Understanding the Higgs boson with the Large Hadron Electron Collider

Studying an electron - proton collision

Jonathan Esteves, Prof. Bruce Mellado

UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

Background picture is called 'Higgs boson" done by a digital artist named Celemiri, taken from http://nevsedni-svet.cz/wp-content/uploads/2014/05/Higgs_Boson_by_Celemiri.jpg

Introduction

•Currently CERN is planning on having an ep collider facility running with proton energy 7000 GeV and electron energy of 60 GeV. The price of the accelerator grows rapidly with the electron energy.

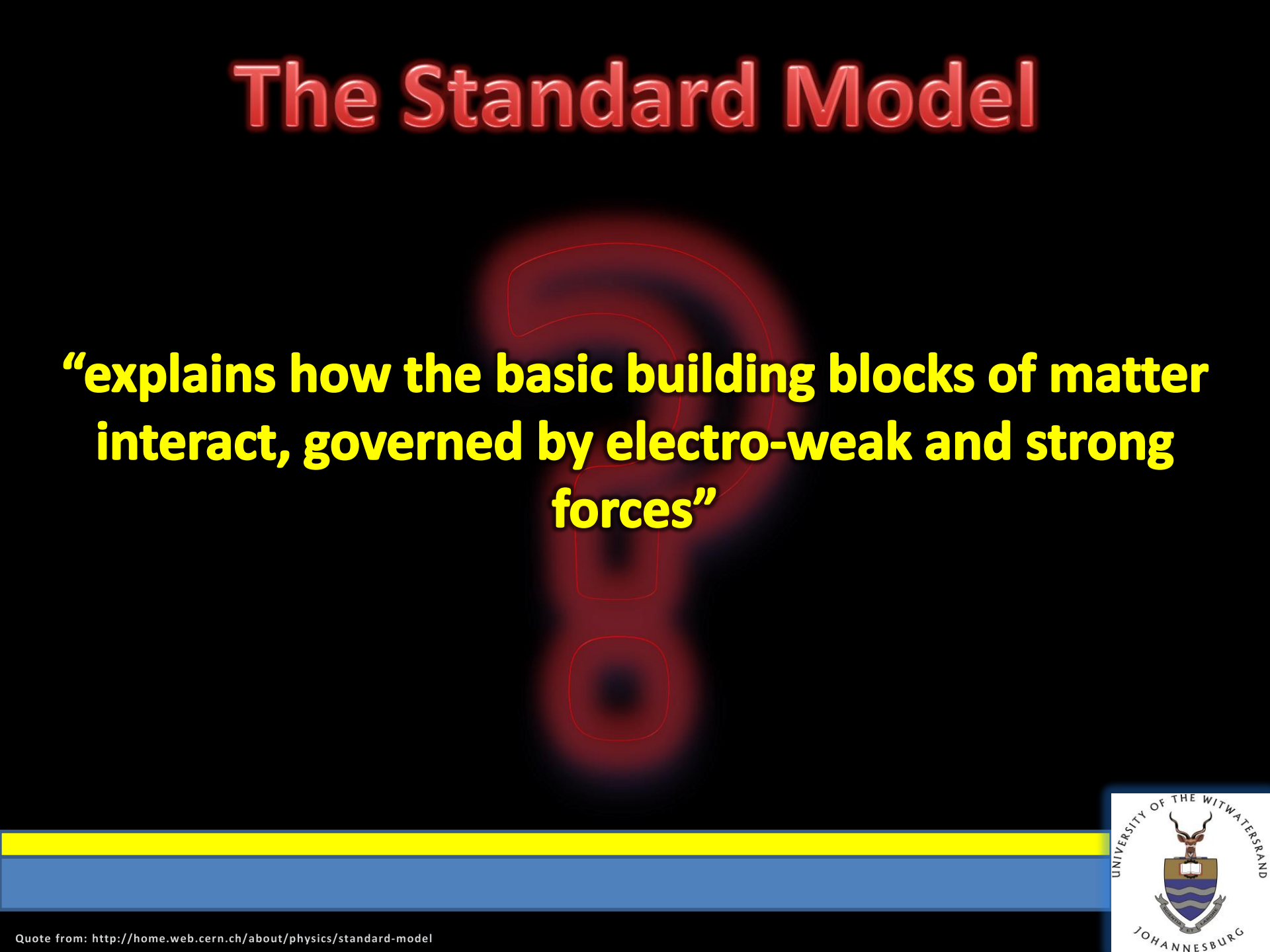
•This project is aimed at studying the effect of decreasing the electron energy in an electron-proton collision with the production of the higgs boson.

• This is in the interest of finding an optimal, economic electron energy for an electron - proton collision without compromising on the validity of the results. Using results obtained in this project, it was found that using electron energy between 40 GeV and 60 GeV would be sufficient to measure the higgs boson properties.

Presentation overview

1. Briefly describe the standard model of fundamental interactions
2. Introduce the elementary particles
3. Discuss the higgs boson
4. Collider facilities at CERN
5. Describe the electron – proton collisions studied
6. Illustrate how data was generated
7. Results
8. Conclusion

The Standard Model



“explains how the basic building blocks of matter interact, governed by electro-weak and strong forces”

Quote from: http://home.web.cern.ch/about/physics/standard-model

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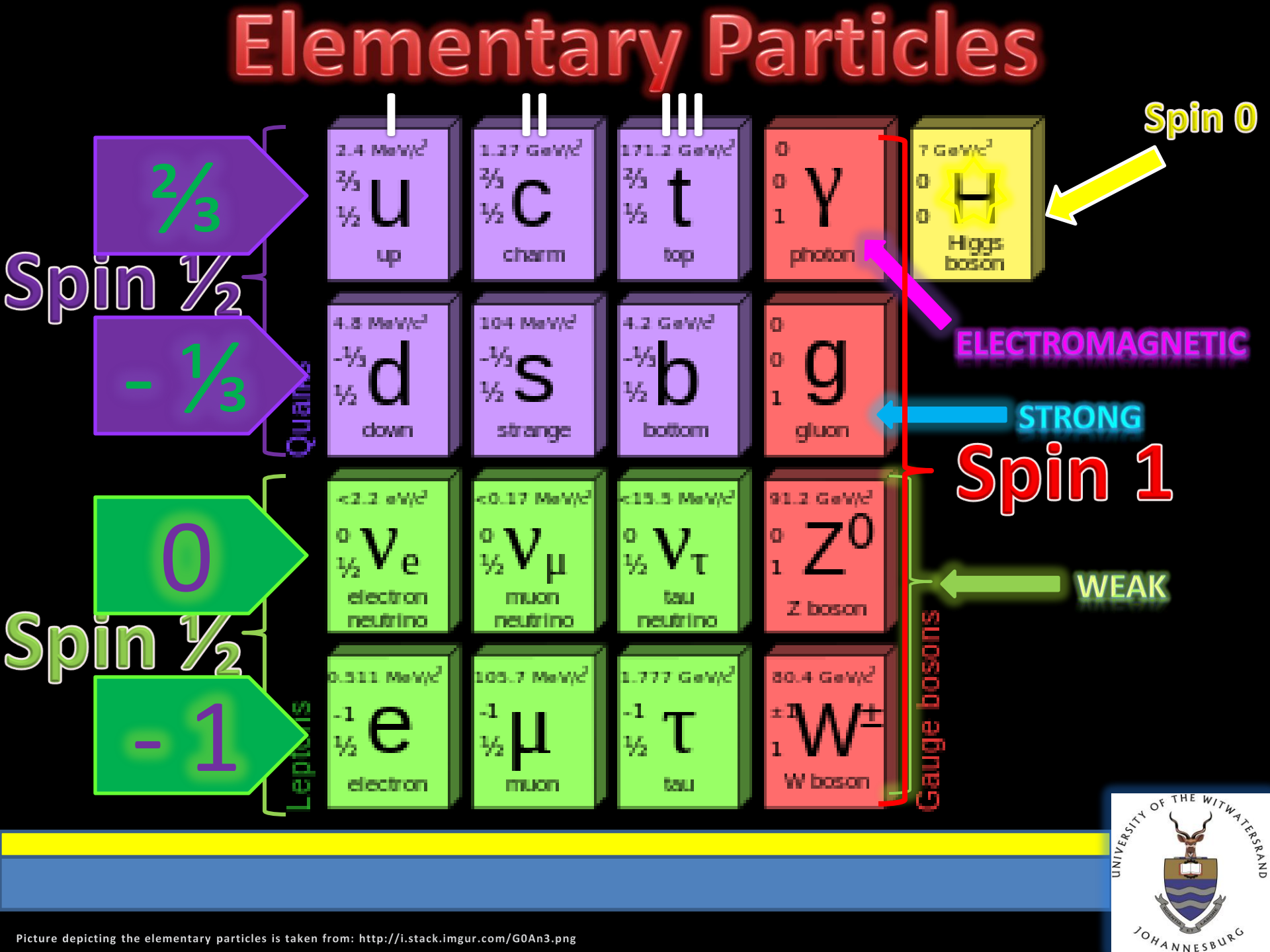
Elementary Particles



Picture depicting the elementary particles is taken from: http://i.stack.imgur.com/G0An3.png

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Higgs boson

As we all probably know , the quickly decaying higgs boson was discovered on July 4th 2012 using the ATLAS and CMS detectors at the Large Hadron Collider.....

but what exactly is the higgs boson ?!?!?!?!

A field, called the higgs field, spans the whole universe and is responsible for the slowing down particles in space, making them acquire mass.

