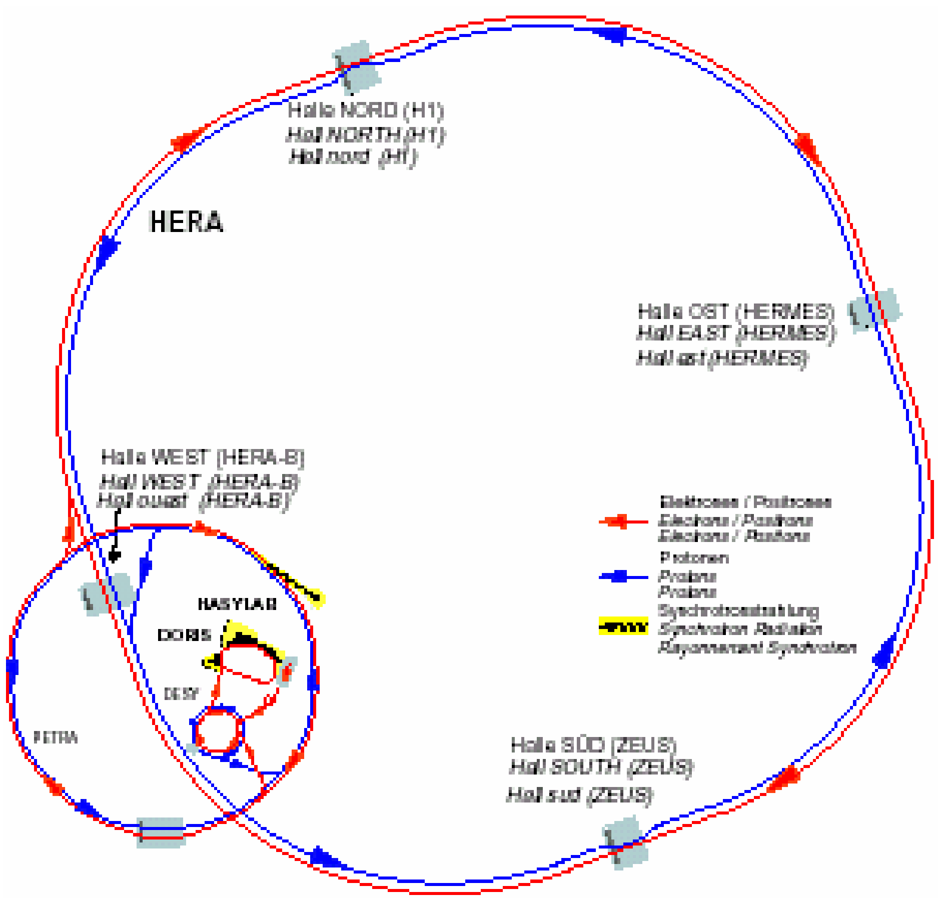
Electron Deuteron Scattering with H1 at HERA



- Introduction
- Physics with deuterons
- H1 upgrade for ed running
- Possible further studies and the necessary H1 upgrades
- Summary and request to PRC

Current list of supporting physicists and institutes

151 physicists…

T. Alexopoulos[3], E. Aschenauer[35], A. Babaev[23], S. Backovic[28], P. Baranov[24], D. Barber[13], A. Belousov[24], N. Bianchi[12], J. Bracinik[25], V. Brisson[27], D. Bruncko[16], A. Bunyatyan[10,34], L. Bystritskaya[23], A. Campbell[13], I. Cheviakov[24], L. Chtarkov[24], G. Cuillo[11], M. Contalbrigo[11], J.G. Contreras[22], J. Dainton[17], P. Dalpiaz[11], M. Danilov[24], E. De Sanctis[12], E.A. De Wolf[2], P. Di Nezza[12], V. Dodonov[10,15], M. Dris[3] A. Dubak[28], V. Efremenko[23], A. Eliseev[24], A. Fantoni[12], A. Fedotov[23], J. Ferencei[13], A. Fomenko[24], J. Gayler[13], R. Gerhards[13], S. Ghazaryan[34], A.A. Glazov[8], L. Goerlich[9], N. Gogitidze[24], L. Gorbov[24], S. Gorbounov[35], T. Greenshaw[17], G. Grindhammer[25], G. Gustafson[20], V. Guzey[5], L. Hajduk[9], I. Herynek[29], K.-H. Hiller[35], A. Hovhannisyan[34], G. Ingelman[33], M. Jacquet[27], L. Joensson[20], H. Jung[20], E. Kabuss[21], S. Kalburov[10], M. Kapishin[10], M. Karlsson[20], V. Kekelidze[10], I. Kenyon[4], C. Kiesling[25], E. Kinney[6], Y. Kiryushin[10], M. Klein[35], P. Kostka[35], S. Kotov[24], A. Knutsson[20], A. Kropivnitskaya[23], W. Lange[35], T. Lastovicka[35], A. Lebedev[24], P. Lenisa[11], S. Levonian[13], K. Lipka[35], E. Lobodzinska[35,9], L. Loennblad[20], N. Loktionova[24], R. Lopez-Fernandez[13], B. Lundberg[20], L. Lytkin[10,15], V. Lubimov[23], E. Malinovski[24], H.-U. Martyn[1], J. Martyniak[9], S. Maxfield[17], G. Medin[28], A. Mehta[17], W. Melnitchouk[26], J. Meyer[13], S. Michine[24], S. Mikocki[9], D. Milstead[17], U. Mjoernmark[20], A. Morozov[10], V. Muccifora[12], P. Murín[16], V. Nagovitsyn[23], T. Naumann[35], P.R. Newman[4], C. Niebuhr[13], A. Nikiforov[24], D. Nikitin[10], G. Nowak[9], W.D. Nowak[35], B. Olivier[13], J. Olsson[13], A. Oussik[24], D. Ozerov[23], C. Pascaud[27], G. Patel[17], D. Pitzl[13], N. Raicevic[28], P. Reimer[29], E. Rizvi[4], R. Roosen[7], A. Rostovtsev[23], S. Rusakov[24], F.P. Schilling[13], V. Shekelyan[25], V. Schroeder[13], T. Sjoestrand[20], T. Sloan[17,40], P. Smirnov[24], Y. Soloviev[24], V. Soskov[24], V. Spaskov[10], B. Stella[31], J. Stewart[35], U. Stoesslein[13], V. Tcholakov[10], G. Thompson[17], P. Thompson[4], D. Traynor[19], I. Tsakov[32], Y. Tsipolitis[3] I. Tsurin[35], J. Turnau[9], E. Tzamarioudaki[3] A. Uraev[23], A. Valkarova[30], P. Van Mechelen[7], I. Vazdik[24], M. Vogt[13], V. Volchinski[34], R. Wallny[19], J. Zacek[30], J. Zalesak[29], Z. Zhang[27], A. Zhokin[23], F. Zomer[27].

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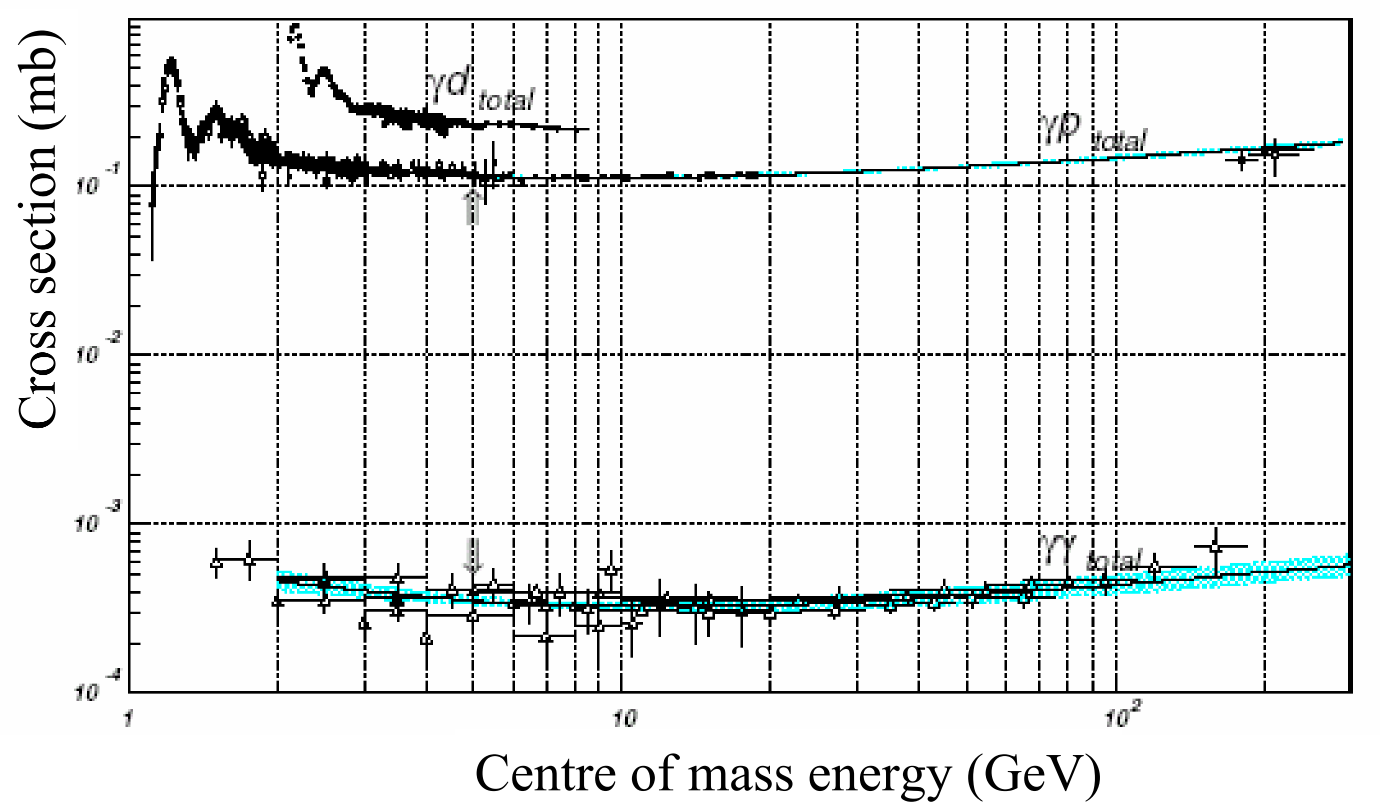
…from 34 institutes

[1] *I. Physikalisches Institut der RWTH, Aachen, Germany*
[2] *Physics Department, Universitaire Instelling Antwerpen, Antwerpen, Belgium*
[3] *National Technical University of Athens, NTUA, Athens, Greece*
[4] *School of Physics and Space Research, University of Birmingham, Birmingham, UK*
[5] *Institut für Theoretische Physik II, Ruhr-Universität Bochum, Bochum, Germany*
[6] *Nuclear Physics Laboratory, University of Colorado, Boulder, USA*
[7] *Inter-University Institute for High Energies ULB-VUB, Brussels, Belgium*
[8] *Enrico Fermi Institute, University of Chicago, USA*
[9] *Institute for Nuclear Physics, Cracow, Poland*
[10] *Joint Institute for Nuclear Research, Dubna, Russia*
[11] *Universita' di Ferrara and INFN-Sez., Ferrara, Italy*
[12] *Instituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, Frascati, Italy*
[13] *DESY, Hamburg, Germany*
[15] *Max-Planck-Institut für Kernphysik, Heidelberg, Germany*
[16] *Institute of Experimental Physics, Slovak Academy of Sciences, Košice, Slovak Republic*
[17] *Department of Physics, University of Liverpool, Liverpool, UK*
[18] *Queen Mary and Westfield College, London, UK*
[19] *University of Los Angeles, USA*
[20] *Physics Department, University of Lund, Lund, Sweden*
[21] *Institut für Kernphysik, Universität Mainz, Mainz, Germany*
[22] *Departamento de Fisica Aplicada, Cinvestav Merida, Yucatan, Mexico*
[23] *Institute for Theoretical and Experimental Physics, Moscow, Russia*
[24] *Lebedev Physical Institute, Moscow, Russia*
[25] *Max-Planck-Institut für Kernphysik, München, Germany*
[26] *Jefferson Lab, Newport News, USA*
[27] *LAL Orsay, Universite de Paris-Sud, IN2P3, Orsay, France*
[28] *University of Podgorica, Montenegro*
[29] *Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic*
[30] *Faculty of Mathematics and Physics, Charles University, Praha, Czech Republic*
[31] *Dip. di Fisica Universita di Roma Tre and INFN Roma 3, Rome, Italy*
[32] *Institute for Nuclear Research and Nuclear Energy, Academy of Sciences, Sofia, Bulgaria*
[33] *Department of High Energy Physics, Uppsala University, Sweden*
[34] *Yerevan Physics Institute, Yerevan, Armenia*
[35] *DESY, Zeuthen, Germany*

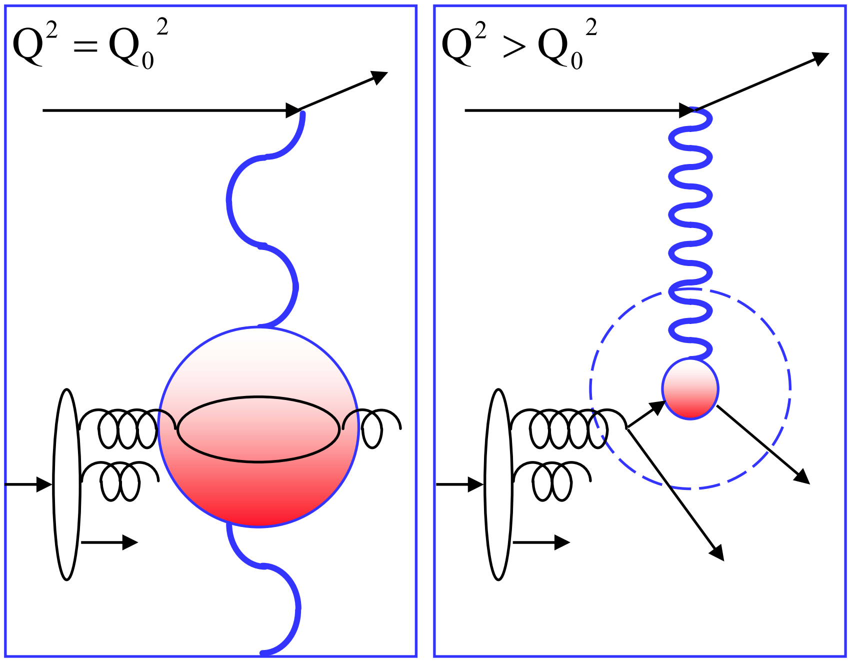
Introduction – why an electron deuteron programme?

