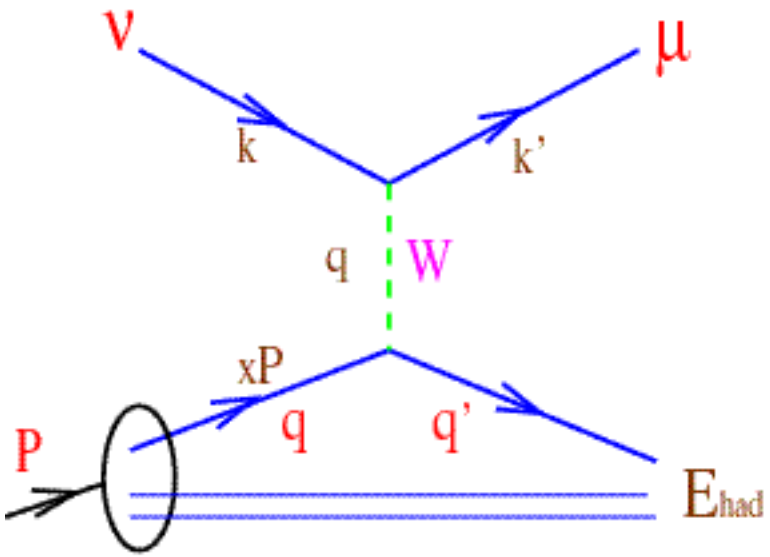
Neutrino Scattering Kinematics



3 indep. kinematic variables

$Q^2 = -q^2 = -(k-k')^2$

(four momentum transfer)

$x = Q^2 / 2ME_{had}$

(fractional quark momentum)

$y = E_{had}/E_k$

(inelasticity)

Measure θ_μ p_μ E_{had}

Derive $k=E_\nu$, Q^2 ,x,y

y is related to cm scattering angle

Overview of Structure Functions and Parton Distributions

H. Schellman et al.

10^{20} negative muons per gr/cm^2 of target (~10 cm H_2, 150 μm Fe)

Acceptance is quoted for a 50 cm radius fiducial volume

50 GeV muon beam

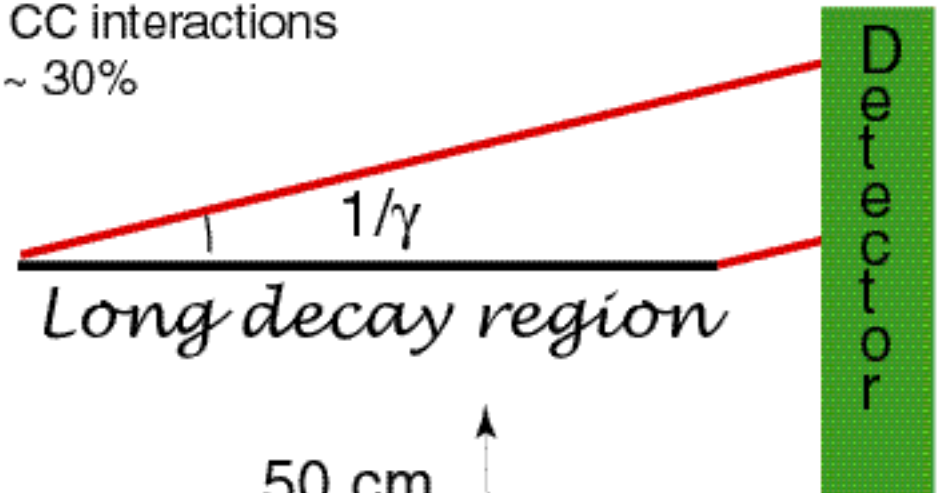
7M ν_μ interactions
3M anti-ν_e CC interactions
50% acceptance

