# Electroweak Corrections to the Decay $A^0 \longrightarrow \gamma\gamma/gg$

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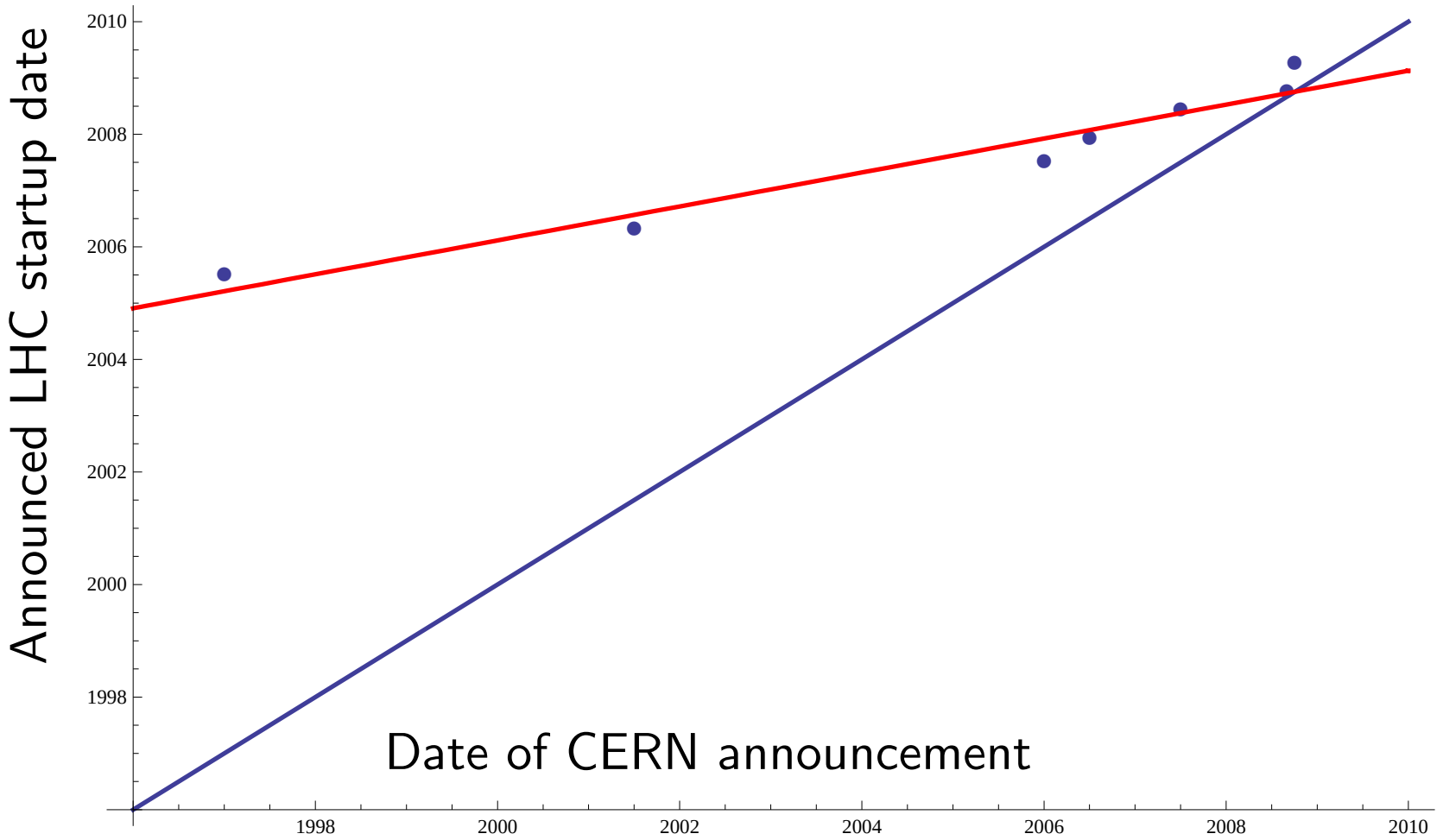
# LHC Startup Date



