Bounds on Z' from 331 Models at the LHC

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Why the 331 Model ?

- It provides an elegant answer for the problem of the three families. Nontrivial anomaly cancellation takes place between families.
- Explanation of the heavy top quark. It treats the third family differently from the others.
- Lepton family number is not required to be conserved.
- It foresees a number of new gauge bosons (vectors and scalars).

Limits on new neutral gauge bosons obtained by the LHC are usually model dependent. We interpret the LHC results in terms of Z' couplings given by two version of the 331 model.

Two versions of the 331 Model

The charge operator the defines the model is given by

$$\boxed{Q = T_3 - \beta T_8 + X I}$$

Where T_3 and T_8 are the generators that satisfy the SU(3) algebra, X is the U(1) charge and β is the parameter that defines the model version. We consider two values for the parameter β:

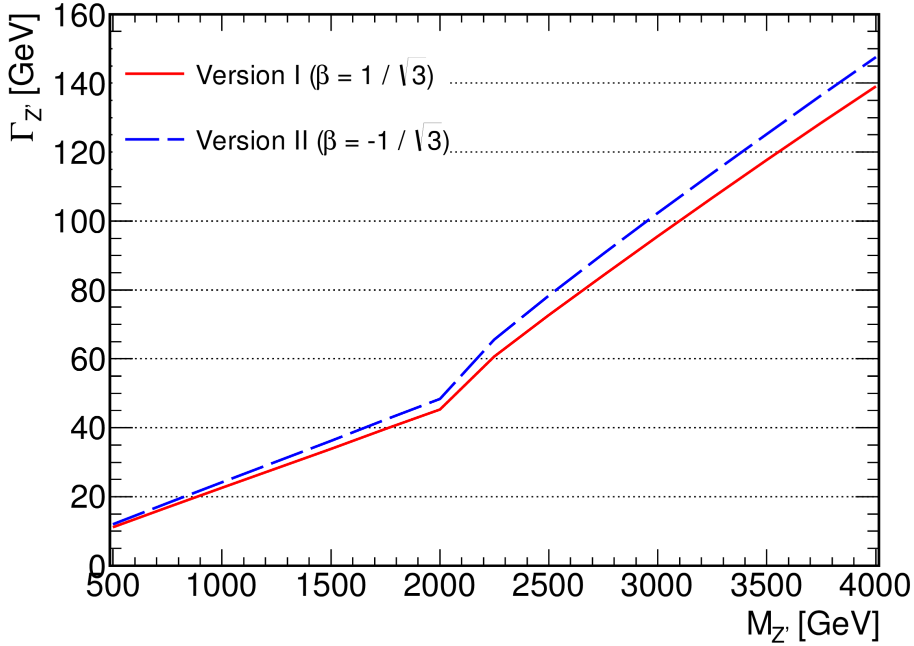
Version I: $\beta = \frac{1}{\sqrt{3}}$ **(RHN Model)**

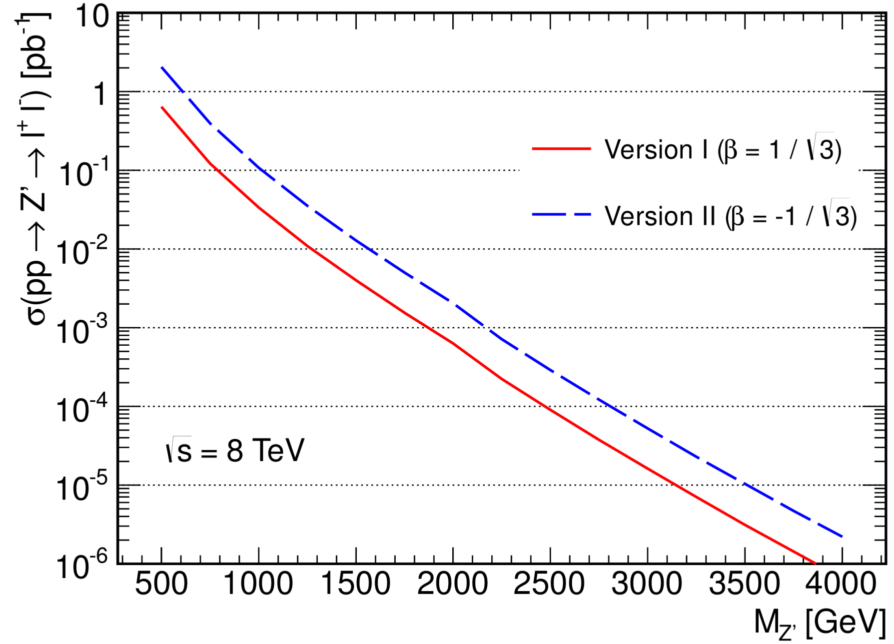
Version II: $\beta = -\frac{1}{\sqrt{3}}$ **(Oezer Model)**

