DOE Site Visit at Argonne

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September 24, 2009

Highlights from recent research

A central theme of my main research interest is the mechanism of electroweak symmetry breaking.

I am shifting the focus from model-building to more "collider physics" oriented projects.

Mostly recently, I have been concentrating on a "global study" of the correlation between

"Space of Models"

$\Updownarrow$

"Space of Signatures"

It is generally believed that a Higgs(-like) boson gives mass to all particles upon EWSB.

The majority of theoretical work on the Higgs is motivated by the naturalness principle:

Why is the electroweak scale (the Fermi scale ~ 200 GeV) so much smaller than the other fundamental scale (Planck scale ~ 10^{19} GeV) we know of?

There are two approaches to address this question:

1) Supersymmetry: Higgs is light because of an enlarged space-time symmetry
2) Composite Higgs: Higgs is light because of an enlarged global symmetry. (Higgs ~ Pion!)

By studying properties of the Higgs (both theoretically and experimentally) we could probe the precise mechanism of EWSB and related new physics.

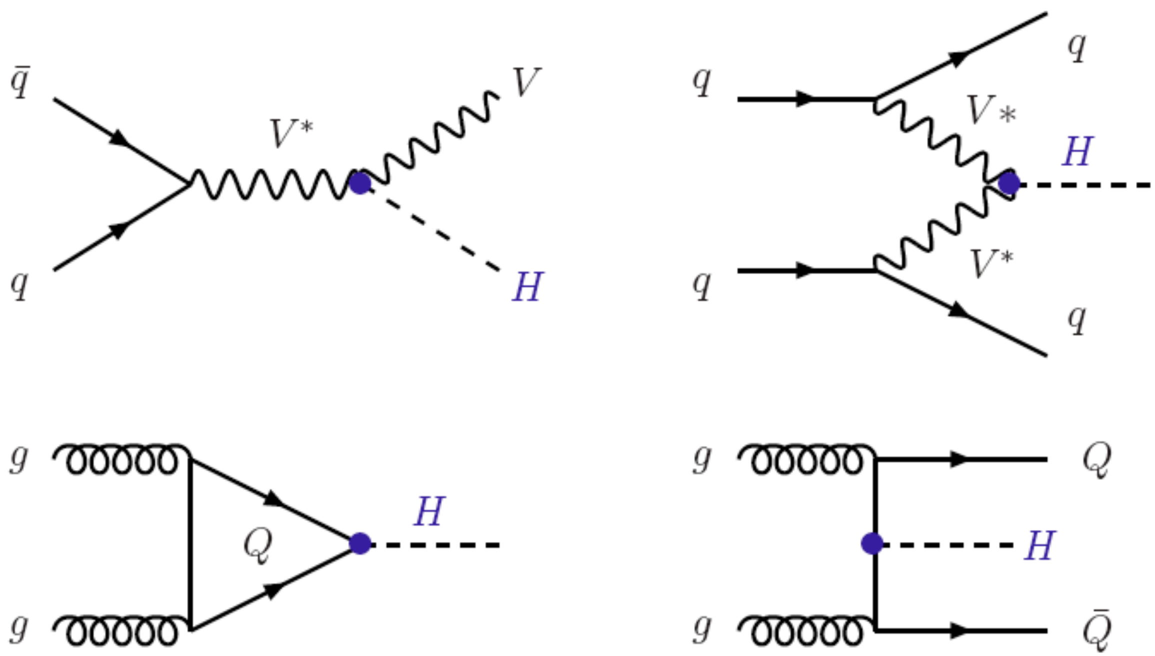
Let me first give a brief overview of the search for the Higgs at the Tevatron and the LHC, so as to motivate the theory part of this talk.

We know the precision electroweak measurements from LEP prefer a (light) Higgs boson, but unfortunately LEP didn’t find the Higgs.

The focus has now shifted to Tevatron and the LHC:

Main production mechanisms of the Higgs at hadron colliders:

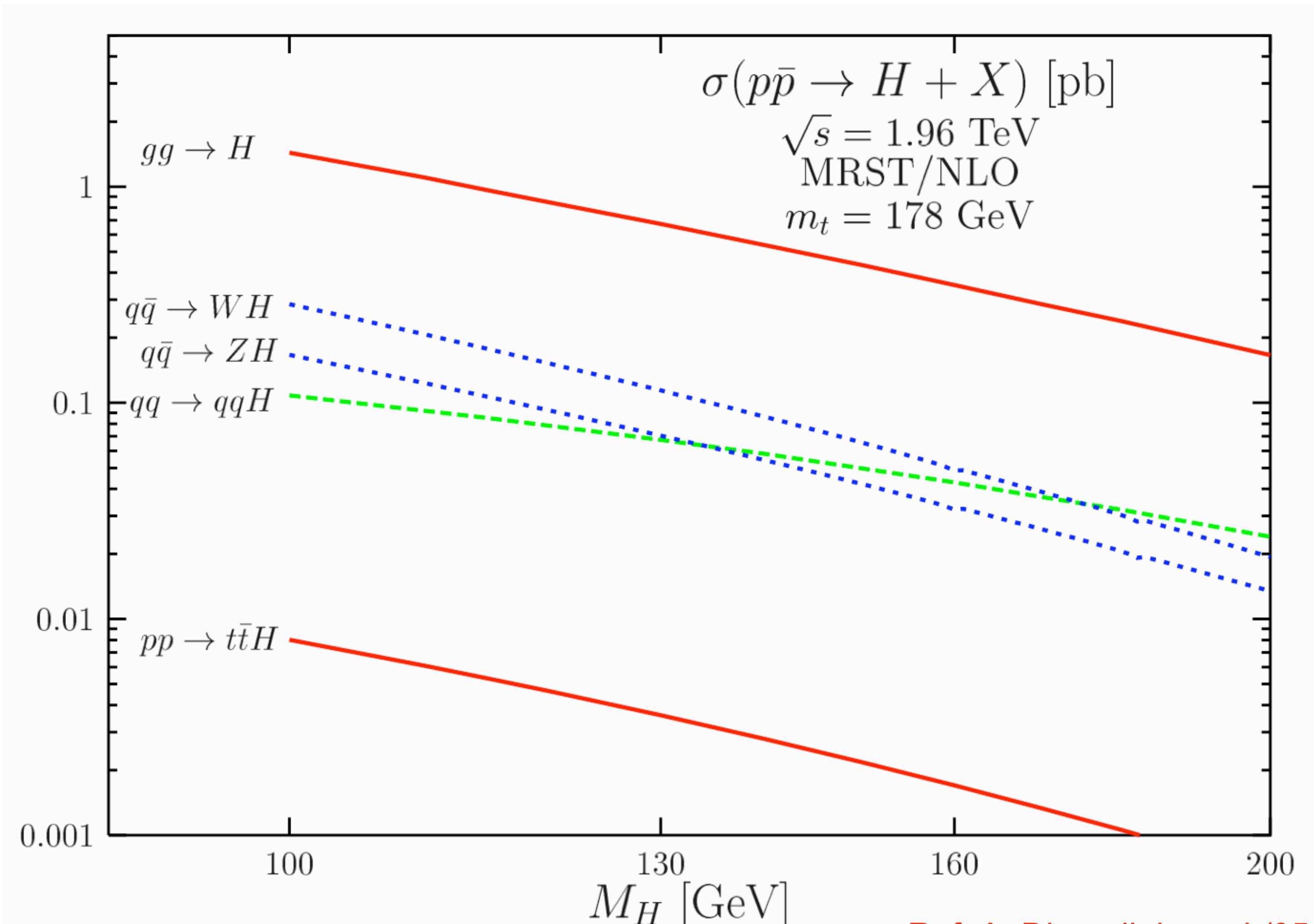
$$\begin{aligned}
\text{associated production with } W/Z: &\quad q\bar{q} \longrightarrow V + H \\
\text{vector boson fusion}: &\quad qq \longrightarrow V^*V^* \longrightarrow qq + H \\
\text{gluon} - \text{gluon fusion}: &\quad gg \longrightarrow H \\
\text{associated production with heavy quarks}: &\quad gg, q\bar{q} \longrightarrow Q\bar{Q} + H
\end{aligned}$$



Ref: A. Djouadi, hep-ph/0503172

Among them gluon fusion is the dominant mechanism!

At Tevatron:



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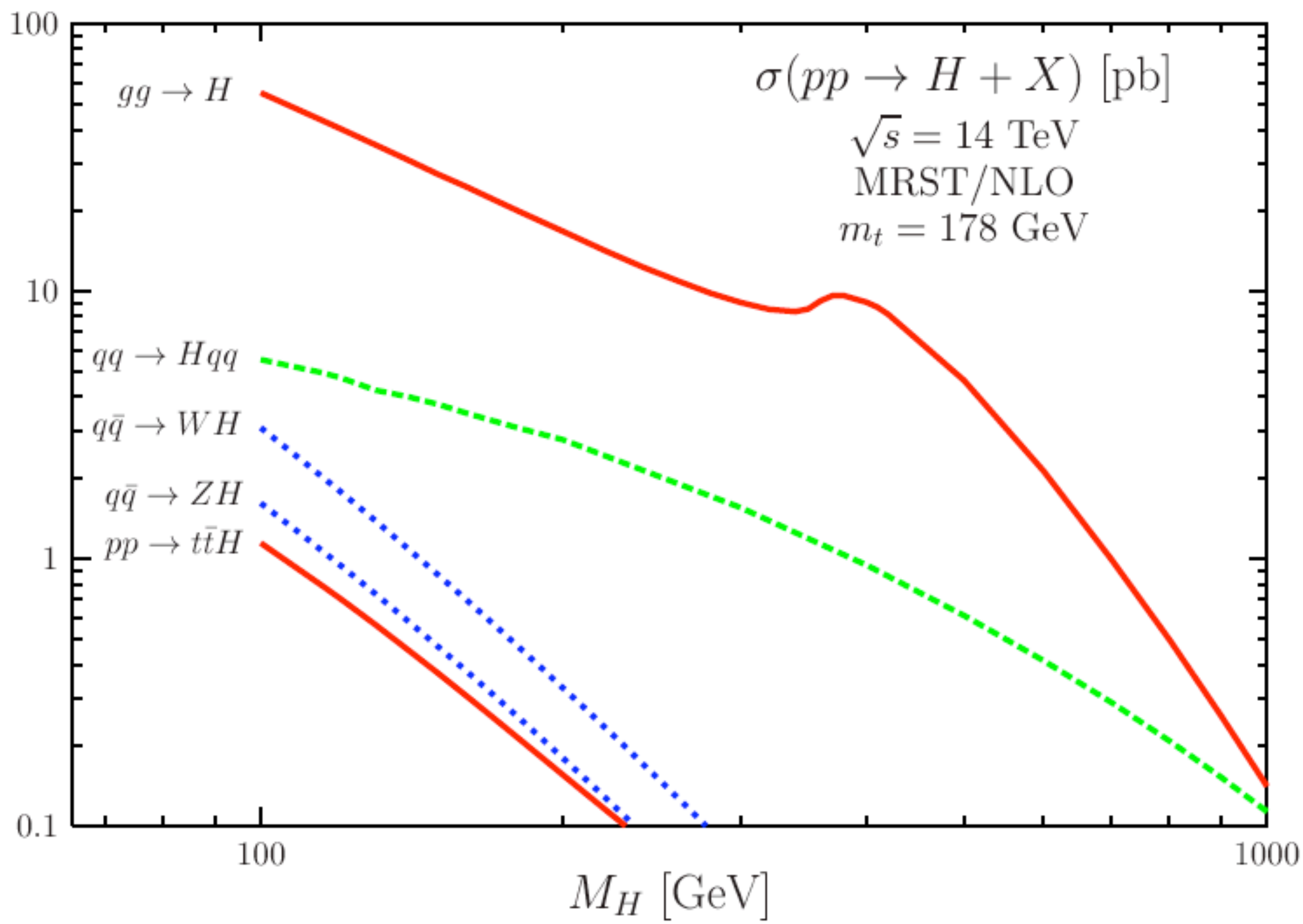
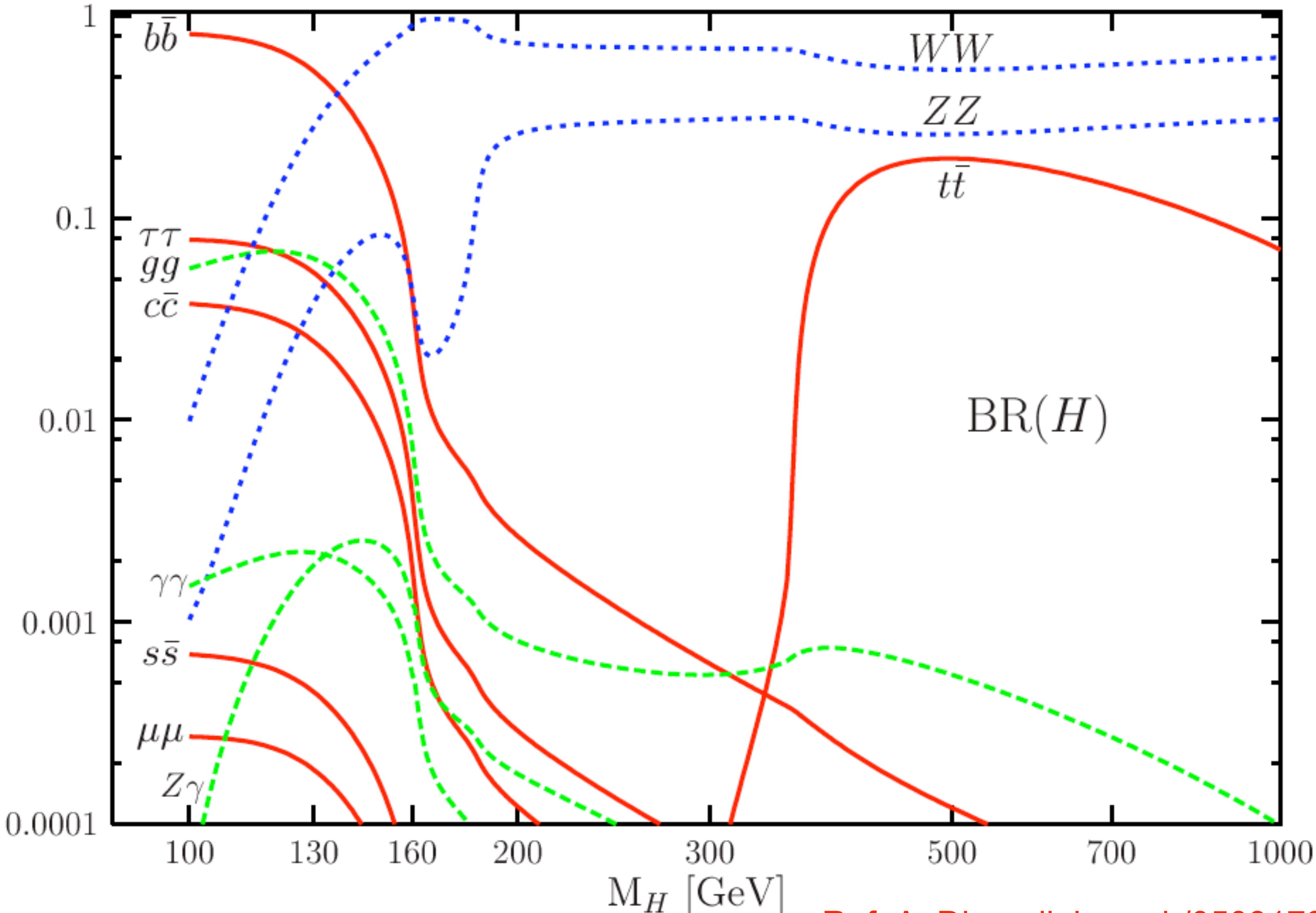
At LHC:



$\sigma(pp \to H + X)$ [pb]
$\sqrt{s} = 14$ TeV
MRST/NLO
$m_t = 178$ GeV
$gg \to H$
$qq \to Hqq$
$q\bar{q} \to WH$
$q\bar{q} \to ZH$
$pp \to t\bar{t}H$
100
10
1
0.1
100
1000
M_H [GeV]

Decay channels depend on the Higgs mass:



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- For low Higgs mass $m_h \leq 150$ GeV, the Higgs mostly decays to two b-quarks, two tau leptons, two gluons and etc.

- In hadron colliders these modes are difficult to extract because of the large QCD jet background.

- The silver detection mode in this mass range is the two photons mode: $h \to \gamma\gamma$, which like the gluon fusion is a loop-induced process.

- The beauty of loop-induced processes is they are very sensitive of new physics at higher energy scales.

- We are motivated to study one particular observable: the gluon fusion production rate of the Higgs boson.

- One useful theoretical tool is the effective Lagrangian approach:

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \frac{1}{\Lambda^2}\sum_i (c_i \mathcal{O}_i + h.c.) + \mathcal{O}\left(\frac{1}{\Lambda^3}\right)$$

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- Pick a model, compute the effective coefficients, and scan through allowed parameter space.
- Making some simple dynamical assumptions to encompass a large class of models:
  1) Higgs is supersymmetric.
  2) Higgs is composite.

Which approach to use depends on what questions one wants to ask. We are interested in structural and global questions such as:

- Is physics at the electroweak scale natural?
- Is the Higgs boson fundamental or composite?
- If new particles are discovered, who ordered them? Are they responsible for canceling the Higgs quadratic divergences?

In this regard, neither of the first two approaches seems useful.

I have been working on the global (theoretical) perspective of the gluon fusion production of the Higgs in the "Space of Models."

In 2007 I studied this observable in minimally supersymmetric standard model (MSSM) with R. Dermisek. (hep-ph/0701235)

We find this observable is very useful in understanding the naturalness (fine-tuning in the Higgs mass) in MSSM.

With R. Rattazzi and A. Vichi, I studied the gluon fusion production rate for a large class of composite Higgs models.(arXiv:0907.5413)

We found a strong statement:

The gluon fusion production rate of the Higgs is always reduced from the SM expectation.

In addition, we found the Higgs coupling to fermions is also always reduced from the SM expectation.

In the end, we could really learn a lot by measuring this observable precisely!