ADVANCED EXAMPLES: UPDATES AND PLAN

Luciano Pandola
INFN – Laboratori Nazionali del Sud, Catania

for the Advanced Examples Working Group

21st Geant4 Collaboration Meeting, Ferrara, September 12th-16th, 2016

Advanced examples

Advanced examples are Users' applications that simulate a specific experimental setup

Wide experimental coverage:

- HEP (15%)
- Space science/astrophysics (20%)
- Medical physics and radiobiology (40%)
- Detector technologies and others (25%)

Wide Geant4 coverage:

- Geometry features
- Magnetic field
- Physics (EM and hadronic)
- Biological processes
- Hits & Digits
- Analysis
- Visualisation, UI

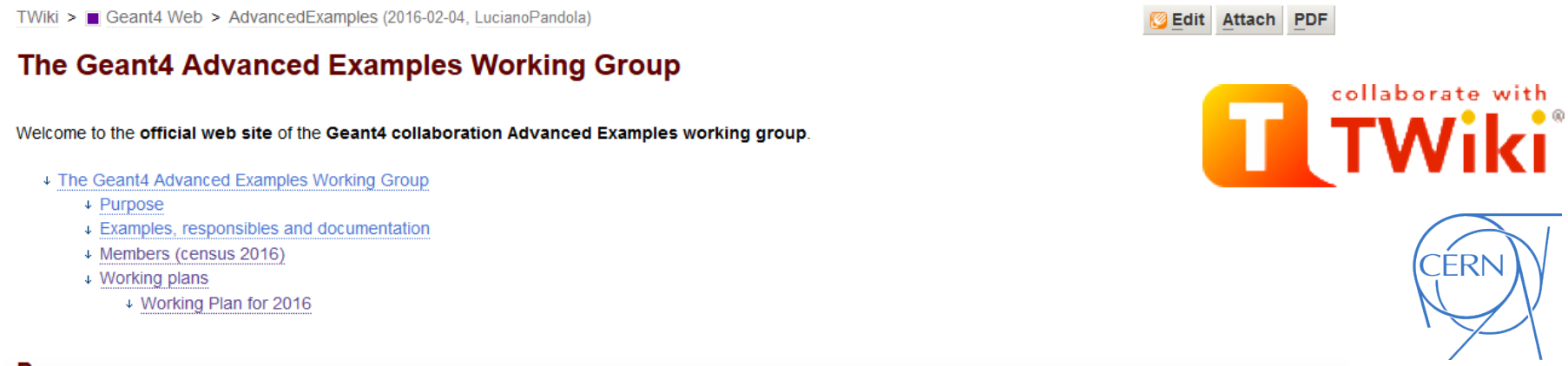
- Investigate, evaluate and demonstrate Geant4 capabilities in various experimental environments
- Provide guidance to Geant4 users in realistic experimental applications
- Provide connection between developers and users of GEANT4

Advanced examples WG – basic facts

coordinator: L. Pandola (INFN-LNS)
deputy: F. Romano (INFN-LNS)

- **15 members** (1.5 FTE in census 2016)
- **21 examples** (some examples moved to **`extended/`** since 10.2)

`https://twiki.cern.ch/twiki/bin/view/Geant4/AdvancedExamples`


TWiki > Geant4 Web > AdvancedExamples (2016-02-04, LucianoPandola)

Edit Attach PDF

The Geant4 Advanced Examples Working Group

Welcome to the **official web site** of the **Geant4 collaboration Advanced Examples working group**.

