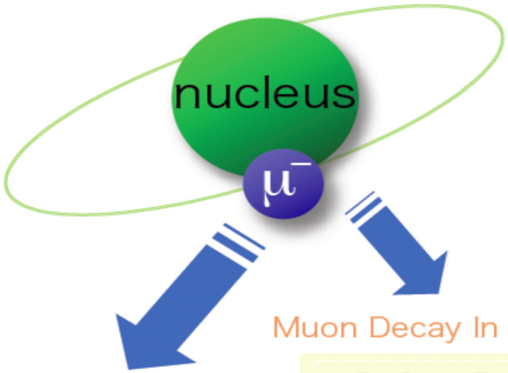
COherent Muon to Electron Transition

- **COMET à J-PARC**
- **COMET-France**
- **ESPP**
- **Biennale 2021**

COMET en principe

1s state in a muonic atom



Muon Decay In Orbit

$\mu^- \rightarrow e^- \nu \bar{\nu}$

nuclear muon capture

$\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)$

Neutrino-less muon nuclear capture (=μ-e conversion)

$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$

✓ Signal:

monoenergetic electron
104.96 MeV for Al, 95.56 MeV for Au

✓Main background：

Muon Decay in Orbit （10^{-16}）
Radiative muon Capture

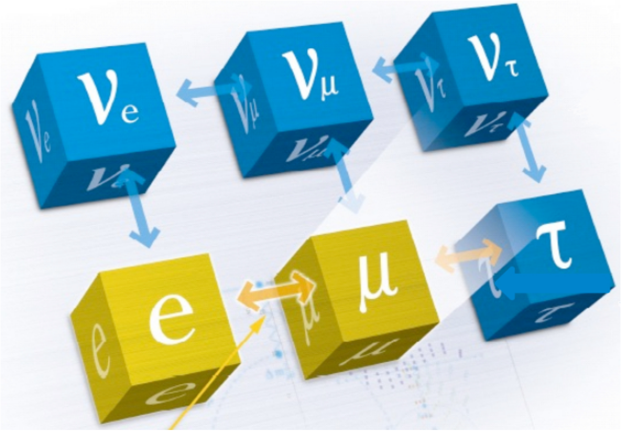
$$\mu^-(A,Z) \to \gamma(A,Z-1)^* \nu_\mu$$

Radiative pion capture

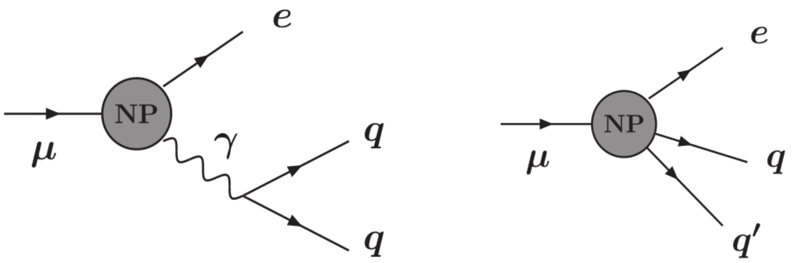
$$\pi^- + (A,Z) \to (A,Z\text{-}1)^* \to \gamma + (A,Z\text{-}1)$$
$$\gamma \to e^+ e^-$$

✓ No limit from random background

Quark mixing Nobel 2008
Oscillations Neutrino Nobel 2015



charged lepton mixing



Schematic description of the two (tree level) effective contributions to μ–e conversion: on the left (right) panel, the photonic (four-fermion/contact) interaction. The shaded circles denote a BSM flavour violating interaction.

cLFV (charged Lepton Flavor Violation)

