Rare Decays of the Pseudoscalar Higgs

TeV4LHC@BNL Workshop

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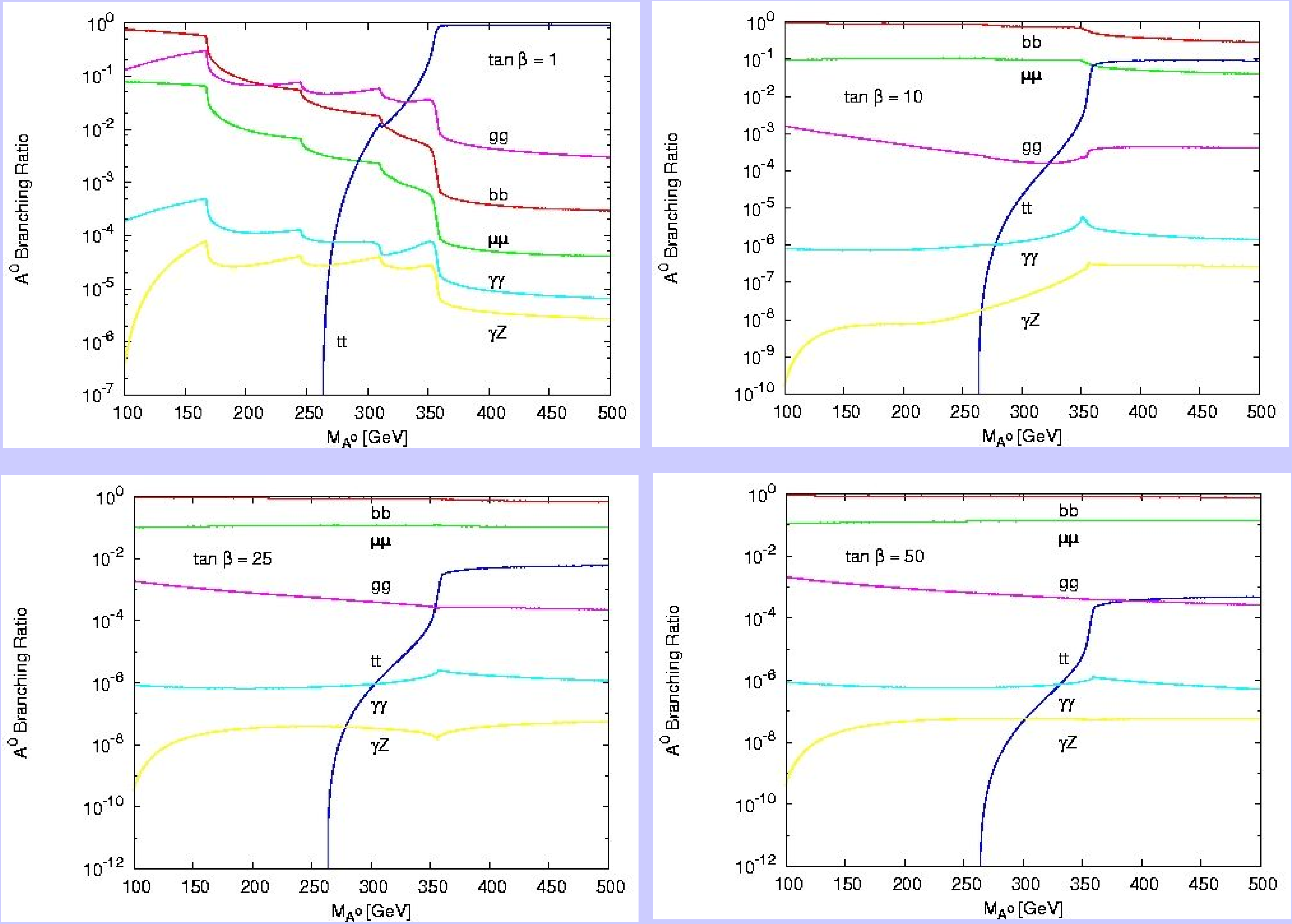
Outline

