I.SAVIN @ PRAGUE IN 2011

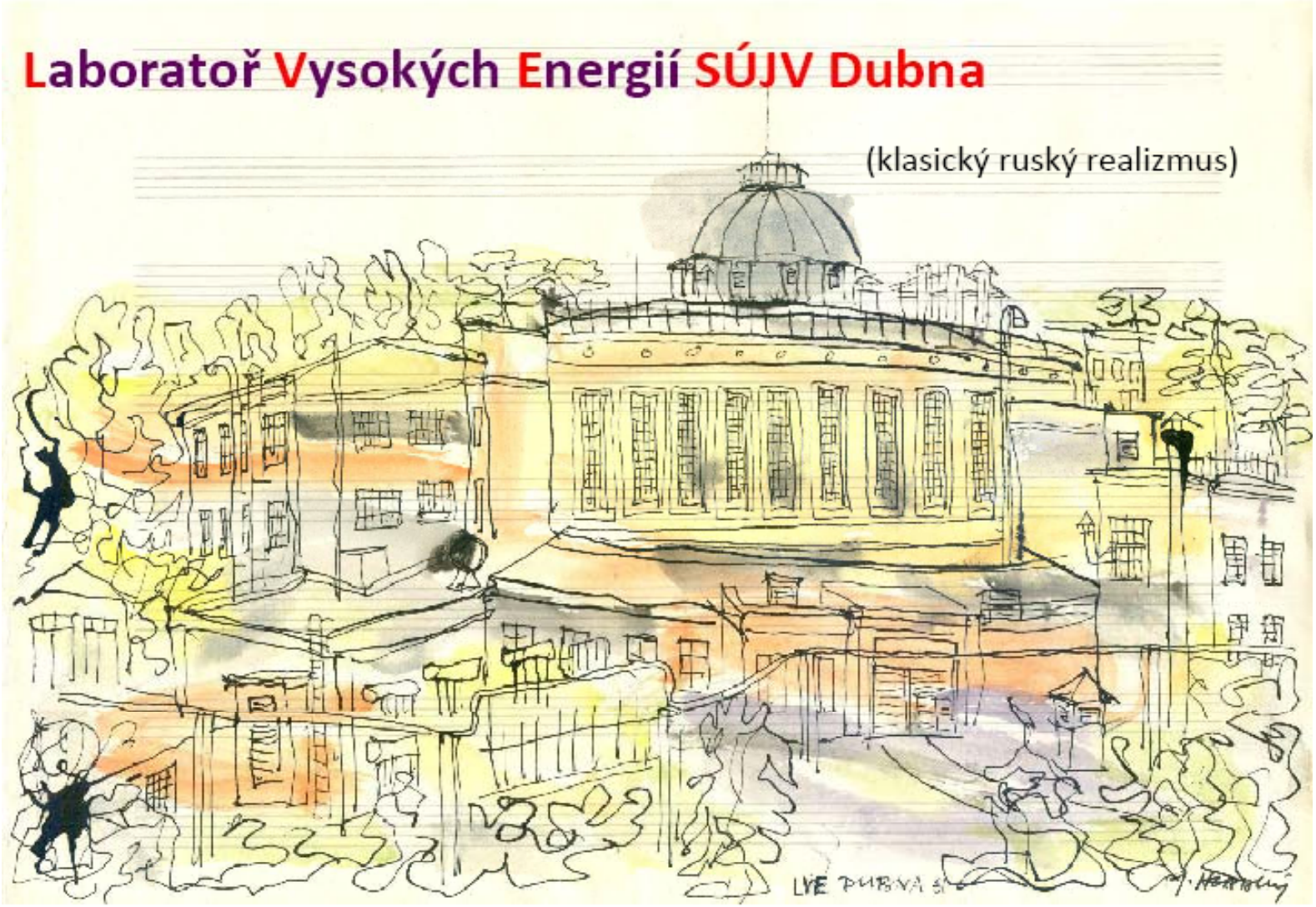
MY LIFE TIME COLLABORATION WITH CZECH PHYSICISTS IN HIGH ENERGY PHYSICS EXPERIMENTS

I.Savin, JINR, Dubna

OUTLINE

1. Introduction.
2. Experiments @ 10 GeV JINR synchrophasotron (1955-1965):
   -detector development,
   -elastic scattering of positive and negative pions.
3. Experiments @ 70 GeV IHEP proton synchrotron (1968-1974):
   -neutral kaon regeneration,
   -neutral kaon decays.
4. Experiments @ 450 GeV CERN proton synchrotron:
   -NA-4 (1974-1991),
   -COMPASS (from 1995).
5. Conclusions.

Prague, 26 May, 2011



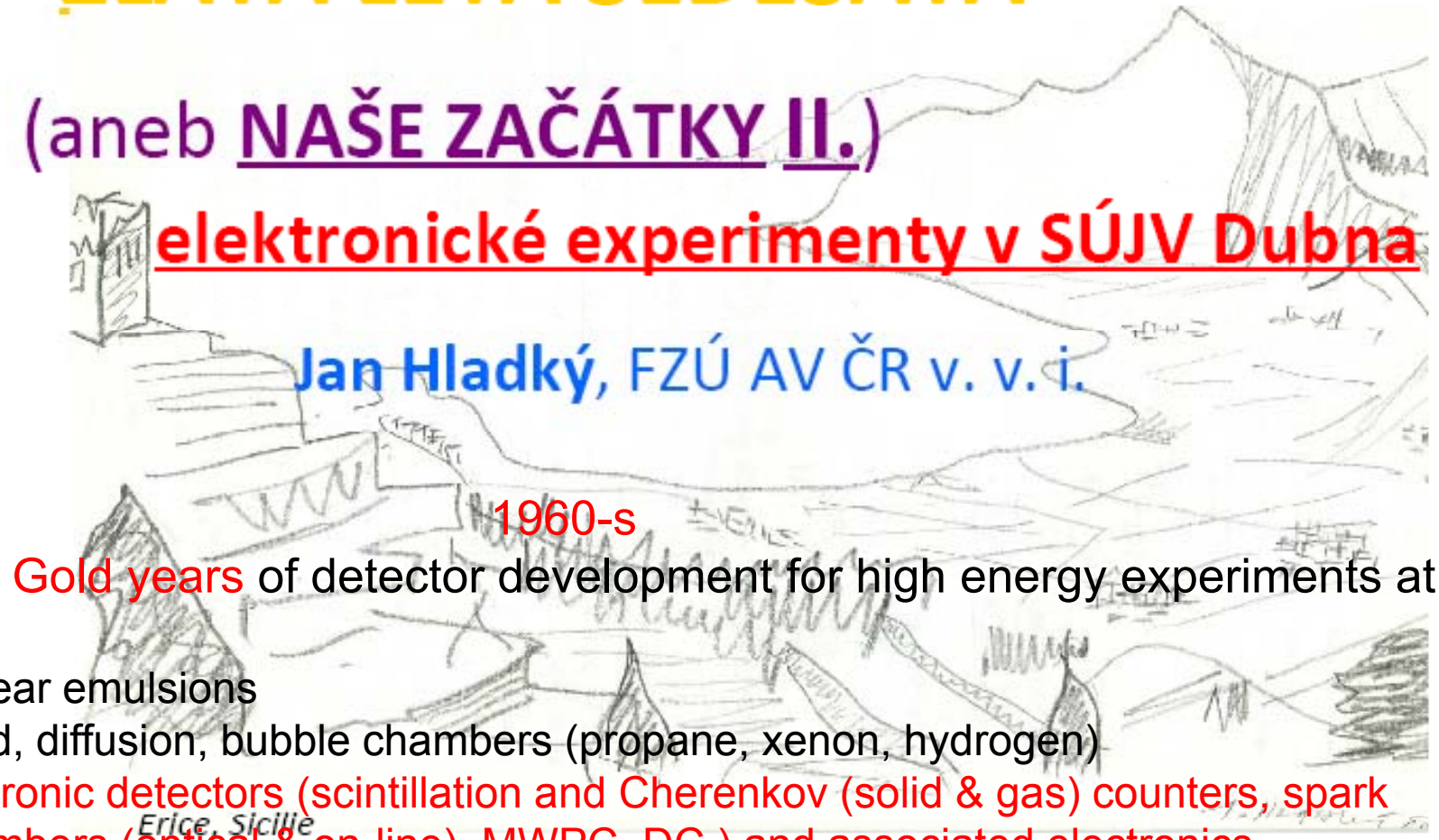
10 GeV proton synchrophasotpon, largest in the world at the time, put in operation in 1957

ČÁSTICOVÁ
ZLATÁ LÉTA ŠEDESÁTÁ

(aneb **NAŠE ZAČÁTKY II.**)

elektronické experimenty v SÚJV Dubna

Jan Hladký, FZÚ AV ČR v. v. i.



1960-s

were Gold years of detector development for high energy experiments at LHE:

-nuclear emulsions
-cloud, diffusion, bubble chambers (propane, xenon, hydrogen)
-electronic detectors (scintillation and Cherenkov (solid & gas) counters, spark chambers (optical & on-line), MWPC, DC) and associated electronics

První jiskrové komory v LVE Dubna

experiment

$\pi^+ p \rightarrow \pi^+ p$

(rozptyl na úhly blízké 180°).

Skupina
A.L. Ljubimova.

SPARK CHAMBERS FOR MEASUREMENTS OF ELASTIC BACKWARD SCATTERING OF POSITIVE PIONS BY PROTONS

B. N. Guskov, J. Hladký*), A. L. Ljubimov, A. T. Matiushin, I. A. Savin, A. S. Vovenko
Joint Institute for Nuclear Research, Dubna, USSR

The paper deals with multiplate spark chambers employed in measurements of elastic π^+ backward scattering. The basic characteristics of the spark chambers and their time variation are described and the measured recording efficiencies for one particle against a high background of other particles are given.

1. INTRODUCTION

In this paper a description is given of spark chambers used in an experiment on elastic $\pi^+ p$ backward scattering [1, 2] and of their basic characteristics.

Figure 1 shows the layout in the beam of positive pions of the apparatus used in measurements of elastic $\pi^+ p$ backward scattering. In this experiment two spark

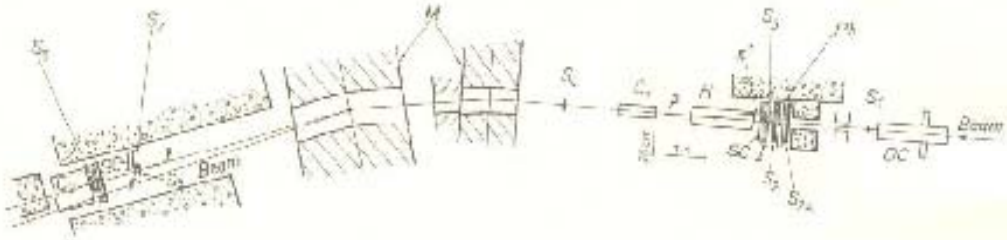
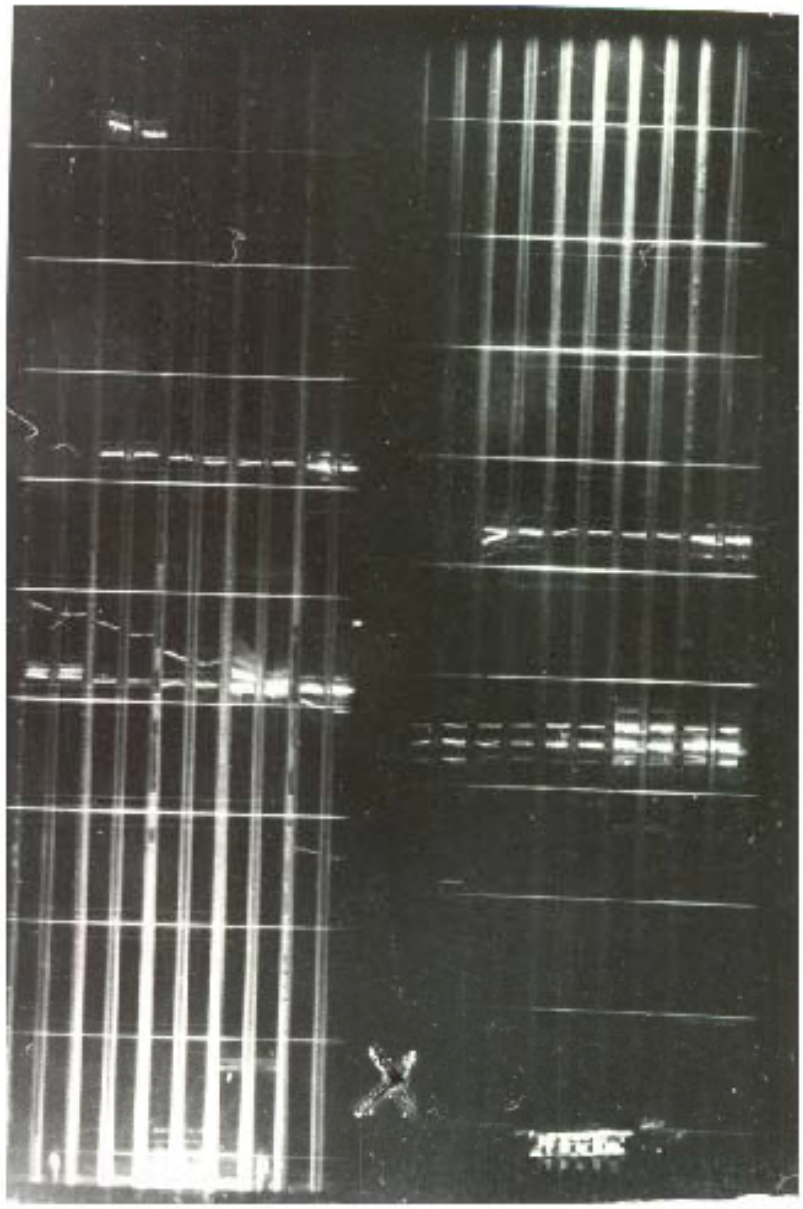


Fig. 1. Apparatus set-up for measurements of elastic backward scattering. S_1 to S_7 — scintillation counters, DC — differential gas Čerenkov counter, C_1 and C_2 — threshold gas Čerenkov counters, H — hydrogen target, SC I and SC II — spark chambers, M — magnetic spectrometer, Pb — collimator.

Jiskrová komora II

pro registraci více částic



Problémy s plyny z plexiglasu

a průbojem VN v rozích atd.

УДК 539.1.073.2

ВЛИЯНИЕ ФОНОВОЙ ЗАГРУЗКИ НА ЭФФЕКТИВНОСТЬ ИСКРОВОЙ КАМЕРЫ

А. С. ВОВЕНКО, М. Я. ВЫРЕПКОВА, Я. ГЛАЦКИ, Б. Н. ГУСЬКОВ, А. Л. ЛЮБИМОВ, И. А. САВИН

Объединенный институт ядерных исследований, Дубна

(Получено 3 декабря 1966 г.)*

Исследована эффективность многопластинчатой искровой камеры в условиях большой фоновой загрузки. Показано, что эффективность регистрации «запускающей» частицы падает, если фоновая частица проходит через искровую камеру после «запускающей» частицы, но до момента подача на камеру высоковольтного импульса. При этом влияние фоновых частиц на эффективность регистрации запускающих частиц тем сильнее, чем больше интервал времени между прохождением «запускающей» и фоновой частиц. Приведено возможное объяснение этой зависимости и высказаны рекомендации по повышению эффективности искровых камер в тяжелых фоновых условиях.

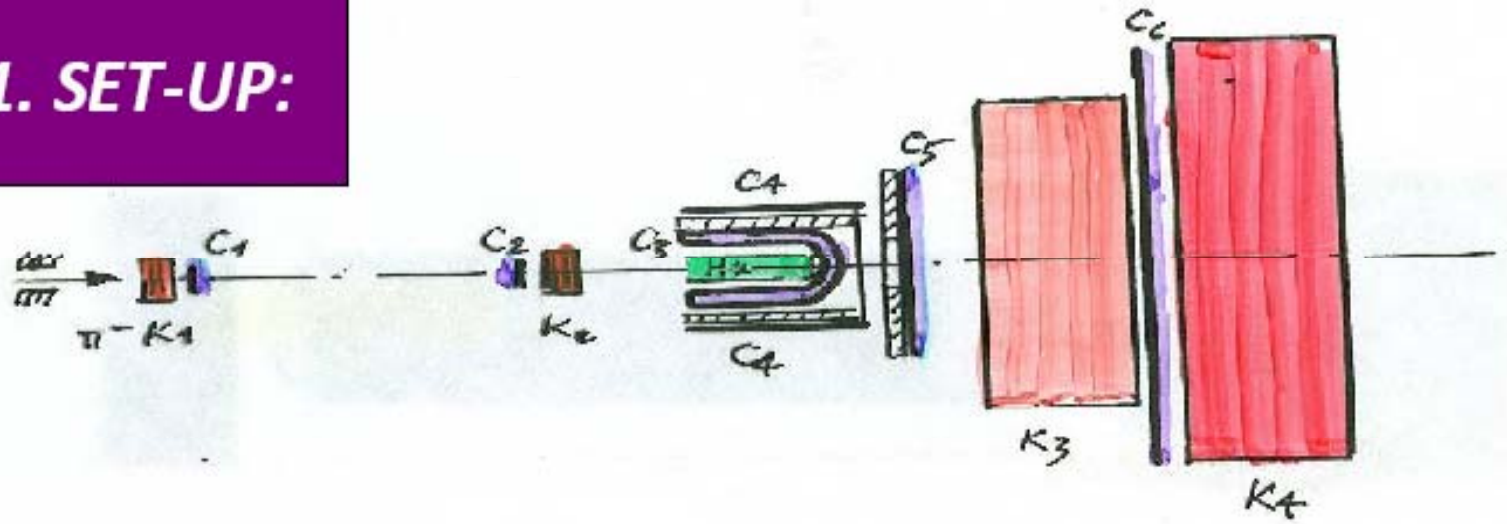
První jiskrová komora v SÚJV pracující na 2 a více částic

1. DUBNA-PRAGUE-WARSZAW experiment

$\pi^- p \to \pi^0 n$

charge exchange at E = 4 GeV

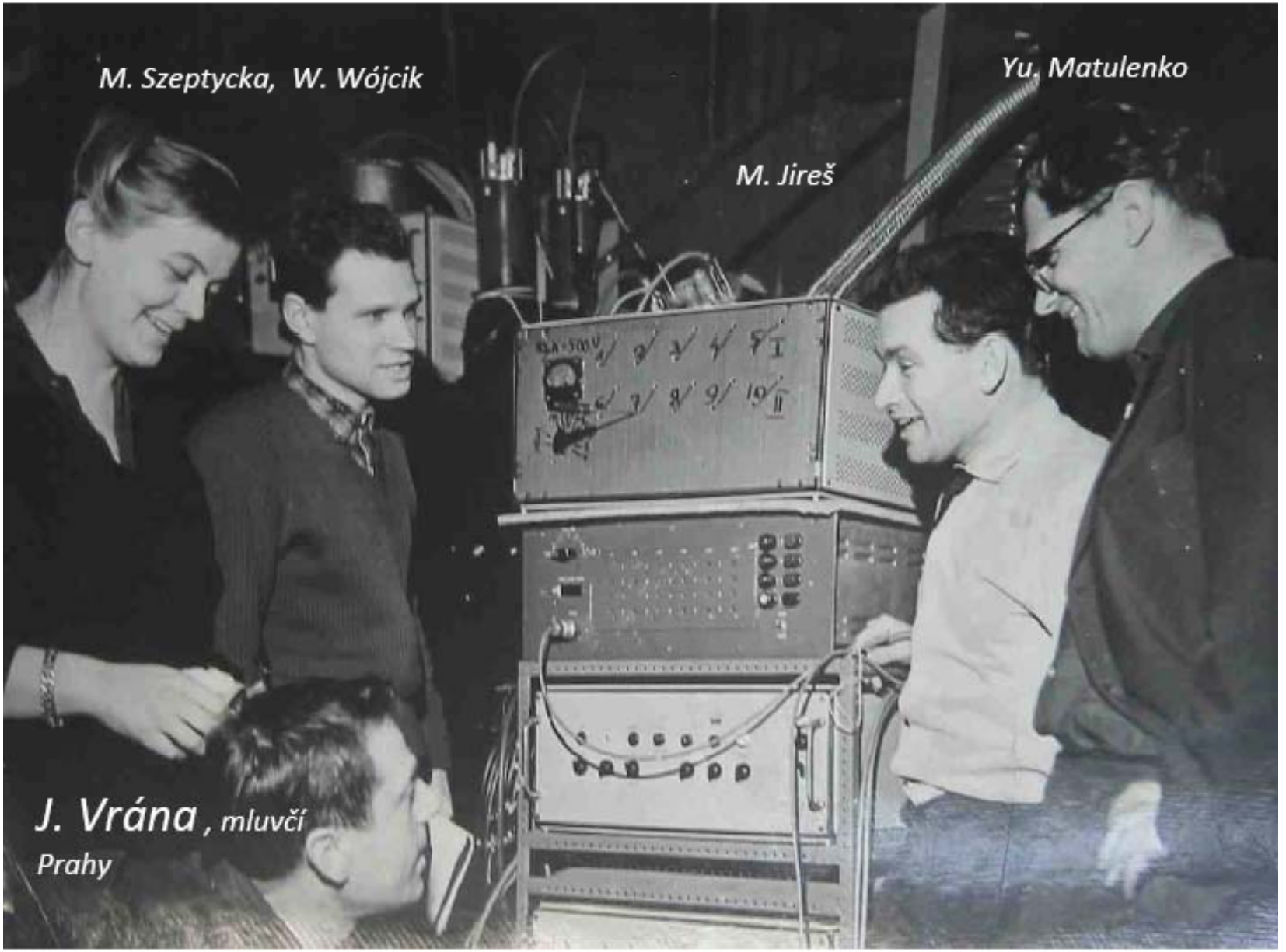
1. SET-UP:



