8.882 LHC Physics

Experimental Methods and Measurements

Sophisticated Selections: Likelihoods/Neural Networks

[Lecture 21, April 27, 2009]

Organization

Lecture schedule

- next week Wednesday replaced with Tuesday at 10:00?

Project 2

- no additional hand-in yet

Project 3

- looks fine, people did not have significant questions

Conference Schedule

- worked out

Lecture Outline

Sophisticate Selections

- likelihoods
- neural networks

Sophisticated Selections: Why?

Cut based selections

- well defined and intuitive selection process
- can be optimized from the outside (cut ordering)
- simple to implement and monitor
- study is straight forward, uncertainties easy
- simplistic as each variable has to comply with signal signature, no backup possible

More sophisticated methods (likelihoods, ANN *etc.*)

- allow for multidimensional considerations of an event
- must be at least as good as cut based analysis
- more difficult to comprehend, process and result
- study of uncertainties usually more difficult
- implementation and optimization less obvious

Likelihoods as Cut Variables

Idea

- for each variable has a PDF for signal and background
- calculate likelihood for each object to be signal by

$$L_{\text{signal}} = P_{\text{signal}} / (P_{\text{signal}} + P_{\text{background}})$$

- so for perfect signal (background) $L_{\text{signal}} = 1 \;\; (0)$

- each component is given as

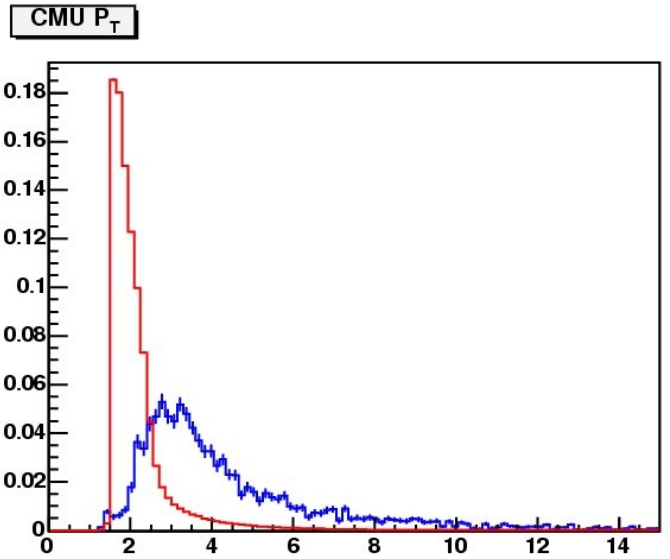
$$P_{\text{signal}} = P_{\text{signal},1} * P_{\text{signal},2} * \ldots$$

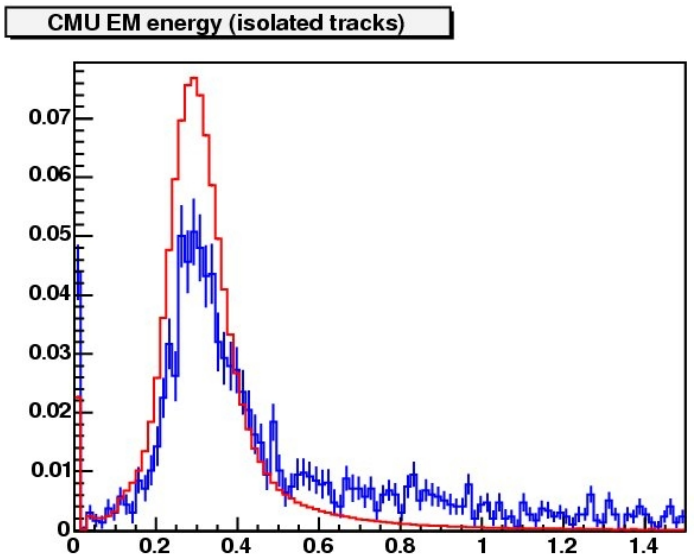
$$P_{\text{background}} = P_{\text{background},1} * P_{\text{background},2} * \ldots$$

