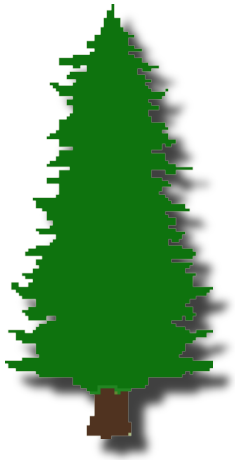
Elementary Particle Physics at the Highest Energies with the ATLAS Experiment

Jason Nielsen

Department of Physics

Santa Cruz Institute for Particle Physics

University of California, Santa Cruz

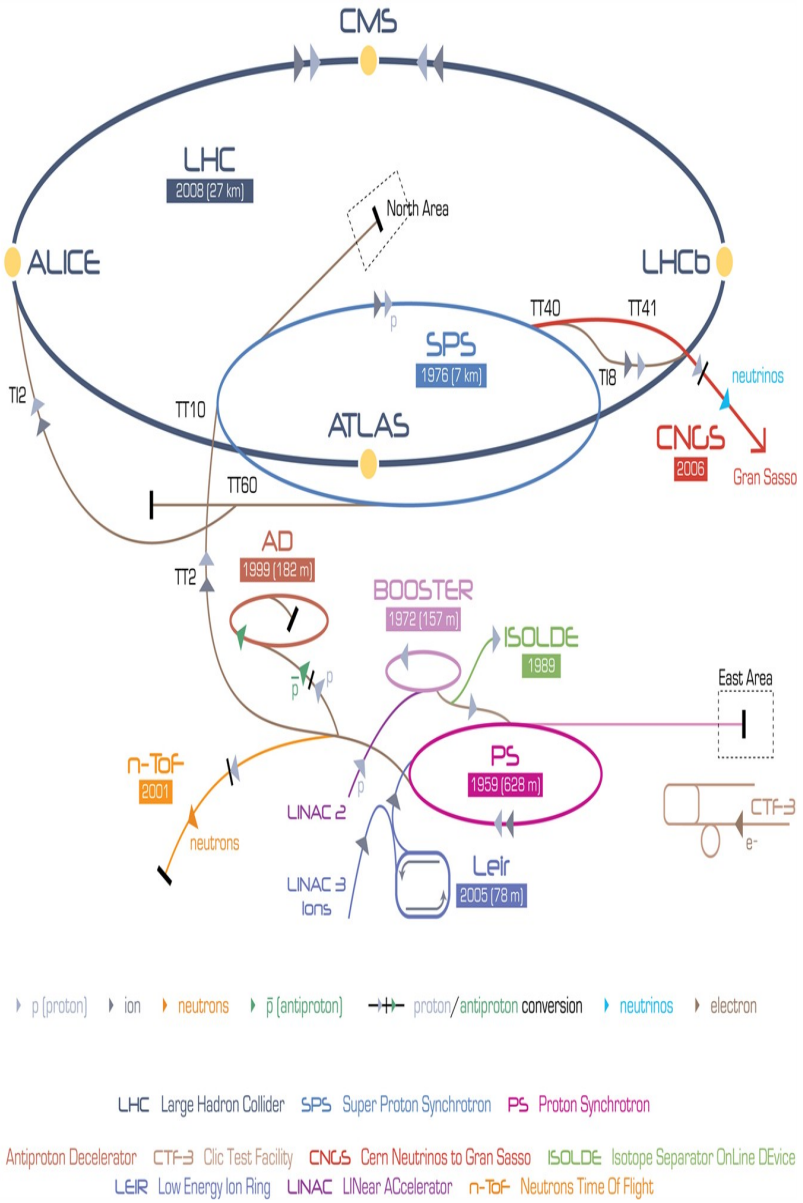


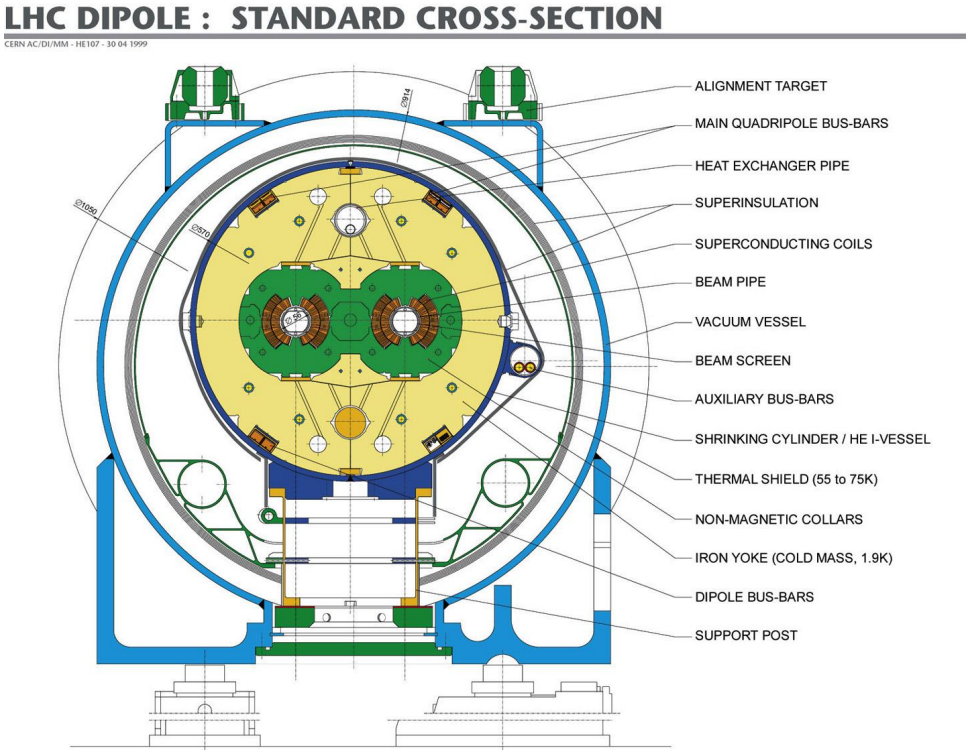
UCSC Physics 205
January 23, 2012

Motivation: Accessing the Terascale

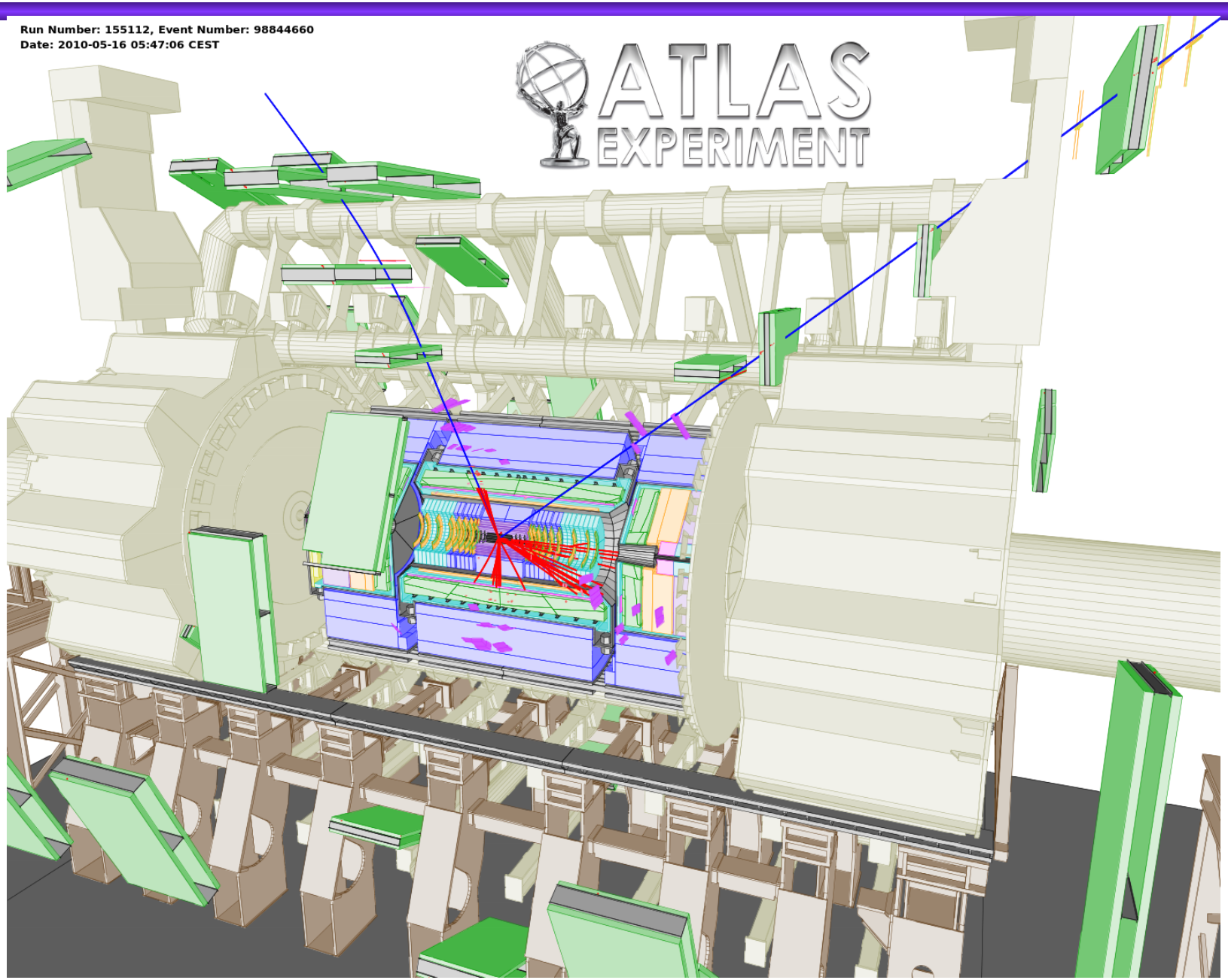
- Expect new physics (Higgs, SUSY, DM, ??) to compensate for irregularities encountered in the Standard Model
  - "Energy frontier" vs "intensity" and "cosmic" frontiers
- UCSC group was one of the first US groups to begin involvement in ATLAS after SSC cancellation in 1994
- Studying proton-proton collisions at 0.9-14 TeV energies
- Research in this field requires
  - Electronics skills for experimental apparatus
  - Knowledge of reconstruction and analyis software
  - Good grasp of current results in underlying theory
  - Ability to work in international collaboration