The higgs boson is formed by the excitation of the higgs field, which is achieved by a proton-proton or an electron-proton collision.

So it is no surprise that without the higgs boson, particles would continue moving at the speed of light; making the formation of solid objects impossible.

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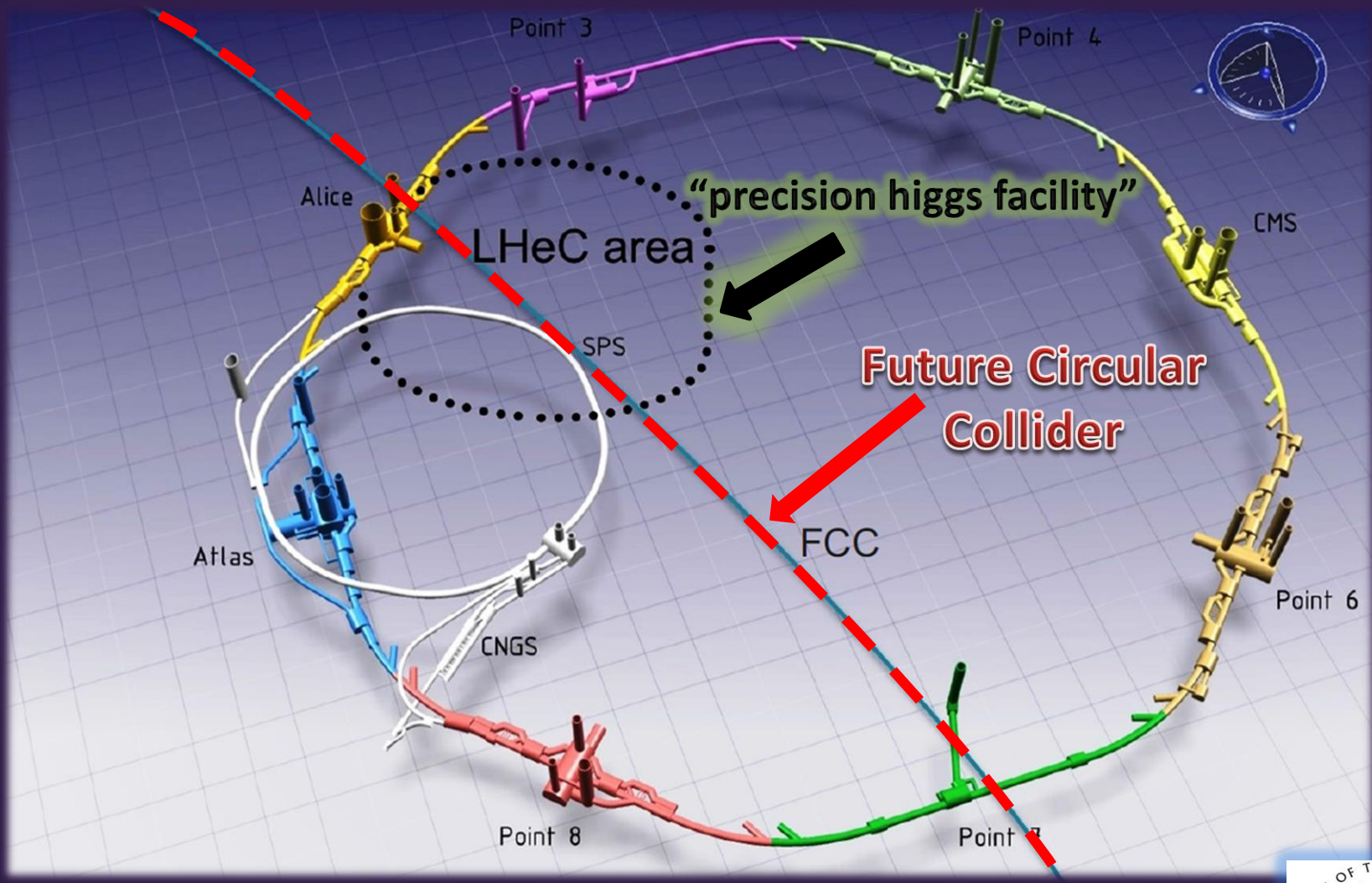
Background "High Energy Physics" picture is taken from: http://f1.bcbits.com/img/a4290076777_10.jpg

Future LHeC at CERN's LHC



Picture of LHC and picture of the LHeC detector are taken from: http://lhec.web.cern.ch/figures
Quote "precision Higgs facility" taken from http://lhec.web.cern.ch/lhec

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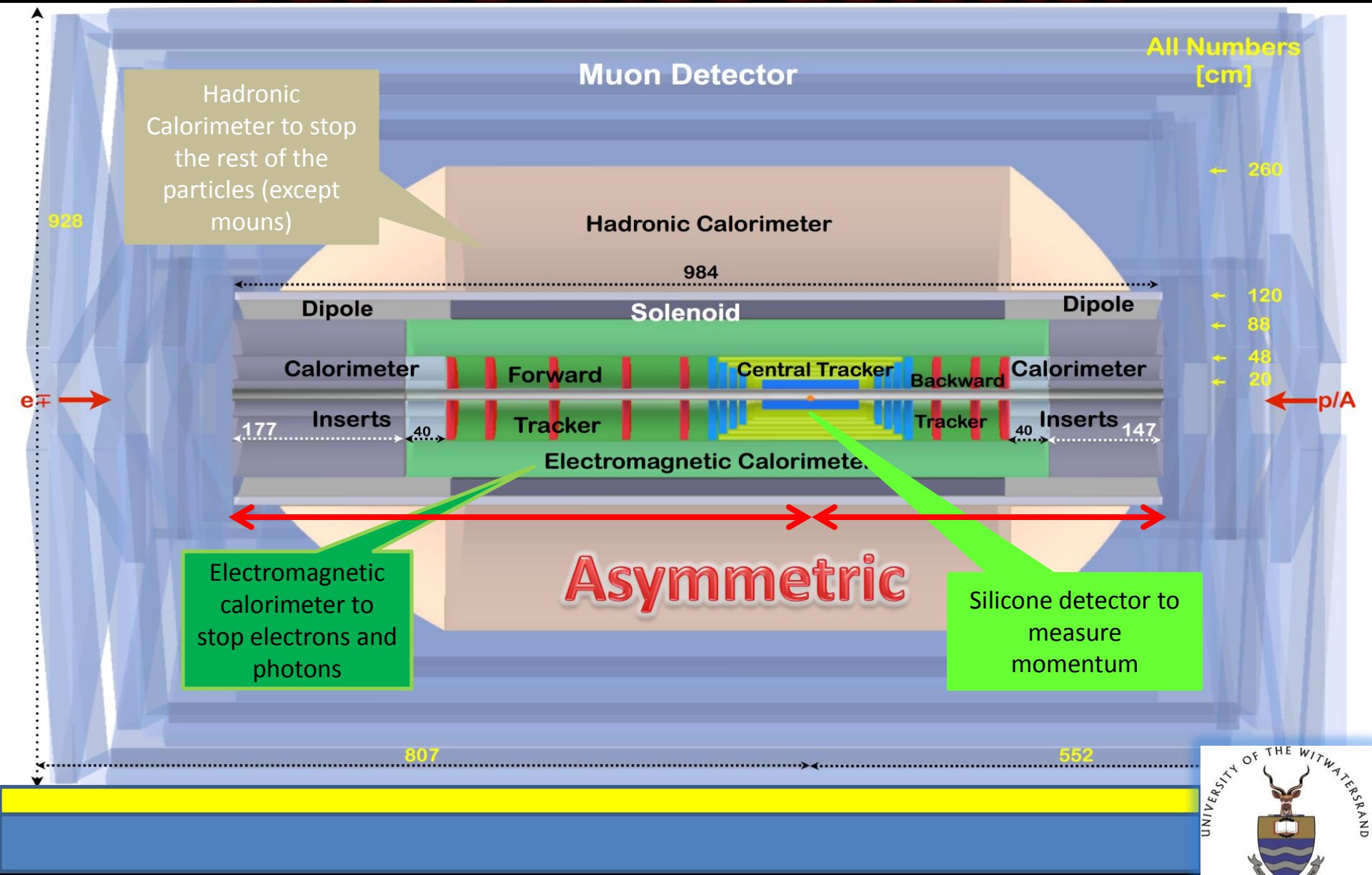
Future LHeC detector



Picture of the LHeC detector are taken from: http://lhec.web.cern.ch/figures
Quote "precision Higgs facility" taken from http://lhec.web.cern.ch/lhec

