$\Phi \to \tau\tau$

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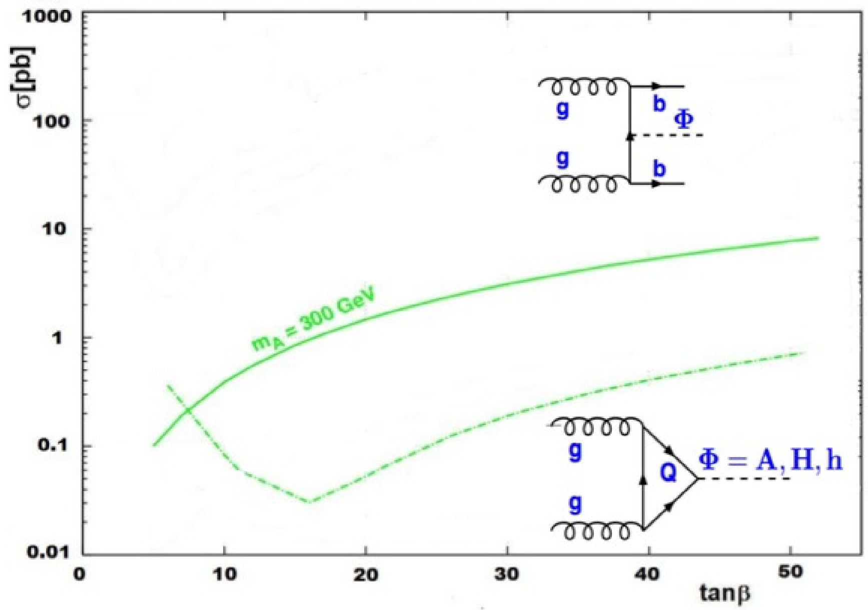
Theory and Motivation

- 2 Higgs doublets in MSSM
- 8 degrees of freedom
  - → 3 Gauge-Bosons W^+, W^-, Z
  - → 5 Higgs-Bosons
    - h, A, H, H^+, H^-
- Pseudoscalar A decays mainly into fermions
  - Motivation for the considered MSSM Higgs production processes and decay channels

MSSM is just a particular model for Higgs-Doublet-Models in general:
→ Look at model-independent interpretations of the data, too

- On tree level Higgs masses defined by m_A and tanβ
  - m_A – mass of A
  - tanβ – ratio of the vacuum expectation values of the Higgs doublets



Analyzed channels and datasets

- eμ + eτ + μμ + μτ + ττ
  - The fully hadronic ττ channel is new to BSM analysis
  - Planed to add ee channel for paper

- 4.9 fb^{-1} at 7TeV and 19.8 fb^{-1} at 8TeV
  - ττ uses only 8TeV dataset (=18.3 fb^{-1})

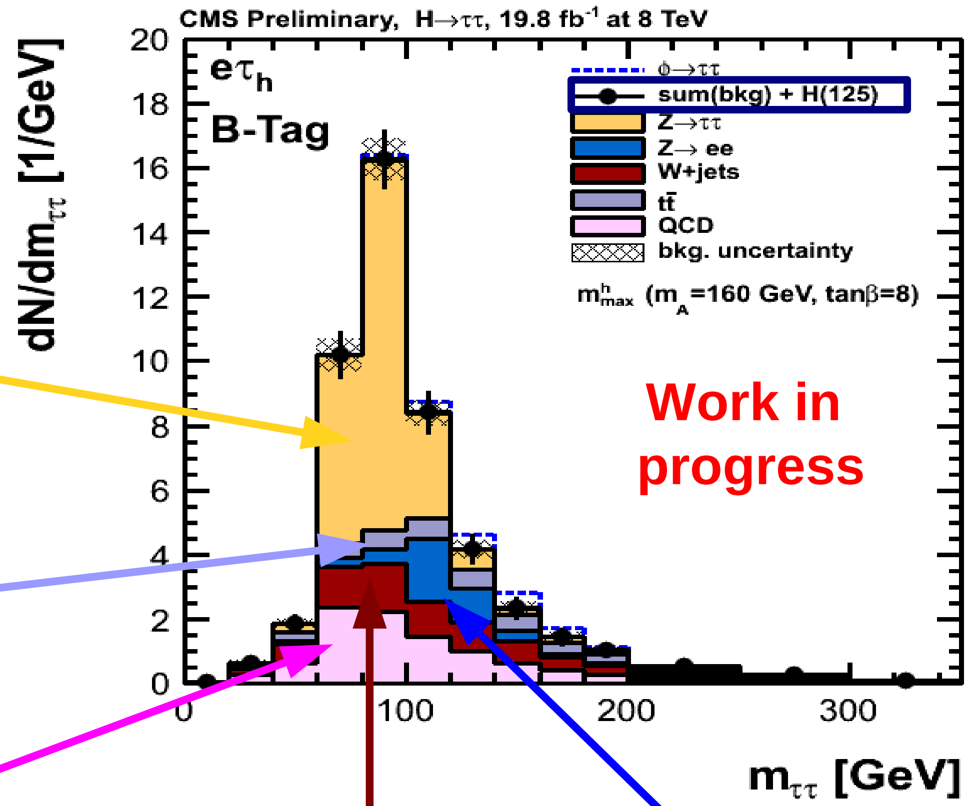
Event selection

- Two well reconstructed, isolated leptons of opposite sign:

channel	p_T	$\|\eta\|$	p_T	$\|\eta\|$
$e\mu$	> 20 GeV (e/μ)	< 2.3 (e/μ)	> 10 GeV (μ/e)	< 2.3 (μ/e)
$e\tau$	> 24 GeV (e)	< 2.1 (e)	> 20 GeV (t)	< 2.1 (τ)
$\mu\mu$	> 20 GeV (μ)	< 2.1 (μ)	> 10 GeV (μ)	< 2.1 (μ)
$\mu\tau$	> 20 GeV (μ)	< 2.1 (μ)	> 20 GeV (τ)	< 2.3 (τ)
$\tau\tau$	> 45 GeV (τ)	< 2.1 (τ)	> 45 GeV (τ)	< 2.1 (τ)

- $e\mu$: $D_\zeta = P_\zeta - 1.85 \cdot P_\zeta^{vis} > -20$ GeV
- $e\tau$, $\mu\tau$: $M_T < 30$ GeV
- $\mu\mu$: Special BDT trained for rejection of $Z/\gamma^* \rightarrow \mu\mu$ events

Background estimation in $\Phi \rightarrow \tau\tau$



$Z/\gamma^* \rightarrow \tau\tau$:
- Embedding: in $Z \rightarrow \mu\mu$, replace μ by sim. τ decay
- Normalized from $Z \rightarrow \mu\mu$ events

ttbar:
- From simulation
- Normalization from sideband

QCD:
- Normalization & shape taken from SS/OS or fakerate

Di-boson/W+jets:
- From simulation or data
- Normalization from sideband

$Z/\gamma^* \rightarrow ee\ (\mu\mu)$:
- From simulation or data
- Corrected for jet $\rightarrow \tau$, $e/\mu \rightarrow \tau$ fakerate

Categorization

B-Tag:

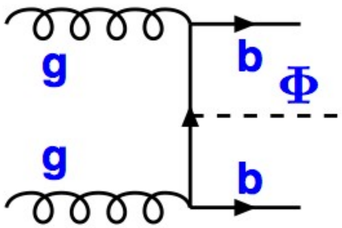
$\geq$ 1 b-tagged jets with p_T > 20 GeV
< 2 jets with p_T > 30 GeV

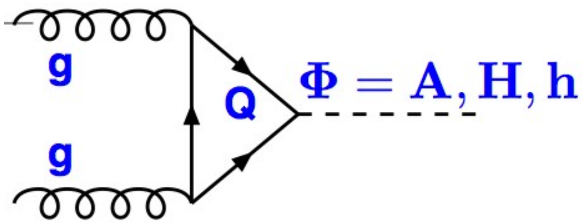
Sensitive to bbΦ

No-B-Tag (inclusive):

no b-tagged jets with p_T > 20 GeV

Contains rest of signal events.





