

Quark and squark contributions to Higgs + 2 jet via gluon fusion

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- **The Higgs + 2 jet process**
- **Results**
- **Summary and future prospects**

★ in collaboration with Dieter Zeppenfeld

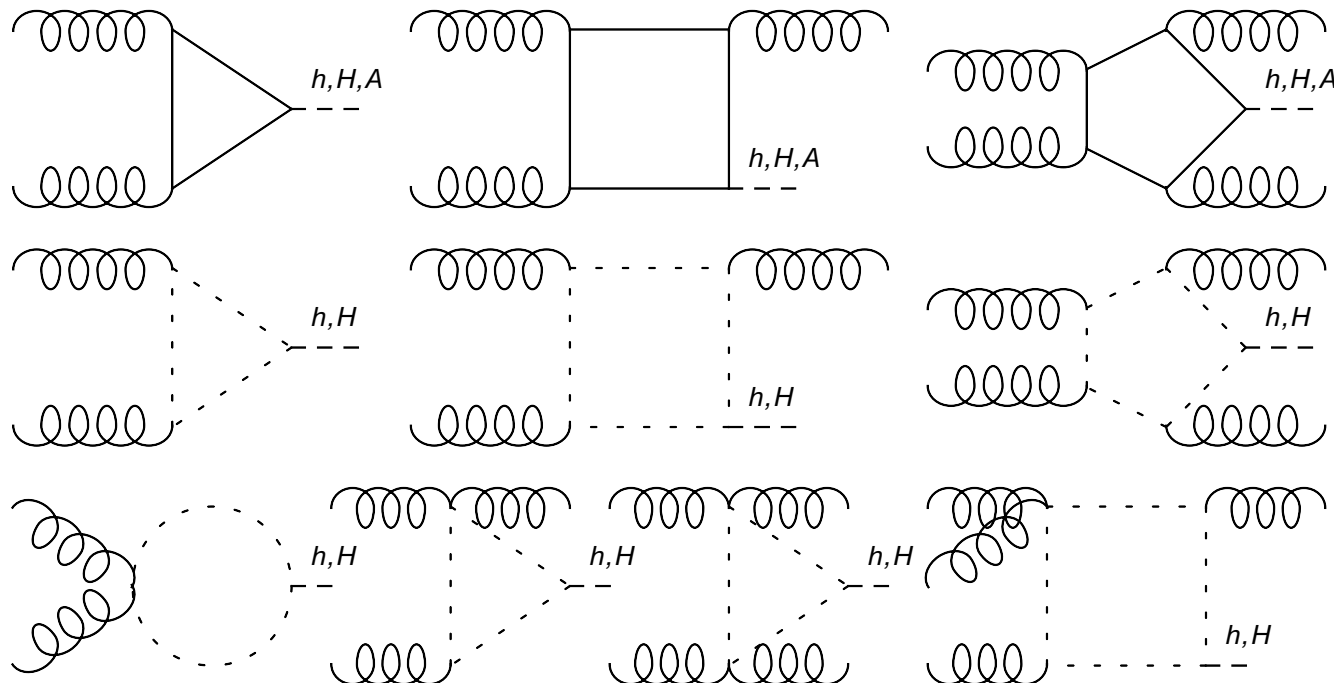
Subprocesses and topologies (1)

- Higgs = H_{SM}^0 and h^0, H^0, A^0 (MSSM)

- contributing subprocesses:

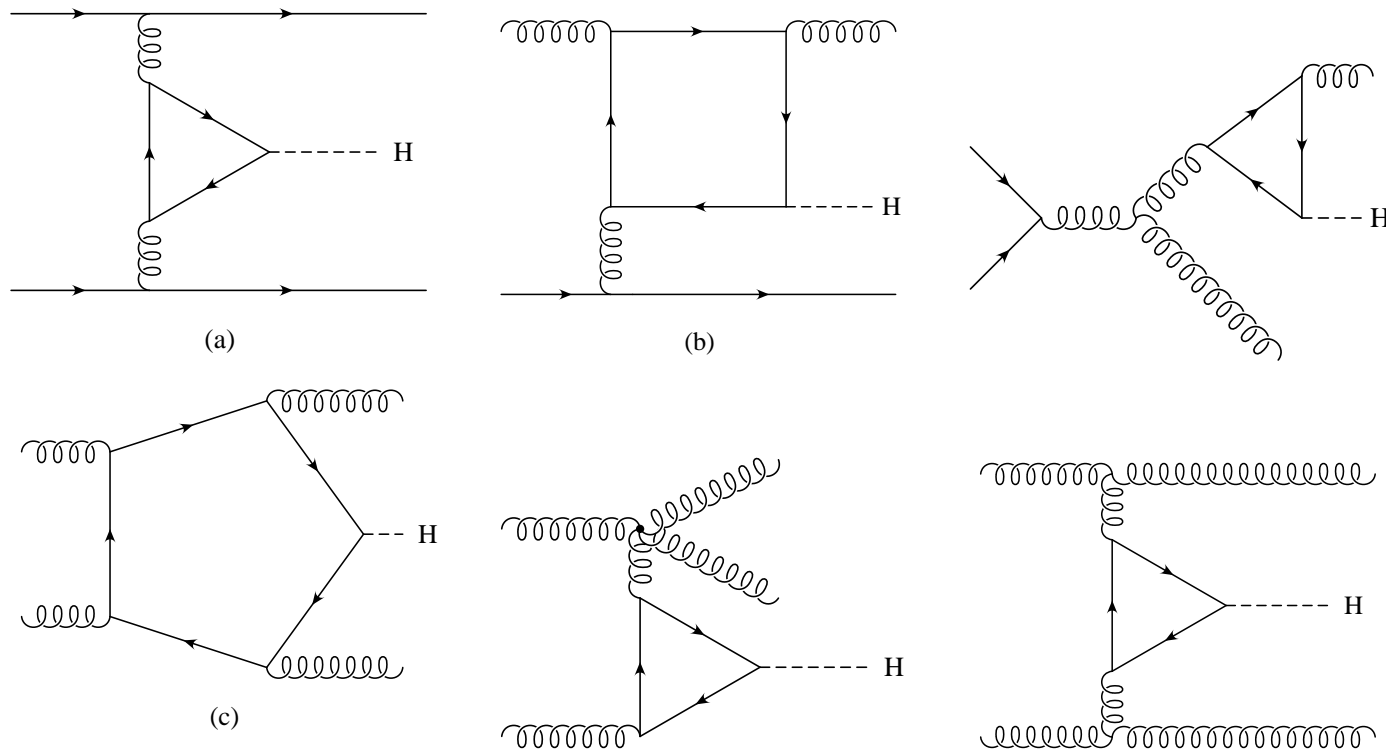
$$qq \rightarrow qq\text{Higgs}, \quad qg \rightarrow qg\text{Higgs}, \quad gg \rightarrow gg\text{Higgs} \quad + \quad \text{crossed processes}$$