Limites actuelles et attendues

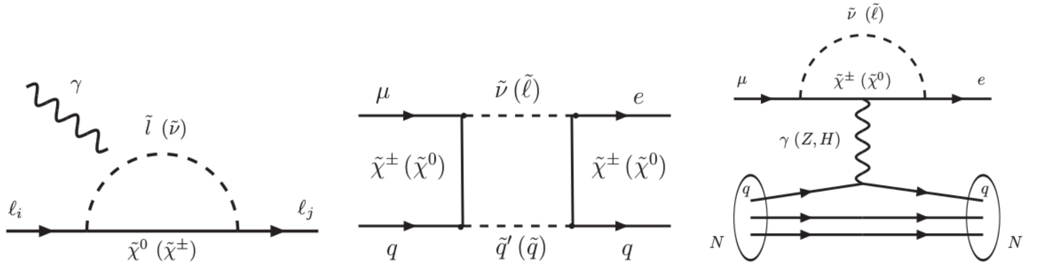
process	present limit	future	
$\mu \to e\gamma$	$<4.2 \times 10^{-13}$	$<10^{-14}$	MEG at PSI
$\mu \to eee$	$<1.0 \times 10^{-12}$	$<10^{-16}$	Mu3e at PSI
$\mu N \to eN$ (in Al)	none	$<10^{-16}/10^{-17}$	Mu2e / COMET
$\mu N \to eN$ (in Ti)	$<4.3 \times 10^{-12}$	$<10^{-19}$	PRISM
$\tau \to e\gamma$	$<1.1 \times 10^{-7}$	$<10^{-9} - 10^{-10}$	superKEKB
$\tau \to eee$	$<3.6 \times 10^{-8}$	$<10^{-9} - 10^{-10}$	superKEKB
$\tau \to \mu\gamma$	$<4.5 \times 10^{-8}$	$<10^{-9} - 10^{-10}$	superKEKB
$\tau \to \mu\mu\mu$	$<3.2 \times 10^{-8}$	$<10^{-9} - 10^{-10}$	superKEKB/LHCb

COMET en théorie

$$\mathrm{BR}(\mu \to e\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{k=1,3} U_{ej}U^{*}_{\mu j}\frac{m^2_{\nu_j}}{M^2_W}\right|^2 \simeq \mathcal{O}(10^{-55}\text{–}10^{-54})$$

$$\mathrm{BR}(\mu \to e\gamma) \sim \frac{\alpha}{4\pi}\left(\frac{M_W}{M_{\mathrm{SUSY}}}\right)^4 \sin^2\theta_{\tilde{e}\tilde{\mu}}\left(\frac{\Delta m^2_{\tilde{\ell}}}{M^2_{\mathrm{SUSY}}}\right)^2$$

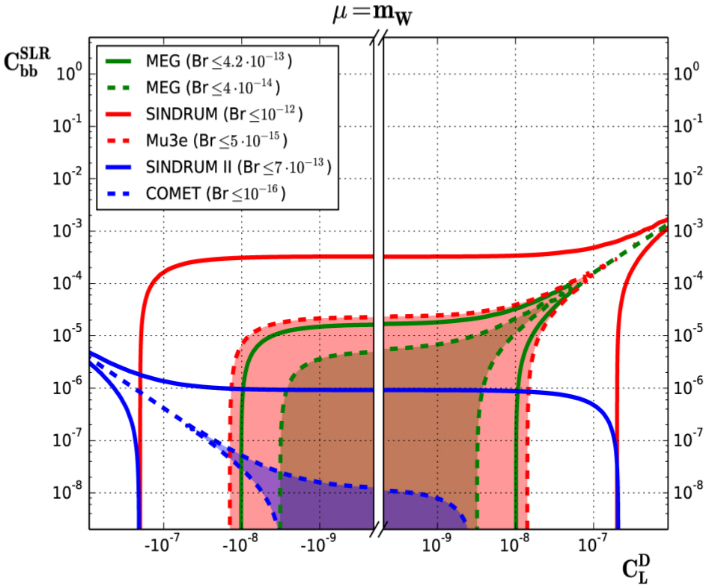
$$\mathrm{CR}(\mu^- N \to e^- N) \approx \mathcal{O}(\alpha) \times \mathrm{BR}(\mu \to e\gamma)$$