- The chosen categorization is Higgs-p_T independent in order to stay as model independent as possible

Bin-by-bin (bbb) uncertainties

- Allowed bbb for all backgrounds in all channels

- Add bbb uncertainty if
  the bin-error/bin-content > 5%
  - 2003 added (might change since work in progress)

- Drop bbb uncertainty if
  pulls of bin-by-bin uncertainties • size of the prefit uncertainty < 10% of bin-content
  - 1696 dropped (might change since work in progress)

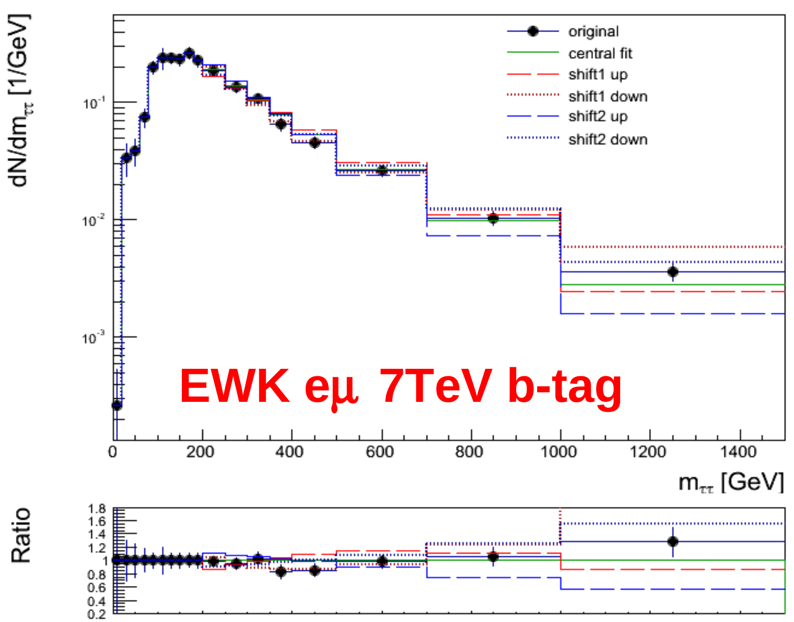
Tail-fitting

- For the high mass tails (typically $M_{\tau\tau}$ > 150 GeV) of several backgrounds an analytic fit is performed

$$f = \exp[-m_{\tau\tau}/(c_0 + c_1 m_{\tau\tau})]$$

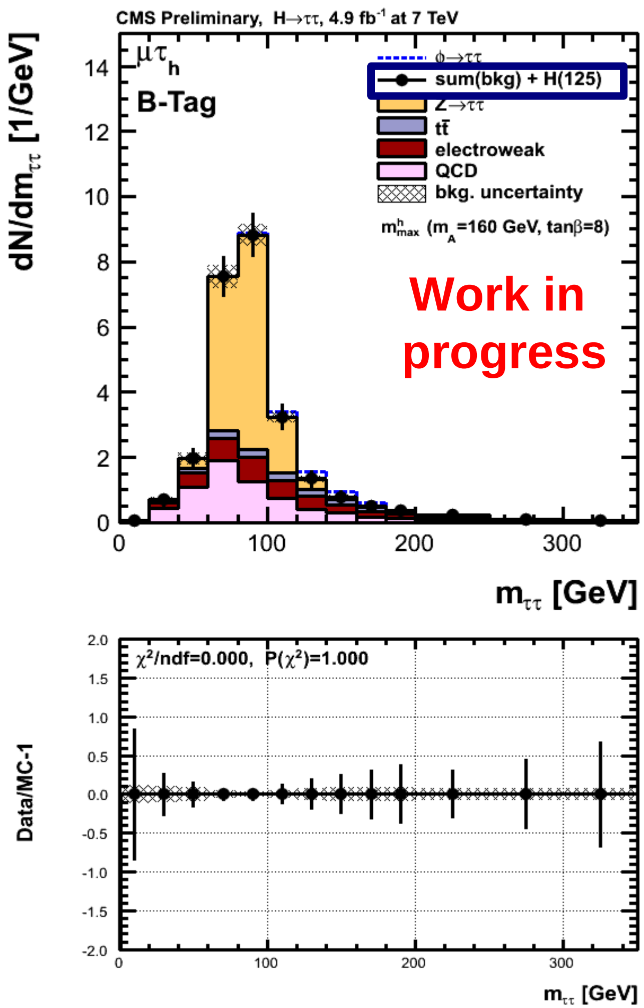
- Used to estimate background in bins where MC-statistic is limited
- Uncertainties on the shape of the fit function are accounted by adding two shape nuisance parameters (corresponding to the two free parameters in the fit)
- Corrects for possible systematic miss modeling of the high mass tails

	no-btag	btag
e-mu (7TeV)	EWK,ttbar,Fakes	EWK,ttbar
e-mu (8TeV)	EWK,ttbar,Fakes	EWK,ttbar
e-tau (7TeV)	QCD,W	-
e-tau (8TeV)	QCD,TT,W	QCD,TT,W
mu-tau (7TeV)	QCD,W	QCD
mu-tau (8TeV)	QCD,TT,W	TT,W
tau-tau (8TeV)	QCD	QCD

