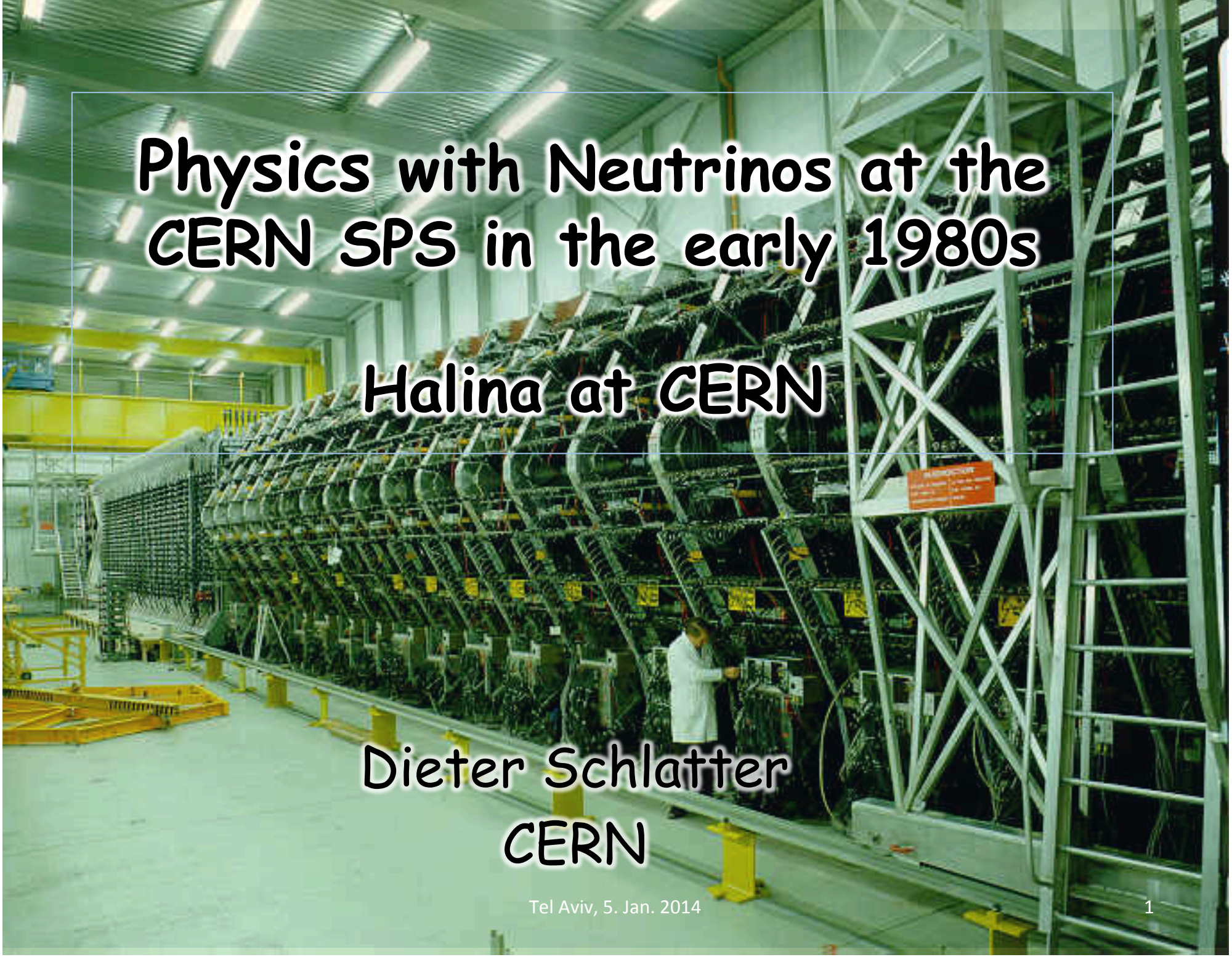


Physics with Neutrinos at the CERN SPS in the early 1980s

Halina at CERN

Dieter Schlatter
CERN

Physics landscape at the end 1970s

- Parton model for nucleon

  -> partons are fractionally charged quarks (gluons postulated)

$$\int_0^1 x \cdot [u(x) + \bar{u}(x) + d(x) + \bar{d}(x)]dx = 1 - \varepsilon \qquad \varepsilon \approx 0.5$$

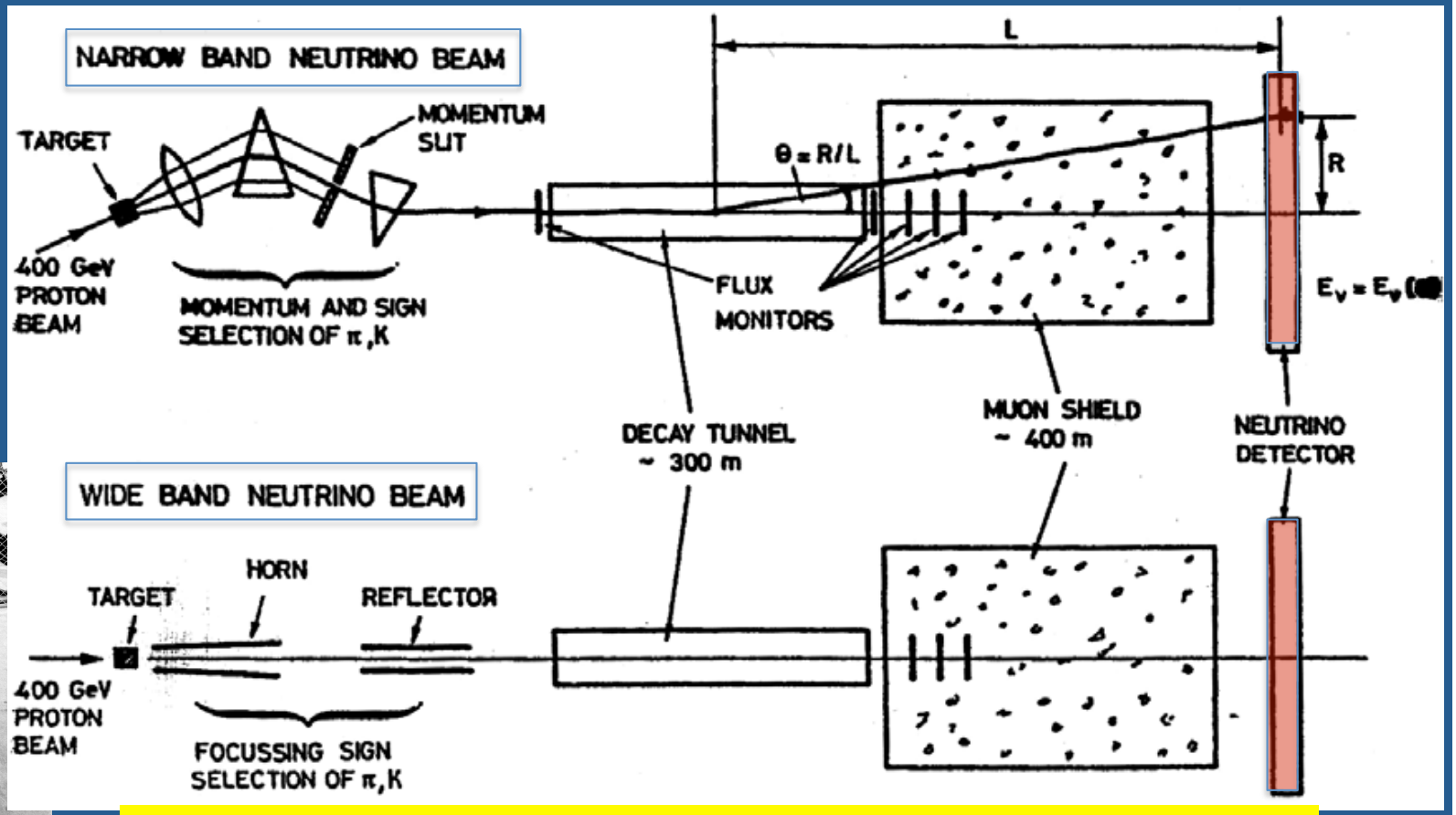
- Charm quark was discovered 1974
- QCD, a theory for strong interaction
- Neutrinos may have mass and oscillate?

