

Understanding the Higgs boson with the Large Hadron Electron Collider

Studying an electron - proton collision

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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

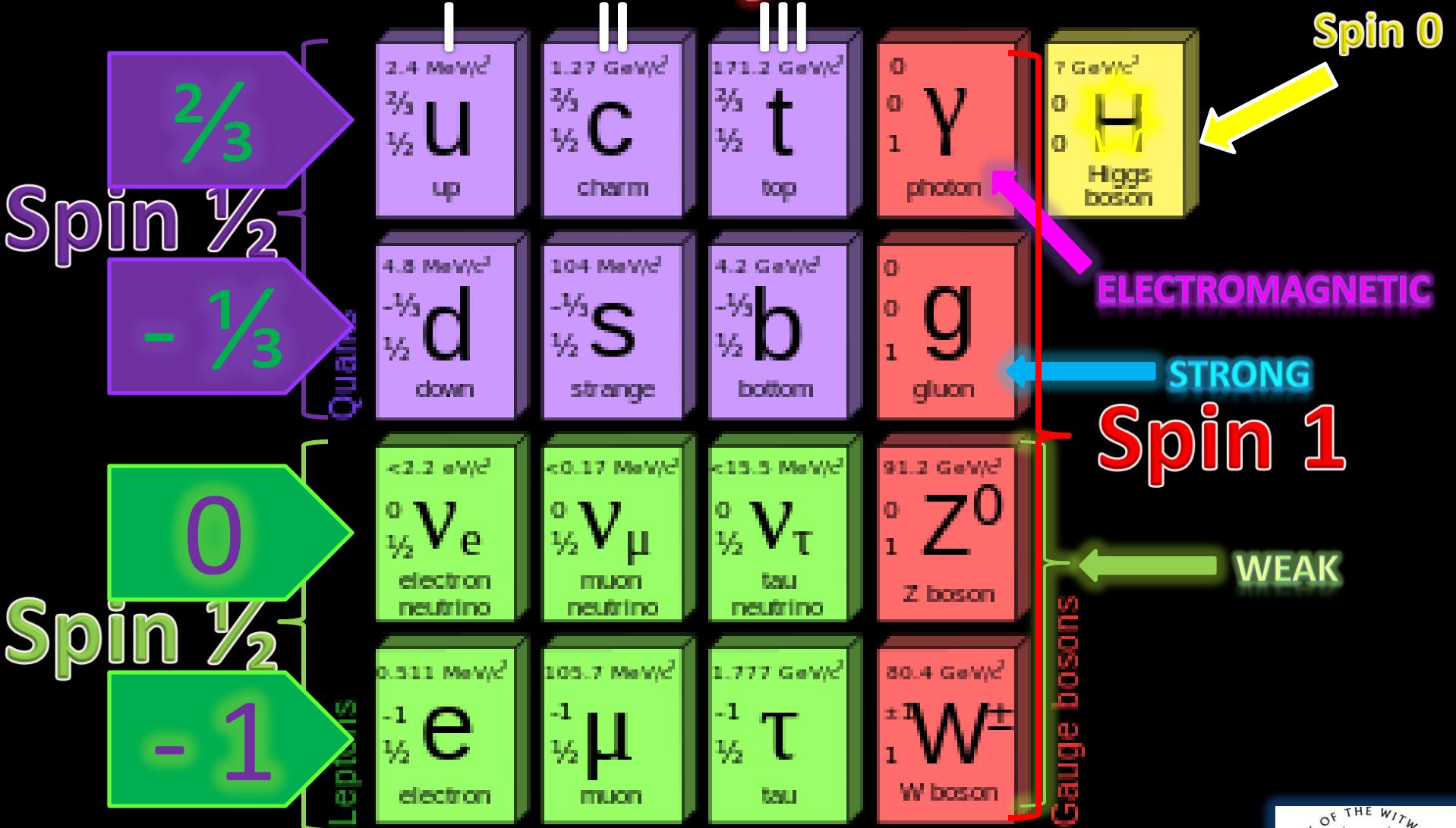


The Standard Model

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



Elementary Particles



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 ?!?!?!

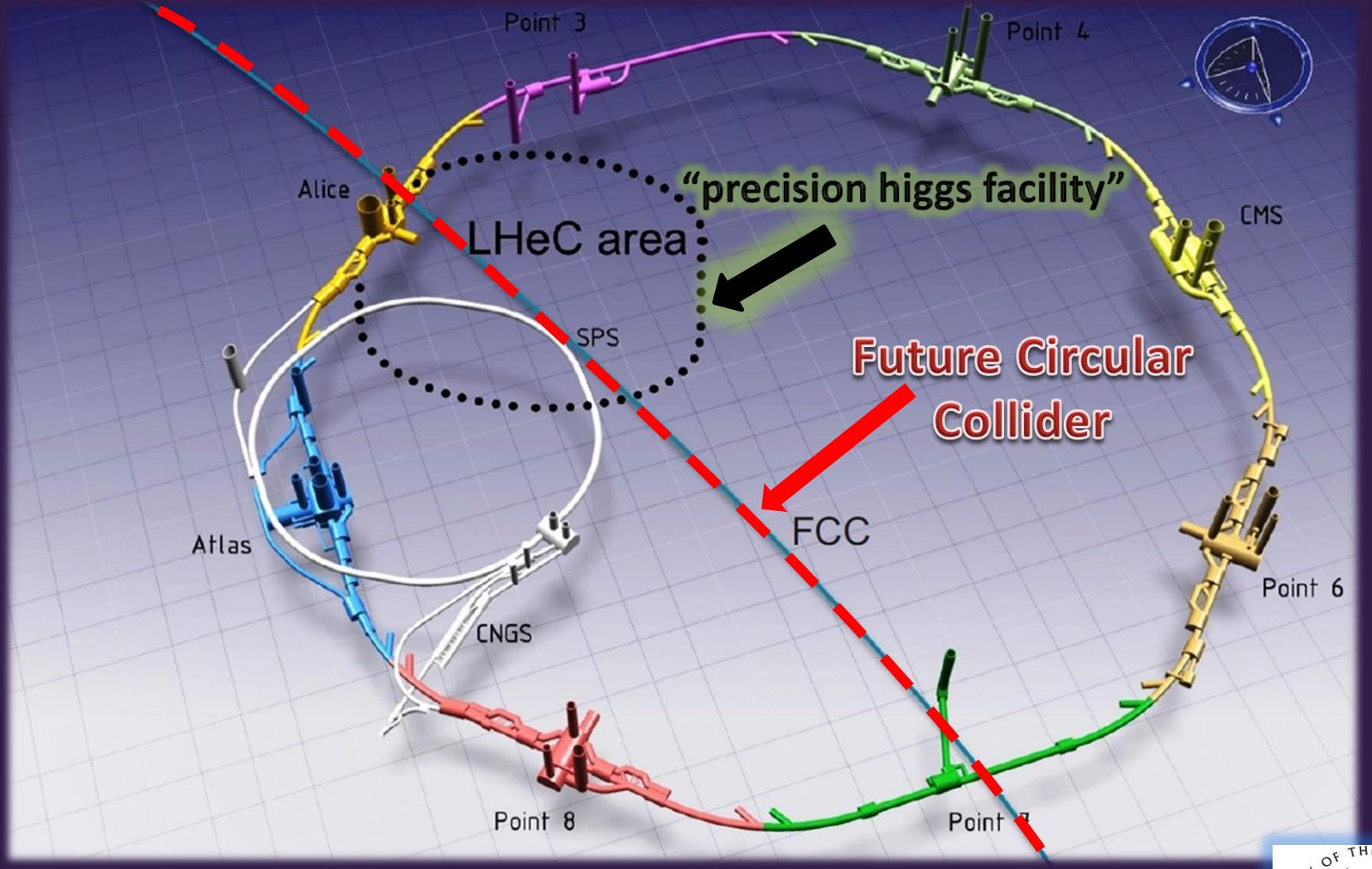
A field, called the higgs field, spans the whole universe and is responsible for the slowing down particles in space, making them acquire mass.

