Restoring Parity at High Energies

Brehmer, Hewett, Kopp, Rizzo, Tattersall 1507.00013
Blas, Hewett, Reuter, Rizzo 1603.ASAP

RENCONTRES DE MORIOND
50
since 1966

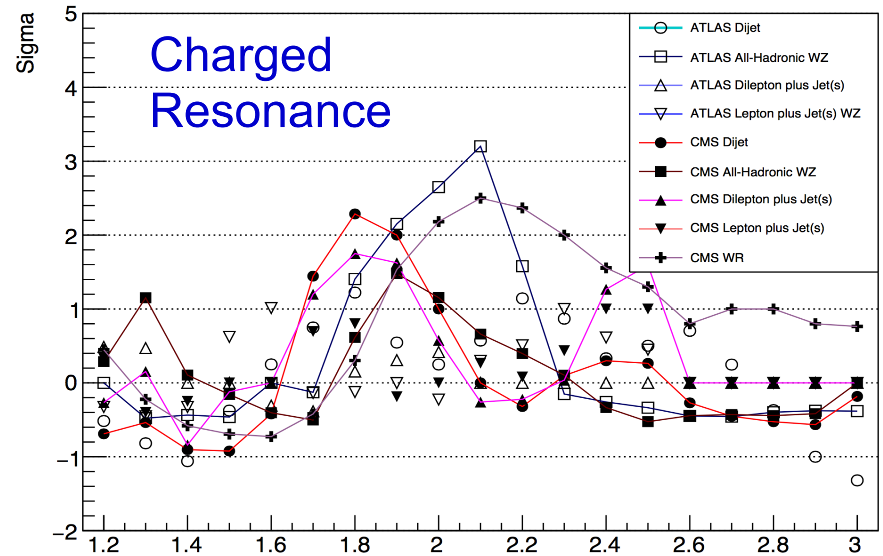
J. Hewett, Moriond 2016

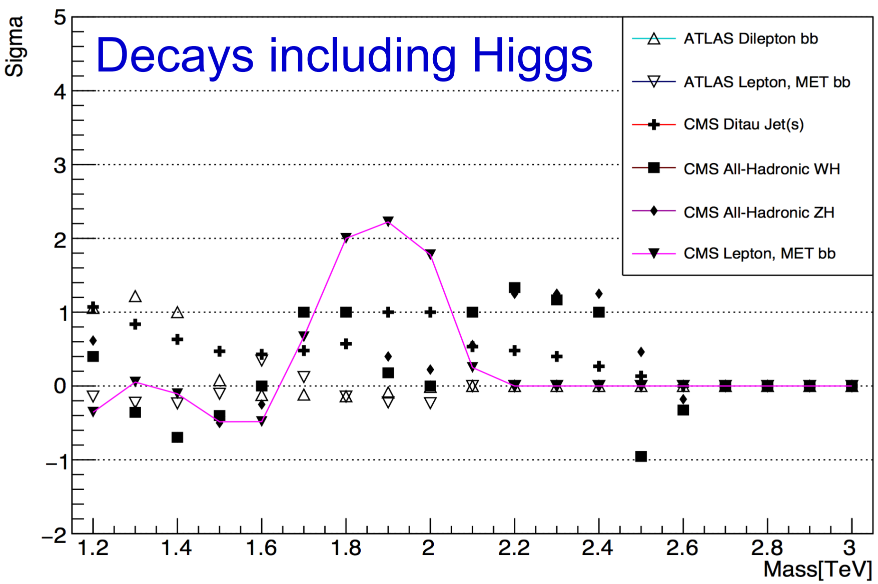
SLAC NATIONAL ACCELERATOR LABORATORY

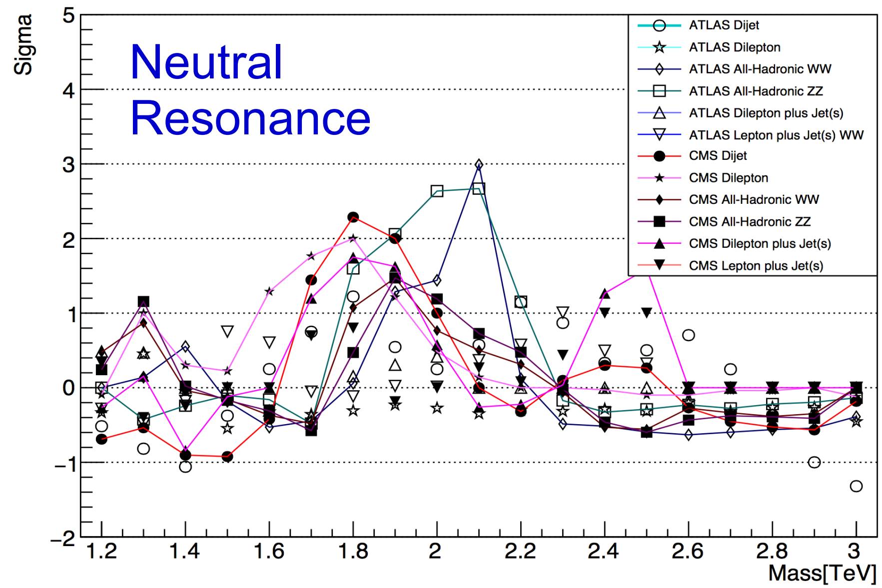
Les Houches Summary of 8 TeV Data

- Excesses in multiple channels between ~ 1.6 - 2.0 TeV

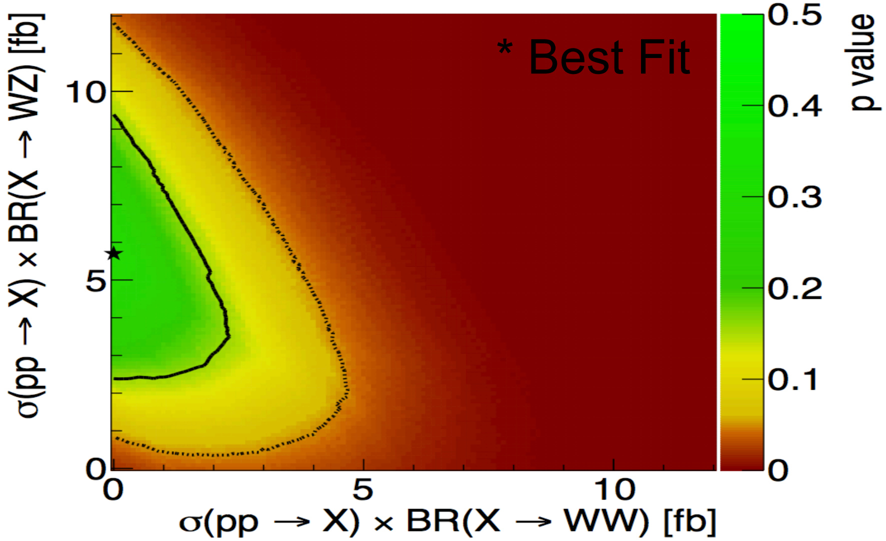
Brehmer etal, 1512.04357

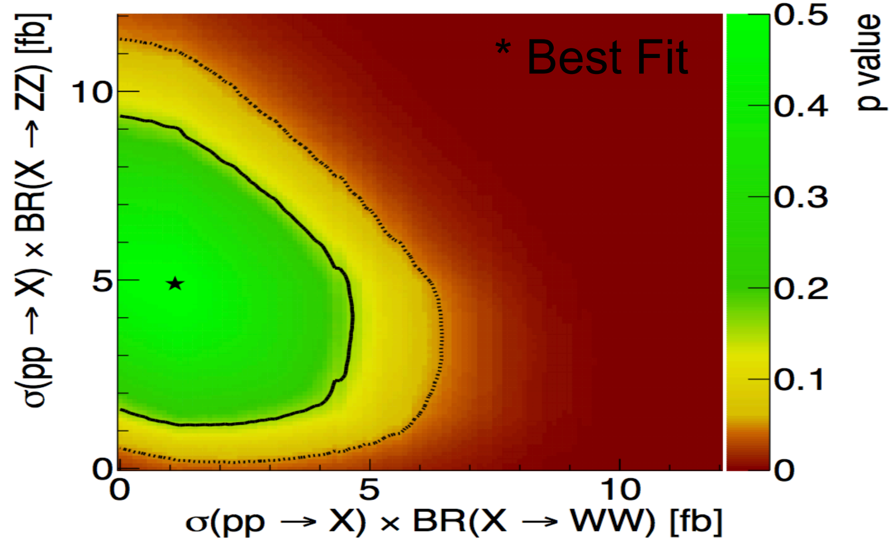




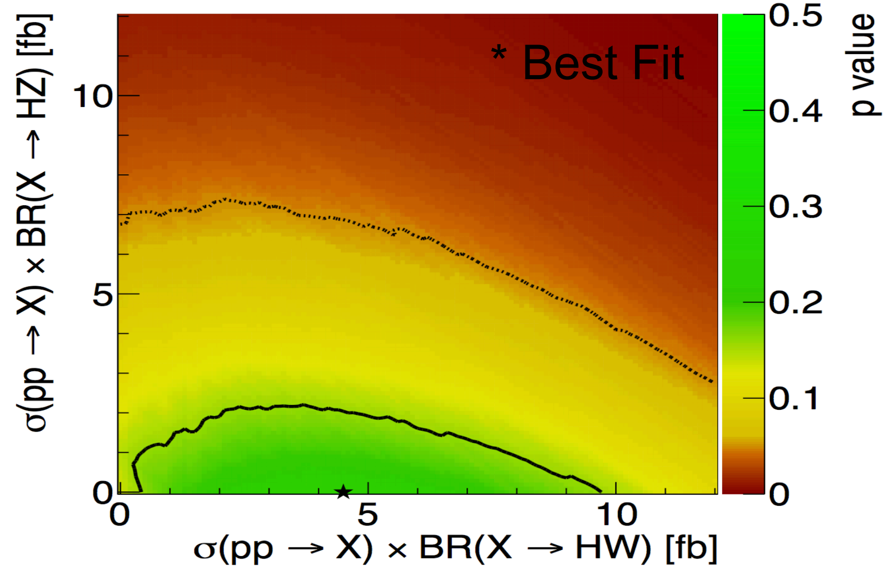


Model independent fit: Boson final states

