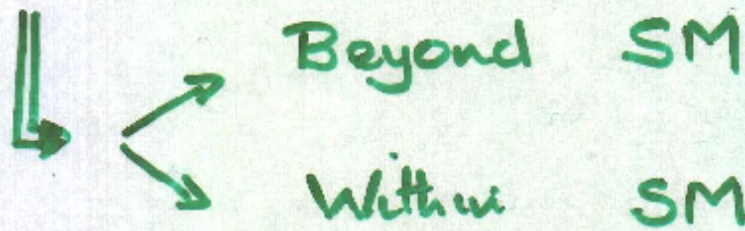


The Future in DIS

- Dominated by HERA I $\rightarrow$ HERA II



Capabilities of modified/upgraded experiments

Beyond the Standard Model

Revolution around the

corus, i.e. **compositeness**
with 'Regge trajectories',

$$\ell^*, q^*, \dots$$

or **large extra dimensions**,
i.e. string theory at TeV scale,
with Kaluza-Klein towers,
novel contact interactions, ...

Unification, far away,

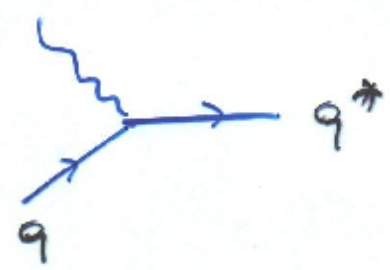
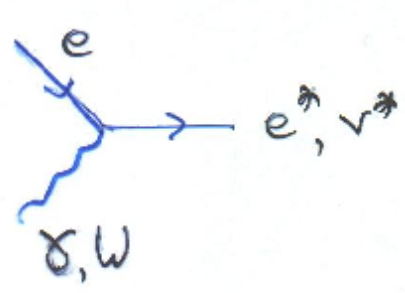
with **SUSY** around the corus, i.e.

$$\tilde{\ell}, \tilde{q}, \tilde{\tau}, \dots$$

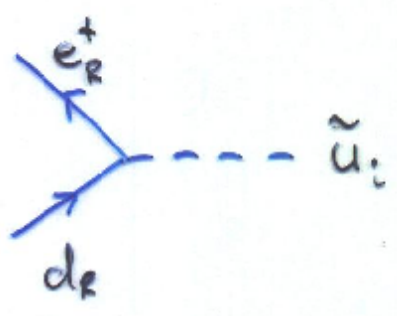
and **small neutrino masses**,
so far the only evidence for
physics beyond the SM,
lepton flavour violation, ...

New particles and interactions

excited leptons and quarks

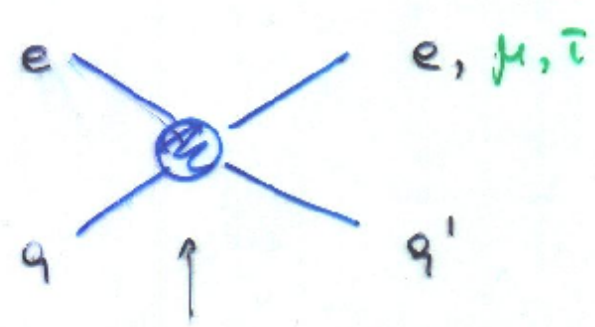


scalar quarks (or leptoquarks), e.g.,



$$\propto \lambda_{it}$$

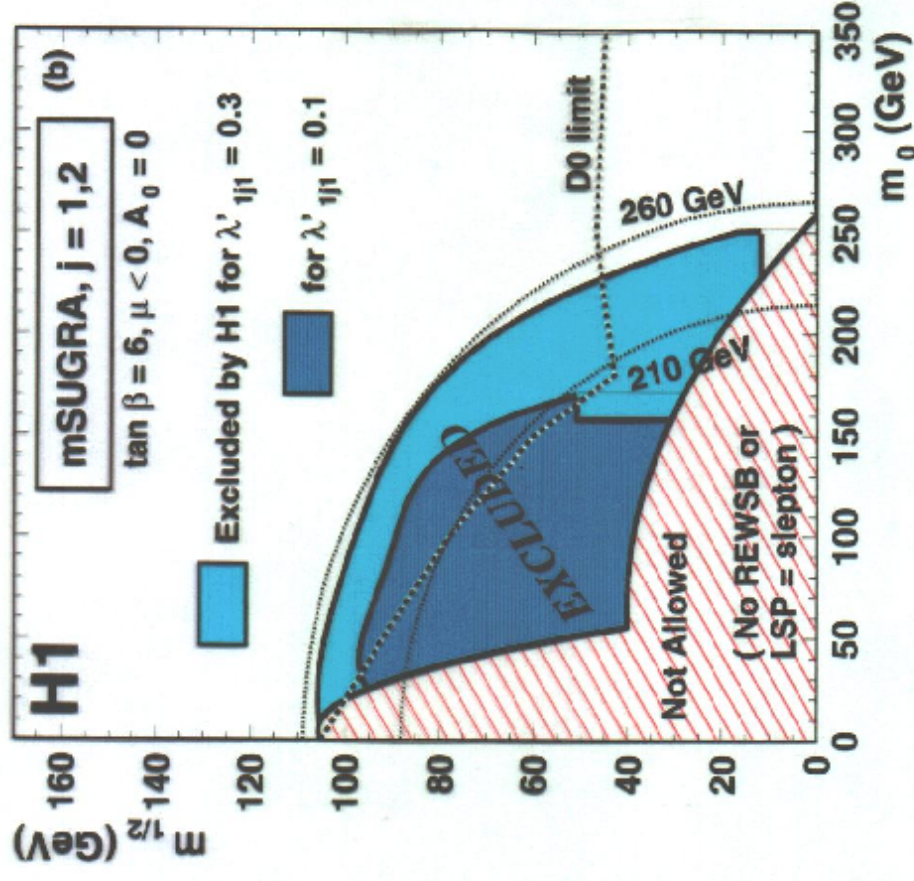
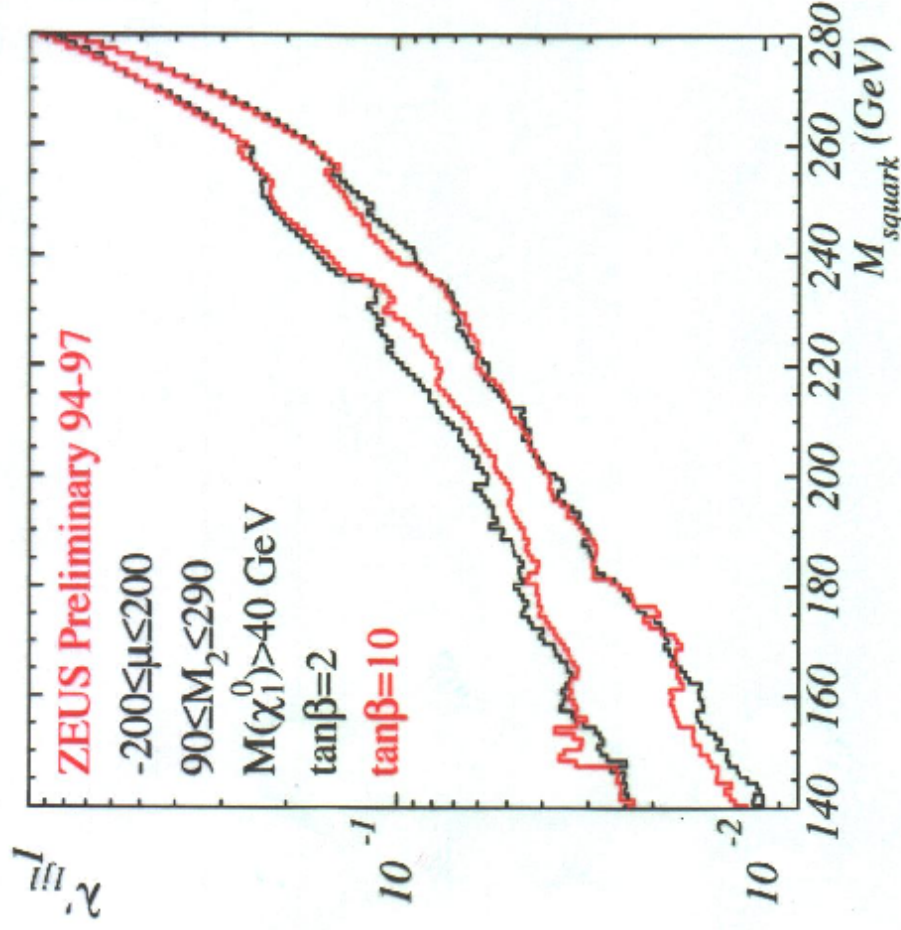
contact interactions



heavy particles, Kaluza-Klein gravitons, ...

important : lepton flavour violation

Limits in SUSY parameter space



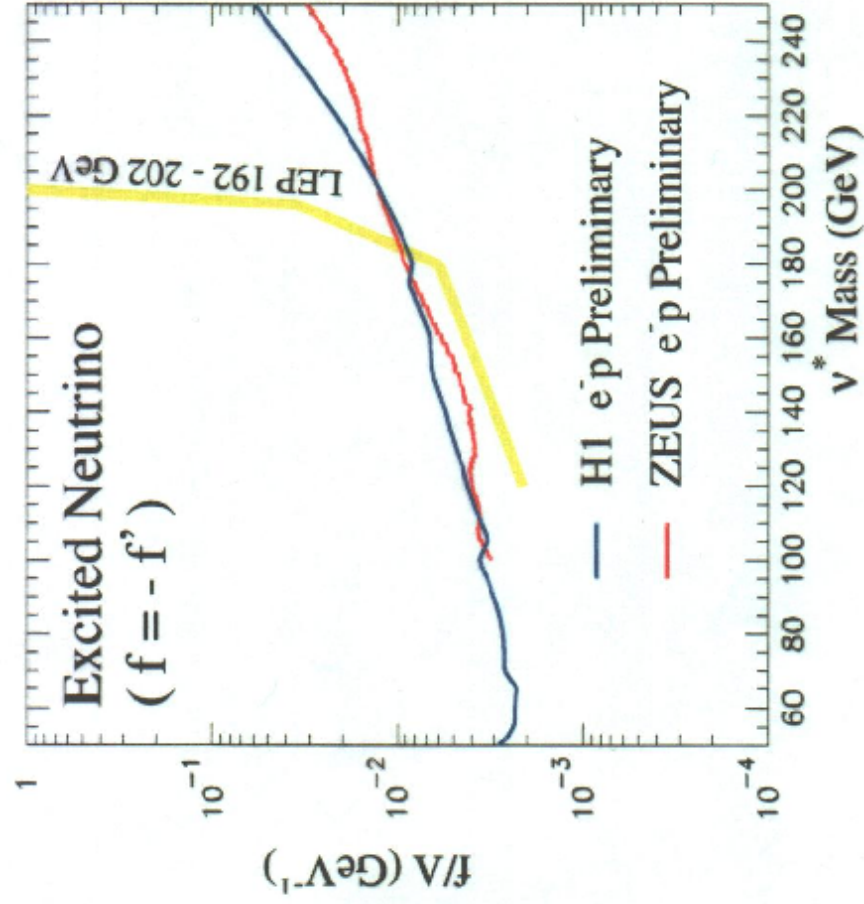
- Unconstrained MSSM: limits variation in parameter scan

