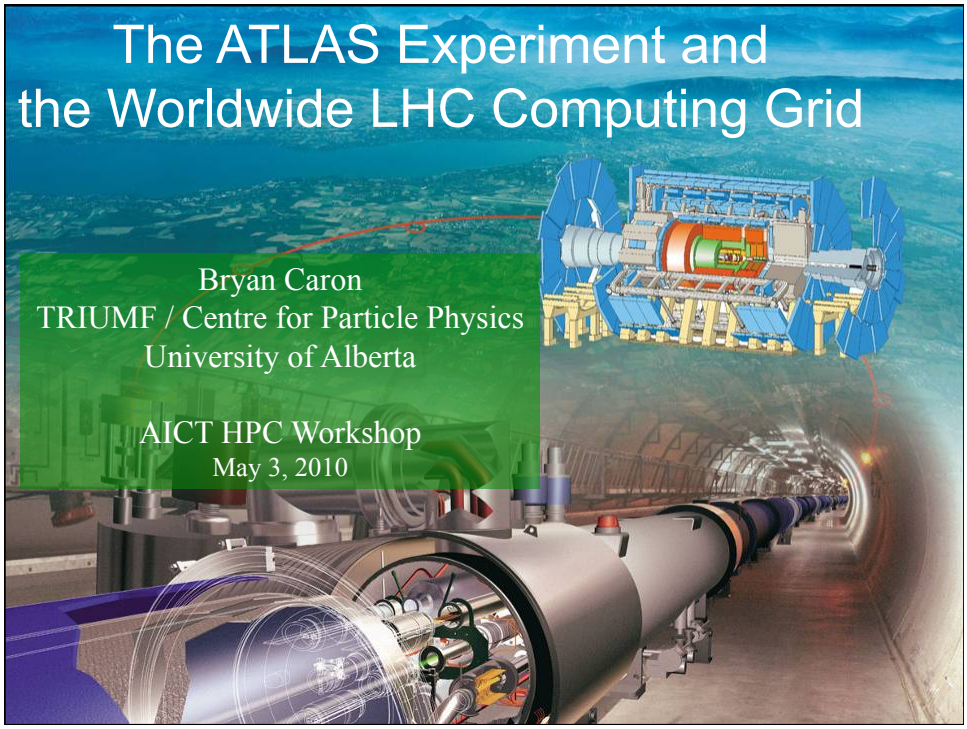
The ATLAS Experiment and the Worldwide LHC Computing Grid



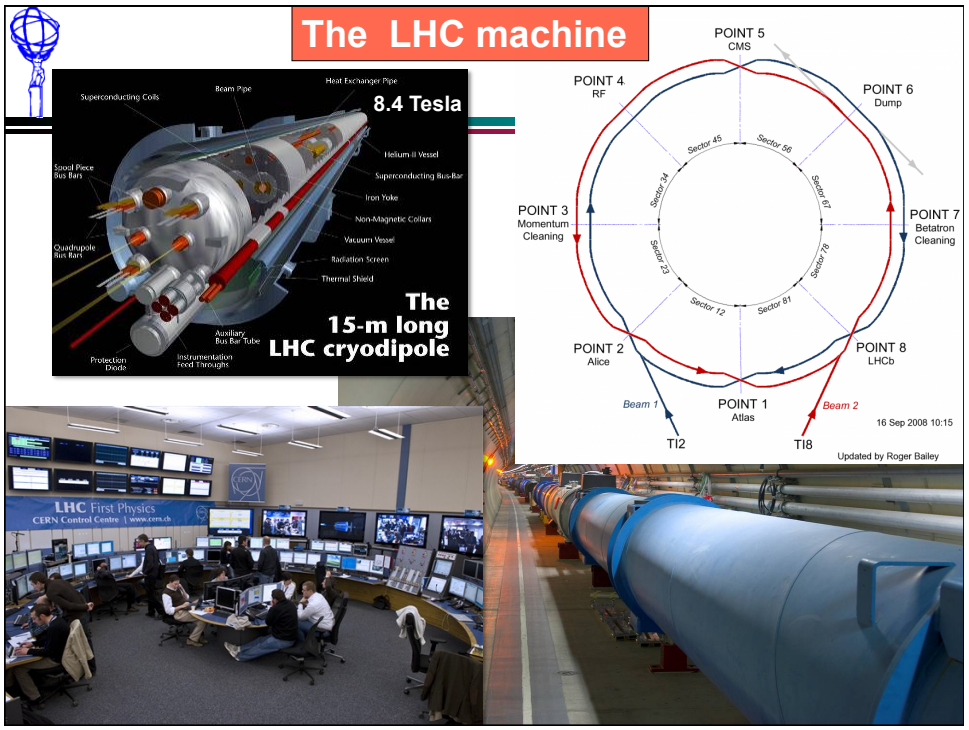
Bryan Caron
TRIUMF / Centre for Particle Physics
University of Alberta

AICT HPC Workshop
May 3, 2010

Outline

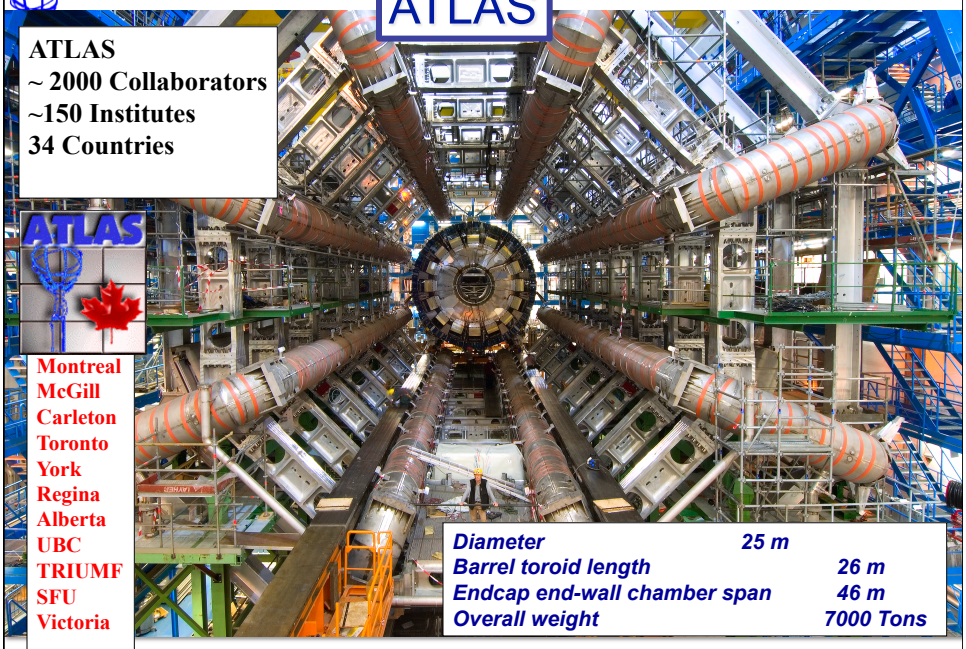
- The Physics
- The Challenge
- The Tools : The World-wide LHC Computing Grid
  - LHC and ATLAS-Canada Computing Model
  - Distributed Data Management
  - Large Scale Distributed Analysis
  - Operations and Monitoring
- Summary and Conclusions
  - LHC and ATLAS Status
  - Outlook for 2010/2011

