Latest developments in GAMOS

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International Conference on Monte Carlo Techniques for Medical Applications (MCMA 2017)

Outline

- Introduction
  - *MC applications*
  - *An easy and flexible framework*
- DICOM management
- Protontherapy tutorial
- Radiotherapy geometry modules
- GAMOS from a web browser
- Code robustness
- Summary

MC applications

- Often the use a MC simulation is a difficult task for a non-expert software user
  - In the case of Geant4 most of the application has to be written in C++

- **Several applications try to facilitate the use of MC in a specific field**
  - Providing an scripting language tailored to the field

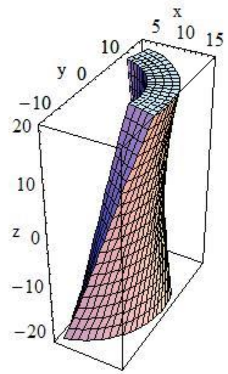
MC applications

But users find some problems with these applications

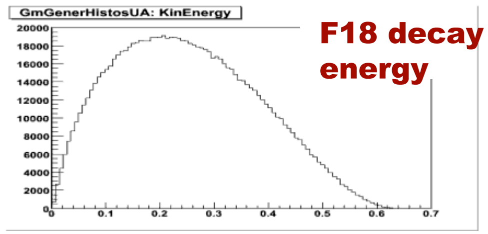
1. User wants to **describe some input** not included in the application
   - A peculiar volume shape, a new primary generator position distribution, some option in the physics,…
2. User wants to have some kind of output or **detailed information** to debug or understand some part of the simulation, and the application only provides a **limited amount of output possibilities**
   - Dose from the gammas that entered the phantom with small energy, energy lost by particle traversing a volume as a function of the initial energy, …
3. The available applications **cover a limited amount of physics fields**, and many users do not find an appropriate one for their needs

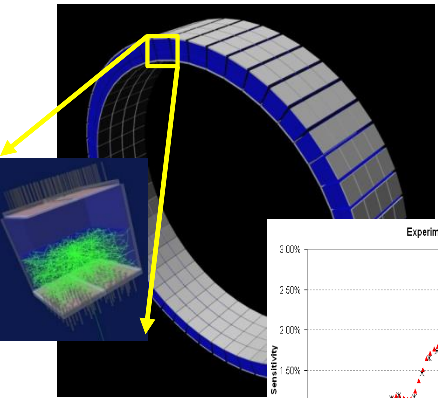
An **easy**…

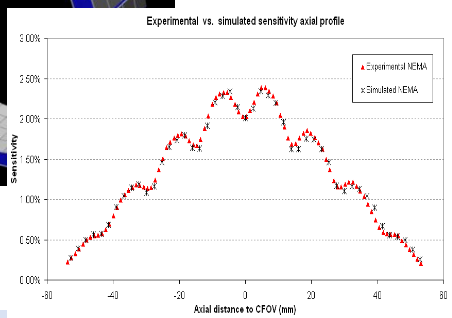
An scripting language, instead of C++, plus many tools to facilitate the definition of input and output

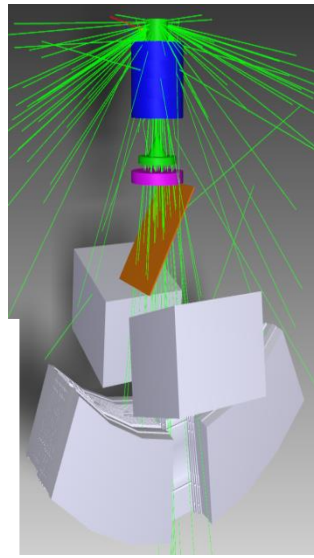


- ✓ Any geometry in a text file format
  - ➢ Including superposition's of parallel geometries
  - ➢ Several modules to define in a few lines the most complicated parts (jaws, multi-leaf collimators, range modulators,…)
- ✓ Dozens of distributions for primary particles: position, direction, energy and time
- ✓ Any available Geant4 physics
- ✓ + 30 scorers, including error calculation
- ✓ Many optimization options



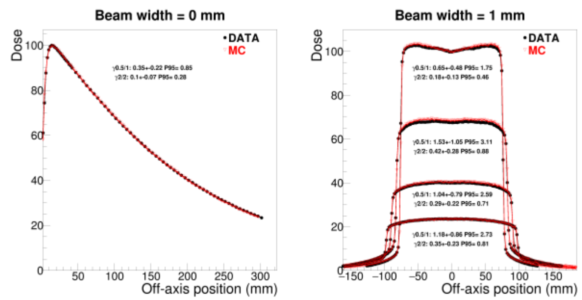




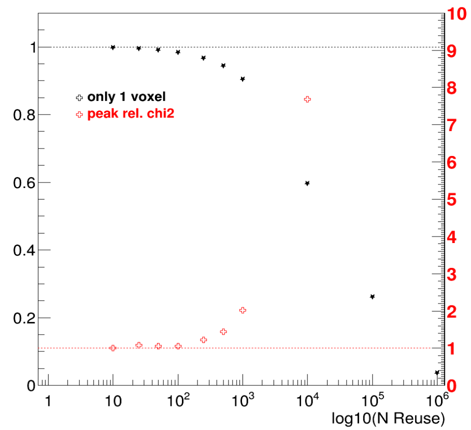


Applications focused of a physics field:

γ/e- radiotherapy,
proton/ion radiotherapy,
PET, SPECT, Compton Camera, tissue optics, γ spectroscopy, shielding



… and flexible framework



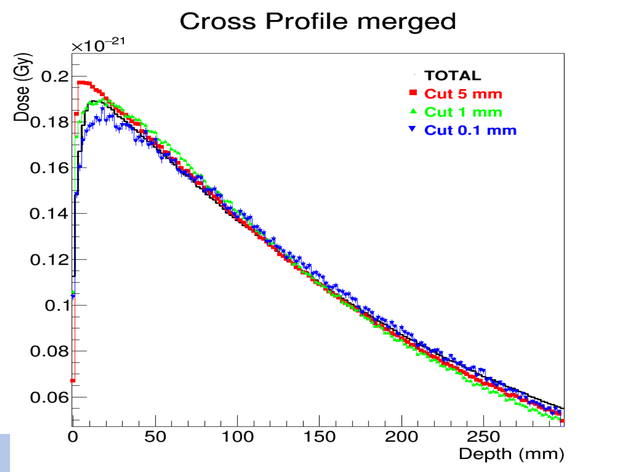
Extensive use of plug-in technology

- ✓ User can easily extend the framework to satisfy a new requirement
- ✓ Any Geant4 example can be transformed into a GAMOS example

