COLLIDER PHENOMENOLOGY OF THE HIGGSLESS MODELS

Maxim Perelstein, Cornell U.

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based on hep-ph/0412278 (PRL94:191803,2005) with A. Birkedal and K. Matchev

- The experimentally verified theory of particle physics is "SM sans Higgs" (SM-H)

- In SM-H, elastic scattering of massive gauge bosons (e.g. $W_L^+ W_L^- \to W_L^+ W_L^-$) becomes strongly coupled at

$$\Lambda \sim \frac{4\pi M_W}{g} \sim 1.8 \text{ TeV}$$

- Operators suppressed by $1/\Lambda^n$ will be generated and need to be included in precision electroweak fits

- EW precision experiments require $\Lambda > 5 - 10 \text{ TeV}$ - strongly coupled EWSB ruled out?

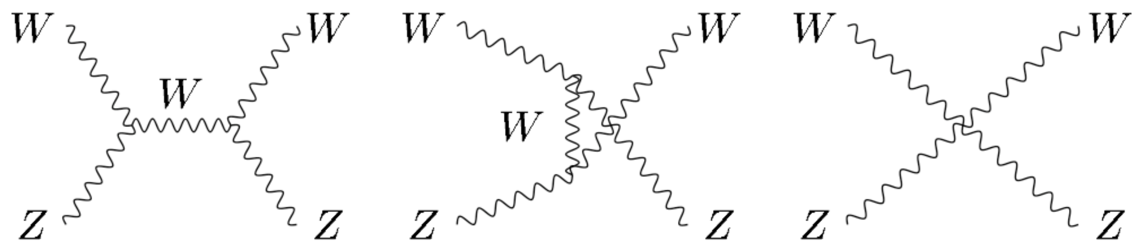
The “Higgsless” Approach

[Csaki, Grojean, Terning, Murayama, Pilo, ‘03-04]

- Introduce new particles around the TeV scale, coupled to the SM W/Z bosons
- Diagrams involving new particles cancel the growing pieces of the W/Z scattering amplitudes at high energies
- Cancellations are due to symmetries of the theory (5D locality, gauge invariance)
- Raise the cutoff Λ to the required 5-10 TeV range

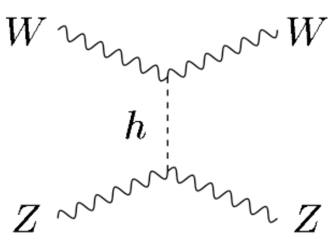
Example: Unitarity in $W_L^{\pm} Z_L \to W_L^{\pm} Z_L$ Scattering

SM sans Higgs:



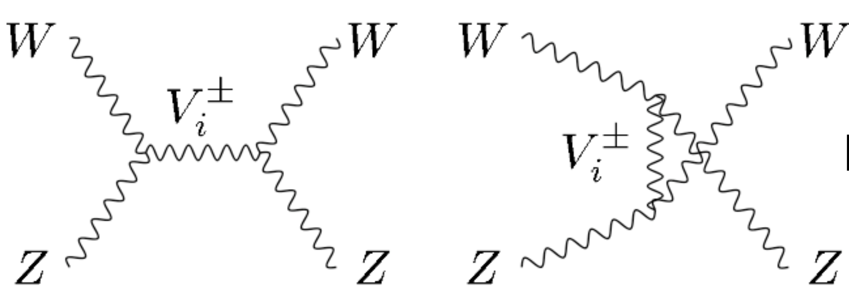
$$\mathcal{M} \propto E^2$$

SM:



