The Abdus Salam
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IAEA
International Atomic Energy Agency

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Deep inelastic scattering off pions.

B. Povh
Max Planck Inst. fuer Kernphysik
Germany

DIS off Pions

Bogdan Povh
Max-Planck-Institut fuer Kernphysik, Heidelberg

Pion signature in experiment:

Gottfried Sum rule
Polarized structure function
Forward neutrons in DIS

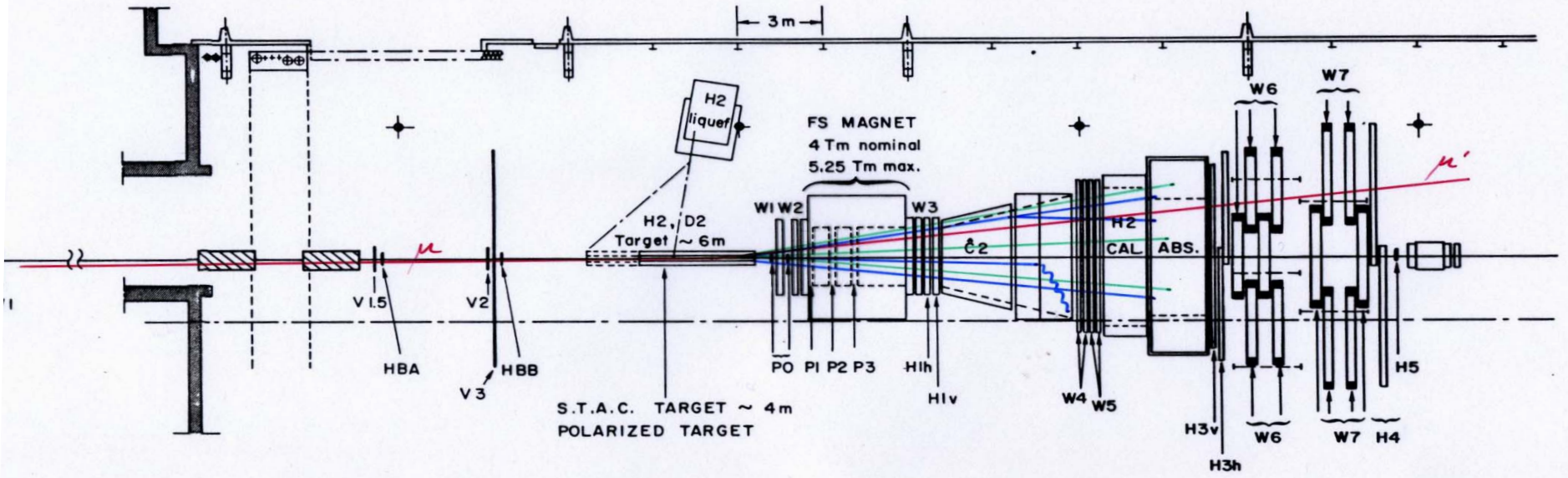
DIS on Proton and Deuteron

- Gottfried sum rule
- Spin structure function

Pion signature

NMC detector at CERN

Deep inelastic scattering of muons off protons and deuterons



Experiment NA2: Electromagnetic Interactions of Muons

Gottfried sum rule

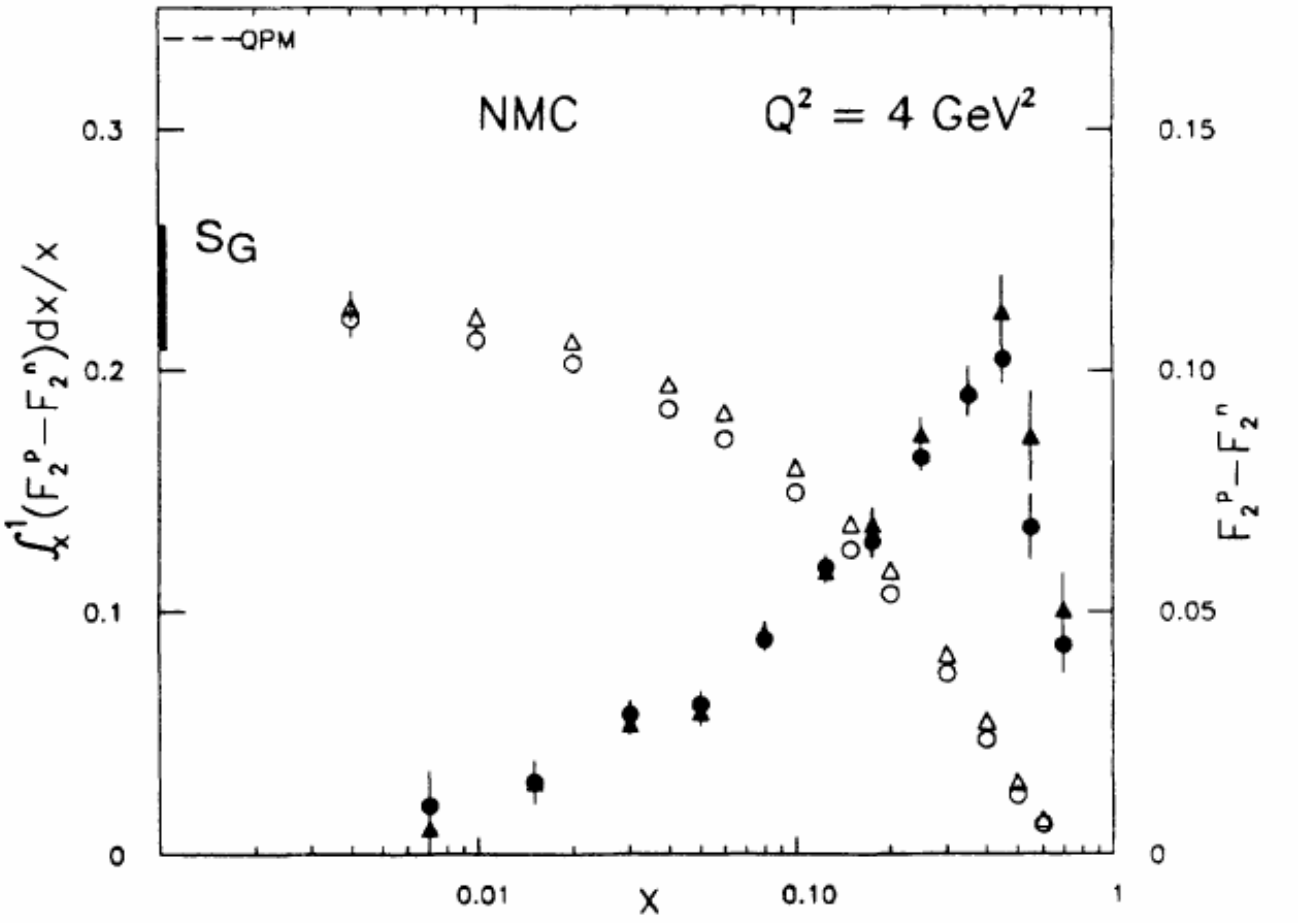
$$\int \frac{dx}{x} F_2(Q^2, x) = \int dx . z_i^{\,2} q_v(Q^2, x) + \int dx . sea$$

