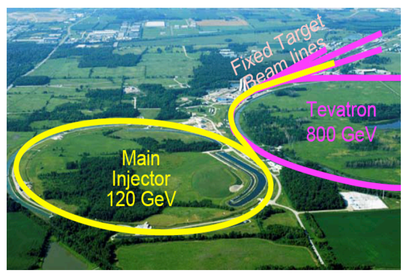
Study of Quark Energy Loss via Drell-Yan Process in p+A Collisions at Fermilab E906/SeaQuest Experiment



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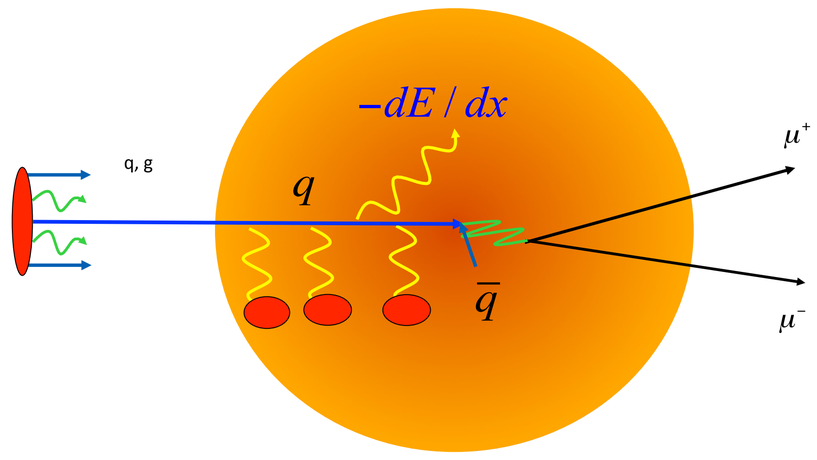
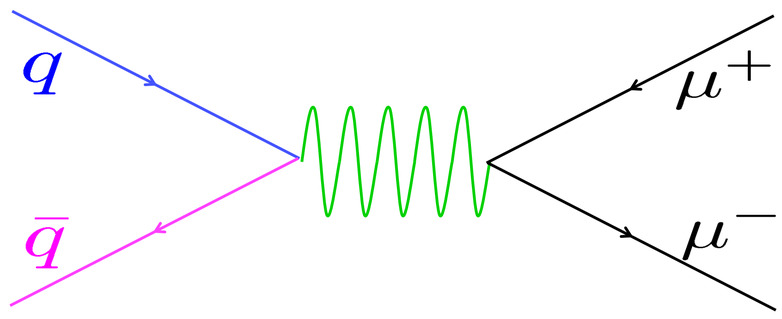
Motivation: Energy loss of charged particles and photons (X-rays) through dense media has long been used as the fundamental probe for matter properties. The precise agreement between theoretical calculations and experimental measurements on the stopping power has been proved a great success of the quantum electromagnetic dynamics (QED). However, when it comes to the constitution of nuclei, quarks and gluons, whose interactions are dominantly described by the quantum chromo dynamics (QCD), the stopping power of nuclear matter for quarks is largely unknown.

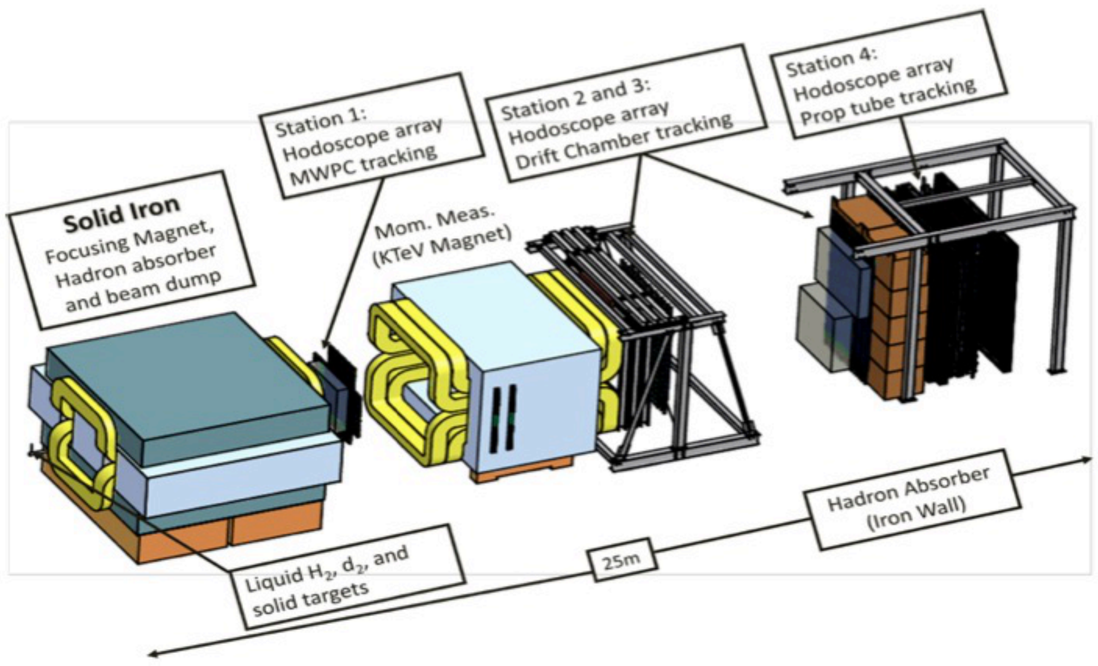
The Drell-Yan process in proton-nucleus (p+A) collisions provides a clean probe to measure the initial-state energy loss of the fast parton traversing through nuclear medium since the final state particles (leptons) do not interact strongly with the nuclear medium.

