PIP-II Facility for Muon CLFV Experiments

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3 April 2019

INTRODUCTION

- There are three main muon CLFV processes: $\mu \to e\gamma$, $\mu \to 3e$, and $\mu^- N \to e^- N$

Process	Sign of Muon	Pulsed/Steady Beam	Location
$\mu \to e\gamma$	Stopped	steady	PSI
$\mu \to 3e$	Stopped	steady	PSI
$\mu N \to eN$	Captured	pulsed	FNAL

- $\mu \to e\gamma, 3e$ are decay processes; examine *stopped* μ^+ decays, need μ^+ since we don't want a capture
- $\mu N \to eN$ is a capture process; examine μ^- captures
- Time Structures are different
  - backgrounds for the decay process rise as Intensity/Duty factor from accidental coincidences (grossly oversimplifying backgrounds but this is the core point)
  - background for $\mu N \to eN$ is pion-induced, requiring pulsed beam to allow pions to decay

Next-Gen Experiments

- For $\mu \to e\gamma$ and $\mu \to 3e$ about $\times 100$ current intensity
- For $\mu N \to eN$, see Mu2e-II.

- Can PIP-II do all three, and better?
  - PSI uses about 1% of its beam to power 10^8 μ^- decays/sec from a stopped muon beam (really stop π and let them decay; monochromatic, polarized muons)
  - 10^8 muons/sec with about 1% of the PSI beam at 1.1MW
  - Plan to upgrade by about $\times 100$ in HIMB (high intensity muon beam) but this is uncertain and complicated. `https://indico.phys.vt.edu/event/34/contributions/701/attachments/617/785/Papa_Nufact2018_HiMB.pdf`
  - Talked with experimenters on MEG, Mu3e. Depends on strength of tie to PSI but not uninterested.
- **would have a muon CLFV program with about 600 people moving among experiments, not unlike SBN**

Why Are The Decay Experiments Done Better Here?

- In theory, at least, could go well beyond $\times 100$ with a "greenfield" experiment
- power available at PIP-II – at PSI, muon program power is shared with other parts of their program and muons are in fact small
- possible advantage of new style of beam
  - a main background to decays is accidentals (two decay in time window, combined fakes signal)
  - size of background drops as vertex resolution improves
  - for $\mu \to e\gamma$, vertex resolution improves as stopping position (range R) becomes more tightly defined
  - $\Delta R \sim p^{3.5}$; if we could go below stopped muon beam energy, could improve resolution quickly

Capture Solenoid + SCRF

- Instead of a high-power 1MW PSI-style target from which we pick off a small number of muons,
  - Use a capture solenoid/lens or other device to focus π^+ into a beam from PIP-II protons
    - time structure so fast that it's effectively DC (PSI is 300 psec every 19 nsec)
    - Let π^+ decay and form muon beam (so far this sounds like neutrino experiments!)
    - Now slow down muons to $\sim$ 10 MeV/c (or any other momentum you like) with SCRF (a few meters?) and get $\Delta R \propto p^{3.5}$ smaller
- Talked to PIP-II and of course not discouraging but no resources. Talked to NIU and IIT about a Master's student. Need some dedicated time to see if this is on the mass shell.

Mu2e Beam

- $\sim 3 \times 10^{10} \mu^- /\text{sec}$ at 8 kW in pulsed beam, 30–40 MeV/c muons (but not monochromatic!)
- rotatable collimator at center of S-curve chooses μ^- or μ^+
- (ahem) "just" rotate collimator to select μ^+ and use 800 MeV PIP-II CW beam instead of 8 GeV pulsed beam from Delivery Ring, send off to decay experiments
- could we build a single Production Solenoid and split at central collimator?
- or even look at forward-muons? (Mu2e looks at backwards-going)
- but maybe 100 kW is not completely wrong
  - loss in rate from transport, cooling, . . .
  - but we can make $> 10^{10} \mu^- /\text{sec}$; Mu2e-II should deliver $\mathcal{O}(10^{12}) \mu^- /\text{sec}$ at 100 kW