Quark Energy Loss in Cold Nuclear Matter at the E906 Experiment

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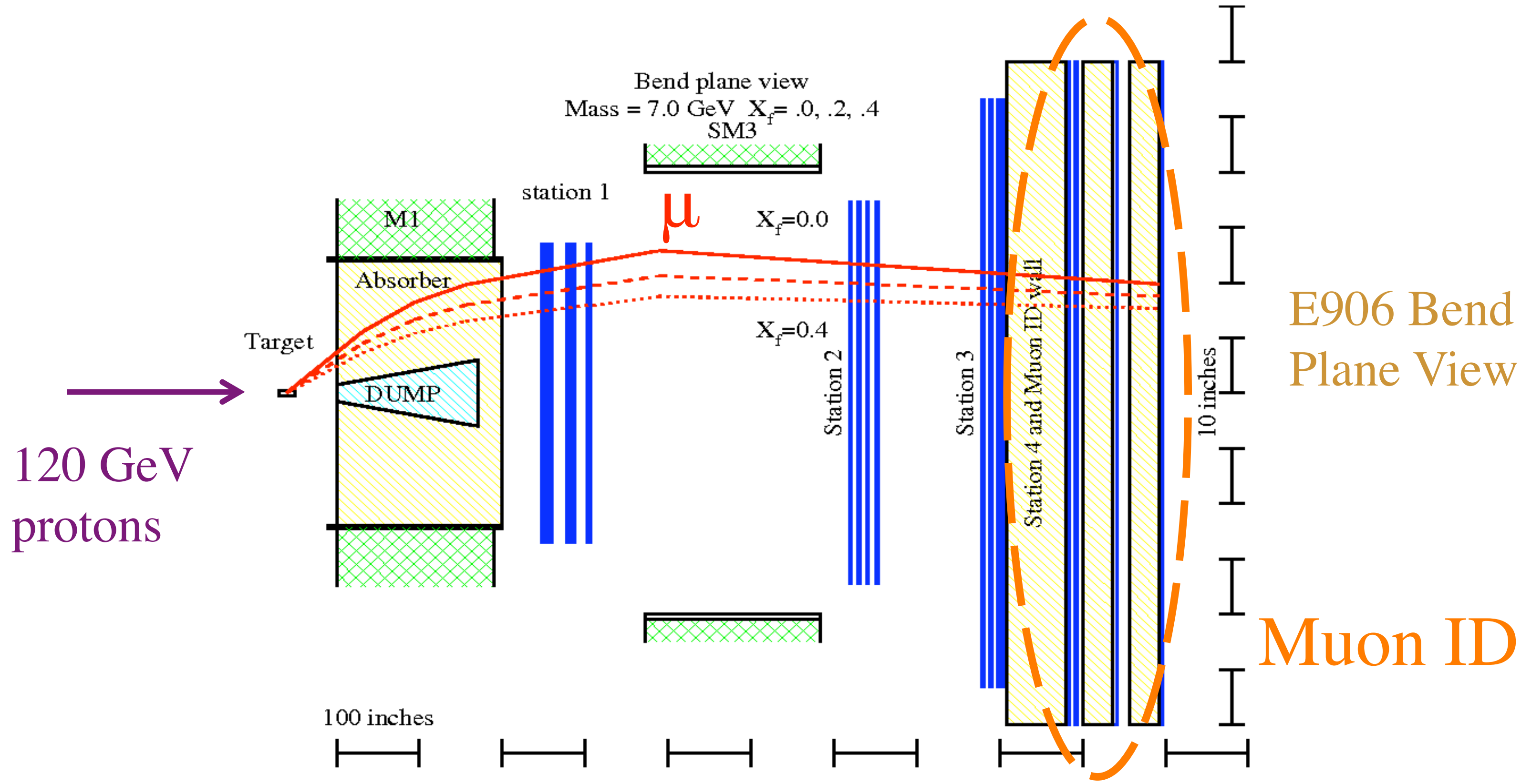

LANL Medium Energy Nuclear Physics Review
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Physics

Energy loss in cold nuclear matter is unknown!

- Theoretical form of energy loss is unclear -
  - fundamentally different than pure E-M eloss
  - linear or quadratic dependence on path length?
  - radiative or collisional energy loss dominant?

