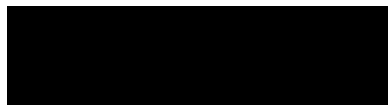
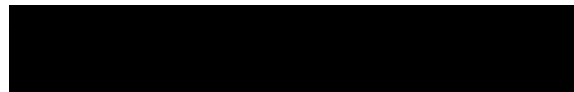


UST Global Internship Program

Title: Simulations for Dark
Matter



High Energy Physics
(Standard Model)



Dark Matter



Mad Graph



Geant 4

High Energy Physics

What is High Energy Physics?

It is the branch of [physics](#) that studies the nature of the particles that constitute [matter](#) and [radiation](#), usually investigates the irreducibly smallest detectable particles and the [fundamental forces](#) necessary to explain their behaviour.

Main Models: Standard Model, Supersymmetry etc..

The currently dominant theory explaining these fundamental particles and fields, along with their dynamics, is called the [Standard Model](#).

Standard Model

Standard Model of FUNDAMENTAL PARTICLES AND INTERACTIONS

The "Standard Model" is a term used to describe the quantum theory that includes the theory of strong interactions (quantum chromodynamics or QCD) and the unified theory of weak and electromagnetic forces (electroweak). Gravity is included in this chart because it is one of the fundamental interactions even though not part of the "Standard Model".

FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2,...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass, GeV/c ²	Electric charge	Flavor	Approx. Mass, GeV/c ²	Electric charge
ν_e electron neutrino	$< 7 \times 10^{-8}$	0	u up	0.005	2/3
e electron	0.000511	-1	d down	0.01	-1/3
ν_μ muon neutrino	< 0.0003	0	c charm	1.5	2/3
μ muon	0.106	-1	s strange	0.2	-1/3
ν_τ tau neutrino	< 0.03	0	t top (initial evidence)	170	2/3
τ tau	1.7771	-1	b bottom	4.7	-1/3

Spin is the quantum angular momentum of particles. Spin is given in units of \hbar , which is the quantum unit of angular momentum, where $\hbar = 6.58 \times 10^{-25}$ GeV s = 1.05×10^{-34} J s.

Electric charges are given in units of the proton's charge. In SI units the electric charge of the proton is 1.6×10^{-19} coulombs.

The energy unit of particle physics is the electron-volt (eV), the energy gained by one electron in crossing a potential difference of one volt. Masses are given in GeV/c² (remember $E = mc^2$), where $1 \text{ GeV} = 10^9 \text{ eV} = 1.6 \times 10^{-10}$ joules. The mass of the proton is $0.938 \text{ GeV}/c^2 = 1.67 \times 10^{-27} \text{ kg}$.

BOSONS

force carriers
spin = 0, 1, 2,...

Unified Electroweak spin = 1	Mass, GeV/c ²	Electric charge	Strong or color spin = 1	Mass, GeV/c ²	Electric charge
γ photon	0	0	g gluon	0	0
W^-	80.22	-1			
W^+	80.22	+1			
Z^0	91.187	0			

Color Charge

Each quark carries one of three types of "strong charge," also called "color charge." These charges have nothing to do with the colors of visible light. There are eight possible types of color charge for quarks. Just as electrically charged particles interact by exchanging photons, in strong interactions color-charged particles exchange gluons.

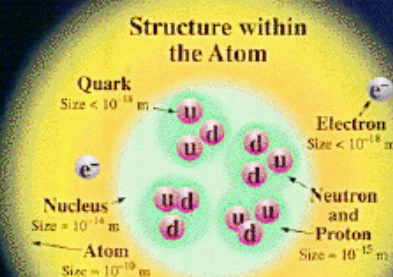
charged particles exchange gluons. Leptons, photons, and W and Z bosons have no color charge and hence no strong interactions. One cannot isolate quarks and gluons; they are confined into color-neutral hadrons. This confinement (binding) results from multiple exchanges of gluons among the color-charged objects.

Confinement

As color-charged particles (quarks and gluons) are separated, the color forces between them approaches a constant value and the energy in the color force field increases. This energy eventually is converted into additional quark-antiquark pairs (see the figures below). The objects that finally emerge are color-neutral combinations called hadrons (mesons and baryons).

Residual Strong Interactions

The strong binding of the color-neutral protons and neutrons in form nuclei is due to residual strong interactions between their color-charged constituents. It is similar to the residual electrical interaction which binds electrically neutral atoms to form molecules. It can be viewed as the exchange of mesons between the hadrons.



If the protons and neutrons in this picture were 20 cm across, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

PROPERTIES OF THE INTERACTIONS

Sample Fermionic Hadrons					
Baryons qq _i q and Antibaryons $\bar{q}\bar{q}\bar{q}$					
Symbol	Name	Quark content	Electric charge	Mass, GeV/c ²	Spin
p	proton	uud	+1	0.938	1/2
\bar{p}	anti-proton	$\bar{u}\bar{u}\bar{d}$	-1	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Ω^-	omega	sss	-1	1.672	3/2

Matter and Antimatter

The every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol. Particle and antiparticle have identical mass and spin but opposite charges. Some recently created baryons (Λ , Σ , Ξ , Ω) and Λ and Ξ and Ω are their own antiparticles.

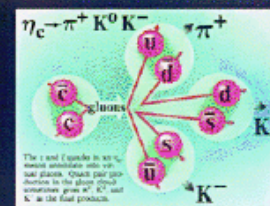
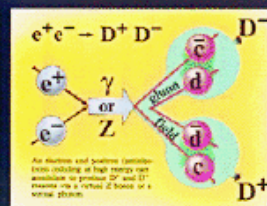
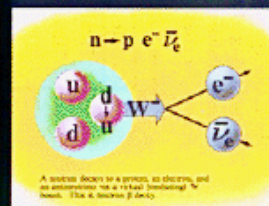
Figures

These diagrams are an artistic interpretation of physical processes. They are not meant to have the measured scale. From right to left, the diagrams show the production of the particles, the decay of the particles, and the annihilation of the particles.

Copyright © 1997 CERN

Property	Interaction	Gravitational			Weak (Electroweak)			Electromagnetic		Strong	
		Mass - Energy			Flavor			Electric Charge		Fundamental	
Acts on:		All			Quarks, Leptons			Electrically charged		Color charge	
Particles experiencing:		All			W^+ W^- Z^0			γ		Quarks, Gluons	
Particles mediating:		Graviton (not yet observed)								Gluons	
Strength for two u quarks at:		10^{-41}			0.8			1		25	
(relative to electromagnetic):		10^{-41}			10^{-4}			1		60	
for two protons in nucleus		10^{-36}			10^{-7}			1		Not applicable to hadrons	

Sample Bosonic Hadrons					
Mesons $q\bar{q}$					
Symbol	Name	Quark content	Electric charge	Mass, GeV/c ²	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	-1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
D^+	D	$c\bar{d}$	+1	1.869	0
η_c	eta-c	$c\bar{c}$	0	2.979	0

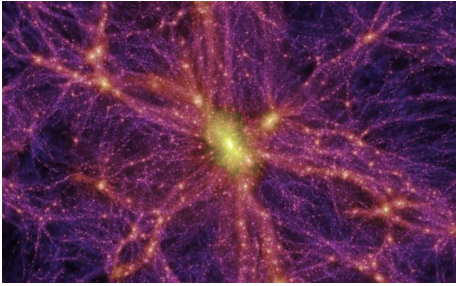


Contemporary Physics Education Project (CPEP)

CPEP is a non-profit organization of teachers, physicists, and others, for information on the chart, software, book, and other materials on classroom activities, and web pages, look on WWW at <http://peg.mt.gov/peg.html>, send e-mail to peg@peg.mt.gov or write: CPEP, MS 50-305, Lawrence Berkeley Laboratory, Berkeley, CA 94720. Corporate and private educators as well as national laboratory funding have been and remain critical to the success of this project.

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Dark Matter

What is it?

It is a hypothetical type of [matter](#) distinct from Standard Model (ordinary matter such as [protons](#) and [neutrons](#)), [neutrinos](#) and [dark energy](#). The existence of dark matter would explain a number of otherwise puzzling astronomical observations. The name refers to the fact that it does not emit or interact with [electromagnetic radiation](#), such as light, and is thus invisible to the entire [electromagnetic spectrum](#).

