Simulation Project Overview

Based on the project plan submitted to and approved by the SC2 March 14, 2003

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for the Simulation Project leadership team

Applications Area Meeting

March 19, 2003

Development of the Simulation Project Plan

- Current simulation project leadership team (project leader and subproject leaders):
  - John Apostolakis (Geant4 Subproject)
  - Andrea Dell'Acqua (Generic Simulation Framework Subproject)
  - Alfredo Ferrari (FLUKA Integration Subproject)
  - Fabiola Gianotti (Physics Validation Subproject)
  - Torre Wenaus (Simulation Project)
- Simulation subproject plans developed by this team in consultation with one another, the experiments, Geant4, FLUKA
- Milestones are on the aggressive and optimistic side! May be revised after further discussions with experiments and evaluations of needs and available manpower
- Plan approved by the SC2 in their meeting last Friday

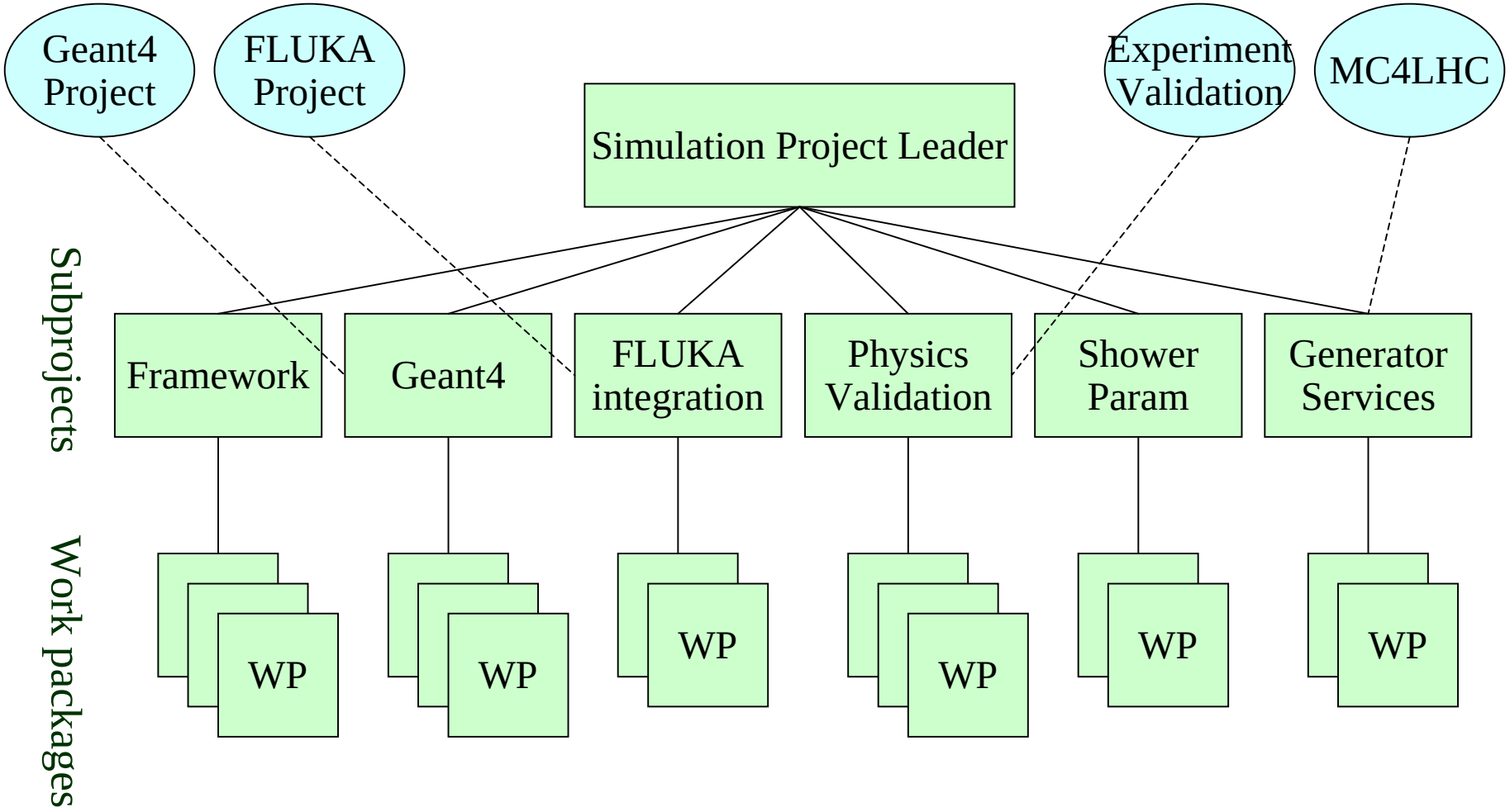
Outline

- Overall organization
- Subprojects
  - Description
  - Work packages
  - Priorities
  - Milestones
- Personnel – addressed primarily in spreadsheet
- High level project milestones
- Summary

