ 0.75 (1.5) TeV
  - increase f by 1/3 (2/3) for μ = 50 (140)

- input to statistical analysis : invariant di-jet mass in ± 500 GeV window around Z' mass

μ = 50, 14 TeV, 300 fb^{-1}

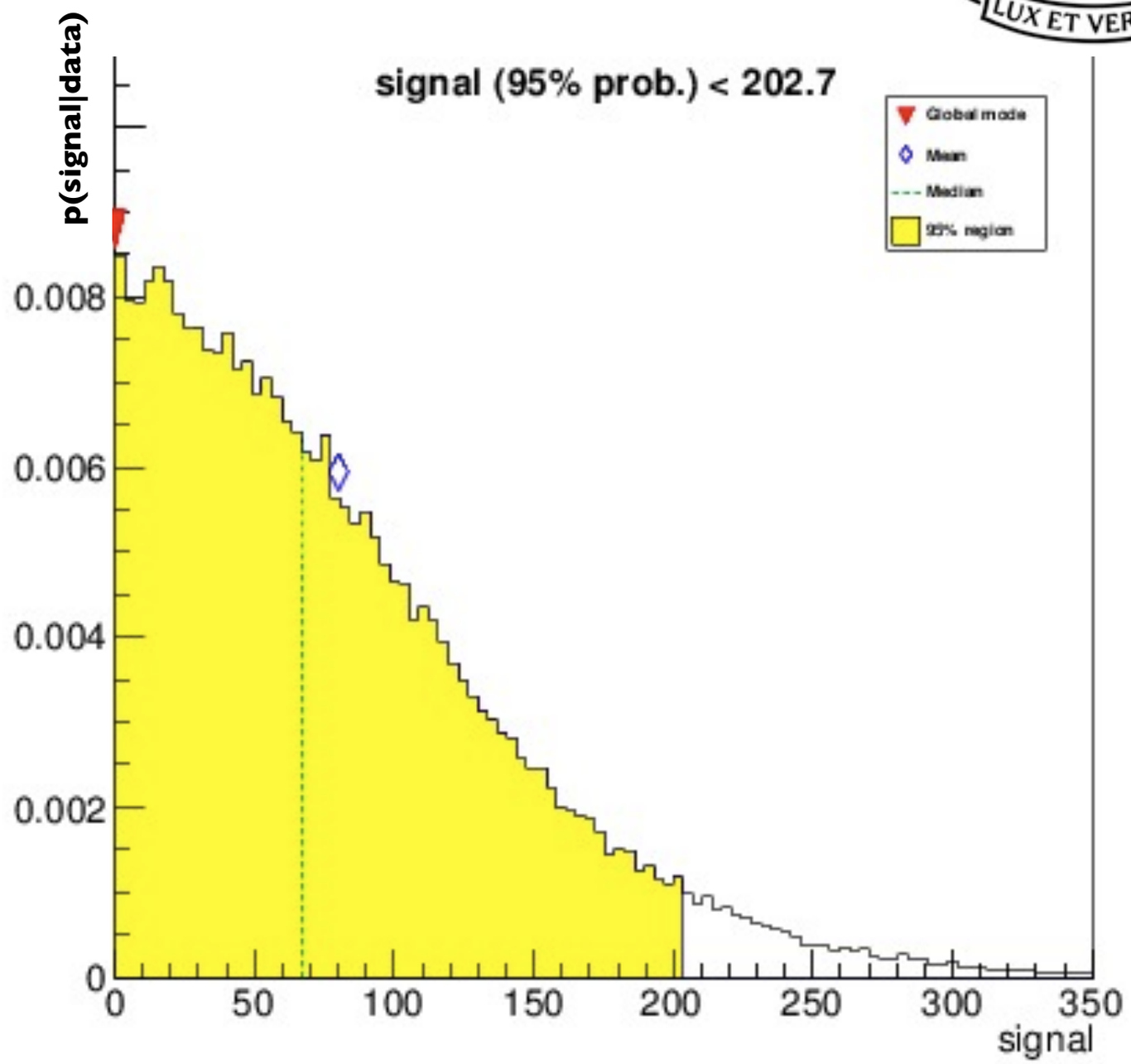


Limit Setting and Systematic Uncertainties

- Calculating expected 95% CL limits on Z' production
- Bayesian Analysis Toolkit [arXiv:0808.2552]
- Statistical uncertainty on limits from 1000 sets of pseudo-data

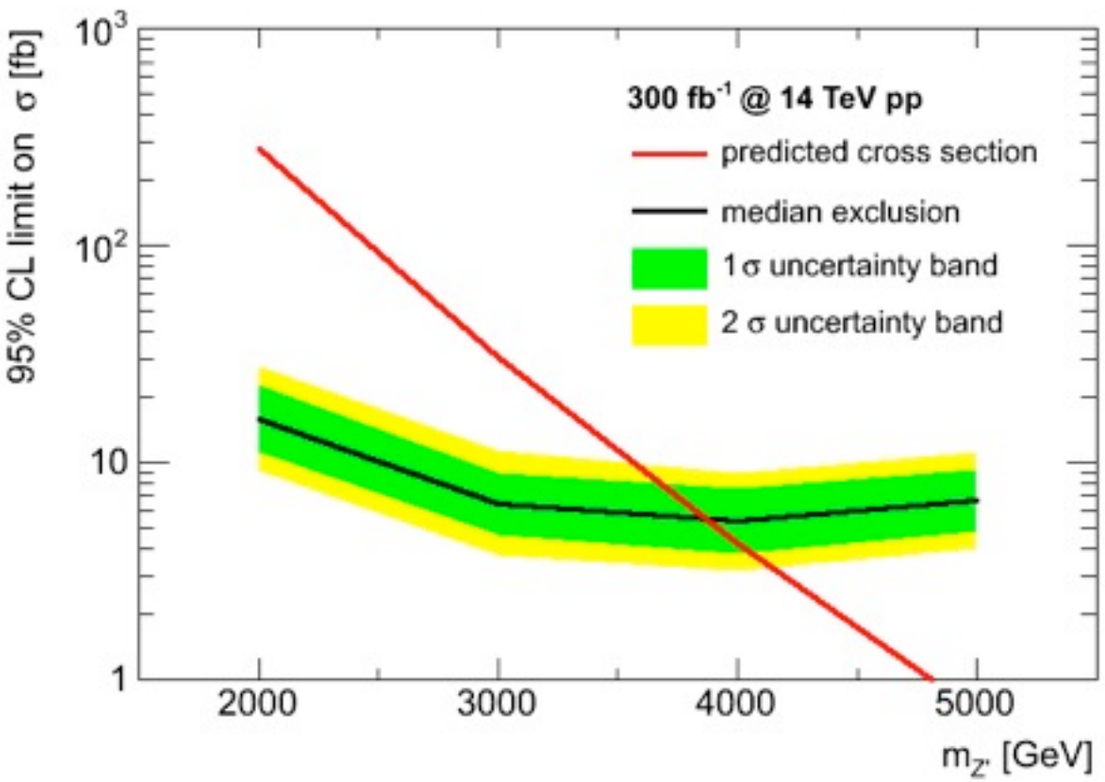
- Systematic uncertainties :
  - QCD expected to be DD

	value	process
ttbar normalization	±10%	ttbar
QCD normalization	±50%	QCD
JES	±2%	Z', ttbar
b-tagging efficiency	±10%	Z', ttbar

