U.S. ATLAS

Status of ATLAS

Howard Gordon (for the ATLAS Collaboration)
BNL

Special Thanks to Peter Jenni, Mike Tuts, Manuella Vincter, Alex Grillo, Frank Taylor, Abe Seiden, Michael Ernst, Dirk Zervas and others...

ATLAS Collaboration

(Status Oct. 2008)

37 Countries
169 Institutions
2340 Scientific Authors total
(1817 with a PhD, for M&O share)

U.S.: 480 Scientific Authors

395 with Ph.D 22%

150 Graduate Students

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, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, Casablanca/Rabat, 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, 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, UFRJ Rio de Janeiro, 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

U.S. ATLAS People at CERN (full time)

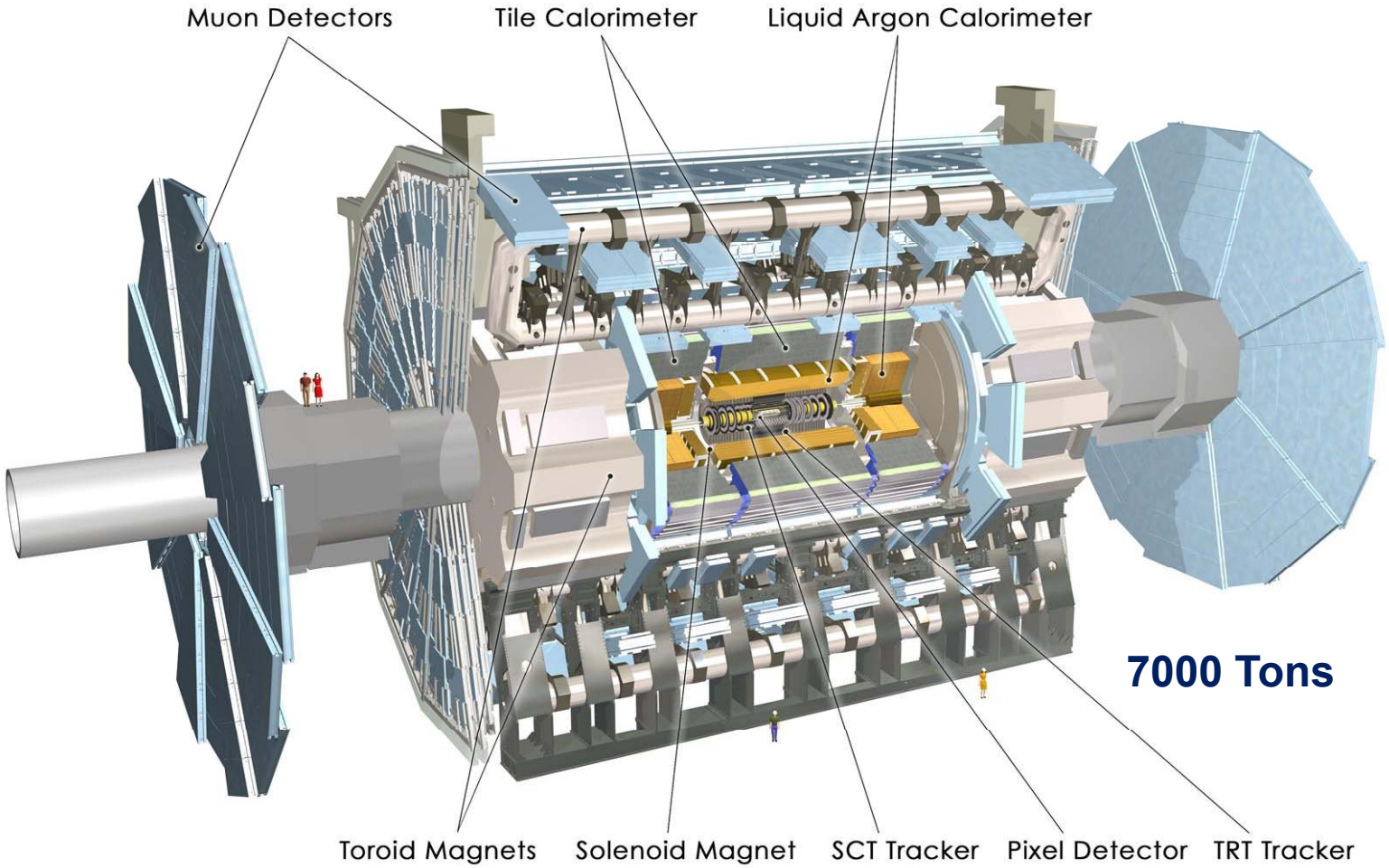
- 19 Professors
- 21 Scientists
- 76 Post Docs
- 76 Graduate Students
- 36 Professionals
- 4 Technicians
- 232 Total

ATLAS superimposed to
the 5 floors of building 40

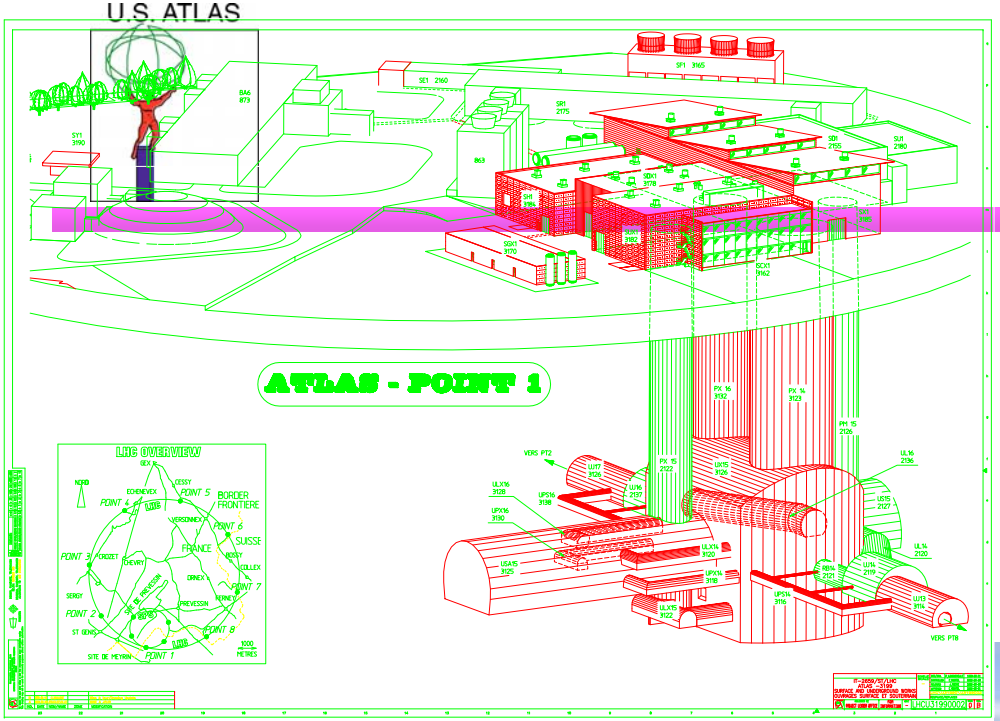
ATLAS Strengths:
1) Stand alone μ system; 2)Highly segmented calorimeter: γ pointing

45 m

24 m

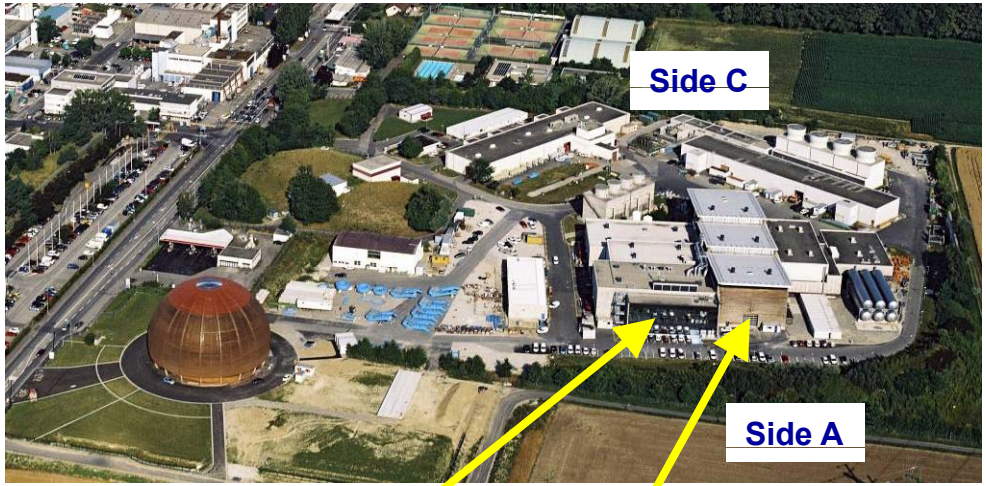


7000 Tons



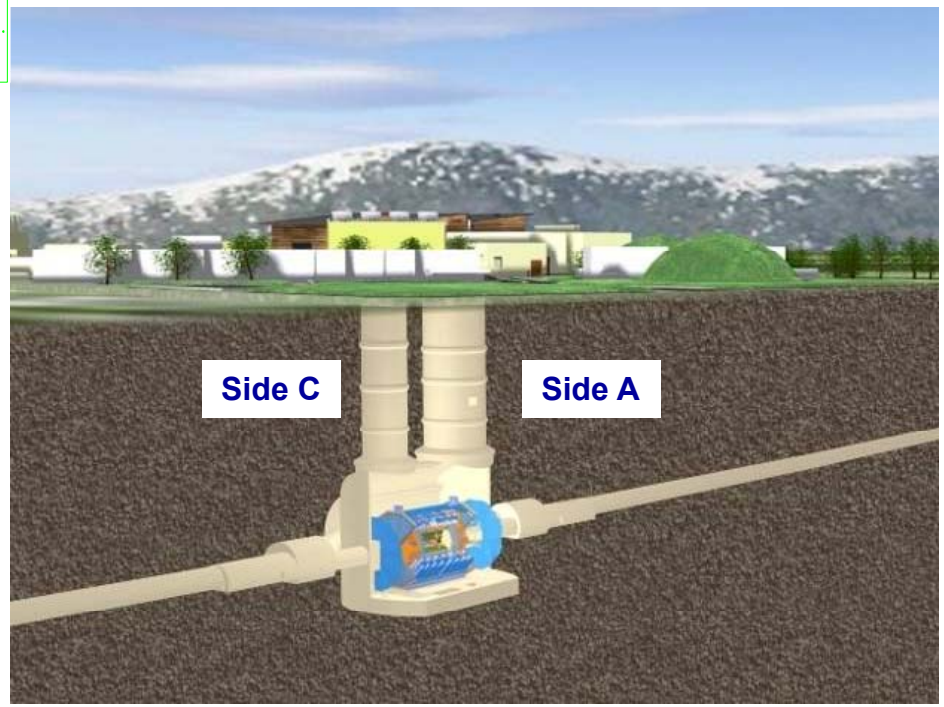
The Underground Cavern at Point-1 for the ATLAS Detector

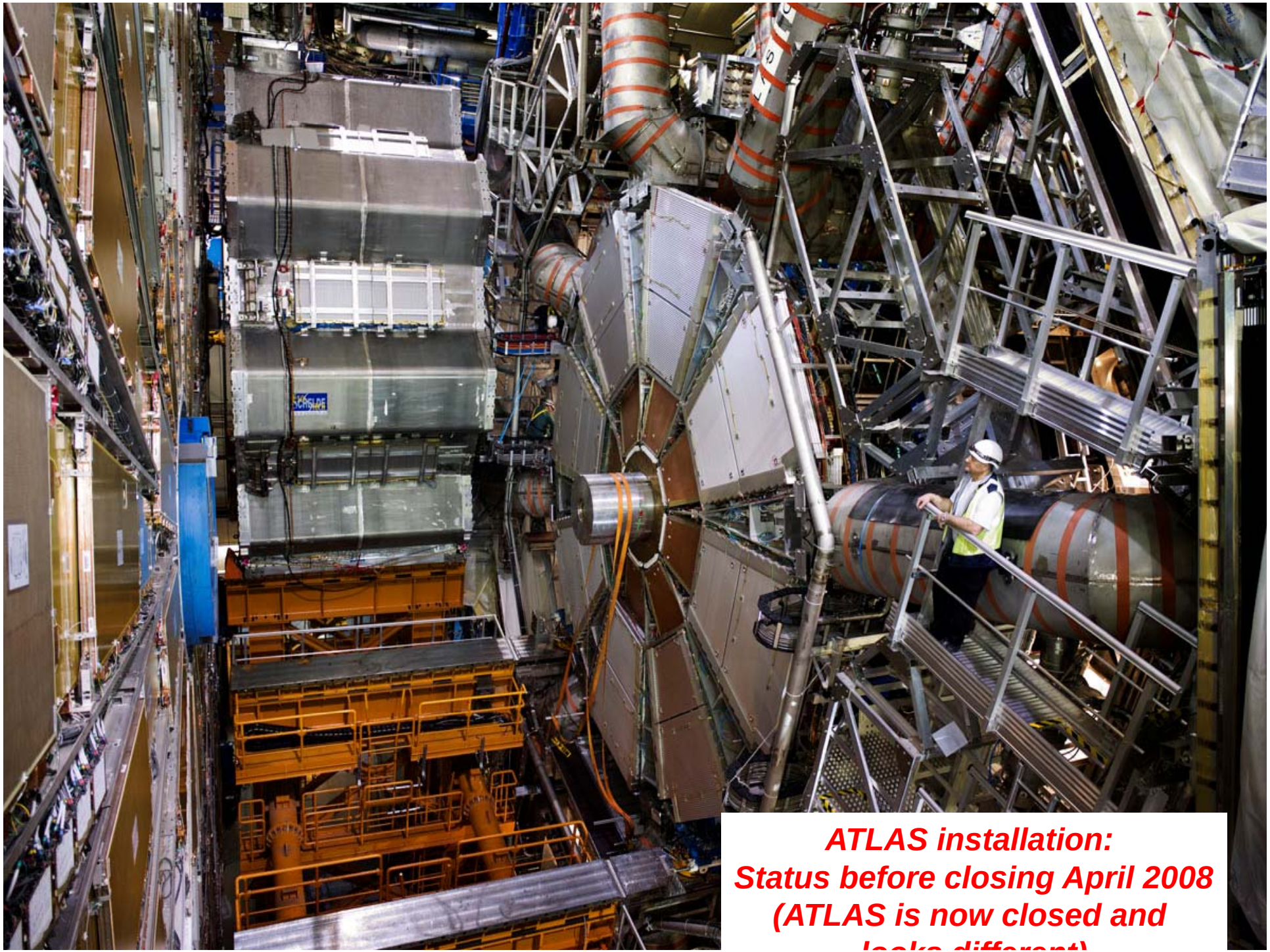
Length = 55 m
Width = 32 m
Height = 35 m