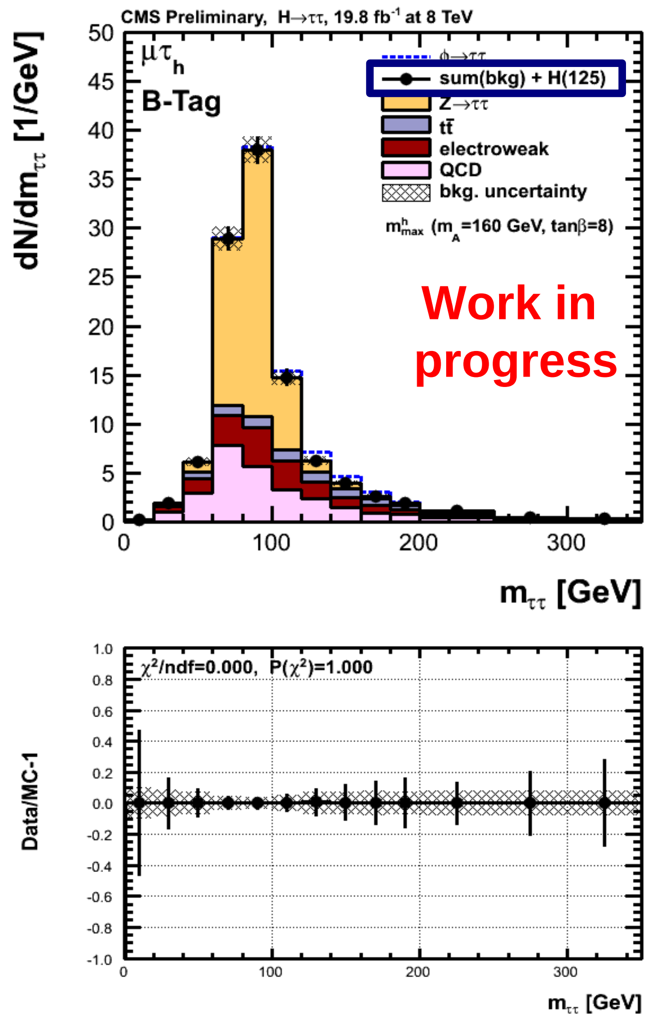


Postfit – $\mu\tau$ b-tag

7TeV

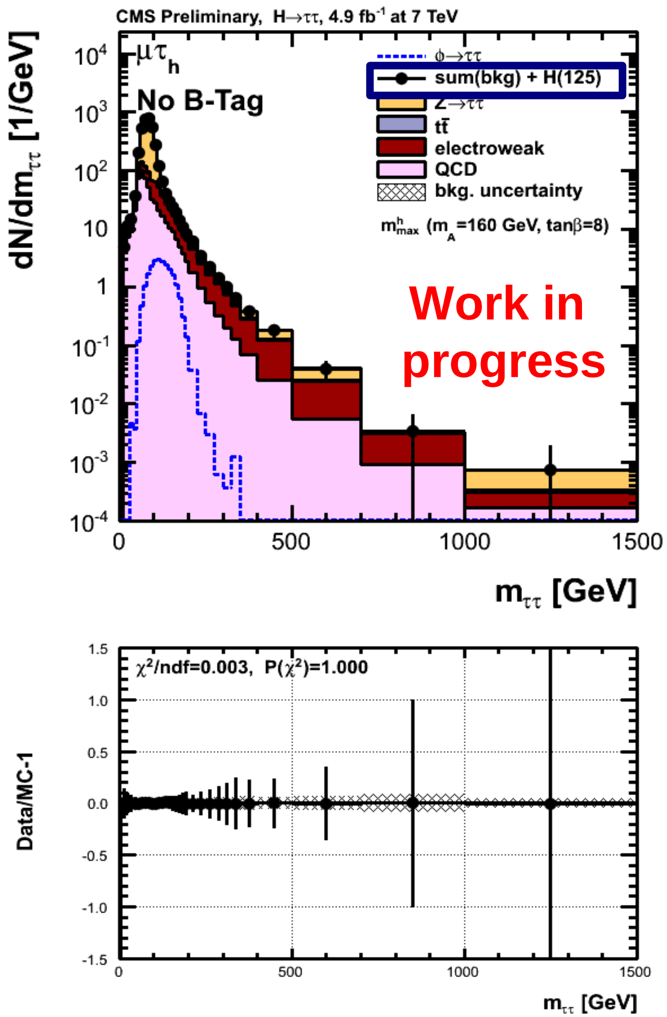


8TeV

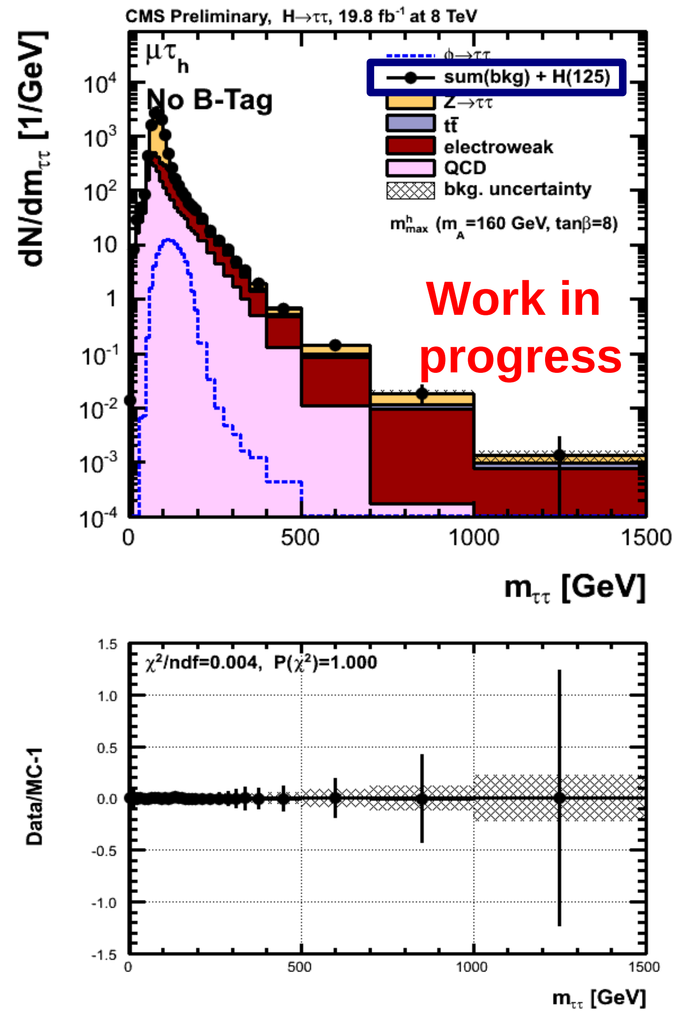


Postfit – $\mu\tau$ no-b-tag

7TeV

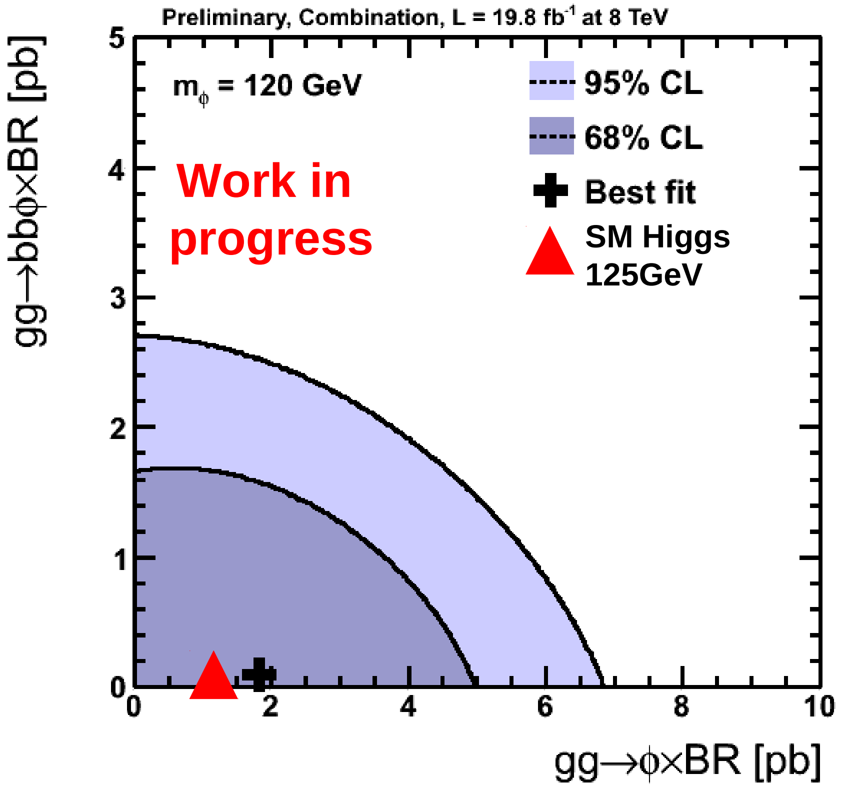


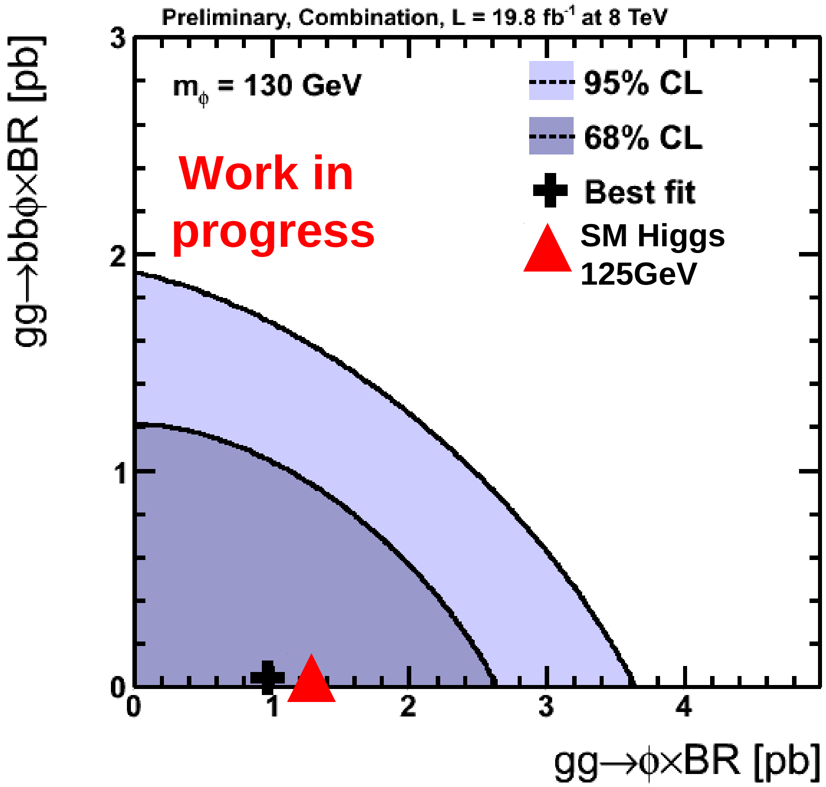
8TeV



2D Likelihood scan - ggΦ vs bbΦ - SM-injected

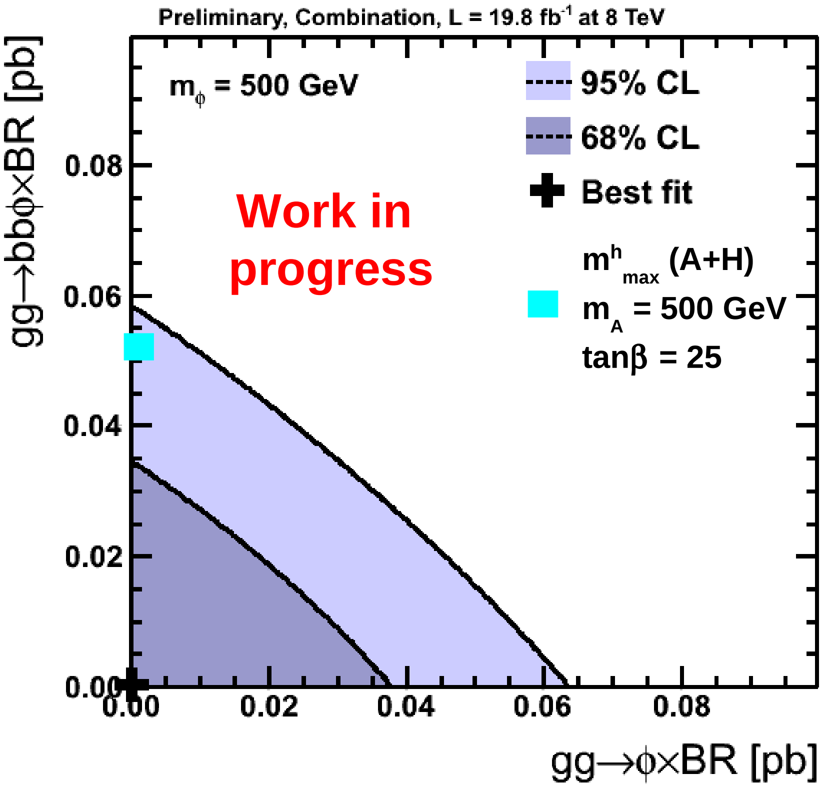
- A simple 2D likelihood scan of the ggΦ-bbΦ plane is performed





