

Search for exotic pion decays

Saul Cuen-Rochin
(TRIUMF)

for the  collaboration [Canada, China, Japan, Mexico, UK, US]

A. Aguilar-Arevalo, M. Aoki, M. Blecher, D.I. Britton, D.A. Bryman, D.vom Bruch, S. Chen, J. Comfort, S. Cuen-Rochin, L. Doria , P. Gumplinger, A. Hussein, Y. Igarashi, S. Ito, S. Kettell , L. Kurchaninov, L. Littenberg, C. Malbrunot, R.E. Mischke , T. Numao, D. Protopopescu, A. Sher, T. Sullivan, and D. Vavilov

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$\pi^+ \rightarrow e^+ \nu$ Branching Ratio

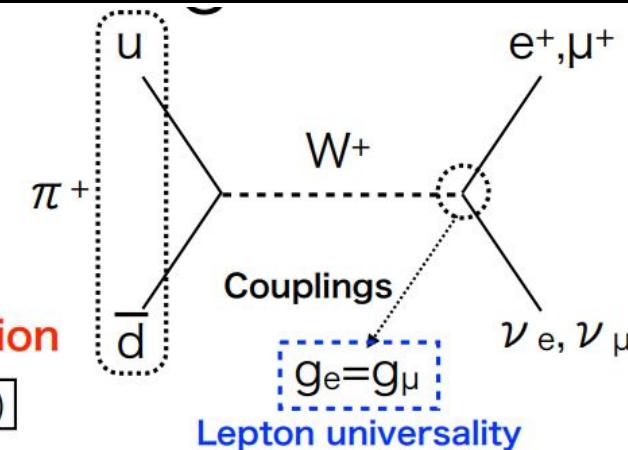
- $\pi^+ \rightarrow e^+ \nu$ branching ratio in SM

$$R_{\text{SM}}^\pi = \frac{\Gamma[\pi^+ \rightarrow e^+ \nu(\gamma)]}{\Gamma[\pi^+ \rightarrow \mu^+ \nu(\gamma)]}$$

$$= (1.2352 \pm 0.0002) \times 10^{-4}$$

$\pi^+ \rightarrow e^+ \nu$ decay: **helicity suppression**

V.Cirigliano, I.Rosell, PRL 99 231801 (2007)