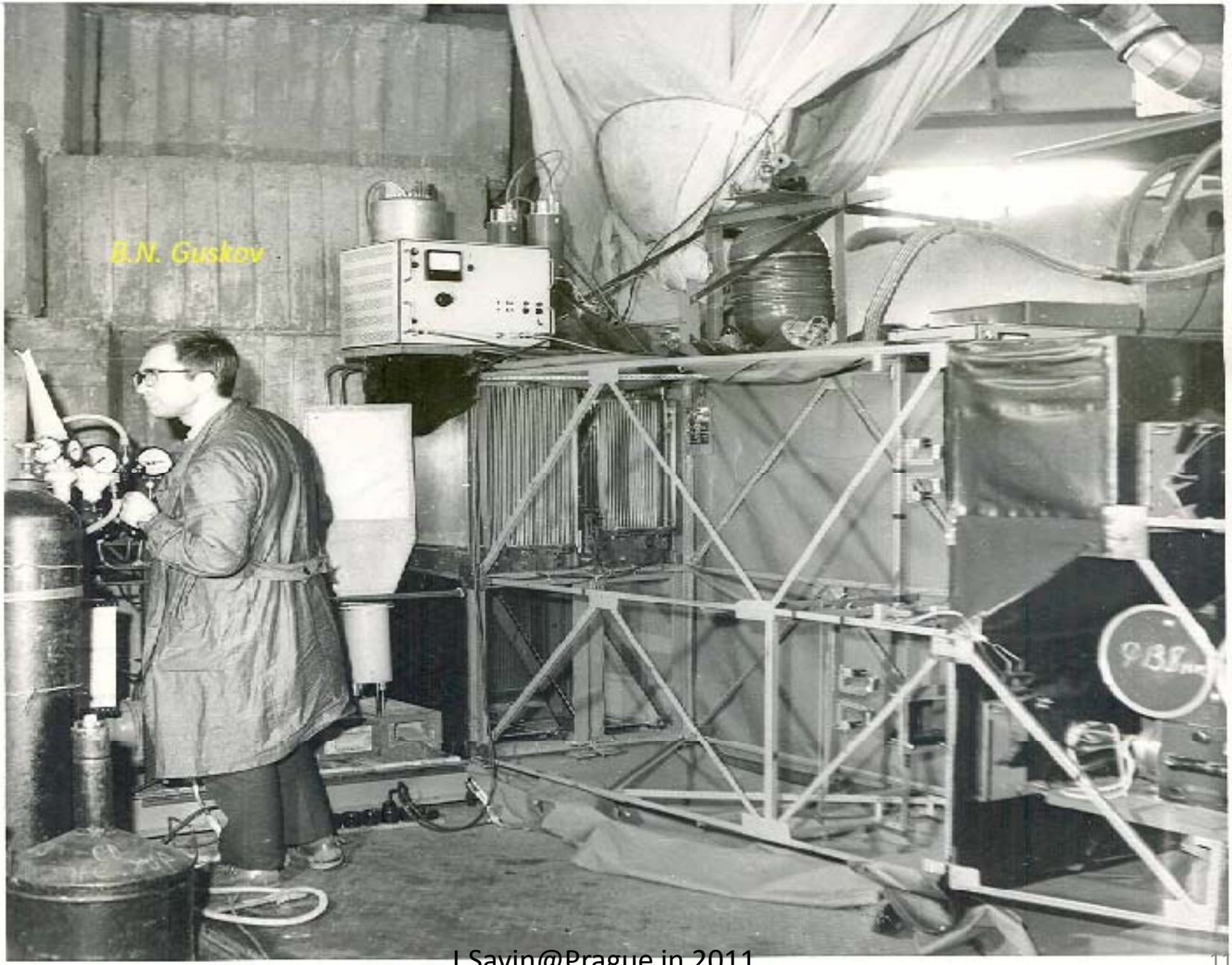
SCINT. COUNTERS

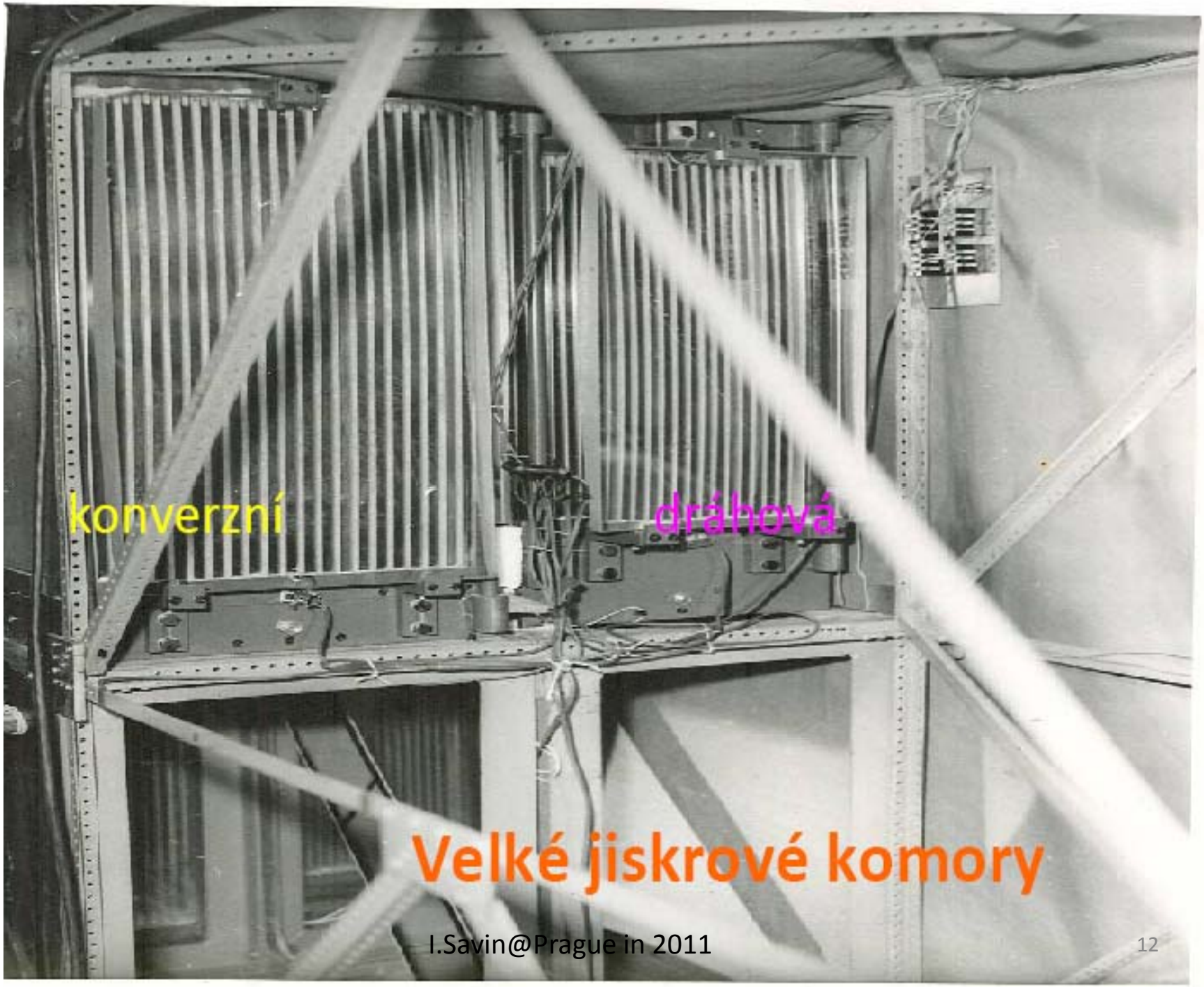
OPTICAL SPARK CHAMBERS

Pb



I.Savin@Prague in 2011


B.N. Guskov



Velké jiskrové komory

RESULTS:

Assuming the exchange of one Regge pole, connected with gamesan, and using the relation

$$\cdot X(t=0) = \operatorname{tg}\left(\frac{\alpha_0(0)\,\pi}{2}\right)$$

of the intercept $\alpha_0(t=0) = 0.46 \pm 0.06$. This value is in agreement with the results given by other authors [6, 8, 9].

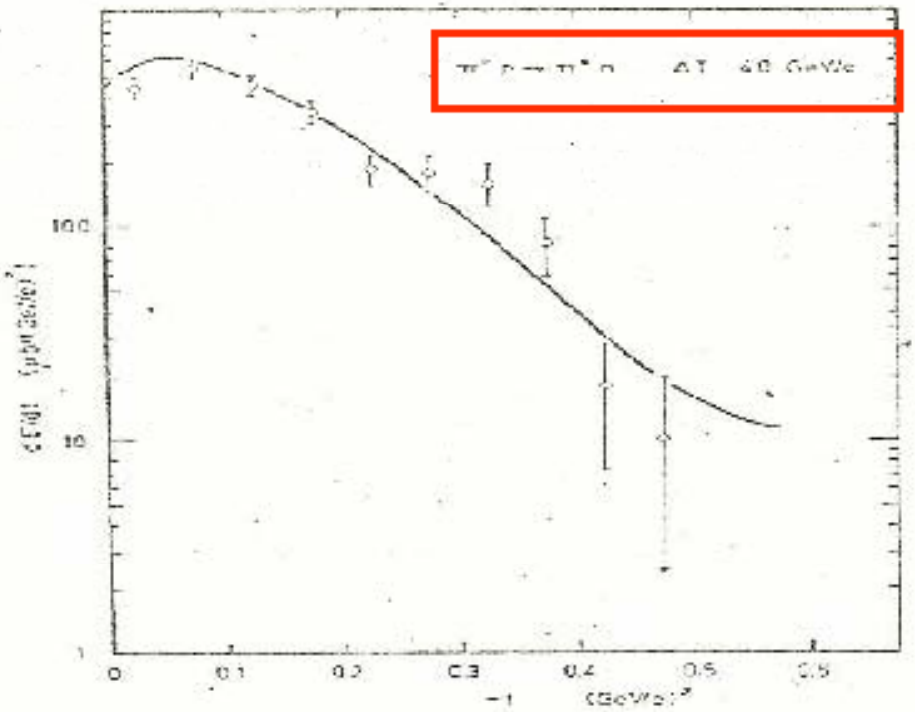


Fig. 3. Differential cross section for reaction $\pi^+ p \to \pi^0 n$. The solid line represents the Regge pole prediction [6].

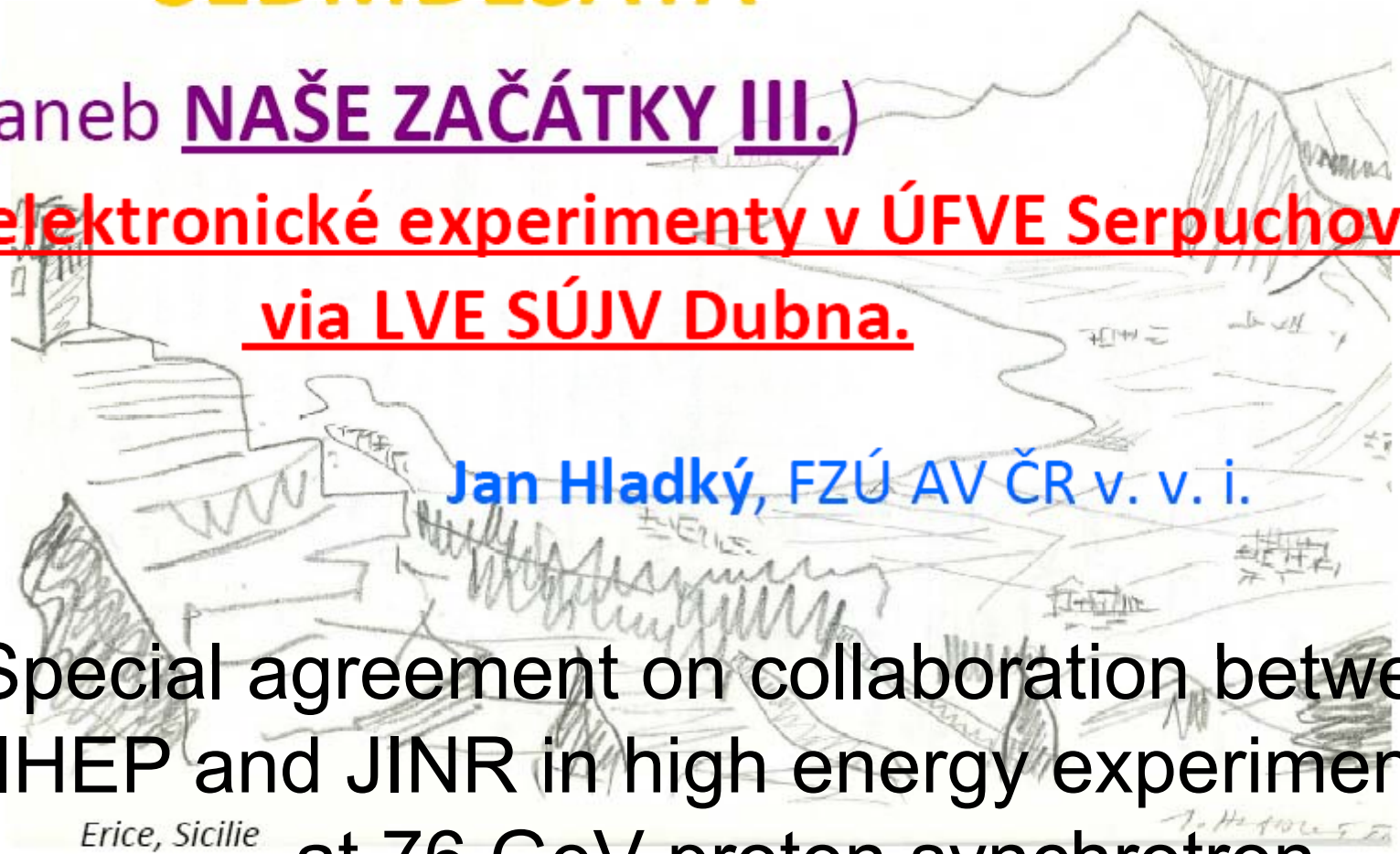
The authors would like to thank Dr R. Sosnowski for his initiative in having proposed the experiment and Professors I. V. Chuvilo and M. Danysz and Dr J. Pernegr for many valuable discussions during the work. We are also indebted to Dr J. Vrána and to Mr M. Jirsa for help in the preparatory stages of the experiment and during the measurements.

ČÁSTICOVÁ ZLATÁ LÉTA SEDMDESÁTÁ

(aneb **NAŠE ZAČÁTKY III.**)

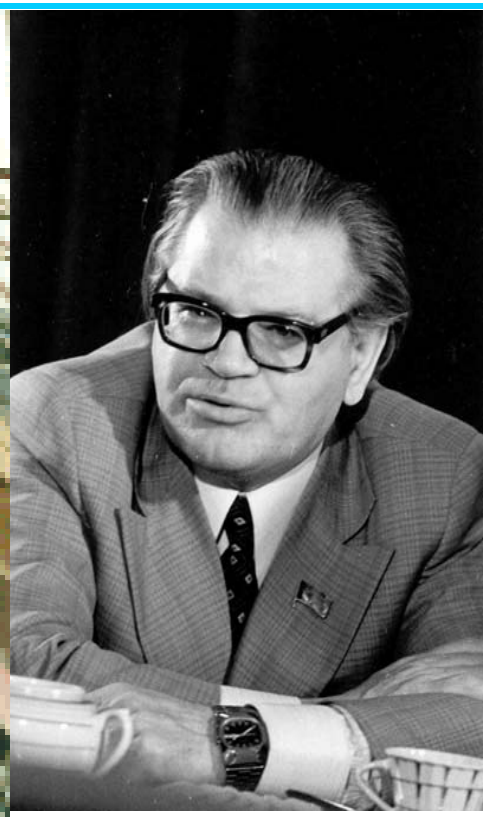
elektronické experimenty v ÚFVE Serpuchov via LVE SÚJV Dubna.

Jan Hladký, FZÚ AV ČR v. v. i.



Special agreement on collaboration between IHEP and JINR in high energy experiments at 76 GeV proton synchrotron

Experiments at U-70 at Serpukhov



A.Logunov

Director of IHEP

U-70 parameters: 76 GeV, largest in the world, put in operations in 1967

The collaboration, extended later by the new members, has performed a number of experiments - BIS, CHARM, EXCHARM

BIS experiment at U-70

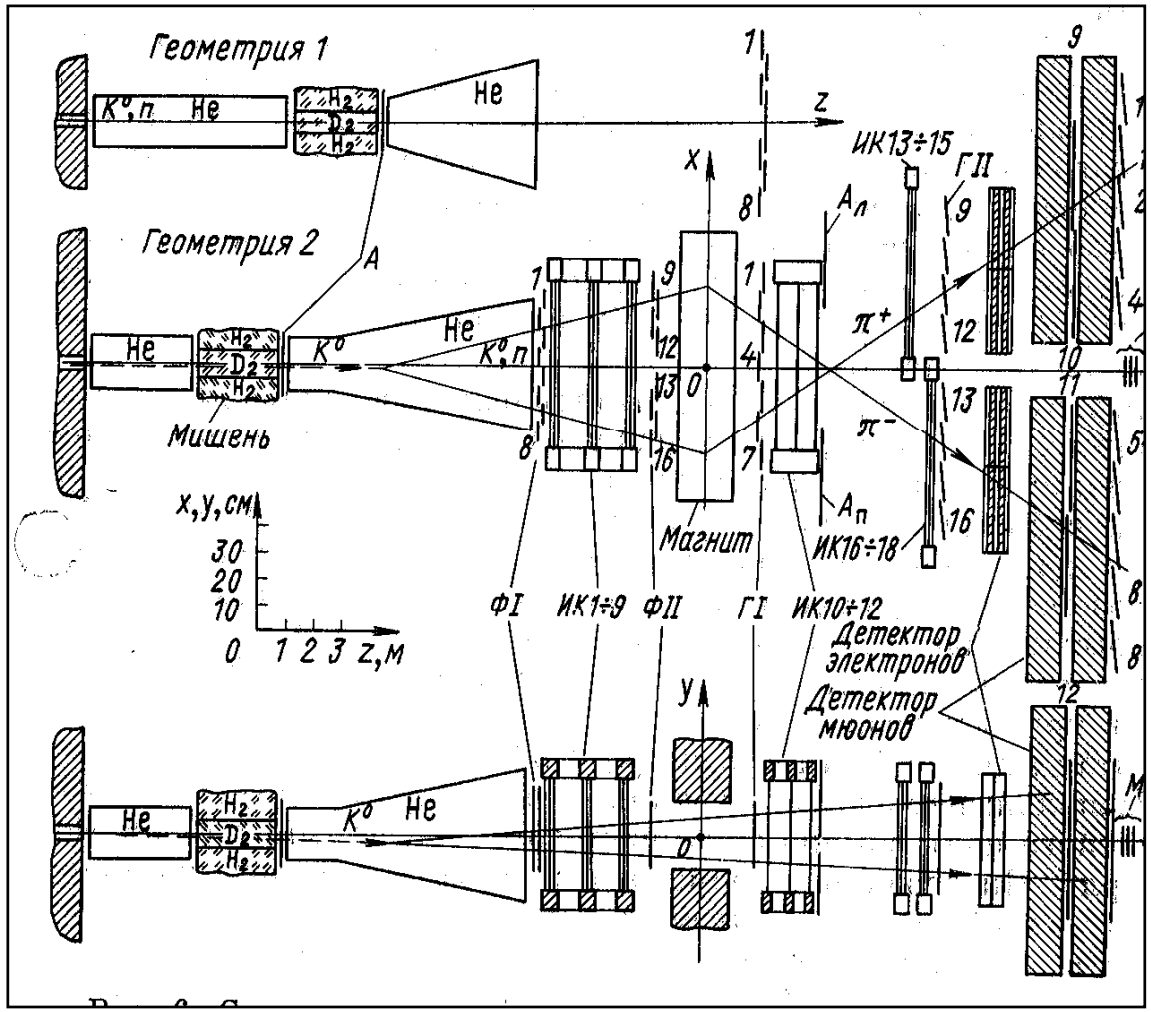
One of the first experiments at U-70 –

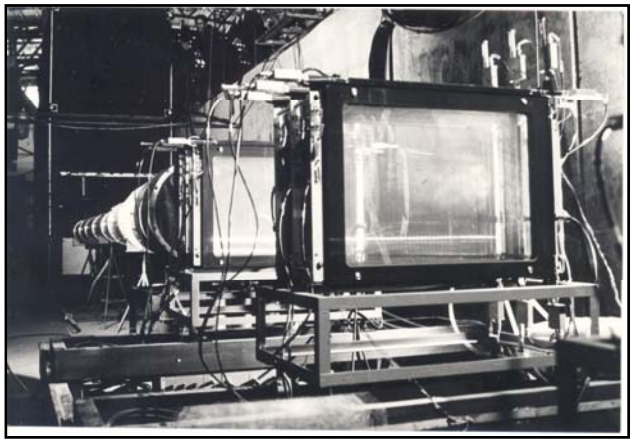
Study of K^0_L – K^0_S regeneration in Hydrogen, Deuterium and Carbon

The goal of experiments:

study of energy dependence of the transmission regeneration amplitude in the momentum range 10 – 50 GeV/c, that is an equivalent to measurement of the difference of total cross-sections of K^0 and $\bar{K}^0$ interaction with a matter.