ATLAS Control Room

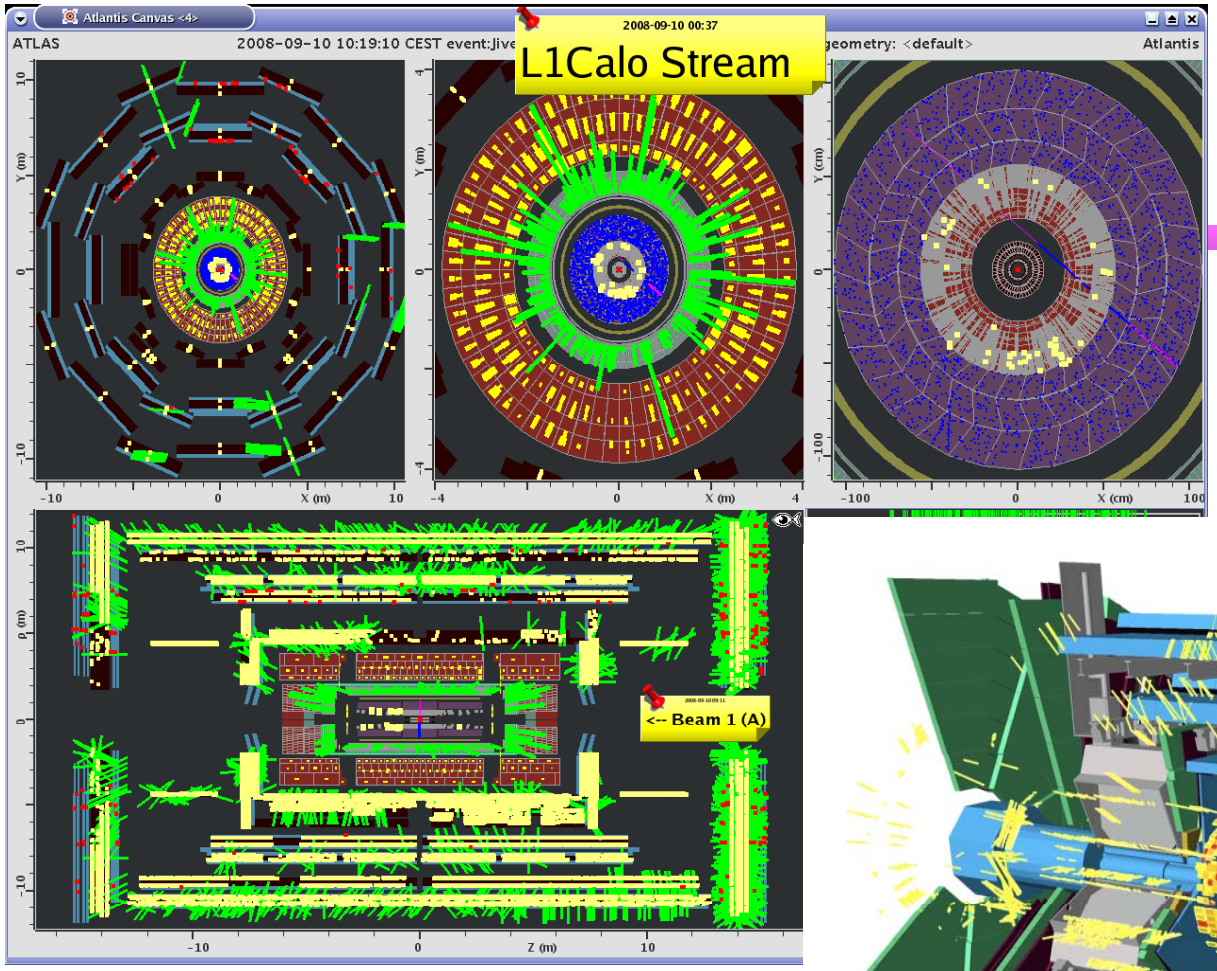
Assembly Building





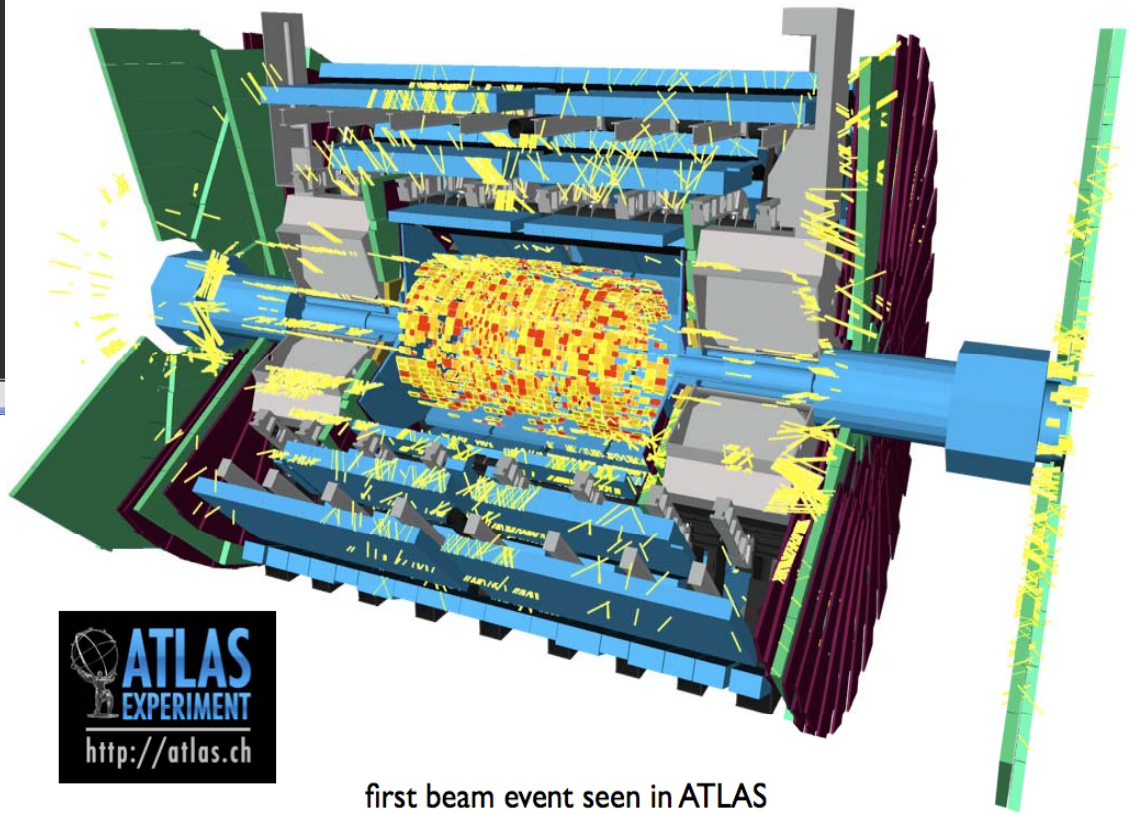
ATLAS installation:
Status before closing April 2008
(ATLAS is now closed and
looks different)

First Single Beam seen in ATLAS Sept. 10, 2008



Online display

The very first beam-splash event from the LHC in ATLAS on 10:19, 10th September 2008



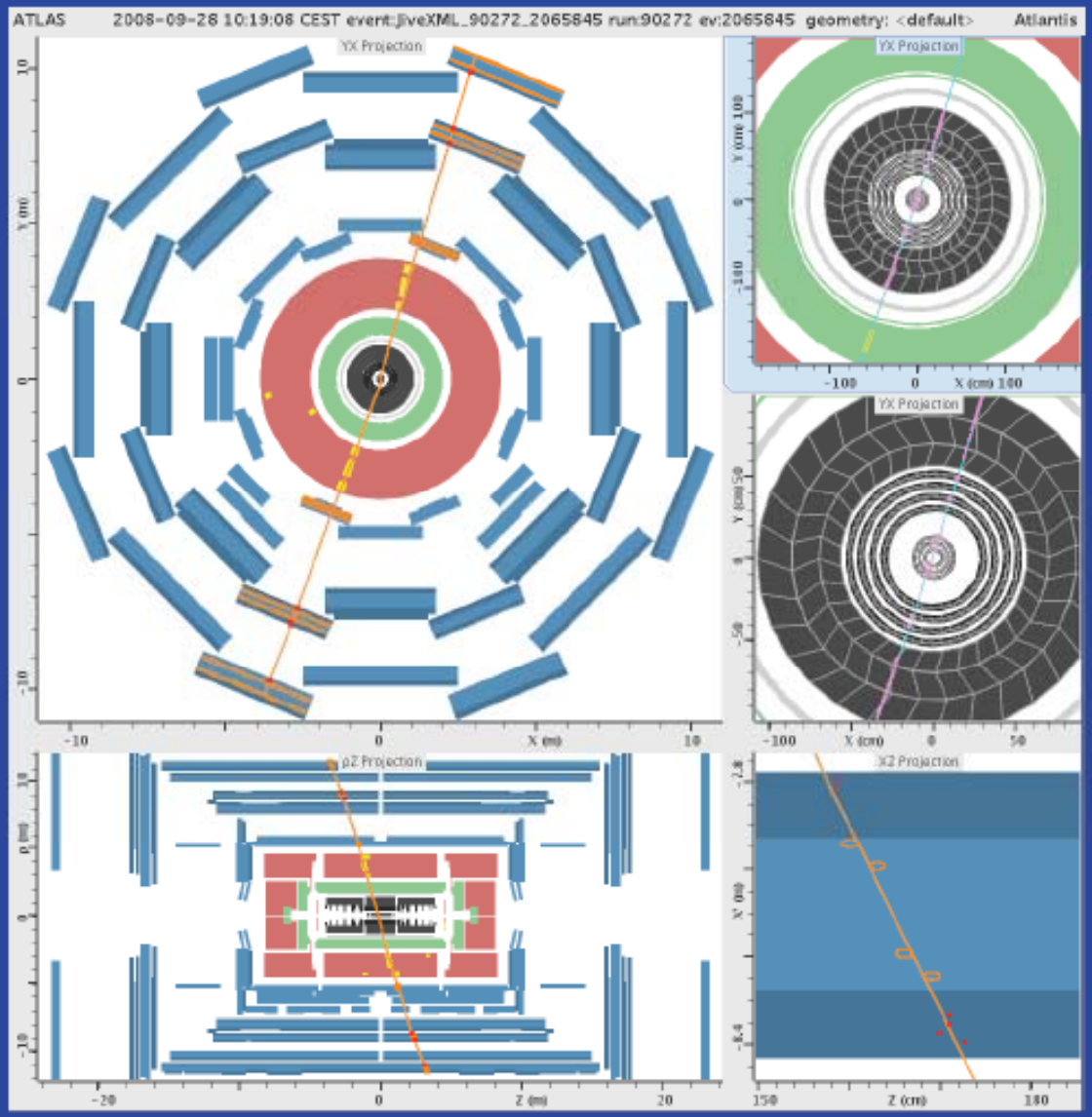
first beam event seen in ATLAS

Pixels were off on purpose

Offline display

Typical Cosmic Ray Event in ATLAS

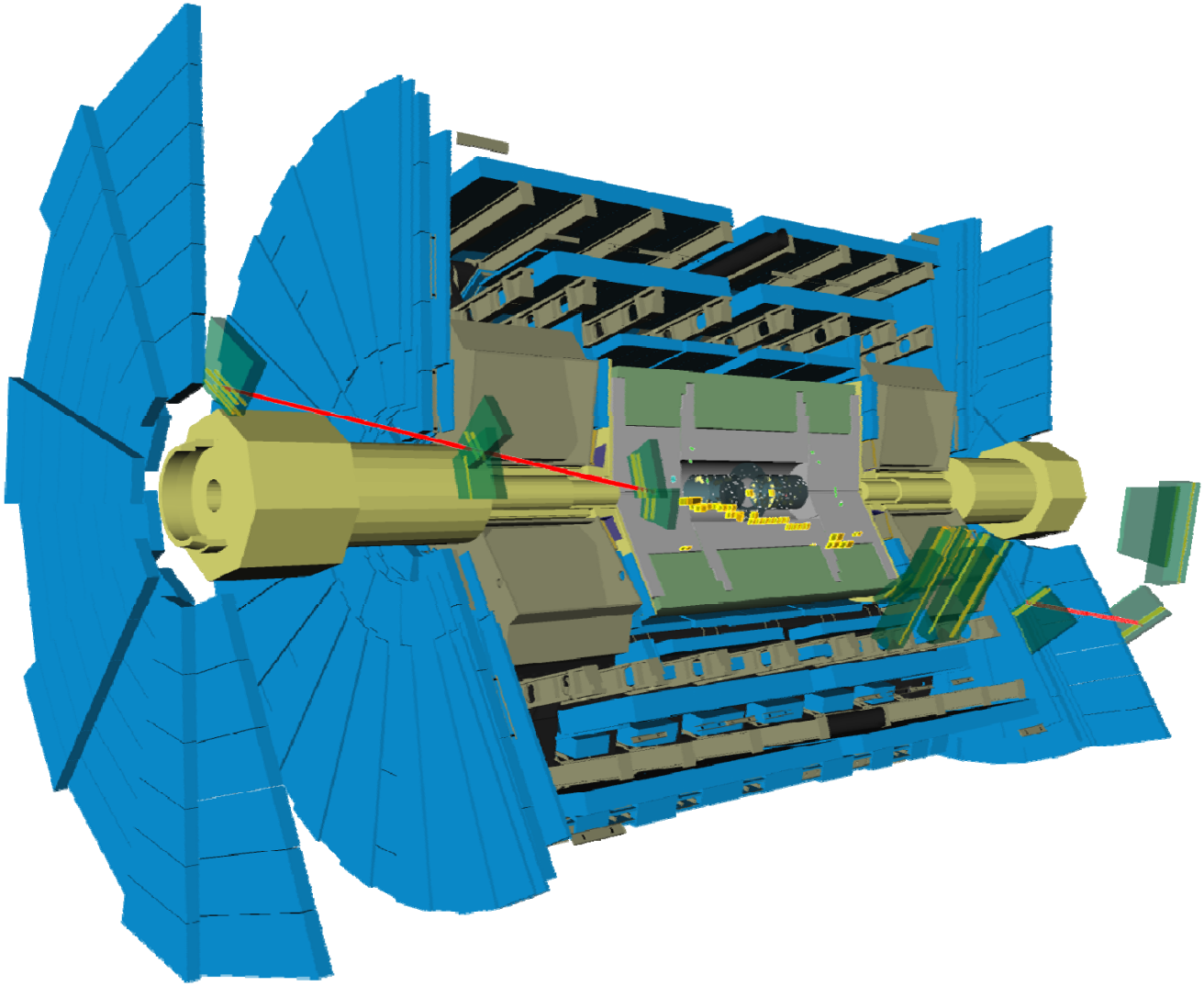
- Reconstruction in good shape for different magnet and detector configurations
  - Solenoid only field needs final validation
  - Conditions are continuously updated



Atlantis Event Display
Cosmic run 90272
Full magnetic field
All systems in
(except CSC)

(Maria Jose Costa Mezquita)

Another Cosmic Ray Event



Integration of the U.S. into ATLAS

- The U.S. integrated into almost all systems of ATLAS:
  - Inner Tracker: Pixels, Silicon Strips, Transition Radiation Tracker
  - Liquid Argon
  - TileCal
  - Muon
  - Trigger/Data Aquisition
  - Technical Coordination
  - Computing (Jim Shank)
  - Physics Analysis