Large Hadron Collider





ATLAS Experiment at the LHC

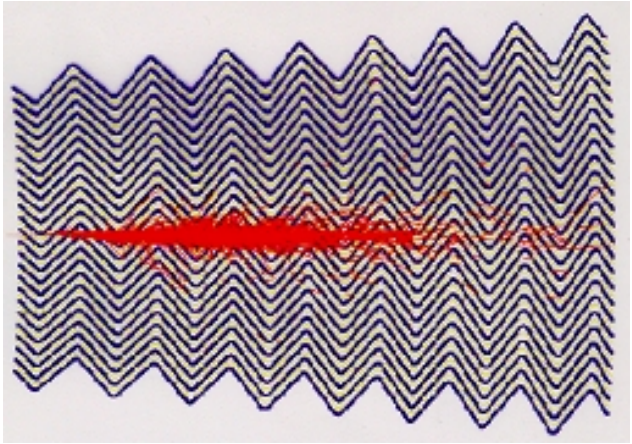


Why is the Detector Apparatus So Big?

In fact, it is just big enough to measure particle kinematics accurately!

Calorimeter

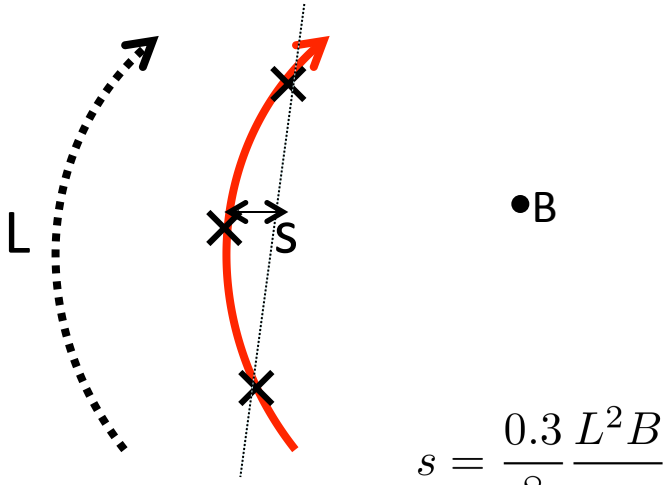
Particle deposits energy by showering in dense absorber medium



Remaining energy $E(x) = E(0)e^{-\rho x / X_0}$
(X_0 is measure of energy loss in medium)

Spectrometer (Tracker)

Charged particle moves along helix under influence of strong B field



$$s = \frac{0.3}{8}\frac{L^2 B}{p_T}$$

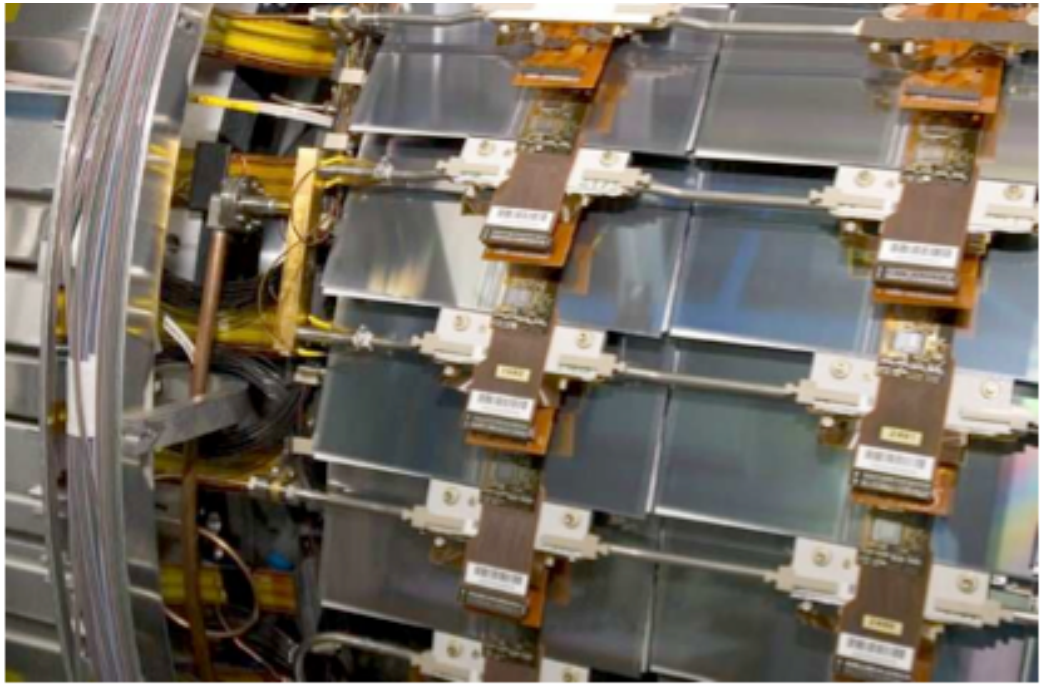
Measuring sagitta of 1 TeV muon requires large L and large B