$$S_G = \int \frac{dx}{x} (F_2^{\,p} - F_2^{\,n}) = \frac{1}{3}$$

$$(\frac{4}{9} + \frac{4}{9} + \frac{1}{9})^p - (\frac{4}{9} + \frac{1}{9} + \frac{1}{9})^n = \frac{1}{3}$$

$\int dx\ sea = 0$ for flavour symmetric sea

$$S_G \neq \frac{1}{3} \text{ but } S_G = 0.235 \pm 0.026$$



Toy model

$$|u\rangle = \sqrt{1-\frac{3}{2}a}\,|u'\rangle + \sqrt{a}\,|d'\pi^+\rangle + \sqrt{\frac{a}{2}}\,|u'\pi^0\rangle$$

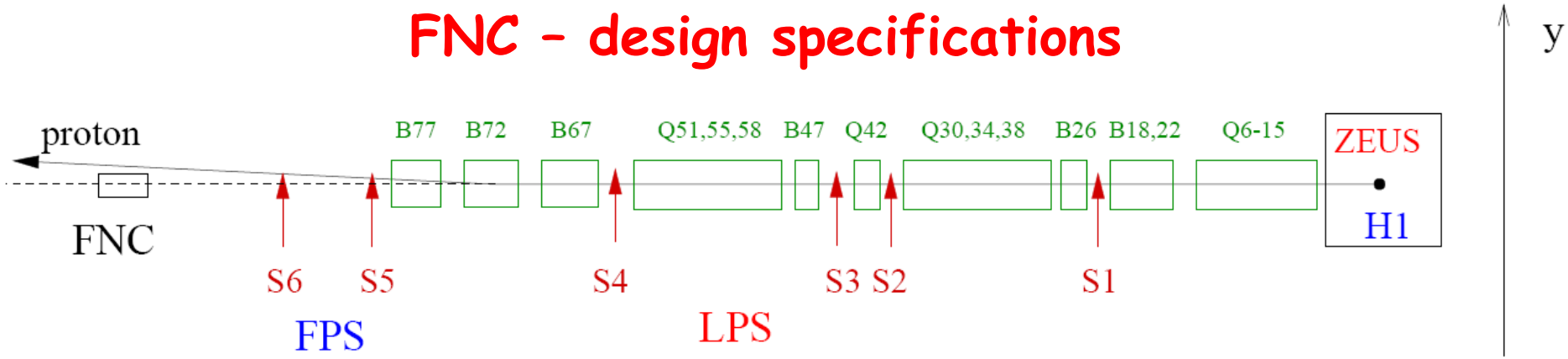
$$|d\rangle = \sqrt{1-\frac{3}{2}a}\,|d'\rangle + \sqrt{a}\,|u'\pi^-\rangle + \sqrt{\frac{a}{2}}\,|d'\pi^0\rangle$$

$$\left|\langle d'\pi^+|u\rangle\right|^2 = a \qquad \left|\langle u'\pi^0|u\rangle\right|^2 = \frac{a}{2}$$

$$a = 0.20 \pm 0.02$$

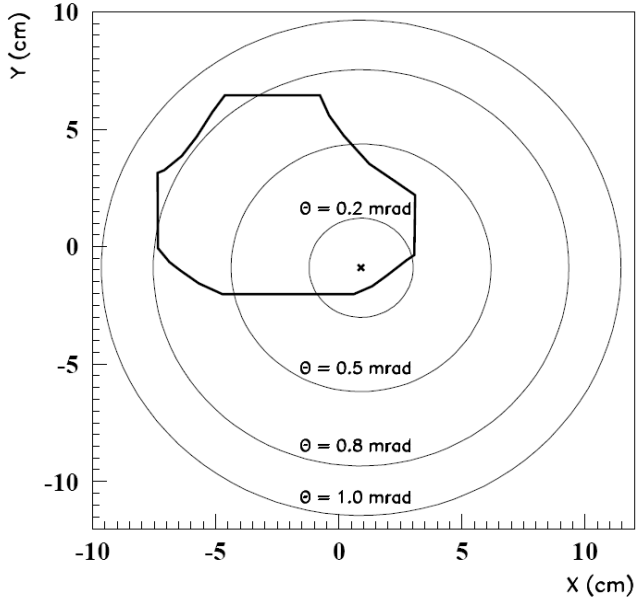
- Forward Neutron Calorimeters at H1 and ZEUS at DESY