250 GeV muon beam

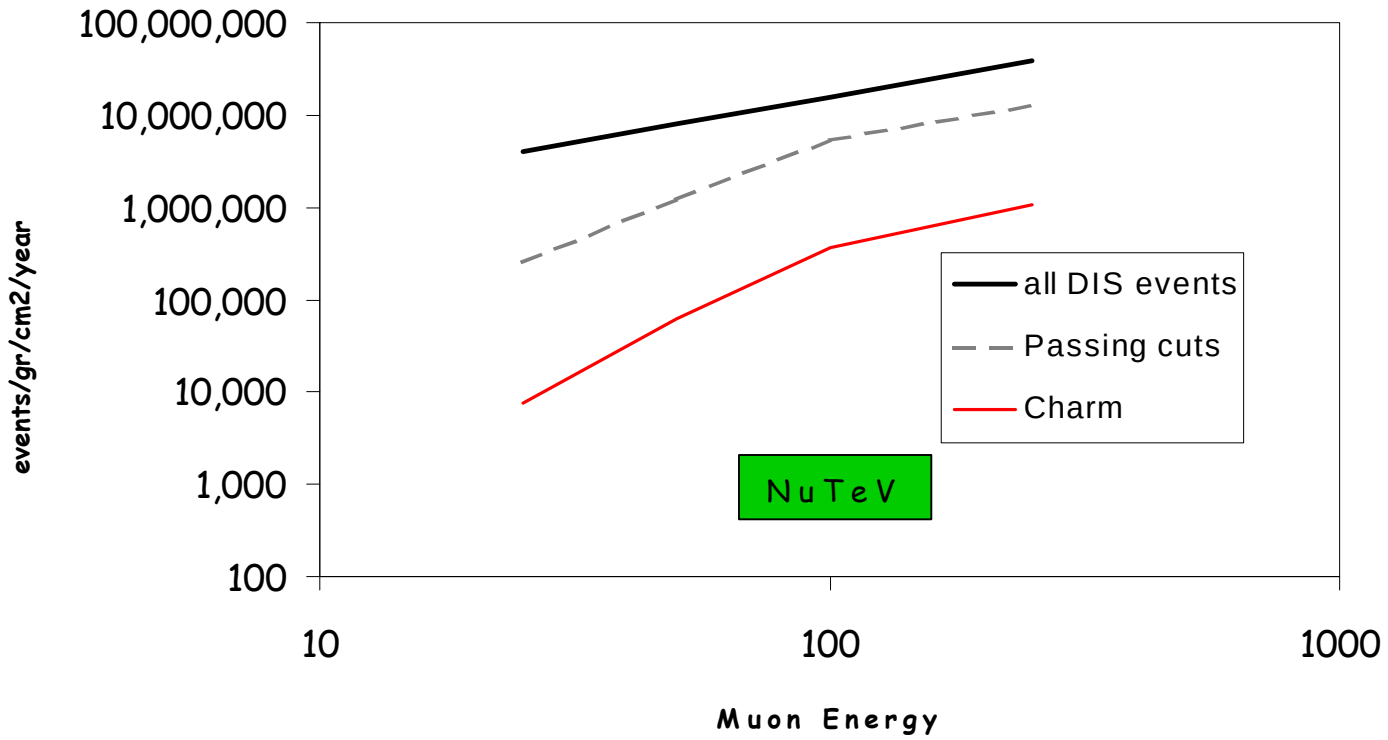
35M ν_μ CC interactions --> CCFR 10^{10} events/year
15.3M anti-ν_e CC interactions
acceptance ~ 70-95%