U.S. Leadership Positions in ATLAS

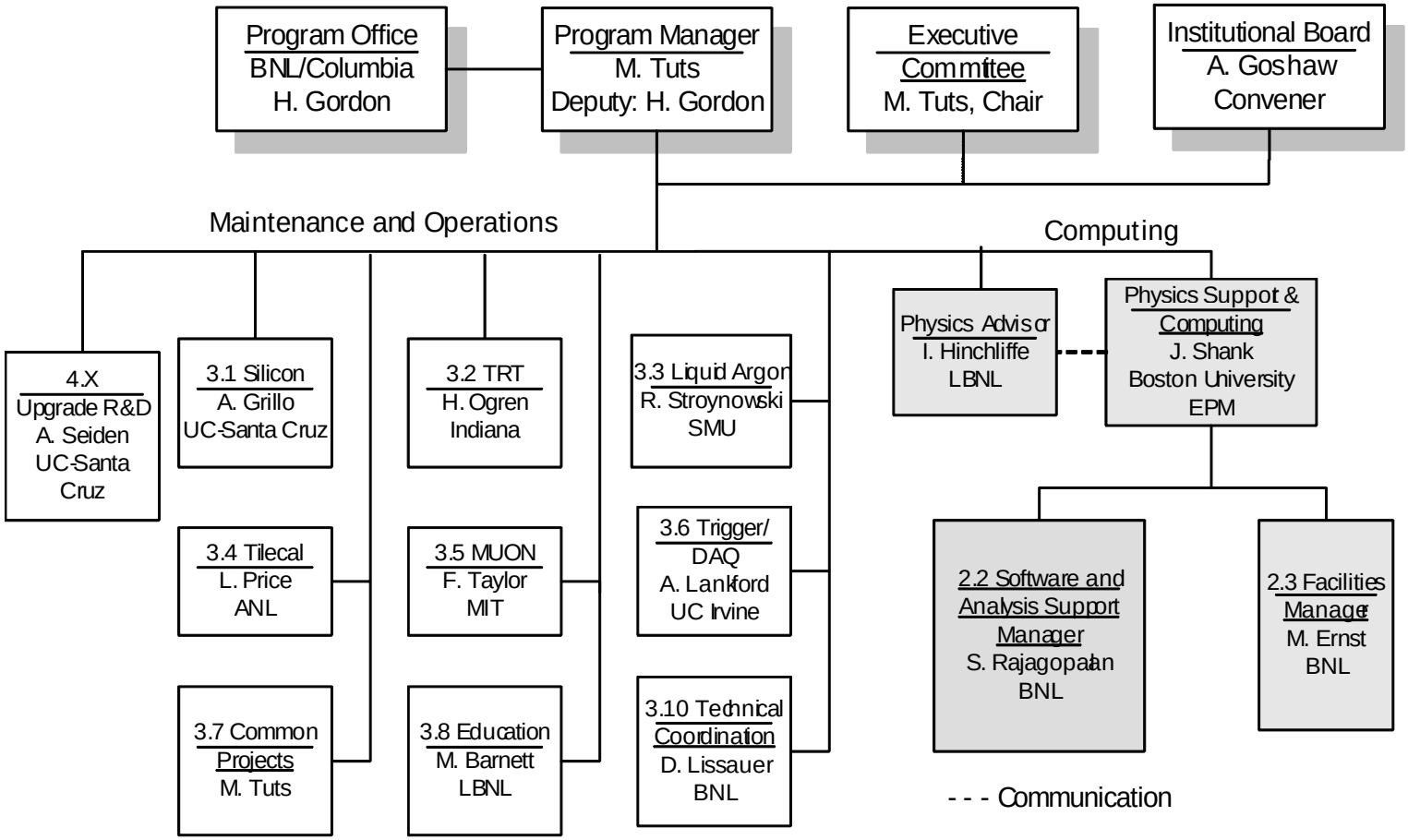
- Andy Lankford (UC Irvine): Deputy Spokesperson starting 3/1/09
- Bob Stanek (ANL): TileCal System Leader
- Kevin Einsweiler (LBNL): Pixel System Leader
- Mike Tuts (Columbia): Executive Board
- Tom LeCompte (ANL) Deputy Physics Coordinator (will be PC 6/1/09)
- Ketevi Assamagan (BNL): Higgs Convener
- Peter Steinberg (BNL): Heavy Ion Convener (NP)
- David Quarrie (LBNL): Software Project Leader
- Jim Shank (Boston): ATLAS Distributed Computing Project Co-leader

ATLAS Status

- All systems are working well except the readout of the Cathode Strip Chambers (U.S. responsibility)
- Magnet Systems (10 toroid coils and solenoid) are working well
- The software and computing systems are working and would have been ready for collisions
- Commissioning with cosmic rays is still in progress and more refined calibration and alignment of the detector is in progress
- ATLAS has defined a shutdown schedule for maintenance and repairs starting soon being ready for collisions 3/31/09

US ATLAS ORGANIZATION CHART

US. ATLAS Research Program Organization as of July 14, 2008

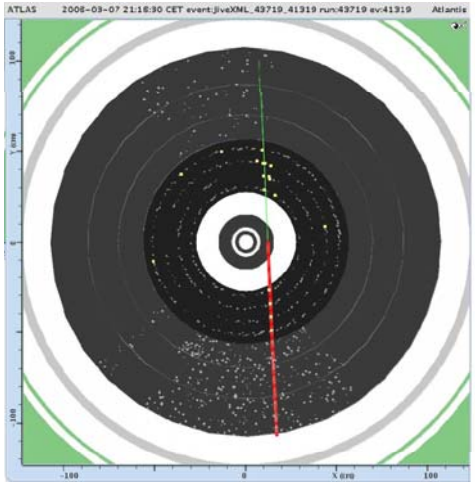


U.S. ATLAS

Kevin Einsweiler and Erik Anderson inspecting the ATLAS pixel detector just before it is inserted into its final location.

3.1 SILICON PROGRESS

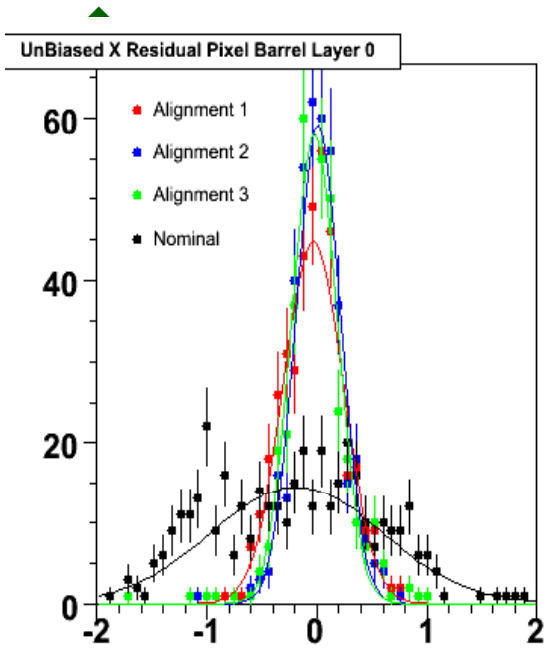
- **US Institutions: Columbia, Iowa State, Iowa, Berkeley/LBNL, New Mexico, Ohio State, Oklahoma, UC Santa Cruz, UT Dallas, Wisconsin**
- **Retrofit of evaporative cooling system heaters complete and operating in Pixel and SCT detectors. However work will continue during the shutdown.**
- **First cosmic runs with pixels: mid-September!**

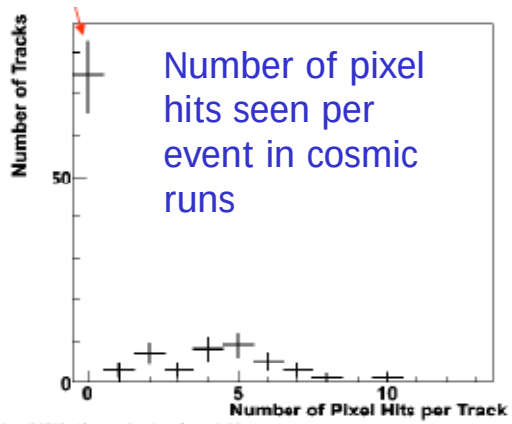


Single Cosmic Ray Track in SCT & TRT

7 pixel hits and 16 SCT hits: one hit in every layer!

Initial alignment of SCT and pixel with cosmic rays:

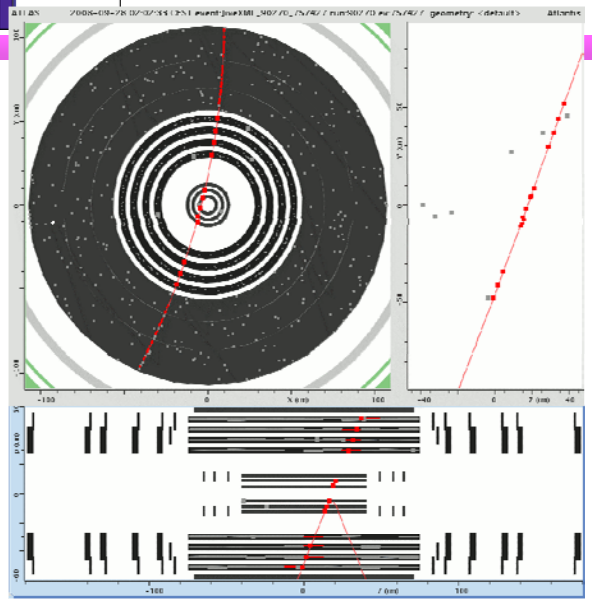




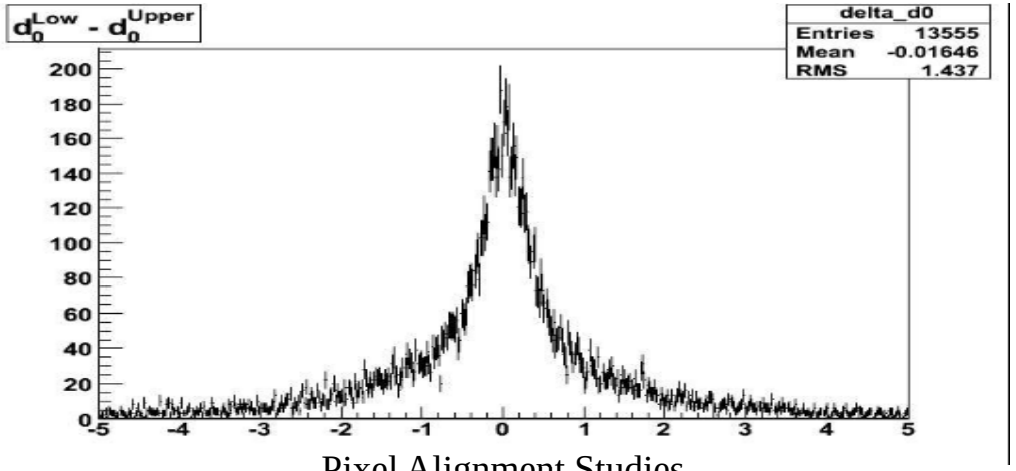
Number of pixel hits seen per event in cosmic runs

U.S. ATLAS

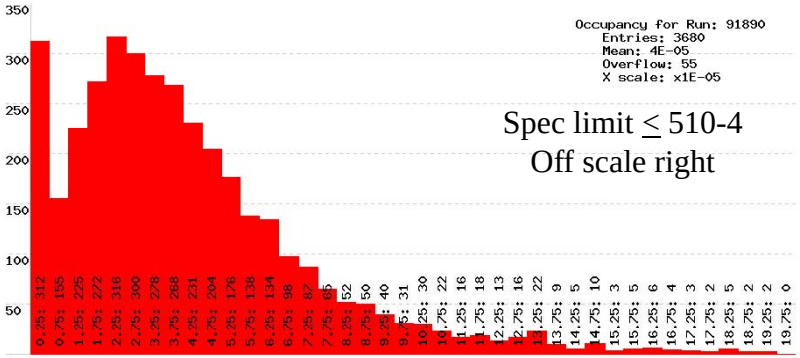
3.1 Silicon Operations



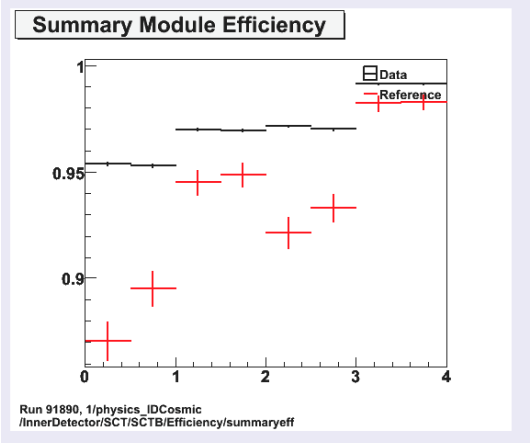
Cosmic Ray Track through TRT, SCT and Pixels



