Elementary Particle Physics at the Highest Energies with the ATLAS Experiment

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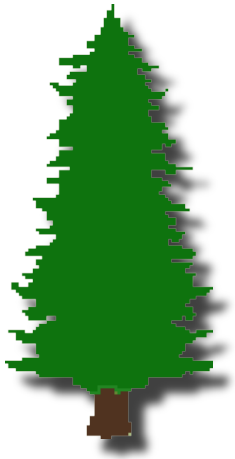


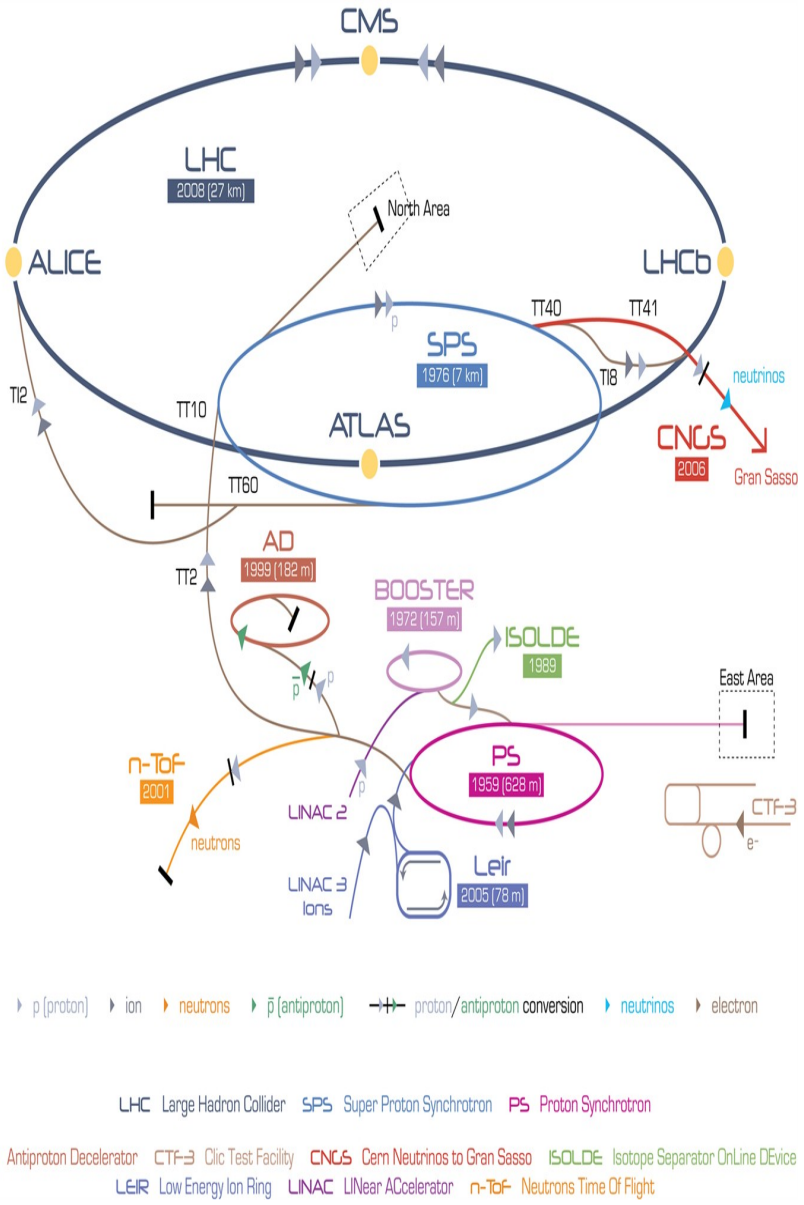
UCSC Physics 205

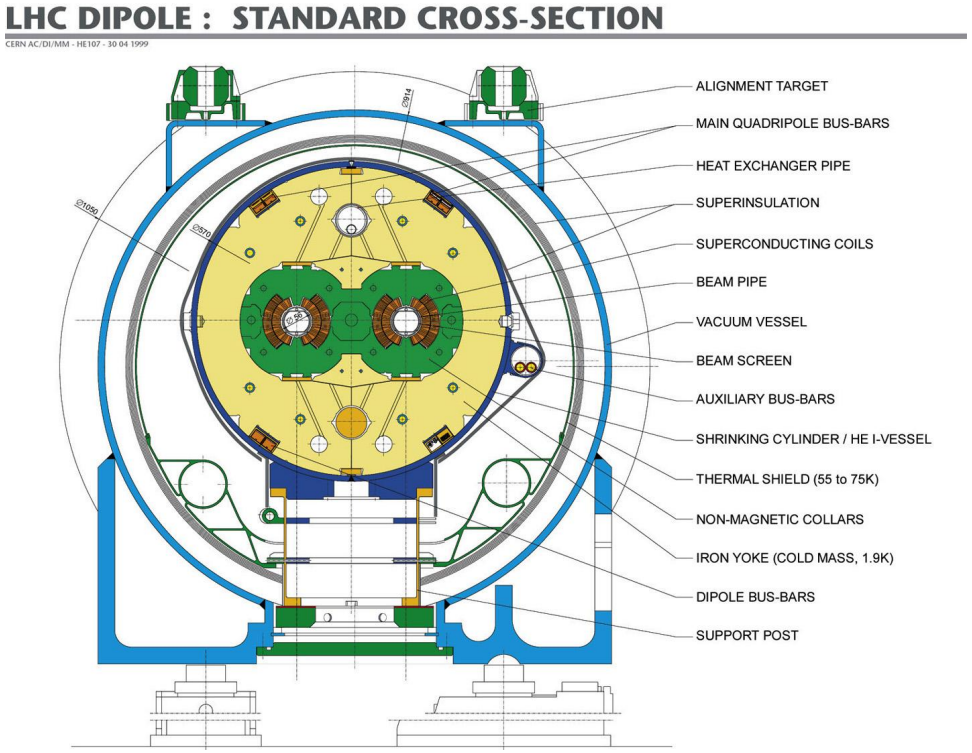
January 13, 2014

High-Energy Collider Physics

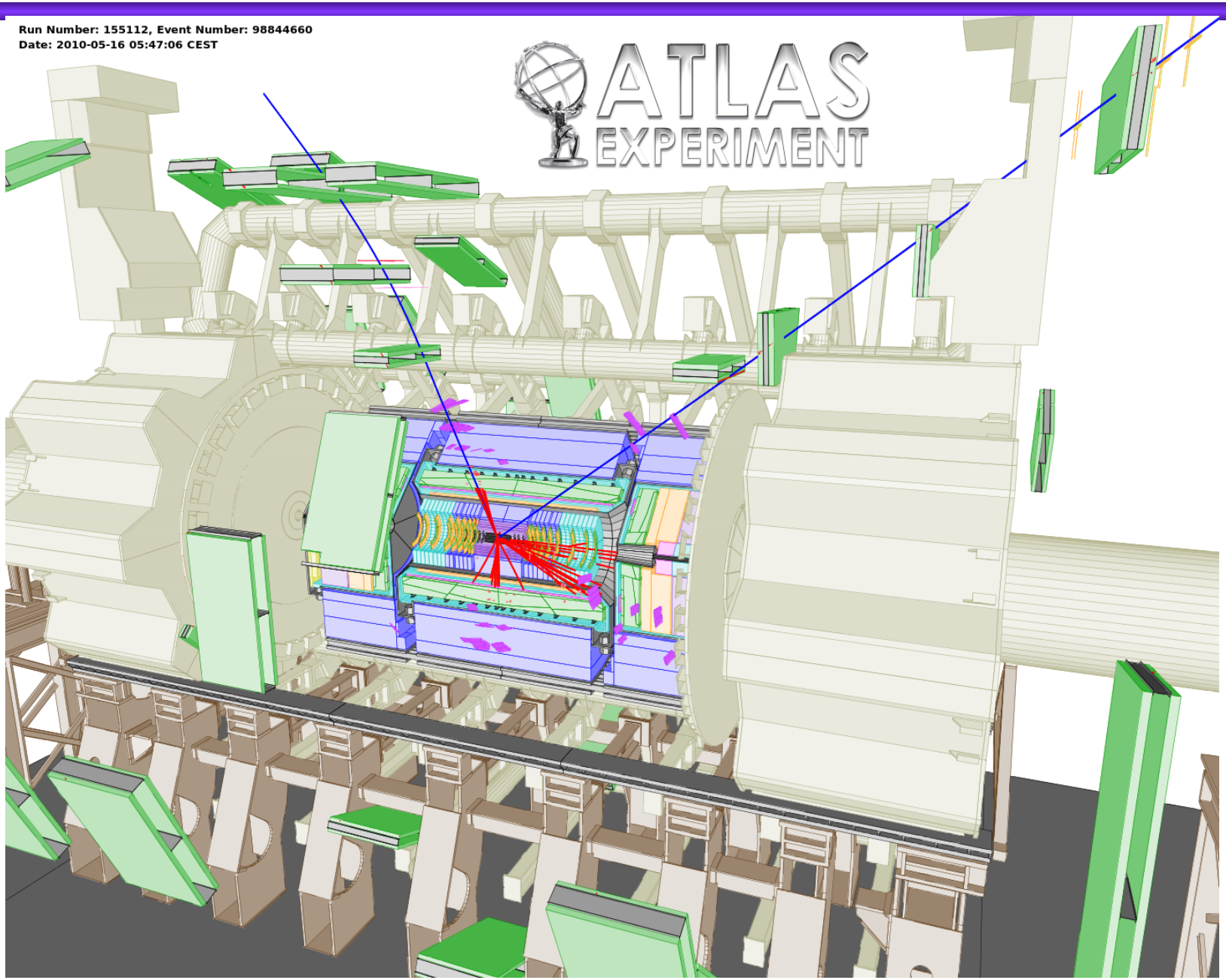
- Addressing the **big questions of particle physics**
  - Is the Standard Model of electroweak symmetry breaking and quantum chromodynamics complete?
  - What is the nature of the unknown dark matter?
- Studying proton-proton collisions at 0.9-14 TeV energies
  - UCSC group was one of the first US groups to begin involvement in ATLAS after SSC cancellation in 1994
- 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 at CERN