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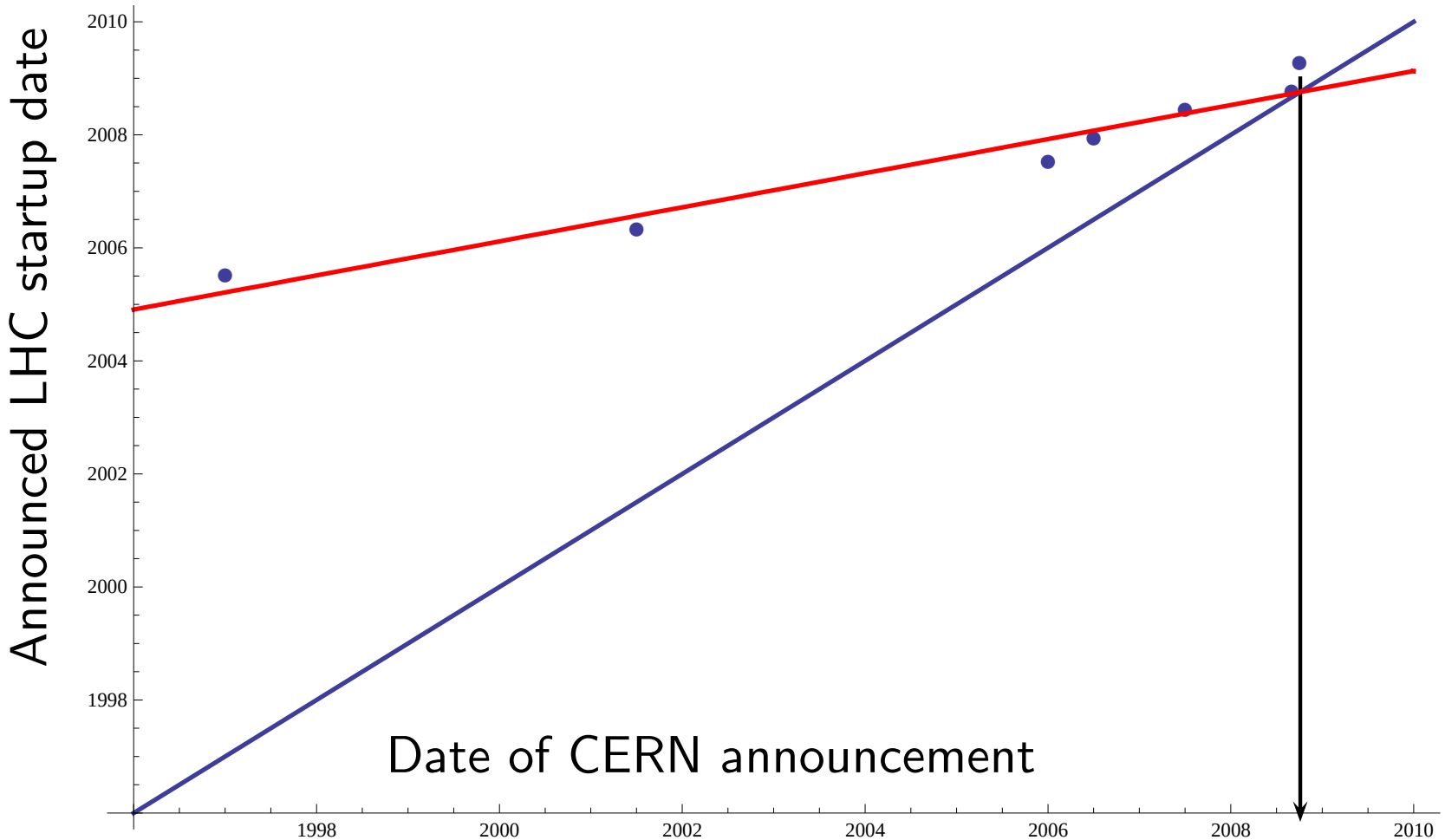



10th September 2008. . .

# The Two Higgs-Doublet Model (2HDM)

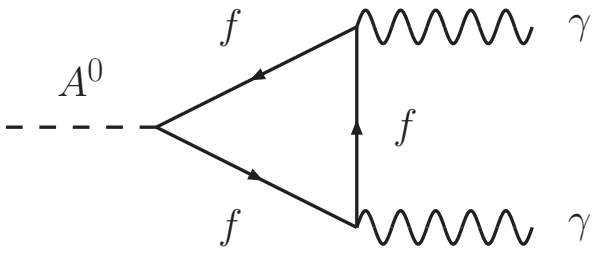
## Standard model: One doublet of scalar fields

- Non-vanishing vev $v$
  $\Rightarrow$ Masses for $Z$, $W^{\pm}$ and chiral fermions
- One physical scalar field $H$

