Studying new physics with precision electroweak observables in multi-TeV e^+e^- collisions

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based on work done with Marco Battaglia (CERN & UCSC)

Exploring BSM physics indirectly

- Multi-TeV e^+e^- collider: a precision machine. $\sqrt{s}$ comparable to LHC; indirect sensitivity may take us well beyond 10 TeV!
- Even if NP present at the TeV scale $\rightarrow$ still heavier states are likely to exist
- Indirect searches complementary - theoretically and experimentally - to more "mainstream" studies (Higgs physics, SUSY)
- Also, ideal to make full use of polarization!

Exploring BSM physics indirectly

- Worth exploring the simplest scenario: new massive neutral bosons
- Plenty of (well-known) motivations. Theory:
  1. GUTs with rank > 4 gauge groups ($SO(10)$, E_6 ...)
  2. String models phenomenological realizations
  3. ADD Extra Dimensions
  4. Strong EW breaking - Composite/Little Higgs - Warped Extra Dimensions
- And Experiment: $e^+e^- \to f\bar{f}$, clean, "easy" signal

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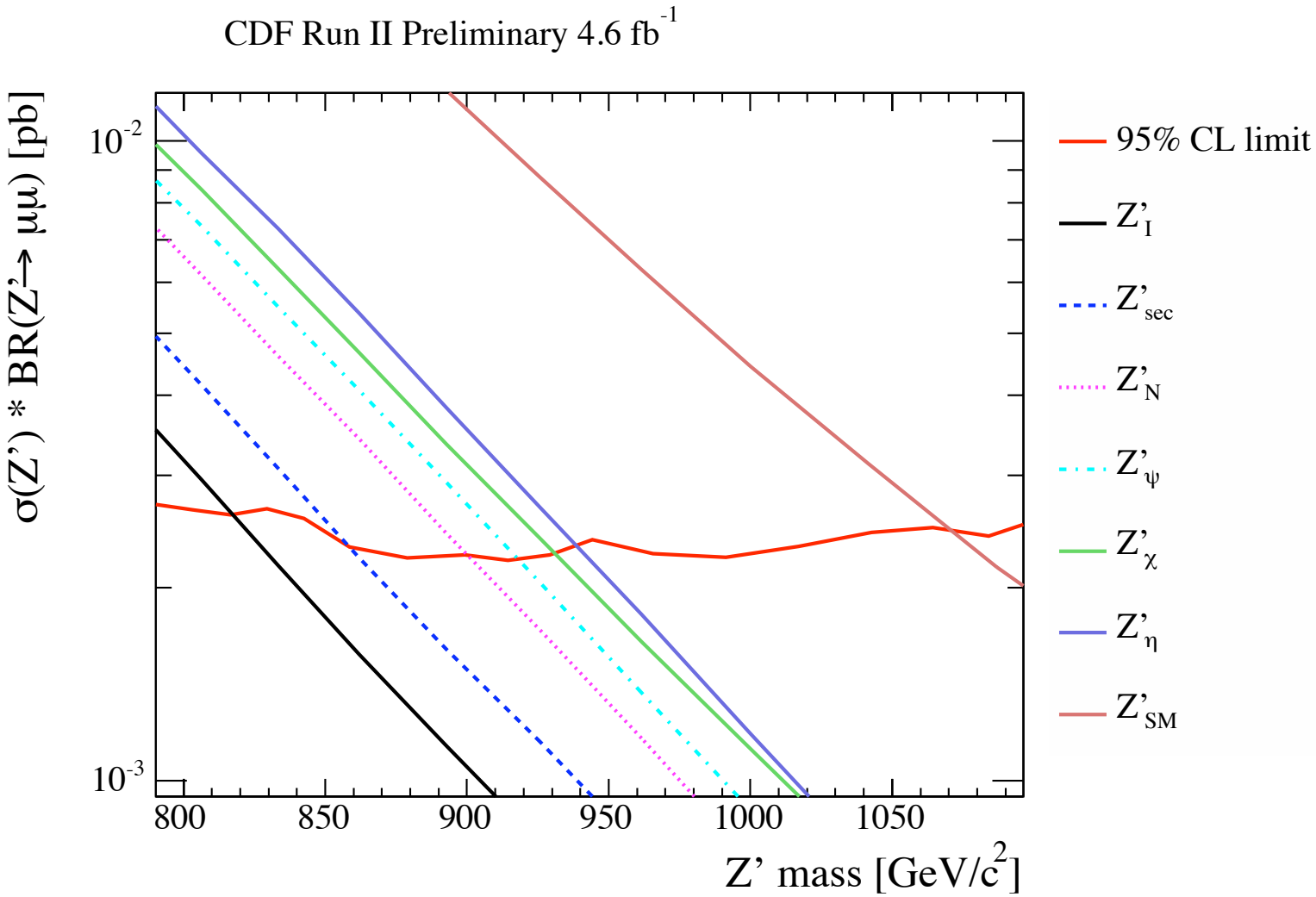
Z': current limits



