

# The SeaQuest experiment

Markus Diefenthaler

University of Illinois at Urbana-Champaign

# The SeaQuest collaboration

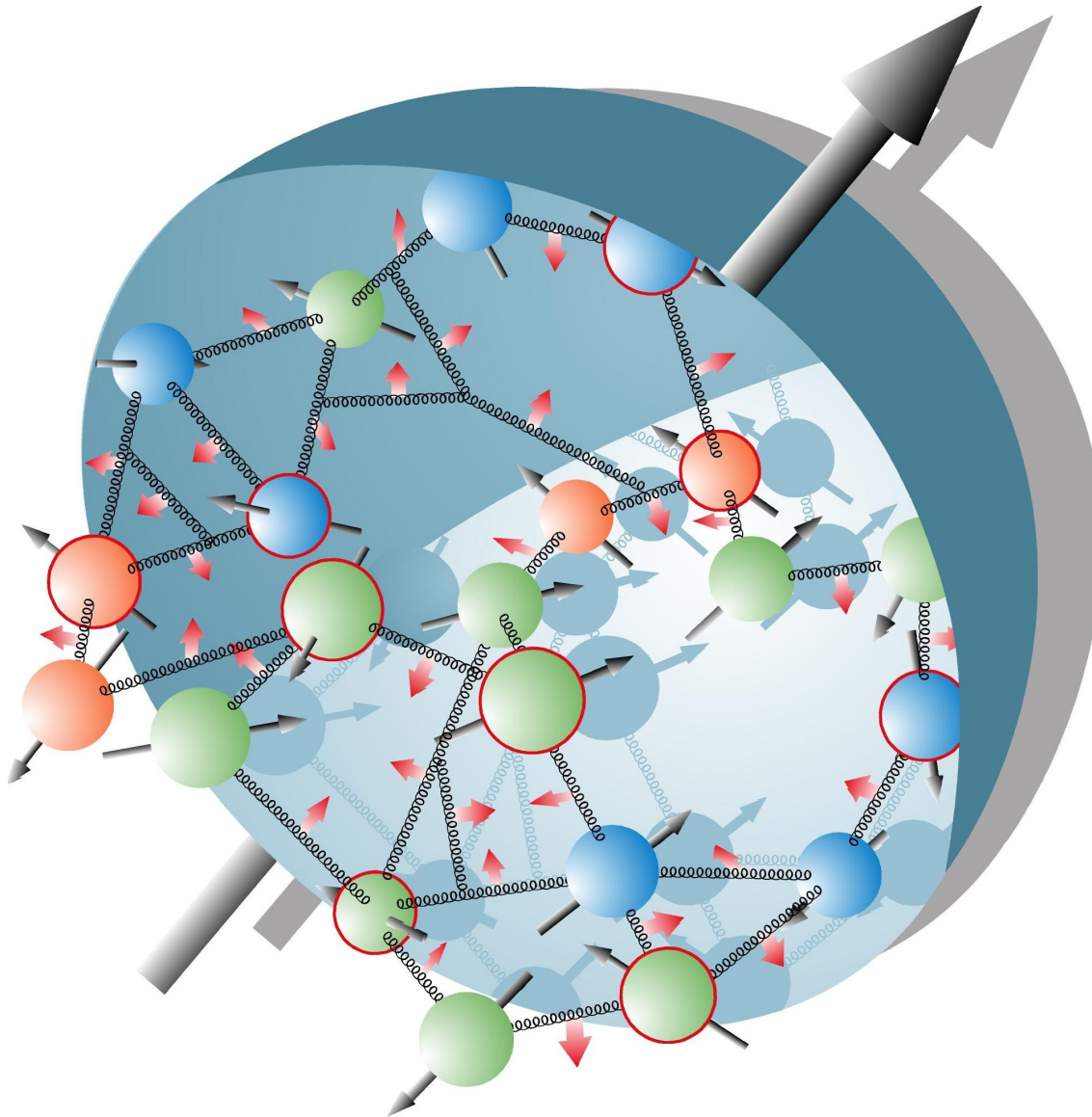
- **Abilene Christian University:** Donald Isenhower, Tyler Hague, Rusty Towell, Shon Watson
- **Academia Sinica:** Wen-Chen Chang, Yen-Chu Chen, Shiu Shiuan-Hal, Da-Shung Su
- **Argonne National Laboratory:** John Arrington, **Don Geesaman** (*co-spokesperson*), Kawtar Hafidi, Roy Holt, Harold Jackson, David Potterveld, **Paul E. Reimer** (*co-spokesperson*), Josh Rubin
- **University of Colorado:** Ed Kinney, J. Katich, Po-Ju Lin
- **Fermi National Accelerator Laboratory:** Chuck Brown, Dave Christian, JinYuan Wu
- **University of Illinois:** Bryan Dannowitz, Markus Diefenthaler, Dan Jumper, 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, Ken-ichi Nakano, Florian Sanftl, Toshi-Aki Shibata
- **Yamagata University:** Yoshiyuki Miyachi