Each of these choices lead to different couplings between the ordinary leptons and the Z'.

Dilepton Production

To investigate the 331 Z' at LHC, we consider the process $pp \rightarrow \ell^+ \ell^- X$ (ℓ=e, μ)





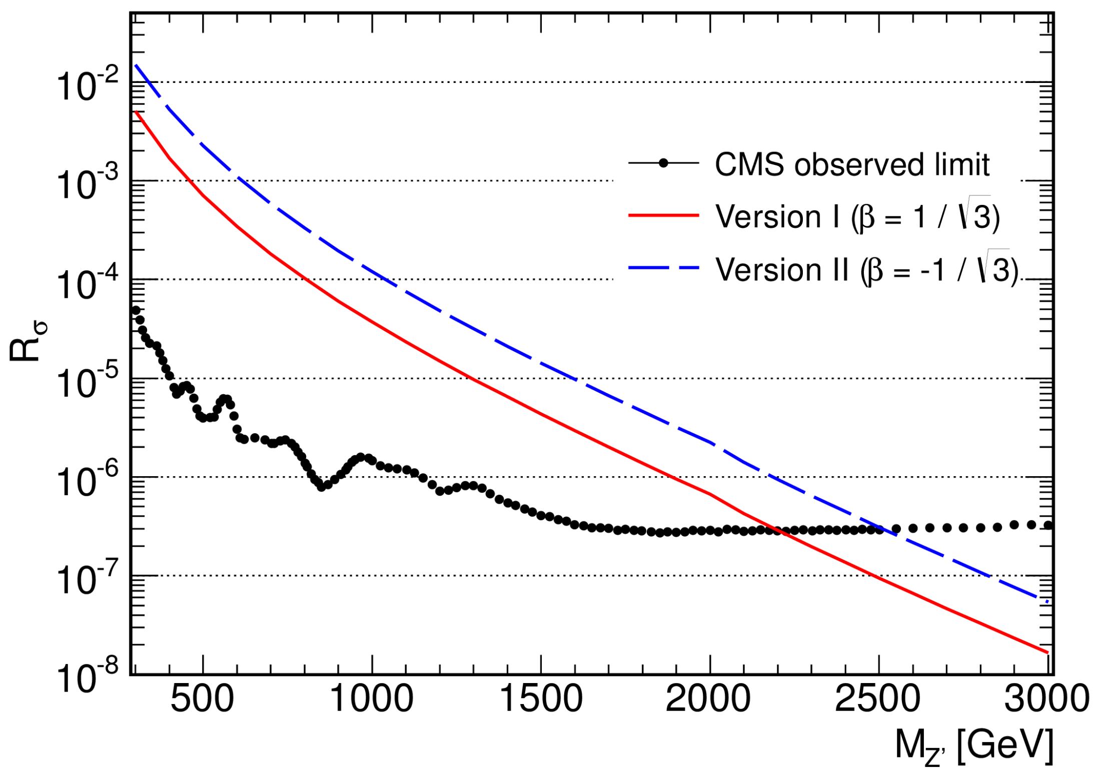
The Z' width is narrow in both models, varying from 2% to 4% of Z' mass in the range considered.

Version II is the most optimistic.

