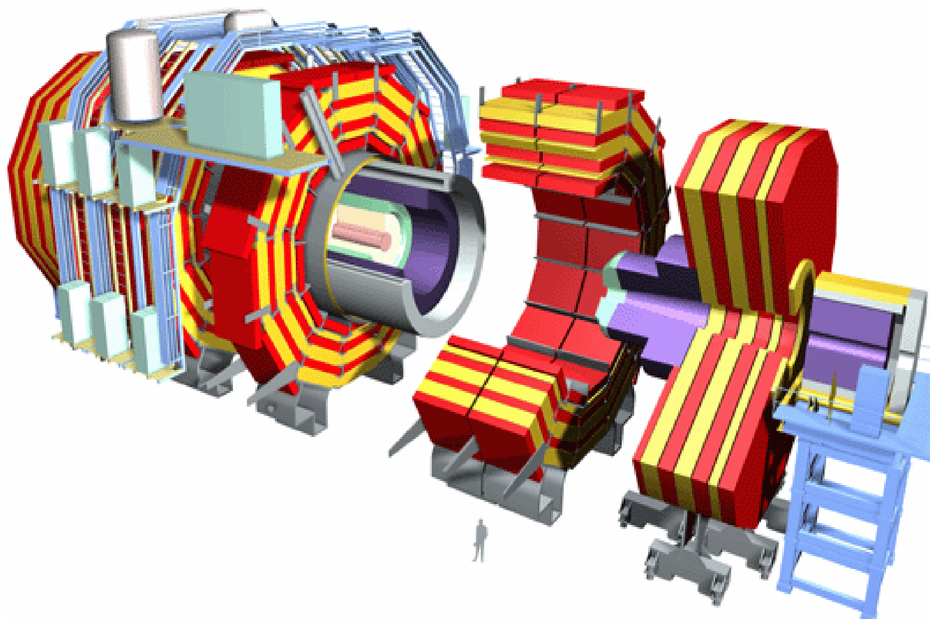
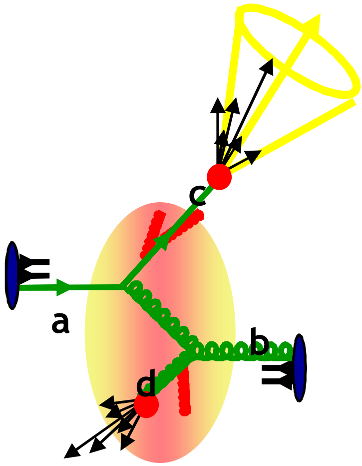
Jet Quenching Plans and Needs
- CMS -





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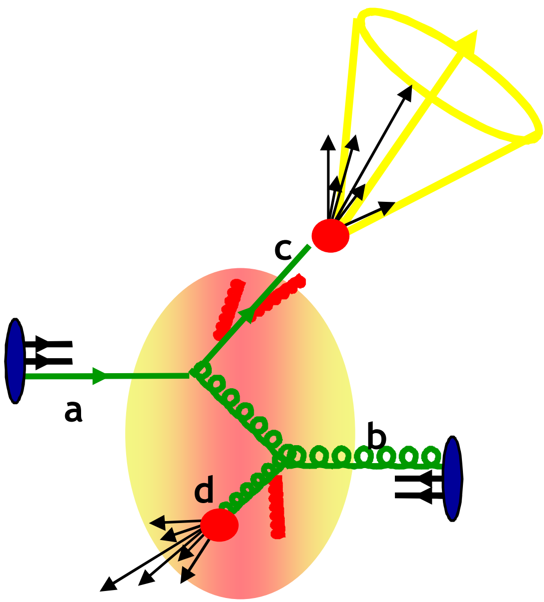
TEC-HQM Collaboration Meeting

CERN 2009

Measuring Parton Energy Loss

- We want to study parton energy loss in heavy ion collisions using reconstructed jets
- Experimentally:
  - Reconstruct jets in the detectors
  - Assemble DiJets (γ-Jets)
  - Analyze jet properties
- Physics measurements:
  - Jet E_T spectra
  - Jet Jet Angular correlations
  - Jet fragmentation functions and shape
  - Jet+γ, Jet+Z correlations
  - Tagged heavy quark jets (b, c)
- Compare measurements to Theory
  - Jets are not uniquely defined objects
  - Experience from HEP shows making sense of jet measurements requires very close collaboration between theory and experiment
    - MC Generators, Common jet finders, PDF's