# Acknowledgment



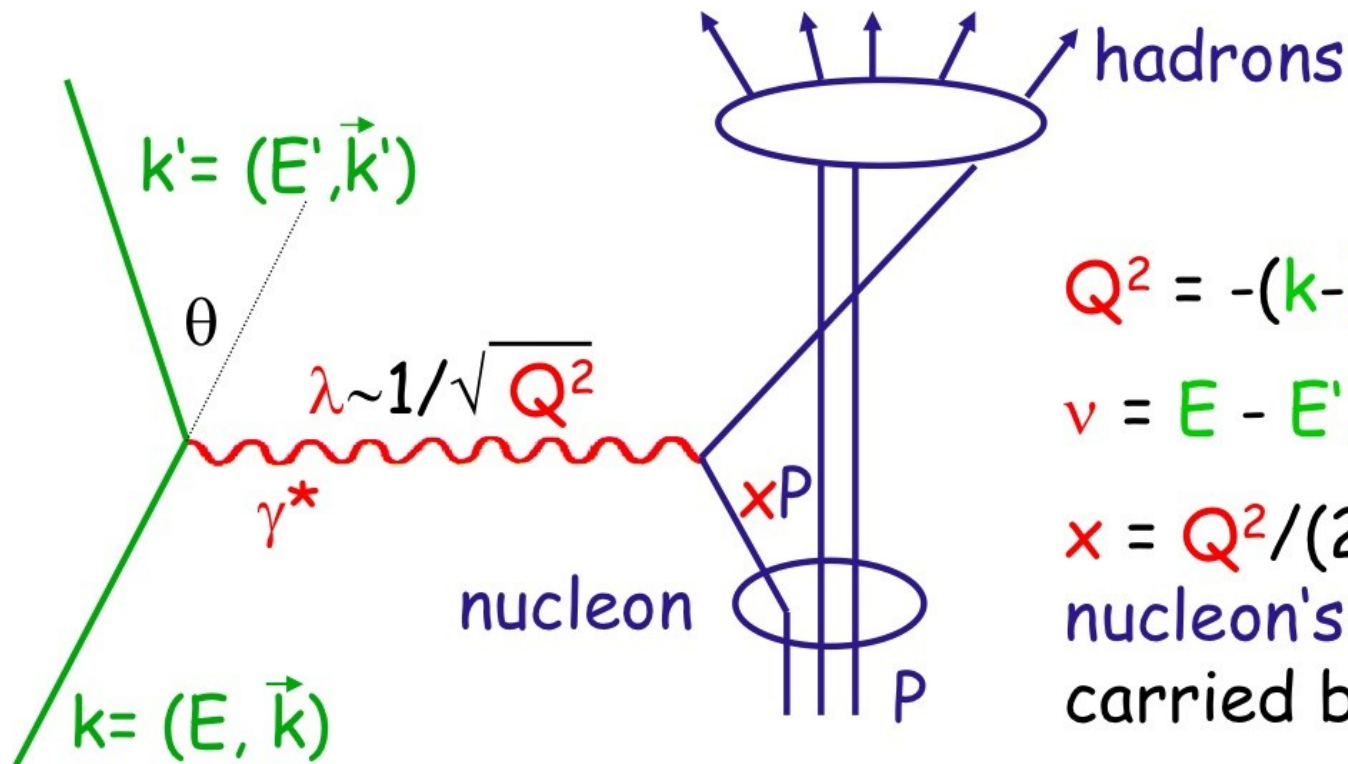
# The inner structure of the nucleon



Quarks $\text{spin} = 1/2$		
Flavor	Approx. Mass $\text{GeV}/c^2$	Electric charge
<b>u</b> up	0.003	$2/3$
<b>d</b> down	0.006	$-1/3$
<b>C</b> charm	1.3	$2/3$
<b>S</b> strange	0.1	$-1/3$

Strong (color) $\text{spin} = 1$		
Name	Mass $\text{GeV}/c^2$	Electric charge
<b>g</b> gluon	0	0

# Deep-inelastic lepton-nucleon scattering

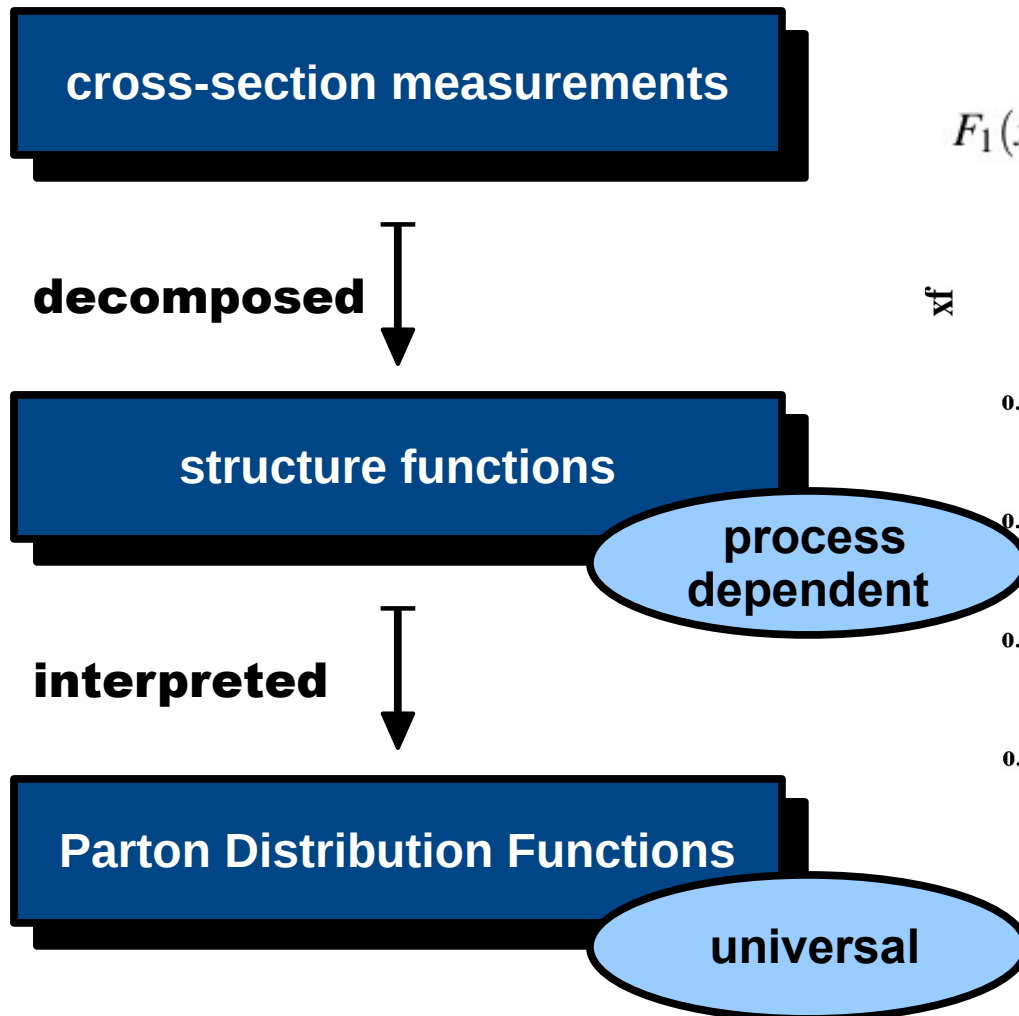


$$Q^2 = -(k - k')^2 = 2EE'(1 - \cos\theta)$$

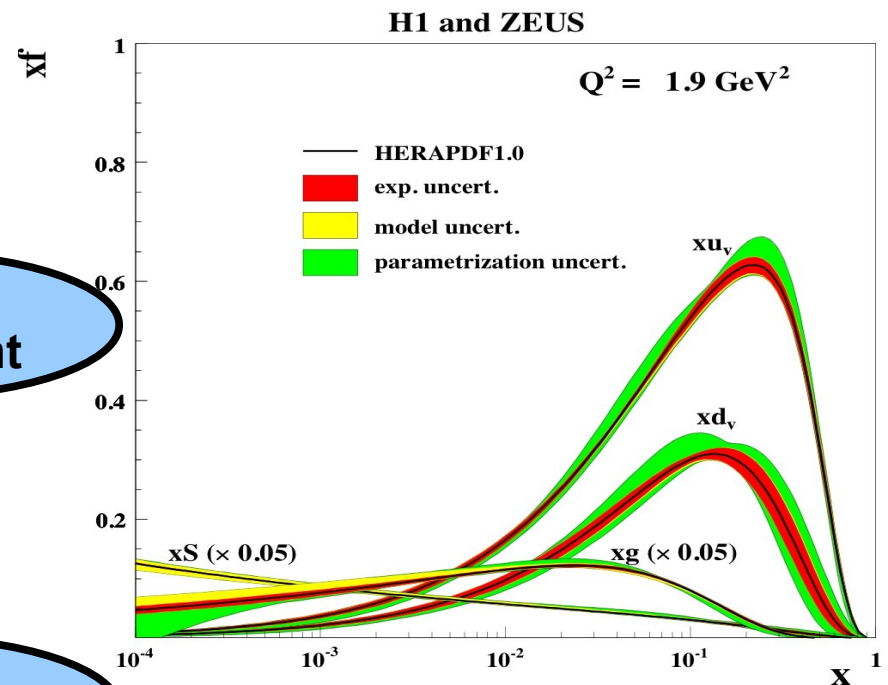
$$v = E - E', \gamma = v/E$$

$x = Q^2/(2Mv)$  = fraction of nucleon's momentum  $P$ , carried by struck quark

# Probing the inner structure



$$F_1(x, Q^2) = \sum_q e_q^2 \left( f_1^q(x, Q^2) + f_1^{\bar{q}}(x, Q^2) \right)$$





