SO(10) at the LHC

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Summary

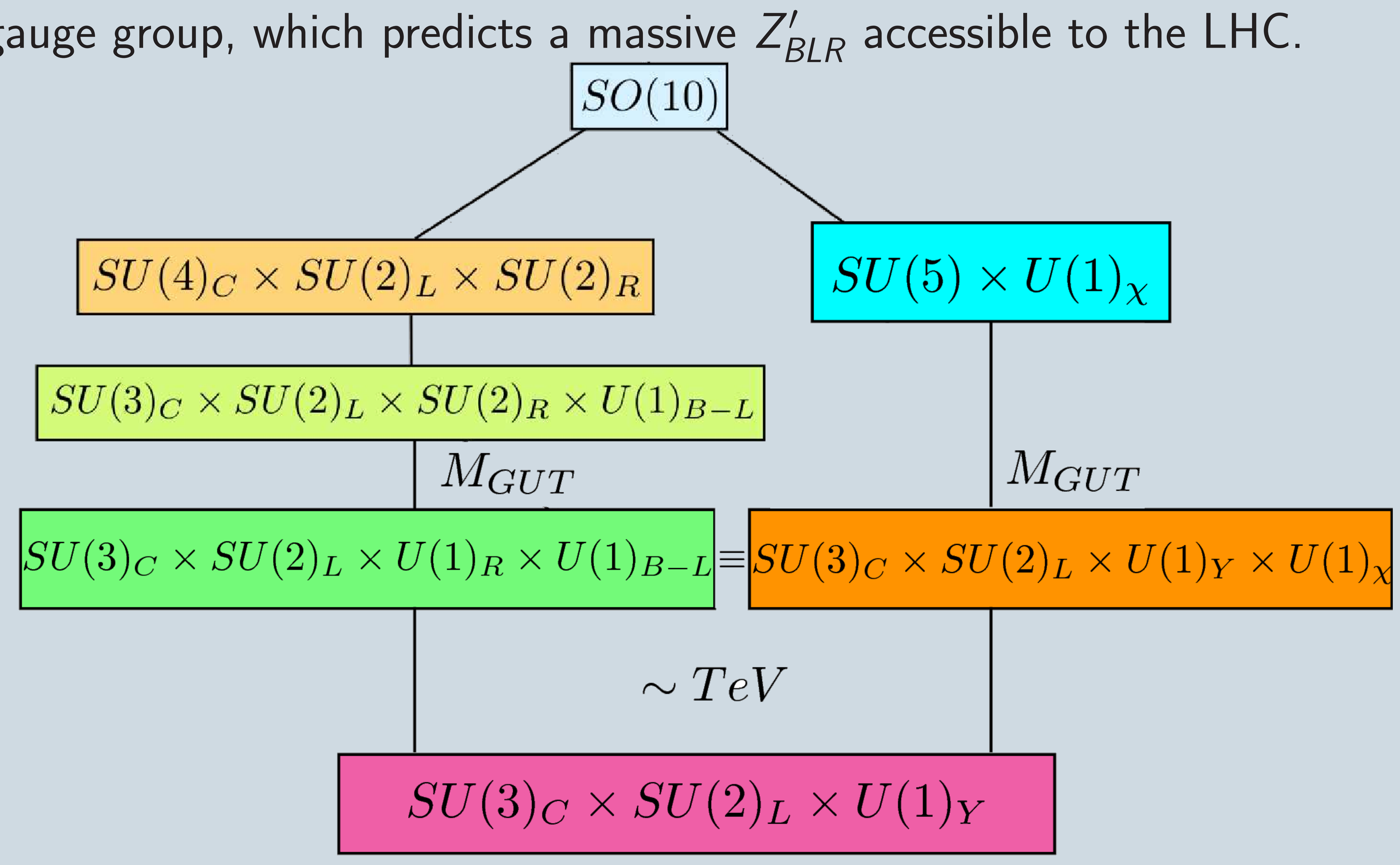
We compare Z's arising from the Grand Unified Theory (GUT) model $SO(10)$. In particular we focus on the Abelian subgroup $U(1)_R \times U(1)_{B-L}$, which breaks to the Standard Model (SM) hypercharge, $U(1)_Y$, known as the "BLR" model [1, 2], which we compare to the well-known $B-L$ model [3], based on the gauge group $U(1)_Y \times U(1)_{B-L}$.

We use Drell-Yan production and decay as the discovery channel at the Large Hadron Collider (LHC). By exploiting the Forward-Backward Asymmetry (A_{FB}), one may distinguish the BLR model from the $B-L$ model at the High Luminosity (HL)-LHC.