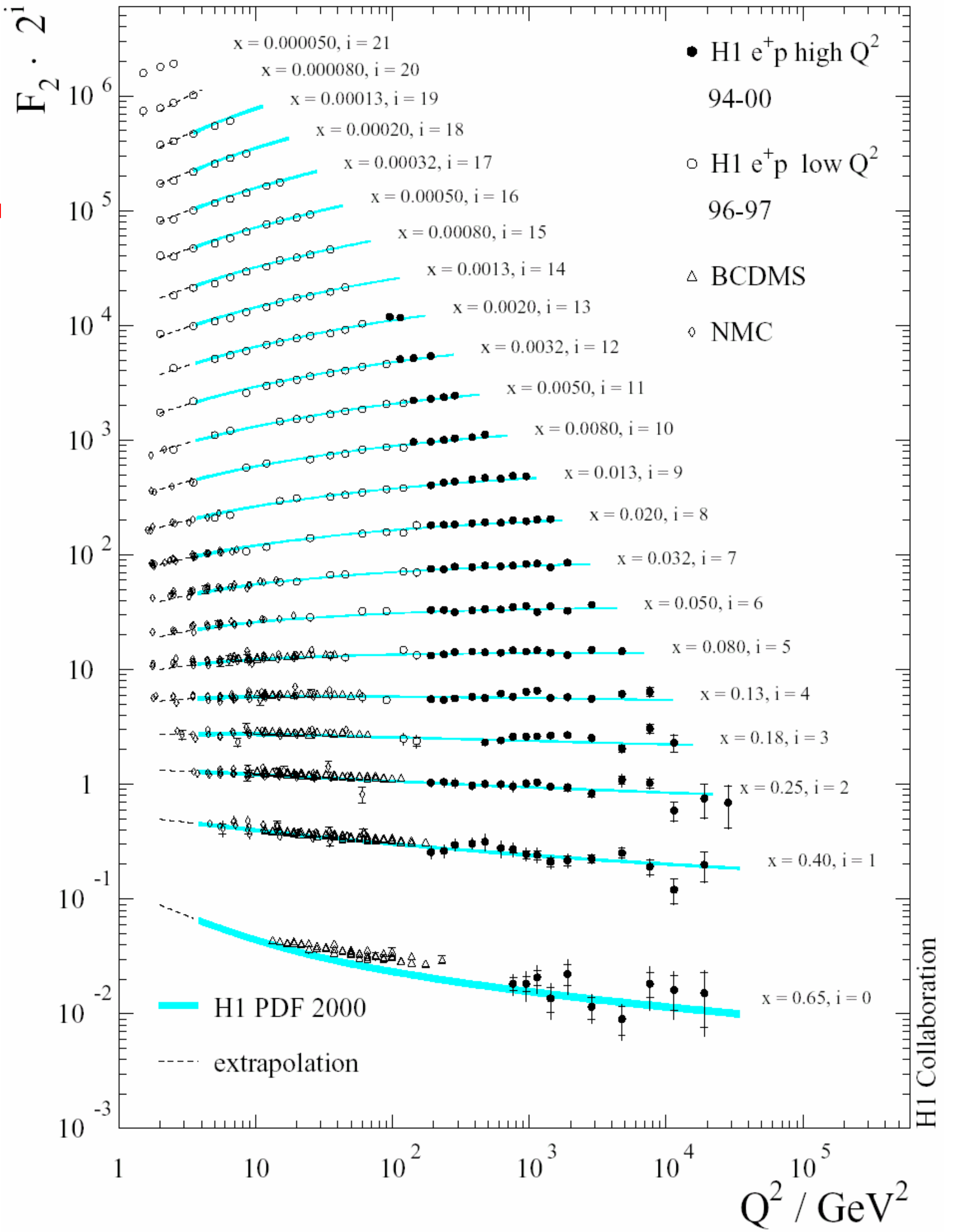
- Surprisingly little is known about the deuteron, and hence the neutron, at high energies.



Introduction

- Current HERA inclusive data beautifully described by QCD.

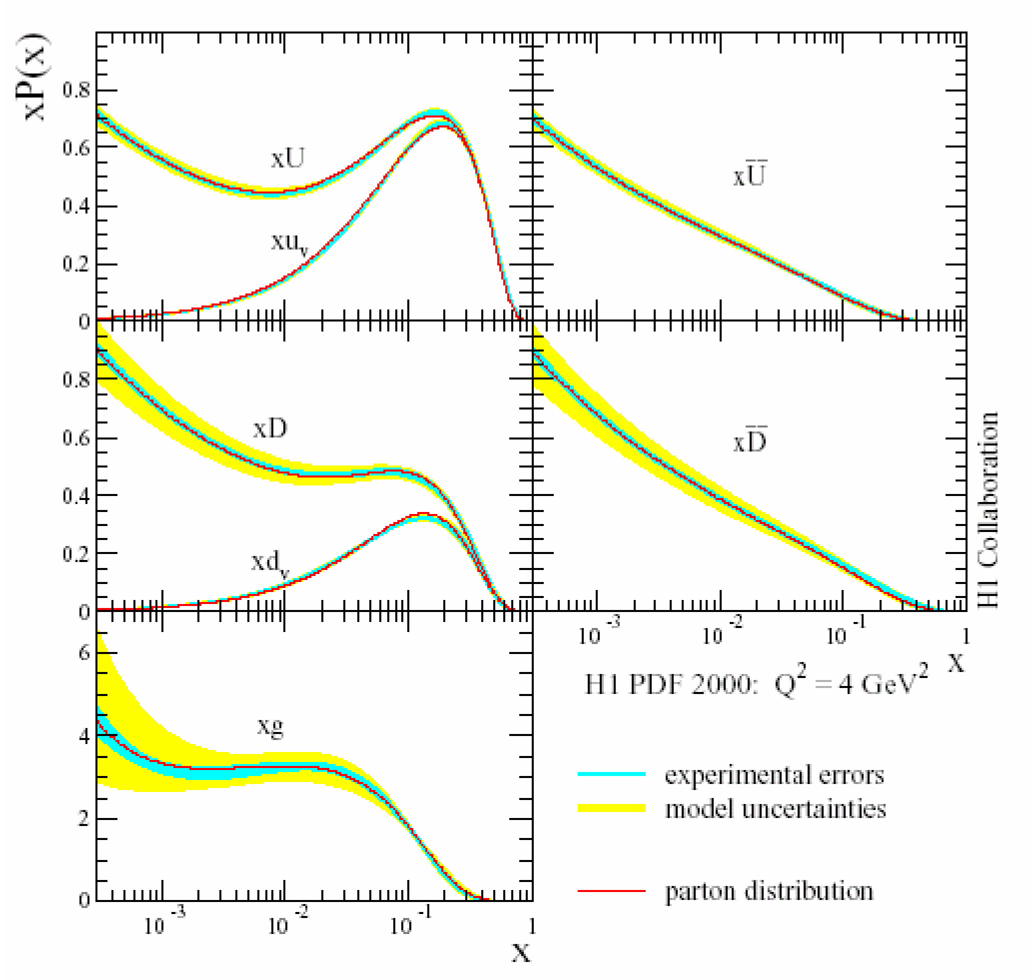




Introduction

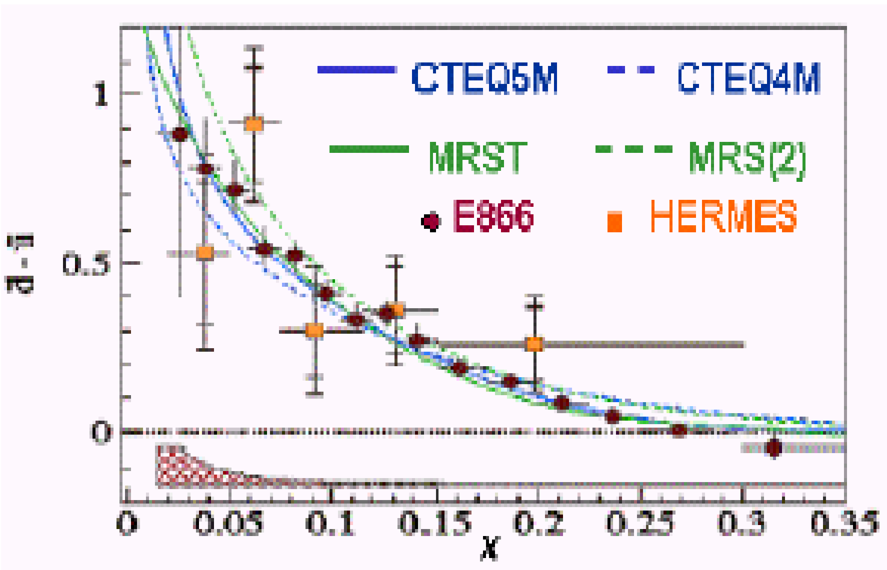
- Fit using NLO DGLAP formalism allows determination of PDFs…
- …and competitive measurement of strong coupling constant:
  $\alpha_S(M_Z^2) = 0.1150 \pm 0.0017(\text{exp.})\,^{+0.0009}_{-0.0005}(\text{mod.}) \pm 0.005(\text{scale}).$
- Why continue beyond 1 fb^{-1}?
- Aim: determine over as wide a kinematic range as possible the PDFs $g(x, Q^2), \bar{u}, \bar{d}, u_v, d_v, s, c, b$ and measure with increased precision $\alpha_s(Q^2)$.

- H1 (+BCDMS) PDFs:

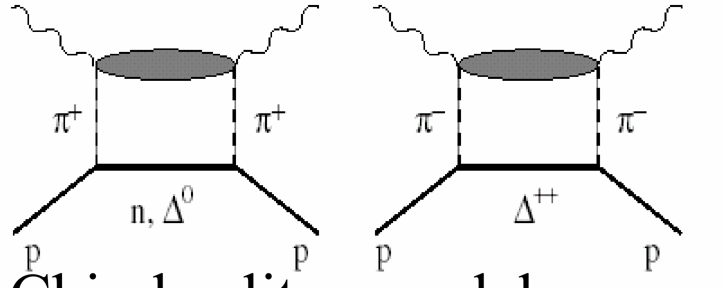


Structure functions and PDFs

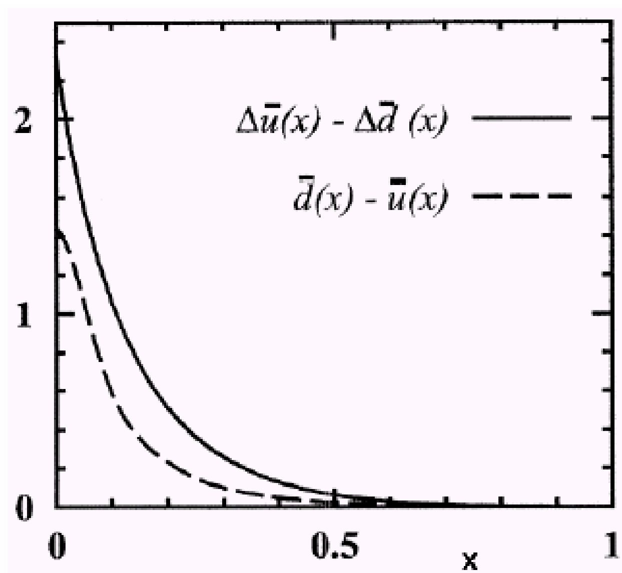
- Extractions of PDFs assume $\bar{d} = \bar{u}$ at low x.
- Plausible as both $m_u \sim 3$ MeV and $m_d \sim 6$ MeV $\ll \Lambda_{QCD}$.
- But look at available data…