Simulation Project

- Mandated by SC2 in Dec to initiate simulation project, following the RTAG recommendations
- Discussions and planning since then have led to the project plan discussed here, guided by the RTAG
- Organized as a single, large but cohesive, broadly scoped project with several subprojects
  - Relatively thin overall project leader job
    - Overall vision, coherence, organization, planning, communication
    - Interim: Torre Wenaus
  - Strong subproject leaders
    - Direct technical leadership of activities
  - Subprojects divided into work packages
  - Lots of contact and collaboration across subprojects
    - Close relationships, low walls to promote collaboration
- Highly dependent on strong experiment participation

Project Organization



Simulation Subprojects

- Generic simulation framework
  - Subproject leader: Andrea Dell'Acqua
- Geant4
  - Subproject leader: John Apostolakis
- FLUKA integration
  - Subproject leader: Alfredo Ferrari
- Physics validation
  - Subproject leader: Fabiola Gianotti
- Shower parameterisation
  - Lead participants under discussion
- Generator services
  - Subproject leader: Awaiting MC4LHC input

Generic Simulation Framework Subproject

Andrea Dell'Acqua

- Principal goal, of interest to all experiments: run different simulation engines from the same generic infrastructure
  - Support Geant and FLUKA
  - Access information in a standardized way that does not depend on the engine in use
- Gather precise requirements and use cases
- Design interfaces and provide implementations for the needed engines
  - Re-use of existing implementations is a must
  - ALICE Virtual Monte Carlo as a starting point to build on if it meets requirements
- Simulation framework must be integrated in the LCG software infrastructure and architecturally consistent with the blueprint
- Modification and/or adaptation of Geant4 believed necessary to use it from within experiment software frameworks
  - Collaboration between this subproject and Geant4 subproject
- Also involves framework functionality such as scripting, visualization, MC truth management

Framework WP1: General infrastructure

- Framework requirements gathering
- Generic interfaces and specific implementations
- Steering (may be one and the same with scripting)
- High level services: material service, DB interface, …
- Scripting and interactivity (using SEAL)
- Graphics (coordination with PI)

- Participants:
  - The RTAG10 team (experiment simulation leaders) and probably a few others including some participation of LCG-supported people
  - Collaboration with SEAL, PI, POOL

Framework WP2: MC truth and generator intfc

- Generic interface to generators
- Particle stacks
- Event manipulation
- Particle level and vertex level filtering
- Storing decay particles and vertices

- Participants:
  - Some of the RTAG10 team
  - Joint work with Generator Services Subproject

Framework WP3: Geometry & detector infrastructure

- Evaluate ROOT geometry – functionality and navigation capability
- Subdetector support and interactive geometry construction
- Sensitive detectors, field management, cut management, etc.
- Evaluate existing solutions for detector description
  - Develop a proposal for work in this area, drawing on the detector description RTAG report, to submit to the SC2 for approval
  - Implement/interface automatic builders from XML descriptions
  - Transient description – GeoModel or other
- Participants:
  - Participation of detector description and other experiment people will be needed
  - Probably some participation from LCG-supported people, possibly RTAG10 team

Framework WP4: Infrastructure for physics configuration

- Expand on existing functionality in order to
  - improve on existing G4 situation
  - support other engines (FLUKA)
- Participants:
  - G4, FLUKA people involved in physics configuration
- Strong connection to the Physics Validation Subproject
  - Requirements and specific configurations from them

Simulation Framework Priorities

- Short term:
  - MC truth and interface to generators (WP2)
    - Solution that applies to Geant4 as-is must be found ASAP
  - Gather requirements for framework (WP1)
  - Generic framework interfaces (WP1)
- Middle term:
  - G4 implementation (WP1)
  - FLUKA implementation (WP1/FLUKA subproject)
- Longer term:
  - Geometry and detector infrastructure (WP3)

