The Zürich Phenomenology Workshop
Zürich, Jan 9-11, 2012

New Higgs Production Mechanism in Composite Higgs Models

José Santiago

Física Teórica y del Cosmos
Universidad de Granada

A. Carmona, M. Chala, J.S. in preparation

Outline

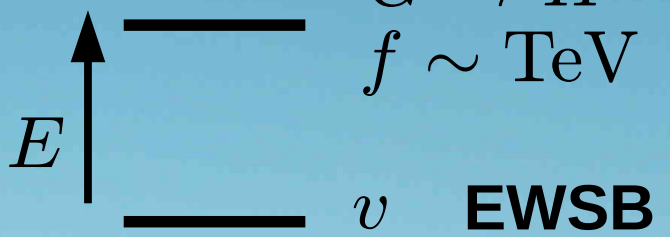
- Composite Higgs Models
- Resonances in Composite Higgs Models
- New Quark Production Mechanism
  - Stealth gluon
- New Higgs Production Mechanism
- Which Higgs?
- Sample case
- Conclusions

Composite Higgs Models

- The Higgs boson is a composite state of a new strongly coupled interaction

H

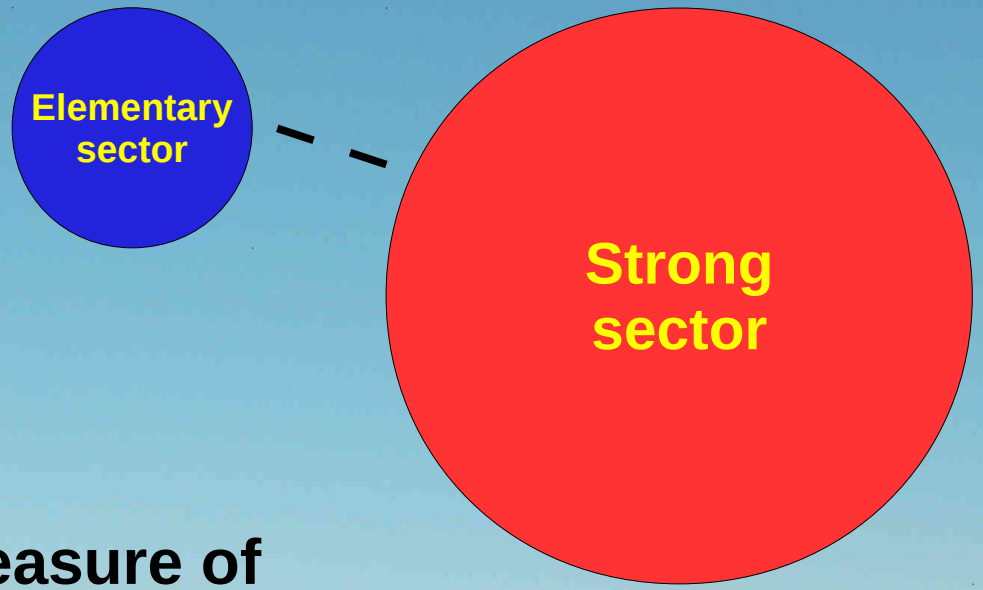
Higgs mass protected by its finite size
Extra protection if Higgs is a pseudo Goldstone boson



$\mathrm{SM} \subset H$

$$\xi \equiv \frac{v^2}{f^2}$$

Measure of compositeness



New Resonances in CHM

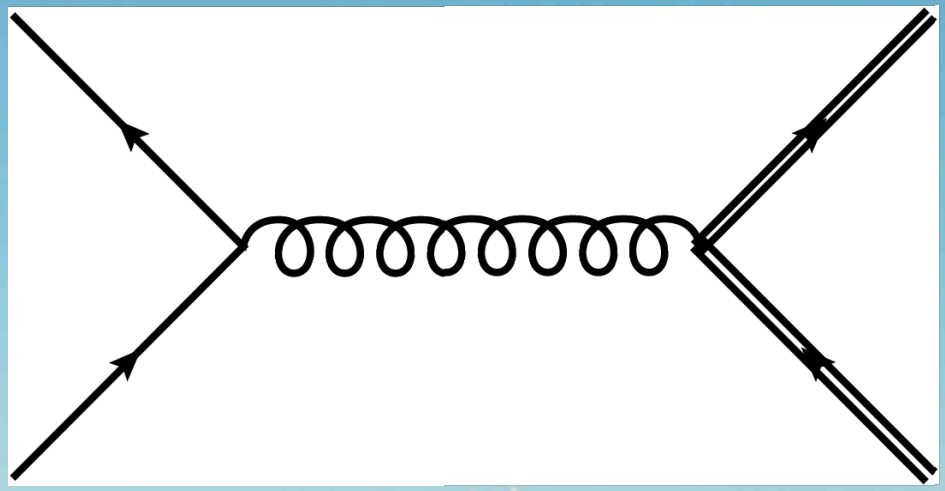
- Vector Resonances:
  - Unitarization
  - EWPT
  - Can be coloured
- Fermion Resonances:
  - Naturalness
  - EWPT
  - Naturally light
- Other resonances:
  - Scalar, tensor, ...

Agashe, Contino, Pomarol '04, Contino, Da Rold, Pomarol '06, Carena, Ponton, Santiago, Wagner '06-'07, Barbieri, Bellazzini, Rychkov, Varagnolo '07, Lodone '08, Pomarol, Serra '08, Gillioz '08, Barbieri, Isidori, Pappadopoulo '08, Anastasiou, Furlan, Santiago '09, Panico, Wulzer '11, De Curtis, Redi, Tesi '11, Contino, Marzocca, Pappadopoulo, Rattazzi '11,
...
...
...

New Quark Production Mechanism

- New fermion resonances can be:
  - Pair produced (QCD)

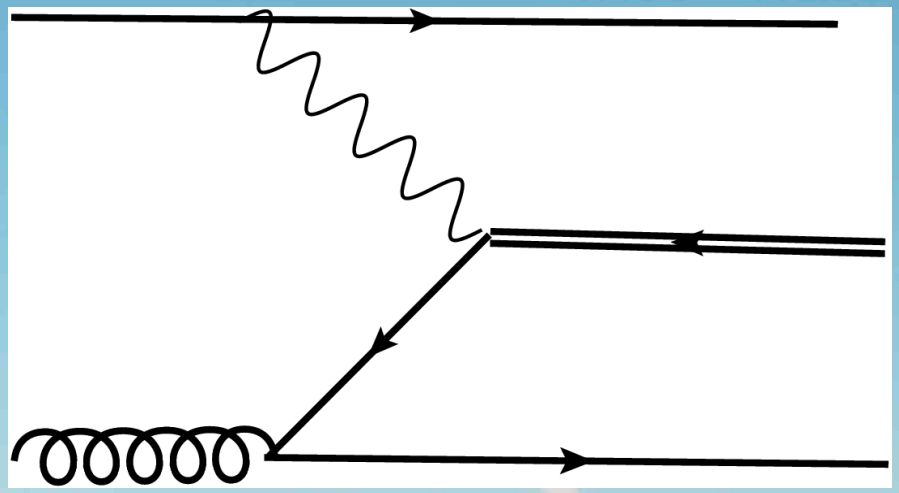
...
...
Contino, Servant '08
Aguilar-Saavedra '09
Dissertori, Furlan, Moortgat, Nef ' 10

