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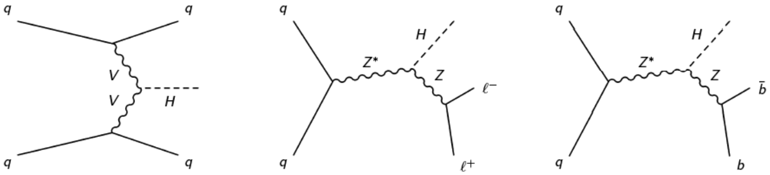
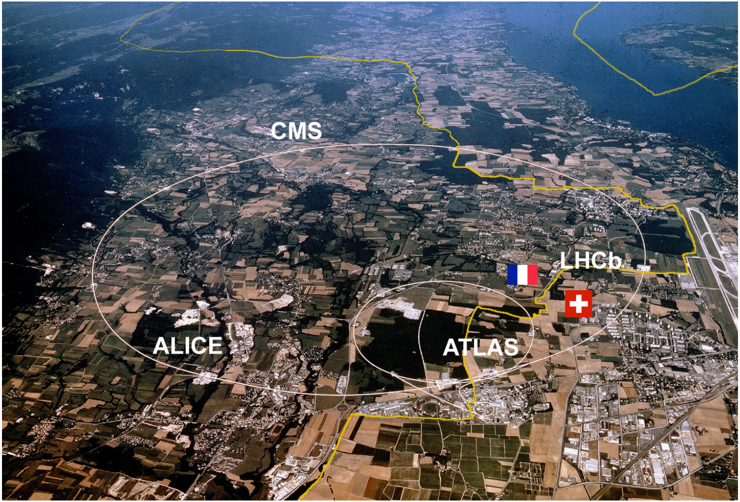
Searches for invisible decay modes of the Higgs boson with the CMS detector

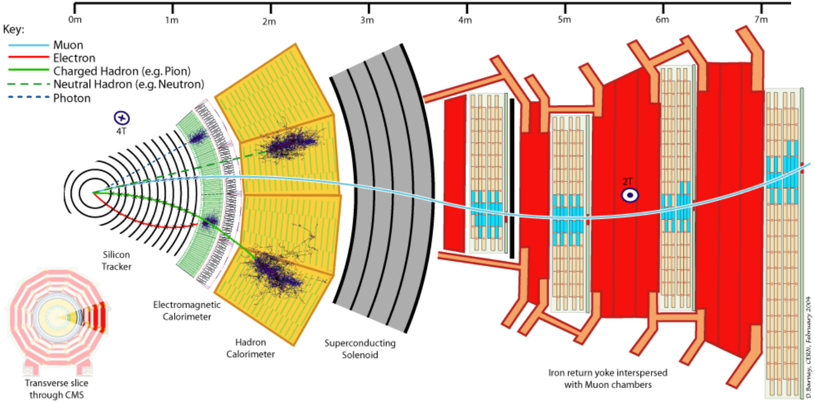
P. Dunne - Imperial College London



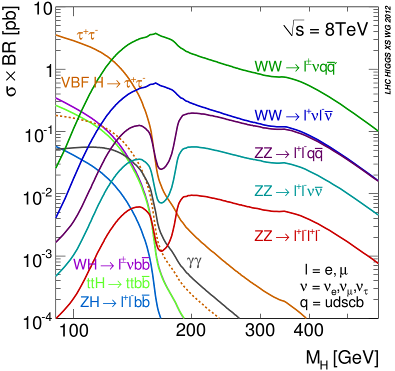
CMS and the LHC

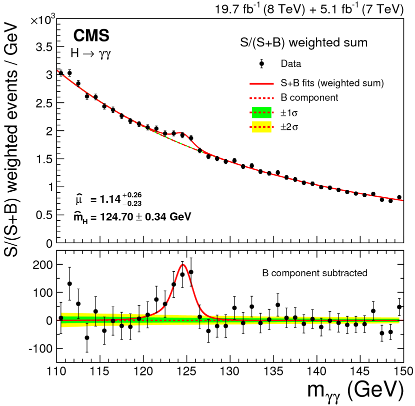


CMS


0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
D.Barney, CERN, February 2004

The Higgs Boson





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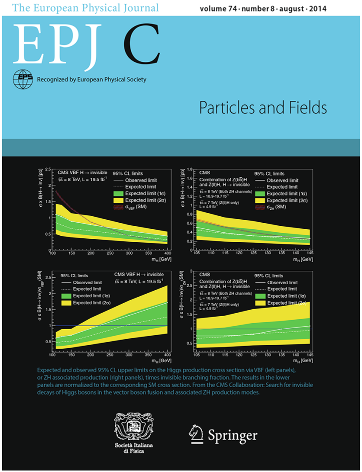
Why Higgs to Invisible?



