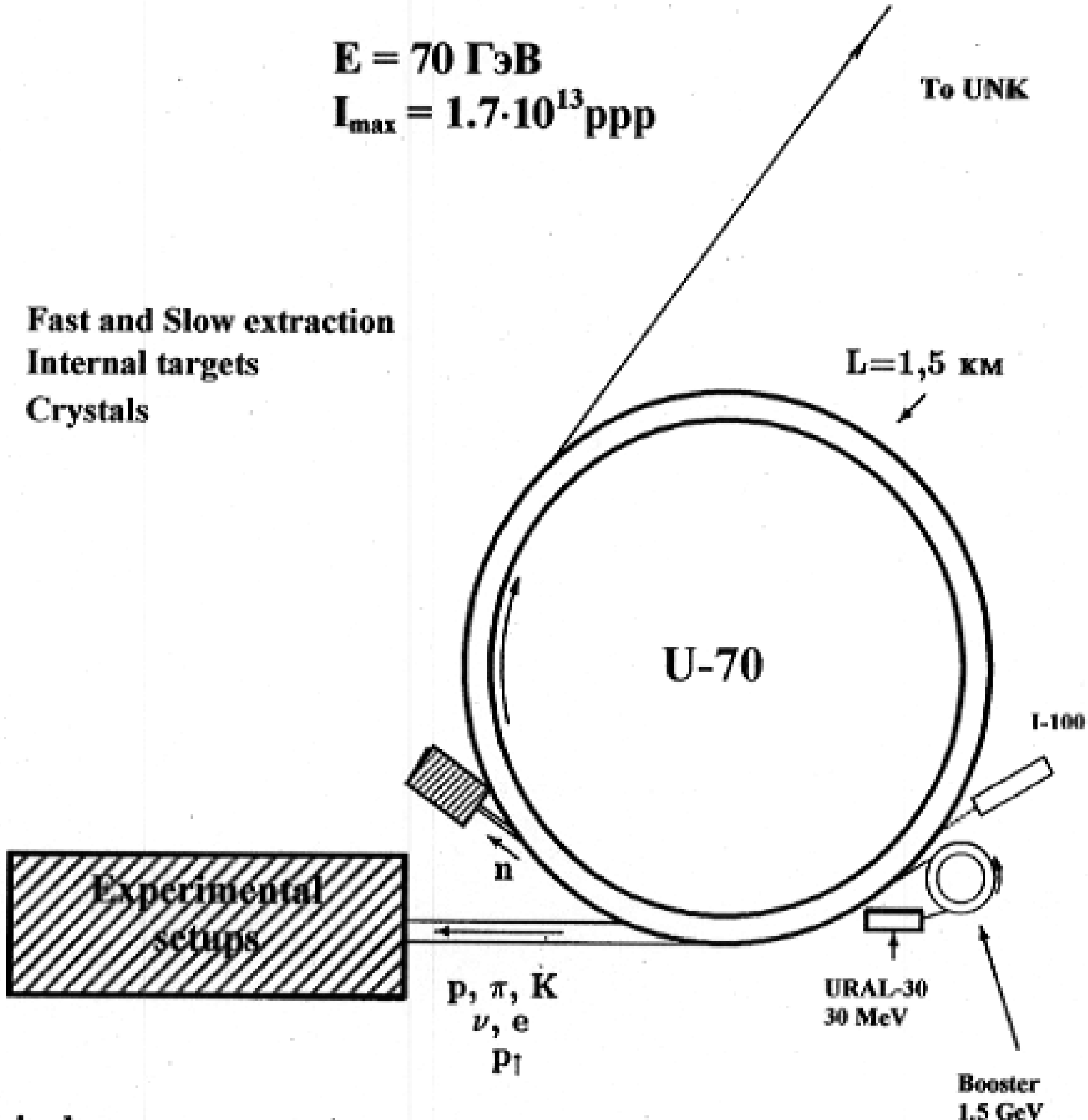
70 GeV proton Synchrotron (U-70)