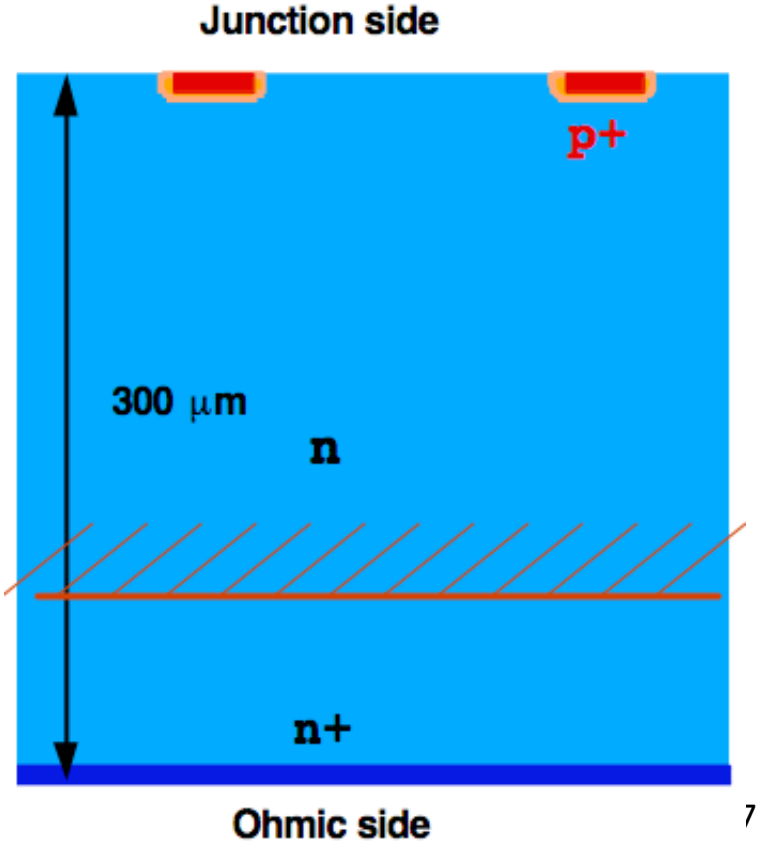
ATLAS Collaborators at UCSC

Sofia Chouridou
Dan Damiani
Alex Grillo
Tae-Sung Kim
Andrew Kuhl
Alexander Law
Alan Litke
Bill Lockman
Peter Manning
Jovan Mitrevski
Hartmut Sadrozinski
Bruce Schumm
Abe Seiden
Vitaliy Fadeyev
Forest Martinez-McKinney
Ned Spencer
Max Wilder

