Search for low mass Higgs-boson like resonances at CMS

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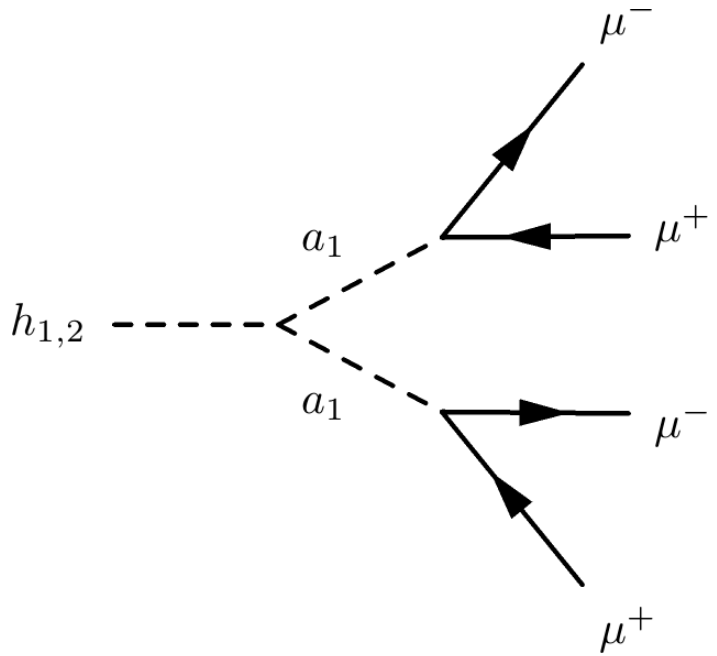
Introduction

- Discovery of the SM Higgs boson is not just the end of a search but the first step to explore the answers to the hot questions of physics
- Two Higgs double Model (2HDM) is a generic extension of the SM Higgs sector gives rise to 5 physical Higgs bosons, A°, h°, H°, $H^{\pm}$
- Similarly, such 5 physical Higgs bosons are predicted in the minimal extension of the SUSY model (MSSM), of which h° can be the observed 125 GeV Higgs boson and the others stand at high masses
- NMSSM introduces a singlet field on top of the 2 Higgs doublets in MSSM, leads to 7 physical Higgs bosons ($a_{1,2}$, $h_{1,2,3}$, $H^{\pm}$) which one or two of them can be lighter than 125 GeV

Pair production of light boson decaying into muons

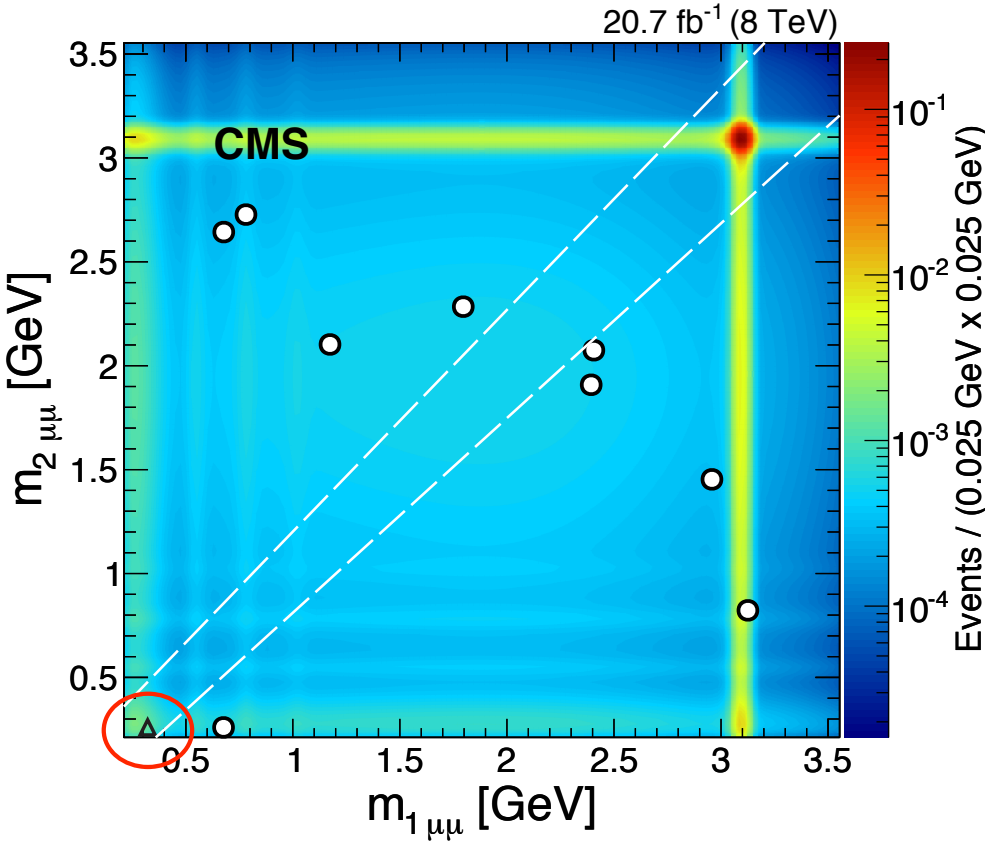
arXiv:1506.00424v1



- Search for light Higgs boson with 4 muons in final state
- $h_{1,2}$ is the observed 125 GeV Higgs boson and a_1 can be light and couple to fermions proportional to their mass
  - Large $\mathcal{B}(a_1 \to \mu^+\mu^-)$ if $2m_\mu < m_{a1} < 2m_\tau$
- Selecting 4 muon with p_T above 8 GeV and building two boosted isolated dimuons

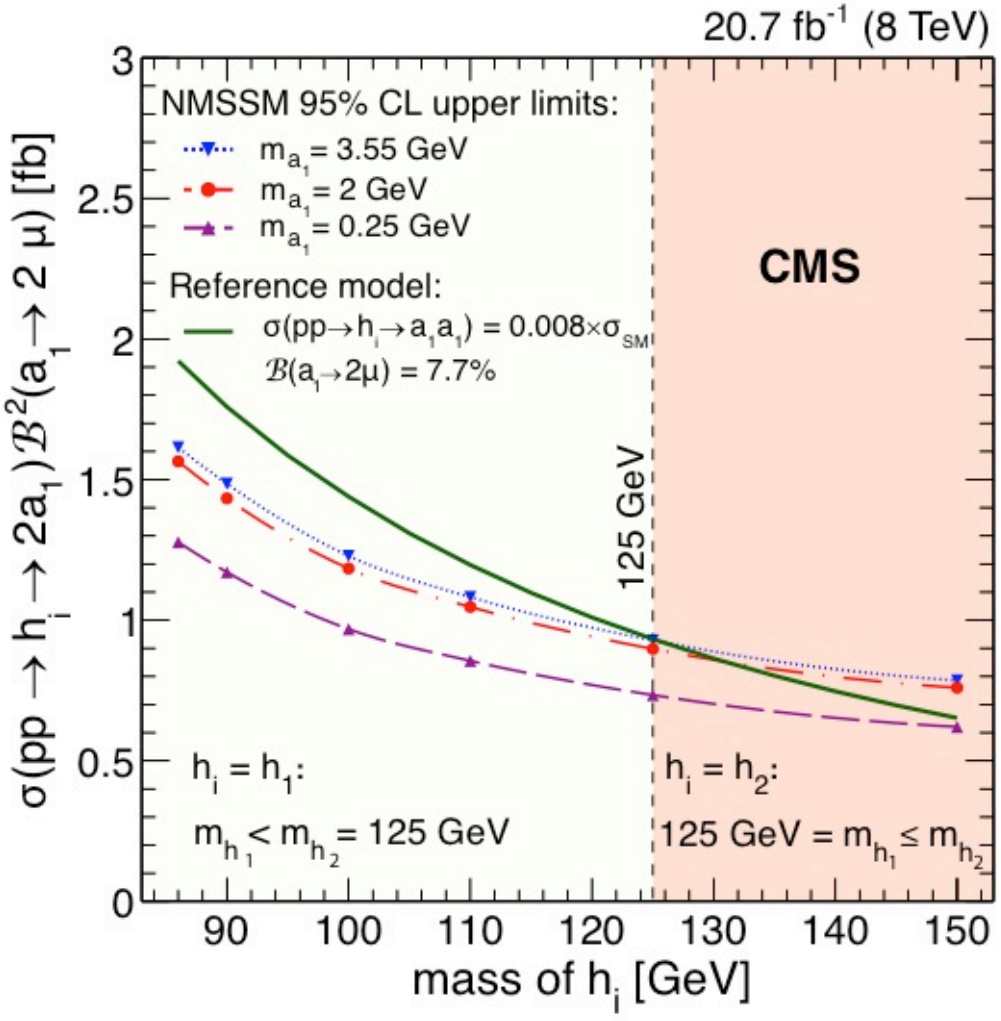
Background estimation

- The main background is bb
  - semi-leptonic decay of b and c quark
  - via resonances $\omega, \rho, \phi, J/\psi$
  - genuine dimu + mu + charged track faking mu
- Direct J/ψ is estimated from data requiring 2 dimu pair consistent with J/ψ mass
- Other SM processes are estimated with MC



