U.S. ATLAS

U.S. ATLAS in the Next Decade

Brookhaven

March 6, 2008

A. Seiden

UCSC

Outline of Talk

- Introduction to U.S. ATLAS Collaboration.
- Research Program now and into future.
- Construction Requests for SLHC:

  1) Organization of R&D.

  2) New Inner Detector.

  3) Other Detector Components.
- Budget Summary.

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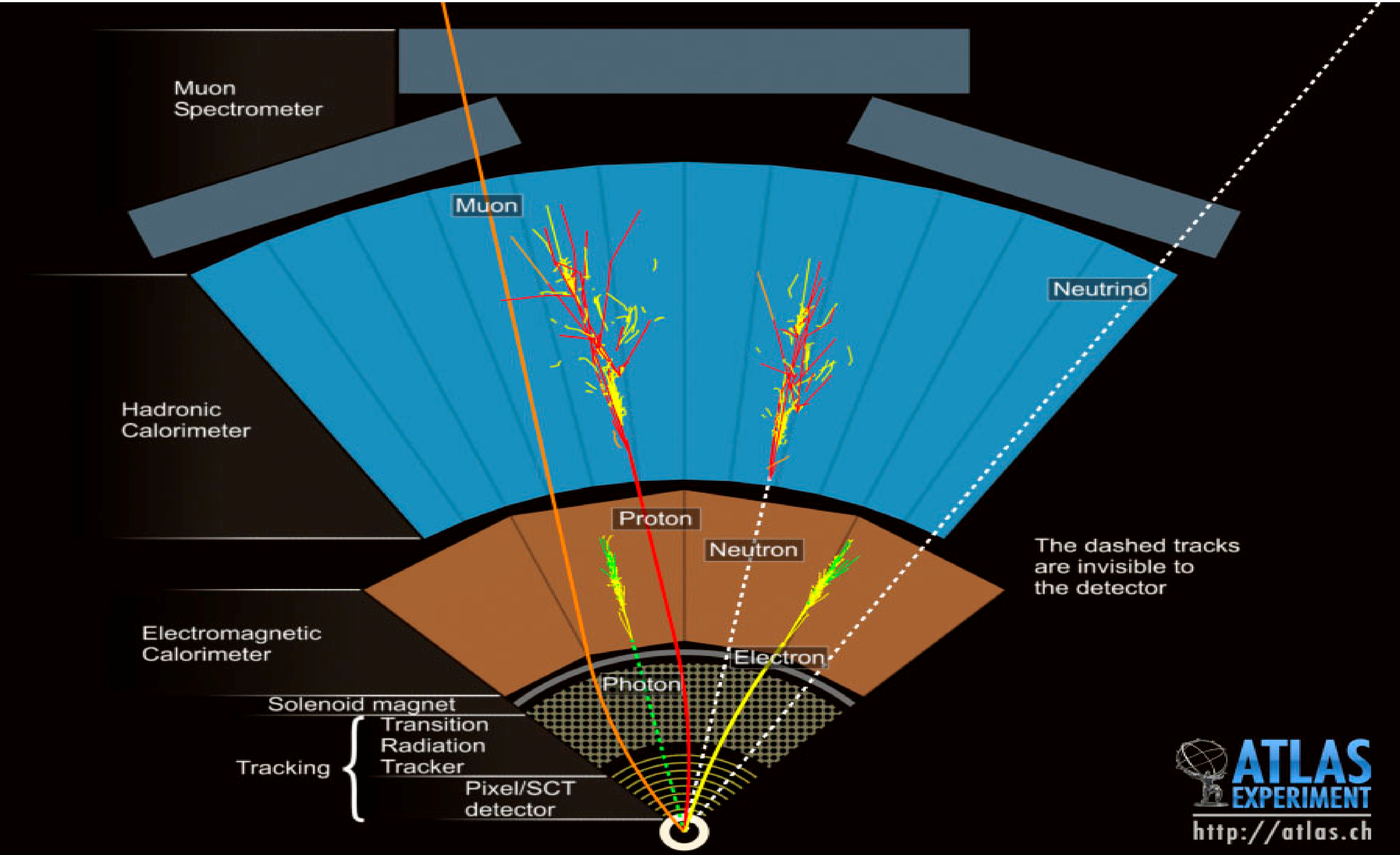
Detector Capabilities Required at the LHC



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US ATLAS Construction Project

MUON SYSTEM

Monitored Drift Tubes (MDT)

Cathode Strip Chambers (CSC)

Resistive Plate Chambers (RPC)

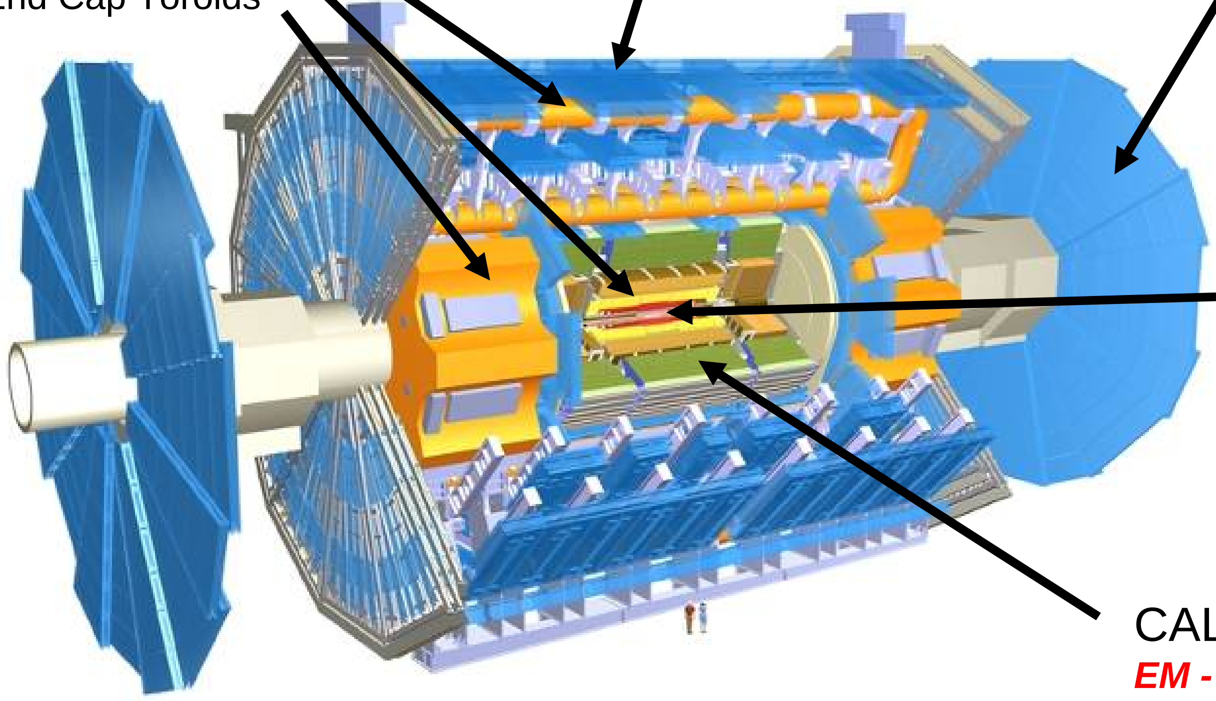
Thin Gap Chambers (TGC)

