How we get things done at MINOS

Gregory Pawloski
Stanford University

MINOS specifics

- Purpose
  - 2 detector, long baseline, oscillation experiment
    - $\nu_\mu \rightarrow \nu_\tau$, $\nu_\mu \rightarrow \nu_e$, $\nu_\mu \rightarrow \nu_s$ at atmospheric Δm^2
  - Cosmic Ray Studies, Cross sections, Etc.
- Timeline
  - Running with NuMI beam since 04-2005
  - Currently running

MINOS specifics

- Number of active computing users
  - ~140 Authors → ~70 active computing users (email & power point doesn't count)
  - ~15 active computing users are at Fermilab
  - Most active users take advantage of Fermilab facilities
    - Computation:
      - MINOS Cluster
        - » Cluster of 27 Linux nodes for both interactive and batch use
        - » Some dedicated to various tasks: ie building releases
      - Condor batch submission
        - » MINOS Cluster
        - » Grid through glideins: GP and CDF Farms
      - FNALU (hopefully no one is using this since lsf went away)

MINOS specifics

- Most active users take advantage of Fermilab facilities
  - Storage:
    - AFS Space: 196 50GB-volumes + various other volumes
      - » Home areas for MINOS Cluster (500 MB / user)
      - » MINOS software release builds
      - » Read accessible through glidein grid jobs via parrot
      - » Otherwise “obsolete” user storage area
    - BlueArc (Began using around end of 2007)
      - » 57.5 TB space to store reconstructed data files and user generated data
      - » read/write accessible through grid jobs
    - DCache/ENSTORE via SAM or dcap access of pnfs path
      - » Store raw, reco, and analysis group data/mc files
  - Offline Database, CVS repository

MINOS specifics

– non-Fermilab facilities
  - MC production at Caltech, Minnesota, Rutherford, Tufts, William & Mary farms
  - Investigating use of TACC (Texas Advanced Computing Center, UT Austin) allocations on Ranger (Lonestar) Teragrid system with 63k (6k) CPUs
    - MC Production
    - Data & MC Reconstruction
    - Analysis
    - Could significantly decrease timescales for production
  - Users can make local copies of MINOS software releases (MINOSSOFT) and DB

MINOS Framework

- What framework is used for reconstruction (C++)
  - loon executable configured via ROOT C++ macro
    - Homegrown (Turn of the century software, few other options)
    - ROOT based framework provides support services needed by application (libraries loaded on the fly, ie gSystem->Load())
  - Define sequence of job modules to perform a task
    - Single record corresponds to a beam spill (multiple events/spill)
    - Algorithm objects receive/output candidate objects (tracks, showers, etc)
    - Create handles to access pointers to TObjects managed by Minos Object Mapper (MOM)
    - Database interface tools – calibration & alignment constants, etc
  - Input/Output root file with tree structure

