DIS2010:

XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects

EW & Searches WG Summary - Theory

Stefano Moretti

(NExT Institute, Southampton & RAL)

Composite Vectors at the LHC

ández.

- If heavy vectors exist with a mass in the 500 − 1000 *GeV* range, they will most likely be discovered at LHC in single production or in association with one standard gauge boson.

Ele

LHC

4 SM gauge bosons in the final state.

	di-leptons	tri-leptons
VBF (Gauge Model)	16	3
DY (Gauge Model)	5	1
VBF (Composite Model)	28	6
DY (Composite Model)	18	4

- Strongly coupled, as composite Higgs, Higgs as a PGB, Strongly Interacting Light Higgs, composite vectors, 5D Higgless models.

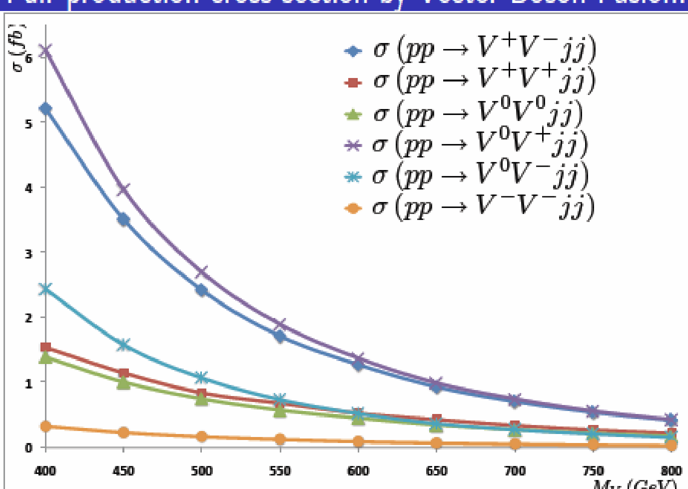
However, there are two problems

- the violation of unitary in WW scattering, if evaluated at the tree-level with $\mathcal{L}_{\text{eff}}^{\text{Univ}} = \mathcal{L}_{\text{gauge}}^{\text{SM}} +$ EW chiral Lagrangian
- the bad agreement with data of the electroweak observables S and T, if evaluated at the one-loop level with $\mathcal{L}_{\text{eff}}^{\text{Univ}}$, ≈ 3 TeV as ultraviolet cut-off.

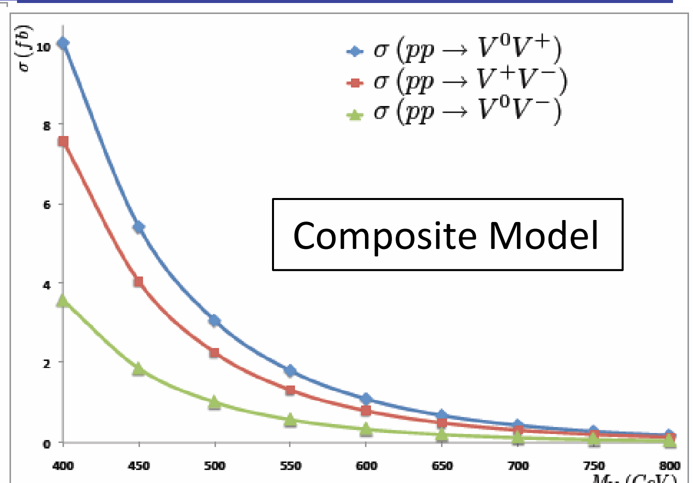
These problems point toward the existence of new degrees of freedom below the cut-off. This motivates the introduction of heavy vectors fields

If heavy vectors exist with a mass in the 500 -100 GeV range, they Will most likely be discovered at the LHC

Pair production cross section by Vector Boson Fusion.



Drell Yan Pair production cross sections.

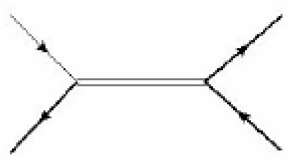


Charge asymmetry of top quarks

Paola Ferrario

Testing new physics in top production

Colored resonances decaying to top-antitop pairs could leave a sign



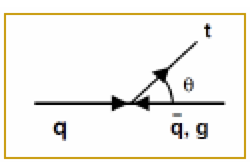
$$\mathcal{L}_{\text{res.}} \equiv i g_s \bar{\psi}_q \gamma^\mu (g_V^q + g_A^q \gamma_5) R_\mu^a T_a \psi_q$$

- Chiral color models and axigluons (purely axial-vector coupling)
- Colorons (purely vector coupling)
- Top color models
- Kaluza-Klein excitations in extra dimensional RS models

Typical signature: peak in the differential cross section

Other possibility: a sizable charge asymmetry

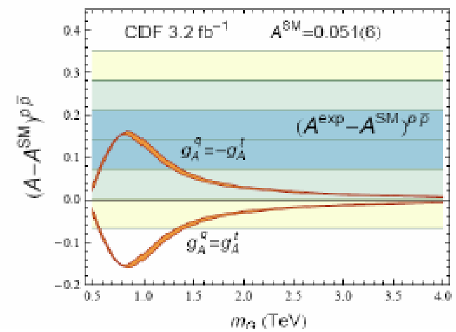
$$A(\cos\theta) = \frac{N_t(\cos\theta) - N_{\bar{t}}(\cos\theta)}{N_t(\cos\theta) + N_{\bar{t}}(\cos\theta)}$$



Can resonances generate an asymmetry?

