Mu2e-doc-1950

Mu2e Interests in Concurrency

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November 21, 2011

Mu2e Interests in Concurrency

- The Mu2e experiment is still in an R&D phase.
- Working schedule:
  - CD-1 review planned for ~May 2012
  - Construction start ~2 years later.
  - Start of operations ~4 years later.
- Expect to have interests in concurrency in both online and offline worlds.
  - Online: not started to seriously think about it.
  - Offline: some (preliminary) thoughts presented here
- I doubt that we will drive developments in concurrency.
  - This talk will explain why.
- There is one important use case for shared memory.

MC Needs (1)

- Signal events are single track events.
  - Samples of 10,000 to 20,000 are large enough.
- Large background samples are needed but each event is a single track that can be generated independently of all other background samples.
- Only a very tiny fraction of background samples actually make hits in the detector.
- Embarrassingly parallel solution works well:
  - Run lots of single particle MC (grid).
  - Write out only events that make hits.
  - Overlay background hits on signal events (interactive).
  - Peak virtual size O(1 GB) today. But …

MC Needs (2)

- Background overlay is done with MC analog info (ie pre digitization).
- Could parallelize digi formation since there is a step in which each channel is done separately.
  - But the time spent doing this is tiny.
  - It would be cool but it's not a performance driver.

Reconstruction Needs (1)

- Can do 10,000 events in a few hours, with many tools compiled –O0, full debug mode, with full diagnostics enabled and without trying to speed up the algorithm.
  - Don't yet have benchmarks with optimization and without full diagnostics. Will need those for CD1.
- Obvious speedup is event-level parallelism.
  - Could use concurrency to implement this but it is not necessary.
- Peak virtual size O(1 GB) (with full diagnostics). But …

Reconstruction Needs (2)

- We know of places in our algorithms that could use concurrency:
- obvious spots for sub-event parallelism.

But …

- Our existing magnetic field map:
  - Consists of field values on a grid.
  - Simulation needs: O(300 MB)
  - Reconstruction needs: O(100 MB).
- Need to expand the mapped volume (MC only):
  - Guess: 600 MB, even with coarser grid where appropriate.
- Would like to save CPU by pre-computing the interpolation coefficients from the grid points.
  - Guess: increases the size to 18 GB for MC and 3 GB for RECO.
- For a long MC run, the map is constant.
- For main line reconstruction, the map is constant.
- Need only one copy of the map for all cores on one machine.

A Final Comment

- Processing any one event, MC or RECO, ranges from sub-second to a few seconds.
  - No payoff on using sub-event parallelism to speed-up single events for debugging.
- An exception: tracing a single particle in the muon beamline or tracing a neutron anywhere has a long tail to tens of seconds.
  - Still no payoff for sub-event parallelism: I don't know how to parallelize tracing a single particle.

Conclusion

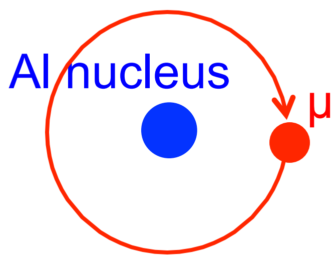
- Mu2e has one clear need to share readonly memory, among many process in one box.
- Individual events are either very fast or do not parallelize nicely.
- Event-level embarrassingly parallel solutions work well.

