COMPUTER MODELING OF THE PRODUCTION MODE OF MSSM HIGGS BOSON

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Mass reconstruction of MSSM Higgs boson, arXiv:1904.11525 [hep-ph]

PLAN OF THE TALK

- *Properties of Higgs boson;*
- *tt decay of A boson;*
- *b-tagging algorithm;*
- *Comprehensive computer modeling;*
- *pp →A →tt process;*
- *Results of calculations;*
- *Conclusions.*

PROPERTIES OF HIGGS BOSON

Yukawa coupling to fermions:

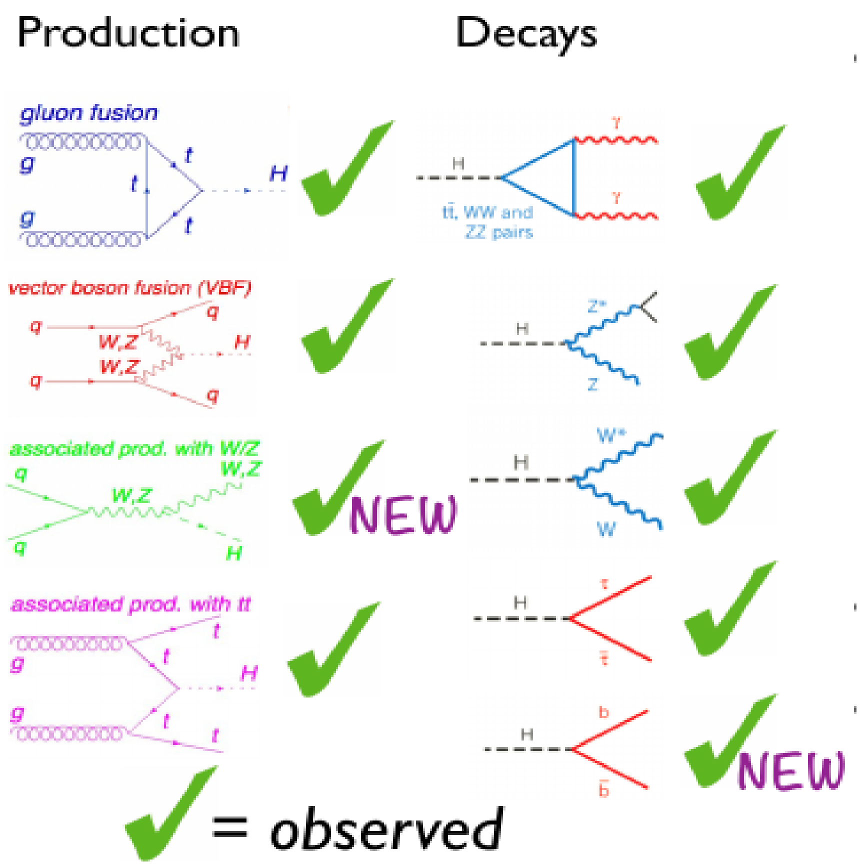
Top-quark: ttH **80 fb^{-1}**
6.3σ (5.1σ) obs (exp) arXiv:1806.00425

Beauty-quark $H \to bb$: **80 fb^{-1}** New
5.4σ (5.5σ) obs (exp) ATLAS-CONF-2018-036

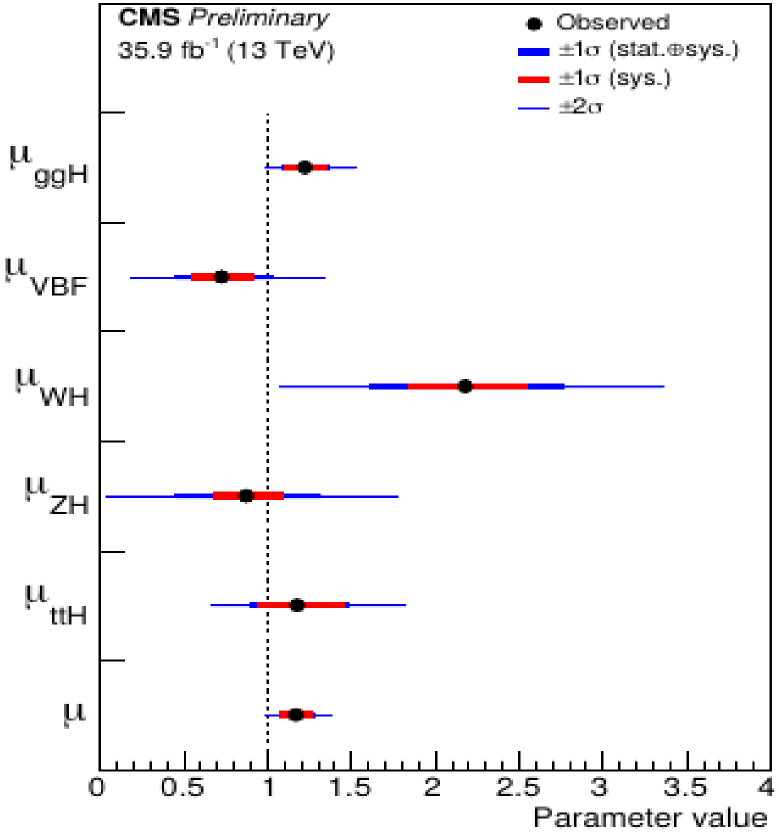
Tau-lepton: $H \to \tau\tau$
6.4σ (5.4σ) obs (exp) ATLAS-CONF-2018-021