Goals of the study

- "Get a feeling" of a Multi-TeV e^+e^- collider potential by looking at different models, understand the magnitude of expected effects, comparing them to realistic experimental errors
- Compare the impact of several observables; understand how well various models could be distinguished
- See the impact of polarization

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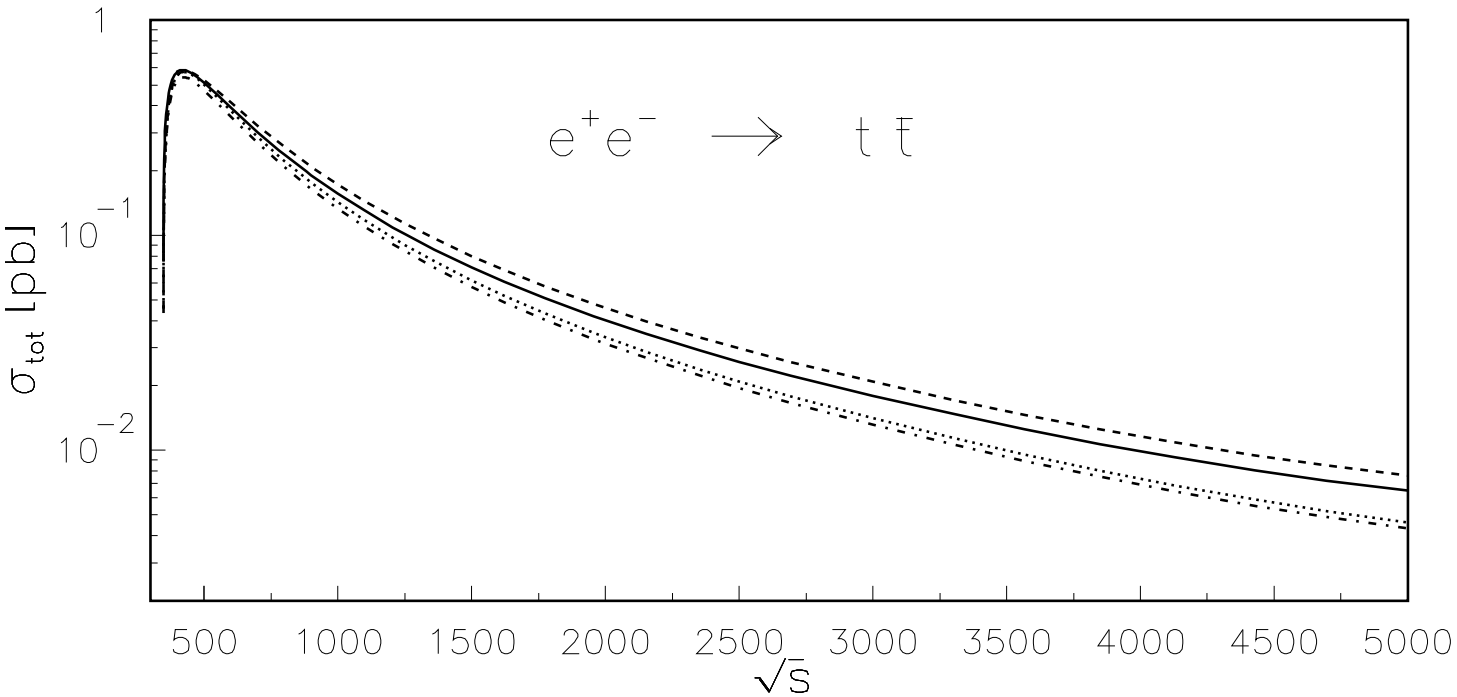
Strategy of the study

