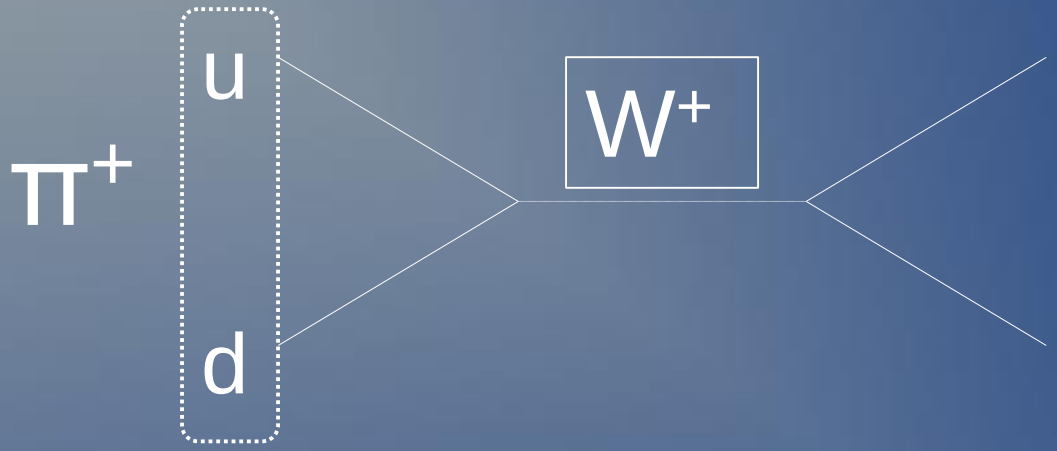
Precise Measurement of Rare Pion Decay (with bonus neutrino stuff)

Tristan Sullivan

CAP Congress 2019

on behalf of the PIENU collaboration

Pion Decay



$M_\pi = 139.6$ MeV

$E_e = 69.3$ MeV

$E_\mu = 4.1$ MeV

$$R_\pi = \frac{\Gamma((\pi \to e\,\nu) + (\pi \to e\,\nu\,\gamma))}{\Gamma((\pi \to \mu\,\nu) + (\pi \to \mu\,\nu\,\gamma))} = (1.2352 \pm 0.0002) \cdot 10^{-4}$$

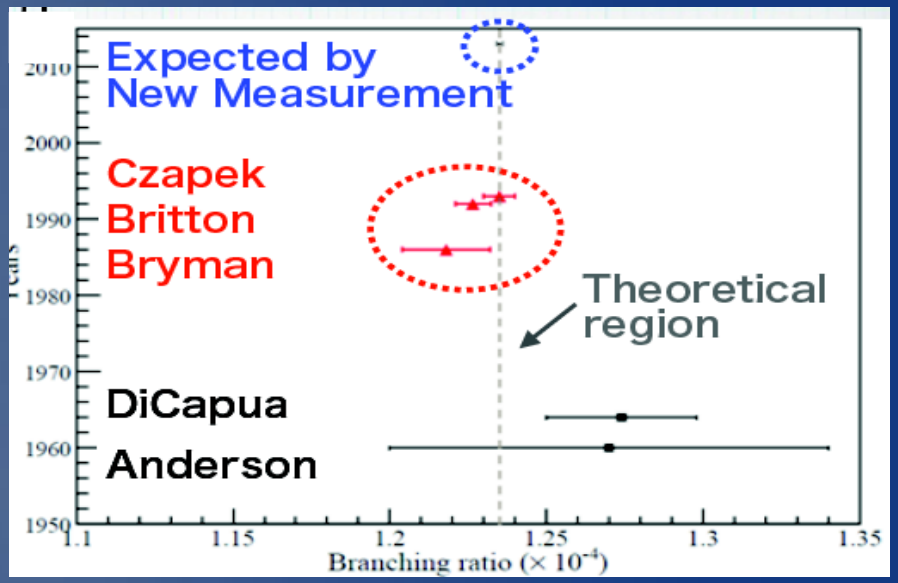
V. Cirigliano and I Rosell, JHEP **0710** 005 (2007).