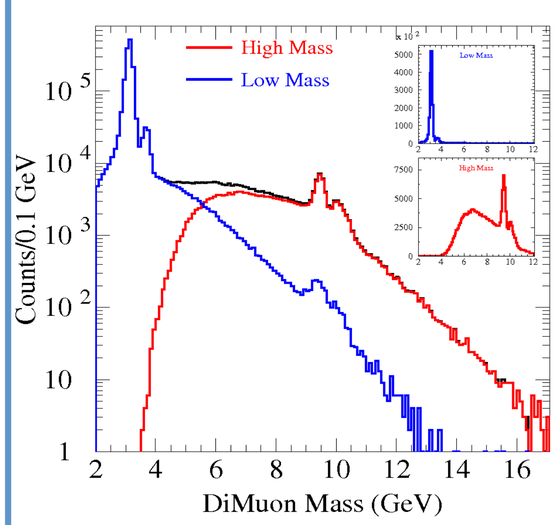


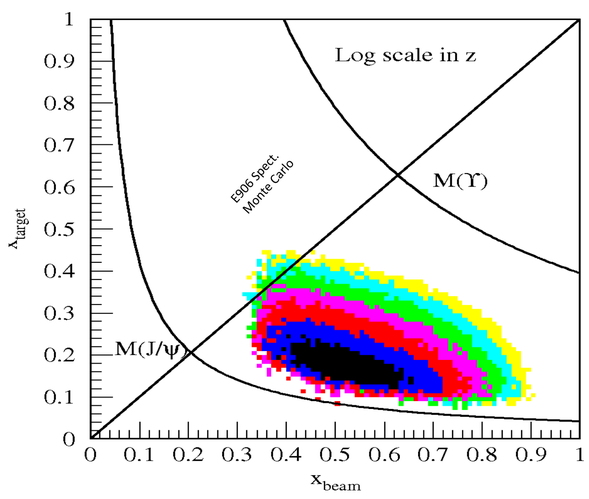


E906/Seaquest Experiment

The E906/Seaquest Experiment plans to use Drell-Yan scattering to measure the antiquark structure of both the nucleon and nucleus, to measure absolute Drell-Yan cross sections and to examine partonic energy loss. This experiment will use the 120 GeV/c proton beam extracted from the Fermilab Main Injector. The Experiment has started the first data taking in March and April 2012.



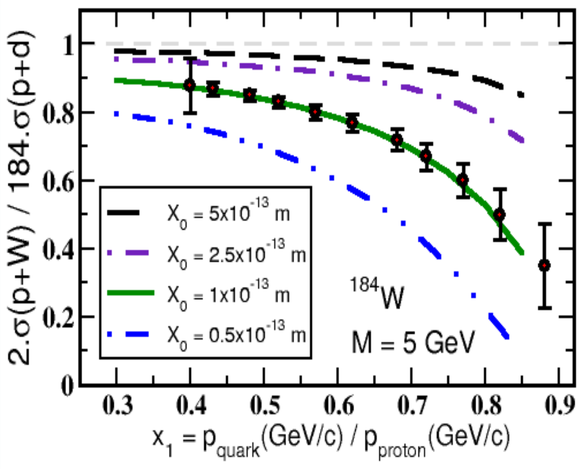




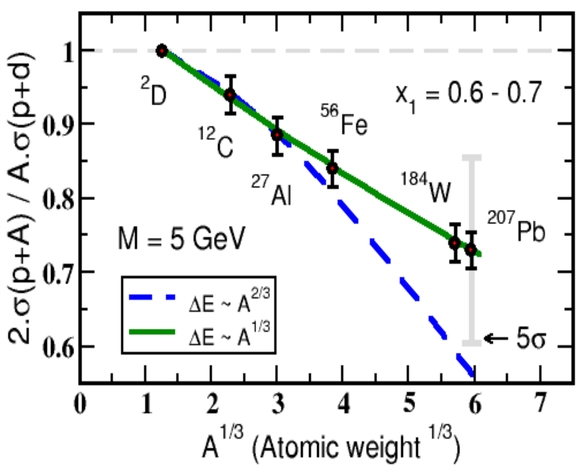
Quark Energy Loss Measurements

The energy loss of fast quark moving through nuclei mediun can be measured via the Drell-Yan process where the incoming fast quark from the projectile annihilates with an anti-quark from the target and produces high energy di-muon pair. Such energy loss effect will show up in a difference of the produced dimuon energy spectra from the simple proton+proton/deuteron (p+p/D) and proton+heavy nucleus (p+A) collisions. By comparing the experimental data and theoretical model calculations, we can derive the fast quark energy loss in the heavy nuclei A.

We propose to measure Drell-Yan dimuons, 4 < M < 9 in GeV, with the approved E906 experiment at Fermilab with a 120 GeV high luminosity proton beam and nuclear targets such as ^{1}H (^{2}D), ^{27}Al and heavy nuclei like ^{184}W. By systematically studying dimuon production as a function of nuclear mass number and momentum fraction x_1, we will directly determine the quark energy loss in cold nuclear matter.



(1) Experimental sensitivity at a dimuon mass of 5GeV to different quark radiation lengths in nuclear matter with the expected beam luminosity on tungsten (W) and deuterium (d) targets.



(2) Nuclear mass dependence of the ratio of the Drell-Yan yields, normalized to the deuterium reference, and clearly demonstrates that the measurement can distinguish between the two leading theoretical models for the path length dependence of quark energy loss at the 5σ level.

Conclusion: Our results will be the first unambiguous measurement of the partonic energy loss in normal nuclear medium and thereby provide a benchmark for the theoretical models of quark energy loss in heavy ion collisions, which will significantly constrain various models of quark energy loss mechanisms, and advance our understanding of parton energy loss in hot nuclear matter QGP.