# The proton sea

- **constituent quark model:**

pure valence description

- **perturbative sea:**  $g \rightarrow q\bar{q}$

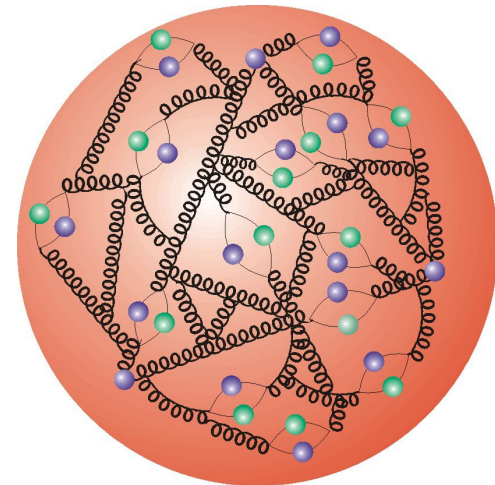
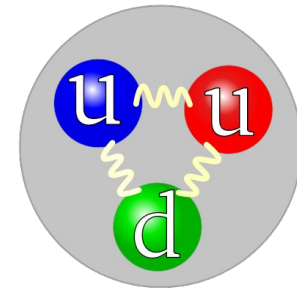
flavor-symmetric,  $\bar{u} = \bar{d}$

- **analysis of NMC data:**

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

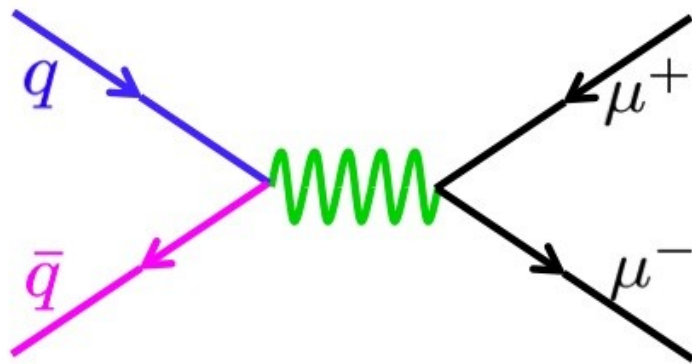
- data shows  $\bar{d} > \bar{u}$  (up to 50%)

- **alternate degrees of freedom of sea**

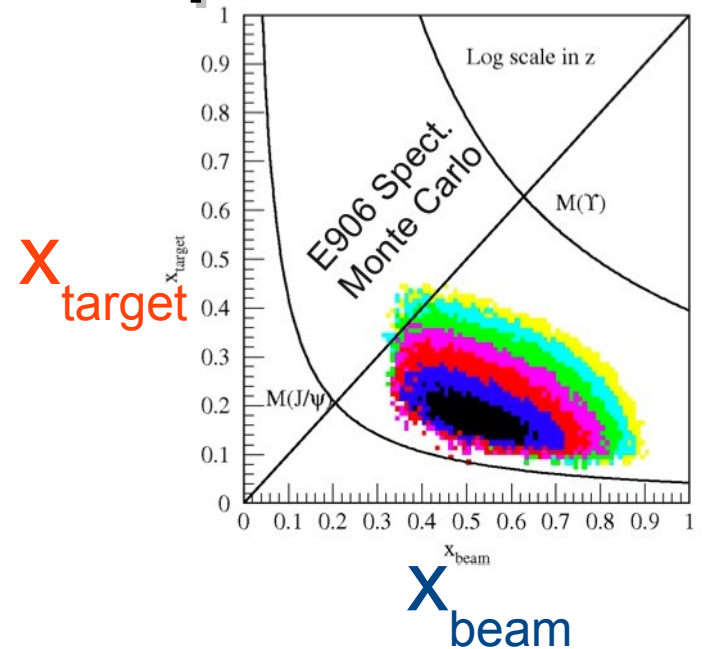
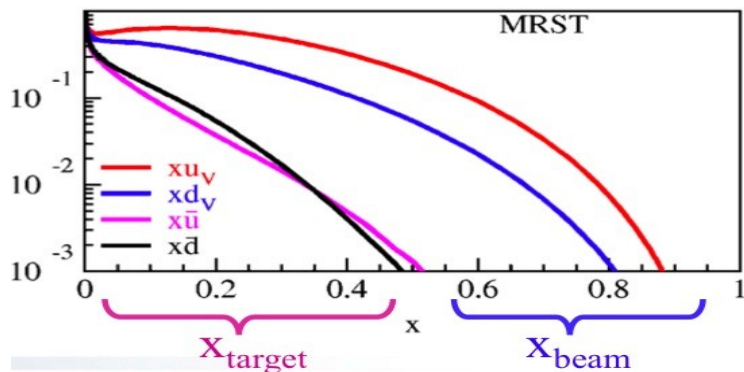


# A laboratory for sea quarks

## 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

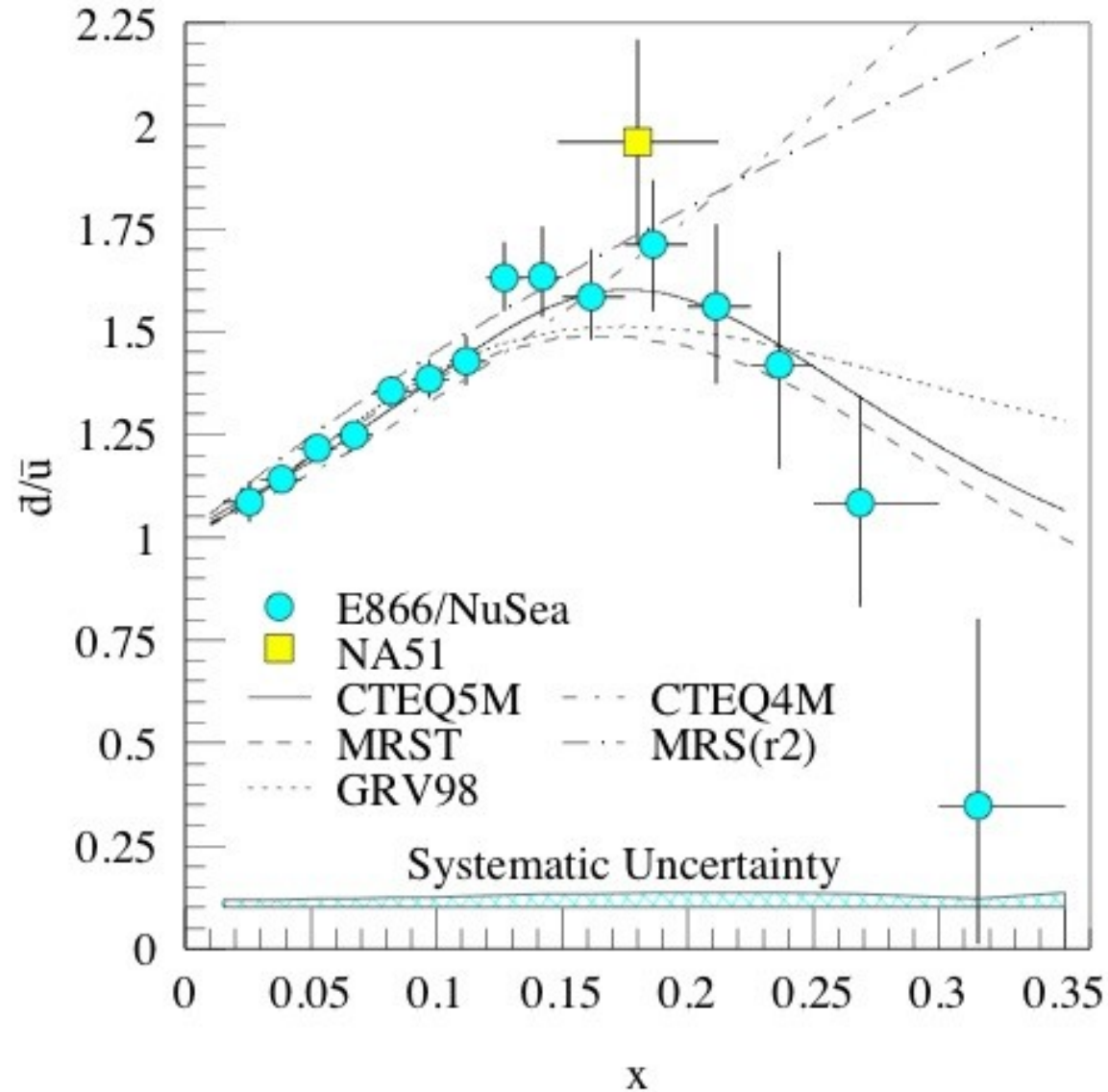
- **analysis of cross-section differences**
  - sensitivity to  $\bar{u} - \bar{d}$  in valence region

