MINOS+ Physics and Computing

(Analysis Coordinator Presentation)

Andy Blake, Cambridge University

MINOS+ collaboration meeting,
Fermilab

Thursday 19th February 2015

Overview

1. **MINOS+**
   ☆ Current status, working groups, physics
2. **Data reduction and Analysis**
   ☆ Data products, data flow, main analysis tools
3. **Perspectives**

MINOS+

- **MINOS+ now in second year of a 3-year (10×10^{20} POT) run.**
  - Follows on from 7-year MINOS experiment, which ended in 2012.
- **Currently analysing both MINOS and MINOS+ data.**
  - MINOS:
    - ☆ Have now finalised/published most physics results.
  - MINOS+:
    - ☆ First event spectra shown at Neutrino 2014 (1.7×10^{20} POT).
    - ☆ Preparing updated results based on first year of data (3×10^{20} POT).
    - ☆ Collecting/validating/calibrating second year of data ($\sim1\times10^{20}$ POT).
- **MINOS+ builds on MINOS techniques, software and people.**
  - MINOS software tools and data products are well-established.
    - ☆ But must be maintained, and developed/optimised for MINOS+.
  - All physics relies on distributed processing (i.e. The Grid!)
  - MINOS+ physics output is limited by manpower.
- **Lots of analysis work ahead! (MINOS+ data set will triple in size).**

MINOS+ Working Groups

"Three-layer cake"

Working groups & convenors

Computing:

- **Infrastructure** — A. Kreymer
- **Core Software** — No official support
- **Simulation** / **Batch Processing** — ← A. Schreckenberger →, M. Zielinski

↓

Physics Tools:

- **Data Validation** — A. Blake, A. Perch
- **Calibration** — A. Aurisano, R. Toner
- **Reconstruction** — Z. Pavlovich, L. Whitehead
- **Beam Systematics** — A. Holin, A. Radovic, A. Schreckenberger

↓

Physics Analysis:

← Oscillation Physics →

- **Standard Oscillations** — R. Nichol, P. Vahle
- **Sterile Neutrinos** — J. Coelho, J. Evans, M. Kordosky
- **Exotic Physics** — D. Naples, G. Pawloski