2D Likelihood scan - ggΦ vs bbΦ - SM-injected

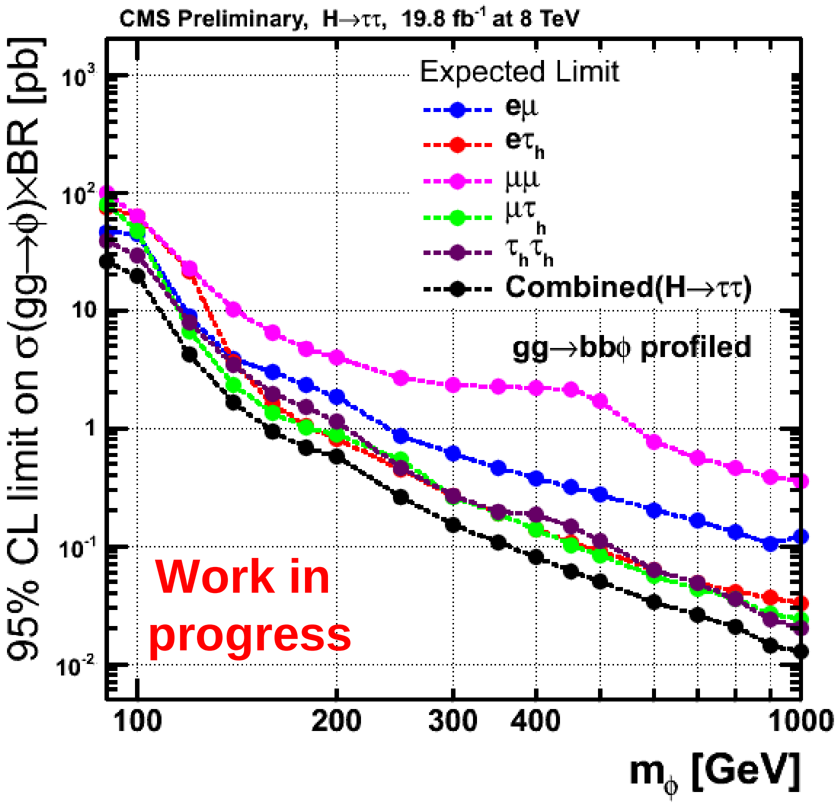
- Possible to test different BSM scentarios



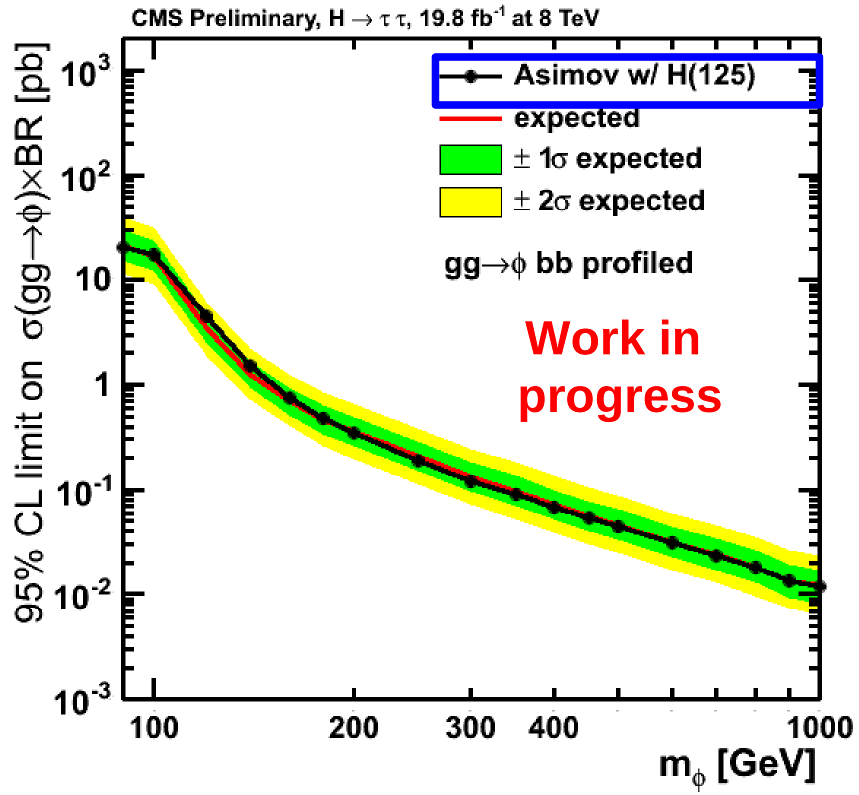
Limits on σ(ggΦ) * BR(ττ)

- Calculating upper limit on σ*BR(ggΦ → ττ) while σ*BR for bbΦ is profiled

Limits on σ(ggΦ) * BR(ττ)
comparison of expected Limits



Limits on σ(ggΦ) * BR(ττ)

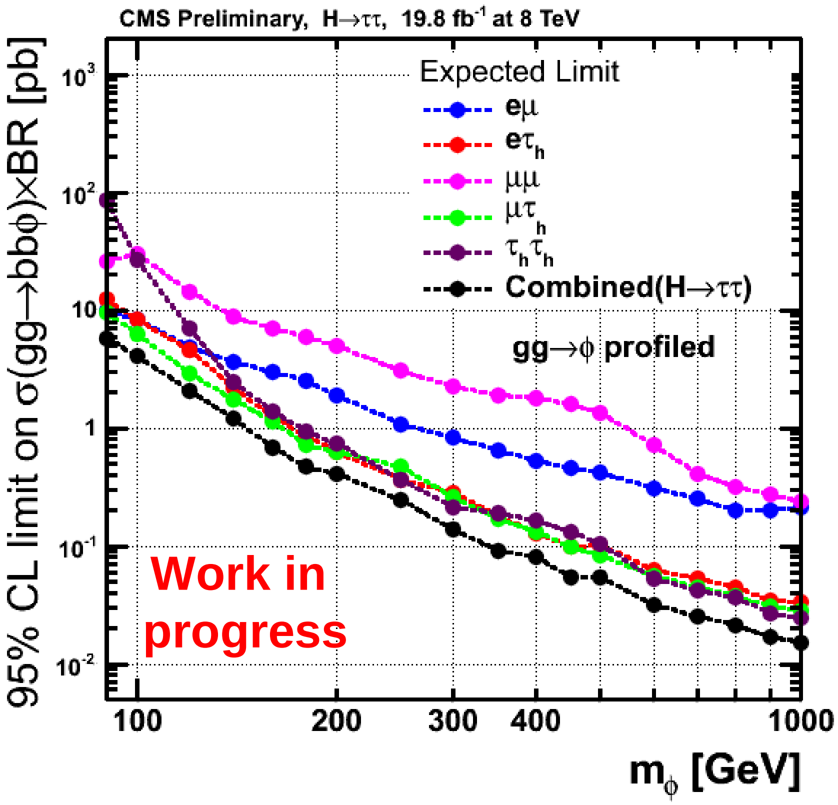


combined

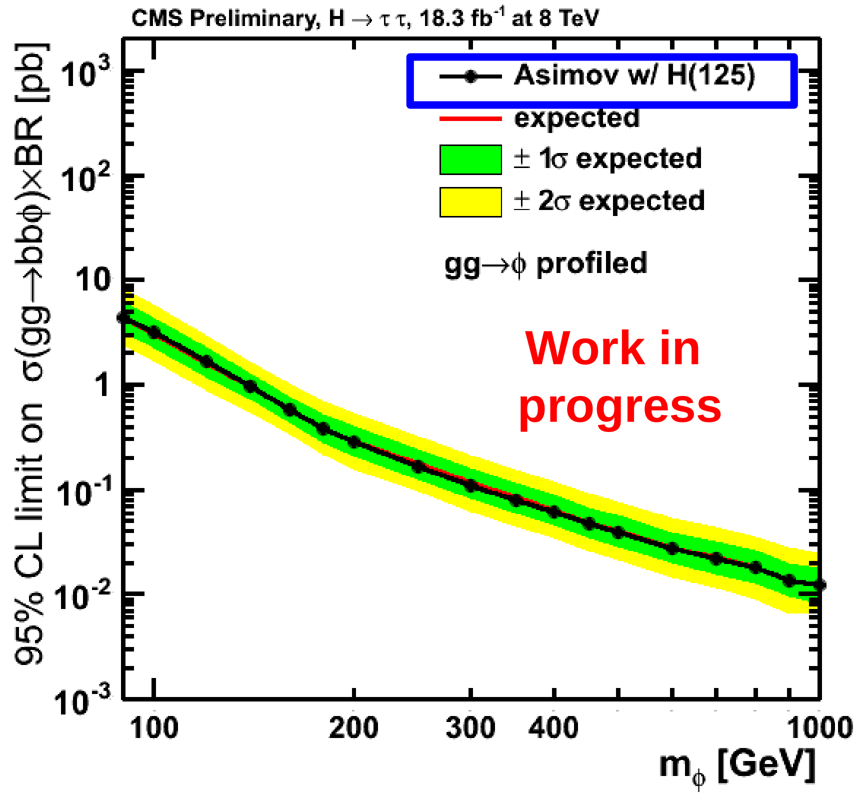
Limits on $\sigma(bb\Phi)$ * BR($\tau\tau$)

