Prospects for Higgs Boson Searches with CMS

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on behalf of the CMS Collaboration

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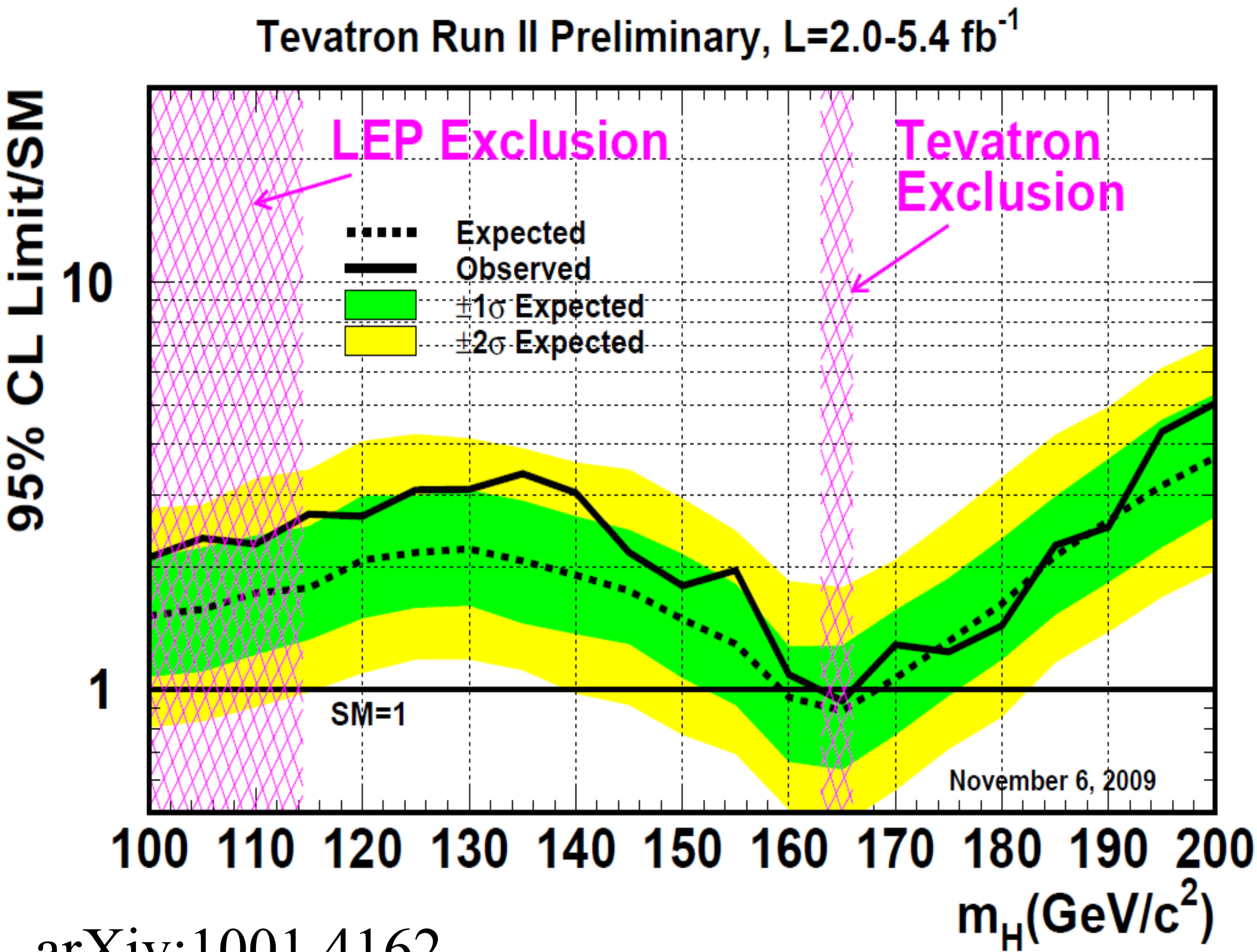
Higgs Landscape

LHC at 7 TeV: 100 pb^{-1} by Nov 2010 and 1 fb^{-1} by end of 2011



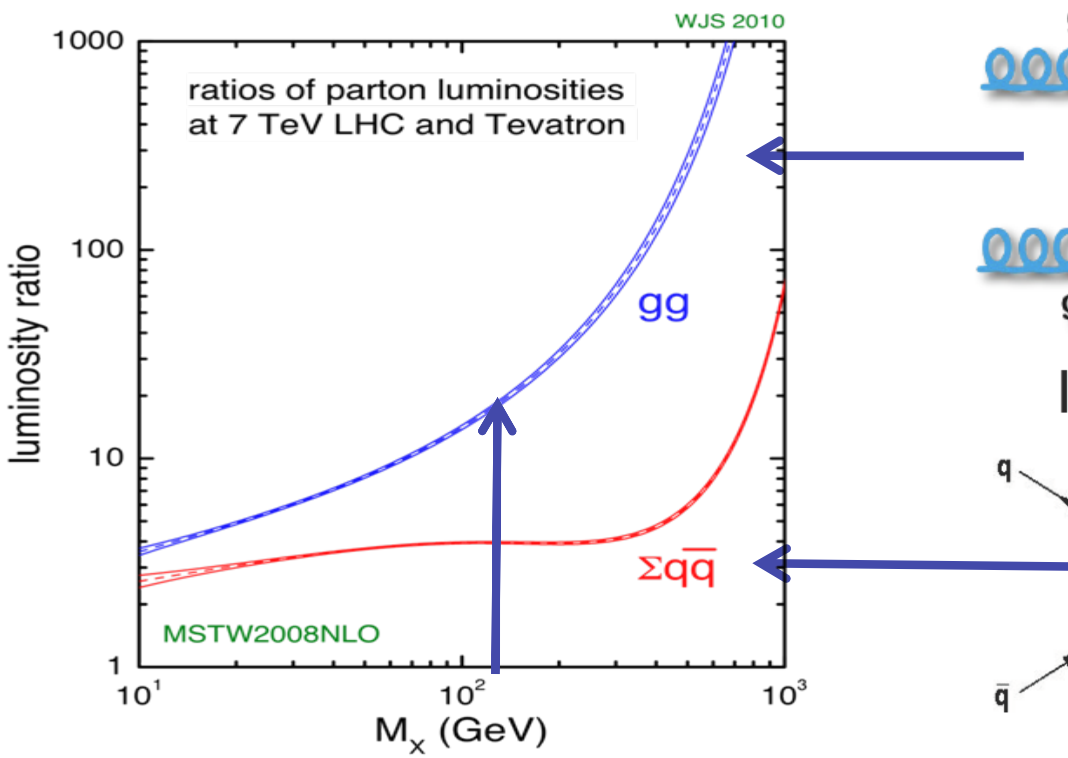
arXiv:1001.4162

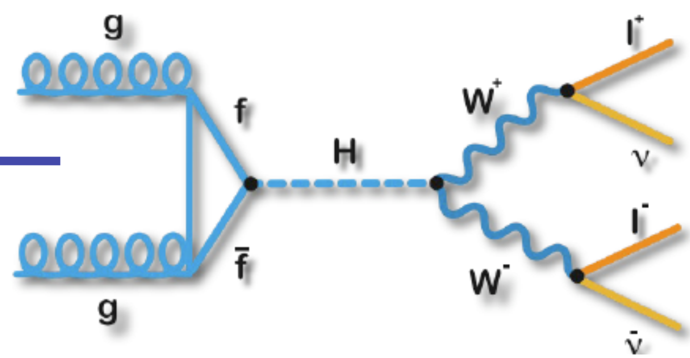
LHC Landscape

❖ For M_X > 140 GeV, the gg luminosity is 15 times higher than at Tevatron while dominant bkgds for $H \to WW/ZZ$ are produced mainly through qqbar

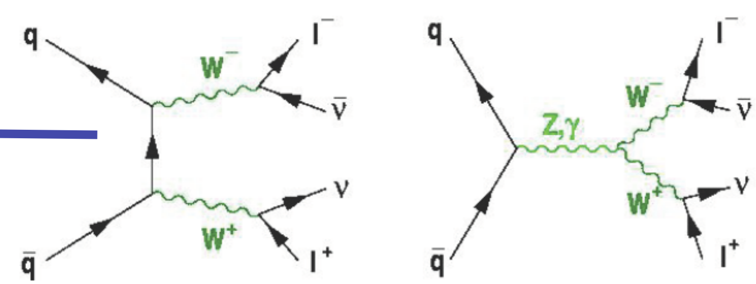
❖ For M_X < 140 GeV, the S/B for Higgs-strahlung ($qq \to VH$) at the LHC is not as favorable with main bkgds coming from ttbar, W/Z+bbar (gg-fusion processes).

Need to use the $\gamma\gamma$ mode where the QCD background is challenging.



