

Exploring lepton flavor violation at an e^-e^- linear collider

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work in progress with Tim Tait (University of California, Irvine)
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Charged Lepton Flavor Violation

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$$\tau^- \not\rightarrow \mu^+ \mu^- \mu^-$$

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- If neutrino masses are included in the SM,

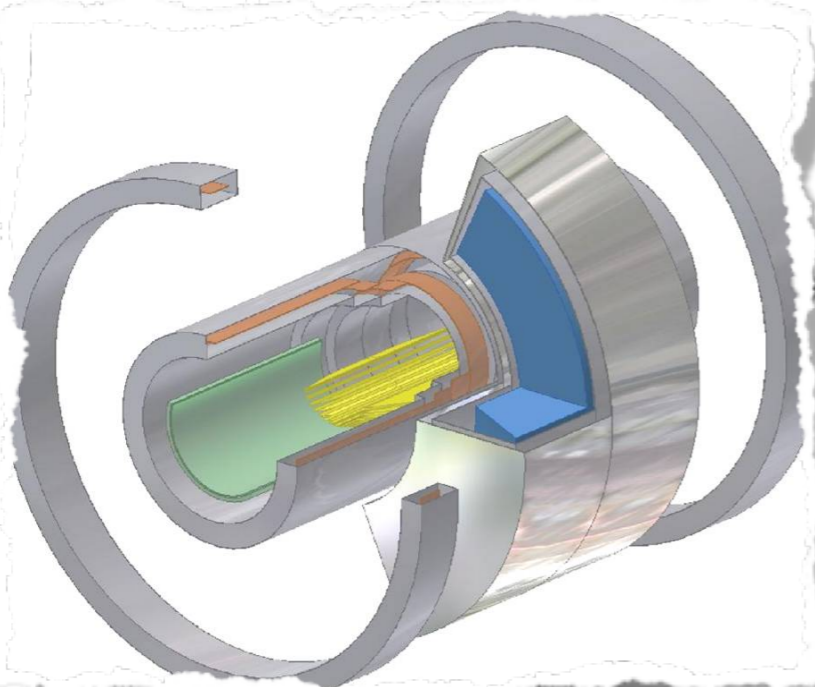
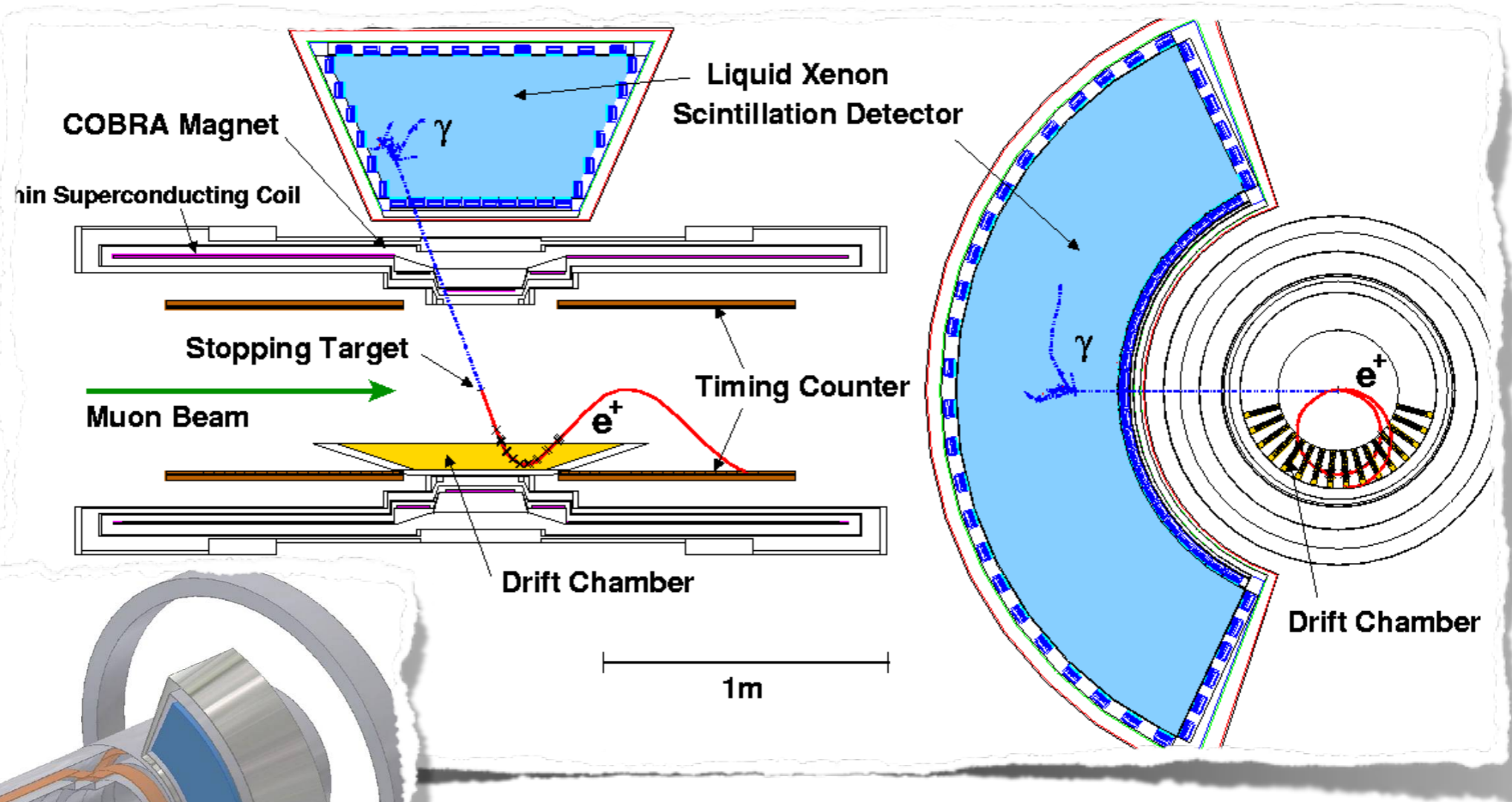
$$\text{BR}(\mu \rightarrow e \gamma) \sim \mathcal{O} \left(\frac{m_\nu^4}{m_W^4} \right).$$

