Answers to PAC Questions on Higgs Searches at CDF and DØ

PAC Meeting August 27, 2010
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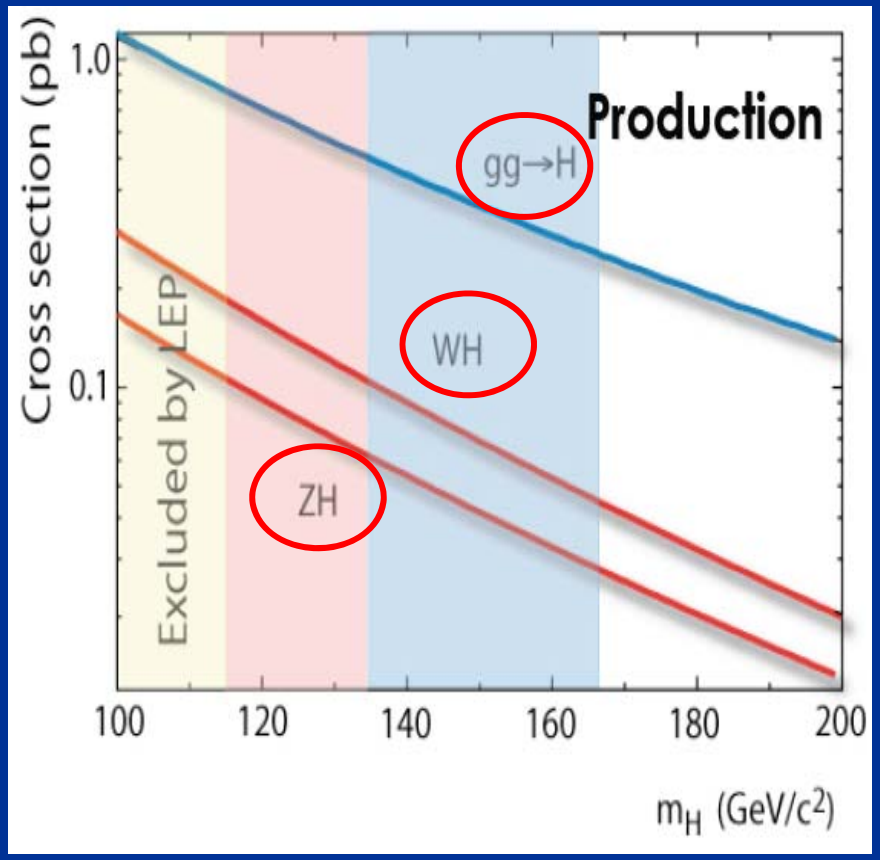
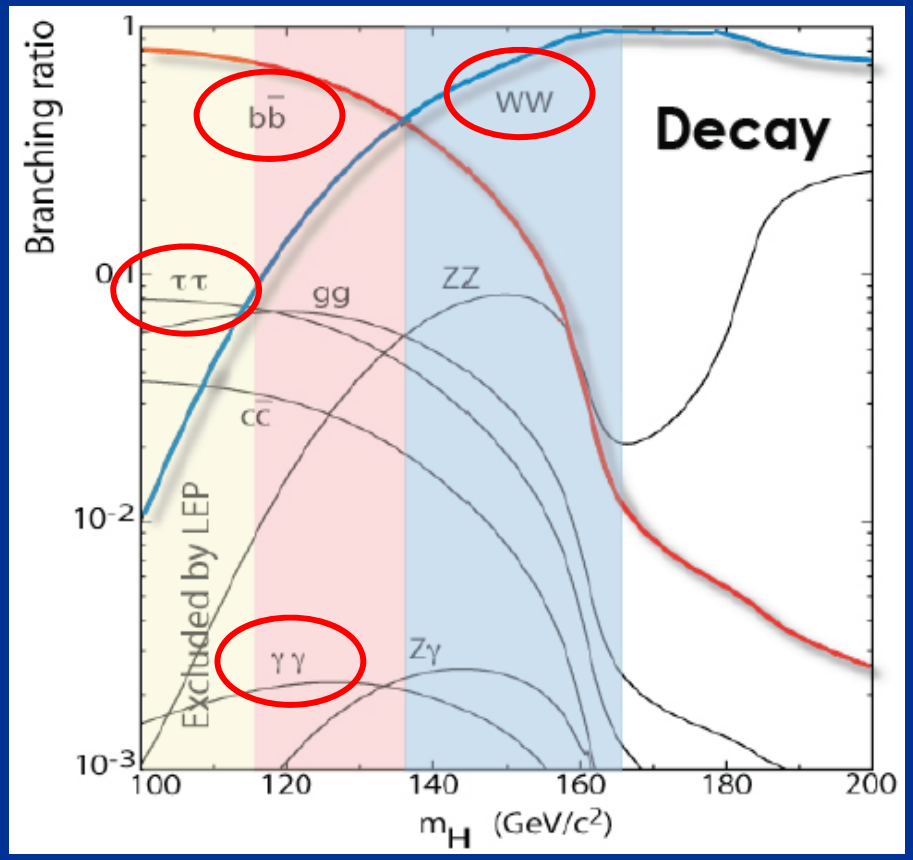
on Behalf of CDF and DØ Collaborations

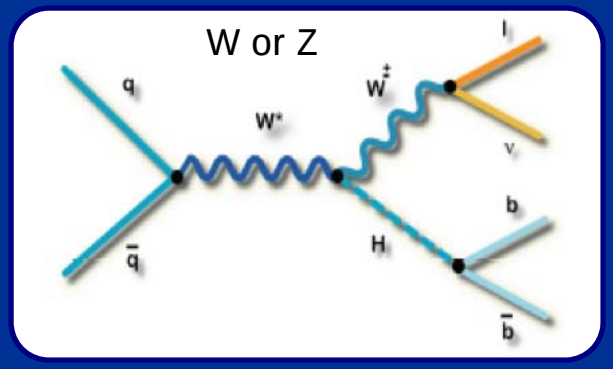
Talk Outline

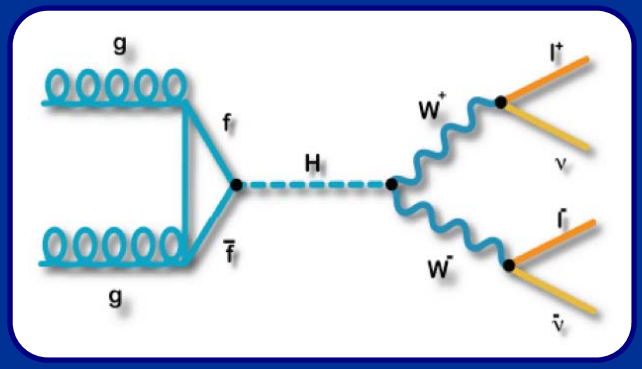
- Status of the Higgs searches
- Questions after June 2010 PAC meeting
  - Compatibility of current excess with Higgs signal
  - Higgs mass resolution
  - Effect of radiation aging of the detectors on Higgs sensitivity
  - Future improvements in Higgs search analyses
- Summary – exciting and compelling opportunity to see Higgs boson!

Higgs Production and Decays at the Tevatron

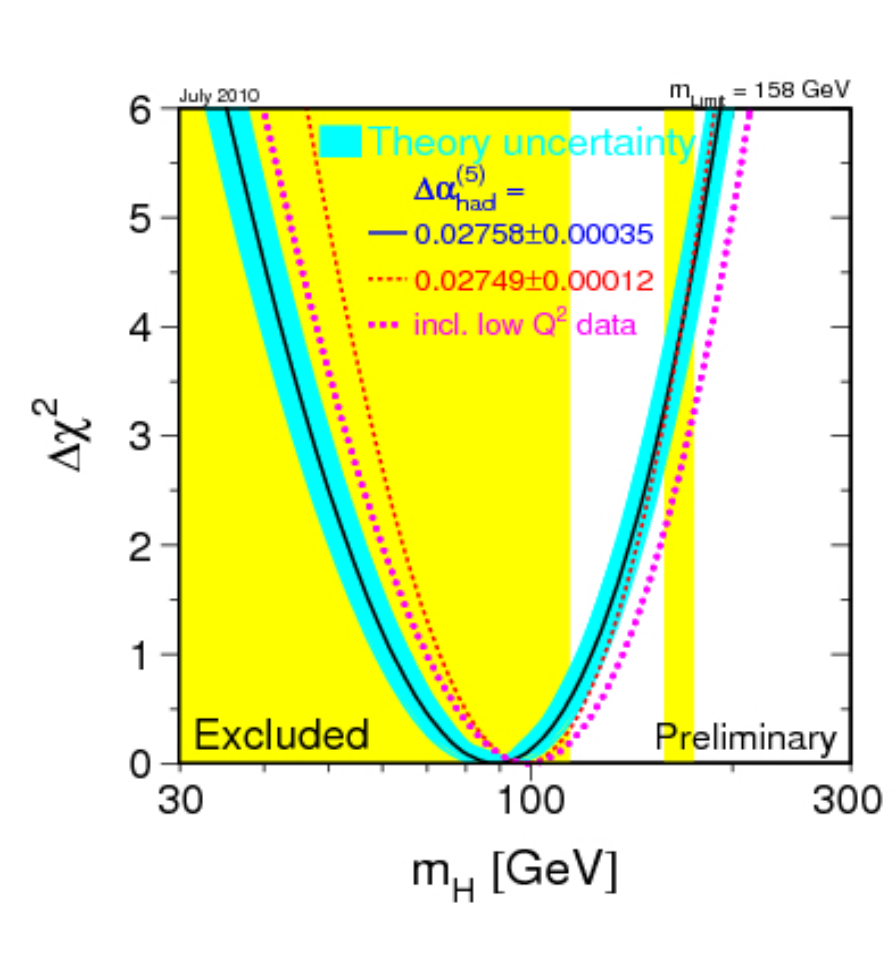


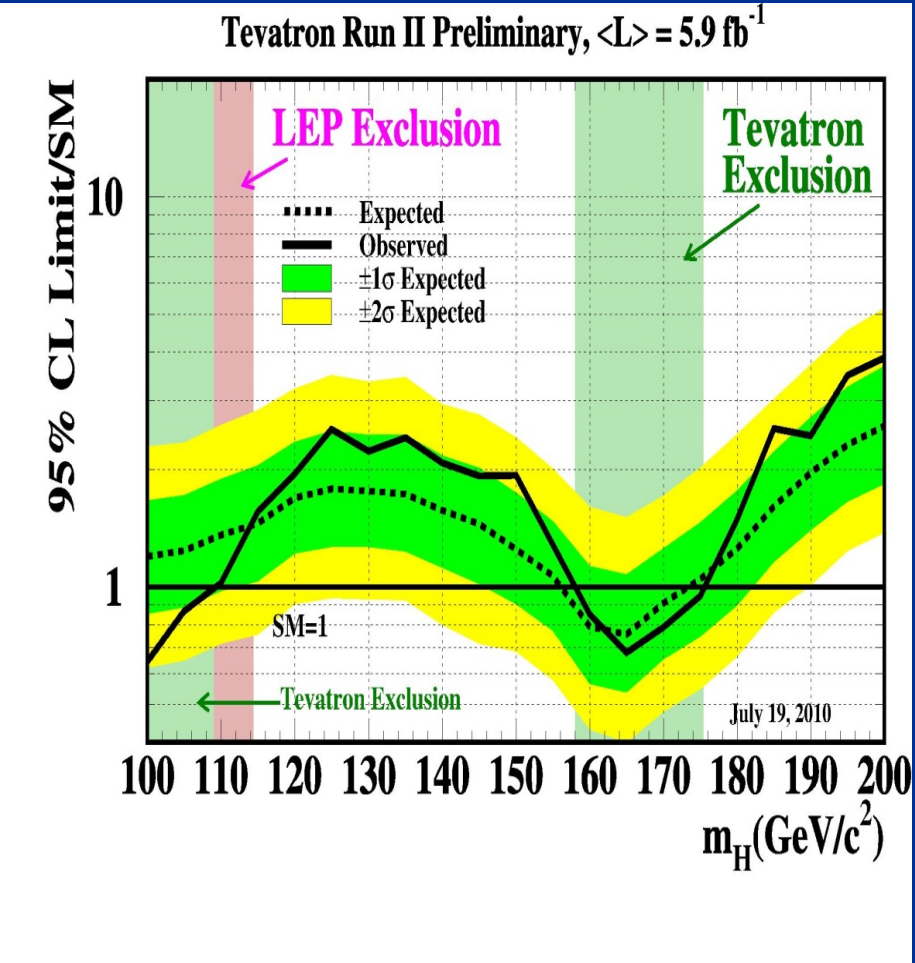






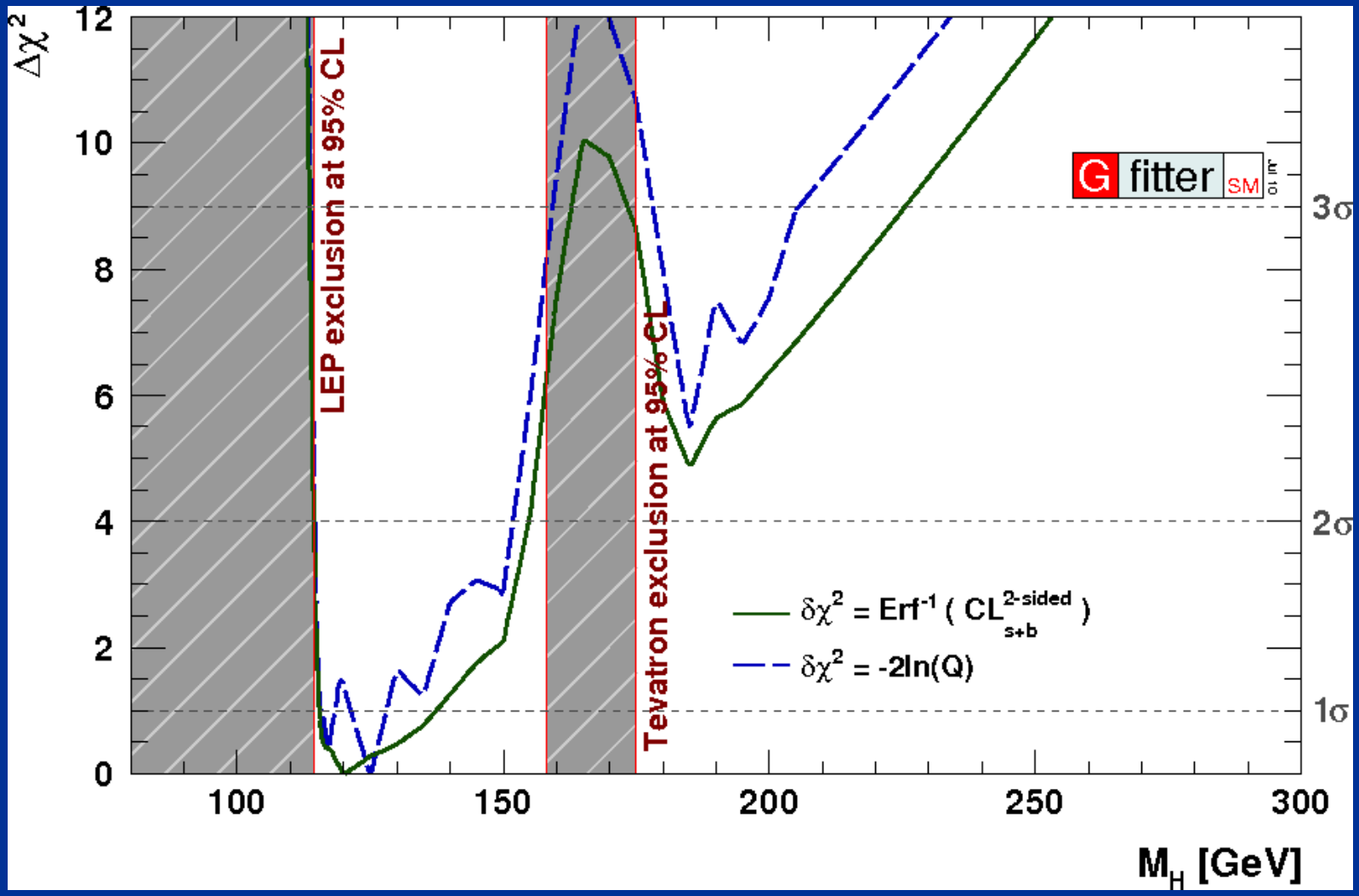
Current Status of Higgs Searches





- **Electroweak fits, including precision W and top quark masses from the Tevatron**
- **Direct searches at LEP, Tevatron and in the future, LHC**