Not behaving as a black box, but letting the user understand in detail each aspect of the simulation

- ➢ A new concept, **GAMOS data**, plus the use of **filters and classifiers**, allows to satisfy with a few user commands requirements as complex as:
  - Write in a file the logarithm of the energy of the gammas that reach the phantom only if they have left some energy in the jaws
  - Plot the X vs. Y position of each step in the source volume only if the particle or one of its descendants will reach the detector

Flexible use of the verbosity of each event/track /track step and each package independently

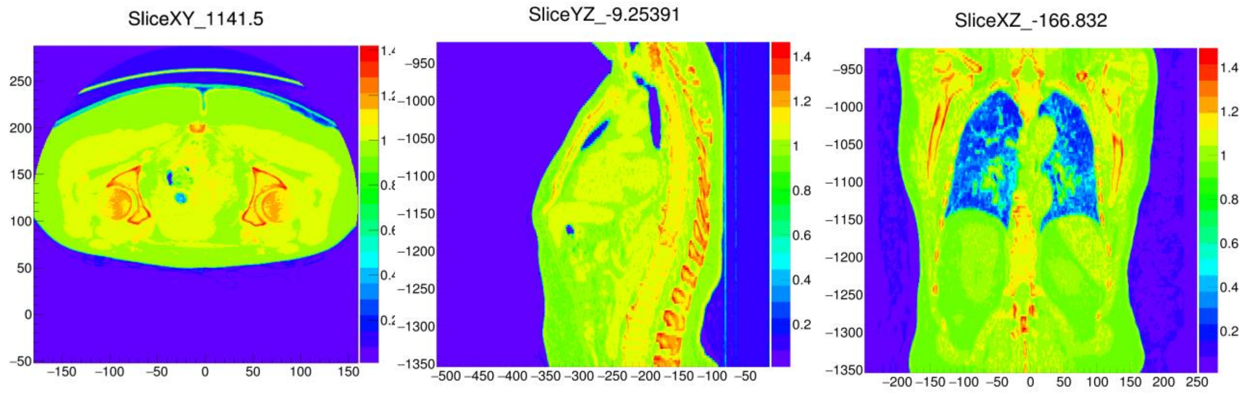


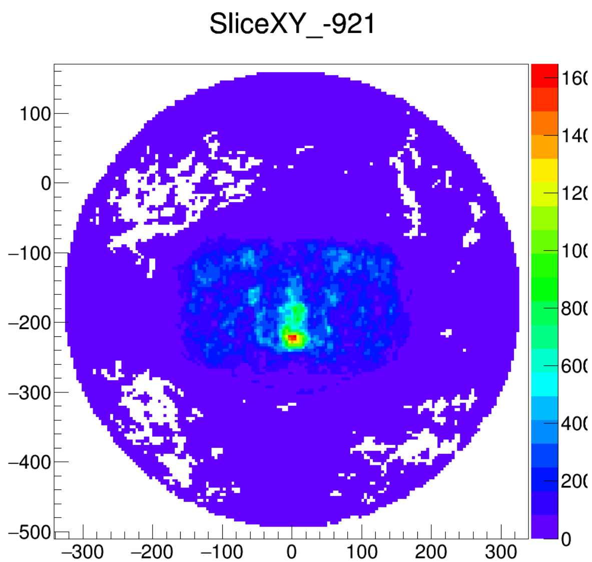
DICOM management

New DICOM data processing based on *DcmTk* software

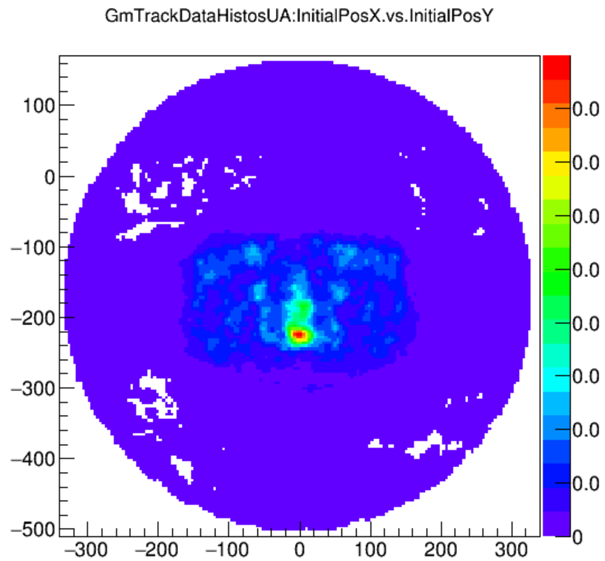
Can process any DICOM CT image, even in compressed format

✓ Tested of dozens of image sets





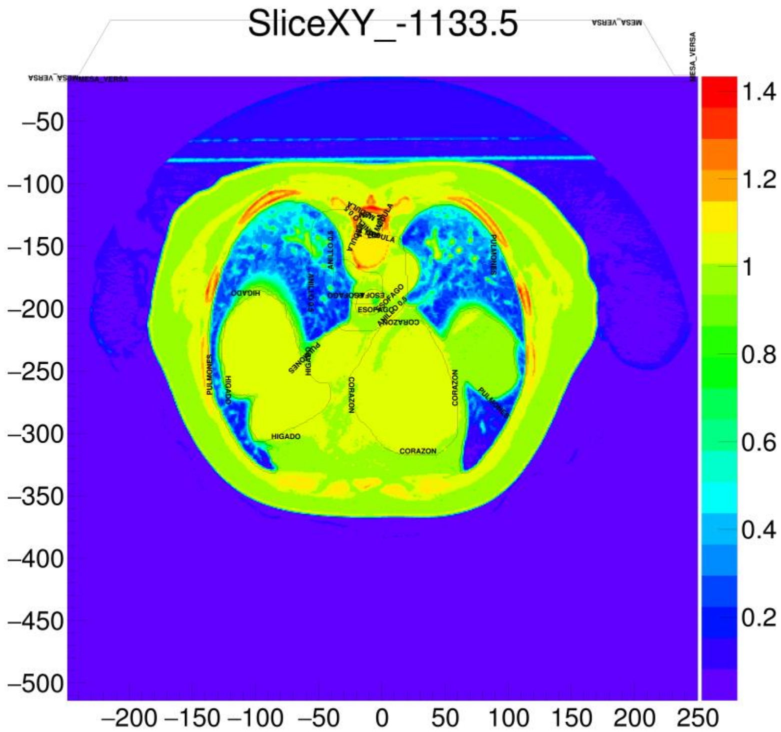
DICOM PET image



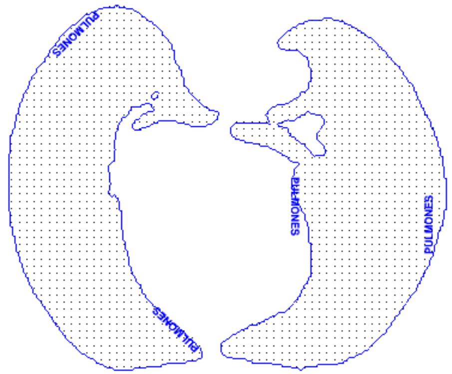
Initial position of GAMOS source particles

