Data Challenge

(Do We Really *REALLY* Understand Our Results)

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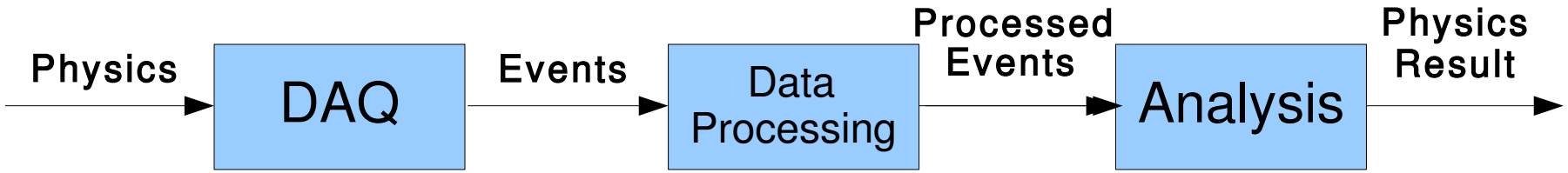
Data Challenge

- **Most IceCube physics analyses lack a natural signal**
- **Data challenge** is the following generic process:
  - A simulated signal is added to the data
  - The data is analyzed, and the signal is either discovered at the expected level, or it is not
- **Data challenge** accomplishes the following:
  - Detects errors in DAQ, data processing, and analysis
  - Ensures those performing analysis understand their data and methods **before** physics results are obtained
  - Aids interpretation of physics results

What Can Go Wrong?



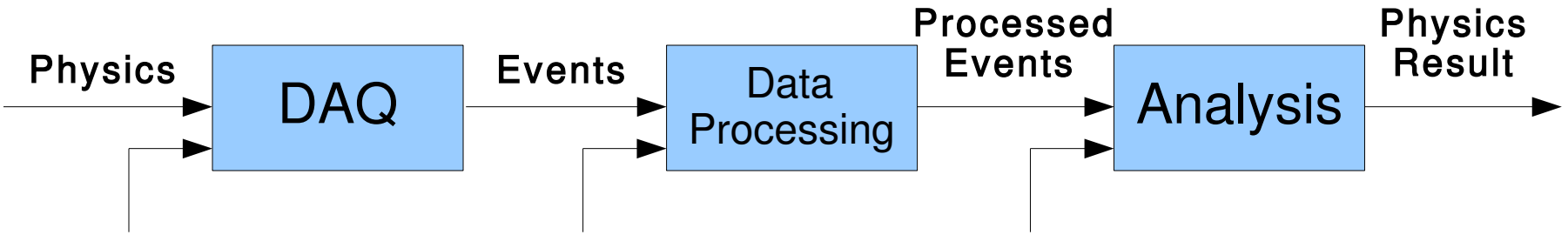
- System timing
- DAQ hardware and software failures

- Angular reconstruction
- Energy reconstruction
- Coordinate transformations

- Data selection
- Analysis methods

- We want to ensure the entire system is working properly from physics to analysis result