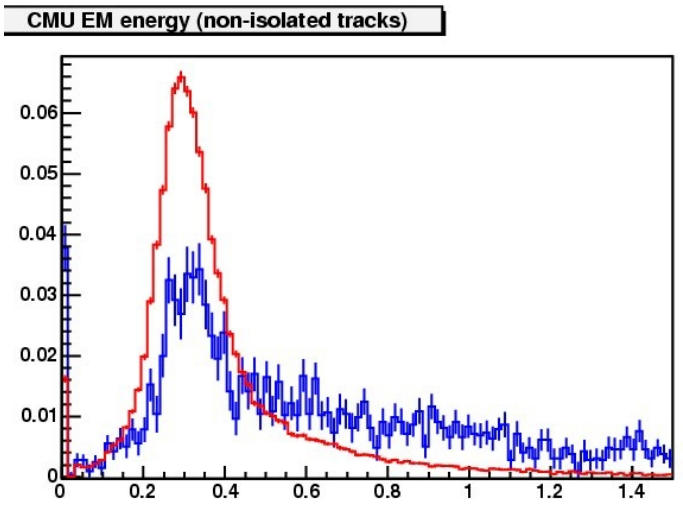
Signal and Background Distributions

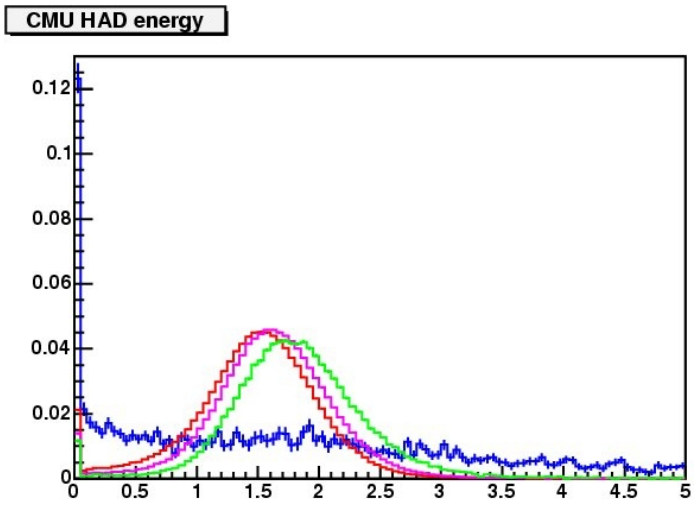
Source

- grabbed from some CDF presentation
- selection for soft muons flavour tagger
- red – protons
  blue – muons