Cross-sections

- **Near Detector Physics** — N. Graf, A. Mann

Atmospherics & Cosmic rays

- **Physics of the Universe** — M. Goodman, R. Gomes, P. Schreiner

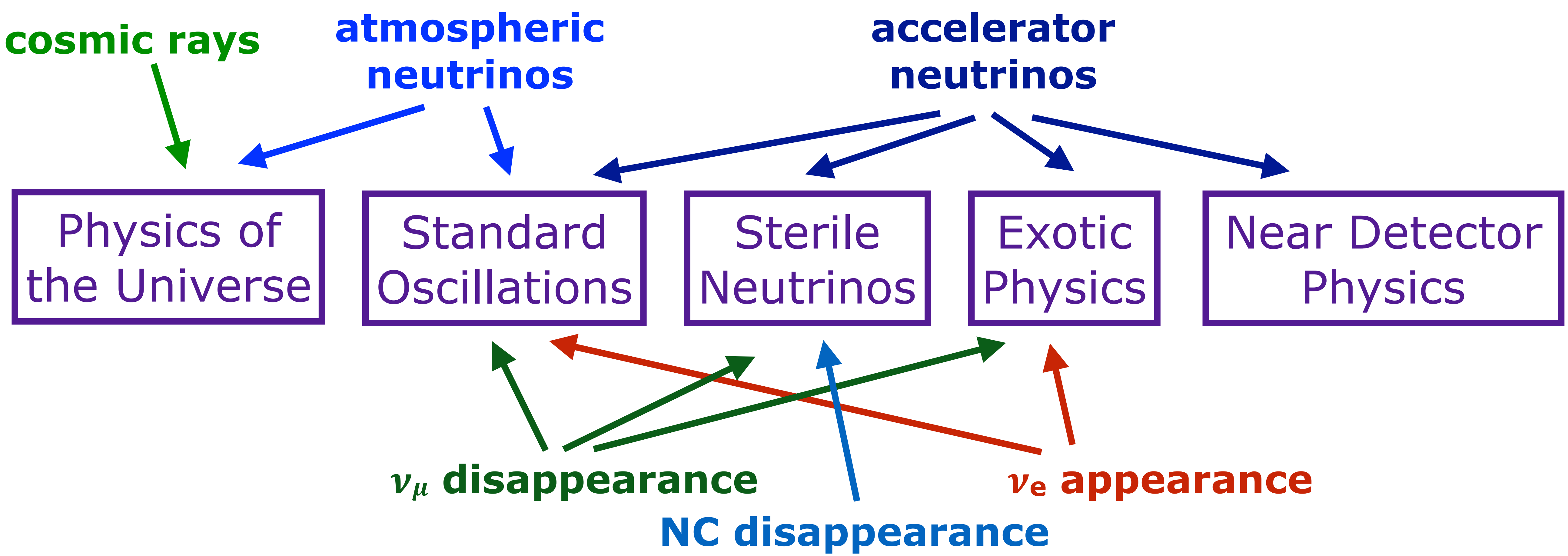
Reconstruction & Analysis

- **Reconstruction has three main passes (corresponding to the three main sources of event):**

  accelerator neutrinos   **atmospheric neutrinos**   **cosmic rays**

- **Analysis tools developed around event types:** ν_μ **CC** **NC** ν_e **CC**

- **Physics analyses are an interplay of sources and event types:**



Main Data Products

Data formats	Applications
(All formats are ROOT-based)	
Raw Data	Data Validation
↓	
Standard Ntuples (SNTPs)	Calibration Event Display Libraries for Event Identification
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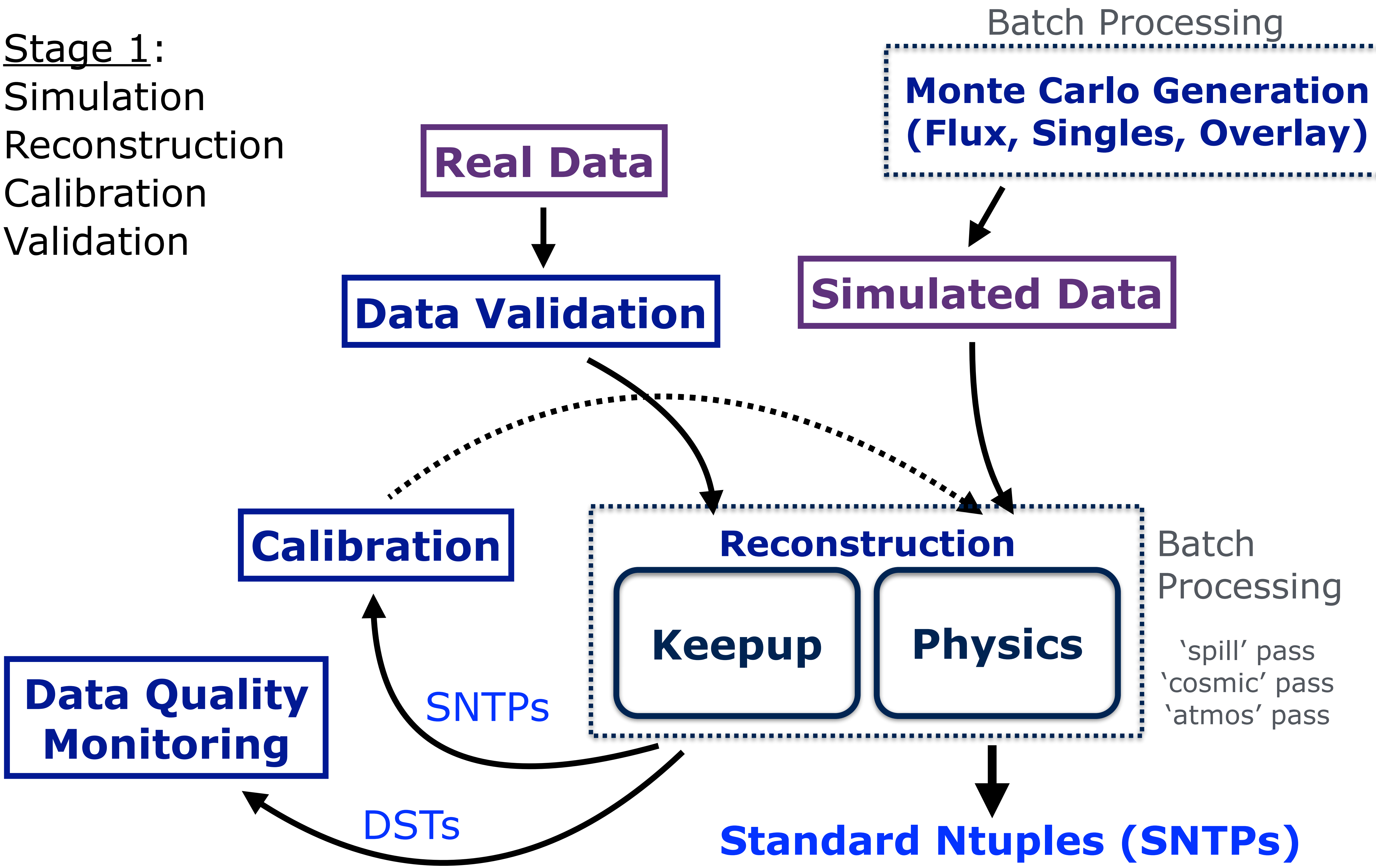
Data Summary Trees (DSTs)	Data Quality Monitoring Beam fits Oscillation Physics

