(Theory for) Charged lepton flavour violation

searching for indirect signals of new physics

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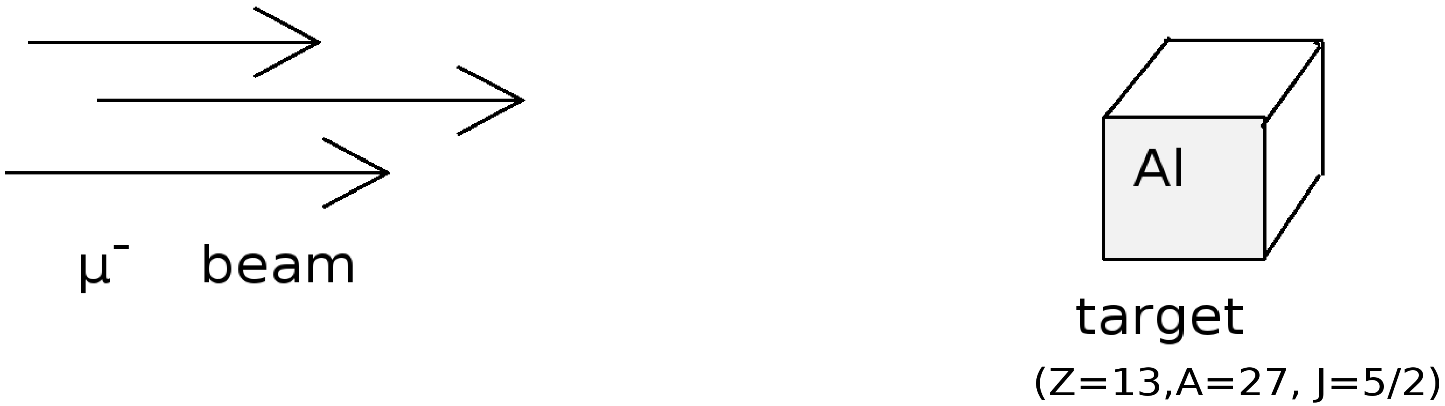
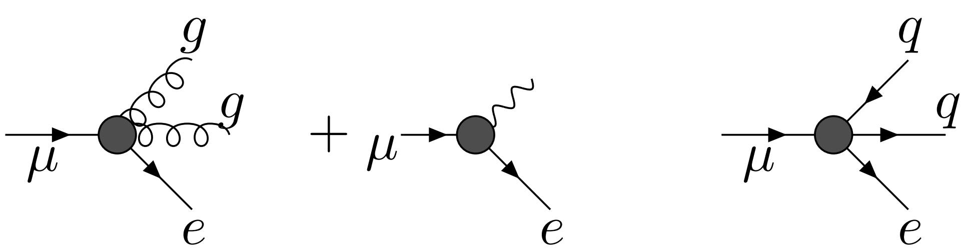
1. *New, theory* proposal

2. Aim: develop France-Japan collaborations in theoretical calculations of CLFV
   - current project: calculations of spin-dependent $\mu \rightarrow e$ conversion — Cirigliano, Davidson, Kuno 1703.02057
   - hope that other interested theorists will join

Spin-dependent $\mu \to e$ conversion (on Aluminium)



- μ^- captured by Al nucleus, tumbles down to $1s$. $(r \sim Z\alpha/m_\mu \gtrsim r_{Al})$
- μ converts to e $(E_e \approx m_\mu)$ via



$$(\overline{e}\Gamma P_Y \mu)(\overline{q}\Gamma q) \quad , \quad q \in \{u, d, s\}$$

$$\Gamma = \{I, \gamma_5, \gamma, \gamma\gamma_5, \sigma\}$$

- previously calculated for V, S nucleon currents, which sum coherently across nucleus ("Spin Independent" $\Rightarrow A^2$ enhancement) Kitano,Koike,Okada

