Symmetry is fundamental to our understanding
of the basic laws of physics

Mass is always associated with symmetry breaking

Easier to discover the symmetry: e.g. SU(2) x U(1)

Harder to discover the symmetry breaking mechanism,
i.e., **Higgs?**

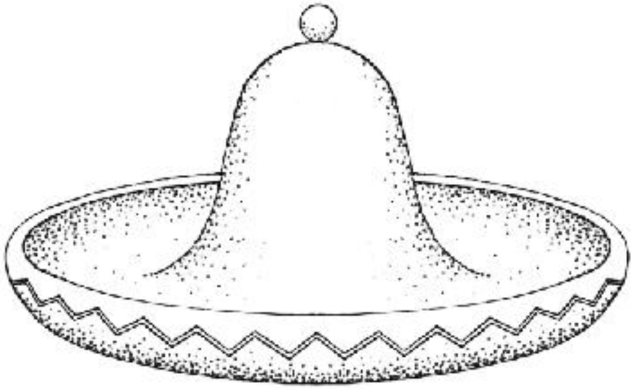
Understanding Electroweak Symmetry breaking is essential for significant progress in our understanding of the physical world.

Carries major implications for:

Dark Matter & Dark Energy
Is there SUSY?   Extra Dimensions?
New Forces?
Is String Theory correct?
Flavor physics, masses and mixings
Neutrino masses and mixings
Rare processes
…..

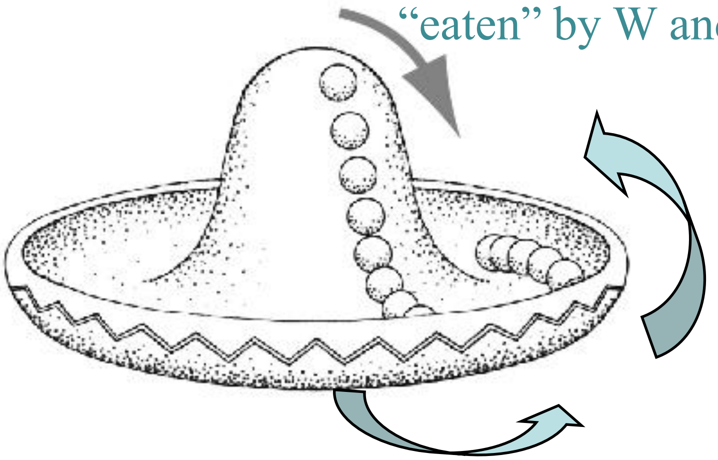
Spontaneous Symmetry Breaking "hides" the SU(2) x U(1) symmetry

preserves renormalizability, unitarity, good high energy behavior, etc.



To understand EWSB, we must observe new particles, such as the Higgs boson.

Nambu-Goldstone Bosons: "eaten" by W and Z



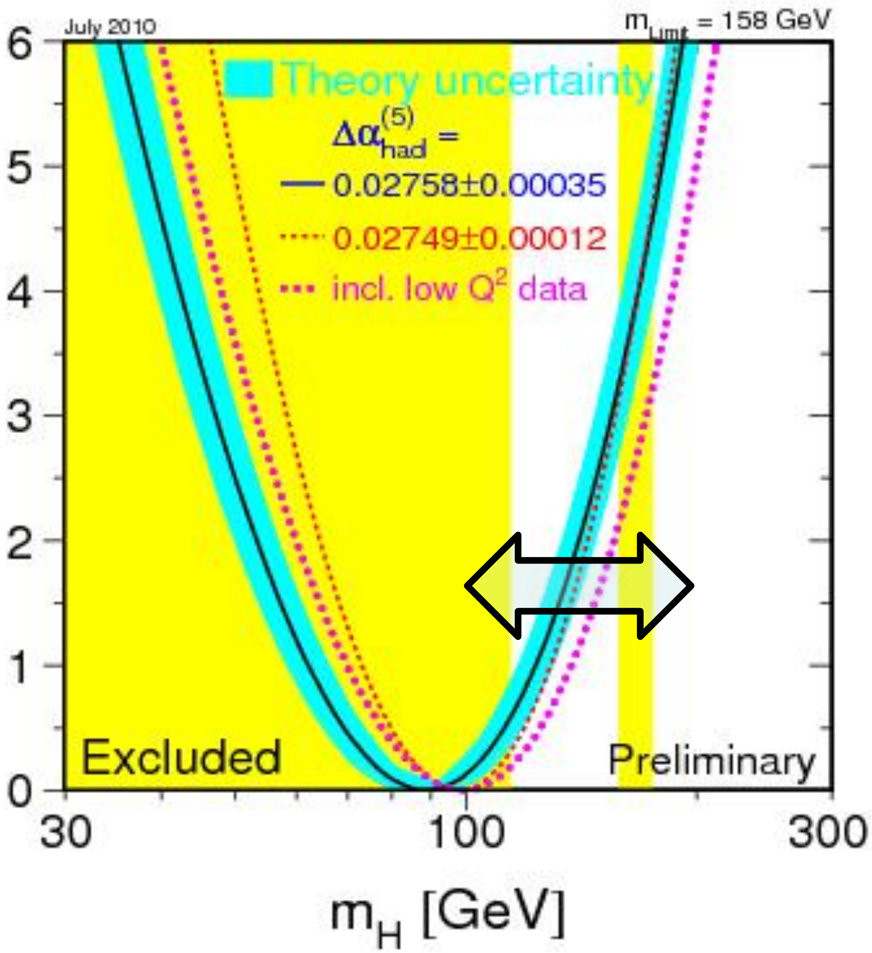
Not finding the Standard Model (SM) Higgs boson will contradict the Standard Model and place severe constraints on the physics beyond.

"Higgs Boson": radial oscillation = massive mode

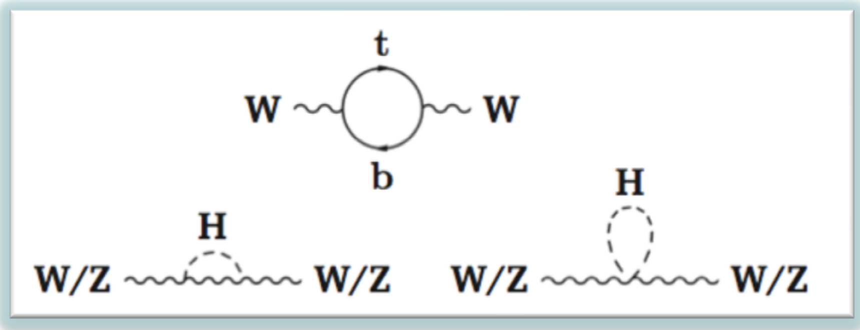
The Standard Model Predicts a Low Mass Higgs

Precision electroweak result:

$114 < M_H < 185$ GeV @ 95% C.L.