Diagrams for photonic interaction, and $\mu^- N \to e^- N$ conversion via box and penguin diagrams, arising from SUSY R-parity conserving interactions, χ denotes a neutralino or chargino, $\tilde{l}$ represents a scalar lepton (charged or neutral) and $\tilde{q}$ stands for a scalar quark.

$$\Gamma(\mu^- N \to e^- N) = \frac{m^5_\mu}{4\Lambda^4}\left|eC^D_L D_N + 4\left\{G_F m_\mu m_p S^{(p)}_N\left(\sum_{q=u,d,s}\frac{C^{SLL}_{qq}+C^{SLR}_{qq}}{m_\mu m_q G_F}f^{(q)}_{Sp} + \tilde{C}^L_{gg}\cdot\right.\right.\right.$$

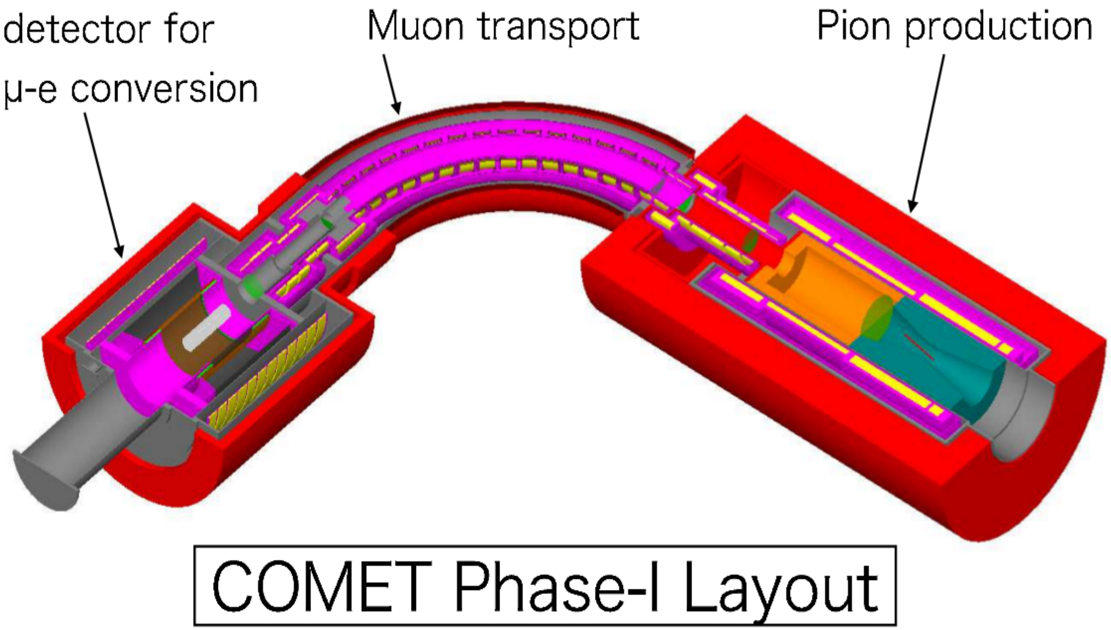
$$\left.\left.\left. + V^{(p)}_N\left(\sum_{q=u,d,s}(C^{VRL}_{qq}+C^{VRR}_{qq})f^{(q)}_{Vp}\right) + p \to n\right\}\right|^2 + L \leftrightarrow R.$$