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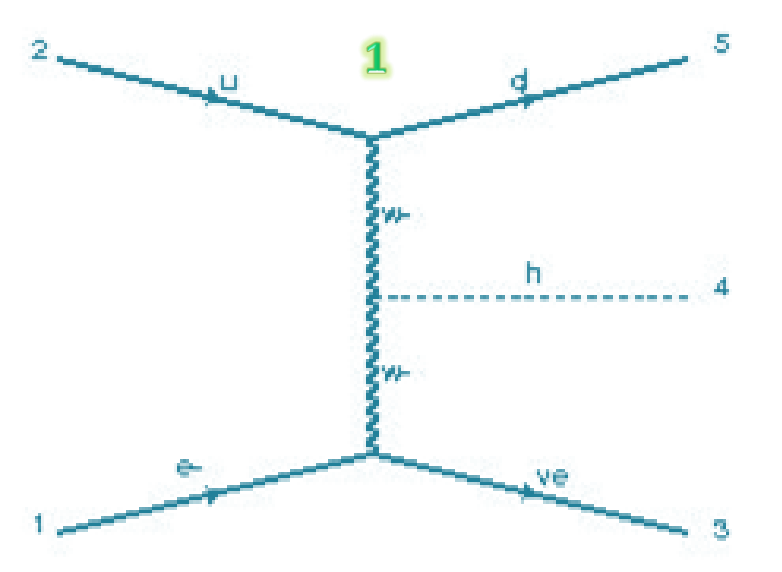
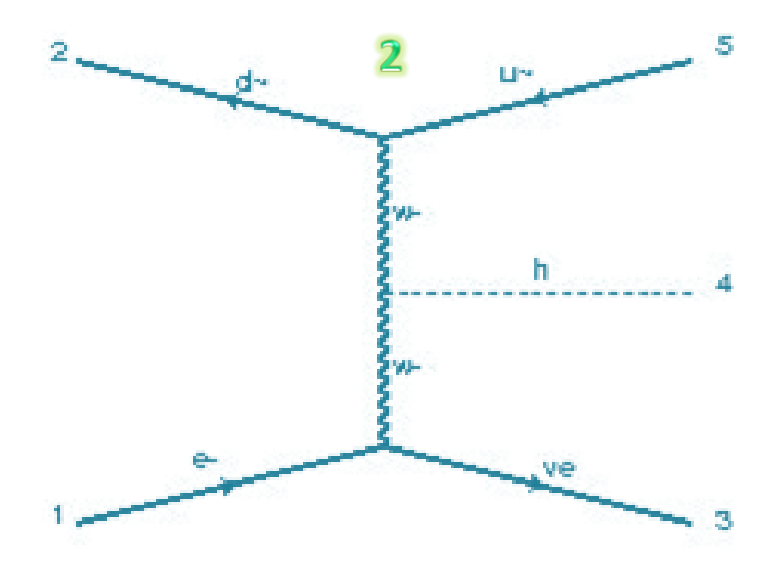
Higgs production process:

electron + proton -> electron neutrino + higgs + jet (initiated by dbar or u)



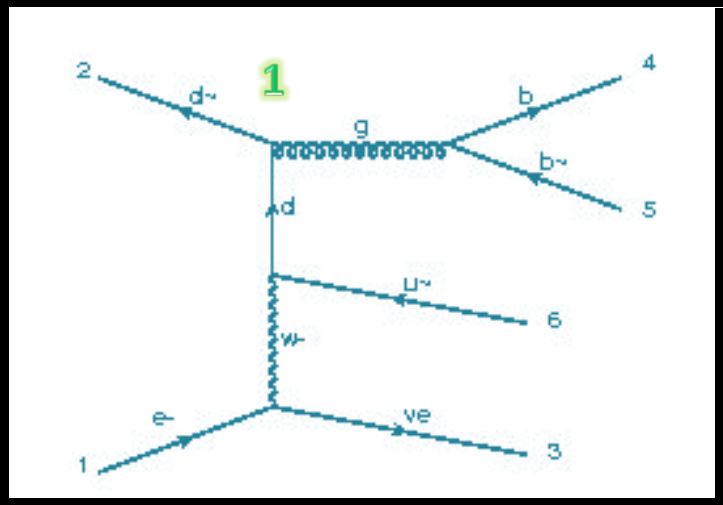


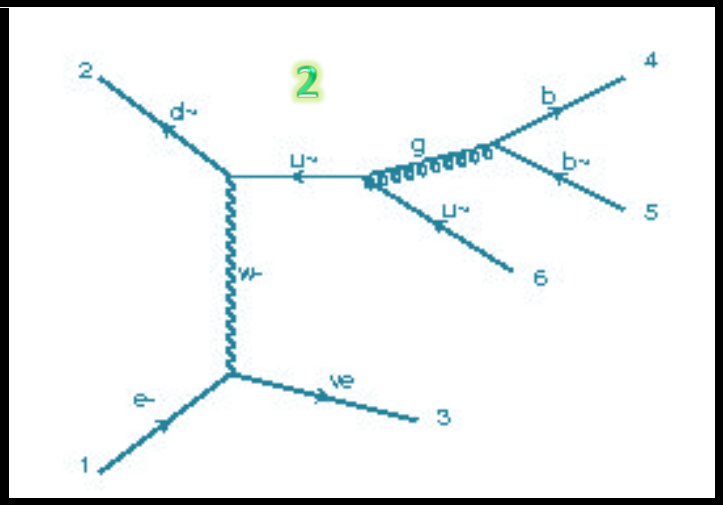
The higgs will quickly decay into a pair of bottom quarks.

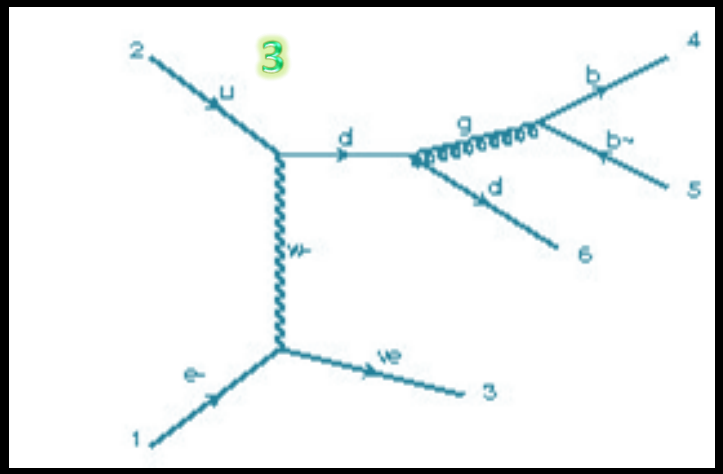
Feynman diagrams from: http://madgraph.hep.uiuc.edu/

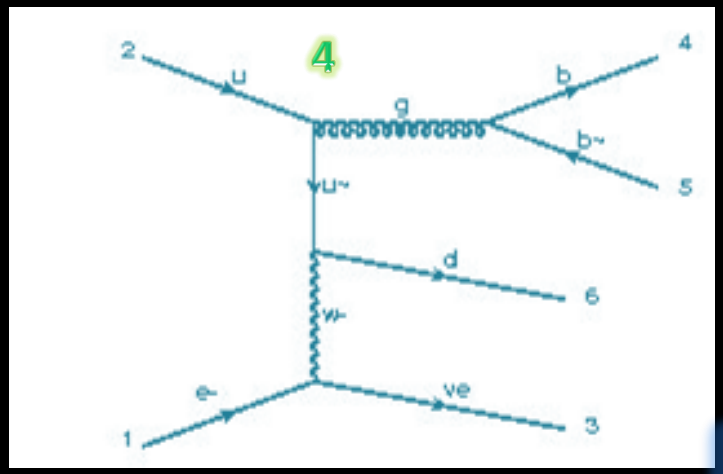
Background process:

electron + proton -> electron neutrino + bottom quark + bottom anti-quark + jet









Feynman diagrams from: http://madgraph.hep.uiuc.edu/

Data generation

- Monte Carlo events were generated using the Illinois MadGraph website.
- 50 000 events were generated for each process at different electron energies.
- 10 GeV -> 100 GeV (increments of 10 GeV)
- This resulted in a total of 300 kinematic distributions which were analyzed and the data was collected

Background picture is conceptual computer artwork of the higgs boson, taken from: http://www.sciencephoto.com/static/slides/2506/576x340/c0114124.jpg

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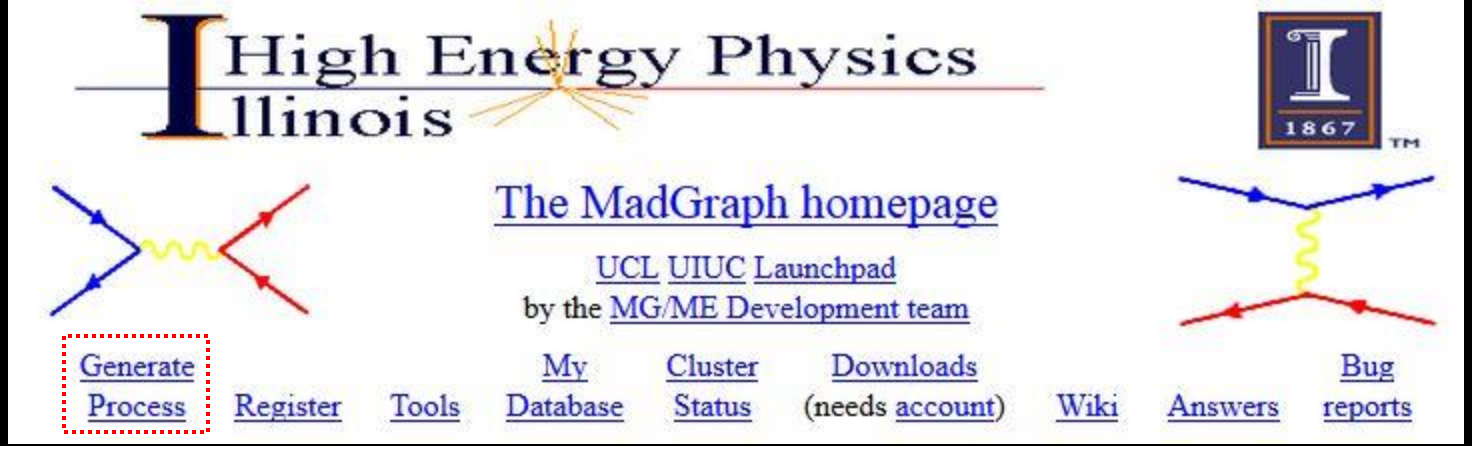

Generate processes online using MadGraph 5

To improve our web services we request that you register. Registration is quick and free. You may register for a password by clicking here.
Please note the correct reference for MadGraph5_aMC@NLO, arXiv:1405.0301 [hep-ph].