Muon $H \to \mu\mu$: **80 fb^{-1}** New
$\sigma_{limit}/\sigma_{SM}$<2.1 (obs) ATLAS-CONF-2018-026

Charm-quark: $H \to cc$:
$\sigma_{limit}/\sigma_{SM}$<104 (obs) PRL 120 (2018) 211802



PROPERTIES OF HIGGS BOSON



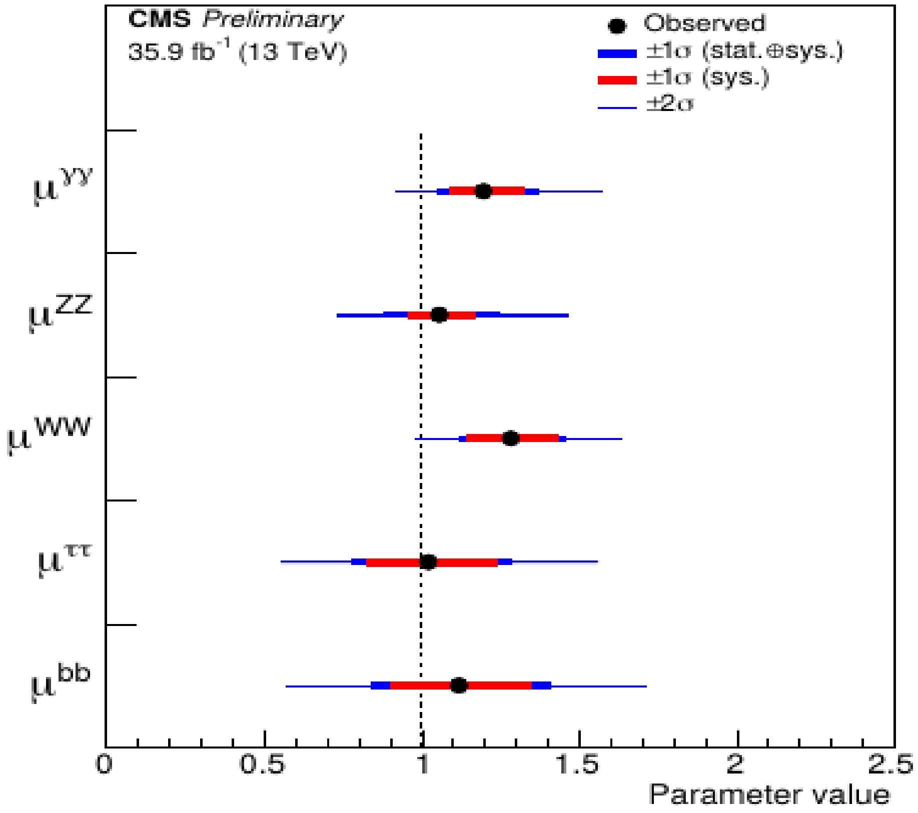
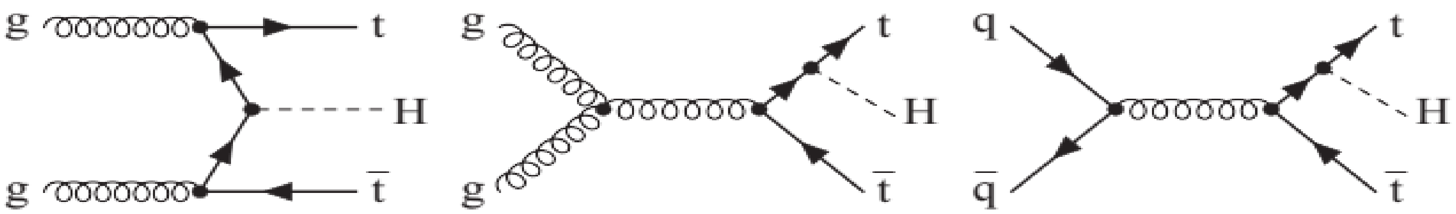
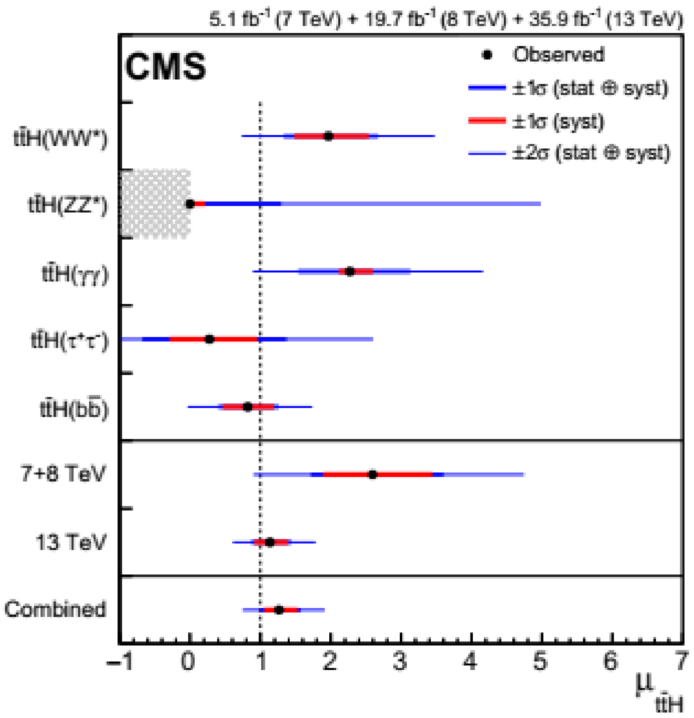