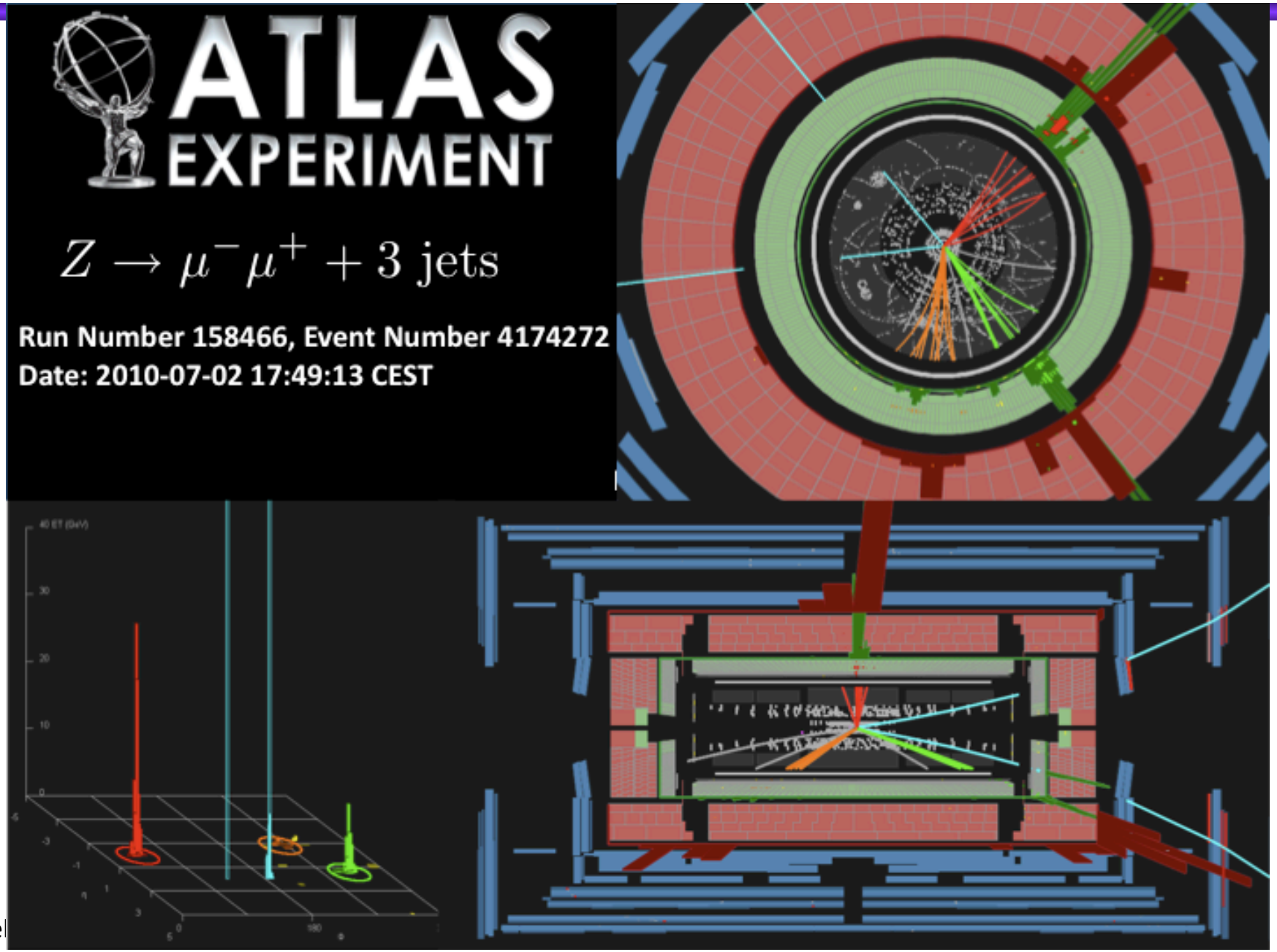
ATLAS Semi-Conductor Tracker

- Segmented strips; p-n junction; depletion region
- Relatively cheap way to cover large cylindrical area
  - Segmentation in z (giving "pixels") can improve resolution
- Collaboration with Japan, UK, and others





ATLANTIS Event Display



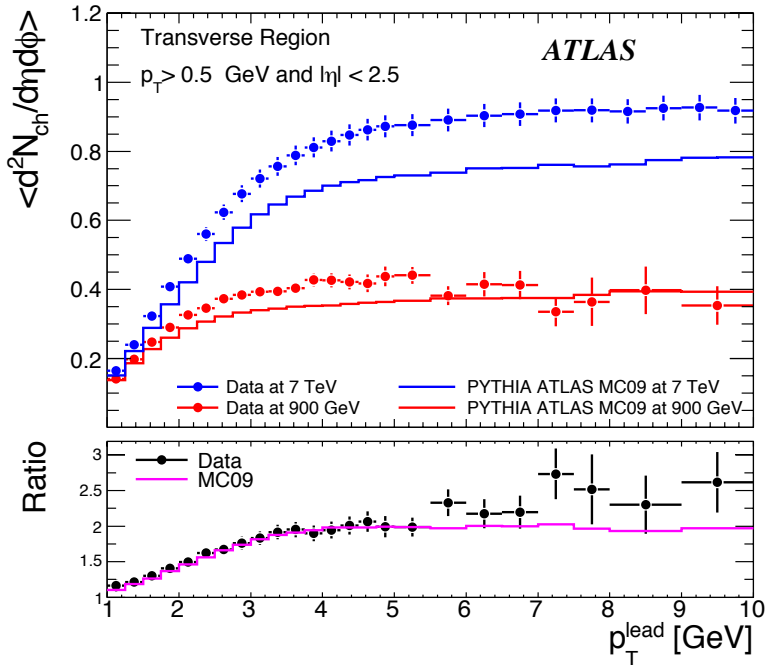
Search for New and Measure the Old

- Measuring SM physics processes allows us to test our detailed calculations to
  - Calibrate the detector performance
  - Confront established models of proton interactions
  - Check properties of high-mass particles produced in large quantities
- Searching for new physics predicted by SM and BSM
  - New particles in theories of supersymmetry
  - Higgs bosons from SUSY theories and from SM
  - Universal extra dimensions
- Some new particles may be dark matter candidates, too