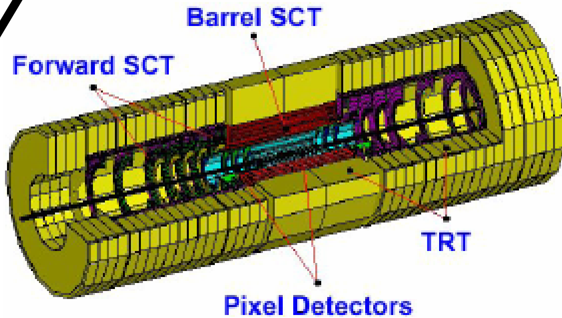
MAGNETS

8 Barrel Toroids

Central Solenoid

End Cap Toroids





INNER DETECTOR (ID)

Pixels

Silicon Strip (SCT)

Transition Radiation Tracker (TRT)

CALORIMETERS

EM - Liquid Argon – Lead

HAD - Scintillator Tile

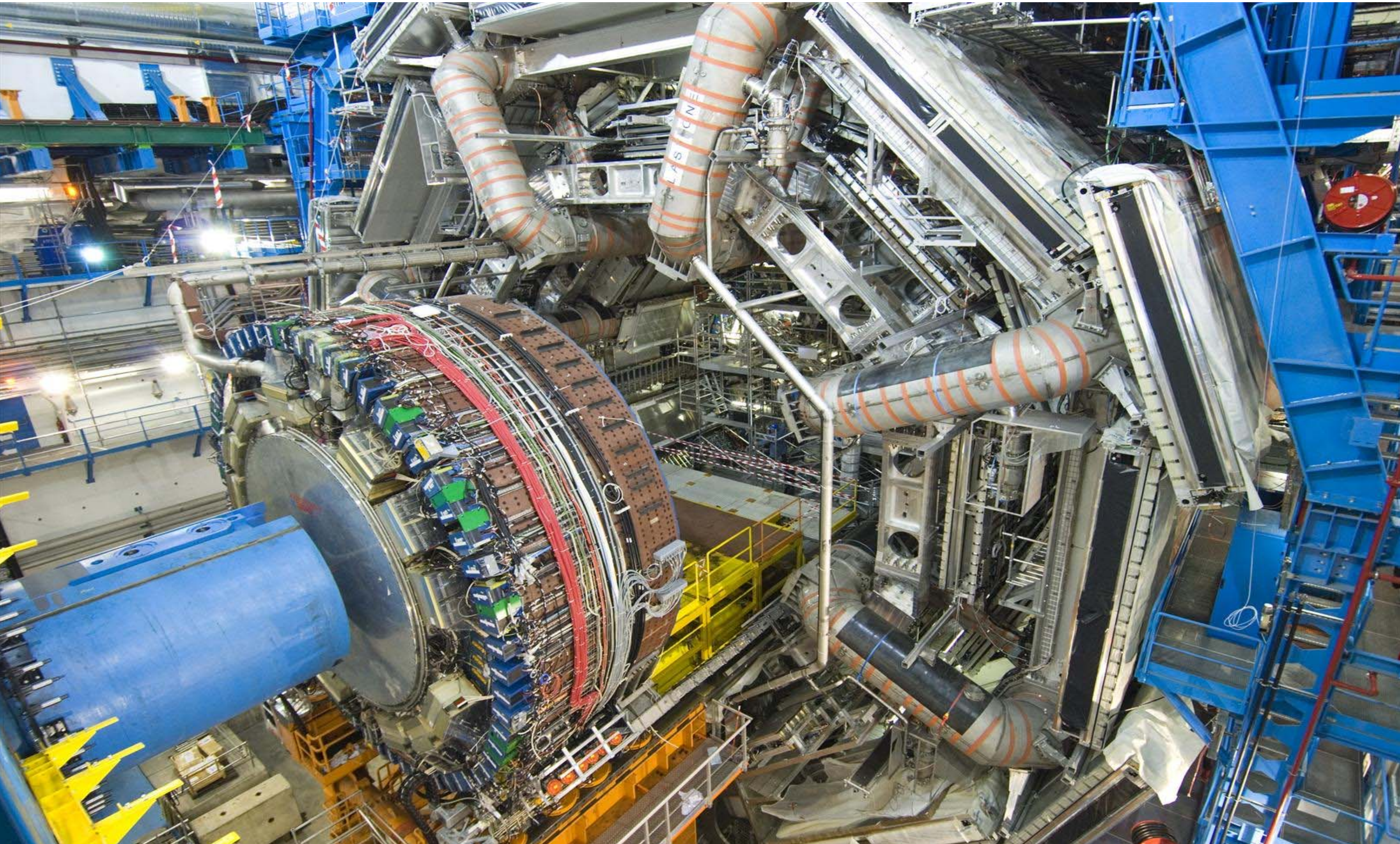
Diameter 25m

Length 46m

Weight 7,000 tons

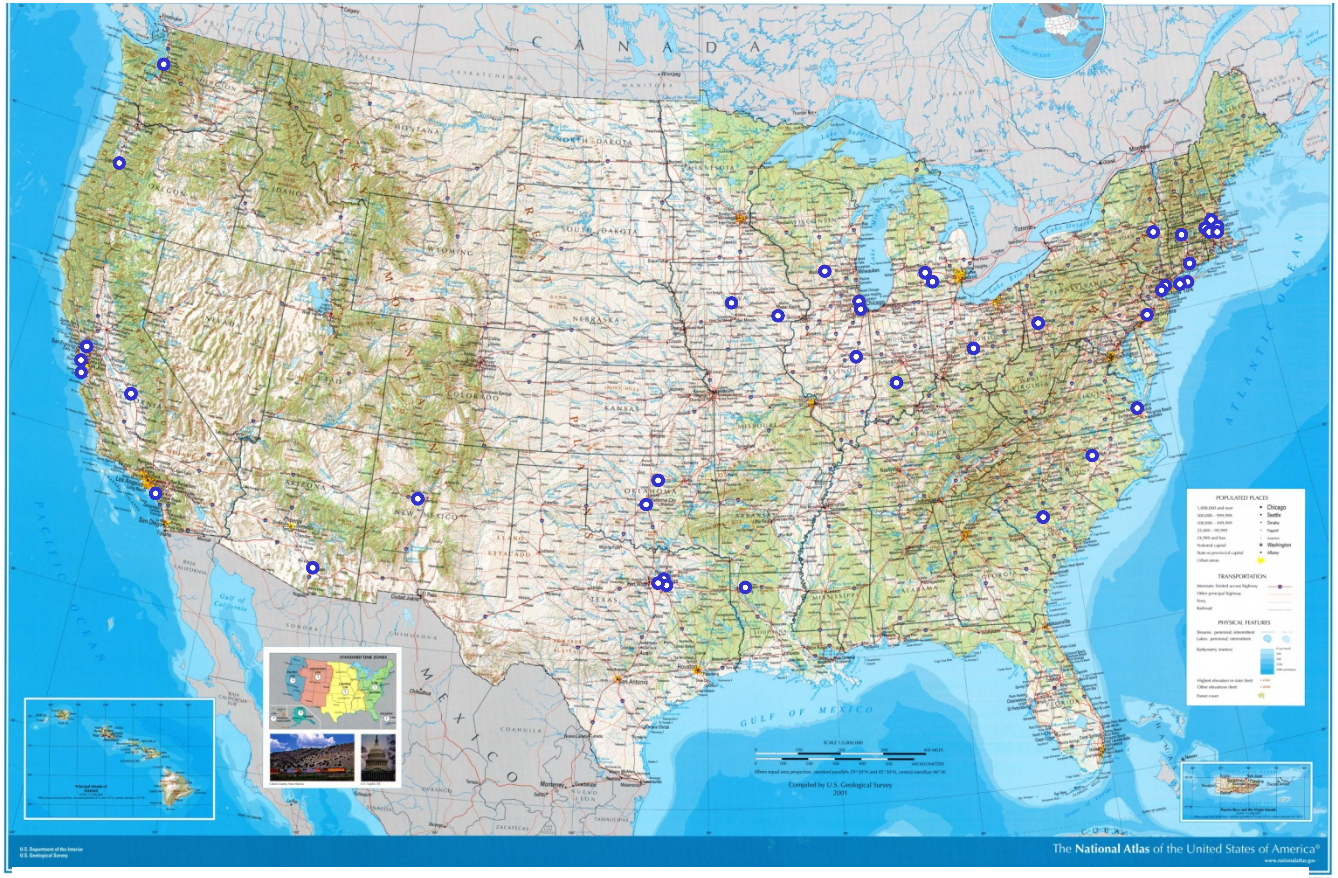
Red – indicates US involvement

Before ATLAS Closed Up



US ATLAS

- ATLAS
  - 166 institutions
  - 2,095 active physicists
- US ATLAS
  - US ~20% of overall ATLAS
  - 43 institutes
  - 420 active physicists including ~125 students
  - BNL host lab



Albany, ANL, Arizona, UT Arlington, Berkeley LBL and UC, Boston, Brandeis, BNL, Chicago, Columbia, UT Dallas, Duke, Fresno State, Hampton, Harvard, Indiana, U Iowa, Iowa State, UC Irvine, Louisiana Tech , Massachusetts, MIT, Michigan, MSU, New Mexico, NIU, NYU, Ohio State, Oklahoma, Oklahoma State, Oregon, Pennsylvania, Pittsburgh, UC Santa Cruz, SLAC, SMU, South Carolina, SUNY Stony Brook, Tufts, Illinois Urbana, Washington, Wisconsin, Yale

US Roles in International ATLAS

- US is key partner in ATLAS:
  - Executive Board (30 members total, chaired by spokesperson)
    - Kevin Einsweiler, Mike Tuts, John Parsons, David Quarrie, Bob Stanek, Frank Taylor
  - Technical Coordination
    - David Lissauer
  - Computing
    - David Quarrie, David Malon, Ian Hinchliffe, Steve Goldfarb, Paolo Califiura, Sacha Vanyashin, Stephen Gowdy, Jim Shank, Fred Luehring, Vahko Tsulaia, Hong Ma, Stephane Willocq
  - Detector Systems Management & Steering Groups
    - Kevin Einsweiler, Bob Stanek, Frank Taylor, Maurice Garcia-Sciveres, Alex Grillo, John Parsons, Hong Ma, Francesco Lanni, Steve Goldfarb
  - Physics & Combined Performance Coordination
    - Brian Cole, Tom LeCompte, Peter Loch, Jimmy Proudfoot, Ian Hinchliffe, Srini Rajagopalan
  - Education & Outreach
    - Michael Barnett
  - Upgrade
    - David Lissauer (project office), Abe Seiden (upgrade steering group)