- contributing loop topologies:



Subprocesses and topologies (2)

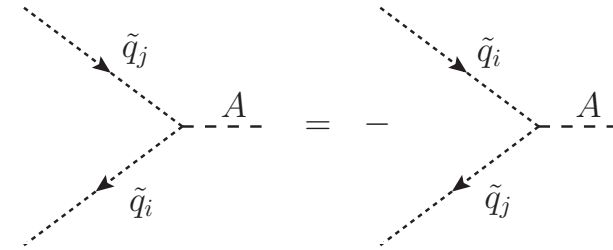
- starting point: tree-level diagrams for $2 \rightarrow 2$ parton scattering



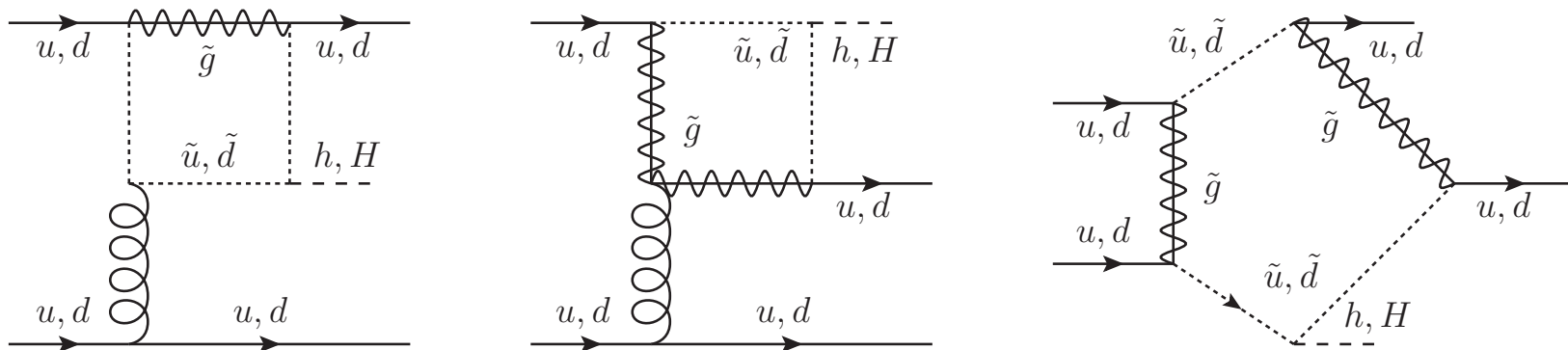
- subprocesses: a) $q\bar{q} \rightarrow q\bar{q}H$; b) $qg \rightarrow qgH$; c) $gg \rightarrow ggH$

Couplings of neutral Higgs bosons to squarks

- coupling $\tilde{q}_i \tilde{q}_j A^0$ of the \mathcal{CP} -odd Higgs boson A^0 to squarks is **zero** for $i = j$ with $i, j = \{L, R \text{ oder } 1, 2\}$ -basis