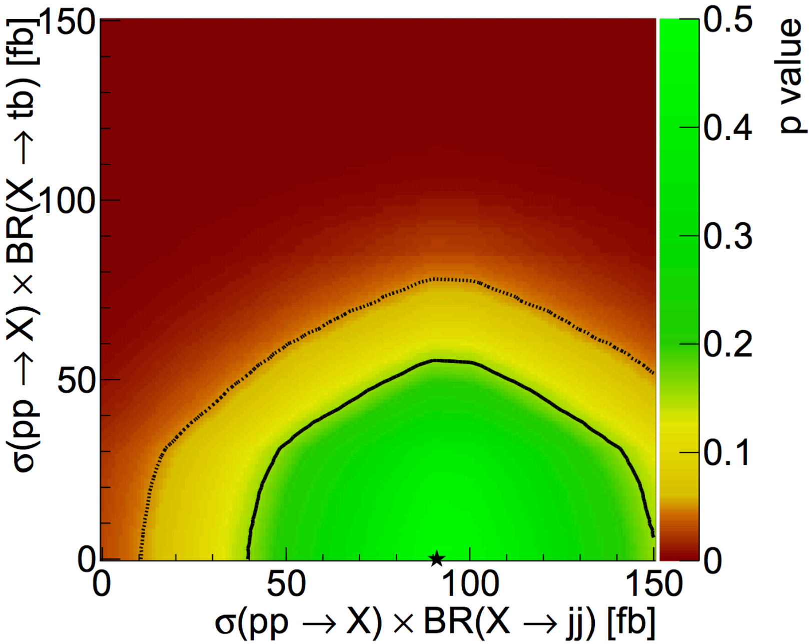




- Slight preference for a charged resonance



Model independent fit: Fermion final states



- Some tension w/ tb – alleviated w/ RH-CKM
- WZ/ZZ/Wh give similar cross sections
- Signal region overlap for WZ/ZZ
- Motivation for charged resonance

Fitted cross sections

Process	Fitted cross section [fb]	Upper bound (90% CL)
$pp \to X \to WZ^1$	$5.7^{+3.6}_{-3.3}$	11.8
$pp \to X \to ZZ^1$	$5.0^{+4.3}_{-3.4}$	11.3
$pp \to X \to WH$	$4.5^{+5.2}_{-4.0}$	15.5
$pp \to X \to jj$	91^{+53}_{-45}	170
$pp \to X \to tb$	0^{+11}_{-0}	38
$pp \to X \to tb$ (without ATLAS $bb\ell\nu$ [13])	0^{+39}_{-0}	60