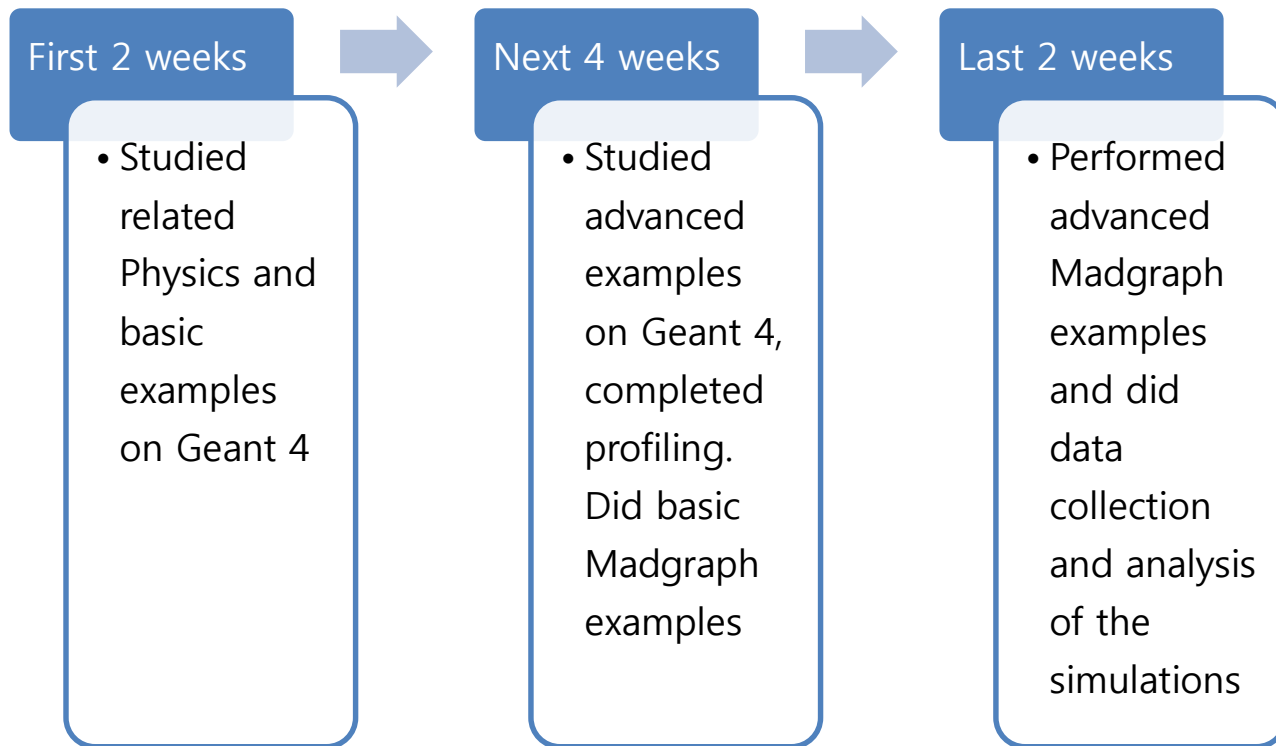
Observational Evidence:

Galaxy rotation curves

Gravitational lensing

Cosmic Microwave Background Radiation etc ..

Timeline of my internship



Two main things that I did:

- Madgraph
- Geant 4 profiling

Madgraph

What's Madgraph ?

Madgraph is a fortran-based software package that is used for high-energy physics analysis, most often for particle colliders.

It's basically an implementation of Feynman diagrams of particle interactions

What did I do?

- Studied two following interactions to learn the system:

$$e^+ e^- \rightarrow \mu^+ \mu^-$$

$$e^+ e^- \rightarrow e^+ e^-$$

- And three **Dark Matter** background interactions:

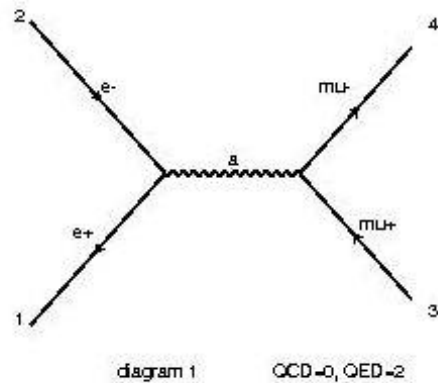
$$e^+ e^- \rightarrow \nu \mu \bar{\nu}$$

$$e^+ e^- \rightarrow \nu e \bar{\nu}$$

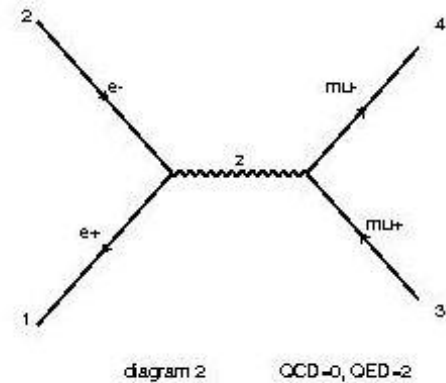
$$e^+ e^- \rightarrow \mu^+ \mu^- \mu^+ \mu^-$$

$$e^+ e^- \rightarrow \mu^+ \mu^-$$

Energy (Me G1	G2	Sum	
10.1	24.11	0.008618	24.119
10.1	24.11	0.008618	24.119
20	47.02	0.3569	47.372
30	23.54	1.81	25.345
47	10.06	332.9	342.9
50	42.39	8.924	51.318
100	2.288	0.4986	2.7867
150	1.017	0.1688	1.1862
200	0.5723	0.08692	0.65924
250	0.366	0.0535	0.41946
300	0.2543	0.03631	0.29065
350	0.1869	0.02634	0.21321
400	0.143	0.02	0.163
450	0.133	0.01571	0.12871
500	0.09155	0.01268	0.10423



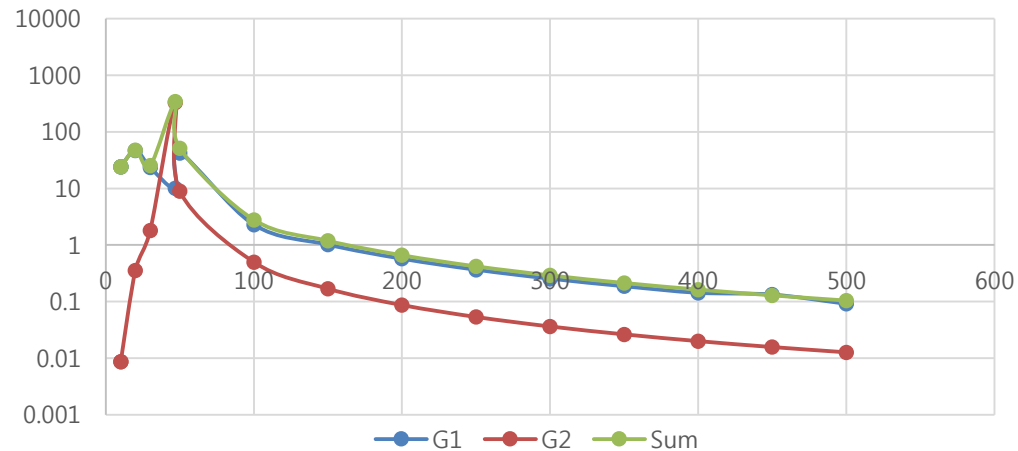
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QCD=0, QED=2

$$e^+ e^- \rightarrow \mu^+ \mu^-$$

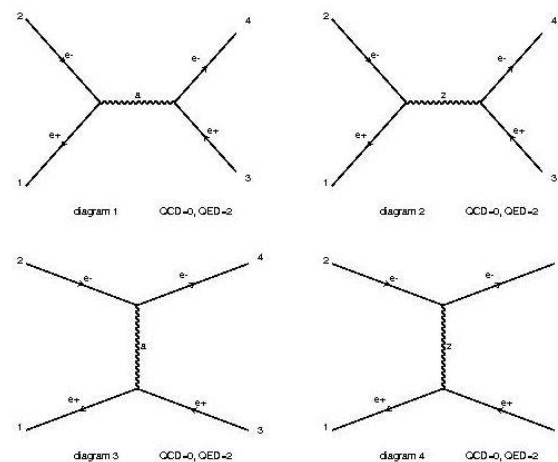
Cross
Section
(Pb)



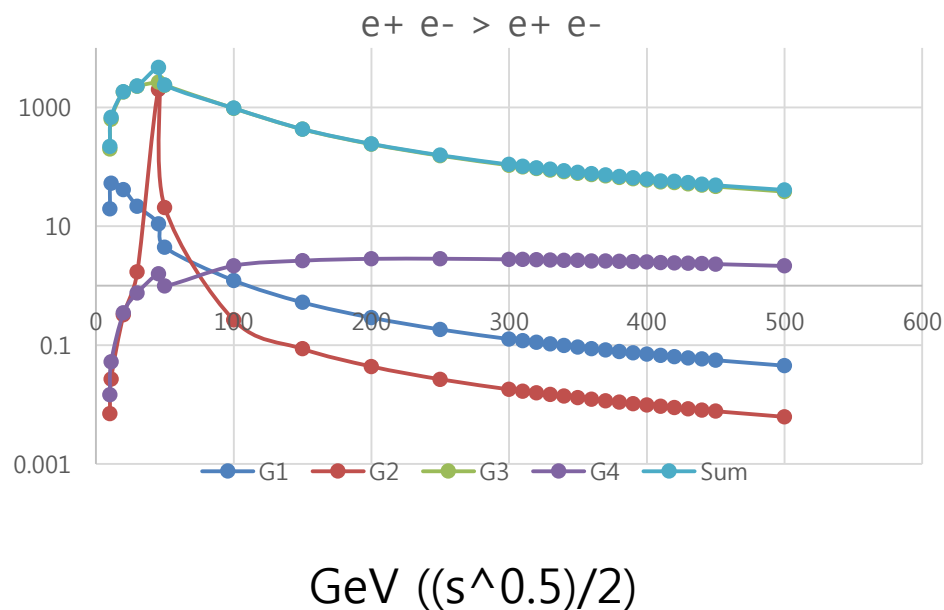
GeV $((s^{0.5})/2)$

$$e^+ e^- \rightarrow e^+ e^-$$

Energy (MeV)	G1	G2	G3	G4	Sum
10.1	19.61	0.007005	199.5	0.01455	219.13
11	52.45	0.02679	625.3	0.05199	677.8
20	41.35	0.325	1808	0.349	1823.024
30	21.73	1.692	2262	0.7551	2286.6
45.5	10.97	1992	2653	1.572	4658
50	4.412	20.65	2350	0.9915	2376.6
100	1.223	0.2647	960.6	2.162	964.3
150	0.522	0.08646	426.2	2.631	429.41
200	0.2892	0.04368	239.4	2.822	242.58
250	0.183	0.02659	153	2.834	156.06
300	0.1263	0.01797	106	2.769	108.88
310	0.1181	0.01676	99.4	2.743	102.17157
320	0.1107	0.01567	93.28	2.72	96.131
330	0.1041	0.01469	87.65	2.693	90.459
340	0.09799	0.0138	82.58	2.667	85.234
350	0.09227	0.01298	77.81	2.65	80.565
360	0.08728	0.01224	73.52	2.609	76.233
370	0.08265	0.01156	69.81	2.578	72.48221
380	0.07822	0.01094	66.07	2.547	68.705
390	0.07418	0.01036	62.72	2.515	65.32
400	0.0706	0.009832	59.66	2.484	62.224
410	0.06716	0.009342	55.13	2.43	57.642
420	0.06399	0.008889	54	2.418	56.488
430	0.06102	0.008467	51.55	2.384	54.001
440	0.05827	0.008076	48.69	2.34	51.095
450	0.05563	0.007715	46.41	2.304	48.773
500	0.04505	0.006215	38.12	2.142	40.718715

