MSSM-Higgs + jet production at the LHC

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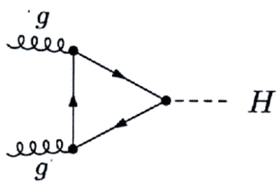
outline :

- Higgs + Jet in the Standard Model
- Higgs + Jet in the MSSM
- Results

• Higgs + Jet in the Standard Model

Higgs production @ LHC mainly via gluon fusion:



Detection ($m_H \approx 100-140$GeV): mainly via the rare decay $H \to \gamma\gamma$.
→ difficult ! huge background

– Higgs + Jet [R.K. Ellis et al. '87; Baur, Glover '89]

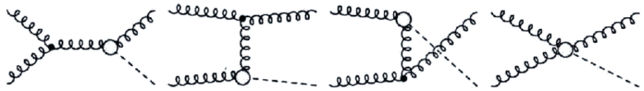
idea: study events with a high-p_T hadronic jet.

advantage:
* richer kinematical structure compared to inclusive Higgs production.
→ better S/B ratio
→ allows for refined cuts

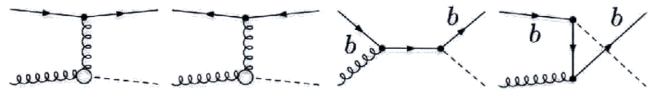
disadvantage:
* lower rate than inclusive Higgs production
* signal and background only known in LO
→ large theoretical uncertainties (so far)

H+jet, partonic processes (mostly loop-induced):

- $gg \to Hg$ (≈ 50 - 70 % of total rate)



- $qg \to Hq, \bar{q}g \to H\bar{q}$ (≈ 30 - 50 % of total rate)



- $q\bar{q} \to Hg$ (rate small)

Recently simulated: $pp \to H+\text{jet}, H \to \gamma\gamma$

[Abdullin et al. '98 & '02]

Result: H+jet production (with $p_{T,\text{jet}} \geq 30$ GeV, $|\eta_{\text{jet}}| \leq 4.5$) is a promising alternative (supplement) to the inclusive SM Higgs production for $m_H \approx 100-140$GeV,

but theoretical predictions need improvement.

[Abdullin et al., ATLAS TDR '99]

• Higgs + Jet in the MSSM

Motivation:

* promising simulation results in the SM case
* MSSM prediction for h^0 + jet not known yet
* process loop-induced: potentially large effects from virtual particles

– partonic processes

similar to the SM:

gluon fusion	$gg \to h^0 g$,
quark-gluon scattering	$q(\bar{q})g \to h^0 q(\bar{q})$,
$q\bar{q}$ annihilation	$q\bar{q} \to h^0 g$

but:

* different Higgs Yukawa-couplings

$$g^{\text{SM}}_{q\bar{q}H} = \frac{e}{2s_W}\frac{m_q}{m_W} \longrightarrow g^{\text{MSSM}}_{q\bar{q}h^0} = \frac{e}{2s_W}\frac{m_q}{m_W} f_q(\alpha,\beta),$$

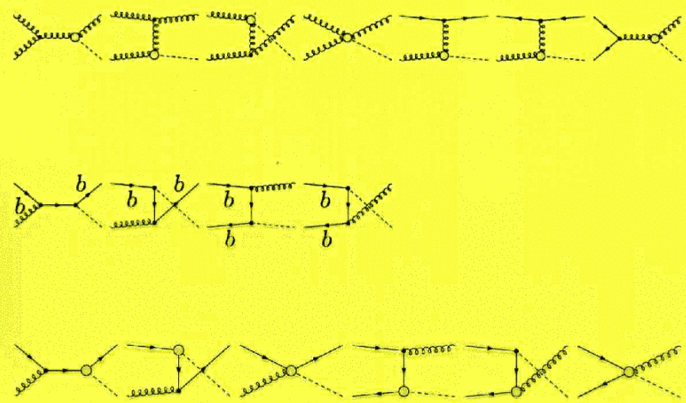
$$f_{u_I}(\alpha,\beta) = \cos\alpha / \sin\beta$$

$$f_{d_I}(\alpha,\beta) = -\sin\alpha / \cos\beta$$

→ mainly change of overall rate

* additional superpartner-loops (even additional topologies)