- mSUGRA: For reasonably large λ' values, HERA exclusion exceeds TeVatron limits

DESY 01-021

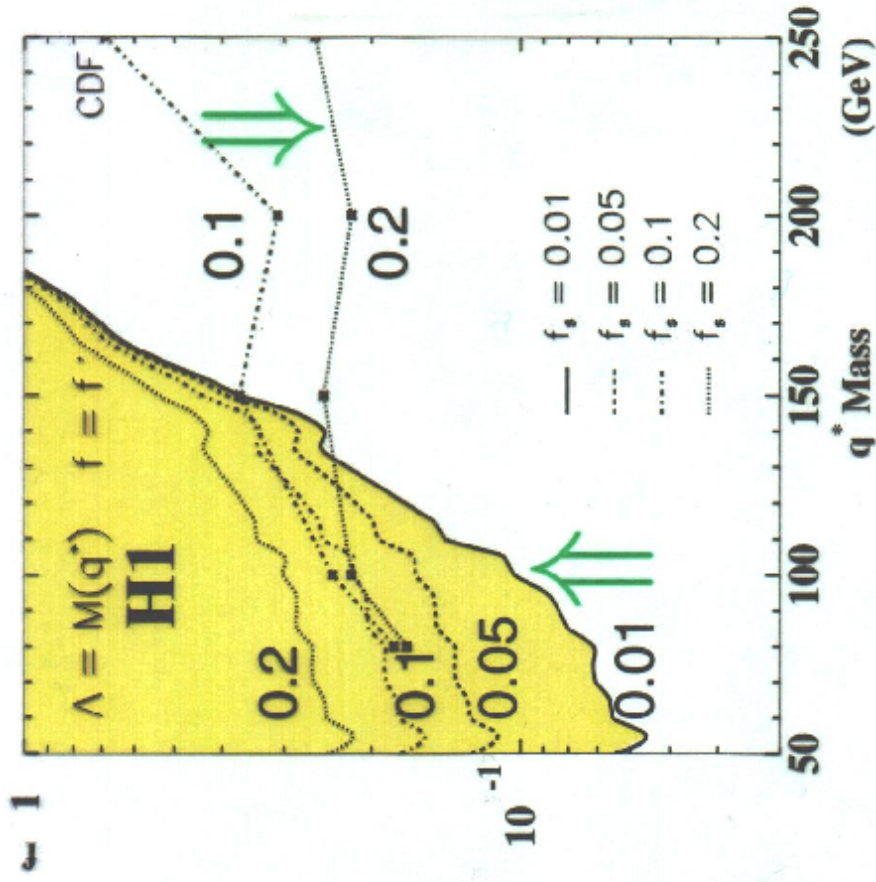
Limits on Excited Fermions

e.g. Excited Neutrinos



**HERA extends LEP limits
beyond $M > 200$ GeV**

Excited Quarks

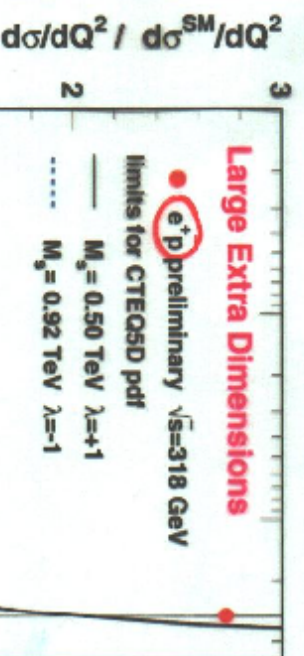
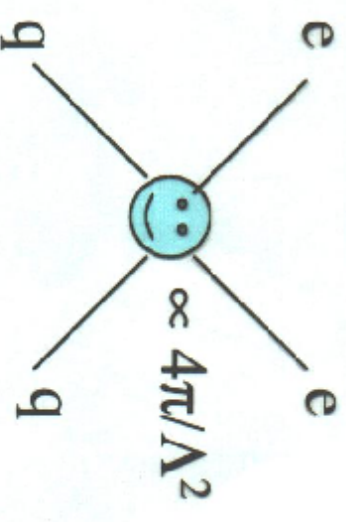


Limit on f for $\Lambda = M(q^*)$

$\Rightarrow$ HERA more sensitive for small f_s

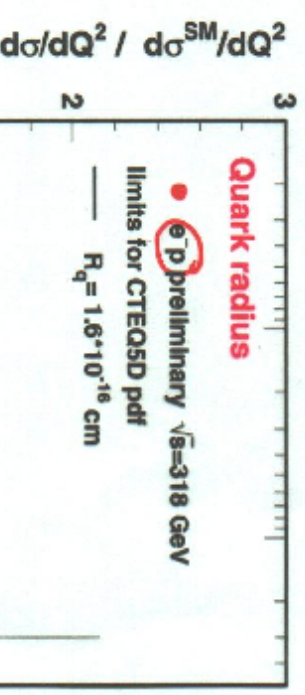
Contact Interactions

- Look for deviation at highest Q^2
Probed distance $= 1/Q \sim 0.001$ fm for $Q^2 \sim 10^4$ GeV²
- General $eeqq$ CI: limits depend on chirality combination (LL, LR, VV, AA....), up to **9 TeV**
- Comparable to LEP ($e^+e^- \rightarrow$ hadrons), TeVatron (Drell-Yan)
- Limits also set on some specific models:



← Kaluza-Klein graviton exchange in **Large Extra Dimension** models

Interpretation in quark form factor:
 $F = (1 - R^2 Q^2 / 6)$
R: quark “radius”



Example: SUSY SM with R_p yields

connection between ν -mixing and $\tilde{g}$ production

Pickel, WB

neutrino mass matrix

$$m_{\nu ij} = m \ f_{ij}$$

$< 1\text{eV}$

seesaw or loops

O(1)

at ν 's : $\sin^2 2\theta_{\text{atm}} \approx 1$

sol ν 's : LMA favoured

SUSY SM :

$$W = l_{ei} \bar{E}_i^c L_i H_1 + l_{di} \bar{Q}_i D_i^c H_1 + \dots$$

$\begin{pmatrix} \nu_e \\ e_e \end{pmatrix}$

$\begin{pmatrix} H^0 \\ H^- \end{pmatrix}$

same weak isospin
and hypercharge

motivates R_p -violating interactions :

$$W_R = \frac{1}{2} \lambda_{ijk} L_i L_j E_k^c + \lambda'_{ijk} L_i Q_j D_k^c$$

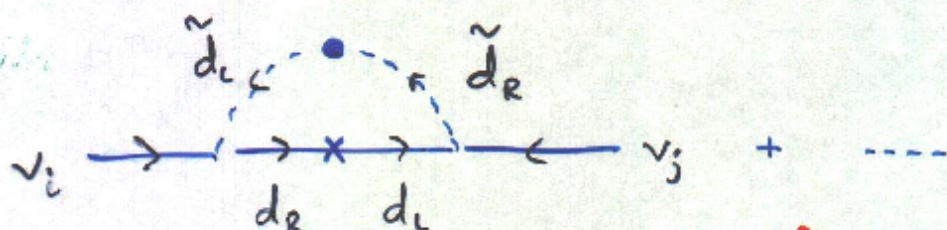
implies lepton number violation, c.f.

Gouvea, Lola, Toke, hep-ph/0008085

Ausatz für R_p -violating couplings, $L_i \sim H_i$,

$$\lambda'_{ijk} = \lambda'_i h_{djk}, \quad \lambda_{ijk} = \dots, \quad \lambda'_i = O(1)$$

i.e., 'flavour alignment'; Majorana ν -masses:



$$m_{\nu ij} = m_{\nu}^{(d)} \lambda'_i \lambda'_j + \dots, \quad \text{large mixing}$$

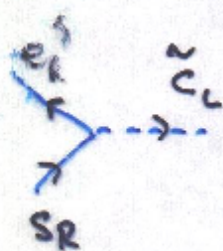
$$m_{\nu}^{(d)} \simeq \frac{N_c}{16\pi^2} \frac{A_d v_1^2}{m_d^2} \text{tr}[(h_d h_d^\dagger)^2]$$

FCNC: $\Delta S = 1, 2$, $\Delta B = 1, 2$ suppressed due to 'flavour alignment'; most 'dangerous':

$$\text{BR}(D^0 \rightarrow \mu\mu, \mu e) \sim 10^{-5}, \quad \text{BR}(\tau \rightarrow e^+ e^- e_\mu) \sim 10^{-5}$$

close to exp. limits!

Predictions: $\lambda'_{iii} \sim \frac{m_i}{v} \tan\beta \sim 0.003$ (0.004, $\beta\beta\alpha$)



$$\lambda'_{122} \sim \frac{m_s}{v} \tan\beta \sim 0.05$$

$$H(37 \text{ pb}^{-1}): 0.29$$

within reach
at HERA II!

