Status of the measurement of the flavor dependence of light-quark sea in the SeaQuest experiment

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Representing the SeaQuest Collaboration

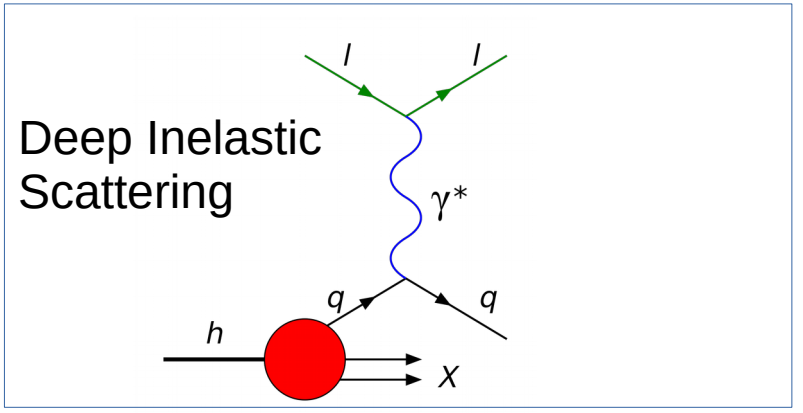
SeaQuest
E906

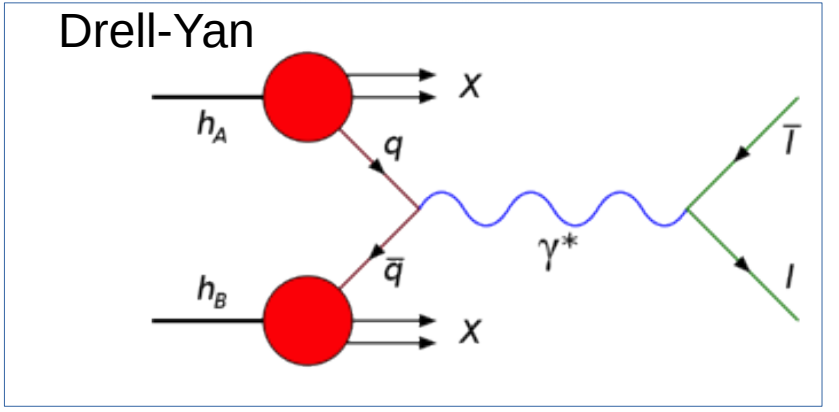
Outline

- The Drell-Yan process
- Flavor asymmetry of the nucleon sea
- SeaQuest experiment
- Status of D_2/H_2 cross section ratio (new!)

Drell-Yan process

- Related to DIS via crossing symmetry
- Provides information complementary to DIS
- Directly probes antiquarks

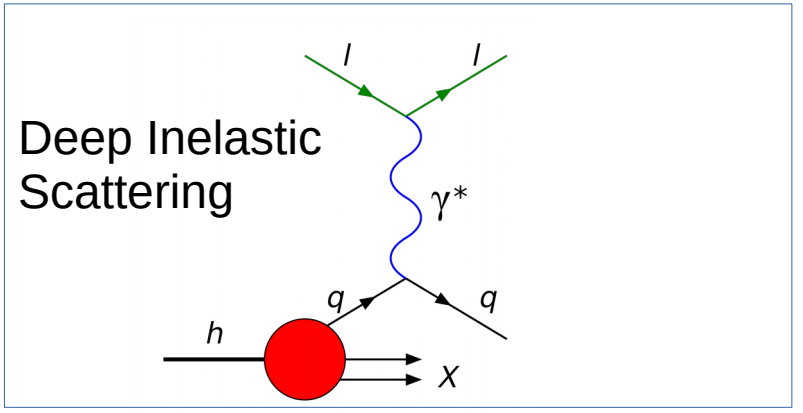


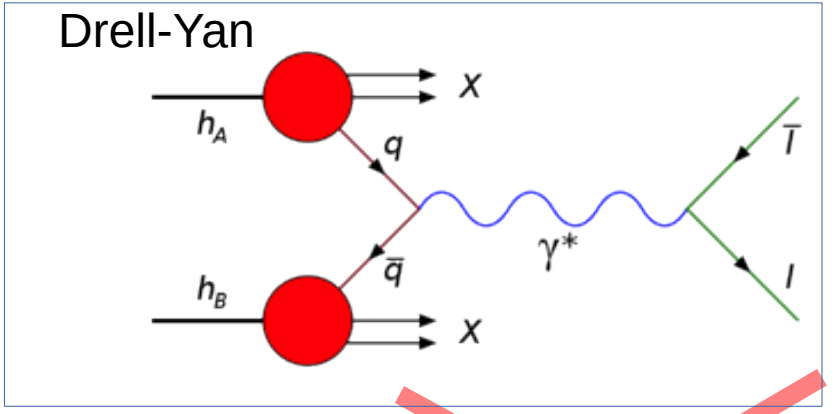


$$\frac{d^2\sigma_{DY}}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9sx_1x_2}\sum_i e_i^2[q_i(x_1)\bar{q}_i(x_2) + \bar{q}_i(x_1)q_i(x_2)]$$

Drell-Yan process

- Related to DIS via crossing symmetry
- Provides information complementary to DIS
- Directly probes antiquarks