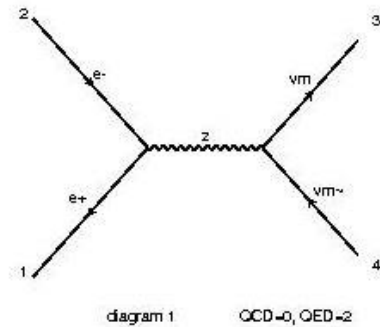


Cross
Section
(Pb)



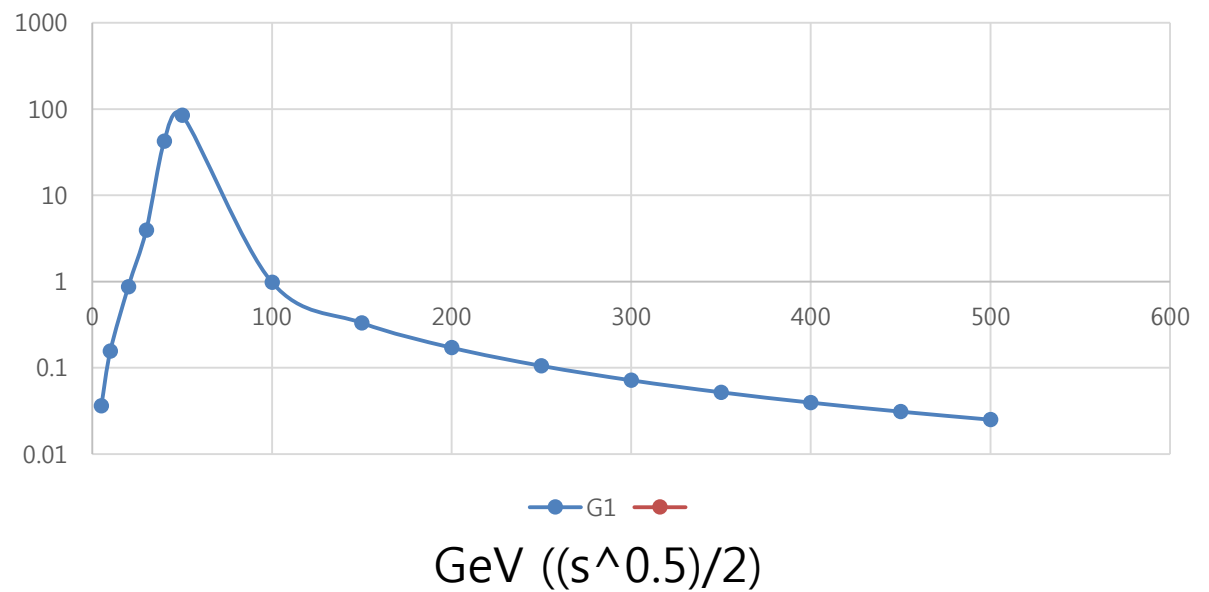
$$e^+ e^- \rightarrow \nu \mu \bar{\nu}$$

Energy (MeV)	
5	0.03617
10	0.156
20	0.8701
30	3.951
40	42.32
50	85.12
100	0.97938
150	0.33157
200	0.17094
250	0.10521
300	0.07155
350	0.05191
400	0.039427
450	0.030981
500	0.024996



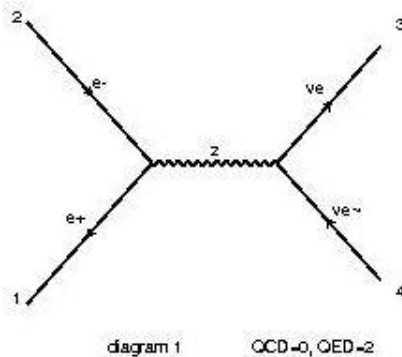
$$e^+ e^- \rightarrow \nu \mu \bar{\nu}$$

Cross
Section
(Pb)

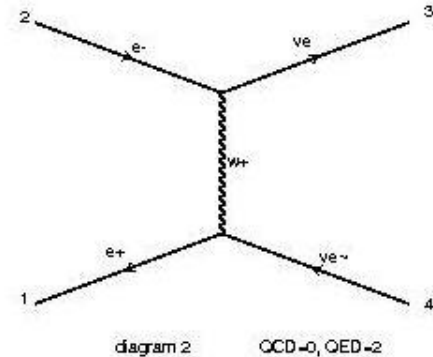


$$e^+ e^- \rightarrow \nu e \bar{\nu}$$

Energy (Me)	G1	G2	Sum
5	0.02108	0.1367	0.15774
10	0.08881	0.5124	0.60121
20	0.438	1.525	1.9634
30	1.573	1.627	3.2005
45.5	3948	14.34	3962.7
50	128.6	29.78	158.4
100	1.279	39.4	40.674
150	0.4101	44.29	44.699
200	0.2077	47.27	47.475
250	0.1268	49.1	49.232
300	0.08585	50.31	50.397
350	0.06212	51.15	51.216
400	0.0471	51.76	51.805
450	0.03697	52.22	52.256
500	0.0298	52.56	52.586



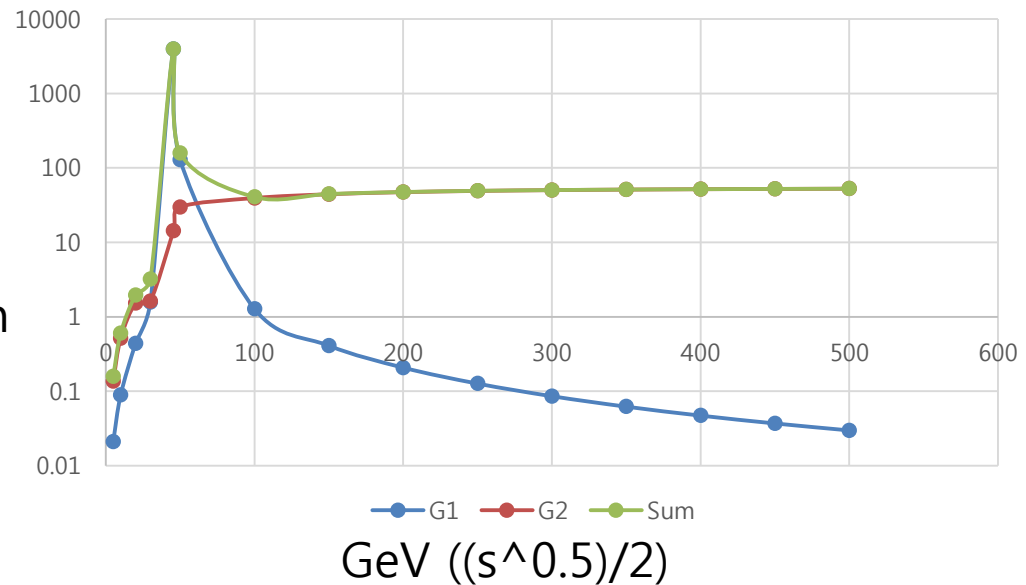
QCD=0, QED=2



QCD=0, QED=2

$$e^+ e^- \rightarrow \nu e \bar{\nu}$$

Cross
Section
(Pb)