Figure 2. The total result of the mode of formation (left) and the mode of decay (right) of the Higgs boson.

$$\mu_i = \frac{\sigma_i}{(\sigma_i)_{\mathrm{SM}}} \quad \text{and} \quad \mu^f = \frac{\mathrm{BR}^f}{(\mathrm{BR}^f)_{\mathrm{SM}}}.$$

PROPERTIES OF HIGGS BOSON





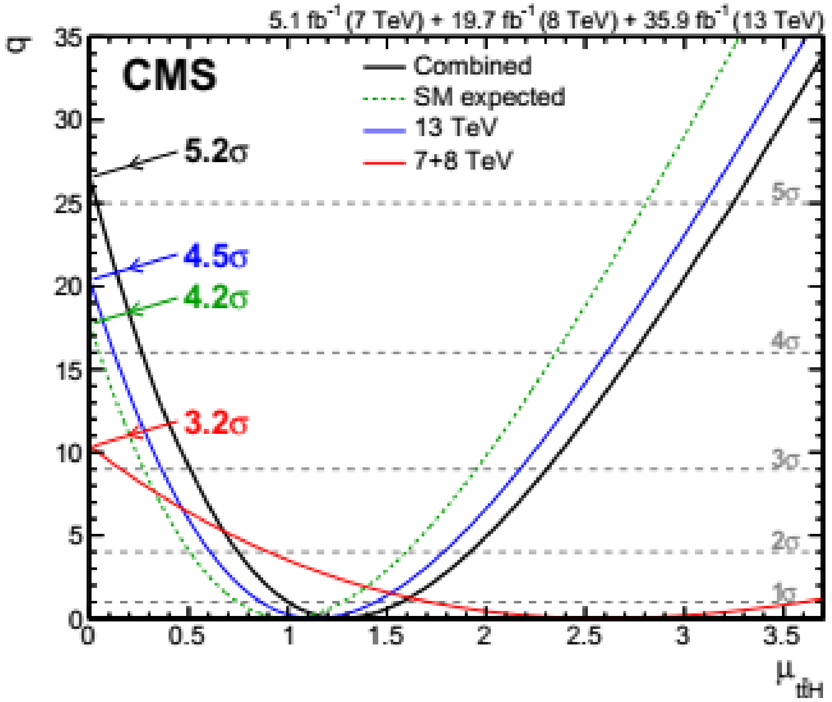


Figure 1. Modes of the Higgs boson decays (left) and test statistics q for all decay channels at energies 7 + 8 TeV and at 13 TeV.