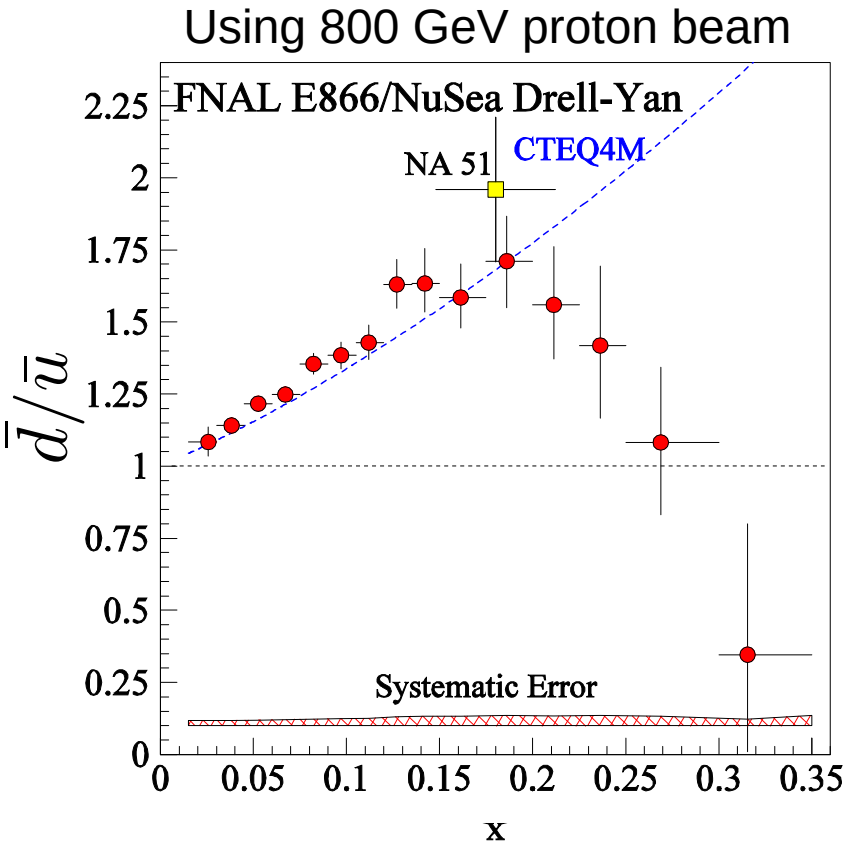
$$\frac{d^2\sigma_{DY}}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9sx_1x_2}\sum_i e_i^2[q_i(x_1)\bar{q}_i(x_2) + \bar{q}_i(x_1)q_i(x_2)]$$

Observation of flavor asymmetry of nucleon sea

- $\frac{\sigma_{pd}(x)}{2\sigma_{pp}(x)} \approx \frac{1}{2}\left(1 + \frac{\bar{d}(x)}{\bar{u}(x)}\right)$

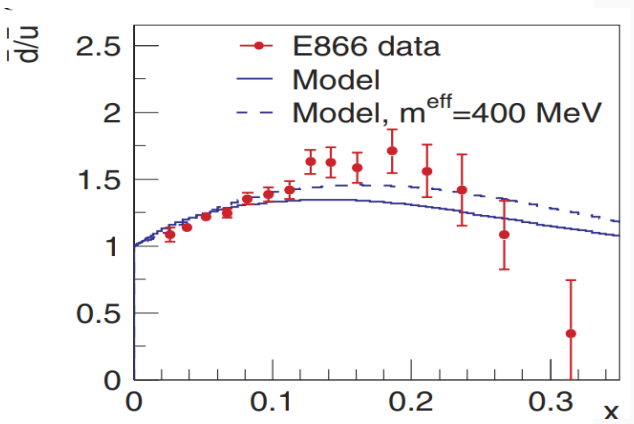
$x_F >> 0$

- Significant deviation of $\bar{d}/\bar{u}$ from 1
- Asymmetry has a strong dependence on *x*
- Can *x* dependence be explained?



Possible explanations

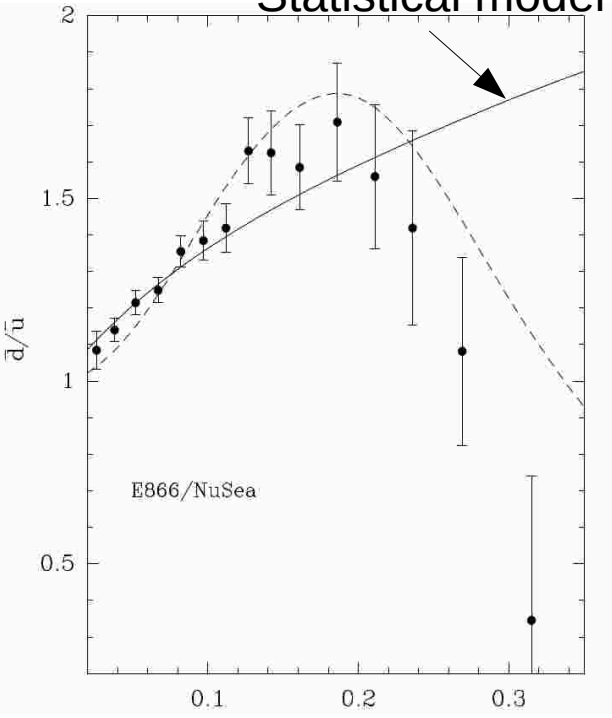
- Pion Cloud model
- Chiral Quark model
- Statistical Model
- Rise at low x well explained
- None explain drop at high *x*
- Need more accurate measurement at high *x*



Meson Cloud Model with physical pion mass and floating pion mass (dashed)