- **measurement of cross-section ratios**

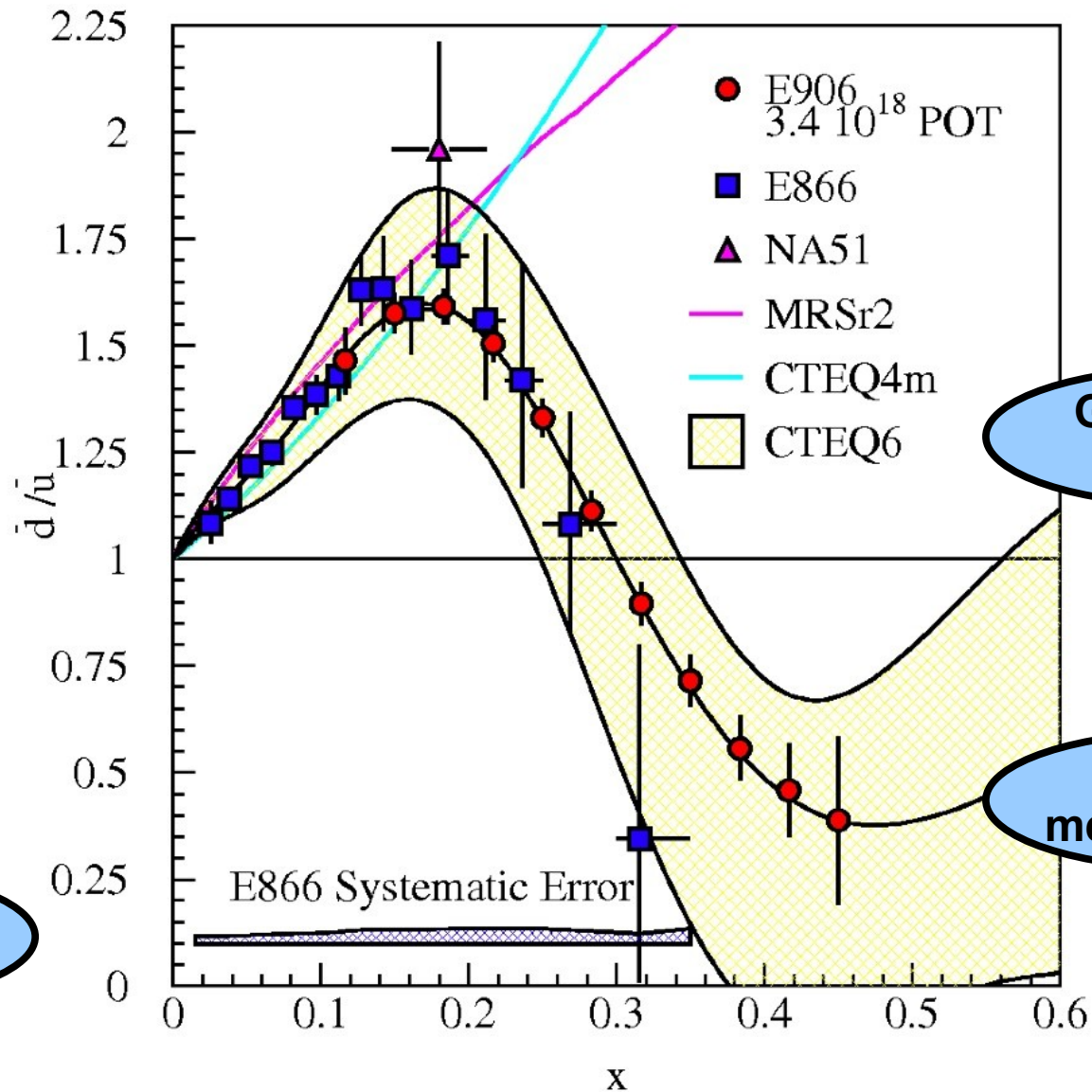
$$\left. \frac{\sigma^{pd \rightarrow \mu^+ \mu^-}}{\sigma^{pp \rightarrow \mu^+ \mu^-}} \right|_{x_b \gg x_t} \approx \frac{1}{2} \left[ 1 + \frac{\bar{d}(x_t)}{\bar{u}(x_t)} \right]$$

