technische universität
dortmund

Collider signatures for asymptotically safe extensions of the SM

Stefan Bißmann

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Asymptotic Safety Meets Particle Physics
16-19 December, Dortmund

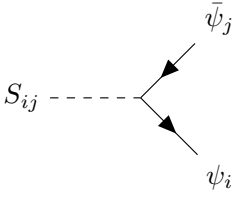
In collaboration with Gudrun Hiller and Clara Hormigos-Feliu

Background image: https://twiki.cern.ch/twiki/pub/AtlasPublic/EventDisplayRun2Physics/Run284213Evt1927020336_VHbb_1lepton_2.png

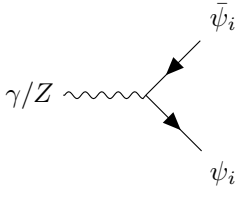
Introduction

Asymptotically safe extensions of the SM

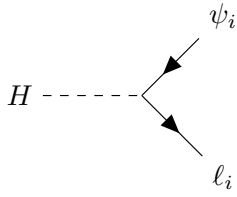
- Asymptotic safety connected to flavor physics [Hiller, Hormigos-Feliu, Litim, Steudtner (2019)]
- New vector-like fermions ψ_i and scalars S_{ij} ($M \sim \mathcal{O}(\text{TeV})$)
- BSM interactions with SM particles (depend on model)
- Explain anomalous magnetic moments $\Delta a_{e,\mu}$
- Large flavor symmetry group $\rightarrow$ universal couplings



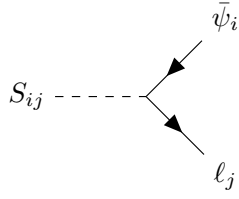
$\mathcal{L} \sim y\bar{\psi}_L S \psi_R$



$\mathcal{L} \sim \bar{\psi} \not{D} \psi$



$\mathcal{L} \sim \kappa \bar{\ell}_L H \psi_R$



$\mathcal{L} \sim \kappa' \bar{\ell}_R S^\dagger \psi_L$

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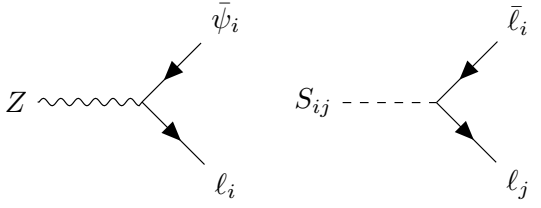

$$\mathcal{L} \sim \bar{\psi} \not{D} \psi + \bar{\ell} \not{D} \ell + \mathcal{L}_{\text{Yuk}}$$

Introduction

New Physics at the LHC

- Data from pp collisions at up to $13\,\text{TeV}$
- Ongoing searches for BSM signatures
- First searches for VL leptons $\rightarrow$ CMS, ATLAS

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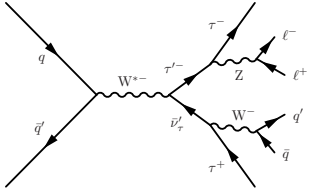

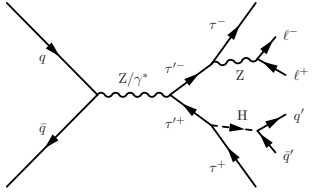

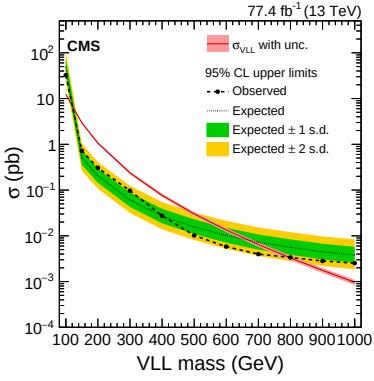

[CMS Collaboration (2019)]

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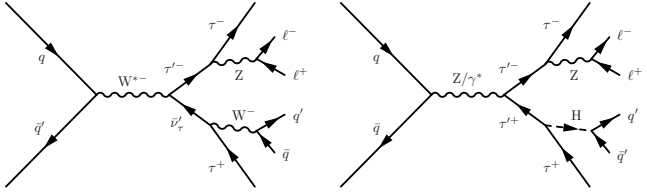
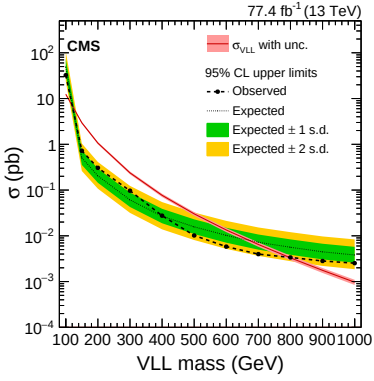




[CMS Collaboration (2019)]

