# Precise predictions for SUSY processes at the ILC

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# MOTIVATION

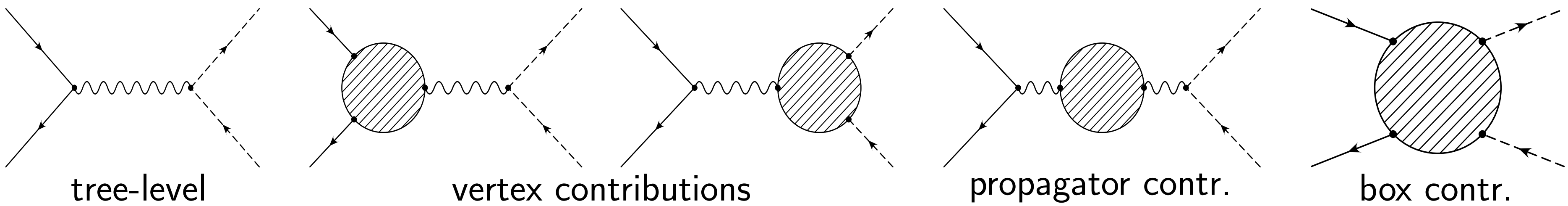
- Important goals of the ILC - confirmation of SUSY
  - identifying the SUSY breaking scenario
  - investigating the grand unification

- Precision predictions needed along with precisely defined input parameters.

- Neutralino, chargino, sfermion production processes provide access to the SUSY parameters

$$(M, M', M_Q^2, M_U^2, M_D^2, M_E^2, A_t, A_b, A_\tau), (\mu, \tan\beta)$$

# $\mathcal{O}(\alpha)$ CORRECTIONS TO PRODUCTION PROCESSES I.




## SFERMION (3rd gen.) results:

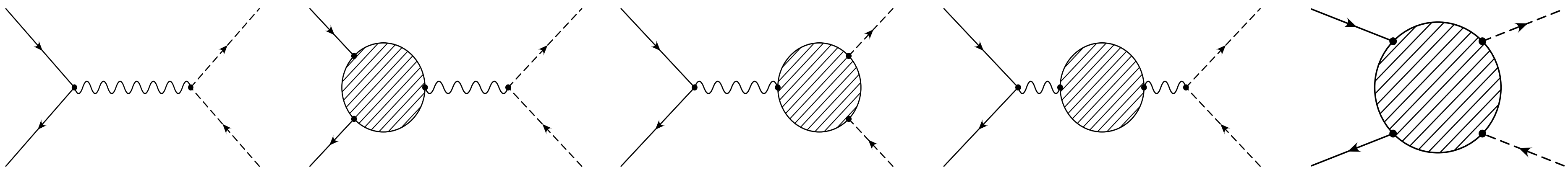
- SUSY-QCD corrections
  [Arhrib, Capdequi-Peyranere, Djouadi '95]
  [Eberl, Bartl, Majerotto '96]
- Yukawa corrections without box
  [Eberl, Kraml, Majerotto '99]
- electro-weak corrections
  [Arhrib, Hollik '03]
  [Kovarik et al. '04]

## NEUTRALINO/CHARGINO results:

- chargino corrections
  [Blank, Hollik '00]
- neutralino corrections
  [Öller, Eberl, Majerotto '04]
- chargino corrections
  [Fritzsche, Hollik '04]

- Calculations presented here - $\mathcal{O}(\alpha)$ corrections to production processes

# $\mathcal{O}(\alpha)$ CORRECTIONS TO PRODUCTION PROCESSES II.




- Total cross-section $\sigma^{\rm tot} = \sigma^{\rm tree} + (\Delta\sigma^{\rm QCD}+)\ \Delta\sigma^{\rm weak} + \Delta\sigma^{\rm QED}_{uni} + \Delta\sigma^{\rm QED}_{rem}$
- QED- corrections - Bremsstrahlung $\sigma(e^+e^- \to X\gamma)$ + higher order initial state radiation

