Vector Boson productions and Higgs searches in CMS

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Jet reconstruction and spectroscopy at hadron colliders

18-19 April 2011 *INFN Pisa*

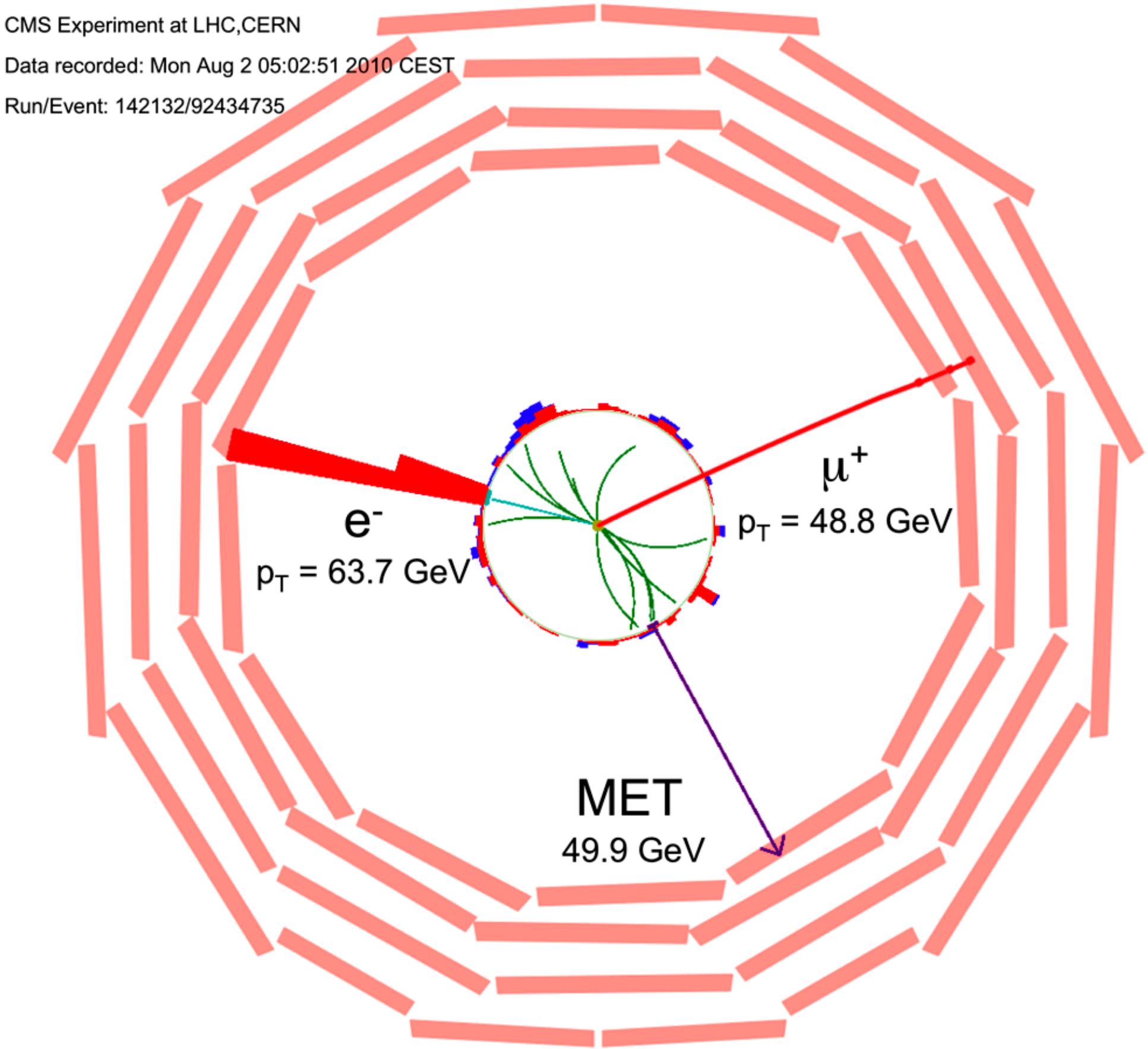
ingredients

- the data *in the backup*
- Vector Boson productions
- Higgs searches
- conclusions

diboson production

- electroweak sector in the SM crucial to demonstrate the experimental understanding at new energy frontier
- *WW* production is the dominant and irreducible background to $H \rightarrow WW$ searches
- *a*nomalous *T*riple *G*auge boson *C*ouplings (*aTGC*) from New Physics would lead to different cross sections and kinematics in diboson production in WW / $W\gamma$ / $Z\gamma$

WW cross section

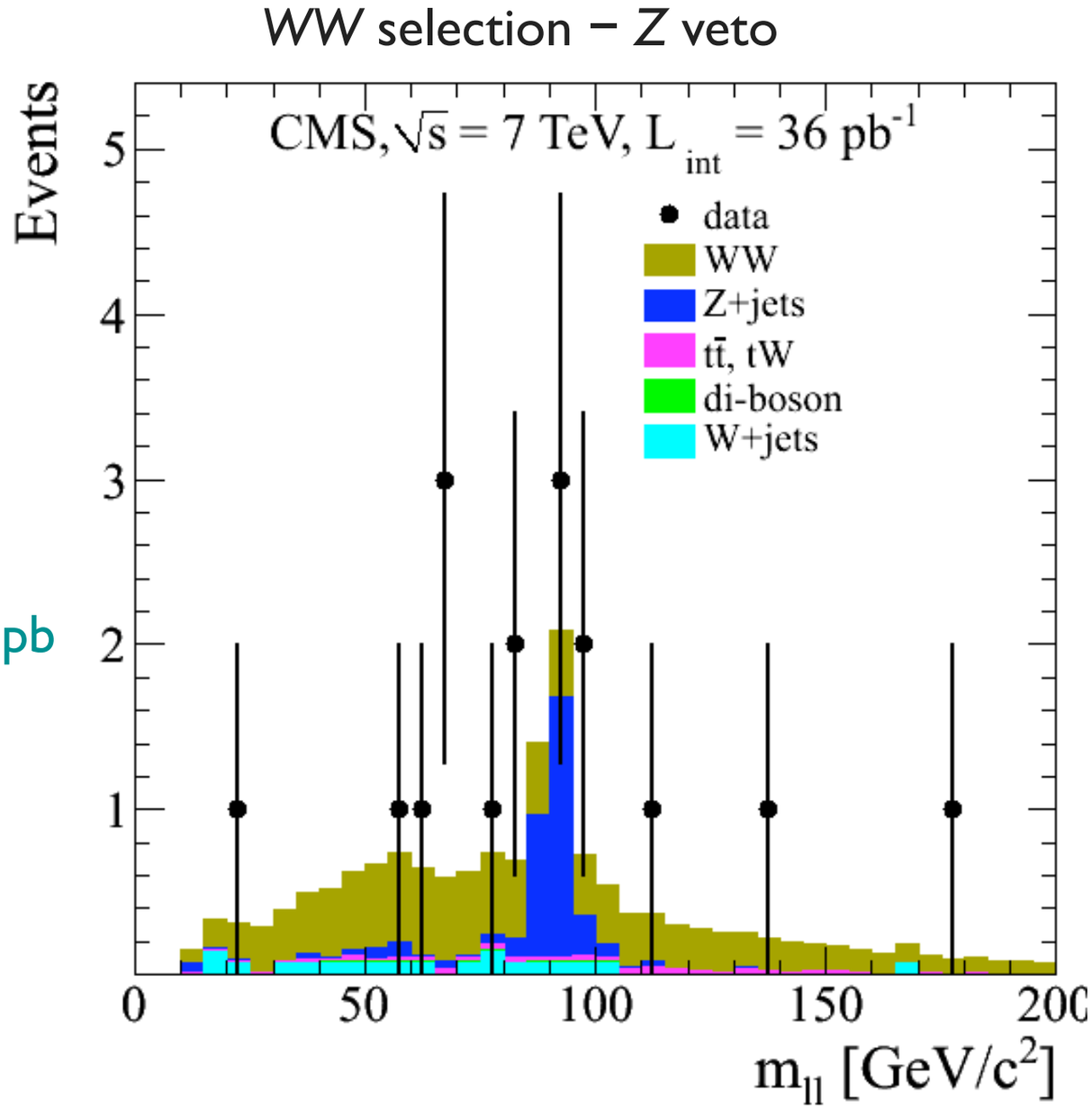

CMS Experiment at LHC,CERN
Data recorded: Mon Aug 2 05:02:51 2010 CEST
Run/Event: 142132/92434735
e-
pT = 63.7 GeV
μ+
pT = 48.8 GeV
MET
49.9 GeV

background rejection / estimation

- *signal* = 2 leptons + large MET
- *W* + *jets* background
  - jets can fake leptons ➠ **apply tight lepton ID** + lepton *pt* > 20 GeV
  - estimated from data ➠ extract fake rate in a fake enriched sample
- *Drell-Yan* background
  - expect no MET ➠ **apply tight MET cut** + *Z* mass veto in ee, μμ
  - estimated from data
- *top* background
  - $t \rightarrow bW$ ➠ **reject with jet veto**
  - estimated from MC + cross-check on data
- other backgrounds (*WZ* / *ZZ* / *Wγ*)
  - estimated from MC

cross section measurement

- 13 data candidates
- 3.3 ± 0.5 ± 1.1 estimated background
- σ = **41.1** ± 15.3 (stat) ± 5.8 (syst) ± 4.5 (lumi) pb
- NLO prediction = **43 ± 2** pb