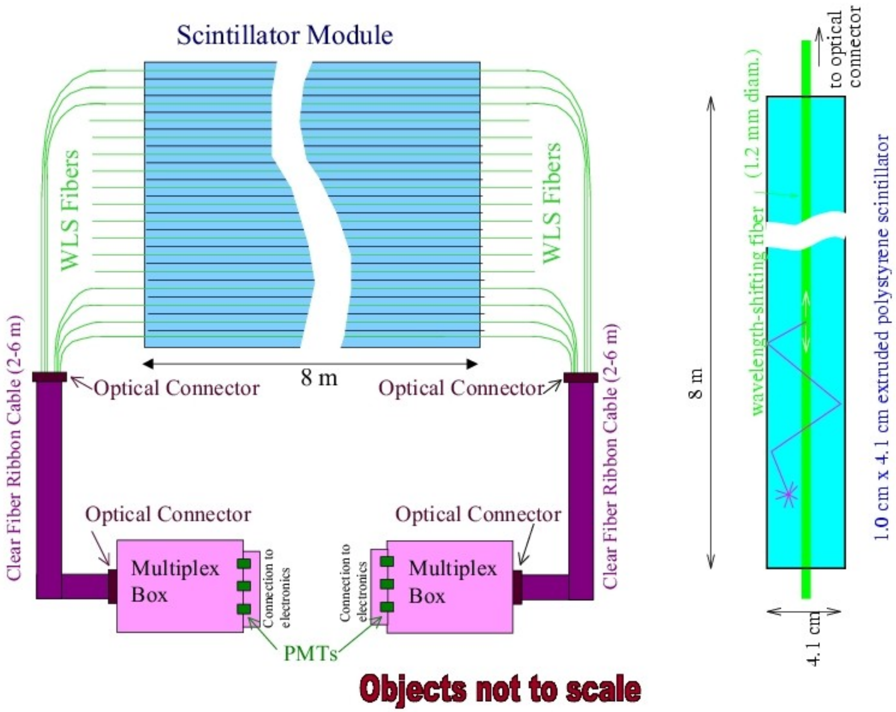
MINOS Framework

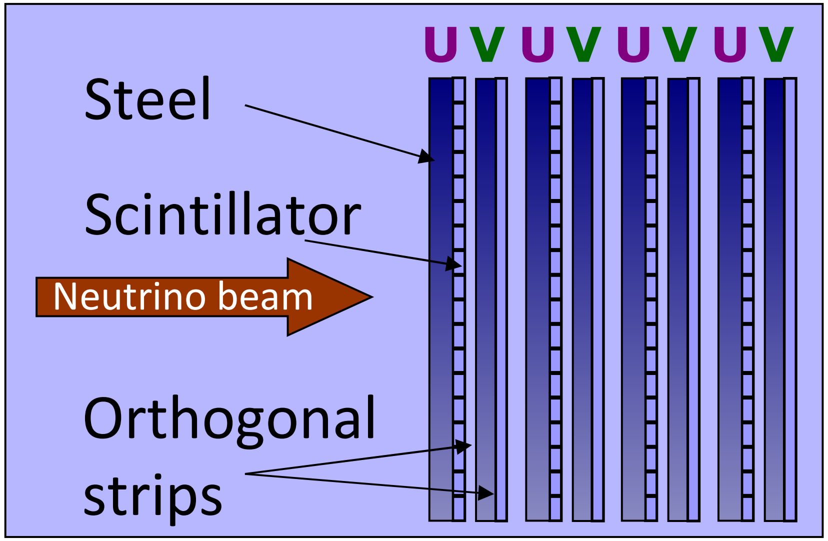
- What is used for data analysis (C++)
  - loon based
  - Individual analysis group produces special set of Physics Analysis Ntuple files (PAN files) from reconstructed standard ntuple file (SNTP files)
    - Records are reco'ed events instead of spills
  - Access SNTP and PAN records through framework job modules or standard ROOT SetBranchAddress() and GetEntry() commands
    - Can make simple plots via TTree->Draw()
    - New people can learn quickly

MINOS Framework

- What is used for simulation (FORTRAN,C++)
  - ν flux files (PAW based) from GNuMI (GEANT3 beam simulation)
  - GMINOS (FORTRAN) → GENIE + VMC (C++)
    - NUEGEN event generator (Moving to GENIE)
    - GEANT3 simulation of particle through detector → energy deposited in scintillator (Moving to ROOT VMC)
  - DetSim & PhotonTransport (part of reco C++ framework)
    - Apply calibration constants in reverse to get expected PEs
    - Final simulated raw ADCs with appropriate digitization