Pixel Alignment Studies
Difference in closest approach to beam line

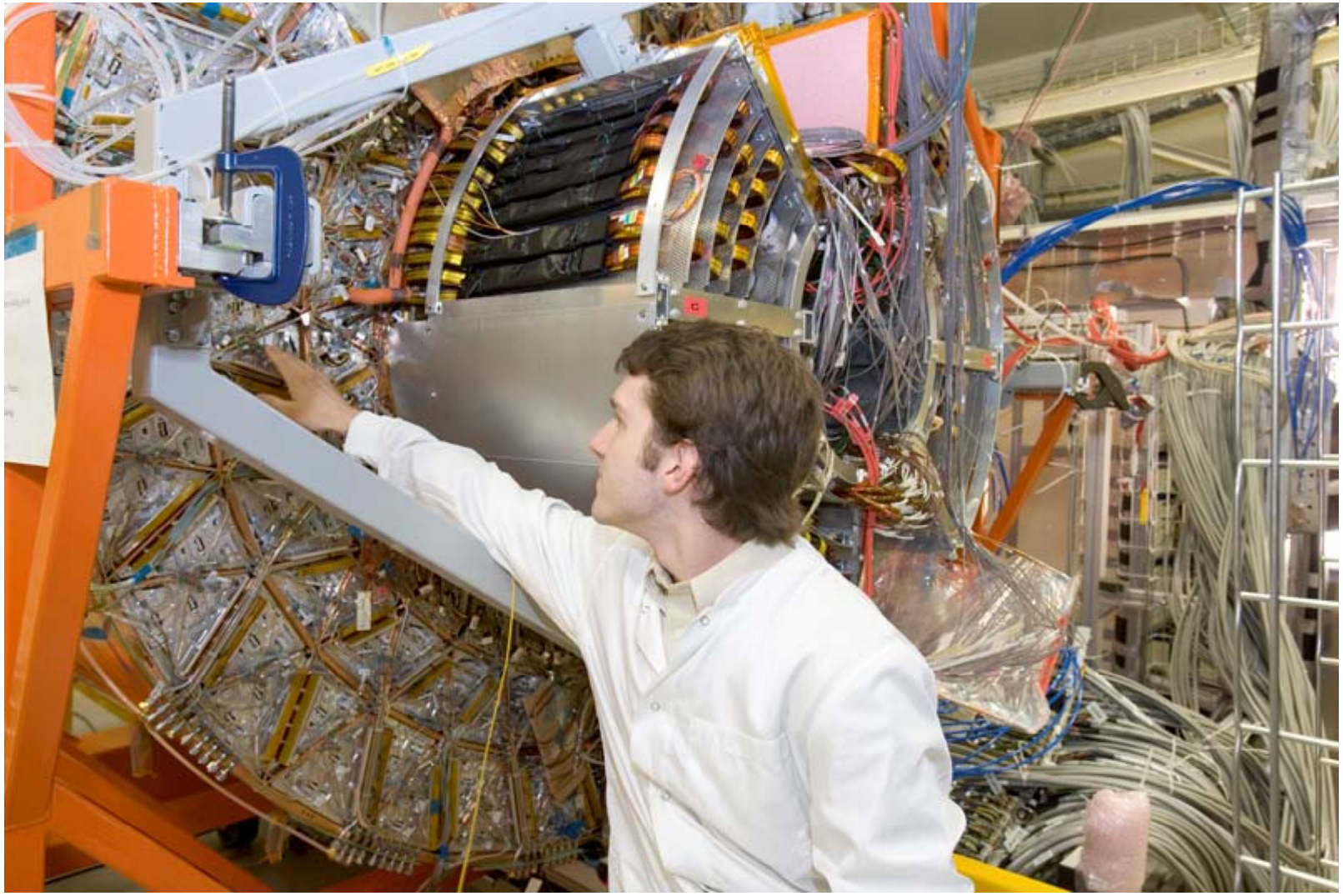


SCT Noise Occupancy
No interference from TRT or Pixels



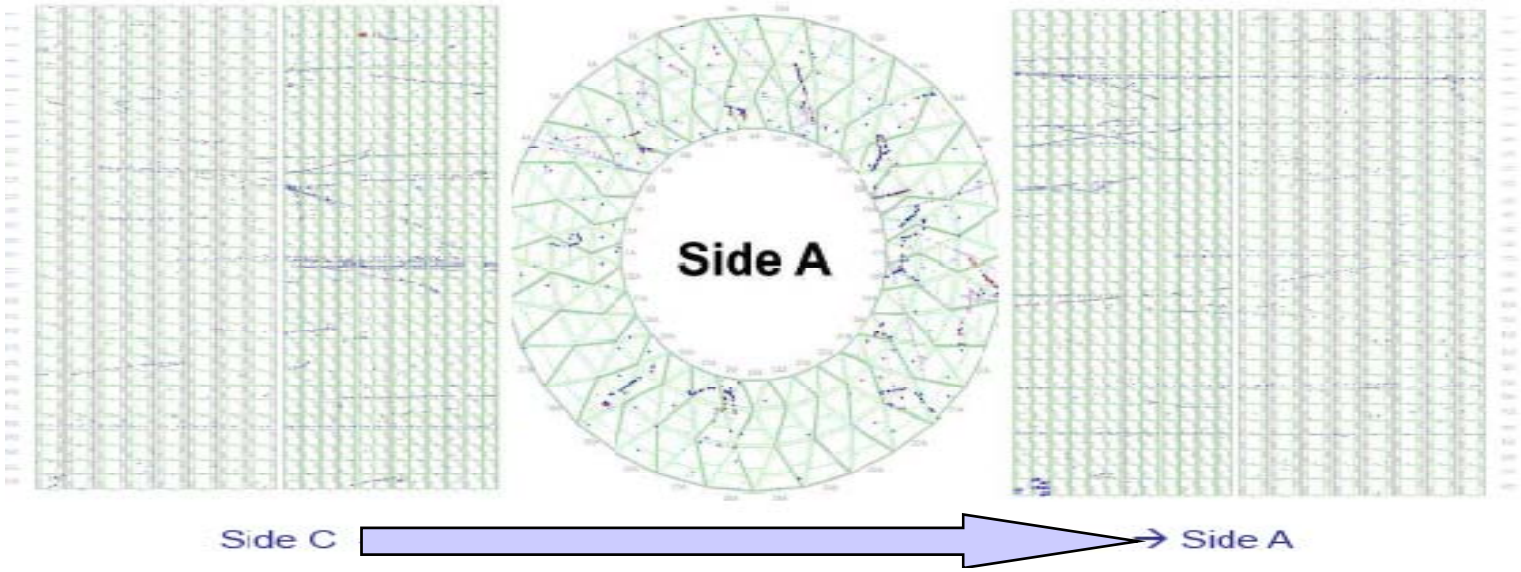
Track Efficiency of SCT Barrel
Red “reference” points from run with early calibration

Barrel TRT and SCT



3.2 TRT PROGRESS

- US Institutions: Duke, Hampton, Indiana, Penn, Yale
- Inner Detector integration is completed
  - Cosmic runs have been very successful
  - Timing, voltage, delay scans routine; stable operation
  - Monitoring tools improved with experience (histograms, forensic tools both on-line and off-line)
  - Active gas recirculation system tested with Ar (M8), was switched to Xe in September 2008
  - Cosmic rays from Endcap C through Barrel to Endcap A



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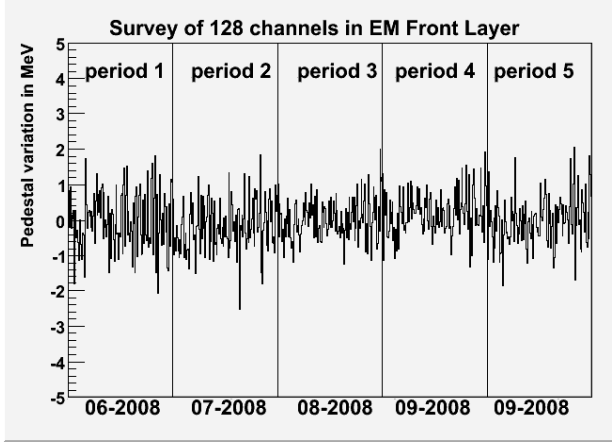
U.S. Barrel Liquid Argon Cryostat and Signal Feedthroughs for Barrel and EndCap

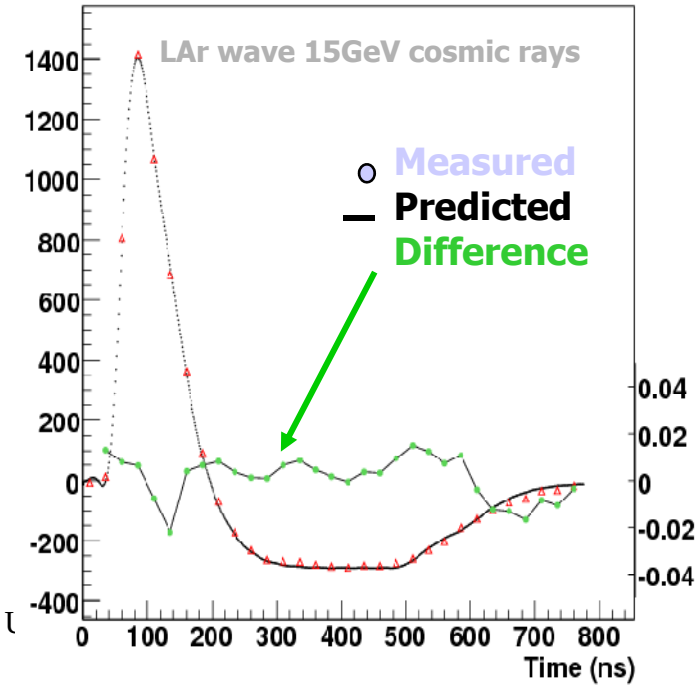
U.S. ATLAS

We also had our share of problems

3.3 LAR CALORIMETER PROGRESS

- US Institutions: Arizona, BNL, Columbia, Pittsburgh, Stony Brook, SMU
- All 183,296 channels are being readout
- Electromagnetic (EM)
  - < 0.1% single dead channels
  - No dead HV regions
  - A few percent of channels with HV lower than nominal (corrected in DSP)
- Forward Calorimeter (FCal)
  - 1.7% channels require some correction
  - Two Δφ=0.2 regions with bad HV lines (require additional corrections)
- Hadronic End-Cap (HEC)
  - <0.1% dead channels uniformly distributed



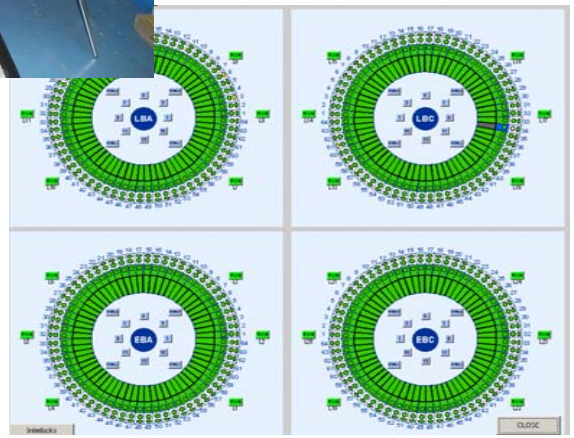


Extended Barrel TileCal

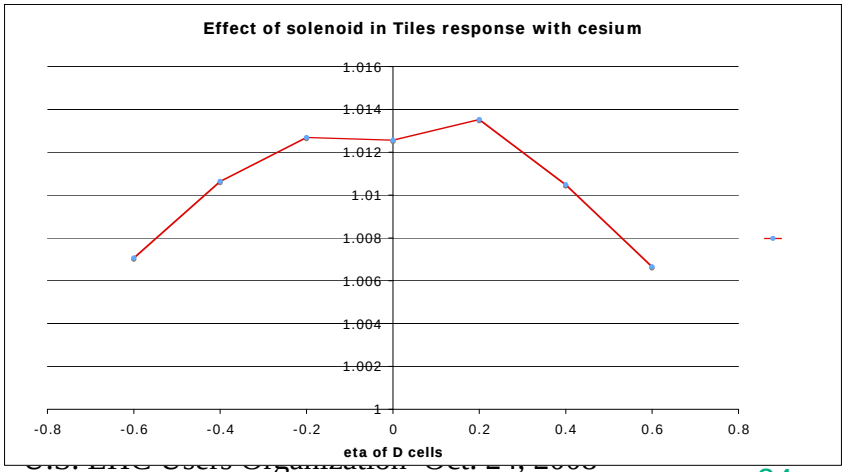
3.4 TILE CAL PROGRESS

- **U.S. Institutions: ANL/NIU, Chicago, MSU, UTA, UIUC**
- **Calorimeter working well after hardware commissioning**
  - ***Including modification of all LV power supplies and refurbishment of all readout drawers***
  - ***All drawers powered by both LV and HV***
    - ***LBC34 in special mode for HV***
  - ***Only 20 cells (of 5000) are not usable for physics now***
  - ***Still significant list of "lesser" problems for attention in shutdown***
- **No problems with front-end electronics and power supplies during magnetic field testing**
  - ***PMT gains appear stable***
  - ***~1.5% increase in the tiles' light response when solenoid field is on***

LVPS & drawer refurbishment



Online display of LV and HV status

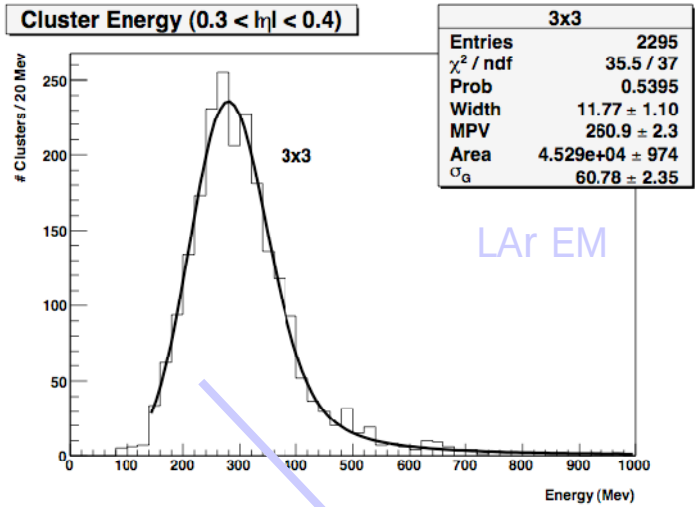


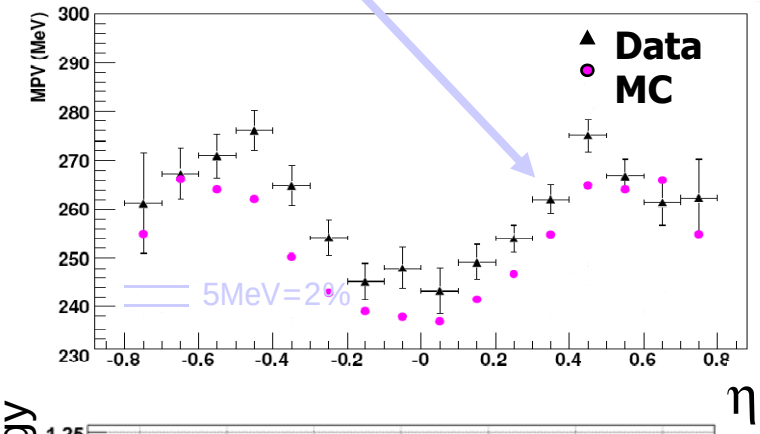
Light response vs eta position with field

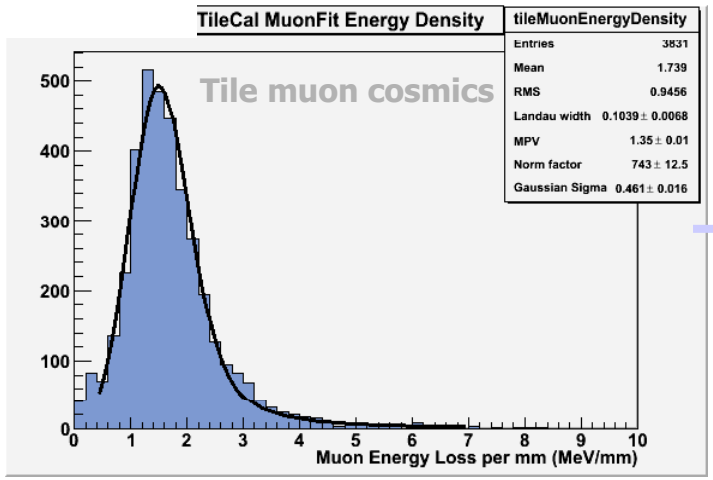
24

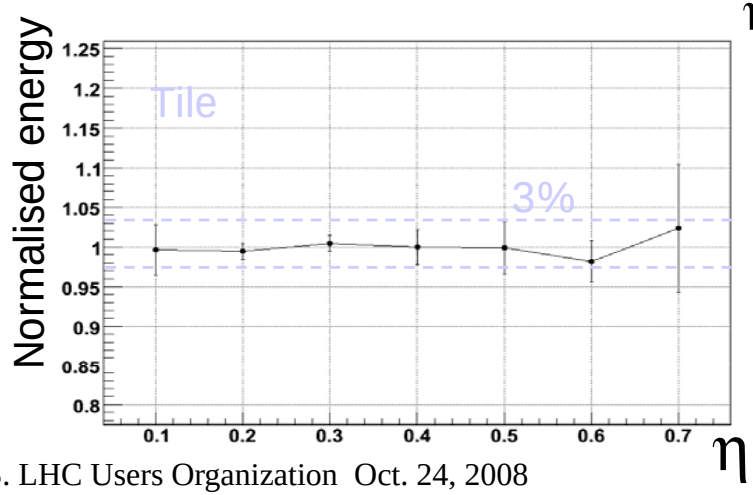
Calorimeter performance

- Energy reconstruction
  - LAr EM: Reconstruct E with 3x3 calorimeter cells, comparison to Landau
    - energy η dependence agreement, though there is a 5% systematic uncertainty on the MC prediction
  - Tile: energy deposited by μ vs. η, normalised by distance traveled in tile
    - energy scale&uniformity tested to 2-3%



