A Guaranteed Discovery at Future Muon Colliders (MuC)

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A no-lose theorem for a future muon collider program

If \((g-2)_{\mu} = \text{new physics}\),

- Fixed target experiments + MuC (E\text{cm} \sim \text{TeV} \text{ and } L \sim 10 \text{ ab}^{-1}) will cover models with \text{new SM singlets}.

- Higher energy MuC (E\text{cm} \sim 10-60 \text{ TeV}) will cover \text{nightmare scenario} models with \text{new heavy EW states}.
**Muon g-2**

- **Singlet Models**
  - Suppressed chirality flip and EWSB insertion

- **High-Scale EW Models**
  - Enhanced chirality flip
  - Enhanced EWSB insertion

\[ \Delta a_{\mu} \sim \frac{\text{couplings}^n}{M_{BSM}^m} \]

Note: The only guaranteed coupling to SM fermions is to muons!
**MuC Requirements**

- **Singlet Models**

  - Fixed-target experiments
  - LHC ?
  - Violate Perturbative Unitarity
  - Large couplings
  - Unitarity violation
  - "Empirical" Fine tuning (Higgs and muon mass)

  - ~ 1 TeV Muon Collider
  - ~ 3 TeV (≤ 10 ab⁻¹)
  - ~ 10 TeV Muon Collider
  - ~ 30 TeV (≤ 100 ab⁻¹)

- **High-Scale EW Models**

  - Reasonable assumptions
    - $y_{BSM} \sim 1$
    - $N_{BSM} < 10$

  - ~ 1 TeV
  - ~ 30 TeV (≤ 100 ab⁻¹)
  - $M_{BSM}$

  - LHC

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**BSM Masses**

- **Neutral** states below $\sim 15$ TeV

- **Charged** states below $\sim 25$ TeV

Thanks!
Extra...
Muon g-2

\[ \mathcal{L}_{\text{eff}} = C_{\text{eff}} \frac{v}{M^2} (\mu_L \sigma^{\nu \rho} \mu^c) F_{\nu \rho} + \text{h.c.} \]

• Singlet Models

  The Higgs provides both the chiral flip and the EWSB

\[ \Delta a_\mu \sim \frac{g_*^2 m_\mu^2}{12 \pi^2 M^2} \sim 10^{-9} g_*^2 \left( \frac{300 \text{ GeV}}{M} \right)^2 \]

• EW Models

  Chiral enhanced

\[ \Delta a_\mu \sim \frac{y^3 m_\mu v}{8 \pi^2 M^2} \sim 10^{-9} C_{\text{eff}} \left( \frac{20 \text{ TeV}}{M} \right)^2 \]

Naive: \( \sim \text{PeV} \)

Perturbative Unitarity: \( \sim 100 \text{ TeV} \)
BSM Masses

Charged lightest states: \( \sim 25 \text{ TeV} \)

Worse case scenario, to rely on Drell-Yan production. No needed.
As large masses implies large couplings.

\[ \sigma_S \sim 1 \text{ fb} \]

Neutral lightest states: \( \sim 15 \text{ TeV} \)

Worse case scenario, invisible decay so signal = gamma + MET

\[ \sigma_B \sim 1 \text{ pb} \rightarrow \sim 10 \text{ fb} \quad (p_T > 1 \text{ TeV}) \]

\[ \sigma_S \sim 1 \text{ fb} \]

\[ \sigma_S \sim \left( \frac{y^2}{M^2} \right) y^2 \]