Wγ / Zγ cross section

selecting candidates

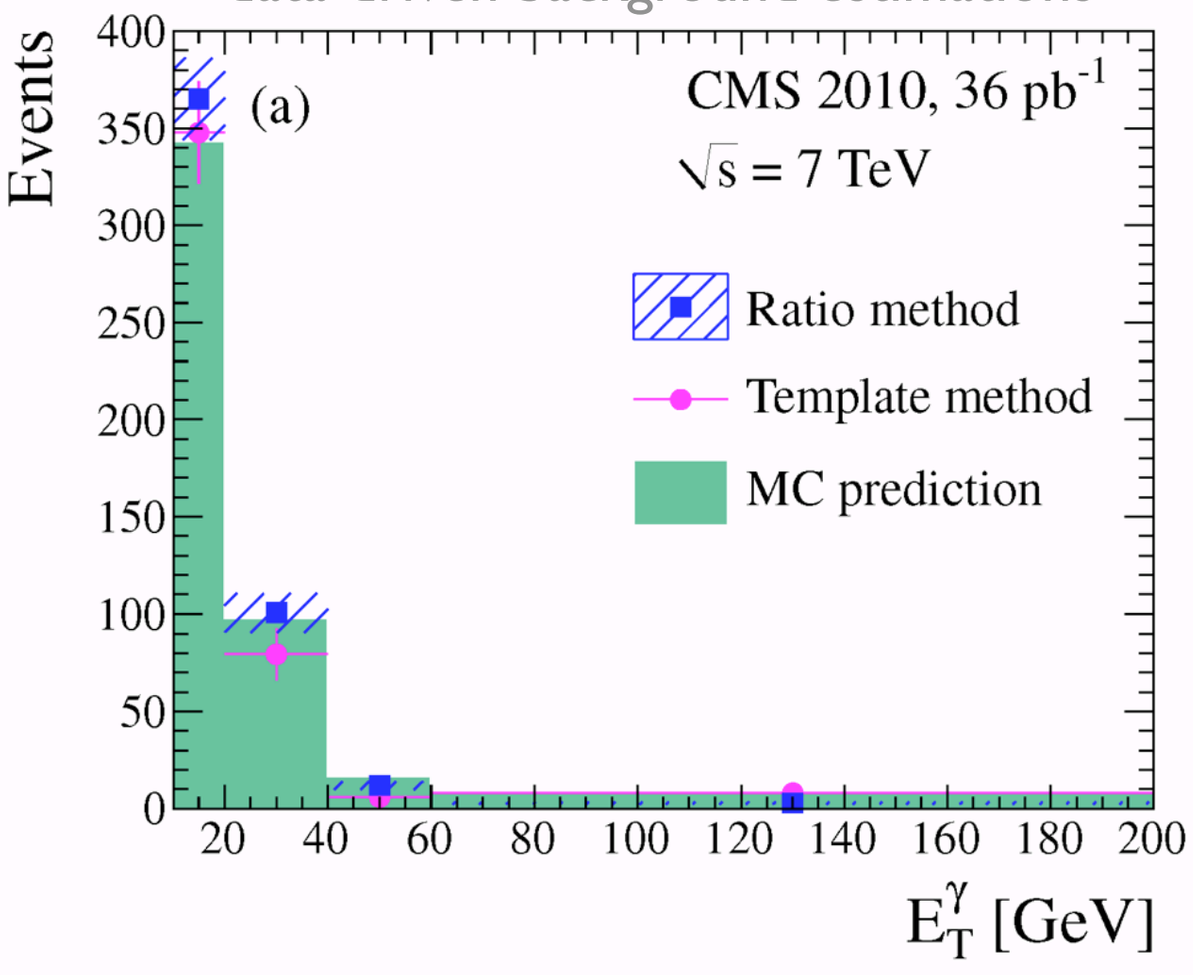
- isolated photon
  - pt > 10 GeV
  - $\Delta R(\ell, \gamma) > 0.7$ (to suppress FSR)
- $W\gamma$
  - one prompt isolated lepton (ℓ = e, μ)
  - pt > 20 GeV
  - large MET
- $Z\gamma$
  - two prompt isolated leptons ($\ell\ell$ = ee, μμ)
  - $M_{\ell\ell} > 50$ GeV
- counting experiment yield extraction
  - data-driven techniques to estimate background

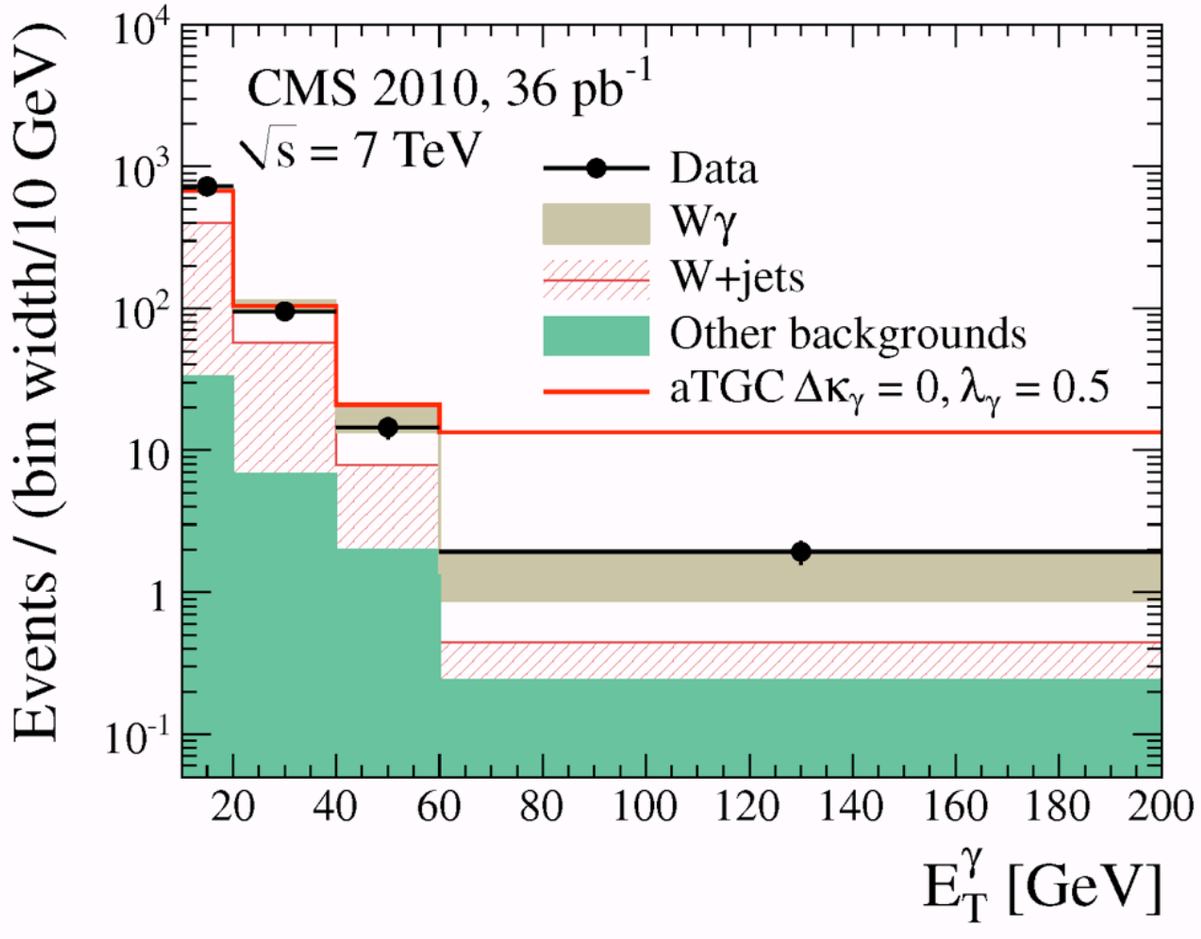
background estimation

- *W*/*Z* + jets
  - jets can fake photons ➠ **require photon to be isolated**
  - use "ratio method" to estimate leftover in data region
    - measure (*Et*-dependent) ratio of non-isolated photon candidates to isolated ones in a QCD-enriched sample
    - correct for photon + jet contamination using MC
    - fold the (*Et*-dependent) ratio in *W*/*Z* + non-isolated photon samples to obtain the *W*/*Z* + jets background
- other backgrounds (*top*, multijets) much smaller
  - estimated from MC

