ATLAS: M&O, Commissioning, Performance

BNL DOE REVIEW, MAY 2010

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OUTLINE

• An Executive Summary:
  – Detector, Software & Performance
  – Re-emphasizing the points made at the plenary session.

• Details
  – Liquid Argon (LAr)
  – Cathode Strip Chambers (CSC)
  – Trigger
  – Performance

• Summary

• Highlighting BNL role in each of these activities.
ATLAS: Data Collection

- Collected \( \sim 8 \text{ nb}^{-1} \) with stable beams
  - with peak luminosities of \( 6 \times 10^{28} \text{ cm}^{-2} \text{ s}^{-1} \)
  - Most of this coming this past weekend: 5/15
- 96.5\% of luminosity delivered with stable beams has been recorded.
- Driven primarily by minimum-bias triggers.

![Graph showing ATLAS Online Luminosity](image-url)

**Total Integrated Luminosity [nb⁻¹]**

- Total Delivered: 7.6 nb⁻¹
- Total Recorded: 7.08 nb⁻¹

**Integrated Luminosity [nb⁻¹/day]**

![Graph showing ATLAS Online Luminosity](image-url)

**Peak Luminosity [10²⁷ cm⁻² s⁻¹]**

- LHC Delivered
- Peak Lumi: \( 60.0 \times 10^{27} \text{ cm}² \text{ s}^{-1} \)
LHC plans in the coming months:

• Successfully operating now with $2 \times 10^{10}$ protons/bunch.
  - With up to 3 colliding bunches in machine.
• Plans to double the total beam current ~ every two weeks
  - Proposal to increase bunch intensity up to $10^{11}$ protons/bunch
    • Gives rise to about 4 to 5 interactions/crossing
  - Or twice the number of bunches with half the protons/bunch
    • More manageable pile-up conditions
LHC plans in the coming months:

• Last Weekend (5/15):
  – 3 colliding bunches each with $2 \times 10^{10}$ protons.
  – Peak Luminosity at $6 \times 10^{28}$ cm$^{-2}$ s$^{-1}$.
  – Collected $> 3$ nb$^{-1}$ over the weekend.

• Until end of June:
  – Increasing intensity to $10^{11}$ protons/bunch
  – Increasing to 16 bunches and peak L up to $10^{30}$ cm$^{-2}$ s$^{-1}$ (mid-June)
  – Expect 1 pb$^{-1}$ by end of June

• Longer time-scale:
  – Intermittent running at lower bunch intensity/higher # of bunches possible to have lower pile-up samples available for studies.
  – Increasing inst. luminosity to $10^{32}$ cm$^{-2}$ s$^{-1}$ by year end.
  – 100 pb$^{-1}$ accumulation by year end
  – 1 fb$^{-1}$ by end of 2011 (before first major shutdown).
DETECTOR

• Detector R&D, construction and operations has been a key strength at BNL for the past several decades.
  – Significant expertise, in collaboration with Instrumentation Division.

• In ATLAS, our contributions include:
  – Liquid Argon Calorimeter
    • Barrel Cryostat, cryogenics
    • Signal Feedthroughs
    • Barrel Cold Electronics
    • Front-end electronics and crates
    • Low Voltage Power Supplies
    • System Tests
  – Cathode Strip Chambers
    • Production of all chambers
    • On-detector electronics

Continue to maintain and operate these detectors
SOFTWARE

• Significant contribution early on in Simulation & Reconstruction software:
  – Coupled to our interests and expertise in detector sub-systems
  – Driven by the need to understand detector performance.
  – Today, we continue to be involved in detector software, but naturally diversified in contributing to related performance studies.

• We continue to contribute to Core Software development including:
  – Core software for offline reconstruction (Athena)
  – Database
  – Distributed Analysis and production software.
  – Driven by our need to adapt and use of the software components remotely. In collaboration with Physics App. Software (PAS) group.
  – Much of this is U.S. ATLAS Operations program funded effort, but with active participation of core-program physicists.
TRIGGER & PERFORMANCE

• Our interests and contribution to performance studies relate directly to our detector interests:
  – electron/photons
  – jets
  – taus
  – muons

• Involved in trigger performance and related software development.

• Experience from D0 has been critical to our successful contributions to ATLAS.

• Close collaboration with several groups, in particular nearby U.S. ATLAS institutes, including Stony Brook.
LEADERSHIP roles in ATLAS and U.S. ATLAS

• **ATLAS:**
  – ATLAS Trigger Coordination *(Rajagopalan)*
    • One of the five principal activity areas in ATLAS
  – ATLAS Liquid Argon Software & Data Preparation Coordination *(Ma)*
  – Current ATLAS Physics Group Conveners:
    • SUSY, Higgs, Heavy Ions *(Redlinger, Assamagan, Steinberg)*
  – ATLAS Jet Trigger *(Begel)*
  – ATLAS Distributed Analysis Operations *(Klimentov)*
  – Membership in several ATLAS steering groups.