Code can be generated either by:

e- p > ve h j
&
e- p > ve bb~ j / h

I. Fill the form:

Model: SM — Model descriptions

Input Process: — Examples/format

Example: p p > w+ j j QED=3, w+ > l+ vl

p and j definitions: p=j=d u s c d~ u~ s~ c~ g

sum over leptons: l+ = e+, mu+; l- = e-, mu-; vl = ve, vm, vt; vl~ = ve~, vm~, vt~

Submit

These screen shots were taken from the MadGraph website: http://madgraph.hep.uiuc.edu/

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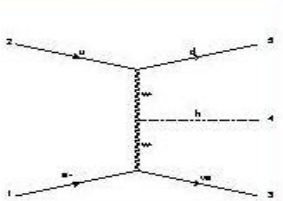
MadEvent Card for e- p > ve h j

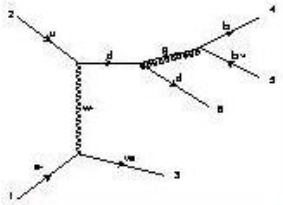
Created: Sat May 31 08:21:00 CDT 2014

Process: e- p > ve h j
Model: sm



Links	Status
Process Information	Generation Complete
Code Download	Available
On-line Event Generation	Available (access restricted)
Results and Event Database	11 runs available

Process: e- p > ve b b~ j/h
Model: sm



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These screen shots were taken from the MadGraph website: http://madgraph.hep.uiuc.edu/

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Collider and cuts

Choose an option for the run_card.dat: Use the present file

The present run_card.dat [Edit run_card.dat]

The default file

Upload a run_card: [Browse...] No file selected.

Choose the number of sequential runs requested (be carefull if > 1 !): 1

Plotting Card

Choose an option for the plot_card.dat: Use the present file

The present plot_card.dat [Edit plot_card.dat]

The default file

Upload a plot_card: [Browse...] No file selected.

[Send] the form to generate the cards.

These screen shots were taken from the MadGraph website: http://madgraph.hep.uiuc.edu/

Run Card

```
#*********************************************************************
# Number of events and rnd seed                                      *
# Warning: Do not generate more than 1M events in a single run       *
# If you want to run Pythia, avoid more than 50k events in a run.    *
#*********************************************************************
 50000 = nevents ! Number of unweighted events requested
     0       = iseed   ! rnd seed (0=assigned automatically=default))
#*********************************************************************
# Collider type and energy                                           *
# lpp: 0=No PDF, 1=proton, -1=antiproton, 2=photon from proton,      *
#                                         3=photon from electron     *
#*********************************************************************
     0      = lpp1    ! beam 1 type
     1      = lpp2    ! beam 2 type
    10      = ebeam1  ! beam 1 total energy in GeV
  7000      = ebeam2  ! beam 2 total energy in GeV
#*********************************************************************
```

Electron energy

These screen shots were taken from the MadGraph website: http://madgraph.hep.uiuc.edu/

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Plot Card

Step size

Range

```
#*********************************************************************
#
# Do NOT put spaces at the beginning of the following lines!
# Begin PlotRange # This is TAG. Do not modify this line
pt          10    0   400    # bin size, min value, max value
et          10    0   800    # bin size, min value, max value
etmiss      10    0   400    # bin size, min value, max value
ht          20    0  1000
y           0.2   -8   8      # etc.
mij         20    0  1000
dRij        0.1   0    12
#delta_phi  0.1   0   3.1
#X1         1     0   100
#XYZA1      1     0   100
# End PlotRange # This is TAG. Do not modify this line
#*********************************************************************
```

These screen shots were taken from the MadGraph website: http://madgraph.hep.uiuc.edu/

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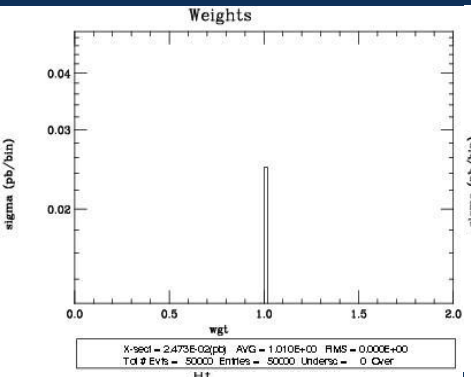
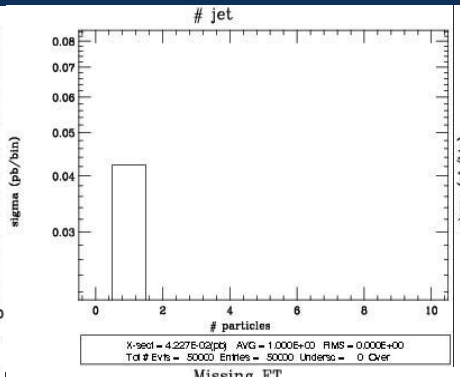
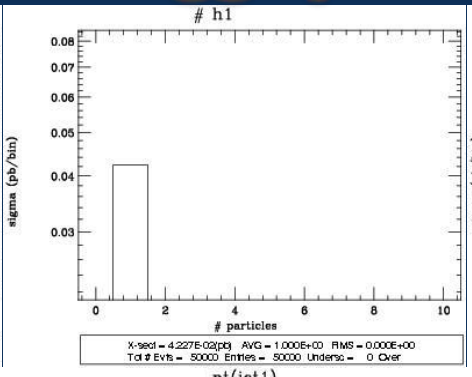
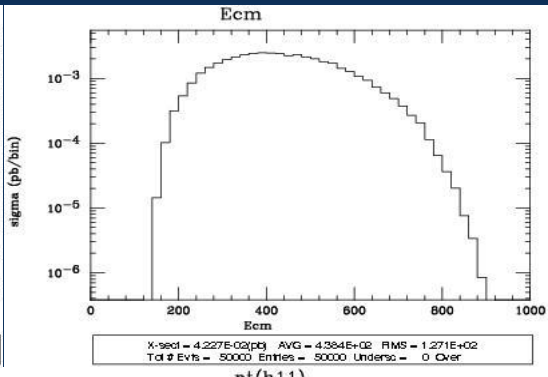
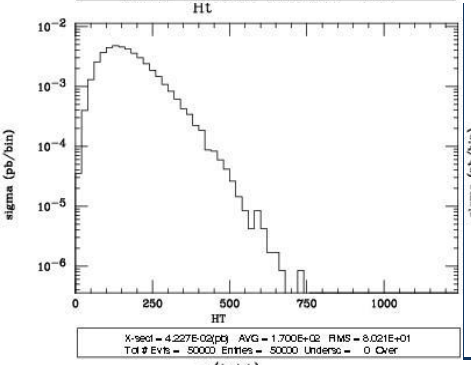
Kinematic distributions of Higgs process at 30 GeV