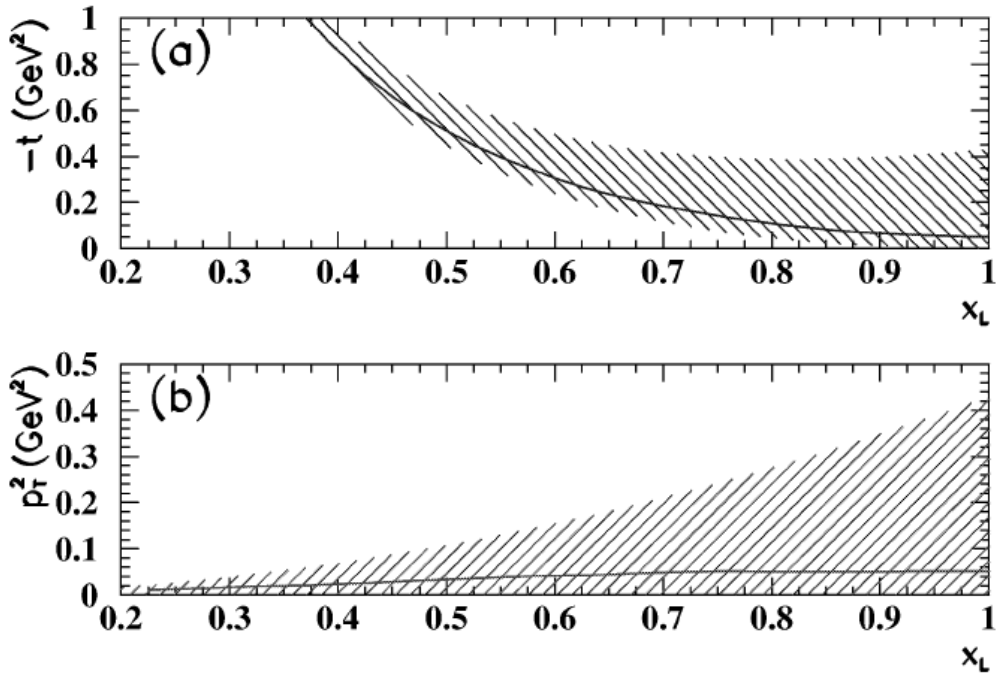
FNC – design specifications



The size and weight of FNC is defined by the space available in HERA tunnel

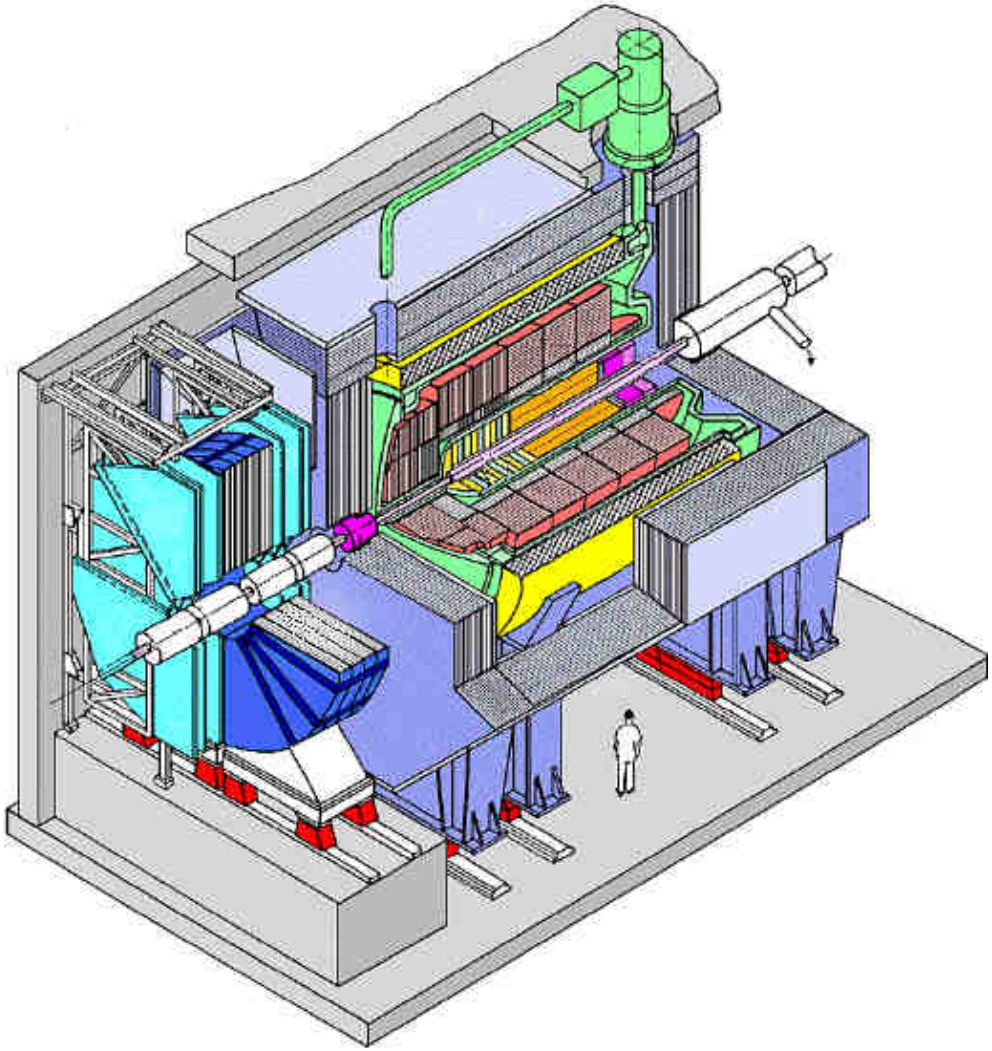
- position– 105m from the interaction point, size ~ 70 x 70 x 200cm^3 , weight <10t
- geometrical acceptance is limited by beam-line elements <0.8mrad
- should work in high radiation environment





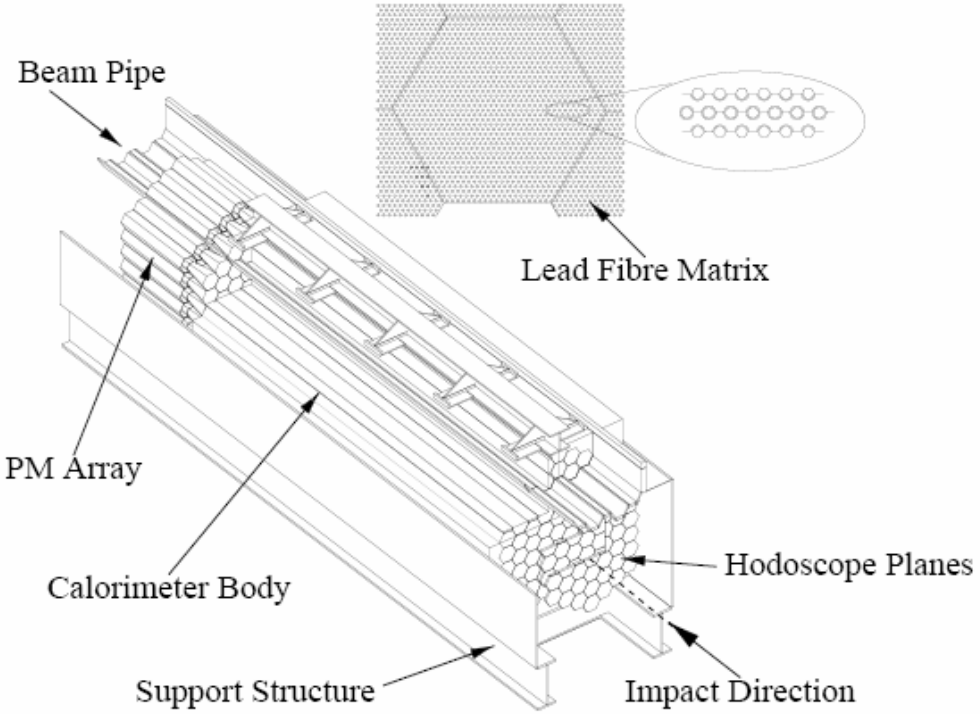
A.Bunyatyan “Physics with FNC”