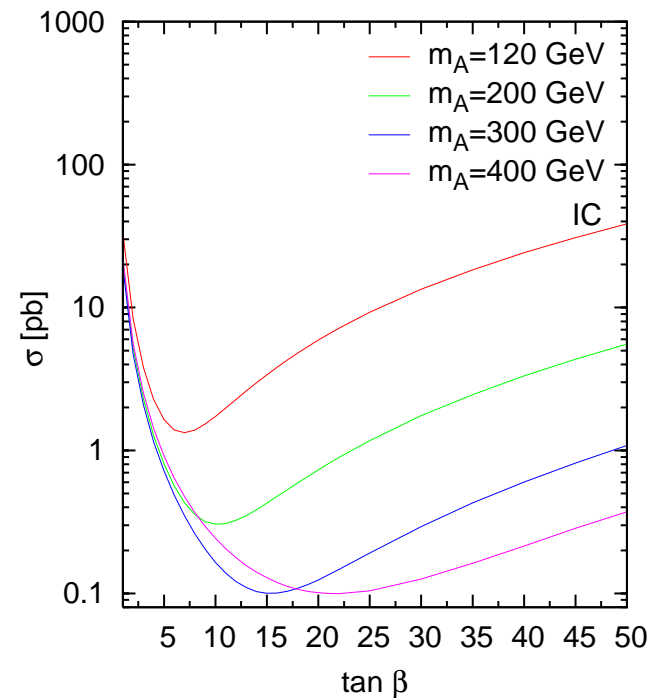
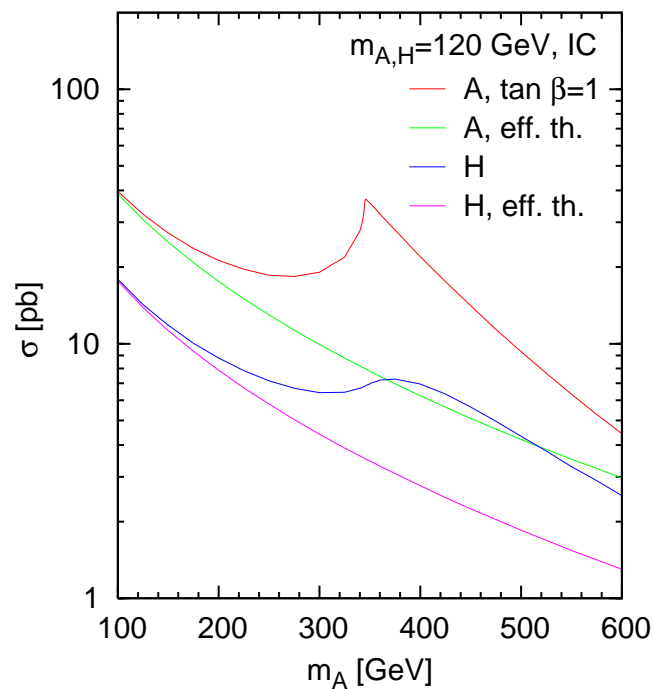
- coupling of Higgs boson to sfermions is **not** proportional to the sfermion mass but to the fermion mass
 - offdiagonal LR mixing terms are proportional to fermion masses
 - appreciable only for the **third generation**
- squark-gluino vertices allow **box** and **pentagon** diagrams also for **quark-scattering**



- but **through-going fermion lines** of two generations imply small Higgs couplings
- ⇒ additional diagrams with gluinos are neglected

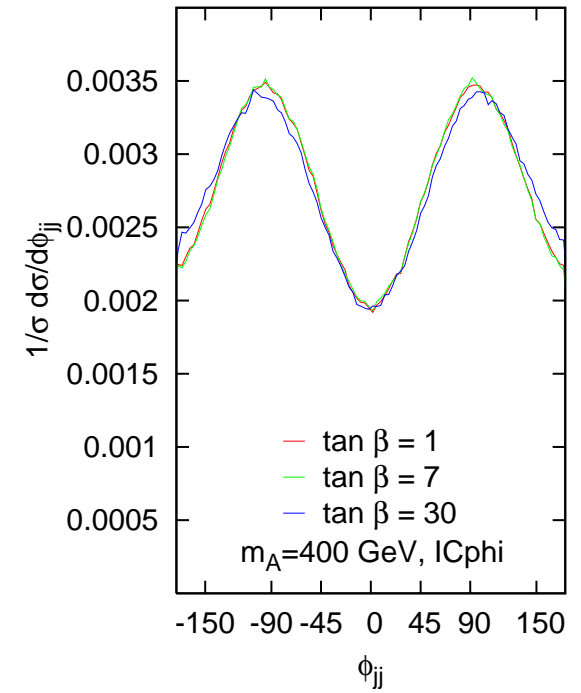
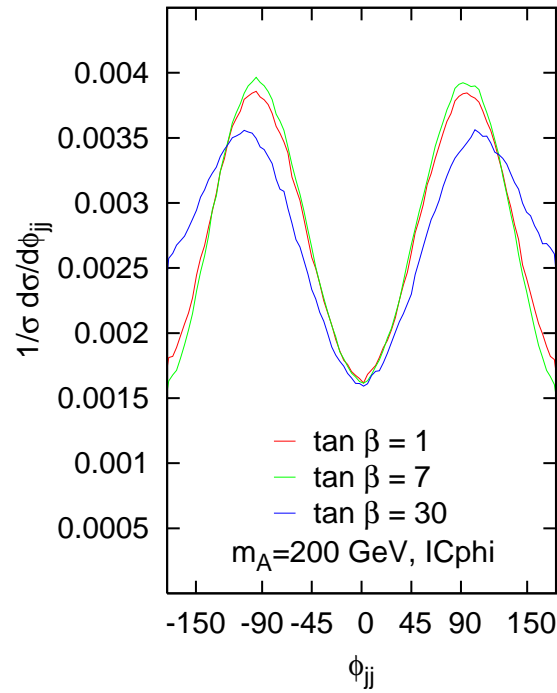
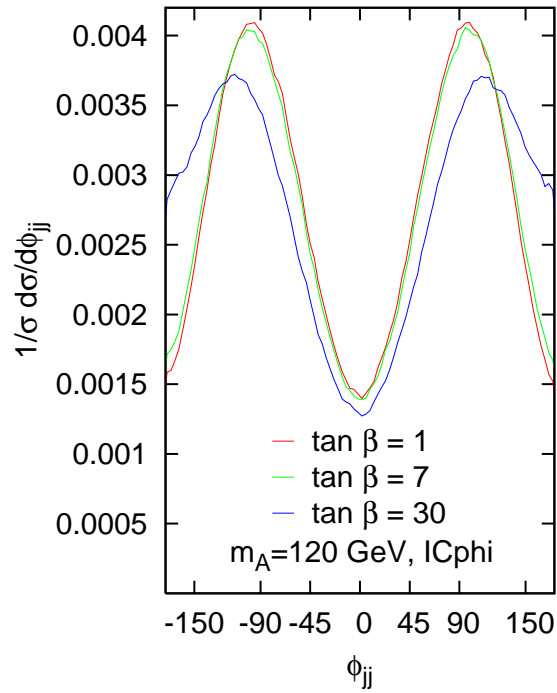
Results for the \mathcal{CP} -odd Higgs boson A (1): cross sections