$$e^+ e^- \rightarrow \mu^+ \mu^- \mu^+ \mu^-$$

Energy(MeV)	G1	G3	G5	G7	G33	G35	G36	G39	Sum
20.9	0	0	0	0	0	0	0	1.44E-18	1.44E-18
30	4.01E-07	1.05E-10	2.97E-08	8.45E-12	1.99E-05	7.24E-09	7.40E-09	2.54E-12	2.03E-05
40	3.62E-06	1.63E-09	5.37E-06	2.45E-09	9.04E-05	2.63E-07	2.60E-07	1.42E-10	9.99E-05
50	6.25E-06	5.46E-09	2.50E-05	2.66E-08	1.09E-04	1.64E-06	2.07E-06	1.65E-09	1.45E-04
70	9.24E-06	4.51E-07	3.71E-06	1.93E-07	2.02E-04	3.98E-04	4.02E-04	1.75E-06	1.02E-03
80	9.55E-06	1.21E-06	2.83E-06	3.58E-07	1.95E-04	4.24E-04	4.21E-04	8.36E-06	1.06E-03
100	1.05E-05	3.54E-06	2.31E-06	7.75E-07	2.04E-04	3.94E-04	4.07E-04	1.07E-03	2.09E-03
120	1.02E-05	5.05E-06	1.95E-06	9.43E-07	1.45E-04	3.27E-04	3.28E-04	1.08E-03	1.90E-03
140	9.65E-06	6.27E-06	1.67E-06	1.05E-06	1.16E-04	2.64E-04	2.62E-04	9.03E-04	1.56E-03
150	9.76E-06	6.45E-06	1.40E-06	1.10E-06	1.07E-04	2.35E-04	2.35E-04	8.25E-04	1.42E-03
170	8.81E-06	6.99E-06	1.44E-06	1.12E-06	8.67E-05	1.99E-04	1.99E-04	6.81E-04	1.18E-03
190	7.55E-06	7.38E-06	1.12E-06	1.24E-06	7.45E-05	1.71E-04	1.71E-04	5.76E-04	1.01E-03
200	7.72E-06	7.25E-06	1.09E-06	1.18E-06	6.97E-05	1.57E-04	1.58E-04	5.28E-04	9.29E-04
220	6.15E-06	7.21E-06	9.18E-07	1.16E-06	6.07E-05	1.36E-04	1.37E-04	4.49E-04	7.98E-04
240	5.78E-06	7.65E-06	8.86E-07	1.18E-06	5.44E-05	1.17E-04	1.21E-04	3.81E-04	6.90E-04
250	5.89E-06	7.42E-06	8.70E-07	1.18E-06	5.05E-05	1.11E-04	1.16E-04	3.53E-04	6.45E-04
270	5.76E-06	7.37E-06	7.40E-07	1.18E-06	3.45E-05	9.79E-05	9.93E-05	3.07E-04	5.64E-04
290	5.33E-06	7.24E-06	6.70E-07	1.09E-06	4.04E-05	8.76E-05	8.85E-05	2.66E-04	4.96E-04
300	5.32E-06	7.13E-06	6.15E-07	1.08E-06	3.81E-05	8.47E-05	8.43E-05	2.47E-04	4.68E-04
320	4.76E-06	7.12E-06	6.20E-07	1.06E-06	3.37E-05	7.47E-05	7.57E-05	2.16E-04	4.14E-04
340	4.21E-06	6.97E-06	5.54E-07	1.04E-06	3.21E-05	6.69E-05	6.92E-05	1.94E-04	3.75E-04
350	4.04E-06	6.38E-06	5.59E-07	1.01E-06	3.04E-05	6.34E-05	6.66E-05	1.83E-04	3.56E-04
370	3.98E-06	6.49E-06	4.75E-07	1.02E-06	2.66E-05	5.97E-05	5.96E-05	1.58E-04	3.16E-04
390	3.73E-06	6.19E-06	4.84E-07	9.50E-07	2.45E-05	5.46E-05	5.44E-05	1.39E-04	2.84E-04
400	3.76E-06	6.41E-06	4.61E-07	9.12E-07	2.39E-05	5.25E-05	5.35E-05	1.32E-04	2.73E-04
420	3.29E-06	5.85E-06	4.51E-07	8.37E-07	2.16E-05	4.64E-05	4.73E-05	1.15E-04	2.41E-04
440	3.17E-06	5.87E-06	4.35E-07	8.75E-07	2.00E-05	4.45E-05	4.45E-05	1.07E-04	2.26E-04
450	2.78E-06	5.69E-06	4.22E-07	8.74E-07	1.89E-05	4.17E-05	4.26E-05	9.58E-05	2.09E-04
470	2.96E-06	5.74E-06	3.99E-07	8.26E-07	1.81E-05	3.96E-05	3.99E-05	9.05E-05	1.98E-04
490	2.52E-06	5.30E-06	3.77E-07	7.87E-07	1.69E-05	3.68E-05	3.68E-05	7.98E-05	1.79E-04
500	2.68E-06	5.43E-06	3.87E-07	7.67E-07	1.61E-05	3.55E-05	3.57E-05	7.58E-05	1.72E-04

