

The E-906 / SeaQuest experiment at Fermilab

Markus Diefenthaler

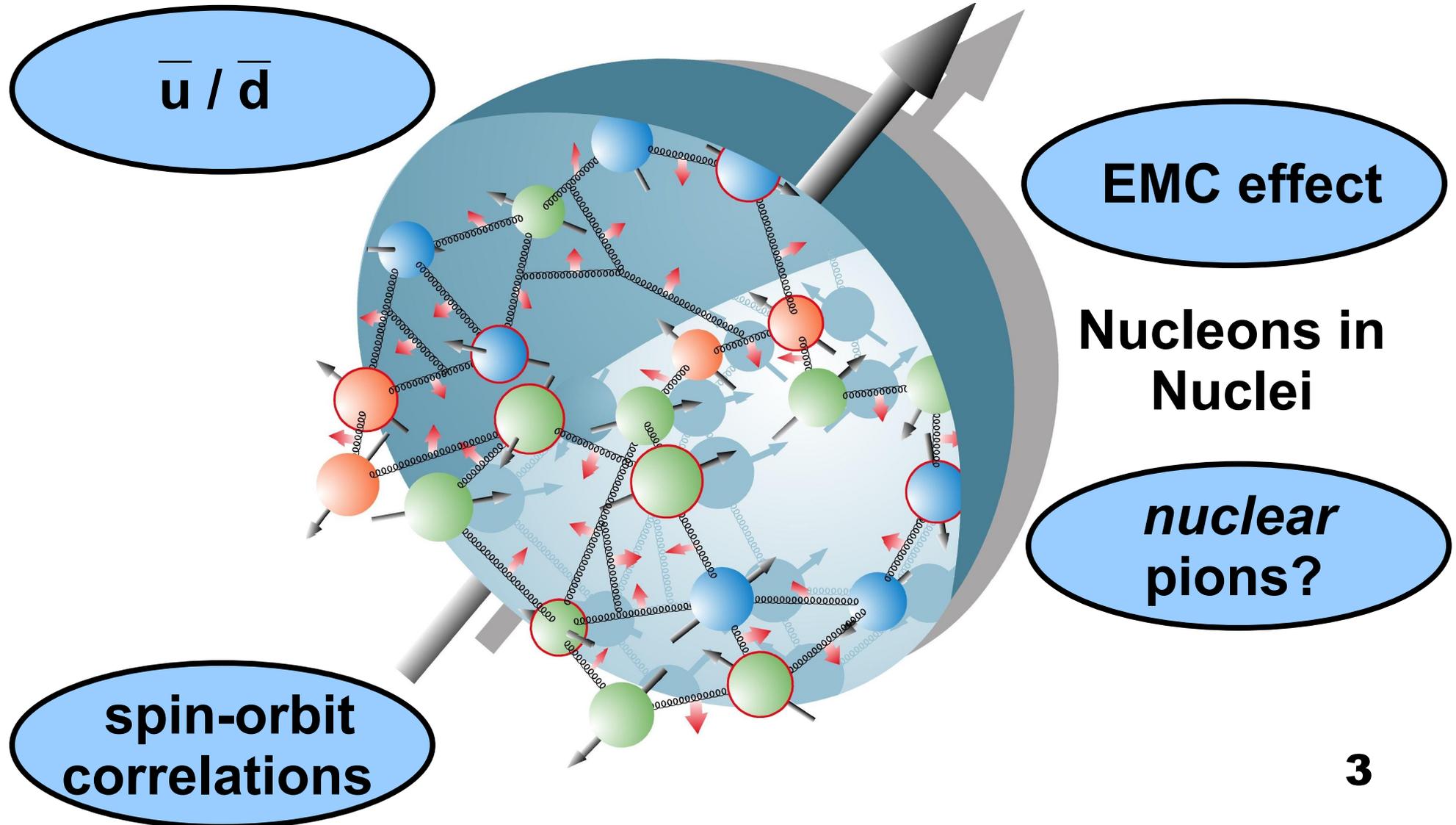
University of Illinois at Urbana-Champaign



The SeaQuest collaboration

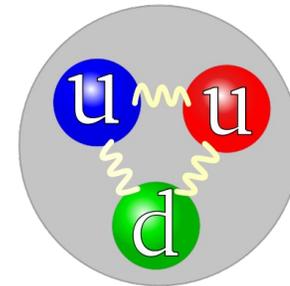
- **Abilene Christian University:** Donald Isenhower, Tyler Hague, Rusty Towell, Shon Watson
- **Academia Sinica:** Wen-Chen Chang, Yen-Chu Chen, Shiu Shiuan-Hal, Da-Shung Su
- **Argonne National Laboratory:** John Arrington, **Don Geesaman** (*co-spokesperson*), Kawtar Hafidi, Roy Holt, Harold Jackson, David Potterveld, **Paul E. Reimer** (*co-spokesperson*), Josh Rubin
- **University of Colorado:** Ed(ward) Kinney, Joseph Katich, Po-Ju Lin
- **Fermi National Accelerator Laboratory:** Chuck Brown, Dave Christian, Jin-Yuan Wu
- **University of Illinois:** Bryan Dannowitz, Markus Diefenthaler, Bryan Kerns, Naomi C.R Makins, R. Evan McClellan, Jen-Chieh Peng
- **KEK:** Shin'ya Sawada
- **Ling-Tung University:** Ting-Hua Chang
- **Los Alamos National Laboratory:** Christine Aidala, Gerry Garvey, Mike Leitch, Han Liu, Ming Liu, Pat McGaughey, Joel Moss, Andrew Puckett
- **University of Maryland:** Betsy Beise, Kazutaka Nakahara
- **University of Michigan:** Chiranjib Dutta, Wolfgang Lorenzon, Richard Raymond, Michael Stewart
- **National Kaohsiung Normal University:** Rurngsheng Guo, Su-Yin Wang
- **University of New Mexico:** Younus Imran
- **RIKEN:** Yoshinori Fukao, Yuji Goto, Atsushi Taketani, Manabu Togawa
- **Rutgers University:** Lamiaa El Fassi, Ron Gilman, Ron Ransome, Brian Tice, Ryan Thorpe, Yawei Zhang
- **Tokyo Tech:** Shou Miyaska, Kenichi Nakano, Florian Sanftl, Toshi-Aki Shibata
- **Yamagata University:** Yoshiyuki Miyachi **2**

