“Geant4 for Education” Application

Geant4 Users Conference
November 4 2005, Bordeaux

Hajime Yoshida
Naruto University of Education

Geant4 for Education Workshop

September 12 – 16 , Naruto University of Education, sponsored by KEK program
http://erpc1.naruto-u.ac.jp/~geant4/

After ten years of Geant4, Geant4 is now in the second cycle of its life cycles.
Objective : Not to teach Geant4 but to use it to teach

Participants = Developers and course material creators

Name	affiliation	category	fields/backgrounds
Michel Maire	LAPP, Annecy	Geant4 developer	HEP
Dennis Wright	SLAC, Stanford	Geant4 developer	HEP
Koichi Maruyama	Kitasato Univ.	Geant4 user	medical sciences
Tomoyuki Hasegawa	Kitasato Univ.	Geant4 user	radiological technology
Katsuya Amako	KEK	Geant4 developer	HEP
Takashi Sasaki	KEK	Geant4 developer	HEP
Koichi Murakami	KEK	Geant4 developer	HEP
Go Iwai	JST/KEK	Geant4 user	HEP
Satoshi Kameoka	JST/KEK	Geant4 user	Nuclear Physics
Hajime Yoshida	Naruto UE	Geant4 developer	HEP
Yoshihiro Kawanishi	Naruto UE	Geant4 UI	Technology Education

Michel’s course materials for HEP/NP

- Michel worked as a course material creator
  - Not for Geant4 but to introduce physical concept to students
- Based mainly on the geometry and physics list of the examples/novice/N03 and extended/em/testEms
  - Compton ~10 slides
  - Gamma conversion ~ 25 slides
  - Ionization ~40 slides
  - Em shower ~13 slides etc.
- Courseware including
  - ~38 exercises
  - Histogramming
  - Answers are given in the form of macro files
- Much more interactivities necessary

The Use Case and Requirements：

for medical education

1) Radiation Physics in Medical Education

2) **Simulation Tools for Radiation Physics related Lectures and Laboratories**

1) By Koichi MARUAYAMA

2) By Tomoyuki Hasegawa

Allied Health Sciences &

Graduate School of Medical Science

Kitasato University

Kitasato University

- Private University commemorating
  Dr. S. KITASATO(1853-1931)
  Discovered pest bacillus（ペスト菌）
  Purely cultured tetanus bacillus （破傷風菌）
  Established serotherapy（血清療法）
  Candidate of the 1st Novel Prize for Medicine

- General University of Life Sciences
  - Seven Schools for LS
  - Seven Graduate Schools for LS

Program for RT (Medical Physicist)

-medical, physical and clinical-

Radiobilogy
Radiation Physics
Laboratory in Electrical and Engneering & Electronics
Image Anatomy
Medical Physics
Radiation Detection and Measurement
Radiochemistry
Nuclear Medicine Technology
Medical Imaging Technology
Imaging Equipment
Radiological Equipment (Practice)
Radiation Protection
Radiation Protection (Practice)
Meidical Informatics
Medical Radiation Detection & Measuremnt
Radiation Detection and Measurement(Practice)

Introduction to Patient Care
Radiation Oncology
Radiation Therapy Technology
Radiation Therapy Technology (Practice
Laboratory and Clinical (Practice)
Radiation Therapy Equipment
Digital Imaging System Engineering
Imaging Informatics
Radiation Science(Exercise)
Radiological Technology
Graduation Thesis
Diagonstic x-ray Equipment
Magnetic Resonance Imaging
Digital Imaging Equipment
Medical Imaging Processing
Introduction to Risk Mangement
Clinical Training

Conventional Laboratory Scenes with Radiological Equipments and Machines

Among three,
A) Radiation Detection & Measurement
(3-hour Practice x 13)

- Ten groups of the 3rd grade students practice each week
  - Dose measurement for diagnostic x-rays
  - Proportional, GM counters
  - Activity measurement with a Curie meter
  - NaI(Tl) & HPGe detectors
  - Coincidence measurement etc.
- Presentation by a group of the students at the end of the semester
- Use a EGS4 code provided by KEK

A Special Laboratory Scene with Simulation Tools

- Including under-graduate, graduate students, medical physicists, and radiological technologists

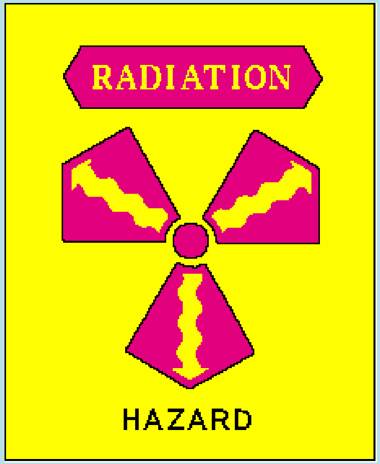
From a Students' Presentation
電子と光子の相互作用
Interaction of electrons and γ

（2班班員） second team

苫米地　修平　　　三反崎 宏美

守谷 芽実　　　八木下 順子

黒川 恭代　　　鈴谷 佳子



背景 background

相互作用の理解を妨げる原因

why the understanding of the interactions is difficult?

→**放射線が目に見えないから！**

Because the radiation is invisible

EGS４

電子と光子の物質中での相互作用をシミュレーション

する計算コード Visualize the interactions

・モンテカルロ※法 What is Monte Carlo method?