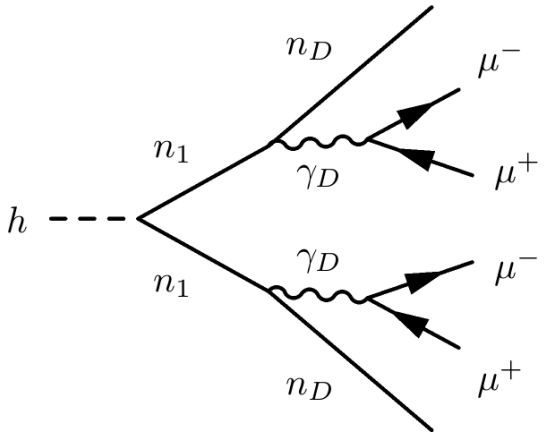
2.2 ± 0.7 BG v.s 1 events in data

Interpretation of results in NMSSM

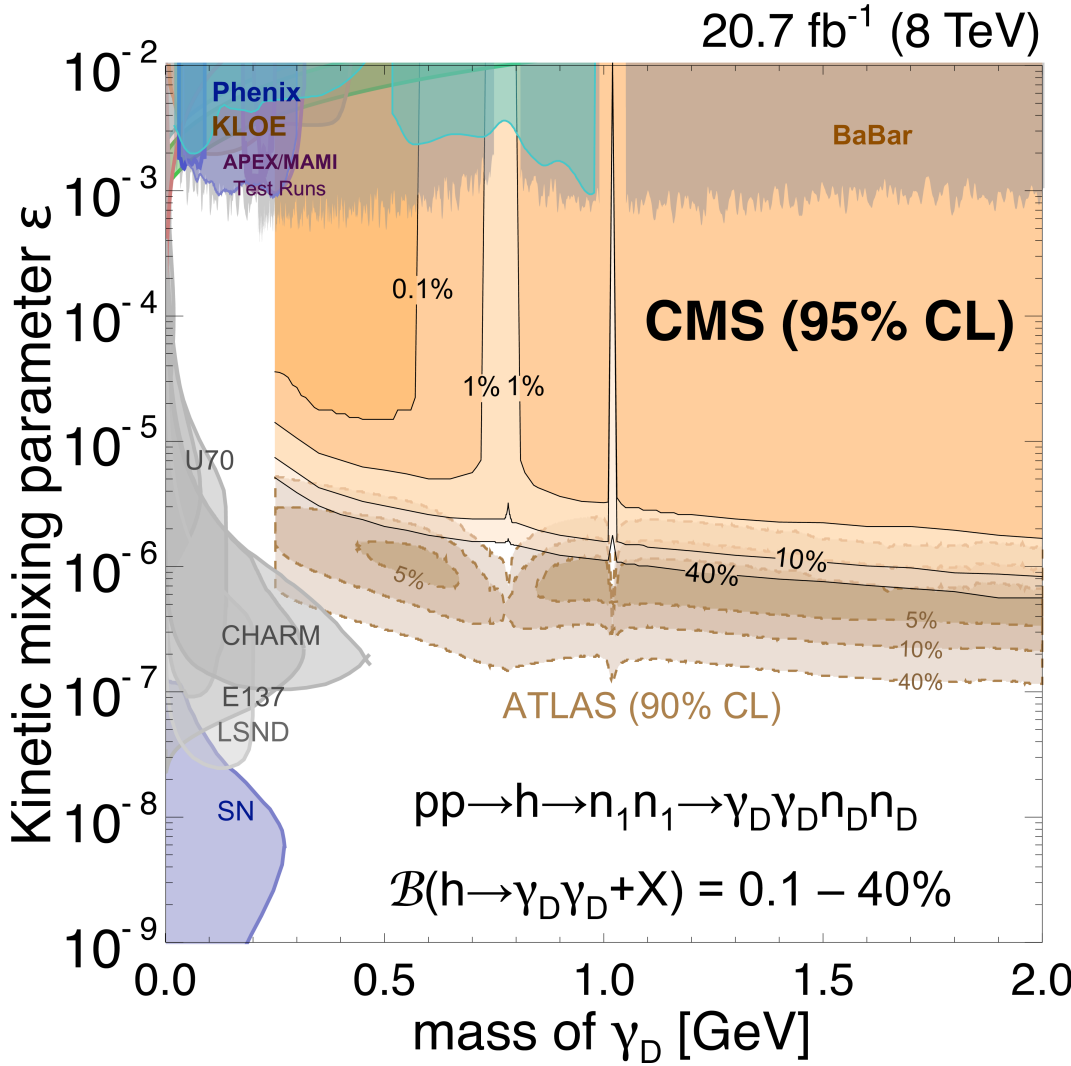


- Limit on the cross-section time branching fraction of h_i to 4μ in terms of h_i mass
- Limit is more stringent for lighter a_1.
- A benchmark point with $\mathcal{B}(a_1 \to \mu^+\mu^-) = 7.7\%$ is excluded

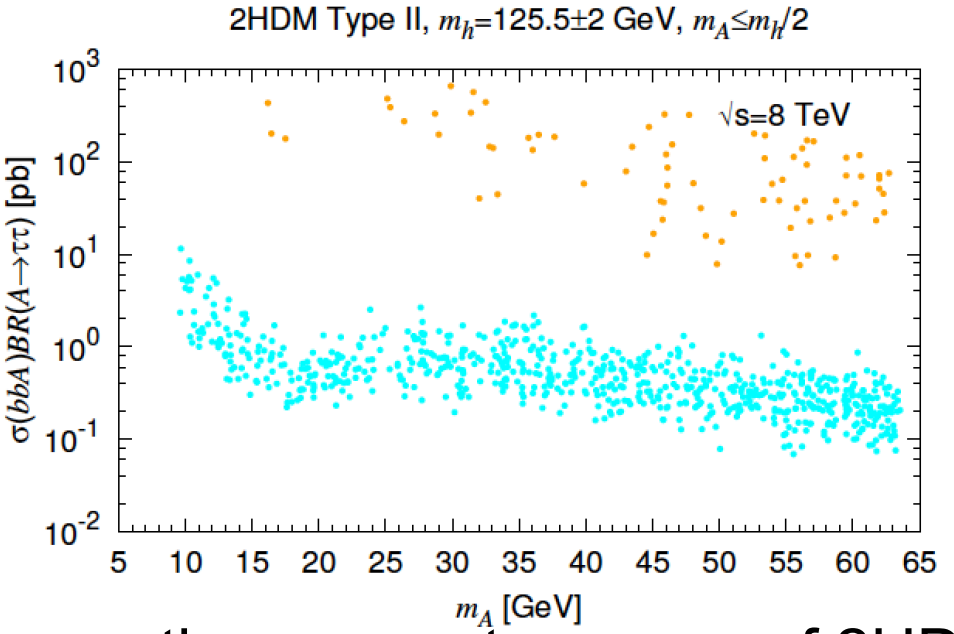
Interpretation of results in Dark SUSY model



- Dark SUSY motivated by excess observed by Pamela/Fermi exp. in the positron fraction in primary cosmic rays
  - m $\gamma_D < 2\,m_p$ (not such excess for antiproton)
- The search constrains a large area of phase space, previously unconstrained



Light pseudoscalar boson decaying to a pair of taus



J.Gunion et al
arXiv:1412.3385

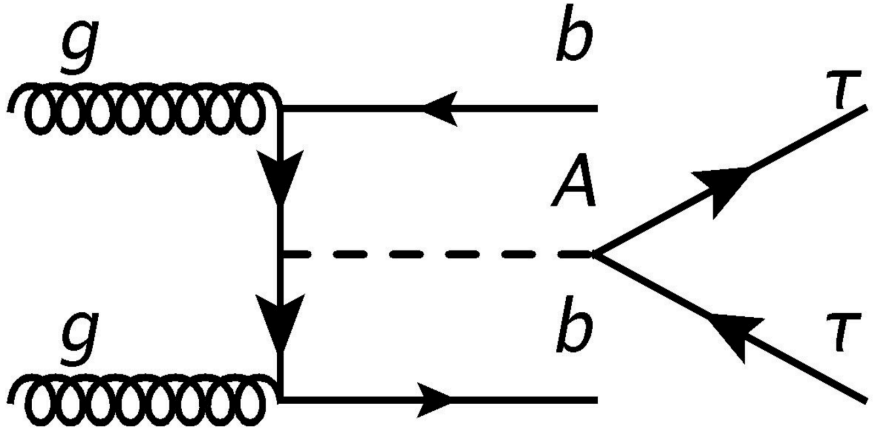
sgnY$_b$= -sgnY$_t$

sgnY$_b$ SM-like

- After full scan over the parameter space of 2HDM Type II, implementing all constrains from LEP, Tevatron and LHC, still light pseudoscalar boson with large cross-section can exist
- Positive Yukawa coupling:
  - $\sin(\beta-\alpha) \sim 1$, $\cos(\beta-\alpha) > 0$ and low Higgs mixing parameter
- Negative Yukawa coupling:
  - $\sin(\beta+\alpha) \sim 1$, small $\cos(\beta-\alpha) < 0$