Observable LFV =
new physics!

The MEG Experiment

Paul Scherrer Institut, Switzerland

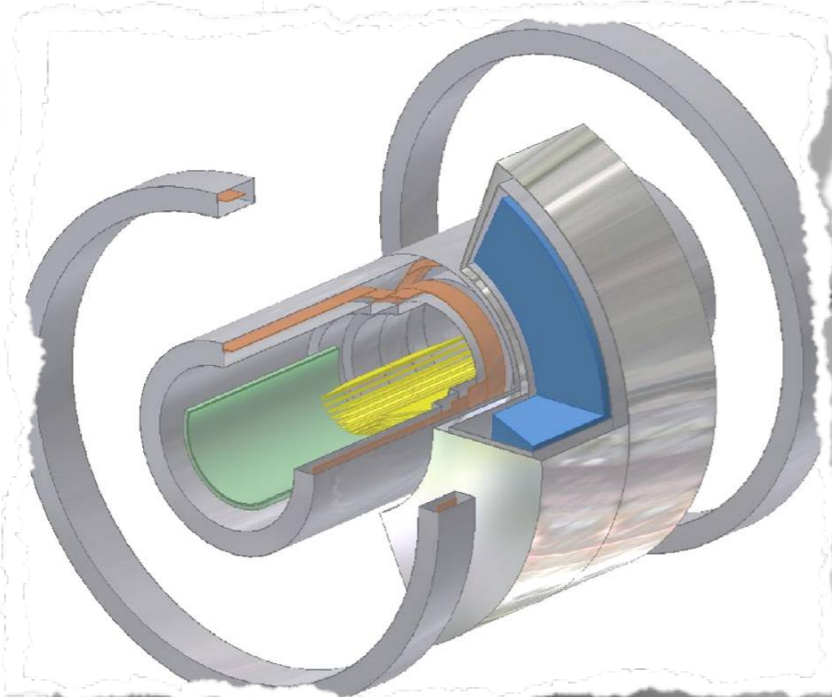
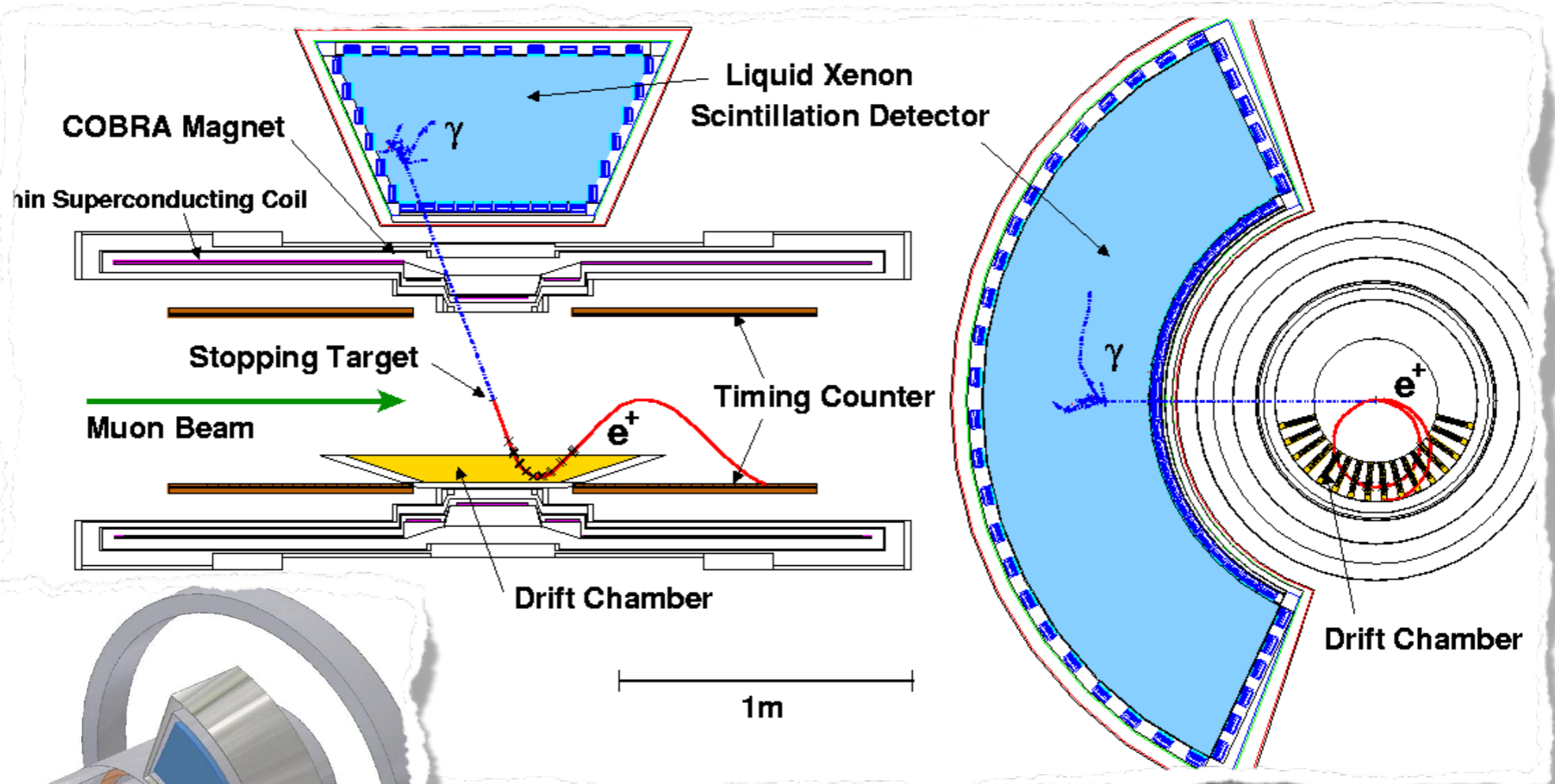
Operating
since 2008



The MEG Experiment

Paul Scherrer Institut, Switzerland

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~360 trillion muon decays
observed.

No $\mu \rightarrow e\gamma$.

Keep
looking.



(MEG) Where We Will Be



...from a talk by Toshinori Mori (2013)