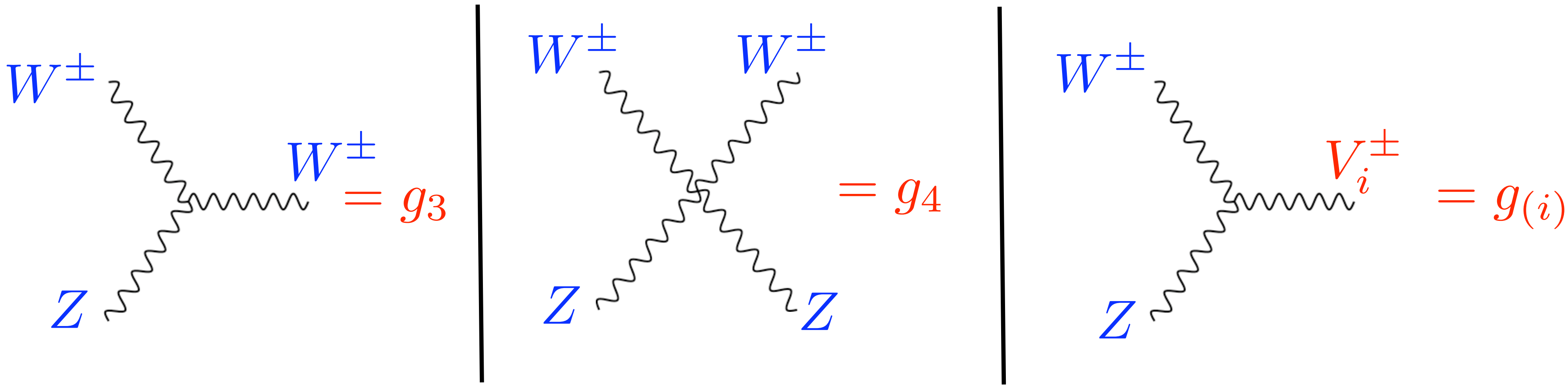
$$\mathcal{M} \propto E^0\,!$$

Higgsless:



$$\mathcal{M} \propto E^0\,!$$

Cancellation requires SUM RULES:



$$g_4 = g_3^2 + \sum_i g_{(i)}^2$$

$$2(g_4 - g_3^2)(M_W^2 + M_Z^2) + g_3^2 \frac{M_Z^4}{M_W^2} = \sum_i (g_{(i)})^2 \left[3M_i^2 - \frac{(M_Z^2 - M_W^2)^2}{M_i^2} \right]$$

- 5D Higgsless models satisfy the sum rules exactly $(i = 1 \ldots \infty)$
- 4D "deconstructed" Higgsless models satisfy the sum rules to a few % $(i = 1 \ldots N_s)$
  [Foadi, Gopalakrishna, Schmidt, Chivukula, Georgi, MP,...]
- The sum rules are independent of the model-building details (e.g. the fermion sector) $\Rightarrow$ GENERIC prediction of Higgsless mechanism
- This translates into robust predictions for the LHC

- Simplifying assumption: sum rules saturated by the 1st resonance (checked several models - true to a few %) ⇨ 1-parameter model:

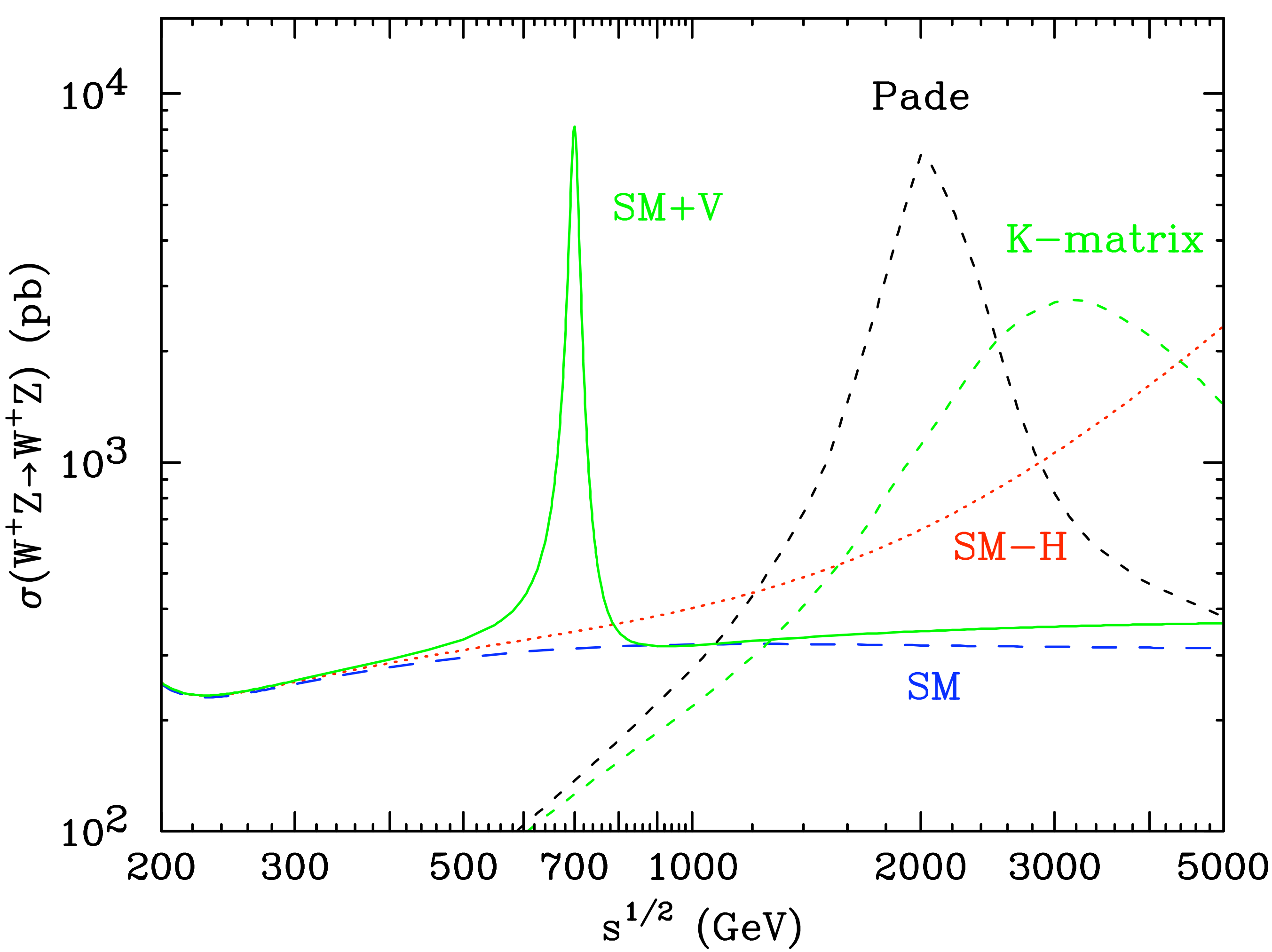
$$g_{(1)} = \frac{g_3 M_Z^2}{\sqrt{3} M_W} \frac{1}{M_1}$$