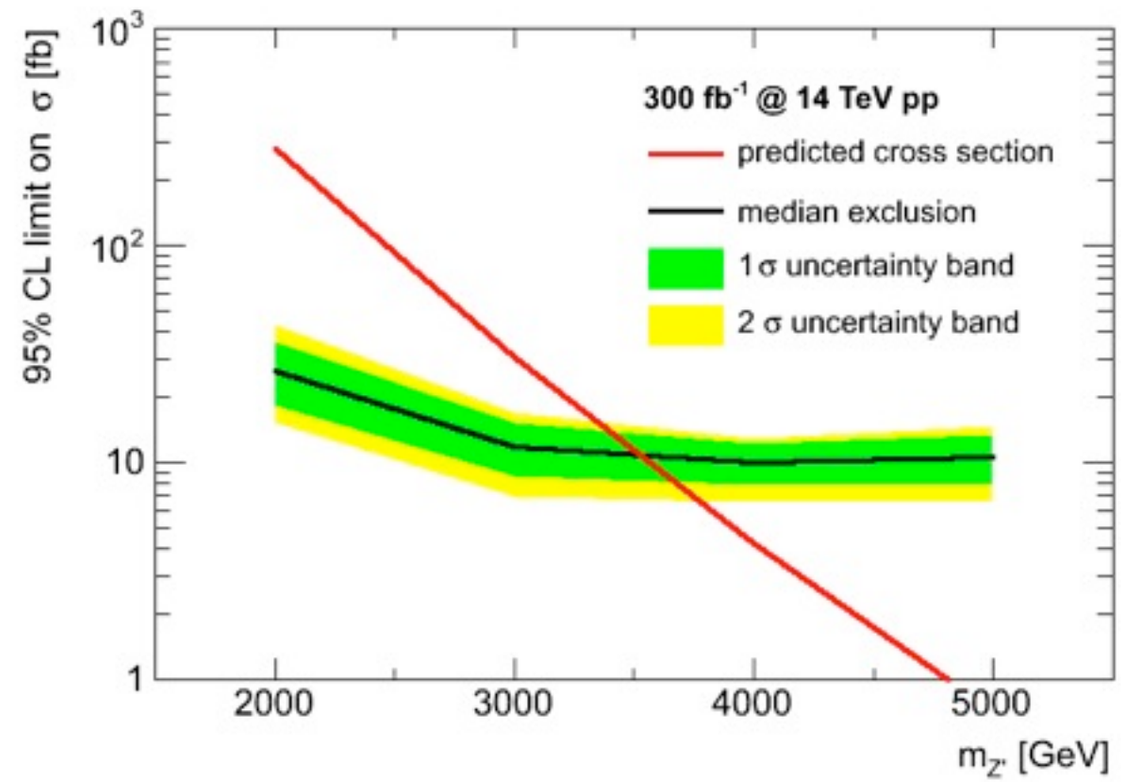


Results (1/3)