Low Energy Observables

...as a guide to collider observables

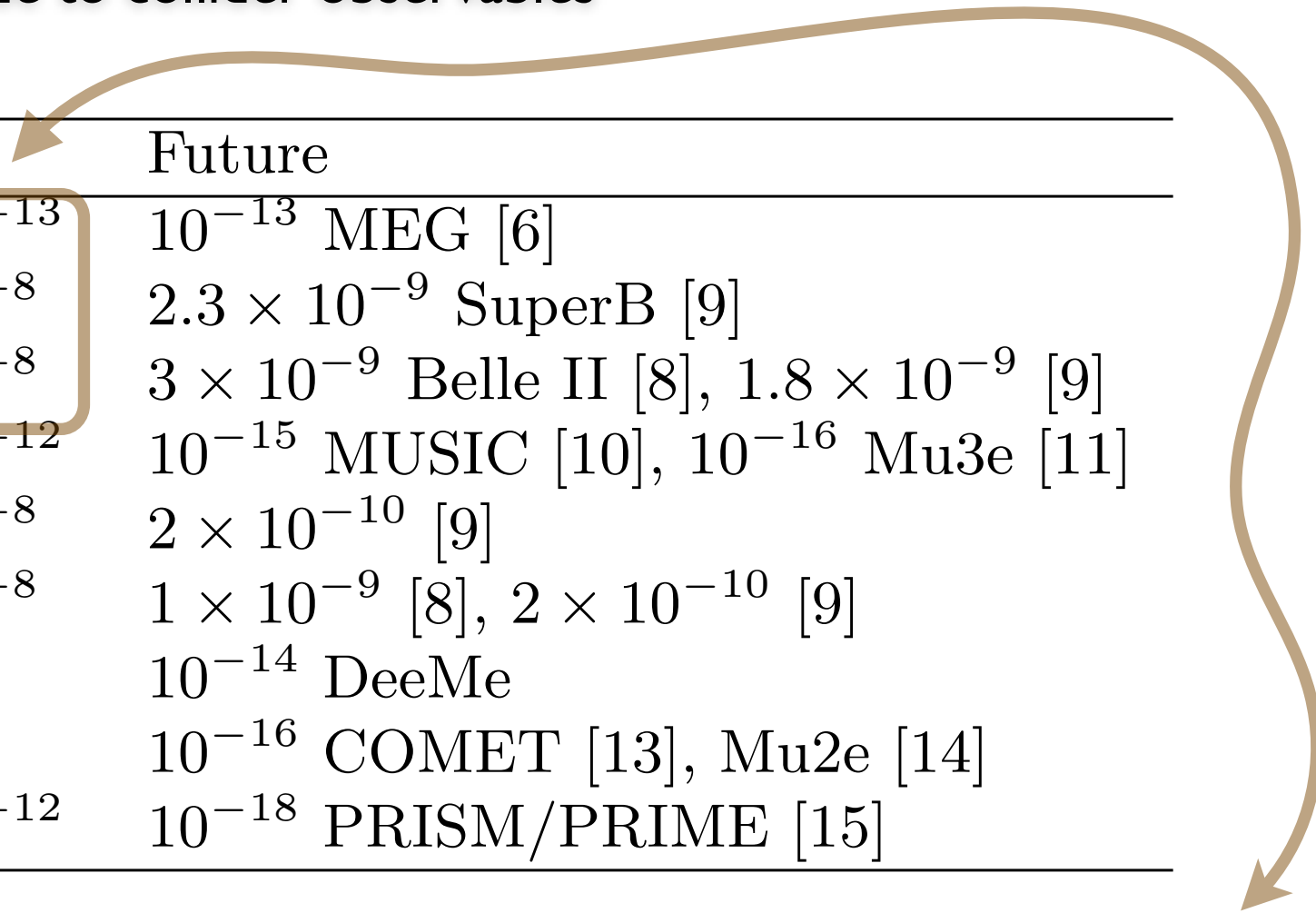
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...as a guide to collider observables

Observable	Limit	Future
$\mu^+ \rightarrow e^+ \gamma$	5.7×10^{-13}	10^{-13} MEG [6]
$\tau^+ \rightarrow e^+ \gamma$	3.3×10^{-8}	2.3×10^{-9} SuperB [9]
$\tau^+ \rightarrow \mu^+ \gamma$	4.4×10^{-8}	3×10^{-9} Belle II [8], 1.8×10^{-9} [9]
$\mu \rightarrow eee$	1.0×10^{-12}	10^{-15} MUSIC [10], 10^{-16} Mu3e [11]
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$\mu^- \text{ SiC} \rightarrow e^- \text{ SiC}$	none	10^{-14} DeeMe
$\mu^- \text{ Al} \rightarrow e^- \text{ Al}$	none	10^{-16} COMET [13], Mu2e [14]
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$\tau \rightarrow e\gamma$ ($\mu\gamma$) limits are too strict for ILC

\Rightarrow We turn to 4-fermion contact operators for ILC studies.

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Strong but not that strong.

$ee \rightarrow \tau e$ is observable at the ILC.

($ee \rightarrow \mu e$ is strongly constrained.)

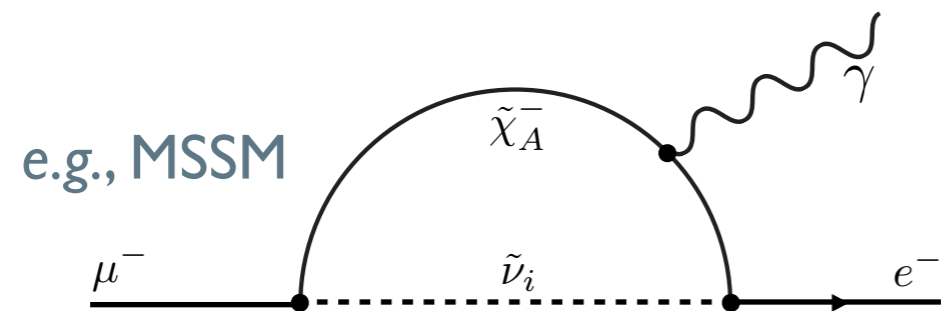
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Suppressing the Penguin

