The SLAC ATLAS Program: Challenges and Opportunities

David MacFarlane and Su Dong
For the SLAC ATLAS group

Outline

- Introduction and overall strategic direction
  - Overview of challenges, opportunities and goals
- Survey of current ATLAS activities
  - Activities on pixel and tracking systems, DAQ and high-level trigger (HLT) systems, and simulations
- Planned growth and future direction for ATLAS program
  - Moving from R&D to major roles for upgraded pixel and TDAQ systems
  - Expanded computing role and plans for west coast center
- Conclusions

Why was it crucial for SLAC to join ATLAS?

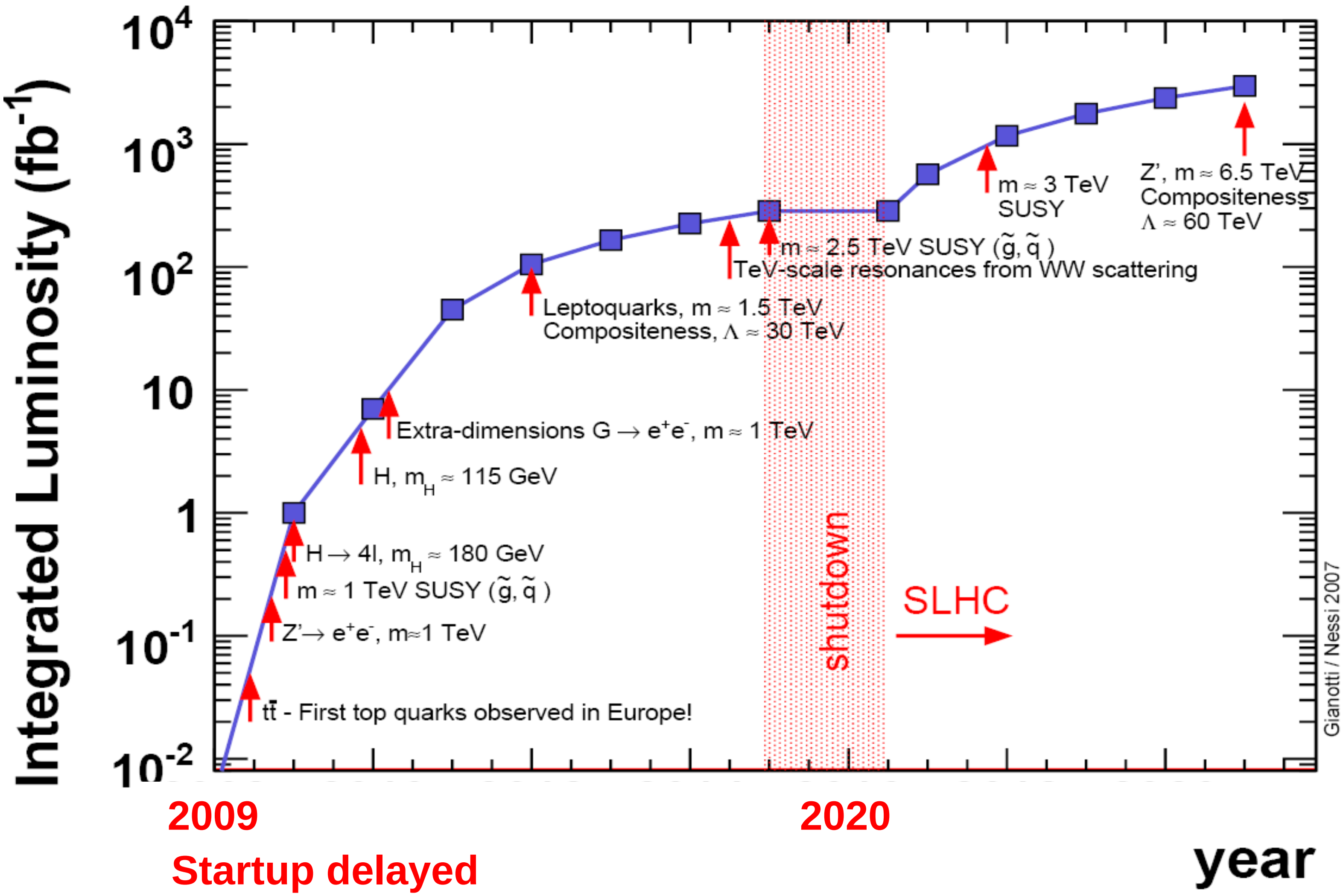
- The most compelling questions in particle physics can only be addressed at the energy frontier
- The best way of sustaining a vibrant energy frontier community for a future linear collider is to be engaged now
- The energy frontier is the highest priority program for the national user community & our traditional user base
- ATLAS is the future for our accelerator-based program, and therefore the glue tying together the HEP program at SLAC

Led to SLAC to become a member of ATLAS in July 2006

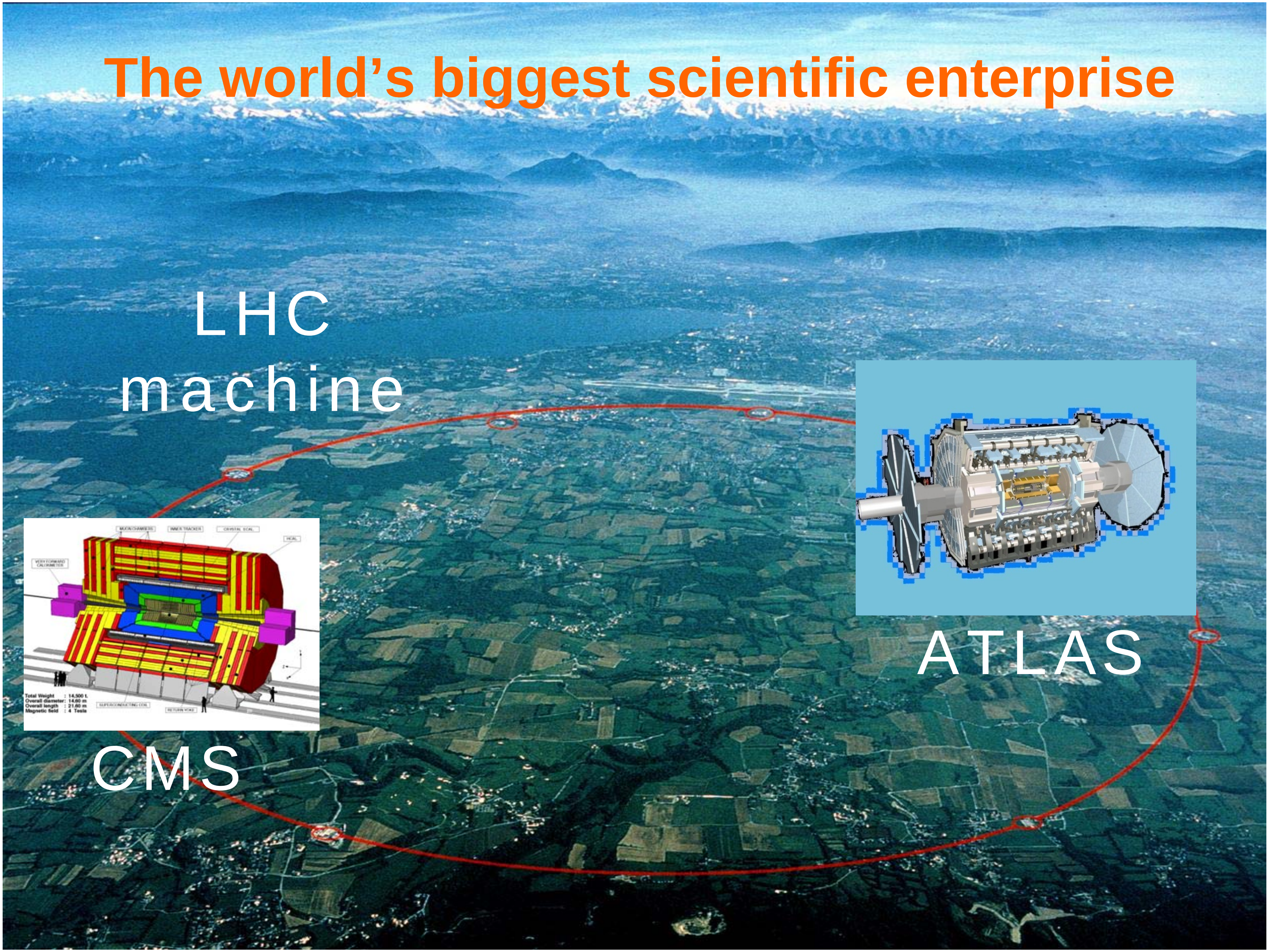
Initial challenges and opportunities

- Late entry into a major worldwide collaboration with established players and institutional responsibilities
  - Major impact still achieved by operating in a service mode to resolve many real issues arising during commissioning over the last 3 years
- Core capabilities and unique expertise from constructing & operating BABAR are now being applied to ATLAS
- Gaining agreement from OHEP for substantial growth has been difficult with OHEP reorganization along program lines
- Our goal is to significantly strengthen the US ATLAS effort by the infusion of a large and experienced SLAC team

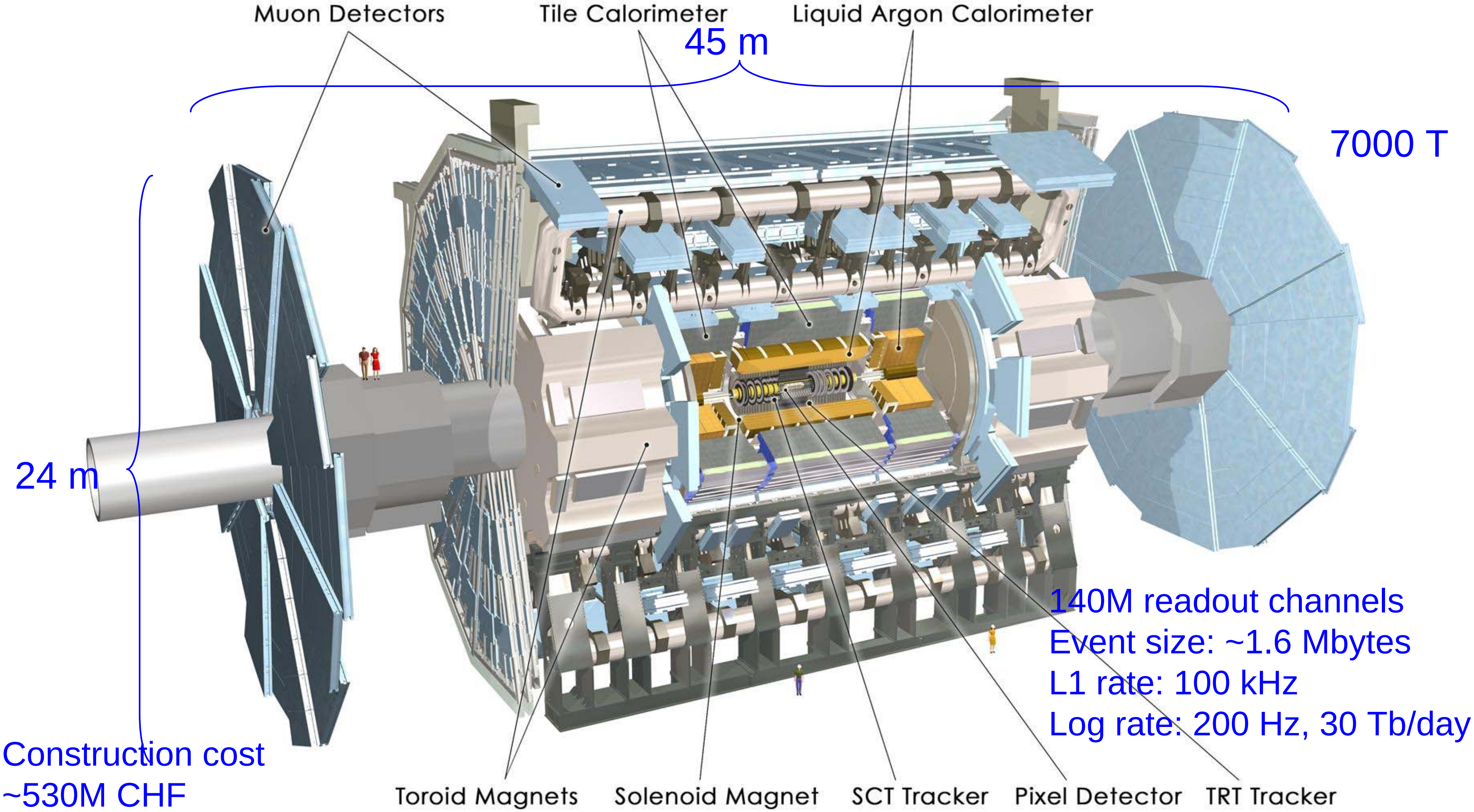
Physics opportunities at the LHC



The world's biggest scientific enterprise



Orientation: The ATLAS detector



Construction cost
~530M CHF

Partnering in a world-wide project

ATLAS Collaboration

(as of March 2009)

37 Countries
169 Institutions (38 from US)
2800 Scientific participants total
(1870 with a PhD, for M&O share)

Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Brasil Cluster, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Ritsumeikan, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

Who is involved from SLAC?