Exclusion Limits at 8 TeV

The CMS collaboration have combined results from 7 and 8 TeV to set 95% CL limits on the ratio of the cross section times branching ratio for Z' to that of SM

$$R_\sigma = \frac{\sigma(pp \to Z' \to \ell^+\ell^-)}{\sigma(pp \to Z/\gamma \to \ell^+\ell^-)}$$



The limits on the Z' mass are

Version I : $M_{Z'}$ > 2.20 TeV

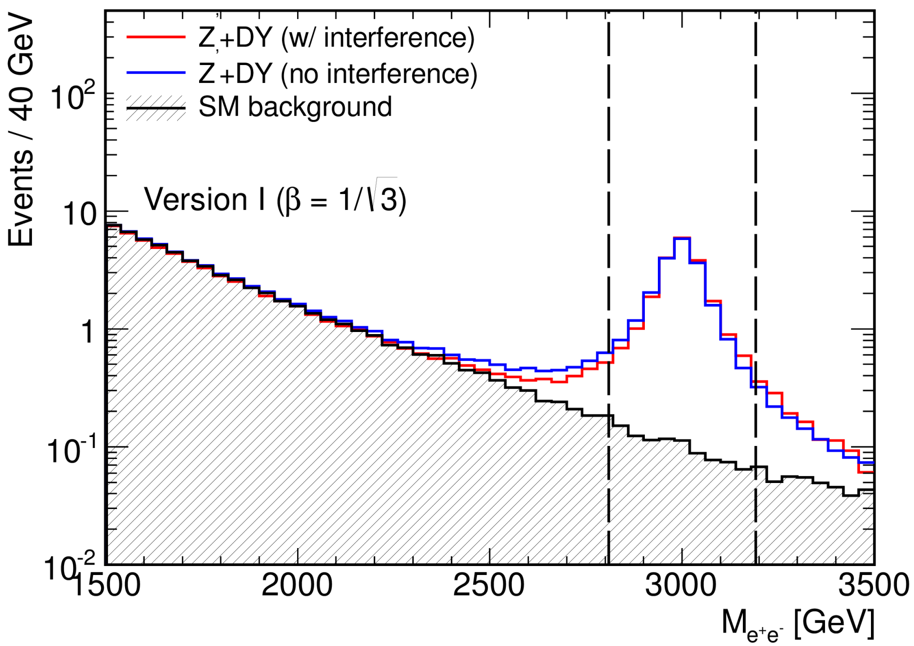
Version II: $M_{Z'}$ > 2.51 TeV

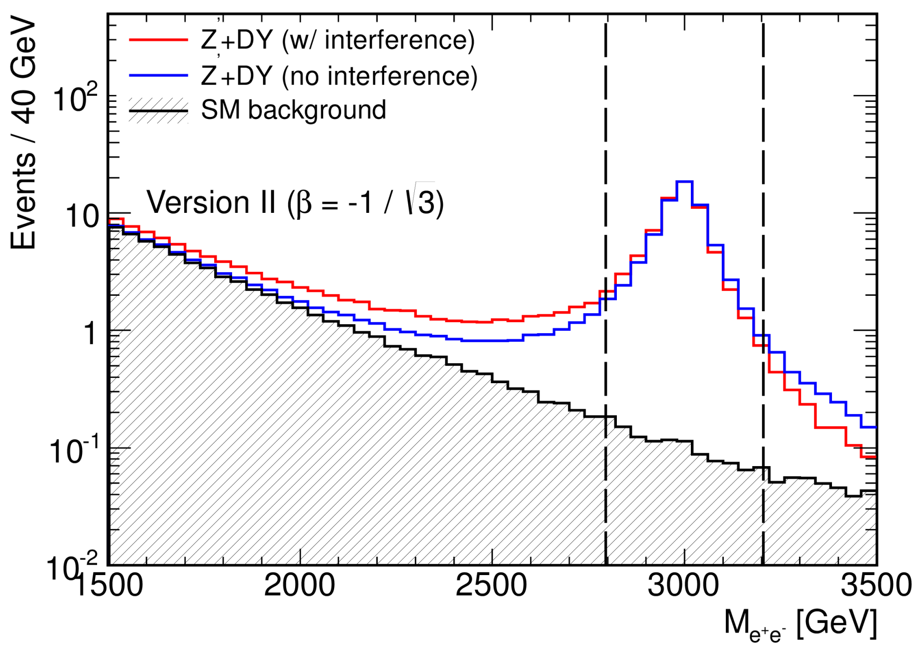
Discovery Potential at 14 TeV

What is the minimal integrated luminosity needed to claim a Z' discovery at LHC with energy of 14 TeV ?