Necessary Modifications of the Forward Direction

Challenges

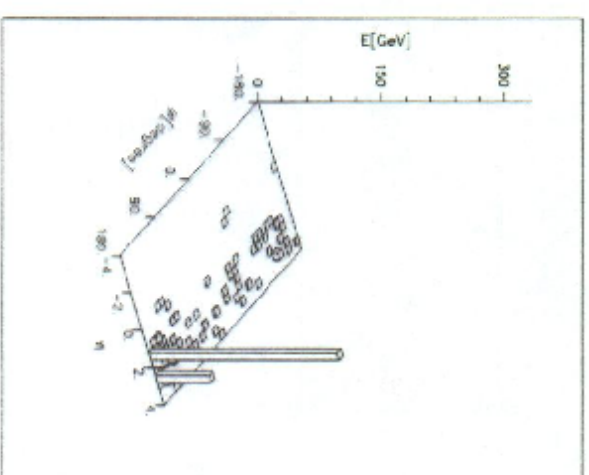
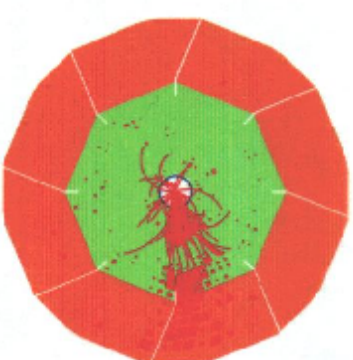
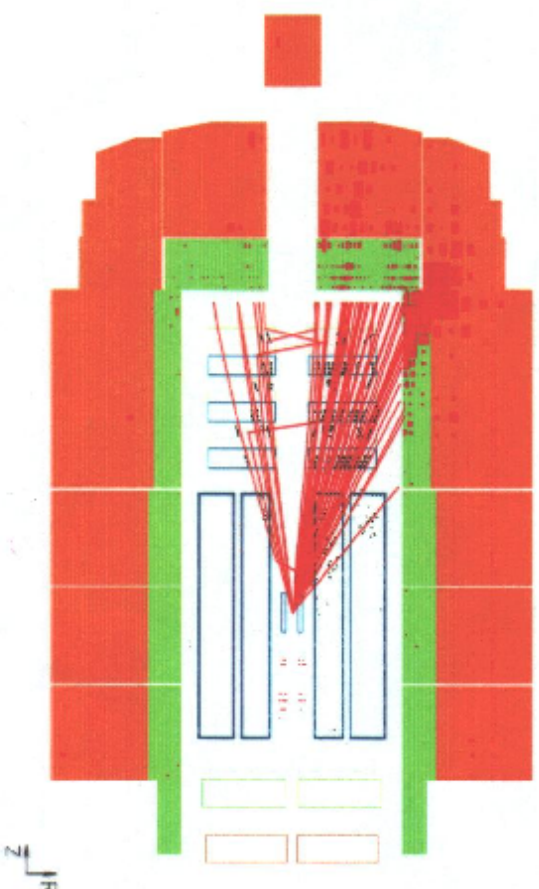
- track density
- separation of electrons/photons and hadrons

Solution

- Forward Tracker (FTD) with more redundancy
- Silicon detector (FST) close to interaction point

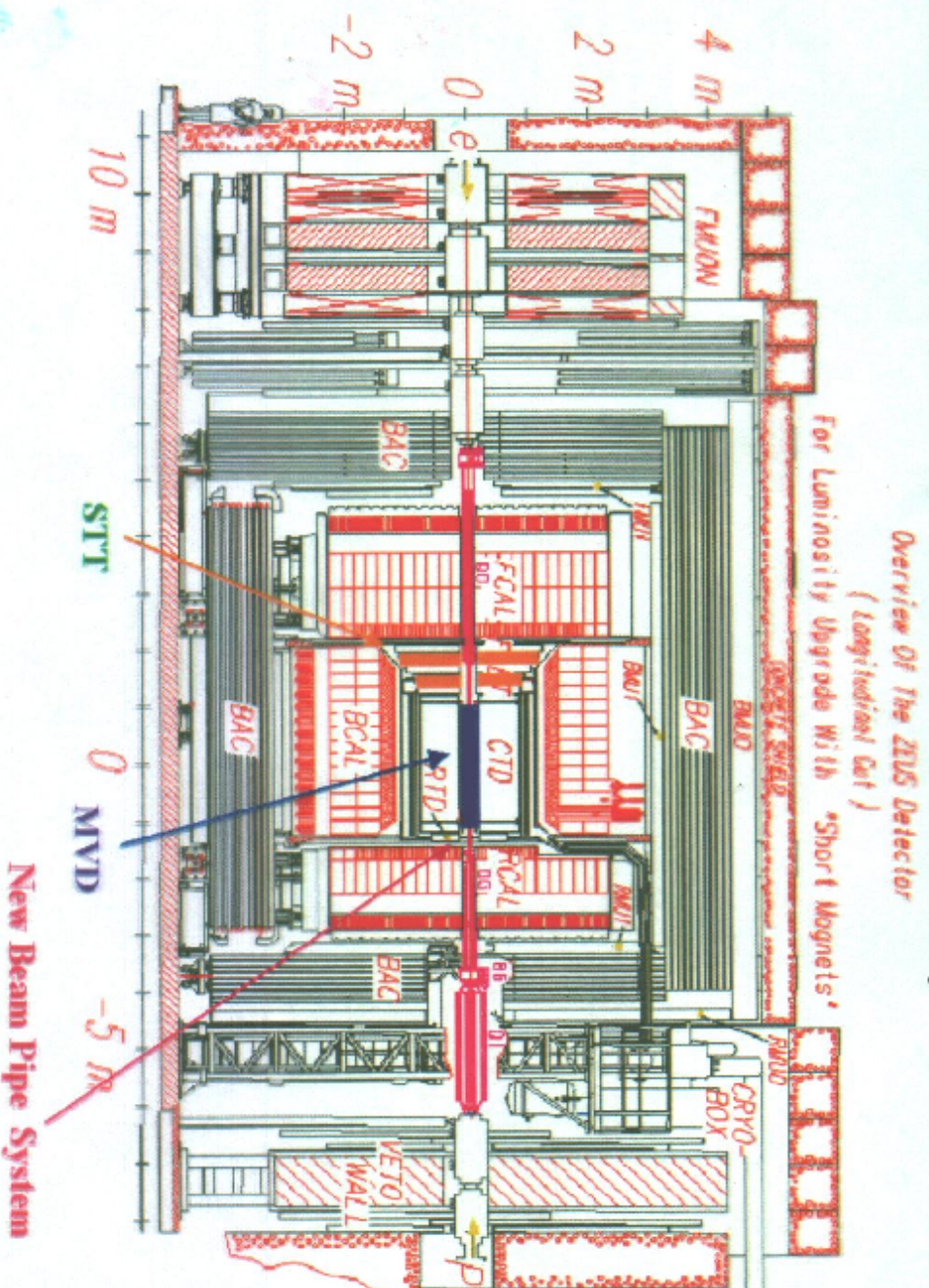
CC event

$P_t = 140 \text{ GeV}$



HERA II Physics

- Both ZEUS & H1 have made major upgrades in order to utilise the increase in HERA luminosity to the full.



Lumi
Monitor

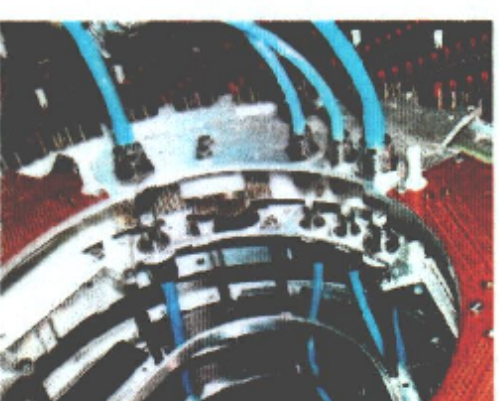
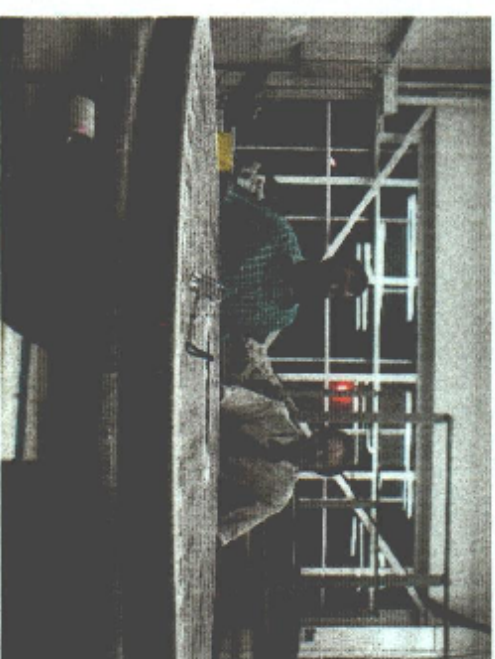
Detectors take Shape

FTD

- 3 modules
- 8 wire planar chambers replace radial modules and TRD
- more redundancy
- pattern recognition/ambiguities