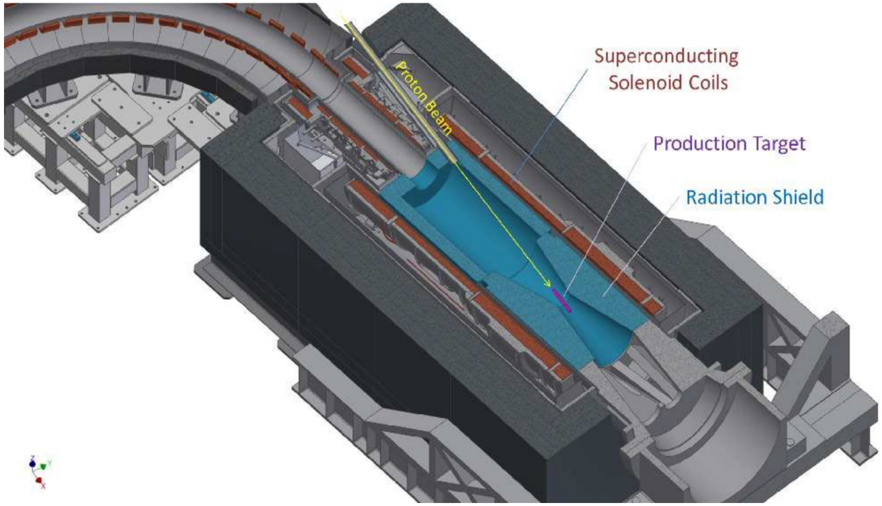


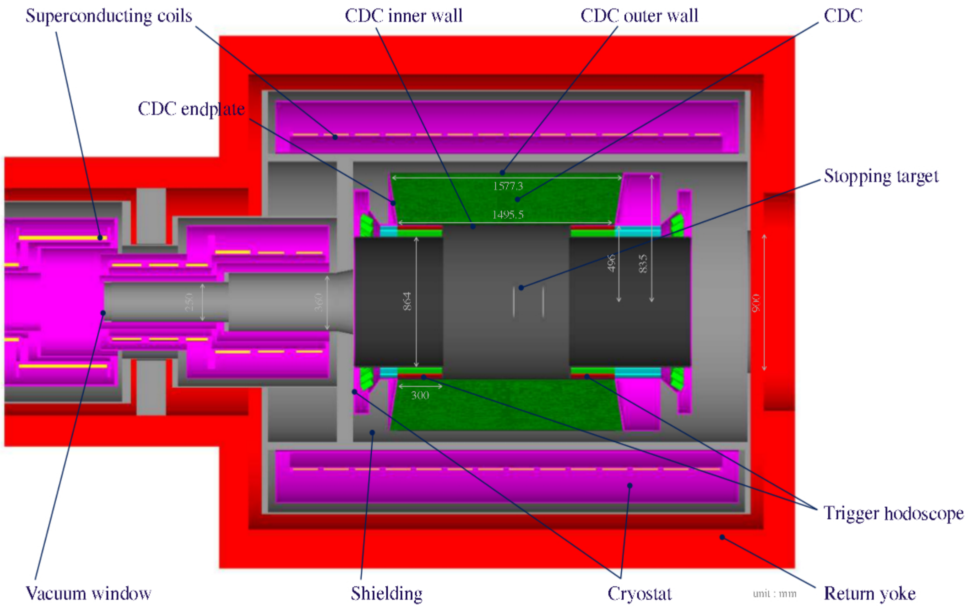
Allowed regions in the $C^D_L - C^{SLR}_{bb}$ parameter space, from $\mu \to e\gamma$ (green), $\mu \to 3e$ (red) and $\mu \to e$ conversion (blue), for current experimental bounds (full lines) and future sensitivities (dashed lines).