- Faculty:
  – Su Dong, David MacFarlane, Ariel Schwartzman (Asst Prof), Andy Haas (Panofsky Fellow)
- Scientific staff:
  – Makoto Asai, Rainer Bartoldus, Mark Convery, Norman Graf, Philippe Grenier, Jasmine Hasi, Michael Kelsey, Chris Kenney, Peter Kim, Martin Kocian, Richard Mount, Tim Nelson, Rich Partridge, Bill Wisniewski, Dennis Wright, Charles Young
- Technical staff:
  – Karl Bouldin, Ric Claus, Gunther Haller, Ryan Herbst, Mike Huffer, Jim McDonald, David Nelson, Marco Oriunno, Jim Panetta, Andy Salnikov, Leonid Sapozhnikov, Douglas Smith, Wei Yang, Matthias Wittgen

Who is involved from SLAC?

- Postdocs:
  - Ignacio Aracena, Sarah Demers, Matthew Graham, Per Hansson, Claus Horn, Paul Jackson, Silke Nelson, Michael Wilson
- Graduate Students:
  - Bart Butler, David Miller, Dan Silverstein, Jim Black

Organizing themes of SLAC/ATLAS plan

Theme 1: Pixel System

White paper Sections I.A, III.A, III.B, III.C, III.D, III.E, & III.G

Theme 2: DAQ and trigger

White paper Sections I.B, & III.H

Theme 3: Simulations

White paper Sections I.E, & III.F

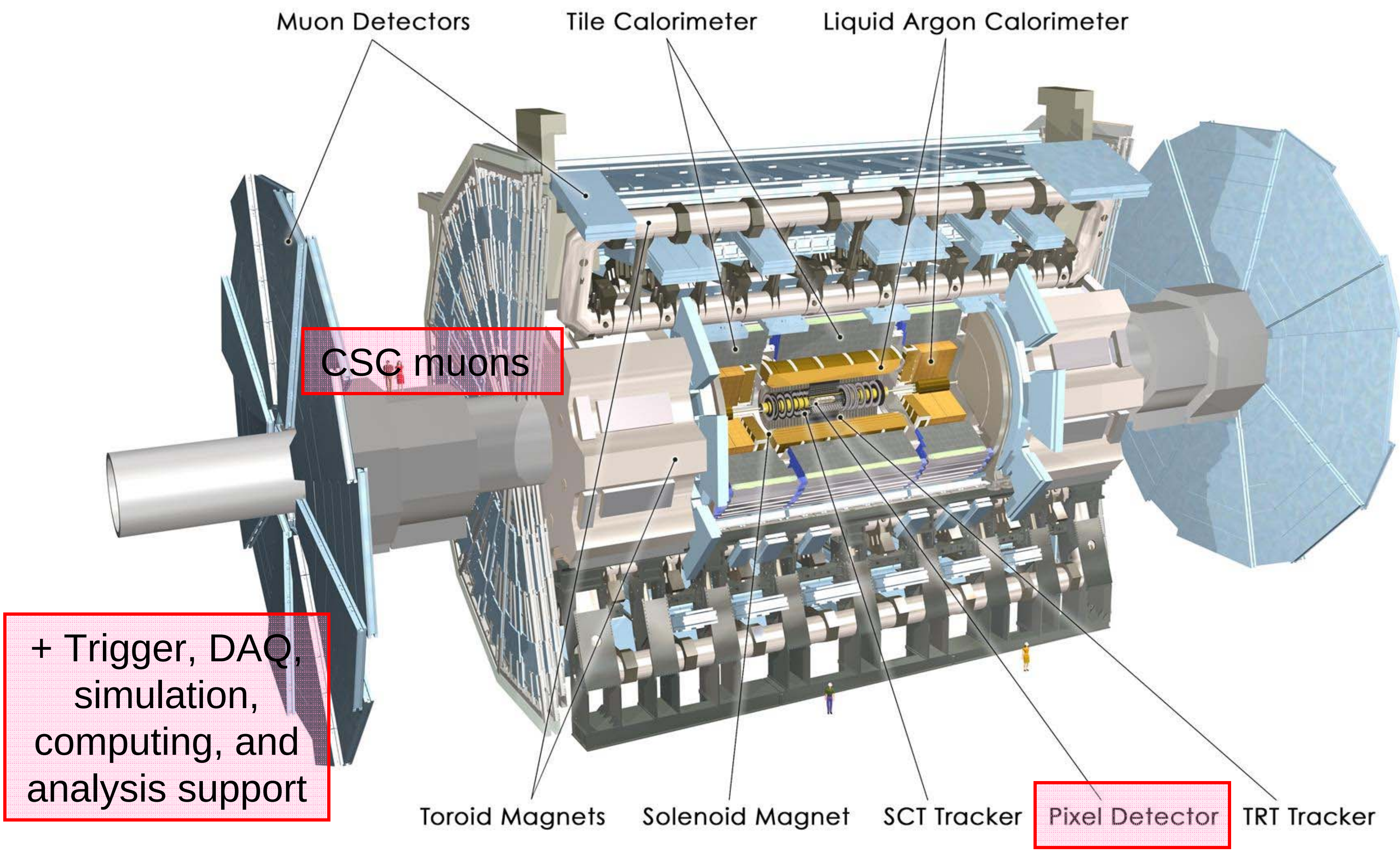
Theme 4: Tier 2 Center & potential Western Data Analysis Facility

White paper Section II

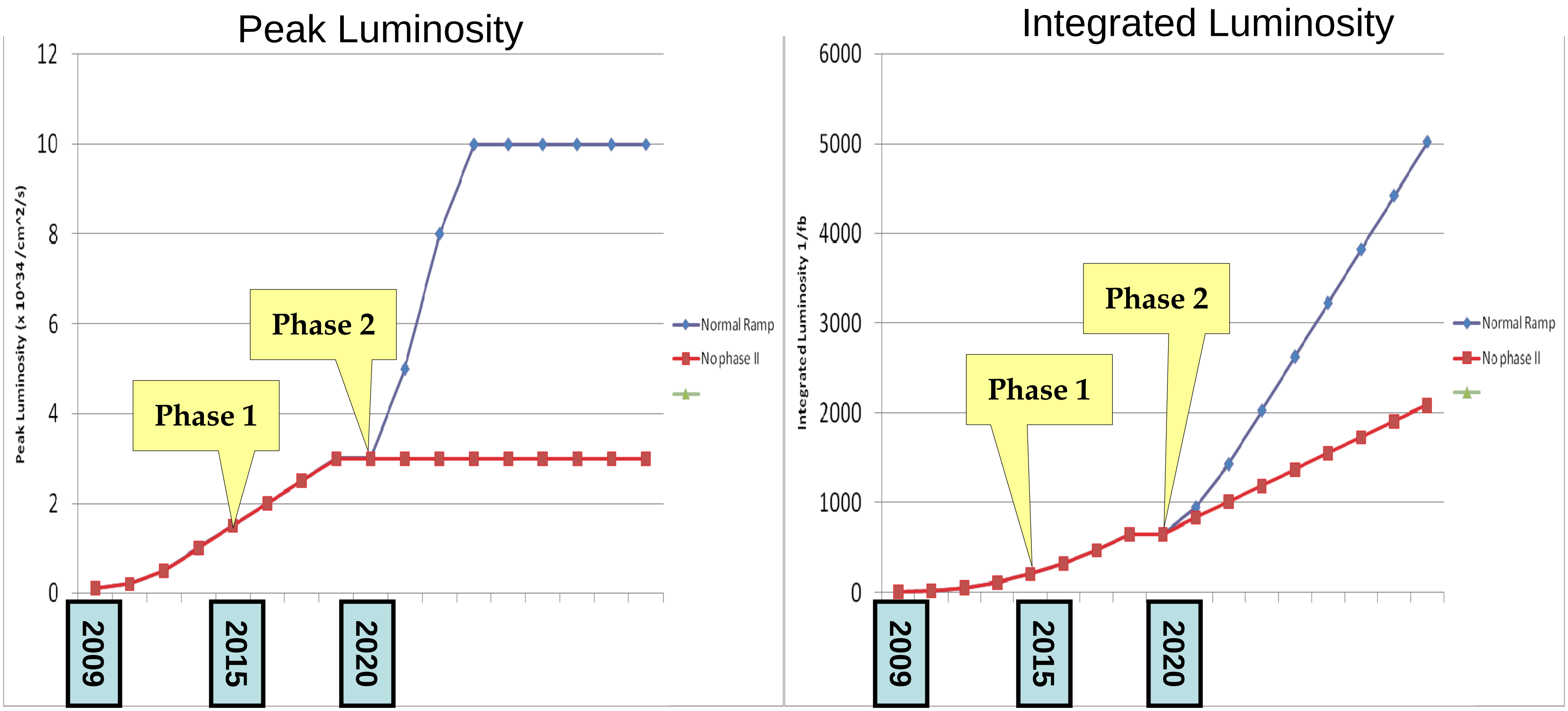
Theme 5: The Bay Area as an ATLAS physics center

White paper Section I.D, I.F, & IV

Orientation: The ATLAS detector



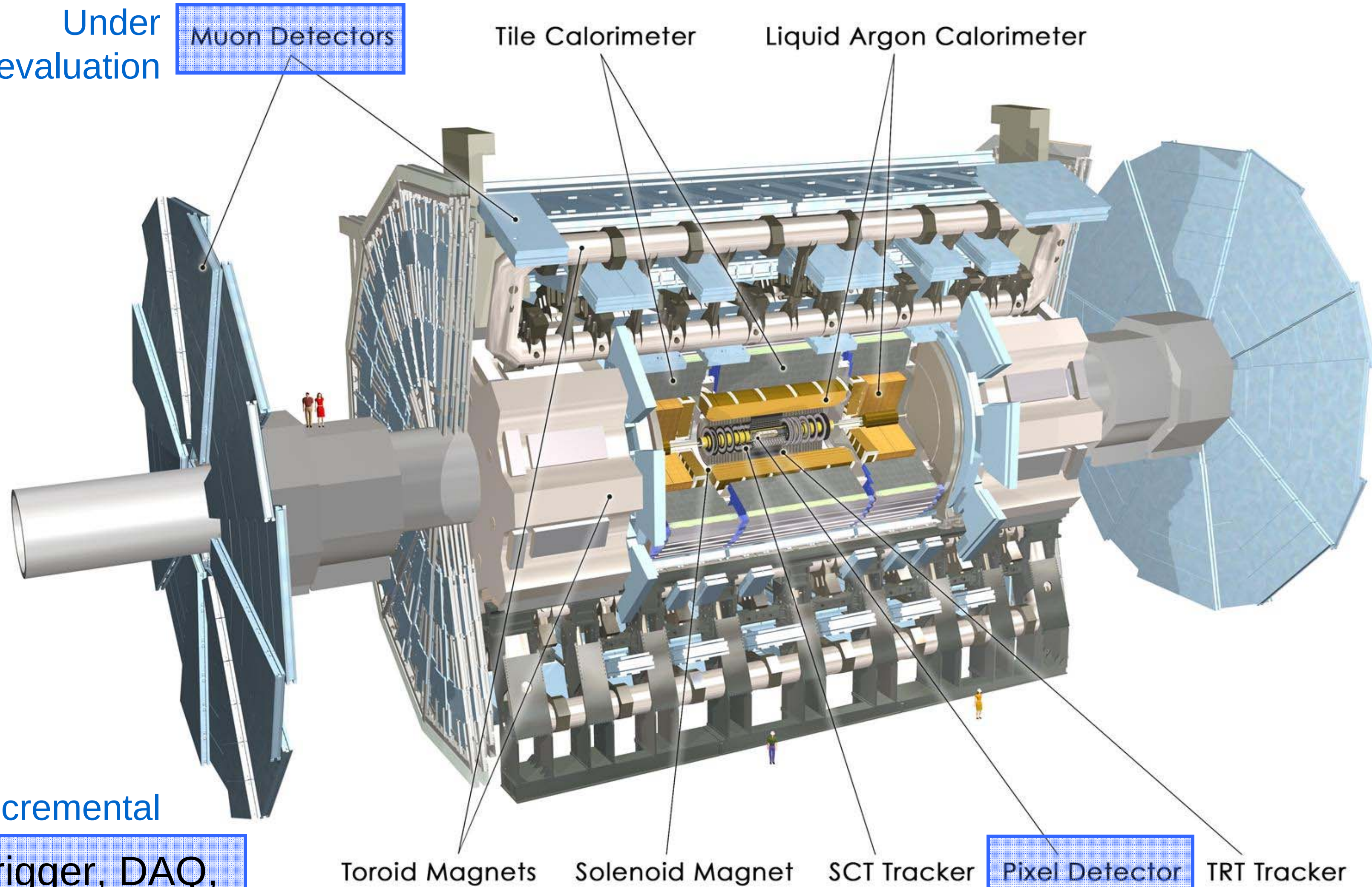
LHC luminosity and upgrade planning



Phase 1: peak luminosity $3x10^{34}$ and 700 fb^{-1}
Phase 2: peak luminosity $1x10^{35}$ and 3000 fb^{-1}

