Physics Tools and Physics Preparations

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Ariel Schwartzman
Washington, 11-June-2009

SLAC
NATIONAL ACCELERATOR LABORATORY

Outline

- Physics Tools
  - Algorithms and techniques for jet reconstruction, energy scale, and b-tagging. Development of simple methods, more suitable for early data.
- Physics Preparations
  - Standard Model measurements with top quarks.
  - New physics searches.

Physics Tools

Physics Performance and Tools

Initial physics efforts concentrated on building the foundations of physics analysis, through improving physics signature reconstruction:

- establish performant and robust physics reconstruction, calibration, and analysis tools to allow effective exploration of the first LHC physics.
- introduce new reconstruction and calibration techniques with less reliance on detailed Monte Carlo simulations and complex algorithms.
- extend reconstruction capabilities to unconventional signatures.

The Jet/ME_T/b-Tag Analysis Group (I)

Initiated by SLAC in August 2007, today consists of 12 active collaborators from 5 US and 1 Latin American ATLAS institutions. Weekly meetings at CERN.

- introduced several new techniques in ATLAS:
  - incorporation of tracking and vertexing information into jet reconstruction.
  - development of data-driven methods and new *schemes* for jet calibration.
  - Simpler and more robust approaches to jet reconstruction and calibration for early data.

10 ATLAS internal notes, 3 APS presentations, 2 US ATLAS regional workshops, several new official software packages, many algorithms integrated to ATLAS main stream reconstruction and calibration.

The Jet/ME$_T$/b-Tag Analysis Group (II)

SLAC:
- Bart Butler
- David Miller
- Ariel Schwartzman

Columbia University:
- David Lopez
- Zach Marshall
- Kerstin Perez

U.C. Santa Cruz:
- Jason Nielsen

Harvard University:
- Shulamit Moed

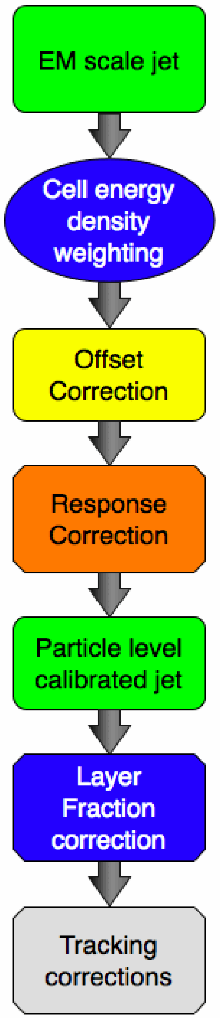
BNL:
- Stephanie Majewski

Universidad de Buenos Aires:
- Gaston Romeo
- Ricardo Piegaia
- Laura Silva

Jet Energy Scale

SLAC is leading several aspects of the jet energy scale determination in ATLAS:

- Factorized approach combining Monte Carlo and data-driven corrections. Initiated the development of the ATLAS-wide multi-step jet calibration framework.
- Pile-up energy corrections.
- Improved techniques to restore the jet energy response.
- Techniques to improve energy and direction resolution *after* calibration.
- Track-based energy corrections.



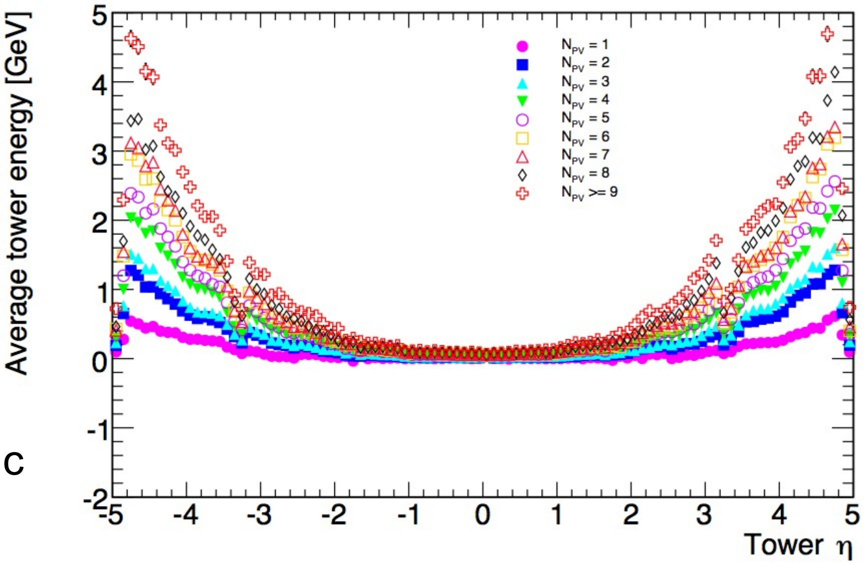
Pile-up Energy Correction: Offset

Subtract, on an average way, the contributions to the jet energy not originating from the primary interaction.

Developed and implemented 3 different techniques:

- Tower based (D0)
  - not applicable to cluster-based jets
- Random cone (CDF)
  - not applicable to non-Cone jets
- Object-based (new approach)
  - Use photon+jet balance as a function of the number of primary vertices. Valid for any jet algorithm, and hadronic scale (cell energy density weighting)

David Miller



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Layer Fraction Energy Corrections

Apply energy response corrections as a function of the energy fraction deposited in longitudinal calorimeter layers *after jet energy scale calibration*:

- Decouples energy calibration from resolution improvement.
- Simple: uses 3 energy fractions.
- Can be derived from data.
- Energy resolution comparable to more complex (and Monte Carlo based) weighting calibration schemes.