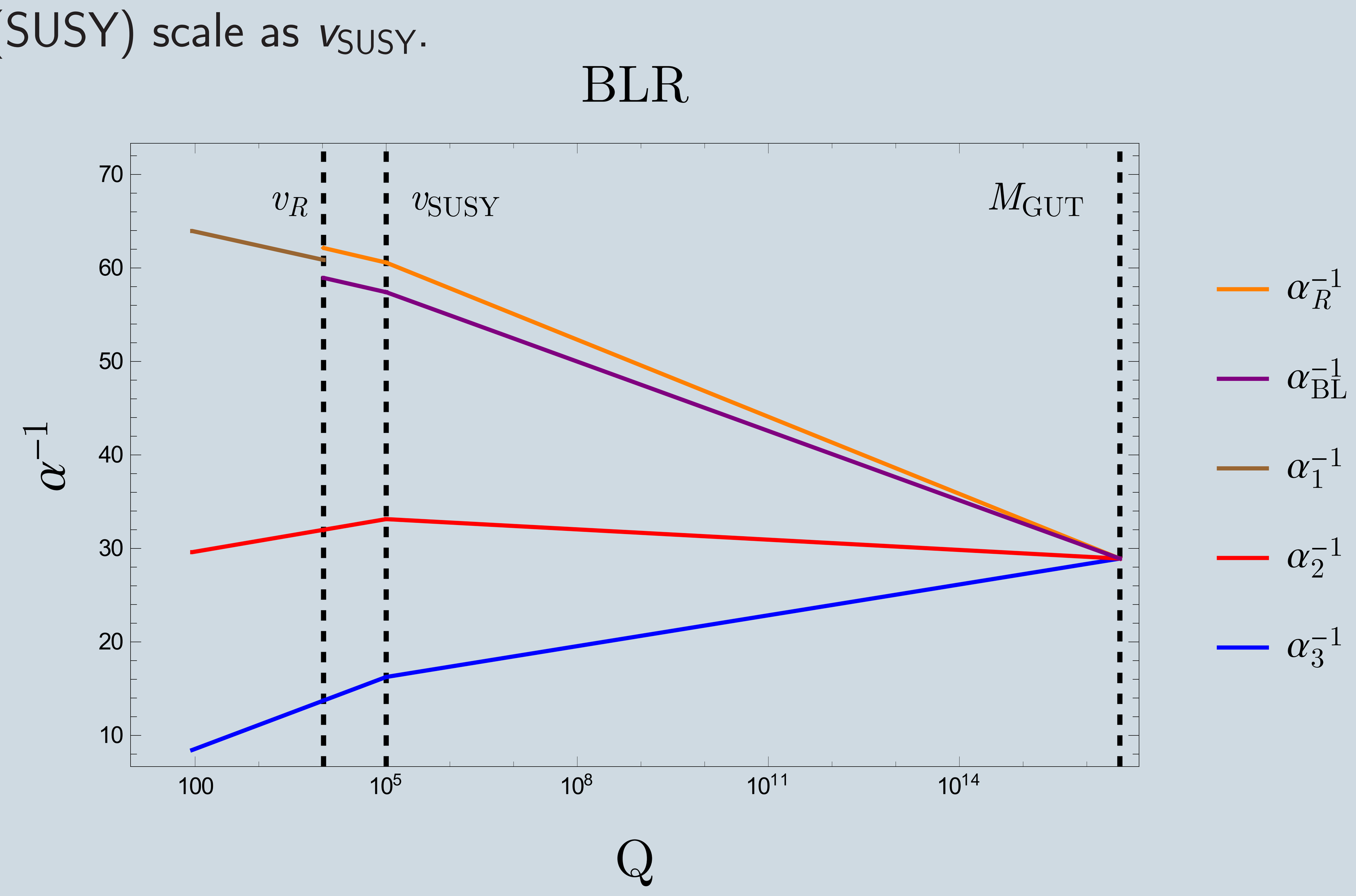
By distinguishing to which model a Z' belongs, one may learn about the high (GUT) scale theory governing nature from low (collider) energy physics.

Explaining the BLR

We consider the breaking $SO(10) \to SU(3)_C \times SU(2)_L \times U(1)_R \times U(1)_{B-L}$ which may survive down to the TeV scale before being broken to the SM gauge group, which predicts a massive Z'_{BLR} accessible to the LHC.