Deep inelastic neutrino – nucleon scattering

- Neutrino (ν_μ) beam at SPS
- CDHS(W) experiment

- EW physics
  - "Weinberg angle"
  - charm production
- QCD
  - Structure of proton
  - "Scaling violation" of $F(Q^2)$ -> gluon radiation
  - Strong coupling constant
- Search for neutrino oscillations

SPS Neutrino beam (1977-1998)



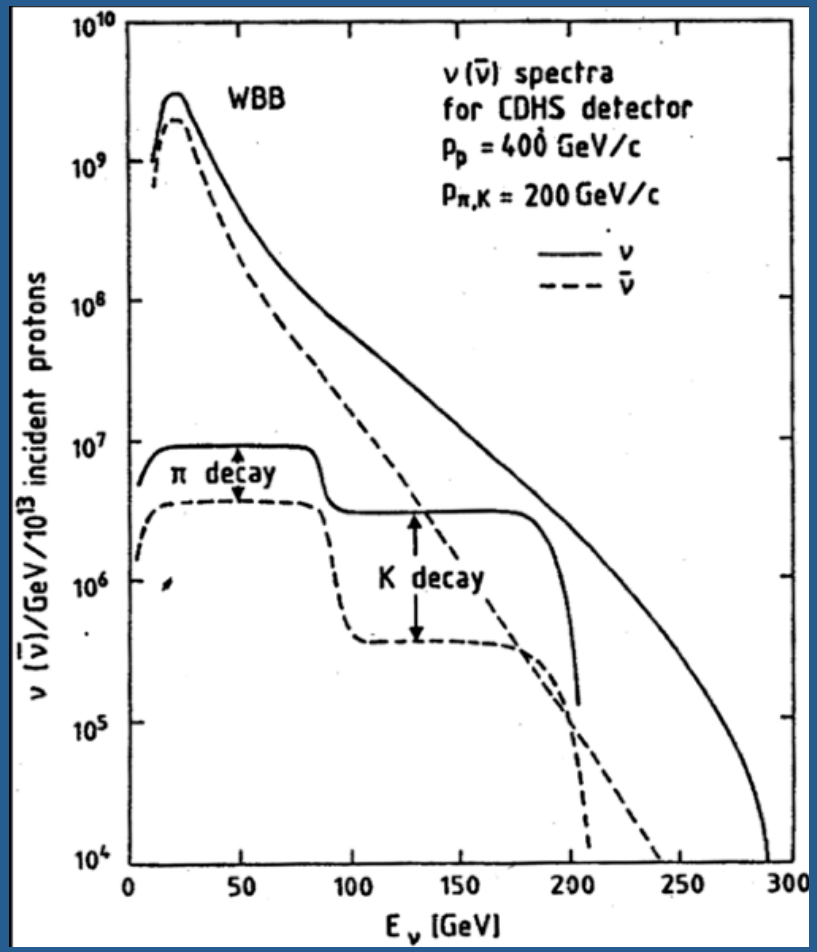
van der Meer horn

<---------- 880 m ---------->

SPS Neutrino beam

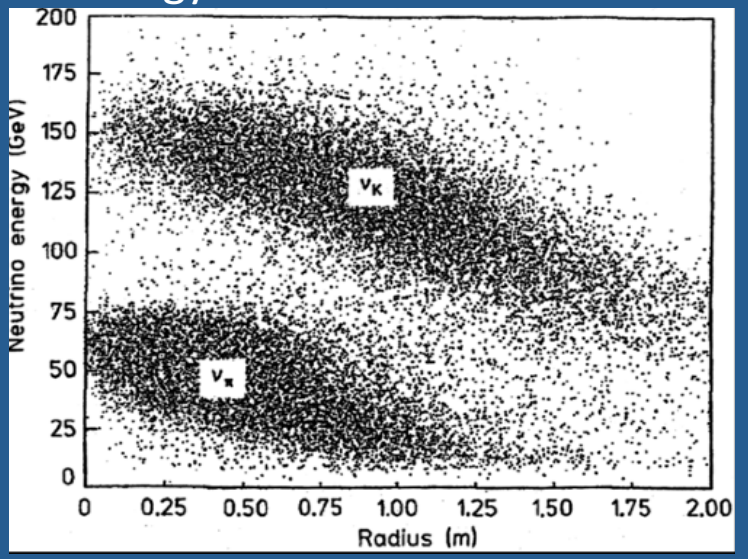
2 types: Wide-Band Beam and Narrow-Band Beam