Experimental Status

$R_{exp} = (1.2327 \pm 0.0023) \cdot 10^{-4}$

Good agreement but ~10 times less precise

Still one of the best tests of lepton universality

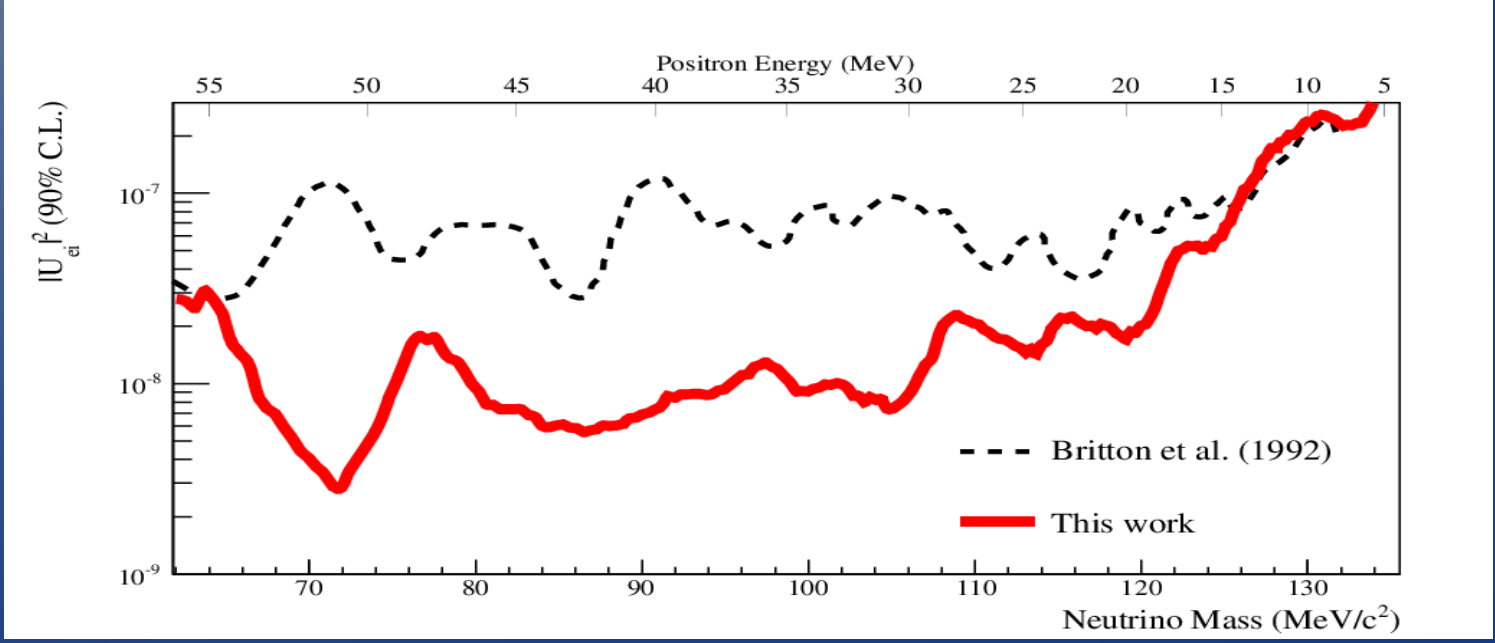


Decay Mode	g_μ / g_e	Year
τ —> μ / τ —> e	1.0018 ± 0.0014	2010
π —> μ / π —> e	1.0004 ± 0.0012	2015
K —> μ / K —> e	0.996 ± 0.005	2011
K —> πμ / K —>π e	1.002 ± 0.002	2007
W —> μ / W —> e	0.997 ± 0.010	2008