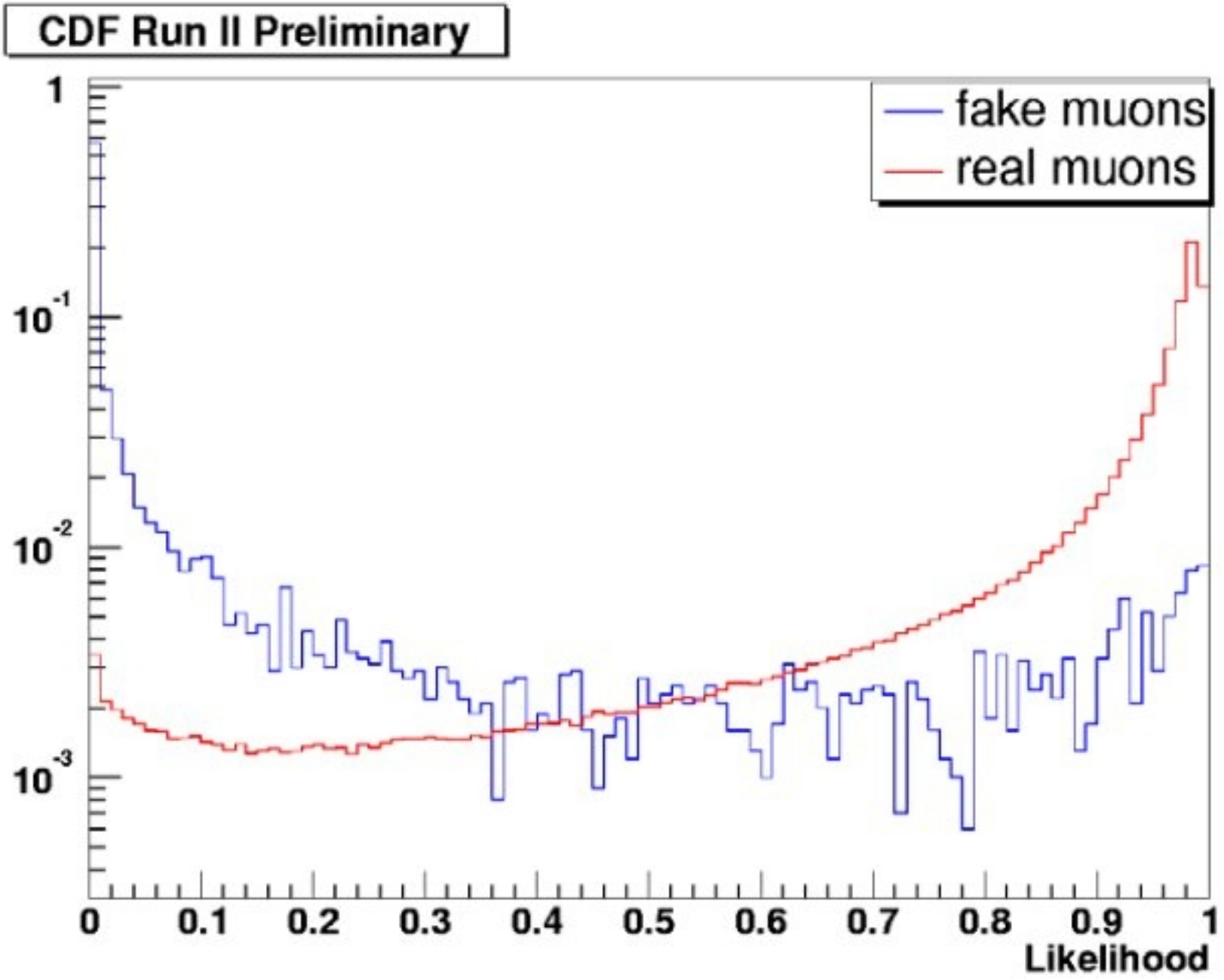






- Three muon p_T ranges: $p_T < 2$ GeV (red), $2 < p_T < 3$ GeV (magenta), $p_T > 3$ GeV (green)

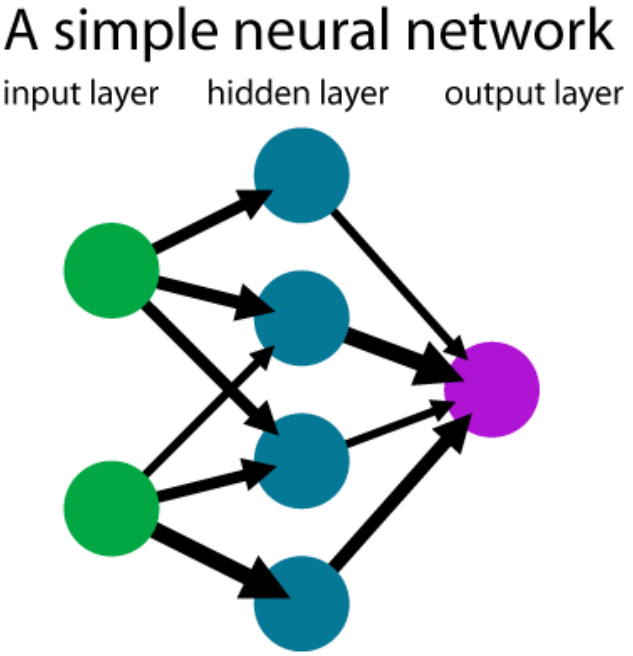
Overall Likelihood for Muons



Neural Networks

From wikipedia:

- "Traditionally, the term Neural Network had been used to refer to a network or circuit of biological neurons. The modern usage of the term often refers to artificial neural networks, which are composed of artificial neurons or nodes."
- "Artificial neural networks are made up of interconnecting artificial neurons (programming constructs that mimic the properties of biological neurons). Artificial neural networks may either be used to gain an understanding of biological neural networks, or for solving artificial intelligence problems without necessarily creating a model of a real biological system."



Applying an Artificial Neural Network

Sample creation

- make samples representing signal and background
  - careful do not train on data you use later
  - Monte Carlo is easier but often unreliable, study variables
  - sometimes NN chains needed: muon id, then upsilon id
  - this is the important step, all depends on the proper samples
- train the network on those samples
- network returns for each event a number between 0 and 1 corresponding to 0 == background and 1 == signal
- apply the trained ANN to the data and decide where to choose the cut on the ANN variable
- optimization becomes straight forward
- use TMVA class with root... I had not yet the chance to try but it is supposed to be very good

Neural Networks

For our course

- use a pre-packaged ANN implementation: ANN, SNNS, Neurobayes
- toolbox very convenient to use for neural nets: TMVA

Conclusion

Sophisticated selections

- likelihoods: allow combination of many different variables
- variables have predefined signal and background shapes
- ANN – Artificial Neural Networks allow combination of many different variables
- full signal and background samples have to be provided
- training of the network is essential and has various issues
- systematic uncertainties are more complex to study with the more complex selection process

Next Lecture

Higgs Searches and Other Essentials

- guest lecturer?!
- overview over the High p_T physics and Higgs searches and some general searches in particular