Left-Right Symmetric Model Basics

SLAC

$G_{EW} = SU(2)_L \times SU(2)_R \times U(1)' \rightarrow SU(2)_L \times U(1)_Y$

Pati, Salam '74
Mohapatra, Pati '75

- Right-handed neutrinos
- New gauge fields
  - » W_R & Z_R with couplings $\kappa = g_R/g_L$
- New Higgs fields with vev v_R
  - » Doublet Higgs:
    - Dirac neutrinos
    - Strong constraints from $W_R \rightarrow l\nu$ Run I searches (4.4 TeV for κ=1)
  - » Triplet Higgs: $(\Delta_L^{\pm}, \Delta_{R,L}^{\pm\pm})$
    - Majorana right-handed neutrinos w/ mass N_l ~ mass W_R
    - $W_R \rightarrow lN_l$ avoided if mass N_l > mass W_R
    - $U(1)'$ can be identified as $U(1)_{B-L}$
  - » Bi-Doublet Higgs to generate fermion masses with vevs $k_{1,2}$
- Right-handed CKM matrix

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    - U(1)' can be identified as $U(1)_{B-L}$
  - Bi-Doublet Higgs to generate fermion masses with vevs $k_{1,2}$
- Right-handed CKM matrix: assume $|V_{ij}^L| = |V_{ij}^R|$

Right-handed gauge sector

- $W_L - W_R$ mass matrix

$$\mathcal{M}_{\mathcal{W}}{}^2 = \begin{pmatrix} m_W^2 & \beta_w m_W^2 \\ \beta_w m_W^2 & m_{W_R}^2 \end{pmatrix}$$

- Diagonalized by mixing

$$\tan 2\phi_w = \frac{-2\beta_w m_W^2}{m_{W_R}^2 - m_W^2}$$

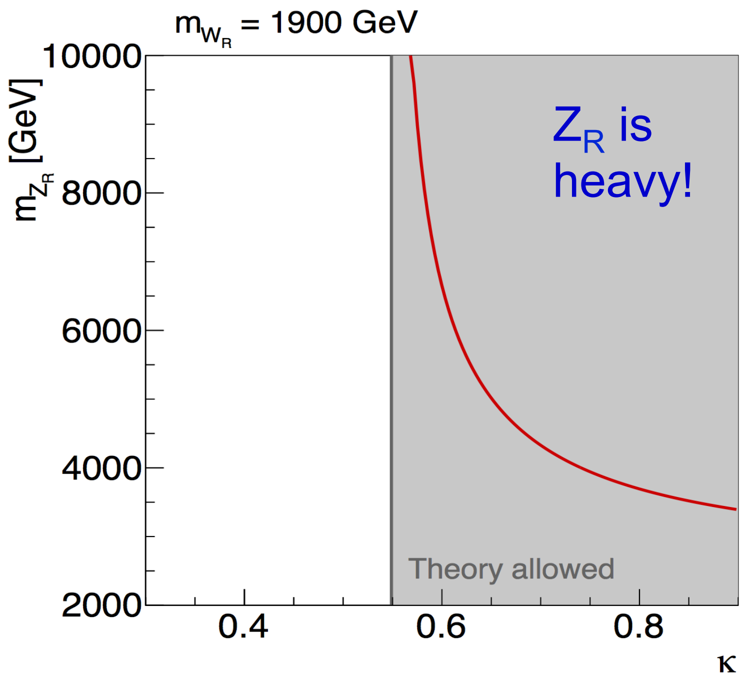
where with 1 bi-doublet

$$\beta_w = 2\kappa \tan\beta / (1 + \tan^2\beta)$$

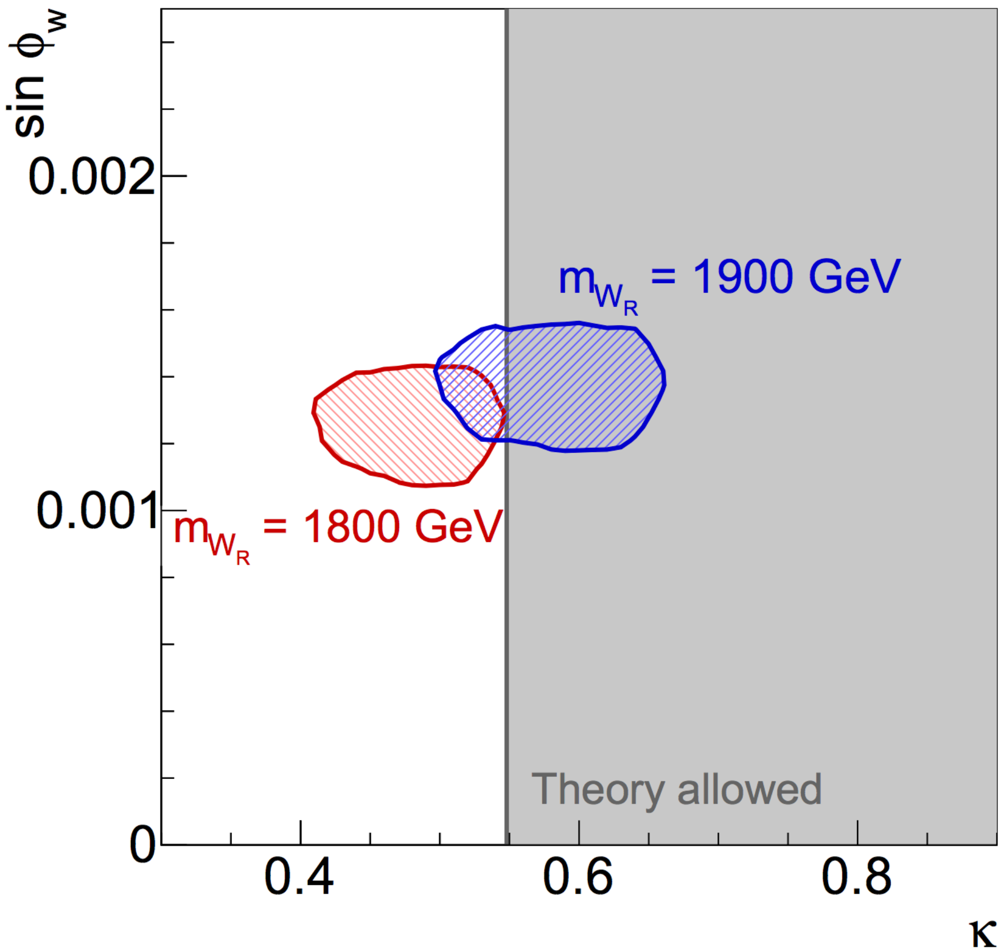
- W_R/Z_R mass ratio set by theory

$$\frac{m_{Z_R}^2}{m_{W_R}^2} = \frac{\kappa^2(1-x_w)\rho_R}{\kappa^2(1-x_w) - x_w} > 1$$

