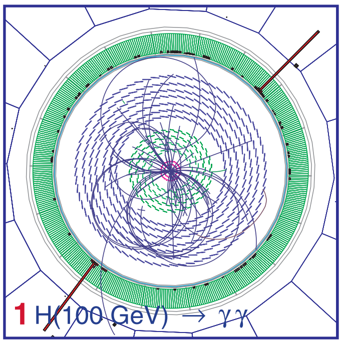
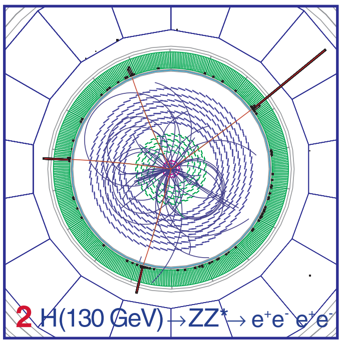
CMS
CERN LHC

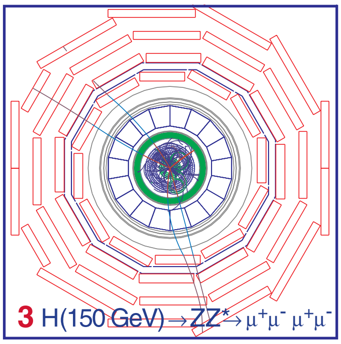
Higgs physics

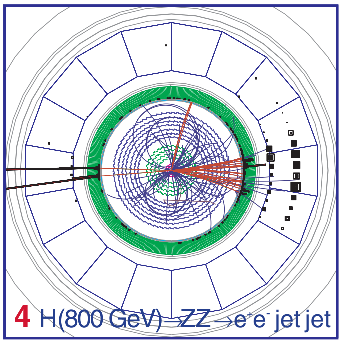
The Standard Model (SM) of Particle Physics has unified the Electromagnetic interaction (carrier: γ) and the weak interaction (carriers: W^+, W^-, Z^0). Yet these four bosons are very different: the γ is massless whereas the $W^\pm$ and Z^0 are quite massive (80 – 90 GeV). In the framework of the SM particles acquire mass through their interaction with the Higgs field. This implies the existence of a new particle: the Higgs boson H^0. The theory does not predict the mass of the H^0, but it does predict its production rate and decay modes for each possible mass. CMS has been optimized to discover the Higgs in the full expected mass range $0.08\ \mathrm{TeV} \lesssim M_H \lesssim 1\ \mathrm{TeV}$

The decay signature of the Higgs depends on its mass:

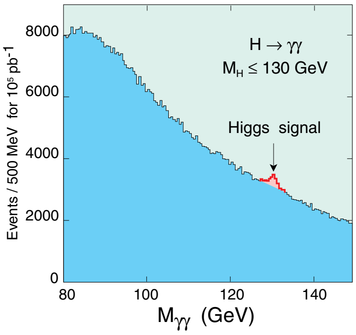

1 $H(100\ \mathrm{GeV}) \rightarrow \gamma\gamma$


2 $H(130\ \mathrm{GeV}) \rightarrow ZZ^* \rightarrow e^+e^-e^+e^-$

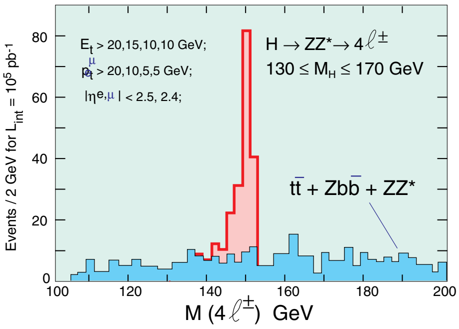

3 $H(150\ \mathrm{GeV}) \rightarrow ZZ^* \rightarrow \mu^+\mu^-\mu^+\mu^-$


4 $H(800\ \mathrm{GeV}) \rightarrow ZZ \rightarrow e^+e^-$ jet jet

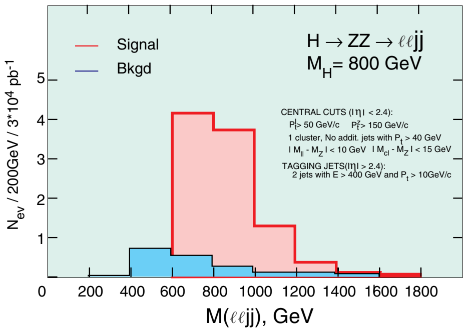
1. $H^0 \rightarrow \gamma\gamma$ is the most promising channel if M_H is in the range 80 – 140 GeV. The high performance $PbWO_4$ crystal electromagnetic calorimeter in CMS has been optimized for this search. The $\gamma\gamma$ mass resolution at $M_{\gamma\gamma} \sim 100$ GeV is better than 1%, resulting in a S/B of ≈1/20. With larger data samples ($\geq 10^5\ \mathrm{pb}^{-1}$) the "associated" modes ($pp \rightarrow WH^0$ and $pp \rightarrow t\bar{t}H^0$) should give higher S/B ratios for the same H^0 decay channel

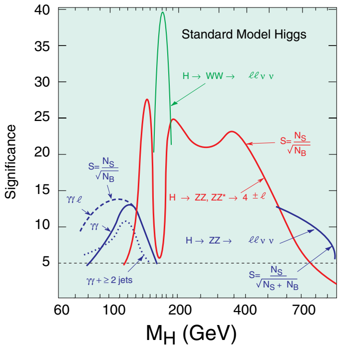


2-3. In the M_H range 130 - 700 GeV the most promising channel is $H^0 \rightarrow ZZ^* \rightarrow 2\ell^+2\ell^-$ or $H^0 \rightarrow ZZ \rightarrow 2\ell^+2\ell^-$. The detection relies on the excellent performance from the muon chambers, the tracker and the electromagnetic calorimeter.
For $M_H \leq 170$ GeV a mass resolution of ~1 GeV should be achieved with the 4 Tesla magnetic field and the high resolution of the crystal calorimeter



4. For the highest M_H, in the range 0.5 - 1 TeV, the promising channels for $10^5\ \mathrm{pb}^{-1}$ are $H^0 \rightarrow ZZ \rightarrow \ell^+\ell^-\nu\nu$, $H^0 \rightarrow ZZ \rightarrow \ell^+\ell^-$ jj and $H^0 \rightarrow W^+W^- \rightarrow \ell^\pm\nu jj$.
Detection relies on leptons, jets and missing transverse energy (E_t^{miss}), for which the hadronic calorimeter(HCAL) performance is very important





Observability of the SM Higgs in CMS with $10^5\ \mathrm{pb}^{-1}$. The CMS detector can probe the entire mass range up to $M_H \sim 1$ TeV with a signal significance well above 5σ

Some extensions of the Standard Model involve a richer set of Higgs bosons: in the Minimal Supersymmetric SM there are five new bosons (h^0, H^0, A^0, H^+, H^-). Their discovery involves the use of more complicated signatures, such as the identification of a jet as coming from b quarks