- Simple Z'(s) models studied with CalcHEP/CompHEP
- Born approximation: big radiative corrections neglected
- Example calculation of EW corrections[1]:



Born **Ew corr.** **Ew corr, $s' = 0.7\,s$ cut**
Ew corr, $s' = 0.7\,s$ cut and $\cos\theta = 0.95$ cut

[1] from hep-ph/0412251

Strategy of the study

- Cross sections and LR and FB Asymmetries systematically analyzed (with polarization)
- Take results at a qualitative level; theoretical uncertainty is big but should be reducible to 1% or less

The Models Part I: "standard" Z'

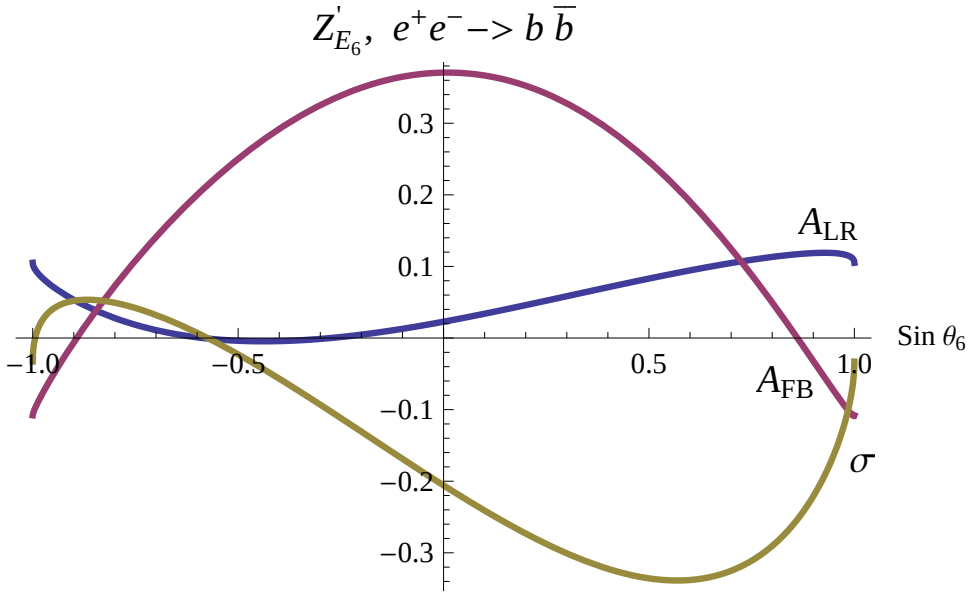
- Sequential Z': benchmark
- Minimal Z': most economical mode. No exotics except the $Z' + \nu_R$s. Anomaly cancellation. Includes several well studied models: Z'_{LR}, Z'_Y, Z'_{B-L}.
  New neutral interaction term:

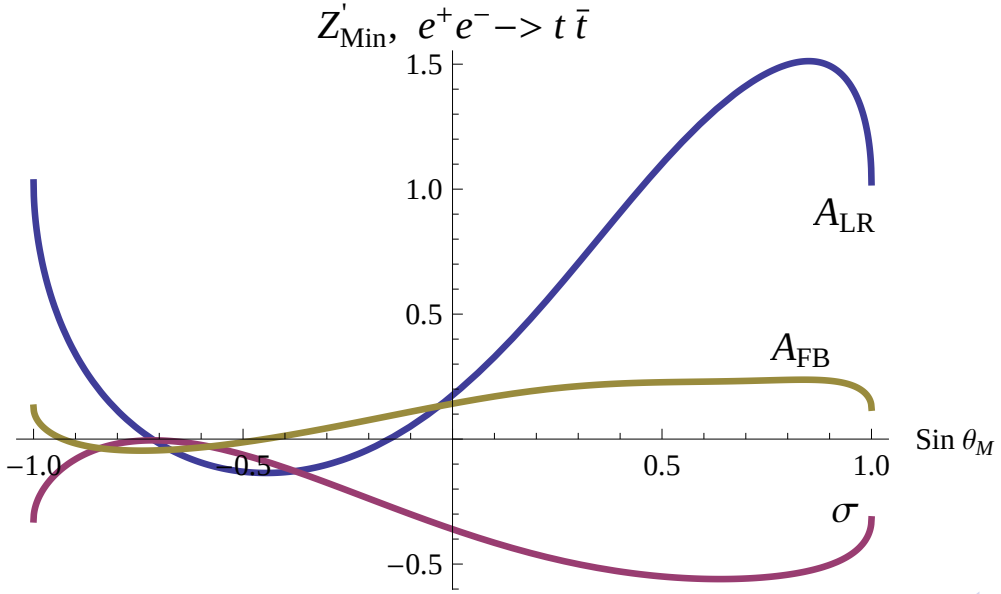
$$\mathcal{L}_{int} = i\, g_Z Z'_\mu\, \bar{f}\left(\gamma^\mu \tilde{g}_Y Y + \tilde{g}_{BL}(B-L)\right) f$$