Potential Phase 1 US ATLAS upgrade projects

Under evaluation

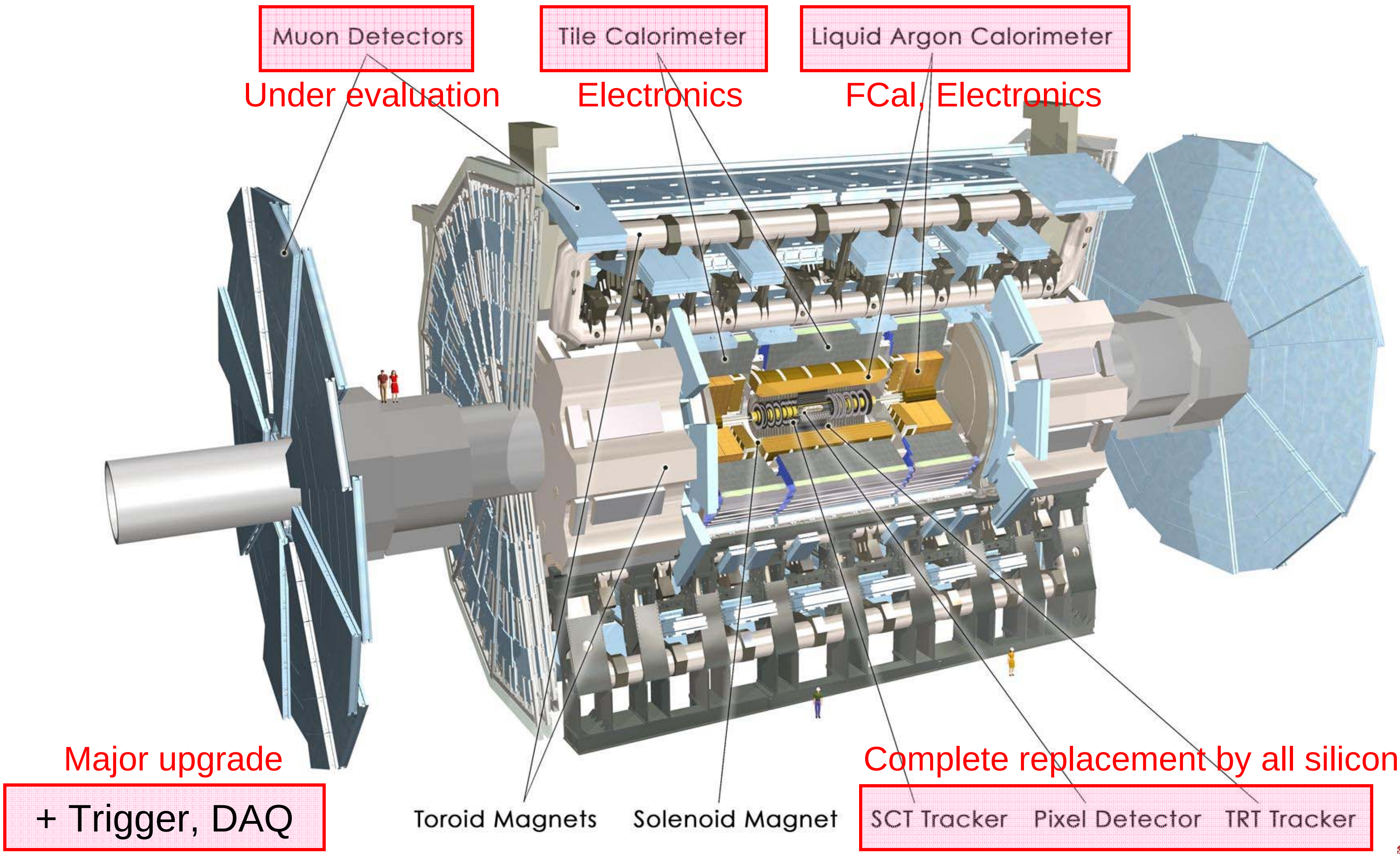


Incremental

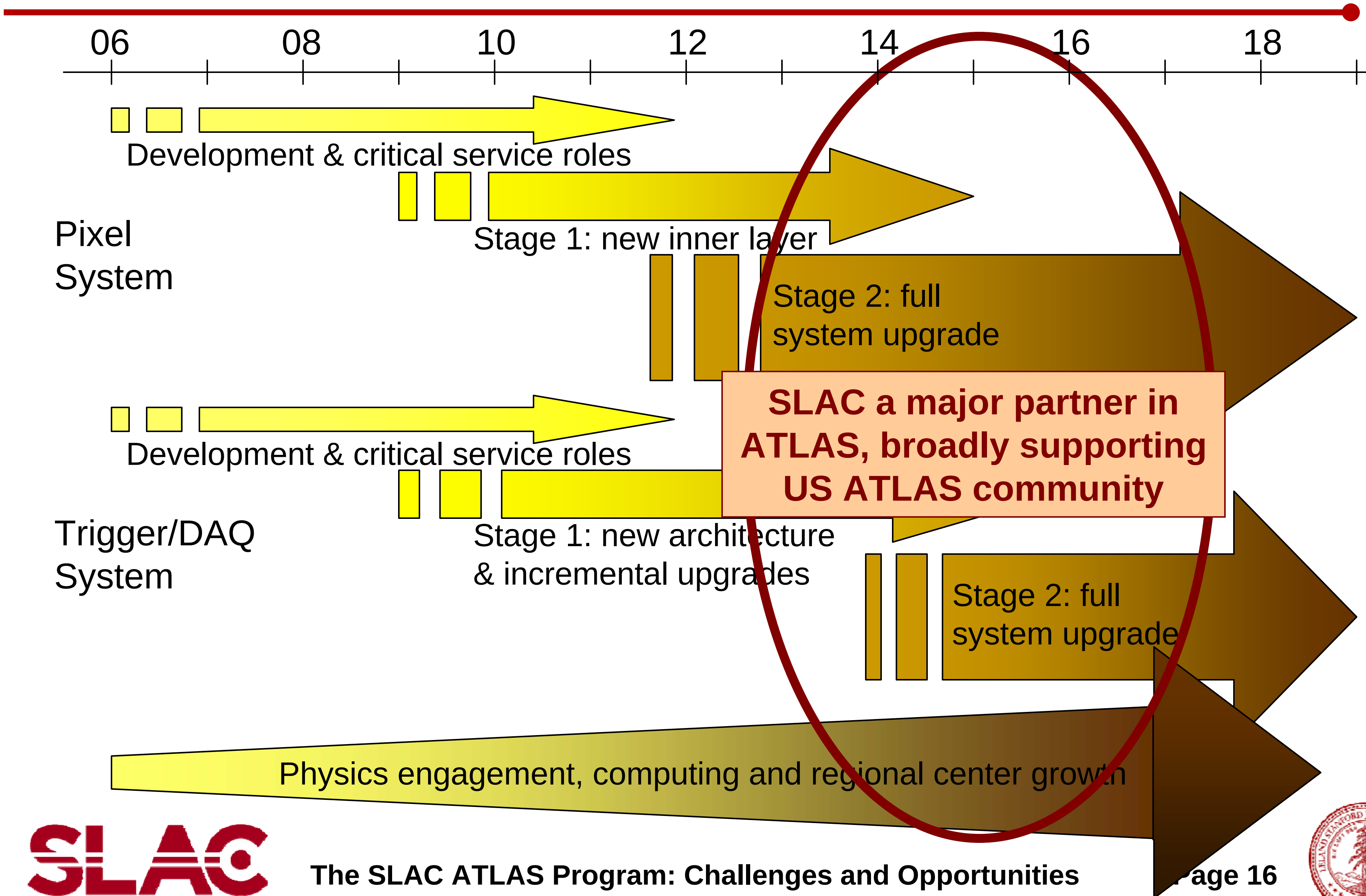
+ Trigger, DAQ,

Insertable B Layer

Potential Phase 2 US ATLAS upgrade projects



What is the overall long-term SLAC strategy?



What is our strategy for taking on ATLAS tasks?

- Engage in experimental tasks after weighing several different considerations:
  - Importance and urgency of ATLAS needs
  - Match to core competence at SLAC
  - Recognizing and incorporating our own ideas in defining tasks
  - Connection to our physics interests
  - Synergy with other areas of SLAC involvement
  - Synergy with future directions at SLAC
  - Synergy with local US community interests
- Not narrowly focused on one subsystem, but have tried to maximize integral impact to best utilize individual expertise
- Establish a broad base to allow future growth

Theme 1: Pixel System and tracking

- Motivation
  - Interests on b-tag related physics topics (experience from SLD/D0)
  - Experience on pixel/silicon detectors (SLD/SiD/MK-II/GLAST/BaBar)
  - Synergy with future silicon based experiment e.g. SiD

Current ATLAS pixel and tracking system activities:
Scientific staff: Martin Kocian, Tim Nelson, *Ariel Schwartzman*, Charles Young
Technical staff: Matthias Wittgen
Postdocs: Per Hansson, Claus Horn, Paul Jackson, Michael Wilson
Graduate Students: Bart Butler, David Miller, Dan Silverstein

Project lead, *Faculty*

Theme 1: Pixel System and tracking

Current ATLAS effort:

- Management responsibilities
  - Pixel run coordinator 2008-2009 (Charlie Young)
  - Pixel monitoring coordinator 2007-2008 (Charlie Young)
- Calibration and system tests
  - Pixel Read Out Driver (ROD) DSP software
  - Pixel calibration software analysis framework and system tests
  - Pixel environment monitoring software tools
  - Early pixel endcap surface cosmic test
- Tracking
  - Tracking alignment improvement with interactions displaced in Z
  - Tracking and pixel performance studies

Assisting the integration of affiliated university groups (U Iowa, Fresno State)

Theme 2: DAQ and High Level Trigger (HLT)

- Motivation:
  - Connection of trigger to physics strategy
  - Experience from BABAR in particular
  - Strong electronics and online software capability at SLAC

Current ATLAS DAQ and HLT system activities:
Scientific staff: Rainer Bartoldus, Philippe Grenier, *Andy Haas*, *Su Dong*
Technical staff: Andy Salnikov
Postdocs: Ignacio Aracena, Sarah Demers, Silke Nelson
Graduate Students: David Miller, Dan Silverstein

Current ATLAS CSC ROD system activities
Technical staff: Ric Claus, Gunther Haller, Ryan Herbst, Mike Huffer, Jim Panetta, Leonid Sapozhnikov

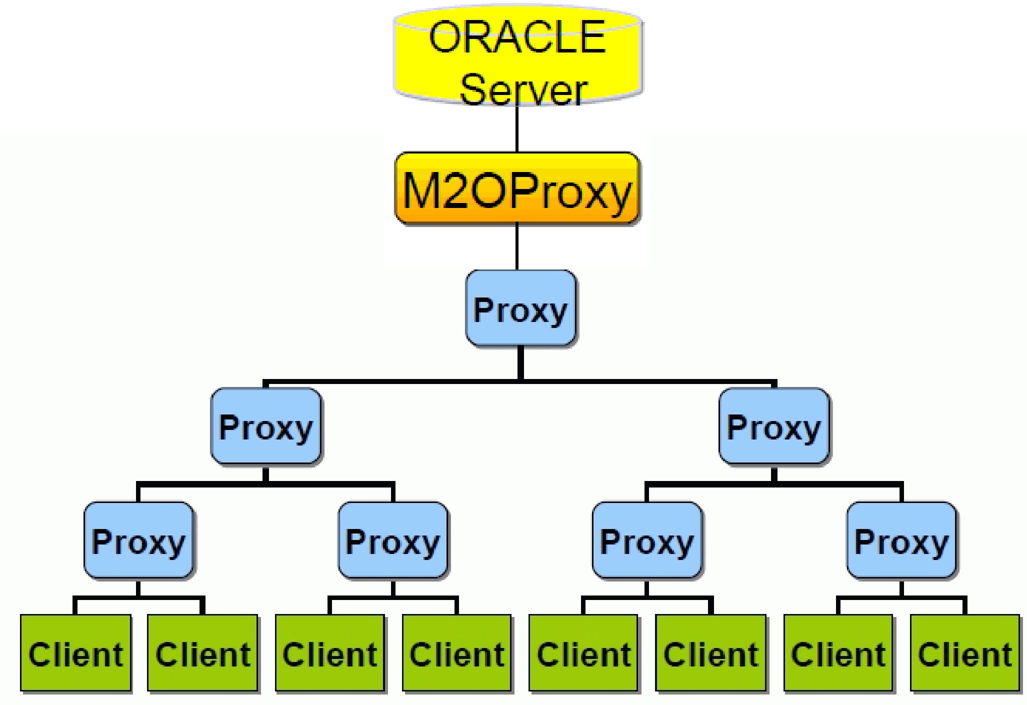
Theme 2: DAQ and HLT

Current ATLAS effort: DAQ and HLT

- HLT:
  - System for prompt configuration of the HLT farm (2000 nodes)
  - HLT commissioning
  - HLT trigger algorithm development: jet/Missing E_t, Tau, b-tag
  - Development of online beam spot monitoring, redistribution to HLT algorithms and display for LHC
- DAQ:
  - Implementation of partial event build capability to maximize DAQ bandwidth utilization for calibration
  - Support for UCI and commissioning of the muon Cathode Strip Chamber (CSC) Read Out Driver (ROD) system with major restructuring of software architecture and new firmware