Initial State $$\frac{\Delta E}{E} \propto \frac{L}{\lambda_g} \times const(2) \times \ln \frac{E}{Q_0}$$

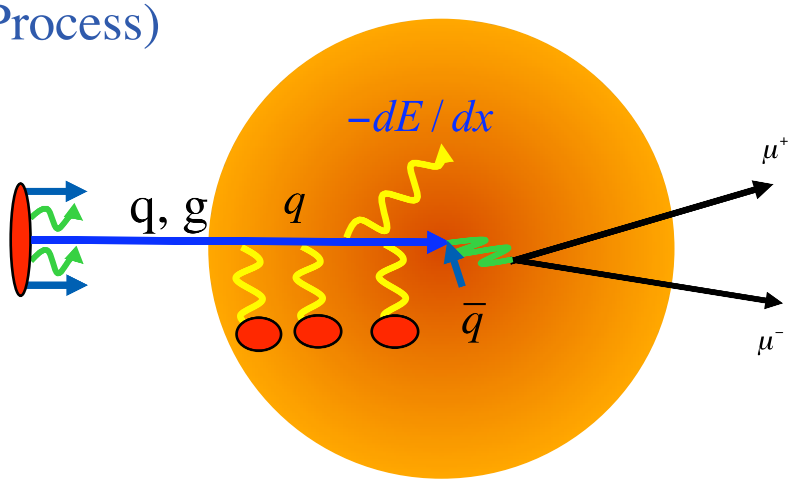
Final State $$\frac{\Delta E}{E} \propto \frac{\mu^2 L^2}{\lambda_g} \frac{\ln E / Q_0}{E} const(3)$$

from Vitev

- Experimental bounds from Drell-Yan (E772 and E866)
  - range from 0 to ~2.3 GeV / fm,
  - depending on the amount of nuclear shadowing
- Energy loss in nuclear matter is an important baseline for measurements of QGP formation at RHIC
- E906 will make the first definitive measurement
  Lower beam energy eliminates shadowing region

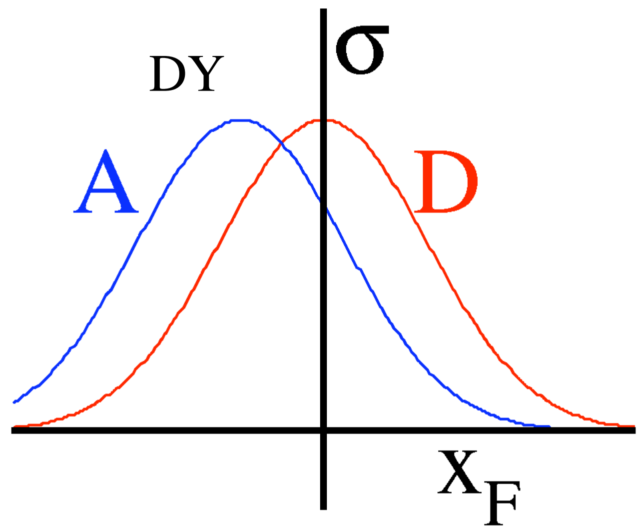
The E906 Energy Loss Measurement

$$q + \overline{q} \rightarrow \gamma^* \rightarrow \mu^+ + \mu^-$$ (Drell-Yan Process)



- Minimal final-state interactions of the detected particles.
- No shadowing correction at moderate X_2

Energy loss reduces x_1 and x_F in nuclei versus proton



E906 Sensitivity to Quark Energy Loss

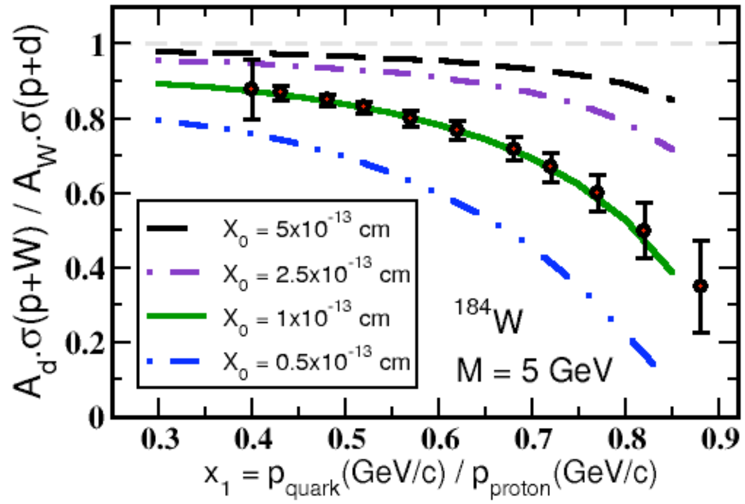
- For radiation lengths X_0 = 1 x 10^{-13} m can achieve sensitivity ~ 20%