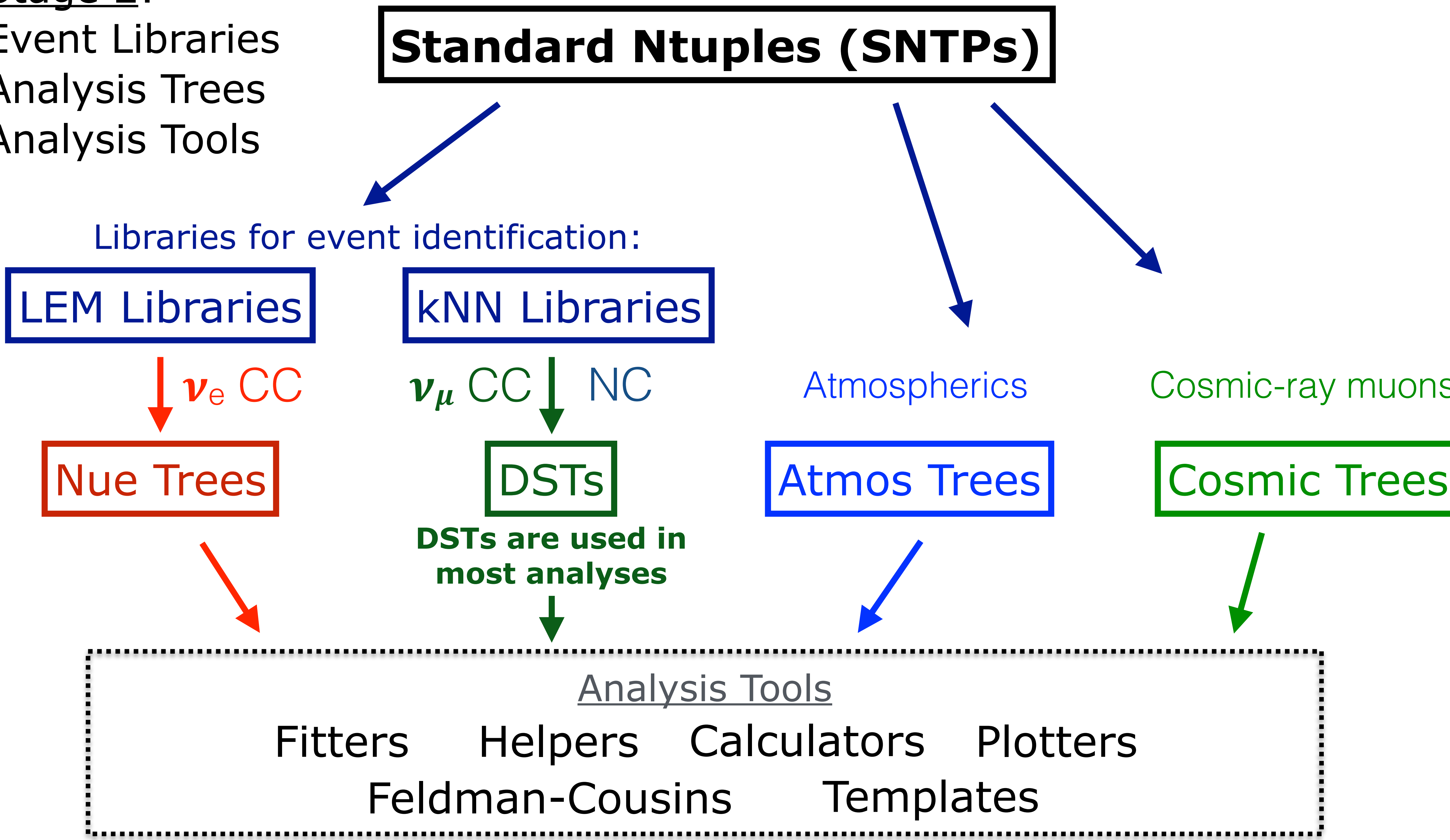
Data Reduction: Stage 1

<u>Stage 1</u>:
Simulation
Reconstruction
Calibration
Validation



Data Reduction: Stage 2

Stage 2:
Event Libraries
Analysis Trees
Analysis Tools



Data Processing

What runs on The Grid?