Analysis Strategy

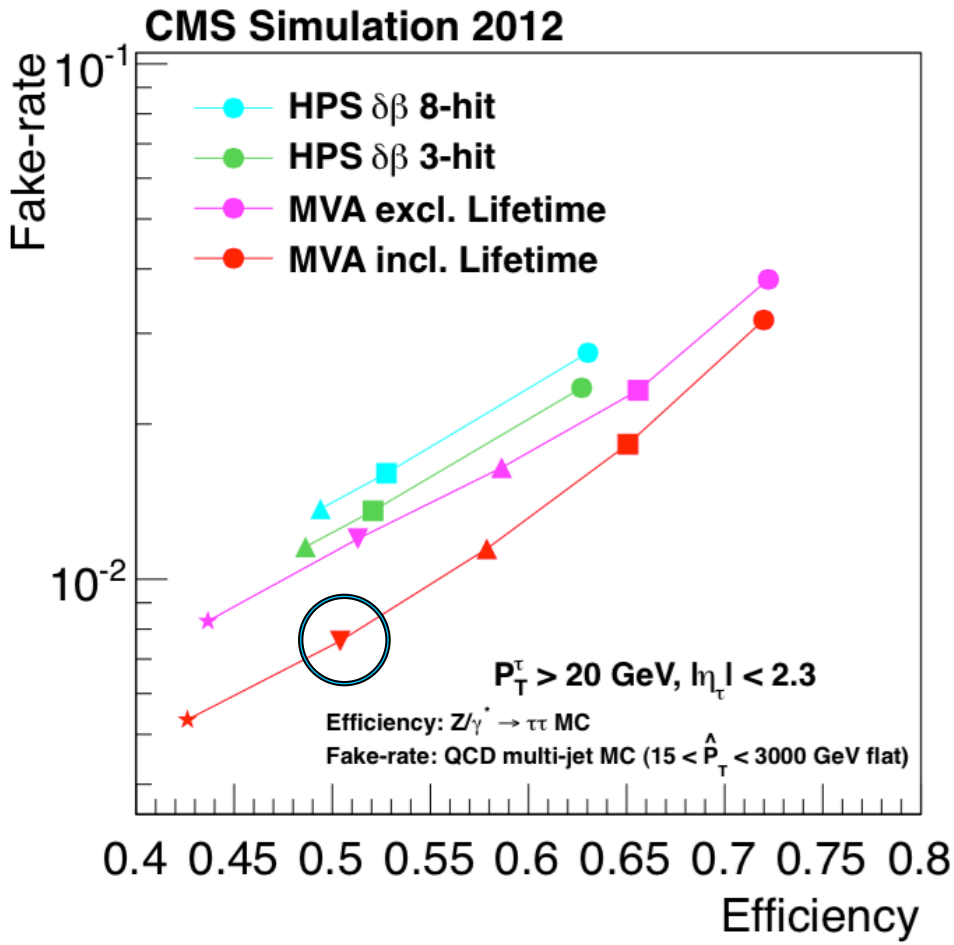
HIG-14-033



- First look at light pseudoscalar Higgs boson for mass range between 25 and 80 GeV
- Search is done in three most sensitive channels $\mu\tau_h$, $e\tau_h$, $e\mu$
- Requiring a pair of leptons + at least one b-jet (b jets are soft)
- Selection is as loose as possible (just a bit above the trigger threshold), due to the low acceptance.

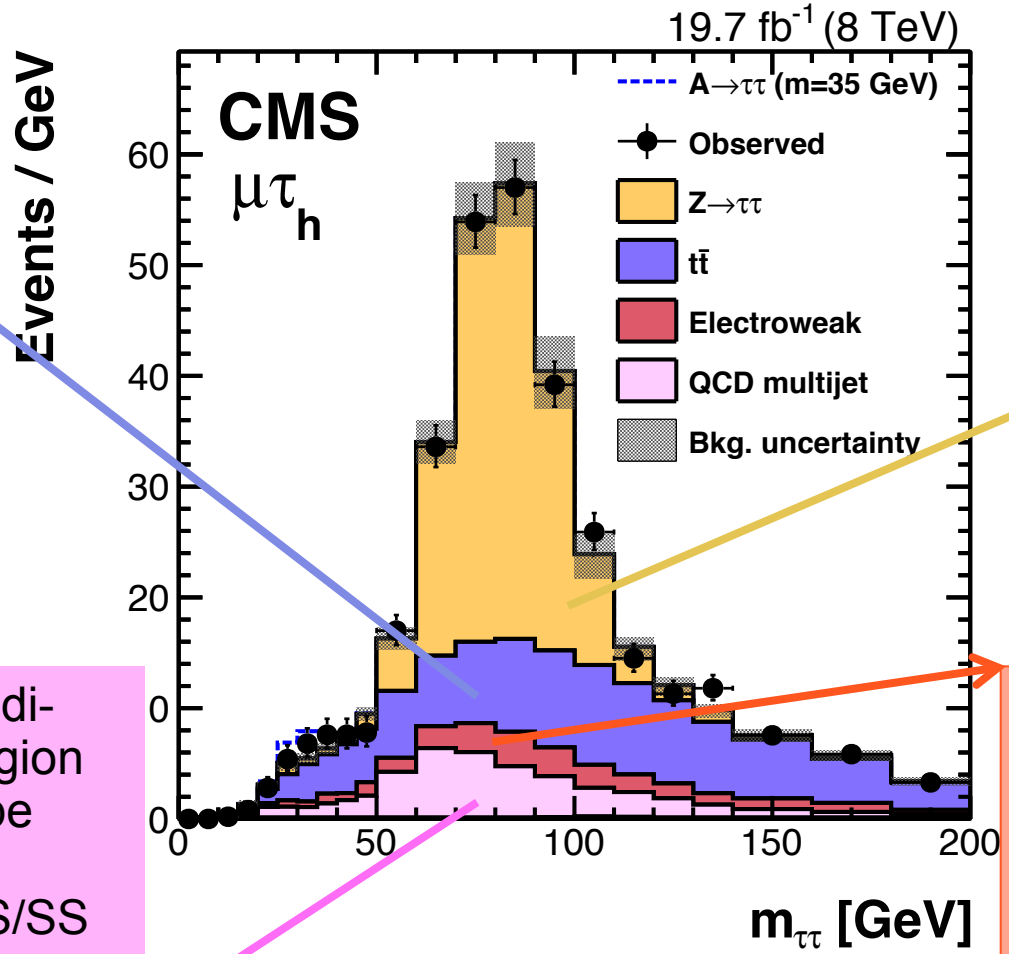
New Tau Identification/Isolation

- New tau identification/ isolation in CMS using the multivariate techniques and tau lifetime information
- About 40% reduction in jet mis-identification rate for the same reconstruction efficiency comparing to the cut based isolation
- Reconstructed ditau mass, $m_{\tau\tau}$, is used as the observable



Background estimation

tt: Main background due to the presence of real b jet in the event (estimated from MC using NLO cross-section)

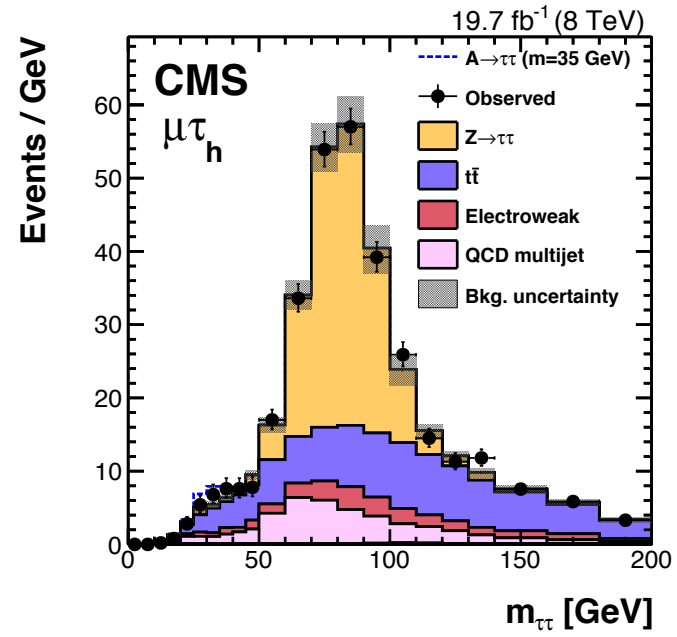


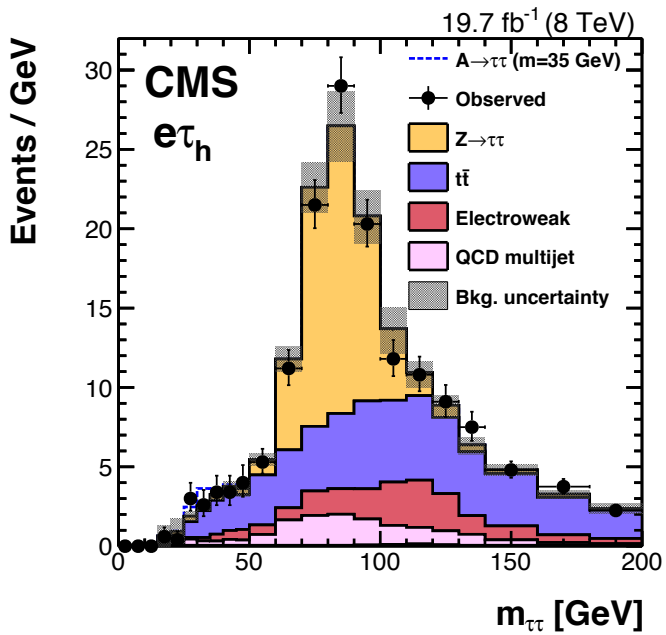
DY+Jets:
Shape estimated from data using Embedded technique.
Normalization from NLO cross-section