Combined Status of Higgs Searches

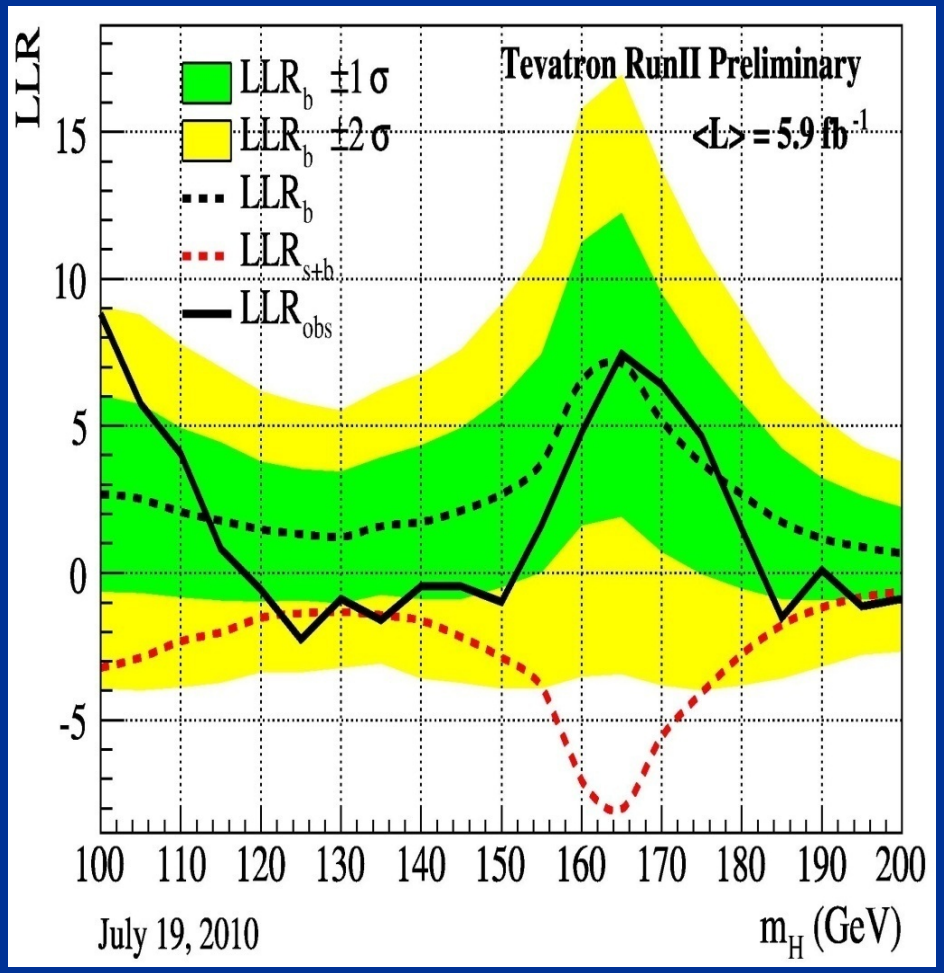


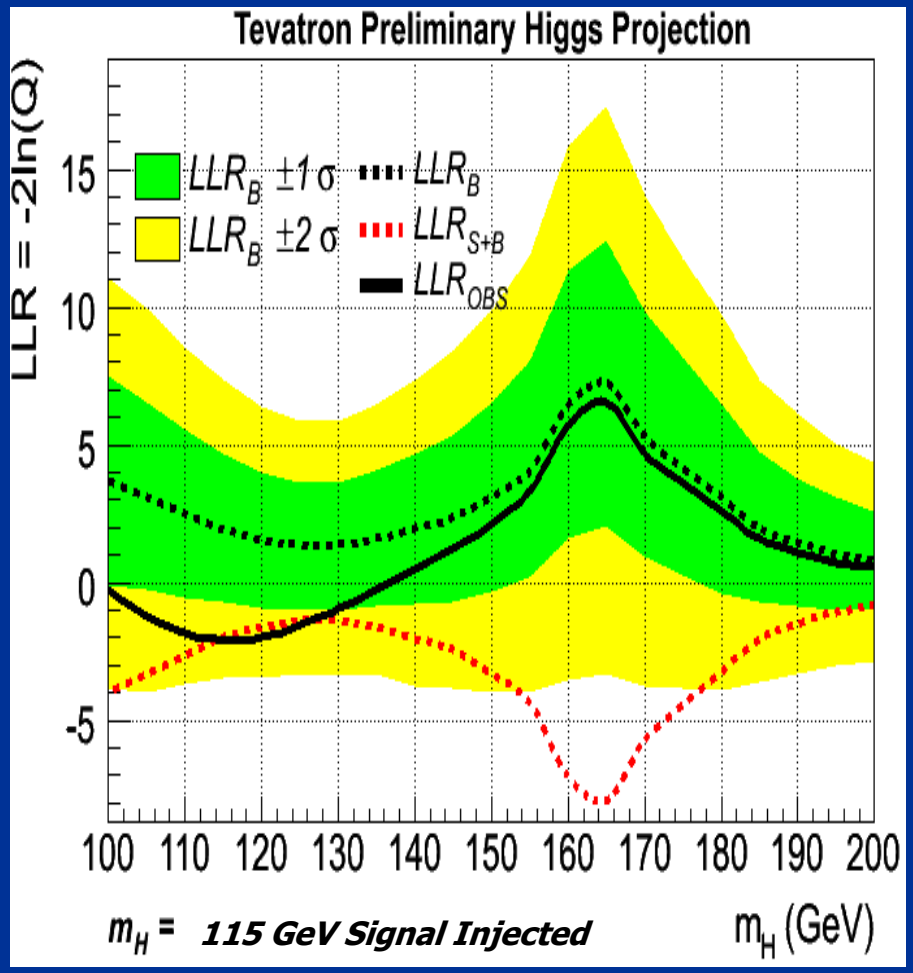
Low mass Higgs preferred: below ~150 GeV

PAC Questions from June 2010 Meeting

- **Q1 – is current excess in the broad range 115-150 GeV consistent with behavior expected from true signal?**
- **Q2 – what is Higgs mass resolution assuming evidence for Higgs boson is found**
- **Q3 – impact on Higgs analysis due to the detectors degradation during extended run**
- **Q4 – analysis improvements required to reach projected Tevatron Higgs sensitivity**

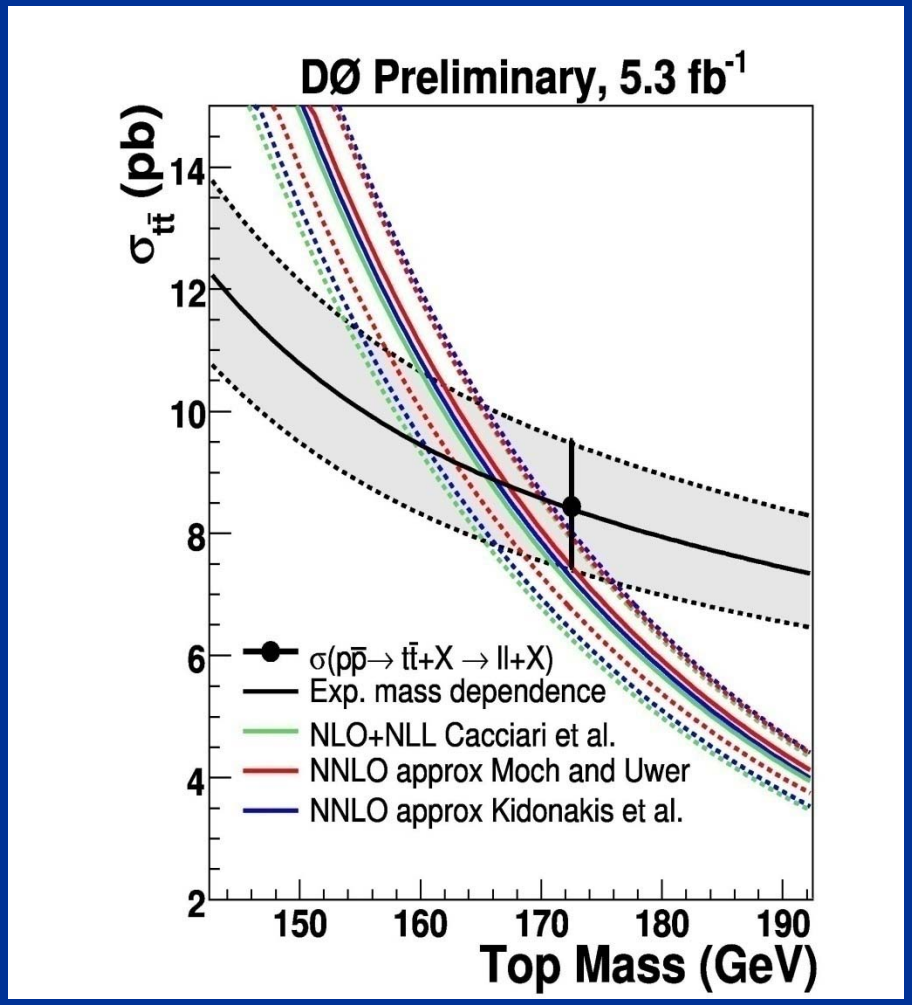
Excess in the 115-150 GeV Region

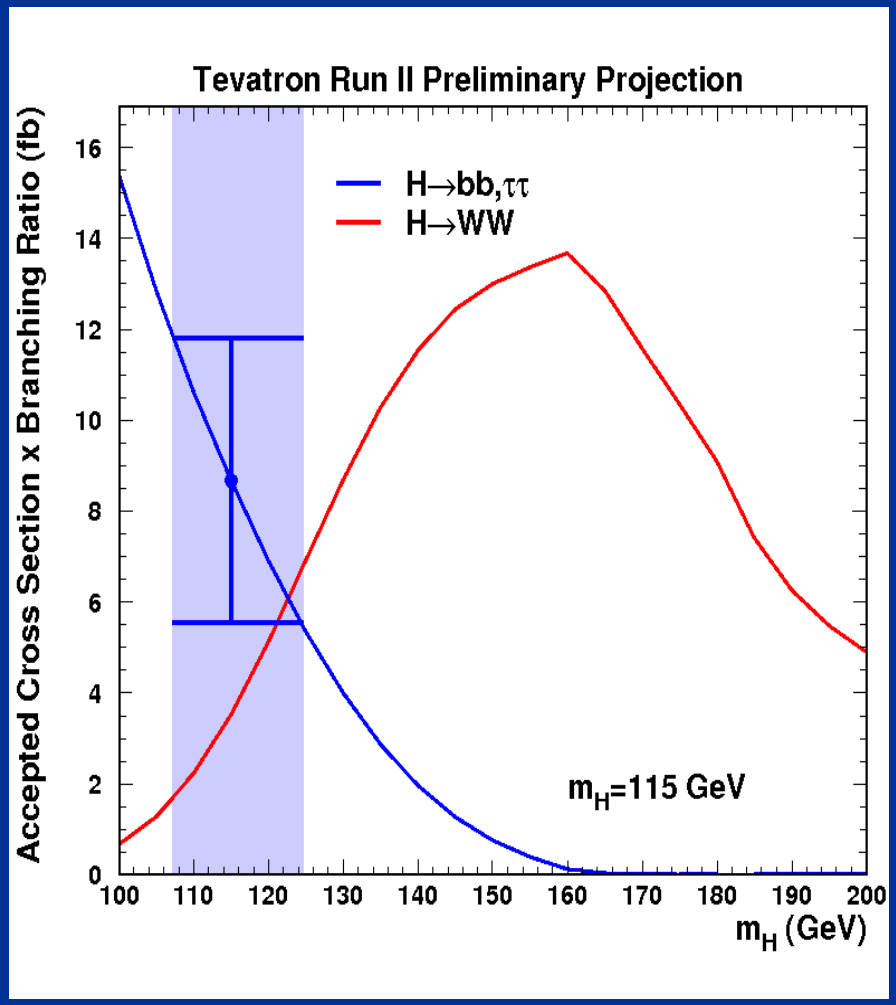




- **Inject Higgs signal with 115 GeV mass and calculate "observed" LLR curve**
- **Q1/A1: current excess is in agreement with low mass signal hypotheses**

