ν Scattering from Hydrogen and Deuterium -
What we can *still* learn?

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What we can *still* learn from ν data with deuterium and hydrogen.

1) Precise flavor and valence/sea separations of parton distributions.

2) Charge symmetry violations at partonic level (provide partial resolution of NuTeV anomaly).

3) Paschos-Wolfenstein ratio determination of weak mixing angle (ala NuTeV) with simplest isoscalar target, Deuterium.

- No hydrogen/deuterium target experiments since bubble chamber experiments.
- High intensity beams to allow studies not possible in bubble chamber era.
- Precise free proton measurements provide critical constraint to separate nuclear effects from nucleon structure in nuclear target measurements.

d/u with hydrogen target

$$\frac{d^2\sigma^{\nu}}{d^2\sigma^{\bar{\nu}}}(x,y) \sim \frac{d(x)}{u(x)} \cdot \frac{1}{(1-y)^2}$$

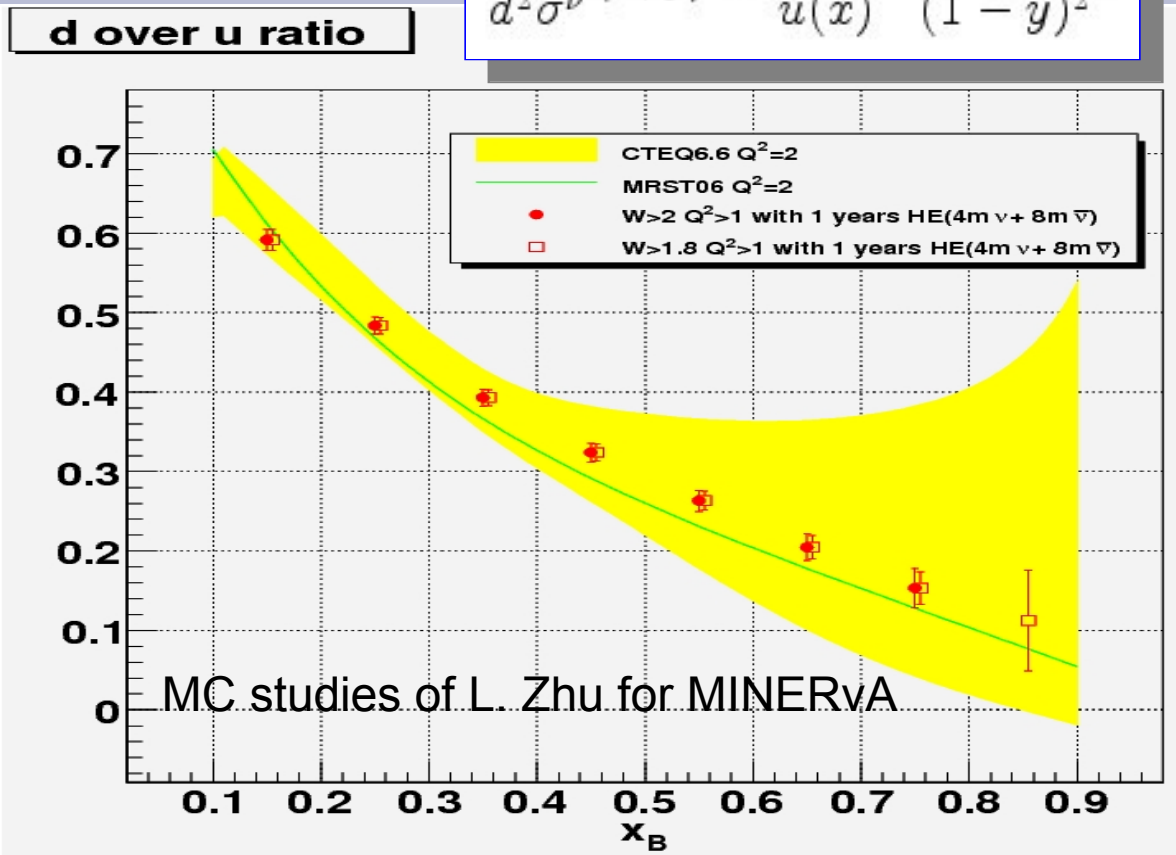
Statistical uncertainties Estimated with:

→ Minerva cryotarget and Acceptance.

→ Subtraction of empty target background.

→ High Energy NuMI tune.

→ ~1 year running.



Statistical precision and kinematic reach to large *x* improves with

1. **higher intensity**
2. **higher neutrino energies**

Charge symmetry violations

Complimentary ways to determine from ν beam:

1. Proton target:

   Compare ν-p flavor separations to F_{2n}/F_{2p} from electron scattering

2. Deuterium target:

   ν / νbar ratio provides direct measure of CSVs.