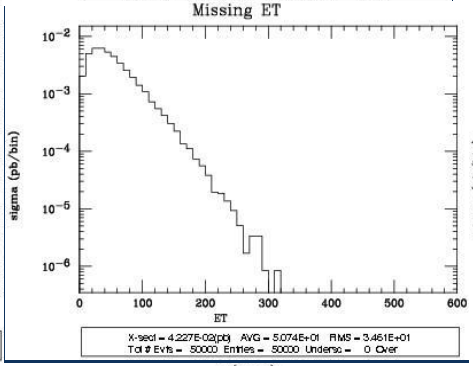


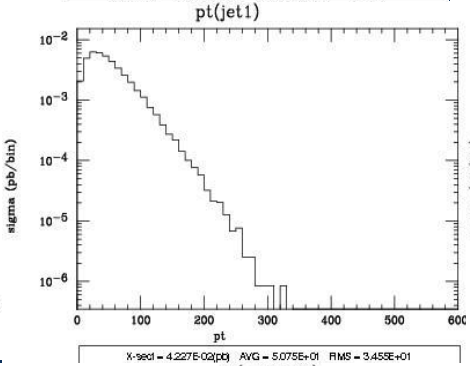


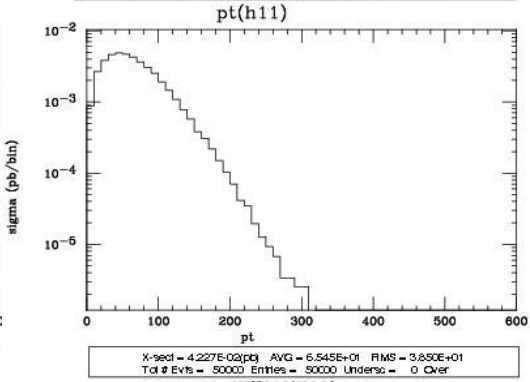


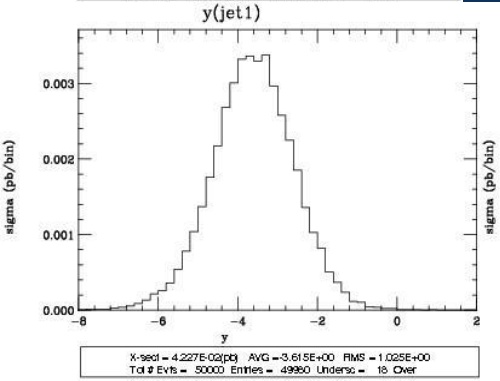


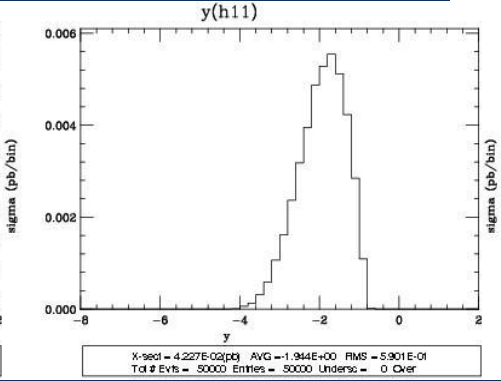


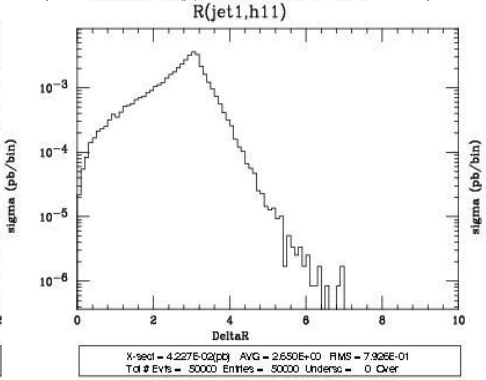


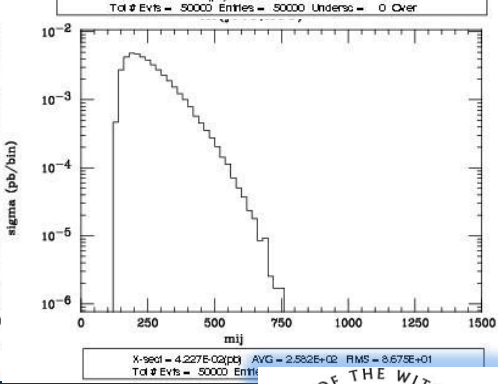












These screen shots were taken from the MadGraph website: http://madgraph.hep.uiuc.edu/

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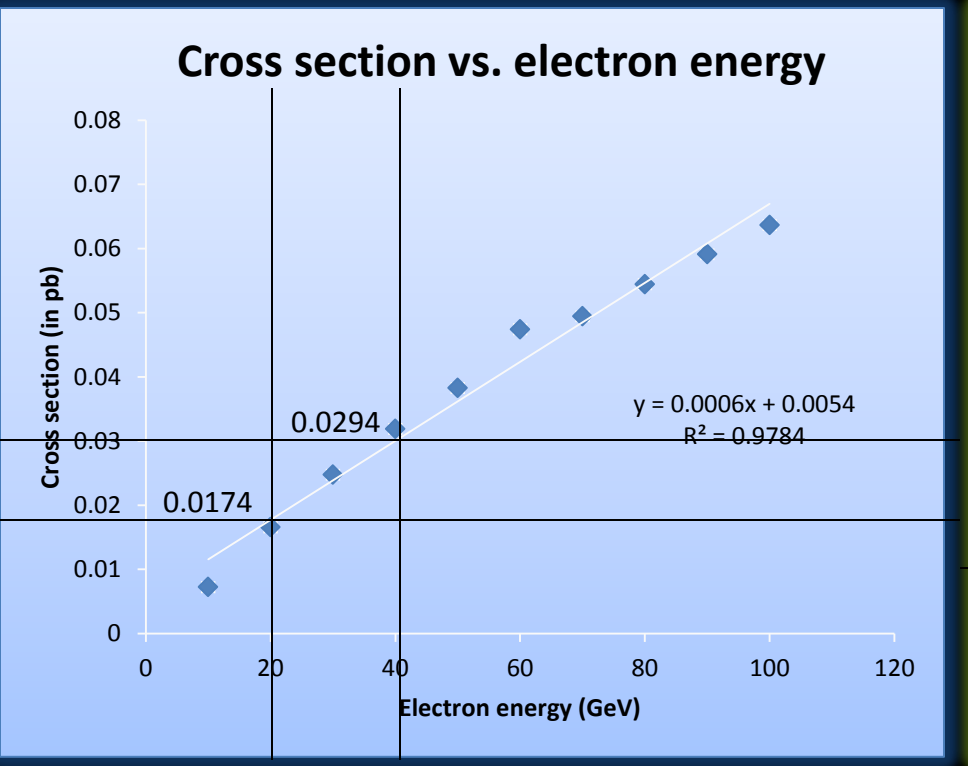
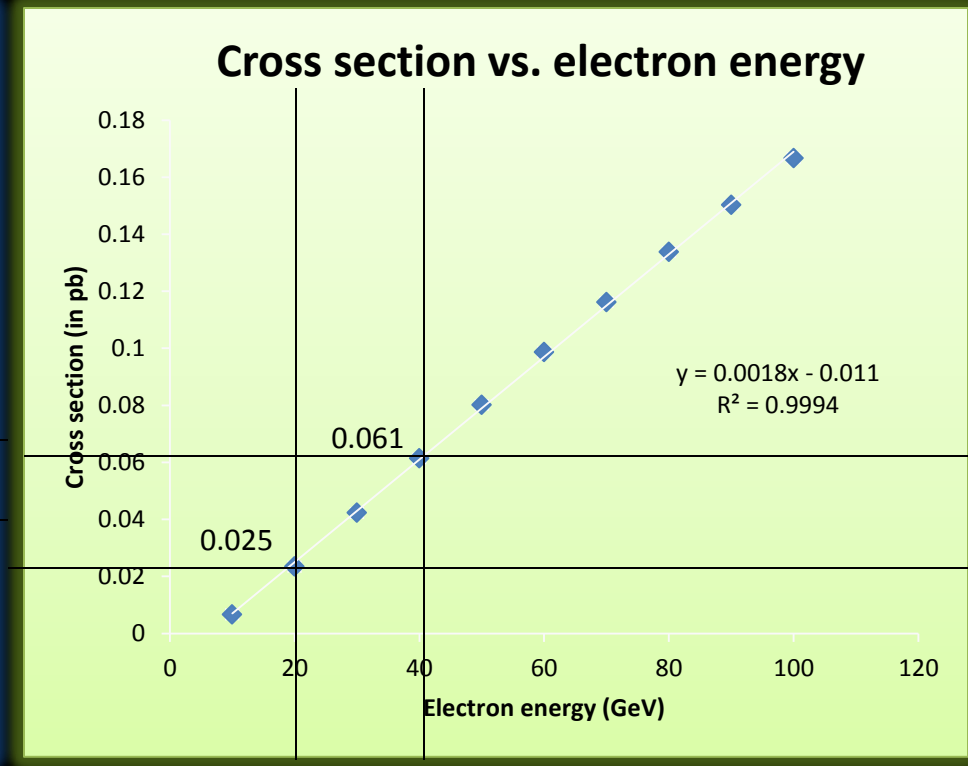
Results

Higgs process



Background



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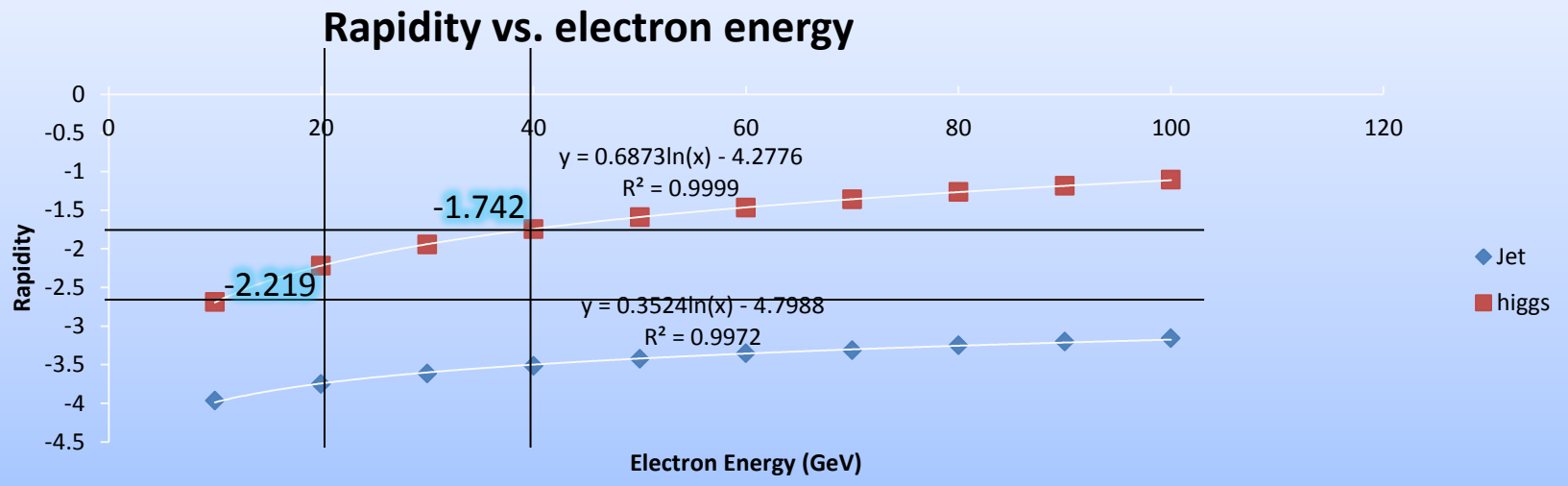
Results