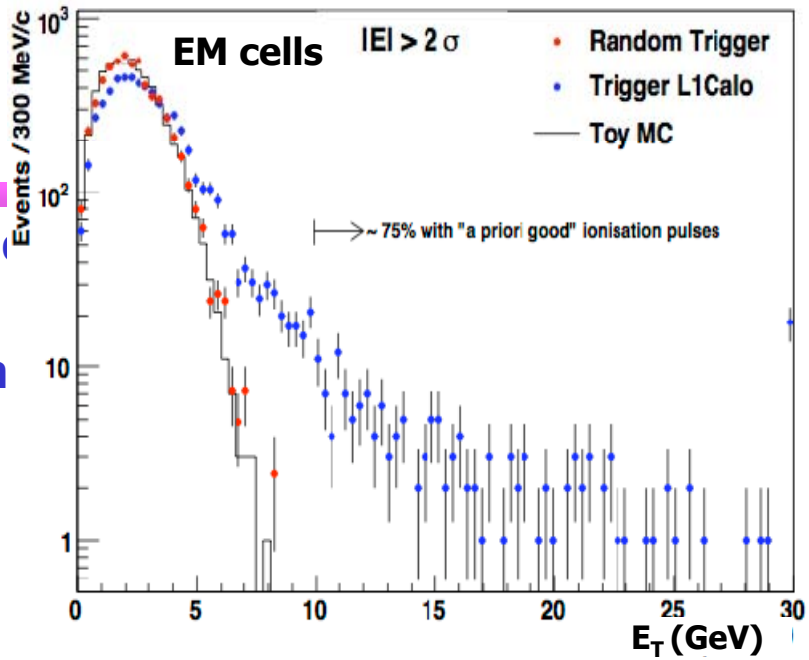




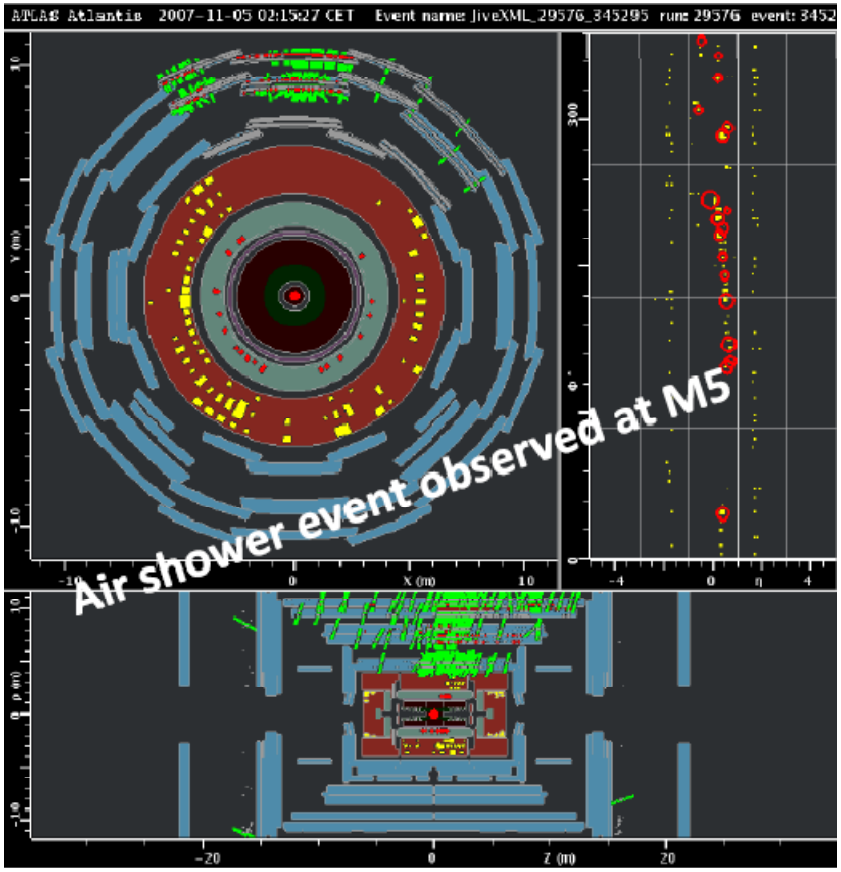


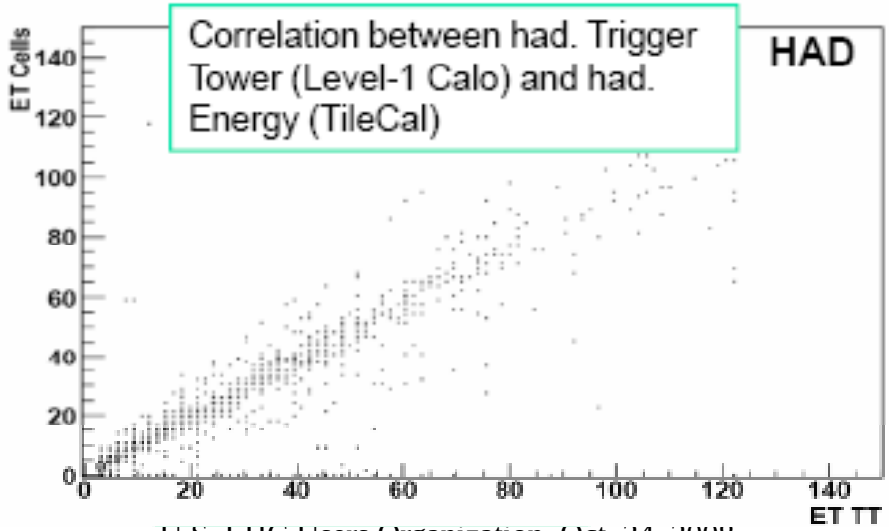
Calo/trigger performance

- Correlation between energy as measured in calorimeter and as seen in L1 trigger
- Impact of air showers as sources of non IP jets: reduced though timing cuts

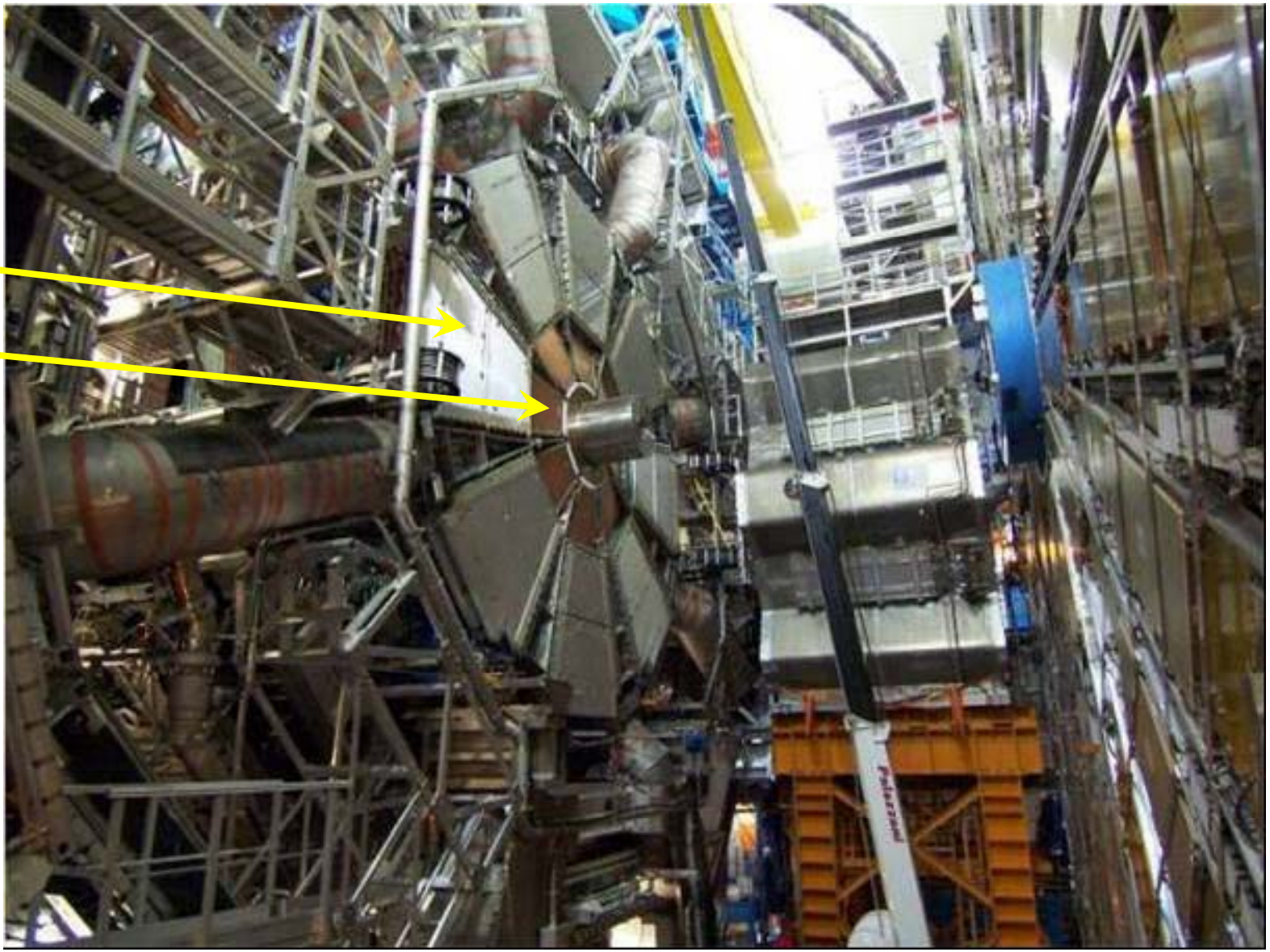


$E_T = \sqrt{(\Sigma E_{T,x}^2 + \Sigma E_{T,y}^2)}$



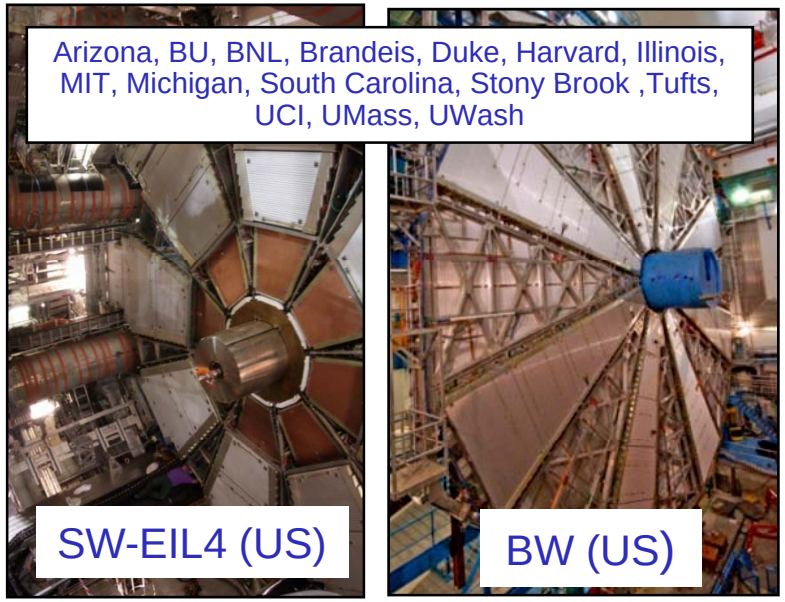


Muon EndCap MDT and CSC Chambers



WBS 3.5 Muon System Status

- All US-made components are commissioned
  - Have taken extensive cosmic ray data with both the RPC barrel trigger and the TGC endcap trigger
    - Data are useful for hardware operational tests as well as refinement of software and calibration
  - Alignment system operational – azimuthal & polar
    - Design resolution is being approached
      - 45 to 50 μm vs. design 40 μm
  - System operated well during the beam splash tests in September
    - But CSCs did not participate due to ROD rate and stability problem