Energy spectrum

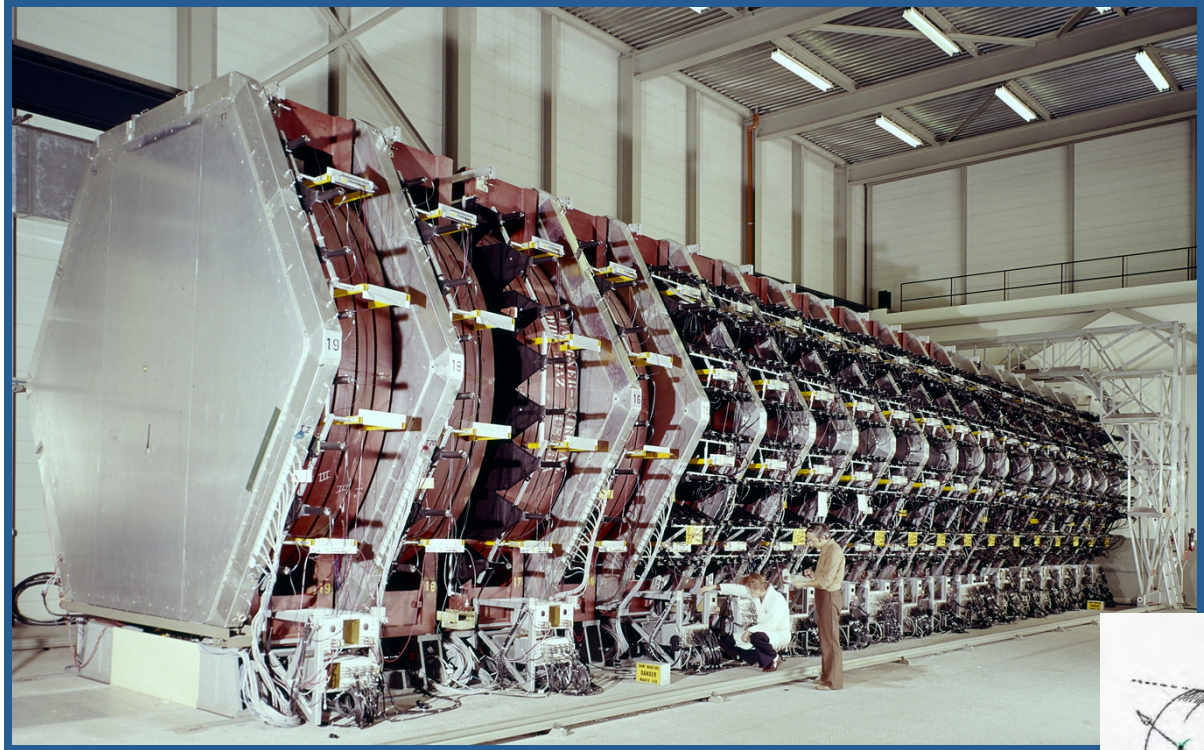


NBB

Energy vs radius at detector



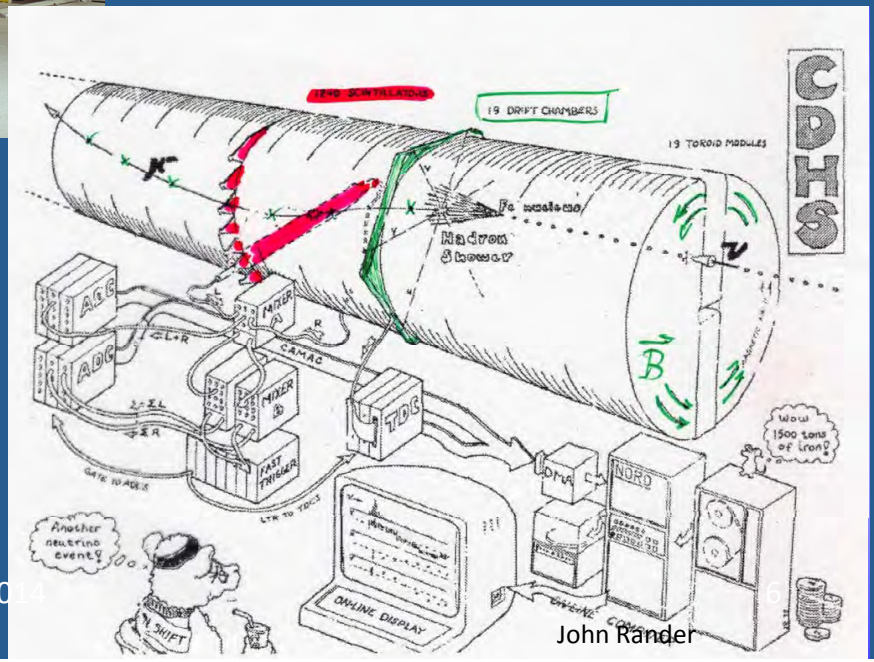
The CDHS Experiment
1977-1985



1977-79:
CERN
Dortmund
Heidelberg
Saclay
~ 35 members

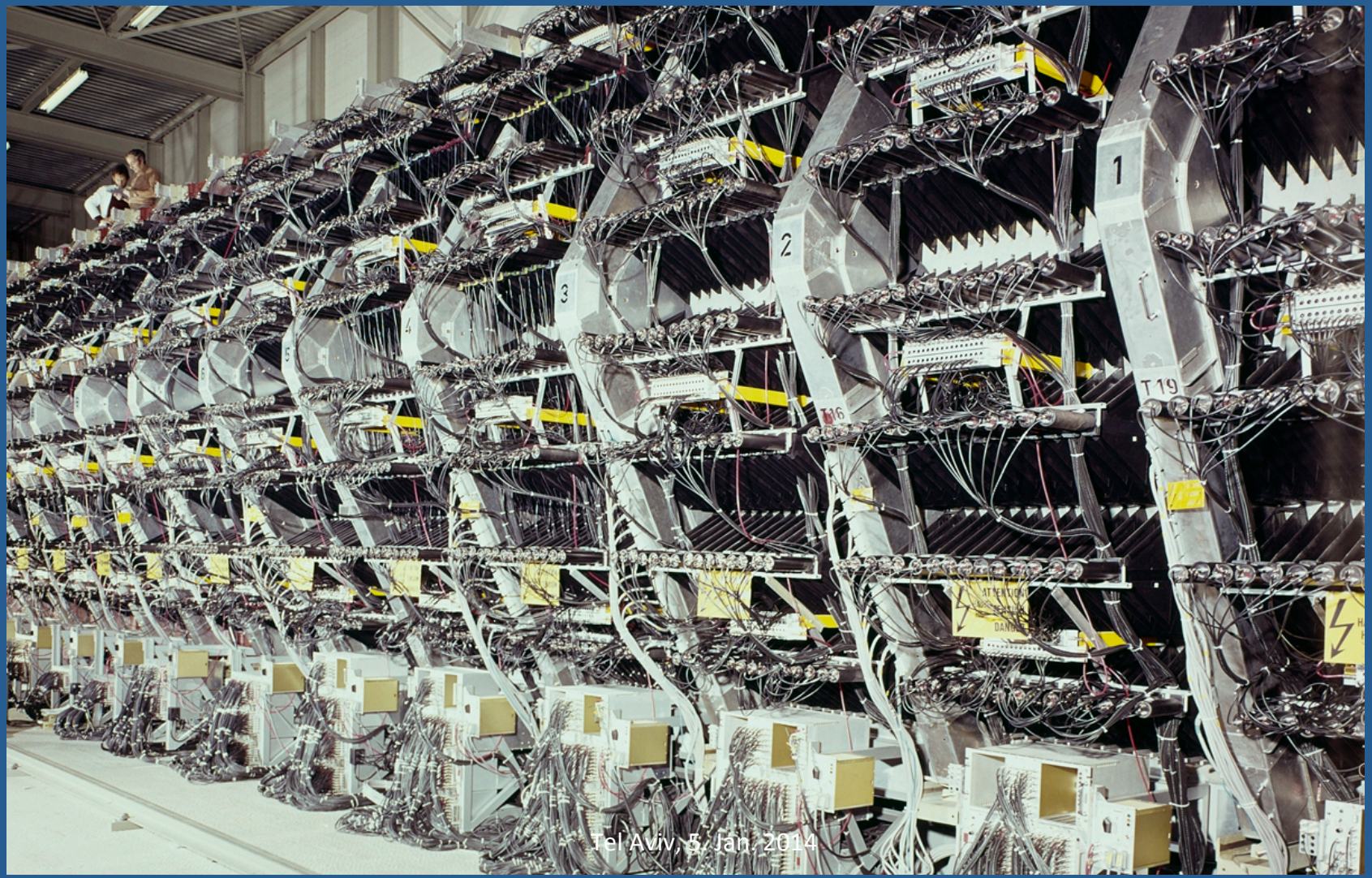
1980-85:
CDHSW (+Warsaw)

- 20 m long
- 1.8 m radius
- 1200 t iron (magnetized)
- 19 drift chambers
- 1500 scintillators
- 3000 PMs

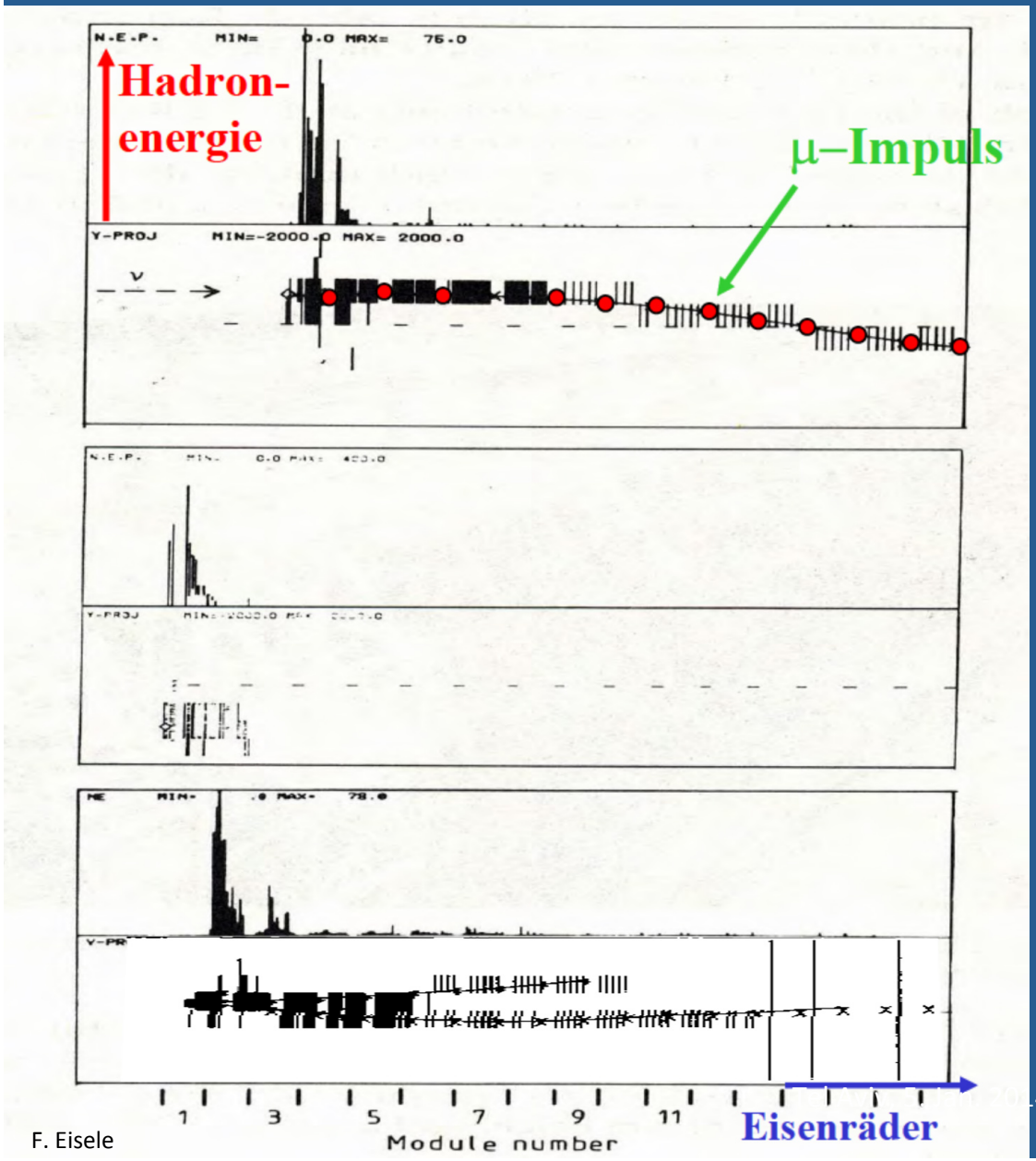


Fe-scintillator calorimeter

~ 3000 photomultipliers + 19 drift chambers interleaved.
Magnetized iron



Events in the detector



$\nu + N \rightarrow \mu + X$

charged current (W exchange)