To answer this question, we calculate the number of background (Drell-Yan) and signal events expected in the processes $pp \rightarrow \ell^+ \ell^- X$ considering an overall efficiency of 66% for electrons and 43% for muons.

Although the Z' interfere with the Drell-Yan processes, the interference is minimal, and signal and background are treated as independent.

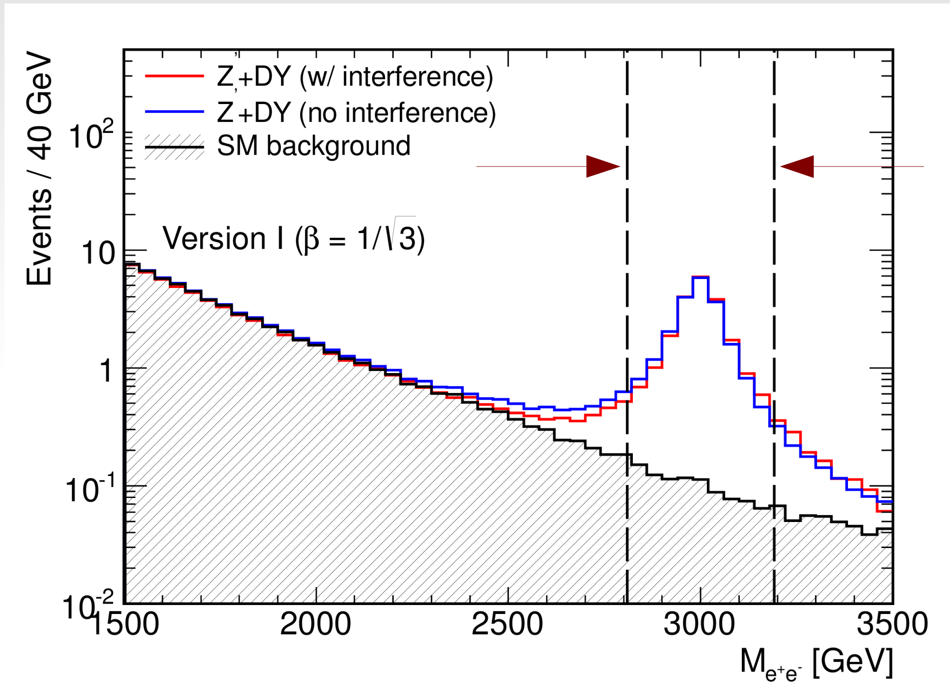




Discovery Potential at 14 TeV