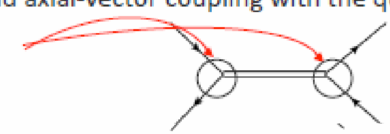
Chiral color models: **SU(3)L x SU(3)R → SU(3)C**

- New color-octet massive gauge boson: the axigluon
- Only axial-vector coupling with the quarks, same strength as QCD
- At the Tevatron, a negative asymmetry is disfavoured at two sigmas

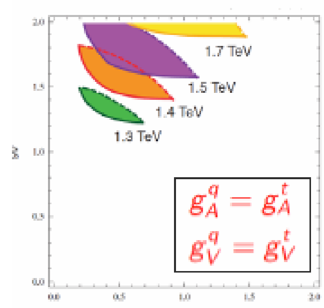


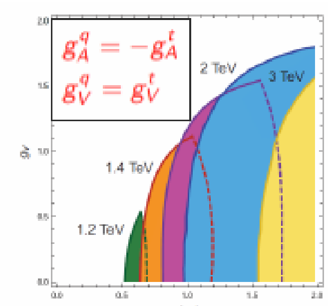
Flavor-dependent vector and axial-vector coupling with the quarks

$$g_s(g_V^q \gamma^\mu + g_A^q \gamma^\mu \gamma_5)$$



Asymmetry → lower bound on the couplings, invariant mass distribution → upper bound





The charge asymmetry at the LHC

pp is symmetric → FB asymmetry vanishes

But a charge asymmetry **exists** in selected kinematic regions

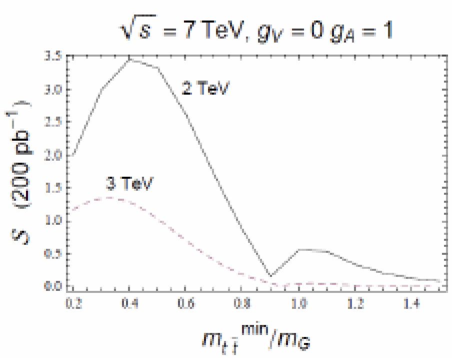
$$A_C(y_C) = \frac{N_t(|y| \le y_C) - N_{\bar t}(|y| \le y_C)}{N_t(|y| \le y_C) + N_{\bar t}(|y| \le y_C)}$$

- depends on a maximum rapidity
- if yc >> 1, it vanishes
- it has opposite sign to the partonic asymmetry

Main problem: 85 % events is gg, i. e. symmetric!

Solution: at low x the gluon contribution dominates → cuts on the top-antitop invariant mass eliminate low x momenta where gluon density is bigger than the quark one

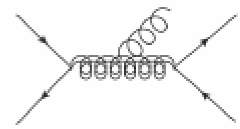
HEAVY RESONANCES



The charge asymmetry at the LHC: t-tbar + jet

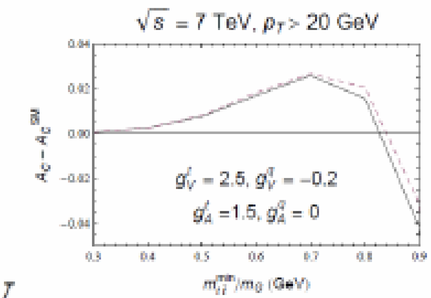
Some models don't produce asymmetry in the inclusive process

Look in ttbar + jet!



Ex. Kaluza Klein excitations of SM gluons

Kaluza Klein gluon excitation



$m_G = 1.5$ TeV

- Room for improvement in statistic at the Tevatron → better constraint from AFB.
- Flavor universal couplings strictly constrained, larger parameter space for $g_A^q = -g_A^t$
- Central asymmetry at the LHC in a selected kinematic region: both inclusive and t tbar + jet processes have maximum significance for relatively small cuts on the invariant mass.
- Promising measurement, although challenging: waiting for a huge statistic!