$\nu + N \rightarrow \nu + X$

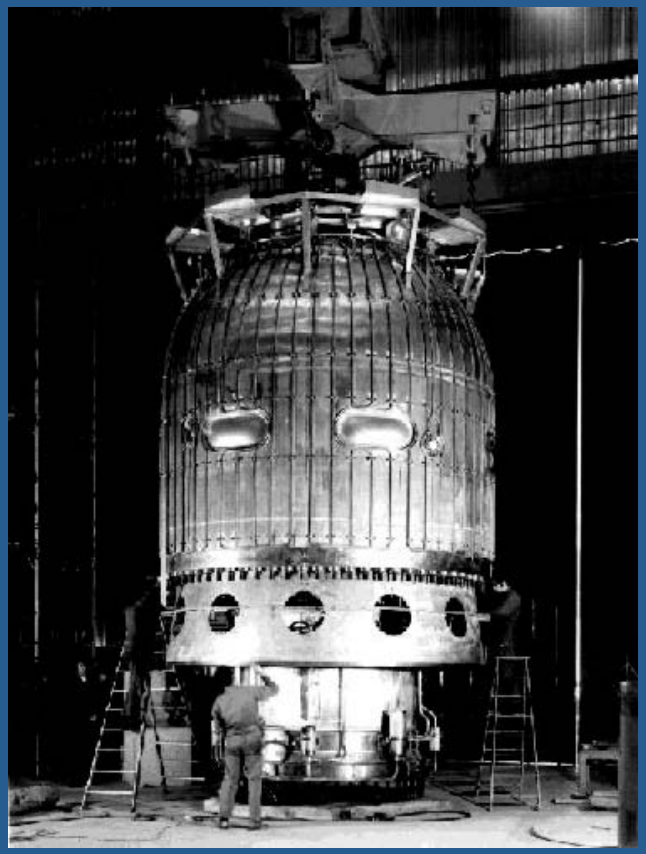
neutral current (Z exchange)

$\nu + N \rightarrow \mu^+ + \mu^- + X$

CC + charm decay

Some Team members

CERN Competition in same ν beam



- BEBC
  1976-84

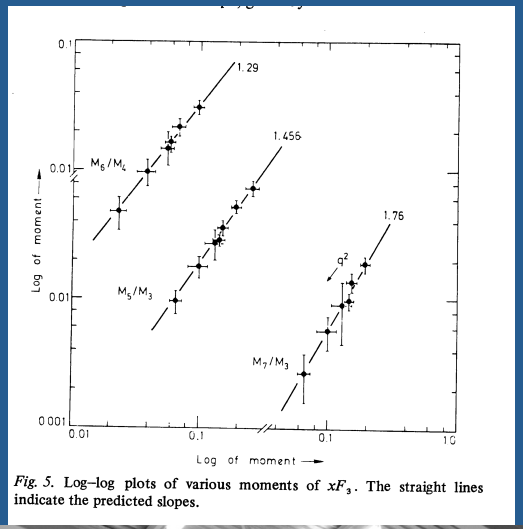
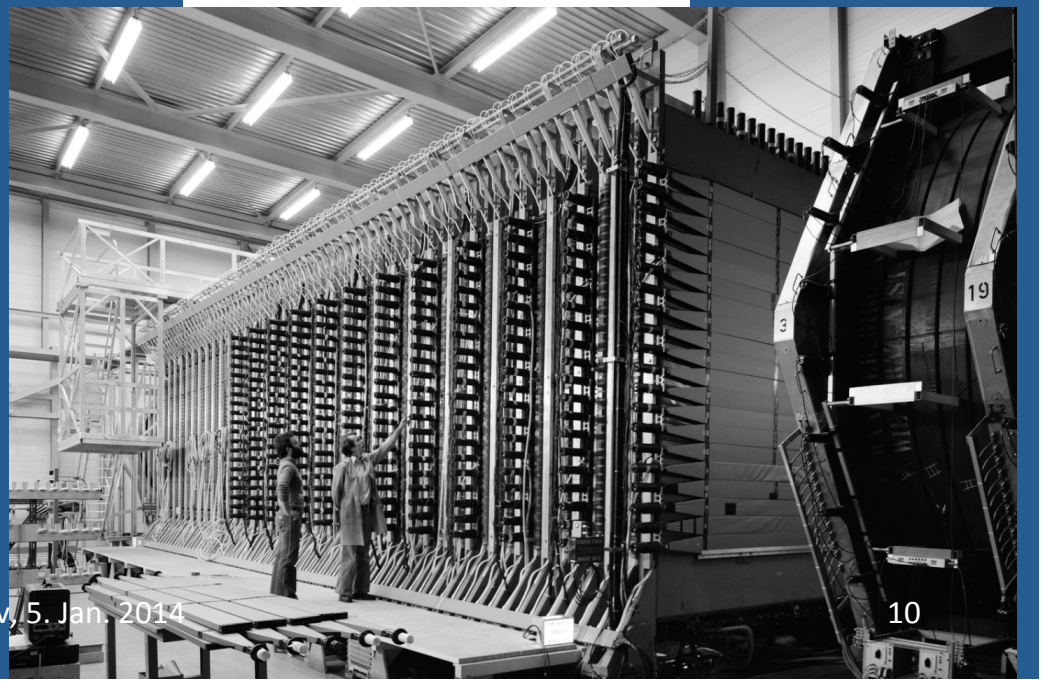


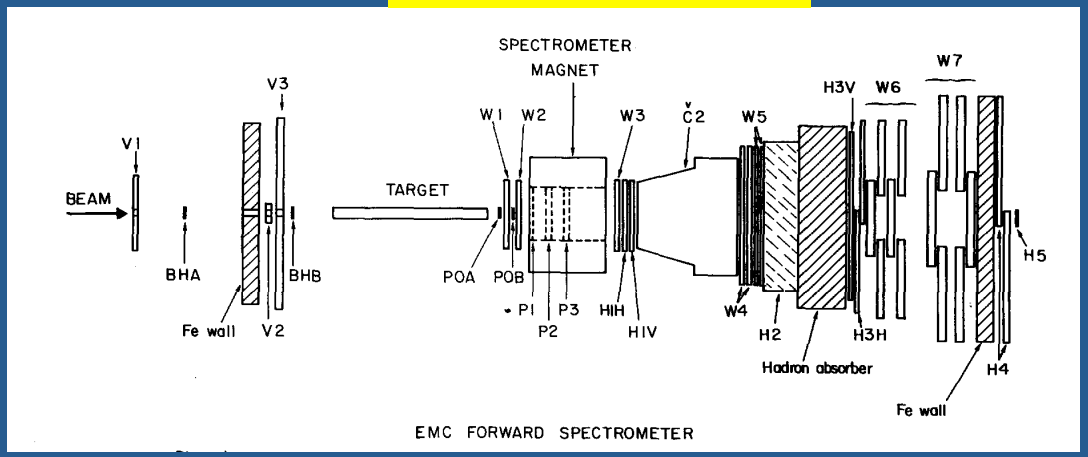
Fig. 5. Log–log plots of various moments of xF_3. The straight lines indicate the predicted slopes.