Proton Collisions & W/Z Boson Production

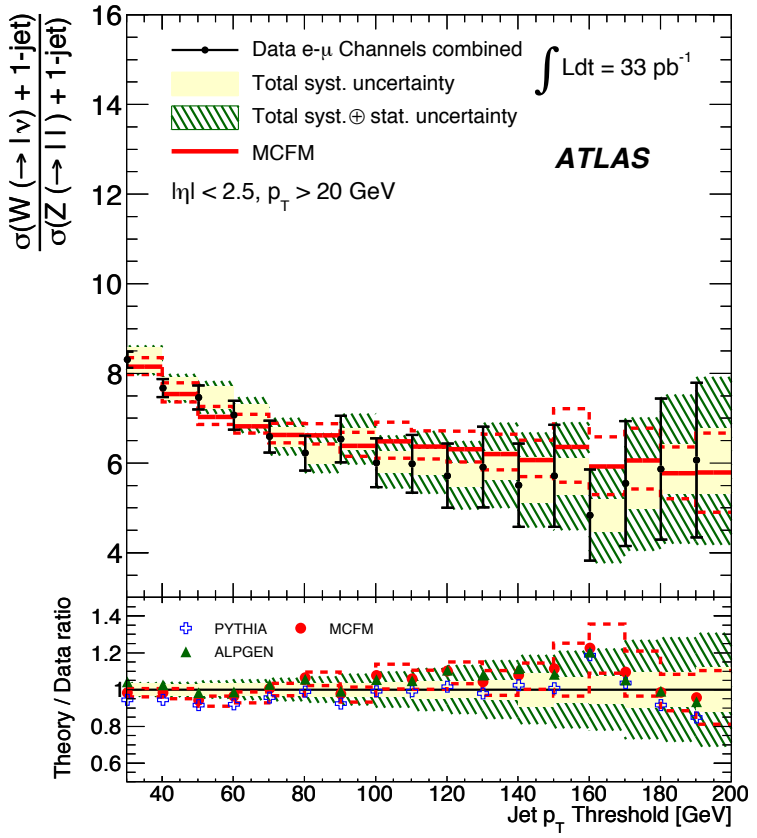
Multiple parton interactions

Interaction models failed to predict the number and momentum of charged particles produced



Retuned interaction models for use at 7 TeV and beyond

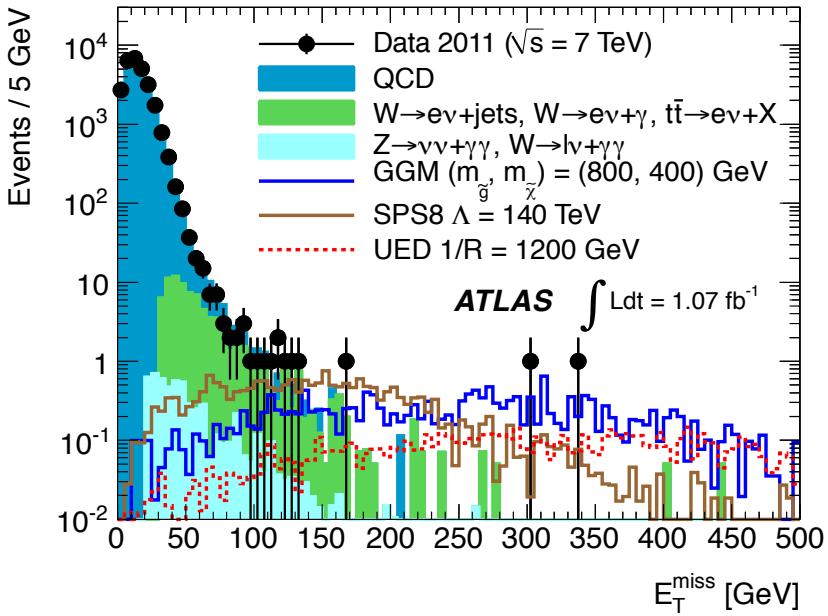
Ratio of W production to Z production

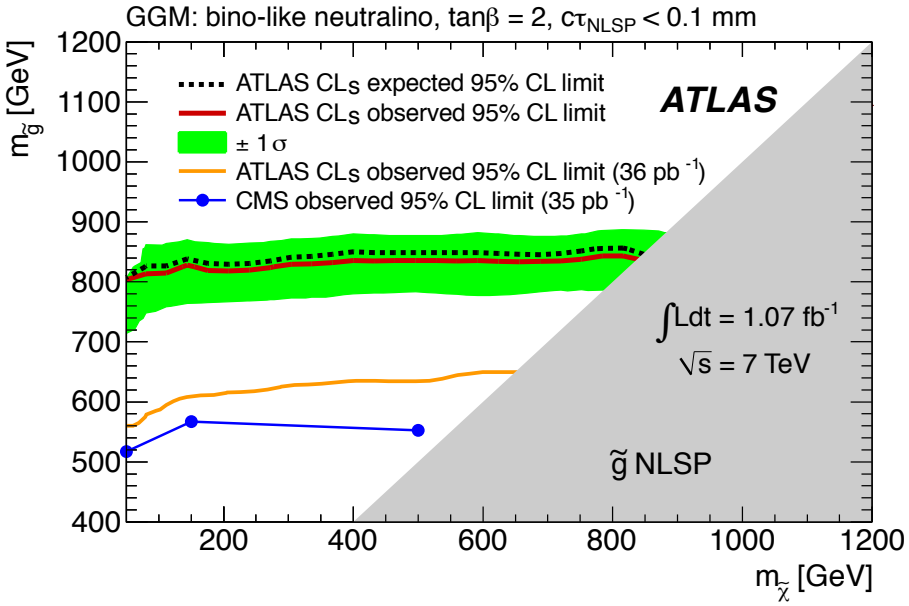


Hot topic in perturbative QCD theory, where first precision calculations are being made right now