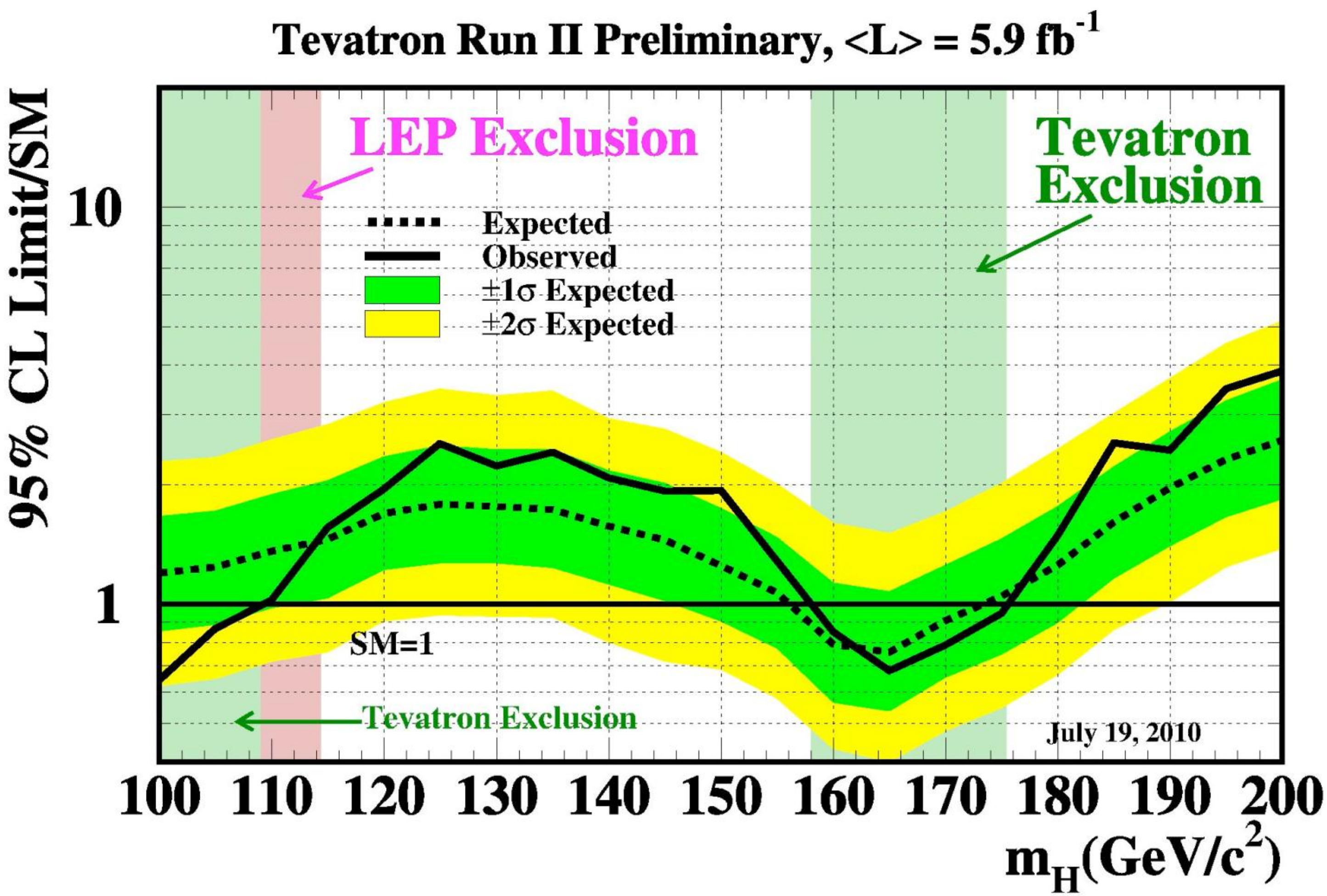


http://lepewwg.web.cern.ch/LEPEWWG/



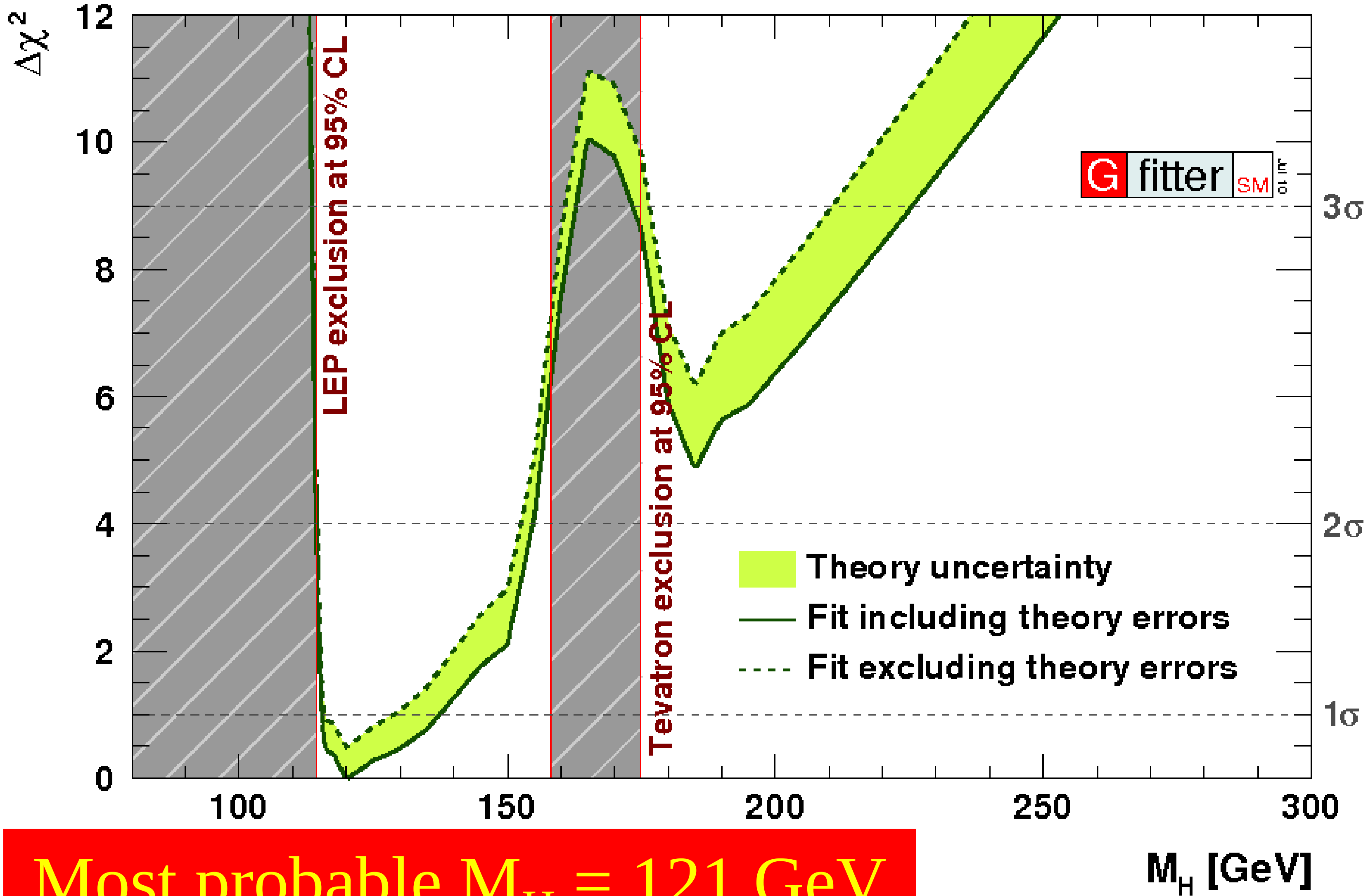
This region must be thoroughly explored!

