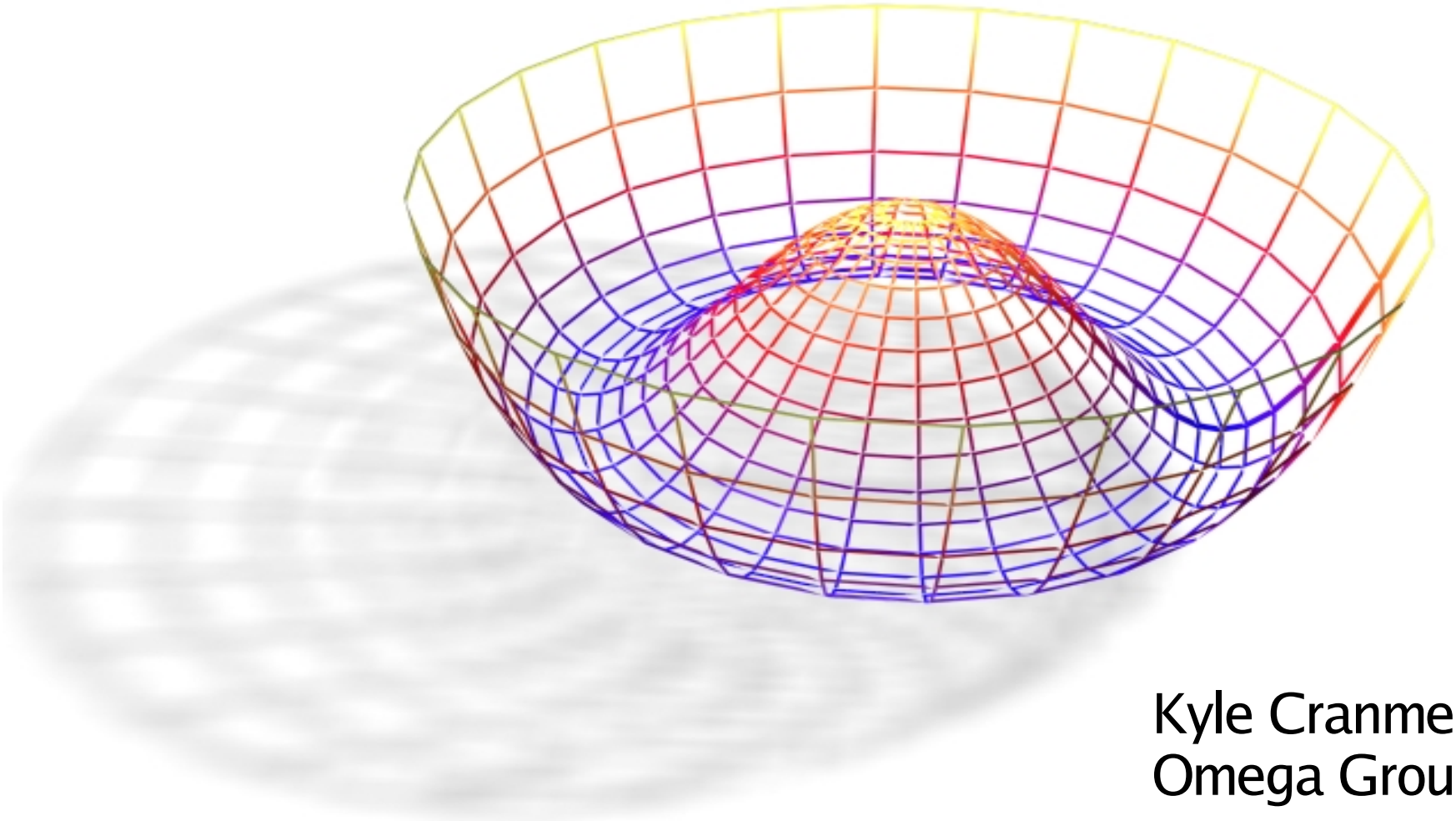
BNL's Role in ATLAS Physics



Kyle Cranmer
Omega Group

BNL's Involvement In ATLAS Physics

- Areas of Active Involvement
- Preparations to Meet our Physics Goals
  - Analysis Strategies & Statistical Methods
  - Physics Analysis Tools
  - Reconstruction, Calibration & Commissioning
- Contributions to the High Level Trigger
  - Electron/Photon, Jets & MissingET
  - Fast Data Unpacking
- BNL Analysis Support Center & Analysis Forum coordination
- Super-LHC

Physics Analysis Highlights

BNL Presentations at the ATLAS Physics Workshop in Rome

- Hong Ma: Di-boson Studies with Multi-Lepton Final States
- Kyle Cranmer: Weak Boson Fusion Higgs to Tau Tau
- Frank Paige: SUSY Overview
- Davide Costanzo: Inclusive SUSY Signatures
- Sanjay Padhi: Jet Calibration Studies

June 2005

BNL Presentations at the 2nd North American ATLAS Physics Workshop (Aug. 05, Toronto)

- Francesco Lanni: Electronics Commissioning & Calibration
- Hong Ma: Cosmic Ray Run using LAr Calorimeter
- Torre Wenaus: Dataflow & Data Management
- Kyle Cranmer: Hadronic Final State in the Trigger
- Frank Paige: SUSY in the First Days of ATLAS
- Srini Rajagopalan: Close-out Summary
- Howard Gordon: Leading Discussion

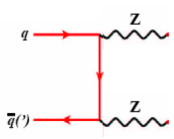
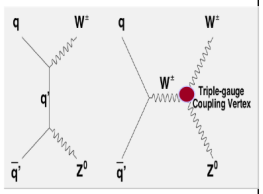
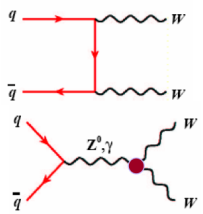
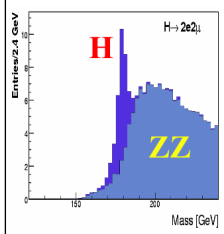
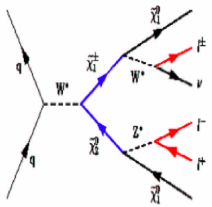
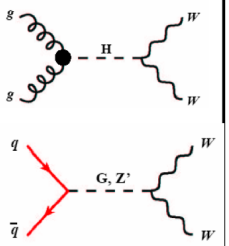
BNL Presentations at the US ATLAS Beyond the Standard Model Workshop (Mar. 2005, Columbia)

- Ketevi Assamagan: Doubly-charged Higgs to $\mu\mu$
- Davide Costanzo: SUSY Coannihilation studies
- Kyle Cranmer: Automated analysis procedures for high dimensional models
- Hong Ma: Software tools at BNL
- Frank Paige: SUSY Overview

BNL Presentations at the US ATLAS Beyond the Standard Model Workshop (Jan. 2006, LBNL)

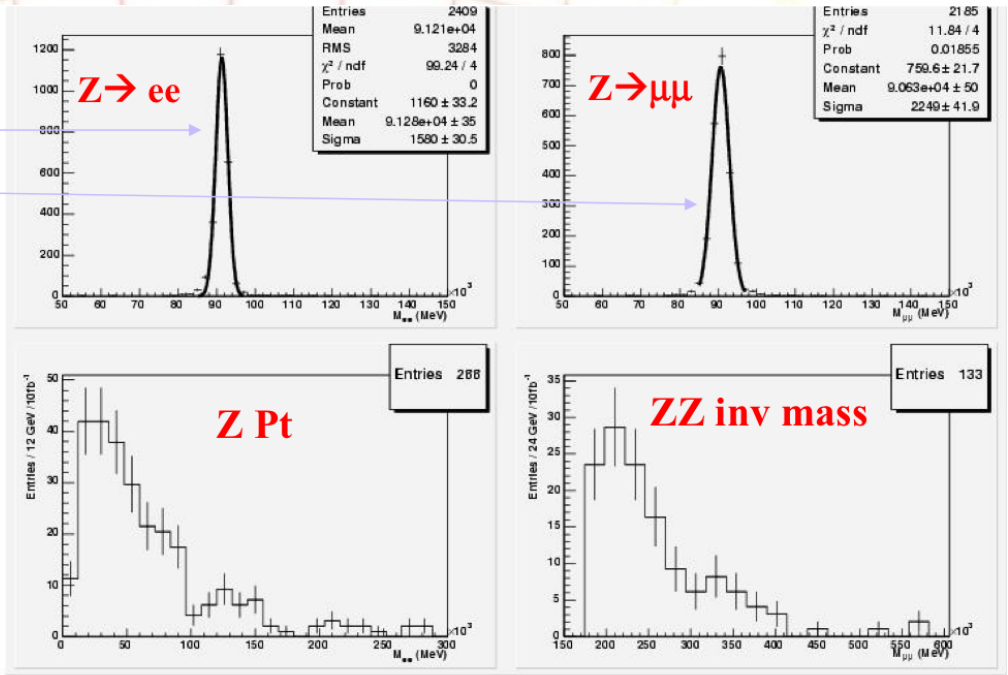
- Ketevi Assamagan: Charged Higgs
- Kyle Cranmer: Jet / MissingET Triggers
- Howard Gordon: Status of ATLAS
- Frank Paige: Reconstruction Validation
- In addition Ketevi Assamagan and Kyle Cranmer led a half-day physics analysis tools tutorial

Di-Boson Studies

Leptonic decay modes	ZZ-> $\ell^+\ell^-\ \ell^+\ell^-$	ZW-> $\ell^+\ell^-\nu\ \ell$	WW-> $\ell^+\nu\ \ell^-\nu$
SM • Triple-gauge couplings • New physics control samples			
Discoveries H→ ZZ, WW SUSY Z'→ WW G → WW ρ_T→ ZW Z_LW_L, Z_LZ_L			