25 GeV muon beam

3.5M ν_μ CC interactions
1.5M anti-ν_e CC interactions
acceptance ~ 30%



Charged current event rates at near detectors

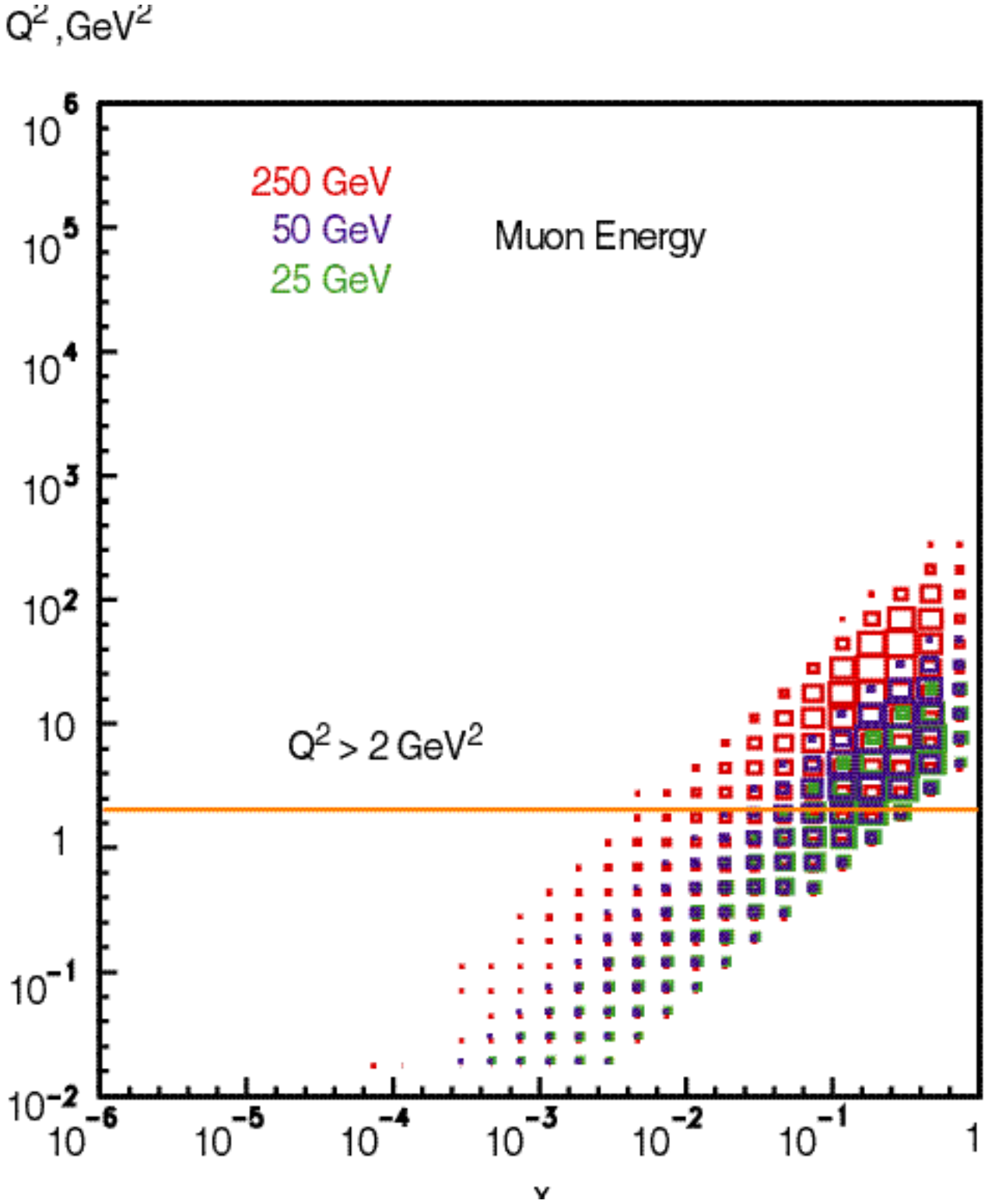


At 50 GeV, 7.9M events/gr/cm^2/year

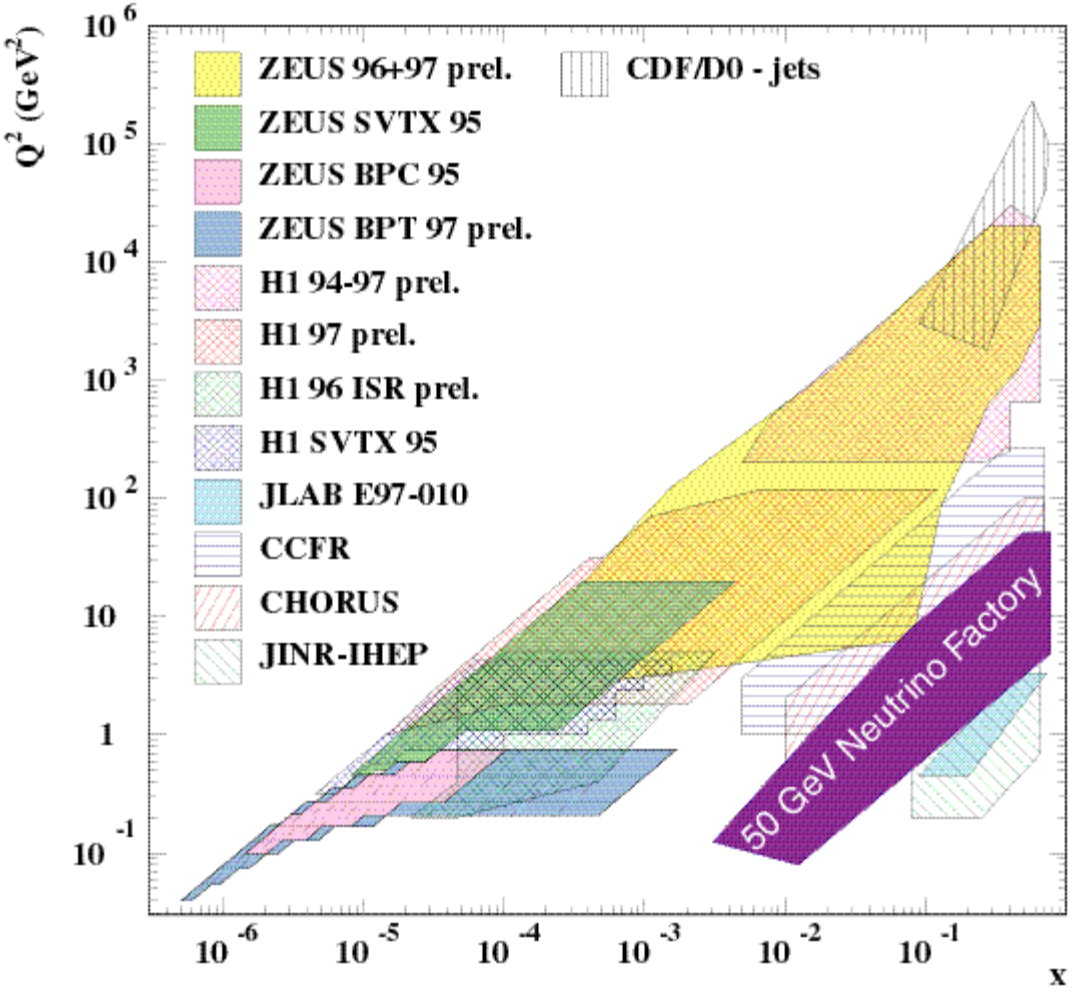
But only 22% are within 20 cm radius

(82% pass loose kinematic cuts)

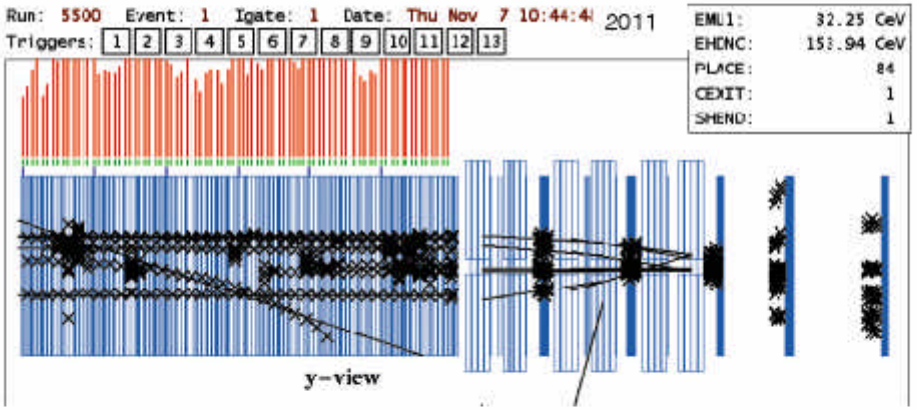
1000 times current experiments!