where κ > 0.55 is physical region

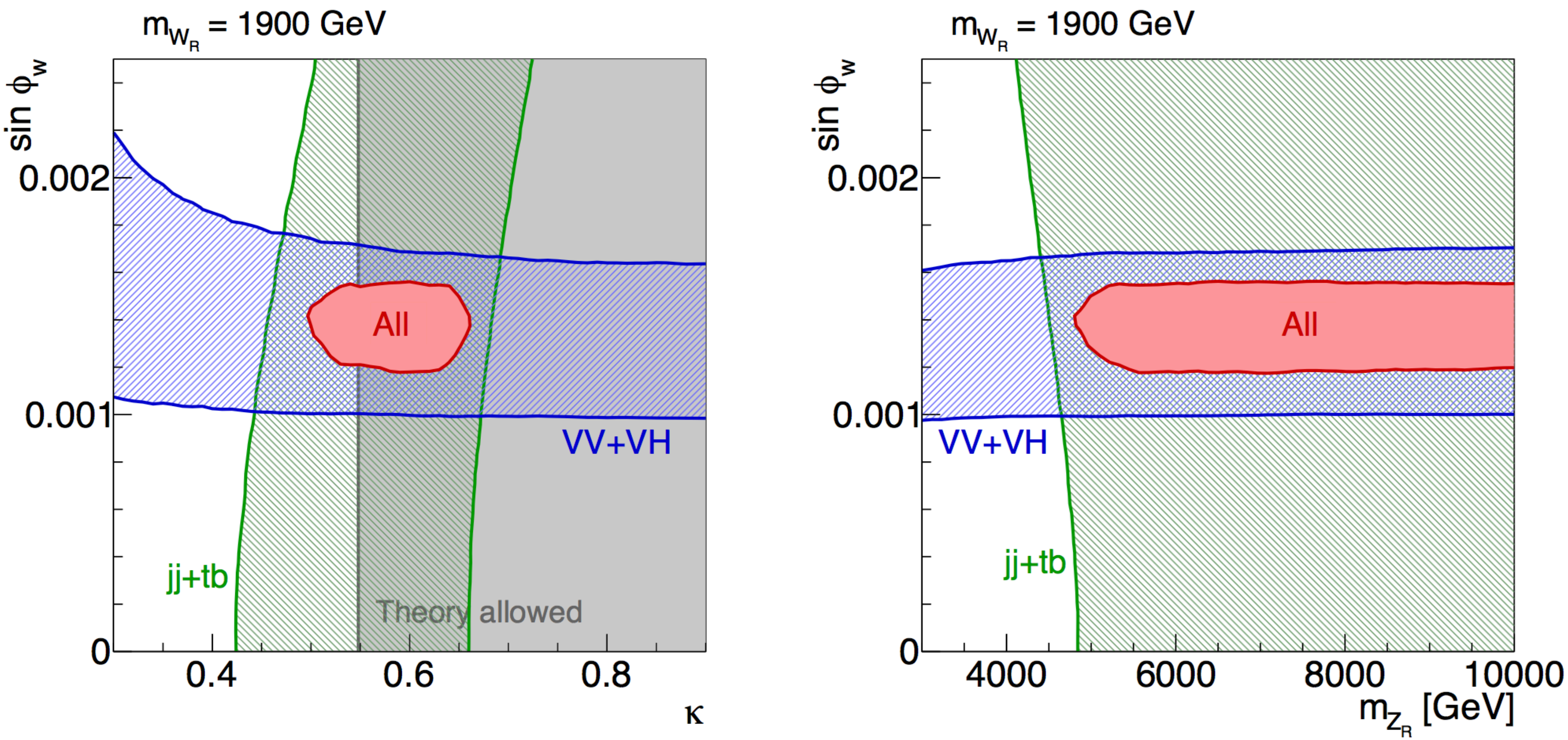


LRM fit to Run I data



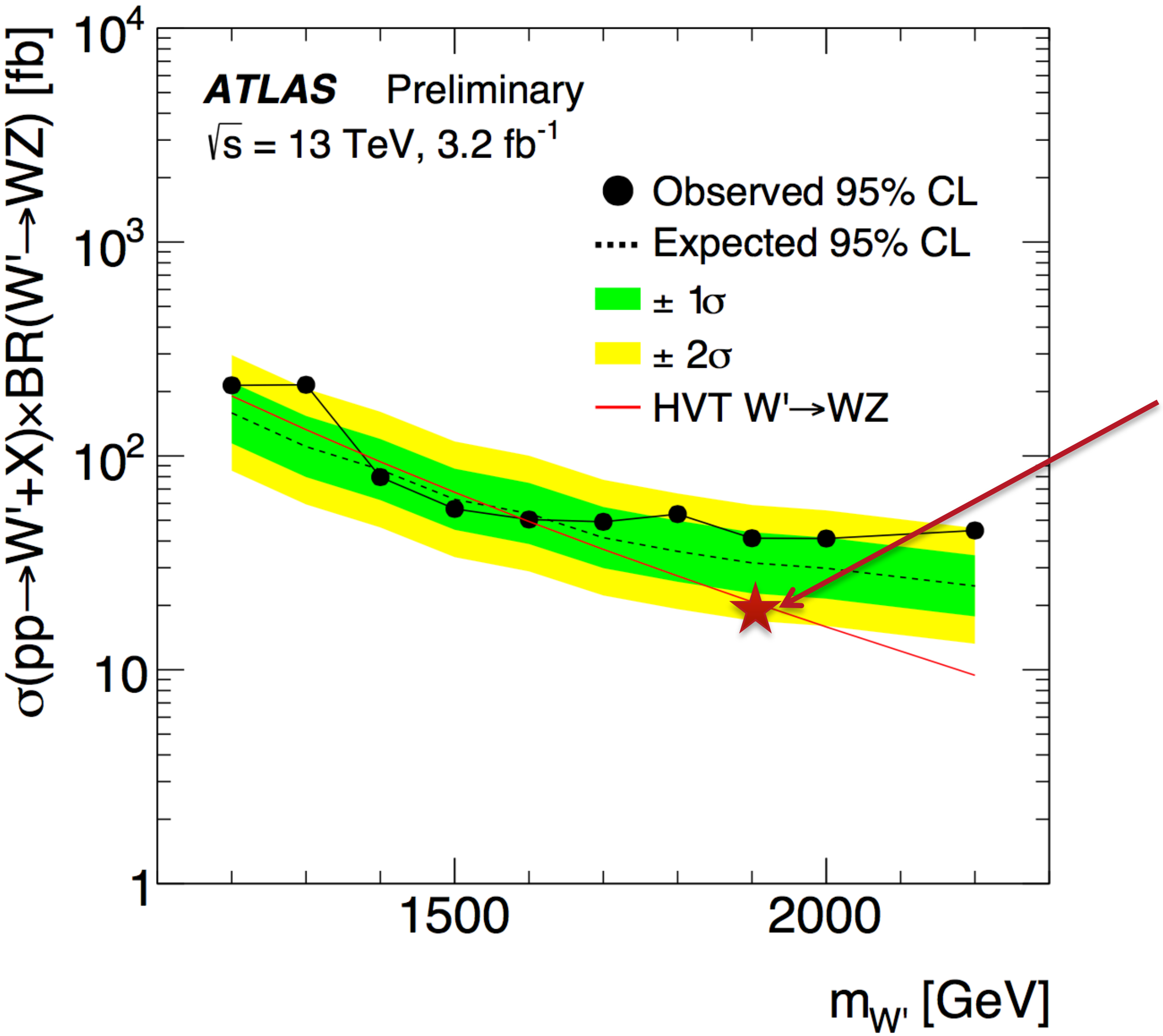
1.8 TeV W_R fit lies outside of physical region (@ 68% CL)