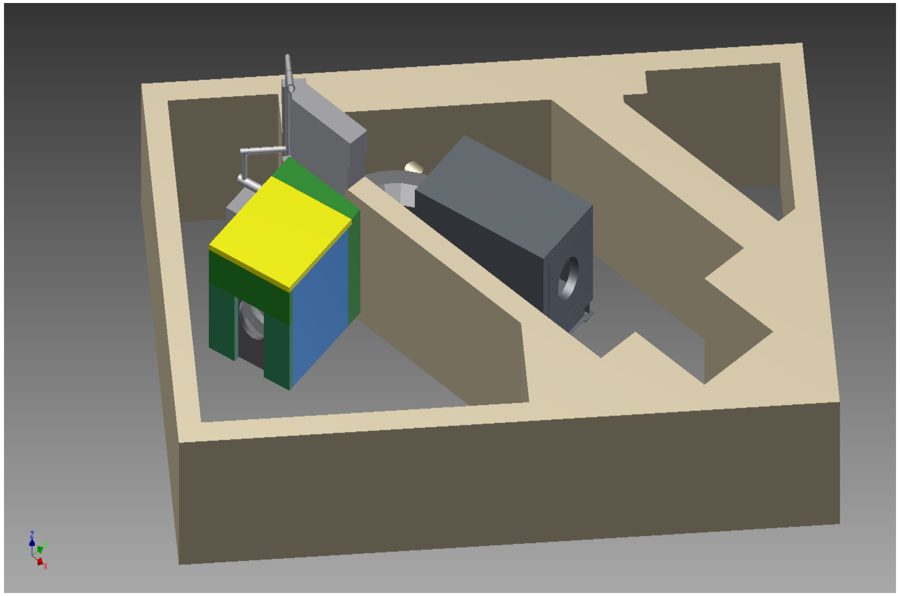
TDR 2019 bientôt publié dans **PTEP** (Prog. Theor. Exp. Phys.)

COMET en pratique









COMET en per(pro)spective

COMET-France : master projet approuvé fin 2018 pour 3 ans

LPNHE Frédéric K. , Wilfrid, Patricia et Dorian (Osaka U.)
Tracking GENFIT2, Track Finding Algorithms
MC production Management, gitlab,
Collaborateurs Etrangers

INPL Patrice L., Tibor : Data Storage Management , iRODS

LPC-Caen Jean-Claude, Gilles B., Gilles Q.
proton-cible , simulation du faisceau avec MCNPX et PHITS
Faisceaux tests avec des neutrons au GANIL

LPClermont Cristina, Valentin avec Anna Teixeira (Théorie)
RPC pour le CRV, simulation des muons cosmiques

CC-IN2P3 CPU, gestion de la ferme, Stockage et Partage (iRODS)

2019 année de mise en place avec approbation du CB COMET

2020 passage en CSI-IN2P3, MoU et DMP… *avec de nouveaux membres du LPNHE ?* ….

Moyen-Long terme (Phase I – Phase II) : prise de données en …..

ESPP

COMET

J.-C. Angélique, C. Cârloganu, W. da Silva, A. Drutskoy, M. Finger,
D. N. Grigoriev, T. Kachelhoffer, F. Kapusta, Y. Kuno[1], P. Lebrun,
R. P. Litchfield, D. Lomidze, D. Shoukavy, A. M. Teixeira, I. Tevzadze,
Z. B. Tsamalaidze, Y. Uchida, V. Vrba, K. Zuber

A submission to the 2020 update of the European Strategy for Particle Physics on behalf of the COMET collaboration.

Abstract

The search for charged lepton flavour violation (CLFV) has enormous discovery potential in probing new physics Beyond the Standard Model (BSM). The observation of a CLFV transition would be an undeniable sign of the presence of BSM physics which goes beyond non-zero masses for neutrinos. Furthermore, CLFV measurements can provide a way to distinguish between different BSM models, which may not be possible through other means. So far muonic CLFV processes have the best experimental sensitivity because of the huge number of muons which can be produced at several facilities world-wide, and in the near future, new muon beam-lines will be built, leading to increases in beam intensity by several orders of magnitude. Among the muonic CLFV processes, $\mu \to e$ conversion is one of the most important processes, having several advantages compared to other such processes.

