Physicist's Summary

Asher Kaboth 21 Sept 2016

Thank you!

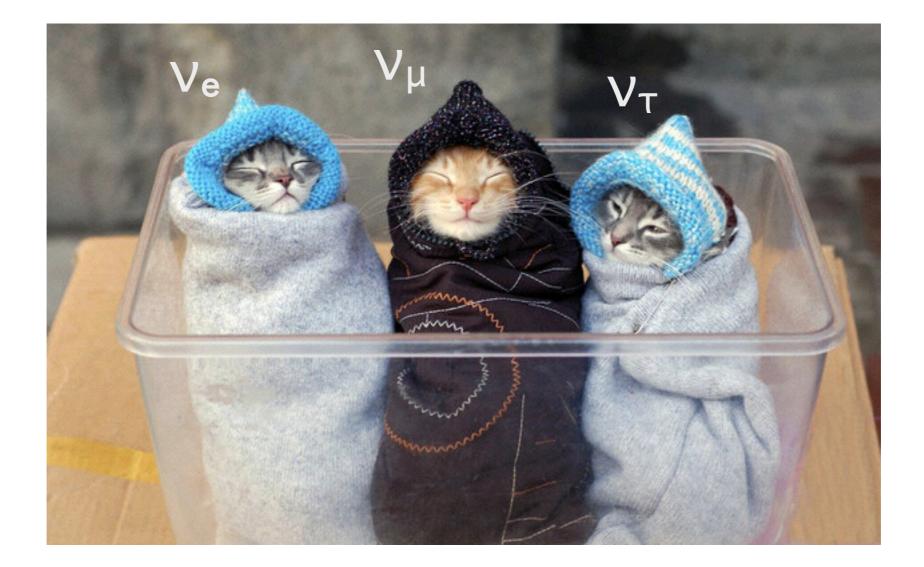
- Thank you to the organizers!
- Thank you to the panel members for the interesting discussion!
- Thank you to the attendees for all your contributions!

Reminder

PhyStat-v Kashiwa has an in-progress summary document of the discussions there: <u>www.hep.ph.ic.ac.uk/~yoshiu/PhyStat-nu-</u> <u>IPMU-2016-Summary-Draft</u>

Let's think about a summary document for this meeting!

Pictures of Cute Animals are Obligatory



A ToDo List

<u>Possible Future</u> <u>Neutrino Prizes:</u>

 Nature of the Neutrino (Majorana (2) v Dirac (4))

컆

- Observing CPV in Neutrino Sector $(\sin\delta \neq 0)$ Pilar Coloma, Christopher Backhouse, Shao-Feng Ge
- Demonstrating the Existence of the Sterile Neutrinos Aixin Tan, Zarko Pavlovic
- Observation of New Physics in Neutrino Sector? Neutrino Decay, Non-Standard Interactions,
- A convincing Model of Neutrino Masses and Mixing with confirmed predictions. Everyone, basically!

Starting Point

Almost here!

One thing I learned:

- collaboration might converge on high-level statistical procedure.
 Put in likelihood / probability model and turn the crank.
- Practical improvements to analysis mainly lie in techniques used for modeling the data ! (eg. systematics, ND->FD extrapolation, etc.)
- Useful to factorize discussion & software in terms of modeling and high-level statistical procedure

This is still a good idea!

Oscillation Analyses





Statistical Approaches for IceCube, DeepCore, and PINGU Neutrino Oscillation Analyses

Joshua Hignight for the IceCube-PINGU Collaboration

MICHIGAN STATE

September 21st, 2016

Sensitivity to CP violation in neutrino oscillation experiments

Pilar Coloma Fermilab

Based on: Blennow, PC, Fernandez-Martinez, arXiv: 1407.3274 [hep-ph] JHEP 1503 (2015) 005