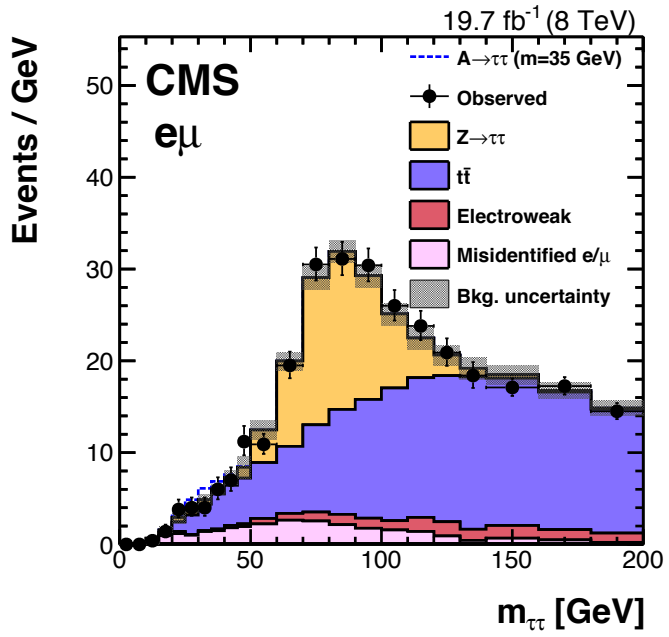
QCD multijet: using di-lepton same sign region to estimate the shape and normalization.
Mass dependent OS/SS ratio from loosely isolation leptons control region

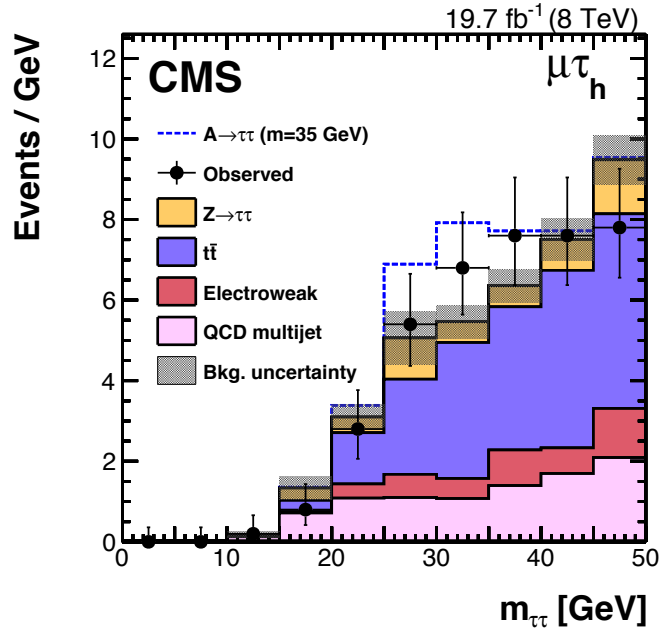
W+Jets: Normalization estimated from data at high m_T region, shape from simulation
Other small backgrounds (diboson, singleTop, SM Higgs), estimated from simulation.

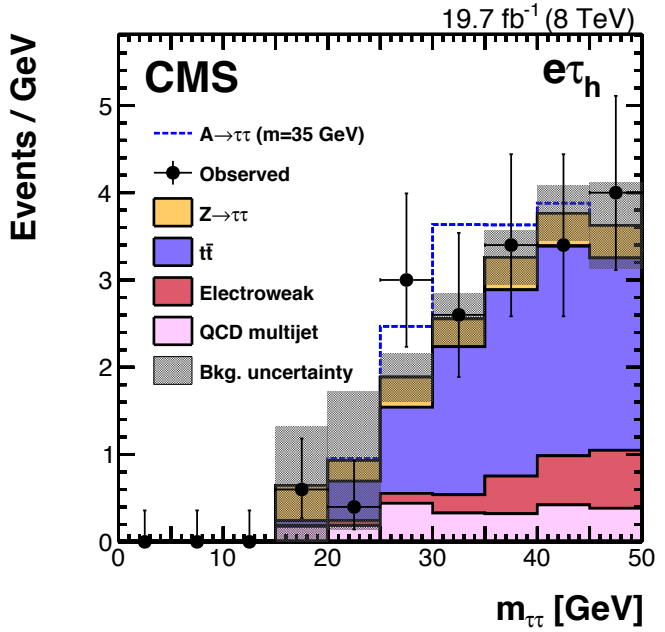
Mass Distributions

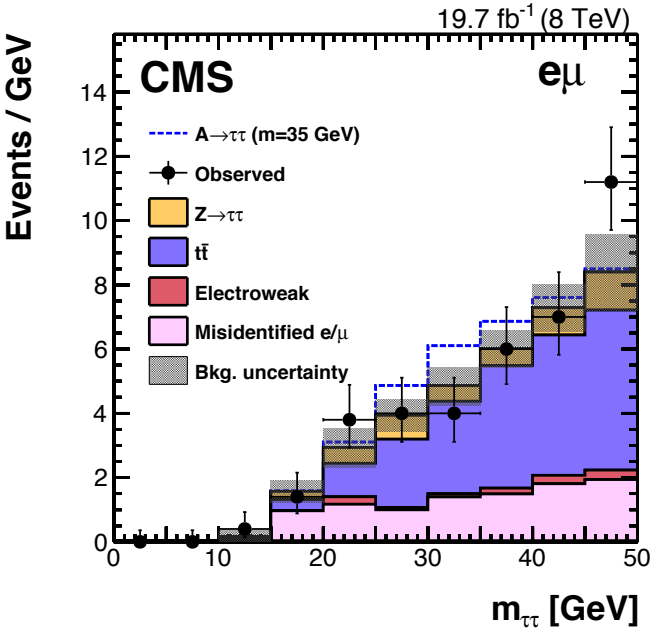






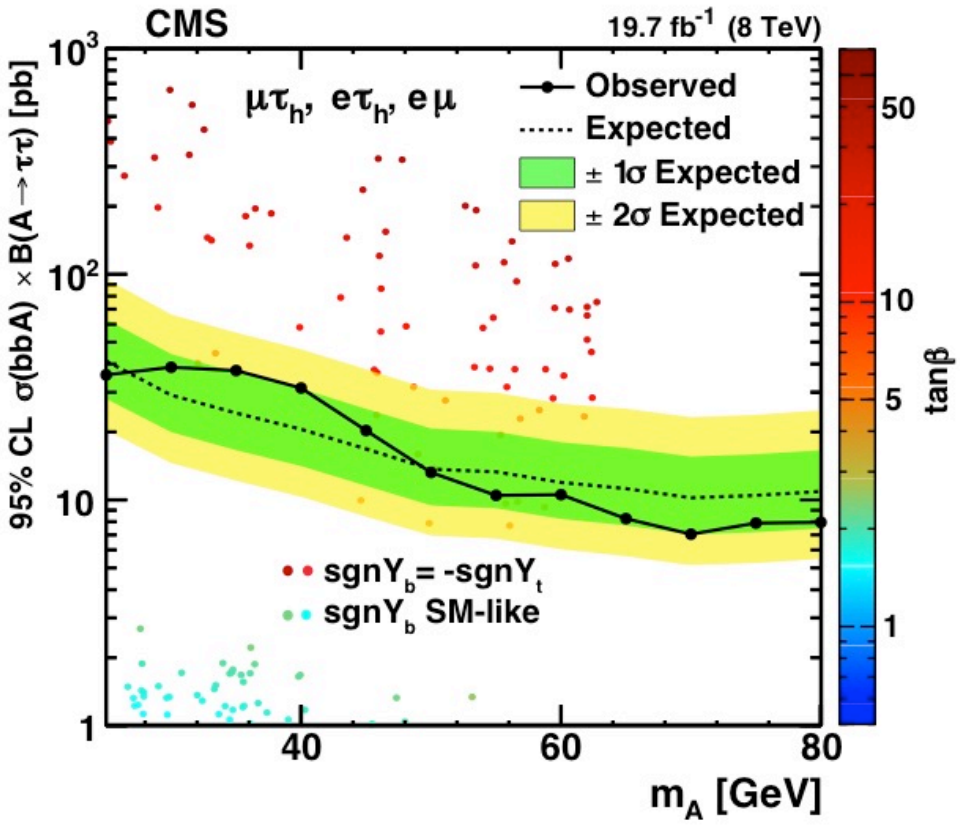






Limit

- Combined limit is mainly driven by $\mu\tau$ channel
- Limit varies between ~ 10 and 40 pb
- Orange and blue points are obtained from scan of 2HDM including all existing constraints from LEP, Tevatron and LHC for different coupling types.
- These results almost exclude the light pseudoscalar Higgs boson with negative Yukawa coupling