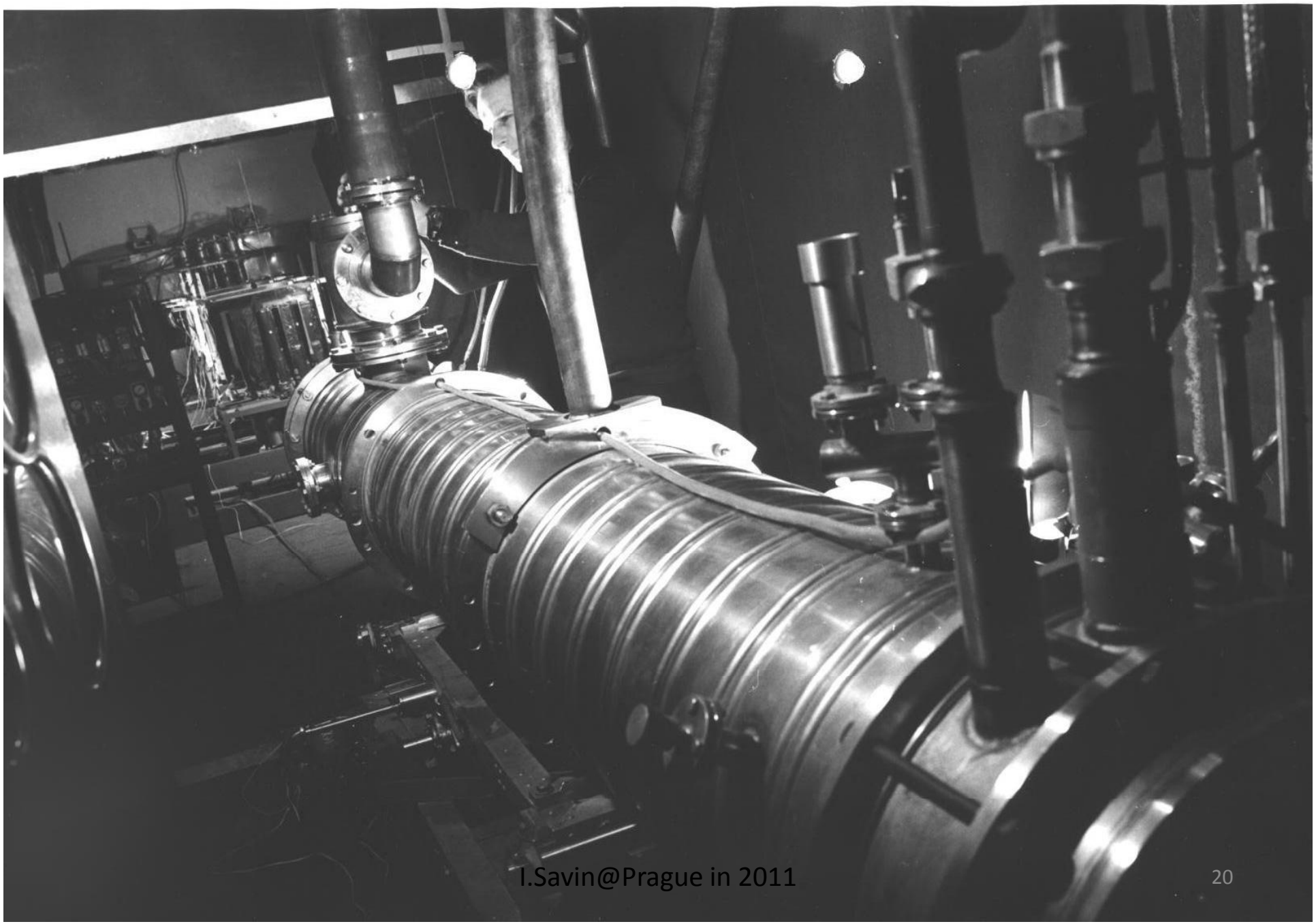
BIS lay out


Геометрия 1
Геометрия 2
K°,n
He
A
K°
Мишень
x,y,см
30
20
10
0 1 2 3 z,м
z
x
y
ИК13÷15
ГII
Aл
π+
π−
Aп
Магнит
ИК16÷18
ФI
ИК1÷9
ФII
ГI
ИК10÷12
Детектор электронов
Детектор мюонов



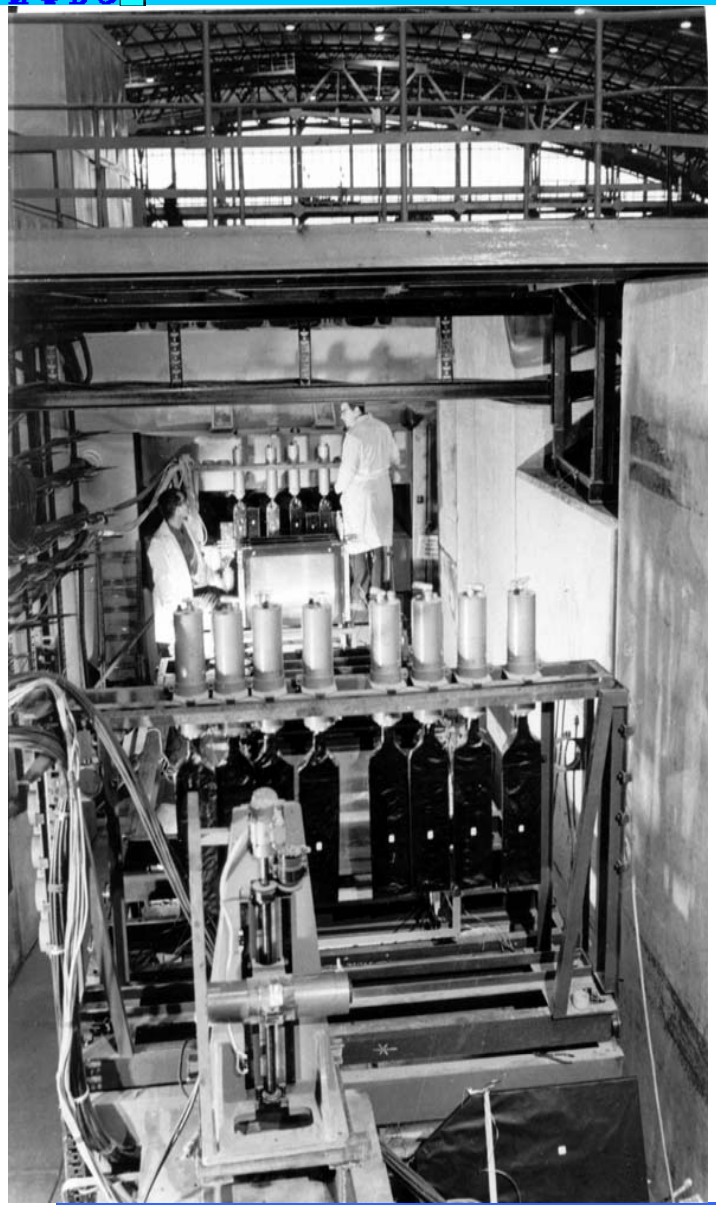
BIS properties

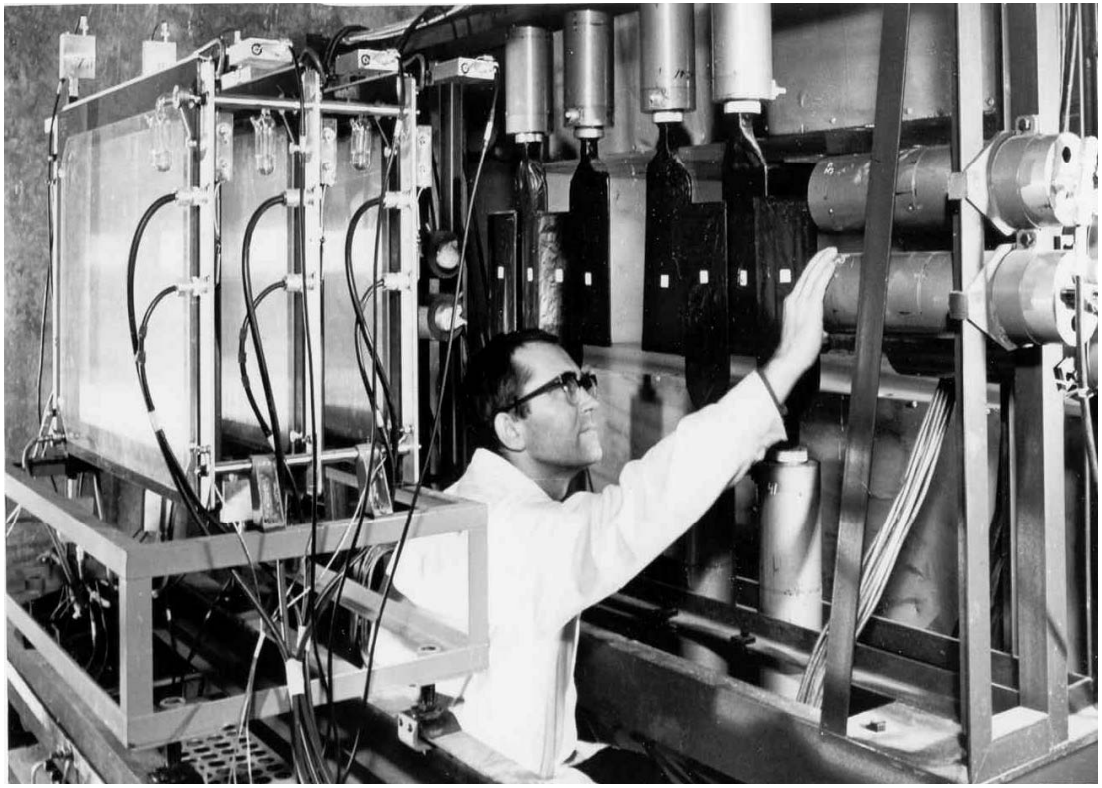
- **crossing geometry for selections of** $K^0_L, K^0_S \rightarrow \pi^+\pi^-$ **,**
- **3 m long H_2 and D_2 targets, C-target with d~1 g/cm^3,**
- **He filled decay volume,**
- **e – and μ - detectors for registration of** K^0_{e3} **and** $K^0_{\mu 3}$ **decays,**
- **Si- hodoscopes for decay pattern oriented triggers,**
- **hadron calorimeter for beam monitoring,**
- **set of 18 spark chambers with magnetostrictive read out,**
- **BESM-3M on line, optimized soft ware,**
- **world class apparatus at the time of executions.**



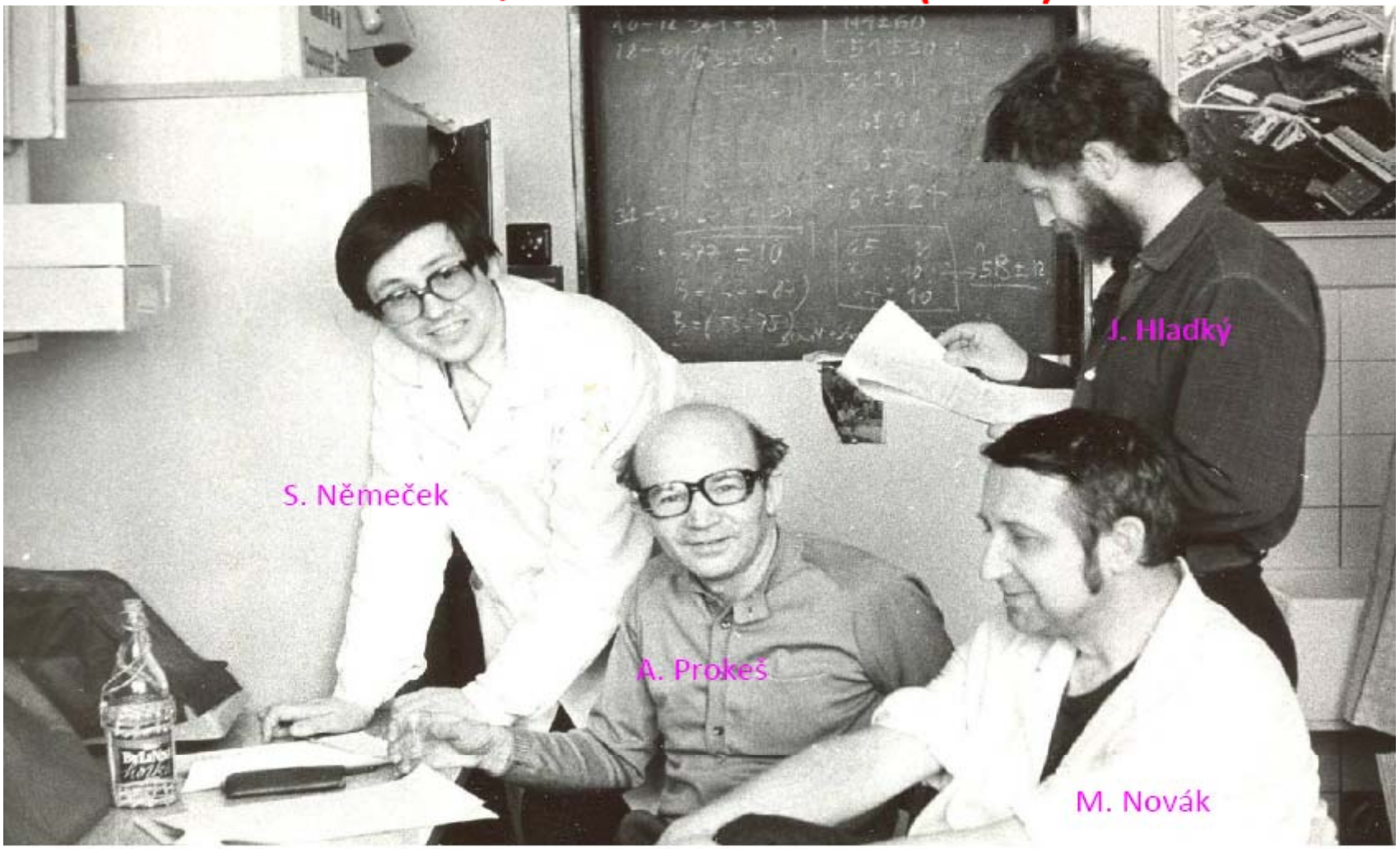
I.Savin@Prague in 2011

Experiment on K^0_L – K^0_S regeneration





FÚ ČSAV Praha, místnost č. 223 (1977)



BIS data analysis in Prague

Contributions of Czech physicists to BIS:

-participation in the setting up of the experiment and on-line software,

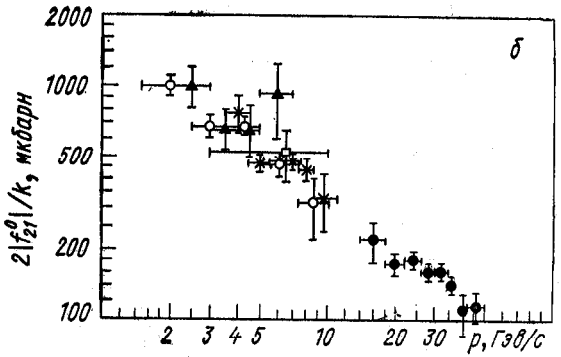
-data taking and analysis on
K0-long-K0-short regeneration from Carbon (full Prague responsibility),D and H,
K0-long decay form factors,
searches for new vector mesons and charm particles,

-preparations of new experiments with upgraded BIS – CHARM,EXCHARM

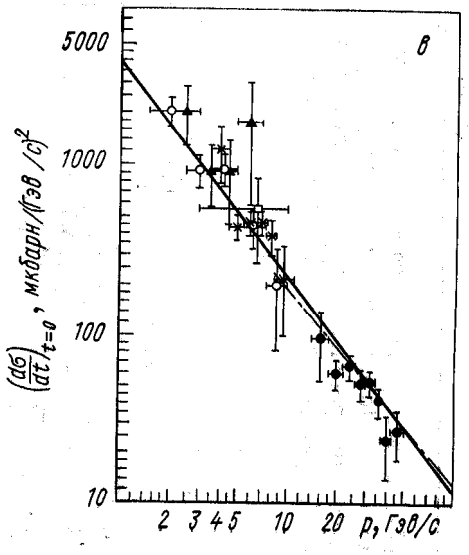
BIS main results

-Interference between $K_L^0 \to \pi^+\pi^-$ and $K_s^0 \to \pi^+\pi^-$ regenerated in H_2, D_2 and C has been observed at high energies for the first time.

-The modulus and phase of the regeneration amplitudes have been measured in the energy range 10 – 50 GeV.

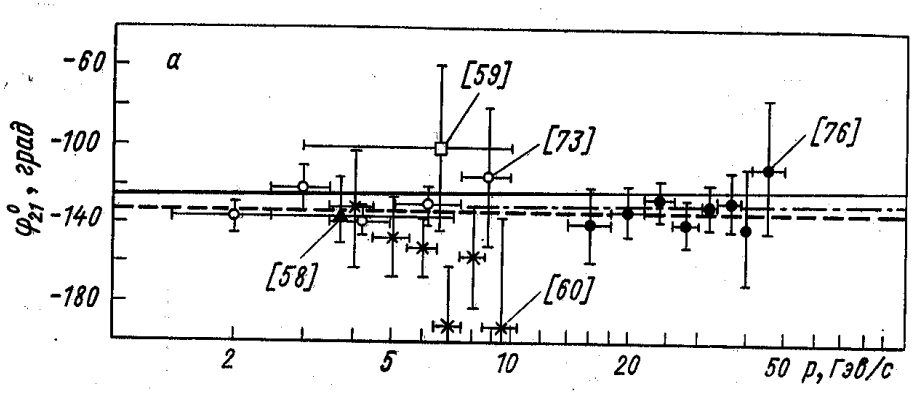


-The modulus and differential cross section of the transmission regeneration as a function of momentum follow the power low predicted by the CAM model and Pomeranchuk theorem -

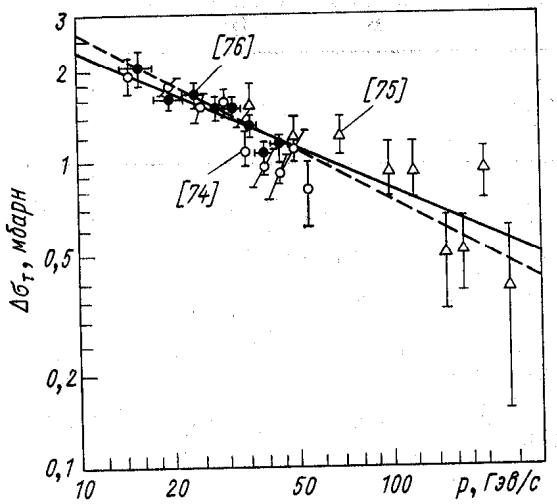


BIS main results

-The phase of the regeneration amplitude is energy independent, its value is in agreement with prediction from the crossing symmetry and analytic properties of scattering amplitude.

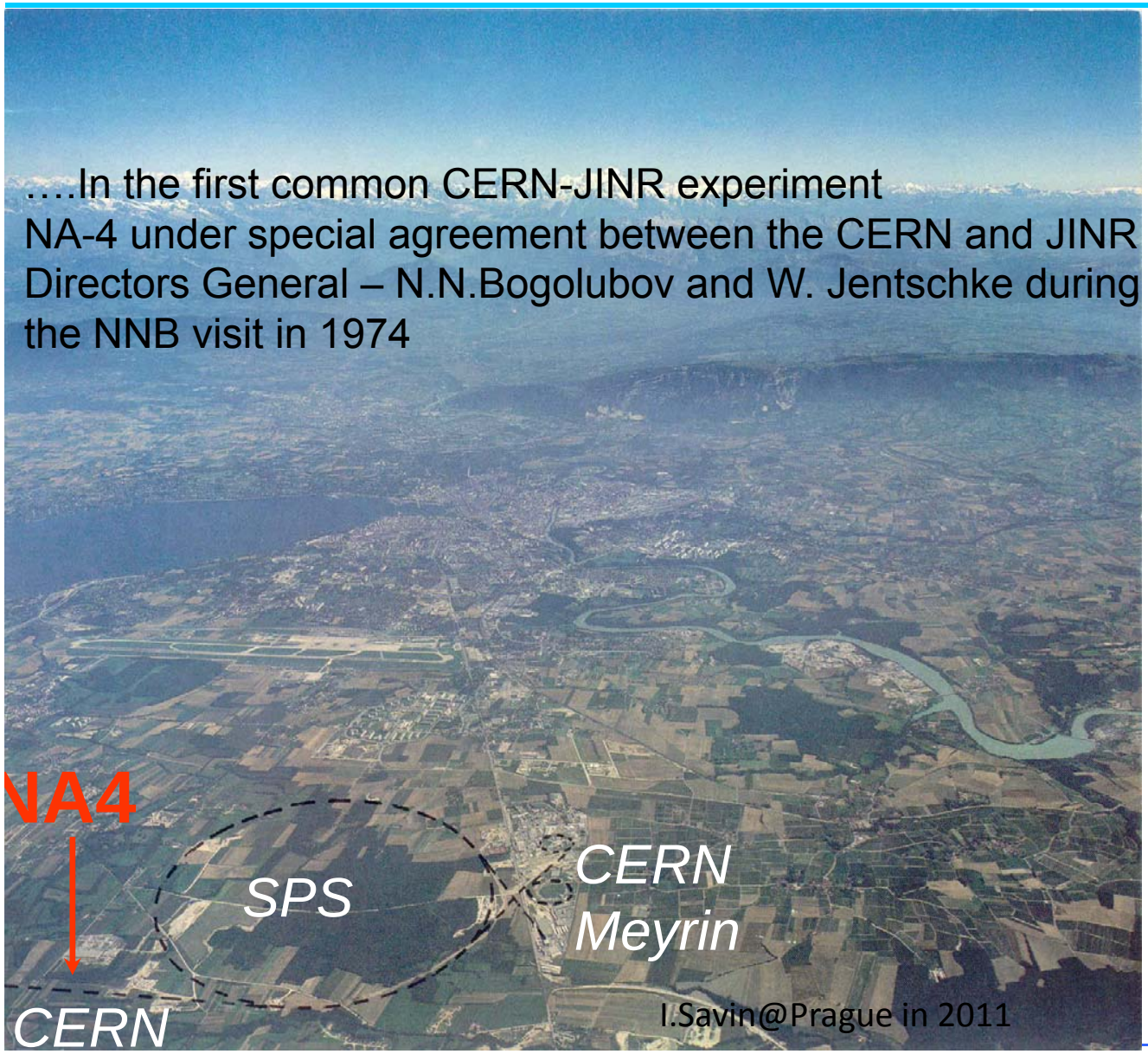


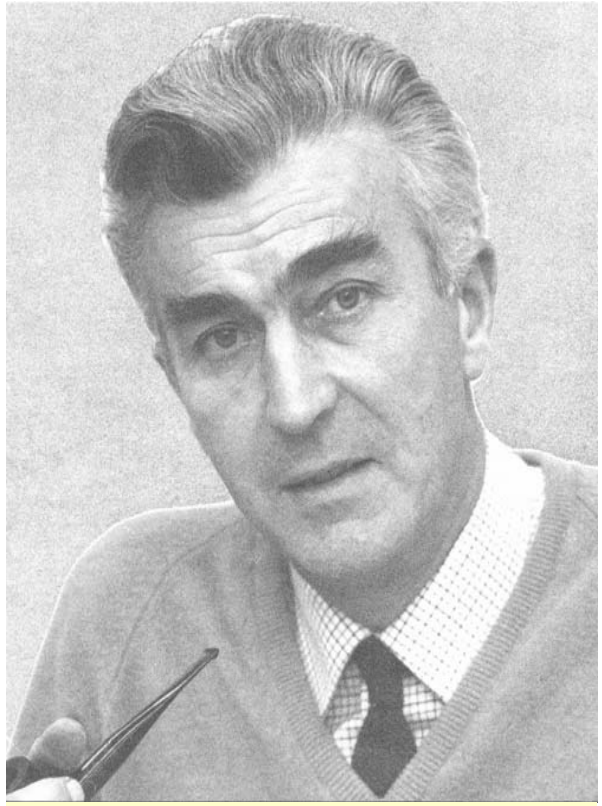
-The $K^0 p$ and $\overline{K}^0 p$ total cross section difference has a power low ~Ap^{-n}. Rising of the K^+n total cross section was predicted and confirmed at IHEP by direct measurements



Members of the Berlin, Budapest, Dubna, Moscow, Prague, Sofia ,Tbilisi Collaboration

Collaboration at CERN 450 GeV SPS...





John Adams

Director of the SPS project – Super Proto Synchrotron,

later CERN Director

JINR @ the NA4 experiment:
the success story of an early CERN-JINR collaboration

R.Voss,Symposium in honour of Igor Savin's 80th, Dubna, 7 December 2010

Original proposal SPSC/P19: CERN-Munich-Rome!