$E = 70$ ГэВ
$I_{max} = 1.7 \cdot 10^{13}$ppp

- Fast and Slow extraction
- Internal targets
- Crystals



Main beam parameters

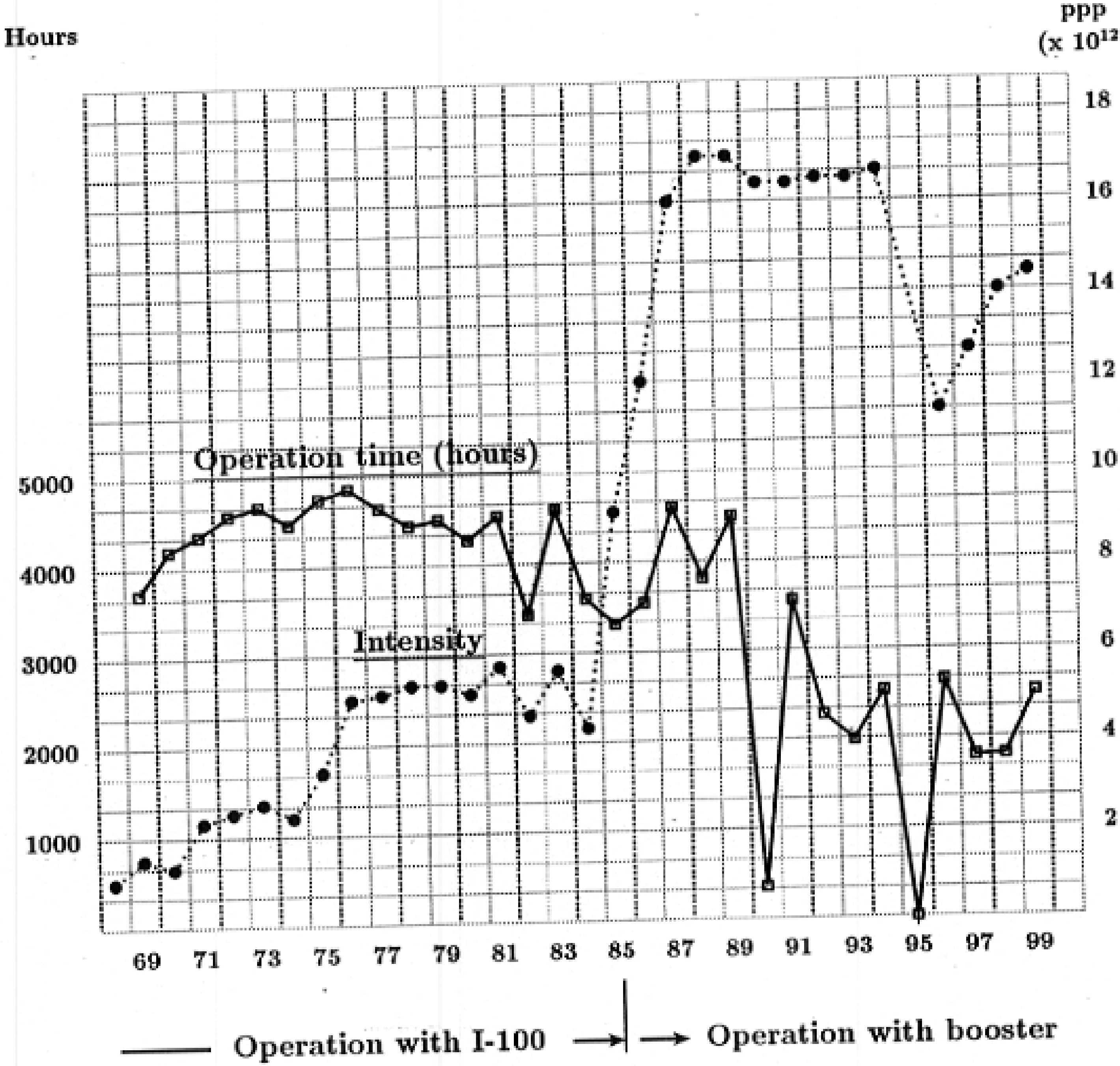
Protons:

	Fast	Slow	Crystals
I	$1{,}5 \cdot 10^{13}$	$\leq 1 \cdot 10^{13}$	$\leq 4 \cdot 10^{11}$
t	5 мкс	≤ 2 с	≤ 2 с

Secondaries:

π^-	20 ÷ 60 ГэВ/с	$10^7 \div 10^6$
K^-	20 ÷ 60 ГэВ/с	$10^6 \div 10^5$
e^-	30 ÷ 40 ГэВ/с	$10^7 \div 10^6$
ν_μ	2 ÷ 20 ГэВ	10^7
p↓	40 ГэВ/с	10^7
n	37 ГэВ	10^7