- The Geant4 Advanced Examples Working Group
  - Purpose
  - Examples, responsibles and documentation
  - Members (census 2016)
  - Working plans
    - Working Plan for 2016

Purpose

The Advanced examples illustrate **realistic applications of Geant4** in typical experimental environments. They are developed in collaboration with user groups expert in the corresponding experimental domain. The examples code can be downloaded together with the Geant4 Toolkit in the directory geant4/examples/advanced

Examples, responsibles and documentation

collaborate with TWiki

CERN

Examples and responsibles (10.3.beta) – I

Example	Responsible	Description
air_shower	B.Tomè	Detection system for cosmic ray shower simulation
amsEcal	M.Maire	Simulation of an Electromagnetic calorimeter
brachytherapy	S.Guatelli	Dosimetry for endocavitary, interstitial and superficial brachytherapy
composite_calorimeter	A.Dotti	A composite electromagnetic and hadronic calorimeter
ChargeExchangeMC	A. Radkov	Simulation of charge exchange real experiment performed at the Petesburg Nuclear Physics Institute (PNPI, Russia)
eRosita	M.G.Pia, et el.	PIXE simulation with Geant4
gammaknife	F. Romano	A device for Stereotactic Radiosurgery with Co60 sources for treatment of cerebral diseases
gammaray_telescope	F.Longo	A simplified typical gamma-ray telescope (such as GLAST), with advanced description of the detector response
hadrontherapy	G.A.P.Cirrone, F. Romano	Simulation of a transport beam line for proton and ion therapy
human_phantom	S. Guatelli	Internal dosimetry

Examples and responsibles (10.3.beta) – II

Example	Responsible	Description
Iort_therapy	G.Russo	Simulation of a IORT device
lAr_Calorimeter	A.Dotti	Simulation of the Forward Liquid Argon Calorimeter of the ATLAS Detector at LHC
medical_linac	C.Andenna, et al.	A typical LINAC accelerator for IMRT,
microbeam	S.Incerti	Simulation of a cellular irradiation microbeam line using a high resolution cellular phantom
microelectronics	M. Raine	Simulation of tracks of few MeV protons in silicon
nanobeam	S.Incerti	Simulation of a nanobeam line facility
purging_magnet	J.Apostolakis	Electrons travelling through the magnetic field of a strong purging magnet in a radiotherapy treatment head
radioprotection	S.Guatelli, J. Davis	Microdosimetry with diamonds and silicum detectors for radioprotection in space missions
underground_physics	A.Howard	A simplified typical dark matter detector (such as the Boulby Mine experiment)
xray_fluerescence	A.Mantero	Elemental composition of material samples through X-ray fluorescence spectra
xray_telescope	G.Santin	A simplified typical X-ray telescope (such as XMM-Newton or Chandra)

Recent updates and developments

- General maintainance and cleaning of obsolete methods/physics
  - Changed physics in **`gammaray_telescope`**, **`composite_calorimeter`** and **`undeground_physics`**
  - Minor revision of **`hadrontherapy`**
- Migration to g4analysis tools and MT
  - **`iort_therapy`** last to be migrated to g4tools
  - 18/21 examples have g4analysis tools
  - 16/21 examples support MT
- Recent/foreseen specific updates on
  - **C++11** specific features
  - Hadrontherapy
    - New round of validation with fresh dedicated data at >2 energies, within the **G4MSBG group**
    - Code clean-up, full implementation of RBE/LET
  - Brachytherapy
    - Validation against AAPM Task Group 43 Report
    - New source model and data for intercomparison

Critical items

- Advanced examples are typically complex Geant4 applications
  - Maintainance and upgrade **not-so-easy** by people other than the original developer(s)
- Some examples are *de-facto* orphans
  - Still, some of them are "references" in the respective communities, so not viable to drop them from the release
  - Only a few examples actively developed
- The design is **old** and not tailored to MT
  - Migration possible (and done), but not straightforward/natural
- Demonstrate g4analysis and C++11 features
  - e.g. G4Parameter and g4tools, which also help MT-compliance
  - Major upgrades should be performed by original developer(s)
    - This is a problem for orphan examples, but also for others (people are usually overbooked).
  - Minor things doable: **`override`**, **`auto`**, etc. → still, manpower issue

Brachytherapy validation

CENTRE FOR MEDICAL RADIATION PHYSICS
UNIVERSITY OF WOLLONGONG AUSTRALIA

- D. Cutajar, S. Guatelli, J. Poder
- The TG43 report recommends the dose rate for a cylindrical source be expressed in 2D coordinates in terms of **separable functions**

