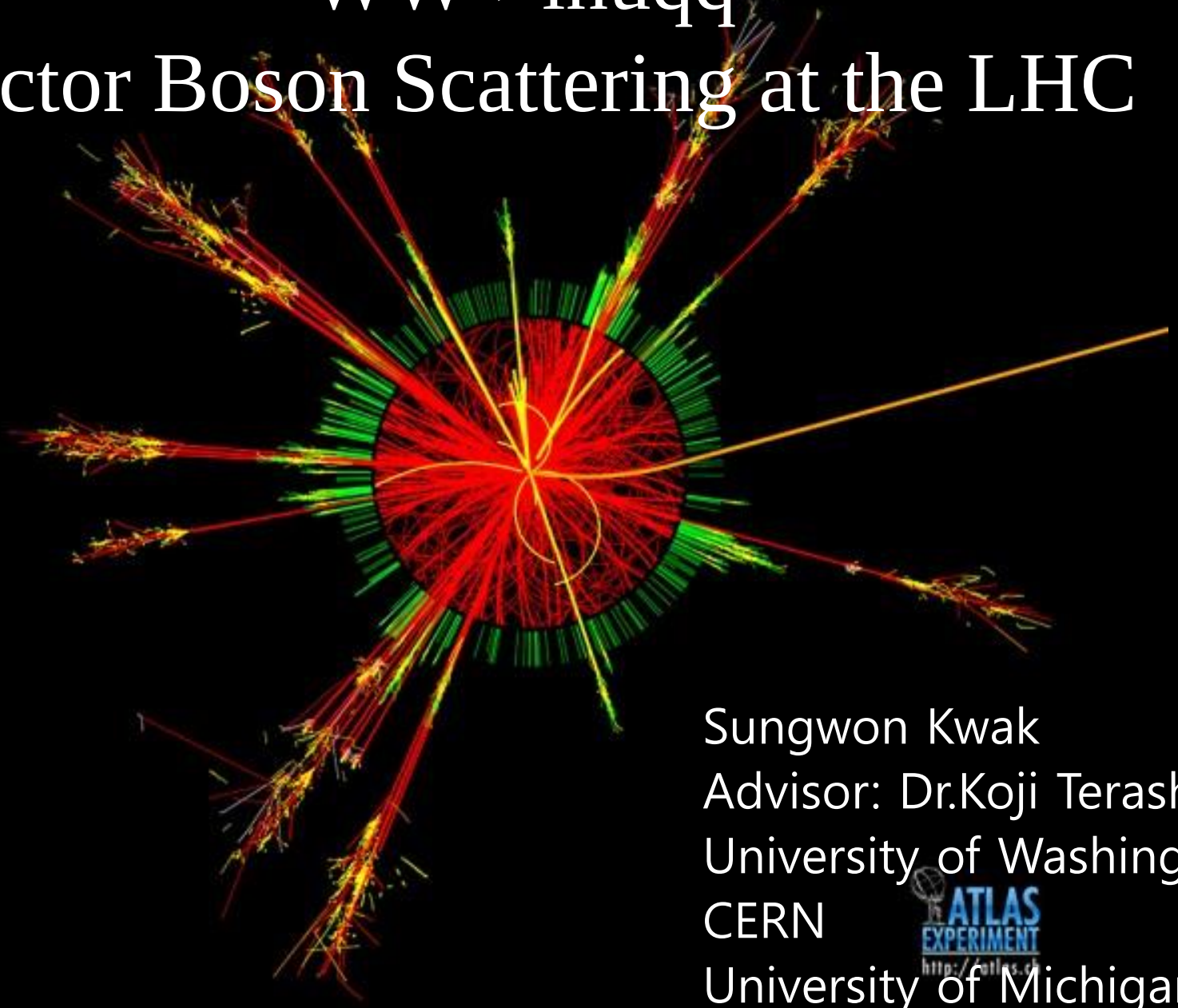
WW->lnuqq
Vector Boson Scattering at the LHC



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University of Washington
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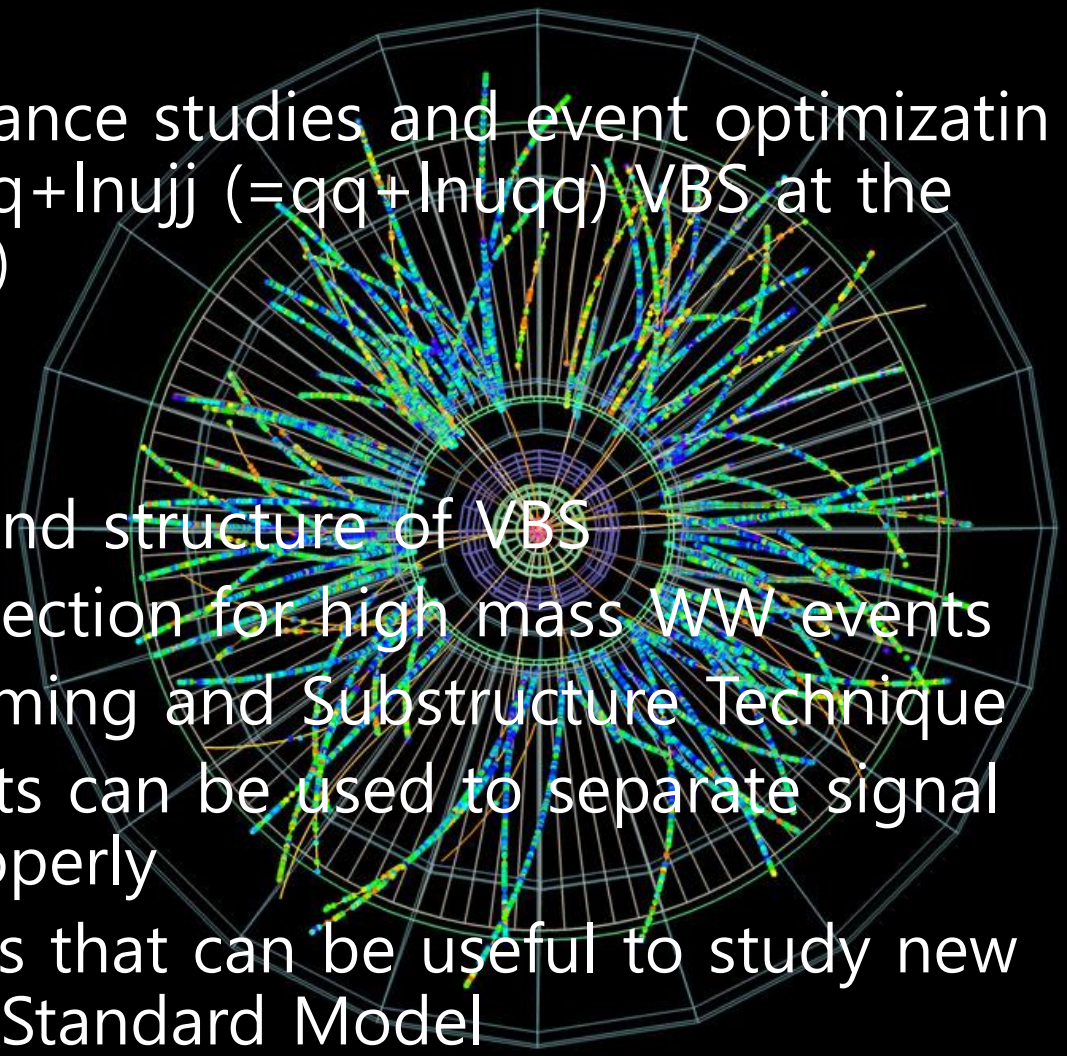
Introduction

Title:

Merged jet performance studies and event optimizatin for the qqWW -> qq+lnujj (=qq+lnuqq) VBS at the LHC. (ATLAS project)



Goal:

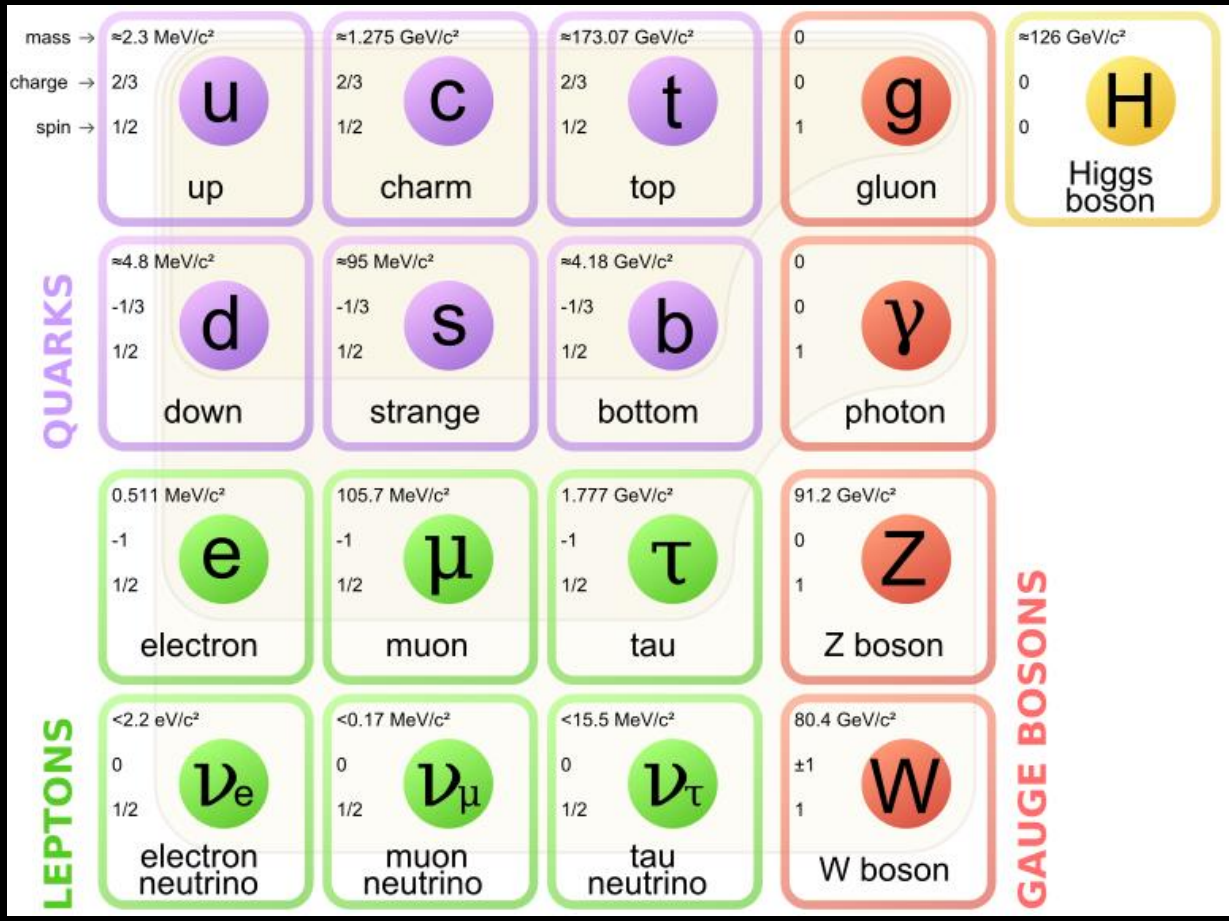
1) Study dynamics and structure of VBS
2) Perform event selection for high mass WW events
3) Perform Jet Grooming and Substructure Technique
4) Check if my results can be used to separate signal and background properly
5) Calculate variables that can be useful to study new physics beyond the Standard Model

Standard Model (SM)

- Lepton: e, muon, tau
- And their neutrinos

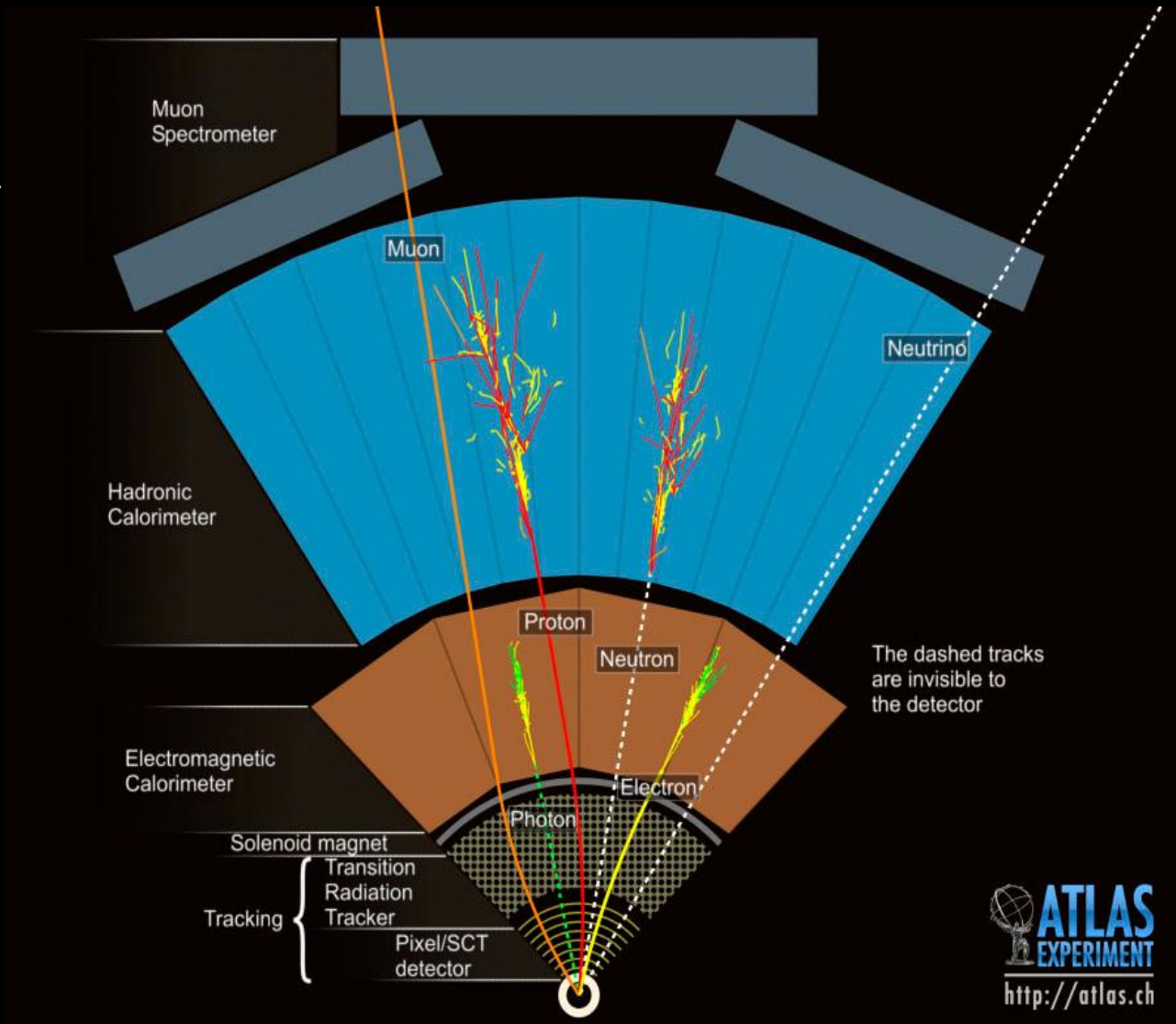
- W, Z vector boson has 1 spin.

- VBS produces leptons(l), neutrinos(nu), and quarks(q)
- Ex) WW->lnuqq or lnulnu, ZZ->4leptons, etc