Neutrinos

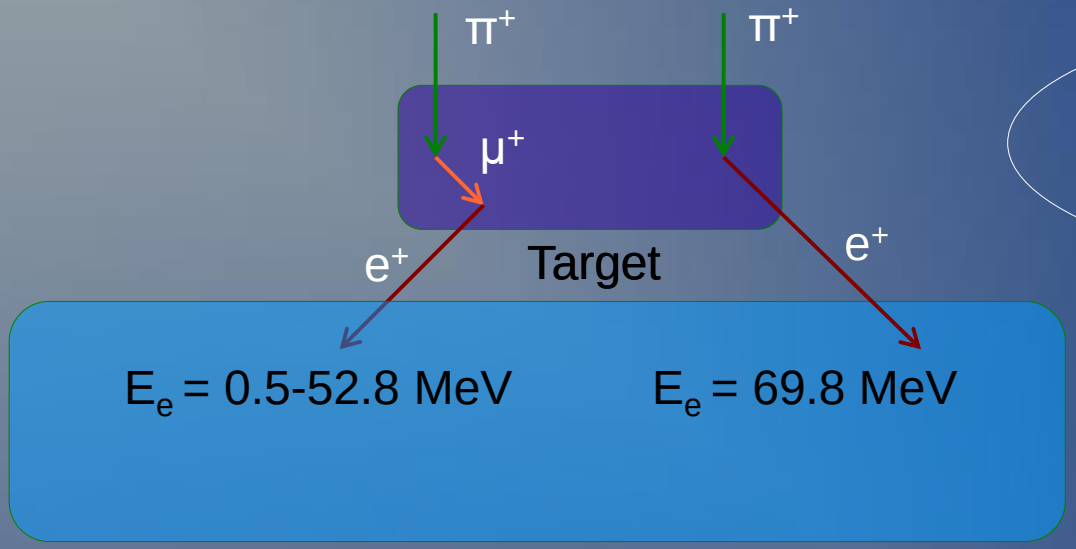
PIENU stops pions to make a precise measurement of the rate for the rare decay $\pi \rightarrow e\,\nu$.

It is also sensitive to $\pi \rightarrow e\,\nu_h$ for $60 < M_\nu < 135$ MeV/c^2 and sets impressive limits on the coupling of a ν_h to the electron ($|U_{ei}|^2$)



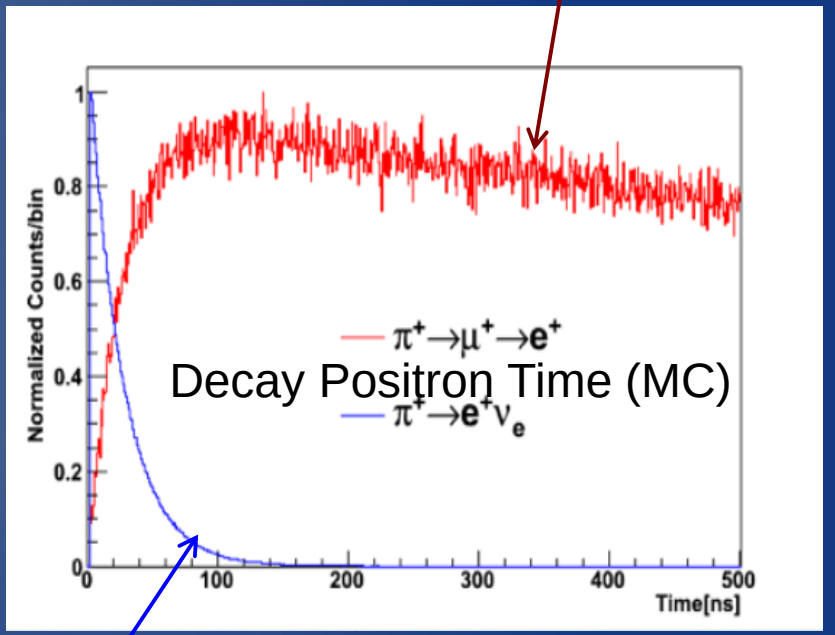
A. Aguilar-Arevalo *et al.*, Phys. Rev. D **97**, 072012 (2018)