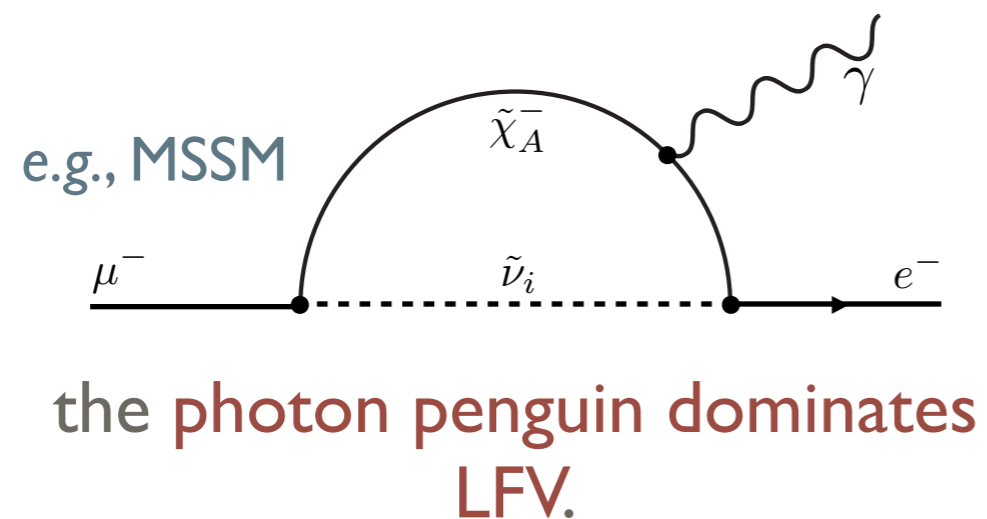
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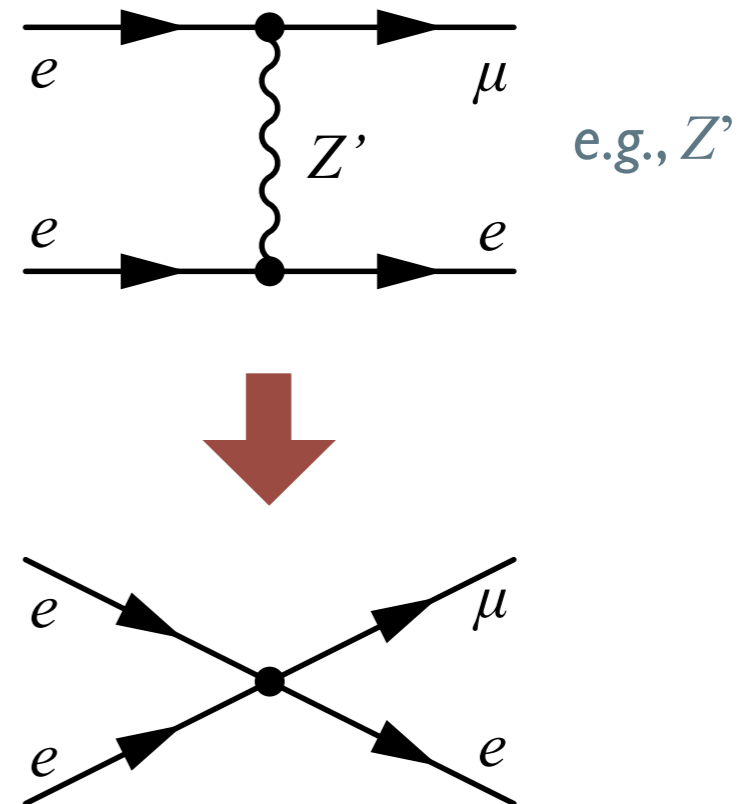
the photon penguin dominates
LFV.

Suppressing the Penguin

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Consider: contact operators via tree-level LFV via bosons.