Levels of Data Challenge



True physics signal

- Flasher events
- Moon shadow

End-to-end test of system

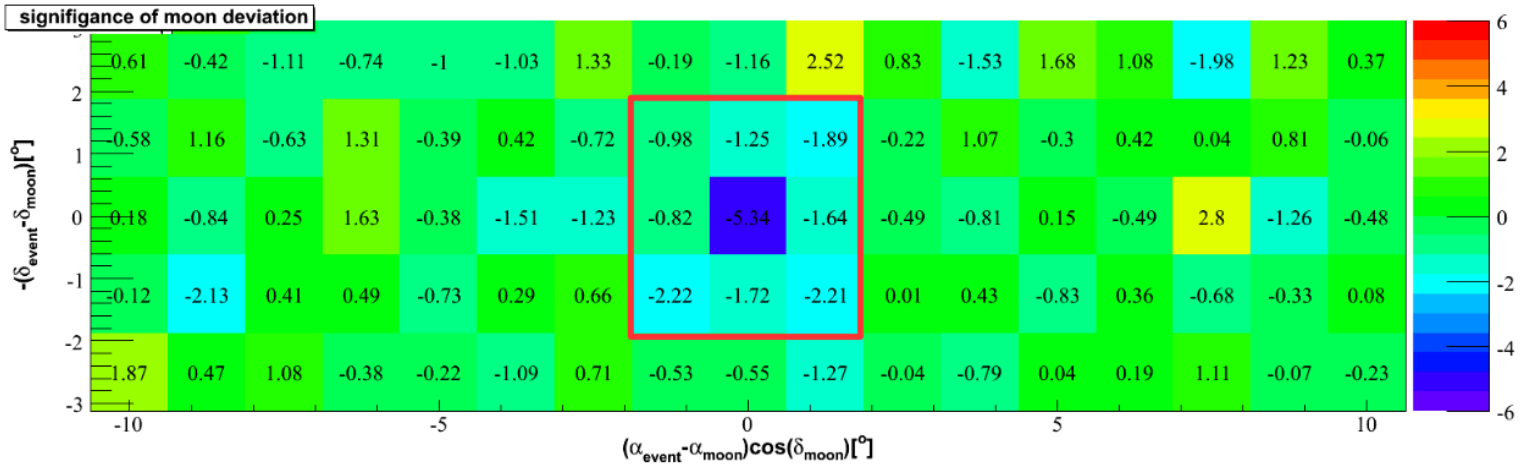
Simulated signals

- ν_μ sources
- Cascades
- Tau double-bangs

- Data challenges at lower levels are more informative, but they are also more difficult

What We've Learned from the Moon

- The moon blocks cosmic rays and acts as a muon calibration source



- We observe the moon shadow with a significance consistent with the expected value (5.34σ/6.1σ)
  - Evidence DAQ and Data Processing are working properly
  - Focus on analysis-level data challenges