The Large Hadron Collider
LHC accelerator ring 27 km circumference
France
ALICE
CMS
CERN
ATLAS
LHC-B
7 TeV protons
Switzerland


The LHC machine
8.4 Tesla
The 15-m long LHC cryodipole
POINT 5 CMS
POINT 6 Dump
POINT 7 Betatron Cleaning
POINT 8 LHCb
POINT 1 Atlas
POINT 2 Alice
POINT 3 Momentum Cleaning
POINT 4 RF
Beam 1
Beam 2
TI2
TI8
16 Sep 2008 10:15
Updated by Roger Bailey
LHC First Physics
CERN Control Centre

ATLAS

ATLAS
~ 2000 Collaborators
~150 Institutes
34 Countries



Montreal
McGill
Carleton
Toronto
York
Regina
Alberta
UBC
TRIUMF
SFU
Victoria

Diameter	*25 m*
Barrel toroid length	*26 m*
Endcap end-wall chamber span	*46 m*
Overall weight	*7000 Tons*

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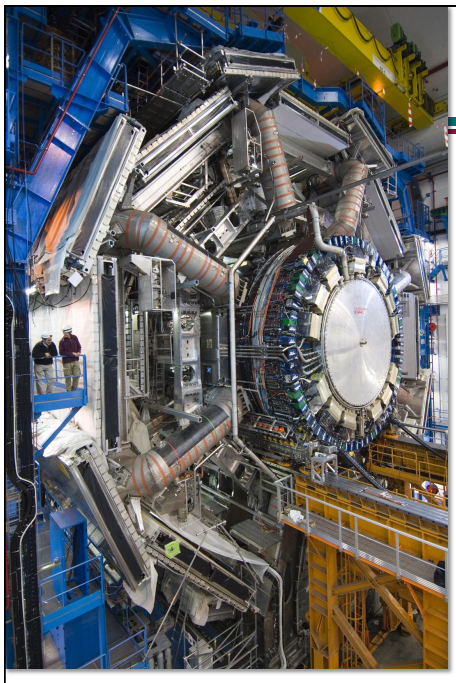
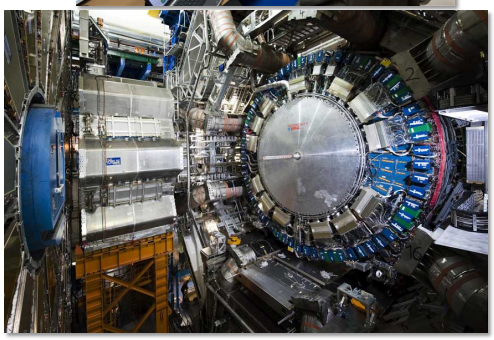
ATLAS





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Objectives of ATLAS and LHC

- One of the principle objectives: Discover the **Higgs** particle
  - Existence is fundamental to the Standard Model and many particle theories
- Some of the most fundamental questions in physics still to be answered:
  - What gives particles masses?
  - Why are there 3 types of quarks and leptons?
  - Are there more types of particles and forces to be discovered at higher energies?
  - How can gravity be incorporated into the Standard Model?

LHC Data Challenge

• A particle collision = an event
• 40×10^6 collisions/second
• Our goal is to count, trace and characterize all the particles produced and fully reconstruct the process.

• After filtering, 100 collisions of interest per second
• > 1 Megabyte of data digitised per collision
recording rate > 1 Gigabyte/sec
• 10^{10} collisions recorded each year
stored data > 10 Petabytes/year of data

1 Megabyte (1MB)
A digital photo

1 Gigabyte (1GB)
= 1000MB
5GB = A DVD movie

1 Terabyte (1TB)
= 1000GB
World annual book production

1 Petabyte (1PB)
= 1000TB
Annual production of one LHC experiment

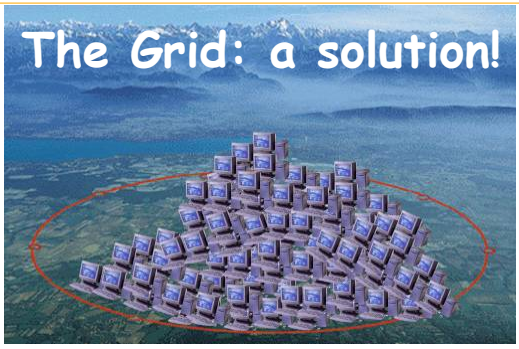
1 Exabyte (1EB)
= 1000 PB
3EB = World annual information production

LHC Processing Challenge

LHC data analysis requires a computing power equivalent to ~ 100,000 of today's fastest PC processors!

Where will the experiments find such a computing power?

Nowhere near enough at CERN!



What is the Grid?

- The name Grid is chosen by analogy with the electric power grid:
  - plug-in to computing power without worrying where it comes from.
- The Grid is an emerging infrastructure that provides:
  - seamless access to computing power
  - data storage capacity distributed over the globe.