Searches for Supersymmetry

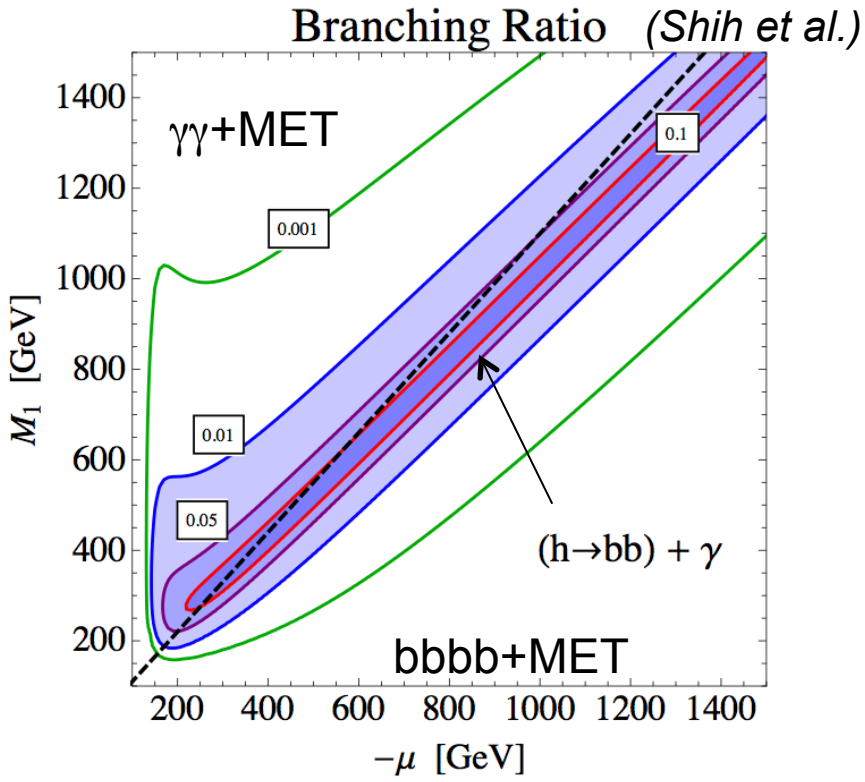
- Non-resonant diphoton production with non-interacting gravitinos (dark)
- Photon conversion recovery is the key to high efficiency
- World's best sensitivity to General Gauge Mediation models of GMSB



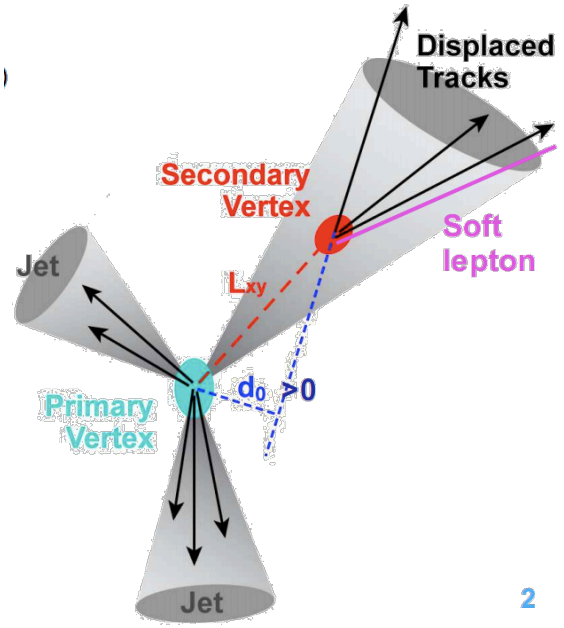


Searches for Higgs Bosons

- Neutralinos may even decay to SUSY Higgs bosons, which decay in turn to b-quarks



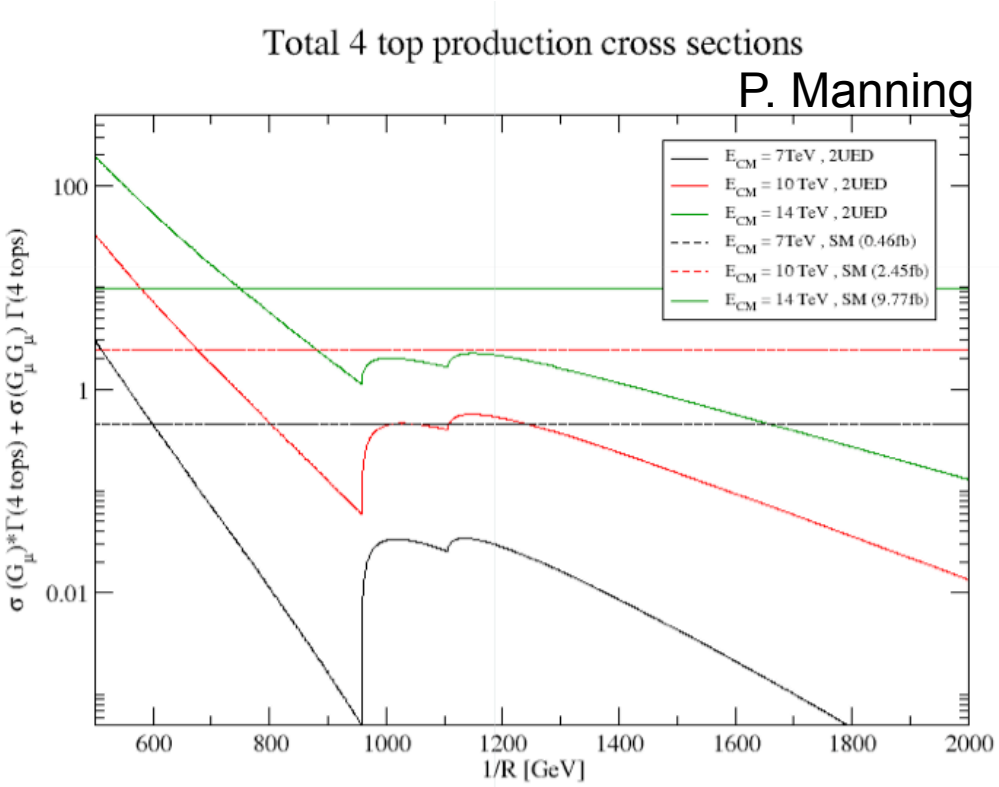
- Low-mass Standard Model Higgs bosons also decay most often to b-quarks, "tagged" by precision track vertexing