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

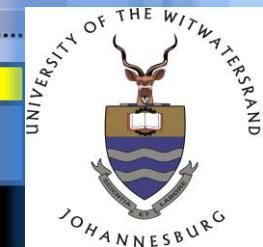
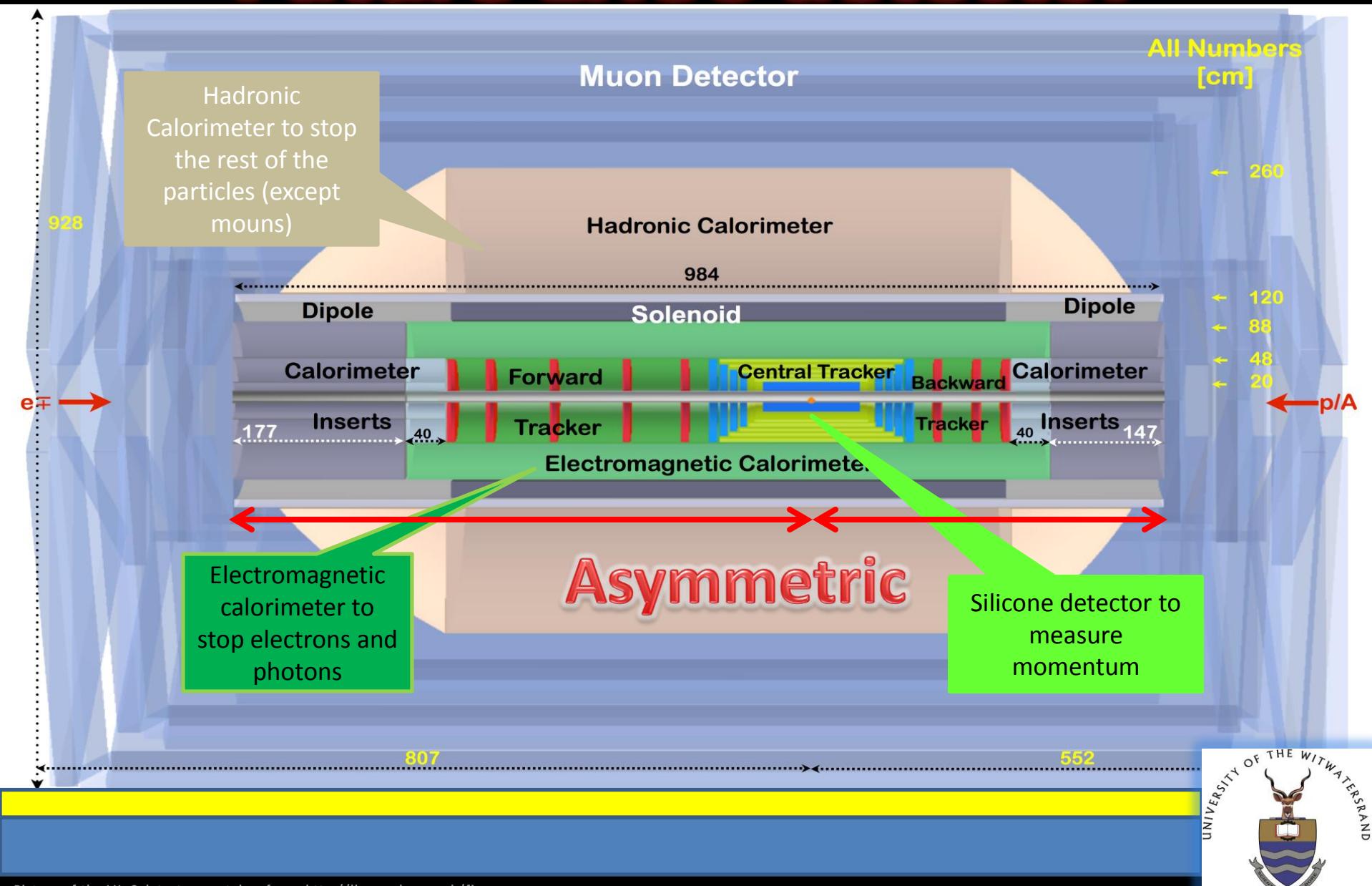
So it is no surprise that without the higgs boson, particles would continue moving at the speed of light; making the formation of solid objects impossible.



Future LHeC at CERN's LHC

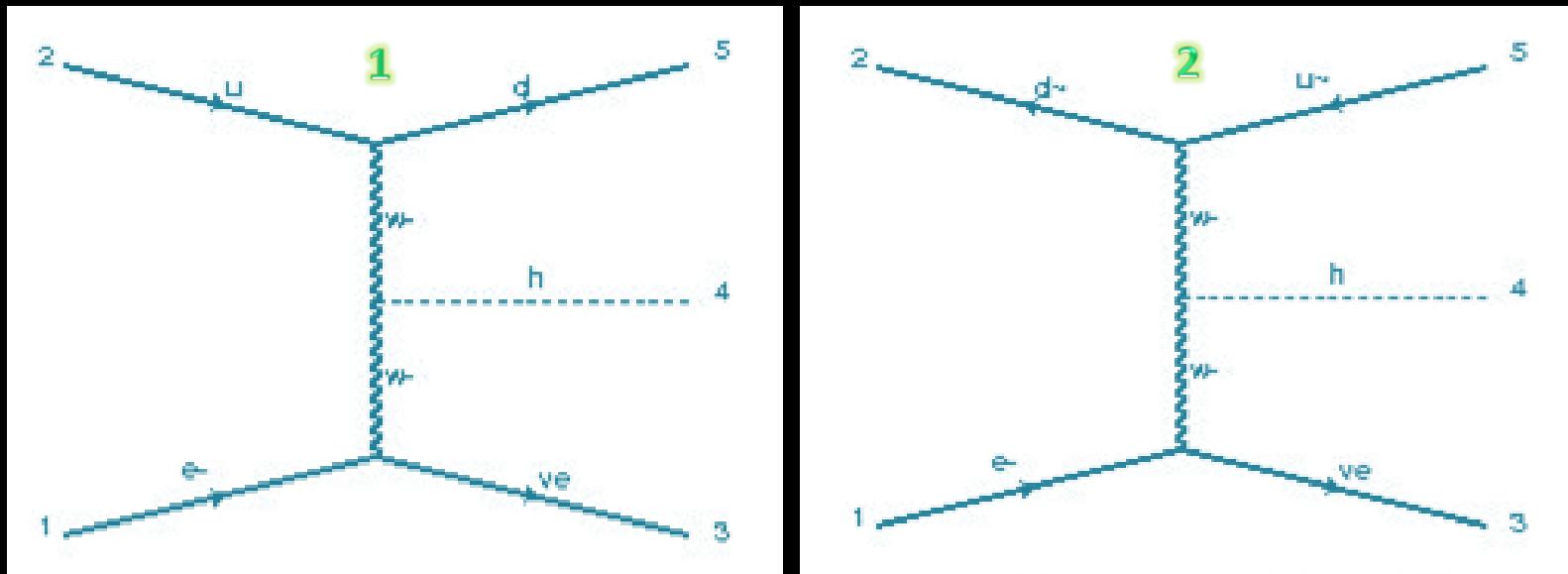


Future LHeC detector



Higgs production process:

electron + proton \rightarrow electron neutrino + higgs + jet (initiated by $d\bar{u}$ or u)

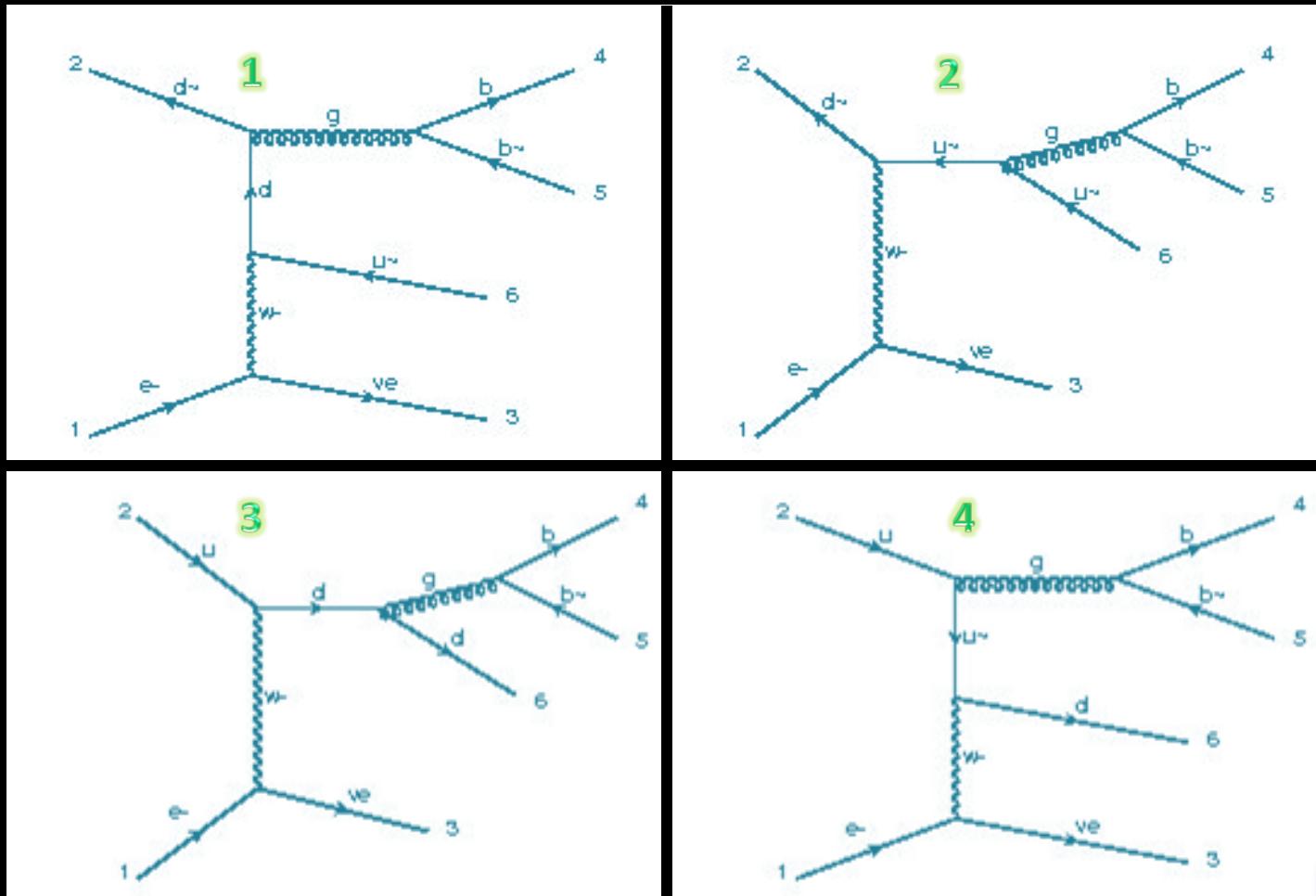


DThe higgs will quickly decay into a pair of bottom quarks.