U-70 OPERATION



Upgrade of U-70

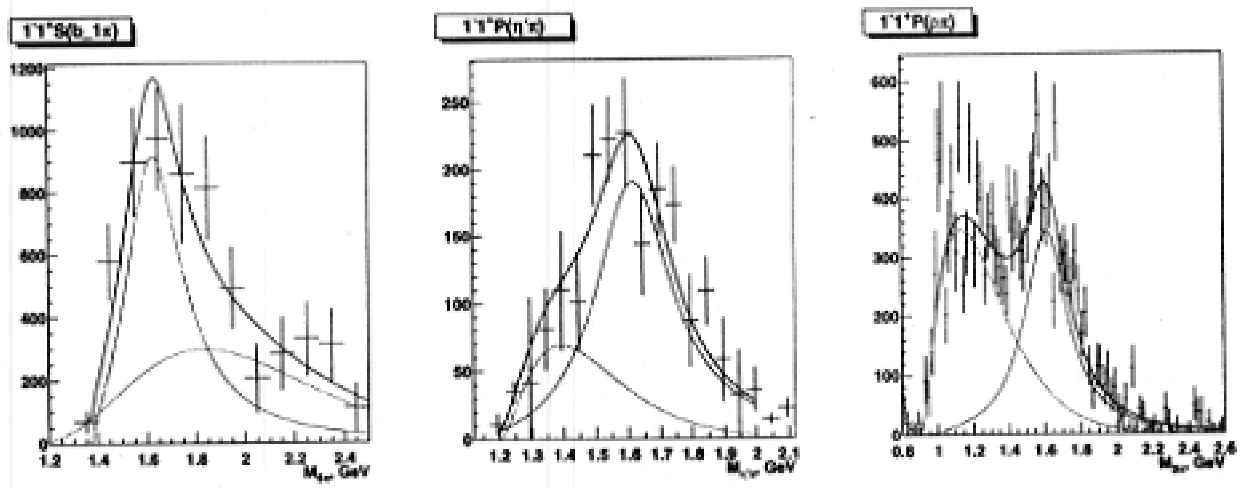
70 GeV PS	• Vacuum chamber	completed
	• RF upgrade	completed
	• Correction system	40 of 120 assembled
	• Controls and Beam Diagnostics	2000
	• Main power supply system	commissioned
Booster 1.5 GeV	• Charge exchange injection	2000
	• Controls and Beam Diagnostics	commissioned
Linac	• RFQ 30 MeV (7 MeV RFQ is ready)	2000
	• Source of H^- (prototype tested)	2000

GOALS

	Intensity (ppp)	Transverse emittance	Longitudinal emittance
Before	$1.7 \cdot 10^{13}$	$\pi \cdot 200\ mm \cdot mrad$	$400\ \frac{MeV}{c} \cdot m$
After	$5.0 \cdot 10^{13}$	$\pi \cdot 150\ mm \cdot mrad$	$300\ \frac{MeV}{c} \cdot m$

Zaitsev
VES

Fit to the $1^{-}1^{+}$ wave intensity in the $b_1\pi$, $\eta'\pi$, $\rho\pi$ channels