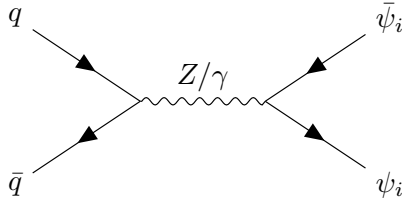
$\Rightarrow$ Exclusion limits **model-dependent**

$\Rightarrow$ Perform dedicated study for asymptotically safe models [Hiller, Hormigos-Feliu, Litim, Steudtner (**in prep.**)]

Cross sections at the LHC

Preparation

- Consider singlet model [Hiller, Hormigos-Feliu, Litim, Steudtner (in prep.)]
- VL leptons ψ_i: (**1**,**1**, -1) under $(SU(3),SU(2),Y)$, $N_F = 3$ generations, masses M_i
- $N_F^2 = 9$ scalars S_{ij}, masses M_{ij}^S
- Pair-production at LHC



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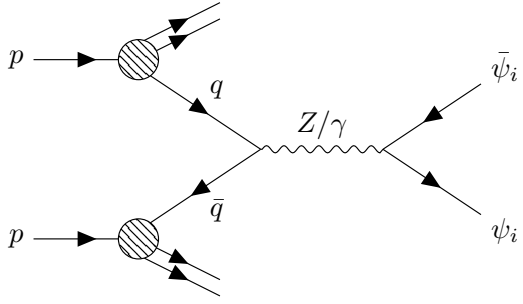

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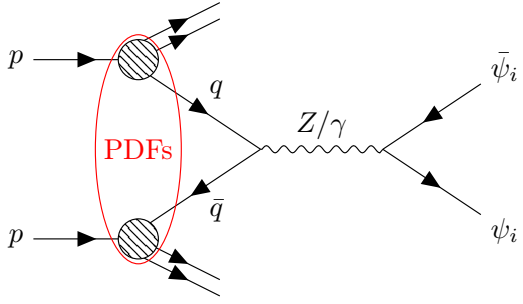
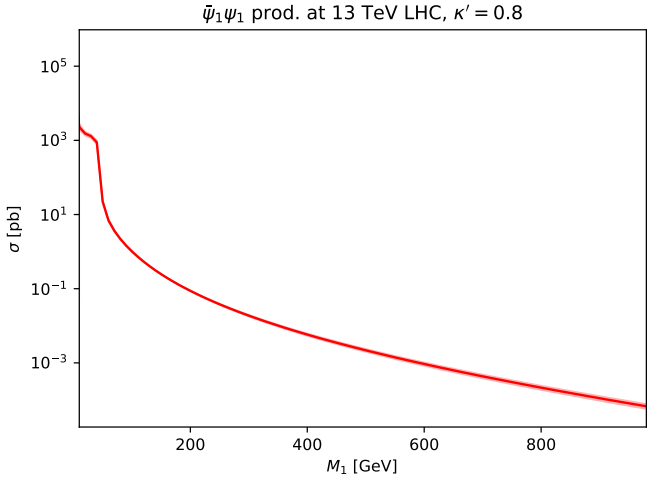


Computation

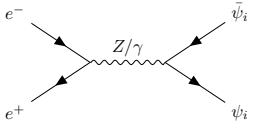
- Apply MadGraph [Frederix, Frixione, Hirschi, Pagani, Shao, Zaro (2018)]
- PDF set: CT10 [Guzzi, Nadolsky, Berger, Lai, Olness, Yuan (2011)]

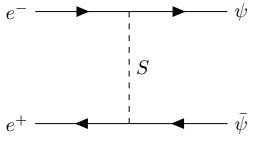


Cross sections at the lepton colliders

Preparation

- Consider previous singlet model [Hiller, Hormigos-Feliu, Litim, Steudtner (in prep.)]
- Pair-production at e^+e^- collider ($3\,\text{TeV}$)

