How to tell apart non-standard EWSB mechanisms

Veronica Sanz
CERN and YORK
Moriond 2012

In this talk

What is standard?

EWSB by elementary scalar(s)

includes SM and SUSY

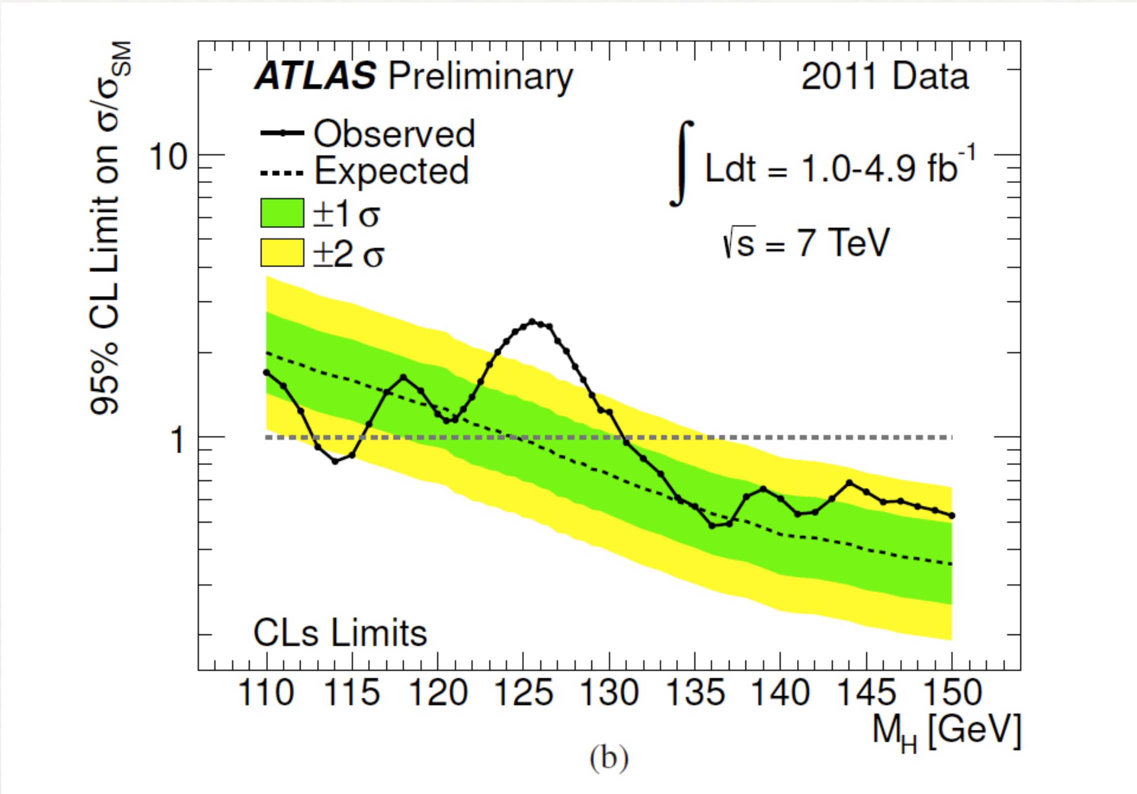
What is non-standard?

EWSB by
-composite scalar
- no scalar at all

includes Little Higgs, Extra-Dimensions and Technicolor

Composite Scalar - Motivation

What if there is a Higgs?



(b)

Light scalar

Need stabilization mechanism

(or we have no clue about QFT)

Symmetries

Fermionic SUSY

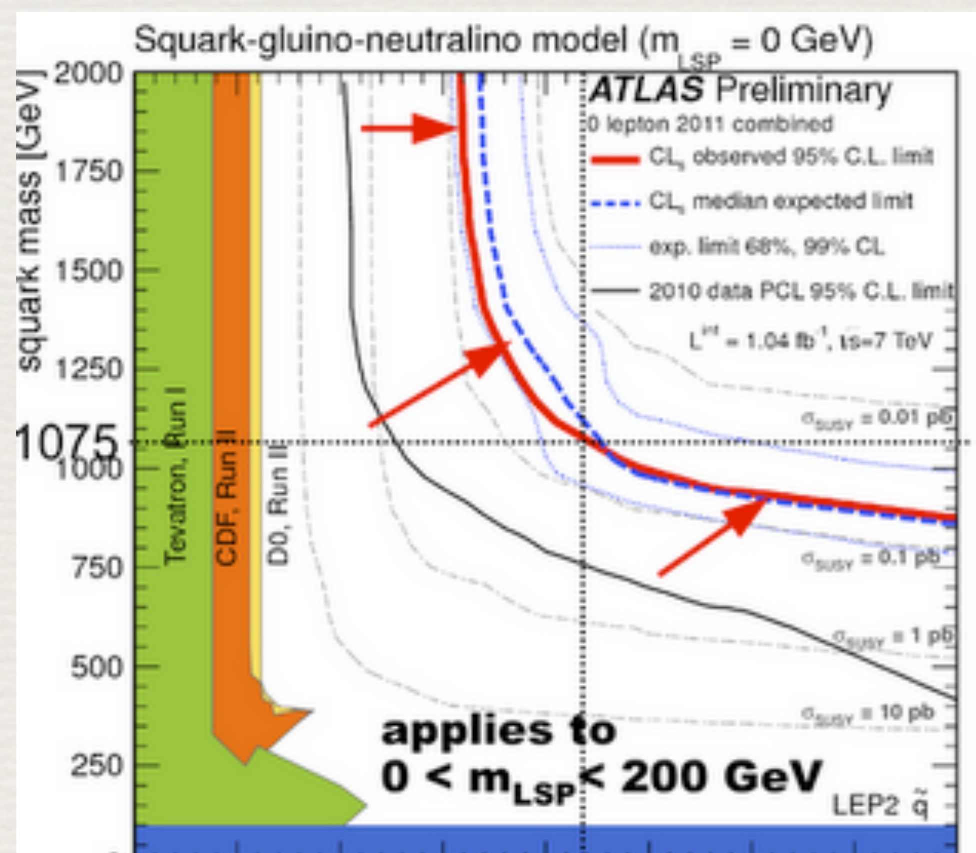
Bosonic Goldstone

since SUSY may not be there to save the day

Higgs as a PGB

like the pion of QCD

composite Higgs



Composite Scalar - Realizations

Composite Higgs is realized in
Little Higgs, Extra-Dimensions and Technicolor

symmetry PGB
-Little Higgs, TC: new 4D symmetry
-Extra-dimensions: SM 5D gauge= 4D gauge+GB

