

Computer simulation of radiation protection using the Geant4 toolkit

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AGENDA

- INTRODUCTION
 - GEANT4 Background.
 - The application of GEANT4 software.
 - Physical Simulation.
- AIMS & OBJECTIVES
- COMPUTATIONAL METHODOLOGY
- RESULTS & DISCUSSION
- CONCLUSION

<http://cern.ch/geant4>

Geant 4

Geant4 is a toolkit for the simulation of the passage of particles through matter. It has been developed and maintained by a world-wide Collaboration of approximately 100 scientists.

GLAST
Gamma-ray Large Area Space Telescope

ATLAS at LHC CERN

Its application areas include high energy physics, astrophysics and nuclear physics experiments, medical, accelerator and space science studies.

Borexino
at Gran Sasso Laboratory

ESA XMM
X-ray telescope

BaBar at SLAC

CMS at LHC CERN

High energy μ
Courtesy of L3

Photon attenuation
Low energy photons
Courtesy of the Italian Nat. Inst. for Cancer Research

An abundant set of Physics Processes handle the diverse interactions of particles with matter across a wide energy range.

Neutrons
Courtesy of CMS

Stopping μ
absorption
nuclear deexcitation
CERN/ETHZ
Exp. ATLAS

Geant4 exploits advanced Software Engineering techniques and Object Oriented technology to achieve transparency of physics implementation.

Budker Inst. of Physics IHEP Protvino MEPHI Moscow Pittsburg University

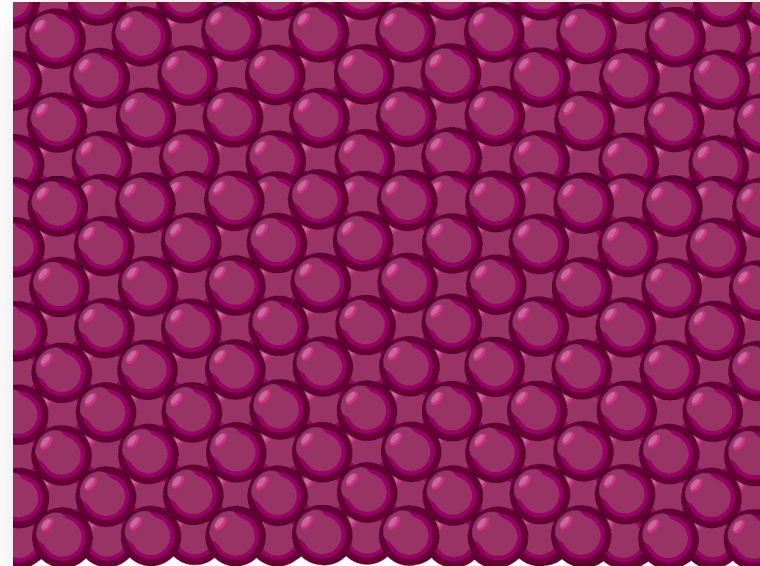
introduction

GEANT4 Background

GEANT4:- Geometry ANd Tracking .

Geant4 is a toolkit for the simulation of the passage of particles through matter using Monte Carlo methods.

Monte-Carlo method is a numerical method to solve applied mathematical problems by simulation of random variables and statistical analysis of their characteristics.



introduction

GEANT4 Background



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Overview

Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The three main reference papers for Geant4 are published in Nuclear Instruments and Methods in Physics Research A 506 (2003) 250-303, IEEE Transactions on Nuclear Science 53 No. 1 (2006) 270-278 and Nuclear Instruments and Methods in Physics Research A 835 (2016) 186-225.

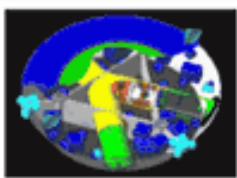
Applications



A sampling of applications, technology transfer and other uses of Geant4

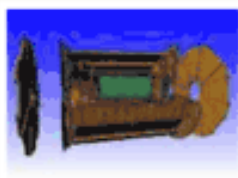
[printer-friendly version](#)

User Support



Getting started, guides and information for users and developers

Publications



Validation of Geant4, results from experiments and publications

Collaboration



Who we are: collaborating institutions, members, organization and legal information

