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 proton

 -> partons are fractionally charged quarks   (gluons postulated)

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

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

Physics with neutrinos

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

- EW physics
  - Weinberg angle
  - charm production
- QCD
  - Structure of proton
  - "Scaling violation" -> gluon radiation
  - Strong coupling constant
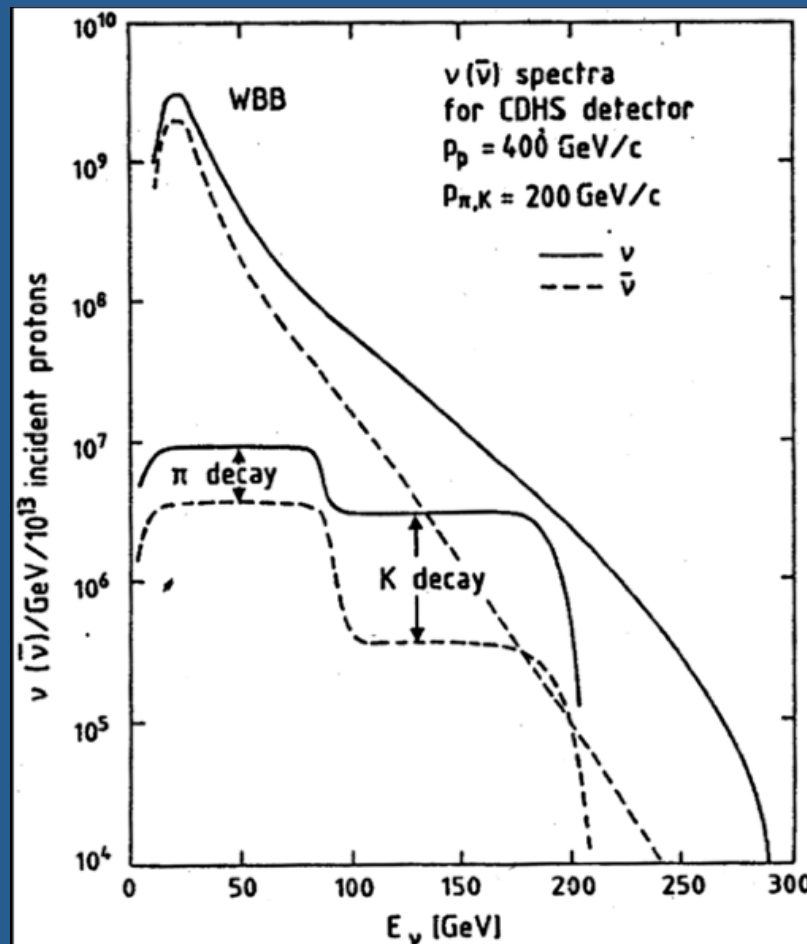- Search for neutrino oscillations

SPS Neutrino beam (1977-1998)
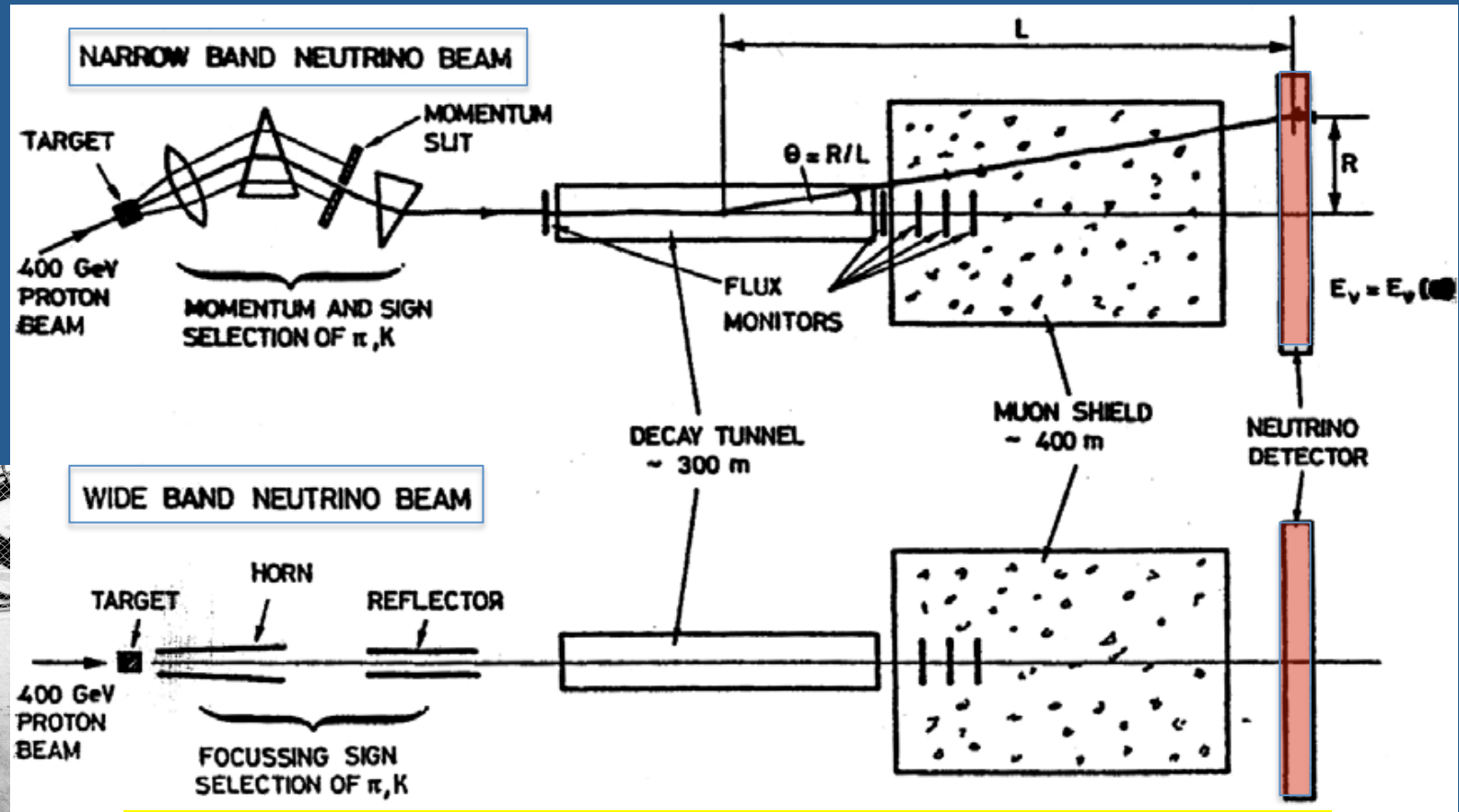
<------------------------------ 880 m   ------------------------------>
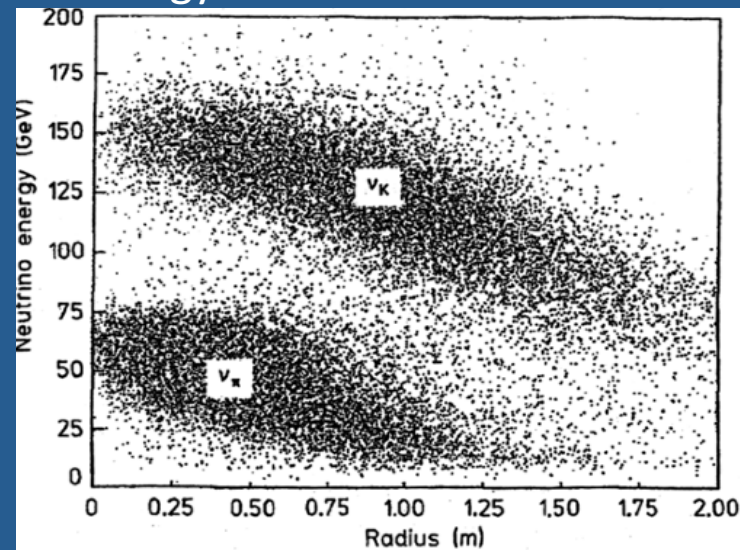
van der Meer horn