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

# Insights into the proton sea



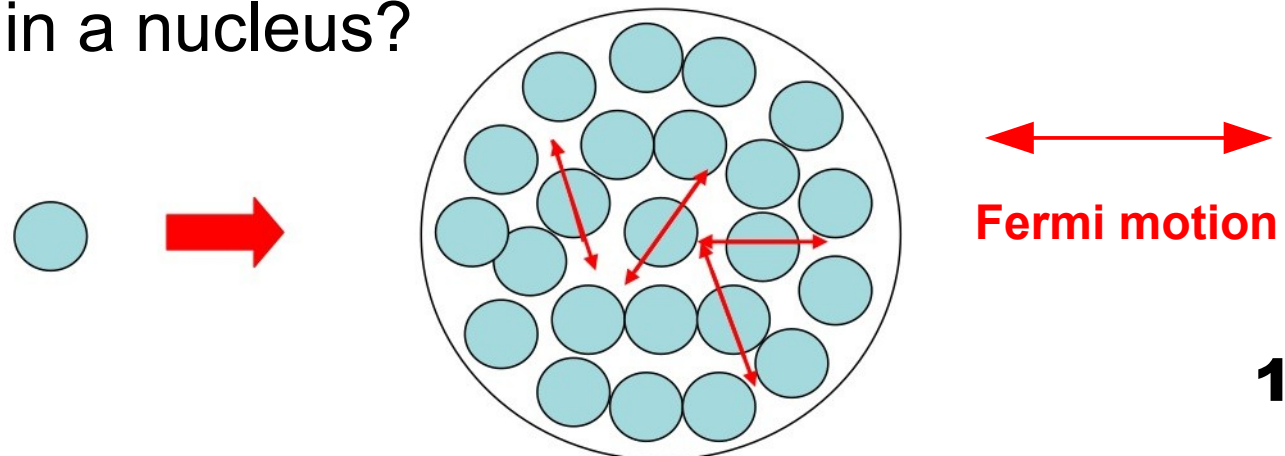
# Insights into the proton sea



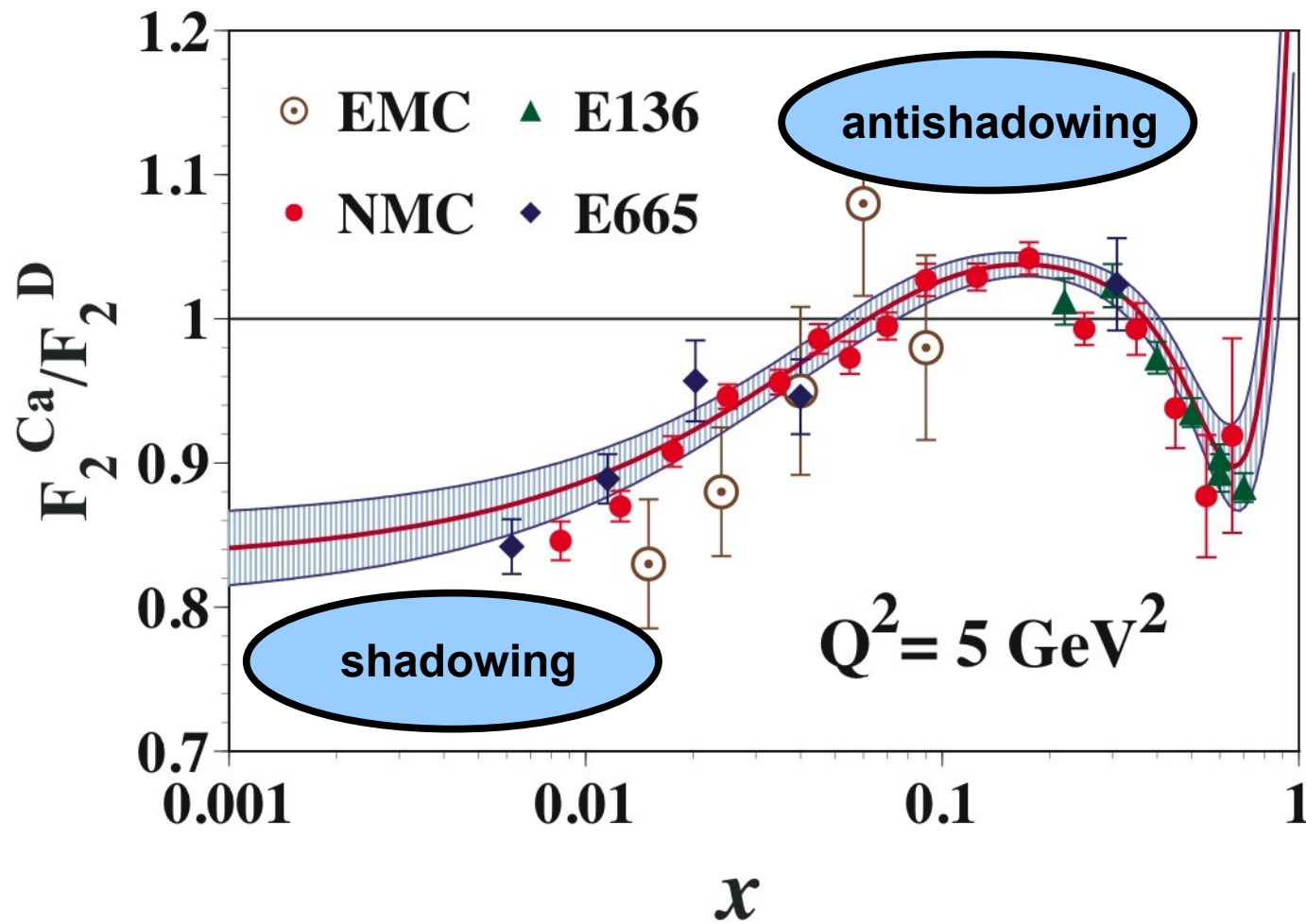


# Nucleons embedded in nuclei

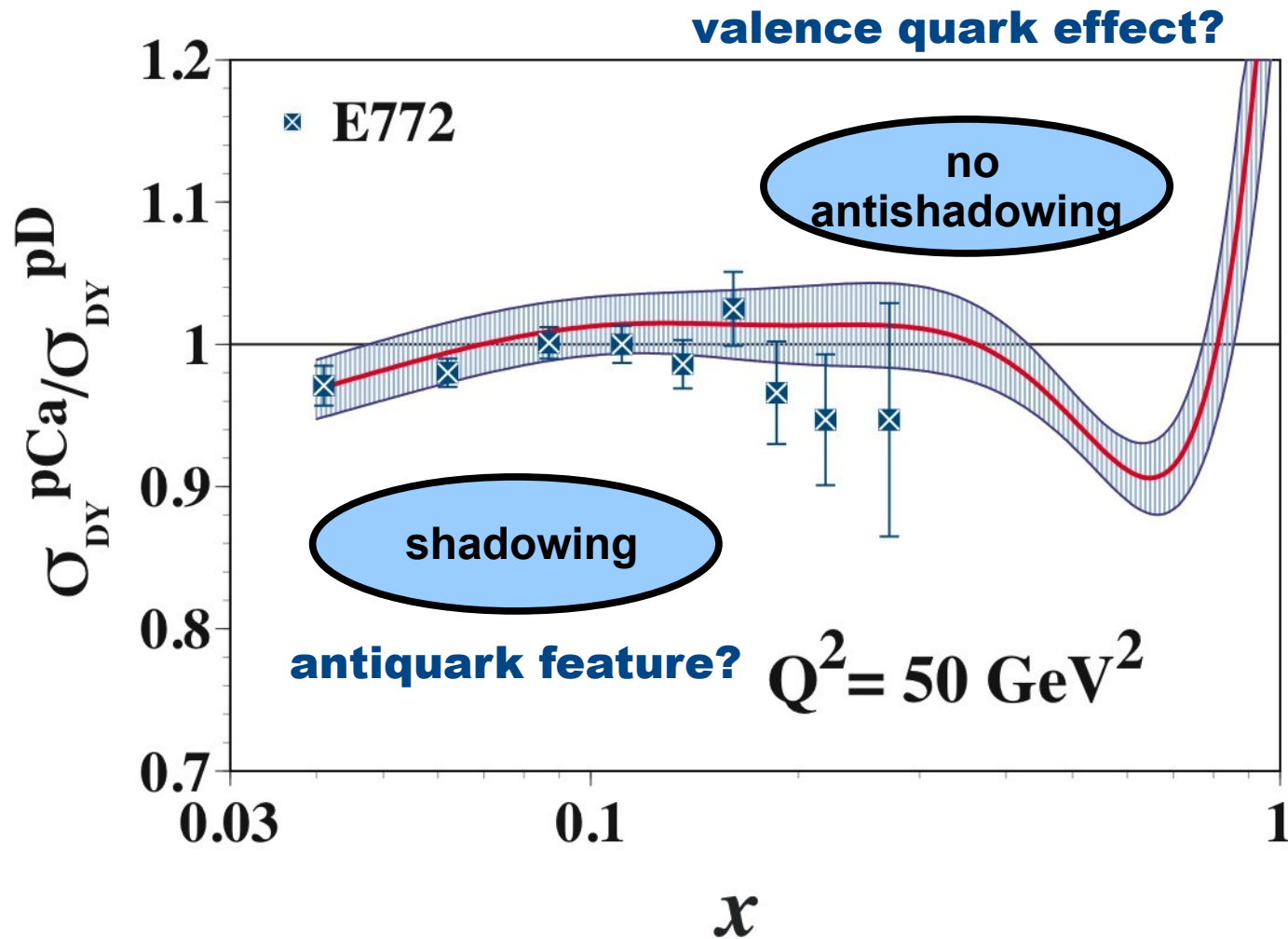
- Do quarks and gluons play any role in the understanding of nuclear forces?
- Can the model of nuclear forces be replaced by a fundamental theory based on the strong interaction between quarks and gluons?
- Is confinement influenced by the nuclear medium?
- Do nucleons change their internal properties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