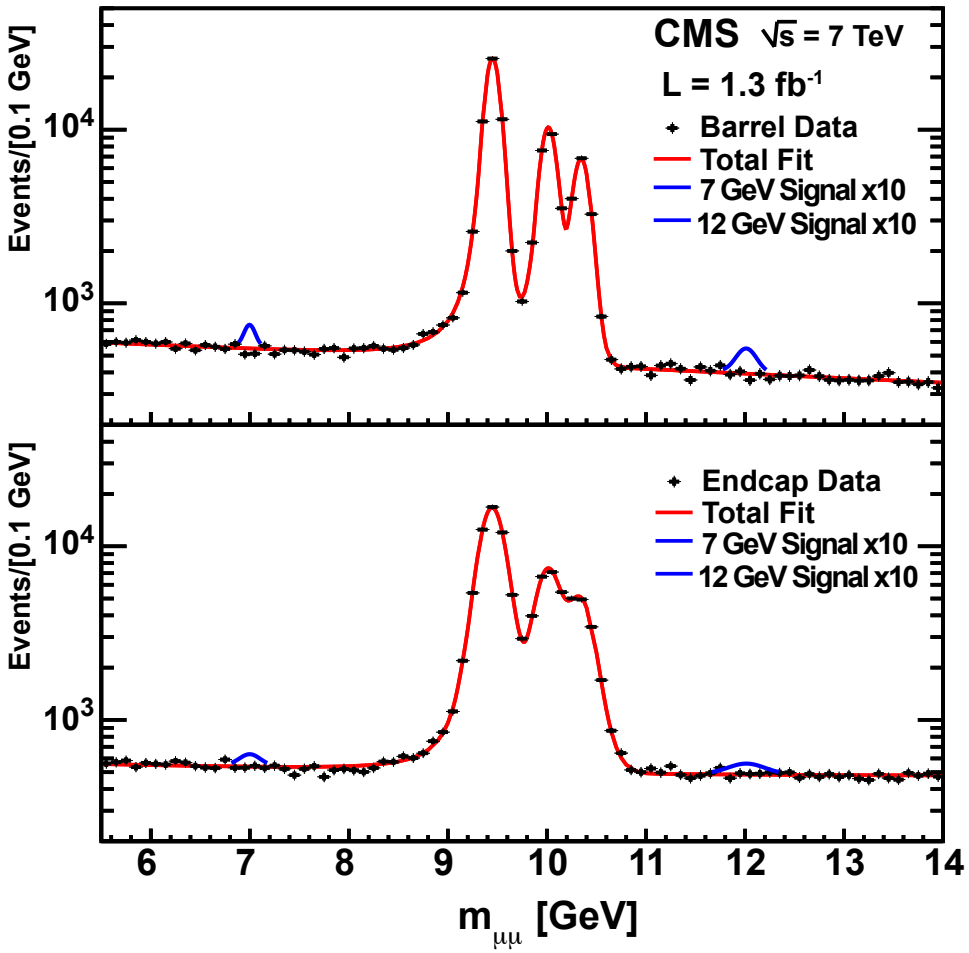


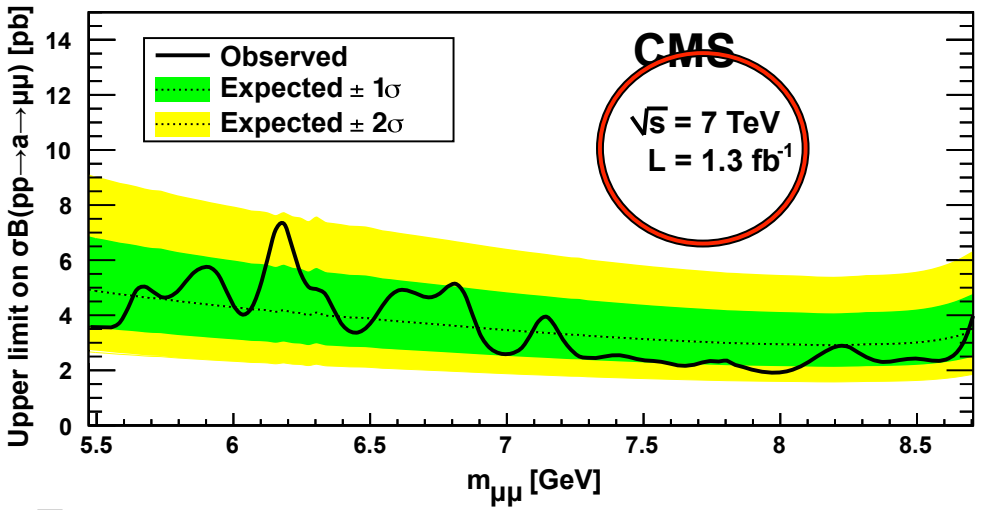
Conclusion

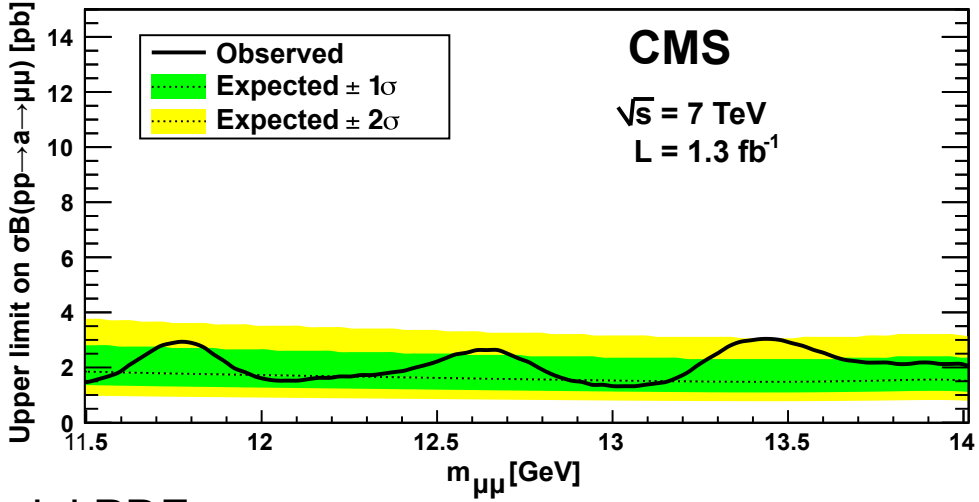
- Several new analyses in CMS looking for light Higgs bosons
- Search of h_1 to a pair of a_1 decaying into muons
  - Results interpreted in both NMSSM and dark SUSY models
  - Large phase space of the mass of dark photon vs kinetic mixing parameters is excluded
- Search for a light pseudoscalar Higgs boson in the 2HDM
  - The light pseudoscalar in the Type II of 2HDM and negative Yukawa coupling is almost excluded
- Many more new CMS results on light bosons are in the process and will appear soon. *Lightly stay tuned !*