Radial dose
Anistropy function

$$D^{*}(r,\theta) = S_k . \lambda . [G(r,\theta) / G(r_0,\theta_0)] . g(r) . F(r,\theta)$$

- Implement calculation in brachytherapy according to the recommendations
- Compare results from Geant4 against Granero data (2007) used for source consensus data for TG43 based dose planning systems (ESTRO.org)
  - Flexisource ^{192}Ir Brachytherapy Source
  - Reference data and ROOT macros to compare Geant4 vs. data included in the release (radial dose and anisotropy)

NEW

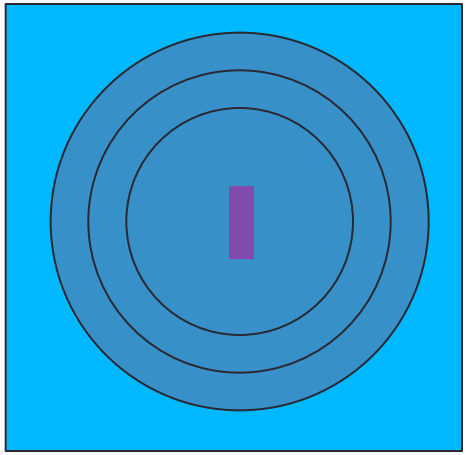
NEW

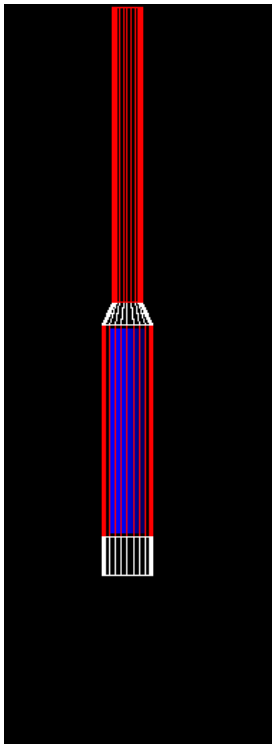
Brachytherapy MC simulation

CENTRE FOR MEDICAL RADIATION PHYSICS

UNIVERSITY OF WOLLONGONG AUSTRALIA

- Source placed in the centre of an 80x80x80 cm^3 liquid water phantom
- 200 concentric scoring shells surround the source
  - From 1 mm to 20 cm radius
  - Thickness: 0.1mm
- The user can switch different **EM physics lists**
  - Standard option 3, 4, Livermore, Penelope
- Energy deposition within the shells
- Radial Dose Function and Anisotropy Function data calculated from the dose deposition





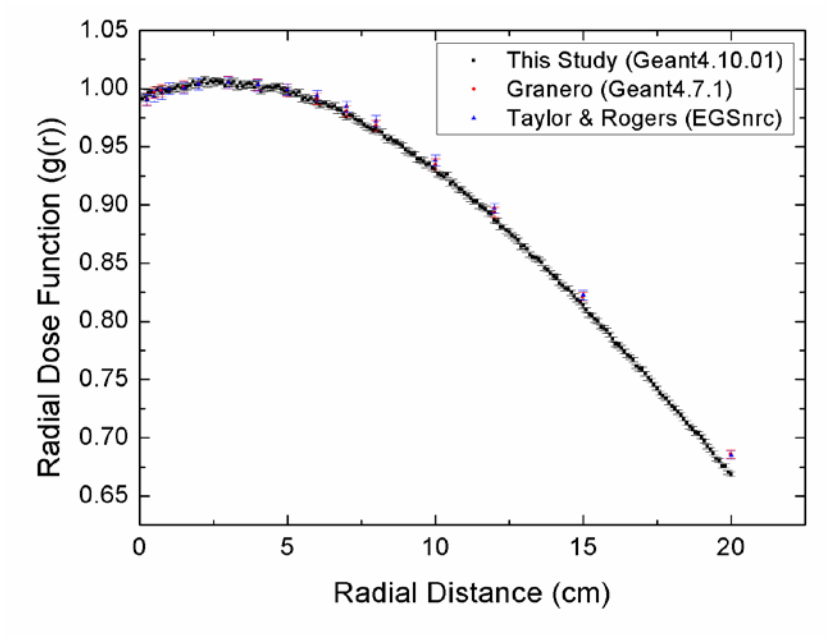
Flexisource ^{192}Ir Brachytherapy Source

