



# Geant4 Physics for Fermilab Scientific Program

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# Geant4 and Intensity Frontier Experiments



- There is a need to increase the emphasis in Geant4 on the physics relevant to Fermilab Intensity Frontier (IF) experiments.
  - It is important to:
    - monitor and improve Geant4 simulation of relevant physics processes
    - monitor and influence the evolution and development Geant4 Physics Lists\*
    - improve the existing Physics Lists documentation
- \* Geant4 Physics List is a named collection of particles, cross-sections and models (including their parameters) used to simulate physics processes



- Continuation of current periodic validation efforts (internal Geant4 tests)
  - intermediate and high energy hadronic interactions ( $\sim 1-150\text{GeV}$ ) (hadron nuclear interactions)
  - stopping/capture processes
  - gamma nuclear interactions ( $\sim 0.5\text{GeV}$ )
- Continuation of the support and evolution of the Geant4 Validation Repository
- Creation of a local Geant4 Physics List documentation
  - lists description, application and hints on modifications
- Creation of an infrastructure to monitor, enhance and develop Geant4 Physics Lists



- Enhancement of our current Geant4 validation efforts
  - Extension of internal Geant4 tests in which we are currently involved (and therefore we can modify the code)
    - covering more processes important to the Intensity Frontier Experiments
    - including monitoring of relevant observables at the Geant4 Physics List level (as opposed to a process/model level)
  - Creation of a local art based Geant4 validation and test package (giving us more physics coverage freedom)
    - covering all processes and kinematic regions important to the Intensity Frontier Experiments not only at the process/model but also at Physics List level
    - facilitating customization and creation of new Physics Lists



- The Geant4 external validation package is going to be based on the locally developed/supported art framework further leveraging our department's expertise
  - it could be used as a template for new groups starting to use Geant4
- Locally developed tests and documentation would be fed back to the Geant4 Collaboration

# Milestones (next few months)



- Documentation Improvements
  - Migration of the current local Geant4 web pages to a new SharePoint based website
  - Creation of documentation of relevant Geant4 Physics Lists and their aspects using the above website
  - Creation of a list of relevant physics processes and observables (and its prioritization)
  - Documentation of the data needed for the validation
    - as to, if it is preset (i.e. in use), available or not known to exist
- Enhancement of the internal Geant4 tests
  - restructuring/refactoring of the current tests
  - addition of a Physics Level test
- Creation of the *local art* based Geant4 validation package
  - the first step would be to implement a Physics List level test of selected observables



- Internal Geant4 validation tests
  - a set of tests exists and is in use; for historical reasons, the tests predominantly used to cover observables and energy ranges of interest to LHC experiments
    - hadronic processes, intermediate energies
      - $\sim 1\text{GeV} - \sim 30\text{GeV}$  hadrons (mainly protons, pions) on C, U and other targets
    - hadronic processes, high energies
      - $\geq \sim 30\text{GeV} - \sim 150\text{GeV}$  hadrons (mainly protons, pions) on C and other targets
    - gamma-nuclear interactions
      - $\sim 0.5\text{GeV}$  gammas on Cu, Pb
    - stopping/capture processes
  - they are standalone packages being run periodically (at CERN and locally) as a part of Geant4 Collaboration Hadronic Physics Group validation process
    - the results from the local tests are uploaded to the Validation Repository
  - the tests are being refactored and a test covering observables at the Physics List level is being added
  - new observables are being added with the focus on the Fermilab Experiments (e.g. muon stopping tests and more high energy hadronic distributions were added since last summer)



- Internal Geant4 validation tests
    - an example of test results uploaded to the Validation Repository
- <http://g4validation.fnal.gov:8080/G4ValidationWebApp/G4ValHAD.jsp>  
 test19  
 (Hadronic Processes, High Energy),  
 protons on Carbon,  
 158GeV/c

The screenshot shows the Geant4 Validation WebApp interface. At the top, there is a navigation bar with links for Home, Validation Overview, Release Highlights, Electromagnetic, Hadronic, LHC-feedback, and Expert. Below this is a search bar and a list of hadronic tests. The main content area displays the details for test19, including its name, responsible person (J. Yurba), description, Geant4 version, observable, reaction, and status. A table of test conditions is also shown, detailing the target (Carbon), energy (158 GeV/c), and particle (proton). Finally, a results section contains five plots comparing simulation models (ftfp, qgsp) with experimental data (exp.data) for various hadronic processes.

Name of the Test:	test19
Responsible:	J. Yurba (Fermilab)
Description:	high energy test, provides comparison with NA61 (31 GeV/c proton beam) and NA49 (158 GeV/c proton beam) data sets.

Geant4 Version:	geant4-9.6-p01
Observable:	average density of p, pbar, n, pi+, or pi- as a function of xF
Reaction:	p on C
Status:	public

Test Conditions	
Name	Description
last-modified	2013-02-21 16:13:55 CST
Target	Carbon
Energy	158 GeV/c
Particle	proton
Comment	Both FTF and QGS models are backed with PreCompound model
Model	FTF(P), QGS(P)
Reference	N.Abgrall et al., Phys.Rev. C84, 034604 (2011)
Reference	<a href="#">see further details</a>
Score:	passed
Type:	expert

**Results**

proton + C -> X + proton      proton + C -> X + antiproton      proton + C -> X + neutron

proton + C -> X + pi+      proton + C -> X + pi-

Each plot shows the average density of particles as a function of xF. The legend for all plots is: ftfp (red line), qgsp (blue line), and exp.data (black triangles).





- Interacting with the Experiments
  - Held a meeting (early March) with neutrino experiments to seek their input and establish communication channels
  - Participated in follow-up meetings
- Working on documentation
  - new local website was setup by SharePoint support group last week
  - the local Geant4 web pages are being migrated to it
- Working on improving and adding more flexibility to Geant4 muon stopping code  
(with Kevin Lynch (CUNY/Mu2e) and people from Geant4 Hadronic Group)
  - Initial restructuring was done by the original author last summer
  - We have subsequently added additional configurability to the code
  - We have submitted a correction pertaining to the bound muon capture and decay rate code (relevant to Mu2e) last month
    - it was included in the official Geant4 patch release (9.6.p02) last week
- External Geant4 validation package
  - at the design/prototyping stage



- Based on the validation tasks and feedback from the Fermilab community (and in response to the Geant4 developments)
  - continue ongoing testing of Geant4 releases documenting results in the Validation Repository
  - maintain and enhance the infrastructure and documentation
    - add more monitored observables and processes
    - collect data needed for validation
      - possibly suggest new test beam experiments
    - update Physics List documentation and their tests as the lists evolve
    - maintain and enhance the Validation Repository as needed
  - make or request Geant4 physics enhancements depending on which group is responsible for a given area of the code