Higgs process



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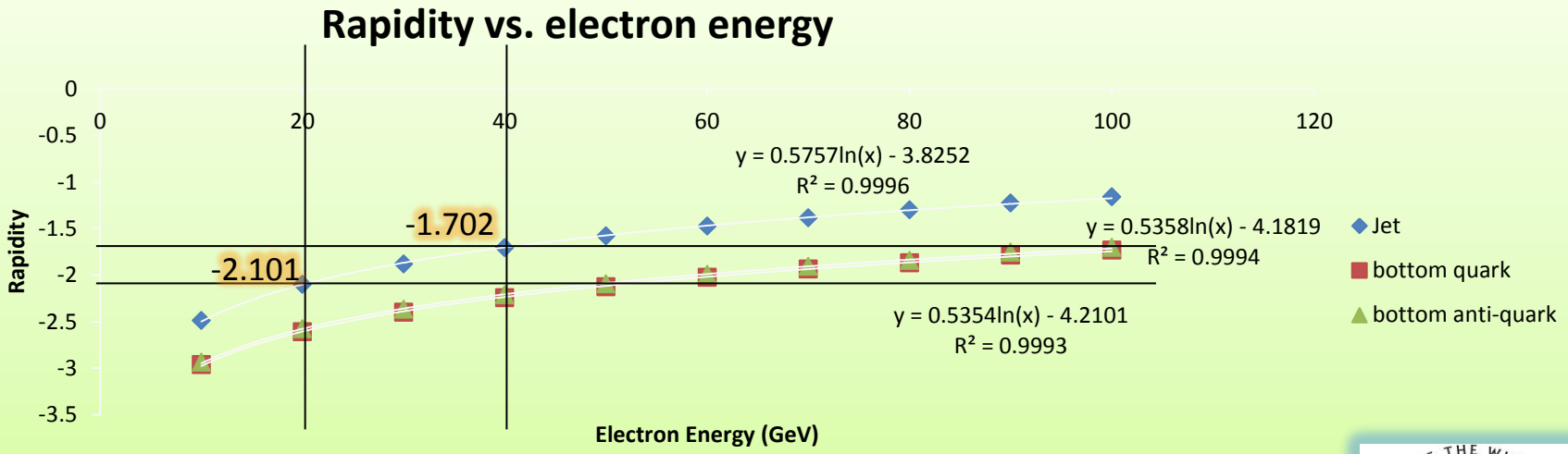

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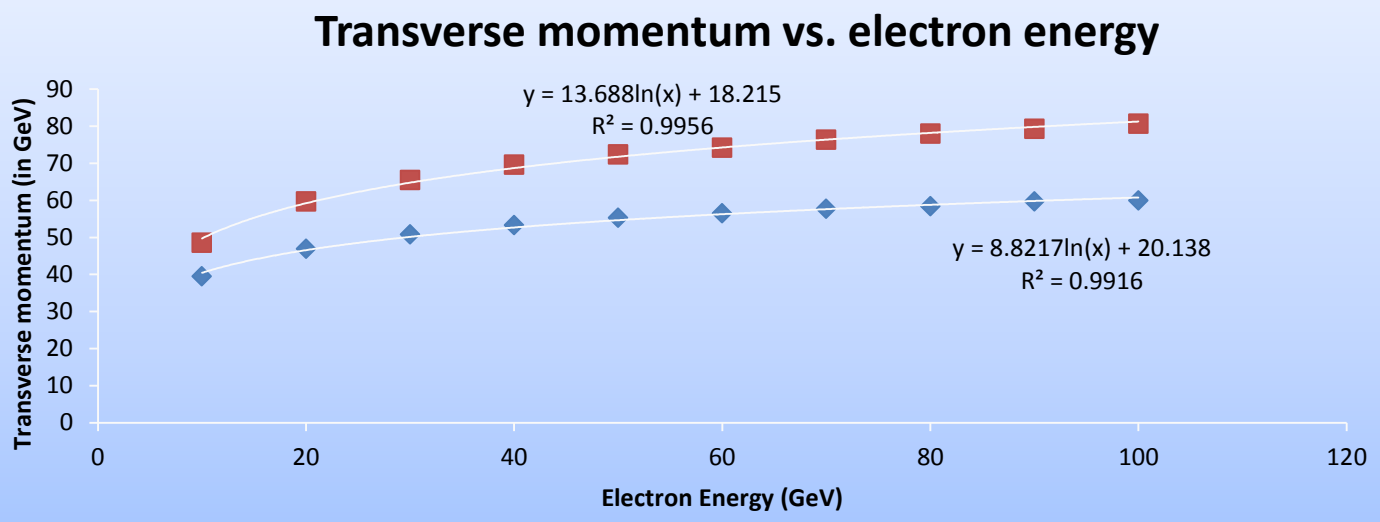
Higgs process



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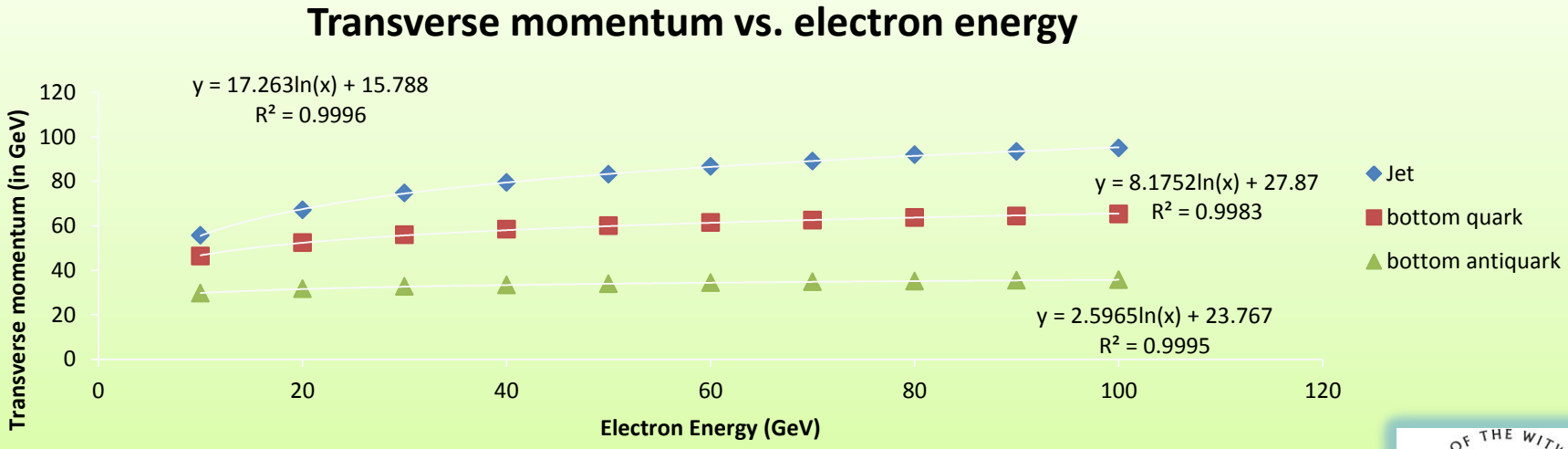

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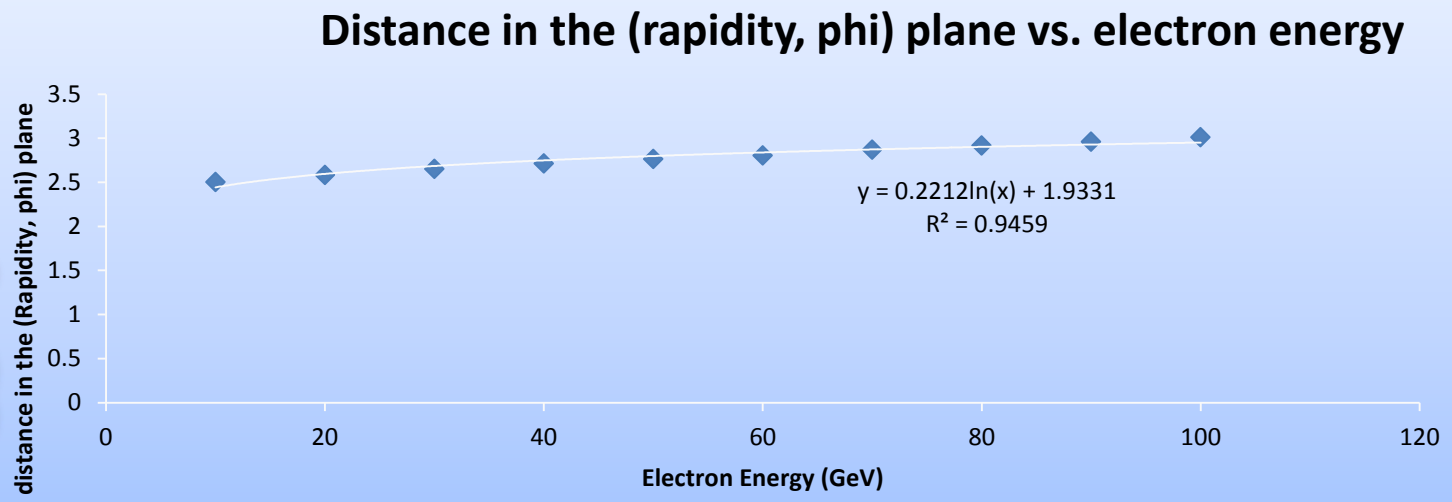
Higgs process