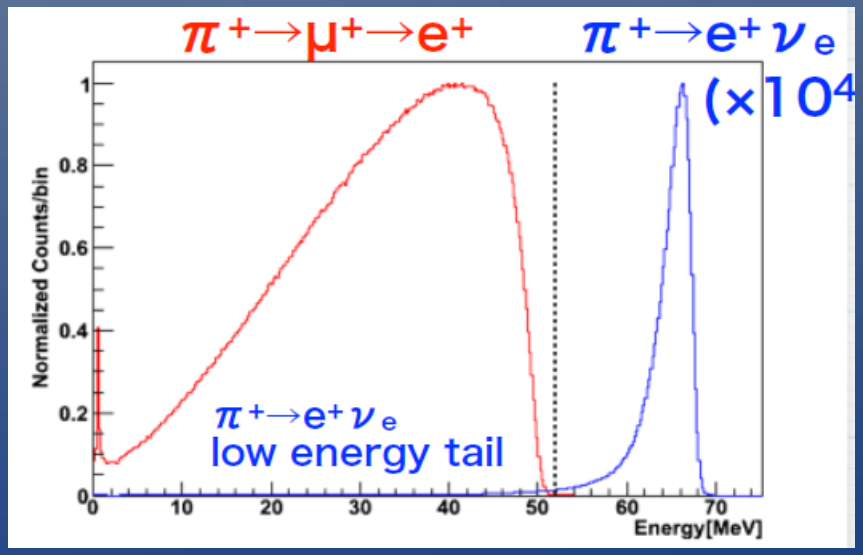
Experimental Technique



$\pi^+ \longrightarrow \mu^+ \longrightarrow e^+$

$N_{PIMU} / (\tau_\mu - \tau_\pi) \times (e^{-t/\tau\mu} - e^{-t/\tau\pi})$





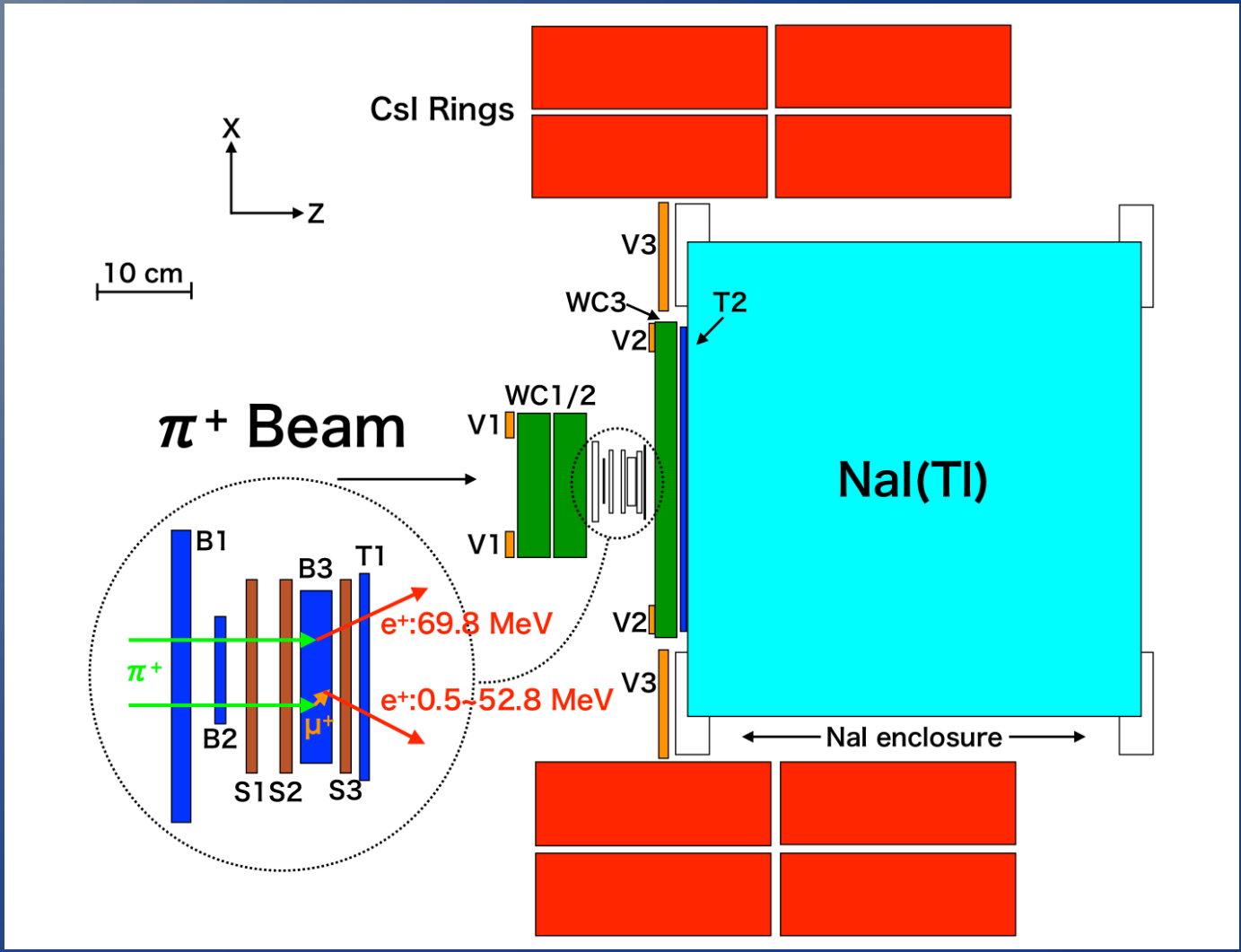
Decay Positron Energy (MC)