Simulation Framework Personnel Profile

- Manpower estimates based on leveraging relevant effort in validation, G4, FLUKA, generator services subproject (else would be higher)
- Phase 1 – Requirements and high level design (now to ~June)
  - 1.5 expert FTEs. Covered by RTAG10 team.
- Phase 2 – Basic design and implementation (from June)
  - Content of this can vary widely, depending on phase 1 outcome
  - Worst case: 3-4 FTEs
    - ~1-2 FTEs more than we can now identify
  - Best case: 1.5-2 FTEs
    - Covered by RTAG10 team with small amount of help
- Phase 3 – Geometry (from summer? Concurrent with Phase 2, so different manpower)
  - Possibly a big item. Scope and manpower has to be assessed. Would need to be a pooling of existing experiment effort.

Simulation Framework Milestones

- 2003/4/30: Complete generic framework requirements survey
- 2003/5/31: Decide generic framework high level design, implementation approach, software to be reused
- 2003/6/30: Generic framework components and interfaces defined
- 2003/7/31: Detector description proposal to SC2
- 2003/11/30: Generic simulation framework prototype available with G4 and FLUKA engines
  - Proof of principle FLUKA implementation
    - Not tied to making source code public, which will come later
  - Assuming we use FLUGG; else FLUKA timescale is longer
- 2004/9: First generic simulation framework production release

Geant4 Subproject

John Apostolakis

- Geant4 participation of CERN, LCG, LHC experiments
- Geant4 development, validation, integration, support, maintenance
- Active personnel: 10-11 FTEs
- Activities will also support other (sub)projects – physics validation, generic simulation framework, shower parameterisation, SPI
- Work packages:
  - WP1 – Geometry, field and transportation
  - WP2 – System testing, software management and releases
  - WP3 – EM physics and error propagation
  - WP4 – Hadronic physics
  - WP5 – Coordination

Geant4 WP1: Geometry, field and transportation

- Maintenance and support of geometry & field components
- Refinement, maintenance, support of new cut region functionality
  - Test beam and full detector support; robustness
- Field integration algorithm performance and refinement
- Abstract navigator and transportation design and prototyping
- User requirements for geometry and traceability matrix
- Additional biasing tools and completion of the first biasing verification benchmark
- Coordination of additional geometry/transportation milestones

Geant4 WP2: System testing, sw mgmt, releases

- General user/developer support for software management
- Testing for scheduled releases, patches, monthly development tags
- Release management
- Local release installations, installation scripts, web distribution
- Platform and compiler support
- Improvements to 'production' systems
  - Refined automation, presentation of testing results
  - Bonsai and Bugzilla improvements: assignment of responsibilities, security assessment
  - Documentation and improvement of build, test scripts
- On all these points: *synchronize with SPI wherever possible*
- Migration to standard C++: vectors, namespaces
  - Changes to 'global' category and assistance to others

Geant4 WP3: EM Physics and Error Propagation

- EM physics
  - Further development of EM 'cuts per region'-enabled processes
    - Refinement and support of first release
    - Creation of subsystem tests
  - Refinements of EM design and implementation for specialization of multiple scattering
  - Specialized processes for gaseous and TR detectors
  - Creation of initial 'statistical' tests for test beam validation
- Error propagation
  - Development and verification of 'Geant4e'
  - Requirements collection and analysis for additional capabilities
- Support for validation and use of G4 EM physics
  - Handling problem reports, anomalous results, inquiries regarding EM physics processes: undertaking part of these support activities
  - Collaboration with the Physics Validation Subproject

Geant4 WP4: Hadronic Physics

- Aligned with LHC needs, guided by requirements (c.f. Validation WP1, WP5)
- Development, maintenance and verification
  - π and K induced reactions in binary cascade model
  - Extended hadronic verification, including for models in cascade region
  - Revision of physics lists for LHC, HEP use cases
  - Revision of pion cross sections
  - Additional items
- Support for Validation and use of G4 hadronic physics
  - Handling problem reports, anomalous results, inquiries regarding hadronic physics processes, particularly from LHC experiments
  - Collaboration with the Physics Validation Subproject

Geant4 WP5 – Coordination

- **Coordination internal to LCG**
  - With LHC experiments regarding requirements, schedules, results
  - With other apps area, simu (sub)projects
    - Validation: Strong ties with experiment validation; maintain and enhance with the Validation subproject
    - Framework: Geant4 integration. Will need detailed requirements to carry needs to outside Geant4 experts
    - SEAL: CLHEP is in use. Potentially others, eg interactivity
    - SPI: Potential use(s) under discussion.
    - PI: Use of AIDA; visualisation, other TBD.
- Coordination with external Geant4 contributors
  - Coordination with the Geant4 collaboration
  - Representation and current chairing of TSB
  - Communication in the creation of the G4 collaboration workplan.