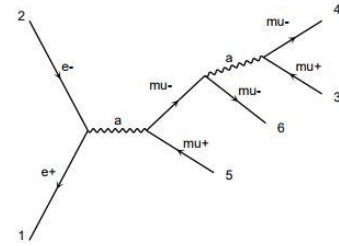


diagram 1 QCD=0, QED=4

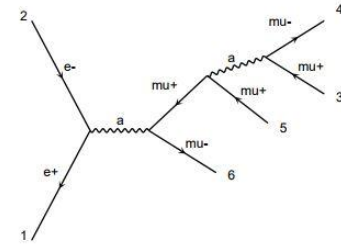


diagram 2 QCD=0, QED=4

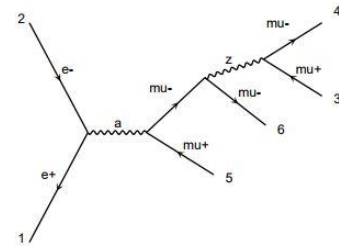


diagram 3 QCD=0, QED=4

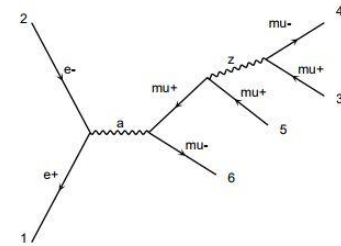


diagram 4 QCD=0, QED=4

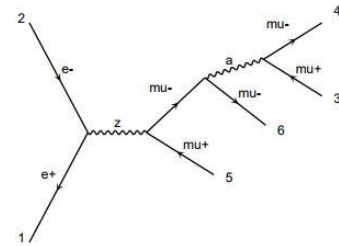


diagram 5 QCD=0, QED=4

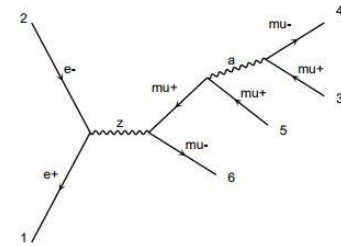


diagram 6 QCD=0, QED=4

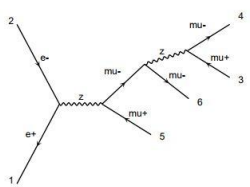


diagram 7 QCD=0, QED=4

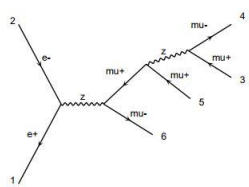


diagram 8 QCD=0, QED=4

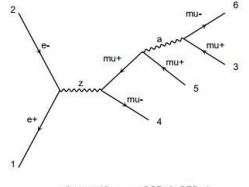


diagram 13 QCD=0, QED=4

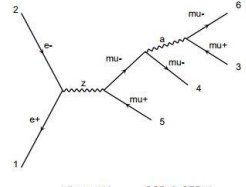


diagram 14 QCD=0, QED=4

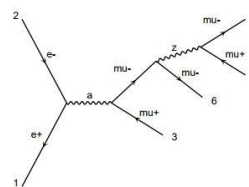


diagram 19 QCD=0, QED=4

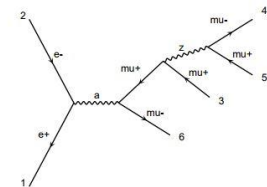


diagram 20 QCD=0, QED=4

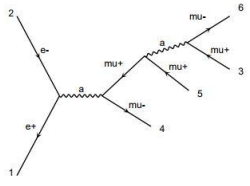


diagram 9 QCD=0, QED=4

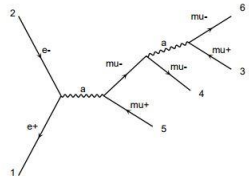


diagram 10 QCD=0, QED=4

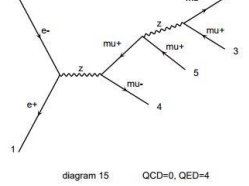


diagram 15 QCD=0, QED=4

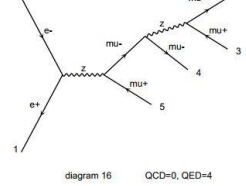


diagram 16 QCD=0, QED=4

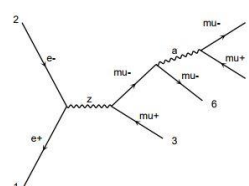


diagram 21 QCD=0, QED=4

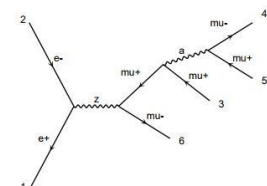


diagram 22 QCD=0, QED=4

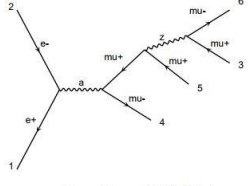


diagram 11 QCD=0, QED=4

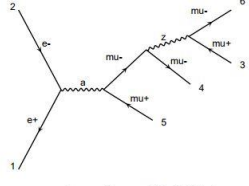


diagram 12 QCD=0, QED=4

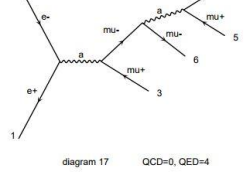


diagram 17 QCD=0, QED=4

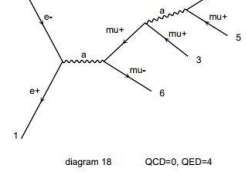


diagram 18 QCD=0, QED=4

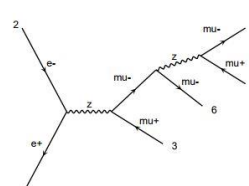


diagram 23 QCD=0, QED=4

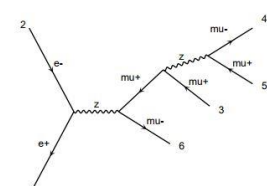


diagram 24 QCD=0, QED=4

Diagrams made by MadGraph5_aMC@NLO

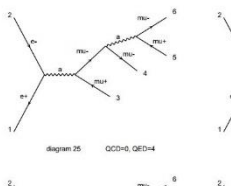


diagram 25 QCD=0, QED=4

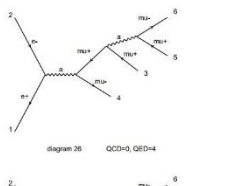


diagram 26 QCD=0, QED=4

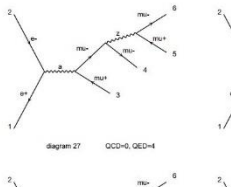


diagram 27 QCD=0, QED=4

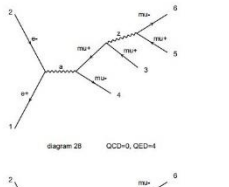


diagram 28 QCD=0, QED=4

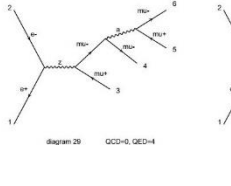


diagram 29 QCD=0, QED=4

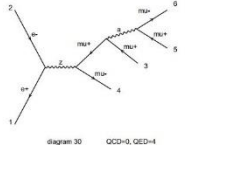


diagram 30 QCD=0, QED=4

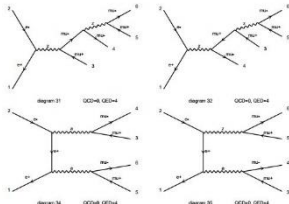


diagram 31 QCD=0, QED=4

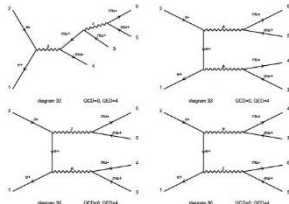


diagram 32 QCD=0, QED=4

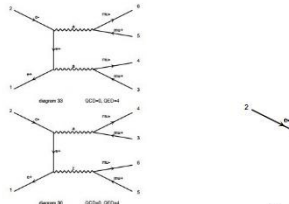


diagram 33 QCD=0, QED=4

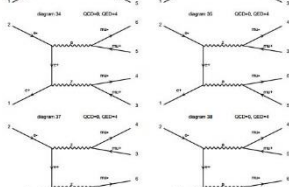


diagram 34 QCD=0, QED=4

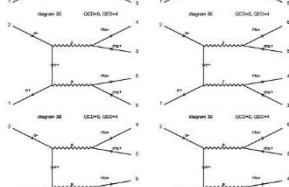


diagram 35 QCD=0, QED=4

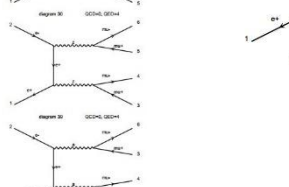


diagram 36 QCD=0, QED=4

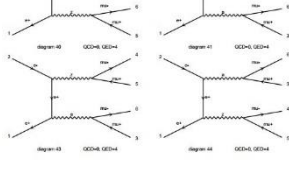


diagram 37 QCD=0, QED=4

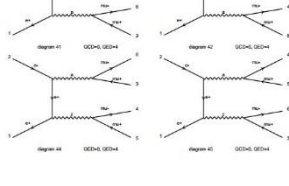


diagram 38 QCD=0, QED=4

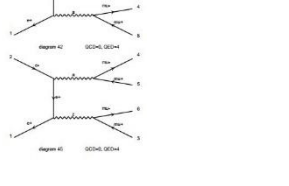


diagram 39 QCD=0, QED=4

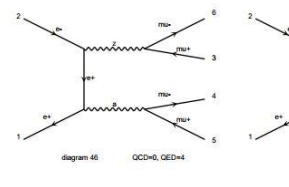


diagram 46 QCD=0, QED=4

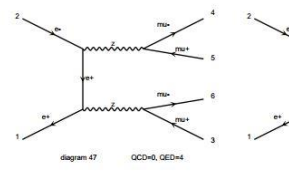


diagram 47 QCD=0, QED=4

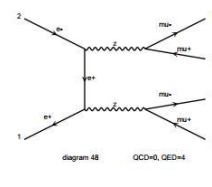
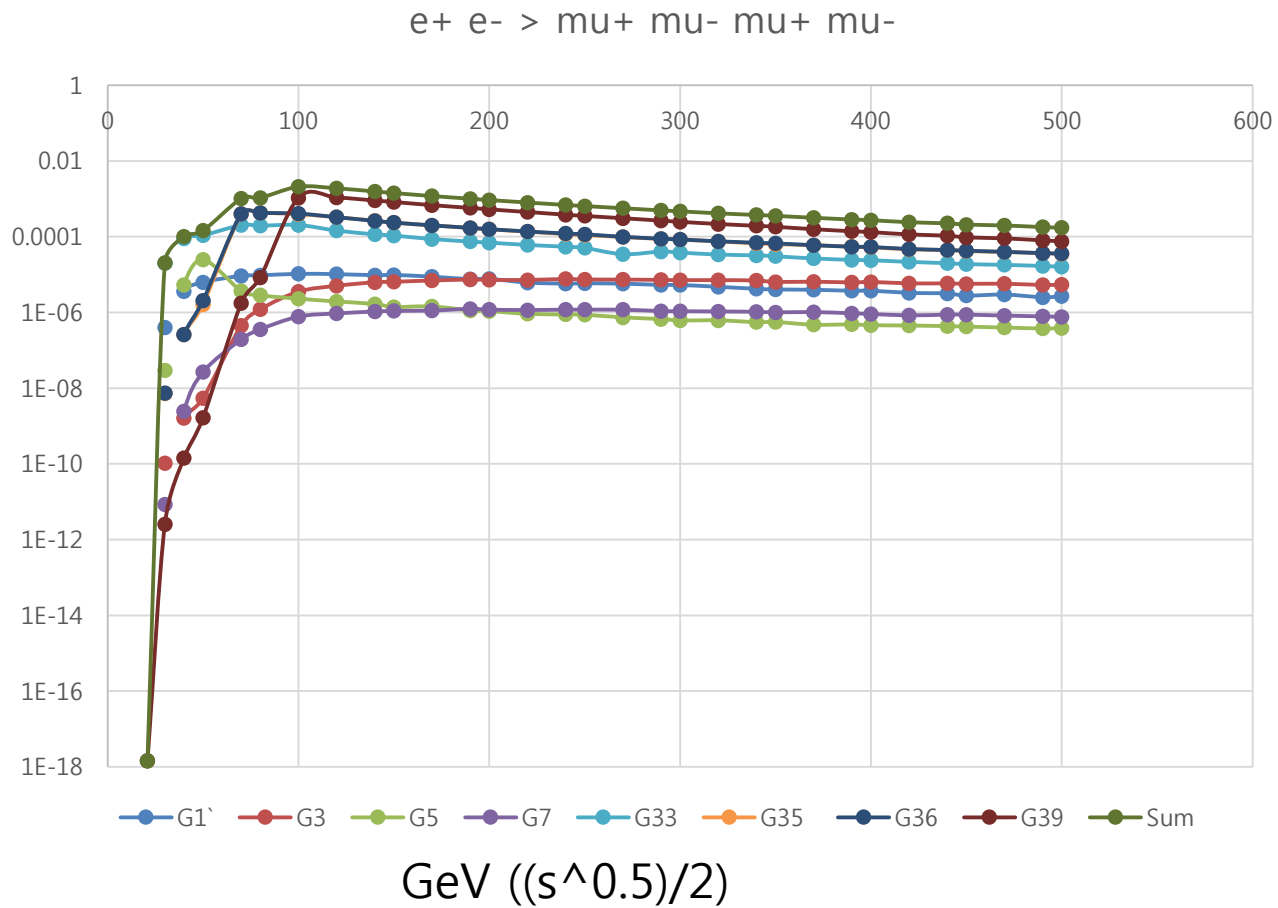


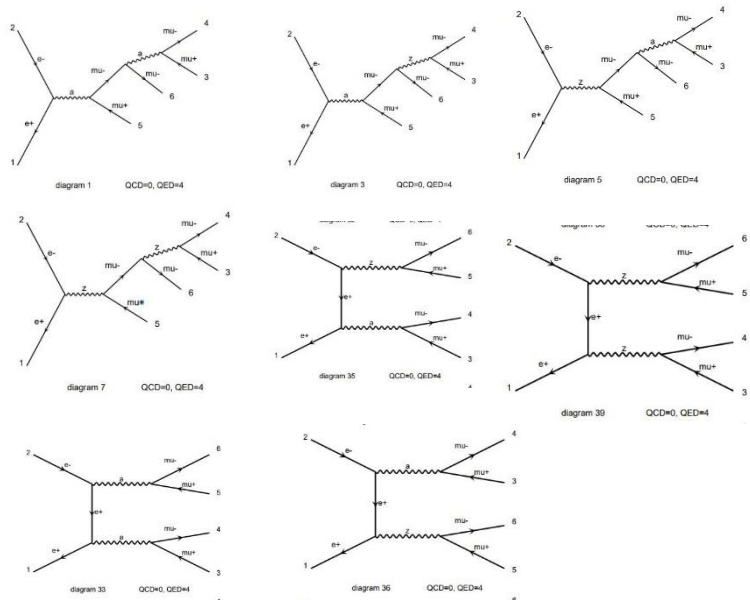
diagram 48 QCD=0, QED=4

$$e^+ e^- \rightarrow \mu^+ \mu^- \mu^+ \mu^-$$

Cross
Section
(Pb)