The number of signal and background events is determined within a window

$$[M_{Z'} - 2\Gamma_{Z'}, M_{Z'} + 2\Gamma_{Z'}].$$

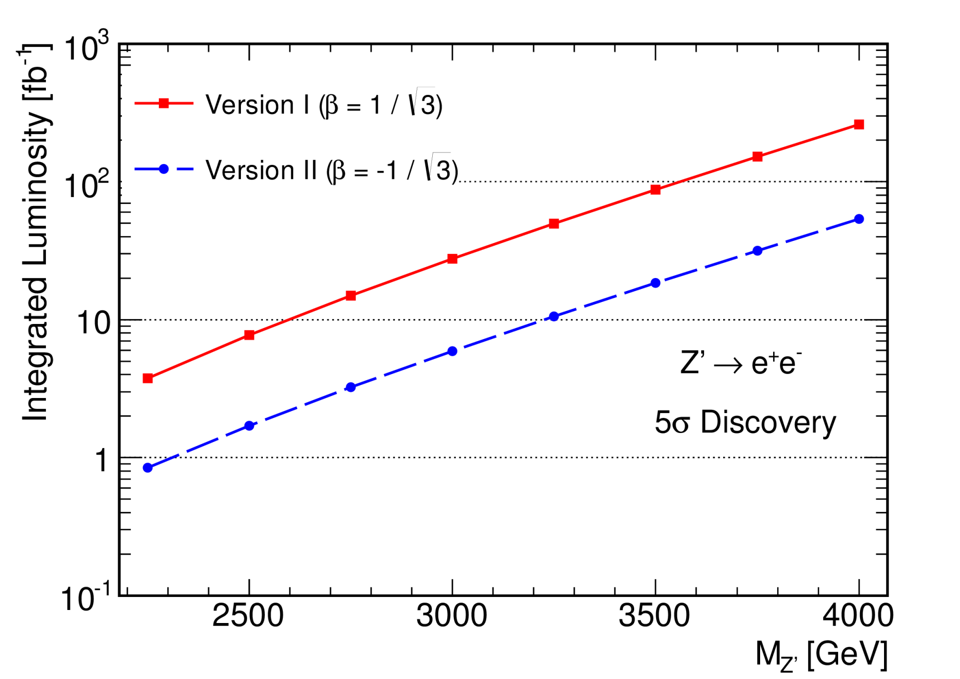


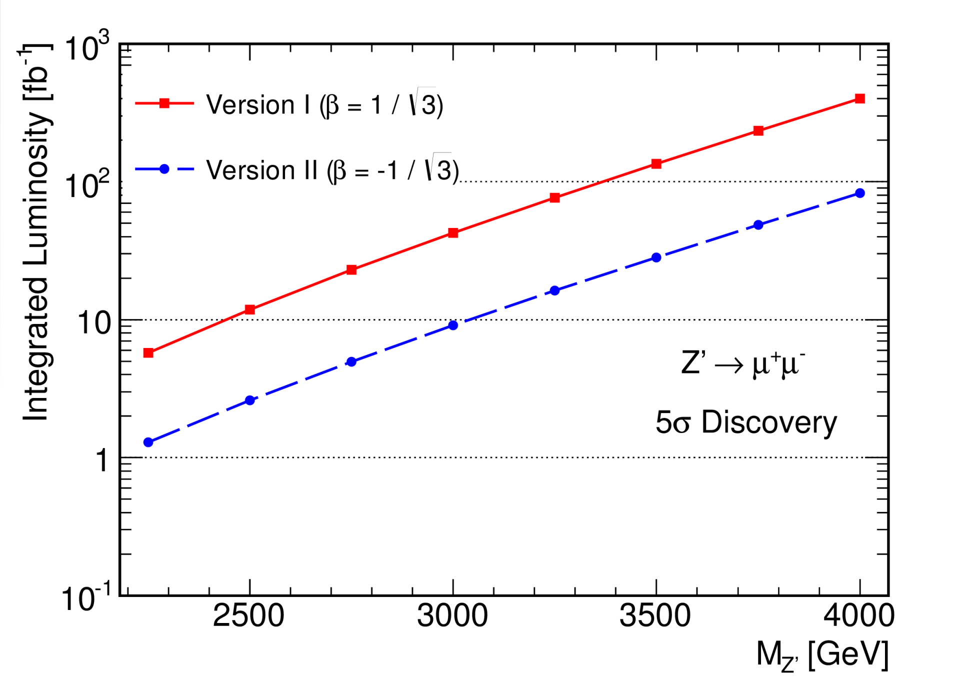
The significance of a signal in this window is obtained via the estimator

$$S = \sqrt{2\left(\left(N_s + N_b\right)\ln\left(1 + \frac{N_s}{N_b}\right) - N_s\right)}$$

Discovery Potential at 14 TeV

Integrated luminosity required to have a 5σ Z' discovery in the electron and muon channel.