Status of Tevatron Higgs Searches



About 25% of 114 – 185 GeV region now excluded

Combining all the Higgs information

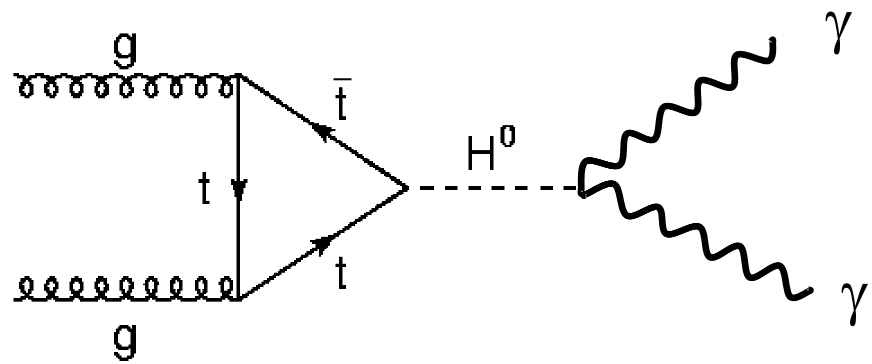


Most probable M_H = 121 GeV

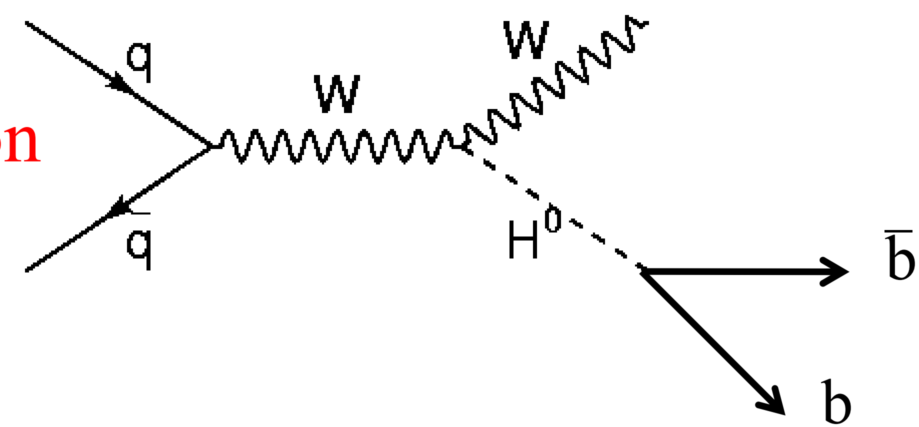
Exploring the Low Mass Region LHC and Tevatron are complementary:

LHC: gluon fusion

Tevatron uses this mode for higher mass h -> WW

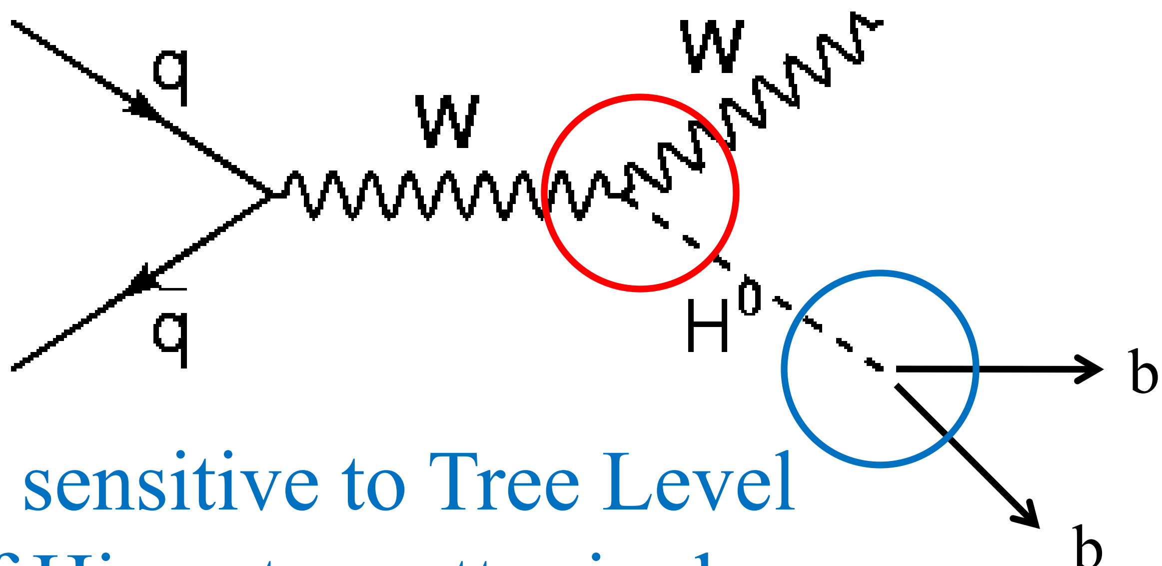


Tevatron: $q\bar{q}$ annihilation associated production



Standard Model Complementarity:

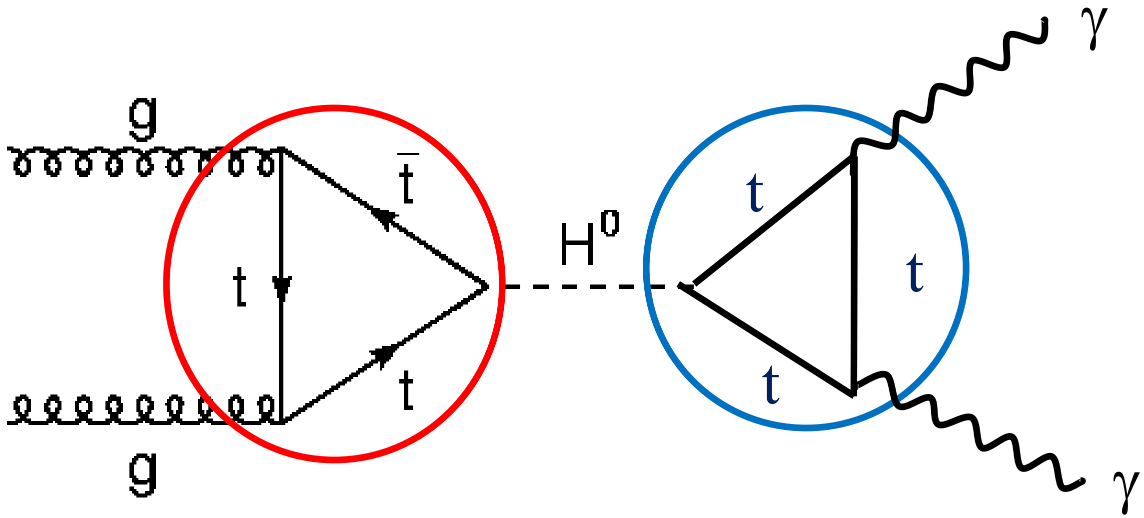
Tevatron is sensitive to Tree Level couplings of Higgs to gauge bosons in production:



Tevatron is sensitive to Tree Level coupling of Higgs to matter in decay

Standard Model Complementarity:

LHC is sensitive to Loop Level
(top loop) effects in production:



LHC is sensitive to Loop Level
(top and W loop) effects in decay.

Observation of Associated Production at LHC may be possible,but requires dissecting high-ET jet substructure:

Difficult: > **30 fb^{-1}** @ 14 TeV

August 19, 2009

ATLAS PUBLIC NOTE

August 19, 2009

ATLAS Sensitivity to the Standard Model Higgs in the *HW* and *HZ* Channels at High Transverse Momenta

Assuming perfect background understanding:

M_H = 120 GeV: 3.7 σ

If 15% bkgnd uncertainty, get: 3.0 σ

Tevatron: 3.6 σ at 16 fb^{-1} .

Cocktail of backgrounds

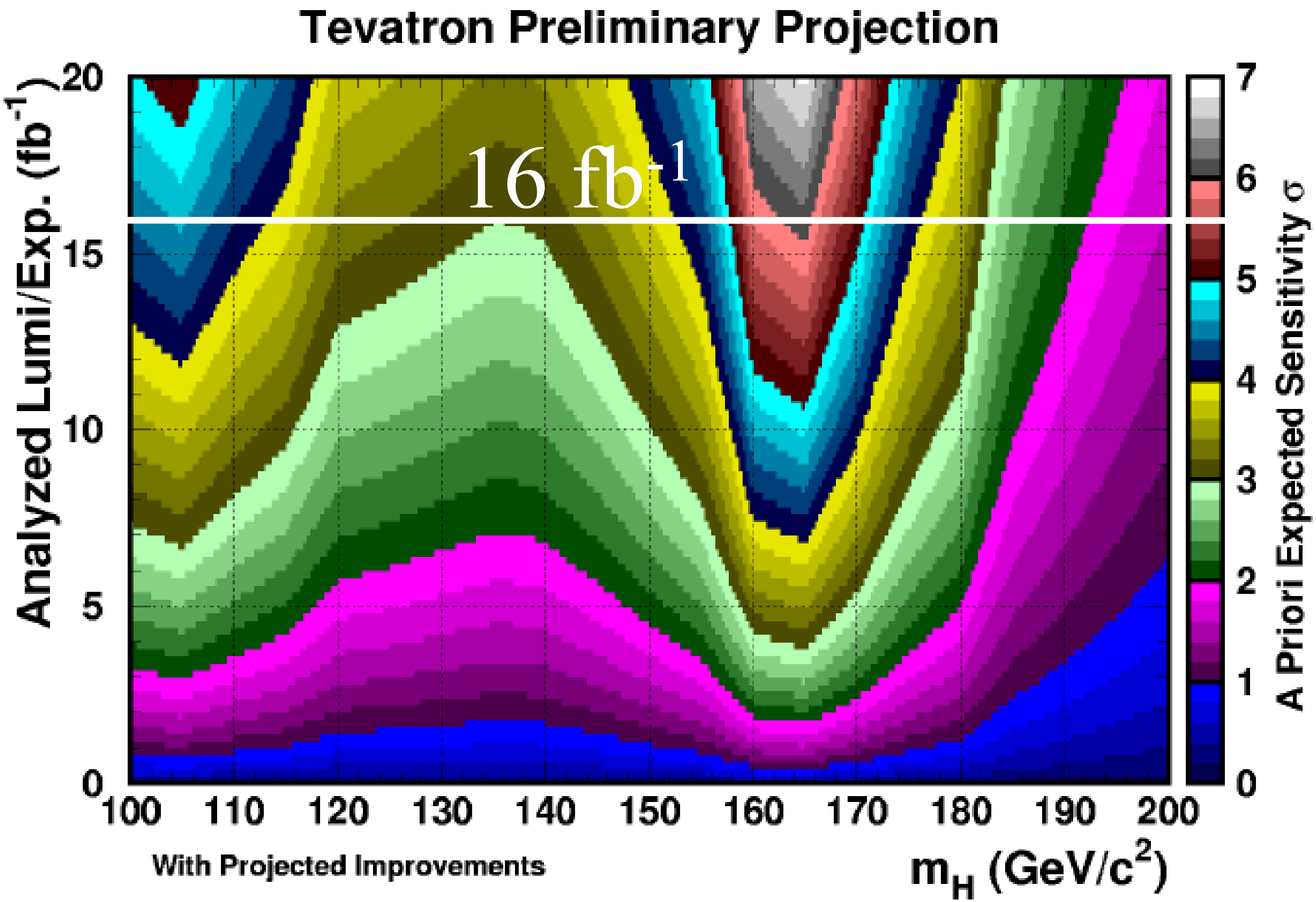
J. M. Butterworth, A. R. Davison, M. Rubin and G. P. Salam, "Jet substructure as a new Higgs search channel at the Large Hadron Collider," arXiv:0810.0409 [hep-ph].