Q^2, GeV^2
250 GeV
50 GeV
25 GeV
Muon Energy
$Q^2 > 2\ GeV^2$
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x

Deep Inelastic Scattering Experiments



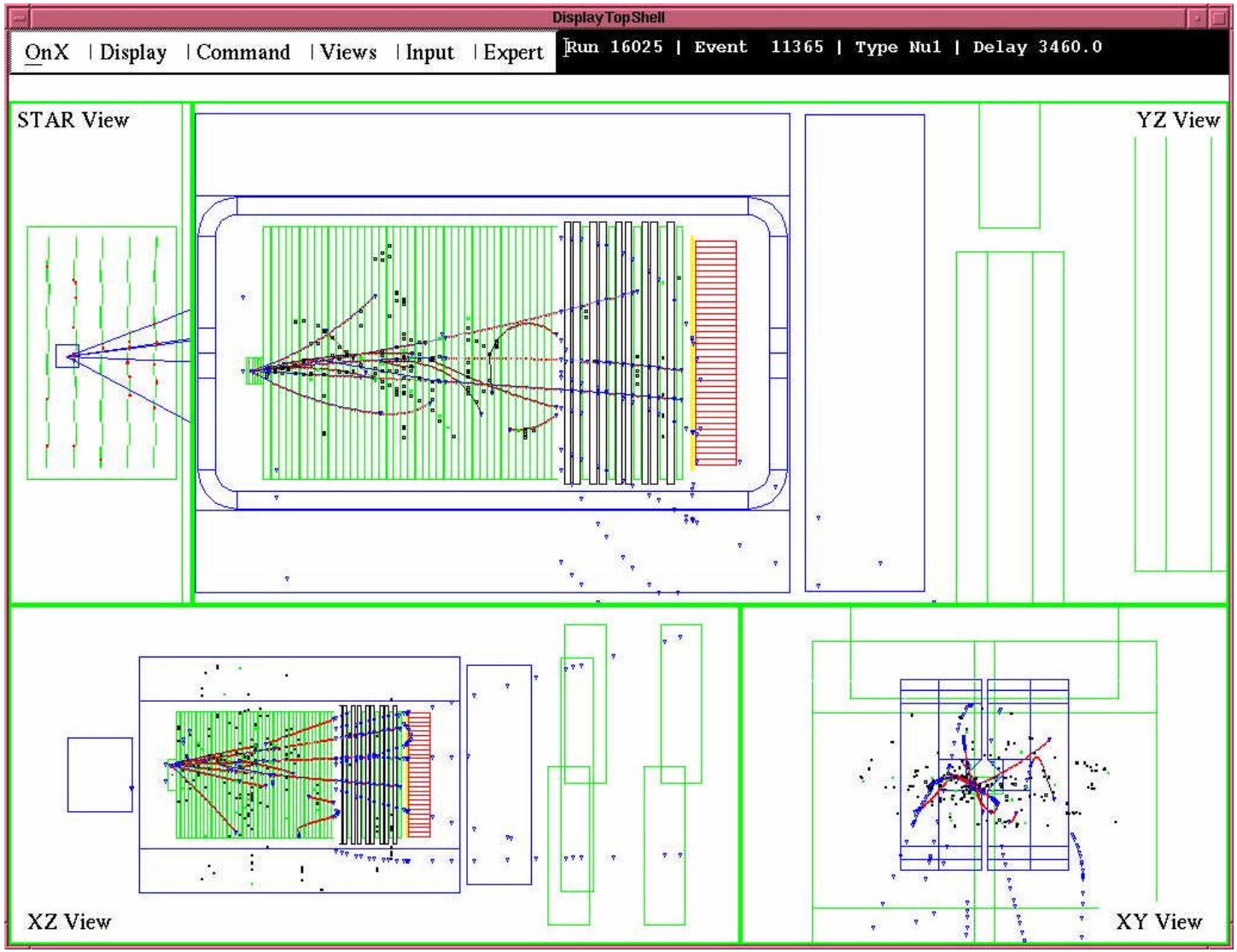
Event rate in 600 ton detector is
300 events per spill at
50 GeV machine 2×10^{20} μ/year



Harris/McFarland '97

Detector like NOMAD

10 kg targets in front of tracking/calorimetry



How do we measure quarks?