- The Grid is, for the time being, many Grids
- Grids are a framework for Resource Virtualisation
- Grids will rely on new models of Inter-Organisational Security
- Grids will be used by Virtual Organisations
- Grids are a platform for Resource Discovery
- Grid Services will be based on Web Services

Grid development has been driven by the academic community

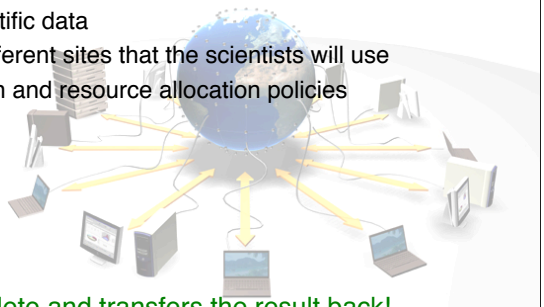
Industrial variants are on-demand computing, Utility computing

How does (should) it work?

• The Grid relies on advanced software, called middleware, which ensures seamless communication between different computers and different parts of the world

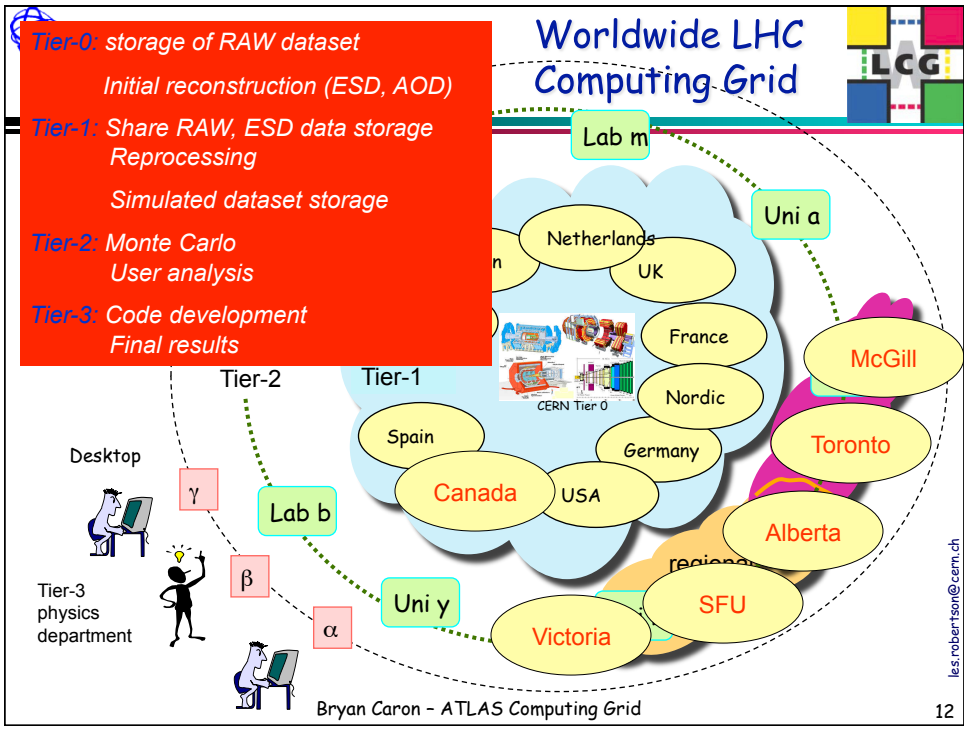
The GRID middleware:

- Finds convenient places for the scientist's computing task to be run
- Optimises use of the widely dispersed resources
- Organises efficient access to scientific data
- Deals with authentication to the different sites that the scientists will use
- Interfaces to local site authorisation and resource allocation policies
- Runs the jobs
- Monitors progress
- Recovers from problems



… and ….

Tells you when the work is complete and transfers the result back!



The Canadian Computing Model

- Tier-1 at TRIUMF:
  - Raw data storage; event reconstruction; expert personnel
  - Dedicated facility funded through CFI-EOF (2007-2011)
- Tier-2 Centres in the Universities:
  - East (Toronto, McGill) and West (UVic, SFU, Alberta) Tier-2 Federations
  - Monte Carlo simulation & physics analysis
  - Organized and independent user access patterns will have peaks and valleys
  - Will use shared facilities in the HPC Consortia (CFI-NPF)
- Resources for common ATLAS contributions and additional Canadian-only use
  - Grid-accessible cpu and storage for Canadian ATLAS users

3 – 4 PB of raw data + 2.5 PB of secondary data generated each year
(200 Hz, 14 hours/day, 200 days/year for nominal operations)
Canadian share/responsibility is 5%

Keys to Grid Usability

- Building a production level infrastructure
- Building robust services
- Building a good operations strategy
- Providing support
  - Grid Computing Infrastructure
  - Distributed Data Management
  - Large Scale Distributed Analysis
  - Operations and Monitoring

Grid Computing Infrastructure

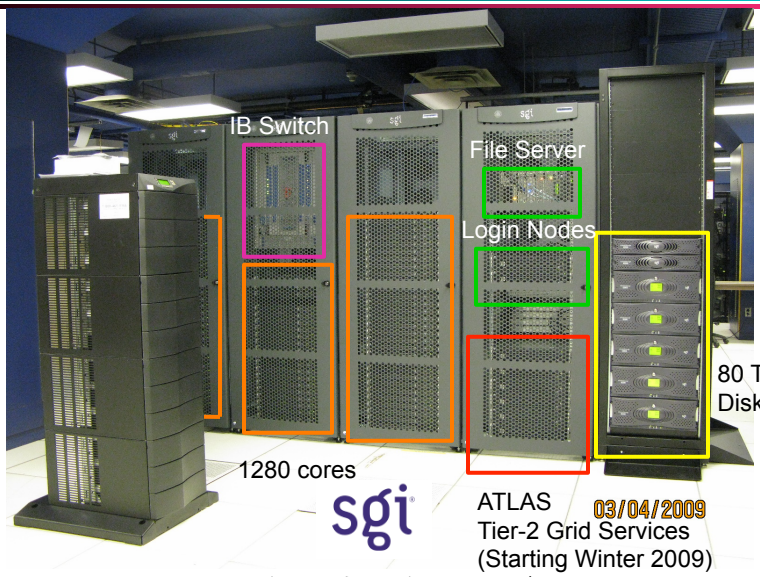
ATLAS Resource Requirements

- TRIUMF Tier-1 Centre
  - 1210 cpu slots,
    2.1 PB disk (usable),
    1.6 PB tape
- Tier-2 Centres (Sum)
  - ATLAS Canada
    WLCG commitment is
    approx. 5% of totals

