

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

Hadrontherapy

A Geant4 Open Source application for proton and ion therapy
studies

G.A.P. Cirrone
cirrone@lns.infn.it

October 16, 2009

Main actual and past contributors

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

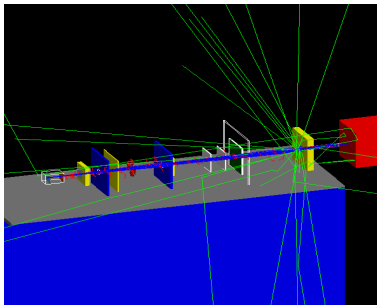
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



G.A.P.Cirrone, G.Cuttone, F.Di Rosa, S.E.Mazzaglia, F.Romano
INFN-LNS, Catania (I)

S.Guatelli

University of Wallongong (Australia)

P.Kaitaniemi, A.Heikkinen

University of Helsinki and Helsinki Institute for Physics, Helsinki (Finland)

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

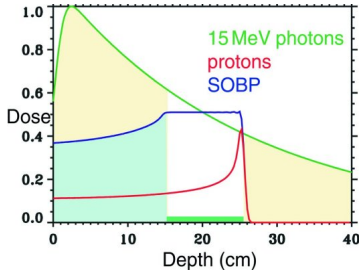
1 Advanced Examples and Hadrontherapy

- Hadrontherapy in Geant4 9.2
- Hadrontherapy in Geant4 9.3
- The geometry solution
- Thin and thick target experiments
- The physics solution

2 Other featured added or in progress

- Stopping powers calculation
- Linear Energy Transfer (LET)
- Minor adds

Proton/ion therapy and the Monte Carlo approach



- Penetration depth is well-defined and adjustable
- Dose to normal tissue minimized
- No dose beyond target

Why Monte Carlo can be essential

- Dose distribution verification and Treatment Planning commissioning
- Beam line transport optimization
- RBE evaluations
- Take into account the physics of particle interactions on a particle-by-particle basis using theoretical models or experimental cross-section data
- Consider tissue inhomogeneities by using specific material properties

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2
Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

The Geant4 examples categories

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced Examples and Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

`.... /geant4Version/examples/`

- 1 The *Novice* examples
- 2 The *Extended* examples
- 3 The *Advanced* examples

Novice examples

They show the basic characteristics and potentialities of a Geant4 application: visualization, parameterizations, etc

Extended examples

Are related to particular aspects: electromagnetic physics, hadronic physics, electrical and magnetic field, etc

Advanced examples

They reproduce real experimental apparatus and detectors

Hadrontherapy is an Advanced Examples

The Geant4 examples categories

..../[geant4Version/examples/](#)

- 1 The *Novice* examples
- 2 The *Extended* examples
- 3 The *Advanced* examples

Novice examples

They show the basic characteristics and potentialities of a Geant4 application: visualization, parameterizations, etc

Extended examples

Are related to particular aspects: electromagnetic physics, hadronic physics, electrical and magnetic field, etc

Advanced examples

They reproduce real experimental apparatus and detectors

Hadrontherapy is an Advanced Examples

The actual version of Hadrontherapy

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

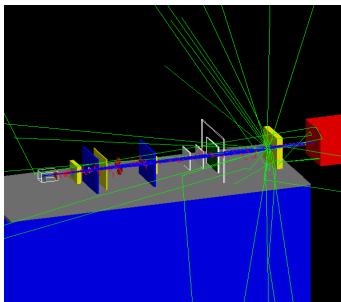
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



- Included in the Geant4 9.2 release
- Permits the **accurate design of a proton/ion transport beam line** with all the elements
- Resulting doses and fluences curves are reconstructed in a **water voxelized phantom**
- Proton and ion physics process and inclusion of the Physics Lists and Reference Physics list