ATLAS Experiment at the LHC

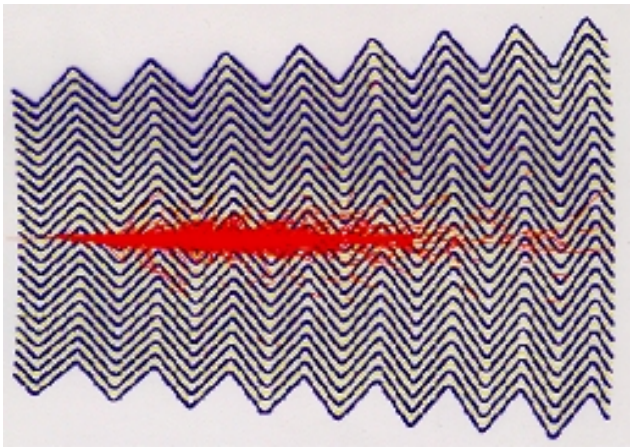


Why is the Detector Apparatus So Big?

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

Calorimeter

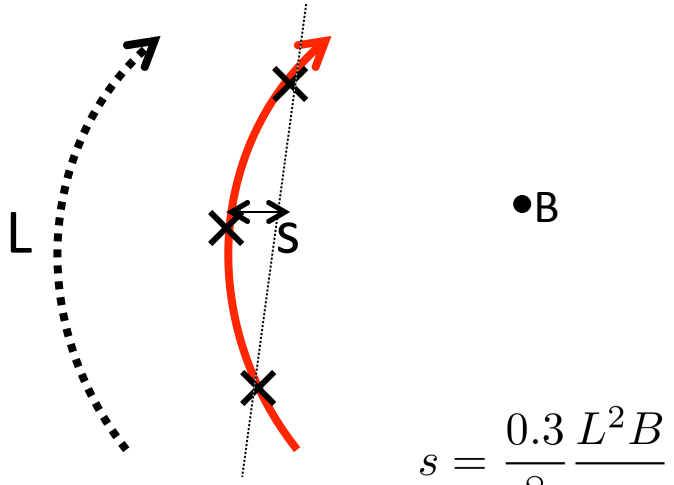
Particle deposits energy by showering in dense absorber medium