$\pi^+ \longrightarrow e^+$

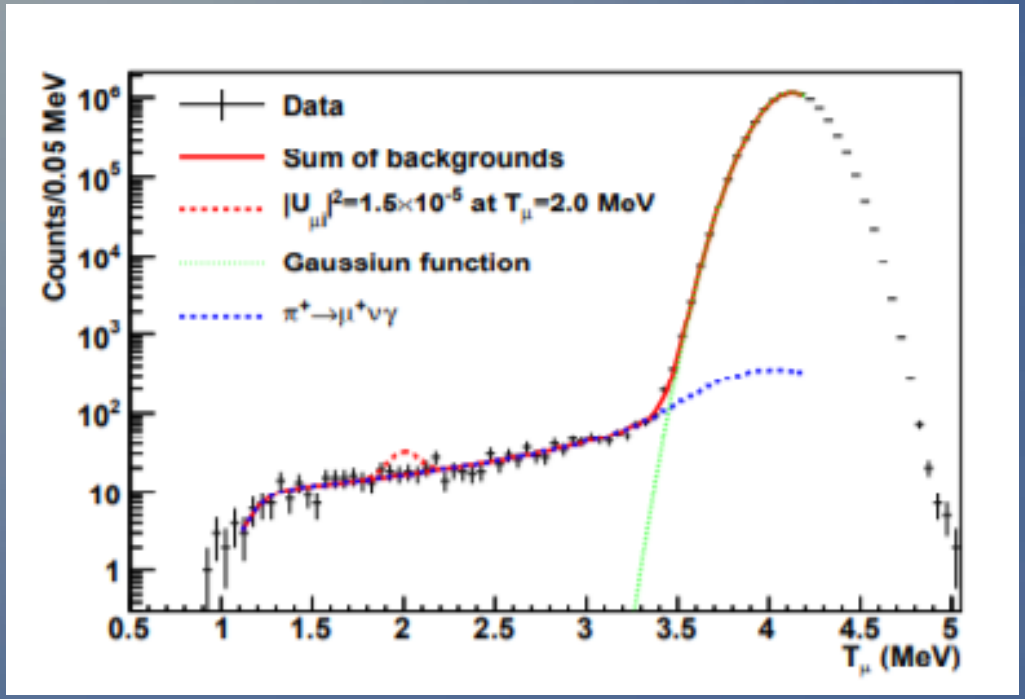
$(N_{PIE} / \tau_\pi)\, e^{-t/\tau\pi}$

Detector

- B1 rate 50-60 kHz
- Acceptance ~ 20%
- Energy Resolution 2.2% (FWHM) at 70 MeV
- 19 radiation lengths of NaI, 9 of CsI
- Sub-ns time resolution from waveform fits of plastic scintillator PMTs
- Event time Tpos defined as T1time - B1time
- Wire chambers & silicon strips for π^+ beam and decay e^+ tracking