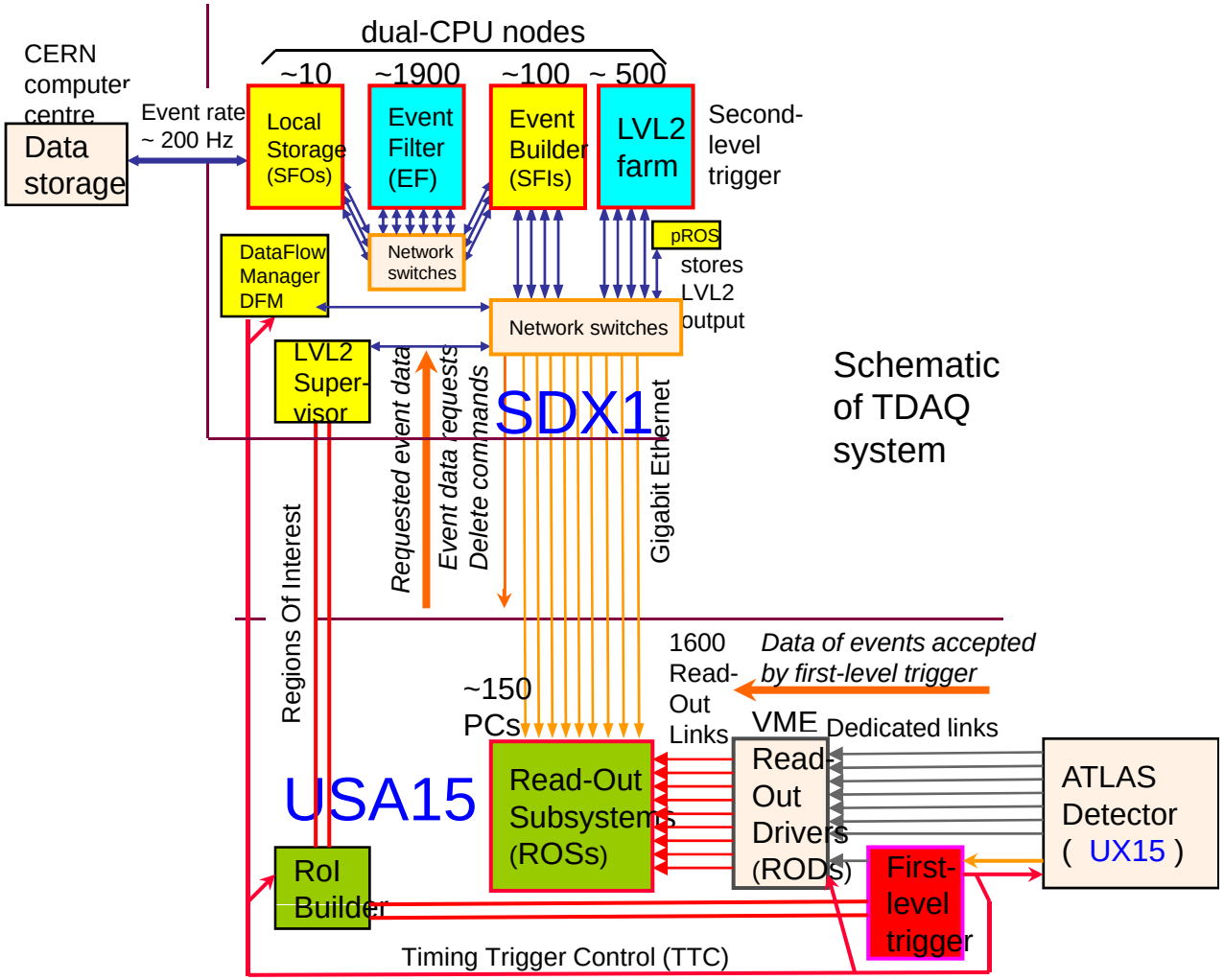


EE chambers Staged - will be installed during shutdowns
US alignment

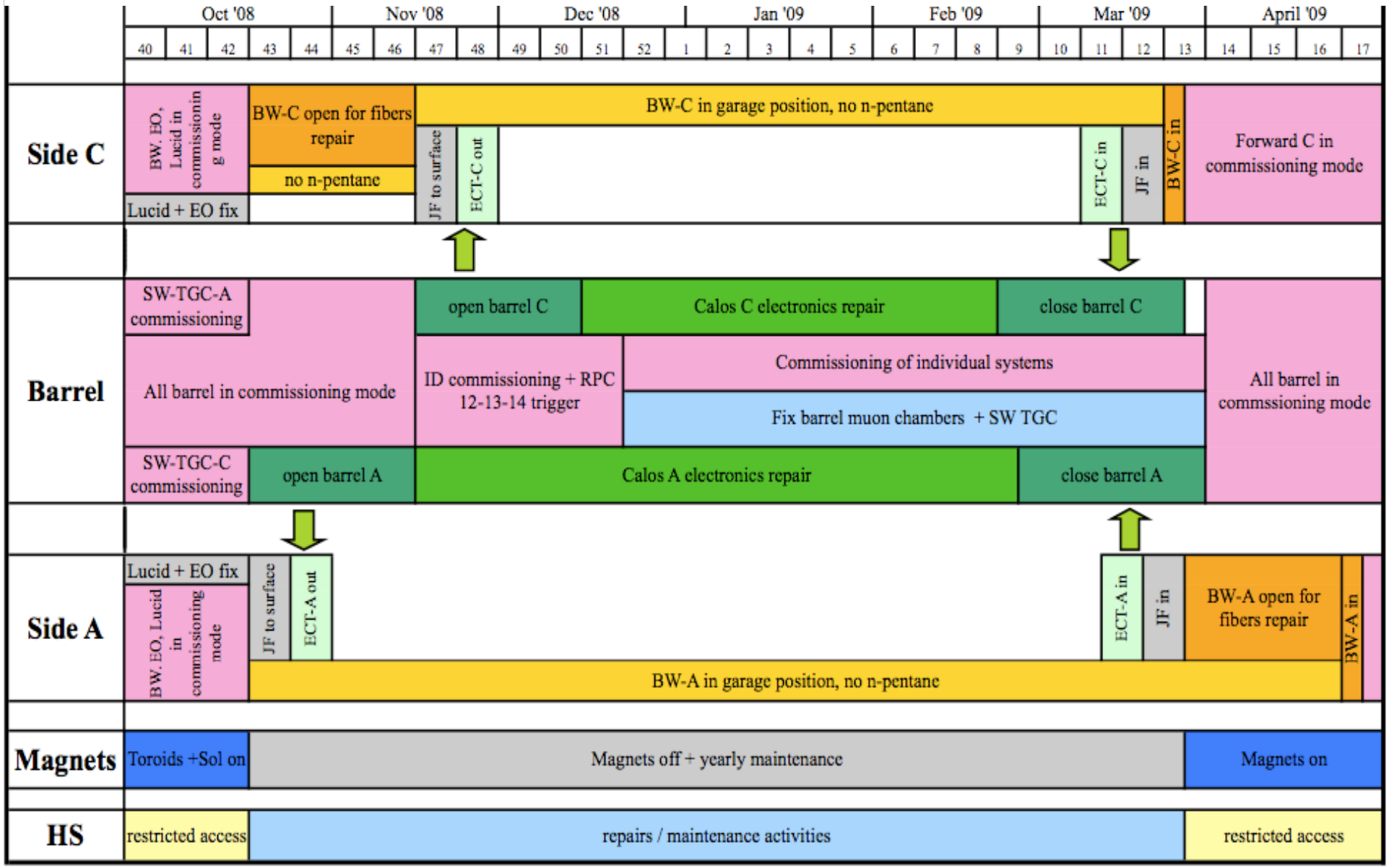
High Level Trigger Farm

3.6 TDAQ M&O

- US Institutions: UCI, MSU, ANL, Wisconsin, BNL, NYU, Arlington, Oregon, SLAC
- Hardware
  - Install/ commission
- DAQ/HLT Software
  - Integration/ test
- Trigger Selection & Algorithms
  - Testing/ refinement
- Data Quality Monitoring
  - Improved tools for maintenance & operation
- Currently in intense commissioning and support of detector commissioning

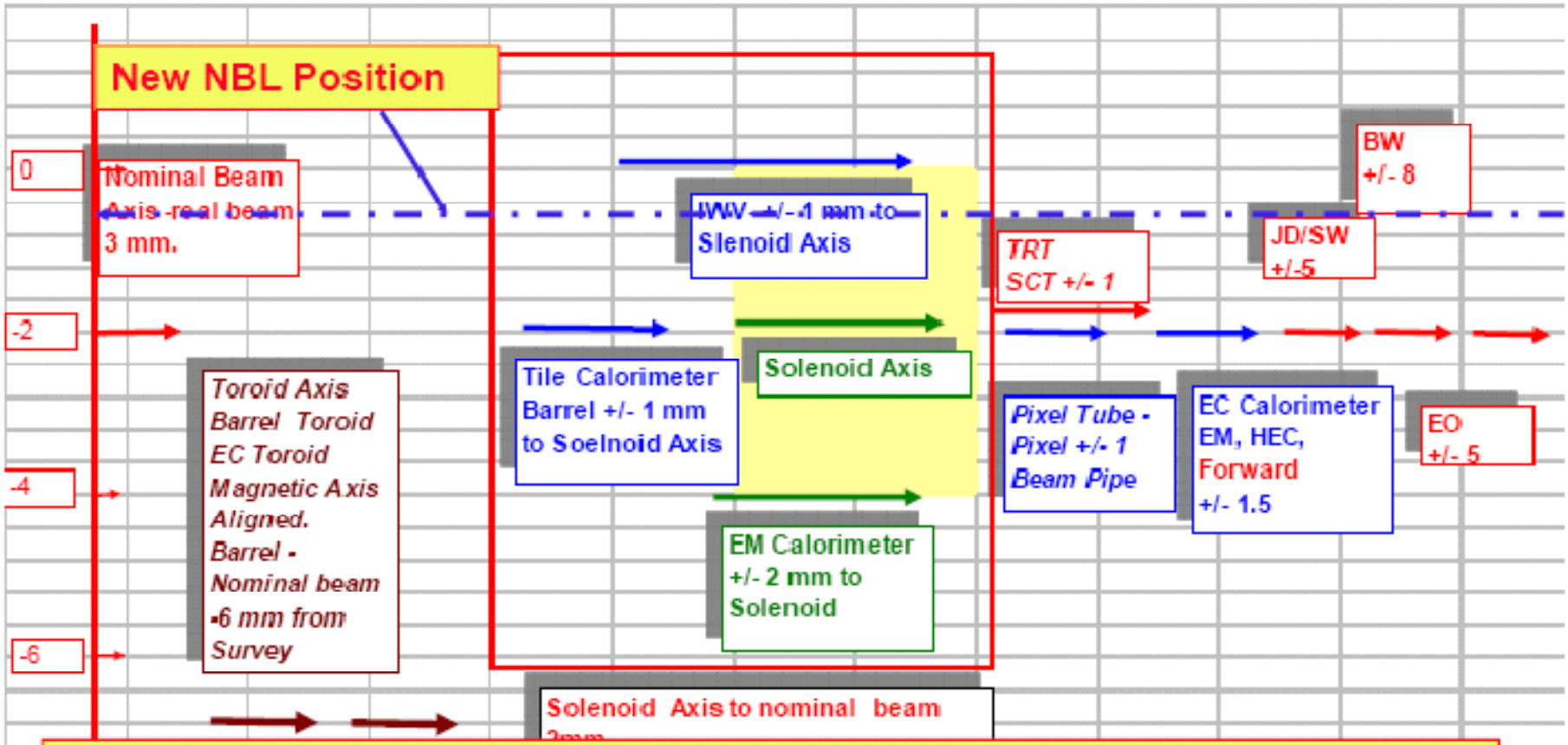


We have a detailed plan for the maintenance work to be completed before being ready for beam collisions next spring.



(Marzio Nessi)

An Example of Work in Technical Coordination



ATLAS is still "Dynamic" – need to keep monitoring.

Interact with the Machine.

Stability after movement.(Open/Close)

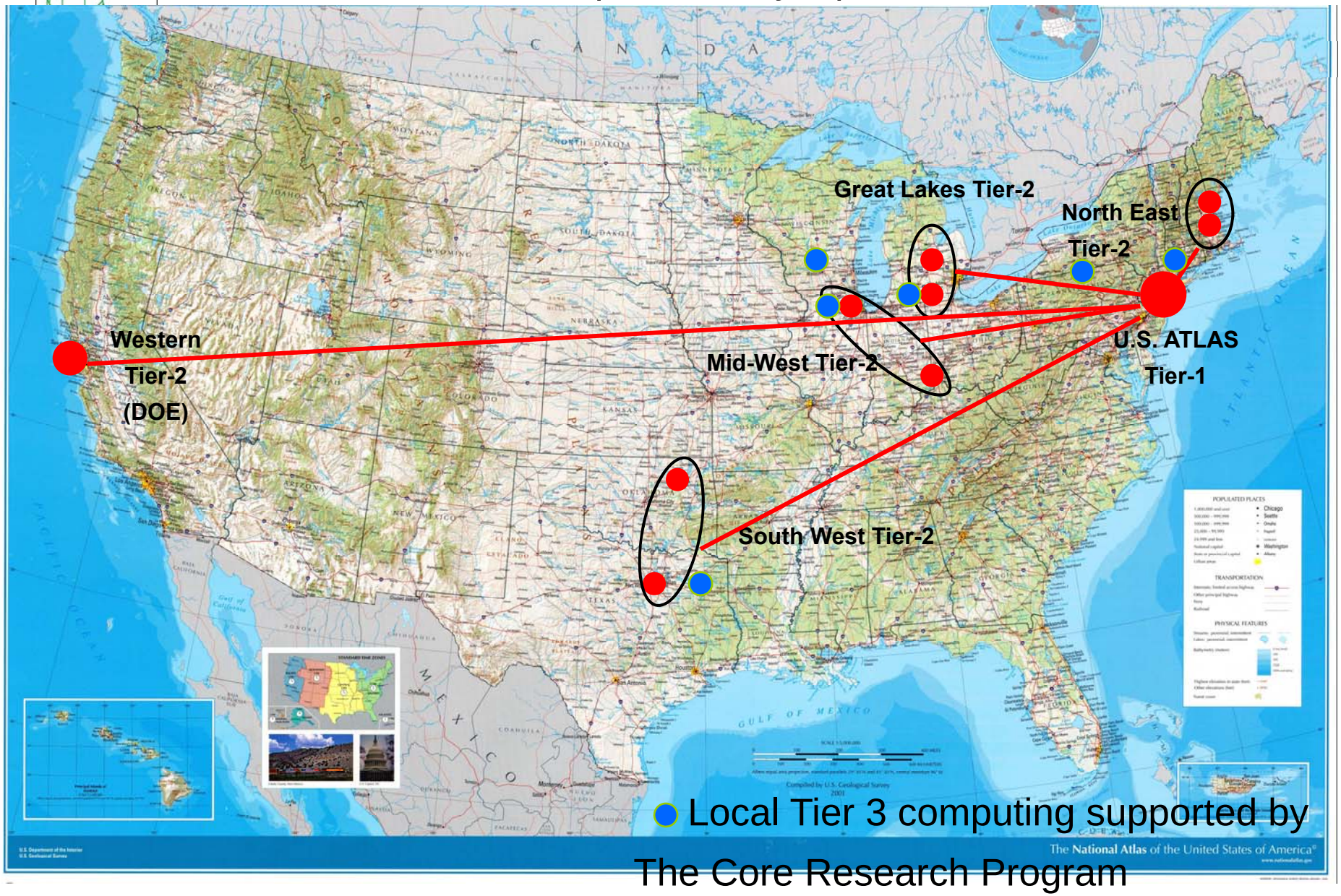
2.1 ANALYSIS SUPPORT (RECENT ACTIVITIES)

- Weekly U.S. Physics meeting focusing on data analysis of Cosmic and FDR (1 and 2).
- Many Jamborees at the three Analysis Support Centers
  - Six single Jamborees with average of 27 participants each
  - One dual jamboree (joint ANL-BNL) : 42 participants
    - Positive feedback on all jamborees
  - 3-way jamboree was held on September 9-12.
    - Focused on preparing for remote analysis with real data.
- Second Annual American Physics Workshop
  - Simon Frasier University, Burnaby, BC, Canada, June 16-18, 2008
  - Focus on early physics and tools to extract first results
  - Very productive tutorial on final day.
- Latin American Computing Workshop
  - 3-day workshop, March 2008, Buenos Aires
  - Several Americans (with NSF support), including students participated and conducted a series of tutorials, lectures to support our Latin American colleagues.

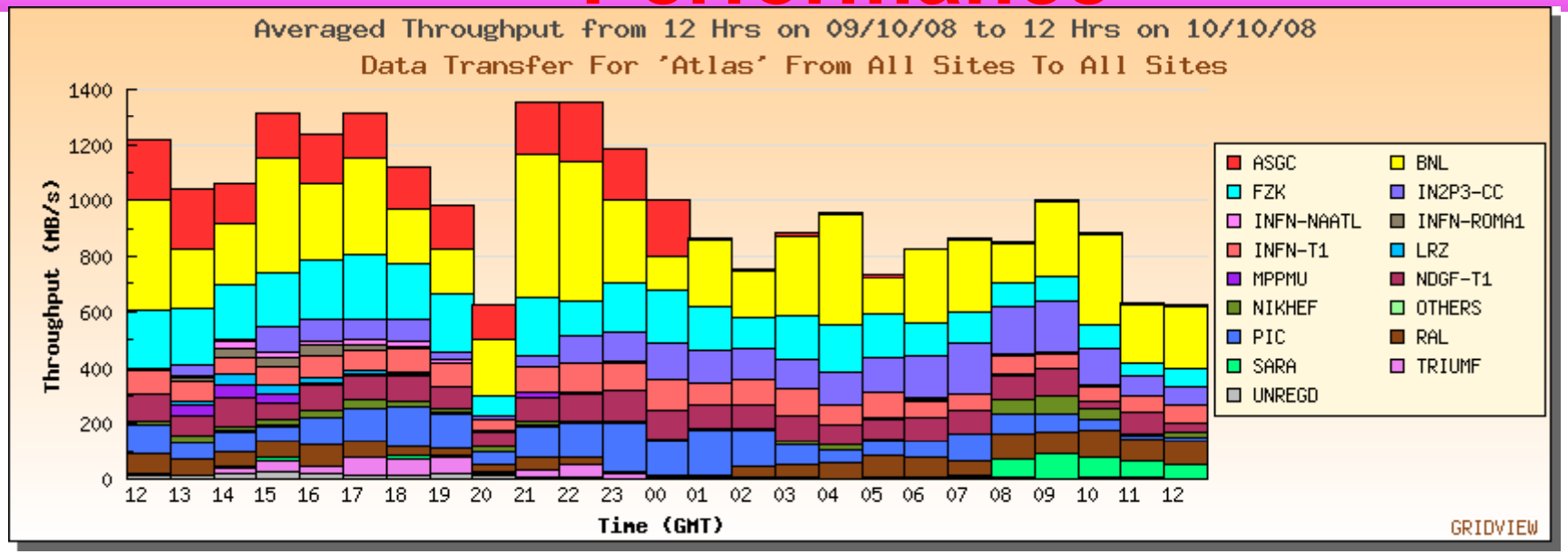
Jamboree class

Latin American Workshop, Buenos Aires, March 2008

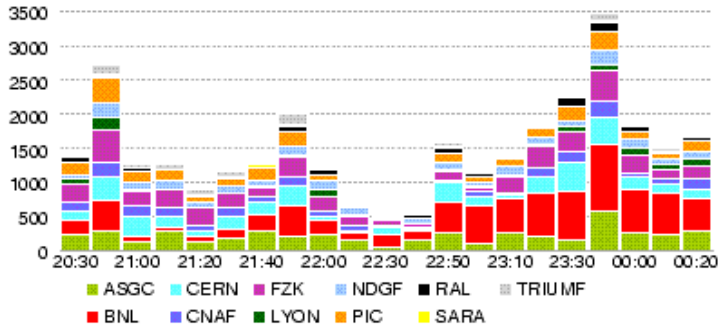
U.S. ATLAS Tier 2 Sites Empowered by Open Science Grid



ATLAS Data Replication Performance



Transfer performance for ATLAS Cosmic Data Replication from CERN to all ATLAS Tier-1 & Calib. sites



lata at a rate of >500MB/s

The maximum rate observed so far for transfers between CERN and the ATLAS Tier-1 sites is 3,500 Megabytes per second

Upgrade R&D

- Active Silicon work
  - Inner Pixel layer (b) inserted into the beam pipe (~2013)
  - The eventual complete replacement of the Inner Detector – all silicon (no TRT) (~2017)
  - Pixels, Strip staves, electronics, optical links
- Also lots of progress on Liquid Argon Electronics which is >x10 more radiation hard

Pixel Readout Chip Development

- A chip called FE-I4 is being developed in 130nm CMOS for ATLAS pixel upgrades. Results were presented at TWEPP08 and Pixel2008 conferences.