" Reconstructing W or Z associated $H \to b\bar{b}$ production would typically involve identifying a leptonically decaying vector boson, plus two jets tagged as containing b-mesons. Two major difficulties arise in a normal search scenario. The first is related to detector acceptance: leptons and b-jets can be effectively tagged only if they are reasonably central and of sufficiently high transverse momentum. The relatively low mass of the VH (i.e. WH or ZH) system means that in practice it can be produced at rapidities somewhat beyond the acceptance, and it is also not unusual for one or more of the decay products to have too small a transverse momentum. The second issue is the presence of large backgrounds with intrinsic scales close to a light Higgs mass. For example, $t\bar{t}$ events can produce a leptonically decaying W, and in each top-quark rest frame, the b-quark has an energy of $\sim 65\,\text{GeV}$, a value uncomfortably close to the $m_H/2$ that comes from a decaying light Higgs boson. If the second W-boson decays along the beam direction, then such a $t\bar{t}$ event can be hard to distinguish from a WH signal event. "

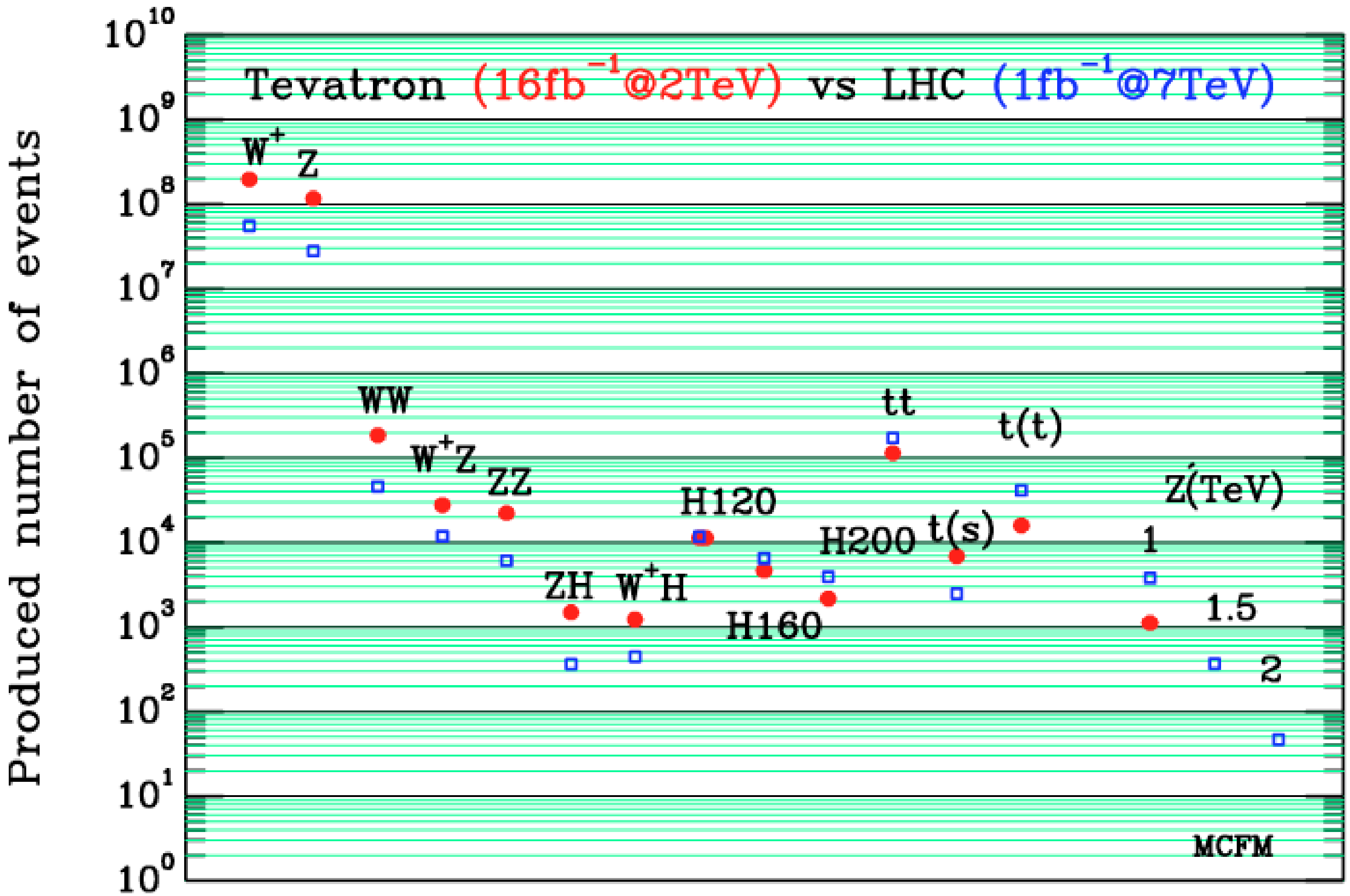
The Tevatron is ppbar; LHC is pp.