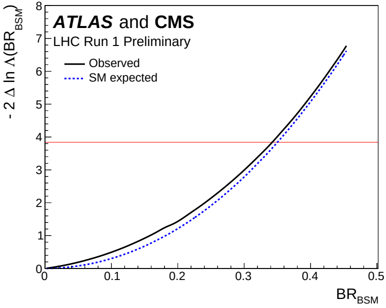
Why Higgs to Invisible?

Experimental motivation

- At the end of run 1 significant BSM Higgs properties are not excluded:
  - Limit from ATLAS+CMS on $BR_{BSM} \sim 35\%$

Theoretical motivation

- Many BSM theories predict Higgs boson decays to invisible final states:
  - e.g. SUSY, extra dimensions, fourth-generation neutrinos
- These final state particles are often dark matter candidates



CMS-PAS-HIG-14-009

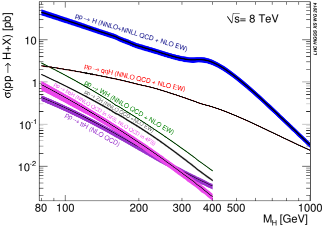
Direct and Indirect Searches

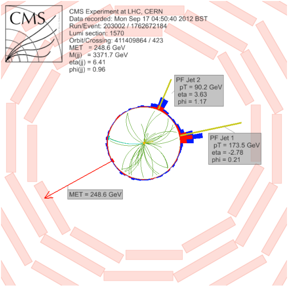
Indirect searches

- BSM Higgs decays affect the total Higgs width:
- Visible decays can, therefore, constrain the invisible branching fraction

Direct searches

- Direct searches must be performed in channels where the Higgs recoils against a visible system
- We look in the VBF, W/ZH and ggH channels

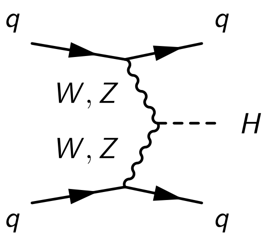


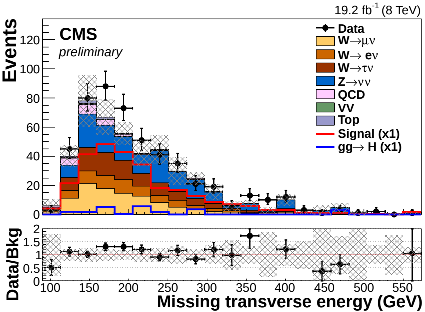


VBF outline

Signal Topology and Selection

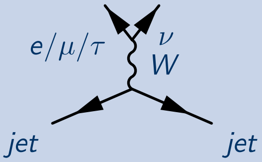
- Two high p_T VBF jets with large rapidity separation
  - no activity between jets
- Large missing transverse momentum (MET)
  - Cut hard to remove backgrounds





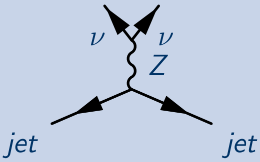
Backgrounds

W+jets



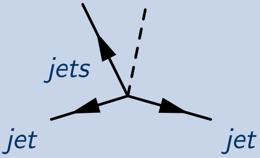
- Veto leptons

Z+jets



- Irreducible

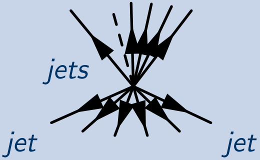
QCD - multijet



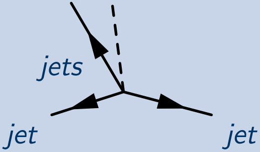
- See next slide

Reducing QCD Backgrounds

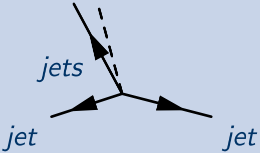
MET significance



VS



min$\Delta\phi$(j,MET)



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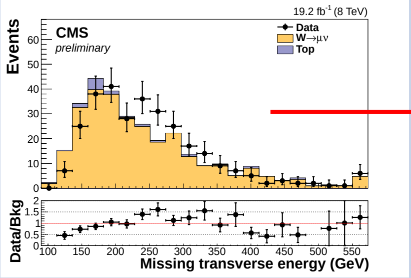
Background estimation

Data Driven Background Estimation

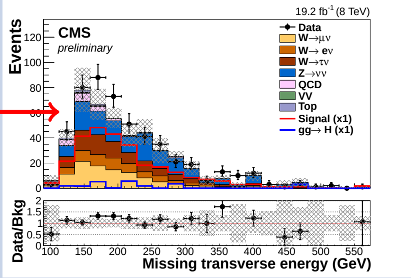
- Choose control region enriched in background
- Use MC signal-control ratio to go to signal region:

$$N^{signal}_{Bkg} = (N^{control}_{obs} - N^{control}_{otherbkgs}) \cdot \frac{N^{signal}_{MC}}{N^{control}_{MC}}.$$

