Particle Physics Project Prioritization Panel (P5)

Report to HEPAP

October 26, 2010

P5 Meeting October 15/16

- DOE and NSF asked HEPAP to reconvene the P5 Panel to give advice on the desirebility of extending the Tevatron run at Fermilab past the presently scheduled turnoff at the end of 2011 for three years into 2012, 13, and 14.
- P5 held a meeting on October 15 and 16 near Washington DC to consider this issue.

P5 Membership

Charles Baltay (Yale University), Chair

Hiroaki Aihara (University of Tokyo)

James Alexander (Cornell University)

Daniela Bortoletto (Purdue University)

James Brau (University of Oregon)

Peter Fisher (M I T)

Josh Frieman (Fermilab) Telephone

Fabiola Gianotti (CERN)

Donald Hartill (Cornell University)

Tor Raubenheimer (SLAC)

Andrew Lankford (U C Irvine)

Joseph Lykken (Fermilab) Telephone

William Marciano (Brookhaven)

Jay Marx (Cal Tech) Telephone

Steve Ritz (UC Santa Cruz)

Marjorie Shapiro (Berkeley) Telephone

Henry Sobel (U C Irvine)

Robert Tschirhart (Fermilab)

Carlos Wagner (Argonne)

Stanley Wojcicki (Stanford) Telephone

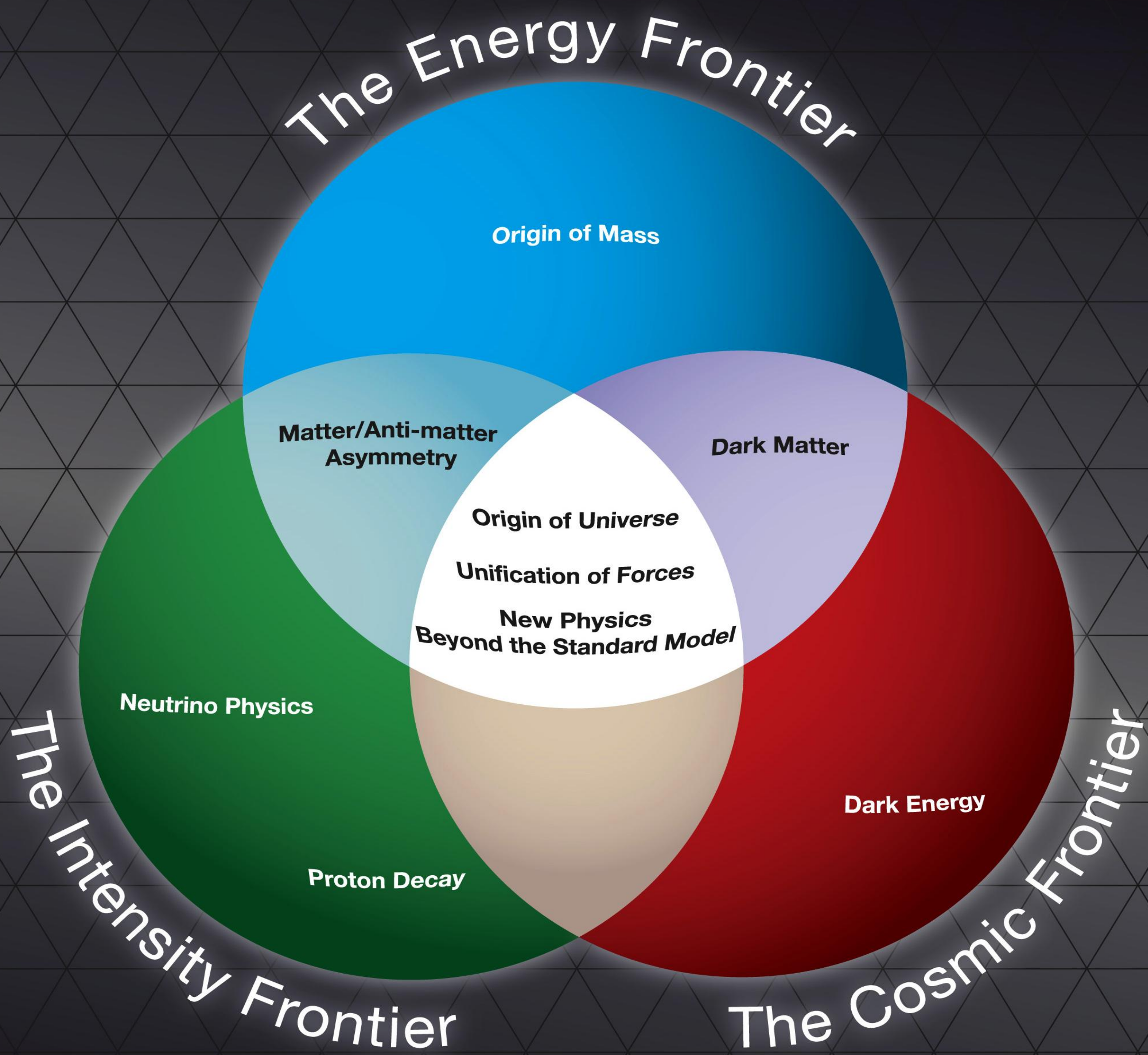
Mel Shochet (University of Chicago) (Ex-Officio)

US Particle Physics: Scientific Opportunities

A Strategic Plan for the Next Ten Years

Report of the
Particle Physics Project Prioritization Panel

May 29, 2008


The Energy Frontier
Origin of Mass
Matter/Anti-matter Asymmetry
Dark Matter
Origin of Universe
Unification of Forces
New Physics Beyond the Standard Model
Neutrino Physics
Proton Decay
Dark Energy
The Intensity Frontier
The Cosmic Frontier

The P5 plan developed in 2008

- P5, after a lengthy in depth study, developed a 10 year plan for the US particle physics program that was accepted by HEPAP on May 29, 2008.
- The agencies, DOE and NSF, have followed this plan since then to the best of their ability.
- At the October 2010 meeting P5 reexamined this plan and reaffirmed it as the best way forward for our field.