PROPERTIES OF HIGGS BOSON

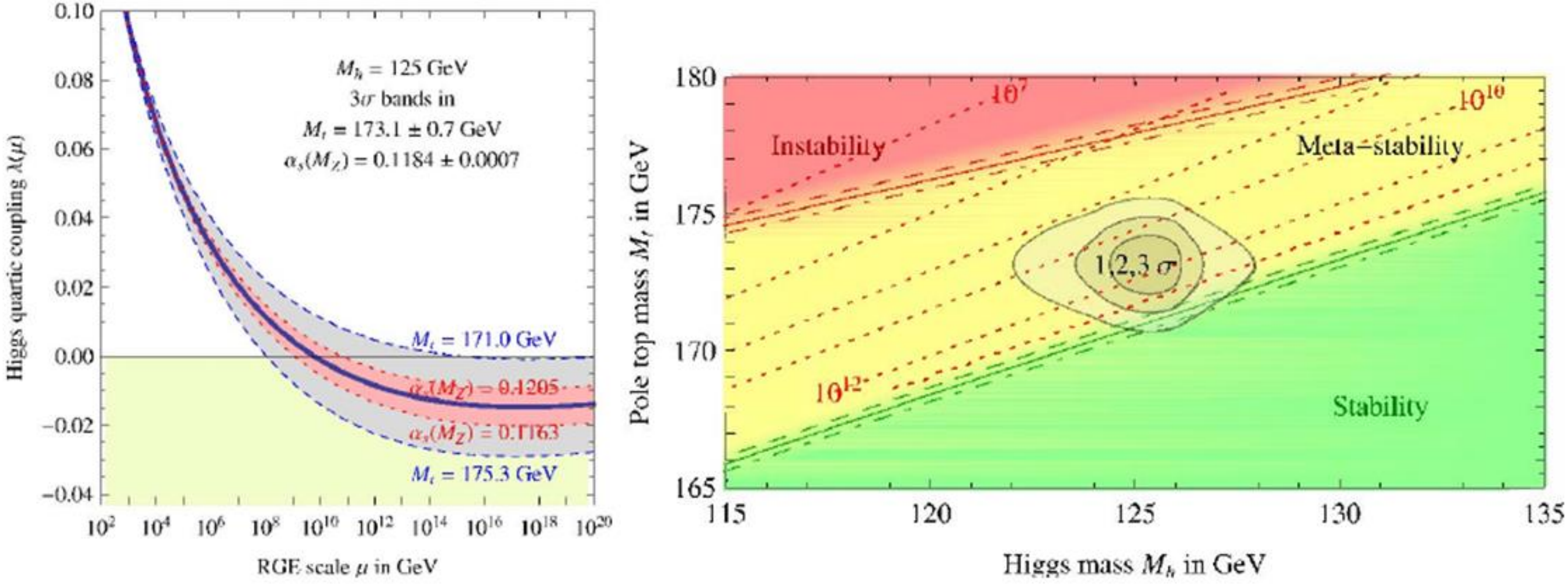


Figure 2. *Left*: RG evolution of λ varying M_t and α_s by $\pm 3\sigma$. *Right*: Regions of absolute stability, metastability and instability of the SM vacuum in the M_t–M_h plane in the region of the preferred experimental range of M_h and M_t (the gray areas denote the allowed region at 1, 2, and 3σ). The three boundaries lines correspond to $\alpha_s(M_Z) = 0.1184 \pm 0.0007$, and the grading of the colors indicates the size of the theoretical error. The dotted contour-lines show the instability scale Λ in GeV assuming $\alpha_s(M_Z) = 0.1184$.

PROPERTIES OF HIGGS BOSON

$$
\begin{aligned}
\mathcal{L} = {} & \kappa_3 \frac{m_H^2}{2v} H^3 + \kappa_Z \frac{m_Z^2}{v} Z_\mu Z^\mu H + \kappa_W \frac{2m_W^2}{v} W_\mu^+ W^{-\mu} H \\
& + \kappa_g \frac{\alpha_s}{12\pi v} G_{\mu\nu}^a G^{a\mu\nu} H + \kappa_\gamma \frac{\alpha}{2\pi v} A_{\mu\nu} A^{\mu\nu} H + \kappa_{Z\gamma} \frac{\alpha}{\pi v} A_{\mu\nu} Z^{\mu\nu} H \\
& + \kappa_{VV} \frac{\alpha}{2\pi v} \left(\cos^2\theta_W Z_{\mu\nu} Z^{\mu\nu} + 2\, W_{\mu\nu}^+ W^{-\mu\nu} \right) H \\
& - \left(\kappa_t \sum_{f=u,c,t} \frac{m_f}{v} f\overline{f} + \kappa_b \sum_{f=d,s,b} \frac{m_f}{v} f\overline{f} + \kappa_\tau \sum_{f=e,\mu,\tau} \frac{m_f}{v} f\overline{f} \right) H.
\end{aligned}
$$

PROPERTIES OF HIGGS BOSON

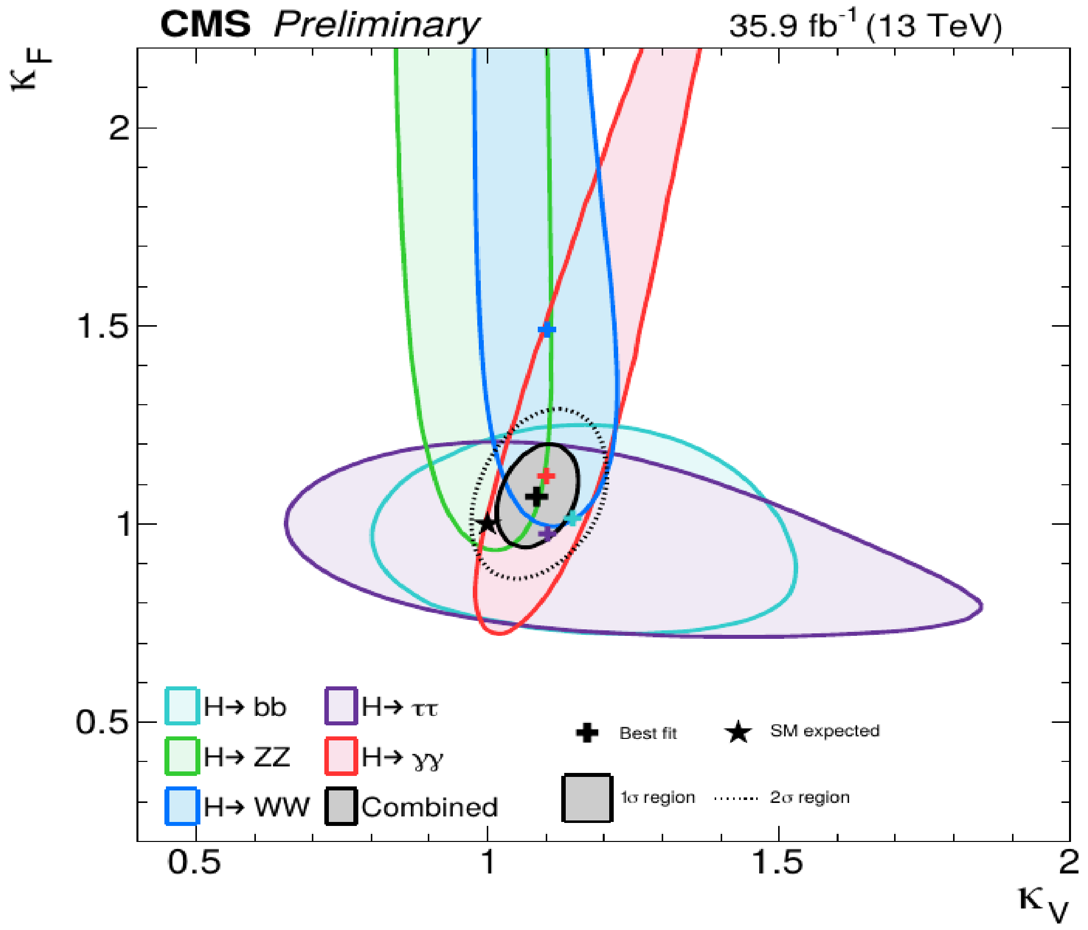


Figure 3. 1σ and 2σ CL fields in the κF and κV parameters space.