- Brief review of the Pseudoscalar Higgs
- Current MSSM branching ratios
- Squarks and squark mixing
- New three point functions
- New decay widths and squark contributions
  - $A^0 \rightarrow \gamma Z^0$
  - $A^0 \rightarrow Z^0 Z^0$
- Improved branching ratios
- Conclusion

MSSM and the Pseudoscalar

- MSSM has five physical Higgs bosons
- One CP-odd Pseudoscalar (A^0)
- Couples differently to up- and down-type quarks as well as up- and down- type squarks
- Interested in top and bottom quarks and stop and sbottom squarks
- The parameter tan(β) (partially) controls the ratio of up- and down- type contributions
- Pseudoscalar has no tree-level coupling to $W^{\mp}/Z^0$ vector bosons
- Need one-loop level contributions



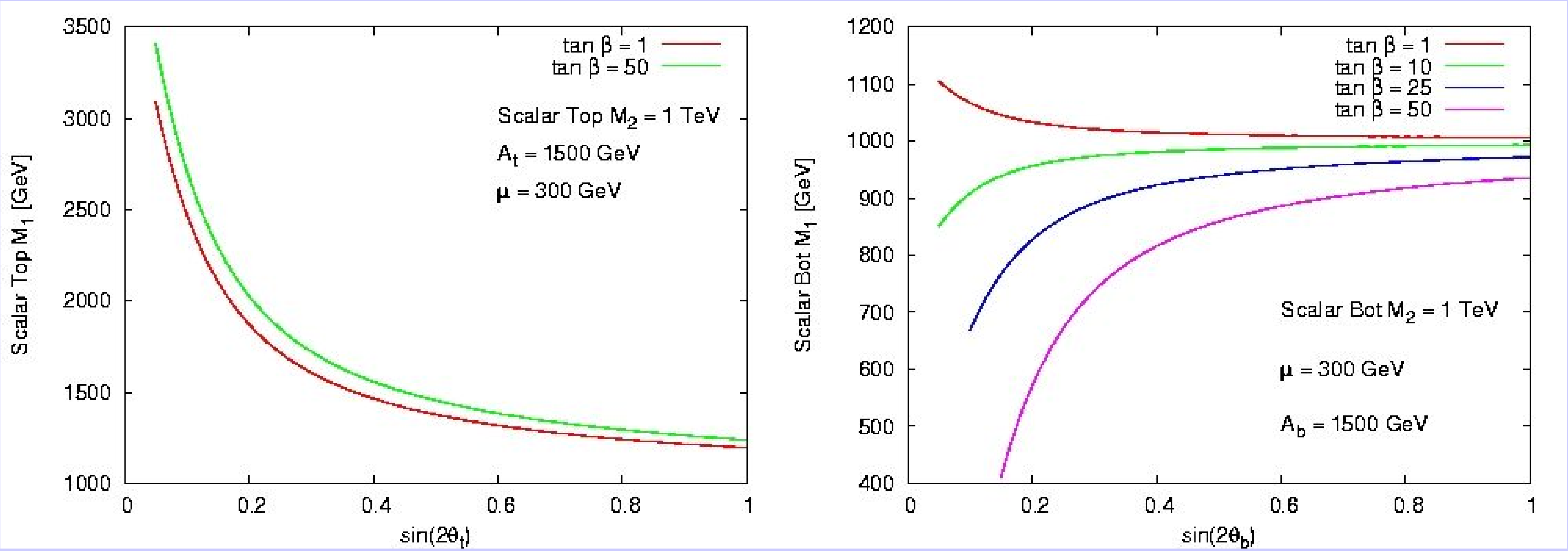
HDecay Output

Squarks and Squark Mixing

- R/L handed quarks have scalar super-partners (denoted with tilde)
- Right and left handed squarks can mix into different mass eigenstates
- This is done squark by squark in the simplest case (ignore generational mixing)
- Introduce angles to diagonalize the mass eigenstates for each squark

$$\begin{aligned}\tilde{q}_1 &= +\tilde{q}_R c_q + \tilde{q}_L s_q \\ \tilde{q}_2 &= -\tilde{q}_R s_q + \tilde{q}_L c_q\end{aligned}$$

- The mixing angles are not completely free parameters
- We pick m_2 and Lagrangian parameters