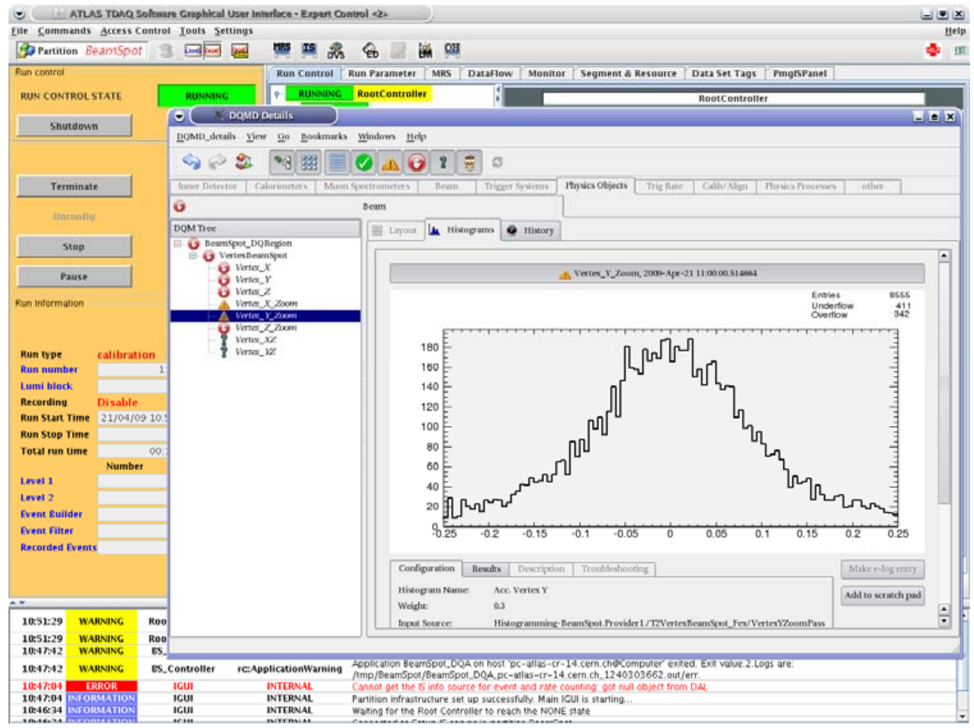
Example: HLT Configuration DbProxy

- 30MB configuration data for 16000 processes simultaneously
- Extra burden of translation between Oracle and MySQL
- Core SLAC expertise in online DB from BABAR



Example: Online Beam Spot

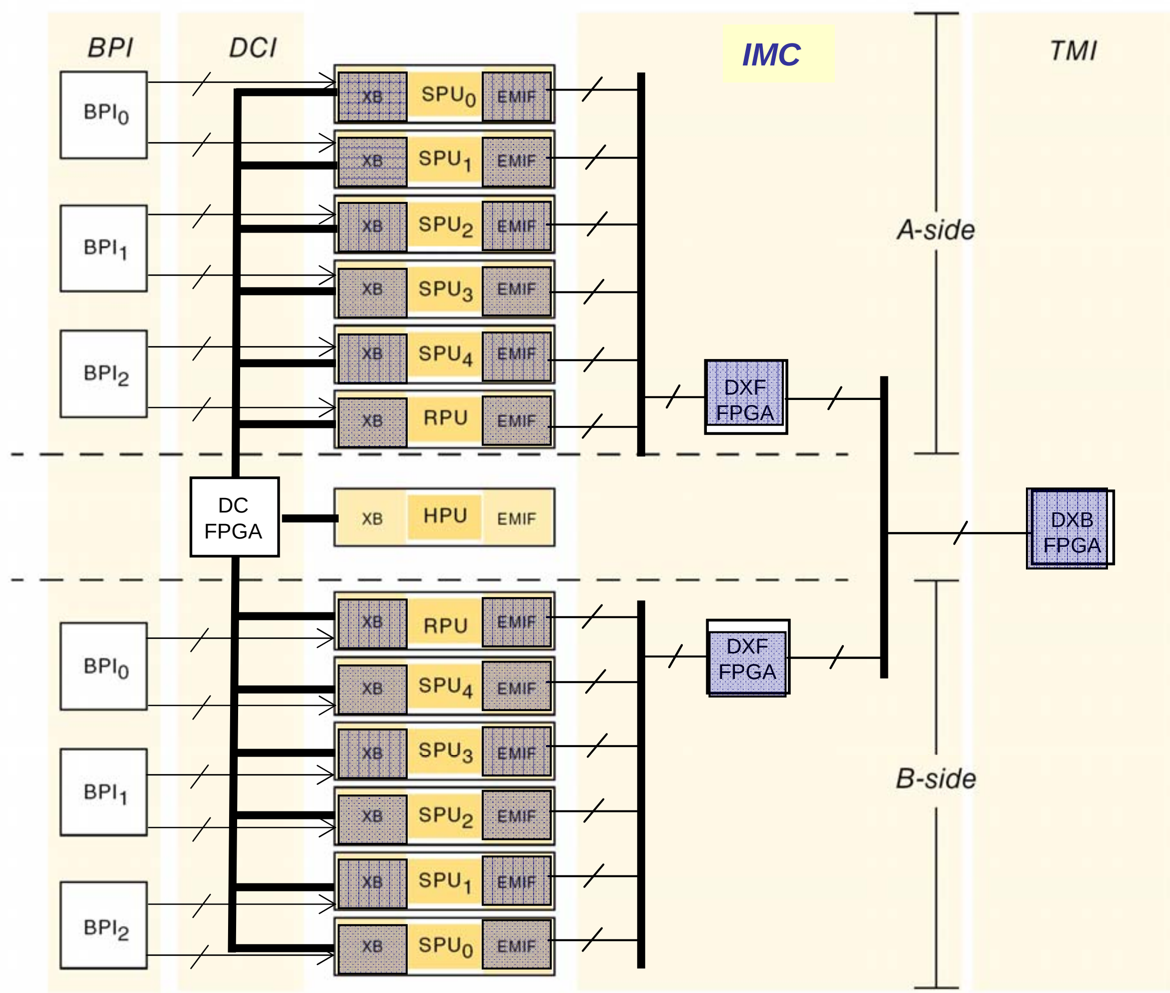
- SLAC initiative to establish project as part of HLT
- Complications in collections from 500 computer nodes and redistribution to HLT processes
- BABAR/SLD experience
- Synergy between pixel and HLT effort, and physics interest



Key monitoring information for LHC
First exploration of ATLAS ↔ LHC interface

Example: CSC ROD development

- Essential for muon CSC system
- Leverage strong electronics and DAQ expertise at SLAC to rapidly engage
- Major changes to firmware and software infrastructure
- Supporting university effort and US ATLAS responsibility

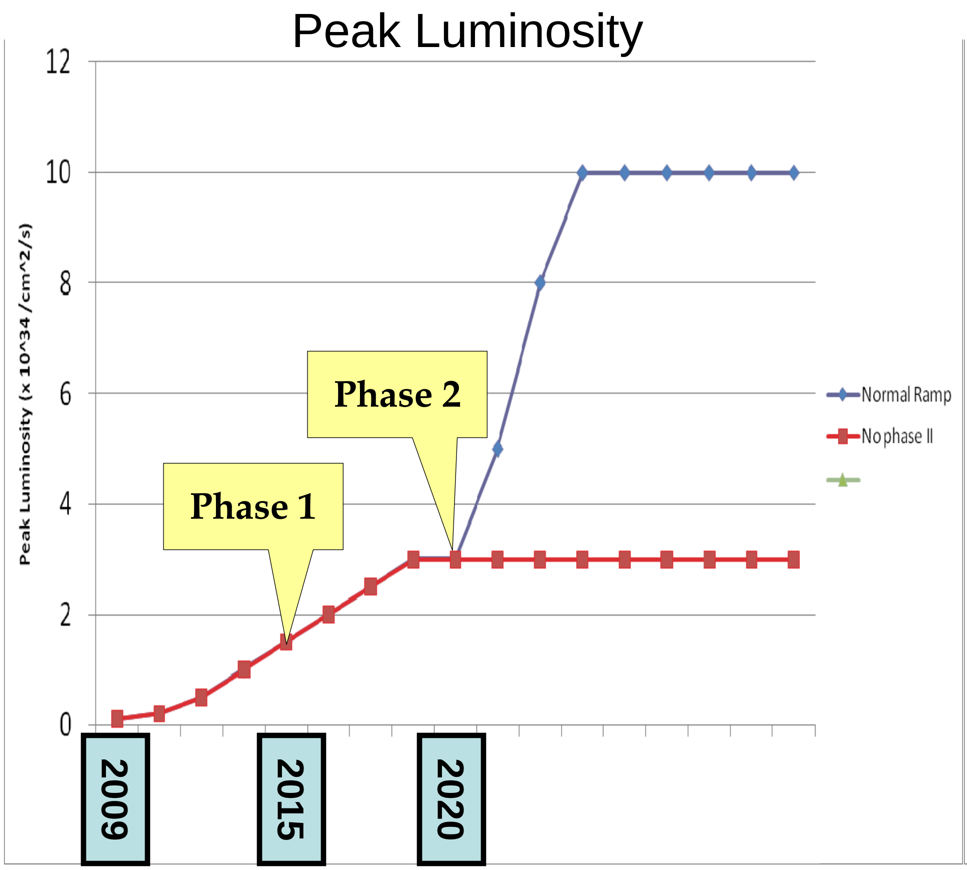


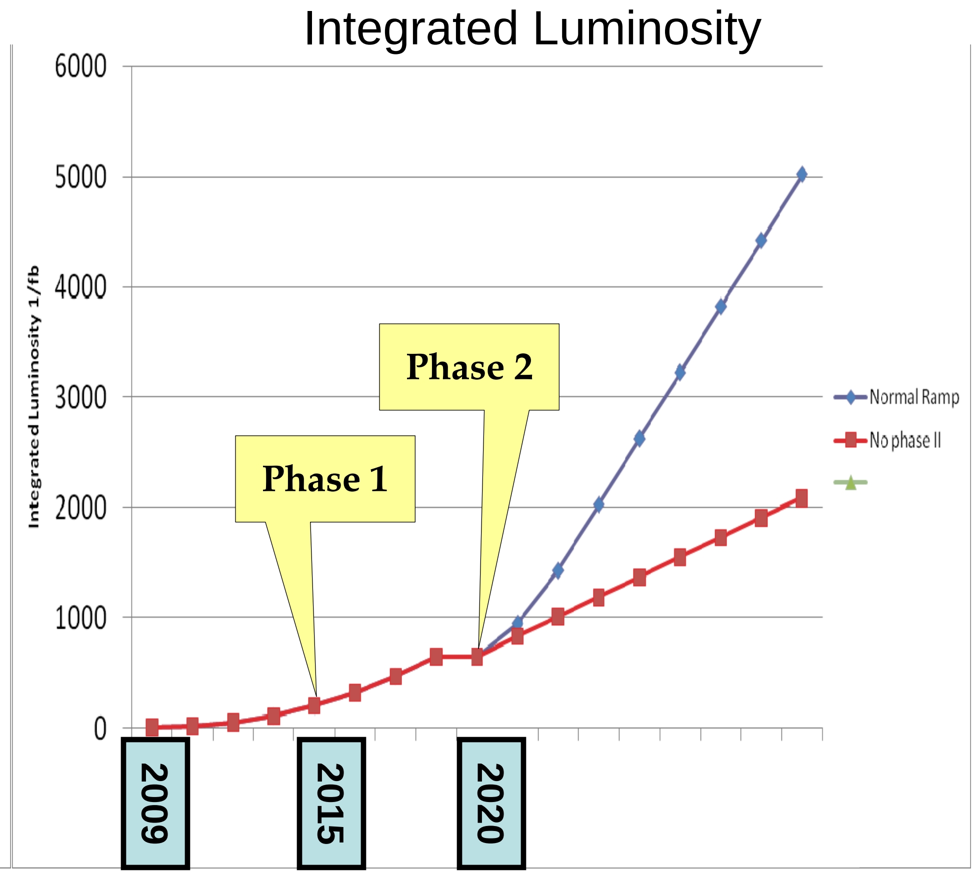
Theme 3: Simulations

- Current ATLAS effort: GEANT4 core support, performance enhancement and background simulations
  - First round speed up with fast shower
  - Muon simulation: proper geometry volume definitions
  - physics validation, and other improvements to the code
  - Contributions to data event overlay to simulation and zero-bias background event sampling
  - Recent FLUKA effort to simulate cavern backgrounds
  - Leading next steps in performance improvement and background studies with Charlie Young as ATLAS simulation coordinator