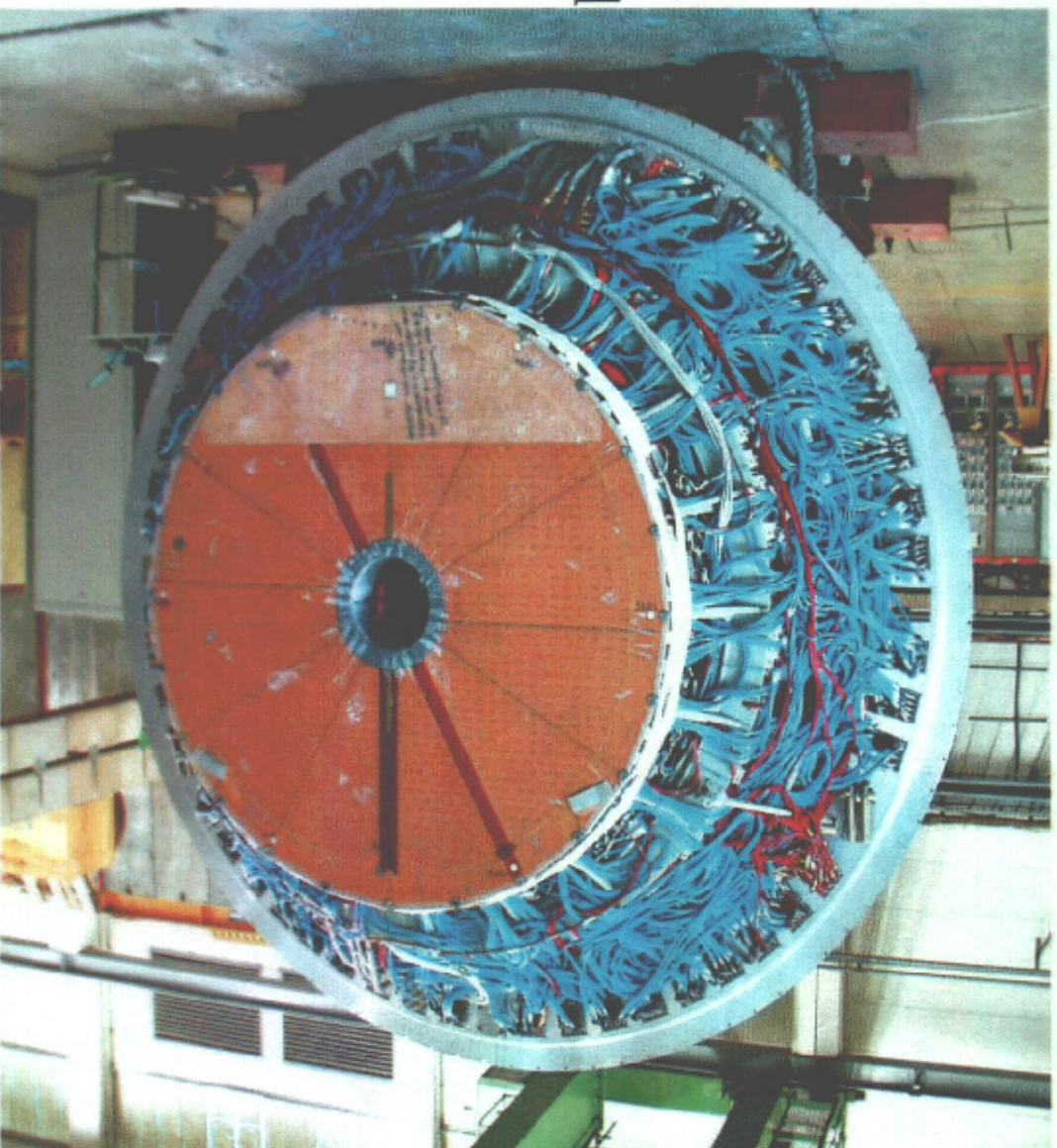
FST

- 5 planes of Si detector to cover small angle acceptance
- design taken from BST
- sophisticated detector insertion mechanism required



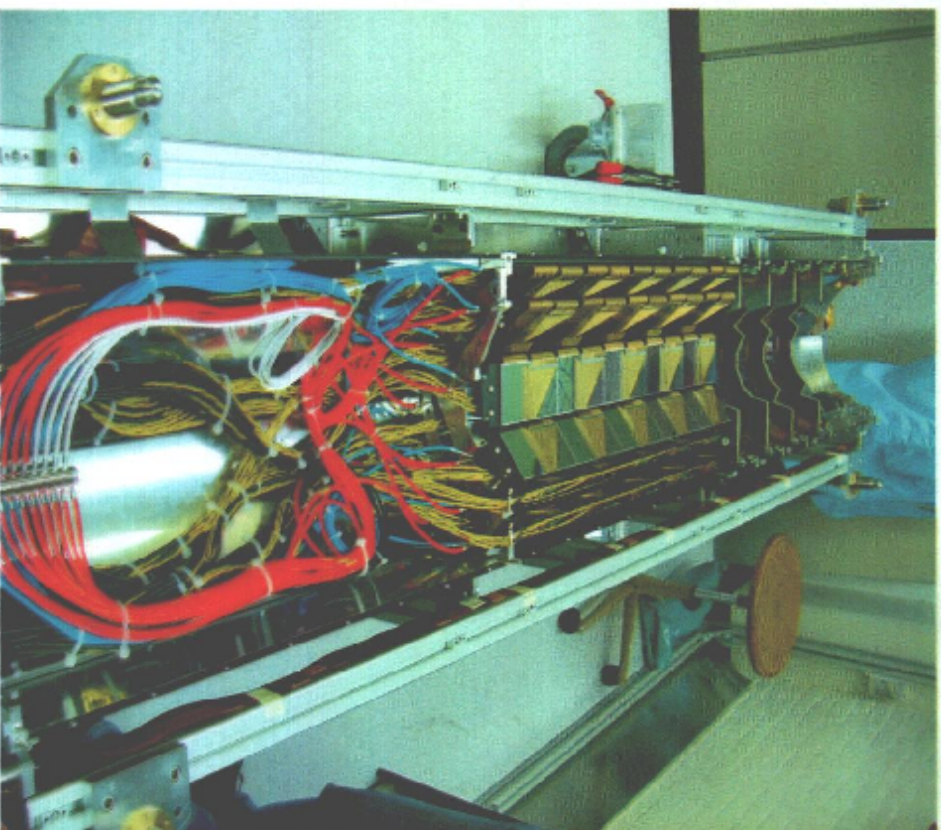
Forward Physics

- ZEUS major upgrade in forward direction replacement of TRD's with two stations of straw-tube chambers, each with 3 stereo layers.
- The forward wheel in the MVD also give improved resolution in forward direction.



Vertex Region

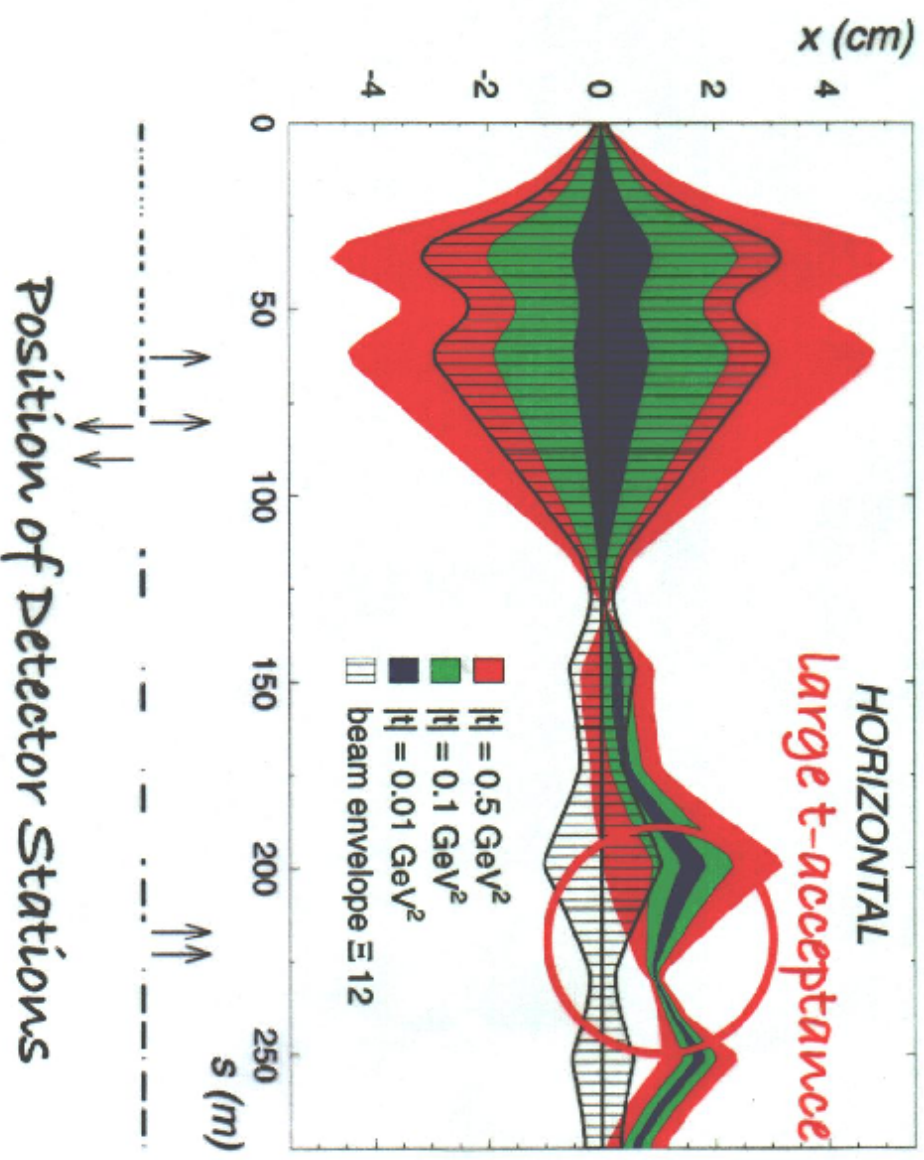
- The ZEUS MVD is a silicon strip detector constructed from n-type silicon with p+type implants and 20μ pitch strips, readout with 120μ pitch. There are 712 sensors and $> 200K$ readout channels.



