# THE DIS GROUP

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H. Schellman*, P. Spentzouris, E. Stern, J. Yu,
& friends...

*conveners

H. Schellman
11-9-97

We explored 2 DIS scenarios

200 GeV/$\mu$ × 1000 GeV p

250 GeV/$\mu$ → $\nu_\mu \bar{\nu}_e$ on fixed target

7 talks → lots of work

# Presentations

joint w/ ν group

- Future Charged Lepton-Proton Colliders S. RITZ
- Design for a μp Collider V. SHIRTSEV
- High Energy ν Physics at a μ Collider Complex B. KIN
- Neutrino Oscillations w/ BooNe R. Stefanski

Prospects for Photoproduction M. KLASEN

Neutrino DIS O. HARRIS

Neutrino SES (Shallow Elastic Scattering) P. SPENDOURIS

$\sin^2\theta_W$ with Neutrinos J. YU E. STERN

Backgrounds N. Molkov

V. Shiltsev

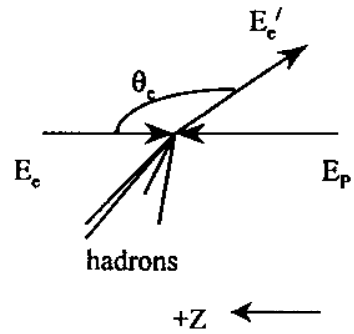
# $\mu$ - p Collider Baseline Parameter Assumptions

$E_\mu$= 200 GeV
$E_p$=1000 GeV
Maximum $Q^2$~ $8 \times 10^5$ $GeV^2$
$L$=$1.3 \times 10^{33}$ $cm^{-2}s^{-1}$
=> annual integrated luminosity 10 $fb^{-1}$

Compare with HERA:
$E_e$=27.5 GeV
$E_p$=800 GeV
Maximum $Q^2$~$9 \times 10^4$ $GeV^2$
Lifetime integrated luminosity: 1 $fb^{-1}$

# ep Collider Kinematics

(neutral current case)