- Extensive use of FeynArts & FormCalc & LoopTools (FF) packages
- On-shell renormalization: $\alpha(M_Z)$ or $G_\mu$, $\text{pole masses}$
- SPS1a' point input (transformed to on-shell parameters)
- Renormalization scheme and input parameters compatible with the SPA project

# $\overline{\rm DR}$ vs. ON-SHELL INPUT PARAMETERS

$$\text{SPA input} = \begin{tikzcd}[column sep=huge, row sep=huge]
\begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix}_{\overline{\rm DR}} \arrow[r, "\text{diag}"] \arrow[d, "\delta_1"'] & \begin{pmatrix} m_{1} & 0 \\ 0 & m_{2} \end{pmatrix}_{\overline{\rm DR}} \arrow[d, "\delta_2"] \\
\begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix}_{\rm OS} \arrow[r, "\text{diag}", "\Delta \text{M}"'] & \begin{pmatrix} M_{1} & 0 \\ 0 & M_{2} \end{pmatrix}_{\rm OS} = \text{Pole masses}
\end{tikzcd}$$

- Counterterm $\delta_2$ example

$$M_i\,(\text{pole}) = m_i^{\overline{\rm DR}} - \hat{\Sigma}\,(q^2 = M^2_{i,\textsf{pole}})$$

- Counterterm $\delta_1$ more involved + one must include finite shifts $\Delta$M for consistence
- Two different but equivalent methods to include the finite shifts $\Delta$M available

[Eberl, Majerotto, Kincel, Yamada '01], [Fritzsche, Hollik '02]

# INPUT PARAMETERS & SPA-PROJECT

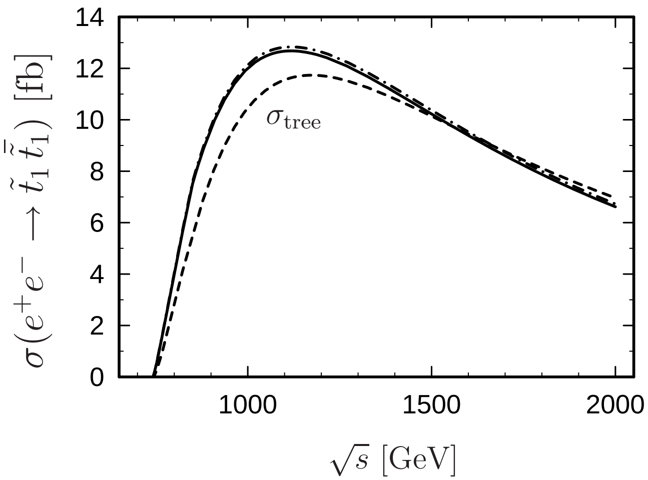
SPA project - SUSY parameters $\overline{\mathrm{DR}}$ and Pole masses (where possible) $\longrightarrow$ talk by W.Hollik

- SPS1a' $\overline{\mathrm{DR}}$ parameters given at scale $Q = 1\mathrm{TeV}$

Example: Comparison of values between SPS1a' $\overline{\mathrm{DR}}$ parameters & OS parameters (after finite shifts)

| Parameters | SPS1a' [GeV] | OS input [GeV] |
|---|---|---|
| $\tan\beta$ | 10 | 10.307 |
| $M_1$ | 103.216 | 100.320 |
| $M_2$ | 193.305 | 197.028 |
| $\mu$ | 402.872 | 399.936 |
| $M_{Q_3}$ | 471.259 | 507.234 |
| $M_{D_3}$ | 501.353 | 538.920 |
| $M_{U_3}$ | 384.585 | 410.107 |
| $M_{L_3}$ | 179.493 | 181.776 |
| $M_{E_3}$ | 109.872 | 111.568 |