$b_1\pi$ $\eta'\pi$ $\rho\pi$

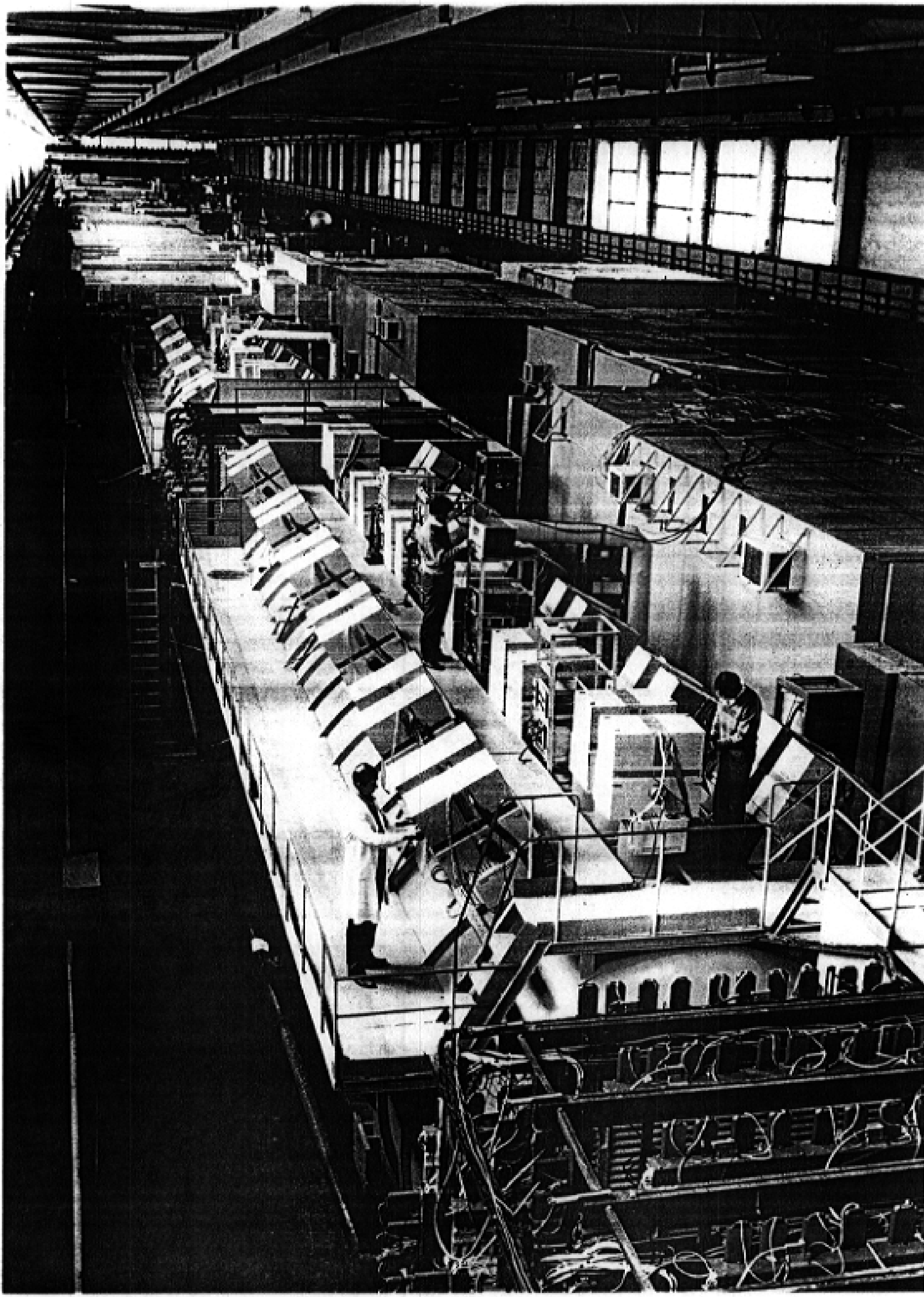
Signal parameters:

$$M = 1.58 \pm 0.03\,GeV,\ \Gamma = 0.30 \pm 0.03\,GeV.$$

if the $b_1\pi$ and $\eta'\pi$ are fitted

$$M = 1.61 \pm 0.02\,GeV,\ \Gamma = 0.29 \pm 0.03\,GeV$$

if the $b_1\pi$, $\eta'\pi$ and $\rho\pi$ are fitted



PROGRAM
of the investigations with U-70 and further perspectives

- Meson Spectroscopy (VES, GAMS-4π)
- Exotic baryons (SPHINX, EXCHARM)
- Rare decays of kaons (ISTRA, TNF)
- Spin effects (RAMPEX)
- Cosmic muons and hadron showers (BARS)
- Experiments with separated kaon beam (project OKA)