134 selected ZZ Events for 10 fb^{-1}

Di-Bosons decaying leptonically are an important process for many interesting new physics searches



Hong Ma is studying in detail instrumentational effects which ultimately limit our understanding of these final states

SUSY Background Determination

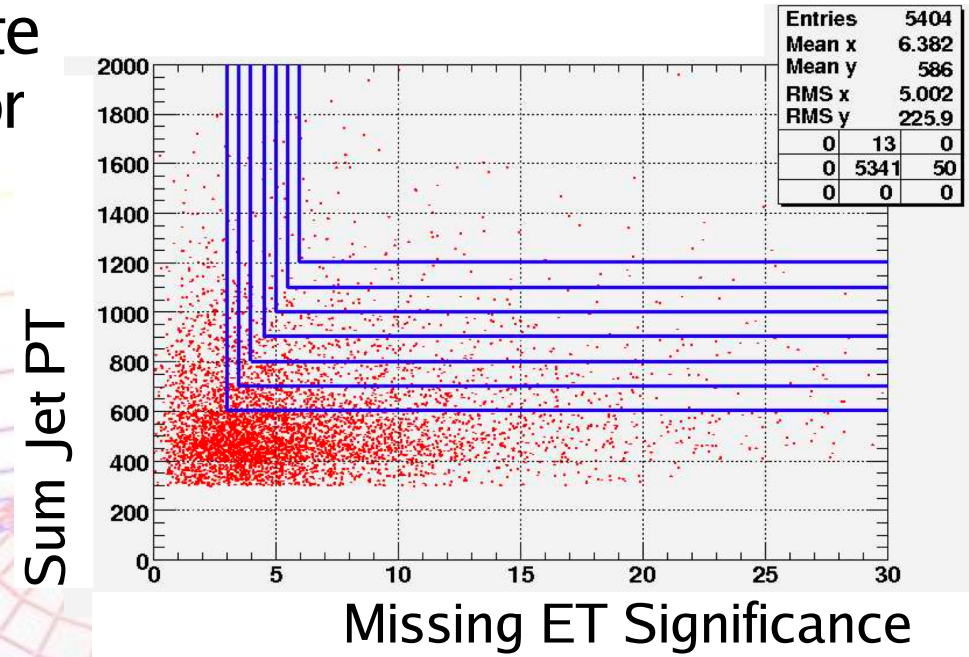
George Redlinger is exploring alternate methods to determine backgrounds for inclusive SUSY searches

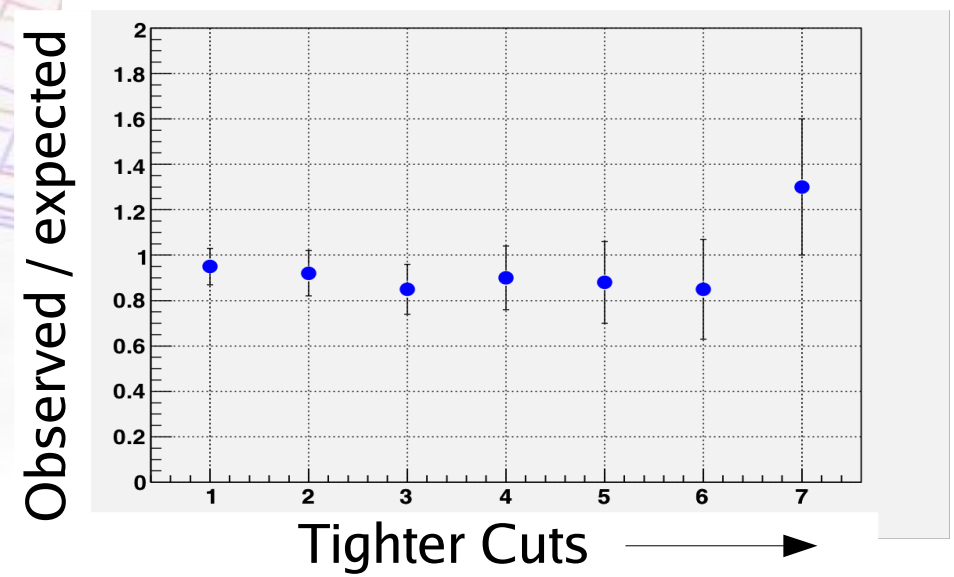
Identify two uncorrelated variables

Use "double-side-band method" to extrapolate to signal region

B	Blinded Signal Region
A	C

Background in Signal Region = C x B /A



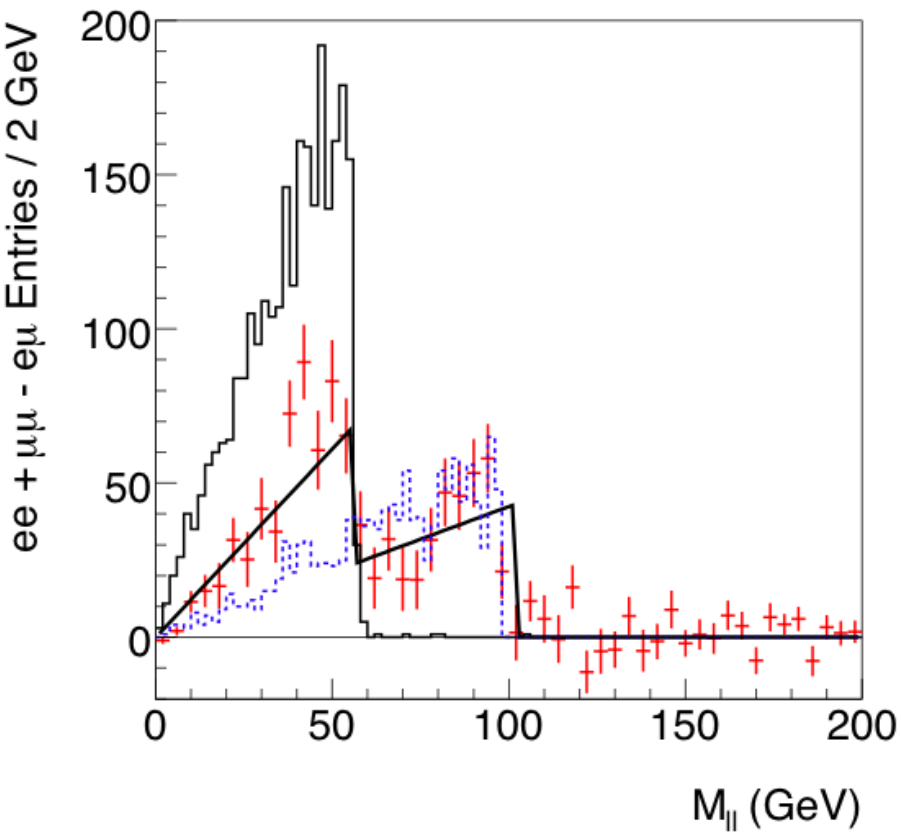


Endpoint Analysis for Coannihilation Point

Frank Paige continues to be a leader in the effort to determine SUSY parameters from data

Cascade decay $\tilde{\chi}_2^0 \to \tilde{\ell}^{\pm}\ell^{\mp} \to \tilde{\chi}_1^0 \ell^+ \ell^-$ gives endpoint at

$$M_{\ell\ell}^{\max} = \frac{1}{M_{\tilde{\ell}}}\sqrt{(M_{\tilde{\chi}_2^0}^2 - M_{\tilde{\ell}}^2)(M_{\tilde{\ell}}^2 - M_{\tilde{\chi}_1^0}^2)}$$

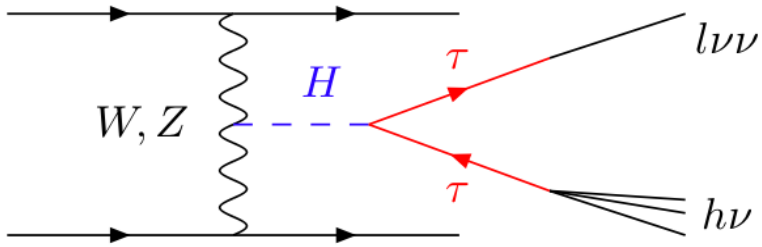


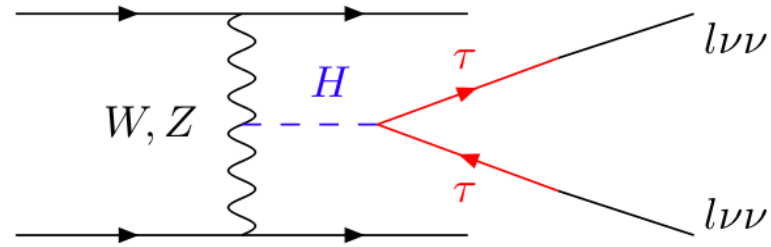
Enhance edges via "flavor subtraction"

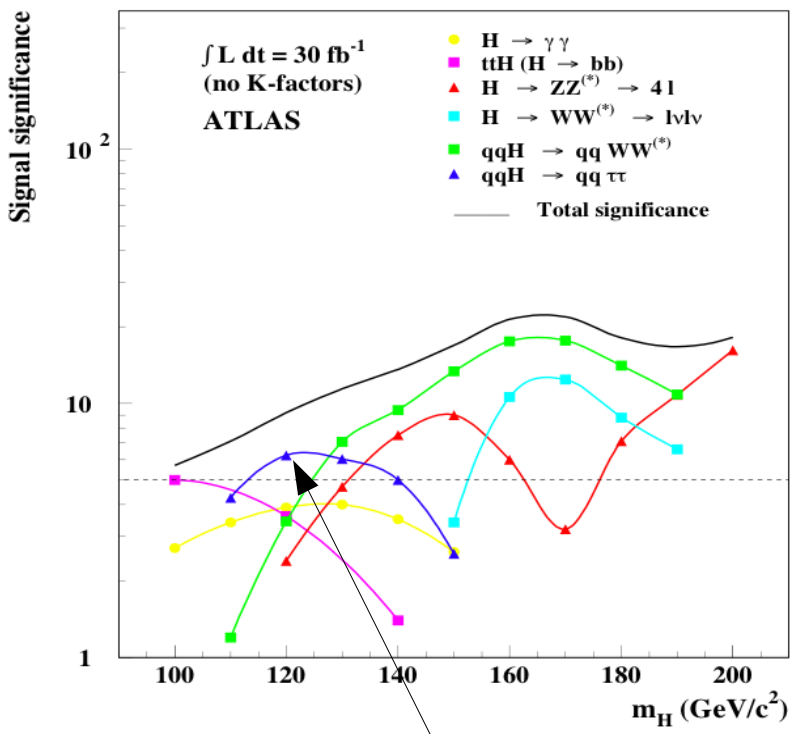
Observe expected edges at 58 and 100 GeV

Low efficiency with respect to MC truth (in black), needs work.