Tier-2 CPU (kHS06)	*Old 2010*	*New 2010*	*2011*	*2012*	*Main components*
Simulation production	114	65	65	65	Tier-2 fraction of simulation
Group activities	32	38	49	52	Large scale skimming and slimming jobs
User activities	94	123	164	178	User analysis
Total	***240***	***226***	***278***	***295***	To summary table 3

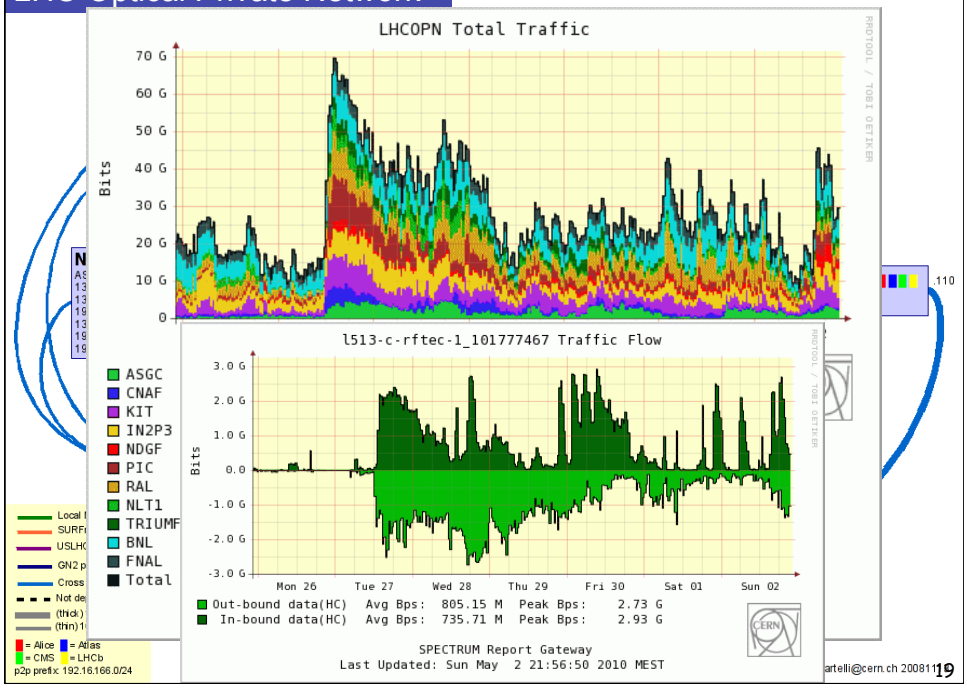
Tier-2 Disk (PB)	*Old 2010*	*New 2010*	*2011*	*2012*	*Main components*
Current RAW data	0.3	0.4	0.3	0.1	On request for debugging
Real data	7.0	11.3	19.7	19.7	AOD+DESD for analysis
Simulated data	9.2	7.7	11.1	15.2	AOD+DESD for analysis
Calibration and alignment inputs	0.2	0.2	0.3	0.3	Calibration data
Group data	1.9	2.8	4.6	5.5	dESD & dAOD from group analysis
User data	1.8	1.2	1.8	2.4	Scratch space
Buffers	0.6	0.6	0.6	0.6	For simulation
Total	***21***	***24***	***38***	***44***	*To summary Table 3*

WestGrid–Alberta Cluster "Checkers"

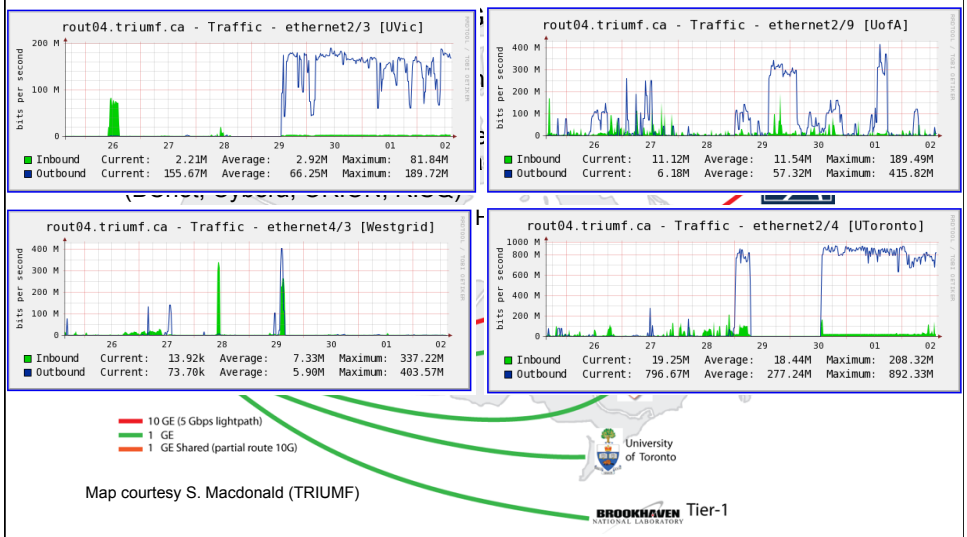


LHC Data Network

LHC Optical Private Network



ATLAS-Canada Network



Map courtesy S. Macdonald (TRIUMF)

Bryan Caron – ATLAS Computing Grid

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Grid Infrastructure

- Common grid services installed at CA Tier-1 and Tier-2s
  - LCG Compute Element via GLite middleware
    - Computing resources
  - Storage Element based upon dCache
    - Disk based (tape additionally required at the Tier-1)
  - LCG site BDII and MONitoring services
    - Information System
  - LCG WorkerNode client interface applications
    - Data file staging to/from WorkerNode, …
  - Central distribution of ATLAS software releases and conditions databases
  - Additional highly specialized services required at TRIUMF Tier-1
    - Oracle (ATLAS Conditions and Tag data),
    - File Transfer Service (data movement between sites),
    - ATLAS VO-Box (ATLAS Data Management),
    - LHC File Catalogue (file location and meta-data),
    - TOP-BDII (information system), …