Current ATLAS simulation activities:
Scientific staff: Makoto Asai, Norman Graf, Michael Kelsey, Peter Kim, Charles Young, Dennis Wright

LHC luminosity and upgrade planning

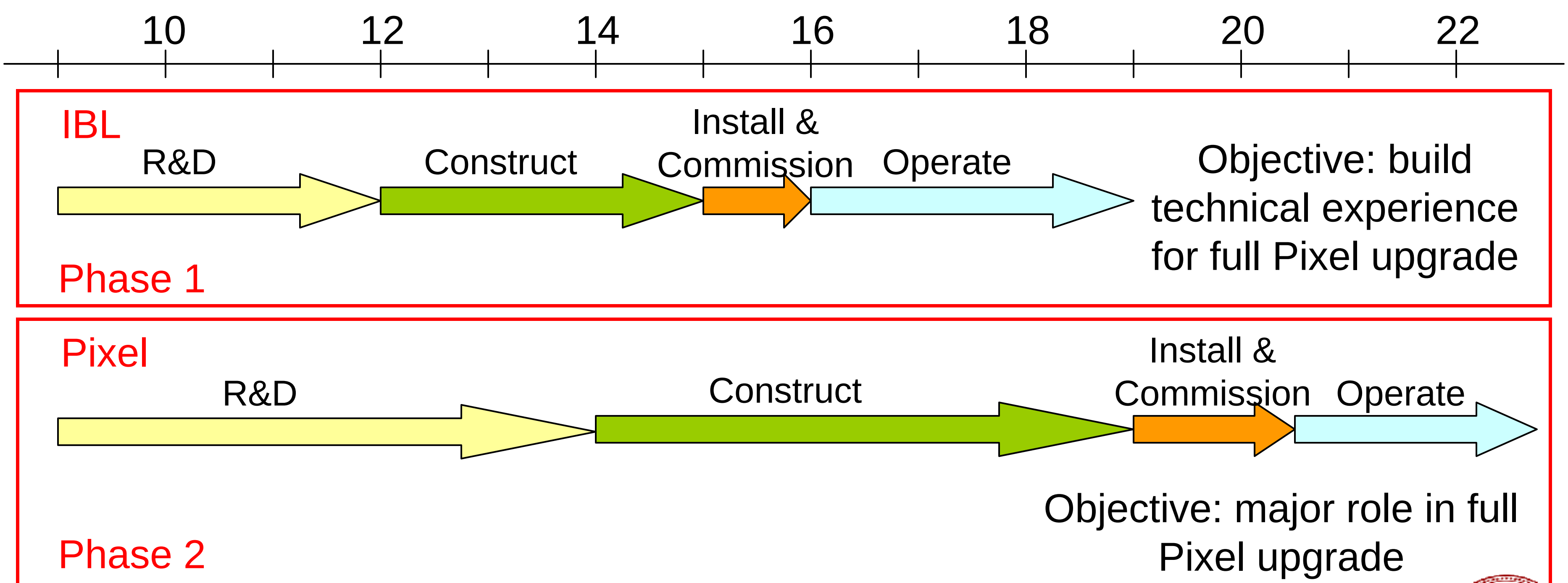




Phase 1: peak luminosity 3×10^{34} and 700 fb^{-1}
Phase 2: peak luminosity 1×10^{35} and 3000 fb^{-1}

SLAC/ATLAS program in the next decade

- Theme 1: Major player in Pixel upgrade construction and eventual operations
  - Build on the mechanical & electrical design and device development capability



Theme 1: Upgrade Pixel System and tracking

- ATLAS pixel and tracking system R&D related activities
  - Phase 1: Pixel Insertable B-Layer (IBL) development project
  - Phase 2 (but some may become phase 1):
    - Pixel upgrade 3d sensors
    - Tracking upgrade mechanical designs
    - Pixel upgrade data transmission and stave electrical design
    - Silicon strip detector barrel stave electrical design
    - Tracking upgrade test stand and DAQ

Future IBL and full pixel upgrade R&D activities:

Scientific staff: Mark Convery, Philippe Grenier, Per Hansson, Jasmine Hasi, Paul Jackson, Chris Kenney, Peter Kim, Martin Kocian, *David MacFarlane*, *Su Dong*, Bill Wisniewski, Charles Young

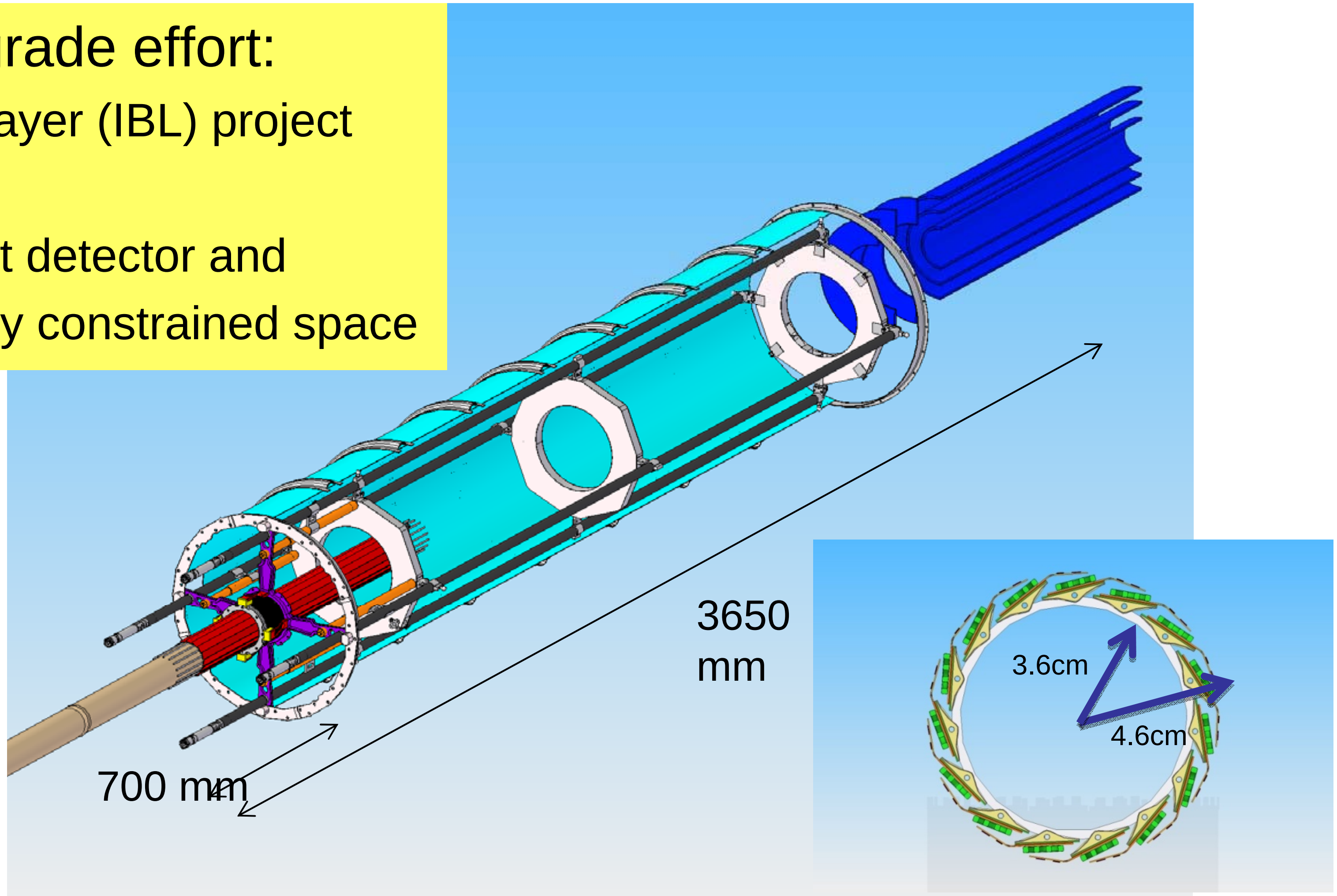
Technical staff: Karl Bouldin, Ric Claus, Jim McDonald, David Nelson, Marco Oriunno

Theme 1: Upgrade Pixel System and tracking

Stage 1 upgrade effort:

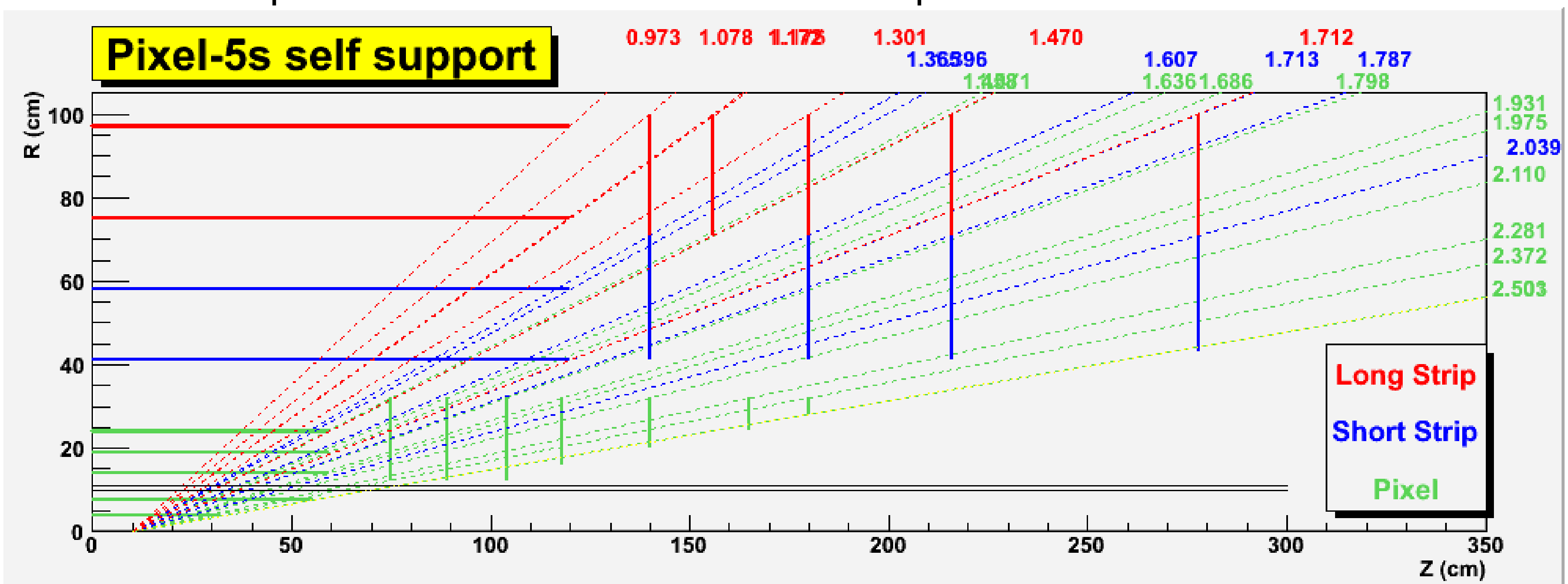
Insertable B-Layer (IBL) project

Challenge to fit detector and services in very constrained space



Theme 1: Upgrade Pixel System and tracking

- Stage 2 Upgrade: replacement Pixel System for super LHC
  - 1m radius, 6m long all silicon tracking system
  - ~8m^2 pixel detector and ~65m^2 silicon strips



