ATLAS – Physics and Computing

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November 10, 2004

Berkeley Lab

LBNL activities

Two major areas

- Tracking system using Silicon Strips and pixel
- Physics Simulation and Software

Kevin will discuss the former, I will discuss that latter.

In addition, the International ATLAS coordinator for Education and Outreach is from LBNL (M. Barnett)

ATLAS GROUP

Physics Division

Senior Physicists
- M. Barnett
- A. Ciocio
- K. Einsweiler
- M. Garcia-Sciveres
- M. Gilchriese
- C. Haber
- I. Hinchliffe
- S. Loken
- R. Madaras
- M. Shapiro
- J. Siegrist
- G. Stravropoulos

Postdoctoral Fellows
- D. Costanzo
- M. Dobbs
- H.-C. Kaestli
- A. Korn
- A. Saavedra
- S. Vahsen
- M. Zdrazil

Technical Staff
- S. Dardin
- T. Weber
- R. Witharm

Graduate Students
- A. Deisher
- M. Leyton
- J. Muelmenstaedt
- S. Senz
- J. Virzi
- M. Wahl

Undergraduates
- D. Boesh
- J. Feigelman
- E. Feng
- J. Haller
- H. Hindi
- J. Liang
- D. Wu

Retirees
- J. Alonso
- R. Ely
- F. Goozen
- J. Lys
- G. Trilling

Visitors
- T. Katainen
- J. Kuokkanen
- P. Zarzhitsky
- F. Zetti

Engineering Division

Engineers
- E. Anderssen
- N. Hartman
- E. Mandelli
- G. Meddeler
- A. Smith

Technical Staff
- J. Hellmers
- T. Johnson
- D. Jones
- R. Post
- R. Powers
- C. Tran
- C. Weldon
- J. Wirth

Undergraduates
- K. Baccigalupi

NERSC

Senior Scientists
- D. Quarrie

Computer Scientists
- P. Calafiura
- C. Leggett
- M. Marino

Postdoctoral Fellows
- W. Lavrijsen

LHC Status and Schedule

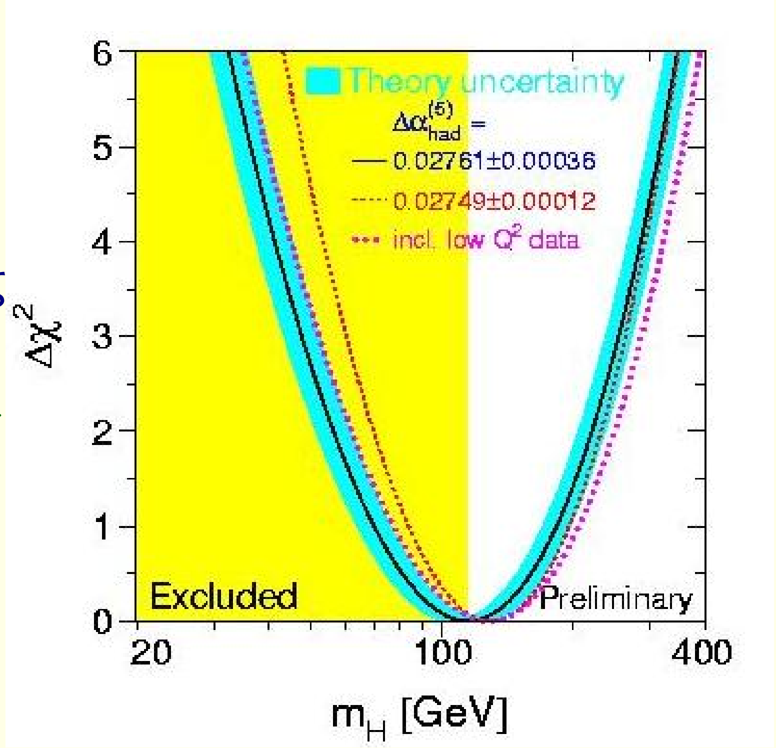
- 14 TeV pp: $7\times$ Tevatron
- Low luminosity $\mapsto 10$ fb^{-1} per year: $10\times$ Tevatron
- High luminosity $\mapsto 100$ fb^{-1} per year.
- New energy frontier at *very* low luminosity $\mapsto 1$ fb^{-1}.
- First Collisions – Summer 2007
- Operation in "low luminosity mode" for 3 years$\rightarrow 2\times 10^{33}$ cm^{-2} sec^{-1}
- 1 month per year of heavy ion running: Energy density $10\times$ RHIC.