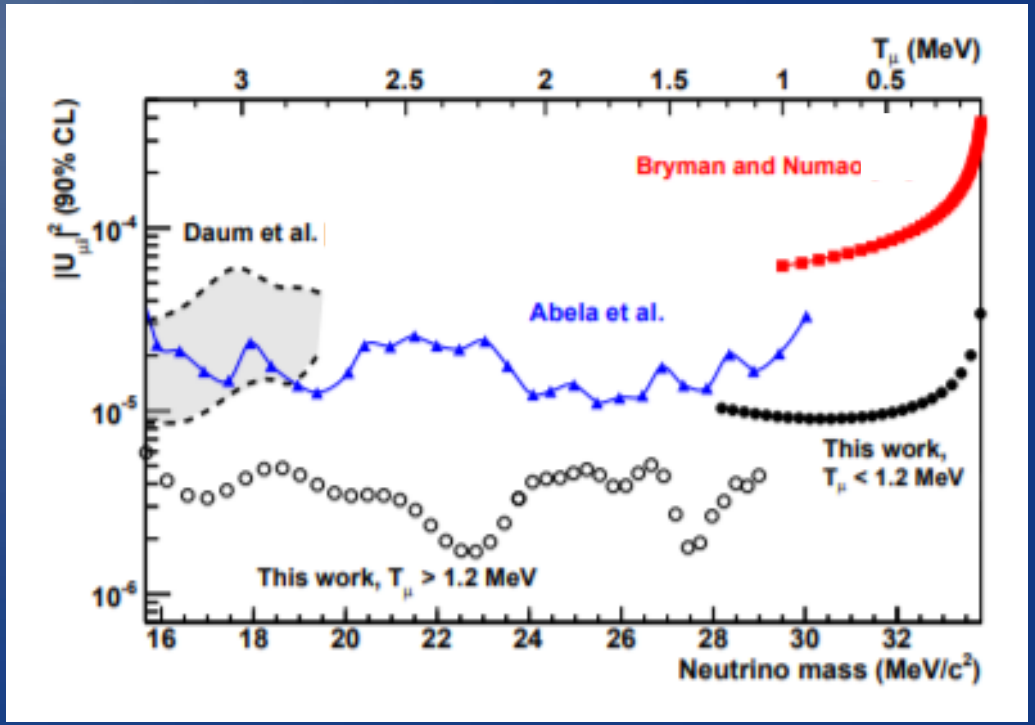


Muon Neutrinos



Muon energy spectrum in target counter

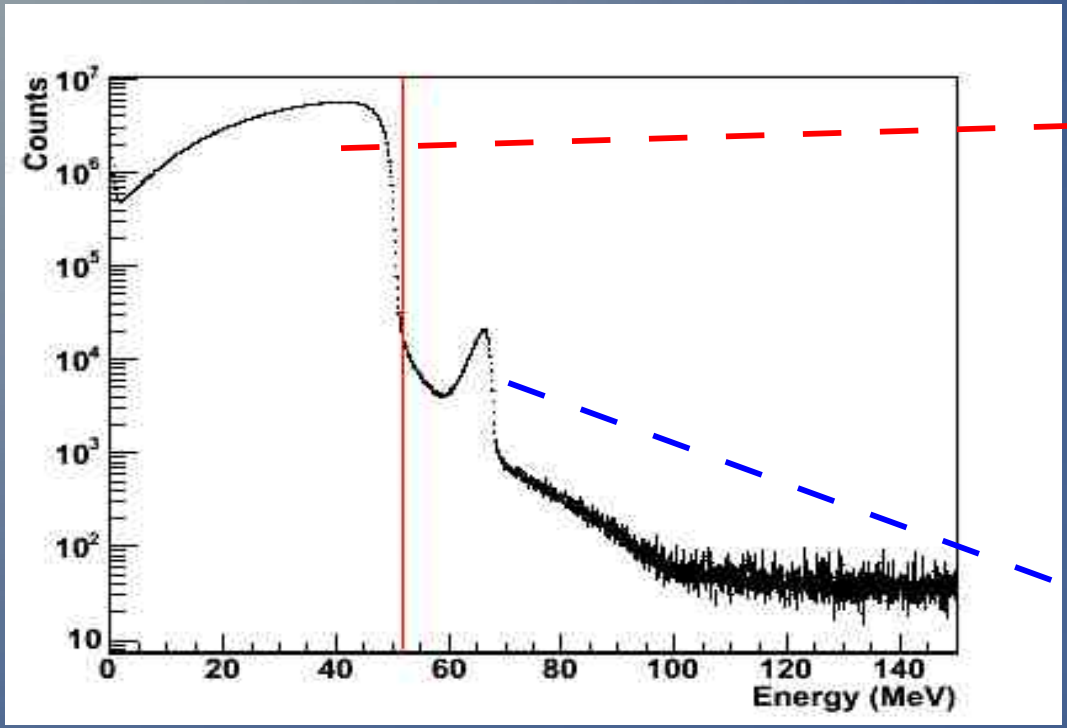
A heavy neutrino could cause an extra peak to appear