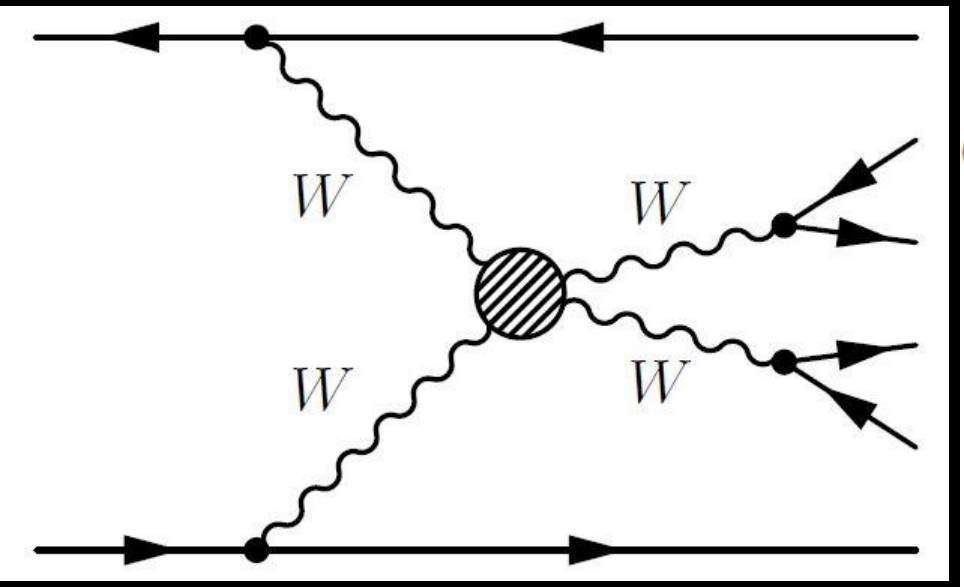


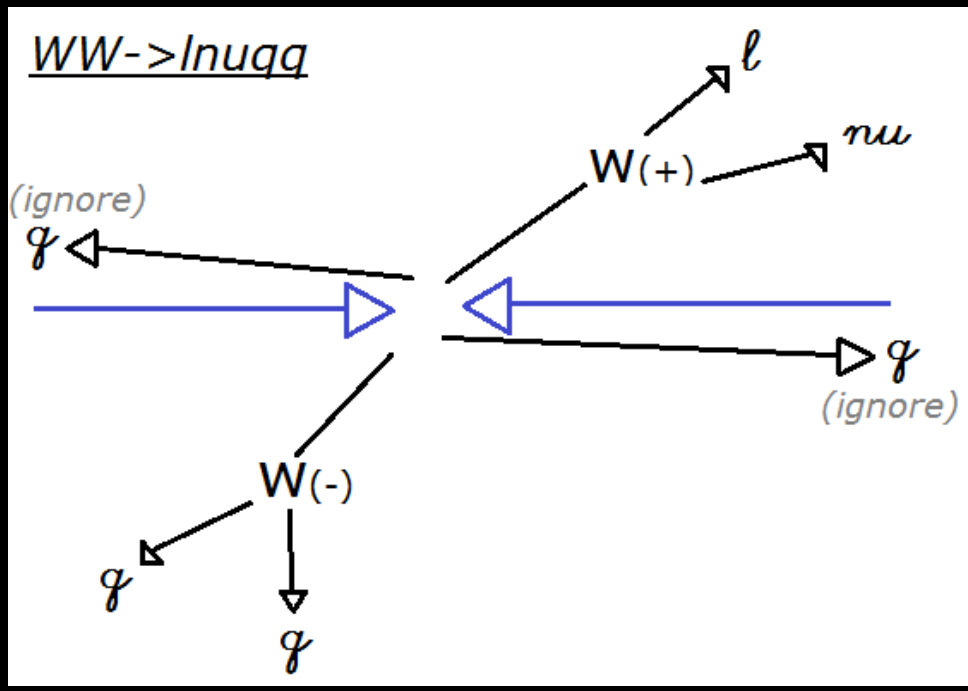
How ATLAS Detect?

- Measure current from charged particles
- Electrons and photons are absorbed by the electromagnetic calorimeter(Orange)
- Proton and Neutron are measured by the Hadronic Calorimeter(Blue)
- Unstable particles (short lifetime) decay before reaching detector



What is VBS?





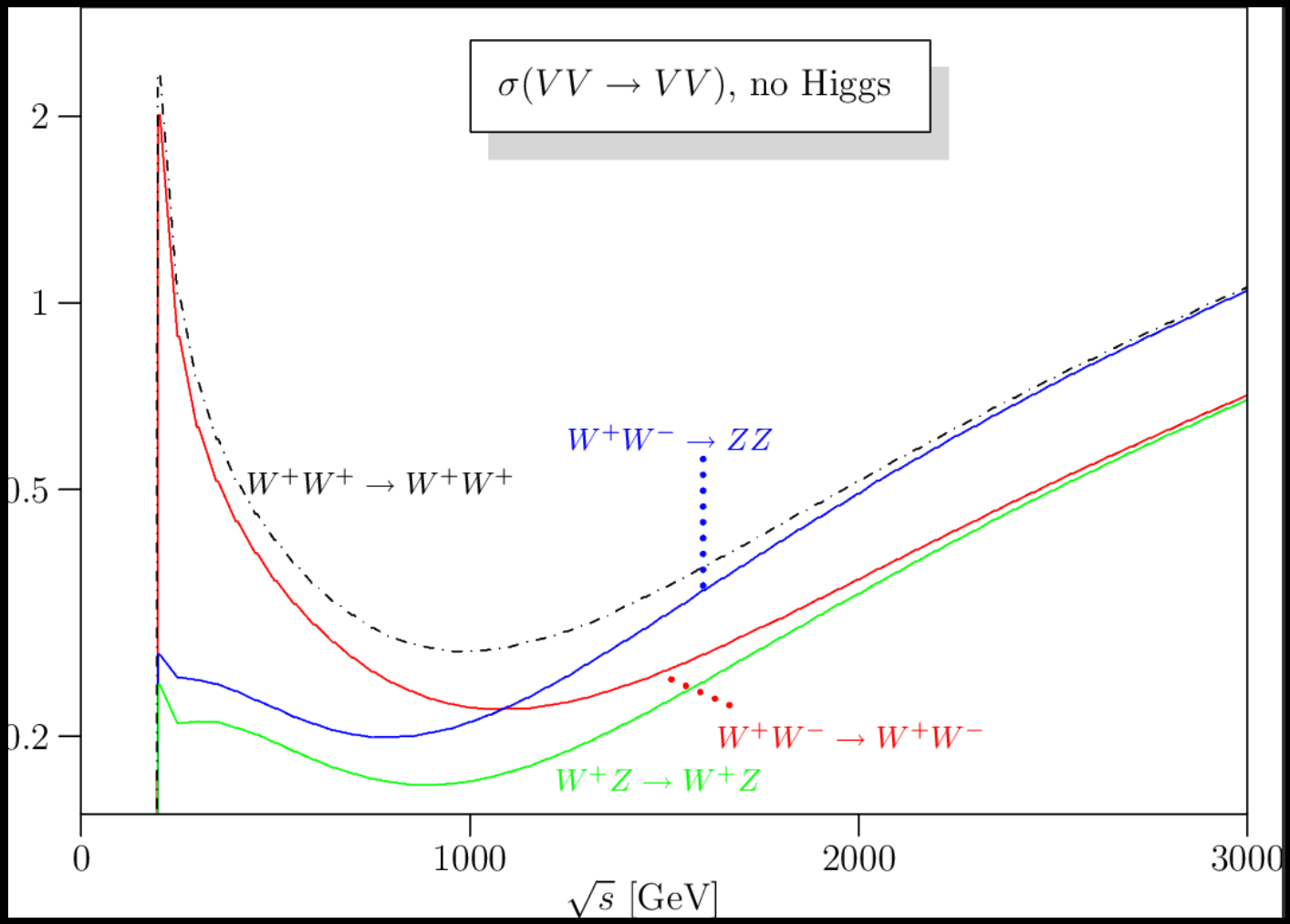
- VBS WW/WZ/ZZ/W+W-/W-W-/W+W+/etc collide and decay into lnulnu/lnuqq/etc
- Signal and Background are produced after the collision

- Signal: Jets with real substructure (what we are interested in)
- Background Jets radiated from gluons/ligt quarks

VBS

- There are many research have been done on WW->lnulnu for its large signal, but that also means this process has relatively large background
- My research focuses on WW->lnuqq
  relatively low background and signal
- Separating signal from background is important to know what's happening in the collision