Geant4 Subproject – Other Issues

- Performance evaluation
  - Performance of ‘full’ Geant4 programs, particularly LHC experiment simulation
- Modularity
  - Assistance in defining requirements and milestones
  - Coordination / follow-up
- Benchmarks
  - Collaboration with benchmarking activity in validation subproject
- Additional manpower needs
  - Benchmarking and performance evaluation: .25-0.5 FTE
  - EM physics (specialized processes): 1.0 FTE
  - BREPS development & testing and CAD interface: 1.0 FTE

Geant4 Subproject Priorities

1) Development and refinement of 'cuts per region' capabilities
   - EM region-enabled processes
2) Study of performance in full LHC-detector simulation for well-identified important use cases
3) Revised physics lists, including modeling options from Geant4 5.0 and taking into account the experience from validation
4) Refinement of testing, for improved presentation of results
5) Development of modeling, including π induced reaction in binary cascade

Geant4 Subproject Milestones

- Pre-production Geant4 development release that includes improved ‘cuts-per-region’ capabilities. March 2003
- Production-quality Geant4 version that includes the ‘cuts-per-region’ capability. Target date: to be agreed with G4, not later than June 2003
- …

- N.B. Timing and content of the upcoming releases are subject to TSB approval. The workplan (and thus upcoming releases) are agenda items in the March 18th Geant4 meeting

FLUKA Integration Subproject

Alfredo Ferrari

- Very positive that the head of FLUKA has accepted to lead this subproject
- CERN participation in FLUKA development proper not via the applications area and this subproject
  - CERN-INFN agreement on FLUKA established
- Subproject involves FLUKA integration with the generic framework
- Expect to take advantage of ALICE's FLUKA connections and experience
- Nature of the task depends on the approach taken to the generic framework
  - Impression so far is good alignment between existing FLUKA-ALICE effort (FLUKA user action interface, FLUGG interface to G4 geometry) and project needs; good potential for re-use
  - Expand ALICE-FLUKA discussions on interfaces etc. to other experiments via this project
- Manpower an issue

Physics Validation Subproject

Fabiola Gianotti

- The G4 validation program that originated in ATLAS and has since broadened, moves to this project
- Subproject scope broader than G4: simulation physics validation in general
- Largely coordination and communication with efforts taking place within the experiments; not a large effort directly in this LCG project
  - A team with active participants in each experiment
- Including also
  - Simulation testing and benchmarking tools
  - Validating the adequacy and usability of the simulation infrastructure and environment

Physics Validation Work Packages

- WP1 – Impact on LHC physics
- WP2 – Input from the LHC test beams
- WP3 – Geometry for physics validation
- WP4 – EM physics
- WP5 – Hadronic physics
  - WP5a – Calorimetry
  - WP5b – Tracking
  - WP5c – Background radiation
- WP6 – Special needs
- WP7 – Physics validation from outside LHC
- WP8 – Validation of the simulation environment
- WP9 – Editorial, organizational

Validation WP1: Impact on LHC Physics

- 1.1) Revisit and collect physics requirements for the simulation packages from the four LHC experiments
- 1.2) Evaluate/monitor the impact of a given uncertainty/inadequacy of the simulation on physics (e.g. e/pi ratio on compositeness) for the four experiments
- 1.3) Compare G4 and FLUKA (and G3 if geometry is available) for some benchmark physics processes outside the test beam reach
  - i.e. electrons, muons and jets in the TeV range, charged pion/neutron interactions in the GeV range

Validation WP2: Input from the LHC test beams

- 2.1) Collect information about which test beam data are available in the various experiments and which data are going to be collected next Summer
- 2.2) Understand which "special data" for the simulation validation should one collect in the framework of already planned test beam runs
- 2.3) Understand if the experiments can perform some dedicated tests for the validation of the simulation
  - e.g. the ATLAS pixel test beam to study hadronic interactions