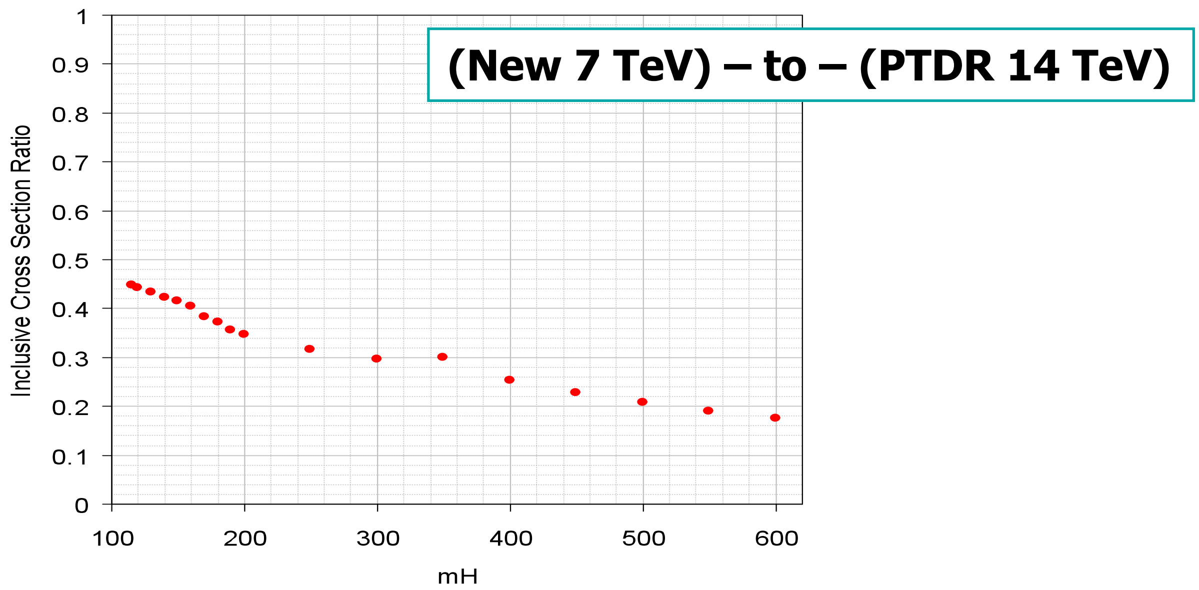


Irreducible backgrounds:



7 TeV Projections ($H \rightarrow ZZ$; WW; $\gamma\gamma$)

- Started with results from our Higgs studies for 14 TeV and rescaled both signal and bkgd. to 7 TeV. "14 TeV" search methods were optimized for discovery: room for improvement.
- Systematic uncertainties also rescaled conservatively, and possible correlations taken into account.
- Use σ(NNLO) for $gg \rightarrow H$ (30% gain over NLO) , NLO for VBF & VH
- Not correcting for higher acceptance at smaller $\sqrt{s}$, up to 20% effect.
- Uniform statistical analysis: use re-scaled event counts and re-evaluated systematic errors; derive exclusions with modified frequentist (CL_s) and significance with profile likelihood.

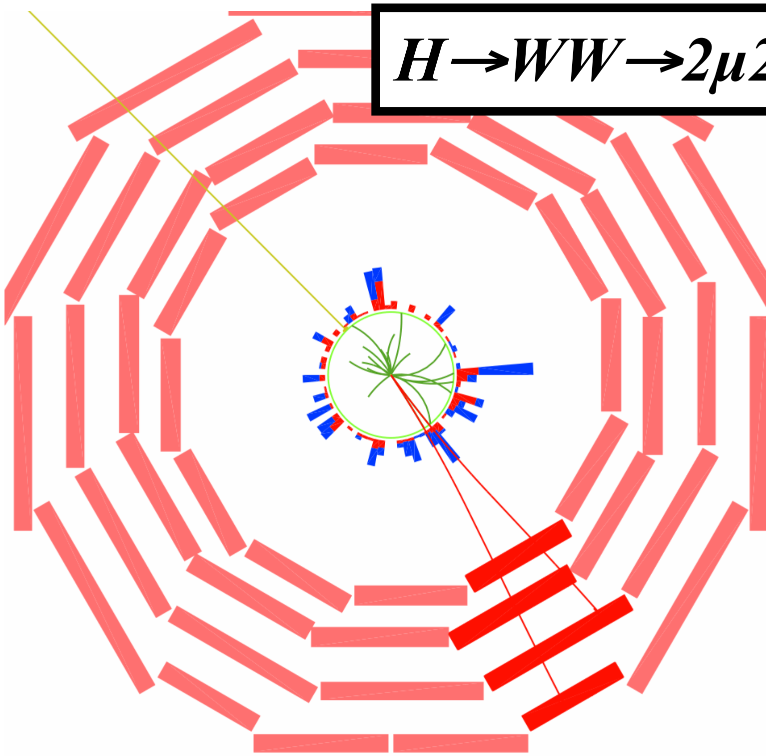


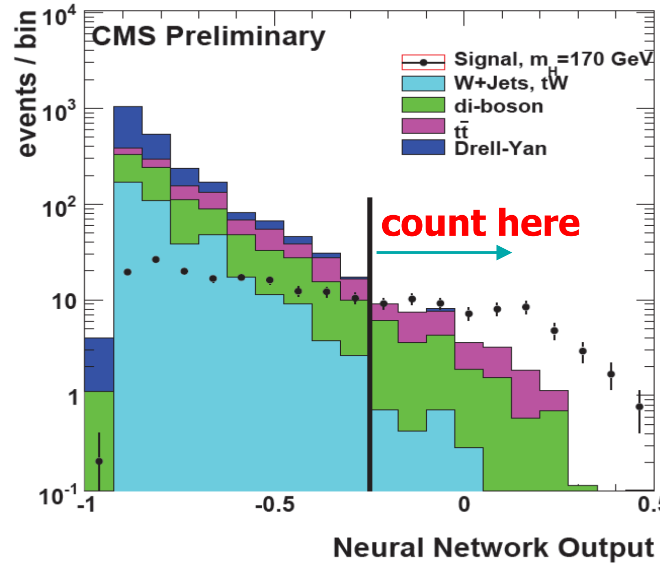
Standard Model $H \to WW \to 2\ell 2\nu$

- Treat μμ, ee, eμ separately
- Require two isolated leptons + MET, jet veto
- Cut on the MVA output [Counting experiment]
- Main backgrounds to be assessed using data-driven techniques: WW, tt, W+jets

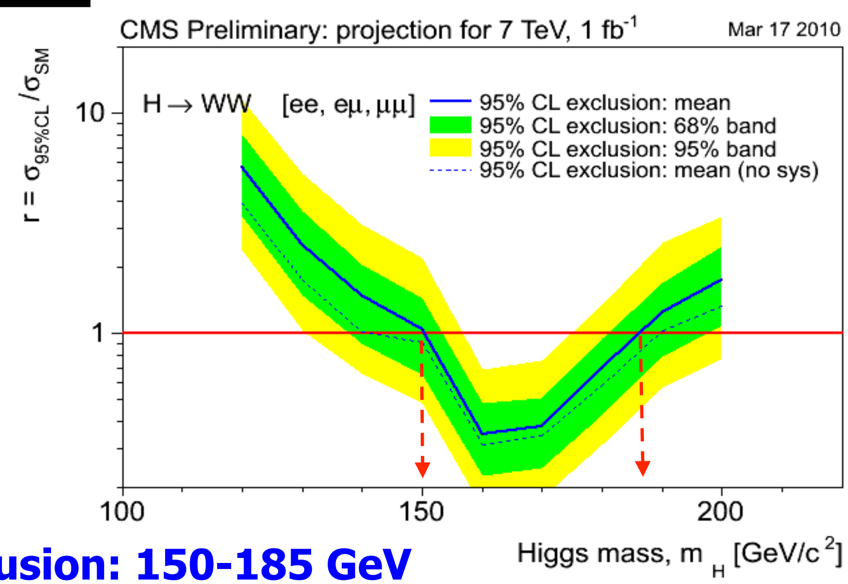
Pros: Large signal production rate

Cons: No mass peak; systematics very important





$H \to WW \to 2\mu 2\nu$ (MC)