Story of the Hadrontherapy example

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

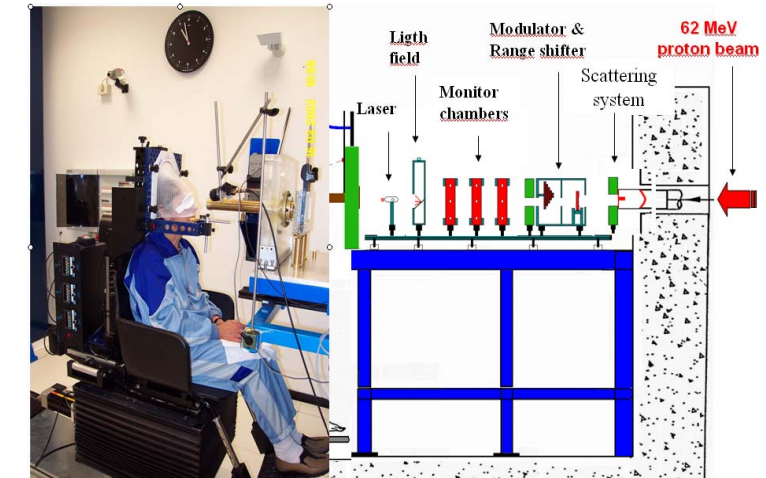
Linear Energy
Transfer (LET)

Minor adds

- **Middle 2003:** the first version of the example is ready and 1D dose distribution can be calculated only for proton beams
- **Middle 2004:** the first release of Hadrontherapy is inserted in the official Geant4 release
- **2005:** data validation of depth distribution curves is completed and the capability of validate a treatment planning system is demonstrated. A 3D voxelisation is provided
- **2006:** A complete physics is provided also for ions and first comparison of dose distribution carried out
- **2007:** The choose of physics models is completely updated: the use of Physics Lists is now possible via macro command
- **2008:** Use of the Reference Physics Lists and first work on the possibility to change interactively the geometry
- **2009:** A geometry controller is provided to change different geometrical set-ups. Dose distributions, thin and thick target experiments as well as the calculation of simple parameters (like stopping powers) is now easy
- **2009:** ROOT scripts and data folders added

The actual version of Hadrontherapy

Up to now Hadrontherapy permitted the simulation the proton beam line for the eye treatment installed here in Catania



G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2
Hadrontherapy
in Geant4 9.3

The new
geometry
solution
Thin and thick
target
benchmark
studies
New physics
solution

Other features
added or in
progress

Stopping powers
calculation
Linear Energy
Transfer (LET)
Minor adds

The actual version of Hadrontherapy

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

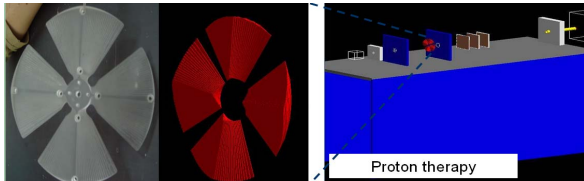
Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

Each element of the beam line has been simulated and results have been compared with experimental data (62 AMeV proton beam on water phantom)



- Generic beam line configuration
- 3D dose distribution calculation using a sensitive detector with cubic voxels: a sensitive detector region coupled with the Read Out Geometry is adopted

The actual configuration for physics models

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

The Physics List

- The actual version of the program has many class files for the implementation of physics models. The name of the files start with EM, HE, HI to indicate Electromagnetic, Hadronic Elastic or Hadronic Inelastic physics models.

This can generate confusion

- In December we added the possibility to use the reference Physics Lists.
- These are already compiled libraries packaging electromagnetic as well as hadronic models in the same place

They are downloaded with the Geant4 code:

G4INSTALL/source/physics_list

In this version we suggested Users to use the QGSP_BIC package containing standard EM models and the Binary Cascade for proton-nucleus and nucleus-nucleus interactions.

Also Lowenergy libraries produced anyway good results in terms of dose deposited

Suggested physics models, the case of a proton Bragg peak

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

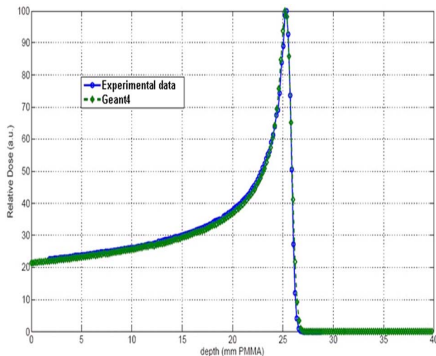
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