The inner structure of the nucleon



The proton sea

- **constituent quark model:**
pure valence description

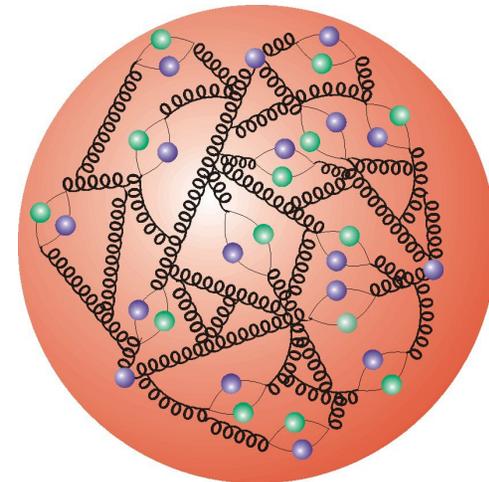


- **perturbative sea:** $g \rightarrow q\bar{q}$
flavor-symmetric, $\bar{u} = \bar{d}$

- **analysis of NMC data:**

$$\int_0^1 [\bar{d}(x) - \bar{u}(x)] dx \neq 0$$

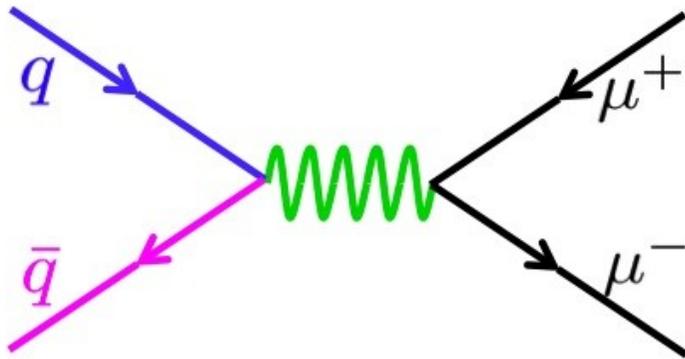
- data shows $\bar{d} > \bar{u}$ (up to 50%)



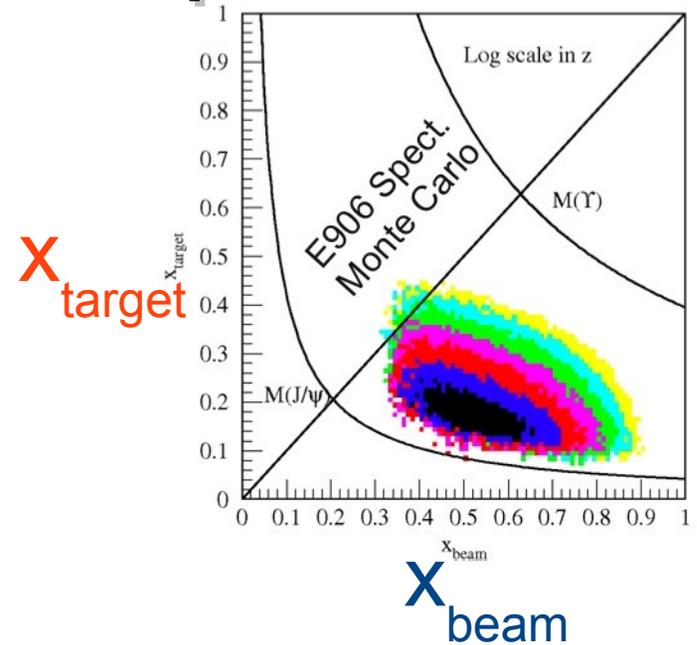
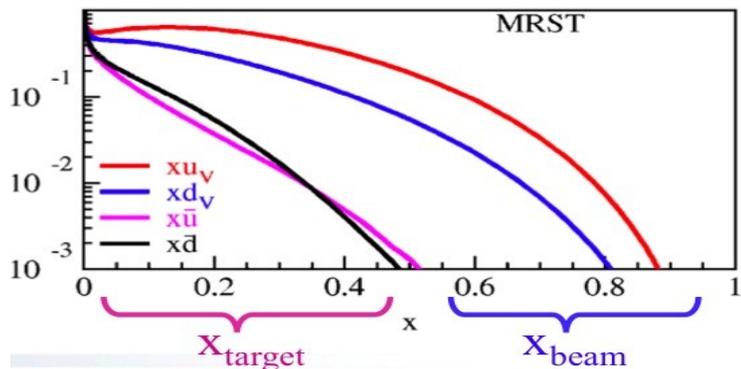
- **alternate degrees of freedom of sea**

A laboratory for sea quarks

The Drell-Yan process



$$\frac{d^2\sigma}{dx_b dx_t} = \frac{4\pi\alpha^2}{9x_b x_t s} \sum_q e_q^2 [\bar{q}_t(x_t)q_b(x_b) + q_t(x_t)\bar{q}_b(x_b)]$$