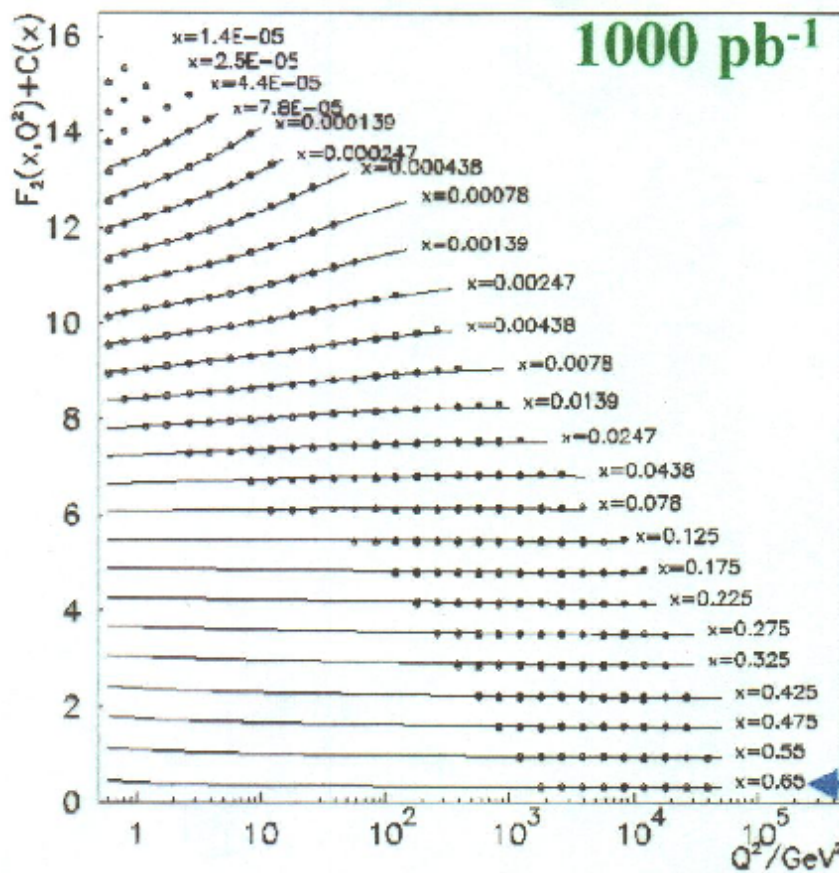
Very Forward Proton Spectrometer

- increase proton acceptance in forward direction for $|t| \leq 0.5 \text{ GeV}^2$
- at 200 m proton beam is well separated from scattered p (detector has to be installed in cold section of ring)
- detector to be installed in first major shutdown after 2002 running

Benefits for inclusive measurements, $\nu\mu$, jets, charm



- The Structure Function F_2



High Precision F_2

Large x, Q^2 range



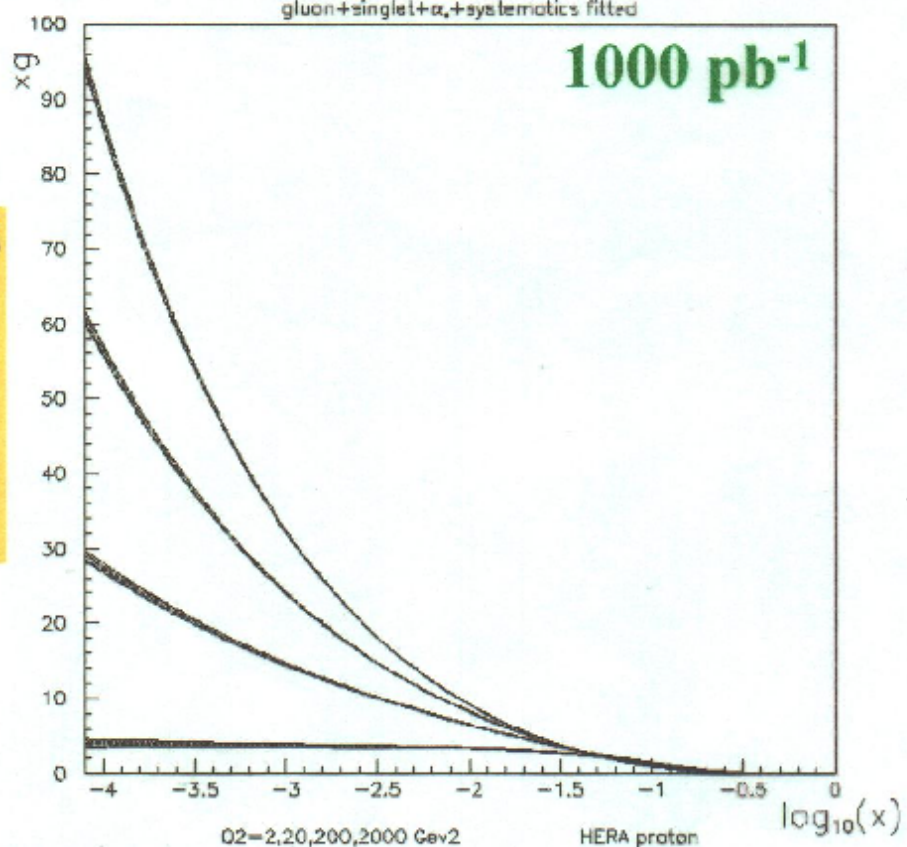
α_s and xg

$x = 0.65$

$Q^2 = 4 \times 10^4$

$$\Delta\alpha_s \leq 0.003$$

$$\frac{\Delta[xg]}{xg} \approx 3\%$$



Polarisation physics

- The accurate measurement of polarisation opens up a completely new domain of HERA physics at high Q^2 .

$$\sigma_{e^+p}^{CC} \propto (1 \pm P)$$

P = polarisation

Resolution on M_W

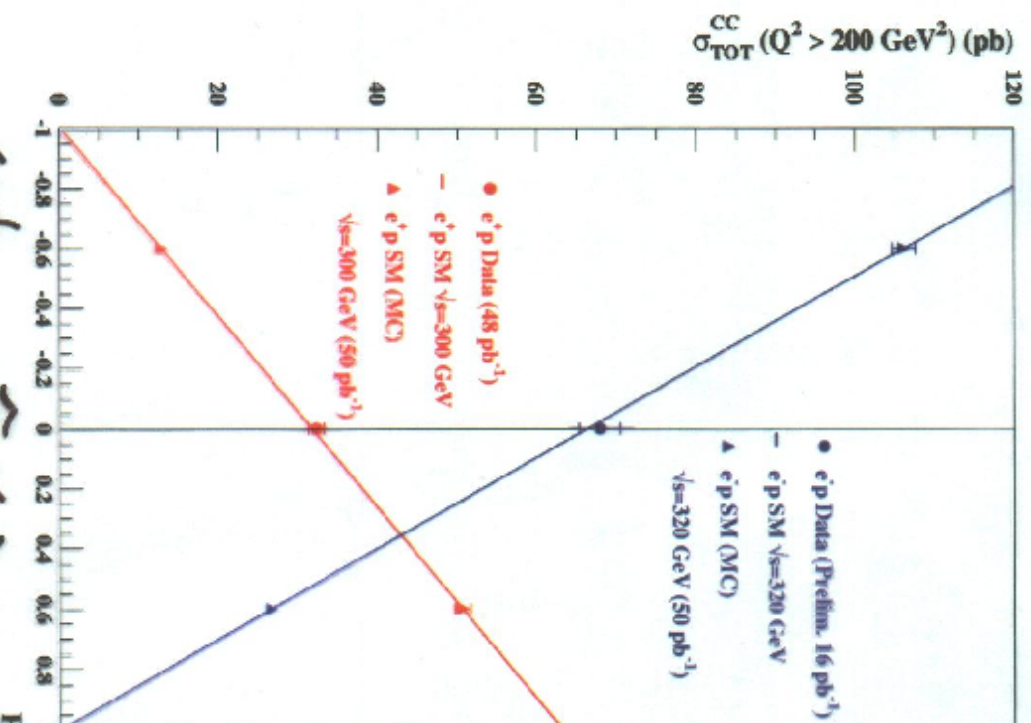
80 MeV

Exclusion limit

$$M_W(R) > 400 \text{ GeV}$$

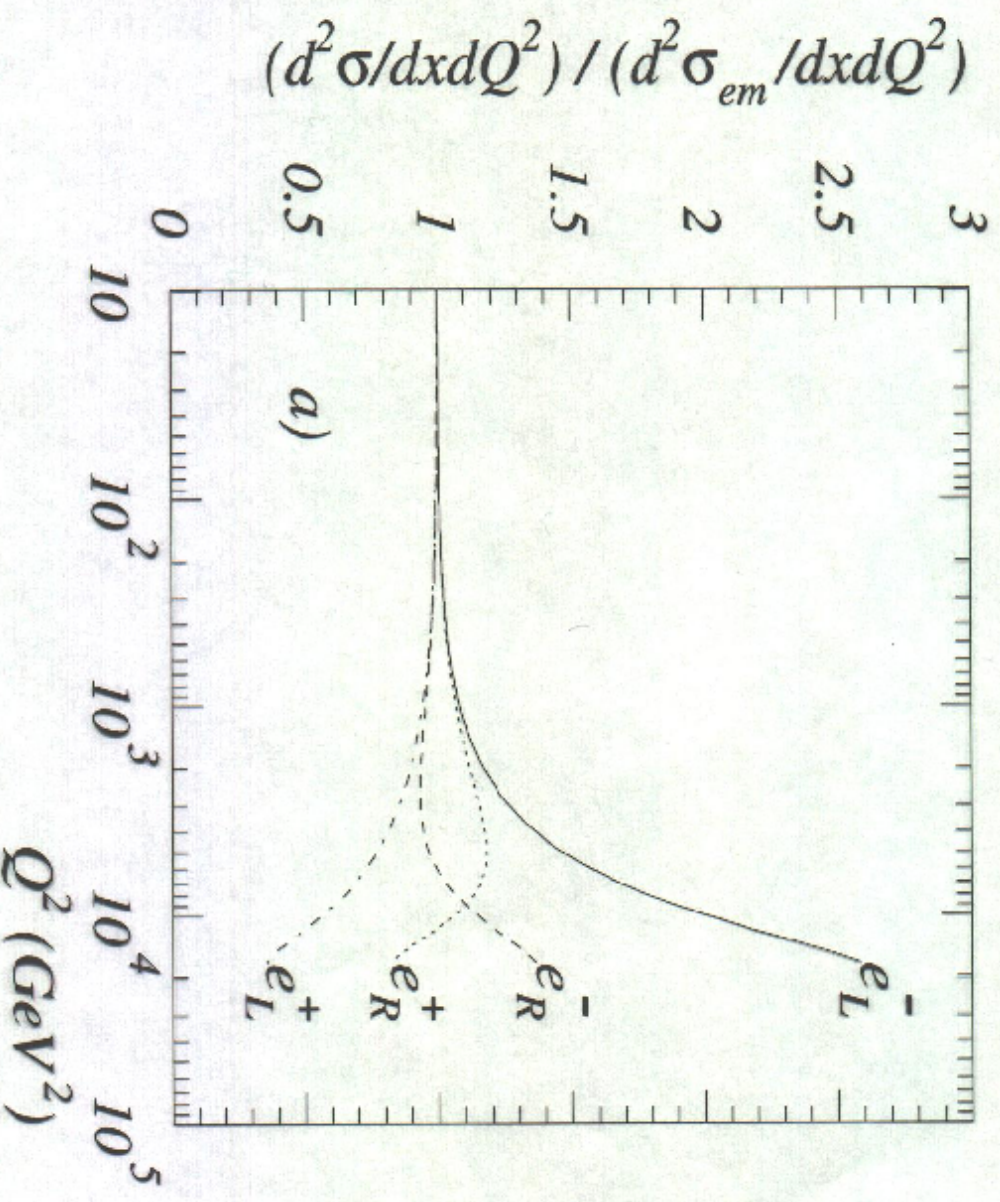
$$\sigma(e^+p \rightarrow \tilde{e}_L \chi) \propto \eta_{12}^{\prime 2}$$

$$\sigma(e^+p \rightarrow \tilde{e}_L \chi) = 0$$



Polarisation physics

- Polarisation dependence of cross-sections is a LARGE effect
- For example,
 @ $Q^2 = 10^4 \text{ GeV}^2$,
 $x = 0.2$,
 $\sigma(e_L^-) / \sigma(e_R^-)$
 is almost
 a factor 2, and
 can be
 measured to
 about 10%
 tot. uncertainty