#2. Requires few percent determination of ν and νbar flux.
e.g. elastic ν–e – see previous talk
(Currently being studied by MINERνA)

Sensitivity to charge symmetry violations

1. Hydrogen determination:

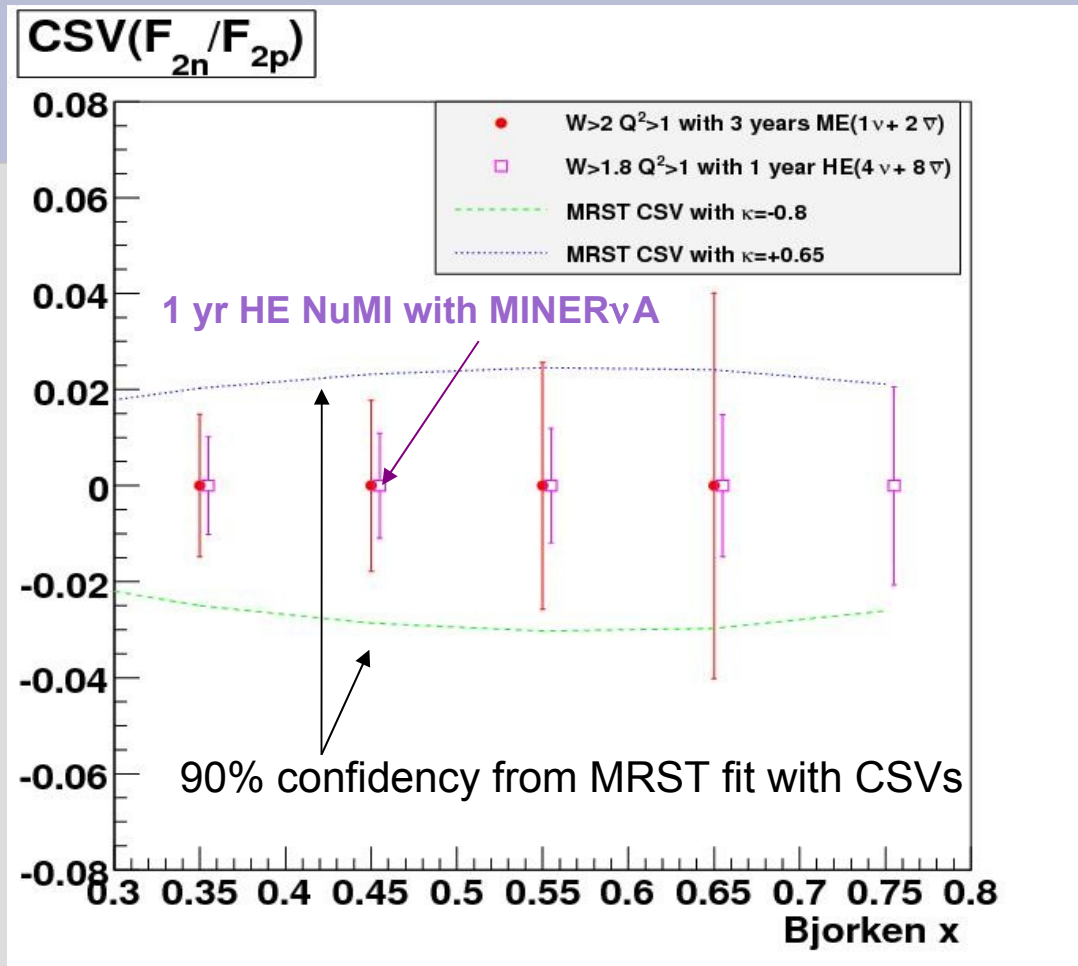
$$\mathrm{CSV}(F_{2n}/F_{2p}) = \frac{F_{2n}}{F_{2p}} - \frac{4d_p+u_p}{4u_p+d_p}$$

From JLab BoNuS — From ν-p

2. Deuterium determination:

$$u_p - d_n = -(d_p - u_n) \equiv \delta(x)$$

$$2\delta(x)/[u(x)+d(x)] \sim 1-(1-y)^2\frac{d^2\sigma^{\nu D}}{d^2\sigma^{\bar{\nu} D}}$$



→ Deuterium comes from single experiment, but need well determined flux
→ Full power comes from including in PDF fits.

Summary

⟶ high intensity ν beam on H_2 + D_2 targets could provide:

1. nucleon partonic structure (including possible CSV effects) and

2. weak mixing angle measurement.