statistics only

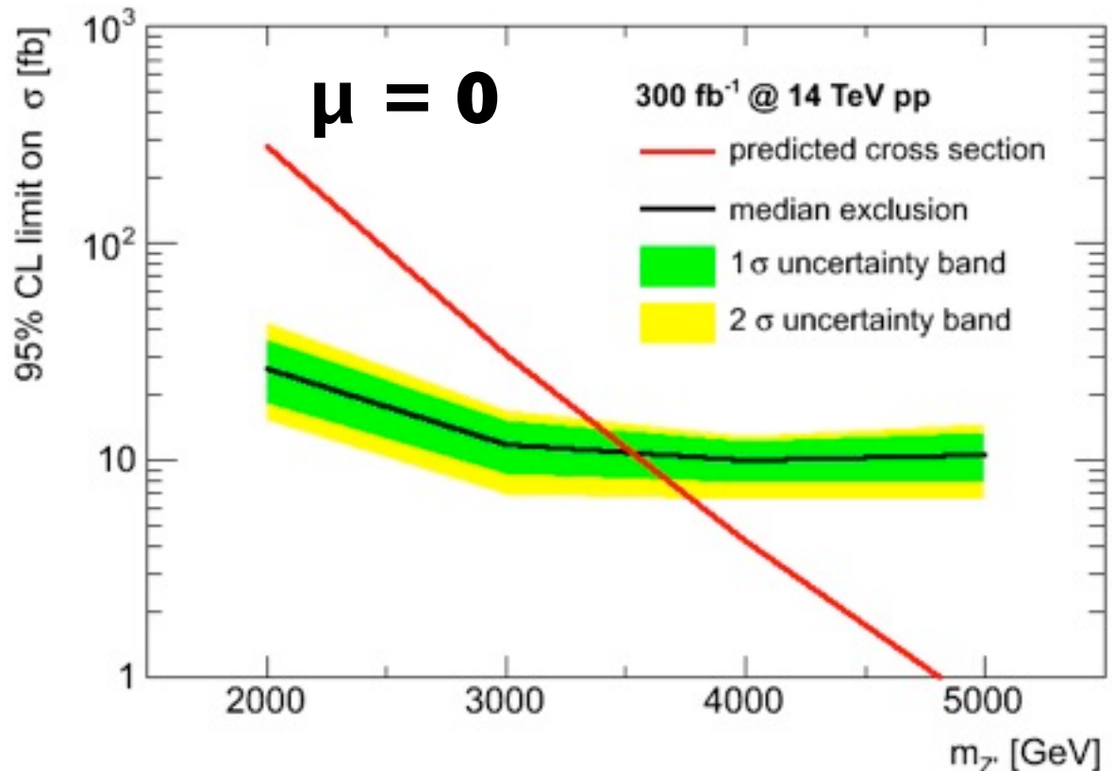


with systematics

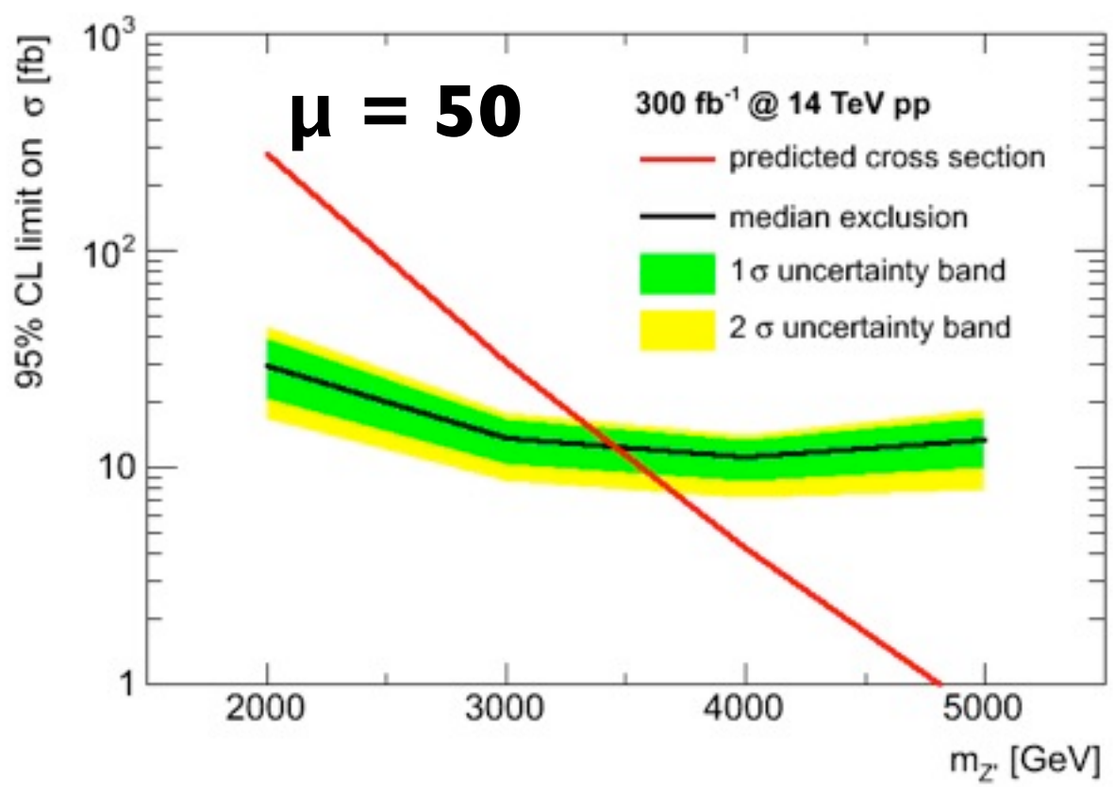


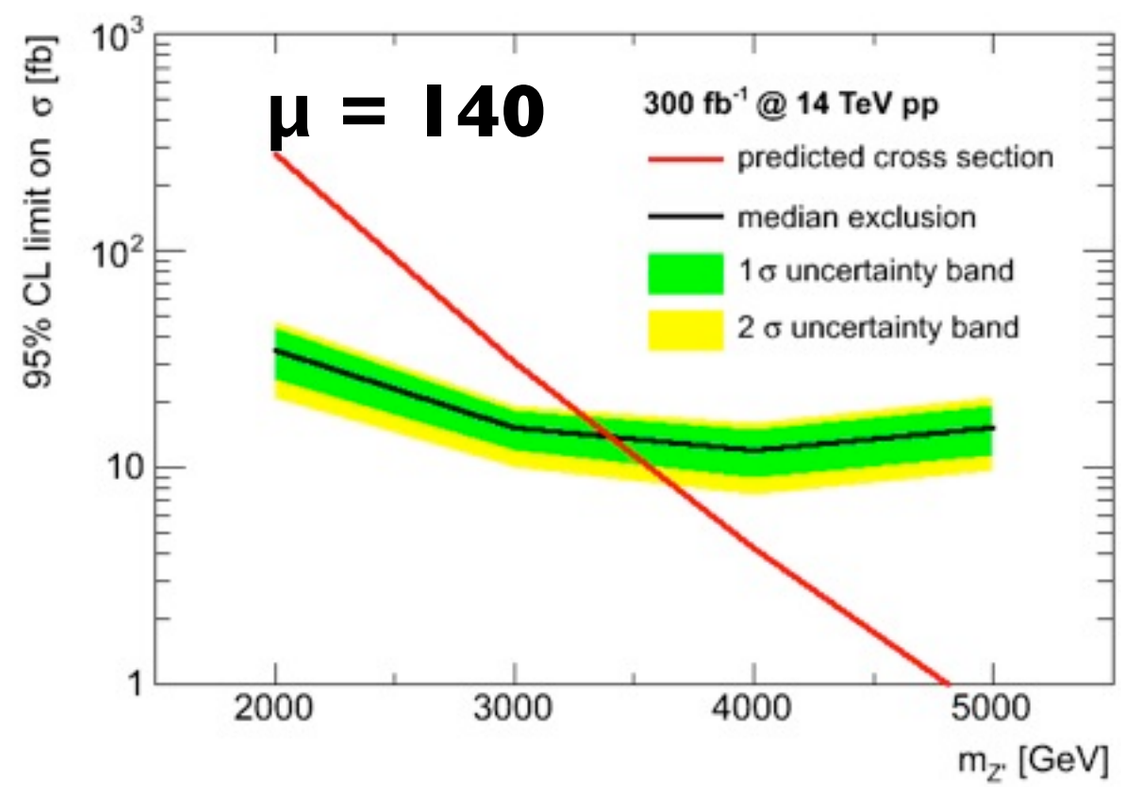
- Results at μ = 0
- Systematic uncertainties decrease sensitivity

Results (2/3)