Composite Scalar-Generic features

scalar resonance WW unitarization

non-SM scalar: deviations

$$\xi = \frac{v^2}{f^2}$$ degree of fine-tuning

Giudice, Grojean, Pomarol and Rattazzi '07

Theory study 300 ifb @ 14 TeV for $\xi > 0.2$

$4\pi f$

f

v

composite Higgs
already unitarize WW

$\xi \to 0$ SM-like

generic features are too SM-like

Composite Scalar-Common features

s=1 ex. Z', ρ_{TC}, Z_{KK}

not crucial for WW scattering

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Extra-Dimensions and TC-type → see next

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s=1/2

ex. T, Q_{KK}, techni-baryons

New heavy quarks
mix with SM quarks

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light quarks

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New heavy quarks mix with SM quarks → 3rd gen → 4th gen?

New heavy quarks mix with SM quarks → light quarks → see next

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Guimaraes, Fok, Lewis, VS
in preparation

i.e. massive spin-2 resonance = smoking gun of extra-dimensions?

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G	$\hat{G}$
KK-graviton	TC-type impostor

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c_i overlap G with fields i and $M \sim$ TeV

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Lorentz and gauge → no dimension-4

flavor and CP invariant → dimension-5 same as in $T_{\mu\nu}$

$\hat{G}$ couples like G

same spin determination

How do we distinguish them?

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$$R_{g/\gamma} = \frac{Br(\to gg)}{Br(\to \gamma\gamma)} = \frac{8c_g^2}{c_\gamma^2}$$

In any extra-dimension of the type

$$ds^2 = w(z)^2 \left(\eta_{\mu\nu} dx^\mu dx^\nu - dz^2\right)$$

↓ example UED,RS

$$G: \quad R_{g/\gamma} = 8$$

$\hat{G}$ can produce any other ratio

How to tell apart 1st generation RH or LH compositeness?

Martin and VS JHEP (2010)
Redi,VS, Weiler in preparation

Composite baryons and elementary quarks mix

$$\mathcal{L}_{mixing} = \lambda^u_{L,R}\, u_{L,R} \bar{U}_L + (u \to d) \qquad y \propto \lambda_L \lambda_R$$

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1st generation compositeness! Flavor?

MFV if composite sector flavor invariant

Redi, Weiler '11

- Left-handed compositeness: $\lambda_{Lu} \propto Id\,, \quad \lambda_{Ld} \propto Id$
  $\lambda_{Ru} \propto y_u\,, \quad \lambda_{Rd} \propto y_d$
- Right-handed compositeness: $\lambda_{Lu} \propto y_u\,, \quad \lambda_{Ld} \propto y_d$
  $\lambda_{Ru} \propto Id\,, \quad \lambda_{Rd} \propto Id$

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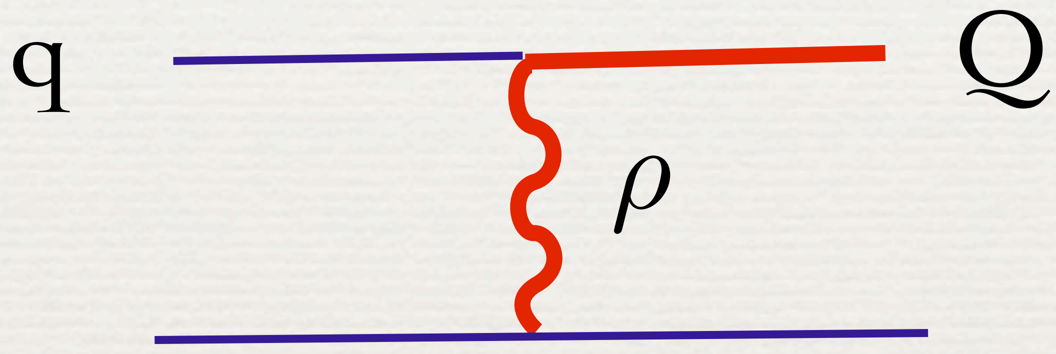
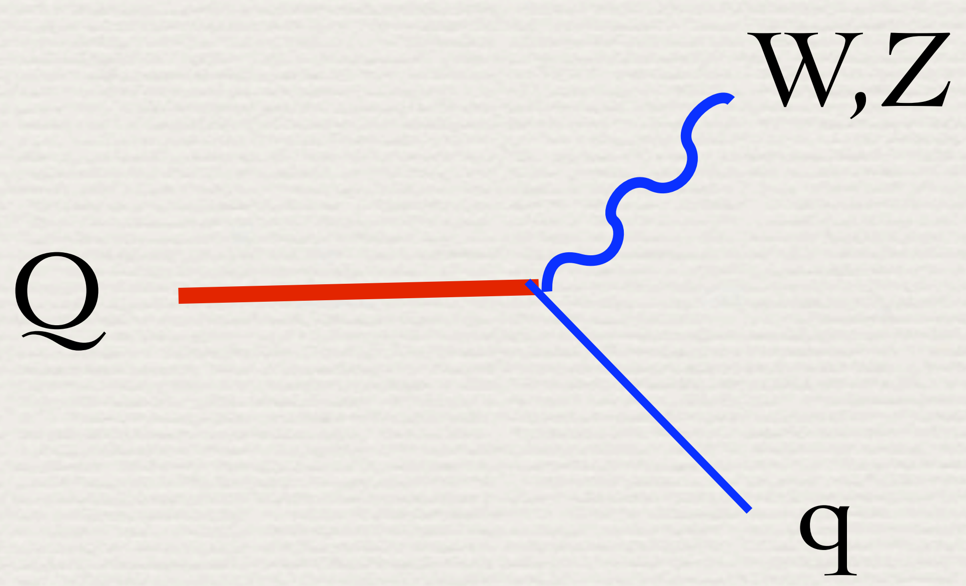
MFV ⟶ half of the proton could be composite

How to tell apart 1st generation RH or LH compositeness?