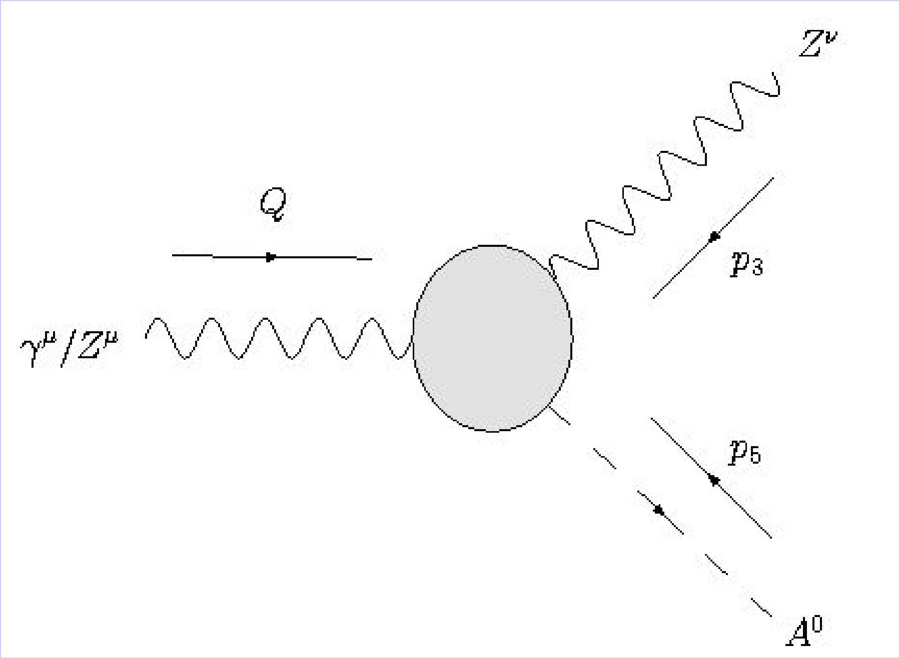
$$\sin(2\theta_t)=\frac{2\,m_{top}(A_t-\mu\cot\beta)}{m_{\tilde{t}_1^2}^2-m_{\tilde{t}_2^2}^2}$$

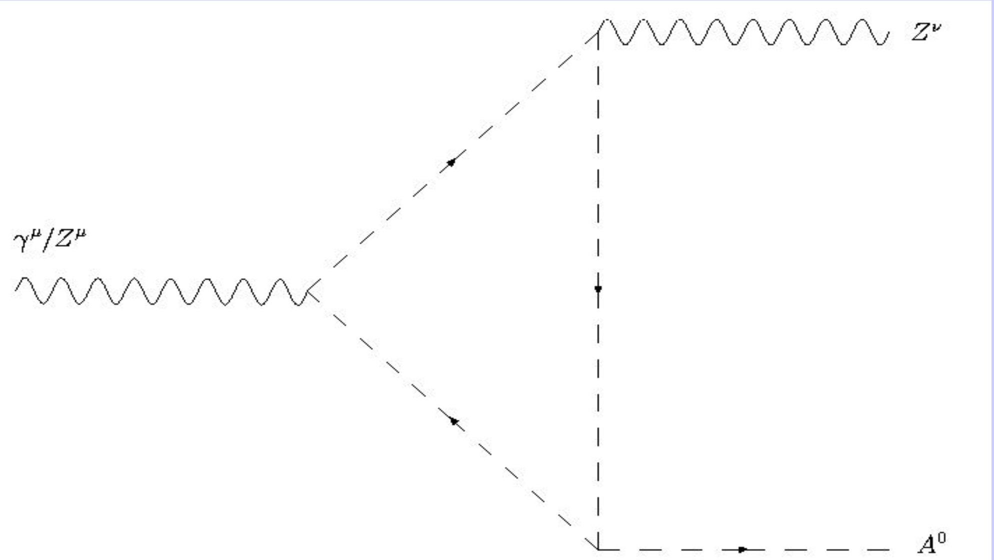
$$\sin(2\theta_b)=\frac{2\,m_{bot}(A_b-\mu\tan\beta)}{m_{\tilde{b}_1^2}^2-m_{\tilde{b}_2^2}^2}$$