SPS Neutrino beam

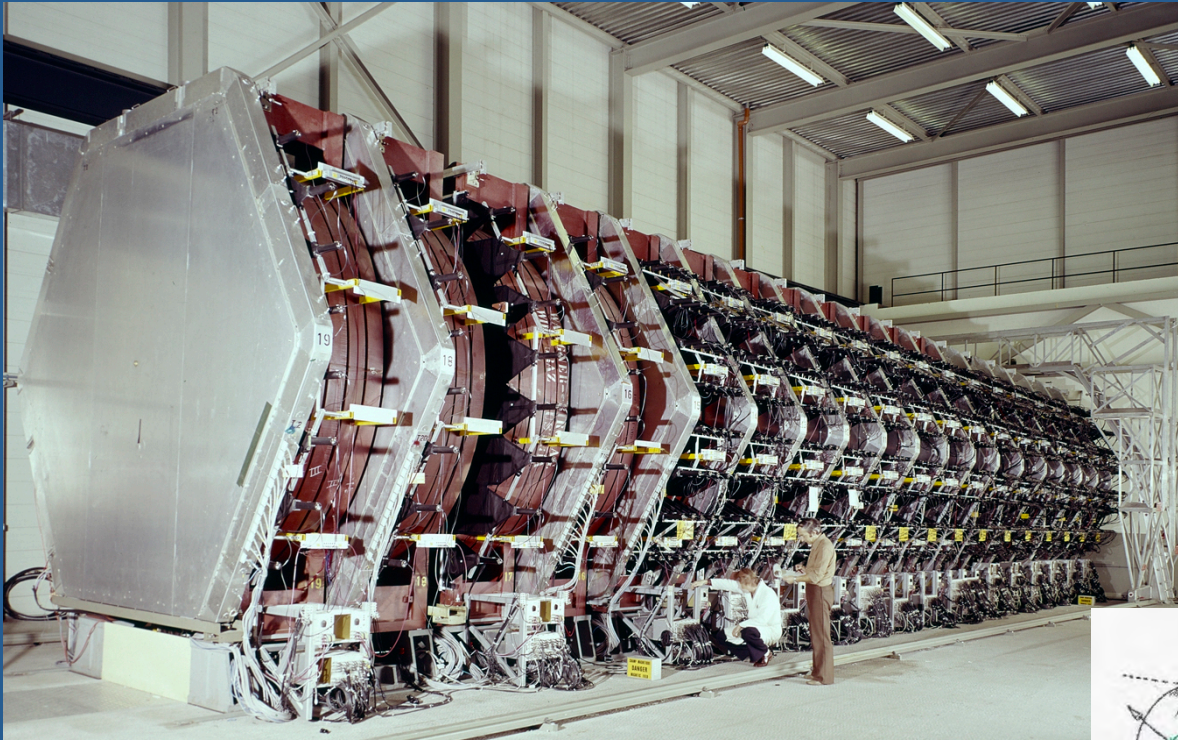## 2 types: Wide-Band Beam and Narrow-Band Beam

Energy spectrum

$\nu (\bar{\nu})$ spectra for CDHS detector
$p_p = 400$ GeV/c
$P_{\pi,K} = 200$ GeV/c

WBB

π decay

K decay

NBB
Energy vs radius at detector

ν_K

ν_π

The CDHS Experiment
1977-1985

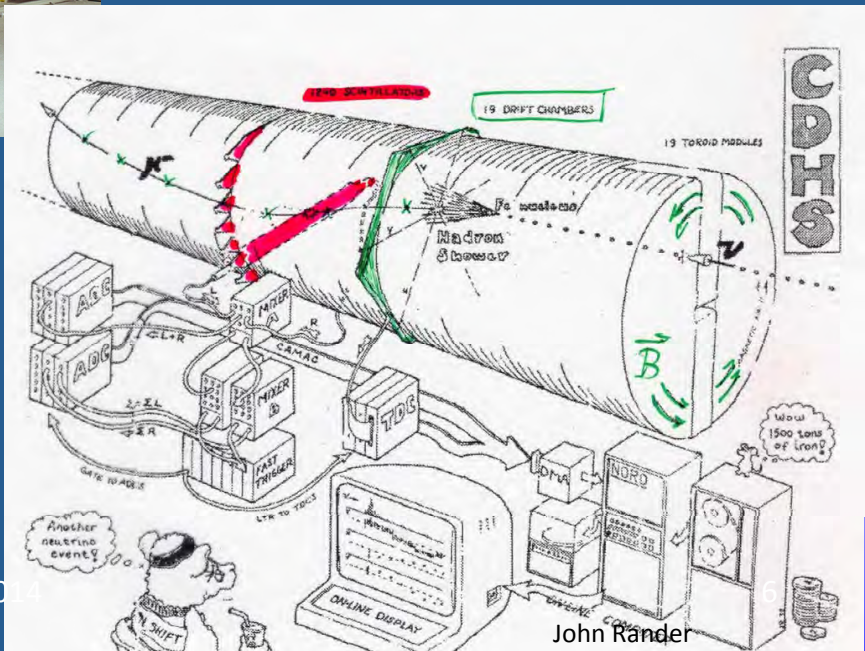1977-79:
CERN
Dortmund
Heidelberg
Saclay
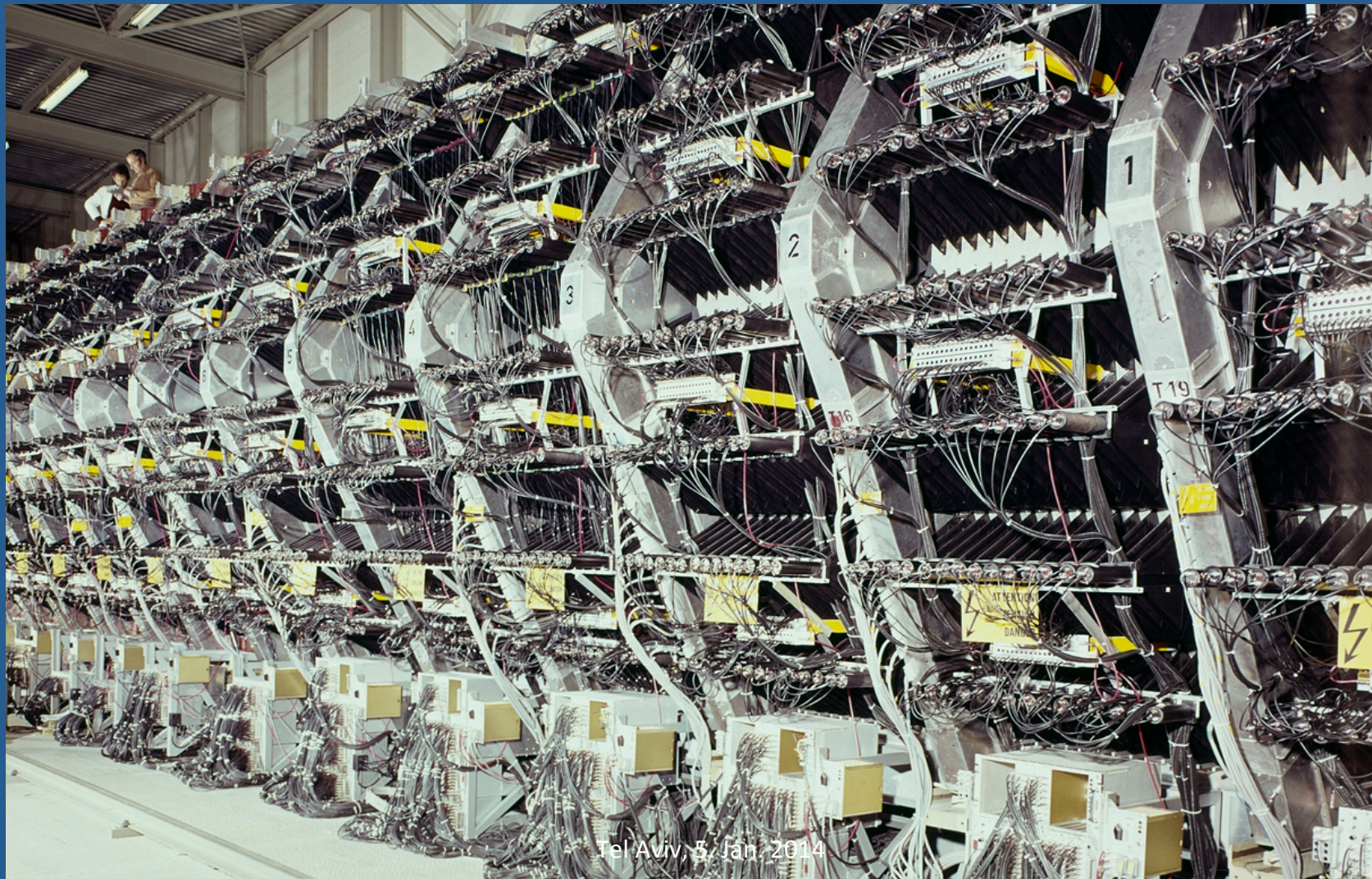~ **35 members**