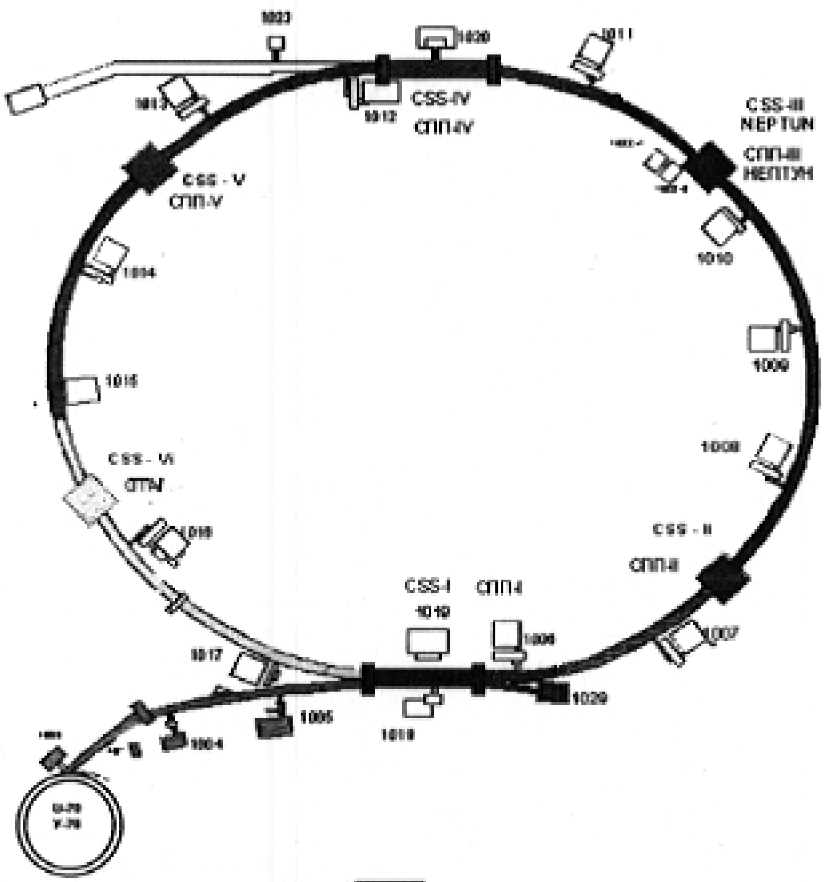
Participants

IHEP, ITEP
INR, PNPI
JINR
MSU, MPhEI

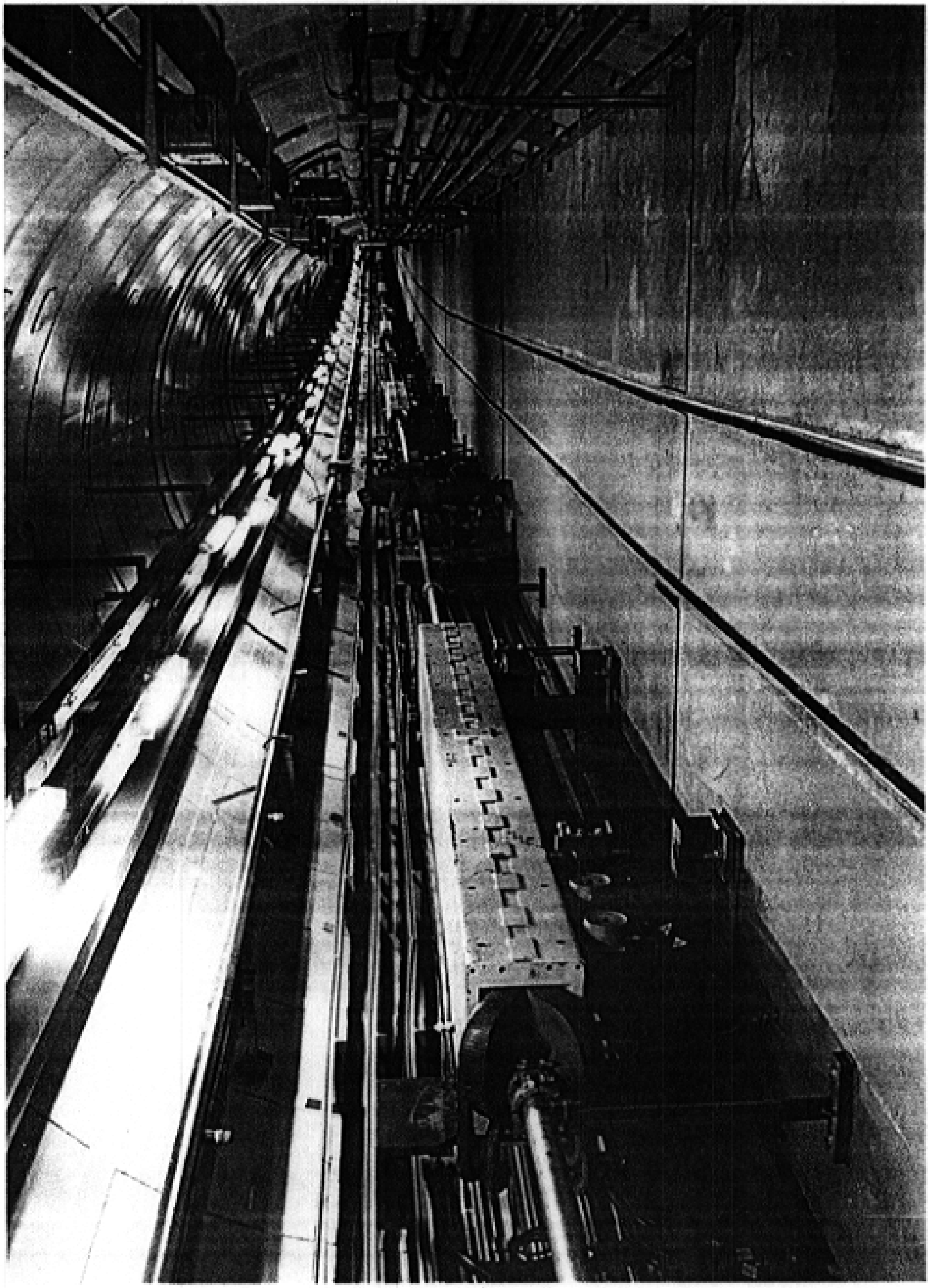
CERN (Italy, Germany, France, Belgium)
UoM (USA)
KEK (Japan)