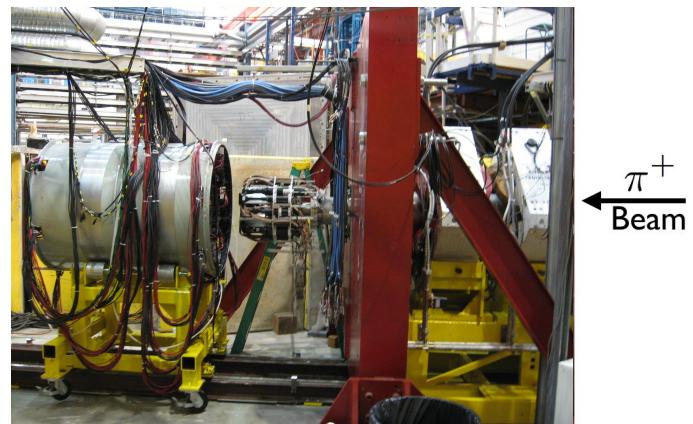
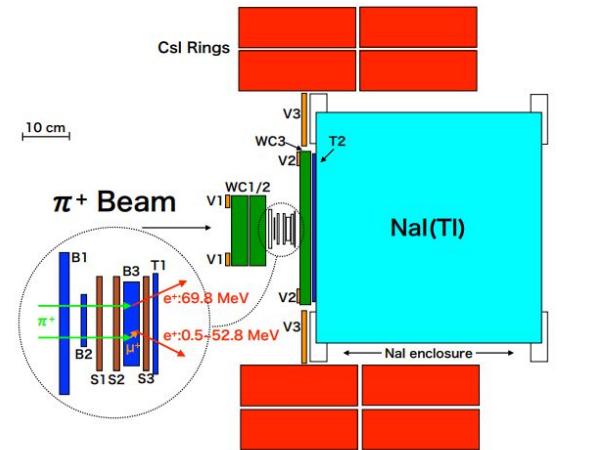
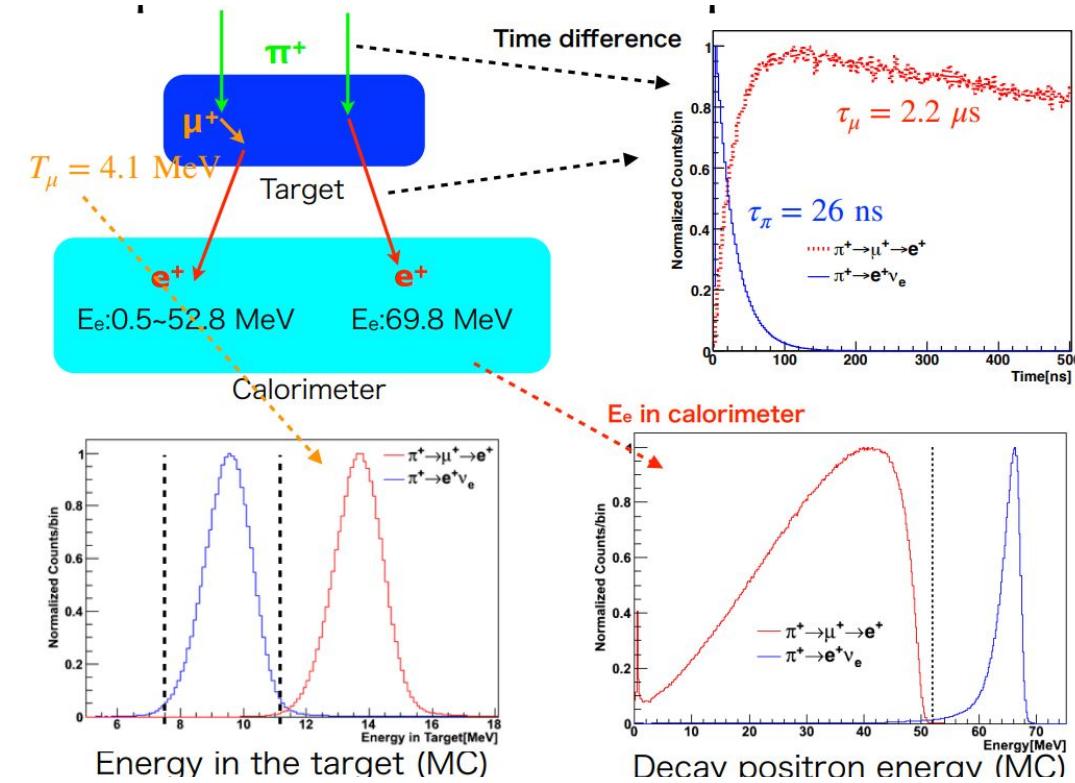


- Lepton universality test:** R-parity violating SUSY, charged Higgs, Leptquarks, heavy neutrino couplings.
- The PIENU at TRIUMF was performed to measure the pion branching ratio R^π with precision of <0.1%.
- Initial PIENU result (0.24% precision)

$$R_{\text{exp}}^\pi = [1.2344 \pm 0.0023(\text{stat}) \pm 0.0019(\text{syst})] \times 10^{-4}$$

Phys. Rev. Lett. 115 071801, (2015)