News

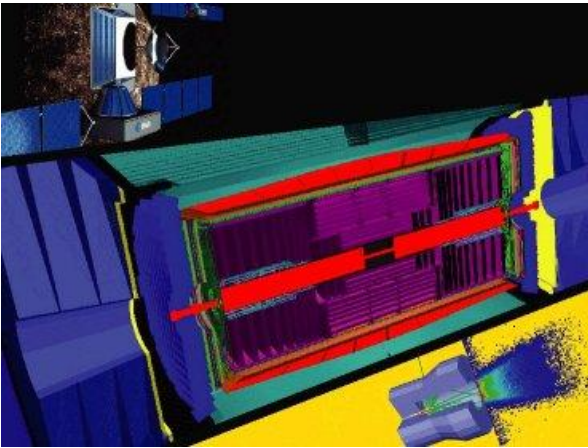
- 28 Jun 2019
Release 10.6-BETA is available from the [BETA Download](#) area.
- 17 Apr 2019
Patch-01 to release 10.5 is available from the [Download](#) area.
- 13 Mar 2019
[2019 planned developments](#)
- 12 Feb 2019
Patch-03 to release 10.4 is available from the [source archive](#) area.

Events

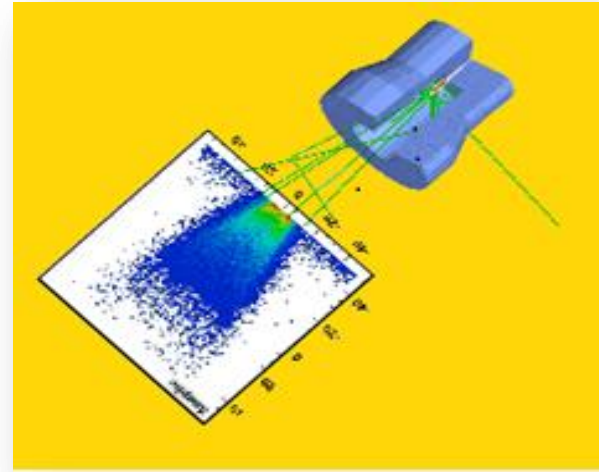
- 8th International Geant4 School, Belgrade (Serbia), 17-22 November 2019.
- 4th Geant4 School, University of Wollongong, Australia, 2-5 December 2019.
- 25th Geant4 Collaboration Meeting, IPISA Laboratory, Rennes (France), 21-25 September 2020.