Within a *single* experiment

⟶ ***Ideal*** **detector would be bubble chamber with Muon tagger and calorimetry downstream.**

Backup

$\nu\ e \rightarrow \nu\ e$ as a Standard (Model) Candle

* Only involves fermions and is well calculable in SM

* The differential cross section in $T = KE_e$ at tree level is

$$\frac{d\sigma}{dT} = \frac{2G_F^2 m_{e^2}}{\pi}\left(a^2 + b^2 - 2b^2\frac{T}{E_\nu} + b^2\left(\frac{T}{E_\nu}\right)^2 - abm_e\frac{T}{E_\nu^2}\right)$$

$< 10^{-3}$

With

	ν	νbar
a	$(\frac{1}{2} - s^2)$	$-s^2$
b	$-s^2$	$(\frac{1}{2}-s^2)$

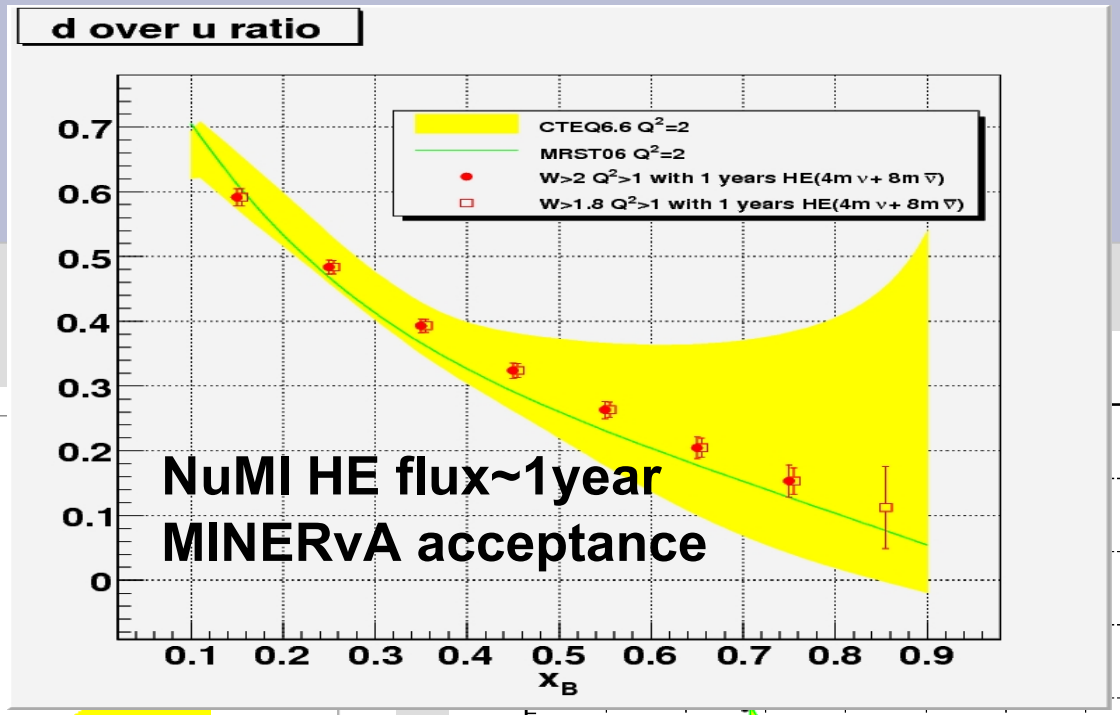
$s^2 = \sin^2(\theta_W) \sim 0.23 \sim 1/4$