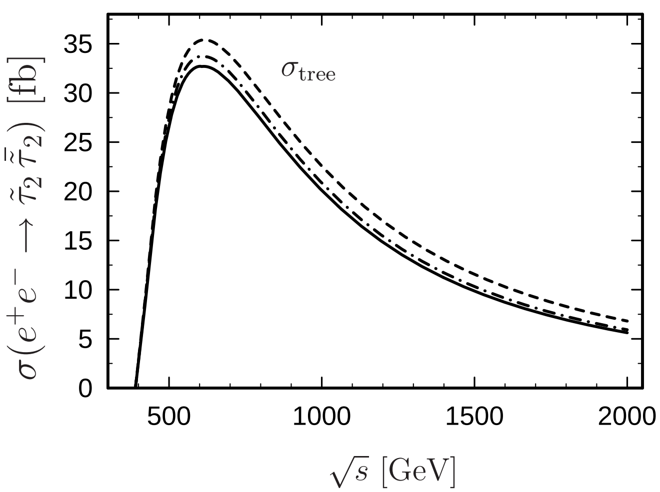
# WEAK CORRECTIONS DEFINITION




SPA weak corrections definition

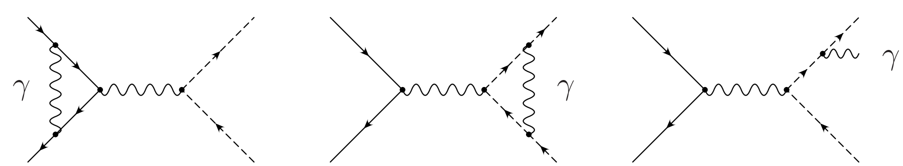
$$d\sigma^{\text{weak}} = d\sigma^{\text{virt+soft}} + \frac{\alpha}{\pi}\left(\left(1 - L_e - \Delta_\gamma\right)\log\frac{4\Delta E^2}{s} - \frac{3}{2}L_e\right)d\sigma^{\text{tree}}$$

- $\Delta E$ cut-off independent, subtracted contributions $L_e = \log\frac{s}{m_e^2}$
- Universal definition applicable to every process




Feynman diagram weak corrections definition

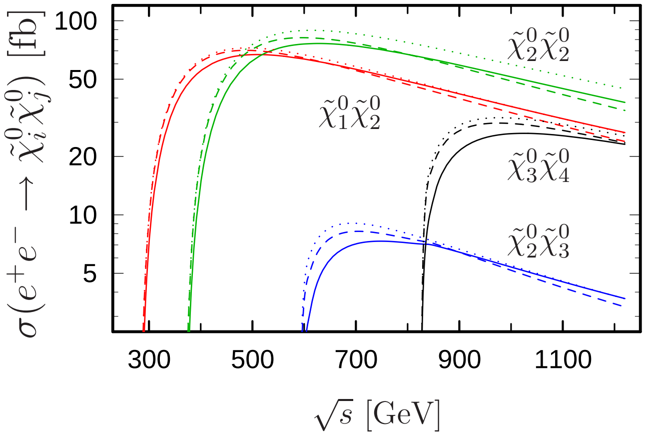
Include all diagrams except those with an additional photon e.g.