1980-85:
CDHSW (+**W**arsaw)

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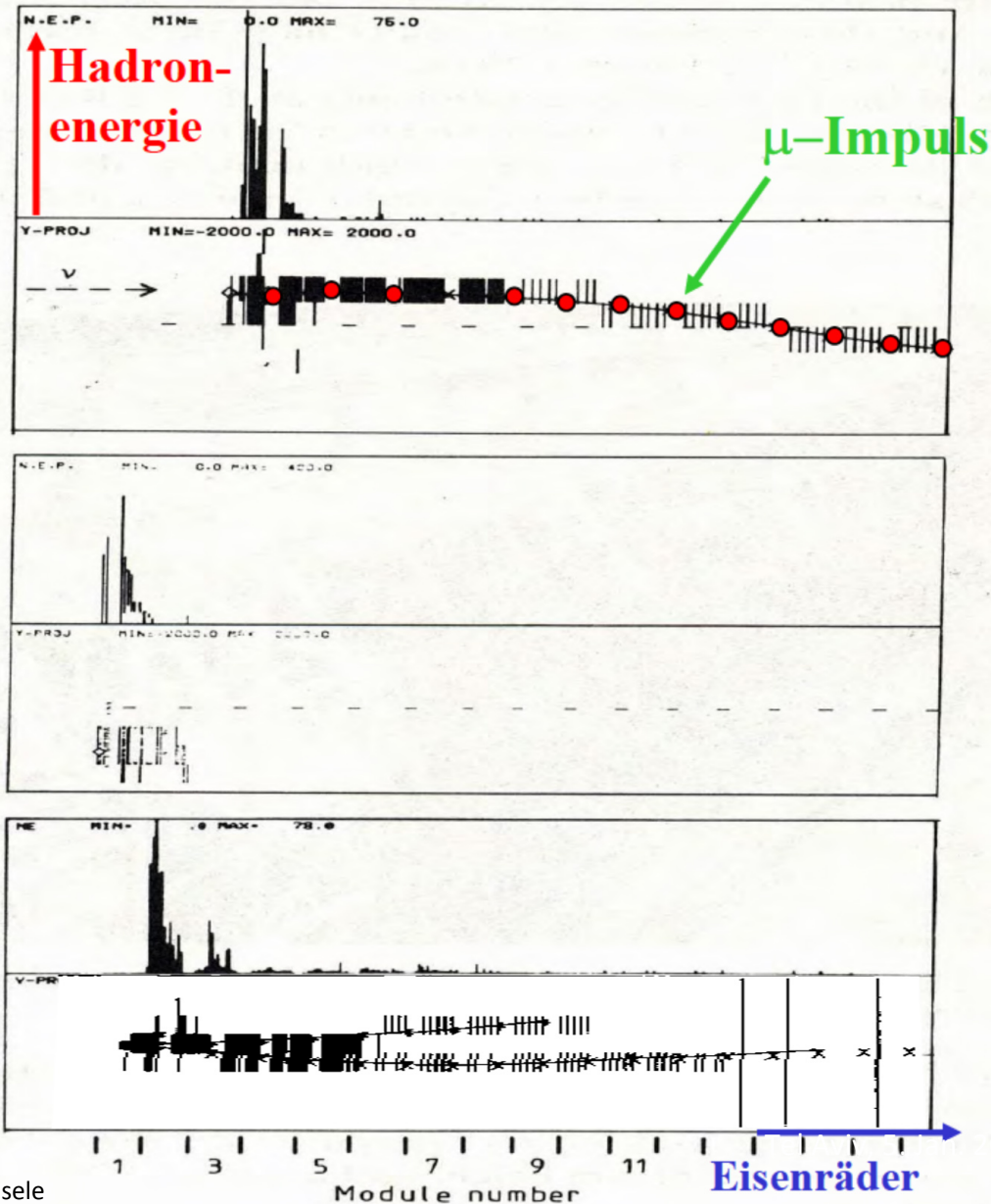- 1500 scintillators
- 3000 PMs

Tel Aviv, 5. Jan. 2014

John Rander

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)

