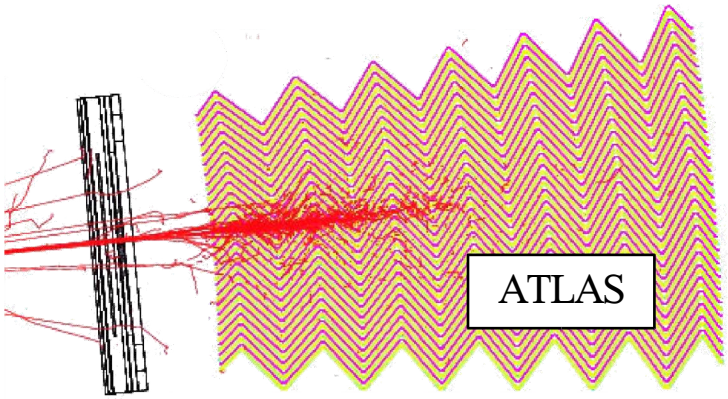
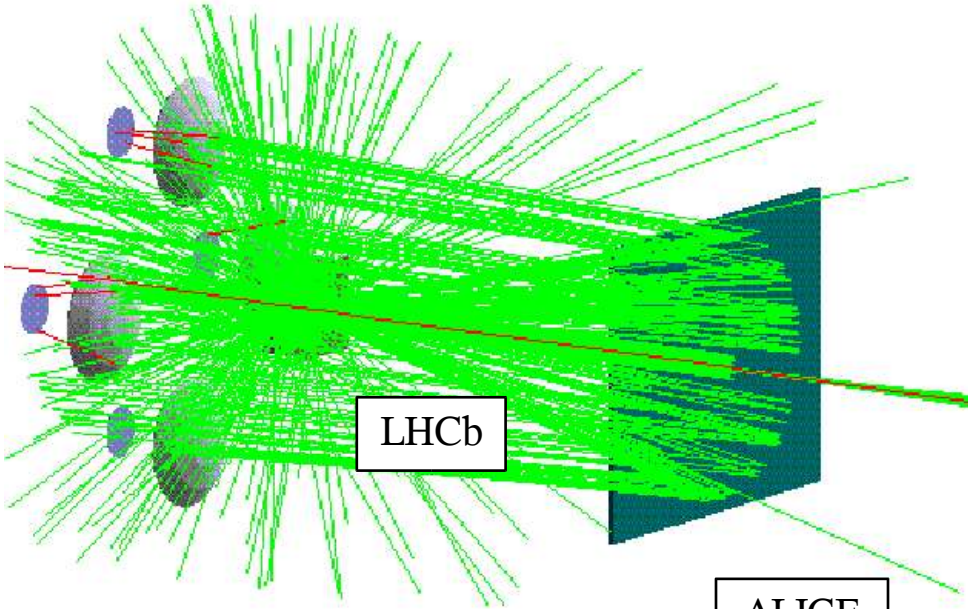
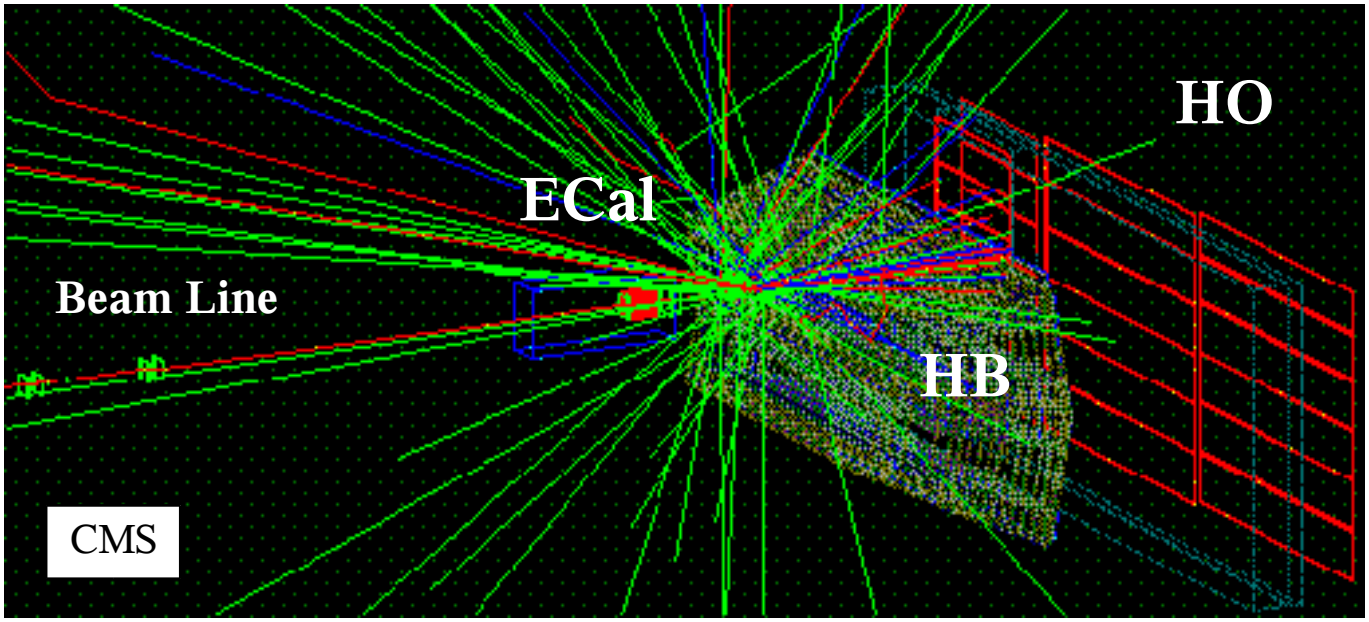
The Simulation Physics-Validation Sub-Project

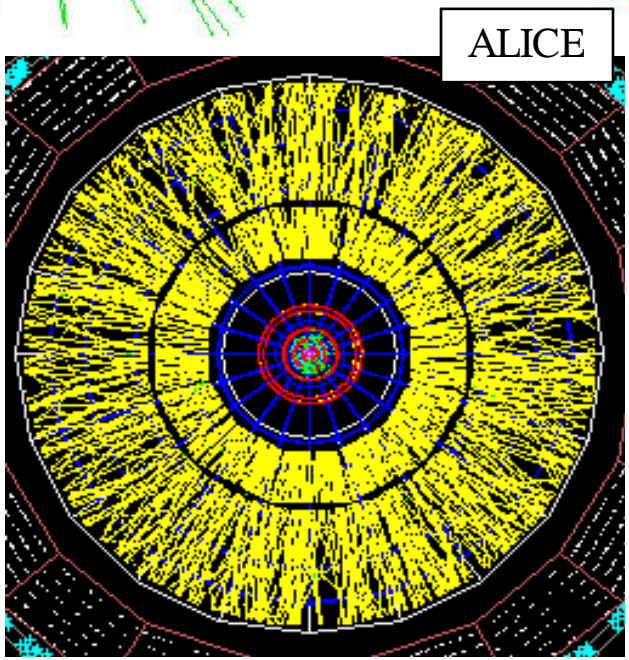


Juerg Beringer
and
Fabiola Gianotti
for the
Simulation Physics-Validation Project

