PHY 2407S
Hard Scattering in Hadron-Hadron Collisions: Physics and Anatomy

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This advanced graduate course will summarize how we understand the process by which hard scattering events, characterized typically by high transverse-momentum (P_T) processes, occur in energetic hadron-hadron collisions, and what effects have to be understood and taken into account in order to make robust measurements and discoveries of new phenomena. The course will focus on the 7-14 TeV proton-proton collisions produced by the Large Hadron Collider, but will use examples from experience gained at the 2 TeV proton-antiproton Tevatron Collider. The anatomy of a hard-scattering event will be dissected, and we'll discuss each element through the interplay between the theoretical and phenomenological framework and the experimental challenges.

This course is targeted at graduate students in particle physics experiment, theory or phenomenology who already have a background in relativistic quantum field theory and the Standard Model of particle physics.

I. Introduction (1 lectures)

- Basic anatomy of a collision (sub-process hard scatter, ISR/FSR, underlying event and pileup)
- Collider considerations (luminosity, beam backgrounds, multiple interactions)
- Detector implications (acceptance, segmentation, resolution and efficiencies)
- Example: Top quark Pair Production

II. Basic Phenomenology of a Hard Scattering Process (2 lecture)

- The structure of the proton (PDFs, PDF uncertainties)
- The hard-scattering sub-process (strategies for calculation, uncertainties)
- Example: Drell-Yan W Boson Production; Higgs Boson Production

III. Underlying Event, ISR and FSR (2 lectures)

- Initial and final state radiation
- The nature of the underlying event (not just another soft collision)
- Example: Energy Flow at the Tevatron
- Pileup issues at 40 MHz
- Example: Calorimetry Pileup Effects

IV. Production and Identification of Jets (2 lectures)

- QCD Inclusive jet production
- The anatomy of a jet

- Fragmentation and hadronization
- Jet clustering issues (cone algorithms, clustering effects, overlaps)
- Jet energy calibration
- Example: Quark Substructure

V. Production and Identification of Charged Leptons (2 lectures)

- Inclusive single-lepton production (heavy quarks, Z/W, DY)
- Identification of electrons, muons and tau Leptons
- Background considerations
- Efficiency calculations
- Example: Dilepton from Top Quark Decay

VI. Neutrinos and Missing Energy (1 lectures)

- Basic philosophy
- Limitations arising from Calorimetry
- Background processes
- Example: Missing Et in SUSY Events

VII. Acceptance and Efficiency Calculations (1 lecture)

- Strategies
- Sources of uncertainties
- Monte Carlo calculations
- Choice of Detector Simulation
- Improving precision/reducing uncertainty
- Example: Z Production