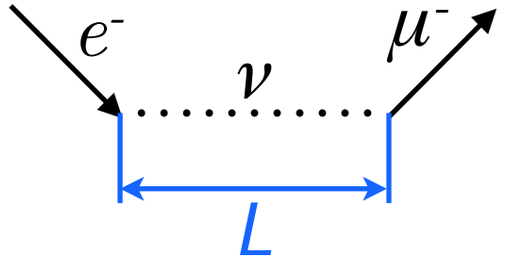
COMET-2 4 cLFV

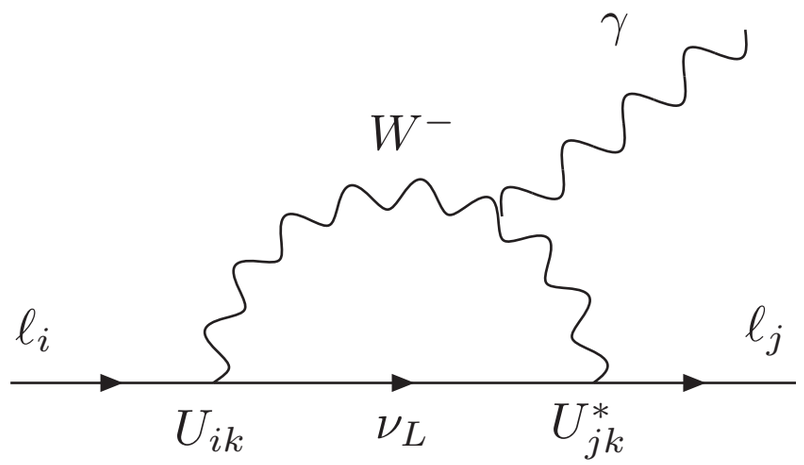
Charged Lepton Flavour Violation

with COMET2, and other projects

Why looking for cLFV?



- Neutral Lepton Flavour Violations(/transitions): exist!!!
- Why not charged LFV? (local, $L=0$, version of neutrino oscillation)
- Truly rare processes: e.g. BR($\mu \rightarrow e\,\gamma$) < 10^{-12}
- « No » SM background: e.g. BR($\mu \rightarrow e\,\gamma$)$_{SM}$ ~ 10^{-54}
- Crucial to reveal or discriminate certain mechanisms of neutrino mass, e.g. involving sterile neutrinos



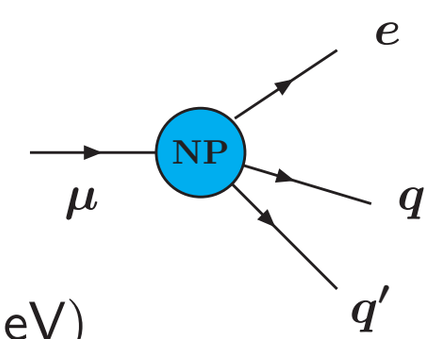
ν_s and cLFV in muonic atoms: μ-e conversion

- **Muonic atoms:** 1s bound state formed when μ^- stopped in target

  SM processes: $\mu^- \to e^- \nu_\mu \bar{\nu}_e$ (decay in orbit); $\mu^- + (A, Z) \to \nu_\mu + (A, Z-1)$ (nuclear capture)

- **cLFV $\mu^- - e^-$ conversion: $\boldsymbol{\mu^- + (A, Z) \to e^- + (A, Z)}$**

  coherent conversion, increases with Z (maximal for $30 \leq Z \leq 60$)



- **Event signature:** single mono-energetic electron

  $$E^{\mathrm{N}}_{\mu e} = m_\mu - E_B(A, Z) - E_R(A, Z), \quad E^{\mathrm{Al,\ Pb,\ Ti}}_{\mu e} \approx \mathcal{O}(100\ \mathrm{MeV})$$