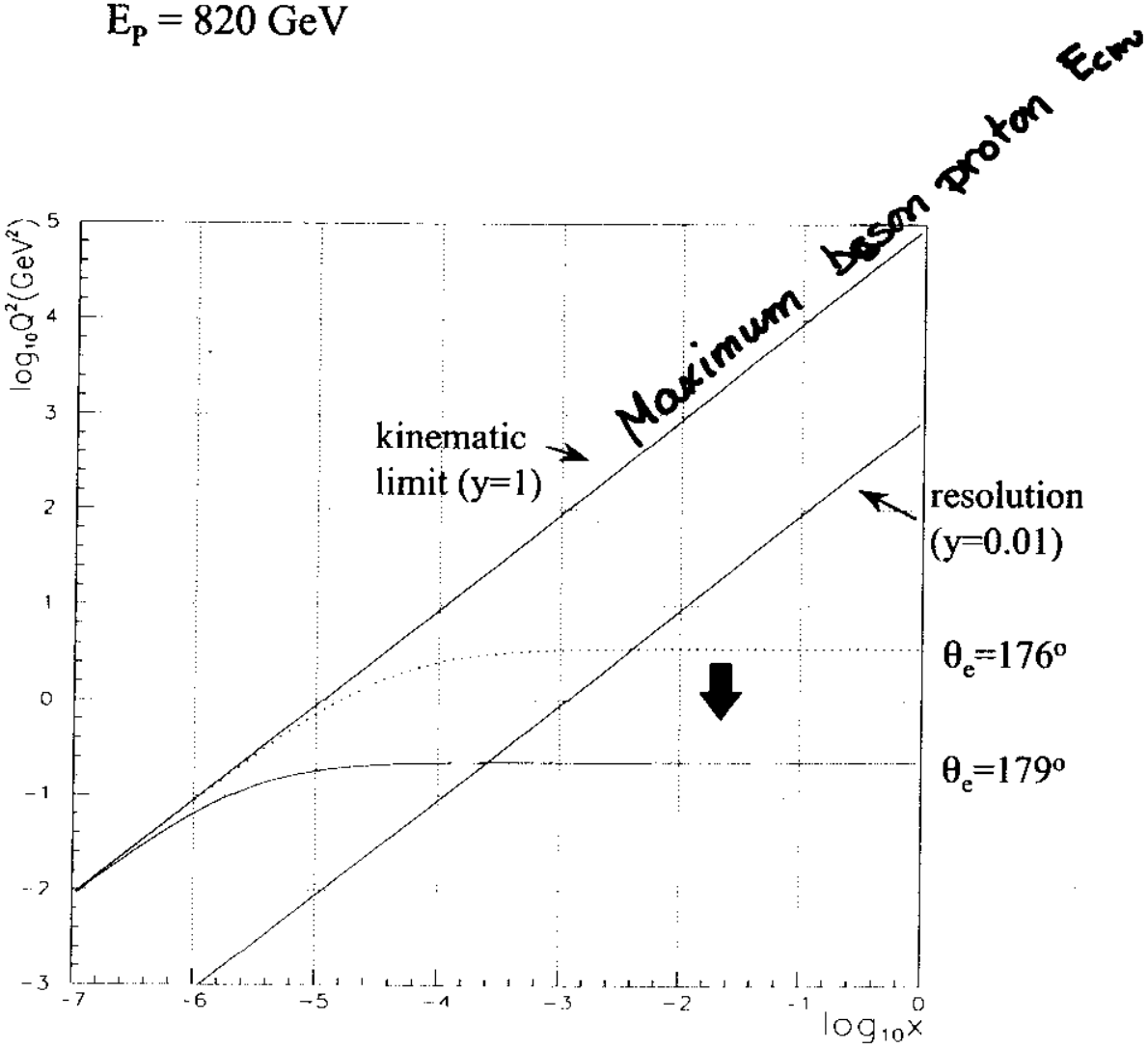



$s = 4\, E_e\, E_p$

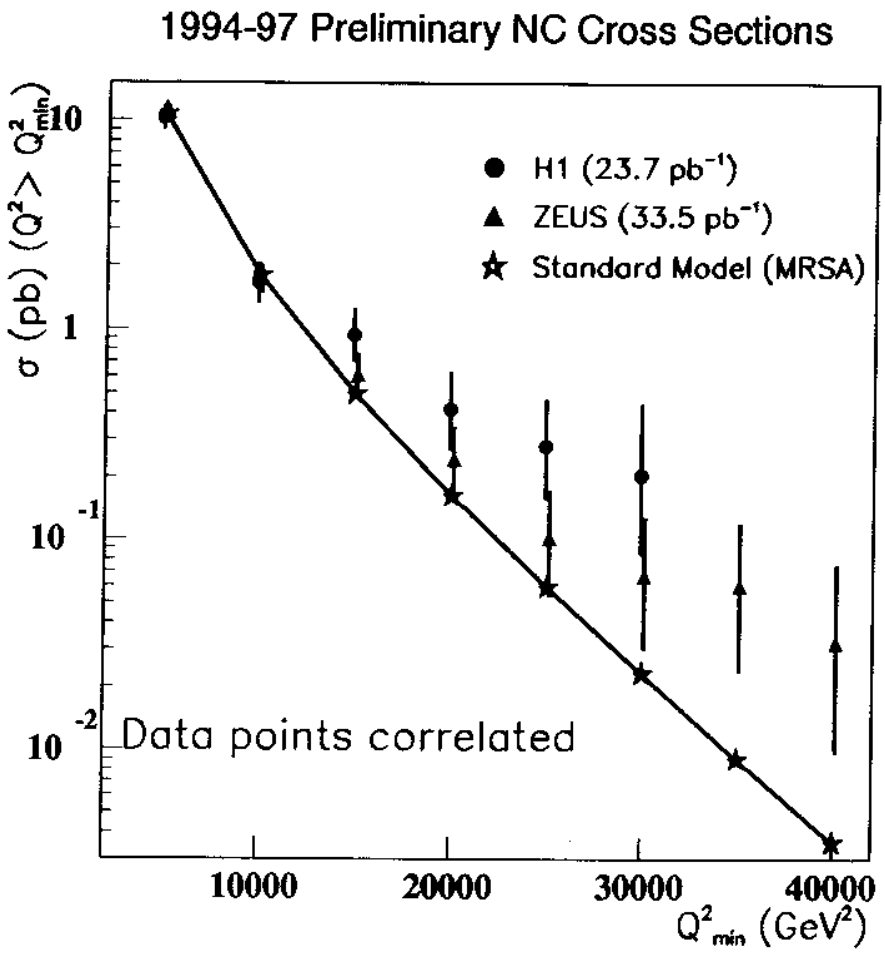
$Q^2 = s\, x\, y$

HERA: $E_e = 30$ GeV

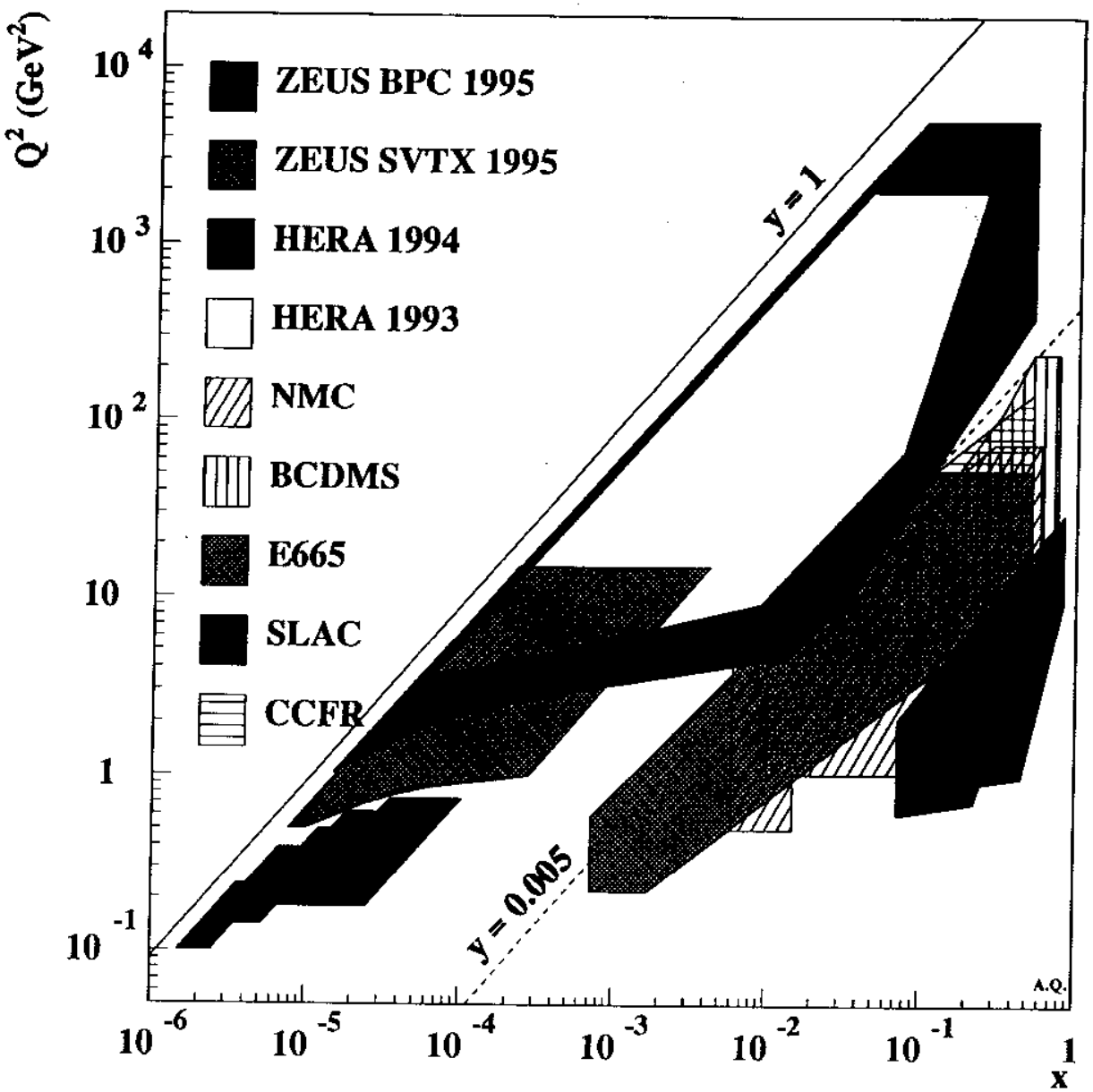
$E_p = 820$ GeV



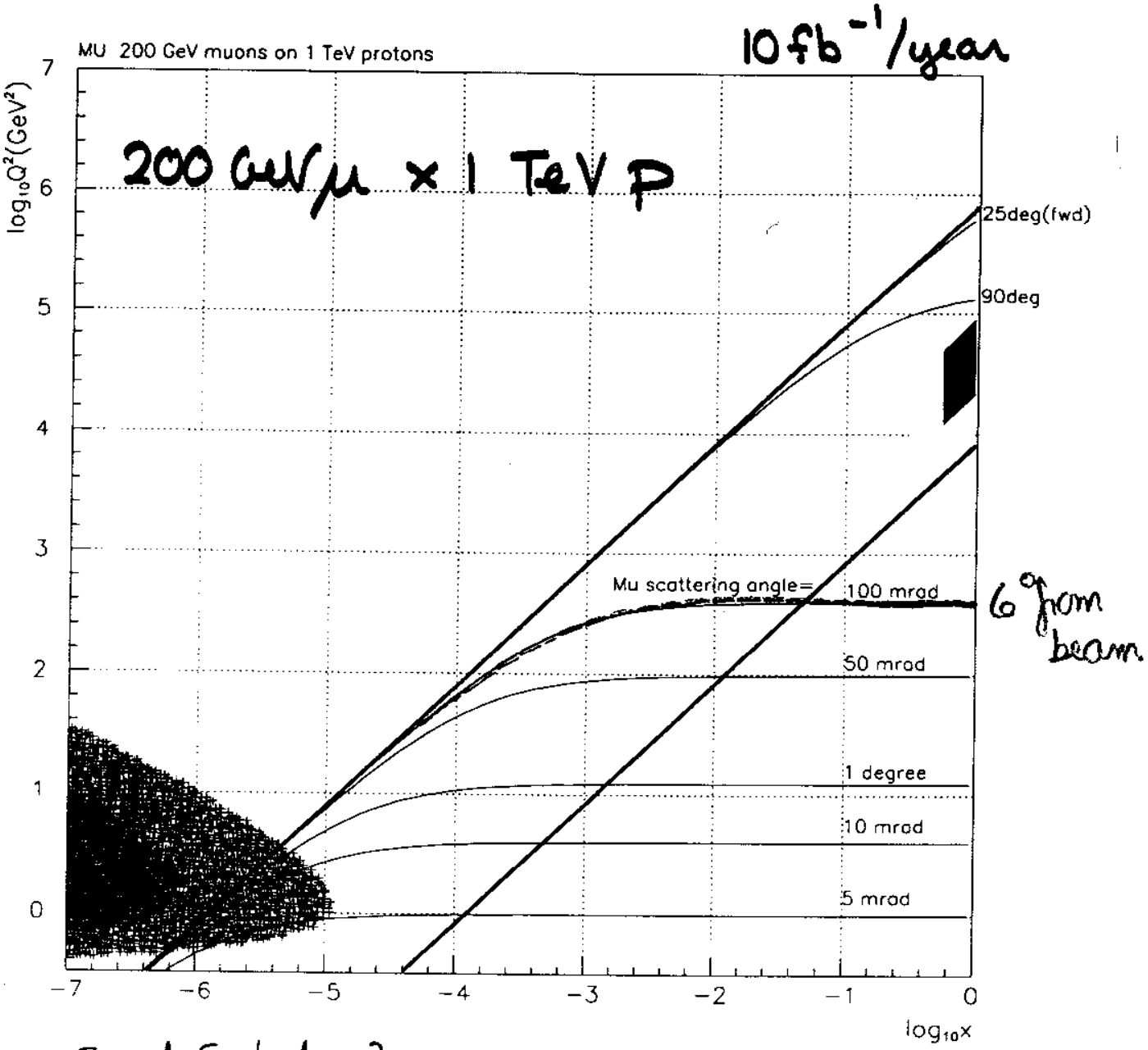
# H1 and ZEUS Cross Sections for $Q^2 > Q^2_{\rm min}$




**H1 and ZEUS are consistent.**


ZEUS BPC 1995
ZEUS SVTX 1995
HERA 1994
HERA 1993
NMC
BCDMS
E665
SLAC
CCFR
y = 1
y = 0.005
A.Q.
$Q^2$ (GeV$^2$)
$10^4$
$10^3$
$10^2$
10
1
$10^{-1}$
$10^{-6}$
$10^{-5}$
$10^{-4}$
$10^{-3}$
$10^{-2}$
$10^{-1}$
1
x

