IceCube: Evolving Work Flows

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#### Overview

- The Basics of IceCube
- Data Handling
- Computing Model
- Summary

#### The IceCube Neutrino Observatory

- A kilometer scale neutrino detector
- Located at geographic South Pole
- Detects Cherenkov light from neutrino interactions







# Location, Location, Location

- Why the South Pole?
- Lots of ice a great detection medium
- The ice is very clear
- Thick ice sheet sensors deep enough to provide significant background reduction



#### **IceCube Overview**

- 400 people
- 39 Institutions
- 11 Countries
- **Exotic Locales**

#### The IceCube Collaboration



Chiba University Clark Atlanta University

Deutsches Elektronen-Synchrotron Ecole Polytechnique Fédérale de Lausanne Georgia Institute of Technology Humboldt Universität Lawrence Berkeley National Laboratory Ohio State University Pennsylvnia State University

Fonds Wetenschappelijk Onderzoek-Vlaanderen (FWO-Vlaanderen) Federal Ministry of Education & Research (BMBF)

**RWTH Aachen University** Southern University and A&M College Stockholm University Stony Brook University Technische Universität München Universität Bonn Universität Dortmund Universität Mainz Universität Wuppertal

Université libre de Bruxelles Université de Mons University of Adelaide University of Alabama University of Alberta University of Alaska Anchorage University of California-Berkeley University of California-Irvine University of Canterbury University of Delaware

University of Geneva University of Gent University of Kansas University of Maryland University of Oxford University of the West Indies University of Wisconsin-Madison University of Wisconsin-River Falls Uppsala Universitet Vrije Universiteit Brussel

The Swedish Research Council (VR) University of Wisconsin Alumni Research Foundation (WARF) US National Science Foundation (NSF)



#### Ruhr-Universität Bochum International Funding Agencies Fonds de la Recherche Scientifique (FRS-FNRS)

Swedish Polar Research Secretariat

German Research Foundation (DFG) Deutsches Elektronen-Synchrotron (DESY) Knut and Alice Wallenberg Foundation







# Data Volume

- Event rate of 3000 Hz
- I TB/day raw data
- Reduced to I00 GB/day
  - Based on available satellite bandwidth
- Tapes shipped North every year



# **Computing Model**

- University of Wisconsin Madison Tier 0
  - Raw data collection and archive
  - Data production to Level 3
  - Coordinate simulation production
- DESY-Zeuthen Tier I
  - Second copy of Level 2 data
  - Hold simulation data sets in Europe



# Tier 0 Capacity

- Compute cluster
  - 1400 cores, memory at least 4 GB/core
  - HTCondor managed
- Experimental data
  - I PB Lustre filesystem
- Simulation data
  - I.2 PB Lustre filesystem
- Analysis data sets
  - 250 TB Lustre filesystem



## **Data Production**

- Level I
  - Filtered stream from Pole
- Level 2 Science Ready
  - Calibrations, basic reconstructions
  - Common processing needed by all analyses
- Level 3 set by each working group
  - Event selection
  - Stream separation



# **Simulation Production**

- Driver of our distributed computing
- Collaboration institutions contribute to simulation production
- Production is coordinated with a central DB at UW Madison
- Output is collected at either DESY-Zeuthen or UW Madison



# Simulation Framework

- Software framework to coordinate components
- Central DB at UW-Madison to coordinate and track production
- First versions were monolithic photonics tables made grids difficult
- Newer versions broken into finer steps



# Simulation

- Event generation
  - CORSIKA for cosmic ray background
  - Several neutrino generators
- Photon propagation
  - Lookup tables
  - Direct simulation on GPUs
- Detector simulation



# First Monolithic WorkFlow

corsika

photonics\_ WAITING

photonics\_ WAITING

trashcan

photonics\_6 WAITING COMPLETE

photonics\_4 WAITING

photonics\_8

WAITING

ic40files

COMPLETE

PROCESSING

hitfilter

ic20files

COMPLETE

rootfiles

WAITING

- This was a single job
- A data set is O(100,000) jobs
- Long Photonics chain
- Lots of waiting
- Multiple detectors simulated
- Worked Locally, grids difficult



# OSG – Attempt 1

- Refactor work flow using DAGMan
- glideinWMS is now on the scene
- + lots of local caching and clever job routing





# Workable with caching











#### The Name

- Or: what happens when you give clever grad students a mission and some time
- Derived from HAL-9000 (2001: A Space Odyssey)
  - -IBM << I == HAL
  - -HAL << I == GZK
- GZK is a predicted limit on the energy of cosmic rays



#### The Hardware

- 6x Dell C6145 series chassis for CPUs
- 3x Dell C410 Chassis for GPUs
  - 16x GPUs each
  - nVidia Tesla M2070



## The Place

- CHTC pool
- Shared resource Available to other CHTC users
- WID/MIR data center
- 29 U of rack space
- 15 KW power dissipation



#### The Reason

- Improves the science
  - Eliminates many binning artifacts associated with tables
  - Required many improvements to our understanding of the ice
- Greatly reduces the need for Photonics tables



# Simplifies the Work Flow





# OSG Attempt 2

- Move top tier of DAG to OSG
- Results:
  - GPU processing at UW
  - Use local GPUs if available
- Turns our "tables problem" into a data movement problem – may be more tractable



#### Approach

- Start small scale with CHTC resources
  - Submit machine and glideinWMS
  - Shake out the bugs and surprises
- Add IceCube resources as needed to feed the beast
  - CVMFS software distribution, remaining tables
  - Squid caching
  - Expand gridFTP service



#### Future Workloads

- Analysis get Jane the Physicist doing regular analysis using OSG
- Data processing (Level 2 production)
- Reformatting old data into archival format



#### GPUs

- Better integration with HTCondor
- CPU/GPU ratios 2:1, 1:4 ?
- Limit jobs to assigned GPUs



# Summary

- IceCube is a km scale neutrino detector
- Work well locally with HTCondor
- Expanding to OSG involves work
- Extensive use of GPUs
- We may not be the coolest experiment on the planet, but we are one of the coldest.



# Credits

- Juan Carlos Diaz-Velez, David Schultz IceProd framework
- Dima Chirkin, Claudio Kopper GPU simulation development
- Heath Skarlupka GPU wrangling
- CHTC Hosting the GZK cluster, OSG support, HTCondor GPU efforts
- UW Madison Fast networks
- NSF IceCube M&O funding



#### **Questions?**