CERN/SPSC/74-79
SPSC/ P19
1 August 1974

AN EXPERIMENT TO EXTEND THE INCLUSIVE DEEP INELASTIC MUON SCATTERING ON HYDROGEN AND DEUTERIUM TO THE HIGHEST ENERGIES AND FOUR-MOMENTUM TRANSFERS AVAILABLE AT THE SPS*)

F. Krienen, F. Muller, B. Narosha, C. Rubbia**) and G. Tarnopolsky
CERN, Geneva, Switzerland

L. Baum, H. Hilscher, U. Meyer-Berkhout, D. Schinzel,
A. Staude and R. Voss
Sektion Physik der Universität, München, Germany

G. Brosco, F. Ceradini, M. Conversi, M. Ferrer and R. Santonico
Istituto di Fisica dell'Università, Roma
INFN - Sezione di Roma, Italy

CERN/SPSC/74-108/P19/Add.2
8 November 1974

Addendum by Dubna,CERN,Munich,Roma

ADDENDUM TO THE PROPOSAL FOR AN EXPERIMENT TO EXTEND THE INCLUSIVE DEEP INELASTIC MUON SCATTERING ON HYDROGEN AND DEUTERIUM TO THE HIGHEST ENERGIES AND FOUR-MOMENTUM TRANSFERS AVAILABLE AT THE SPS

I. Golutvin, V. Kukhtin and I. Savin
Joint Institute for Nuclear Research, Dubna, USSR

F. Krienen, F. Muller, B. Naroska, C. Rubbia*) and G. Tarnopolsky
CERN, Geneva, Switzerland

L. Baum, H. Hilscher, U. Meyer-Berkhout, D. Schinzel,
A. Staude and R. Voss
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G. Brosco, F. Ceradini, M. Conversi, M. Ferrer and R. Santonico
Istituto di Fisica dell'Università, Roma
INFN - Sezione di Roma, Italy

ABSTRACT

Cost estimates and time-table are given. The total cost [12 MSF to which we add a 10% contingency] is to be shared as follows: 4.5 MSF for Dubna, 6 MSF for CERN, and 2.7 MSF to CERN Member States. We can be ready for the initial commissioning of the muon beam.

Co-operation with CERN at SPS

1975

A Proposal is approved to build an apparatus and study inclusive deep inelastic muon scattering on nucleons and nuclei to the highest energies and four-momentum transfers available at the SPS - the NA4 experiment by the BCDMS collaboration:

B	Bologna, INFN, Italy
C	CERN
D	Dubna, JINR
M	Munich University, Germany
S	Saclay, CEN, France

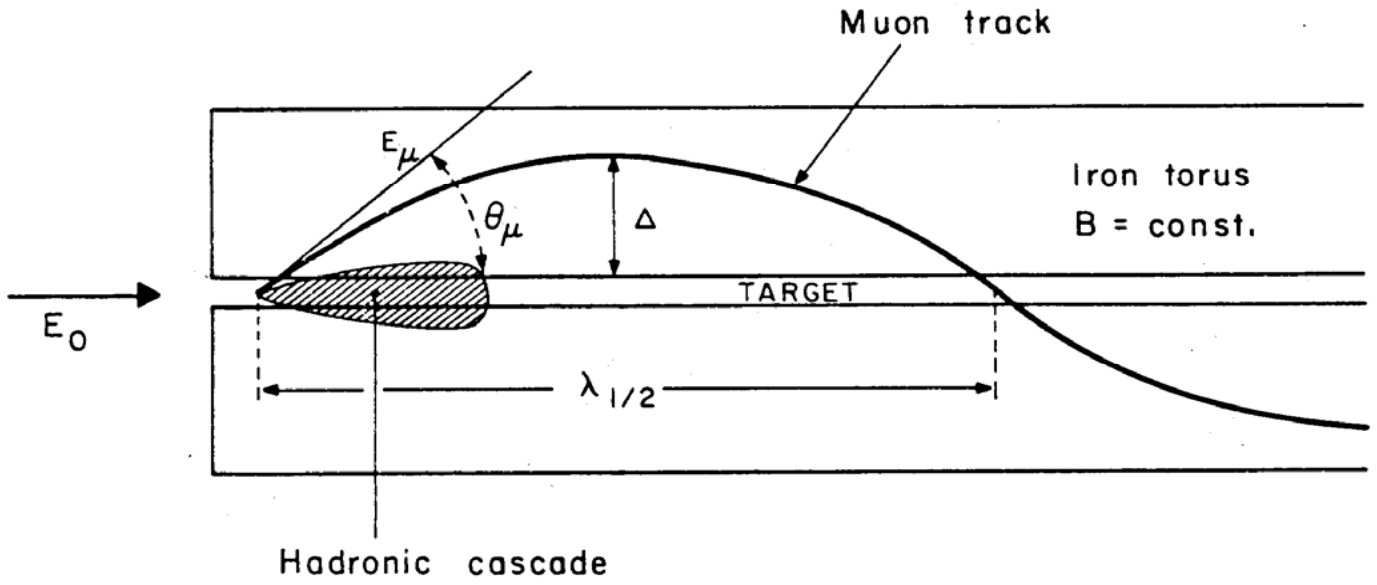
The first JINR – CERN (USSR – CERN) experiment at CERN

JINR=USSR , Bulgaria, Czechoslovakia, DDR, Hungary

A1

NA4 – the First JINR-CERN Experiment

DIS muon trajectory in the toroidal magnetic field



$$\lambda_{1/2} = 6.66\ p_T / B$$

$$\Delta = \frac{M}{0.3B}\ \frac{Q^2}{Q^2_{max}} \quad \rightarrow M/0.3\ B \sim 1.5\ m$$

Слайд 33

A1 Admin; 04.03.2011

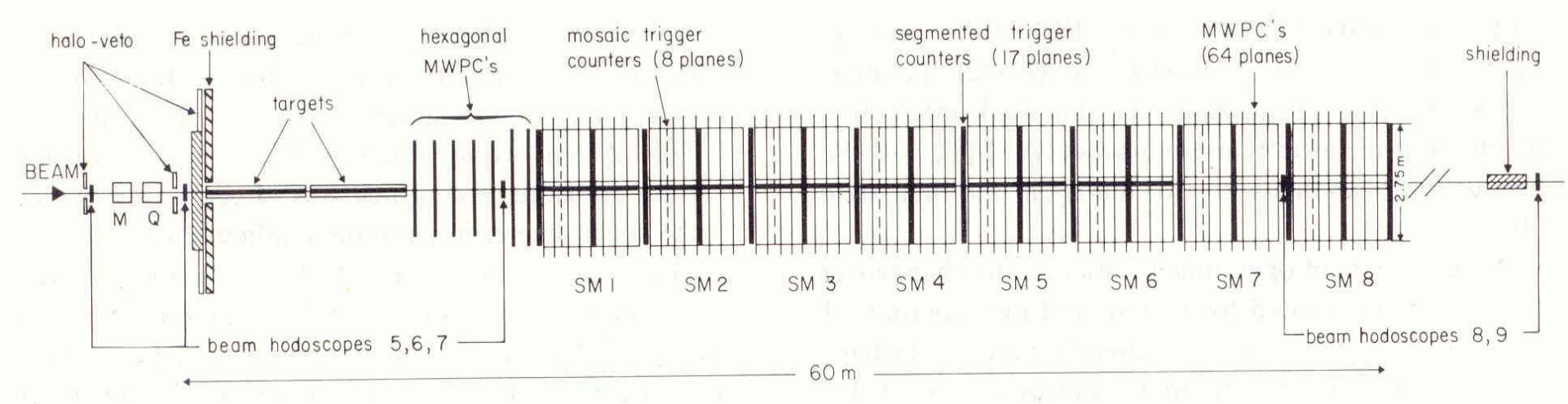
NA4 – the First JINR-CERN Experiment

High Luminosity spectrometer for deep inelastic muon scattering

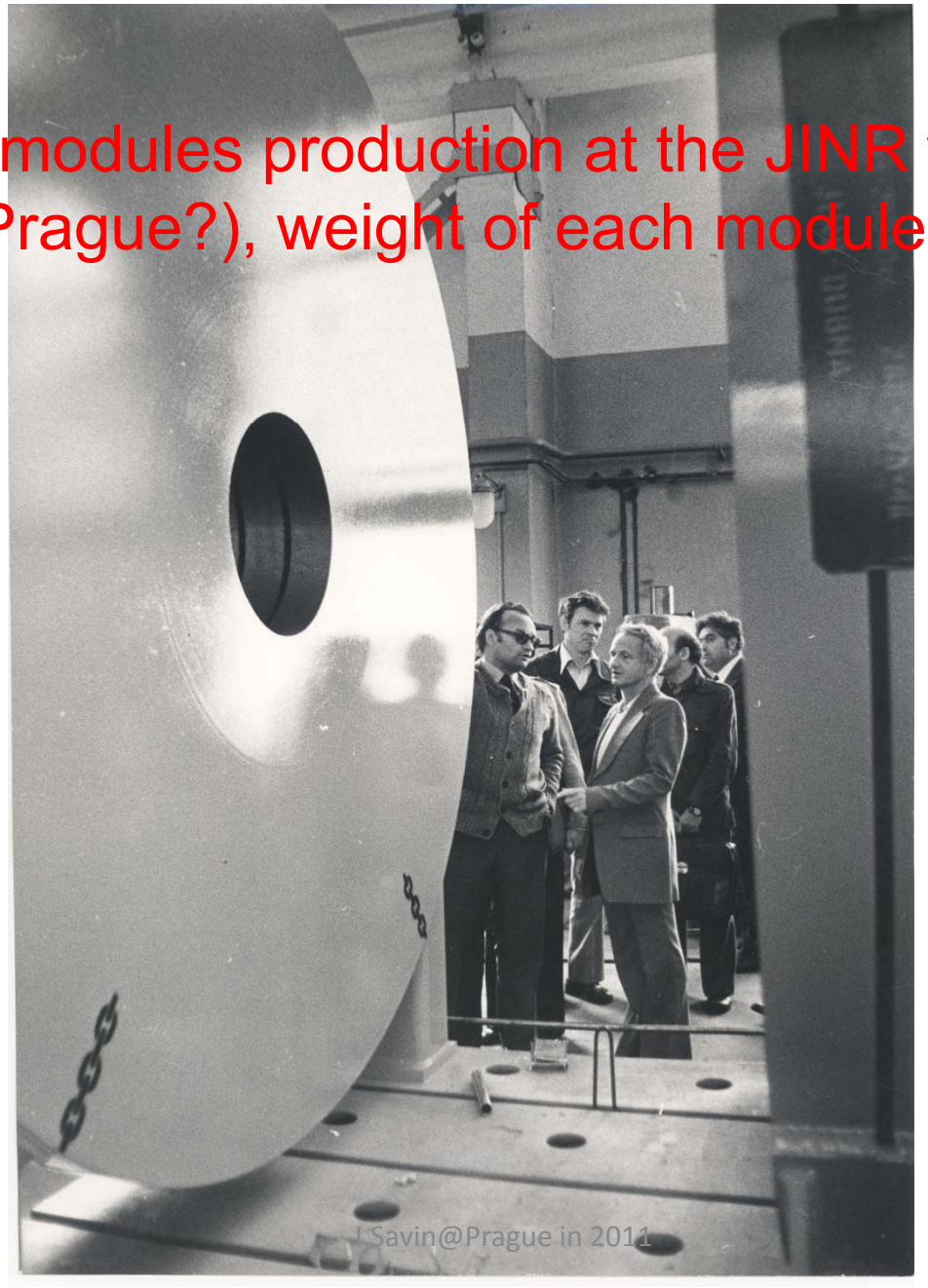
JINR contributions (~30% of total costs): 10 supermodules of iron yoke,

80 halfplanes of MWPC,

7 planes of hexagonal MWPS



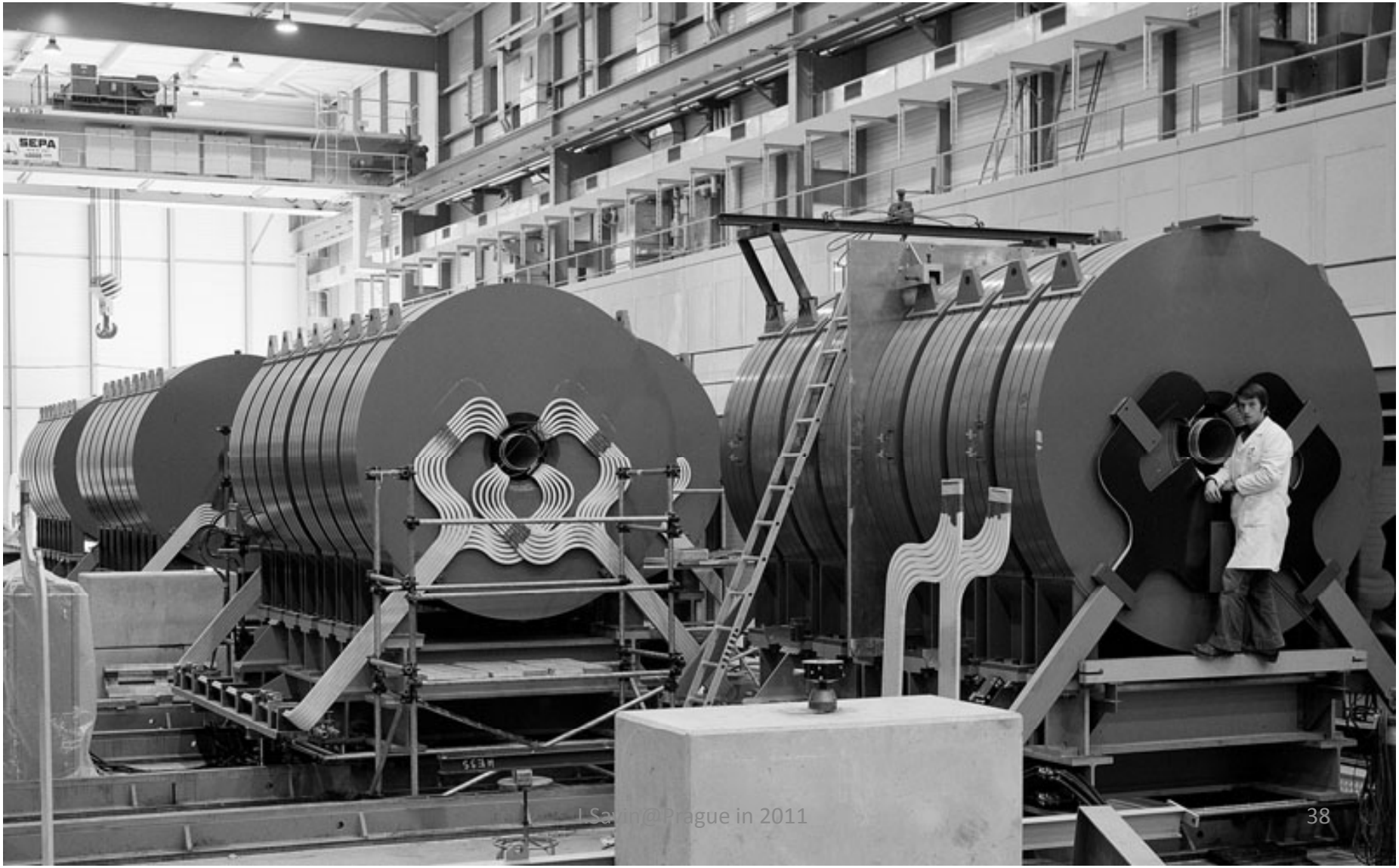
The iron yoke modules production at the JINR workshop
(originally at Prague?), weight of each module is about 20 t.



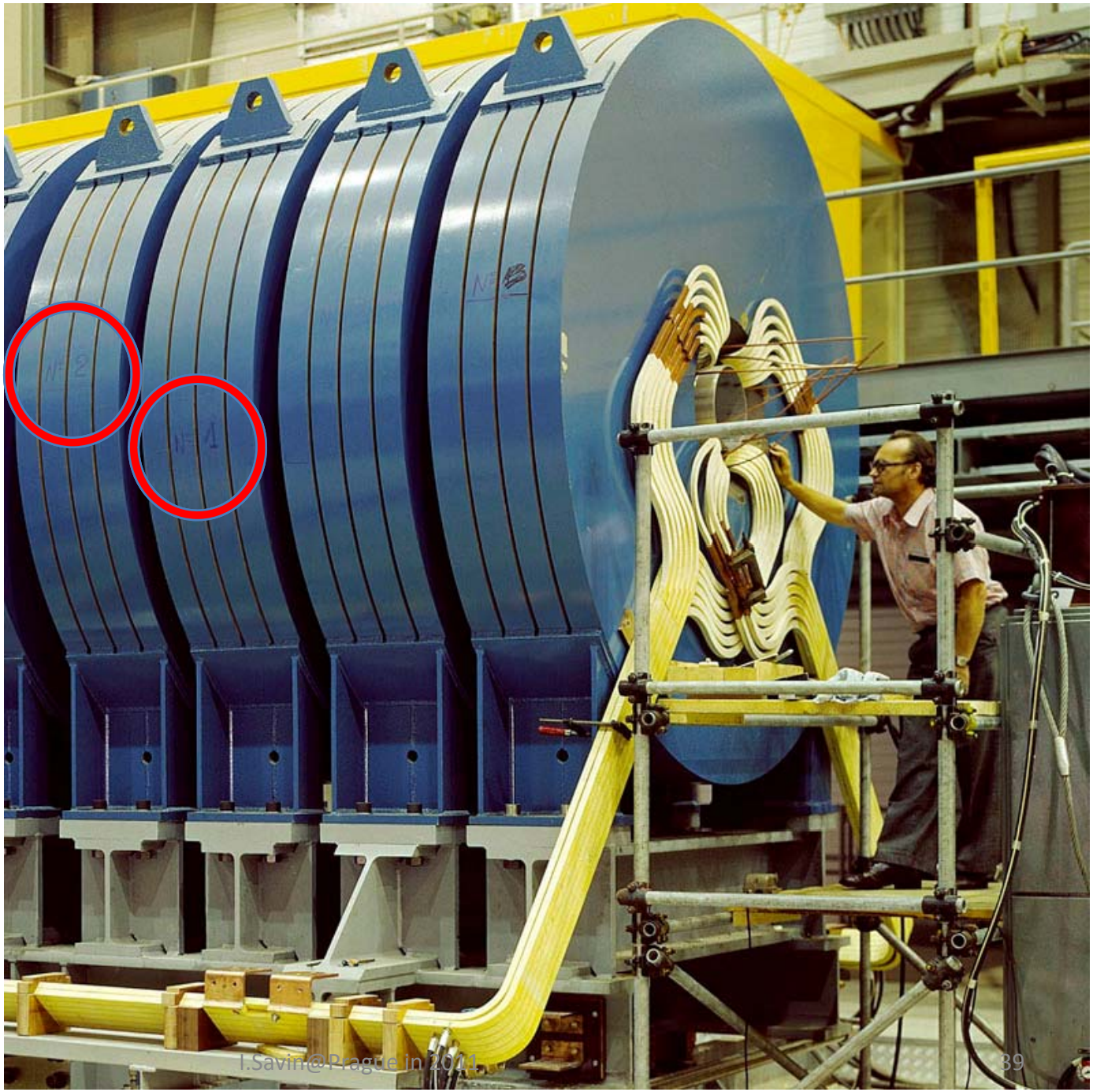
Arrival of first iron modules at CERN (1977), 80 modules in total

Modules are assembled to 10 **Super-modules** …

… the magnet coils are installed …

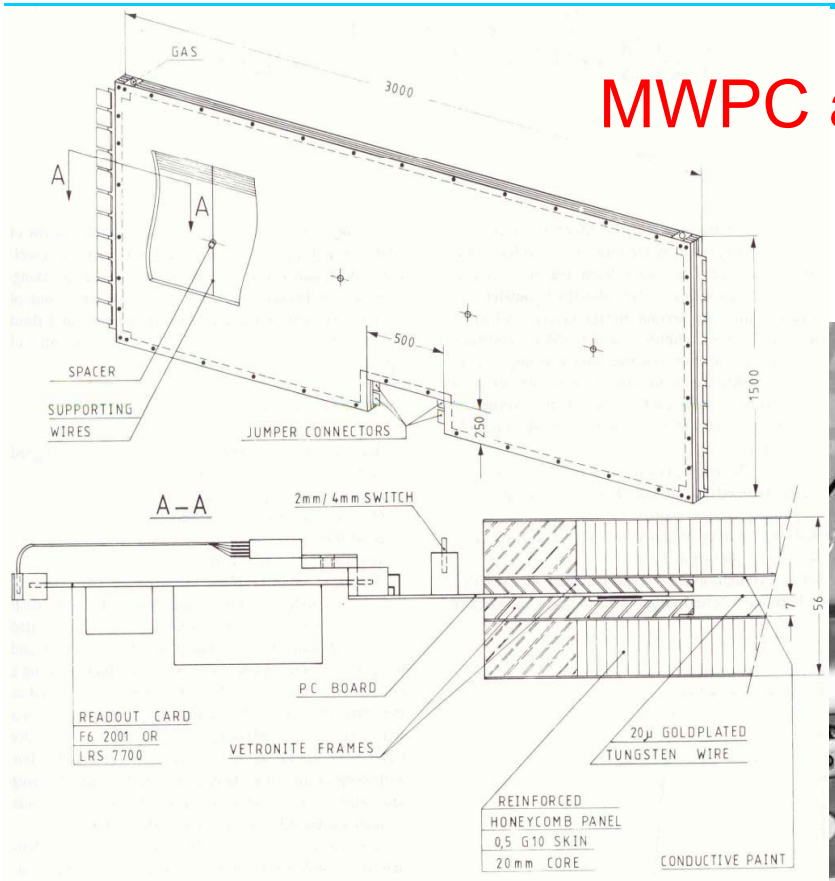


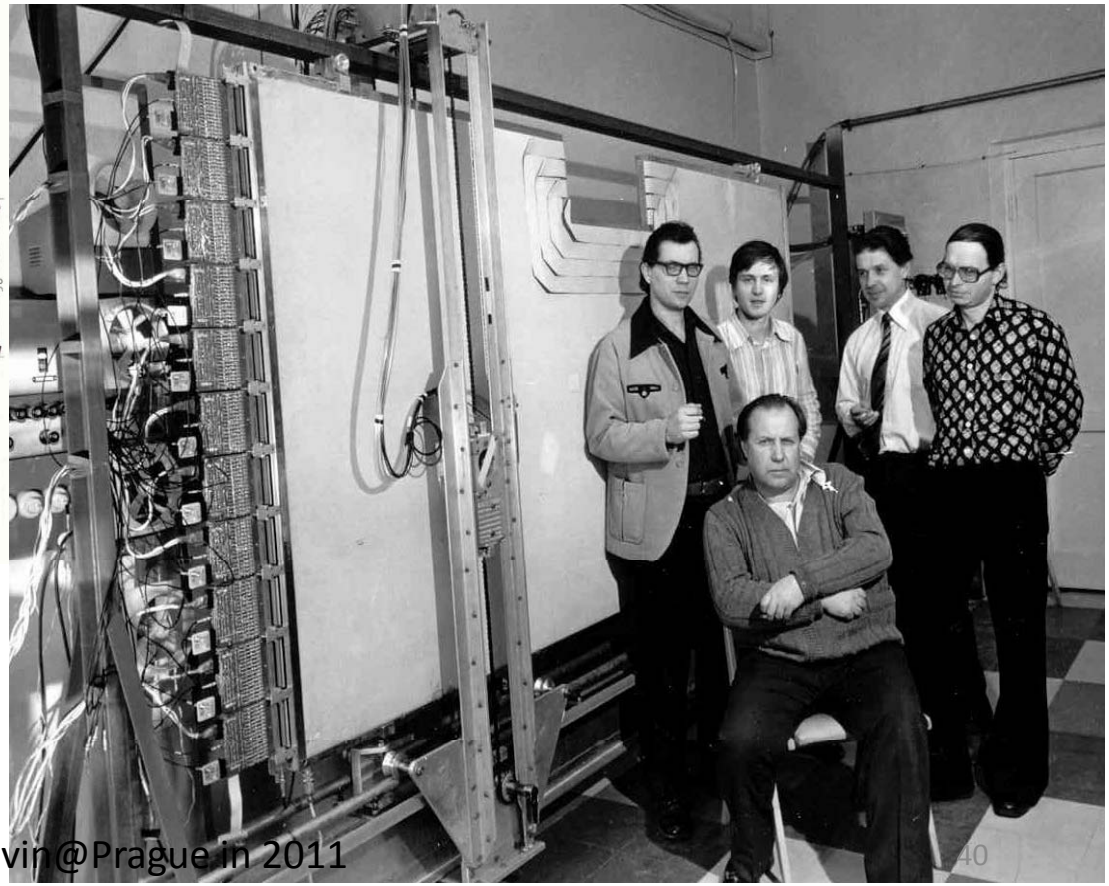
… and undergo a **stringent** quality control!!!