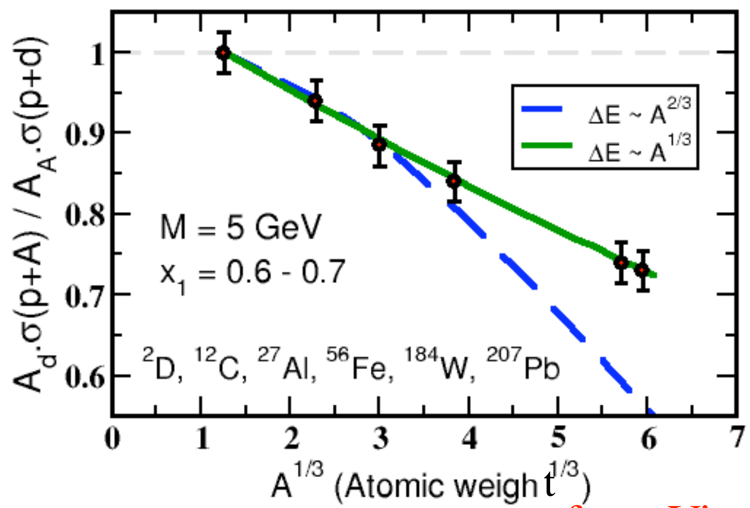
- Clearly distinguish between leading models for L dependence of E-loss (5σ)