LRM fit to Run I data



(See also Dobrescu, Liu 1506.06736; Allanach etal. 1507.01638; Abe etal. 1507.01681; Plus many more)

13 TeV data – a quick comparison



Our prediction is below (just) the Run 2 limit

N_l no longer needs to be lighter than W_R

Additional implications of LRM

Lepton flavor/number violation

- Perform a scan of parameter space, assuming fit to Run I
  - » Fix W_R mass = 1.9 TeV & κ = 0.6 & $V_{CKM}^R = V_{CKM}^L$
  - » Right-handed neutrinos: taking $m_1 < m_2 < m_3$ w/ signed $m_{2,3}$

    $$1 \leq m_i \equiv M_{N_i}/M_{W_R} \leq 10$$
  - » Right-handed PMNS matrix
  - » Charged scalars $\Delta_L^{\pm}$, $\Delta_{R,L}^{\pm\pm}$ $\quad 0.2 \leq m/M_{W_R} \leq 10$
- Subject parameter space to constraints
  - » Rare processes: $0\nu\beta\beta$, $\mu \rightarrow e\gamma$, $\tau \rightarrow l\gamma$, $\mu \rightarrow eee$, $\tau \rightarrow lll'$, $\mu \rightarrow e$ conversion
  - » Muonium oscillations
  - » $e^+e^- \rightarrow l^+l^-$ from LEP2, cross sections and asymmetries
- 2.5M models remain for study

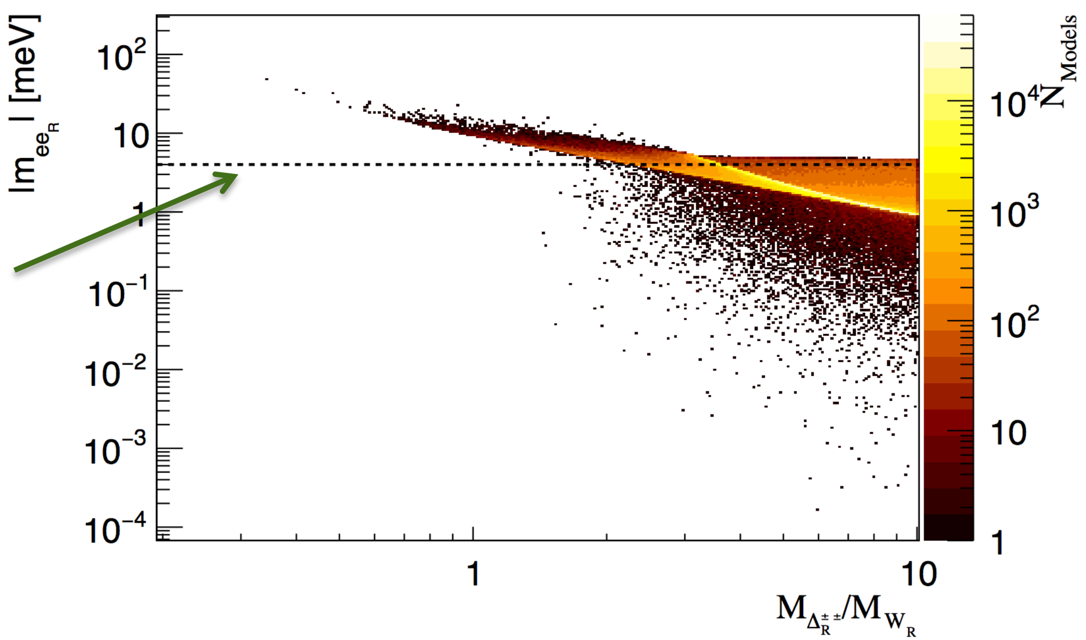
Neutrinoless double-beta decay

- Current limits in Ge^{76} and Xe^{136} (Gerda, EXO-200, Kamland-Zen)
- Probes effective Majorana neutrino mass