Distributed Data Management

Distributed Data Management

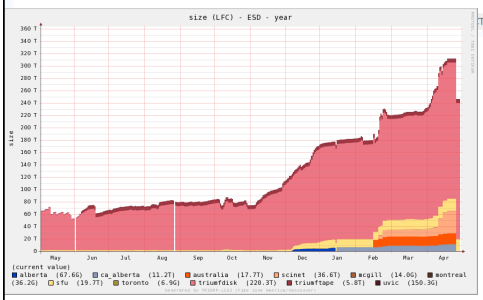
- Distributed Data Management System
  - Baseline Service for Data Distribution and Consolidation, MonteCarlo production and Reprocessing, Data Analysis
  - Provides functionalities for Data Organization (bookkeeping) and Data Transfers
    - Data Organization based on Datasets
      - Collection of Files
      - Unit of data location and data replication, data deletion
    - Data Transfers based on Subscriptions
      - Placement policy, which DDM tries to enforce
- DDM is a Distributed Service
  - Central Catalogs, Accounting Service
    - Hold dataset definitions, subscription requests, Dataset Locations
  - Site Services, Deletion Service
    - Triggering actions to enforce subscriptions
  - Other WLCG services at sites
    - FileTransferService for data movement (at T1s), StorageElements (at T1/T2s), File Catalogs (at T1s) hold information about single files placement
  - Command Line Interfaces

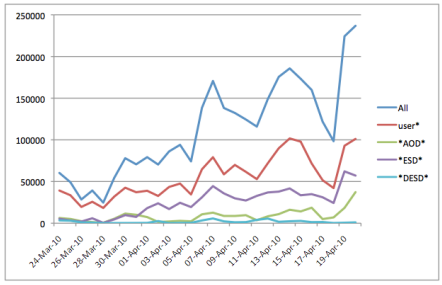
Data Management Dashboard

Activity Summary ('2010-05-02 20:10' to '2010-05-03 00:10' UTC)

Click on the cloud name to view list of sites

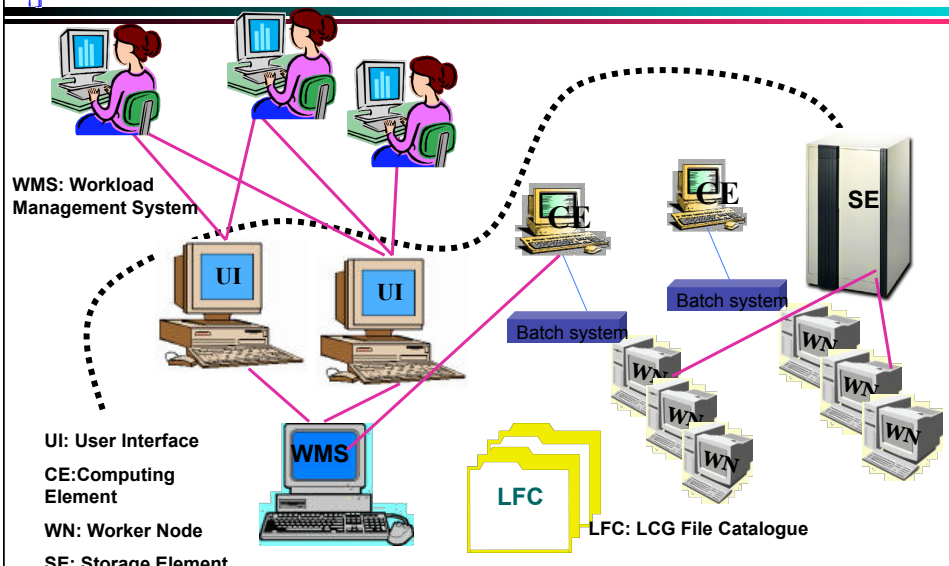
	Transfers			Registrations		Errors			Services
Cloud	Efficiency	Throughput	Successes	Datasets	Files	Transfer	Registration	Services	Grid
ASGC	97%	213 MB/s	10240	131	10240	282	0	0	
BNL	98%	1039 MB/s	22059	536	22329	511	0	0	
CERN	90%	92 MB/s	16876	117	17017	1792	0	0	
CNAF	58%	45 MB/s	2750	256	2766	1994	0	0	
FZK	99%	521 MB/s	16014	768	16020	224	0	0	
LYON	96%	384 MB/s	19698	513	19768	777	0	0	
NDGF	92%	48 MB/s	3273	163	3271	269	0	0	
PIC	91%	20 MB/s	1301	181	1309	130	0	0	
RAL	90%	756 MB/s	20309	433	20303	2133	0	0	
SARA	88%	266 MB/s	10201	219	10215	1389	0	0	
TRIUMF	99%	387 MB/s	16745	260	16763	152	0	0	



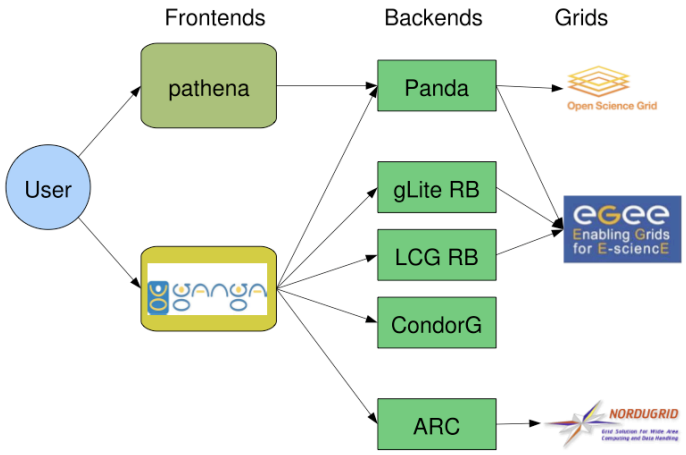


Large Scale Distributed Analysis

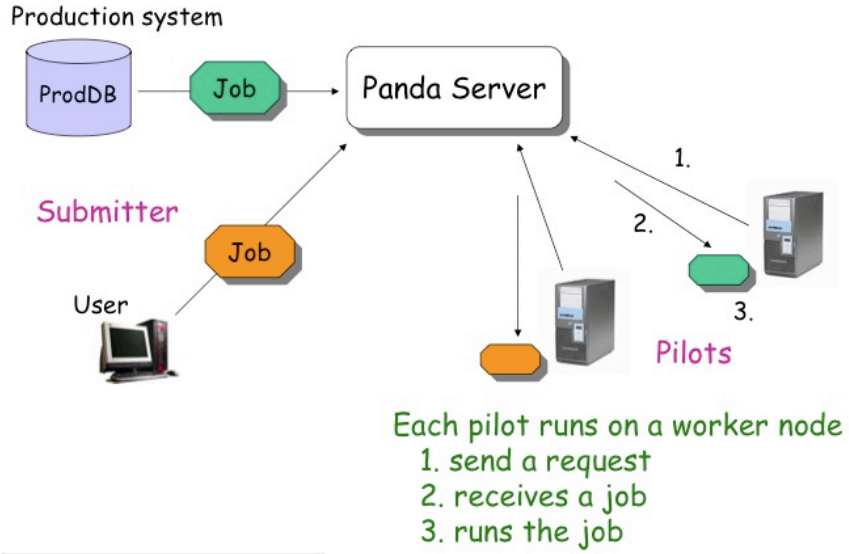
How does a Physicist use the LHC Grid?