This is a very tight schedule BUT work has started on further increases in Luminosity

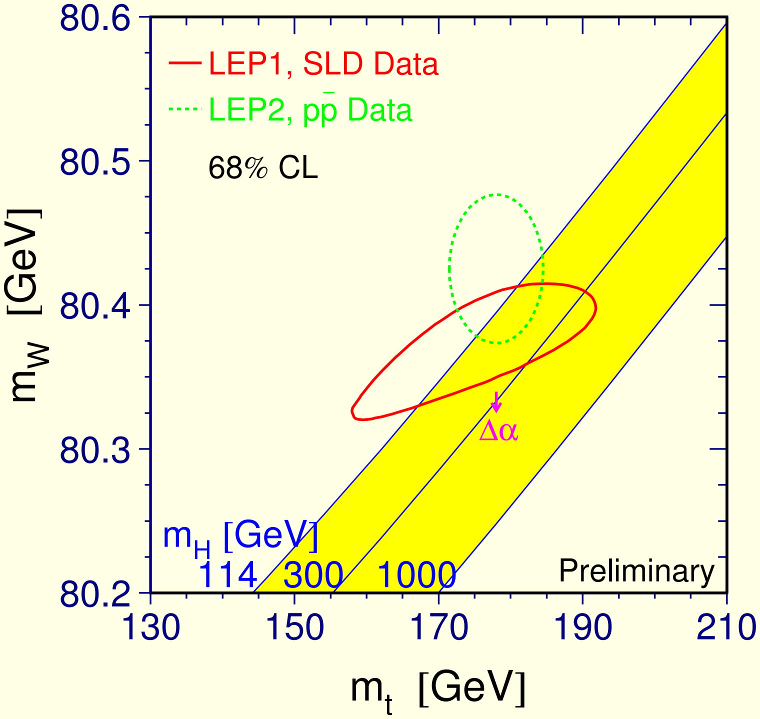
The Status of Physics

Standard Model provides an excellent description of experimental phenomena.
Precision of better than 1% is achieved (LEP/SLC asymmetries, W/Z masses *etc*)
Need at least one extra particle to give mass to W/Z and all quarks/leptons — Higgs

Plot shows $\Delta\chi^2$ as function of Higgs mass using all existing data
Direct searches for the Higgs failed: $Mass > 114 GeV$



Inference of Top mass from precision measurements agrees with direct observation



If the SM is right, then $M_H < 250 GeV$

If SM is not complete, could have many Higgs, SUSY, Extra dimensions, No weakly coupled Higgs...

Open question is "What breaks ElectroWeak symmetry?"

There must be new physics yet to be discovered with mass below $\sim$ TeV.

ATLAS's Task

Find the particle(s) responsible for mass generation.

Could be Higgs, many Higgs's, Supersymmetry (SUSY), Extra dimensions

Power of LHC is its enormous mass reach relative to current facilities.

Even low luminosity will open a new window.