> Phystat-nu Workshop Fermilab Sep 19th, 2016

Long-Baseline Neutrino Experiment Analysis Techniques

 $\mathbf{PhysStat}\text{-}\nu$

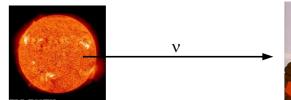
Christopher Backhouse

California Institute of Technology

February 5, 2015

LBL analysis

Statistical Issues for the Solar Neutrino Researcher





Scott Oser University of British Columbia PhyStat-v 2016 September 20, 2016

C. Backhouse (Caltech)

February 5, 2015 1 / 30

Short-baseline analysis techniques

Zarko Pavlovic

Xin Qian

Statistical Methods used in

Reactor Neutrino Experiments

BNL





PhyStat-nu Fermilab 2016

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Good Points

- It looks like most experiments consider their approximations!
- There's a wide variety of methods, frequently on the same experiment

Things to Work On

- My biggest request: show the diagnostics!
 - There's lots of algorithms:MCMC, F-C, MultiNest, etc
 - Diagnostics for each are different, but all important
- What do we communicate to the future?

Consensus?

- We're pretty much on the right track!
- Treatment of systematics is important here, especially in model tests

Unfolding

• Lots of discussion here!

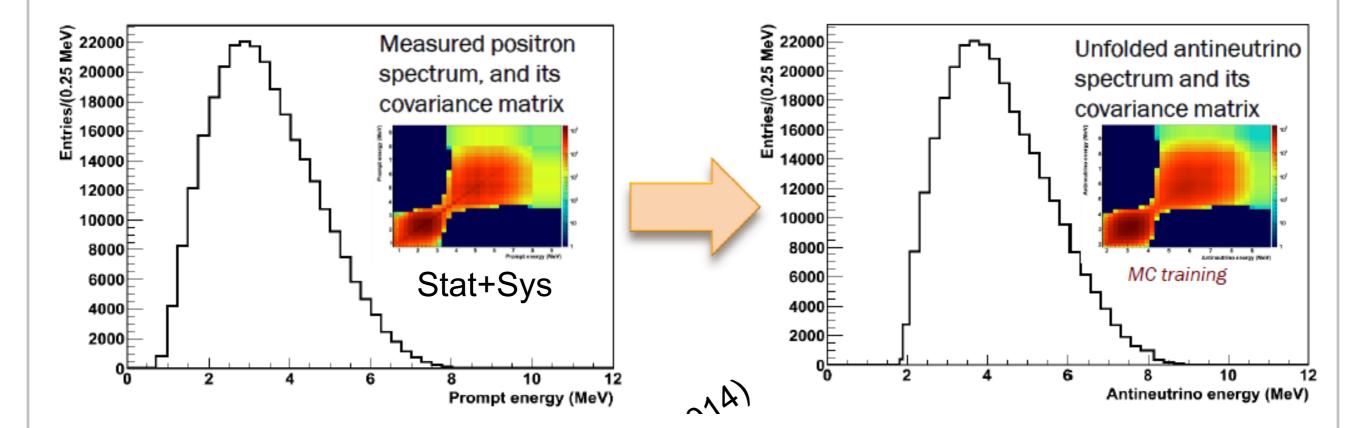
• What to do in different situations?

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<u>https://arxiv.org/pdf/</u> 1607.07038v1.pdf