Jet Definitions

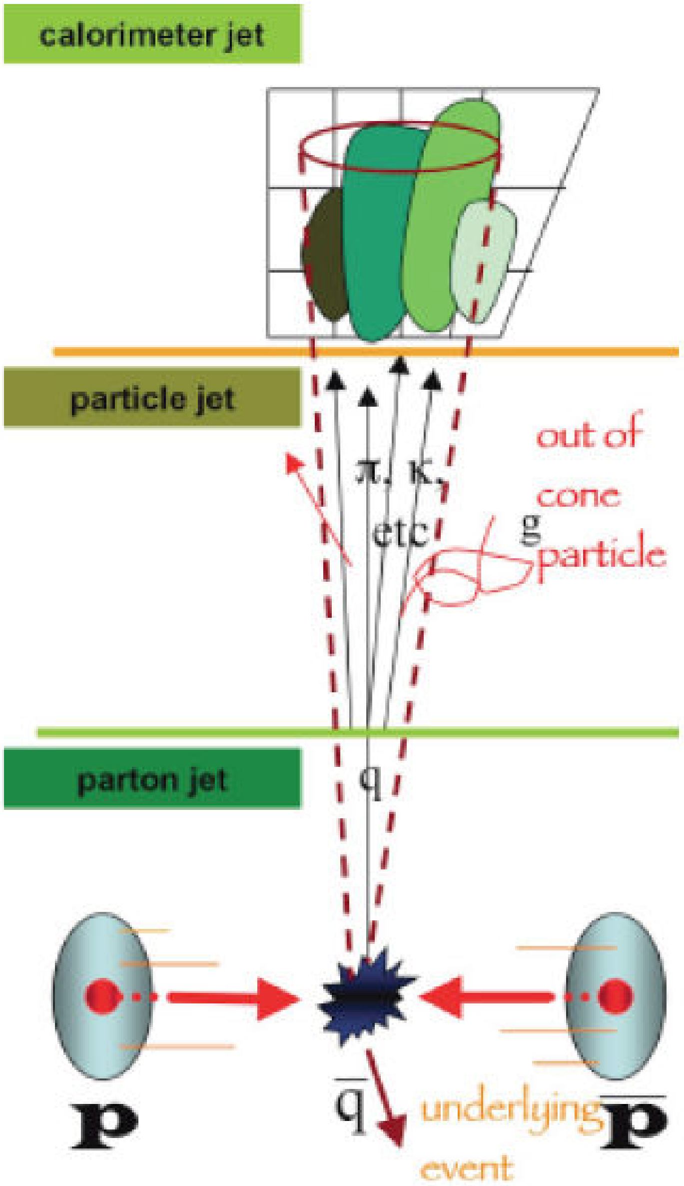
1) Parton jet
- This is what we can calculate

2) Final state particle jet
- Fragmentation/hadronization
- Non-pertubative
- MC generators rely on parameterizations of experimental data

3) Calorimeter Jet
- This is what we measure in the detector

- **Need to associate final state particles with initial parton**
  - No unique way of doing this!
  - Jet algorithms
  - Use consistent algorithms when comparing to Models