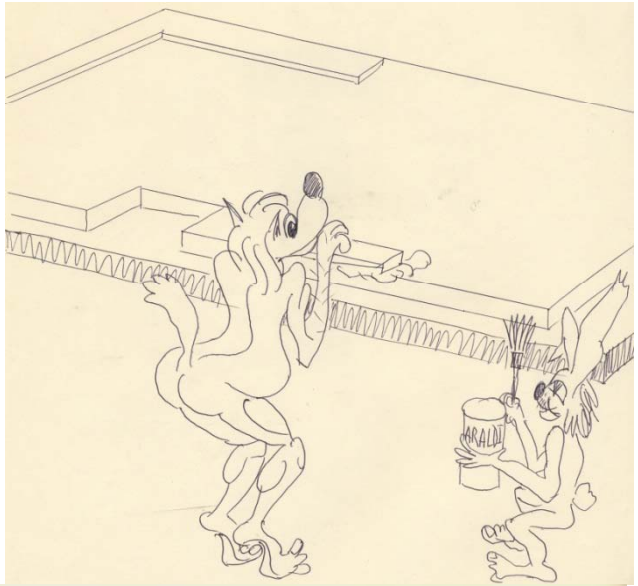
MWPC production at Dubna

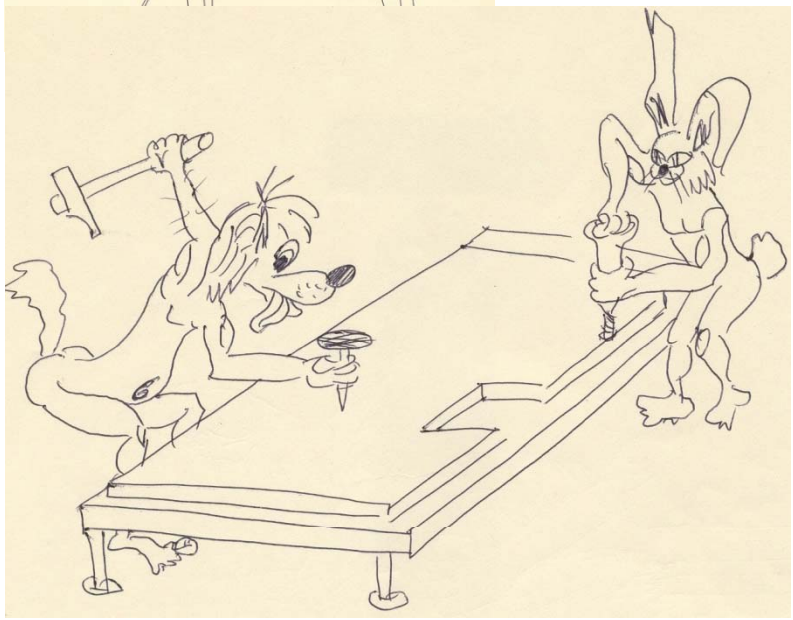
MWPC are designed by I.Golutvin et al….

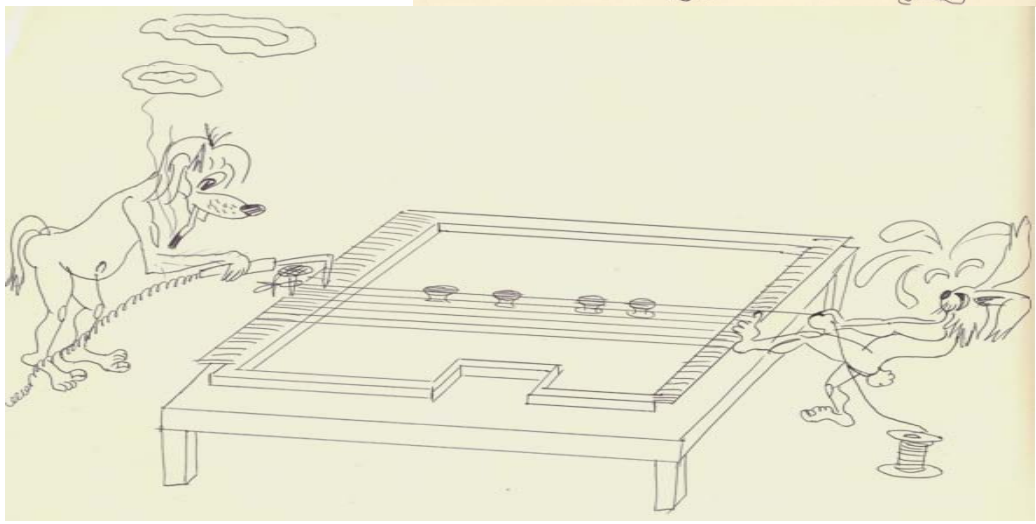




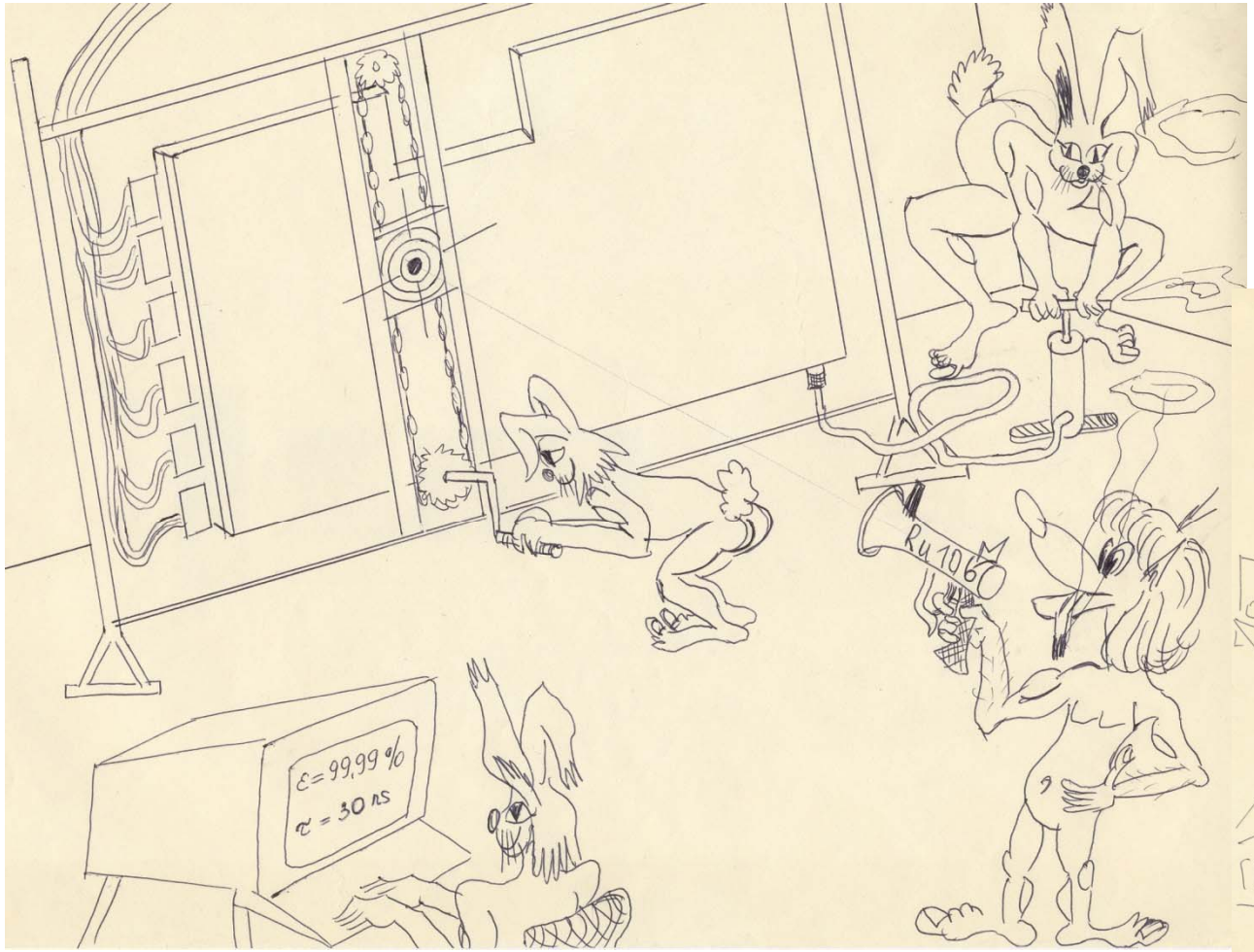
…….produced…..







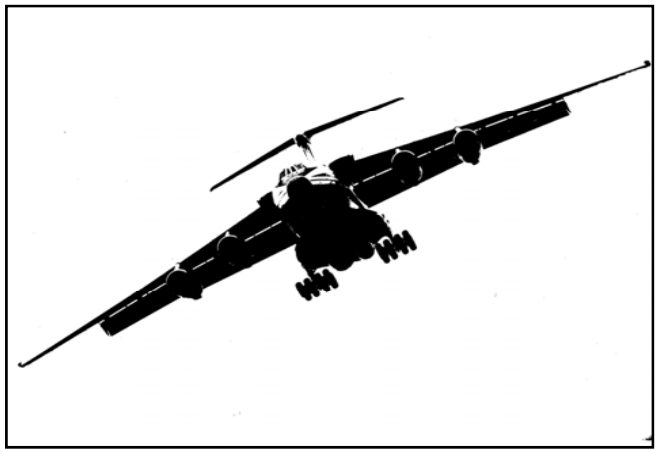
…..tested……



I.Savin@Prague in 2011

…inspected by the important visitors…

…..
transported
to Geneva
by air …

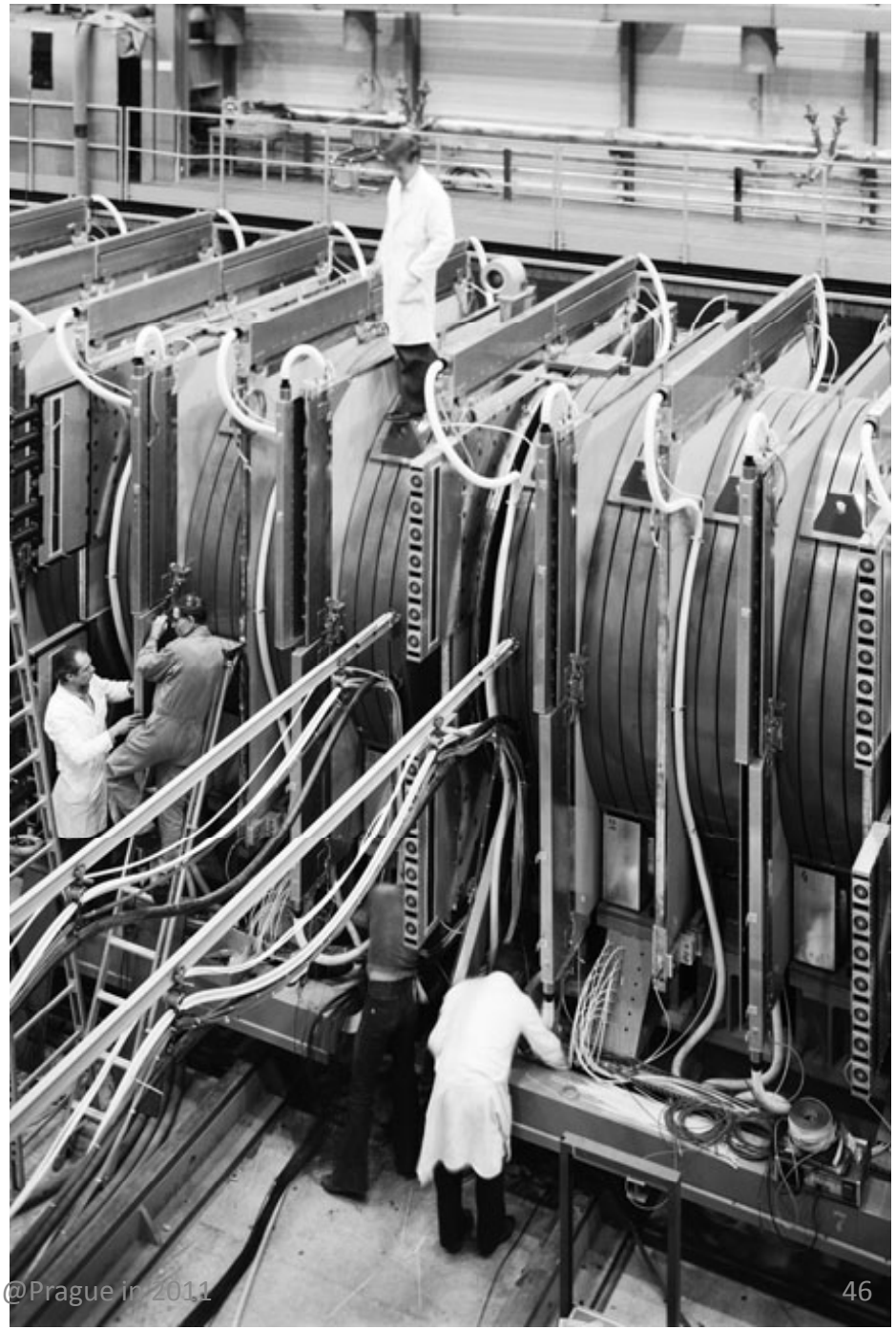


(First commercial
flight ever of IL-76
to the West,
February,1978)

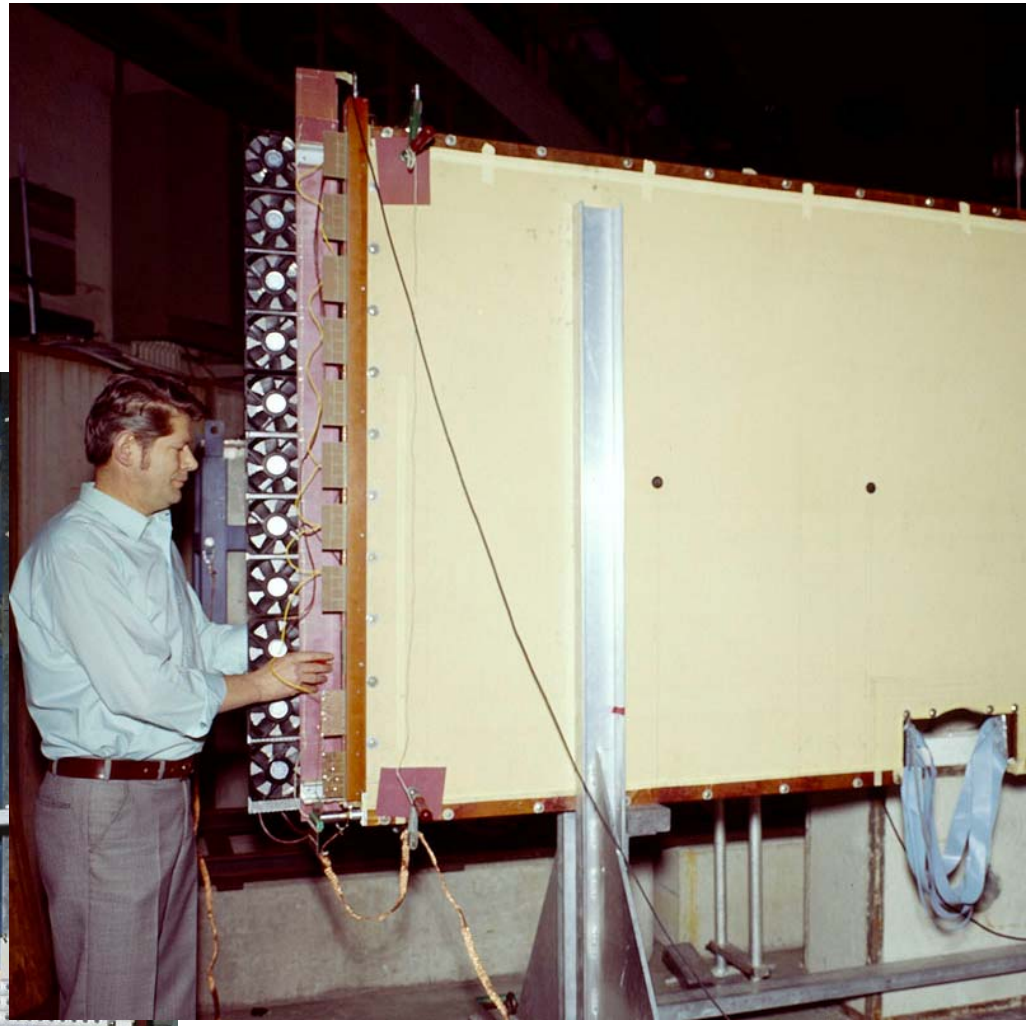
...unloaded under the eyes of an important delegation

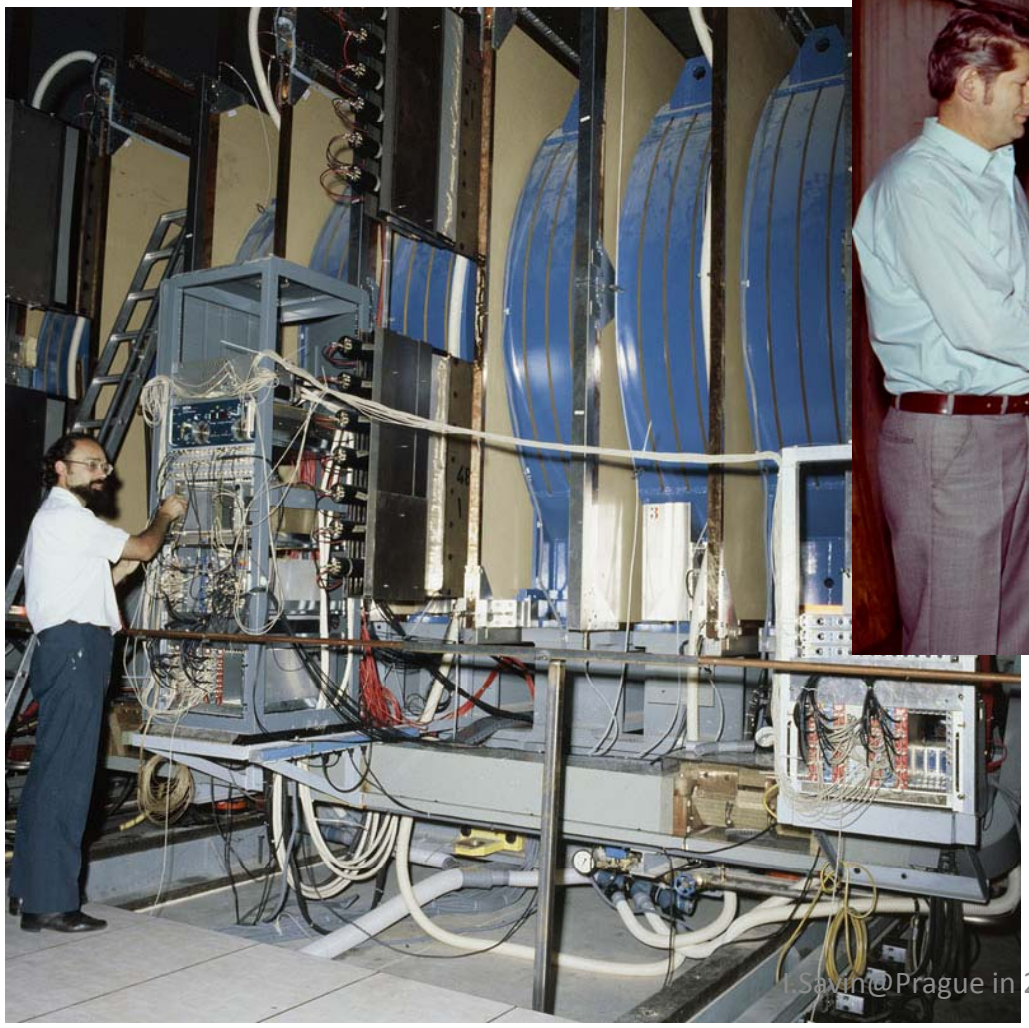
…

… installed in the Spectrometer ….