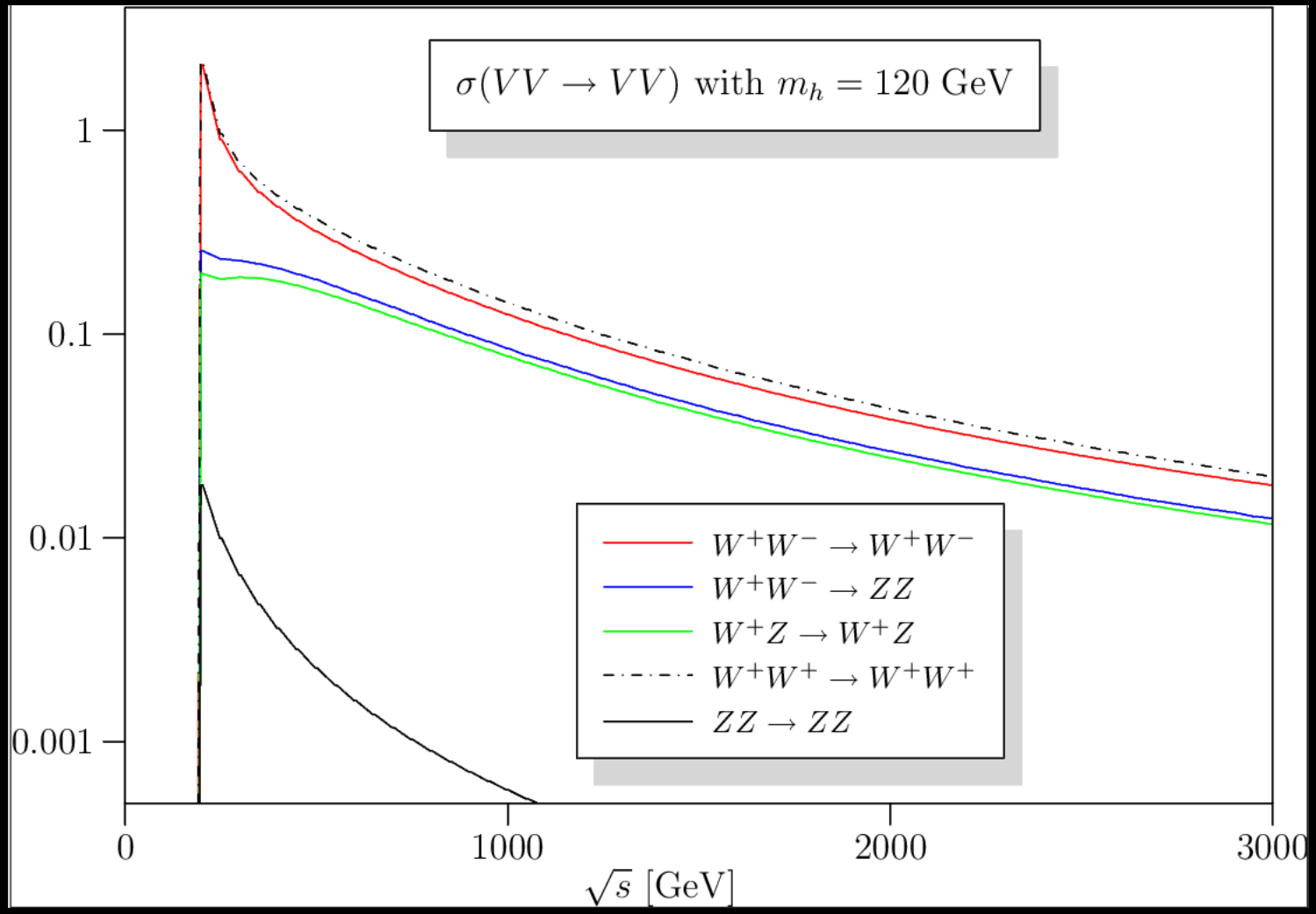
if No Higgs…



- Y-axis: Cross section, X-axis: s =Scattering Energy
- Without Higgs, Cross section -> infinite! Oh, no!

Plots from http://arxiv.org/abs/0806.4145

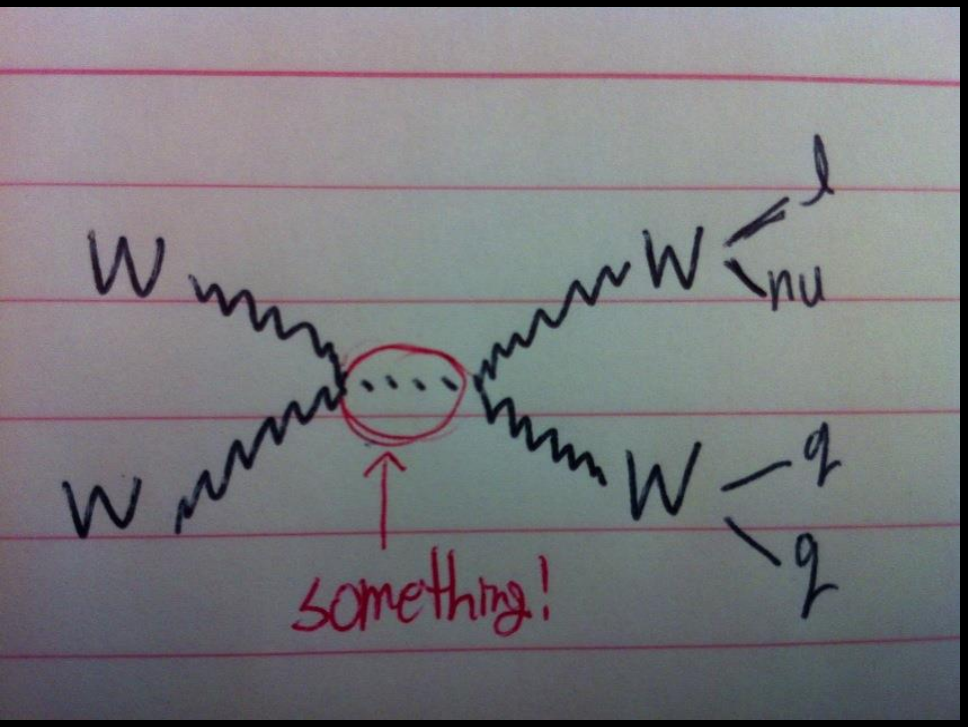
SM with Higgs

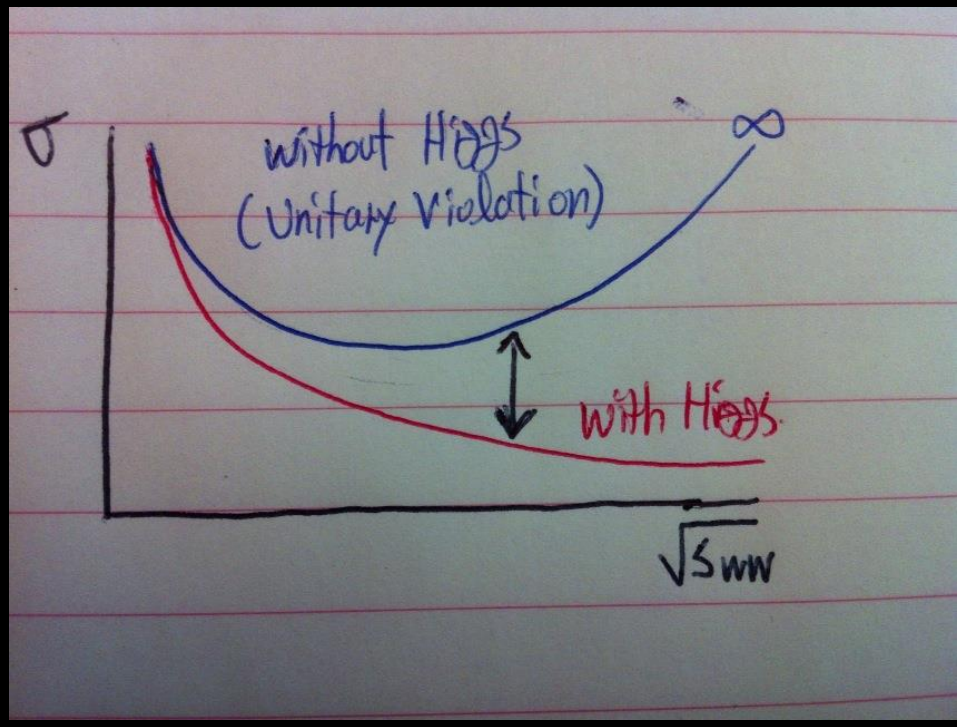


- Higgs saves the world! (...maybe not)