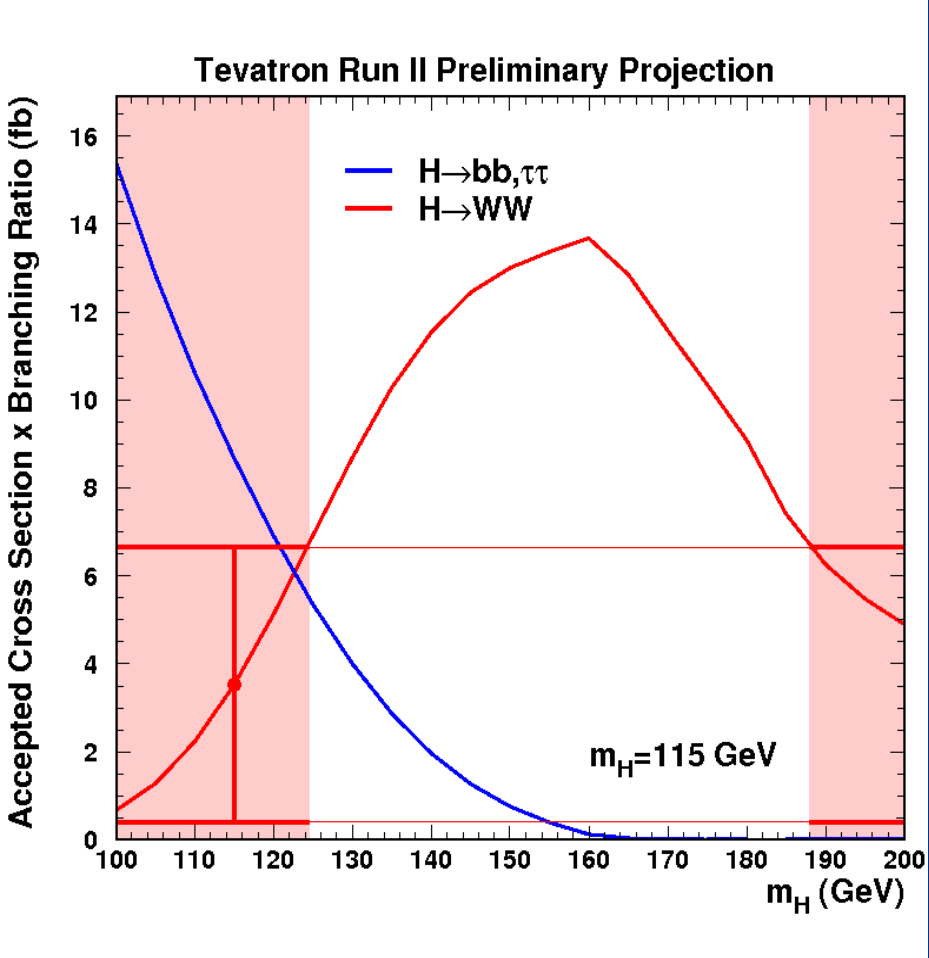
Achievable Higgs Mass Resolution

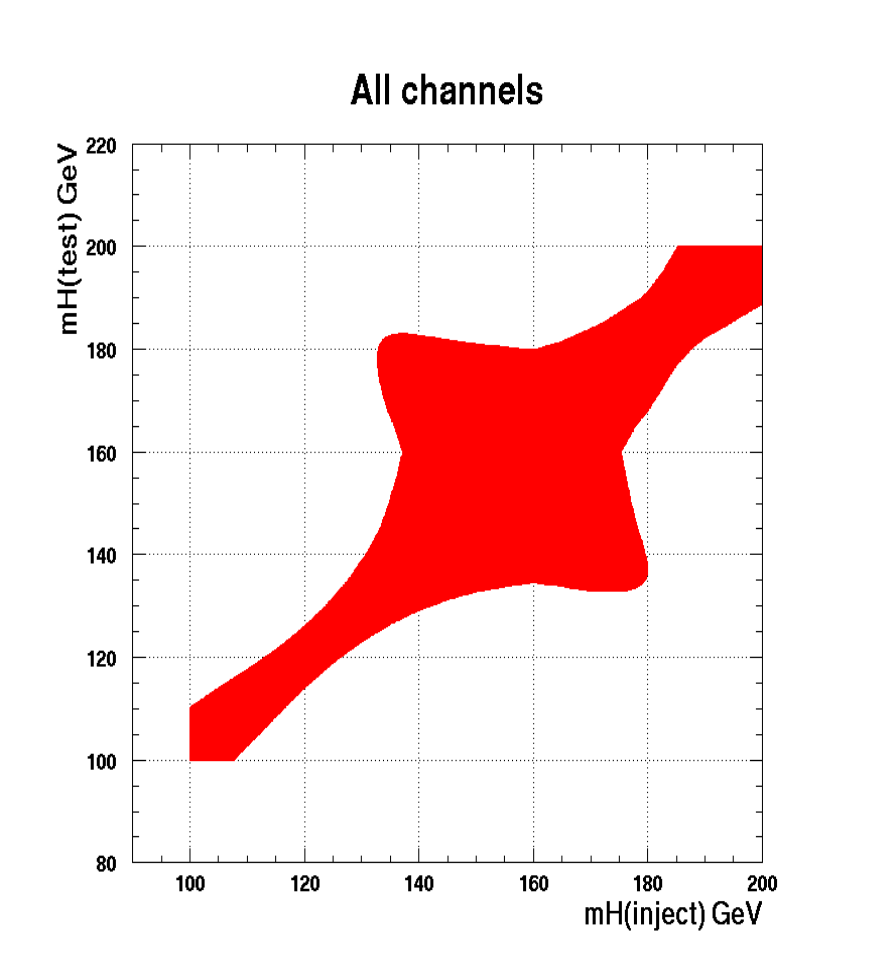




- **Steeply falling cross sections provide opportunity to measure Higgs mass with high accuracy based on cross section measurements**
- **Unique feature of H → bb channel at the Tevatron**

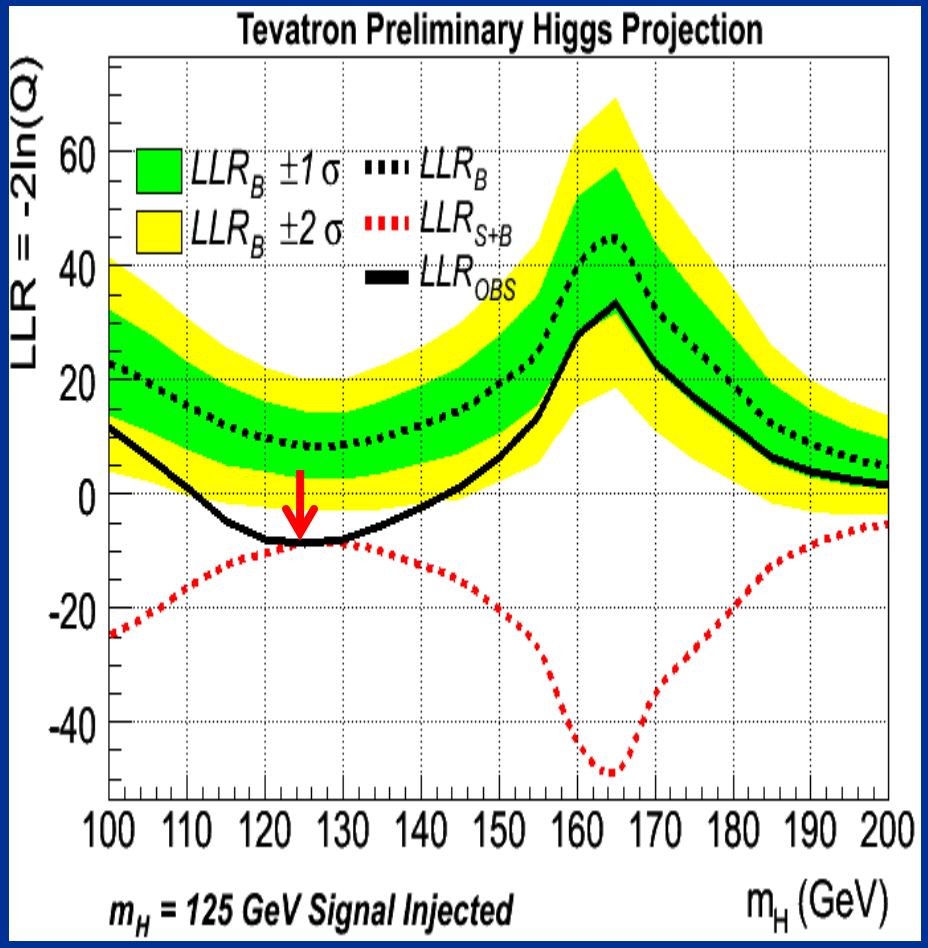
Higgs Mass Resolution from Cross Sections

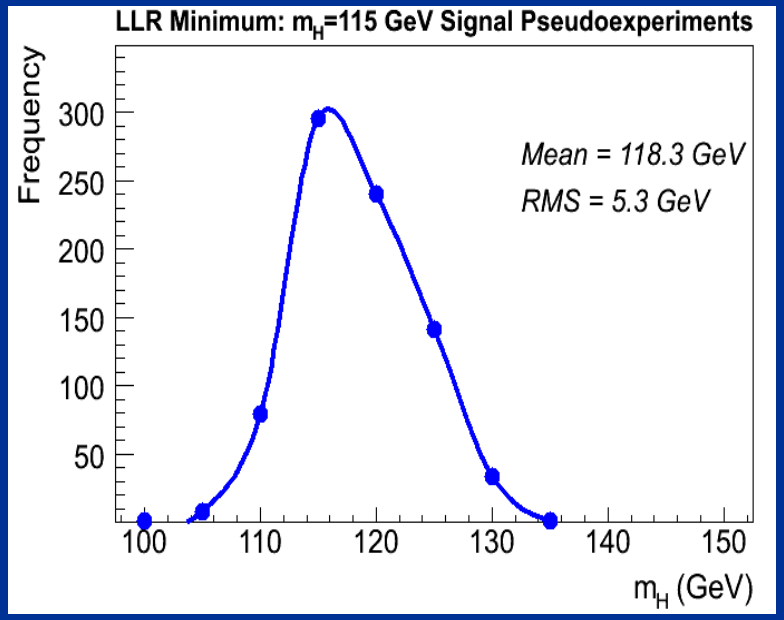


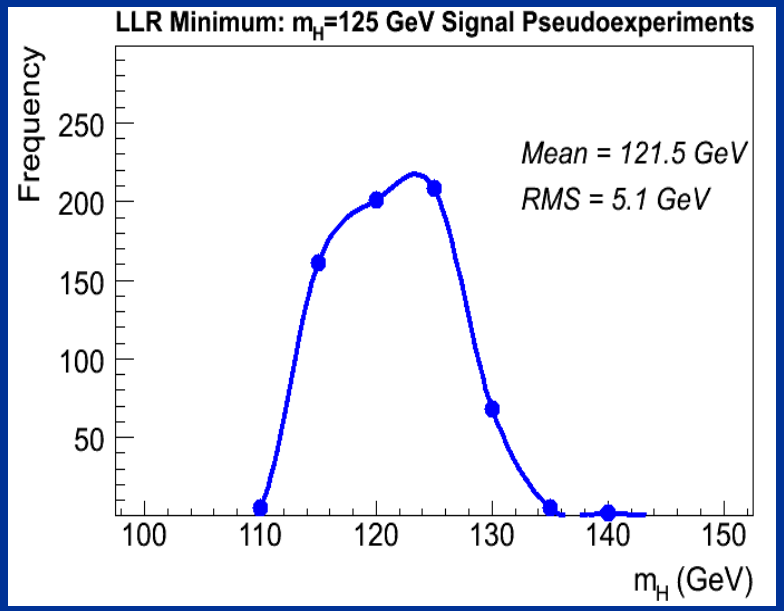


- **Mass resolution is ~6 GeV at Higgs mass of 125 GeV**
- **Above mass of 135 GeV resolution degrades**

Pseudo Experiments



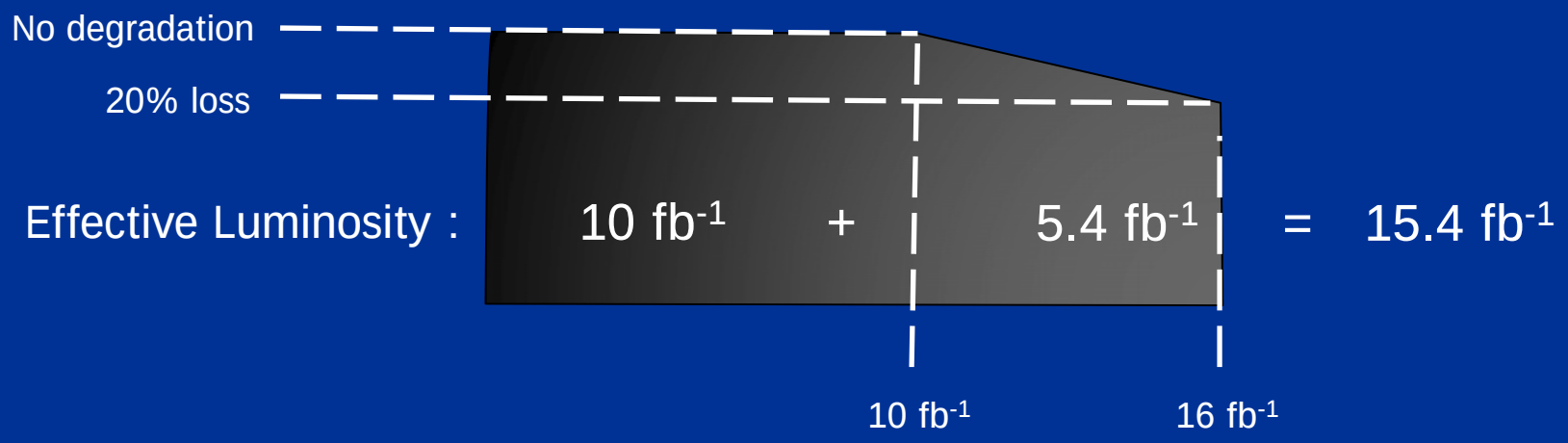




- **Perform 800 injection pseudo-experiments with 3 sigma evidence set**
- **Q2/A2: Higgs mass resolution is ~6 GeV for Higgs mass below 135 GeV**

Effects of radiation aging on Higgs sensitivity - CDF

- **Aging expected only in silicon vertex detector**
  - **Affects only b-tagging efficiency**
  - **No degradation is expected in the first 10 fb^{-1} of acquired data**
- **Slow degradation in single b-jet tagging efficiency up to ~10%**
  - **~20% for double b-tagging**