Charged Lepton Flavour Violation using Intense Muon Beams at Future Facilities

A. Baldini, D. Glenzinski, F. Kapusta, Y. Kuno, M. Lancaster,
J. Miller, S. Miscetti, T. Mori, A. Papa, A. Schöning, Y. Uchida

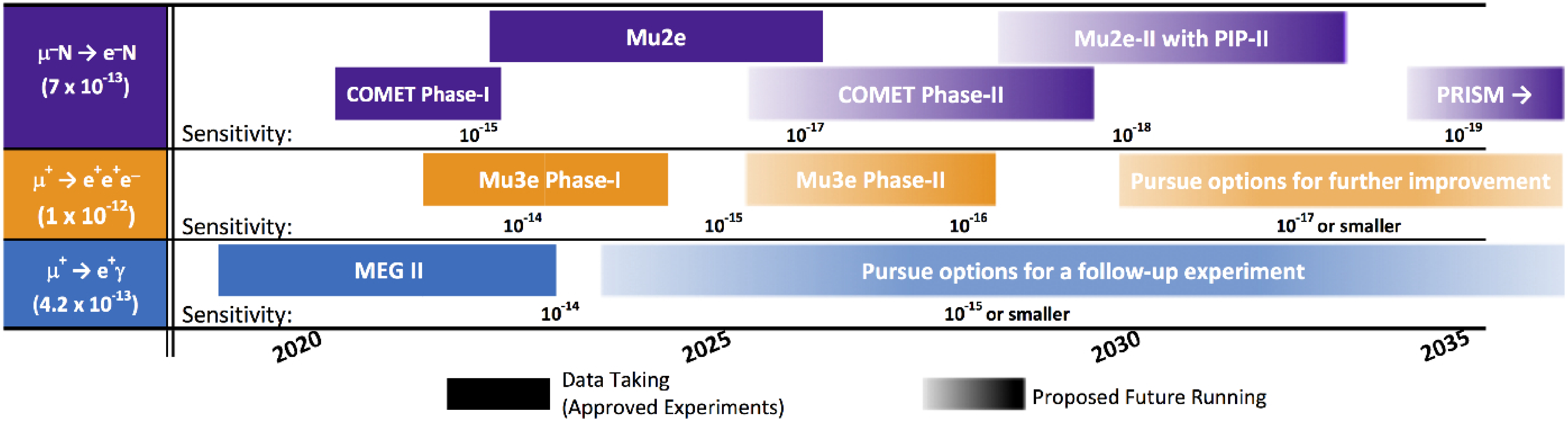
A submission to the 2020 update of the European Strategy for Particle Physics on behalf of the COMET, MEG, Mu2e and Mu3e collaborations.

Abstract

Charged-lepton flavour-violating (cLFV) processes offer deep probes for new physics with discovery sensitivity to a broad array of new physics models — SUSY, Higgs Doublets, Extra Dimensions, and, particularly, models explaining the neutrino mass hierarchy and the matter-antimatter asymmetry of the universe via leptogenesis. The most sensitive probes of cLFV utilize high-intensity muon beams to search for $\mu \to e$ transitions.

We summarize the status of muon-cLFV experiments currently under construction at PSI, Fermilab, and J-PARC. These experiments offer sensitivity to effective new physics mass scales approaching $\mathcal{O}(10^4)$ TeV$/c^2$. Further improvements are possible and next-generation experiments, using upgraded accelerator facilities at PSI, Fermilab, and J-PARC, could begin data taking within the next decade. In the case of discoveries at the LHC, they could distinguish among alternative models; even in the absence of direct discoveries, they could establish new physics. These experiments both complement and extend the searches at the LHC.

Searches for Charged-Lepton Flavor Violation in Experiments using Intense Muon Beams



Derniers commentaires perso

Groupe PMPP :

Phénoménologie et Modélisation pour la Physique des Particules

et/ou

Physique avec des Muons à J-PARC (COMET, g-2/EDM)
et
Photon-Photon (ILC(?), CEPC, FCC-ee)

Première biennale en 1982 dans la mairie de Vézelay
(imagine un dortoir chez les nonnes
avec une bataille de polochon)

Dernière à Montpellier 2019