beam: valence quarks at high-x
target: sea quarks at low/intermediate-x

Probing the proton sea

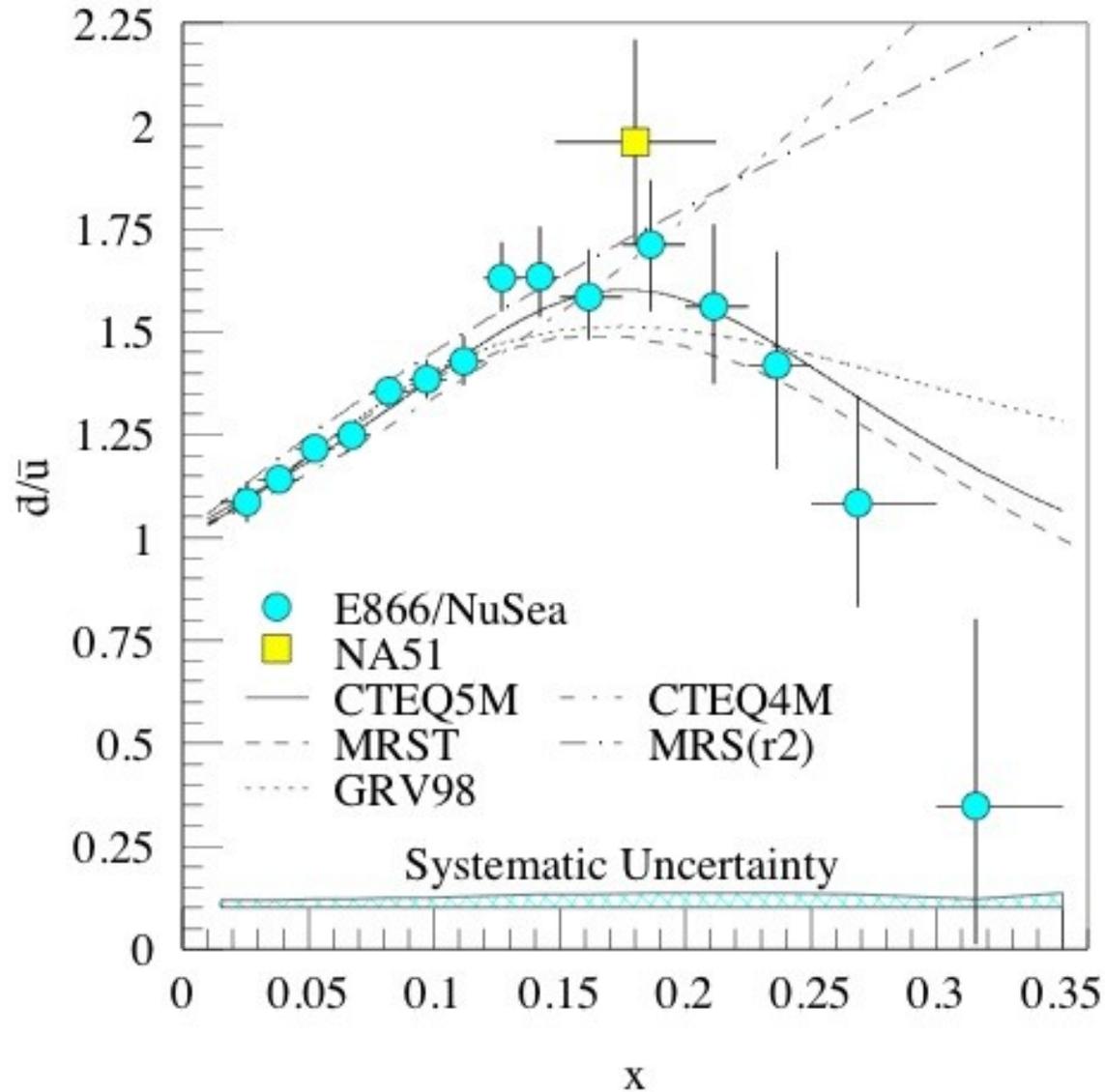
- **analysis of cross-section differences**
 - sensitivity to $\bar{u} - \bar{d}$ in valence region

- **measurement of cross-section ratios**

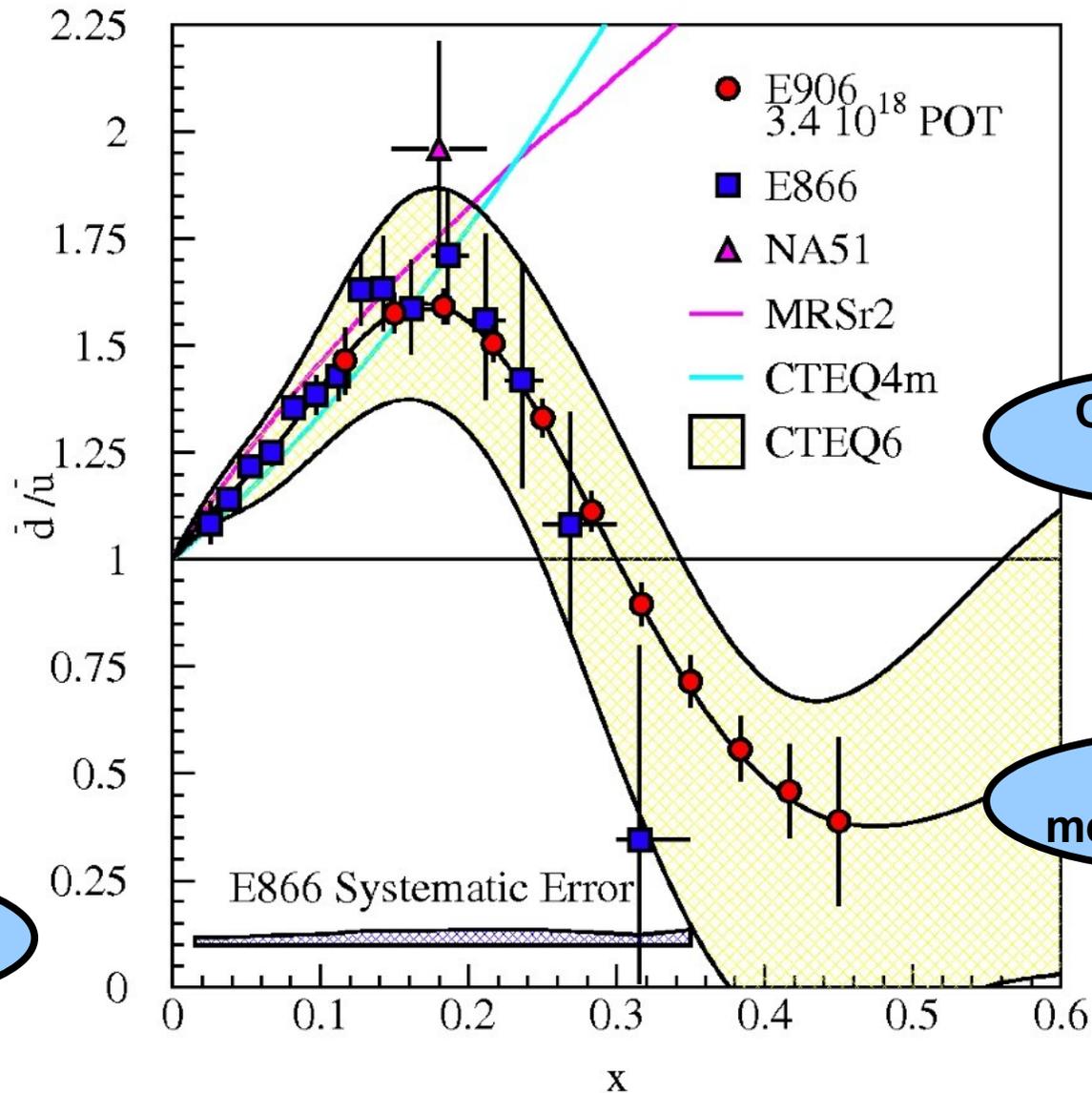
$$\left. \frac{\sigma^{pd \rightarrow \mu^+ \mu^-}}{\sigma^{pp \rightarrow \mu^+ \mu^-}} \right|_{x_b \gg x_t} \approx \frac{1}{2} \left[1 + \frac{\bar{d}(x_t)}{\bar{u}(x_t)} \right]$$

- sensitivity to \bar{u} and \bar{d} in **proton sea**
- models for the **origin of sea quarks**