US ATLAS Research Program

- US ATLAS "Research Program" (RP) follows from US responsibilities on the construction project
  - Major component of US HEP program
- Research Program covers technical personnel and equipment in three areas:
  - Maintenance & Operations (M&O)
  - Software & Computing (S&C)
  - Upgrade Research and Development (R&D)
- RP has been and continues to be extensively reviewed by outside panels of experts reporting to DOE & NSF.
  - Last review 2/08 (https://indico.bnl.gov/conferenceDisplay.py?confId=65)
- Equally critical to the success of US ATLAS is what is not covered by RP:
  - Physicists, students and their travel COLA are in the "Core" program
  - Local institutional computing (sometimes called "Tier 3"), which is part of the ATLAS computing model
  - Especially with the declining $, there is a large need for more travel and COLA funds ~$2M

Research Program Activities

- M&O
  - FY08 supports about 66 technical FTE's
  - Includes common "per author" costs (so called cat A&B common costs)
  - Unique Roles in all subsystems (Muons, LAr, TRT, TileCal, Silicon, TDAQ)
    - Commissioning, pre-operations, long-term maintenance and steady state operations
- S&C
  - FY08 supports about 67 technical FTE's
  - Facilities: Tier 1 computer center at BNL (out of 10 in ATLAS); 5 Tier 2 computer centers (out of ~30 in ATLAS) (+ Tier 3 not on RP); linked by grid software (interoperable between Open Science Grid (OSG) in US and WLCG in Europe)
  - Software: core software including production and distributed analysis, distributed data management, databases, user support
  - Analysis Support Centers at BNL, ANL, LBNL & Analysis Support Group
- Upgrade R&D
  - FY08 supports about 23 technical FTE's
  - R&D for upgrade to higher luminosity (next slides), has been critical to readiness to begin construction on an upgrade

U.S. ATLAS Research Program Needs

Fiscal Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Current DOE Guidance	24,600	25,500	27,500	28,500								
Current NSF Guidance	9,000	9,000	9,000	9,000	Note 1							
Total Current Guidance	33,600	34,500	36,500	37,500								
Our Real Needs	33,600	41,500	41,975	43,125	44,850	46,644	48,510	50,450	52,468	54,567	56,750	Note 2
Commissioning of Upgrade								3,000	4,000	2,000		Note 3
Software and Computing for Upgrade							2,000	3,000	4,000	2,000		
Total Research Program Request to P5	33,600	41,500	41,975	43,125	44,850	46,644	50,510	56,450	60,468	58,567	56,750	
Total Research Program Request to P5 (FY08$)	**33,600**	**39,904**	**38,808**	**38,338**	**38,338**	**38,338**	**39,919**	**42,897**	**44,183**	**41,148**	**38,338**	

Note 1	The current NSF Cooperative Agreement ends in 2011 and we are unsure of what the future NSF funding will be.
Note 2	At the DOE/NSF Review 2/4/08 we presented real needs for the Research Program of > $7M in excess of the guidance. We ask for this starting in FY0
Note 3	The plan for extra RP needs to support Upgrade Construction: Pre-operations, rebuilding the Software Framework, and an increase in CPU and Disk for the larger and more complicated events.

Justification for $7M increase in FY09, also needed in subsequent years:

1) $2.2 M Overhead at BNL;
2) Computing needs: 0.730M All ESD on Disk; 2.057M 50% more capacity in Tier 1 for U.S. Physicists;
3) M&O needs: 0.739M TDAQ Critical Personnel; 0.900M Critical LAr Personnel; 0.128 TileCal Calibration Facility;
4) Upgrade R&D to stay on schedule: 0.500M Upgrade R&D for TileCal, Muon and TDAQ;
5) Exchange Rate loss in last year 0.700M and still tanking. **Total is $7.954M+**

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Upgrade R&D Program

The ATLAS R&D program is aimed at a detector that can handle an order of magnitude higher LHC luminosity than the present detector. The inner detector has a limited lifetime estimated to be 7 years after reaching design luminosity (10^{34}), based on radiation damage, although the inner pixel layer is likely to not survive that long. The TRT is limited by occupancy and will not function well beyond the design luminosity. Thus the tracker will have to be replaced even in a scenario with modest luminosity increases.

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Organization of ATLAS Effort

R&D Work is based on an international ATLAS Upgrade R&D project, with defined goals and participants, led by a broadly representative steering group. Individual projects are established through Upgrade documents for each area, reviewed by two internal ATLAS referees and endorsed by the full collaboration.

Have established an Upgrade Project Office (led by David Lissauer of BNL) to guide the infrastructure issues of the Upgrade plan, which are crucial given the constraints on power, cabling, and the amount of material for the new inner detector. The office will oversee large scale mechanics, cooling, etc., and organizes reviews of the various upgrade R&D areas.

Have initiated a layout group to provide the simulation input needed to arrive at an optimum (from the point of view of cost, performance and material burden) layout for a new inner detector. Resulted in a Strawman layout, which provides basis for R&D projects as well as costing for a construction project. The inner detector replacement is the largest and most expensive part of the upgrade.

21 Participating U.S. Institutions

- Arizona
- BNL
- Chicago
- Hampton
- Harvard
- Hawaii
- LBNL
- New Mexico
- Nevis Lab/Columbia
- NYU
- Ohio State
- Oklahoma
- Oklahoma State
- Penn
- SLAC
- SMU
- South Carolina
- SUNYSB
- UC Santa Cruz
- Washington
- Yale

Present program has broad participation of many excellent groups. These groups are providing strong intellectual leadership in a number of critical upgrade areas. Work on the Inner Detector and Liquid Argon has been ongoing for over three years. Work on the muon system and triggering is starting this year. Tile cal. group is also now carefully evaluating performance expectations, but is not yet included in our list of institutions.

The R&D program for the inner detector moves from individual components, which require radiation testing (FY06-FY08), to more highly integrated structures (FY09-FY11), which will form the basis of a TDR.