- no squark contributions
- the coupling to down-type quarks is enhanced by $\tan \beta$
- interference effects of bottom- and top-quark loops were taken into account



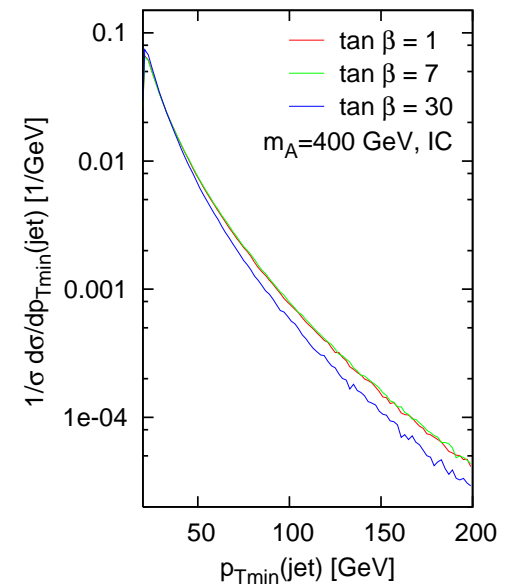
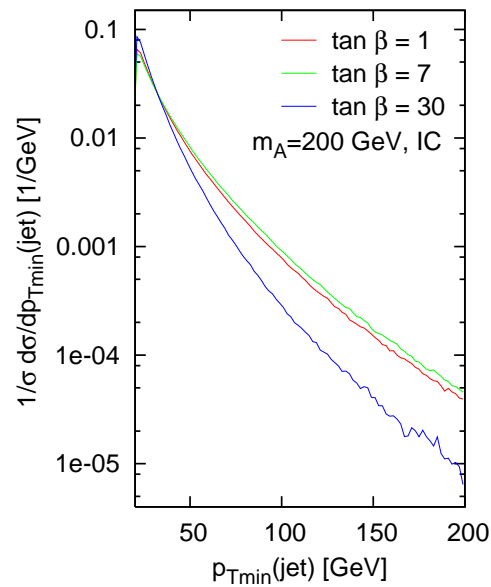
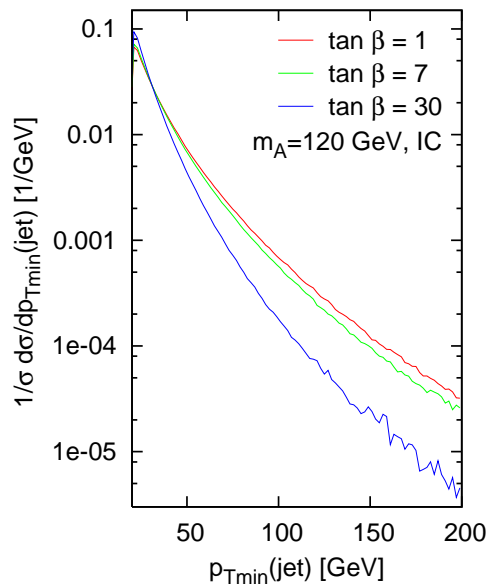
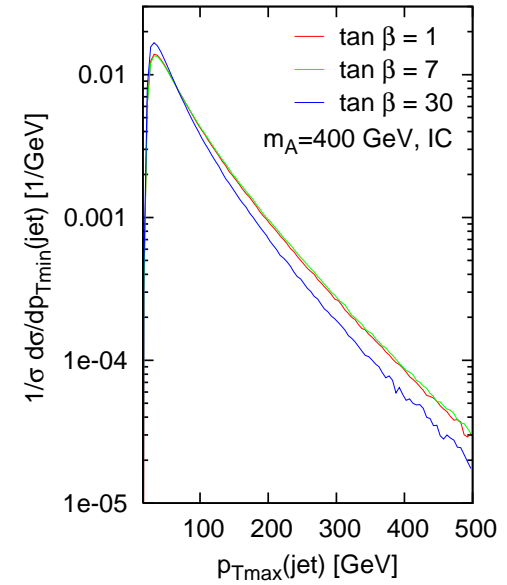
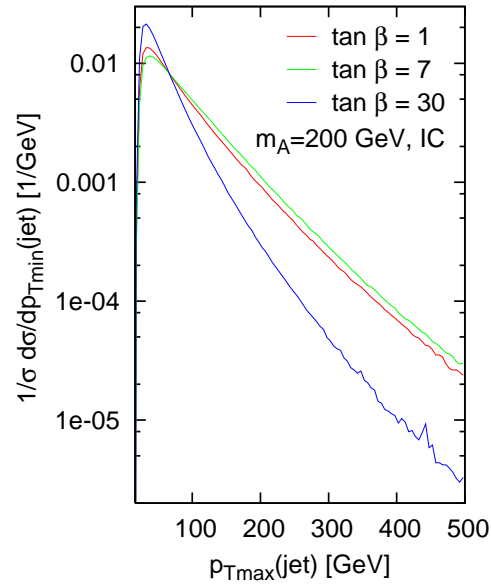
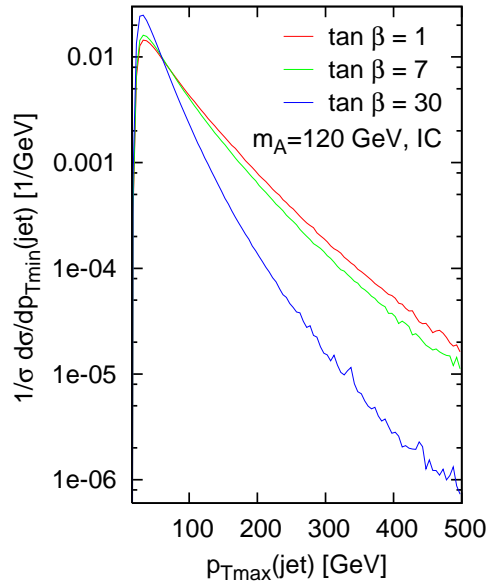
- inclusive cuts (IC): $p_{Tj} > 20$ GeV; $|\eta_j| < 4.5$; $R_{jj} > 0,6$

