Systematics in HEP:

Paper studies, *Introduction*

AMSDA workshop 2009, 12.-14. Oct 2009, Karlsruhe
Olaf Behnke (DESY)

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- **Main idea: study standard methods to propagate systematic uncertainties into final measurement observables**
- **Not: how to calibrate your detector**

Observables in HEP and selected papers

- **Finding a new particle signal or new production mode**
- **Determine particle properties: mass, lifetime, spin, production & decay modes,**
- **Derived observables and fitting underlying theory parameters**
- **Averaging of correlated measurements**

Search for resonance decays to lepton+jet at HERA and limits on leptoquarks, **ZEUS**, PHYSICAL REVIEW D 68, 052004 2003 **Group A**

Search for single top quark production in ep collisions at HERA, **H1** ,Eur. Phys. J. C 33, 9–22 (2004) **Group D**

Measurement of the W Boson Mass, **D0**, PRL 103, 141801 (2009), Definition and Treatment of Systematic Uncertainties in High Energy Physics and Astrophysics, **Sinervo,** PHYSTAT2003 **Group C**

Study of B0 --> rho+rho- decays and constraints on the CKM angle alpha, **BABAR,** PRD 76,052007 (2007) **Group E**

Combination of **CDF** and **DØ** Results on the Mass of the Top Quark arXiv:0903.2503v1 HOW TO COMBINE CORRELATED ESTIMATES OF A SINGLE PHYSICAL QUANTITY, **Lyons, Gibaut, Clifford** NIM A270 (1988) 110-117 **GROUP B**

Your task list

- **Monday: Start reading/digesting the alloted paper (>1h)**
- **Tuesday:**

14:00-15:50 & 16:10-17:30

Preparation of the student group presentations on systematics techniques

(Desktop room / Seminar room 3.1 / 8.2 (and 10.1 / Kleiner Hoersaal B))

Suggestion: Discuss the paper extensively in your group in the first hour and prepare the presentation in the remaining time

Note: Tutors for each paper are available/around all the time

- **Wednesday:** ***show time***

14:00-16:15 student group presentations in two half plenaries – every group presents its results

Presentation guide

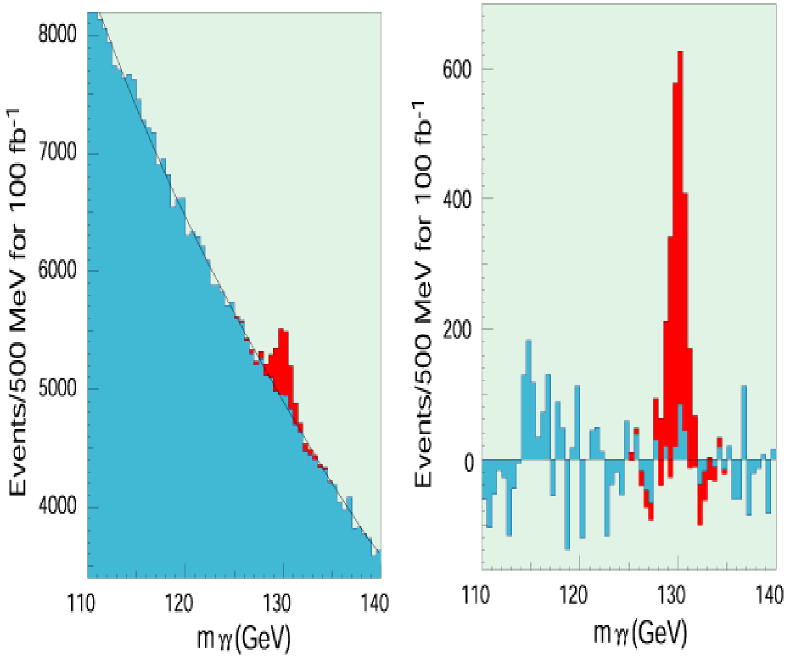
The 15'+5' presentations should contain: (number of slides)

- **Physics motivation of the paper (1)**
- **Explanation of the basic method of the measurement (1)**
- **Possibly some info on detector/experiment (<=1) and on data selection cuts (<=1)**
- **The results (1-2)**
- **A discussion of the systematic uncertainties covering (5-10)**
  - **What are the main systematic uncertainties**
  - **How are the source uncertainties estimated (as far as it is described) and what is their size**
  - **How are the source uncertainties propagated to the final measurement observables and what are the resulting uncertainties**

  Discussion pro and cons of the systematic treatment and form an opinion if you find it appropriate
- **A conclusion/summary of your analysis of the paper (1)**

Sources of systematic Uncertainties (not complete!)