A New Opportunity

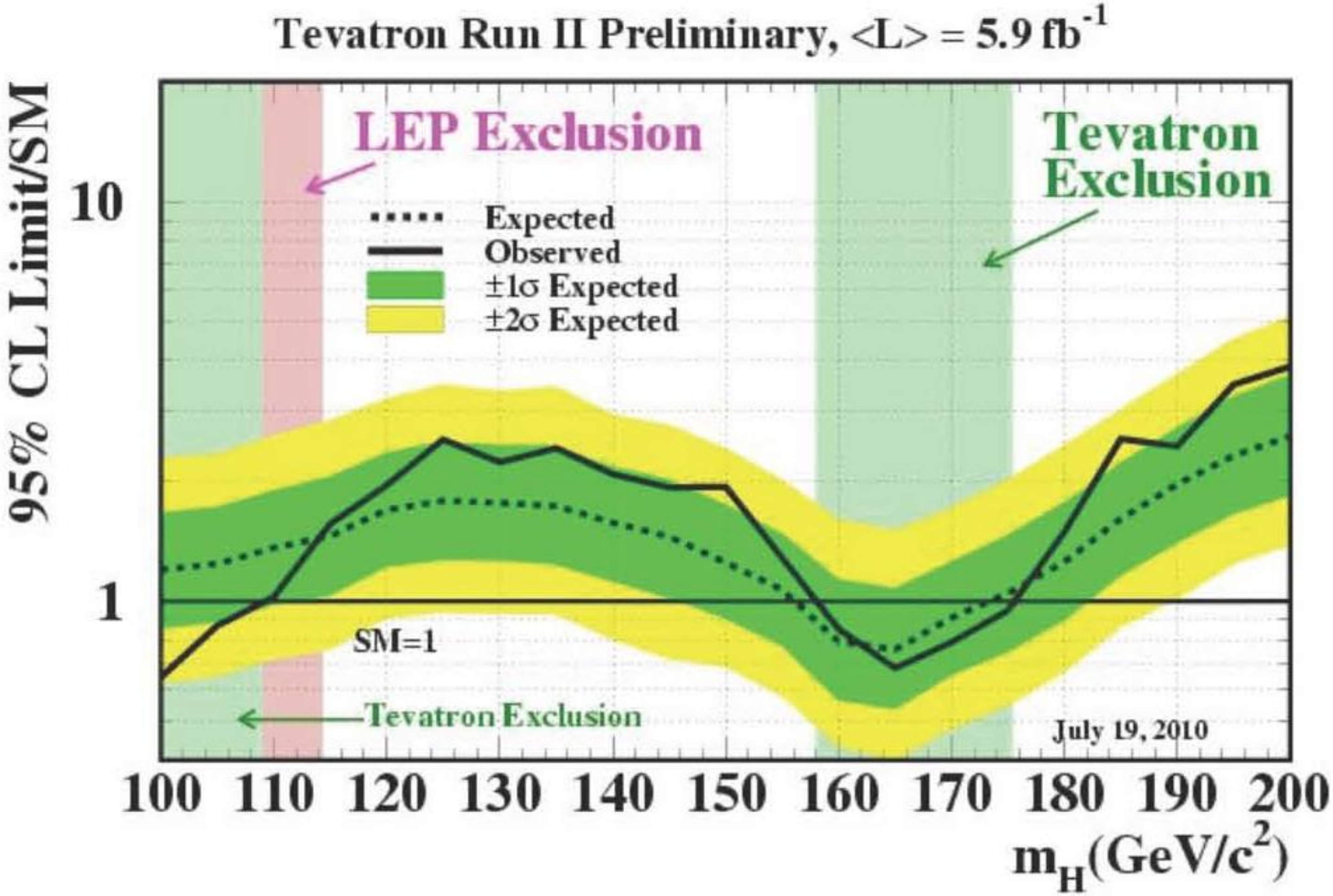
- The Tevatron Collider and its experiments, CDF and DO, have performed extremely well in the past two years.
- The analysis techniques of the two experiments have increased considerably in sophistication allowing the sensitivity to new science to increase more rapidly than the increases due to improved statistics alone.

A New Opportunity

- The Tevatron experiments are now at the point where they significantly enter the region of the Standard Model Higgs Boson
- With an extended run they would have significant sensitivity over the entire Higgs mass range favored by the precision electroweak measurements

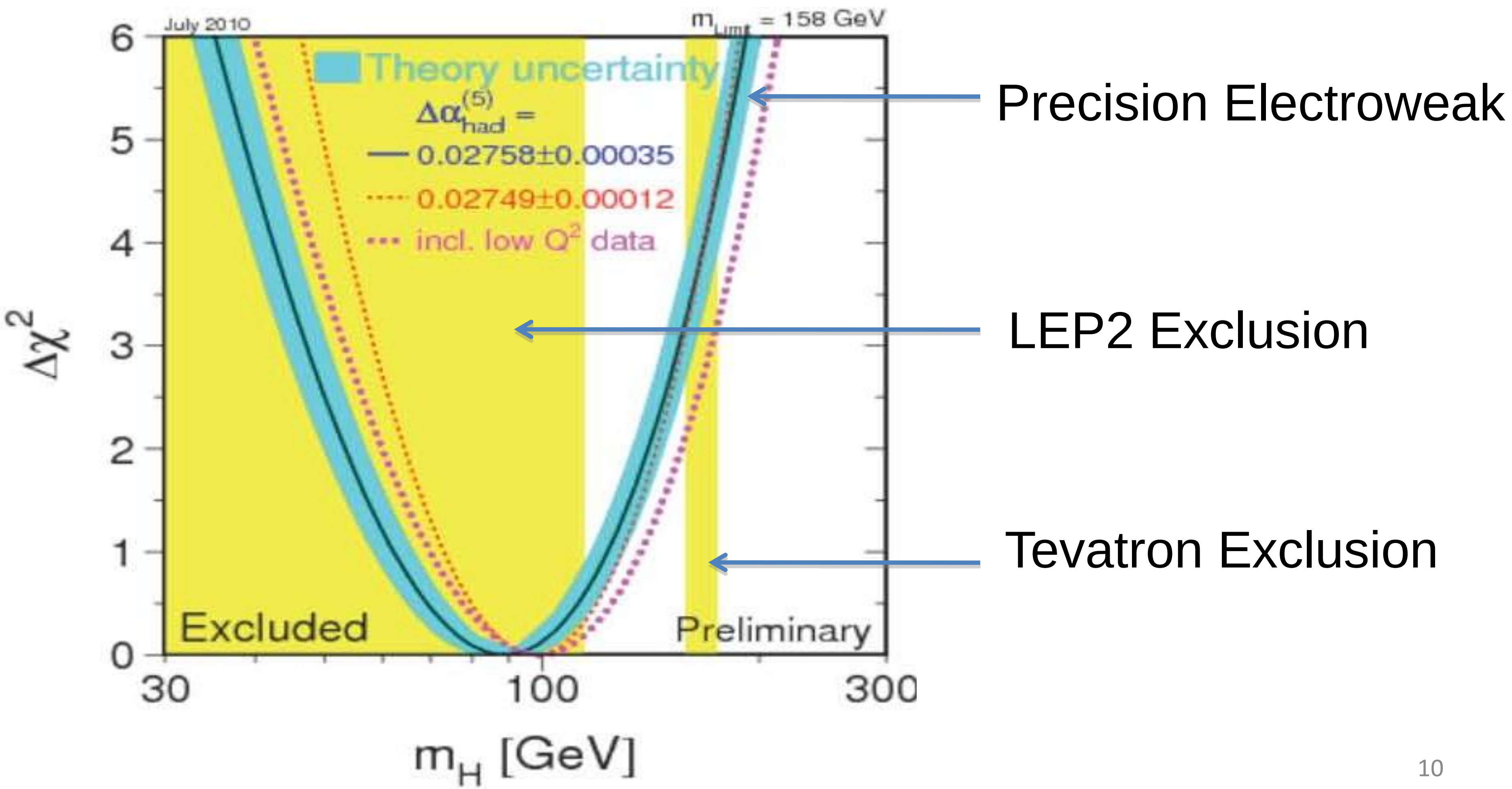
The Tevatron is in the Higgs Game!!