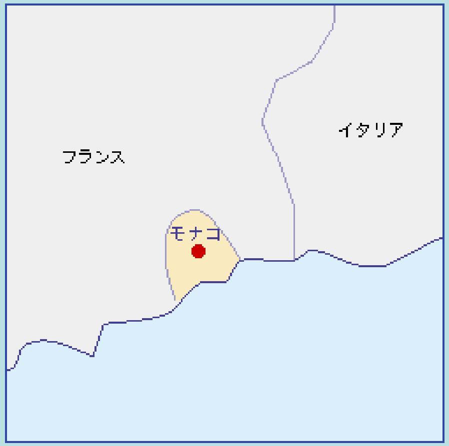
乱数を用いて行う計算

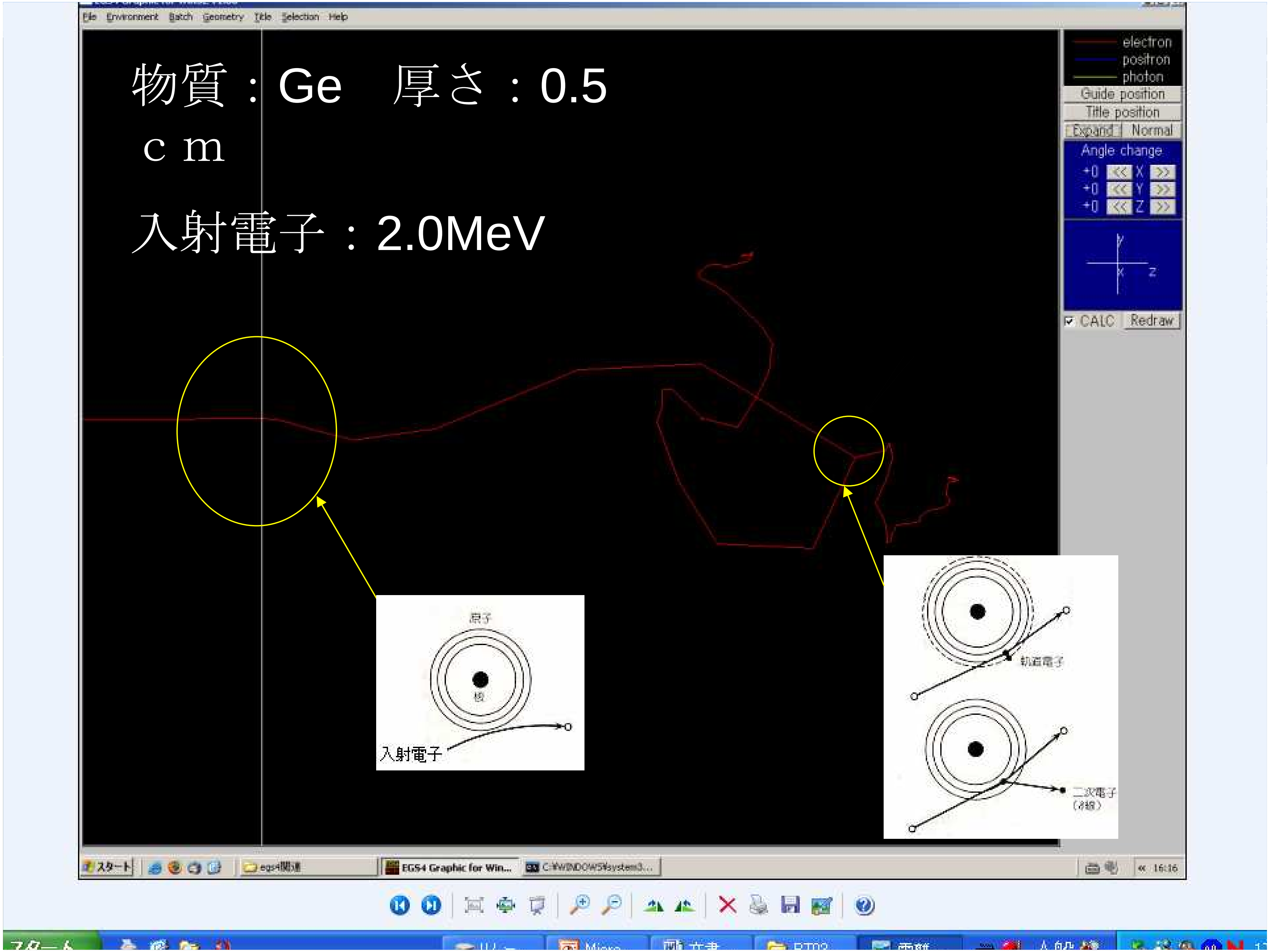
※モンテカルロ

モナコ公国の首都

92年当時の優勝は

A・セナ

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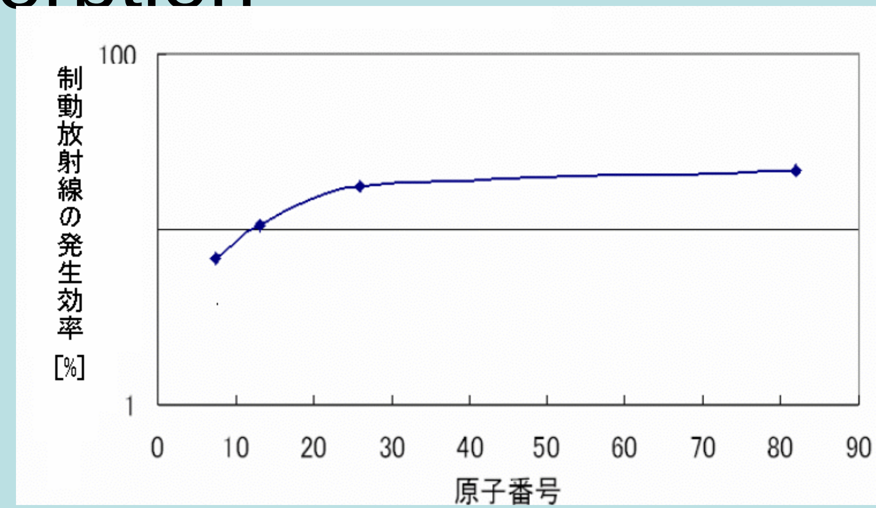
軌道電子
二次電子
EGS4 Graphic for Win...
16:16