Control Region: Single Muon



Signal Region: Lepton veto



VBF results

- Number of events within one σ of the SM expectation:

Total background	$439.7 \pm 41.0(\mathit{stat.}) \pm 55.8(\mathit{syst.})$
VBF H(inv.) assuming B(H→inv)=100%	$273.4 \pm 31.2(\mathit{syst.})$
ggF H(inv.) assuming B(H→inv)=100%	$22.6 \pm 15.6(\mathit{syst.})$
Observed data	508

- Set limits on σx$B(H \rightarrow inv)$
  - Perform a single bin counting experiment using CL_S method
  - Observed(expected) 95% C.L. limit on $B(H \rightarrow inv)$ is 0.57 (0.40)

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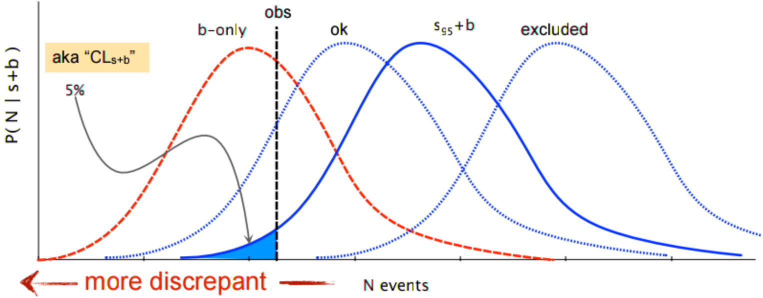
What does this mean?

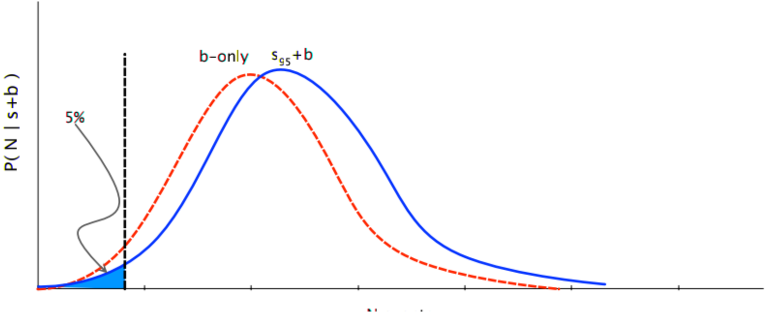
CLs

- Want to exclude signal models which are less than 5% likely to give data
- Exclude everything where shaded area (CL_{S+B}) is $< 5\%$



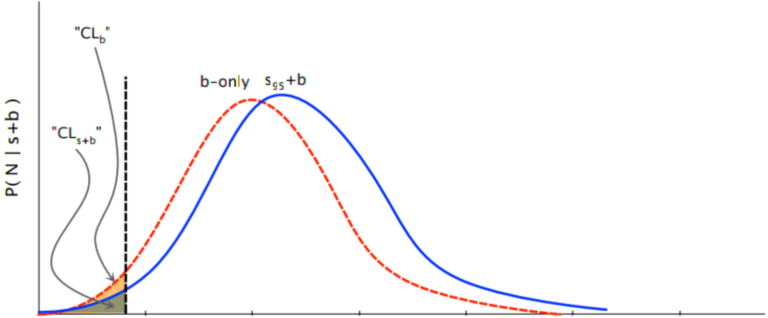
CLs

- What if background only model is also unlikely?
- What if you have no sensitivity even to the background?
- Risk of overexcluding



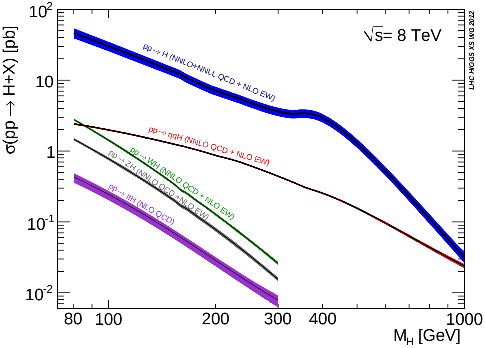
CLs

- $CL_S = \frac{CL_{S+B}}{CL_B}$
- Gets bigger if CL_B is small too
- Avoids overexcluding



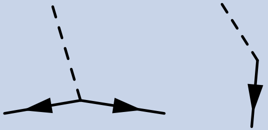
Combinations - Assumptions

- Want to improve limit using constraints from other channels
- Need to be careful that the quantity they set limits on is the same
- We assume that the Higgs we're looking at is produced as in the SM