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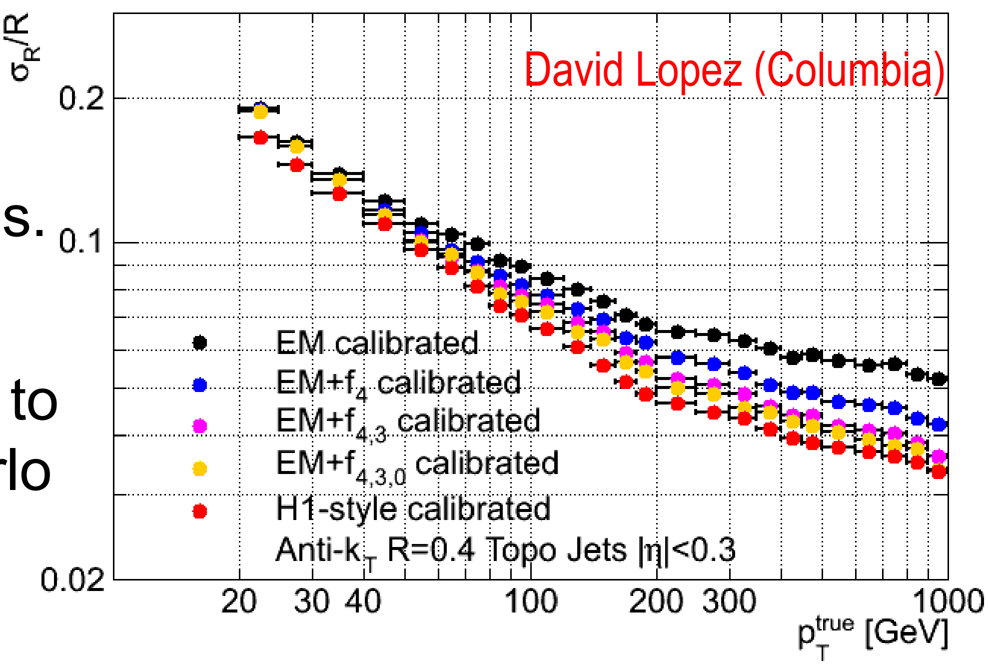


Tracking Input To Jet Reconstruction

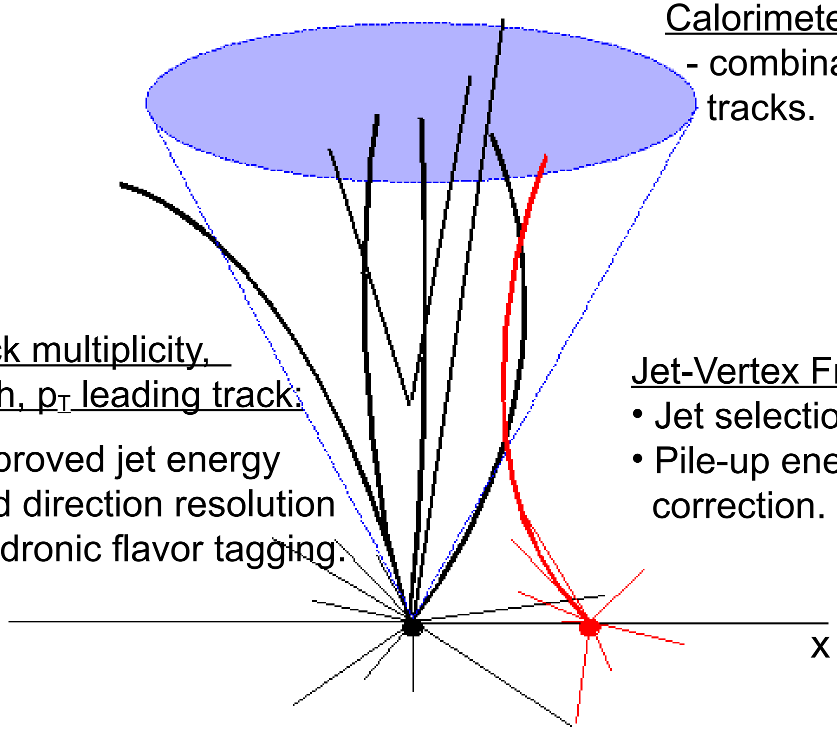
SLAC is leading a research program to use tracking to <u>improve calorimeter-jet energy and direction resolution:</u>

- New approach, conceptually different from "particle-flow".

<u>Calorimeter clusters:</u>
- combination with tracks.

<u>Track multiplicity, width, p_T leading track:</u>
- improved jet energy and direction resolution
- Hadronic flavor tagging.

<u>Jet-Vertex Fraction:</u>
- Jet selection.
- Pile-up energy correction.



Tracks are used to extract information about jet fragmentation, dead material, non-compensation, pile-up, and out-of-cone energy:

– Track-based energy (and direction) corrections.

Track-based Jet Reconstruction

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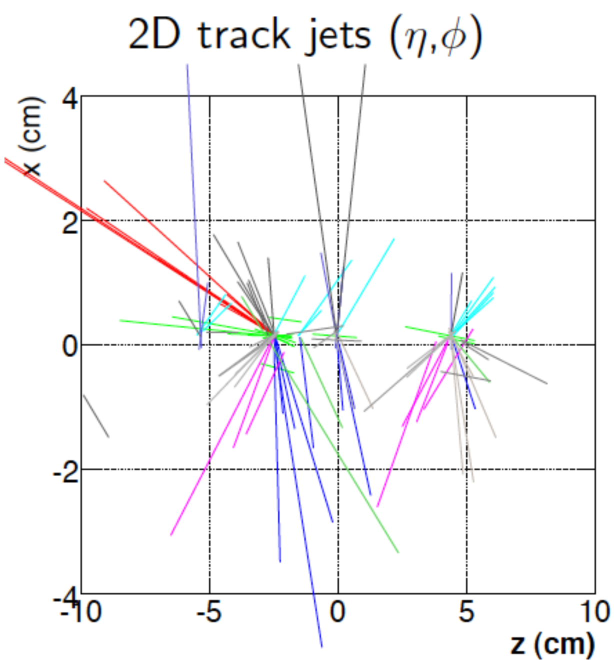
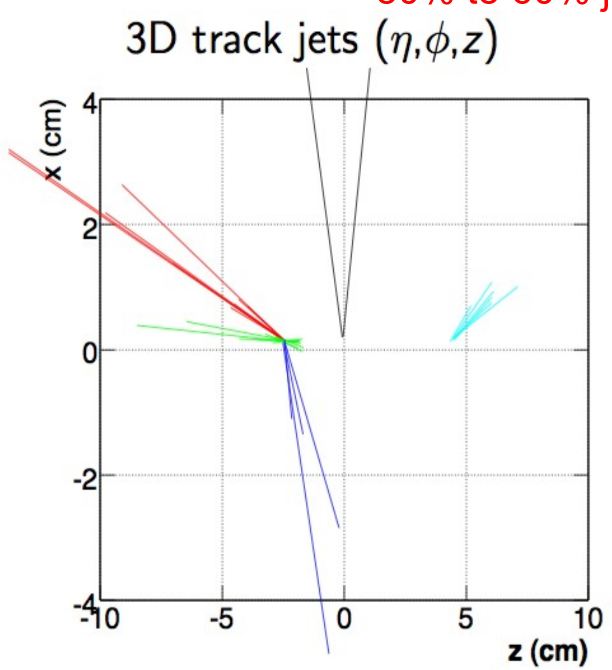
Bart Butler