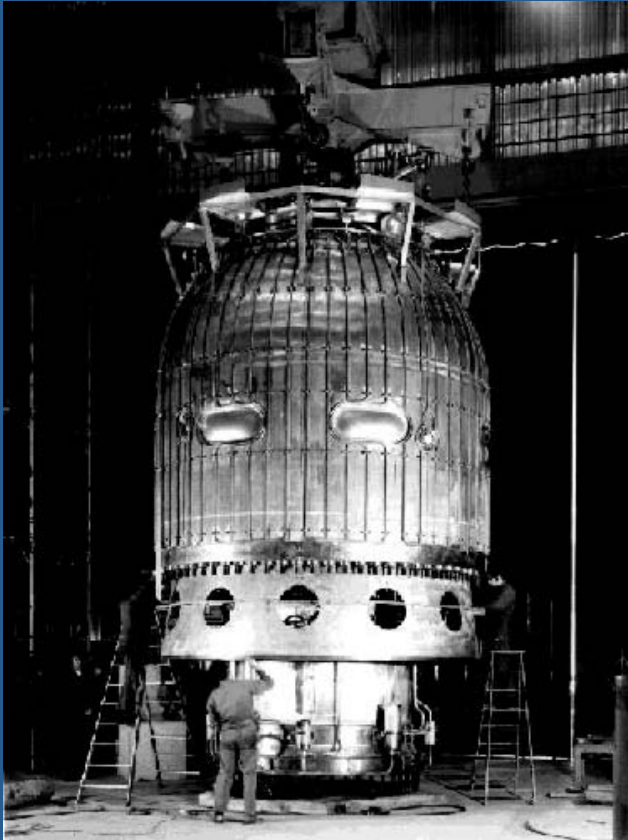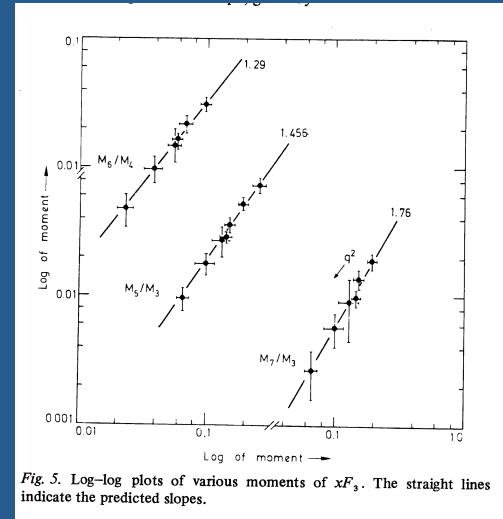$\nu + N \rightarrow \mu^+ + \mu^- + X$
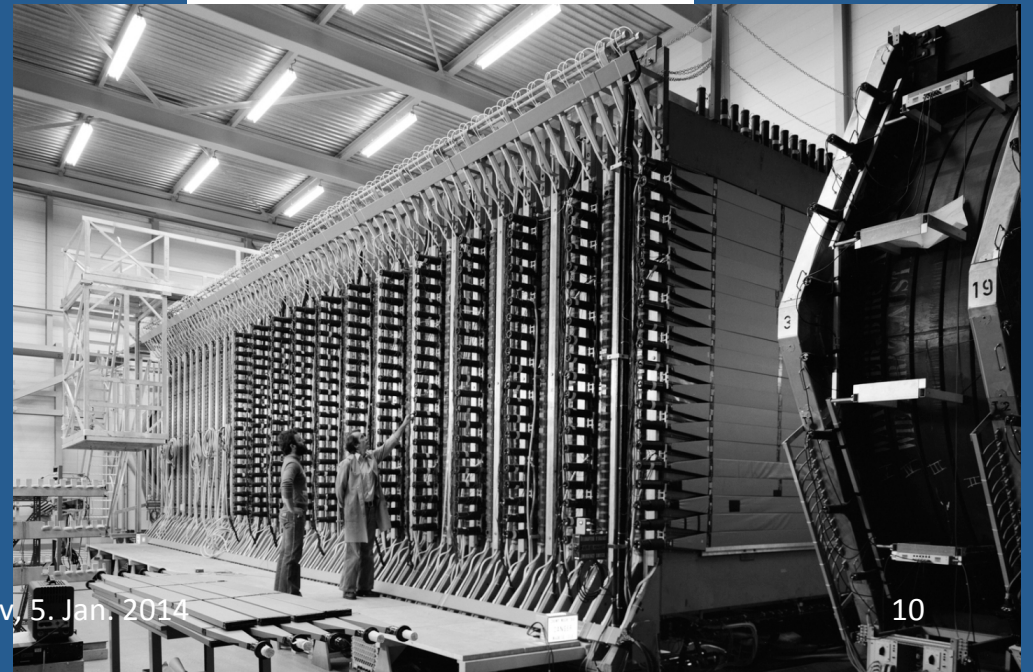CC + charm decay

F. Eisele

Some Team members

CERN Competition in same ν beam

- **BEBC**
  1976-84
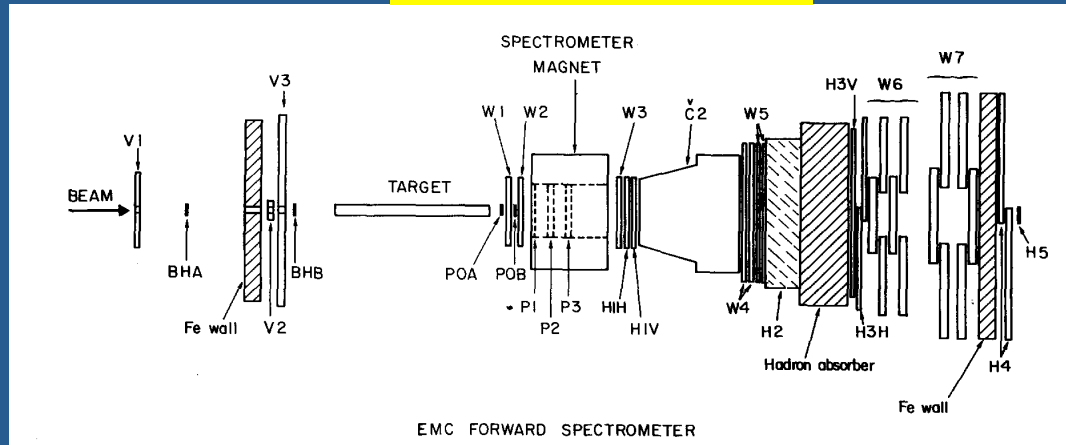

Fig. 5. Log–log plots of various moments of xF_3. The straight lines indicate the predicted slopes.