- E_6-based Z': notable nonminimal GUT-inspired scenario. The Z' interaction:

$$\mathcal{L}_{int} = i\, \sqrt{\frac{5}{3}} g \frac{s_\theta}{c_\theta} Z'_\mu\, \bar{f}\left(\gamma^\mu c_{\theta_6} Q^f_{\chi\,(L,R)} + s_{\theta_6} Q^f_{\psi\,(L,R)}\right) f$$

Results: standard Z'

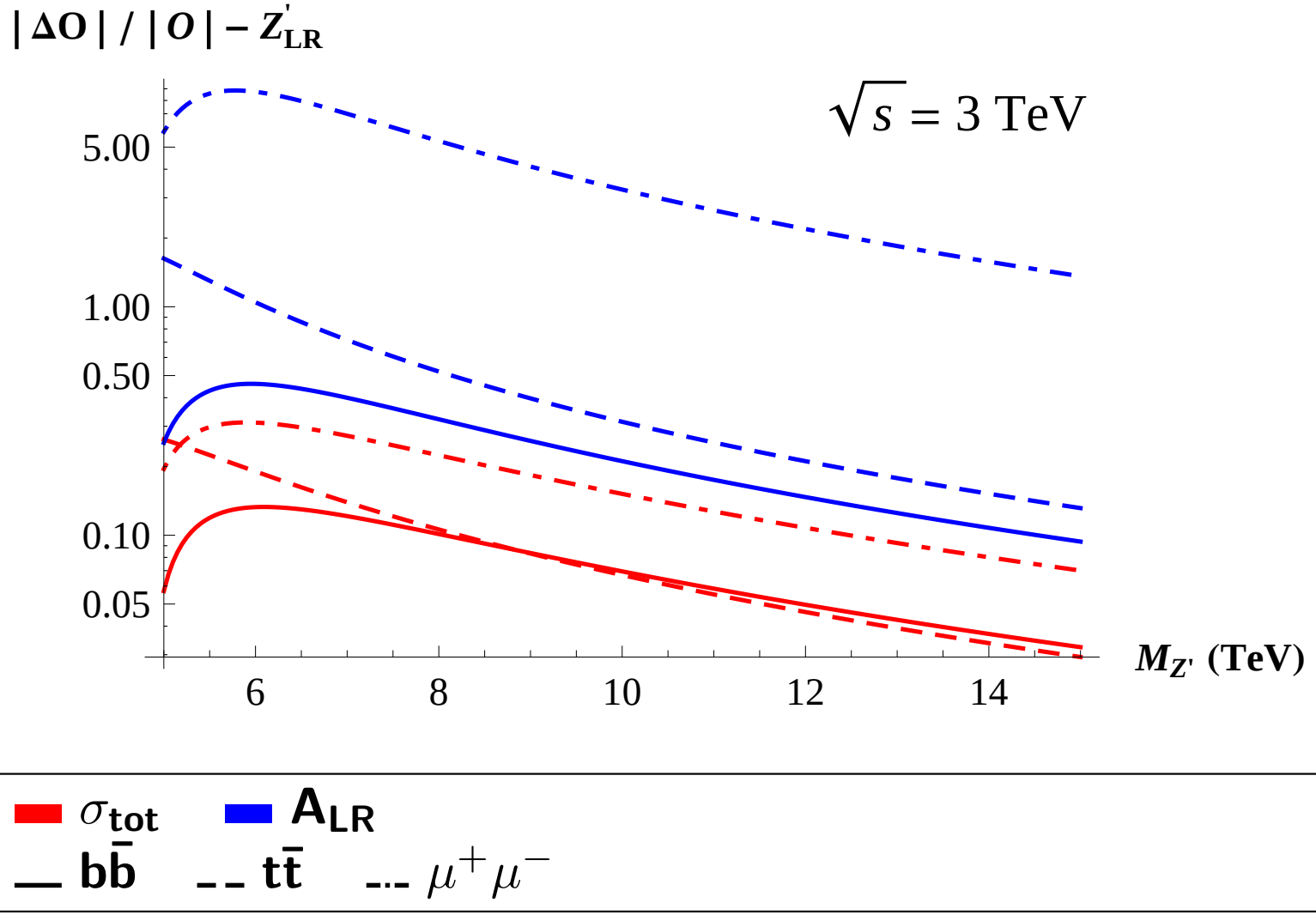




Model comparison:

Pattern of observable deviations vs. model