ICHEP 2010



Higgs Mass Range of Interest

$115 \text{ Gev} < m_H < 158 \text{ Gev}$

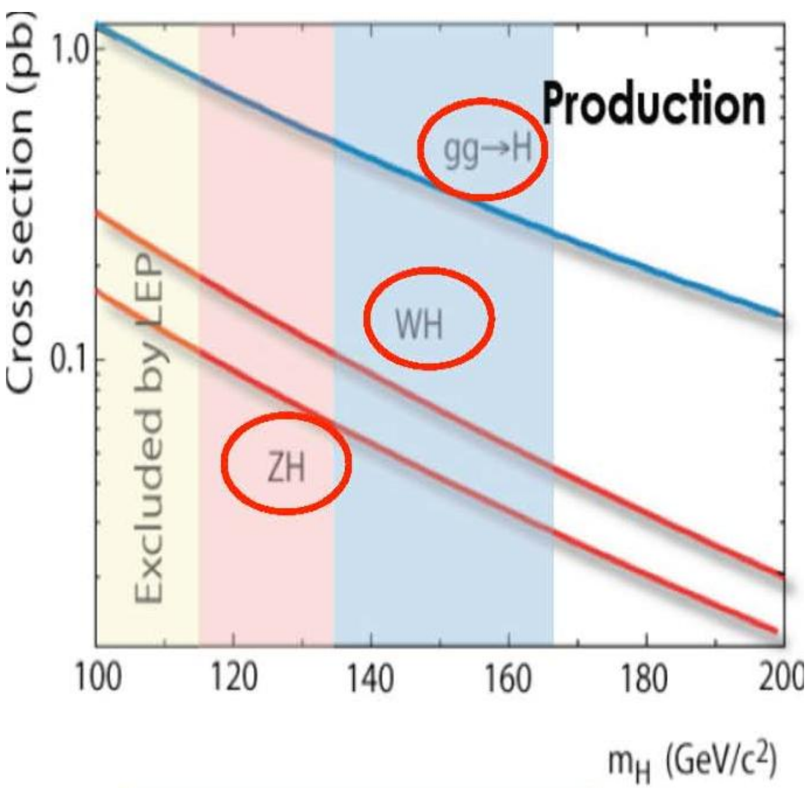


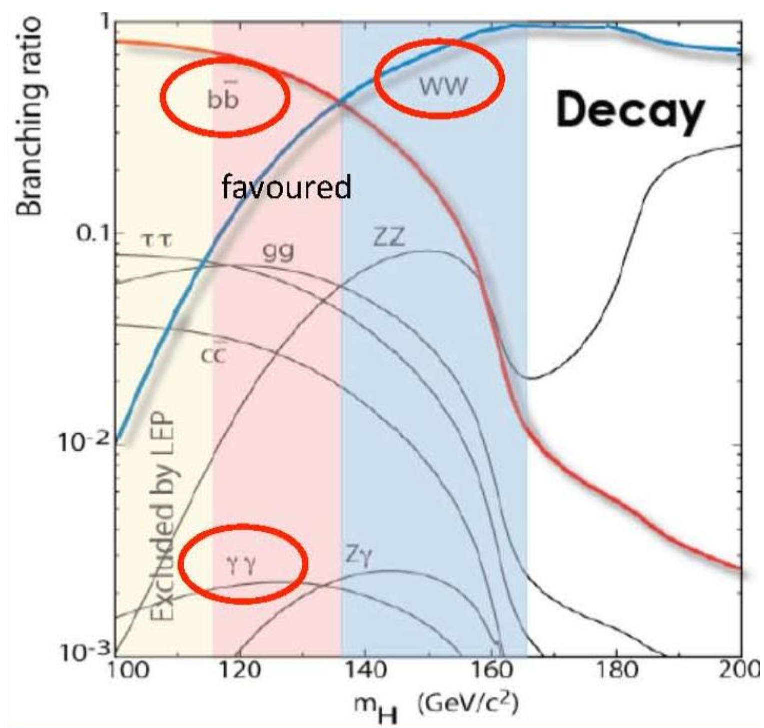
Three dominant processes of interest

$q + \bar{q}$ -> WorZ + H -> $b + \bar{b}$ Best at $115 < m_H < 135$ Gev

g+g -> H -> $\Upsilon + \Upsilon$ $m_H < 135$ Gev, LHC only

g+g -> H -> W + W Best at $135 < m_H < 158$ Gev





Expected Tevatron Luminosities

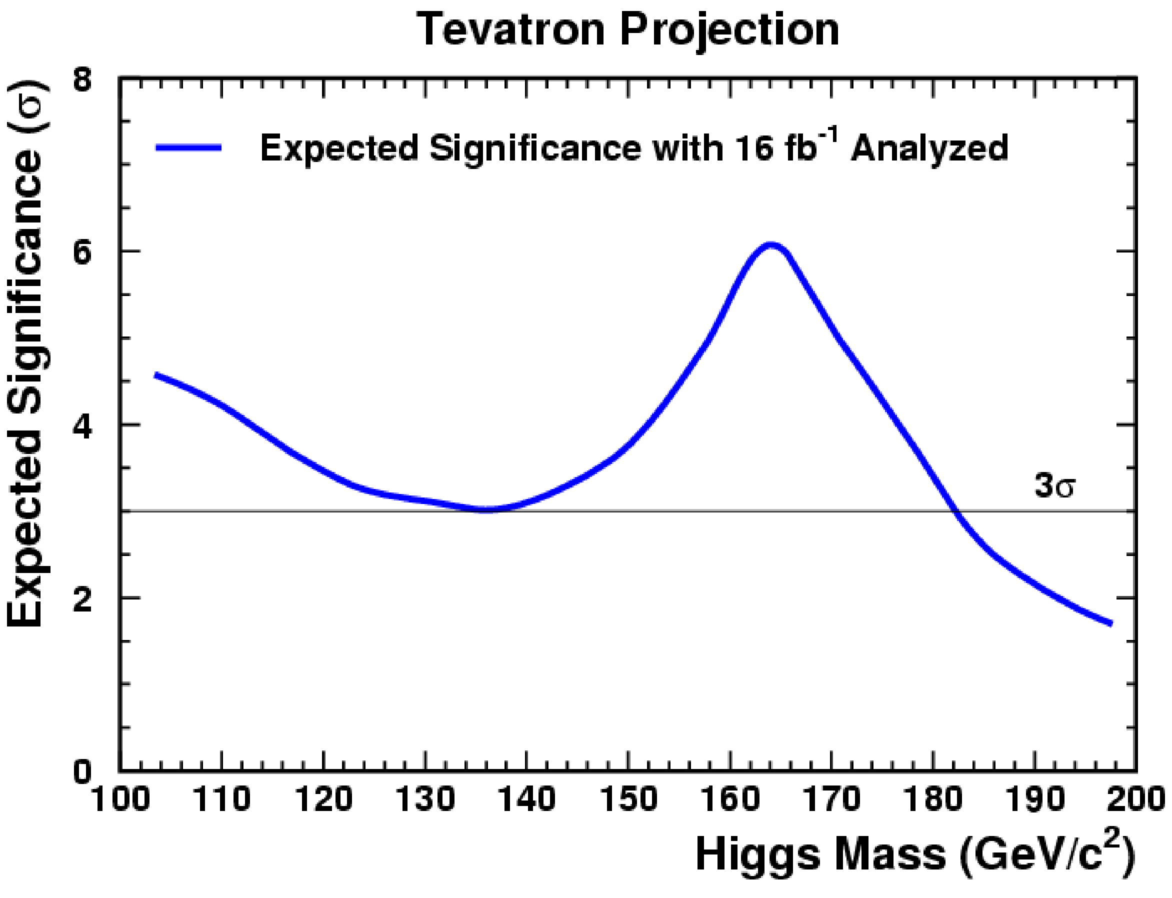
- Typically 85% of the luminosity delivered by the Tevatron is recorded and of sufficient high quality to be used for Higgs searches.