Charge Lepton DIS (HERA, E665,NMC, SMC)

Sensitive to charge only

$4/9\ (u+c+\bar{u}+\bar{c}) + 1/9\ (d+s+\bar{d}+\bar{s})$ on protons
$3/18\ (u + d + \bar{u} + \bar{d}) + 4/9\ (c+\bar{c}) + 1/9\ (s+\bar{s})$ on D_2

Drell Yan
Sensitive to products

$4/9\ (u\bar{u} + c\bar{c}) + 1/9\ (d\bar{d} + s\bar{s})$ for proton-proton

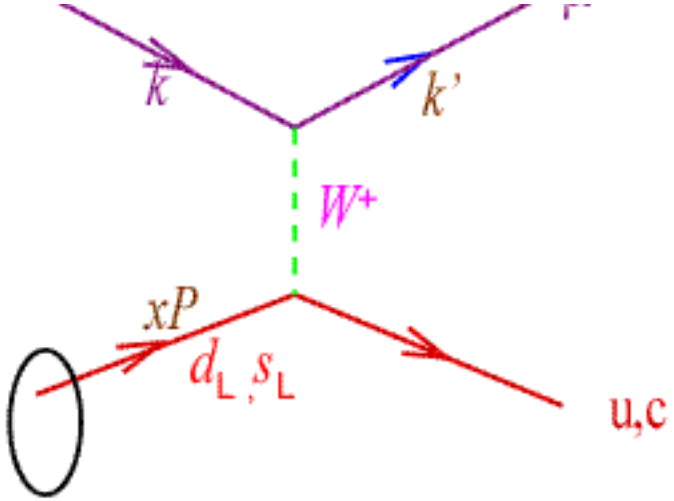
PPbar -> W

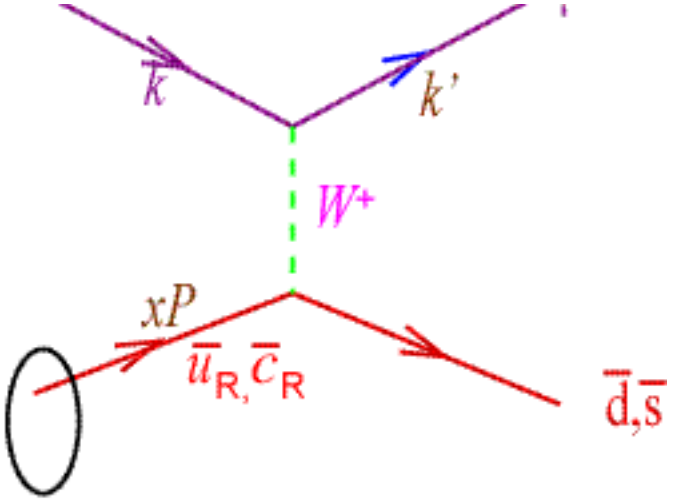
$ud + sd + cu \ldots$

PP -> W

$u\bar{d} + s\bar{d} + c\bar{u} \ldots$

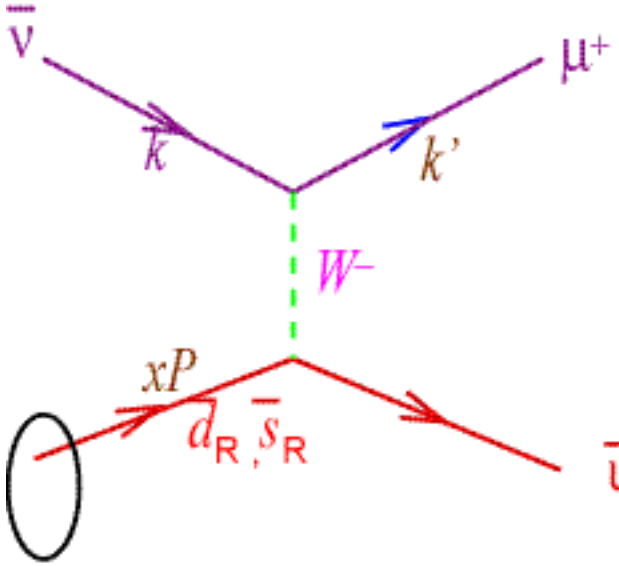
Only way to really get anti-quarks is processes with a W. Neutrinos, LHC, HERA at high Q^2