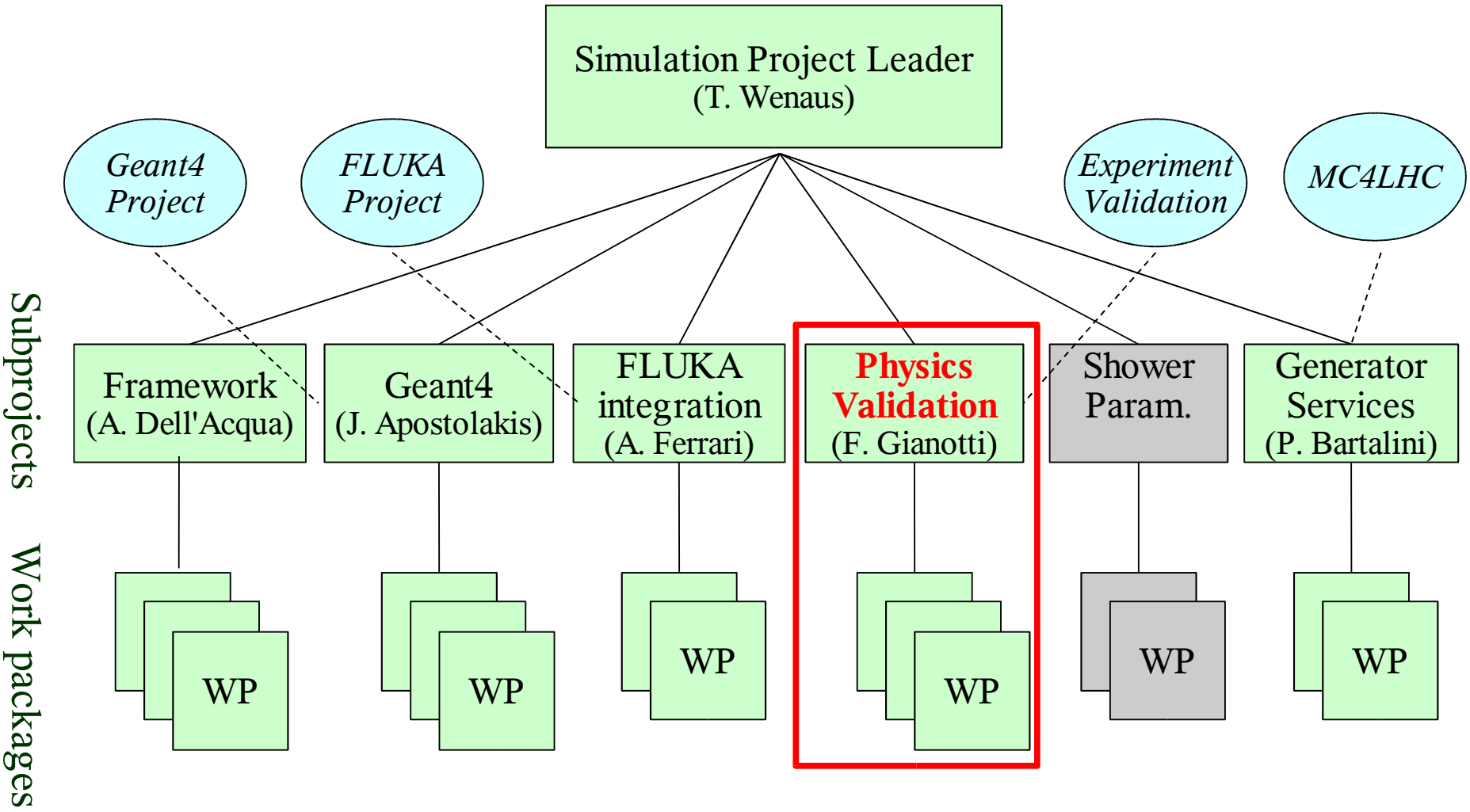


- Goals and plans
- Examples of work done so far and first results
- Summary and outlook





Simulation Project Organization



Goal of physics validation: assess adequacy of the simulation physics and environment for LHC physics

What Do We Need to Validate?

- **Physics of shower packages (Geant4, Fluka) – this is the main goal**
- **Adequacy and usability of simulation environment**
  - E.g. CPU, memory, interactivity as well as generators, MC truth, ...

- **Validation will be based mainly on:**
  - Comparison with LHC detector test-beam data
  - Simulation of complete LHC detectors
  - "Simple benchmarks": thin targets, simple geometries

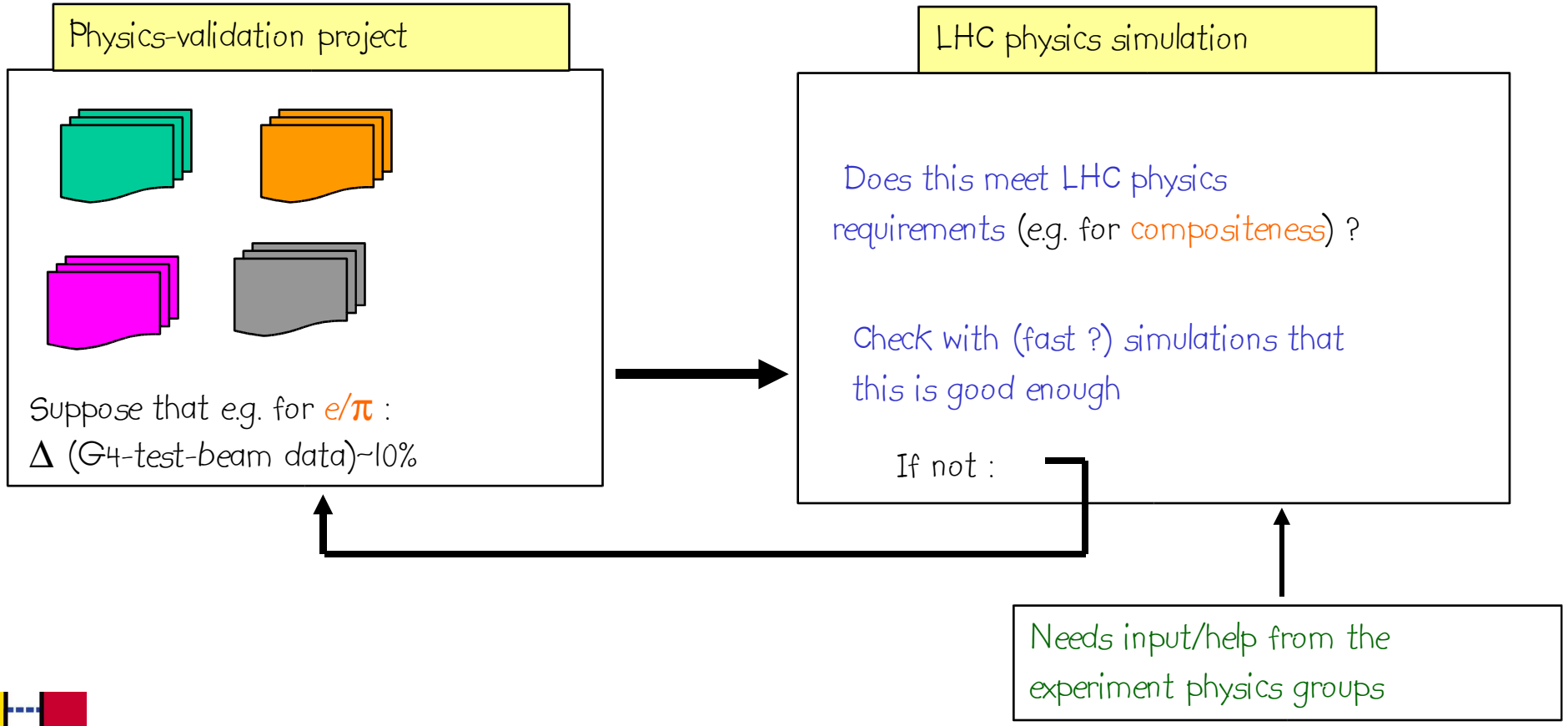
- **Note:**
  - A lot of work already done by LHC experiments and by Geant4, FLUKA teams
  - A lot of work will still be done by the experiments and by the experts
  - Aim of the LHC-wide physics validation project:
    - Primary forum for people to work together on issues of common interest
    - Study coherence of results across experiment and sub-detector technologies
    - Help an experiment in areas where it cannot commit effort at this moment