Overall sensitivity loss

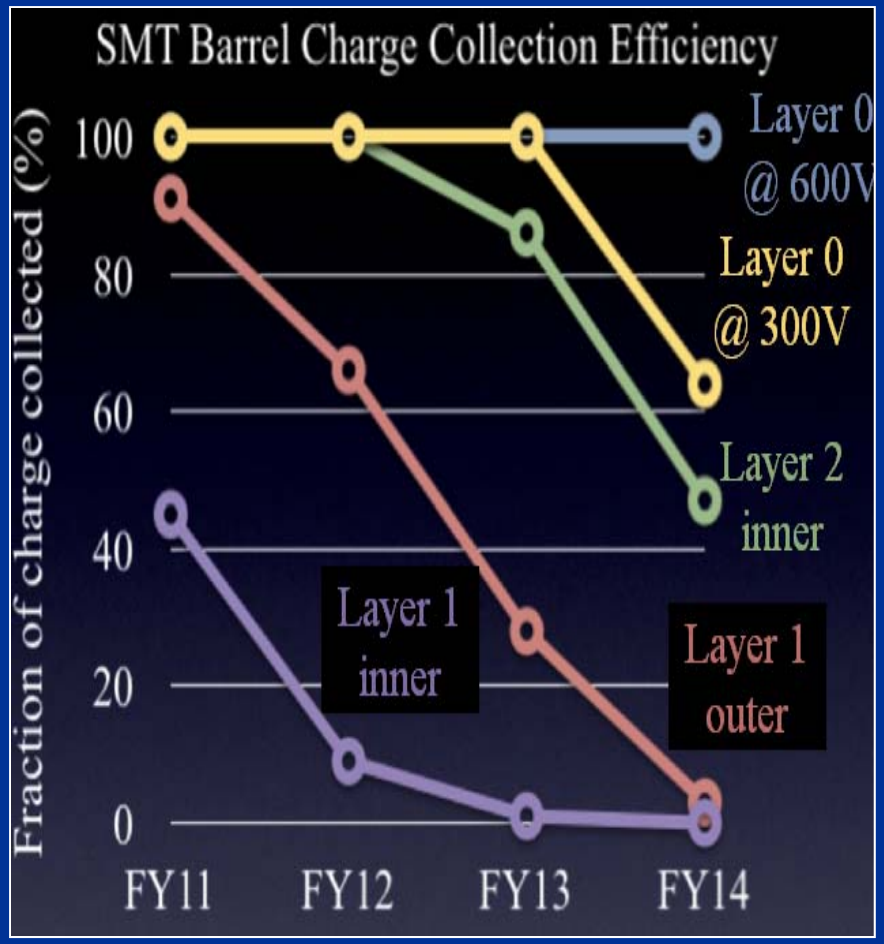
at m_H = 115 GeV : 2%

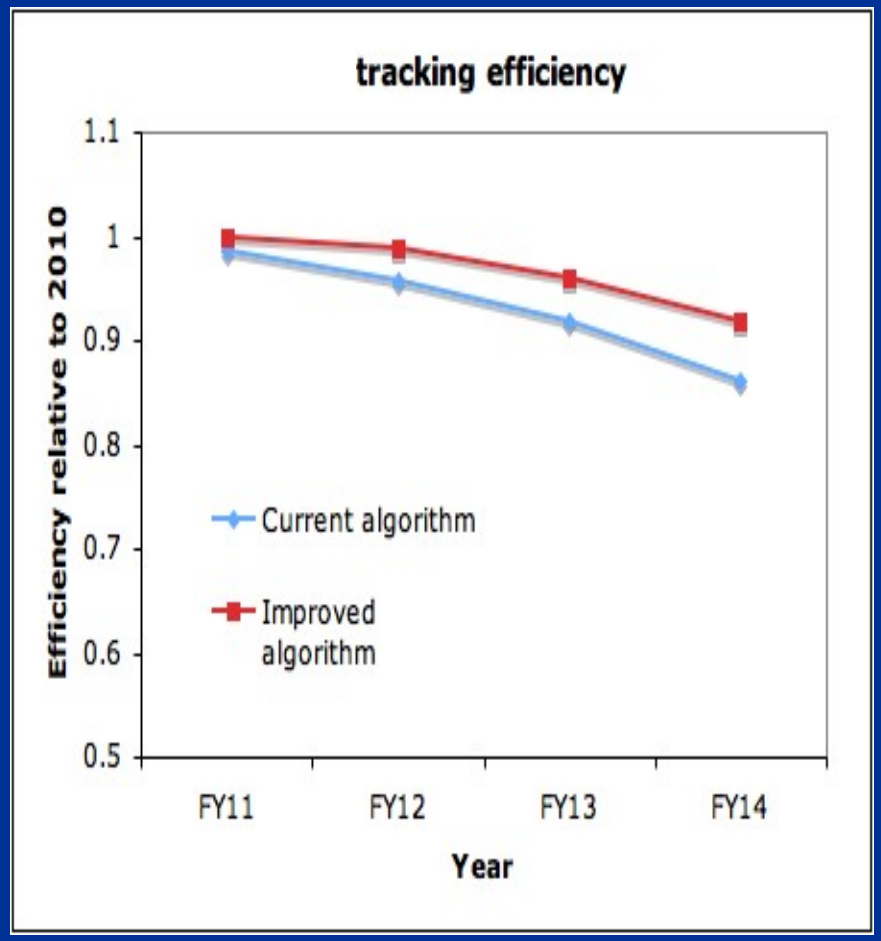
at m_H = 135 GeV : < 1%

at m_H = 160 GeV : ~0%

Aging creates no significant effect on Higgs sensitivity for CDF

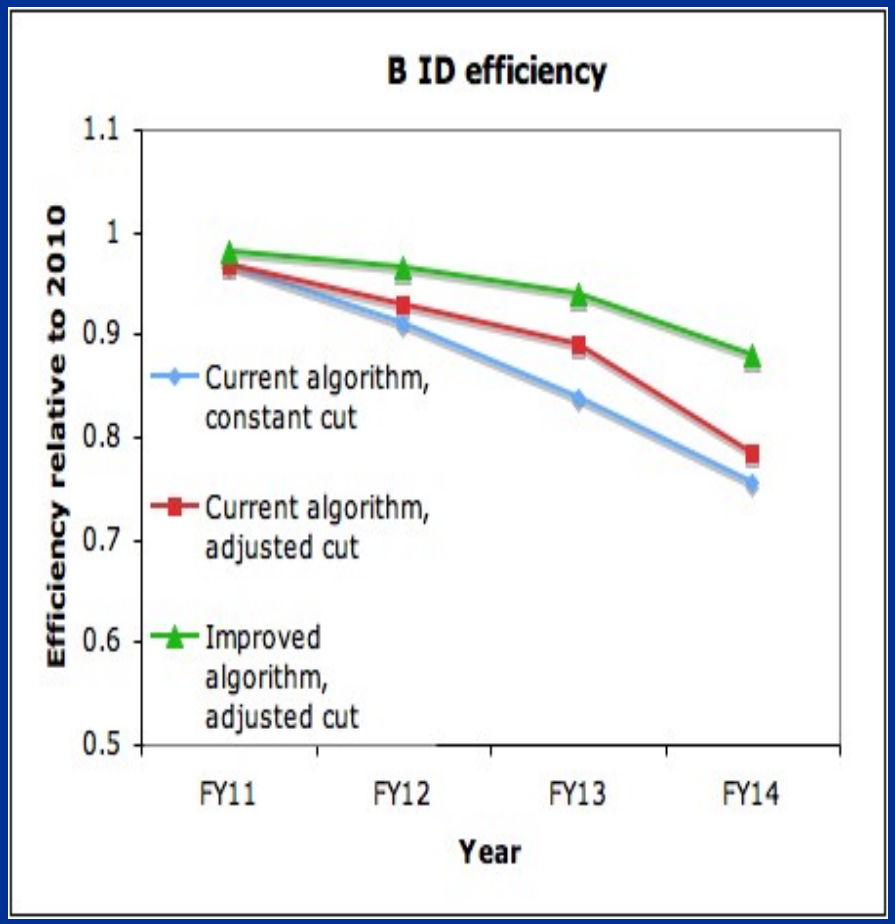
Effect of Detector Radiation Aging - DZero

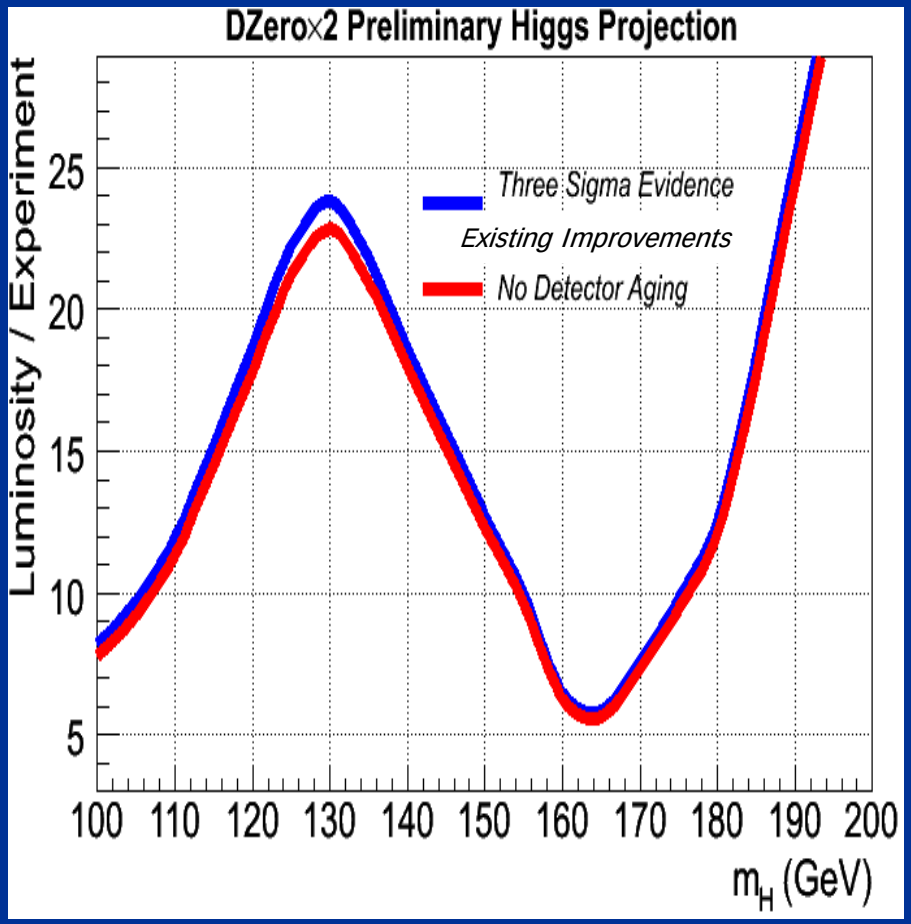




- **At DØ both silicon and fiber tracker are expected to age**
- **Propagated all effects of detectors aging into simulation and used current reconstruction algorithms**
- **After simple algorithms optimization substantial improvements are achieved**

Effects of Radiation Aging - DZero





- **Propagated deterioration of detectors performance to Higgs sensitivity**
- **~10% effect at low mass**
- **Further improvements expected, silicon channels recovery, etc.**
- **Q3/A3: Combined effect on the Tevatron Higgs search of radiation aging is a few %**

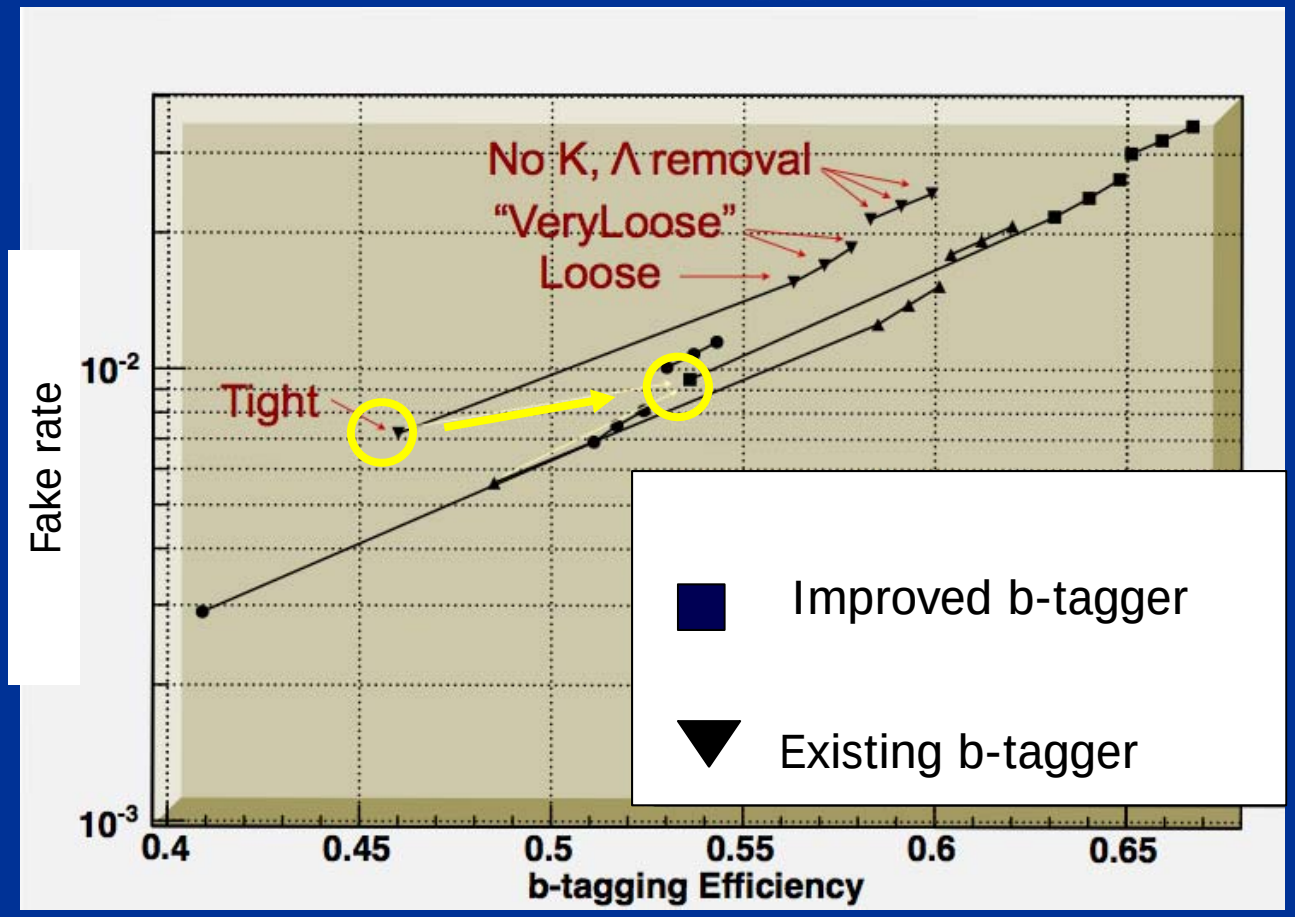
Improvements for 115 GeV Higgs for CDF

Type	Projected improvements	WHlvbb, %	ZHllbb, %	VHMETbb, %
TRIGGERS	Single stub muons	5	3	NO
	Complete OR	5	3	8
	Multivariate turn-on curves	5	DONE	5
LEPTON ID	Multivariate elec ID	10	10	NO
	Multivariate muon ID	5	DONE	NO
OTHER	Relaxed cuts	2	DONE	2
	Track-based variables	5	2	DONE
	Color flow	3	3	3
B-TAGGING	NN B-tags	DONE	6	6
	NN flavor separator	DONE	DONE	5
	Soft-electron b-tag	5	5	5
	Silicon clustering algorithm	15	15	15
JET EN RESOL.	Track + CAL	3	1	DONE
	B-specific NN	DONE	1	3
	PI-0 corrections	5	1	5
TOTAL	All improvements	90%	60%	70%

(Multiplicative total: 1.05*1.05*1.15...)

