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Physics Processes Missing from our Current Simulation Tools

This is the current list –
Please help us to complete it.

Tom Roberts

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Classes of Processes

- Single-particle processes
- Collective effects in vacuum
- Collective effects in matter
- Polarized muon processes
- Normalization
- RF breakdown
- Neutrino processes
- Details

Some of these are implemented in other tools; we need to consider adding to our toolbox and/or enhancing the tools we use.

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Single-Particle Processes

- Accurate multiple-scattering model
  - Several are available in ICOOL
  - Coming to G4beamline
- Energy-loss straggling model (incl. length dependence)
  - Vavilov model vs. Striganov model
- Material dependence of energy loss and straggling
  - ICOOL and G4beamline seem to disagree for LiH
- Correlation of energy loss with multiple scattering angle
- Effect of magnetic field on multiple scattering
- Radiative energy loss in matter for high-energy muons (> ~200GeV)
  - May not be needed if no material is in the beam (vacuum windows, instrumentation, residual gas, …)

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Collective Effects in Vacuum

- Space charge
  - Basic computation in ICOOL
  - Coming soon to G4beamline
- Wake fields
- Beam loading
- Beam-beam interactions
- Electron cloud effects
- Decay of macro-particles
- Interactions of macro-particles

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Collective Effects in Matter

- Space charge screening by material
- Bunch effect on the density term of the single-particle formula for energy loss (plasma density)
- Bunch-induced polarization of material causing intensity-dependent increase in energy loss
  - Can induce an instability
- Effect of matter on wake fields
- For all of the above:
  - Consider dependency on material properties
  - Consider time dependence
    - Head vs. tail of a single bunch
    - Effects involving successive bunches in a train

Polarized Muon Processes

- Effect of ionization cooling on polarization.
  - For applications other than a muon collider or neutrino factory
  - Might it be interesting in a collider to trade a factor of ~100 reduction in luminosity for partially polarized beams?

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Normalization

- Uncertainties remain about the accuracy of the pion production models used.
- Cavitation and other distortions of the mercury jet production target

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RF Breakdown

- While not directly part of the particle simulations, modeling RF breakdown is an important aspect of the overall simulation of a muon collider.
  - Vacuum
  - High-pressure H_2
  - Surface effects and processing
- This is so important that experiments are required.
  - Will affect technology used, so must be done early

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Neutrino Processes

- Surface radiation assessment will require accurate simulations of neutrino interactions
  - Need to significantly increase neutrino interaction cross-sections to make simulations feasible

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Details

- 3-D effects in RF cavity field models
  - Realistic, non-pillbox cavities
  - Couplers
  - HOM absorbers
- Engineering assessments
  - Thermal loads from the beam
  - Thermal loads from muon decay
  - Radiation levels
  - Surely others…
- Ability to model a large and complex detector for background studies
- Surely more…

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Summary

- There are a number of complicated and subtle physics processes not included in our current simulation tools.
- We must expand the list to be as complete as possible.
- There are of course engineering details that won't be needed until accurate simulations of a specific design are needed.
- We ultimately need a set of publications or MuCool notes, estimating the importance of each one.
- We need to implement those that can significantly affect our modeling of facilities.
- There are many other simulation tools available, and we need to assess whether to acquire and use additional tools, or to enhance the ones we already use.