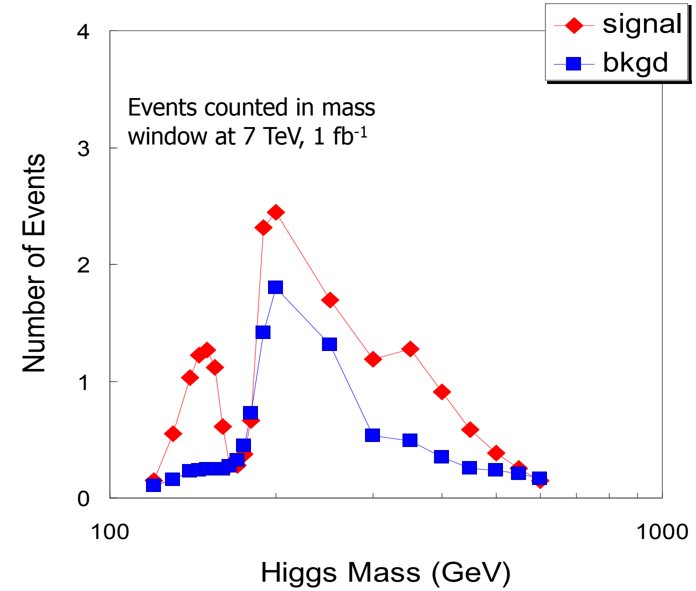
Exclusion: 150-185 GeV
Discovery: 160-170 GeV

Standard Model $H \to ZZ \to 4\ell$

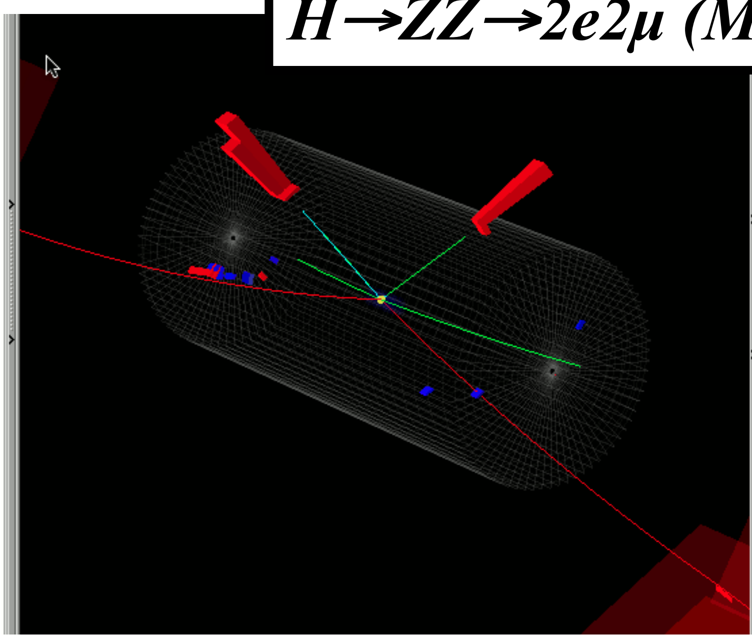
- ❖ **Require four isolated leptons**
- ❖ **Search for a 4ℓ-resonance mass peak [counting in a sliding mass window]**
- ❖ **Use Z-events for a data-driven estimation of the dominant SM background: ZZ**

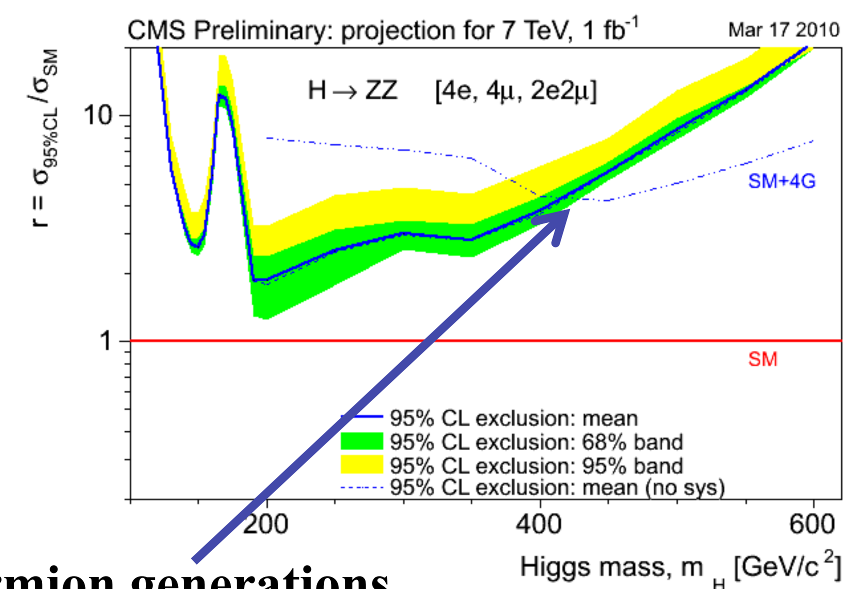
Pros: Mass peak for the signal

Cons: Low signal rate; need to push lepton ID for highest possible efficiency



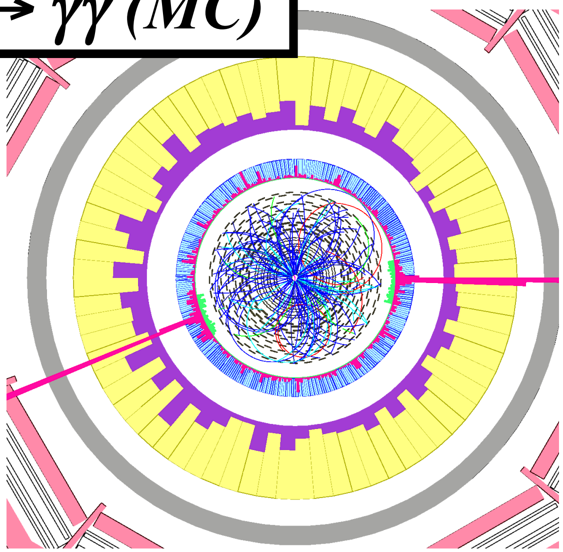
H→ZZ→2e2μ (MC)