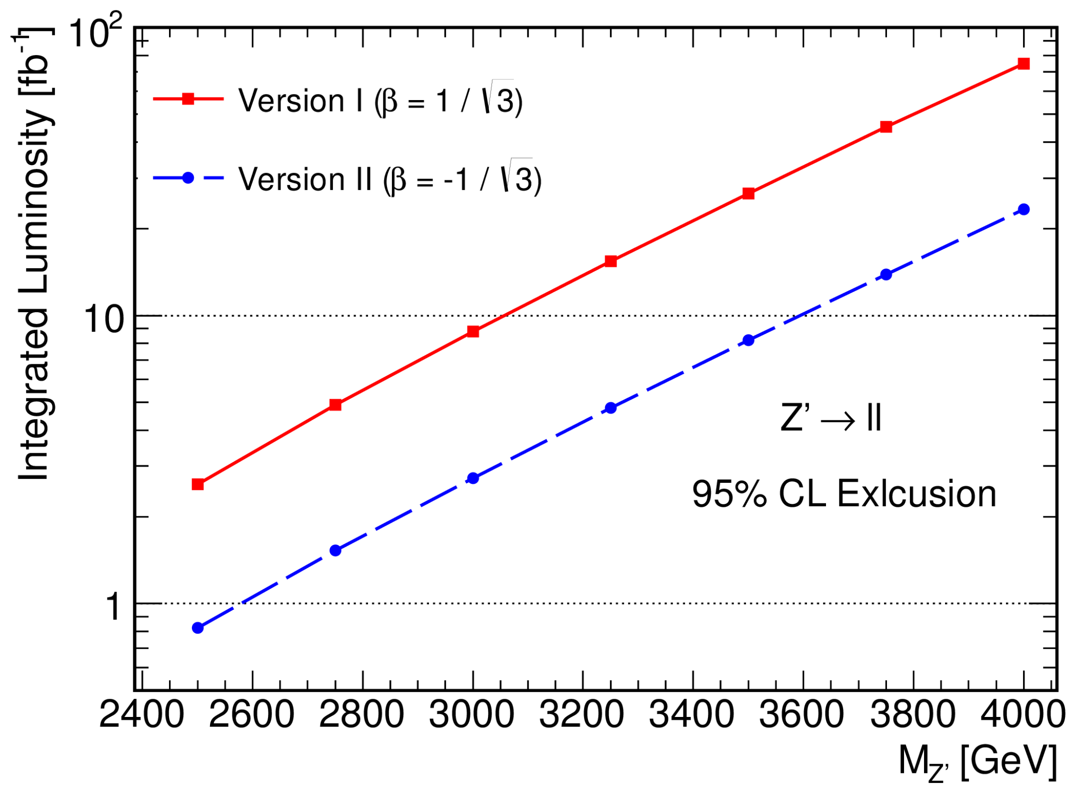




- A Z' with mass just above the exclusion limit (2.5 TeV) can be reach in the first year of LHC operation at 14 TeV.
- For $M_{Z'}$ ~ 4 TeV, it is needed 100 to 250 fb^{-1} of data to observe a signal, depending on the model.

Exclusion Limits at 14 TeV

Assuming that no signal is found, we calculate the expected limits on various Z' mass hypothesis considering different integrated luminosities. This is done by performing 1000 Monte Carlo experiments and combining electron and muon channels.



- With ~23 fb^{-1} the Version II can be excluded up to masses of 4 TeV.
- For Version I, at least three times more luminosity is needed to exclude $M_{Z'}$ = 4 TeV.

Summary

- Lower limits on Z' mass from two version of the 331 model were derived.
- For the RHN Model, a Z' with mass below 2.2 TeV is exclude.
- For Oezer Model, a Z' lighter than 2.5 TeV is excluded.
- In the next LHC run (14 TeV), a 331 Z' with mass of 4 TeV can be observed with integrated luminosity of 100 fb^{-1}.
- A Z' with mass of 4 TeV can be excluded with 20 – 70 fb^{-1} of collision data at 14 TeV.
- For more details, see Phys. Rev. D87, 115014 (2013).