Use PET image data as source position

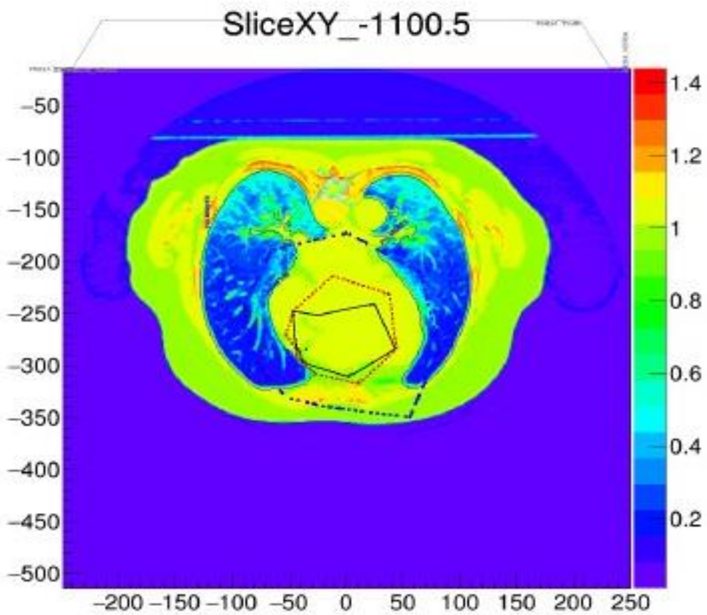
DICOM management



Superimpose RT structures (select line colour, style and width)

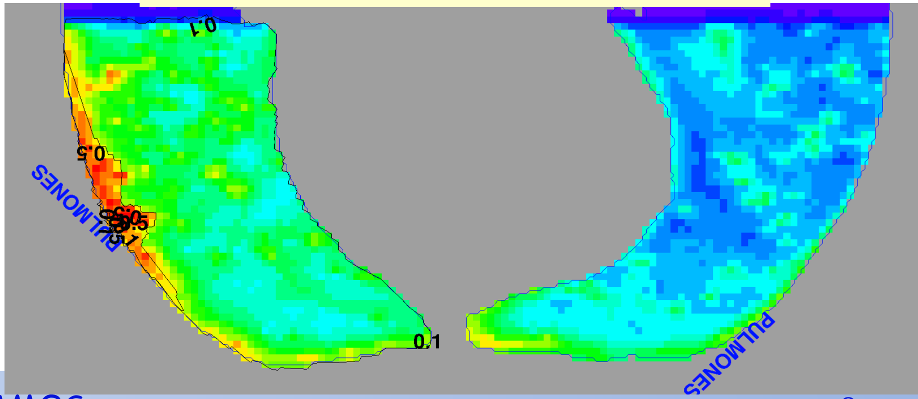


Robust algorithm to identify voxels in structures



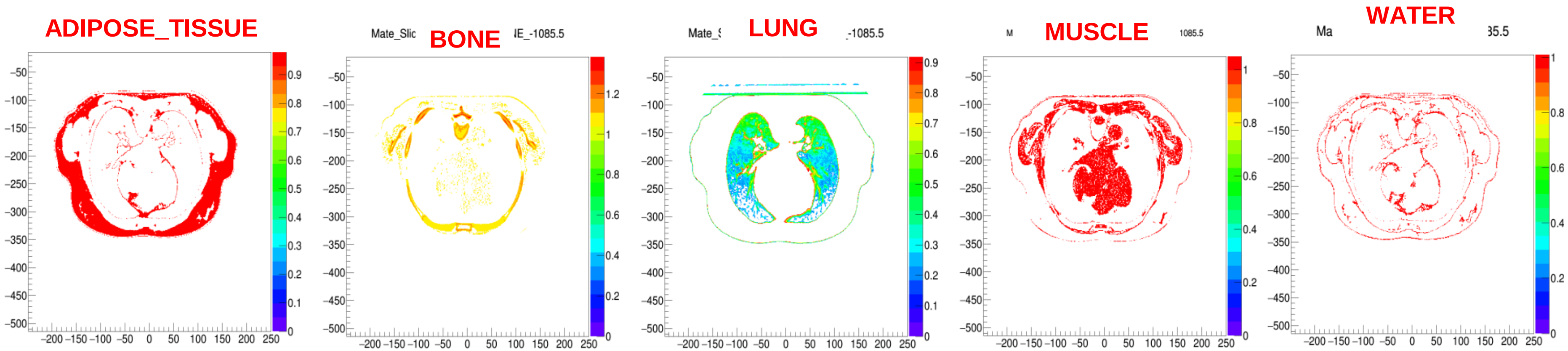
Read RTDOSE and build isodoses lines

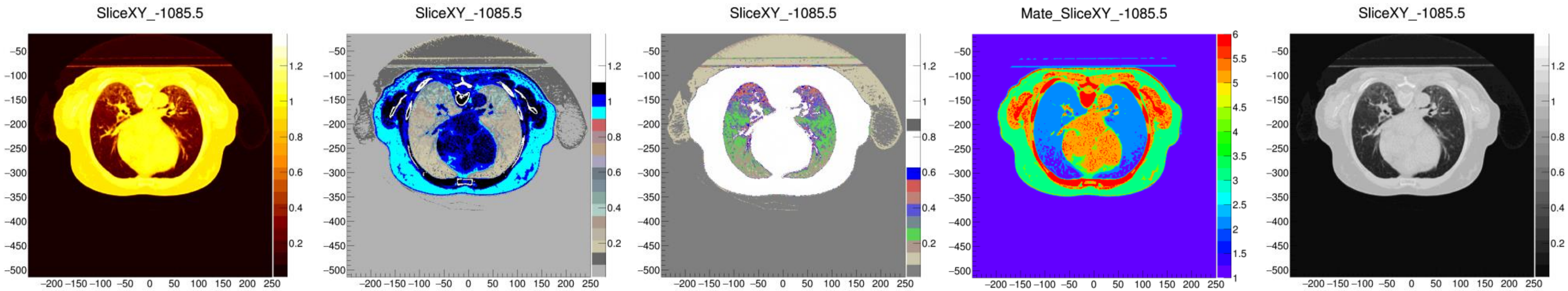
Calculate dose only in selected structures