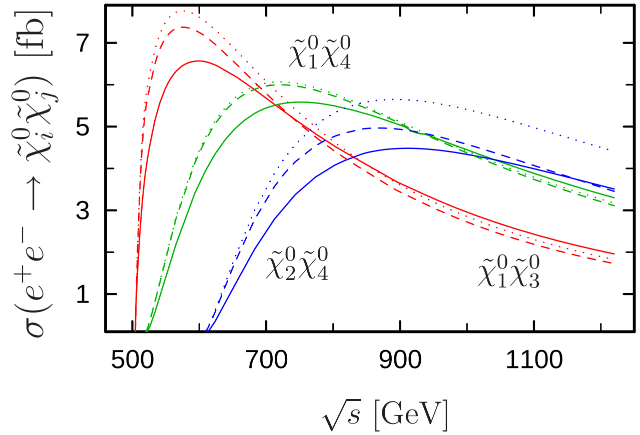



- Definition applicable only to some processes

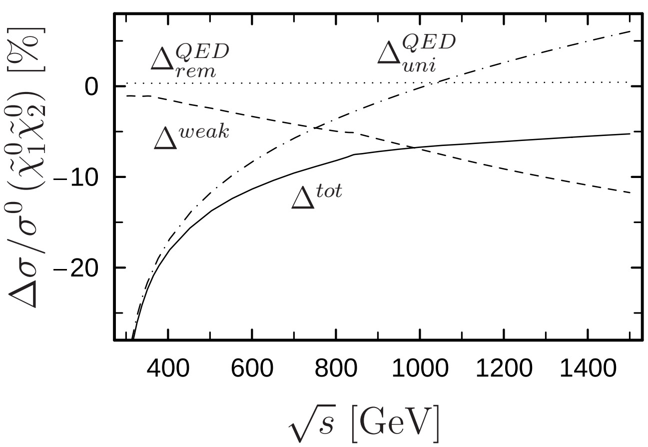
# NEUTRALINO PRODUCTION

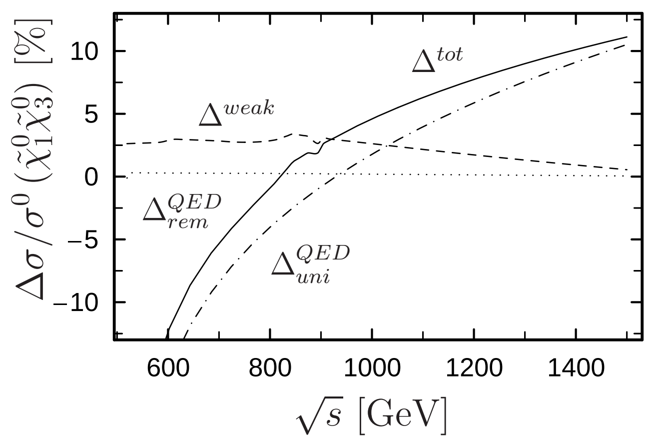
## TOTAL CORRECTIONS



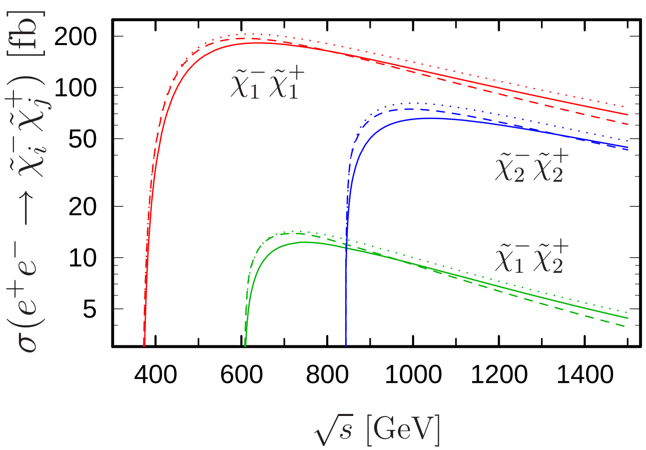

## RELATIVE CORRECTIONS

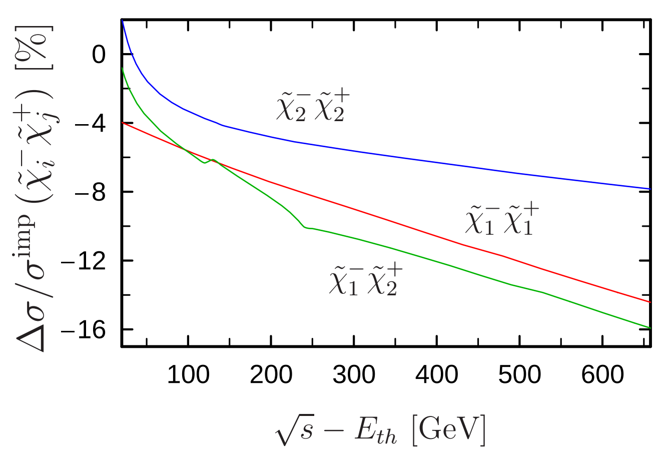


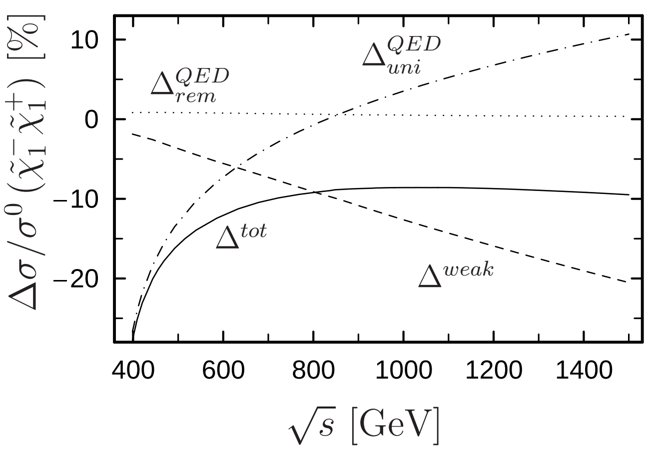