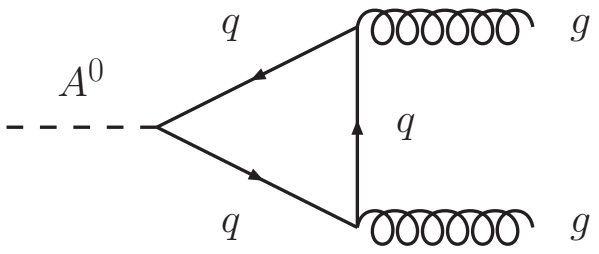
## 2HDM: Two doublets of scalar fields

- Non-vanishing vevs $v_1$ and $v_2$
  $\Rightarrow$ Masses for $Z$, $W^{\pm}$ and chiral fermions
- $\tan\beta = v_2/v_1$
- Five physical scalar fields $h^0$, $H^0$, $A^0$, $H^{\pm}$
- Type II ($\leftrightarrow$ MSSM)

# Production and Decay of $A^0$




$$\Gamma(A^0 \to \gamma\gamma) = \mathcal{O}(10^{-4})$$




$$\Gamma(A^0 \to gg) = \mathcal{O}(10^{-3})$$

- No coupling to vector bosons, small $\cot\beta$ suppresses top contribution $\Rightarrow$ small decay rate
- Large $\tan\beta$ can enhance bottom-quark contribution
- SUSY particles can be considered as decoupled

Importance of these modes mainly for production mechanisms.

# Which corrections are known already?

$A^0 \to \gamma\gamma$: NLO QCD $\mathcal{O}(5\%)$

[Djouadi et. al. '93; Spira et. al. '95; Harlander et. al. '05; Aglietti et. al. '07]

$A^0 \to gg$: NLO QCD $\mathcal{O}(70\%)$

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$A^0 \to gg$: NNLO QCD $(m_t \to \infty)$ $\mathcal{O}(20\%)$

[Chetyrkin et. al. '98; Harlander et. al. '02; Anastasiou et. al. '03]

$gg \to A^0$: NLO SUSY QCD $\mathcal{O}(4\%)$

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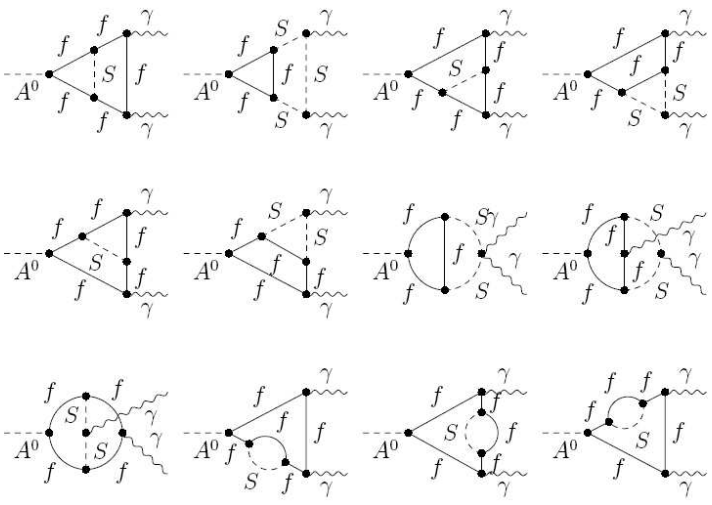
Electroweak corrections?

# Asymptotic Expansion

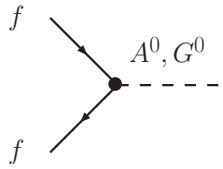
We have extracted the correction of $\mathcal{O}(G_F m_t^2)$
(assuming $M_{h^0}, M_{H^0}, M_{A^0}, M_{H^\pm} < m_t; \quad M_{A^0} < 2M_{H^\pm}, 2M_W$)
using the following



**Setup:**

- Generation of diagrams: `qgraf` [Nogueira '93]
- Asymptotic expansion: `q2e,exp` [Harlander et. al. '98]
- Evaluation of integrals: `MATAD` [Steinhauser '01]

# A Technical Issue

The couplings 

are proportional to $\gamma_5$.

Demanding both

$$\{\gamma^\mu, \gamma_5\} = 0$$

and

$$\mathrm{tr}(\gamma_\mu \gamma_\nu \gamma_\rho \gamma_\sigma \gamma_5) = 4i\varepsilon_{\mu\nu\rho\sigma}$$

is inconsistent in dimensional regularisation!

