Blind Analyses in the High-Statistics Regime with Atmospheric Neutrinos in DeepCore

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[1] J. Klein and A. Roodman, Blind Analysis in Nuclear and Particle Physics, Annual Review of Nuclear and Particle Science 55, (2005)

Blind Analyses

- A blind analysis, in its simplest form, is any measurement done without looking at the answer.

- It was first used by the medical community by using blind randomized clinical trials.
  - Origins dates back to at least 1662 when van Helmont challenged academics of the day to compare their treatments based on theory to his based on experience: [1]

    > *Let us take out of the hospitals, out of the Camps, or from elsewhere, 200, or 500 poor People, that have Fevers, Pleurisies, etc. Let us divide them into half, let us cast lots, that one half of them may fall to my share, and the other to yours ... We shall see how many funerals both of us shall have. But let the reward of the contention or wager, be 300 florens, deposited on both sides.* [2]

[1] A. Roodman, Blind Analysis in Particle Physics, PHYSTAT2003, arxiv:0312102

[2] R. Doll, Controlled trials: the 1948 watershed, British Medical Journal 318, 1217, (1998).

Blind Analyses: Experimenter Bias

- The primary reason to have a blind analysis is to prevent experimenter bias more than experimental bias.
- Because of this, the technique was picked up by physicists as early as 1933.[3]
  - Dunnington used it in his measurement of e/m of the electron.
  - The e/m was proportional to the angle between the electron's source and the detector.
  - He asked his machinist to choose an arbitrary angle around 340^o.
  - Did not discover the true angle until AFTER the analysis was complete.

[3] F.G. Dunnington, Phys. Rev. 43, 404, (1933)

Blind Analyses: Experimenter Bias

- Rutherford was also concerned about bias and once said:

> *It seems to me that in some way it is regrettable that we had a theory of the positive electron before the beginning of the experiments. Blackett did everything possible not to be influenced by the theory, but the way of anticipating results must inevitably be influenced to some extent by the theory. I would have liked it better if the theory had arrived after the experimental facts had been established.* [5]

[4]

- He said this at the 1934 Solvay Conference in reference to Patrick Blackett's discovery of the positron.

[4] J. Heinrich, Benefits of Blind Analysis Techniques http://www-cdf.fnal.gov/physics/statistics/notes/cdf6576_blind.pdf

[5] A. Pais, "Inward Bound" (Oxford University Press, Oxford, 1986)

Experimenter Bias

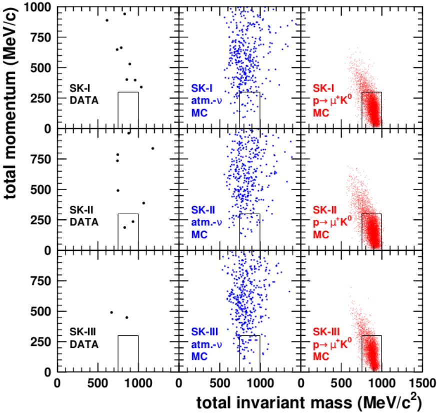
- Experimenter bias can manifest itself in many ways that would effect the physics:
  - Cuts to data are adjusted to bring the answer closer to theoretical values.
  - If multiple analyses are being performed, the primary analysis used for publication is decided after knowing the results.
  - If the results do not agree with theory or other experiments:
    - More checks are done after this is found out, but would not be done if the answer agreed with expectation.
    - Extra systematics are made up to change the answer.
    - Extra cuts are added to bring the answer in line with others.
- Blind analyses can help prevent all of these but is not the only solution.
  - There is no such thing as a perfect blind analysis.
  - They can never prevent fraud.

Types of Blind Analyses

- In essence, as long as the answer is unknown, it is a blind analysis.
- How one hides the answer or how much the answer is hidden is highly dependent on the situation.
- Generally one can divide blind analyses for particle physics into four major categories:
  1. Hidden box method
  2. Shifting methods
  3. Hide some of the data
  4. Hidden answer

Hidden Box

- The hidden box method explicitly hides the signal region.
- Any events in a signal region are kept hidden until the selection cuts, background estimate, and analysis method are complete.
- Well suited for rare decay processes.
- One complication is what size the box should be.