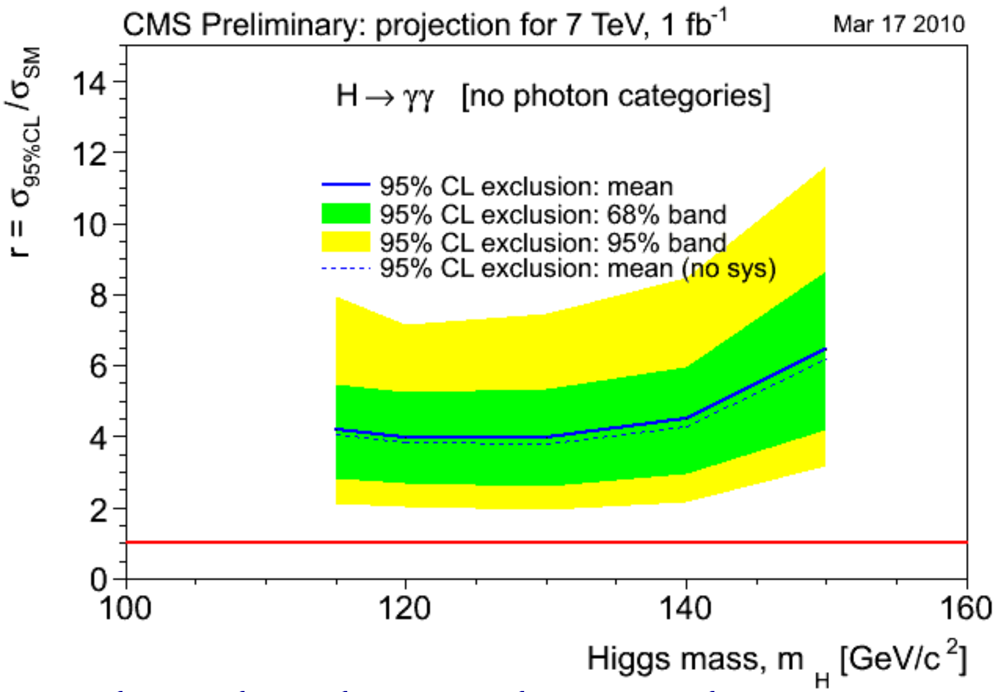




4 fermion generations

$H \rightarrow \gamma\gamma$ Search

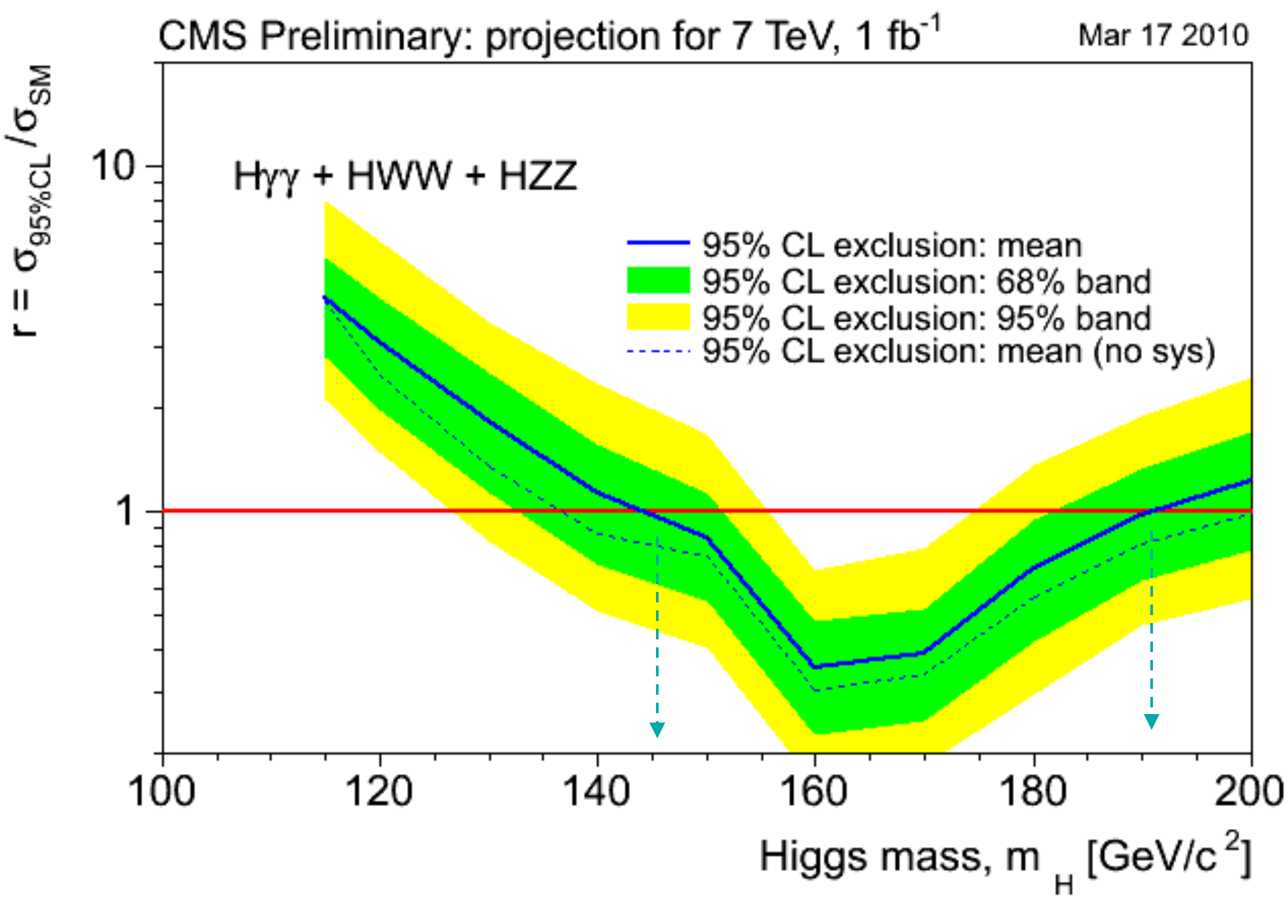




- Method: Categorize events based on the photon shower shape.
- Look for a peak with cut-based or MVA techniques.
- Pros: Clean photon ID, projected 0.7% mass resolution.
- Cons: High background rate; state-of-art ECAL calibration needed.

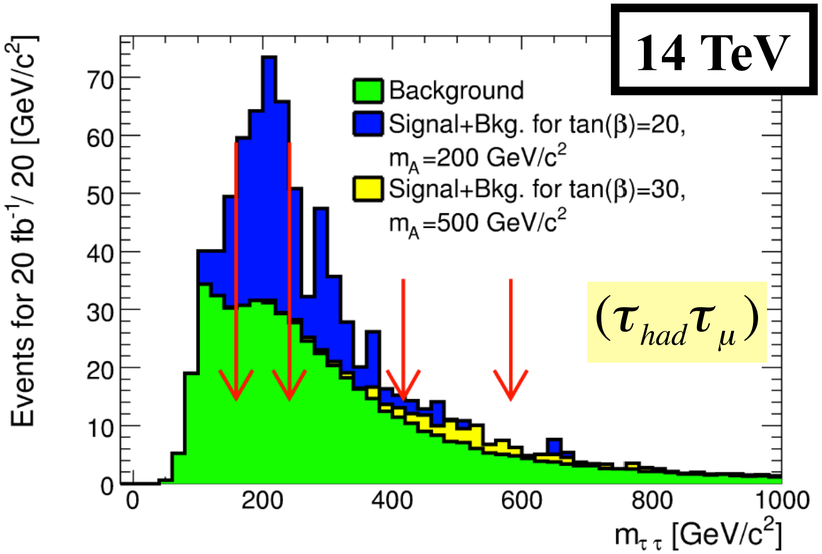
However, for 110 GeV fermiophobic Higgs the production rate 4 times higher than for SM Higgs. The projected exclusion reach at 7 TeV is comparable to the current limits from LEP and Tevatron.

SM Higgs Combination: γγ+WW+ZZ

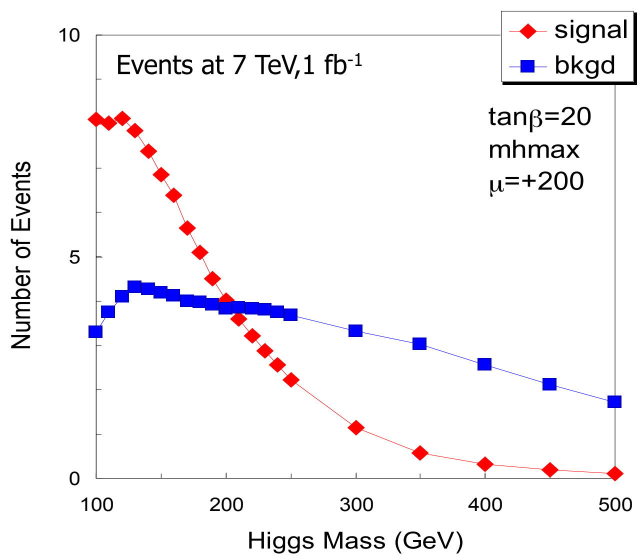


SM Higgs expected 95% CL exclusion range: 145-190 GeV.
Projections are "indicative" and conservative.

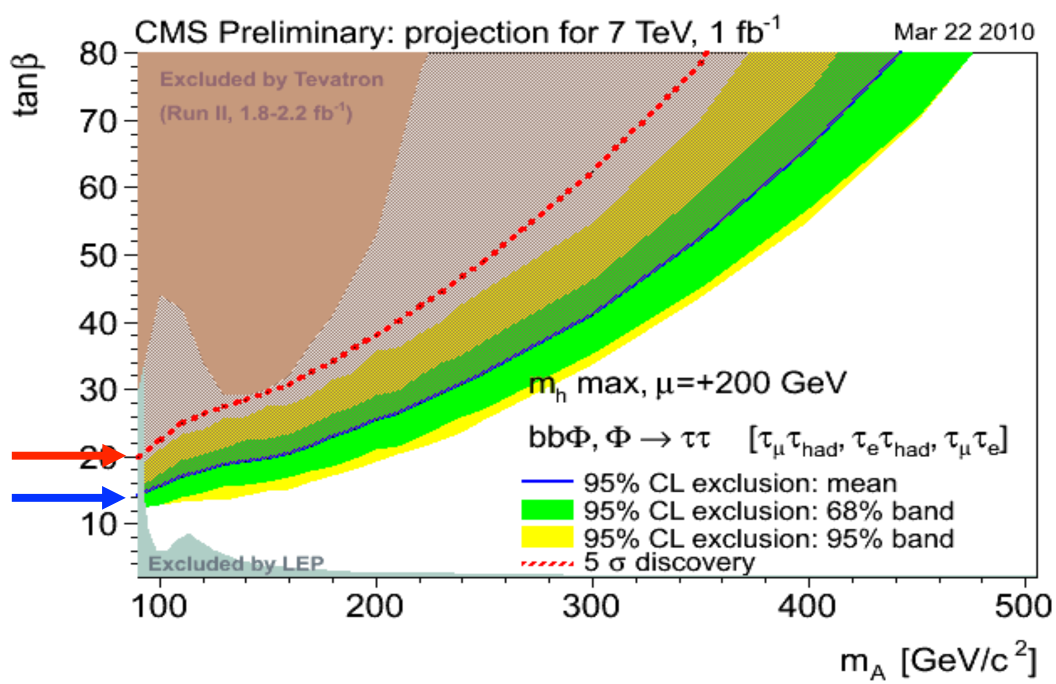
MSSM Higgs pp→bbΦ; Φ→ $\tau^+\tau^-$



- – – Isolated pairs of $(\tau_{had}\tau_\mu),(\tau_{had}\tau_e),(\tau_\mu\tau_e)$
- – – With MET, 1 tagged bjet, veto extra jets
- – – Build $\tau\tau$-mass using collinear approx
- – – Count events in sliding $\tau\tau$-mass window
- – – Dominant backgrounds: $t\bar{t}$, Z+$b\bar{b}$ & Z+$c\bar{c}$
  -- assessed from data