introduction

GEANT4 application



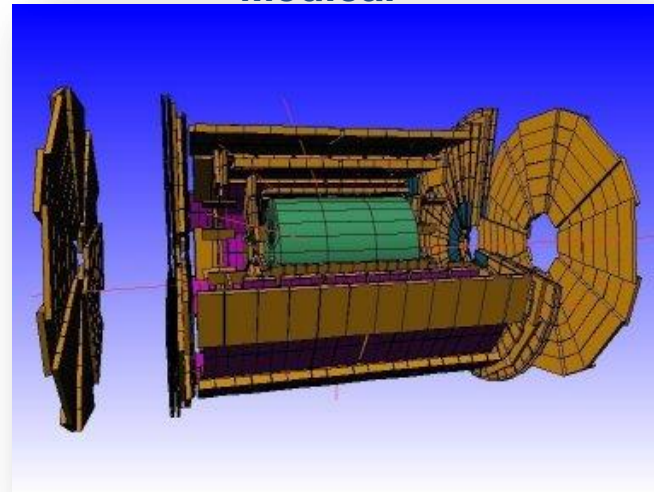
Transfer Technology



Medical



Space and radiation



High energy physics

introduction

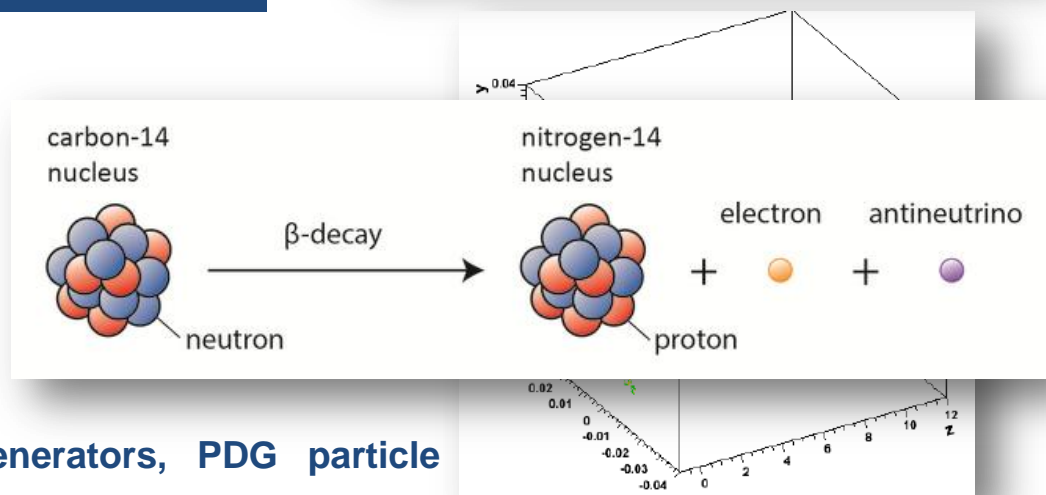
Physical Simulation

A physics simulation starts with a mathematical model whose variables define the state of the system at a given time.

We simulate physical processes and detector response in an experiment being planned or conducted.

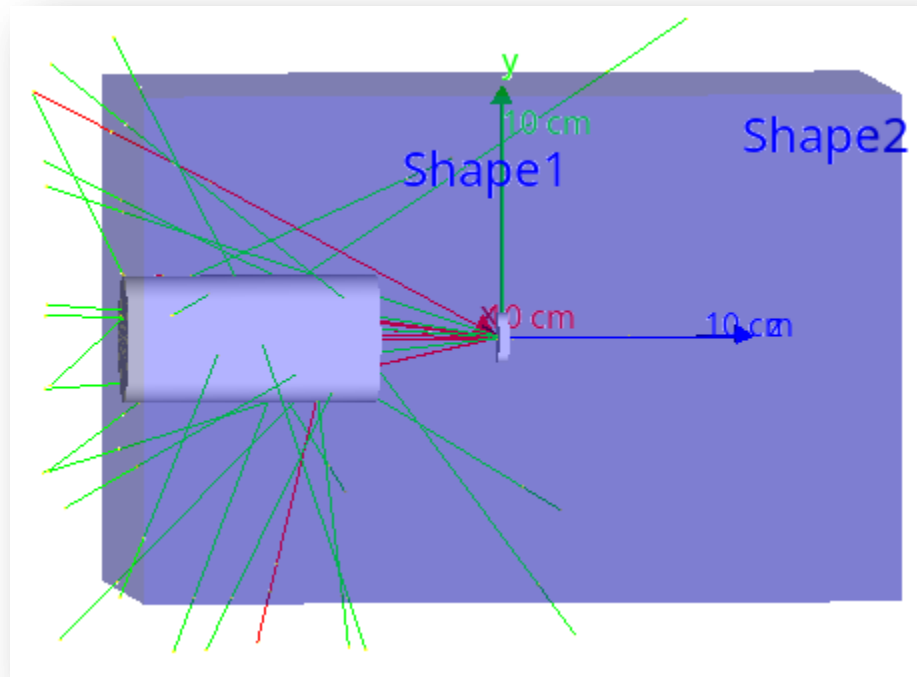
Basic requirements for a simulation system

- Modeling the experimental set-up.
- Tracking particles through matter.
- Interaction of particles with matter.
- Modeling the detector response.
- Run and event control.
- Accessory utilities (random number generators, PDG particle informationetc).
- Visualization of the set-up, tracks and hits.



Aims & Objectives

- Gain practical experience of using the Geant4 toolkit to solve typical problems of radiation protection.
- Calculate flux-to-dose equivalent factor for different radiation type and spectrum.
- Calculate of basic dosimetry quantities useful for radiation protection applications.
- Simulate shielding and radiation protection efficiency.