Background process:

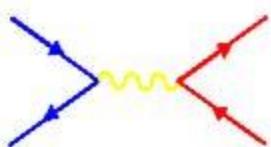
electron + proton \rightarrow electron neutrino + bottom quark + bottom anti-quark + jet



Data generation

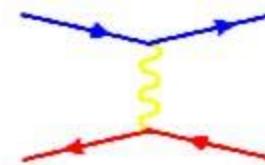
- Monte Carlo events were generated using the Illinois MadGraph website.
- 50 000 events were generated for each process at different electron energies.
- 10 GeV -> 100 GeV (increments of 10 GeV)
- This resulted in a total of 300 kinematic distributions which were analyzed and the data was collected





The MadGraph homepage

[UCL](#) [UIUC](#) [Launchpad](#)
by the [MG/ME Development team](#)



[Generate Process](#)

[Register](#) [Tools](#)

[My Database](#)

[Cluster Status](#)

[Downloads](#)
(needs account)

[Wiki](#) [Answers](#)

[Bug reports](#)

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:

I. Fill the form:

Model:

SM

Input Process:

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](#)

e- p > ve h j

&

e- p > ve bb~ j / h

[Model descriptions](#)

[Examples/format](#)

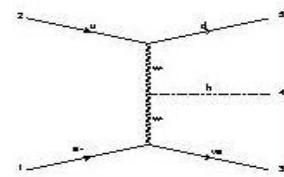


MadEvent Card for e- p > ve h j

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

Process: e- p > ve h j

Model: sm



Links

[Process Information](#)

[Code Download](#)

[On-line Event Generation](#)

[Results and Event Database](#)

Status

Generation Complete

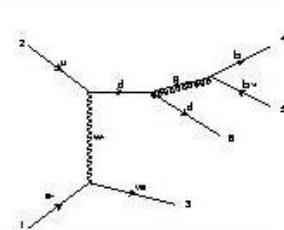
Available

Available (access restricted)

11 runs available

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

Model: sm



Links

[Process Information](#)

[Code Download](#)

[On-line Event Generation](#)

[Results and Event Database](#)

Status

Generation Complete

Available

Available (access restricted)

11 runs available



Collider and cuts

Choose an option for the run_card.dat:

The present [run_card.dat](#)

The [default file](#)

Upload a run_card: No file selected.

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

Plotting Card

Choose an option for the plot_card.dat:

The present [plot_card.dat](#)

The [default file](#)

Upload a plot_card: No file selected.

the form to generate the cards.



Run Card

readconfig_justGrid
run_collider_parameters

this file is used to set the parameters of the run.
Some notation/conventions:

names starting with a '*' are info or comments
* mind the format: value -- variable | comment

running parameters

the name for the run (one word)
run_name = run.tag | name of the run

run to generate the grid pack
run_type = false | gridpack: false - setting up the grid pack
number of events and max size
max_size = no more events than 10 events in a single run
if you want to run smth, avoid more than 50k events in a run.

nEvents = number of simulated events requested
nEvents = 1 | and used if nAssigned is automatically default

Collider type and energy
lhcEnergy = 14000 | 14000 GeV
lhcEnergy = 30000 | 30000 GeV
lhcEnergy = 300000 | 300000 GeV
lhcEnergy = 3000000 | 3000000 GeV

Collision type and energy
lhcType = ee | lhcType = ee - 1-antiproton, 2-photon from proton,
lhcType = ee | lhcType = ee - 2-photon from electron

beam properties
beam1 = -1ppg1 | beam 1 type
beam1 = -1ppg2 | beam 2 type
beam1 = -1ppg3 | initial energy in GeV
beam1 = -1ppg4 | final energy in GeV
beam1 = -1ppg5 | beam 1 total energy in GeV
beam1 = -1ppg6 | beam 1 total energy in GeV
beam1 = -1ppg7 | beam polarization from -100 (left-handed) to 100 (right-handed)
beam1 = -1ppg8 | beam polarization for beam 1
beam2 = -1ppg9 | beam polarization for beam 2

your CodeGen will automatically times alien alphas and its evil.
use -1ppg10 | -1ppg11 | your see (1digit for using lhapdf)
10043 | -1had | hadron number used from the master

renormalization and factorization scales

beam parameters
beam1 = -1beam1 | min distance between gamma and lepton
beam1 = -1beam2 | minimum and maximum invariant mass for pairs
beam1 = -1beam3 | min invariant mass for a jet pair
beam1 = -1beam4 | min invariant mass for a photon pair
beam1 = -1beam5 | min invariant mass of lep-(same flavour) lepton pair
beam1 = -1beam6 | min invariant mass of a b-pair
beam1 = -1beam7 | min invariant mass of a c-pair
beam1 = -1beam8 | min invariant mass of a tau-pair
beam1 = -1beam9 | min invariant mass of a neutrino pair
beam1 = -1beam10 | min invariant mass for all leptons
beam1 = -1beam11 | min invariant mass for mu and nu
beam1 = -1beam12 | min invariant mass for e and nu
beam1 = -1beam13 | min invariant pt for the sum of leptons l1 and l2
beam1 = -1beam14 | min invariant pt for the sum of leptons l1 and l2
beam1 = -1beam15 | min invariant pt for the sum of leptons l1 and l2
beam1 = -1beam16 | min invariant pt for at least one charged lepton
beam1 = -1beam17 | min invariant pt for the leading jet in pt
beam1 = -1beam18 | min invariant pt for the second jet in pt
beam1 = -1beam19 | min invariant pt for the third jet in pt
beam1 = -1beam20 | min invariant pt for the fourth jet in pt
beam1 = -1beam21 | min invariant pt for the fifth jet in pt
beam1 = -1beam22 | min invariant pt for the secondjet in pt
beam1 = -1beam23 | min invariant pt for the third jet in pt
beam1 = -1beam24 | min invariant pt for the fourth jet in pt
beam1 = -1beam25 | min invariant pt for the fifth jet in pt
beam1 = -1beam26 | min invariant pt for the sixth jet in pt
beam1 = -1beam27 | min invariant pt for the seventh jet in pt
beam1 = -1beam28 | min invariant pt for the eighth jet in pt
beam1 = -1beam29 | min invariant pt for the ninth jet in pt
beam1 = -1beam30 | min invariant pt for the tenth jet in pt
beam1 = -1beam31 | min invariant pt for the eleventh jet in pt
beam1 = -1beam32 | min invariant pt for the twelfth jet in pt
beam1 = -1beam33 | min invariant pt for the thirteenth jet in pt
beam1 = -1beam34 | min invariant pt for the fourteenth jet in pt
beam1 = -1beam35 | min invariant pt for the fifteenth jet in pt
beam1 = -1beam36 | min invariant pt for the sixteenth jet in pt
beam1 = -1beam37 | min invariant pt for the seventeenth jet in pt
beam1 = -1beam38 | min invariant pt for the eighteenth jet in pt
beam1 = -1beam39 | min invariant pt for the nineteenth jet in pt
beam1 = -1beam40 | min invariant pt for the twentieth jet in pt
beam1 = -1beam41 | min invariant pt for the twenty-first jet in pt
beam1 = -1beam42 | min invariant pt for the twenty-second jet in pt
beam1 = -1beam43 | min invariant pt for the twenty-third jet in pt
beam1 = -1beam44 | min invariant pt for the twenty-fourth jet in pt
beam1 = -1beam45 | min invariant pt for the twenty-fifth jet in pt
beam1 = -1beam46 | min invariant pt for the twenty-sixth jet in pt
beam1 = -1beam47 | min invariant pt for the twenty-seventh jet in pt
beam1 = -1beam48 | min invariant pt for the twenty-eighth jet in pt
beam1 = -1beam49 | min invariant pt for the twenty-ninth jet in pt
beam1 = -1beam50 | min invariant pt for the thirty jet in pt