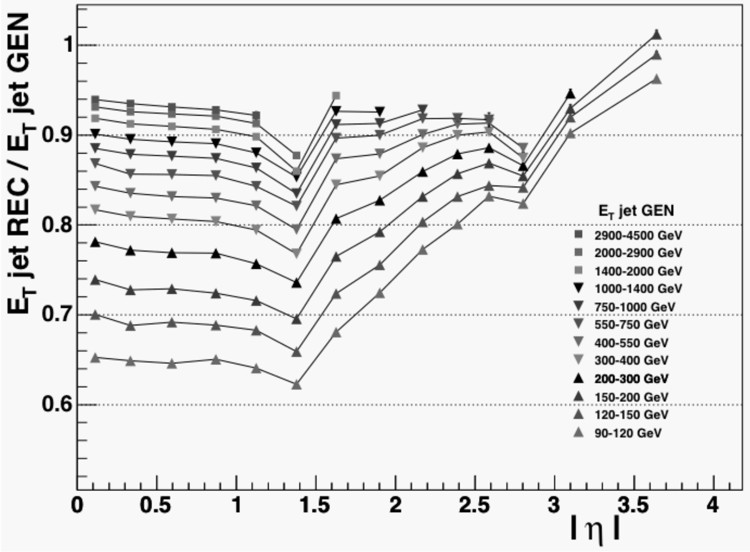
  => Jet Calibration



Jet Calibration (pp)

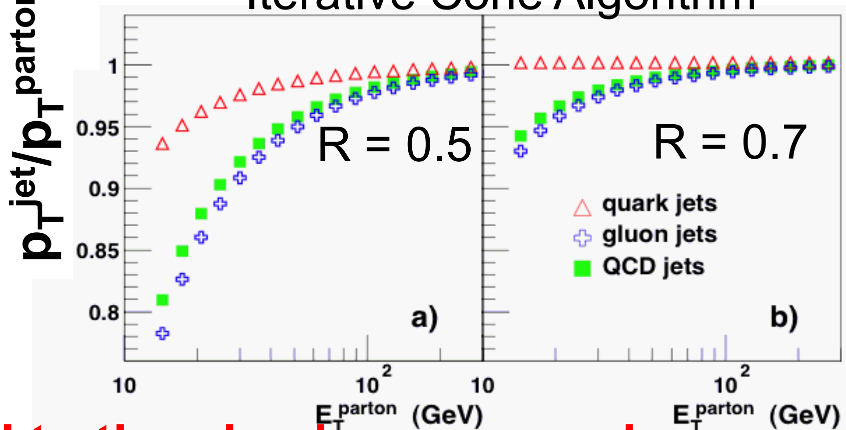
1. Detector response to final state particles

- **Correct for**
  - Gains
  - Non-linearities
  - Gaps between detector segments
- **Use**
  - Hardware calibration
  - Source Calibratrion
  - Dijet Energy balance
  - γ Jet correlations Z,W decays



(from CERN/LHCC 2006-001)

Iterative Cone Algorithm



2. Relate final state particles to initial state parton

- **Depends crucially on a precise description of jet properties and parton mix by event generators**

- **Jet Calibrations are tightly coupled to the physics process in question and to the Jet Algorithm used**
- **Need very large pp datasets to derive Calibrations from data**