Year	L delivered	L analyzed
Now	7 fb^{-1}	6 fb^{-1}
End of 2011	12 fb^{-1}	10 fb^{-1}
End of 2014	20 fb^{-1}	16 fb^{-1}

Sensitivity of an Extended Tevatron Run

3 σ or better sensitivity to a Higgs signal over the entire interesting mass range

Including the H -> b b decay mode at low mass

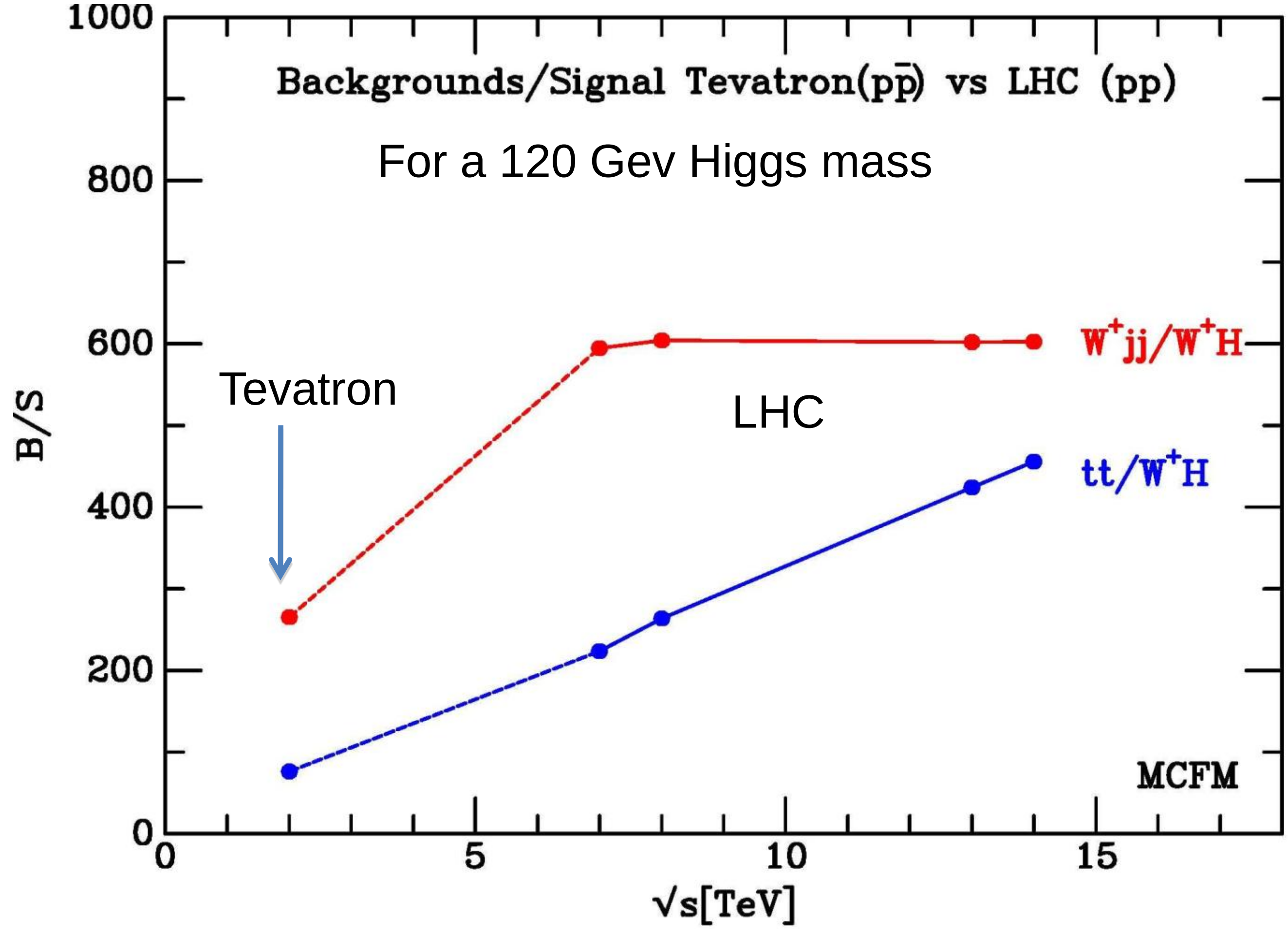


The importance of the H -> b bbar decay mode

- Measures the coupling of the Higgs to b quarks
- The largest branching fraction, and therefore the best decay mode at the Tevatron, for a light Higgs in the most likely mass range of 115 to 135 Gev
- An observation of the Higgs to b bbar decay would provide information on the product of the Higgs production crossection times its decay branching ratio. Comparing this with the standard model prediction would give an indication whether the Higgs is a Standard Model Higgs or something more complicated.
- The main background to the b bbar decay mode comes from t tbar and W+jets production. The crossection for these rise much more rapidly with energy then the associated Higgs production crossection. Therefore the signal to noise is much more favorable at the low energy of the Tevatron

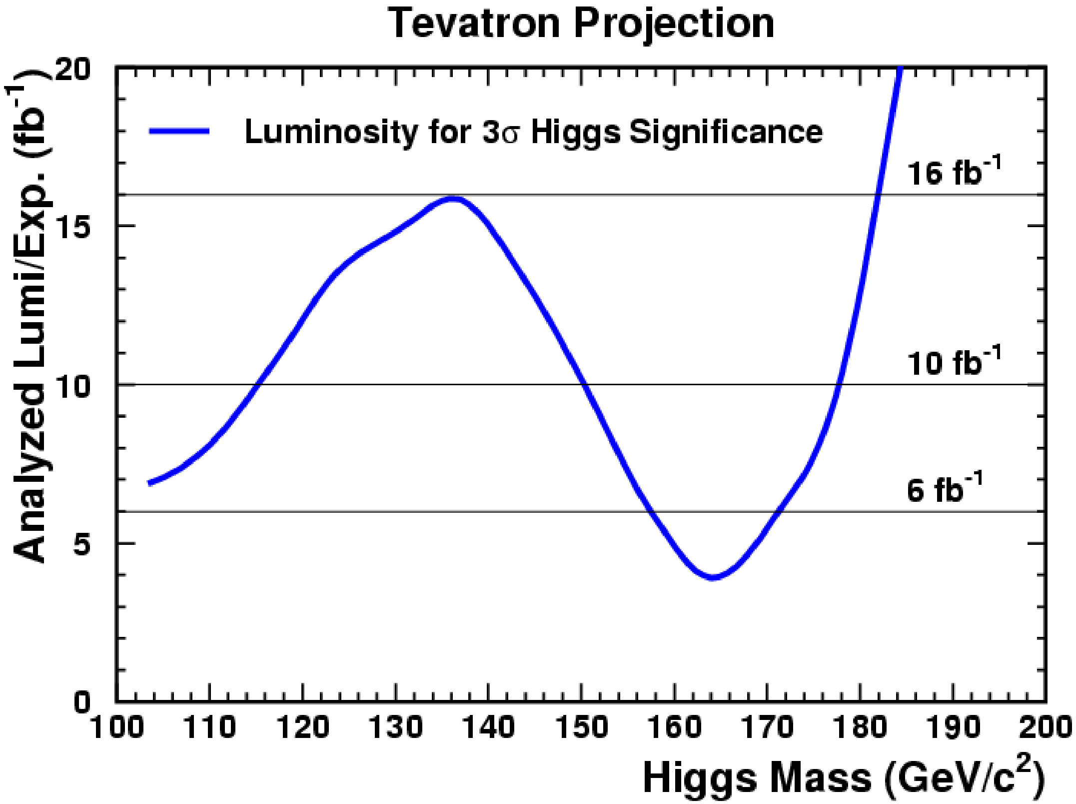
Backgrounds to q+qbar-> W + H, H->b+bbar,

Dominant backgrounds are from t+tbar and W+jets



Why is the 60% increase in luminosity (from 10 to 16 fb^{-1}) so important?