Control the pT's of the jets is sorted by jet index

jet parameters
jet1 = -1jet1 | minimum pt for the leading jet in pt
jet1 = -1jet2 | minimum pt for the second jet in pt
jet1 = -1jet3 | minimum pt for the third jet in pt
jet1 = -1jet4 | minimum pt for the fourth jet in pt
jet1 = -1jet5 | minimum pt for the fifth jet in pt
jet1 = -1jet6 | minimum pt for the sixth jet in pt
jet1 = -1jet7 | minimum pt for the seventh jet in pt
jet1 = -1jet8 | minimum pt for the eighth jet in pt
jet1 = -1jet9 | minimum pt for the ninth jet in pt
jet1 = -1jet10 | minimum pt for the tenth jet in pt
jet1 = -1jet11 | minimum pt for the eleventh jet in pt
jet1 = -1jet12 | minimum pt for the twelve jet in pt
jet1 = -1jet13 | minimum pt for the thirteen jet in pt
jet1 = -1jet14 | minimum pt for the fourteen jet in pt
jet1 = -1jet15 | minimum pt for the fifteen jet in pt
jet1 = -1jet16 | minimum pt for the sixteen jet in pt
jet1 = -1jet17 | minimum pt for the seventeen jet in pt
jet1 = -1jet18 | minimum pt for the eighteen jet in pt
jet1 = -1jet19 | minimum pt for the nineteen jet in pt
jet1 = -1jet20 | minimum pt for the twenty jet in pt
jet1 = -1jet21 | minimum pt for the twenty-one jet in pt
jet1 = -1jet22 | minimum pt for the twenty-two jet in pt
jet1 = -1jet23 | minimum pt for the twenty-three jet in pt
jet1 = -1jet24 | minimum pt for the twenty-four jet in pt
jet1 = -1jet25 | minimum pt for the twenty-five jet in pt
jet1 = -1jet26 | minimum pt for the twenty-six jet in pt
jet1 = -1jet27 | minimum pt for the twenty-seven jet in pt
jet1 = -1jet28 | minimum pt for the twenty-eight jet in pt
jet1 = -1jet29 | minimum pt for the twenty-nine jet in pt
jet1 = -1jet30 | minimum pt for the thirty jet in pt

Electron energy

```

# 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
# *****

# ***** generated selection cuts, according to hep-ph/9801442
# this program, all the other parameters are ignored
# note: progsim, psr and dca are not going to be used
# *****

# 0 - pyquen 1: hadronization code
# 0.4 - algoma 1: hadronization code
# 1.0 - 1.0 in a parameter of eq. (3.4) in hep-ph/9801442
# 1.0 - algoma 2: hadronization code in a parameter of eq. (3.4) in hep-ph/9801442
# note: beam 1: calculate photons from no energy (photons and leptons)
# *****

# 0 - jet cuts
# 0 - momenta 1: minimum rapidity for two jets in the no cut case
# 0 - didxeta 1: minimum rapidity for two jets in the no cut case
# *****

# no crosscut
# *****

-1      = kmedium
0.4     = dpmaxcar
0.4     = dca

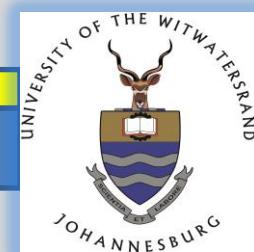
# maximal pdg code for quark to be considered as a light jet
# [otherwise ee b cuts are applied]
# *****

-1      = maxpdgcode 1: maximum jet pdg code
# *****

# jet measure cuts
# *****

0       = output 1: minimum jet jet measure between particles
# *****
```

Electron energy



Plot Card

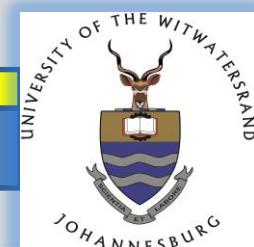
Step size

Range

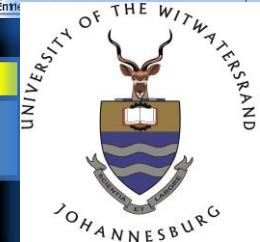
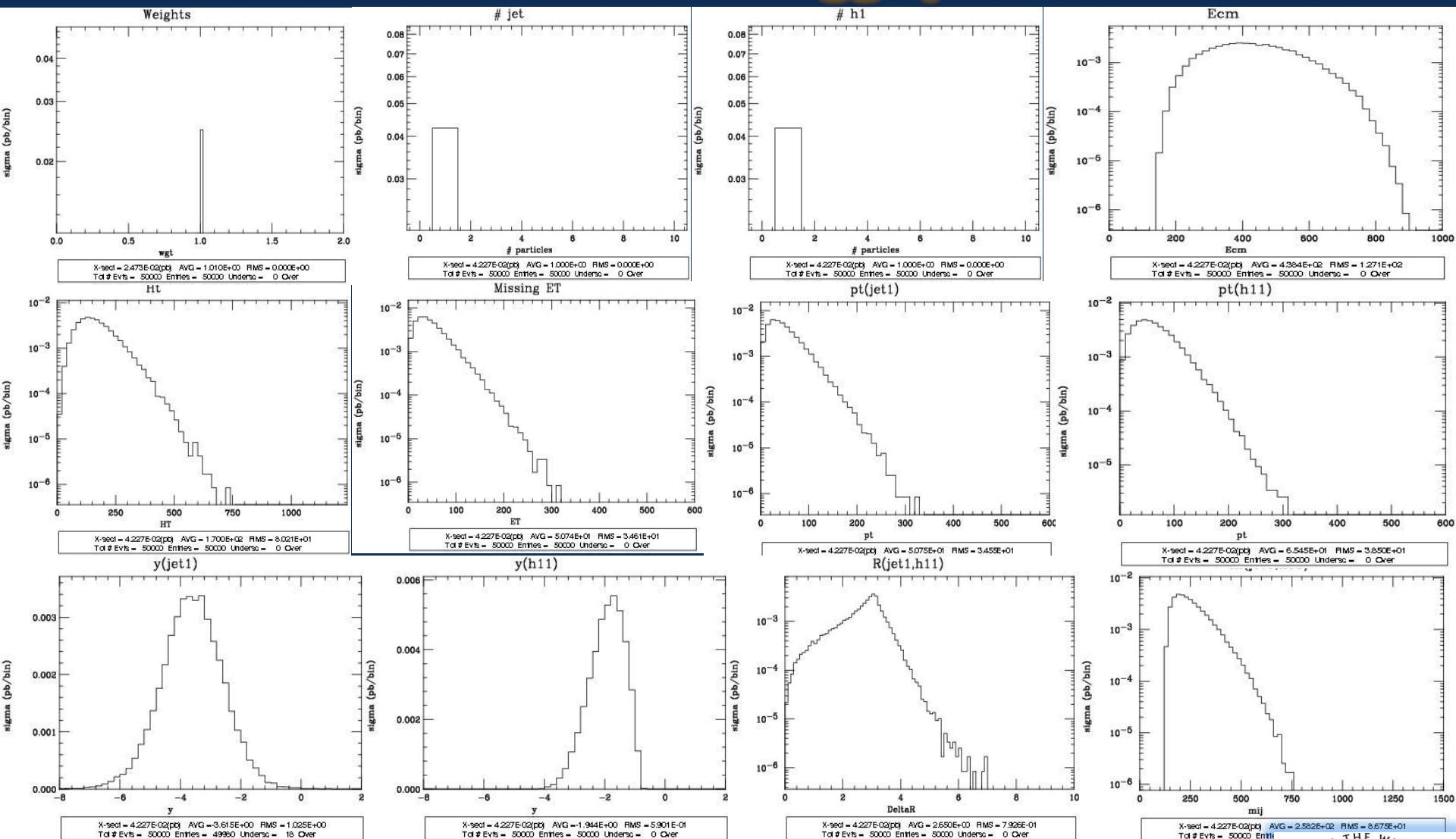
```
# Do Not put spaces at beginning of the following lines!
# Begin PlotRange # This is TAG. Do not modify this line
pt      10   0  400  # bin size, min value, max value
et      10   0  800  # bin size, min value, max value
etmiss   10   0  400  # bin size, min value, max value
ht      20   0  1000
y       0.2  -8  2   # 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
```

- some comments about the plotting options
- 1. in the file `bin_func.f` the functions can be found that can be plotted. (only for off-line usage)
- 2. with the plotting options one can set the number of plots for each of these functions.
- 3. One has to specify for each variable which particles from which class are used to set the plots. Syntax:
 $\text{set } 2\ 4$
means that the transverse energy of the first four particles in the second class will be plotted.
 $\text{set } 1\ 3$
 $\text{set } 2\ 2$
means that for the invariant mass plots the first three particles from the first class and the first two from the second class will be used to plot the invariant mass of two particles. (10 plots)
- 4. the ordering of the particles in a class can be set with the `'ordering_function'`. `ps`, `s` and `st` are valid functions. (no off-line usage) `st` and `stl` can also be used, if defined in `bin_func.f`.
- max number of plots is 200.

```
  * Output for plots
  *
  * no plot spec species at the beginning of the following lines
  * begin when output # this is end, no modify this line
  output <outputname> # set to topdown or graphplot
  plot <plotname> # plot (and out) dec. rev. ? (only for net
  *
  * end when output # this is end, no modify this line
```