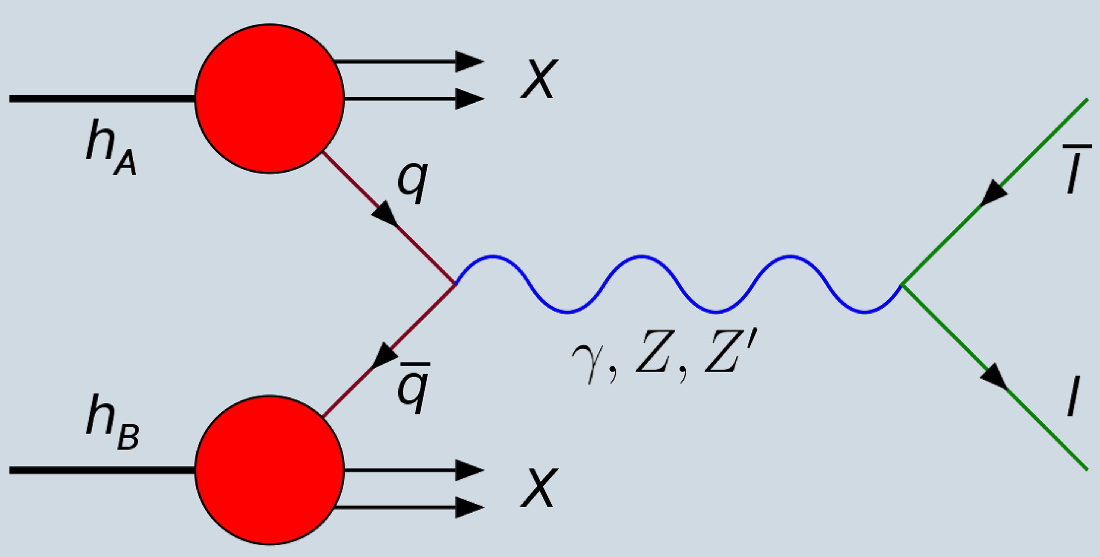


The Z' interaction strength is fixed by gauge couplings, which are determined at low scale by Renormalisation Group Equation (RGE) running from gauge coupling unification at M_{GUT}. The mass of the Z' is fixed by the BLR breaking scale, v_R, and we set the Supersymmetry (SUSY) scale as v_{SUSY}.



Finding Z's at the LHC

The most promising channel to detect a Z' is through Drell-Yan production and decay.



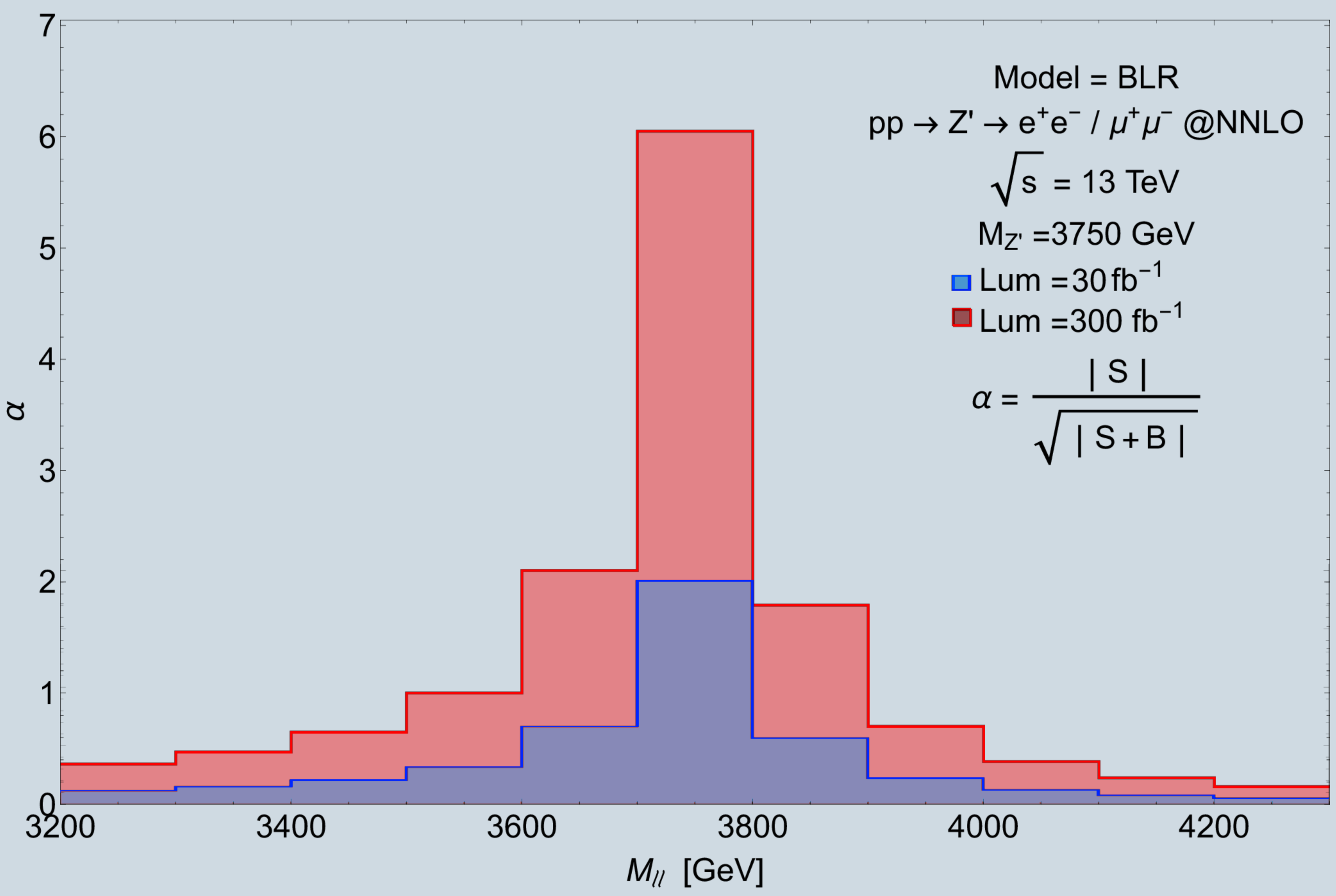
After the $U(1)_R \times U(1)_{B-L} \to U(1)_Y$ symmetry breaking, the Z' has the following coupling to fermions f,