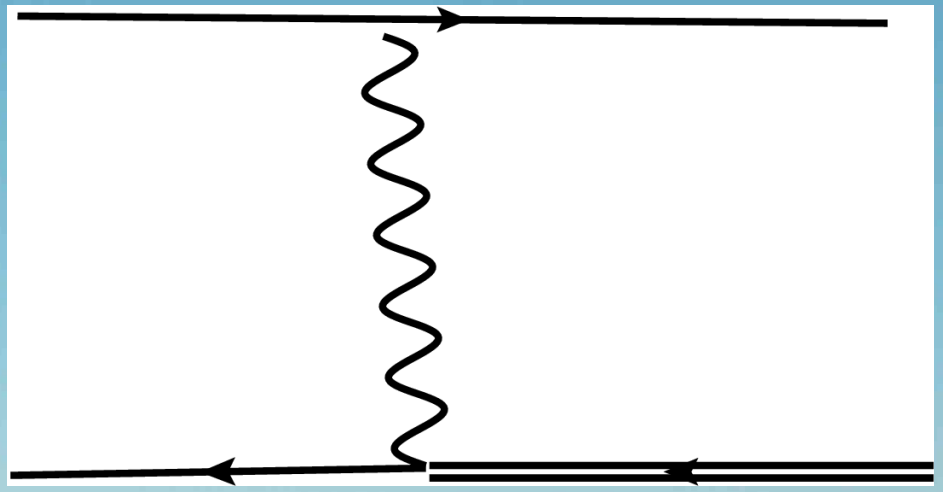


New Quark Production Mechanism

- New fermion resonances can be:
  - Pair produced (QCD)
  - Singly produced (EW)

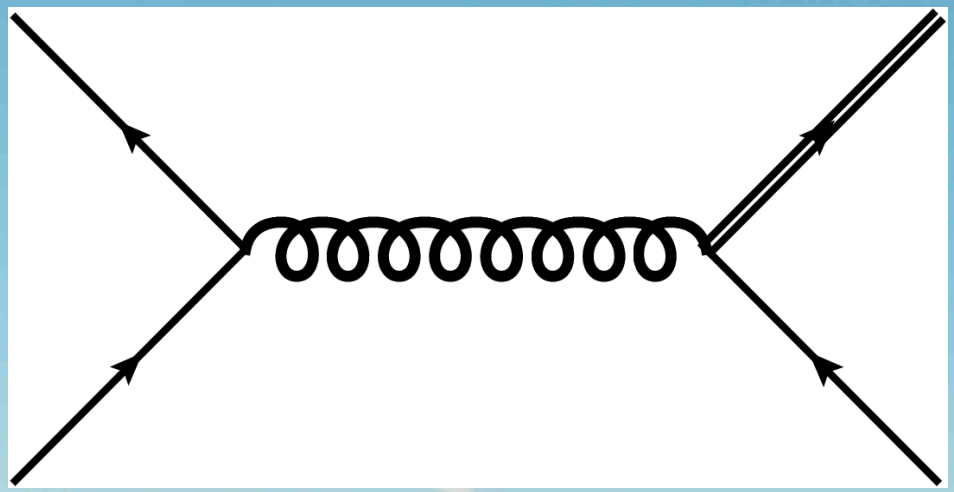
Atre, Carena, Han, Santiago '08
Mrazek, Wulzer '09
Atre, Azuelos, Carena, Han, Ozcan, Santiago, Unel '11





New Quark Production Mechanism

- New fermion resonances can be:
  - Pair produced (QCD)
  - Singly produced (EW)
  - Singly (or pair) produced via vector resonances

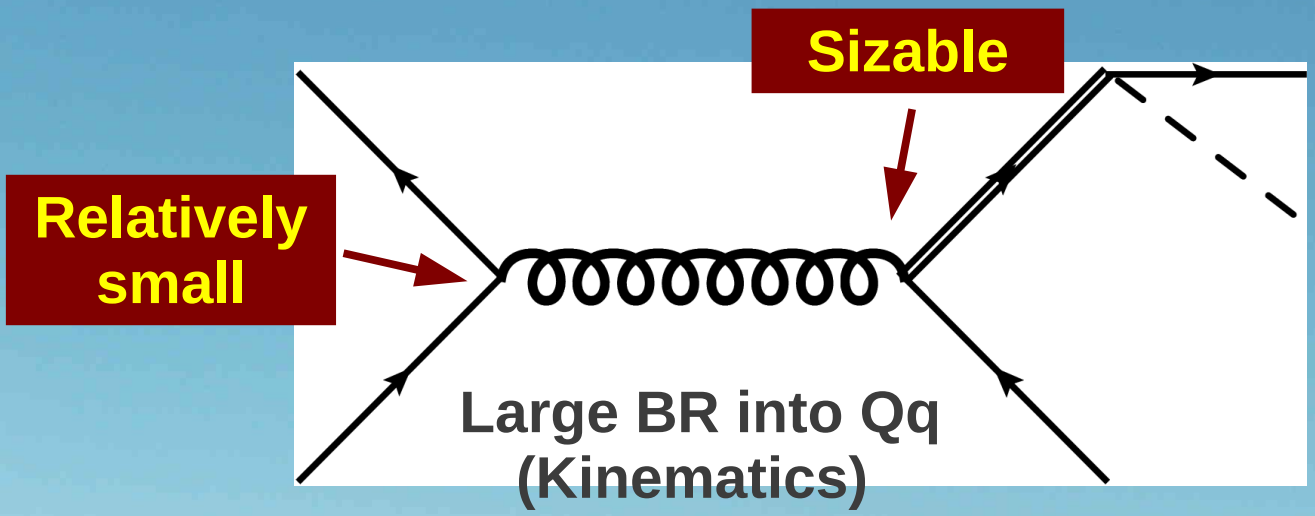


Barcelo, Carmona, Chala, Masip, Santiago '11
Bini, Contino, Vignaroli '11

New Quark Production Mechanism

- New fermion resonances can be:
  - Single production via vector resonances

Barcelo, Carmona, Chala, Masip, Santiago '11
Bini, Contino, Vignaroli '11



$$Wq \approx 50\%$$
$$Zq \approx 25\%$$
$$Hq \approx 25\%$$

  - 3rd Generation (composite top) — Pomarol, Serra '08, ...
  - Light quarks (MFV in CHM) — Redi, Weiler '11

Stealth Gluon

- Can explain the top Forward-Backward asymmetry
  - Light gluon with small axial couplings to light quarks and sizable couplings to new light vector-like quarks