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

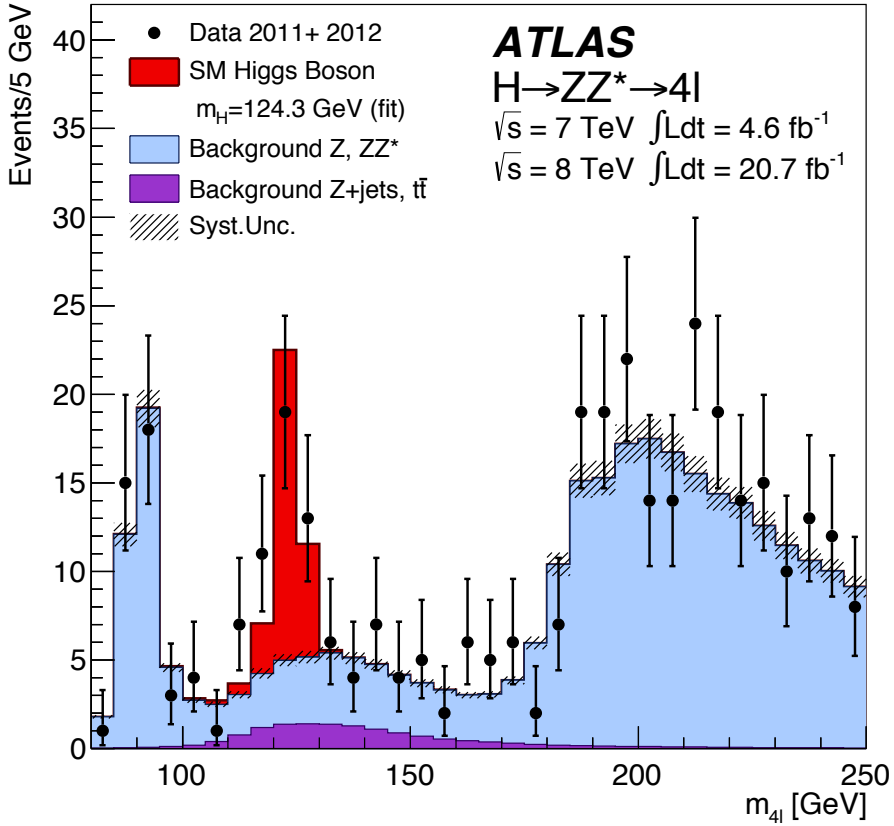
ATLAS Collaborators at UCSC

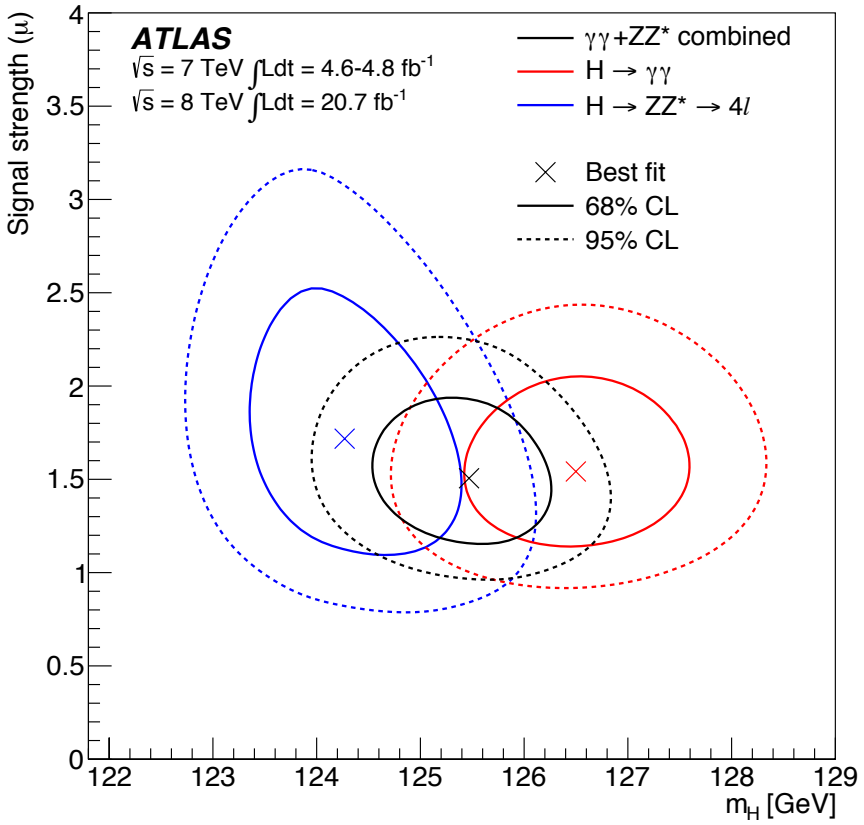
M. Battaglia (faculty)
C. Debenedetti (postdoc)
V. Fadeyev (technical)
A. Grillo (physicist)
A. Kuhl (student)
A. Law (student)
Z. Liang (postdoc)
A. Litke (faculty)
W. Lockman (physicist)
P. Manning (student)
F. Martinez-McKinney (technical)
J. Mitrevski (postdoc)
J. Nielsen (faculty)
J. Pasner (student)
R. Reece (postdoc)
P. Rose (student)
H. Sadrozinski (faculty)
S. Schier (student)
B. Schumm (faculty)
A .Seiden (faculty)
E. Spencer (technical)
M. Wilder (technical)

Personnel are based at SCIPP and at CERN

Discovery of a New Boson in ATLAS

- Announcement on July 4, 2012 of a new boson found in the Higgs search, but is it the Higgs boson?