Wγ simulation *vs* data

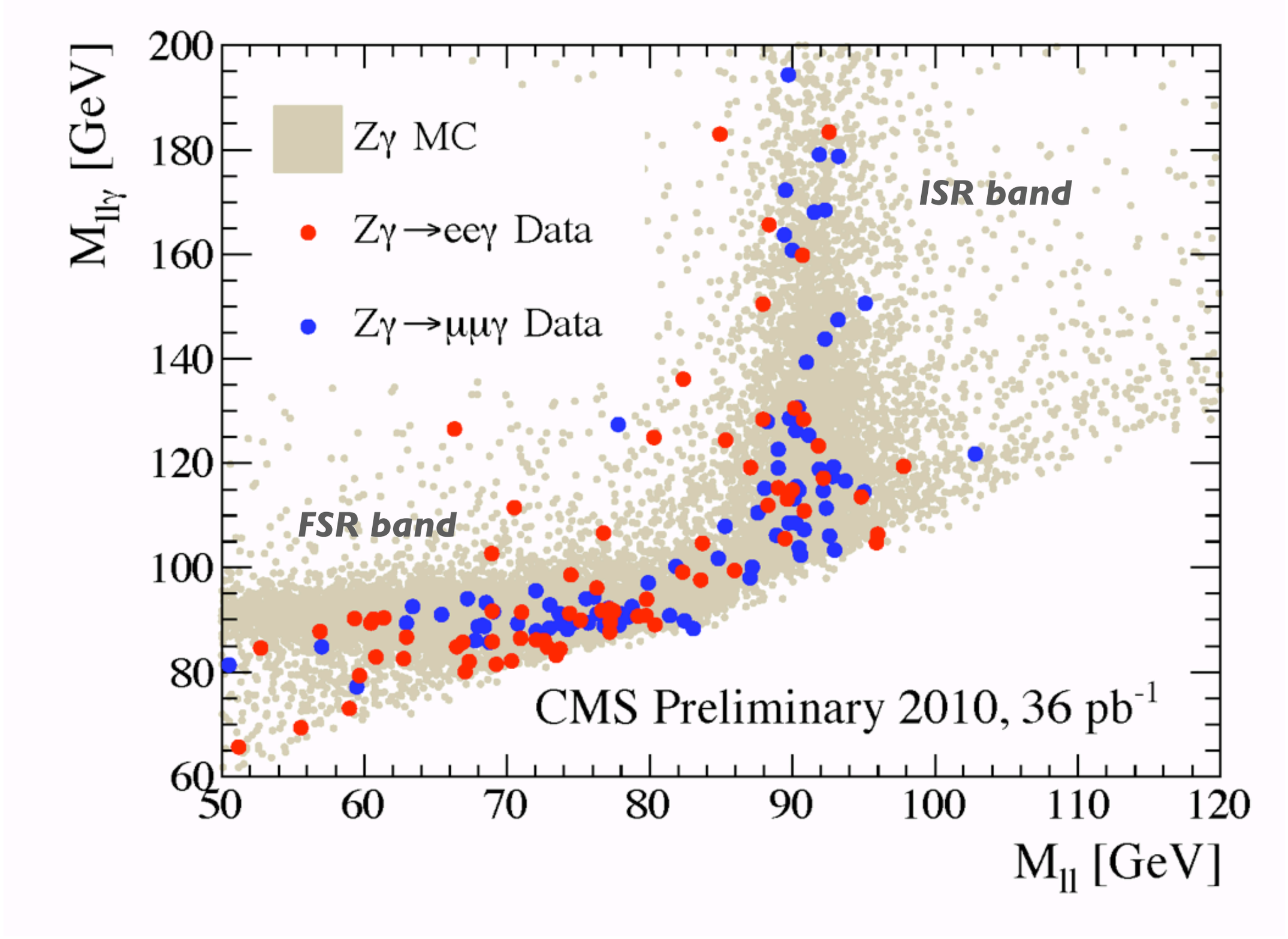
data-driven background estimations





- excellent agreement between various data-driven methods and the prediction from simulation

Zγ simulation *vs* data



cross section measurement

process	observed	background	σ (pb)	NLO prediction (pb)
eνγ	452	220 ± 16 ± 14	56.7 ± 6.9(stat) ± 5.1(syst) ± 6.2(lumi)	49.4 ± 3.8
μνγ	520	261 ± 19 ± 16	55.0 ± 7.2(stat) ± 5.0(syst) ± 6.1(lumi)	
eeγ	81	20.5 ± 1.7 ± 1.9	9.4 ± 1.4(stat) ± 0.7(syst) ± 1.0(lumi)	9.6 ± 0.4
μμγ	90	27.3 ± 2.2 ± 2.3	9.2 ± 1.4(stat) ± 0.6(syst) ± 1.0(lumi)	

- σ measured relative to pre-defined acceptance cuts
  - $Et(\gamma) > 10$ GeV, $\Delta R(\ell,\gamma) > 0.7$
  - $M_{\ell\ell} > 50$ GeV for $Z\gamma$

observation of $Z+b$

interest

- *Z*+*b* production is an important measurement at the LHC
  - as a benchmark channel to the production of *H*+*b*
  - as a SM background to Higgs and New Physics searches with leptons+*b* in the final state
- the *H*+*b* production could be a MSSM discovery channel
  - at high values of tanβ σ(*H*+*b*) is enhanced
  - large theoretical uncertainties of σ@NLO ➠ additional interest in *Z*+*b*

selection

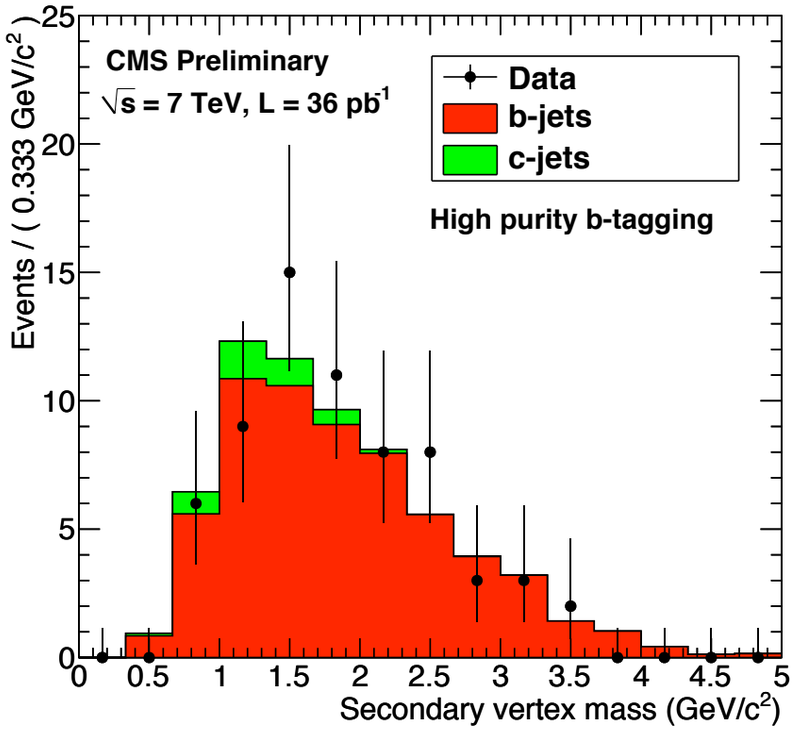
- $Z \rightarrow ee$ / $\mu\mu$
  - *electron pt* > 25 GeV
  - *muon pt* > 20 GeV
  - isolated leptons (small amount of energy in $\Delta R < 0.3$ cone)
- jets with *pt* > 25 GeV and $\Delta R > 0.5$ from leptons
  - apply high-purity *b*-tagging based on secondary vertex flight distance
- to reduce *ttbar* + jets background
  - $60 < M_{\ell\ell} < 120$ GeV
  - MET < 40 GeV
- 29 (36) events pass the ee ($\mu\mu$) selection

cross section ratios

$$\frac{\sigma\left(pp \to Z + b + X\right)}{\sigma\left(pp \to Z + j + X\right)} = \frac{N_{Z+b}^{data}\mathcal{P} - N_{t\bar{t}}^{MC}}{N_{Z+j}^{data}\epsilon_{MC}}$$

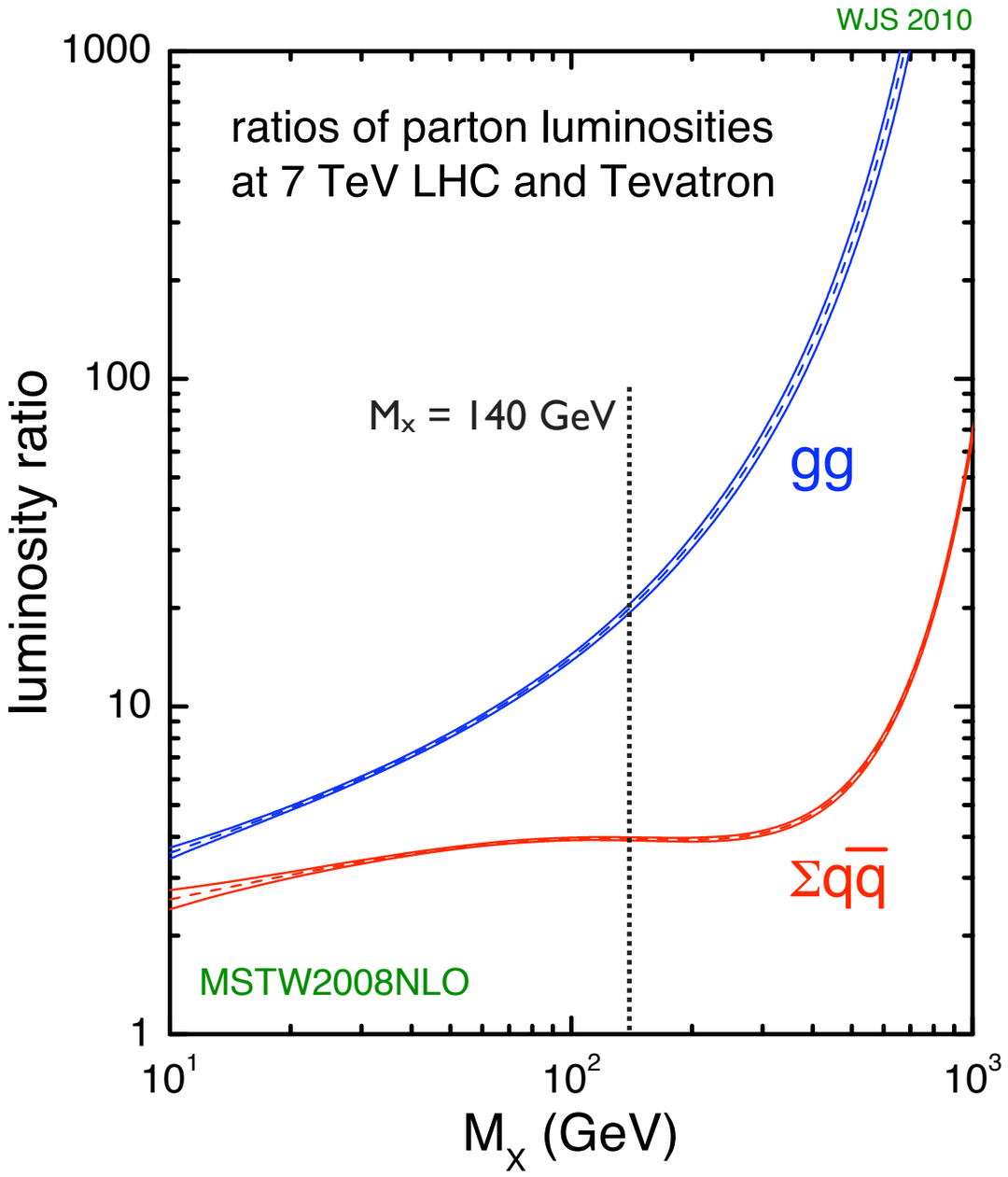
- to extract the purity *P* in *b*-jets
  - fit the secondary vertex mass using a binned likelihood method
  - use template functions for the *b*, *c* and *light* contributions taken from MC