# The EMC effect



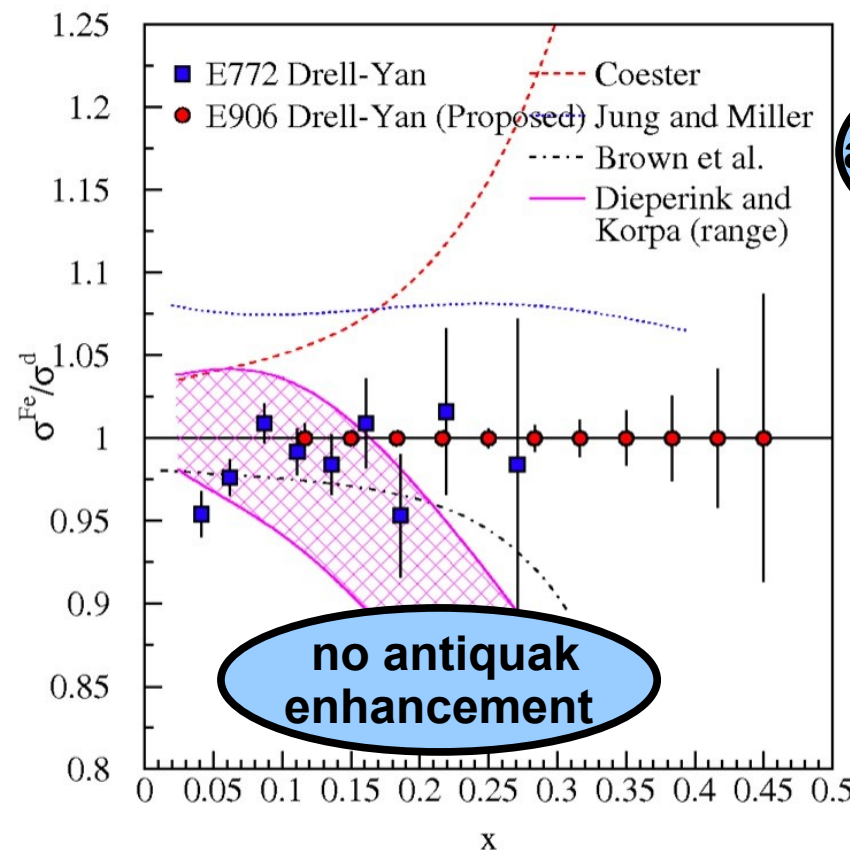
# The EMC effect in Drell-Yan





# The inner structure of a nucleus

- nuclear force mediated by meson exchange



large effects to antiquark PDF predicted as  $x$  increases

- Where are the “nuclear” pions?

# 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?**

# Fermilab Main Injector

The (very successful) past:

**Fermilab E866/NuSea**

- Data in 1996-1997
- $^1\text{H}$ ,  $^2\text{H}$ , and nuclear targets
- **800 GeV proton beam**

The future:

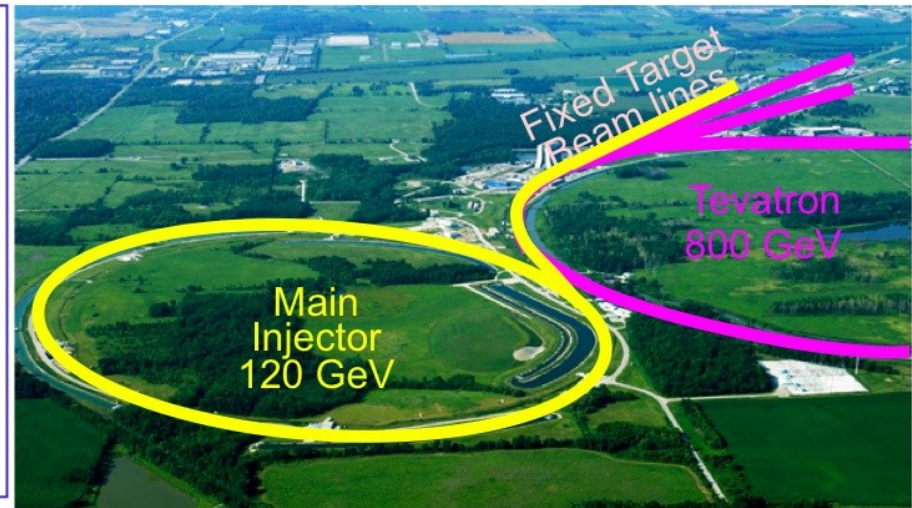
**Fermilab E906**

- Data in 2009
- $^1\text{H}$ ,  $^2\text{H}$ , and nuclear targets
- **120 GeV proton Beam**

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9x_1 x_2} \frac{1}{s} \times \sum_i e_i^2 [q_{ti}(x_t)\bar{q}_{bi}(x_b) + \bar{q}_{ti}(x_t)q_{bi}(x_b)]$$