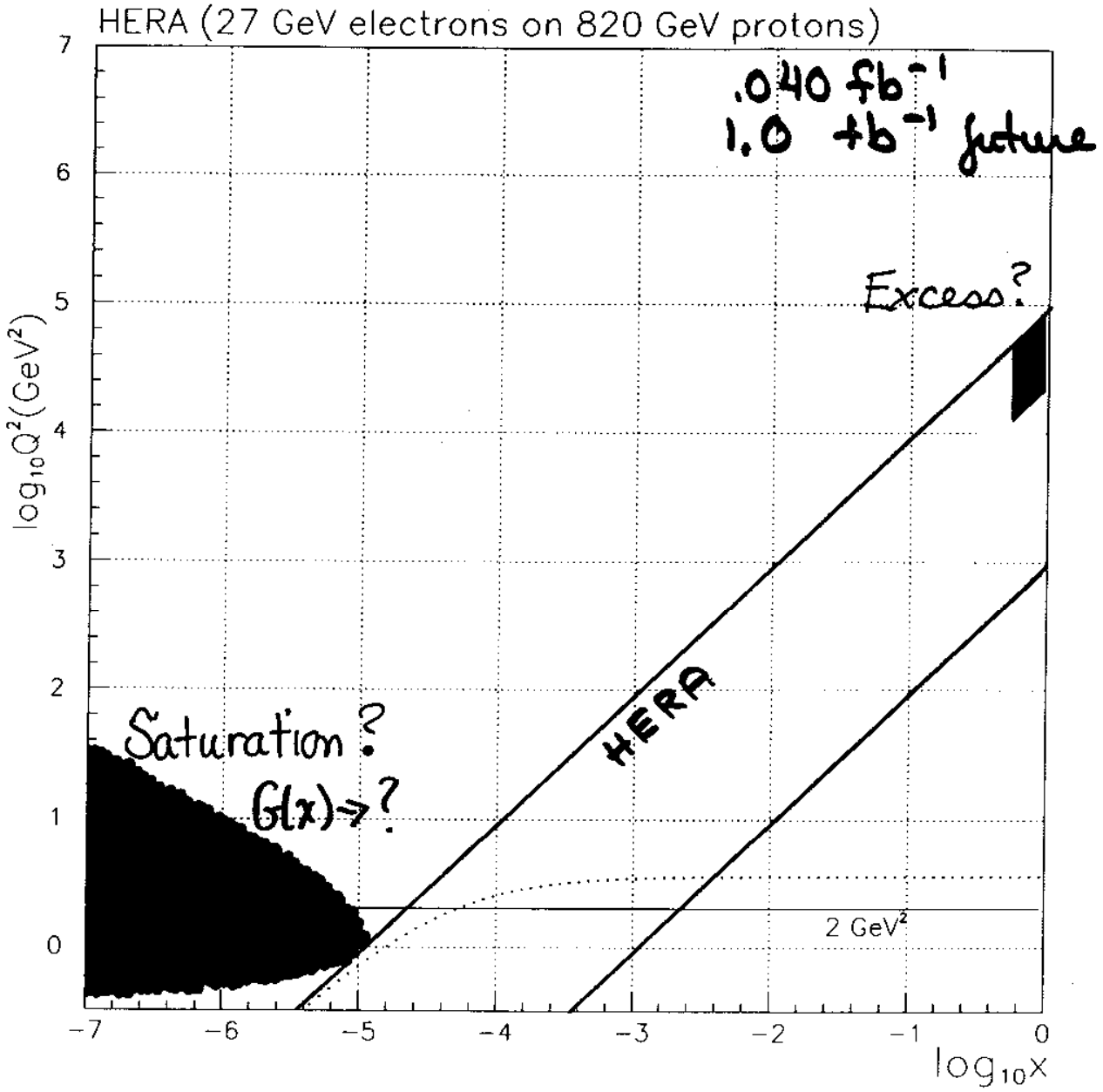
S. Kuhlmann




Great for high $Q^2$

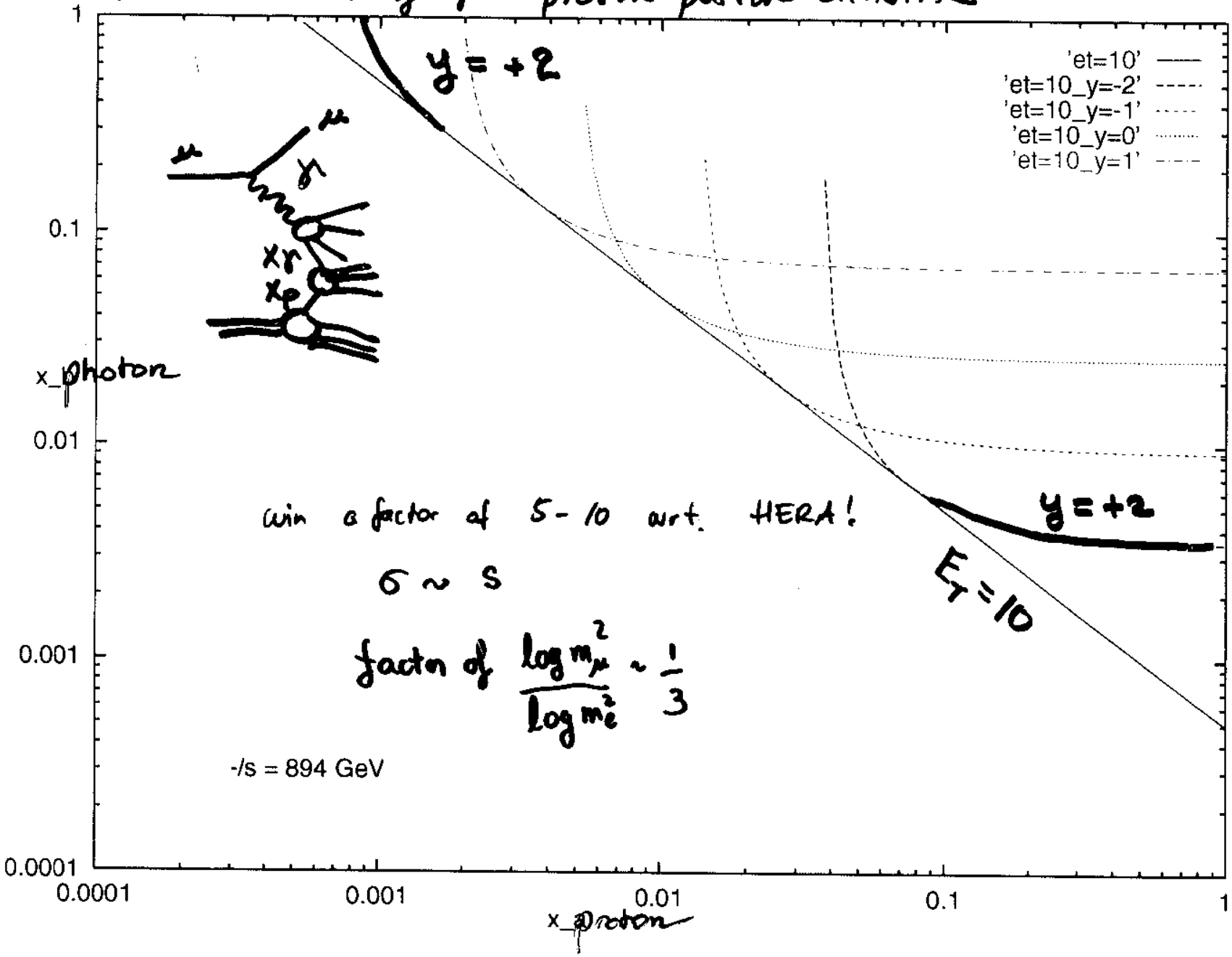
Low x very difficult -- current jet also very close to beamline in backward direction (>175°!)

# Messages from HERA (key regions to study):



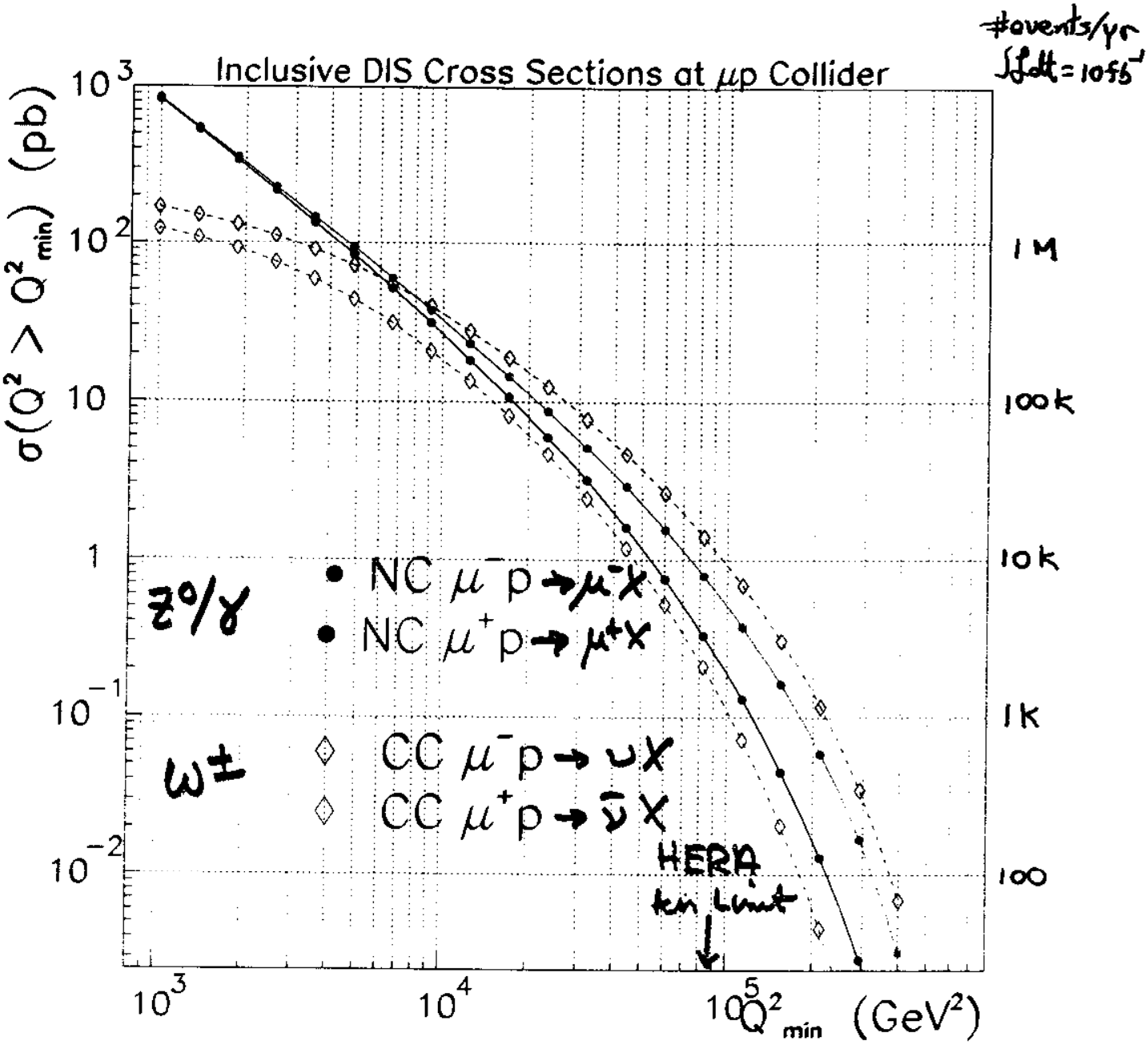
M. Klasen

# Accessible x range for proton parton densities



CC $\mu p \to \nu$ 1 M events/year $Q^2 > 5000$ GeV$^2$

HERA 326 events from Zeus

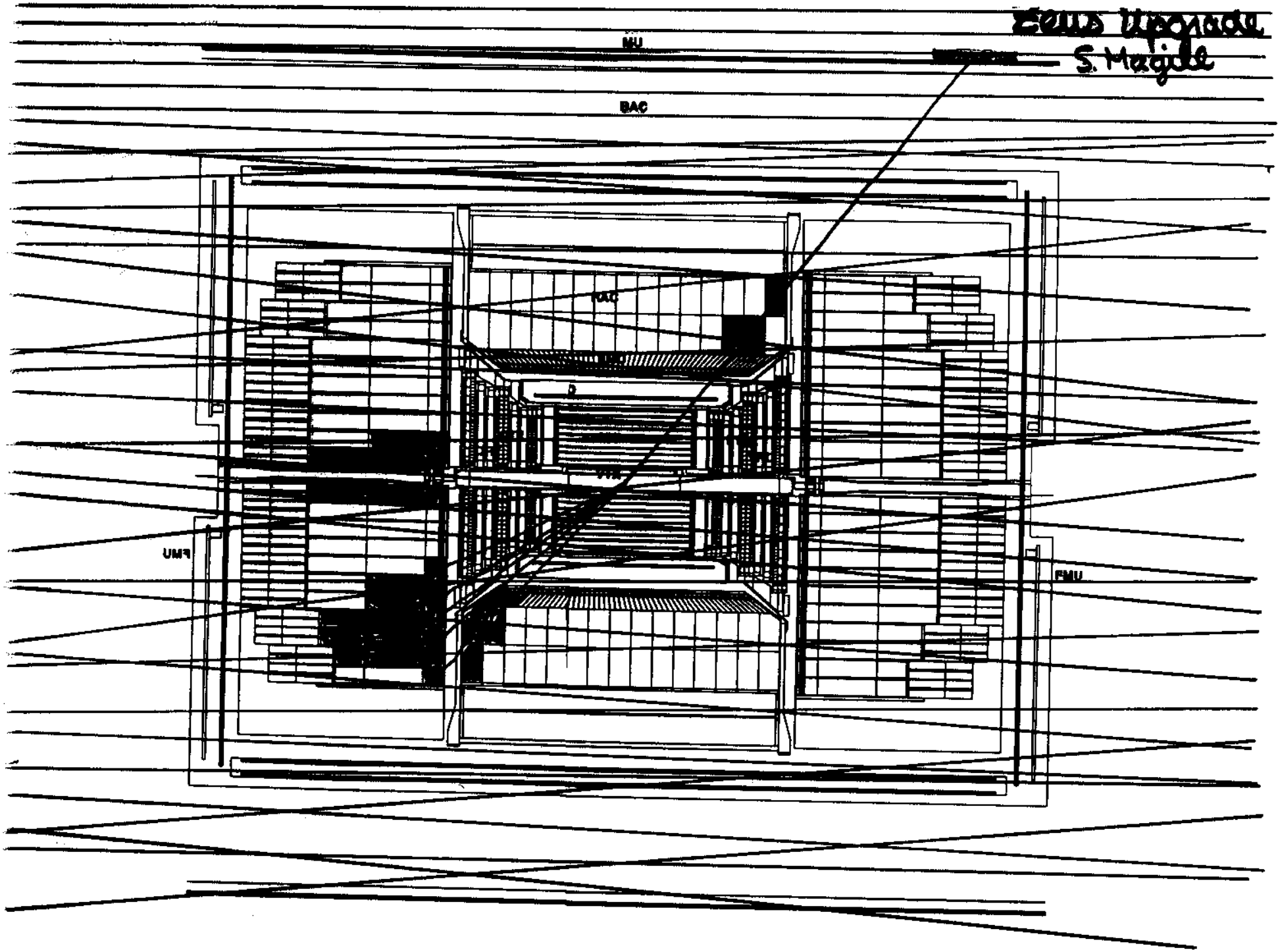



Compare w/ HERA:

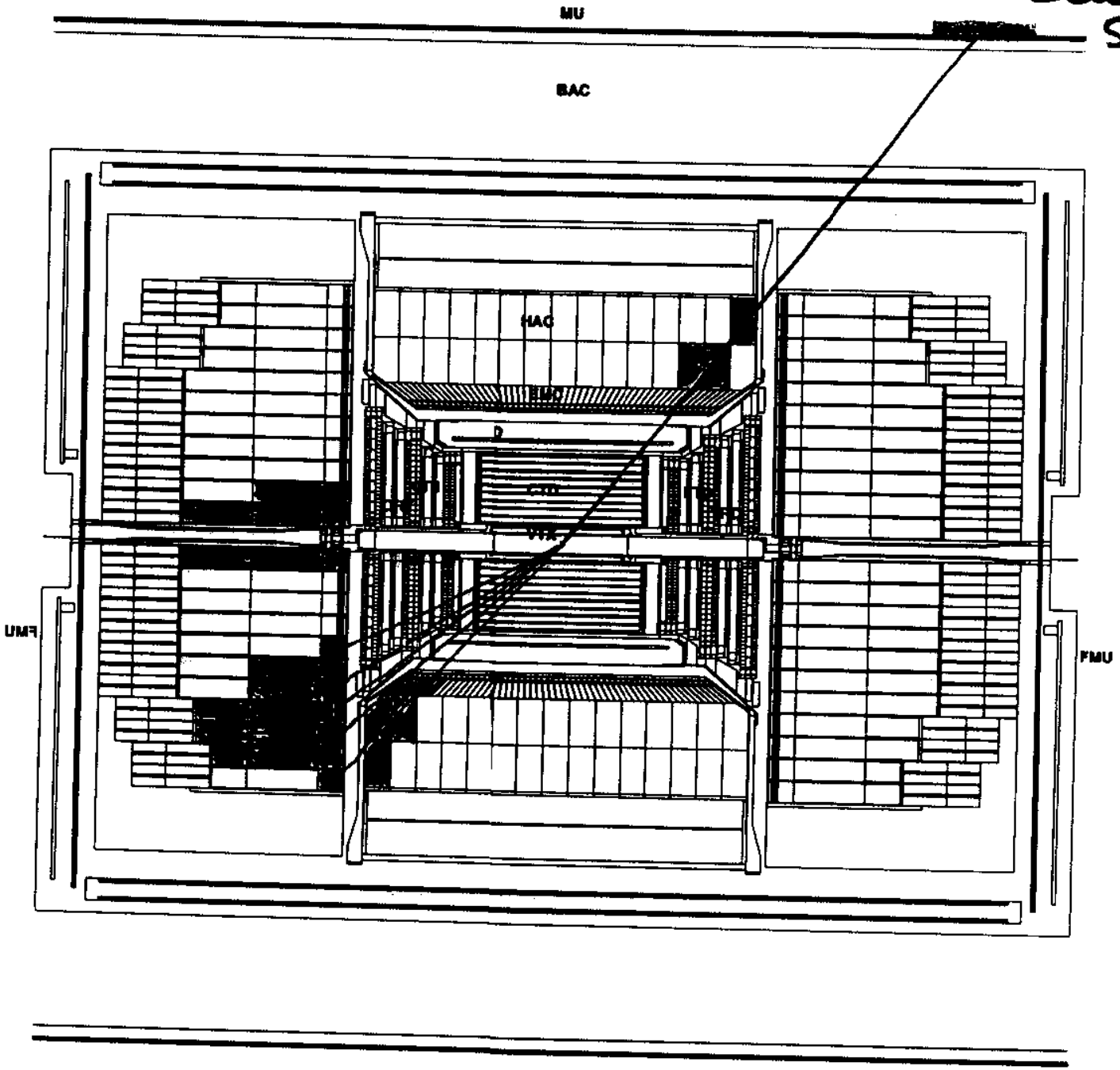
Summer 1997 ZEUS $\int \mathcal{L} dt = 34 pb^{-1} \Rightarrow$ 326 NC $e^+p$ events $Q^2 > 5000$ GeV

HERA lifetime: $\int \mathcal{L} dt \sim 1 fb^{-1}$

Zeus Upgrade
S. Magide



Zeus upgrade
S. Magill



# Leptoquark Production

$$\sigma(\mu p \to LQX) = \frac{\pi}{4s}\lambda^2(J+1)q(\frac{M^2}{s})$$

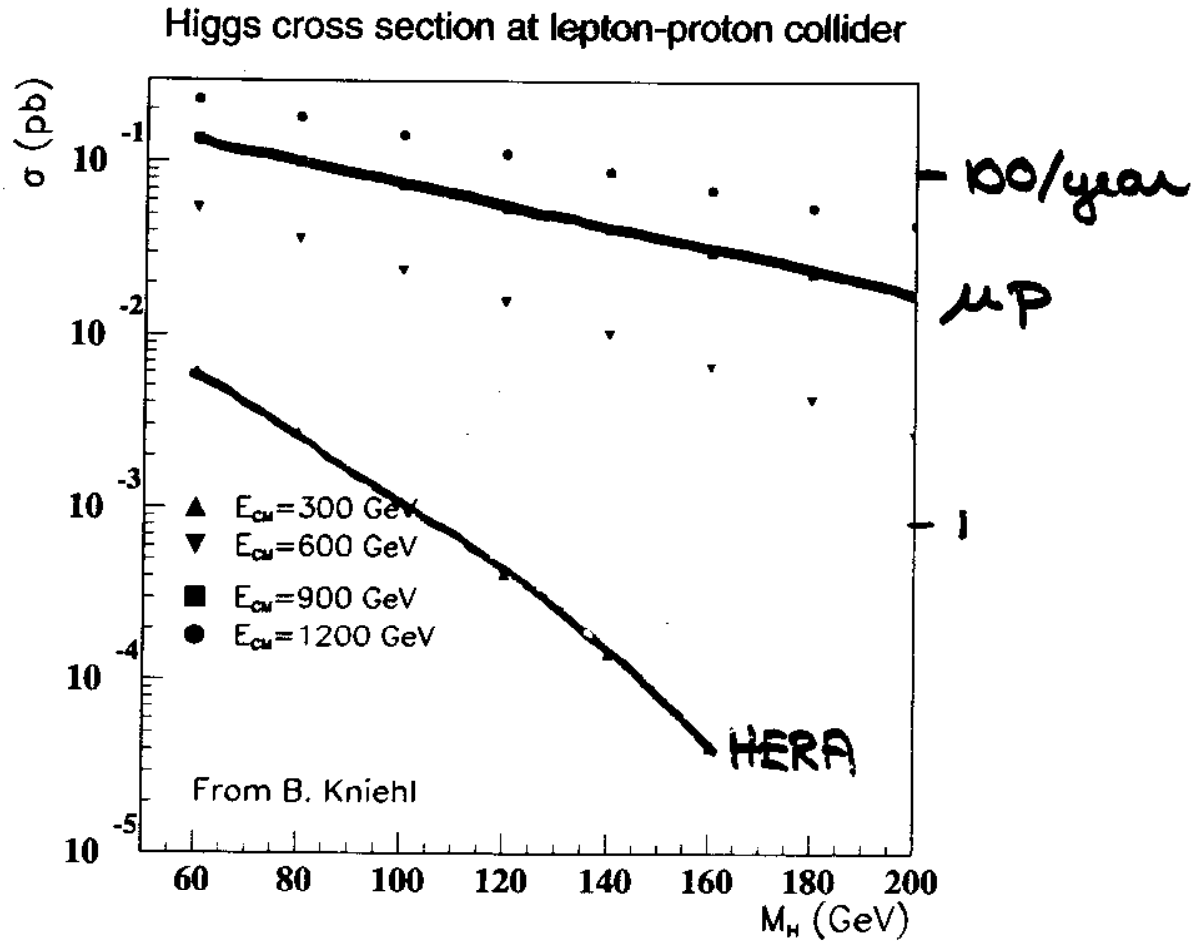
where $q(\frac{M^2}{s})$ is the probability of finding a quark with momentum fraction $x = \frac{M^2}{s}$.

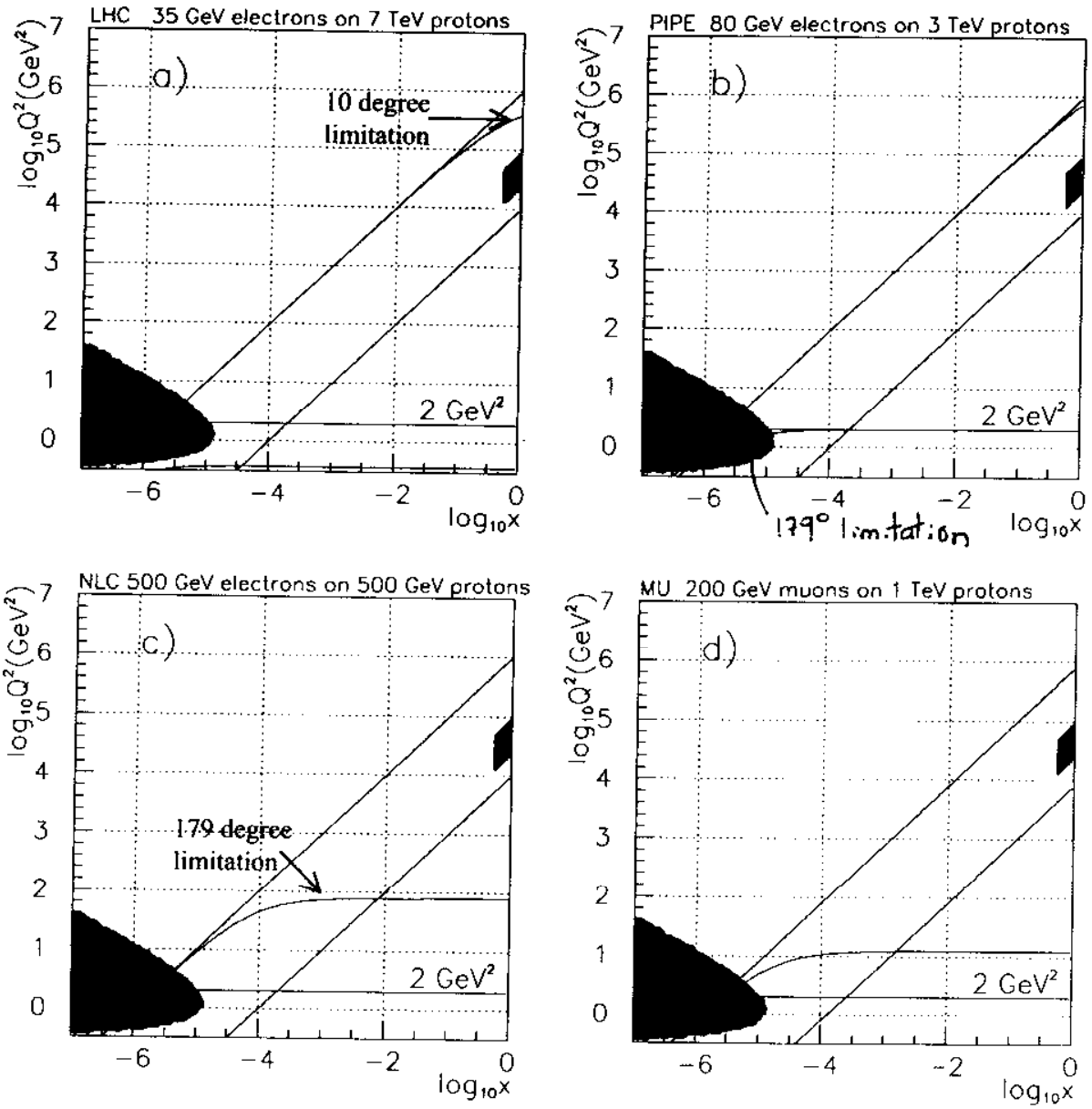
Signature - resonance in $\mu$–jet mass (or $x$).