制動輻射の効率 efficiency of bremsstralung $\eta \fallingdotseq$ kZV

低原子番号 **from low Z_{eff}**

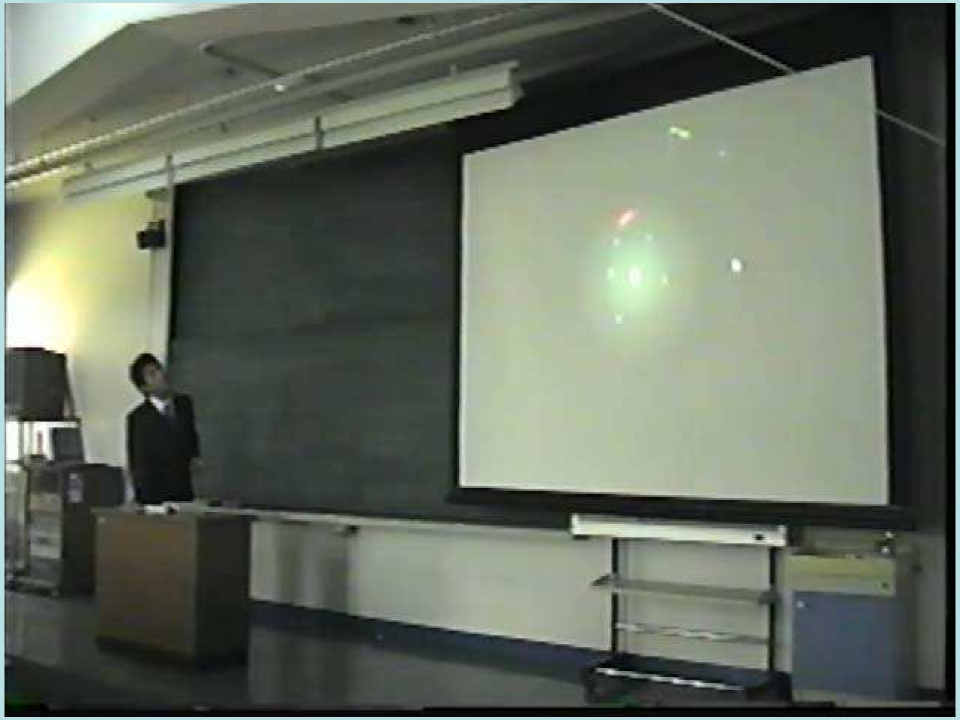
ターゲット内での制動放射線の吸収割合が増える increase of absorption

高原子番号 **to high Z_{eff}**



A Lecture Scene with Multimedia Simulation Tools

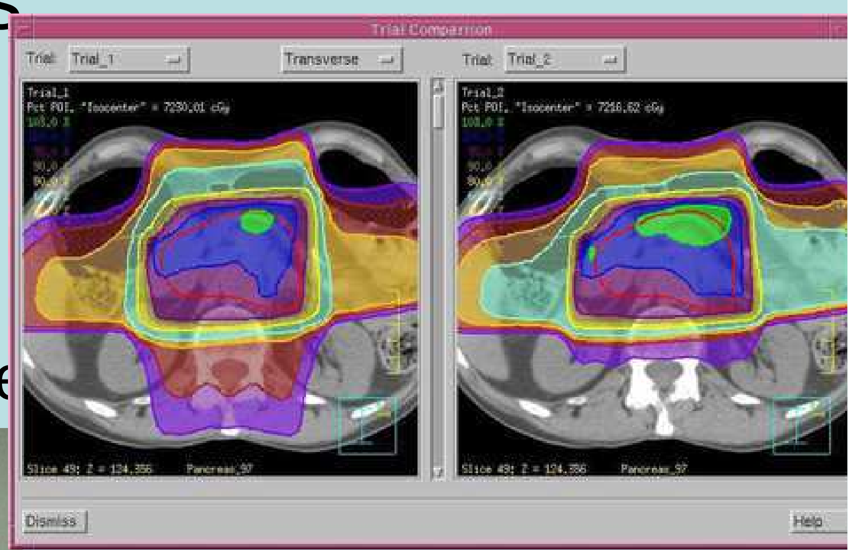
- Some lecture rooms are equipped with a PC and a projector.
- A projector screen and blackboards can be used simultaneously.

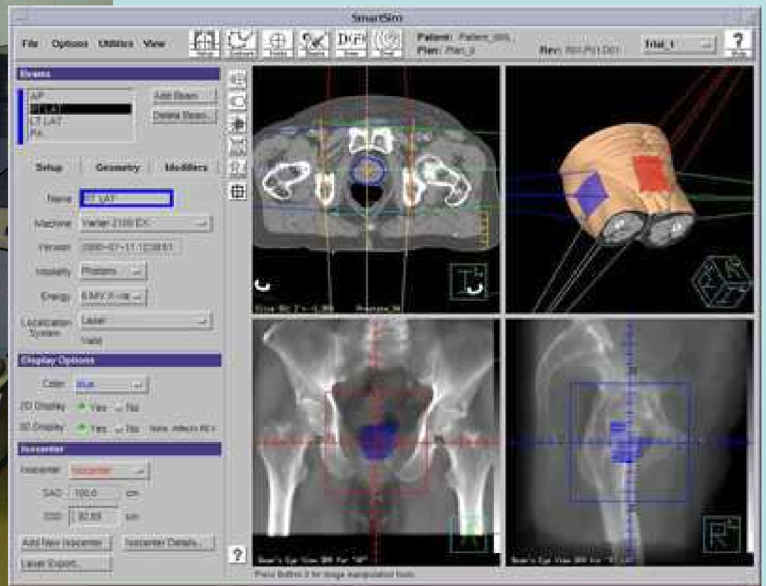


Self-Study and e-Learning Scenes with Simulation Tools

A Laboratory Scene with a Present Simulation Tools

- Radiation Therapy Technology
  - Therapy planning with a commercial software, Pinnacle