- **115 GeV Higgs searches dominated by WH→lvbb, ZH→llbb, VH→METbb**
- **~ 50% gain required in each channel to reach projected sensitivity**

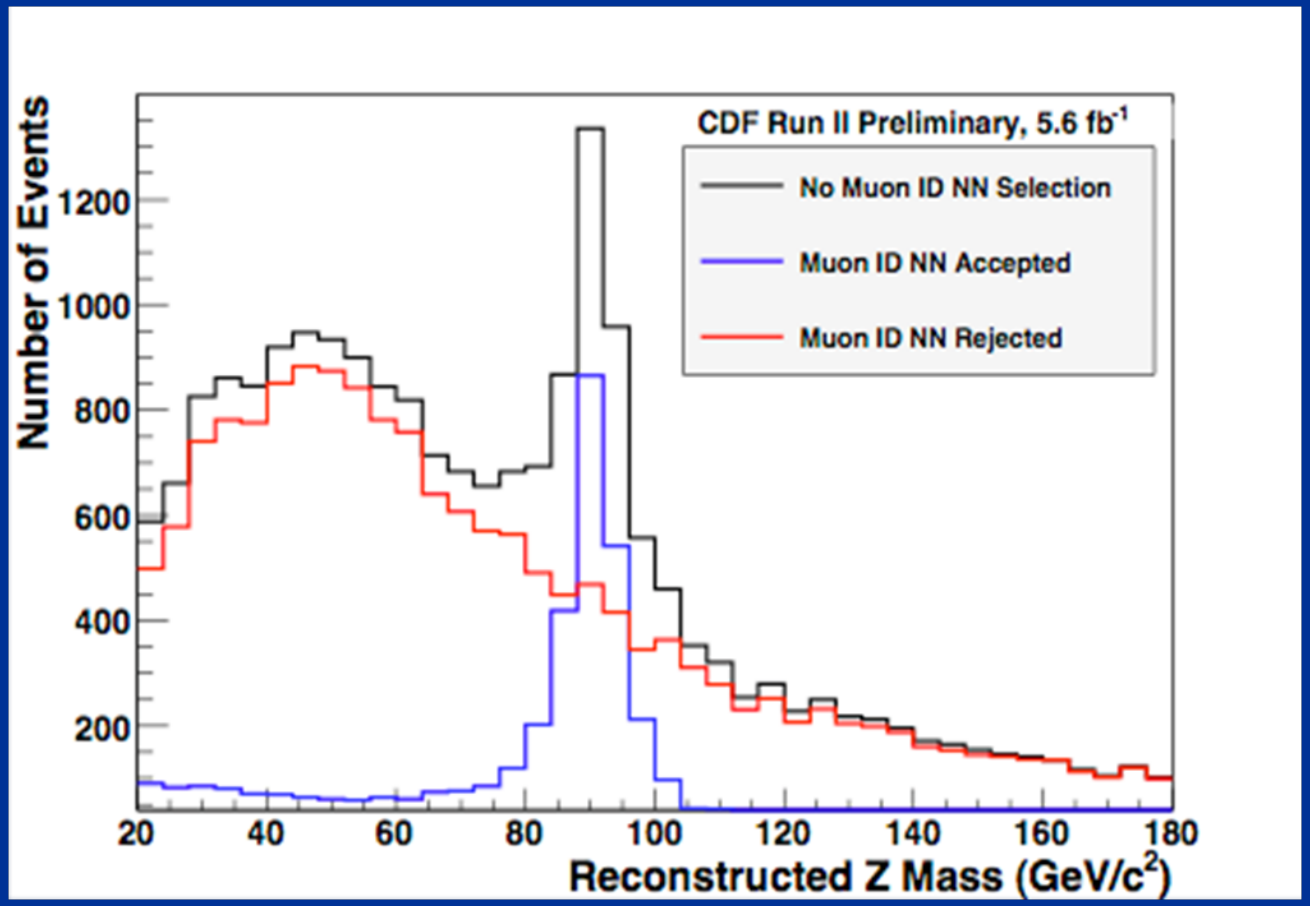
Silicon clustering improvements in CDF b-tagging



- **b-tagging efficiency improves by 15% per jet**
- **Sensitivity is dominated by events with 2 b-tags**
- **Expect 15% gain in sensitivity for WH→lνbb, ZH→llbb, VH→METbb**

CDF Multivariate Lepton ID

- Multivariate electron ID used in H→WW : limits improved by 6%
- Multivariate muon ID used in ZH→llbb : limits improved by 10%
- Adds previously "unused" leptons



- Multivariate lepton ID to be added to ZH→eebb, WH→eνbb, WH→μνbb

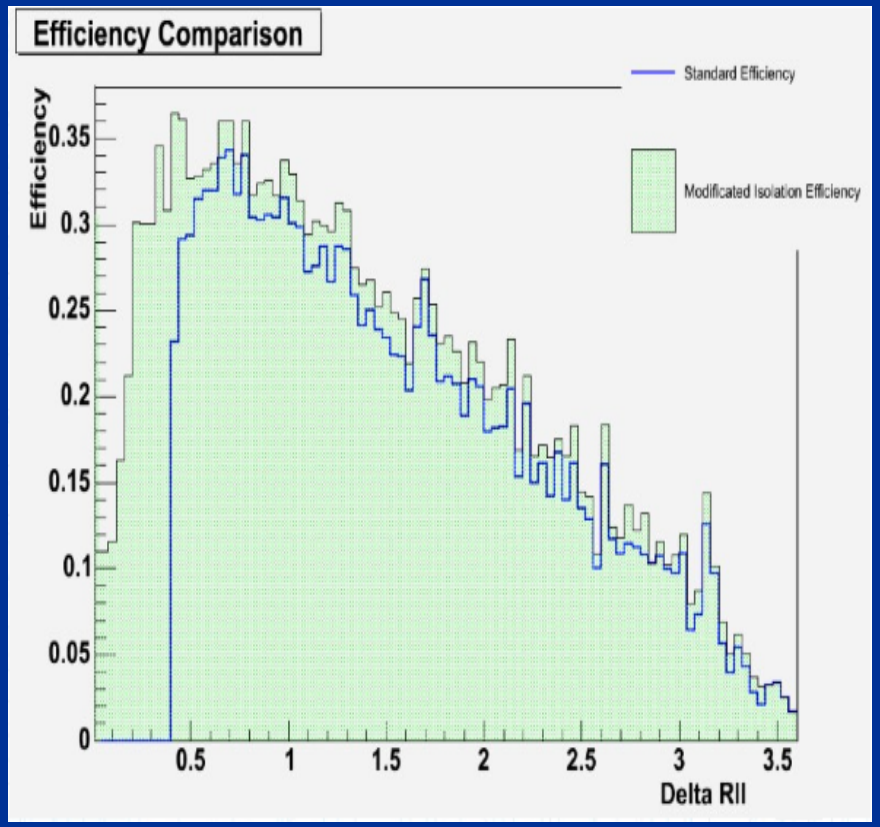
CDF High Mass Expected Sensitivity Improvements

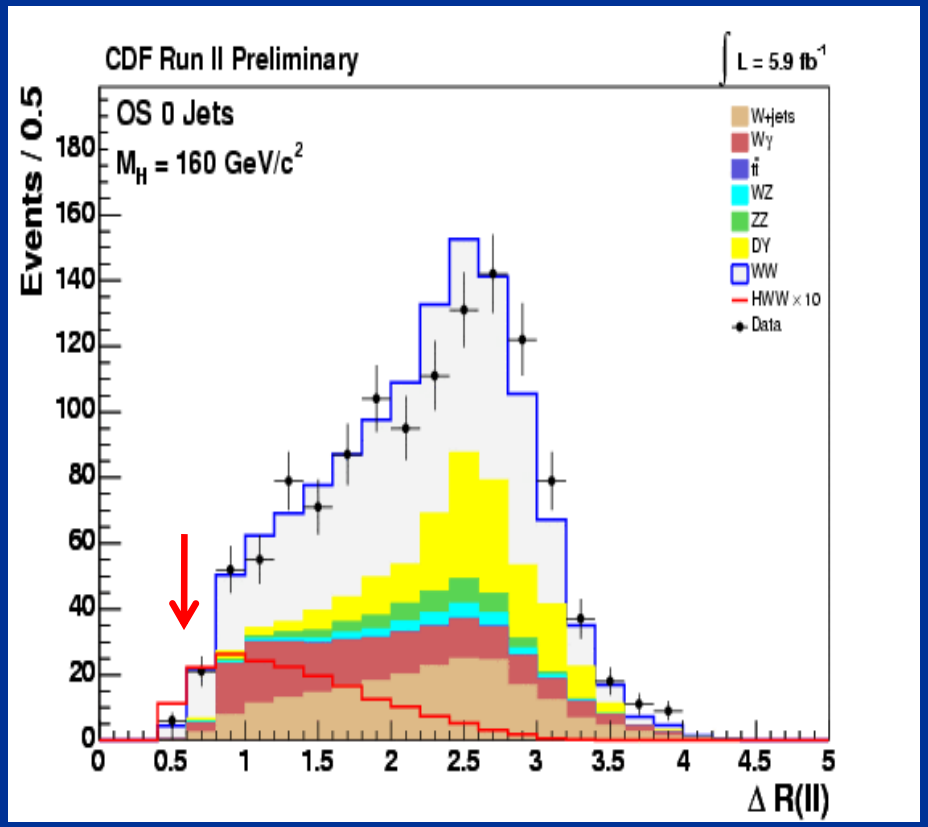
Category	Projected improvements	Gain (%)
LEPTON ID	Modified isolation cuts	15
	Multivariate muon ID	5
	Multivariate forward electron ID	3
	Improved crack electron ID	2
TRIGGER	Incorporate CMU muon trigger	3
	Incorporate low p_T dimuon triggers	2
	Incorporate hadronic tau triggers	1
NEW CHANNELS	H->WW->lvjj	5
	H->ZZ	3
	ZH->ZWW->lllvjj	2
NEURAL NETWORK	Low mass re-optimization	10 *
	Add top mass variable for 2+ jets	1
BACKGROUNDS	Improved fake missing E_T rejection	2
TOTAL		53 (68*)