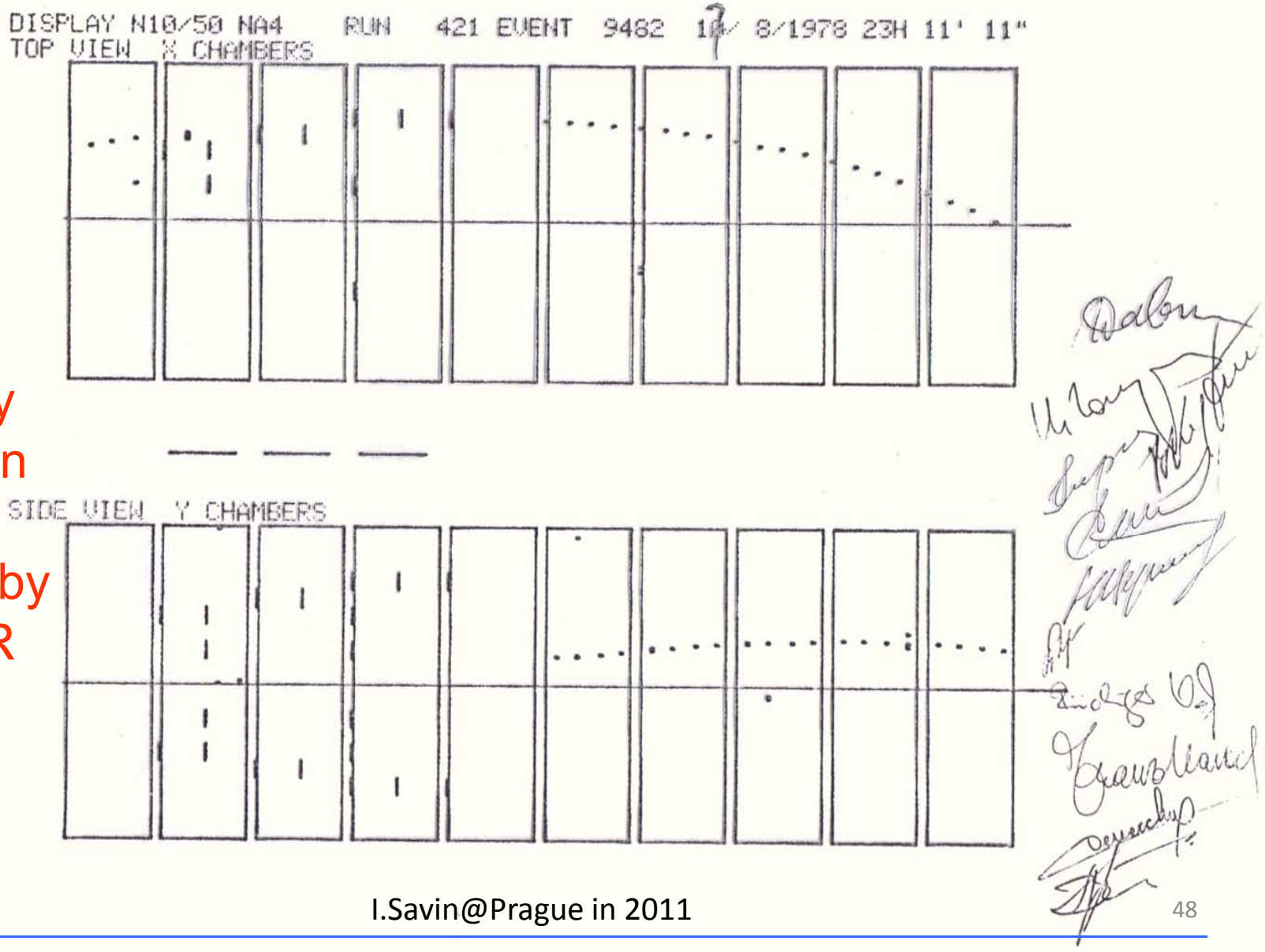
… and with a little help from some good old friends …,





… NA4 is getting ready for physics!

The NA4 technical run, 1978



The very first muon track, recorded by the JINR MWPC

Data taking: 1979 – 1985, analysis up to 1991

Contributions of Czech physicists to NA-4:

-participation in data taking and analysis of main results:
nucleon structure functions F2(x,Q2) and QCD test,
observation of the electro-weak interference,
observation of nuclear effects in SF, including at x>1;

-studies of special aspects of the experiment:
map of the solenoid magnetic field,
muon energy losses,
Fermi motion corrections to DIS,
development of new method of the QCD analysis,
on-line monitoring ,
ect.

The NA4 heritage: the structure function $F_2(x,Q^2)$ of protons.
The EMC and SLAC data corrected after the NA4 publication.

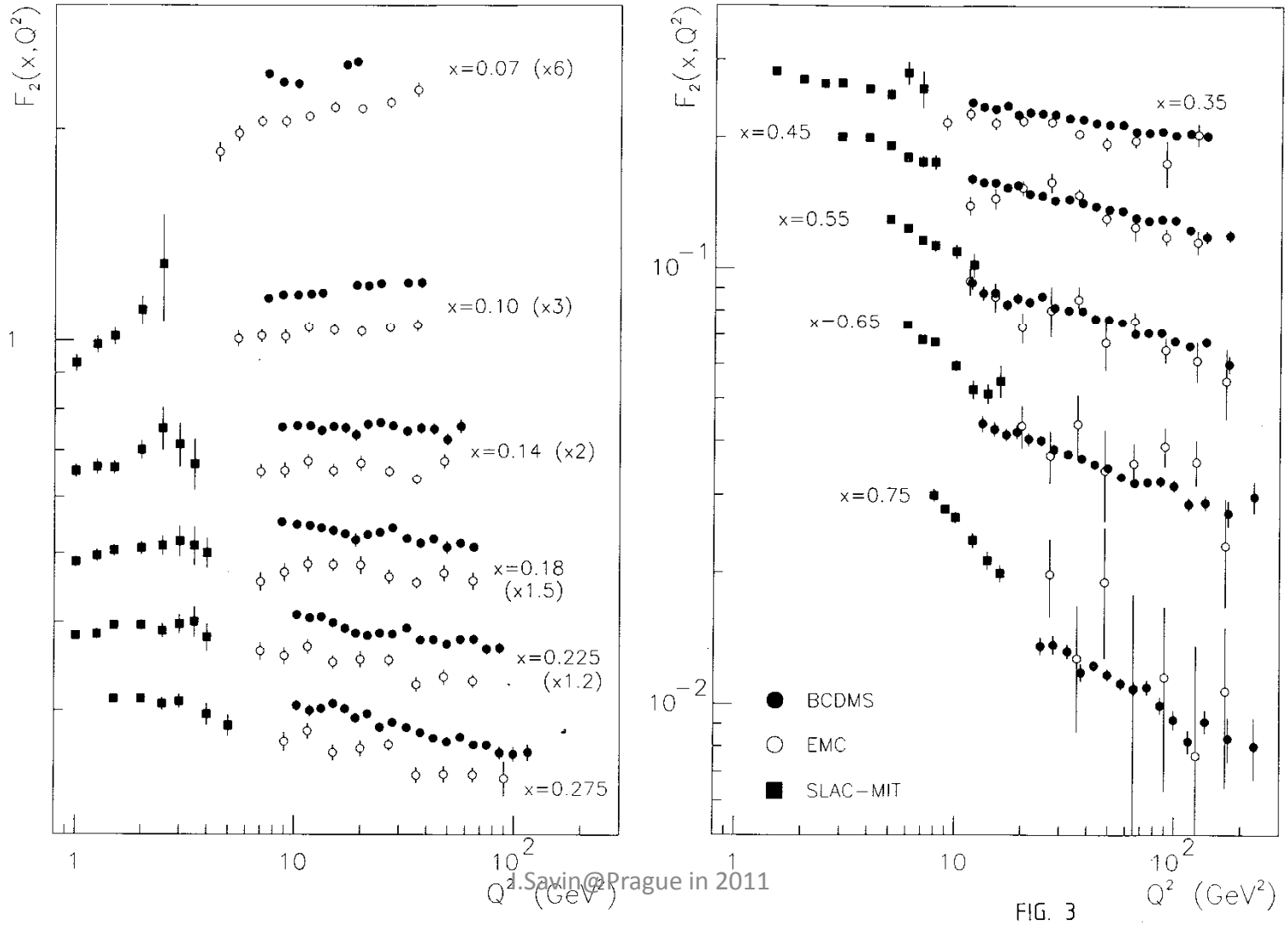
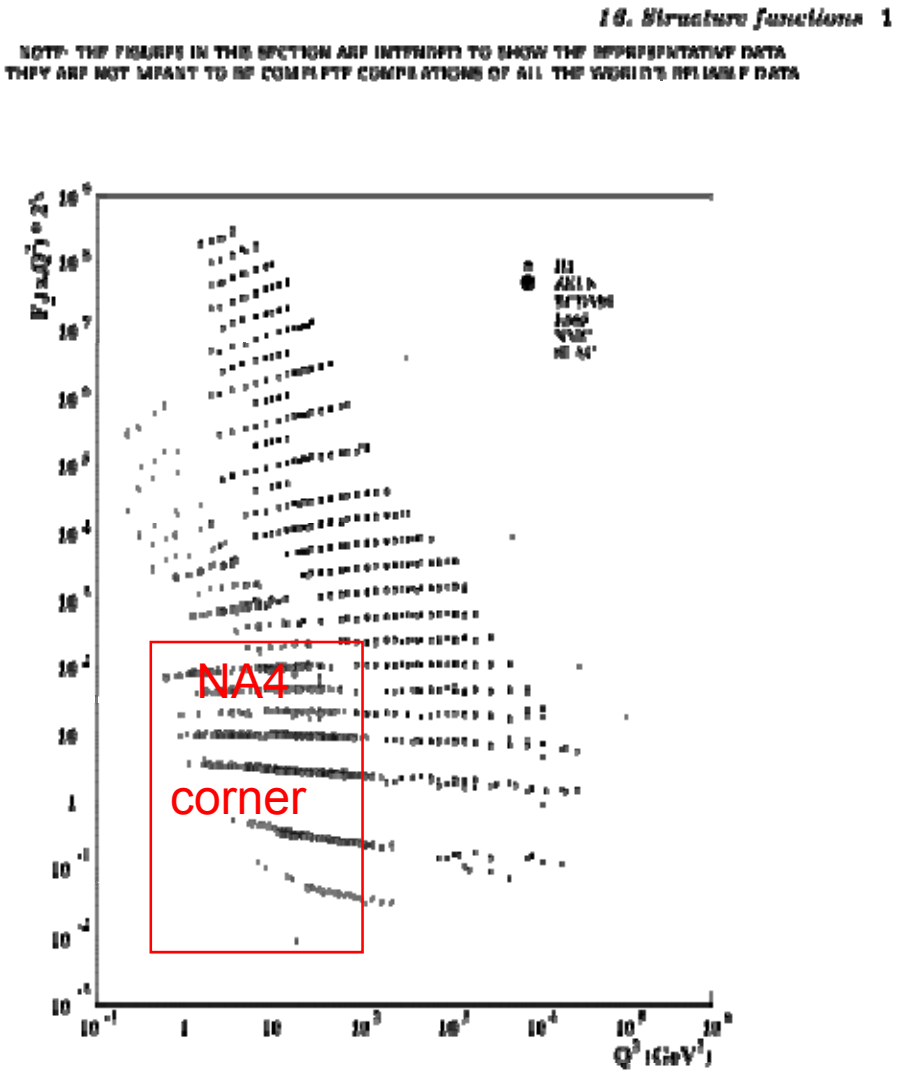


FIG. 3

Still a pillar of today's world set of data on nucleon structure functions!

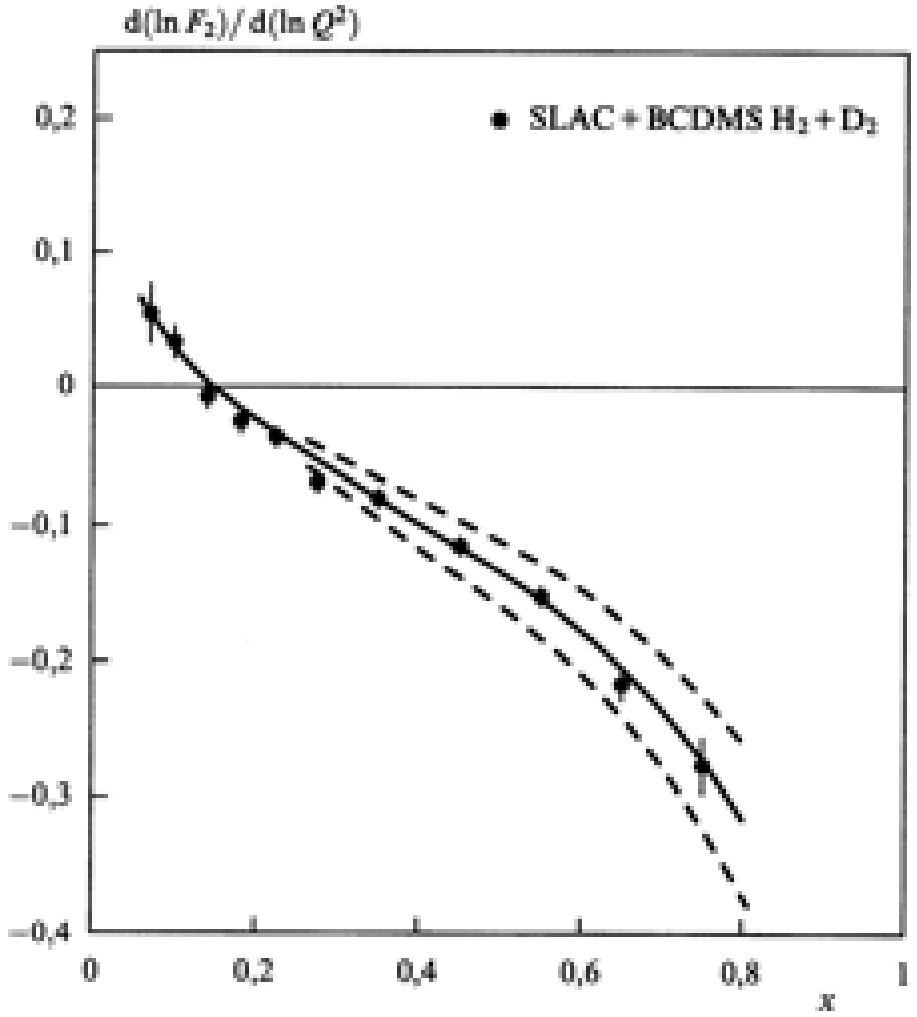
(RPP 2010)



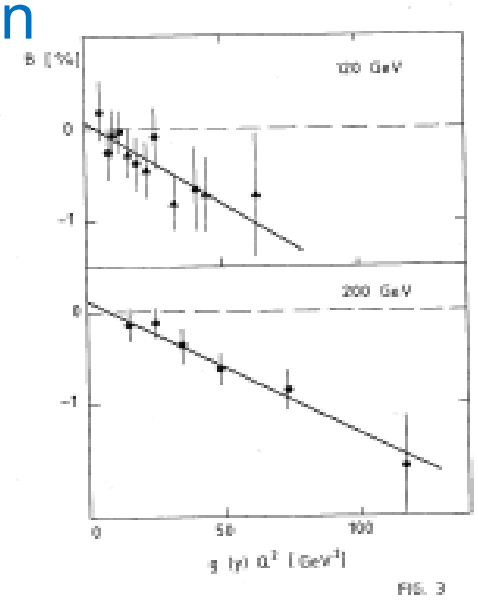
Scaling violations: test of perturbative QCD and measurementof the strong coupling constant

$\alpha_s(M_Z^2) = 0.113 \pm 0.003\ (exp)$
$\pm 0.004\ (th)$

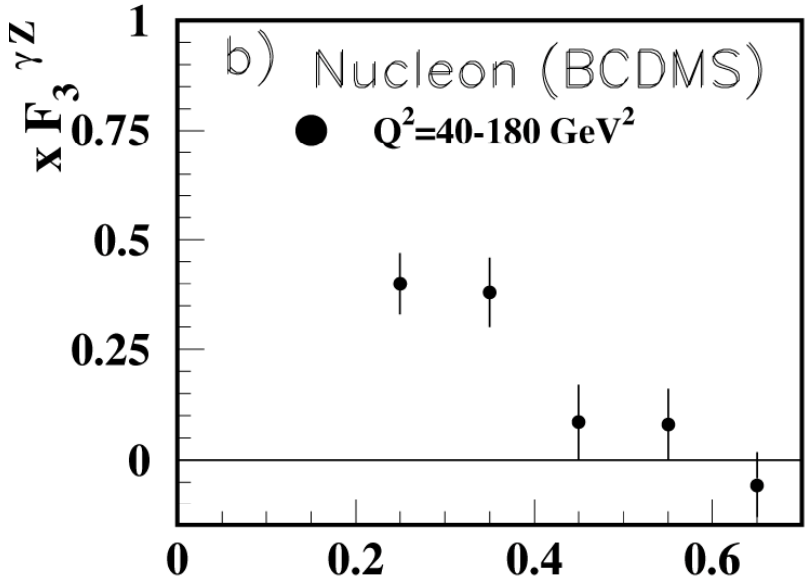
Still a competitive measurement today!



Week-electromagnetic interference has been observed for the first time in the muon-quark Interactions….
(20 years before HERA):

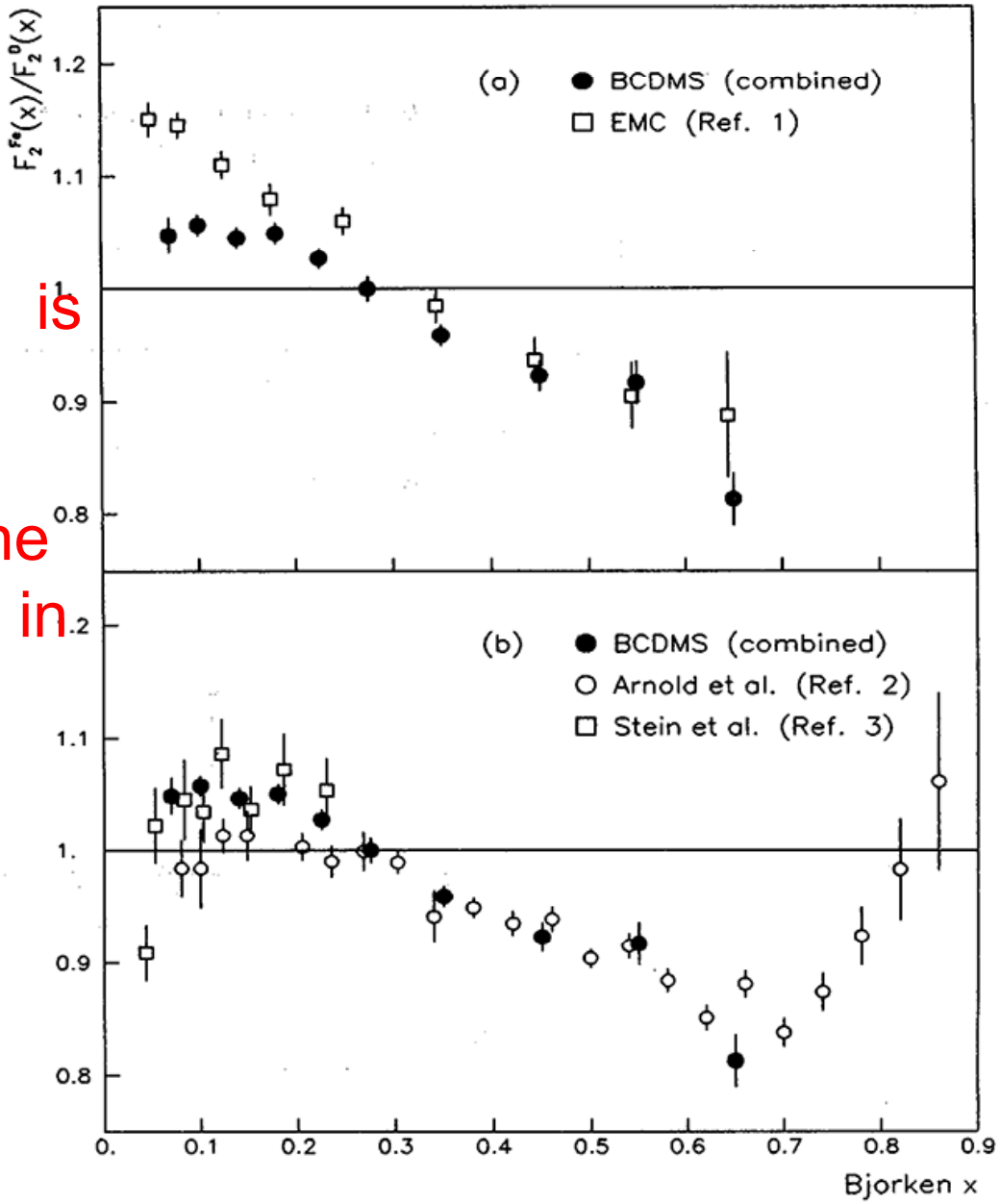


WS/GIM mixing angle and Interference Structure function xF3 have been derived from the measured B-asymmetries….



Other highlights:
Nuclear effects…

Qualitatively the EMC effect is confirmed and corrected:
the structure of free nucleons is different from the structure of nucleons bound in nuclei



SF at x>1, kinematically forbidden
for a muon-nucleon interaction

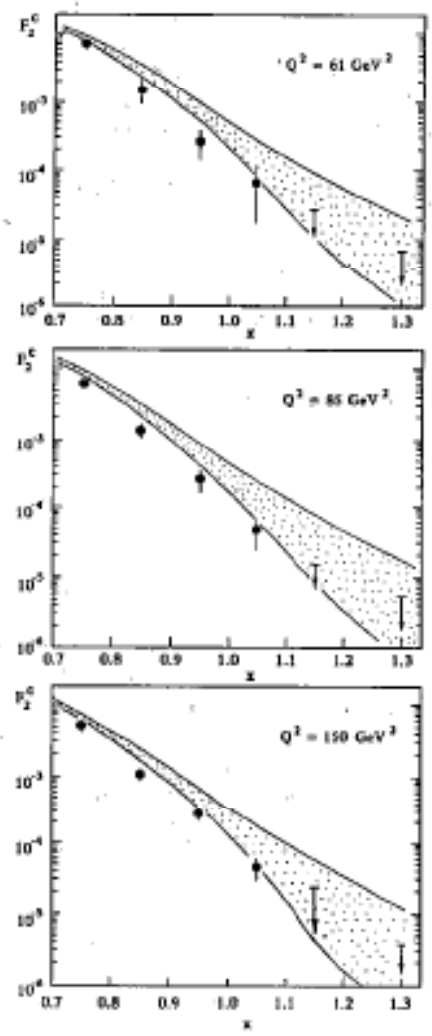


Fig. 7: The nuclear structure function $F_2^C(x)$ as a function of x, at three different values of Q^2. The hatched regions show the range of predictions of ref. [26].

13

COMPASS: THE new fixed target facility at CERN !

