A Roadmap Towards Single Muon Analyses

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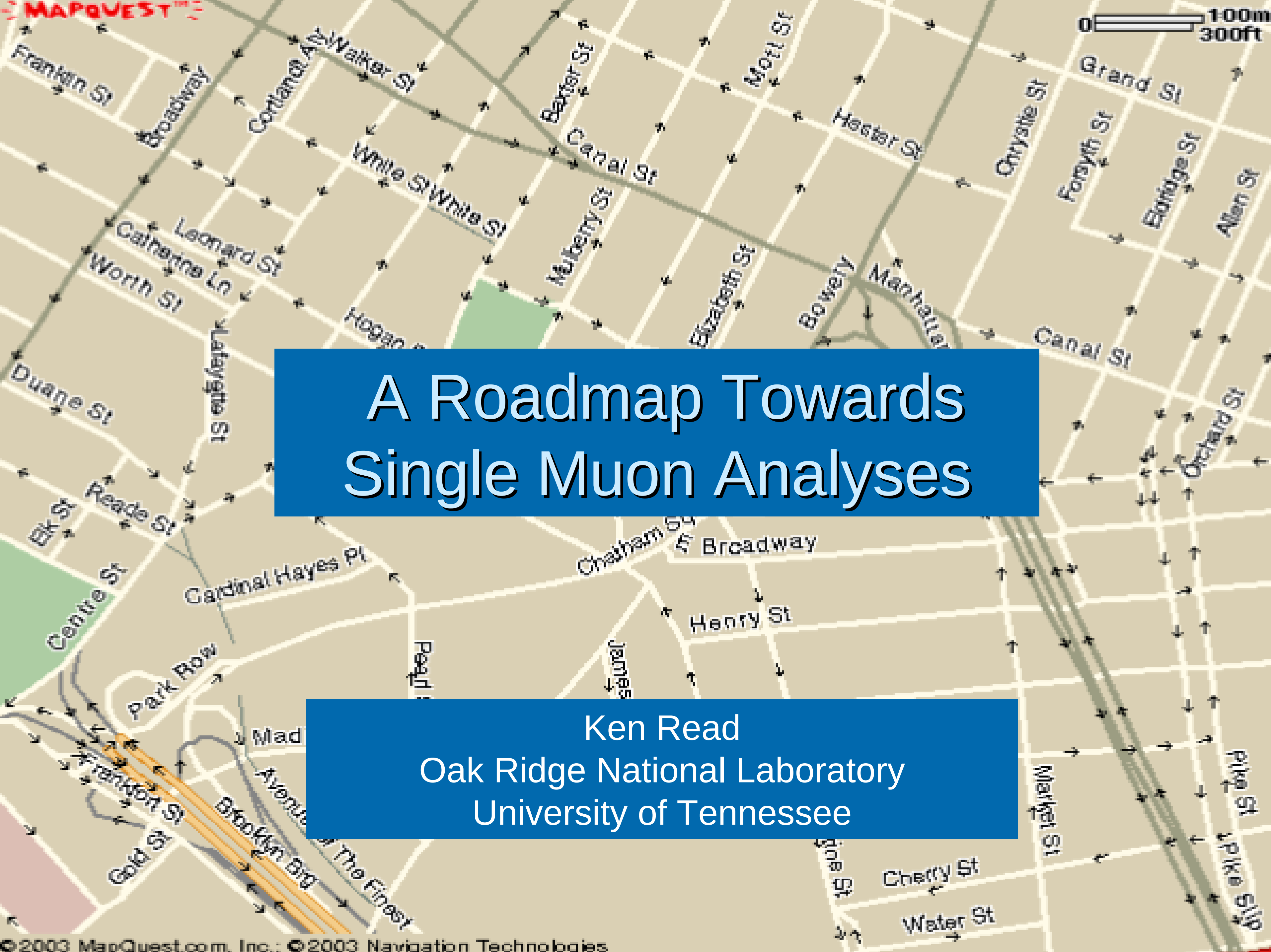


Outline

- Analysis Efforts
- Simulation Tools
- Schedule/Milestones
- New Computing Resources

Overview of Single Muon Analyses

- Signal for open heavy flavor: $c \to \mu$ and $b \to \mu$
- Critical baseline for studying J/Ψ suppression.
- Work done in support of pioneering extracting single muons from unpolarized collisions will be very useful development for the spin program.
- Data sets: Run 2 Au+Au and p+p, Run 3 p+p, d+Au, and Au+Au, Run 4 Au+Au and p+p
- Pursuing analyses to study Open Charm production by measuring the single muon spectrum.
- See previous talk by Ming and PHENIX single electron analyses, for instance.