* Low Higgs mass values only

- **All these improvements are on the top of what has already been achieved**

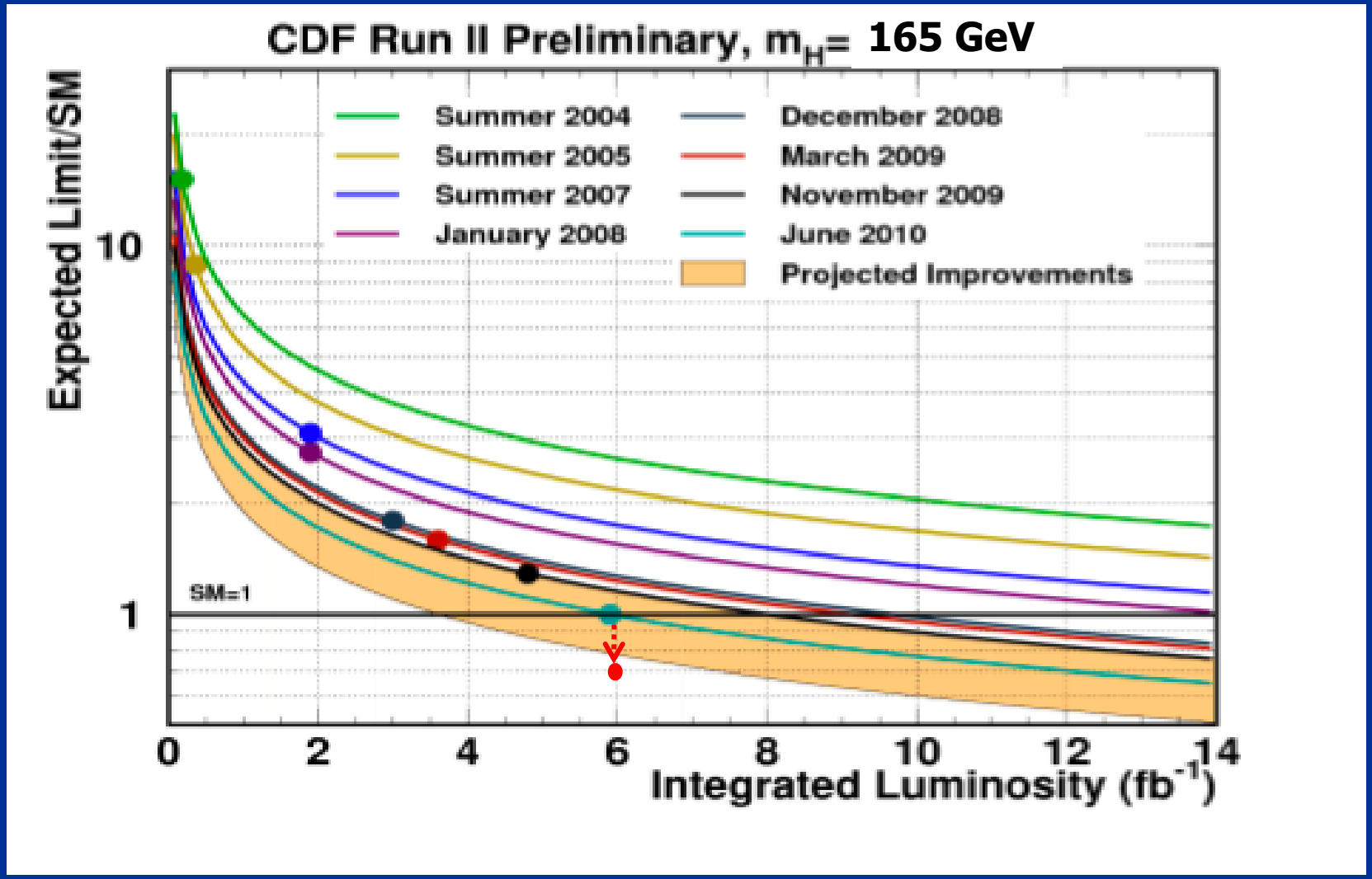
CDF High Mass Sensitivity Improvements





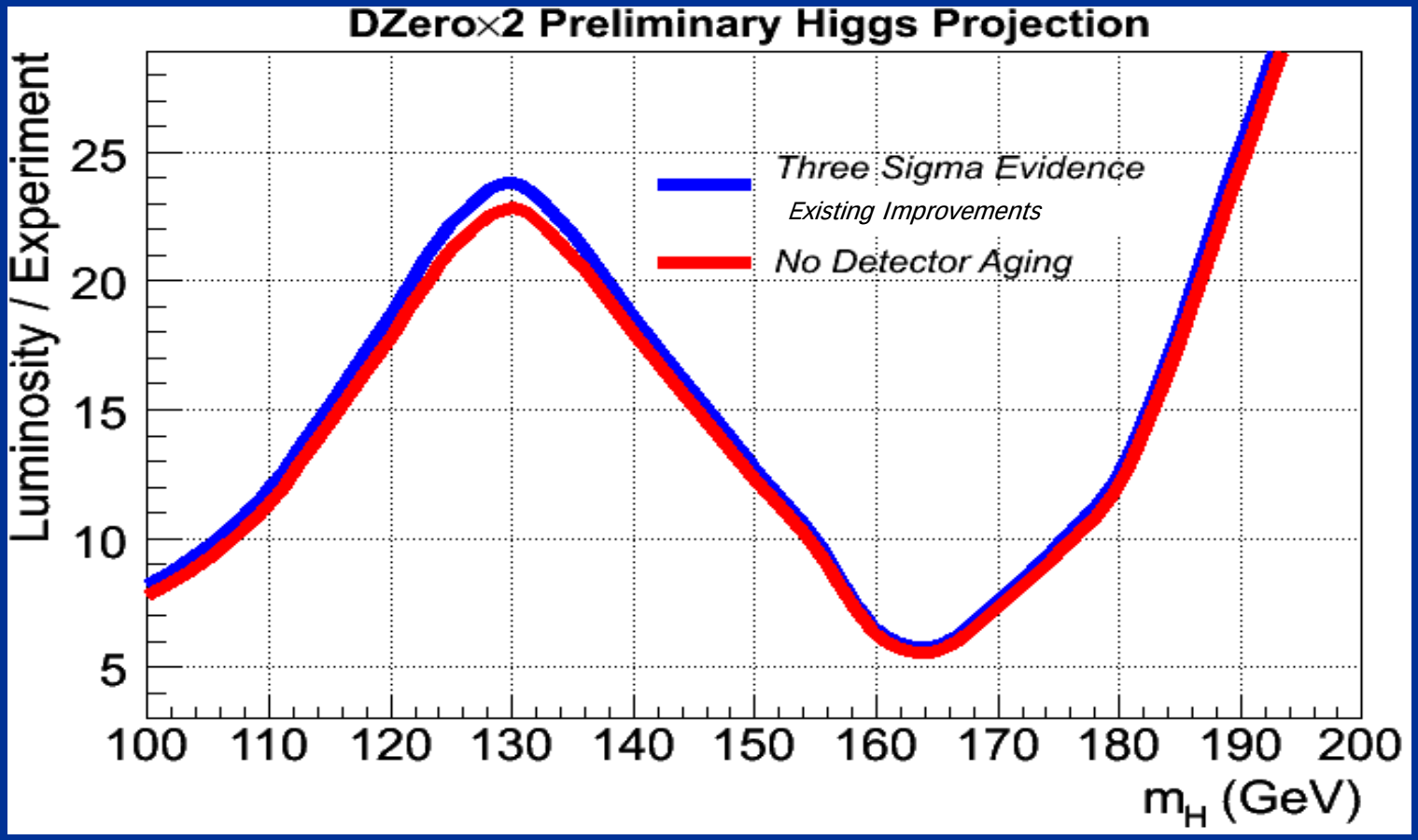
- Large fraction of H->WW->lvlv acceptance is at small values of ΔR(ll)
- Currently events containing leptons within ΔR(ll) of 0.4 are rejected since the leptons affect each others isolation
- Generator-level studies show that simple modifications to isolation algorithms give 17% signal gain
- All of the added events are in high S/B region

CDF High Mass Expected Sensitivity



Based on the current list of expected improvements CDF can do better than original projections

Re-estimated DZero Higgs Sensitivity



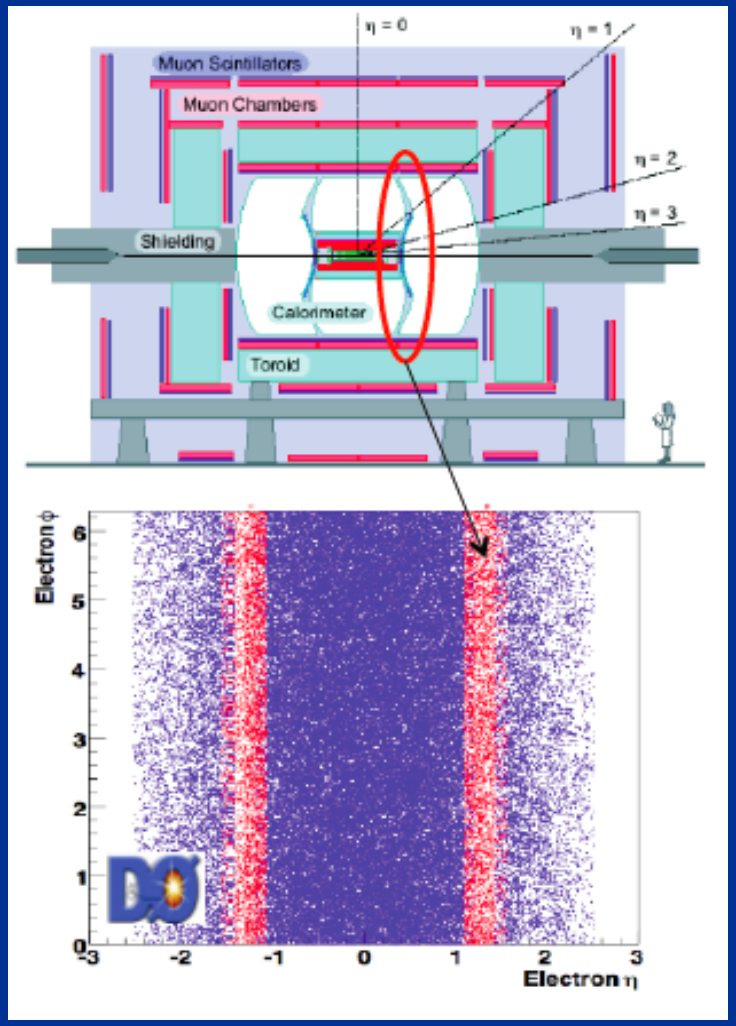
- Performed future Higgs sensitivity estimates "from scratch"
- Started from ICHEP 2010 expected limits separately for all channels
- Added existing improvements → "No Detector Aging" curve
- Added radiation aging effects in conservative scenario → "3 Sigma Evidence"
- Planned improvements are not shown above

DZero Higgs Sensitivity Improvements

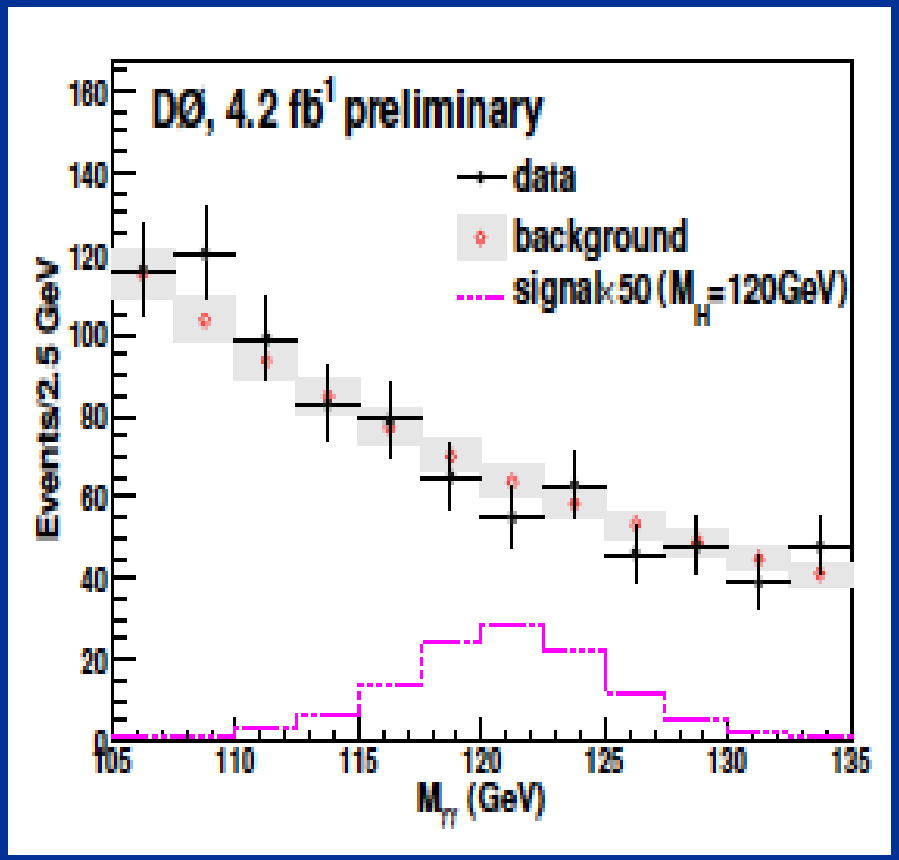
Type	Projected Improvement	WH→lvbb	ZH→llbb	ZH→vvbb	H→WW	Other Channels
Lepton ID	MVA Electron ID	1%	5%	-1%	3%	3%
	Improved MuonID/tracking	4%	3%	-2%	Done	3%
	Add Isolated Tracks	2%	Done	-1%	3%	2%
	Add ICR Electrons	2%	Done	-1%	3%	2%
	Add EC Electrons	Done	Done		Done	2%
	Improved energy scale	1%	2%		2%	5%
Trigger / Reco	Trigger/Reconstruction Efficiency	5%	3%	Done	Done	5%
Jet Selection	Di-jet Mass Resolution	10%	10%	10%		
	MVA B-ID	5%	5%	5%		
	MVA Bottom vs Charm	4%	4%	4%		
MVA Analysis	Enhanced Techniques	10%	10%	10%	10%	10%
	New signal separation variables	5%	5%	5%	5%	5%
	MVA QCD Rejection	3%	1%	Done	3%	3%
	Matrix Element Discriminants	5%	5%	5%	5%	3%
	Kinematic Fitting	5%	Done			3%
Optimization	Track Variables	5%	3%	Done	5%	5%
	Optimized B-ID Usage	3%	3%	3%		
	Optimized Jet Treatment	3%	8%	Done		
New Channels	H→WW→e/mu+tau				5%	
	VH→etau+jj					3%
	H→ZZ					3%
	VH→VVV→trileptons					3%
	Additional Decay Modes	5%	5%	Done	5%	5%
	Existing Improvements:	57%	70%	29%	41%	
	Planned Improvements:	36%	27%	20%	18%	

- **Yellow are cells with existing improvements to be propagated to final analysis**
- **White cells with numbers are the areas the experiment is actively working on**

Improvements in Higgs Sensitivity at DZero

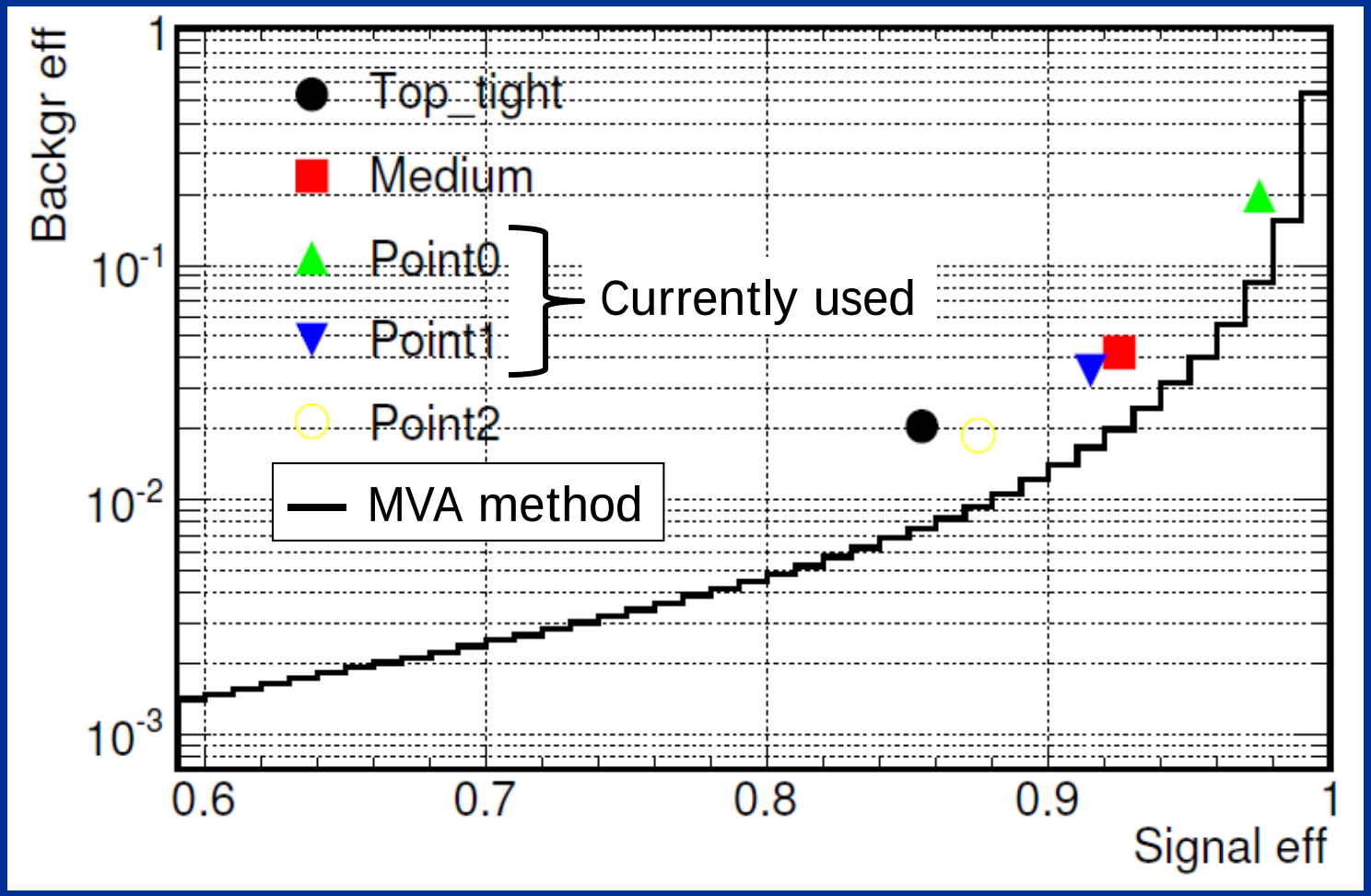


H→γγ



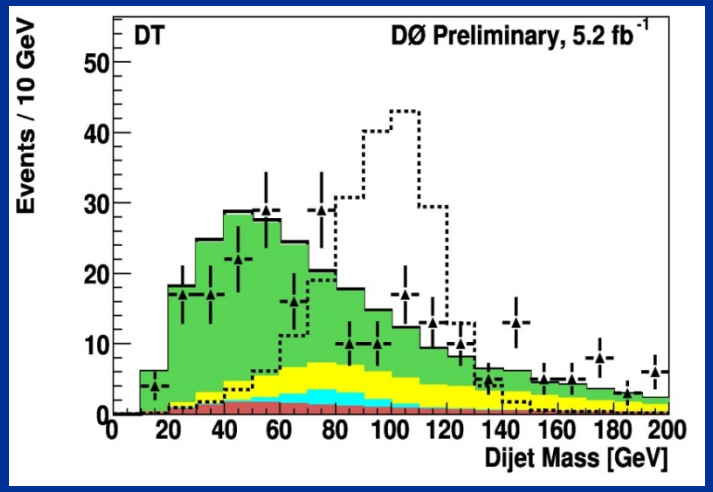
- **Increase in lepton acceptance due to development of identification tools in the regions with poor reconstruction efficiency**
- **Addition of new channels: H+X→γγ+X, H→WW→lνjj, WH→τνbb and others**