DICOM management

Draw per material





64 colour palettes

- ❑ Format of the image file: gif (default), png, eps, ps, pdf, svg, xpm, jpg, tiff)
- ❑ Different verbosity levels (silent/error/warning/info/debug/test)

DICOM management

RTPLAN and RTIonPLAN files

✓ Convert DICOM data to text files, readable by Geant4 ASCII format code
⇨ Geometry and beam data is automatically included

RTPlan_1
:P Number 1
:P NumberOfBeams 1
:P NumberOfFractionsPlanned 1

RTIonPlanBeam_1
:P BeamNumber 1
:P NumberOfControlPoints 42
:P NumberOfRangeModulators 0
:P NumberOfRangeShifters 0
:P VirtualSourceAxisDistance 2029.6
:PS BeamType "STATIC“
:PS RadiationType "PROTON"
:PS ScanMode "MODULATED”

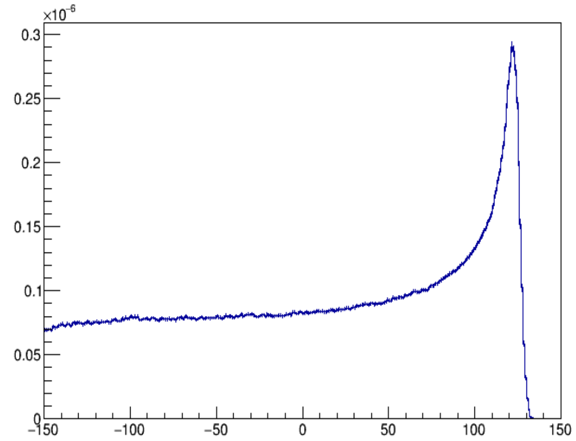
RTIonPlanControlPoint_1_2
:P ControlPointIndex 2
:P CumulativeMetersetWeight 30.7095
:P GantryAngle 270
:P IsocenterPosition_Z 58.5
:P NominalBeamEnergy 195.2
:P NumberOfScanSpotPositions 433
:P ScanningSpotSize 9.44015
:P SnoutPosition 650
ScanSpotPositions
-55.0889 60.6304 0.144369
-48.4519 60.6304 0.152257
…

- ✓ The geometrical parameters can be used directly in the Geant4 ASCII geometry file
- ✓ The beam parameters are managed as a GAMOS Particle Source
  - ➢ **Geometry and source are moved** and **energy changed** after a number of events proportional to the “meterset” of each ControlPoint

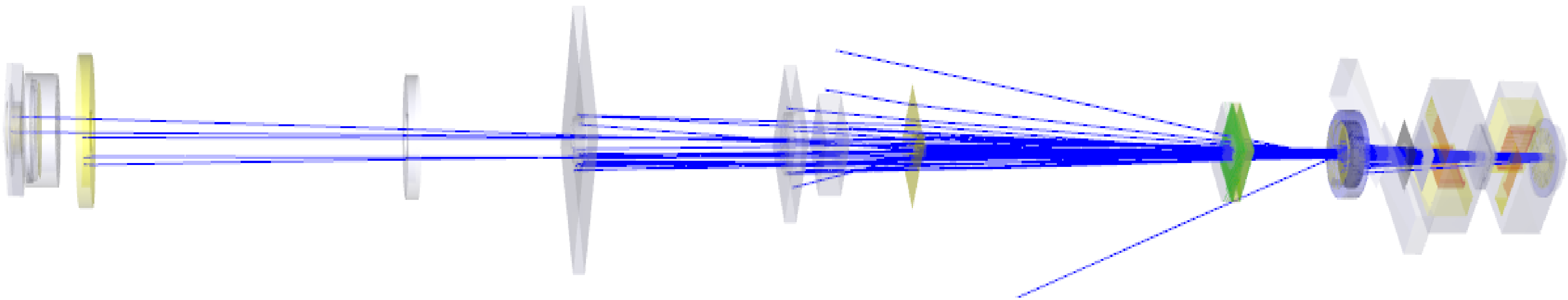
Protontherapy tutorial (E. Mikhailova, UC Davis)

A tutorial meant to make the user self-proficient in proton therapy simulation with GAMOS

- 20 exercises of increasing difficulty
- Should be done following instructions in GAMOS User's Guide…
- … but solutions are given for the user to become self-proficient



- Any ion/proton therapy setup with simple text commands
- Scorers of LET
- Scorers of Relative Biological Efficiency (8 different models)



Radiotherapy Geometry Modules (J.I. Lagares, CIEMAT)

Define complex accelerator parts with a few lines

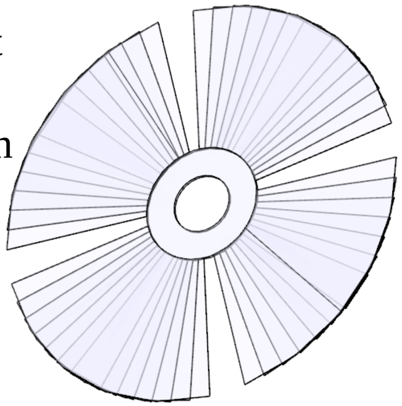
Use radiotherapist point of view

JAWS module:

```
:MODULE JAWS
JAWS_Y  // Name
Y ROUND_DISP // Orientation Leaf_tip_type
10.*cm 10.*cm 40.   / Half-dimensions X/Y/Z
145. 35. // Tip_circle_radius
Tip_circle_centre_Z
12.3 // Half_value_layer
0. 405 100.*cm    // Z_focus Z_centre
Z_isocentre
-10*cm 10*cm  // Field apertures: RIGHT & LEFT
RTUW  ACCEL   // Material Mother_volume_name
```

RANGE MODULATOR module:

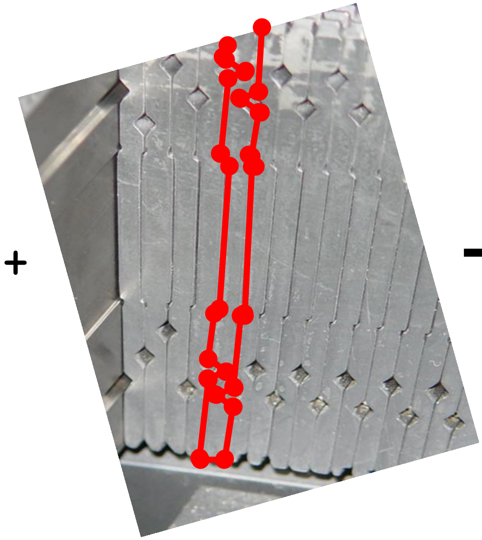
```
:MODULE RANGE_MODULATOR
rangeModulator / Name
85/2 85*2/2 300      // Rcore Rin Rout
4    4    // Nblades  Nsteps
6.5   0.1811111 // thickness angle_span
11    0.12433333
17.1  0.09644444
22.3  0.0953889
```