SUPERSYMMETRY THEORY

$$\frac{1}{\alpha_G} = \frac{1}{\alpha_i(M_Z)} - \frac{b_i^{MSSM}}{2\pi} \ln\left(\frac{M_{GUT}}{M_Z}\right) + \gamma_i + \frac{1}{\alpha_i^{Sthr}} + \Delta_i$$

γ_i contains the two loop contributions to the beta function

one loop threshold corrections to $1/\alpha_i(M_Z)$ $\quad \frac{1}{\alpha_i^{Sthr}} = \sum_{\eta, M_\eta > M_Z} \frac{b_i^\eta}{2\pi} \ln\left(\frac{M_\eta}{M_Z}\right),$

b_i^{MSSM} is the one loop beta function coefficient $\quad \Delta_1 = 0,\ \Delta_2 = -1/6\pi,\ \Delta_3 = -1/4\pi$

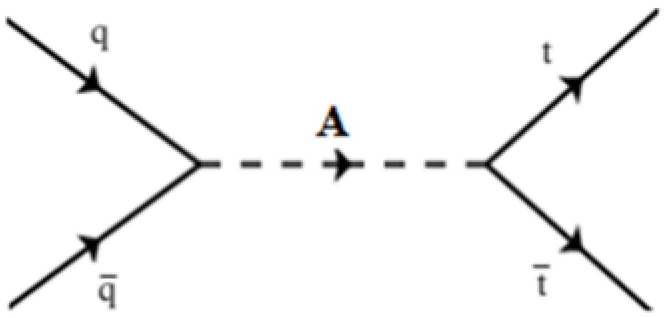
$(16/3)\alpha_3(m_t) \simeq 6Y_t(m_t) + Y_b(m_t)$ $\quad$ for moderate values of $\tan\beta$, it follows that $Y_b(m_t) \ll \alpha_3(m_t)$

we can determine the value of the top quark Yukawa coupling as a function of the strong gauge coupling constant

$$m_t(m_t) \simeq h_t(m_t) \frac{v \tan\beta}{\sqrt{1 + \tan^2\beta}}$$

the top quark Yukawa coupling decreases with increasing tan β

DECAY OF A BOSON



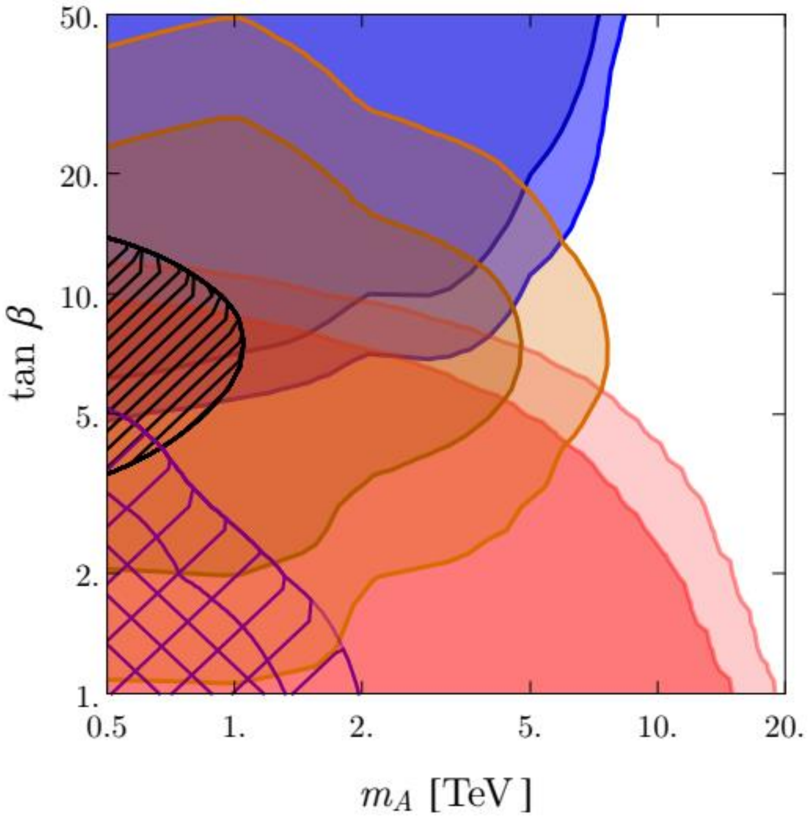
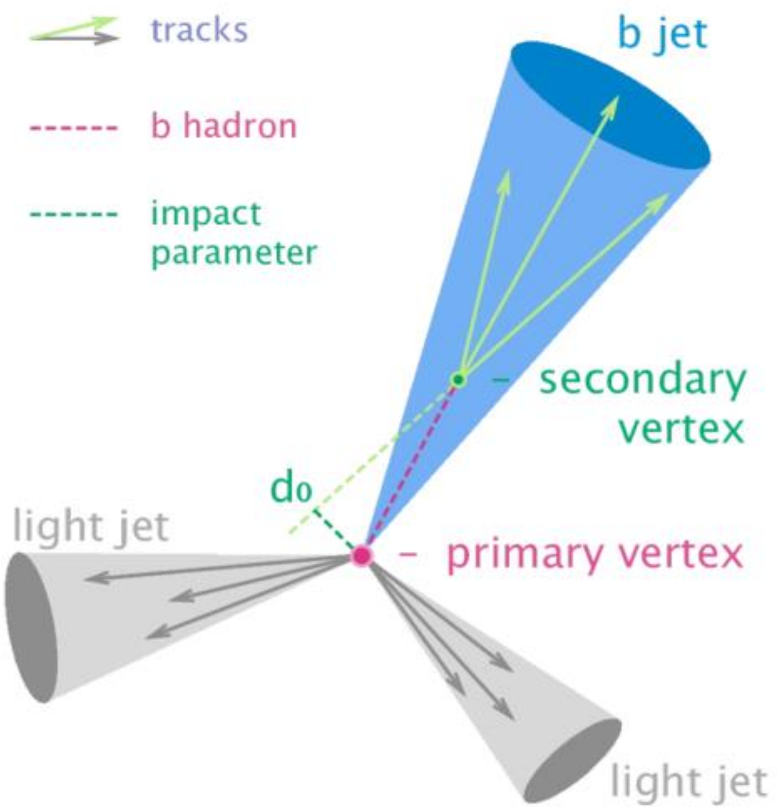