Everything! The following applications are most resource-heavy:

Production:
'central' services

- Monte Carlo generation
- Event reconstruction
- DST generation ➜ Our main analysis tree.

Analysis:
working groups

- Library Event Matching (LEM) **ν_e appearance**
  Separation of ν_e CC from NC interactions by matching to a large library of events.
- Template Fitting **Standard oscillations**
  Calculation of predicted event spectra and fitting to data for a grid of parameters.
- Feldman-Cousins analyses **Sterile neutrinos**
  Generation and fitting of fake data sets for numerical calculation of confidence limits.

Data Processing

- **Big effort in recent months to migrate to new grid tools. We had to modernise (a.k.a. re-write!) our scripts.**
  - Significant investment of time… The old tools were firmly embedded in our software.
- **Upgrades to simulation, reconstruction and analysis:**
  - MC generation
  - Reconstruction.

  } Herculean efforts by Adam S here!
  - DST production.
  - Calibration.
  - Analysis (LEM, templates, FC analyses).
- **Huge progress! Not just migrating software and scripts, but optimising efficiency.**
  - Basis of MINOS+ physics results presented at this meeting. In particular, sterile neutrino FC analysis (Ashley Timmons).
  - Migration efforts ongoing, but analyses now in good shape.

Data Processing

- **MINOS+ currently operates two batch production sites:**
  - ☆ FNAL: Reconstruction.
  - ☆ TACC: MC generation (Will Flanagan, Adam S).
- **At Fermilab, Marek has now established a central role in MINOS+ offline computing and batch processing.**
  - ☆ Running production and roundup scripts.
  - ☆ Chairing weekly offline meetings.
- **Note: MINOS+ shares its Near Detector with Minerva.**
  (Minerva analyse SNTP files from keepup processing).

Perspectives

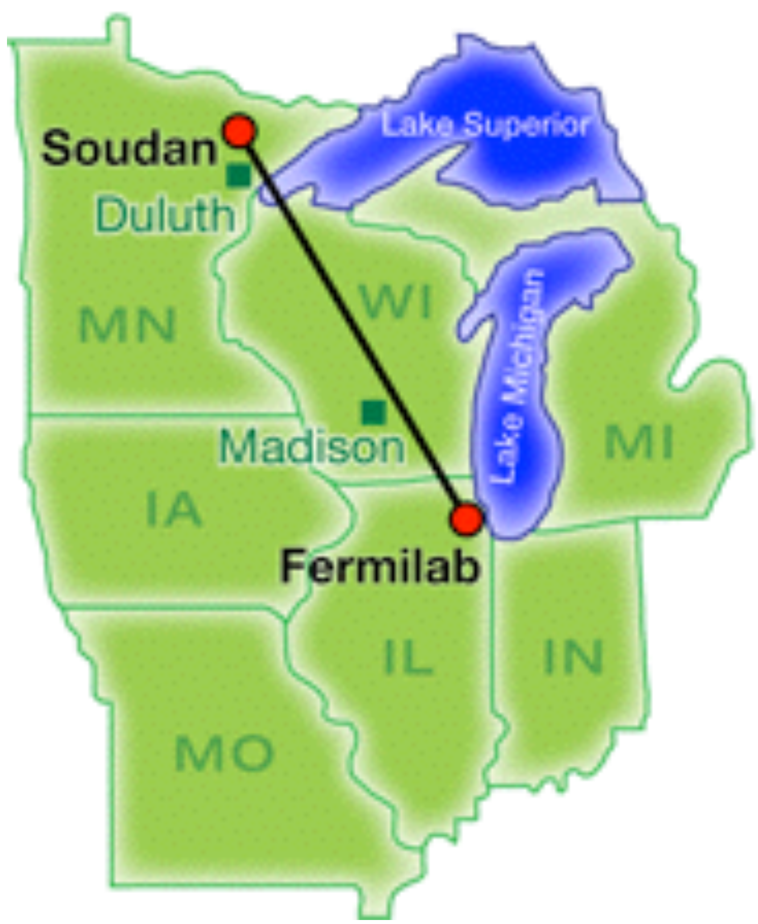
- **Lots of work ahead over coming months and years.**
  - First MINOS+ physics analyses are converging now.
  - Expect that data set will triple in size.
- **Important to maximise physics. Manpower-limited!**
  - Support for core MINOS+ processing will really help here (e.g. Adam S has key role in physics as well as processing).
- **Although MINOS+ is mature, there are still challenges in maintaining software and processing data.**
  - Keeping up with modernisation (jobsub, SAMWEB, SLF6 etc.).
  - Batch processing throws up both old and new problems. Important to develop and retain technical expertise.
- **Big effort in recent months to exploit new grid tools, and optimise their use in our analyses.**
  - Still issues (see Adam's talk), but huge steps forward.