- Also seen by CMS experiment in the same decay modes

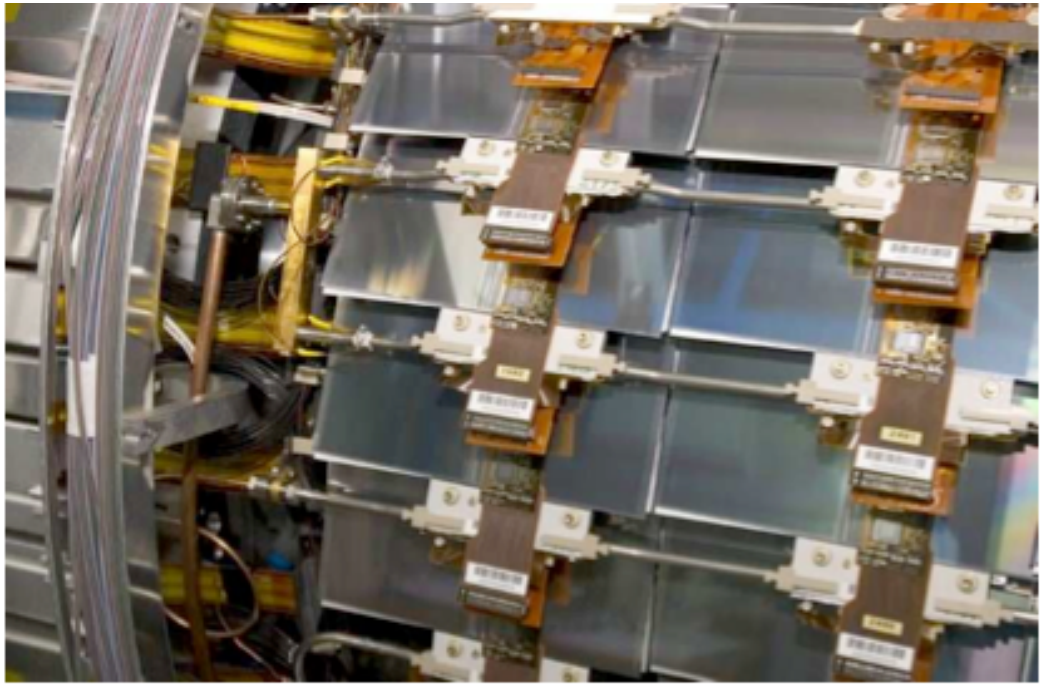
Current ATLAS Physics Topics at UCSC

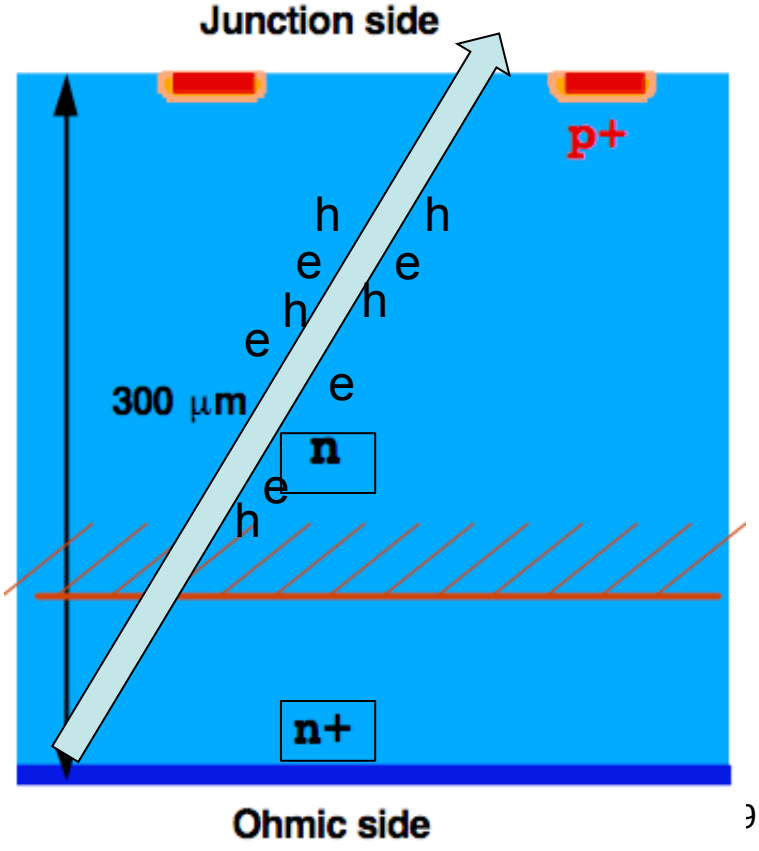
- Searching for new physics predicted in Beyond SM
  - New particles in theories of supersymmetry
  - Universal extra dimensions
- Measuring newly-discovered scalar ("Higgs") boson
- Measuring SM physics processes to test detailed calculations in established models of proton interactions

- These topics rely on development of
  - Precision particle detector technology
  - Robust particle reconstruction algorithms
  - Computing infrastructure for "big data" analysis