SLAC study of the layout geometry

Theme 3: Upgrade Simulations

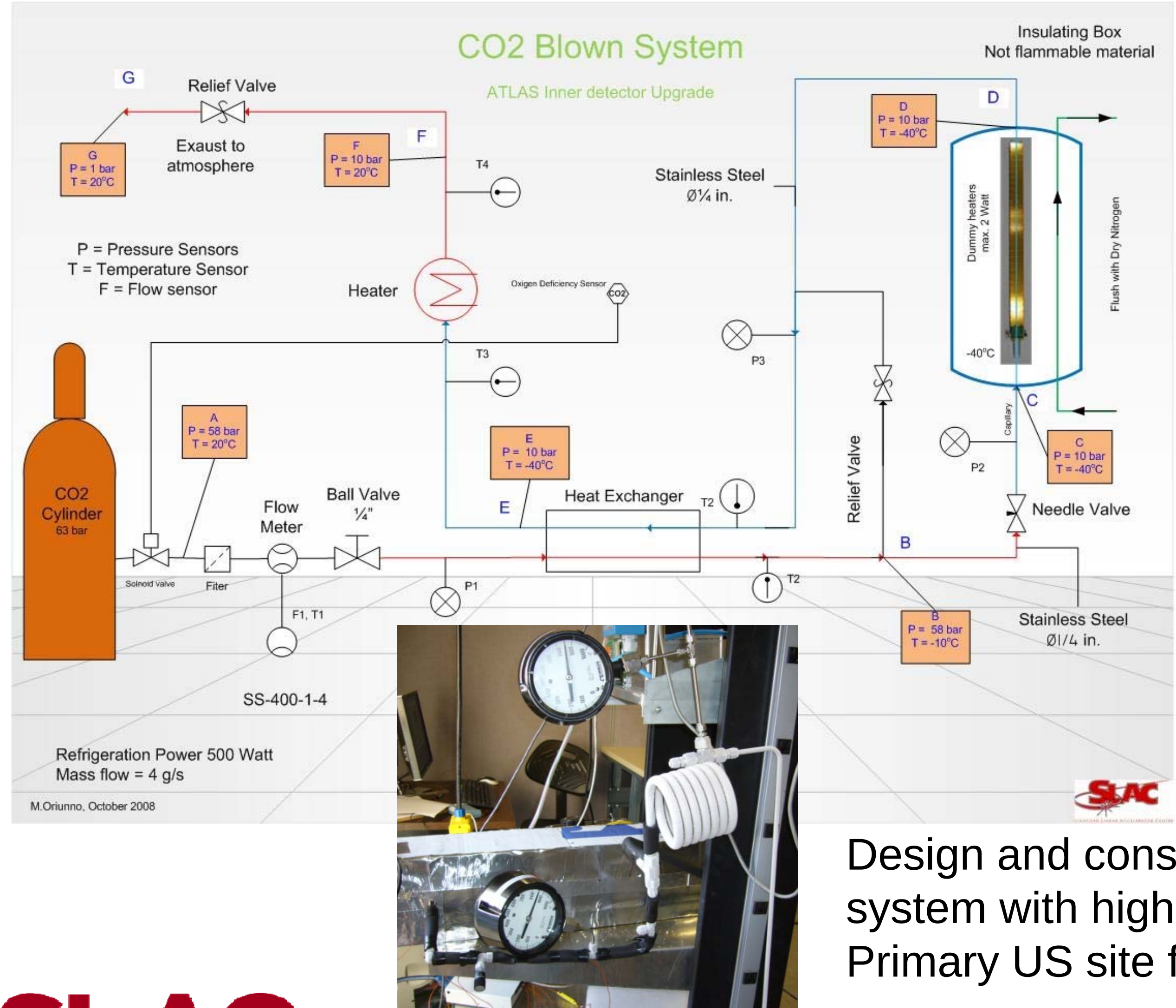
- Pixel and Tracking Systems layout studies
  - Basic upgrade layout design decisions for the future Pixel and Silicon Tracker Systems need simulation support.
  - We propose to use existing ATLAS simulation tool kit in conjunction with the linear collider framework Lcsim (more flexible geometry variations), to provide physics and performance guidance to these design decisions

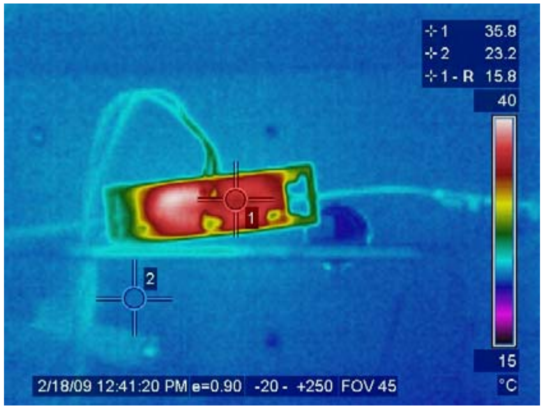
Future ATLAS tracking system simulation activities:
Scientific staff: Rich Partridge, Charles Young
Postdocs: Matthew Graham, Michael Wilson

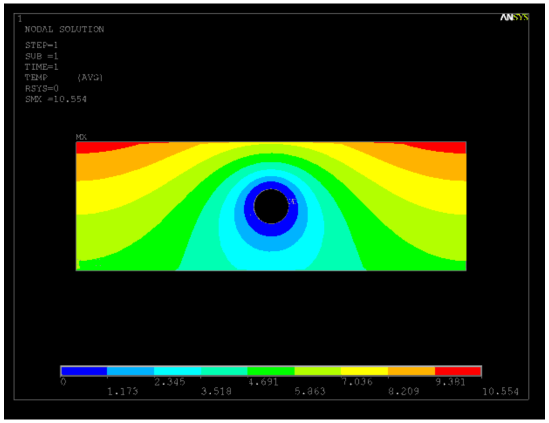
Theme 1: Upgrade Pixel System and tracking

- Upgrade Pixel System for super LHC
  - We are working closely with LBNL/UCSC, and ATLAS as a whole, on various R&D issues towards a super LHC pixel detector:
    - 3d pixel sensors
    - Multi Gbit/s electrical data transmission
    - Electrical stave design
    - CO_2 cooling test facility and thermal tests
    - Mechanical designs
    - New test stand and DAQ
  - Preparing infrastructure as a possible site for assembly and testing.

Example: stave thermal and cooling testing with CO_2



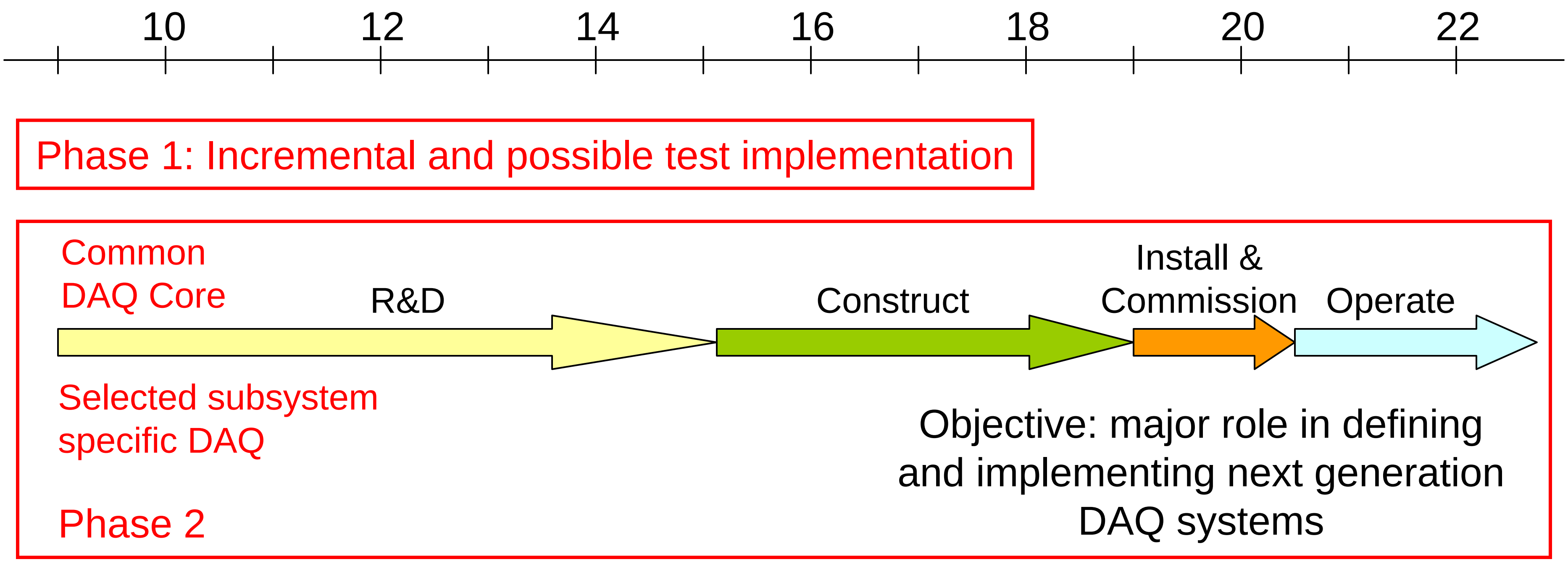




Design and construction of closed loop system with higher capacity in progress. Primary US site for stave cooling tests.

SLAC/ATLAS program in the next decade

- Theme 2: Major player in defining next generation TDAQ architecture
  - Aiming at an integrated common read out system. Sustaining and enhancing core detector electronics system design capability



Theme 2: Upgrade DAQ and HLT

- Some initial directions for DAQ and HLT upgrade

  Challenge of growing data rate:

  – 400 interactions per beam crossing at sLHC

  – HLT farm already needed 2000 computers at phase 1

  Possible approaches:

  – Continuous improvements with adiabatic upgrades expected.

  – Much improved HLT computing resource usage

  – New DAQ infrastructure

Future ATLAS DAQ and HLT system R&D activities:

Scientific staff: Rainer Bartoldus, Martin Kocian, *Andy Haas*, *Su Dong*

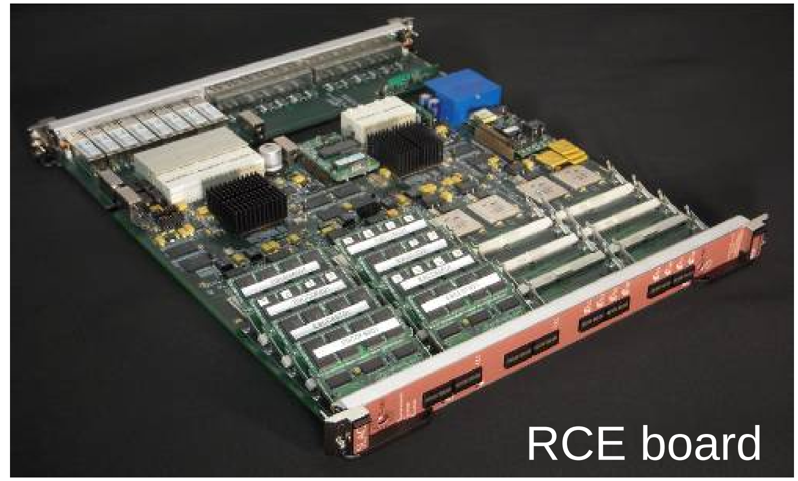
Technical staff: Ric Claus, Gunther Haller, Mike Huffer, Jim Panetta, Andy Salnikov, Matthias Wittgen

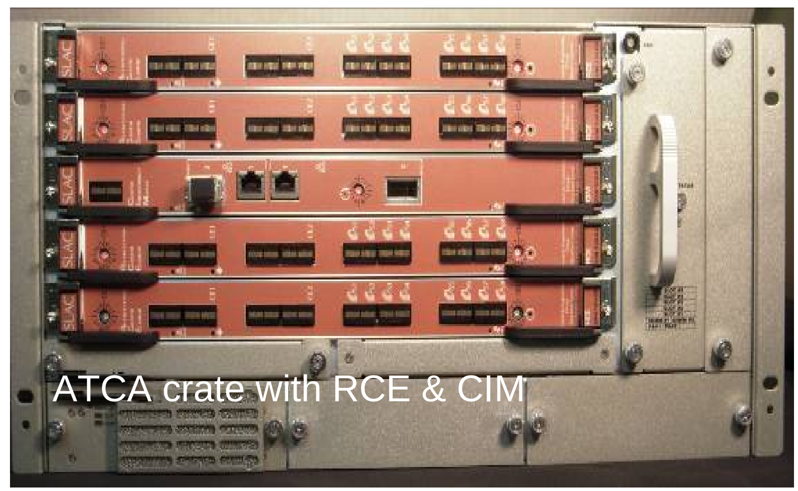
Possible upgrade path for ATLAS TDAQ

- Generic high performance DAQ research at SLAC: Reconfigurable Cluster Element (RCE) concept on ATCA platform
- Well advanced R&D serving many other projects already: Peta-cache, LCLS, LSST
- Proposal to explore common ATLAS ROD development with RCE platform well received. ATLAS wide RCE training planned for June at CERN.