• **U.S. ATLAS:**
  – U.S. ATLAS Deputy Program Manager *(Gordon)*

• These leadership positions reflect our successful role in ATLAS and our ability to make significant contributions to LHC physics.
Role in U.S. ATLAS

• Our expertise in:
  – Detector sub-systems, Software, Trigger and Performance

• Provides a solid platform that will allow us (BNL) to participate in LHC physics analysis.

• Allows us to play a vital role in assisting U.S. physicists with their analysis program:
  – Several universities do not have the same level of expertise in underlying software and particle identification necessary to participate effectively in a physics analysis.
  – Our responsibility as a U.S. ATLAS Analysis Support center necessitates the need to build an “expertise foundation”.
  – Frequent “jamborees”, weekly meetings involving several institutes, personal one-to-one interactions and communication via e-mails etc. provide the vehicle for this assistance.
ATLAS LEVEL OF EFFORT (FY10)
Core Research Program Physicists

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<th>Staff</th>
<th>Post-Doc</th>
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<tr>
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<tr>
<td><strong>Total</strong></td>
<td><strong>2.2</strong></td>
<td><strong>0</strong></td>
<td><strong>2.2</strong></td>
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</tbody>
</table>

M&O

| LAr      | 0.3   | 0.95     | 1.25  |
| Muon     | 0.4   | 0.2      | 0.6   |
| TC       | 0.2   | 0        | 0.2   |
| **Total**| **0.9**| **1.15**| **2.05** |

Performance

| egamma   | 0.4   | 0        | 0.4   |
| Jets     | 0.1   | 0.25     | 0.35  |
| Tau      | 0.4   | 0        | 0.4   |
| Muon     | 0     | 0.2      | 0.2   |
| Trigger  | 1.15  | 0        | 1.15  |
| **Total**| **2.05**| **0.45**| **2.5** |

Physics

| **Total**| **3.75**| **2.2**| **5.95** |

R&D

| **Total**| **3.4**| **0.1**| **3.5** |

Support

| **Total**| **0.8**| **0**   | **0.8** |

**Effort Total** | **13.1**| **3.9**| **17** |

3 staff and 3 post-docs are currently based at CERN.
Operations Tasks

• There are three classes of operations task:
  – Type 1: ATLAS Control Room Shifts (55 per day)
  – Type 2: all other shifts, on-call, validation, … 145/day
  – Type 3: Expert operation tasks, ~ 600 FTE.

• Each institution is expected to contribute to each of these categories proportional to the number of authors.

• For 2010, this share is about:
  – Type 1: ~ 7 shifts per author
    • Requires travel to CERN, putting additional burden on CERN based people
  – Type 2: ~ 19 shifts per author
    • Includes remote data taking shifts
  – Type 3: ~ 0.25 FTE per author.
    • We have ~4 of 17 FTE devoted to M&O + Software activities

• Expect the right share to balance over ~ 3 year period.

• We are meeting our share of Type 3 tasks, but fall short in Type 1 & Type 2.
BNL contribution to recent public notes:

- BNL is contributing to several ongoing performance and physics analysis.
- As an indication of our success, ATLAS produced a “book” on 12/28/2008: "Expected Performance of the ATLAS Experiment: Detector, Trigger and Physics"
- Out of 76 sections WE:
  - Contributed to 21 sections
  - Were reviewers of 5 sections
  - Were editors of 6 sections
    - Muon Reconstruction and Identification: (Adams)
    - Calibration and Performance of the EM Calorimeter (Snyder)
    - The ATLAS Trigger for Early Running (Rajagopalan)
    - Data Preparation for the ATLAS HLT Calorimeter Algorithms (Damazio)
    - Diboson Physics Studies (Ma)
    - Prospects for SUSY Discovery Based on Inclusive Searches (Paige)
THE DETAILS
LAr: Software, Maintenance & Operations

• Low Voltage power supply (Chen, Damazio, Lanni)
  – Design, Production – backup, Maintenance & Operations

• Software:
  – Electronic Calibration software & processing (Tarrade, Damazio)
  – Conditions database for online software (Majewski)
  – LAr Trigger software development (Damazio)

• LAr data quality/performance:
  – Understanding detector problems (Gadfort)
  – Assessing the performance of EM calorimeter with final state electrons (Tarrade)

• Leadership:
  – LAr Software & DataPreparation Coordinator (Ma)
  – LAr Run coordinator (Majewski)
LAr Detector Performance

Distribution of Cell Energy in EM calorimeter compared to Non-Diffractive MC

98.5% operational number of channels in LAr EM calorimeter

Low Voltage Power Supply:
- All 58 are currently operational (five of them have lost some redundancies)
- Backup LV PS prototypes evaluated, vendor selected for production (PRR)
- Installation during 2012 shutdown.
MUONS: CSC

- BNL proposed, designed & built the detectors and on-detector electronics.
- We have full responsibility of the operation and maintenance of detector including services such as low and High voltage, cooling and gas systems.
- 98.5% of the detector fully operational.
- Readout limit extended to 63 kHz, now regularly part of online running.
Trigger: Software & Performance