Distributed Analysis



Panda Job Flow

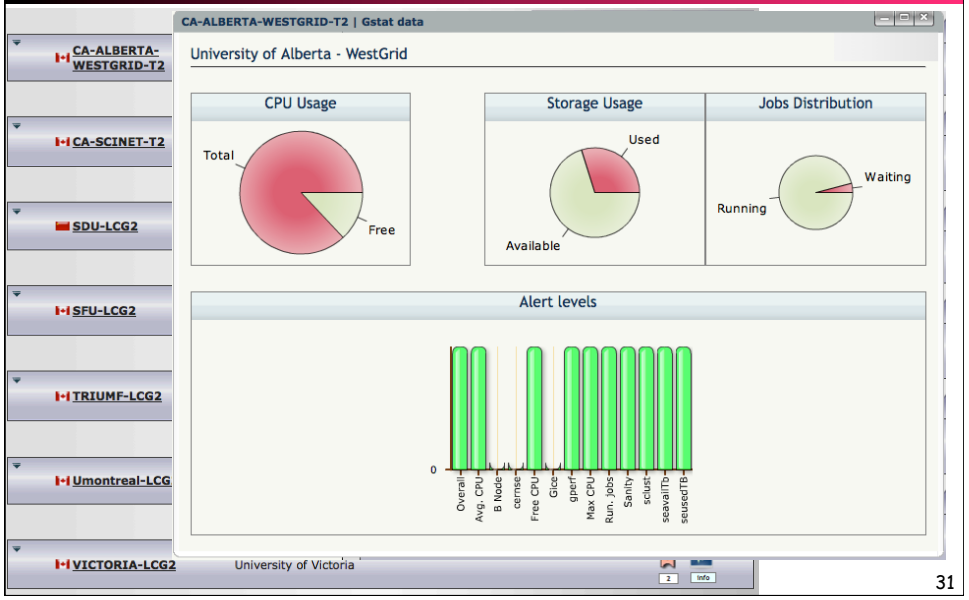


Operations and Monitoring

Distributed Computing Monitoring

- A wide range of tools aimed at **users, shifters, operators and managers**
  - Distributed Data Management dashboard
    - Dataset and file transfer / placement
  - Production System dashboard
    - Production tasks and associated jobs execution
  - Analysis dashboard
    - User jobs on the grid
  - Panda dashboard
    - Activity of Panda on the different clouds
  - Service monitoring dashboard (SLS)
    - Detailed information on the status of site services, central catalogs, …
  - Central Data Replication monitoring
    - A complement to the DDM dashboard
  - Software installations monitoring

Services Monitoring and Metrics



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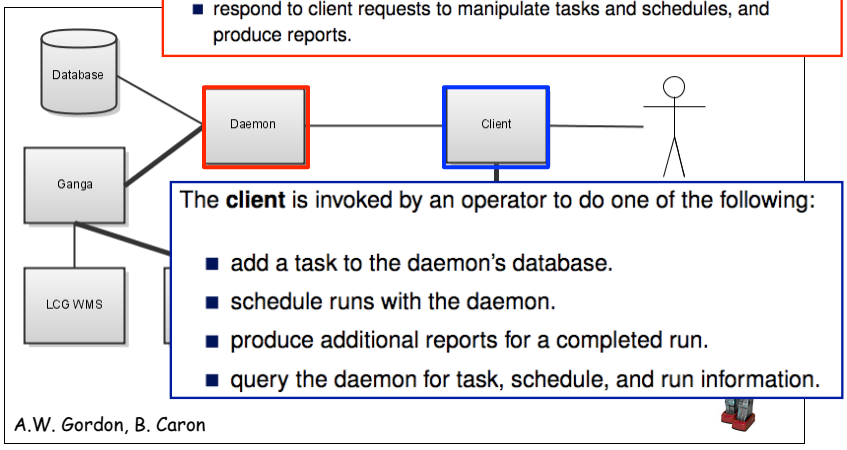
Grid

- HammerClou
  - Automa

The **daemon** runs persistently in the background on some server. It is responsible for:

- keeping track of tasks, schedules, runs, and extracted data in a database.
- using Ganga to submit jobs, monitor their status while they run, and resume monitoring if the daemon gets restarted.
- respond to client requests to manipulate tasks and schedules, and produce reports.



The **client** is invoked by an operator to do one of the following:

- add a task to the daemon's database.
- schedule runs with the daemon.
- produce additional reports for a completed run.
- query the daemon for task, schedule, and run information.