- With systematics
- Increasing pile-up decreases sensitivity

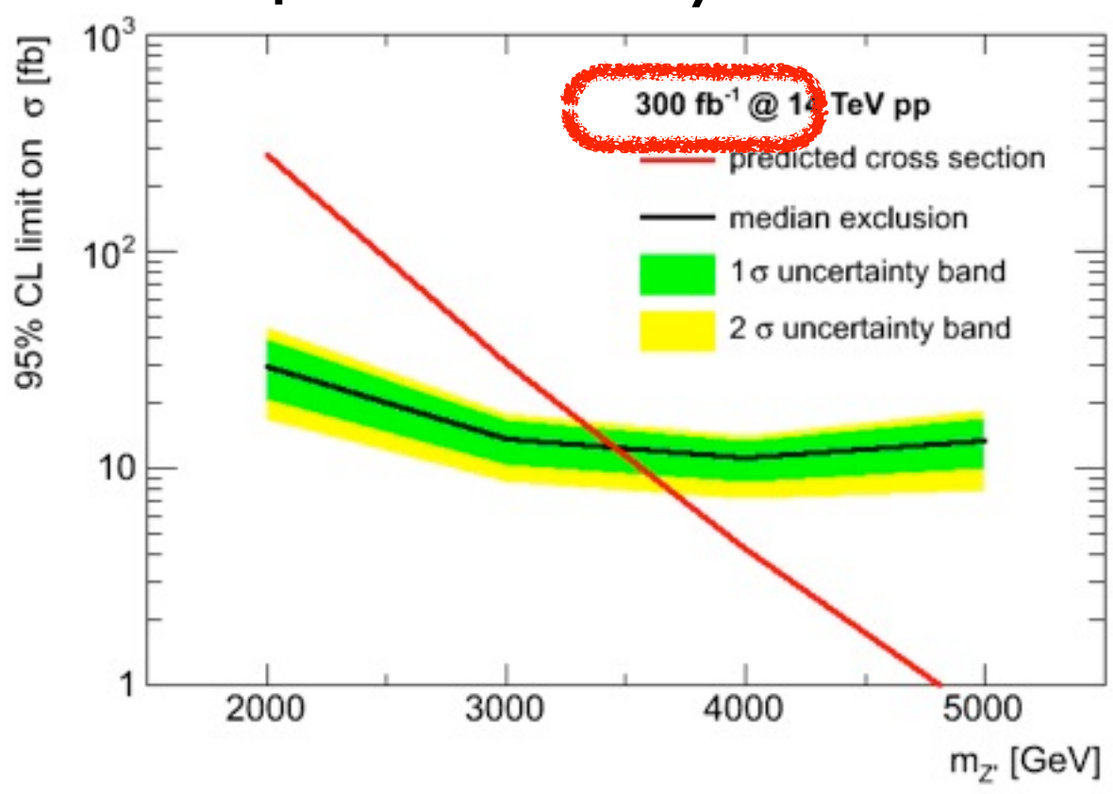




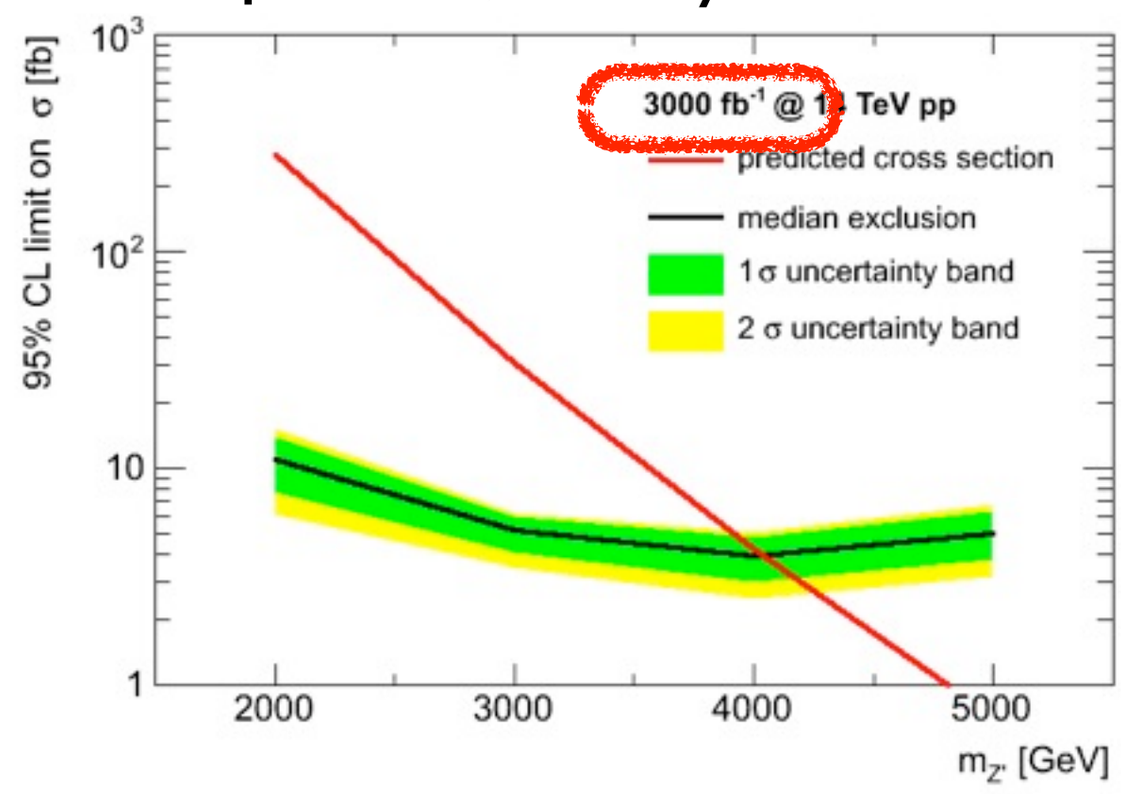
Results (3/3)

	300 fb^{-1} (μ = 50)		3000 fb^{-1} (μ = 140)	
	stat.	stat.+syst.	stat.	stat.+syst.
2 TeV	16 fb	29 fb	5.4 fb	11 fb
3 TeV	6.7 fb	13 fb	2.2 fb	5.2 fb
4 TeV	5.7 fb	11 fb	1.9 fb	3.9 fb
5 TeV	7.6 fb	13.3 fb	2.5 fb	5.0 fb
mass reach (95% CL)	3.9 TeV	3.7 TeV	4.6 TeV	4.1 TeV

μ = 50, with systematics



μ = 140, with systematics



remark: TGraph interpolates linearly – also in log plots → for mass reach cf. table !

Summary

- Presented prospects for search for ttbar resonances at 14 TeV
- Using substructure
- Using more realistic assumptions on b-tagging than implemented in Delphes
- Including main systematic uncertainties

- 300 fb^{-1} : reach sensitivity to O(11 – 13 fb^{-1}) for resonance masses of 3 – 5 TeV
- 3000 fb^{-1} : reach sensitivity to O(4 – 5 fb^{-1}) for resonance masses of 3 – 5 TeV

- Expect to exclude leptophobic topcolor Z' (Γ = 1.2%) up to 3.7 (4.1) TeV for 300 (3000) fb^{-1}

- Searches for top resonances will benefit from running at 14 TeV
- For even higher mass reach will probably need more refined analysis strategies (entering the regime where resolving substructure in fat jets is a challenge with given detector granularity)