$$|m_{ee}|^2 = |m_{ee_L}|^2 + |m_{ee_R}|^2$$

- Tree-level LNV diagrams with N and $\Delta_R^{\pm\pm}$ exchange

Future nEXO sensitivity w/ Barium tagging

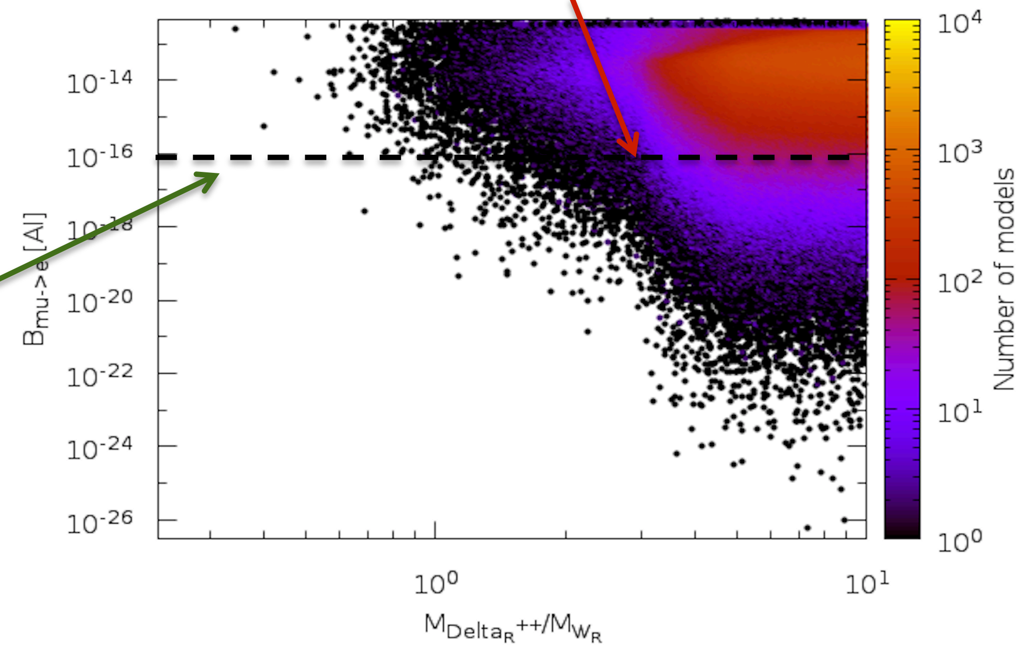


All points consistent with current constraints

Mu2e conversion (μN ➔ eN)

- Current limits for Pb, Ti, Au (SINDRUM II)
- LRM contributions
  - » Tree-level neutral Higgs exchange (small)
  - » 1-loop W_R, $\Delta_L^{\pm}$, $\Delta_{R,L}^{\pm\pm}$ exchange to anapole/dipole vertices
    - Log enhanced
  - » 1-loop W_R exchange in $\mu e Z_i$ vertices
  - » 1-loop W_R box diagrams

Large fraction of models covered!



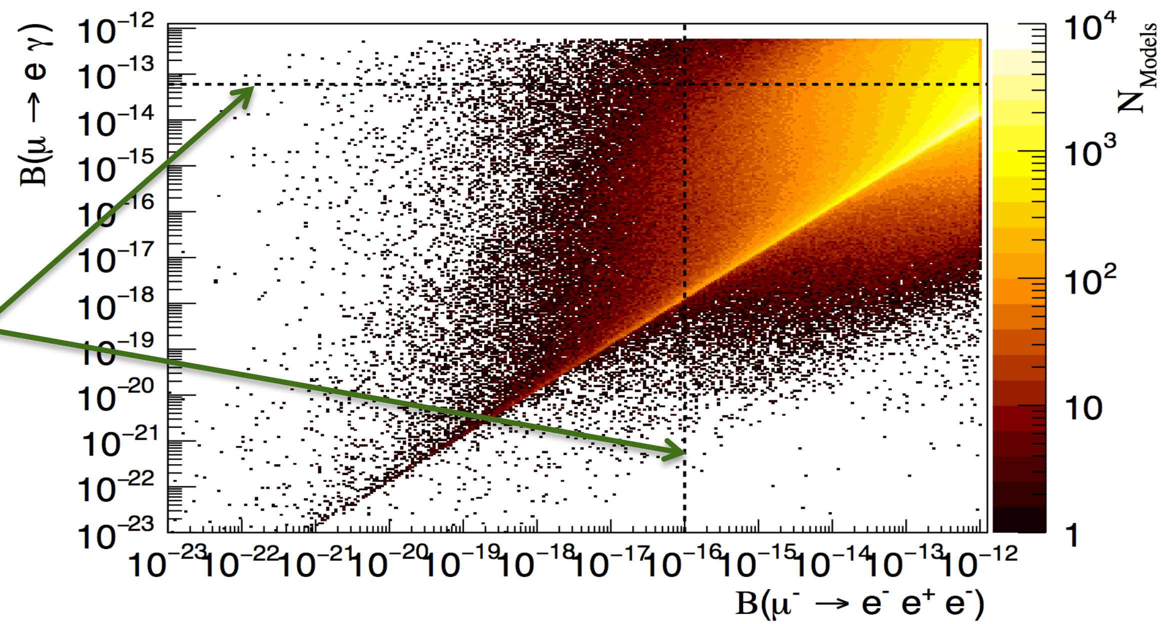
Future Mu2e/ COMET sensitivity

Rare Muon Decays

- Strong current bounds on $\mu \rightarrow e\gamma$ & $\mu \rightarrow eee$ (MEG, SINDRUM)
- LRM contributions to $\mu \rightarrow e\gamma$
  - » 1-loop W_R exchange
  - » 1-loop $\Delta_L^{\pm}$, $\Delta_{R,L}^{\pm\pm}$ exchange
- LRM contributions to $\mu \rightarrow eee$
  - » Tree-level $\Delta_{R,L}^{\pm\pm}$ exchange