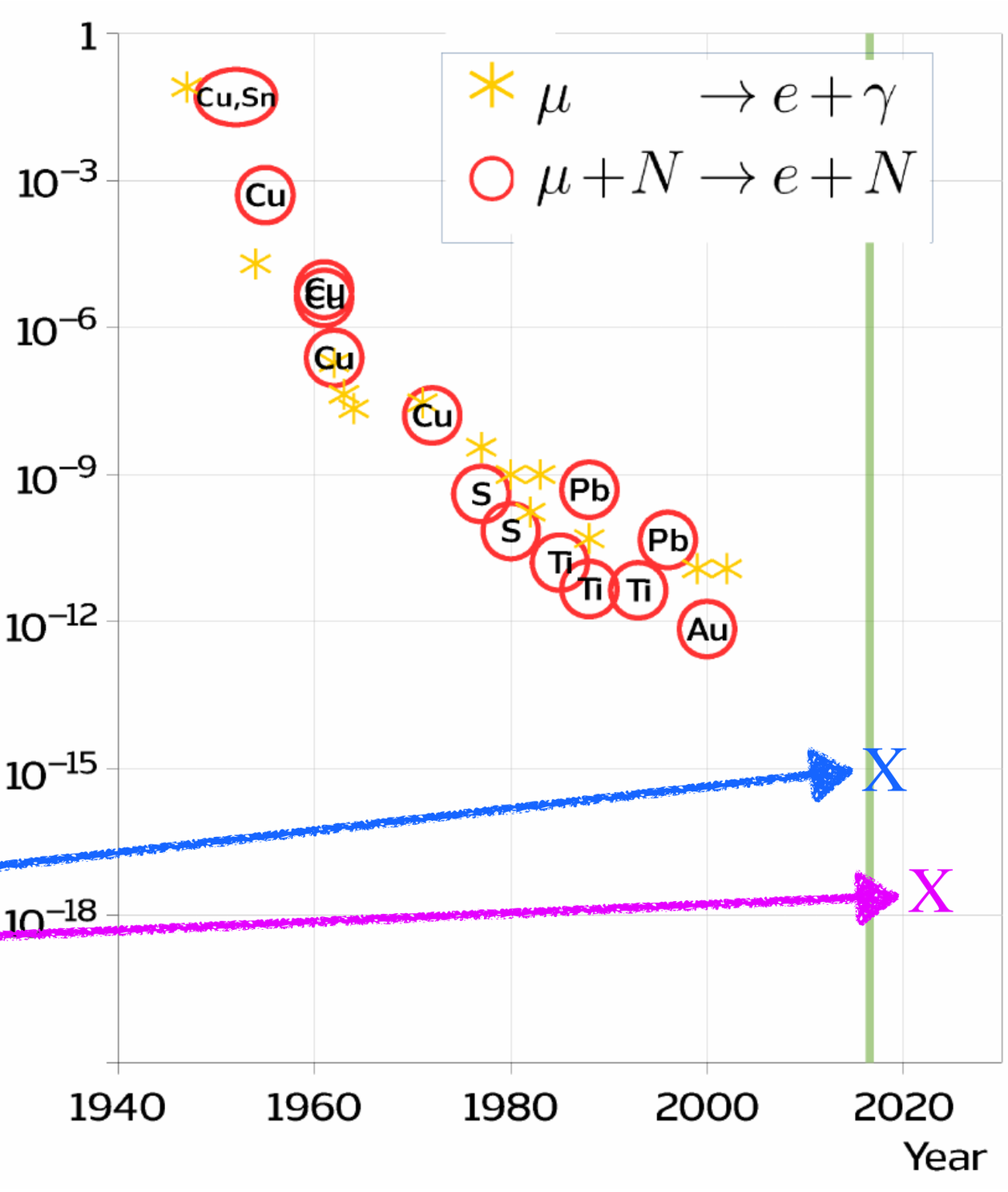
- **Backgrounds** ⇒ only **physics** (e.g. μ decay in orbit); beam (purity), cosmic rays, ...

