

# Slava Rychkov (LPT ENS & UPMC)

Plan:

1. Beyond SM models for super-early LHC ( $10 \text{ pb}^{-1}$ )
2. EWSB-motivated physics ( $1 \text{ fb}^{-1}$ )

# Super-early models

Bauer, Ligeti, Schmaltz, Thaler, Walker 0909.5213

?? Is it possible to find a model such that:

1.  $\sigma(\text{LHC})$  **large** to have  $>10$  signal events already with  $10 \text{ pb}^{-1}$
2.  $\sigma(\text{Tevatron})$  **small** to evade projected 2010 Tevatron sensitivity with  $10 \text{ fb}^{-1}$
3. Large BR to "easy" final states with almost no background (multileptons)
4. Consistency with other existing bounds (e.g. LEP)

??

# Necessary condition

Must be an s-channel resonance, coupled to  $qq$  or  $q\bar{q}$  at tree level

- resonances coupled to  $gg$  (like Higgs) have loop-suppressed couplings
- pair production cross section is suppressed w.r.t. to a resonance by  $\alpha/4\pi$

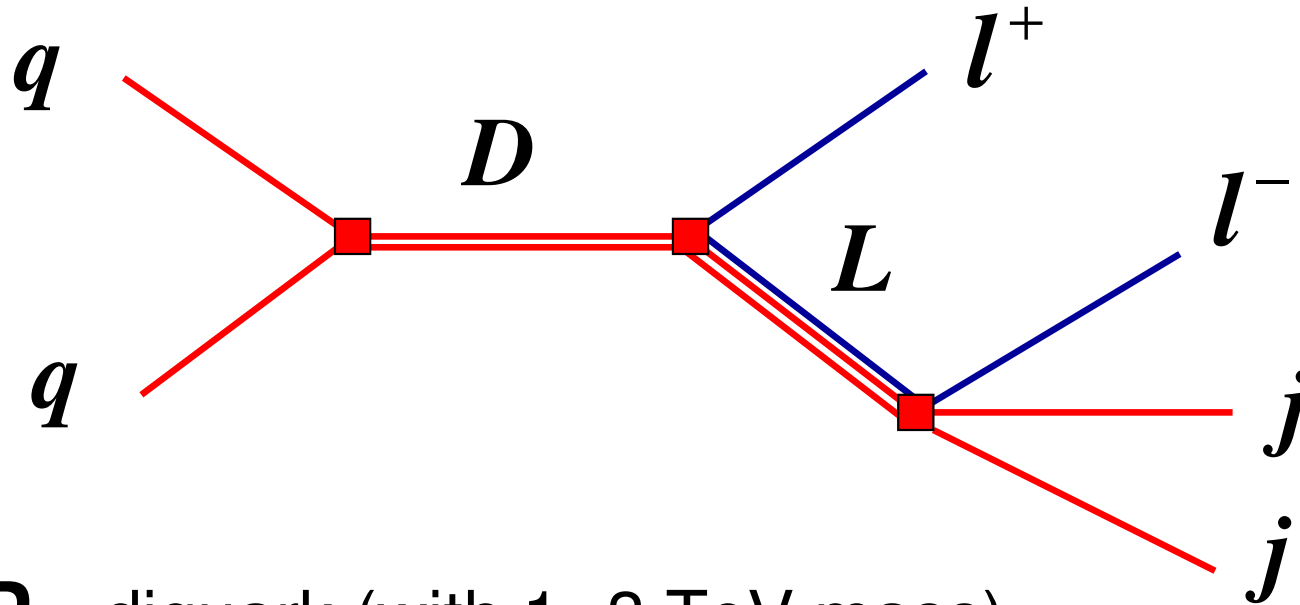
$\Rightarrow \sigma$  too small

# Example 1: electrophobic $Z'$

$$q\bar{q} \rightarrow Z' \rightarrow \mu\bar{\mu}$$

- with  $O(1)$  couplings to **quarks** and **muons**
- mass in 1.5÷2 TeV range
  
- No coupling to **electrons** to avoid LEP-II bounds on 4-fermion operators
- No coupling to **Higgs** to avoid LEP-I bounds on  $Z$ - $Z'$  mixing
- E.g.:  $Z'$  coupled to (anomaly free)  $B-3L_\mu$   
Salvioni, Strumia, Villadoro, Zwirner 0911.1450