Bonus

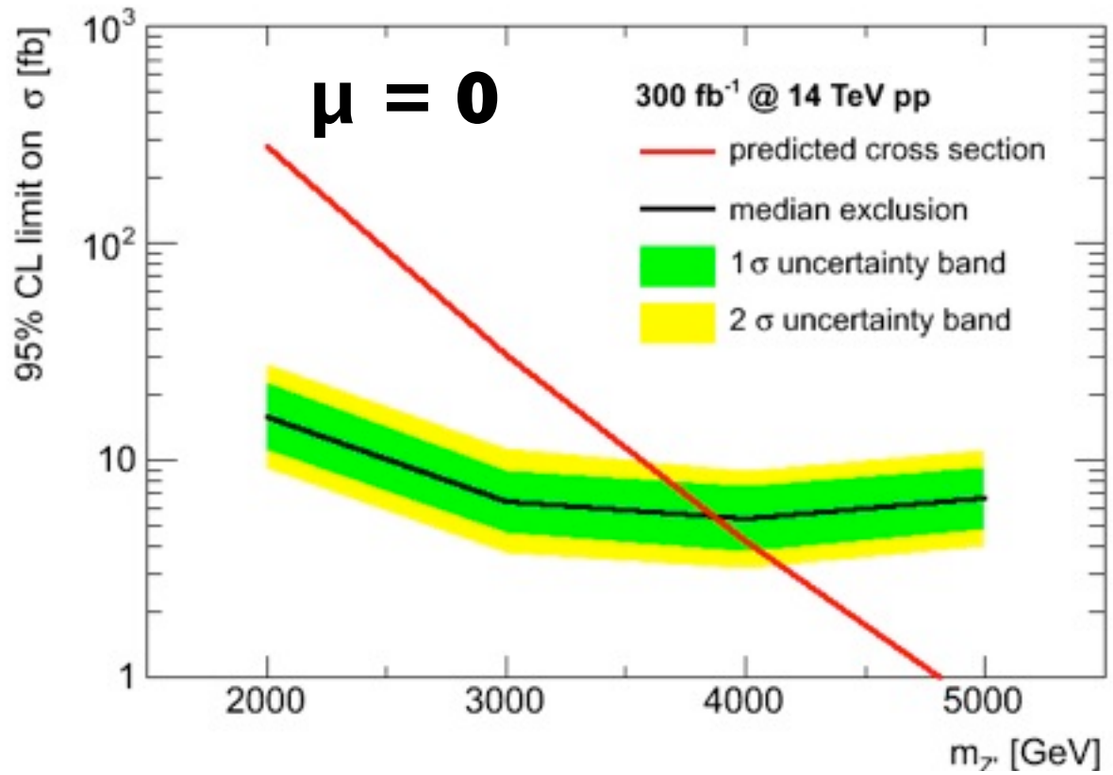
300 fb^{-1}

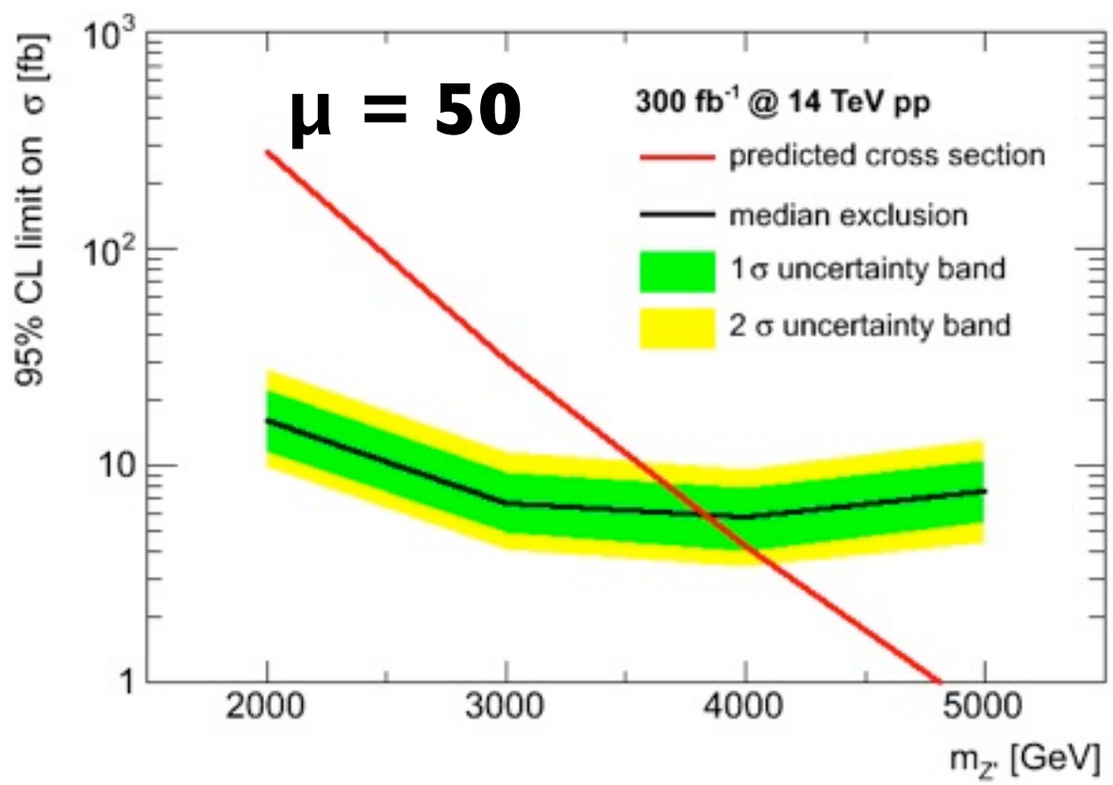
	300 fb^{-1} (μ = 0)		300 fb^{-1} (μ = 50)		300 fb^{-1} (μ = 140)	
	stat.	stat.+syst.	stat.	stat.+syst.	stat.	stat.+syst.
2 TeV	16 fb	26 fb	16 fb	29 fb	17 fb	35 fb
3 TeV	6.4 fb	12 fb	6.7 fb	13 fb	7.2 fb	15 fb
4 TeV	5.3 fb	10 fb	5.7 fb	11 fb	6.2 fb	12 fb
5 TeV	6.6 fb	11 fb	7.6 fb	13.3 fb	8.5 fb	15 fb
mass reach (95% CL)	4.0 TeV	3.8 TeV	3.9 TeV	3.7 TeV	3.9 TeV	3.7 TeV