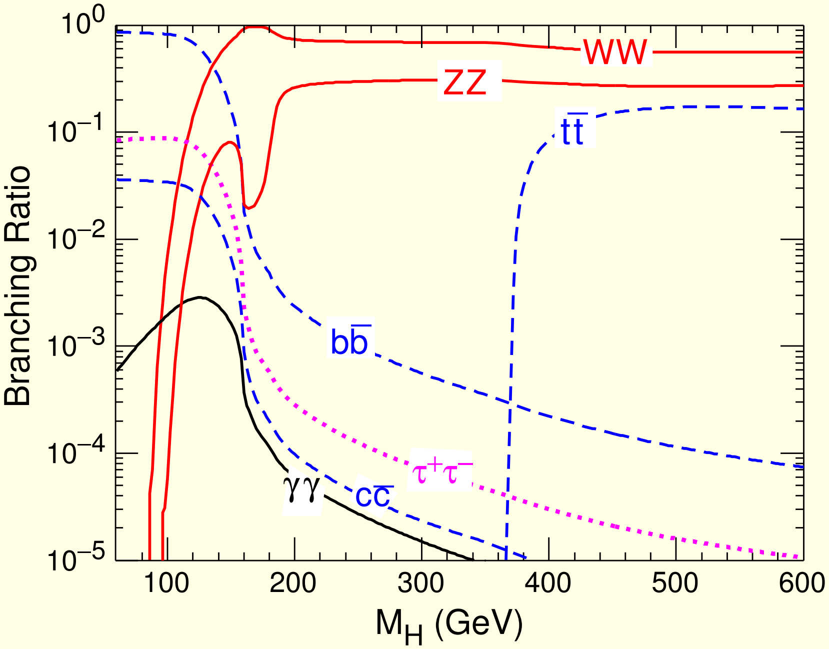
$10pb^{-1}$ (1 day at 1/100 of design luminosity) gives 8000 $t\bar{t}$ and 100 QCD jets beyond the kinematic limit of the Tevatron

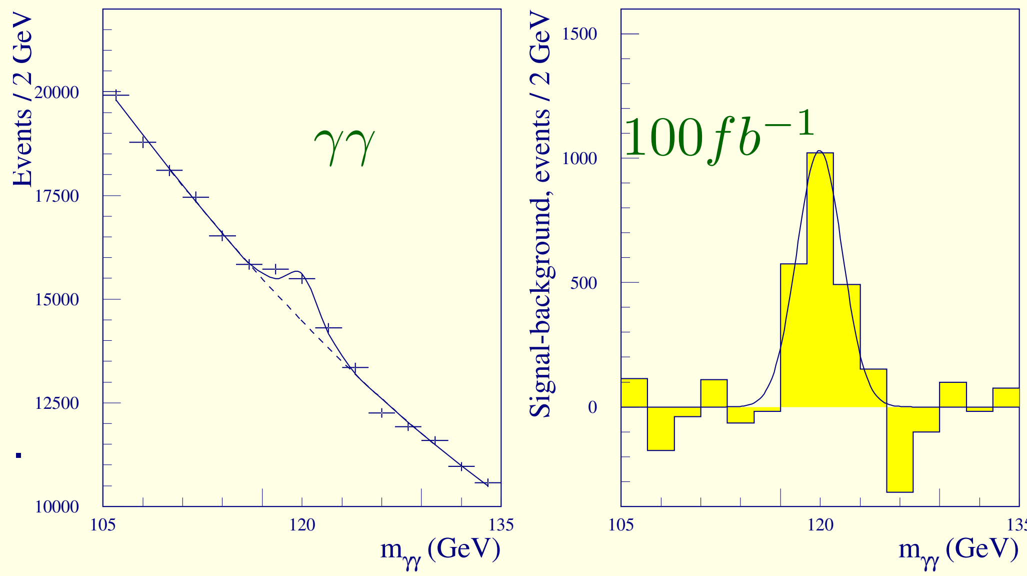
If SUSY is correct, it could be found with $100pb^{-1}$

The ATLAS experiment is better thought of as a facility

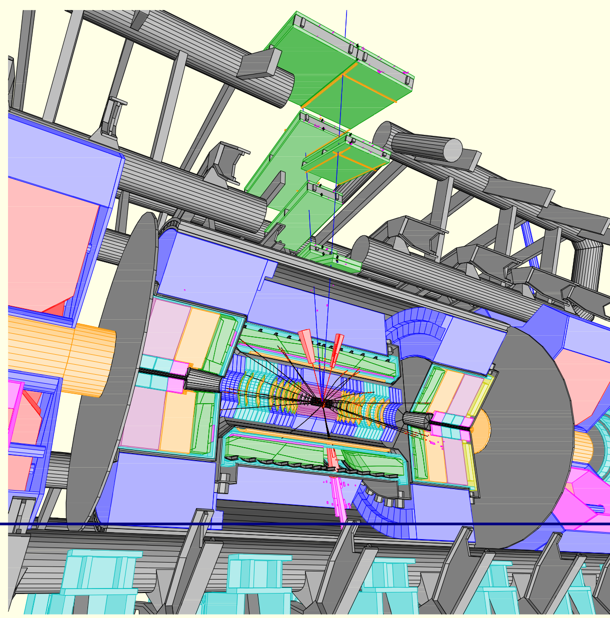
It will make many measurements in areas currently covered by BaBar. LEP, Tevatron, RHIC: Its power lies in its scope and versatility