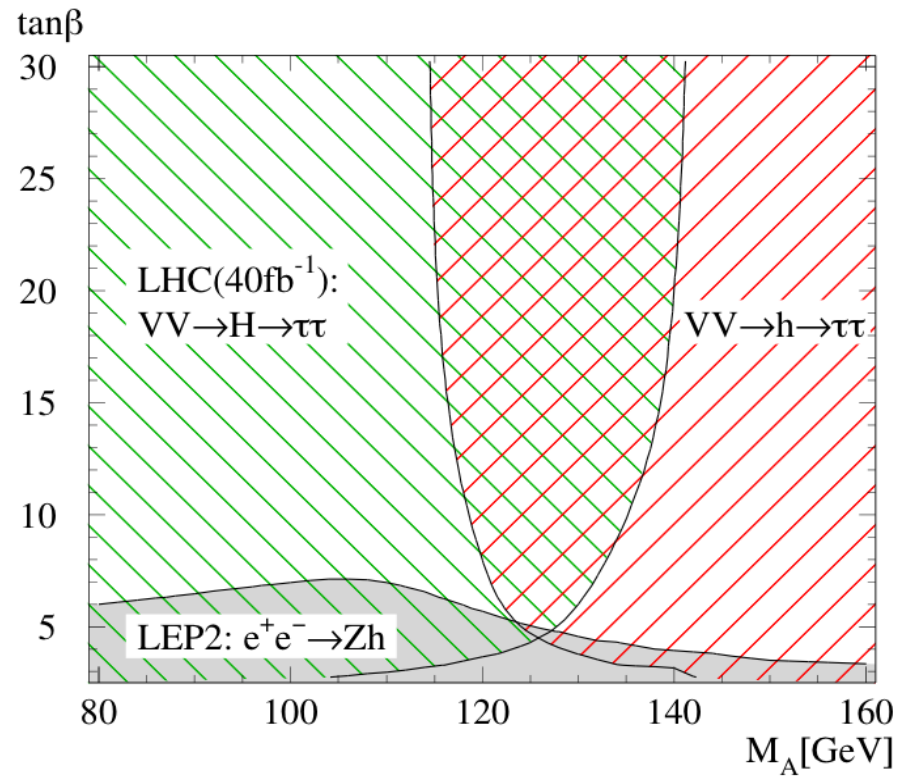
Weak Boson Fusion Higgs -> $\tau\tau$







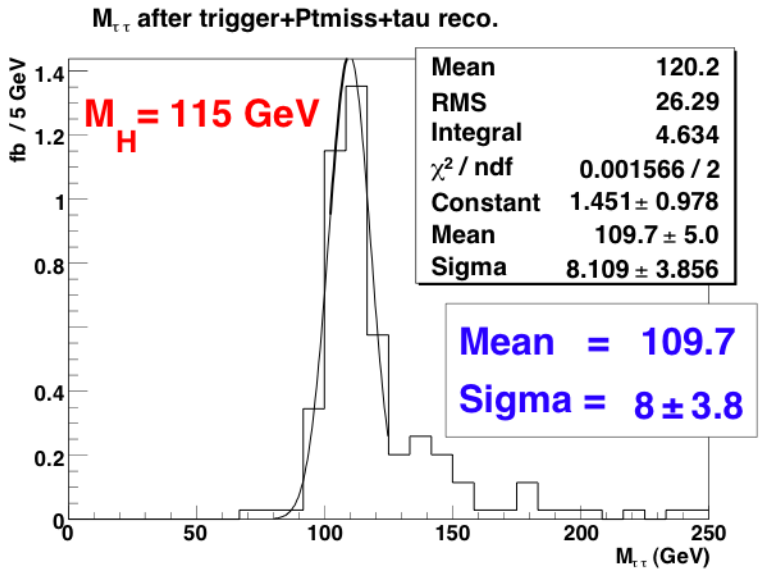
Standard Model (Atlas Scientific Note)



Plehn, et. al hep-ph/9911385

Most powerful channel near LEP limit and very important for MSSM.

Weak Boson Fusion Higgs -> $\tau\tau$



	120 lh	Sci Note	115 lh	10.0.1
Cut Name	σ (fb)	ϵ %	σ (fb)	ϵ %
lepton acceptance	13.7	4.50	12.0	3.66
τ hadron	6.18	45.1	5.81	48.2
forward tagging	1.97	31.8	2.33	40.1
Collinear Approx	1.27	64.4	1.23	52.7
M_T	1.02	80.3	1.0	81.3
E_T^{miss}	0.81	79.4	0.94	94.9
Jet Mass	0.71	87.6	0.89	93.9
Jet Veto	0.63	88.7	0.71	80.6
Mass Window	0.52	82.5	0.60	84.5

Lepton Trigger: $p_T^e > 25$ or $p_T^\mu > 20$

τ-hadron: $p_T^h > 40$

Forward Tagging: $p_{T_{j1}} \geq 40, \quad p_{T_{j2}} \geq 20$
$\eta_{j1} \cdot \eta_{j2} < 0, \quad \Delta\eta_{jj} \geq 4.4$

τ-decay products: $\cos\phi_{lh} > -0.9$,
$0 < x_l < 0.75, \quad 0 < x_h < 1$

$M_T < 30, \quad E_T^{miss} > 30, \quad M_{jj} > 700$

Central Jet Veto: $p_{Tj}^{veto} > 20$, $\quad |\eta_j^{veto}| < 3.2$

$M_H - 10 < M_{\tau\tau} < M_H + 15$

Kyle Cranmer has proposed a kinematic fitting procedure which improves the separation from Z -> $\tau\tau$

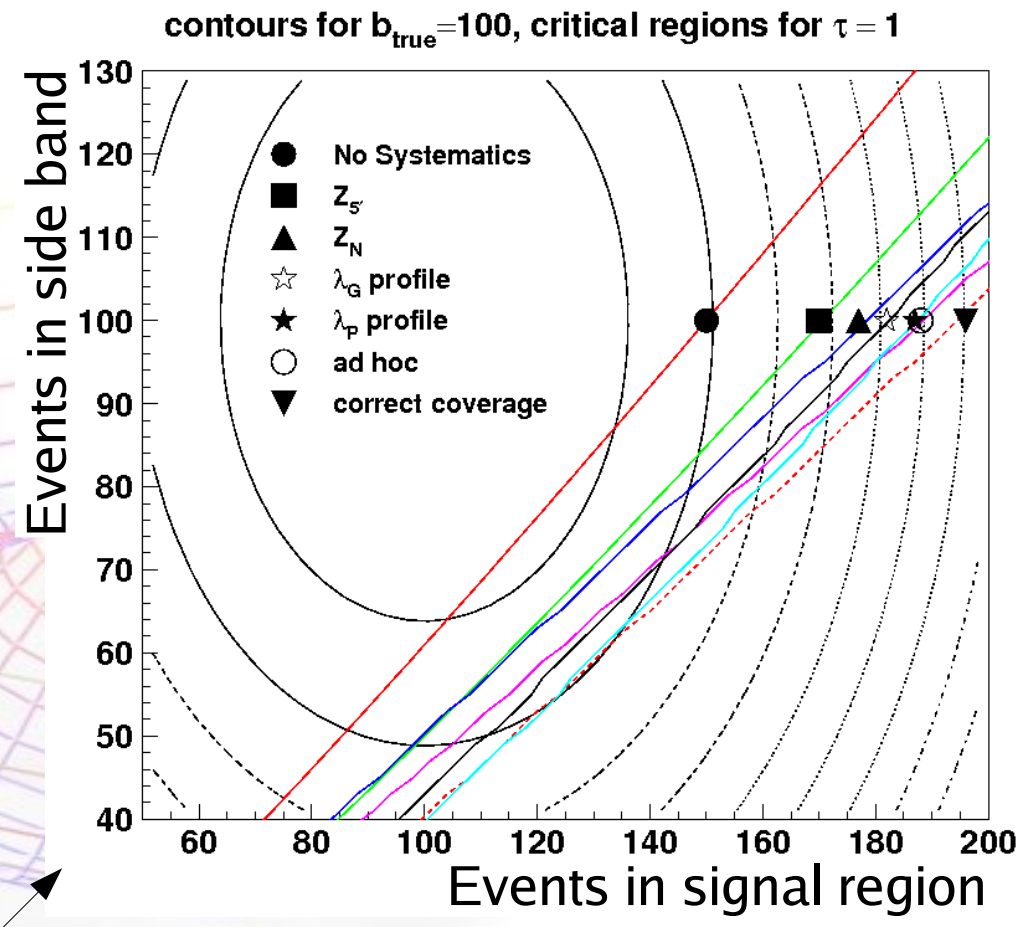
Statistical Methods for the LHC

The LHC will make 5σ discoveries, not set 2σ limits (very challenging)

Some backgrounds channels will have large systematic errors

Most of the common statistical methods in HEP breakdown in this regime

Cranmer is a leader in statistical methods for the LHC.