EXCELLENT

It might be something new…

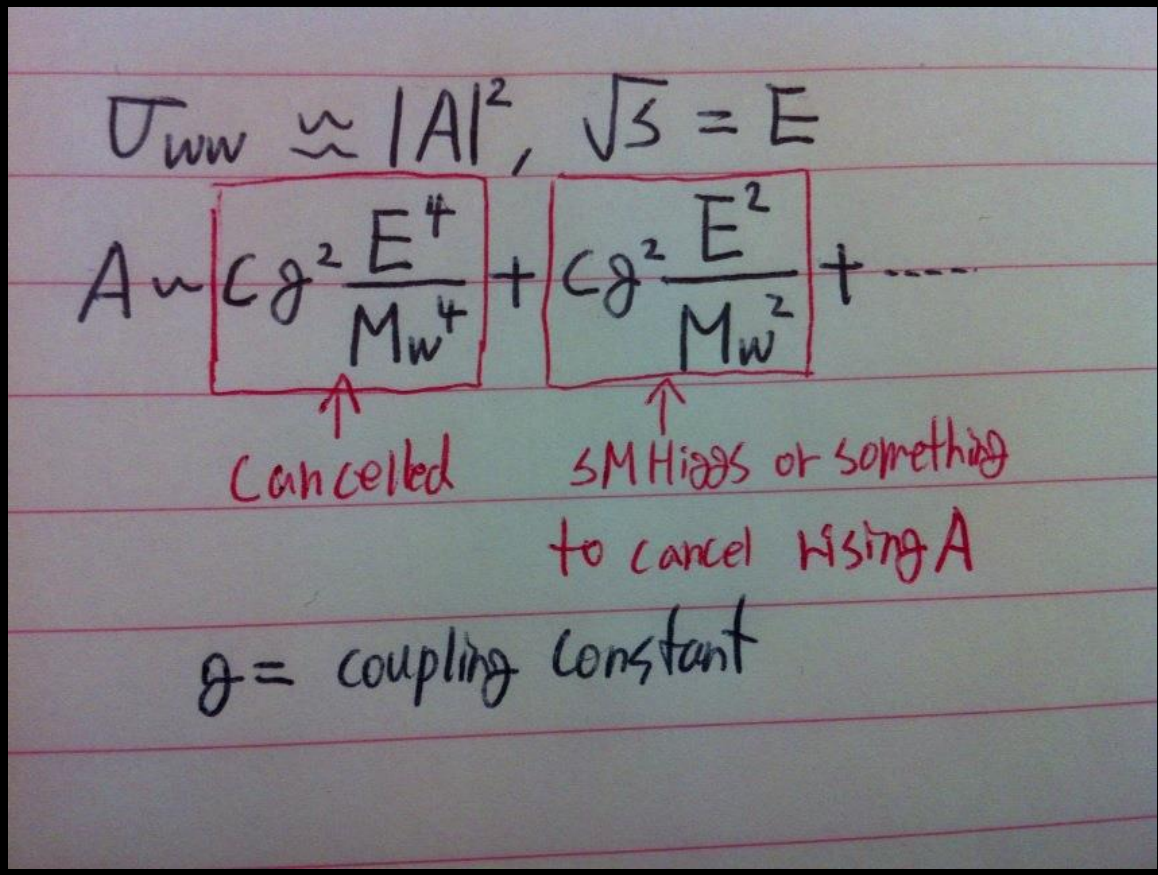




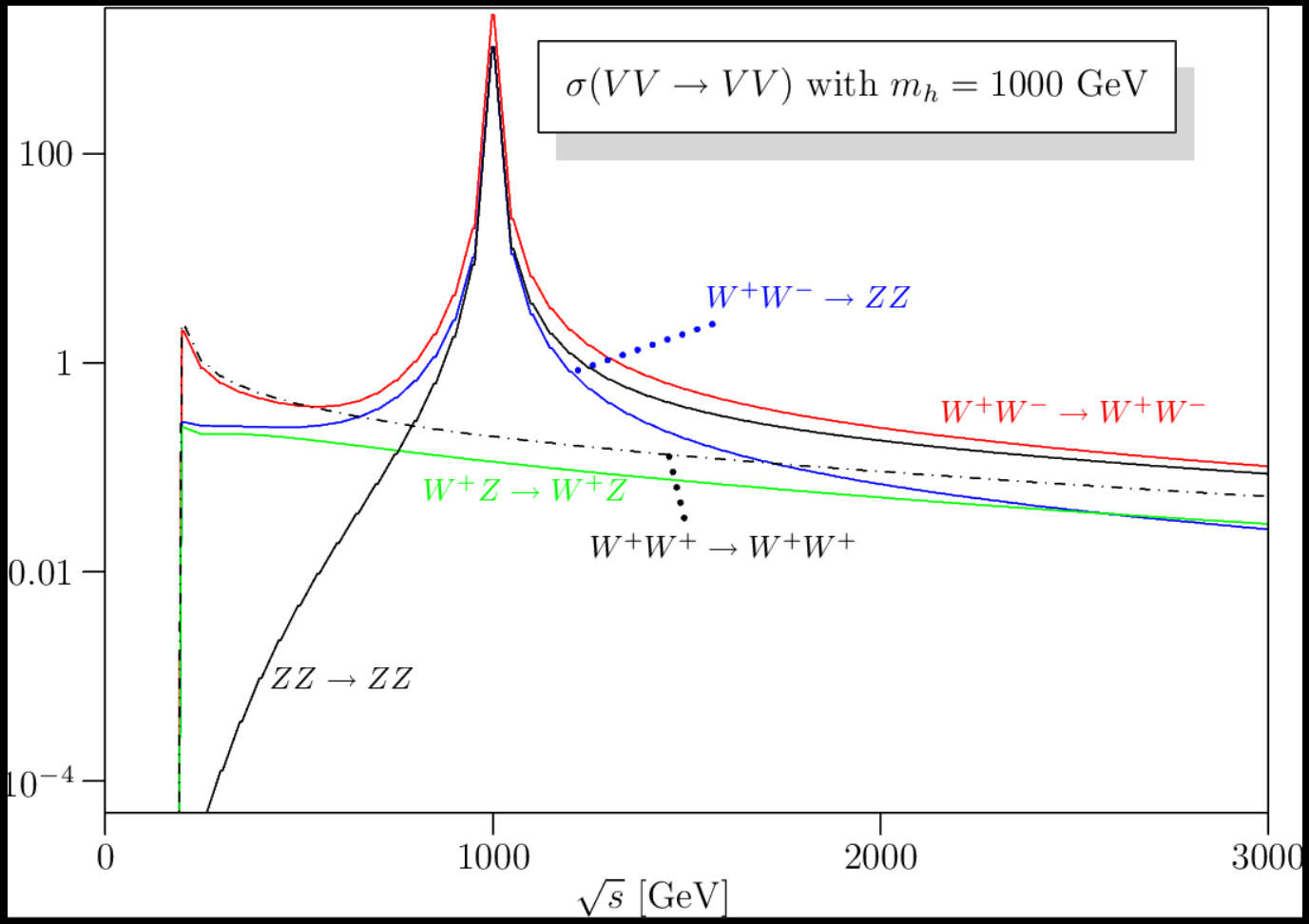
- What if there's no Higgs!?
- Without Higgs, there's unitary violation, so the cross section increases infinitely, but it could be something new instead of Higgs

It might be something new…

- VBS might be something that cancels rising A.
- Maybe there's a new particle behaves like Higgs



Resonance from VBS



- I can be resonance from VBS.
- There are many other mechanisms.

My data

- ttbar (BG 14TeV with lepton filter)
  # tt->bWbW -> blnu+bqq = 4jets
  # b: bottom quarks, so 4 quarks = 4 jets
  # lepton filter –force to have at least one lepton
- WW (BG 14TeV without lepton filter) = 2 jets
  # WW/WZ/ZZ->lnuqq (for my data)
  # lnulnu = no jets, so WW/WZ/ZZ has 2 jets
- WZ (BG 14TeV without lepton filter) = 2 jets
- ZZ (BG 14TeV without lepton filter) = 2 jets
- Mix (signal+resonance, muon only)

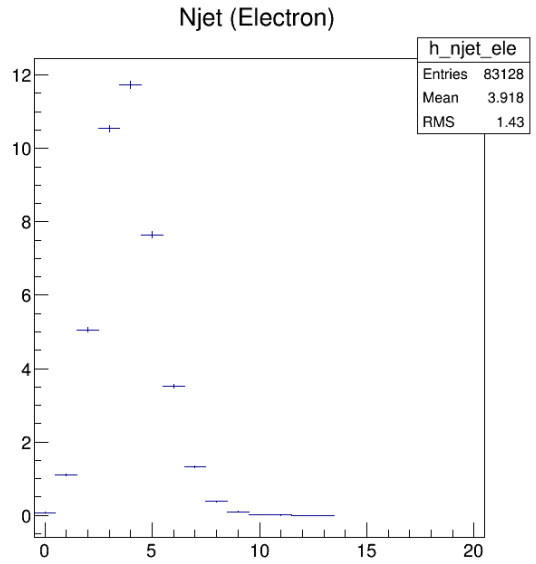
  #VBS WW-> lnuqq signal event which is a mixture of the standard model process of VBS WW -> lnuqq
  + resonance WW -> lnuqq. The resonance mass is 1 TeV, and the coupling of the resonance is 2.5 TeV.

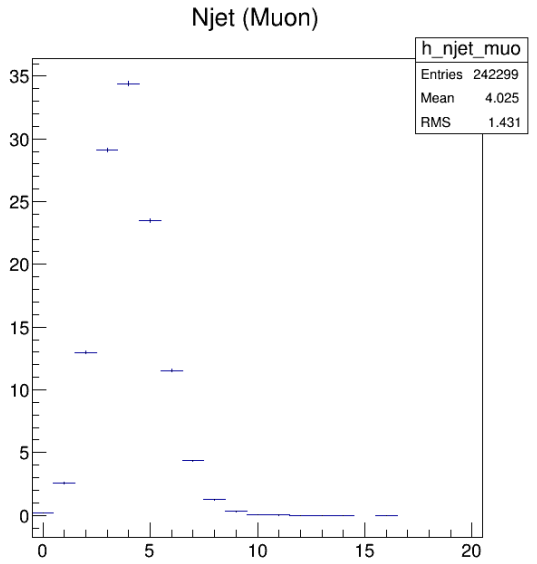
SFrame

- Frame work to analyze HEP data based on ROOT trees. 5~10 times faster than ROOT.
- Usually performed in multiple cycles.
- I use only 1 cycle but still take 4~5 hours (~400GB)
- Frames are already built and can be downloaded, so only modify ‘user’ directory
- Write files such as Analysis1cycle.cxx in user/src for calculating and filling histograms
- Template.h in user/include
- Rootlist.xml in user/config (normalize luminosity, control number of events, etc)