Polarisation physics

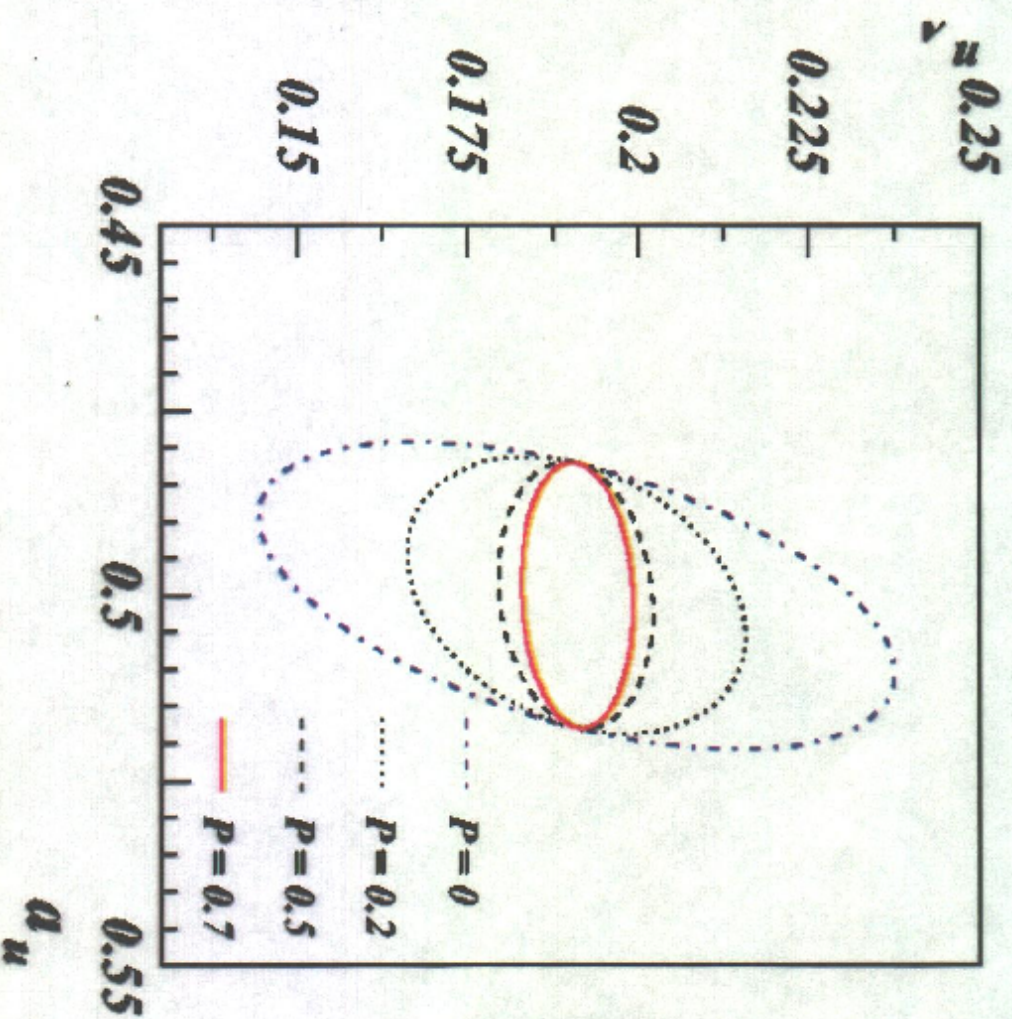
- Quark couplings can be accurately measured, e.g. light quark couplings by looking at differences between $\sigma(L,R)$.

- Great improvement over unpolarised case.