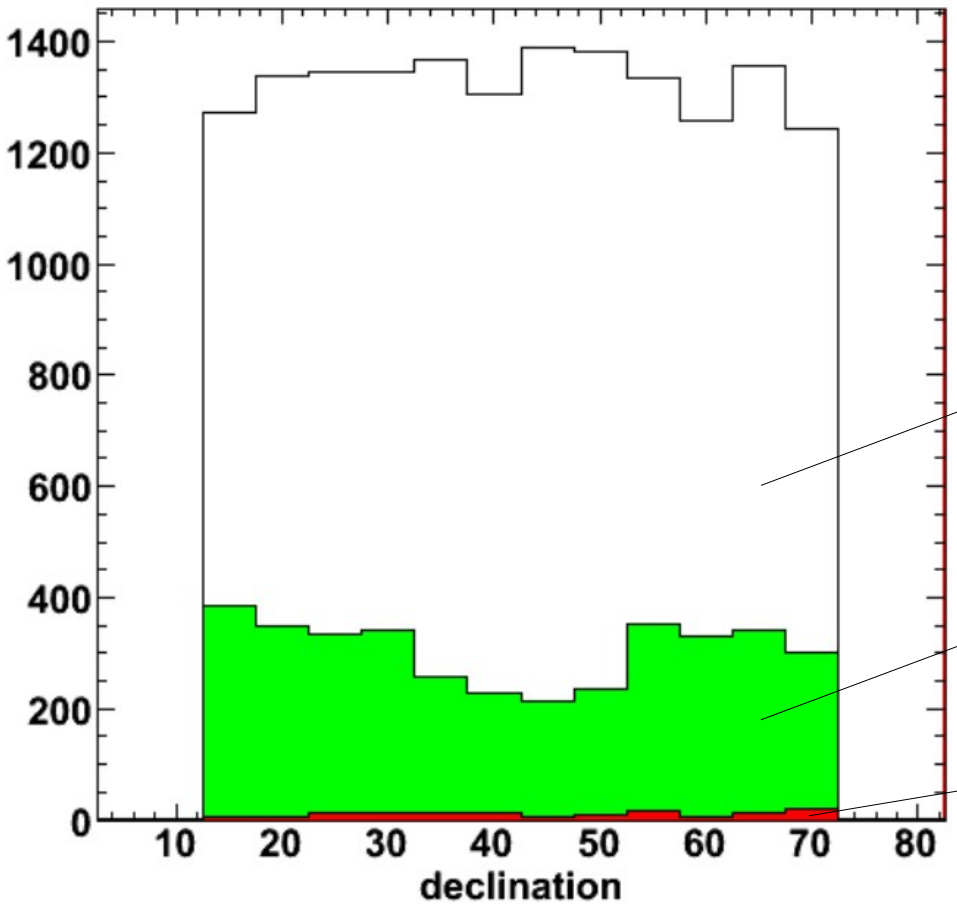
Analysis-Level Data Challenges

- Several objectives of analysis-level data challenges:
  - Verify inserted signals appear in the analysis result
  - Independently measure the analysis performance
    - Confirm type I and type II errors are at the levels specified
  - Judge the interpretation of the result
- In all cases, the analyzer should not know the nature of the added signal

The FDR Data Challenge

- New neutrino point source search method -- controlling the false discovery rate (FDR)
- Evaluate the method using a data challenge
  - Create ~17,000 sky maps with randomized AMANDA data and sources of various strength added
  - Send the set of maps to be analyzed
  - Receive coordinates for any sources discovered
  - Compare coordinates of sources with key: Sources listed within 5^{o} of true location are considered detections; the rest are false discoveries.
- Software tools make this easy