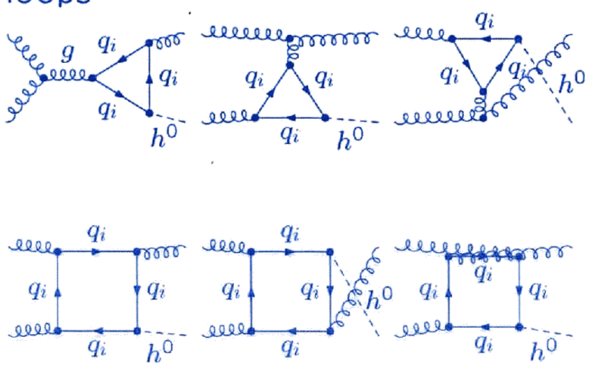
→ angular distribution changed



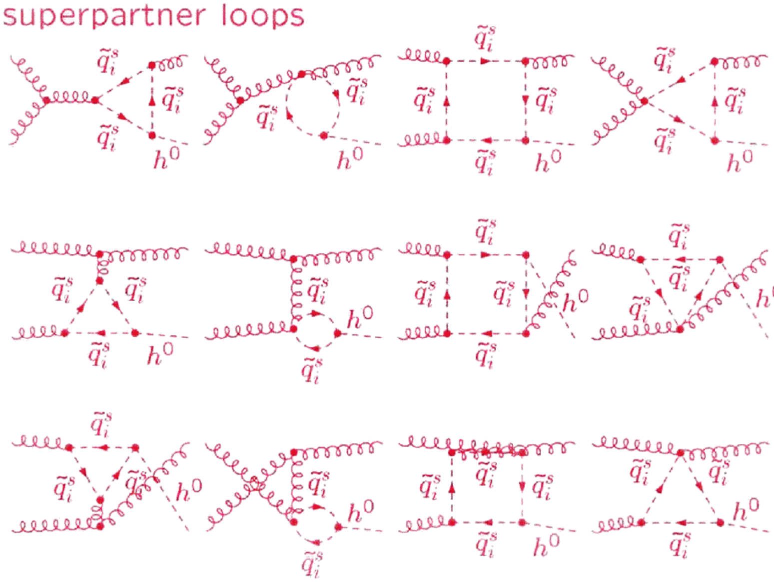
[Higgs + Jet in the MSSM, partonic processes]

gluon fusion, $gg \to h^0 g$

quark loops



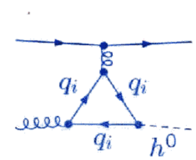
superpartner loops



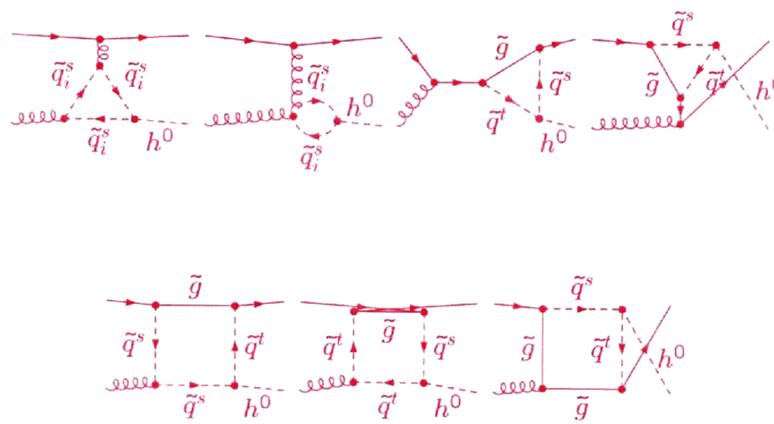
[Higgs + Jet in the MSSM, partonic processes]