Backup Slides

μ to e Conversion at Mu2e

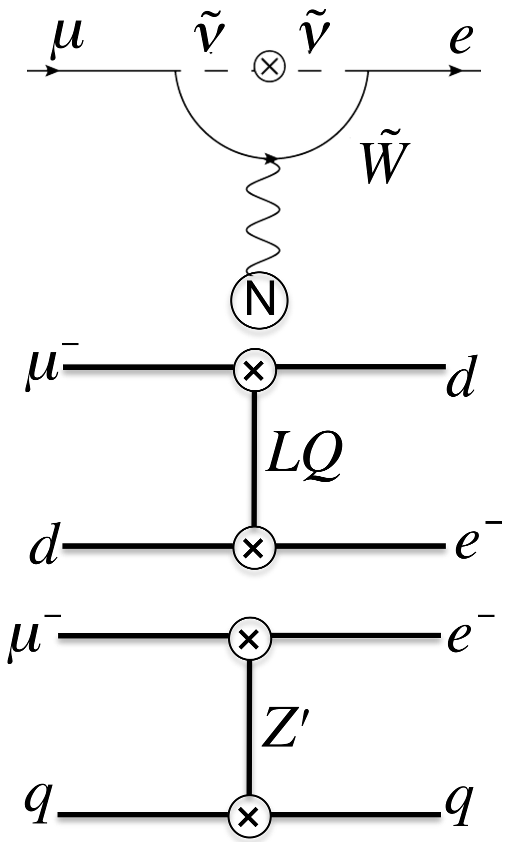
Initial State

- Muonic aluminium



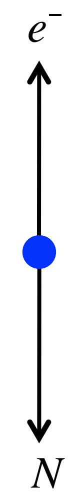
- Bohr radius: ≈ 20 fm
- Nuclear radius: ≈ 4 fm
- Lifetime: 864 ns

New Physics



Final State

- No neutrinos
- 2-body
- Recoiling, intact, unobserved nucleus
- Mono-energetic e^-
  - E=104.97 MeV



- Coherent = no nuclear breakup!

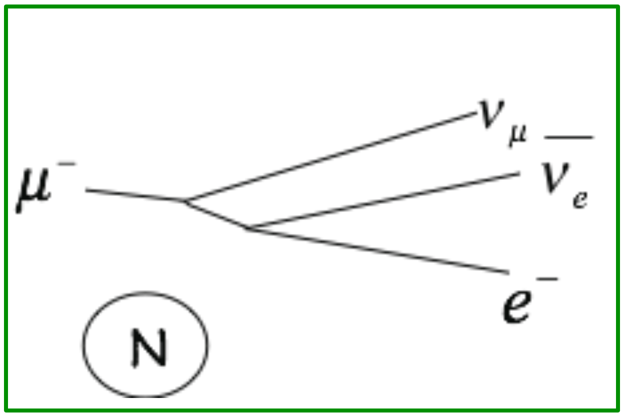
What do We Measure

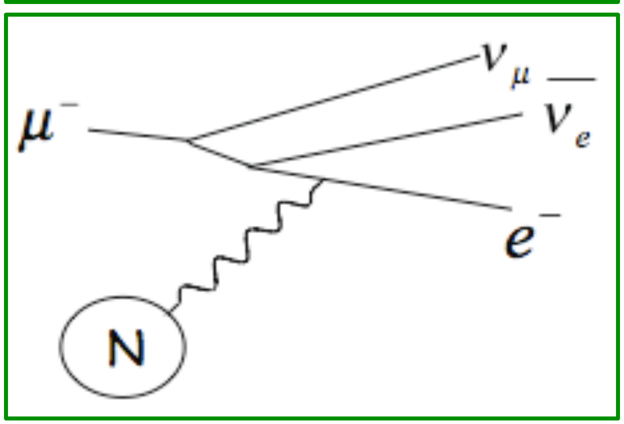
$$R_{\mu e} = \frac{\Gamma(\mu^- + (A,Z) \rightarrow e^- + (A,Z)\,)}{\Gamma(\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)\,)}$$