Back Up

Search for light Pseudoscalar bosons to dimuons

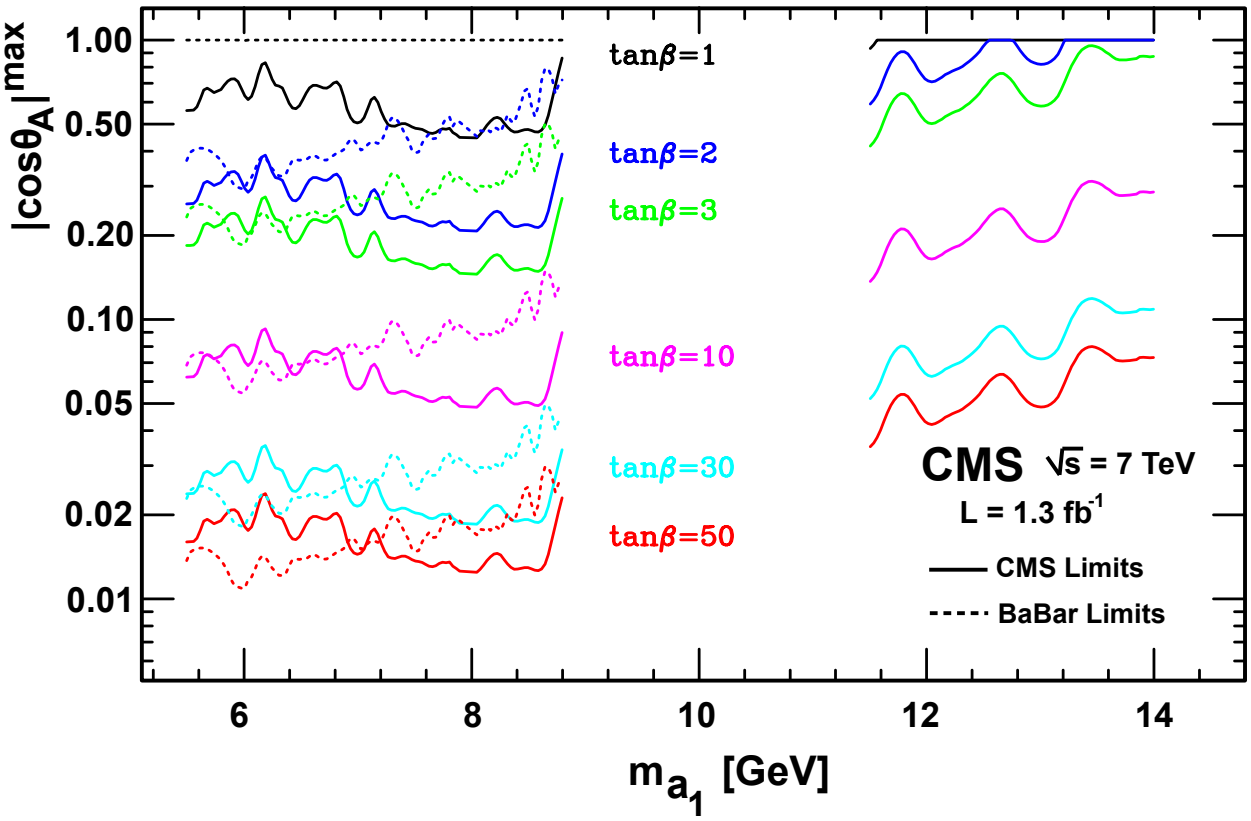






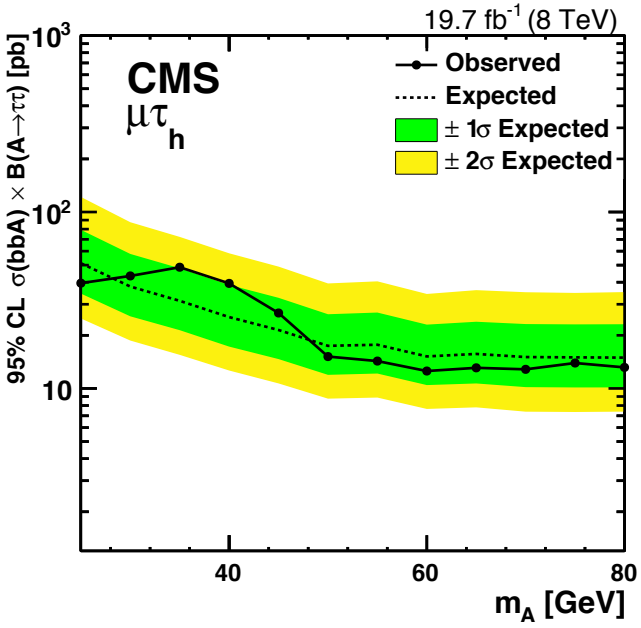
- QCD is continuum BG fitted first-order polynomial PDF
- $\Upsilon(1S), \Upsilon(2S), \Upsilon(3S)$ resonances parameterized via double Crystal Ball (CB) function
- No excess of data on top of the SM background

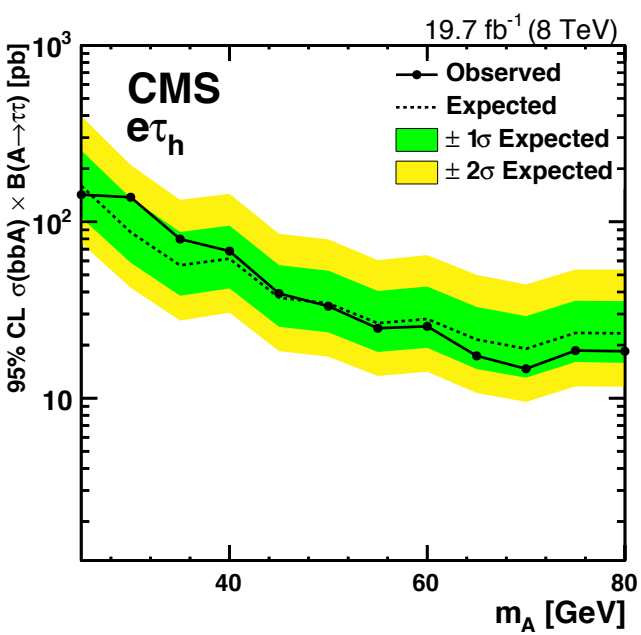
Translating the results in the NMSSM parameter space

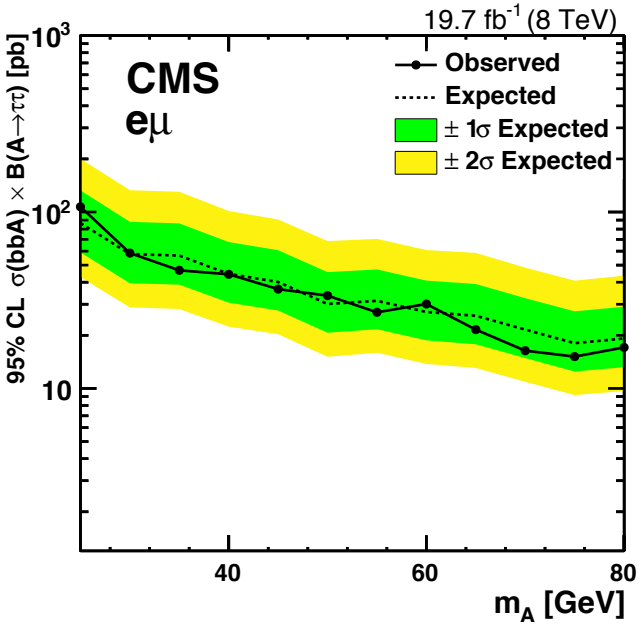


- light a1 is a superposition of the CP-odd doublet scalar in the MSSM sector and the additional CP-odd singlet scalar of the NMSSM:
  $a1 = \cos\theta_A a_{MSSM} + \sin\theta_A a_S$
- Limit on $|\cos\theta_A|$
- Stronger constrains for larger values of the tanβ

Model Independent Limit

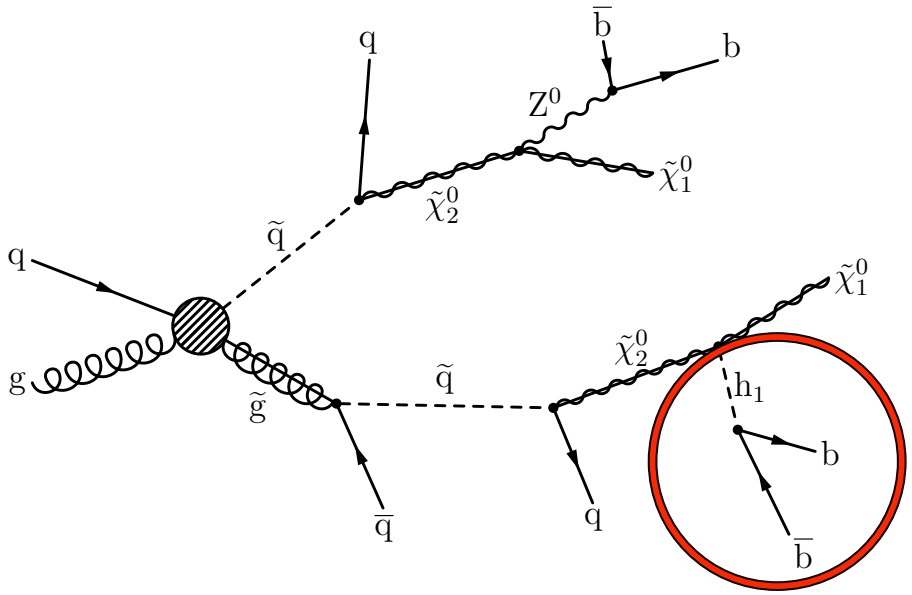






- No significance excess of data is seen on top of the SM background
- Set limit on cross section x branching fractions
- Observed limit is within 1sigma from expected

Light NMSSM Higgs boson in supersymmetric cascade

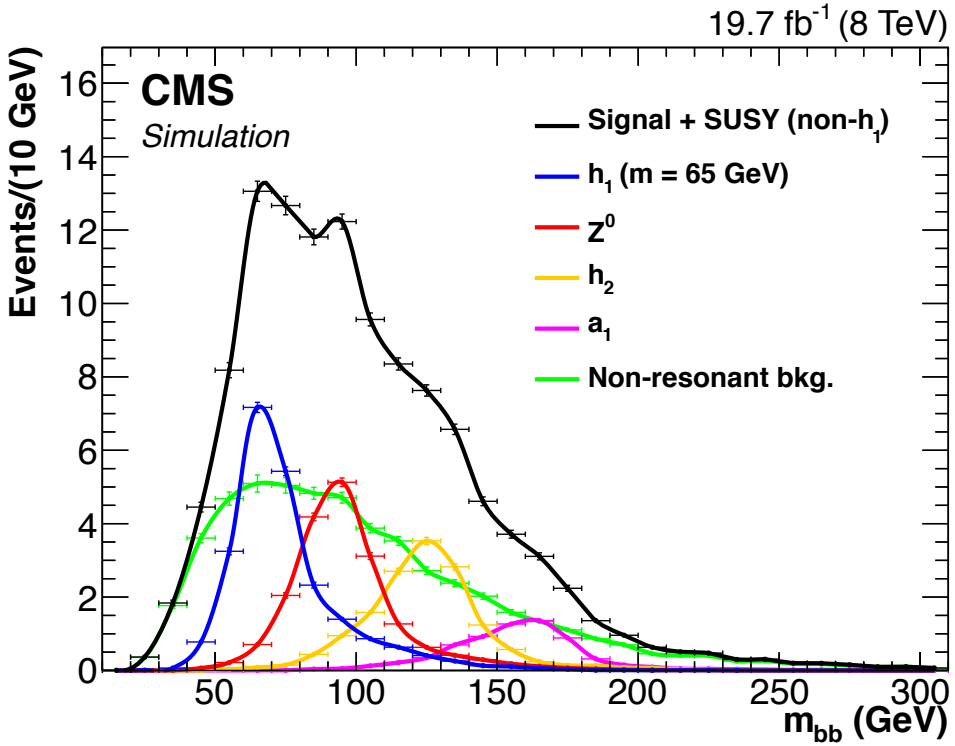


- Hard to detect in conventional LHC search, but might be produced in the decay of neutralinos in SUSY cascades
- In modified P4 benchmark scenario
  - h_1 decays mainly into a pair of b quarks
  - h_2 is the observed 125 GeV Higgs boson
  - Rest of the Higgs bosons are much heavier