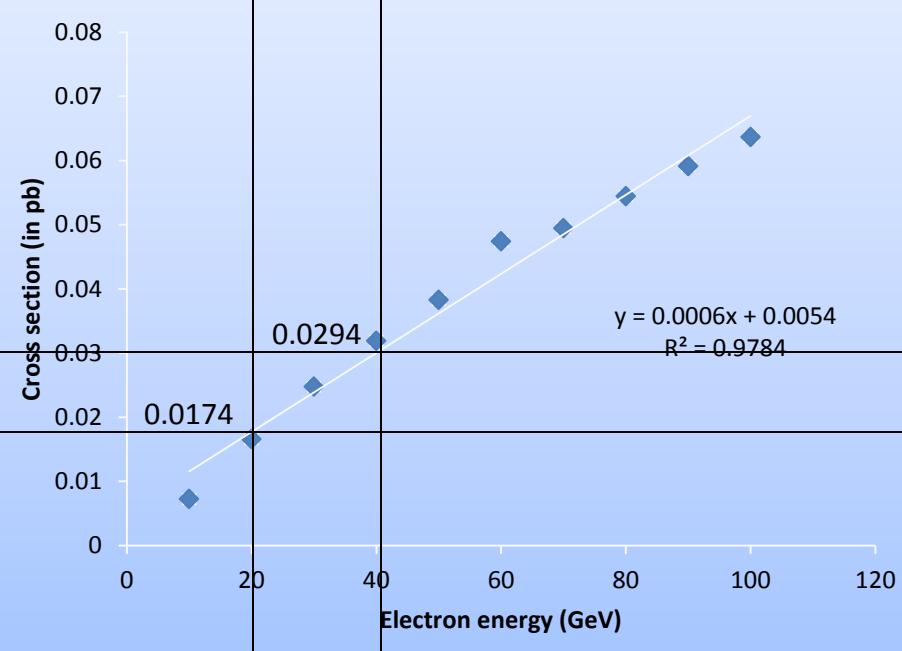
Kinematic distributions of Higgs process at 30 GeV