СОСТО ЯНИЕ ДЕЛ ПО УНК

STATUS OF U-600



Канал инжекции введен в эксплуатацию	Injection system which is under operation
Готовность тоннеля под монтаж электрофизического оборудования - 5,3 км	5,3 km the tunnel ready to hous the electrophysical equipment
Готовность тоннеля под монтаж обще-инженерного оборудования - 10.8 км	10,8 km of the ring tunnel ready to have the conventional components installed
В стадии завершения строительных работ - 4,7 км.	4,7 km of construction work to be completed



IHEP

INTERNATIONAL COOPERATION

1. Physics, Detectors

CERN: DELPHI (LEP), COMPASS (SPS)

ATLAS, CMS, ALICE, LHC-B (LHC)

FNAL: DØ, E-781, MINOS

BNL: E-852, PHENIX, STAR

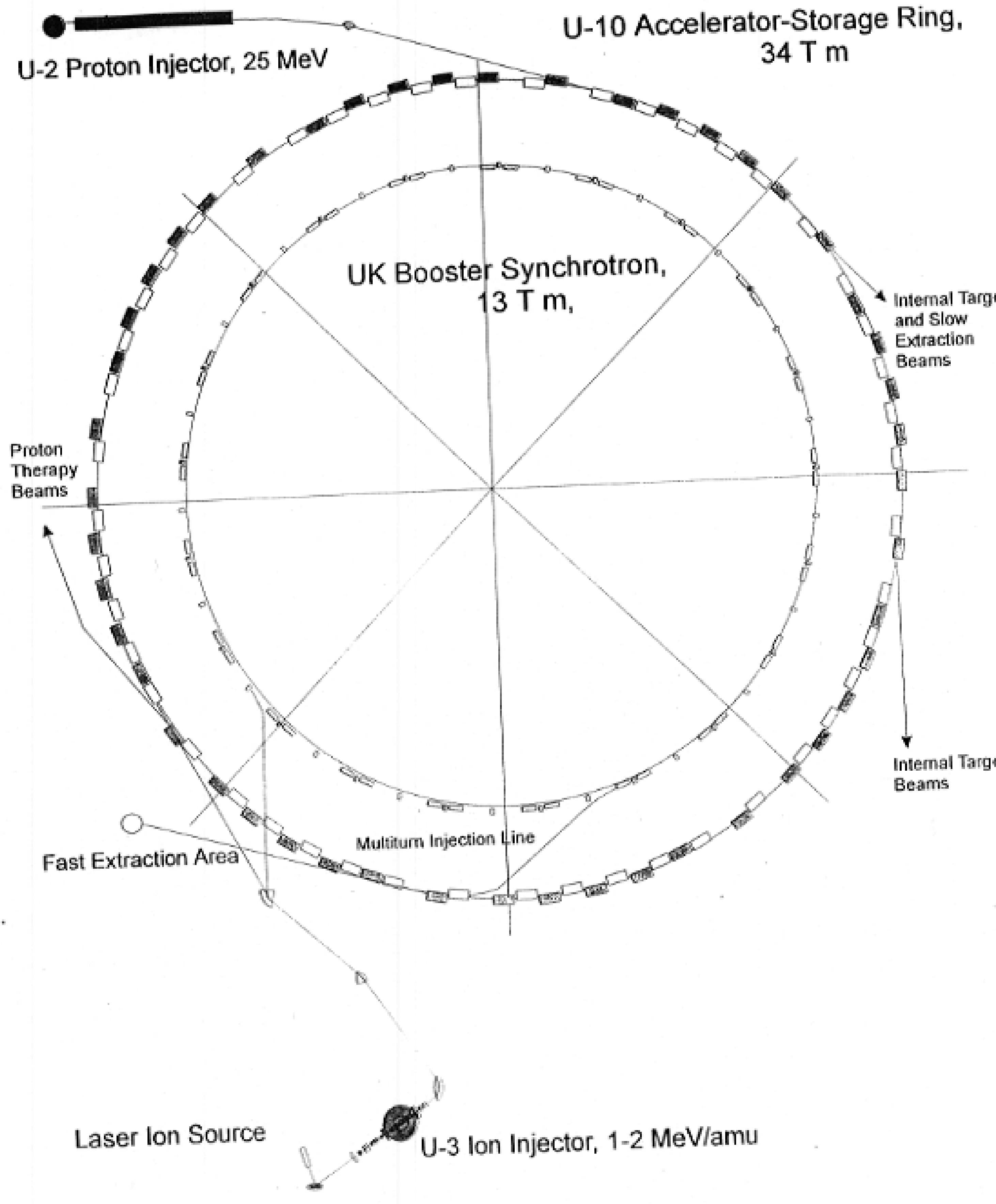
2. Accelerators, Beams

CERN: LHC related tasks (Septum-Magnets for Injection Beam Dump Systems, Energy Dump Resistors, Circuit Breakers, Radiation Fields Calculations, Engineering Design)

FNAL: NuMI (Engineering Design and Calculations, Prototyping)

DESY: 2 Gev TTF-FEL Linac (Beam Dumps, Controls)

250 Gev TESLA



ITEP Accelerator Facility

TWAC - ITEP

Parameters : 10^{13} Co^{25+} $E_i = 0.7$ GeV/u

100 kJ / 100 ns

$P \sim 10$ Tw/g , $\mathcal{P} \sim 120$ Tw/cm^2

special features: Non-Liouvillian stacking technique

prove of final phase space density limitations due to resonances and instabilities