Analysis Strategy

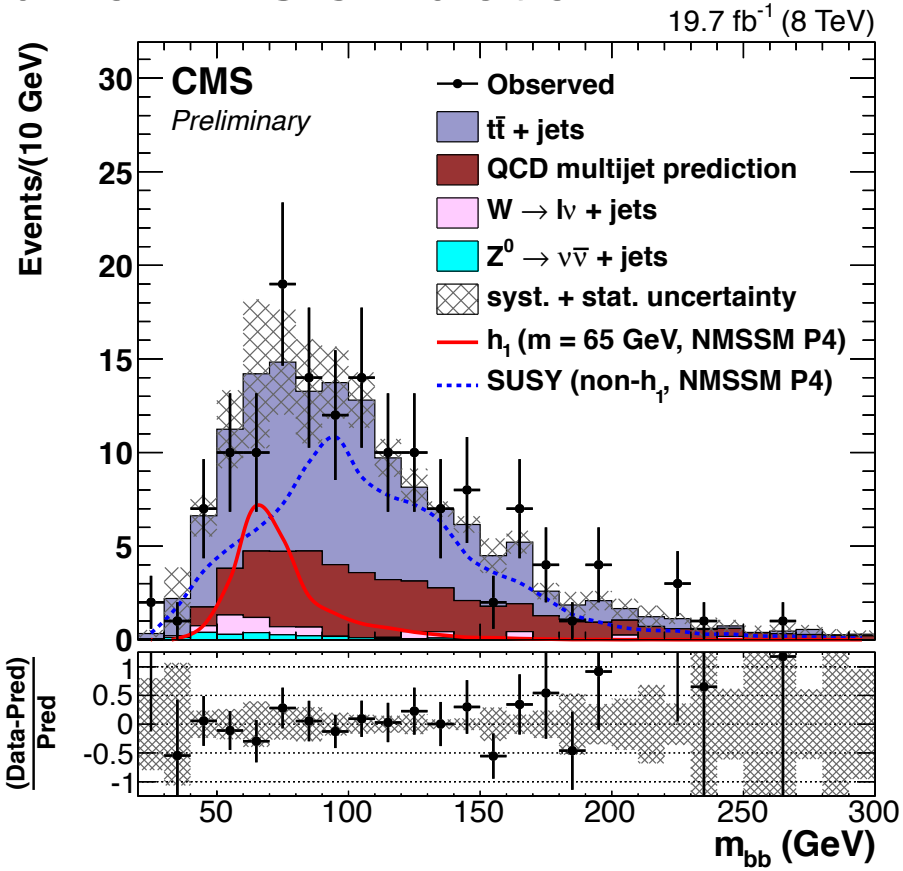
- Events selection based on large hadronic activities (H_T > 750 GeV)
- Large missing Energy from two LSPs (E^T_{miss} > 200 GeV)
- Two moderate b jets from h_1 decay
- Two high-p_T jets from s-quark decays

- m_{bb} as observable
- Two possible searches
  - single peak over the SM background
  - multiple peaks (signal + full SUSY spectrum)

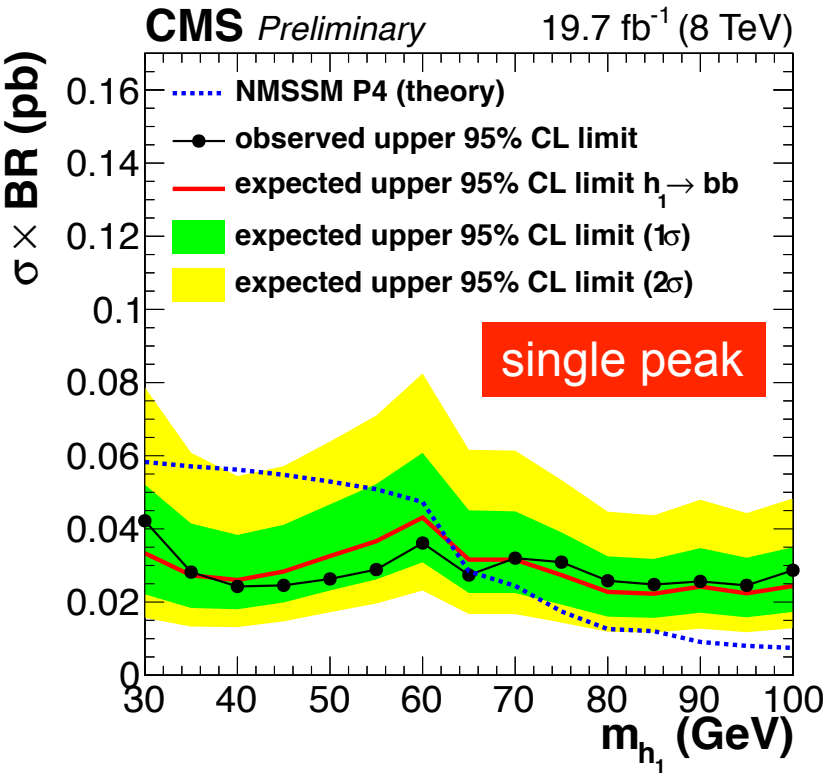


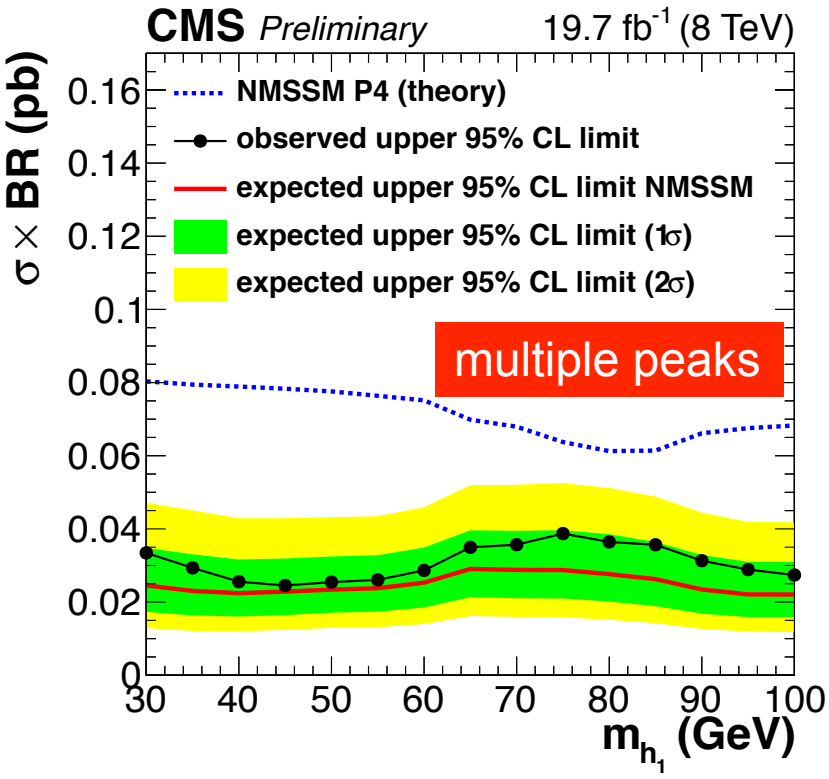
Background estimation

- tt + jets
  - Shape and Normalization(NLO) estimated from MC. Validated in control region
- QCD multije
  - Data-driven estimation for shape and normalization. Validated in control region
- Other small backgrounds are estimated from MC simulation
- Possible signal models are superimposed
- No significant excess on top of the SM background