σ(*Z*+*b*) / σ(*Z*+*j*)	measured	NLO
$Z \to ee$	0.054 ± 0.016	0.043 ± 0.005
$Z \to \mu\mu$	0.046 ± 0.014	0.047 ± 0.005



Higgs searches

Tevatron *vs* LHC



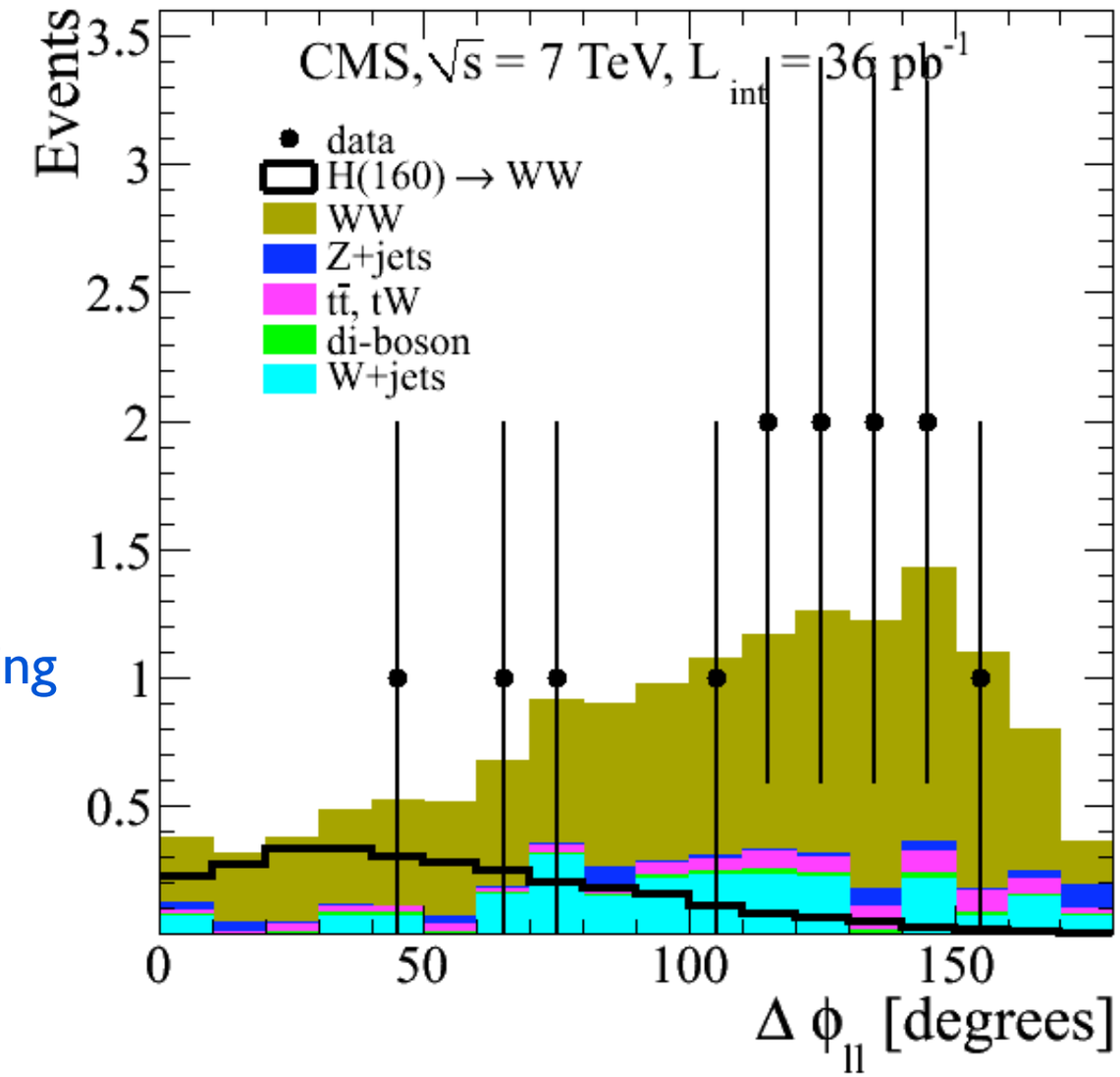
- M_x > 140 GeV
  - σ(*gg*) @ 7 TeV > 15× σ(*gg*) @ Tevatron
  - *WW*/*ZZ* backgrounds originate from *qq* (slow rise)
  - **S/B competitive with 1 fb^{-1}**
- M_x < 140 GeV
  - slow rise in σ(*qq*)
  - *pp* → *VH* rate @ 7 TeV ~ rate @ Tevatron
  - **S small, S/B poor**

$H \rightarrow WW \rightarrow 2l2\nu$

most sensitive channel for early studies

- we look for
  - two isolated leptons with small $\Delta\phi$
  - MET
  - no central jets
- we reject backgrounds by
  - ***WW*** ➠ $\Delta\phi$ and $M_{\ell\ell}$
  - ***ttbar*** ➠ central jet veto + $\Delta\phi$ + $M_{\ell\ell}$ + *b*-tagging
  - ***W+jets*** ➠ tight lepton identification
  - ***DY*** ➠ MET and $M_{\ell\ell}$
  - ***WZ / ZZ*** ➠ 2 leptons + MET + $M_{\ell\ell}$