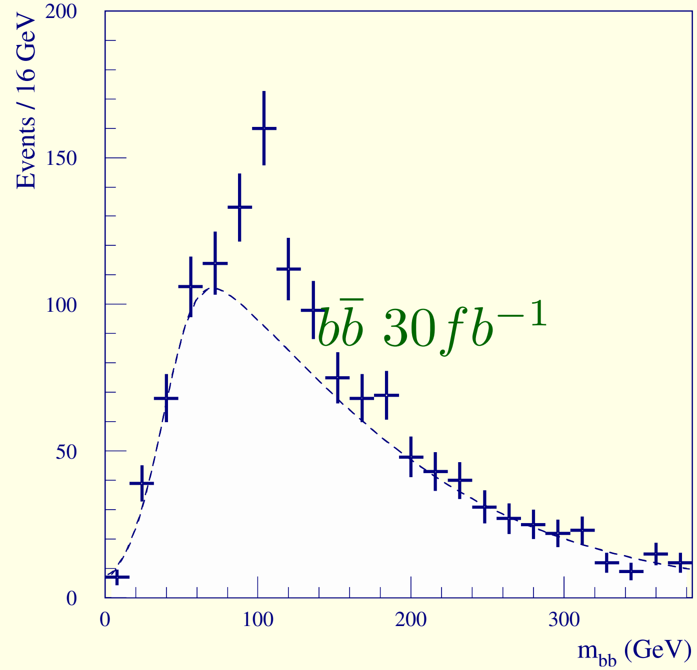
Here's a quick look at the Higgs with ATLAS.....