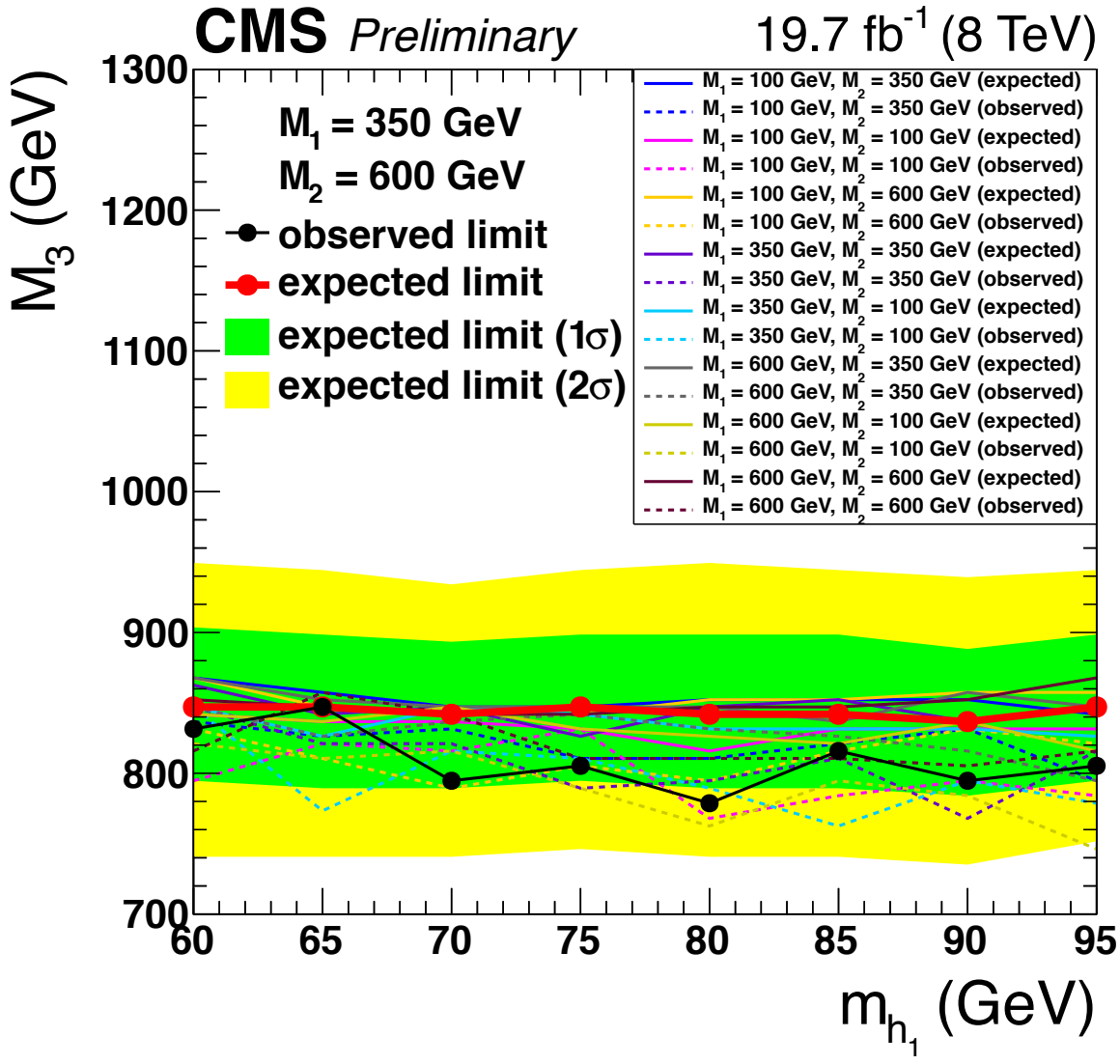
Limit



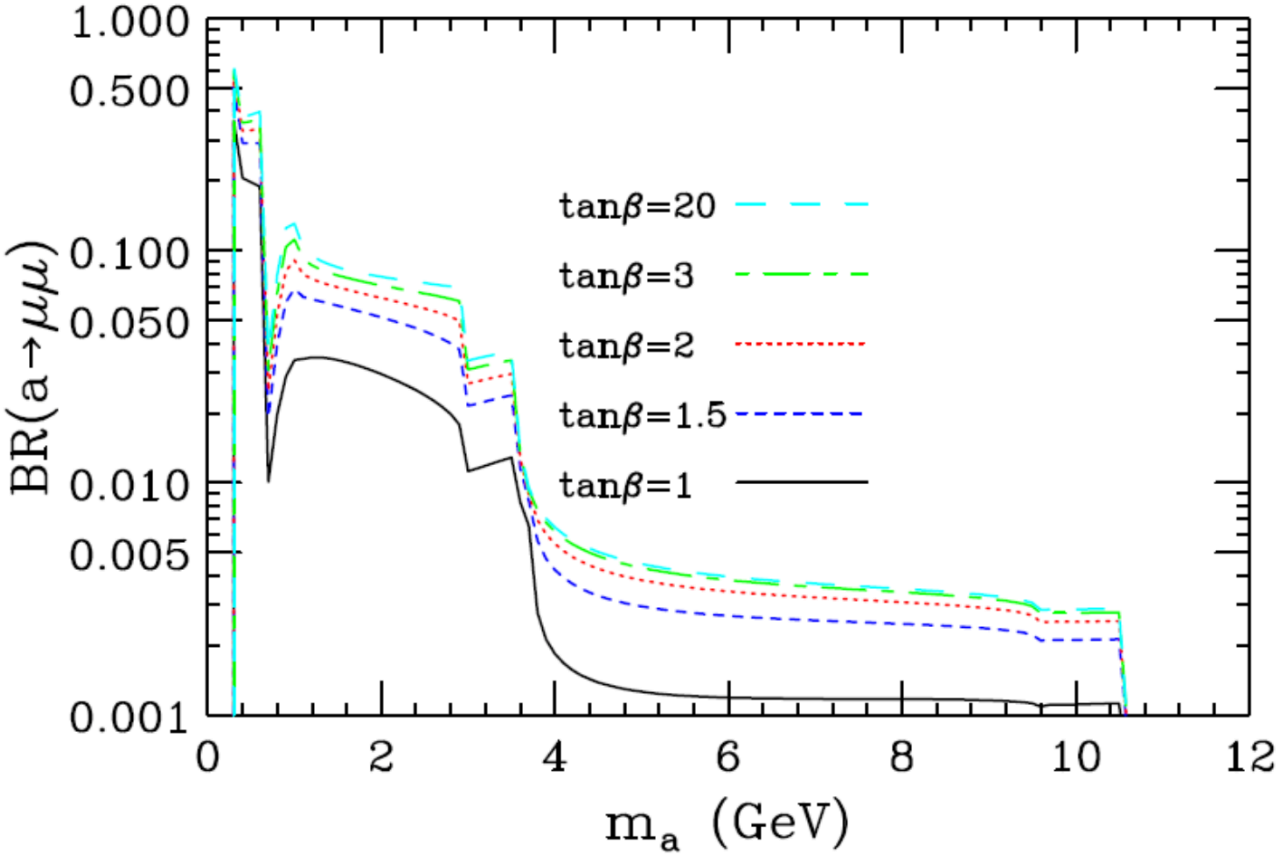


- More stringent limit in the multiple peak search than the single peak search
- The kink feature at left plots around 60 GeV is due to the opening the $h_2 \rightarrow h_1 h_1$ phase space.
- At M_{susy} ~ 1 TeV, NMSSM P4 scenario is excluded for the mass range between 30 and 100 GeV

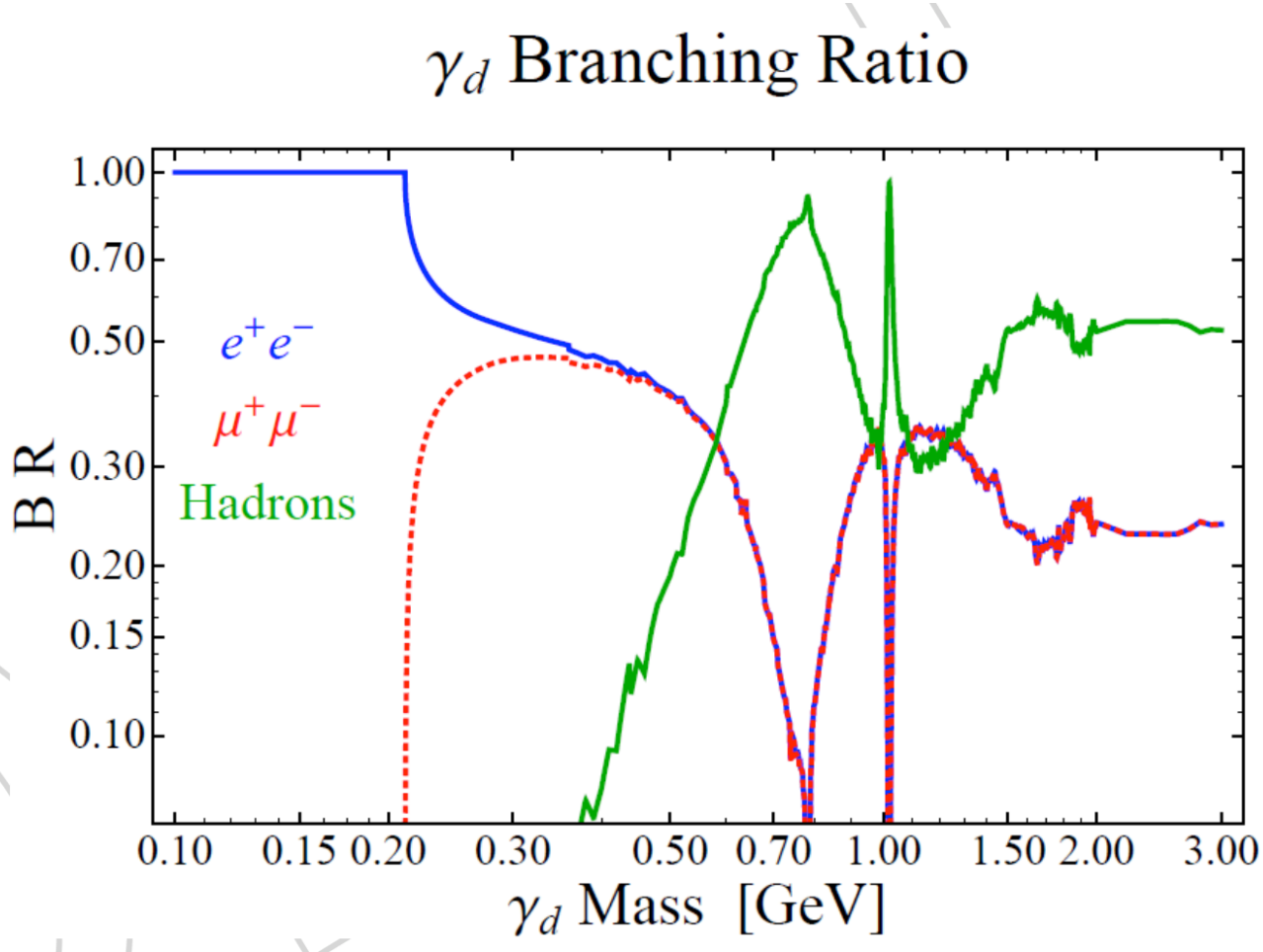
Light NMSSM Higgs boson in supersymmetric cascade



Branching Ratio of light CP-odd Higgs boson $a_1 \rightarrow \mu\mu$



Branching Ratio of γ_D



Experimental constraints for the Dark SUSY scenarios