Single Muon Analysis Efforts Underway

- Run 2 Au+Au (upcoming thesis by Andy Glenn)
- Run 2 p+p (Youngil Kwon, presented later today by KFR).
- Run 3 d+Au data (Youngil and MinKyung)
- Run 4 Au+Au data
  - Youngil and Donald Hornback with some technical help from David Silvermyr have processed small portion of min bias data in order to develop and benchmark selection criteria and test nDST contents. Looking forward to PHENIX min bias production pass.

Roadmap

- Finish revised, clarified Run 2 p+p analysis note asap
  - Finish pioneering this very challenging effort and pave the way for analyses using the other data sets
  - If all goes well, form PPG
- Subsequent analyses will benefit from
  - Having a complete, but simpler, Run 2 analysis in hand
  - More refined exploration of punch-through background
    - Analyze Run 4 pp data with revised definition of Shallow Trigger to study punchthroughs
  - Greatly increased simulation statistics. New Staged Sampling Cloning MC.

Traditional Number of Events Needed

- (10^3 to overcome π/μ rejection factor)(10^3 events/bin)(10 bins in z)(10 bins in η)(5 bins in p_T)(6 bins for particle ID: $\pi^\pm$, $K^\pm$, $p^\pm$)(2 hadronic interaction packages)(2 different MuID square hole shields) = 1.2×10^{10} events
- (10^{10} events)/(10^5 single particle events / 2 CPU-days) = 2×10^5 CPU-days for this analysis
- 2000 days on a farm where we manage to monopolize 100 CPUs 24 hours/day!
- Then, consider subsequent years and other analyses that could benefit.
- Bottom line: If this works, there is a big potential on-going market for it!