- Prediction: a narrow, light resonance in WZ scattering (absent in the SM and 2HDM!)

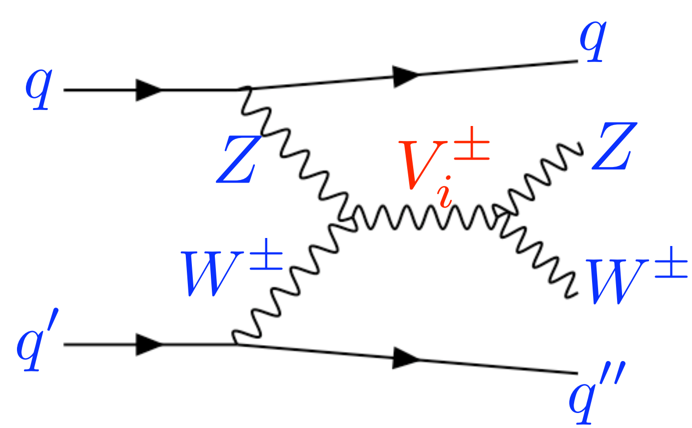
$M_1 \leq 1 \text{ TeV}$ (unitarity)

$$\Gamma = \frac{\alpha M_1^3}{144 s_W^2 M_W^2}$$ (set couplings to fermions to 0)

WZ Elastic Scattering Cross Section in 5 Models



- WZ collisions at the LHC:

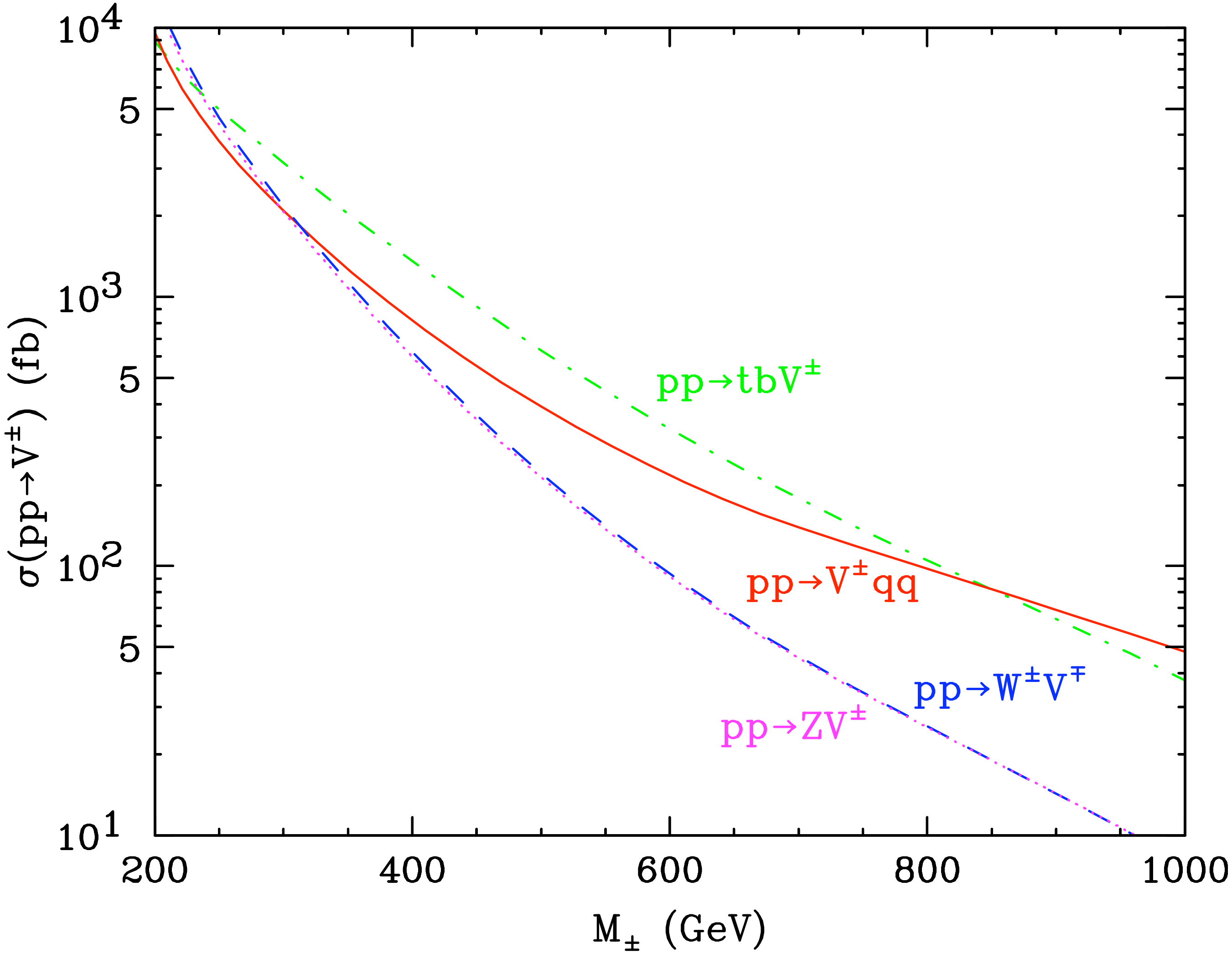


- To suppress backgrounds from the SM s-channel process $q + q' \to WZ$ require 2 observed forward jets