Results for the \mathcal{CP} -odd Higgs boson A (2): Azimuthal-angle distributions



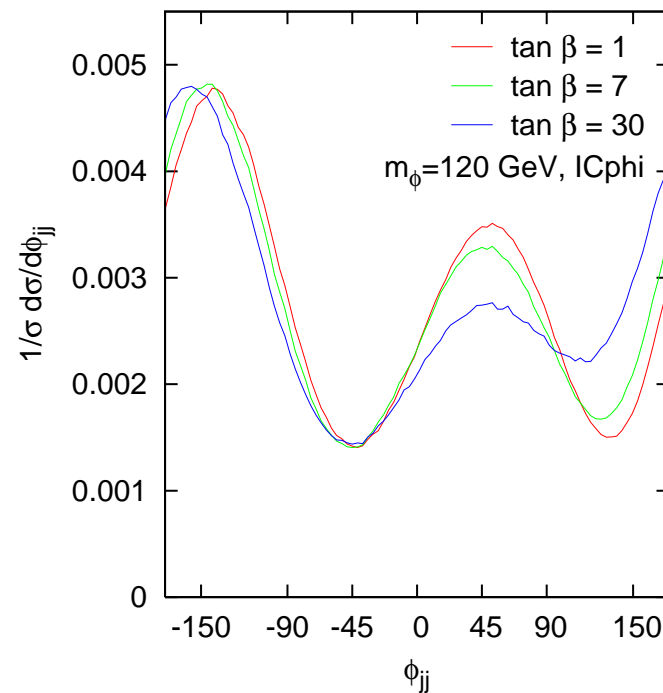
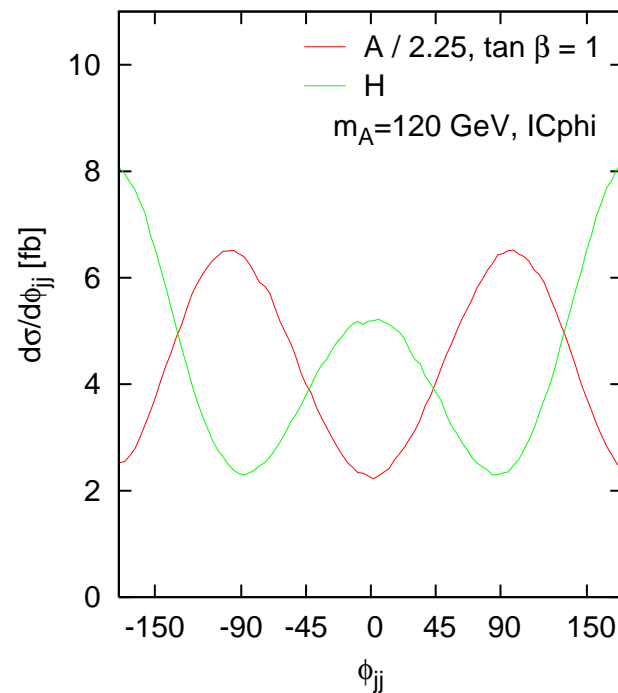
- slightly modified IC: $p_{Tj} > 30 \text{ GeV}$; $|\eta_j| < 4.5$; $R_{jj} > 0.6$; $\Delta\eta_{jj} = 3$