Results

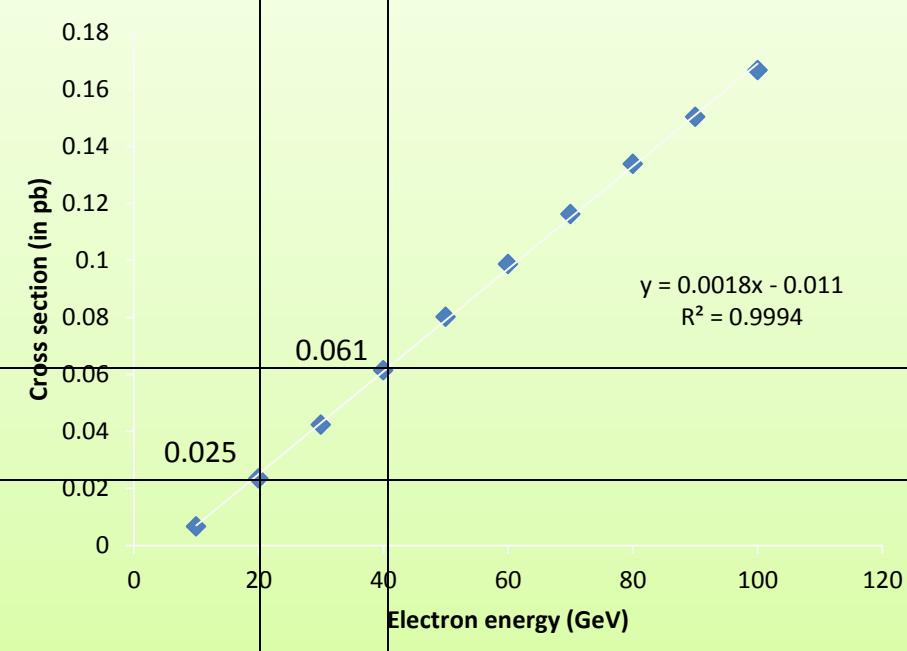
Higgs process

Cross section vs. electron energy



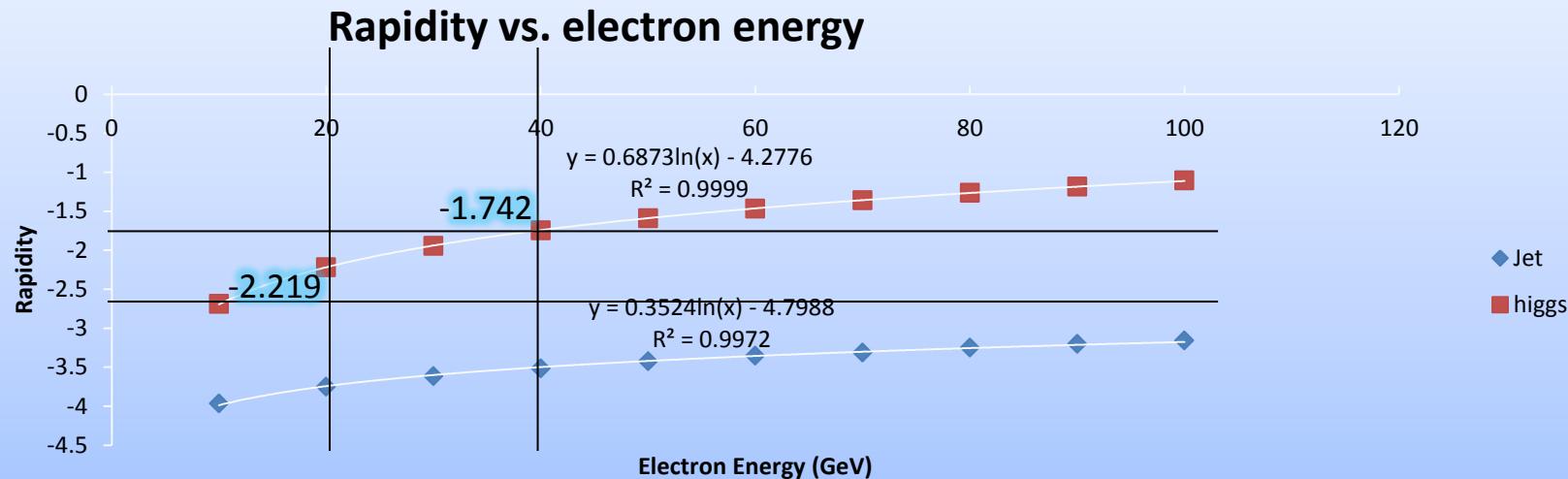
Background

Cross section vs. electron energy

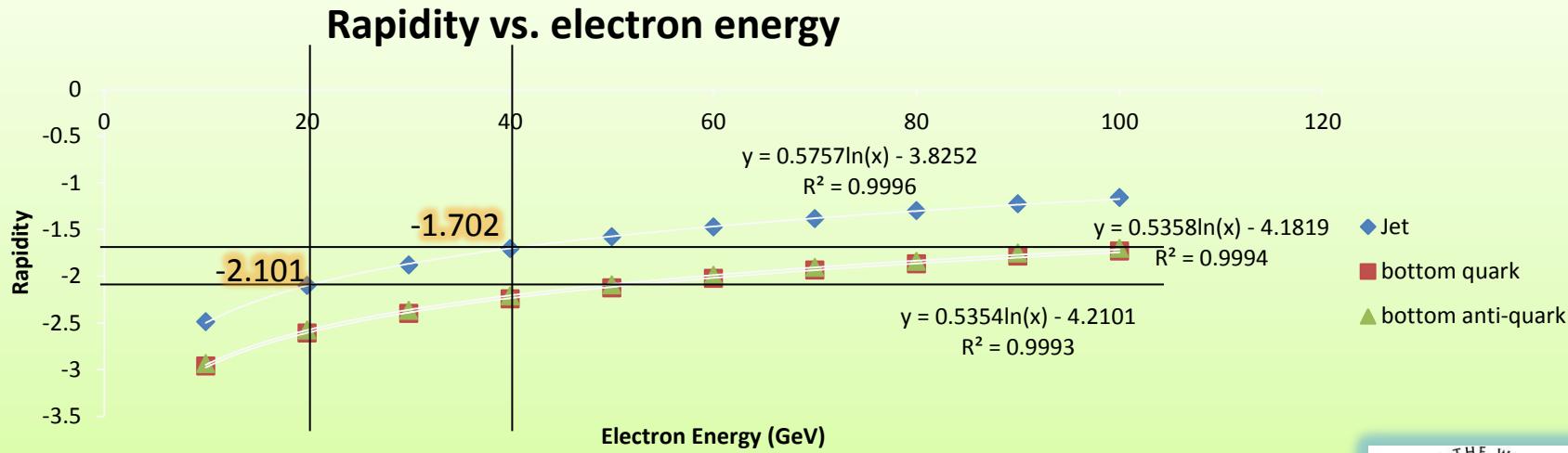


Results

Higgs process



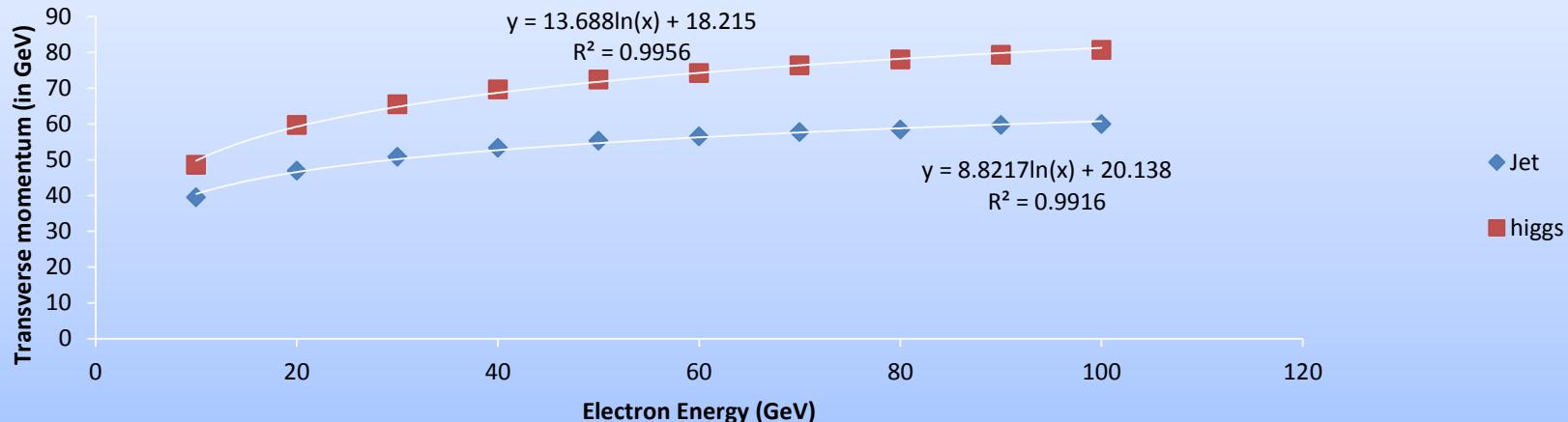
Background



Results

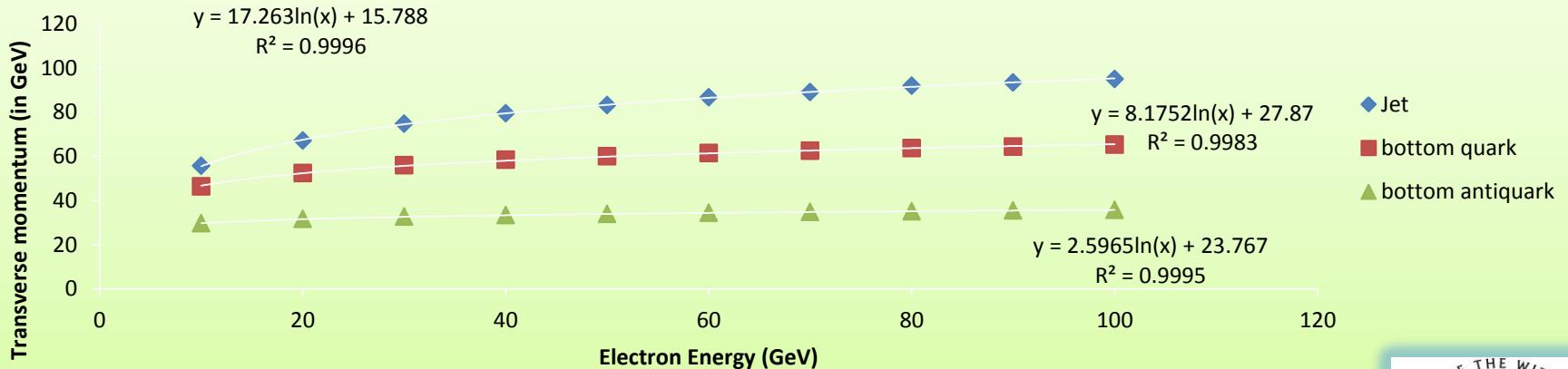
Higgs process

Transverse momentum vs. electron energy



Background

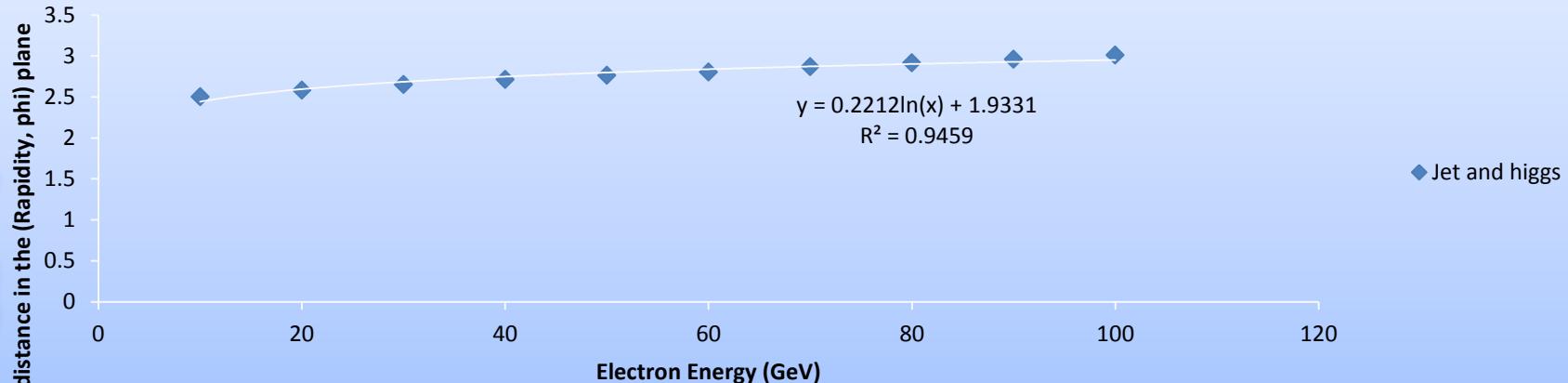
Transverse momentum vs. electron energy