"Statistical Challenges of Searches for New Physics at the LHC" [physics/0511028]

"At this conference, [Cranmer] compares this method with other methods. This is important work that should be "required reading" for those working on these issues at CERN's Large Hadron Collider and elsewhere. "

-Bob Cousins

Preparation For Physics

Physics Analysis Tools

The Analysis Object Data (AOD) is a format of the ATLAS data that will be used for physics analysis and distributed to the Tier 2s.

- BNL has led the effort in developing the AOD classes for electrons, photons, muons, taus, and jets
- This has been done in close collaboration with combined performance groups and physics analysis groups

In addition to the AOD classes, BNL has led the effort in developing tools for physics analysis:

- The "Event View" is an analysis helper with a powerful toolkit for performing complex analysis tasks
- The "ATHENA-Aware Ntuple" provides convenient access in ROOT while maintaining compatibility with the framework
- Distributed analysis tools like PANDA

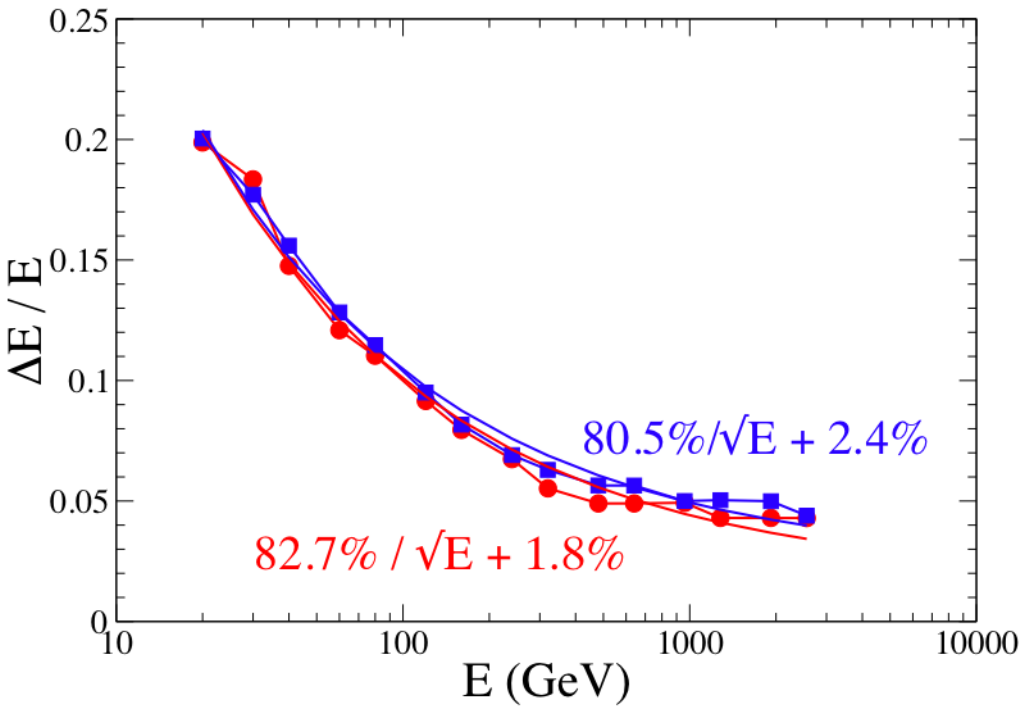
Reconstruction, Calibration & Commissioning Activities

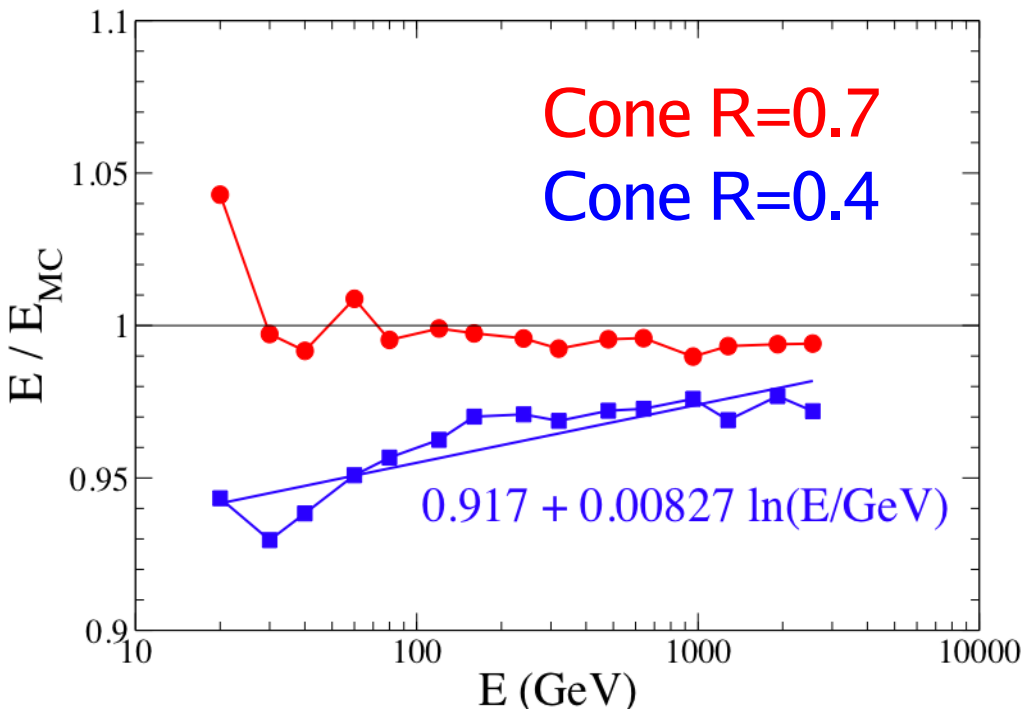
- Pavel Nevski: Energy Flow Reconstruction
- Scott Snyder: EM Cluster Corrections
- Srini Rajagopalan: LAr Performance Coordinator and Calorimeter Software Coordinator
- Hong Ma: LAr Commissioning Analysis Co-coordinator
- Ketevi Assamagan: Muon Reconstruction
- Kyle Cranmer: MissingET Reconstruction & Trigger
- Frank Paige: Hadronic Calibration
- Arthur Moraes: Underlying Event Measurement & Tuning
- Iuliu Stumer: Magnetic Field Mapping

Reconstruction & Calibration

Frank Paige derived the cell-based hadronic calibration constants used at the Rome Workshop for Jets, Taus, and MissingET

- Left: Jet Energy Resolution vs. Jet Energy
- Right: Jet Energy Linearity for two cone sizes
- Efforts are on going to decouple calibration and clustering effects