# CHARGINO PRODUCTION

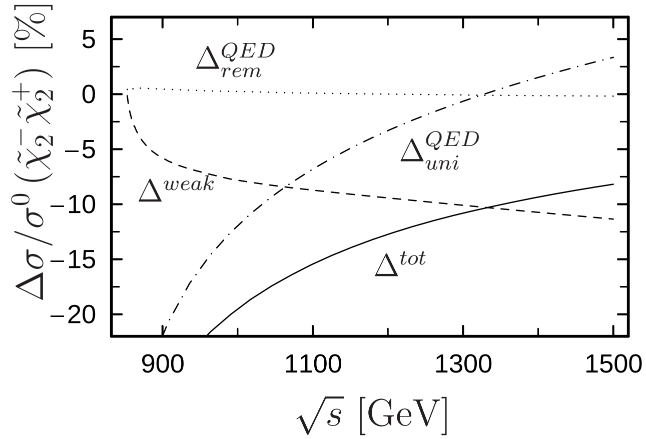
## TOTAL CORRECTIONS



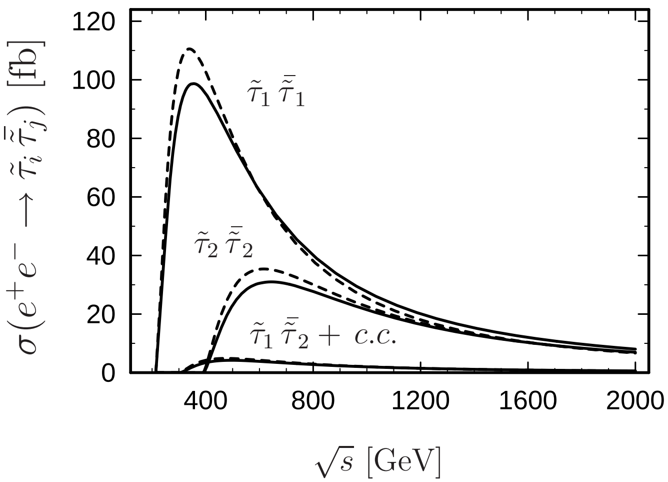

## RELATIVE CORRECTIONS



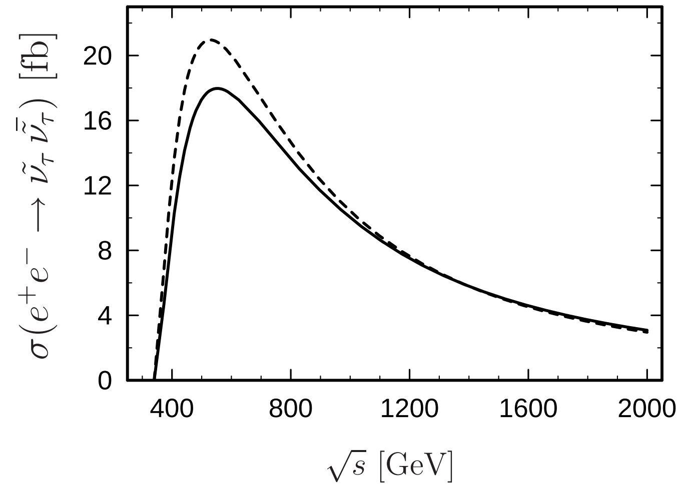



# SLEPTON PRODUCTION (3rd gen.)

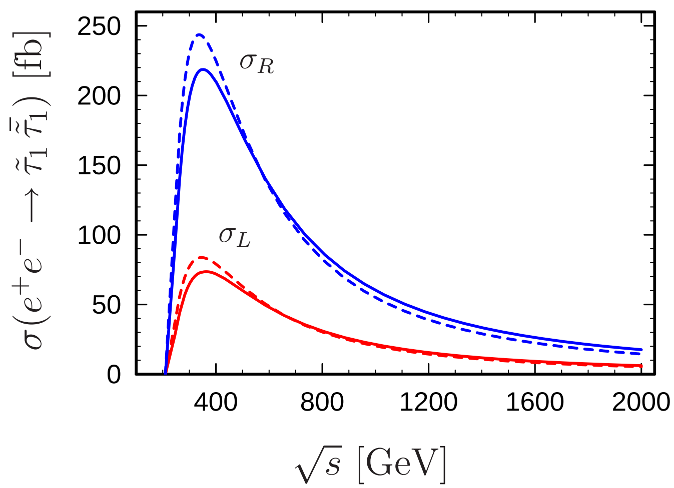
## STAUS




## TAU-SNEUTRINO



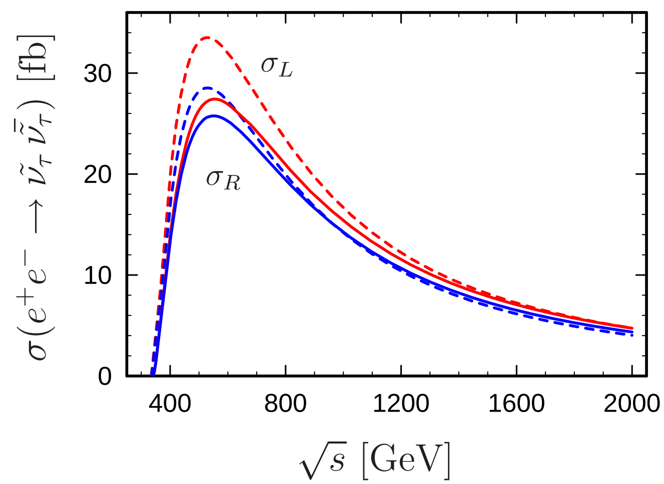