Assume $E_{CM} = 1$ TeV $\mu$P collider with 10 fb$^{-1}$

(95 % CL) limits on scalar leptoquark couplings

| $M_{LQ}$ (GeV) | HERA 95 | HERA 2005 | $\mu$p |
|---|---|---|---|
| 100 | $1.5 \cdot 10^{-2}$ | $2 \cdot 10^{-3}$ | $1.5 \cdot 10^{-3}$ |
| 150 | $2.5 \cdot 10^{-2}$ | $4 \cdot 10^{-3}$ | $2 \cdot 10^{-3}$ |
| 200 | $7 \cdot 10^{-2}$ | $1 \cdot 10^{-2}$ | $2 \cdot 10^{-3}$ |
| 250 | $2.5 \cdot 10^{-1}$ | $4 \cdot 10^{-2}$ | $2 \cdot 10^{-3}$ |
| 500 | | | $5 \cdot 10^{-3}$ |
| 800 | | | $3 \cdot 10^{-2}$ |


Higgs cross section at lepton-proton collider
σ (pb)
10^-1
10^-2
10^-3
10^-4
10^-5
60
80
100
120
140
160
180
200
M_H (GeV)
E_CM=300 GeV
E_CM=600 GeV
E_CM=900 GeV
E_CM=1200 GeV
From B. Kniehl
100/year
μp
1
HERA




For μp and NLC-p collider options, the 179° scattering angle requirement prevents any significant low $x$ study, but the highest $x$ and $Q^2$ region is accessible. <u>Going to low $x$ requires a well-understood beamline spectrometer</u>.

# $\mu p$ conclusions

low $x$ very hard due to
kinematics, angle cutoffs

high $Q^2$ gain $\times 10$ $\mathcal{L}$ vs final HERA
$\times 10$ kinematic limit
in some regions

reach to 900 GeV in mass

Problems?
Backgrounds
Can Tevatron meet $\mu$-col?

# $\nu$ beam Parameters
## 2-options

| | RLA3 | 250 GeV $\mu$-coll |
|---|---|---|
| $E_\mu$ | 250 GeV | 250 GeV |
| | 12 turns | 1560 turns |
| | 533m decay | 10 m decay |
| $\langle E_{\nu_\mu} \rangle$ | 135 GeV | 178 GeV |
| beam size @ 600m | 50% within 25 cm | 50% within 15cm |
| Rate per 40 tons/year | $5\times10^9\ \nu_\mu N$/year | $5\times10^9\ \nu_\mu N$/year |

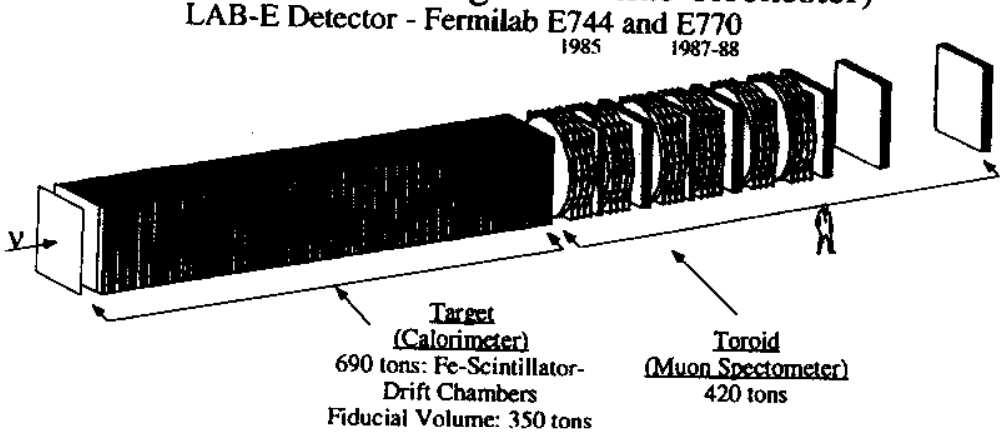
present rates $5\times10^6\ \nu_\mu N$

Factor of 1000!

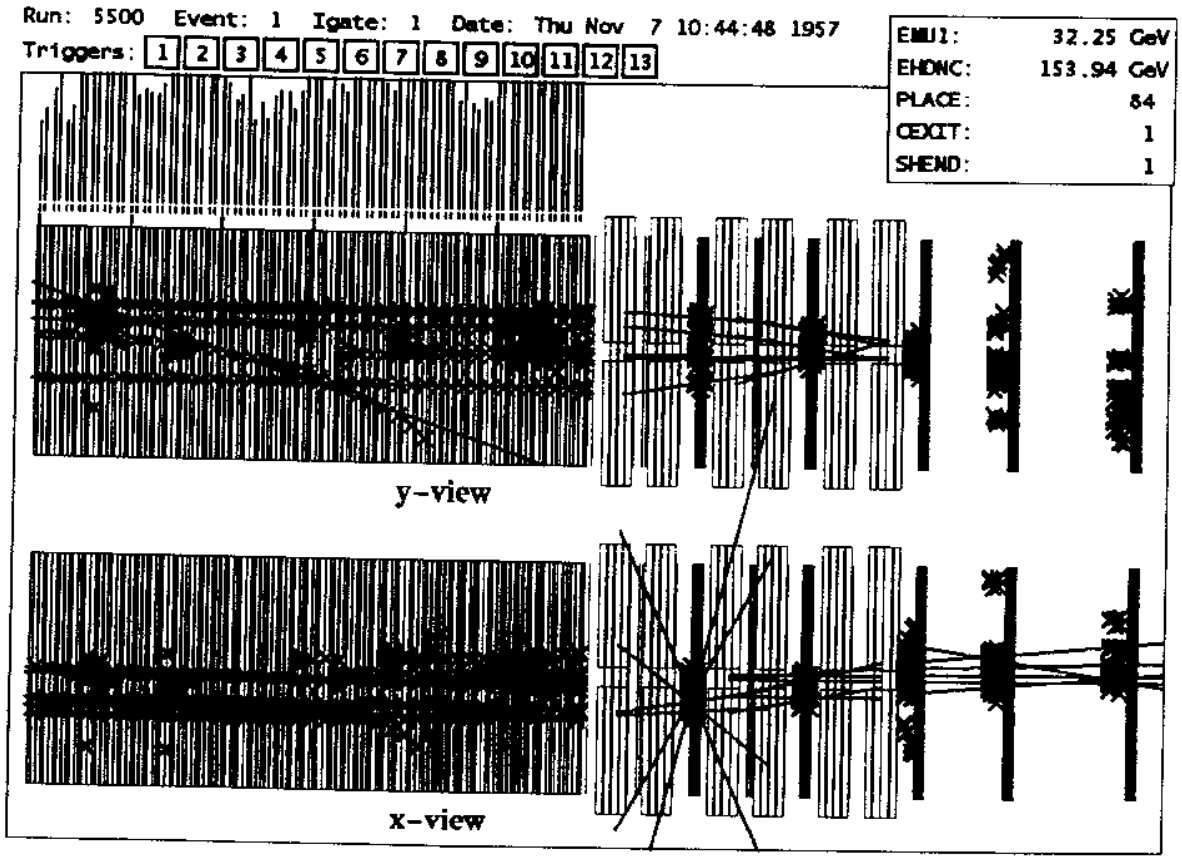
# Too Many Neutrinos?

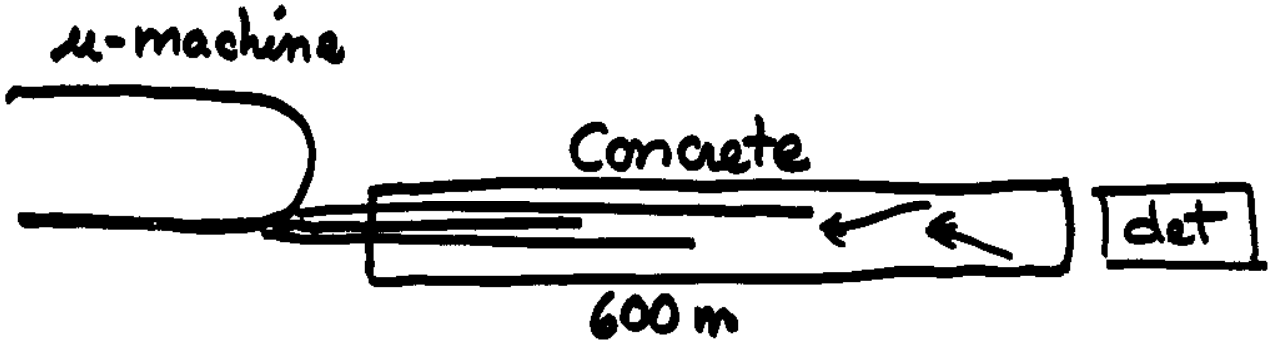
## CCFR (Columbia-Chicago-Fermilab-Rochester)