discover
exclude



7 TeV Outlook

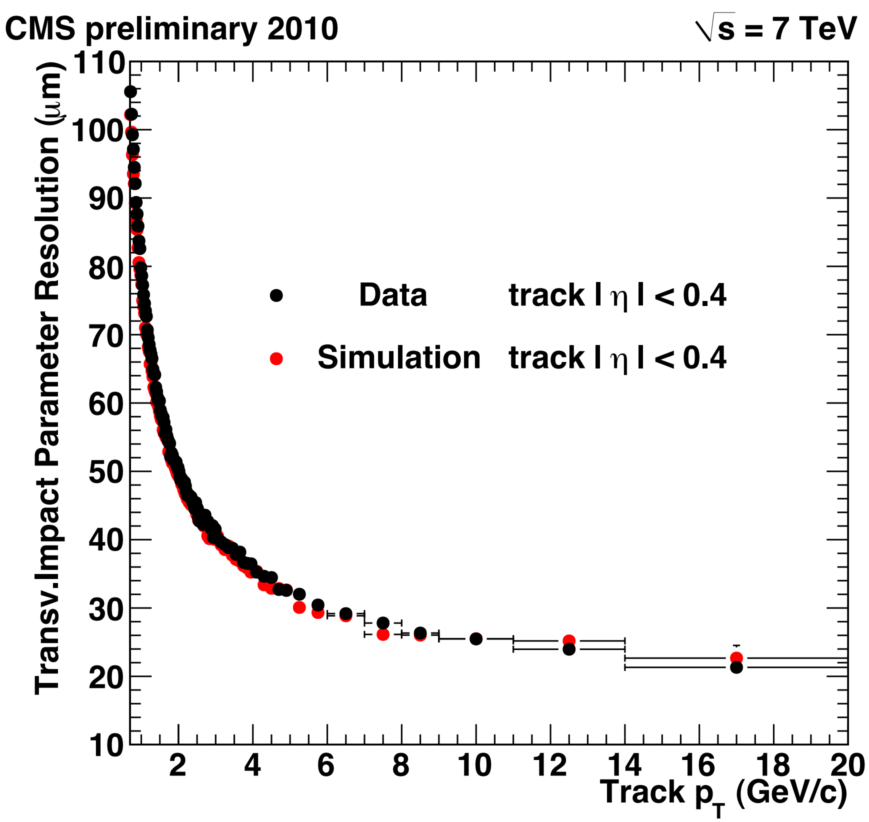
But this is not the end game !

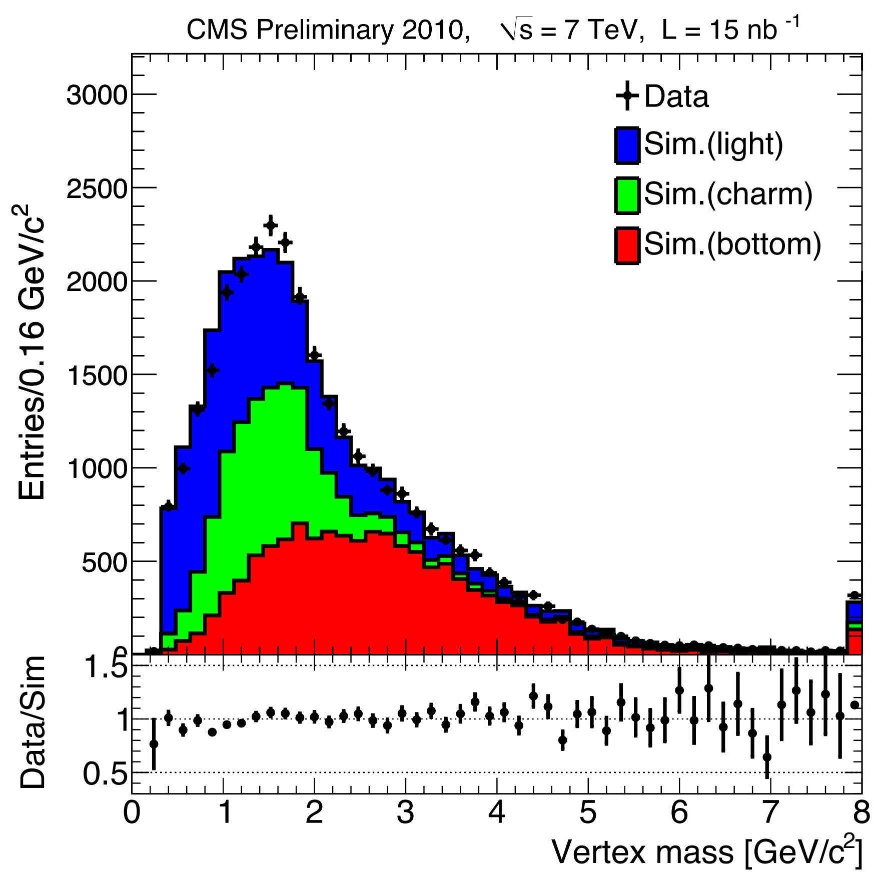
- **The current 7 TeV projections are quite conservative.**
- **Several analysis are being re-optimized and extra channels are being added to the mix.**
- **In the meantime: we continue commissioning the detector and validating our analysis methods.**

Showing just a few highlights.

Tracking Performance

- Transverse impact parameter resolution is better than 30μm.
  Crucial for Higgs mass reconstruction.
- B-tagging performance is as expected.
  Important for associated-bbar background rejection.