- Calculating upper limit on σ*BR($bb\Phi \rightarrow \tau\tau$) while σ*BR for $gg\Phi$ is profiled

Limits on $\sigma(bb\Phi)$ * BR($\tau\tau$) comparison of expected Limits



Limits on σ(bbΦ) * BR(ττ)



combined

BACKUP

Transverse mass M_T and P_ζ variable

- M_T is computed using the transverse mass of the electron (muon) plus the missing transverse energy of the event

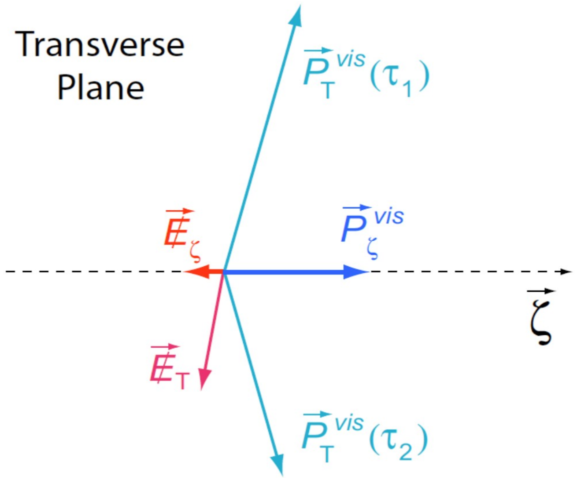
$$M_T = \sqrt{(P_T^\ell + \not{E}_\mathrm{T})^2 - \left((P_x^\ell + \not{E}_x)^2 + \left(P_y^\ell + \not{E}_y\right)^2\right)}$$

- The quantity $D_\zeta = P_\zeta - 1.85 \cdot P_\zeta^{vis}$ utilizes the fact that the angle between the neutrinos and the visible tau decay products is typically small

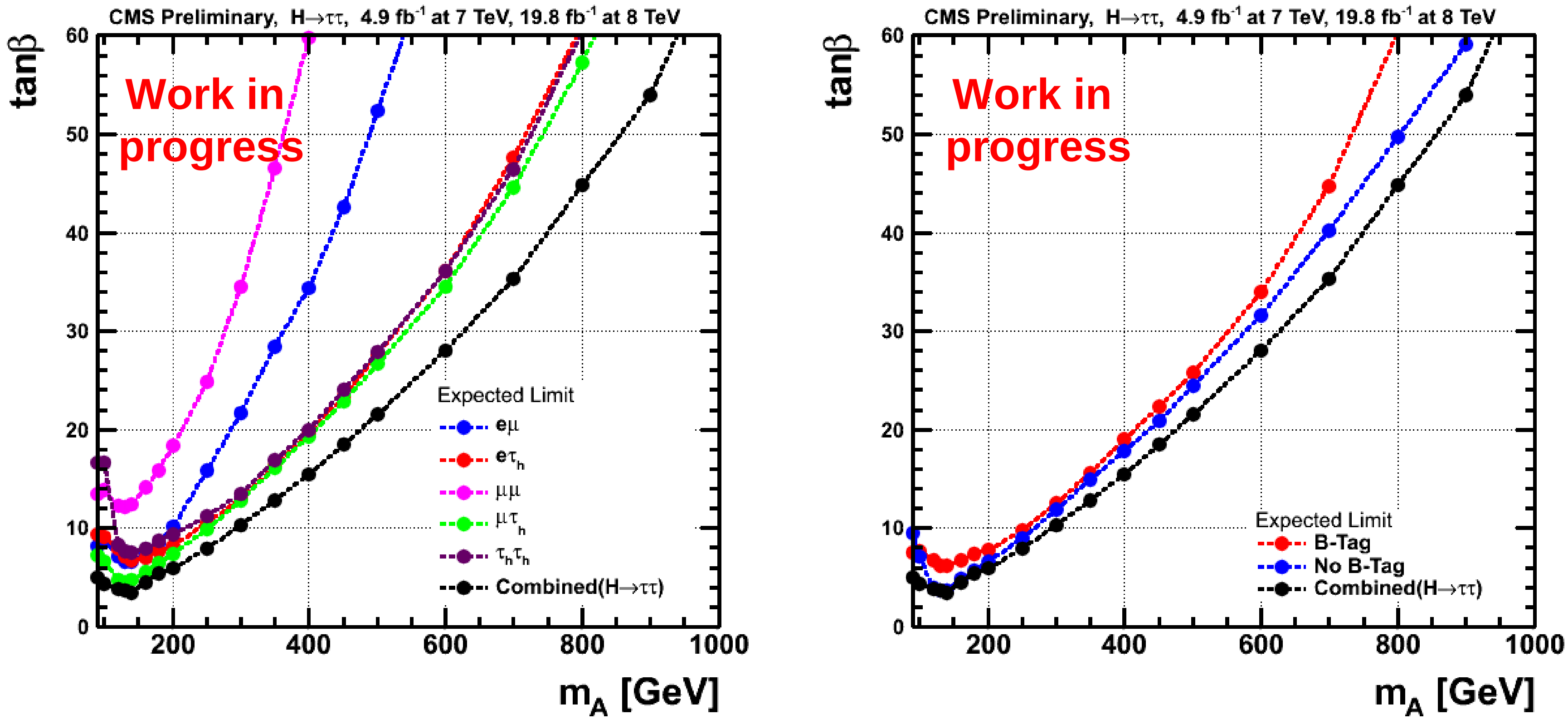
$$P_\zeta = P_T^{vis_1} + P_T^{vis_2} + \not{E}_\mathrm{T}$$

$$P_\zeta^{vis} = \vec{P}_T^{vis_1} + \vec{P}_T^{vis_2}$$

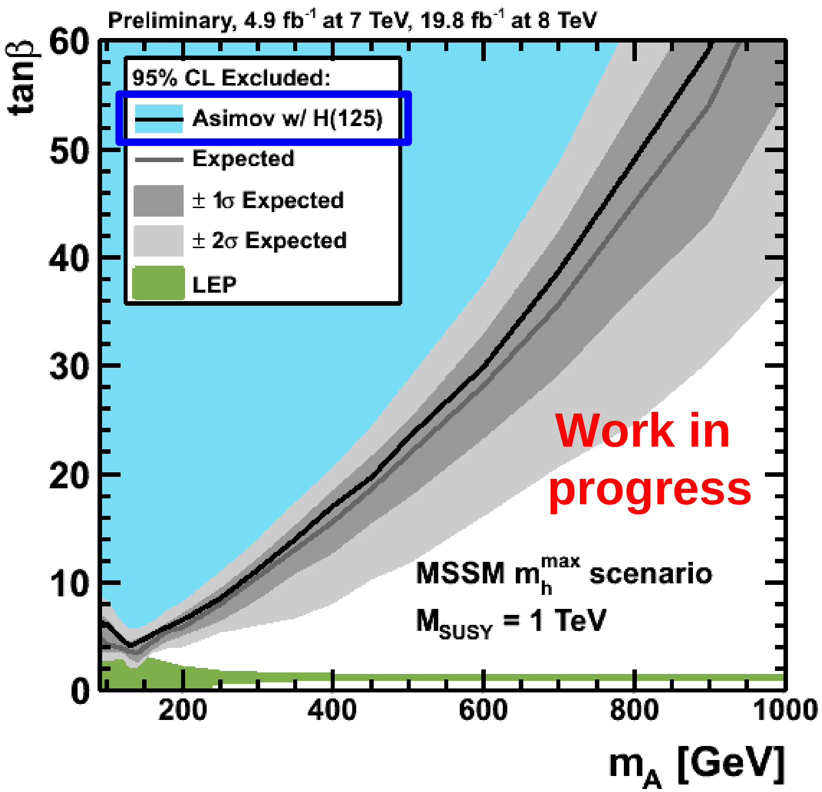
- Both used to suppress various sources of backgrounds mainly W+jets