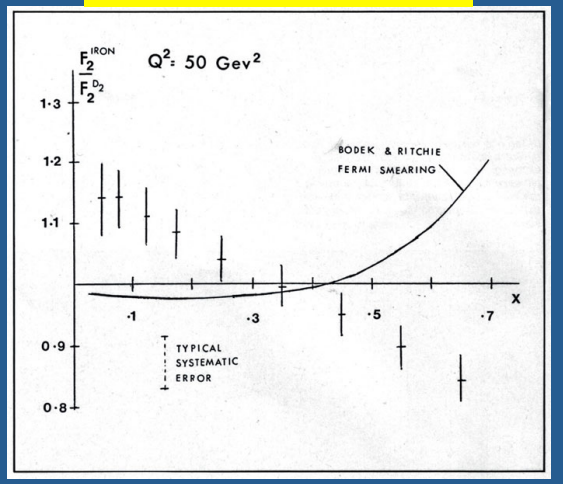
- CHARM -> NC
  1979-84

Muon experiments (EMC + BCDMS), structure functions

EMC spectrometer

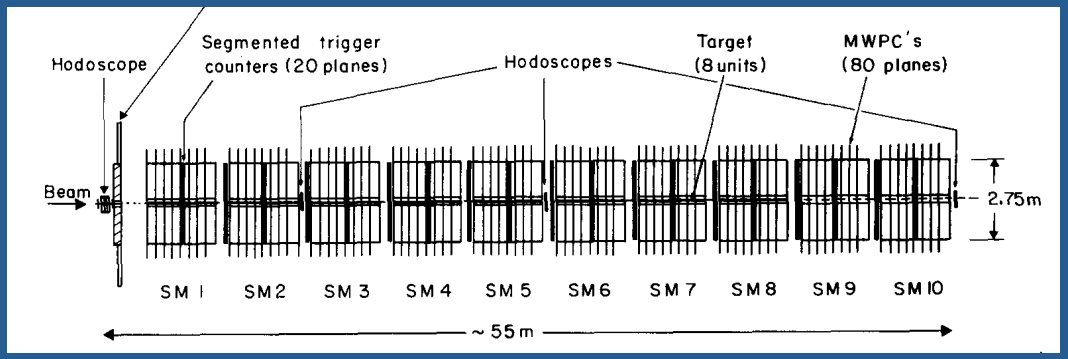


EMC effect, 1982



EMC on F2:

"Measurement of the nucleon structure function *F2* in muon - iron interactions at 120-GeV, 250-GeV and 280-GeV": EMC Coll., PLB, Aug, 1981



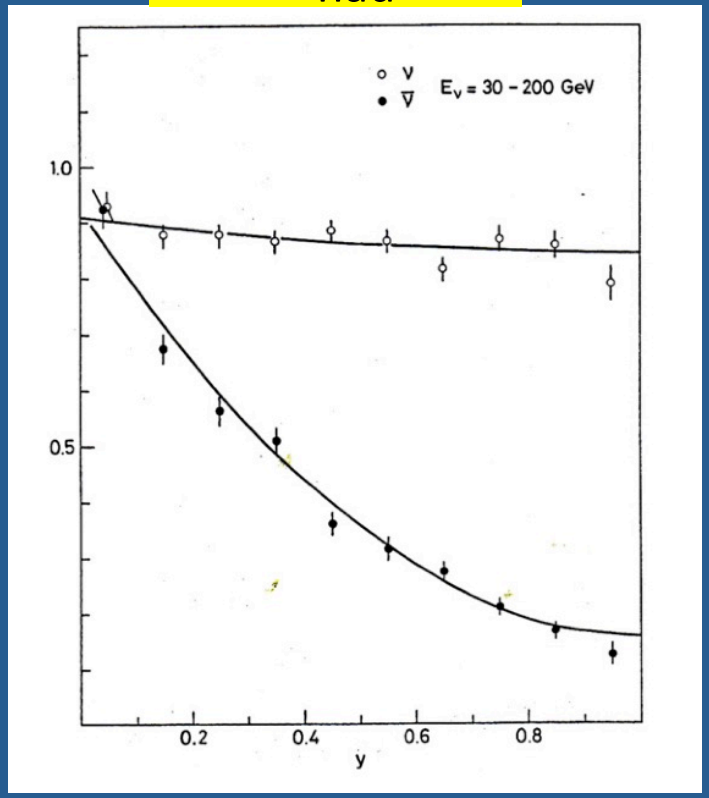
BCMS on F2:

"A measurement of the nucleon structure function from muon-carbon deep inelastic scattering at high Q^2 ": BCDMS-Coll., PLB, Sep. 1981

CDHS Structure of Proton

H. Abramowicz et al., Z.Phys.C (1983)

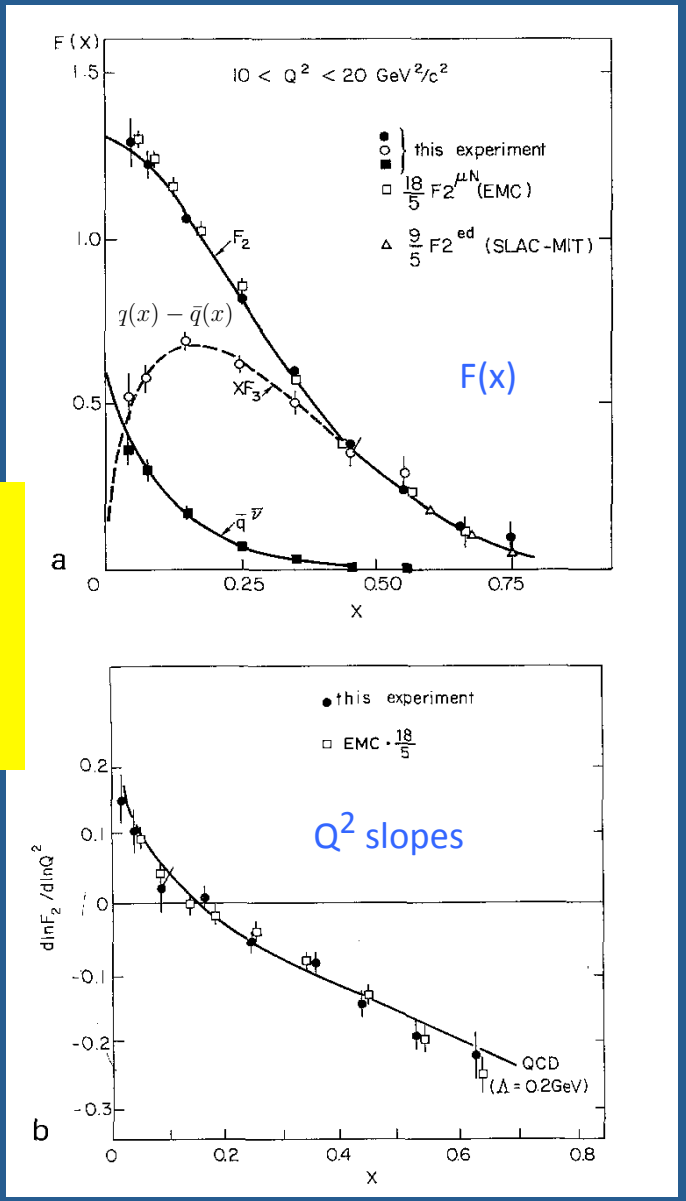
$y \simeq E_{had} / E_\nu$



lines = parton model

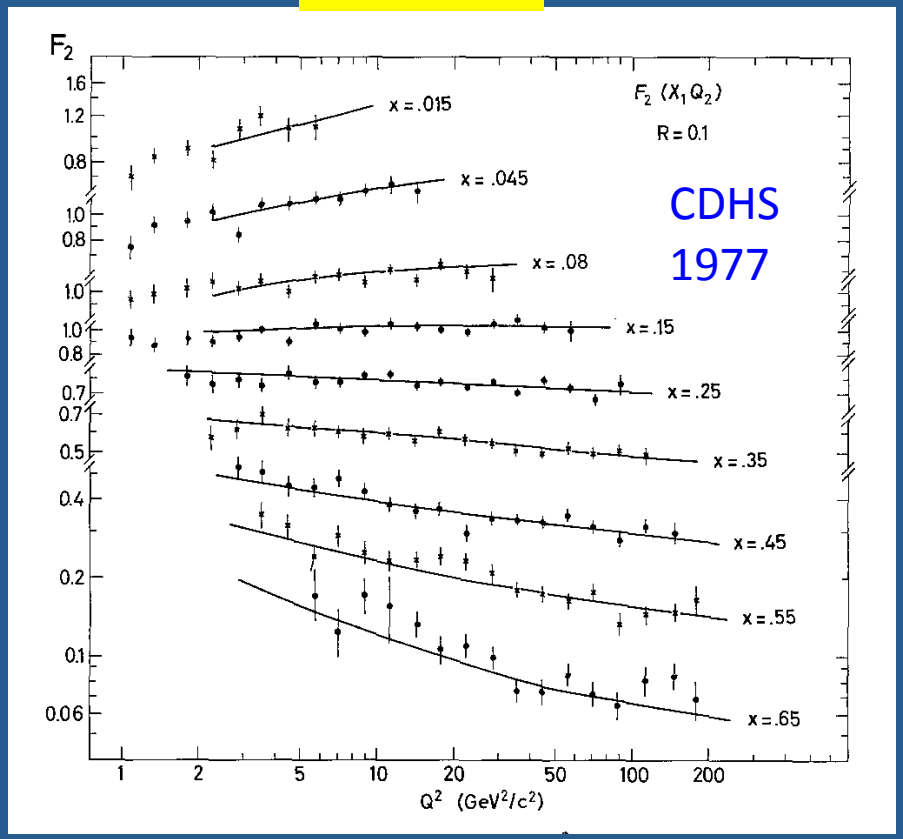
Comparision:
F_2 (νp)
= 9/5 F_2(ed)
= 18/5 F_2(μp)

