A light composite Higgs

at the LHC

(and at linear colliders)

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Collider phenomenology — DESY, October 1st

Light composite Higgs: motivation

Walking technicolor (TC) models can allow for a light composite Higgs

- Scalar $f_0(660)$ in QCD lighter than vector states
- Large N_c scaling argument
- Higgs mass further reduced by walking dynamics?

[Hong, Hsu, Sannino 04]

[Dietrich, Sannino, Tuominen 05]

[Sannino 08]

- Light Higgs can help to unitarize WW scattering

[Foadi, MJ, Sannino 08]

Effective theory for walking technicolor

Lagrangian (NMWT/MWT):

$M \leftrightarrow$ Higgs, $C_{\mathrm{L/R}} \leftrightarrow$ Vector states

$$
\begin{aligned}
\mathcal{L}_{\mathrm{boson}} &= -\frac{1}{2}\mathrm{Tr}\left[\widetilde{W}_{\mu\nu}\widetilde{W}^{\mu\nu}\right] - \frac{1}{4}\widetilde{B}_{\mu\nu}\widetilde{B}^{\mu\nu} - \frac{1}{2}\mathrm{Tr}\left[F_{\mathrm{L}\mu\nu}F_{\mathrm{L}}^{\mu\nu} + F_{\mathrm{R}\mu\nu}F_{\mathrm{R}}^{\mu\nu}\right] \\
&+ m^2\,\mathrm{Tr}\left[C_{\mathrm{L}\mu}^2 + C_{\mathrm{R}\mu}^2\right] + \frac{1}{2}\mathrm{Tr}\left[D_\mu M D^\mu M^\dagger\right] - \tilde{g^2}\,r_2\,\mathrm{Tr}\left[C_{\mathrm{L}\mu}MC_{\mathrm{R}}^{\mu}M^\dagger\right] \\
&- \frac{i\,\tilde{g}\,r_3}{4}\mathrm{Tr}\left[C_{\mathrm{L}\mu}\left(MD^\mu M^\dagger - D^\mu M M^\dagger\right) + C_{\mathrm{R}\mu}\left(M^\dagger D^\mu M - D^\mu M^\dagger M\right)\right] \\
&+ \frac{\tilde{g}^2 s}{4}\mathrm{Tr}\left[C_{\mathrm{L}\mu}^2 + C_{\mathrm{R}\mu}^2\right]\mathrm{Tr}\left[MM^\dagger\right] + \frac{\mu^2}{2}\mathrm{Tr}\left[MM^\dagger\right] - \frac{\lambda}{4}\mathrm{Tr}\left[MM^\dagger\right]^2
\end{aligned}
$$

$$
\mathcal{L}_{\mathrm{fermion}} = i\,\overline{q}_{\dot{\alpha}}^{i}\overline{\sigma}^{\mu,\dot{\alpha}\beta}D_\mu q_\beta^i + i\,\overline{l}_{\dot{\alpha}}^{i}\overline{\sigma}^{\mu,\dot{\alpha}\beta}D_\mu l_\beta^i + i\,\overline{L}_{\dot{\alpha}}\overline{\sigma}^{\mu,\dot{\alpha}\beta}D_\mu L_\beta
$$

Model implementation

LanHEP (A. Semenov)