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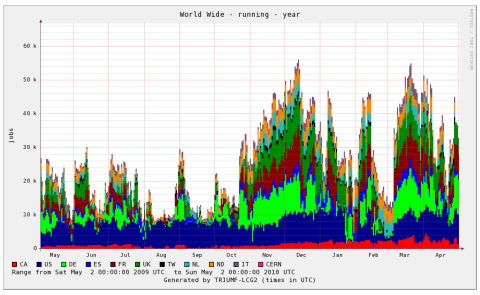
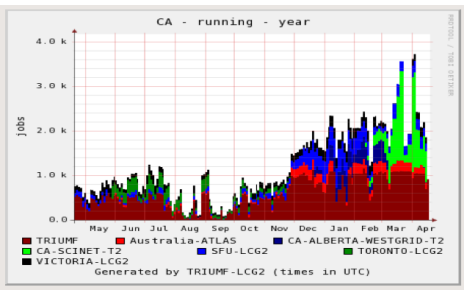
Analysis and Production Monitoring

CA Sites	Job Nodes	Jobs	Latest	Pilot Nodes	defined	assigned	waiting	activated	sent	running	holding	transferring	finished	failed	tot trf	other
Site Name	704	39	05-02 21:15	999	0	127	0	6883	2	2765	117	2515 / 28	2969	39	1%	0% 1%
Australia-ATLAS	30	0	05-02 21:15	51	0	0	0	80	0	208	3	204 / 0	211	0	0%	0% 0%
CA-ALBERTA-WESTGRID-T2	86	1	05-02 21:15	109	0	0	0	379	0	320	4	253 / 0	553	1	0%	0% 0%
CA-SCINET-T2	328	34	05-02 21:15	445	0	0	0	3302	2	1190	74	2029 / 0	353	34	9%	1% 8%
SFU-LCG2	21	0	05-02 20:52	24	0	45	0	0	0	0	0	28 / 28	0	0		
TORONTO-LCG2	0	0	offline	0	0	0	0	0	0	0	0	0 / 0	0	0		
TRIUMF	236	4	05-02 21:15	344	0	0	0	3122	0	1046	36	0 / 0	1852	4	0%	0% 0%
VICTORIA-LCG2	3	0	05-02 21:13	26	0	82	0	0	0	1	0	1 / 0	0	0		

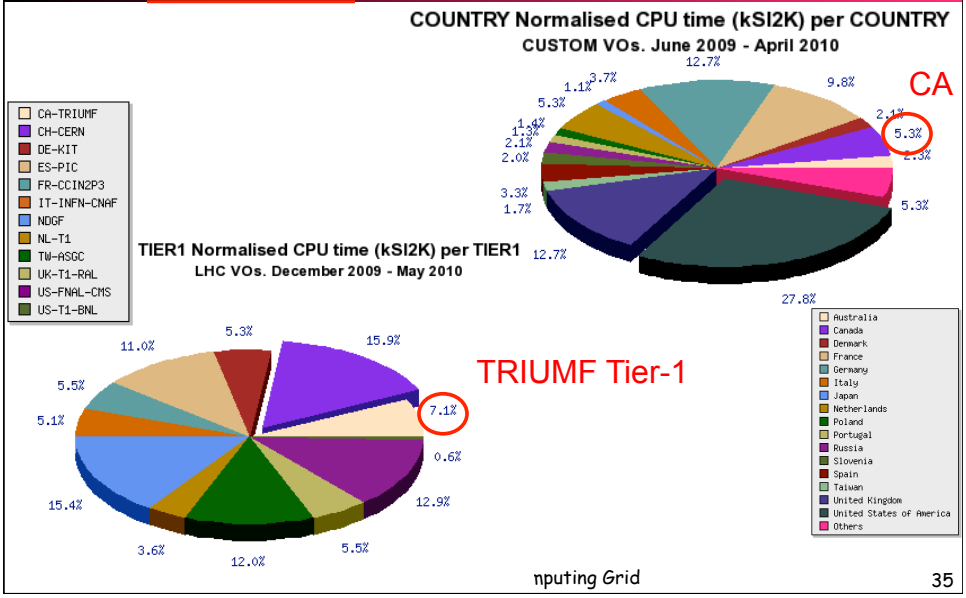




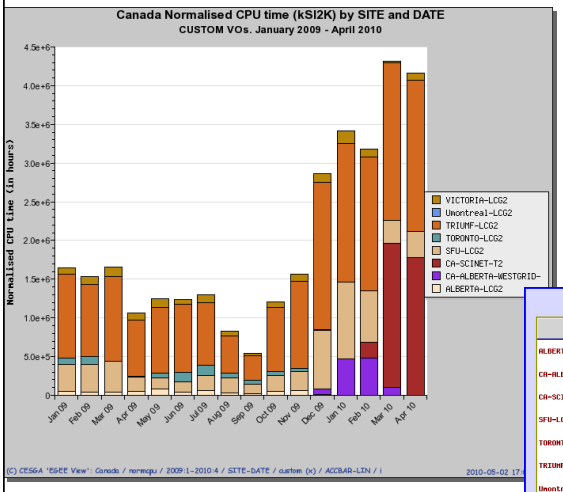
ATLAS-Canada Operations

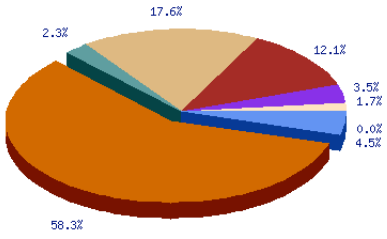
- ATLAS-Canada computing management and technical groups
  - discuss & propose policy to ATLAS investigators (e.g. sharing of resources, interaction with the HPC consortia)
  - share information on hardware and Grid middleware operations
- ATLAS Canada Cloud (Tier-1 + Tier-2s) Operations Twiki
  - Weekly grid services status reports
  - National and institutional production status
  - Local site problem reporting, tracking and solution documentation
- CA ROC (Regional Operations Centre) – est. 2009
- Site Availability and Monitoring Tests and others for diagnostics
- ATLAS Production, Analysis and Data Management Dashboards
- HEPNet Canada teleconferences
- WLCG Workshops
- Central ATLAS Tier-0/1/2/3 Jamborees (coordination)

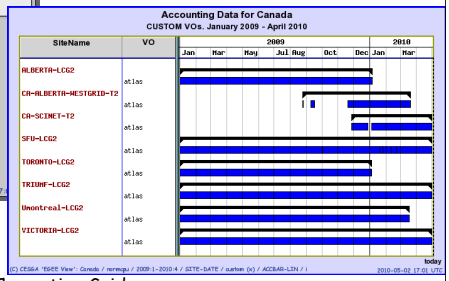
Canadian Contribution to ATLAS Computing