-> partons = quarks with Q=1/3e, 2/3e

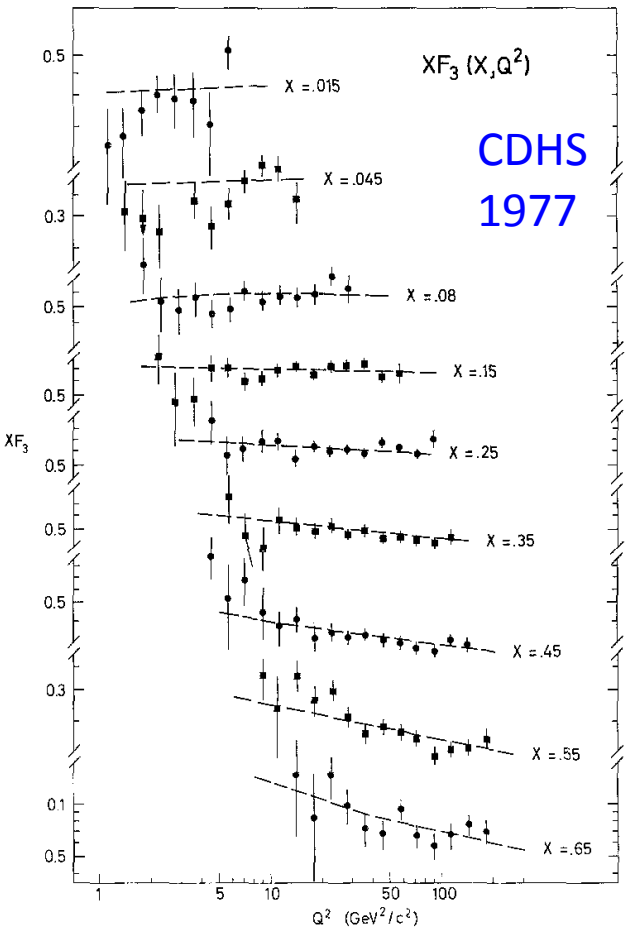


Q^2 evolution of structure functions

$q(x) + \bar{q}(x)$



$q(x) - \bar{q}(x)$

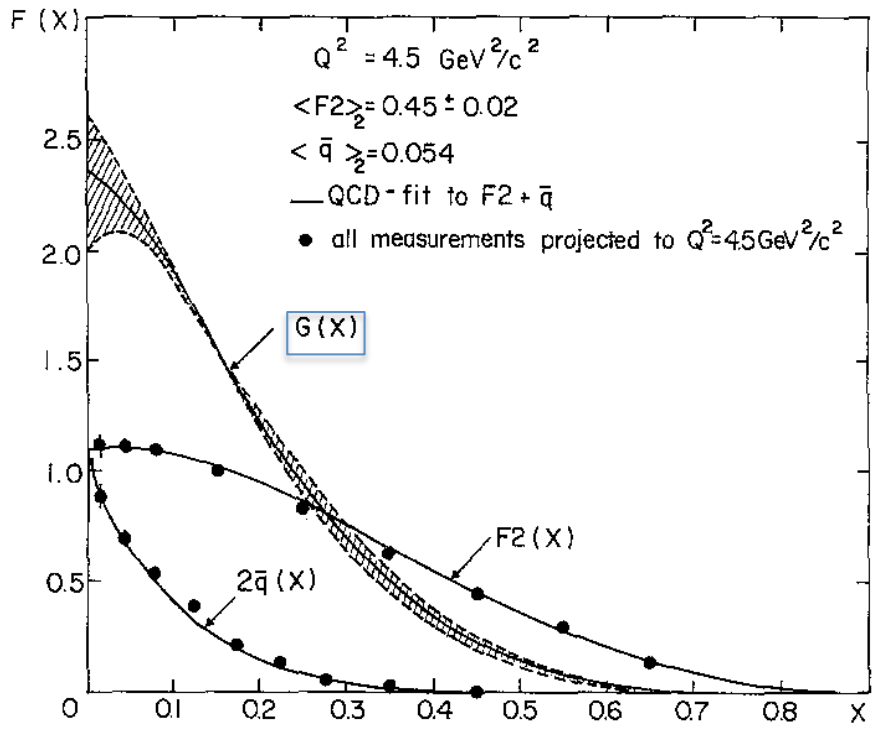


QCD fit with DGLAP evolution equations:
"Scaling violations" agree with gluon emission

Gluon distribution and strong coupling

Combined QCD analysis of $F_2(Q^2,x)$ and $\bar{q}(Q^2,x)$ projection of gluon distribution in the nucleus.

H. Abramowicz et al. Z. Phys.C (1982)



Strong coupling constant and Λ_{QCD} in LO:

$$\alpha_s(Q_0^2) = \frac{12\pi}{25\ln(Q_0^2/\Lambda_{LO}^2)}$$

Result: Λ = 250 (+150 -100) MeV

$\alpha_s(M_Z)$ = 0.128 (10)

Today

RPP(2012): Λ_5= 213 (8) MeV

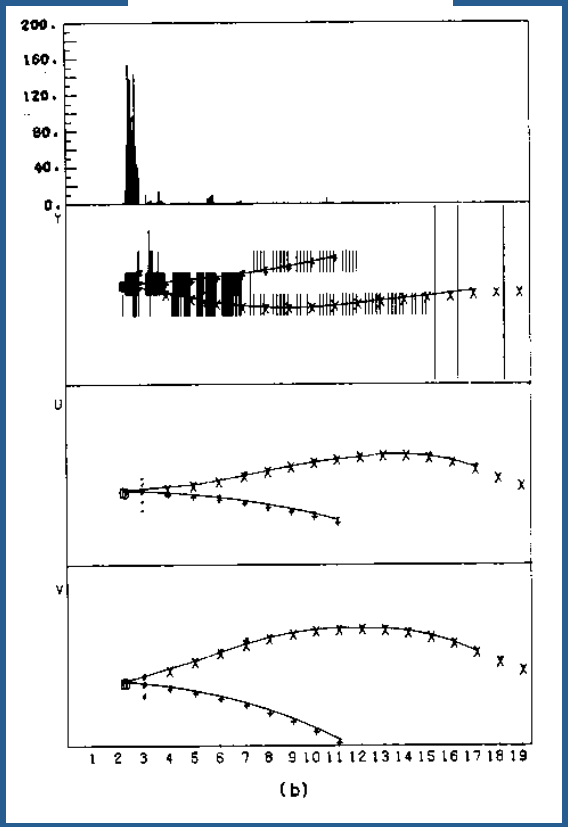
$\alpha_s(M_Z)$ =0.120 (2)

Charm production (GIM)

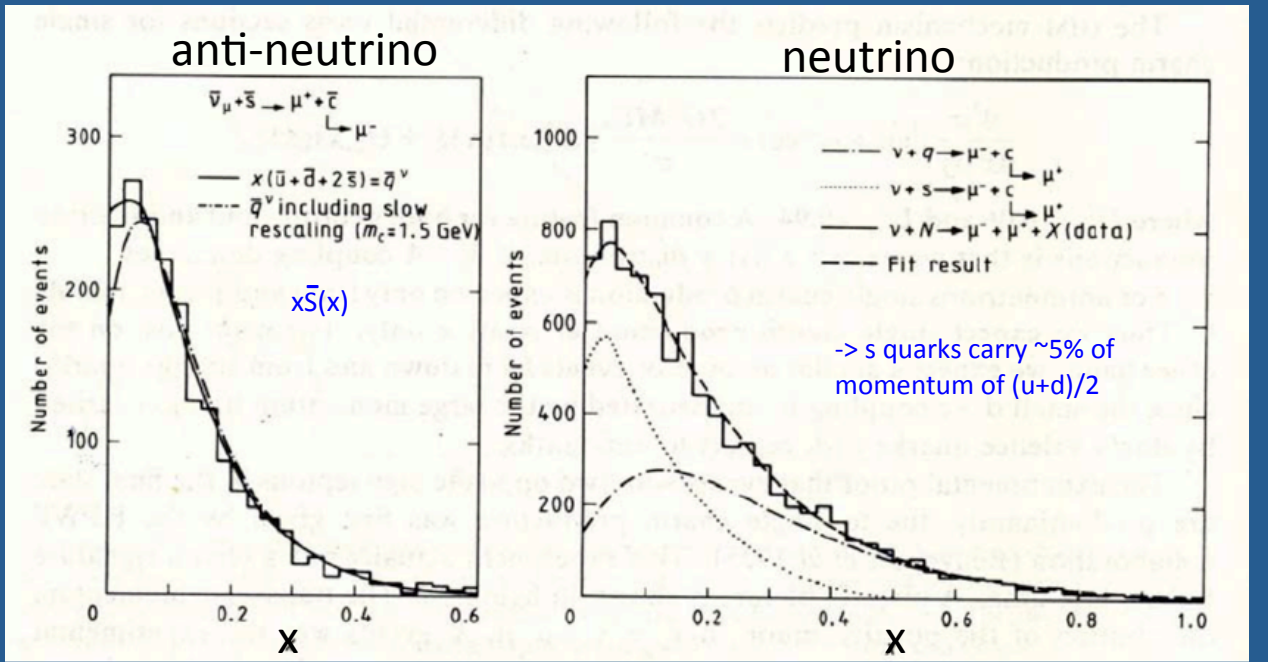
CC event with additional charm quark production and semi-leptonic decay