H1 detector at HERA collider



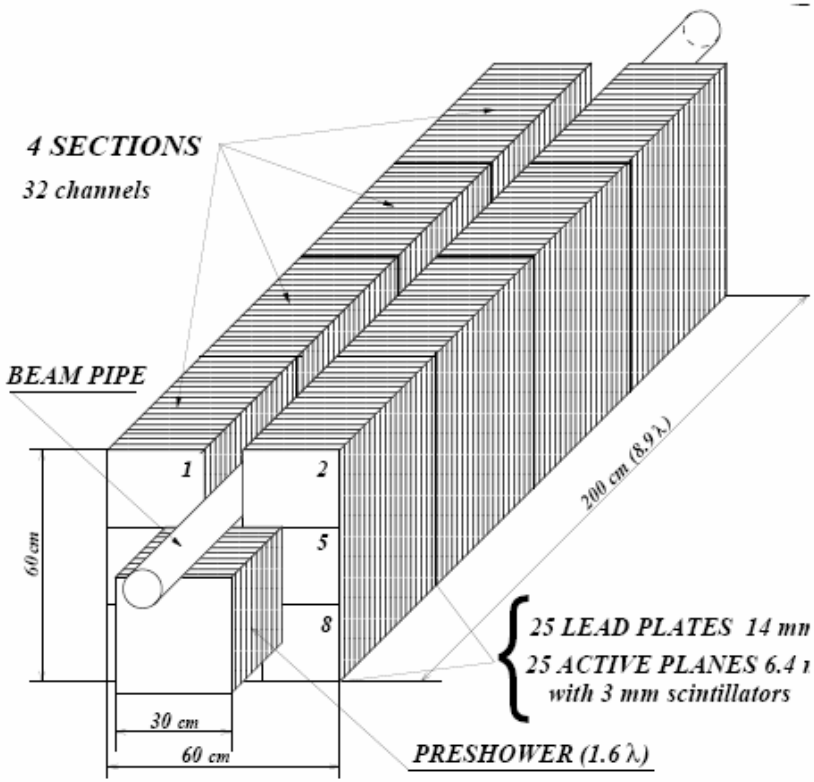
The General view of H1-FNC detector

HERA-1 (1996-2000)



- Spaghetti calorimeter
- 75 modules (1141 fibers in each)
- previously was used in WA89 experiment
- $\sigma_E/E \sim 20\%$ at high E,
- $\sigma_{XY} = 5.13/\sqrt{E[GeV]} \oplus 0.22\ cm$
- In 1998 was upgraded by 'Preshower'
- H1 Collab., *Eur.Phys.J.* C6 (1999) 587.

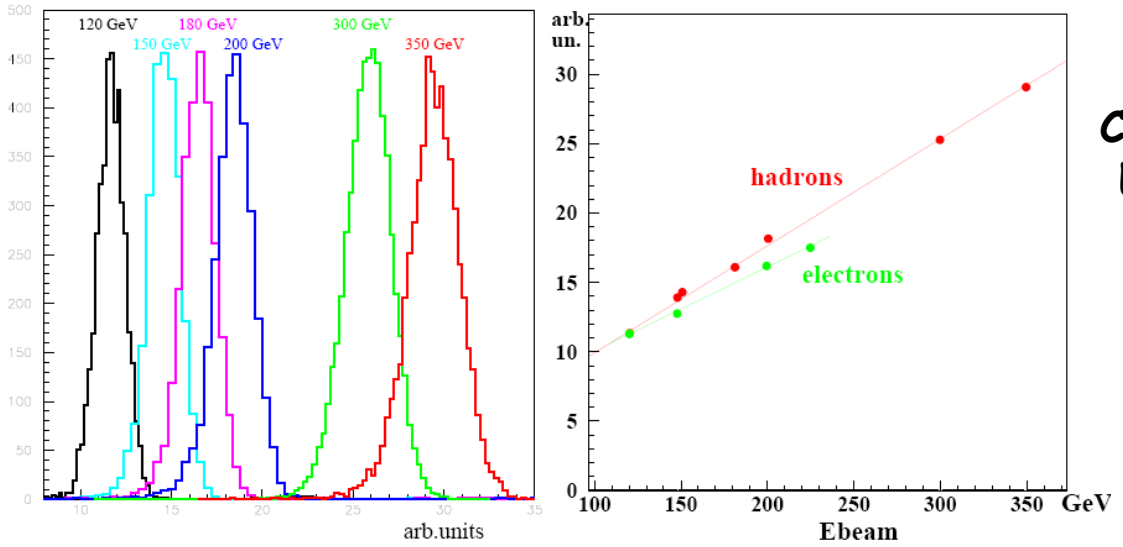
HERA-2 (2002-...)



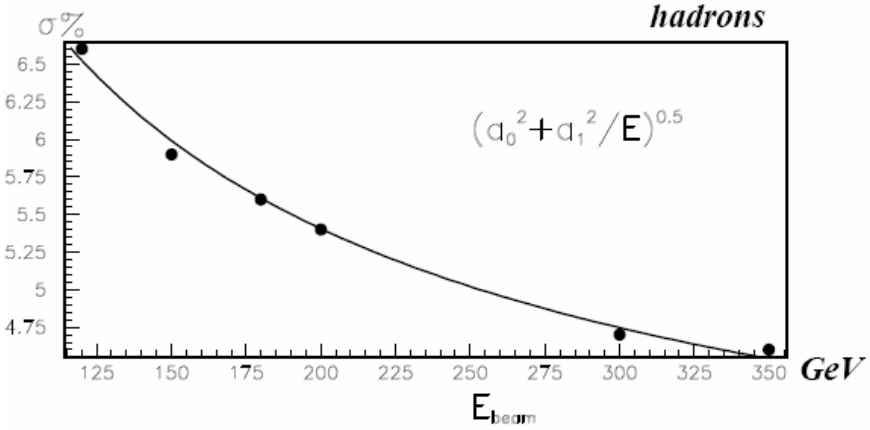
- Preshower + 4 Sections
- each Section consists of 8 Towers
- each Tower is 25 Scintillator tiles