The combination of the improved statistics with the continually improving analysis techniques is expected to get the sensitivity to a Higgs signal over 3 standard deviations over the entire mass range of interest

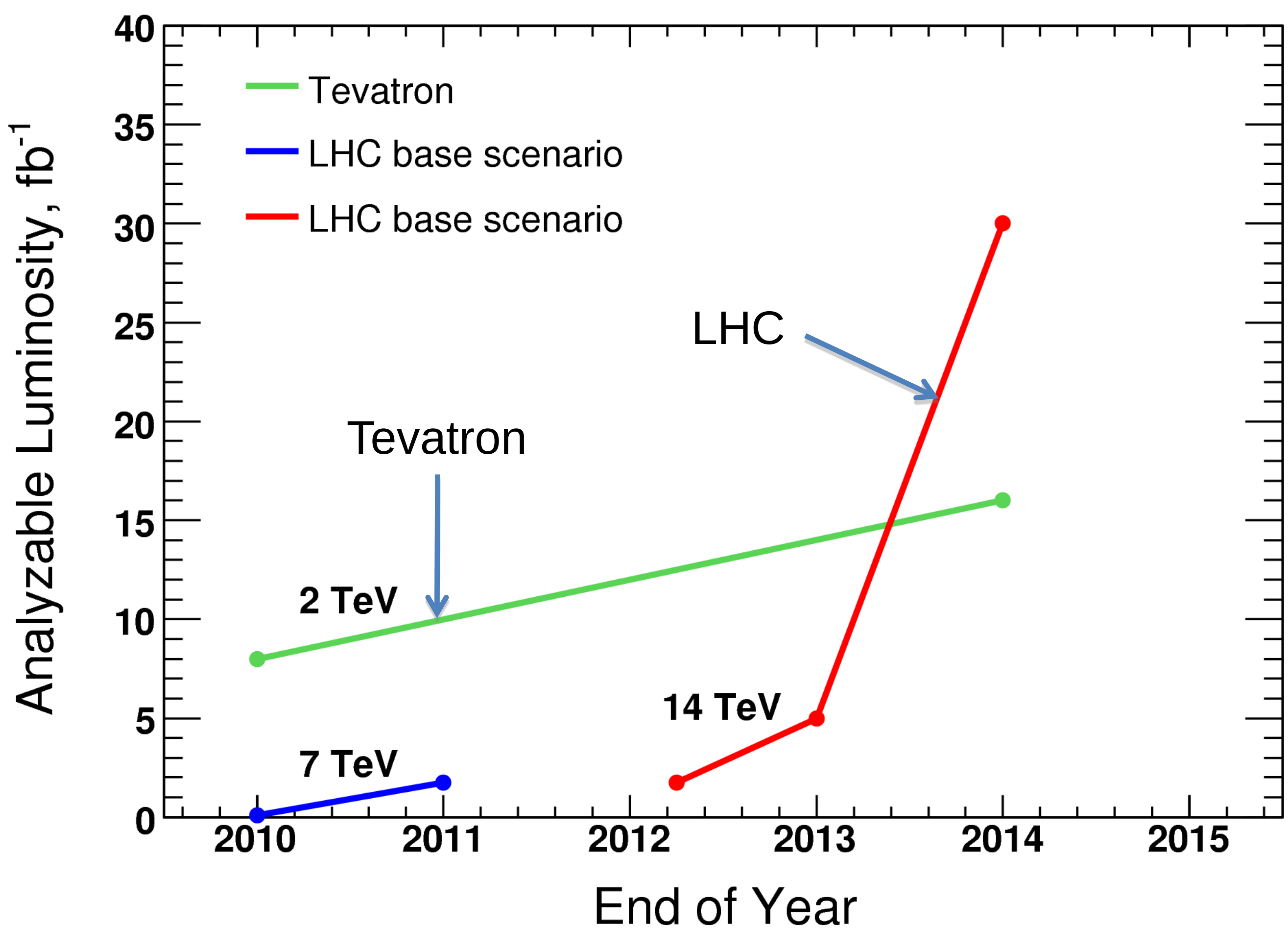


The Outlook at the LHC

- The Base Plan:
  - Accumulate 1 (to 2?) fb-1 at 7 Tev by the end of 2011
  - Shut down in 2012 for ~15 months to prepare for 14 Tev running
  - Accumulate   5 fb-1 at 14 Tev by end of 2013
  - Accumulate 30 fb-1 at 14 Tev by end of 2014
- Possible alternative:
  - Run in 2012 at 7 or 8 Tev to accumulate 5 fb-1
  - Delay 14 Tev Running by a year