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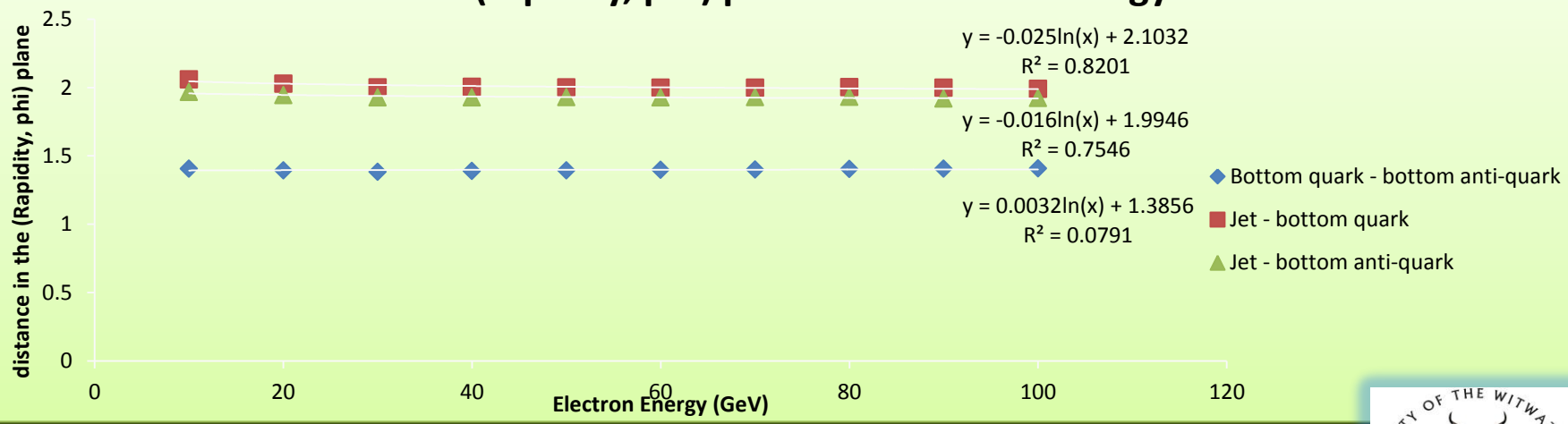

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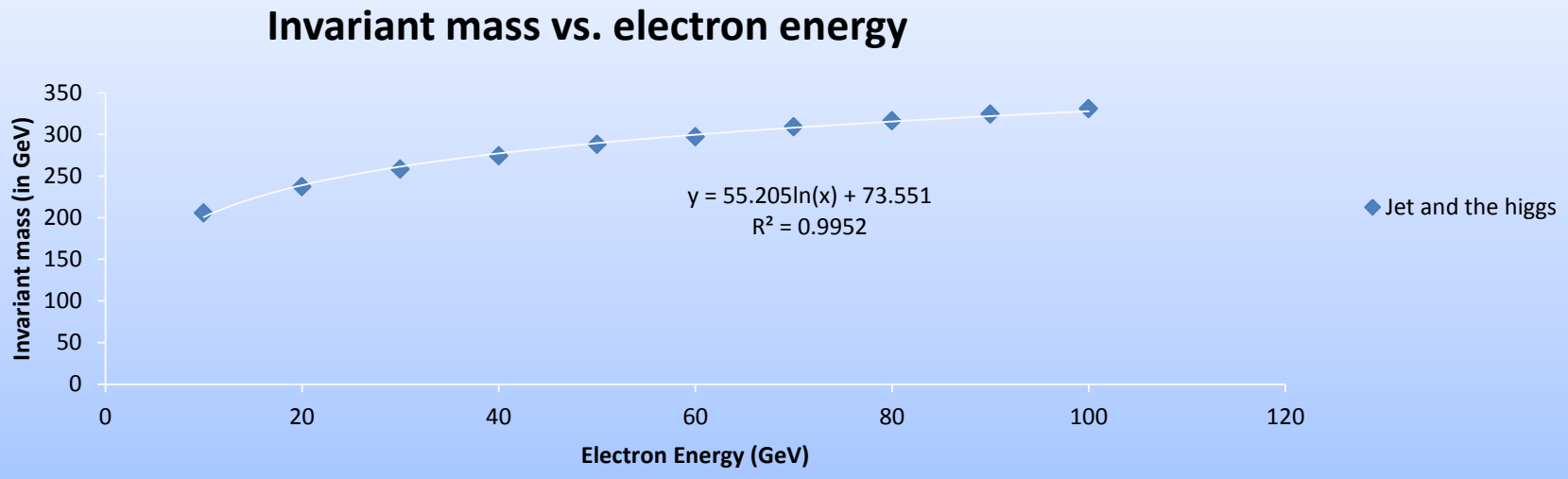
Higgs process



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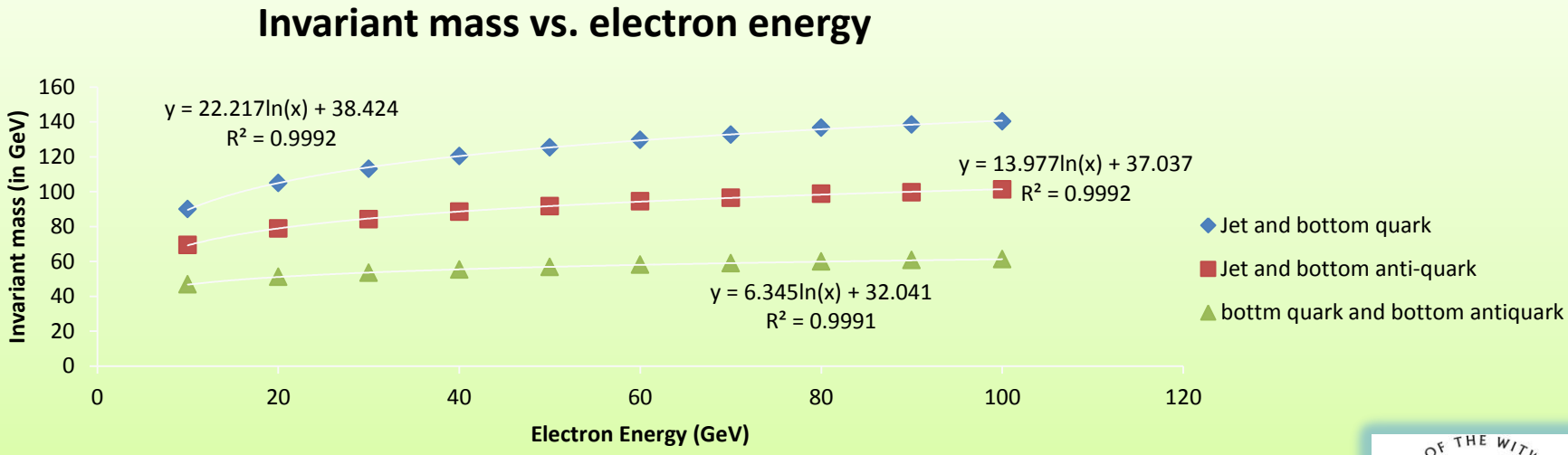

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Conclusion

This project is aimed at studying the effect of decreasing the electron energy in an ep collision to find an optimal, economic electron energy for the study of the higgs boson in the future LHeC facilities at CERN.

The results have shown that using electron energy between 40 GeV and 60 GeV would be sufficient to measure properties of the higgs boson.

Artist concept of elusive higgs boson taken from: http://sojo.net/sites/default/files/mainimages/blog/146928360.jpg

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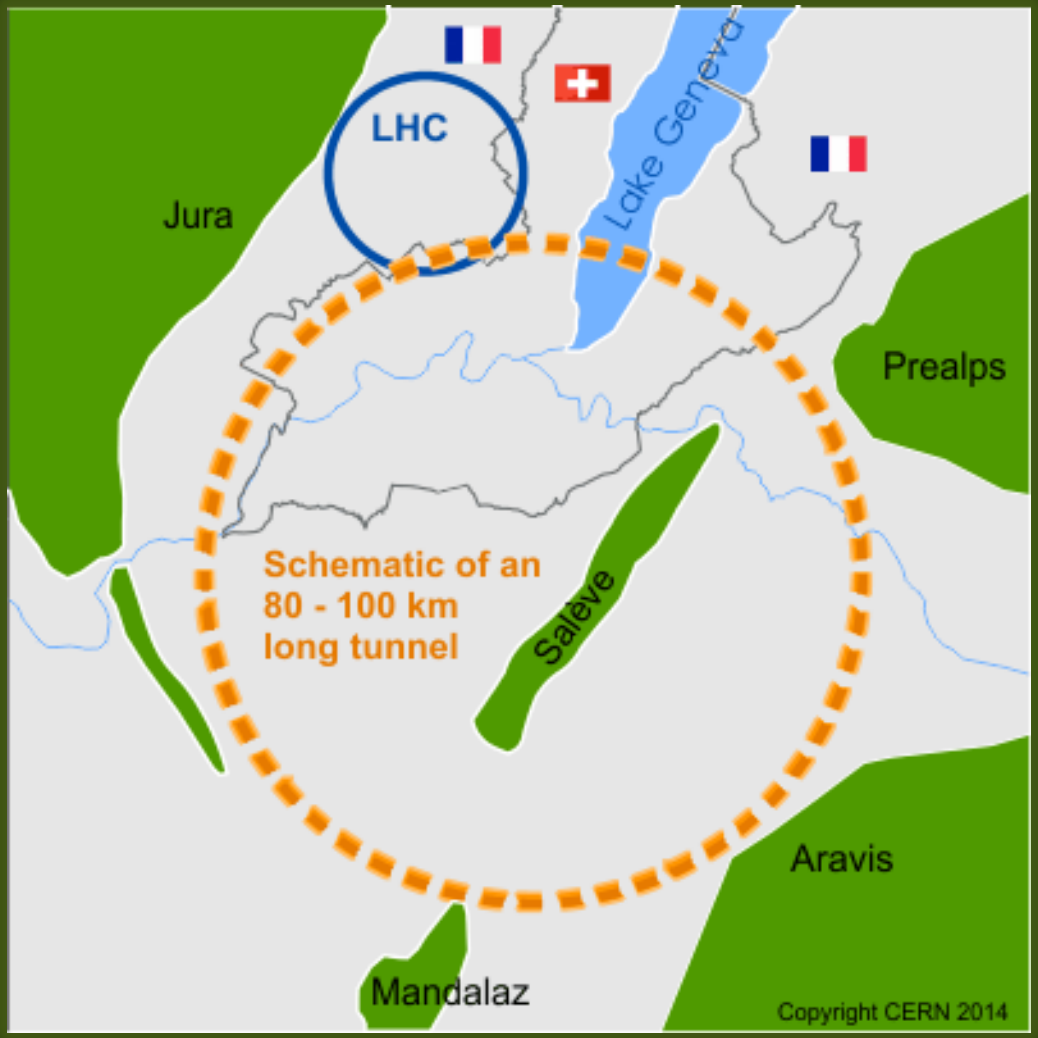
Thank you for your time!!!