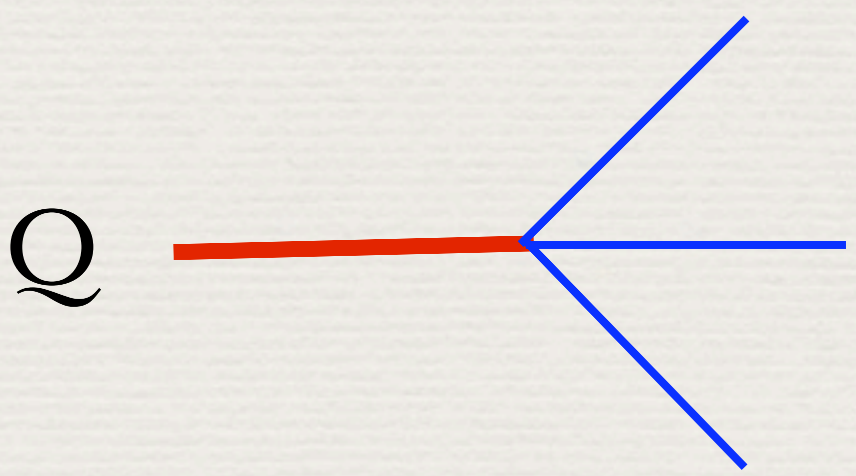
Signature: single production heavy quark



LH compositeness



RH compositeness



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LH compositeness

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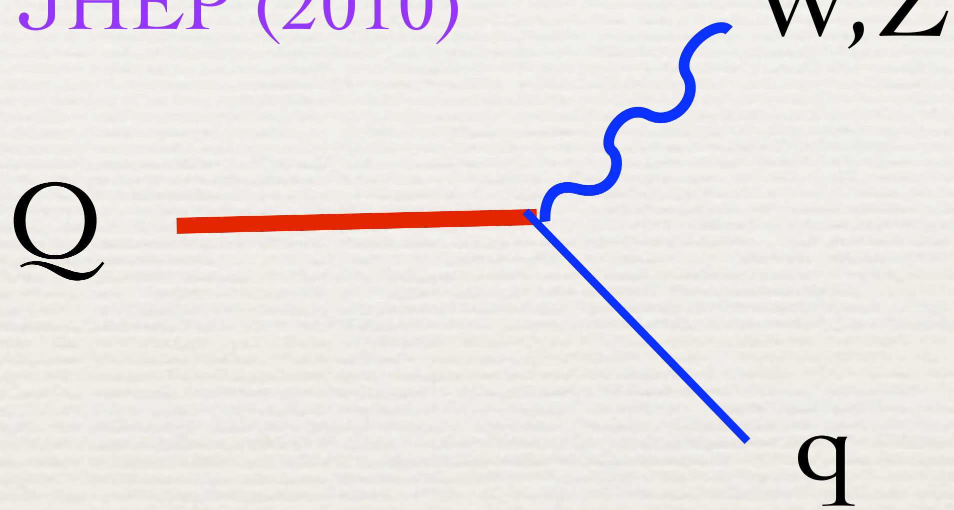
JHEP (2010)



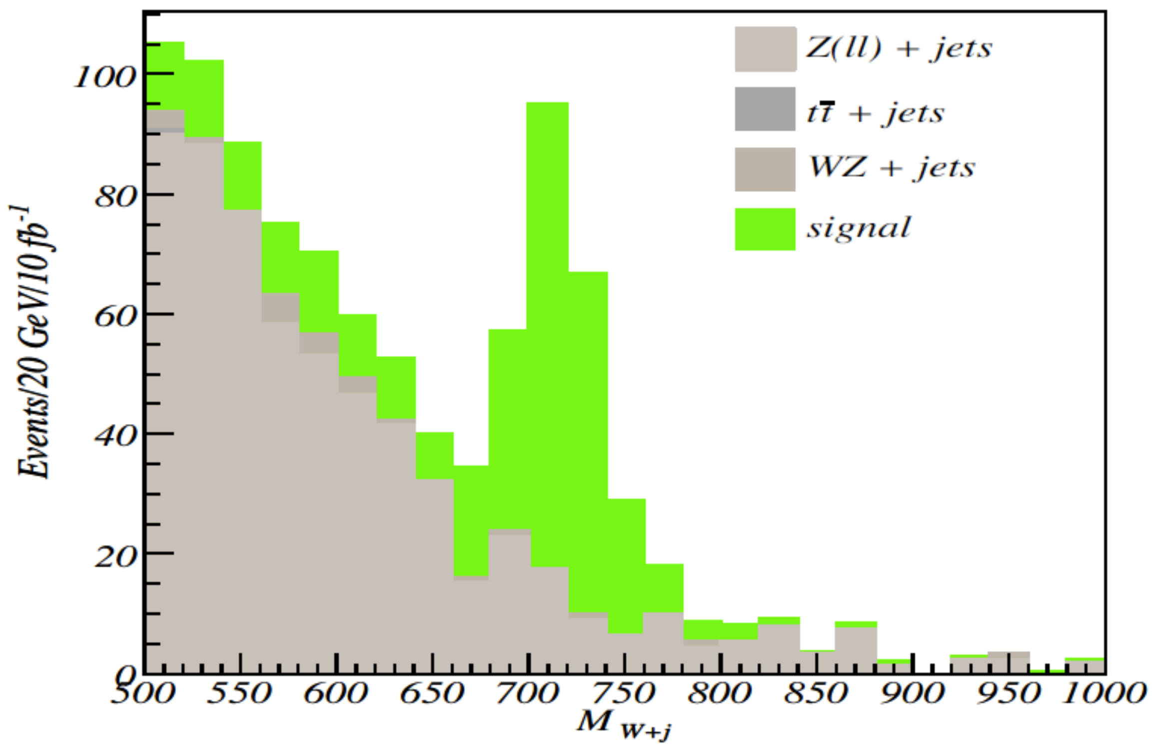


Figure 11: Single production invariant mass reconstruction in the 2 ℓ + 2 j channel.