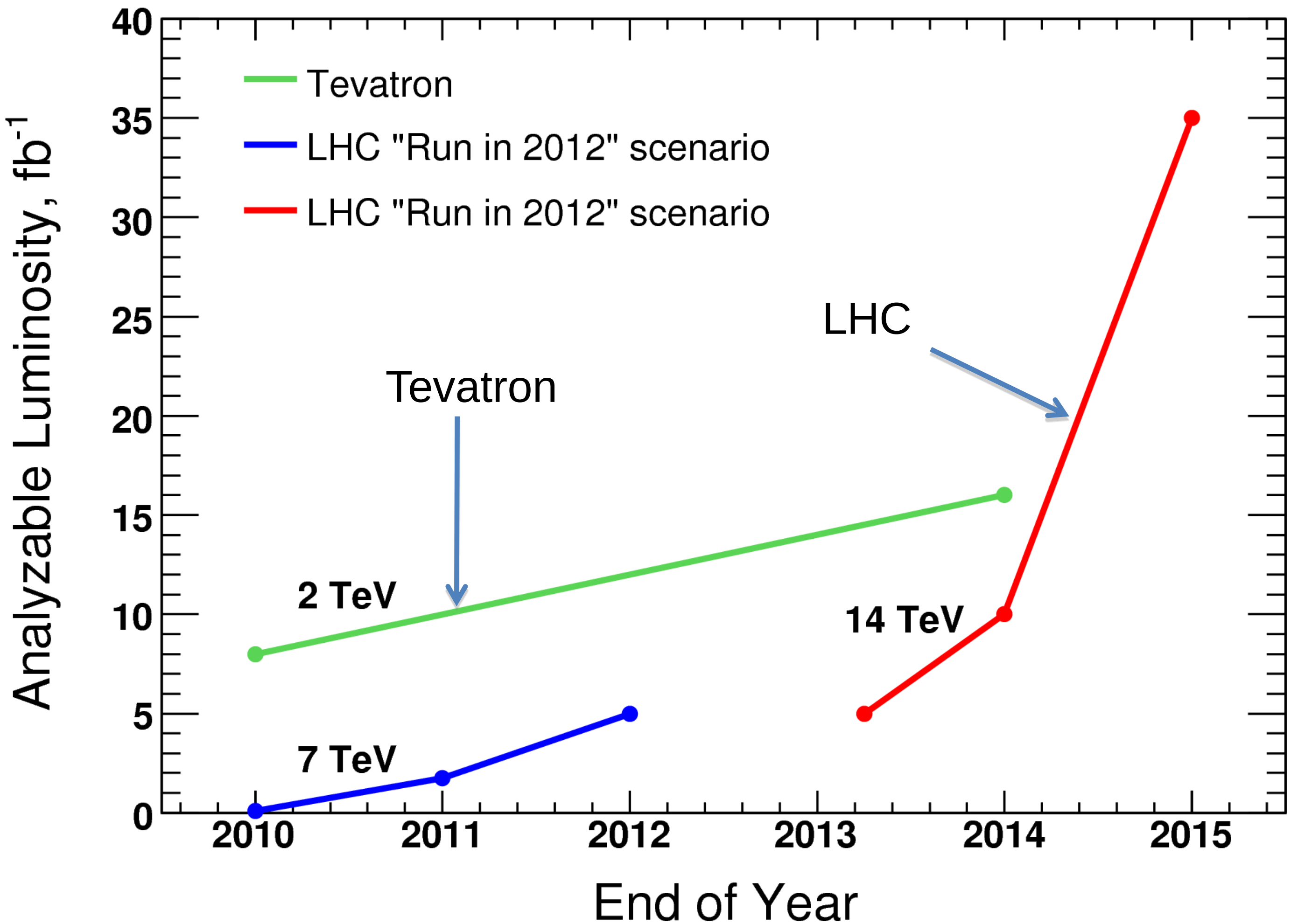
Development of Luminosity with Time

For the LHC Base Plan: shutdown in 2012 for Energy Upgrade



Development of Luminosity with Time

LHC plan with run in 2012,
shutdown for energy upgrade delayed to 2013



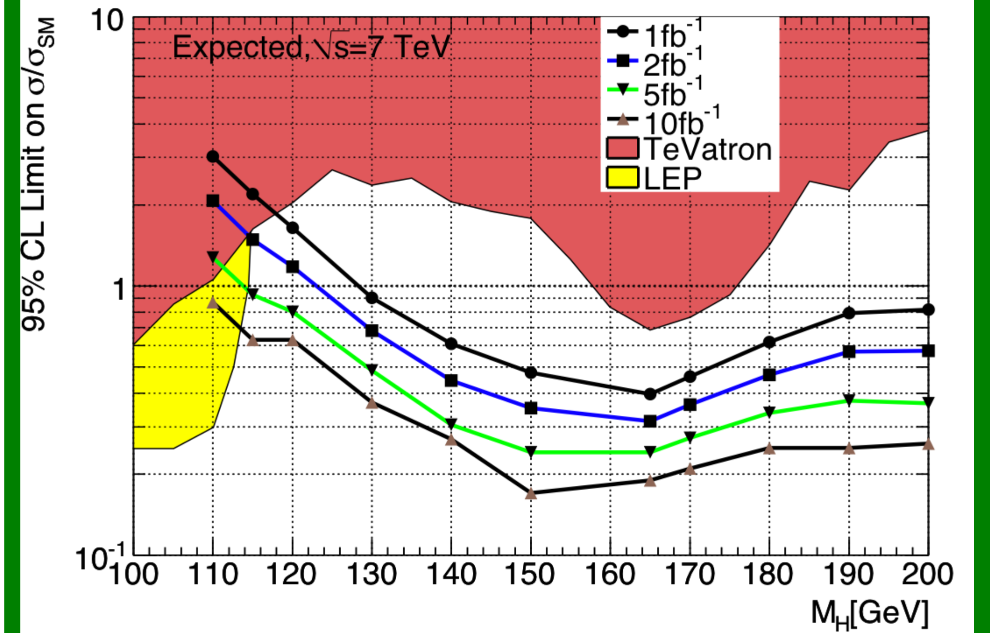
Expected Higgs mass coverage (GeV)

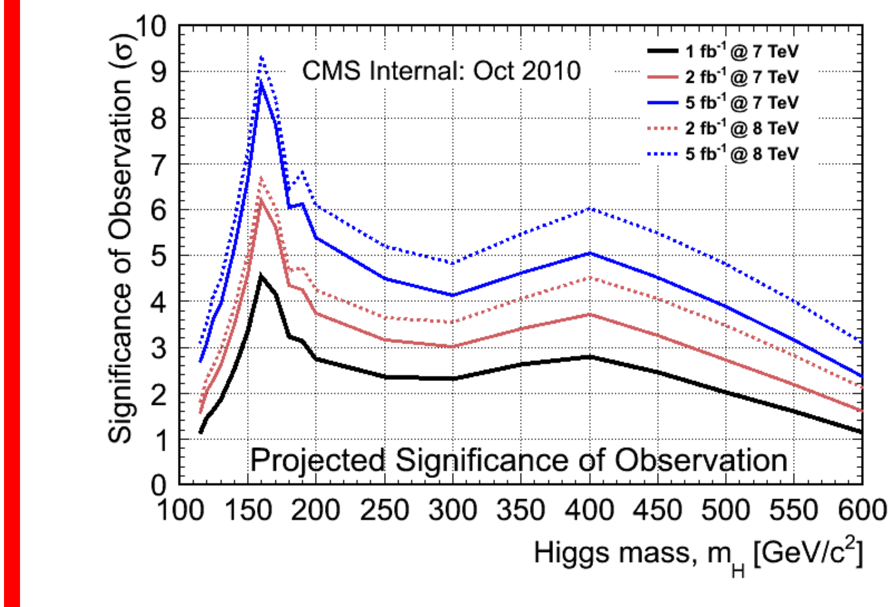
ATLAS and CMS internal and very preliminary

Luminosity per expt and √s	Comments	ATLAS+CMS 95% CL exclusion	ATLAS+CMS 3σ evidence	ATLAS+CMS 5σ discovery
1 fb^{-1} 7 TeV	2011	123-550 GeV	130-450 GeV	152-174 GeV
1 fb^{-1} 8 TeV	2011 (?)	120-570	127-500	150-176
2.5 fb^{-1} 7 TeV	2011 "aggressive"	114-600	123-530	138-220
5 fb^{-1} 7 TeV	2012 (if run)	114-600	114-600	124-510
5 fb^{-1} 14 TeV	2013			> 115
30 fb^{-1} 14 TeV	~2014			H→ bb at 4-5 σ ?

From Fabiola Gianotti

ATLAS internal





Complementarity of the Tevatron and the LHC

- We do not see this as a horse race between the Tevatron and the LHC
- LHC in the long run is clearly the machine to do Higgs Physics
- Solid 5 σ discovery possible only at the LHC
- For the near term, until 2014 when the LHC reaches 30 fb-1 at 14 Tev, the Tevatron could make some significant contributions to elucidate the nature of the Higgs Boson. The two colliders complement each other to paint a clearer picture then either alone.

Complementarity of the Tevatron and the LHC

- In the low mass region (115 to 135 Gev) preferred by the precision electroweak measurements, the Tevatron relies on the dominant H -> $b \bar{b}$ mode while the LHC relies on the rare decay H ->ΥΥ, which is a loop induced effect that is quite sensitive to new physics at the weak scale.
- Thus the two colliders will explore the Higgs in different channels.
- The scientific value of exploring this mass region of the Higgs with complementary channels is very high, given the central importance of the Higgs Boson in our field.

Complementarity of the Tevatron and the LHC

- Extensions of the Standard Model suggest a more complicated Higgs structure. In many of these scenarios the H ->ϒϒ mode is suppressed while the dominant H -> b bar decay mode is more robust.
- Such a suppression might delay the discovery via the γγ mode

Complementarity of the Tevatron and the LHC

- Eventually, after reaching 30 fb-1 at 14 Tev, the LHC will be able to clearly detect the H -> b bbar mode. This can be combined with the Tevatron measurement to yield an estimate of the energy dependence of the Higgs production crossection.
- This will be another valuable check on the nature of the Higgs.

Complementarity of the Tevatron and the LHC

- The Tevatron is a proton-antiproton collider while the LHC is a proton–proton collider. There are other differences such as the b-bbar background is significantly lower at Tevatron energies then at those of the LHC.
- Considering the uncharted nature of the Higgs sector, surprises should not be surprising, and the different properties of the two colliders may compliment each other in ways to help shed more light on the nature of the Higgs sector.