$$-\mathcal{L}^{Z'}_{\mathrm{BLR}} = Z'_\mu \bar{f} \gamma^\mu \left(g_R \cos\theta_{BL} T_{3R} - g_{BL} \sin\theta_{BL} T_{B-L} \right) f,$$

where θ_{BL} parametrises the mixing between the SM hypercharge gauge boson, B, and the Z'; and $(T_{3R},\ T_{B-L})$ are the quantum numbers of the fermions under $U(1)_R$ and $U(1)_{B-L}$, with respective gauge couplings g_R and g_{BL}.

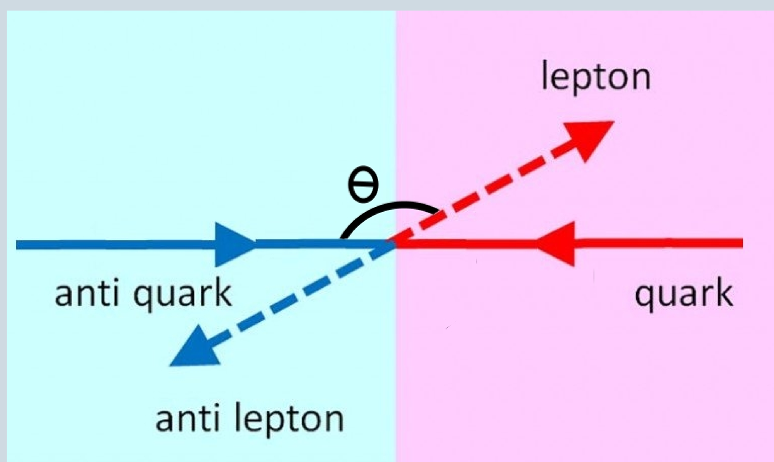
Illuminating Luminosity

Given a luminosity of 30 fb^{-1}, and a Z' of mass $M_{Z'} = 3750$ GeV, one would see $< 2\sigma$ deviations from SM background. At 300 fb^{-1}, this would have a significance $> 6\sigma$.