Findings from this interaction



Found 8 dominant Feynman diagrams from the possible 48

Volume 148B, number 6

PHYSICS LETTERS

6 December 1984

TOTAL AND VISIBLE CROSS SECTIONS FOR MULTILEPTON EVENTS IN e^+e^- COLLISIONS

F.A. BERENDS, P.H. DAVERVELDT and R. KLEISS
Instituut-Lorentz, Leiden, The Netherlands

Received 19 July 1984

We calculate cross sections for e^+e^- scattering into four-lepton final states such as $e^+e^-e^+e^-$, $e^+e^-\mu^+\mu^-$, $\mu^+\mu^-\mu^+\mu^-$, $\mu^+\mu^-\tau^+\tau^-$. We also give exclusive cross sections for all cases where one or more lepton tracks are at large angles to the beams. The calculations are performed using a Monte Carlo event generator which takes into account the complete set of relevant lowest order Feynman diagrams.

Volume 148B, number 6

PHYSICS LETTERS

6 December 1984

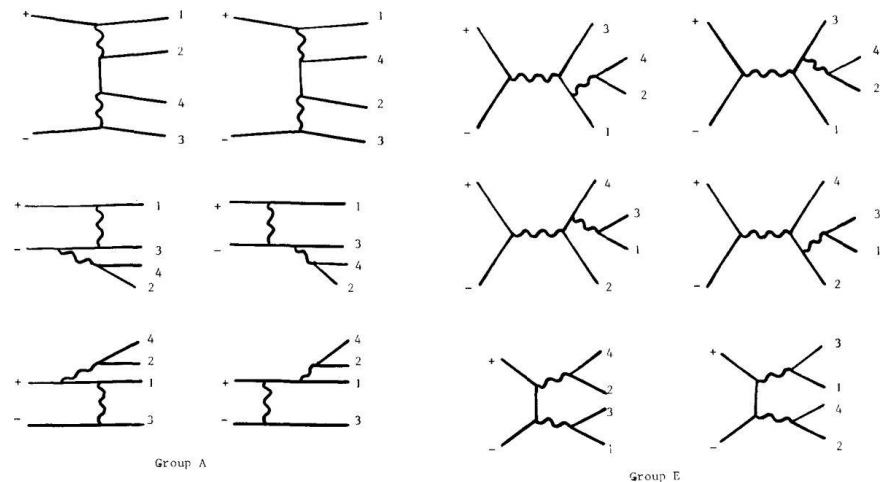


Fig. 1. Feynman graphs for four-lepton production. Groups B, C and D are obtained from A by interchanging, respectively: $1 \leftrightarrow 2$; $3 \leftrightarrow 4$; $1 \leftrightarrow 2$ and $3 \leftrightarrow 4$. Group F is obtained from E by interchanging $1 \leftrightarrow 2$. The groups contributing to the various processes are $\mu\mu\tau\tau$: E; $\mu\mu\mu\mu$: E, F; $ee\mu\mu$: A, E; $eeee$: all groups.

Geant 4 Profiling

What's Geant 4?

Geant4 (for **GEometry ANd Tracking**) is a [platform](#) for "the [simulation](#) of the passage of [particles](#) through [matter](#)," using [Monte Carlo methods](#). It is the successor of the [GEANT](#) series of software toolkits developed by [CERN](#), and the first to use [object oriented programming](#) (in [C++](#))

www.geant4.cern.ch

What did I do?

- Studied four examples to profile following three different versions of Geant 4 on KISTI supercomputer Tachyon 2:
g4 10.01.p01 - sequential
g4 10.03mt - multithread
g4 10.03 - sequential
- Basic : B1 (Energy deposit calculated in a volume)
 B2 (Simulates a fixed target experiment)
 B3 (Simulates a Positron Emitted Tomography System)
)
- Advanced: Brachytherapy (Simulates energy deposit by Iridium, Iodine sources in water)

B1 comparison

Hadronic Processes for He3

Process: hadElastic

Model: hElasticLHEP: 0 eV /n ---> 100 Te

Cr_sctns: Glauber-Gribov nucleus nucleus: 0 eV ---> 2.8

Cr_sctns: GheishaElastic: 0 eV ---> 100 TeV

```

=====
>
=====
=====
Pre-compound/De-excitation Physics Parameters
=====
=====
Type of pre-compound inverse x-section          3
Type of de-excitation inverse x-section          3
Min excitation energy (keV)                     0.1
Level density (1/MeV)                           0.1
Time limit for long lived isomeres (ns)          1e+07
Correlated gamma emission flag                   0
=====
=====

```

g4.10.01 .p01 seq uential	No
G4.10.03 mt	Yes
G4.10.03 sequenti al	Yes

 γ γ

>

 \succ γ \succ γ

✓

Start closing geometry.

G4GeometryManager::ReportVoxelStats -- Voxel Statistics <

Total memory consumed for geometry optimisation: 0 kByt <
Total CPU time elapsed for geometry optimisation: 0 secon <

Voxelisation: top CPU users:

Percent	Total CPU	System CPU	Memory	Volume	<
-----	-----	-----	-----	-----	<
0.00	0.00	0.00	0k Envelope	<	<

Voxelisation: top memory users:

Percent	Memory	Heads	Nodes	Pointers	Tota	<
-----	-----	-----	-----	-----	-----	<
100.00	0k	1	3	4	<	<

<

<

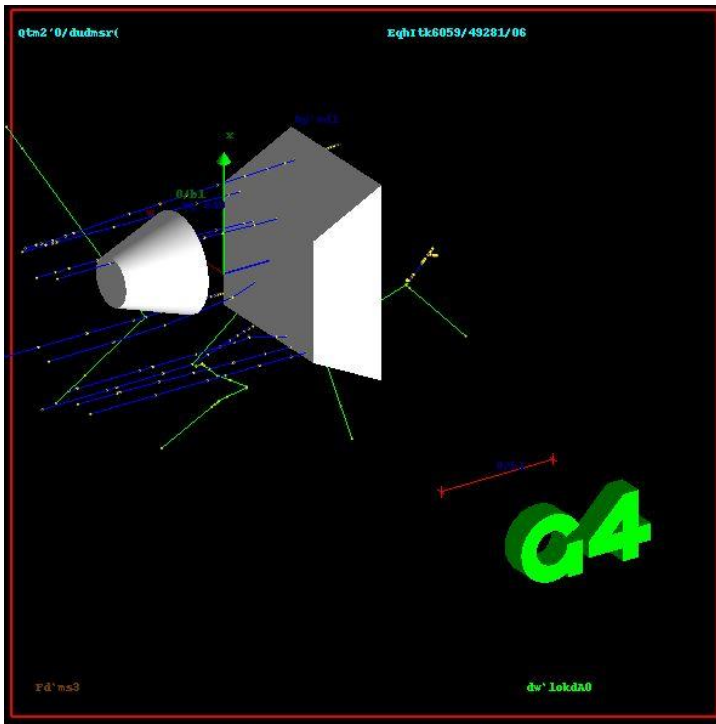
<

g4.10.01 .p01 sequential	Yes
G4.10.03 mt	No
G4.10.03 sequential	Yes

OpenGL graphics B1

Version 10.01.p01

Version 10.03mt

A screenshot of a terminal window showing a series of commands and error messages. The window title is 'Xstart' and the session is 'Session1'. The commands include setting text, visibility, and viewer settings. The errors are related to the G4VisCommandsViewerSet class.

```
phy02@tachyon2a:./scratch2/phy02/tmp2/B1/bin/test
# Attach text to one corner of Shape2, with a small, fixed offset
/vis/scene/add/text 6 7 10 cm 18 4 4 Shape2
#
# To get nice view
# Make the "World" box invisible
/vis/geometry/set/visibility World 0 false
# "Envelope" is transparent blue to represent water
/vis/geometry/set/colour Envelope 0 0 0 1 .3
/vis/viewer/set/style surface
ERROR: G4VisCommandsViewerSet::SetNewValue: no current viewer.
/vis/viewer/set/hiddenMarker true
ERROR: G4VisCommandsViewerSet::SetNewValue: no current viewer.
/vis/viewer/set/viewpointThetaPhi 120 150
ERROR: G4VisCommandsViewerSet::SetNewValue: no current viewer.
#
# Re-establish auto refreshing and verbosity:
/vis/viewer/set/autoRefresh true
ERROR: G4VisCommandsViewerSet::SetNewValue: no current viewer.
/vis/verbose warnings
Visualization verbosity changed to warnings (3)
#
# For file-based drivers, use this to create an empty detector view:
#/vis/viewer/flush
Idle>
```