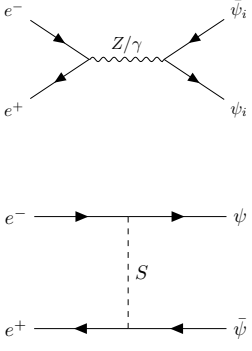


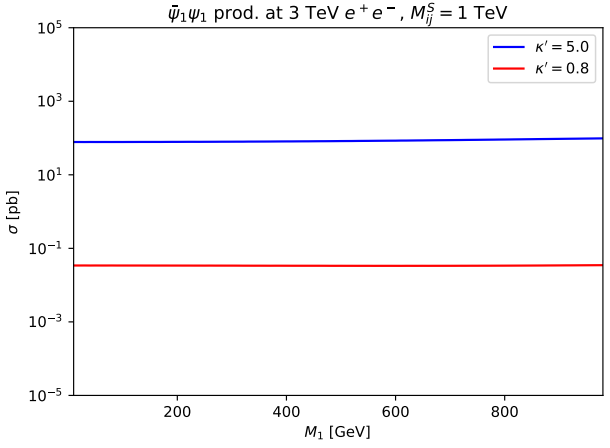


Cross sections at the lepton colliders

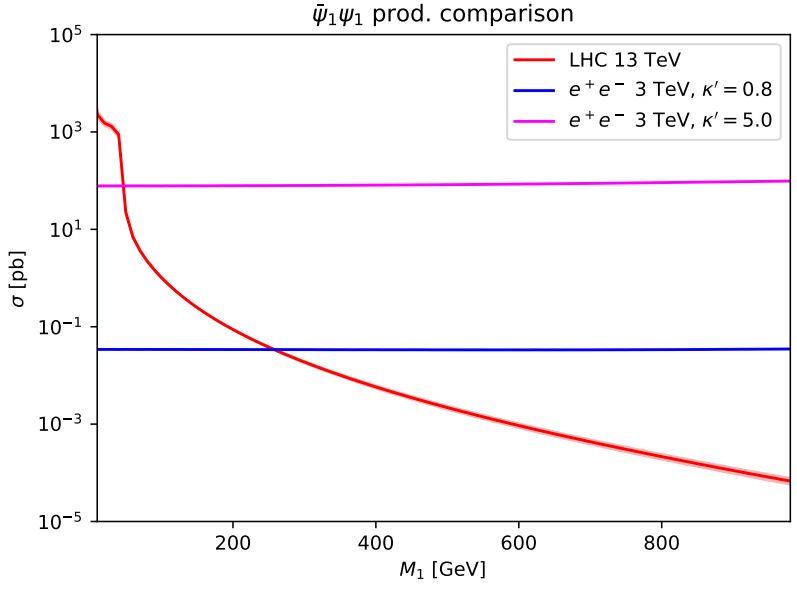
Preparation

- Consider previous singlet model [Hiller, Hormigos-Feliu, Litim, Steudtner (in prep.)]
- Pair-production at e^+e^- collider (3 TeV)