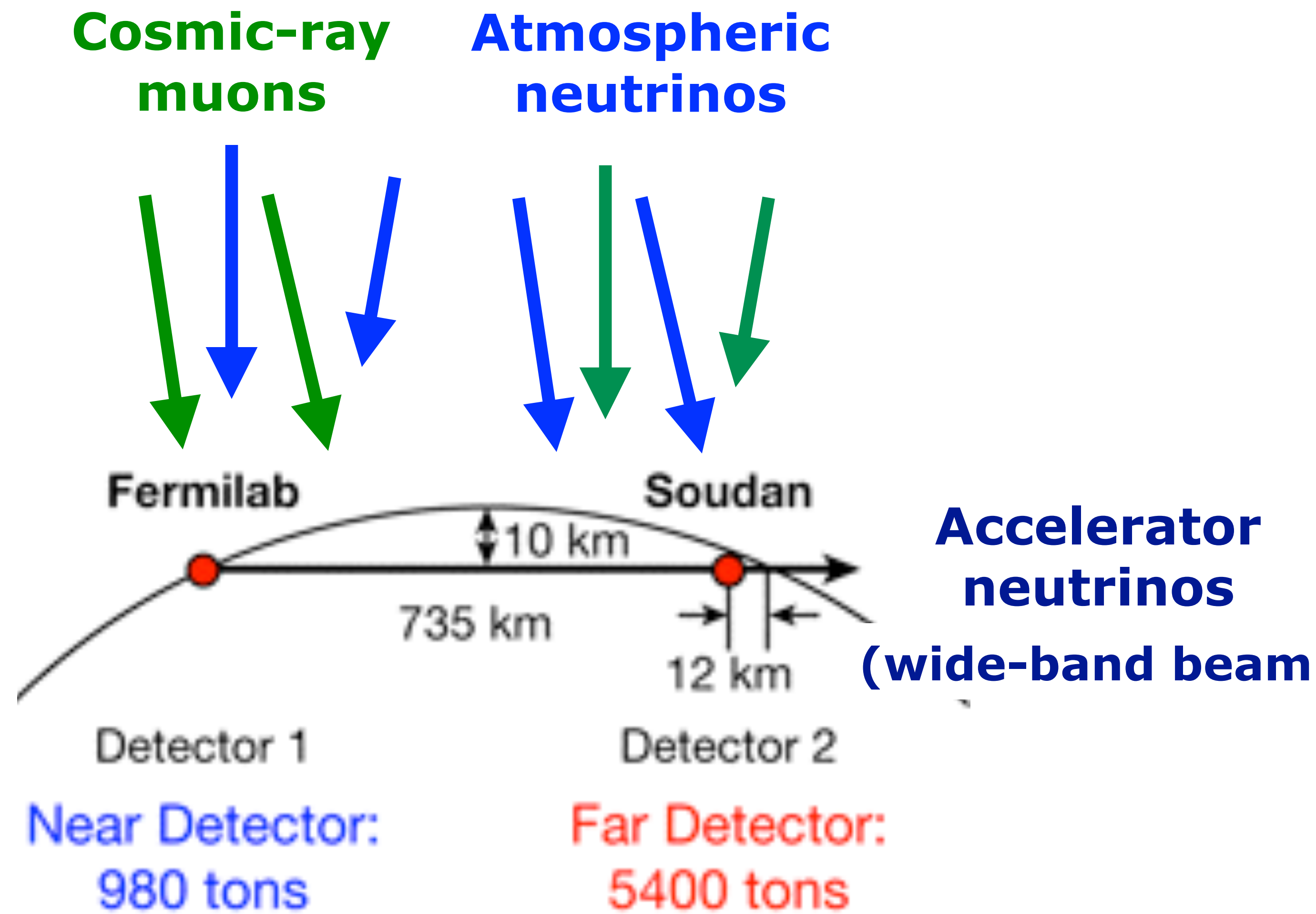
Now on to Adam’s talk…

BACKUP

MINOS+ Physics Topics

- **Multiple detectors and sources - broad range of physics:**





Neutrino oscillations (using accelerator and atmospheric neutrinos):

☆ Precision measurements of standard oscillation parameters.