• Overall Trigger coordination (Rajagopalan)
  – One of the five principal activity areas in ATLAS
• Jet Trigger coordination (Begel)
• Calorimeter trigger software (Damazio)
• Software tools to access trigger decisions during analysis (Begel)
• Measurement of trigger efficiencies: muons, jets. (Begel, Redlinger, Mete)
Trigger operational from Day 1

• Peak Luminosity of $10^{27}$ cm$^{-2}$ s$^{-1}$.
• Primary trigger relied on MinBias trigger scintillator: MBTS_1 (requiring 1 of 32 scintillators)
• Most of High Level Trigger (HLT) was running in “monitoring” mode.
• Min-Bias HLT was enabled to actively reject during first fill.
• Recorded > 97% of delivered data with stable beams.
Trigger performance studies

- Efficiency of L1 Minimum Bias trigger scintillator (MBTS_1 \equiv \text{requiring 1 of 32 scintillators}) at 7 TeV.
- Determined using random trigger based on BPTX (beam pick-ups) with HLT space point counting trigger.
- Efficiency of L1 Electromagnetic (EM) cluster trigger, EM5 (5 GeV in 0.1 trigger tower).
- Determined from min-bias trigger sample requiring offline EM clusters and compared to non-diffractive simulation.

Efficiency of L1 Jet cluster trigger J5 (5 GeV) at EM scale determined from min-bias data and compared to non-diffractive simulation.

Efficiency of L1 Electromagnetic (EM) cluster trigger, EM5 (5 GeV in 0.1 trigger tower).
- Determined from min-bias trigger sample requiring offline EM clusters and compared to non-diffractive simulation.
Trigger commissioning and plans

• Rely largely on min-bias triggers with low luminosity
  – Total output rate to disk ~ 200 Hz at 1.6 MB/event.

• Pre-scale min-bias keeping L1 Calo & Muon un-prescaled with increasing luminosity operating HLT in “monitoring” mode.
  – Until rates for L1 Calo + Muon ~ 150 Hz.

• Trigger menus developed to adiabatically transition to higher luminosities.
  – All items controlled with pre-scale sets that can be updated during a run

• Rate estimation with data ongoing, bootstrapping to higher luminosities.
  – Serve as input in developing pre-scale sets for higher luminosities.

• Efforts underway to understand the effects of pile-up on trigger.
Software

• D3PD maker
  – BNL developed the common framework for ntuple production for performance and physics, allowing physics and performance groups to “plug-in” their tools.
  – BNL also developed the software/ntuples for e-gamma studies.

• AthenaRootAccess
  – Allows access to reconstruction output directly from ROOT.

• StoreGate
  – Transient Data Model Infrastructure with the ATLAS reconstruction framework.

• Production & Distributed Analysis Software.
• Pile-Up and Overlay software.
• Contributions to LAr, Muon & Trigger software applications.
e-gamma performance

BNL personnel active in analysis of first e/gamma data: data/MC comparisons and pi0 search.

ATLAS analysis of early e/gamma data relies on NTuple code developed at BNL.
Muon software & performance

- Lead effort to commission and develop and maintain software for the CSC detector. Run weekly meetings.
- Software development for CSC Simulation & Digitization
- Validate muon performance in releases and report to physics validation
- Carry out studies to evaluate muon performance (efficiency, fakes, isolation, resolution, etc).
- Monitor MC reconstruction jobs
- All these strengthen our ability to contribute to physics with final state muons:
  - Inclusive muon cross section
  - $W'$ to muons

Assamagan, Adams, Nikolopolous
Jets performance

• Principal Contributors: Begel, Ma, Majewski, Paige, Pleier in close collaboration with several other institutions.
• Jet Energy Scale (JES) using Global Calibration Weight scheme
• Determination of JES using tracks in jets; will be used as a cross check on systematic uncertainty for initial JES.
• Determining jet efficiency from data using track jets
• Understanding jet angular resolutions by comparing topoclusters with tracks
• JES corrections for non-isolated jets
• Jet Trigger performance
Jet Performance

Inclusive Jet PT and $\Delta\Phi$ distributions
Measured (black dots) at EM scale and
Compared to PYTHIA.
Only statistical errors are shown.
Tau performance

- Current tau identification based primarily on cut methods.
- Need to explore more sophisticated methods to extract tau candidates, such as boosted decision tree and likelihood methods.
  - Significant experience from D0 on tau identification.
  - Develop, study and implement these methods in ATLAS
  - Leading naturally to involvement in $Z \rightarrow \tau\tau$ and VBF $H \rightarrow \tau\tau$ analysis

Protopopescu, Tarrade, (Patwa)
Summary

• **BNL has a strong expertise in detector R&D.**
  – Has made major contributions to ATLAS LAr and CSC detectors
  – And continues to maintain and operate the detectors.

• **BNL has made significant contributions to related performance areas:**
  – Trigger, egamma, jets, taus and muons.

• **BNL has taken leadership roles in many of these activities.**
  – With memberships in ATLAS Management and several major coordination bodies.

• **BNL plays an essential role in U.S. ATLAS Physics Analysis Support activities.**

• **And BNL will use this established expertise to make major contributions to ATLAS discovery and precision physics and future upgrades to ATLAS detector.**
  – This journey has already begun.