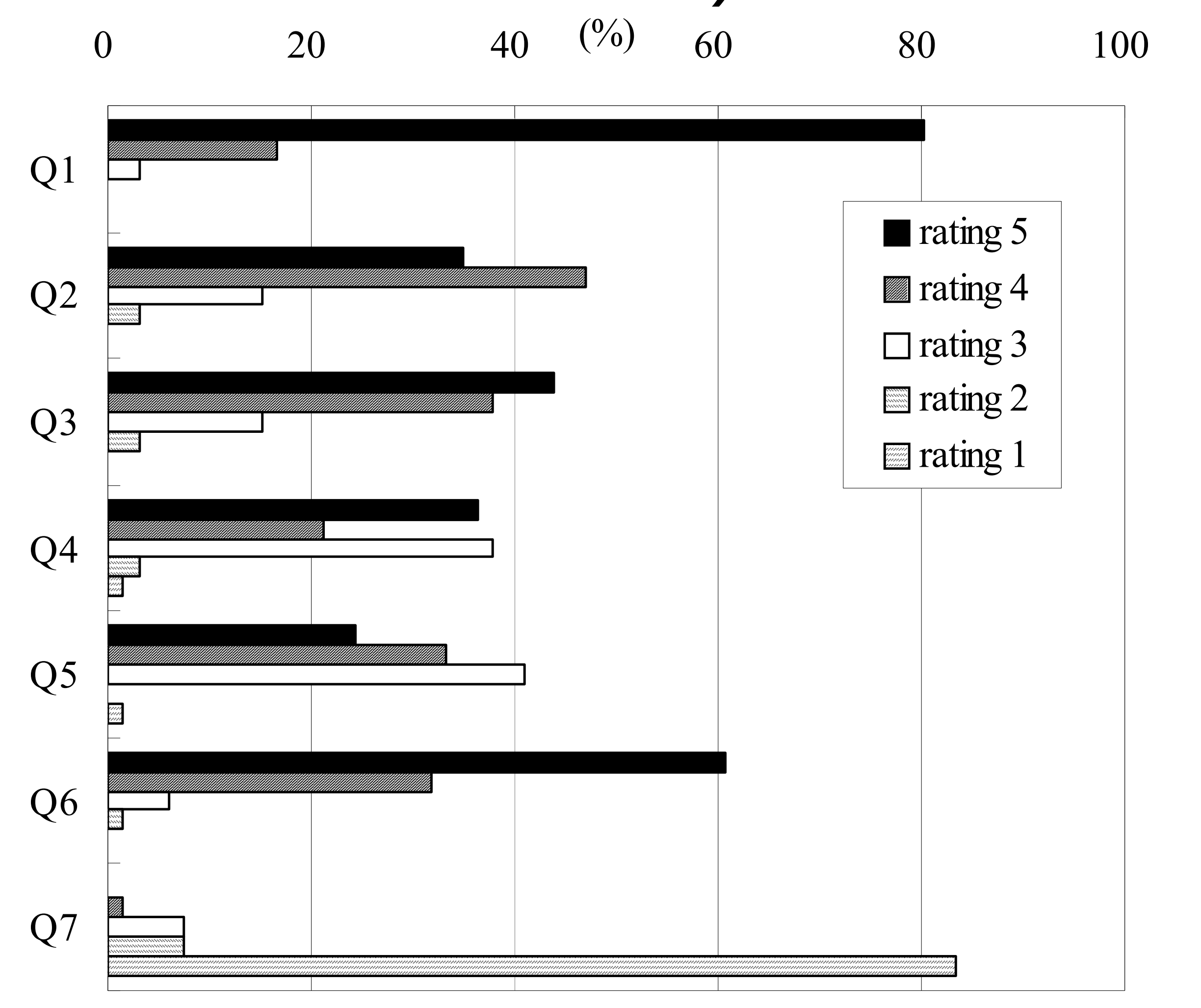
An opinion survey about the usefulness and effectiveness of multimedia educational tools

Questions

1. They are efficient for education and learning.
2. They made me more interested in the subjects.
3. They made me understand the subjects more.
4. They changed the feeling about the medical physics better.
5. They changed the feeling about the radiation better.
6. I recommend them to be used more.
7. I want them not to be used anymore.

- 5 level ratings
  - 5=strongly agree, 4=agree
  - 3=neither agree nor disagree
  - 2=disagree, 1=strongly disagree

A result of a questionnaire about multimedia educational tools (63 students)



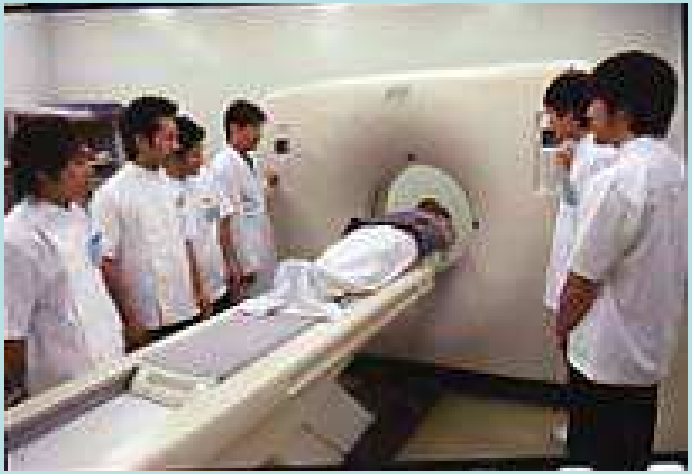
Radiation Equipments to be Simulated

- Radiation Detectors
  - Ionization chamber
  - Proportional chamber
  - GM counters
  - Scintillation detectors
  - etc.