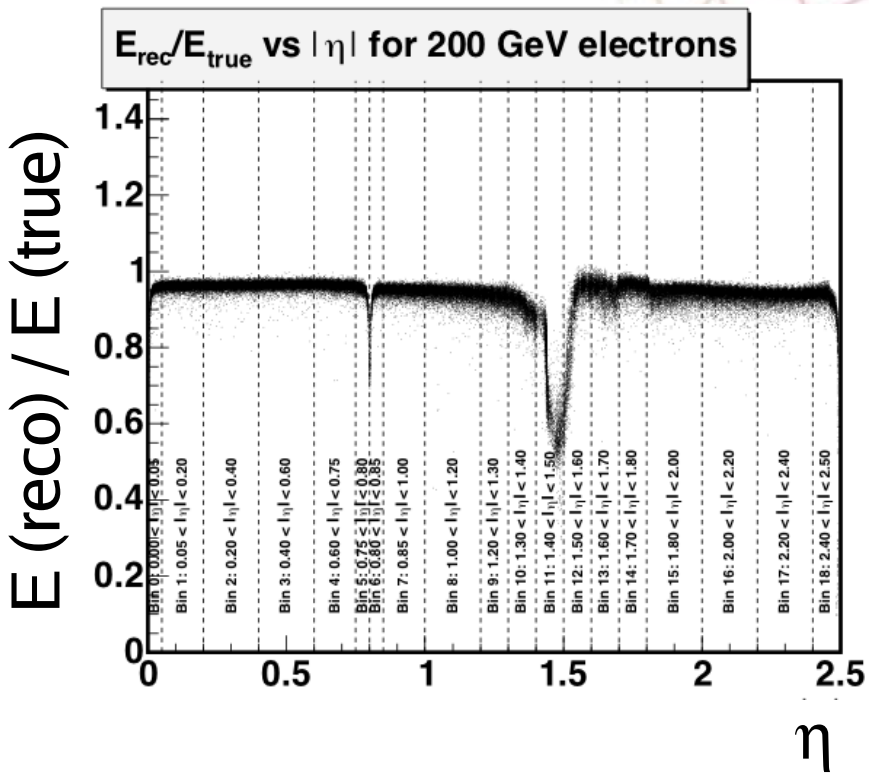


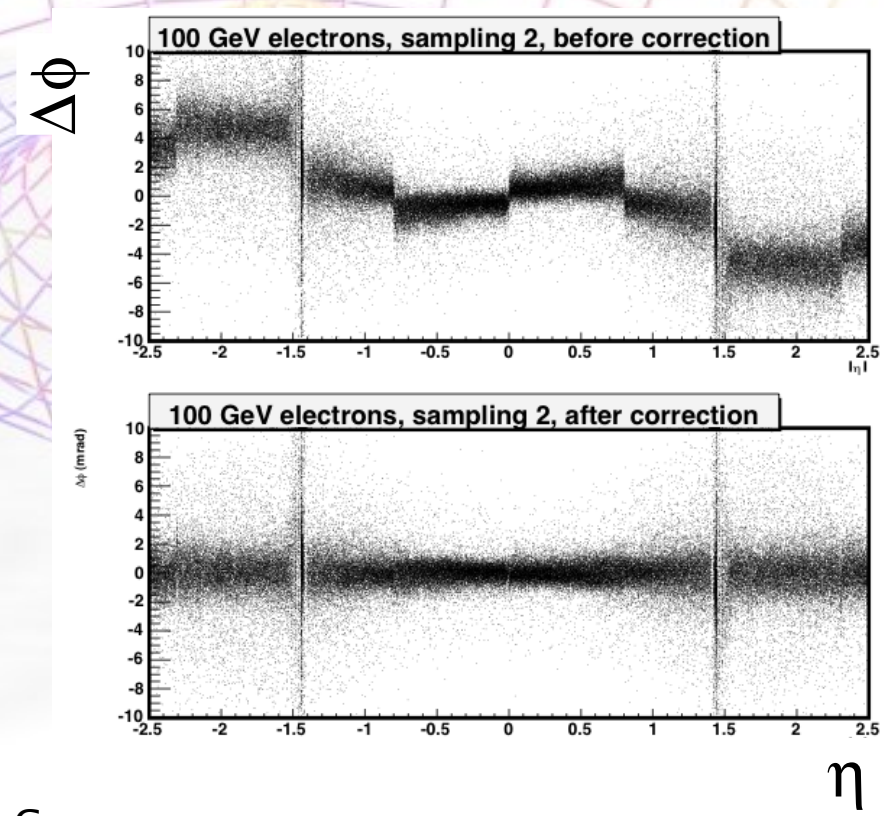


Reconstruction & Calibration

Scott Snyder derived the corrections for EM clusters used for the Rome workshop

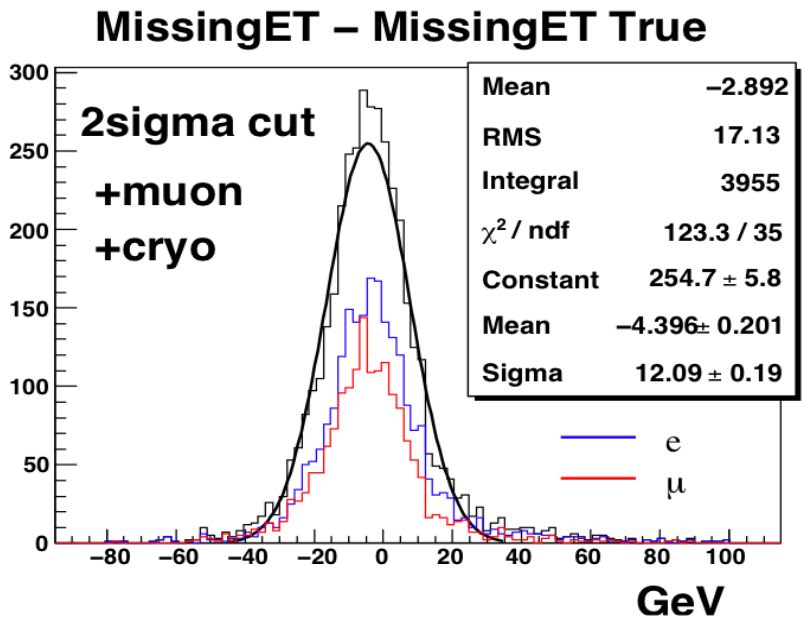
- Left: Calibration constants broken into various η-bins
- Improvement in φ resolution due to φ -modulation

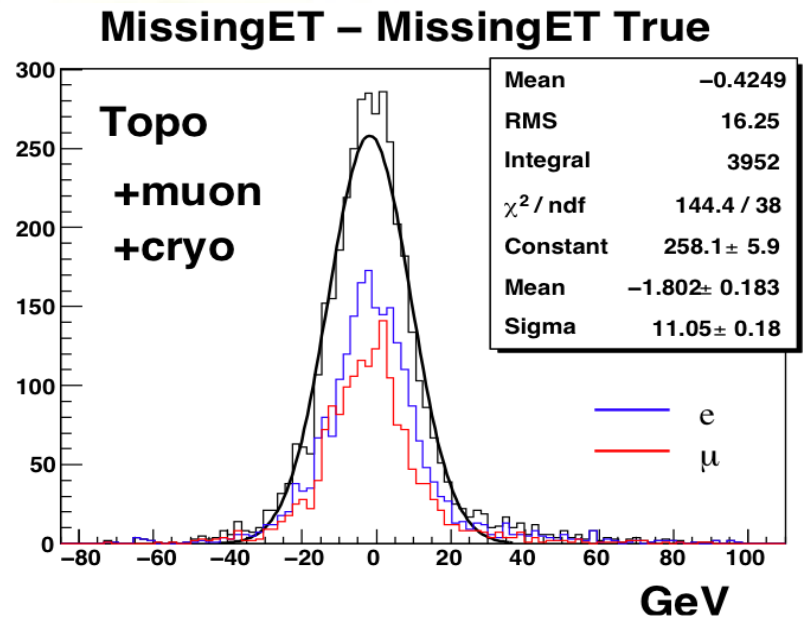




Reconstruction & Calibration

Kyle Cranmer discovered a bias effect in MissingET due to the ATLAS noise suppression strategy.



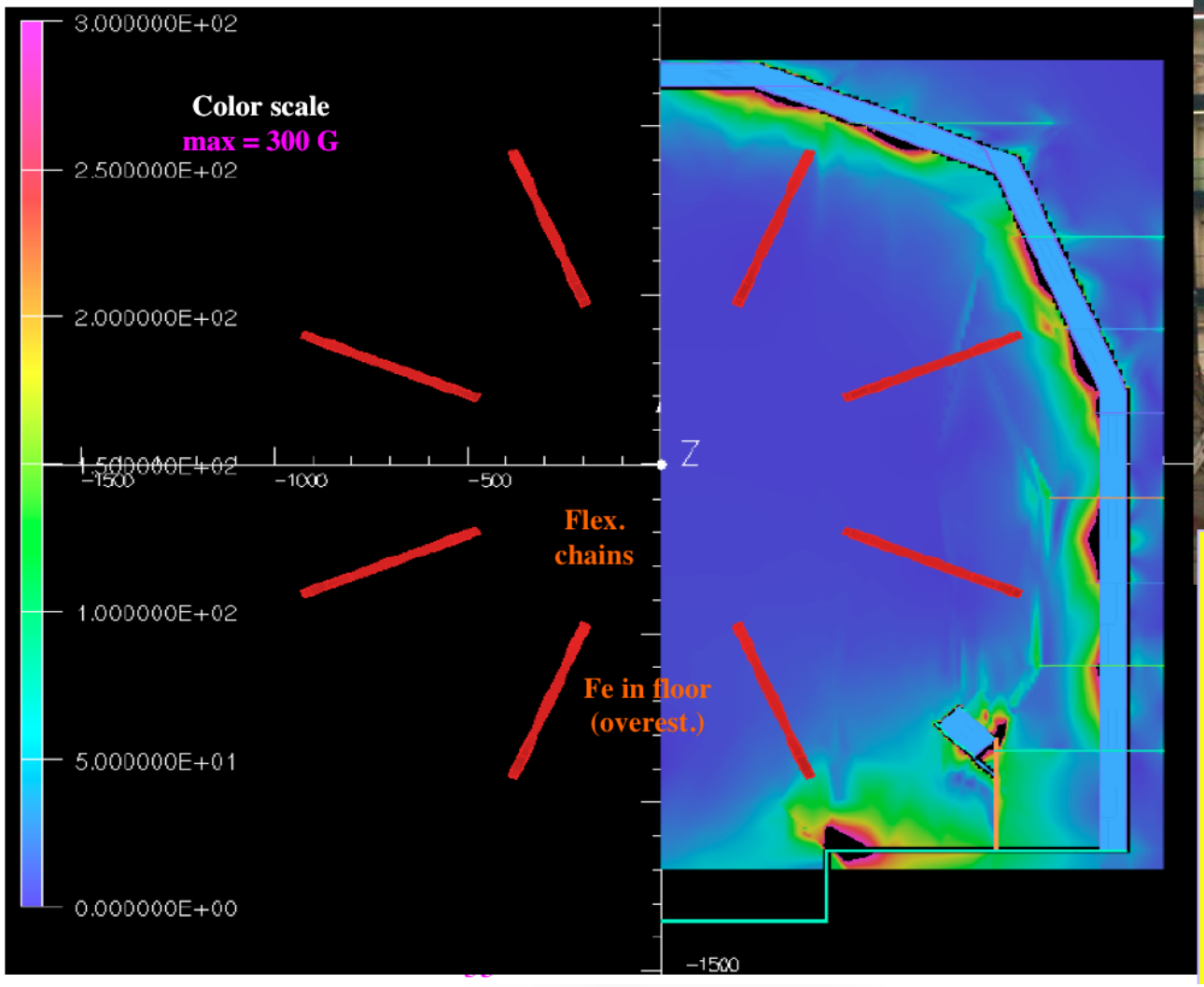


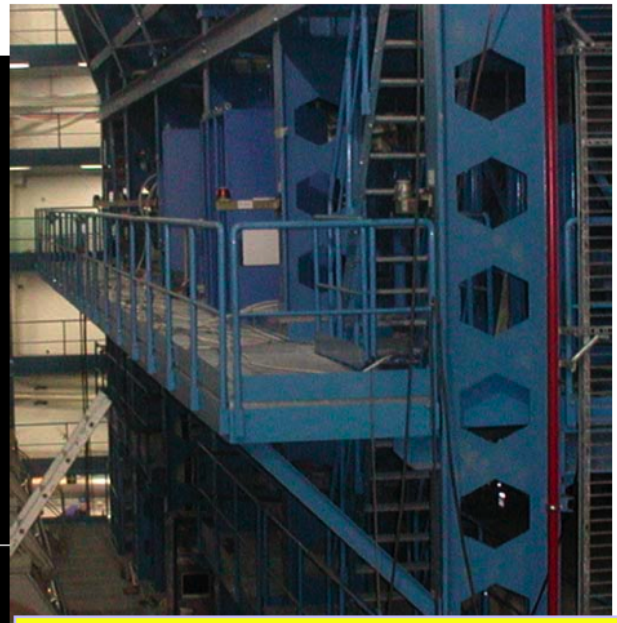
MissingEt biased: A combination of mis-calibration and noise suppression