Results

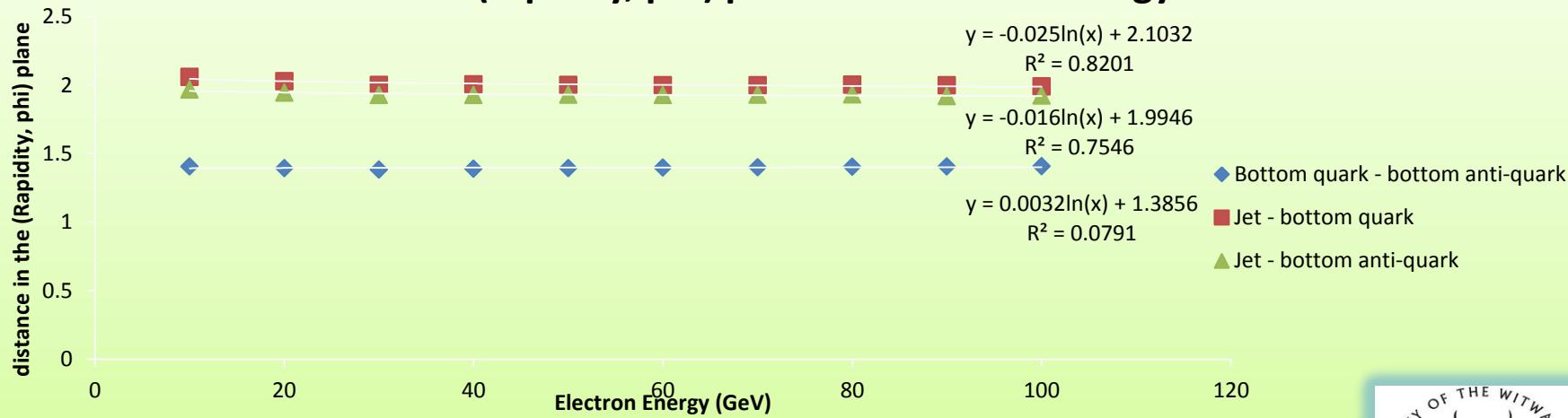
Higgs process

Distance in the (rapidity, phi) plane vs. electron energy



Background

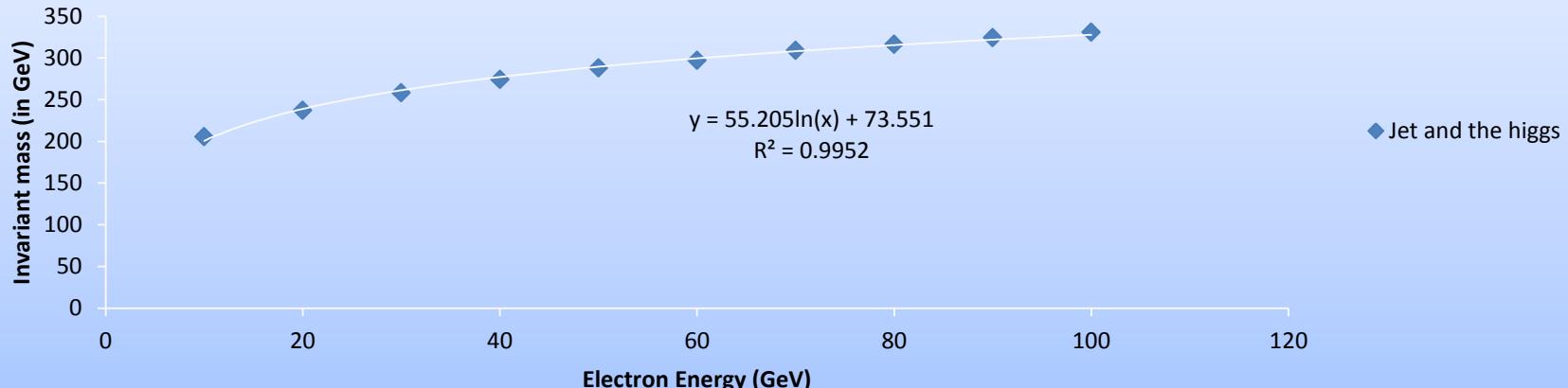
Distance in the (rapidity, phi) plane vs. electron energy



Results

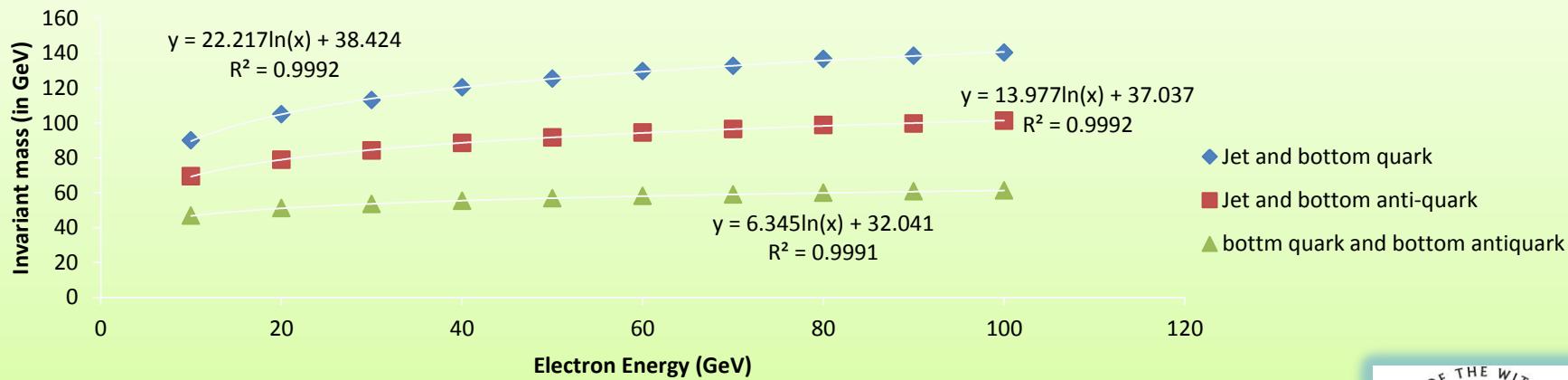
Higgs process

Invariant mass vs. electron energy



Background

Invariant mass vs. electron energy

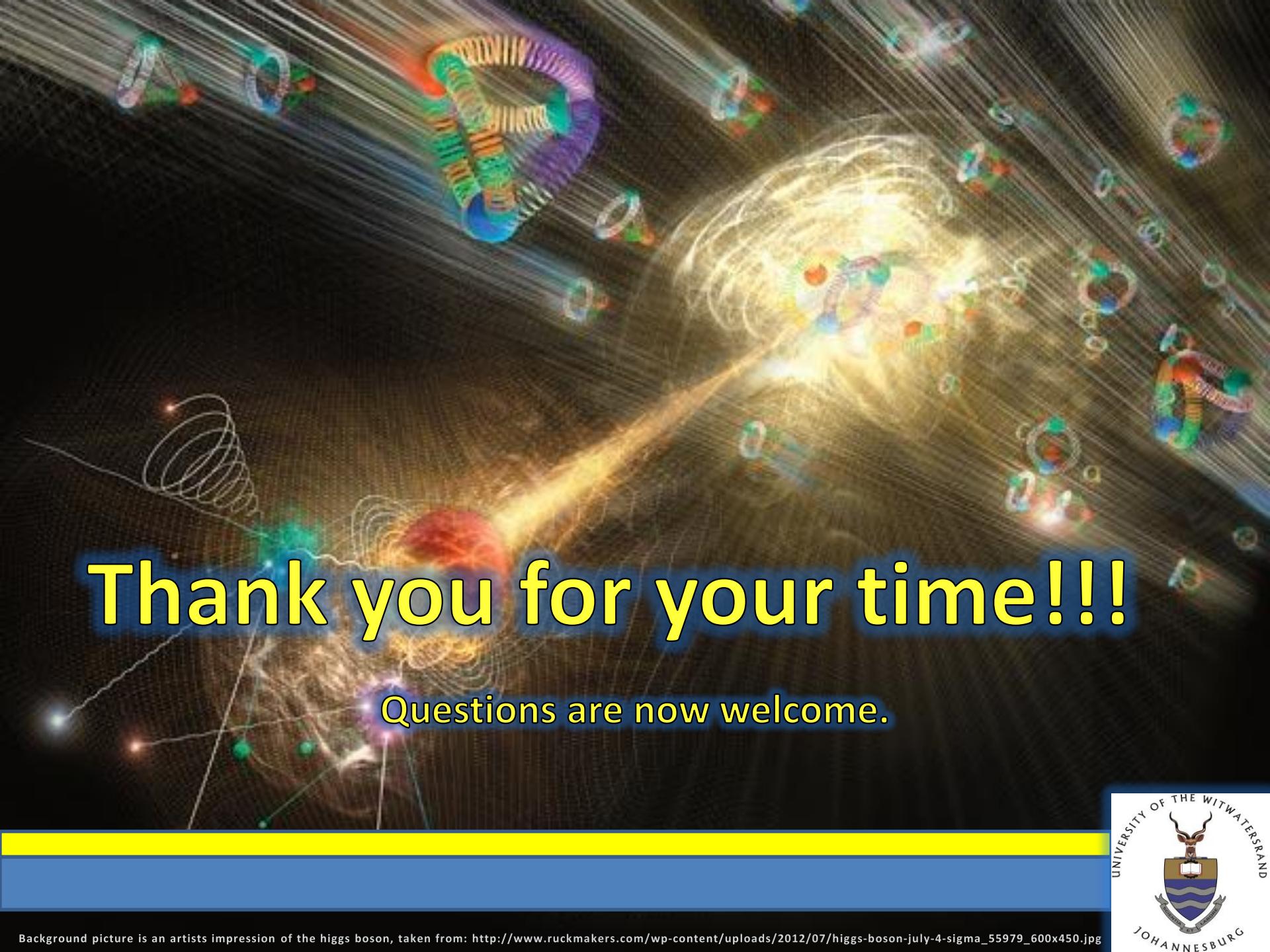


Conclusion

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.