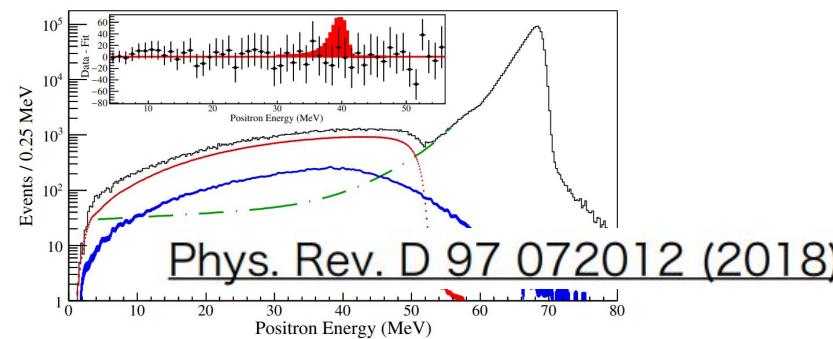
Experimental Technique



Massive neutrino searches

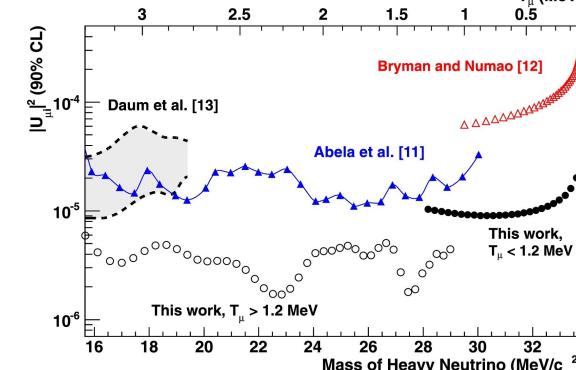
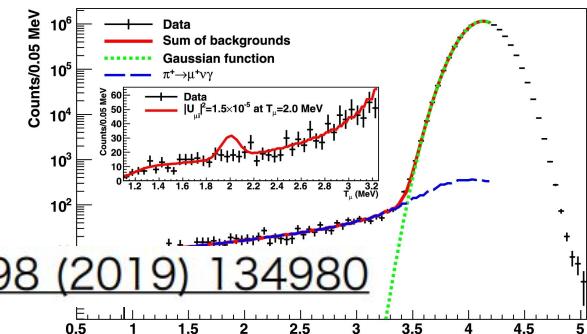
$$\pi^+ \rightarrow e^+ \nu_h$$

Massive neutrino search ($\pi^+ \rightarrow e^+ \nu_h$), resulting in upper limits (90% C.L.) on the neutrino mixing matrix element $|U_{e\mu}|^2$ in the neutrino mass region **60–135 MeV/c²**



$$\pi^+ \rightarrow \mu^+ \nu_h$$

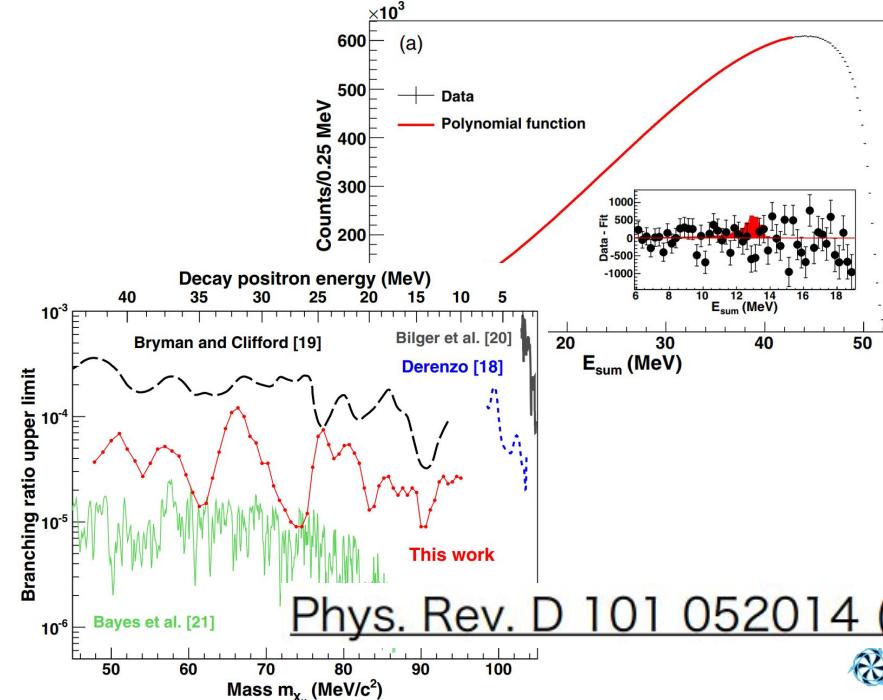
Massive neutrino search ($\pi^+ \rightarrow \mu^+ \nu_h$), resulting in upper limits (90% C.L.) on the neutrino mixing matrix element $|U_{\mu\mu}|^2$ in the neutrino mass region **15.7–33.8 MeV/c²**



Other searches for muon and pion exotic decays

$$\mu^+ \rightarrow e^+ X_H$$

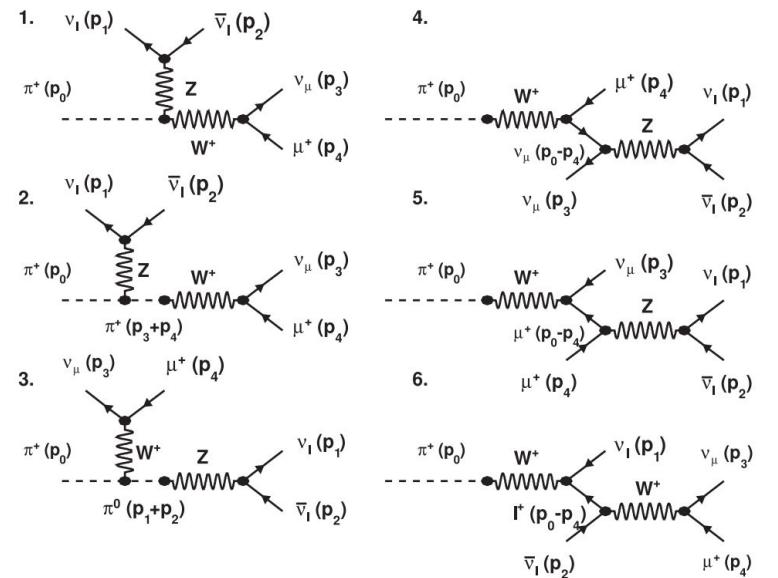
Massive neutral boson search in charged lepton flavor violating muon decay ($\mu^+ \rightarrow e^+ X_H$), resulting in upper limits (90% C.L.) on the branching ratio $\Gamma(\mu^+ \rightarrow e^+ X_H)/\Gamma(\mu^+ \rightarrow e^+ \nu\nu)$ in the X_H mass region **47.8–95.1 MeV/c²**