Electroweak Measurements

- The preference for a light Higgs comes from the electroweak measurements from LEP, SLC, and the Tevatron.
- An extended Tevatron run will provide more precise measurements of the W and the top masses.
- An estimate of these improvements is that, if the central values do not change, the 95% confidence level upper limit on the Higgs mass will come down to around 125 Gev.
- Pushing the precision of these measurements to their limit builds on many years of detector calibration at the Tevatron. The LHC will of course also make these measurements but it might take some years to reach the required level of precision.
- This will bring the electroweak measurements and the direct Higgs mass measurements into an early direct confrontation.

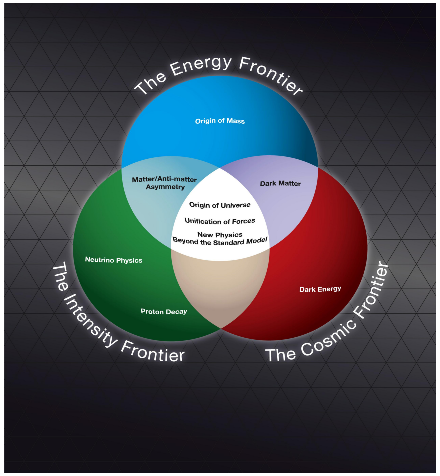
Other Physics

- The justification for an extended Tevatron run rests primarily on the contribution that the tevatron can make in the early days to complement the Higgs seraches at the LHC.
- However an extended run will allow considerable improvements in other important measurements such as t-tbar forward backward asymmetries, CP violation in B decays, etc etc.

Impacts of an Extended Tevatron Run

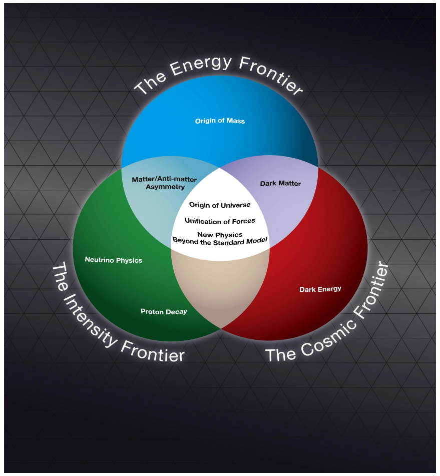
- An extension of the Tevatron run would require considerable resources.
- Fermilab management estimates that, in addition to “ belt tightening” at the laboratory, an extended run would require additional funding of the order of 35M$ per year for four years.
- The panel looked in considerable depth into where these resources could be found within the present HEP budget.
- As mentioned above, the Panel reexamined the ten-year plan it put forward two years ago, and found it to be valid today as a vibrant but lean program to ensure a leading scientific role in our field for the US.

The P5 Roadmap



- The ENERGY FRONTIER
  - The Tevatron
  - The LHC
  - ILC and Accelerator R&D
- The INTENSITY FRONTIER
  - MINOS, MiniBOONE -> NOvA, MicroBOONE ->LBNE,DUSEL
  - Reactor neutrino expts DoubleCHOOZ, DayaBay
  - Precision Meas: Mu-to-e conversion
  - Proton Decay Searches
- The COSMIC FRONTIER
  - Direct Dark Matter Searches
  - Dark Energy from Ground and Space

The P5 Roadmap



- P5 reaffirms this roadmap for the US high-energy physics program.
- The roadmap offers the best path to answering the most crucial questions in elementary particle physics and for maintaining US leadership.
- That program is well under way in all three of the frontiers, and P5 does not recommend altering it significantly.

Impacts on the Fermilab Program

- The Flagship of the Intensity Program at Fermilab, the Long Baseline Neutrino Experiment (LBNE) with neutrino beams to DUSEL must not be impacted in any way by the Tevatron run extension
- Some of the costs of the Tevatron extension can be taken from Fermilab by "belt tightening"
  - Delay the mu-to-e experiment by 6 month
  - Delay the intensity upgrade (400kW to 700 kW) for NOvA
    - This is not so much a fiscal issue
    - The recycler needs to be converted to protons for 700 kW
    - This can not happen while recycler is running with antiprotons for the Tevatron
    - This will reduce protons on target for NOvA for its first three years

Where to find the remaining 35 M$

- The LHC program is the highest priority program in HEP, is already lean, and should not be reduced.
- The LBNE neutrino (and proton decay) experiments to DUSEL , the proton driver and the precision measurement program are an interrelated program, the future of the US national program, and should not be affected.
- The rest of the program consists of important experiments like the direct search for dark matter and studies of the nature of dark energy. The panel recommends no reductions in the funding for these high priority programs.

The P5 Panel Recommendation

- Having examined the physics opportunities that an extended Tevatron run would provide as well as the financial strain it would place on the rest of the HEP program, the panel makes the following recommendation:
- **Recommendation 1: The panel recommends that the agencies proceed with a three-year extension of the Tevatron program if the resources required to support such an extension become available in addition to the present funding for HEP. Given the strong physics case, we encourage the funding agencies to try to find the needed additional resources.**

The P5 Panel Recommendation

- The panel discussed two ways to mitigate the negative effect of an extended Tevatron run on NOvA :
  - explore the possibility of increasing the proton intensity beyond 400 kilowatts without refitting the Recycler
  - increase the detector target mass beyond 14 kilotons. (The detector hall is large enough to accommodate 18 kilotons.)
- Given the importance of neutrino physics which is the heart of the future Intensity Frontier program at Fermilab, the panel makes the following recommendation:
- **Recommendation 2: The panel recommends that Fermilab make a strong effort to minimize the impact of an extended Tevatron run on the NOvA experiment.**