Results for the \mathcal{CP} -odd Higgs boson A (3): p_T distributions of jets



Results for the \mathcal{CP} -odd Higgs boson A (4): TOY-model

- the Azimuthal-angle distribution of the \mathcal{CP} -odd coupling is shifted by 90 degrees compared to the \mathcal{CP} -even case (left panel)
 - can simulate \mathcal{CP} -violating Higgs coupling (right panel): $C_H 1 + C_A i\gamma_5 \sim 1 + \frac{2}{3}i\gamma_5$ (here)
- C_H and C_A denote strenghts of the \mathcal{CP} -odd and \mathcal{CP} -even couplings



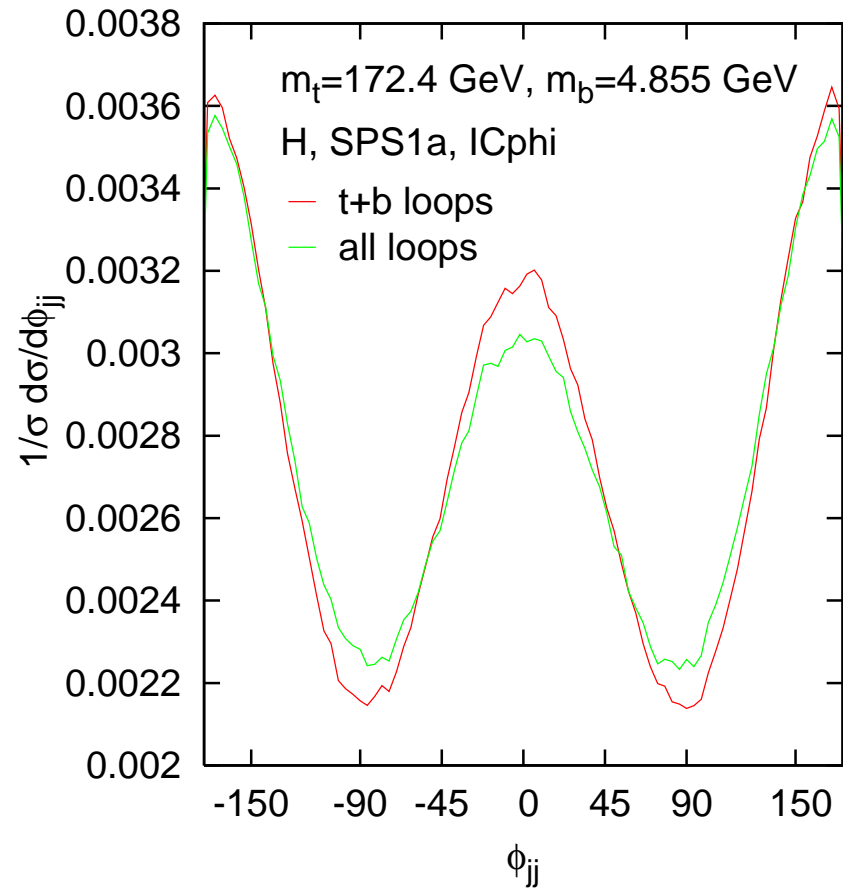
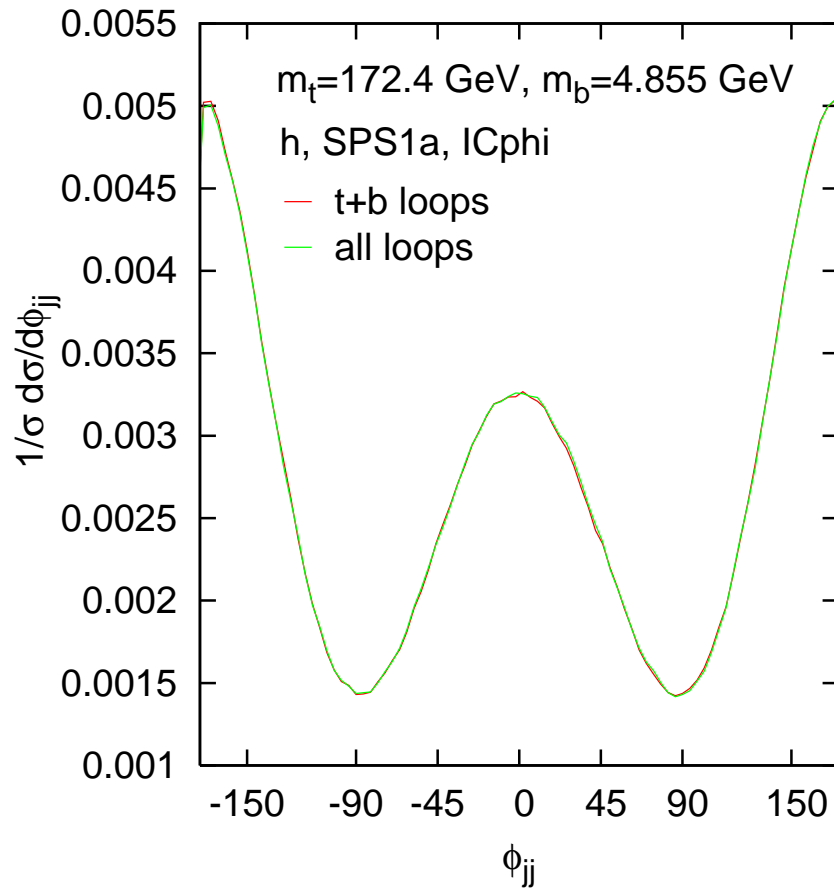
Production of h or H with additional squarks contributions