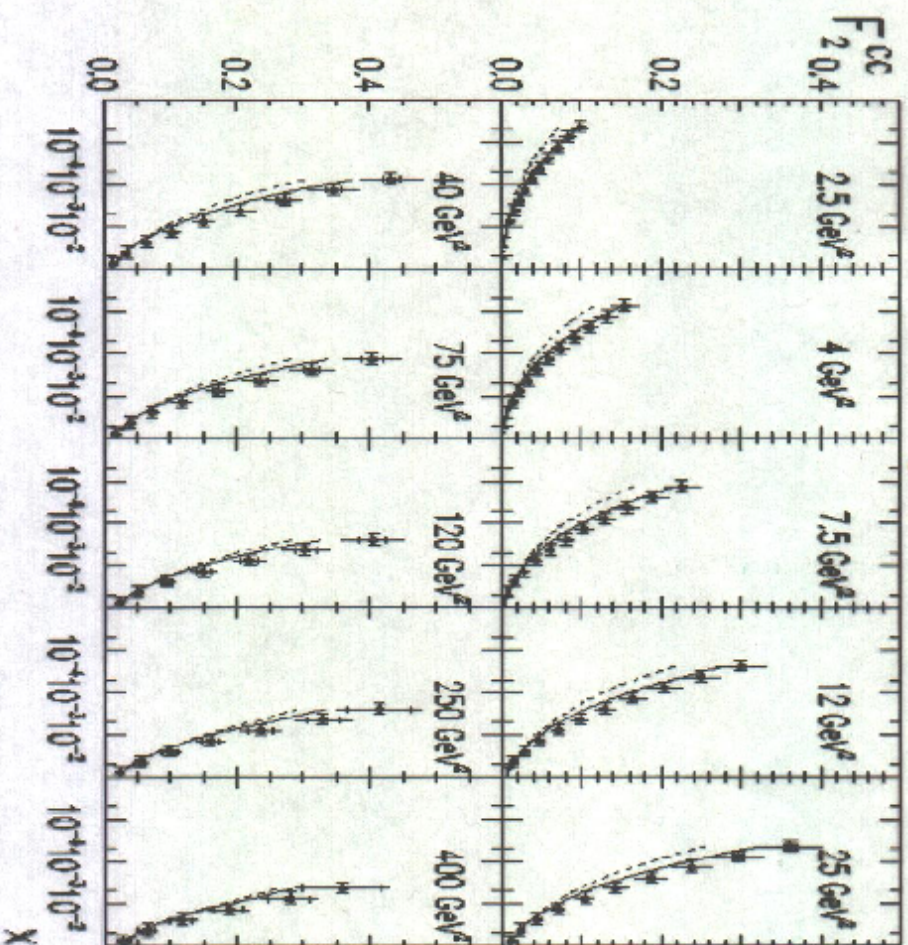
$e_{L,R}^{\pm}, P = \pm 70\%$

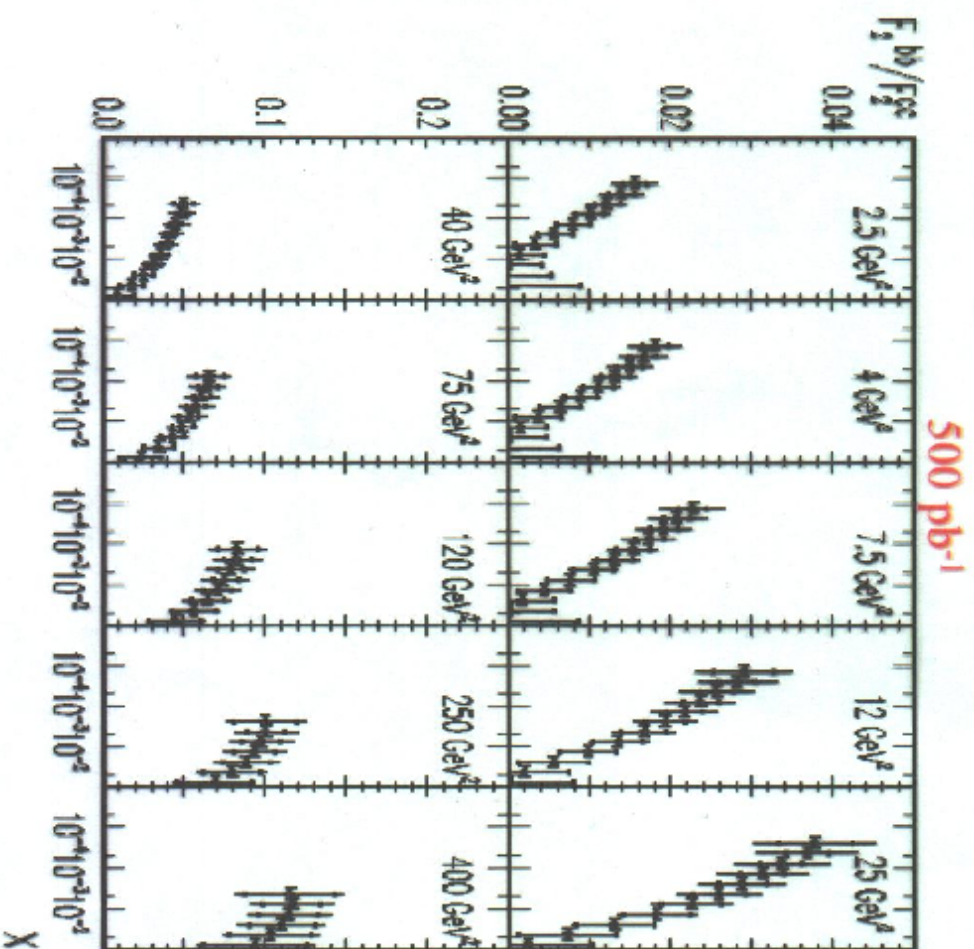
250 pb⁻¹ per beam

	ν	a
u	13%	6%
d	17%	17%

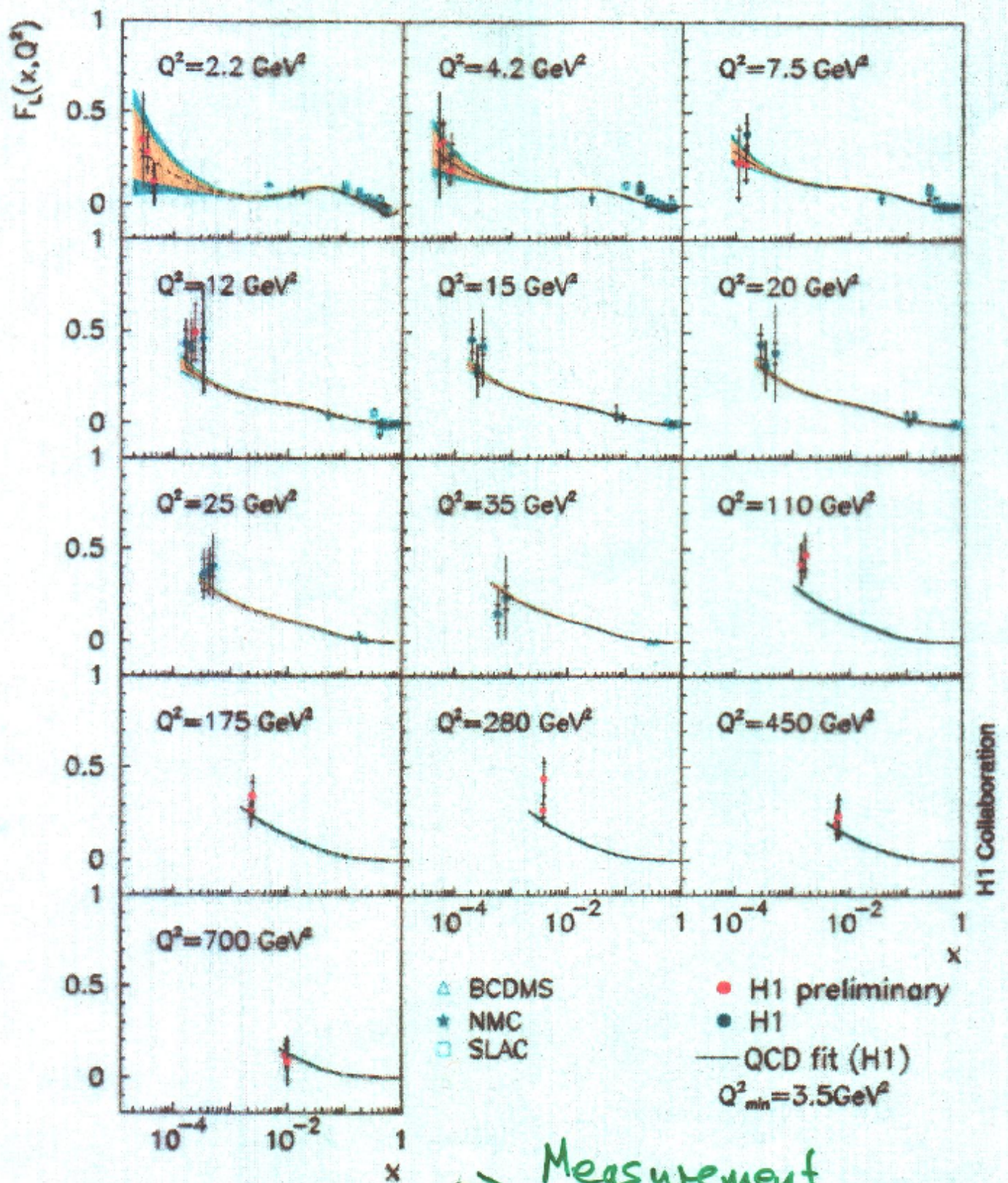


500 pb⁻¹





H1 Results for F_L



⇒ Measurement
↳ Low E_p running

The Future for HERA:

Important continuing role
provided

- High luminosity
- Polarization established
- e^- and e^+

Far Future

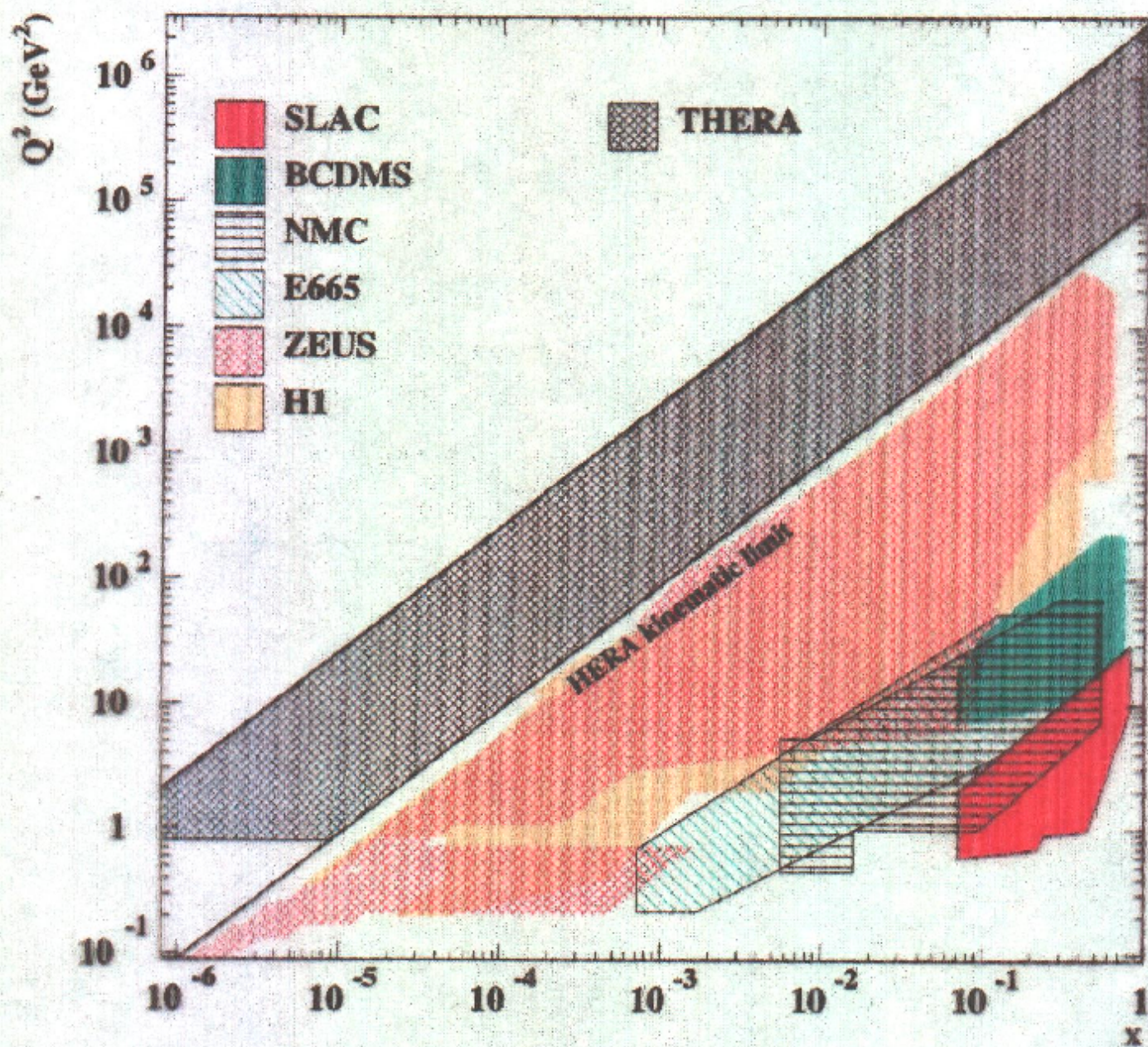
- Tesla $e^+e^- \rightarrow \dots$

↳ THERA

- ν factories/sources ν mixing

↳ "low energy" ν DIS

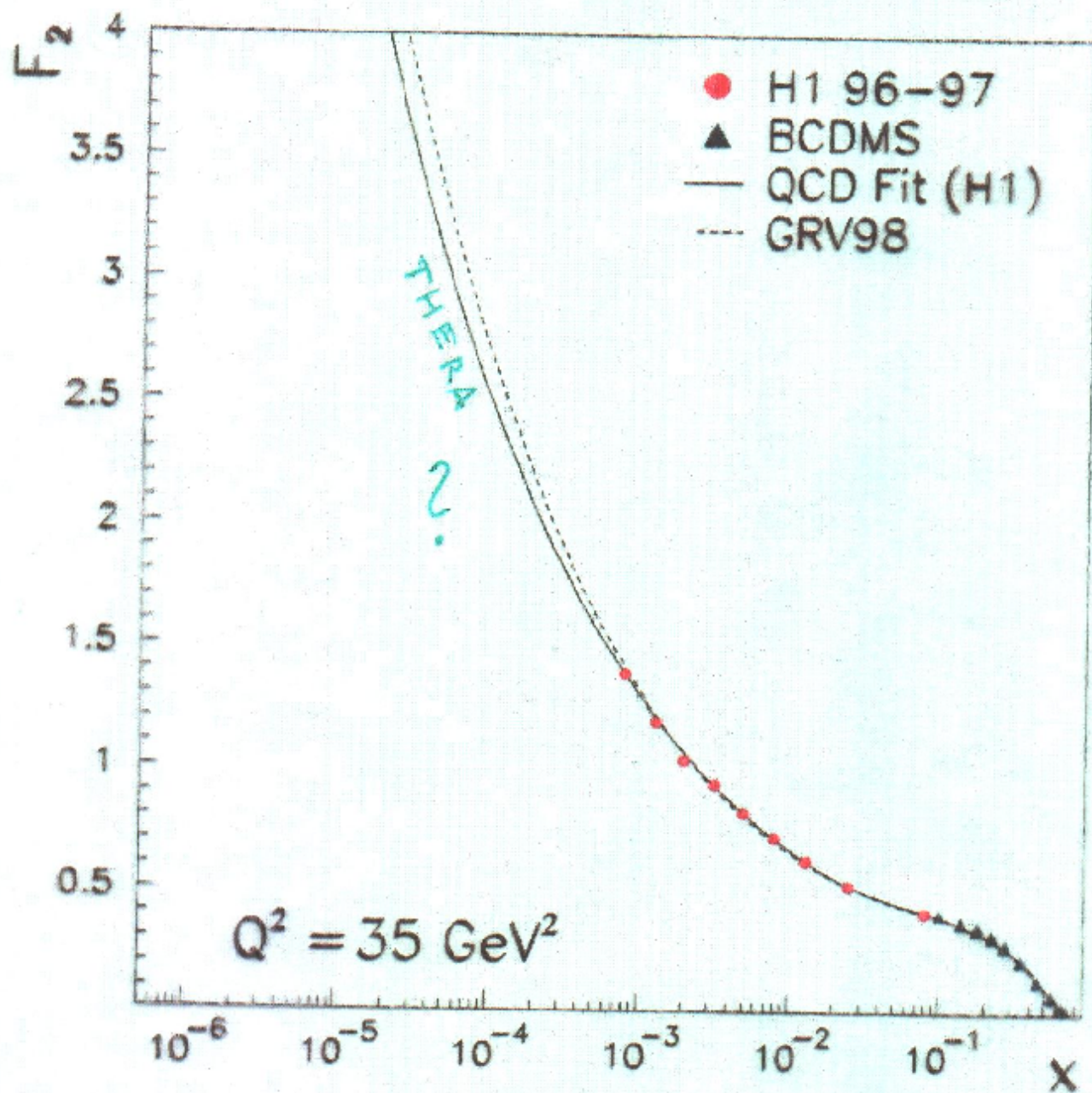
$\nu, \bar{\nu}$ 100% polarized



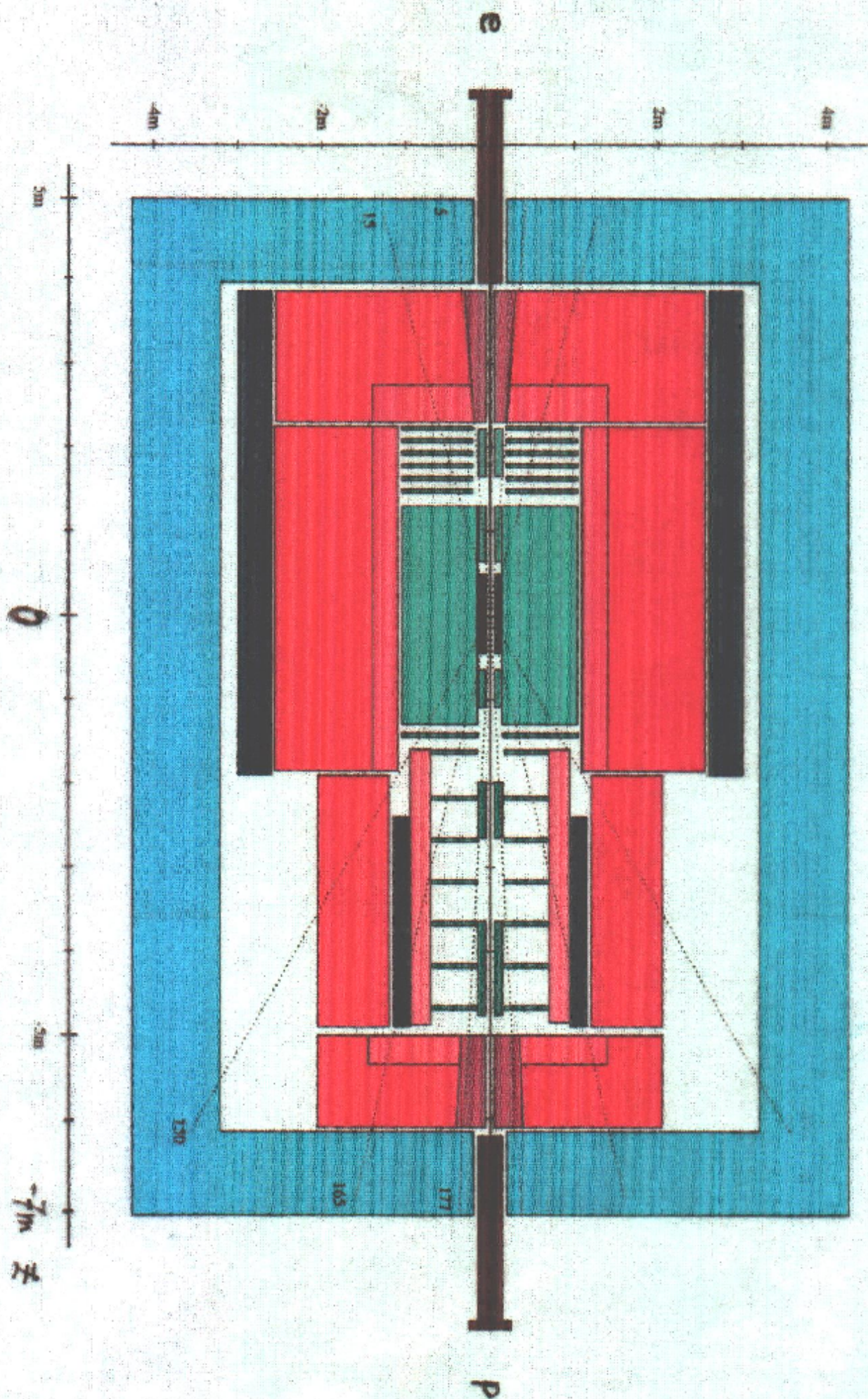
physics: THERA TDR

"thera book"

DESY-LC-Rev 2001-062
Soon to appear - May 04.



THIETA DETECTOR

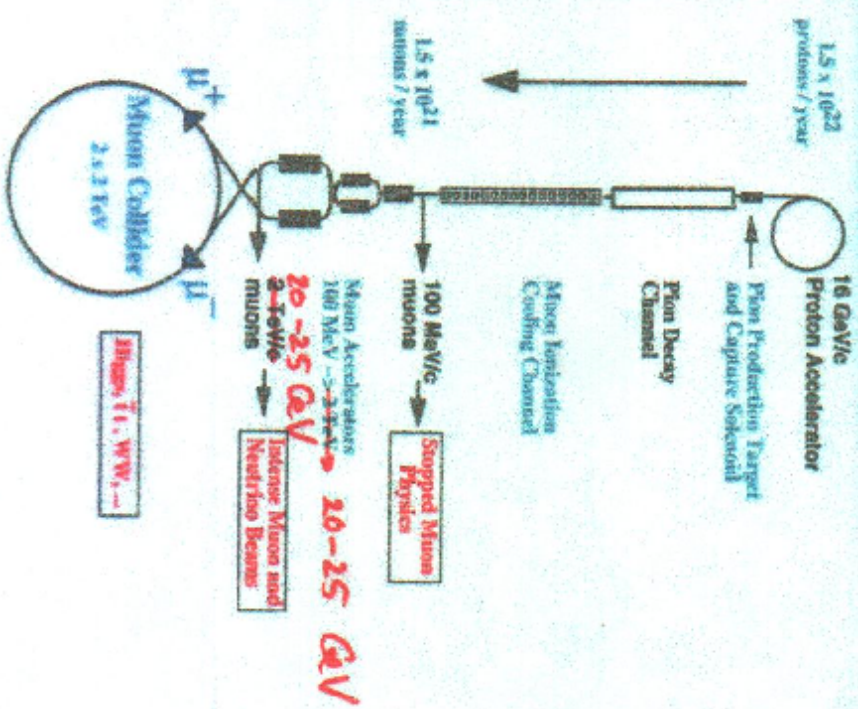




DIS '01
Bologna, Italy
J. G. Morfin
April 2001

work?

- Intense Proton Source (8 - 16 GeV, 10^{21-22} / year)
- Pion Target and Capture Solenoid
- Decay Channel (yield 10^{20-21} muons / year)
- Ionization Cooling Section
- LINAC
- Storage Ring $\rightarrow$ NuFact
- Muon Collider





Neutrino Event Kinematic Domain: FHE - Configuration - MINOS Near Detector

DIS '01
Bologna, Italy
J. G. Martin
April 2001

$\nu\bar{\nu} > 5 \text{ GeV}^2$ (26 M events / year) In units of 10^5 events/year

$Q^2 =$	0	2	4	8	16	$>30 \text{ GeV}^2$
$x = 0$	22.6	.1	.04			
.03	15.6	.6	.1	.05		
.05	17.6	2.4	.5	.06	.01	
.075	14.9	5.6	.6	.2	.02	
.10	11.5	6.5	1.7	.25	.02	
.125	8.9	7.1	3.1	.2	.03	
.15	13.1	11.9	8.5	1.3	.3	
.20	12.1	18.3	17.8	6.5	.8	.01
.30	2.2	13.6	17.1	11.9	2.0	.03
.45	.9	1.7	6.9	6.9	2.8	.2
.65	.1	.5	1.4	.8	.5	.01
1.0						

(Expect $\approx 100,000$ events $x > 0.75$)



SUMMARY

DIS '01
Bologna, Italy
J. G. Morfin
April 2001

- **NuMI/MIDIS** will offer an **intense**, lower energy ν beam to explore with **impressive statistics** and reasonable systematics, among other topics:
 - a first look at measurements of separate $\nu / \bar{\nu}$ F_2 , xF_3 & R
 - study of $\nu / \bar{\nu}$ nuclear effects, particularly HERMES effect!
 - Detailed study of high- x parton distribution functions.
- **NuFact**, a few years after MIDIS, with H_2 , D_2 , and nuclear targets as well as polarized targets:
 - improve statistical and systematic errors of MIDIS measurements
 - Complete ⁴measurements of the partonic spin structure of nucleon
 - High statistics charm production with "clean" final state ($E_\mu \gtrsim 50$ GeV)
 - Precision electroweak measurements; ν - e scattering

Final Remarks

- Large data samples



Progress



expts
phenomenology
theory



Clear HERA view on
topics eg α_s

{ Working Groups }
à la LEP

- HERA II - ~~are~~ important
contributions to
make
- New ideas being developed

⇒ Very Enjoyable & Productive
Workshop