# Ex. 2: Diquark+leptodiquark



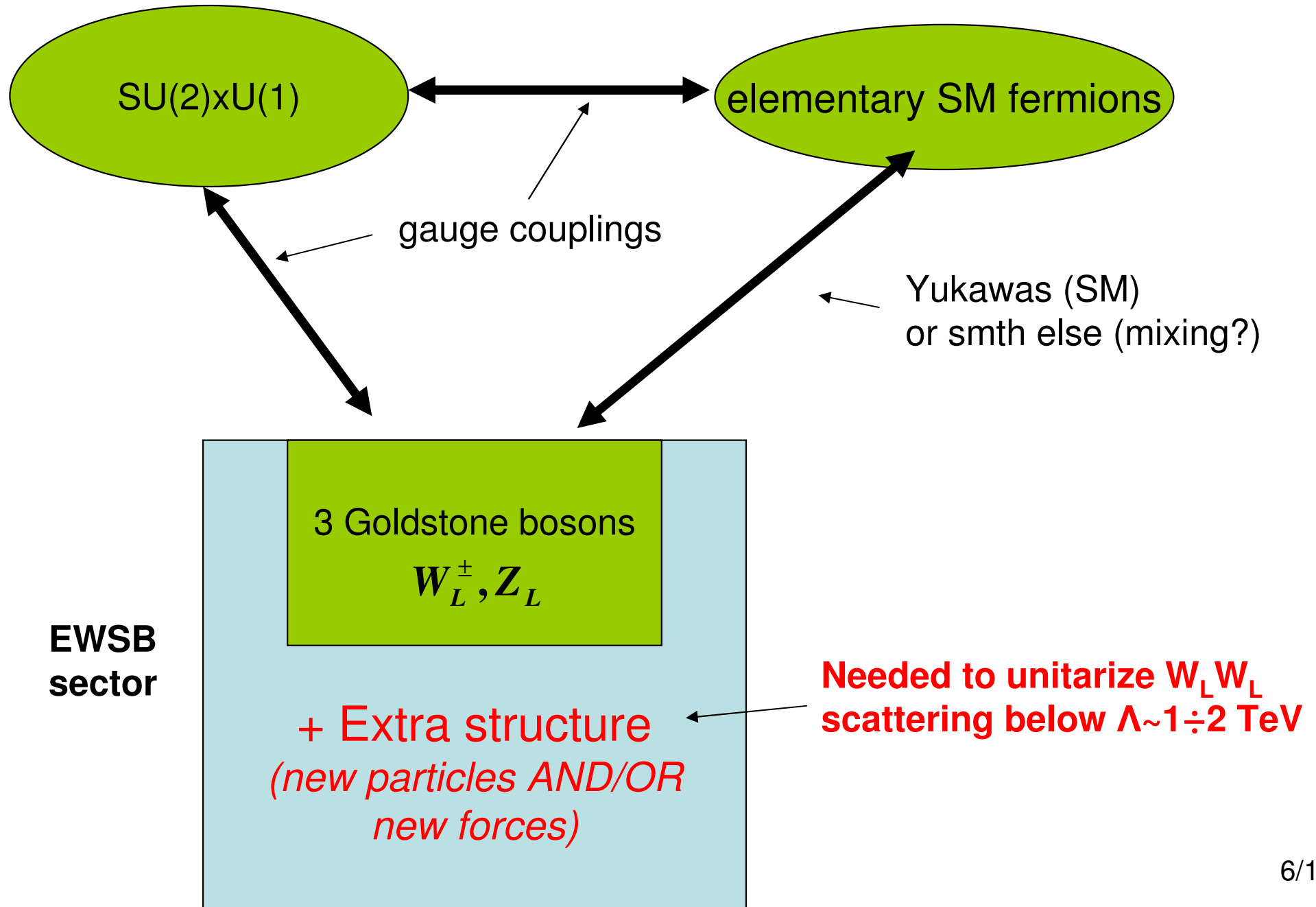
$D$  – diquark (with 1 ÷ 3 TeV mass)