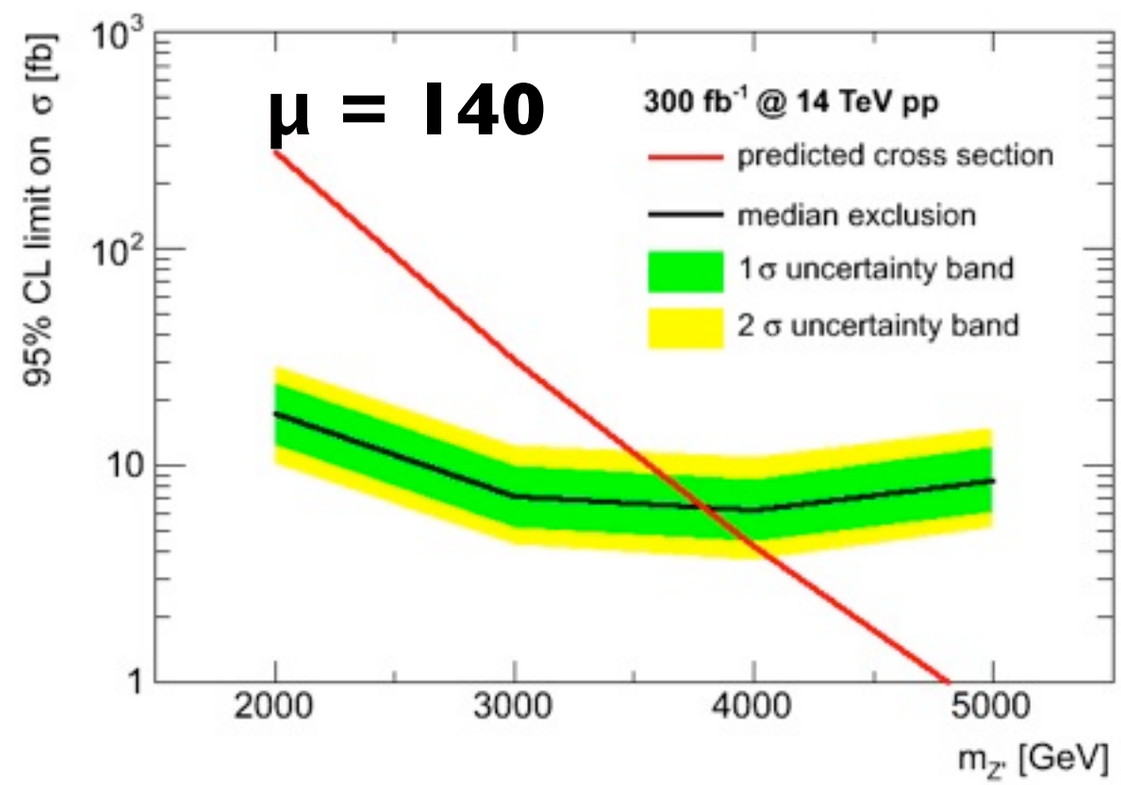
3000 fb^{-1}

	3000 fb^{-1} (μ = 0)		3000 fb^{-1} (μ = 50)		3000 fb^{-1} (μ = 140)	
	stat.	stat.+syst.	stat.	stat.+syst.	stat.	stat.+syst.
2 TeV	4.9 fb	8.1 fb	5.0 fb	8.7 fb	5.4 fb	11 fb
3 TeV	2.0 fb	3.6 fb	2.1 fb	4.3 fb	2.2 fb	5.2 fb
4 TeV	1.5 fb	3.3 fb	1.7 fb	3.6 fb	1.9 fb	3.9 fb
5 TeV	1.9 fb	3.3 fb	2.2 fb	4.3 fb	2.5 fb	5.0 fb
mass reach (95% CL)	4.7 TeV	4.3 TeV	4.6 TeV	4.1 TeV	4.6 TeV	4.1 TeV

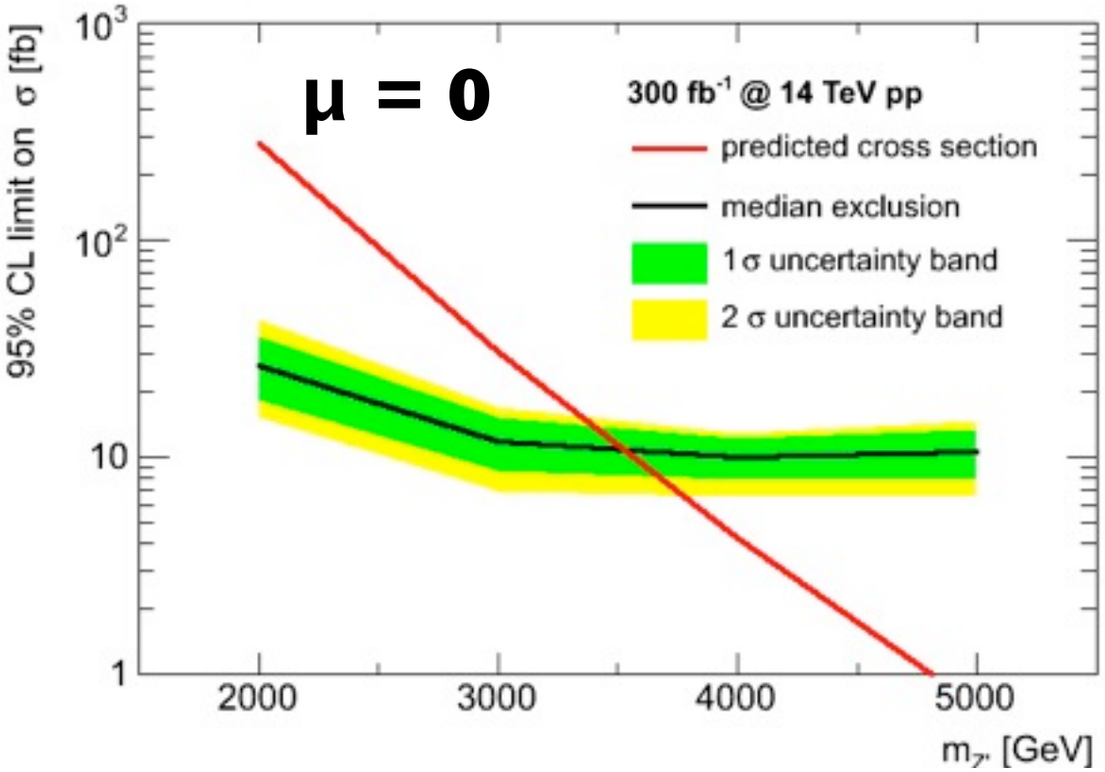
300 fb^{-1} (stat.)