$$H \rightarrow ZZ \rightarrow \mu^+\mu^-e^+e^-$$



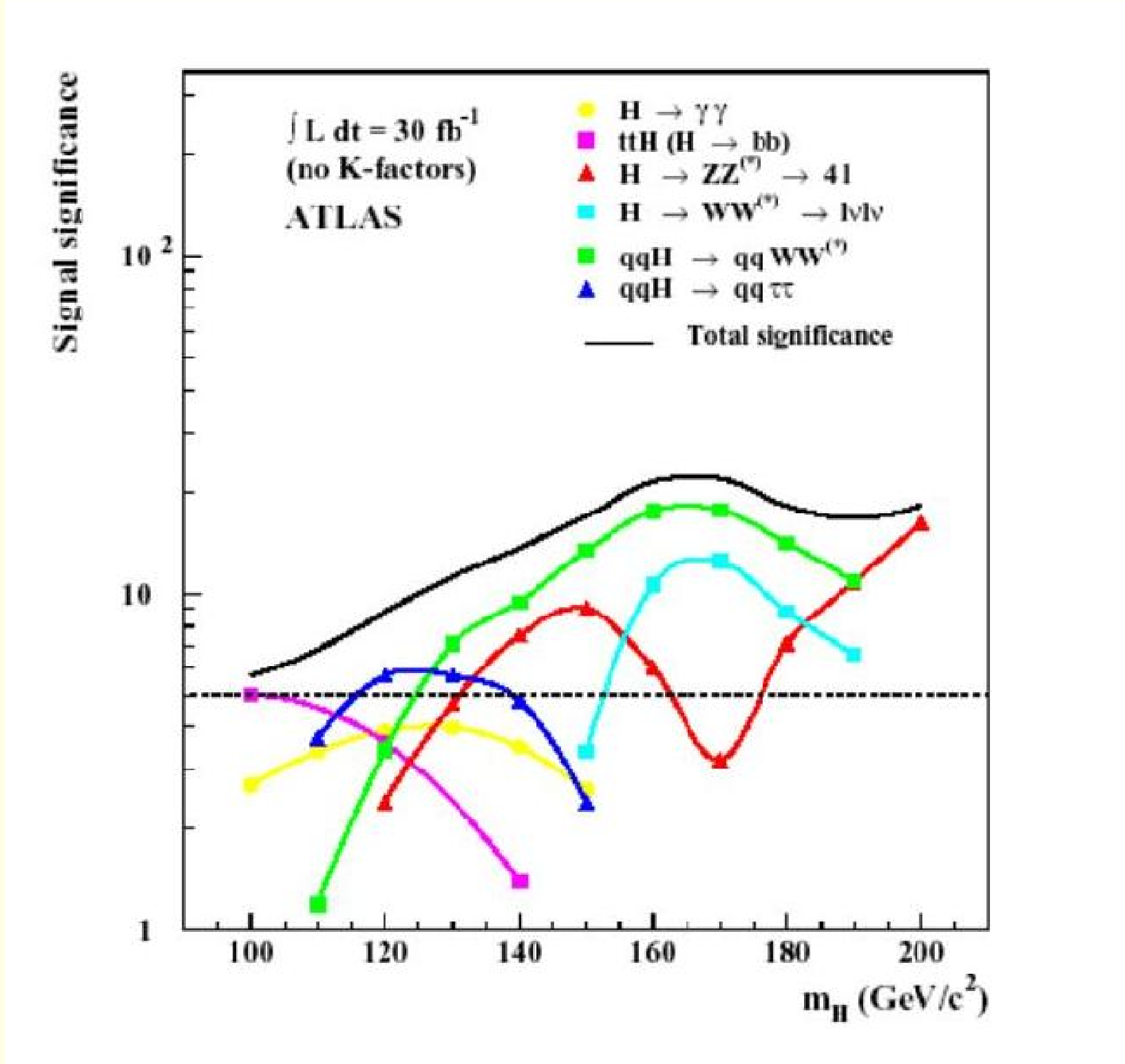


Higgs is not a "typical" LHC discovery as it demanding of luminosity

Plot shows statistical significance for 30 fb^{-1}

Easiest channel depends on mass

The black curve shows the combined result



Physics Organization in International ATLAS

- Organized into 7 groups each with two conveners. (including Matt Dobbs and me from LBNL). Led by overall Physics coordinator (I am his deputy).

- ATLAS produced "Physics TDR" in 1999, summarizing the expected capabilities and the physics program (I was editor of this)

- Current activity is in two areas
  - Studies of new theoretical models and how we can test them.
  - (Much more important) Stress testing the software and developing strategies for handling the data.

How data will be accessed

- Most of the computing power and most of the physicists will not be based at CERN
- ATLAS has a layered GRID model for computing that relies on ~ 7 Tier 1 and ~ 35 Tier 2 centers distributed worldwide and a single Tier 0 site at CERN. The data will be replicated across this system
- Nobody has operated this way before and we need to test it now

This testing, and that of the software, uses a set of "Data Challenges (DC)".
DC1: 2002/2003
DC2: now
DC3: 2005/2006

LBNL's Role in Computing

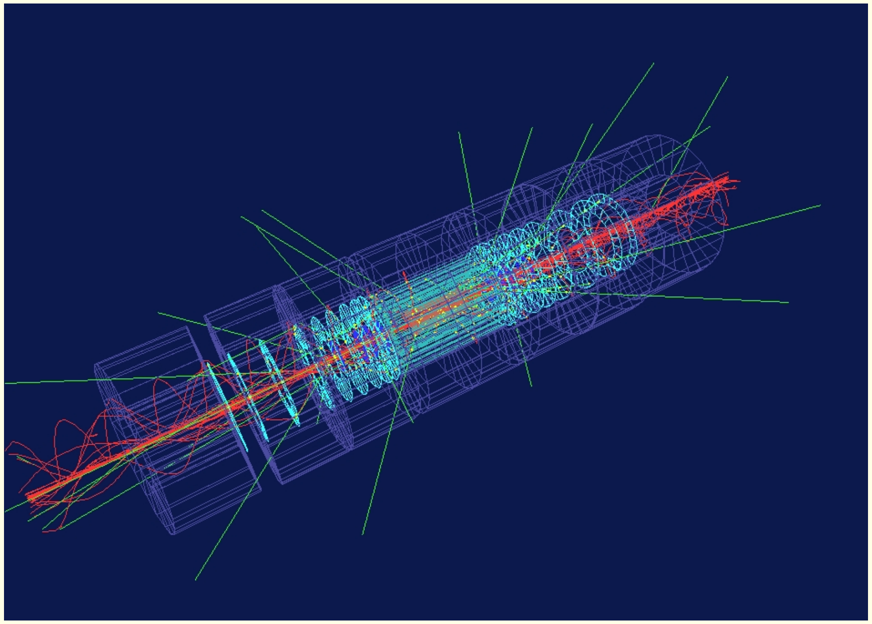
- David Quarrie (currently resident at CERN) is the software project leader.
- The NERSC team (D. Quarrie, P. Calafiura, W. Lavrijsen, M. Marino, C Leggett) is primarily responsible for the "Framework"
  This is the core system under which all of the atlas simulation/reconstruction and physics code operates
  This is funded entirely from ATLAS Project funds.
- Giorgos Stavropoulos (and a small part of me) is responsible for the integrated of event generation that lies at the beginning of the simulation chain