My data (Jets)

- ttbar 4 jets

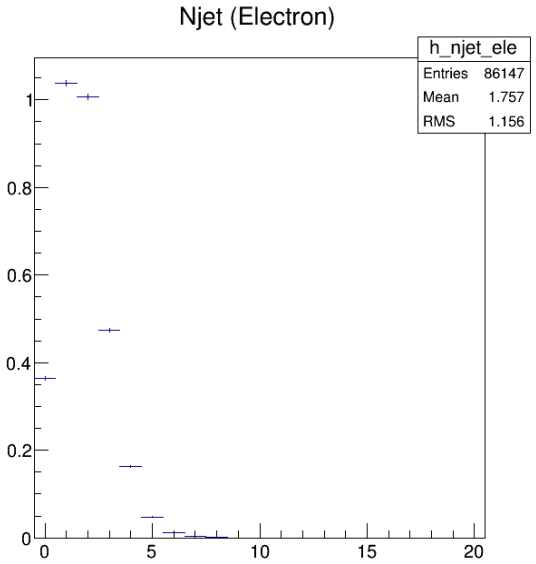


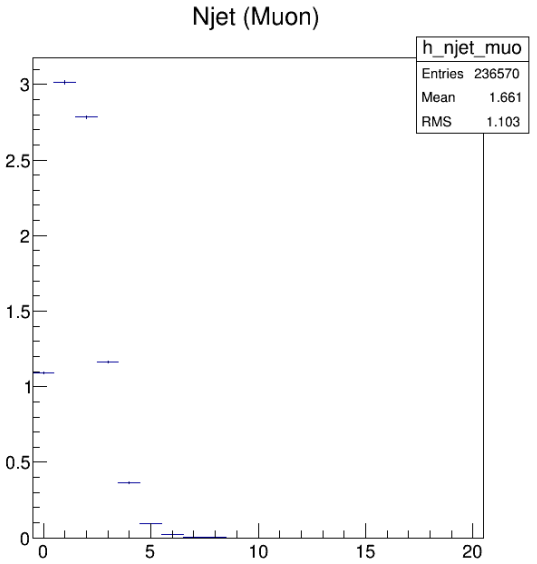


- WW ~2 jets

W can decay hadronically into lnu or leptonically into qq.

WW both can decay hadronically (lnulnu), but not for my data.



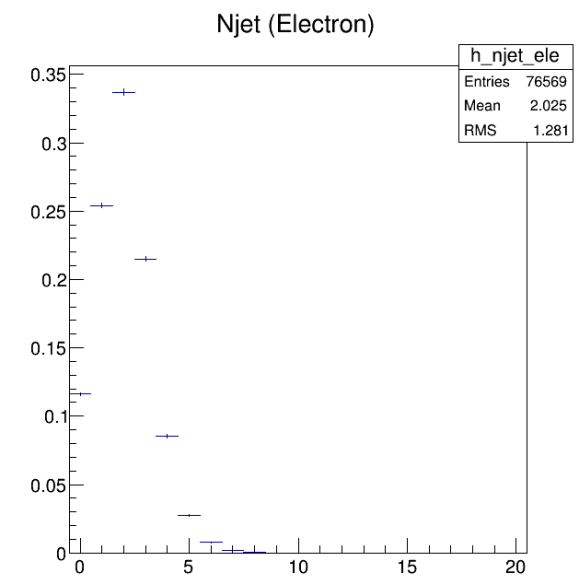


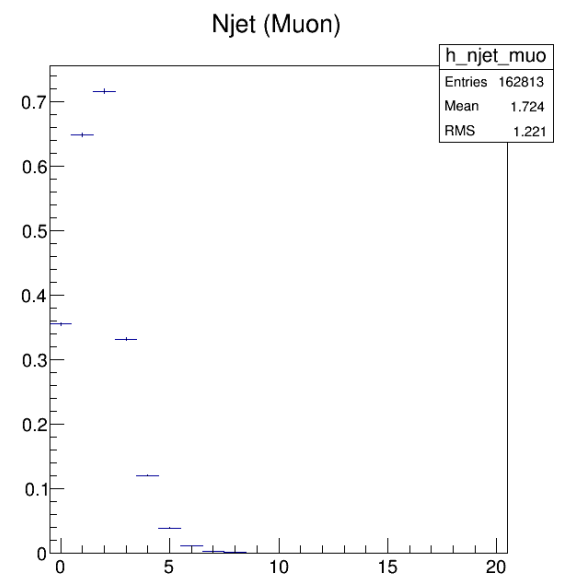
My data (Jets)

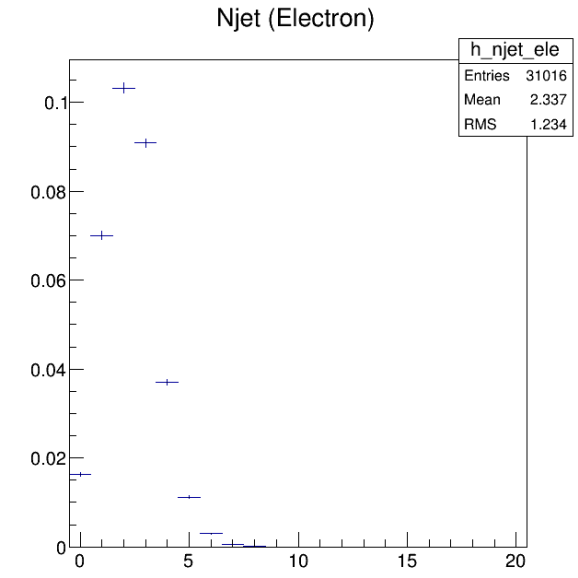
- WZ 2 jets

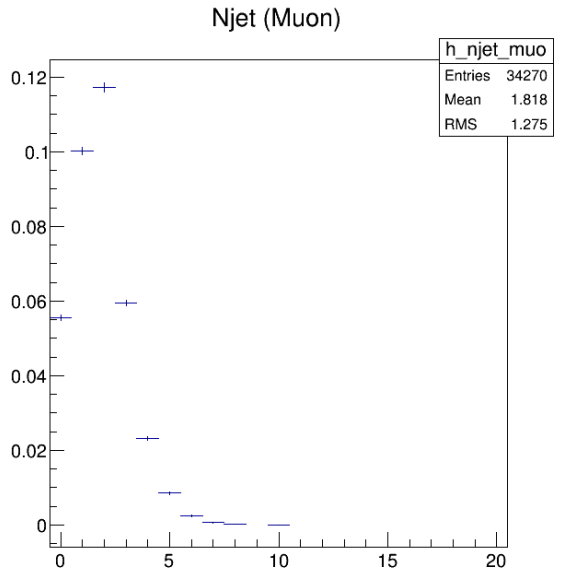
- ZZ 2 jets

Z decays
into lepton ~10% (3.4% x3)
(ee, mumu, tautau)
Into nu by 20%
Into qq by 70%
(uu', dd', bb', ss', cc')