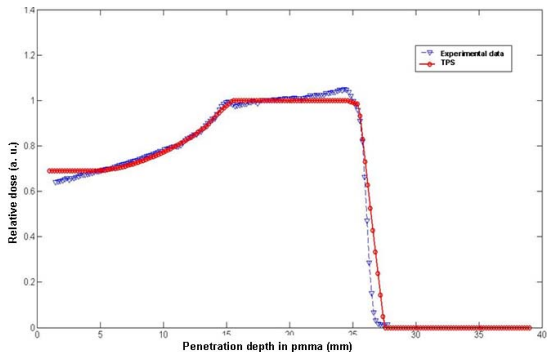


Physics models

- Use of the `physics/addPackage` macro command
- QGSP_BIC
- Transport parameter set as in the `G4EmStandard_opt3`
- `G4EmStandard_opt3` is a physics list particularly tailored for high

Modulated Bragg peak

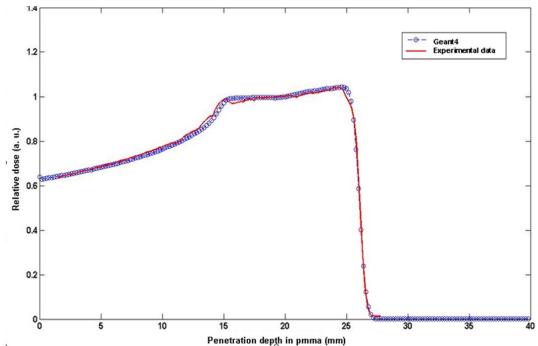
A case of comparison with a treatment planning system



A general better depth dose shape with the Monte Carlo

Modulated Bragg peak

A case of comparison with a treatment planning system



A general better depth dose shape with the Monte Carlo

A real clinical case

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

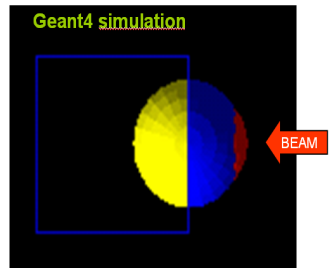
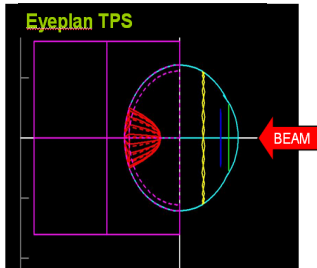
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



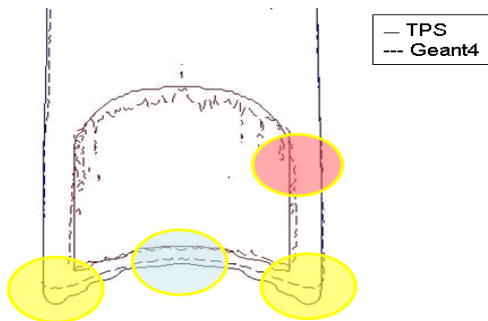
geant4.9.1.p01

In

the Read out Geometry of Hadrontherapy we reconstruct the eye structures

A real clinical case

Monte Carlo ability into the reconstruction of 2D depth dose curves



Regions with worst agreement are emphasized
Long computation times (4 full days for a good accuracy)

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

The new version of Hadrontherapy in Geant4 9.3

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

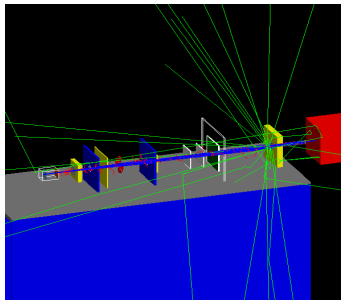
Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

What will be included in the new version

- Included in the Geant4 9.2 release
- New approach for the geometry configuration
- Added functionalities for the calculation of useful parameters (stopping power, etc)
- Proton and ion physics process with the inclusion of the possibility to use physics lists and reference physics lists: great simplification of the physics lists classes



The new version of Hadrontherapy in Geant4 9.3

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

**Hadrontherapy
in Geant4 9.3**

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

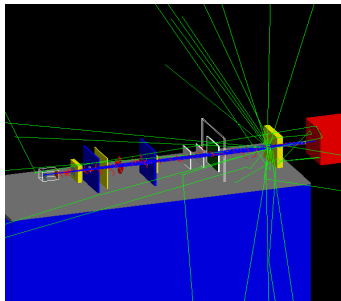
Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

What will be included in the new version

- nuclear physics problems (thin and thick target experiments)
- Folders containing data file and ROOT script for a fast check and test of the results
- New README file based on the use of the web2.0