Work Packages

- WP1 – Impact on LHC physics (LHC physics requirements, impact of simulation inadequacy on LHC physics , etc.)
- WP2 – Input from the LHC test beams (available data, dedicated test beams ?)
- WP3 – Geometry for physics validation (test-beam and LHC-like geometry of experiments in G4/FLUKA and maybe G3)
- WP4 – EM physics validation (comparisons with test-beam data, simple benchmarks, define optimized/recommended physics lists)
- WP5 – Hadronic physics validation (comparisons with test-beam data, simple benchmarks, define optimized/recommended physics lists)
  - WP5a – Calorimetry
  - WP5b – Tracking
  - WP5c – Background radiation
- WP6 – Special needs (e.g. transition radiation, special framework functionality)
- WP7 – Physics validation from outside LHC (collect most relevant results)
- WP8 – Validation of the simulation environment (infrastructure, MCtruth, etc.)
- WP9 – Editorial, organizational (web page, benchmark suite, reports)

What Do We Mean by "Validation"?

- Dominant limitations and systematic uncertainties in LHC physics studies should not come from imperfect simulation
  - Both for searches and for precision measurements



What Will Be the Output of the Project?

- **"Certification" that simulation packages and framework / environment ok for LHC physics**
  - Understanding of weaknesses and strengths of Geant4 / FLUKA
  - Understanding of uncertainties and inadequacies of Geant4 / FLUKA
    - Contribution to systematic errors of measurements when data will be available
- Recommended optimized physics lists, balancing technical against physics performance
- Simulation benchmark suite with relevant plots and tests for automatic (or semi-automatic) validation of future releases
- Final report(s) summarizing the work
- **High-level milestones:**
  - First cycle of EM physics validation by summer 2003 → completed ✓
  - First cycle of hadronic physics validation by end 2003
  - Further iterations in 2004: additional experiment test-beams (e.g. ATLAS combined test-beam); framework and infrastructure validation; ...
  - Write final report(s) end 2004 ?

People and Organization

- **People:**
  - The success of the project depends on :
    - The active participation of the experiments
    - The help and fast feedback of Geant4 / FLUKA physics experts
    - Strong interactions and common work with other Simulation sub-projects
  - Most manpower within the experiments and Geant4 / FLUKA teams
    - E.g. comparisons simulation / test-beam data
  - In addition, from LCG / EP-SFT (as of today):
    - J. Beringer (simple benchmark studies)
    - G. Daquino (study/validate the G4 radiation background simulation in LHCb)
    - M. Gallas (ATLAS combined test-beam simulations)
    - A. Ribon (hadronic interactions in the ATLAS pixel detector)

- **Organization:**
  - Web page: http://lcgapp.cern.ch/project/simu/validation
  - Physics validation meetings, usually on 1st Wednesday of the month (5 meetings so far)
  - Simple benchmark working meetings (5 meetings so far)

Examples of Work Done

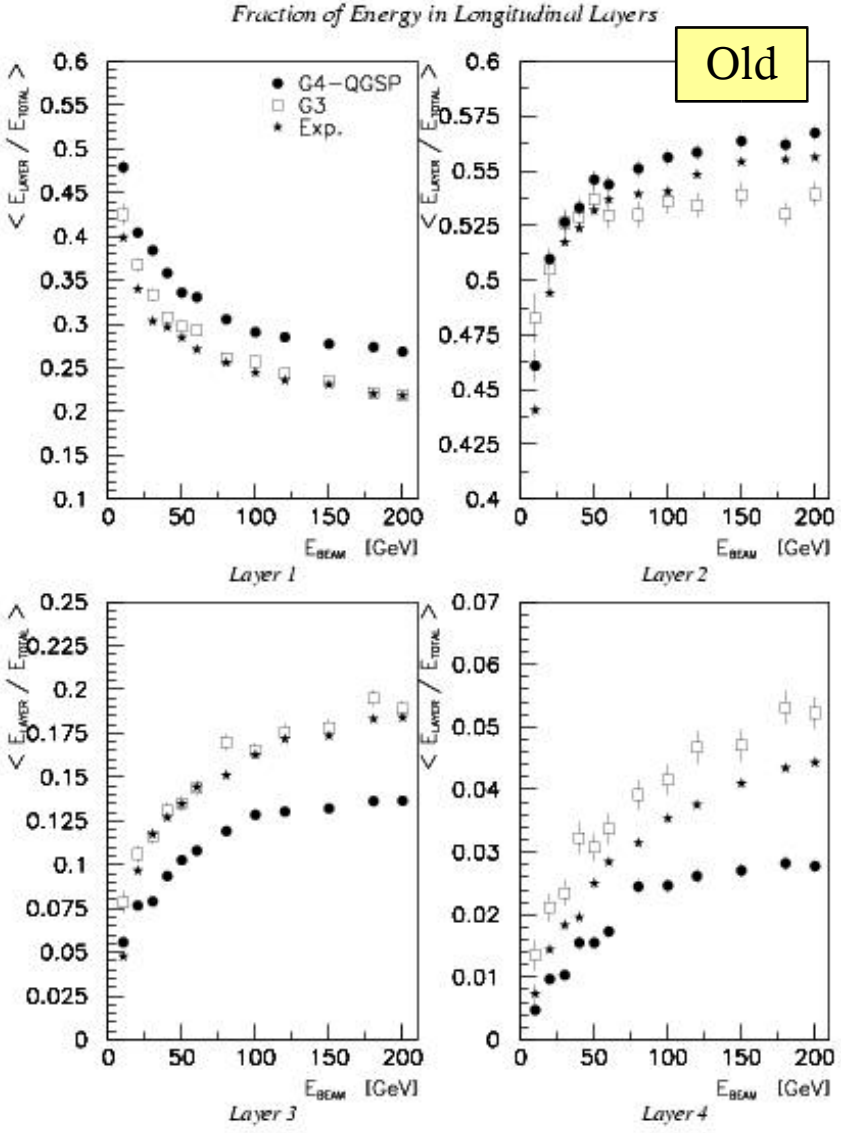
- Physics validation studies made so far revisited
  - Summary talks from experiments and Geant4 / FLUKA experts at the Physics Validation Kick-Off meeting (April 16, 2003)
- Progress with physics validation, for example (see following slides):
  - Pion shower profile in the ATLAS hadronic end-cap calorimeter
  - Pion energy resolution in the CMS ECAL+HCAL prototype
  - ATLAS muon test beam
  - Cluster size and hadronic interactions in the ATLAS pixel detector
  - Double-differential (p,xn) cross section benchmark study
  - ...
- Many more results presented at monthly physics validation meetings
  - All slides available from http://lcgapp.cern.ch/project/simu/validation