Insights into the proton sea



Insights into the proton sea



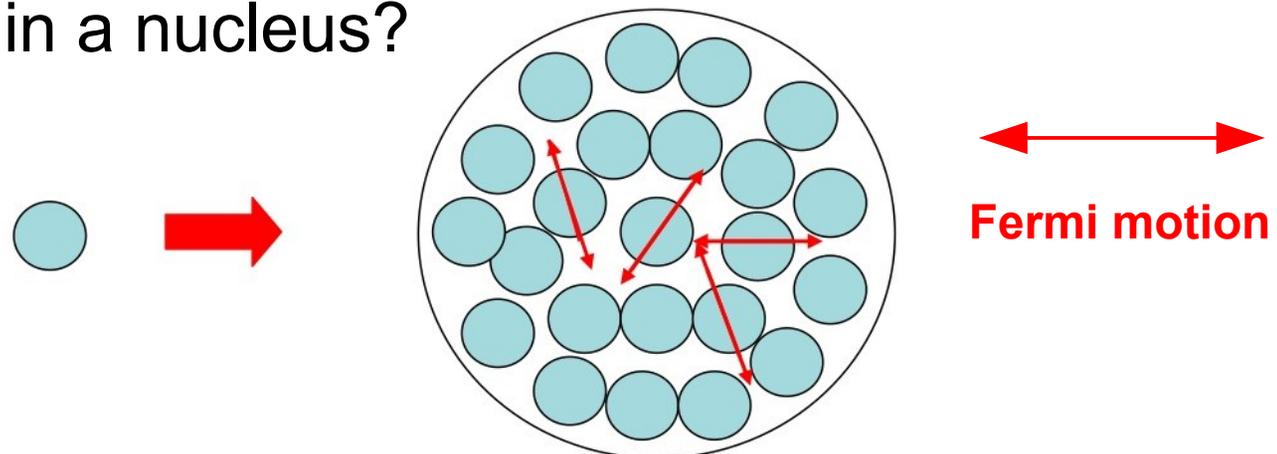
SeaQuest:
Syst. ~ 1%

Global NLO
PDF fit

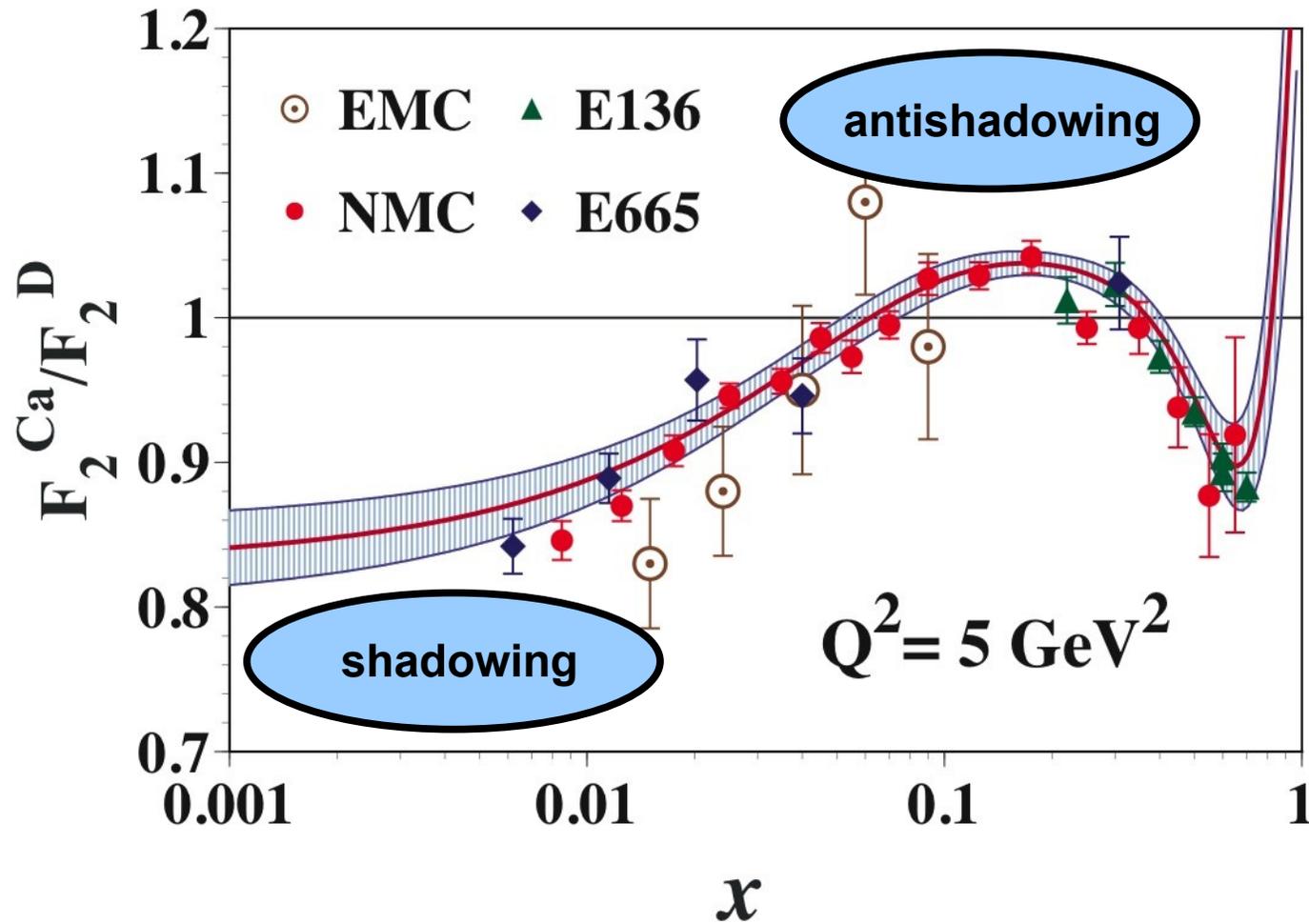
extend
measurement

Nucleons embedded in nuclei

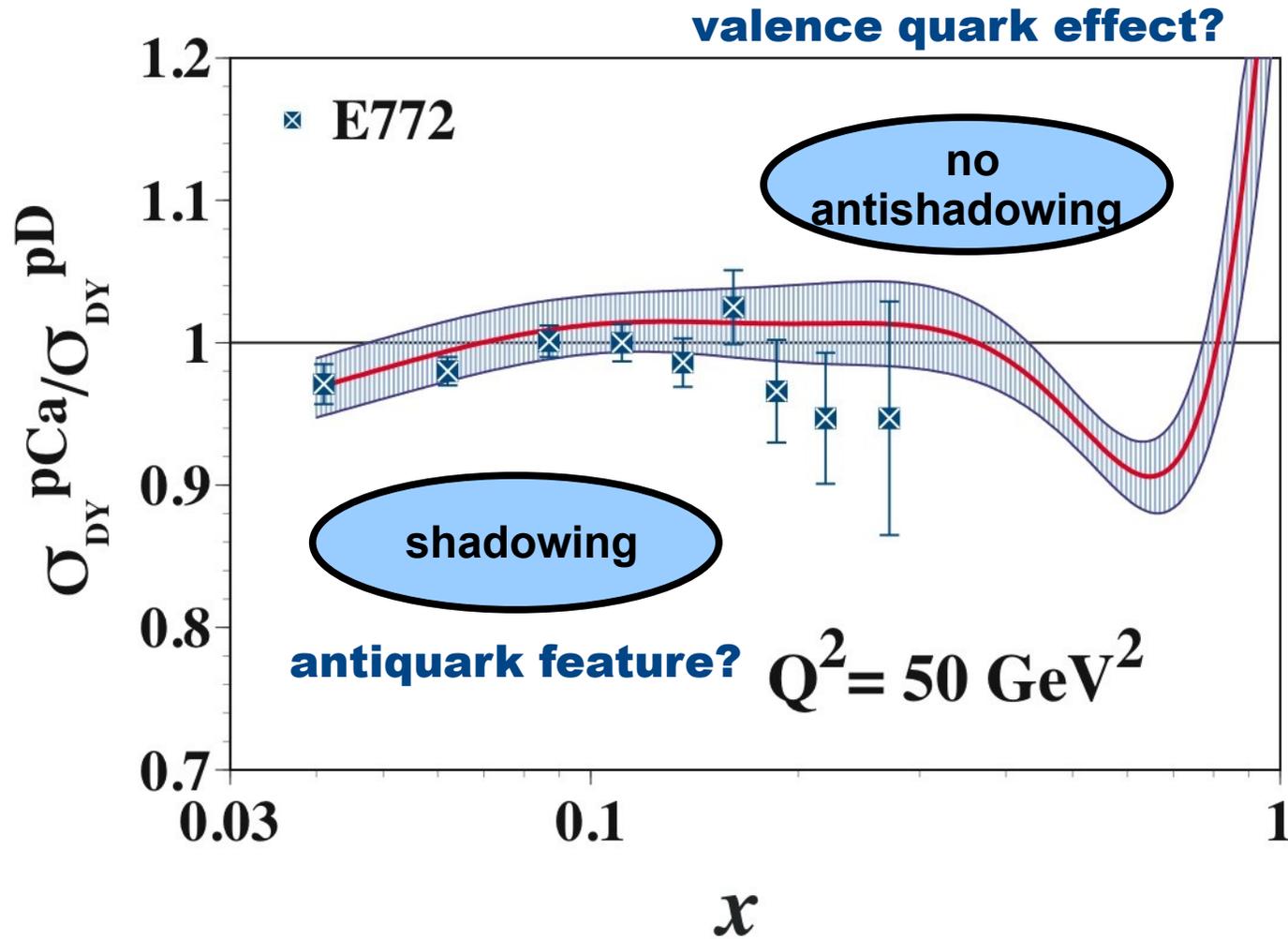
- Do quarks and gluons play any role in the understanding of nuclear forces?
- Can the model of nuclear forces be replaced by a fundamental theory based on the strong interaction between quarks and gluons?
- Is confinement influenced by the nuclear medium?
- Do nucleons change their internal properties when embedded in a nucleus?