B2 comparison

```
Checking overlaps for volume Chamber_PV ... OK!
Checking overlaps for volume Chamber_PV ... OK!
```

```
Checking overlaps for volume Chamber_PV ... OK!
Checking overlaps for volume Chamber_PV ... OK!
> ===== Pre-compound/De-excitation Physics Parameters =====
>
> Type of pre-compound inverse x-section      3
> Type of de-excitation inverse x-section      3
> Min excitation energy (keV)                 0.1
> Level density (1/MeV)                       0.1
> Time limit for long lived isomeres (ns)      1e+07
> Correlated gamma emission flag              0
> =====
>
> FTFP_BERT : new threshold between BERT and FTFP is over the
> for pions : 3 to 12 GeV
> for kaons : 3 to 12 GeV
> for proton : 3 to 12 GeV
> for neutron : 3 to 12 GeV
>
```

```
## Adding tracking cuts for neutron TimeOut(ns)= 10000 Kin
phot: for gases SubType= 12 BuildTable= 0
```

```
## Adding tracking cuts for neutron TimeOut(ns)= 10000 Kin
phot: for gases SubType= 12 BuildTable= 0
```

```
-----
Hadronic Processes for He3
```

```
-----
Hadronic Processes for He3
> Process: hadElastic
> Model: hElasticLEP: 0 eV /n ----> 100 Te
> Cr_sctns: Glauber-Gribov nucleus nucleus: 0 eV ----> 2.8
> Cr_sctns: GheishaElastic: 0 eV ----> 100 TeV
>
PrnProc: He3Inelastic
```

PrnProc: He3Inelastic

```
1 0.0218 -0.0471 -2.08e+03 0 0.00104 0.0601 1
+ G4Track Information: Particle = e-, Track ID = 13, Pa
Step# X(mm) Y(mm) Z(mm) KinE(MeV) dE(MeV) StepLeng
0 0.0169 -0.0505 -2.12e+03 0.00164 0 0 0
1 0.0262 0.0294 -2.12e+03 0.00164 0 0.00164 0.119
+ G4Track Information: Particle = e-, Track ID = 12, Pa
Step# X(mm) Y(mm) Z(mm) KinE(MeV) dE(MeV) StepLeng
0 0.00776 -0.00943 -2.29e+03 0.00191 0 0 0
1 0.0253 0.0535 -2.29e+03 0.00191 0 0.00191 0.151
+ G4Track Information: Particle = e-, Track ID = 11, Pa
Step# X(mm) Y(mm) Z(mm) KinE(MeV) dE(MeV) StepLeng
0 0.00112 -0.00104 -2.42e+03 2.18 0 0 0
1 0.0616 -0.0551 -2.42e+03 1.83 0.355 0.265
2 0.0907 -0.0563 -2.42e+03 0.546 1.29 1.33
3 0.0905 -0.0596 -2.42e+03 0.546 0.546 0.342
```

**g4.10.01.p01 sequ
ential**

No

G4.10.03mt

Yes

G4.10.03 sequential

Yes

**g4.10.01.p01 sequ
ential**

No

G4.10.03mt

Yes

G4.10.03 sequential

Yes

**g4.10.01.p01 sequ
ential**

Yes

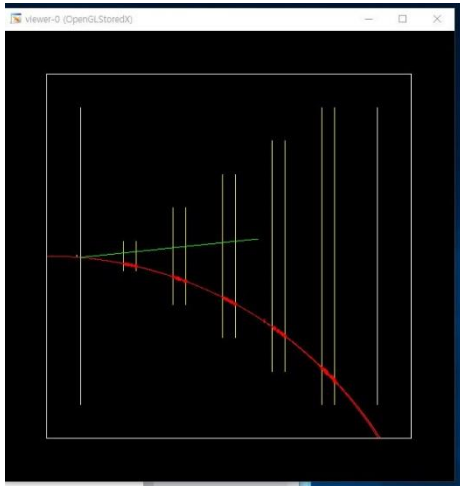
G4.10.03mt

No

G4.10.03 sequential

Yes

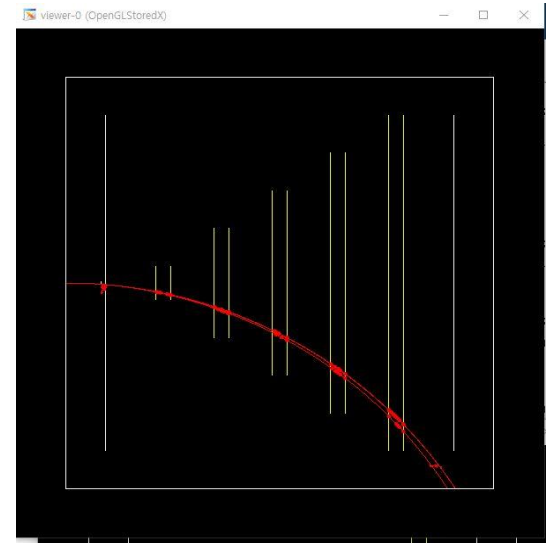
OpenGL graphics B2



V 10.01.p01

```
phy02@tachyon2a:~/scratch2/phy02/tmp2/B2/bintest/B2a
# keep the above two lines but also add:
# /vis/filtering/trajectories/particleFilter-0/invert true
#
# Many other options are available with /vis/modeling and /vis/filtering.
# For example, to select colour by particle ID:
# /vis/modeling/trajectories/create/drawByParticleID
# /vis/modeling/trajectories/drawByParticleID-0/default/setDrawStepPts true
# To select or override default colours (note: e+ is blue by default):
# /vis/modeling/trajectories/list
# /vis/modeling/trajectories/drawByParticleID-0/set e+ yellow
#
# To superimpose all of the events from a given run:
/vis/scene/endOfEventAction accumulate
ERROR: No current sceneHandler. Please create one.
#
# Re-establish auto refreshing and verbosity:
/vis/viewer/set/autoRefresh true
ERROR: C4VisCommands::Set::SetNewValue: no current viewer.
/vis/verbose warnings
Visualization verbosity changed to warnings {3}
#
# For file-based drivers, use this to create an empty detector view:
# /vis/viewer/flush
Idle>
```

V 10.03mt



V 10.01.03

B3 Comparison

```
G4SDManager::AddNewCollection: the collection <crystal/edep>
New sensitive detector <crystal> is registered at /
G4SDManager::AddNewCollection: the collection <patient/dose>
New sensitive detector <patient> is registered at /
```

```
/tracking/verbose 2
#
/run/beamOn 1
### Run 0 start.
```

-----End of Global Run-----
The run was 1 events ; Nb of 'good' e+ annihilations: 0
Total dose in patient : 0.02170800082577139 picoGy

```
tracking/verbose 0
run/beamOn 20
## Run 1 start.
--> end of event: 0
```

-----End of Global Run-----
The run was 20 events ; Nb of 'good' e+ annihilations: 6
Total dose in patient : 0.6048013518350945 picoGy

```

graphics systems deleted.
  Visualization Manager deleting...

```

```
< G4SDManager::AddNewCollection : the collection <crystal
ex> G4SDManager::AddNewCollection : the collection <patient
> G4WT1 >
> G4WT1 >
> G4WT1 > Local thread RunManagerKernel version Name: ge
> G4WT1 >
> G4WT1 >
> G4WT1 >
> G4WT1 >
> G4WT1 >
> G4WT1 > Local thread RunManagerKernel version Name: ge
> G4WT1 >
> G4WT1 >
> G4WT1 >
> G4WT1 > G4SDManager::AddNewCollection : the collection
> G4WT1 > G4SDManager::AddNewCollection : the collection
> G4WT1 > G4SDManager::AddNewCollection : the collection
> G4WT1 > G4SDManager::AddNewCollection : the collection
> G4WT1 >
> G4WT1 > ### == Deexcitation model UatomDeexcitation i
> G4WT1 > DefaultRegionForTheWorld 1 1 0
> G4WT1 > ### == Auger cascade flag: 1
> G4WT1 > ### == Ignore cuts flag: 1
> G4WT1 >
> G4WT1 > ### == Deexcitation model UatomDeexcitation i
> G4WT1 > DefaultRegionForTheWorld 1 1 0
> G4WT1 > ### == Auger cascade flag: 1
> G4WT1 > ### == Ignore cuts flag: 1
> #trackings/verbose 2
#
./run/beamOn 1
### Run 0 start.
```

```

> G4WTO > -----
> G4WTO > -----
-----End of Global Run-----
The run was 1 events ; Nb of 'good' e+ annihilations: 0
Total dose in patient : 0.0653334 picroGy

```

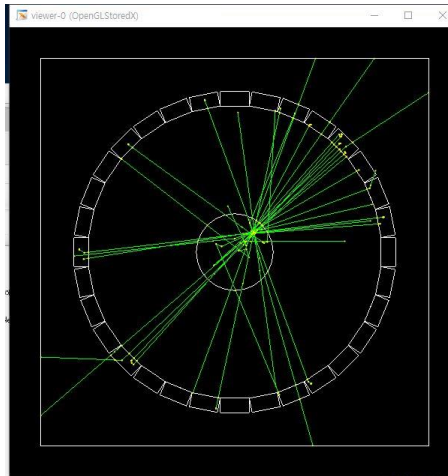
```
#
/tracking/verbose 0
/run/beamOn 20
### Run 1 start.
G4WT0 > ### Run 1 start.
G4WT1 > ### Run 1 start.
G4WT0 >
G4WT0 > -----End of Local Run-----
G4WT0 > The run was 20 F18; Nb of good e+ annihilation
G4WT0 > Total dose in patient : 0.526865903292013 picog
G4WT0 >
G4WT0 >
```

```
-----End of Global Run-----
| The run was 20 events ; Nb of 'good' e+ annihilations: 2
| Total dose in patient : 0.526886 pGy
```