Pion Shower Profile in the ATLAS HEC

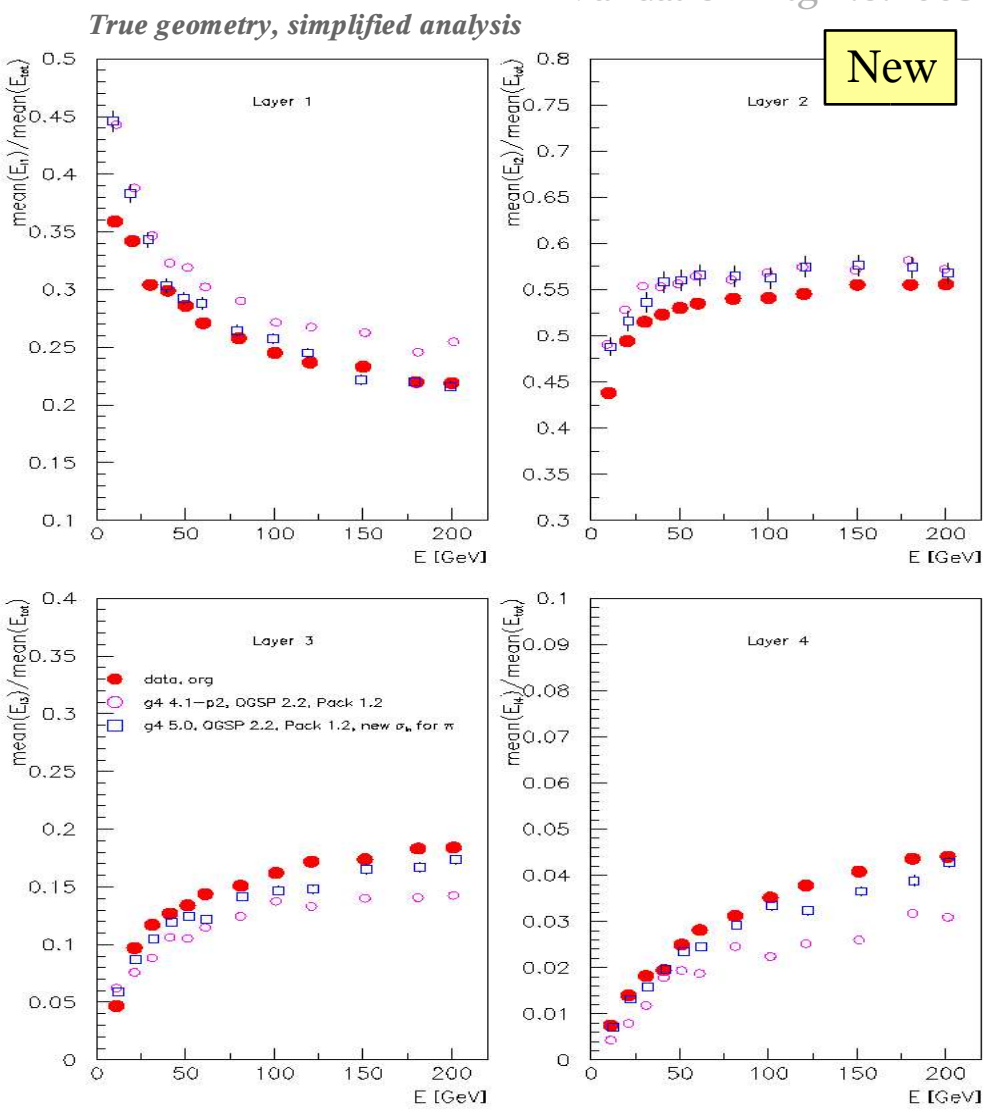
- Improvement in pion shower profile after fixing 10% mismatch in σ_π

J.P. Wellisch, Physics Validation Mtg 4.6.2003

Old



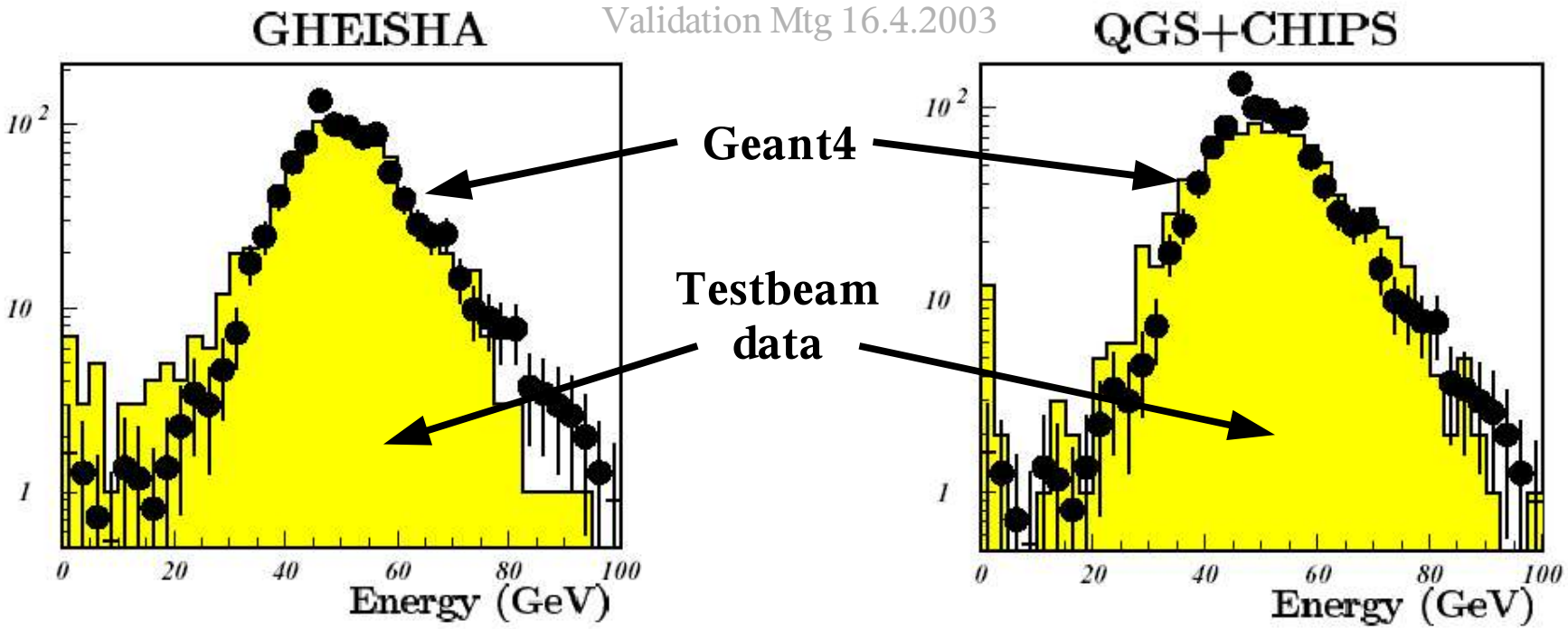
New



Energy Response in the LHCb HCAL

- Energy response of LHCb HCAL to 50 GeV/c pions studied some time ago using "old" Geant4 physics lists