Some Developments in the EU

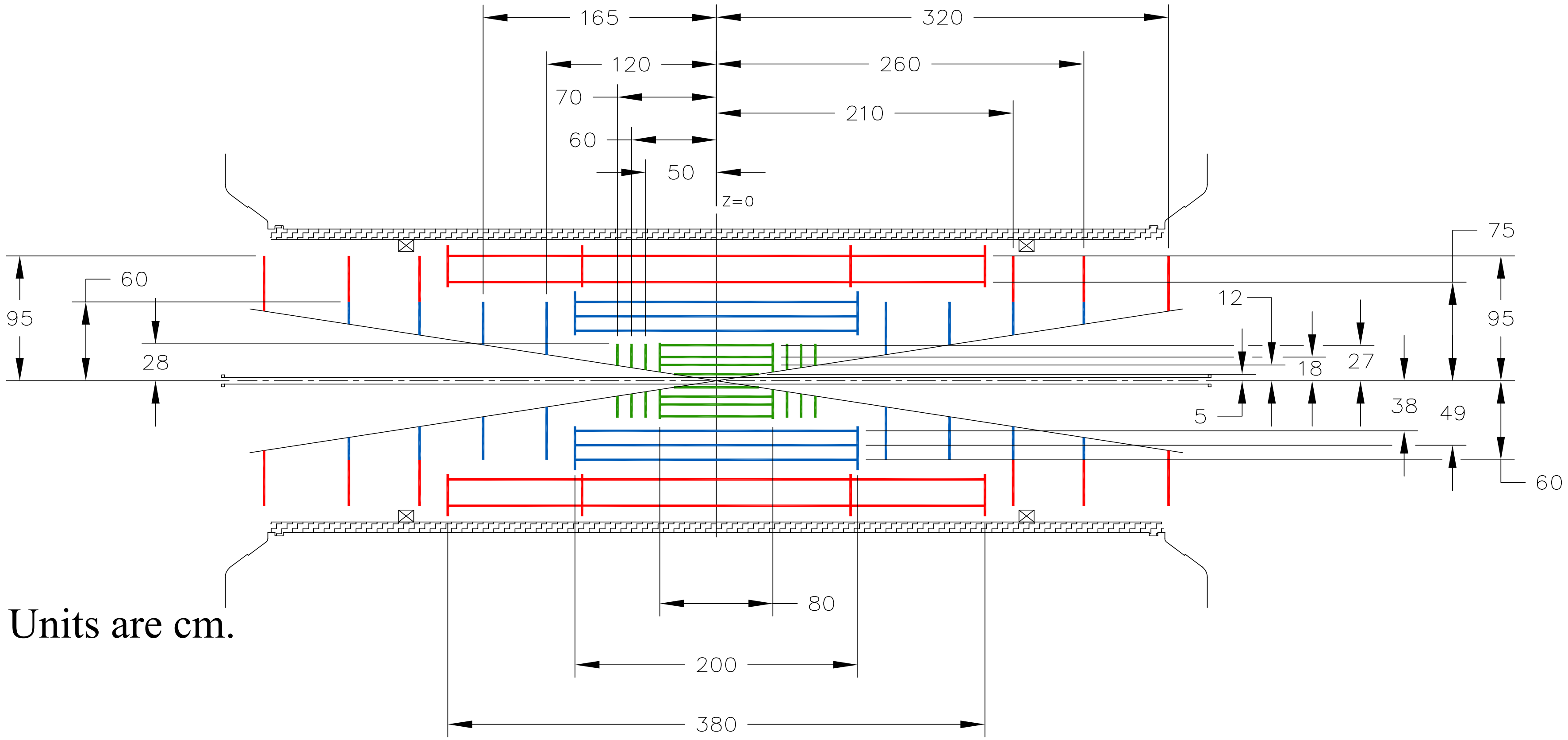
The EU will be providing some support for the preparatory phase for the LHC upgrade. This includes the Project Office, study of radiation issues, and some detector R&D support (Power Conversion). Some of the objectives:

1) Establish the formal structures needed for the ATLAS and CMS upgrade construction project, and through Technical Documentation, Cost and Schedule planning, establish an initial MoU for the Upgrade Construction.

2) Establish Project Office to address the critical technical, integration, and coordination issues of the new detectors, and the technical and managerial tools needed for the project planning and follow up.

The three year project period for this will likely be completed in April 2011.

4+3+2 (Pixel, SS, LS) Inner Detector Strawman



Units are cm.

To evaluate performance have defined a strawman layout. Forms the basis of simulation studies, including occupancies expected in the detectors. Provides basis for costing.

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Cost Drivers: New Inner Detector

Item	Number of Units	Total Production Cost(K$)
3-D Pixel Detectors	12,825	1,791
Outer Pixel Detectors	19,237	2,235
Pixel Frontend Chip Wafers	600	1,997
Construction Flip Chip Modules	27,760	6,766
Inner Strip Detectors	4,320	4,687
Outer Strip Detectors	10,240	11,110
Strip Frontend Chips	361,600	6,902
Inner Hybrids	10,834	2,764
Outer Hybrids	12,840	3,276
	Total	$41,528

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Time Drivers: New Inner Detector

From talk of Heuer two weeks ago: “R&D for machine and detectors has to be vigorously pursued now and centrally organized towards a luminosity upgrade around 2015.” I will take this to provide our goal, which is completion of the upgraded detector at the end of 2015. Note installation is expected to take another 1 to 1.5 years.

Time drivers, which set schedule (assumes that we have finished R&D, and pre-production tests):

Purchase and test of various pixel detectors and frontend chips: 2 years.

Bump bonding and testing the various pixel modules: 2 years.

Assembly into large scale structures and test: 1 year.

Strip detectors have a similarly challenging schedule.

Conclusion: to be ready at the required date, we need to start construction in 2010.

Other Elements of Upgrade

In addition to the inner detector the detector components nearest the beamline will need replacing at 10^{35} luminosity, although we anticipate that they will function well for a few years at 2 to 3×10^{34}. The largest cost will be associated with replacement of elements of the Liquid Argon detector. These will be:

1) The very forward electromagnetic calorimeter.

2) The frontend electronics for the whole liquid Argon, which is not sufficiently radiation resistance to function for many years at 10^{35}. This is a very complex system composing the full chain of electronics for high precision data collection and triggering from many channels. This was mainly a US deliverable for the present detector and the US groups will have an important role in the upgrade. The R&D program should allow incorporation of technologies not available 10 years ago into the new liquid Argon electronics system.

Much of the current muon system is expected to handle 10^{35} luminosity. However, the Endcap Inner Layer and large rapidity Middle Layer will have to be replaced, ~300 m^2 of detectors.