Simulation

Three main tasks

- Aiding in the initial design of the detector and planning for upgrades (Mostly done)
- Providing "data" to be used in developing/testing the software (*e.g.* reconstruction) that will be used when the data arrives. (Intense activity now)
- Helping interpretation of data (the future)

Costanzo is responsible for description of pixel system and for overall simulation of electronics signals (digitization)



LBNL's role in Physics

- Currently two people involved in physics simulations
  Ramp up in this area will start now as we prepare for data.
- Recent work on SUSY, Little Higgs models
- Data Challenge work on event Generation, simulation and reconstruction validation.

As part of the SUSY work for DC1:: 100K events simulated and reconstructed with new software (LBNL lead role)
Corresponds to $5fb^{-1}$
Needed 50k CPU hrs for simulation: approx half of this was done on PDSF (NERSC at LBNL)
Needed 50k CPU hrs for reconstruction: all of this was done on PDSF.
For DC2:
PDSF is now integrated into Grid3.
Vital testing of GRID computing model

Example physics study using DC data at LBNL: Supersymmetry

- Supersymmetry predicts new particles that partner the Standard Model particles: Squarks, sleptons. gluinos *etc.*
- SUSY is able to explain why $M_W << M_{Planck}$: If so then SUSY particles are in reach of LHC. LHC $\rightarrow$ Bevatrino
- SUSY particles are produced in pairs $\rightarrow$ lightest one is stable: this (LSP) could be the dark matter particle.
- At LHC, squarks and gluinos are produced: these decay into Standard model particles and the LSP
- Therefore we look for quarks (jets), electrons, muons and missing energy (carried off by LSP)

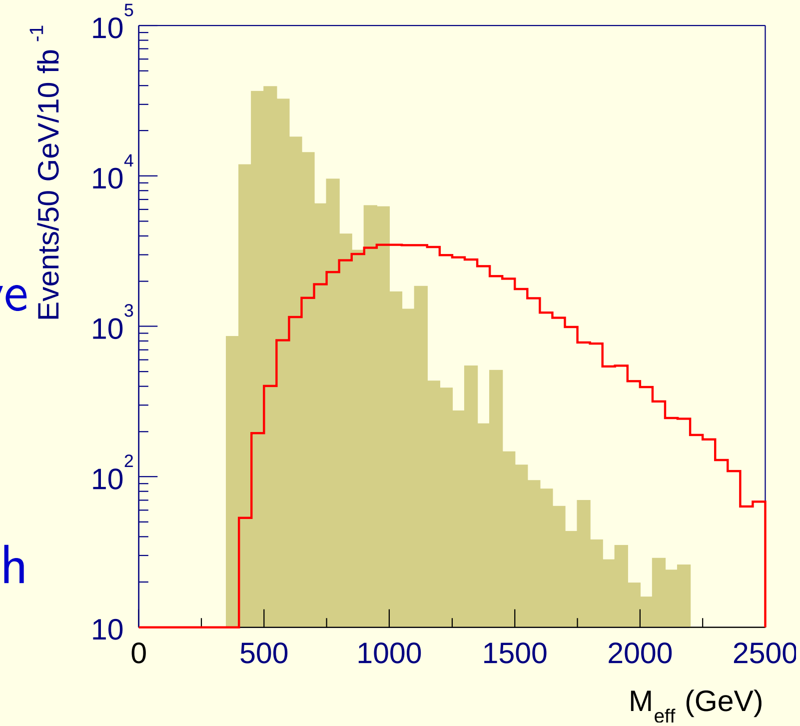
If nature is like this, ATLAS will discover the particles that make up Dark matter