- **CHARM -> NC**
  1979-84

Muon experiments (EMC + BCDMS), structure functions

EMC spectrometer

EMC effect, 1982

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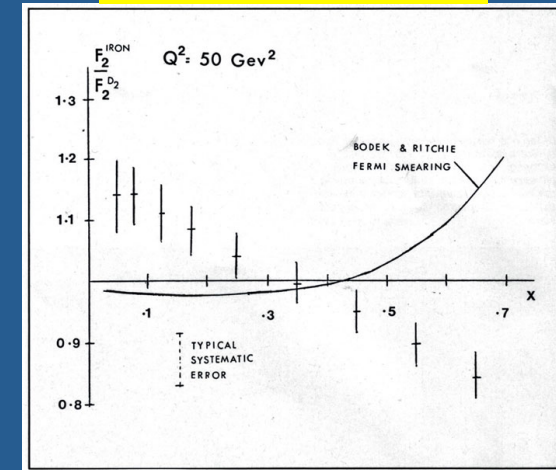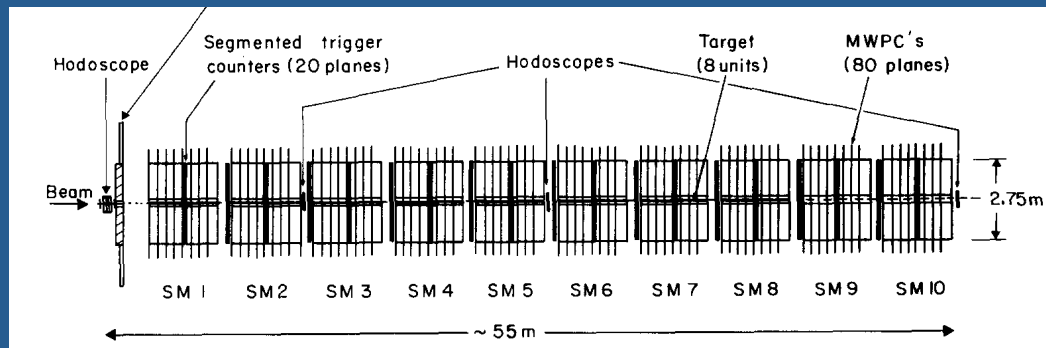
EMC on F2: "Measurement of the nucleon structure function $F2$ in muon - iron interactions at 120-GeV, 250-GeV and 280-GeV": EMC Coll., PLB, Aug, 1981
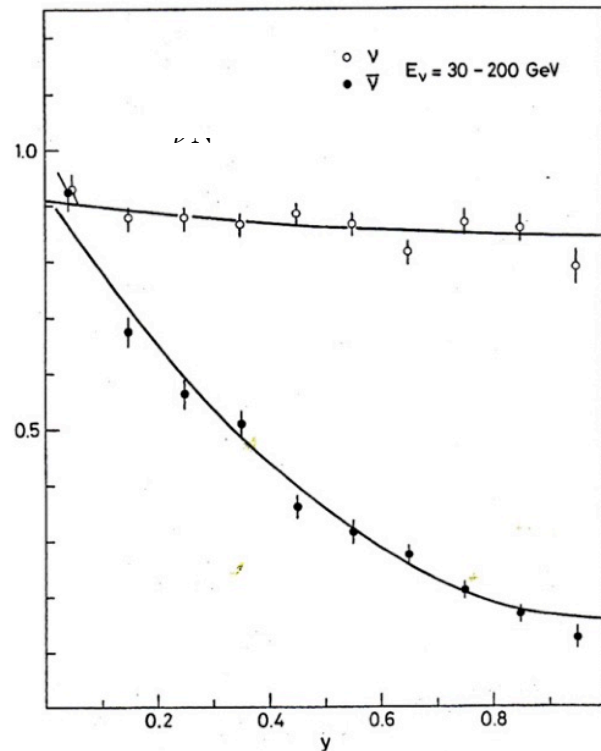

BCMS on F2: "A measurement of the nucleon structure function from muon-carbon deep inelastic scattering at high Q^2 ": BCDMS-Coll., PLB, Sep. 1981

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CDHS   Structure of Proton
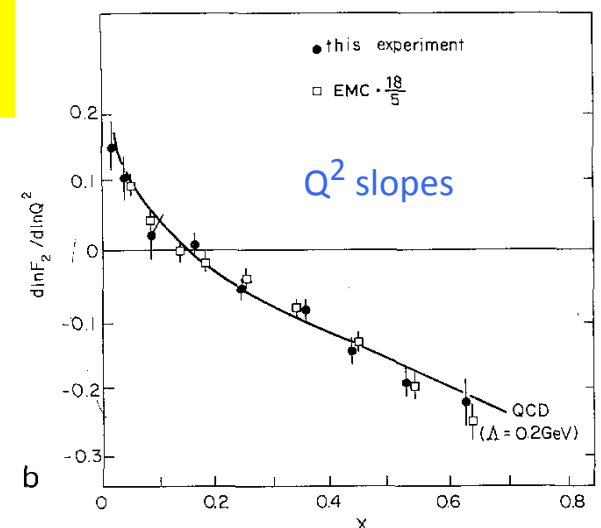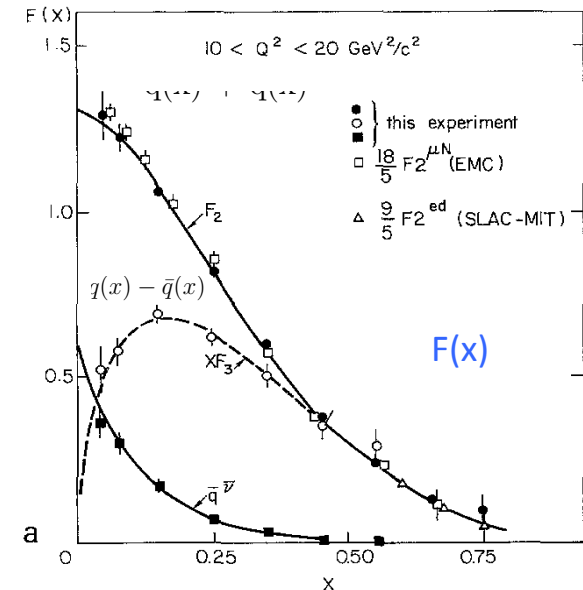
H. Abramowicz et al., Z.Phys.C (1983)

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

lines = parton model
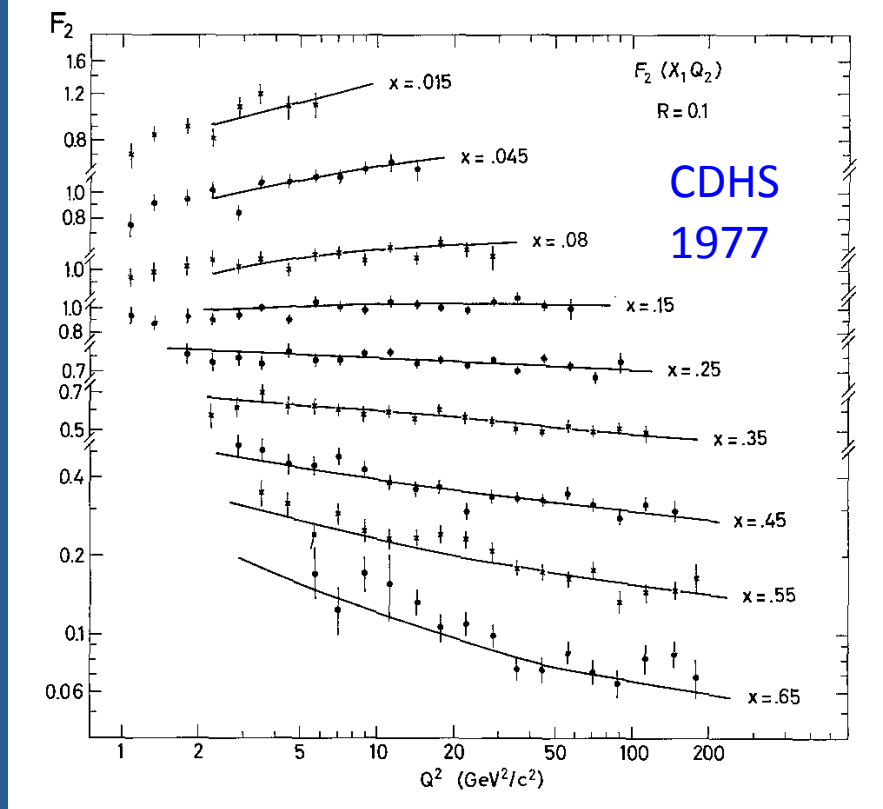
Comparision:
$F_2 (\nu p)$
$= \; 9/5 \; F_2(ed)$
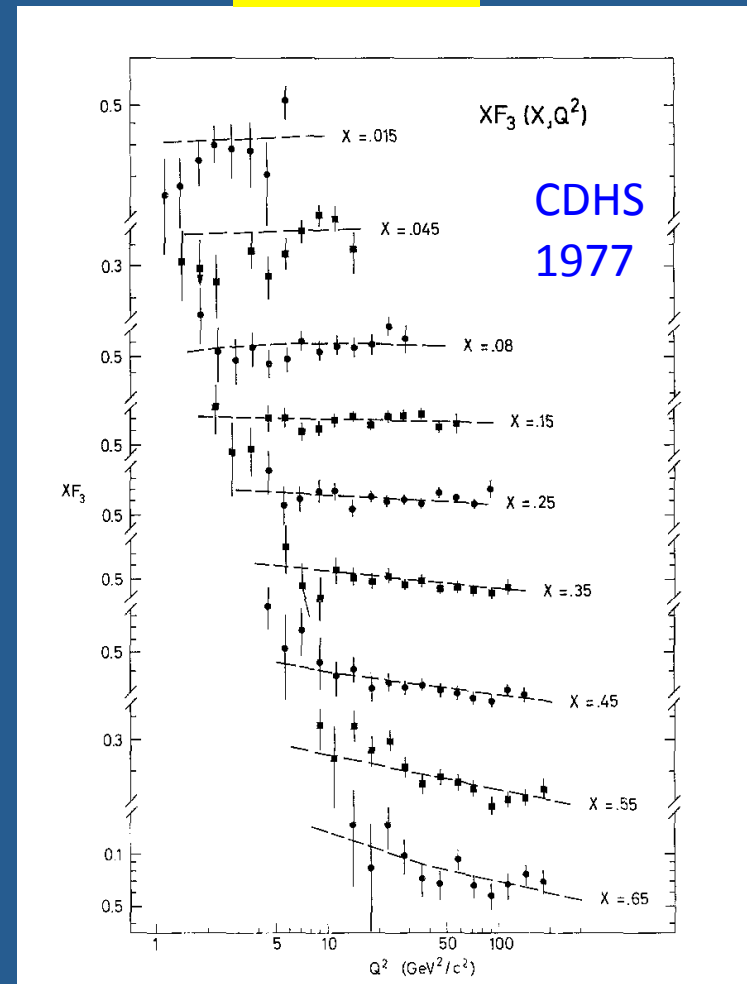$= 18/5 \; F_2(\mu p)$