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Trigger & DAQ Upgrades

- **Challenge:**
  - Increased luminosity => increased rejection required
  - Increased occupancy & pileup => rejection more difficult
- **Strategy:**
  - As luminosity grows beyond design value, increase pT thresholds + make triggers more exclusive.
- **Phase 1: ~3x10^{34} ~2013**
  - Add topological info to LVL1 trigger (i.e. E_T,φ,θ of trigger objects).
  - Add LVL 1.5 tracking trigger (hardware).
  - Scale DAQ bandwidth & HLT processing.
  - Enhance software performance.
  - ~175 FTE-yr, ~15M$ M&S (over 3 yr)
- **Phase 2: ~10^{35} ~2016-17**
  - Upgrade hardware triggers.
  - Replace Front-end to DAQ interface.
  - Scale DAQ bandwidth & HLT processing.
  - Enhance software performance.
  - ~212 FTE-yr, ~26M$ M&S (over 3 yr)

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Upgrade Construction Project Costs (FY08k$s)

	Total		US Share (20%, LAr = 32%)			
	FTEs	M&S $	FTEs	Labor $	M&S $	Total $
Silicon	653	75,562	131	19,060	15,112	34,172
LAr	364	32,265	117	19,019	10,355	29,374
Tile	129	15,662	26	4,031	3,132	7,163
Muon	300	13,310	60	7,953	2,662	10,615
TDAQ	387	41,336	77	14,255	8,267	22,522
Common Funds		50,000	-	-	10,000	10,000
TC	152	2,344	30	6,688	469	7,157
Total	1,985	230,479	441	71,005	49,998	121,003
Contingency	-	-		-	-	60,501
Grand Total	1,985	230,479	441	71,005	49,998	181,504

Phase 2 assuming CD0 in 2011

US ATLAS Share Profile (FY08k$s)

	FY10	FY11	FY12	FY13	FY14	FY15	FY16	Total
Silicon	2,346	3,845	3,932	9,078	9,462	4,859	650	34,172
LAr	-	-		6,051	6,946	8,536	7,841	29,374
Tile	-	-		1,044	1,640	1,892	2,587	7,163
Muon	-	-		1,902	3,627	2,258	2,828	10,615
TDAQ	2,154	2,316	5,009	2,642	2,876	7,526	-	22,522
Common Funds	-	-	-	2,500	2,500	2,500	2,500	10,000
TC	500	500	1,289	1,618	1,435	1,414	400	7,157
Total	5,000	6,661	10,230	24,835	28,487	28,983	16,806	121,002
Contingency	-	3,430	5,320	12,914	14,813	15,285	8,739	60,501
Grand Total	5,000	10,092	15,550	37,749	43,300	44,268	25,545	181,503

Conclusions

Physics at the TeV energy scale has been the highest priority for particle physics for 20 years. Through the efforts of highly integrated international collaborations for the machine and detectors we hope to soon begin the exploration of this new physics regime.

US ATLAS and US CMS are the largest programs in US HEP, involving about half of the community, because the community believes that the TeV scale is where the next great physics discoveries will come from.

US physicists are poised to play a major role in this physics adventure. To succeed will require strong support for students, postdocs, research scientists and faculty (base program) as well as technical personnel involved in keeping the detector and computing systems functioning (Research Program). The Upgrades have already received major attention within the Research Program and will be needed to continue to higher scales and to make measurements for low rate processes. The program is expected to last more than a decade.

We urge the panel to strongly endorse, and put as the highest priority for funding, the US ATLAS, US CMS, LHC machine program, and the Upgrades in all funding scenarios under consideration. They are all part of exploring the TeV scale.

We hope that the scientific results will not only inspire our students but also heighten the public's appreciation for the amazing universe we live in.

Backup Slides

More details on Research Program and Upgrades!

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Examples of Critical Roles Supported by the U.S. ATLAS Research Program

- Software framework, data management, and distributed processing all aimed at allowing U.S. physicists to access the real data and analyze it
- Inner Detector Engineer with expertise in cooling
- Technician at CERN capable of work on all Inner Detector systems
- Experts on U.S. built electronics for the Inner Detector, LAr Calorimeter, TileCal, Muon Spectrometer and Level 2 Trigger
- Indispensible computer professionals in TDAQ

Inner Detector Upgrade R&D

Pixels:

(1) Innermost pixel detector has to be completely new concept due to charge trapping. Proposed solution is to use 3-D detector modules. Prototypes have proven the concept. Working with a vendor to develop fabrication capability; first detectors expected soon.

(2) First prototype CMOS readout chip fabricated. Now tested and works very well. An international collaboration is now designing a more complete chip. Expect submission to MOSIS soon.

(3) Radiation hardness of all data transmission components being looked at. Si photodiodes degrade but probably okay. A few VCSEL choices survive. Need to continue these studies.

Strips:

(1) Developing a new structure – stave, which requires significantly less cabling.

(2) Need for a new type of detector: n-on-p detector, which doesn’t need full depletion for successful operation. Hamamatsu n-on-p detectors now ordered, will arrive early in 2008. These will allow both short and long sensors to be made from the same basic detector. If results satisfactory can freeze detector design in 2009.

(3) New front-end needed which uses significantly less power to keep cooling and cabling reasonable. SiGe analog test chip fabricated. Analog section uses six times less power than present chip. Work has also begun on a controller chip to deal with large data volume.

(4) From the point of view of safety and size of the cable plant, need a different way of powering front-ends. Possible solutions: DC-DC converters or serial powering being investigated.

Liquid Argon Calorimeter Upgrade R&D

- Detector Issues:

  Measurement program is under way to understand the effects of increased radiation leading to possible break down of the charge collection in LAr (for example boiling). Mainly an issue for the very forward region.

- The electronics R&D Program aims to utilize new high-performance technologies, not available 10 years ago. This includes:

1) SiGe for the frontend. Design for a chip has been ongoing along with program to validate expected radiation hardness. Work being done in collaboration with inner detector. Radiation hard, high performance ADC also being designed using SiGe.

2) Silicon on Sapphire for a data link. Tests have shown this to be sufficiently radiation hard and goal is to demonstrate a first working prototype system.

3) New FPGA's.

4) New bus structures.

5) Also need to improve the power supply system and match voltages to new components. Benefits from recent work to fix problems in present ATLAS detector. Three vendors being looked at.