Alternative EWSB

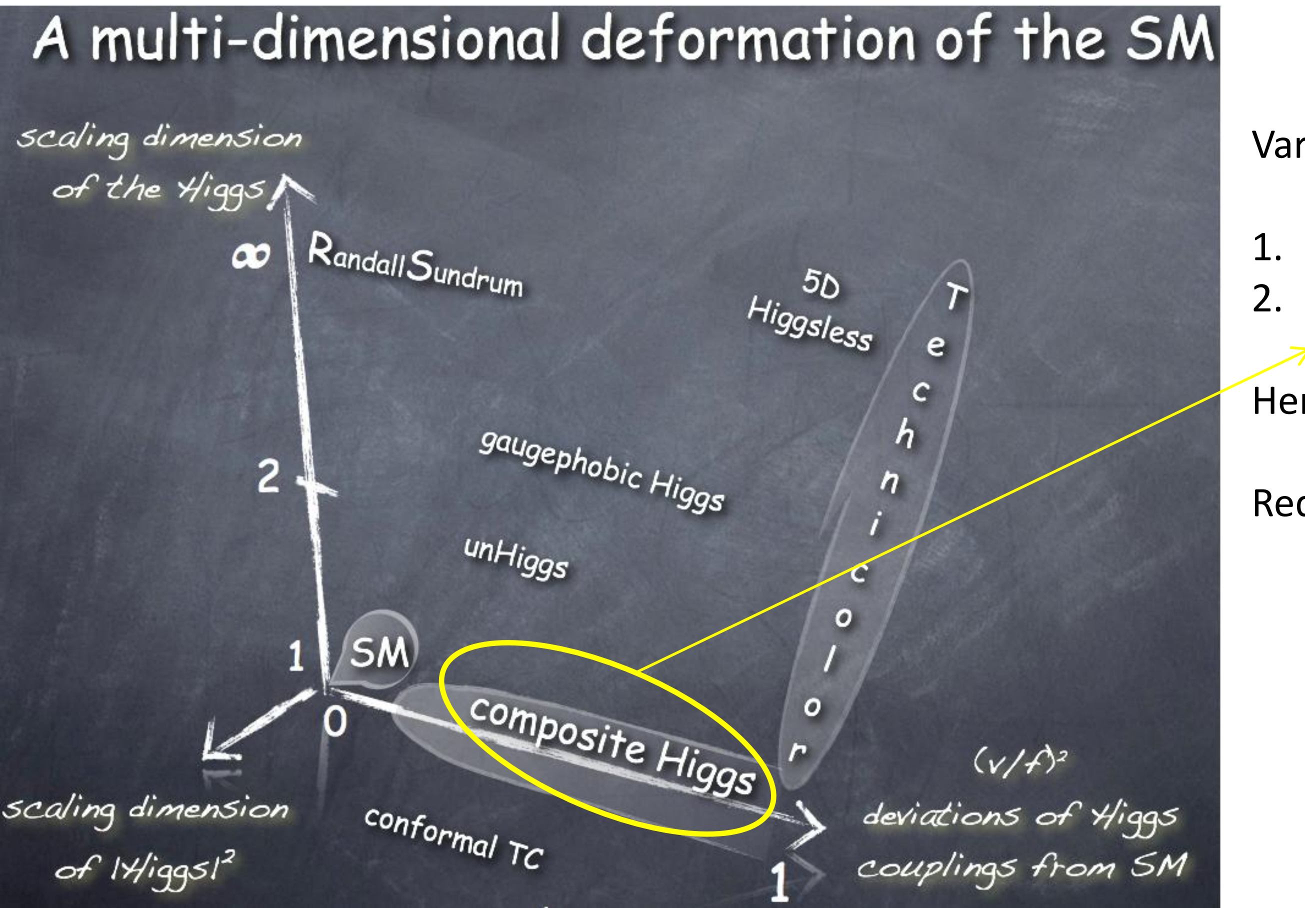
Christophe Grojean

EW interactions need Goldstone bosons to provide mass to W, Z

⇓ ⇓ ⇓ ⇓ ⇓ ⇓

EW interactions also need a UV moderator/new physics

to unitarize WW scattering amplitude



Various EWSB BSM schemes in which

1. No Higgs
2. Composite Higgs

Here assume 4D composite Higgs

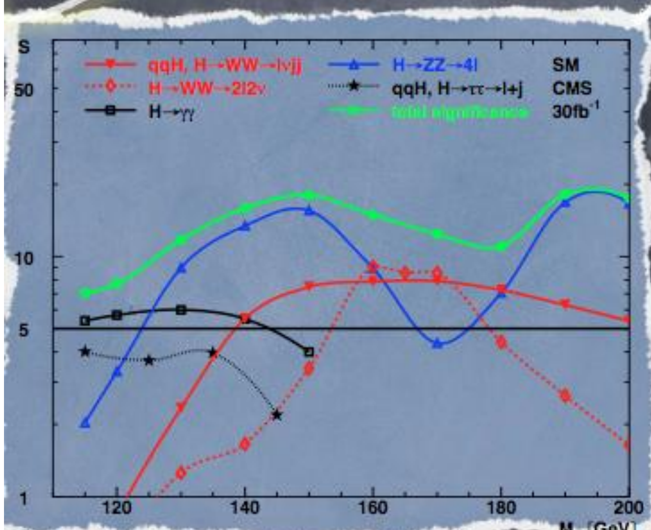
Require different couplings from SM

Composite Higgs search @ LHC

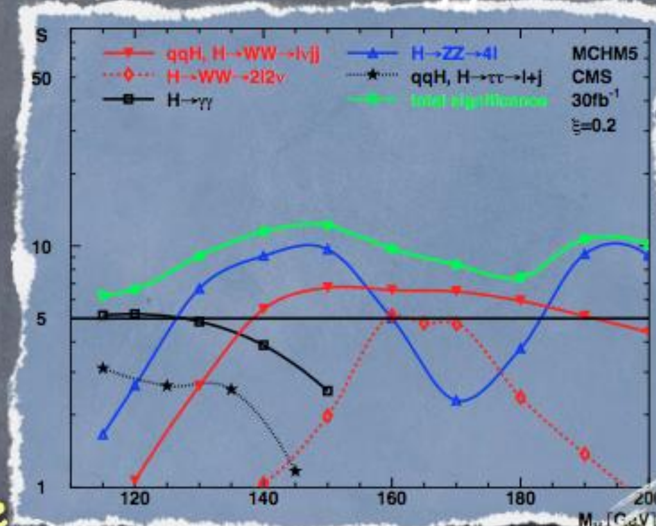
Espinosa, Grojean, Muehlleitner '10

the modification of Higgs couplings and BRs affects the Higgs search

SM

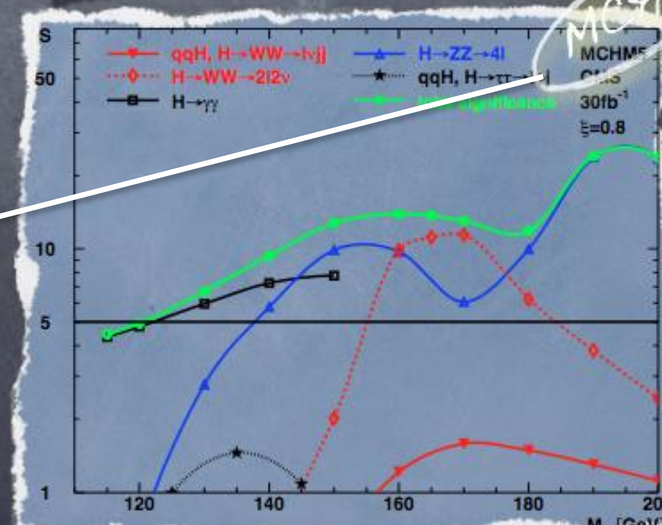


large
compositeness scale



signal significance
for L=30/fb

MCHM5



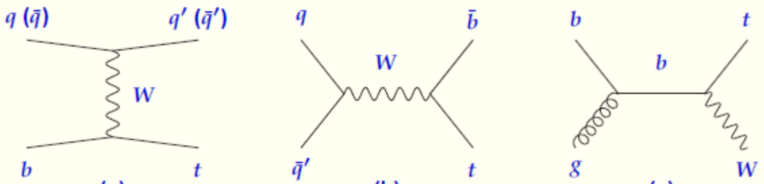
small