1. $n_\ell = 2$, same-flavor, opposite sign leptons and $m_{\ell\ell} = m_Z \pm 20$ GeV
2. $n_j \geqslant 2$, where $p_{T,2nd\,j} > 100$ GeV, $H_{T,j} > 800$ GeV and $m_{jj} < 45$ GeV or $m_{j,j} >$125 GeV
3. $\Delta R_{Z,j} < 2$ for the nearest jet
4. $\not{E}_T < 150$ GeV
5. $m_{Z,j} > 500$ GeV

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LH compositeness

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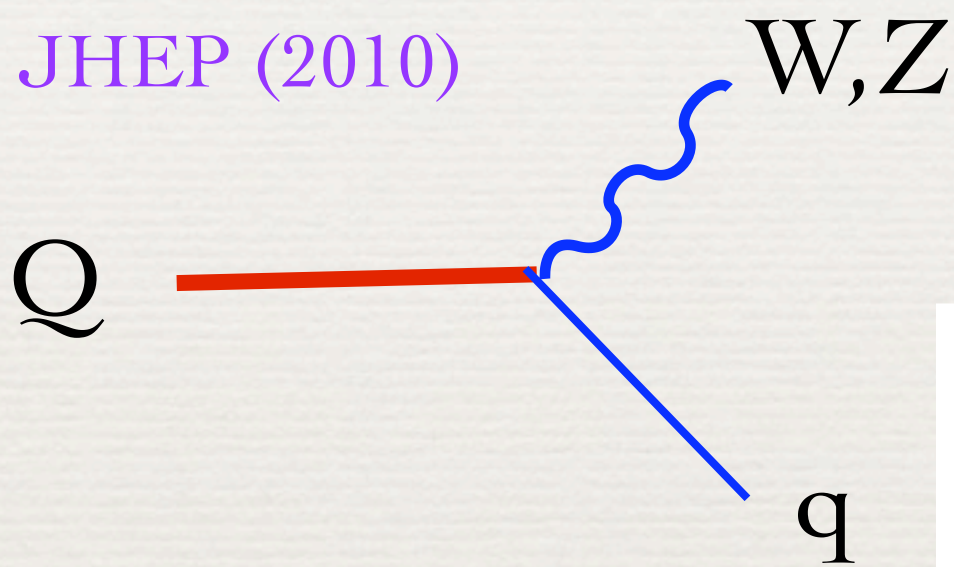
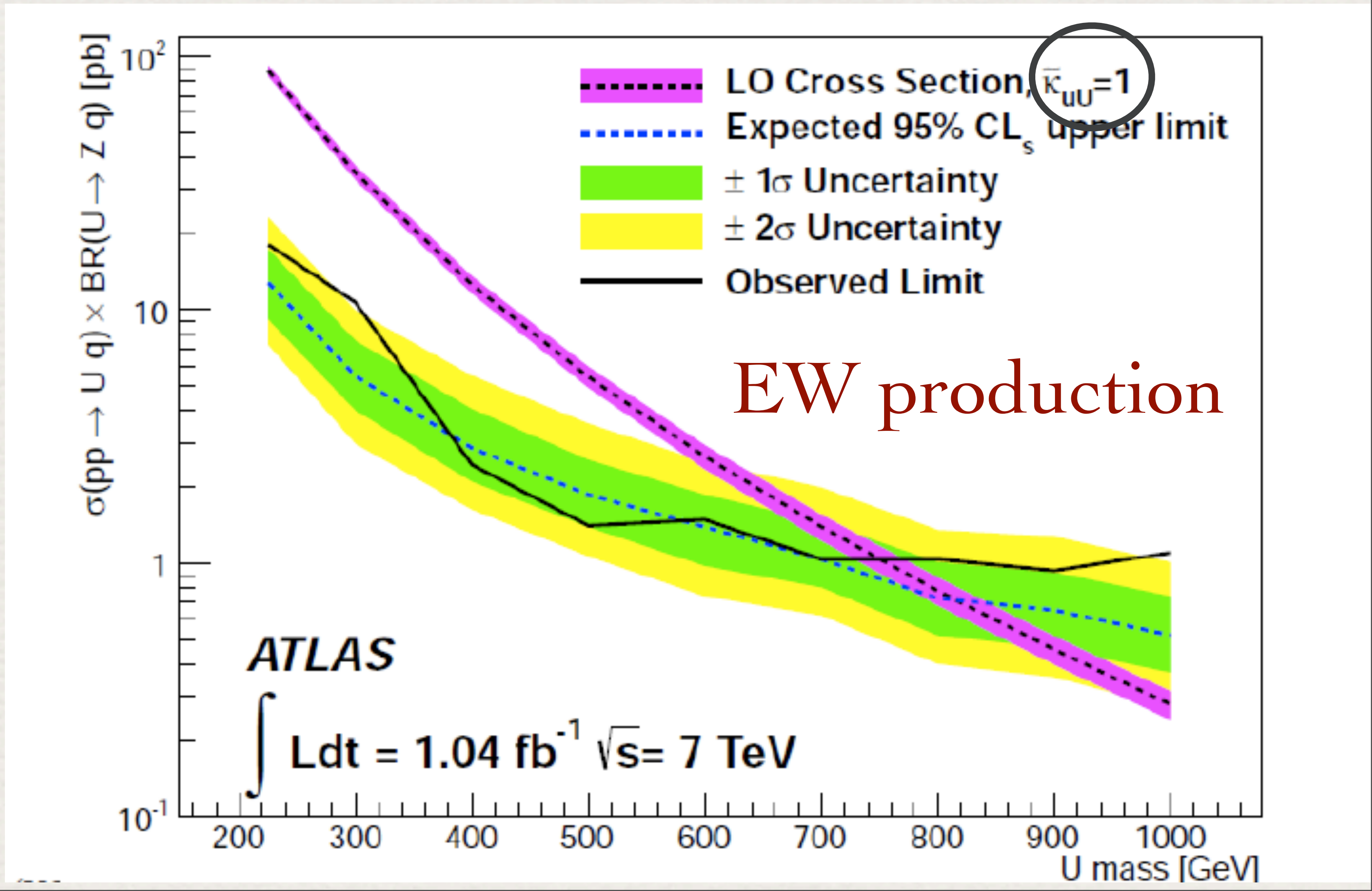