$$\pi^+ \rightarrow \mu^+ \nu\nu\nu, \quad \pi^+ \rightarrow e^+ \nu\nu\nu$$

Search for highly suppressed decays $\pi^+ \rightarrow \mu^+ \nu\nu\nu$ and $\pi^+ \rightarrow e^+ \nu\nu\nu$. First result for $\Gamma(\pi^+ \rightarrow \mu^+ \nu\nu\nu)/\Gamma(\pi^+ \rightarrow \mu^+ \nu) < 8.6 \times 10^{-6}$ and an improvement $\Gamma(\pi^+ \rightarrow e^+ \nu\nu\nu)/\Gamma(\pi^+ \rightarrow \mu^+ \nu) < 1.6 \times 10^{-7}$ were obtained.

Phys. Rev. D 102 012001 (2020)



There is more...

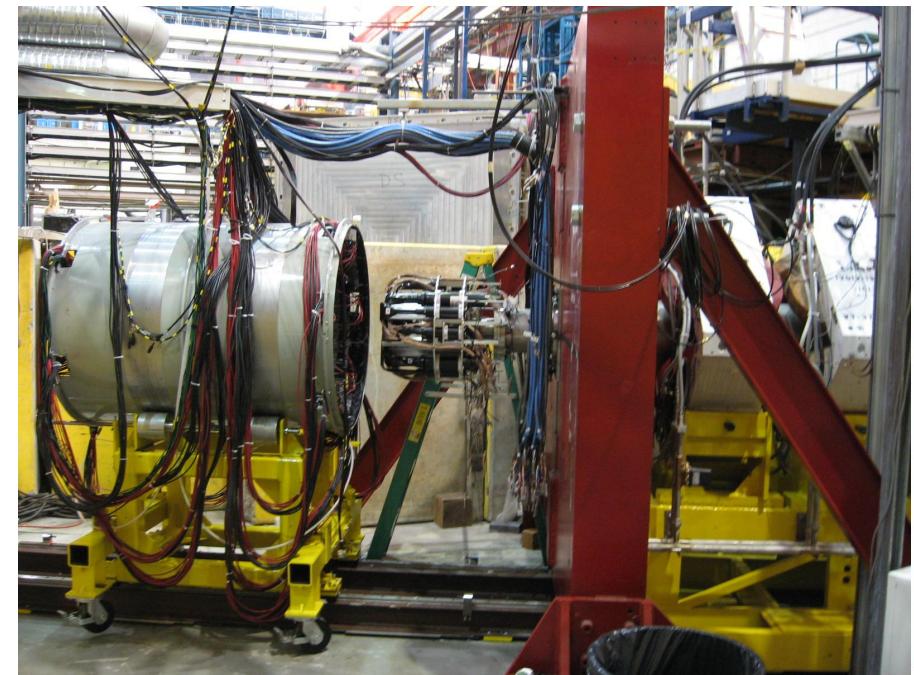
$$\pi^+ \rightarrow l^+ \nu X$$

Search for three body pion decay

- Another exotic pion decay: $\pi^+ \rightarrow l^+ \nu X$ where X is
 - Axion like particles (Phys. Rev. D 101 075002 (2020))
 - Majoron-neutrino couplings (Phys. Lett. 99B 411 (1981))
 - Heavy neutrinos (Phys. Rev. D. 97 075016 (2018))

Details presented by **Shintaro Ito**:

[https://agenda.infn.it/event/24250/contribution
s/129808/](https://agenda.infn.it/event/24250/contribution/s/129808/)



A.Aguilar-Arevalo et al: Nucl. Instr. Meth. A79, 38-46 (2015)