compositeness scale

Minimal composite Higgs model with fermions in the fundamental representation of SO(5)

Single top quark production cross section at hadron colliders

Nikolaos Kidonakis

Partonic processes at LO



(a) (b) (c)

(a) t channel: $qb \to q't$ and $\bar{q}b \to \bar{q}'t$ ($ub \to dt$ and $\bar{d}b \to \bar{u}t$, etc.)

(b) s channel: $q\bar{q}' \to \bar{b}t$ ($u\bar{d} \to \bar{b}t$, etc)

(c) associated tW production: $bg \to tW^-$

Higher-order corrections included here: NNLL

At NLL (NNLL) accuracy requires one-loop (two-loop) calculations in the eikonal approximation

Approximate NNLO cross section from expansion of resummed cross section

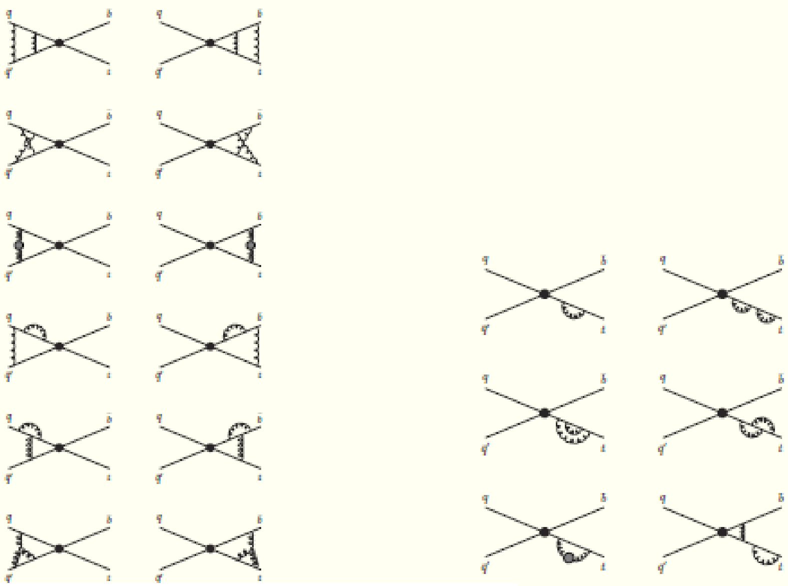
Essential ingredient: two-loop soft anomalous dimension