$$-\Delta E \sim A^{1/3} \text{ (or } \sim L)$$

$$-\Delta E \sim A^{2/3} \text{ (or } \sim L^2)$$

Simulated Quark energy loss only



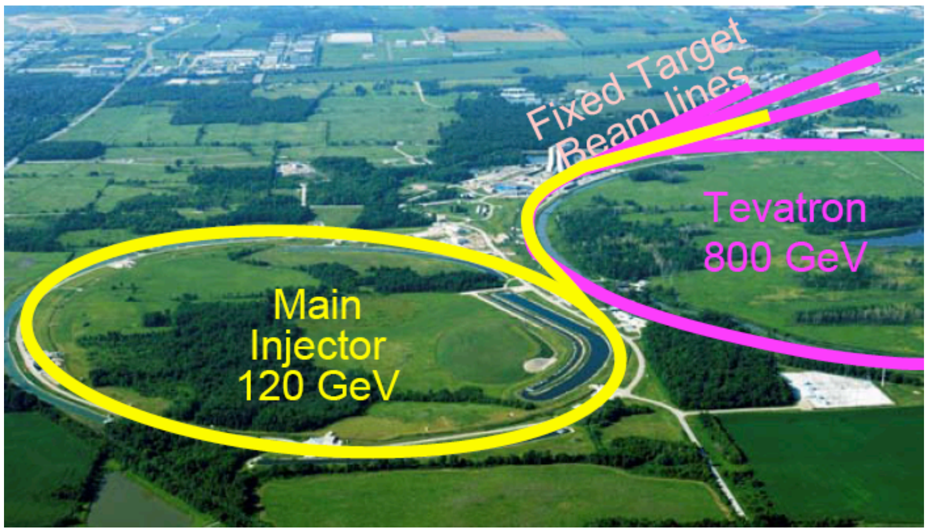


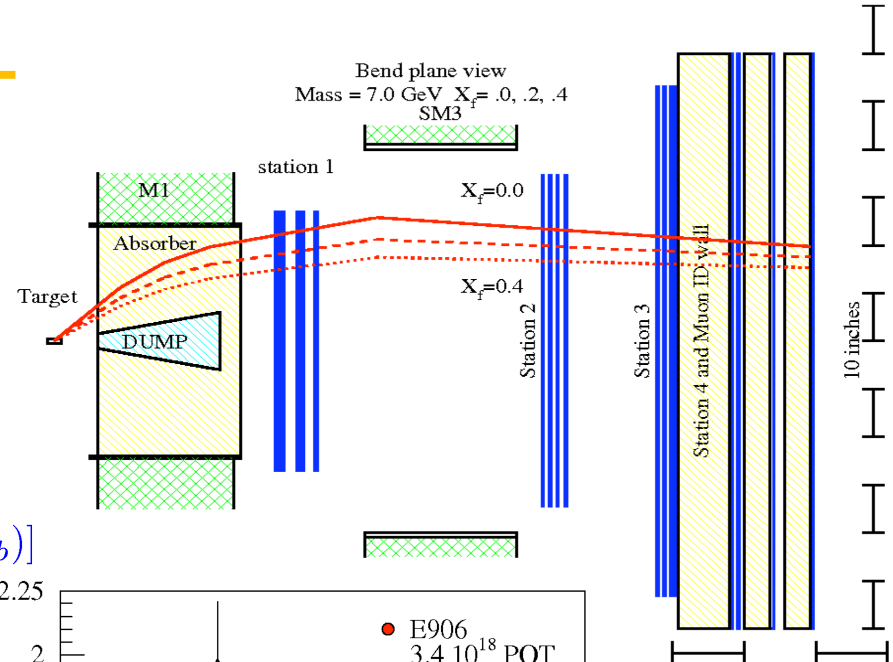
from Vitev

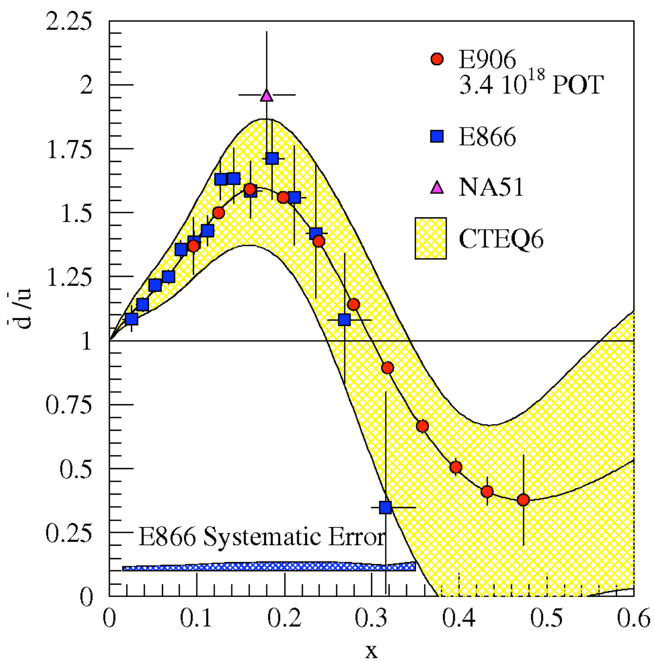
E906/SeaQuest at Fermilab

- -120 GeV proton beam from Main Injector
- -p, d, and other A-targets
- -Starts taking data late 2010

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9x_1x_2}\frac{1}{s} \times \sum_i e_i^2 \left[q_{ti}(x_t)\bar{q}_{bi}(x_b) + \bar{q}_{ti}(x_t)q_{bi}(x_b)\right]$$