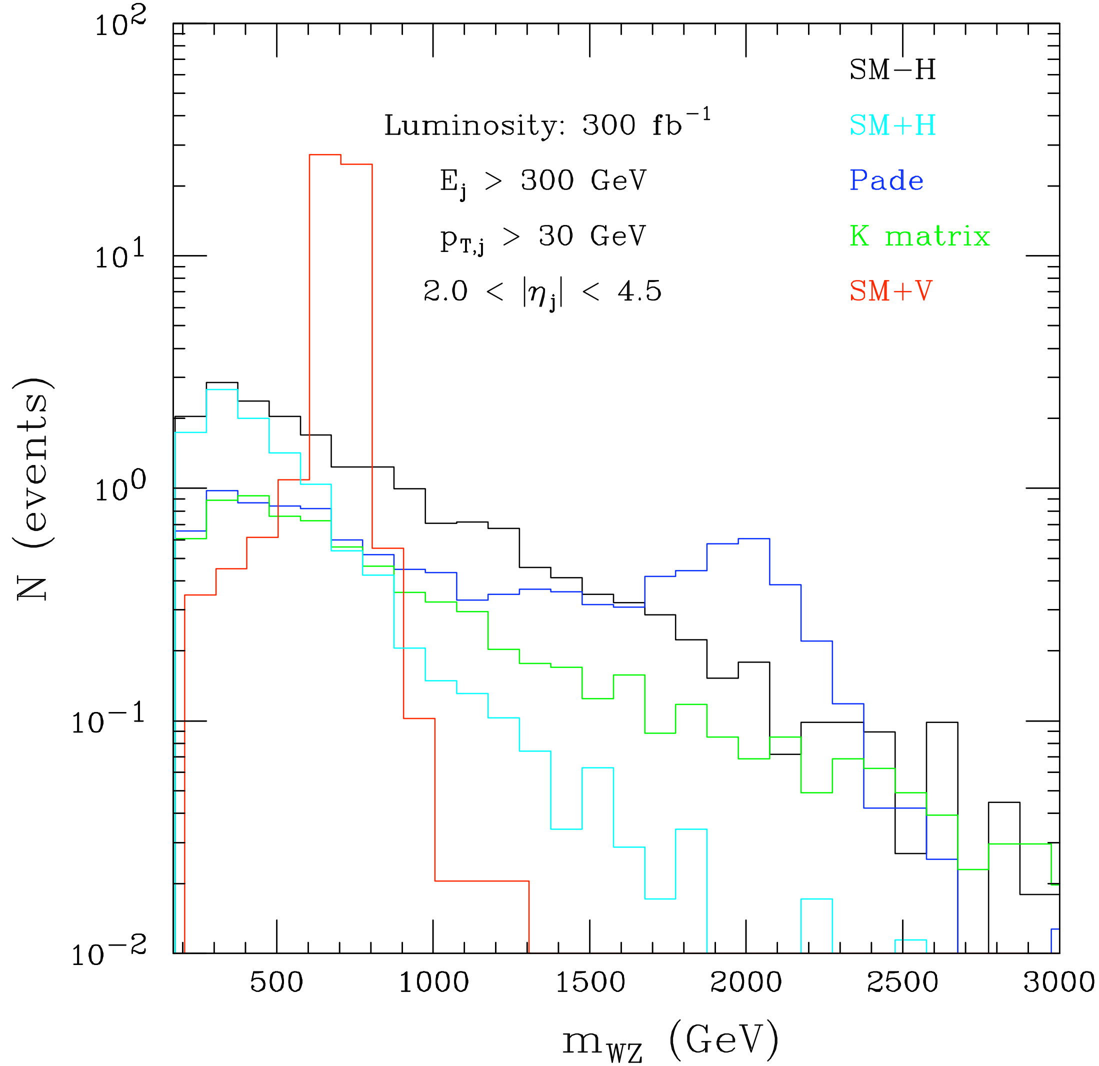
$$(2 \le |\eta| \le 4.5, \quad E > 300 \text{ GeV}, \quad p_T > 30 \text{ GeV})$$

[The same cuts also eliminate the "signal background" from the possible Drell-Yan V_1's!

$V^{\pm}$ production cross section at the LHC



Gold-Plated Channel: 2j+3l+Et_miss, $\sqrt{s_{\ell\ell}} \approx M_Z$



Number of events at the LHC, 300 fb-1

- Discovery Reach at the LHC (10 signal events):

$$M_1 \leq 550 \text{ GeV}, \qquad 10 \text{ fb}^{-1}$$

$$M_1 \leq 1 \text{ TeV}, \qquad 60 \text{ fb}^{-1}$$

- The HL resonance will be discovered, with moderate luminosity

- Mass measurement: $M^2 = s(WZ)$

- Uncertainty dominated by Et_miss - 10%?

- Could the LHC test the sum rule ("prove Higgsless")?

$$g_{(1)} = \frac{g_3 M_Z^2}{\sqrt{3} M_W} \frac{1}{M_1}$$

- Requires a measurement of $g_{(1)}$

- Width measurement - limited by Et_miss resolution, resonance is narrow!

- Rate measurement:

$$\mathrm{Rate} = \sigma_{\mathrm{tot}} \times \mathrm{Br}(\mathrm{V}_1 \to \mathrm{WZ})$$

[pdf uncertainty] [need ALL decay channels!]

Conclusions

- Higgsless models provide an alternative version of strongly coupled EWSB with the strong couplings scale in the 5-10 TeV range
- New vector bosons below 1 TeV are essential to raise the strong coupling scale
- Their couplings to SM Ws and Zs are constrained by two simple sum rules
- LHC will be able to discover them with about 60 fb-1 of data in the WZ fusion channel, but not test the sum rule (ILC?)