parameters in Z'_{E_6} and Z'_{Min}

Results: standard Z'



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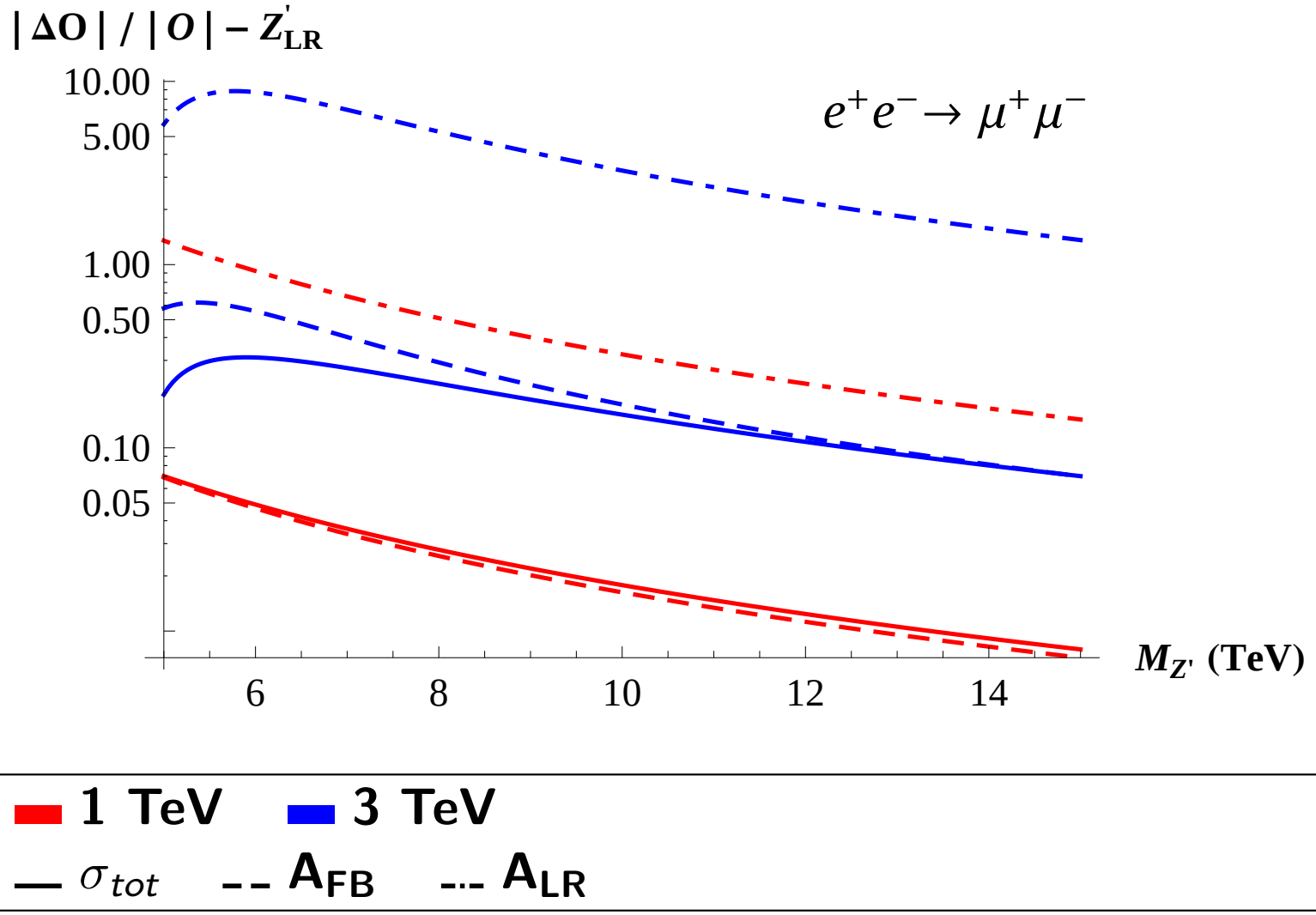
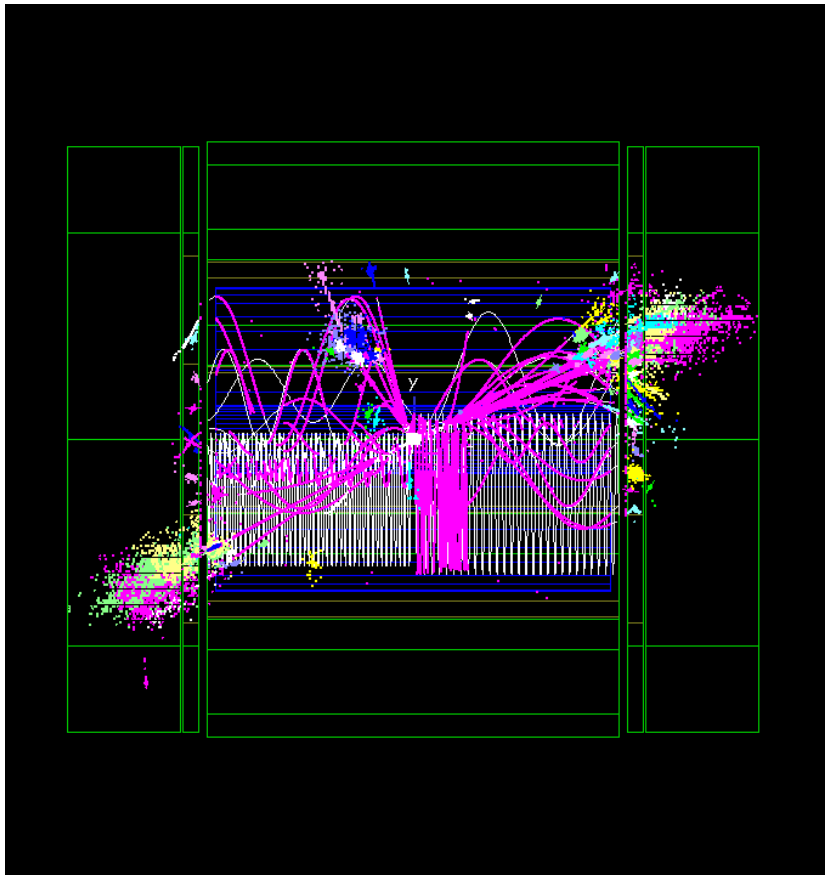