- What happens at low x?
- Why is $\bar{d} \neq \bar{u}$?
- Ideas include Sullivan model:

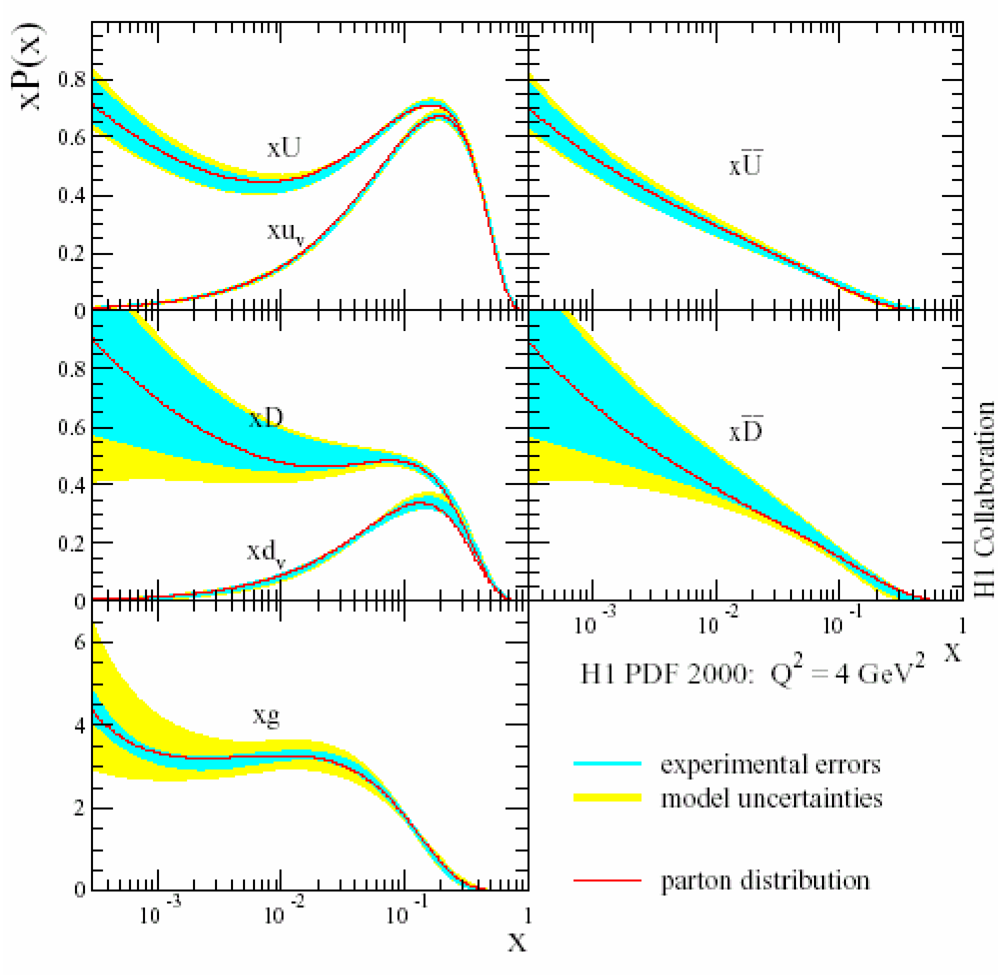


- Chiral soliton model:



Measure $\bar{d}-\bar{u}$

- Remove constraint $\bar{d}=\bar{u}$ at low x.



- Recall:

$$F_2^{\,p} = x\left(\tfrac{4}{9}u_v + \tfrac{1}{9}d_v + \tfrac{8}{9}\bar{u} + \tfrac{2}{9}\bar{d}\right)$$

$$F_2^{\,n} = x\left(\tfrac{1}{9}u_v + \tfrac{4}{9}d_v + \tfrac{2}{9}\bar{u} + \tfrac{8}{9}\bar{d}\right)$$

- Hence:

$$\tfrac{1}{2}\left(F_2^{\,p} + F_2^{\,n}\right) - F_2^{\,p}$$

$$= x\left(\tfrac{1}{6}d_v - \tfrac{1}{6}u_v + \tfrac{1}{3}\bar{d} - \tfrac{1}{3}\bar{u}\right)$$

$$\approx \tfrac{1}{3}x\left(\bar{d}-\bar{u}\right) \text{ at low } x.$$

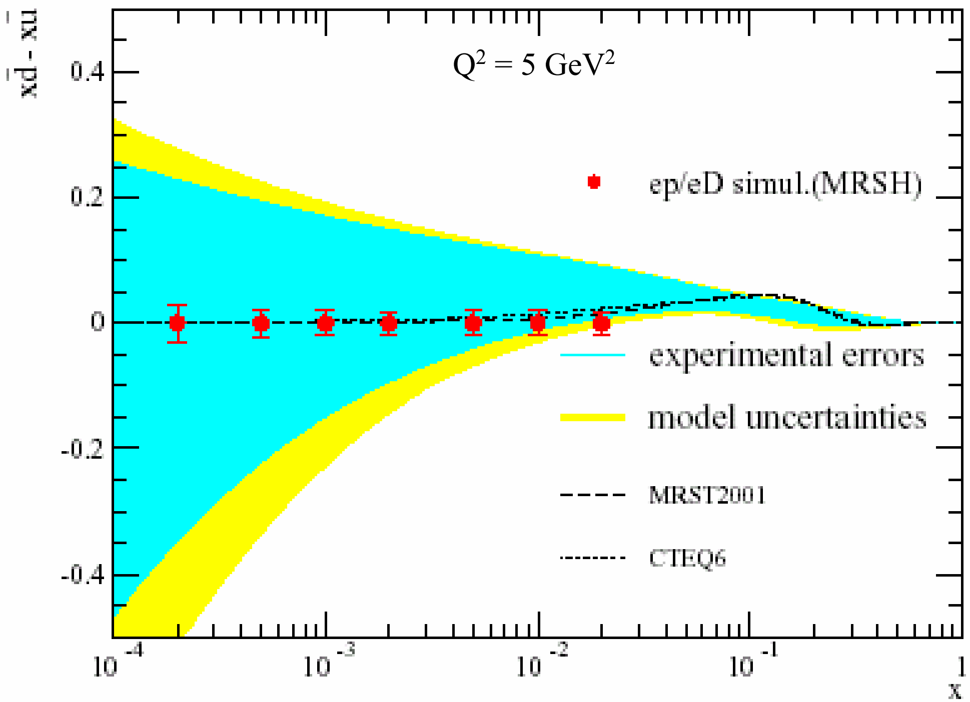
- But "nucleon" structure

$$F_2^{\,N} = \tfrac{1}{2}\left(F_2^{\,p} + F_2^{\,n}\right) \approx \tfrac{1}{2}F_2^{\,d}$$

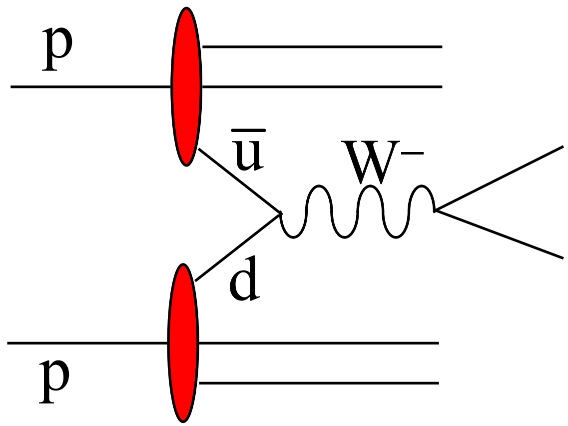
- Need electron-deuteron expt. in HERA kinematic domain.

Measuring $\bar{d} - \bar{u}$

- Measurement with H1, 20 pb^{-1} of ed data:



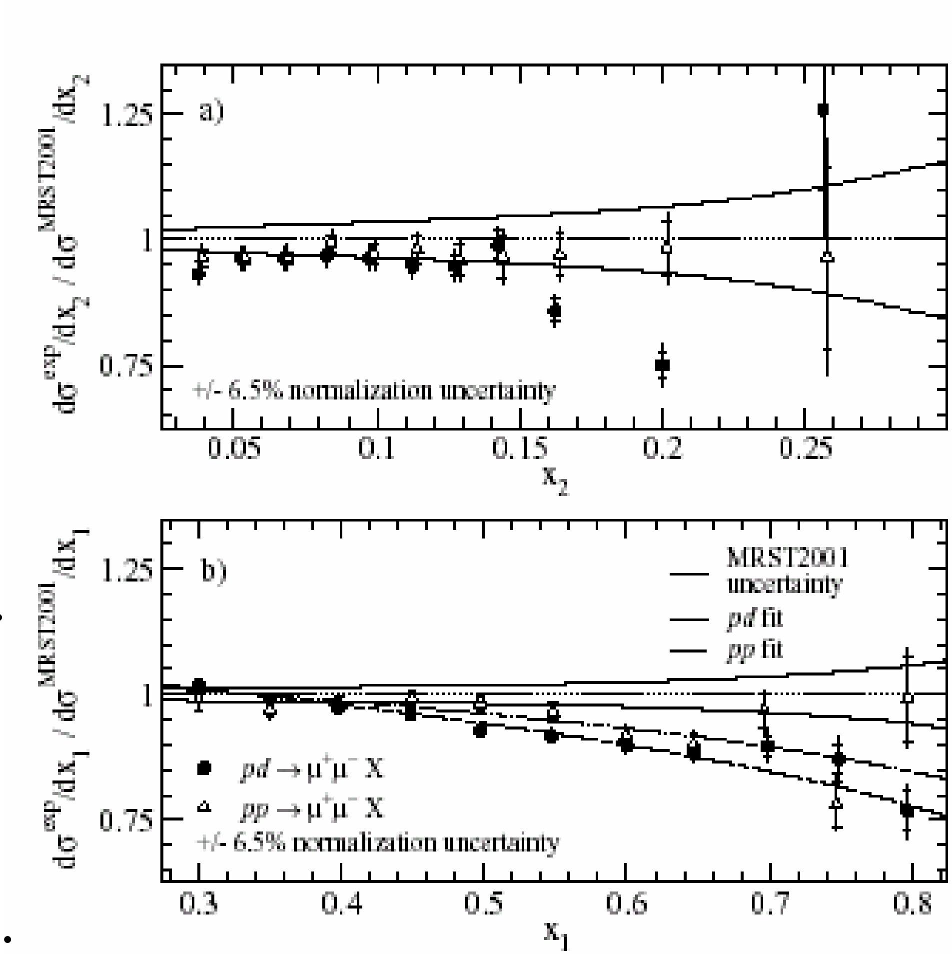
- Determine quark flavour responsible for rise of F_2^p.
- Shadowing corrections can be applied with required precision.
- Important for LHC, e.g. luminosity determination via



- Requires knowledge of sea quark distribution functions at low x.

Valence quarks at large x

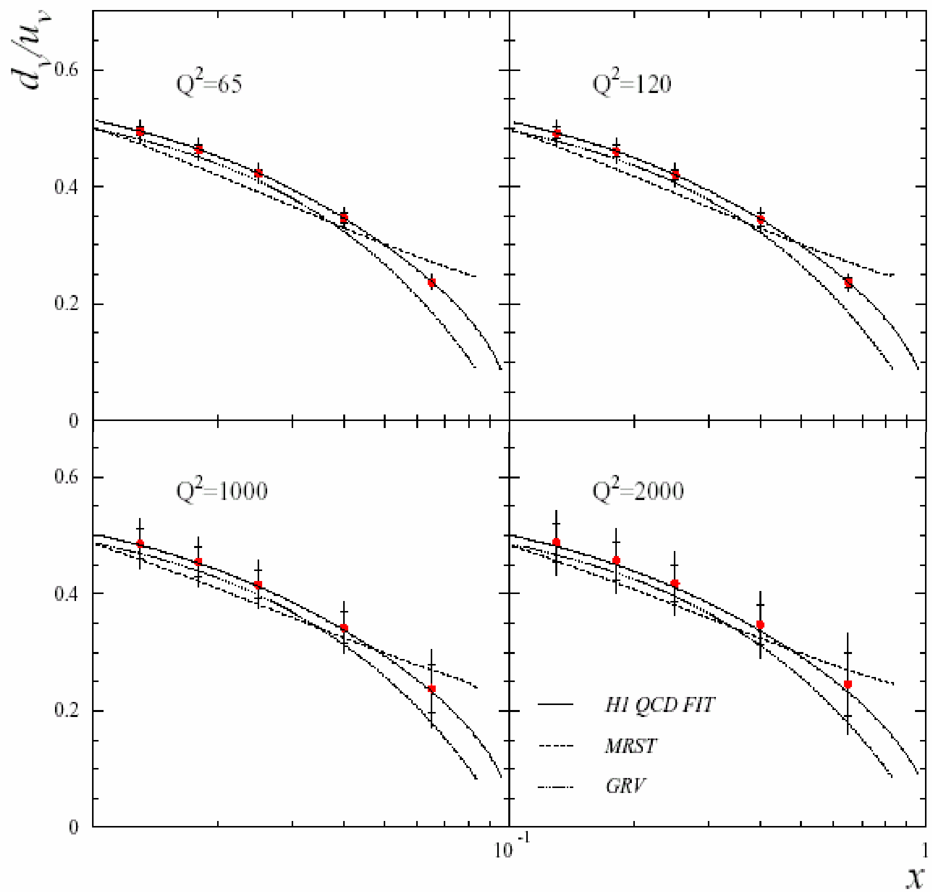
- Understanding of LHC data at highest $m = \sqrt{x_1 x_2 s}$ requires valence quark dist.s at high x.
- Latest E866/NuSea Drell-Yan results imply PDFs too high at large x.
- Measure F_2^n / F_2^p, hence d/u more accurately than possible with CC.
- Expectation:
  $$\frac{1}{4} < \frac{F_2^n}{F_2^p} = \frac{1 + 4\, d_v / u_v}{4 + d_v / u_v} < \frac{2}{3}$$
  d/u = 0 scalar diquark dominance.
  d/u = ½, naïve SU(6).