- bias = 4.4 GeV when noise suppressed with 2σ cut
- bias = 1.8 GeV when noise suppressed with TopoClusters

This effect is important for Z/H -> $\tau\tau$, W mass,etc

The ATLAS Magnetic Field



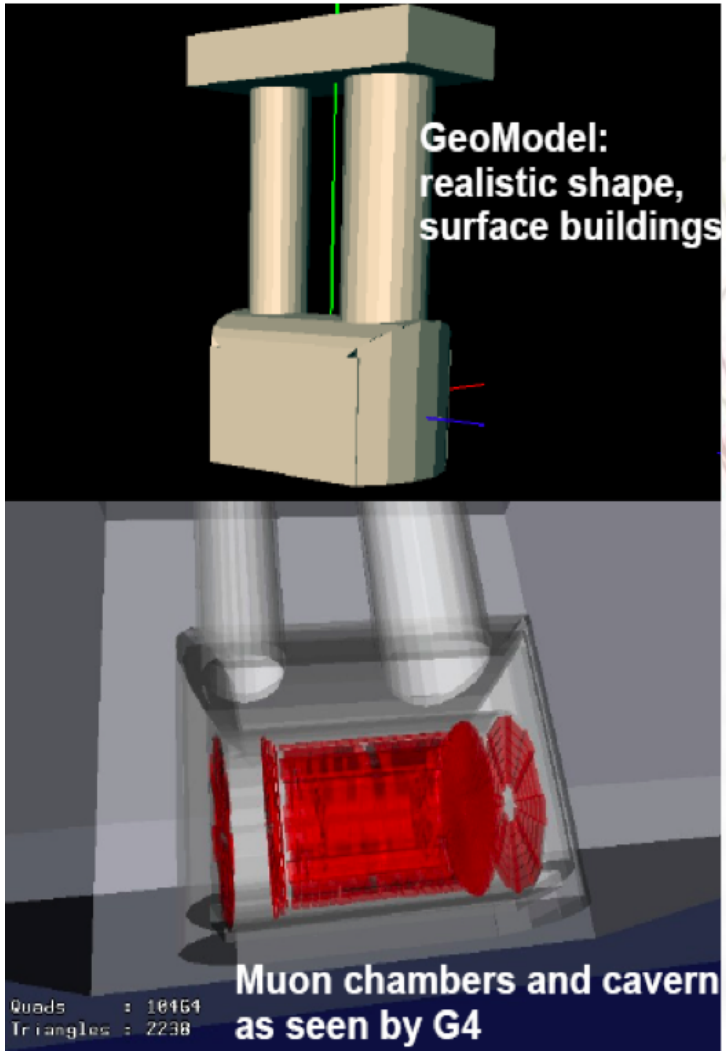


Stumer (BNL)

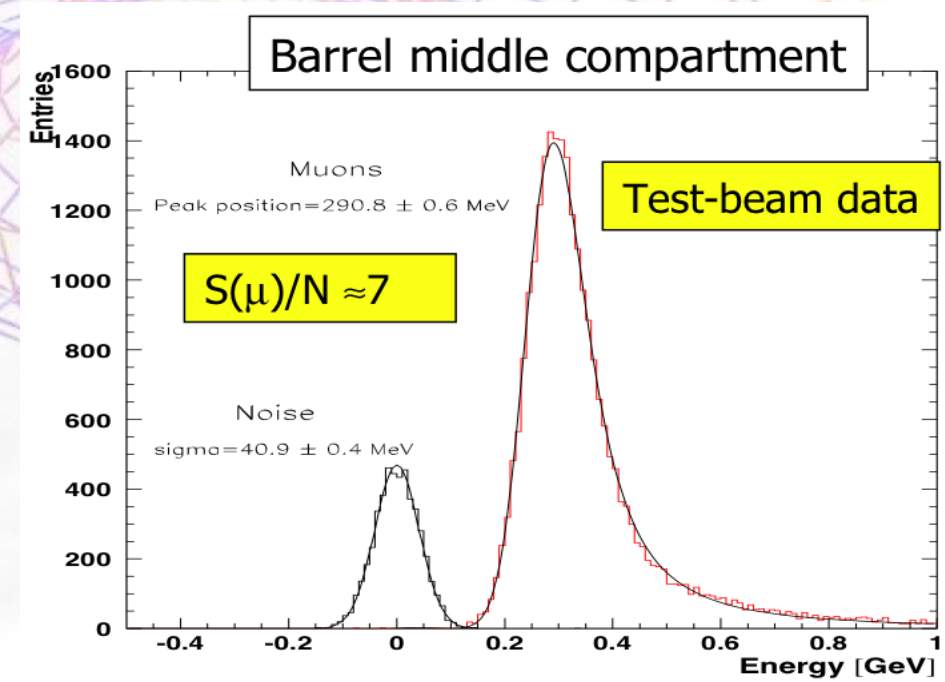
Field deviations of 200-300 Gauss in the outer chambers. We need to know it to 10-20 Gauss!

Physics Commissioning with Cosmics

Hong Ma coordinates the LAr analysis commissioning activities



- Demonstrate software calibration + database are working
- Time & Amplitude Inter-calibration in η
- Find bad channels (HV problems, etc.)

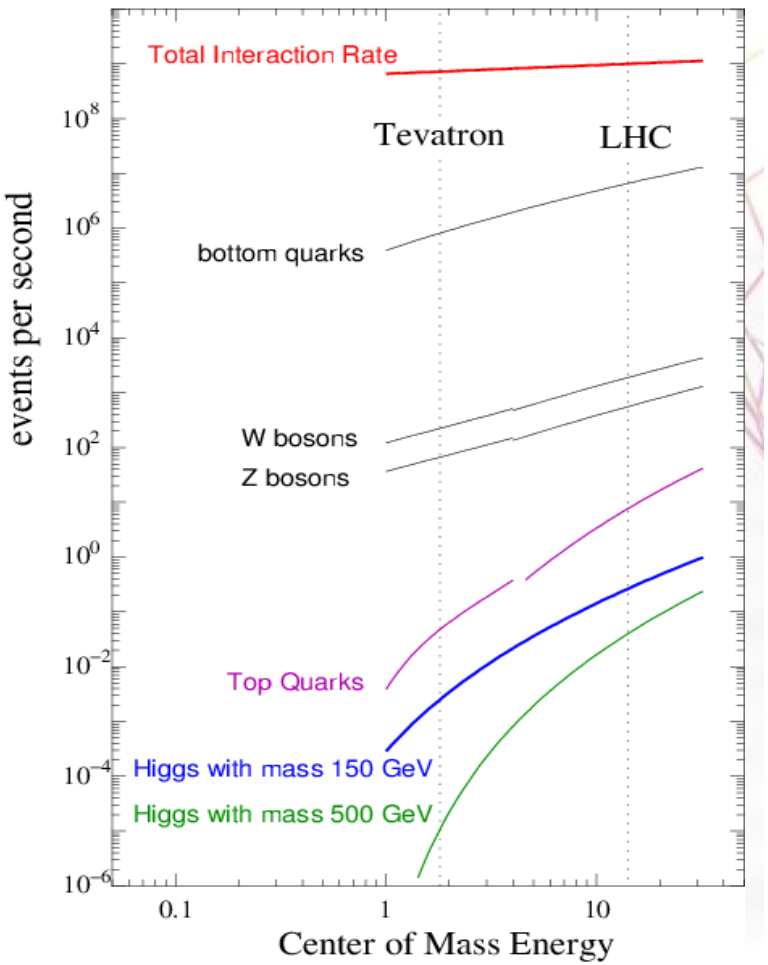


High Level Trigger

Triggering at the LHC

Only 1 in 500,000 events will be stored to disk

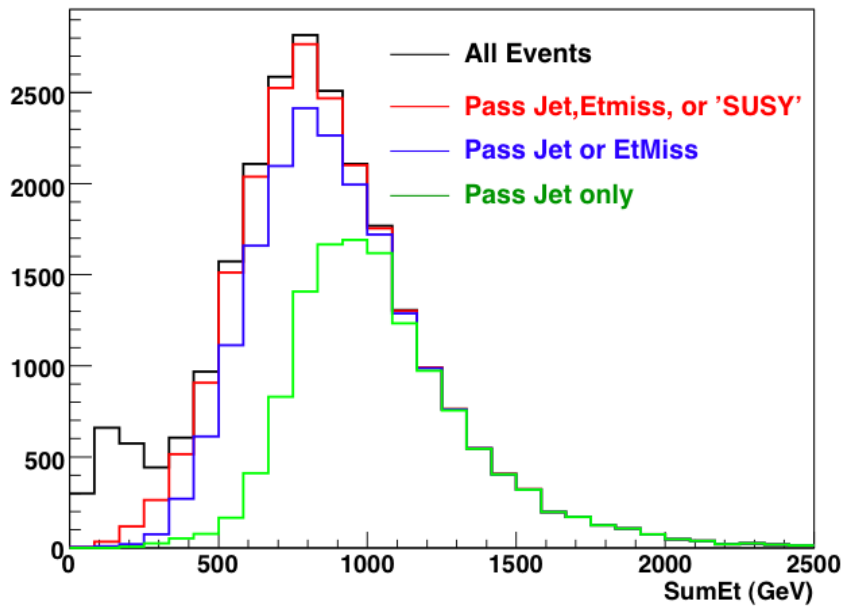
The trigger is a vital piece of our preparedness for physics