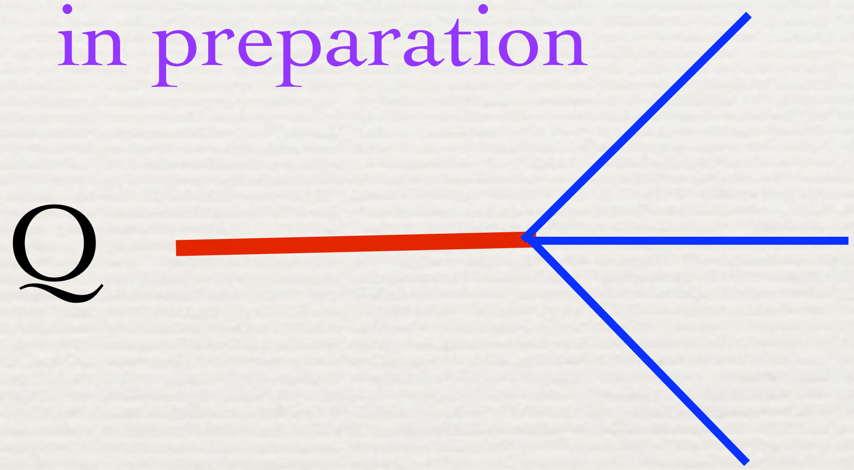
ATLAS-PH-EP-2011-193.
Lepton channel w/ 1 ifb.

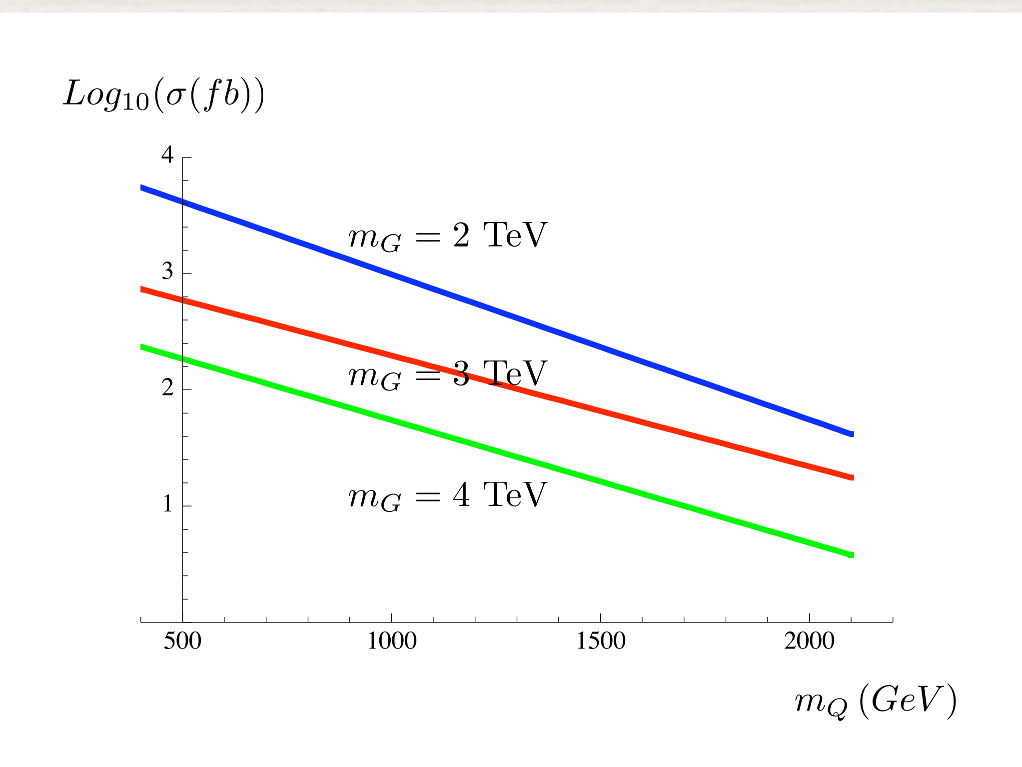


How to tell apart 1st generation RH or LH compositeness?

RH compositeness

Redi, VS, Weiler
in preparation





Looking at current bounds and discovery prospects

BGs: multijet, W+jets, Z+jets, top pair and single top

ATLAS-PH-EP-2011-154

Rejection: exclude dijet near W or Z and veto b-tagging, cut on leading jet

QCD generated with ALPGEN -> PYTHIA
signal xsecs mQ=1 TeV, mG=2 TeV

Cuts	QCD 4 jets (fb)	Signal (fb)
basic cuts	2×10^9	1300
$p_T^{lead} > 700$, $p_T > 200$	100	354
$p_T > 200$	2900	556
$p_T > 100$	3.5×10^5	1040
$p_T^{lead} > 500$, $p_T > 100$	9000	830
$p_T^{lead} > 500$, $p_T > 200$	670	495