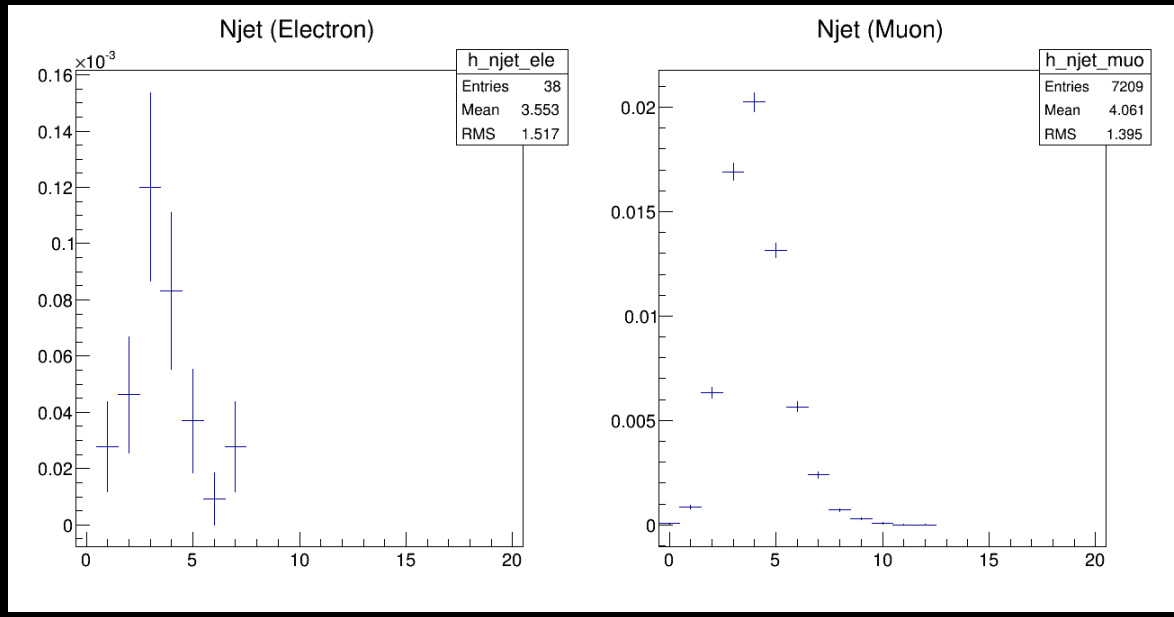




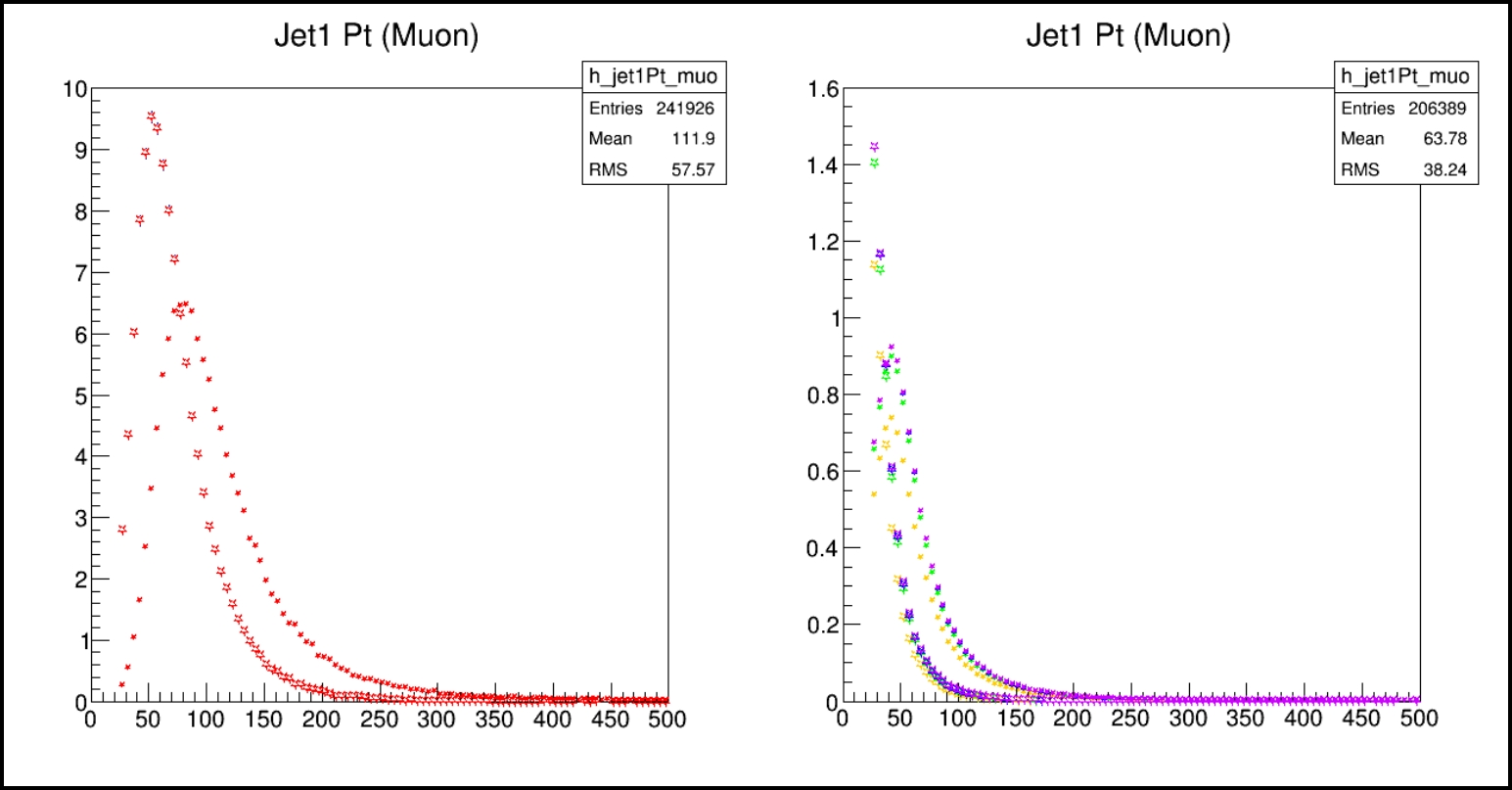
My data (Jets)

- Mix(signal+resonance)

  qqWW->lnuqq+qq, so 4 jets

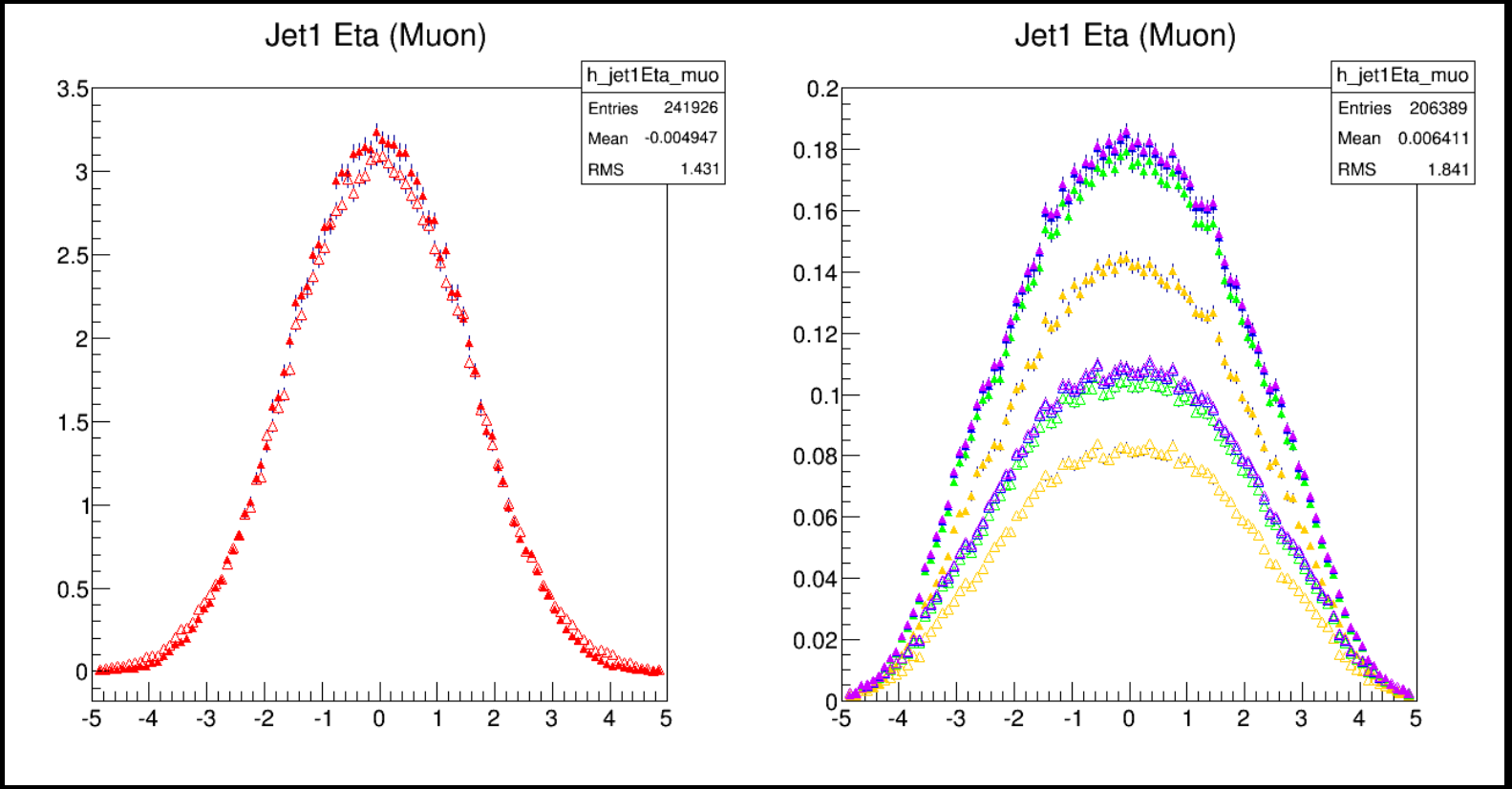


Pt of Jet1, Jet2 (muon)