The new version of Hadrontherapy in Geant4 9.3

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

**Hadrontherapy
in Geant4 9.3**

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

What is in progress

- Development of class files for the calculation of the LET
- Development of an active beam line (see talk by Shin Jungwook in the next session)
- Basic configuration in which Users can add simple geometries and materials to calculate basic parameters
- Graphical interface using the QT libraries
- Set up for a simple magnetic spectrometer

Block scheme of the possibility to control the geometry

Independent blocks for **Particle Source**, **transport beam line** and **Detectors**; The green block can be fully personalized and independent from voxelized detector

The source point
Energy, particle,
spot size, etc



Region simulating a
water phantom



The beam line set-up
that can be chosen via
macro commands:

- **passiveProtonBeamLine**
- **activeProtonBeamLine**
- **simpleBeamLine**

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

The Geometry control

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

Possibility to interactively change the beam line transport set-up
The GeometryController switches between geometries and
GeometryMessenger connects the controller to the Geant4 user
interface

```
void HadrontherapyGeometryController::SetGeometry
(G4String name)
```

```
G4cout <<" Activating geometry " << name
<< if (name == "IAEA"
registerGeometry(new IAEADetectorConstruction());
G4cout <<"IAEA geometry activated" << G4endl;
HadrontherapyDetectorConstruction *pDetector
= new HadrontherapyDetectorConstruction();
registerGeometry(pDetector);
else
G4cout << " Unknown geometry : " << name <<
".Geometrynotchanged." << G4endl;
```

..... with the ProtonPassiveBeamLine

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

**The new
geometry
solution**

Thin and thick
target
benchmark
studies

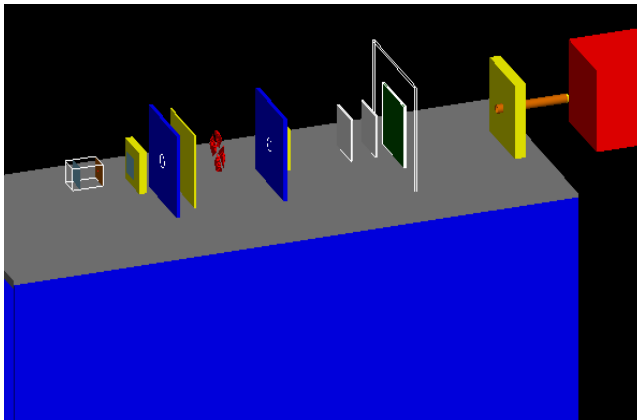
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



..... with the **ActiveBeamLine**

Shin Jungwook from Korean NCC

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

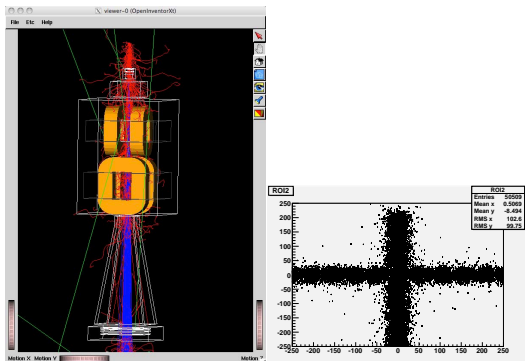
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



#135MeVprotons

/run/initialize

/user/phantom/mask 0x110 mm 1 1

/APBL/SCAN/SetFieldX 0.2 tesla

/run/beamOn 1000

/APBL/SCAN/SetFieldX 0.4 tesla

IAEA Benchmark geometry

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

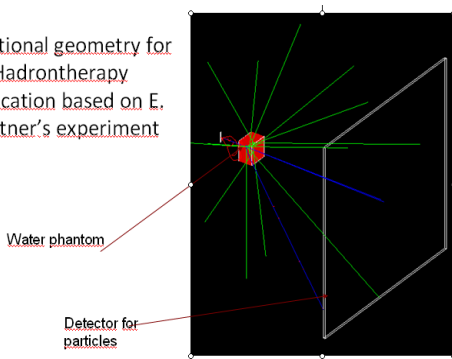
Linear Energy
Transfer (LET)

Minor adds

The Geometry controller permits to Hadrontherapy to become a tool for thin-thick experiment comparisons