$$M_G \sim 850 \text{ GeV}$$

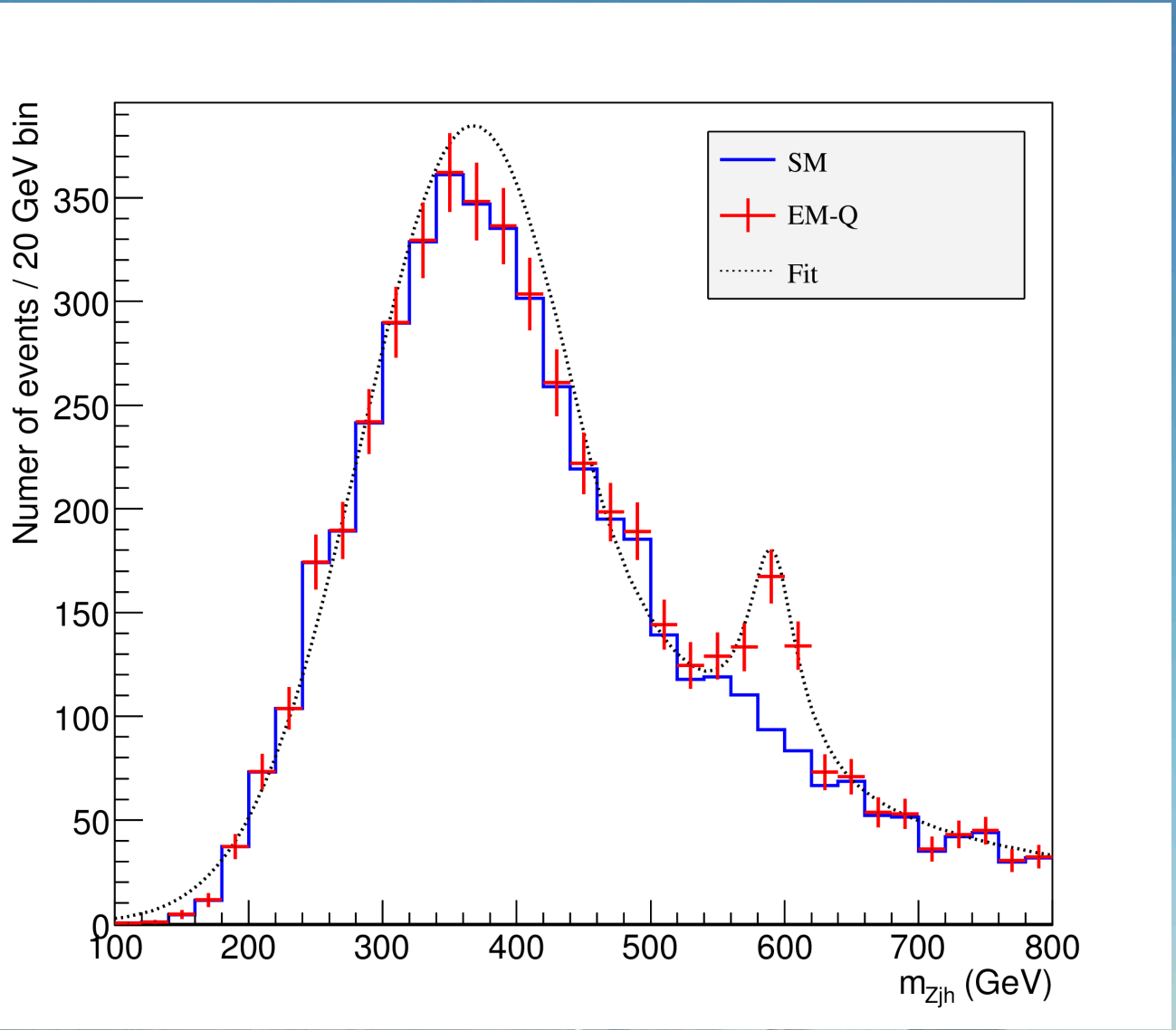
$$\Gamma(M_G) \sim 0.7 M_G$$

New channels (qQ) open up at 600 GeV

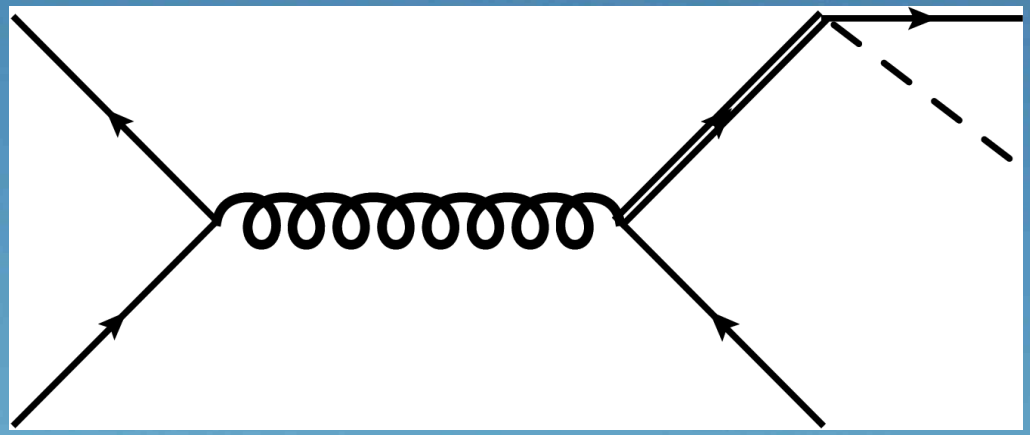
- Difficult to see with current analyses but can be fully probed with dedicated analyses (W,Z channels)

Barcelo, Carmona, Masip, Santiago '11
Barcelo, Carmona, Chala, Masip, Santiago '11

Stealth Gluon



New Higgs Production Mechanism



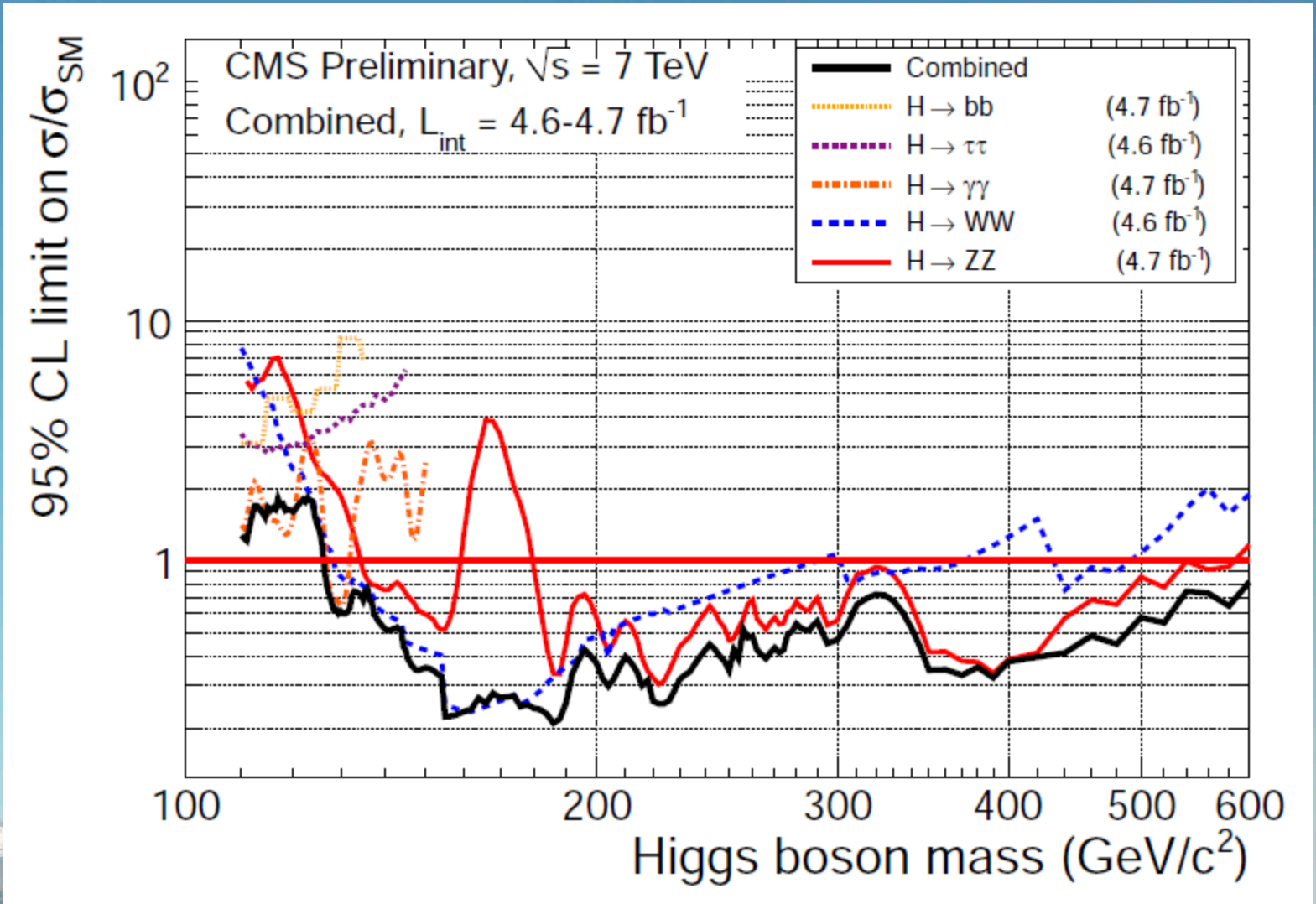
- Higgs decays previously unexplored in this channel