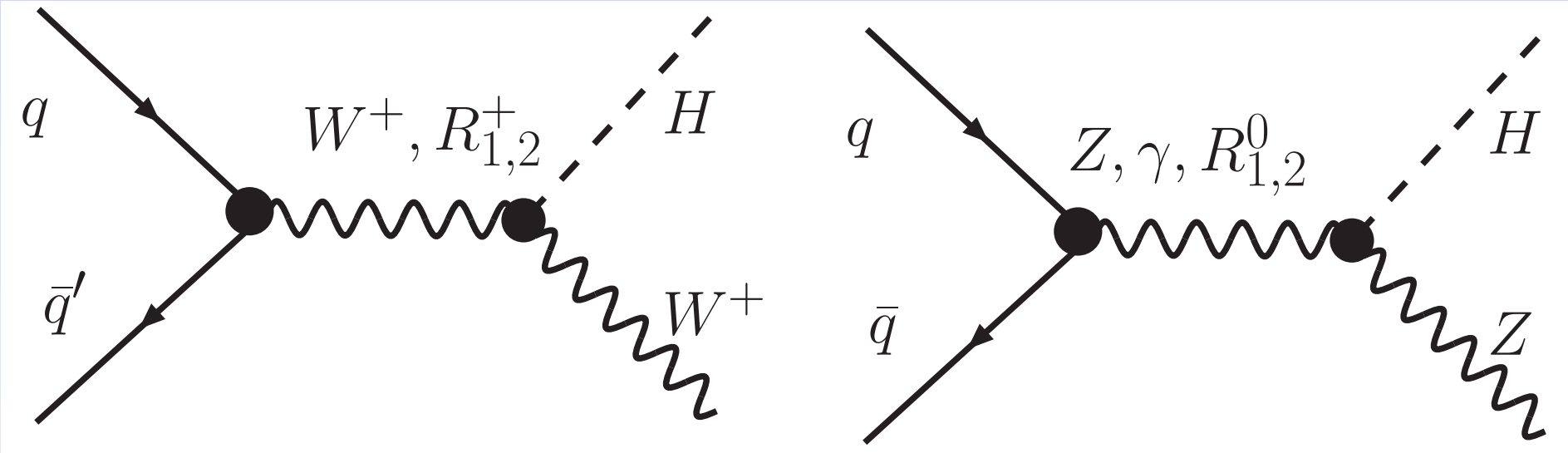
- Automatic generation of Feynman rules

CalcHEP (A. Pukhov)

- Parton level cross sections and event generation

Technicolor Higgs at the LHC

Associated Higgs production



Modified by the presence of composite light vector states

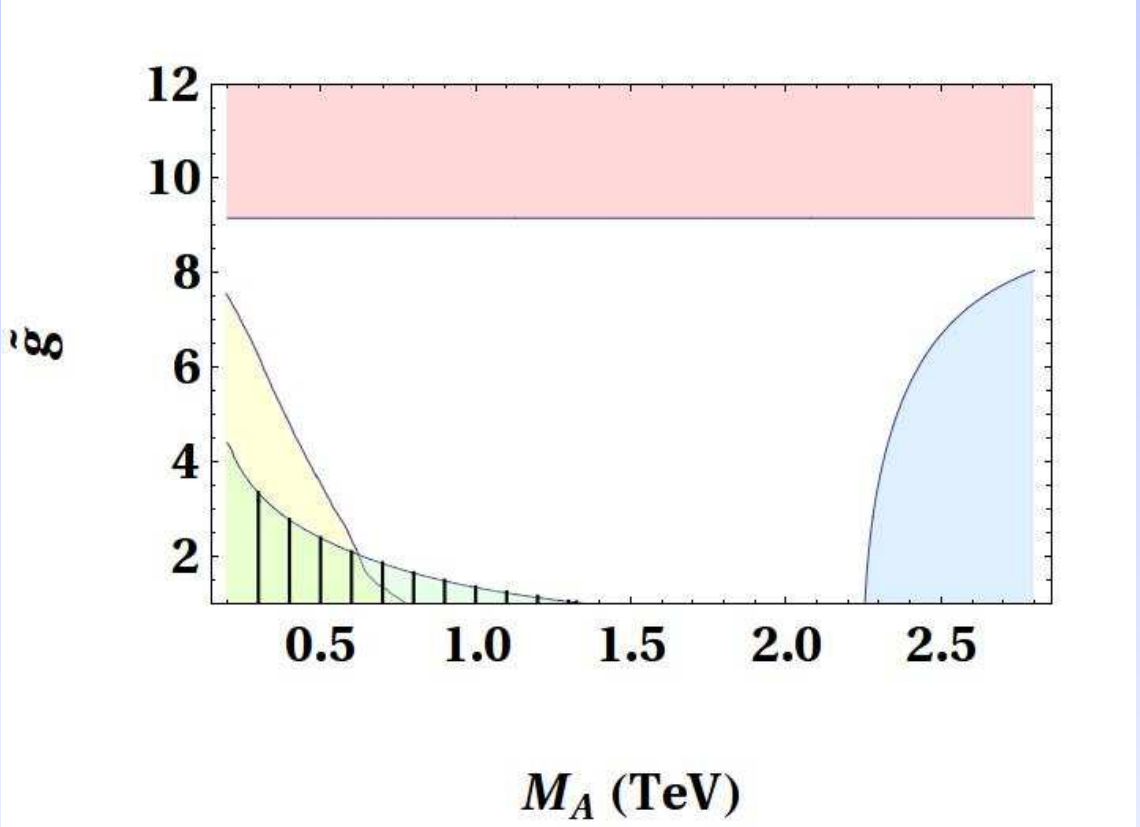
WSR $\Rightarrow M_A < M_V$

See arXiv:0809.0793 (A. Belyaev, R. Foadi, M. T. Frandsen, MJ, A. Pukhov, F. Sannino)

Technicolor Higgs at the LHC

Constraints on:

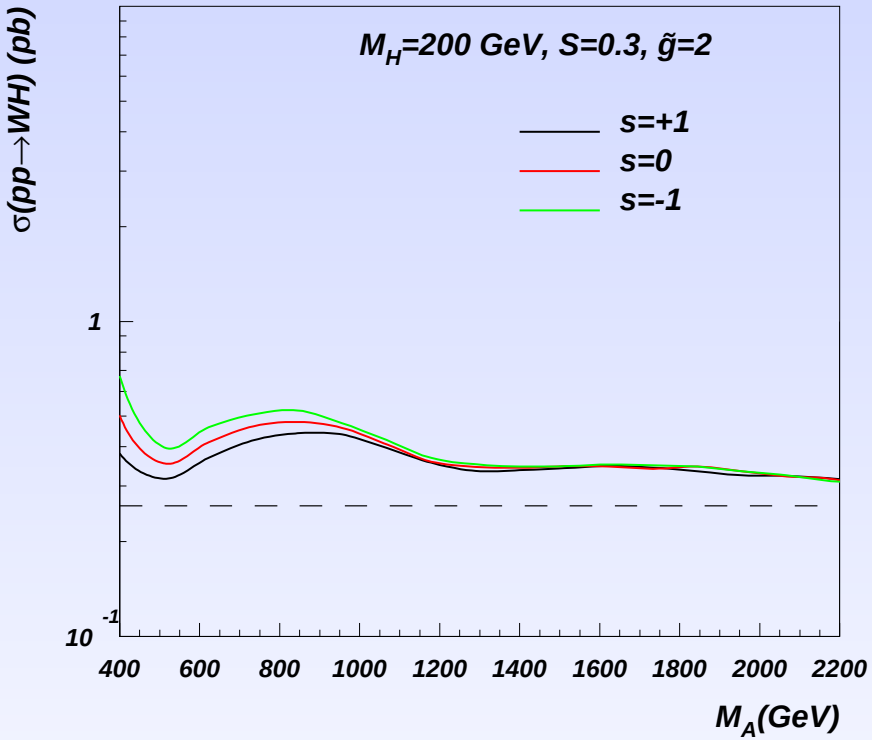
- Vector mass scale M_A
- TC coupling strength $\tilde{g}$: mixing of W/Z and TC vectors $\mathcal{O}\left(g/\tilde{g}\right)$

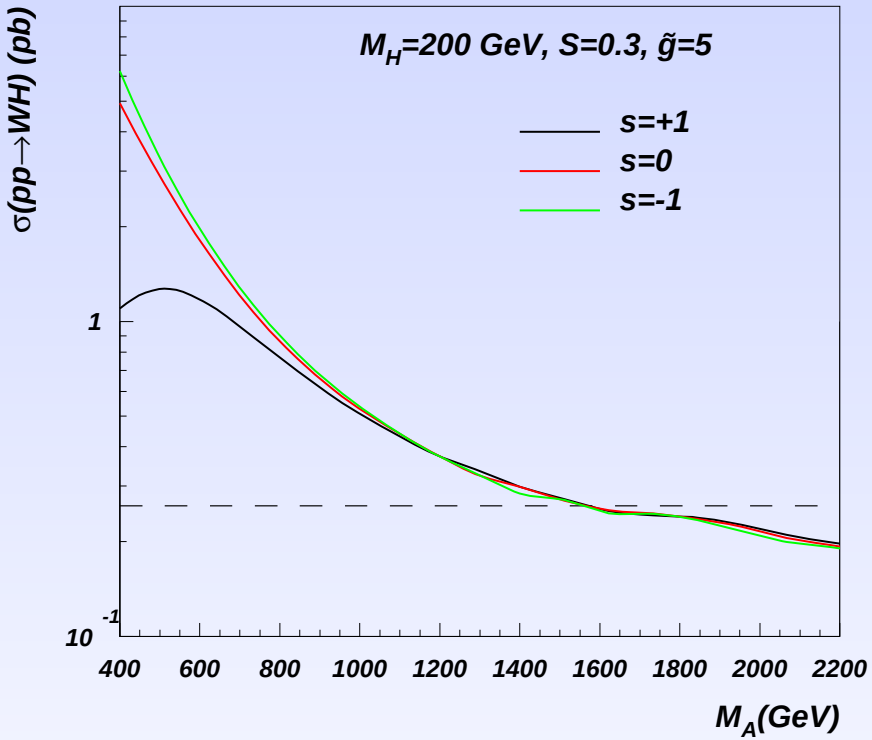


Bounds from EW precision data, consistency of our approach, and Tevatron searches still allow relatively light vectors