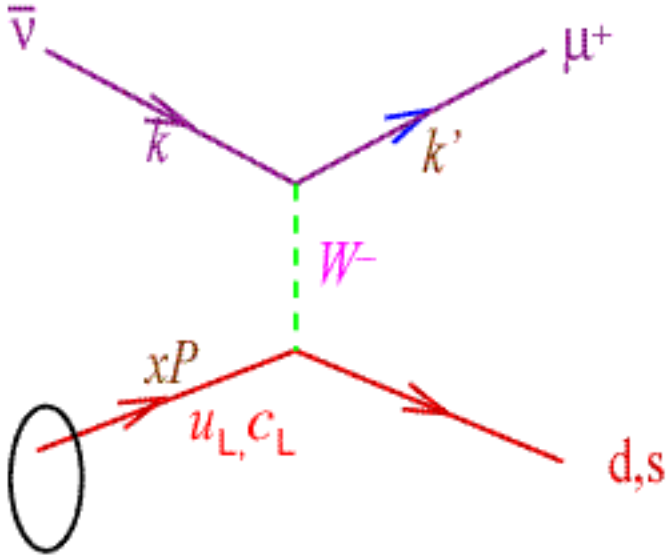


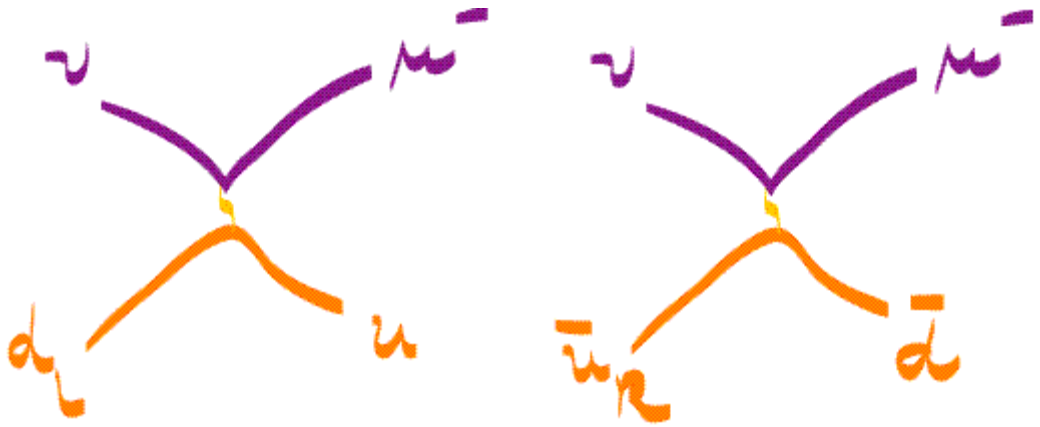
Neutrino Scattering only sees negative quarks
Can separate quark from anti-quark by helicity

S=1



S=0





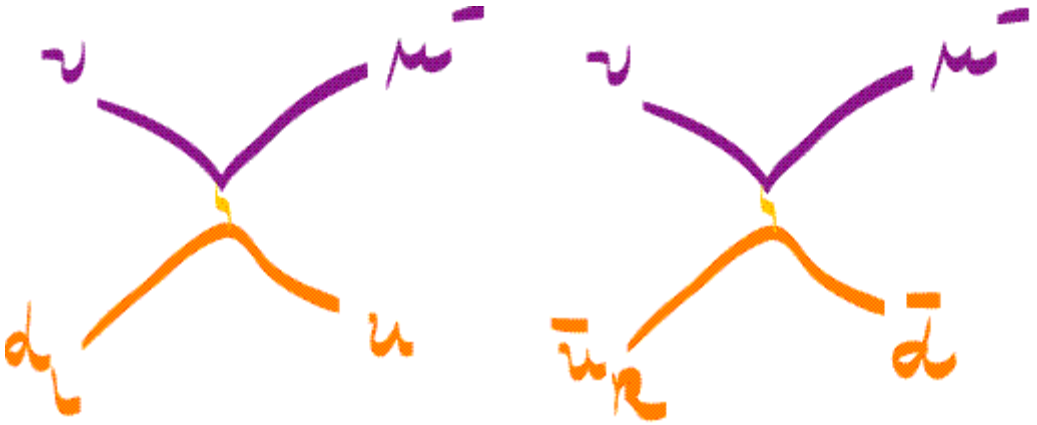
νp scatter

$$\frac{d\sigma}{dx\,dy} \sim x d_L + x u_R (1-y)^2 + x s_L$$

$$d_L = \frac{1}{2}(d + \delta d)$$

$$u_R = \frac{1}{2}(u - \delta u)$$

$$(\Delta d = \delta d + \delta \bar{d})$$



νn scatter

$d_L \rightarrow$ 'u'$_L$ ← proton
$\bar{u}_R \rightarrow$ 'd̄'$_L$ ← junctions
$s_L \rightarrow$'s'$_L$

$$\frac{d\sigma^{\nu n}}{dx\,dy} \sim x\text{'}u\text{'}_L + x\text{'}\bar{d}\text{'}_L(1-y)^2 + x s_L$$

16 cross sections

present

ν $\bar{\nu}$ ✓

1 $(1-y)$ ~

p n ~

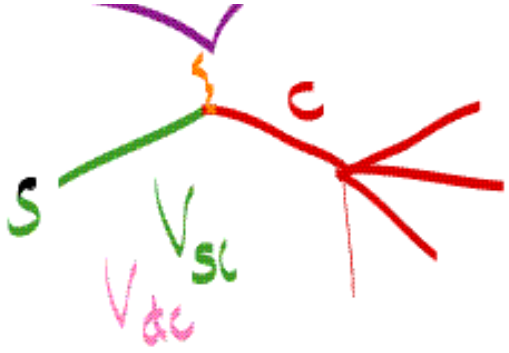
$\uparrow\downarrow$ $\uparrow\uparrow$ —