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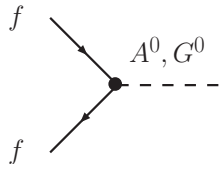
The couplings 

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$$\Rightarrow \text{HV Scheme}$$

# The HV Scheme

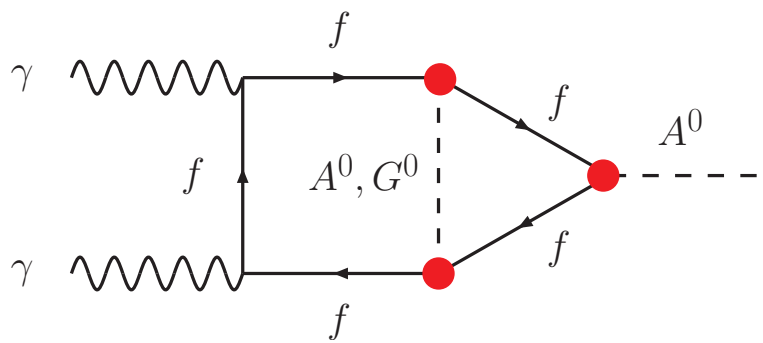
Demand

$$\begin{aligned} \{\gamma^\mu, \gamma_5\} &= 0, \quad \text{if } \mu = 0, 1, 2, 3, \\ [\gamma^\mu, \gamma_5] &= 0, \quad \text{otherwise,} \end{aligned}$$

and retain

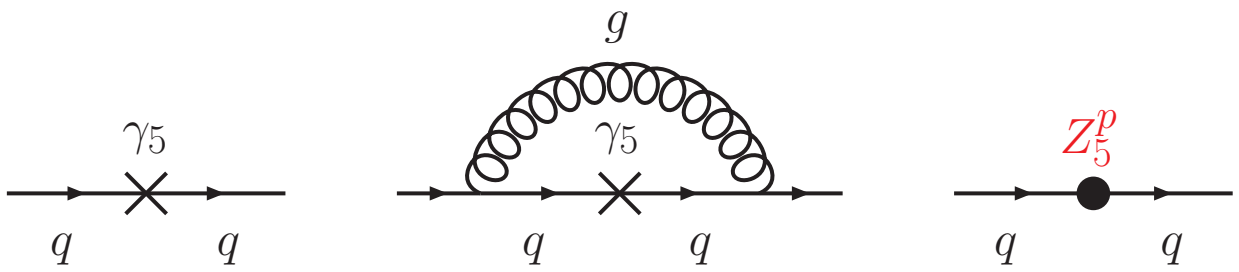
$$\mathrm{tr}(\gamma_\mu \gamma_\nu \gamma_\rho \gamma_\sigma \gamma_5) = 4i\varepsilon_{\mu\nu\rho\sigma}.$$

Traces in diagrams like




have been evaluated independently by
TRACER[Jamin et. al. '93] and our own FORM[Vermaseren '00] – routine