Collaboration of designers from 5 institutes (LBNL + 4 European).

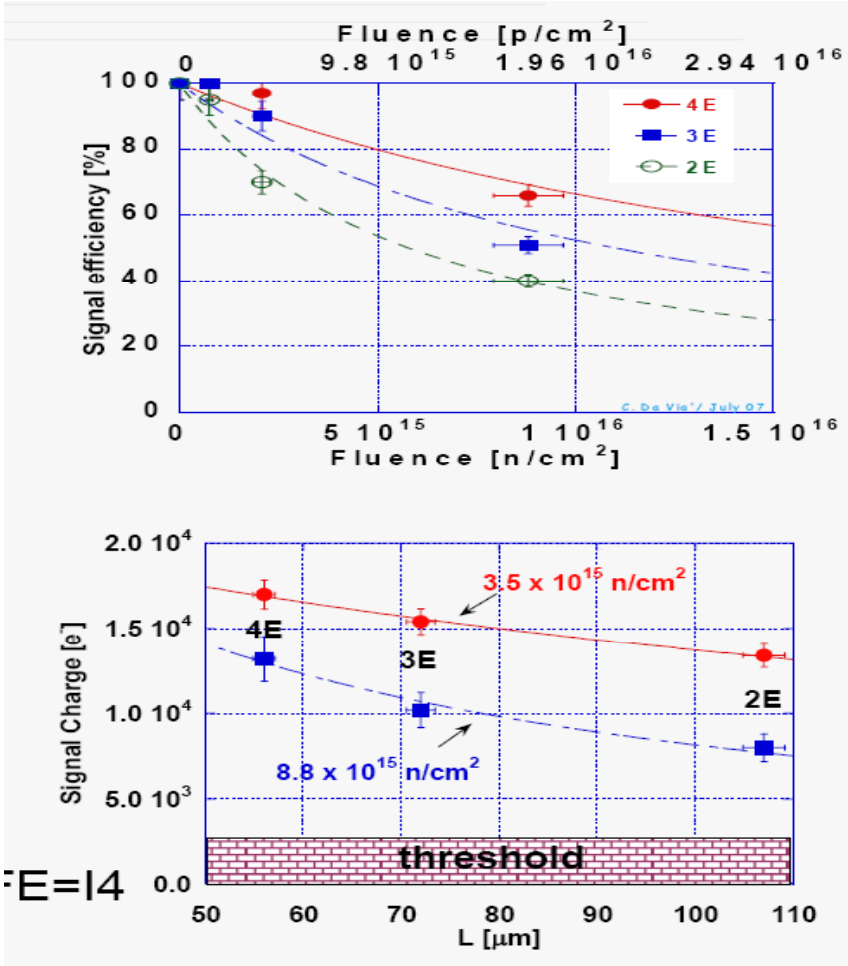
- Main advances of FE-I4:
  - 4x larger pixel array size to reduce material overhead and module assembly cost (2cm x 1.9cm chip size).
  - Smaller pixels (62% of present) and reduced analog precision (4x faster ADC) to function with >99% efficiency at higher track occupancies
  - Lower current consumption per unit area thanks to greatly increased digital functionality inside the pixel chip
    - FE-I3 data storage = 1.5 bits/pixel, FE-I4 = 40 bits/smaller pixel
  - First HEP on-chip x2 DC-DC power converter included in design.
- A suite of 3 test chips were fabricated in FY08 (5% scale pixel array, LVDS chip, SEU register chip).
  - First irradiations already performed (LANL, CERN). Good results so far, provides basis for FEI4.
- Analog layout close to final. Digital design in progress.
- Target final design review March 09, full wafer engineering run Summer 09.

3-D Pixel Detector Development

- **Focus on production scaling and industrialization.**
- **Productions at SINTEF (European collaborator driven and funded) and Stanford.**
- **Technology development in parallel (irradiation, modeling, operation of assemblies). A number of runs have been completed and several planned for next year.**

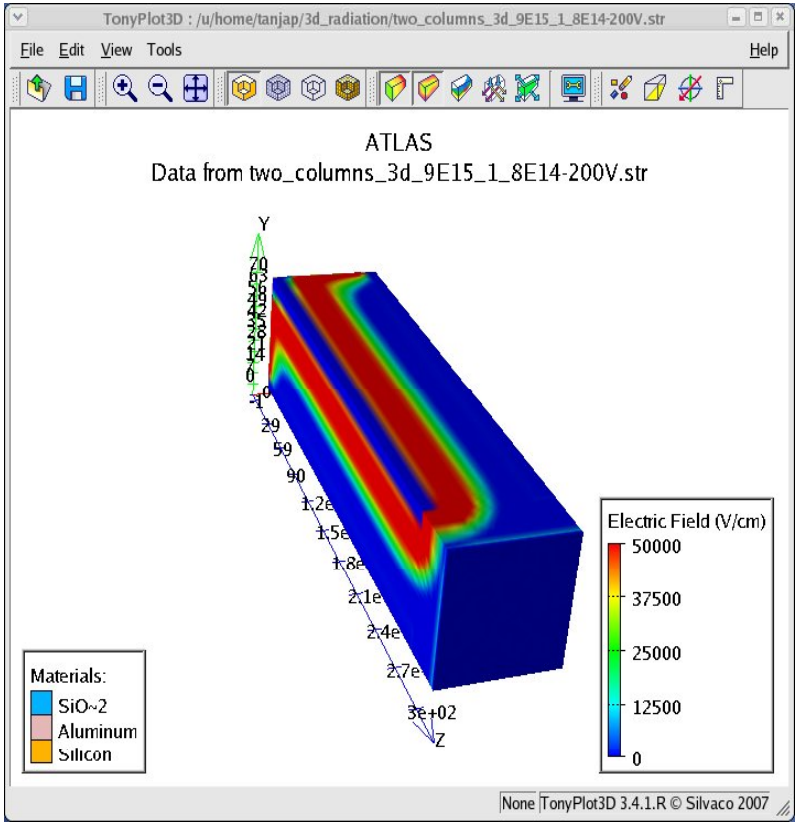
Run completion date	Oct. 2008	Jul. 2008	Nov. 2008	Apr. 2009	Sept. 2009
facility	Stanford	SINTEF	Stanford	Stanford	SINTEF
sensor type	3D	3D	planar active edge	3D	3D
start date		Dec. 2006	Jun. 2008	Nov. 2008	Nov. 2008
Number of wafers	3	25	8	6	25
Number FE-I3 tiles /w	30	54	12	>10	39
Number of I4 mini-tiles /w	0	0	14	>10	0
Number of FE-I4 tiles /w	0	0	2	>2	2
Yield	50%	8%*			
Modules produced/expected	/ 20	10 / 10			
Bump bonding facility	Stanford	IZM	Stanford	Stanford/IZM	IZM

3-D Silicon Pixel Detector Irradiation Results



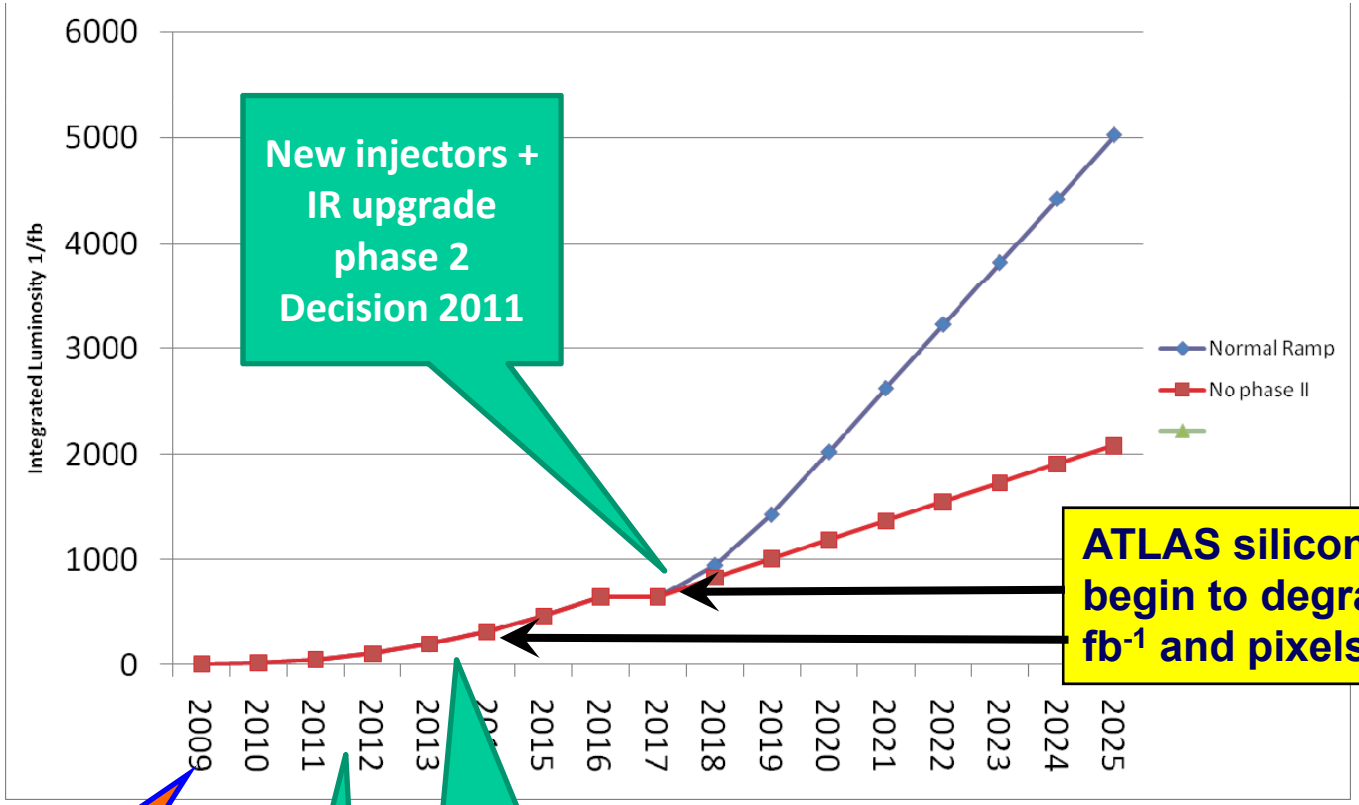
Recent irradiation results. 4E, 3E, 2E refer to number of columns connected to one electronics channel.

9×10^{15} n_{eq}/cm^2



Device simulation results.

We are planning for an Upgraded Detector since CERN has approved a Phase 1 upgrade to the LHC – This will allow an increase in Physics Reach of ~30%



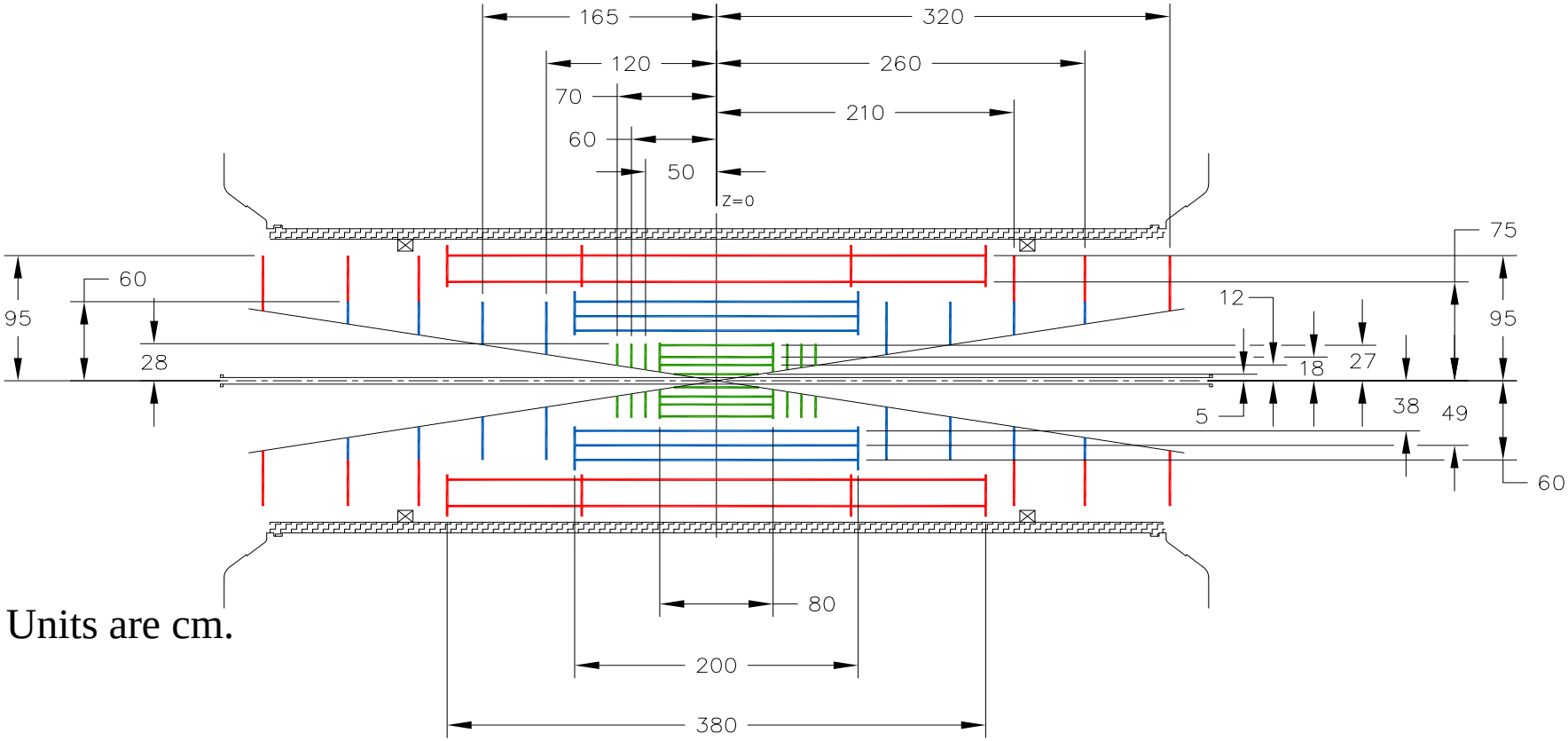
300 fb^{-1} ~ 3 years at 10^{34} – nominal program