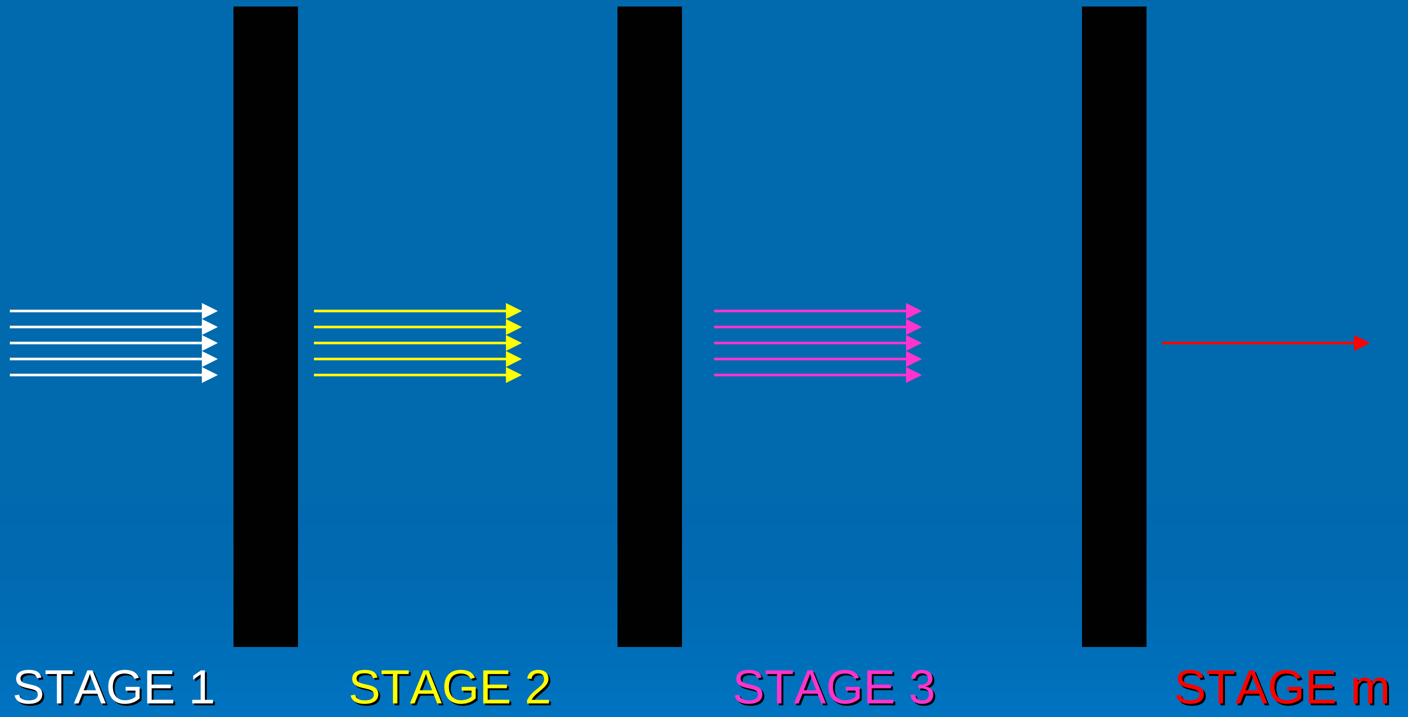
Single Muon Simulations

- Even though we measure the free-decay spectra, we need simulations to know the efficiency and extend it to higher $p_{T.}$
- Even though we can use data to study punchthroughs in intermediate gaps of the MuID, we need simulations to correct for detector inefficiencies and be able to simulate through to the last gap. (Will further benefit from the Run 4 p+p shallow triggered data.)
- The simulation is sensitive to the hadronic interaction model used: FLUKA, GHEISHA, …. (Exponentially sensitive to the difference in such packages.) Will use data to check the predictions for intermediate gaps ("data driven approach").
- Since only ~ 1 out of 10^3 hadrons from the vertex results in a muon passing through the MuID (that's good!), using a full simulation requires millions of events to be simulated and reconstructed in order to obtain sufficient statistics for each bin in particle ID, z, η, and p_T (that's bad!).

Single Muon Simulations

- Weight the z distribution according to the minimum bias z-vertex distribution.
- Weight the momentum spectrum and impose the K/π ratio using measurements from the PHENIX central arms.
- To get the parent hadron momentum spectrum, we can use spectra measured in the PHENIX central arms adjusted for the difference in rapidities.
- This approach should be acceptable for the purposes of this simulation, with the assignment of an appropriate systematic error.
- Both PYTHIA and results from BRAHMS Au+Au data support this approach.

Successive Sampling/Cloning Simulation PowerPoint Animation



Successive Sampling/Cloning Simulations

- SSC simulations
- Divide the simulation in to a series of successive stages.
- Stage 1
  - Using a traditional simulation (single particle generator, PISA, GEANT) sample the identities and momenta of particles coming out of the first significant amount of absorber (nosecone). Stop there to save on CPU and just save identities, hits, and momenta for any particles with enough momentum to get to the MuID.

Successive Sampling/Cloning Simulations

- Stage 2
  - For each of those particles "sampled" in Stage 1, make n clones which are (traditionally) simulated through to the back of the next major piece of material.
  - "n" may be about 10 and is chosen by making a compromise between the need for accuracy (avoiding non-statistical fluctuations and artifacts) and the limits on available CPU resources.

Successive Sampling/Cloning Simulations

- Stage m
  - Continue as indicated above
  - Obtain a huge number of weighted events in far less CPU time
- This one approach/project works for both the free decay simuations, the decay in material simulations, and the punchthrough simulations. I.e., just “one” simulation project to pursue.

More on Technique

- Note: Use a different random number seed to re-launch each of the n clones at every stage.
- If only ~1 in 10 hadrons punches through layer i on average, set n_i to 1 / (1/10) = 10 for stage i. This avoids producing uninteresting events without introducing significant artifacts.
- Need to produce and reconstruct less final full events than a traditional simulation by a factor of $n_1 \, n_2 \, n_3 \ldots n_{m-1}$.
- Or more simply, if we ultimately typically only make "interesting events" (having a punchthrough survivor at the back of the MuID), the new method needs less resources than a traditional simulation by 1/(π/μ rejection ratio) = 1/(2.5×10^{-4}) = 4000. (Actually, not quite this good since now every event is full.)
- A 2×10^5 CPU-day project becomes a feasible 50 CPU-day project with no serious introduction of artifacts. (I.e., after stage m, in general, every final event is completely different without even partial duplication of hit ancestry).