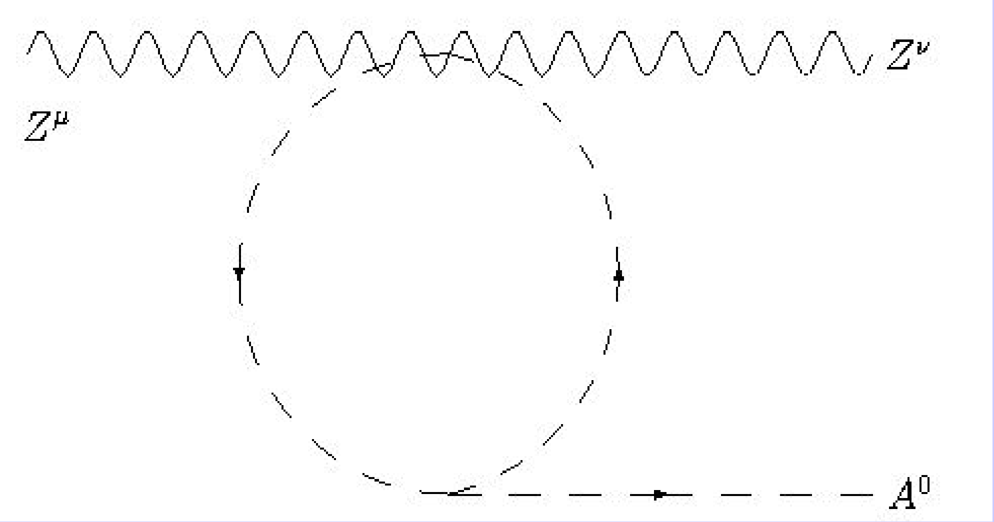
Three Point Functions

- Quark contributions are known, squark contributions are not known
- Need to generate the one-loop three-point squark contributions ($\Gamma^{\mu\nu}$)
- These contributions come in two types for our processes (triangle and bubble)
- The squark contributions do not interfere with the quark contributions (tensor structure)
- This could be a window into the squark mixing (may not be optimal)
- What do they look like?

Feynman Diagrams







Squark loops need not be mass eigenstate diagonal

Need These Three-Point Functions

$$A^0(p_5)\to\gamma/Z^0(-Q^\mu)Z^0(-p_3^\nu)$$

$$i\Gamma^{\mu\nu}_{\gamma/Z,susy}=\eta^{\mu\nu}A^q_{\gamma/Z}+Q^\nu p_3^\mu E^q_{\gamma/Z} \qquad i\Gamma^{\mu\nu}_{sm}=\epsilon^{\mu\nu\alpha\beta}p_{3,\alpha}Q_\beta$$

$$A^q_\gamma=\frac{-ie^2\tilde{A}_q s_q c_q}{s_w c_w}\Big\{s_q^2T_q^3\big[C_{24}(112)+C_{24}(221)-2C_{24}(111)$$

$$-2Q_q[B_0(21)-B_0(22)]\big]-Q_q^2s_w^2[B_0(22)-B_0(11)]\Big\}-\Big\{s_q\leftrightarrow c_q;1\leftrightarrow 2\Big\},$$

$$E^q_\gamma=A^q_\gamma(B_0\to 0;C_{24}\to C_{12}+C_{23}),$$

$$A^q_Z=\frac{-ie^2\tilde{A}_q s_q c_q}{4s_w^2c_w^2}\Big\{c_q^4(T_q^3)^2\big[C_{24}(121)+C_{24}(211)-2C_{24}(111)\big]$$

$$-c_q^2T_q^3Q_qs_w^2\big[C_{24}(122)+C_{24}(121)+C_{24}(211)+C_{24}(221)-4C_{24}(111)\big]$$