Questions are now welcome.

Background picture is an artists impression of the higgs boson, taken from: http://www.ruckmakers.com/wp-content/uploads/2012/07/higgs-boson-july-4-sigma_55979_600x450.jpg

Extra slides



Schematic diagram taken from: https://espace2013.cern.ch/fcc/Schematic%20and%20Layout/For%20Presentations/FCC-1402031030-JGU_SchematicHighContrast800pxCopyright.png

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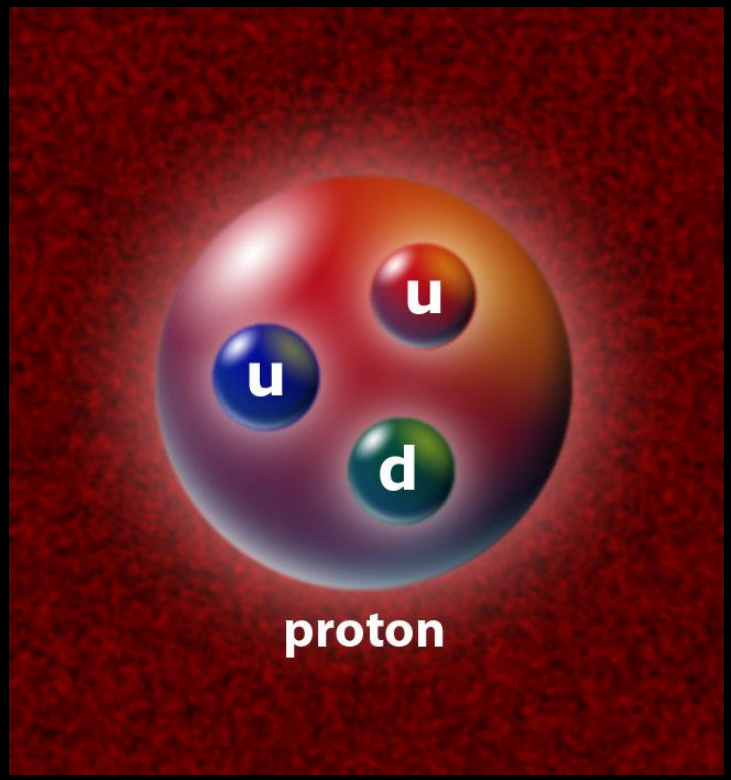
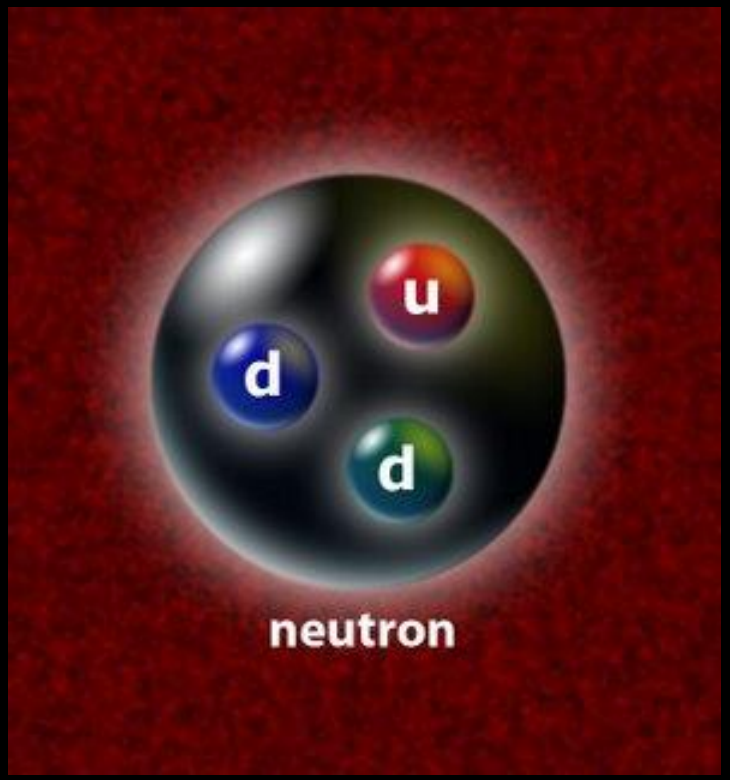
Extra slides

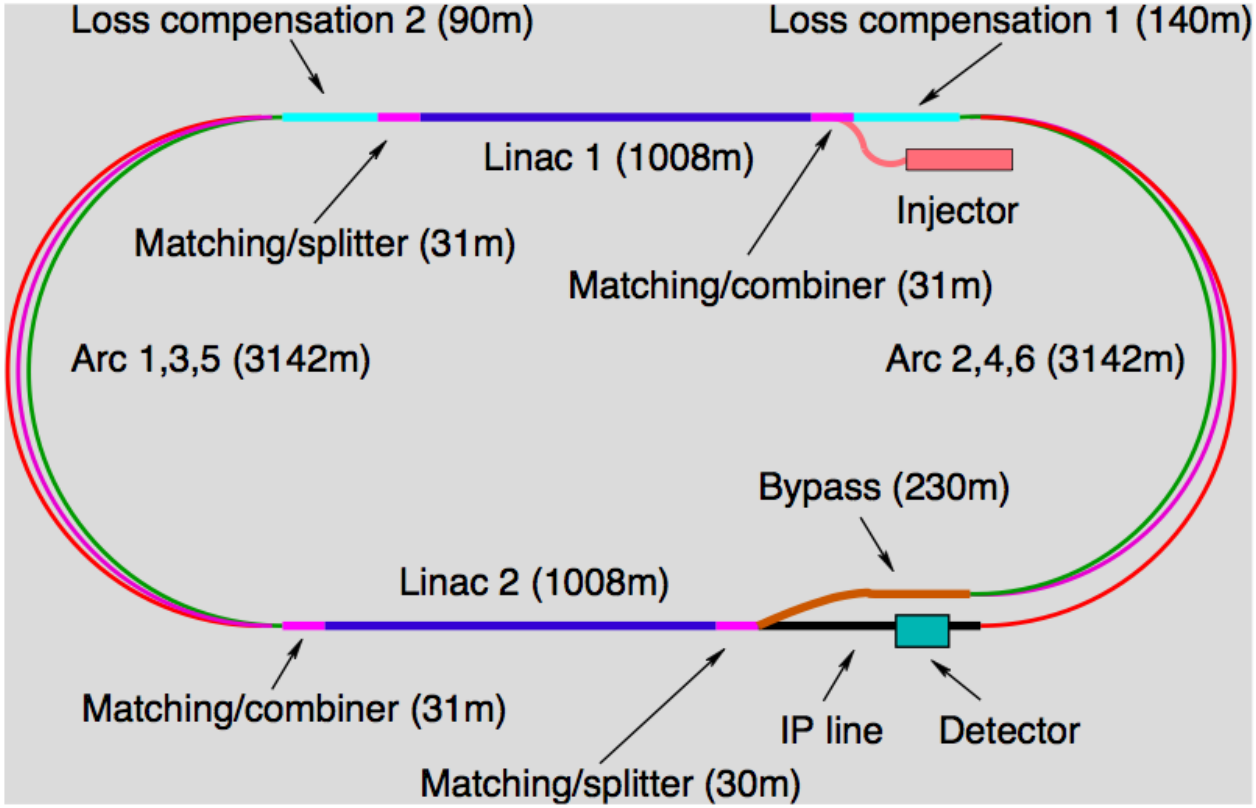




Picture of proton taken from: http://www.quantumdiaries.org/wp-content/uploads/2012/01/proton.jpg
Picture of neutron taken from: http://img4.wikia.nocookie.net/__cb20081128034656/quimica/es/images/2/2f/Neutron.jpg

Extra slides

CDR: Physics, Accelerator, Detector



JPhysG:39(2012)075001, arXiv:1206.2913 http://cern.ch/lhec

CDR: default design. 60 GeV. $L=10^{33}cm^{-2}s^{-1}$, P< 100 MW → ERL, synchronous ep/pp