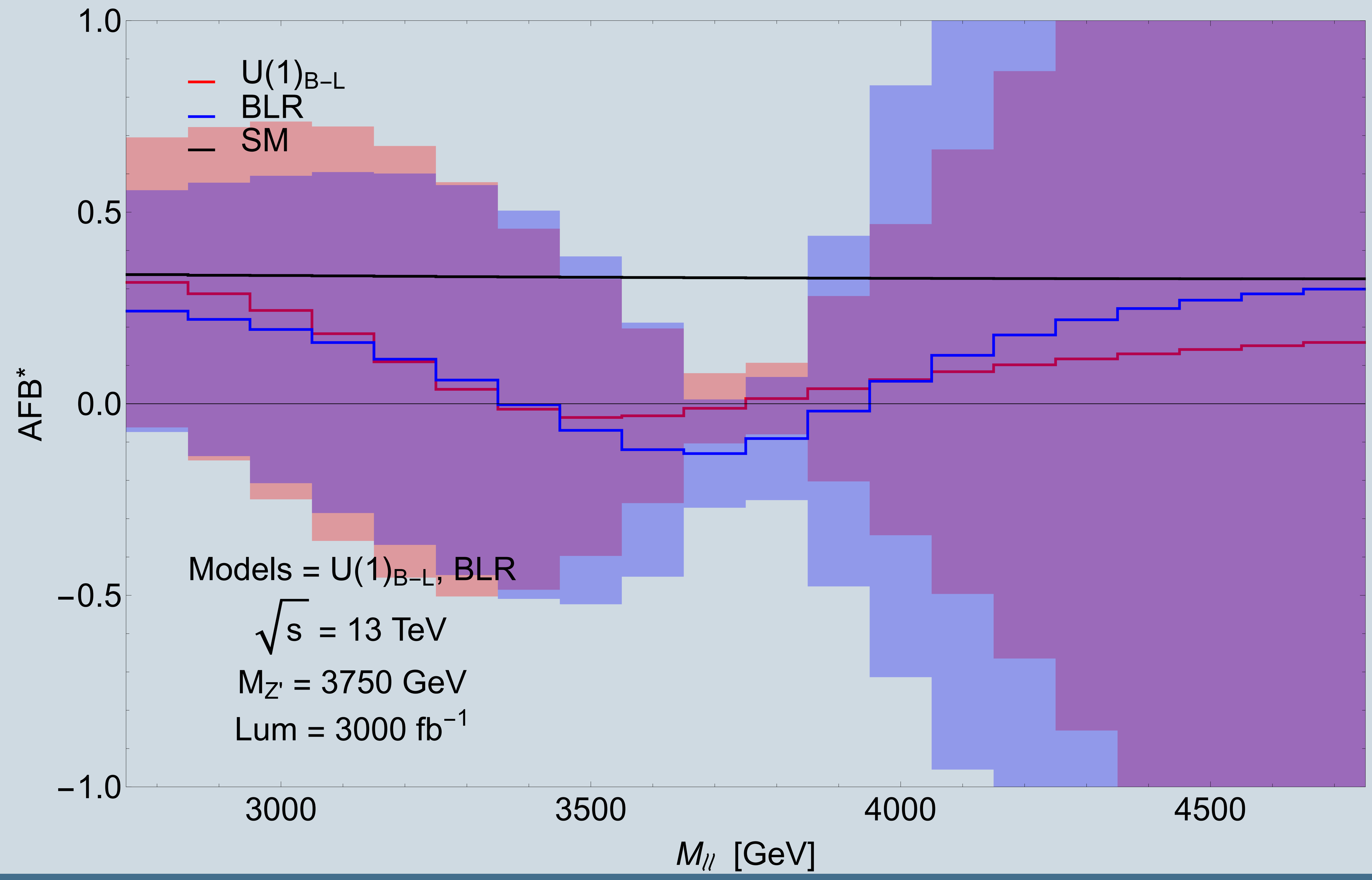
Whose Z' is that?

Forward-Backward Asymmetry, A_{FB}, measures the difference in the number of events where $\theta > 90°$ (a "backward" event) vs $\theta < 90°$ ("forward"). These are driven by the differences in vector (L+R) and axial (L-R) couplings.



Forward-Backward Asymmetry

Distinguishing two similar models, e.g. the B-L from the BLR, requires large statistics. We show below the A_{FB} vs binned invariant dilepton mass, shaded with 1σ bounds, driven by statistics. Although the differences are slight, one may hope to distinguish these two models at the HL-LHC.



[1] S. J. D. King, S. F. King and S. Moretti, Phys. Rev. D 97 (2018) no.11, 115027 doi:10.1103/PhysRevD.97.115027 [arXiv:1712.01279 [hep-ph]].

[2] M. Malinsky, J. C. Romao and J. W. F. Valle, Phys. Rev. Lett. 95 (2005) 161801 doi:10.1103/PhysRevLett.95.161801 [hep-ph/0506296].

[3] S. Khalil and A. Masiero, Phys. Lett. B 665 (2008) 374 doi:10.1016/j.physletb.2008.06.063 [arXiv:0710.3525 [hep-ph]].