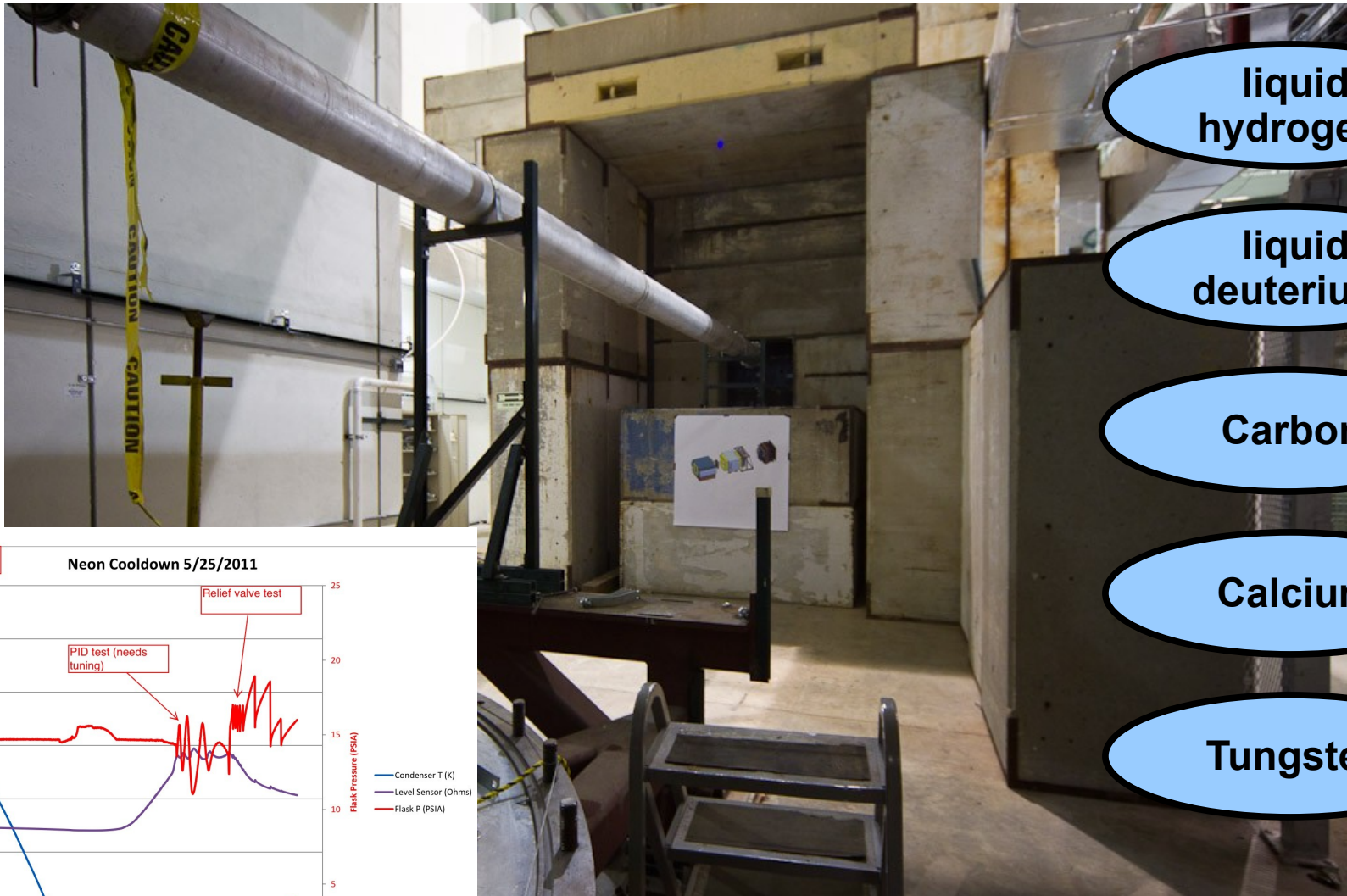
- Cross section scales as  **$1/s$** 
  - **$7\times$**  that of 800 GeV beam
- Backgrounds, primarily from  $J/\psi$  decays scale as  **$s$** 
  - **$7\times$**  Luminosity for same detector rate as 800 GeV beam