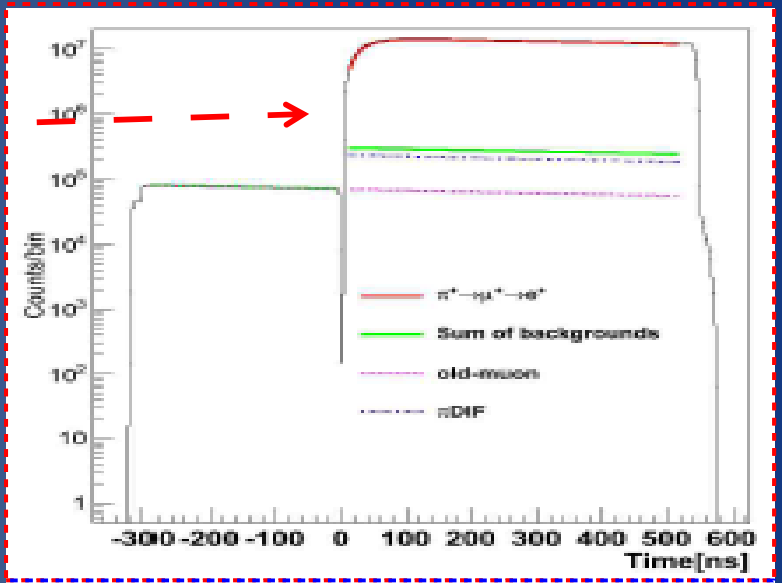


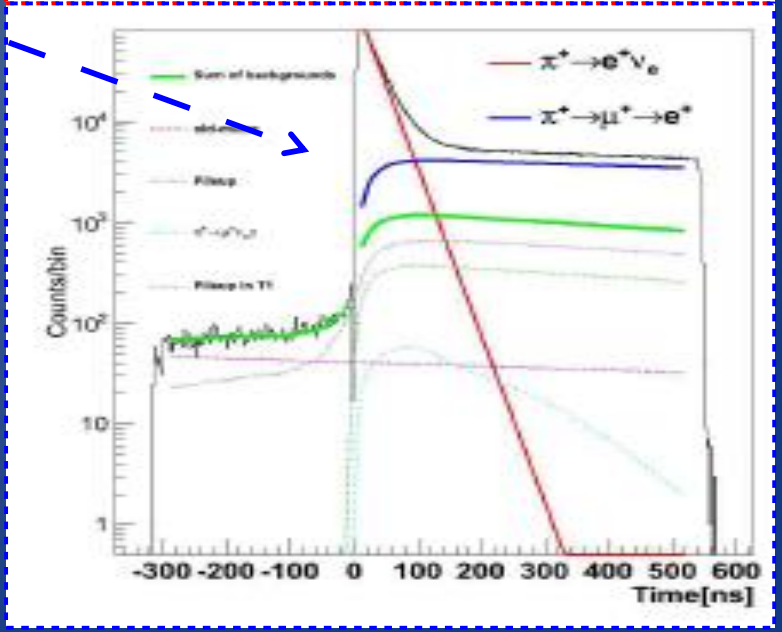
Resulting limits on the mixing parameter of the heavy neutrino