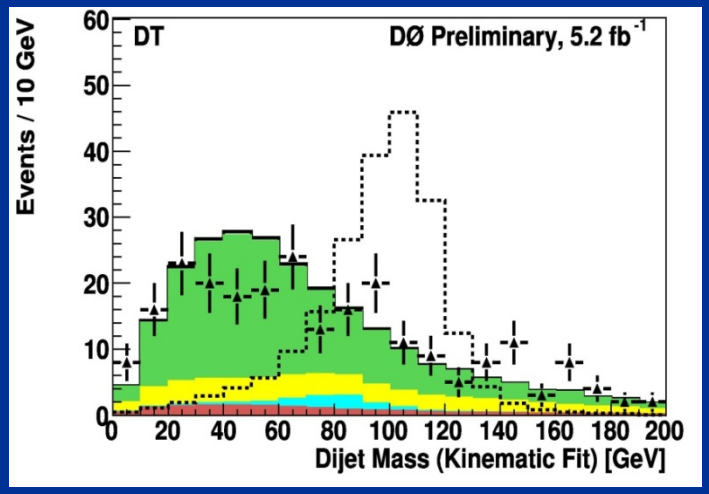
Improvements in Higgs Sensitivity at DZero

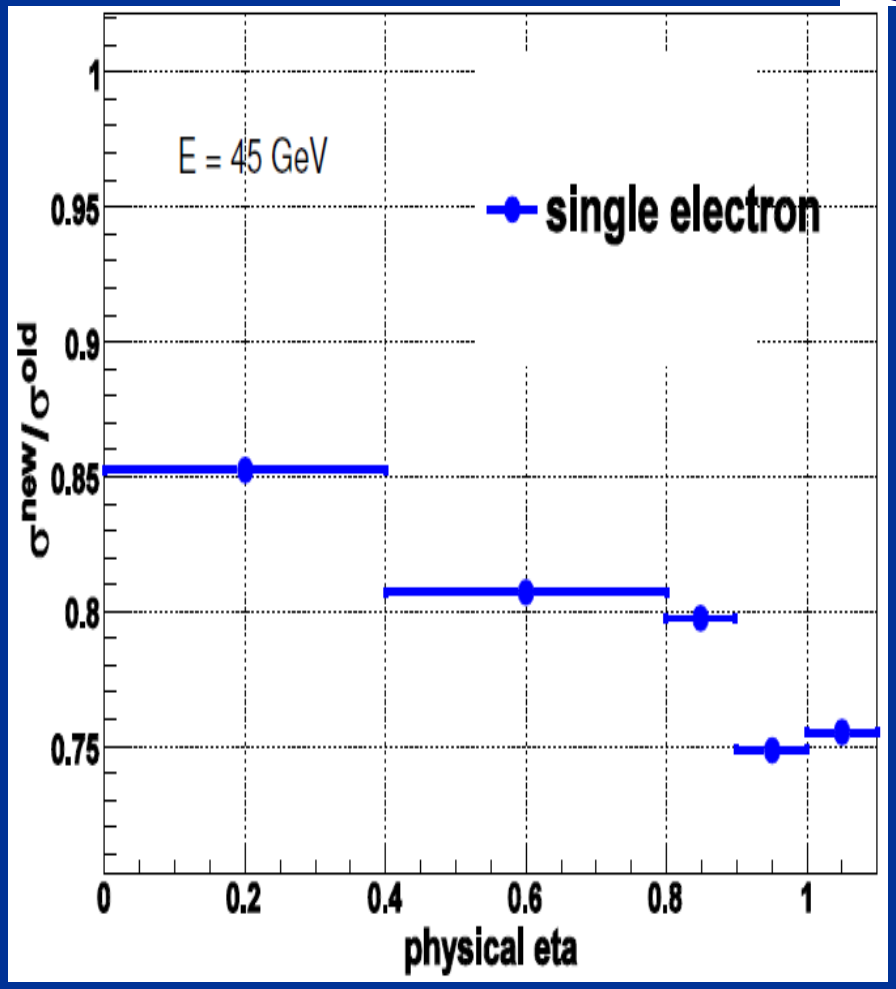


- **Improve electron identification using multivariate analysis methods**
  - **Utilizing full available information**

Improvements in Higgs Sensitivity at DZero

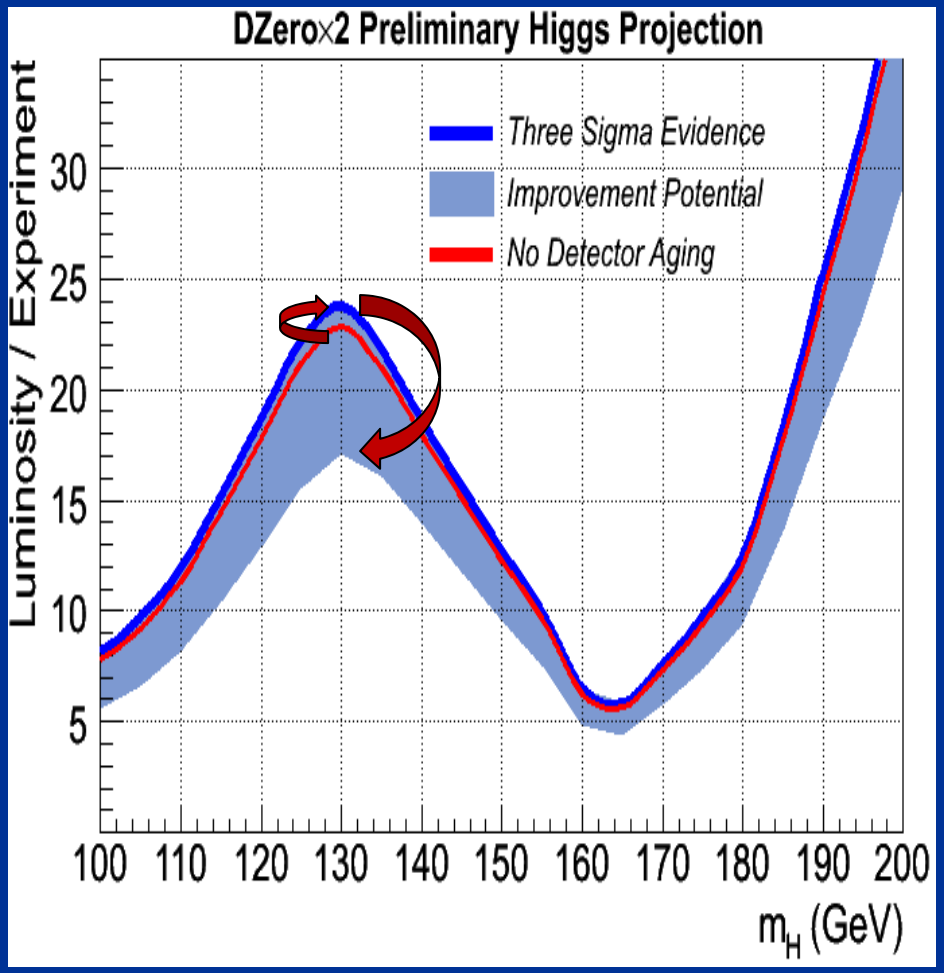


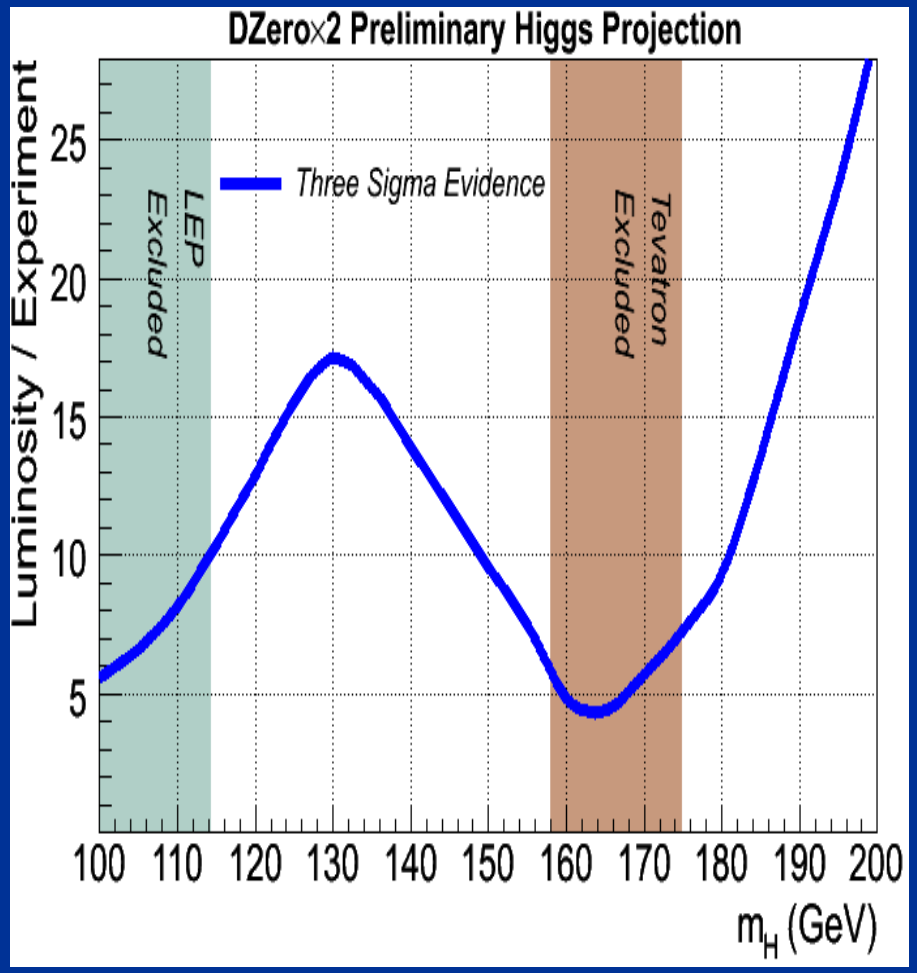




- **Improvement in di-jet mass resolution due to kinematic fitting**
  - **Reduction of ~15% in di-jet mass width**
- **Improvement in electron energy resolution (and Z width) by using pre-shower**
  - **To reduce backgrounds**