LAB-E Detector - Fermilab E744 and E770



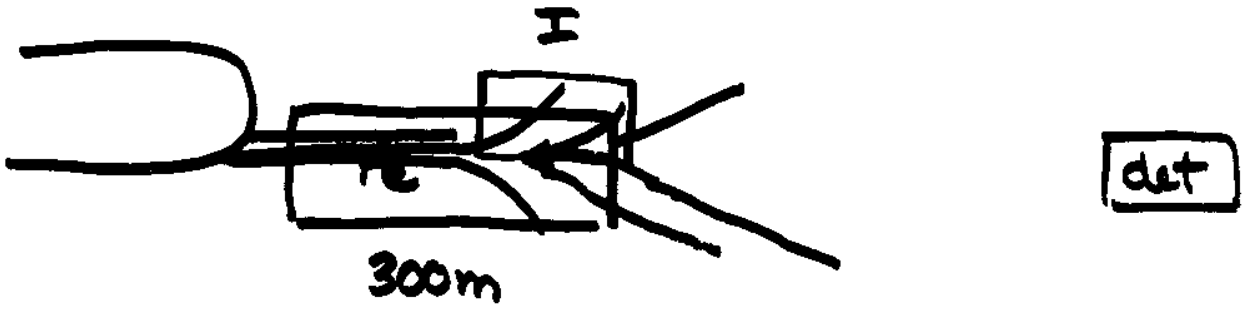

## NuTeV: 600 m downstream of RLA3, one turn






range out machine μ

but ~ 4μ / event
due to $\nu_\mu N \to \mu X$
in dump!




magnetized iron
1T × 100m lowers
rate due to regenerated μ

Present $\nu$-experiments

Statistics $\Rightarrow$ massive targets

Fe, Ca, .... $\Rightarrow$ Nuclear effects
Emulsion — up to 30% rel protons

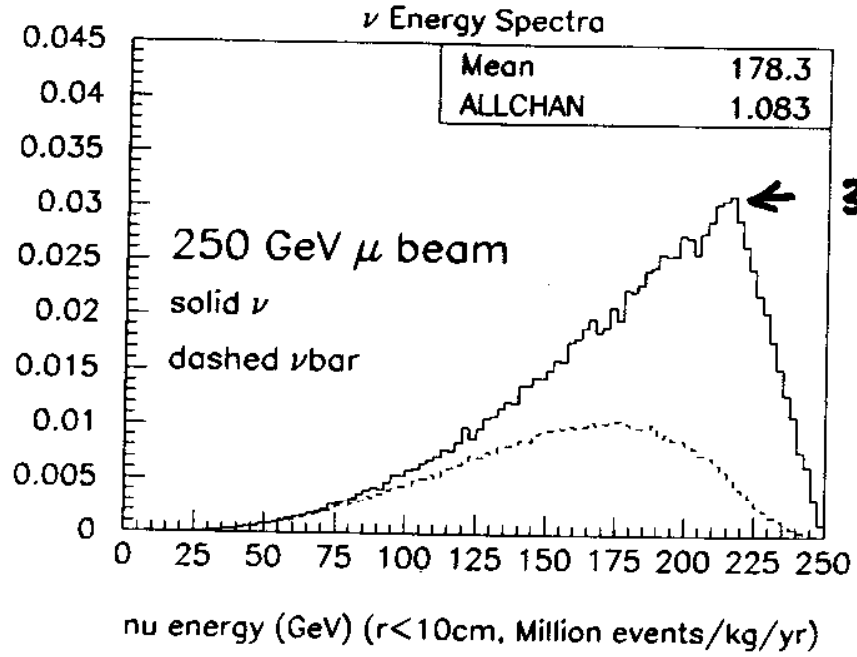
Fe, Ca, $\Rightarrow$ poor angular resolution
coarse grain — $\Delta\theta \sim 10\,mr$
or fine grain — $x \gtrsim 0.01$ only
poor E resolution

But still:

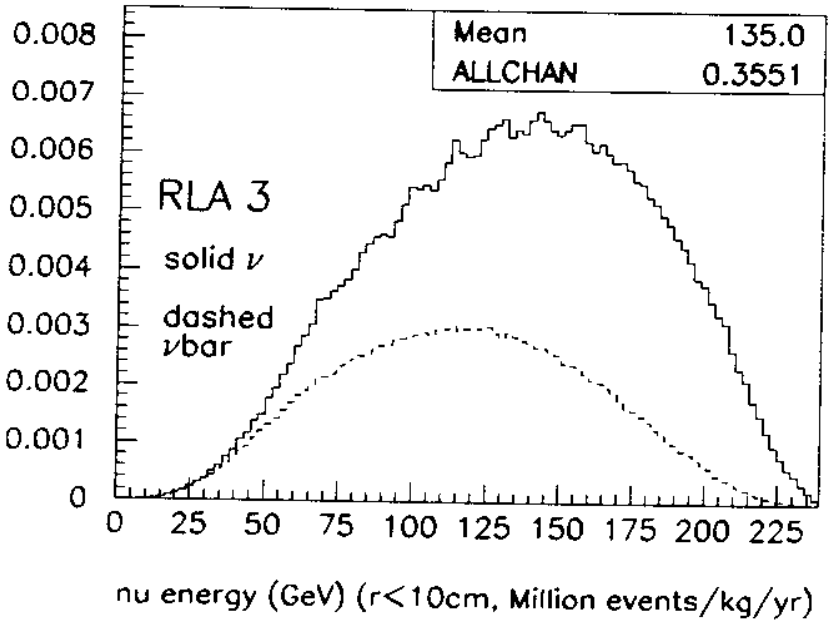
Only source of $q$-$\bar{q}$ competitive $V_{dc}$, $\sin^2\theta_W$

# νN Energy Spectra

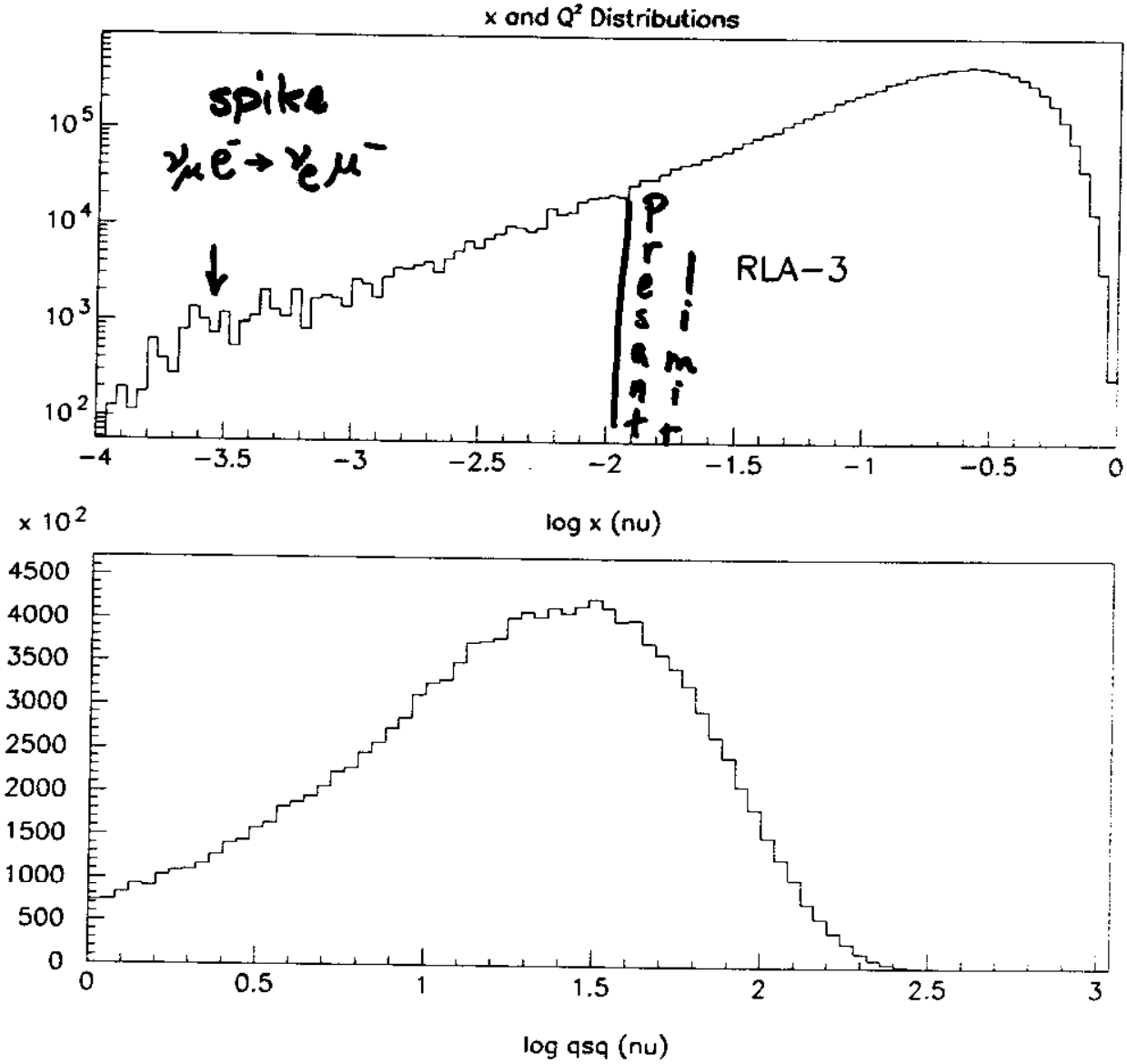
(σ weighted)



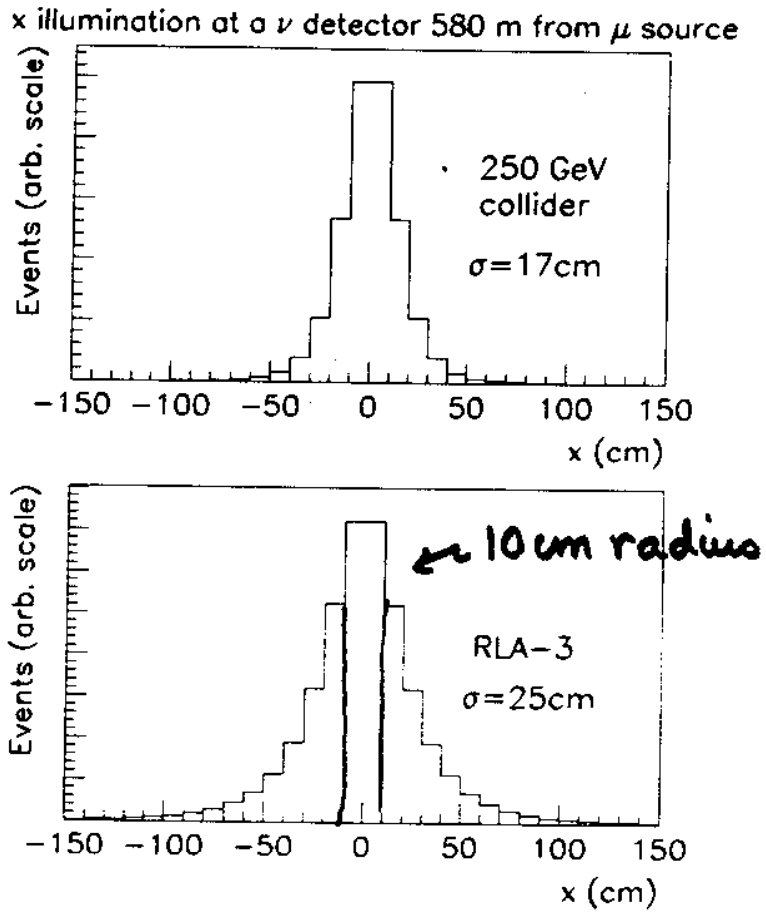

30K events /2 GeV



# Events/year vs kinematics



Beam size 600 m from μ source



Present metric

interactions / KT / year ~ $10^7$

$\mu$ collider metric

interactions / cm $H_2$ / year

| | RLA-3 | 250 GeV $\mu$ col |
|---|---|---|
| <10 cm radius | 7.5 K/year | 24 K/year |
| all $\nu$ | 65 K/year | 94 K/year |

1 m $H_2$ target $\Rightarrow$ 6-10 M events/year

A wild idea

1 m $H_2$ ~ 1 event/second

15 Hz rep rate

⟹ High Resolution Bubble Chamber ?