Example: User can select the IAEA benchmark geometry:

- Additional geometry for the Hadrontherapy application based on E. Haettner's experiment



IAEA Benchmark geometry

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

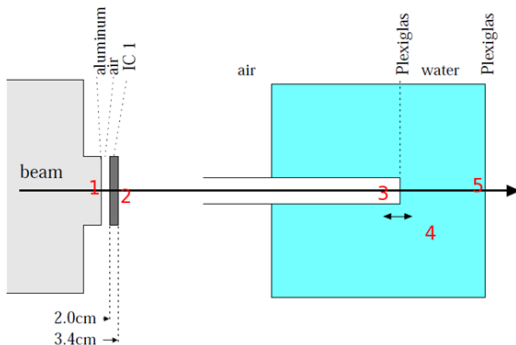
Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

E. Haettner, *Experimental study on carbon ion fragmentation in water using GSI therapy beams*,
Master of Science Thesis, Kungliga tekniska hogskolan, Stockholm



The depth of the water target is adjusted varying the thickness of the Hadrontherapy phantom

IAEA Benchmark geometry, some result

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

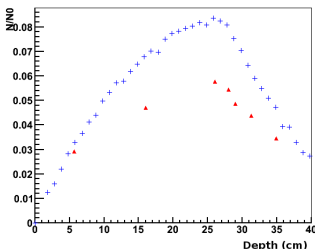
Stopping powers
calculation

Linear Energy
Transfer (LET)

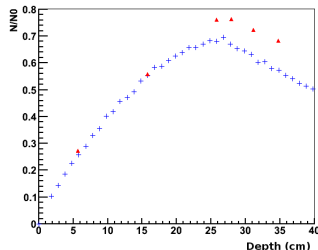
Minor adds

- ^{12}C , 400 AMeV in Water target
- G4EmStandard_Opt3 + Binary Cascade
- Yield is number of particle produced as respect the number of incident ions
- **Red points** represent the experiment

Li yields 0-10 degrees



H yields 0-10 degrees



Thank to P. Kaitaniemi and G.Danielsen for the effort in this

Physics models in Hadrontherapy

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- Great simplification of the physics classes contained in the Hadrontherapy folder
- We strongly suggest the use of Physics Lists and Reference Physics Lists for a minor risk and for a strong feedback to developers.
- Not all models are available with Physics Lists (i.e. G4QMD or INCL/ABLA)

Three different approach for the definition of the physics models

- The User can construct his/her own files specifying each process-model (Not suggested)
- The User can use the Physics Lists
'`/physic/addPhysics`' command
- The User can use the Reference Physics Lists
'`/physic/addPackage`' command

Please give a look into the `HadrontherapyPhysicsList.cc` class file

Physics models in Hadrontherapy

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- Great simplification of the physics classes contained in the Hadrontherapy folder
- We strongly suggest the use of Physics Lists and Reference Physics Lists for a minor risk and for a strong feedback to developers.
- Not all models are available with Physics Lists (i.e. G4QMD or INCL/ABLA)

Three different approach for the definition of the physics models

- The User can construct his/her own files specifying each process-model (Not suggested)
- The User can use the Physics Lists
'`/physic/addPhysics`' command
- The User can use the Reference Physics Lists
'`/physic/addPackage`' command

Please give a look into the `HadrontherapyPhysicsList.cc` class file

Physics models in Hadrontherapy

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- Great simplification of the physics classes contained in the Hadrontherapy folder
- We strongly suggest the use of Physics Lists and Reference Physics Lists for a minor risk and for a strong feedback to developers.
- Not all models are available with Physics Lists (i.e. G4QMD or INCL/ABLA)

Three different approach for the definition of the physics models

- The User can construct his/her own files specifying each process-model (Not suggested)
- The User can use the Physics Lists
'`/physic/addPhysics`' command
- The User can use the Reference Physics Lists
'`/physic/addPackage`' command

Please give a look into the `HadrontherapyPhysicsList.cc` class file

Physics models in Hadrontherapy

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- Great simplification of the physics classes contained in the Hadrontherapy folder
- We strongly suggest the use of Physics Lists and Reference Physics Lists for a minor risk and for a strong feedback to developers.
- Not all models are available with Physics Lists (i.e. G4QMD or INCL/ABLA)