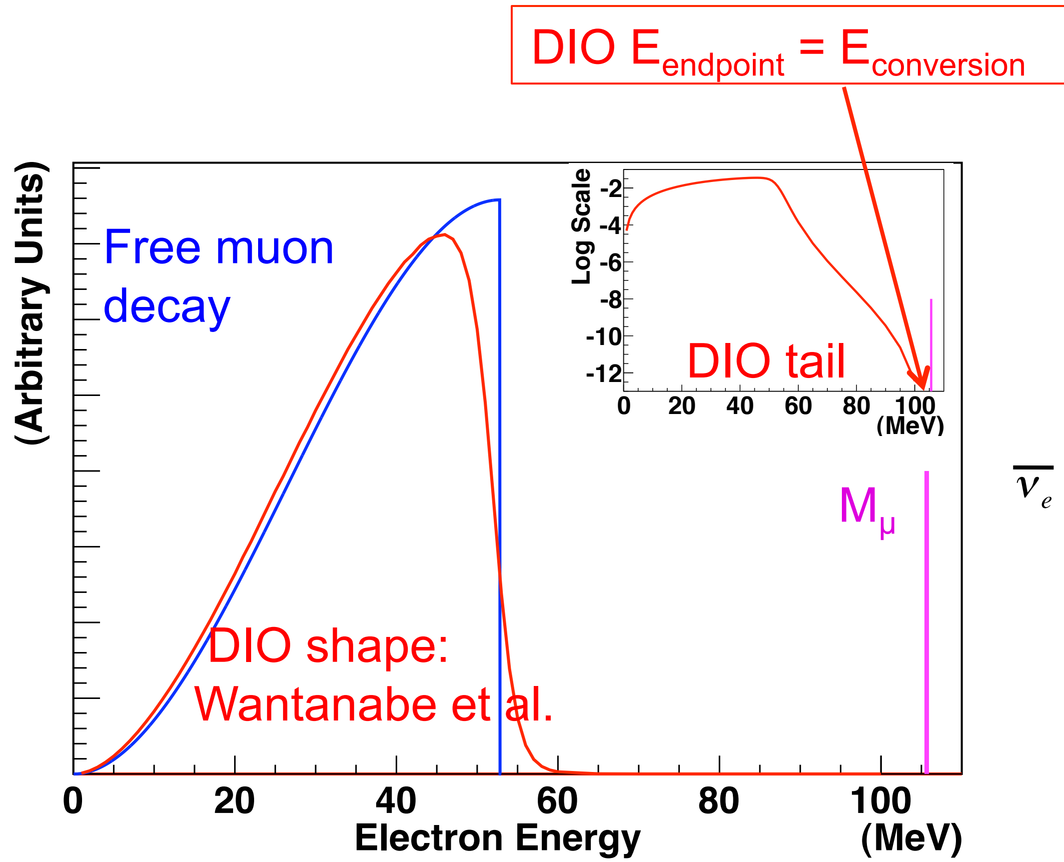
- Denominator: normal muon nuclear capture.
  - Count the number of stopped muons, using muonic X-ray lines.
- SM rate is non-zero but is immeasurably small.
- Any observation is evidence for physics beyond the Standard Model.
  - Sensitive to new mass scales up to O(10,000 TeV).
- Previous best: Sindrum II
- An earlier experiment: TRIUMF-104 (TRIUMF TPC)

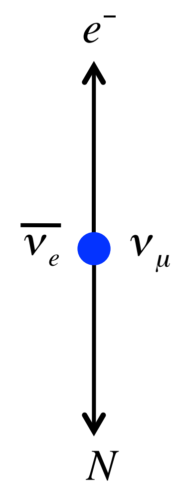
Decay-in-Orbit: Irreducible Background

Decay of muonic aluminium:
40% decay in orbit (DIO)