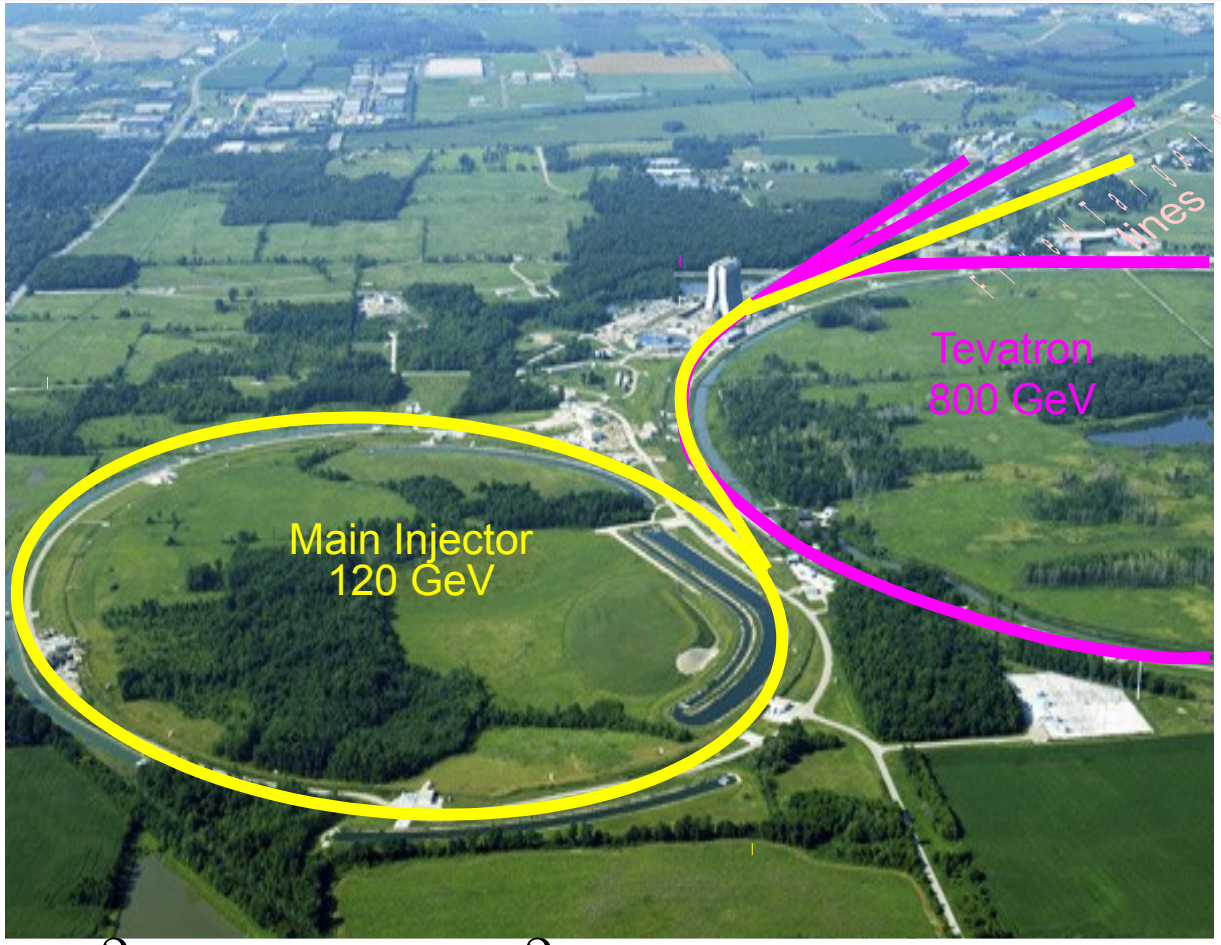
J. Alwall and G. Ingelman.
PRD, 71:094015, 2005.

Statistical model



Dashed line: global fit to data

Bourrely, Soffer, Buccella.
Eur. Phys. J. C 23, 487–501 (2002)



SeaQuest
E906

- 120 GeV proton beam
- Completely new detector apparatus
- ~10x instantaneous intensity

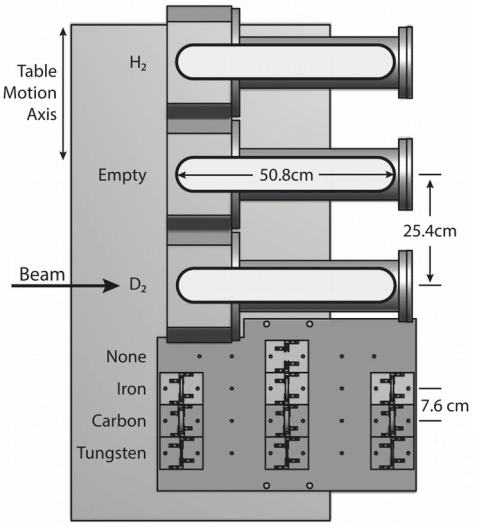
$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9sx_1x_2} \sum_i e_i^2 [q_i(x_1)\bar{q}_i(x_2) + \bar{q}_i(x_1)q_i(x_2)]$$

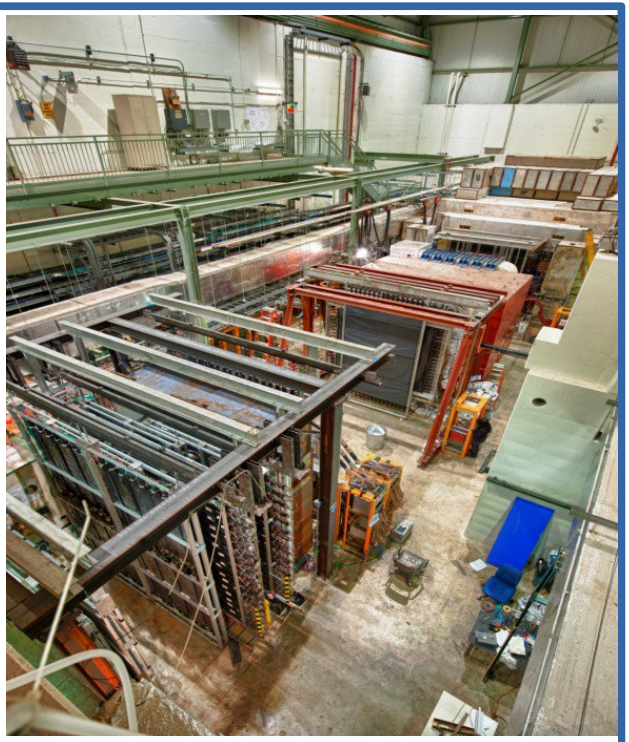
Fermilab E906/SeaQuest Collaboration

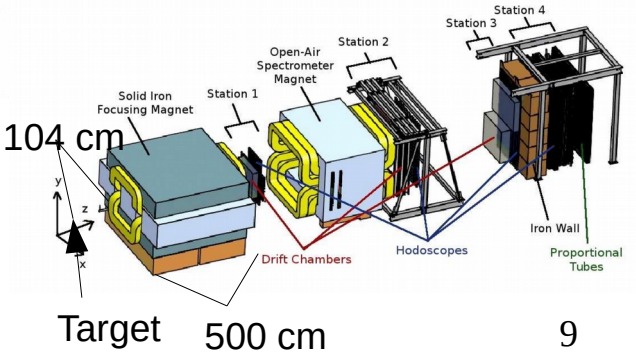
- Abilene Christian University
- Academia Sinica
- Argonne National Laboratory
- University of Colorado
- Fermi National Accelerator Laboratory
- University of Illinois
- KEK
- Los Alamos National Laboratory
- Mississippi State University
- University of Maryland
- University of Michigan
- National Kaohsiung Normal University
- RIKEN
- Rutgers, The State University of New Jersey
- Tokyo Tech
- Yamagata University