700 fb^{-1} ~ data accumulated until 2016

1700 fb^{-1} ~700 + 5 years at 3x10^{34} Phase 1

3000 fb^{-1} ~5 years at 10^{35} – Phase 2

For ATLAS we would completely replace the Inner Detector, and upgrade the Trigger/DAQ and FCAL

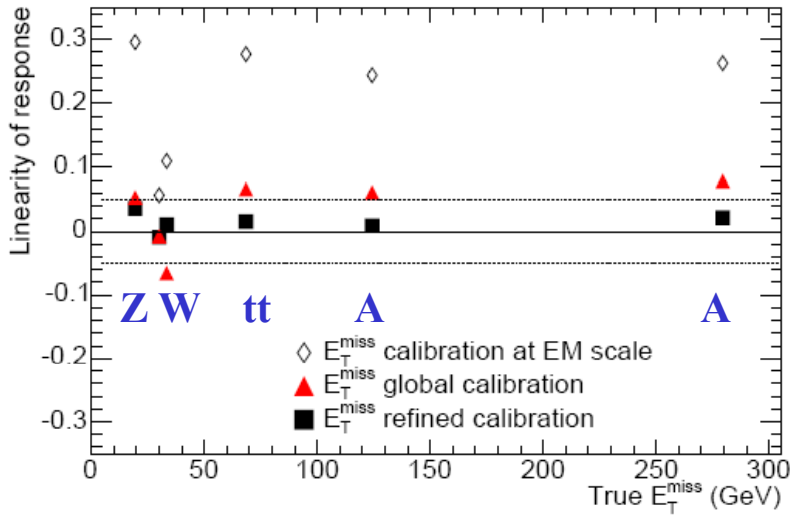


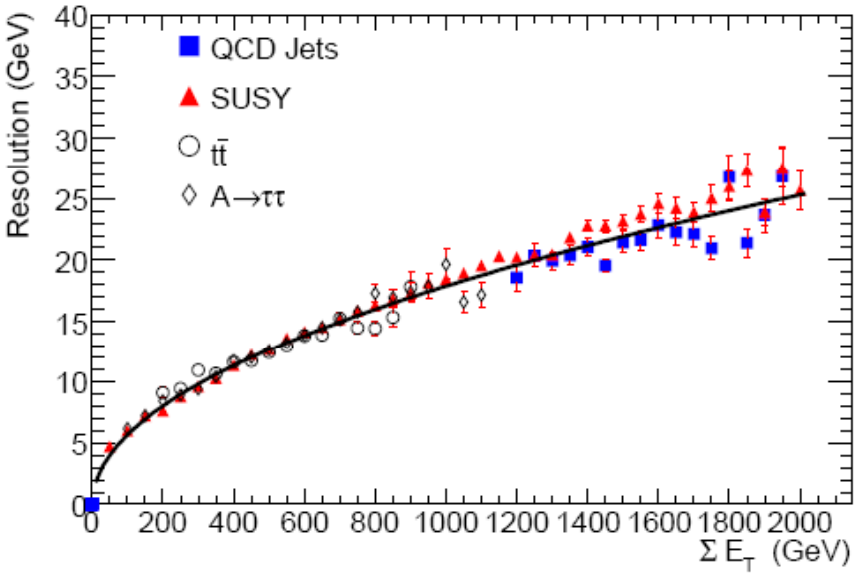
Units are cm.

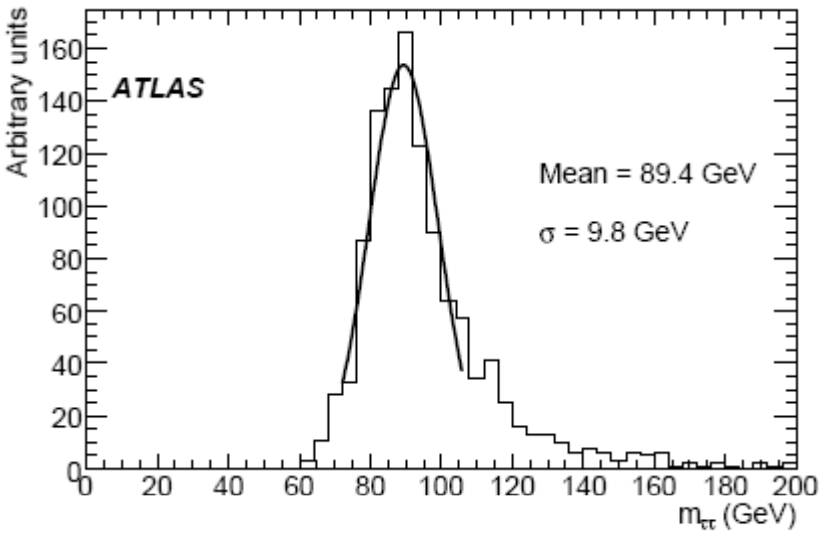
Expected performance: $E_T$miss

$E_T$miss at EM energy scale ~30%
refined with
- muons
- electrons
- jets

$E_T$miss scale ~ 5%
$E_T$miss resolution $0.57\sqrt{E}$
First check: $Z\rightarrow\tau\tau$
energy scale 2%



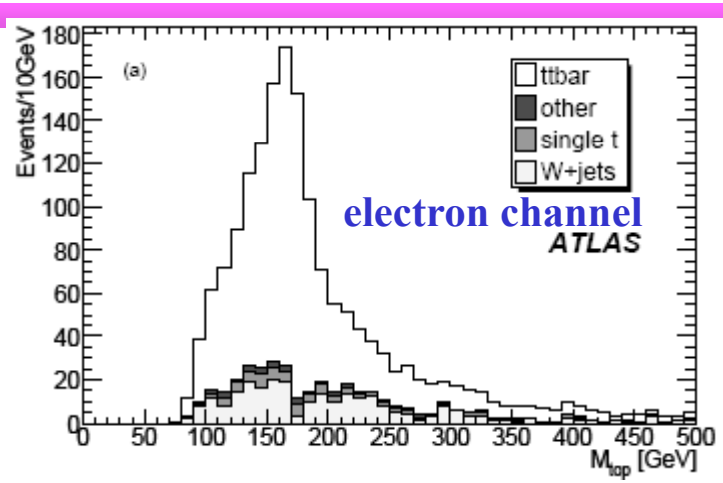


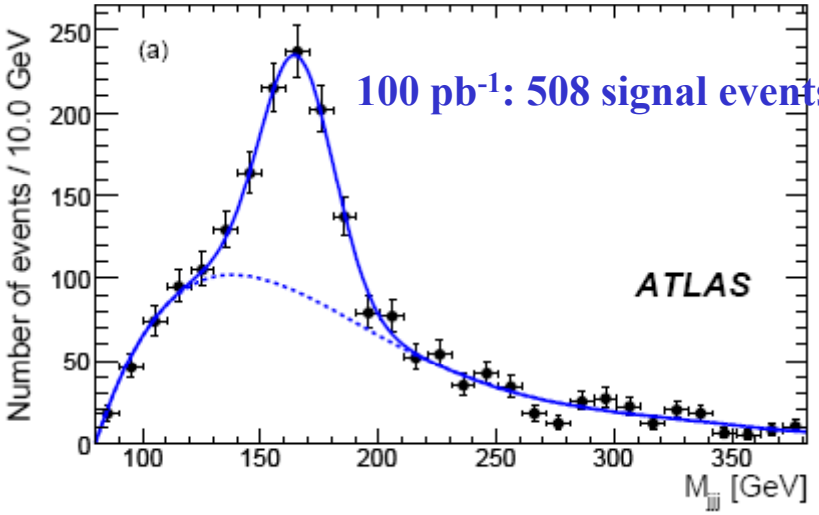


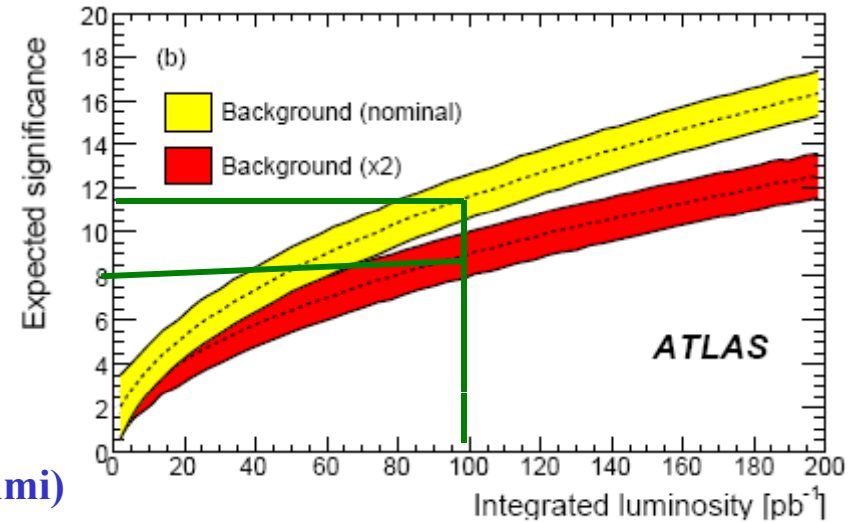
Standard model: top quark

The LHC top quark factory
→semi-leptonic top quark events
no b-tagging used

First physics:
- 100 pb^{-1} clear signal even with QCD bg x2
- signal purity for the muon/electron channel 80%





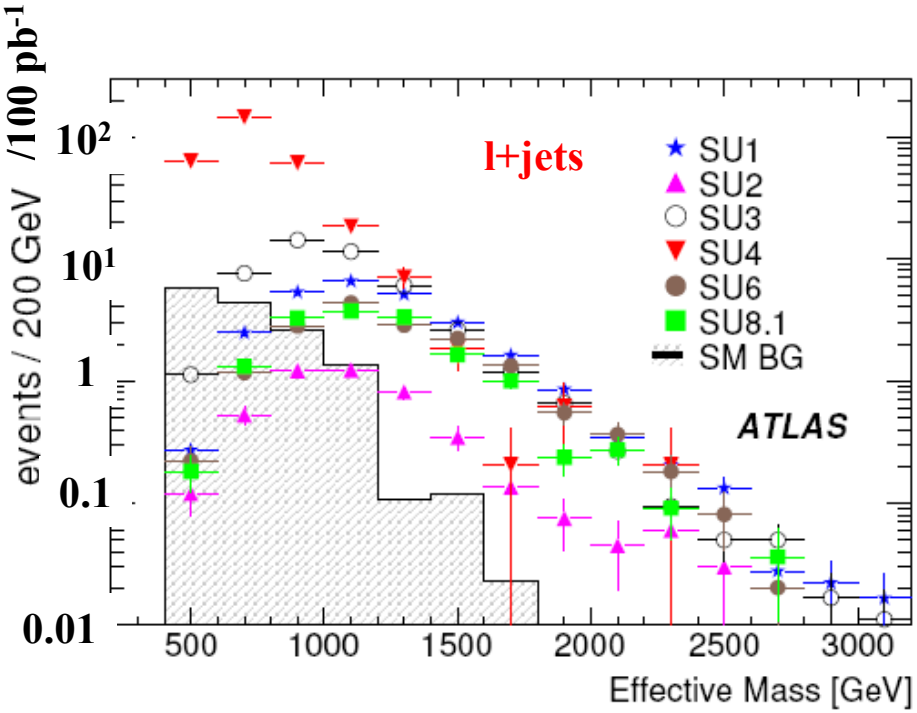


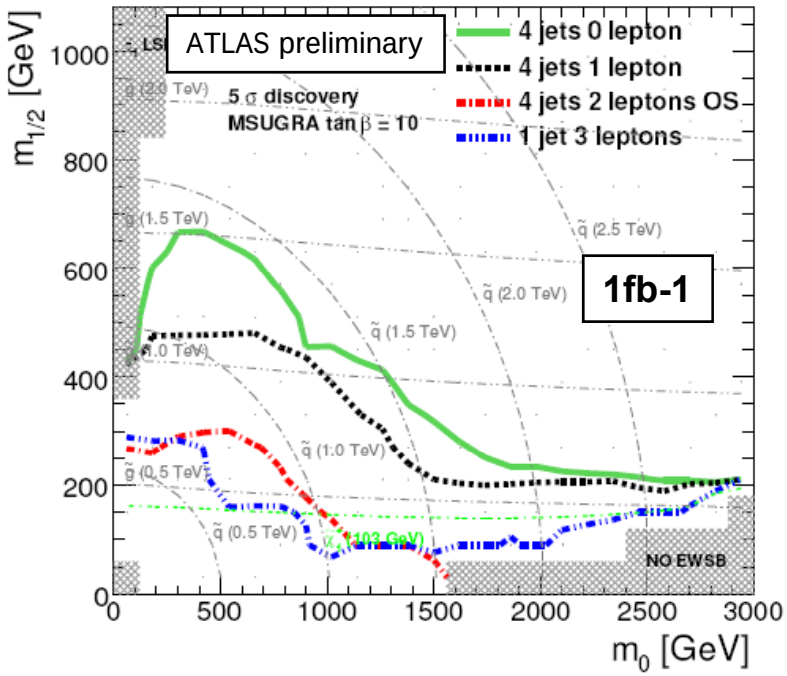
$\Delta\sigma/\sigma$ = 7% (stat) ± 15% (syst) ± 3% (pdf) ± 5%(lumi)

New physics: Supersymmetry

Large cross sections for gluinos and squarks:
- multi-jet + large $E_T$miss (+leptons)
- necessitates understanding of all components

Define effective mass:
- sum of jet p_T and $E_T$miss
- require one lepton
- less statistics, but cleaner





Sensitivity:
- $10pb^{-1}$ ~400GeV sensitivity=TeVatron
- $1\ fb^{-1}$ ~ 1.5TeV (all jets)
- $1\ fb^{-1}$ ~ 1TeV (1lepton + jets)

Physics Prospects

- We would benefit from the full 14 TeV
  - Prospects are that the LHC will still start up at <=10 TeV
- Still the prospects for some high cross section discovery in the first year or two is high: Supersymmetry, Extra Dimensions, Micro Black Holes
- The potential for the discovery of the Higgs boson is still very high over the full mass range (as opposed to a narrow range at the Tevatron) – but it will take several years of data taking.
- We are really looking forward to the collisions hopefully next spring and the start of the physics discoveries.
- I did not have time today – but we also have an extremely effective program for Heavy Ion Collisions and are planning for some DOE NP support.