e.g.: $\nu_\mu + d \rightarrow \mu^- + c$, $c \rightarrow s + \mu^+ + \nu_\mu$

dimuon event

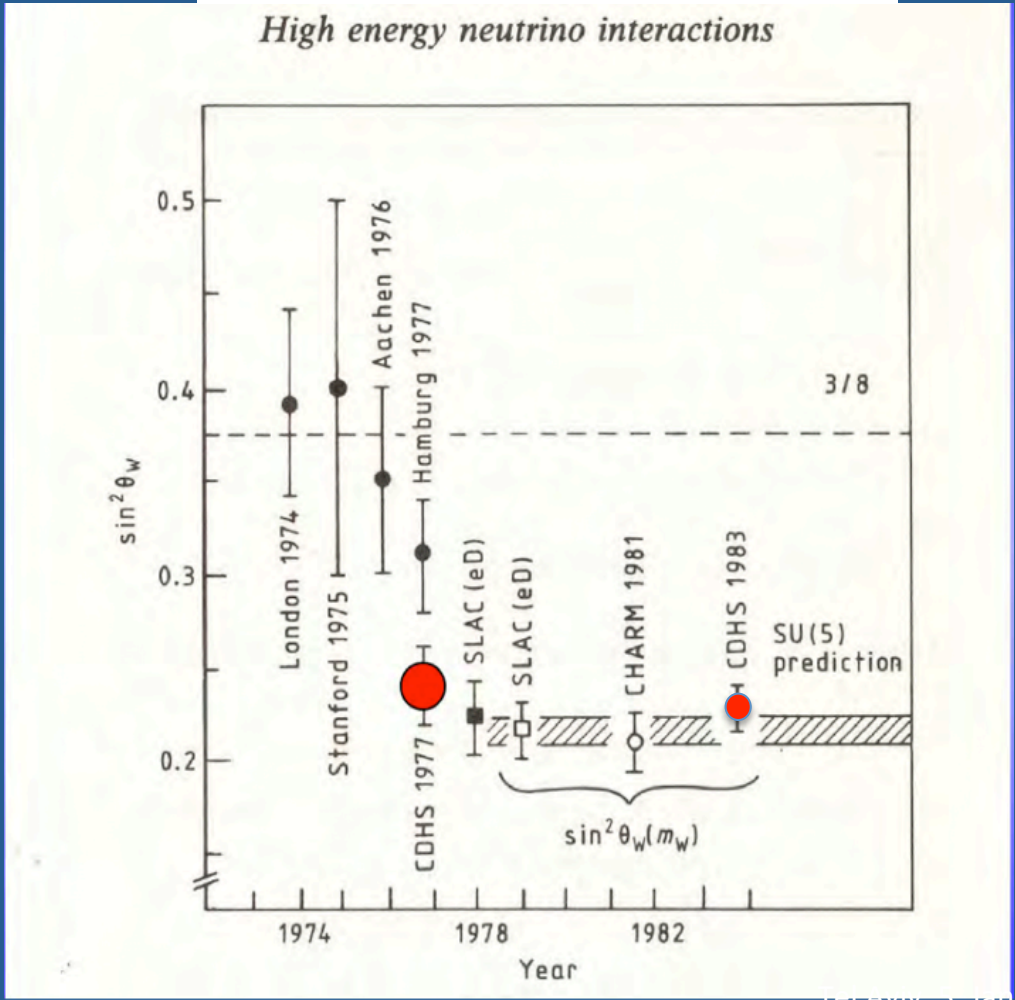


H. Abramowicz et al., Z. Phys. C (1982)



Electroweak mixing parameter, $\sin^2\theta_W$
"Weinberg angle"

H. Abramowicz et al. Phys.Rev.Lett.(1986)



Using neutral-charged current ratio:

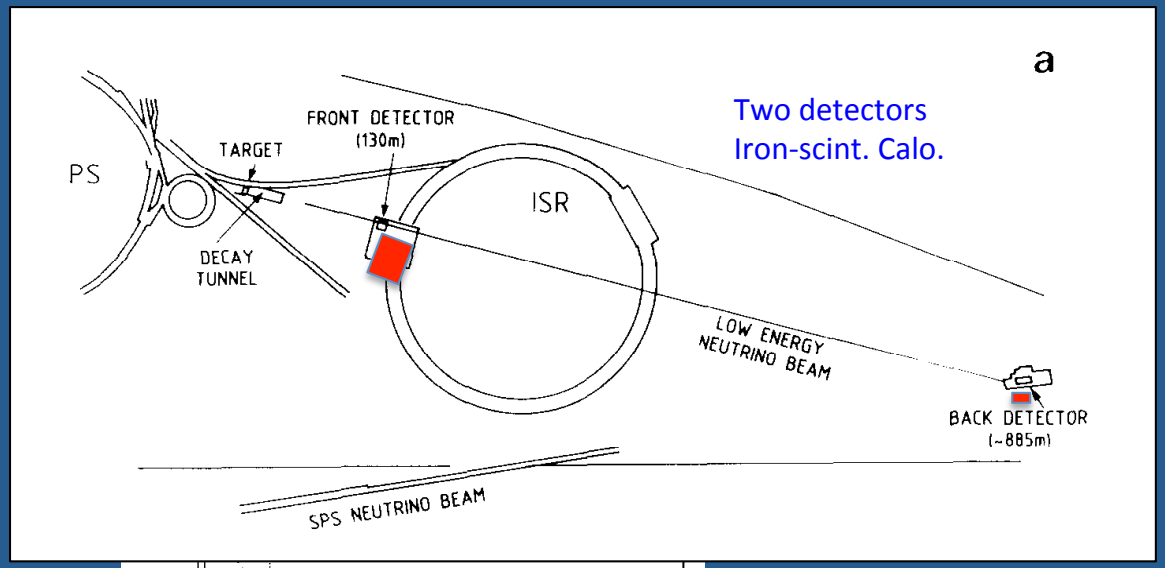
First measurements
Gargamelle: $\sin^2\theta_W = 0.3 - 0.4$

Early CDHS: $\sin^2\theta_W = 0.24 \pm 0.02$

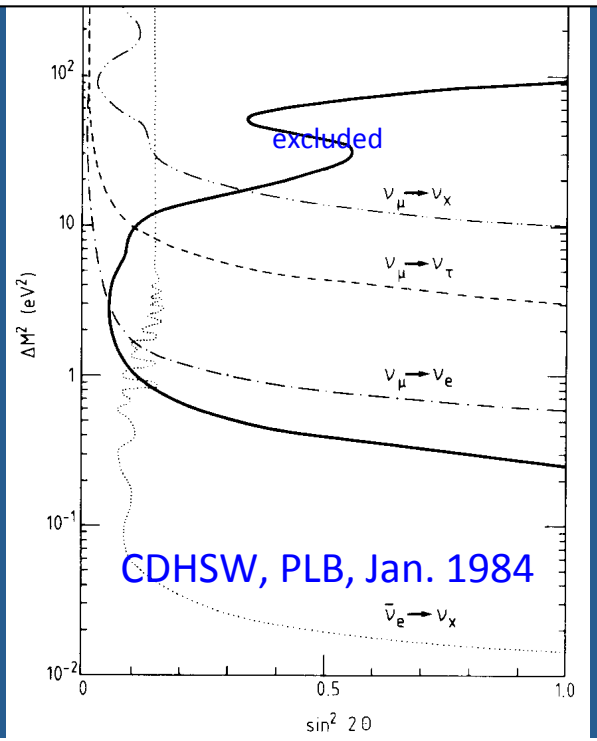
GUT in SU(5): $\sin^2\theta_W \sim 0.2$!