For Tevatron the signal/bkgnd is better for H -> bb

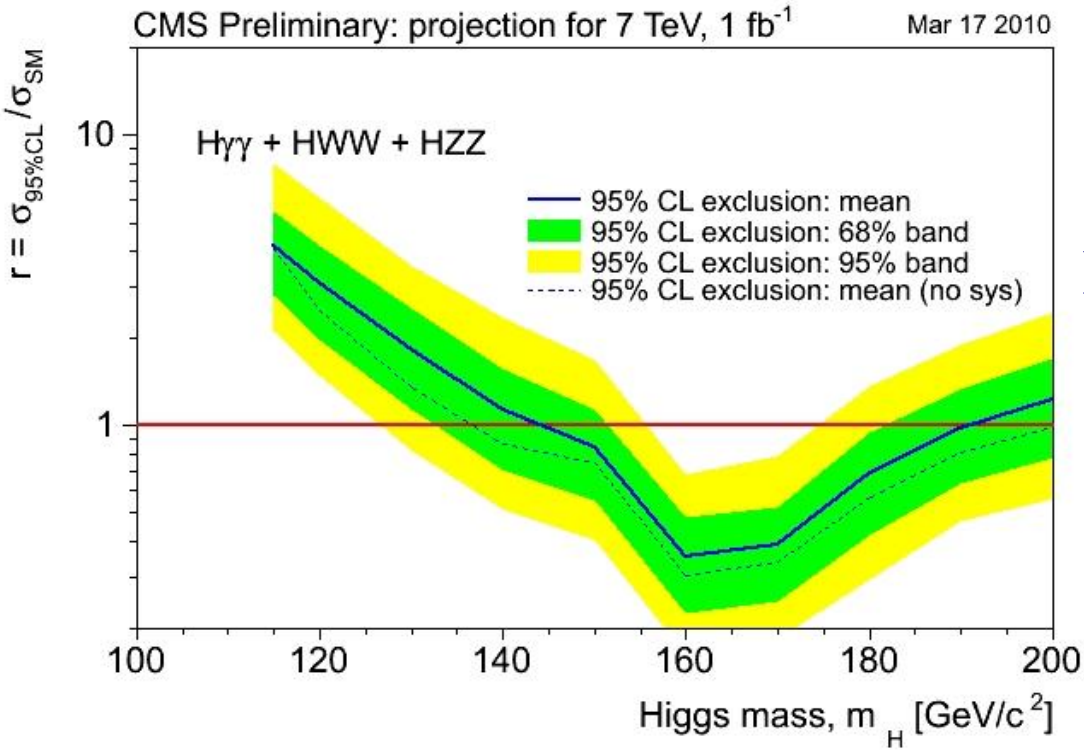
H -> bb sensitivity Run-IIE $\geq$ 3 sigma



Most other processes are complementary at LHC 1 fb^{-1} @ 7 TeV vs. Run-IIE



Low mass Higgs at the LHC in the $\gamma + \gamma$ mode



Low int. luminosity (1 fb^{-1}):

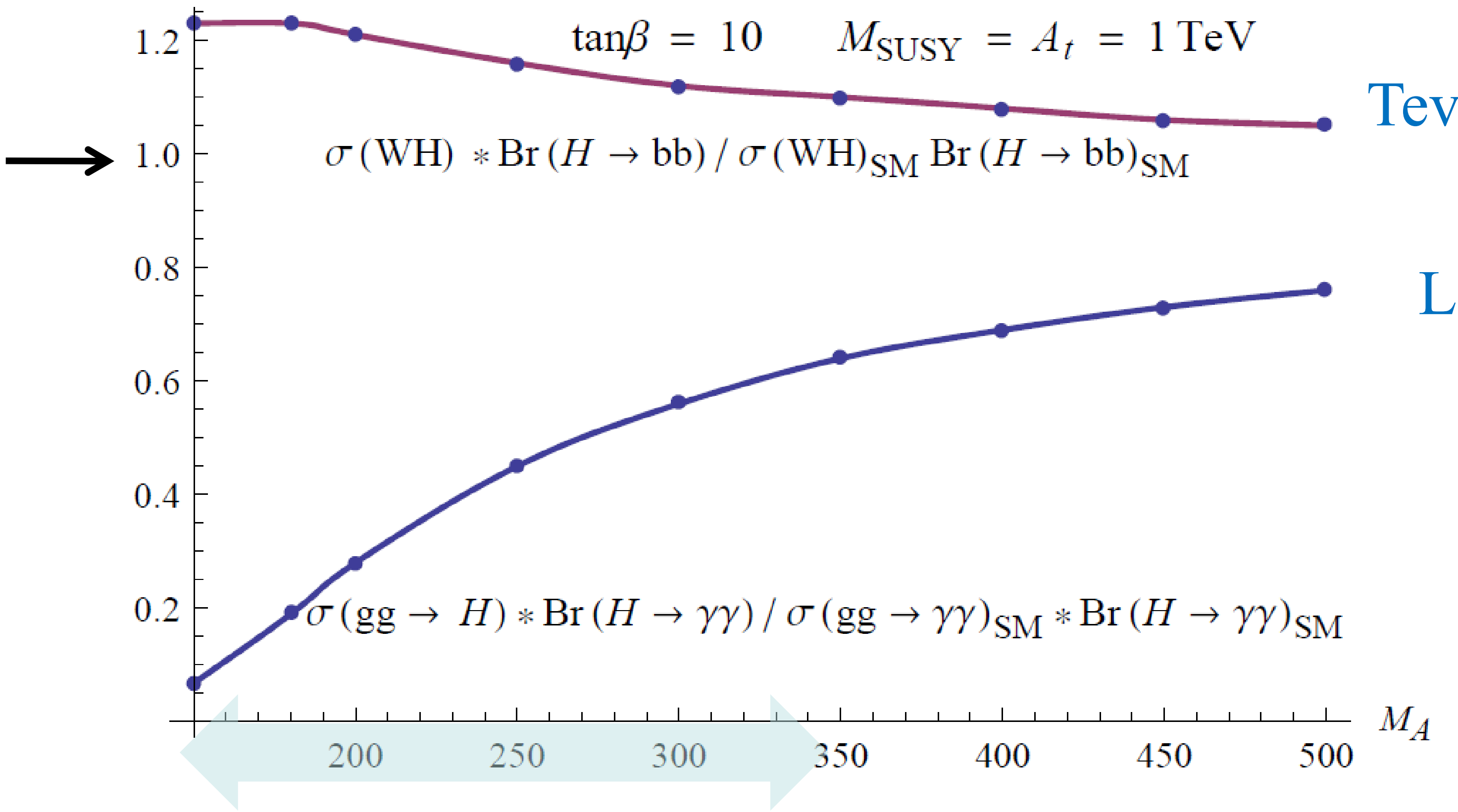
$$gg \to H \to \gamma\gamma$$

Sensitivity to SM Higgs in $\gamma\gamma$ requires more than 1 fb^{-1} @ 7 TeV.