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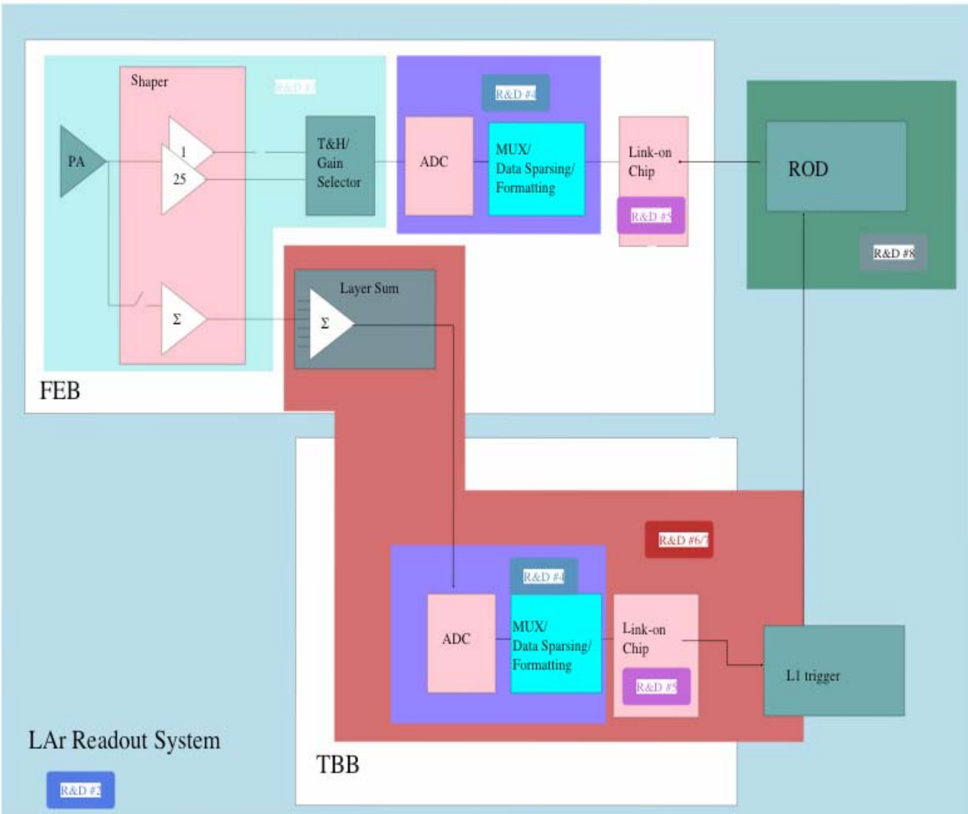
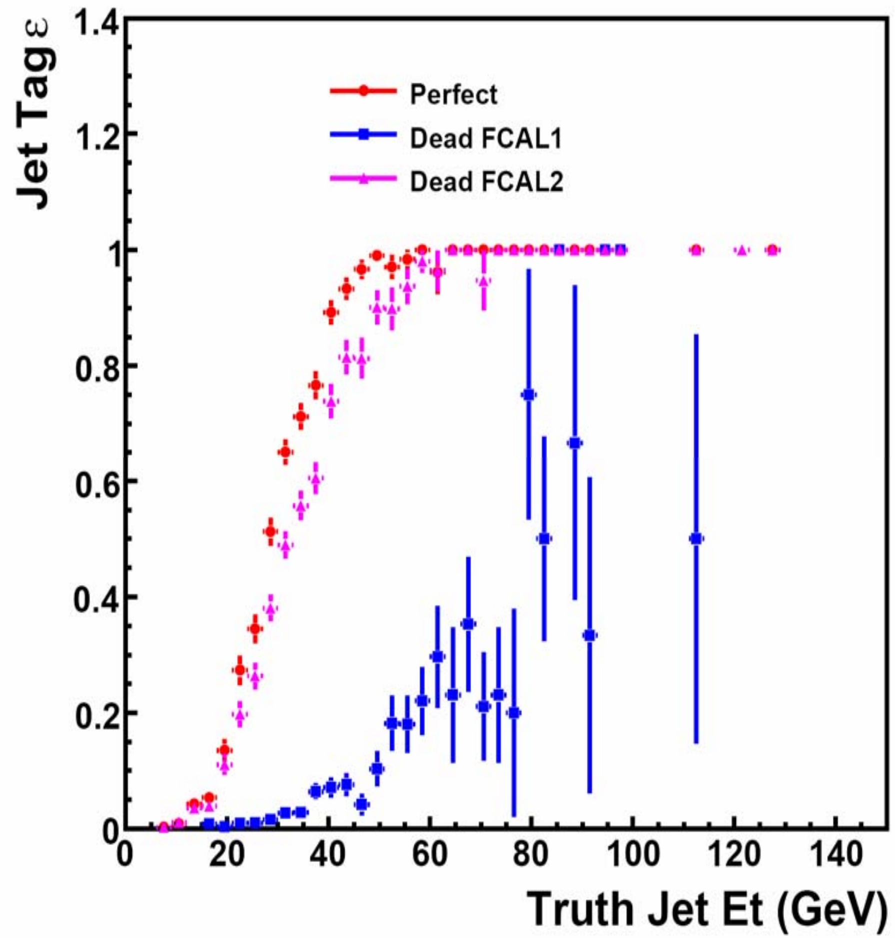
Liquid Argon Electronics R&D