Our EFT Model

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Possible 4-fermion operators (10):

- (pseudo) scalar (4): $e.g., [\bar{e}e][\bar{\tau}\tau], [\bar{e}\gamma^5 e][\bar{\tau}\tau], \dots$
- (axial) vector (4): $e.g., [\bar{e}\gamma^\mu e][\bar{\tau}\gamma_\mu \tau], [\bar{e}\gamma^\mu \gamma^5 e][\bar{\tau}\gamma_\mu \tau], \dots$
- (anti-symmetric) tensor (2): $[\bar{e}\sigma^{\mu\nu} e][\bar{\tau}\sigma_{\mu\nu} \tau], \epsilon^{\mu\nu\rho\sigma} [\bar{e}\sigma_{\mu\nu} e][\bar{\tau}\sigma_{\rho\sigma} \tau]$

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Our lagrangian choice:

$$-\mathcal{L} \supset (v_{LL}[\bar{e}\gamma^\mu P_L e][\bar{\tau}\gamma_\mu P_L e] + v_{RR}[\bar{e}\gamma^\mu P_R e][\bar{\tau}\gamma_\mu P_R e] \\ + v_{LR}[\bar{e}\gamma^\mu P_L e][\bar{\tau}\gamma_\mu P_R e] + v_{RL}[\bar{e}\gamma^\mu P_R e][\bar{\tau}\gamma_\mu P_L e]) + \text{h.c.}$$

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Complimentary observables:

(unpolarized spins)

$$\Gamma(\tau^- \rightarrow e^+ e^- e^-) = \frac{m_\tau^5}{1,536\pi^3} [2(|v_{LL}|^2 + |v_{RR}|^2) + (|v_{LR}|^2 + |v_{RL}|^2)]$$

$$\sigma(e^+ e^- \rightarrow e^+ \tau^-) = \frac{s}{12\pi} [(|v_{LL}|^2 + |v_{RR}|^2) + (|v_{LR}|^2 + |v_{RL}|^2)]$$

↳ Studied by Ferriera, Guedes, Santos (2007)

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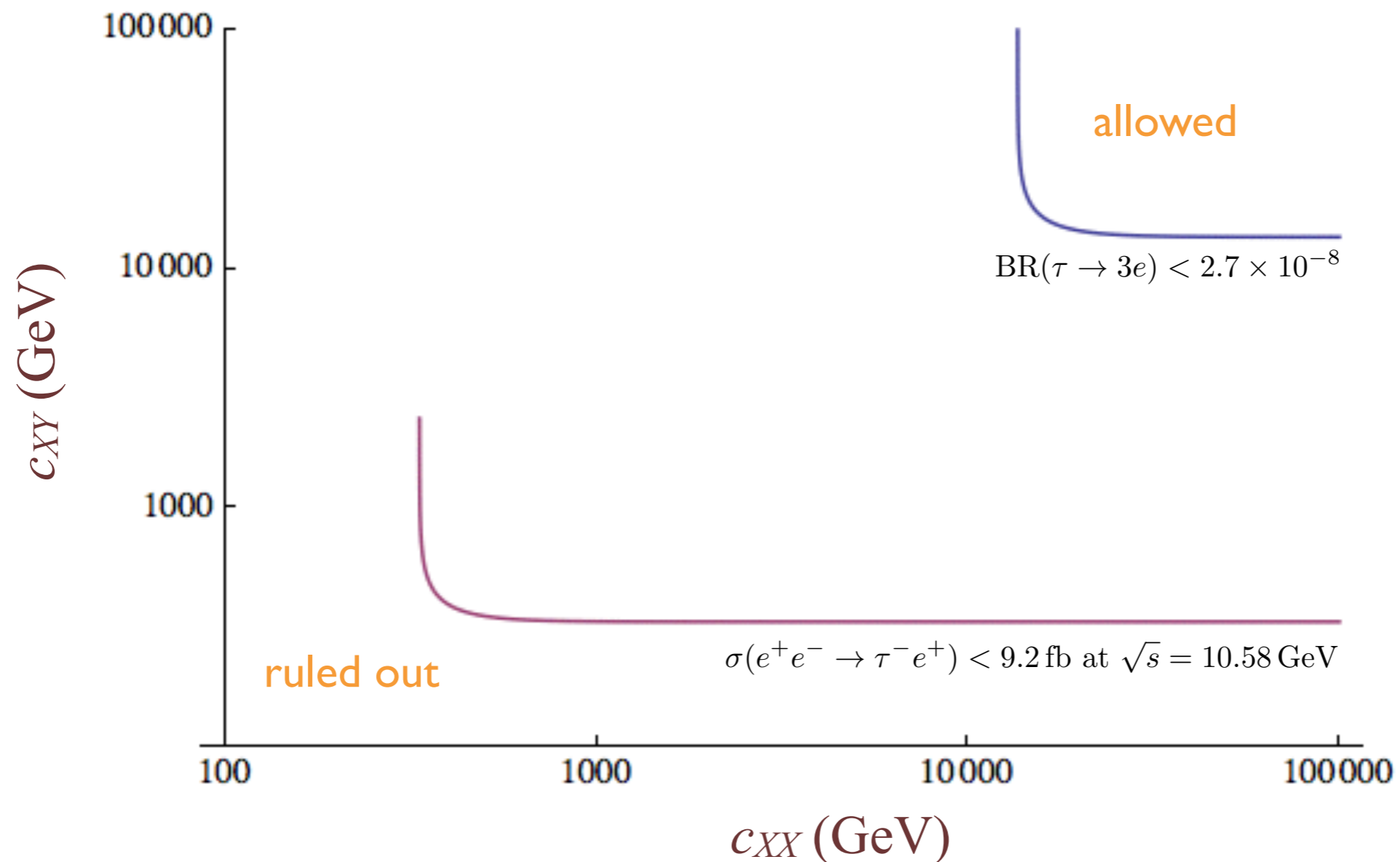
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c 's in GeV units