Complementarity in Theory Space

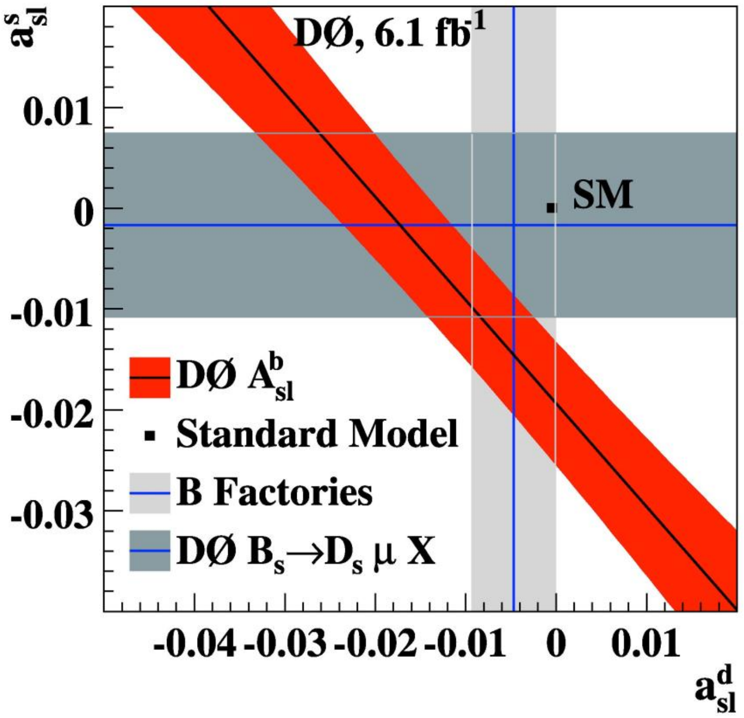
Tevatron and LHC involve different processes
implying different sensitivities to new physics beyond the SM

MSSM: 2 Higgs doublets; more parameters $M_h \sim 120$ GeV



Hints and Other Excesses Abound

Example:



Dzero finds evidence for matter-antimatter asymmetry in the production of muon pairs with 3.2 sigma significance.

Enormous interest in science community and public.

Measurement exploits perfect symmetry of proton-antiproton initial state – unique to Tevatron.

More data needed.

CDF

STRENGTH OF THE COLLABORATION

- Before June PAC meeting we performed a quick survey of the collaboration by email. Out of 59 institutions, 50 were interested in an extended run.
- In response to PAC request for a more accurate assessment we have taken a full survey, talking to every institution directly and discussing their projected involvement.
- We asked them to assume the following scenario:
  1. Tevatron run is extended for 3 years beyond 2011
  2. Their funding remains constant at 2010 level.

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CDF

CDF COLLABORATION projections

2009 Survey/ Current Survey /Actual

"RUN III" (2012–2014)

	2009	2010	2011	2012	2013	2014
Tot FTE	292	249/278	191	141/184	179	176
U.S.	46%	48%/51%	50%	46%	46%	46%
postdocs	71	65/72	47	29/48	46	45
students	100	77/91	51	33/60	57	55
fac. level	121	107/115	93	79/76	76	76

- Actual 2010 numbers turn out larger than projected in 2009, staying at 2009 level. This has always been the case in past surveys.

Notes:
- #'s are in FTE
- faculty level = teaching and non-teaching faculty + lab scientists

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CDF

Effort Required to Operate CDF Today

	Today
Operations	40 FTE
Offline	15 FTE
Management	10 FTE
Algorithms	10 FTE
Total Effort	75 FTE

- 40% less than a few years ago. Might still shrink a bit.
- This is the effort required to do everything in CDF operations except physics analysis
- This leaves 110 FTE for physics
- This is enough for Higgs analysis (30 FTE) and much more.

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D-Zero

Effort Reports

Task	2008	2009
Algorithms	26	27
Computing	16	13
Management	19	19
Operations	55	52
Sum	**116**	**111**
Student Supervision	18	15
Analysis	173	151
Total	**307**	**277**

- Yearly, detailed “Effort Reports” for every collaboration member.
- About 90 FTEs needed to operate the experiment.
- Physics Group FTEs: Higgs 42, Top 32, other groups ~15 each.

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Future Manpower

Within the last two weeks we performed a complete survey of all groups asking them to provide manpower estimates for 2012-2014.
Groups were asked to assume that funding is available.

Category	2012	2013	2014
Academics/Senior Researcher	94	89	86
Postdocs	71	64	62
Students	80	76	73
Total FTEs	**244**	**228**	**220**

- Excellent return rate: 93% of the collaboration responded.
- Most of the collaboration committed for the full three years.
- Sufficient manpower for experiment operation and physics programme.
- Past experience shows that these estimates tend to be conservative.