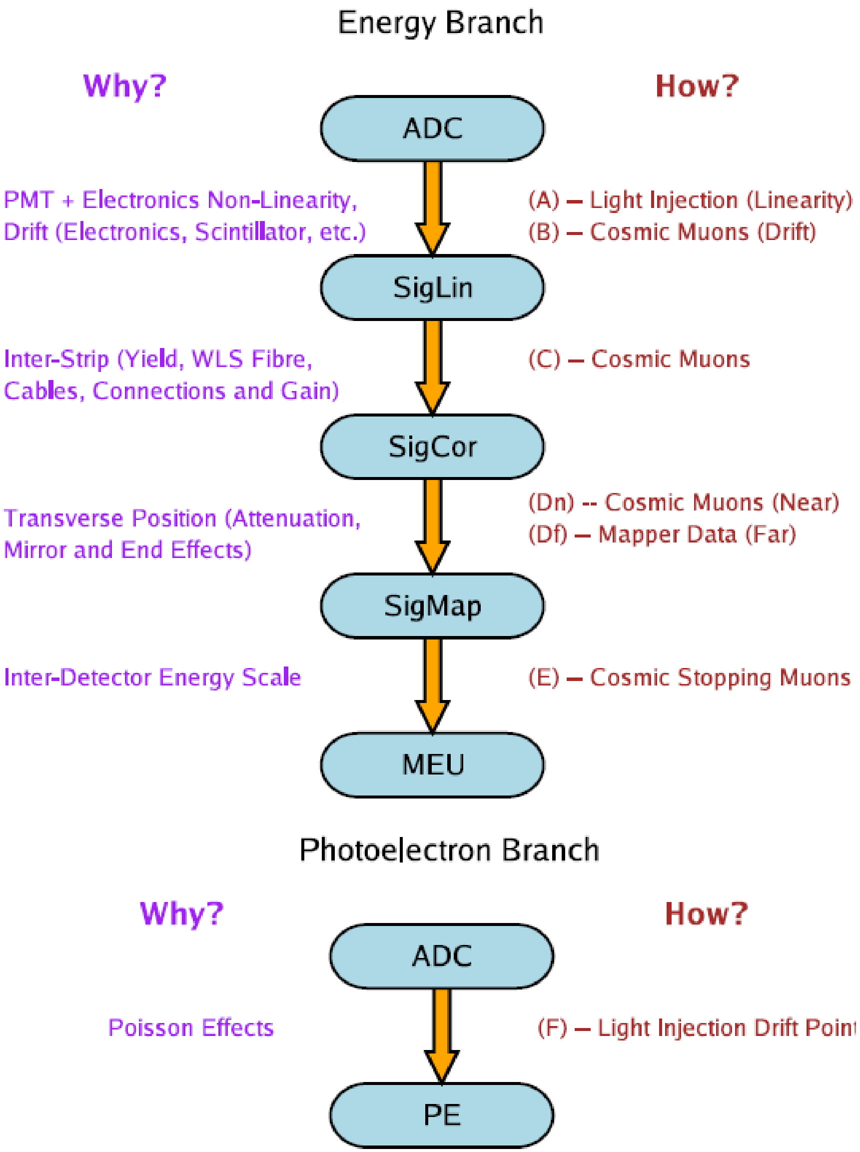
MINOS Calibration





- Before you can know how we calibrate, you need to know what we calibrate
- MINOS detectors in under 10 sec.
  - Tracking Calorimeter
    - Plane of Steel
    - Plane of scintillator strips with PMT readout
    - Plane of steel
    - Plane of scint. rotated 90^{o}
    - Repeat...
    - B-field everywhere
- Calibrate ADC readout of strips

MINOS Calibration



ADC to MIP Energy Unit Calibration Constants

Nonlinearity Correction

- Method: Light Injection •Interval: Every month

Drift in Median Response Over Time

- Method: Cosmic Muons •Interval: Every day

Channel-to-Channel Variations

- Method: Cosmic Muons •Interval: Every 3 (1) months for FD (ND)

Attenuation Correction

- Method: 1)Mapper Data •Interval: Once
  2)Cosmic Muons

MIP Calibration

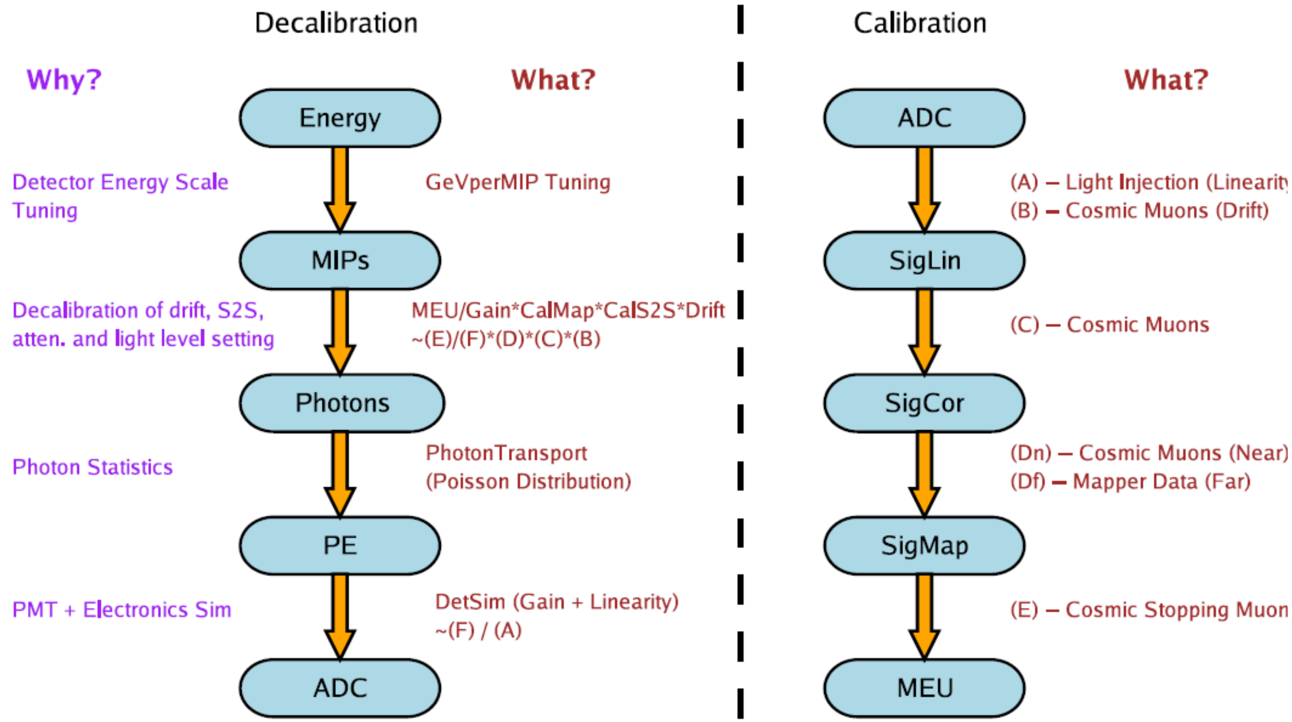
- Method: Cosmic Muons •Interval: Once per analysis data set