Universal Extra Dimensions

- All particles propagate through 4+2 dimensions
  - Addresses weakness of gravity relative to other forces
  - Two compactified dimensions give rise to tower of excited modes (new particles – dark matter?)

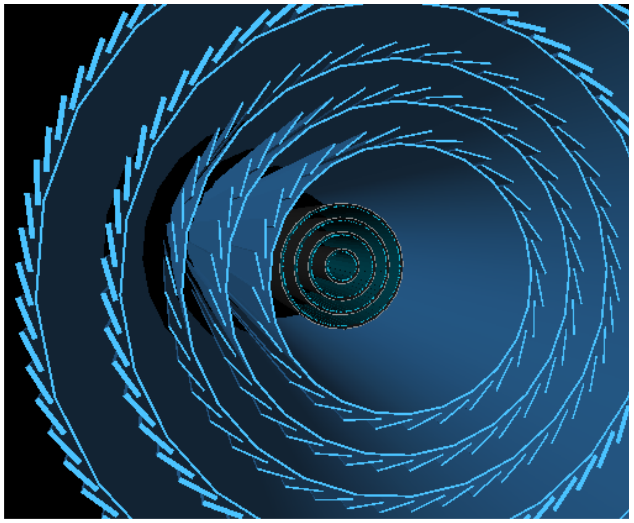
- Certain 2UED scenarios predict direct production of 4 top quarks – impressive number of particles in the event

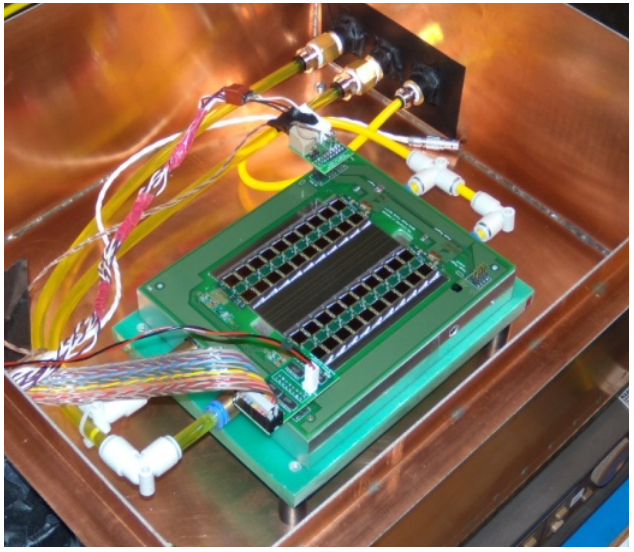


Proposed LHC & ATLAS Upgrade

- New high-mass particles are produced rarely, so it has been proposed to increase the LHC luminosity (sLHC) and increase the overall rate of pp collisions
- Expect fluences of 10^{16} neutron equivalent / cm^2 in inner detector over lifetime of the experiment
  - Requires radiation-hard detectors, fast readout of tens of thousands of important track points
- Working on research & development for
  - Inner "B-Layer" addition: pixel layer near beamline
  - Phase I: perhaps replace inner layers of pixel detector
  - Phase II: replace entire tracking detector

ATLAS Tracker Upgrade R&D





- Radiation-hard silicon sensor technology
- SiGe low-power analog preamplifier design
- High-speed data transmission on thin cables
- Construction of prototype detector modules
- Simulation of performance

Summary

- UCSC ATLAS group is contributing strongly to studies of physics at the energy frontier
  - Searches for new particles
  - Precision measurements of the Standard Model

- Hope that we will see new physics beyond the Standard Model this year or during a 14 TeV run in late 2014
  - Some tantalizing hints of the Higgs boson

- SCIPP laboratory hosts R&D on the proposed detector upgrades for the ATLAS experiment tracking systems

Possible LHC pp Run Schedule

- 2010-2011: 7 TeV, collected 5 fb^{-1} total
- 2012: 7 TeV, plan to collect 15 fb^{-1} more
- 2013-2014: 18-month shutdown to install IBL
- 2014-2017: 14 TeV, 50 fb^{-1} (1 x 10^{34} $cm^{-2}s^{-1}$)
- 2018: 12-month shutdown for "Phase 1" upgrade
- 2019-2021: 14 TeV at full design luminosity, 300 fb^{-1}
- 2022: 12-month shutdown for "Phase 2" upgrade
- 2023-2030?: 14 TeV, potentially 3000 fb^{-1}

Other high-energy colliders, including ILC, also in design phase