Physics Performance

EM Physics: Observations

- Two apparently independent EM physics models have led to user confusion:
  - Different results for identical geometry
- New heavy ion stopping models not fully available.
- Documentation hard to find for:
  - Validation papers for various models.
  - Comparisons to data.
  - Trade off between accuracy and speed for various range cuts and models.

EM Physics: Recommendations

- Provide guidance on selection between the two models for specific species, energies, etc.
- Integrate models into a single package for EM physics, similar to the situation with hadronics; thus allowing the possibility of using one model in one energy range and the other in another energy range.
- Encourage the rapid integration of ICRU 73 heavy ion stopping
- Setup a validation webpage for EM physics
  - Provide detail references for validation papers for various models
  - Comparisons to data etc…
- Provide guidance about trade off between accuracy and speed for various range cuts.

Hadronics

- The FLUKA hadronic physics package has been identified by many users as a mature and carefully benchmarked code, best suited for their specific applications.
  - Some HEP experiments that would like to use GEANT4 have not done so because of the absence of FLUKA physics in GEANT4.
- On the other hand, FLUKA is more difficult to use than GEANT4 for detailed full detector simulation due to
  - the missing standard user interface for hit generation
  - the combinatorial geometry which make coding of complex geometries difficult.

Geant4 / FLUKA relation

- A possible solution to the previous problems is the FLUKA Virtual Monte Carlo (VMC) implementation developed by the ALICE collaboration.
- However, many existing HEP experiments have already Geant4 based simulation frameworks.
- It is impossible to combine the FLUKA physics model with GEANT4 physics models.
- **As in the previous two Geant4 reviews the committee notes that there is a strong request to use the FLUKA hadronic model with Geant4.**

Geant4/FLUKA

- The Committee recommends to talk to the FLUKA collaboration to find a cooperative way to provide the user with the best features of GEANT4 and FLUKA.
  - For example, implement a loosely coupled interface between Geant4 and FLUKA hadronic physics.

G4 Hadronic Physics

- Since the last review a serious effort has been undertaken by the Geant4 collaboration and the LCG Physics Validation group to test and validate the Geant4 hadronic transport models.
  - Thin and thick target validation
  - Ongoing full set-up simulations
  - Comparison to calorimeter test beam data (ATLAS, CMS)

G4 Hadronic Physics

- In particular the comparison to test beam data has pointed to important shortcomings of the G4 hadronic models in the low and intermediate momentum region (0.1 – 5 GeV)
  - Wrong description of the longitudinal shower shapes
    - “starts too early stops too early”
  - Wrong description of the radial shower shapes
    - too narrow

G4 Hadronic Physics

- Although possible solutions have been sketched during the review the committee is concerned not to see a detailed planning (milestones, manpower) for an improvement of the hadronic package.
- The committee recommends to put in place a set of simple hadronic benchmarks which allow to identify such very basic problems like disagreement with well-known shower shapes.

Other Hadronics Issues

- The space community has a strong need to have accurate prediction of triple differential cross sections (energy, mass, and angle) for recoiling particles from all interactions, including heavy mass ion-ion reactions.
- We recommend that the Geant4 developers accelerate the physics model development to address this need.

Computing Performance

Observations

- CPU optimization is critical for LHC experiments and other heavy users such as medical and space applications.
- Saving CPU time is saving real money (and effort).
- Multi-prong approach is needed.
  - Optimization of GEANT4 toolkit. Computing professionals have made an impact in some areas.
  - Trade-off between CPU time and simulation detail. This is a user choice. However, help from GEANT4 is crucial in choosing physics models, parameter values, optimizing geometry, etc.
  - Variance reduction techniques (VRT). It can greatly enhance the impact of CPU power. A number of VRT are available in GEANT4.

Recommendations (1)

- Systematically track code performance, separately for each part of the code, and model by model.
- Perform systematic checks on
  - Architecture, compiler/options
  - Memory usages
  - Multi core CPUs/advanced instructions
- Encourage users to do the same and provide feedback.
- Extend the work of computing professionals to review and optimize other parts of the code.

Recommendations (2)

- Provide a plan regarding the expected performance in the next few years.
- Create a document on performance optimization guides. This information probably already exists and just needs to be collected. Educate users on the most efficient way to use GEANT4 for his application.
- Provide a simple mechanism for users to turn off “irrelevant” processes for a given region. This can potentially save significant CPU time with little or no impact on physics.

Documentation, Validation and Usability

Documentation: Observations (1)

- GEANT4 has provided among others
  - Application Developers Guide.
  - Installation Guide.
  - Getting Started.
  - Users Guide for Toolkit Developers.
  - LXR reference guide.
  - FAQ.
  - Tutorial.
- Effort underway to move into DocBook format, and to use MathXML for the physics manual.

Documentation: Observations (2)

- Application Developers Guide can be “user unfriendly”.
- Not all documentation is up to date. A number of web links are broken.
- No clear recommendation about the validity ranges for the many physics models (e.g. the two EM models) and the different Physics Lists.
- Limited number of references to validation and benchmarking papers are available on the GEANT4 web.
- Limited information about the connection between the physics models and how they are implemented.

Documentation: Recommendations (1)

- Provide clear recommendations when the different packages and Physics Lists should be used and their validity ranges.
- Document the limitations, and validity and applicability ranges of the different hadronic and EM models.
- When models have overlapping validity ranges, as in the case of the two EM models, document the tradeoffs.
- Update the documentation on the web. Periodically review the web site to keep it up to date.

Documentation: Recommendations (2)

- Accomplish the migration to DocBook and MathXML.
- Improve code documentation. For example, replace current software reference manual with:
  - DOXYGEN.
  - Improved documentation in README which can be browsed in LXR.
  - Other solutions.
- Describe the connection between physics models and how they are implemented.
- Provide greater details in release notes.
- Reduce the number of documents by combining some documents, as planned.

Validation: Observations

- Many different Physics Lists with different physics models.
- Testing for a planned release lasts 3 weeks with validation tests and Q/A checks.
- Regular new releases: one major and a minor per year.
  - Beta tested.
- Different computer platforms and compilers are supported.
- Started a database of experimental data for physics validation.
- Limited systematic comparisons with available experimental data.
- Limited systematic comparisons with other MC transport codes.
- No blind tests.

Validation: Recommendations

- Create a common validation procedure, possibly automated, to be run at every release.
- Define a procedure that quantifies the validation results, and make them easily available to users.
- For example,
  - Timing checks with the most relevant results incorporated into release notes.
  - Benchmarking against other MC transport codes.
  - “Recruit” additional beta testers from different user communities.
  - Provide repository for experimental data and validation results provided by others.
  - Insure information transfer with other code developers and experimentalists.
  - Provide references of validation and benchmarking on the web.

Usability: Observations

- GEANT4 provides many tutorials and workshops. This is very much appreciated by the user community.
- Insufficient exchange among users, and particularly from different user groups.
- Response to user questions occasionally have significant delays.

Usability: Recommendations

- Provide better support to implement user driven physics models.
- Consider a user community supported Wiki as a collaborative tool where users can contribute.
- Simplify the installation procedure particularly for novice users, e.g.
  - Standard installation with default values.
  - A template spec file for RPM installation.
  - Better documentation.

Other Issues

Manpower

- Manpower stretched very thin.
  - Core S/W.
  - Physics models.
  - Infrastructure, validation, user manual, etc.
- Some can be recruited from user community, e.g. physics models.
- Others necessarily dedicated GEANT4.
- Provide a plan for manpower need over the next few years.
- Encourage GEANT4 to seek additional funding and support for such personnel as needed.