Bottoms and Tops ...

- If we're looking at fermion pairs $\rightarrow \mu^+\mu^-$ the easiest channel
- The expected detector performance, however, is such that it is interesting to extend the analysis to tops and bottoms
- theoretically, it is interesting to check realistic scenario where couplings to the 3^{rd} generation of quarks are either favoured or disfavoured
- b and t event reconstruction under study; preliminary efficiency estimates are 0.75 for bottoms and 0.8 for tops.
- Preliminary estimate of experimental errors @$1ab^{-1}$:

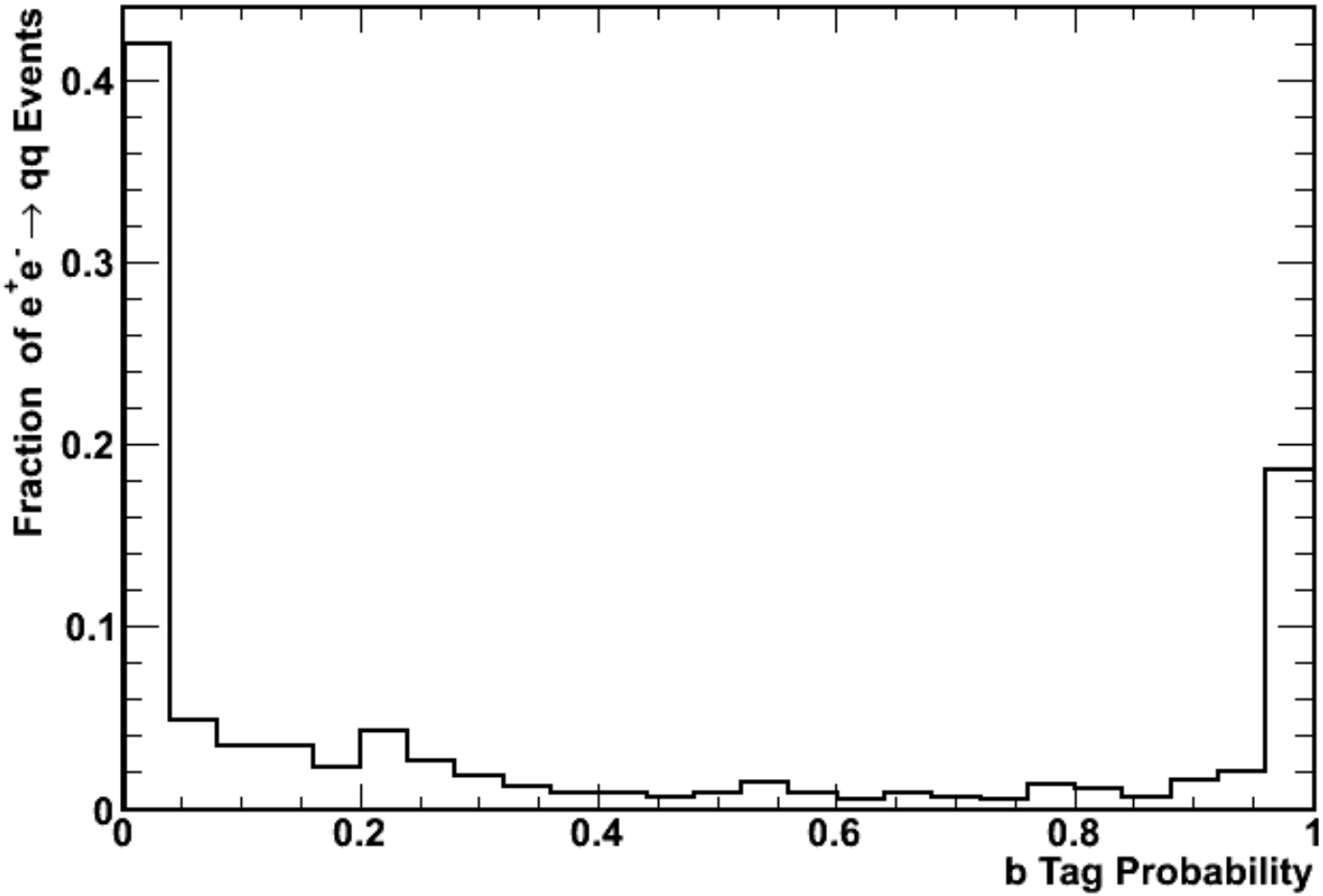
$$\frac{\Delta\sigma}{\sigma_{b\bar{b}}} \simeq 0.015, \quad \frac{\Delta\sigma}{\sigma_{t\bar{t}}} \simeq 0.008, \quad \frac{\Delta A_{FB}}{A_{FB}} \simeq 0.015$$

Preliminary!



Event reconstruction simulation in detector model CLIC_ILD

Preliminary!



b-tagging response ($e + e - - > qq$ with $E_jet > 750GeV$ - full Mokka simulation and Marlin reconstruction)

Models Part II: composite Z'

- Z' coupling usually family independent: don't want large FCNCs
- Are there a good theoretical motivation to look at $b\bar{b}$ and $t\bar{t}$?
- At least one: Warped Extra Dimensions, dual to composite Higgs sector / Strong EW breaking
- A minimal well-studied model based on $SU(2) \otimes SU(2) \otimes U(1)$ symmetry on a slice of AdS_5.
  $\rightarrow$ Study lowest-lying KK resonances
- The top mostly a composite $\rightarrow$ preferential coupling to the extra gauge bosons $\rightarrow$ greatly enhanced production