The EMC effect

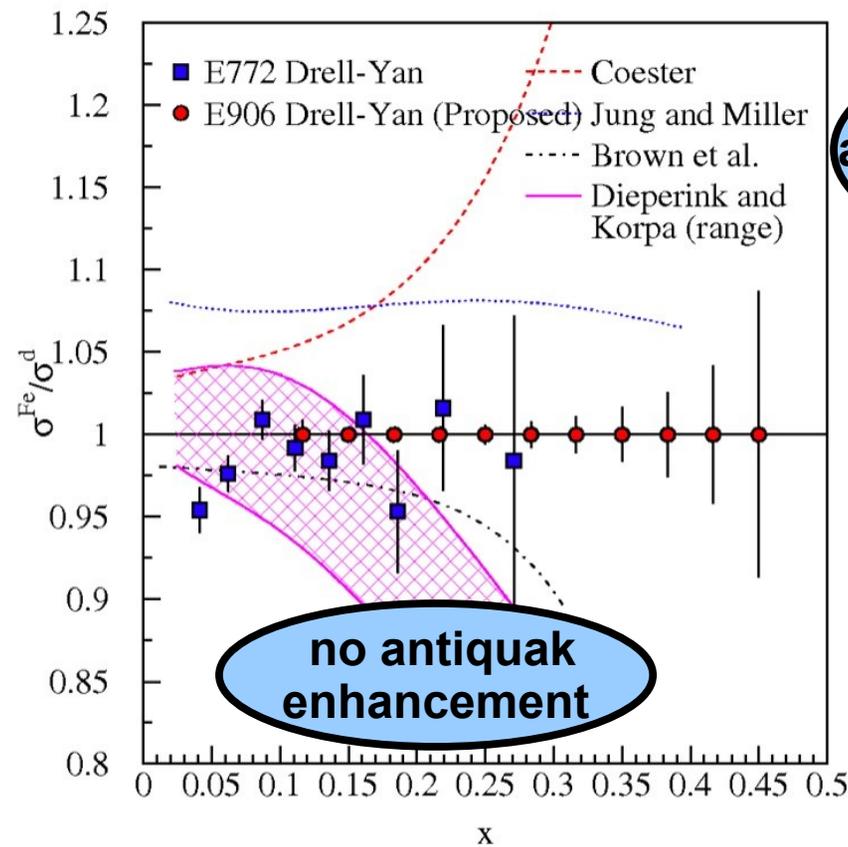


The EMC effect in Drell-Yan



The inner structure of a nucleus

- nuclear force mediated by meson exchange



large effects to antiquark PDF predicted as x increases

no antiquark enhancement

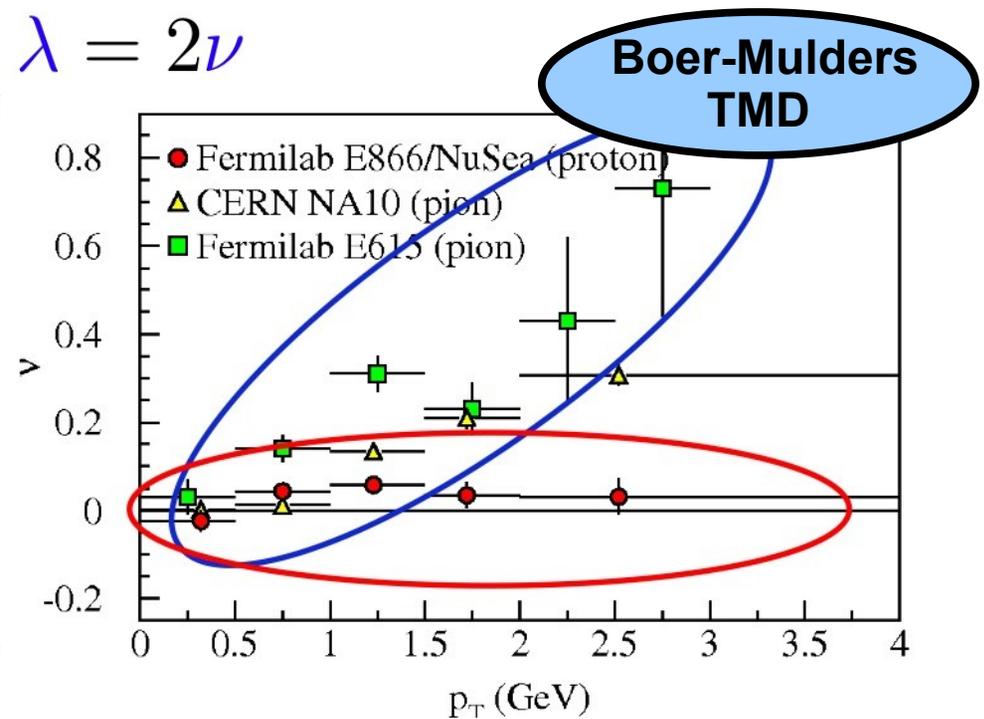
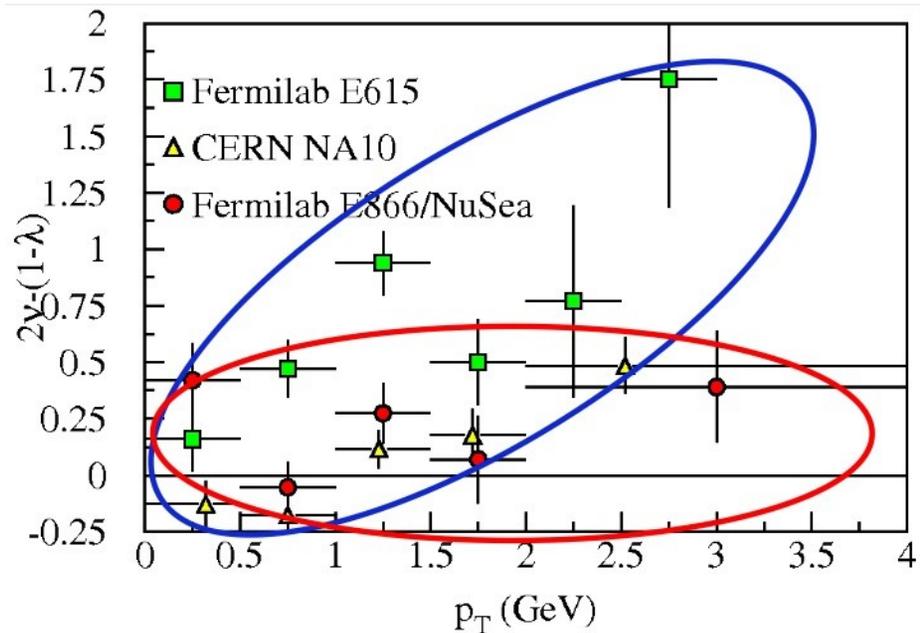
- Where are the *nuclear* pions?

Spin-orbit correlations

- angular dependence of the Drell-Yan cross-section:

$$\frac{d\sigma}{d\Omega} \propto 1 + \lambda \cos^2(\theta) + \mu \sin(2\theta) \cos(\phi) + \frac{\nu}{2} \sin^2(\theta) \cos(2\phi)$$

- Lam-Tung relation:** $1 - \lambda = 2\nu$



The SeaQuest mission

- **significant increase in physics reach**
- unique access to **sea quarks at high-x**
- **What is the structure of the nucleon?**
 - What is \bar{d} / \bar{u} ?
 - What are the origins of the sea quarks?
 - What is the high-x structure of the proton?
 - How are quark spin and orbital motion correlated?
- **What is the structure of nucleonic matter?**
 - Where are the *nuclear* pions?
 - Is antishadowing a valence effect?
- **Do colored partons lose energy in cold nuclear matter?**

The proton beam for SeaQuest



- 2×10^{12} protons / s for 5s spills each minute
- **120 GeV** proton beam instead of a 800 GeV proton beam (as used for E-866 / NuSea):
 - Drell-Yan cross section scales as **1/s**
 - J/Ψ decay (dominant background) scales as **s**
 - **50x** luminosity as E-866 (for same rate)