Figure 4. Exclusion sensitivity for neutral heavy Higgs bosons. The low tan*b* region (red) is covered by ttH, H -> tt. The intermediate tan*b* region (orange) is covered by b-associated production with H -> tt decays. The large tan*b* region (blue) is covered by b-associated production with *tt* decays.

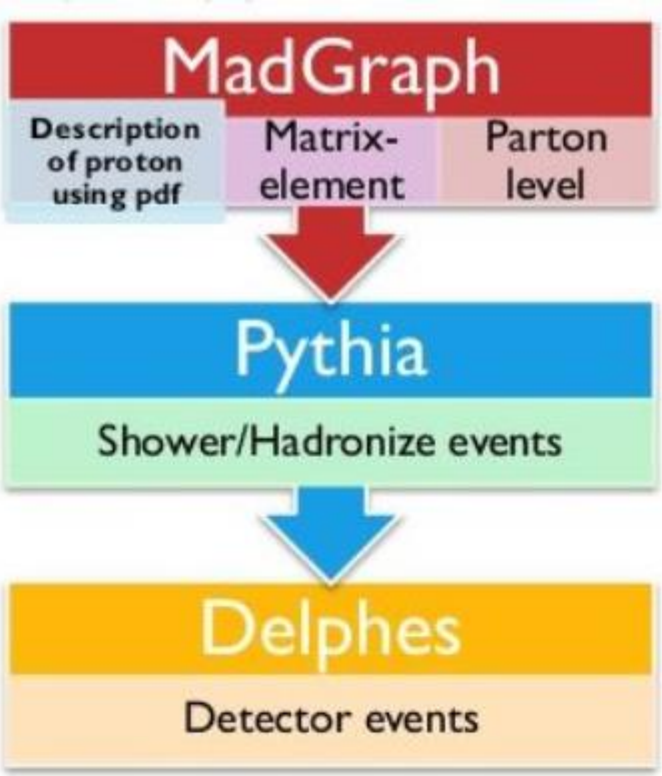
[1] N. Craig, J. Hajer, Y. Li, T. Liu, H. Zhang, *Heavy Higgs bosons at low* tanb*: from the LHC to 100 TeV*, JHEP 01 (2017) 018.

B-TAGGING ALGORITHM

- Hadrons with b-quarks are long-lived;
- The presence of a secondary vertex;
- Tracks with a large impact parameter;
- Bottom quarks are more massive ~ 5 GeV, therefore decay products have large pT;
- b-jets have a large multiplicity and invariant mass.