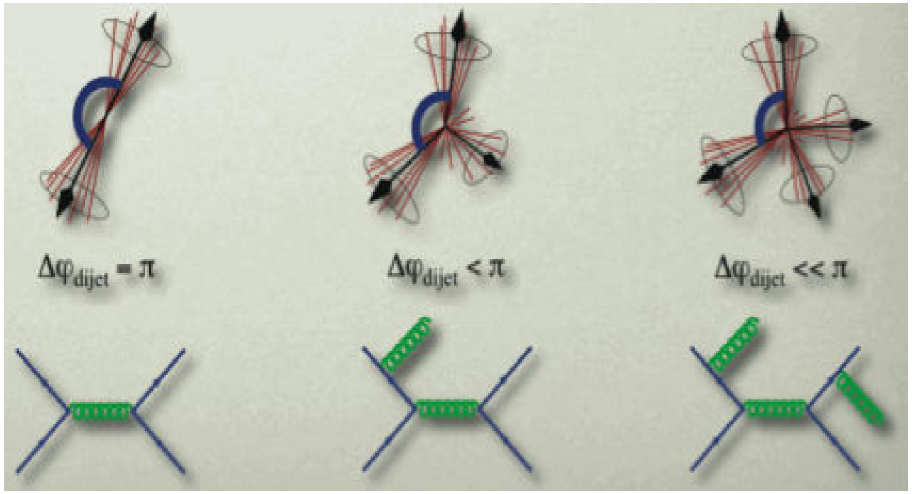
General Remark on Jet Studies

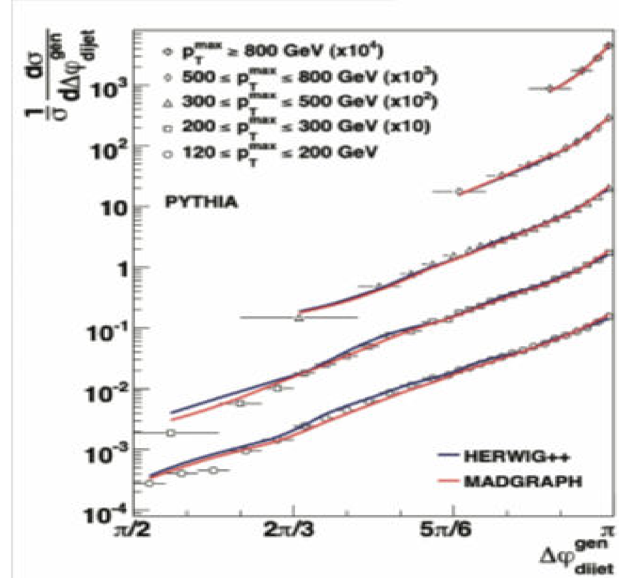
- In p+p collisions
  - N particle final state -> 2 parton initial state
  - Use reliable MC techniques to connect Theory and Experiment
- In Heavy Ion Collisions
  - O(200) * N_{pp} particle final state -> X * 2 partons…
  - Parton energy loss modifies the relation between final state particles and the initial parton
    - This is the effect we want to measure !
    - But: eliminates our calibration channels
- MC Simulation for HI jet studies
  - Simulate the full multi jet final state
  - Initial state parton mix not trivially calculable
  - Include model of parton energy loss and fragmentation in MC generator
  - Have full access to the final state particles of each parton
    - Process each parton pair separatly with MC jet finder
    - HYDJET Event generator is a first attempt
  - In general we need more sophisticated tools for detailed jet studies in HI

Initial State

- **Light quark jets, gluon jets and heavy quark jets have different fragmentation properties**
  - **Experimentally: different detector responses**
  - **Theory: parton flavor dependence of quenching**
- **Need to know the relative abundance of jet flavor in a given sample**
  - **Experimentally: try restrict the kinematics or production channels to select the processes**
    - Y-Jet
    - Z-jet
    - Dijets in dijet mass and center of mass bins to restricts the kinematic region of the the PDF we are probing
  - **Theory: PDF's are important**
    - HI: Saturation effects, shadowing etc.

DiJets, γ-Jets, Angular correlations



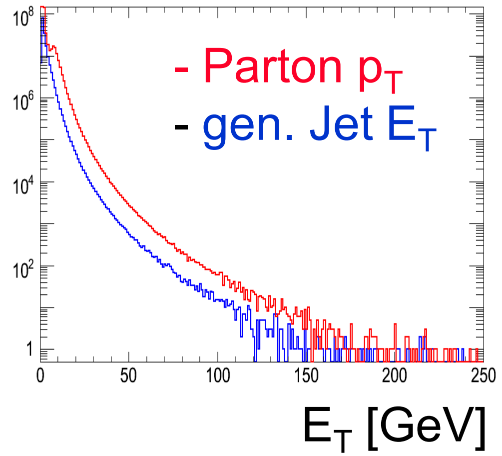


- Angular correlation can control the contribution of NLO processes
  - Gluon vs quark jet content
- HI Specific
  - k_T broadening
  - Decorrelation due to collisional energy loss
- Jet Jet angular correlations are a measurement in its own right
  - DiJet, γ-Jet reconstruction based on angular correlation is important input for more detailed analysis of jet properties

Final state jet E_T

- **Parton energy loss breaks the relation between the parton E_T and the final state jet E_T**
  - **"Out-of-cone" radiation**
  - **Path length dependence/Surface bias**