  Aguila, Kane, Quiros '89, Aguila, Ametller, Kane, Vidal, '90, Aguilar-Saavedra '06 (QQ QCD pair production)

- Production cross section can be sizable (quite independent of Higgs compositeness)
- Kinematics is very distinctive
- Can provide further info on the composite sector

Which Higgs?

CMS: HIG-11-032-pas



Which Higgs?

- If SM-like (small compositeness)

$$128\ \mathrm{GeV} \leq m_H \leq 525\ \mathrm{GeV}\ \text{excluded at}\ 99\%\ \mathrm{CL}$$

  - Htt is the only relevant channel
- If compositeness is non-negligible new possibilities open up: **Espinosa, Grojean, Mühlleitner '10 + private communication**
  - $m_H \approx 133\ GeV, \quad \xi = 0.2 - 0.3$ in MCMH_5
  - $m_H \approx 310\ GeV, \quad \xi = 0.2 - 0.3$ in MCMH_5
  - Gluon fusion quite suppressed $\approx (1-2\xi)^2/(1-\xi)$
  - VBF suppression $\approx \xi$ (but kinematics very different)
- Many more in non-minimal CHM **Chala, Santiago, in preparation**

Gripaios, Pomarol, Riva, Serra '09, Mrazek, Pomarol, Rattazzi, Redi, Serra, Wulzer '11

Sample case

- Hevy Higgs: $m_H \approx 310\ GeV, \quad \xi = 0.3$ in MCMH_5
- BR as in SM (only VV relevant final states)
- Gluon fusion reduced by ~80%
- VBF reduced by ~30%

$$M_G = 1.5\ \mathrm{TeV}, \quad M_Q = 750\ \mathrm{GeV}$$

- Couplings taken from **Redi, Weiler '11**

	$\sigma_{SM}[10\%\ \mathrm{VBF}]$
$\sigma(pp \to Hqq \to W^+W^-qq) \approx 0.5\ \mathrm{pb}$	$1.4\ \mathrm{pb}$
$\sigma(pp \to Hqq \to ZZqq) \approx 0.2\ \mathrm{pb}$	$0.6\ \mathrm{pb}$

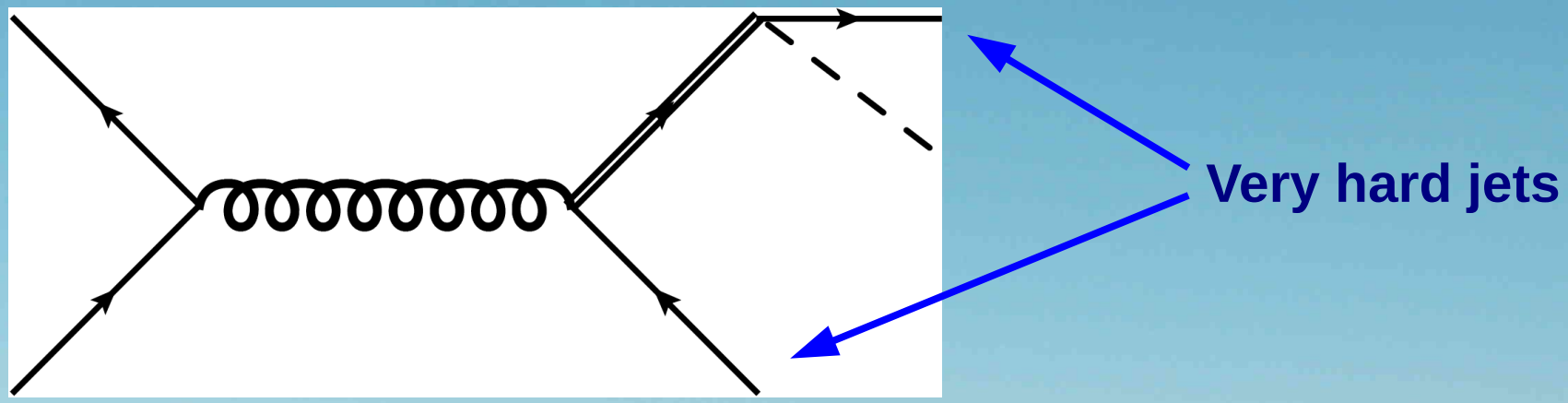
- Very clean signal (SM-like plus very hard jets)

Sample case

- Simulations done with:
  - Madgraph 4 (signal)
  - Alpgen (backgrounds)
  - PYTHIA (showering/hadronization)
  - Delphes (detector simulation)
- Main backgrounds considered:
  - W,Z + 1-4 jets
  - tt+0-4 jets
  - ZZ, WW, WZ + 0-2 jets