ADC to Photoelectron Calibration Constants

- Method: Light Injection •Interval: Every day

MINOS Calibration

MC Simulation



- Simulation relies on decalibration-calibration scheme to convert GEANT energy deposits into low level detector quantities
- During MC production run is assigned random date from real world running
- Use calibration constants for that date

MINOS Calibration

- Moving to automated system of scripts to measure calibration constants and store them in offline database (this DB is used by the general user)
- Lag between calibration constants that are valid for a specific date and when data for that date is actually read out from the detector
- Run in 2 reconstruction modes using 2 separate databases (these DBs are used for official production and special-case users)
  - Keep-Up: run reconstruction with nearly valid constants – DB regularly updated and constants ~1 month behind (needed for Data Quality checks)
  - Physics Analyzable: DB updated with constants guaranteed to be valid for specific dates, corresponding data files reprocessed

MINOS Simulation Chain

First you need a neutrino source

ν flux files via GnuMI

- FFREAD card input
- GEANT3 simulation
- PAW ntuple output

MINOS Simulation Chain

Now you need the neutrinos to interact in the detector

ν interaction and truth energy deposits in the scintillator
via GMINOS configured by FFREAD cards

- Sample flux files
- Event generation (NUEGEN)
- Interaction 4 vectors and vertex in detector/rock

- Tracking truth hits in the detector (GEANT3)
- Hits and initial event info stored in fz_gaf file
- ADAMO record for each event

- Near Det. event overlay
- 2 separate lists of ADAMO records
  -- rock or detector interactions
- reco_minos merges a Poisson random number of events from 2 lists into one ADAMO record
  -- mean reflects avg. POT/spill
  - -randomly spread across 8.9us

- Convert fz_gaf (FORTRAN binary) to reroot file (root file)

MINOS Simulation Chain

Now you need the energy depositions to look like raw data

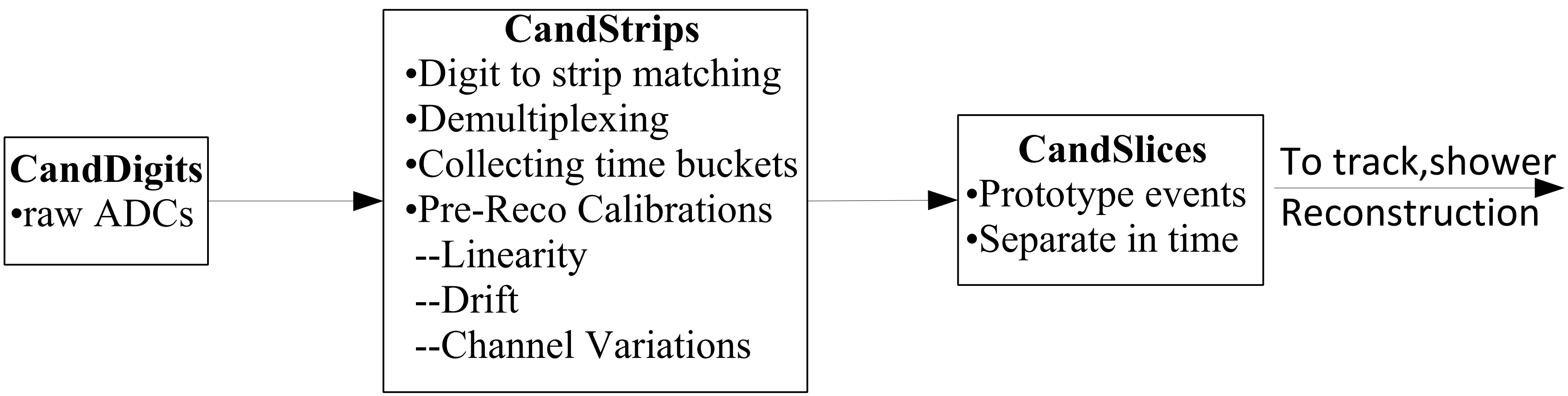
Convert to raw data block via loon job modules
Configured by ROOT macro (part of reco script)