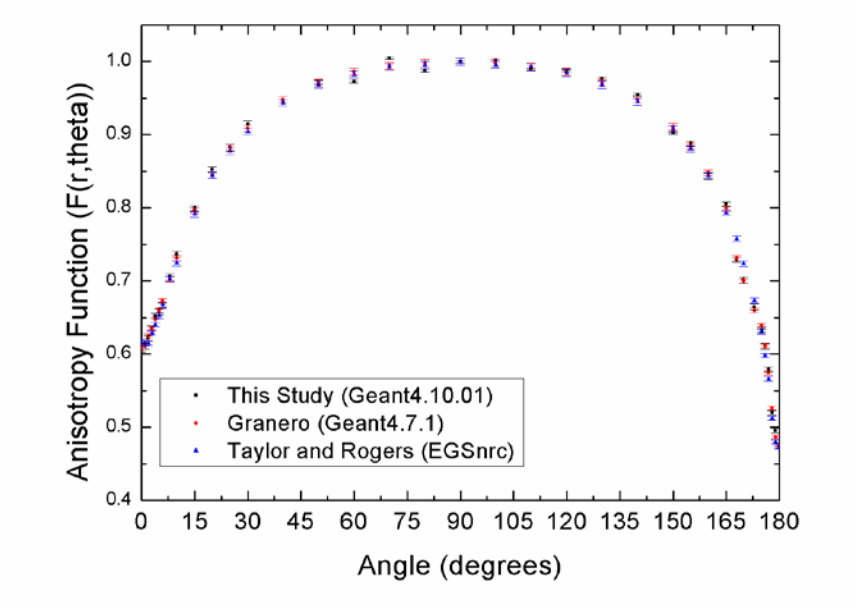
CENTRE FOR MEDICAL RADIATION PHYSICS
UNIVERSITY OF WOLLONGONG AUSTRALIA

Brachytherapy validation - results

- Agreement to within error up to 10cm radial distance (clinically relevant distances)
  - Max discrepancy beyond 0.7% at 20cm
- Anistropy functions for 1cm radial distance
  - Largest errors at sharp angles (lower statistics)