Validation WP3: Geometry for physics validation

- All experiments should have simulations of
  - test beam setup for the various sub-detectors
  - complete detector in the LHC environment
  - simplified geometry, if available, may be useful for radiation background studies
- G4 geometrical description of the above layouts can be fed into FLUKA through the FLUGG interface
- G3 simulations of some of the above layouts would be useful, if available
  - Some experiments (e.g. ATLAS) have this
- Could also be used to evaluate technical performance (CPU, memory, etc.)
    - To be discussed with Framework subproject

Validation WP4: Electromagnetic physics

- 4.1) Compare electron and muon test beam data of the LHC experiments to G4/FLUKA/(G3). All relevant sub-detectors should be tested.
- 4.2) Interact and iterate with G4 and FLUKA physics experts until required precision is achieved (see WP1).
- 4.3) Return uncertainties and discrepancies to WP1
- 4.4) Understand special needs (--> input to WP6).
- 4.5) Understand strengths and weaknesses of G4 vs FLUKA.
- 4.6) Define one or more recommended physics lists and parameters (e.g. range cuts, etc.) for the LHC detector types, which optimise technical performance vs. physics performance
- 4.7) Compare G4/FLUKA for simple benchmark geometries and materials and single incident particles of various energies.

Validation WP5: Hadronic physics

- **Three areas: calorimetry (WP5a), tracking (WP5b), background radiation (WP5c)**
- Compare hadronic interaction test beam data collected with LHC detectors with G4/FLUKA/(G3)
- Interact and iterate with G4 and FLUKA physics experts until required precision is achieved (see WP1).
- Return uncertainties and discrepancies to WP1
- Understand special needs (--> input to WP6)
- Understand strengths and weaknesses of G4 vs FLUKA.
- Define one or more recommended physics lists and parameters (e.g. range cuts, etc.) for the LHC detector types, which optimise technical performance vs. physics performance
- Compare G4/FLUKA for simple benchmark geometries and materials and single incident particles of various energies.
- Background radiation: compare G4/FLUKA/(G3) for simulation of radiation background in caverns
  - Maybe use also MARS?

Validation WP6: Special Needs

- 6.1) Collect the list of physics processes which require a special treatment (e.g. transition radiation in the ATLAS TRT). Explore ways of dealing with these cases.
- 6.2) Collect list of functionalities needed for efficient physics validation
  - e.g. record of the energy lost in nuclear break-up, etc.
- 6.3) Collect list of special requirements for the simulation framework
  - special noise treatments, pile-up, etc.

Validation WP7: Validation from outside LHC

- 7.1) Review the status of the G4 and FLUKA physics validation from outside the LHC.
  - Including e.g. international benchmarks
- 7.2) Understand what are the most useful tests relevant to LHC physics.
- 7.3) Establish cooperation with the most relevant experiments (e.g. BaBar and Belle).

Validation WP8: Simulation Environment Validation

- Effectively utilizing the simulation and evaluating the physics demands a capable infrastructure
- Informed opinions and experiences accrued in this subproject should be fed back via this WP
- 8.1) Validate the adequacy and usability of the simulation infrastructure and environment
  - e.g. generic framework, geometry description, interactivity
- 8.2) Participate in the definition and validation of MCTruth
- 8.3) Validate the shower parameterisation packages

Validation WP9: Editorial, Organizational

- 9.1) Set up and maintain web page
- 9.2) Organise meetings, write minutes, collect relevant plots and information
- 9.3) Edit final document containing outcome of the above work
- 9.4) Prepare a set of benchmark plots to be included in a simulation testing and benchmark suite for "semi-automatic" validation of future G4/FLUKA releases.

Physics Validation Personnel

- WP1, WP8: At least one representative per experiment
- WP4, WP5: At least one representative per subdetector
- WP2, WP6: can be covered by one of the above people per experiment
- WP3: done by the experiments with support from other subprojects (framework, G4, FLUKA)
- Dedicated participation in the subproject itself:
  - 1-2 FTE for WP4 + WP5 (start with 1)
    - compare EM and HAD physics of G4/FLUKA with simple geometries, various materials, and single incident particles over broad energy range.
  - 1 FTE for WP8, possibly shared with Framework Subproject
  - ~1 FTE for WP7 + WP9
- **Total dedicated subproject needs: 3-4 FTEs**
- **Identified so far: ~2.5, from Geant4 team and LCG-supported people**