[6] The Super-Kamiokande Collaboration, Search for Proton Decay into Muon plus Neutral Kaon in Super-Kamiokande I, II, and III, Phys Rev D 86, 012006 (2012)

Shifting

- Another method is simply shifting the answer by some fixed but unknown offset.
- This is exactly what Dunnington did in my earlier example.
- Works well for neutrino physics where L and E are needed to be known.
  - Can shift all energy data points by std::rand()
  - Simply set std::srand(5109989461)
- An advantage of this is it allows two independent groups in different places analyses the data at the same time.
- Does not work well for θ_{23} measurements where it would still be obvious if maximal or not.

Hide some of the data

- In this method part (or most) of the data is hidden.
- Set up the analysis using a small subset or side-band of data.
- Perform all tests with this sub-sample and only look at the other sample when the analysis is finalized.
- Has several draw backs:
  - Sometimes one does not have enough data to not use all of it.
  - If a sub-sample is being used over a side-band, the answer might still be known within some statistical fluctuation.
  - Tuning to the sub-sample can cause the same bias in the larger sample.

Hide the Answer

- As mentioned before, the simplest of all methods is to just not look at the answer.
- This becomes more complicated though:
  - What about distributions that one might be able to infer the answer from.
  - Or the information used to make those distributions.
- The rest of this talk I will discuss what is currently being done with DeepCore analyses and how we try to solve the problems in the high statistics regime.

DeepCore Blind Analyses

- The ideal situation is to setup the entire analysis with only MC.
- Unfortunately, the MC can not always fully replicate the detector or data.
- Because of this, after the analysis is finalized and validated with only MC, we run it on data.
- Fit the model to 100% of the data but ("Blind data fits"):
  - Do not look at the observable space.
  - Do not look at any parameters of physics interest.
  - Only look at goodness of fit.

DeepCore Blind Analyses

- If bad goodness of fit found, improve model until one is achieved.
- After each fit do series of checks.
- Are the contributions of goodness of fit distributed as expected?
  - More pulls from low energies or from specific region of the sky?
    - This would indicate the data is outside the expected range from systematics and there is a problem with the model.
- Do fits to subsets of the data converge to similar values?
  - Do not expect different pulls from systematics for different years.
  - Do not expect physics results to change much between years:
    - If there is enough data, can split it into many subsets and checks RMS of physics parameters without revealing their value.

DeepCore Blind Analyses

- Are the nuisance parameters distributed as expected?
  - Pulling the parameters from the central values is fine, however they should not all be pulled to extremes.
- Have any of the physics parameters gone to unphysical values?
  - The physics values should not show more disappearance then allowed or a negative ν_τ normalization.
  - Implement a simple boolean so fitted value is still obscured.
- All these steps help us know if there is an issue and if so is it with the entire model, one systematic, background estimation, etc.

DeepCore Blind Analyses

- After all these tests have passed and there is a acceptable goodness of fit, more checks are performed before unblinding the results.
- Low and high level distributions are looked at with the fitted systematics and oscillations applied.
  - Need to apply these effects to look more into data/MC agreement.
  - Can easily be done with the code loading the fitted values but not showing them.
  - Should see good data/MC agreement in most variables.
- Only after all these steps, do we look at the final results.
- This method still cannot find every problem.
  - If a problem is found after this process and fixed, we will still show the original results to the community and explain the difference.

Conclusion

- Having a blind analysis is the best way to try and prevent experimenter bias.
- Have been used for many years in both the medical and physics community.
- There are many ways to construct a blind analysis.
  - No single method is especially superior over the others.
- DeepCore analyses must go through a series of tests before fully unblinding.
  - "Blind data fits" are performed on the entire data sample.
  - It must be shown no single systematic is causing any problems.
  - The systematics behave as expected across the entire phase-space.
  - The fits are not in some unphysical region.
  - Low level variables agree with MC with bestfit values applied to MC.