Valence quarks at large x

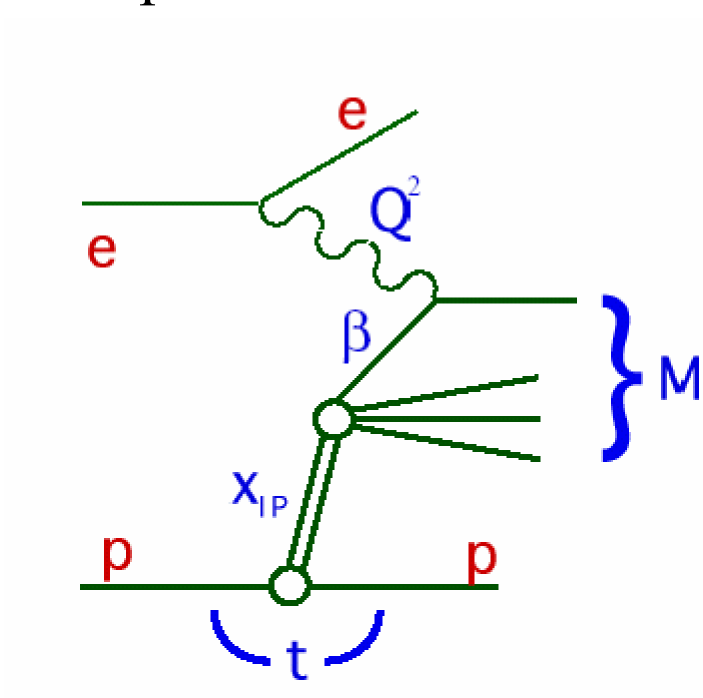
- Tag spectator nucleons to identify e(pn) → eX(n) etc.
- This, plus reconstruction of kinematics from lepton and hadronic (control radiative effects), make HERA measurement unique.
- Needs ep run at E_p = 460 GeV.
- High ed statistics required, important also for CC measurement, F_L and precision measurement of α_s.

- Result of measurement with ed and ep luminosities of 50 pb^{-1}:



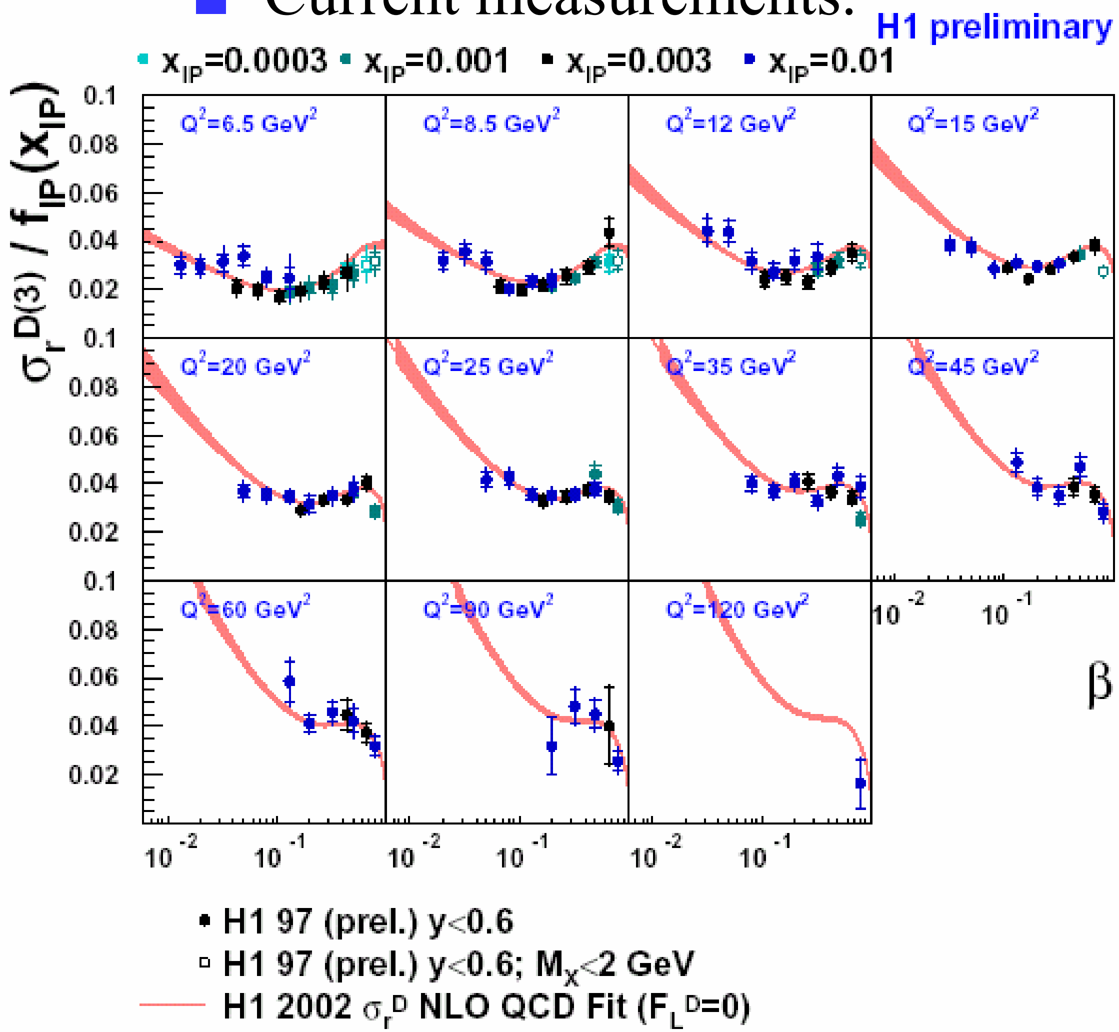
Diffraction

- Deep inelastic diffraction.



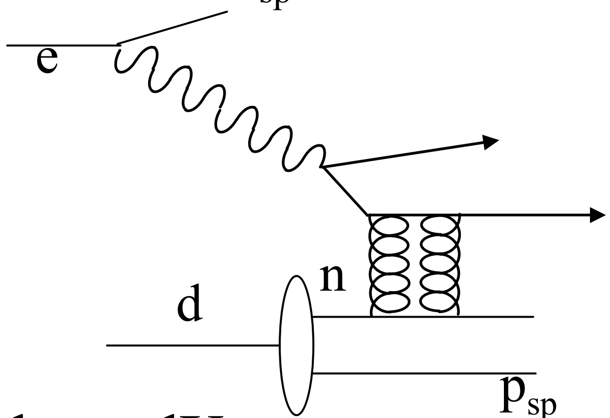
- Hence determine partonic structure of diffraction.

- Current measurements.

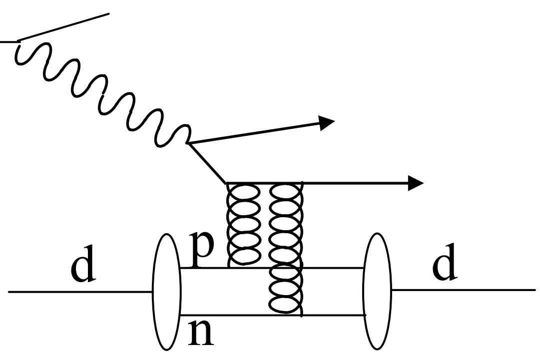


Diffraction

- Running with ed, plus tagging, allows study of:
  - $ed \rightarrow enXp_{sp}$ $(ed \rightarrow epXn_{sp})$



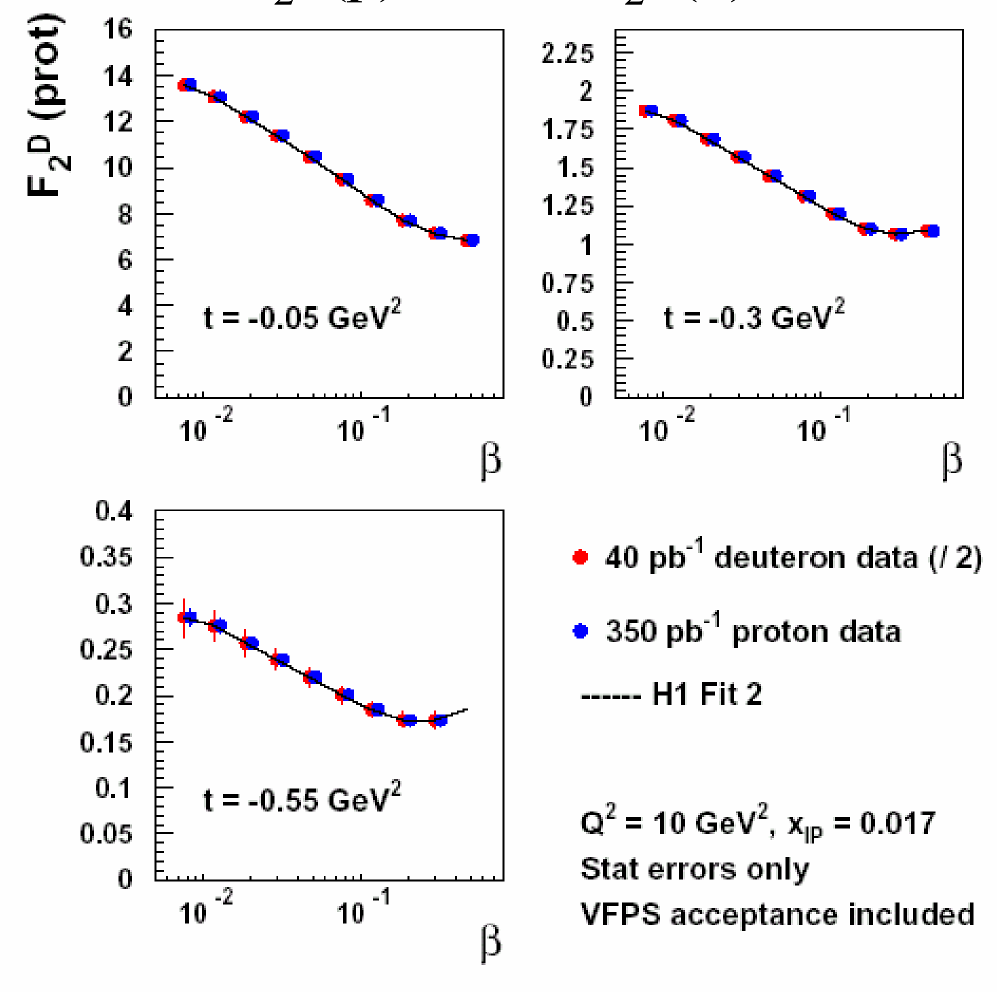
  - $ed \rightarrow edX$



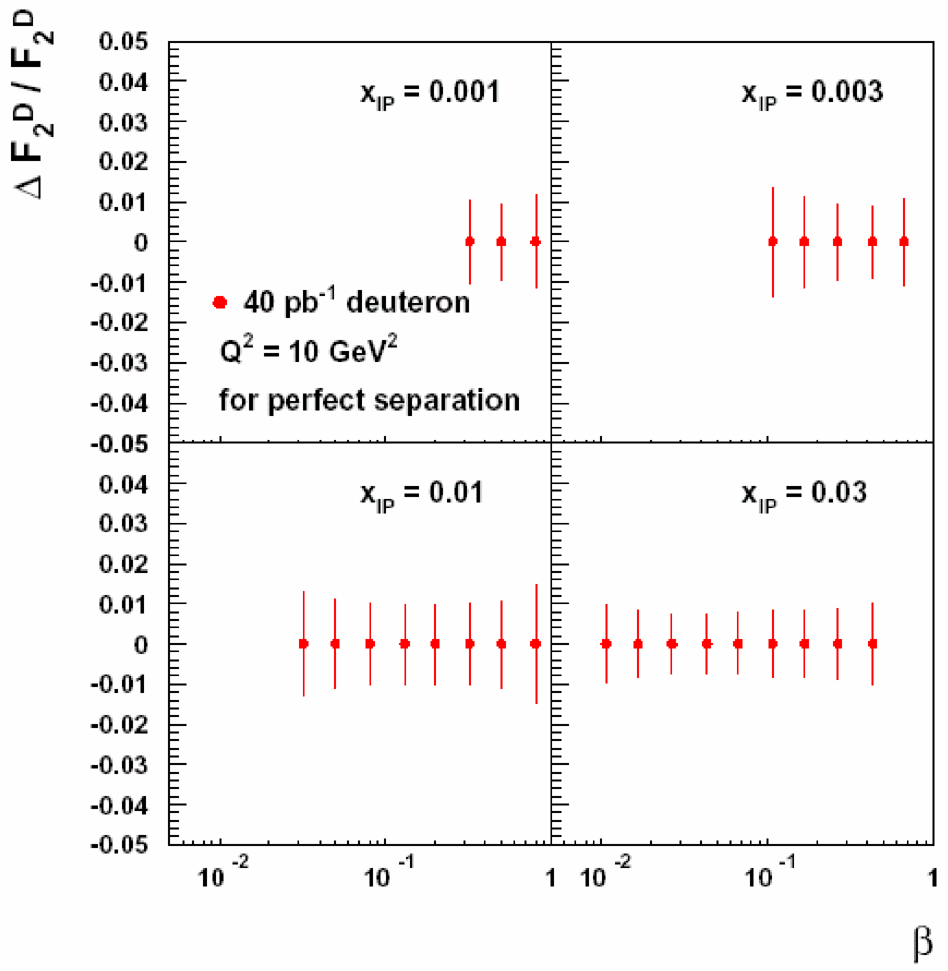
- Is structure of diffractive exchange same in electron neutron and electron proton scattering?
- Is diffractive exchange produced coherently off deuteron same as that from proton?