Cross Section Unfolding 1.4<mark>≍10</mark>³ ×10⁸ Statistical Errors Only Statistical Errors Only vents / 0.05 GeV² $MINER_{VA} \bullet \overline{v} Tracker \rightarrow CCQE$ MINERvA • \overline{v} Tracker \rightarrow CCQE ŝ 10 1.2 Events / 0.05 GeV² = 6.05/6 = 1.01 Data Simulation 50 0.8 + Data 🕂 Data - Monte Carlo - Monte Carlo 0.6 0.4 **POT Normalized POT Normalized** 0.2 0.2 1.01e+20 POT 1 01e+20 POT 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 0.5 1.5 2 10 Reconstructed Q²_{OF} (GeV²) Q_{OF}^2 (GeV²) Reco Bins 0.4 0.6 0.8 1.0 1.2 1.4 = 25.87/6 = 4.31 ×10³ Data Simulation Generated Bjorken x Sum of entries in this bin 6 0.8 5 0.6 0.4 0.6 0.8 1.0 1.2 1.4 3 0.4 Laura Fields I MINER 1/16 = 58.46/6 = 9.74 2 0.2 Data Simulation Ŷ 0.2 0.4 0.6 0.8 1 Reconstructed Bjorken x 0.4 0.6 0.8 1.0 1.2 1.4 constructed Bjorken x 12 Fields I MINERvA 19/09/16

Daya Bay Unfolding

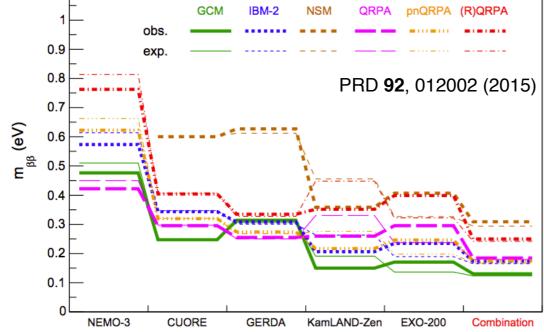


Consensus?

- My sense is that there's a preference for not unfolding—and if doing so, show more diagnostics
- There should be more investment by experimentalists in providing information to outside the experiment to go from physics to detector quantities

$= G^{0\nu} |M^{0\nu}|^2 (n_{\beta\beta}/m_{\rho})^2 m paring Models$

Example of model-dependent NME uncertainty:

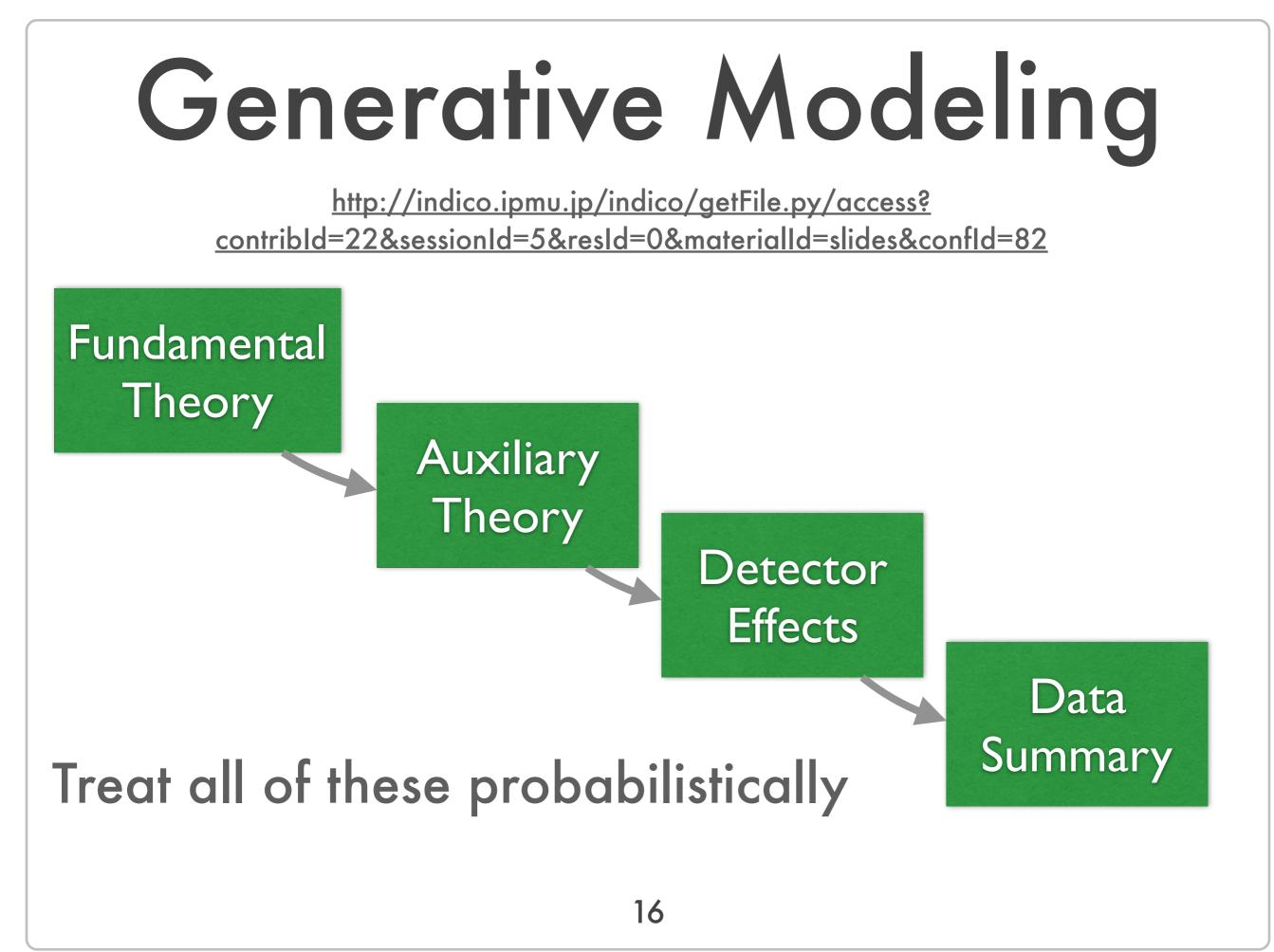


do/dT $_{\pi}$ (10⁻⁴² cm²/MeV/nucleon) MiniBooNE MINERvA PRD 83, 052007 (2011) 15 GENIE GENIE BNB flux, CH, NuMI flux, CH data data 0^L 100 200 300 400 **π[±] Kinetic Energy (MeV)**

This shows up in a number of places! Several different techniques, but problems with inputs, too.

	3+1	$_{3+1}$	3+1	3+1	3+2	$_{3+2}$
	GLO	PrGLO	noMB	noLSND	GLO	PrGLO
$\chi^2_{\rm min}$	306.0	276.3	251.2	291.3	299.6	271.1
NDF	268	262	230	264	264	258
GoF	5%	26%	16%	12%	7%	28%
$(\chi^2_{\rm min})_{\rm APP}$	98.9	77.0	50.9	91.8	86.0	69.6
$(\chi^2_{ m min})_{ m DIS}$	194.4	194.4	194.4	194.4	192.9	192.9
$\Delta \chi^2_{ m PG}$	13.0	5.3	6.2	5.3	20.7	8.6
NDF_{PG}	2	2	2	2	4	4
GoF _{PG}	0.1%	7%	5%	7%	0.04%	7%
$\Delta \chi^2_{ m NO}$	49.2	47.7	48.1	11.4	55.7	52.9
NDF_{NO}	3	3	3	3	7	7
$n\sigma_{ m NO}$	6.4σ	6.3σ	6.4σ	2.6σ	6.1σ	5.9σ