Final: $\sin^2\theta_W = 0.225\ (5)_{exp}\ (3)_{th}$
$+0.013(m_c - 1.5\text{GeV}/c^2)$

Search for ν_μ oscillations

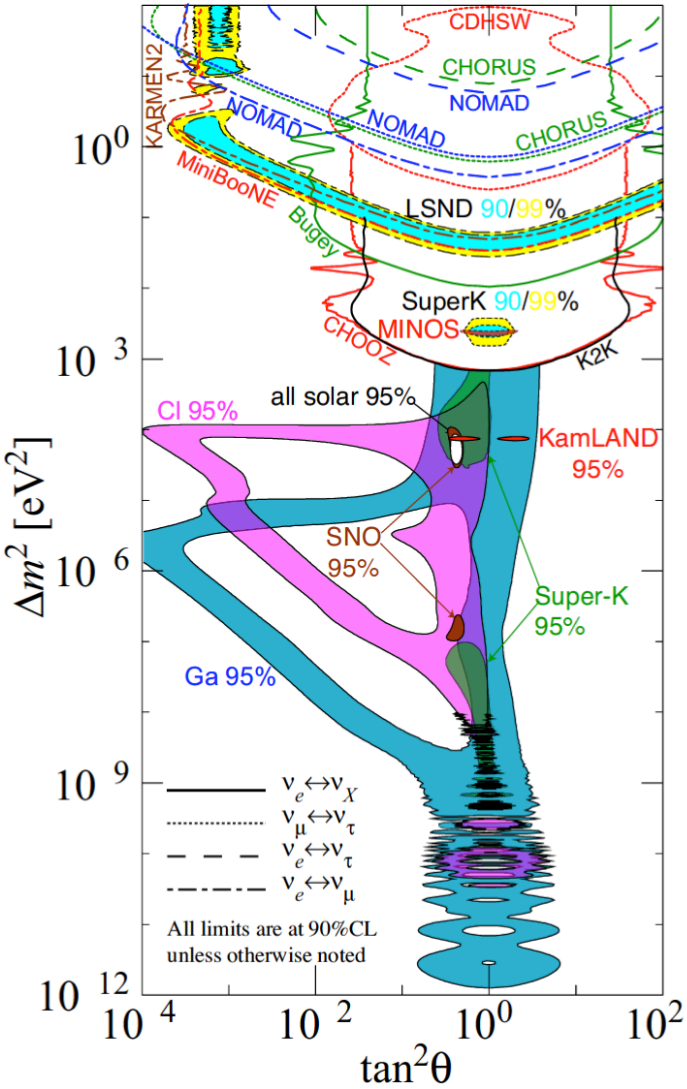


Two detectors
Iron-scint. Calo.



CDHSW, PLB, Jan. 1984

RPP 2013
H. Murayama



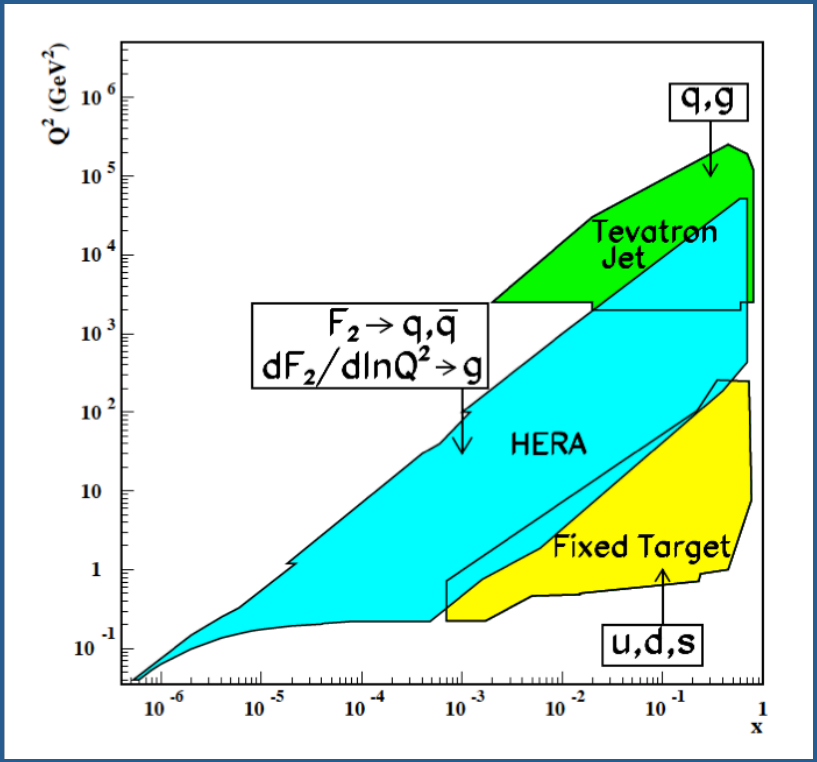
Tel Aviv, 5. Jan. 2014

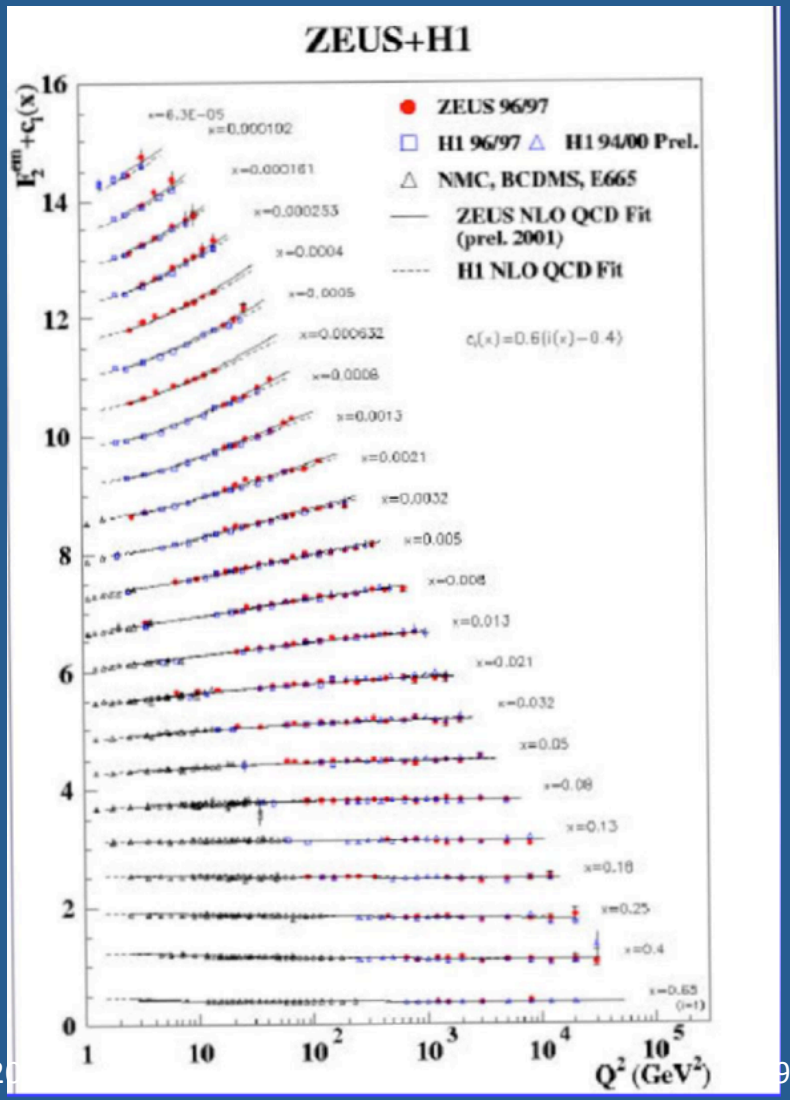
Conclusion

- Neutrinos were an excellent tool to study the Standard Model and the nucleon structure
- CERN SPS neutrino beam and the CDHS detector was a great opportunity
- Understanding "scaling violations" provided first quantitative confirmation of QCD
- First good measurement of $\sin^2\theta_W$

- ep deep inelastic scattering at HERA was a natural continuation

Next came HERA





on the way to Hamburg

on the way to Hamburg