WW selection



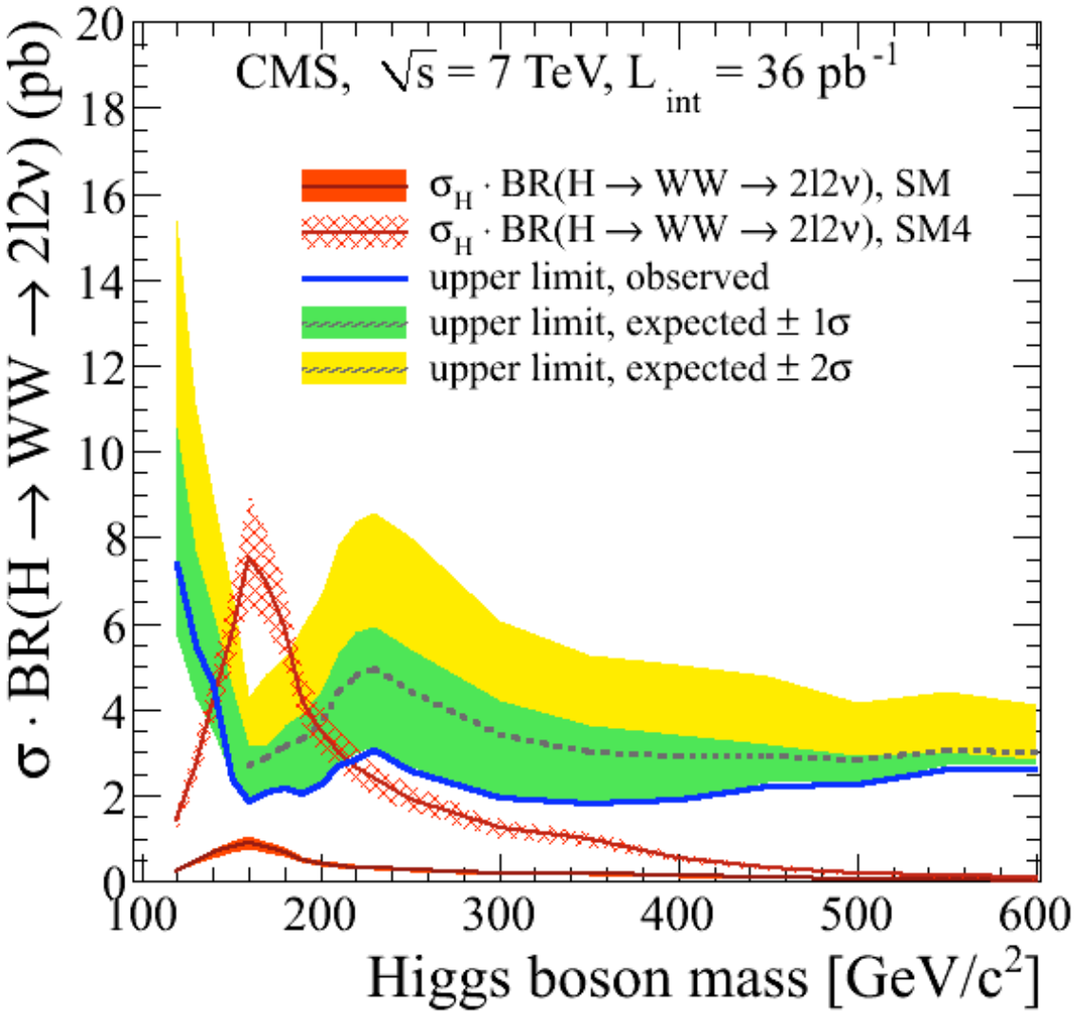
cross section limit

no difference between BDT(*) and cut-based results

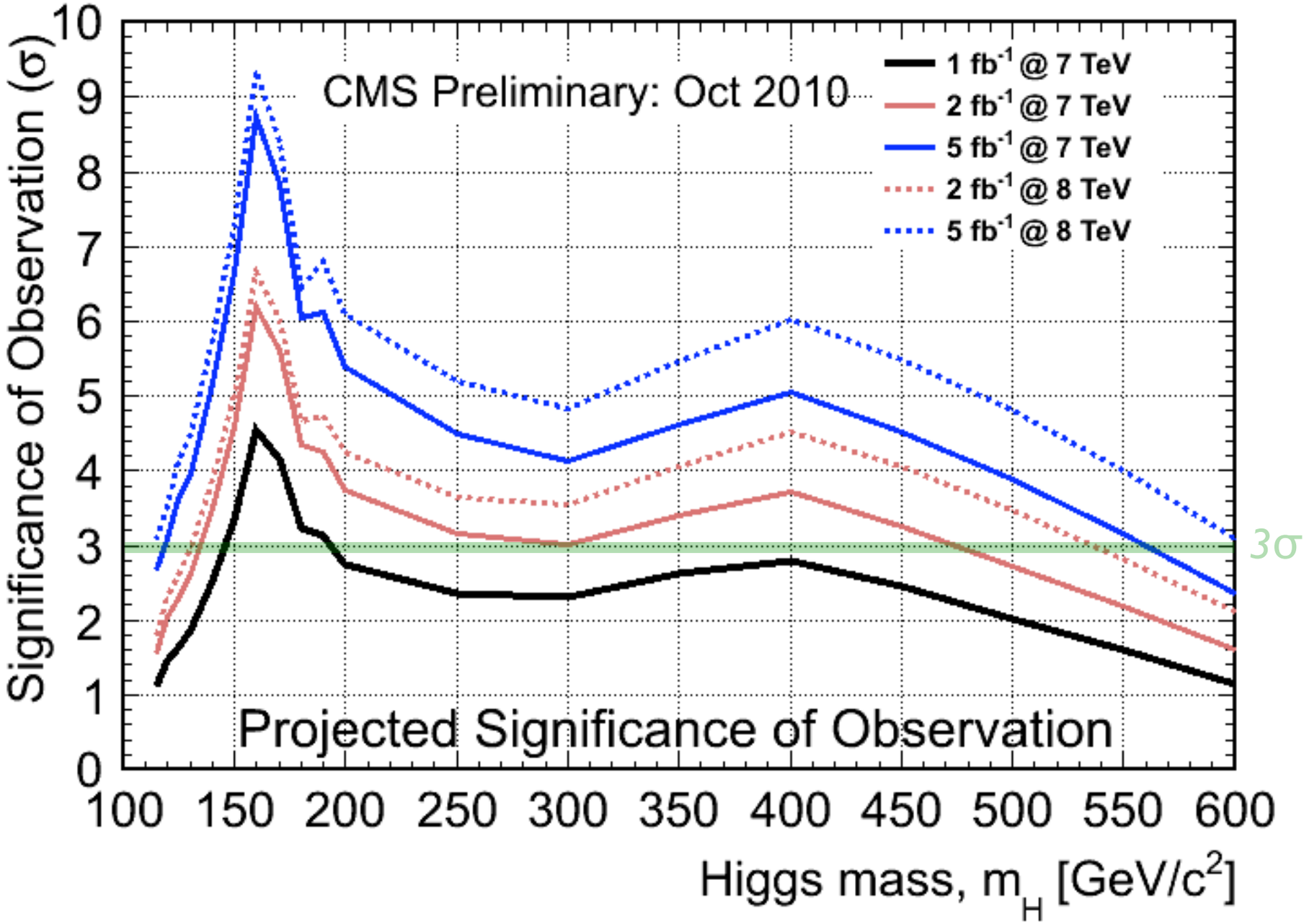
- no signal yet
  - set upper limit
- sensitive to H160 with ×3 data
- sensitive to 4th fermion family models
  - exclude them for 144 < M_H < 207 GeV @ 95 C.L.

(*) Boosted Decision Trees

BDT

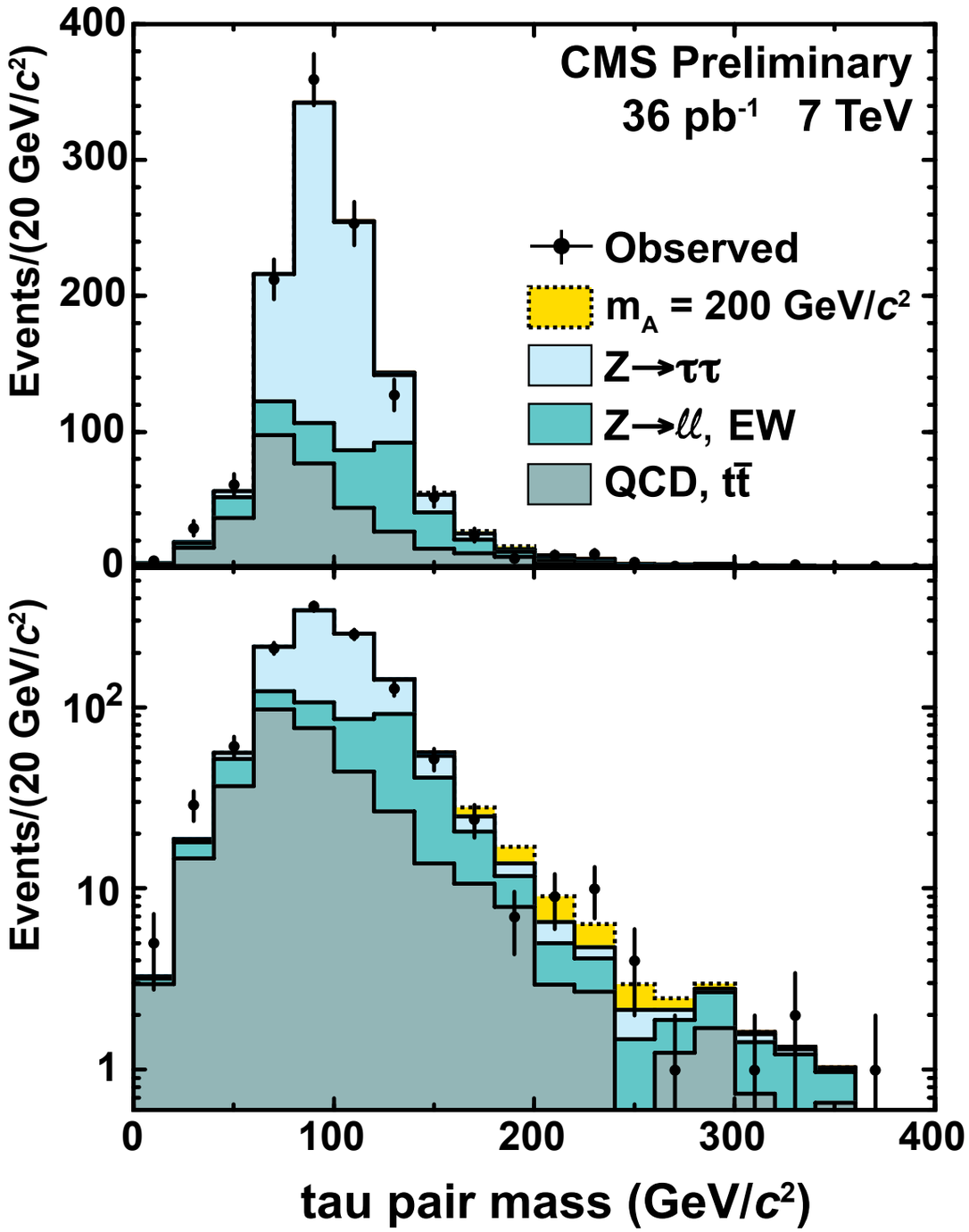


to observe the SM Higgs



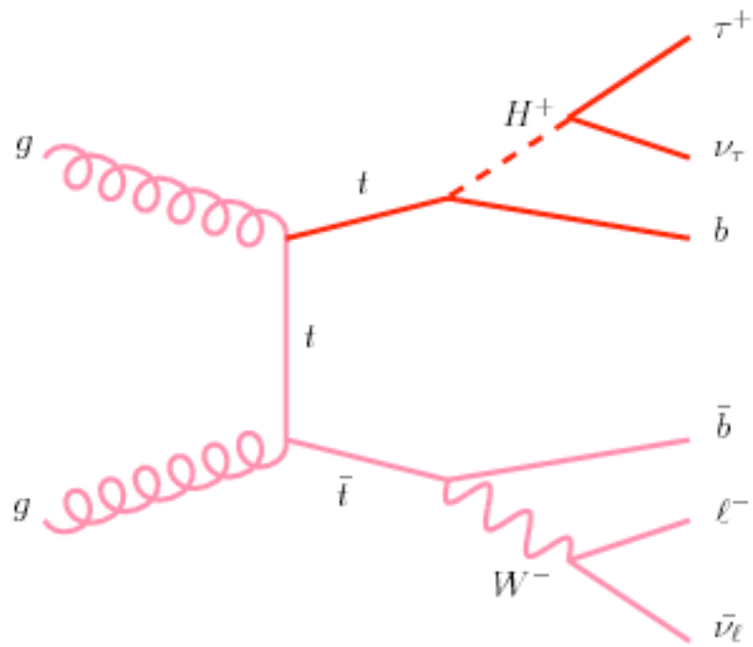
MSSM $\phi \rightarrow \tau\tau$

- $\phi = h / H / A$
- BR to $\tau\tau$ is about 10%
  - consider $\tau\tau$ decays to e-μ, e-*had*, μ-*had*
- main bkg is $Z \rightarrow \tau\tau$
  - MC normalized to $Z \rightarrow \mu\mu$ data
- QCD bkg estimated from
  - ratio of SS to OS dilepton events
  - τ fake rate studies
- no signal excess observed
  - significantly extend previous limits