- **Experimental status (present bounds and future prospects):**

CR($\mu - e$, N) bound	material	year
$\mathbf{4.3 \times 10^{-12}}$	**Ti**	1993
$\mathbf{4.6 \times 10^{-11}}$	**Pb**	1996
$\mathbf{7 \times 10^{-13}}$	**Au**	2006

Experiment (material)	future sensitivity	year
Mu2e (Al)	$\mathbf{3 \times 10^{-17}}$	$\sim$ 2021
COMET (Al) - Phase I (II)	$\mathbf{10^{-15}}$ ($\mathbf{10^{-17}}$)	$\sim$ 2018(21)
PRISM/PRIME (Ti)	$\mathbf{10^{-18}}$	
DeeMe (SiC)	10^{-14}	

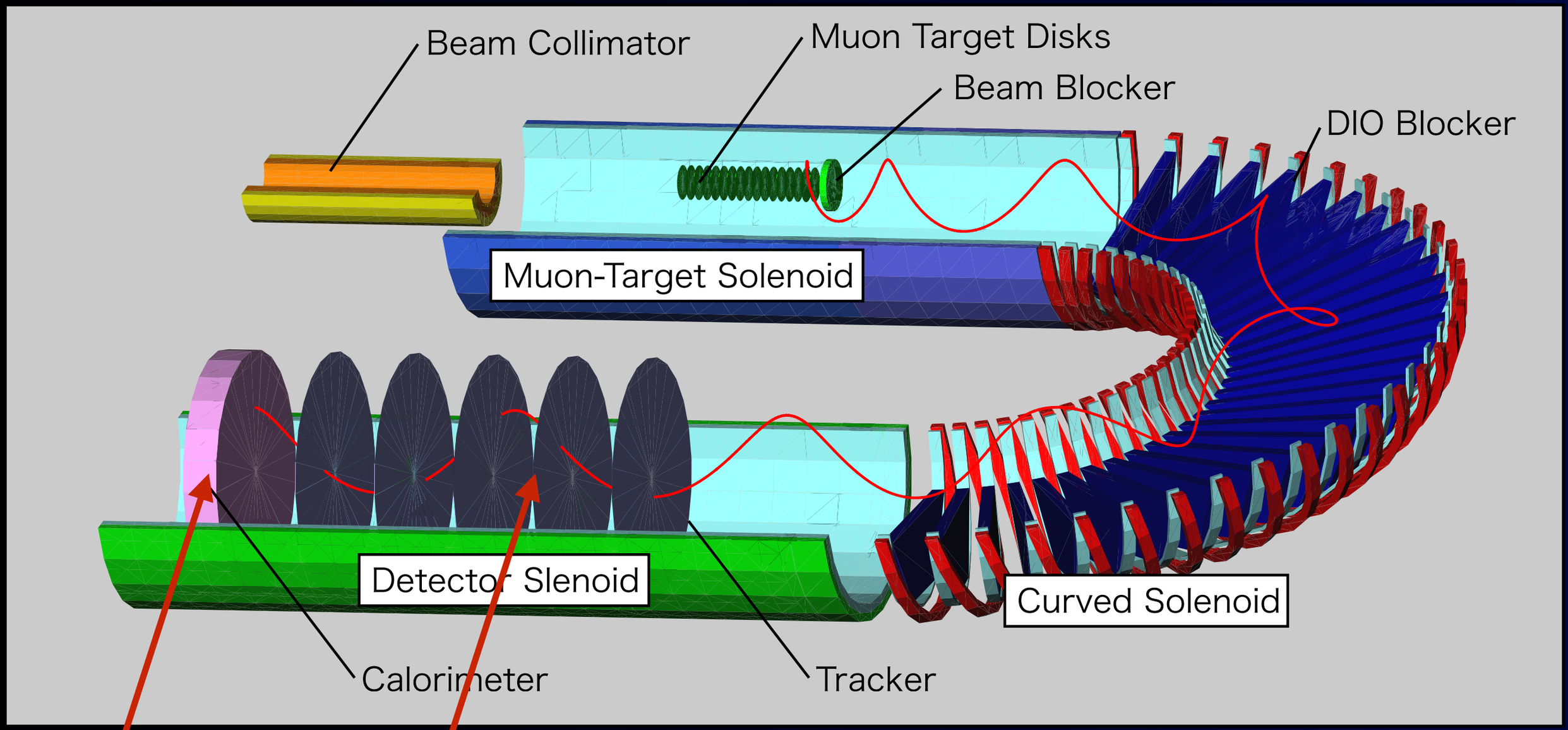
Muon capture: tremendous progress on the way