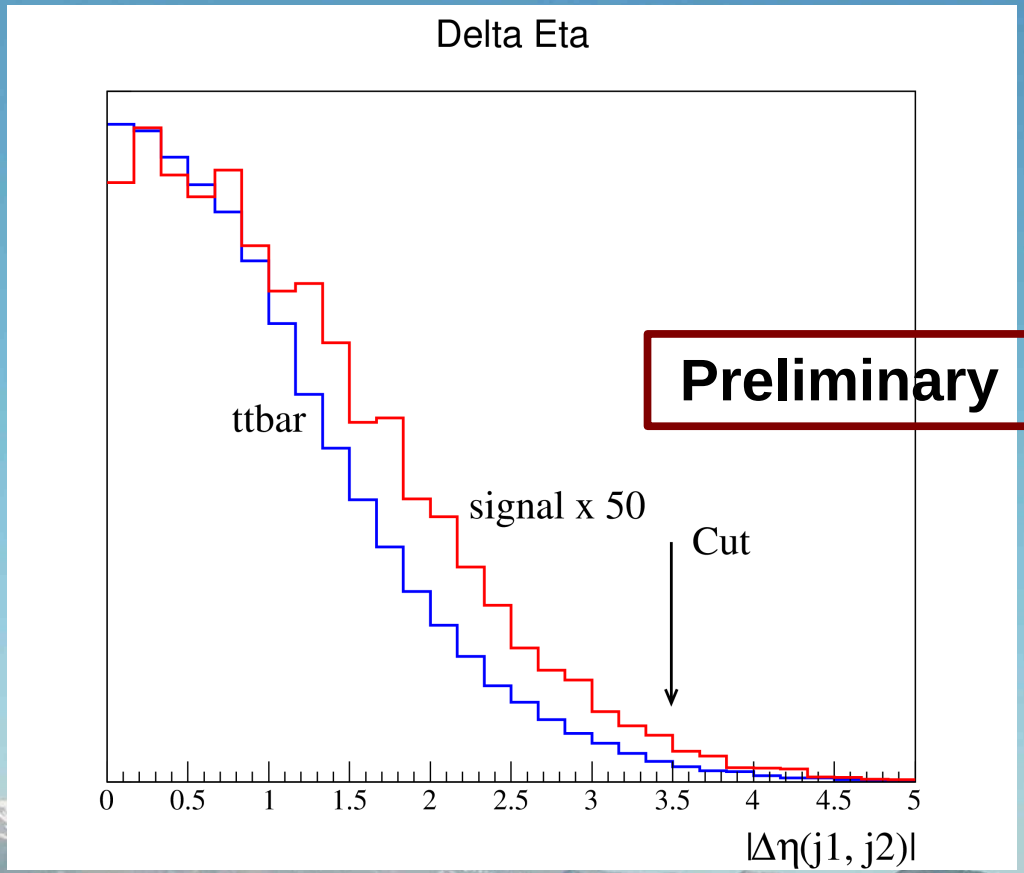
Sample case

- WW (leptonic) channel:
  - Current analyses either 0 or 1 jet or VBF channel (two forward jets with no further central hadronic activity): kills our signal (< 3 events with 20 fb^{-1})



Sample case

- WW (leptonic) channel:
  - Signal quite similar to $t\bar{t}$ in $|\eta(j_1) - \eta(j_2)|$ distribution



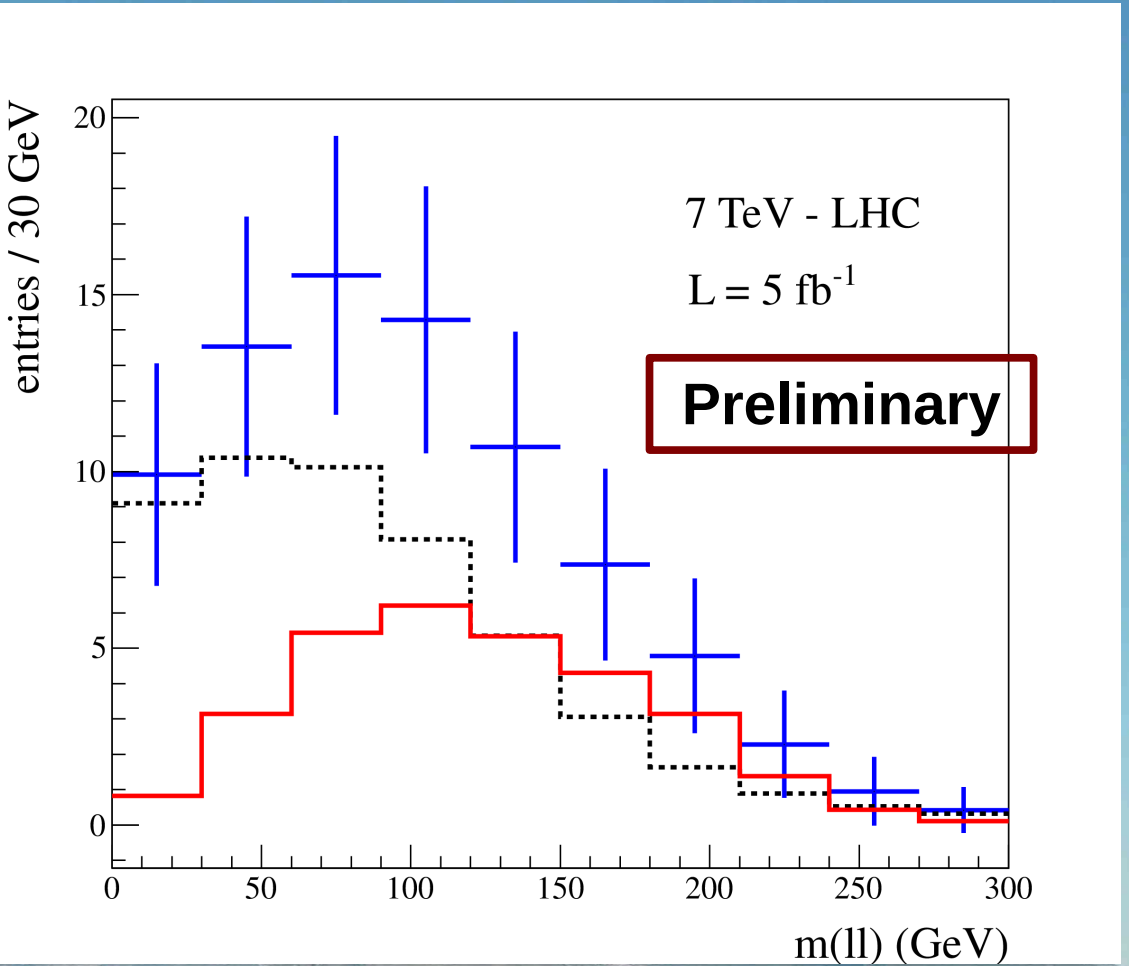
Sample case

- WW (leptonic) channel:
  - Current analyses either 0 or 1 jet or VBF channel (two forward jets with no further central hadronic activity): kills our signal (< 3 events with 20 fb^{-1})
  - Dedicated analysis can find it:
    - 2 leptons, 2 or more jets
    - $E_T(miss) \geq 80\ \mathrm{GeV}$
    - $p_T(j_{1,2}) \geq 300\ \mathrm{GeV}, \quad p_T(l_1) \geq 50\ \mathrm{GeV}$

$$\frac{S}{\sqrt{B}} = \frac{30}{\sqrt{50}} \approx 4 \quad (\text{with } 5\ \mathrm{fb}^{-1})$$