–www-h1.desy.de/h1/www/h1det/calo/fnc/psfiles
/fnc_note2002.ps.gz

The H1-FNC energy response



CERN test-beam
E_{beam}=120-350 GeV



from CERN test-beam measurements
($E_{hadron} = 120 - 350\ GeV$)

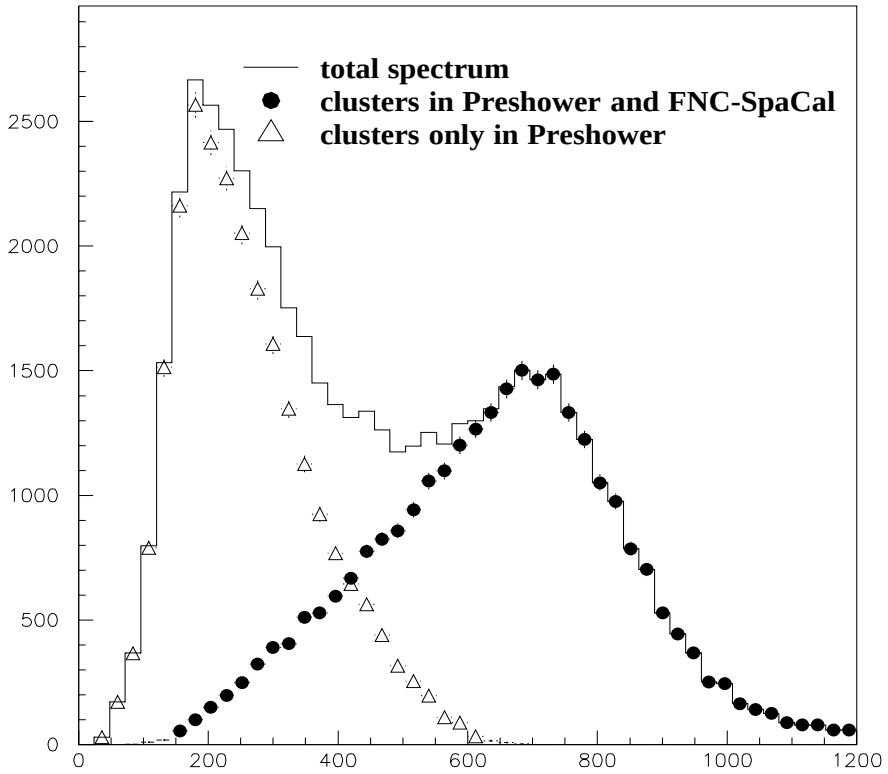
$$\frac{\sigma_E}{E} = \frac{63.4 \pm 4.7}{\sqrt{E[GeV]}} \oplus (3.0 \pm 0.4)\%$$

(Monte-Carlo estimate was $\sim$ 50%).

The results for the electrons
($E_{beam} = 120 - 225\ GeV$) are

$$\frac{\sigma_E}{E} = \frac{30\%}{\sqrt{E[GeV]}} \oplus 2\%$$

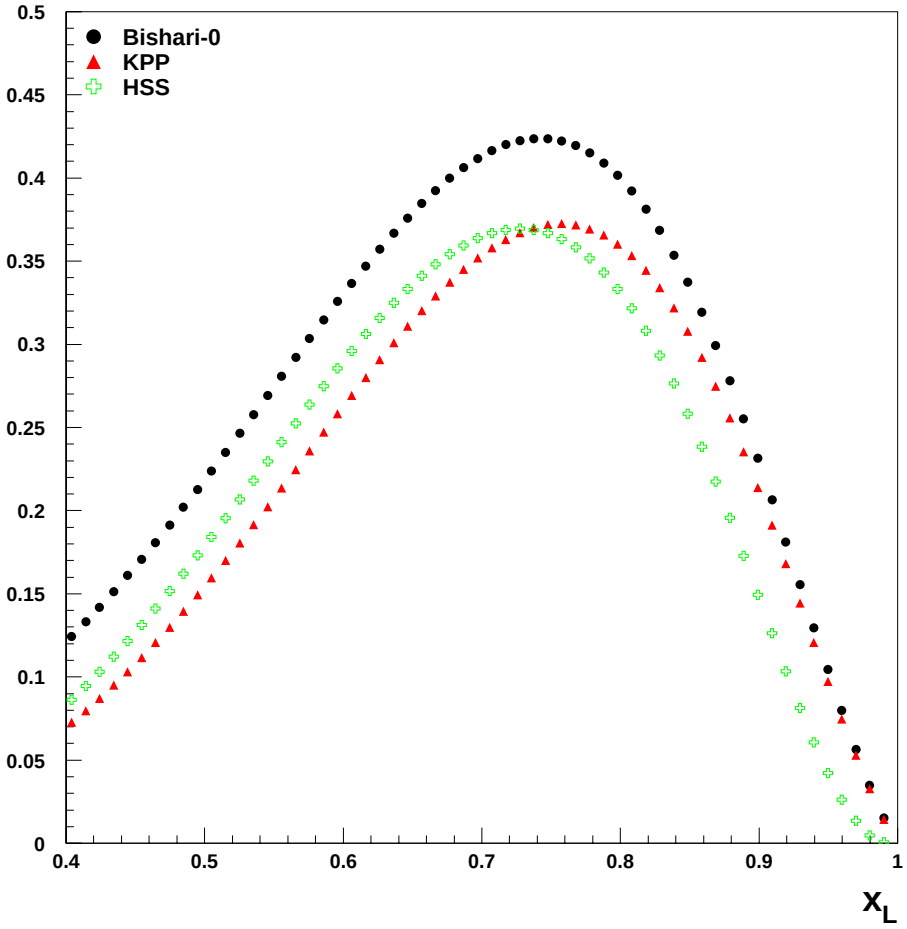
Neutron and photon energy spectrum measured in H1