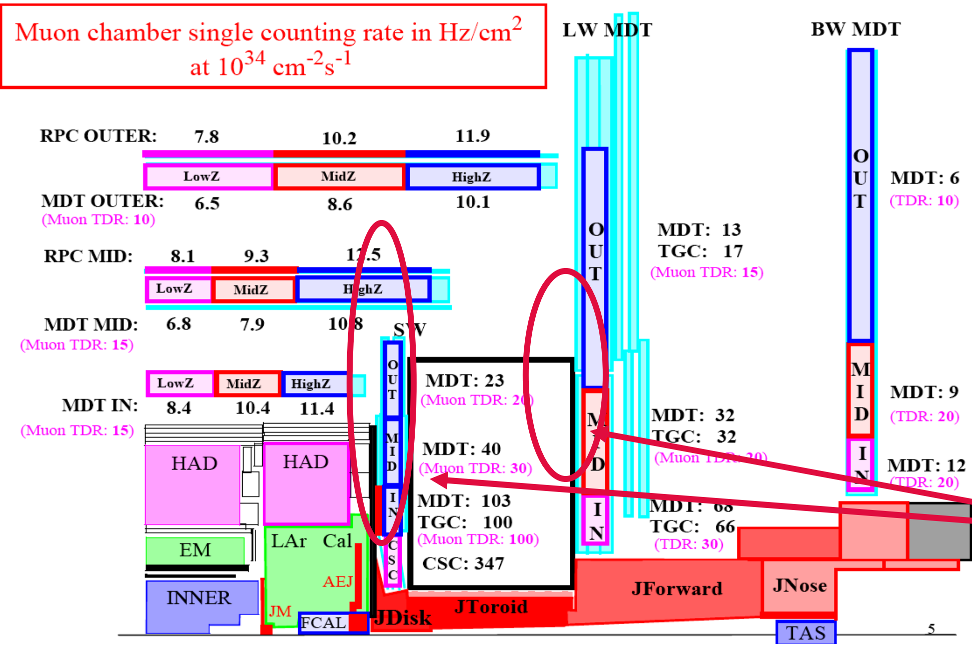
Baseline architecture for the proposed upgraded LAr calorimeter readout. Replaces present system which has 5 boards and many components.

Jet Tagging Efficiency in FCAL



- Recent MC simulations [C. Oram presentation at the FCAL/HEC workshop last December]
- Effects of having one of the FCAL modules dead on the tagging efficiency
- FCAL1 is critical. Having a dead FCAL1 is an option to reject

ATLAS Muon System Upgrade



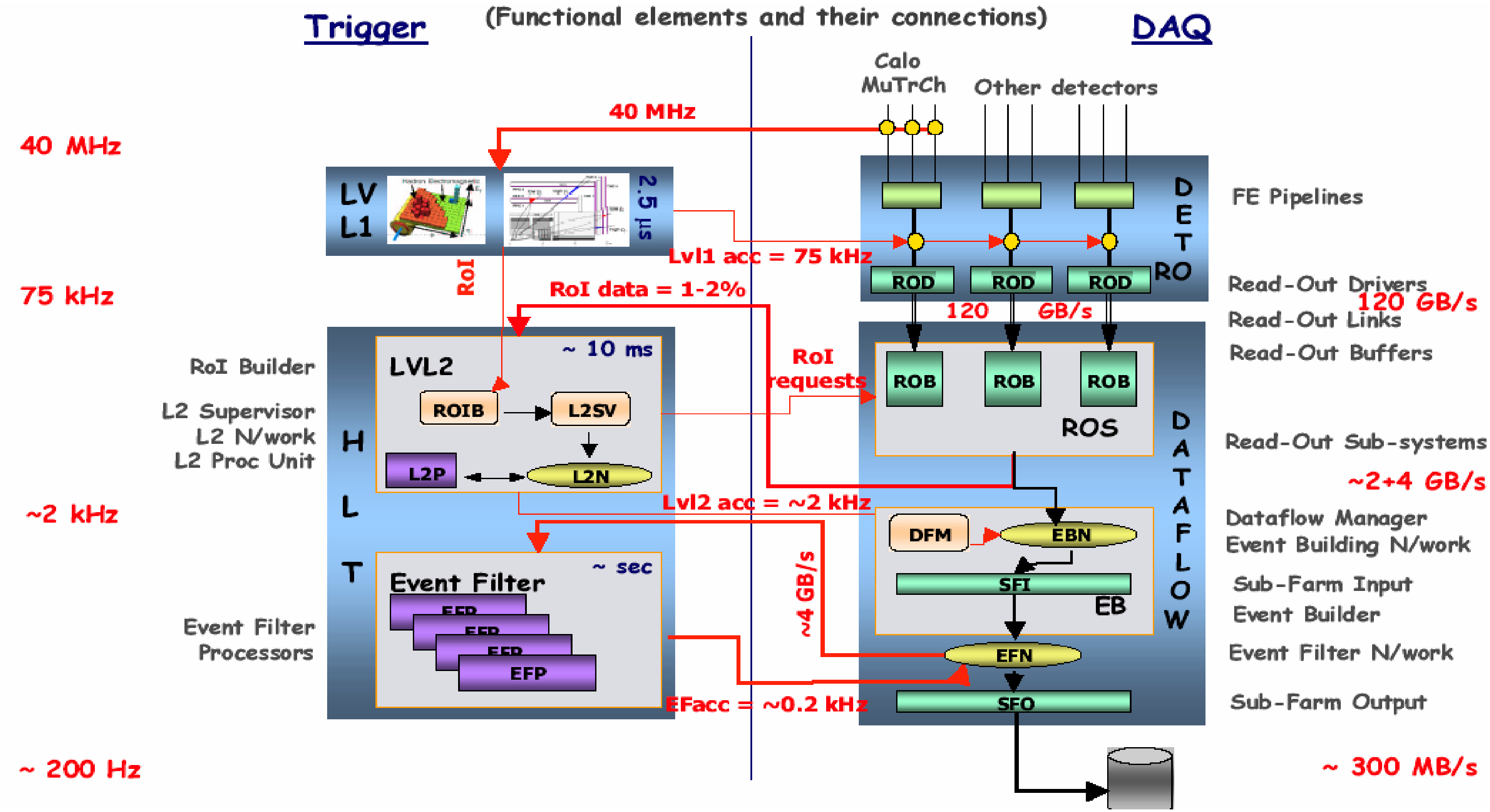
- Much of the current muon system is expected to handle 10^{35} luminosity.
- However, the Endcap Inner Layer and large rapidity Middle Layer will have to be replaced, ~300 m^2 of detectors.

Detectors to be replaced

Most advanced R&D effort for the muon system is based on Bulk Micromegas Technology which offers potential advantages:

- Industrially produced precision components (lower labor cost).
- Possibility of trigger, precision measurement, and transverse coordinate with one detector technology.

ATLAS TDAQ Overview



ATLAS TDAQ Upgrades