E906 Apparatus

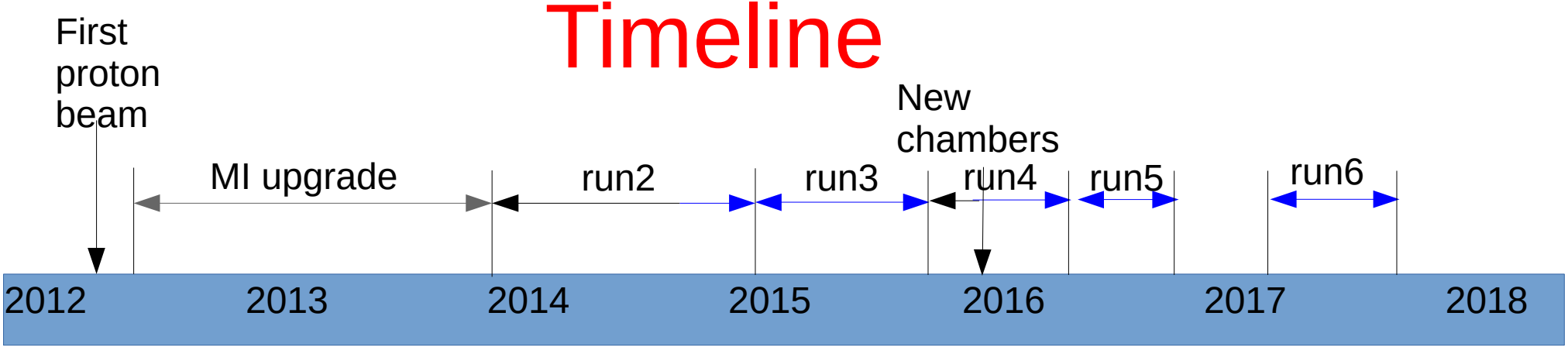
- 120 GeV proton beam on LH_2, LD_2 targets
- New beamline
- New apparatus
- Forward spectrometer ($x_F > 0$)
- Focusing magnet to bend tracks to spectrometer
- Spectrometer magnet to measure momentum of tracks



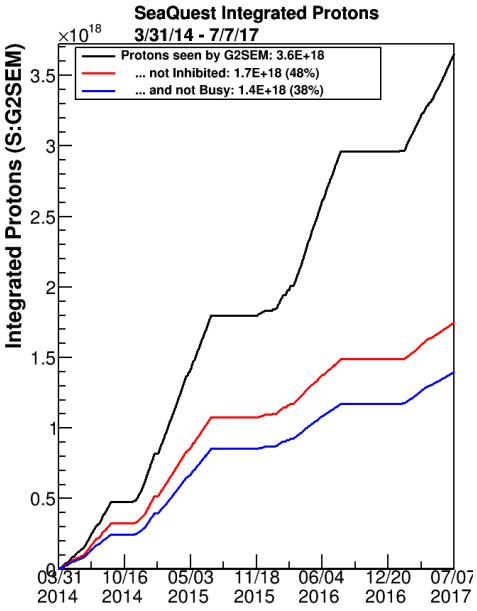




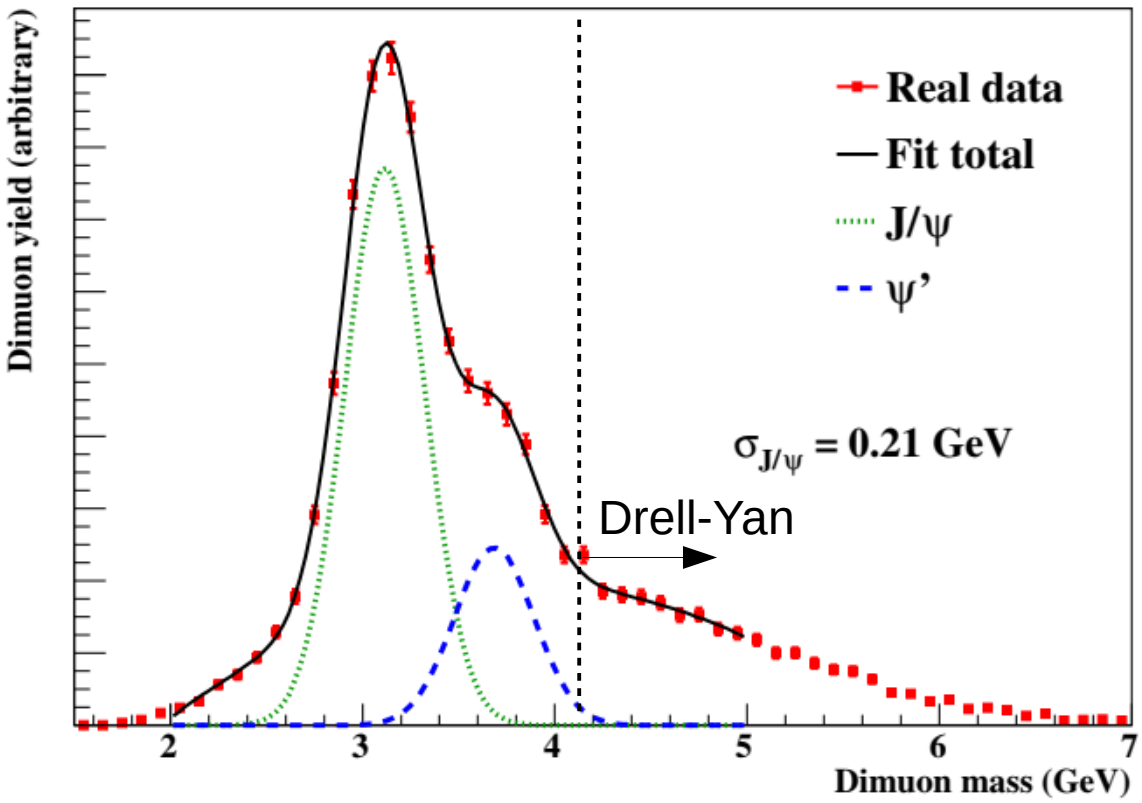
Timeline



- After extensive efforts from 2012, data collection finished in July 2017
- Analysis based on run2 and run3 data