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[2] hep-ph/0612180

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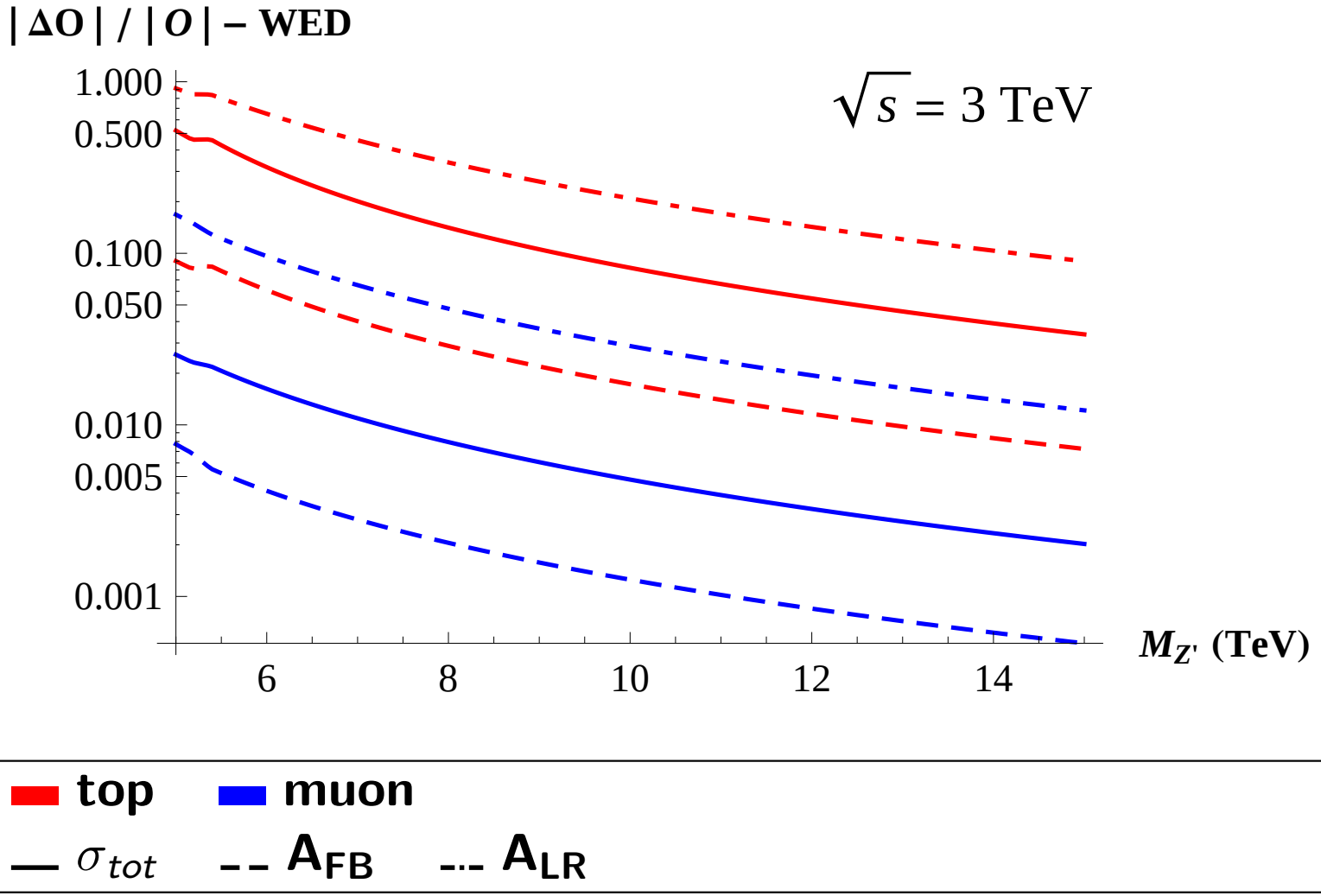
Composite Z': μ vs top



Conclusions

- Multi-TeV e^+e^- collider indirect sensitivity well beyond 10 TeV
- Good potential in discriminating between models
- Polarization is importantas analyzer; it need not be perfect
- Important to look at different fermionic channels (top!)