Mu3e would have good sensitivity

Future sensitivity Mu3e, MEG

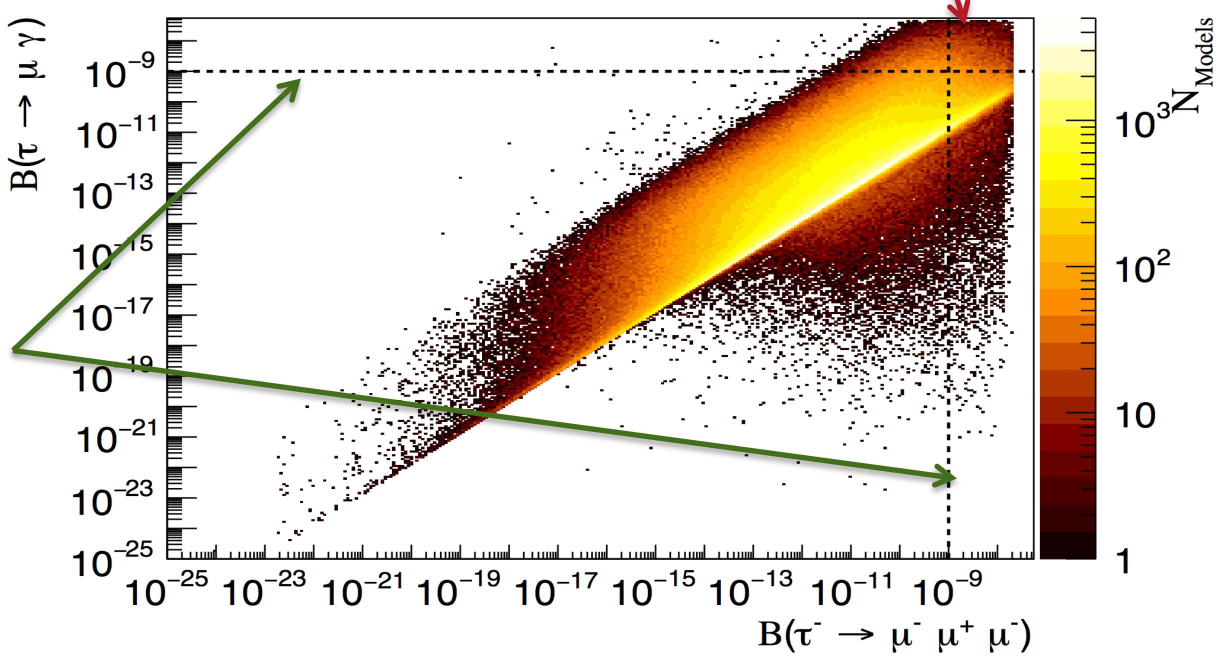


Rare tau decays

- Current limits from BaBar/Belle
- LRM contributions to μ→eγ
  - » 1-loop W_R exchange
  - » 1-loop $\Delta_L^{\pm}$, $\Delta_{R,L}^{\pm\pm}$ exchange
- LRM contributions to μ→eee
  - » Tree-level $\Delta_{R,L}^{\pm\pm}$ exchange