Diffraction

- C.f. $F_2^D(p)$ and ½ $F_2^D(d)$.

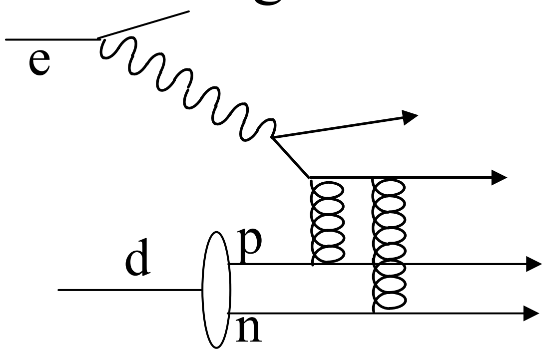


- C.f. diffraction from p and n.

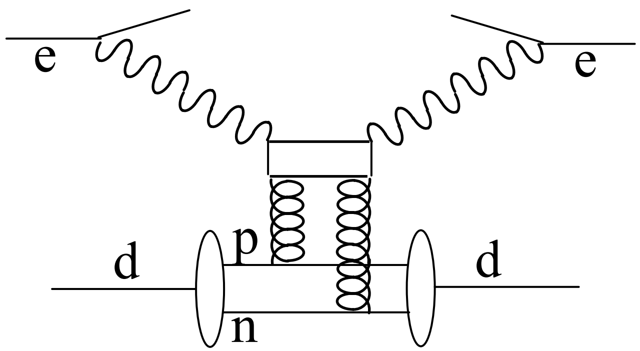


Shadowing and diffraction

- Shadowing…



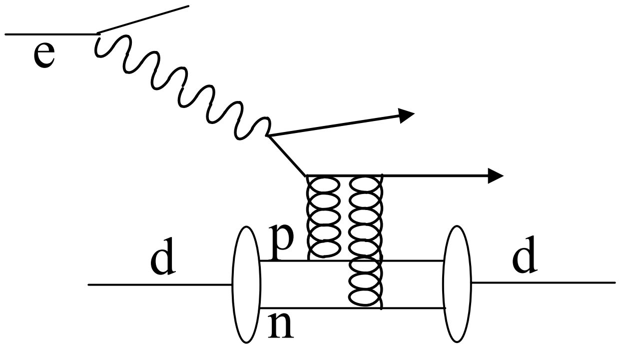
- …related to diffraction.



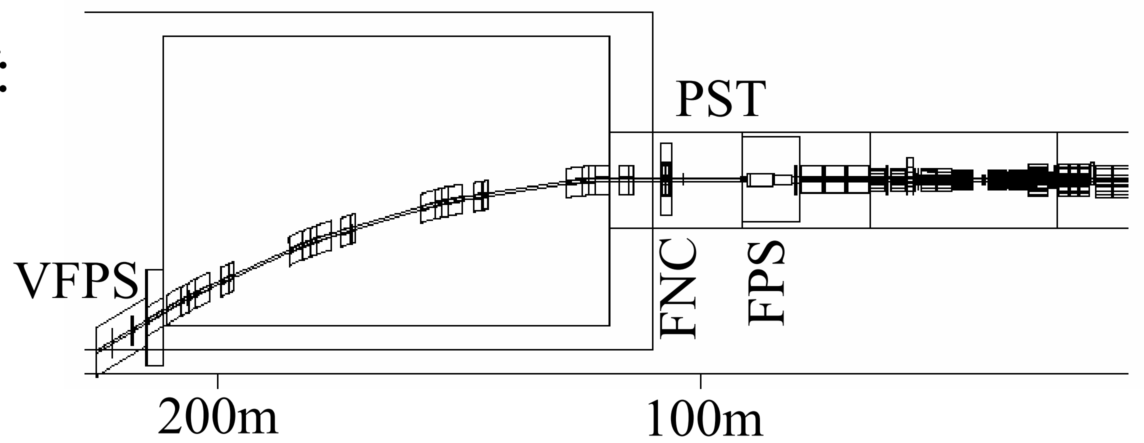
- Measure and check Gribov's relationship between shadowing and diffraction for the first time.
- Use results in correction of measurement of $\bar{d} - \bar{u}$ etc. (precision 1%).
- Effects of shadowing more pronounced with heavier ions.
- HERA running with ed important first step towards possible future eA programme.

H1 upgrade for electron deuteron programme

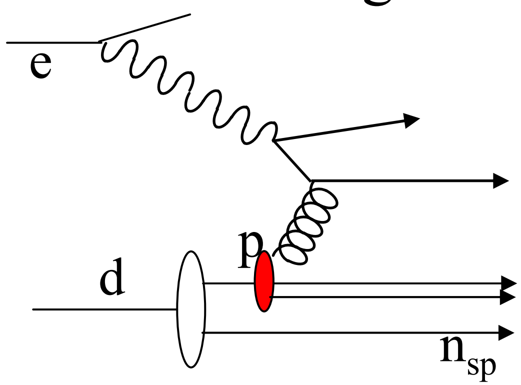
- VFPS allows identification of:

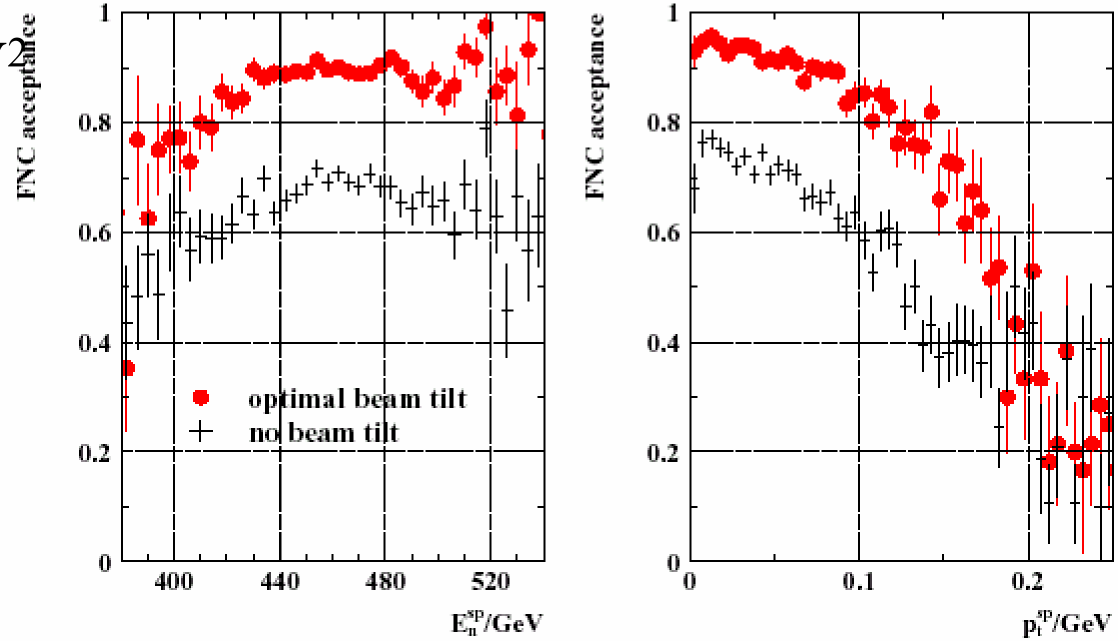


Acc. ~ 100% for $-t < 0.25\ \mathrm{GeV}^2$ and $0.011 < x_P < 0.024$.



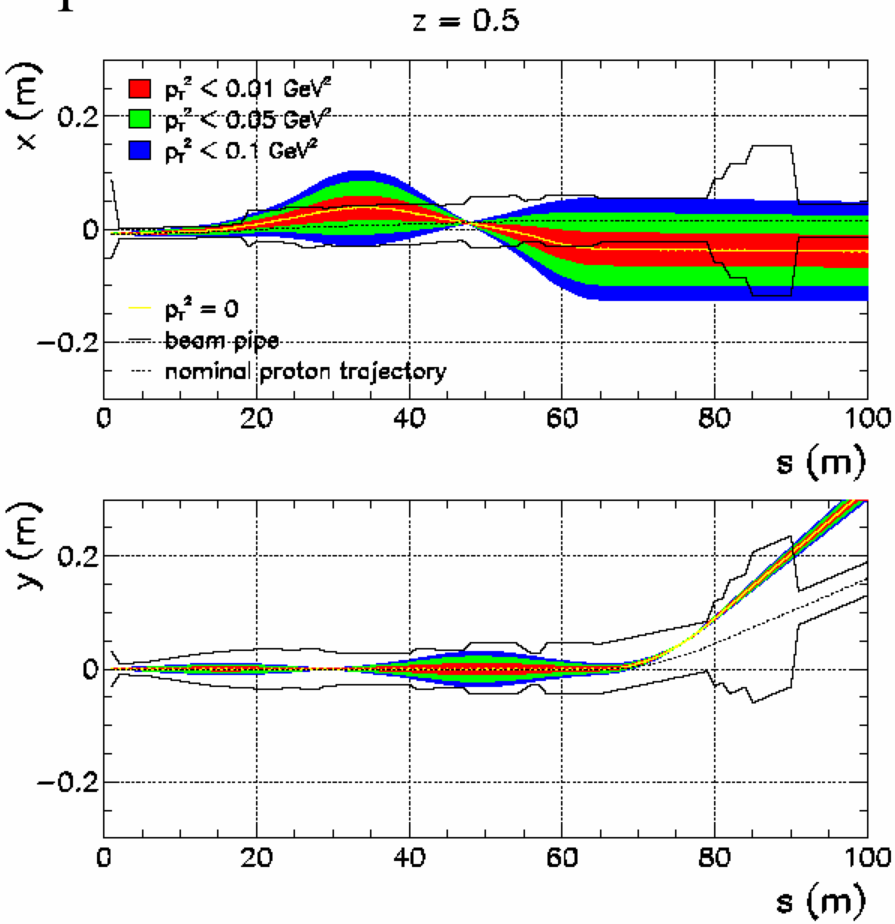
- Current FNC can tag:





Proton spectator tagger design

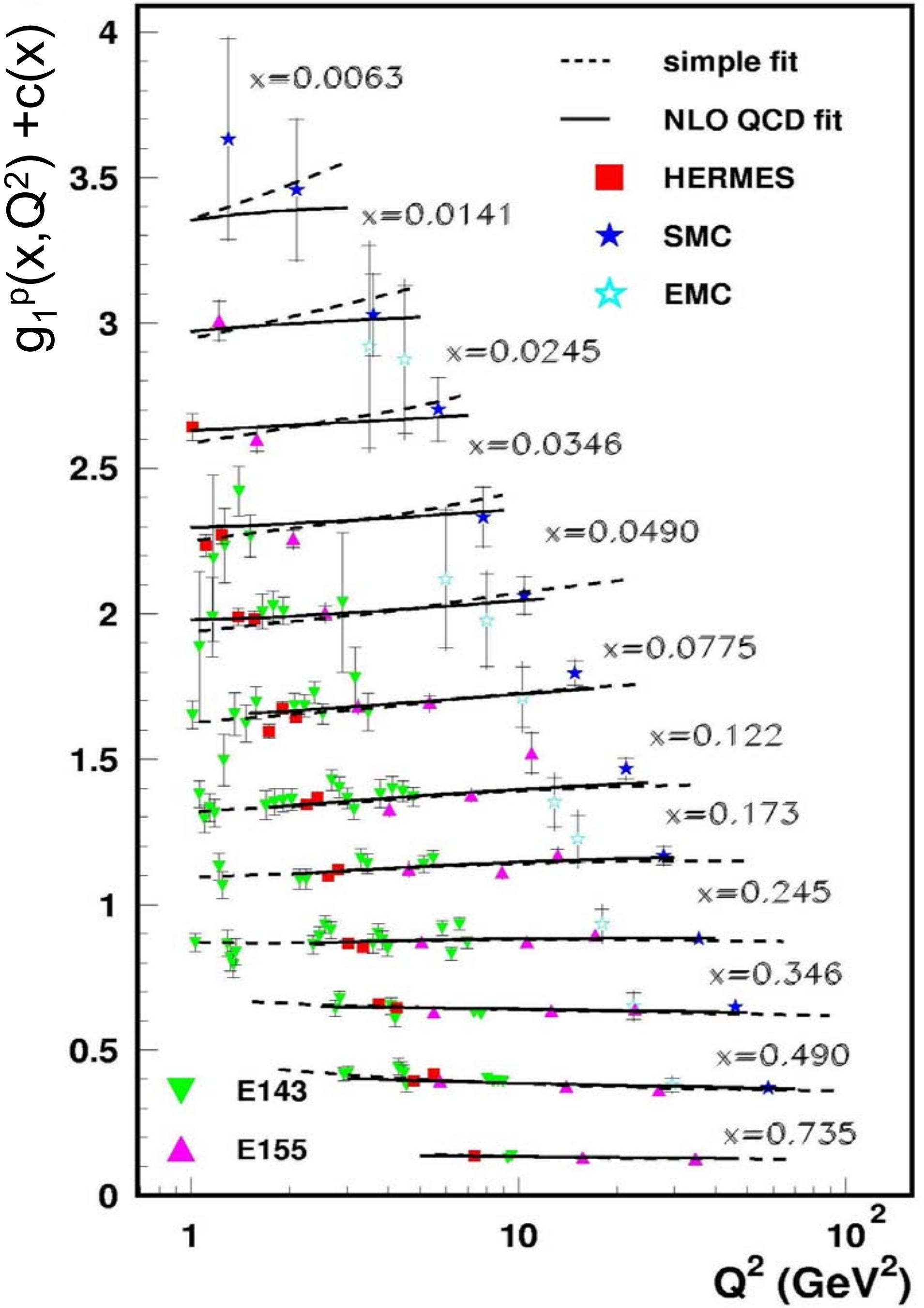
- Beam optics determine possible positions



- Two stations designed, outside beam pipe (exit windows), at about 80m and 95m.
- Scintillating fibre detectors allow measurement of p_{sp} energy to better than 1%.
- Acceptance of 70% (zero tilt) to 95% (optimal beam tilt) achievable with SC magnets in place.
- Higher acceptance requires removal of GO and GG.

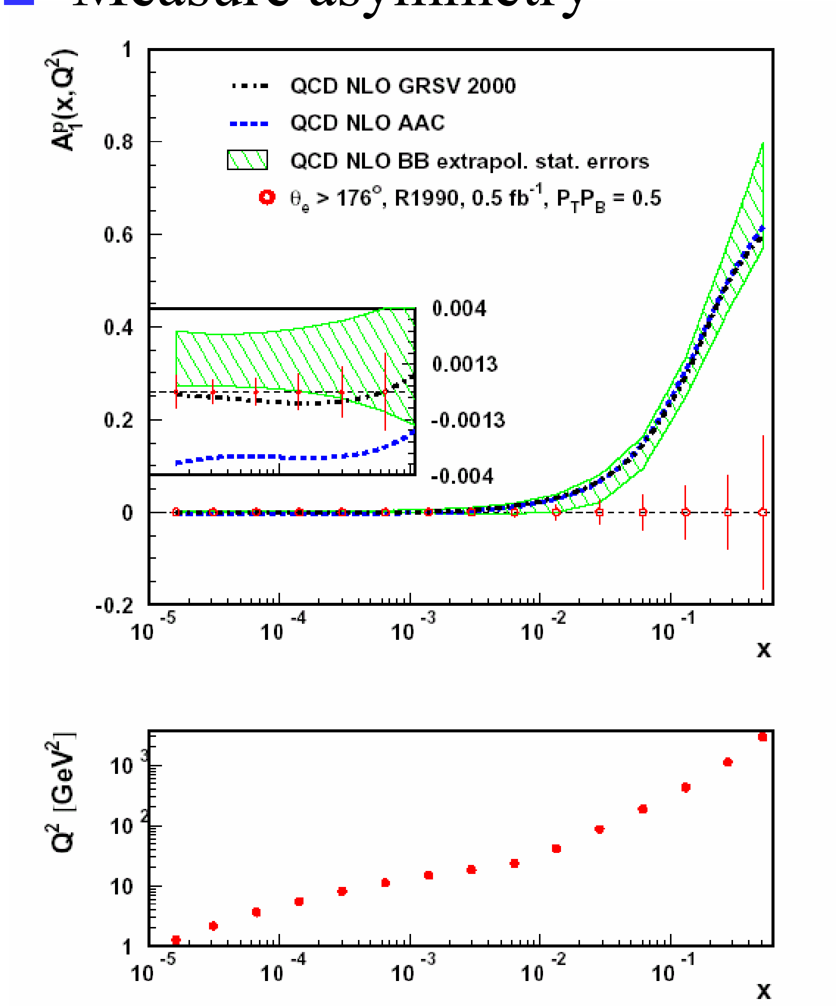
Spin structure measurements

- Proton spin given by $\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$
- Current world data suggest spin carried by quarks $\Delta\Sigma \sim 0.15\ldots0.2$
- Remainder carried by gluons, orbital angular momentum?
- Can measure gluon contribution by studying Q^2 evolution of $g_1(x,Q^2)$.
- NLO QCD fit gives $\Delta G = 0.616 \pm 0.318 \pm 0.400$

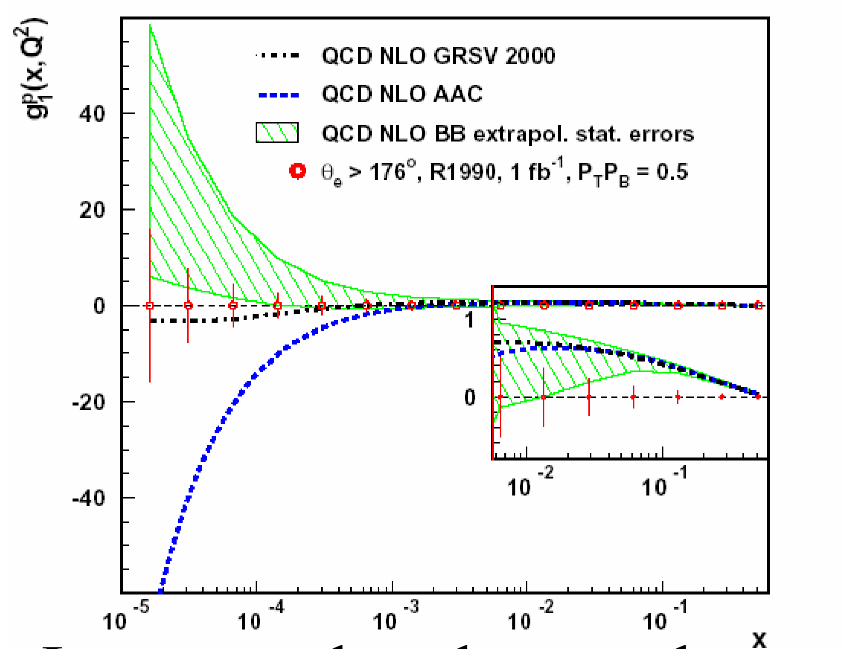


Spin structure measurements with p or d

- Measure asymmetry



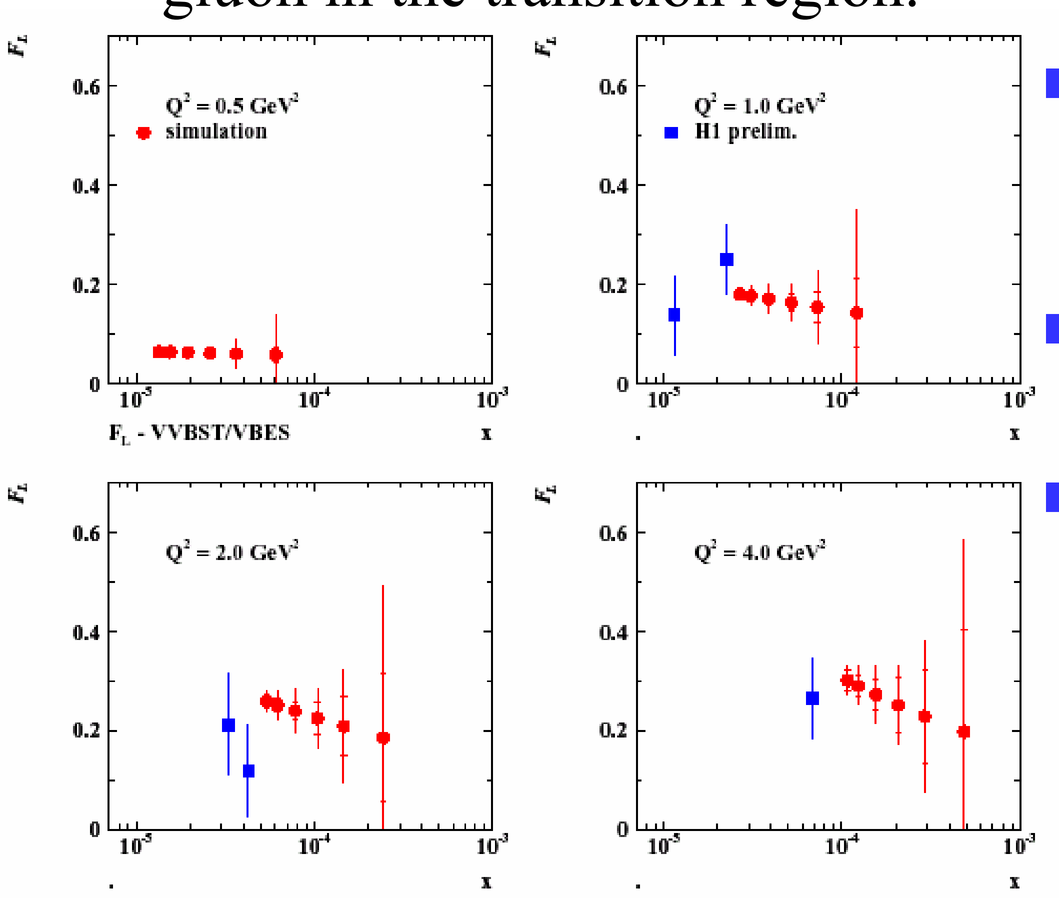
- Extract structure function



- Large x and exploratory low x measurements possible with ~ 100 pb^{-1} and high polarisations.

Low x physics and QCD radiation processes

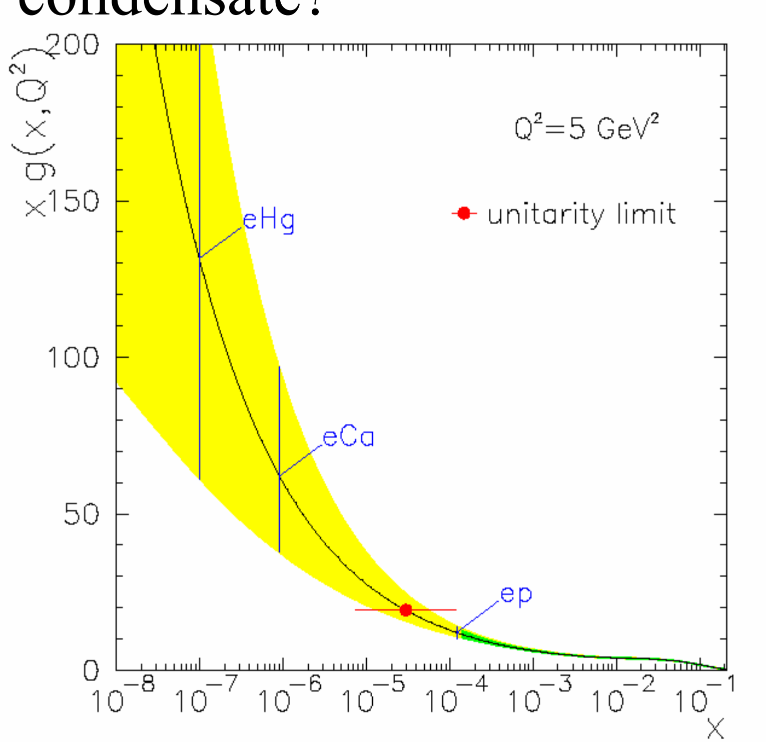
- Measurement of F_L and low x gluon in the transition region.