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

F(x)

Q^2 slopes

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Q² evolution of structure functions

q(x) + q̄(x)
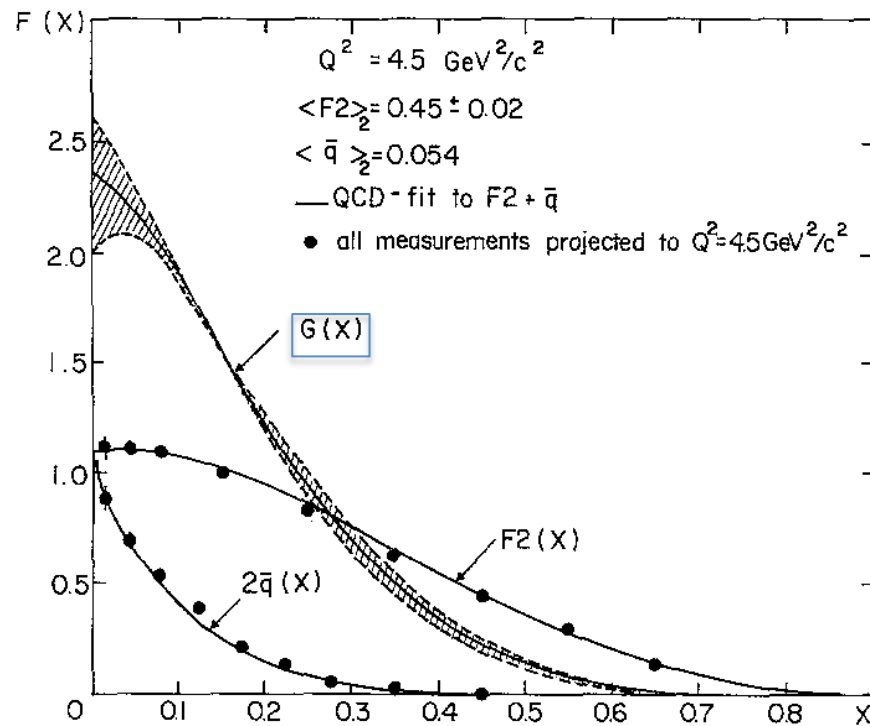
q(x) - q̄(x)

CDHS
1977

CDHS
1977

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)

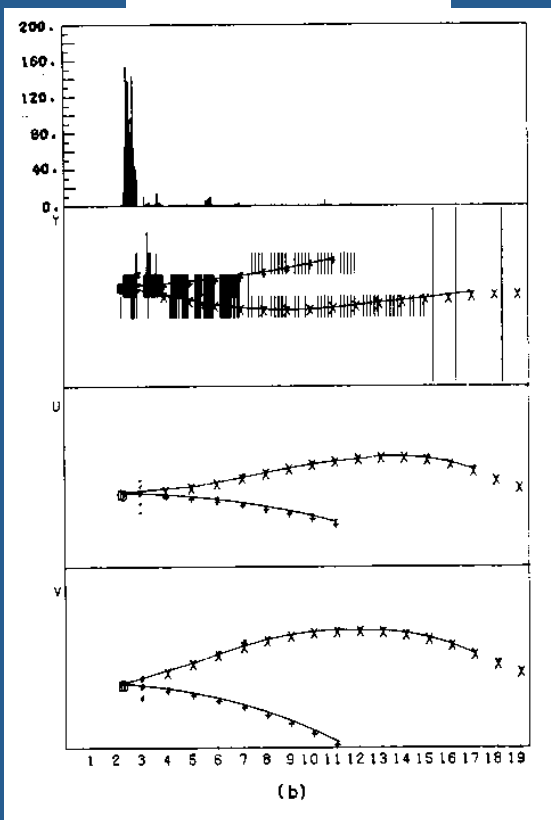Today
RPP(2012): Λ_5 = 213 (8) MeV
$\alpha_s(M_Z)$ = 0.120 (2)

Charm production

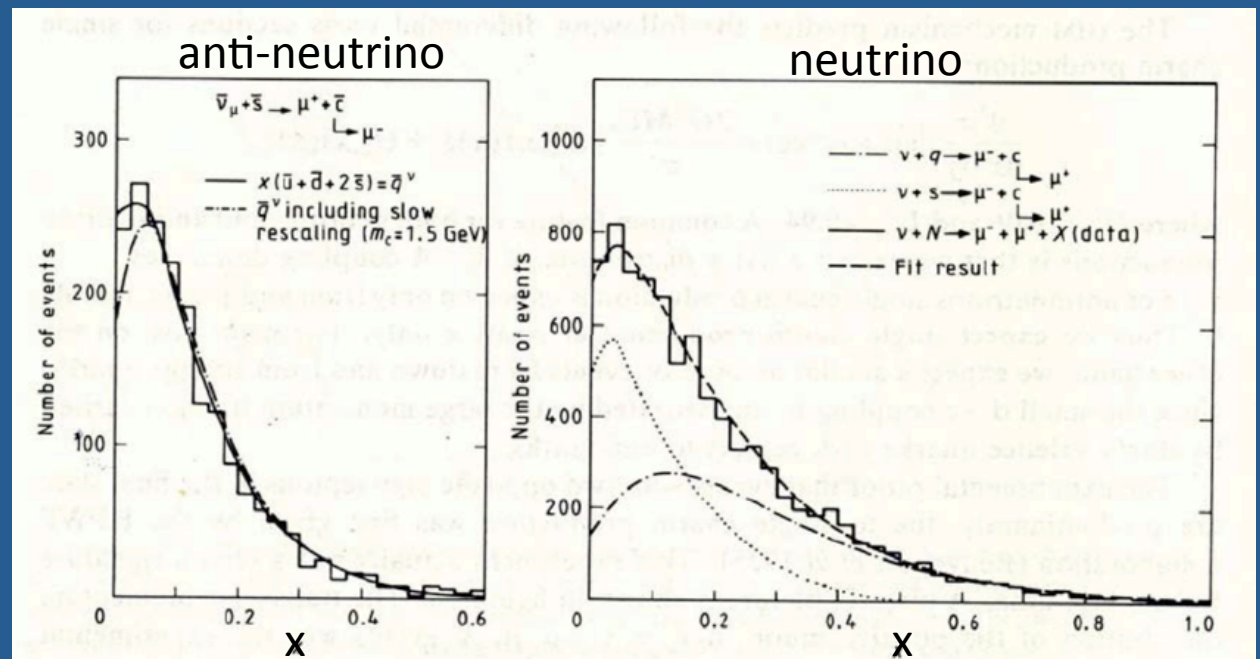CC event with additional charm quark production and semi-leptonic decay