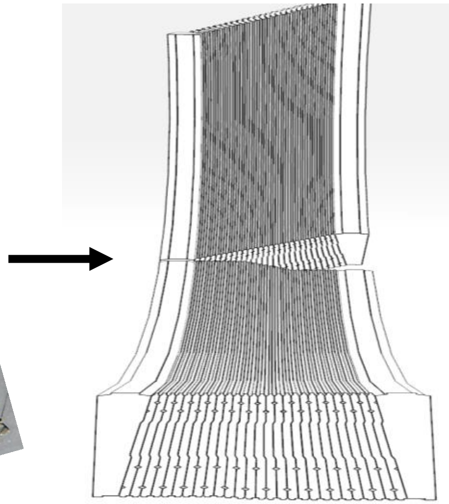


MULTILEAF COLLIMATOR module:

- End leave type Rounded or Straight
- Leaf cross profile as a set of 2D points
- Leaves out-of-focus in cross plane
- Interleaves gap
- Several leaf profiles in one MLC
- Leaves positions calculated from field apertures

+

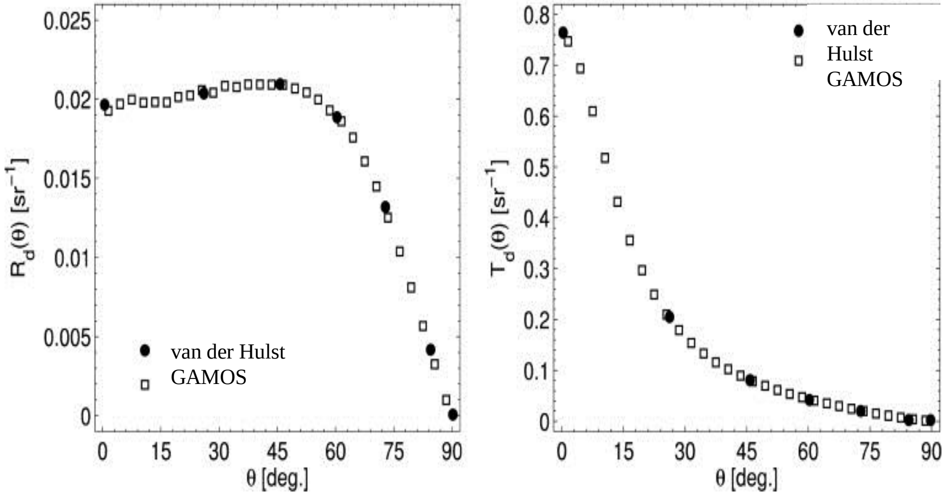




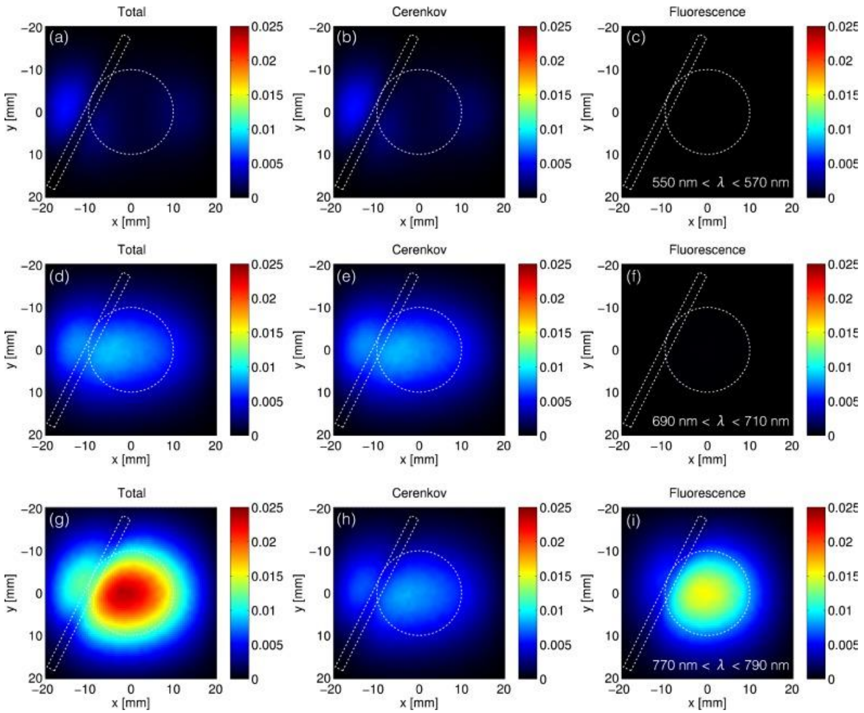
Tissue optics plug-in (A. Glaser, Darmouth Univ.)

- New process for Mie (phase function based upon the Henyey-Greenstein approximation and spectral dependence modulated by the anisotropy)
- Modified Henyey-Greenstein (MHG) scattering (proportional combination of Rayleigh and Mie scattering)

Angularly resolved diffuse reflectance as a function of exit angle



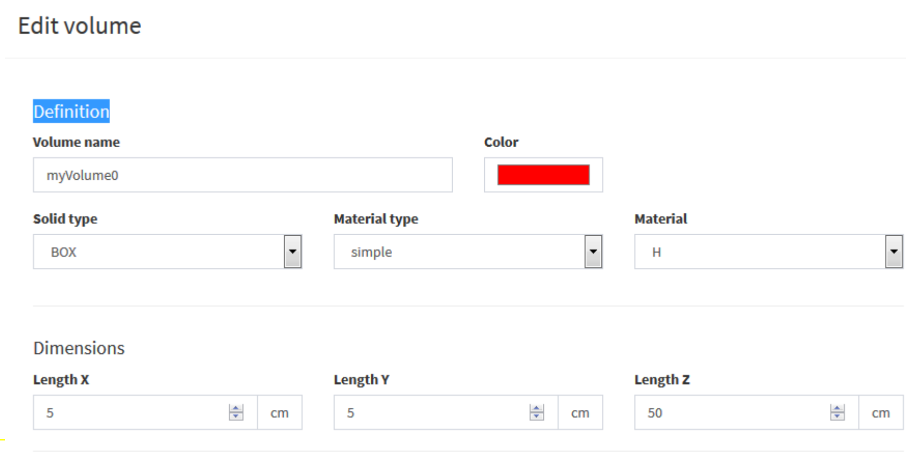
Captured reflectance images for an external radiation beam incident on the tissue volume at different radiation lengths