and 12 unknowns

u $\bar{u}$ δu $\delta\bar{u}$

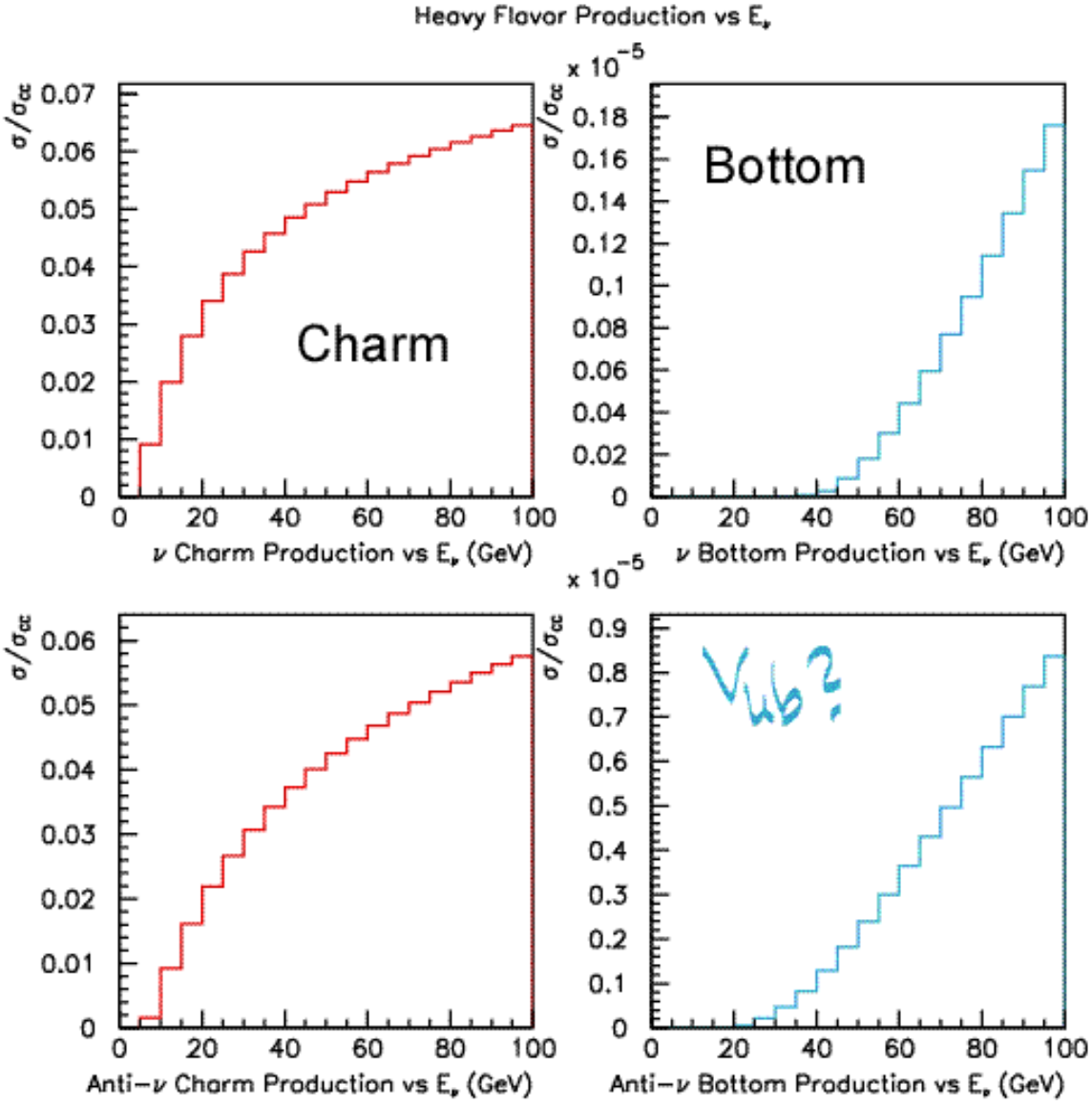
d $\bar{d}$ δd $\delta\bar{d}$

s $\bar{s}$ δs $\delta\bar{s}$



17 M CC events
-> .5-1M charm

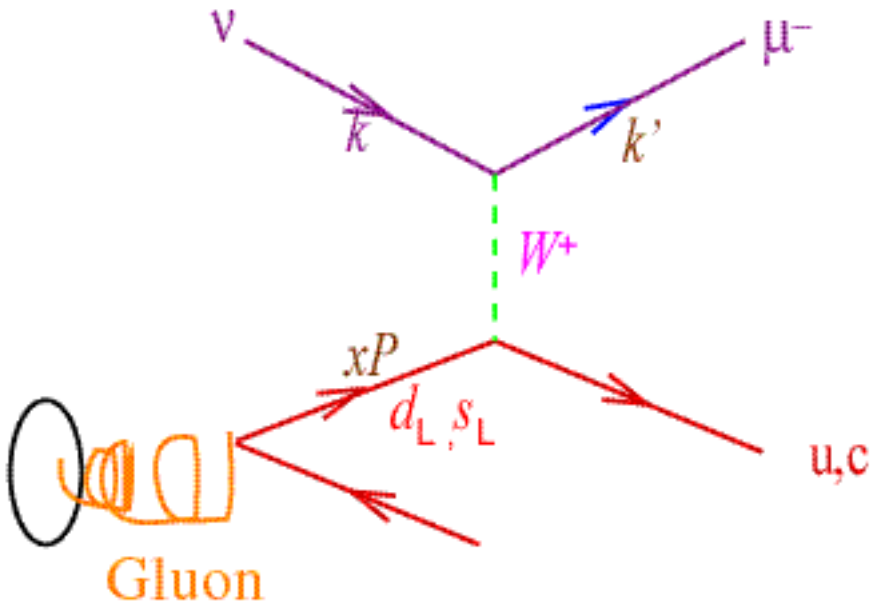
1 ton target
120 M charm



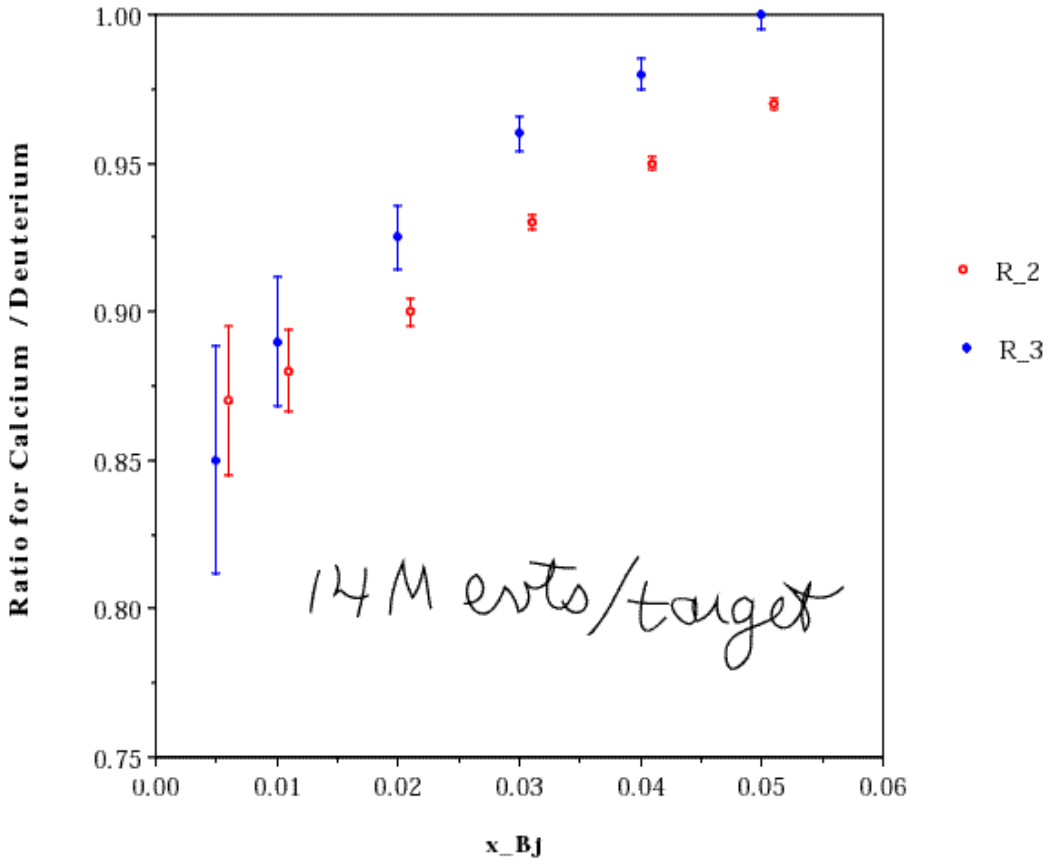
Gluons and QCD?

QCD introduces dependence on gluons and strong coupling.

Differences of cross sections cancel QCD