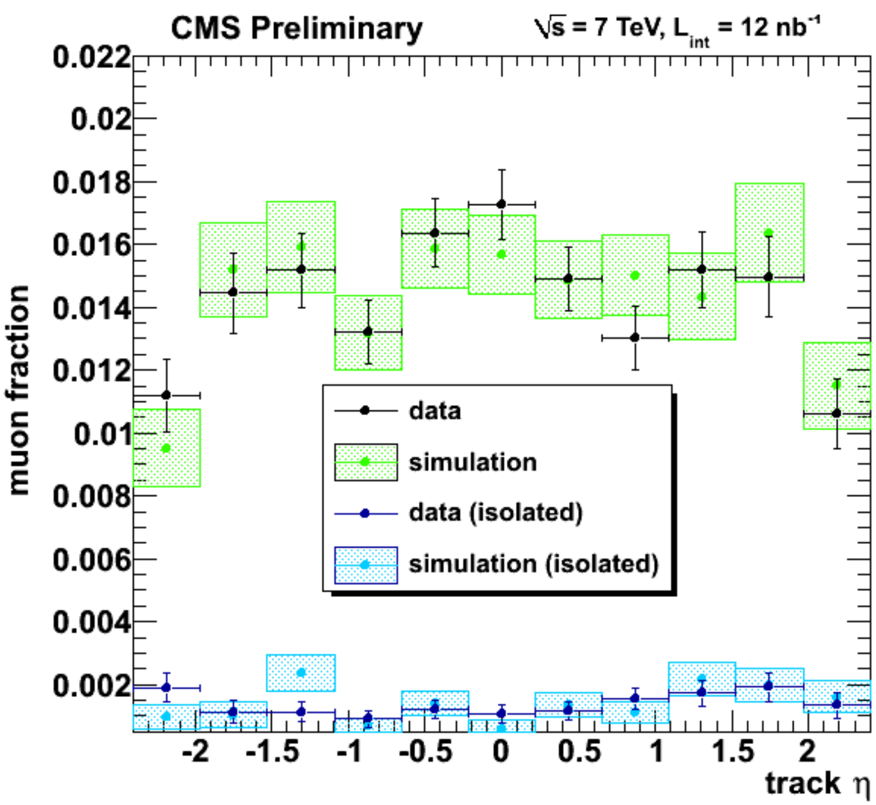


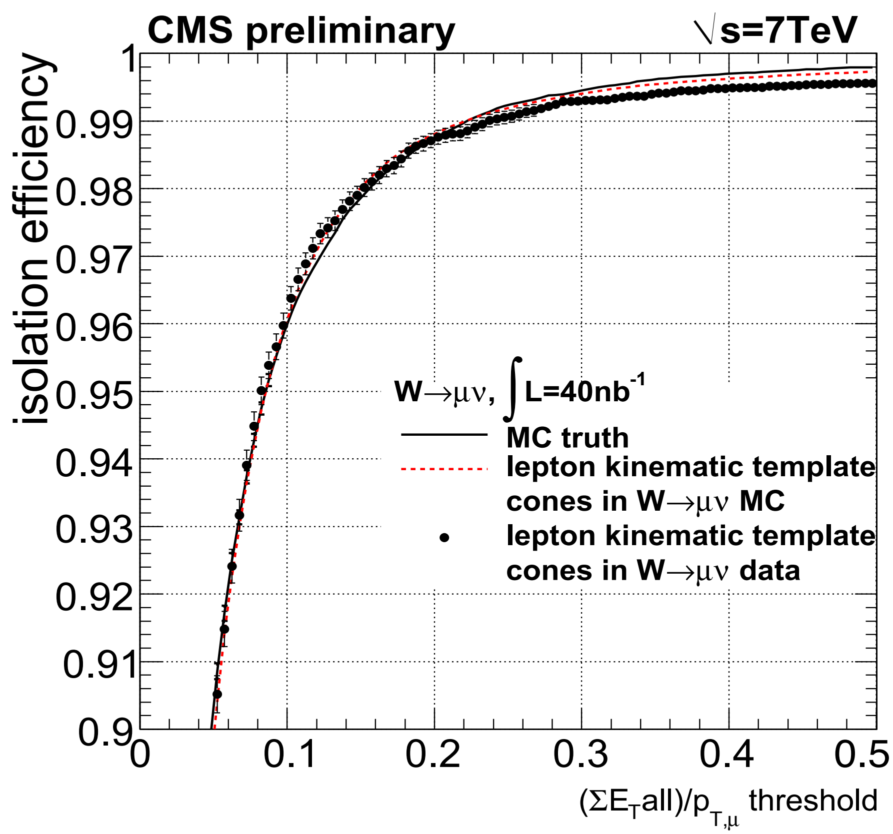


Muon ID Commissioning

Muon ID is crucial for WW and ZZ channels

- **Fraction of tracks identified as muons measured in the inclusive QCD sample. After isolation it is reduced by 90%.**
- **Isolation efficiency for $W \to \mu\nu$ agrees with expectation to better than 1%.**





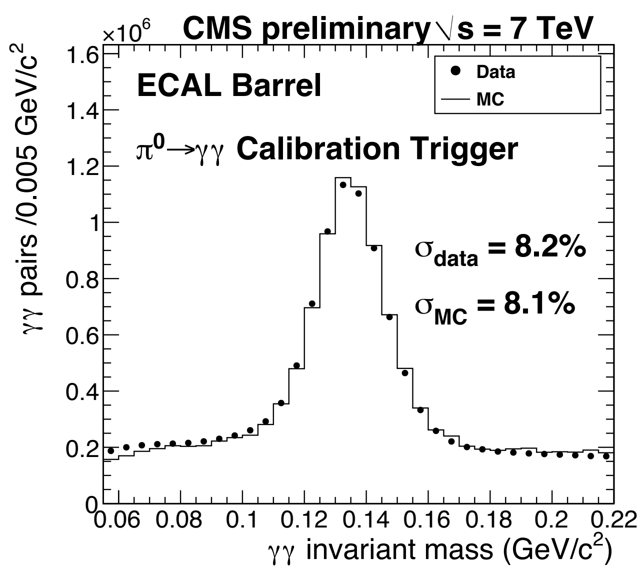
CMS ECAL Calibration

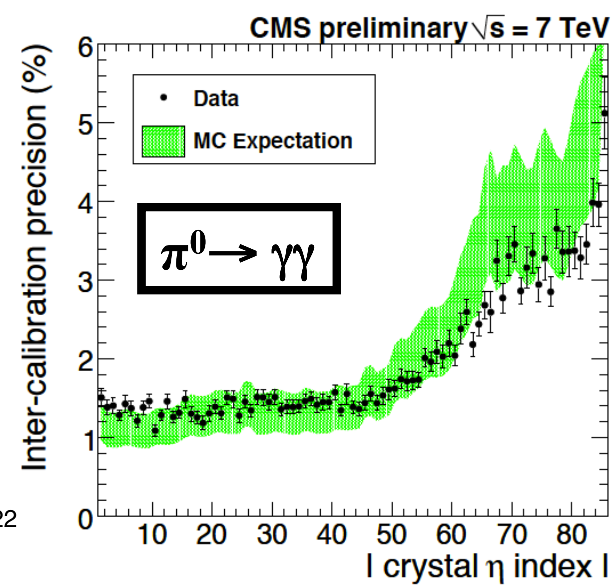
(see P. Gras' talk)

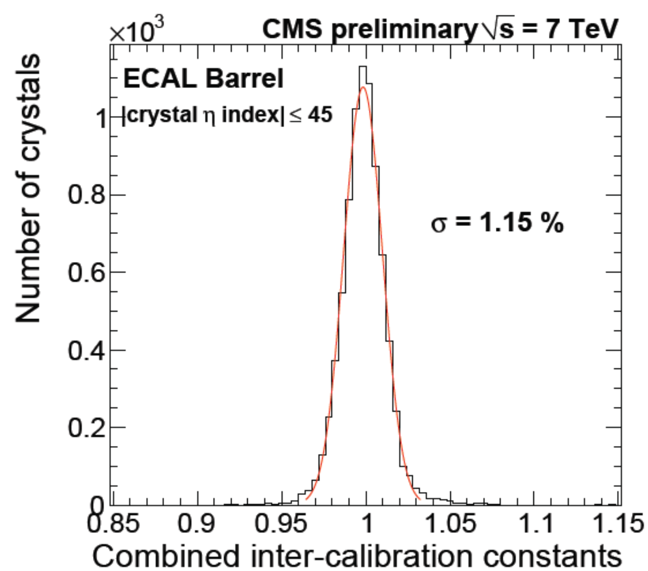
- CMS ECAL is made of 76K PWO crystals. Design-goal energy resolution is 0.5%: crucial for the di-photon channel search.
- Need to achieve in situ calibration precision of <0.5%
- With 100 nb^{-1}, reached in situ 1.1% channel-to-channel precision in the central barrel using neutral pions and φ-invariance method.

Limited by statistics not systematics (200 nb^{-1} update: reached <1%).

Dedicated calibration streams commissioned.