Technicolor Higgs at the LHC

Higgs production cross section in $pp \to WH$ compared to SM



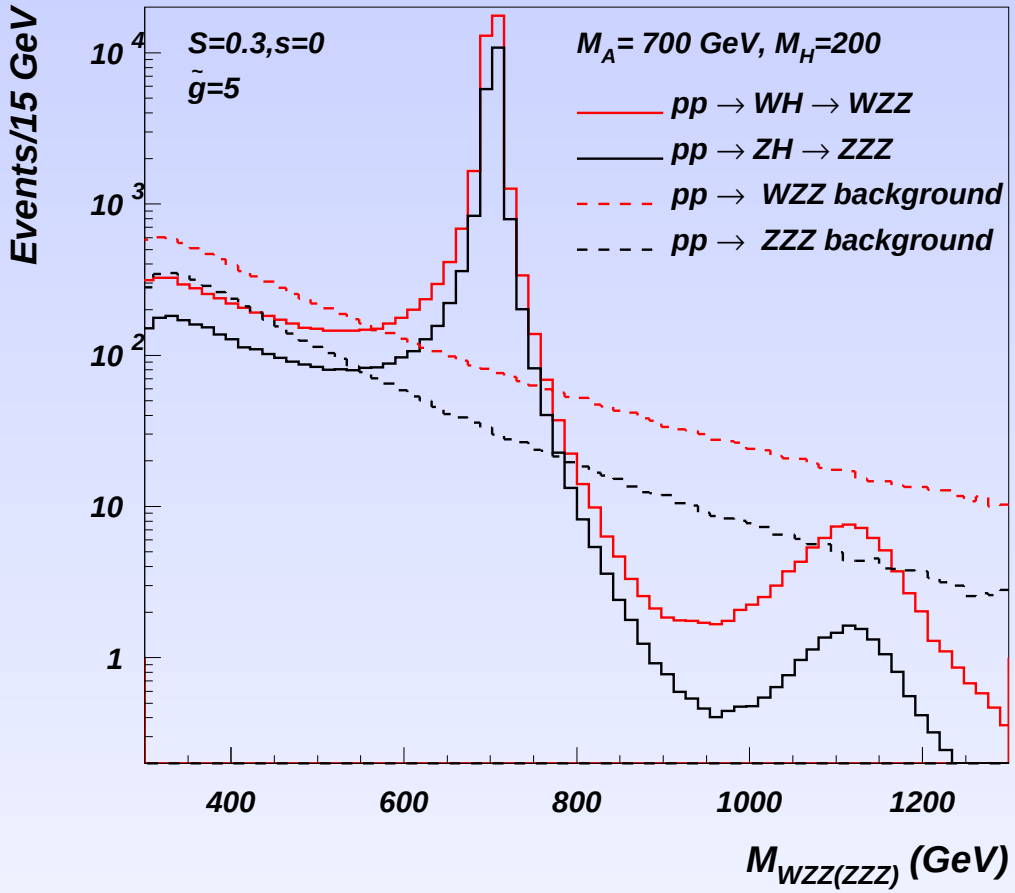


Mostly enhanced

[Zerwekh 05]