FDR Data Challenge Results



Source Not Found

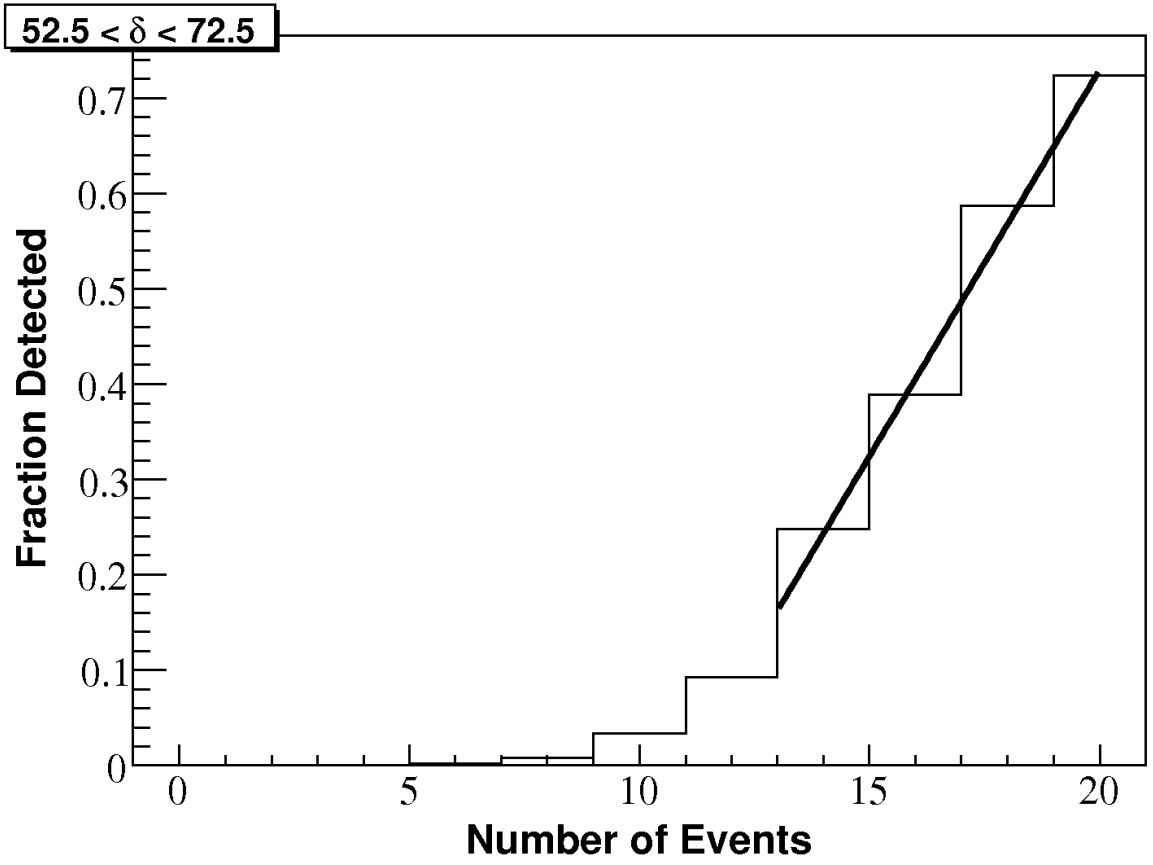
Detections

False Discoveries

- 0.3% of sky maps contain false discoveries (Expected: < 1%)

The FDR Data Challenge

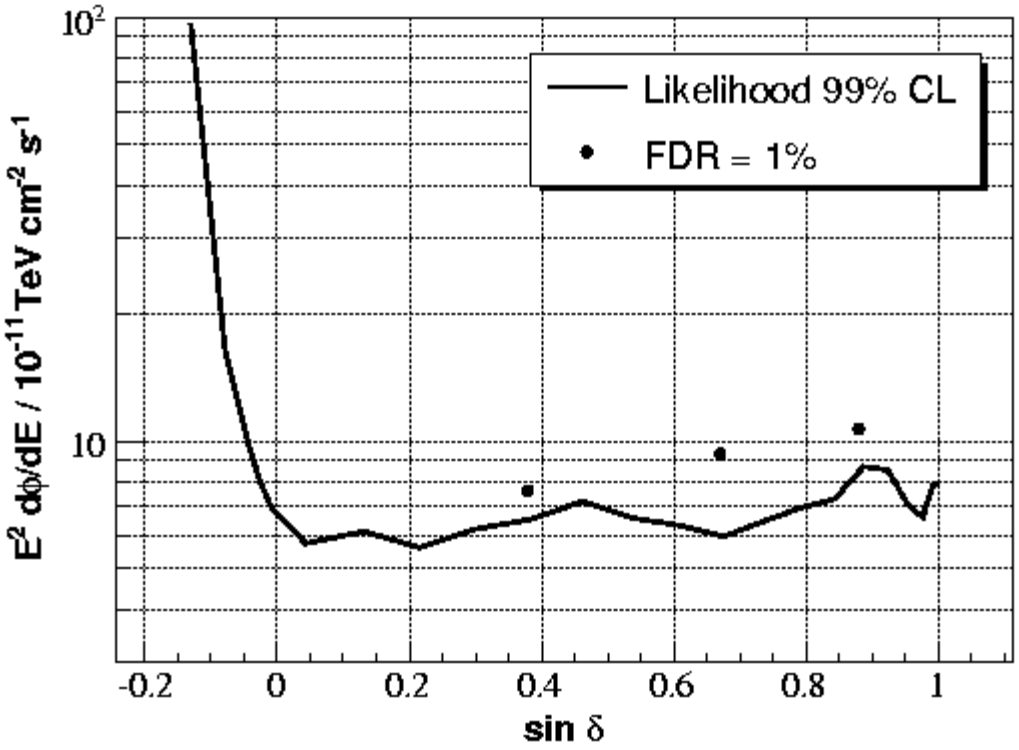
- Detection depends on simulated source strength



- Requires ~17 added signal events to have a 50% chance of detecting a source.

The FDR Data Challenge

- Convert 50% discovery probability event thresholds to flux and compare against the baseline method



- FDR not as sensitive as baseline method, but similar sensitivity was advertised
  - Data had been assumed to be pure atmospheric neutrinos, but actually contains 5% cosmic ray muon background
  - Tighter cuts remove the background and make the method consistent

Future Plans

- Use flasher events as a cascade data challenge
- Further analysis of the moon shadow
  - Systematic pointing errors
  - Measure muon point spread function
- Make data challenges a standard practice for all analysis groups

Summary

- IceCube is committed to using data challenges to ensure understanding of analyses and physics results
- Observation of the moon shadow has provided an end-to-end system test for muons
- FDR data challenge is a successful example of an analysis-level data challenge
- Flasher events will provide an end-to-end test for cascades