quark-gluon scattering, $qg \to h^0 q$

quark loops



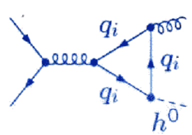
superpartner loops



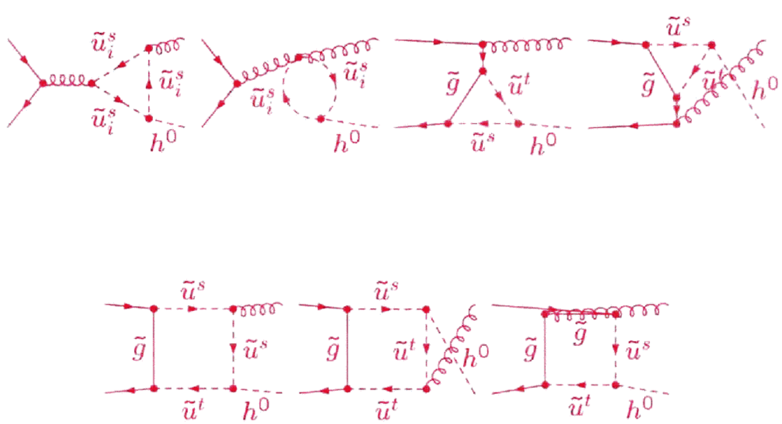
[Higgs + Jet in the MSSM, partonic processes]

quark-antiquark annihilation, $q\bar{q} \to h^0 g$

quark loops



superpartner loops



• Results

– Hadronic cross section @ LHC ($\sqrt{S} = 14$ TeV)

$$\sigma(pp \to h^0 + \text{jet} + X) =$$

$$\int_{\tau_0}^{1} d\tau \left(\frac{d\mathcal{L}^{pp}_{gg}}{d\tau} \, \sigma_{gg \to gh^0}(\tau S) + \sum_q \frac{d\mathcal{L}^{pp}_{qg}}{d\tau} \, \sigma_{qg \to qh^0}(\tau S) + \sum_q \frac{d\mathcal{L}^{pp}_{q\bar{q}}}{d\tau} \, \sigma_{q\bar{q} \to gh^0}(\tau S) \right)$$

with the parton luminosity

$$\frac{d\mathcal{L}^{AB}_{nm}}{d\tau} = \int_\tau^1 \frac{dx}{x} \frac{1}{1+\delta_{nm}} \Big[f_{n/A}(x) f_{m/B}(\tfrac{\tau}{x}) + f_{m/A}(x) f_{n/B}(\tfrac{\tau}{x}) \Big] .$$

The cuts $p_{T,\text{jet}} \geq 30$ GeV and $|\eta_{\text{jet}}| \leq 4.5$ determine τ_0 and the angular integration limits.

The results shown are for the MSSM m_h^{max} benchmark scenario with common squark mass scale M_{SUSY}.

[partonic processes calculated using FeynArts/FormCalc, see : www.feynarts.de]

Scenarios [→ benchmark scen.]