Resource Usage Accounting



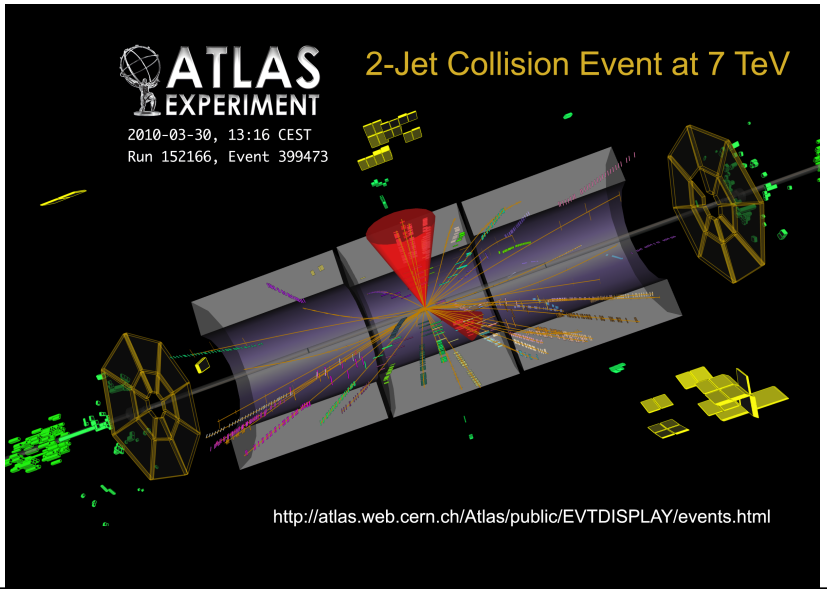




LHC and ATLAS Status

- Well known history of Friday September 19, 2008:
  - Faulty electrical connection between 2 magnets melted at high current during training for 5 TeV in LHC sector 34
    ➔ Large He leak into tunnel
  - Repairs + enhanced detection / protection system installed
- ATLAS resumed global cosmics runs around May 09
- LHC beam physics data-taking period resumes November 2009
  - extended running period of approx. 18–24 months
- Nov 23: colliding beams at 450 GeV per beam
- Nov 30: new record collision energy of 2.36 TeV
  - LHC in technical stop Dec 16 – Feb 2010
- March 19: circulating beams at 3.5 TeV per beam
- March 30: colliding beams at 7 TeV centre-of-mass

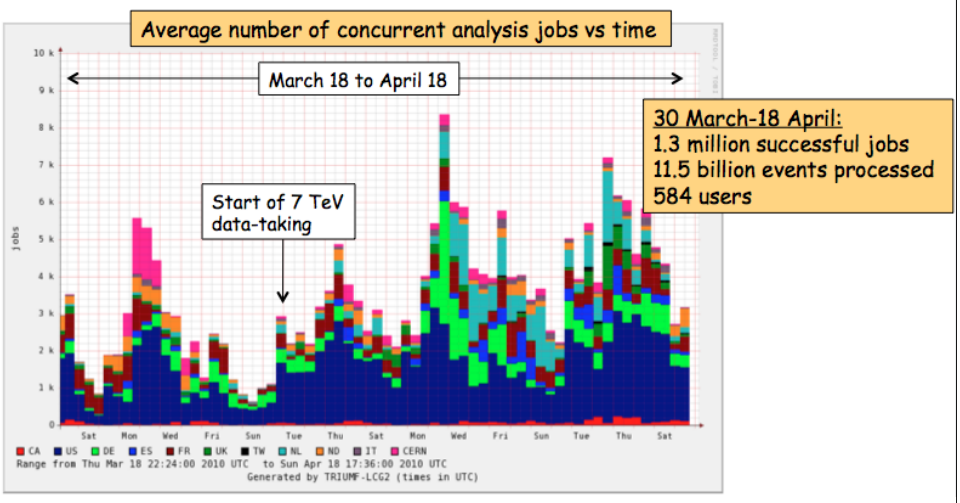
LHC and ATLAS Status



LHC and ATLAS Status

- April 24/25: factor 10 increase in luminosity for 30 hour 'fill' of the accelerator
  - More than double number of collision events recorded during single run compared to all previously collected 7 TeV data
- To Date: total # collision events @ 7 TeV = 66M
- Continuing improvement in LHC beam conditions are targeting 10^4 luminosity increase over 2010 and 2011

User Analysis Activity



Conclusions and Outlook

- Numerous challenges to extract physics from PetaBytes of collected data
- Turn to the World-wide LHC Computing Grid
  - Tiered structure for data distribution and processing
  - Distributed data analysis
  - Distributed data management
  - Operations and monitoring
- ATLAS-Canada Tier-1 at TRIUMF and Tier-2 Centres
  - ATLAS-common and Canadian-specific resource allocations
  - Tier-2 Centres: Analysis and Simulation Facilities
    - Hardware resources for 2010 (and beyond) via HPC Consortia
      - establish smooth stable WLCG operations at the new facilities
      - Strong base of experience in providing the needed ATLAS and LCG services in Canada
- The beam collisions data-taking era has started, and so the future is now!

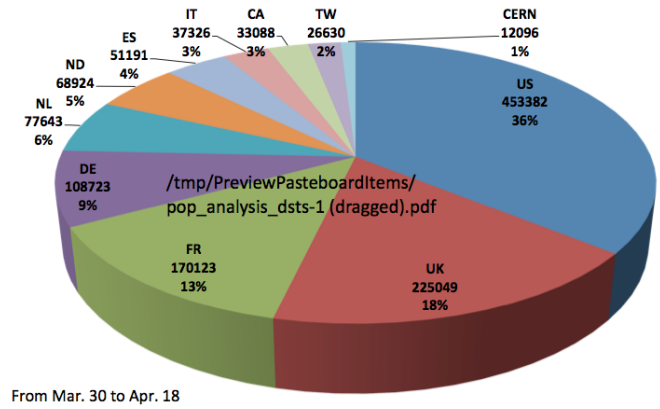
Acknowledgements

- TRIUMF and ATLAS-Canada
  - Tier-2 sites: Alberta, SFU, Victoria, Toronto, McGill
- Our partners in ATLAS Computing
  - WestGrid, SciNet, CLUMEQ
- University of Alberta – AICT, CPP, Physics
- Supporting Organizations
  - NSERC, CFI, Compute Canada, HEPnet Canada, Cybera, CANARIE, …
- The numerous colleagues who contributed material that was included in this presentation

Backup Material

User Analysis Activity

User Analysis Successful Jobs PanDA Backend



From Mar. 30 to Apr. 18
Total: 1.3 million successful jobs, 11.5 billion events processed, 584 users

From Kaushik De