A Global Search

- Select events with at least 4 jets and Missing E_T
  A simple variable:
  $M_{\text{eff}} = P_{t,1} + P_{t,2} + P_{t,3} + P_{t,4} + \not{E}_T$

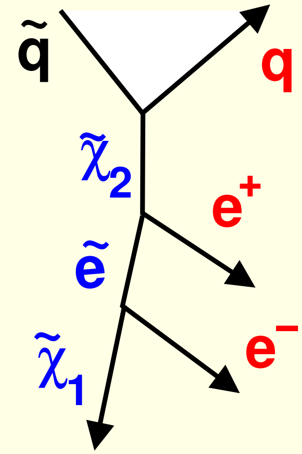
- At high M_{eff} non-SM signal rises above background (shaded histogram)
  Note scale – huge event rate

- Peak in M_{eff} distribution correlates well with SUSY mass scale
  $M_{\text{SUSY}} = \min(M_{\tilde{u}}, M_{\tilde{g}})$
  This example has susy masses around 700 GeV



This signal is characteristic of any new physics at a large mass

Measuring masses: An Example



Decay $\tilde{q_L} \to q\widetilde{\chi}_2^0 \to q\widetilde{\ell}\ell \to q\ell\ell\widetilde{\chi}_1^0$

Produces a pair of e^+e^- or $\mu^+\mu^-$ with an invariant mass in a restricted range

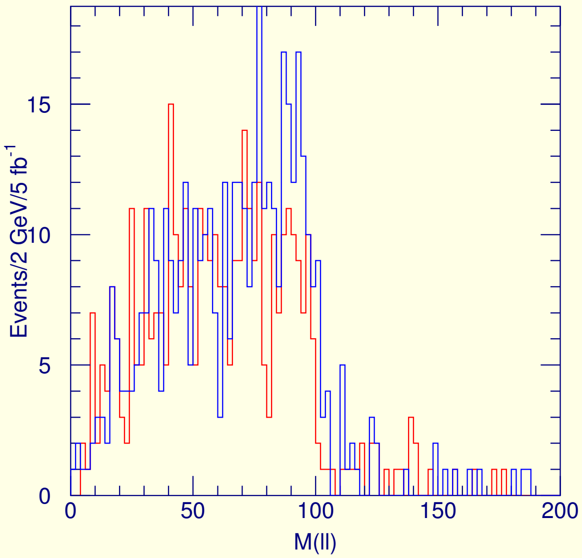
Must measure electrons and jets and determine masses

Including LSP which is not observed (like neutrino in beta decay)

Plot shows invariant mass distribution of $\mu^+\mu^-$ (blue) and e^+e^- (red)

Note this example is $5fb^{-1}$

Standard model background not shown, it is mainly from $t\bar{t}$ and is very small