Coupling Limits

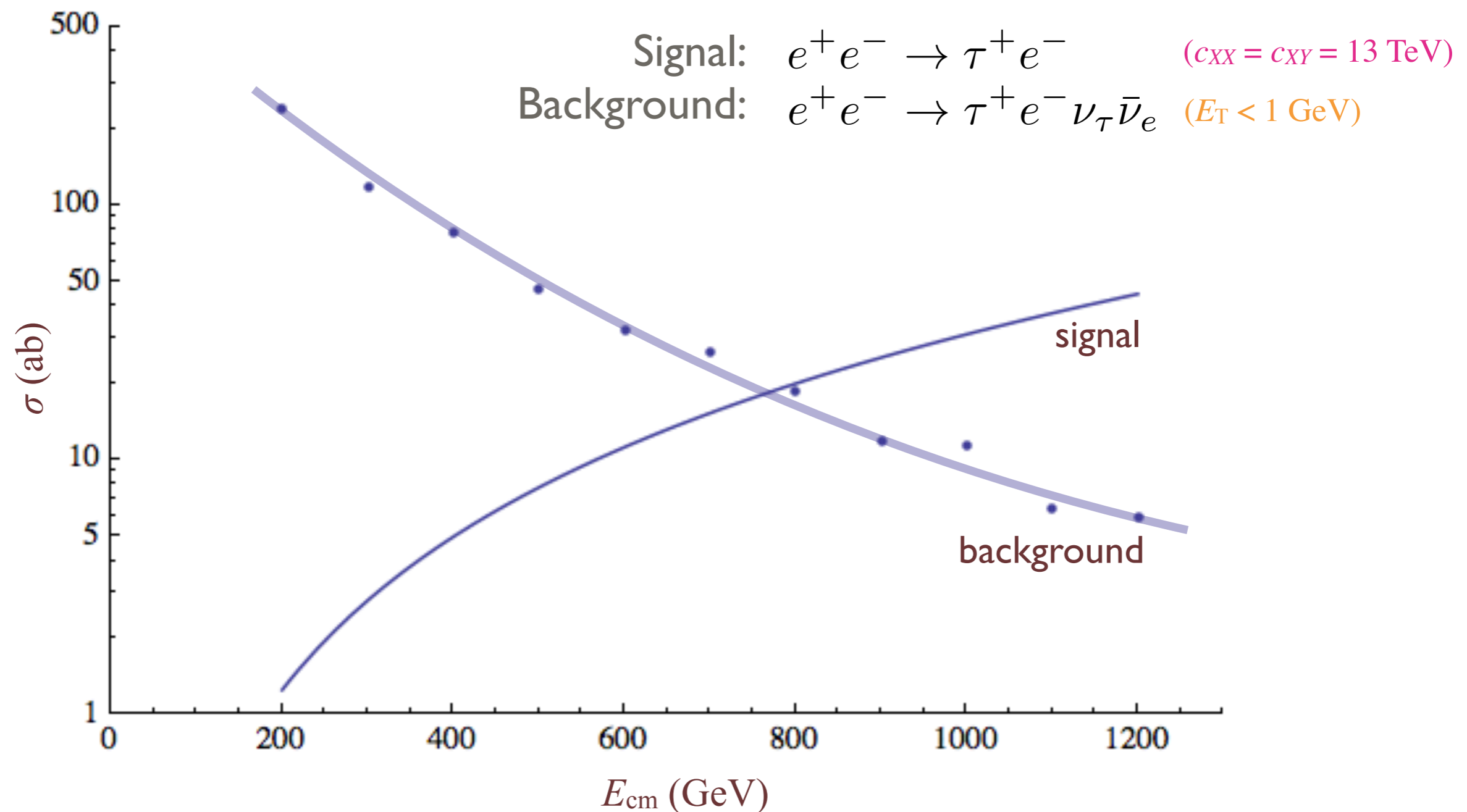


For $O(1)$ couplings, $\tau \rightarrow 3e$ has probed beyond **10 TeV** physics.