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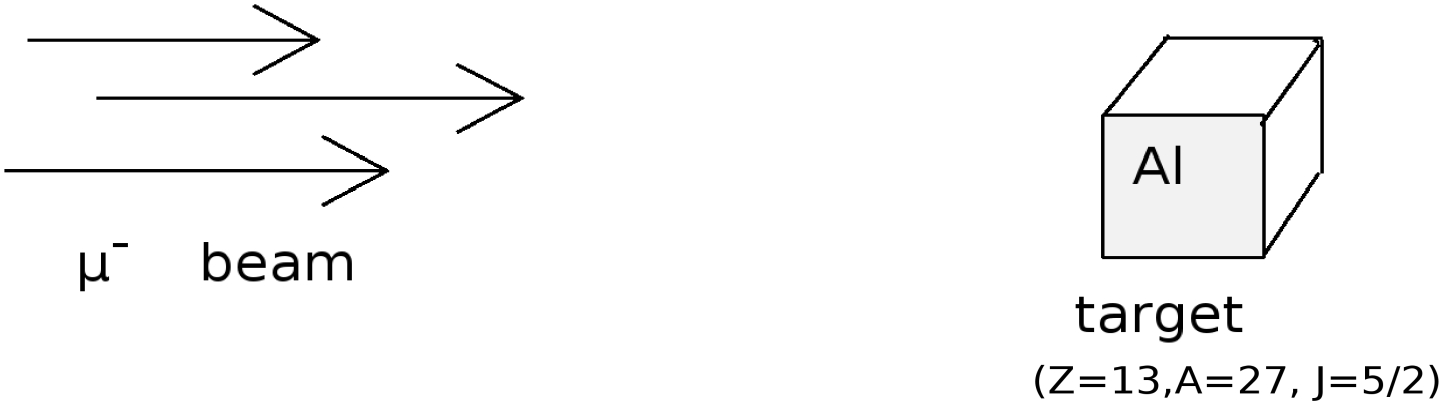

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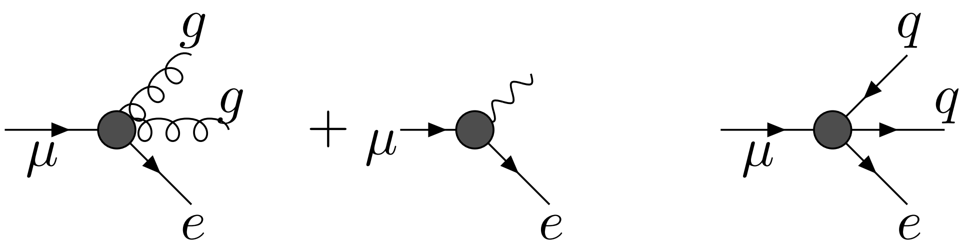

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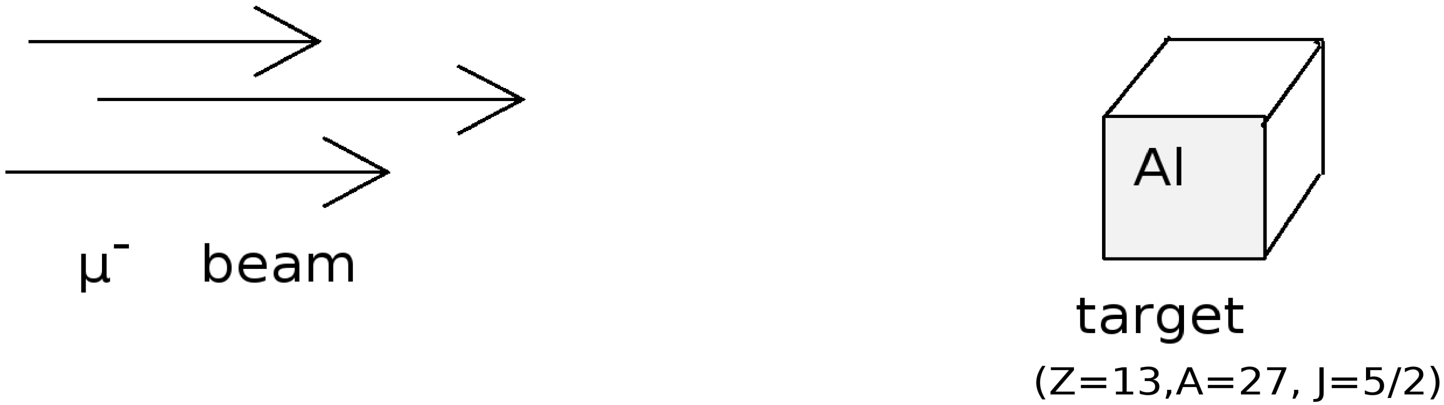
- previously calculated for V, S nucleon currents, which sum coherently across nucleus ($\Rightarrow A^2$ enhancement) Kitano,Koike,Okada
- We want to consider axial and tensor nucleon operators at exptal scale:

$$\mathcal{O}^{NN}_{A,Y} = (\overline{e}\gamma^\alpha P_Y \mu)(\overline{N}\gamma_\alpha\gamma_5 N) \quad , \quad \mathcal{O}^{NN}_{T,Y} = (\overline{e}\sigma^{\alpha\beta} P_Y \mu)(\overline{N}\sigma_{\alpha\beta} N) \ .$$

(not previously studied). Couple to the *spin* of the nucleon.

$\mu \to e$ conversion on Aluminium



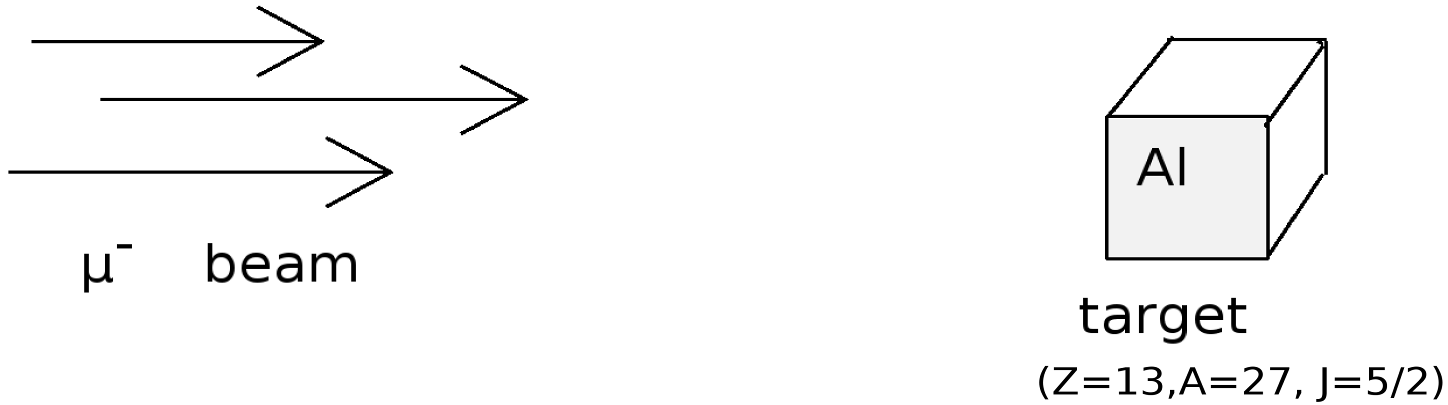
- So start at m_W with A, T *quark* operators: $(\overline{e}\gamma^\alpha P_Y \mu)(\overline{q}\gamma_\alpha\gamma_5 q)$, $(\overline{e}\sigma^{\alpha\beta} P_Y \mu)(\overline{q}\sigma_{\alpha\beta} q)$
  Three contributions to $\mu - e$ conv.

  1. contribute to *spin-dependent* conversion rate
  2. loop contributions to spin-indep rate: $A \to V$ and $T \to S$ Haisch,Kahlhoefer
  3. finite momentum transfer contribution to the spin-indep rate from the tensor

Fitzpatrick,Haxton,etal
CirelliEtal

Summary of our Results and Prospects

Cirigliano,Davidson, Kuno



- Start at m_W with A, T *quark* operators: $(\overline{e}\gamma^\alpha P_Y \mu)(\overline{q}\gamma_\alpha\gamma_5 q)$, $(\overline{e}\sigma^{\alpha\beta} P_Y \mu)(\overline{q}\sigma_{\alpha\beta} q)$
  Three contributions to $\mu - e$ conv.

  1. contribute to *spin-dependent* conversion rate

  nuclear matrix elements for SD dark matter detection with mica

  EngelRTO,KlosMGS

  SD $\mu \to e$ conversion rate smaller than SI rate (no A^2 enhancement)

  depends on different operator coefficients

  2. loop contributions to spin-indep rate: $A \to V$ and $T \to S$

  QED loop effect, largest contribution of tensor, axial operators to $\mu \to e$.