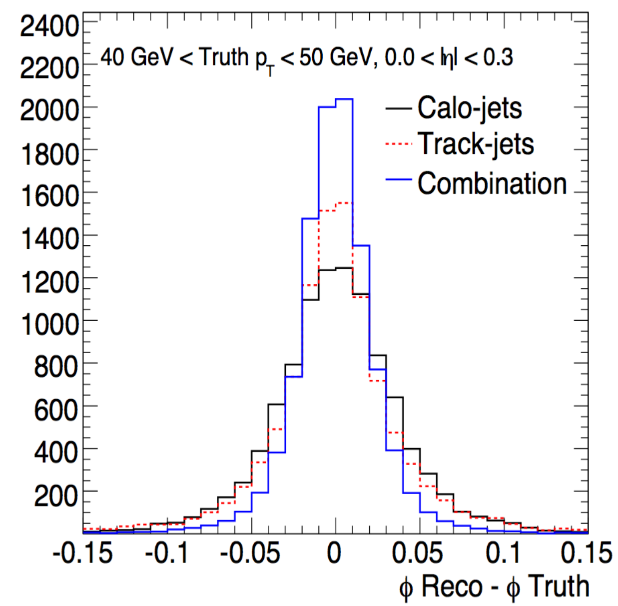
3-dimensional Track-jets (eta,phi,z):

- robust against pile-up (b-tagging)
- independent measurements of charged energy and jet direction.

30% to 60% jet angular resolution improvement







Jet Vertex Association

David Miller

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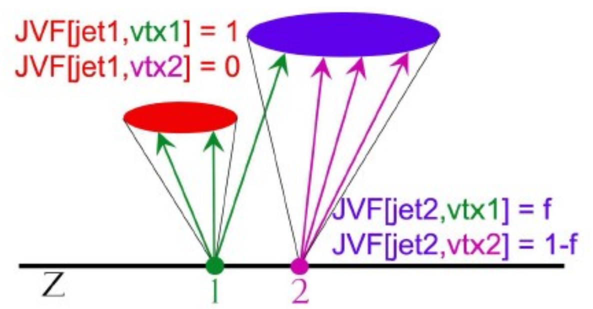
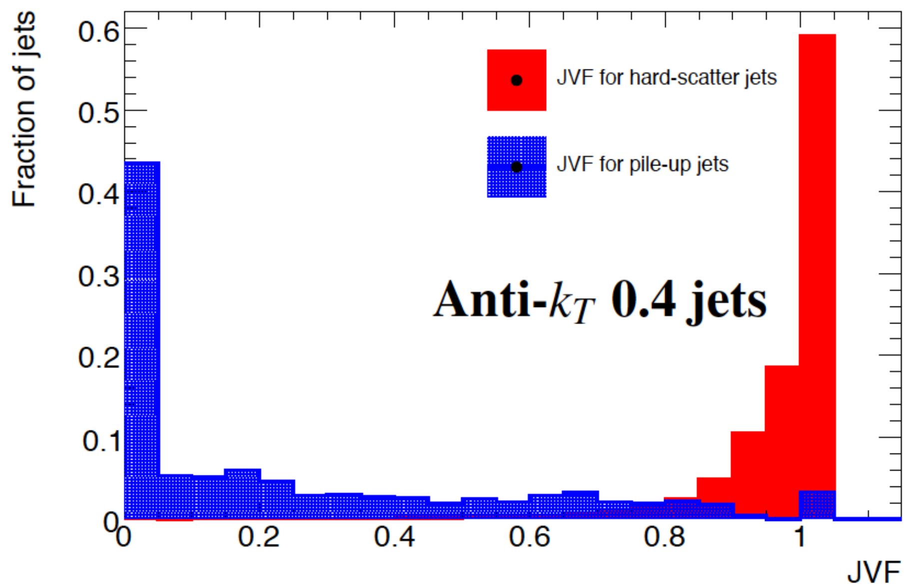
The presence of additional *p-p* interactions can give rise to extra jets and distort kinematic distributions.



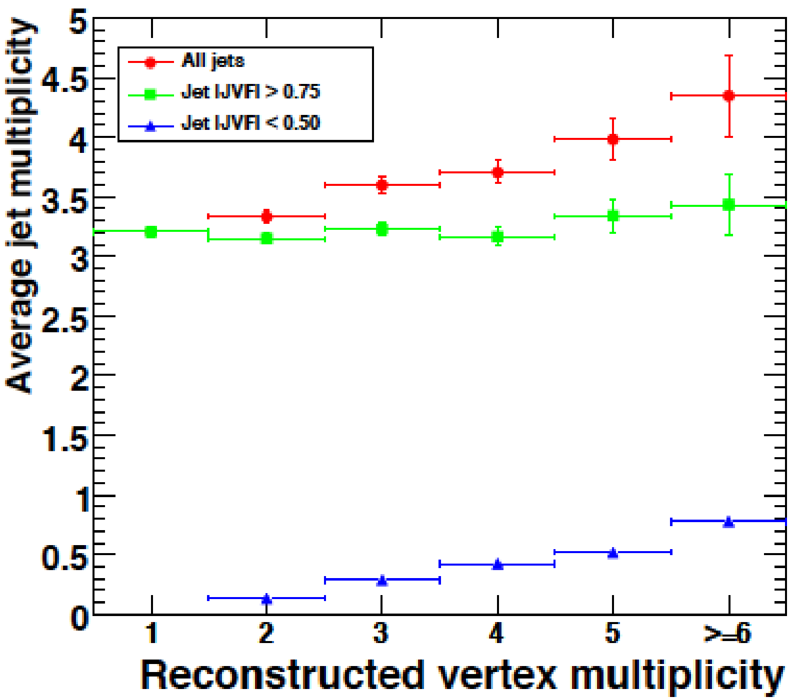
<u>Use tracks and vertices</u> to:

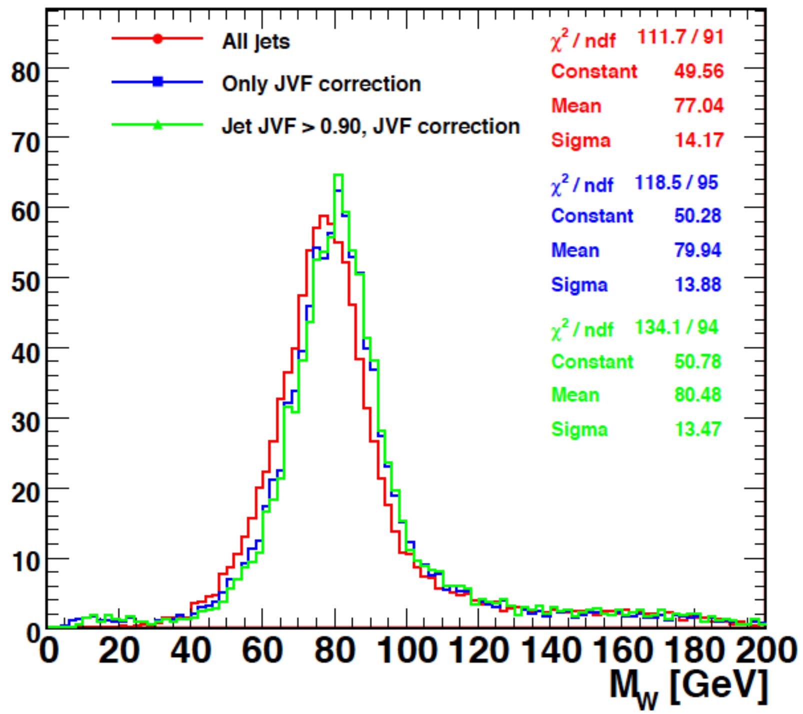
- identify and reject jets originating from minimum bias interactions.
- Subtract energy from additional interactions contributing to hard-scatter jets. (jet-by-jet pile-up correction)



Jet Vertex Association Performance

- Efficient rejection of pile-up jets: jet multiplicity as a function of luminosity becomes constant.
- W mass resolution in top-quark events improves by ~10%

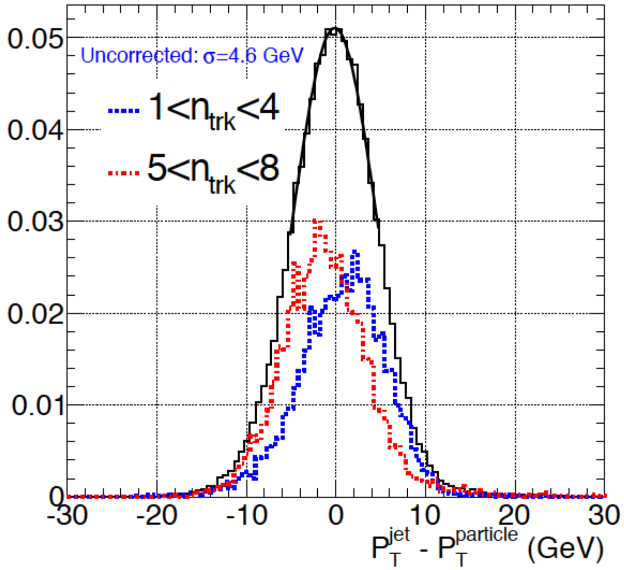


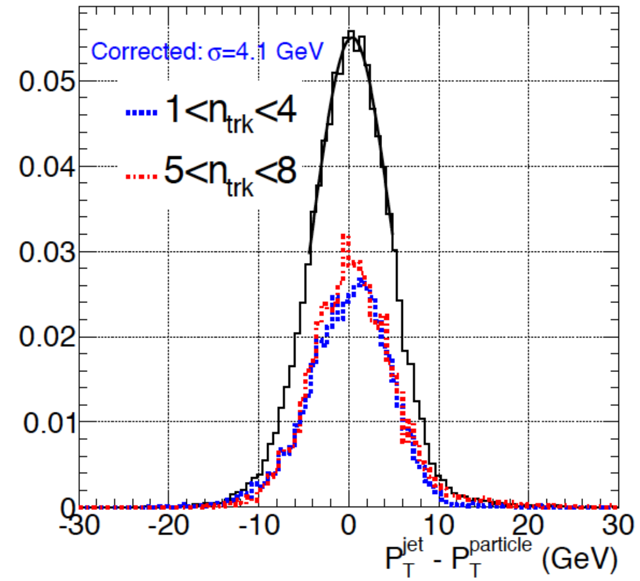


Improving Jet Resolution with Tracks

Use tracking information to adjust the jet energy scale on a jet-by-jet basis to reduce some of the sources of energy fluctuations and improve the jet energy resolution *after jet energy calibration*.