Dimuon mass distribution after event selection

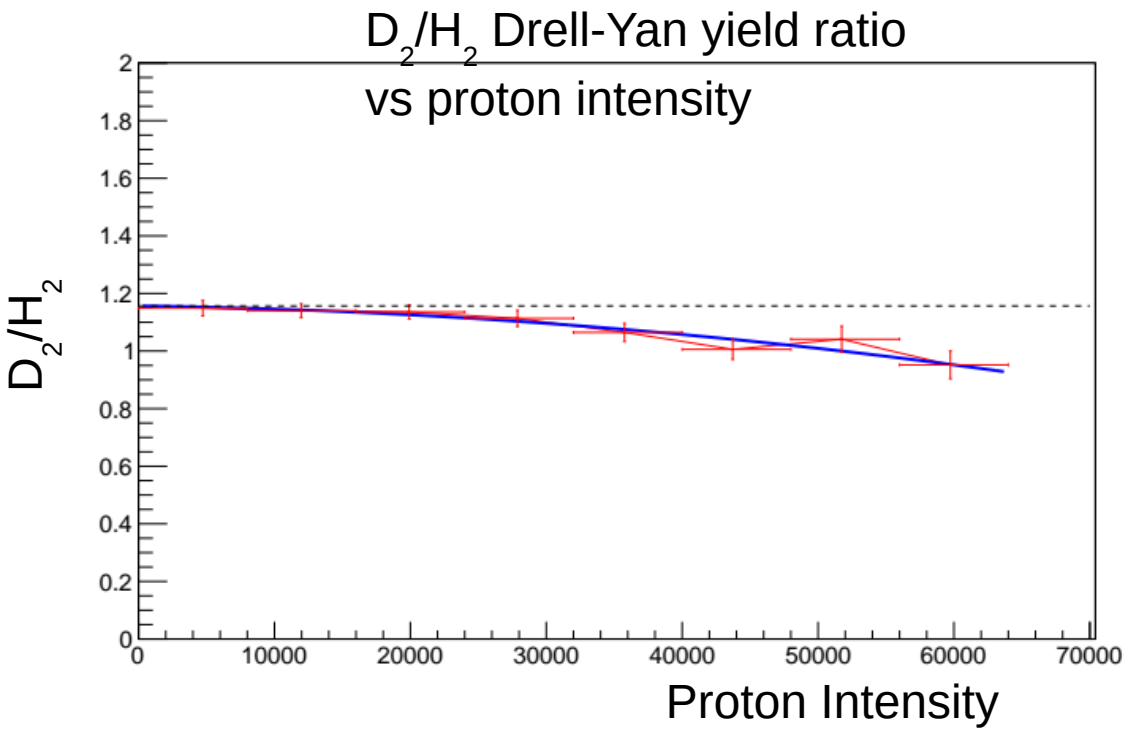


- Analysis cuts designed to select dimuons originating from the target
- Able to resolve J/Ψ and Ψ'
- By applying a cut of mass > 4.2 GeV we can effectively remove J/Ψ and Ψ'

Accidental background

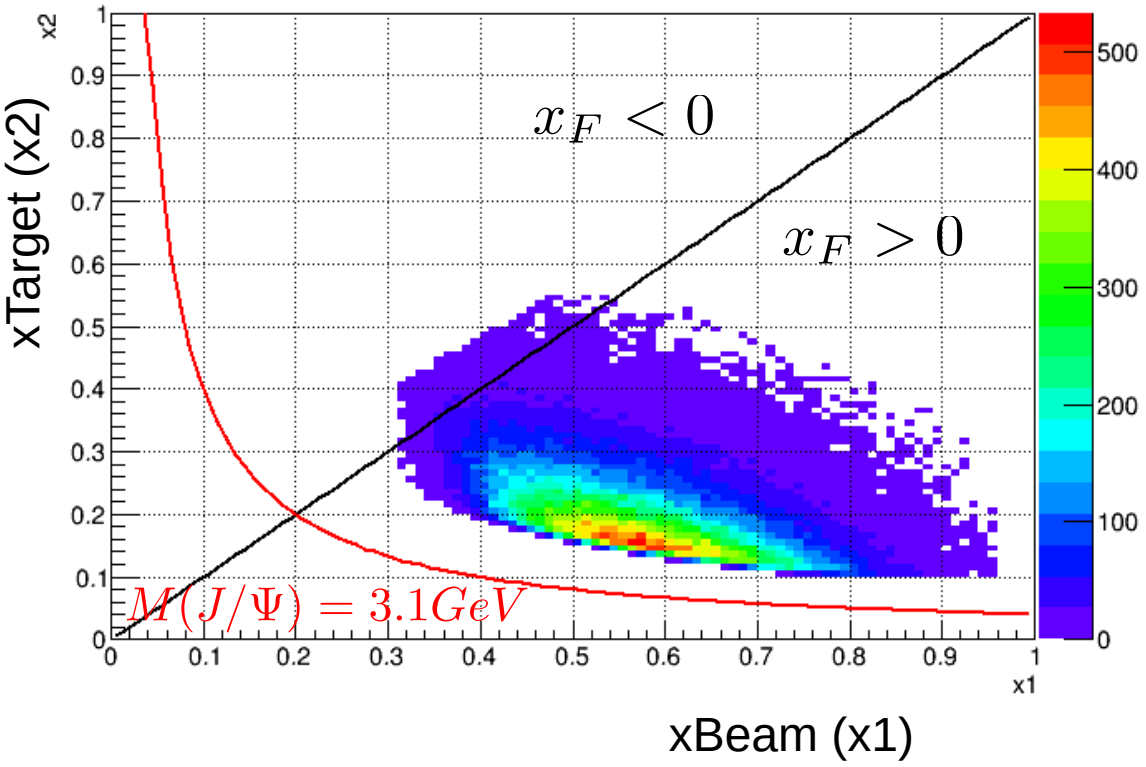
- To get high statistics we run at high intensity ~1e12 protons/ second
- Accidental events: from coincidence of two single muons such as from pion or kaon decay
- Signal event rate: proportional to intensity linearly
- Accidental event rate: proportional to intensity squared or higher