90% hardware operational

can open the way to ignition facility TWAC-2

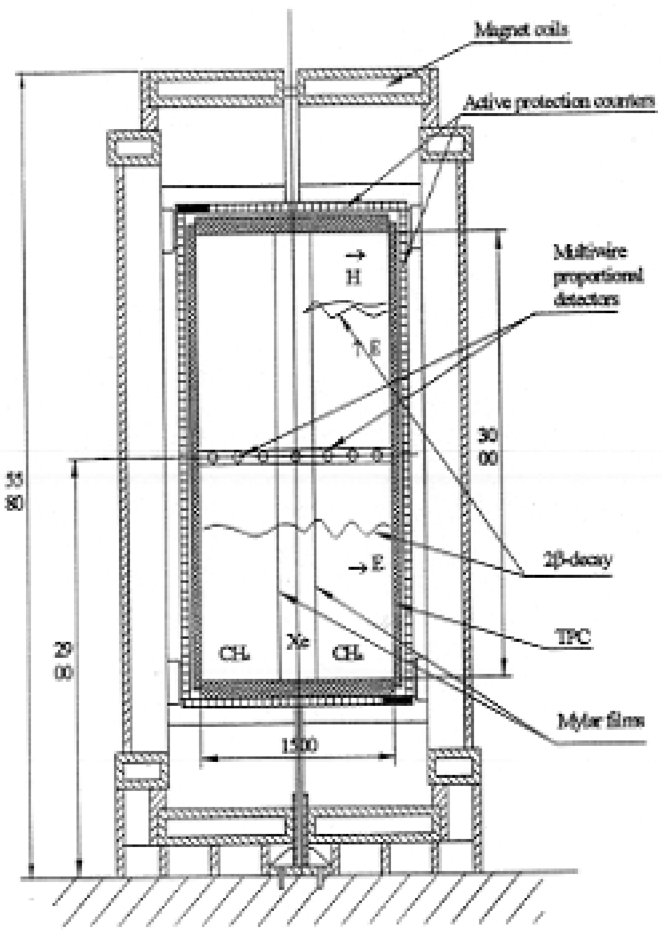
Disadvantages : too high Ei

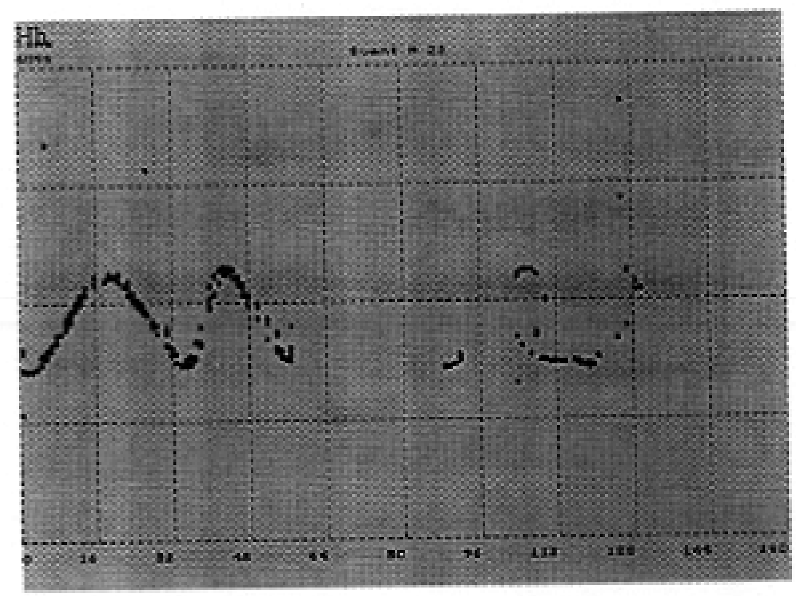
too low ion masses : $A \sim 40 - 60$ a.m.u.

☆ TWAC ⇒ TWAC 2

TPC in magnetic field for $2\beta0\nu$ search (ITEP) 10kg ^{136}Xe

Full visualization of events -> negligible background at sea level





Two projections of detected background event

Sensitivity $T_{1/2}(2\beta0\nu) > 5*10^{24}$ years ($m_{\nu} < 0.5$ev) and even better with ^{150}Nd