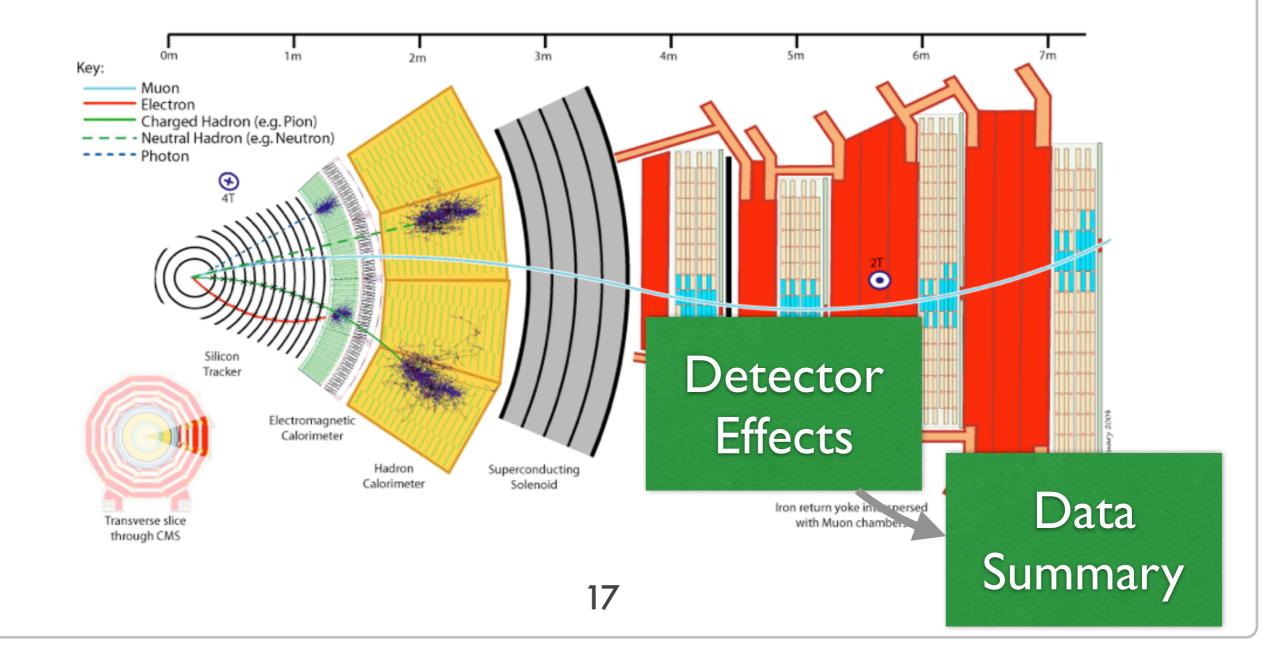
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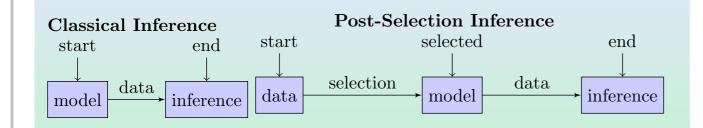
Conceptually: Prob(detector response | particles)

Implementation: Monte Carlo integration over micro-physics

Consequence: cannot evaluate likelihood for a given event



New Ideas from Statisticians



Post-Selection Inference

Todd Kuffner Washington University in St. Louis

PhyStat ν 2016 Fermilab



Bayesian, Fiducial, and Frequentist (BFF): Best Friends Forever?

Xiao-Li Meng

Department of Statistics, Harvard University

- Liu & Meng (2106) There Is Individualized Treatment. Why Not Individualized Inference? Annual Review of Statistics and Its Application, 3: 79-111
- Liu & Meng (2014). A Fruitful Resolution To Simpson's Paradox via Multi-Resolution Inference. The American Statistician, 68: 17-29.
- Meng (2014). A Trio of Inference Problems That Could Win You
 a Nobel Prize in Statistics (if you help fund it). In the Past,
 Present, and Future of Statistical Science (Eds: X. Lin, et. al.),
 535-560.

Final Thoughts

- It's so great to see the neutrino community discussing and integrating these issues!
- Clearly combinations, unfolding, and systematic uncertainties are on your minds—good!
- Let's keep this momentum going:
 - Future PhyStat-v!
 - Think about: does your experiment need a statistics committee? What would that look like? What are you taking back to your experiment and analysis?