Physics Validation Interaction w/other Subprojects

- The success of the Physics validation subproject relies on
  - the active participation of the LHC experiments
  - the help of the G4 and FLUKA physics experts
- Common work with G4 and FLUKA subprojects is mandatory
  - particularly for WP4, WP5, WP6 (physics, special needs)
- The physics validation team will ask for modifications and improvements to the shower packages
  - require fast feedback and reaction from the teams of experts
- WP3 (geometry) requires interaction with the framework, G4 and FLUKA subprojects
- WP8 (environment) requires interaction and common work with the framework and shower parameterisation subprojects

Physics Validation Priorities

Chronological priorities:

1) WP3: geometry; WP2.1: test beam data to be taken this summer; WP1.1: LHC simulation physics requirements
2) WP4: EM physics; WP5a: Hadronic – calorimeter; WP5b: Hadronic – tracking; WP8: environment
3) WP6: special needs; WP1.2: impact of simu deficiencies; WP2.2: 'special data' needed from test beam runs; WP2.3: dedicated test beam tests for validation
4) WP5c: Hadronic – radiation background
5) WP1.3: benchmark physics processes outside test beam reach; WP7: validation outside LHC ; WP9: final report and test suite

Physics Validation Milestones

Primarily ATLAS-driven dates; may change after more consultation with experiments

- End April: Test beam setup of the four LHC experiments available in G4, and soon after in FLUKA
- August 2003: First cycle of EM physics validation complete
  - ATLAS ~ ok; need similar work in CMS, LHCb, ALICE
- End 2003: First cycle of hadronic physics validation complete
  - In view of large scale production (e.g. for CMS Physics TDR) by mid 2004
- 2004: Further iterations until end 2004
  - Include ATLAS combined test beam results
- End 2004: Final validation document complete

Shower Parameterisation Subproject

- Examine integration of GFLASH-like functionality into Geant4 and the simulation framework
  - Model lateral and longitudinal shower profiles and deposit E spots based on profile and sampling fluctuations
- Allow fast parameterisation in calorimetry to coexist with detailed simulation elsewhere

- Participation still under discussion. Ideas, volunteers still needed.
- Presently this is a placeholder for an as yet undefined subproject.

Generator Services Subproject

- Follow recommendations of MC generator RTAG:
  - Generator librarian; common event files, validation/test suite; sw support, and development if needed (HEPMC, HepPDT, …)
  - Oversight and direction from MC4LHC
- MC4LHC is working to identify a subproject leader
- Russian participation is anticipated, as an LCG contribution
  - Specifics remain to be worked out
- Participants will probably collaborate on generator/MCTruth aspects of the generic framework

Simulation Project Personnel

- A detailed but incomplete and rapidly evolving personnel spreadsheet exists
- Several LCG-funded personnel enthusiastically starting (or continuing) work in simulation
  - Consistent with plans; not creating gaping holes
- Experiment participation still to be fleshed out
- The large G4 team will contribute to the other (sub)projects as well
  - Particularly validation
  - Without damaging G4 program or personal expectations
- Manpower needed for FLUKA integration subproject
  - Problem shared by ALICE – seeking common remedy
- Shower parameterisation, generator services not fleshed out

Simulation Project High Level Milestones

- 2003/4/30: Complete generic framework requirements survey
- 2003/5/31: Decide generic framework high level design, implementation approach, software to be reused
- 2003/5/31: Generator librarian and alpha version of support infrastructure in place
- 2003/6/30: Simulation physics requirements revisited
- 2003/6/30: Generic framework components and interfaces defined
- 2003/7/31: Detector description proposal to SC2
- 2003/8/31: 1st cycle of EM physics validation complete
- 2003/11/30: Generic simulation framework prototype available with G4 and FLUKA engines
- 2003/12/31: 1st cycle of hadronic physics validation complete
- 2004/2: Simulation test and benchmark suite available
- 2004/9: First generic simulation framework production release
- 2004/12: Final physics validation document complete

Summary

- A large project organized in subprojects, some large themselves
  - Six subprojects, four with identified leaders and reasonably well understood
  - A fifth, generator services, should take shape quickly
  - The sixth, shower parameterisation, will take time
- Depends on a strong slate of subproject leaders, which we have
- Good technical coherence and collaboration across subprojects
- Manpower needs are substantial
  - Participation from experiments, G4, FLUKA, LCG but holes remain, and much to be firmed up through more discussion
- Schedule based on a quick ramp from now, and strong leveraging of existing activity
  - Code re-use, leveraging existing simulation & validation work