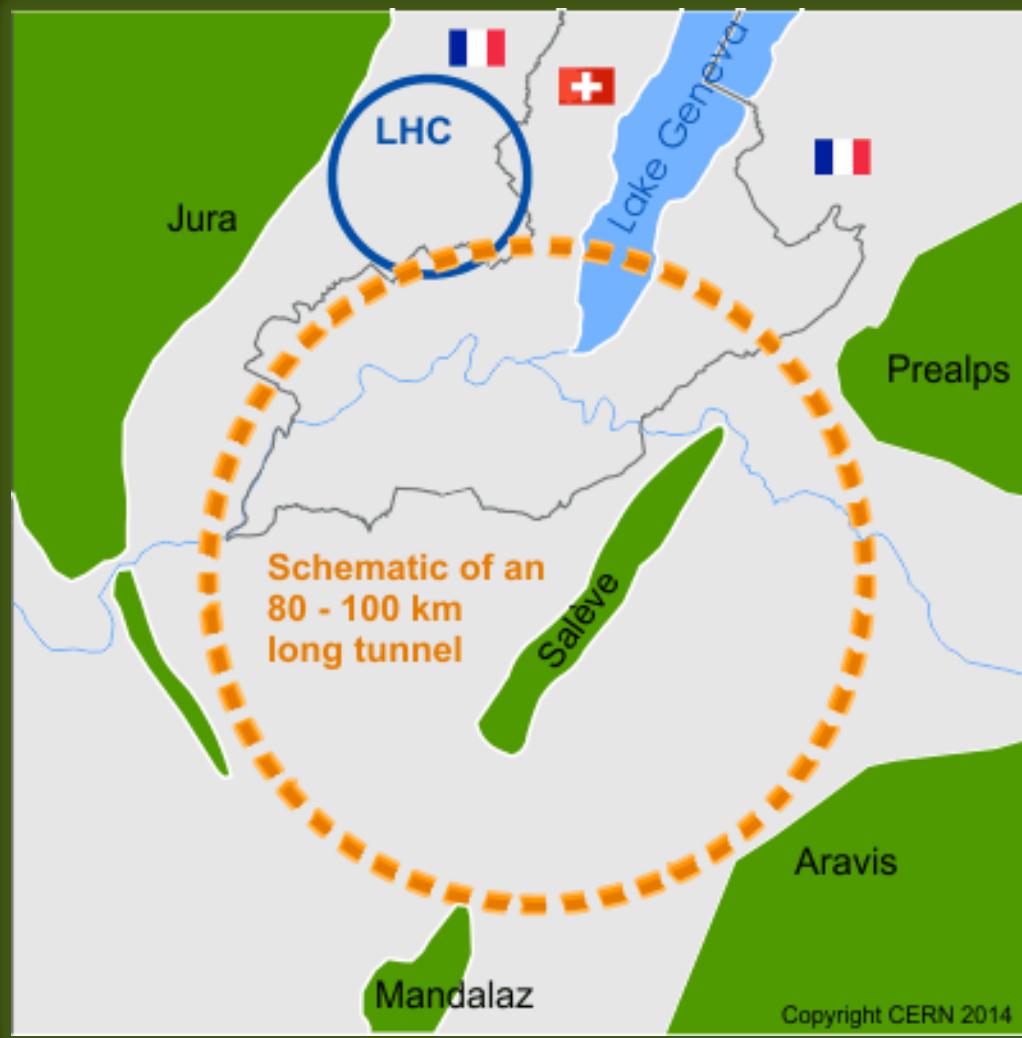


Thank you for your time!!!

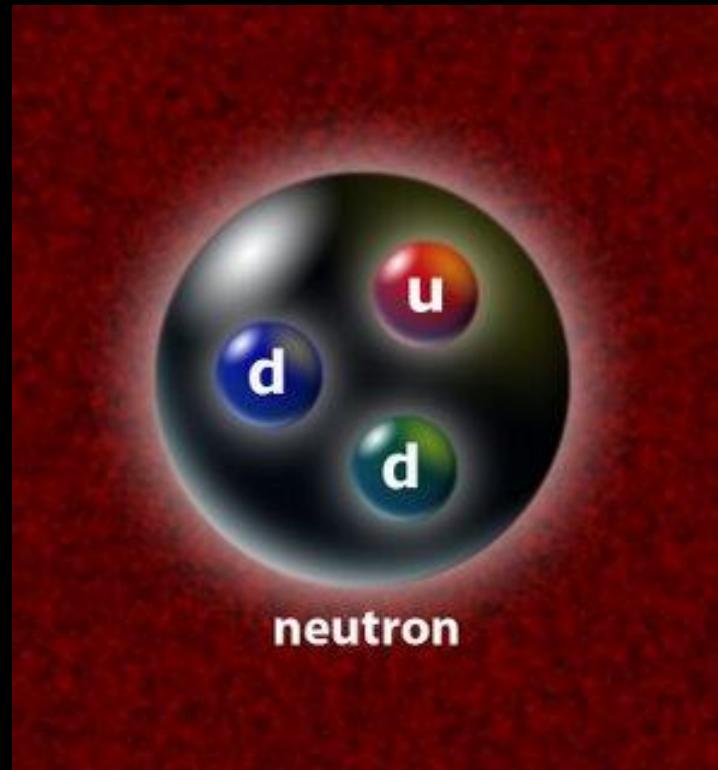
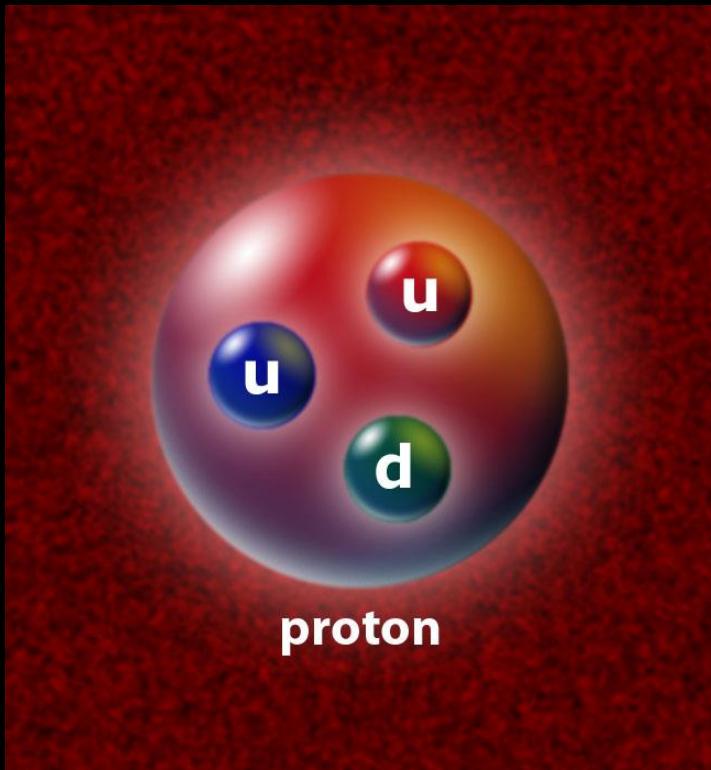
Questions are now welcome.



Extra slides

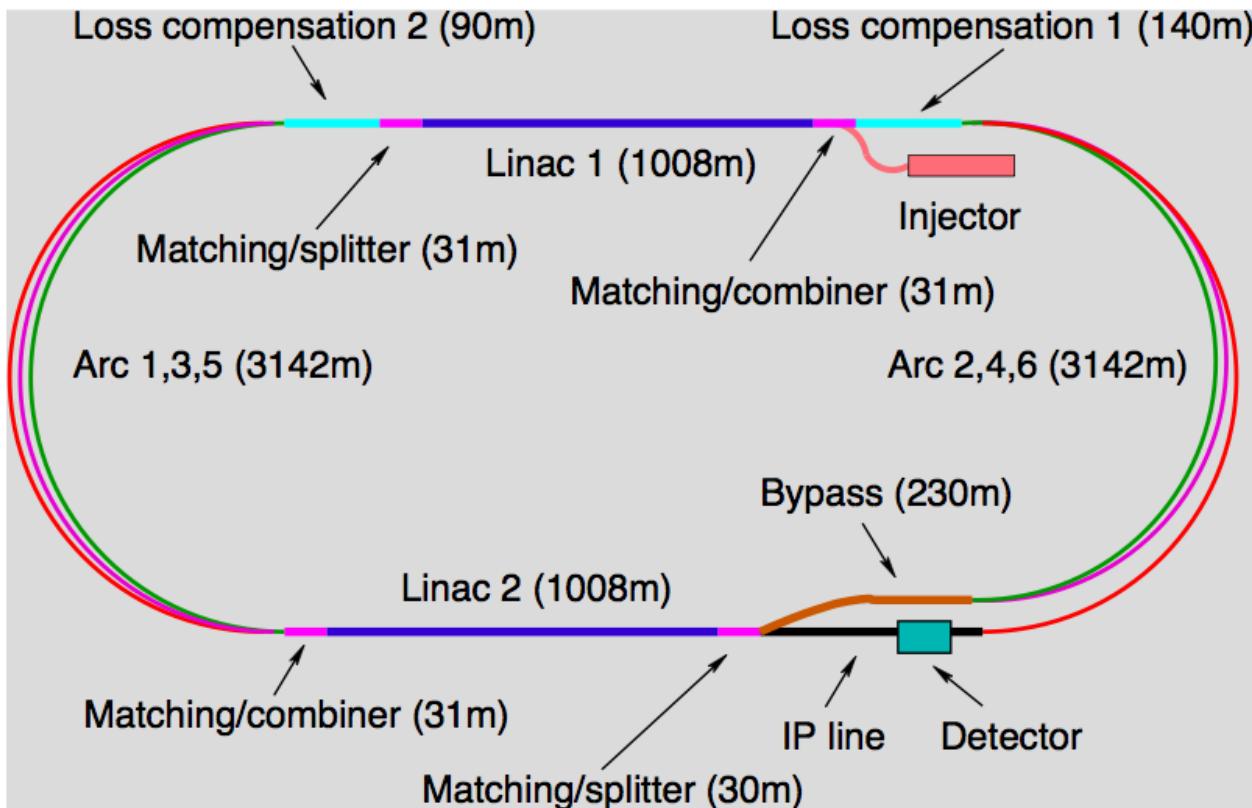


Extra slides



Extra slides

CDR: Physics, Accelerator, Detector



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

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