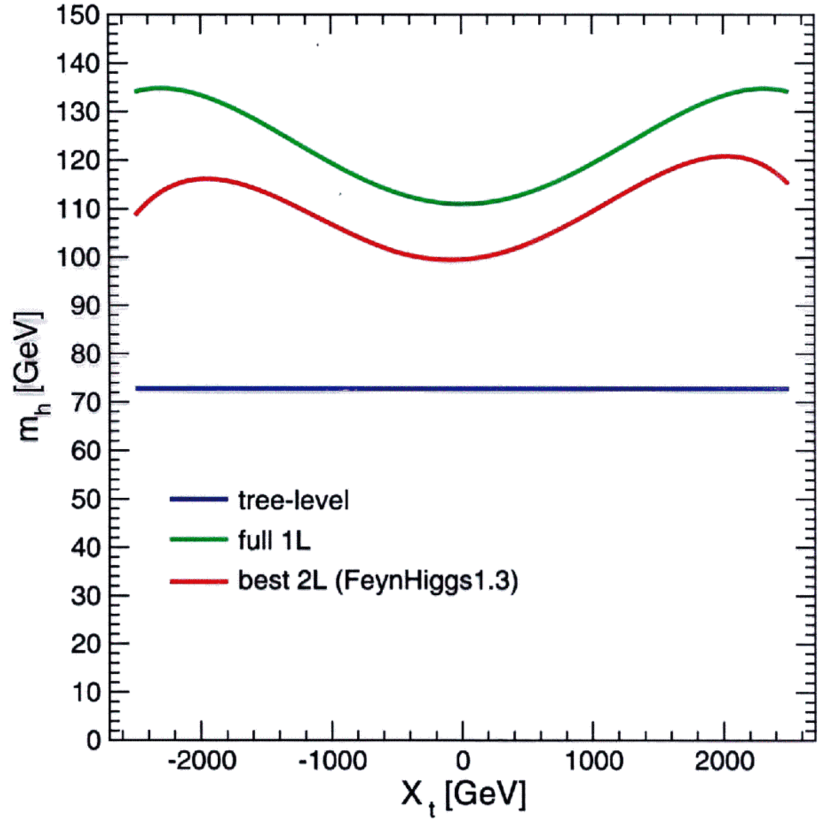
- **no-mixing scenario:**
  unmixed $\tilde{t}$-squarks
  $\tilde{t}_{1,2} = \tilde{t}_{L,R}$ $(X_t = 0)$
  $m_{\tilde{g}} = 800$ GeV

- **maximal-m_h scenario:**
  yields max. value m_h
  $X_t = 2 M_{\tilde{Q}} \equiv M_{SUSY}$

- **large-μ scenario:**
  $\mu = 1$ TeV
  $X_t = -900$ GeV
  $m_{\tilde{g}} = 400$ GeV

[MSSM Higgs Mass]

m_{h^0} prediction at different levels of accuracy:

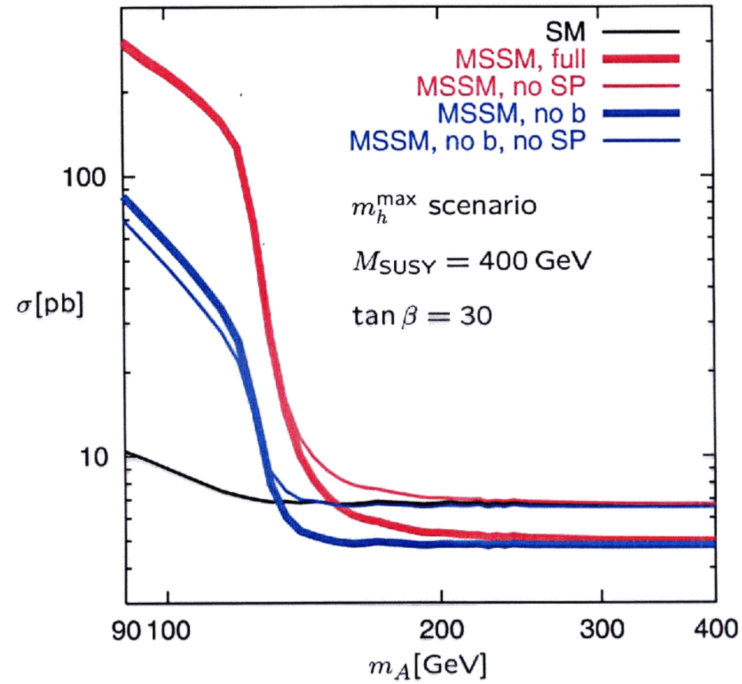


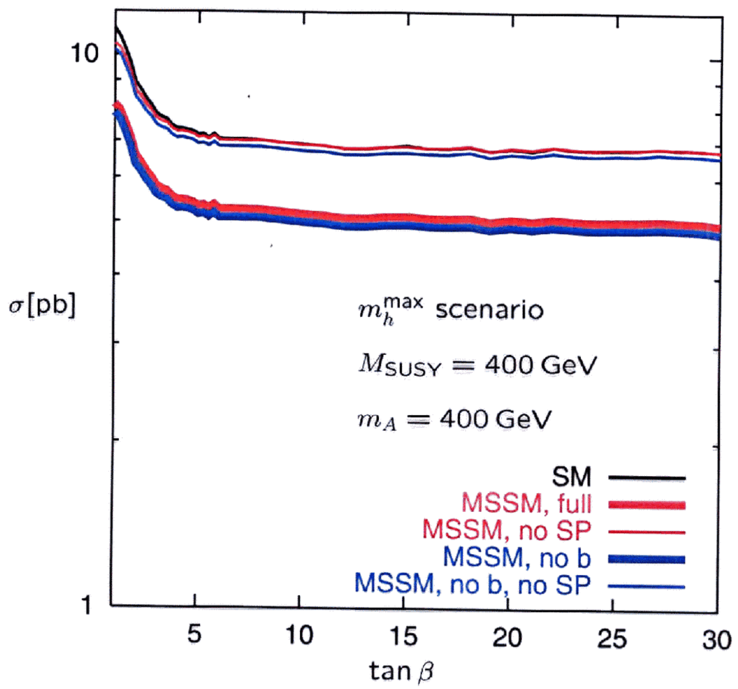
$\tan\beta = 3, \quad M_{\tilde{Q}} = M_A = 1$ TeV, $\quad m_{\tilde{g}} = 800$ GeV

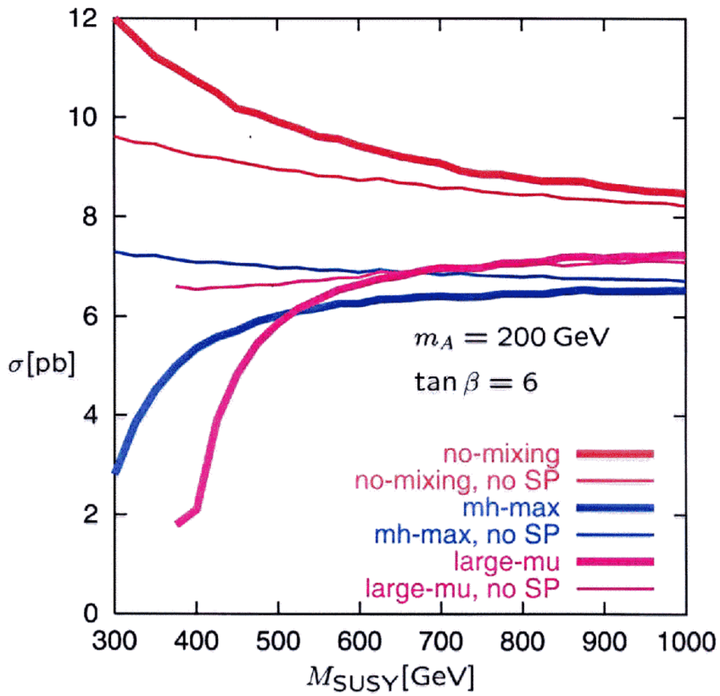
X_t : top-squark mixing parameter

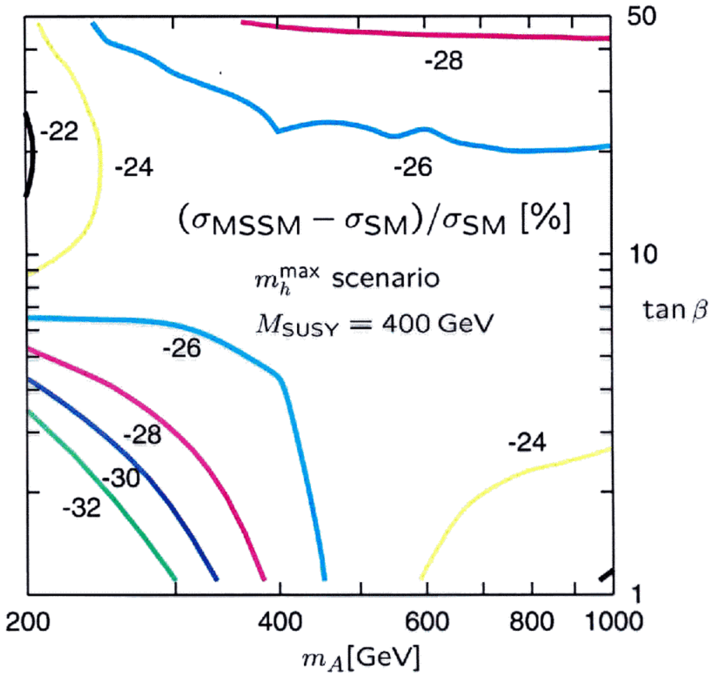
$\begin{pmatrix} M_{\tilde{Q}}^2 & m_t X_t \\ \ldots & \ldots \end{pmatrix} \xrightarrow{\theta_{\tilde{t}}} \begin{pmatrix} m_{\tilde{t}_1}^2 & 0 \\ 0 & m_{\tilde{t}_2}^2 \end{pmatrix}$