# There is still a subtlety...

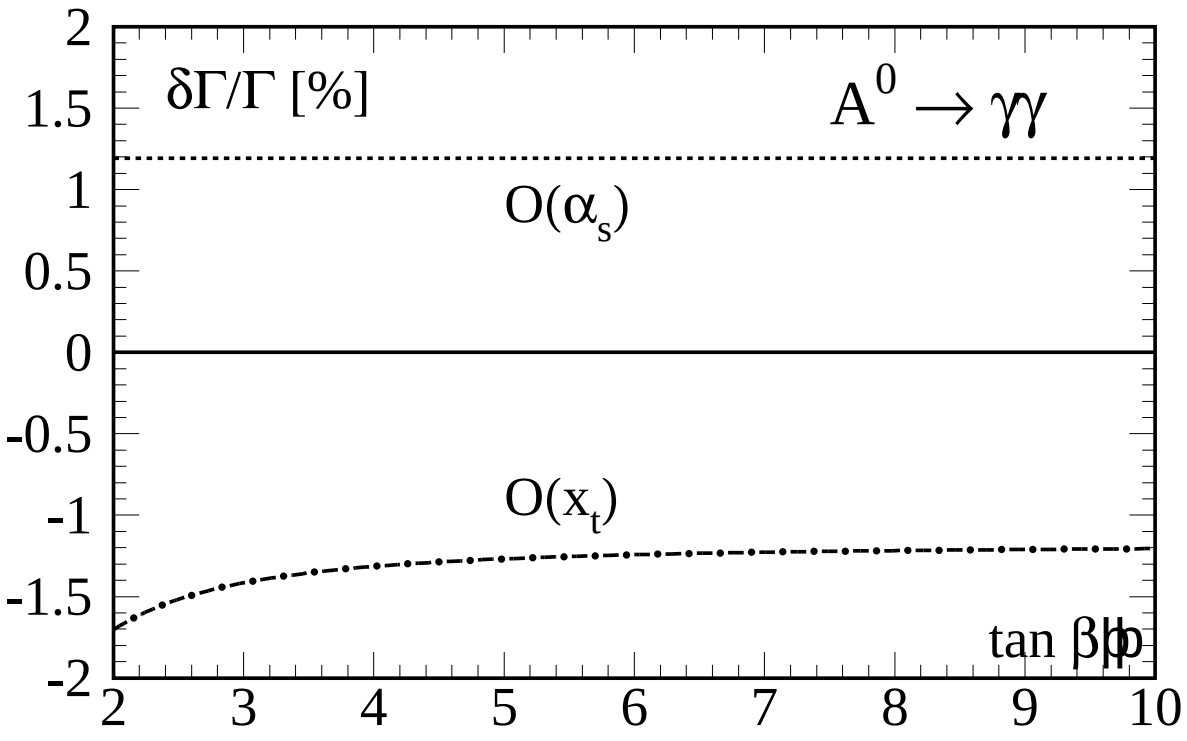



$$\gamma_\mu \not{q} \gamma_5 \not{q} \gamma^\mu = \underbrace{\gamma_\mu \not{q} \not{q} \gamma^\mu \gamma_5}_{\text{anticommuting}} + \underbrace{\gamma_\mu \not{q} (-2 \not{q} \hat{\gamma}^\mu - 2 \tilde{\not{q}} \gamma^\mu + 4 \tilde{\not{q}} \hat{\gamma}^\mu) \gamma_5}_{\text{evanescent}} .$$