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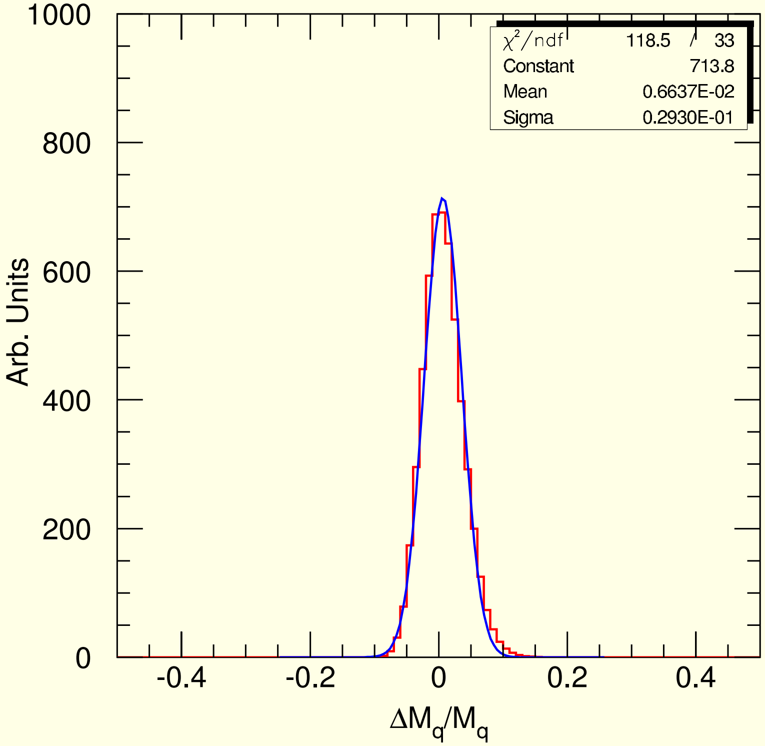
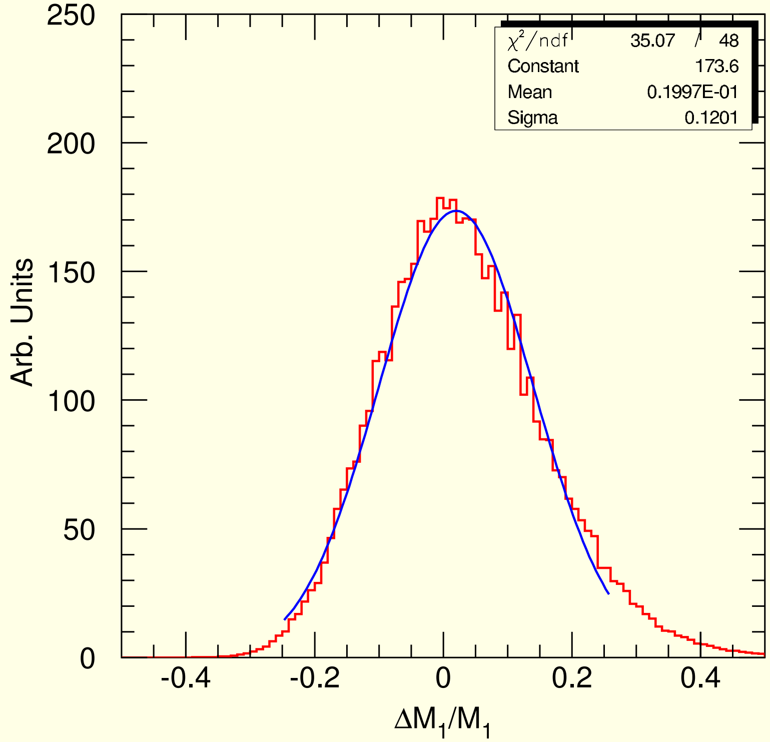
More complicated topologies can be reconstructed starting here and adding jets.

Leads to measurements of some masses to 1 GeV precision and to measurement of the mass of the Dark Matter particle to 10%



. Squark mass



. LSP (DM) mass

Conclusions

- Core software provided by NERSC team has stood up to stress testing: we believe that the design and implementation are sound.
- LBNL physics activity will ramp up during DC3
- The LBNL group needs to start focussing on the physics that we will do with the early data

Some recent Publications from LBNL people on Physics and Computing in ATLAS

- "Full Supersymmetry Simulation for ATLAS in DC1 (2003)" (Hinchliffe, Costanzo *et. al.*)
- "Exploring Little Higgs Models with ATLAS at the LHC (2004)" (Hinchliffe, Costanzo *et. al.*)
- " A Step towards a Comptuing Grid for the LHC Experiments: ATLAS Data Challenge 1" (Hinchliffe, Costanzo, Stavropoulos, Quarrie, Calafiura, Lavrijsen, Marino, Leggett *et. al.*)
- "The StoreGate: a Data Model for the Atlas Software Architecture " (2003) (Calafiura, Quarrie *et. al.*