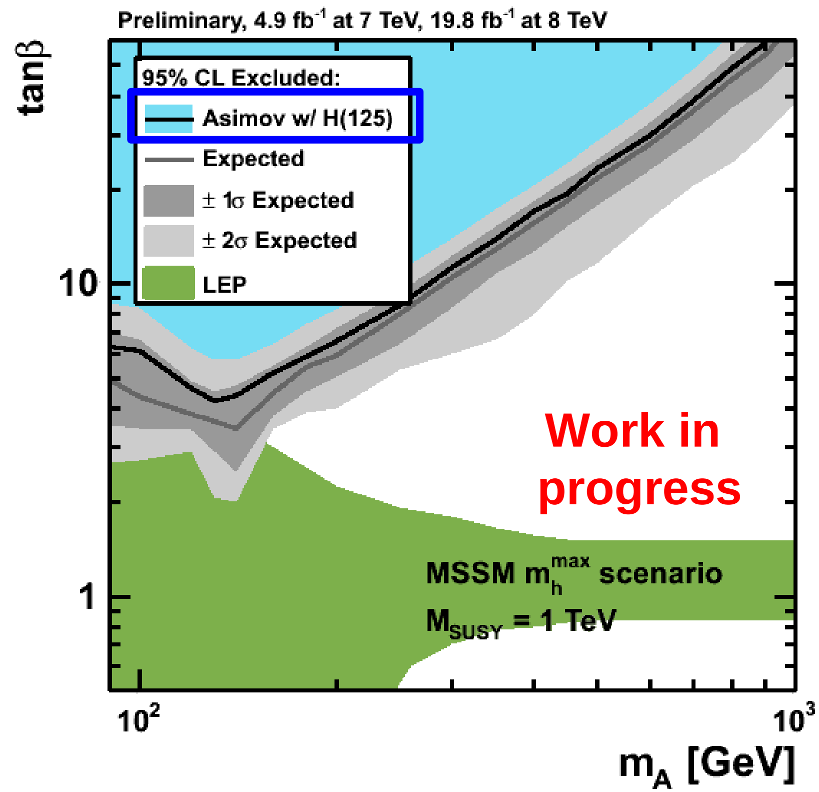
Limits in tanβ-m_A plane
comparison of expected Limits



Combined limit in tanβ-m_A plane

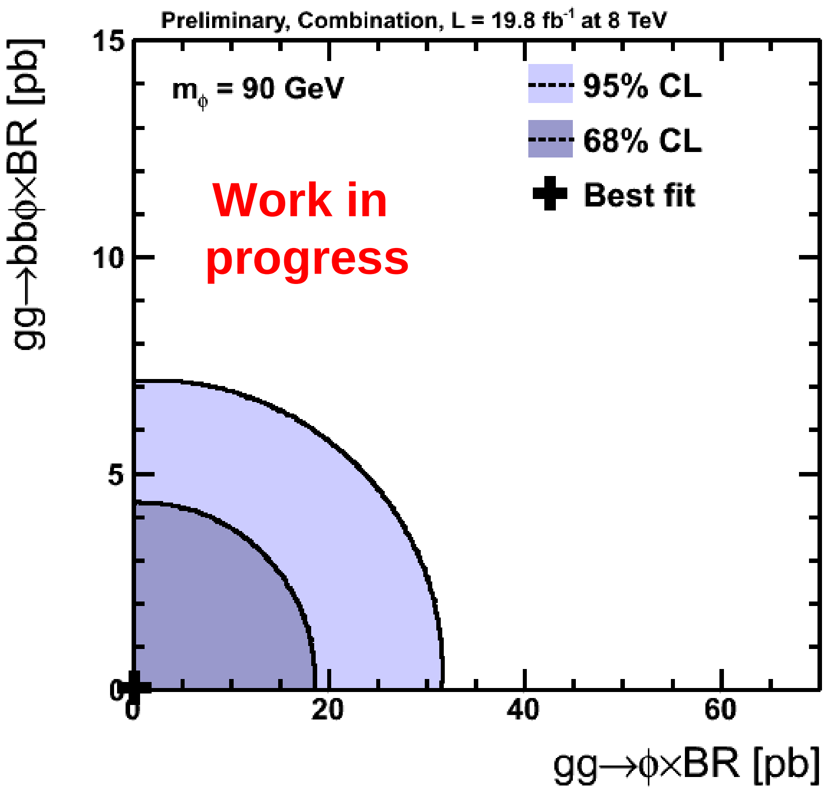


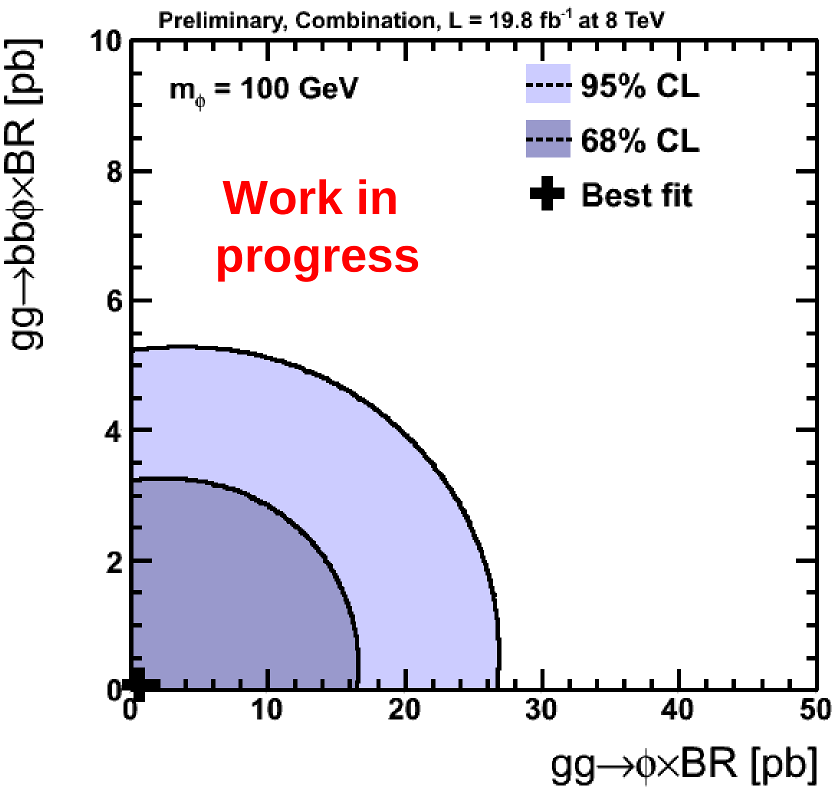
Linear



Logarithmic

2D Likelihood scan - ggΦ vs bbΦ - SM-injected





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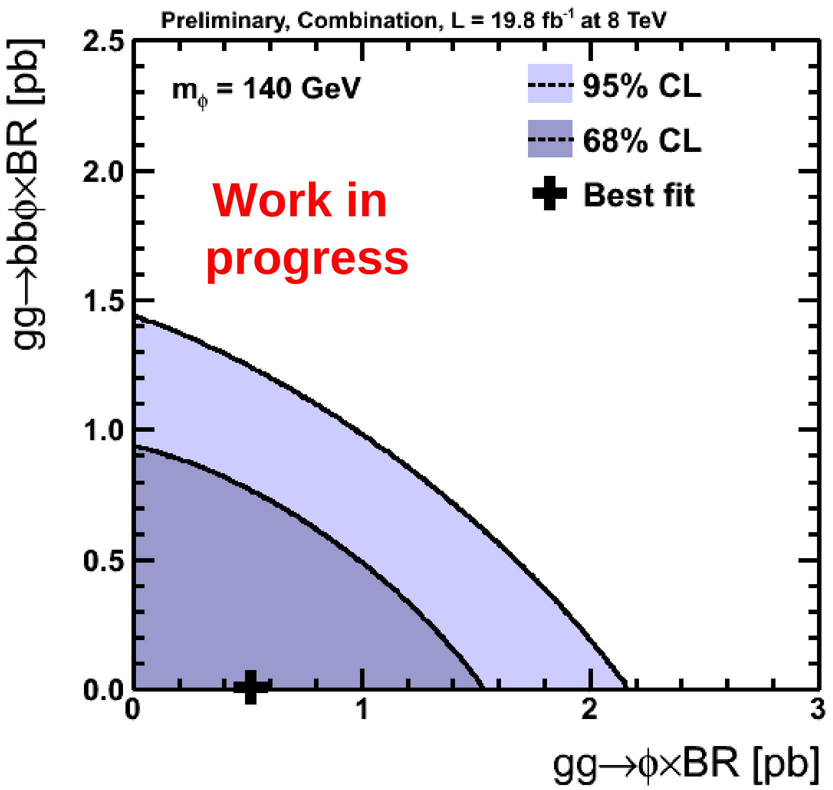