- Steve Armstrong
  - Began BNL High Level Trigger effort
  - Coordinator of calorimeter trigger algs
- Kyle Cranmer
  - coordinator of jet/tau/etmiss
  - author L2 jets & L3 MissingET
- Denis Damazio
  - Improvements to calorimeter byte-stream conversion
  - Electron/Photon L2 triggers
  - L1 rate studies with min. bias

SUSY Trigger Study

Study efficiency of various triggers at coannihilation point



Trigger Name	Efficiency (%)
J400	45
2J350	17
3J165	14
4J110	7
xE200	71
'SUSY' xE70+J70	88
Anything	92
Any w/o SUSY	80
Only Jets	54

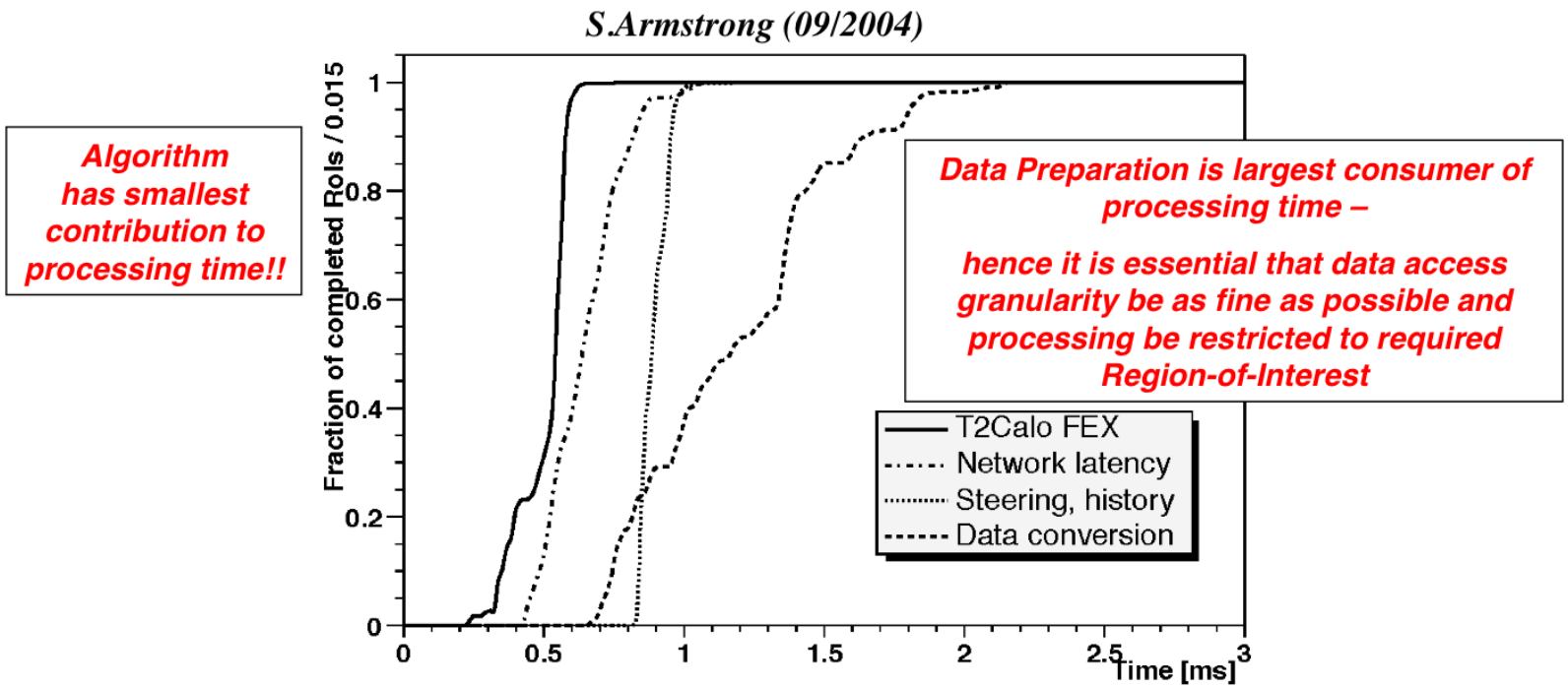
This SUSY point has soft leptons due to small mass splitting

Current list of jet triggers is only about 50% efficient

Clearly we rely heavily on Missing ET signatures

Fast Data Unpacking in the HLT

Data unpacking (from byte-stream) dominates the processing time for most Level2 trigger algorithms



Denis Damazio has streamlined the byte-stream conversion, improving speed by more than a x2 !

Analysis Support

The BNL Analysis Support Center

The mission of the Analysis Support Centers (ASC) is to support the U.S. ATLAS detector performance and physics analysis activities. These centers are expected to provide U.S. ATLAS physicists with training on how to use ATLAS software via tutorials and one-on-one interaction. The ASCs are also expected to support physicists making visits for help with their analysis and/or more advanced software features.

Recent Workshops Hosted by BNL

- e/gamma reconstruction
- b-jet tagging tutorial
- Heavy ion workshop

Recent Visitors to BNL

- Columbia, NYU, Stony Brook
- Boston U., Amherst
- SMU, UT-Arlington
- Iowa, Arizona

BNL's Role in Analysis Support

US-ATLAS Analysis Forum Coordinators

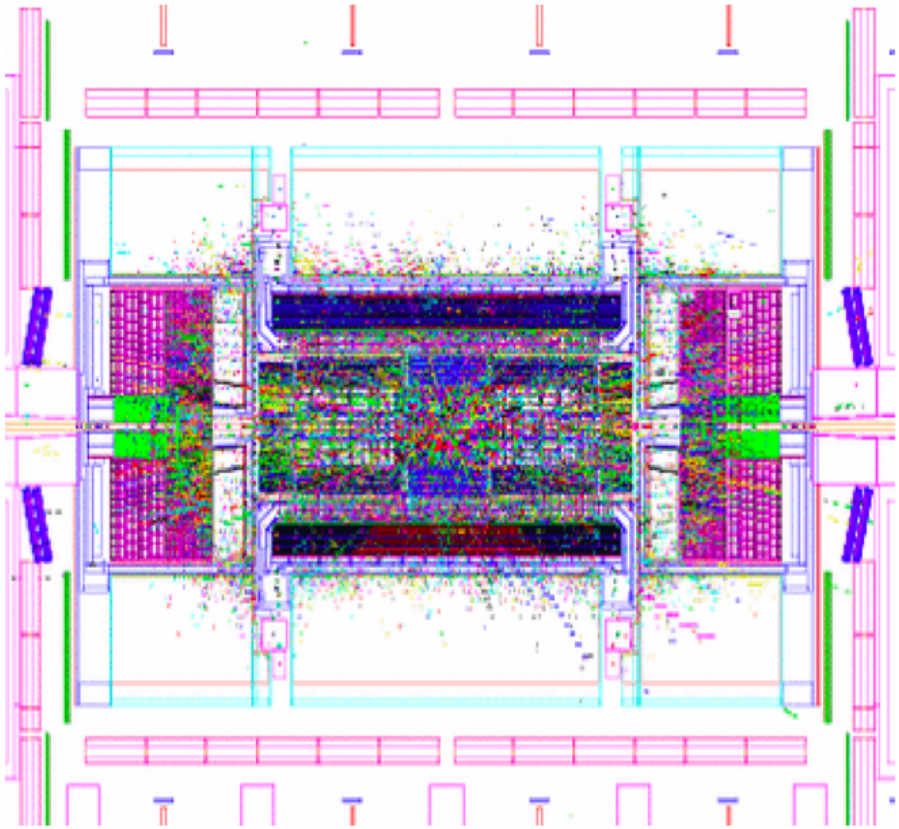
- Kyle Cranmer: Trigger Forum
- Frank Paige: SUSY & Exotics Analysis Forum