  3. finite momentum transfer contribution of tensor to spin-*indep* rate

  $\mathcal{M}_{SI} \sim A m_\mu / m_N \mathcal{M}_{SD}$, comparable to SD contribution.

To do: study whether one can identify models/combinations of operator + coefficients, by changing targets?

BackUp

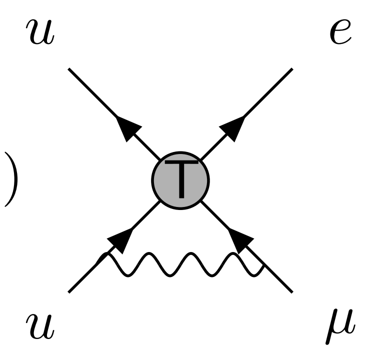
Budget

1 french visit to Japan, 10 days: 1000+10*(150 euros) = **2500 euros** from IN2P3

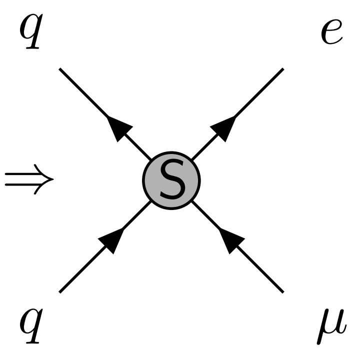
1 japanese visit to France, 10 days: 10*(15kYen) = **150 kYen** from KEK
(additionally request 100 kYen from Osaka U)

Include QED loops between $m_W \leftrightarrow m_\mu$

$C_T(\overline{u}\sigma u)(\overline{e}\sigma P_Y \mu)$



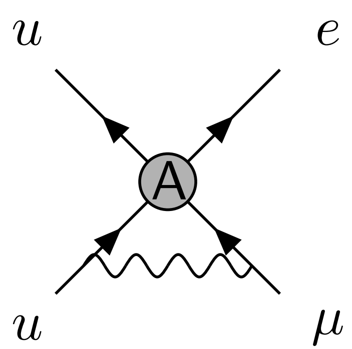
$+\ldots \quad \Rightarrow$



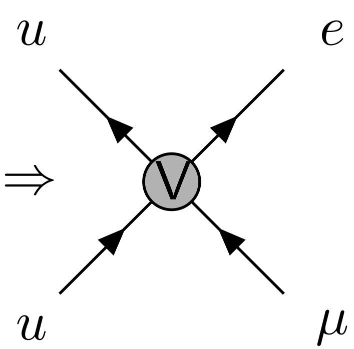
$$64\frac{\alpha_e}{4\pi}\log\frac{m_W}{m_\tau}\; C_T\; (\overline{u}u)(\overline{e}P_Y\mu)$$

$$\Delta C_S(m_\tau) \sim \tfrac{1}{7}C_T(m_W)$$

$C_A(\overline{u}\gamma\gamma_5 u)(\overline{e}\gamma P_Y \mu)$



$+\ldots \quad \Rightarrow$



$$8\frac{\alpha_e}{4\pi}\log\frac{m_W}{m_\tau}C_A(\overline{u}\gamma u)(\overline{e}\gamma P_Y\mu)$$

$$\Delta C_V(m_\tau) \sim \tfrac{1}{50}C_A(m_W)$$

Including the loop effects...

Recall $\Delta C_S^{uu} \sim 1/7 C_T^{uu}$ from RG mixing,
then $\langle p|\bar{u}u|p\rangle \sim 10\langle p|\bar{u}\sigma u|p\rangle$, so $\widetilde{C}_S^{pp} \gtrsim \widetilde{C}_T^{pp}$, and

$$BR(\mu Al \to eAl)_{SI} \sim 0.33(27)^2|.03C_A^{uu} + 2C_T^{uu}|^2$$

(A = 27 for Al)
(Recall that the BR_{SD} induced directly was $BR(\mu Al \to eAl)_{SD} \sim 0.1|C_A^{uu} + 2C_T^{uu}|^2$)

$\Rightarrow$ loop effects change $BR(\mu Al \to eAl)$ by $\left\{ \begin{array}{ll} \mathcal{O}(10^3) & \text{for } u,d \text{ tensor} \\ \mathcal{O}(\text{few}) & \text{for axial} \end{array} \right.$