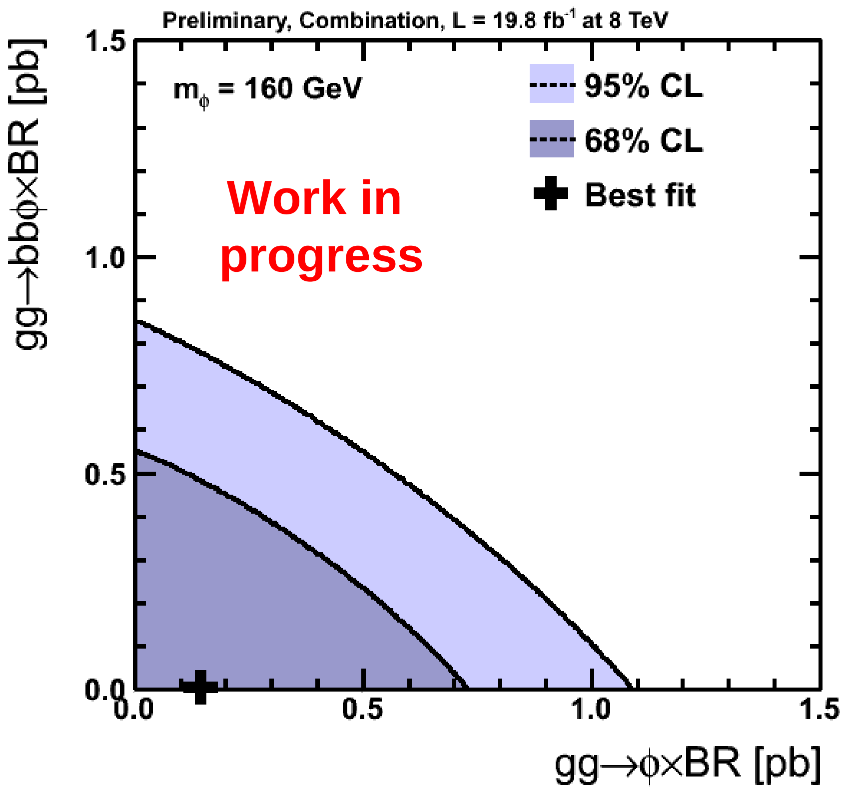

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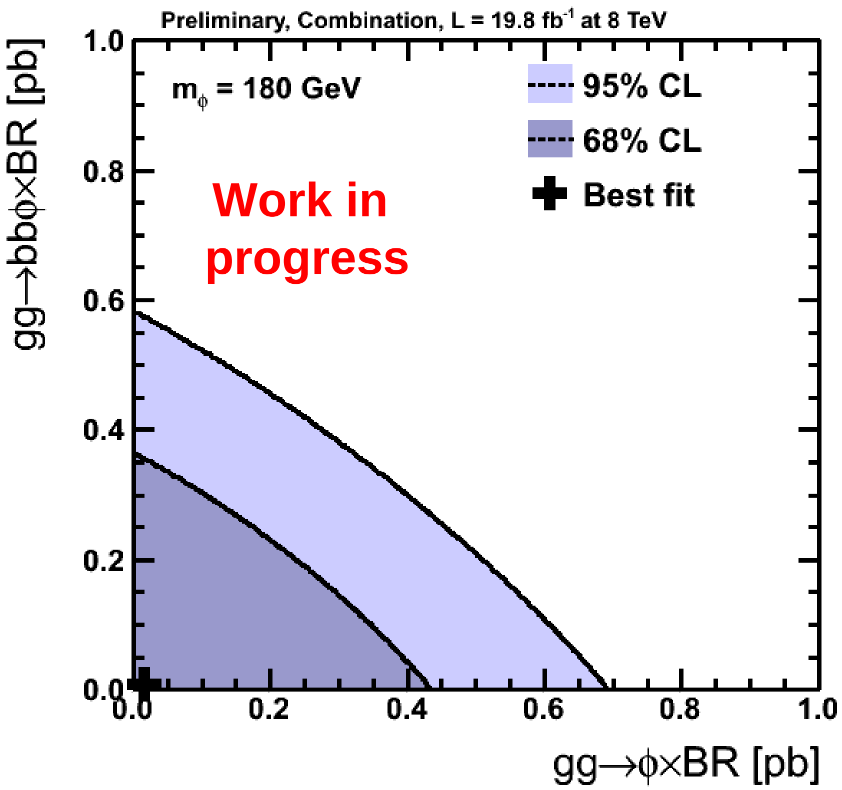

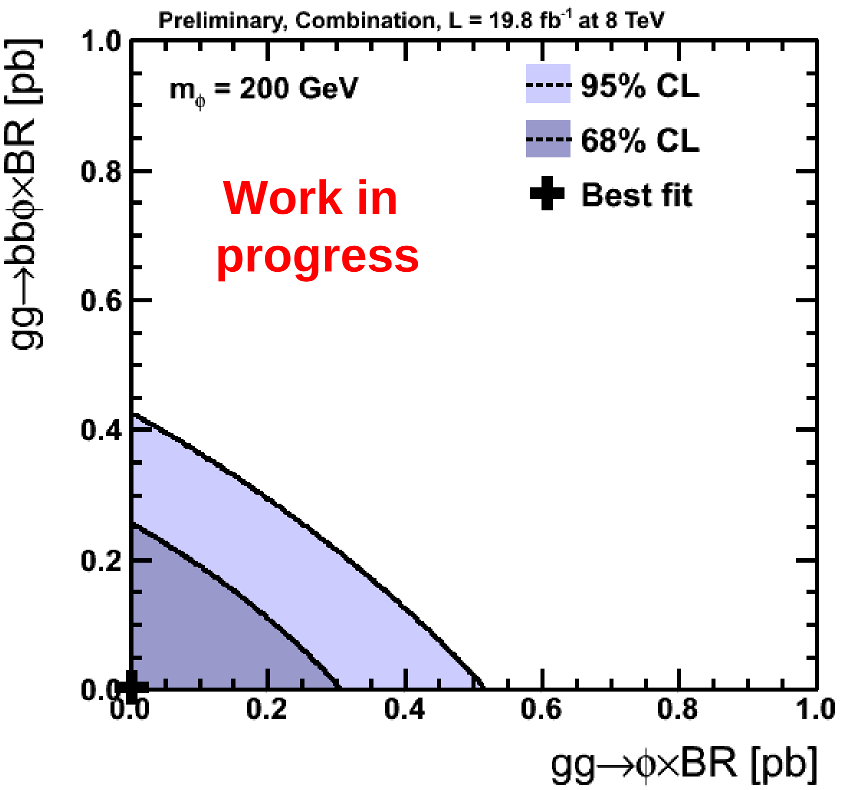

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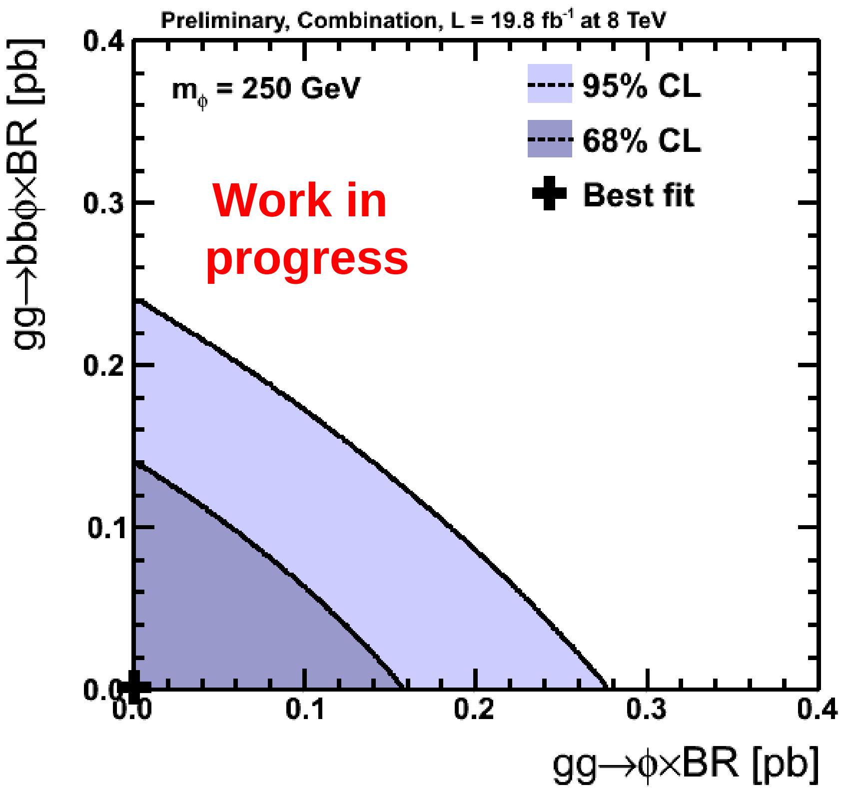