Technicolor Higgs at the LHC

ZZZ and ZZW distributions show axial (and vector) peaks

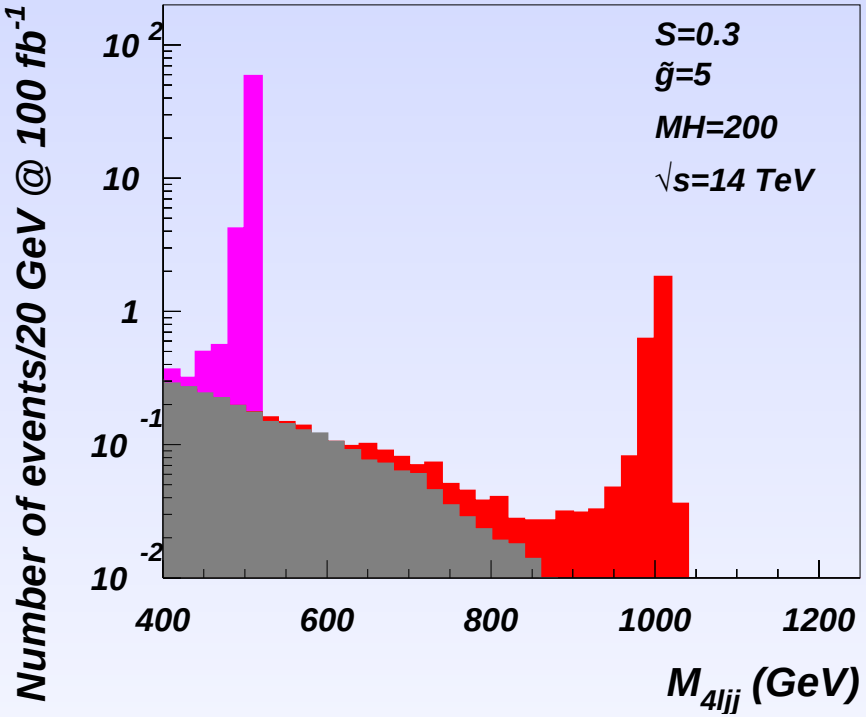


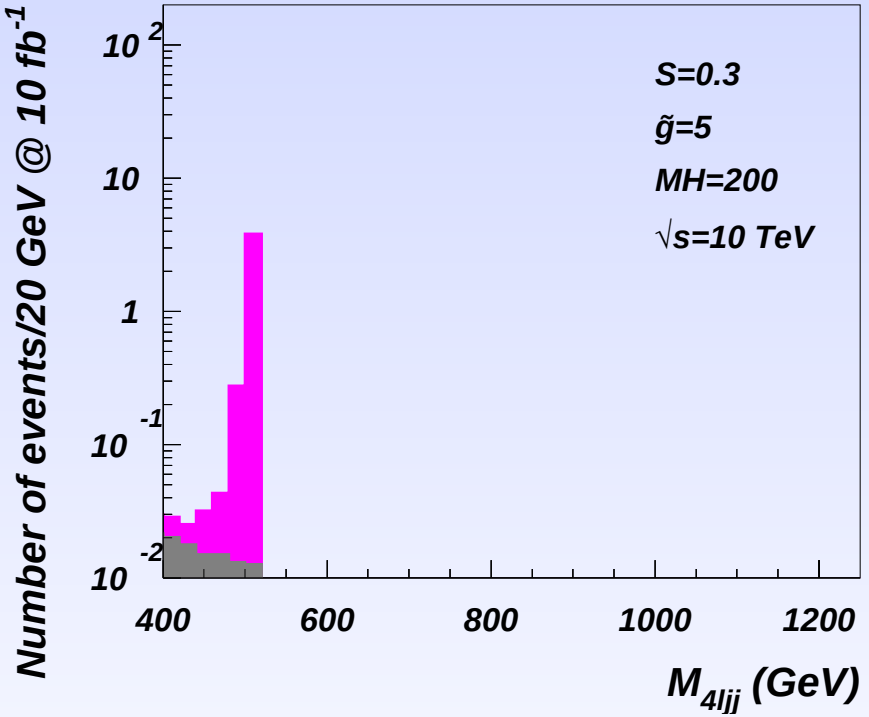
The simplest Higgs-vector coupling assumed here

Technicolor Higgs at the LHC

After complete final state analysis, $pp \to HW \to 4\ell + 2j$

Preliminary plots by M. T. Frandsen ($M_A = 0.5\mathrm{TeV}$)