**50x statistics!**





# The SeaQuest target



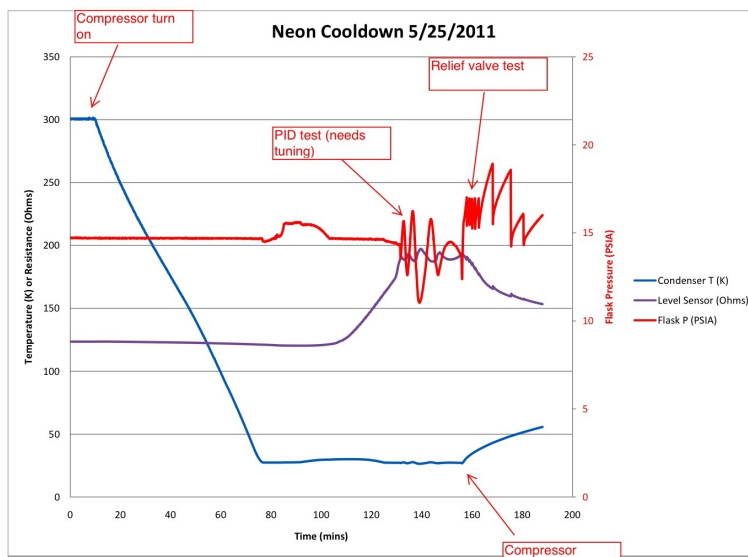
liquid  
hydrogen

liquid  
deuterium

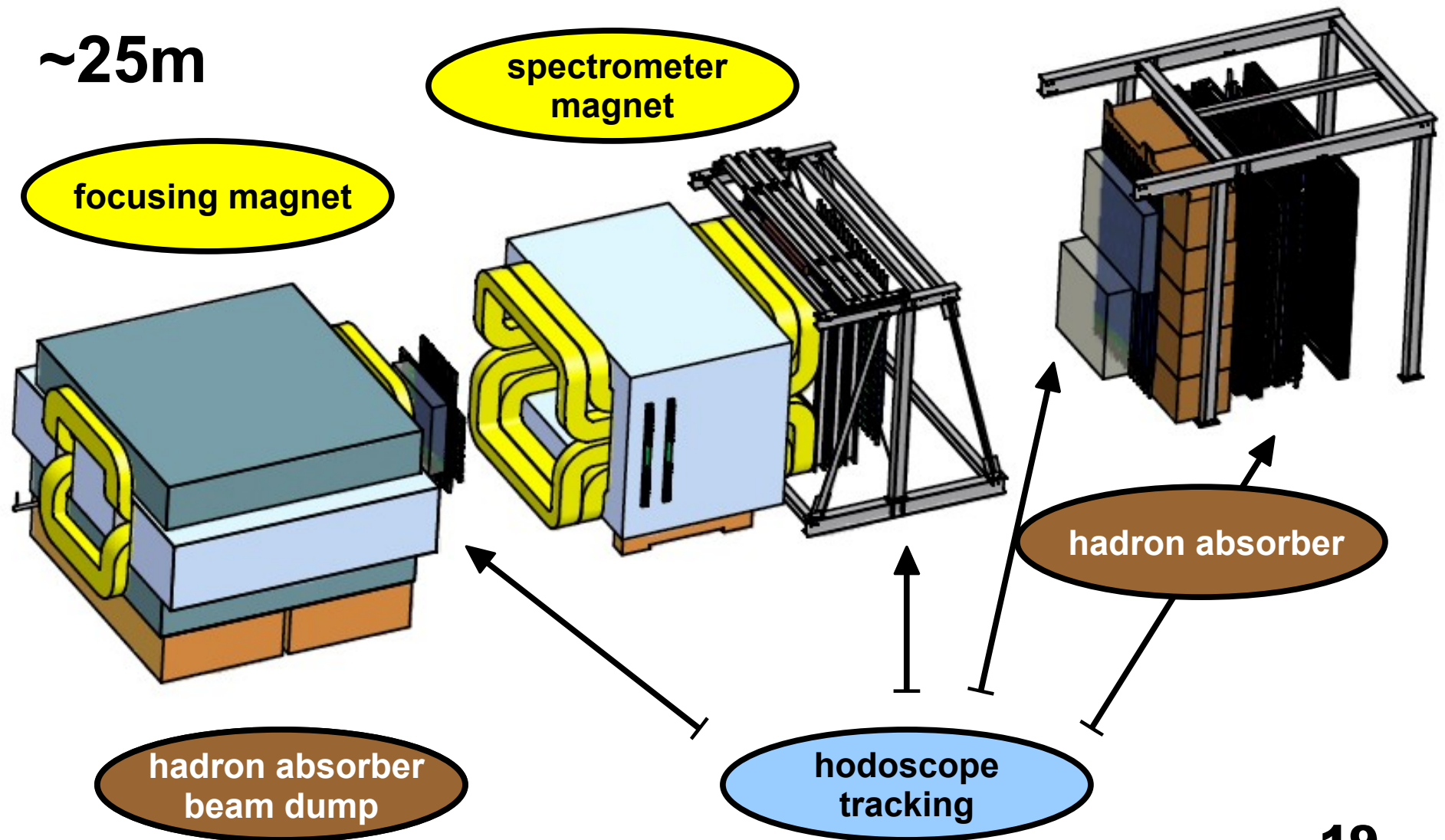
Carbon

Calcium

Tungsten



# The SeaQuest spectrometer





# The SeaQuest slide show

KTeV hall



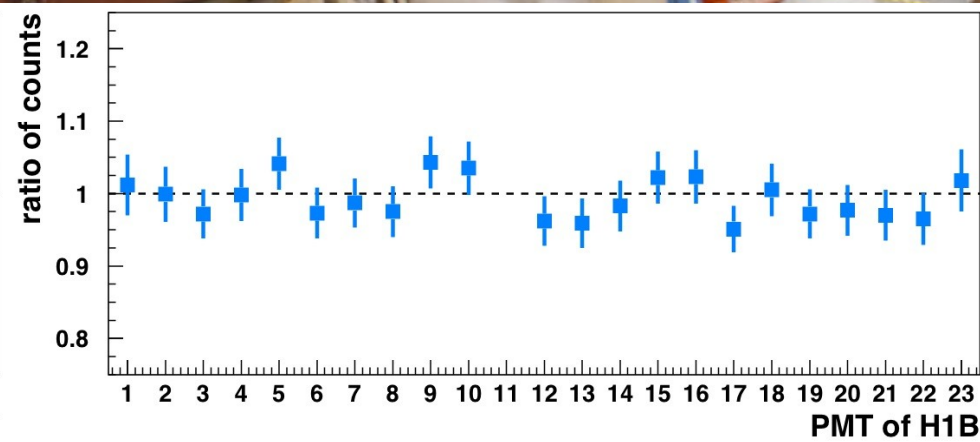
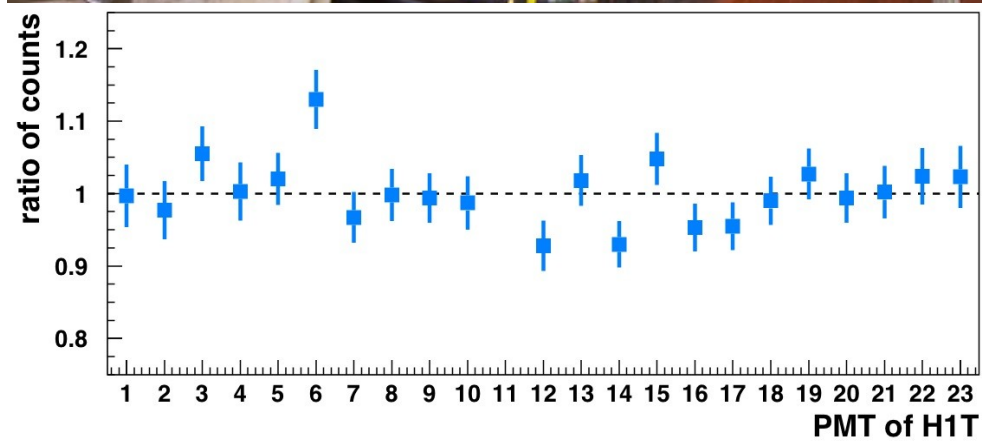
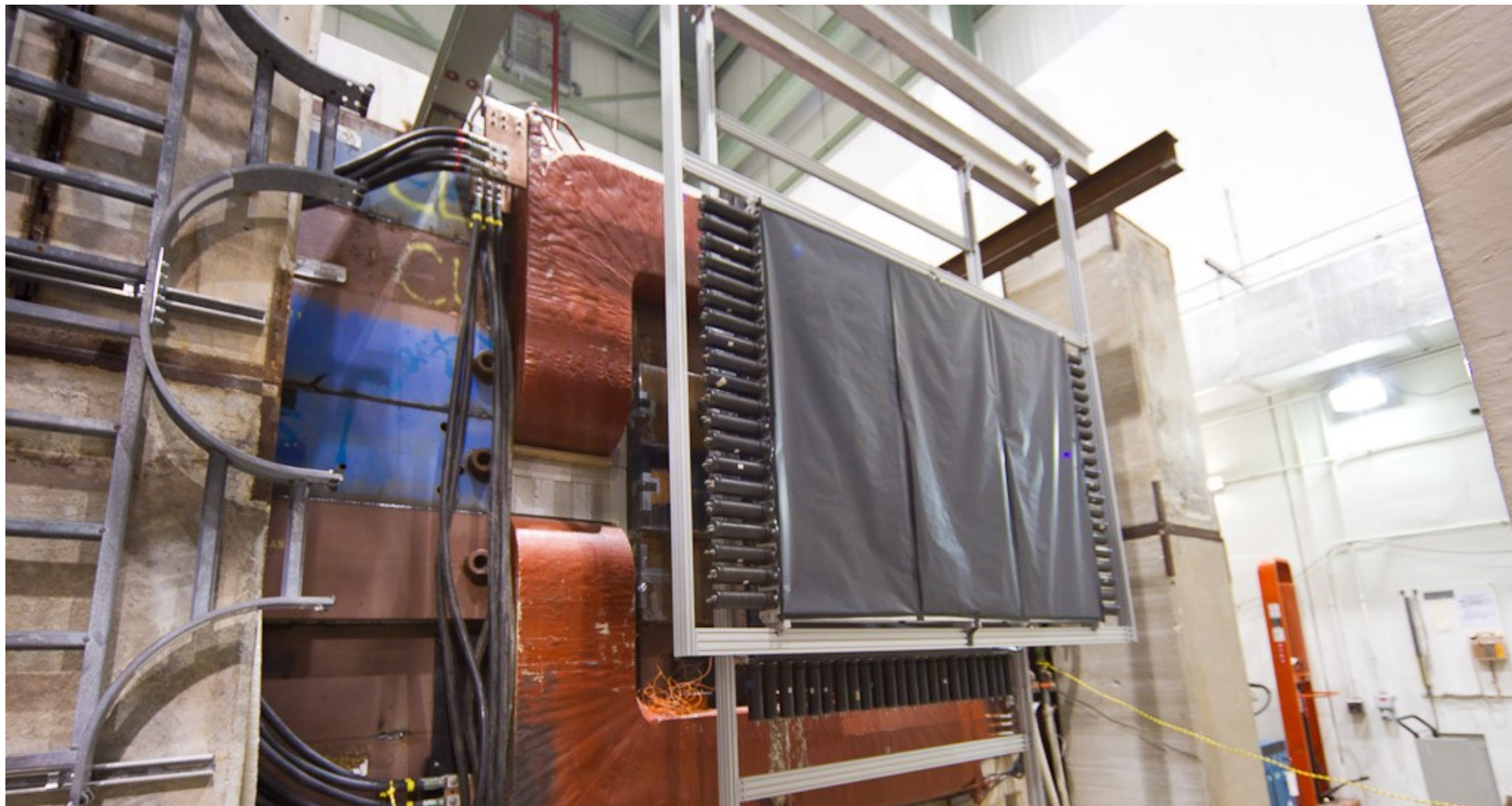












# SeaQuest DAQ

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













# The SeaQuest mission

- work on radiation shielding
- work on wire chambers installation
- **tuned beam hoped for end of June**
- commissioning of the experiment
- **data taking until shutdown**
- **continue data taking after shutdown**
- exciting extensions possible