ATLAS Semi-Conductor Tracker

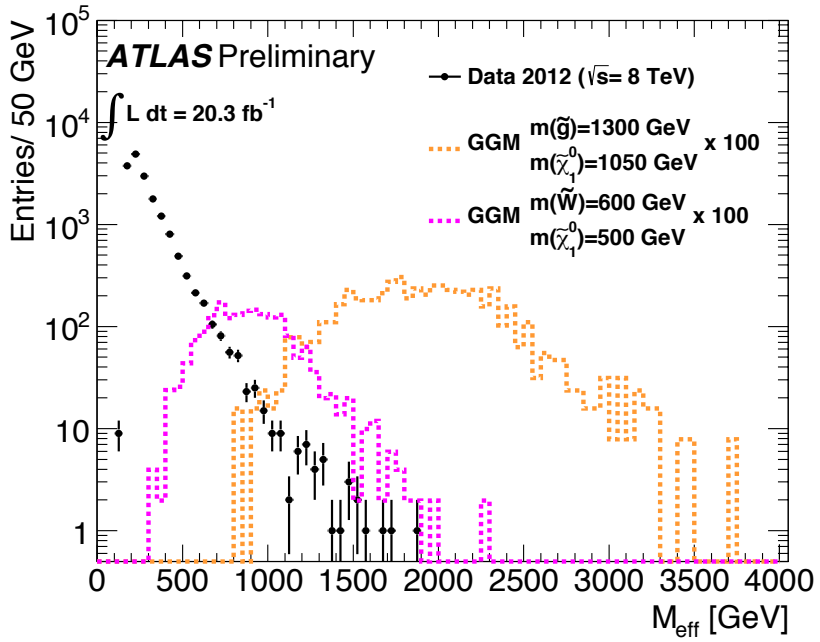
- Segmented strips; p-n junction; depletion region
- Relatively cheap way to cover large cylindrical area
  - Segmentation in z (giving "pixels") can improve resolution
- Collaboration with Japan, UK, and others

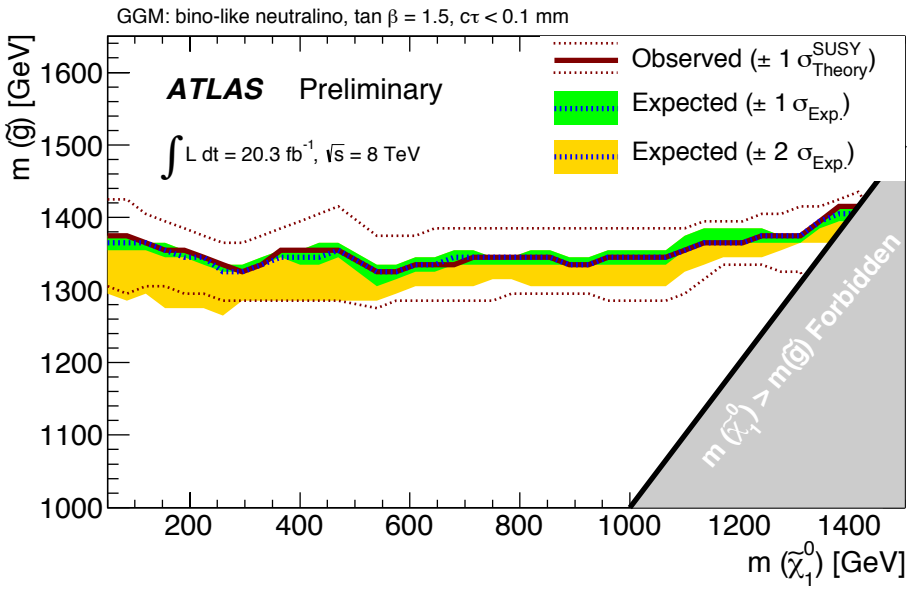




Searches for Supersymmetry

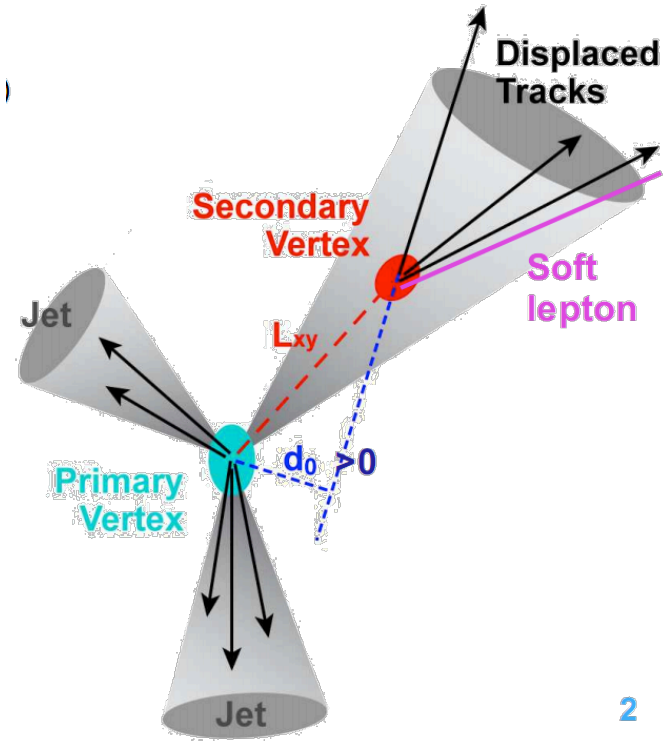
- Non-resonant diphoton production with non-interacting gravitinos (dark)
- World's best sensitivity to General Gauge Mediation models of GMSB
- Our group covers all possible decays of the neutralinos, even to Higgs bosons