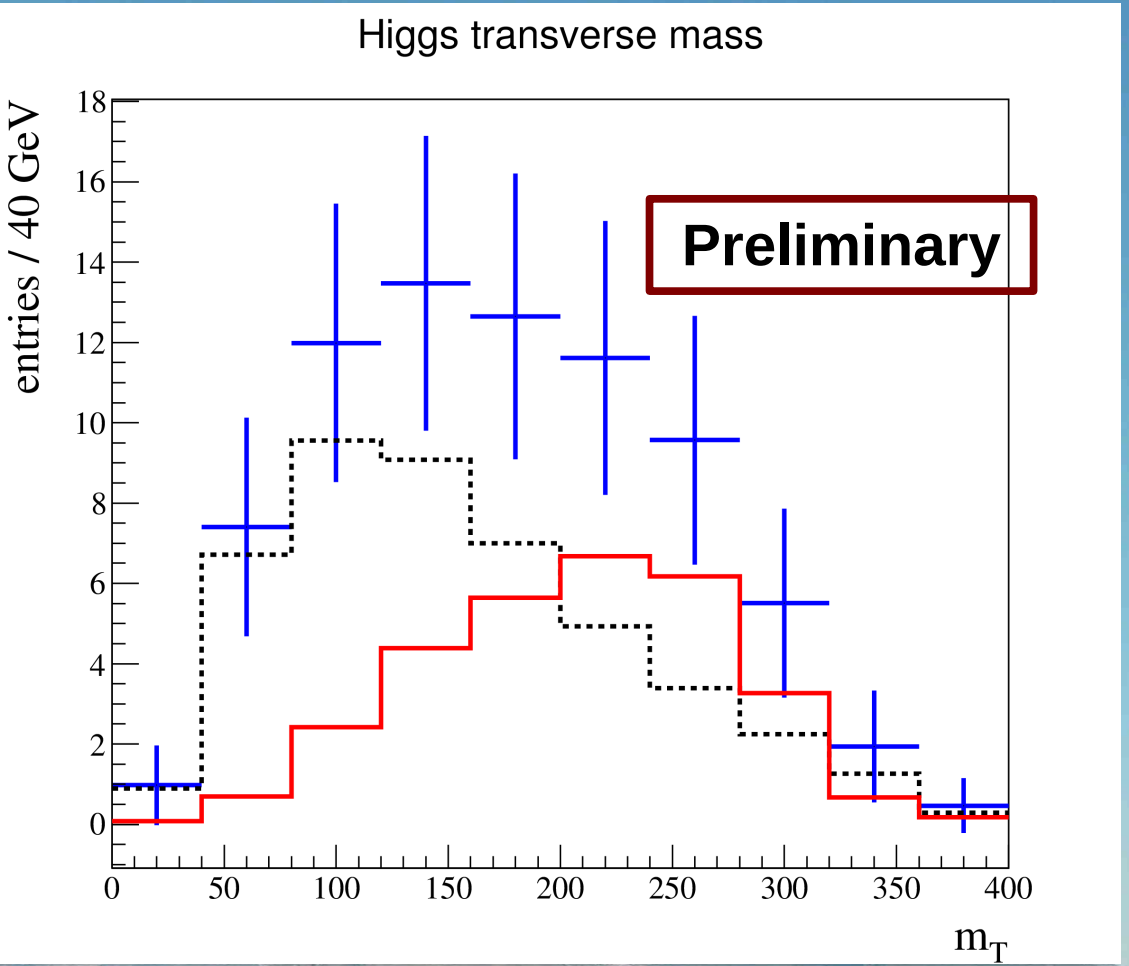
Sample case

- WW (leptonic) channel:
  - Dedicated analysis



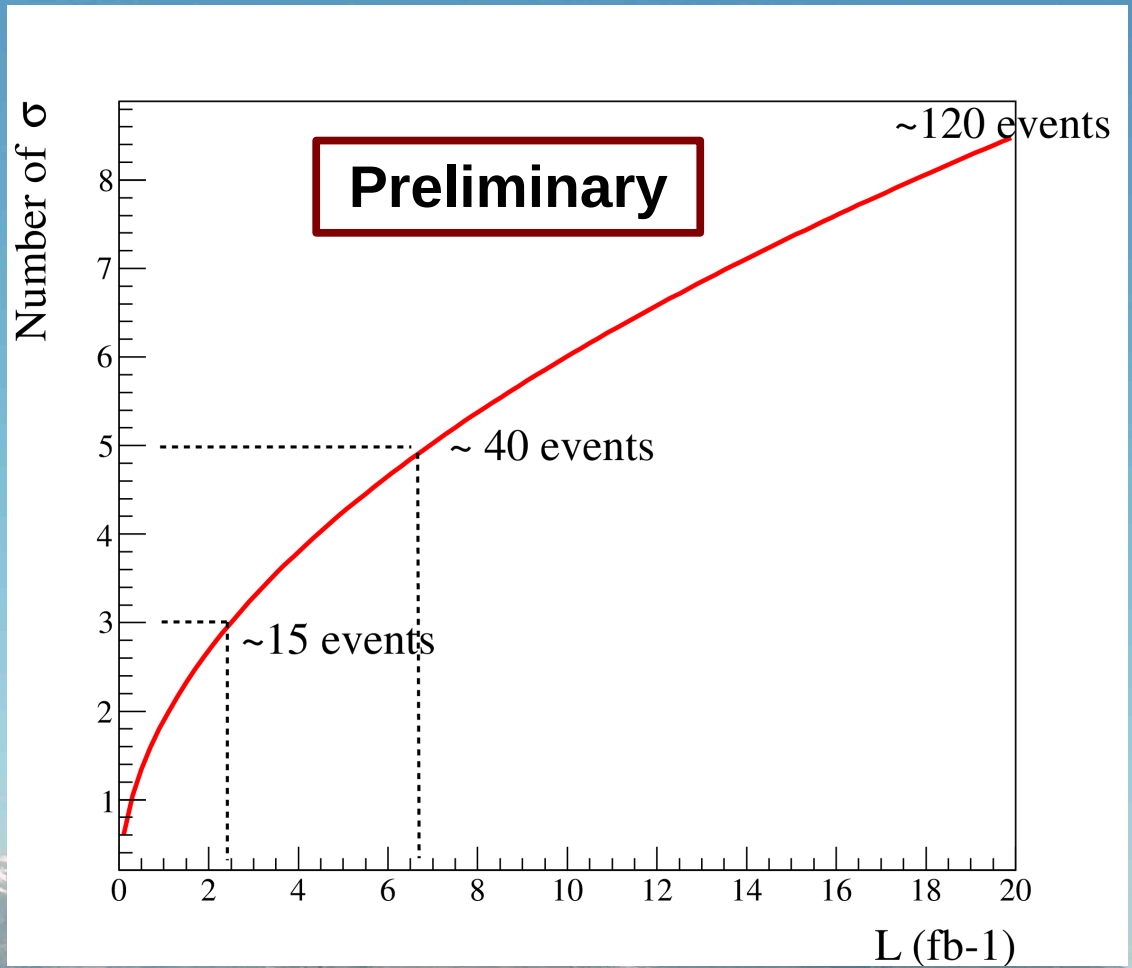
Sample case

- WW (leptonic) channel:
  - Dedicated analysis



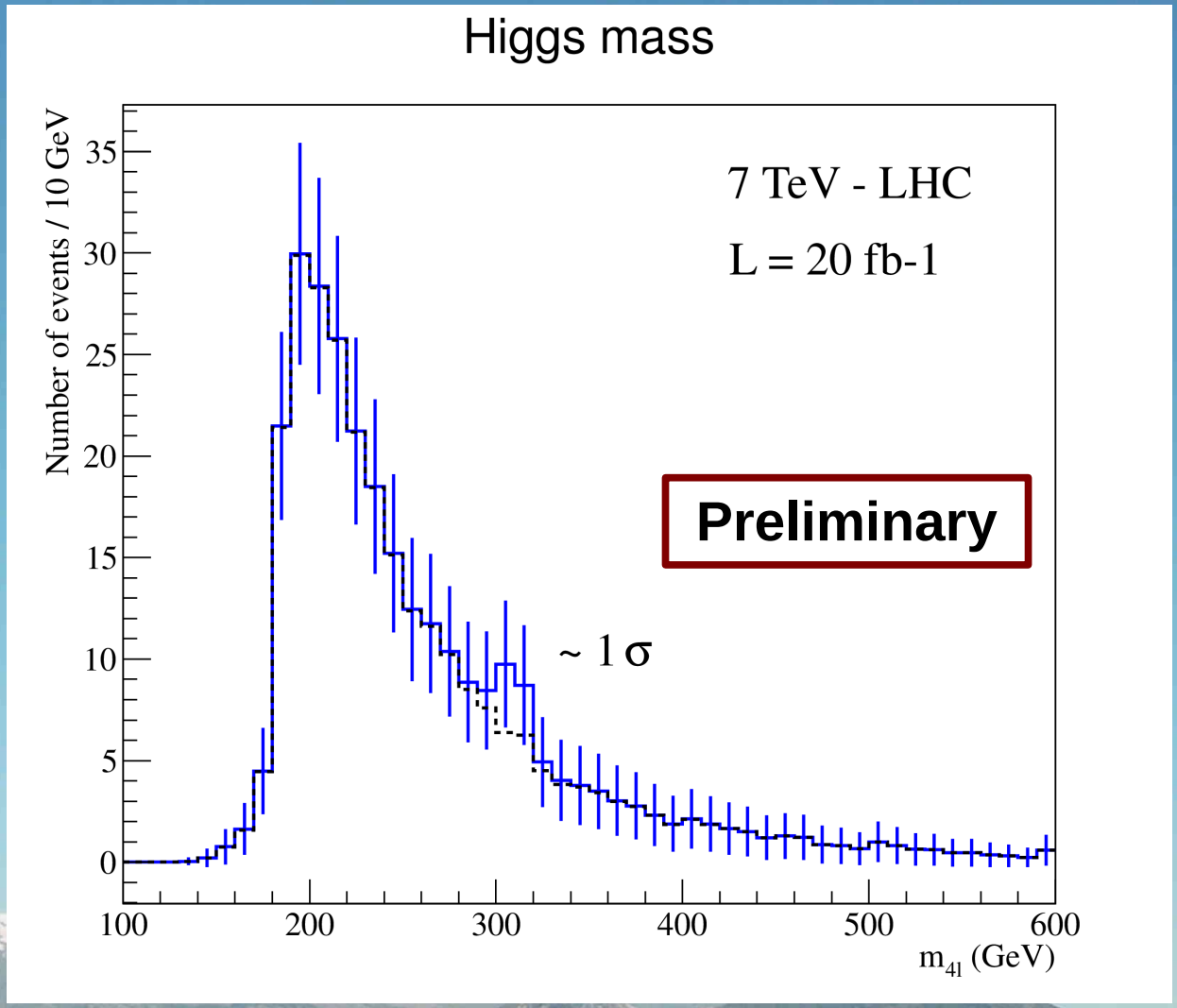
Sample case

- WW (leptonic) channel:
  - Dedicated analysis



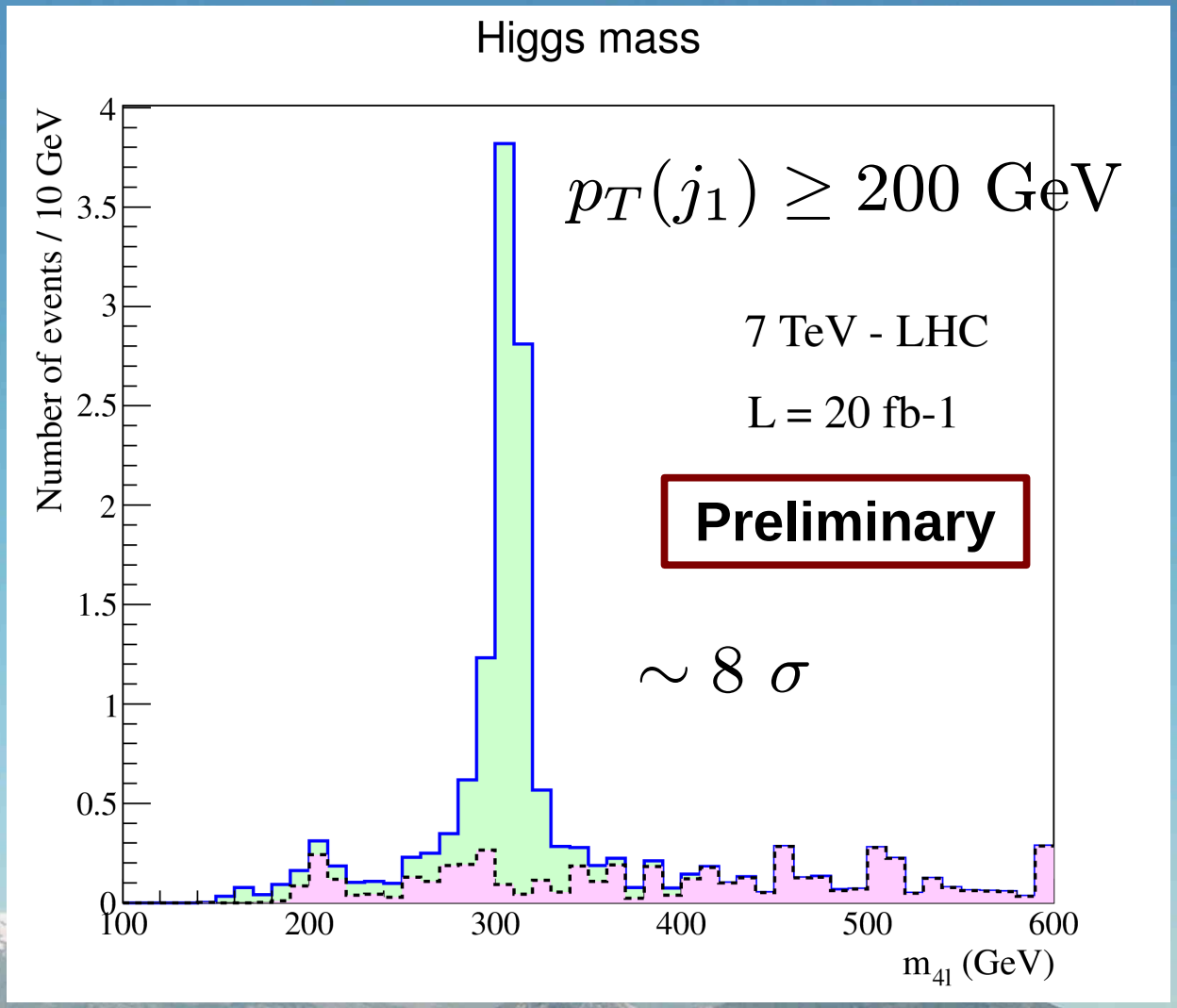
Sample case