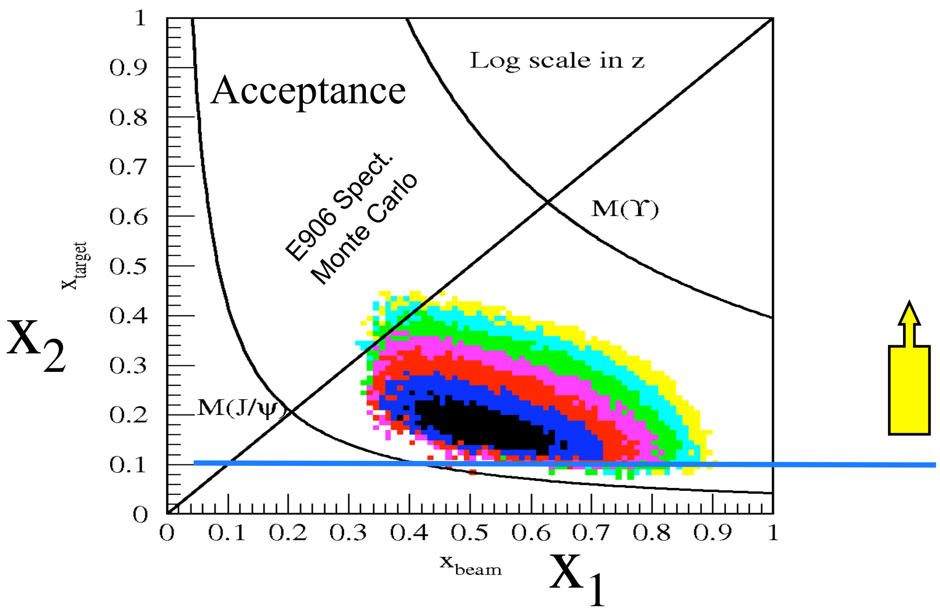






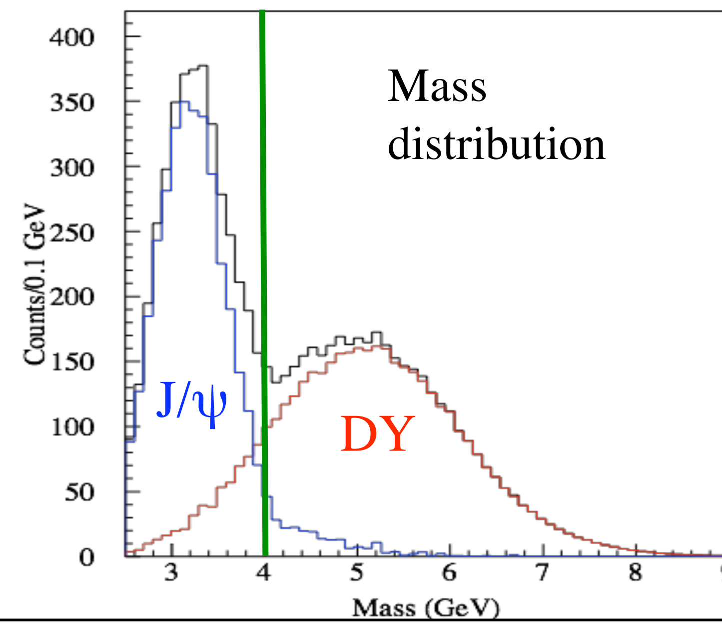
Station 4 Muon ID By LANL

E906 Acceptance and Mass Distribution

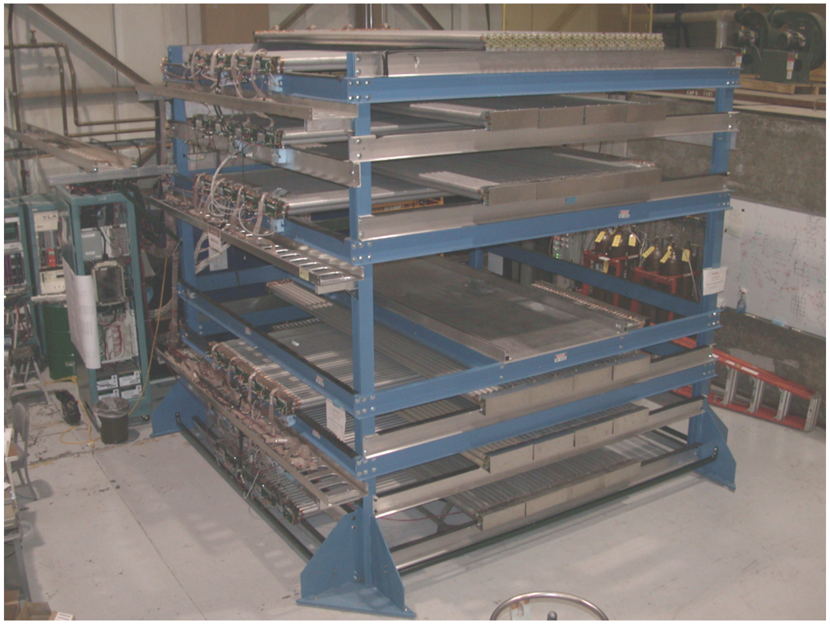


E_{beam}=120 GeV →
No shadowing correction
since $x_2 > 0.1$

Samples masses from
~ 3 to 8 GeV, including
D-Y and J/ψ

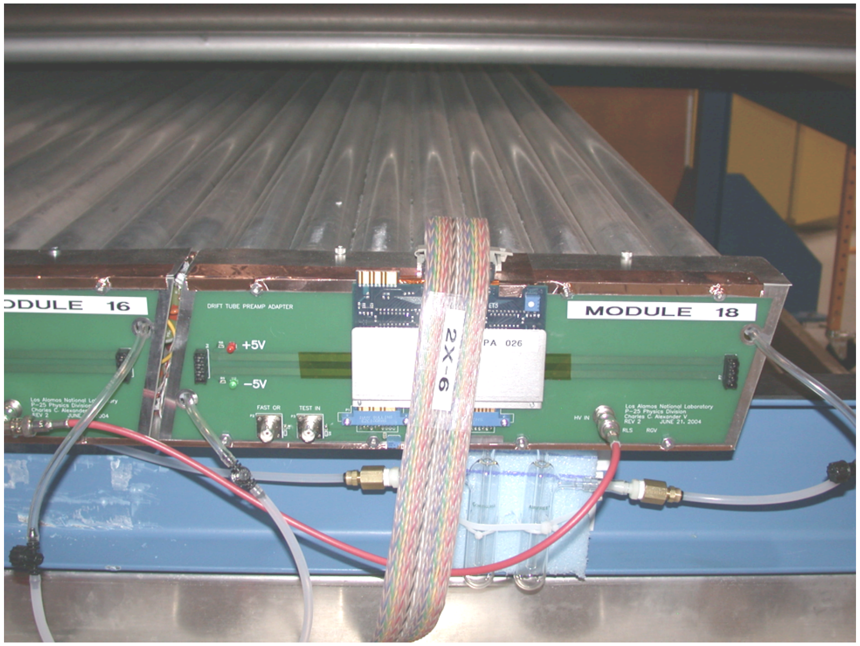


New Muon Identifier Based on µRad Technology



12' long tubes, 6 X layers, 6 Y layers, arranged for vertical muons at LANL

Close-up of one module



Array of 16 tubes plus front-end electronics

- Need 2X and 2Y planes of proportional tubes for E906 muon identifier