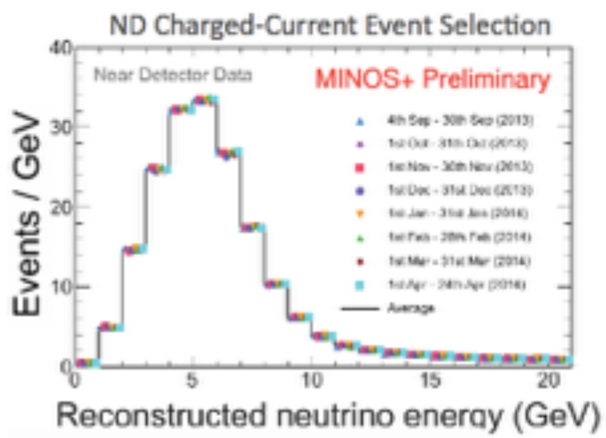
☆ Searches for new physics: sterile neutrino signatures, exotic models (exploiting wide-band accelerator beam).

Neutrino interactions (Near Detector)   Cosmic-ray physics

Physics Tools

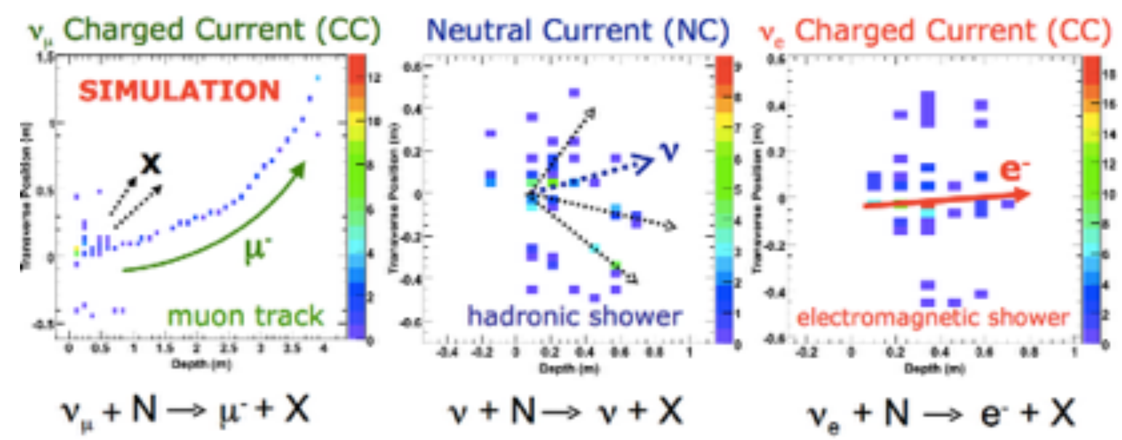
Data Validation

Monitor stability of beam and detectors, and select good physics data.