The SeaQuest target



luminosity:
 $3.4 \times 10^{35} / \text{cm}^2 / \text{s}$

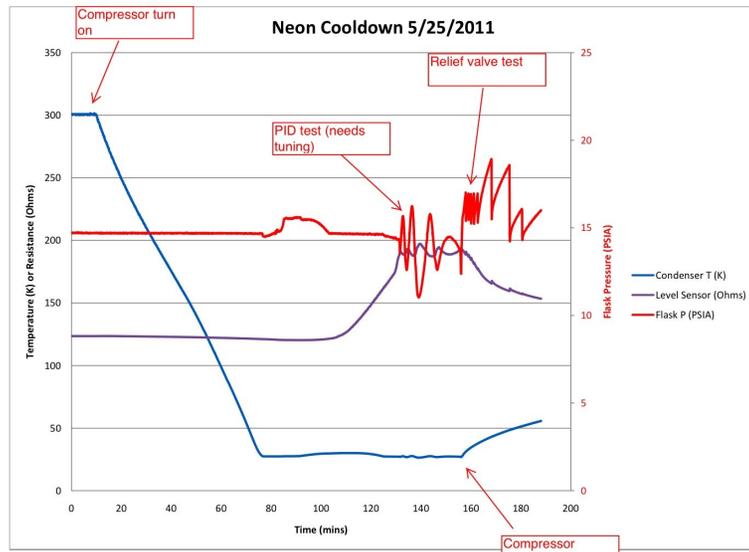
liquid hydrogen

liquid deuterium

Carbon

Calcium

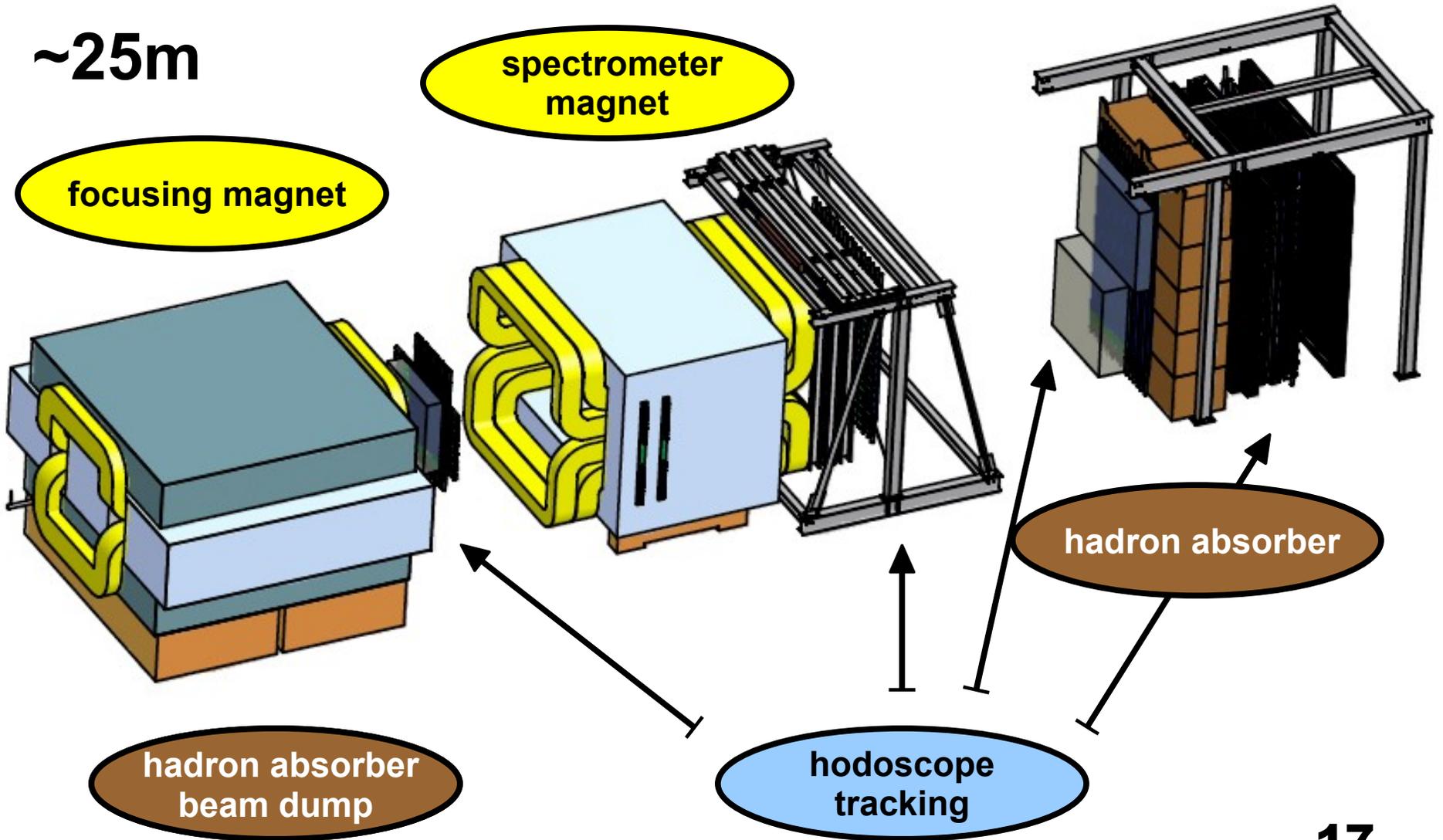
Tungsten



The SeaQuest spectrometer



~25m



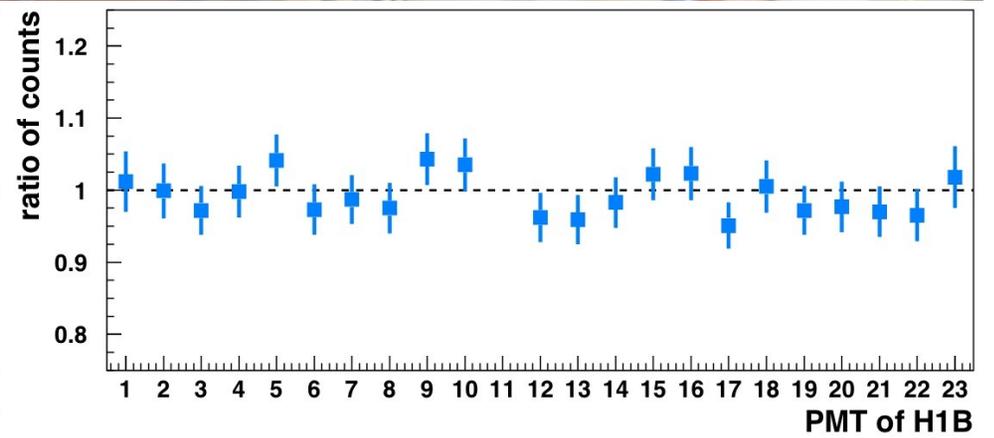
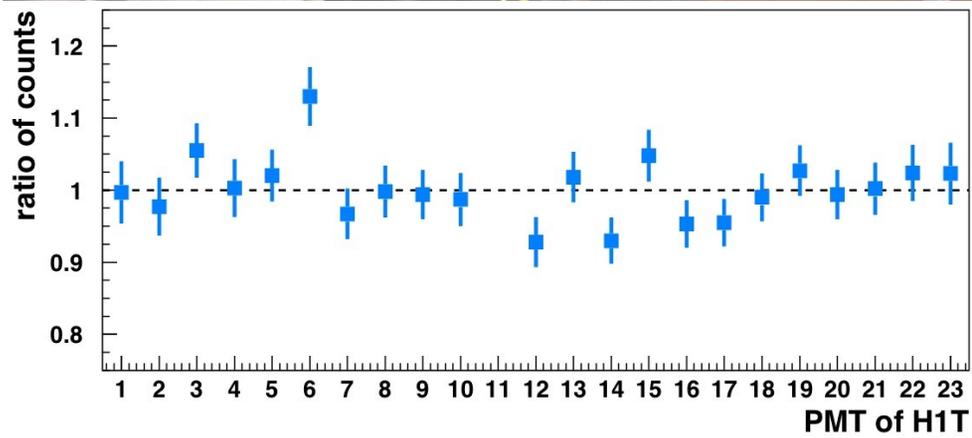
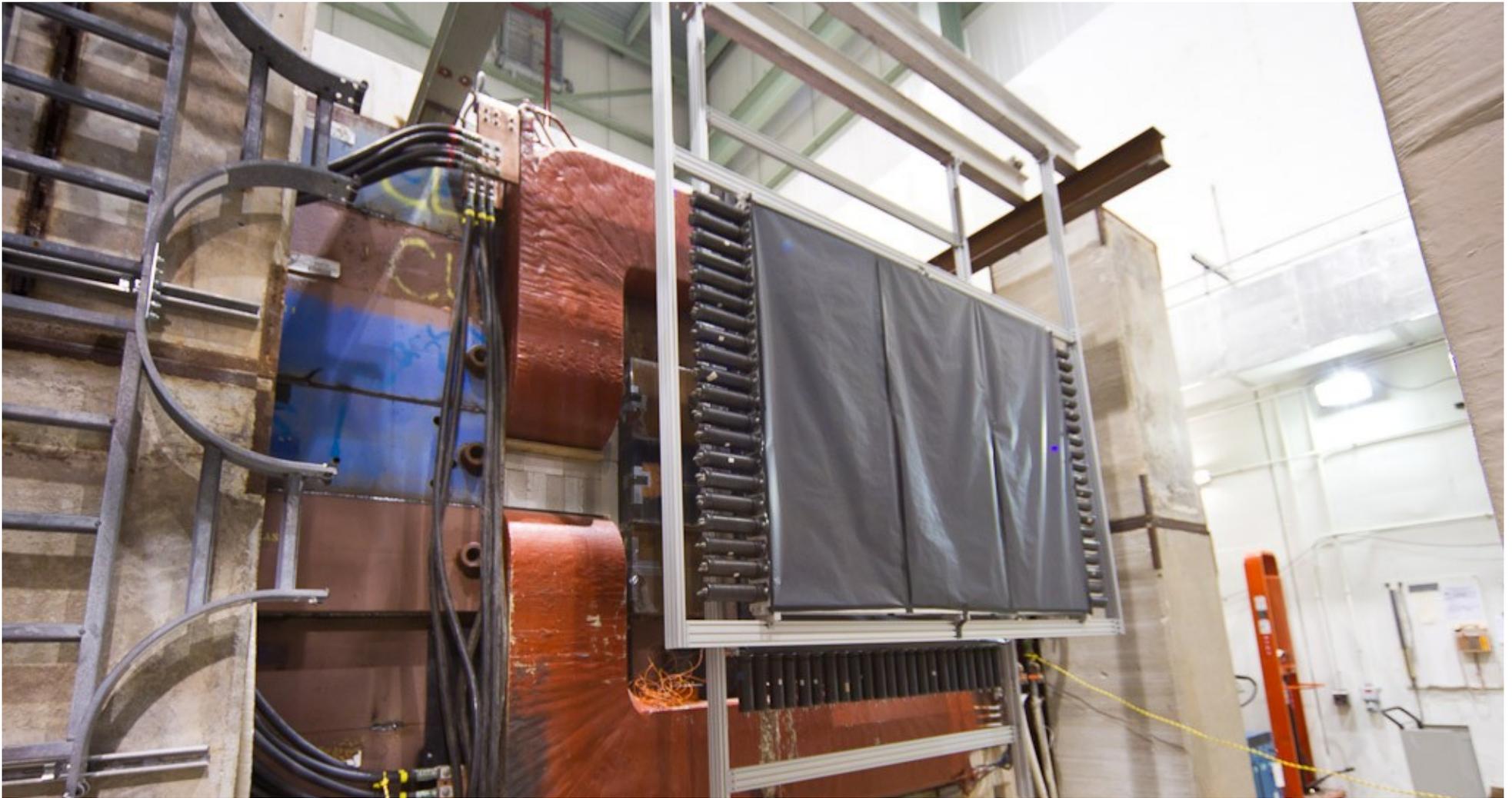
The SeaQuest slide show

KTeV hall



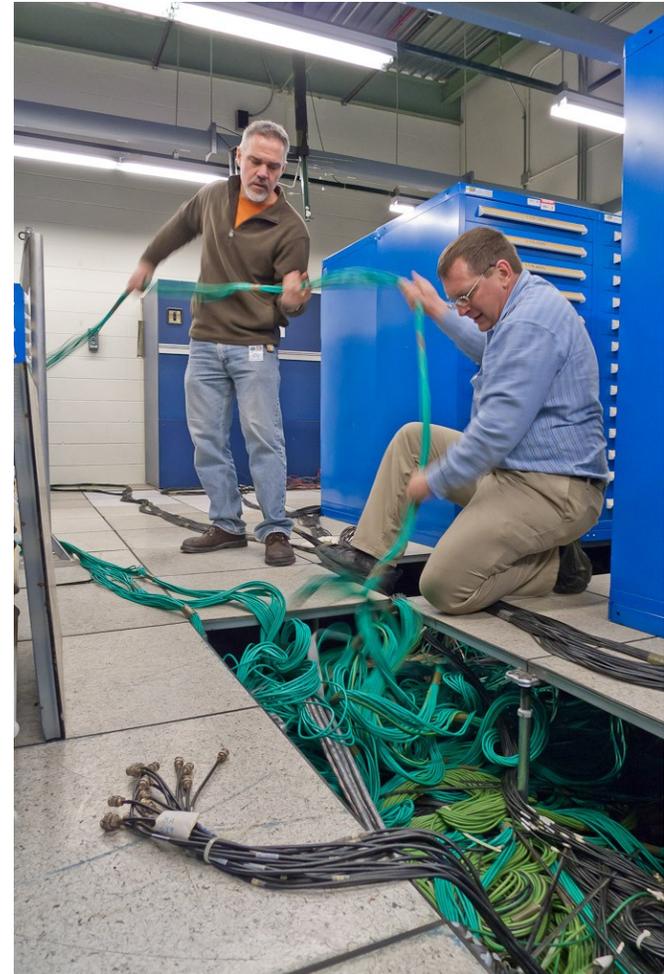






SeaQuest DAQ

- **TDC**, VME based
- **CODA** system
- **MySQL** database
 - calibrations
 - productions
 - online and off-line analysis
- **extensively studied** using cosmics







The SeaQuest mission

unique laboratory for sea quarks at high- x

→ structure of nucleons and nucleonic matter

tuned beam hoped for September

→ final commissioning of the experiment

→ **data taking until shutdown in April 2012**

→ **continue data taking after long shutdown**

exciting extensions possible