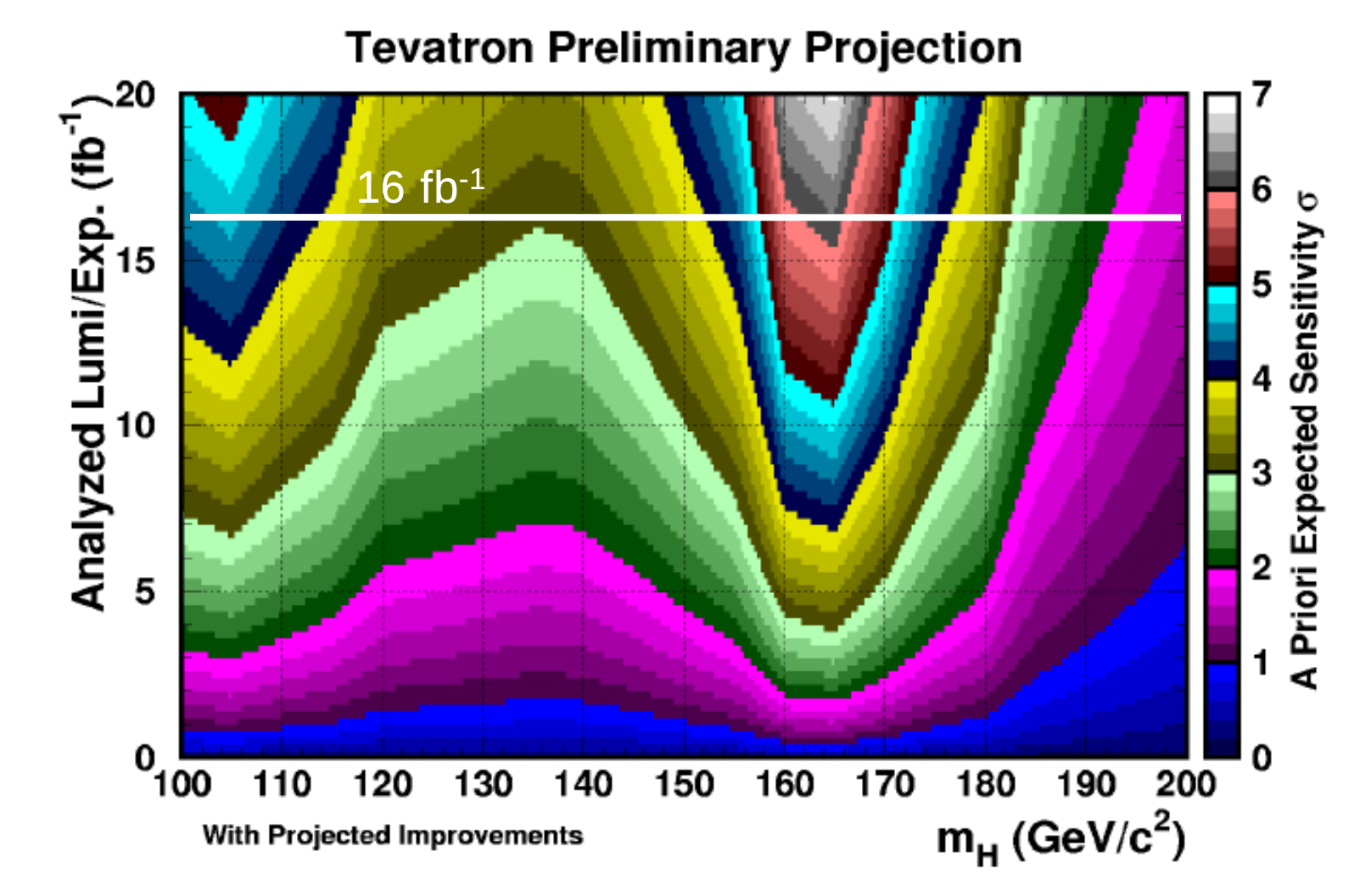
DZero Updated Higgs Sensitivity





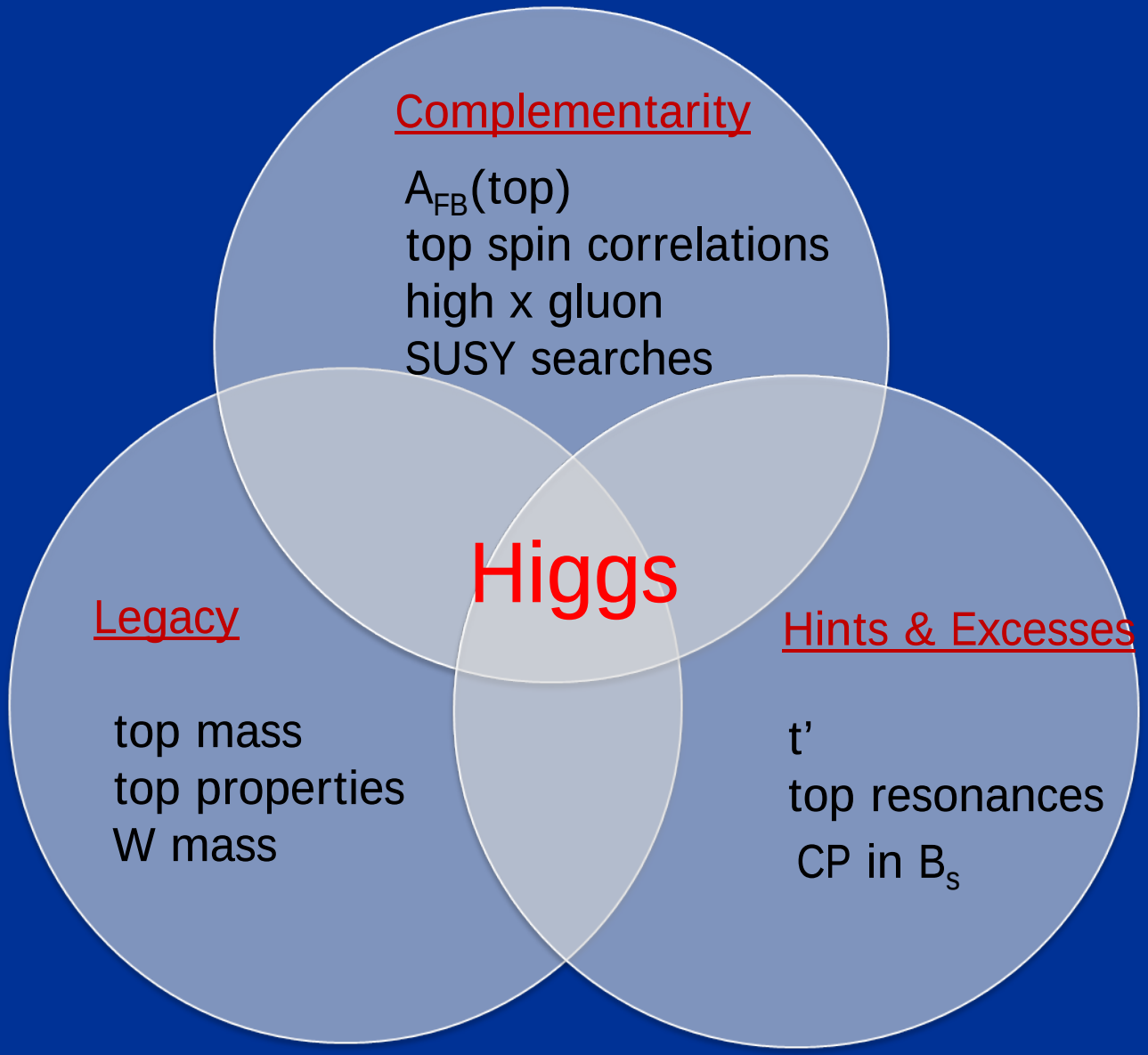
- **After repeating Higgs sensitivity study we are getting similar expectations as in the past**
  - **Radiation aging is now included**
- **Some assumptions are conservative and further improvements are anticipated**

Tevatron Higgs Sensitivity



Q4/A4: After re-evaluation and taking into account recent results Tevatron Higgs sensitivity plot presented to PAC in June 2010 represents our expectations well

Beyond 2011 Tevatron Potential



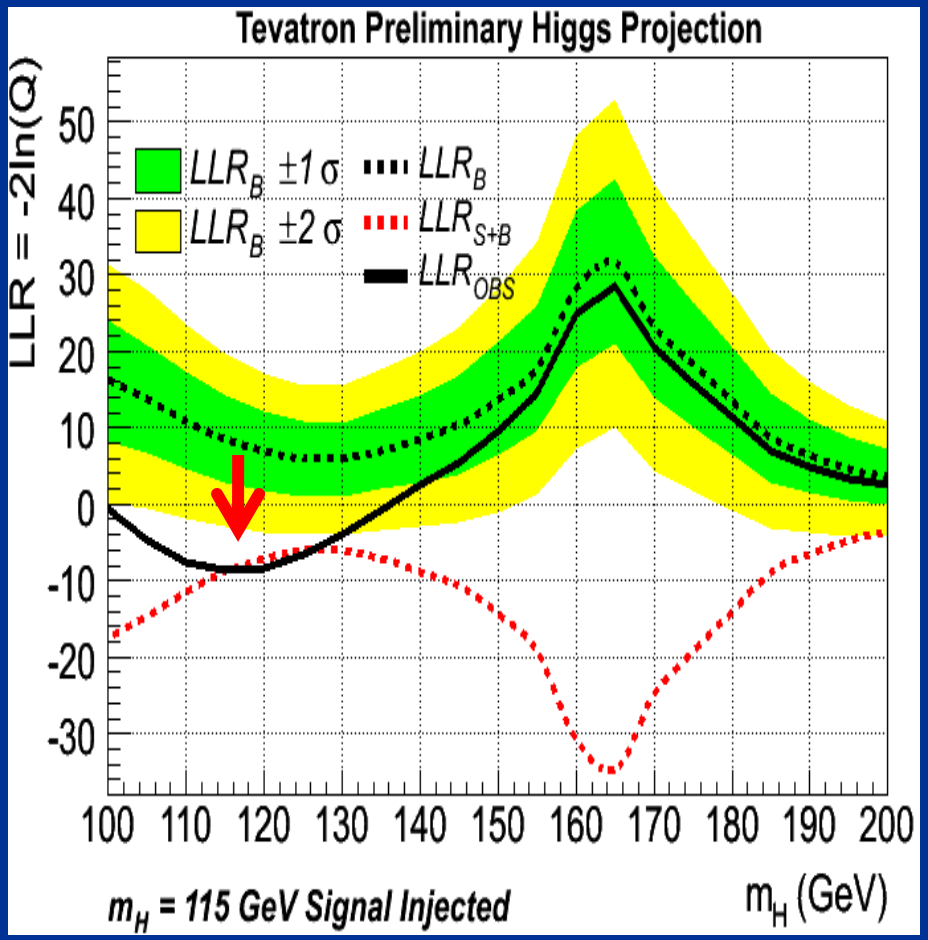
Summary – Tevatron Run Beyond 2011

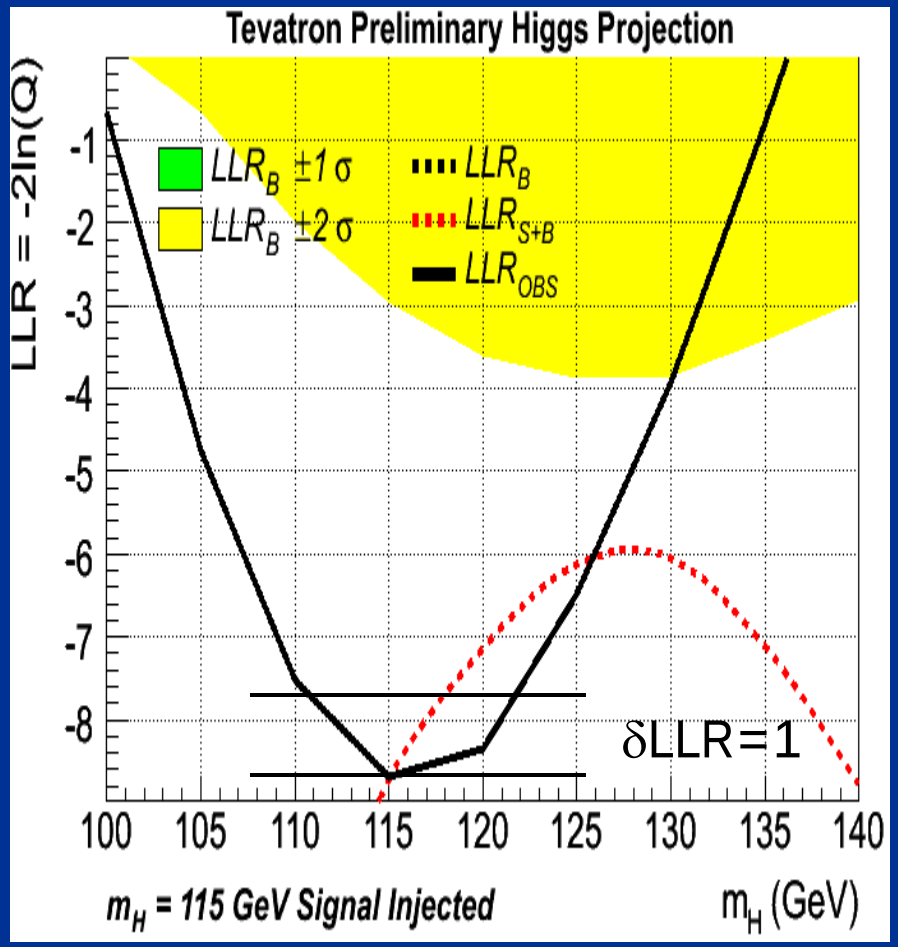
- Adequate collaboration manpower confirmed
- Radiation aging is manageable and affects Higgs sensitivity by a few %
  - Expected to be mitigated further
- Higgs mass resolution of ~6 GeV is expected
- With expected improvements will reach at least 3 sigma sensitivity in all allowed Higgs mass range with extended Tevatron run
  - Unique for the Tevatron H → bb decay mode

CDF and DØ are capable of achieving exciting and compelling opportunity of over 3 sigma Higgs evidence for all allowed mass range

We ask PAC to recommend Tevatron run extension

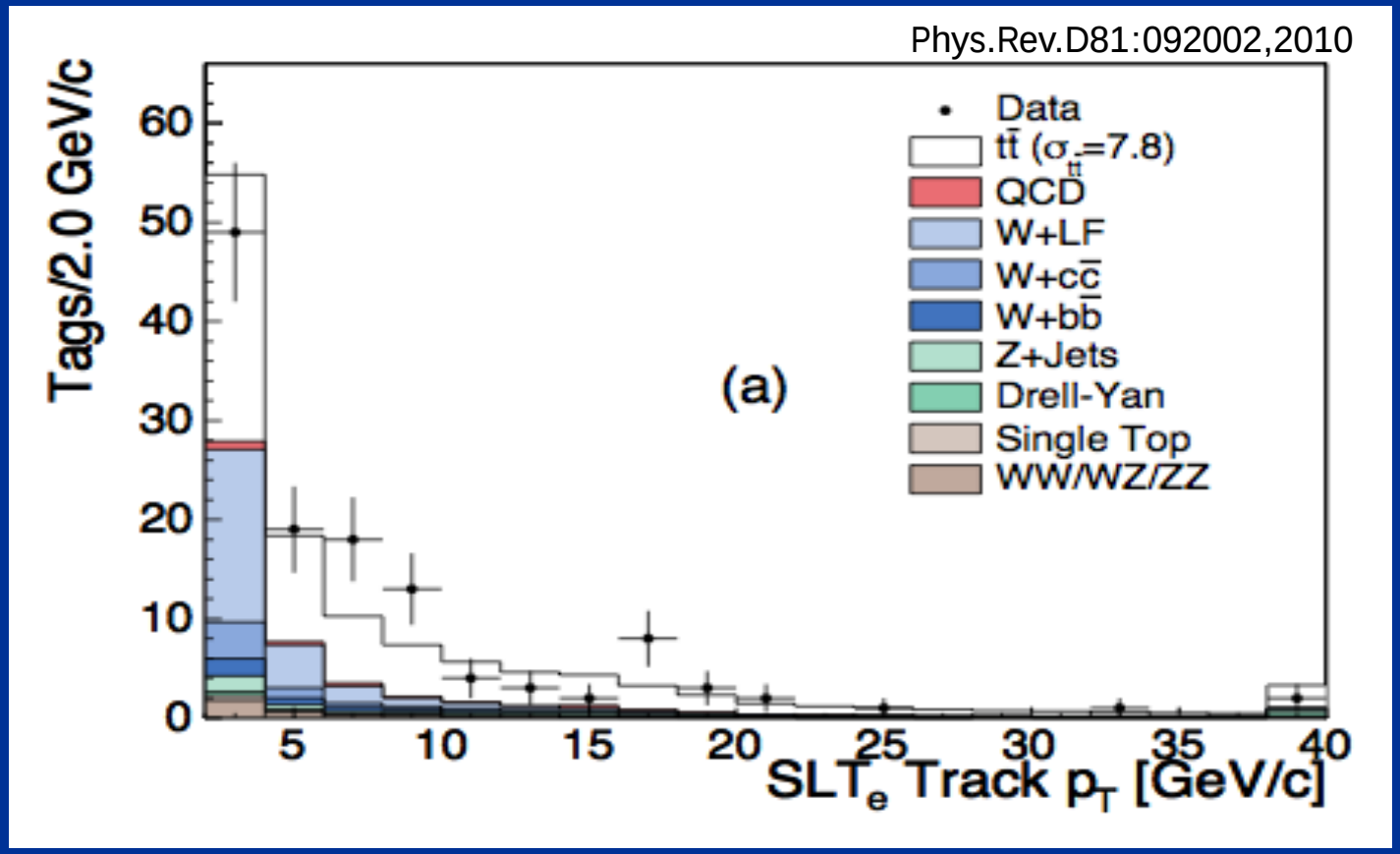
Higgs Mass from LLR Curves





LLR+1 range of the 125 GeV signal injection is ~6 GeV at 125 GeV

Soft Lepton b-tagging at CDF



- **Tagging efficiency for H→bb with soft electron b-tagging algorithm is increasing sensitivity by 5%**
  - **Most valuable in identifying additional low-background, double-tagged events**
  - **Recently used in tt cross-section measurement**