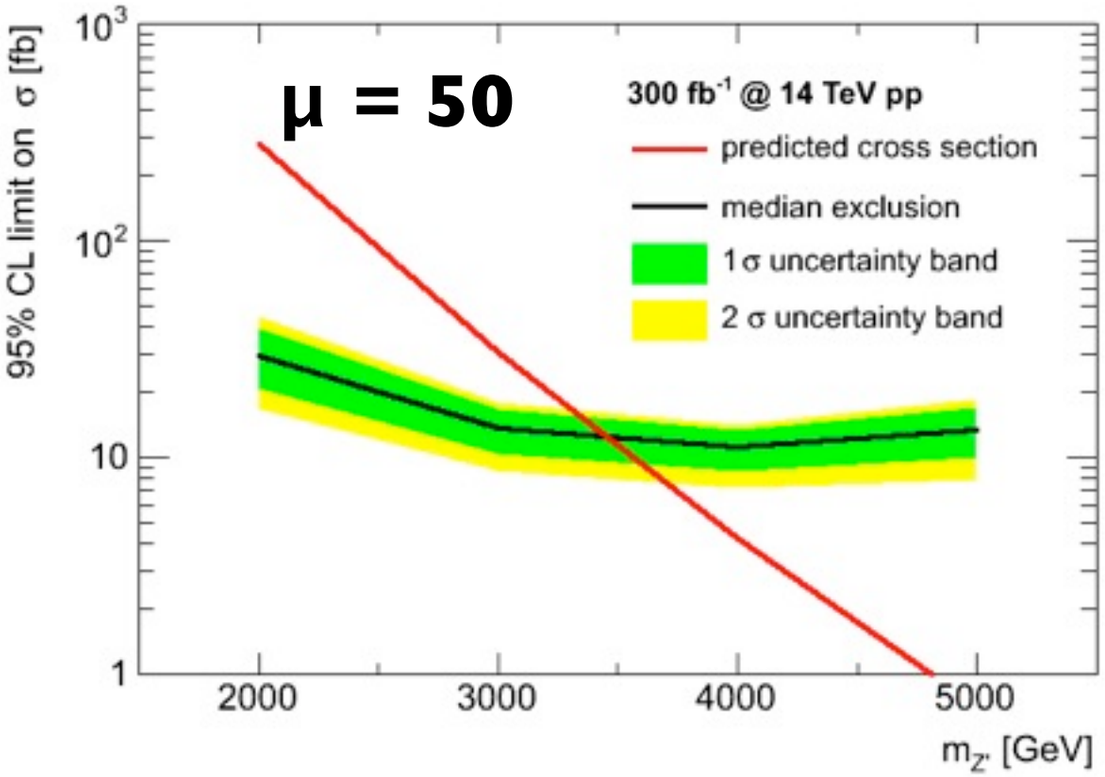

μ = 0
300 fb^{-1} @ 14 TeV pp
predicted cross section
median exclusion
1 σ uncertainty band
2 σ uncertainty band
95% CL limit on σ [fb]
$m_{Z'}$ [GeV]

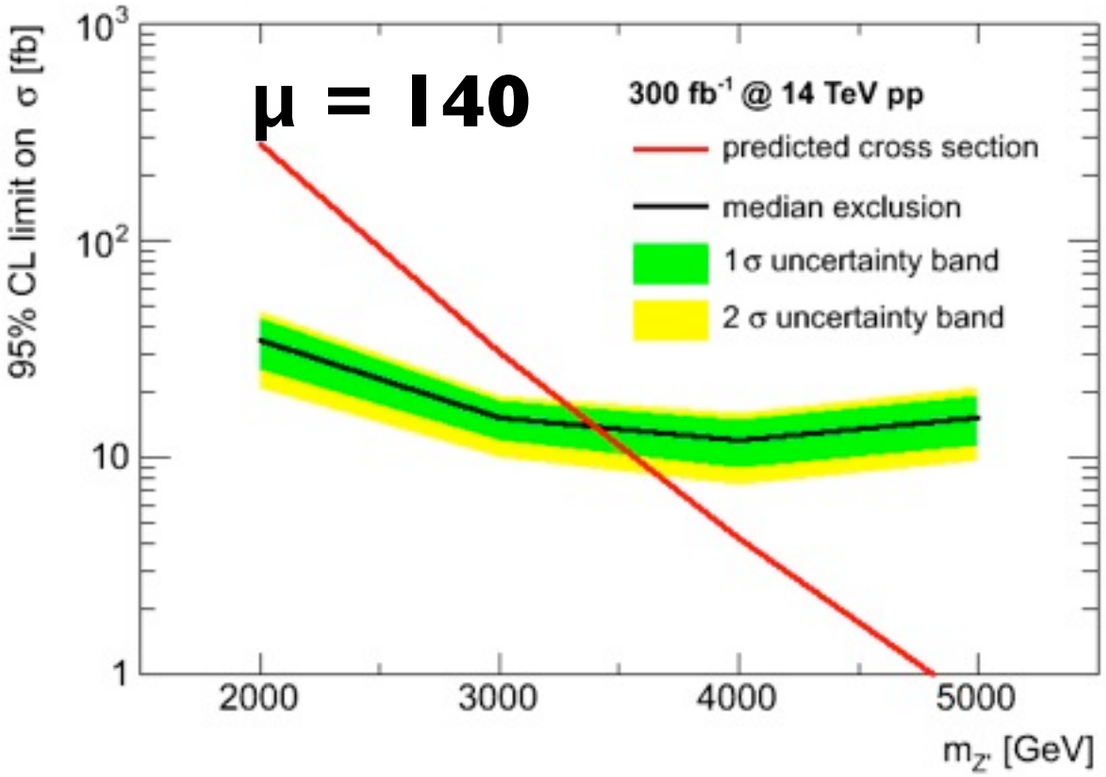

μ = 50
300 fb^{-1} @ 14 TeV pp
predicted cross section
median exclusion
1 σ uncertainty band
2 σ uncertainty band
95% CL limit on σ [fb]
$m_{Z'}$ [GeV]


μ = 140
300 fb^{-1} @ 14 TeV pp
predicted cross section
median exclusion
1 σ uncertainty band
2 σ uncertainty band
95% CL limit on σ [fb]
$m_{Z'}$ [GeV]

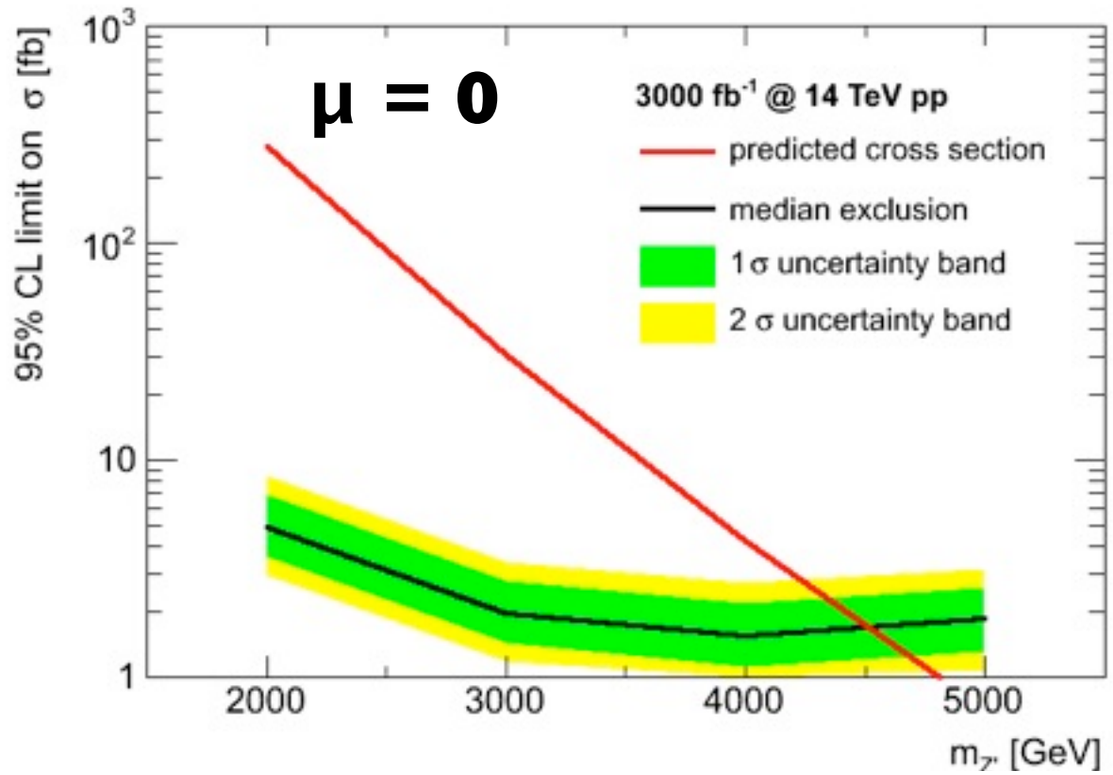
300 fb^{-1} (stat.+syst.)