- chosen benchmark point: SPS1a like

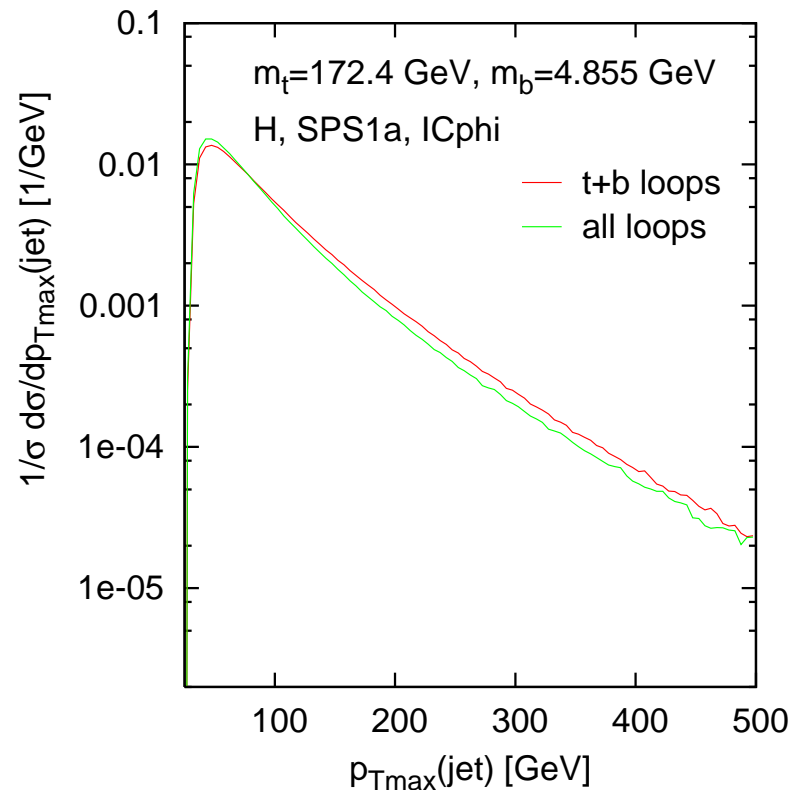
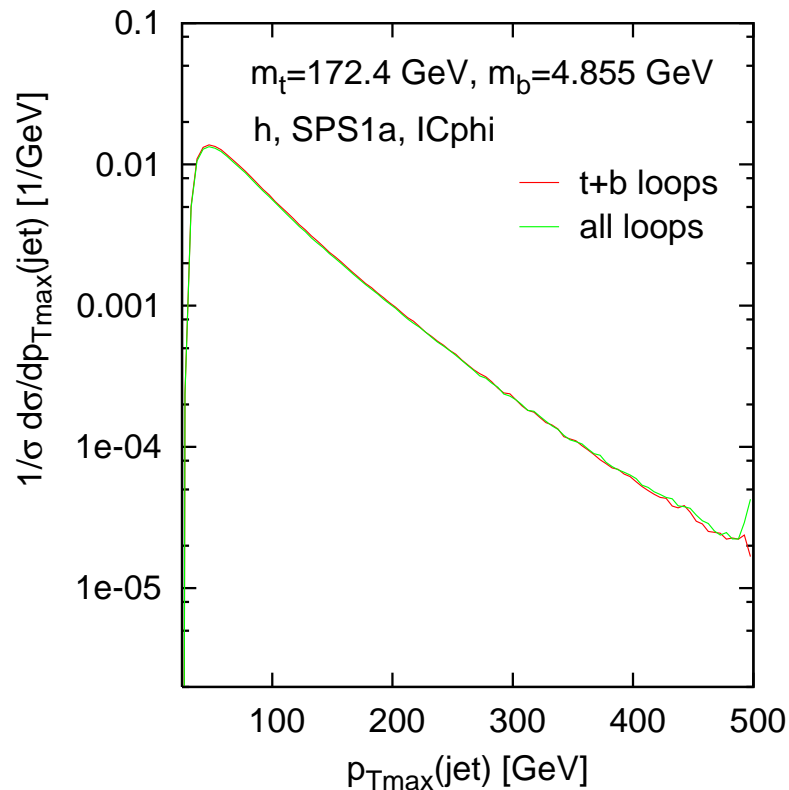
$$\tan \beta = 10, \quad m_{1/2} = 250 \text{ GeV}, \quad m_0 = 100 \text{ GeV}, \quad A = -100 \text{ GeV}, \quad \text{sign } \mu = +$$