- <u>Track multiplicity energy correction</u>:
  - Sensitive to dead material and non-compensation (e/h>1)





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Improving Jet Resolution with Tracks

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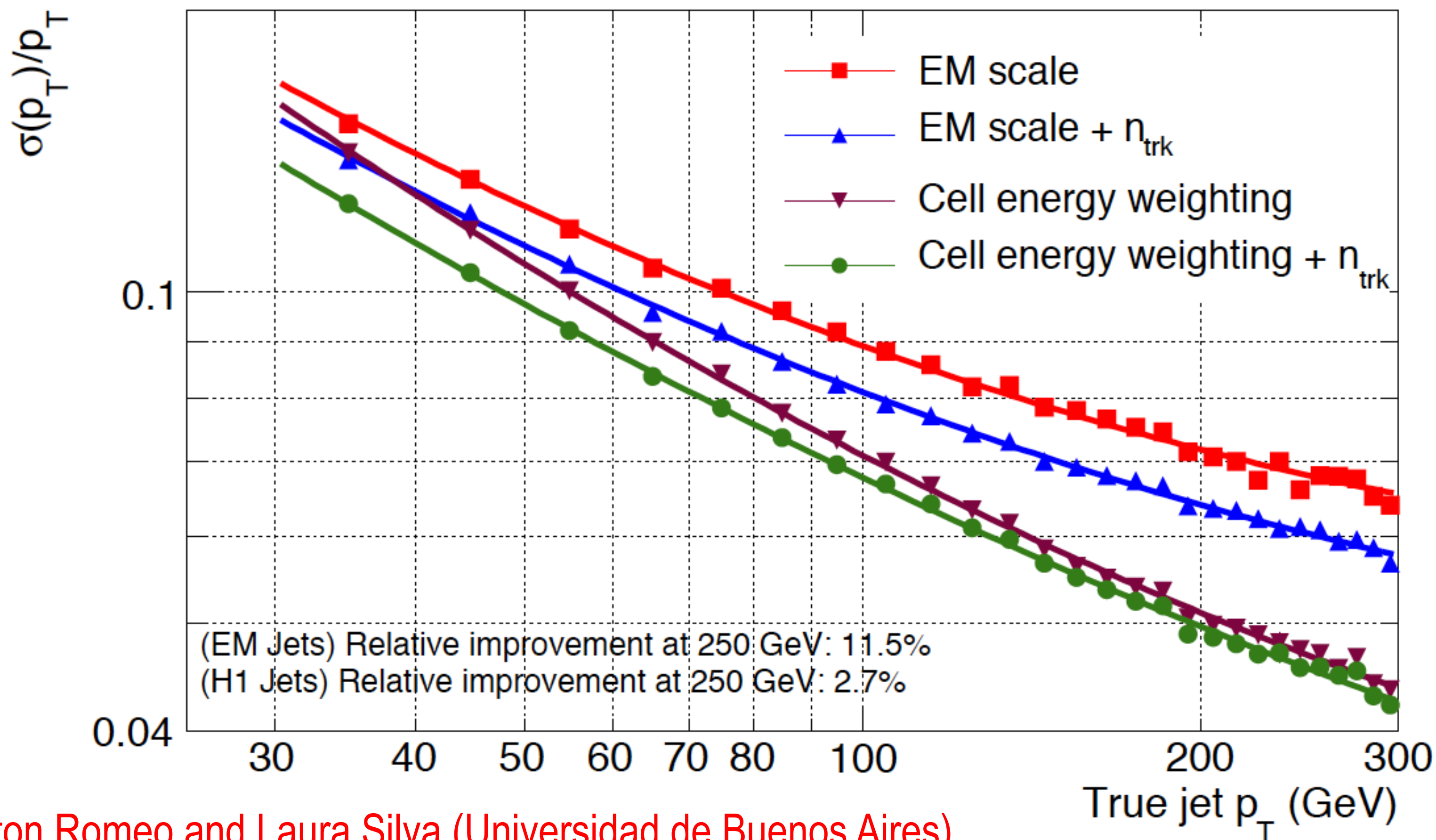
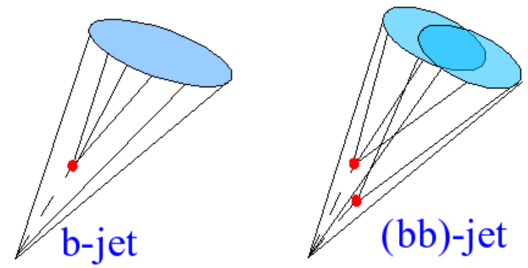


Gaston Romeo and Laura Silva (Universidad de Buenos Aires)
Zach Marshall (Columbia)

b-Tagging: Gluon Splitting Identification

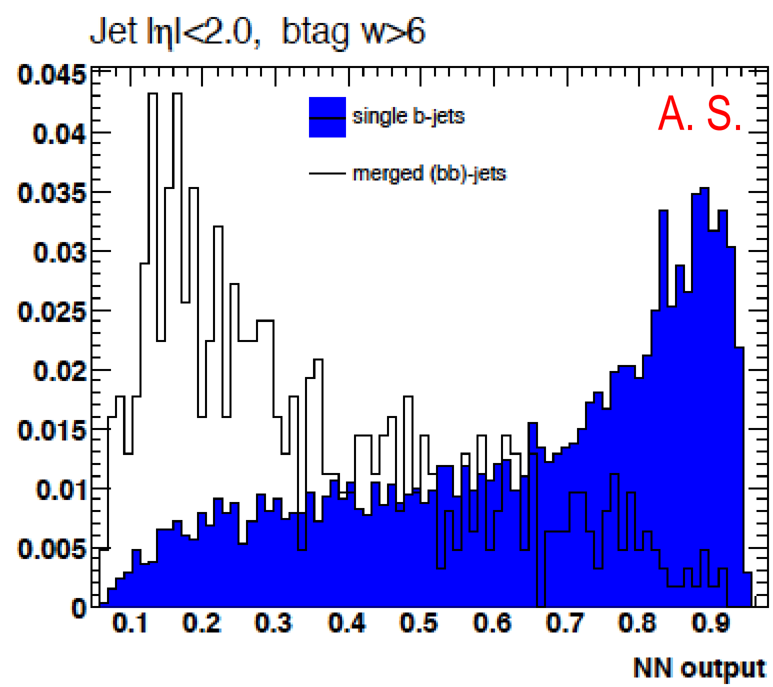
ATL-COM-PHYS-2008-042

The identification of (merged) b-jets from gluon splitting can reduce the b-tag backgrounds to new physics searches with b-jets in the final state.