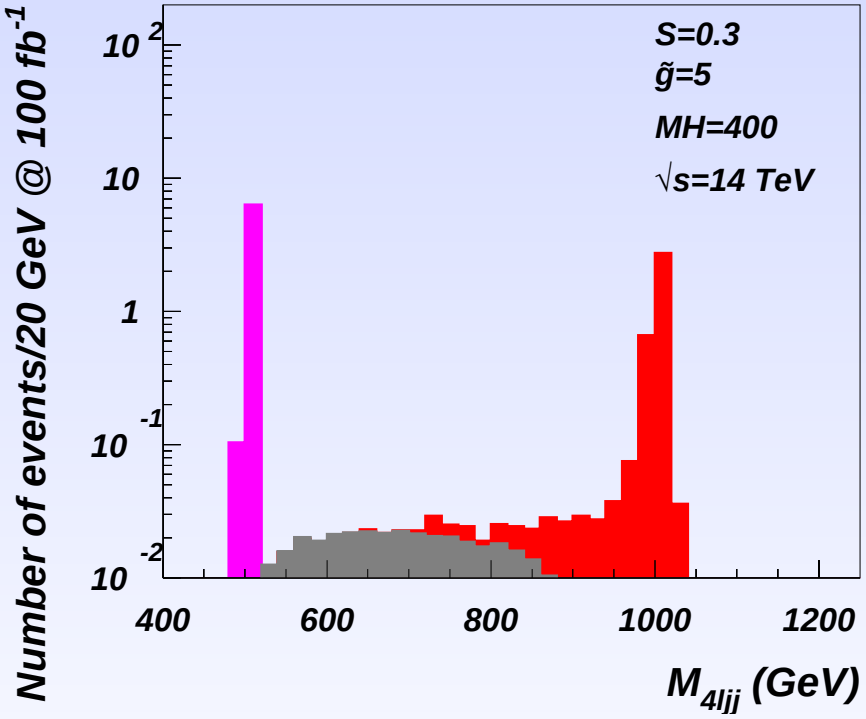


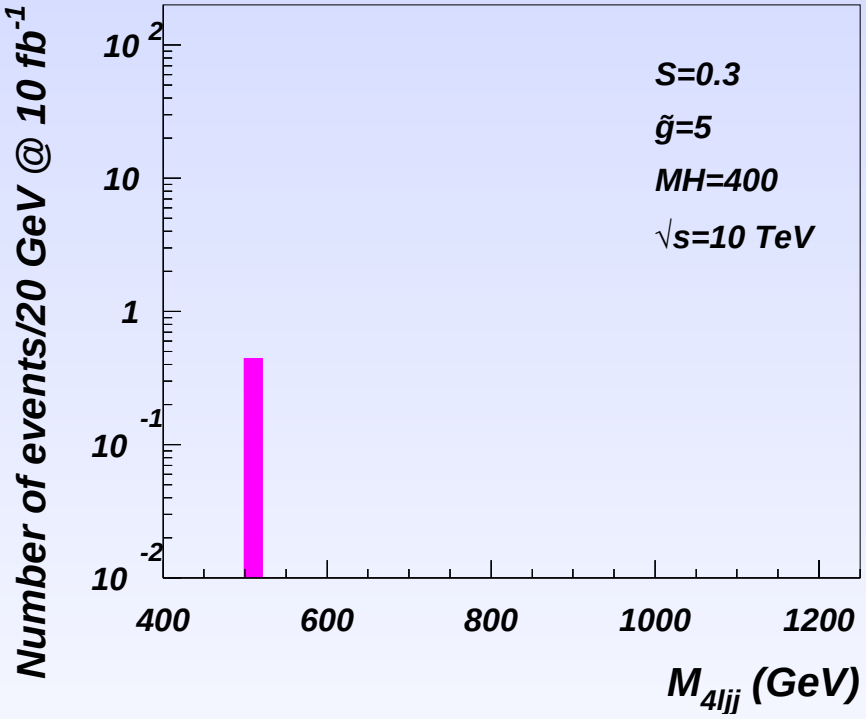


Axial resonance peak clear, but cross section low. . . for vector even lower

Technicolor Higgs at the LHC

$pp \to HW \to 4\ell + 2j$ for higher $M_H = 400\mathrm{GeV}$





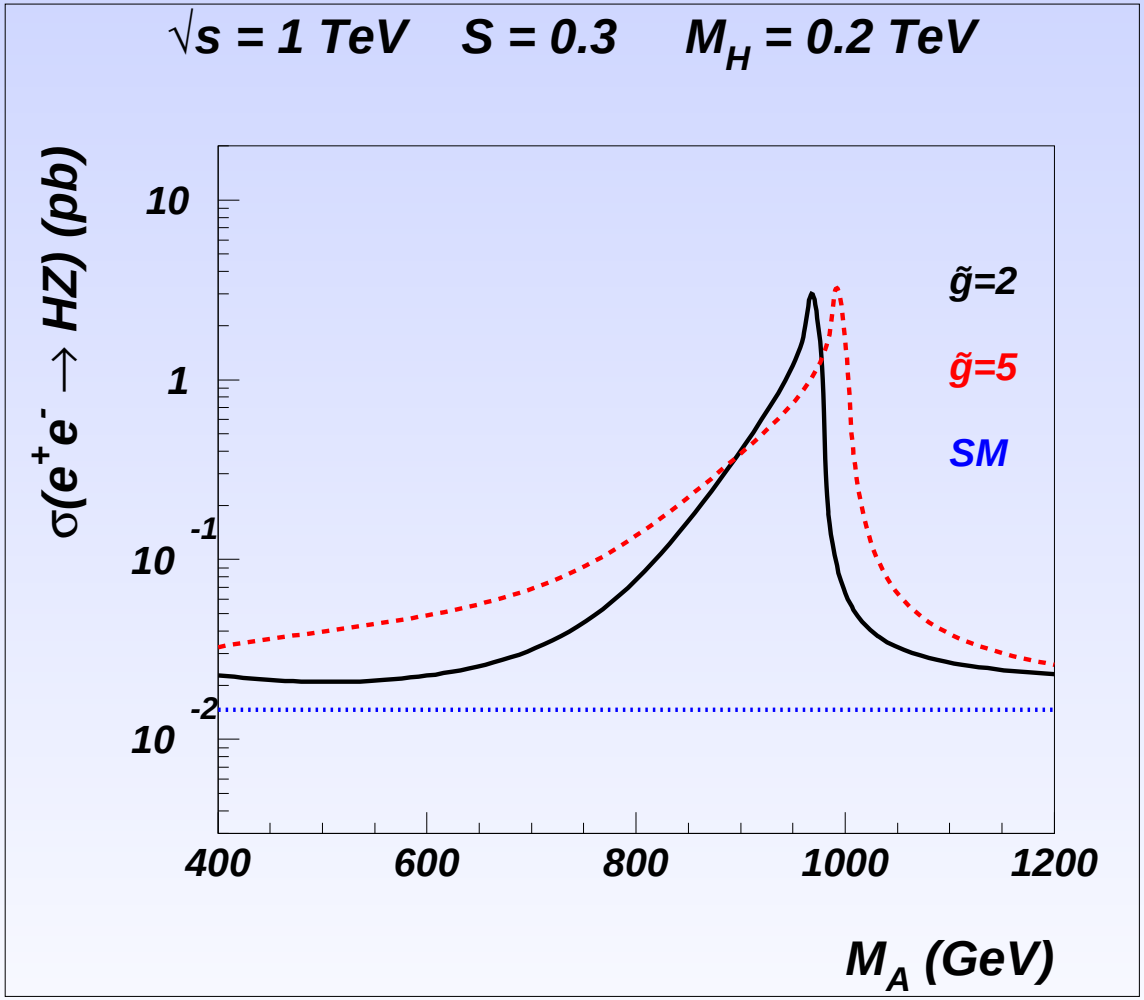
Light composite Higgs at linear colliders