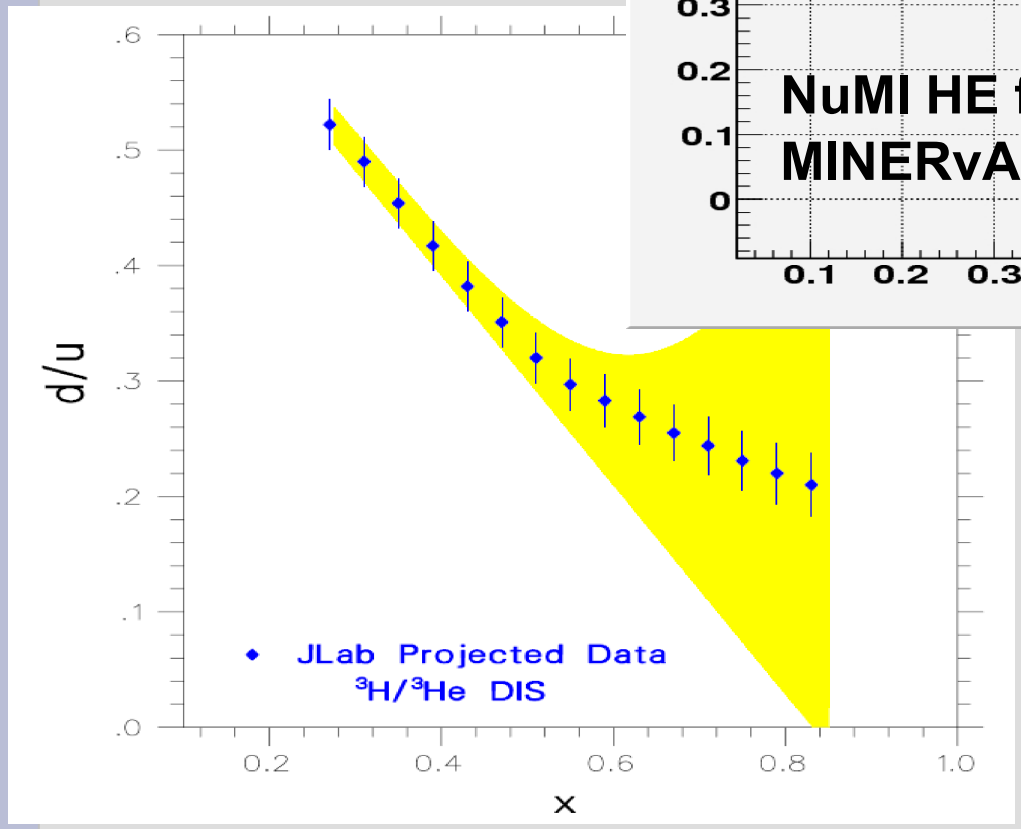
and $(a^2 + b^2)_\nu = (a^2 + b^2)_{\nu\text{bar}} \sim 1/8, \qquad -ab \sim 1/16$

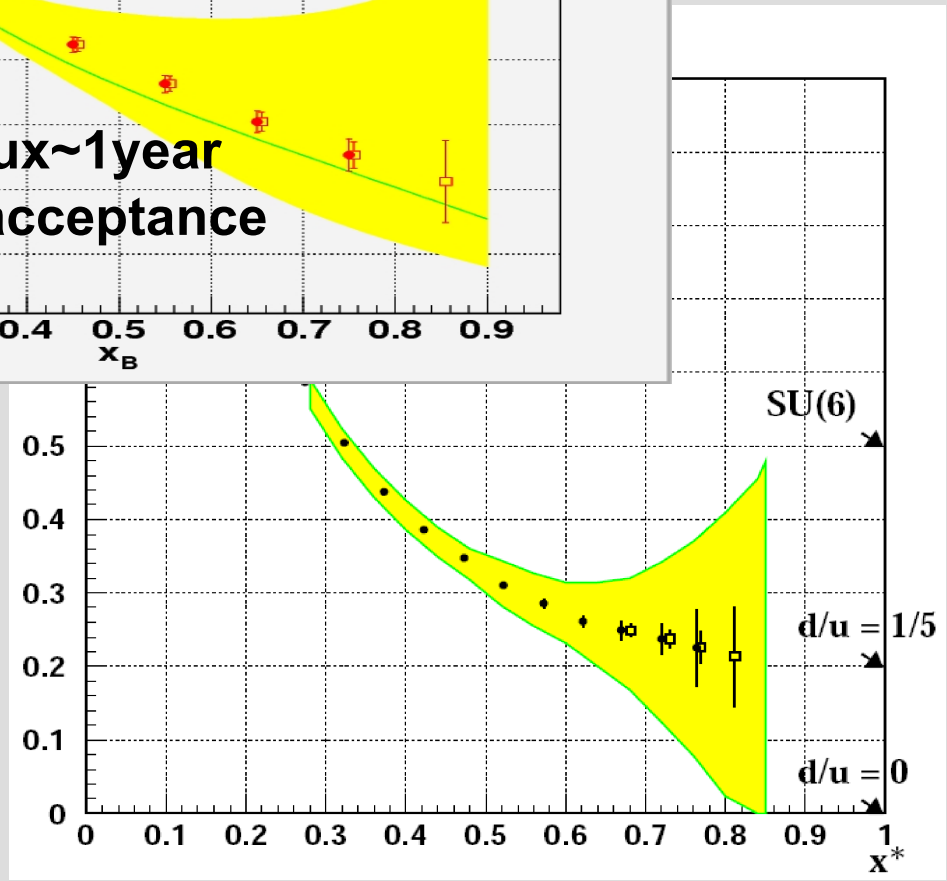
Measured Known Flux to be determined

$$\frac{dN}{dT} = \int dE_\nu \frac{d\sigma}{dT}(T, E_\nu) \cdot \frac{dS}{dE_\nu}(E_\nu)$$

Complementary d/u measurements







MARATHON with A=3 H and He @ 12 Gev

BONUS @ 12 Gev