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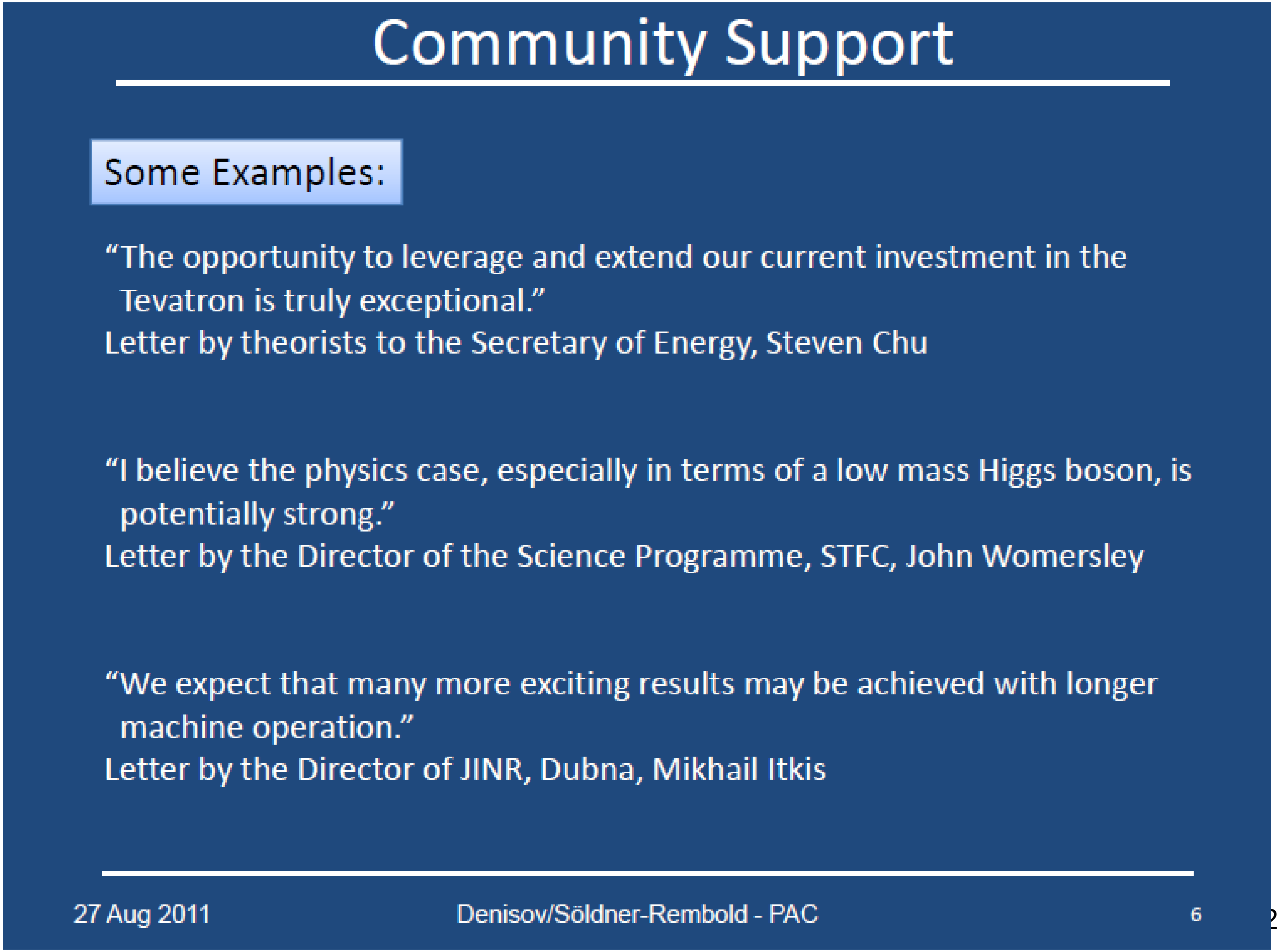
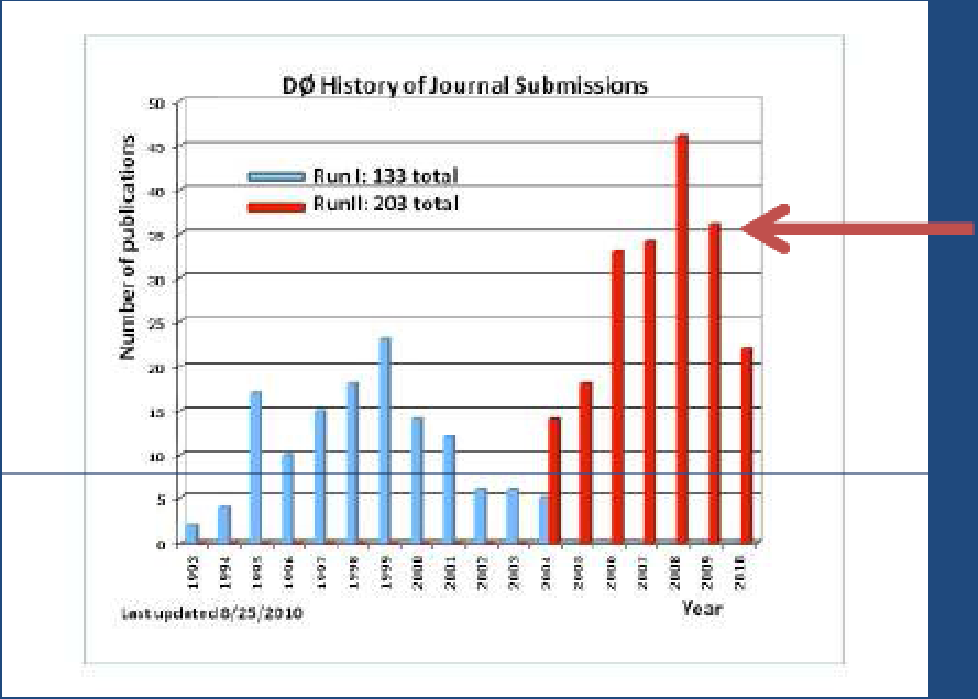

Community Support
Some Examples:
“The opportunity to leverage and extend our current investment in the Tevatron is truly exceptional.”
Letter by theorists to the Secretary of Energy, Steven Chu
“I believe the physics case, especially in terms of a low mass Higgs boson, is potentially strong.”
Letter by the Director of the Science Programme, STFC, John Womersley
“We expect that many more exciting results may be achieved with longer machine operation.”
Letter by the Director of JINR, Dubna, Mikhail Itkis
27 Aug 2011
Denisov/Söldner-Rembold - PAC
6

D-Zero

Physics Output

- stable physics output (expect ~35 papers in 2010).
- 40 parallel and 4 plenary talks for Tevatron at ICHEP.
- Very large number of talks (~200) demonstrate continuing interest in physics programme.



Highlights in 2011:
- "Anomalous Dimuon Asymmetry" accepted by PRL & PRD last week, 42 citations
- "Combination of Higgs Searches in WW decays", published in PRL, 28 citations

SUMMARY

- Finding the Higgs or excluding it in the favored mass region is crucial to understanding nature and to define the strategy for the future of particle physics (LHC, ILC, Muon Collider, etc.).
- For several more years, the Tevatron will have excellent sensitivity to a low mass Higgs boson.
- Tevatron and LHC will provide complementary information to understand EWSB; only the Tevatron will probe couplings to b in near term.
- Many other legacy measurements and searches for new physics in other channels will continue at Tevatron.