Three different approach for the definition of the physics models

- The User can construct his/her own files specifying each process-model (Not suggested)
- The User can use the Physics Lists
'**/physic/addPhysics**' command
- The User can use the Reference Physics Lists
'**/physic/addPackage**' command

Please give a look into the `HadrontherapyPhysicsList.cc` class file

Physics models in Hadrontherapy

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- Great simplification of the physics classes contained in the Hadrontherapy folder
- We strongly suggest the use of Physics Lists and Reference Physics Lists for a minor risk and for a strong feedback to developers.
- Not all models are available with Physics Lists (i.e. G4QMD or INCL/ABLA)

Three different approach for the definition of the physics models

- The User can construct his/her own files specifying each process-model (Not suggested)
- The User can use the Physics Lists
'**/physic/addPhysics**' command
- The User can use the Reference Physics Lists
'**/physic/addPackage**' command

Please give a look into the `HadrontherapyPhysicsList.cc` class file

Our actual choice in Hadrontherapy

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

Suggested physics models for most Medical applications

- Physics Lists approach
 - `/physics/addPhysics standard_opt3;`
 - Validation with the G4EmLivermorePhysics of 9.3 beta version is currently ongoing
 - `/physics/addPhysics elastic;`
 - `/physics/addPhysics binary;`
- Reference Lists approach:
 - `/physics/addPackage QGSP_BIC_EMY`
- The last one is a QGSP_BIC but with the G4EMStandardPhysics_{opt3}

Our actual choice in Hadrontherapy

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

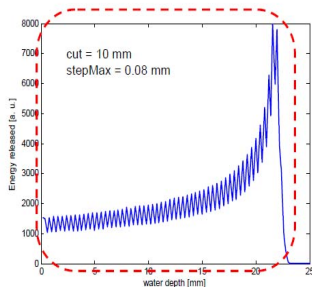
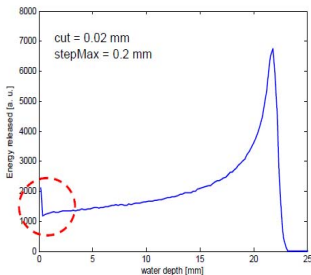
Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- Non physical results can occur for big values of cut threshold and step max if Read Out Geometry is used
- 50 MeV proton beam in water. Slice thickness of 200μ .



This happens as the Read out Geometry does not force the step.

Our actual choice in Hadrontherapy

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

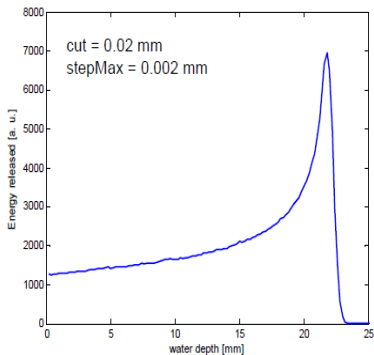
Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- We suggest a Max step value not bigger than the 5% and a cut value not bigger than 10% then the slice thickness

O.K. !!!



Thanks to Dr. F. Romano for investigating this

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- A good accuracy must be reached (i.e. $\leq 5\%$ in the uniformity of the dose distribution, etc.)
- monoenergetic Bragg Peak (1 millions of histories)
 - 6 hrs
 - 2 hrs with a geometry based variance reduction
- modulated Bragg peak
 - from 150 hrs to 45 hrs
- Phase space file is a need we'll provide in the future
- Geometrical variance reduction are User dependent in the beam line but we can make work in the phantom

Simple beam line methods to retrieve basic parameters

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- Stopping power calculations with very simple geometric configuration in SRIM style: just insert a set of energies and retrieve the stopping power table
- Use of the NIST Total Stopping power tables for the verification of stopping powers in elements and compounds
- Use of the `ComputeDEDX()` method (not `GetDEDX()`) to retrieve stopping powers independently by the imposed simulation cuts

Geant4 Stopping powers vs NIST: Elements

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2
Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