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RH compositeness

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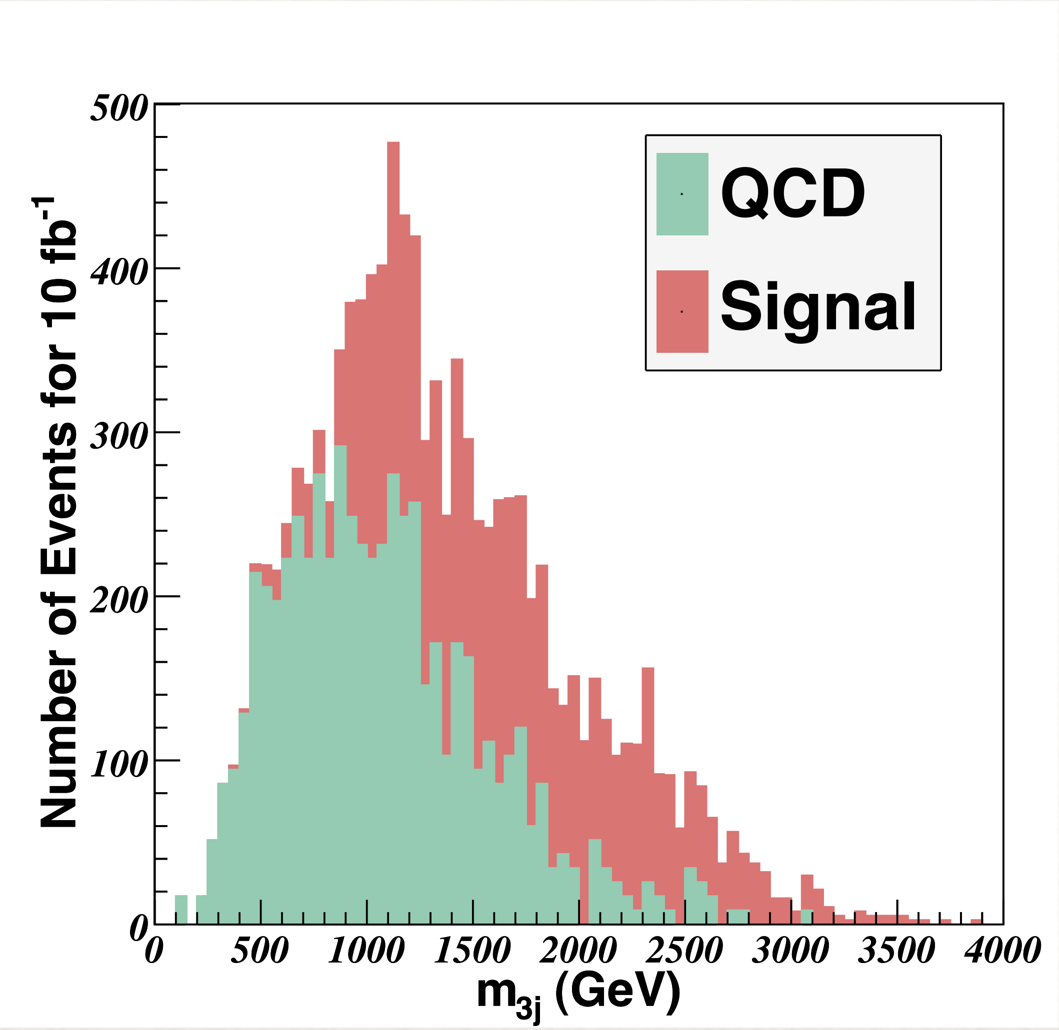
We use two methods: deltaR and leading jet optimized for high-low mQ



No Scalar-Generic features

Realized in warped extra-dimensions and TC-type

s=1 resonances do unitarize WW scattering

THE problem: S parameter

solutions do not abound

- Non-calculable, ignore TCSM — Eichten, Lane Phys. Lett. B '89
- Mechanisms to cancel, warped models
  - Cured Higgsless — Cacciapaglia et al Phys. Rev. D '05