Scenario	no mixing ($m_A = 400$ GeV)		m_h^{max} ($m_A = 400$ GeV)		large μ ($m_A = 400$ GeV)	
$\tan\beta$	6	30	6	30	6	30
M_{SUSY} [GeV]	400	400	400	400	400	400
m_h [GeV]	100.2	104.5	120.2	123.9	121.0	123.3
σ_{all}^{MSSM} ($\sigma_{all,\ no\ SP}^{MSSM}$)	10.57 (9.04)	9.77 (8.51)	5.29 (7.01)	4.96 (6.72)	2.92 (6.80)	2.08 (6.63)
$\sigma_{(gg\to hg)}^{MSSM}$	6.97	6.42	3.46	3.24	1.94	1.37
$\sigma_{(qg\to hq, q=u,\bar{u},d,\bar{d},c,\bar{c},s,\bar{s})}^{MSSM}$	3.30	3.07	1.62	1.52	0.90	0.63
$\sigma_{(qg\to hq, q=b,\bar{b})}^{MSSM}$	0.22	0.20	0.69	0.15	0.05	0.05
$\sigma_{(q\bar{q}\to hg, q=u,d,c,s)}^{MSSM}$	0.05	0.05	0.03	0.03	0.02	0.02
$\sigma_{(b\bar{b}\to hg)}^{MSSM}$	0.03	0.03	0.03	0.02	0.01	0.01
σ_{all}^{SM}	8.93	8.50	7.08	6.74	6.89	6.68
$\sigma_{(gg\to Hg)}^{SM}$	5.85	5.60	4.70	4.47	4.66	4.51
$\sigma_{(qg\to Hq, q=u,\bar{u},d,\bar{d},c,\bar{c},s,\bar{s})}^{SM}$	2.83	2.65	2.19	2.09	2.15	2.08
$\sigma_{(qg\to Hq, q=b,\bar{b})}^{SM}$	0.17	0.16	0.12	0.11	0.04	0.04
$\sigma_{(q\bar{q}\to Hg, q=u,d,c,s)}^{SM}$	0.05	0.05	0.04	0.04	0.04	0.04
$\sigma_{(b\bar{b}\to Hg)}^{SM}$	0.04	0.04	0.03	0.03	0.01	0.01




10
1
σ[pb]
m_h^{max} scenario
M_{SUSY} = 400 GeV
m_A = 400 GeV
SM
MSSM, full
MSSM, no SP
MSSM, no b
MSSM, no b, no SP
5 10 15 20 25 30
tan β


12
10
8
6
4
2
0
σ[pb]
m_A = 200 GeV
tan β = 6
no-mixing
no-mixing, no SP
mh-max
mh-max, no SP
large-mu
large-mu, no SP
300 400 500 600 700 800 900 1000
M_{SUSY}[GeV]



Summary

- Higgs+jet production is a promising alternative to inclusive Higgs production
- Main production channel@LHC is gluon fusion (loop-induced)
- Differences for MSSM h^0 and H_{SM} sizeable

  Large effects from virtual squarks
- Large tree-level contributions from b quarks for $M_A < 150$ GeV
- NLO calculation required