Result submitted to PRL; also on arxiv:1904.03269

Raw Branching Ratio Extraction





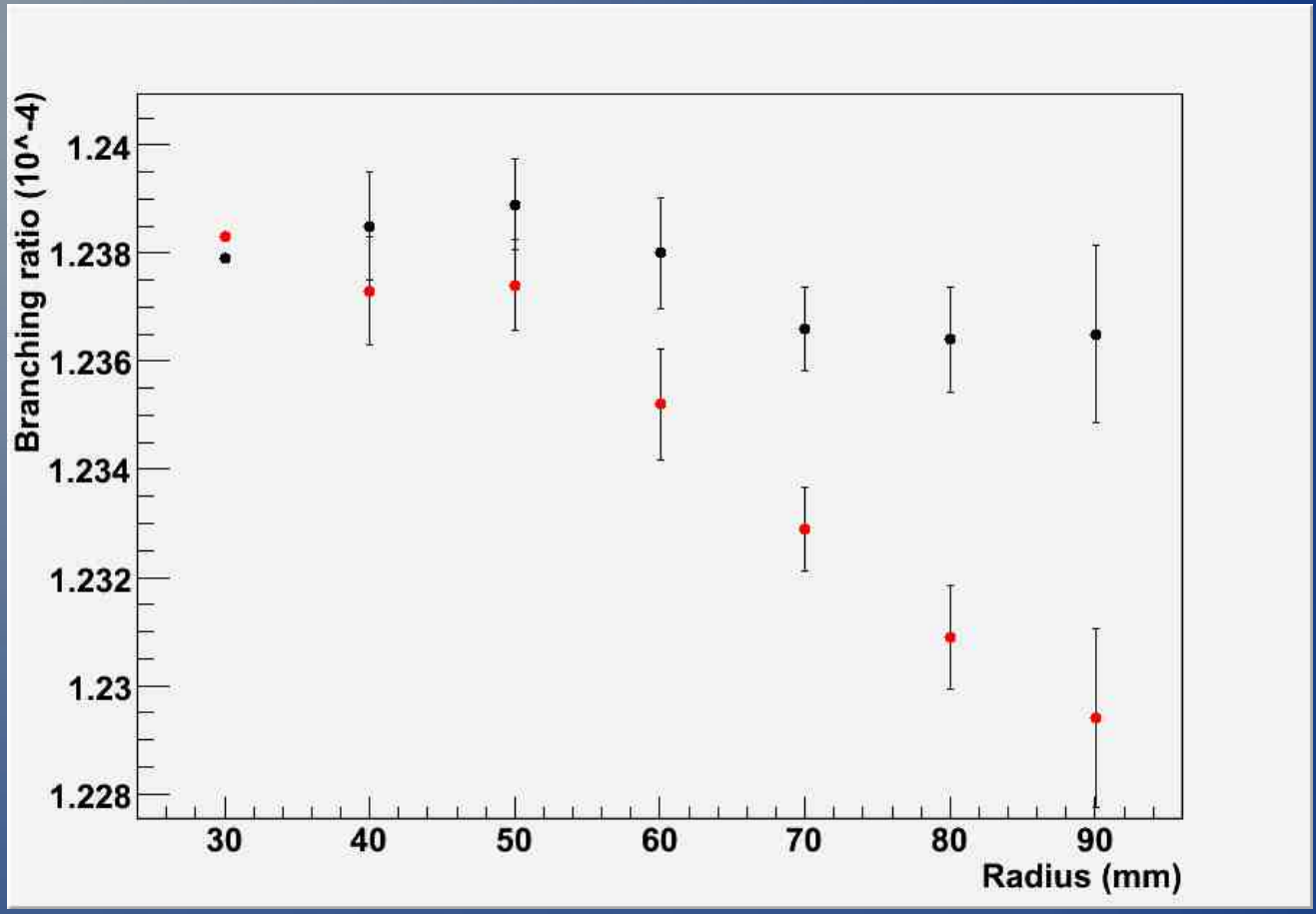


- Data from 2010-2012
- 2 x 10^6 clean π —> e ν events
- Fitting time spectra simultaneously gives raw branching ratio:

R_{raw} = [1.2xxx ± 0.0012 *(stat)* ± *0.0010 (syst)]* · 10^{-4}

PRELIMINARY

Radial dependence



The branching ratio should be stable as we vary the radius in which we accept events

In November 2017, a dead layer present in the detector was found to be missing from the simulation code

The red points are before the modification, the black points are after

Error bars are on the change from the point at 30 mm

Error Budget

PRELIMINARY

Statistics	0.1%
Time Fit	0.04%
Cuts	0.06%
Tail Correction	0.05%
Other corrections	0.03%
Total	0.13%

Stay tuned for unblinding!