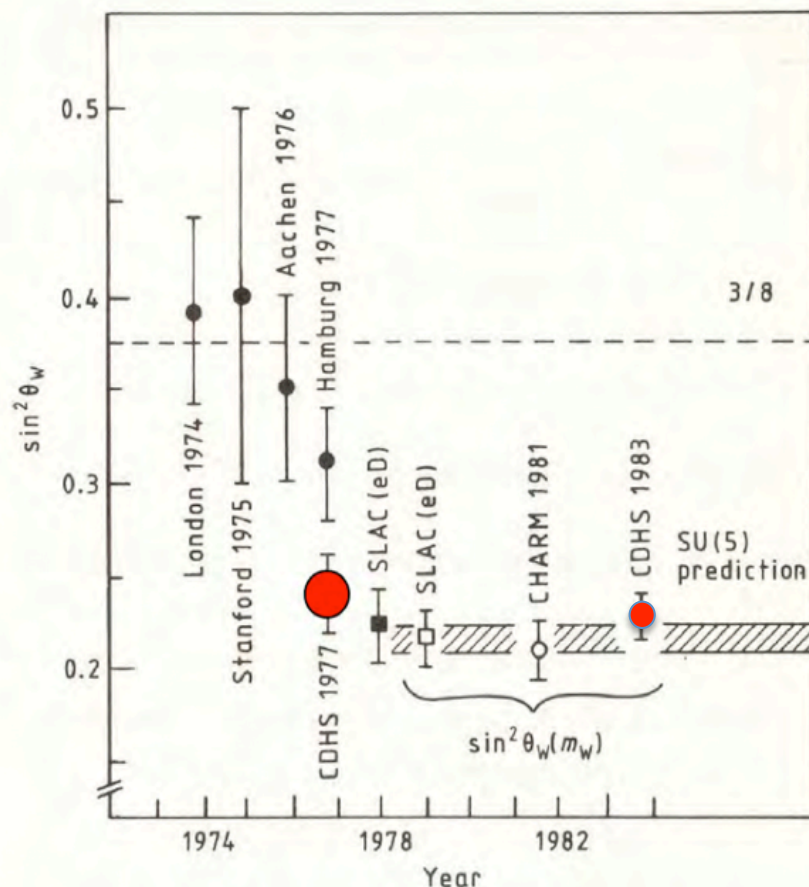e.g.: $\nu_\mu + d \rightarrow \mu^- + c$, $c \rightarrow s + \mu^+ + \nu_\mu$

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)

High energy neutrino interactions

Using neutral-charged current ratio:

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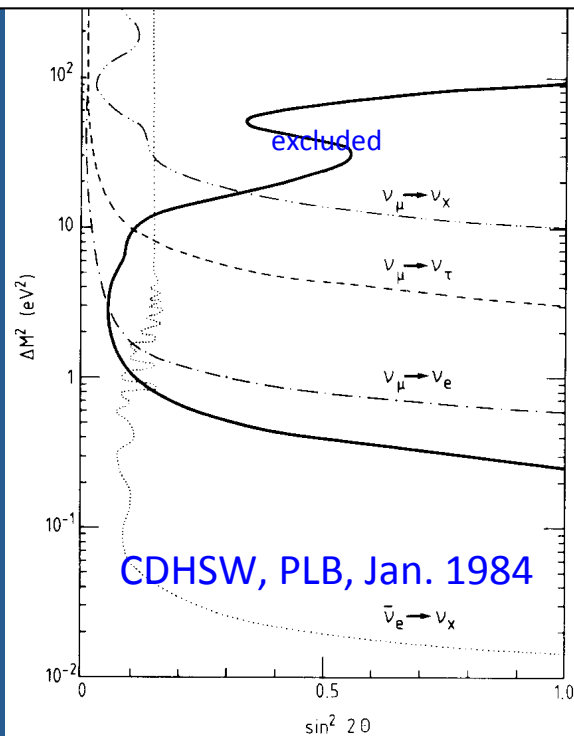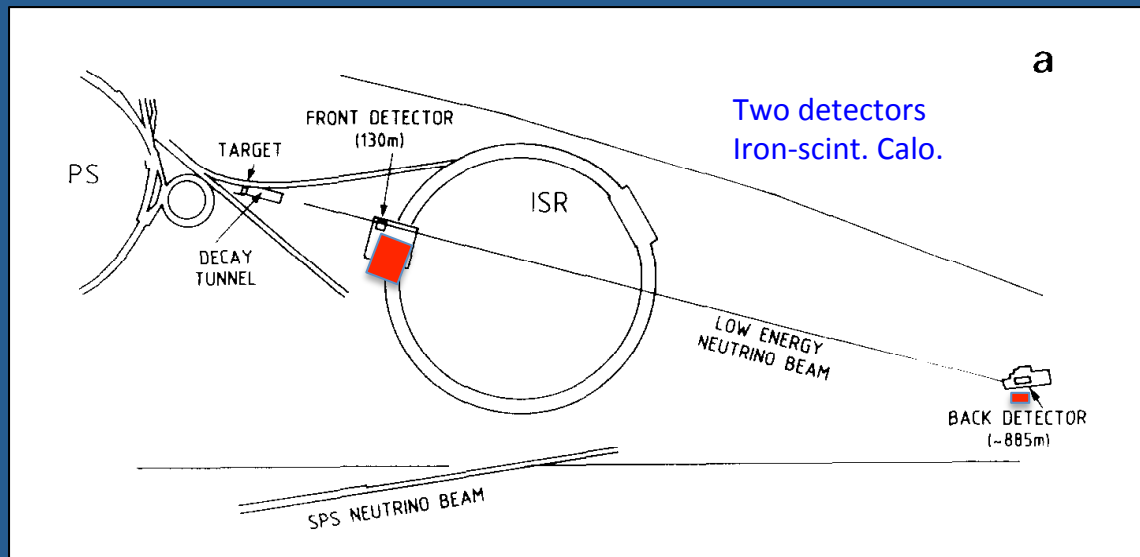 Gargamelle: $\sin^2\theta_W$ = 0.3 - 0.4