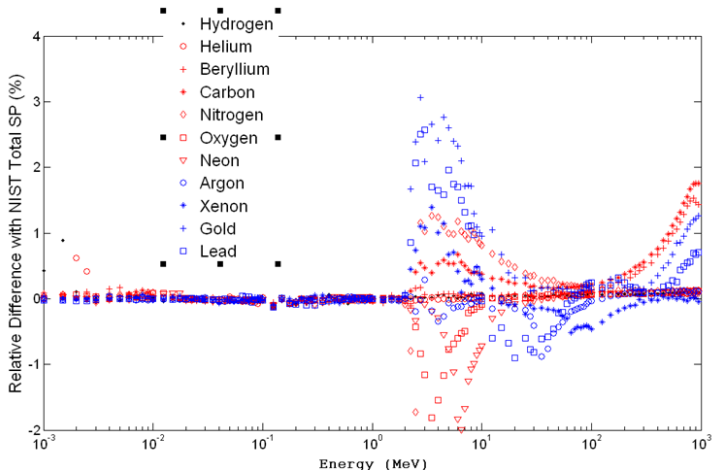
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



Geant4 Stopping powers vs NIST: Compounds

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2
Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

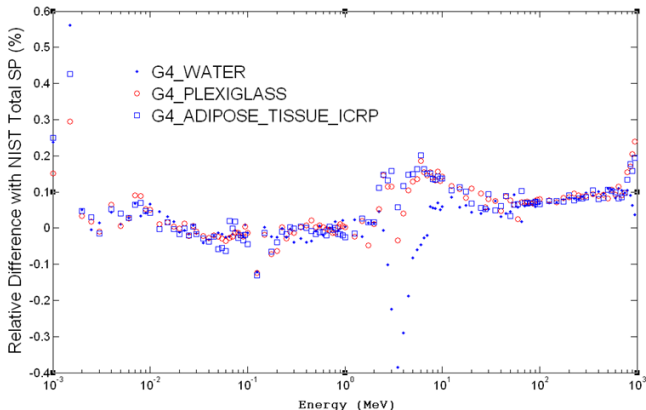
New physics
solution

Other features
added or in
progress

**Stopping powers
calculation**

Linear Energy
Transfer (LET)

Minor adds



Thanks to Enrico Mazzaglia for add this feature

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

- We are implementing methods to calculate Linear Energy Transfer (LET) in both proton and carbon beams
- LET values and fluences are essential parameter for the estimation of radiobiological models
- class for LET calculation will be inserted for the use with Hadrontherapy in the next future (June 2010)
- Radiobiological models is the next step

Linear Energy Transfer: monoenergetic protons; Medical Physics, Vol.30, No.5, May 2003

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2
Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

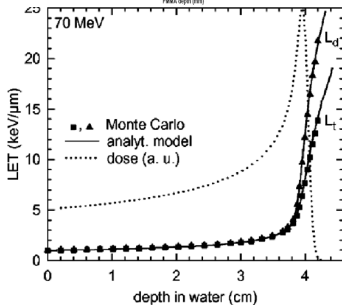
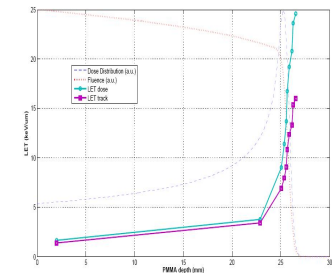
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



Linear Energy Transfer: monoenergetic protons; Medical Physics, Vol.30, No.5, May 2003

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2
Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

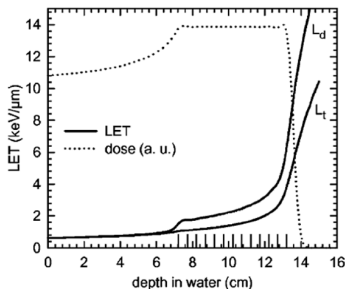
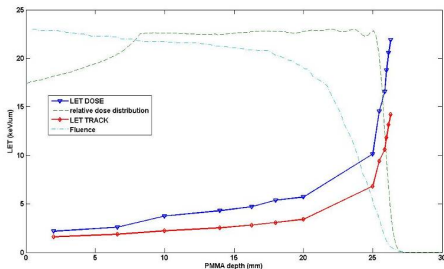
New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



Linear Energy Transfer for Carbon beam

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

**Linear Energy
Transfer (LET)**

Minor adds

This case, that is more complicated for the fragments contribution is also under study.