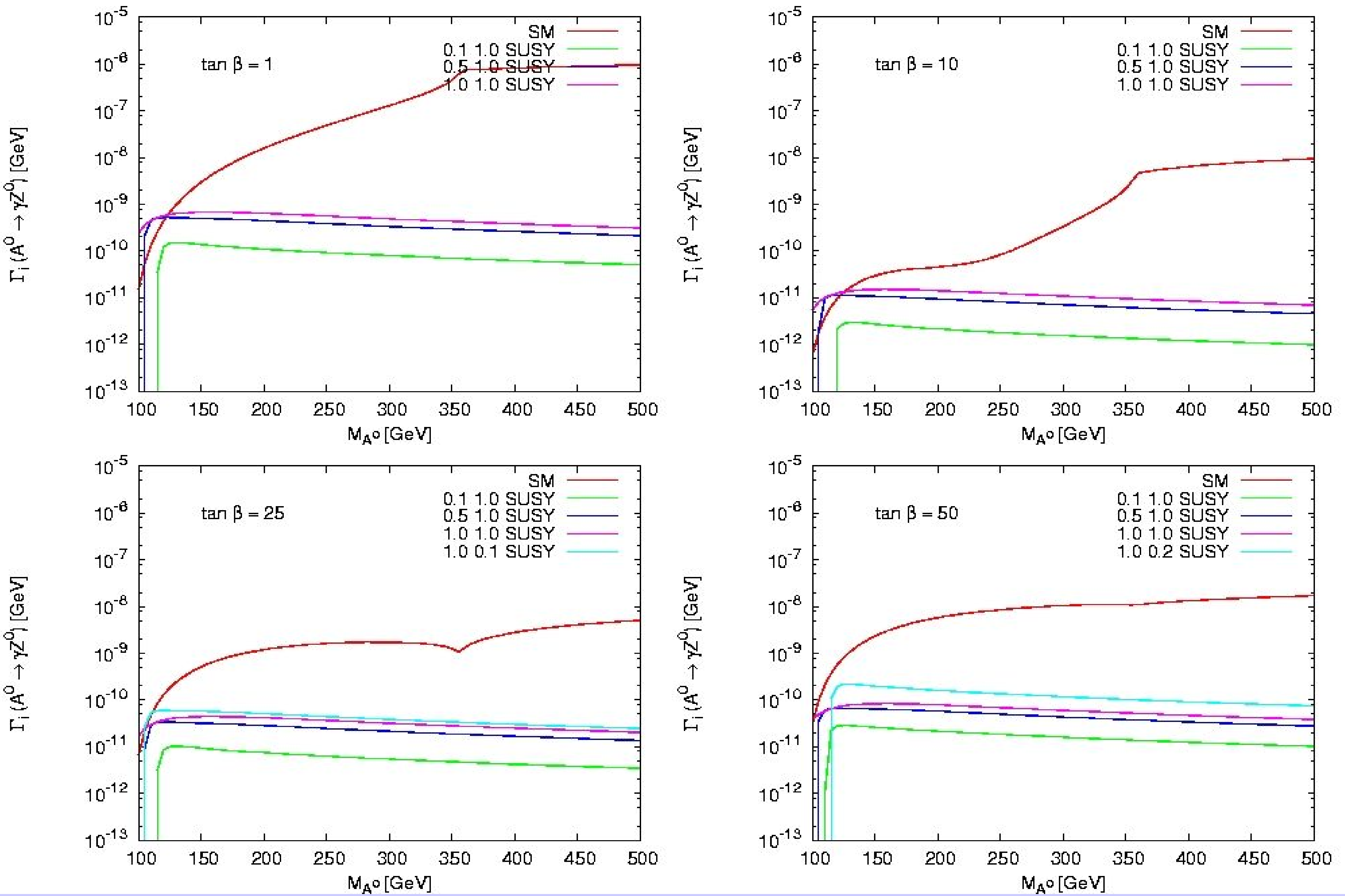
$$+4c_q^2T_q^3\big[B_0(12)-B_0(22)\big]-2Q_qs_w^2\big[B_0(22)-B_0(11)\big]$$

$$+Q_q^2s_w^4C_{24}(111)-s_q^2c_q^2(T_q^3)^2\big[C_{24}(122)+C_{24}(121)+C_{24}(112)+C_{24}(221)\big]\Big\}$$