Station 4 Muon Identifier Design and Performance

Design:

- 2 X and 2 Y layers, coverage ≥ 250 * 250 cm
- Aluminum drift tubes for good position resolution → track matching to Station 3 drift chambers
- Each plane constructed of 2 staggered rows of 2” diameter tubes for excellent efficiency and reasonable channel count
- Well tested design with 1000’s of operational tubes.

Test results at LANL:

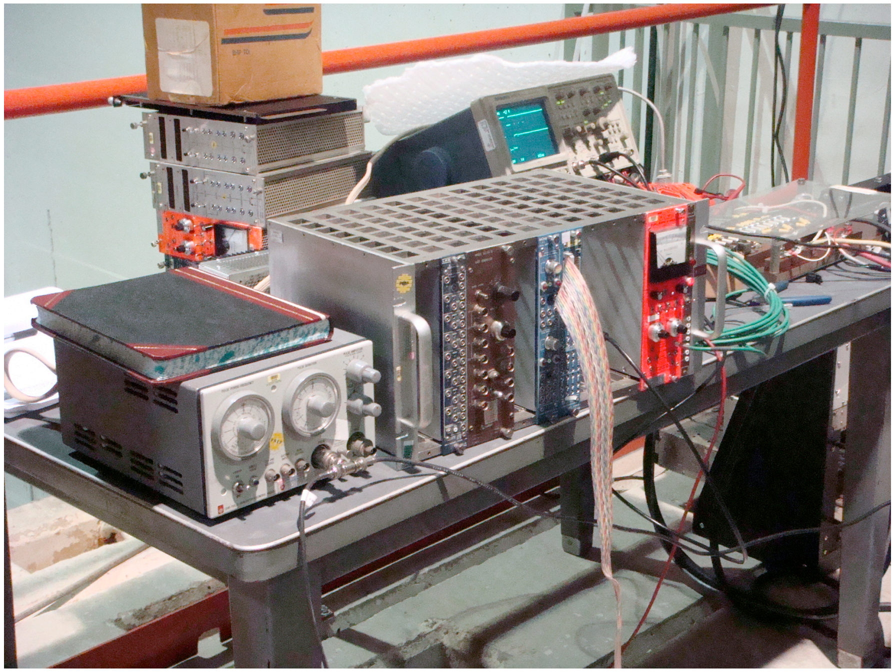
- Ar - isobutane 70:30 gas mix
- HV = +2300V
- ~300 micron resolution averaged over entire array
- ~99.5% efficiency, consistent with tube wall thickness
- Maximum drift time ~ 1600 ns