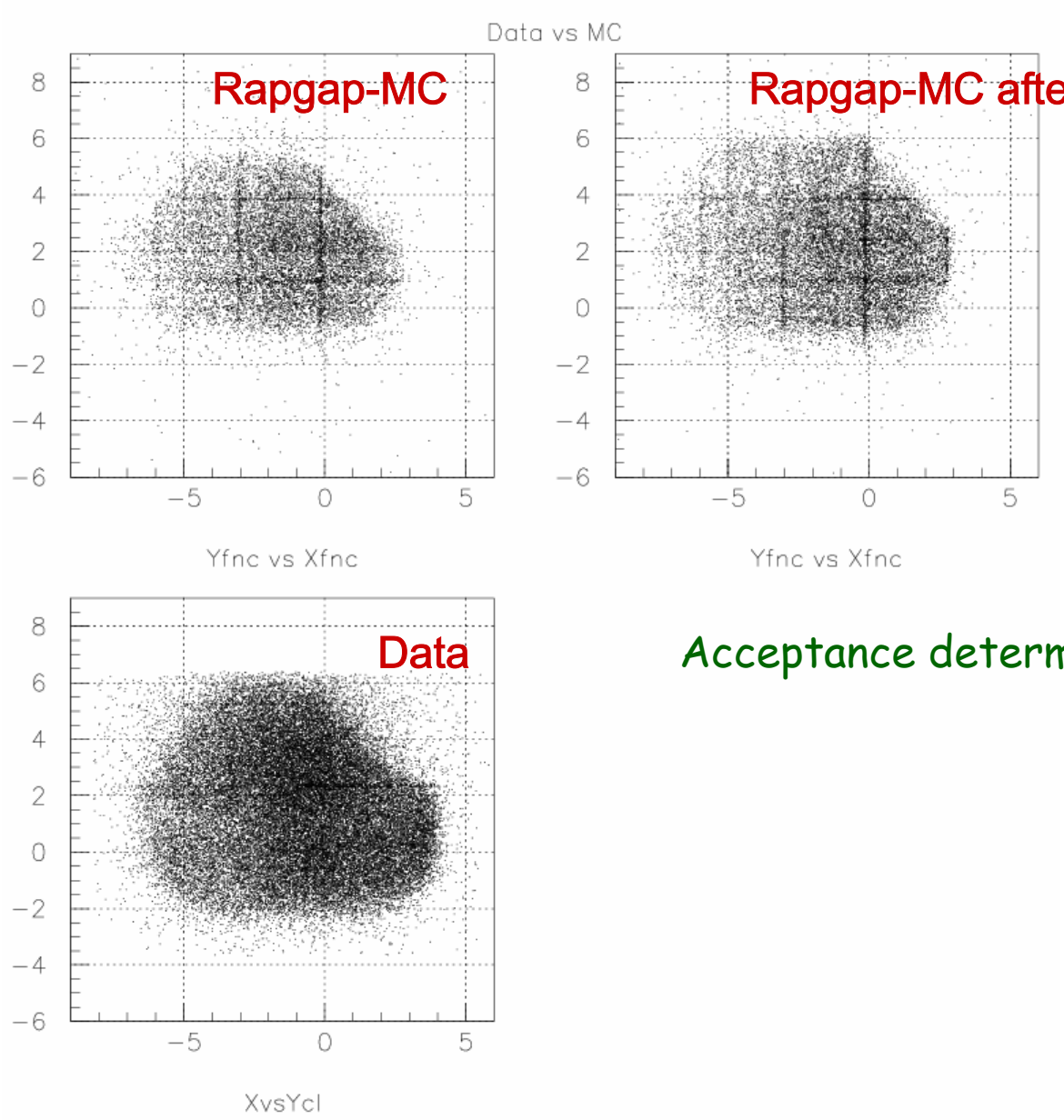


-cluster in Preshower = photon,
-cluster in main calorimeter and/or Preshower = neutron

Different pion fluxes used in analysis (different form factors)

$$f_{\pi^+/p}(x_L,t) = \frac{1}{2\pi}\frac{g^2_{p\pi n}}{4\pi}(1-x_L)^{1-2\alpha(t)}\frac{-t}{(m_\pi^2-t)^2}|G(t)|^2$$





Acceptance determined by MC

H1 Publications:

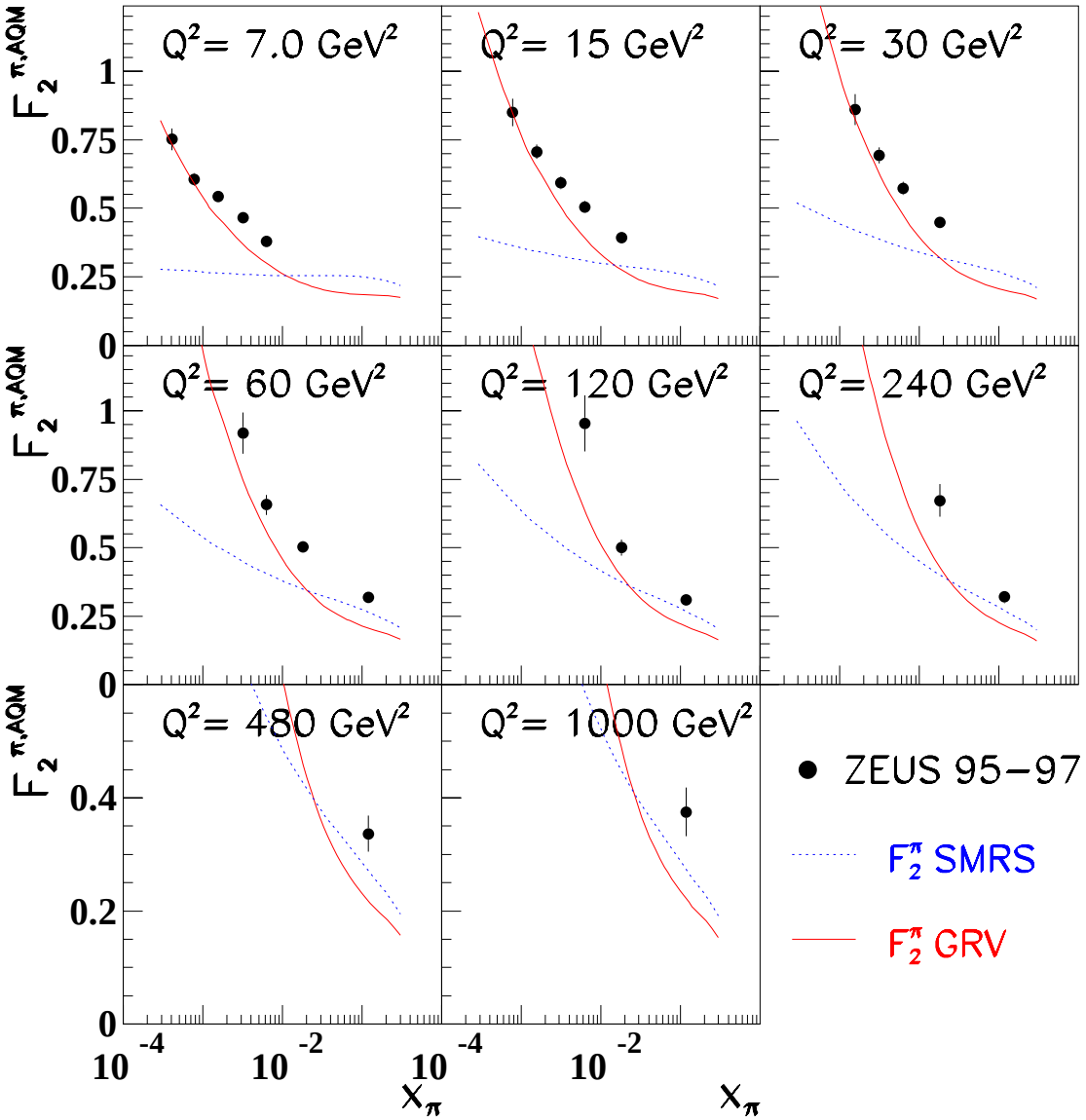
- "Measurement of leading proton and neutron production in DIS at HERA" DESY-98-169