Radiological Equipments to be Simulated

- X-ray Equipments
  - X-ray tube, filaments, rotating anodes, filters
  - image intensifiers, X-ray detectors, grids
  - tube-voltage, contrast, energy spectra, etc.

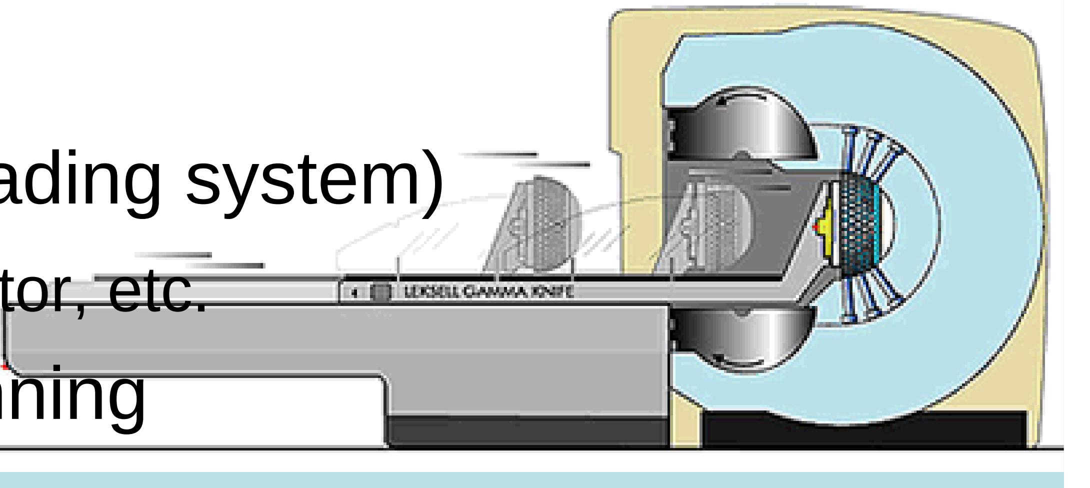
- X-ray CT scanners
  - rotating X-ray tube and detectors
  - tube-voltage, beam hardening, etc.

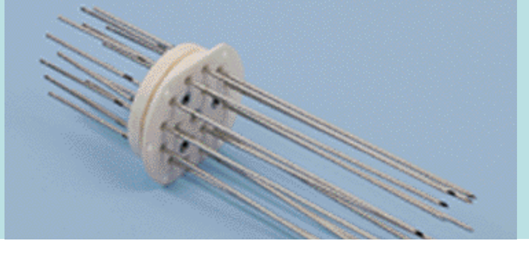


- Etc.

Radiological Equipments to be Simulated

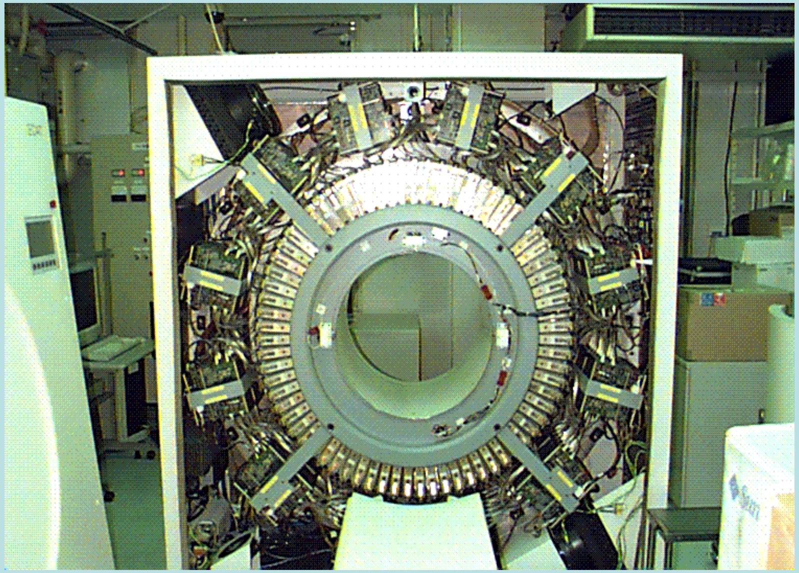
- Linac, Microtron, etc.
  - accelerator, bending magnet
  - target, flattening filter, equalize
  - collimator, etc.
- Gamma knife
  - isotope source
  - collimator helmet, etc.
- RALS (remote after loading system)
  - isotope source, applicator, etc.
- Radiation therapy planning





Radiological Equipments to be Simulated

- Gamma camera, SPECT, PET
  - scintillation detectors
  - collimators, septa, shields
  - phantoms
  - data processing and imaging



Various Phantoms to be Simulated

Summary(1)

Simulation tools are useful for lectures, laboratories, and self-study (e-learning):

- For lectures (handled by teachers)
  - Easy to understand demonstration
  - Some quantitative calculation, etc.
- For laboratories (handled by students and teachers)
  - More quantitative calculation is important, etc.
- For self-study and e-learning (handled by anyone)
  - Better to be a PC program, Easy to handle, Speed, etc.

Could be useful for clinical staffs and researchers as well as students, as a part of the post-graduation education.