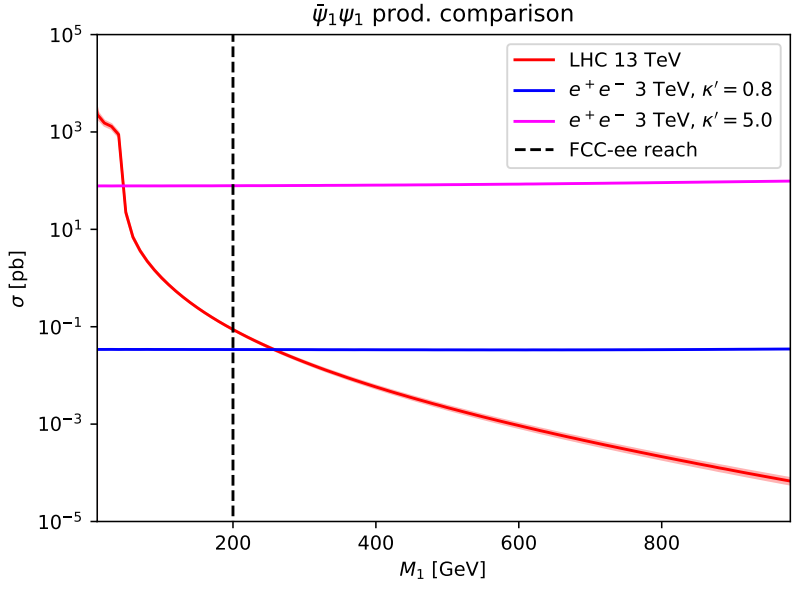




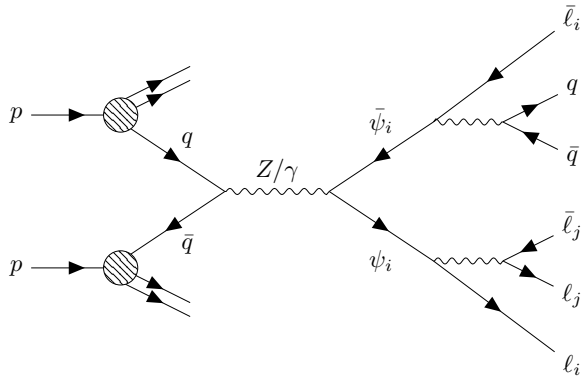
Collider comparison



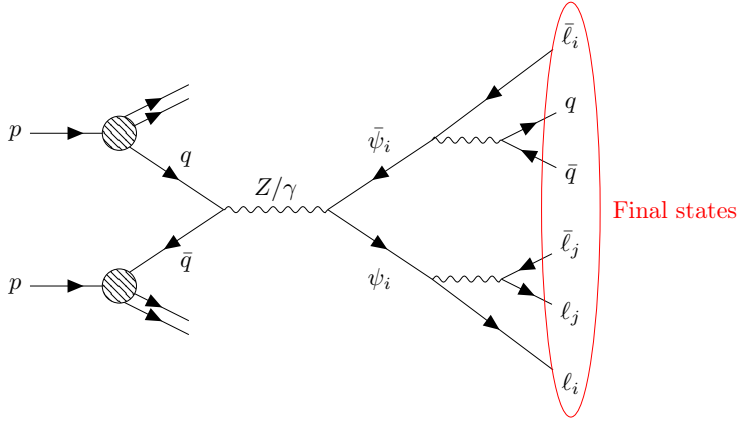
Collider comparison



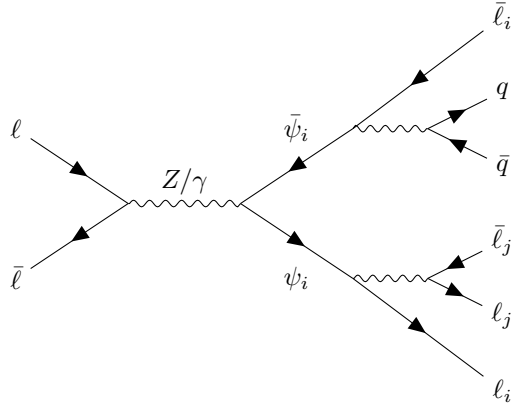
Next steps


p
p
q
$\bar{q}$
Z/γ
$\bar{\psi}_i$
ψ_i
$\bar{\ell}_i$
q
$\bar{q}$
$\bar{\ell}_j$
ℓ_j
ℓ_i

Next steps


p
p
q
$\bar{q}$
Z/γ
$\bar{\psi}_i$
ψ_i
$\bar{\ell}_i$
q
$\bar{q}$
$\bar{\ell}_j$
ℓ_j
ℓ_i
Final states

Next steps


$\bar{\ell}_i$
q
ℓ
$\bar{\psi}_i$
$\bar{q}$
Z/γ
$\bar{\ell}_j$
$\bar{\ell}$
ψ_i
ℓ_j
ℓ_i

Conclusion

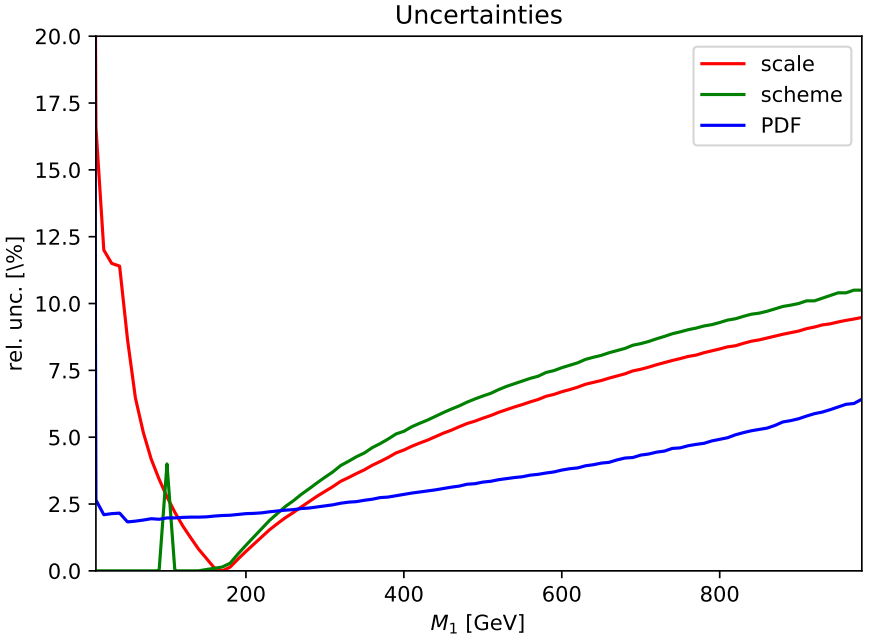
Summary

- First connection of collider physics and AS model [Hiller, Hormigos-Feliu, Litim, Steudtner (**in prep.**)]
- Can already be probed at LHC
- Lepton colliders can provide better insights
- Important test complementary to low energy observables
- NP can be just around the corner

Outlook

- Single production as well as scalar production
- Include final states (!)
- Comparison to LHC data
- Study different (i.e. realistic) future colliders (CLIC, FCC-ee)

Extra slides


Uncertainties
scale
scheme
PDF
rel. unc. [\%]
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
200
400
600
800
M_1 [GeV]