- "Measurement of dijet cross sections in ep interactions with a leading neutron ",
DESY-04-247

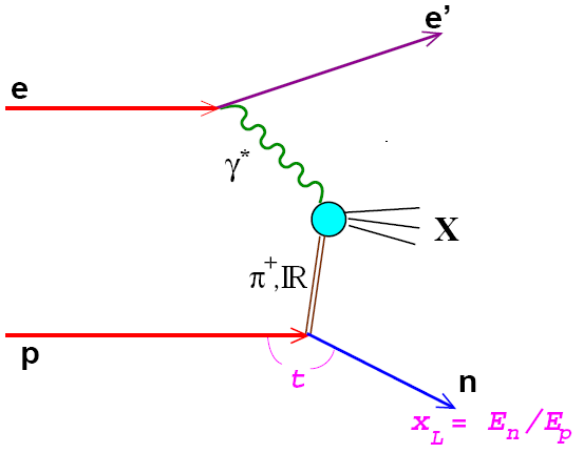
ZEUS Publications:

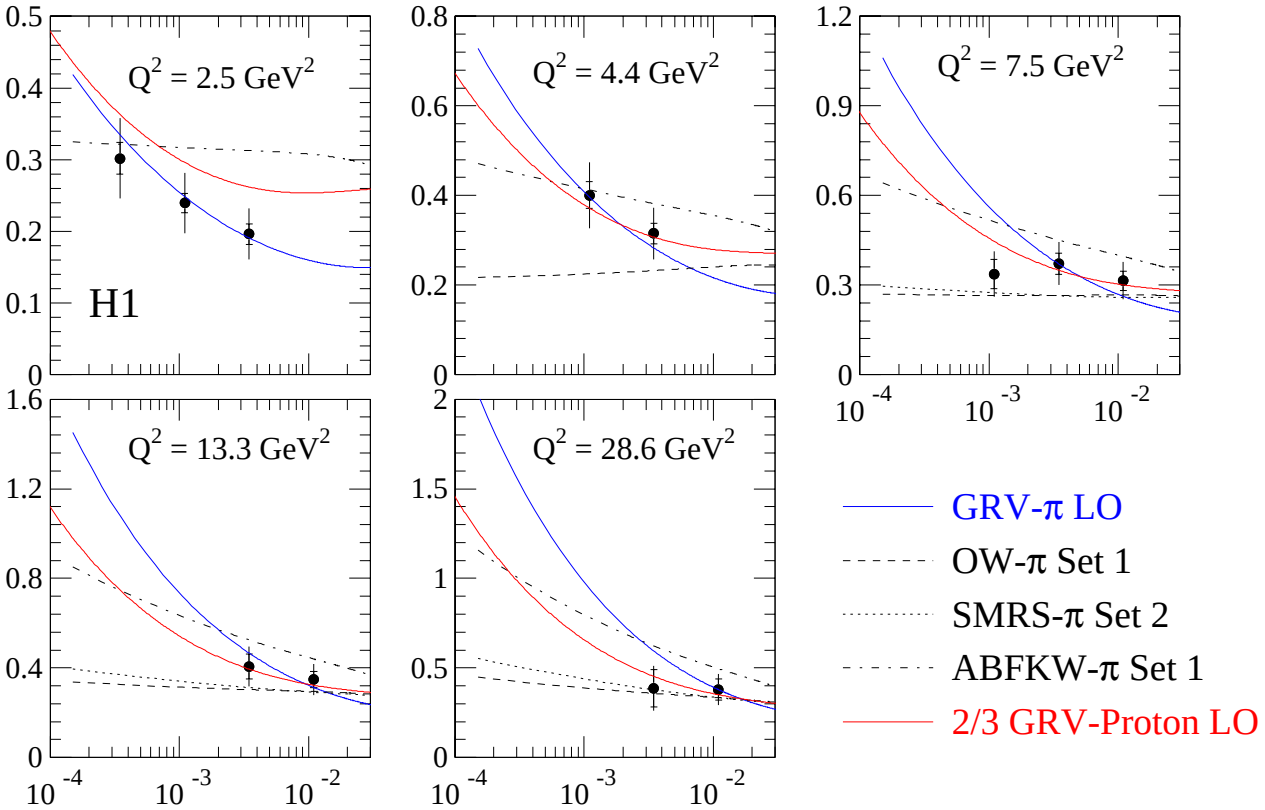
- "Study of the pion trajectory in the photoproduction of leading neutrons at HERA"
  DESY-04-037
- "Photoproduction of D* mesons associated with a leading neutron""
  DESY-03-221
- "Leading neutron production in ep collisions at HERA"
  DESY-02-039
- "Measurement of dijet cross sections for events with a leading neutron in photoproduction at HERA"
  DESY 00-142
- "Observation of events with an energetic forward neutron in DIS at HERA"
  DESY 96-093

F_2^{π} from ZEUS



$$\frac{F_2^{LN(3)}(z=0.7)}{\Gamma\pi}$$





Data show sensitivity to the parameterizations of the pion structure function (constrained for x (=β)>0.1 from the fixed target experiments).