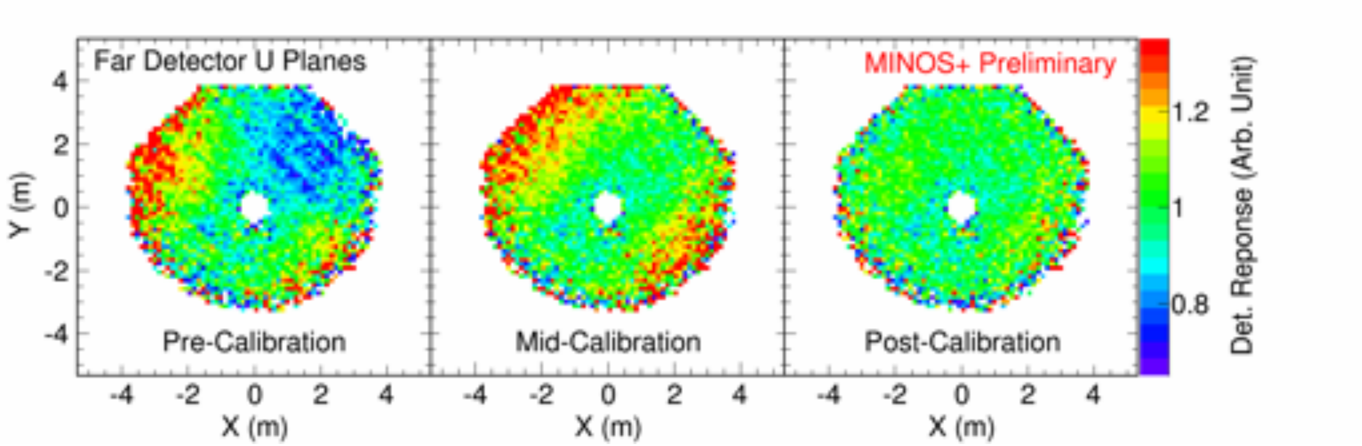
Reconstruction

Support pattern recognition and neutrino event reconstruction algorithms



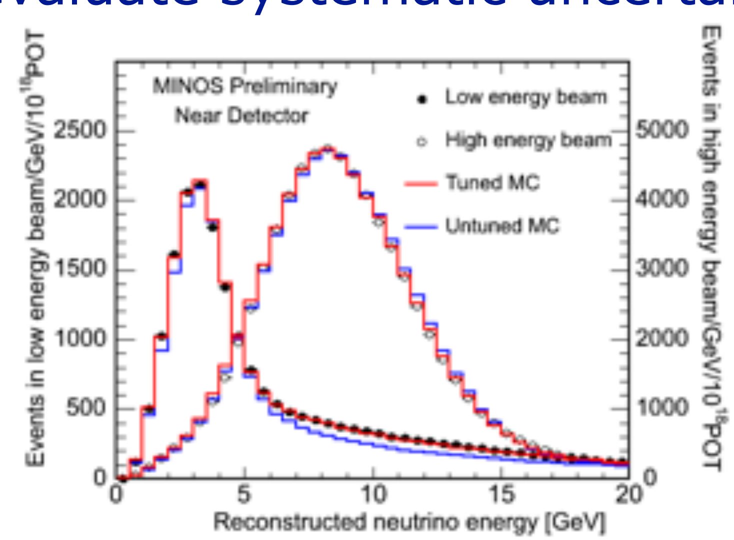
Calibration

Correct for response in each detector, and between detectors.



Beam Systematics

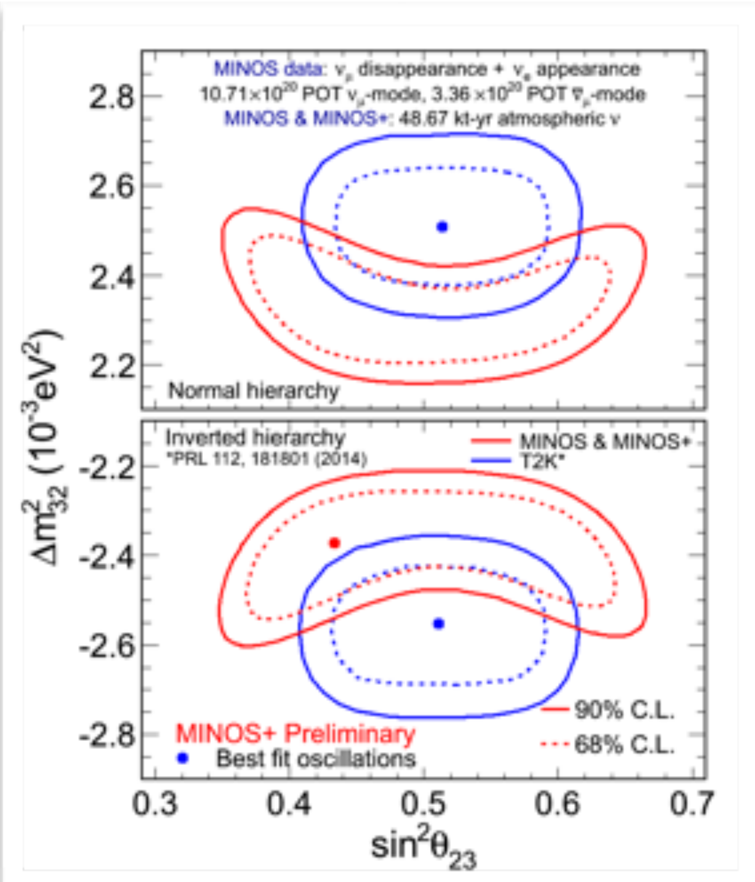
Improve simulation of beam flux, and evaluate systematic uncertainties.



Physics!