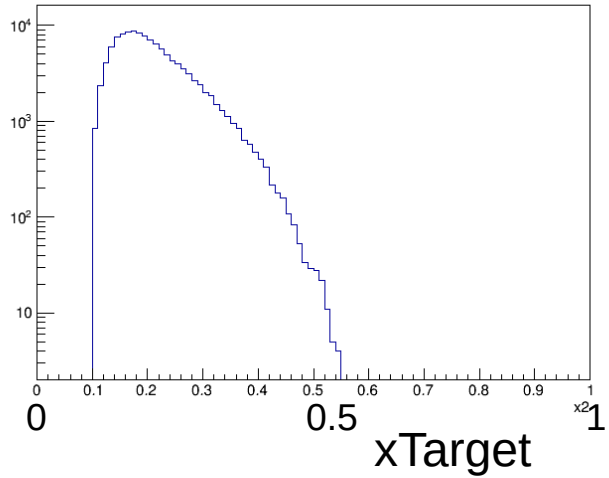
D_2/H_2 cross section ratio from intensity extrapolation method

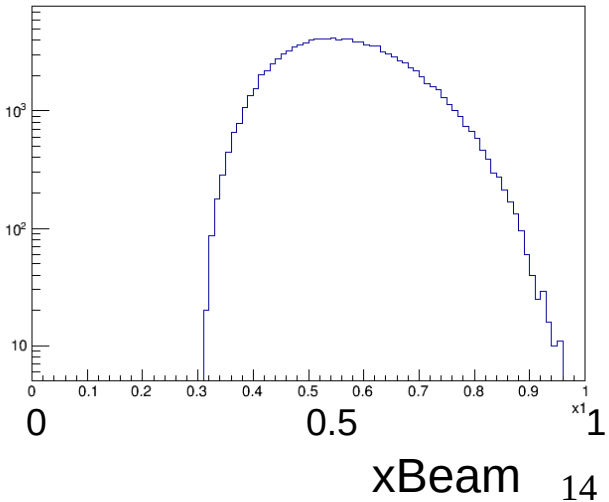


- By extrapolating the normalized D_2/H_2 D-Y yields ratio to zero intensity, all forms of rate dependence can be removed
- The intercept gives the D_2/H_2 cross section ratio