Summary(2)

Possible subjects and themes:

- Radiation Therapy, Radiological Technology
  - Interaction of radiation with a body, phantoms and various radiological equipments
  - Energy deposits distribution, Production of secondary particles
  - etc.
- Radiation Physics, Medical Physics
  - Basic interaction of radiation in various materials, including production of secondary particles
  - etc. Simulation in slow motion will be helpful.
- Radiation Measurement and Detection, Radiological Equipment
  - Interaction of radiation in objects and detectors
  - Data processing
  - Imaging
  - etc.
- And so on ………

Thoughts on Education and Geant4 by Katsuya Amako

- Possible approaches to reduce user's hesitation about using Geant4
  - Short/medium term
    - Physics validations
    - Workshops
    - Start a join project
    - Seminars / lectures
    - …….
  - Long term
    - Education of a younger generation
      - This is the main subject of this workshop

- **Education: a longer term**
  - **Write a “good” text book**
    - **It’s a tough job**
    - **It needs to cover radiology, simulation physics, …..**
    - **…….**
  - **Based on an existing “good” text book, demonstrate that Geant4 reproduces basic data quoted in it**
    - **Is this a way worth to pursue?**
    - **Which book is a possible candidate for this?**

Interactivity

Geant4 Python Interface

- for educational use -

K.Murakami

(KEK)

13/Sep/05

Contexts in Educational Application

- We should take care of two user layers;
  - Contents Creators (*teachers*)
  - End Users (*students*)

- For Contents Creators
  - Python interface can wok as component bus.
  - Modularizing, combining, and using components
    - Material / Geometry (predefined geometry / easy geometry setup)
    - Physics list (EM, Hadrons, Ion)
    - Detector response (Calorimeter / Tracker)
    - Analysis packages (ROOT, HBOOK, AIDA, ...)
    - Visualization
    - GUI (Qt, Tk, ...) / Web applications (mod-python, CherryPy)
- For End Users
  - Scripting with Python is NOT essential!
    - Of course, they can play with scripting.
    - They are not necessarily required to learn Python language.
  - GUI / Web applications should be presented.
    - They can be built on the Python interface.

Project Aim of Geant4Py

- Generic and straight forward approach of Pythonization of Geant4
  - not specific to particular applications
  - minimal dependencies of external packages
    - only depending on *Boost-Python*, which is a common, well-established and freely available library.
- To be available in *environments* category