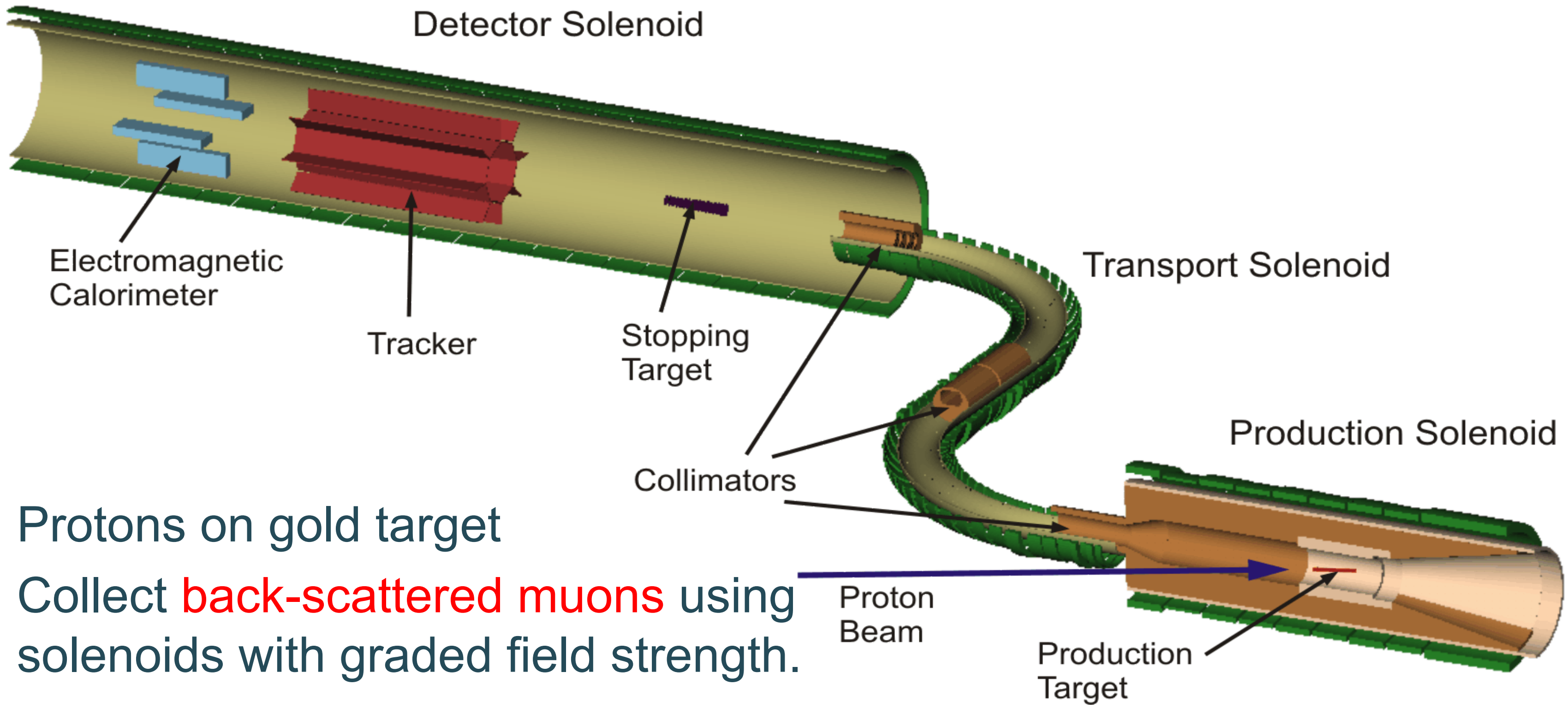








Making Muonic Al



- Protons on gold target
- Collect back-scattered muons using solenoids with graded field strength.
- Transport muons to thin foils stopping targets.
- Many non-muons arrive in time with muons: prompt backgrounds.
- Lifetime of muonic aluminium is 864 ns
    - Wait for prompt backgrounds to decay!

A Cartoon of Mu2e

1) Make a low momentum muon beam.
2) Shoot it at target of many thin Al foils.
3) Some muons will range out in the first foil, some in the next foil, …
4) Stopped muons will be captured to form muonic atoms.
5) Wait until the prompt backgrounds decay away.
6) Measure the energy spectrum of electrons that escape the foils.
   - Using standard HEP techniques: straw tracker and crystal calorimeter
7) Measure/estimate backgrounds in the signal region.
8) Systematics, systematics and more systematics
9) Open the box: is there an excess at the conversion energy?

Sensitivity

- For a 3.6×10^{20} protons on target:
  - Expect < 0.17 ± 0.7 background events in the signal region.
  - $R_{\mu e} \approx 2.3 \times 10^{-17}$ single event sensitivity.
  - $R_{\mu e} < 6 \times 10^{-17}$ limit at 90% C.L.
  - 10,000 × better than previous limit (SINDRUM II).
  - Sensitive to masses up to O(10,000 TeV).
  - For SUSY visible at the LHC: $R_{\mu e} \approx O(10^{-15})$
    - Expect 40 events on a background of 0.17 ± 0.7
- Stay tuned: http://mu2e.fnal.gov.