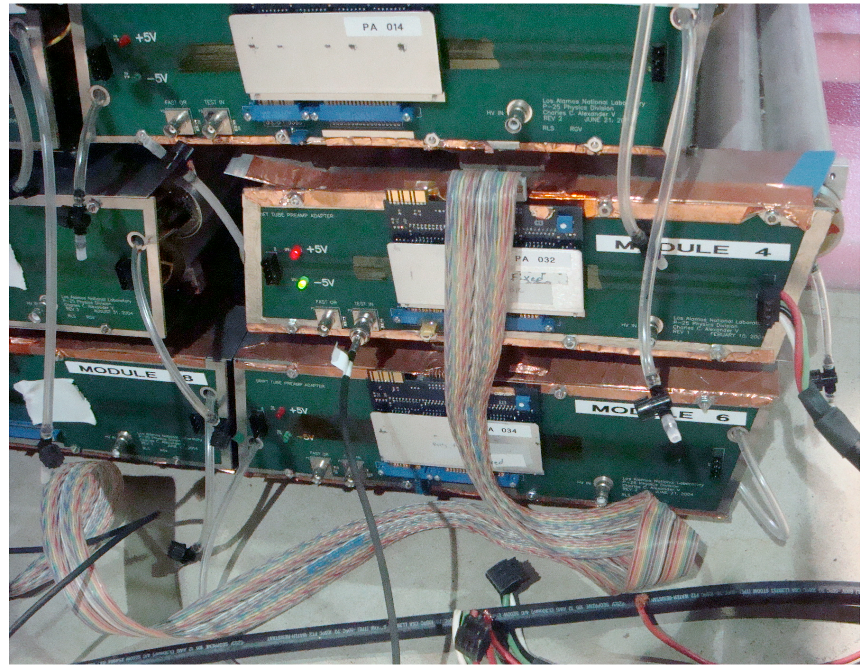
E906 Muon ID Status

Prop tubes unpacked at kTeV hall in early summer after 3 day truck drive

48 12’ modules, each with 16 staggered 2” tubes

Test Bench at FNAL: HV, LV, Pulser, etc





All tubes tested with HV, most OK.

All ECL electronics channels pulsed and checked, a few are dead.

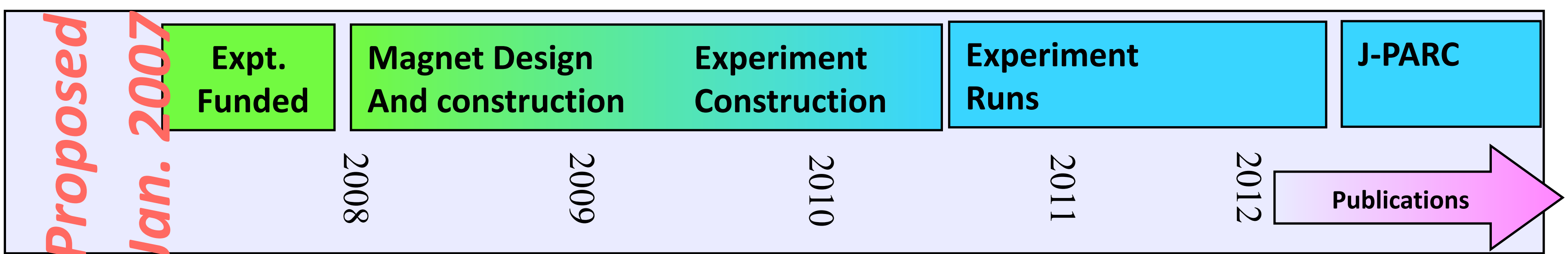
We have more than enough spares for tubes and electronics, only need 24 modules

Next steps : Final tests with gas, repairs as needed, install modules on support frames, cable into DAQ system

E906/Drell-Yan timeline

- Spectrometer upgrade funded by DOE/Office of Nuclear Physics (already received $538k in FY07) and LANL LDRD ER grant (FY08-10)
- Fermilab PAC reaffirms earlier approval decision in Fall 2006
- Scheduled to run in 2010 for 2 years of data collection
  - Liquid H_2 and D_2 targets for dbar/ubar
  - Solid targets for energy loss

- Apparatus available for future program at J-PARC
  - Significant interest from collaboration for continued program here



Fermilab E906/Drell-Yan Collaboration

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Backup slides

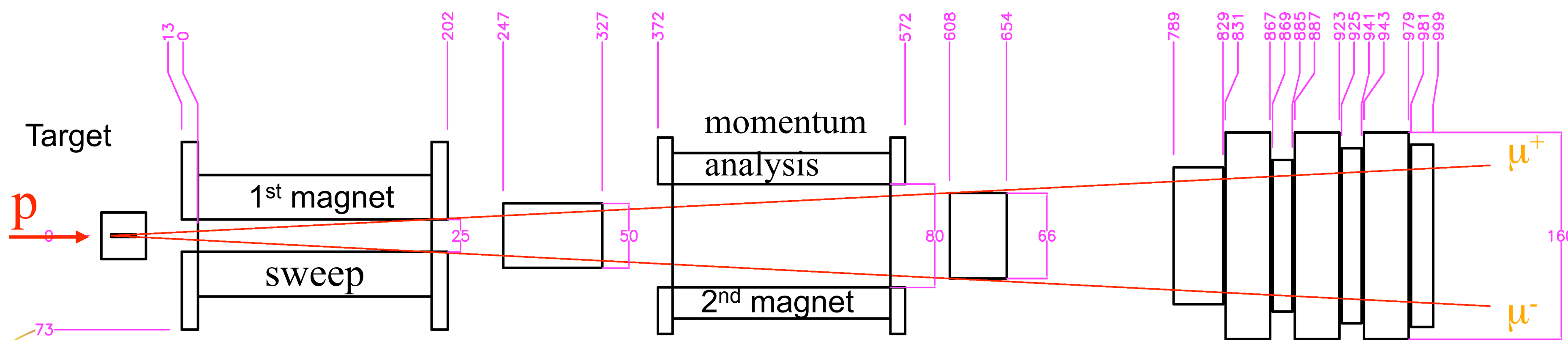
Module and channel counts

4 planes required for E906: 2 X and 2 Y, ~250 x 250 cm area

6 modules per plane provides 244 x 366 cm area.