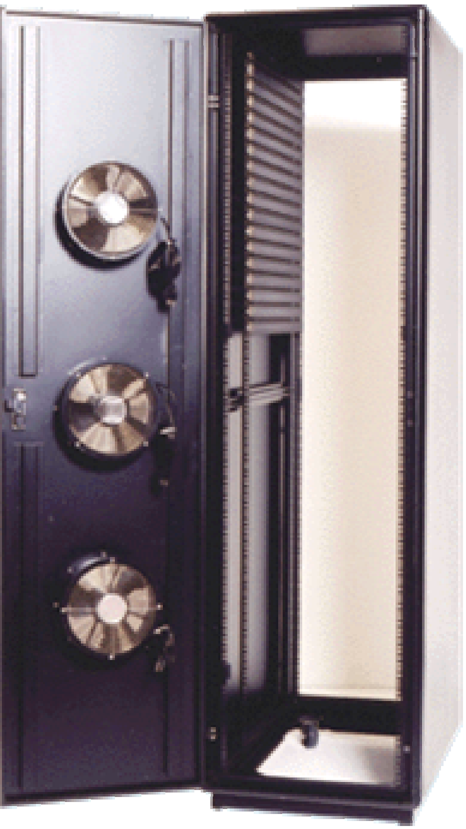
SSC Technicalities

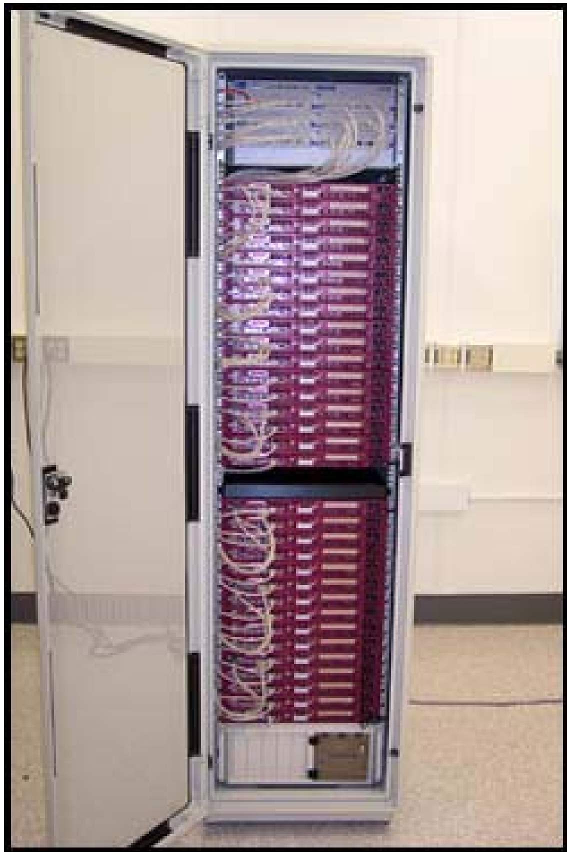
- All of this is working and tested!
- Need to implement “ancestry propogation” so that will have complete final events with full MC ancestry info.
- Can run the simulation either on the new ORNL farm or the increased Vanderbilt VAMPIRE farm.

Schedule

- July
  - Revised Run 2 p+p single muon analysis note completed
  - Finish SSC ancestry propogation
  - Run 4 min bias production underway
- August
  - Run 2 PPG working on draft publication
  - MC production underway
- September: Youngil moves to US to join our team at UT.
- October: DNP

13 dual CPU Xeon compute nodes in a 40U rack



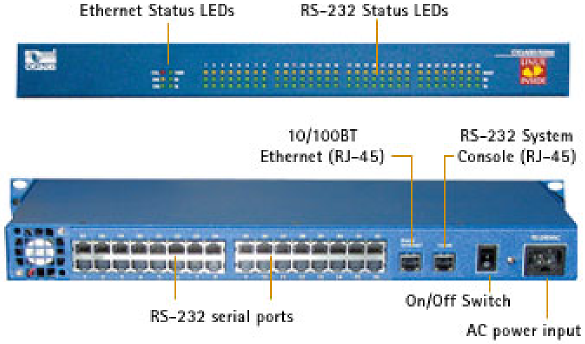


Design and rack space allows straightforward expansion to 25 nodes

24 port gigabit ethernet managed switch

12 Terabytes of hot-swappable RAID5 storage in 3 chassis.

HERANS LINUX FARM



Console server and monitor

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