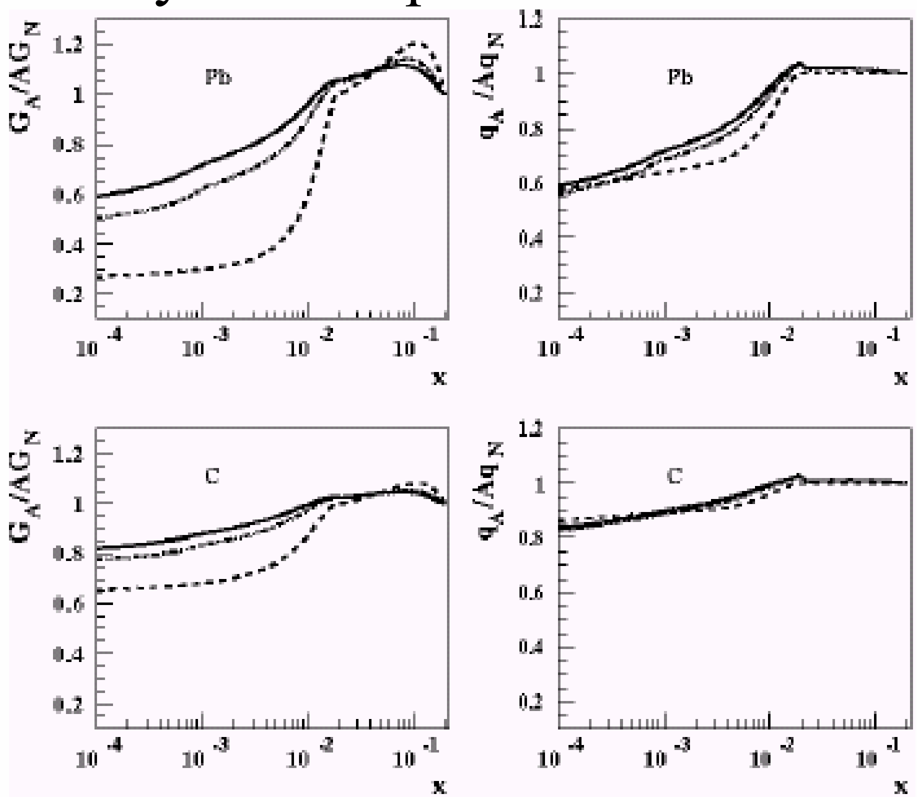
- Requires upgrade of backward region.
- Study of QCD radiation processes over large rapidity range "forward jets".
- Requires upgrade in forward region.
- Measurement of GPDs and the "3D" structure of the proton.

Study of saturation and nuclear parton distributions.

- Overlap of gluons from different nucleons in nucleus leads to high parton densities within kinematic reach of HERA, colour glass condensate?



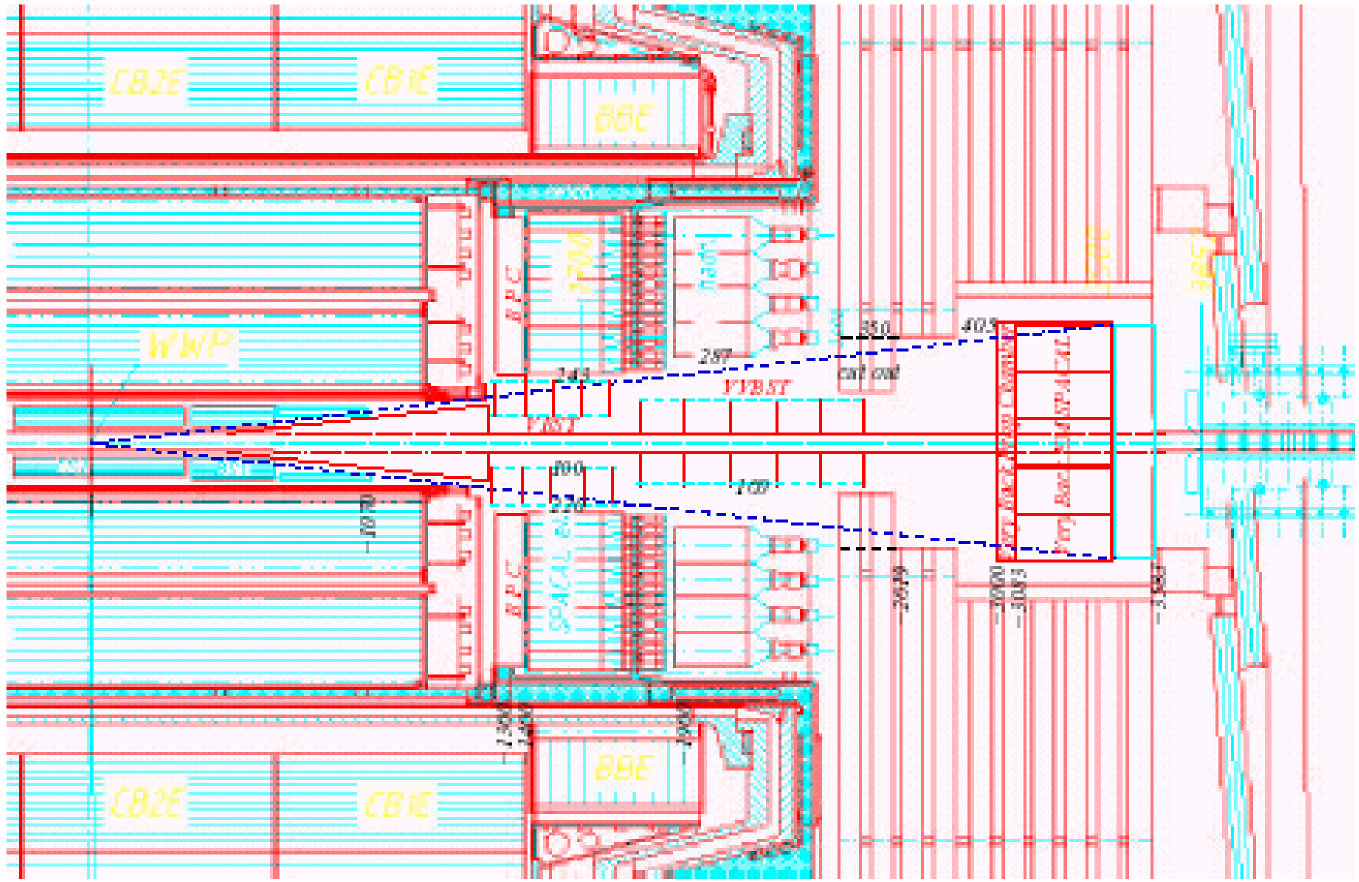
- Study nuclear parton distributions.



- Diff. = 50% of x-sect? BB limit.
- C.f. RHIC/LHC heavy ion physics.

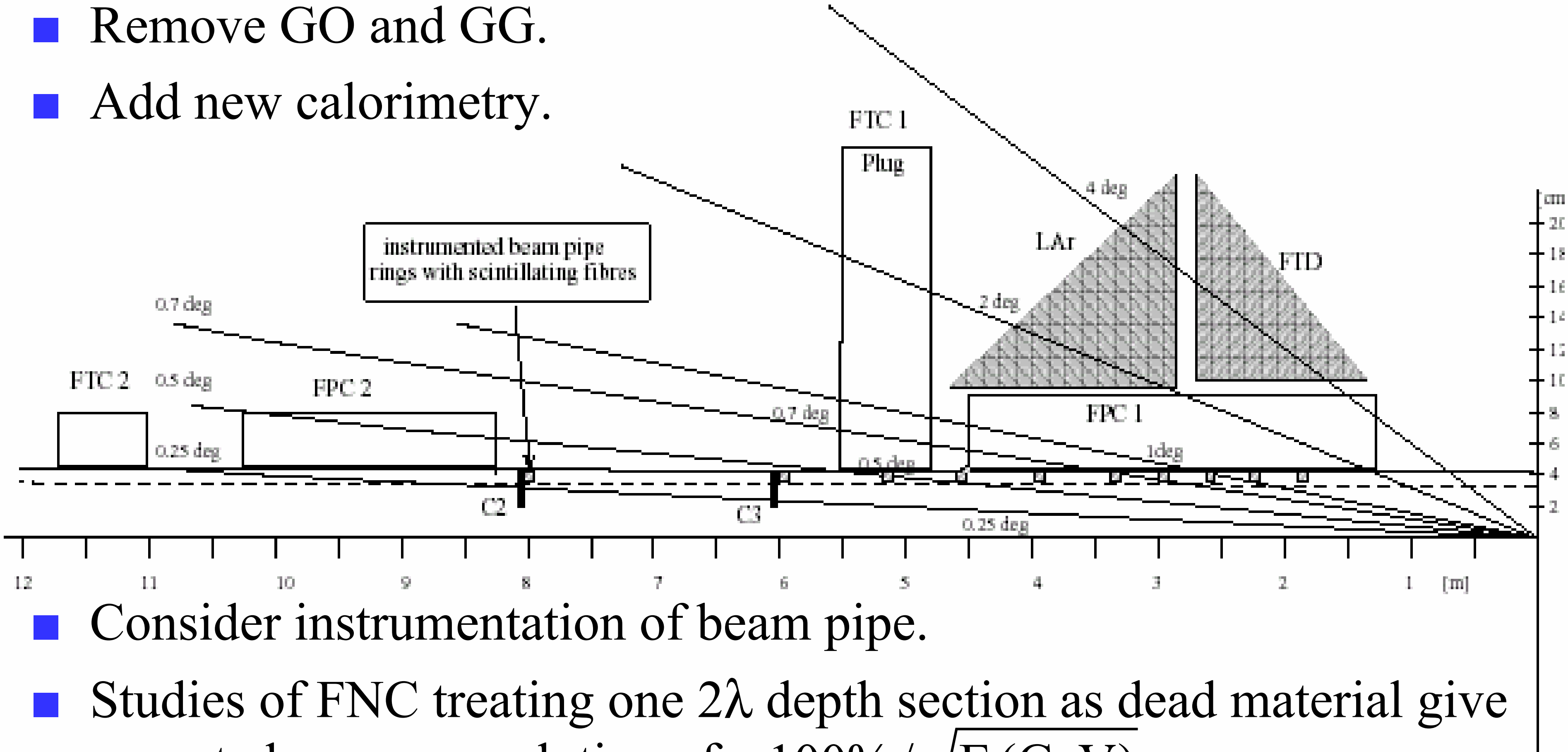
H1 backward upgrade to access low x and Q^2

- Remove GO and GG.
- Add (very) backward:
  - SpaCal.
  - Prop. chamber.
  - Silicon tracking stations.
- Proposed detectors based on current H1 technology.
- Upgrade acceptance $0.1 < Q^2 < 10\,\mathrm{GeV}^2$.



H1 upgrade to measure forward jets

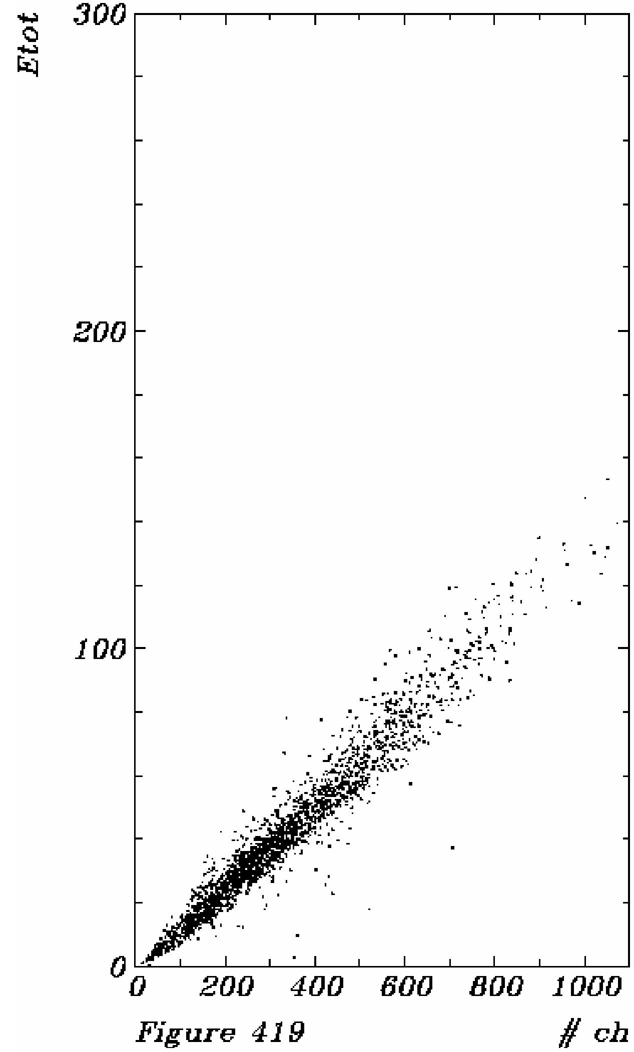
- Remove GO and GG.
- Add new calorimetry.



- Consider instrumentation of beam pipe.
- Studies of FNC treating one 2λ depth section as dead material give expected energy resolution of $\sim 100\% / \sqrt{E\,(\mathrm{GeV})}$.