Geant4 10.1
10^{10} histories



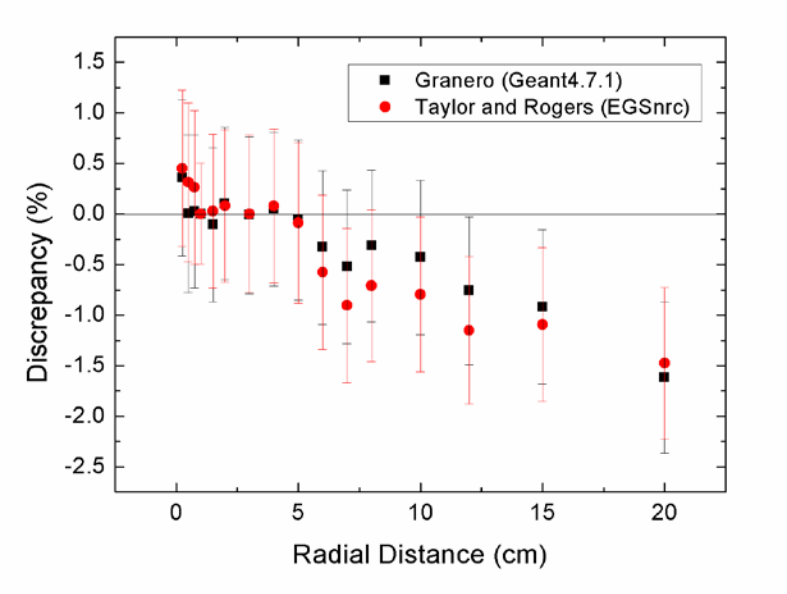


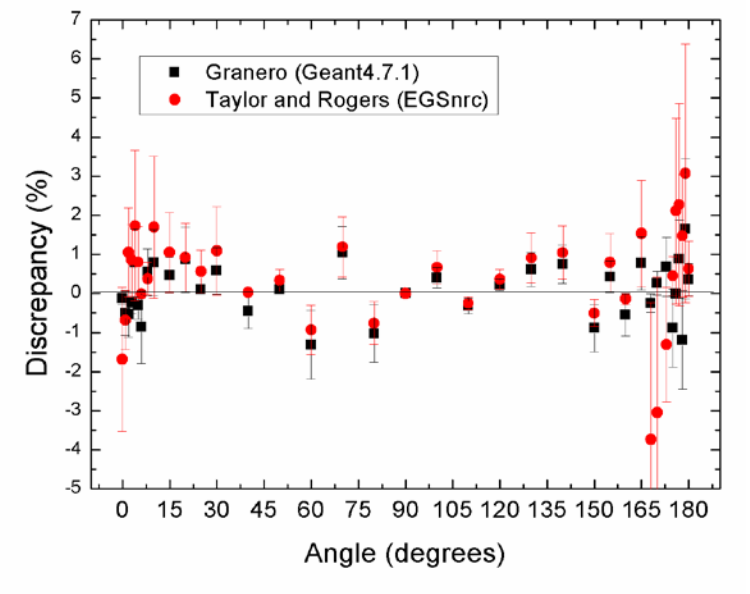
CENTRE FOR MEDICAL RADIATION PHYSICS
UNIVERSITY OF WOLLONGONG AUSTRALIA

Brachytherapy validation - results

- Agreement to within error up to 10cm radial distance (clinically relevant distances)
  - Max discrepancy beyond 0.7% at 20cm
- Anistropy functions for 1cm radial distance
  - Largest errors at sharp angles (lower statistics)

Geant4 10.1
10^{10} histories





Worplan for 2016

- Mainteinance and bux fix (1,2)
- Introduction of some C++11 specific features/utilities in the examples (2) [*]
- Validation and implementation in hadrontherapy of the LTE/RBE modeling derived by experimental measurements (2)
- Testing suite against the TG43 reference by using the brachytherapy advanced example (2)
- Introduction of the Polarized physics list in the GammaRayTel example, to build an experiment for polarised gamma detection (2)
- Include a specific nuclear medicine use-case within the example human phantom (2) [*]

Summary and conclusions

- Situation a bit too much *static*, also due to many orphan examples
  - Only a few examples are regularly followed by the original developers
- **Major work performed** in the past few years with g4analysis and MT migrations
  - The vast majority of the examples have now g4tools and are MT-compliant
  - Next steps will be a basic demonstration of C++11 funcionalities and a better integration of g4analyis tools (in the MT perspective)
- Basic maintainance and bug fixing are performed and guaranteed
- Difficult to plan major upgrades, especially for the orphans

BACKUP

Migration to g4tools (2016)

air_shower	Iort_therapy
ams_Ecal	lAr_Calorimeter
brachytherapy	medical_linac
composite_calorimeter	microbeam
ChargeExchangeMC	
	nanobeam
eRosita	purging_magnet
gammaknife	radioprotection
gammaray_telescope	underground_physics
hadrontherapy	xray_fluerescence
human_phantom	xray_telescope
	microelectronics

Migration to MT (2016)

air_shower	Iort_therapy
ams_Ecal	lAr_Calorimeter
brachytherapy	medical_linac
composite_calorimeter	microbeam
ChargeExchangeMC	
	nanobeam
eRosita	purging_magnet
gammaknife	radioprotection
gammaray_telescope	underground_physics
hadrontherapy	xray_fluerescence
human_phantom	xray_telescope
	microelectronics

Summary and conclusions

- General review of the code and maintenance
- Bug fixes
- New developments have been carried out
- New Twiki web page available
- More than 75% of the examples migrated both to G4tools and MT (just a few still remaining)