Early CDHS: $\sin^2\theta_W$ = 0.24 ± 0.02
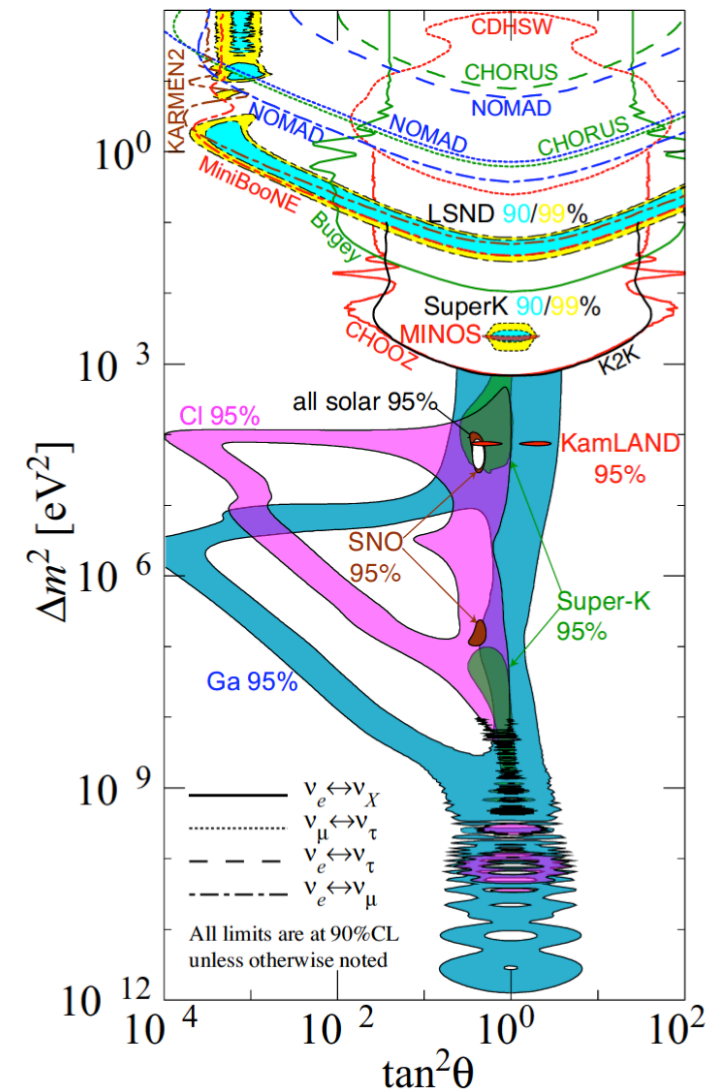
GUT in SU(5): $\sin^2\theta_W \sim$ 0.2 !

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

Search for ν_μ oscillations

a

Two detectors
Iron-scint. Calo.

RPP 2013

H. Murayama

CDHSW, PLB, Jan. 1984

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

- ep scattering at HERA became a natural continuation

Next came HERA
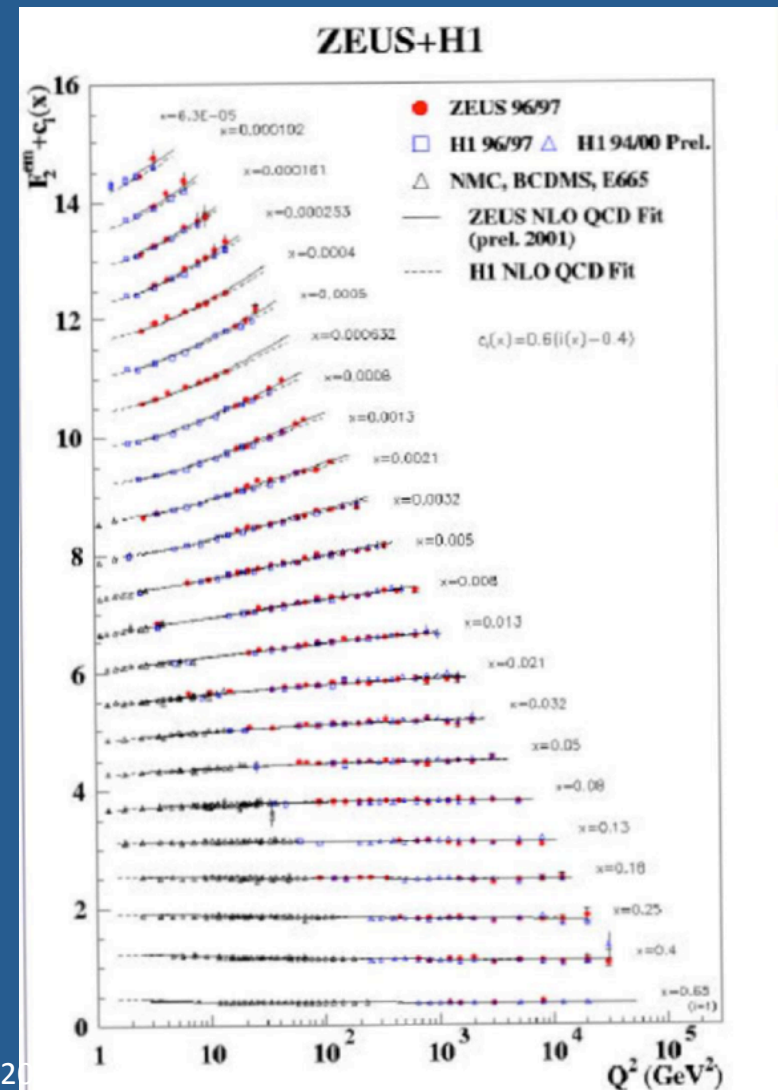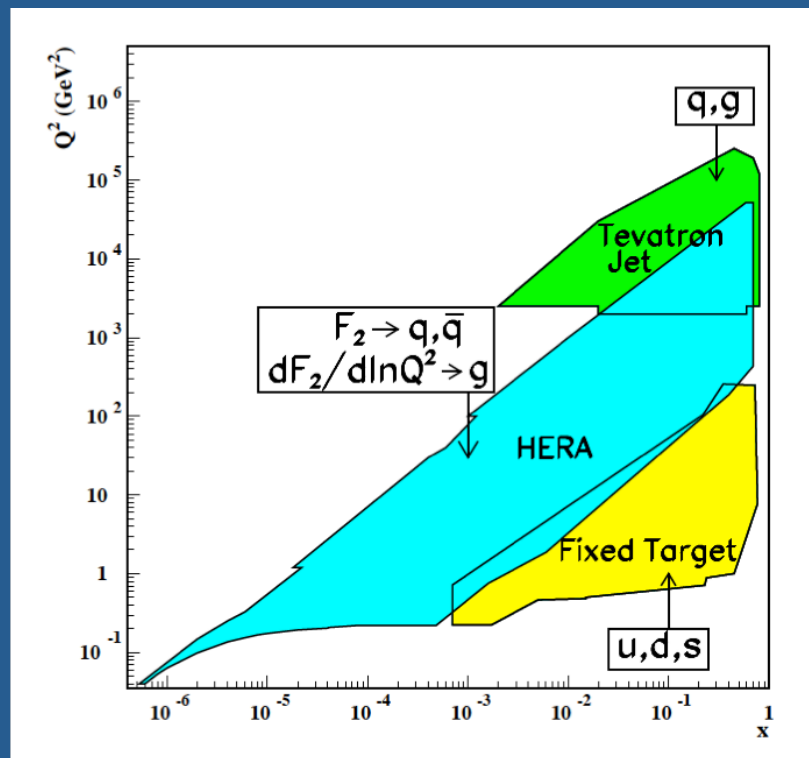
on the way to Hamburg

on the way to Hamburg

Happy birthday!

Halina