- Developed a neural network to <u>separate merged from single b-jets</u> based on tracking, calorimeter and track-jet substructure information.

50% b-jet efficiency @ 95% gbb rejection
90% b-jet efficiency @ 50% gbb rejection



Other Physics Tools/Projects

- b-jet energy scale:
  - Semi-leptonic muon and electron correction (D. Lopez, S. Moed)
- Jet energy resolution measurement:
  - di-jet balance and bi-sector method (G. Romeo, R. Piegaia)
- Jet reconstruction efficiency measurement:
  - Photon tag + track-jet technique (S. Majewski)
- Towers with noise suppression:
  - Robust against pile-up effects, regular grid allows simpler calibration schemes (D. Miller)
- New simple jet energy response correction (D. Lopez)
- Configurations of close-by-jets (D. Hellmich - Boon, Germany)
- High Level Trigger b-tagging algorithm development, and optimization for hadronic top analyses (D. Miller)

Physics Preparations

Physics Analysis

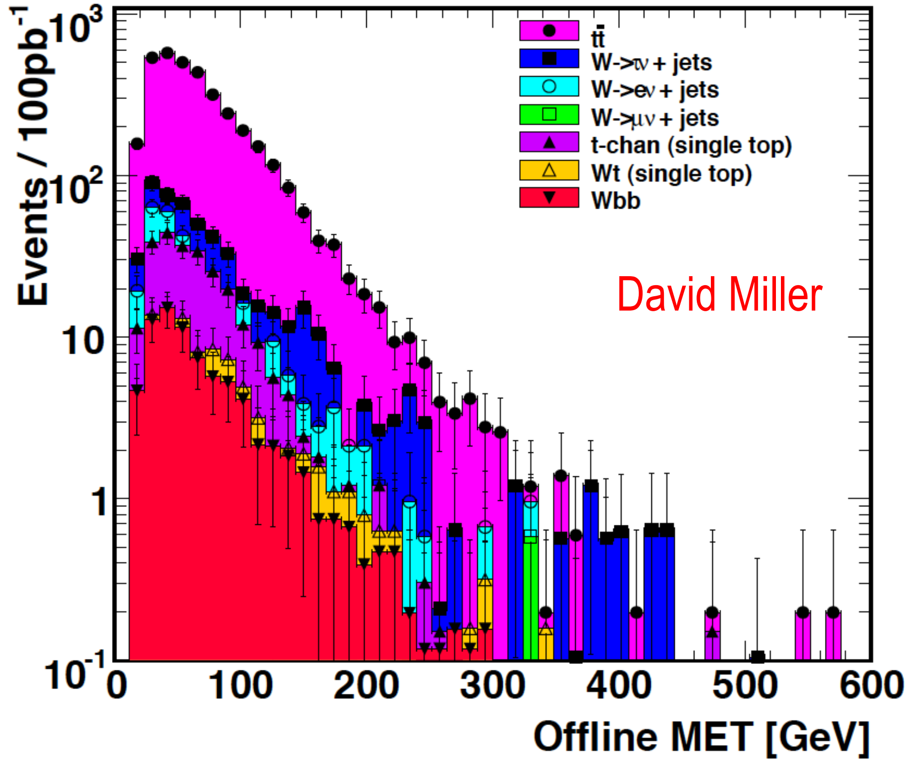
Initial focus around two main topics:

- Standard model measurements of top quark physics
- Searches for new physics

- Members of the SLAC team with previous experience in leading similar analysis at the Tevatron.
- Detector, trigger, and software experience of the group.
- Strong connection with SLAC theorists.
- Link between LHC physics and astrophysics at SLAC.

$t\bar{t}$ Cross Section in the b+ME_T channel

- Sensitive to all leptonic W decays, in particular taus.
- Orthogonal to the lepton+jet data-set.
- Measure top x-section and probe for super-symmetry at the same time.

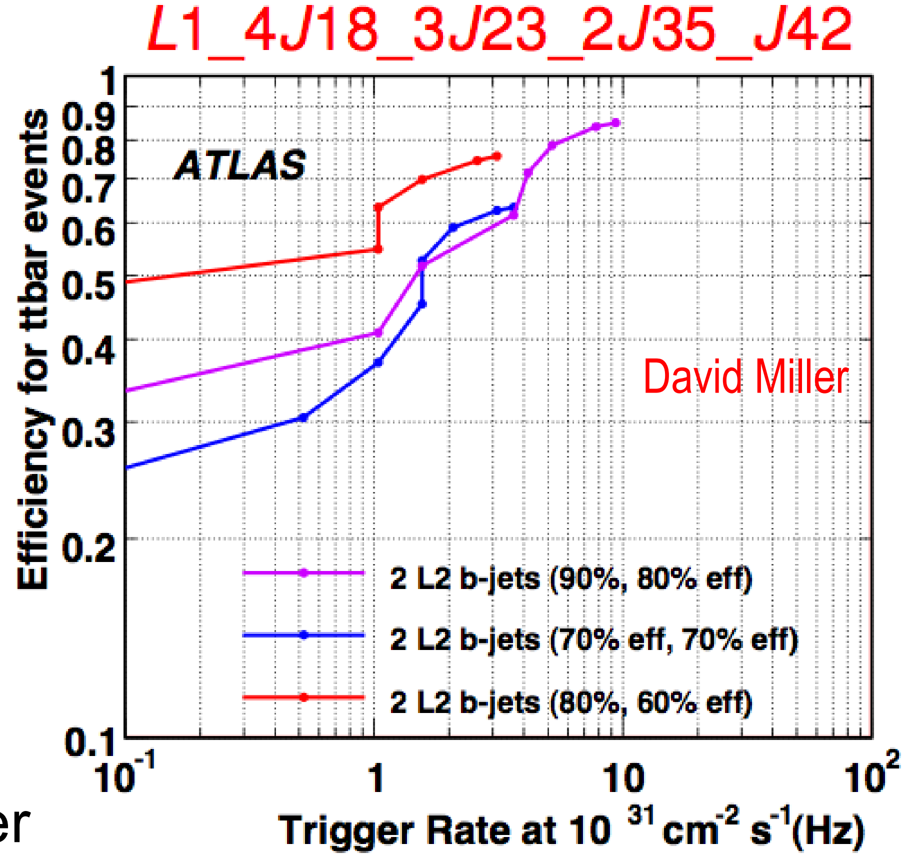


Uses experience with top physics at the Tevatron, and the tools we have developed for jet, ME_T, b-tagging, and trigger.