H^+

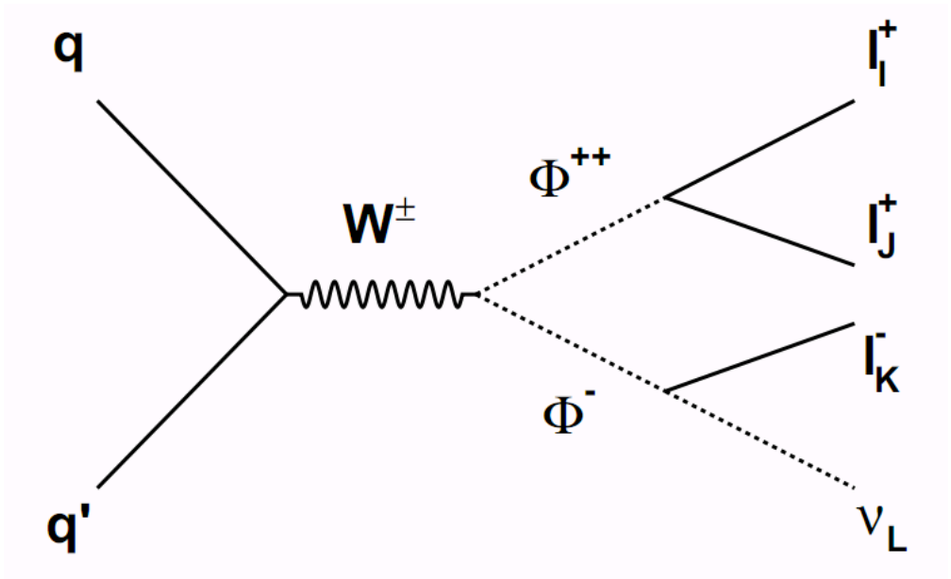
- look for H^+ in $t \rightarrow H^+b \rightarrow \tau\nu b$
  - if $M_H < M_{top}$
- look for e/μ + 2 jets + MET + hadronic τ

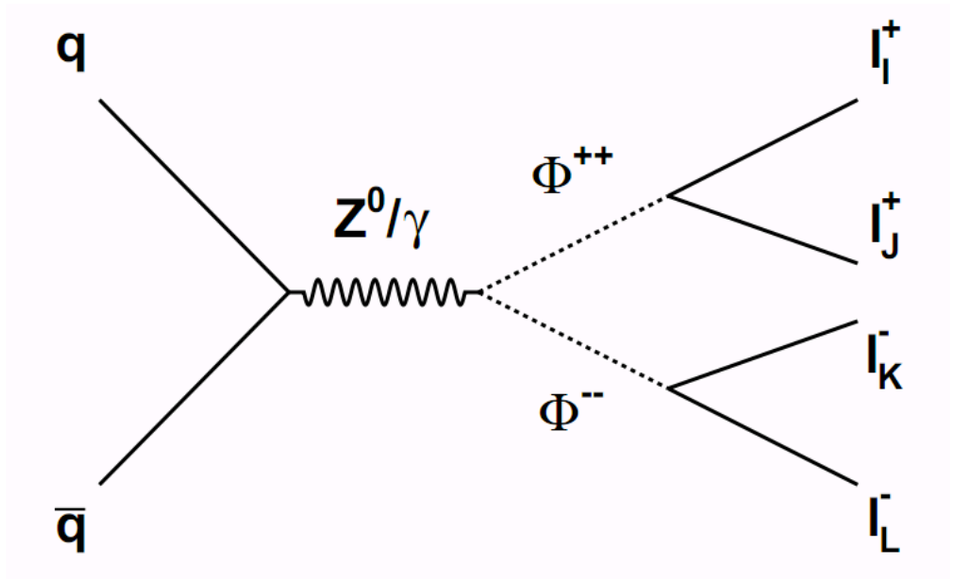


- no signal found
- upper limit on BR($t \rightarrow H^+b$) $\cong$ 0.25
  - for $80 < M_H < 140$ GeV
  - assume BR($H^+ \rightarrow \tau\nu$) = 1

ϕ^{++}

- inclusive search performed in events with 3 / 4 isolated leptons
- with 36 pb^{-1} $\phi^{++} \rightarrow WW$ forbidden kinematically
- no signal excess observed ➠ set 95% C.L.
  - $M_{\phi^{++}} > 156$ GeV in the μμ channel
  - $M_{\phi^{++}} > 154$ GeV in the eμ channel
  - $M_{\phi^{++}} > 144$ GeV in the ee channel





conclusions

- measured several diboson cross sections
  - in agreement with SM
- searched for anomalous TGC
  - in agreement with SM

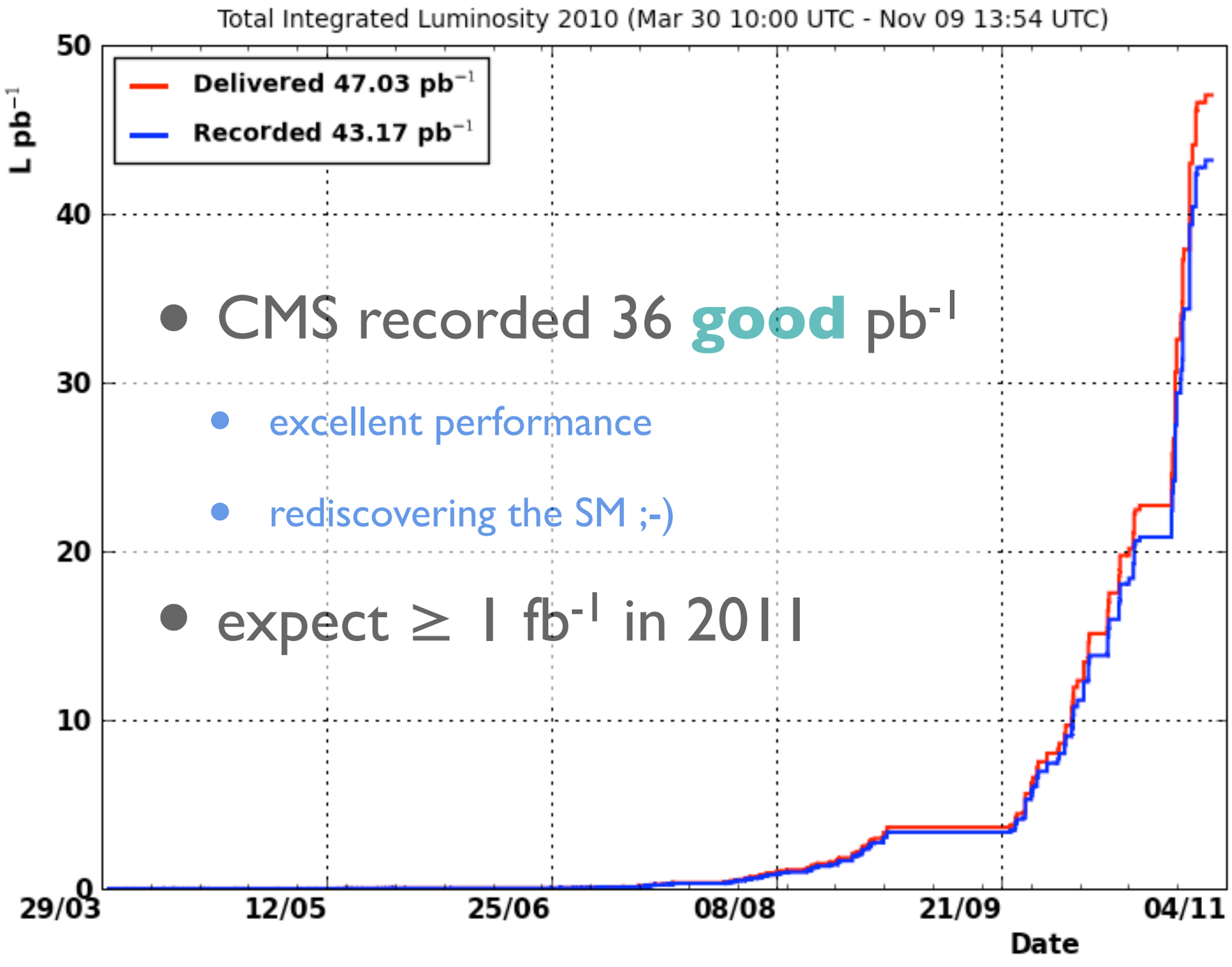
❁ *with 2011 data same measurements will seriously test the SM*