COMPASS - History

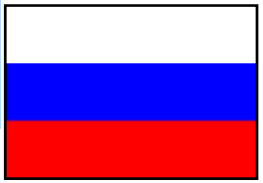
- 1996 COMPASS proposal
- 1997 conditional approval
- 1998 MoU

- 1999 – 2001 construction & installation
- 2001 technical run

- 2002 - 2011 data taking
- COMPASS-II @CERN at least until 2015

The COMPASS Collaboration
(230 Physicists from 12 Countries)

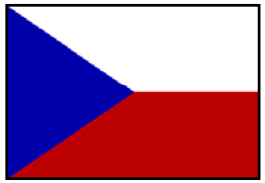
- Dubna (LPP and LNP), Moscow (INR, LPI, State University), Protvino



CERN

- Bielefeld, Bochum, Bonn (ISKP & PI), Erlangen, Freiburg, Heidelberg, Mainz, München (LMU & TU)

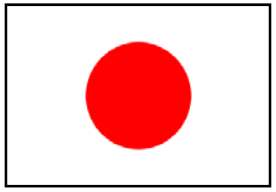
- Warsaw (SINS), Warsaw (TU)



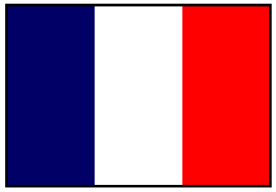
Prague

Helsinki

Nagoya



Lisboa



Saclay

Torino(University,INFN), Trieste(University,INFN)

Tel Aviv

- Burdwan,
- Calcutta

Czech physicists participate in the Dubna & Prague teams

COMPASS Physics Goals

With muon beam:

nucleon spin structure

- **Gluon Polarization $\Delta G/G$**
- Transverse spin structure function $h_1(x)$
- Flavor dependent polarized quark helicity densities $\Delta q(x)$
- Spin dependent fragmentation functions
- Diffractive VM-Production

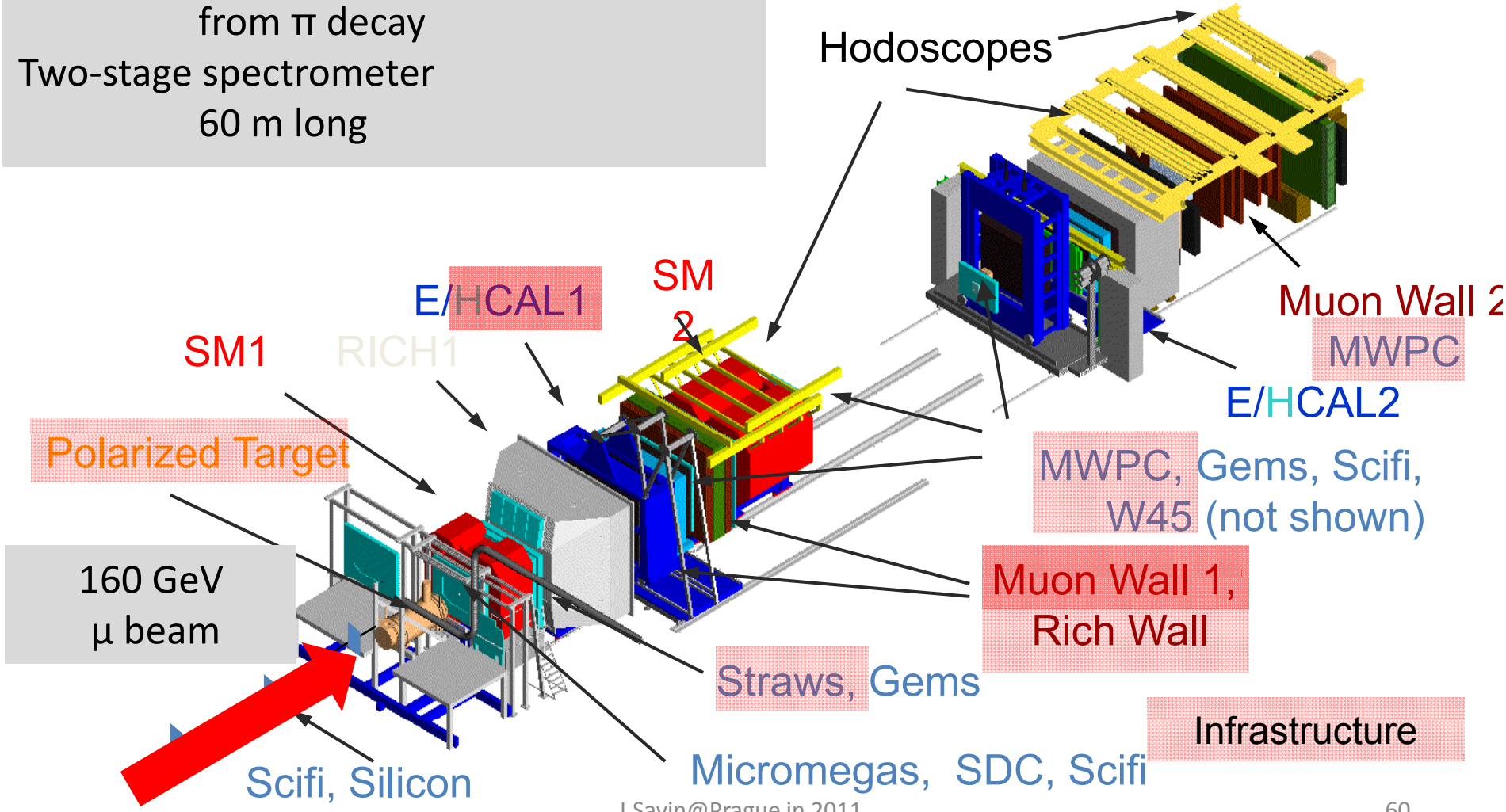
With hadron beam:

hadron spectroscopy

- **Primakoff-Reactions**
  -polarizability of π and K
- **Glueballs and hybrids**
- **Charmed mesons and baryons**
  -semi-leptonic decays
  -double-charmed baryons

COMPASS

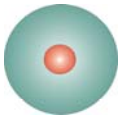
Beam: 160 GeV μ^+, pol. 80%
from π decay
Two-stage spectrometer
60 m long



Parton Distribution Functions

Three twist-2 PDFs

q(x)
$f_1^q(x)$

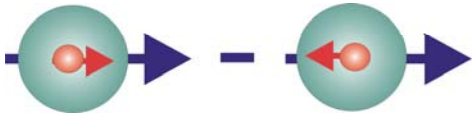


unpolarised PDF

quark with momentum *xP* in a nucleon

well known – unpolarized DIS

Δq(x)
$g_1^q(x)$

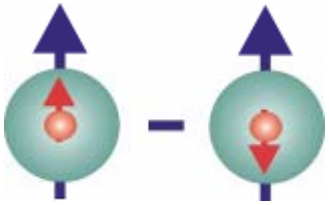


helicity PDF

quark with spin parallel to the nucleon spin in a longitudinally polarised nucleon

known – polarized DIS

$\Delta_T q(x)$
$h_1^q(x)$



transversity PDF

quark with spin parallel to the nucleon spin in a transversely polarised nucleon

chiral odd, poorly known

Factorization & x-sect. asymmetries

- Inclusive scattering

$$A_1 = \frac{\sum_q e_q^2 \Delta q(x, Q^2)}{\sum_q e_q^2 q(x, Q^2)}$$

Semi-inclusive scattering

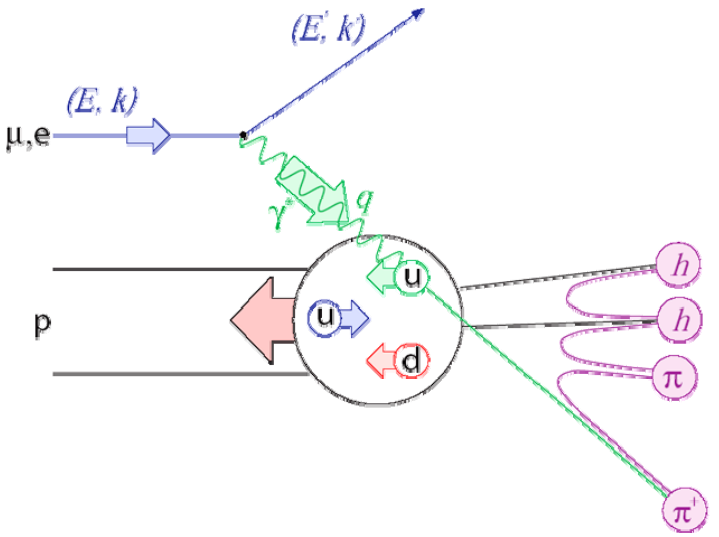
$$A_1^h = \frac{\sum_q e_q^2 \Delta q(x, Q^2) D_q^h(z, Q^2)}{\sum_q e_q^2 q(x, Q^2) D_q^h(z, Q^2)}$$

long. double spin asymmetry

$$A_{Coll} = \frac{\sum_q e_q^2 \Delta_T q(x) \Delta_T^0 D_q^h(z, p_T^h)}{\sum_q e_q^2 q(x) D_q^h(z, p_T^h)}$$

transverse single asymmetry

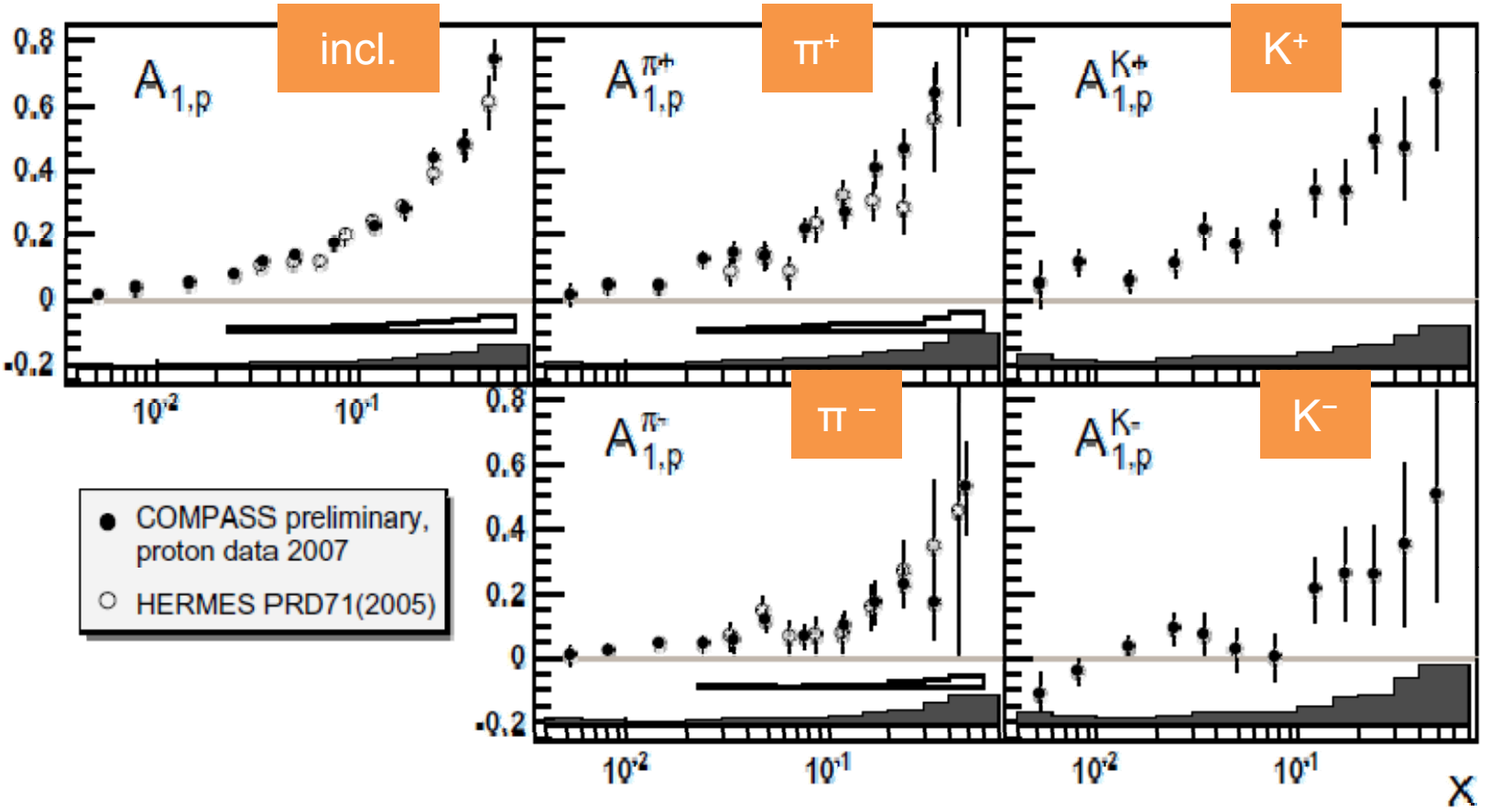
$$z = E_h/\nu$$



HILIGHTS of COMPASS RESULTS on NUCLEON SPIN STRUCTURE

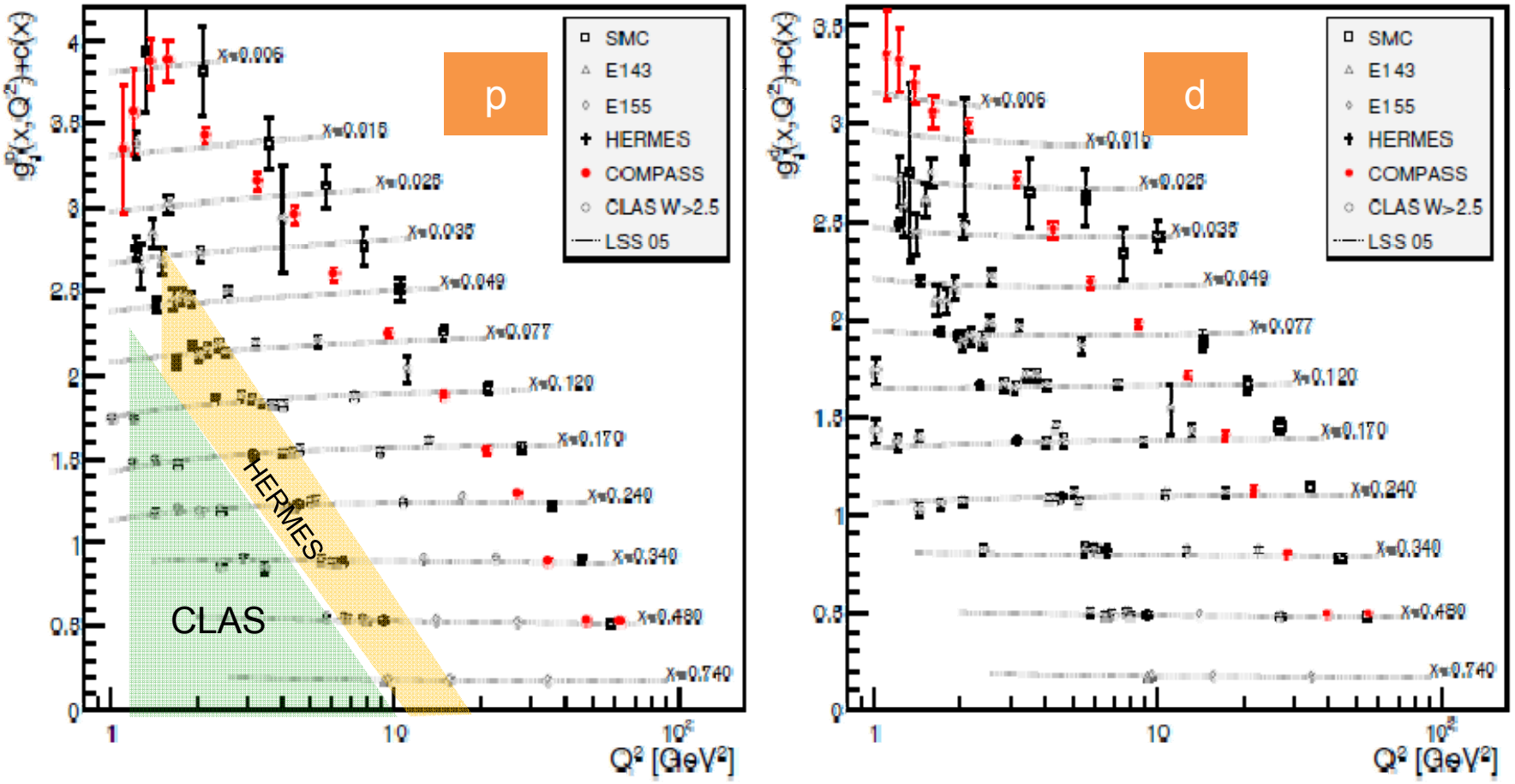
Proton asymmetries

- incl. & semi-incl. asymmetries,
- similar data for deuteron

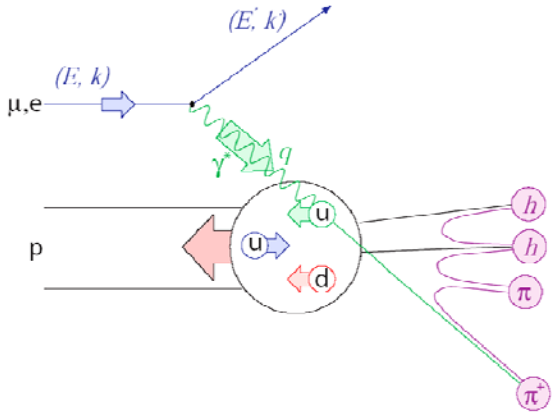


Q^2 evolution of $g_1(x,Q^2)$

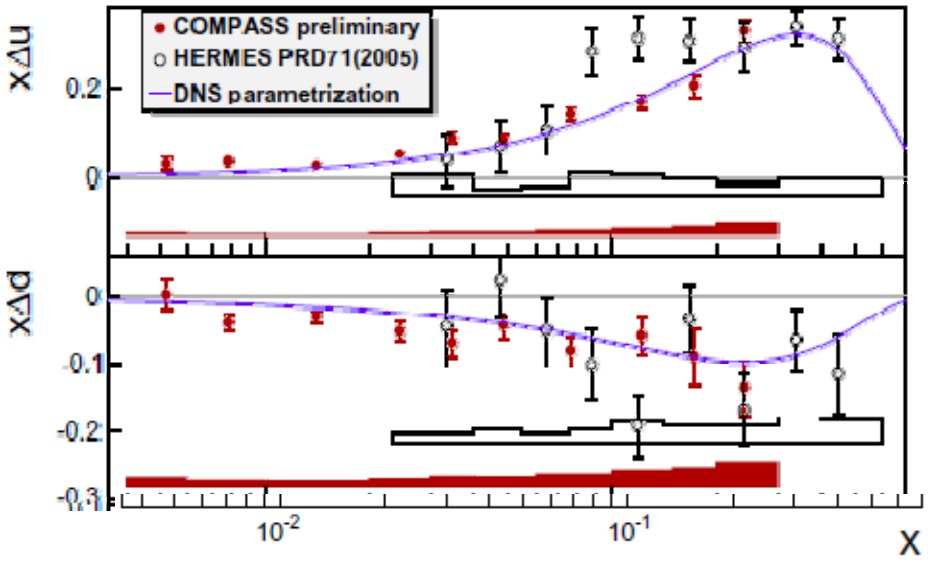
- Q^2 dependence *of* g_1 data related to gluon polarization (DGLAP)
- Limited kinematic range (c.f. unpol. HERA)