## POLARIZED $\tilde{\tau}_1\,\bar{\tilde{\tau}}_1$




$P(e^-) = 80\%$

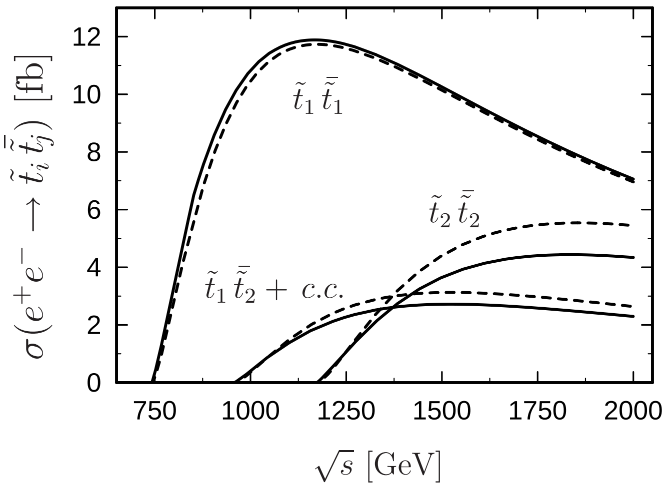
$P(e^+) = 60\%$

## POLARIZED $\tilde{\nu}_\tau\,\bar{\tilde{\nu}}_\tau$

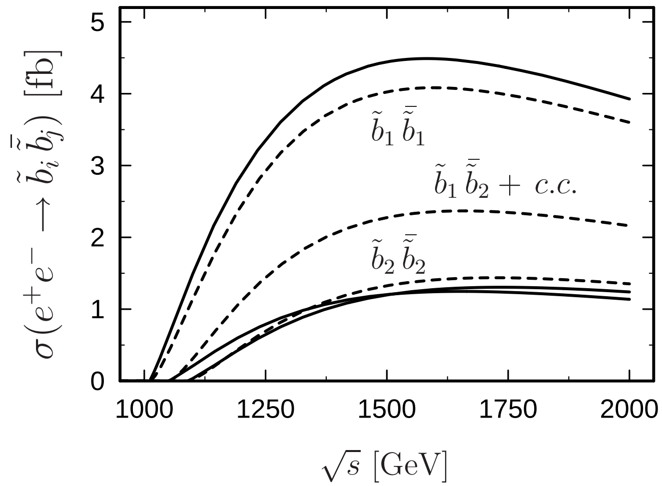


# SQUARK PRODUCTION (3rd gen.)

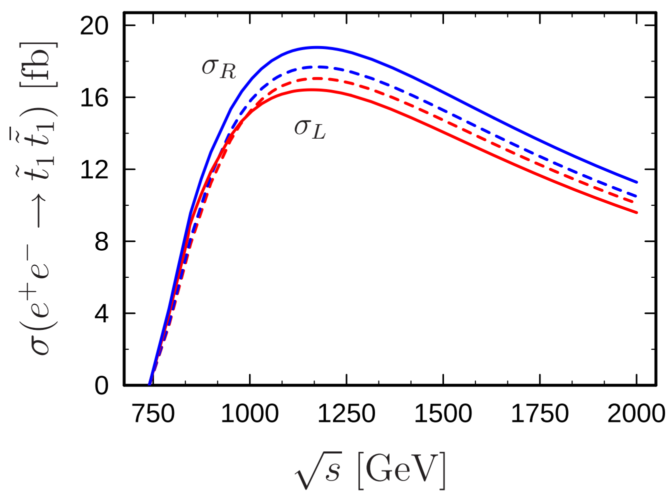
## STOPS




## SBOTTOMS



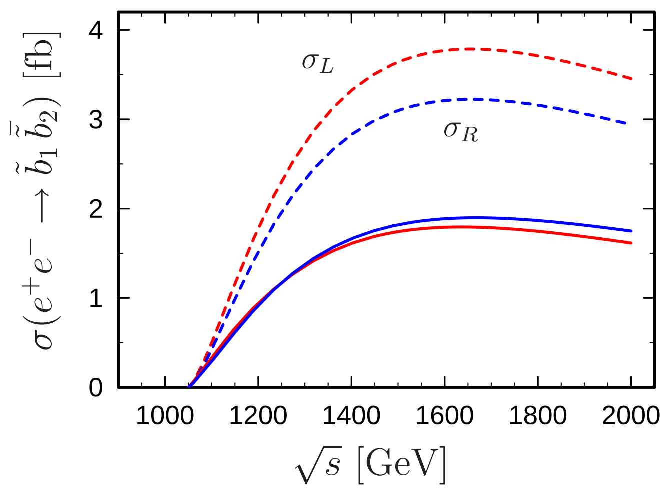

## Polarized $\tilde{t}_1 \bar{\tilde{t}}_1$




$P(e^-) = 80\%$

$P(e^+) = 60\%$

## Polarized $\tilde{b}_1 \bar{\tilde{b}}_2$



# CONCLUSIONS

- Precise predictions and input essential when identifying SUSY breaking scenario

- Full $\mathcal{O}(\alpha)$ corrections to different production processes have been presented

- Compatible input parameters $\longrightarrow$ directly comparable numerical results