- MC assigned real world time (calibration constants)
- Run RerootToTruthModule,PhotonTransport,DetSim modules
  - Stores truth info (SimSnarl)
  - Decalibrates hits to photons
  - Propagates photons through fiber
  - Simulate digitization (DaqSnarl)

Now you have raw detector data + truth info

MINOS Analysis Chain

Reconstruction of raw data record (1 spill)
ROOT macro defines sequence of job modules that take candidate objects and produce new ones



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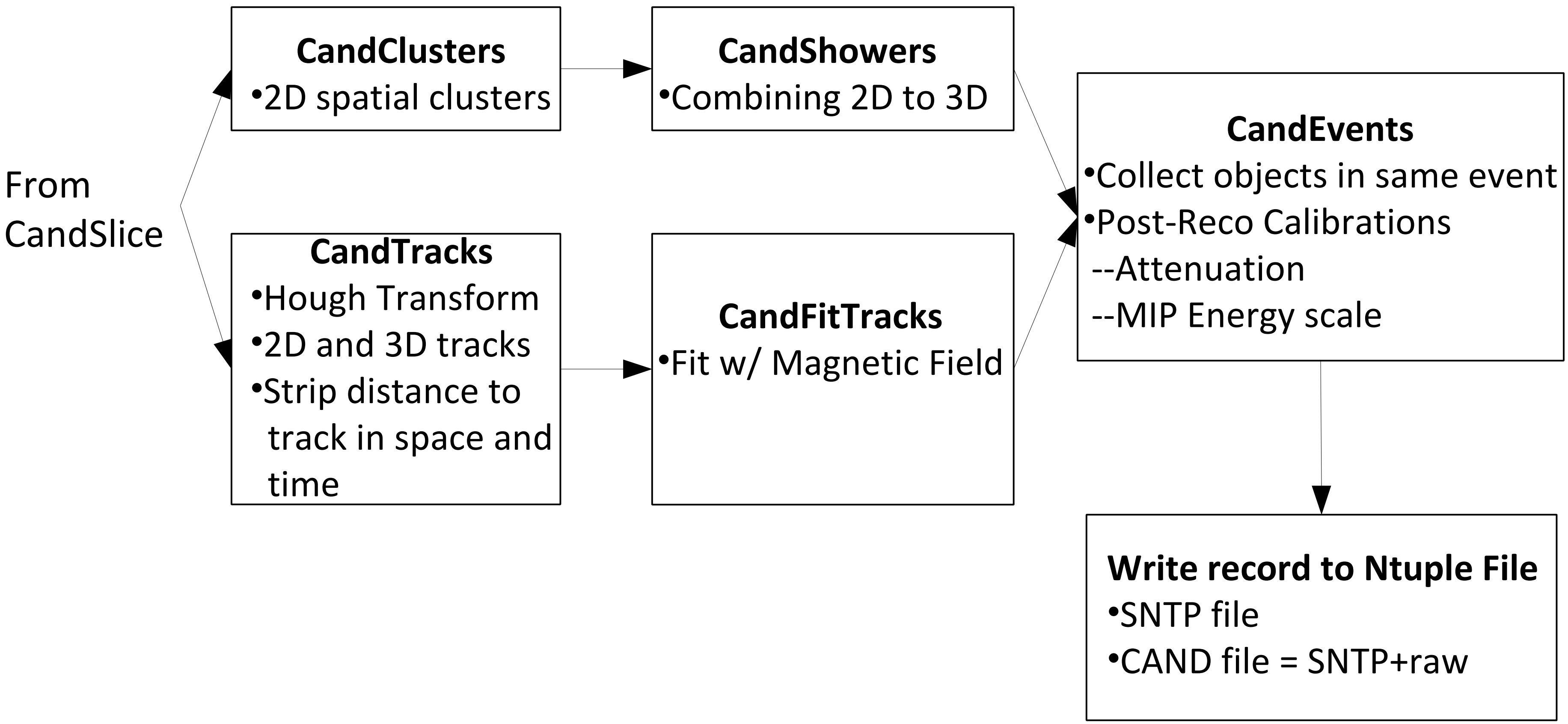
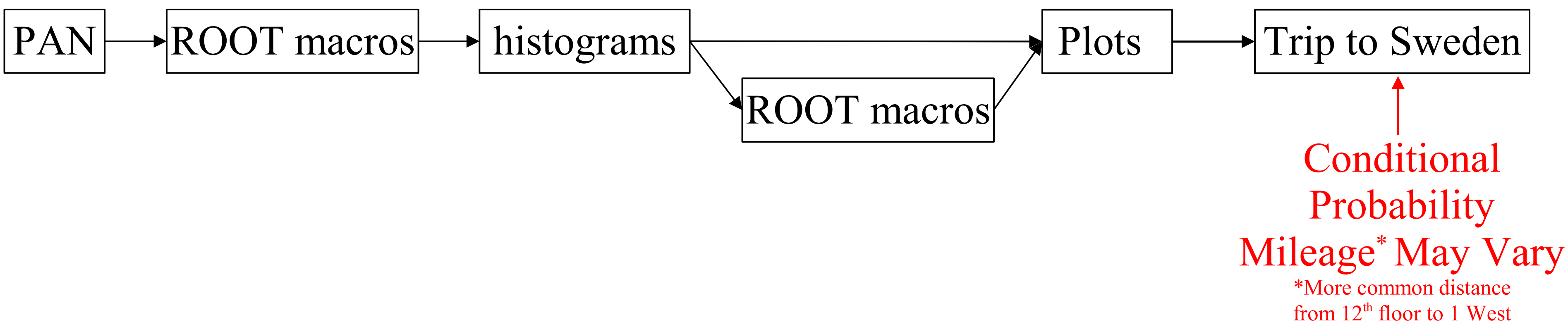