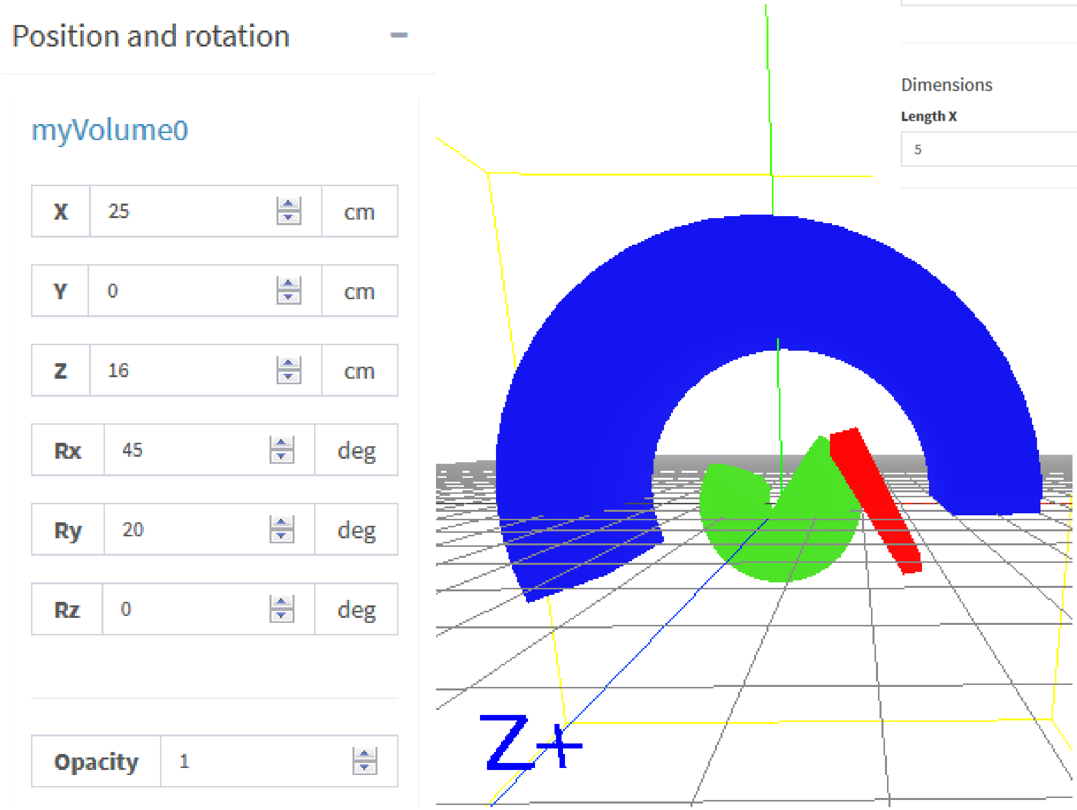
- User-defined scattering process (wavelength-dependent scattering phase function explicitly defined by the user)
- New source distributions

GAMOS from a Web browser (A. Fernández, Guadalinfo)

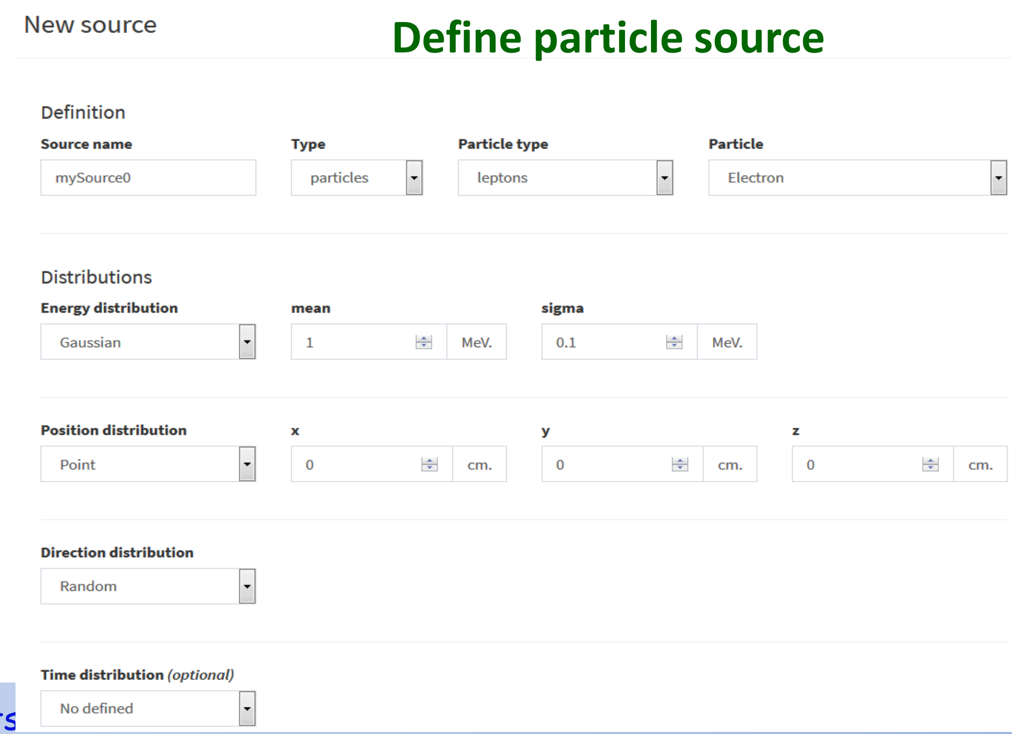
Run GAMOS without installing it!
Interactive tools to define input and output



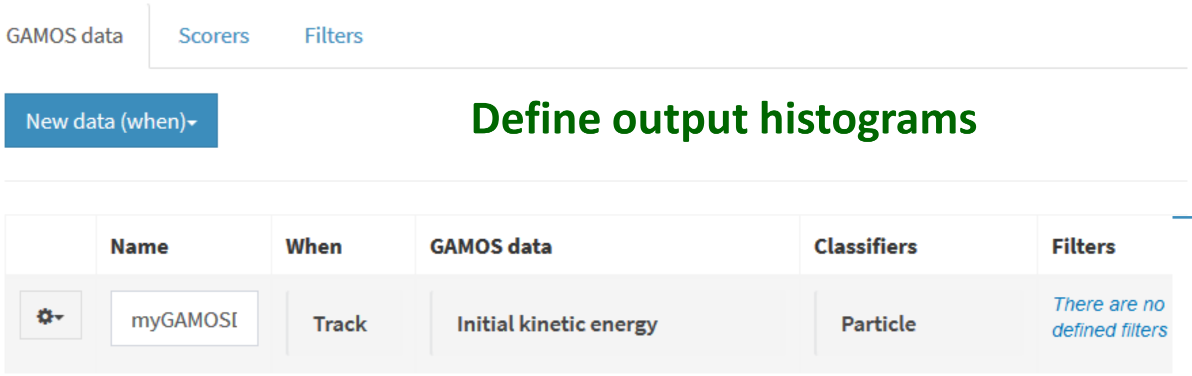
Graphical tool to define and visualize geometry instantaneously