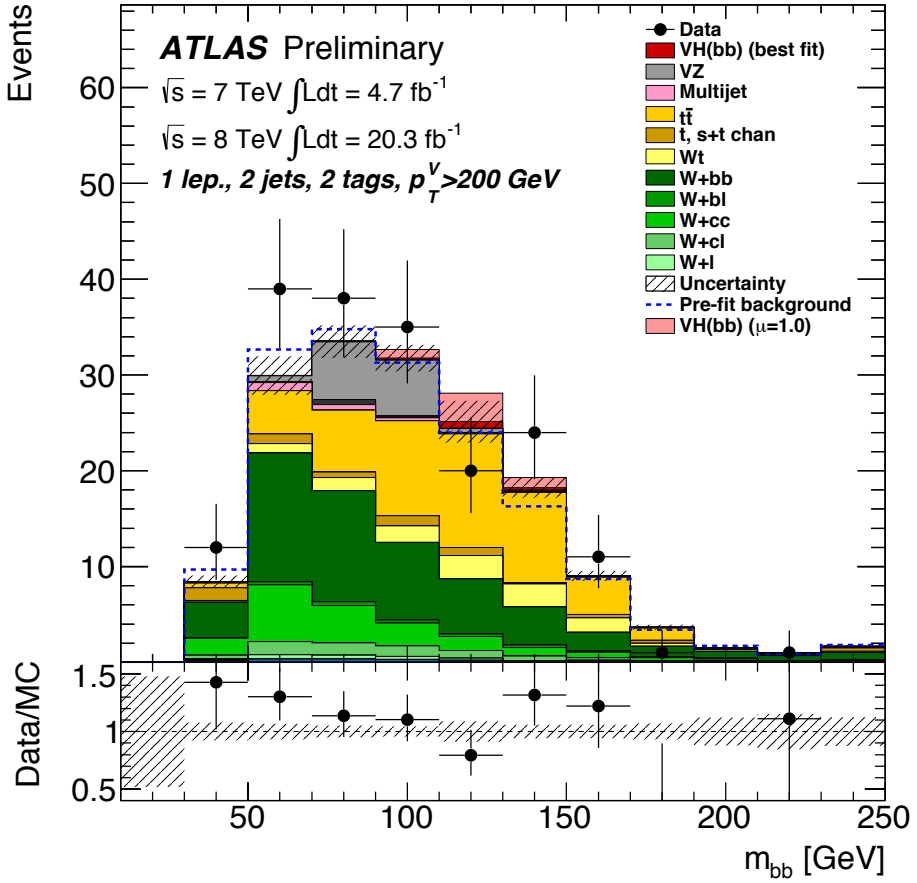


Searches for Higgs Bosons

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



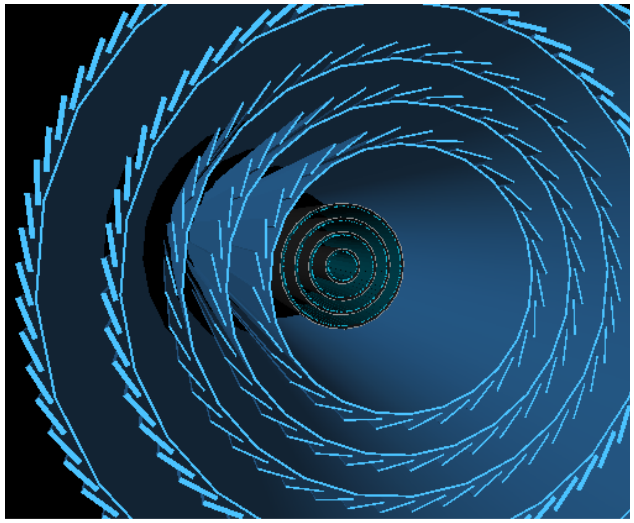
- Difficult but important measurement of the most common Higgs boson decay: is it as expected?

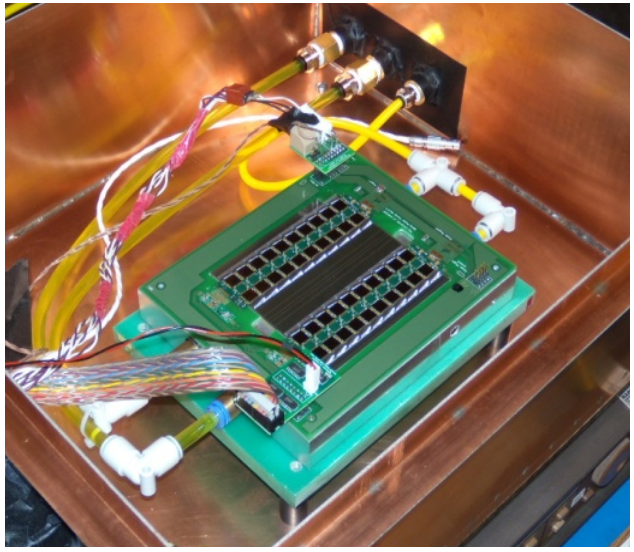


Proposed LHC & ATLAS Upgrade

- 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, used to improve secondary vertex identification
  - Phase II: replace entire tracking detector

