IceCube – What drives us?

- Novel instrument in multiple fields
- Broad science abilities, e.g. astrophysics, particle physics, and earth sciences
- Lots of data that needs to be processed in different ways
- Lots of simulation that needs to be generated
Multi-Messenger Astrophysics

- Observing astrophysical phenomena in using multiple astrophysical “messengers”
  - Transient phenomena – mergers of compact objects, flaring objects, supernovae, etc.
  - Continuous sources – Pulsars, AGN, etc.
- What is a “messenger”?
  - Traditionally
    - Electromagnetic (EM) emission – Radio, IR, Optical, X-Ray, Gamma
    - Cosmic Rays – Particles
  - Today
    - EM emission – Same as before with a focus on Gamma and Optical
    - Cosmic Rays – Particularly extremely high energy (EeV / particle)
    - Neutrinos
    - Gravitational waves (GW)
Multi-Messenger Astrophysics – IceCube

- Want to alert the community at large about interesting events
- Majority telescopes have a minute area of the sky they cover
- Need to be as precise and fast as possible, else wasting valuable telescope time or will miss source (transient sources)
- Optical model of ice is very important factor
- IceCube alerted community on 22 Sept 2017 about a muon neutrino coming from close to Blazar TXS 0506+056
- Follow-up by multiple telescopes
Multi-Messenger Astrophysics - Alert

- At pole analysis identifies event and sends preliminary alert to community
- “Northern” analysis determines whether the event is interesting – Refines location
• “Northern” processing is mostly refining the location on sky
• IceCube has developed a multitude of energy and directional reconstructions
• Trade-off between speed and accuracy
  • At pole
    • All events: Speed >>> Accuracy
    • “MMA” events: Speed > Accuracy
  • “North”
    • “Physics” events: Speed >> Accuracy
    • “MMA” events: Accuracy > Speed
    • “Really MMA” events: Accuracy >> Speed
• Big question is still the ice optical model – Not all reconstructions support
Reconstruction – Accuracy

- Most accurate directional reconstruction comes by scanning across the sky
  - Split sky into constant surface area pieces
  - Test each directional hypothesis against likelihood
  - Create directional likelihood map
  - Gives most probable direction and error
- Each hypothesis calculation is independent – Easy to split up workload across O(1000[000]) or cores
Current Scan

- Start with a rough estimate
- Zoom in on “hot” region with more detailed scan
- Step through scans until we have reach detector resolution

- Need to repeat scan to get systematic errors
- Shift in systematic space and re-scan
- Mostly useful for internal studies
Current Scan – Distributing Work

- Master-worker setup
- Worker resource requirements are the same
- Master makes decision about next scan
- Data communication via ZeroMQ
  - Easy to use and setup – Experience in other applications
  - Scaling an issue
    - Issue with communicating over the grid – Firewall issues
    - Over 2000 cores it can’t keep up
- Using HTCondor for scheduling workers
Cloud/ AWS gives us the ability to scale quickly – “Burst” into cloud

Reduce time to result!
  - Go to detector resolution immediately
  - 3000 core hours needed in O(10 min)

Data movement via RabbitMQ
  - Container deployment – Avoid Erlang/BEAM knowledge/headache
  - Many Source, many sinks
  - Higher scaling than ZeroMQ > 5000
  - Planning on replacing most Monte Carlo production data data movement

Scaling in a single cloud zone limited by AWS – Current spot scaling limit 5000

Multi-zone/multi-core needed to get to large scaling
  - Orchestration layer for data to reduce transfer cost
  - Are there sufficient multi-core instances in a zone?
Cloud Scaling Tests – EAGER

- Can scale to > 80k cores across 3 cloud and 28 zones within ~20 min
- Processed 300k jobs within 100 minutes
- Need multi-cloud, multi-zone deployment to reach this level
- Used HTCondor to do testing and matching
- Question whether this would work in master-worker setup with RabbitMQ
- Funded through EAGER for SC19 demo
- For other results from testing see talks regarding cloud networking
• MMA follow-up requires massive amounts
• AWS/cloud can provide means to reduce time to result for “bursty” applications – MMA follow-up ideal
• Data distribution for “bursty” application an issue
  • ZeroMQ doesn’t scale well
  • RabbitMQ scales
  • Cross-zone data transfers are costly
• Multi-zone vs. multi-core instances an open question
Thank you!

Questions?