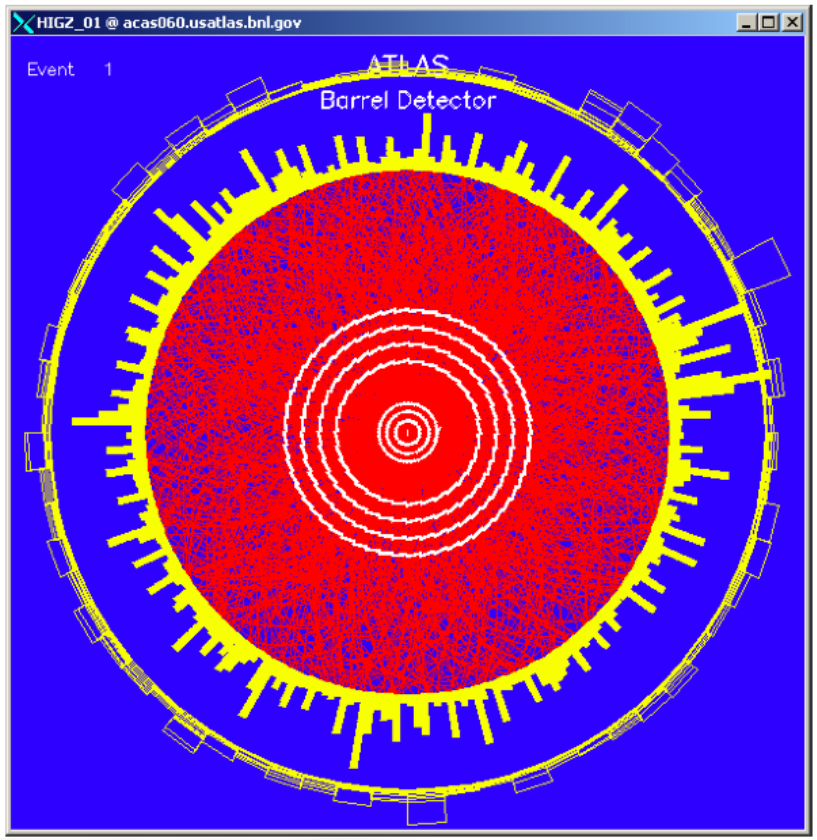
Hong Ma: US ATLAS Analysis Support Group in 2005

US-ATLAS Analysis Support Group Contacts:

- Ketevi Assamagan: Physics Analysis Tools
- Tadashi Maeno: Distributed Analysis
- Alex Undrus: Software Support

Super-LHC: A Luminosity Upgrade



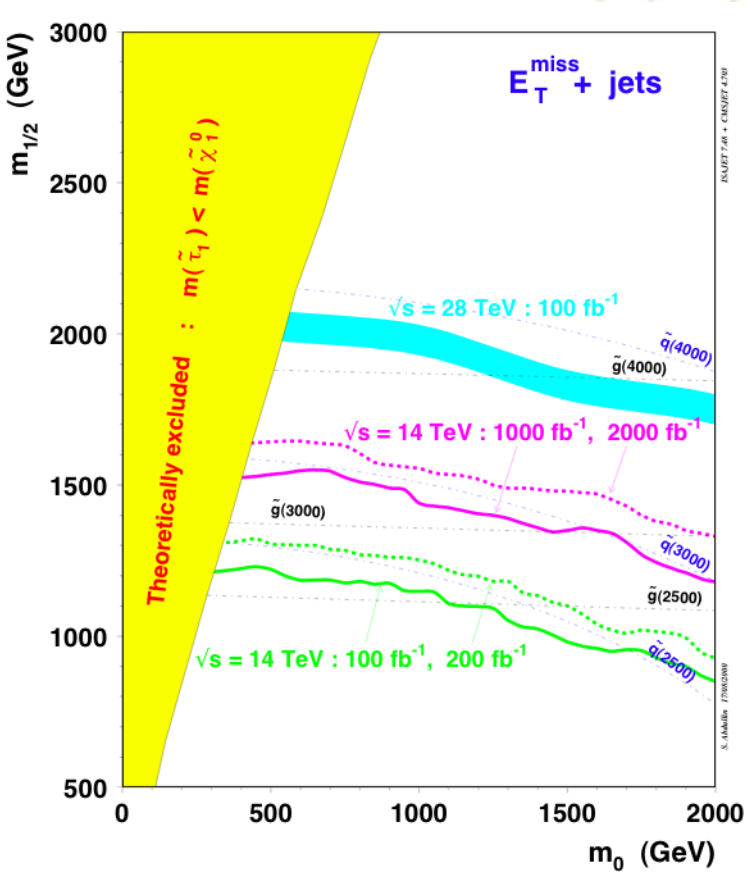


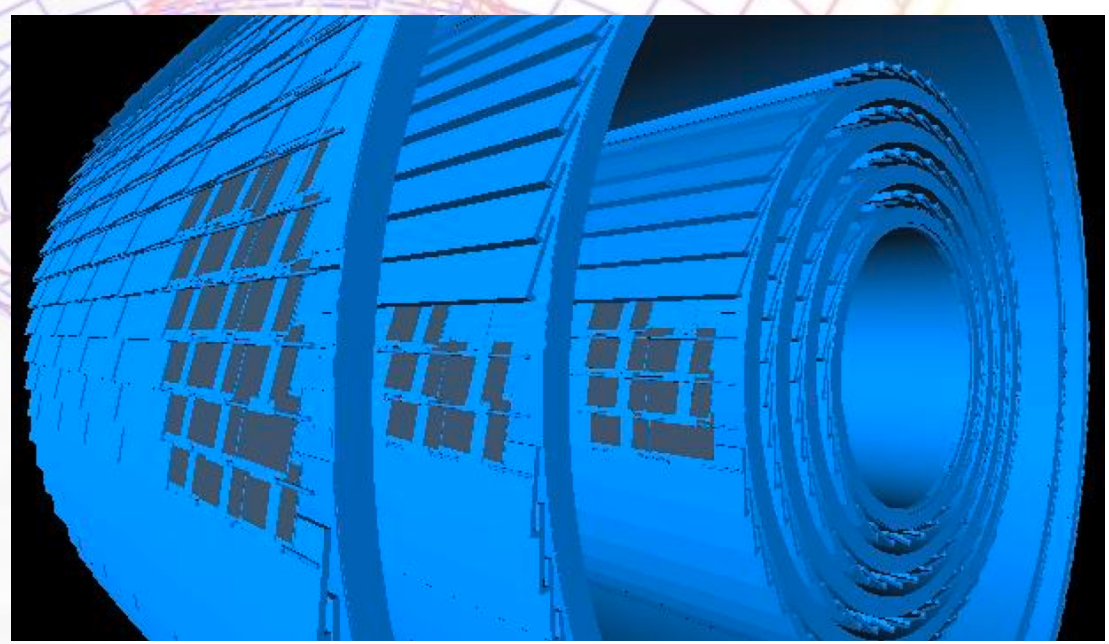
At 10^{35} cm^{-2} s^{-1} expect ~200 min. bias collisions per 25ns bunch crossing

Super-LHC: A Luminosity Upgrade

Frank Paige contributed to the ATLAS & CMS document outlining the physics potential of a luminosity upgrade

David Lissauer, Francesco Lanni, and Pavel Nevski have started R&D efforts for a luminosity upgrade



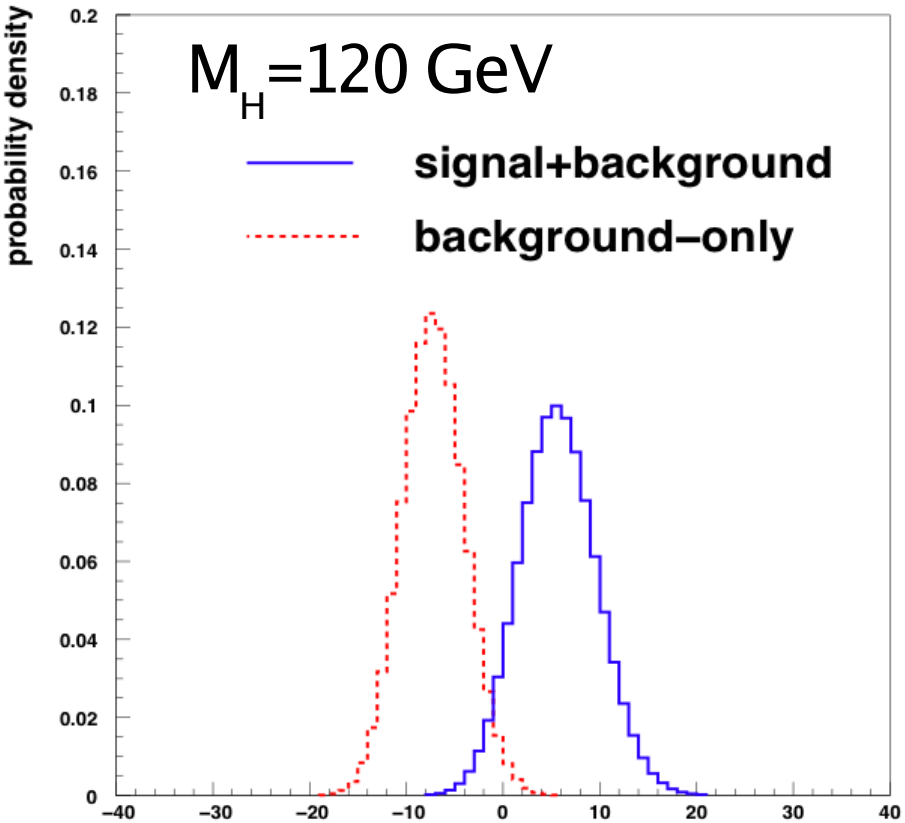


Higgs -> $\mu\mu$ at the LHC ?!

Kyle Cranmer is collaborating with Tilman Plehn on a general technique to determine *analytically* the expected significance of an ideal search performed at the LHC.

As an example qqH -> qq$\mu\mu$

- Previous published cut analysis expected 1.8σ / experiment / 300 fb^{-1}
- With this technique we expect:
  - 3.7σ / experiment for 300 fb^{-1}
  - 5.2σ ATLAS+CMS
- The SLHC could see H->$\mu\mu$



log likelihood ratio (300 fb^{-1})

Summary

- BNL continues to play an active role in physics analysis within ATLAS and US-ATLAS
- Our focus is on preparing for analysis with real data
  - Commissioning, Reconstruction, Calibration, & Trigger
- As an Analysis Support Center, BNL continues to
  - Organize workshops and tutorials
  - Provide expertise for Support Groups & Analysis Fora
- BNL has taken a leading role in R&D efforts for a luminosity upgrade of the LHC

We eagerly anticipate data taking in 2007!