- high statistics runs with about 16 million points
- Higgs masses: $m_h=115 \text{ GeV}$, $m_H=400 \text{ GeV}$
- considered loop particles: $m_t=172.4 \text{ GeV}$, $m_b=4.855 \text{ GeV}$,
 $\tilde{t}_1=400 \text{ GeV}$, $\tilde{t}_2=585 \text{ GeV}$,
 $\tilde{b}_1=520 \text{ GeV}$, $\tilde{b}_2=550 \text{ GeV}$

Results for h and H (1): Azimuthal-angle distributions



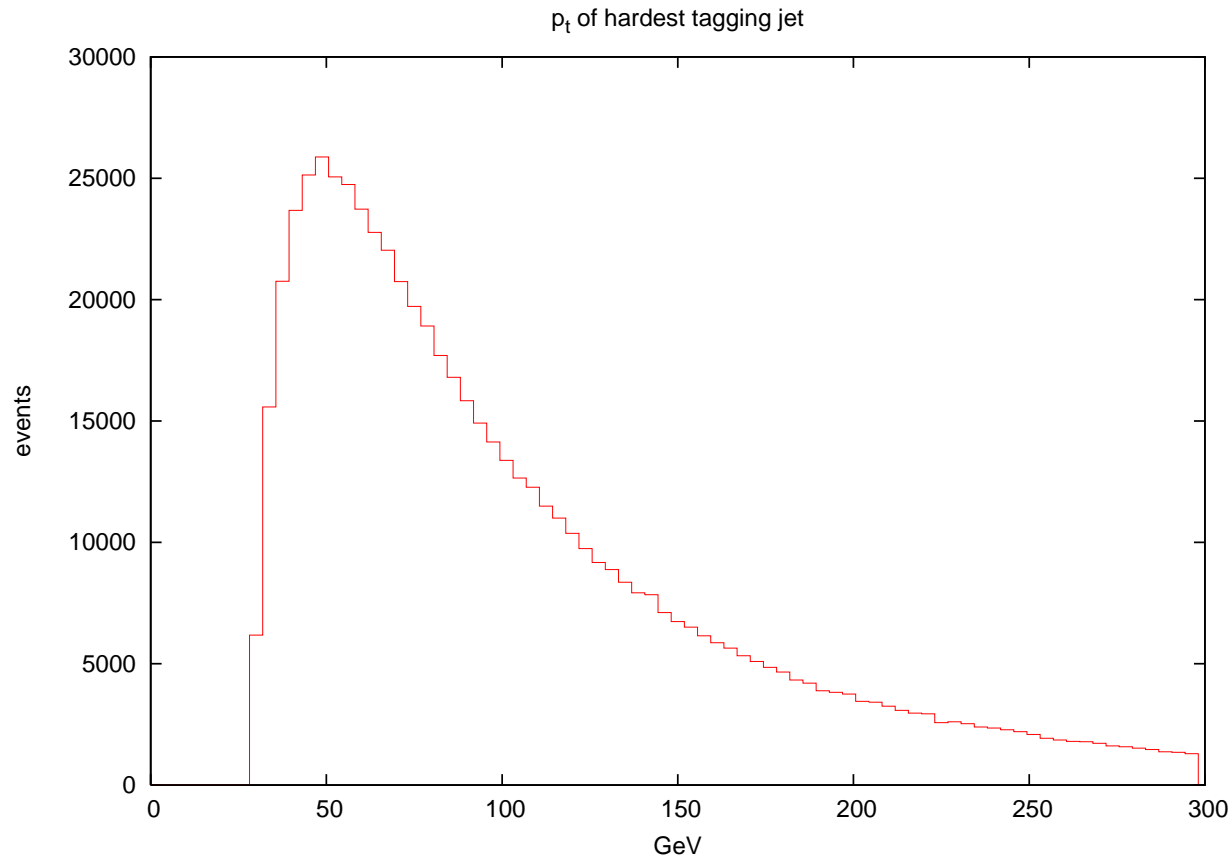
Results for h and H (2): p_T distributions



	$\sigma_h (t + b)$ [fb]	σ_h (all) [fb]	$\sigma_H (t + b)$ [fb]	σ_H (all) [fb]	$\sigma_A (t+b)$ [fb]
IC	15613.7 ± 9.6	18637.1 ± 16.6	110.0 ± 0.09	234.12 ± 0.2	240.9 ± 0.11
ICphi	1694.0 ± 0.9	2023.2 ± 1.1	12.3 ± 0.01	23.43 ± 0.02	29.2 ± 0.02

Results and future prospects

- following features and couplings are available in the VBFNLO/GGFLO
 - **Les Houches interface** (implemented by diploma student Ken Arnold)



- gluon fusion part of VBFNLO was connected via Les Houches interface to the parton shower generator Herwig++

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 - H_{SM} to top and bottom quarks (also effective couplings)
 - A^0 to top and bottom quarks (also effective couplings)
 - h^0, H^0 to top and bottom quarks
 - h^0, H^0 to $stop_{1/2}$ and $sbottom_{1,2}$ (next version)
 - TOY-model for \mathcal{CP} studies
- future prospects:
 - investigation of further benchmark points
 - investigation of change of the azimuthal angle distribution if one further jet is added

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work in progress...