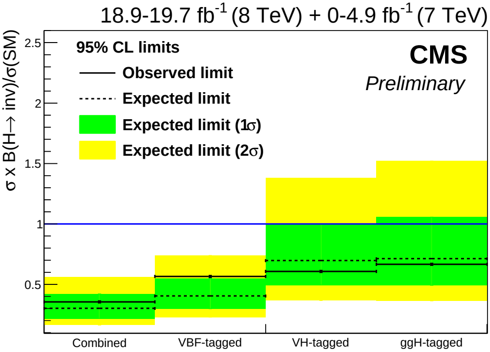
Combinations - Correlations

- Objects in one analysis might be very different from objects in others
  - Energy scales and other uncertainties may or may not be correlated
- Measurement in one channel can constrain uncertainties in other channels



Combination Results

- The individual limits on $\sigma x B(H \rightarrow inv)$ from all channels are combined
  - SM production cross-sections are used to interpret this as a limit on B(H→inv)



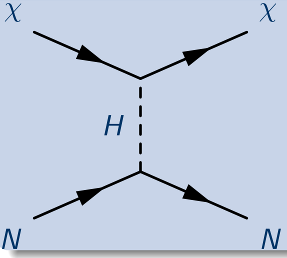
Observed (expected) limits on B(H→inv) at 95% C.L. for m_H=125 GeV

Channel	Limit/%
VBF-tagged	57(40)
VH-tagged	60(69)
ggH-tagged	67(71)
Combined	36(30)

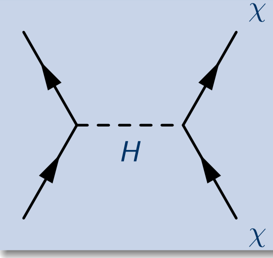
Signatures of Dark Matter (DM)

- If DM couples to the Higgs the following diagrams are possible

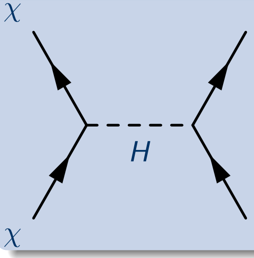
Direct Detection - e.g. LUX



Invisible Higgs - LHC



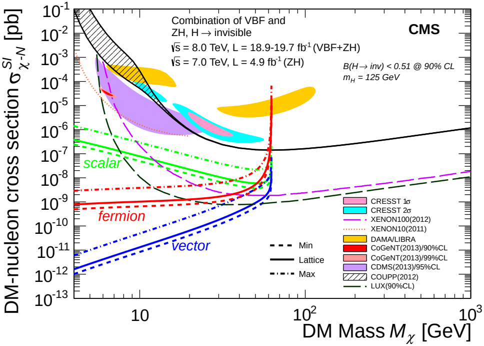
Annihilation - e.g. WMAP



- Limits on $\mathcal{B}(\mathrm{H}\rightarrow\mathrm{inv})$ therefore constrain Higgs Portal DM models
  - These constraints are directly comparable to those from other experiments

Dark Matter Interpretation

- Previously used an effective field theory model which translates B($H \to inv$) into a DM-nucleon cross-section
- Consider three DM spin scenarios: scalar, vector, Majorana fermion:
  - all but one go to infinity as the mass goes to zero
- Need new models - watch this space



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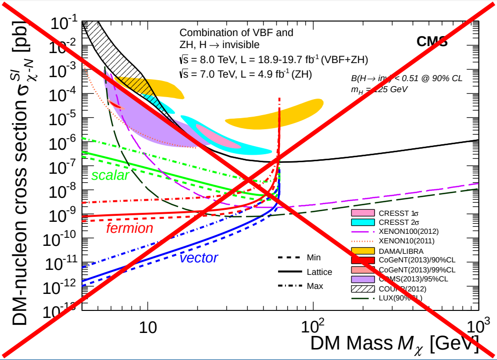
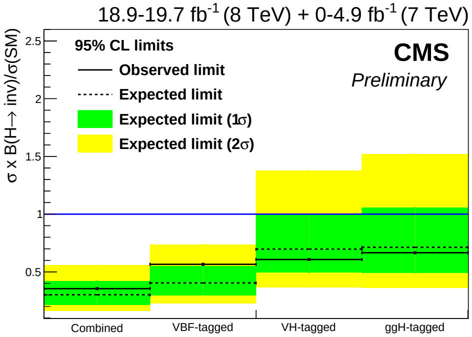


Conclusions

- We have set limits on invisible decays of the Higgs using the VBF channel
- This has been combined with other channels to give tighter limits
- We can use these limits to constrain dark matter models but we need to be careful



Backup