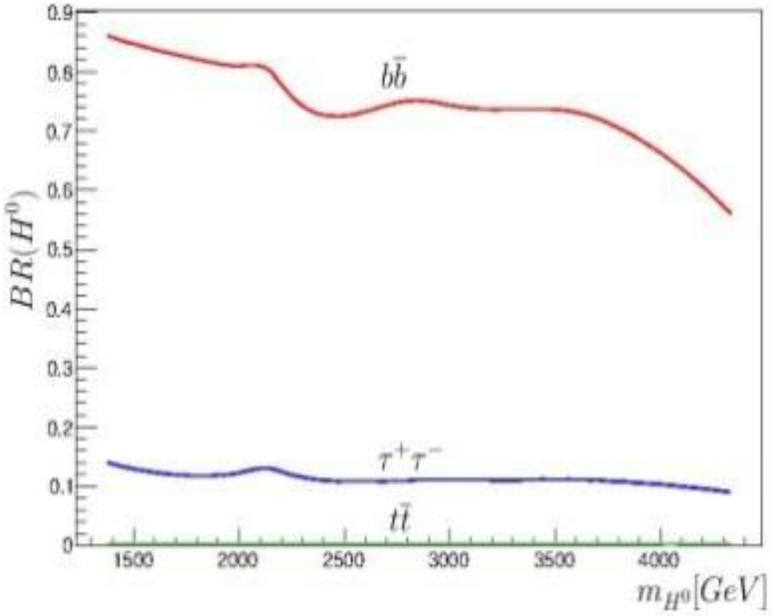


COMPREHENSIVE COMPUTER MODELING



- With the help of the program MadGraph, we carried out a calculation of the production cross sections of the processes under consideration. Simulation of further developments, i.e. all information on decomposition products and their kinematic data was produced using the Pythia program.
- For our calculations with Pythia we used the latest experimental constraints on the low tanβ region covered by H → tt processes, [1901.05269].
- The response of the detector to the resulting array of events was carried out using Delphes program. We made a selection of events on the basis of additional kinematic restrictions associated with the peculiarities of the reactions under consideration and the b-tagging method.

A DECAY PROCESS



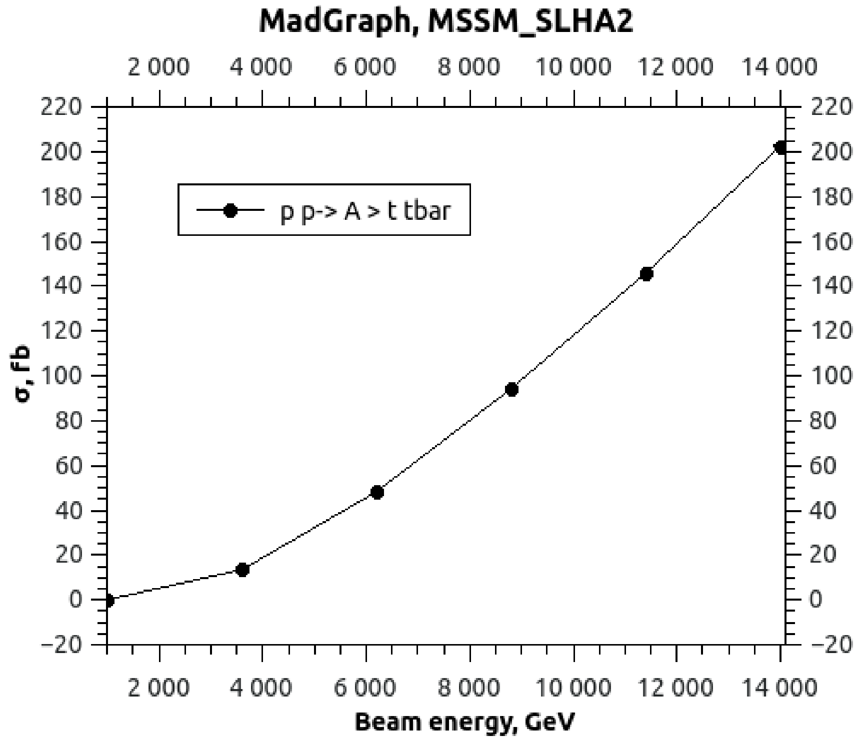


Figure 5. The branching fractions of H 0 to bb (red), τ + τ − (blue), tt (green).

Figure 6. Production cross section of the pp→A→tt process.

RESULTS OF CALCULATIONS

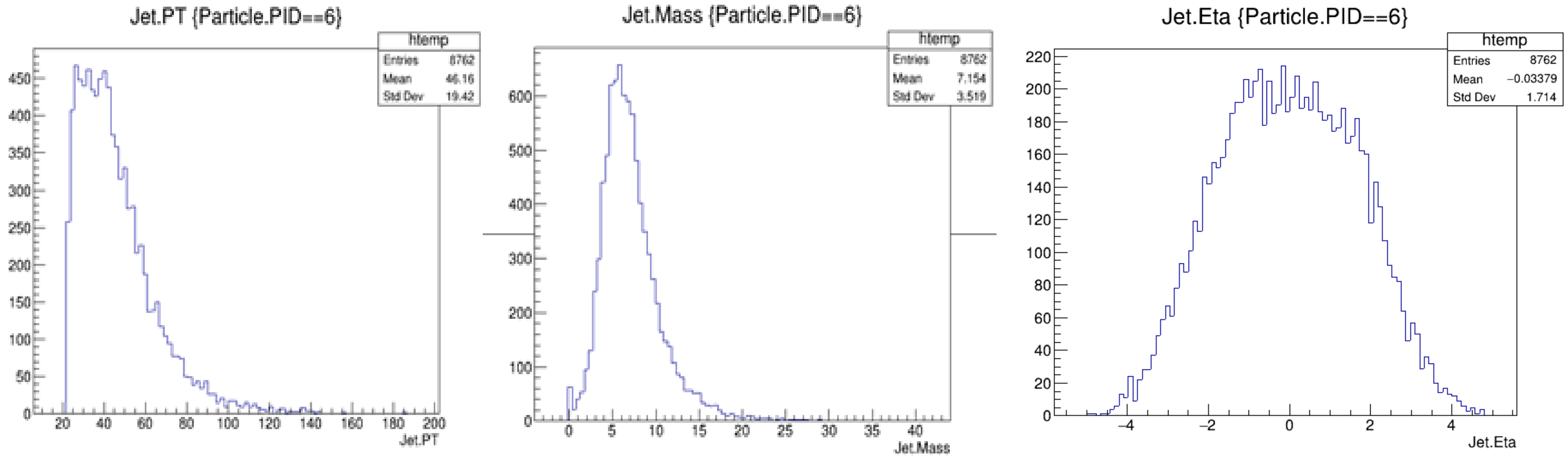


Figure 7. Modeling of kinematic properties of jets from the reaction pp→A→tt a) jet p_T distribution (left) and jet mass (right); b) jet eta distribution.