    (s=1)-(s=1/2) cancellation
  - Holographic TC — Hirn,VS Phys. Rev. Lett. '06

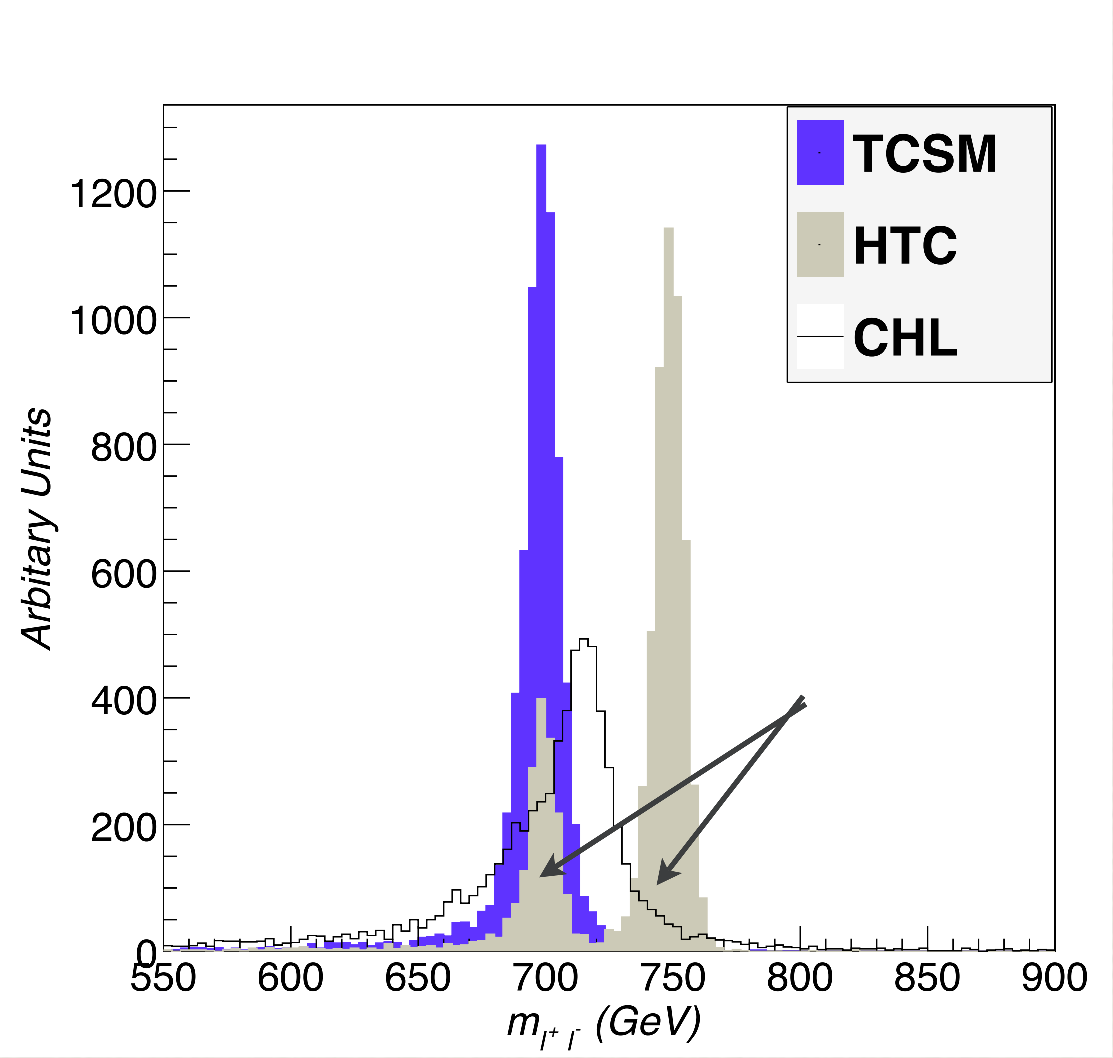
    s=1 cancellation

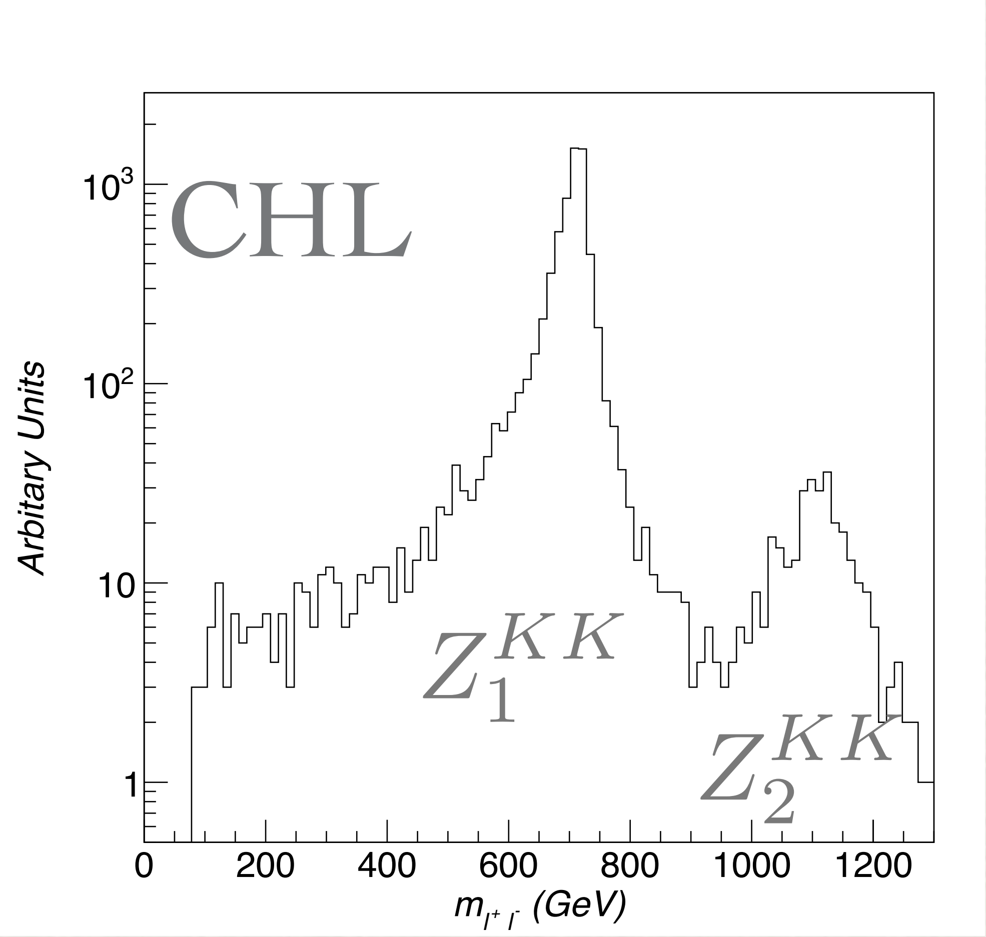
How to tell apart scenarios of dynamical EWSB?

In dileptons...

Banerjee, Martin and VS
JHEP (2012)

1. Invariant mass





MG> PYTHIA> ATLFAST and DELPHES
@7 TeV

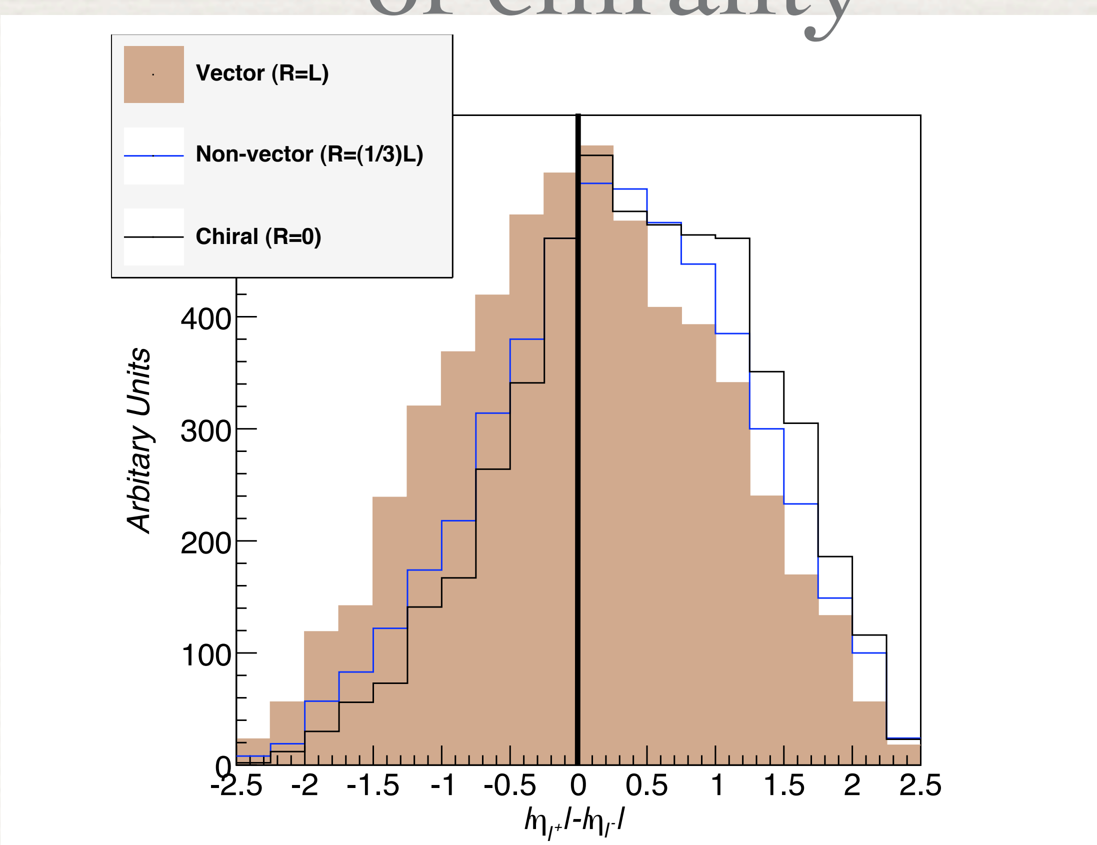
How to tell apart scenarios of dynamical EWSB?