Experiment (material)	future sensitivity	year
Mu2e (Al)	3×10^{-17} [360]	$\sim$ 2021
COMET (Al) - Phase I	3×10^{-15} [362]	$\sim$ 2018
COMET (Al) - Phase II	3×10^{-17} [362]	$\sim$ 2021
PRISM/PRIME (Ti)	10^{-18} [364]	
DeeMe (SiC)	10^{-14} [365]	

Table 3.8: Future sensitivities for CR($\mu - e$, N).

COMET Detectors



ECAL

Straw Tracker

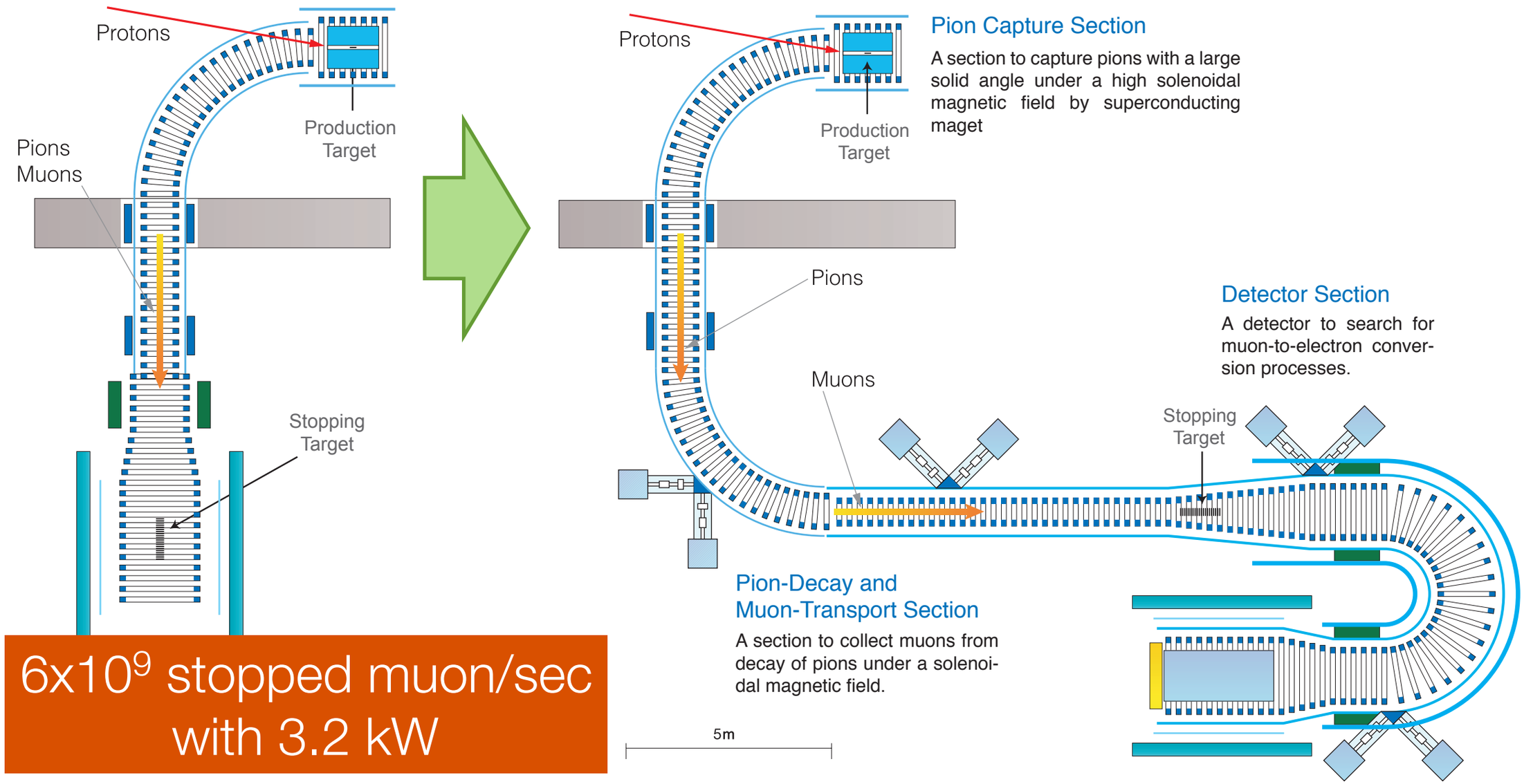
(# of straw stations is not determined)