Computational Methodology & software

■ C++:-

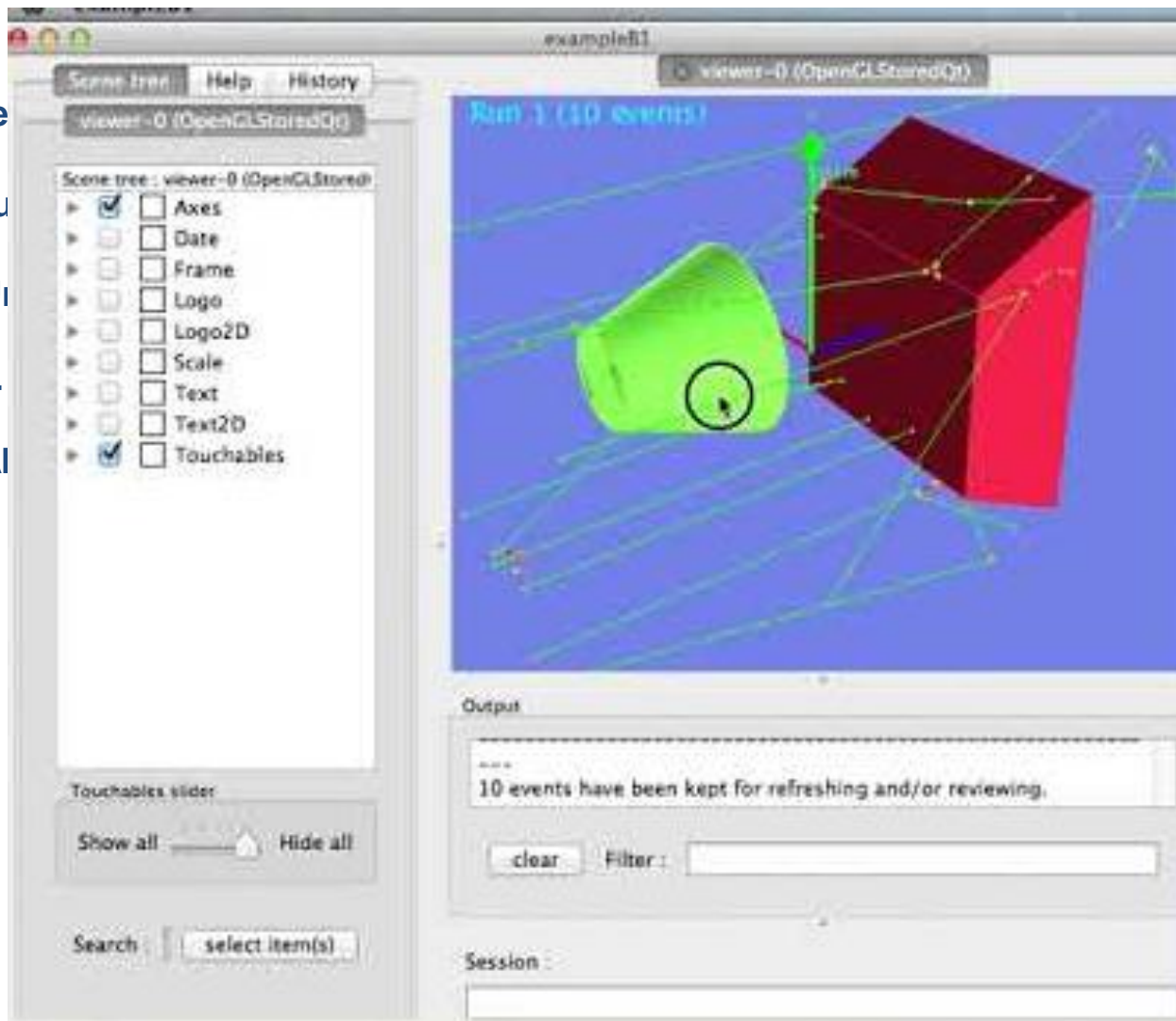
□ Ge

■ Unix/Linu

□ U

■ Geant4:-

□ AI



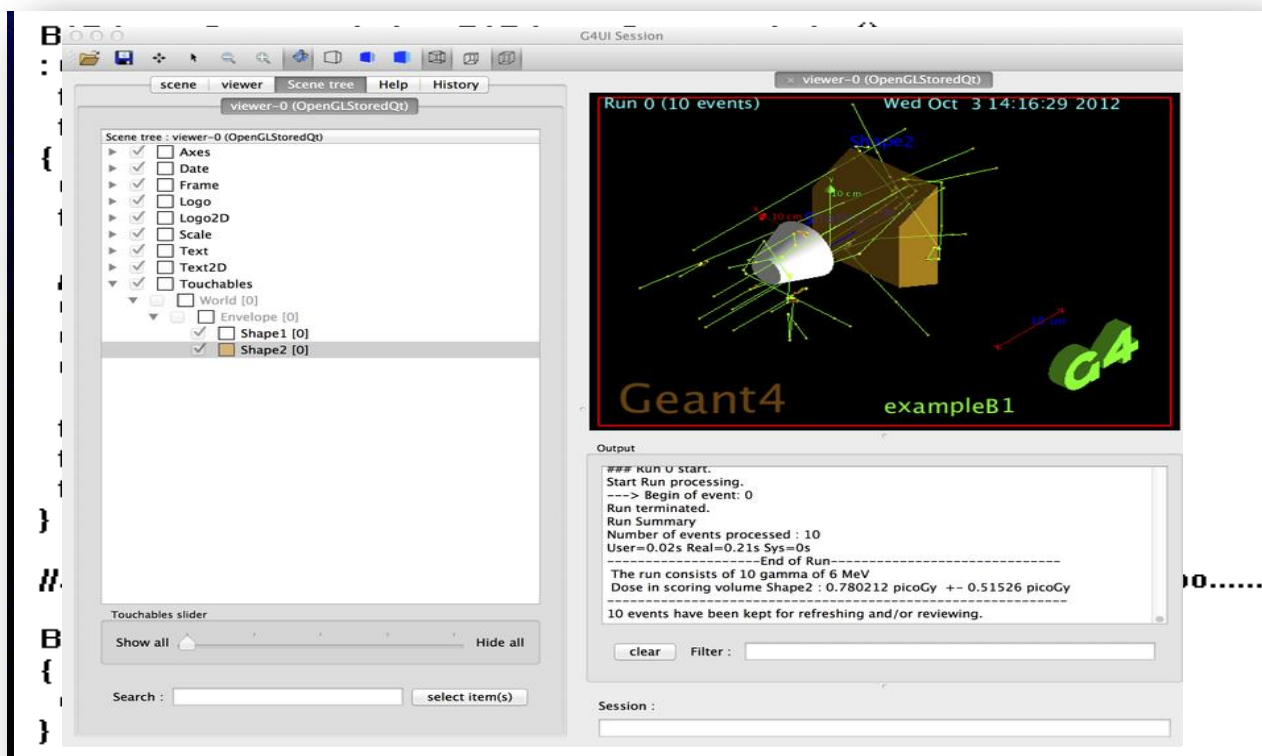
andatory.

Results & Discussion

Geant4 program

■ Task I:- Geometry Modification and running the simulation using Geant4.

- ❑ Source `~/geant4/bin/geant4.sh`
- ❑ Kate `./src/B1PrimaryGeneratorAction.cc`
- ❑ `./exampleB1`
- ❑ `/run/beamOn 10`



The screenshot displays the Geant4 graphical user interface (GUI) for a simulation session. The main window is titled "G4UI Session" and contains a 3D visualization area and a terminal window.

3D Visualization: The central 3D view shows a complex geometry of a particle detector. A white, semi-transparent sphere represents a primary particle source. A yellow, rectangular volume represents a detector component. A green, rectangular volume represents another detector component. The text "Geant4" and "exampleB1" are visible in the 3D view. A "G4" logo is also present. The date and time "Wed Oct 3 14:16:29 2012" are displayed in the top right corner of the 3D view.

Scene Tree: On the left side, there is a "Scene tree" panel showing the hierarchy of objects in the simulation. The tree is titled "viewer-0 (OpenGLStoredQt)". The objects listed are:

- World [0]
- Envelope [0]
- Shape1 [0]
- Shape2 [0]

The "Shape2 [0]" object is selected, and its properties are shown in the "Touchable slider" panel below the scene tree. The "Show all" button is active, and the "Hide all" button is disabled.

Terminal Output: The terminal window at the bottom right shows the output of the simulation. The text is as follows:

```

Run 0 (10 events)      Wed Oct 3 14:16:29 2012

### Run U start.
Start Run processing.
----> Begin of event: 0
Run terminated.
Run Summary
Number of events processed : 10
User=0.02s Real=0.21s Sys=0s
-----End of Run-----
The run consists of 10 gamma of 6 MeV
Dose in scoring volume Shape2 : 0.780212 picoGy +- 0.51526 picoGy
10 events have been kept for refreshing and/or reviewing.
  