LET calculation of ^{12}C and fragments are in progress

Thanks to F. Di Rosa for investigating and test these issues
Also follow the talk of Ivan Petrovic in the next session

- Graphical User Interface using the interface with the QT libraries
 - User will be able to perform the main operations (set of particle, energy, histories, etc) graphically
 - We are working for include this in the next release but we are not sure
- New README file approach
 - README in a Google document, open to all Developers that can modify and improve it
 - The README file is also accessible from the web:
<http://g4advancedexamples.lns.infn.it/examples-list-folder/hadrontherapy>
 - More flexible and in manual configuration
 - The pdf is inserted in the release
- Folders are added containing experimental data and ROOT scripts for comparisons
- User can immediately run a simulation with a recommended macro, run a ROOT script (if ROOT is installed) and see the comparison with a set of reference data

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

README file of Hadrontherapy, a Geant4 application for proton and ion radiotherapy

HADRONTHERAPY

a Geant4-based application for proton and ion radiotherapy

I. [AUTHORS](#)

- [Main Authors](#)
- [Contributing Authors](#)
- [Past contributors](#)

II. [HADRONTHERAPY: WHAT IT IS, WHAT IT DOES AND WHAT IT WILL PROVIDE](#)

- [Folder structure of Hadrontherapy](#)
- [Description of the \macro folder](#)
- [Future challenges](#)

III. [DOWNLOAD AND INSTALLATION](#)

- [SOFTWARE SET-UP](#)
- [Environment variables](#)

IV. [GEOMETRICAL SET-UP.](#)

- [The water phantom to collect informations](#)
- [The Proton passive beam line class file](#)
- [Alternative geometry for the IAEA benchmark](#)

V. [PHYSICS](#)

- [Approach 1:](#)
- [Approach 2:](#)
- [Approach 3:](#)

VI. [INTERACTIVE COMMANDS](#)

- [Visualisation](#)
- [How to run the example](#)

VII. [SIMULATION OUTPUT](#)

- [ASCII file](#)
- [Setting the name of the output file](#)
- [Use of the AIDA interface](#)
- [Use of the ROOT analysis](#)

G.A.P.Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds



[home](#)
[Protected](#)
[pagina](#)
[discussion](#)
[history](#)
[notify me](#)

G4EMU

The [Geant4](#) European Medical User Organization

A meeting place for the rapidly growing Geant4 medical user community of Europe and Geant4 developers

What G4EMU is:
The idea of G4EMU was launched in 2006 by Aatos Heikkinen and Pablo Cirrone with the aim of space for the European Medical Physics community that uses Geant4 as simulation tool.

The principal scope is to bring together this community in order to make easier the scientific exchange of issues and practical advices and to contribute to the development of new collaborations and a toolkit.

The main characteristic of this community want to be the full-opening for everyone who share his/her experience.

The G4EMU idea want closely follow the philosophy of the analogous G4NAMU for the North America.

The G4EMU community actually communicates using this wiki, and a mailing list will be soon available. Everyone interested can join to G4EMU and can modify and add contents to these pages. To join send an e-mail to [Pablo Cirrone](#).

In the next future new G4EMU web page will be released and a web space will

Azioni

- Iscriviti a questo Wiki
- Cambiamenti Recenti
- Gestisci Wiki

Cerca

Navigazione

Home

- GEANT4
- GEANT4 MEMBERS
- GEANT4 MEDICAL RESOURCES
- MONTE CARLO IN RADIATION TREATMENT
- ARTICLE COLLECTIONS
- EUROPEAN GROUPS
- MEDICAL APPLICATIONS



Rank: 6 (max 50)
Tot. visits: 2311

G.A.P. Cirrone
cirrone@lns.infn.it

Advanced
Examples and
Hadrontherapy

Hadrontherapy
in Geant4 9.2

Hadrontherapy
in Geant4 9.3

The new
geometry
solution

Thin and thick
target
benchmark
studies

New physics
solution

Other features
added or in
progress

Stopping powers
calculation

Linear Energy
Transfer (LET)

Minor adds

THANK YOU

$$L_t(\mathbf{x}) = \frac{\int_0^\infty \varphi_r(\mathbf{x}) S(r) dr}{\int_0^\infty \varphi_r(\mathbf{x}) dr}$$

$$L_d(\mathbf{x}) = \frac{\int_0^\infty \varphi_r(\mathbf{x}) S^2(r) dr}{\int_0^\infty \varphi_r(\mathbf{x}) S(r) dr}$$