W. Pokorski, Physics Validation Mtg 16.4.2003

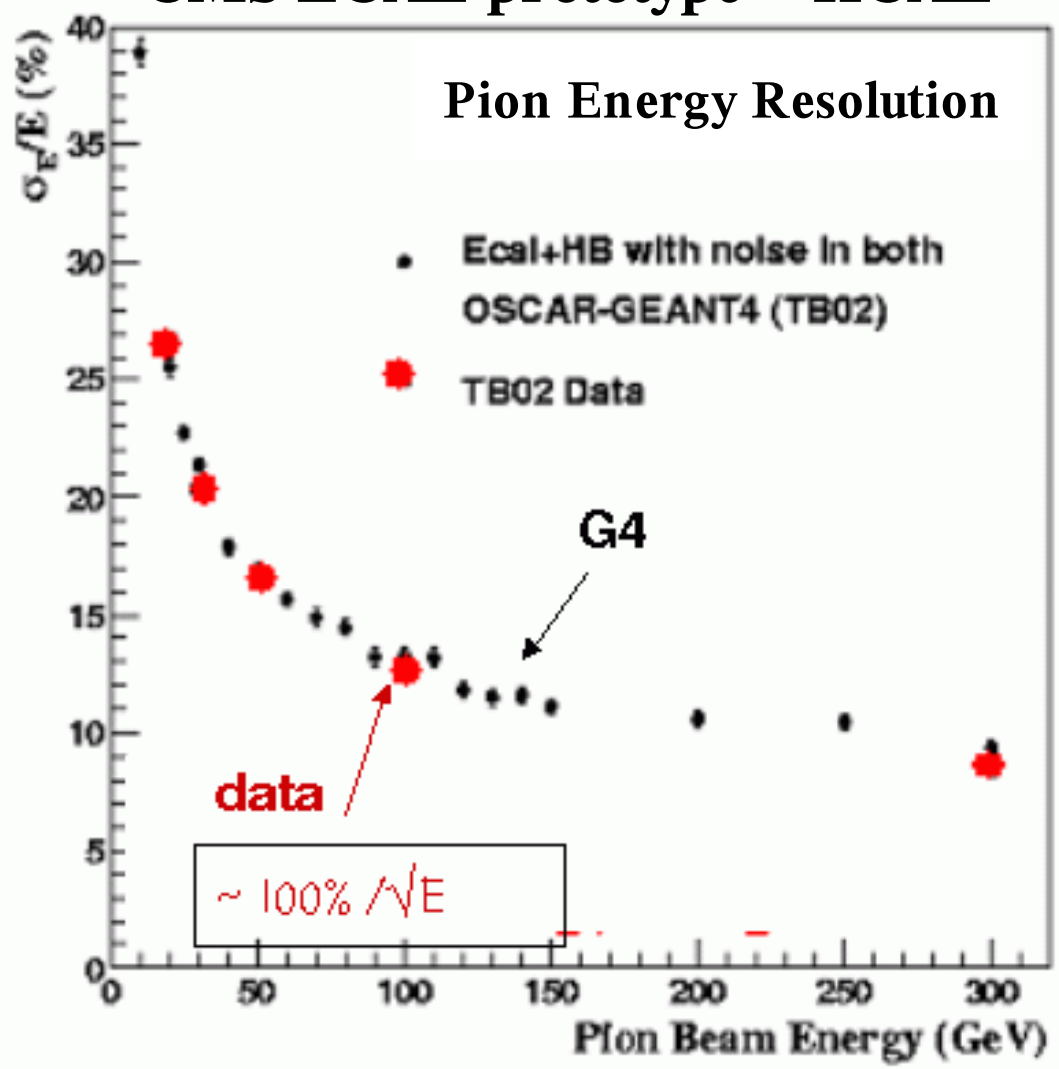


- Study will now be redone using the physics list that was found to be best for ATLAS
  - Example of cross exchange between experiments

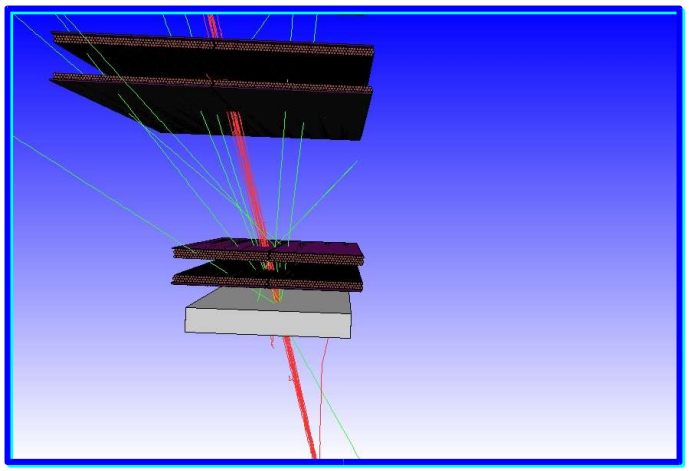
Pion Energy Resolution in CMS

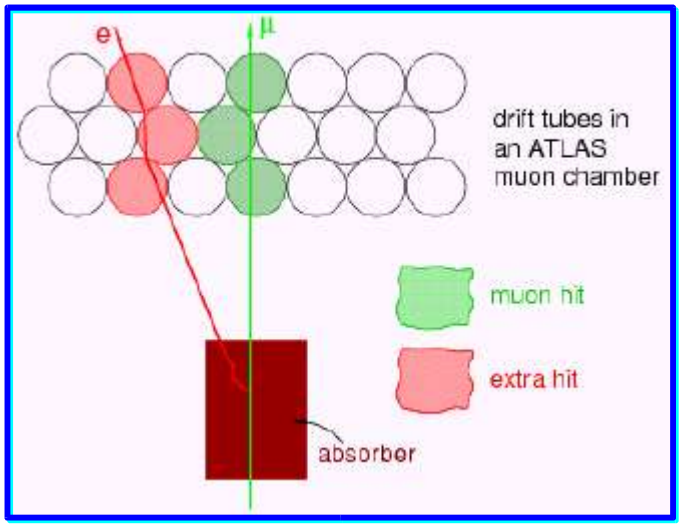
V.D. Elvira, Physics Validation Mtg 14.5.2003