Tohoku

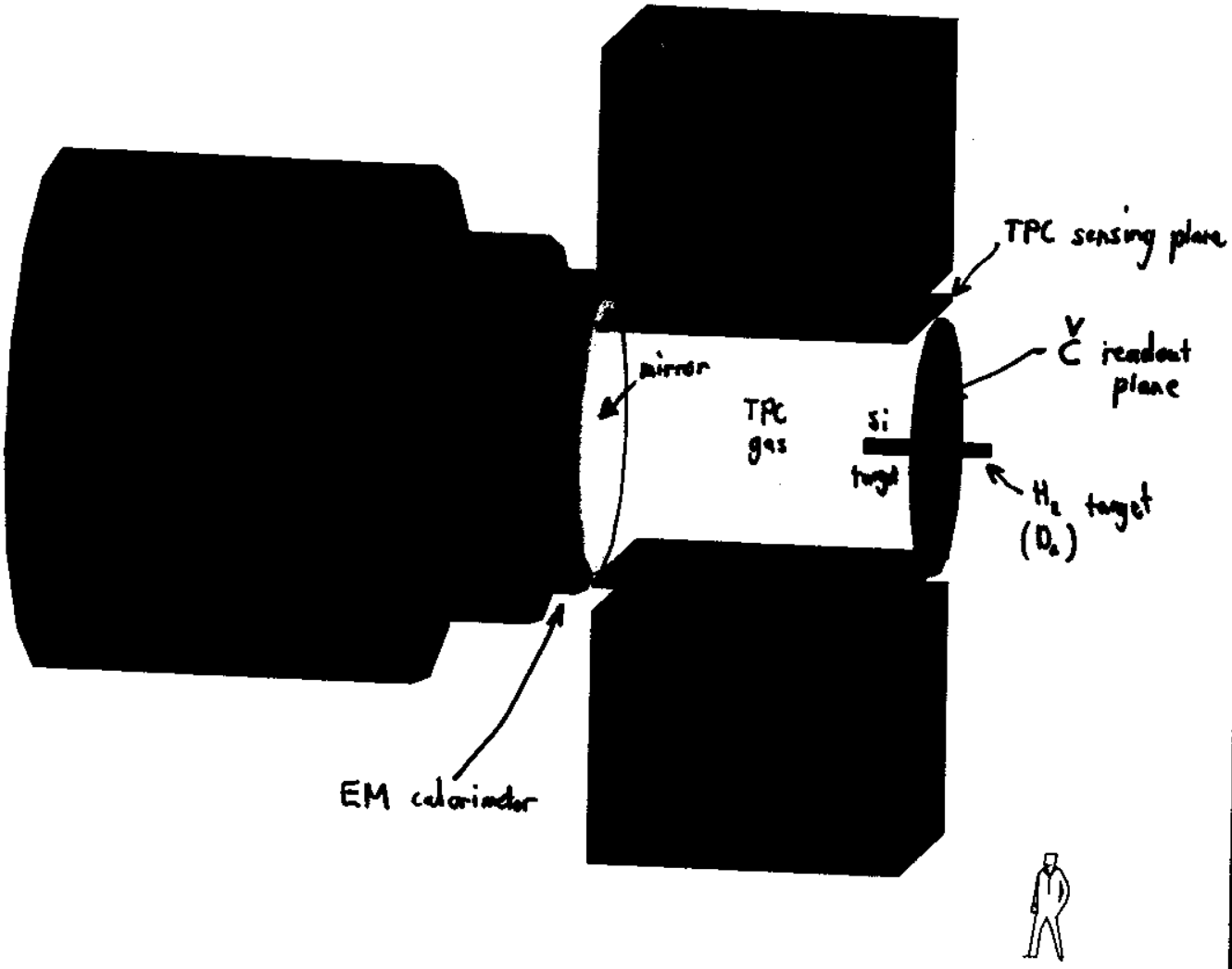
Slac 40" → charm

2010 CCD readout

S. Kung

# General Purpose ν Detector

4/11/97



$\sin^2\theta_W$ from $Z^0$ vs $W^\pm$ exchange rates

10M $\nu_\mu, \bar{\nu}_\mu$ events / year

$\longrightarrow$ Stat error = 0.2 %

Major source of error at present

charm cross section

Solution: measure it!

$\nu_e$ contamination in beam

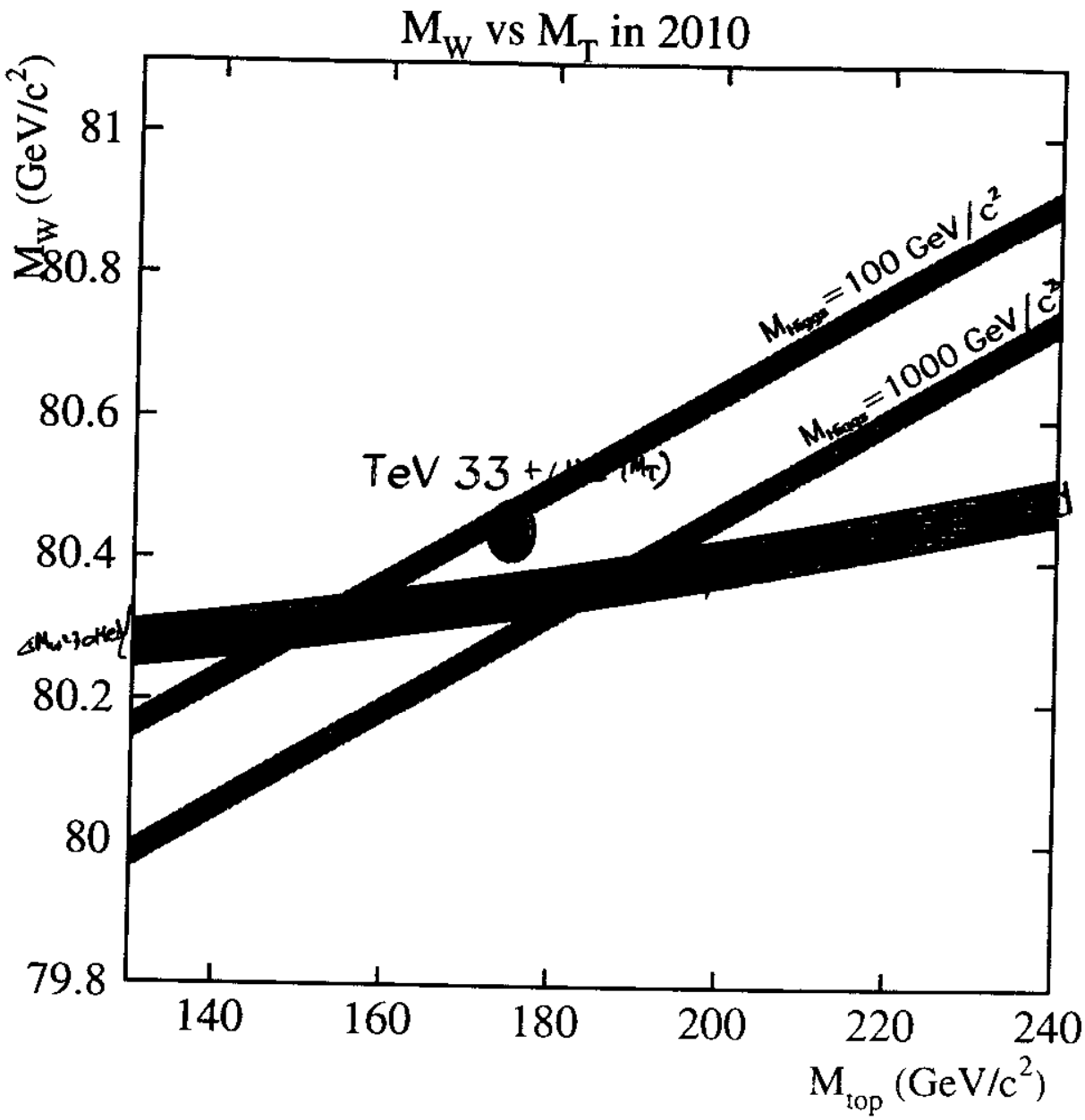
looks like

CC NC

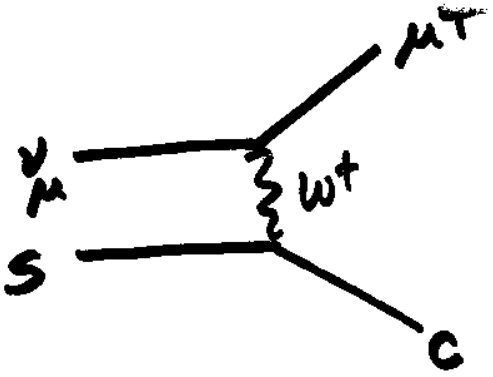
Solution: low density detector
measure $e^\pm$
double statistics