Comparison of LN production rate for different processes (ZEUS)

$$r^{D^*}(x_L > 0.49) = 6.55 \pm 0.76(\text{stat.})^{+0.35}_{-0.45}(\text{syst.})\%$$

$$r^{\text{DIS}}(x_L > 0.49) = 5.8 \pm 0.3\%,$$

$$r^{jj}(x_L > 0.49) = 4.9 \pm 0.4\%,$$

$$r^{\gamma p}(x_L > 0.49) = 4.3 \pm 0.3\%.$$

e.g. $r^{\gamma p} < r^{jj} < r^{D^*} \leq r^{\text{DIS}}$

➔ Absorption - ratio depends on the transverse size of virtual photon

Estimation of the probability of the $p \rightarrow n+\pi^+$ in DIS from the neutron rate in DIS extrapolating to the full energy range (for three different pion fluxes}

$$\frac{2}{3} P_{n\pi} = \left| \left\langle n\pi^+ \middle| p \right\rangle \right|^2 = 0.16 \pm 0.01$$

$$0.18 \pm 0.01$$

$$0.25 \pm 0.01$$

SU(2) chiral model

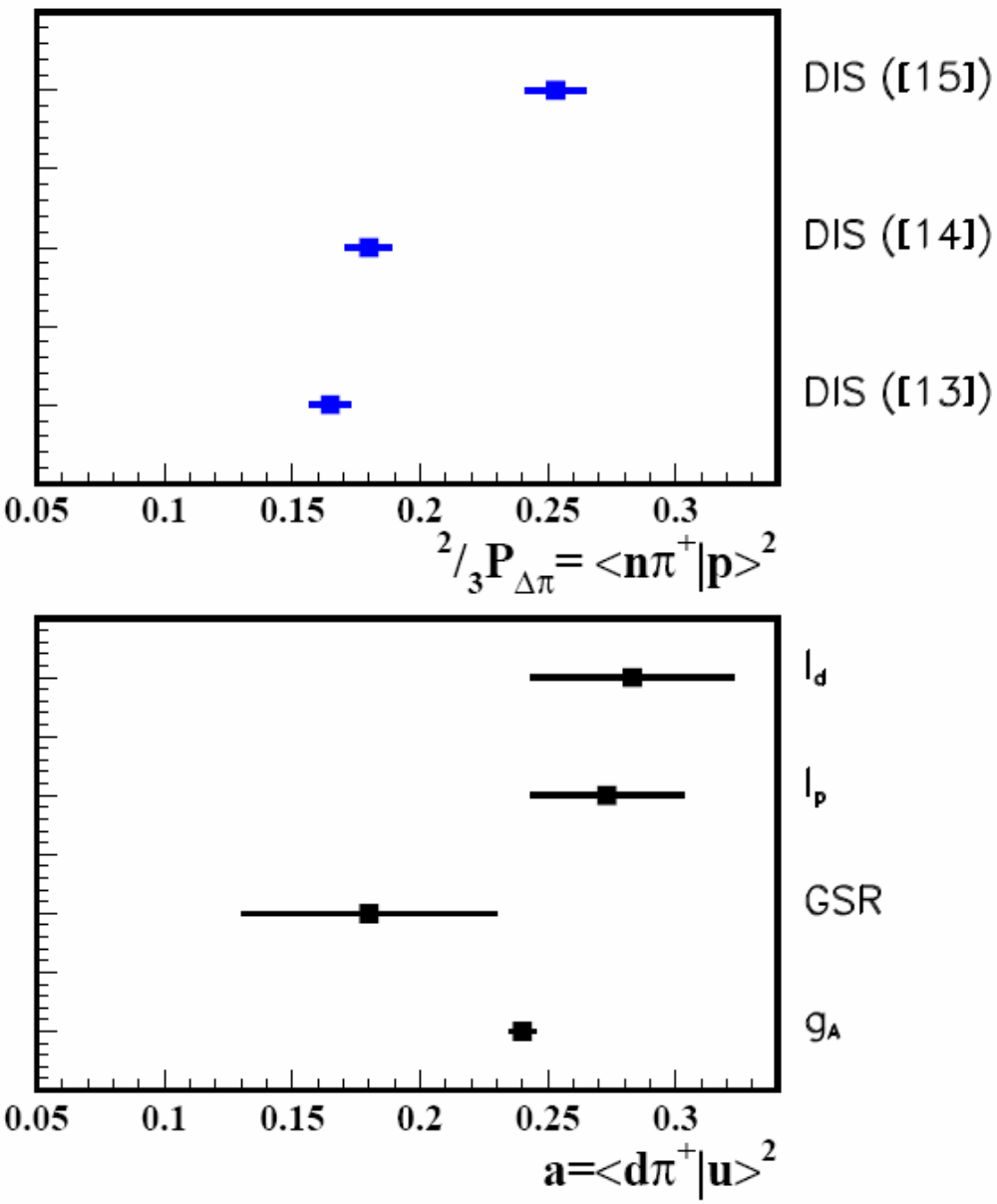
$$g_A = (1-a)\frac{5}{3}$$

$$g_A = 1.267 \pm 0.003$$

$$a = 0.240 \pm 0.002$$

Conclusions

Conclusions

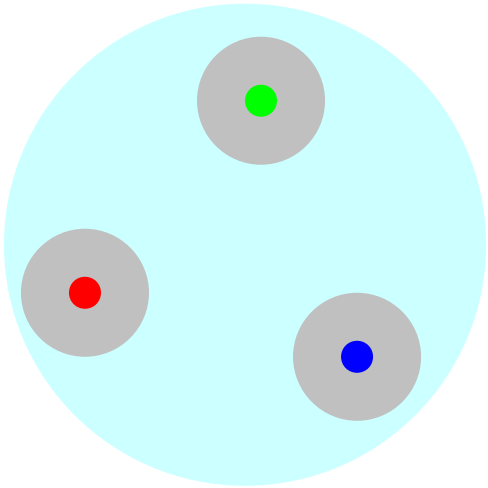


$$|u\rangle = \sqrt{1-\frac{3}{2}a}\,|u'\rangle + \sqrt{a}\,|d'\pi^{+}\rangle + \sqrt{\frac{a}{2}}\,|u'\pi^{0}\rangle$$

$$|p\rangle = \alpha|3q\rangle + P_{N\pi}|3q\pi\rangle + P_{N2\pi}|3q2\pi\rangle + P_{N3\pi}|3q3\pi\rangle$$

The constituent quarks are a superposition of the massive quarks and pions

Conclusions



Gluonic structure of the nucleon-

resolution on the order of 0.3 fm