- Example: asymmetric double b-tag L2 trigger signature.

$t\bar{t}$ Cross Section in the b+ME_T channel

- Developed new, robust, high level b-tag trigger algorithm (chi2-tagger)
  - Based on *data-driven* resolution templates
- Increase acceptance for signal events by lowering L1 jet energy thresholds.

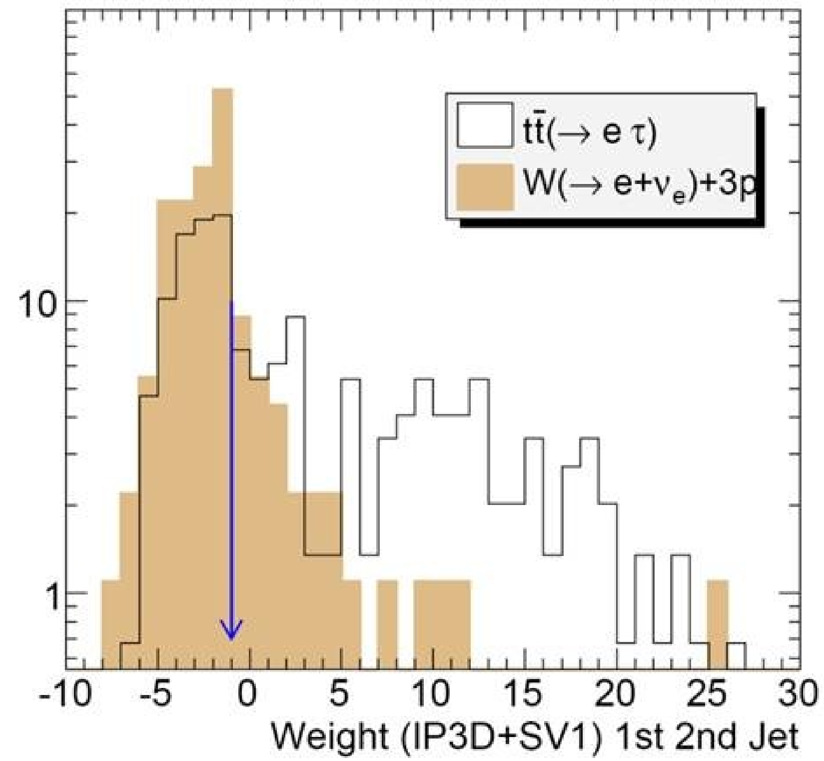


An asymmetric double b-tag trigger signature results in improved performance at low rates, compared with standard L2 b-tag items.

Top-quark Semi-leptonic Tau Decays

Sarah Demers

- Large production cross section.
- Establish the tau identification, vital for many new physics searches with taus in the final state.
- Measure top x-section and search for charged Higgs at the same time.

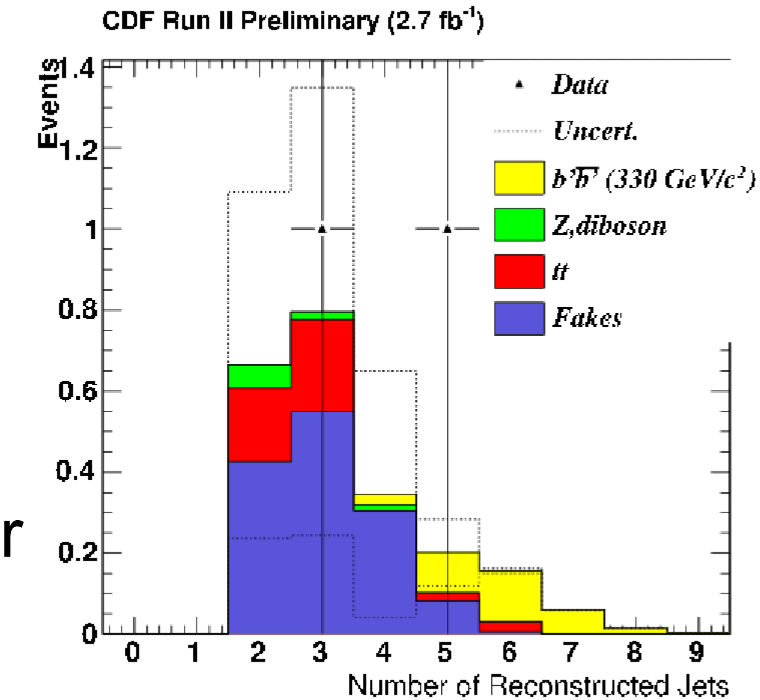


Uses our experience in tau data quality and validation, b-tagging, jets, and MET.

Same Sign di-lepton Search

Michael Wilson, in collaboration with D. Berge (CERN), D. Whiteson (UC. Irvine)

Search for new quark-like fermions in same-charge di-lepton events with first ATLAS data.