- searched for several Higgs bosons
  - no signal yet

❁ *can discover Higgs in a wide mass range with 1 fb^{-1}*

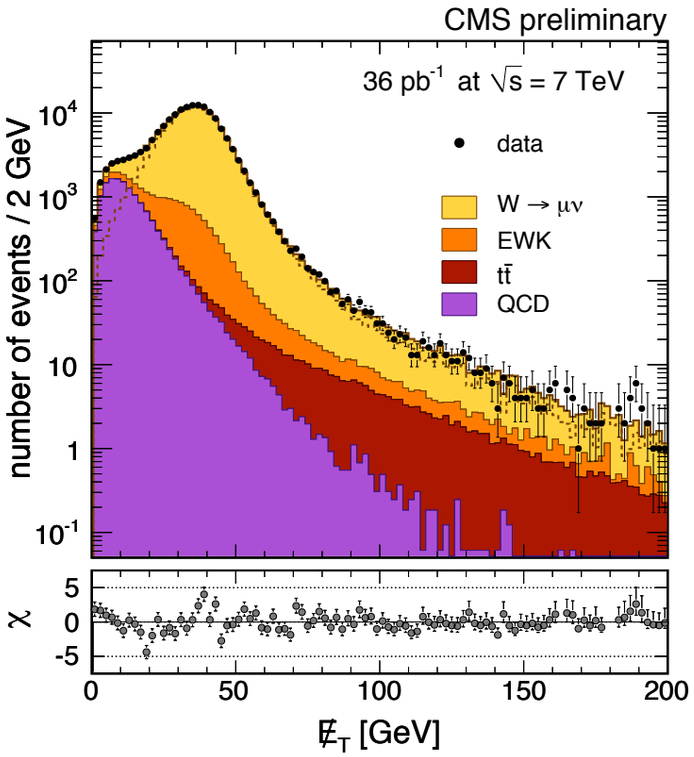
backup

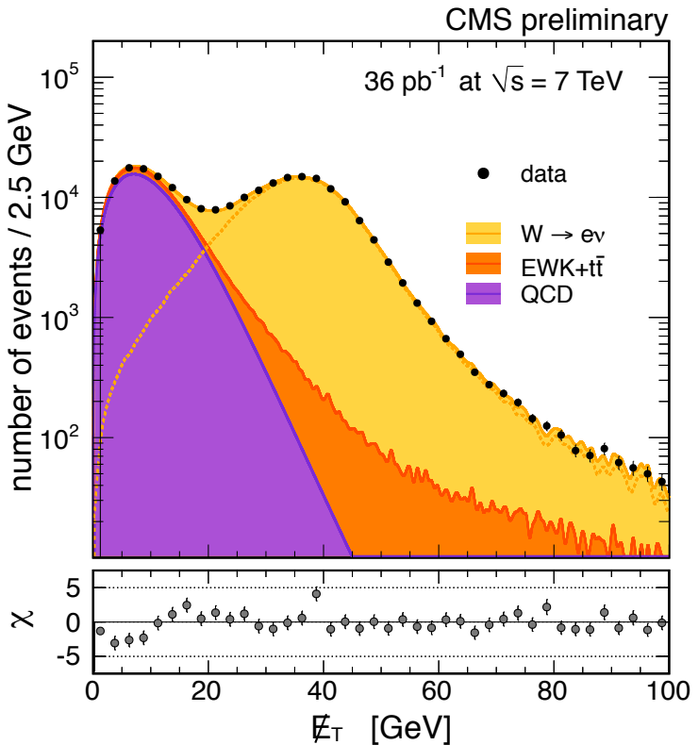
the data

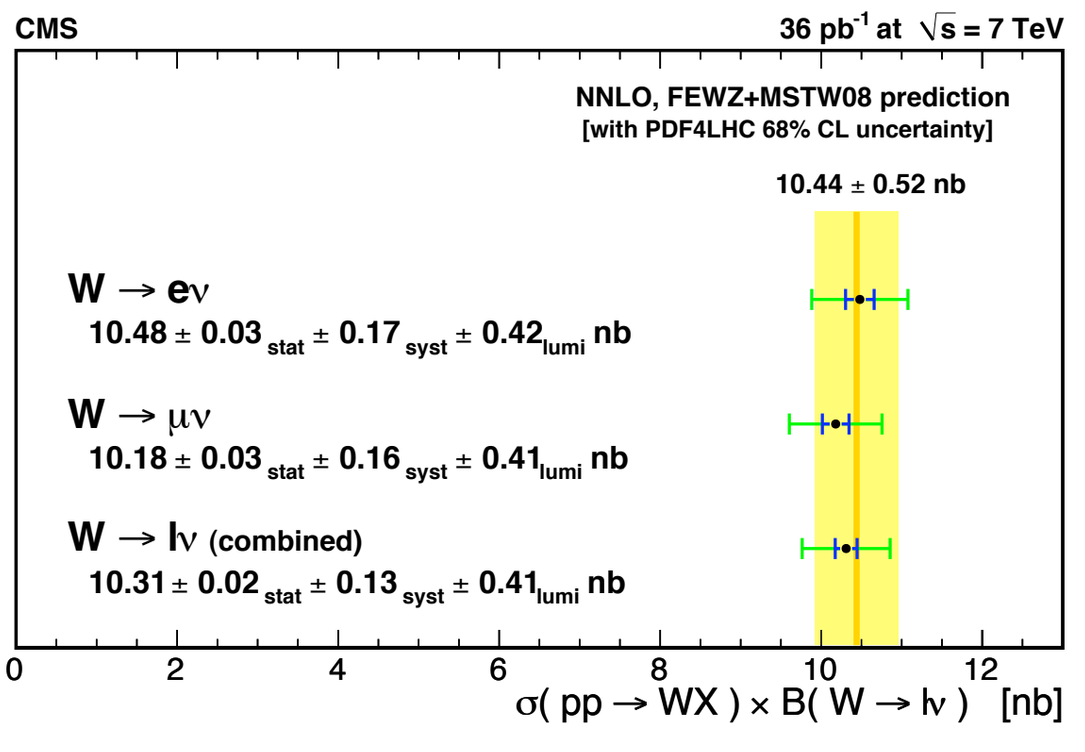


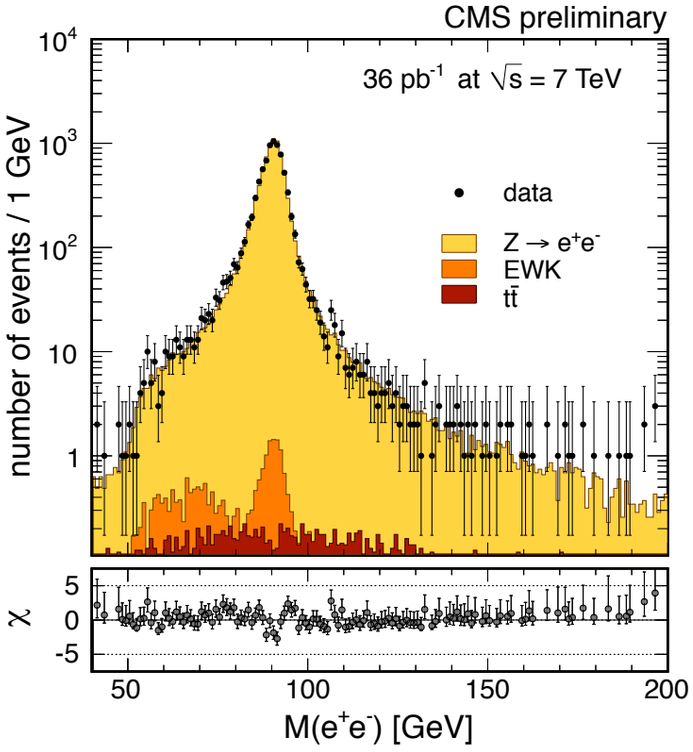
- CMS recorded 36 **good** pb^{-1}
  - excellent performance
  - rediscovering the SM ;-)
- expect ≥ 1 fb^{-1} in 2011

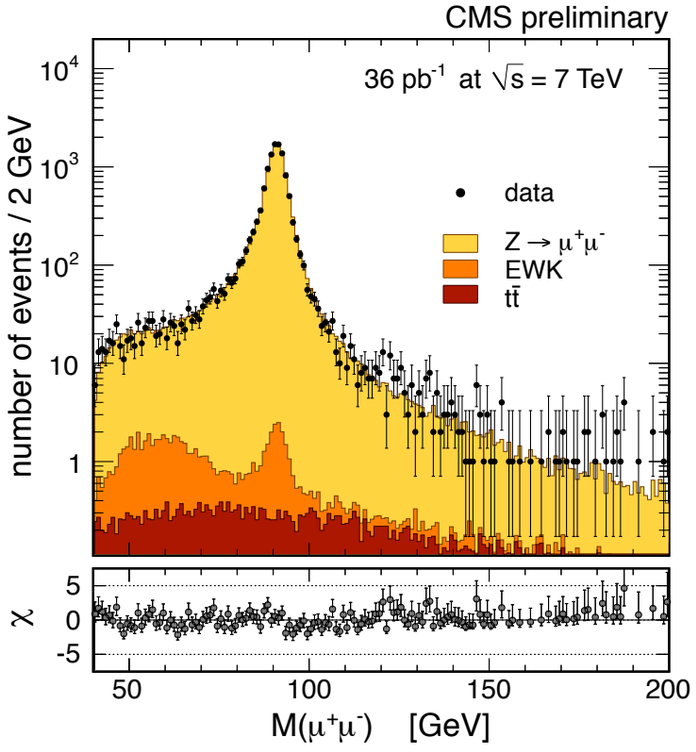
inclusive *W* and *Z* production cross sections