Work in progress with A. Belyaev, R. Foadi, M. T. Frandsen, and F. Sannino

Associated production

$\sigma(ee \to HZ)$

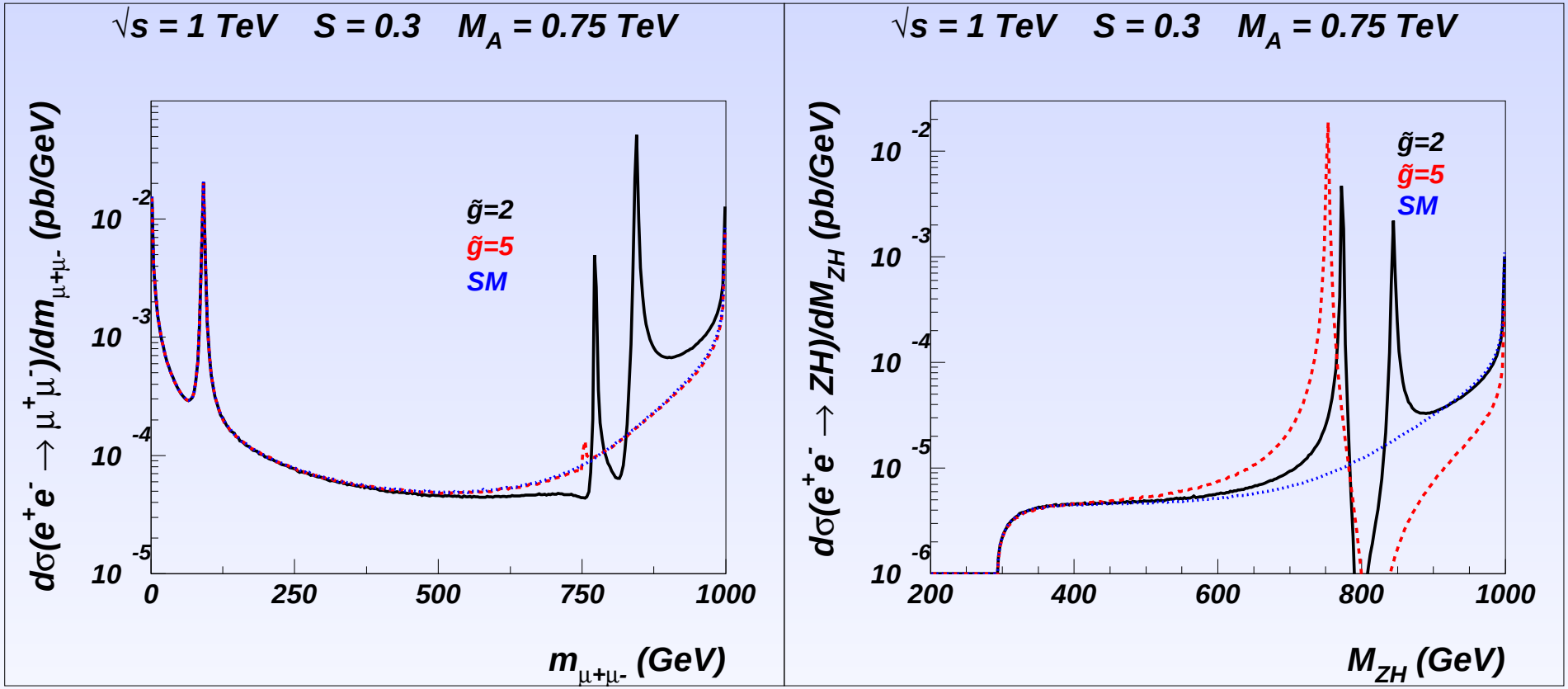
(Full analysis $ee \to ZZZ \to \text{leptons/jets}$ to be done)



Light composite Higgs at linear colliders

Fixed energy $\sqrt{s} = 1\ \mathrm{TeV}$: $ee \to \mu\mu$ and $ee \to HZ$

complementary for large/small $\tilde{g}$. Preliminary!