Many of the following sources will play a role e.g. for measurement of cross-section pp-> HX, H-> $\gamma\gamma$



- **Acceptance:** dead regions of detectors, visible region and extrapolations outside
- **Efficiency:** Trigger, Calorimeter, Tracker, Pid-detectors, selection cut efficiencies
- **Detector resolutions (core and tails), scales and biases:** tracks: momentum and spatial resolution at origin, resulting mass peak and vertex resolutions, particles: position and energies in electromagnetic and hadronic calorimeter, energy flow objects and reconstruction of complete hadronic final state reconstruction, missing transverse momentum (for neutrinos), time dependent detector performances & background conditions
- **Background subtraction:** absolute normalisation, shapes, unkown backgrounds
- **Procedural uncertainties:** use (tuned) MC predictions with limited statistics for Signal and Background shapes or fit with parametrised shapes, likelihood construction for fit, fit interval, data unfolding (bin to bin migrations)
- **Model/Theory uncertainties:** Acceptance corrections with MC depend on underlying physics model, branching ratios; theory uncertainties: electroweak & QCD higher order corrections, PDF uncertainties

Evaluation/propagation of sys. uncertainties

Note: this is often a most crucial and difficult aspect and a main topic for this paper study project

Some principal methods, example: hadronic energy scale uncertainty for top mass measurement (with one top -> bW -> bjj)

- **appropriate variations of the Monte Carlo simulations:** e.g apply shift to hadronic energy flow objects in MC by assumed scale uncertainty
  - **Map the applied shifts in MC on final measurements:**
    - just do it by repeating the whole analysis with +- 1 sigma shifts in MC -
    - throw the dice (e.g. 1000 times), calculate each time a gaussian random number x (with sigma=1) and smear the hadronic energy flow objects in MC by x*sigma and repeat the whole analysis and take the resulting rms values of the measured observables as uncertainties – this procedure is often needed for analyses with: fits of MC signal and background templates to data (discriminant) distributions to determine the signal.
- **Fit of systematic parameters from the data itself: e.g.** Fit the hadronic energy scale from the data exploiting contraints (e.g. W mass), this will lead to some statistical increase of the uncertainty of the fitted top mass, ideal method but not always feasible

Closing line: We will come back to such methods in the following two days, enjoy the workshop!

High energy physics analyses and systematic uncertainties - paper studies

General task description: In this workshop session we want to study interesting showcases for the treatment of systematic uncertainties in high energy physics. For this purpose we have selected five publications (plus an auxiliary paper for two of these publications). You will work within a group of a few people on *one* of these papers. It is your task

- to do a quick reading of the paper tonight (we hope you can spend at least 1 hour). You may also start discussing during dinner with your group co-members how to organise yourself in the group.
- in the session Tuesday 13 sep, 14:00 - 17:30: to discuss during the first hour the paper in your group and then to prepare a 15'+5' presentation focussing on the methods used for the determination of systematic uncertainties
- in the session Wednesday 14 sep, 14:00-16:15: present the paper to the other groups.

The presentation should contain (recommended number of slides):

- the physics motivation of the paper (1)
- explanation of the basic method of the measurement (1)
- possibly some info on detector/experiment (≤ 1) and on the data selection cuts (≤ 1)
- the results (1-2)
- a discussion of the systematic uncertainties, the main part of the presentation ($5-10$), covering
  - what are the main systematic uncertainty sources
  - how are the source uncertainties estimated (as far as it is described), and what is their size
  - how are the source uncertainties propagated to the final measurement observables and what are the resulting uncertainties.

  Discuss pro and cons of the systematic treatment and form an opinion if you find it appropriate.
- a conclusion/summary of your analysis of the paper (1).

Technical help:

- Everybody receives a printed paper copy
- The talks can be prepared in OpenOffice. Within the virtual machine, OpenOffice 3.0.1. is installed.
- Figures of the paper can be included in the talks in different ways:
  - copy/paste from the available pdf files using the acrobat reader snapshop tool. Acroread is currently not available but can easily be installed by each user by executing 'sudo apt-get install acroread' The password asked for is the standard user password 'user'.
  - KDE offers Okular as pdf reader. It can also copy images and texts without any problems
  - for some papers tarballs with .eps files might be also retrieved from the corresponding arXiv.org webpages, but this could be rather time-consuming.

Sharing of tasks and supervision/support:

- within a group the tasks should be shared as much as possible amongst all members, for instance the final presentation should be split such that at least two group members have a chance to speak.
- Tutors will be available and approachable during the whole sessions, don't hesitate to ask them.