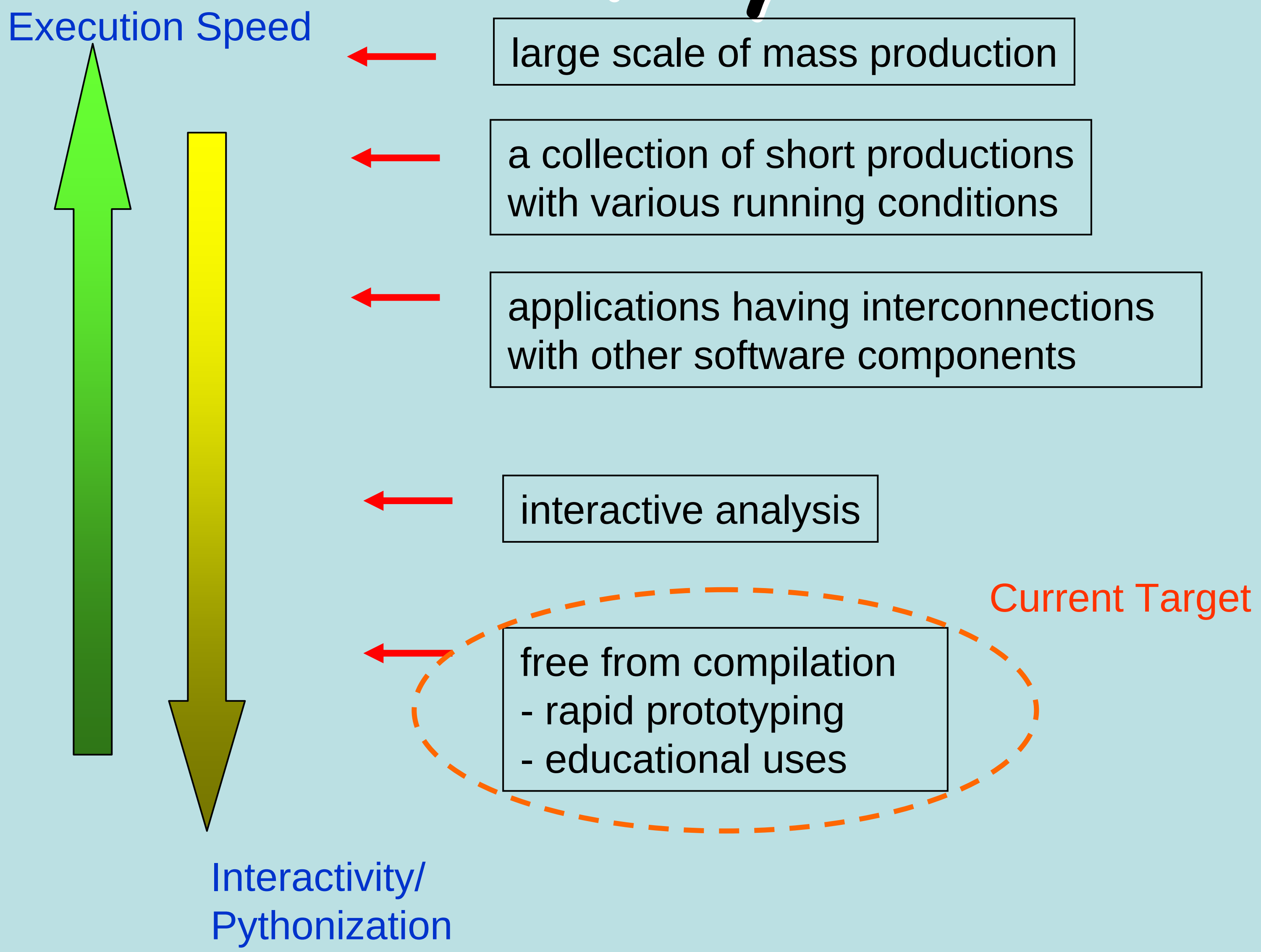
List of Exposed Classes

- **global**
  - G4String
  - G4ThreeVector
  - G4RotationMatrix
  - ...
- **interface**
  - G4UImanager
  - G4UIterminal
- **run**
  - G4RunManager
  - G4VUserDetectorConstruction
  - G4VUserPhysicsList
  - G4UserRunAction
  - G4VUserPrimaryGeneratorAction
  - G4Run
  - ...
- **event**
  - G4Event
  - G4ParticleGun
  - G4UserEventAction
  - ...
- **tracking**
  - G4UserSteppingAction
  - ...
- **track**
  - G4Step
  - G4Track
  - G4StepPoint
  - G4StepStatus
  - G4TrackStatus
  - ...
- **particles**
  - G4ParticleDefinition
  - G4DynamicParticle
  - G4PrimaryParticle
  - G4PrimaryVertex
  - ...
- **geometry**
  - G4VTouchable
  - G4TouchableHistotry
  - G4VPhysicalVolume
  - ...
- **material**
  - G4Material
  - G4NistManager
  - ...
- **visualization**
  - G4VisManager
  - G4VGraphicSystem
  - G4OpenGLStoredX
  - ...

Site-module package

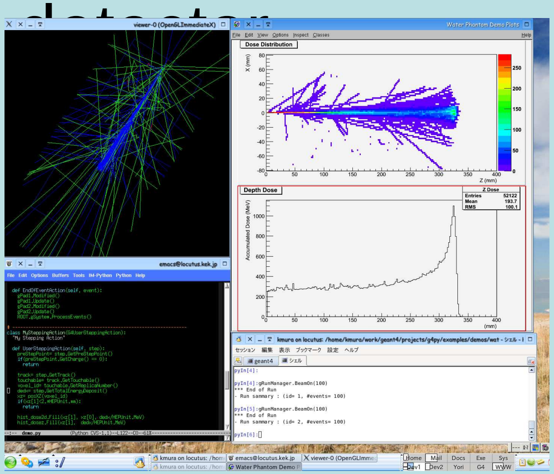
- We will also provide site-module package as pre-defined components.
  - Material
    - sets of pre-defined materials
      - NIST materials via G4NistManager
  - Geometry
    - “exN03” geometry as pre-defined geometry
    - *“EZgeometry”*
      - provides functionalities for easy geometry setup (applicable to target experiments)
  - Physics List
    - pre-defined physics lists
    - easy access to cross sections, stopping powers, ... via *G4EmCalculator*
  - Primary Generator Action
    - particle gun
  - Sensitive Detector
    - calorimeter type
    - tracker type
- They can be used just by importing modules.
- They can be combined and connected to higher application layers (Analysis / GUI components).

Use-case of Pythonization



A Medical Application Example

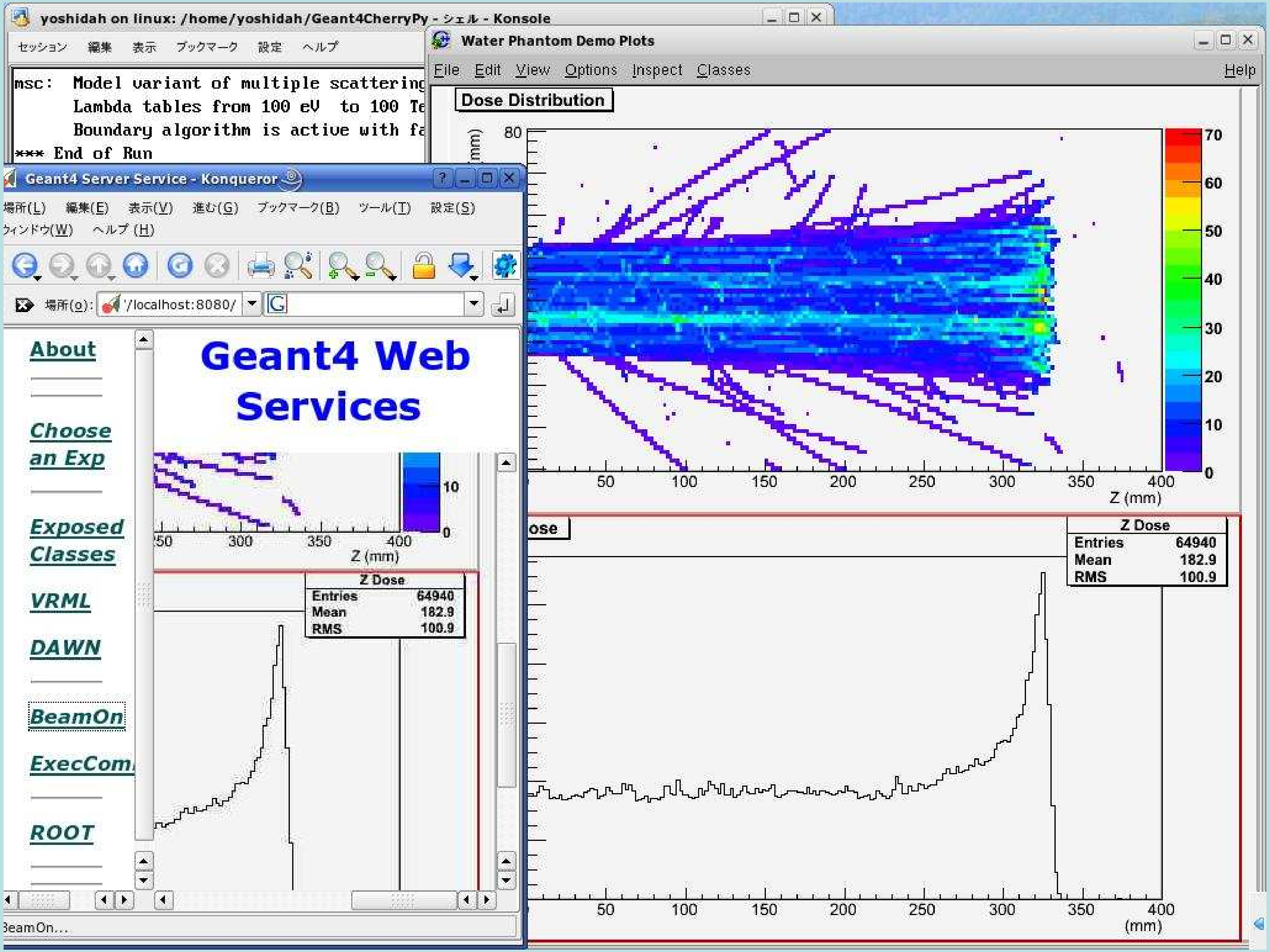
- Several examples of using Python interface are/will be presented.
- An example of “water phantom dosimetry”
  - *This demo program shows that a Geant4 application well co works with ROOT on the Python front end.*
- You can look features of;
  - dose calculation in a water phantom
  - Python implementation of sensitive detector
  - Python overloading of user actions
  - on-line histogramming with ROOT
  - visualization