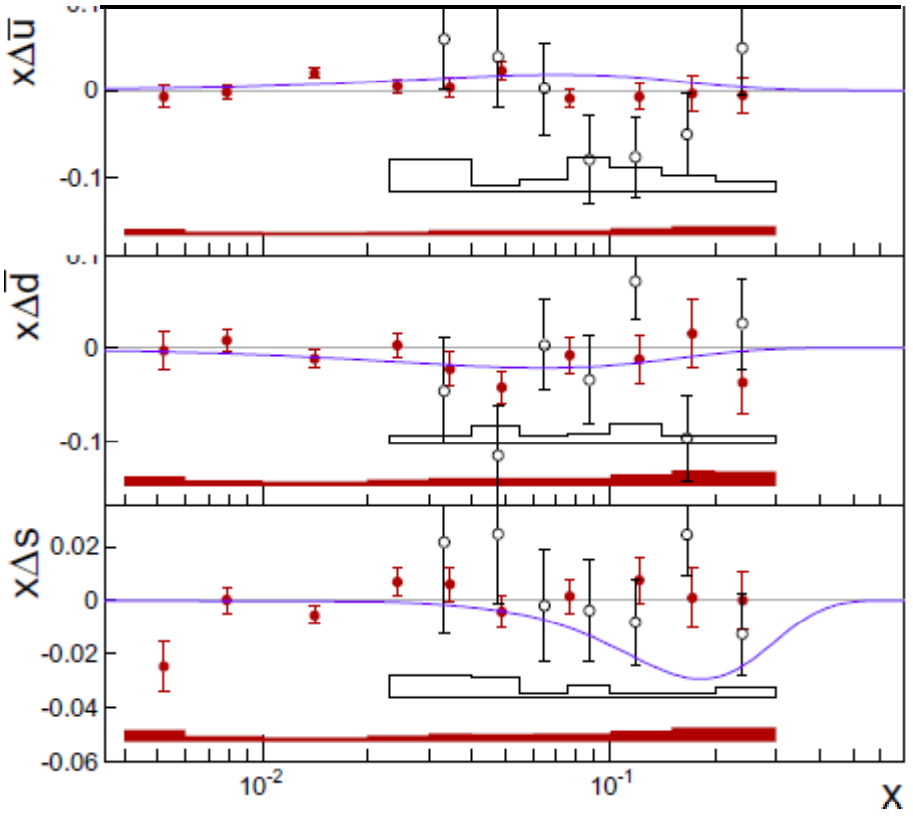


The role of quark flavour



- LO semi-inclusive data analysis

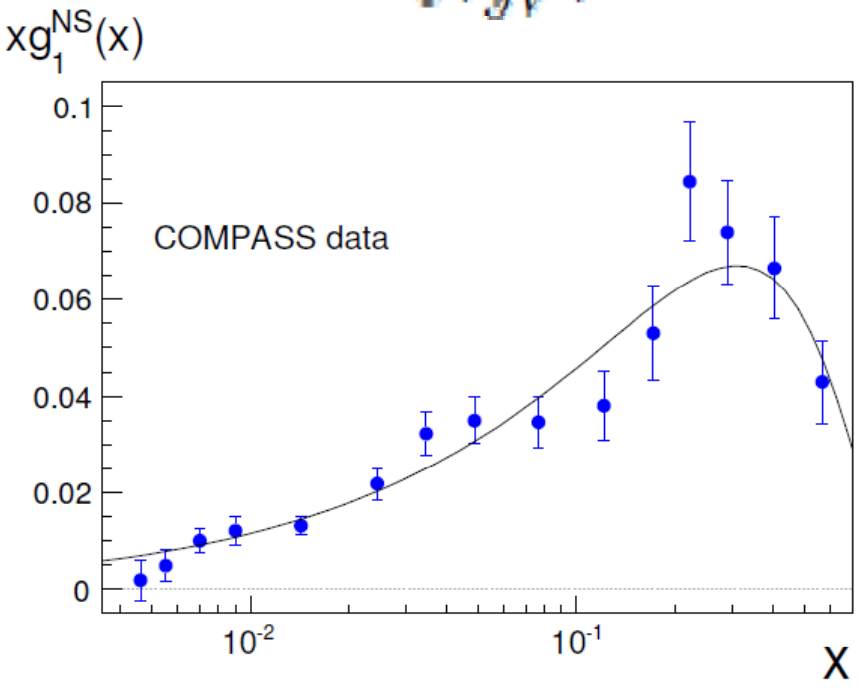


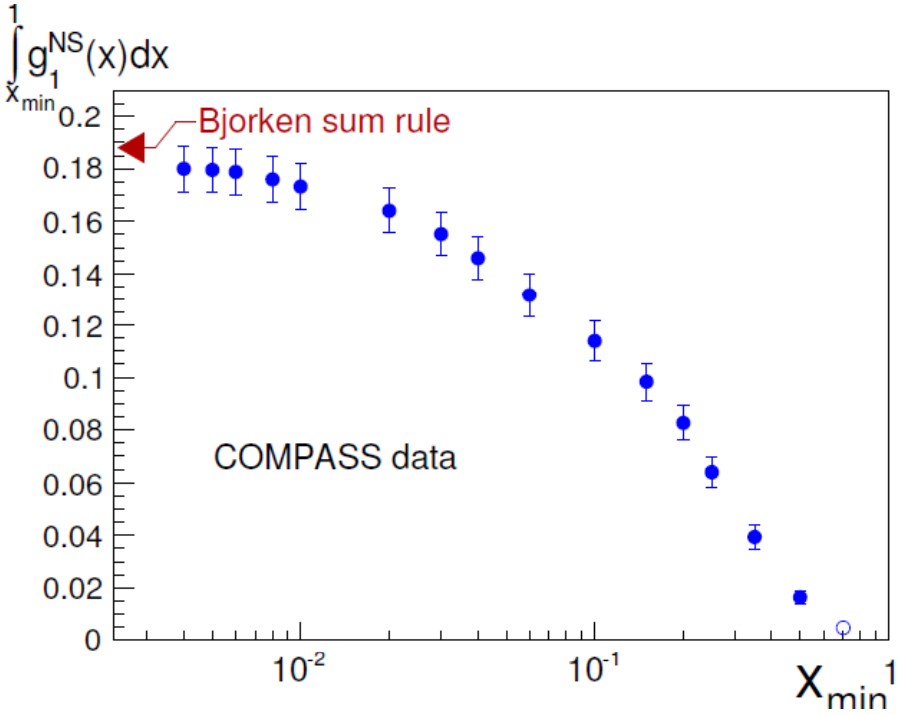


Bjorken sum rule

$$\Gamma_1^{NS}(Q^2) = \frac{1}{6}\left|\frac{g_A}{g_V}\right| C_1^{NS}(Q^2)$$

$$g_1^{NS}(x,Q^2) = g_1^p(x,Q^2) - g_1^n(x,Q^2)$$



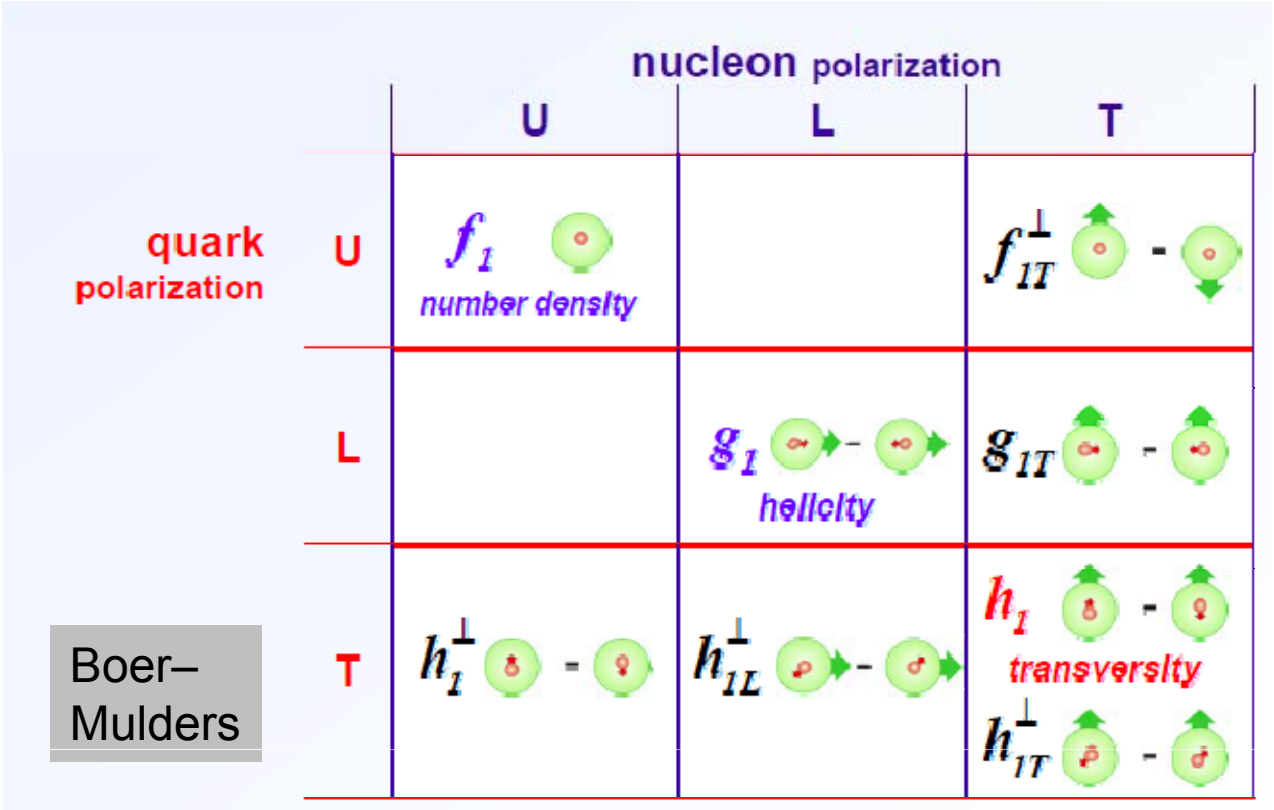


$$|g_A/g_V| = 1.28 \pm 0.07(\text{stat.}) \pm 0.10(\text{syst.})$$

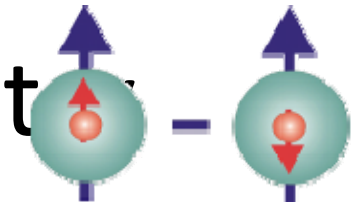
$$|g_A/g_V| = 1.269$$ from neutron β decay

TMD parton distributions

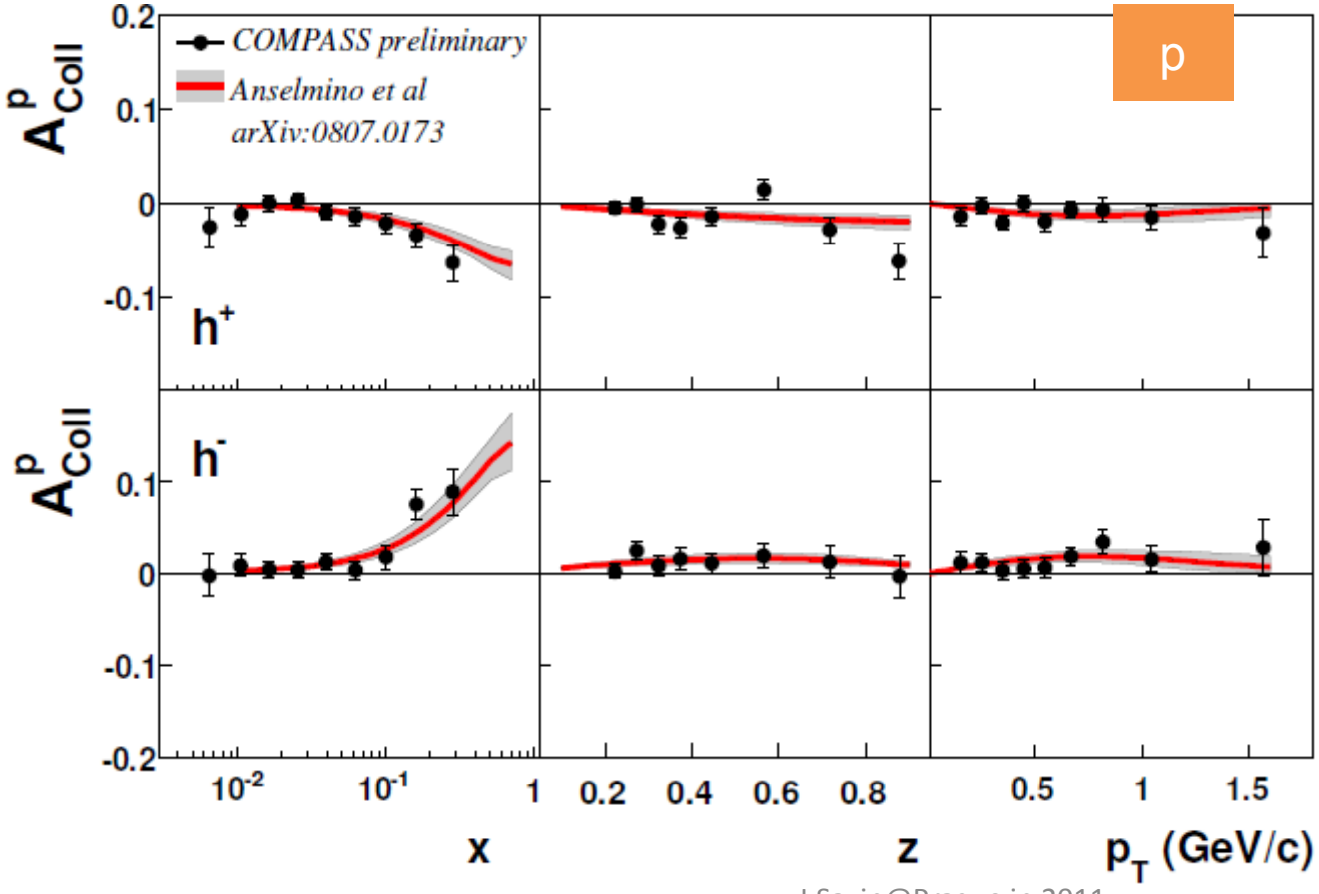
- 8 intrinsic transverse-momentum dependent PDFs at LO
- Azimuthal asymmetries with different angular modulations in the hadron and spin azimuthal angles, Φ_h and Φ_s

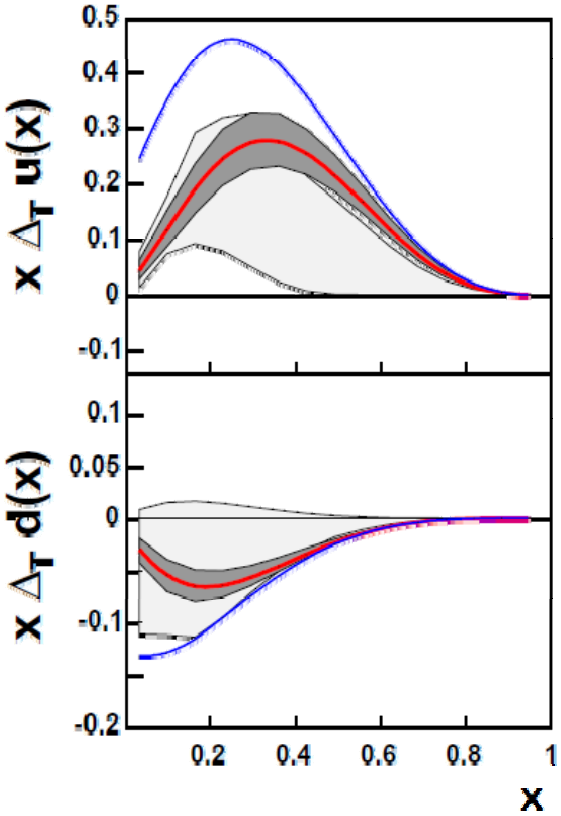


Proton Collins asymmet

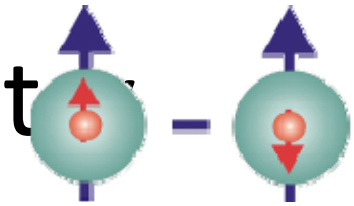


- Fit to COMPASS *d*, HERMES, BELLE (Collins FF, e^+e^-)
- in good agreement with new proton data





Proton Collins asymmet



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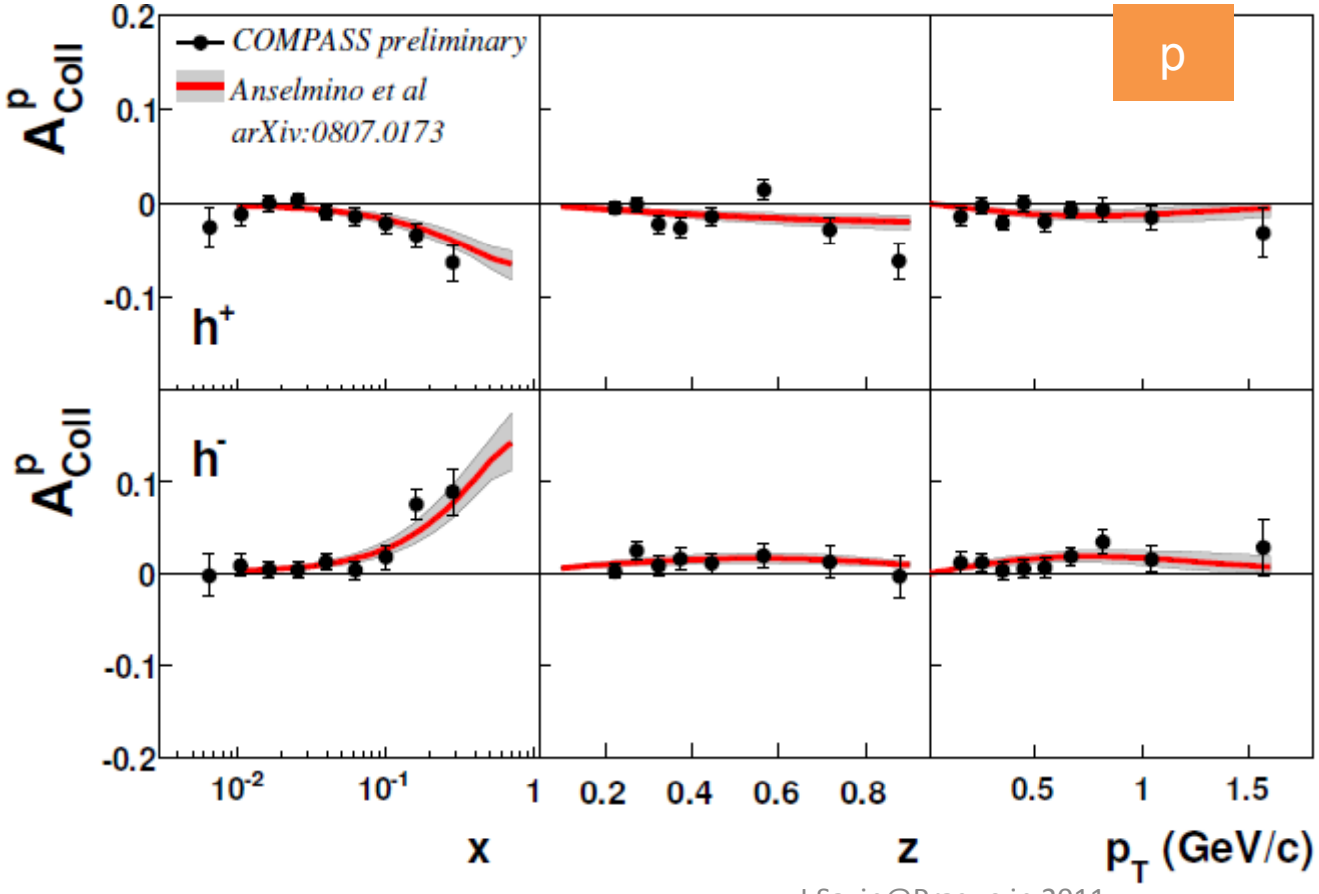

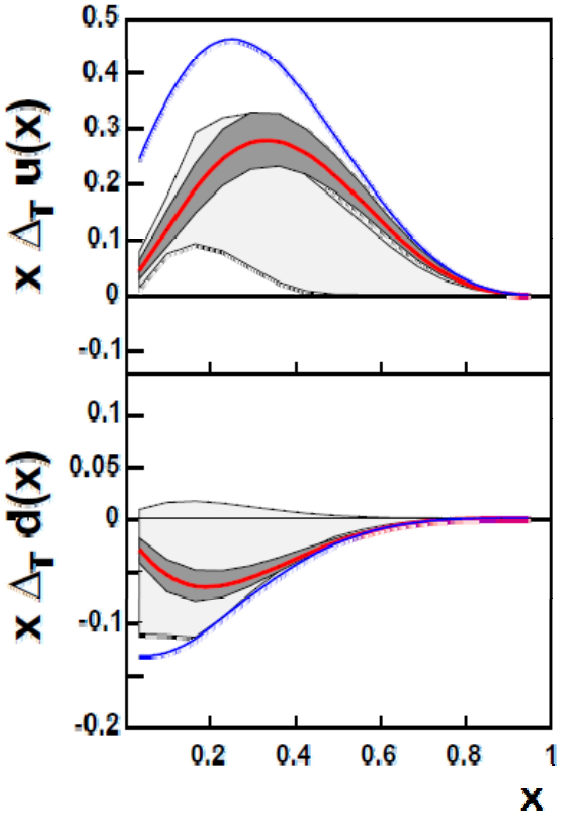

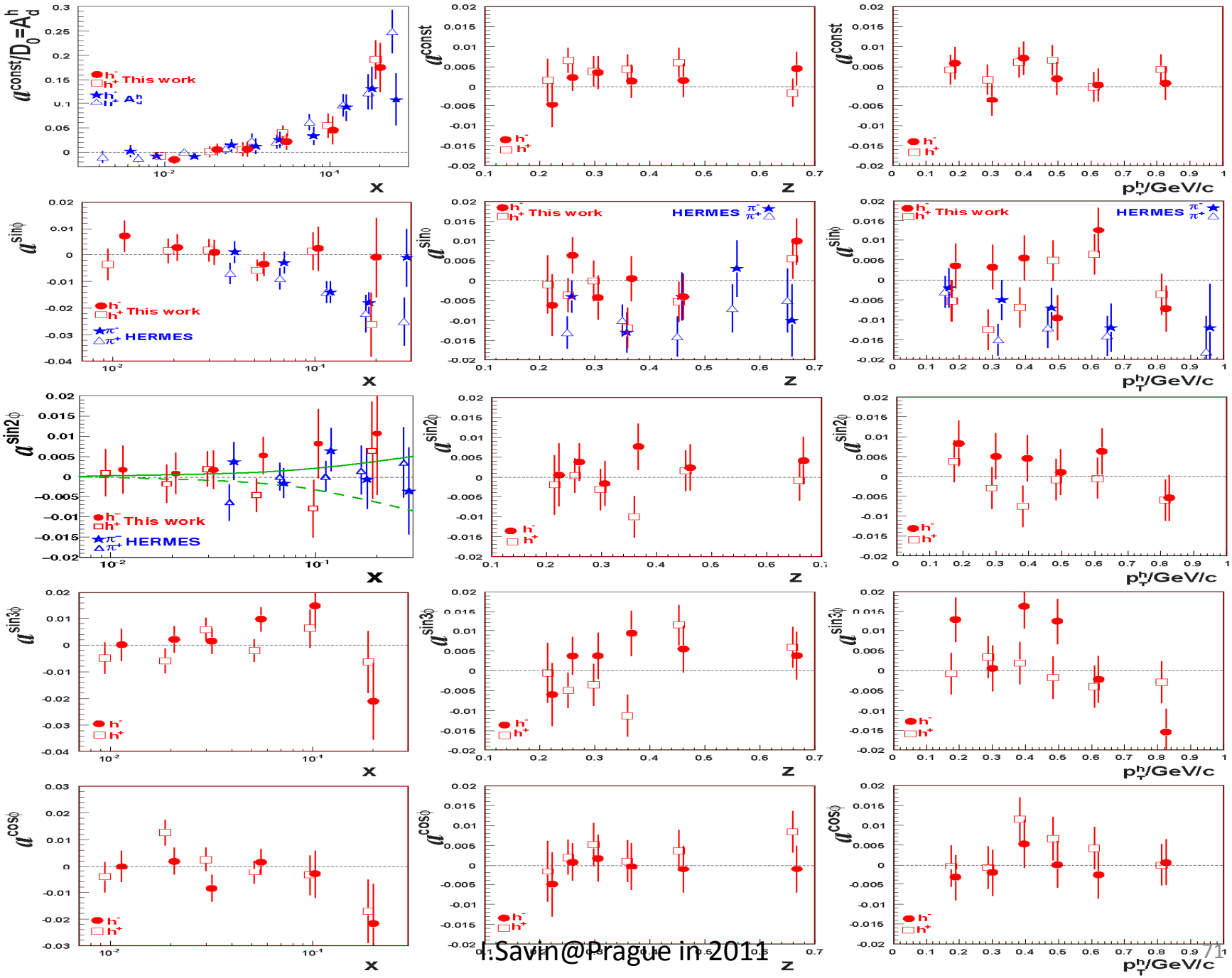
$a^{const}/D_0=A_d^h$
a^{const}
$a^{sin\phi}$
$a^{sin2\phi}$
$a^{sin3\phi}$
$a^{cos\phi}$
h⁻
h⁺
This work
HERMES
A_d^h
x
z
p_T^h/GeV/c

Conclusions

- BIS and NA4 have been the landmark experiments that made original and lasting contributions to the particle physics
- Czech participants of these experiments – J.Cvach, J.Hladky, R.Lednicky, S.Nemechek, M.Nowak, A.Prokesh, P.Reimer, J.Strachota, J.Votruba, J.Zhachek, P.Zavada - can be proud of their contributions
- Experience gained was very important for further participation of Czech physicists in experiments at JINR, DESY, CERN, BNL
- Prague team in COMPASS and annual Prague workshops on spin physics promote the field in the world

Thank you my dear friends and colleagues

Special thanks to Czechoslovakian Academy of Science for awarding me with Gold medal

and to Czech Physics Society for the present valuable award

THANKS TO ALL OF YOU