Responses to Questions by HEPAP

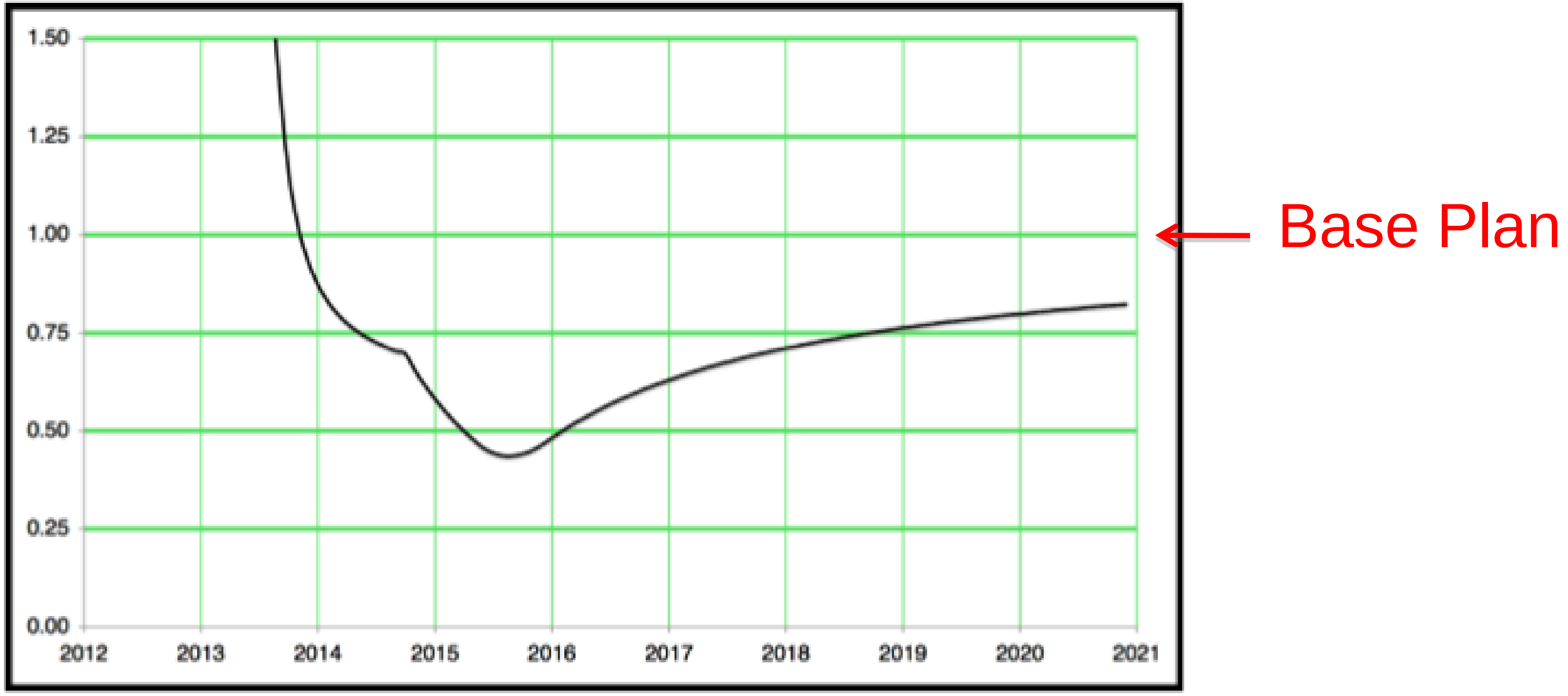
Responses to Questions from HEPAP

1. More details on impacts of a three year Tevatron extension on NOvA

- Refitting of the Recycler from antiprotons to protons would be delayed from 2012 to 2015. This is independent of funding.
  - NOvA would run for 3 years at 400 kW instead of 700 kW. The shutdown to achieve 700 kW would occur in FY2015, when the detector is complete, instead of FY2012 when a small fraction of detector is complete
  - Delay in reaching full equivalent sensitivity is 2 years. After early running, in 2015, would have only half the integrated protons on target

Responses to Questions from HEPAP

- NOvA sensitivity with the Tevatron extension compared to the current base plan



Responses to Questions from HEPAP

2. Clarify Recommendation 2: How can Fermilab mitigate impact on NOvA

- No plans for this have been formally presented to P5. However members of the panel have some information about discussions at Fermilab:
  - There may be a possibility of increasing the proton intensity beyond 400 kilowatts without refitting the Recycler. This may not be very expensive
  - Increase the detector target mass beyond 14 kilotons. (The detector hall is large enough to accommodate 18 kilotons.) There may be some unused NOvA contingency funds that could be used for this purpose.

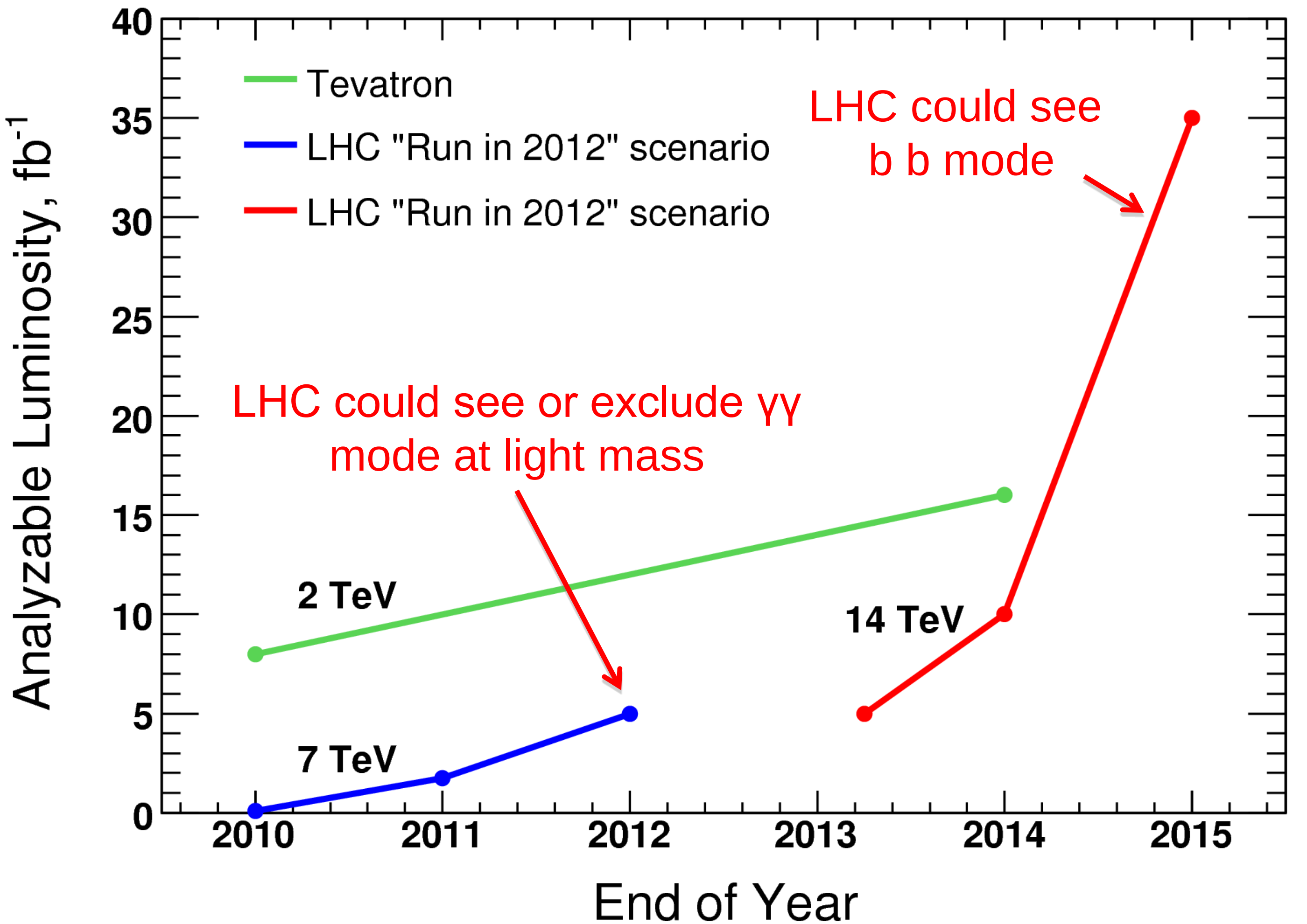
Responses to Questions from HEPAP

3. What if CERN decides to run LHC in 2012?

- Present plan is not to run in 2012 ; shut down in 2012 for 15 months to upgrade to 14 TeV.
- However there has been some discussion that if something exciting is found in 2011 run, LHC might run in 2012.
  - LHC may discover a Higgs or find evidence for a light mass Higgs or exclude a Higgs in the interesting mass region sooner (would rely on the γγ mode at the lowest masses)
  - Running at 14 TeV would be delayed by a year, LHC would see H -> b bbar a year later

Development of Luminosity with Time

LHC plan with run in 2012, shutdown for energy upgrade delayed to 2013



Responses to Questions from HEPAP

4. What is the probability of the Agencies/Congress responding positively to the request for additional funds for an extended Tevatron run?

Who knows???

P5 was told by DOE that if the chances were neglibibly small they would not have asked P5 to make a recommendation on this issue.

Responses to Questions from HEPAP

5. What about funding for University groups?

This is included in Fermilab's estimate of the 35 M$ per year additional resources required for an extended Tevatron run

Responses to Questions from HEPAP

6. Should P5 have recommended to reevaluate the science case for an extended Tevatron run every year

P5 was told that Federal funding is governed by an annual cycle, and the program is reevaluated annually as a matter of course.