Graphics systems deleted.
Visualization Manager deleting...

g4.10.01.p01 sequential	No
G4.10.03mt	Yes
G4.10.03 sequential	No

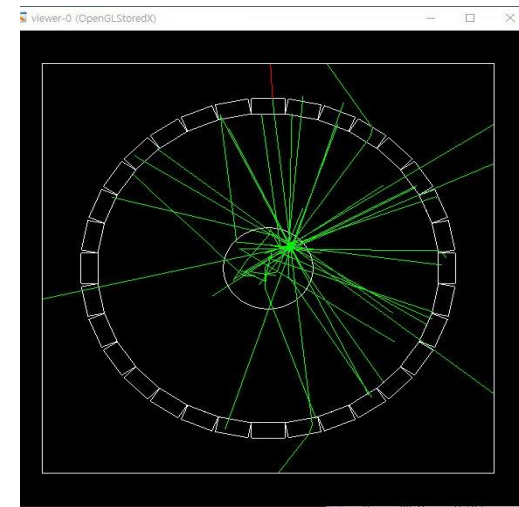
OpenGL graphics B3



V 10.01.p01

```
phy02@tachyon2a://scratch2/phy02/tmp2/B3/bintest/B3b
#
# Many other options are available with /vis/modeling and /vis/filtering.
# For example, to select colour by particle ID:
/vis/modeling/trajectories/create/drawByParticleID
/vis/modeling/trajectories/drawByParticleID-0/default/setDrawStepPts true
/vis/scene/notifyHandlers scene-0
/vis/modeling/trajectories/drawByParticleID-0/default/setStepPtsSize 1
# To select or override default colours (note: e+ is blue by default):
/vis/modeling/trajectories/list
/vis/modeling/trajectories/drawByParticleID-0/set e+ yellow
#
# To superimpose all of the events from a given run:
/vis/scene/endOfEventAction accumulate
ERROR: No current sceneHandler. Please create one.
#
# Re-establish auto refreshing and verbosity:
/vis/viewer/set/autoRefresh true
ERROR: C4VisCommandsViewerSet::SetNewValue: no current viewer.
/vis/verbose warnings
Visualization verbosity changed to warnings {3}
#
# For file-based drivers, use this to create an empty detector view:
/vis/viewer/flush
Idle>
```

V 10.03mt



V 10.01.03

Brachytherapy Comparison

```
.... G4ScoringMessenger::MeshBinCommand - G4ScoringBox
/score/quantity/energyDeposit eDep
/score/close
/score/list
G4ScoringManager has 1 scoring meshes.
G4ScoringBox : boxMesh_1 --- Shape: Box mesh
Size (x, y, z): (15, 15, 15) [cm]
# of segments: (300, 300, 300)
displacement: (0, 0, 0) [cm]
registered primitive scorers :
  0 eDep
/control/execute iridium_source_primary.mac
/gps/particle gamma
/gps/energy 356.0 keV
/gps/pos/type Volume
/gps/pos/shape Cylinder
/gps/pos/radius 0.30 mm
/gps/pos/halfz 1.75 mm
/gps/pos/centre 0, 0, -1.975 mm
/gps/ang/type iso
/run/beamOn 1000
/run/geometryModified
```

```
> /score/mesh/nBin 801 801 1
.... G4ScoringMessenger::MeshBinCommand - G4ScoringBox
/score/quantity/energyDeposit eDep
/score/close
/score/list
G4ScoringManager has 1 scoring meshes.
G4ScoringBox : boxMesh_4 --- Shape: Box mesh
Size (x, y, z): (10.0125, 10.0125, 0.0125) [cm]
# of segments: (801, 801, 1)
displacement: (0, 0, 0) [cm]
registered primitive scorers :
  0 eDep
| /run/beamOn 5000
<
<
<
<
<
<
<
<
<
<
/run/geometryModified
```

g4.10.0
1.p01 s
equenti
al

No

G4.10.0
3mt

Yes

G4.10.0
3 seque
ntial

Yes

```
ICRU49NucStopping : Emin= 0 eV Emax= 1 M
```

```
ICRU49NucStopping : Emin= 0 eV Emax= 1 M
```

```
### === Deexcitation model UAtomDeexcitation is activated fo
DefaultRegionForTheWorld
```

```
<
<
```

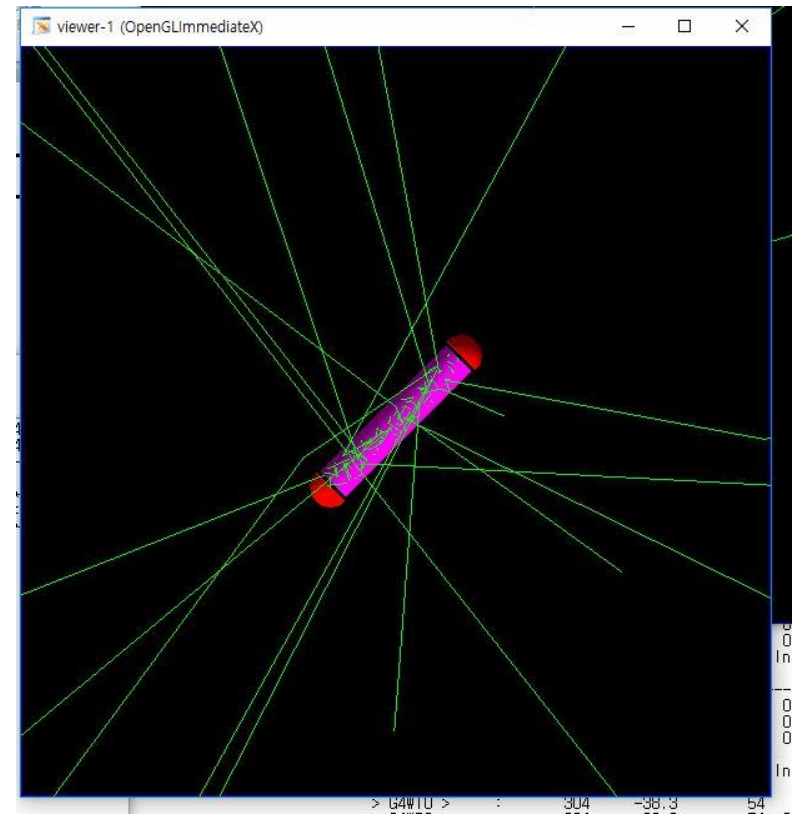
```
msc: for alpha SubType= 10
RangeFactor= 0.2, stepLimitType: 0, latDisplacement: 0 |
===== EM models for the G4Region DefaultRegionForTheWo
UrbanMsc : Emin= 0 eV Emax= 10 T |
```

```
msc: for alpha SubType= 10
RangeFactor= 0.2, stepLimitType: 0, latDisplacement: 1
===== EM models for the G4Region DefaultRegionForTheWo
UrbanMsc : Emin= 0 eV Emax= 1 T
```

OpenGL Brachytherapy

```
phy02@tachyon2a:./scratch2/phy02/tmp/brachy2/brachyt...  
"/vis/modeling/trajectories/create/drawByAttribute" and  
"/vis/Filtering/trajectories/create/attributeFilter" commands:  
G4TrajectoriesModel:  
Event ID (EventID): G4int  
Run ID (RunID): G4int  
G4SmoothTrajectory:  
Charge (Ch): unit: e+ (G4double)  
Track ID (ID): G4int  
Initial kinetic energy (IKE): G4BestUnit (G4double)  
Initial momentum magnitude (IMag): G4BestUnit (G4double)  
Initial momentum (IMom): G4BestUnit (G4ThreeVector)  
No. of points (NTP): G4int  
PDG Encoding (PDG): G4int  
Parent ID (PID): G4int  
Particle Name (PN): G4String  
G4SmoothTrajectoryPoint:  
Auxiliary Point Position (Aux): G4BestUnit (G4ThreeVector)  
Step Position (Pos): G4BestUnit (G4ThreeVector)  
ERROR: No current sceneHandler. Please create one.  
ERROR: G4VisCommandsViewerSet::SetNewValue: no current viewer.  
Visualization verbosity changed to warnings (3)  
Graphics systems deleted.  
Visualization Manager deleting...  
1580% [phy02@tachyon2a bintest]$
```

V 10.03mt



V 10.01.03

Conclusion of Geant 4 profiling

- **Found errors** in OpenGL in 10.03mt version, led to reinstallation of Geant 4 at KISTI's supercomputer Tachyon 2. New version 10.03 sequential installed
- Found **three** main differences in three versions:
 - Both versions 10.03mt and 10.03 have new physics features such as deexcitation parameter data (in short, they give more info than 10.01.p01)
 - 10.03mt has **additional information** in output files as G4MT0 and G4MT1
 - Both sequential versions, 10.01.p01 and 10.03 give some information about the **memory** used

Future Prospects

Got interested in Deep Learning and its application in high energy physics

Using Geant 4, I can work in not only particle physics but also space physics, radiation in medicine, microelectronic radiation and nuclear physics

- It was an amazing experience!

Thank you!