CMS ECAL prototype + HCAL

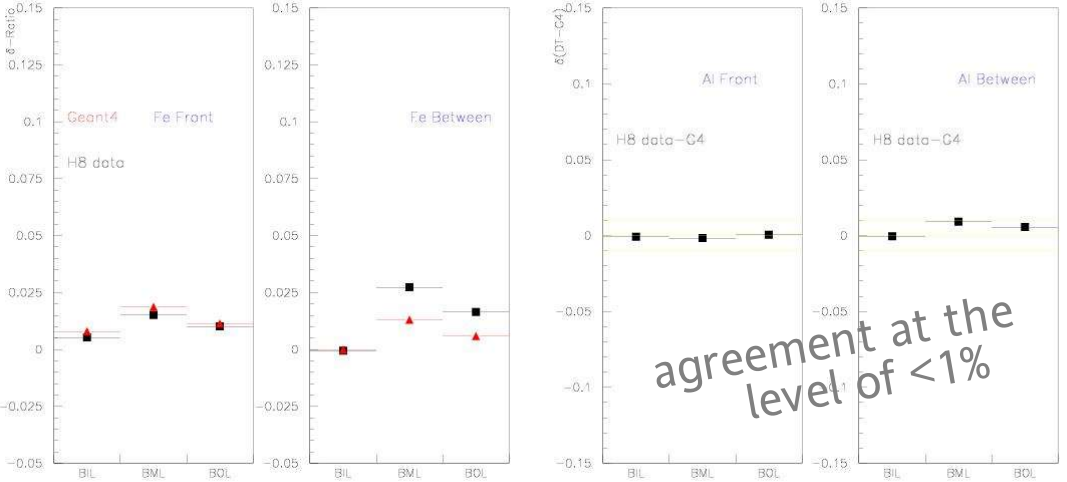


ATLAS Muon Test Beam





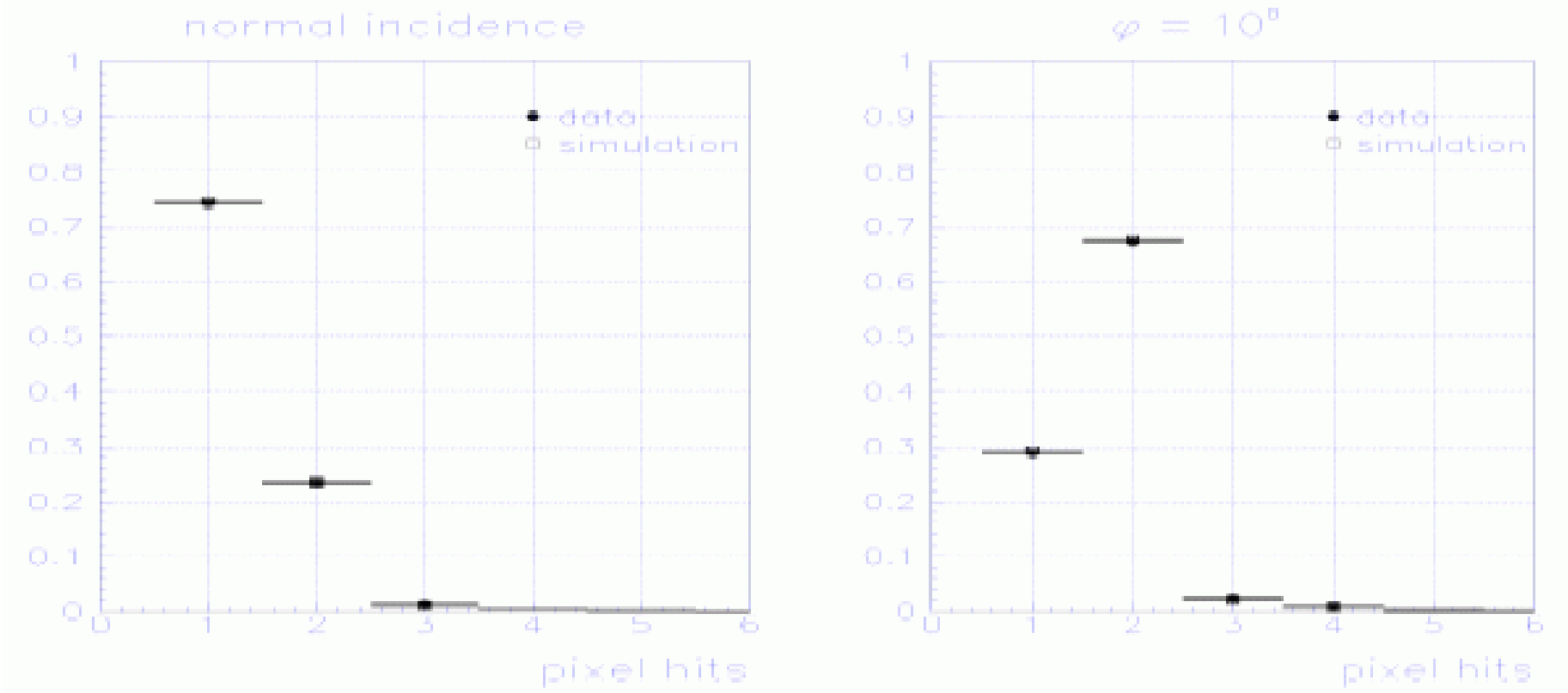
- Extra hits produced in dedicated testbeam setup with Al and Fe targets (10, 20 and 30 cm deep) about ~37 cm from first chamber or between the chambers
- Probability for extra hits measured in data at various muon energies (20-300 GeV)
- Geant4 can reproduce the distance of the extra hit to the muon track quite well



A. Rimoldi, Physics Validation Mtg 16.4.2003

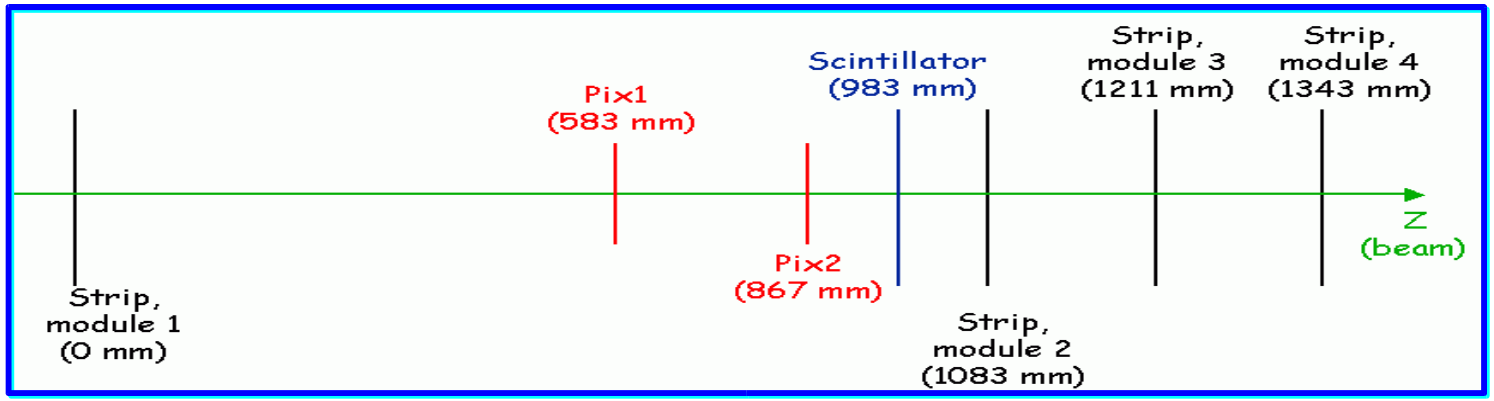
Cluster Size in the ATLAS Pixel Test Beam