RESULTS OF CALCULATIONS

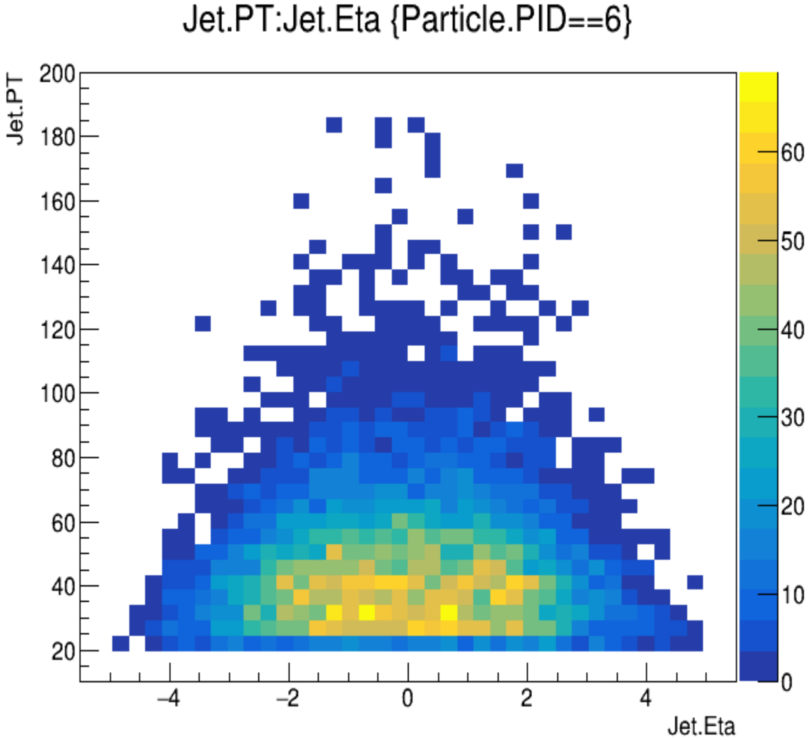


Figure 8. Distribution for jets in the momenta and angles for the reaction pp→A→tt.

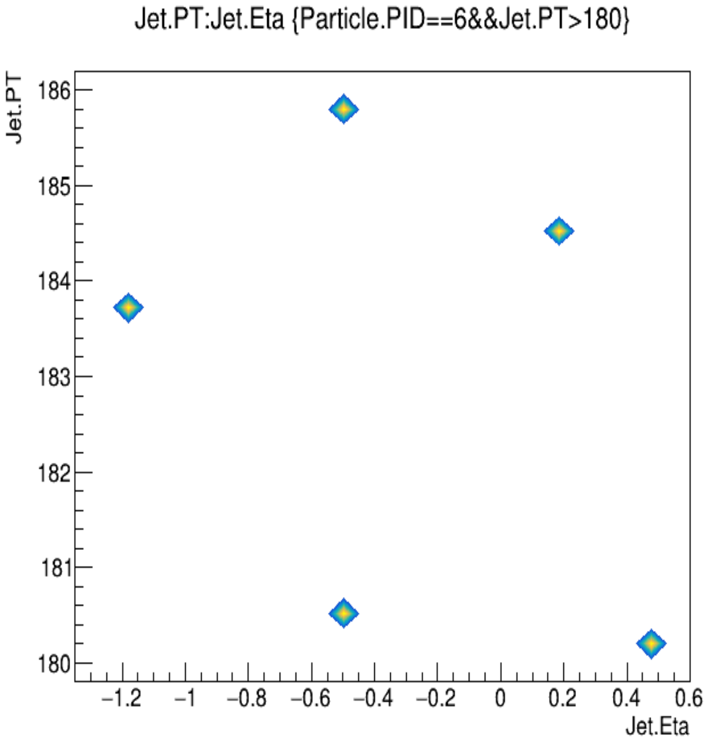


Figure 9. The most energetic jets in the p_t range 180-186 GeV/c and jet eta>|1.2| for the reaction pp→A→tt.

CONCLUSIONS

- *We have considered one of the most important channels of the MSSM Higgs boson production and decay.*
- *Since this channel is associated with the formation and decay of top quarks, whose properties shed light on the instability of an electroweak vacuum, the study of such reactions seems to us the most relevant.*
- *MSSM Higgs bosons are the lightest supersymmetric particles predicted by supersymmetry. Therefore, finding their masses at the LHC collider is possible in the near future, which would remove a lot of theoretical questions related to symmetries and unification of interactions.*
- *Using programs to simulate the processes and response of the detector, as well as strict kinematic cuts on the angles and momenta of particles associated with the experimental data, we calculated the mass of A boson equal to 370 GeV/c.*