Proposals for Educational Use

- Resources currently available can be exposed to Python modules, which can be distributed as *pre-compiled* modules.
  - Michel's materials for EM
  - Denis' proposals for Hadrons
  - Medical applications for educational use.
  - Scattered resources can be collected as *an educational module package*.
  - End users will be free from compilation.
- GUI applications should be provided.
  - They can be created based on the Python software bus.
  - Web applications
    - CherryPy (refer to Hajime's talk)
  - TKInter, pyQt, ... are available for building GUI.
- Analysis tools can/should be connected.
  - ROOT/AIDA has Python interface.

Geant4 Web Service
H. Yoshida



Discussions by participants

- Concrete and realistic “standard” geometries must be provided whose geometrical data must be available publicly.
- Some generic geometries which can be customized by teachers will be useful to create their own courseware
- We need interactivities for courseware creators to customize for their own

Geometry subgroup report

Generic detector components for education

List of components for medical education

- Standard ionization chambers
  - Track visualization in and around
  - Build up cap
  - Total number of created ions
- Curie well chamber
- Gamma camera
  - Number of photons
  - Energy spectrum
- PET
- GM counter
  - Track visualization

Geometry subgroup report - HEP and NP

- Tracking
  - Vertex chamber
  - Drift chamber
  - TPC
  - MWPC
- Calorimetry
  - Sampling energy and position
  - Crystals
- PID
  - Cerenkov
  - ToF
  - dE/dX
- Absorbers

Interactivity subgroup

- EZgeometry
  - NISTmanager has been wrapped and Go demonstrated how to exchange a material
  - Implement N02 equivalent using EZgeometry
  - Voxelization and replica are available now
  - CVS repository of g4py and site-modules are available. Users' forum is provided.
  - http://www-geant4.kek.jp/projects/Geant4Py
- Analysis : Excel format is a preferable one?

Ideas for Geant4 Physics Education
- Hadronic physics list -

Dennis Wright (SLAC)

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Naruto University of Education
12-16 September 2005

Navigating Geant4 Hadronics

- Model/Process catalog <= waited by many
  - work in progress
  - will allow a user to find out:
    - which processes may be assigned to which particles
    - which models may be assigned to which processes
    - which cross sections may be assigned to which processes
    - which physics lists use which processes
  - exercise for student:
    - find the appropriate model for anti-proton inelastic scattering at 300 GeV
    - how may processes (hadronic + electromagnetic) are available for elastic proton scattering

How to Build a Physics List (1)

- Space radiation environment toy example
  - understand the physics to be studied: particles, energies
    - cosmic rays: 85% protons, 14% alpha, + C, N, O; most effects in 100 MeV to 20 GeV range
    - Van Allen belts: electrons up to 10 MeV, protons ~10 – 100 MeV
    - solar particles: protons up to a few GeV
    - diffuse gamma background: 0.1 – 200 MeV
  - decide which electromagnetic processes to use
    - refer to novice example N03
    - use e-, e+, gamma processes listed there
    - use N03 processes for p and alpha

How to Build a Physics List (2)

- Space radiation environment toy example
  - decide which hadronic processes, models, cross sections to use
    - G4PhotoNuclearProcess with G4GammaNuclearReaction model
    - G4HadronElasticProcess with G4LElastic model for p, alpha
    - G4ProtonInelasticProcess with G4LEProtonInelastic model
    - G4AlphaInelasticProcess with G4LEAlphaInelastic model
    - default cross sections
  - are unstable particles needed?
    - if so, need G4Decay

Exercises

- Thin target experiment
  - simple box target, mono-energetic beam
  - histogram outgoing angle, energy, multiplicity
  - change energy, models, cross sections -> observe results
- Model tester
  - build a stand-alone application which invokes one hadronic model at a time
  - histogram final state information
- Test beam experiment
  - hadronic calorimeter
  - look at collected energy resolution
  - look at e/pi

Physics subgroup
Physics lists for medical

- A common physics list must be provided -> done!.
- Medical max < 1 GeV
- Start with N03
  - Switching on/off any processes
  - Hadronic processes
    - P elastic, inelastic
    - N elastic, inelastic
    - π
    - Ion
    - Radioactive decays, generic decays
  - Choice of models
    - LEP, Bertine, Binary cascade
  - Process can be turned on one by one. Range cut and step size must be easily modifiable
  - Only the hadronic processes can be visualized – Michel’s magic

Physics list for HEP/NP

- We must provide a pre-built list each of whose processes can be turned on/off one by one
- Fixed models are to be used
- Can control the number of secondaries