Quick estimate $\Delta \sin^2\theta_W \leq .5$ %

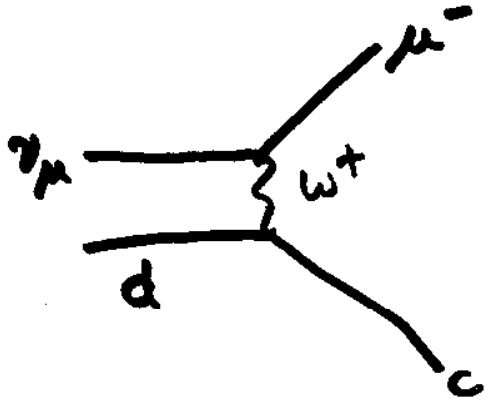
$\Delta M_W$ 30 - 50 MeV


$M_W$ vs $M_T$ in 2010
$M_W$ (GeV/c$^2$)
81
80.8
80.6
80.4
80.2
80
79.8
140
160
180
200
220
240
$M_{top}$ (GeV/c$^2$)
$M_{Higgs}$=100 GeV/c$^2$
$M_{Higgs}$=1000 GeV/c$^2$
TeV 33

# Charm Production

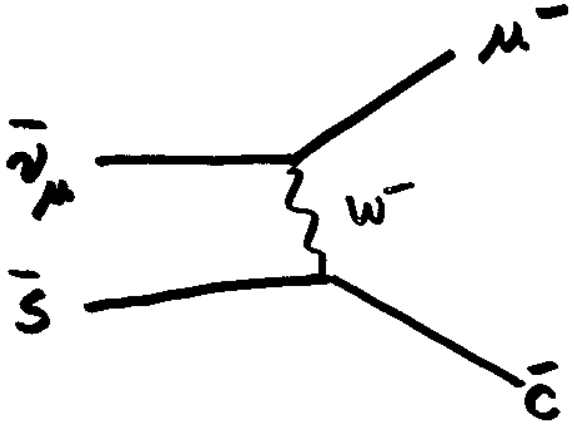



$|V_{sc}|^2$



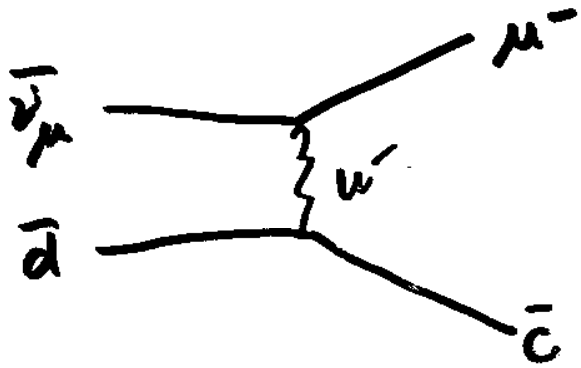

$|V_{dc}|^2$

100,000 reconstructed/year on 1 m $H_2$ target



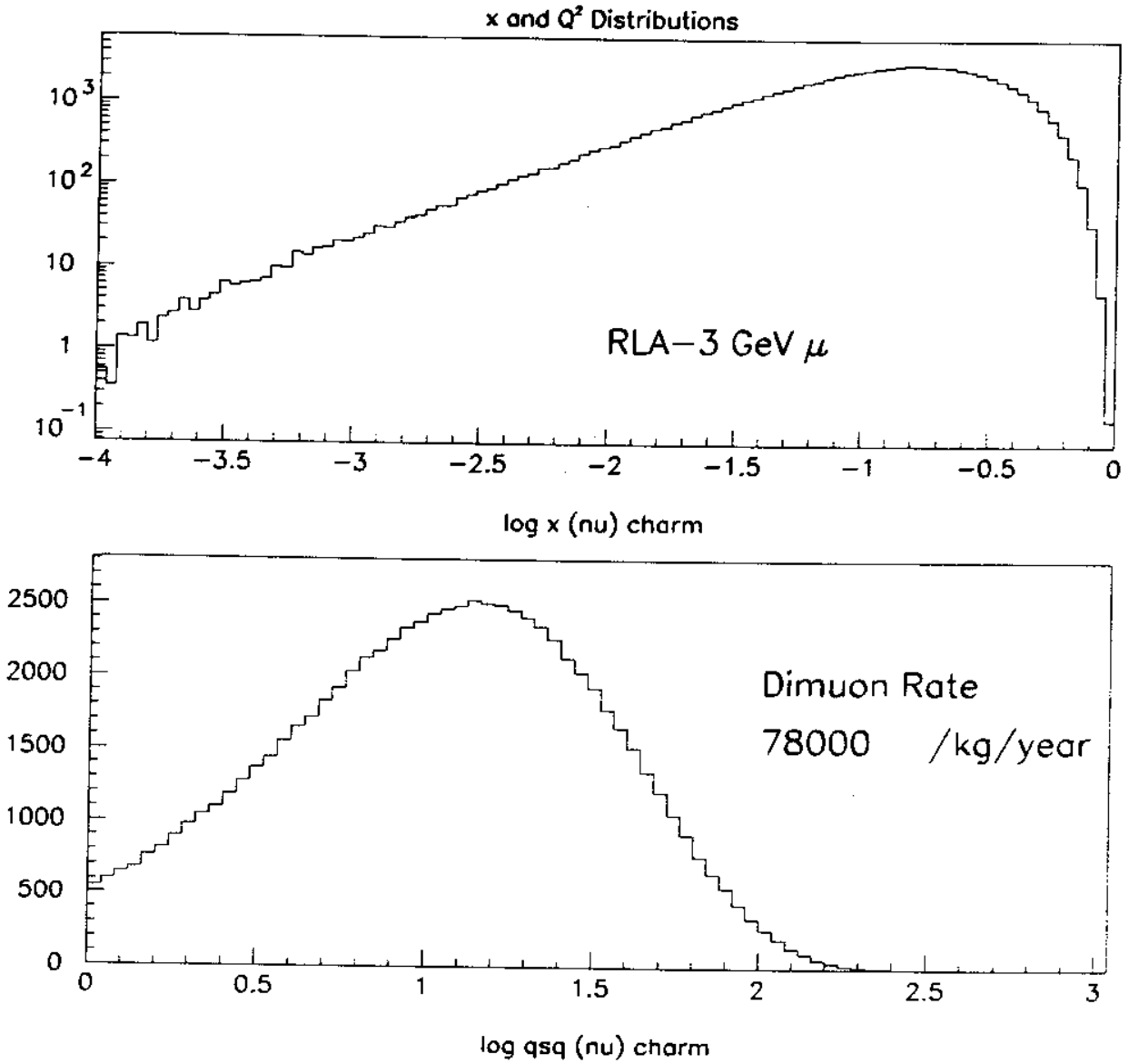

$|V_{sc}|^2$

$|V_{dc}|^2$
$s, \bar{s}$




$|V_{\bar{d}c}|^2$

ν-nuno


x and Q² Distributions
RLA−3 GeV μ
log x (nu) charm
Dimuon Rate
78000 /kg/year
log qsq (nu) charm

# Spin Physics!

Where does spin of proton come from?

$\nu_\mu$ only likes left-handed quarks
right-handed $\bar{q}$

$\bar{\nu}_\mu$ only likes right handed quarks
left handed $\bar{q}$

Extreme limit s quark spin || p

$\nu_\mu s \to \mu^- c$ only with polarization

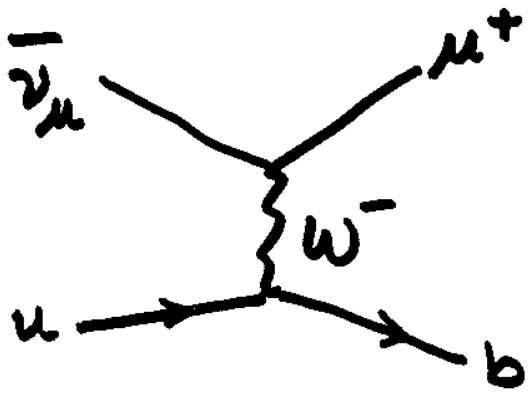
$\bar{\nu}_\mu \bar{s} \to \mu^+ c$ " " "

Big (200kg) target → 1M events/year

$\Delta s$ to $\sim 2\%$

# B-physics

D. Naples
A. Aprosian




$\sim |V_{ub}|^2$

Silicon target ($\sim 3\,m\,H_2$)

$30{,}000\ \nu_\mu N * (.005)^2 \times 3\%$ acceptance

$|V_{ub}|^2$

$= 20$ events/year

---

Longer straight sections

More target

More running

Lots of $V_{ub}$

$\nu$ conclusions

$\mu$ decay is <u>the</u> way to make $\nu$!

1000 times present flux

better understood beam

~ FREE!

RLA3 is already a great machine

But can $\mu$-col have longer straight sectons

(B.K. 100 m)

Needs:

Both $\mu p$ and $\nu$ options need reversable polarity in $\mu$-rings

$\mu$-polarization also helps $\mu p$

Future:

Resolution studies
Detector designs
Shielding studies
....

# νN FIXED TARGET

| νN FIXED TARGET | NuTeV | RLA-3 | μ Collider 250 GeV |
|---|---|---|---|
| $\langle E_\nu \rangle$ GeV | 140 | 135 | 178 |
| $\sqrt{s}$ GeV | 16 | 16 | 19 |
| Event rate *(per cm L-$H_2$)* | 700 Tons Fe | [redacted] K *r=10cm*<br>65 K *total* | 24 K *r=10cm*<br>94 K *total* |
| Events* *(1 meter L-$H_2$)* | ~ $10^6$ | ~ $10^7$/year | ~ $10^7$/year |
| $F_2(x,Q^2)$ | Good stats. Nuclear Target | Use H or D targets to eliminate Nuclear Corrections | |
| $x F_3(x,Q^2)$ | Large x Stats limited. | Improved measurement in x < 0.1 region | |
| $R = \sigma_L/\sigma_T$ | | | |
| $F_2^{Charm}$ | ~ $10^{3-4}$ Stats limited | Improved measure of $\kappa$ $m_c$ $\sin\theta_W$ 6% of CC rate | |
| $V_{ub}$ | | | ~20 Events |
| | | | |

* Note, we obtain excellent statistics using light targets. This is an important consideration when comparing $F_2$ from charged and neutral current experiments.

# μ P COLLIDER

| μ P COLLIDER | HERA | μ P | μ P |
|---|---|---|---|
| $\mu \otimes P$ GeV | $30 \times 820$ | $50 \times 1000$ | $200 \times 1000$ |
| $\sqrt{s}$ GeV | 314 | ~ 450 | ~ 900 |
| Luminosity | 0.05 $fb^{-1}$ *now*<br>1 $fb^{-1}$ *future* | 10 $fb^{-1}$ / year | 10 $fb^{-1}$ / year |
| $F_2(x,Q^2)$ | Excellent stats.<br>x to $10^{-5}$ | Extend high $Q^2$ region.<br>Small x is difficult. | |
| $x F_3(x,Q^2)$ | CC & NC | | |
| $R = \sigma_L/\sigma_T$ | | | |
| $F_2^{Charm}$ | γ-production,<br>D*, diffraction | ? | |
| $F_2^{Bottom}$ | | ?? | |
| $V_{ub}$ | | | |
| | | | |
| | | | |