Splitting the data into x_2 bins

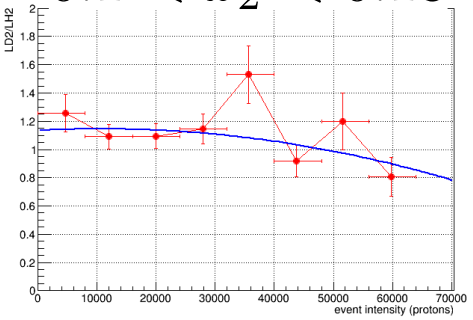




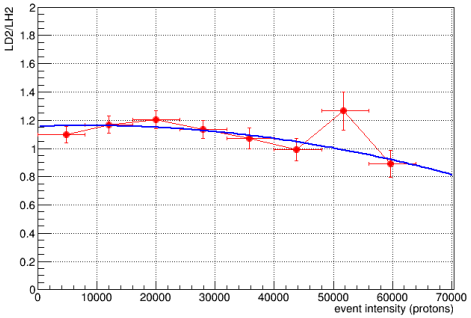


D_2/H_2 cross section ratio from intensity extrapolation method

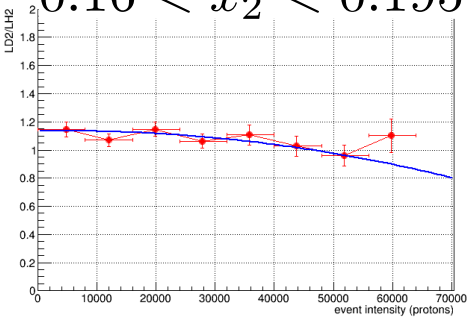
$0.1 < x_2 < 0.13$



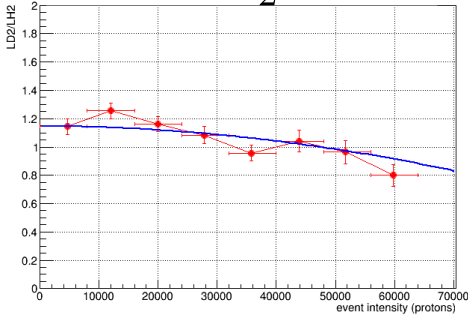
$0.13 < x_2 < 0.16$



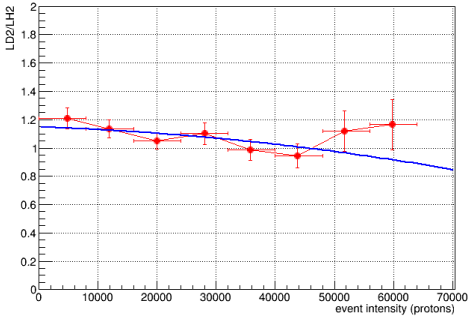
$0.16 < x_2 < 0.195$



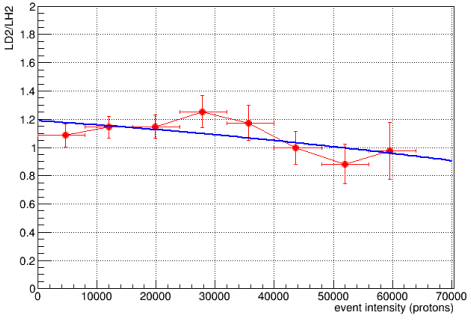
$0.195 < x_2 < 0.24$



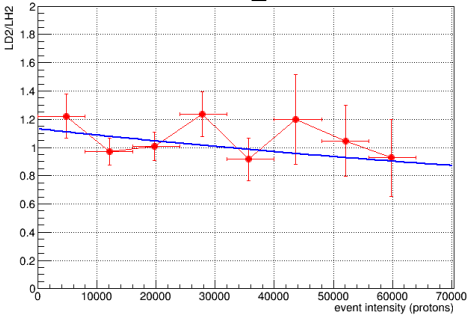
$0.24 < x_2 < 0.29$



$0.29 < x_2 < 0.35$



$0.35 < x_2 < 0.45$

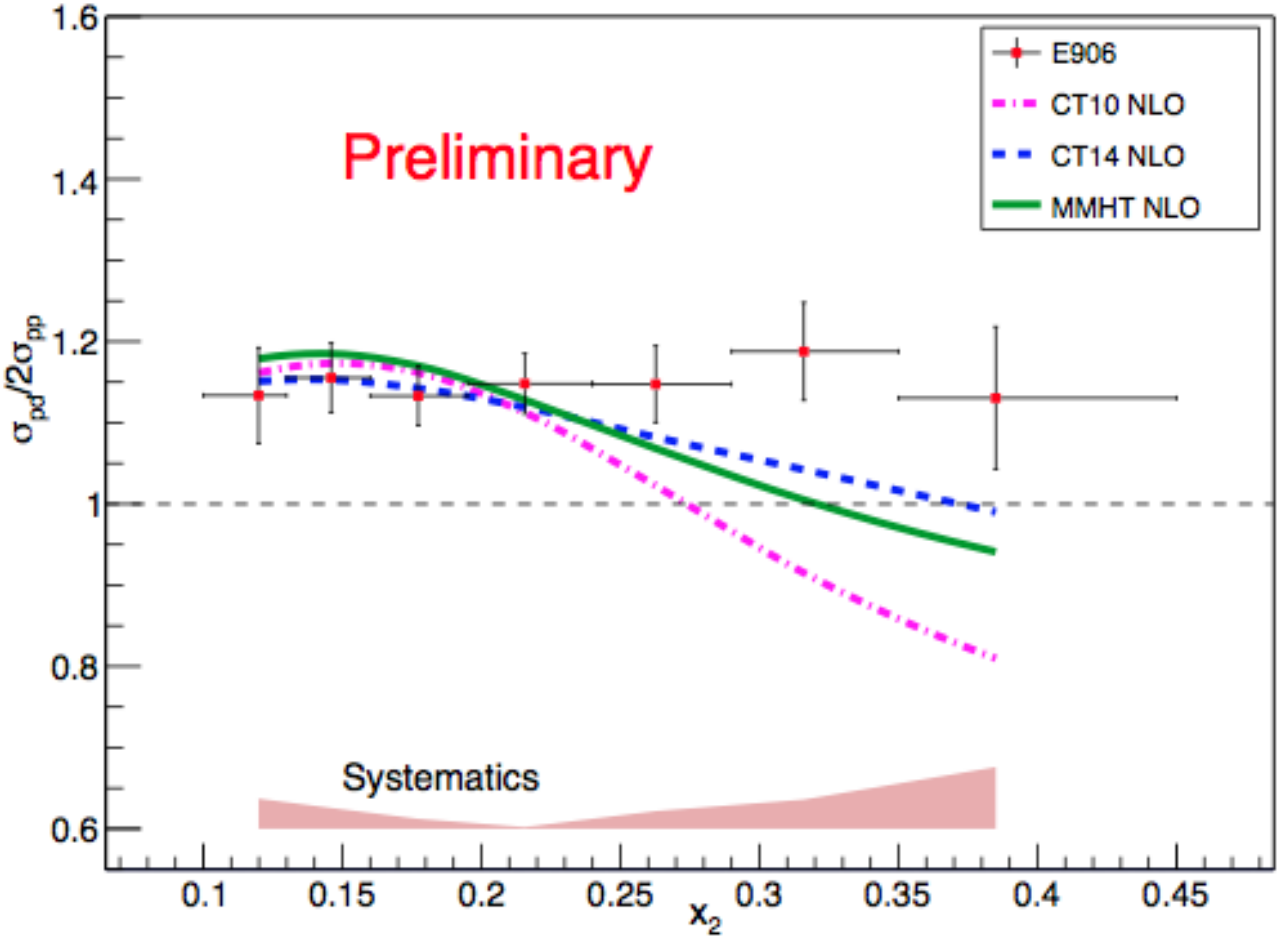


- The intercept gives the D_2/H_2 cross section ratio

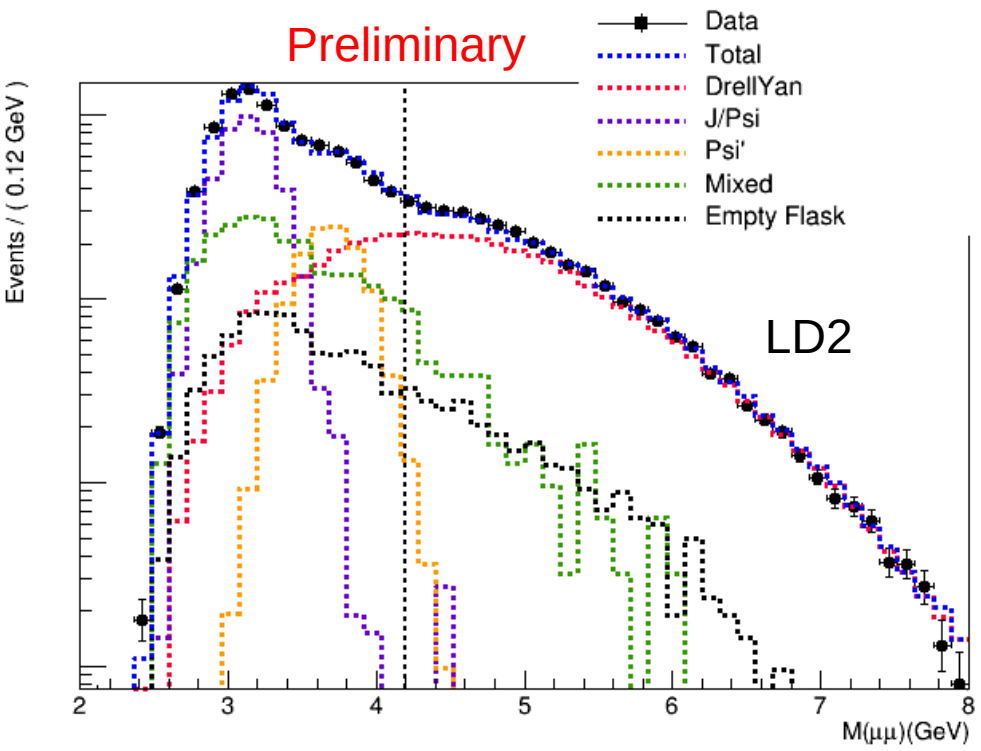
Systematics

- Extrapolation functional fit
- Negligible
  - Choice of intensity binning and range
  - Target contamination
  - Empty flask subtraction
  - Target length
  - Beam intensity
  - $J/\Psi, \Psi'$ tail contamination
  - Event selection cuts

Drell-Yan cross section ratio



Cross check with the mass fit



- Performing a component fit to the mass spectrum