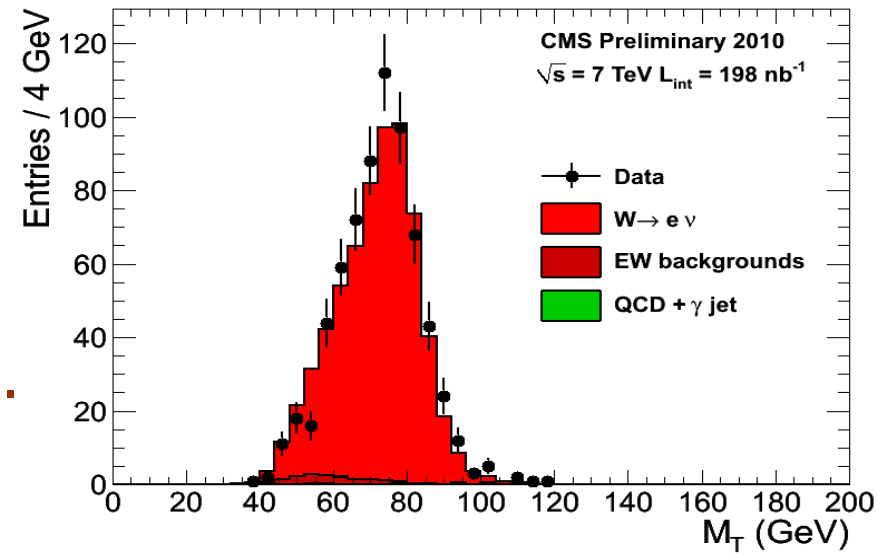


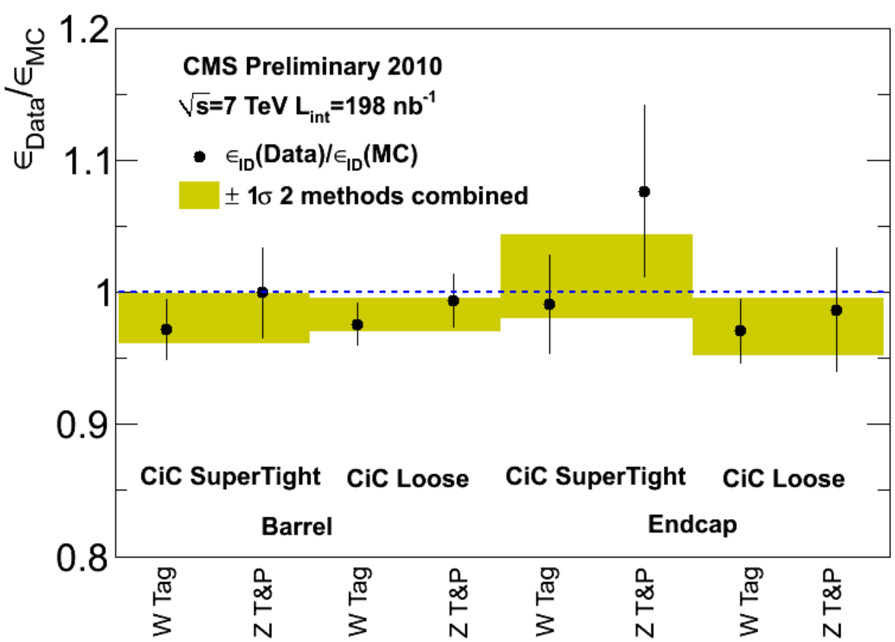


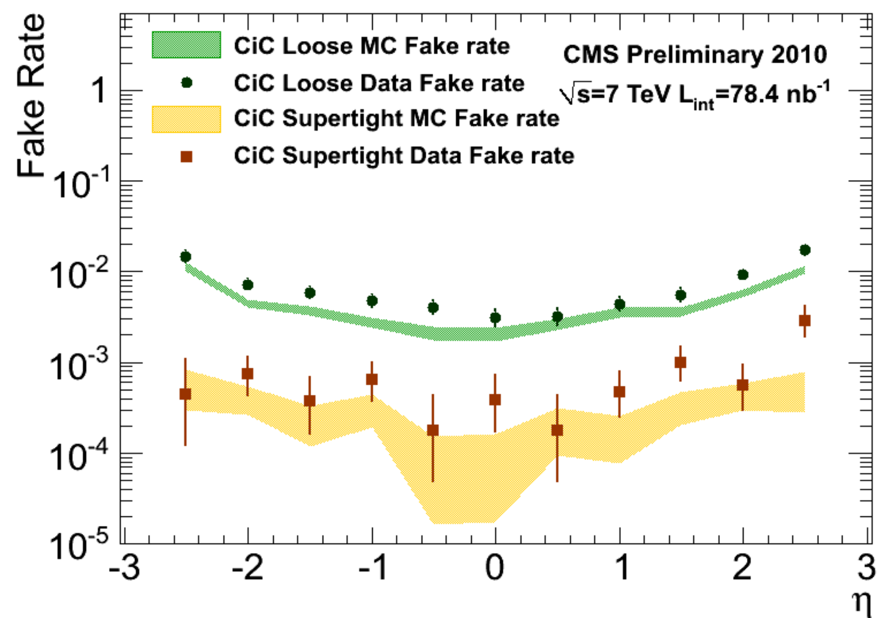
Electron ID and Fake Rate

(see R. Salerno's talk)

- **Both the inclusive and *W→ eν* electron spectra agree well with expectations.**
- **Electron efficiency measured in situ. Good agreement between different methods and with simulation. Fake rates as low as <0.1%.**







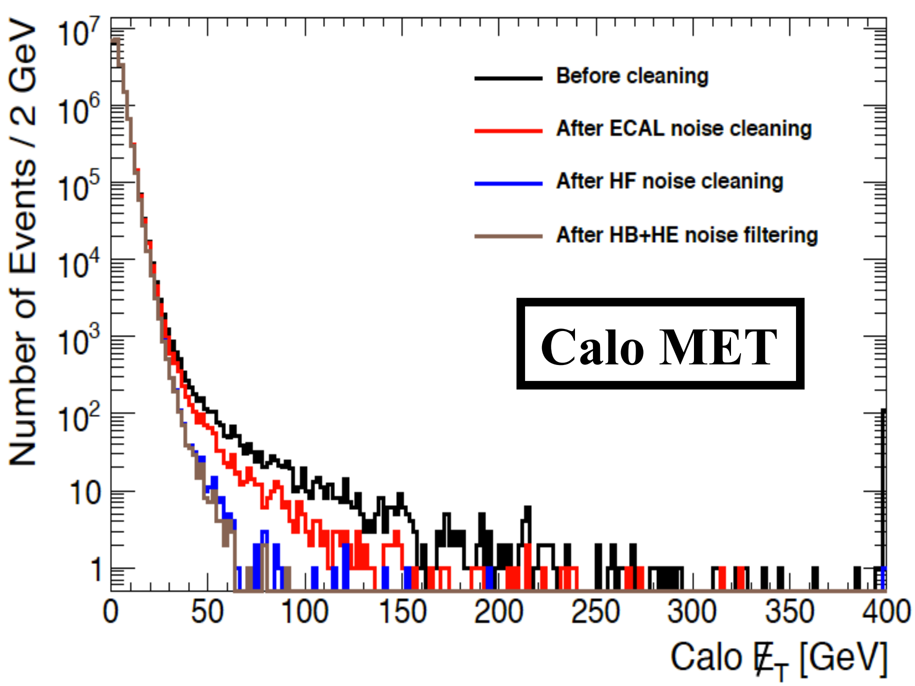
MET Performance

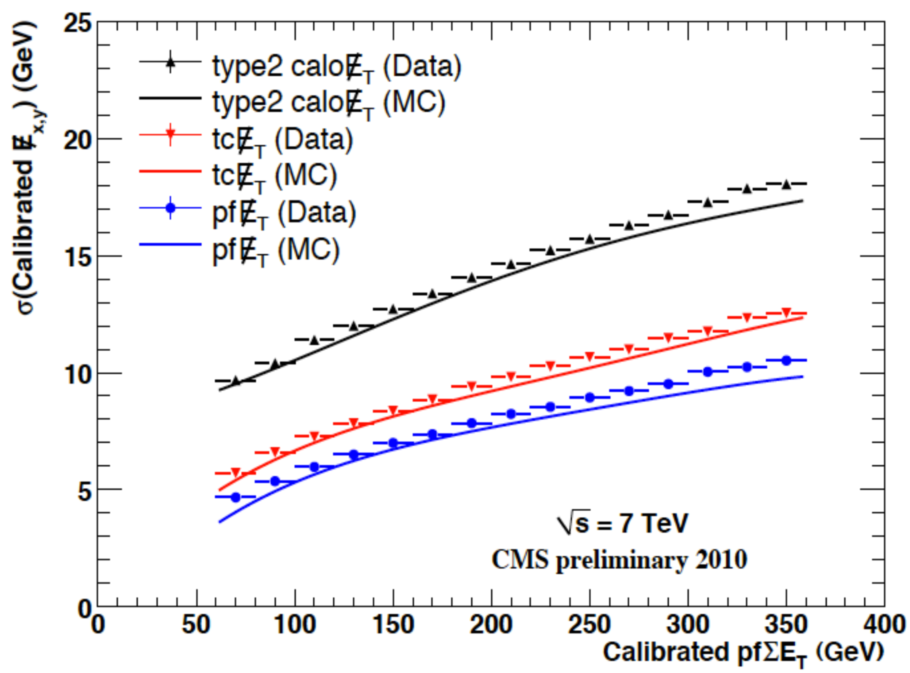
(see J. Weng's talk).

MET reconstruction and calibration important for H→WW

- ❑ **Noise in calorimeters is well understood and under control.**
- ❑ **Excellent transverse MET resolution obtained.**

Three methods: Calo (ECAL+HCAL); Track-corrected Calo; Particle flow (identifies individual stable particles in an event).