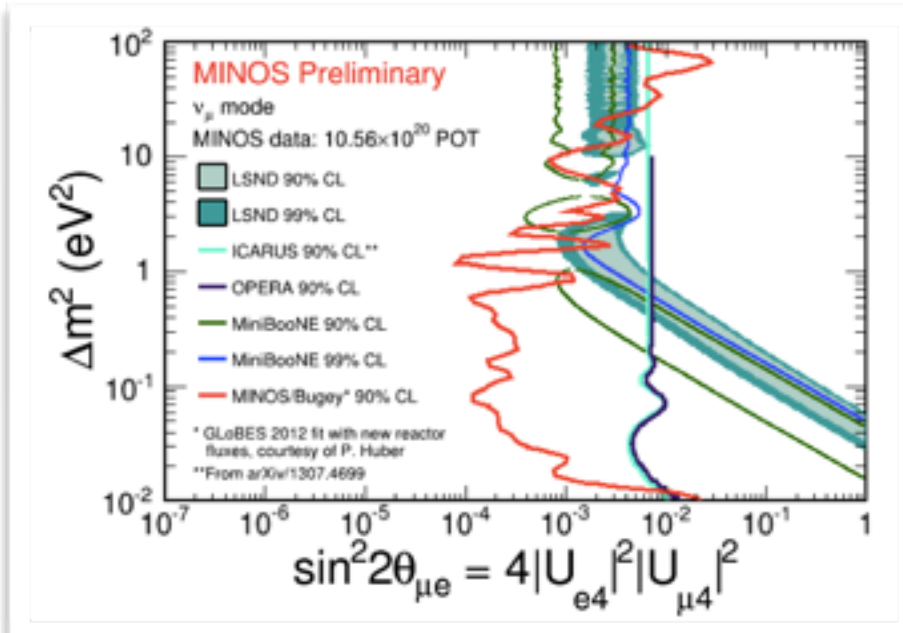
- **Cutting edge (and unique) neutrino oscillation physics:**

Standard Oscillations



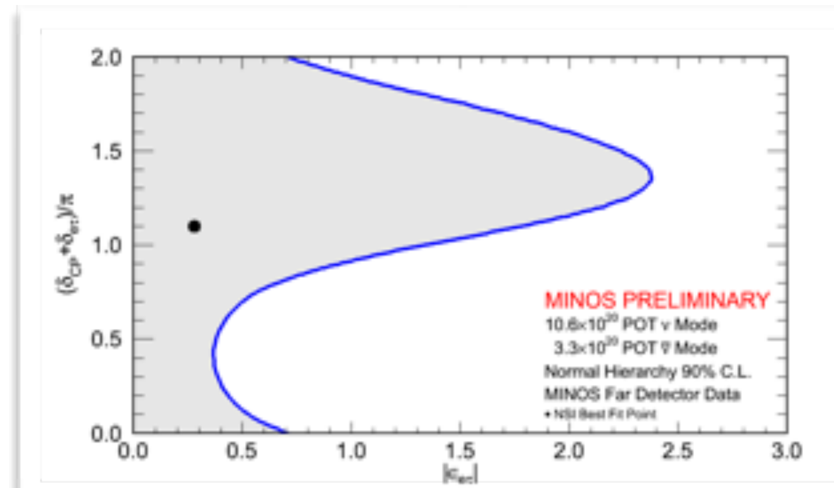
ν_μ disappearance
&
ν_e appearance

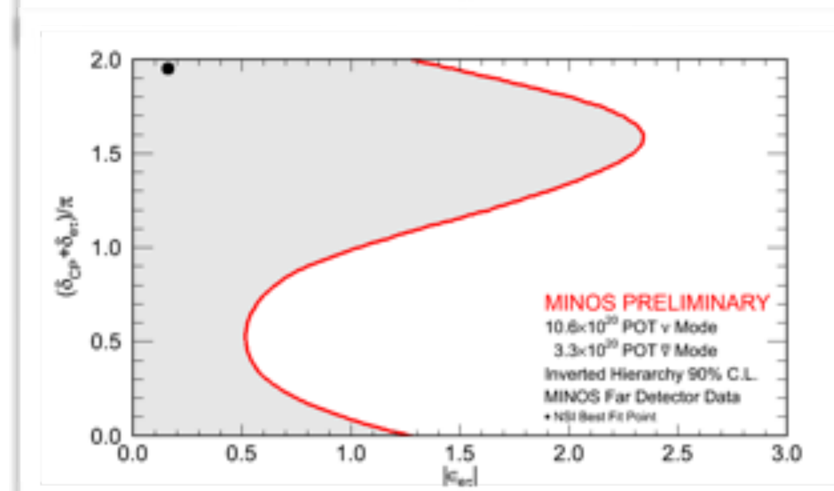
Sterile Neutrinos



ν_μ disappearance
&
NC disappearance

Non-standard Interactions





ν_e appearance