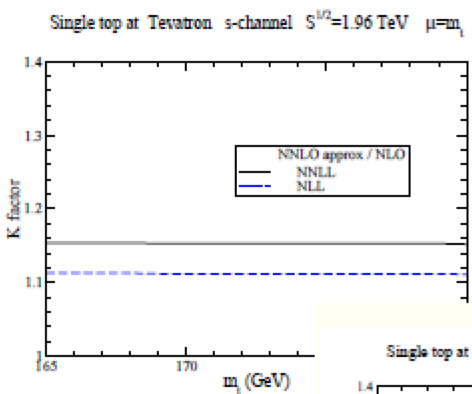
N. Kidonakis, Phys. Rev. Lett. 102, 232003 (2009), arXiv:0903.2561 [hep-ph]

This allows NNLL resummation

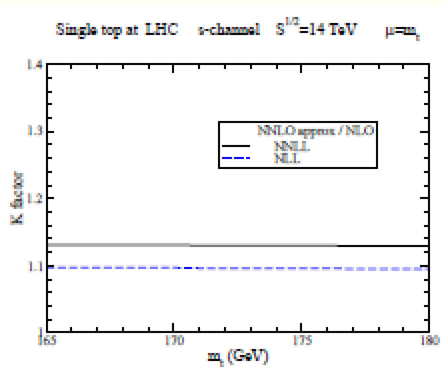
Single top quark production - s channel

Two-loop eikonal diagrams



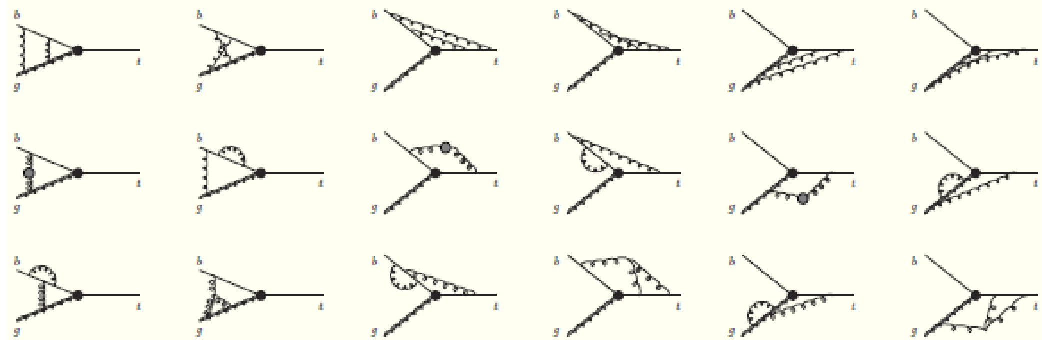


+10 %



Associated production of a top quark with a W^-

Two-loop eikonal diagrams



+ top quark self-energy graphs

NNLO approx corrections increase NLO cross section by $\sim 8\%$

- Single top production - Tevatron data consistent with theory
- Theoretical progress in higher-order QCD corrections at NNLL
- NNLO approx corrections for s-channel production are significant at Tevatron and LHC
- NNLO approx for $bg \to tW^-$ at LHC: relatively large cross section
- NNLO approx for $bg \to tH^-$ at LHC: large corrections

$pp(gg+gq) \to h + jet \to \tau^+\tau^- + jet$ at the LHC

Rui Santos

Why Higgs production via gluon fusion with $H \to \tau^+\tau^-$?

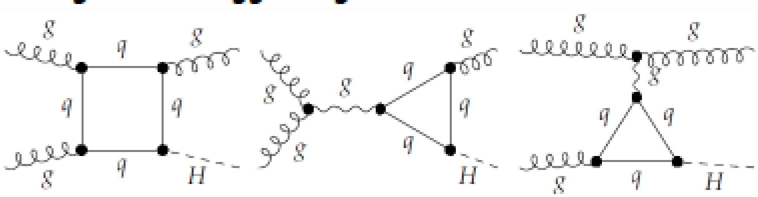
- Very light Higgs is not ruled out (reduced coupling to gauge bosons)
- BSM may enhance both production and decay
- Test Yukawa couplings

Why Higgs + jet with $H \to \tau^+\tau^-$?

- When the transverse momentum of the Higgs is small the two taus are moving back to back.
- The resolution in the tau pair invariant mass will be poor and the signal difficult to extract.
- A high p_T jet allows the reconstruction of the transverse momentum of the taus.