- ZZ-> 4l channel: Analysis in ATLAS-CONF-2011-162



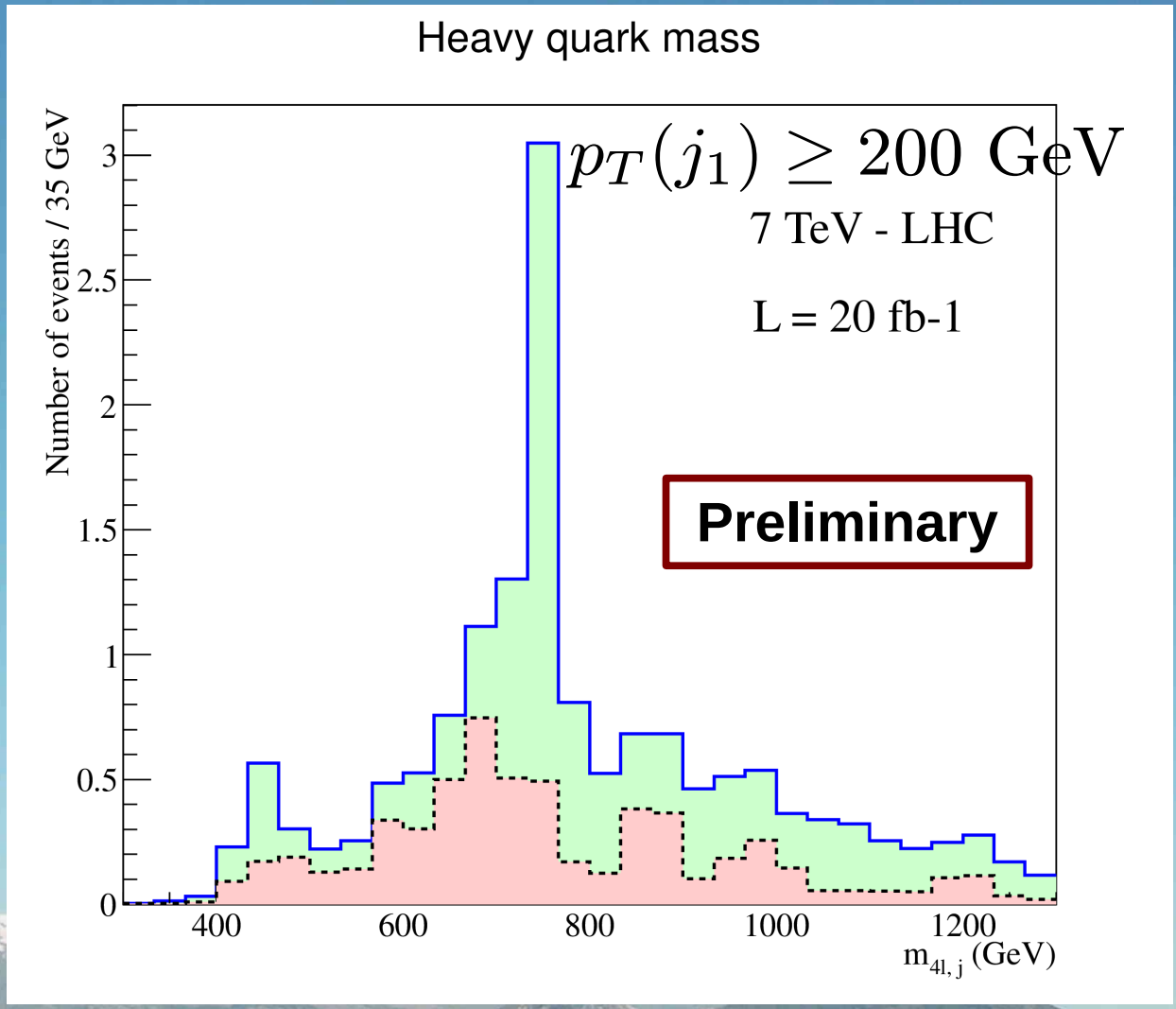
Sample case

- ZZ-> 4l channel: Analysis in ATLAS-CONF-2011-162



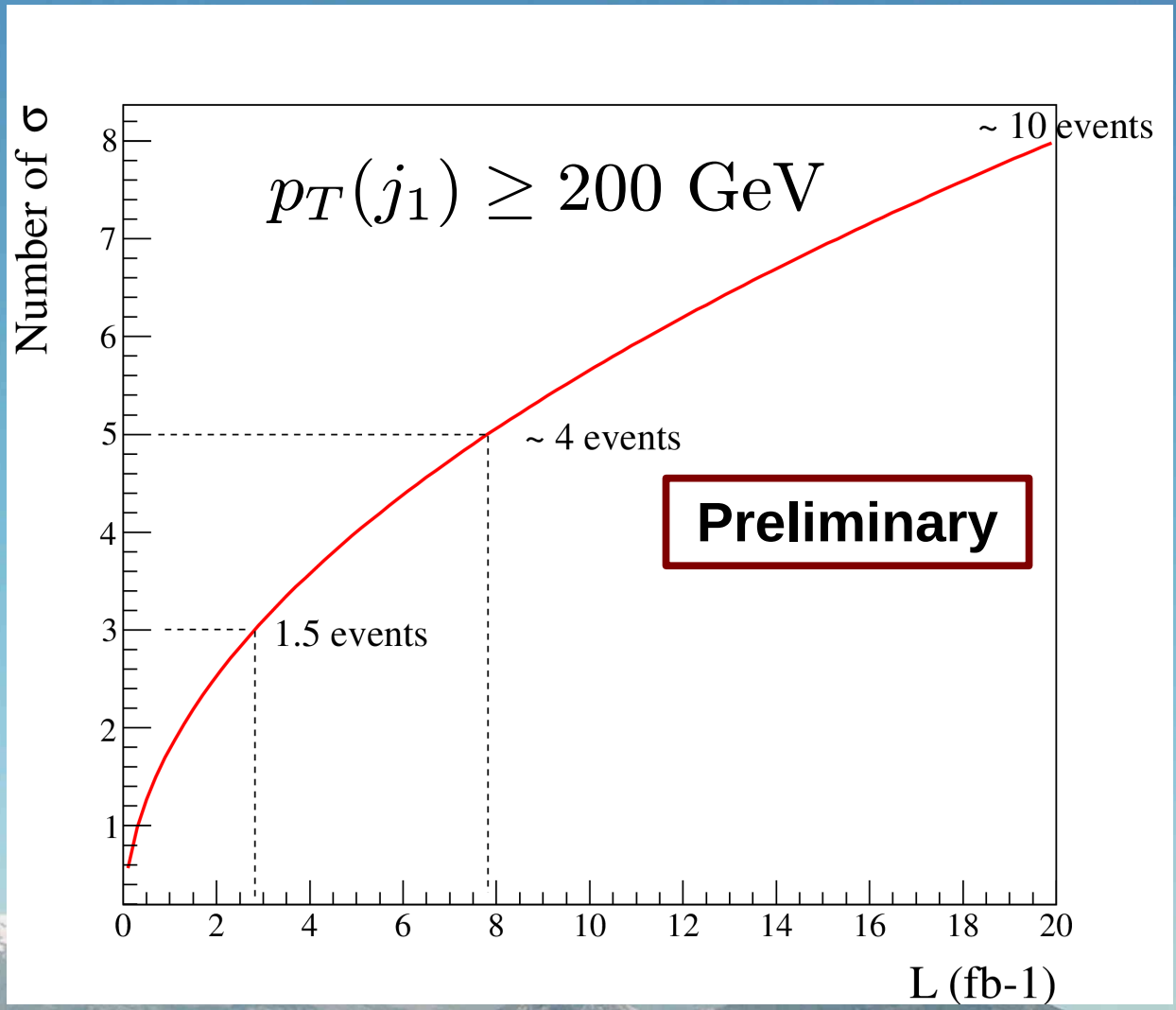
Sample case

- ZZ-> 4l channel: Analysis in ATLAS-CONF-2011-162



Sample case

- ZZ-> 4l channel: Analysis in ATLAS-CONF-2011-162



Conclusions

- Higgs data finally arrived!
- Composite Higgs models still quite unexplored Higgs-wise (and otherwise)
- New production mechanism: single production of vector-like quarks through s-channel exchange of colored vector resonance followed by decay to Higgs
  - Can be sizable and quite independent of Higgs degree of compositeness
  - Very distinctive signature: easy to look for
- Use Higgs physics to explore the strong sector