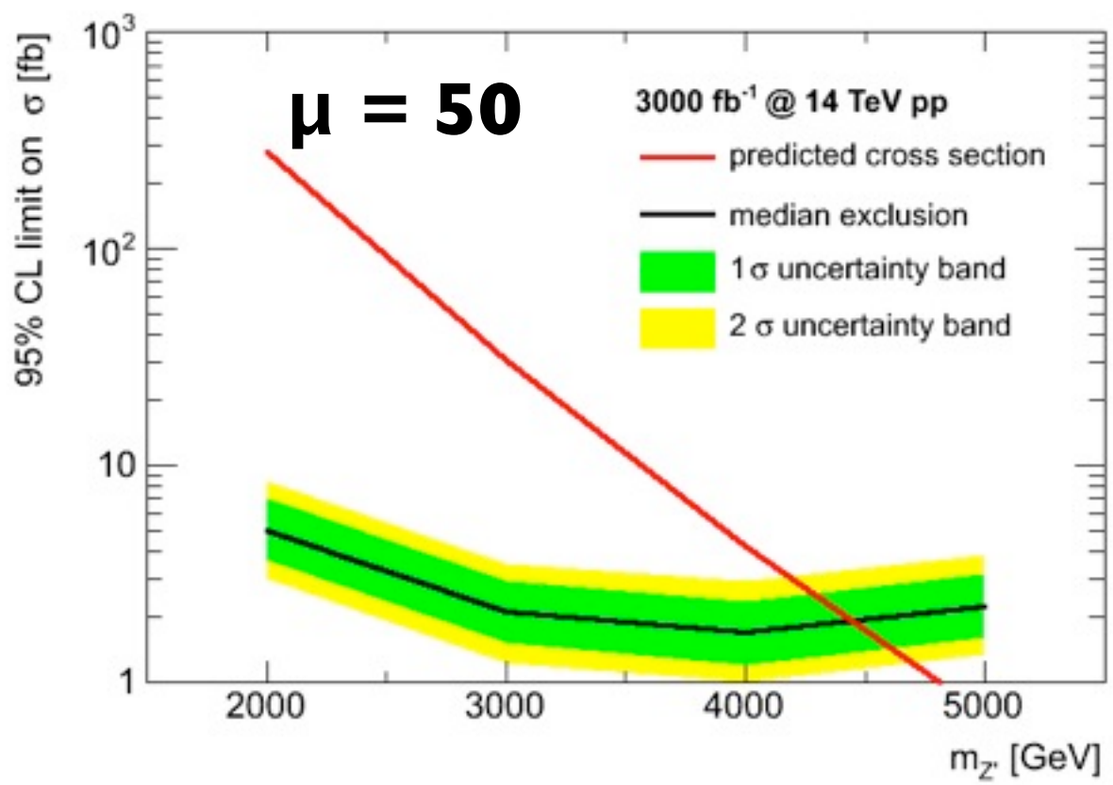


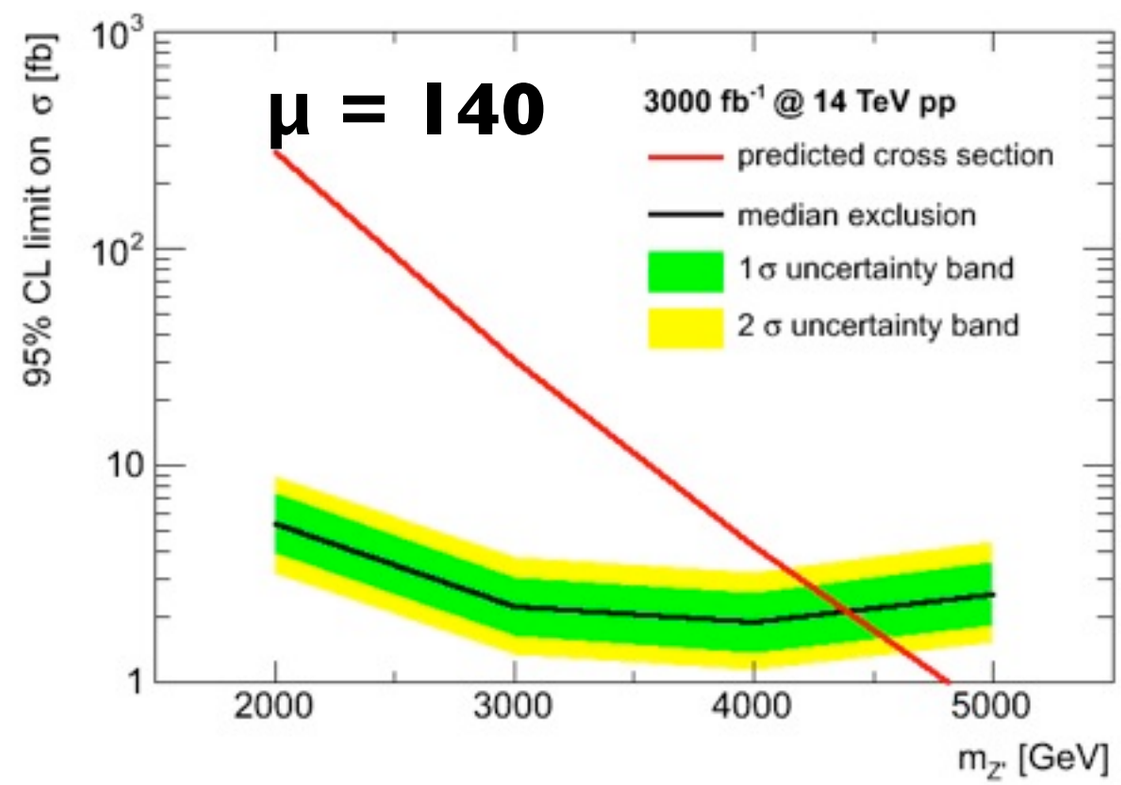




3000 fb^{-1} (stat.)







3000 fb^{-1} (stat.+syst.)