in vacuum under 1T magnetic field

COMET Staged Approach (2012~)

COMET Phase-I

COMET Phase-II



6×10^9 stopped muon/sec with 3.2 kW

Schedule of COMET Phase-I and Phase-II

	JFY	2015	2016	2017	2018	2019	2020	2021	2022	2023
COMET Phase-I	construction									
	data taking									
COMET Phase-II	construction									
	data taking									

COMET Phase-I :
2018 ~
S.E.S. ~ 3×10^{-15}
(for 150 days
with 3.2 kW proton beam)

COMET Phase-II :
2022 ~
S.E.S. ~ $(1.0\text{-}2.6) \times 10^{-17}$
(for 2×10^{7} sec
with 56 kW proton beam)

PRISM/PRIME : Future Search with S.E. sensitivity of 3×10^{-19}

PRISM

COMET

Osaka University

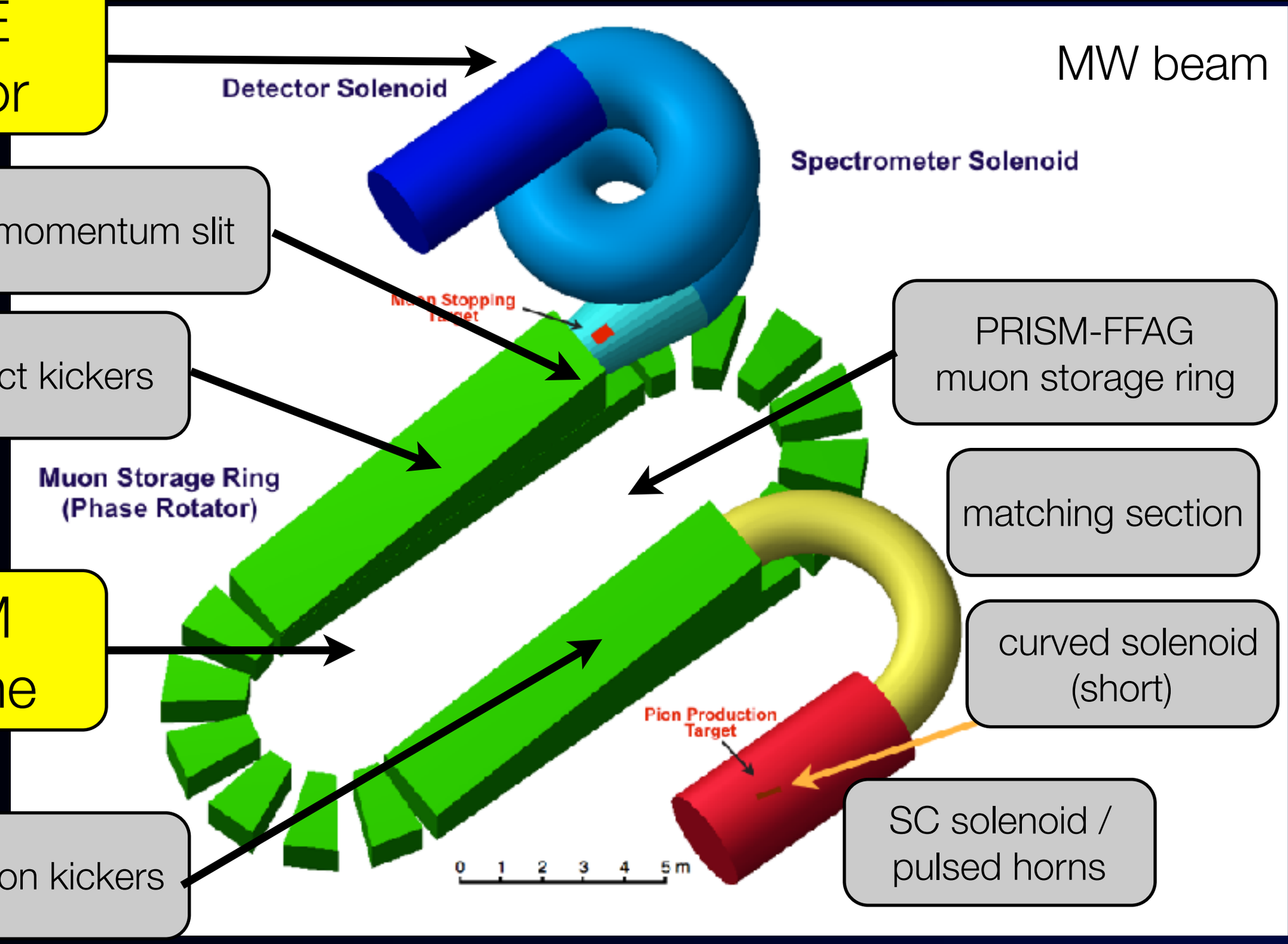
PRIME detector

momentum slit

extract kickers

PRISM beamline

injection kickers



PRISM-FFAG muon storage ring

matching section

curved solenoid (short)

SC solenoid / pulsed horns

ν_s and cLFV in muonic atoms: $\mu + e \to e + e$

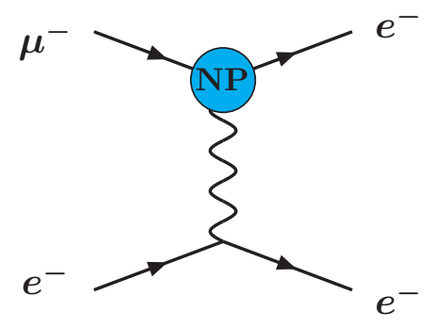
- **Muonic atom decay:** $\mu^- e^- \to e^- e^-$ [Koike et al, '10]

  Initial μ^- and e^-: **1s** state bound in Coulomb field of the **muonic atom's nucleus**

- **Coulomb interaction** increases overlap between

  Ψ_{μ^-} and Ψ_{e^-} wave functions

$$\Gamma(\mu^- e^- \to e^- e^-,\ \mathrm{N}) \propto \sigma_{\mu e \to ee} v_{\mathrm{rel}} \left[(Z-1)\,\alpha\, m_e\right]^3/\pi$$