Sums enhance -> can isolate QCD from other effects -> good α_s measurements



is shadowing the same for $\nu/\bar{\nu}/\ell^{\pm}$?



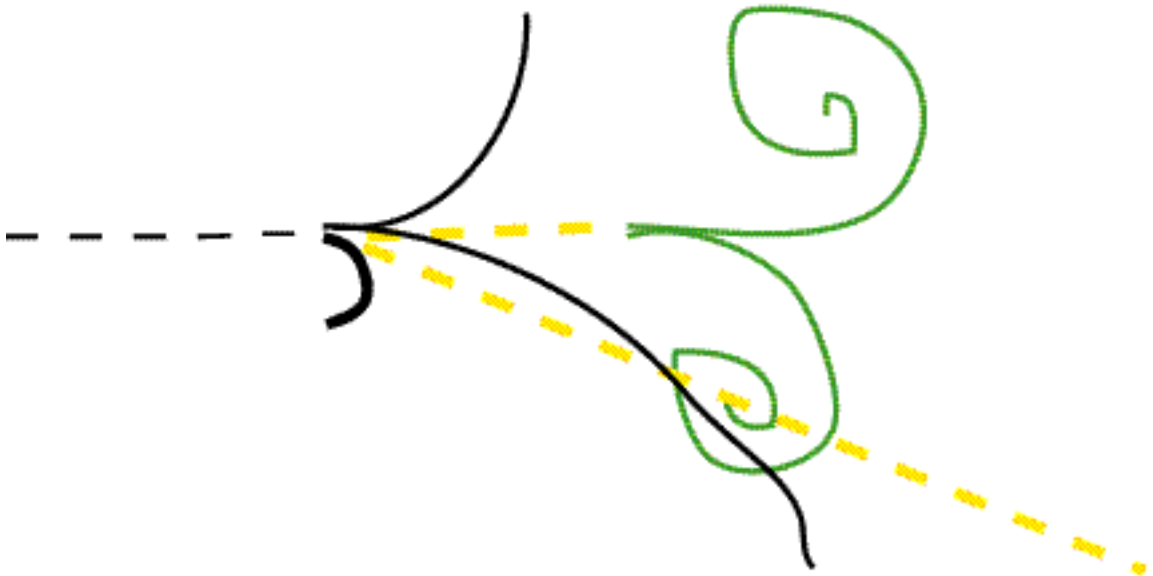
Kulagin
eMarsh

Problem at lower energies

How do you measure kinematics?
Need θ_μ, p_μ and E_{had} to get even E_ν

Muon is fine above 3-4 GeV, just use a magnet

Hadron calorimetry gets much worse as E_{had} decreases!



Can we measure E_{had} < 10 GeV well?