T. Lari, Physics
Validation Mtg 1.10.2003



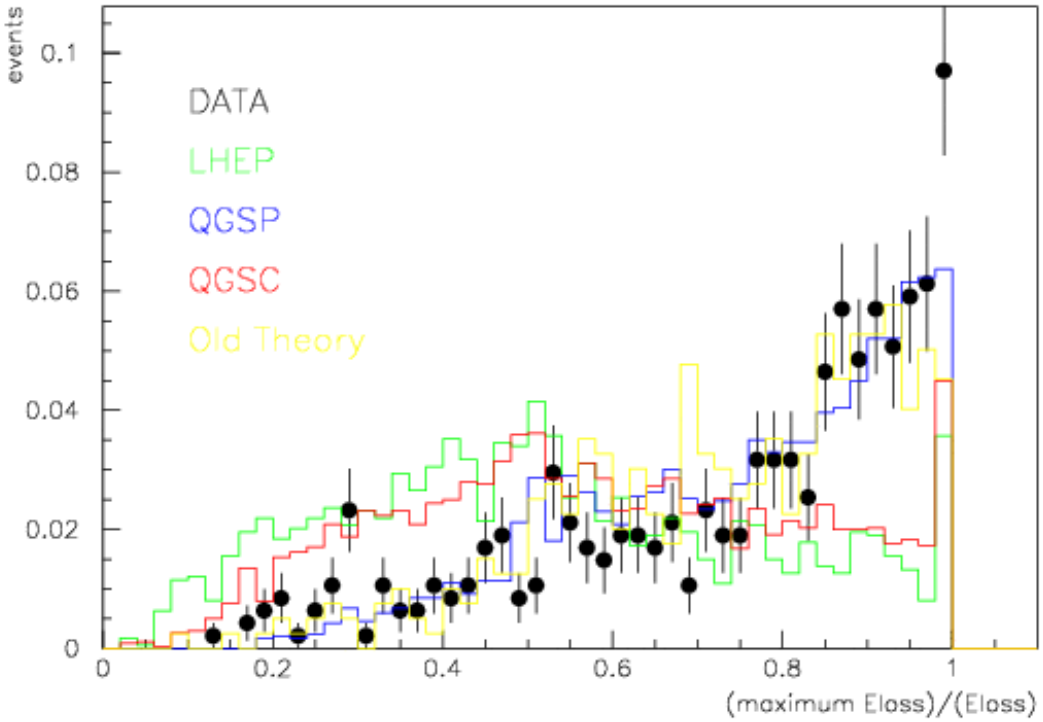
- Summer 2003 data
- Very good agreement between test beam data and simulation at 0° and 10°

Hadronic Interactions in ATLAS Pixel Test Beam



A. Ribon, Physics Validation Mtg 30.7.2003

- Most recent Geant4 physics lists
- QGSP found to be best physics list for ATLAS calorimeter simulation
  - Also best one in this study

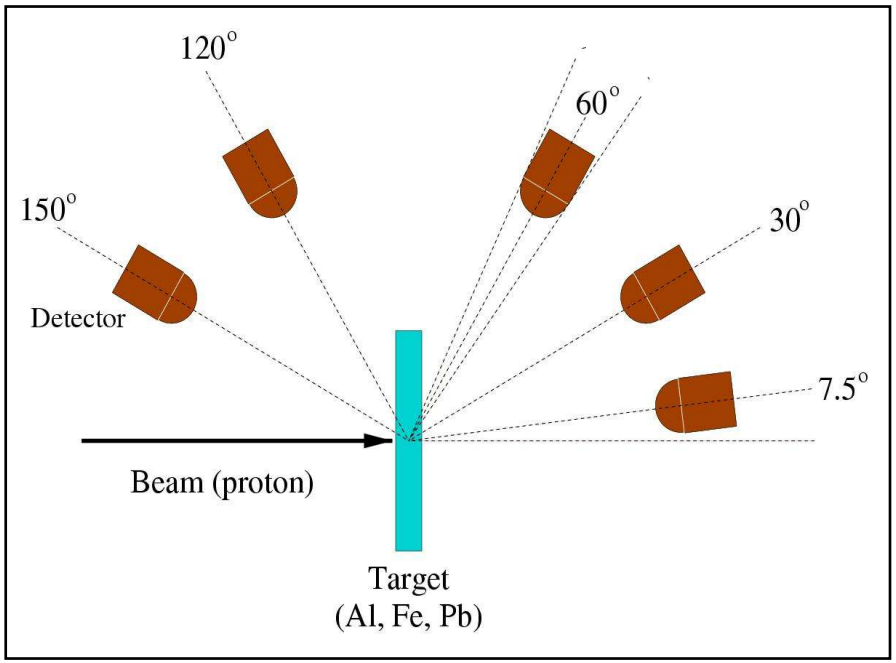


Simple Benchmark Studies

- Predictive power of detector simulation rests on correct simulation of individual microscopic interactions between incident particles and detector material
- Cannot be studied in simple/easy way with LHC detector simulations where multiple interactions/showers/cascades occur
  - Complex phenomenology may average out problems at the microscopic level
- **Study simple benchmark layouts and compare Geant4, FLUKA and experimental data for single incident particles of various energies**
  - Choose benchmarks where experimental data is available
  - Benchmark should be relevant for LHC
- Should repeat these studies with each new release of simulation package
  - Need a (semi-)automatic test suite to repeat these studies when desired

Initial Benchmarks Chosen

- **(p,xn) double differential cross sections**
  - Continuation of earlier work done by I. Gonzalez in ALICE
  - Incident p energies: 113, 256, 597 and 800 MeV
  - Thin targets: Al, Fe, Pb, ...
    - ≤ 1 interaction per incident p
  - Status:
    - Simulation completed
    - Systematic uncertainties under discussion



- **Pion absorption below 1 GeV**
  - Important for e/p, pion E-resolution, etc
  - Status: started
- **Rapidity plots in H/Ar/Xe at 200 GeV (bubble chamber data)**
- **Further studies in the future ... ?**