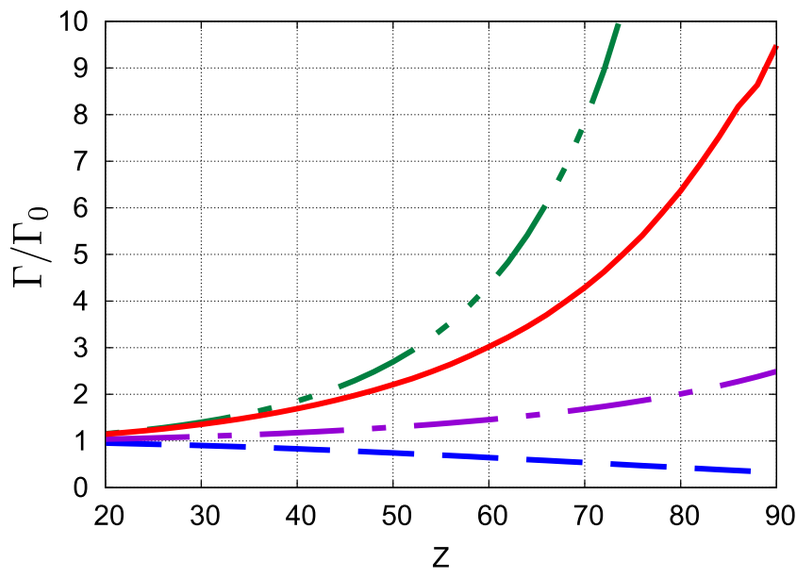
- **Clean experimental signature:** back-to-back electrons, $E_{e^-} \approx m_\mu/2$

  larger phase space than $\mu \to 3e$

- **Rate strongly enhanced** in **large Z atoms**

$$\Gamma/\Gamma_0 \gtrsim (Z-1)^3$$ [Uesaka et al, '15-'16]