Define particle source

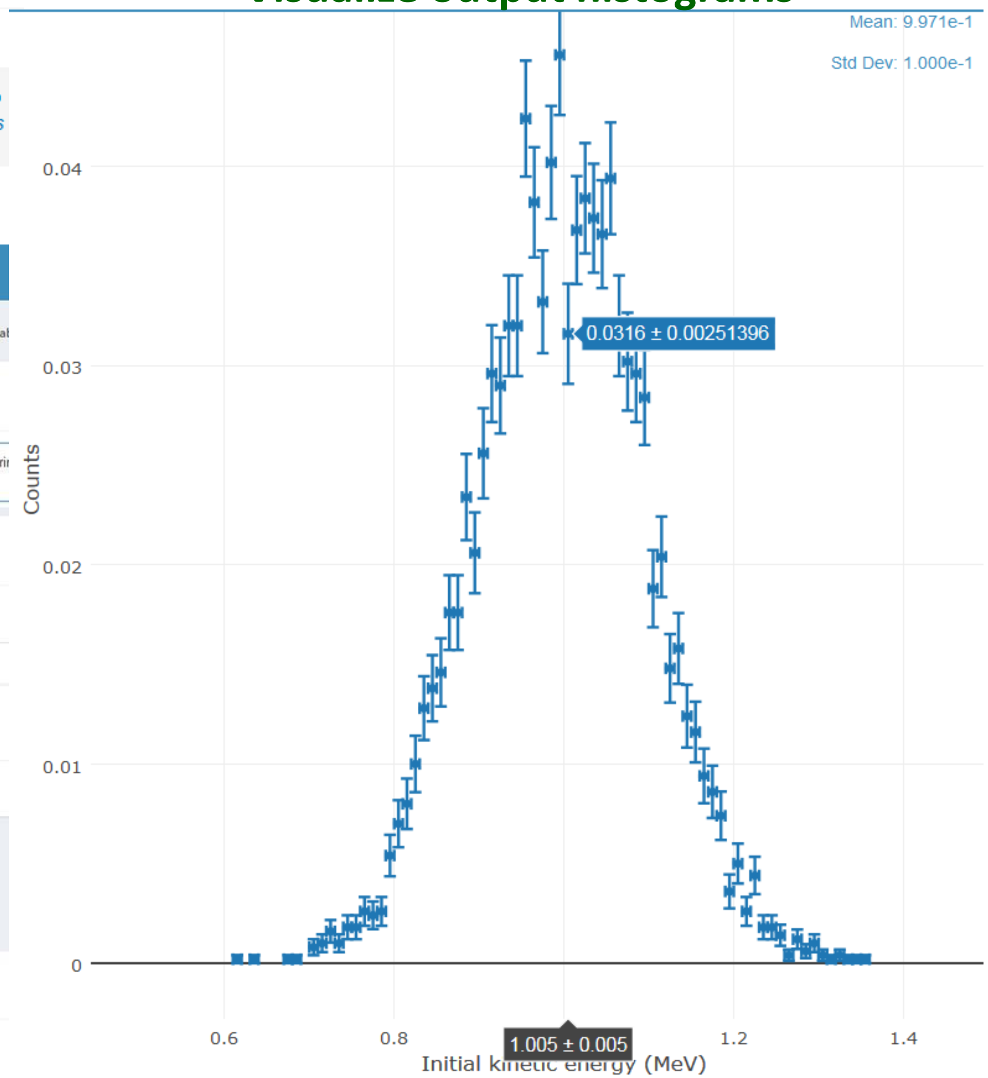


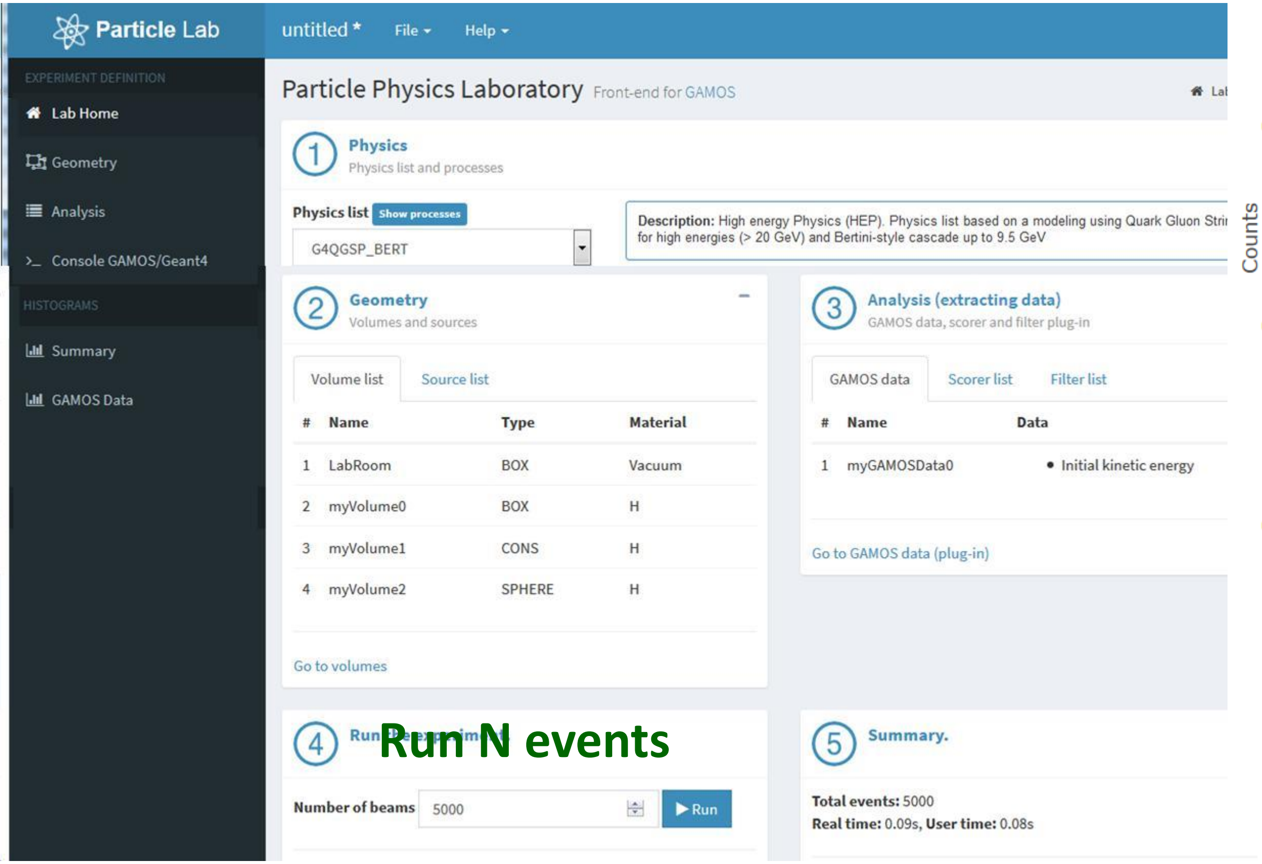
GAMOS from a Web browser



Define output histograms

Visualize output histograms





Run N events

Code robustness

Installation

- Each GAMOS release is tested to be correctly installed in **three different Linux distributions and one MacOS**

Regression testing

- **165 tests** are run to check the stability of the results with respect to previous releases
  - **Automatic statistical test** using a Python-based utility
    - User defines p-value for warning and error
  - Comparison of **over 3,000 variables** and the analysis of **over 8,000 binned Kolmogorov-Smirnov tests of histograms**
  - To help in flattening out the statistical fluctuations, **each test is run 10 times**

Color code: good / warning / bad

Summary

➢ The GAMOS framework has demonstrated to be easy and flexible tool for Geant4 simulations

✓ New functionalities **extend its use in several fields**: DICOM management, ion therapy, tissue optics

✓ New protontherapy tutorial

✓ New tool to use **GAMOS from a web browser**

✓ New tool to check **code robustness**

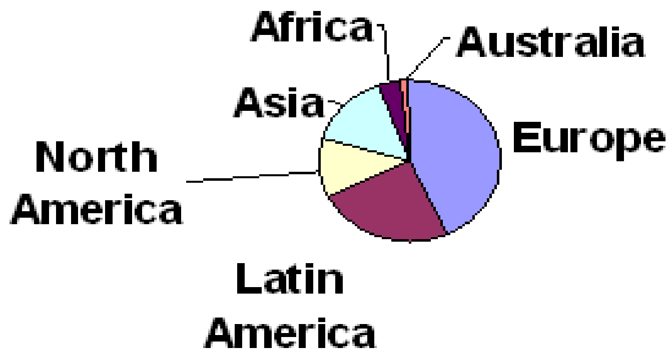
+ 2,500 registered users since August '09

❑ Not only in medical physics

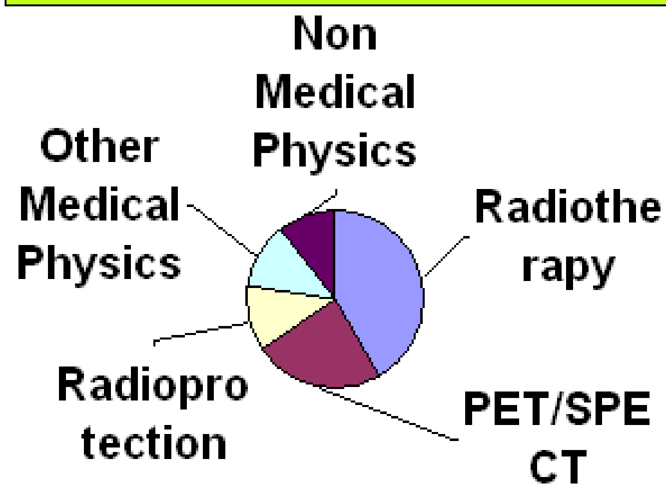
An active community!

+600 conversations with +2,000 messages in GAMOS User's Discussion Forum

Geographical distribution of GAMOS users



Physics fields of interest of GAMOS users



http://fismed.ciemat.es/GAMOS

3rd GAMOS online course:

February 5th – March 2nd 2018

GAMOS plug-in’s

If I want some functionality that GAMOS does not have?

☺ **Best solution for biggest flexibility**: **plug-in’s**

What’s is a plug-in?

It is the same in software that USB in hardware:

The easiest way to add a new device (class), without touching the operative system (framework): no need to install a driver (modify framework classes)

How it works in GAMOS:

- If you want to use, for example, your own physics list instead of one of the GAMOS ones
  - Add one line in **user’s** code

DEFINE_GAMOS_PHYSICS(MyPhysicsList);

  - Code is transformed into a plug-in
  - Automatically it may be selected with a user command

/gamos/physics MyPhysicsList

GAMOS plug-in's

Advantages of plug-in's:

☺ No need to understand how GAMOS works internally (how GAMOS would invoke my code?) or modify GAMOS code

☺ No need to recompile each time I want to alternate between the GAMOS component and my own one

☺ GAMOS has no predefined components: user has full freedom in choosing components

- Any user written code (geometry, primary generator, physics list, sensitive detector, user actions, …) can substitute any GAMOS component while still using the rest of GAMOS utilities
- If you have a working application, you may still use it, while you take profit of the part of GAMOS you like

☺ No restrictions on the way to do things: all Geant4 functionality is available to GAMOS users

Tutorials

Eight tutorials

- ➢ Histograms and scorers tutorial
- ➢ PET tutorial
- ➢ SPECT tutorial
- ➢ Compton camera tutorial
- ➢ Radiotherapy tutorial
- ➢ Shielding tutorial
- ➢ Gamma spectrometry tutorial
- ➢ Plug-in tutorial

- Propose about 10-20 exercises each
  - ❖ Increasing in difficulty
  - ✓ Reference output provided
  - ✓ Solutions provided
  - ⇨ User can do them by her/himself

❑ 18 GAMOS tutorial courses have been given in Europe and America

Documentation

User's Guide:

- Installation
- All available functionality
- How to provide new functionality by creating a plug-in

Software reference manual (doxygen):

- Documentation of the classes and their dependencies

Examples:

- A simple one and a few more complicated ones

test.in:

```
/gamos/setParam GmGeometryFromText:FileName mygeom.txt
/gamos/geometry GmGeometryFromText
/gamos/physics GmEMPhysics
/gamos/generator GmGenerator
/run/initialize
/gamos/generator/addSingleParticleSource my_source gamma 6.*MeV
/run/beamOn 1000
```

and type: `gamos test.in`