...subtract finite contribution by a counterterm $Z_5^p$

$$Z_5^p = 0 \text{ to } \mathcal{O}(G_F m_t^2).$$

# Results: $A^0 \longrightarrow \gamma\gamma$




$M_{A^0} = 100\text{GeV}$

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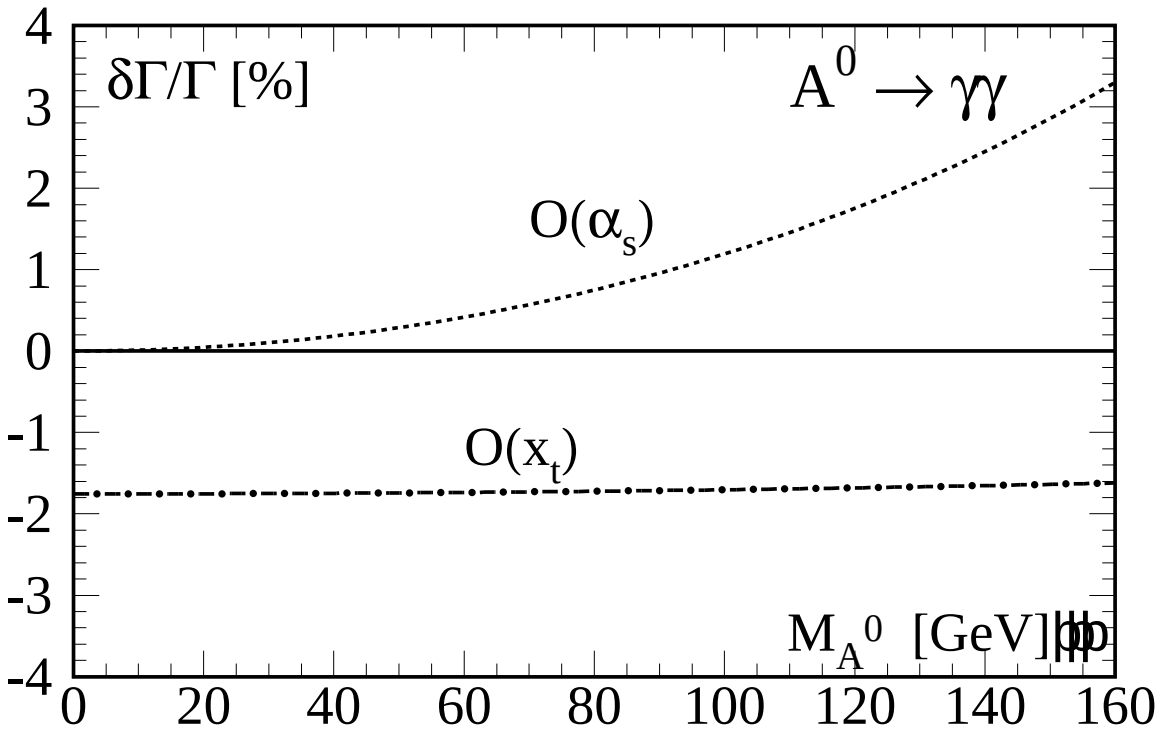
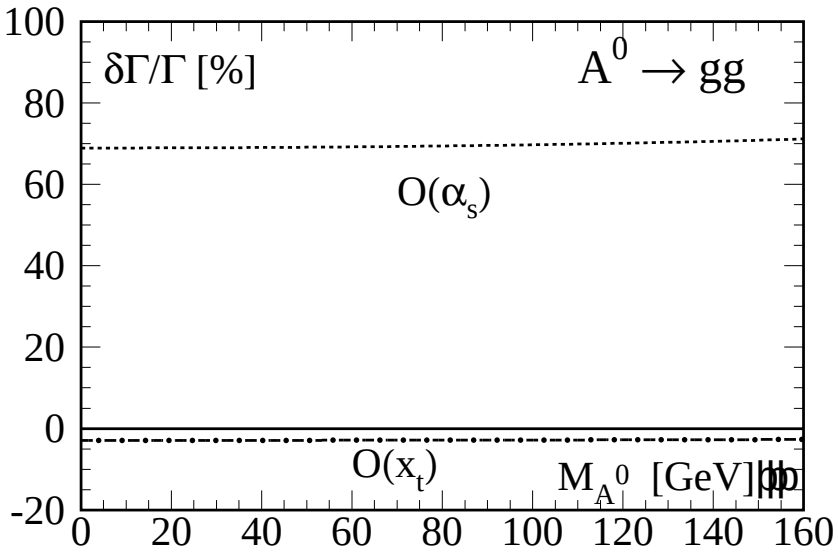



$\tan\beta = 2$

# Results: $A^0 \longrightarrow gg$

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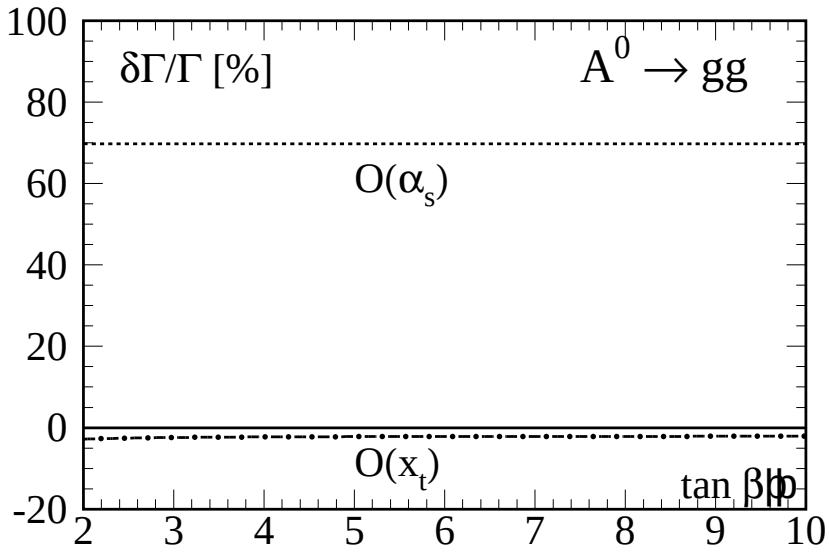


$M_{A^0} = 100\text{GeV}$

# Conclusion

- We have calculated the $\mathcal{O}(G_F m_t^2)$ electroweak corrections to the decay $A^0 \to \gamma\gamma/gg$
- Fermion traces containing odd numbers of $\gamma_5$ matrices $\Rightarrow$ HV scheme
- The corrections are of the same size and opposite sign as QCD corrections for $A^0 \to \gamma\gamma$, and small for $A^0 \to gg$