Pyquen, gen level

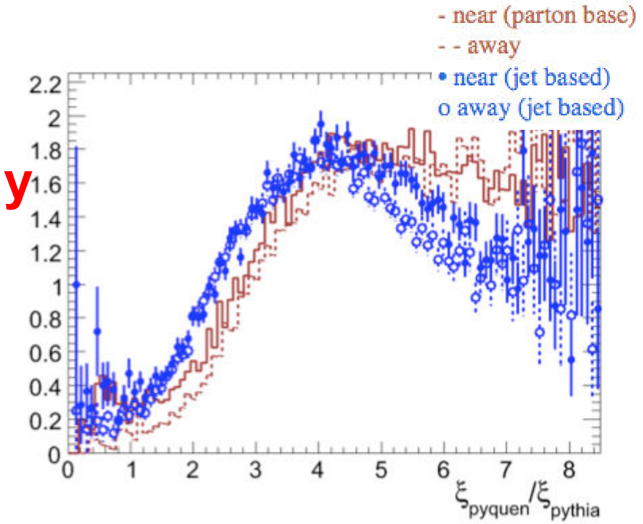


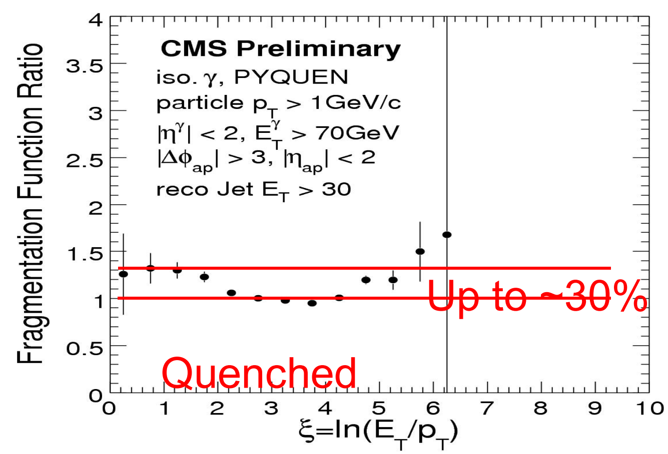
- **Modeling the full final state is essential**
  - **Fragmentation properties**
  - **Include the "lost" energy in the final state**
- **Strategy for physics analysis**
  - **Simulate nuclear geometry**
  - **Simulate continuous parton E_T spectrum**
  - **Apply realistic jet finding algorithm**
    - An ideal jet finder that reconstructs the full parton energy independent of the fragmentation/energy loss model will probably not be available any time soon
  - **Select analysis sample in a fs jet E_T bracket**
- **Study systematic effects using different quenching models**

Frag. Functions and Jet Shapes

- **In medium modifications of Fragmentation functions and Jet shapes should given us more detailled information on the energy loss mechanism.**
  - **Requires knowledge about parton p_T**
  - **Jet calibration to parton level is conceptually difficult**
- **Extract FF from γ-Jet**
  - **At startup statistics limited**
- **DiJets:**
  - **Use final state jet as calibration point?**
    - Experimentally accessible
    - Requires full MC on theory side
- **Beware of biases**
  - **Jet finding efficiency can depend on fragmentation properties**
  - **Measuring FF's in a region with < 100% efficiency will result in biases**

5,000 dijets $\hat{p}_T$ 100 GeV
generator study
p+p Pyquen = quenched
p+p Pythia = unquenched





MC Generators for Quenching

- **Model Technicalities**
  - **Common standardized interfaces**
  - **HepMC, lujets…**
  - **Ideally all models could be included in the GENSER project**

- **Model Input**
  - **Medium characteristics**
    - Temperature, flow profiles
    - Energy density grids
    - Temperature grids
  - **Every model has different input parameters**

- **Model Validation**
  - **In HEP a lot of emphasis is put on validating the generator performance with each release and the correctness of the implementation and interface**

Summary

- **To perform detailed studies of parton energy loss in heavy ion collisions we need:**
  - **A variety of Quenching models implemented in MC generators including:**
    - Nuclear geometry/Initial state
    - Parton mix
    - Path length dependence/surface bias
    - Parton angular correlations
    - Fragmentation properties/jet shapes
  - **Standardized interfaces for generators**
    - Workable defaults
    - Validation!
  - **Close collaboration between theory and experiment**
    - Analyze theory models like data
  - **Common analysis strategies for proposed physics signals between theory and experiment**