2. Charge asymmetry

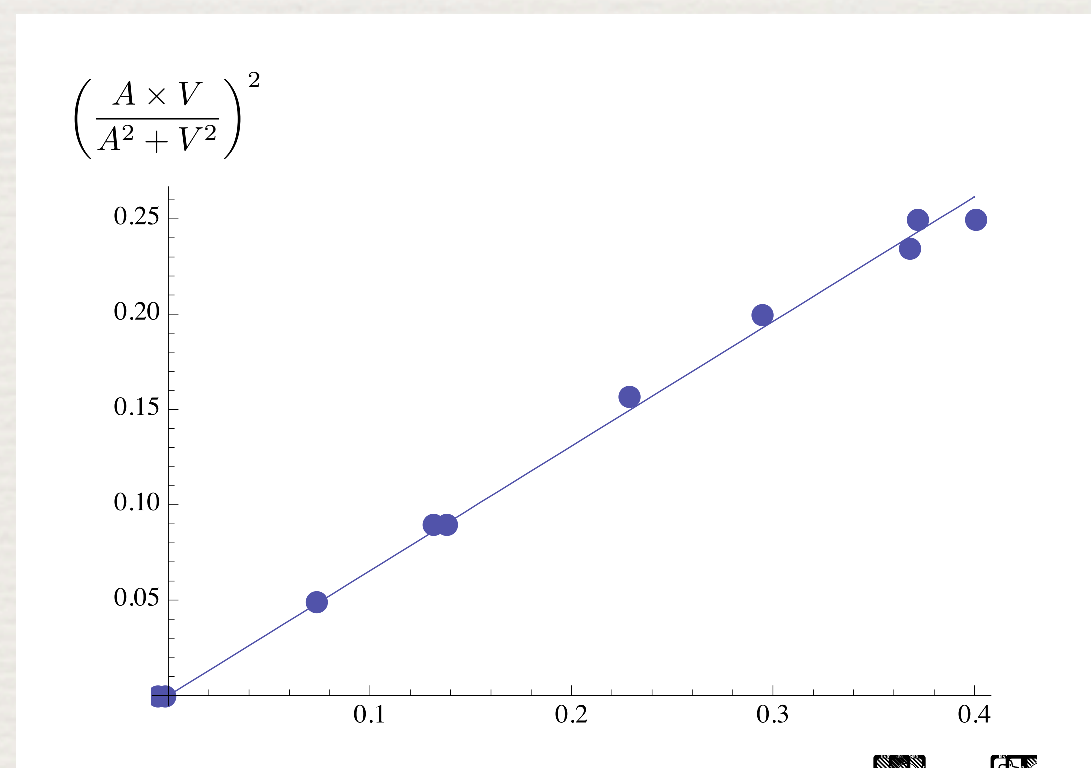
Banerjee, Martin and VS
JHEP (2012)

$$A_{\rm charge} = \frac{N(\Delta\eta > 0) - N(\Delta\eta < 0)}{N(\Delta\eta > 0) + N(\Delta\eta < 0)} \qquad \Delta\eta = |\eta_{\ell+}| - |\eta_{\ell-}|$$

eta asym is a good measure of chirality



can tell V,A admixture



A after simulation

Conclusions

- Non-standard EWSB ideas abound and have a very rich phenomenology.
- May not be easy to discover by just looking at scalar EWSB sector. Need correlations with other signals.
- Tell apart Extra-Dimensions from TC-type: gravitons and its impostor
- Tell apart 1st gen RH or LH compositeness in multijets
- Tell apart different scenarios of DEWSB in dileptons

Operators

	$\hat{O}^{decay}_{\mu\nu}$	CP	coefficients
(a)	$\bar{\psi}\sigma_{\mu\nu}\psi$	$-$	$\hat{c}^a_f$
(b)	$\bar{\psi}\gamma_\mu\partial_\nu\psi$	$+$	$\hat{c}^b_f$
(c)	$\bar{\psi}\gamma^5\gamma_\mu\partial_\nu\psi$	$-$	$\hat{c}^c_f$

nionic operators up to dimension 5 that could lead to two-body
ntribute to $\hat{G}$ decay because $\hat{G}^{\mu\nu}\sigma_{\mu\nu} = 0$. As long as we consi
ily, (c) must vanish as they are CP odd. The only remaining oper
elative 4-momenta of the fermions because of the gauge conditio
term in the Lagrangian is $c^b_f \hat{G}^{\mu\nu}\hat{O}^{decay}_{\mu\nu}$. Expressions for the coeff

	$\hat{O}^{decay}_{\mu\nu}$	CP	coefficients
(a)	$F_\mu^{\ \rho} F_{\rho\nu}$	$+$	$\hat{c}^a_A$
(b)	$\epsilon_{\alpha\beta\mu\delta} F_\nu^{\ \delta} F^{\alpha\beta}$	$-$	$\hat{c}^b_A$
(c)	$F_{\mu\nu}$	$+$	$\hat{c}^c_A$
(d)	$\partial_\mu H\, \partial_\nu H$	$+$	$\hat{c}_\phi$

ratio to gluons
gluon-jet from quark-jet?

1. most models: G coupling to light quarks suppressed

2. Angular correlations

$$\frac{d\sigma}{d\cos\theta^*}(q\bar{q} \to G) = \quad 1 + c_{\theta*}^2 \left(1 - 4s_{\theta*}^2\right) \text{ to fermions}$$

$$= \quad 1 - c_{\theta*}^4 \text{ to gluons },$$

3. Tag light jet using Galliccio-Schwartz techniques