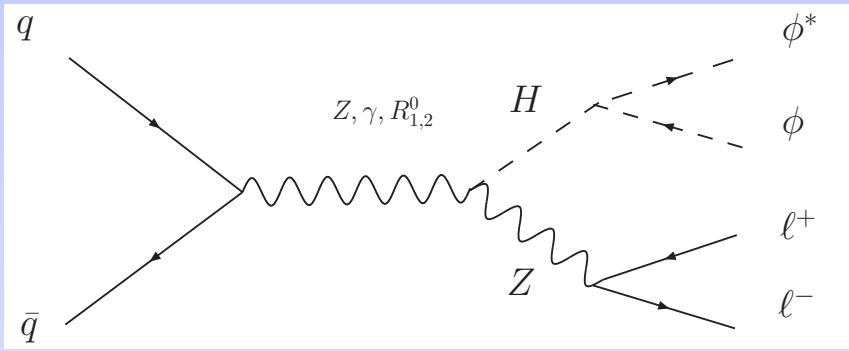


Nontrivial distribution appears due to initial state effects

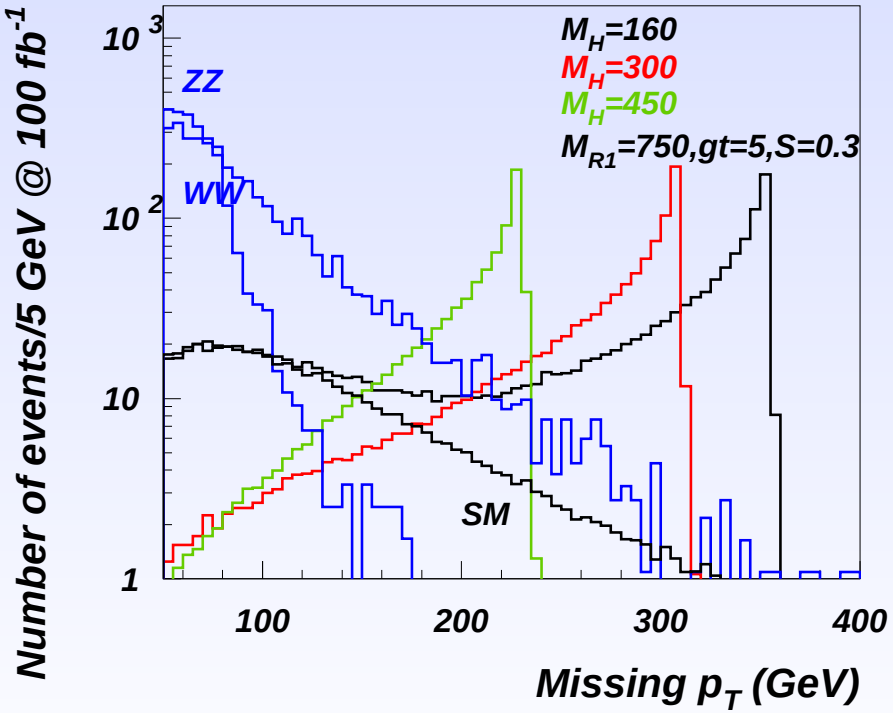
Missing p_T signature

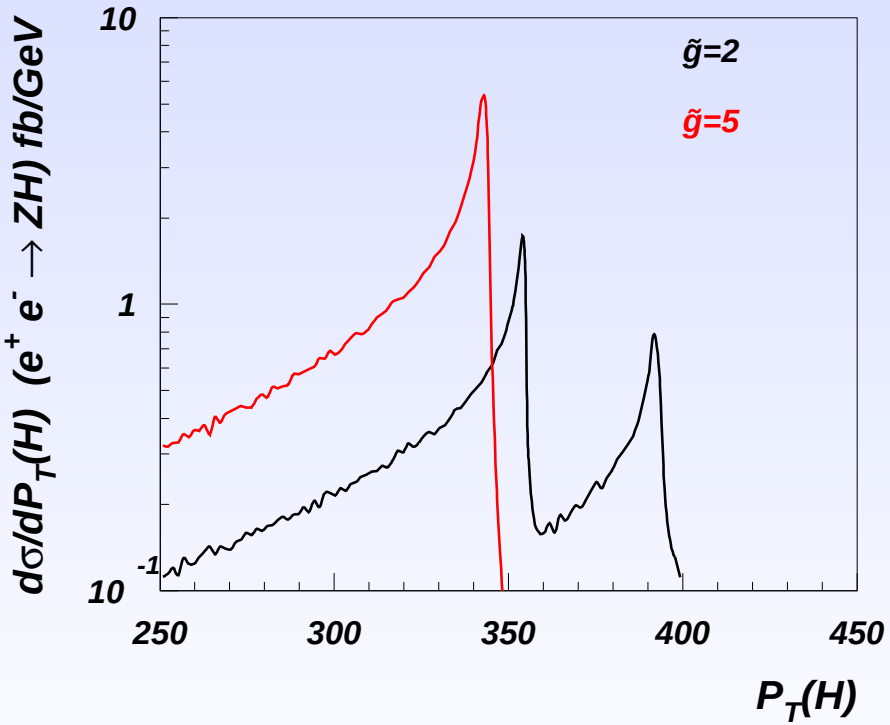
Higgs may also decay to invisible technibaryons or heavy neutrinos

[Foadi, Frandsen, Sannino 08]
[Frandsen, Masina, Sannino 09]



$\sqrt{s}$ = 1 TeV S = 0.3 M_A=0.75 TeV M_H= 0.2 TeV





Conclusion

- Viable walking technicolor models may include a light composite Higgs
- Higgs production most likely enhanced in technicolor
- Vector resonances modify associated Higgs production