- Striking final state:

$$Q\bar{Q} \rightarrow (tW^{\mp})(\bar{t}W^{\pm}) \rightarrow b\bar{b}(l^{\pm}\nu_l)(l^{\pm}\nu_l)(jj)(jj)$$

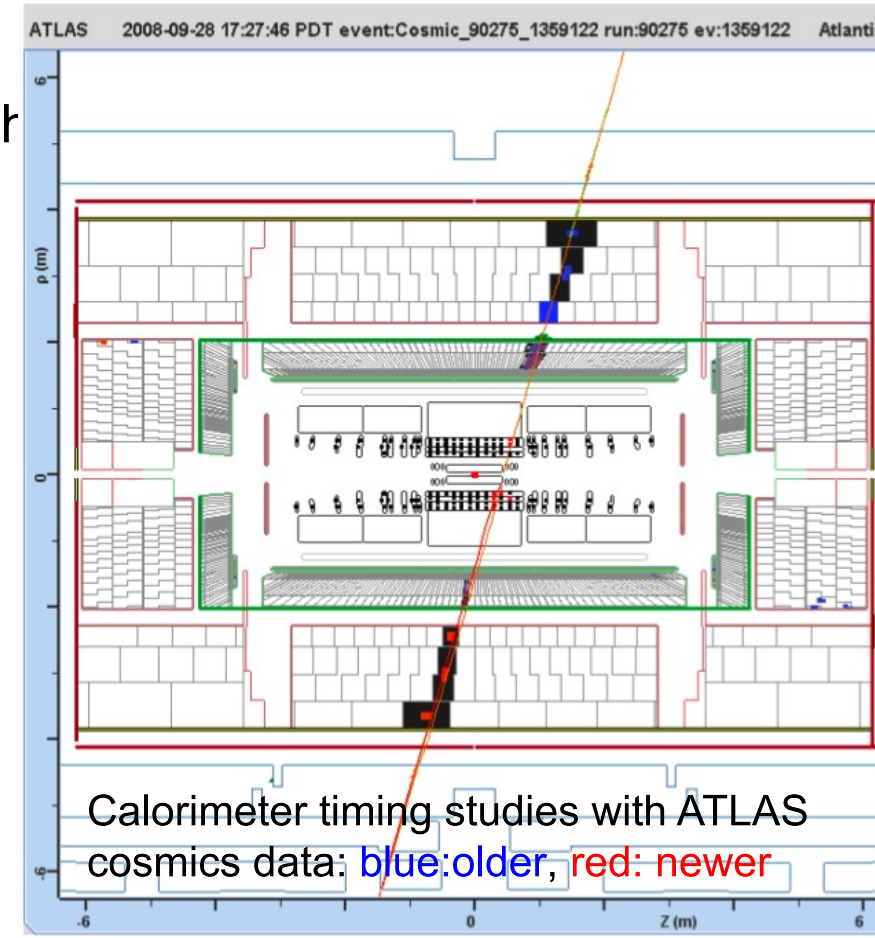
- Standard Model backgrounds are rare (ideal for early ATLAS analyses)

- Use CDF data as a test ground for the ATLAS analysis.

Search for Long Lived Colored Particles

- In split-SUSY gluino is long-lived.
- Some lose enough momentum through ionization to stop in the calorimeter:
  - Decay later to gluon+LSP or qq +LSP
- Signature: large isolated energy deposits in the calorimeter with the rest of the event "empty".
- Extension of a published analysis at the Tevatron, motivated by SLAC theorist.

Very generic search for any long-lived, heavy, colored particle, to be performed on early data.



Calorimeter timing studies with ATLAS cosmics data: blue:older, red: newer

Paul Jackson, Andy Haas

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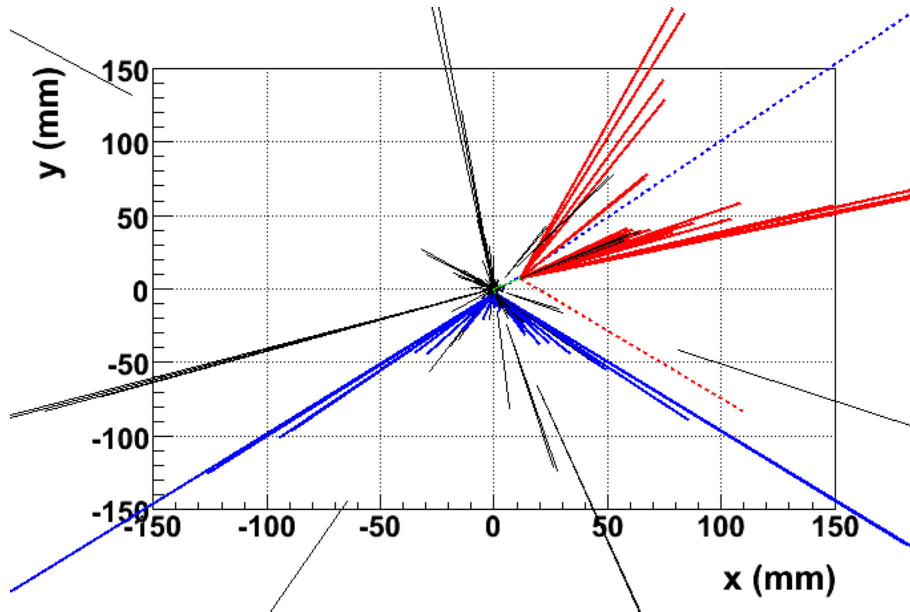
Highly Displaced Vertex Signatures

Several Standard Model extensions predict neutral, weakly-coupled, unstable particles: R_p violating SUSY, Hidden Valley models, etc.

The experimental signature of R_p violating SUSY events, depends on the LSP lifetime.



- RPV couplings lead to striking signatures with displaced vertices.
- ATLAS covers large region of unexplored RPV coupling space.

Extension of ATLAS simulation infrastructure to handle late decays.

Ignacio Aracena, Andy Haas, Claus Horn, Tim Nelson

Additional Physics Analysis Plans

- Search for super-symmetry in the b+ME_T channel:
  - Well motivated both theoretically and experimentally. Understanding the production of third-generation squarks will be key to answer important physics questions.
  - Extension of top quark cross section analysis.
- Search for new physics in events containing top quarks:
  - top+ME_T, top+b, complements searches in b+ME_T final states.
- Search for Higgs decaying to light pseudo-scalars.
- Search for lepton-jets:
  - Motivated by recent models of Dark Matter and astrophysics experiment results.

Summary

- SLAC effort concentrated on building the foundations of physics analysis through reconstruction of fundamental physics signatures:
  - leading contributions to jet reconstruction and calibration.

- Physics preparations focused on Standard Model measurements and new physics searches:
  - Building on combined Tevatron/e^+e^-/HERA experience, detector trigger and software efforts, strong SLAC computing facilities, collaboration with the theory group, and links with astrophysics experiments.