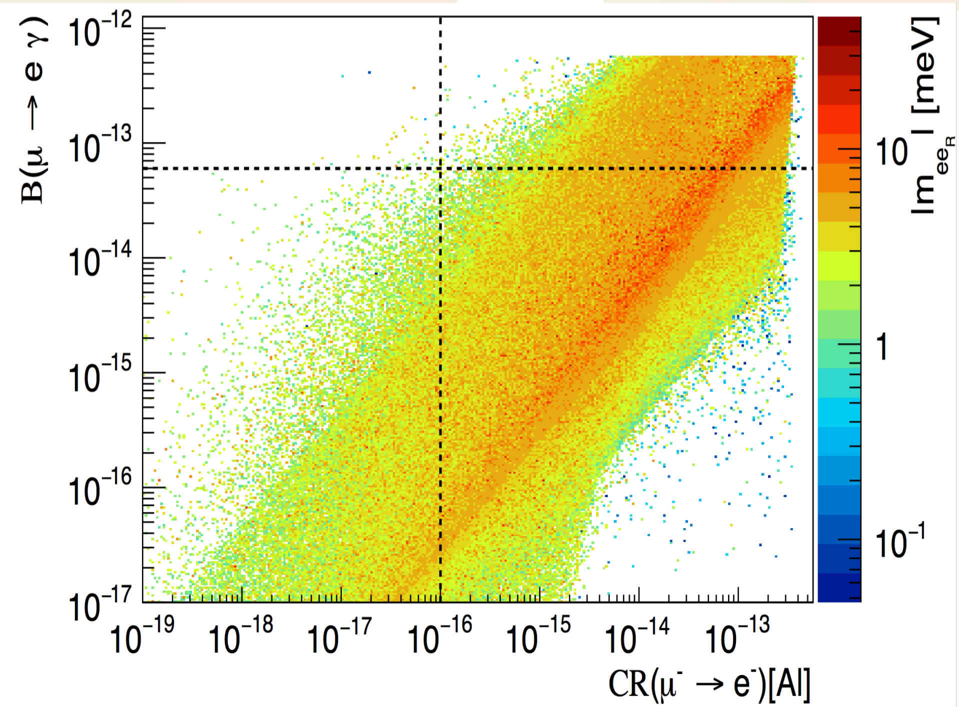
Not much sensitivity

Future sensitivity
for Belle-II, LHCb

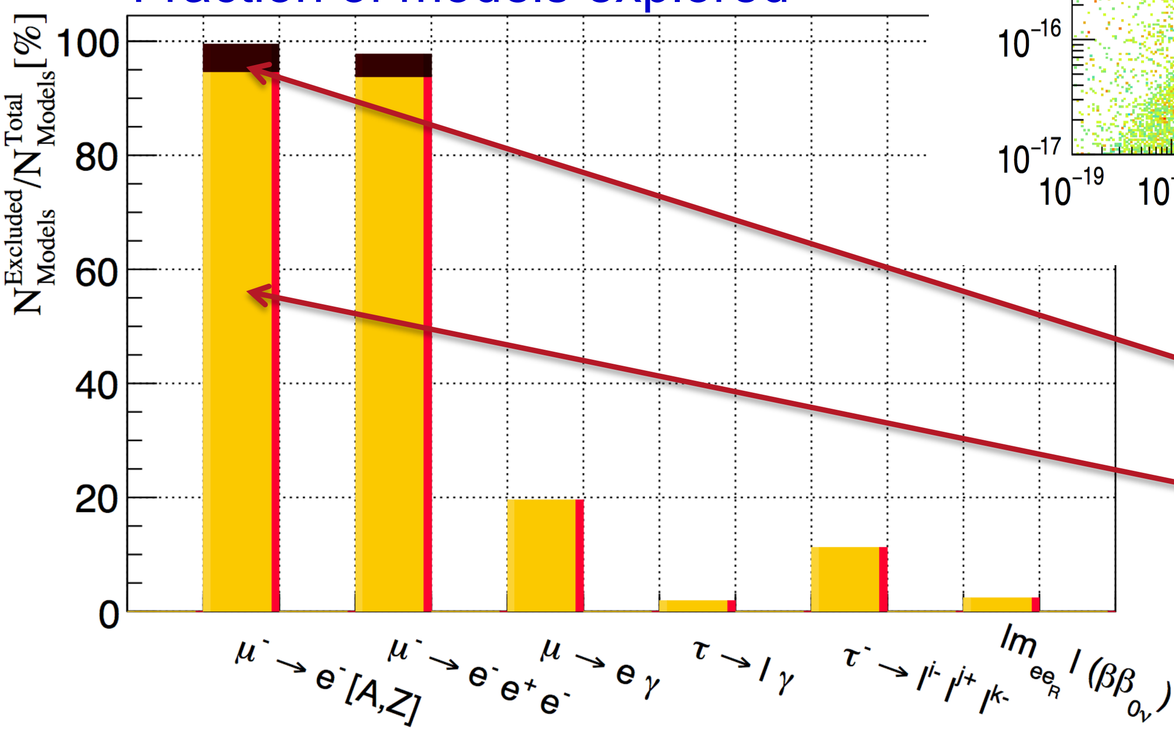


LFV reach comparison

Mu2e/COMET
provide most
powerful probe



Fraction of models explored

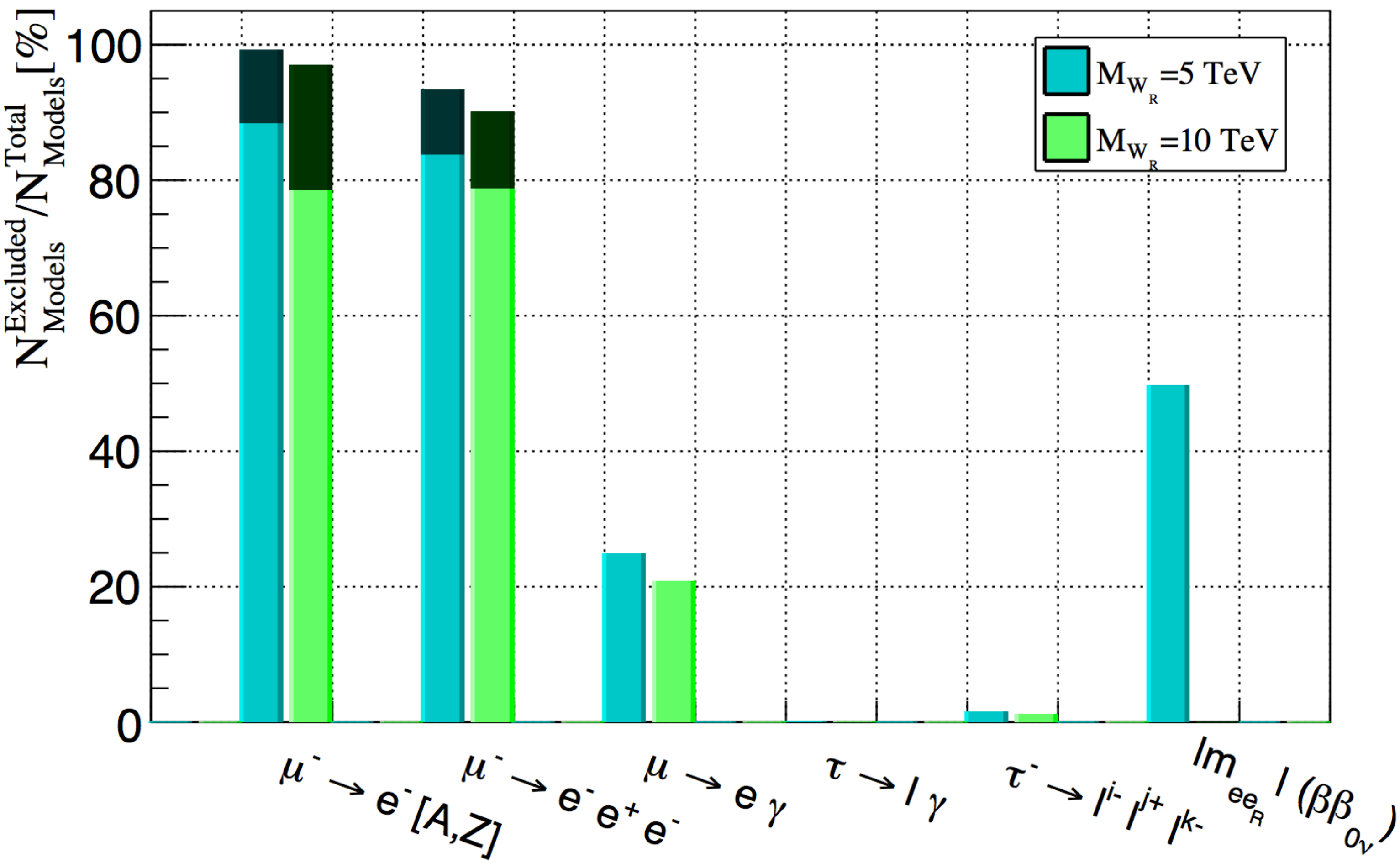


Future upgrade

Planned exp't

Scan with high mass W_R

- Repeat scan for W_R mass = 5, 10 TeV & κ = 1



Right-handed currents in B decays?

High Energy Physics – Phenomenology

Signal of right-handed currents using $B \to K^* \ell^+ \ell^-$ observables at the kinematic endpoint

Anirban Karan, Rusa Mandal, Abinash Kumar Nayak, Rahul Sinha, Thomas E. Browder

(Submitted on 14 Mar 2016)

The decay mode $B \to K^* \ell^+ \ell^-$ is one of the most promising modes to probe physics beyond the standard model (SM), since the angular distribution of the decay products enable measurement of several constraining observables. LHCb has recently measured these observables using $3 fb^{-1}$ of data as a binned function of q^2, the dilepton invariant mass squared. We show that LHCb data implies a 5σ overall signal for new physics and provides unambiguous evidence for right-handed currents, which are absent in the SM. These conclusions are derived in the maximum q^2 limit and are free from hadronic corrections. Our approach differs from other approaches that probe new physics at low q^2 as it does not require estimates of hadronic parameters but relies instead on heavy quark symmetries that are reliable at the maximum q^2 kinematic endpoint.

Comments:	5 pages with 3 figures. One supplementary file included
Subjects:	**High Energy Physics – Phenomenology (hep-ph)**; High Energy Physics – Experiment (hep-ex)
Report number:	IMSc/2016/03/02
Cite as:	arXiv:1603.04355 **[hep-ph]**
	(or arXiv:1603.04355v1 **[hep-ph]** for this version)

Submission history

From: Rahul Sinha [view email]

[v1] Mon, 14 Mar 2016 17:36:28 GMT (1406kb,AD)

Summary

SLAC

- LRM provides an excellent fit to the 8 TeV diboson 'anomalies'
- This is a highly predictive scenario that impacts the other frontiers
- The 8 TeV diboson 'anomalies' have refocused our attention on the LRM scenario
- Strong influence in LFV/LNV processes
- Mu2e has significant reach in this parameter space

We await further 13 TeV data!!!!