  Consider experimental setups for **Pb, U !?**

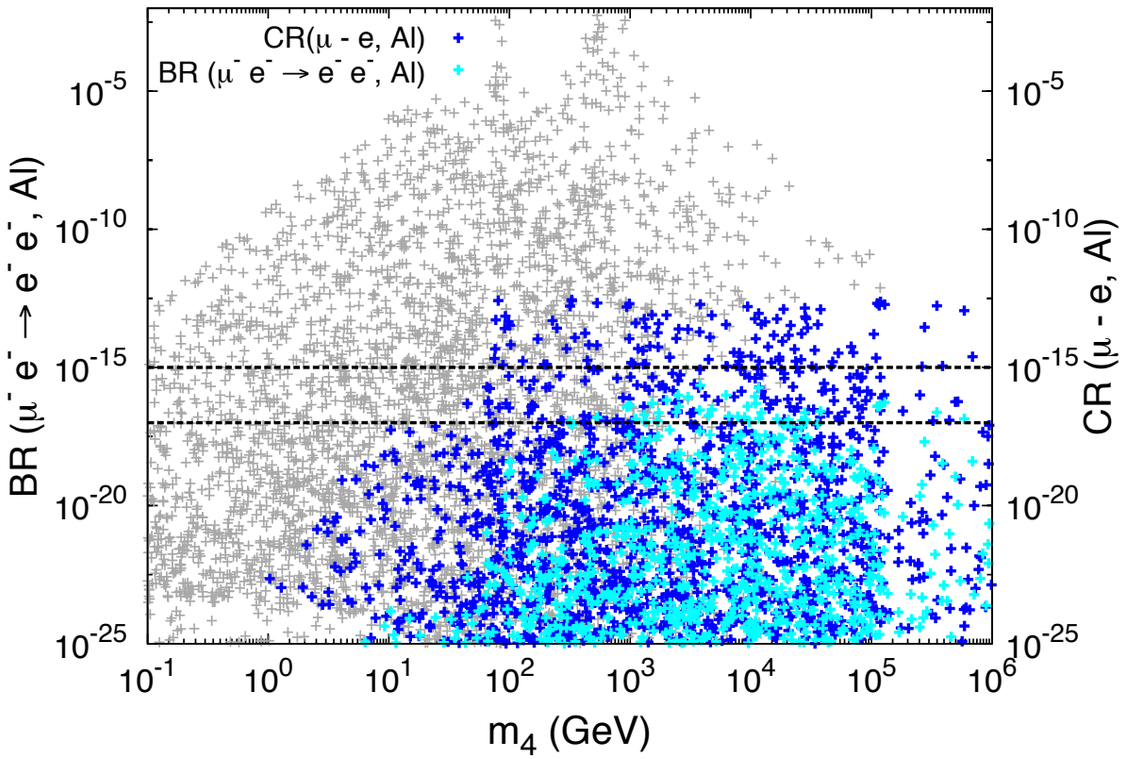


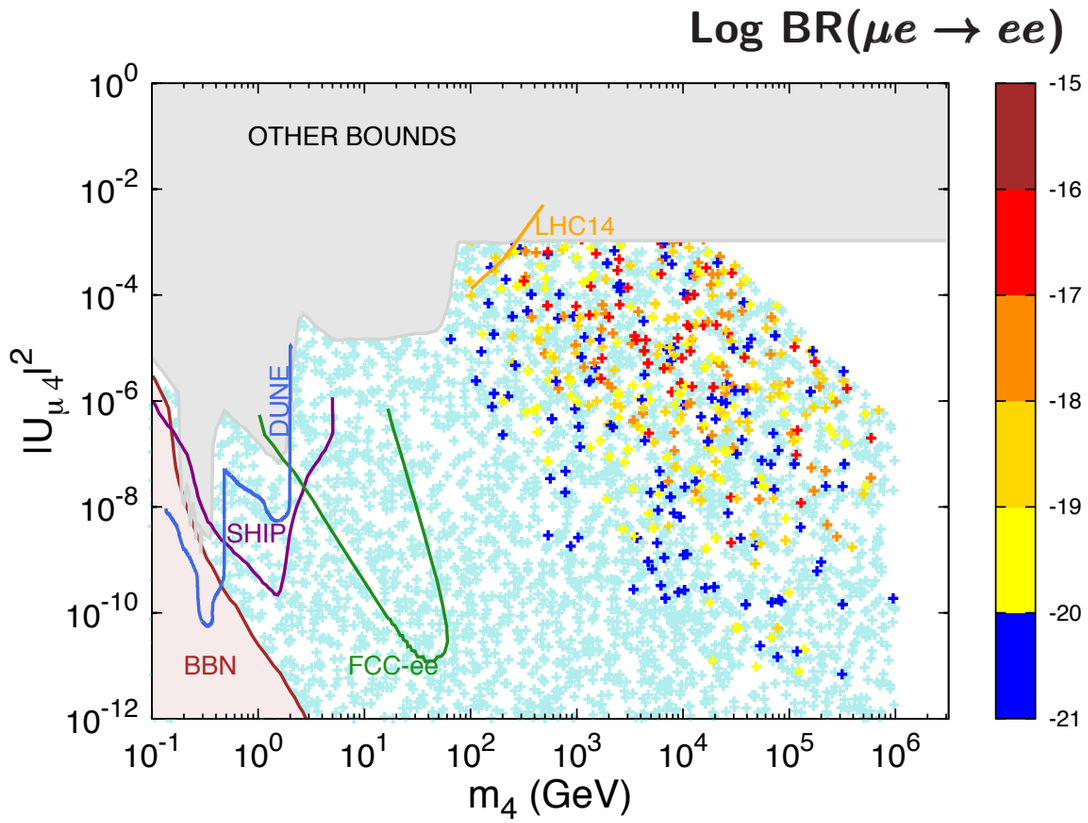
- **Experimental status:** **New observable!**

  Hopefully included in **COMET**'s Physics programme

ν_S and cLFV in muonic atoms: prospects

- **cLFV muonic atom decay $\mu^- e^- \to e^- e^-$ vs $\mu - e$ conversion (Aluminium target)**





"3+1" toy model [Abada, De Romeri and AMT, '15]

- **Sizeable values** for $\mathbf{BR(\mu^- e^- \to e^- e^-)}$ - potentially within **experimental reach!** [COMET]
  probe "heavy mass" regimes unaccessible for **SHiP, FCC, LHC, ...**

- For **Aluminium** [COMET], $\mathbf{CR(\mu - e)}$ appears to have **stronger experimental potential**
  .. consider **"heavy" targets** to probe $\mathbf{BR(\mu^- e^- \to e^- e^-)}$