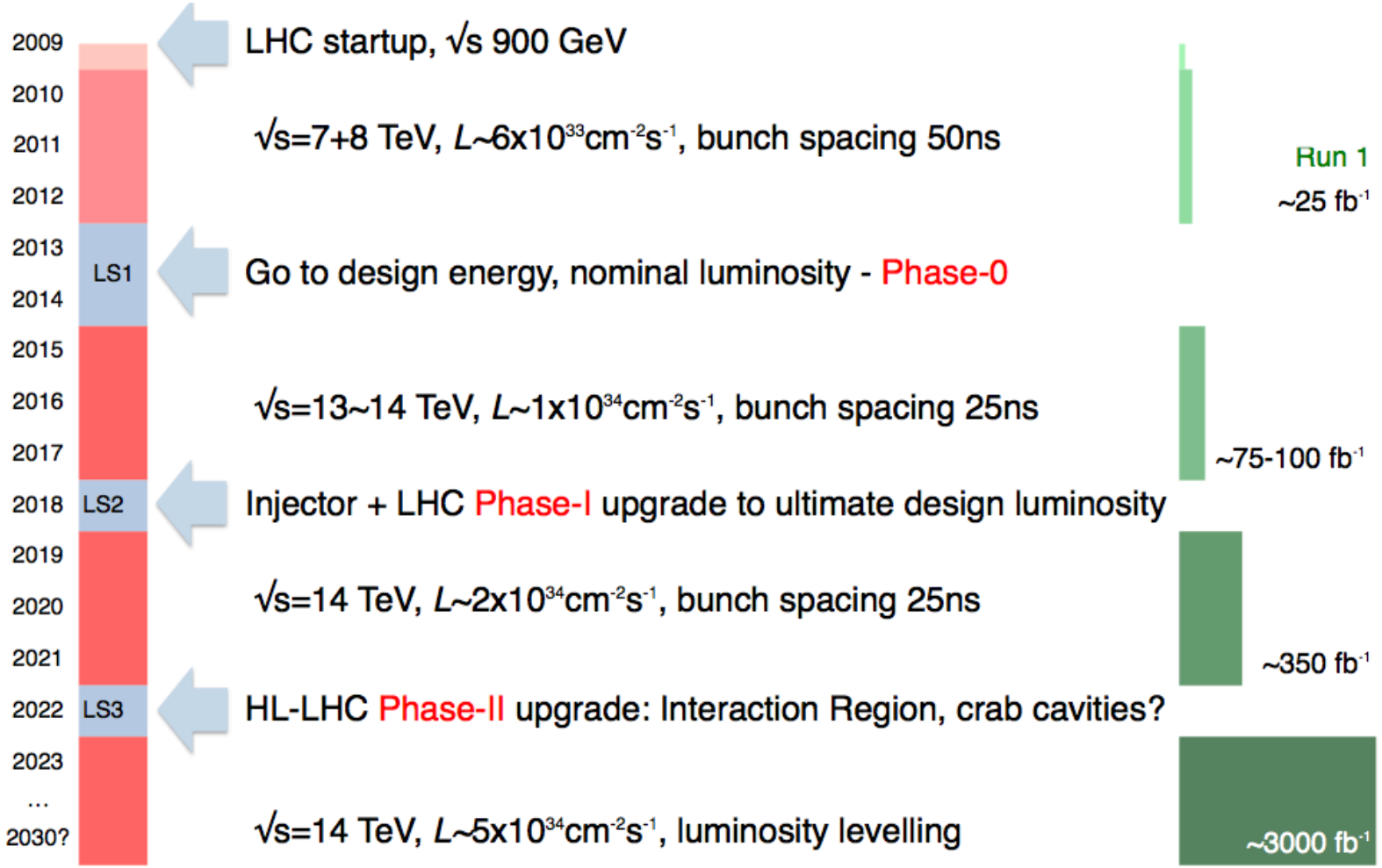
ATLAS Tracker Upgrade R&D





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

Proposed LHC pp Run Schedule



Other high-energy colliders, including ILC, also in design phase
Which is best for studying the properties of the new boson?

Summary

- UCSC ATLAS group: particle physics at the energy frontier
  - Searches for new particles
  - Measurements of Higgs boson
  - Precision measurements of the Standard Model

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