$L$  – leptodiquark

- Renormalizable Lagrangian in 2 lines
- Consistent model (conserves L, B number)

Bauer, Ligeti, Schmaltz, Thaler, Walker 0909.5213

# EWSB : generic structure



Model	Extra structure	Purpose
Standard Model	Higgs boson	Perfect unitarization of $W_L W_L$ scattering

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Minimal SUSY	2HDM extended Higgs sector	Same as above
	<b>Superpartners</b>	<b>Cancel Higgs mass quad. div.</b> (solve hierarchy problem)

# Strong EWSB

Model	Extra structure	Purpose
Strong EWSB ( $\Lambda \sim 1 \div 2$ TeV)	Heavy <b>vector bosons</b> $V^0, V^\pm$ with $M \sim \text{TeV}$ ( <i>techni-<math>\rho</math></i> )	unitarization of $W_L W_L$ scattering (imperfect)
	Heavy <b>non-chiral</b> fermions with $M \sim \text{TeV}$	Give mass to SM fermions via <b>mixing</b> ( <i>partial compositeness</i> )

Model	Extra structure	Purpose
<b>Strongish EWSB</b> ( $\Lambda \sim 10$ TeV)	<b>Pseudo-Goldstone Higgs boson</b>	<ul style="list-style-type: none"> <li>- Partial unitarization</li> <li>- Improves EWPT consistency</li> </ul>
	<b>Heavy vectors</b> $V^0, V^\pm$ with $M \sim \text{few TeV}$	To complete unitarization (still imperfect)
	<b>Heavy non-chiral fermions</b> with $M \sim \text{few TeV}$ (top partners $< \text{TeV}$ )	<ul style="list-style-type: none"> <li>- Give mass to SM fermions via mixing</li> <li>- <b>Cancel top-quark Higgs mass quadratic divergence</b></li> </ul>

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- SM-like Higgs

- in 2HDM at large  $\tan\beta$

- or if new spectacular decay channels

- e.g. lepton jet model:  $H \rightarrow z'z' \rightarrow 4l$

- Gopalakrishna, Jung, Wells 0801.3456

(Higgs portal to a hidden sector;

motivated by astrophysical positron excesses;  
DM annihilation into  $z'z'$ ?)

# (NO) Heavy vector bosons of strong EWSB

- coupling to  $q\bar{q}$  only via **small** mixing with Z
- dominant decay to  $W_L W_L$  (like heavy Higgs)

=> need 50-100 fb<sup>-1</sup>

# (YES) Heavy quarks of strong EWSB

$T^{2/3}, B^{-1/3}$  subject to the usual  $t', b'$  searches

CMS-PAS-EXO-09-012

Top partners with exotic charges:  $T^{5/3}$

Contino, Servant 0801.1679; CMS-PAS-EXO-08-008

$$T^{5/3} \rightarrow W^+ t \rightarrow W^+ W^+ b$$

=> same sign dileptons

# Conclusions

- With  $10 \text{ pb}^{-1}$ , go for super-models
- With  $1 \text{ fb}^{-1}$ , go for
  - large  $\tan \beta$ ,
  - higgs into lepton jets  $H \rightarrow z' z' \rightarrow 4l$
  - heavy vector-like quarks ( $t', b', T^{5/3}$ )



# Backup slides