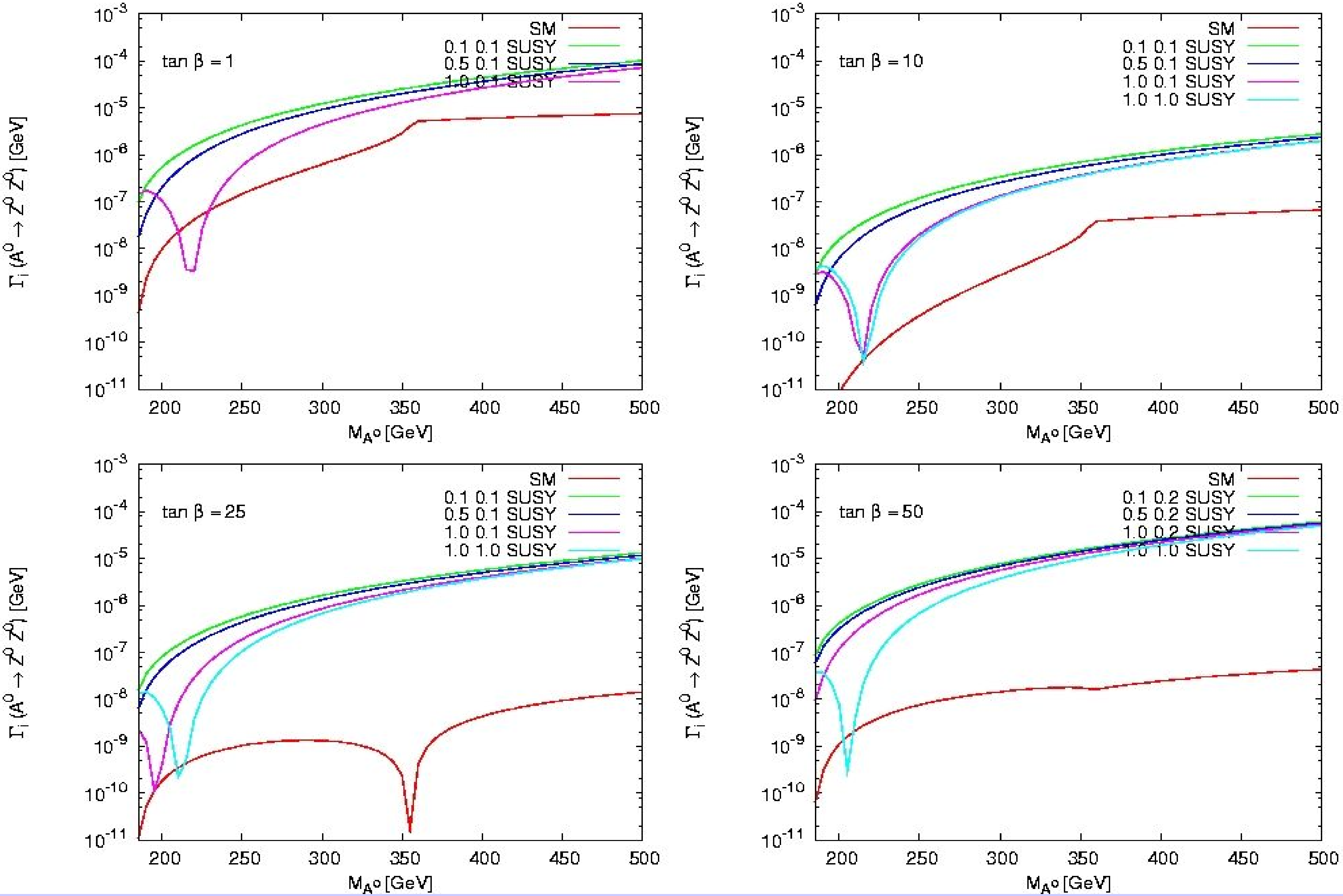
$$-\Big\{s_q\leftrightarrow c_q;1\leftrightarrow 2\Big\},$$