Pixel upgrade example:

- 18 x old pixel detector data rate.
- new Readout Modules with ¼ hardware footprint of the old ROD + S-Link + ROS PC plant is sufficient





Theme 4: Tier 2 and Analysis Facility

- Planning for ATLAS computing and analysis well advanced
  - Based on a 3-tiered & distributed model similar to BABAR
- ATLAS Tier 2 center at SLAC represents about 20% of the installed BABAR computing hardware
  - ATLAS now has access to a much larger pool of available CPU cycles through general queue access to BABAR hardware
- Future ATLAS computing needs may require major additional resources
  - Physics tools and algorithm development with multiple reprocessing of significant fractions of events
  - Alignment calibration & development with calibration data streams
  - Development and validation of high-level trigger algorithms

Theme 4: Tier 2 and Analysis Facility

- Future direction for ATLAS Tier 2 & 3 implementation also needs clarification
  - Hosting Tier 3 centers at SLAC may be an attractive option, both in terms of maintaining efficient operation and sharing CPU resources
  - Present model for limited Tier 2 analysis role may evolve anyway based on real experience with data and analysis
- Working to develop a model for a Western Data Analysis Facility at SLAC
  - Migrate from BABAR dominated to ATLAS dominated computing hardware operation, within site power and cooling capabilities
  - Understand economies of sharing support personnel, CPU and disk hardware across Tier 2 and Tier 3 needs
  - Integrate into US ATLAS and ATLAS planning for Tier 2 & 3 planning and initial experience with data

Theme 4: Tier 2 and Analysis Facility

Current ATLAS Tier 2 activities:

Scientific staff: Richard Mount, Peter Kim

Technical staff: Wei Yang, Douglas Smith + SCCS personnel

Development of plan for future ATLAS computing role

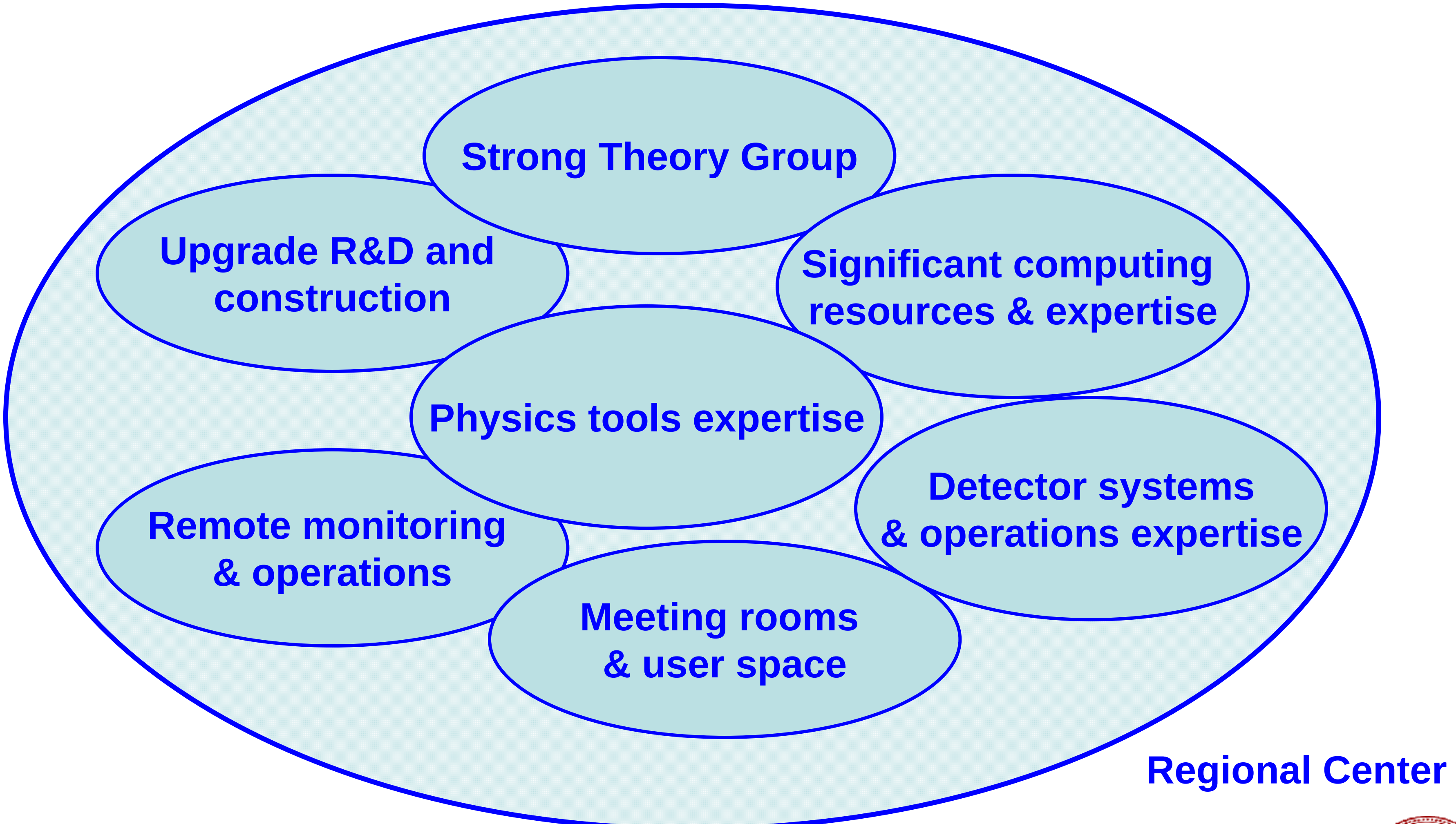
Scientific staff: *Andy Haas*, *David MacFarlane*, Richard Mount

Postdocs: Matthew Graham

Theme 5: The bay area as a west-coast ATLAS center

- CERN cannot host major portions of the LHC collaborations long term
- The Bay Area could play a leading role in supporting LHC physics
  - Concentration of expertise on computing, analysis and detector systems
  - Proximity of physics analysis support centers, capability for hosting workshops, tutorials and seminars
  - Attractive training centers due to a combination of tutorials, available expertise, & participation in upgrade activities
  - Strength of Theory Groups & their strong interest in LHC physics
- Working to create a consensus in the US ATLAS community for a viable regional center role

What are elements of a west-coast center?



Physics tools example: current activities within the Jet/Met/b-tag group

High Level Trigger:

- L2 b-tag: chi2 probability, secondary vertex (A. Schwartzman/SLAC)
- L2 ME_T, mH_T, Jet (I. Aracena/SLAC)

Jet/ME_T reconstruction and energy scale:

- Tower-jet reconstruction/noise suppression (D. Miller/Stanford)
- Jet energy resolution measurement (G. Romeo/U. Buenos Aires)
- Semileptonic b-jet energy scale (D. Lopez/Columbia)
- Missing E_T significance (B. Butler/Stanford and K. Perez/Columbia)

Jet/ME_T improvements using tracks:

- Track-based jet energy corrections (Z. Marshall/Columbia)
- Jet-Vertex Association, pile-up corrections (D. Miller/Stanford)
- ME_T fake rejection using tracks (S. Majewski/BNL)

Hadronic flavor tagging:

- Gluon bb tagging (A. Schwartzman/SLAC)
- Quark/gluon tagging (A. Schwartzman/SLAC)
- b/c flavor separation (A. Schwartzman/SLAC)

accomplishments:

- 10 internal ATLAS notes.
- 5 contributions to public ATLAS notes.
- 2 conference posters.
- 3 APS talks.
- several new official ATLAS software packages.

Summary of challenges to SLAC/ATLAS plan

- Migration of core manpower
  - Viewed as a budget increase in the national proton research program, for which a case must be convincingly argued
  - Need to continue arguing the case for planned expansion of program to match planned ambitions
- Computing role
  - Tier 2 computing role relatively minor compared to capability
  - Need to develop arguments for significantly enlarged scope of computing support anticipating future directions for demand growth
- Regional center concepts for enhancing US role in the LHC is not a demonstrated or accepted paradigm
  - Working with SLUO and US ATLAS to better understand needs of the US community

Summary of challenges to SLAC/ATLAS plan

- Scope of US and SLAC role in ATLAS upgrades
  - Large number of upgrade projects being considered, but OHEP has capped the upgrade budget at $175M for each of ATLAS and CMS
  - ATLAS collaboration just now putting in motion a plan to eventually establish national and institutional roles on upgrades
  - Timescale, particularly for superLHC phase 2, still very uncertain
  - Need to continue working with US ATLAS community to identify high priority upgrades and appropriate US roles
- Overall leadership
  - Continuing to work to engage sufficient faculty and senior staff leadership

Why aren't there more faculty on ATLAS?

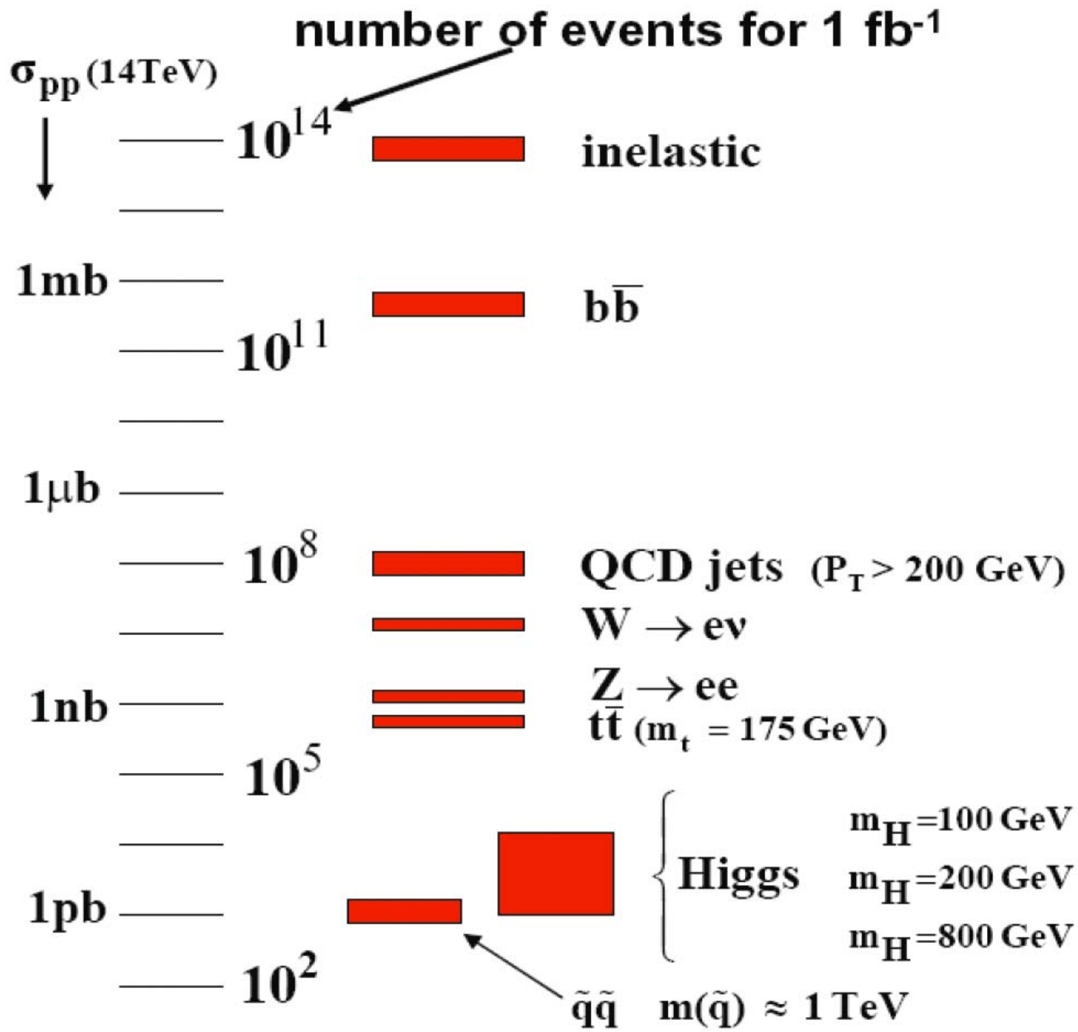
- Total of 8 experimental particle physics faculty, including one junior
  - Current faculty research directions: ATLAS (3), SiD (1.5), EXO (0.5), BABAR (2 + 2 x 0.5)
  - Of the remaining BABAR effort, one will retire, one pursues SuperB, and remaining 2 x 0.5 are moving to LSST & dark energy
  - Further migration to ATLAS will come at the cost of SiD and SLAC's leadership role for the ILC detector program

Overall summary and outlook

- SLAC is moving to significantly expand our role on ATLAS
  - Motivated by sustaining an energy frontier physics program at the LHC in the mid-term and eventually the ILC in the future
  - Matching core capabilities and operational expertise in areas that are unique and/or appropriate for a national lab program
  - A cornerstone of the future accelerator-based HEP program
- Moving forward with indentifying crucial upgrade roles
  - Plan supports some of the crucial system upgrades that are anticipated to be major future responsibilities for the US community
- Taking on appropriate roles for national lab in support the highest priority LHC program
  - Significantly enlarged ATLAS program will provide a strong anchor on the west coast for maximizing return on US investment in ATLAS