H1 upgrade to measure forward jets

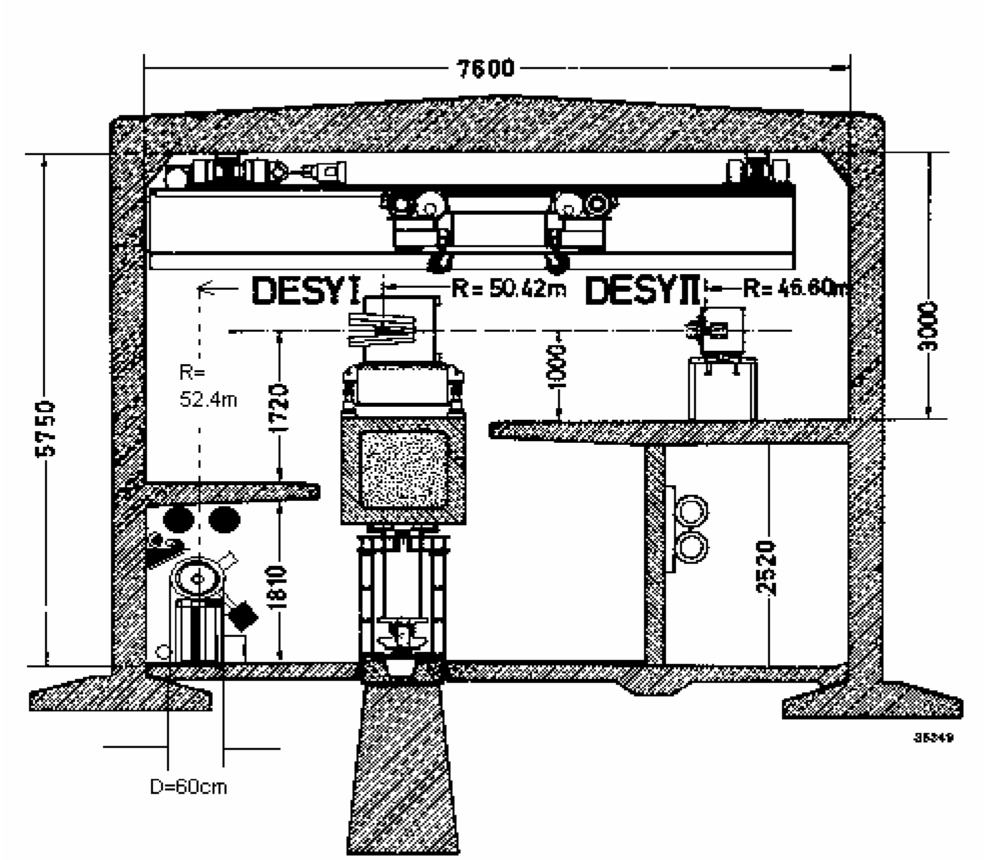
- Use “digital” calorimeters in forward region?
- Combine some tracking capability with energy measurement, improved dead material correction.
- Count cells above threshold in fine-grained calorimeter.
- Studies with H1 LAr calorimeter demonstrate concept.
- Number of cells above threshold in forward LAr highly correlated with deposited energy.



A new injector for HERA?

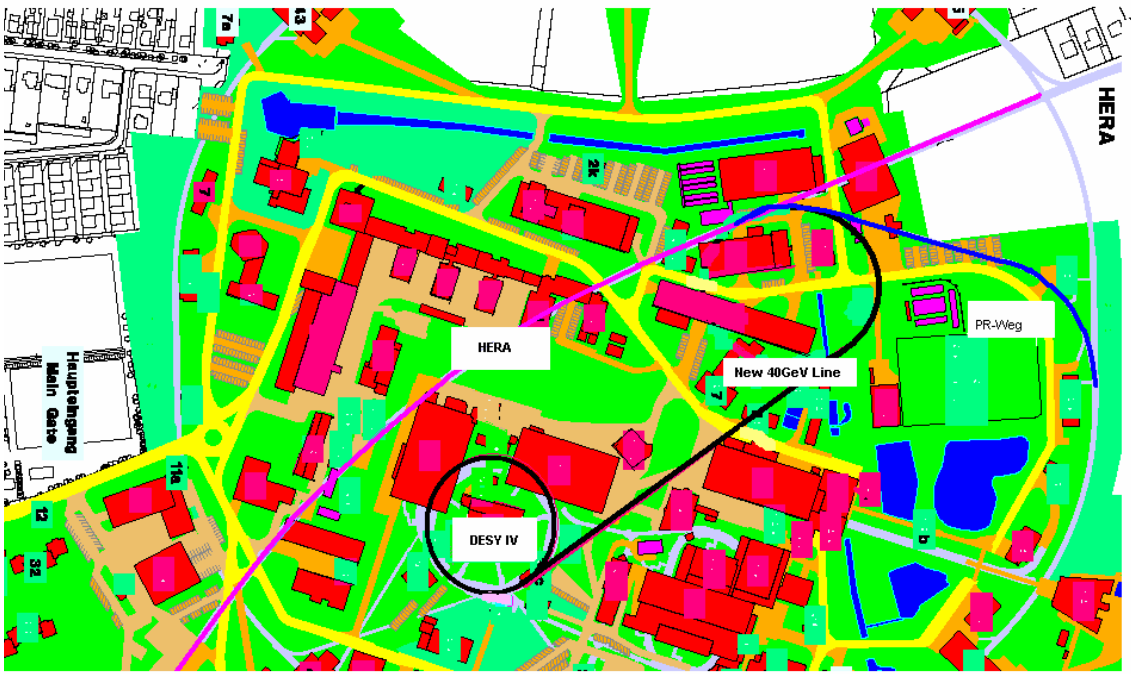
- If PETRA is converted into a light source, new injectors will be needed for HERA.
- A permanent magnet 7 GeV damping ring for electron injection could be constructed in the PETRA tunnel.
- A 40 GeV ring could be constructed in the DESY tunnel.

- New p injector in DESY tunnel:

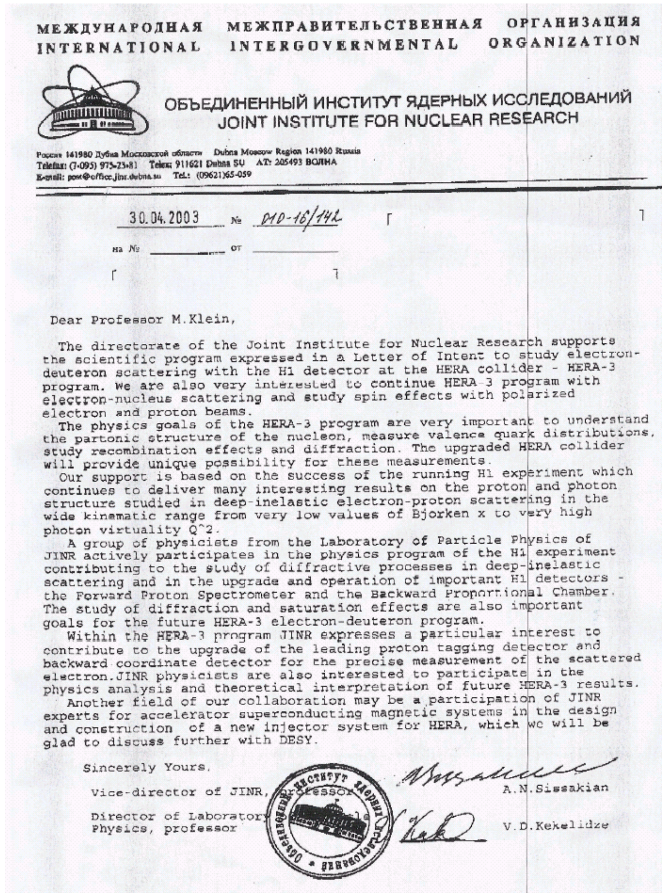


A new injector for HERA?

- The new p injector would require 4 T SC magnets.
- Proton injection path:



- JINR has expressed interest in magnet design and construction.



МЕЖДУНАРОДНАЯ МЕЖПРАВИТЕЛЬСТВЕННАЯ ОРГАНИЗАЦИЯ
INTERNATIONAL INTERGOVERNMENTAL ORGANIZATION

ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ
JOINT INSTITUTE FOR NUCLEAR RESEARCH

Россия 141980 Дубна Московской области Dubna Moscow Region 141980 Russia
Telefax: (7-095) 975-23-81 Telex: 911621 Dubna SU AT: 205493 ВОЛНА
E-mail: post@office.jinr.dubna.su Tel.: (09621)65-059

30.04.2003 № 010-16/142

на № ____ от ____

Dear Professor M.Klein,

The directorate of the Joint Institute for Nuclear Research supports the scientific program expressed in a Letter of Intent to study electron-deuteron scattering with the H1 detector at the HERA collider - HERA-3 program. We are also very interested to continue HERA-3 program with electron-nucleus scattering and study spin effects with polarized electron and proton beams.

The physics goals of the HERA-3 program are very important to understand the partonic structure of the nucleon, measure valence quark distributions, study recombination effects and diffraction. The upgraded HERA collider will provide unique possibility for these measurements.

Our support is based on the success of the running H1 experiment which continues to deliver many interesting results on the proton and photon structure studied in deep-inelastic electron-proton scattering in the wide kinematic range from very low values of Bjorken x to very high photon virtuality Q^2.

A group of physicists from the Laboratory of Particle Physics of JINR actively participates in the physics program of the H1 experiment contributing to the study of diffractive processes in deep-inelastic scattering and in the upgrade and operation of important H1 detectors - the Forward Proton Spectrometer and the Backward Proportional Chamber. The study of diffraction and saturation effects are also important goals for the future HERA-3 electron-deuteron program.

Within the HERA-3 program JINR expresses a particular interest to contribute to the upgrade of the leading proton tagging detector and backward coordinate detector for the precise measurement of the scattered electron. JINR physicists are also interested to participate in the physics analysis and theoretical interpretation of future HERA-3 results.

Another field of our collaboration may be a participation of JINR experts for accelerator superconducting magnetic systems in the design and construction of a new injector system for HERA, which we will be glad to discuss further with DESY.

Sincerely Yours.

Vice-director of JINR, professor A.N.Sissakian

Director of Laboratory of Particle Physics, professor V.D.Kekelidze

Summary

- Many aspects of QCD are still poorly understood.
  - Need complete map of nucleon partonic structure.
  - Precise knowledge of strong coupling.
  - Diffraction and shadowing.
- ed at HERA makes possible unique measurements of electron neutron scattering and the study of CC and diffractive reactions.
- We request support for this programme from the PRC.
- Detailed schedule will be submitted with proposal.
- In the longer term future, HERA and H1 offer further unique possibilities, including the study of:
  - Partonic origins of nucleon spin over a large kinematic range.
  - The transition between DIS and photoproduction.
  - Parton radiation patterns.
  - QCD at high density in eA collisions.

Support from theory community

- Following the DIS 2003 conference, members of the theoretical community announced their support for a future HERA programme.

Letter to the DESY Physics Research Committee and Scientific Council

The HERA collider is a unique facility for studying the high energy limit of QCD. With its superior energy range, polarization of the lepton and potentially the hadron beams and the possibility of accelerating deuterons and heavier nuclei, HERA has the potential to provide data crucial to our developing understanding of QCD. These data cannot be obtained at other facilities and will require a program that extends beyond the currently scheduled ep running. They include high precision measurements of F_L and of F_2 in the transition region from the domain of deep inelastic scattering to that of photoproduction, the study of forward jet production over the largest possible rapidity range and measurements with deuterons. These will allow the development and refinement of new approaches to perturbative QCD, the study of non-perturbative effects, the investigation of QCD radiation patterns over an unprecedented range in x and the completion of the mapping of the longitudinal structure of the nucleon.

Collisions with heavier nuclei will allow the exploration of a new high parton density regime of QCD. New states of matter may appear in this region, such as a saturated "bath" of gluons.

The understanding of spin remains a central problem in high energy physics. HERA running with polarized protons or deuterons would bring a new level of understanding to the outstanding problems of sea and gluon polarization.

The proposed measurements would provide a significant step in the understanding of strong hadronic interactions. This is of fundamental importance, as QCD is a cornerstone of the Standard Model. The measurements are also of great importance for other aspects of high energy particle, astroparticle and nuclear physics. For example, a precise understanding of parton densities is critical for physics at the highest energies and matter densities, from the LHC and heavy ion collisions to high energy cosmic ray showers.

We therefore strongly support further experimentation with the HERA collider beyond the currently planned high luminosity phase.

Signed:

G Altarelli, J Bartels, J Bjorken, M Ciafaloni, Y Dokshitzer, M Drees, V Fadin, M Fontannaz, J Forshaw, L Frankfurt, R Godbole, G Gustafson, G Ingelman, V Kim, B Kniehl, G Kramer, M Krawzyck, G Levin, L Lipatov, L Lönnblad, G Marchesini, L McLerran, Al Mueller, F Olness, R Peschanski, D Ross, M Ryskin, G Salam, E De Sanctis, T Sjöstrand, H Spiesberger, M Strikman, A Szczurek, O Teryaev, W K Tung