What can a linear collider do?

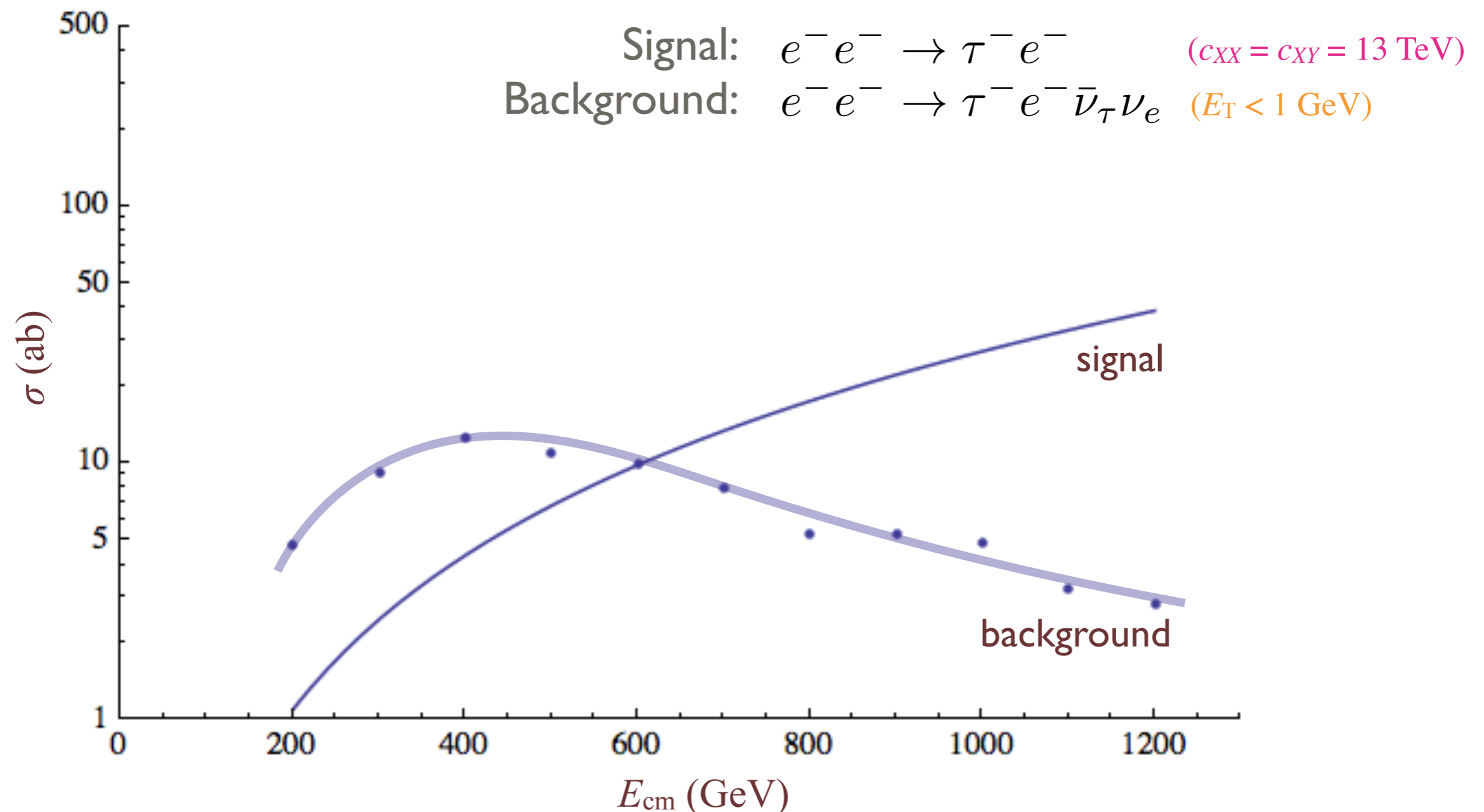
Signal and Background

...at an e^+e^- collider



Signal and Background

...at an e^-e^- collider



Summary

- Observable charged LFV is **unambiguously BSM physics**.
- In an EFT with 4-fermion contact operators as the dominant LFV mechanism,

$$\tau \rightarrow 3e$$

$$e^+e^- \rightarrow \tau e$$

$$e^-e^- \rightarrow \tau^- e^-$$

are **complementary observables**.

- $e^+e^- \rightarrow \tau e$ is observable at the ILC.
- $e^-e^- \rightarrow \tau^- e^-$ is observable at an e^-e^- collider or ILC option.
- These observables probe over **10 TeV physics** with $O(1)$ couplings at a LC.