- Use Monte Carlo for signal events $(J/\Psi, \Psi', DY)$
- Use mixed single track events for accidental background
- Compute D-Y cross section for individual targets
- Preliminary D-Y results show consistent D_2/H_2 ratios

Summary

- SeaQuest data collection completed July 2017
- New extraction of D-Y D_2/H_2 as a function of *x* from 0.1 to 0.45
- New cross section ratio result includes removal of accidental background
- Independent mass-fit method shows consistent D_2/H_2 ratio
- Extraction of $\bar{d}/\bar{u}$ ratio from D_2/H_2 ratio is underway
- Inclusion of data from after 2016 is underway

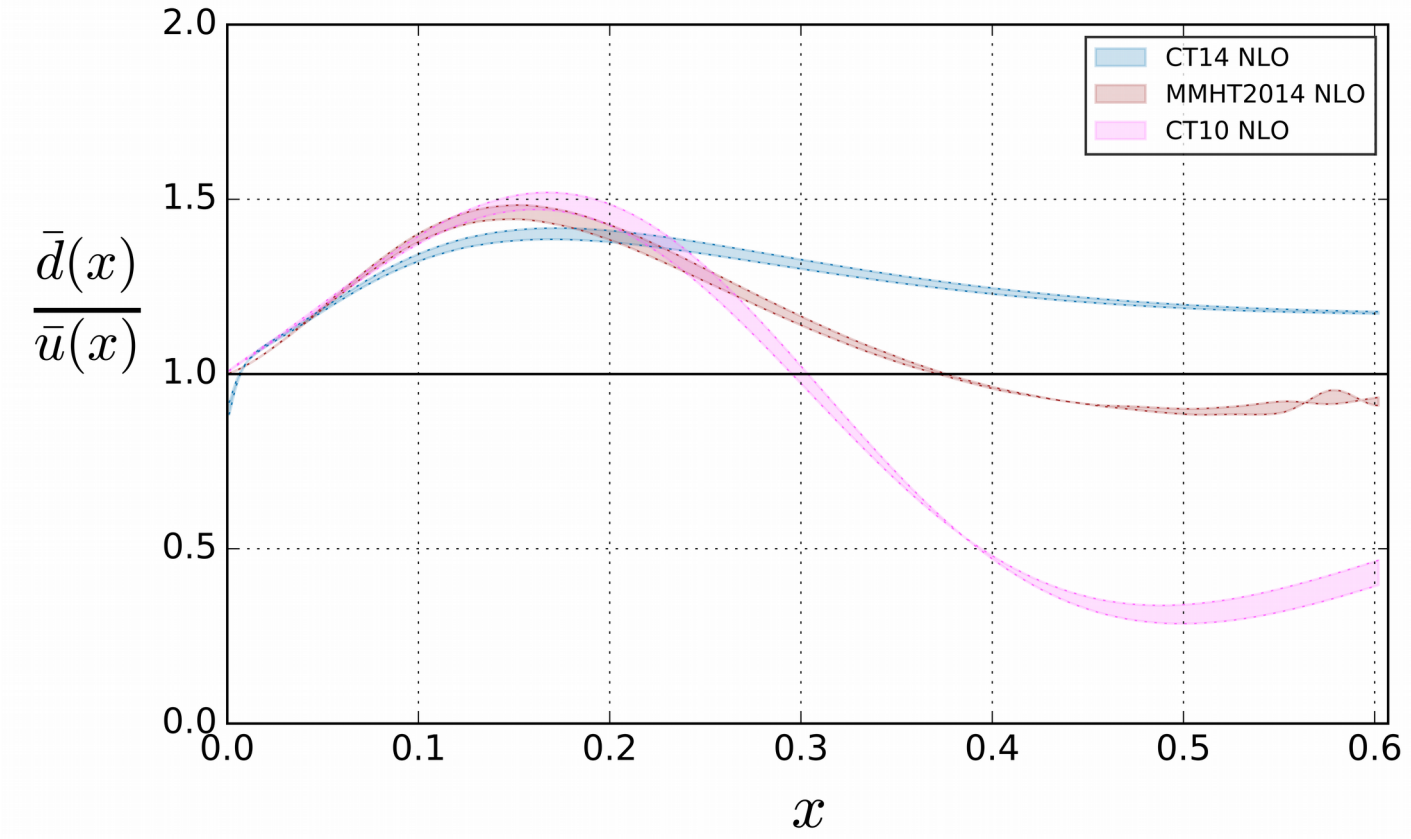
Backup slides

Fit functional form

- For each x2 bin I, the fit function is of the form

$$f_i(Int) = p0_i + (p10 + p11 \cdot x_2)Int + (p20 + p21 \cdot x_2)Int^2$$

$\bar{d}/\bar{u}$ PDFs



- Q between 4.2 and 8.7 GeV

E906 vs E866

- E866 and E906 have different
  - Beam energy (800 vs 120 GeV)
  - Acceptance
  - x_1 distributions
- E886 systematics <1% and not shown