Signal

- Generic diagrams for $gg \to hg$



- $gq \to hq$ also included (approx 20% of total cross section)
- $qq \to hg$ negligible

Two scenarios

- both taus decay leptonically (ll)
- one tau decays leptonically and the other hadronically (lj)

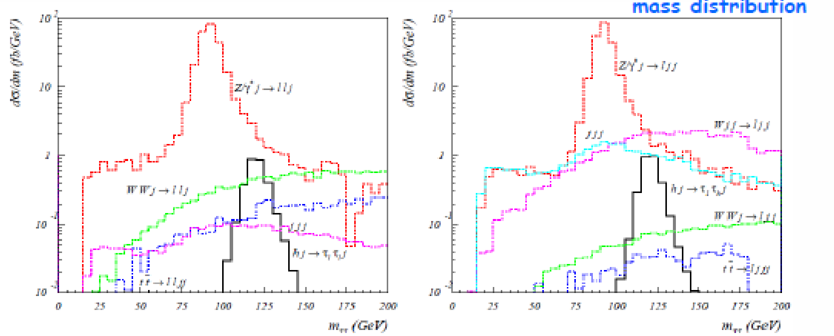
Backgrounds calculated

- $pp \to Z/\gamma^* j$
- $pp \to W^+W^- j$
- $pp \to Wjj$
- $pp \to t\bar{t}$
- $pp \to jjj$

- probability of a jet faking a lepton 10^{-3}
- tau reconstruction efficiency 0.3 $\Longrightarrow$ tau

Results for a 120 GeV SM Higgs boson

Reconstructed invariant mass distribution



m_h (GeV)	$\sigma_{S_{(ll)}}$ (fb)	$\sigma_{B_{(ll)}}$ (fb)	$\sigma_{S_{(lj)}}$ (fb)	$\sigma_{B_{(lj)}}$ (fb)	σ_S/σ_B (%)
120	13.8	109.3	14.1	174.7	15.0

m_h (GeV)	95 % CL exclusion $L(fb^{-1})$	3σ discovery $L(fb^{-1})$	5σ discovery $L(fb^{-1})$
120	1.4	3.1	8.7

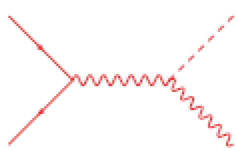
Looks promising - study beyond parton level is needed!

Higgs production via vector-boson fusion at NNLO in QCD

Marco Zaro

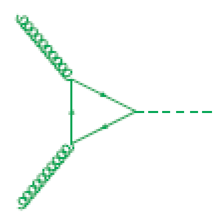
The Higgs production channels @NNLO, on feb 2010

$q\bar{q} \to hV$

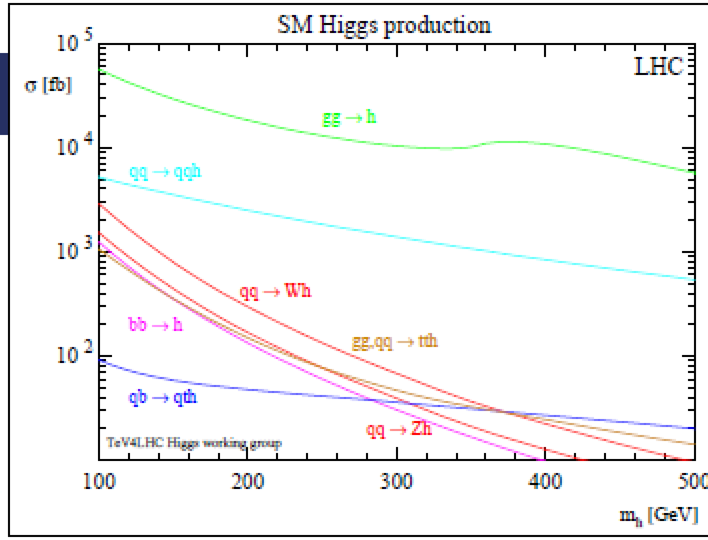


O. Brein, A. Djouadi and R. Harlander, Phys. Lett. B **579**, 149 (2004) [arXiv:hep-ph/0307206].

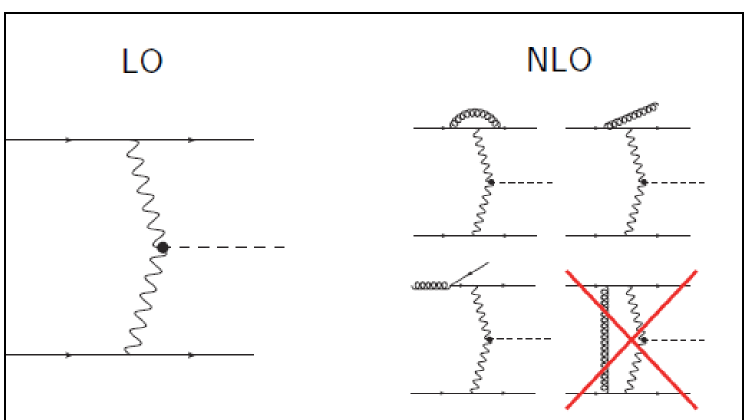
$gg \to h$



C. Anastasiou, K. Melnikov and F. Petriello, Phys. Rev. Lett. **93**, 262002 (2004) [arXiv:hep-ph/0409088].
R. V. Harlander, H. Mantler, S. Marzani and K. J. Ozeren, arXiv: 0912.2104 [hep-ph]

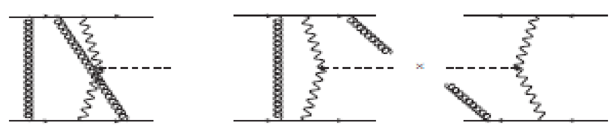


- VBF is an 2 → 3 process (need for some trick t
  at NNLO) ⟶ Structure function approach !