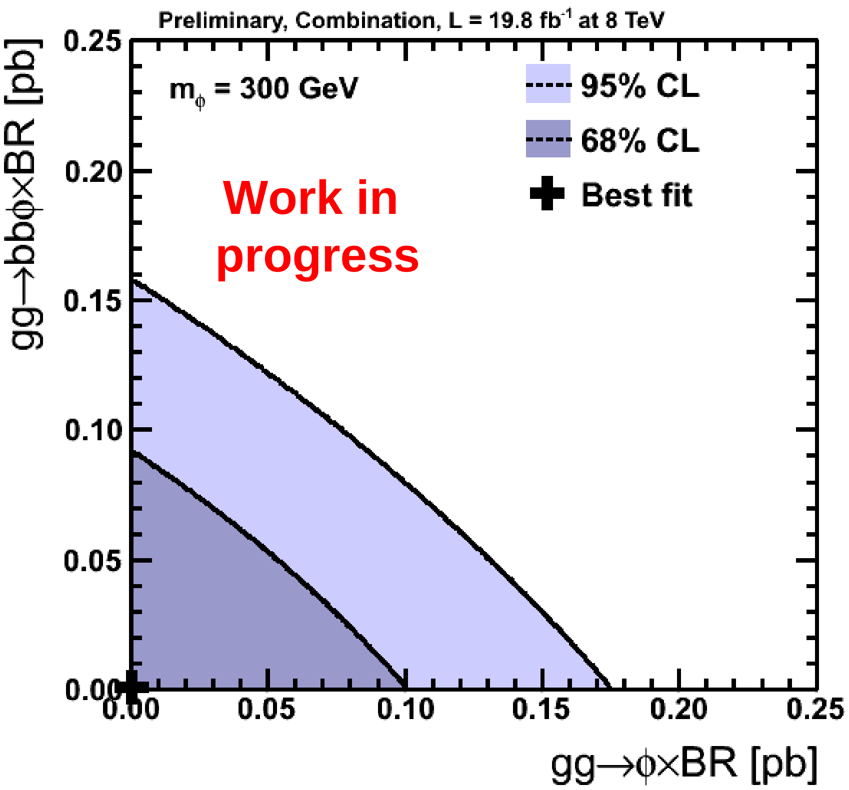

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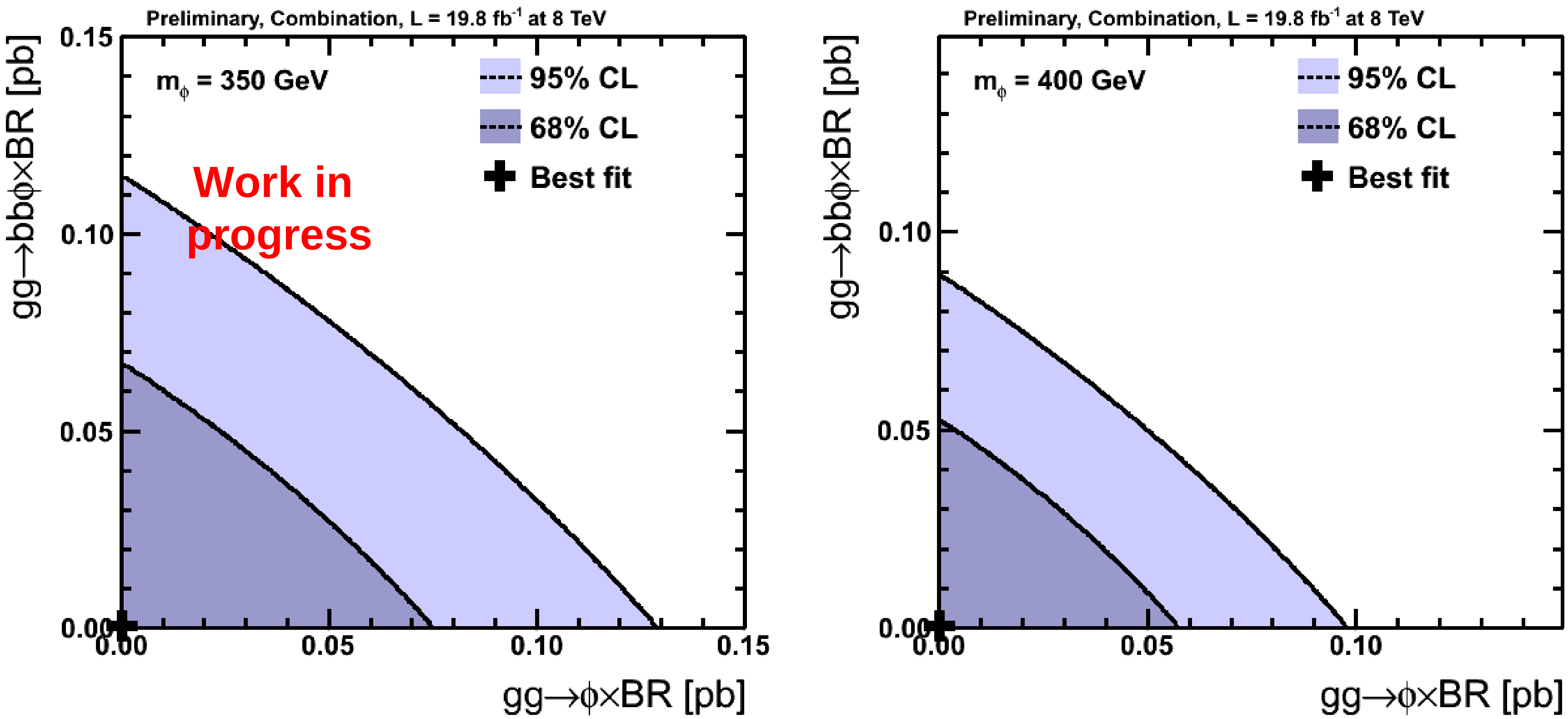

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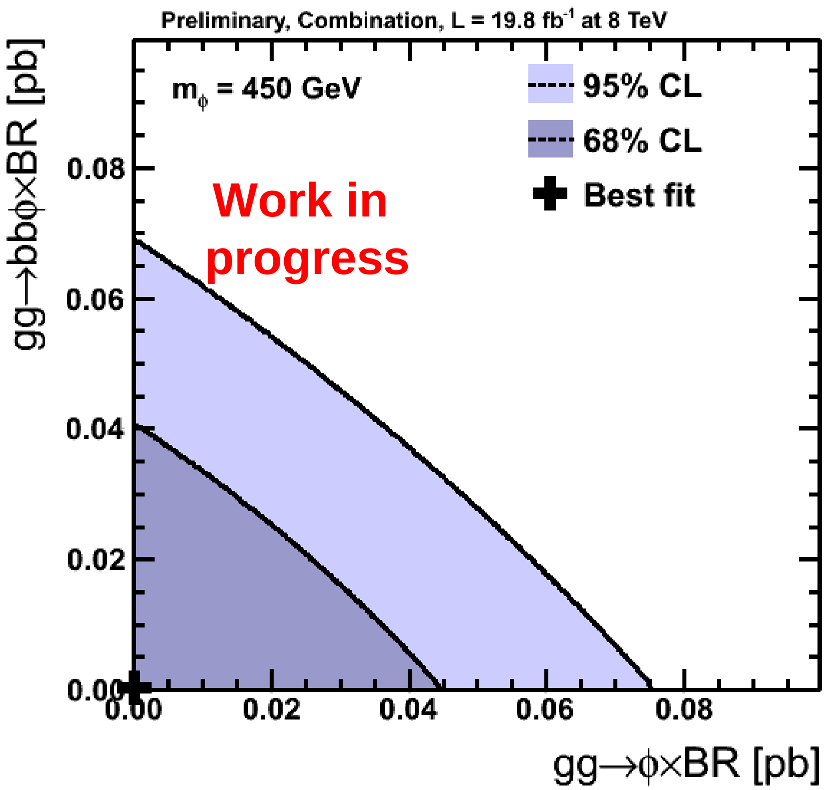

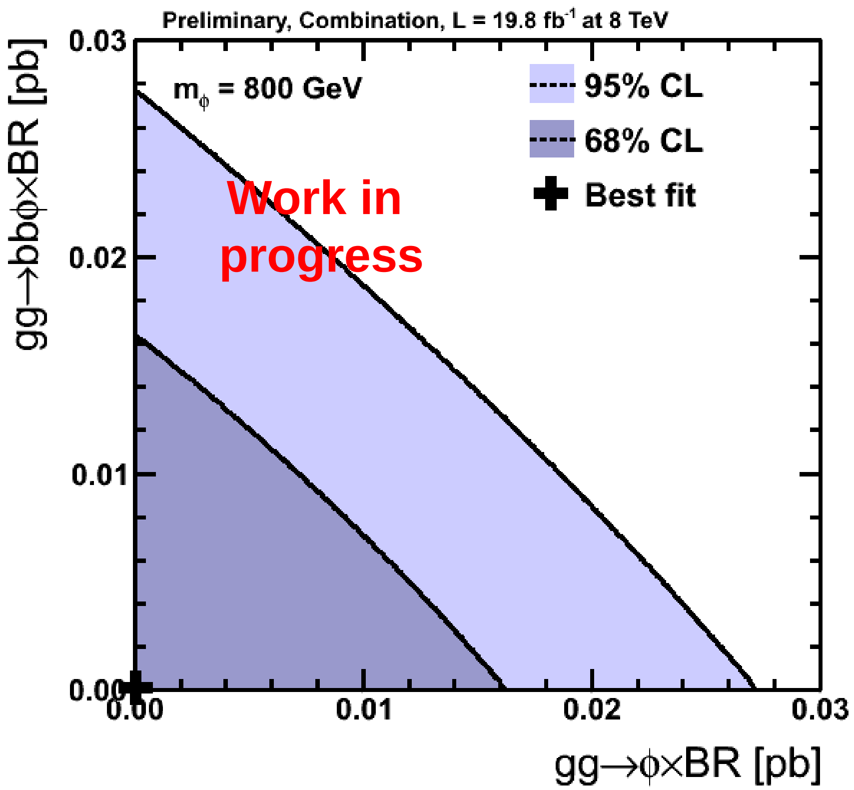

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