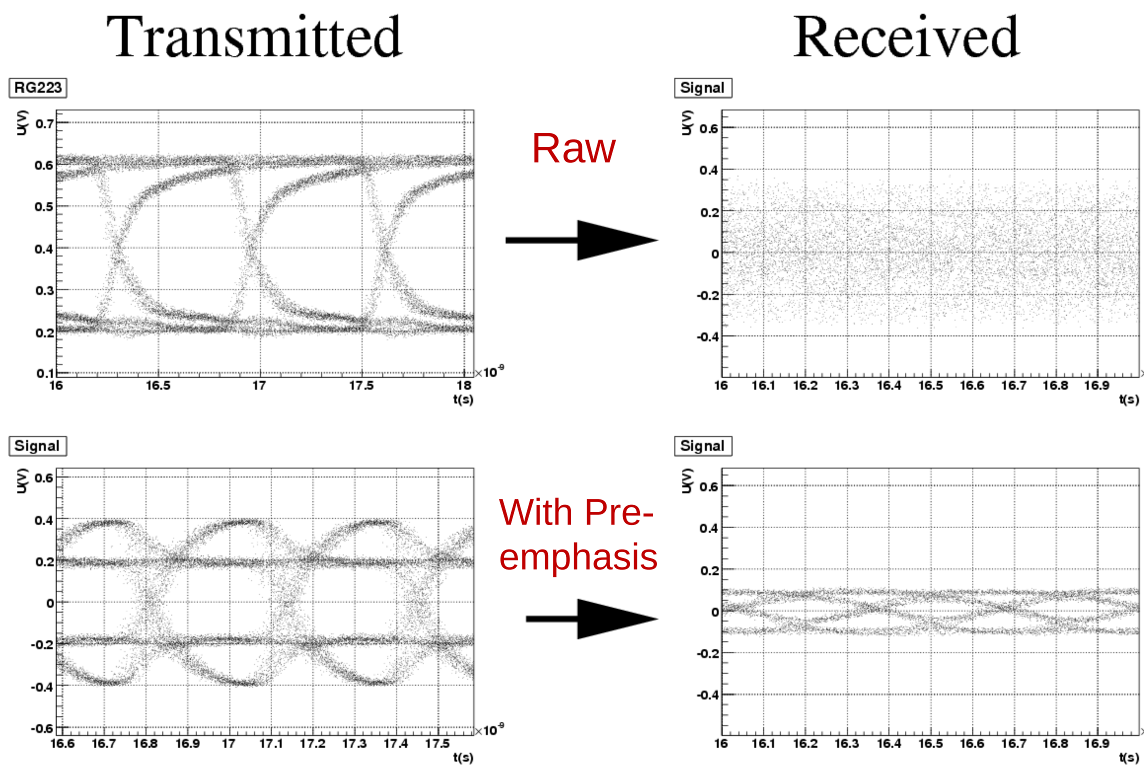
Backup material

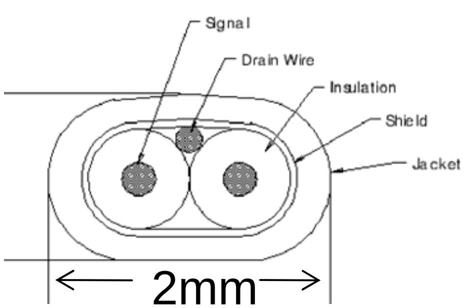
A primer on cross sections at the LHC



Example: data transmission R&D

- sLHC inner pixel radiation dose prohibits optical transmission
- Unique R&D on Gb/s electrical transmission with microCoax and using pre-emphasis and encoding techniques.
- Custom twinax cable



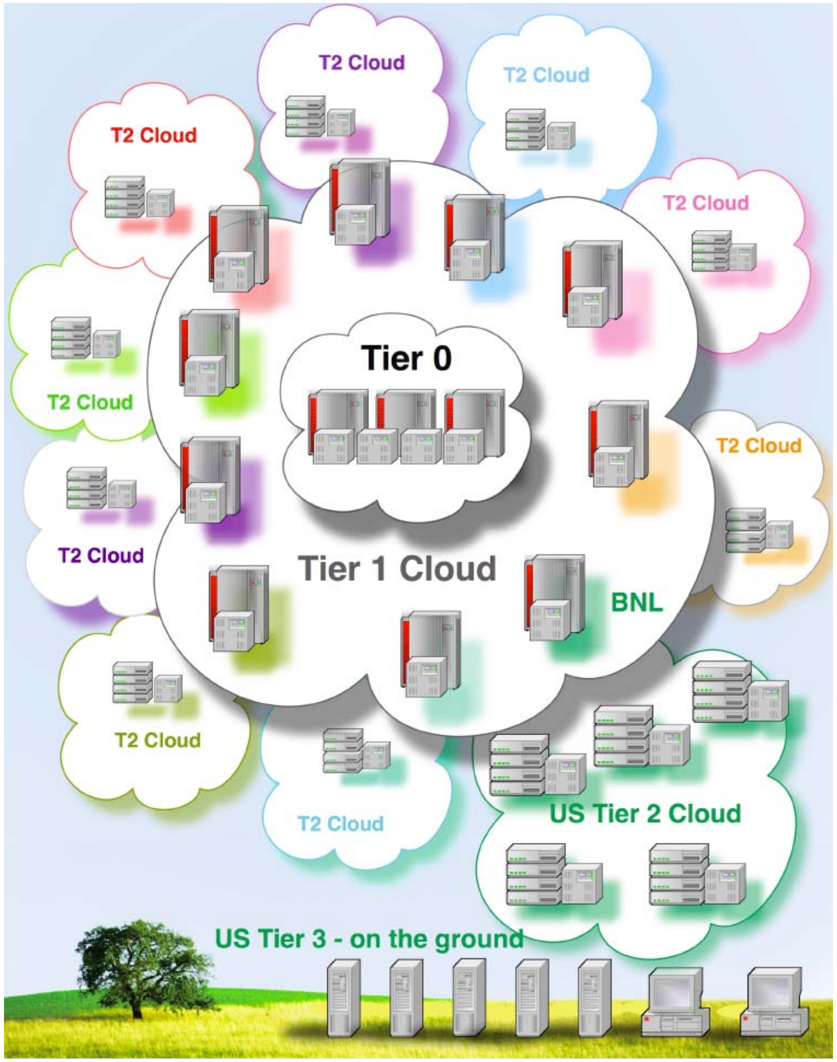


Pre-emphasis demo with LAr kapton cable @ ~1Ghz

Achieved >4Gb/s over 4m with encoding/pre-emphasis

Balancing factors: Transmission quality, radiation hardness, material budget

ATLAS Computing Model



Physics Preparation Activities

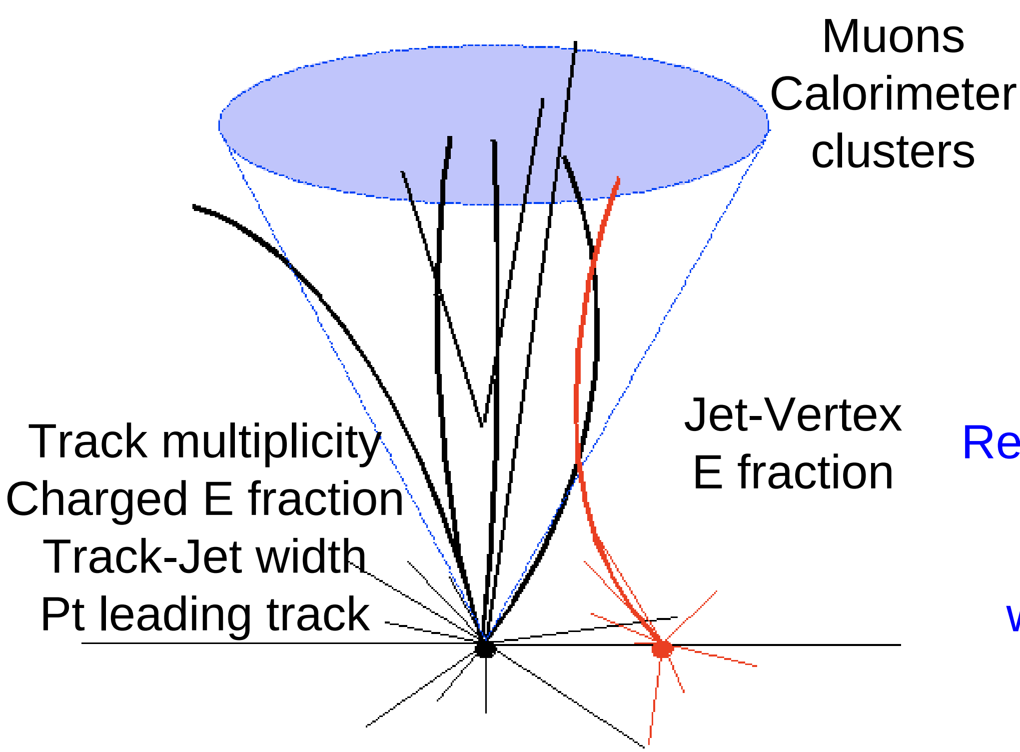
- Emphasis on building expertise on physics signature reconstruction and trigger:
  - Grass root Jet/MissingEt/b-tag analysis group
  - ATLAS jet energy calibration task force coordination (*Ariel Schwartzman*)
  - Trigger algorithm (jet/MET/tau/b-jet) and menu development
  - Tracking and alignment
  - Pileup study / simulation
- Main physics interests in new physics searches, in conjunction with initial SM measurements to assist development and validation of the physics tools.

Current physics analysis topics

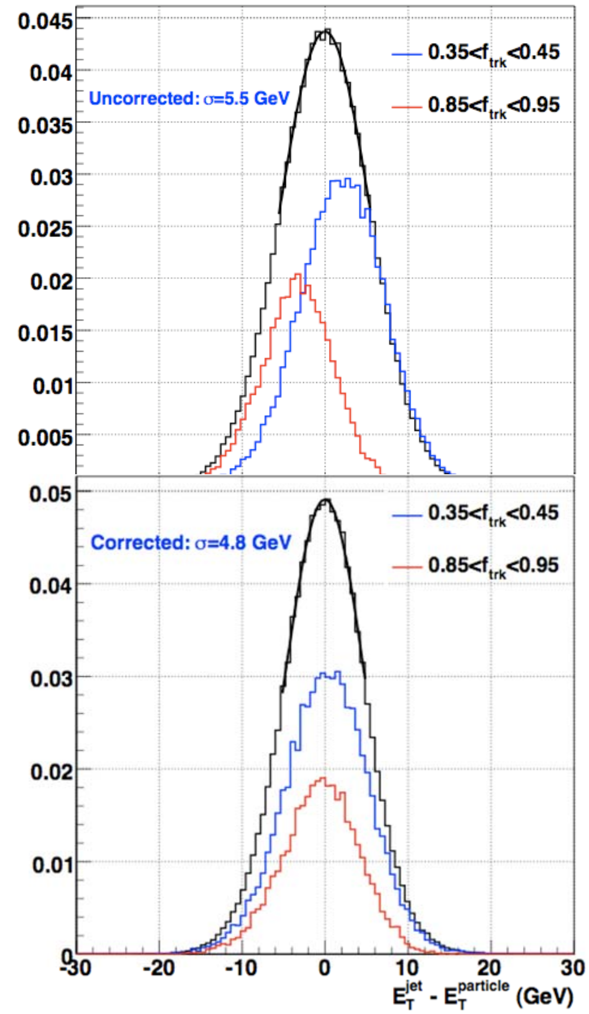
- Measurement of $t \rightarrow \tau + x$
- $t\bar{t}$ cross section with b-jet + MET
- $(tW)(\bar{t}W)$ same sign dilepton search
- R-Parity Violating SUSY search with displaced vertices
- Stopped gluino search
- New physics search with b-jet + MET
- SUSY Higgs from bbH/A production (trigger study)

Example: Tracking input to jet reconstruction

Aim: Improve calorimeter-jet energy measurements using tracks to extract information about jet topology and fragmentation, and correct jet response.



Example:
Reduce jet-by-jet energy fluctuations with tracking



Reflections on Experimental Involvement

- The experimental and upgrade projects where we succeeded well through creativity and expertise has shown to be primarily leveraging experience from recent HEP experiment, in particular BABAR.
- Heading into the future, the ATLAS experience can also be expected to be the primary base for sustained competence for ambitions in future energy frontier endeavor.

superLHC: an inevitable path for HEP ?

- Early discoveries at LHC would imply the effective extra energy reach (~30-40%) at high lumi could uncover additional new particles. That extra reach is likely to have complementary physics to Linear Collider.
- If early phase of LHC not revealing new physics, it would be hard to argue for other new facilities. sLHC will be taking on an even central focus of hope for new physics through its effective additional energy reach.