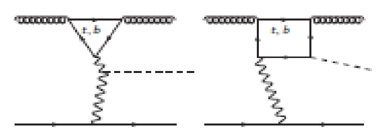
The structure function approach to VBF @ NNLO

- structure function approach is not exact at NNLO
  - double gluon-exchange diagrams (real and virtual)



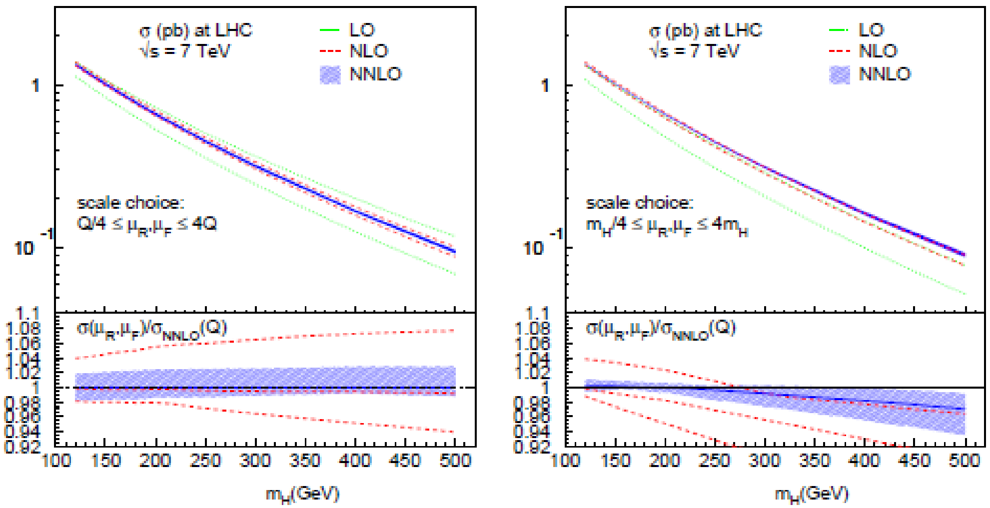
$\frac{1}{N_c^2}$ and kinematically suppressed