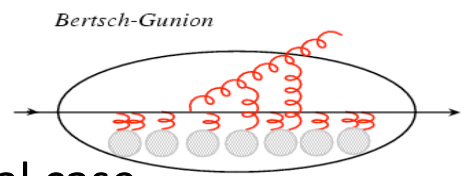
~384 total channels of electronics, 4 channels of +HV

~24 modules required, have 56 available with electronics
Could increase size of station 4, if useful



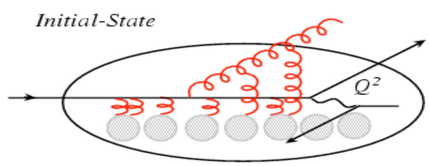
Recent Progress in Parton Energy Loss

Think of the parton (quark) energy in the nuclear rest frame: $E_{\text{iet}} = p_T \cosh(y_{\text{jet}} - y_{\text{target}})$



Ideal case

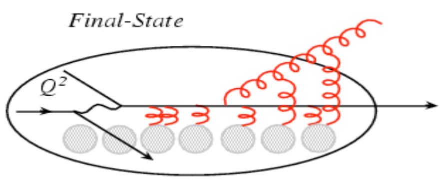
$$\frac{\Delta E}{E} \propto \frac{L}{\lambda_g} \times const(1) \times \ln\frac{E}{Q_0}$$



DY

$$\frac{\Delta E}{E} \propto \frac{L}{\lambda_g} \times const(2) \times \ln\frac{E}{Q_0}$$

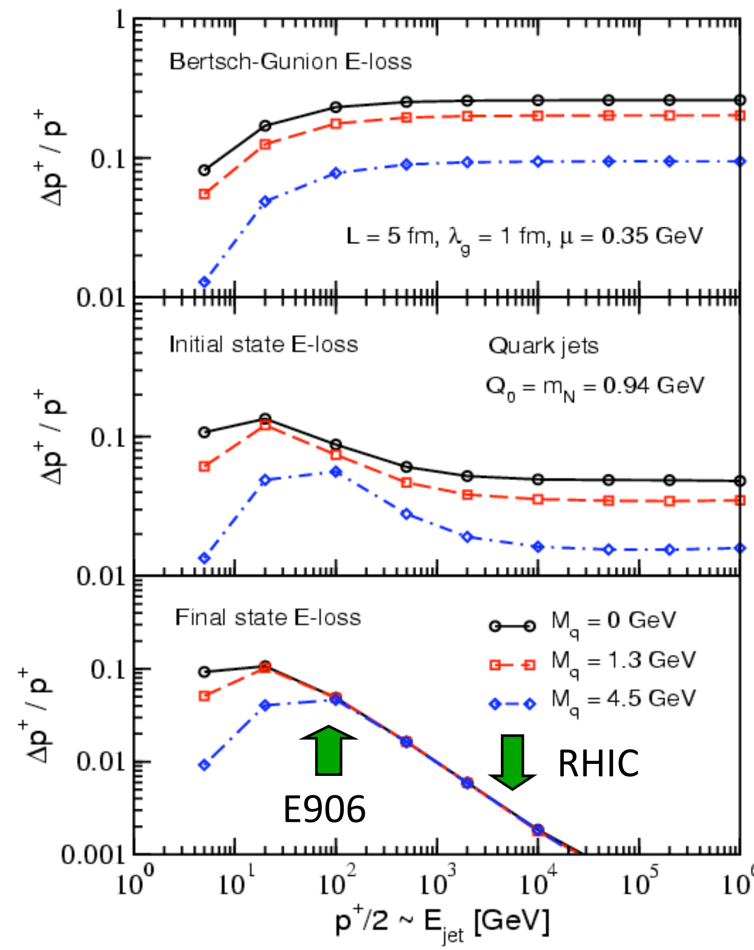
$$const(2) \ll const(1)$$



DIS

$$\frac{\Delta E}{E} \propto \frac{\mu^2 L^2}{\lambda_g} \frac{\ln E / Q_0}{E} const(3)$$

- Initial-state E-loss is large and much larger than final-state energy loss for cold nuclei
- In Drell-Yan we don't have final-state interactions



I. Vitev PRC 75, 064906 (2007)