```

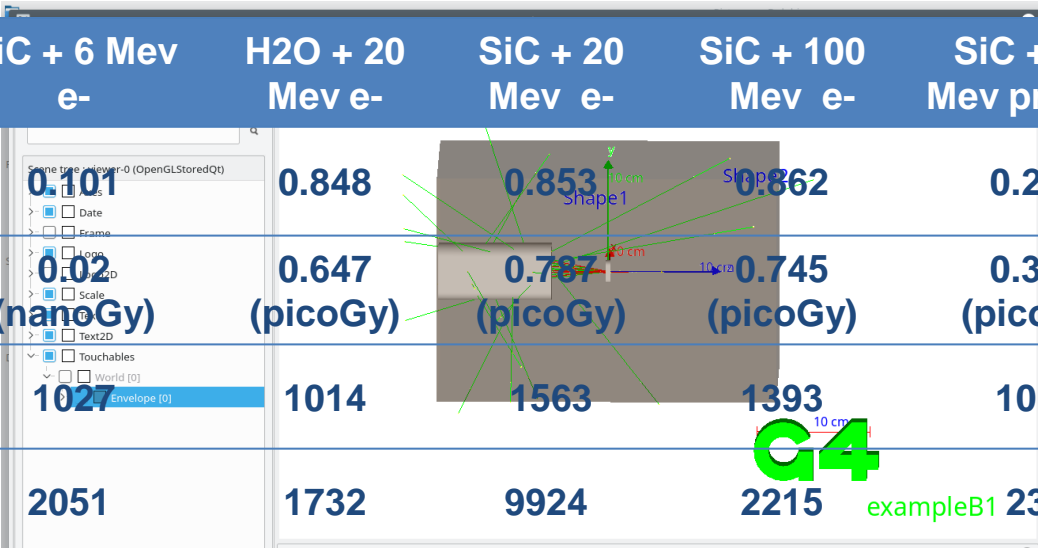
The terminal window also includes a "clear" button, a "Filter:" input field, and a "Session:" input field.

Results & Discussion

Geant4 program

Task II:- Radiation Treatment Dose Distributions using Geant4.

1000 particles	SiC + 6 Mev e-	H2O + 20 Mev e-	SiC + 20 Mev e-	SiC + 100 Mev e-	SiC + 200 Mev protons	SiC + 20 Mev gamma
Dose (nanoGy)	0.101	0.848	0.853	0.862	0.202	0.192
RMS (nanoGy)	0.02	0.647 (picoGy)	0.787 (picoGy)	0.745 (picoGy)	0.377 (picoGy)	0.436 (picoGy)
Incoming particles	1027	1014	1563	1393	1014	544
Outgoing Particles	2051	1732	9924	2215	230	275
In case of electron only						
Incoming particles	28	14	1056	1003	-----	-----
Outgoing Particles	78	10	828	224	-----	-----



Results & Discussion

Geant4 program

10000 particles	SiC + 6 Mev e-	H2O + 20 Mev e-	SiC + 20 Mev e-	SiC + 100 Mev e-	SiC + 200 Mev protons	SiC + 20 Mev gamma
Dose (nanoGy)	0.100	0.850	0.852	0.860	0.204	0.195
RMS (picoGy)	0.40	0.20	0.23	0.22	0.17	0.14
Incoming particles	5245	13822	13838	10204	17266	15597
Outgoing particles	2716	21820	21843	99205	17266	20185
In case of electron only						
Incoming particles	3559	13822	10009	10499	-----	-----
Outgoing particles	647	21820	2284	741	-----	-----

Results & Discussion

Geant4 program

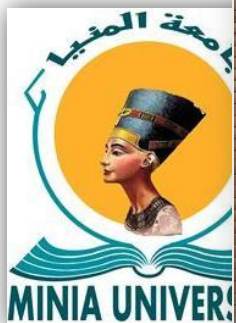
Task III:- The effect of changing the length of Faraday cup in the percentage value using Geant4.

Faraday cup Length	20 mm	40 mm	60 mm	80 mm	100 mm
Incoming Particles	84	101	98	103	94
Outgoing Particles	76	36	30	29	26
Faraday cup efficiency	9.5 %	64%	69%	71%	72%

Conclusion

- **Geant4 clearly provides powerful radiation tools underpinned with comprehensive physics simulation.**
- **The dose rate for a given radiation source and distance were calculated.**
- **Shielding and radiation protection efficiency were simulated using Geant4 software.**
- **Geant4 will continue to be supported and activity developed for foreseeable future and we should look to take advantage of the new features.**

Acknowledgment



Thanks for your

attention