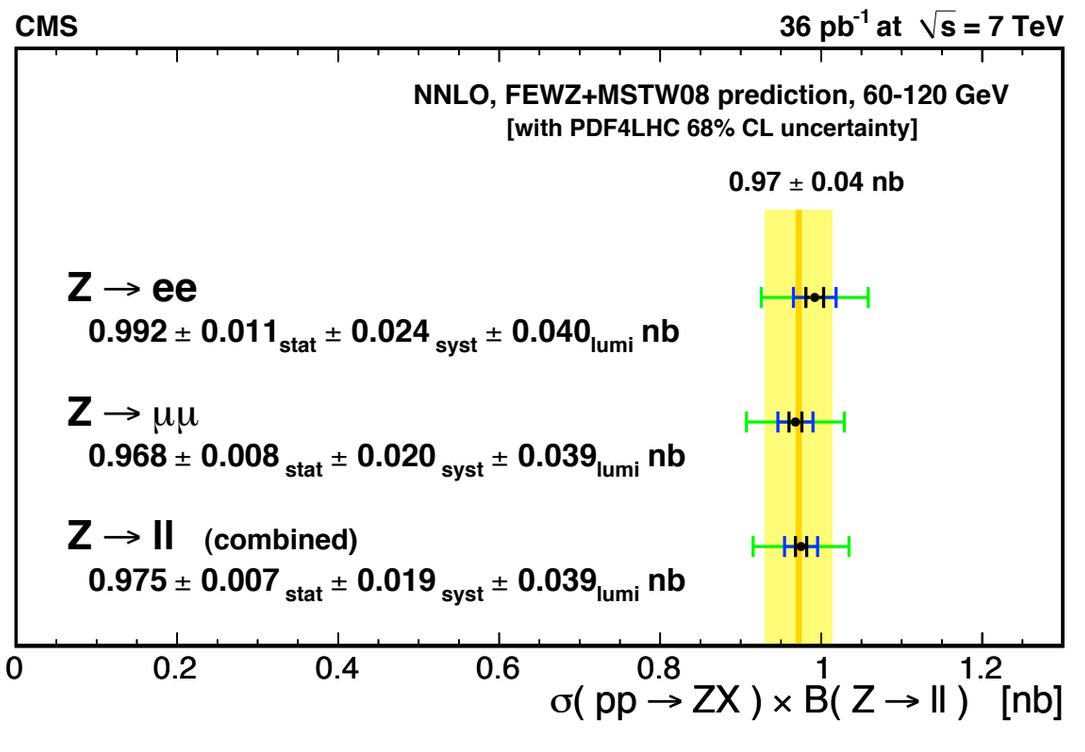












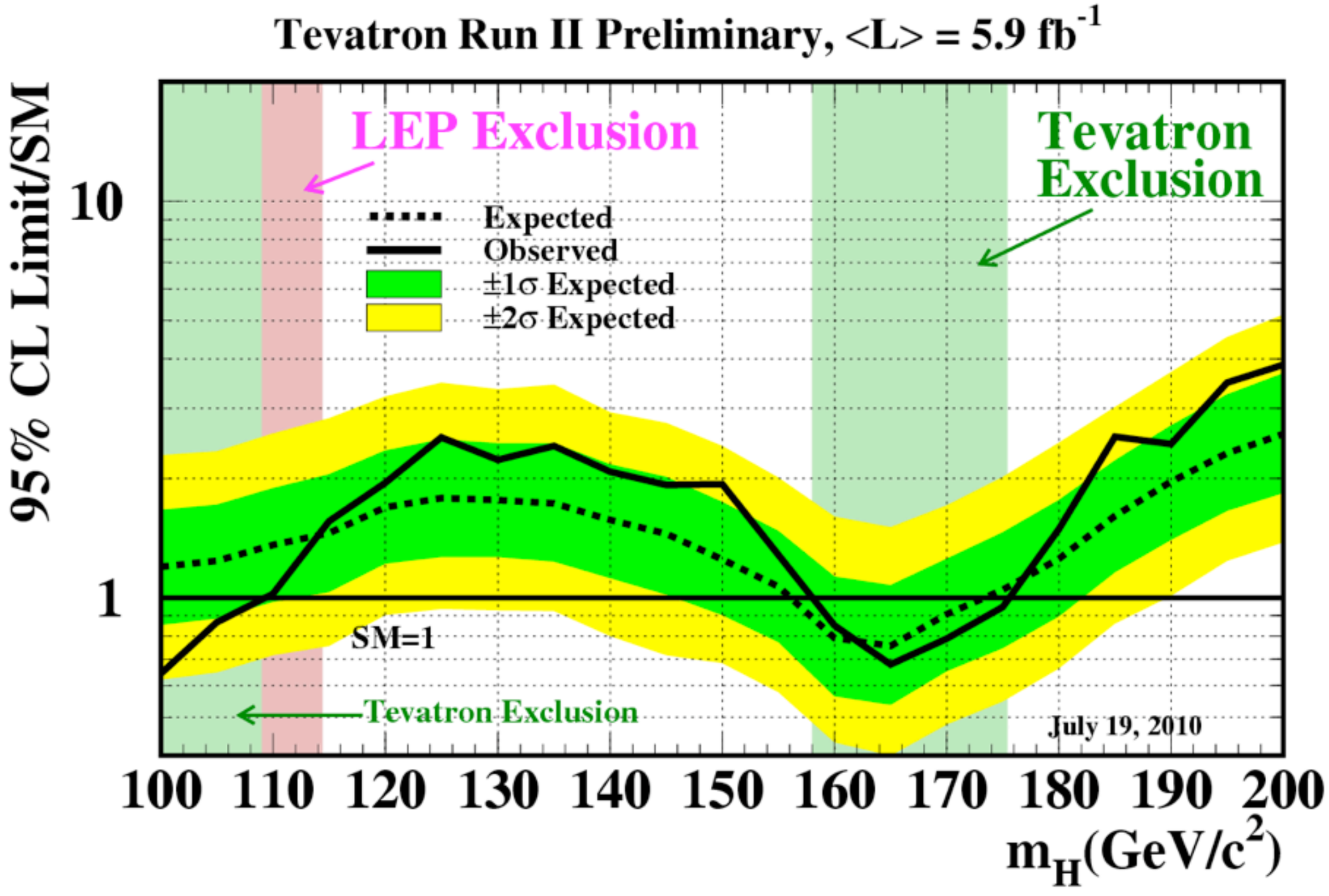
limits on anomalous TGC

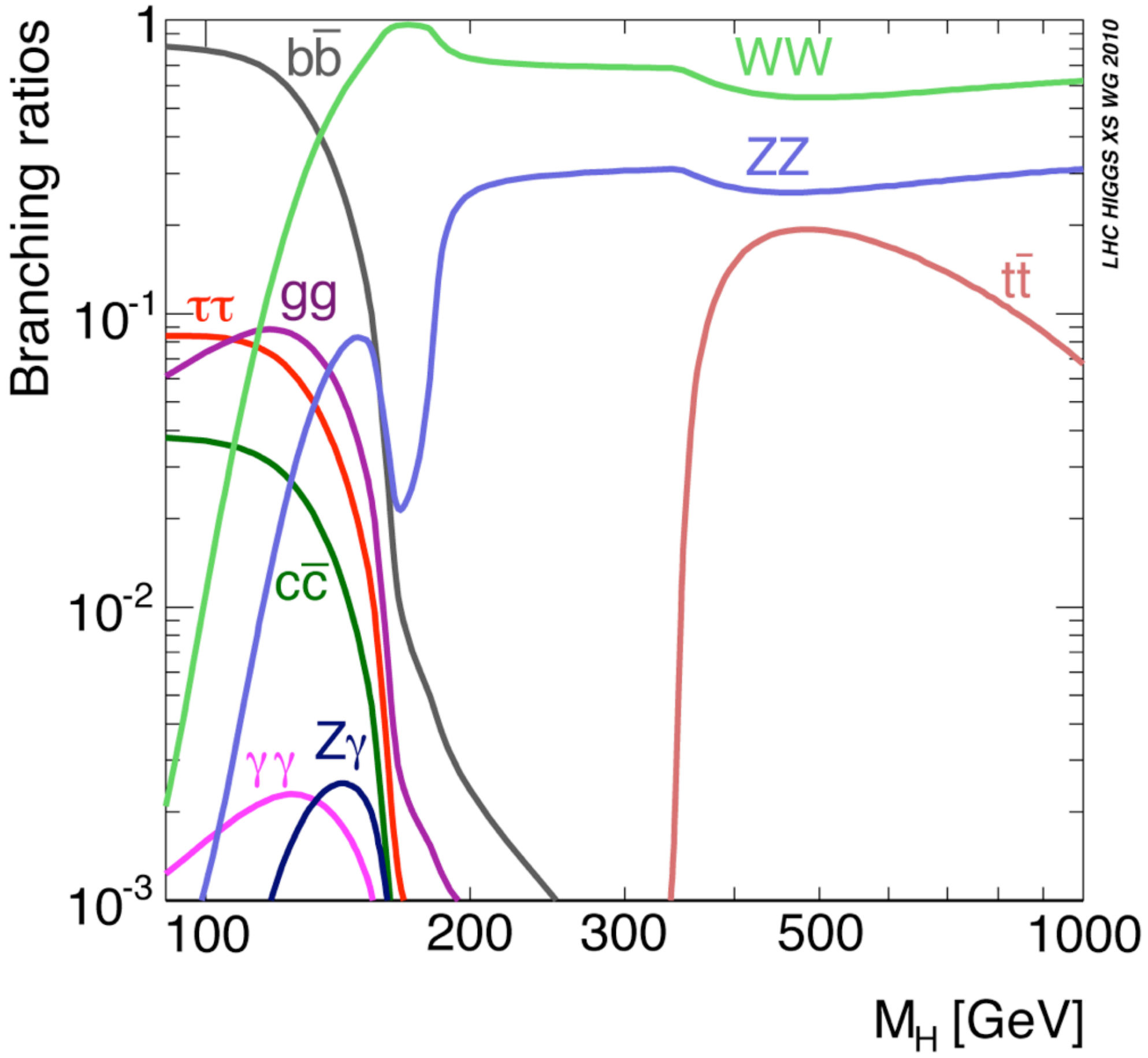
- New Physics involving *WWZ* / *WWγ* / *Zγγ* / *ZZγ* vertex can lead to enhancement in *WW* / *Wγ* / *Zγ* rate and different leading lepton *pt* / photon *Et* distribution from SM
- to extract anomalous Triple Gauge Couplings we fit simultaneously the *WW* / *Wγ* / *Zγ* cross section and leading lepton *pt* / photon *Et* distribution
  - all aTGCs agree with SM predictions and limits are set at 95% C.L.

Z+*b* systematics

- Jet Energy Scale (JES) as a function of *pt* and *eta*
  - 3-6% from absolute and relative scales, offset corrections and pile-up substraction
  - additional (conservative) 5% for *b*-jet JES
- *b*-tagging efficiency
- mis-tagging rate
- pile-up effect
- MET cut effect

Fermilab Today




Branching ratios
1
10^{-1}
10^{-2}
10^{-3}
$b\bar{b}$
WW
ZZ
$t\bar{t}$
$\tau\tau$
gg
$c\bar{c}$
$\gamma\gamma$
$Z\gamma$
100
200
300
500
1000
M_H [GeV]
LHC HIGGS XS WG 2010