MINOS Analysis Chain

Conversion to Physics Analysis Ntuples (PAN)

- ROOT macro defines sequence of job modules
- Each analysis group has own package to produce and read files
- Create high level variables, drop "uninteresting" low level variables
- Create Interaction IDs: v_u CC, v_e CC, NC
- 1 event per record

Typical User Analysis Chain



Describe alignment procedures

- DB Tables with:
  - Strip position in module (mapper measurement, preinstallation)
  - Module position in plane (cosmic ray muons, postinstallation)
  - Plane position (optical survey, installation)
- Two alignment stages
  - Initial: Optical surveys
    - Vulcan Spatial Measurement System
    - Fermilab Alignment and Metrology Group
  - Final: Cosmic ray runs with magnetic field off
    - Reconstruct straight tracks using nominal alignment
    - Measure displacement of hit from track fit
    - Update alignment
    - Verify with independent cosmic run

Fortran or C++?

- Trying to euthanize the FORTRAN (This geezer's got to go)
- Simulation transitioning to C++ interface
  - GMINOS→PTSIM interfacing to ROOT VMC
  - NUEGEN→GENIE
- Reconstruction and analysis in ROOT/C++ framework

What works really well?

- Opinions May Vary:
  - Tree structure to files
    - Make quick plots
    - Straightforward to write simple analysis code if you know ROOT (even if you don't understand the MINOS framework)
      - Especially when one GetEntry() call fills one object that has member objects (with understandable names) that contain all the information that you are interested in for a single event
        - » NueRecord.srshower
        - » NueRecord.srtrack
        - » NueRecod.mctrue
  - Glideins & Parrot
    - More CPUs = GOOD
    - Read access to MINOS software from any grid node

Things to avoid

- Opinions May Vary:
  - Not having an automated calibration
    - Periods with significant lag in calibration constants and keep-up data
      - Are you seeing a feature in new data or is the calibration just too old
  - AFS w.r.t. maximum volume size and disk price
    - Inevitably data files are scattered in various locations