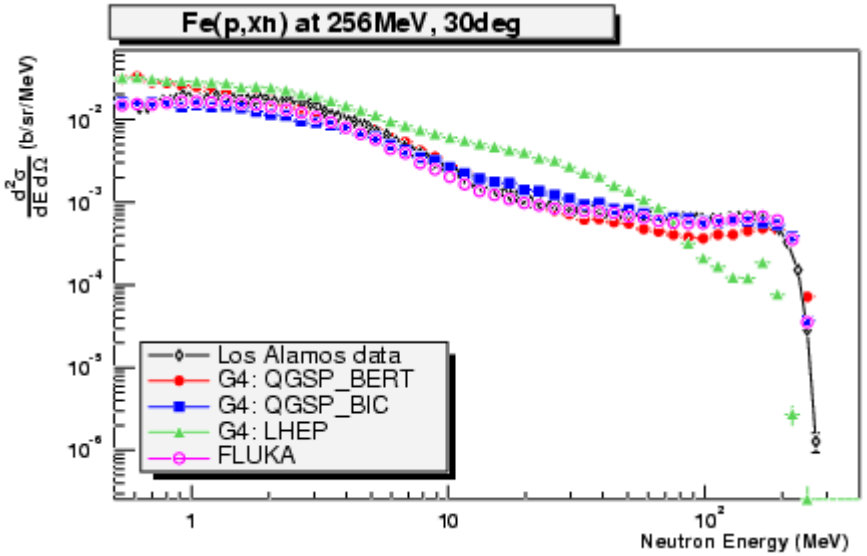
Experimental (p,xn) Data

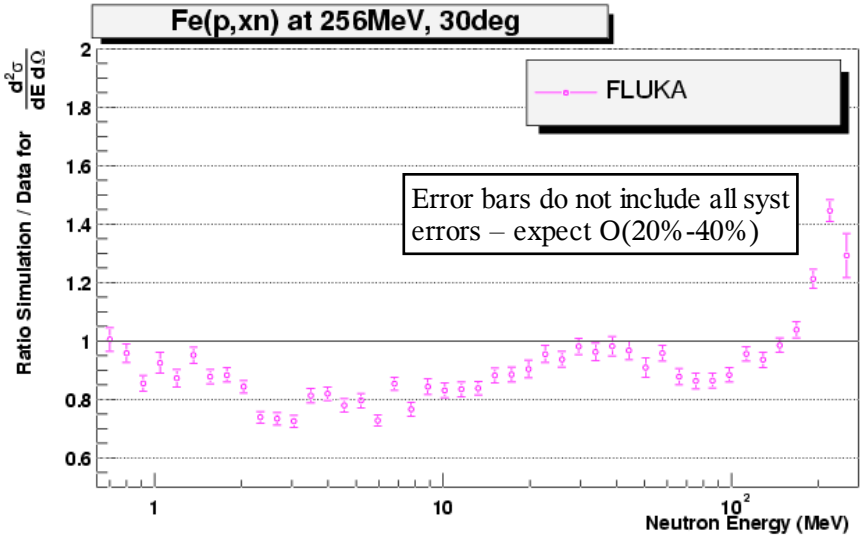
- Different measurements of double-differential (p,xn) cross sections:
  - **"Los Alamos"** data (used as experimental reference data):
    - Nucl Sci Eng volumes 102, 110, 112, 115
    - Measured at LAMPF
    - Typical statistical errors < 5% (except for end-points)
    - Typical systematic errors of ~ 20%
  - **"Hamburg"** data:
    - Phys Rev C47, 1647 (1993)
    - Also measured at LAMPF (different group, detectors, beamline setup)
    - Differences to "Los Alamos" data of up to a factor of ~ 2
  - **"SATURNE"** data:
    - Phys Rev Lett 82, 4412 (1999)
    - Supports "Los Alamos" data for Pb at 800 MeV
- Level of agreement of different measurements and corresponding experimental uncertainty still under discussion

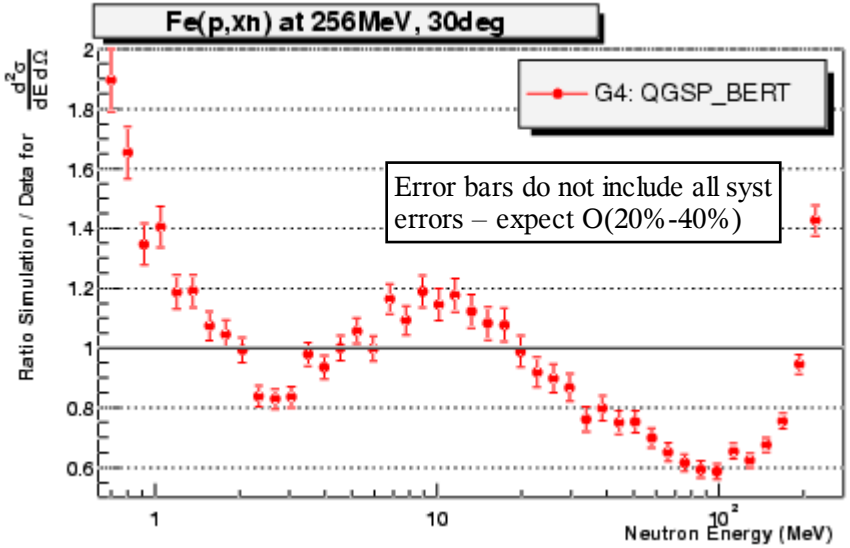
Simulated vs Experimental Cross Sections

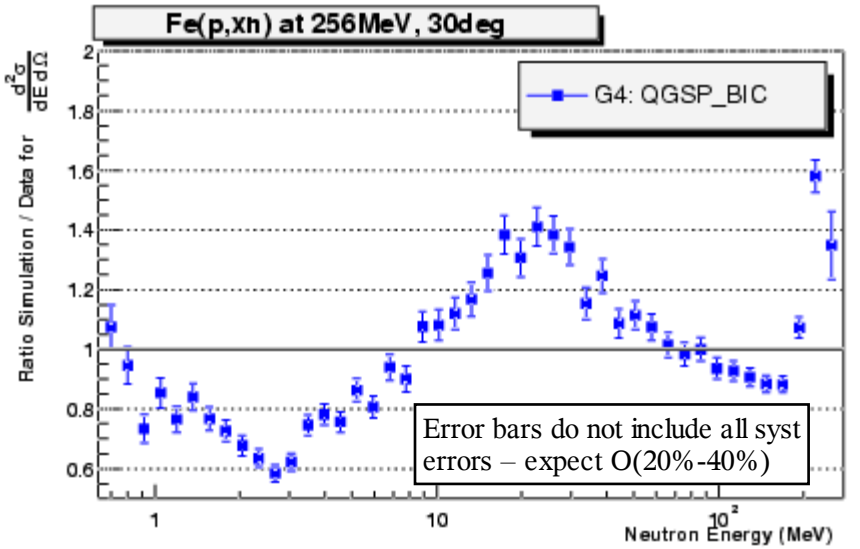
- E.g. Fe(p,xn) production cross sections at 30° (256MeV p):

J. Beringer, Physics Validation Mtg 30.7.2003









Summary and Outlook (I)

- First cycle of EM and hadronic physics validation ~completed
  - **In most cases, Geant4 successfully reproduces test-beam data (equal or better than Geant3)**
- Lots of progress in hadronic physics validation over last few months
  - Large number of results presented at physics validation meetings
- Documentation of hadronic physics lists for LHC has been prepared
- **Comparison of test-beam data with Geant4 for hadronic physics ongoing**
  - Based on ATLAS and CMS calorimeters
  - As well as special data collected with ATLAS pixel detector
  - Most recent Geant4 hadronic physics lists which describe ATLAS HEC and Tilecal well will be tested by LHCb and CMS
- Radiation background studies in LHCb aiming at comparing G4 / Fluka / GCALOR started

Summary and Outlook (II)

- **Two Fluka activities starting:**
  - Update ATLAS Tilecal test-beam simulation
  - Simulate hadronic interactions in ATLAS pixel test-beam setup
  - In the future: CMS HCAL ?
- **First results from simple benchmark studies**
  - (p,xn) double-differential cross sections
  - Study of pion absorption below 1 GeV started
- All experiments have taken test-beam data with many subdetectors this summer
  - **Expect new extensive round of comparison results in next weeks**
- 1-day meeting planned in November or December to discuss validation item by item across experiments
  - E.g. Electron energy resolution, hadronic shower profile, ...
- For further details: http://lcgapp.cern.ch/project/simu/validation/