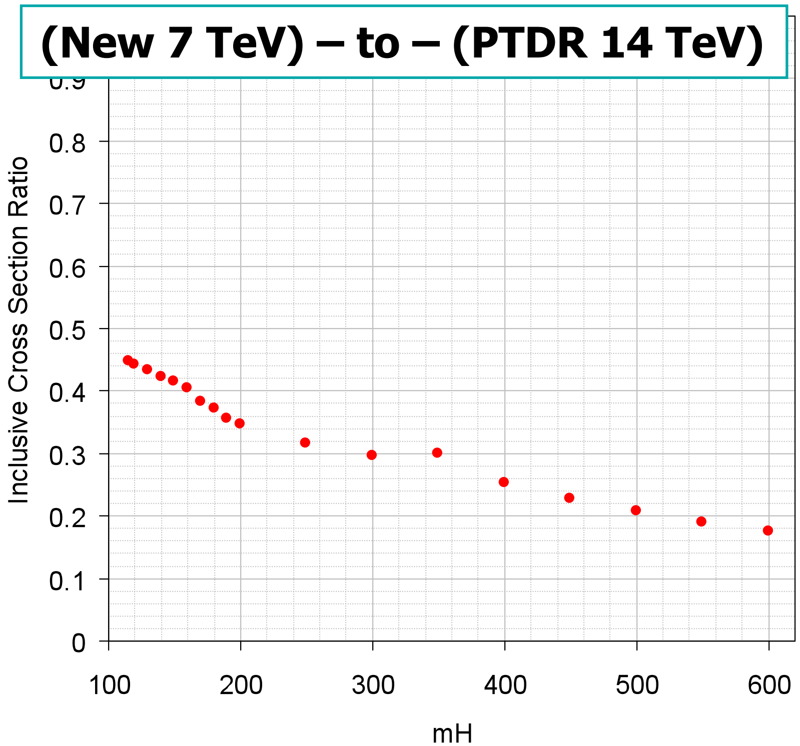
Conclusions

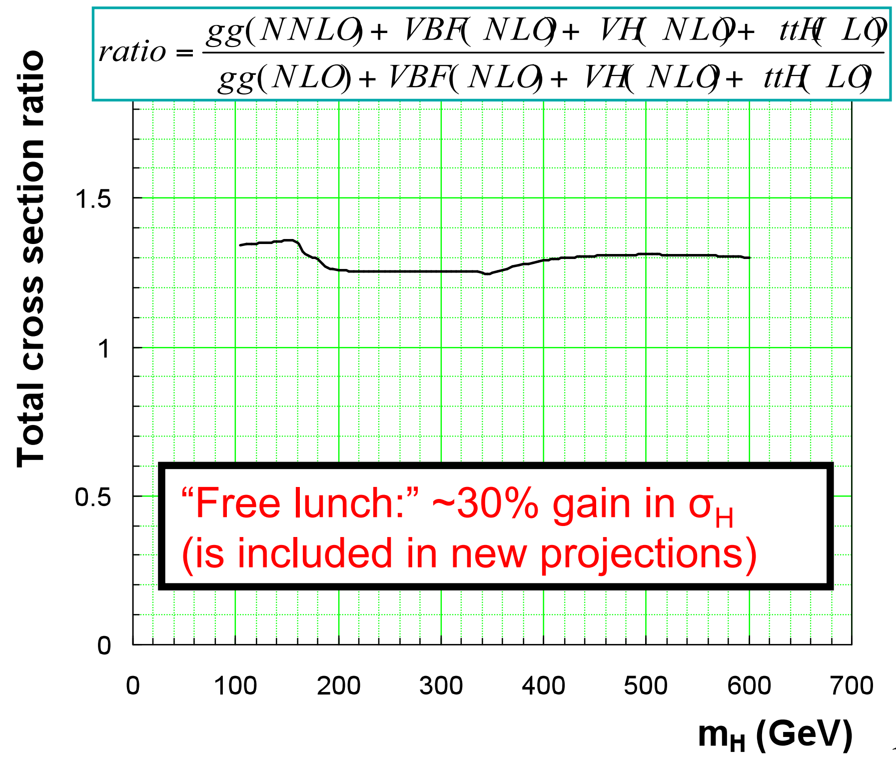
- **CMS is making a good progress to a well-calibrated and understood detector, to be ready for Higgs searches**
- **With 1 fb^{-1} at 7 TeV, CMS will begin to explore a sizable range of Higgs mass**
  - **SM Higgs exclusion range: [145-190] GeV**
  - **Low mass SM Higgs region will require more data**
  - **MSSM Neutral Higgs discovery range: down to $\tan\beta \sim 20$ for small m_A**

BACKUP

7 TeV Projections: March 2010

- **Use already approved results:** started with public 14 TeV results and rescaled both signal and bkgd. to 7 TeV. Methods were optimized for discovery: **room for improvement.**
- Uniform statistical methods used and correlations in syst. uncertainties taken into account.
- **Rather conservative approach was adopted.**
  H→ZZ, H→WW and H→γγ only were considered.

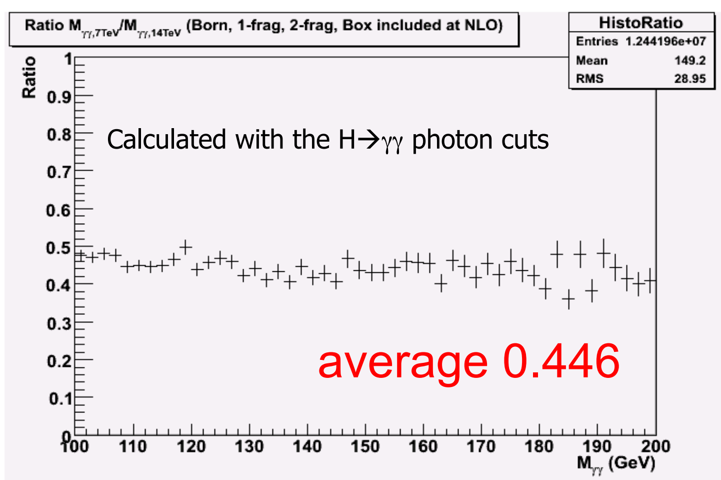




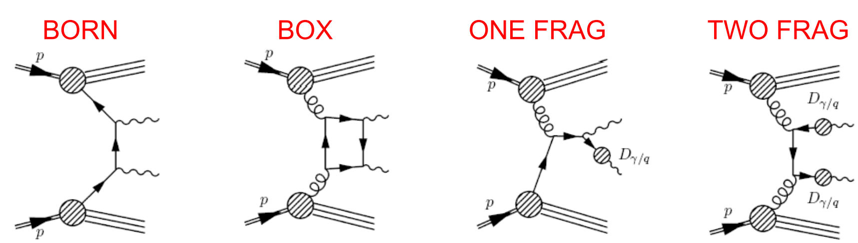
Background Cross Sections used

General background sources

process	$\sqrt{s}$ = 14 TeV	$\sqrt{s}$ = 10 TeV	$\sqrt{s}$ = 7 TeV	comment
$W \to \ell\nu$	3*20283.7	3*14253.7	3*9679.9	MCFM NLO
$DY(20-\infty) \to \ell\ell$	3*3259.7	3*2323.6	3*1606.6	MCFM NLO
WW	112.5	71.4	42.9	MCFM NLO
WZ	51.0	31.4	18.3	MCFM NLO
ZZ	15.6	9.9	5.9	MCFM NLO
$t\bar{t}$	918	415	165	MCFM NLO
Wt	56.1	26.0	10.5	MCFM NLO
tq-t channel	244.6	130.5	62.8	MCFM NLO
tq-s channel	11.9	7.6	4.6	MSTW 2008 NNLO
$W(\to \ell\nu) + \gamma$	54.7*1.8	35.4*1.8	23.2*1.8	NLO k-Factor from Bauer
$Z(\to \ell\ell) + \gamma$	17.5*1.8	11.3*1.8	7.3*1.8	NLO k-Factor from Bauer



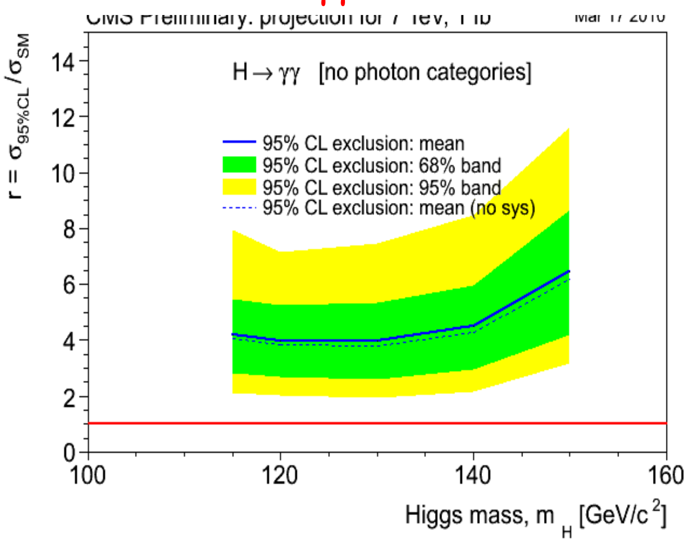
Background Estimate for H→γγ mode



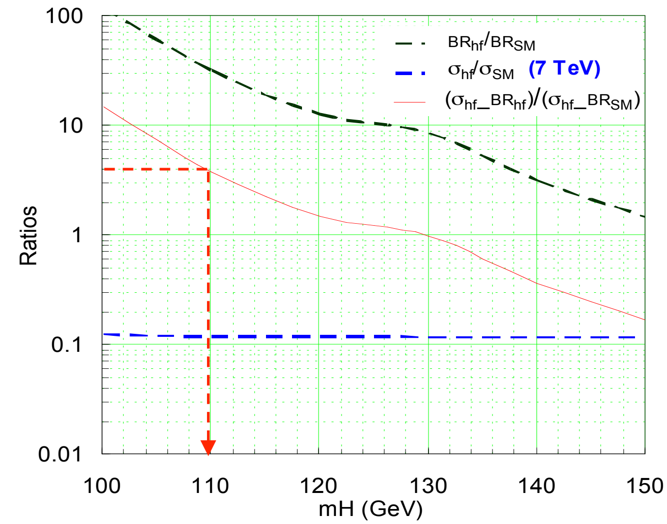
Diphox, Gamma2MC:
born+1frag +2frag + box [all at NLO]

Fermiophobic Higgs: Back-of-Envelope

CMS SM H→γγ exclusion r~4



Fermiophobic/SM ratios



Fermiophobic/SM (see plot on the right)

- gg→H disappears ⇒ loss of a factor of 10 in H cross section [blue line]
- Gain a large factor in BR(H→γγ) [black line]
- CS x BR larger than that of SM up to 130 GeV

If do <u>nothing</u> special (charateristic kinematics) for fermiophobic Higgs,

- r~4 for SM Higgs (see left plot) implies that
- Possibly exclude fermiophobic Higgs with m~110 GeV (see right plot), which is better than Tevatron, comparable to LEP limit