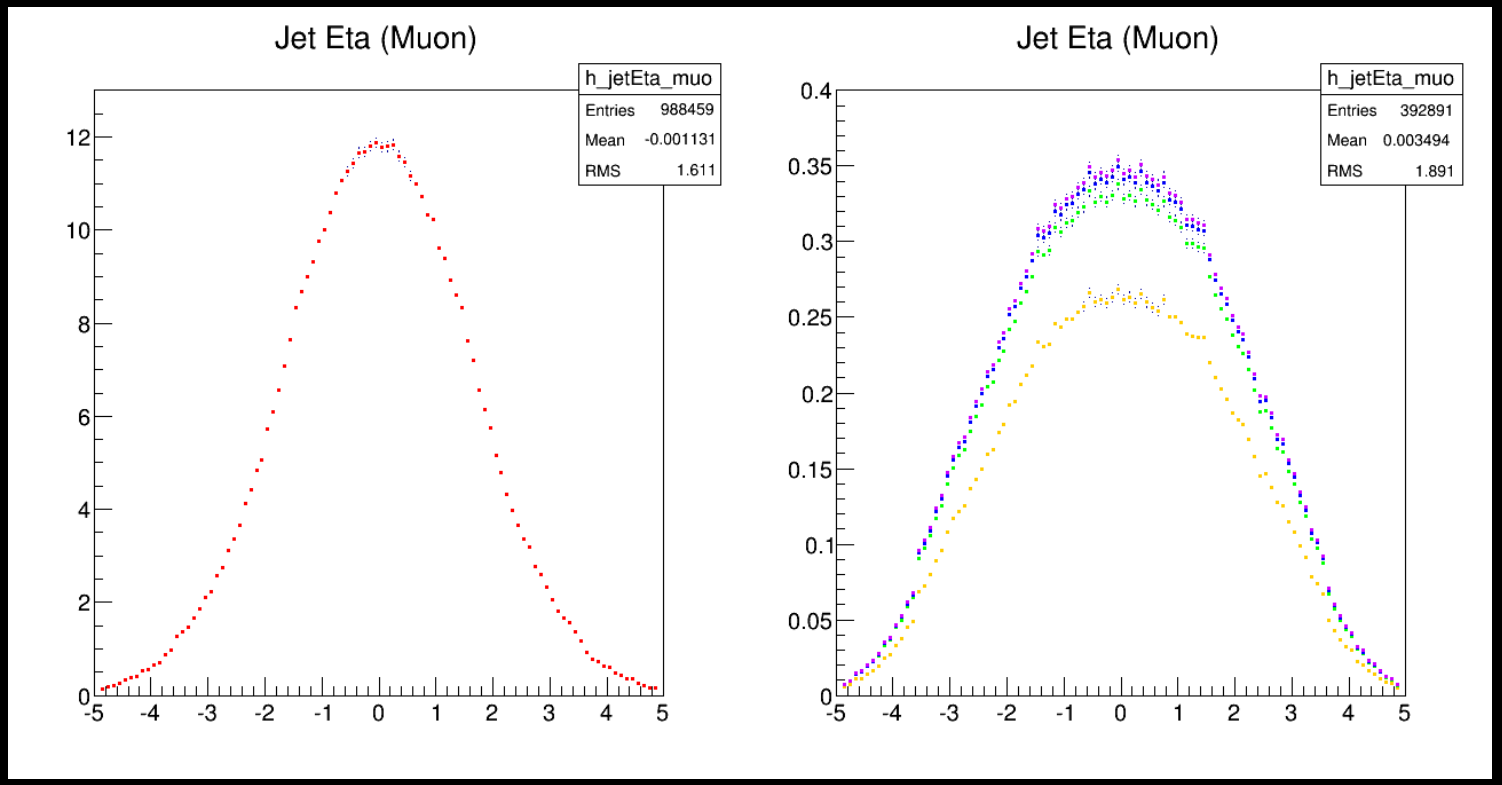
- Red-ttar, Purple-mix(signal+resonance), others-WW/WZ/ZZ BG
- I added mix over BGs
- BG of ttbar was too large… not sure why
- Empty marker = Jet1
- Filled marker = Jet2
- Will be useful to study di-jet mass, and separate signal and BGs

Eta of Jet1, Jet2 (muon)



- After normalization, signal(purple) is relatively small, so I need to re-plot them in log scale.

Total Eta



- This plot is difficult to analyze because of scale so I need to re-plot this as well…
- There are more plots I made, which will be used for future calculations

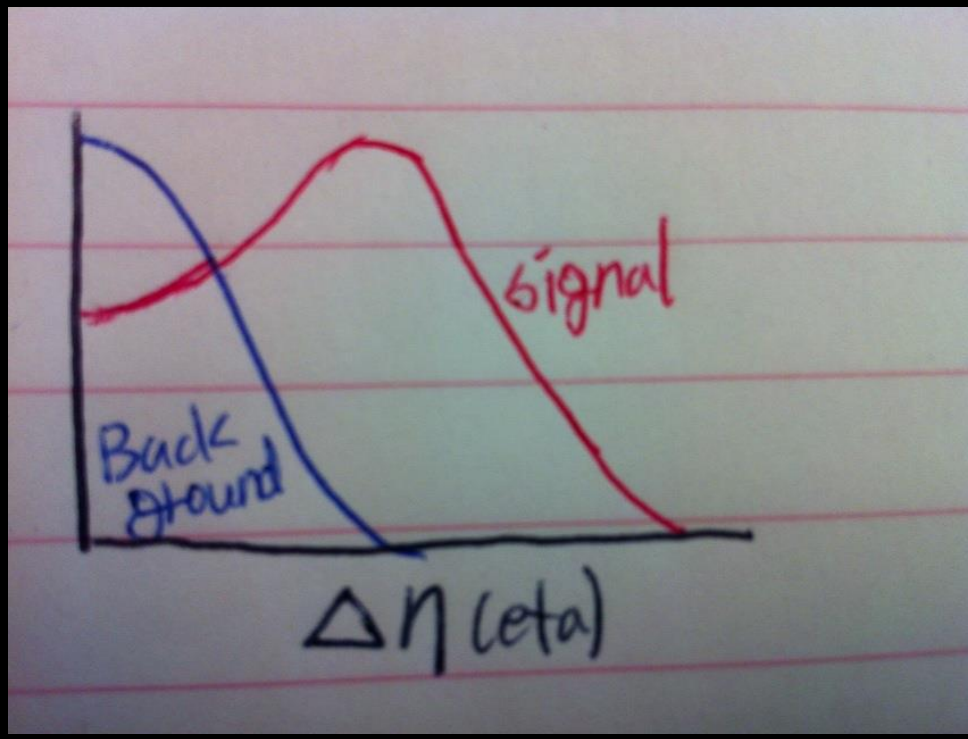
What remains to be done

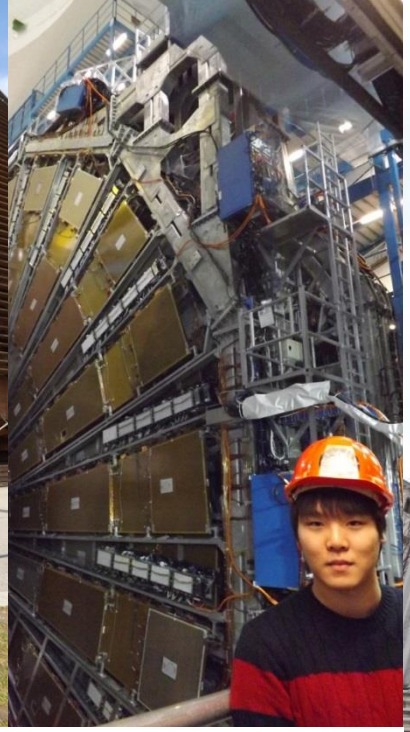
- I will stay here until May1 to continue my research
- Plots:
- Pt of Jet1,2 (with more data)
- Eta of Jet1,2 (with more data)
- Total Eta Separation=Delta Eta (signal and BG)
- Mass of di-jets
- Calculate MET, Phi, Mt from given distribution
- Calculate new variables to compare my WW->lnuqq results with WW->lnulnu results

  (Such as ratio between W->lnu and W->Jets)

Delta total Eta (Eta Separation)

- Not many information about WW->lnuqq exists because of its low signal, but my future results can help to separate signal and BGs properly and improve sensitivity of detector





Will visit soon...
Neuschwanstein Castle in Germany

Thank you! Good Bye!

- Dr.Koji Terashi
- Lounsbery Foundation
- University of Michigan
- CERN-ATLAS

References

- Resonances and Unitarity in Weak Boson Scattering at the LHC http://arxiv.org/abs/0806.4145
- The W_L W_L scattering at the LHC: improving the selection criteria http://arxiv.org/abs/1201.2768
- High Energy WW Scattering at the LHC with the Matrix Element Method http://arxiv.org/abs/1212.3598
- New light on WW scattering at the LHC with W jet tagging http://arxiv.org/abs/1304.4599