$$E^q_Z=A^q_Z(B_0\to 0;C_{24}\to C_{12}+C_{23})$$

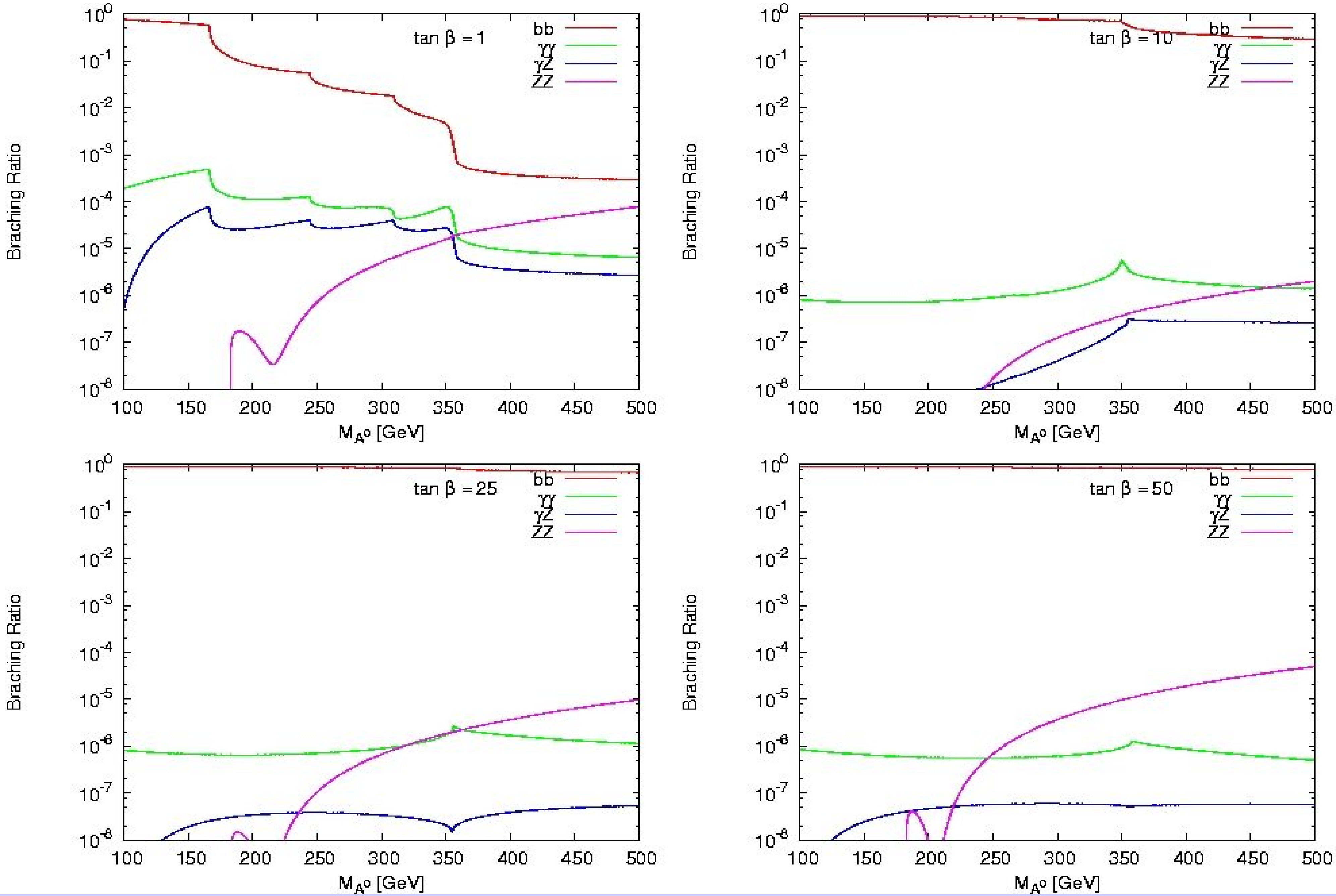
Decay Widths (γZ^0)



Decay Widths (Z^0Z^0)



Branching Ratios



Conclusions

- The γZ^0 channel has negligible squark contributions, particularly at high M_{A0}
  - Maximum with large stop mixing and small sbottom mixing (light squarks)
- The Z^0Z^0 channel can have considerable squark contributions
  - Same maximum as γZ^0 channel
  - Large sbottom mixing introduces a dip in the decay width