  - t/b loop diagrams

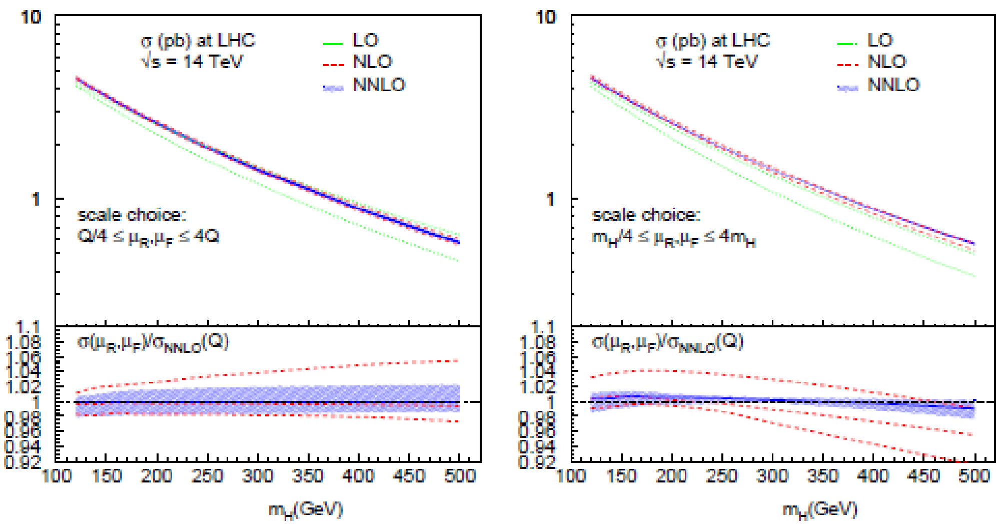


Destructive interference, upper bound at $\mathcal{O}(10^{-3})$

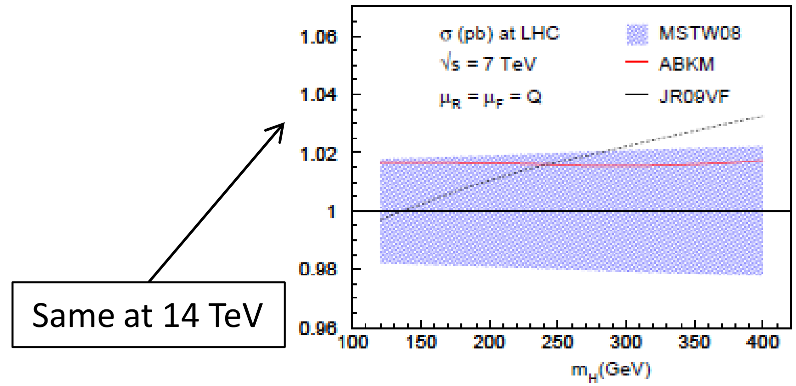
Results at the LHC @7 TeV



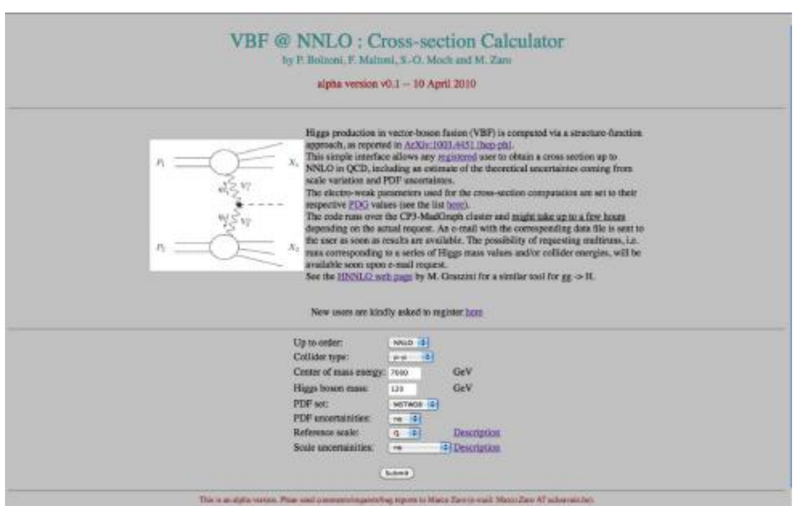
Results at the LHC @14 TeV



PDF uncertainities at the LHC @7 TeV



- LHC is finally ready to look for the Higgs
- VBF is a promising channel both for discovery and precision measurements
- First computation VBF cross-section @NNLO now available
- Theoretical uncertainities lowered at 1 – 2% level
- Web interface available http://madgraph.phys.ucl.ac.be/vbf.html (still alpha version)



Supersymmetric Higgs bosons and beyond

José Francisco Zurita (ITP, Univ. Zürich)

- MSSM Higgs sector is strongly constrained
  - LEP search: $m_h > 90$ GeV
  - MSSM 2 loops: $m_h < 130$ GeV
- Tension can be relaxed with new d.o.f (i.e: NMSSM)
- BMSSM Higgs sectors

Starting point: Effective theory (valid below scale M)

$$W = \mu H_u H_d + \frac{\omega_1}{2M}(1+\alpha_1 X)(H_u H_d)^2$$

Only 2 parameters: $\omega_1, \alpha_1 \sim \mathcal{O}(1)$ Spurion: $X = m_S\, \theta^2$

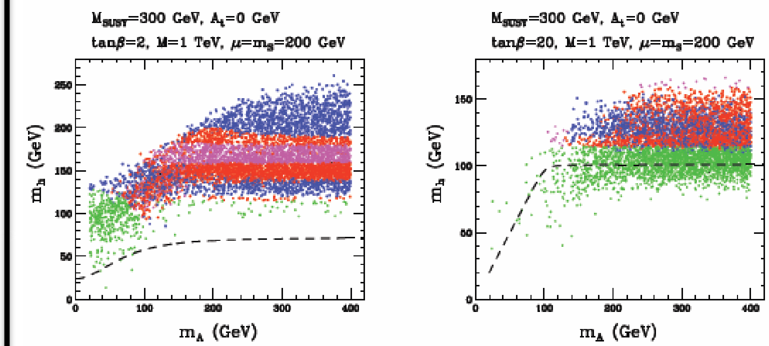
Through order 1/M^2: O(10) operators in Kahler potential

Our choices: • $\mu = m_S = 200$ GeV and $M = 1$ TeV

• $\tan\beta = 2\ (20)$: Low (large) $\tan\beta$ regime.

Scan over 11 parameters

Lightest Higgs mass

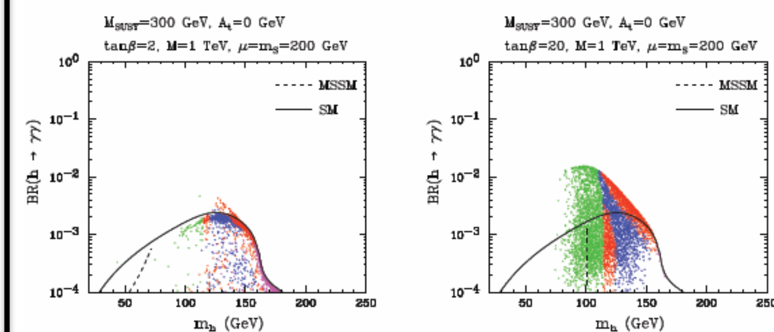


Excluded by LEP Tevatron upgrade → $10\ \text{fb}^{-1} + 50\%$ efficiency in $b\bar{b}$, WW

Excluded by Tevatron Allowed

MSSM: P. Draper, T. Liu, C. Wagner (2009)

Diphoton channel



Excluded by LEP Tevatron upgrade

Excluded by Tevatron Allowed

• Enhancements for large $\tan\beta$.

- Great rise of the lightest Higgs mass, specially for low tangent beta (relax the MSSM tension).