Development of High Power Accelerator for Accelerator Driving Systems (ADS)

Development of linear proton accelerator - driver of Electro-Nuclear Systems:

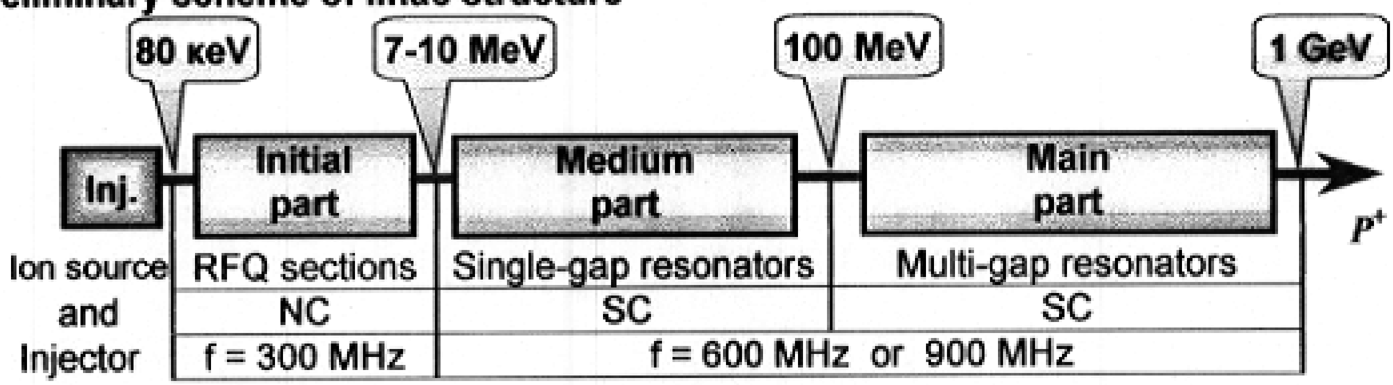
Beam energy	W	= 1 GeV
CW beam current	I	= 30 mA
Beam power	P	= 30 MW

Principal collaborators: ITEP, MRTI, IHEP

Purposes of the ADS:

- transmutation of wastes
- utilization of military Pu
- study of Th fuel cycle as inexhaustible energy resource without of long lived wastes
- high intensity neutron sources for fundamental research
- oecology clean production of tritium

Preliminary scheme of linac structure

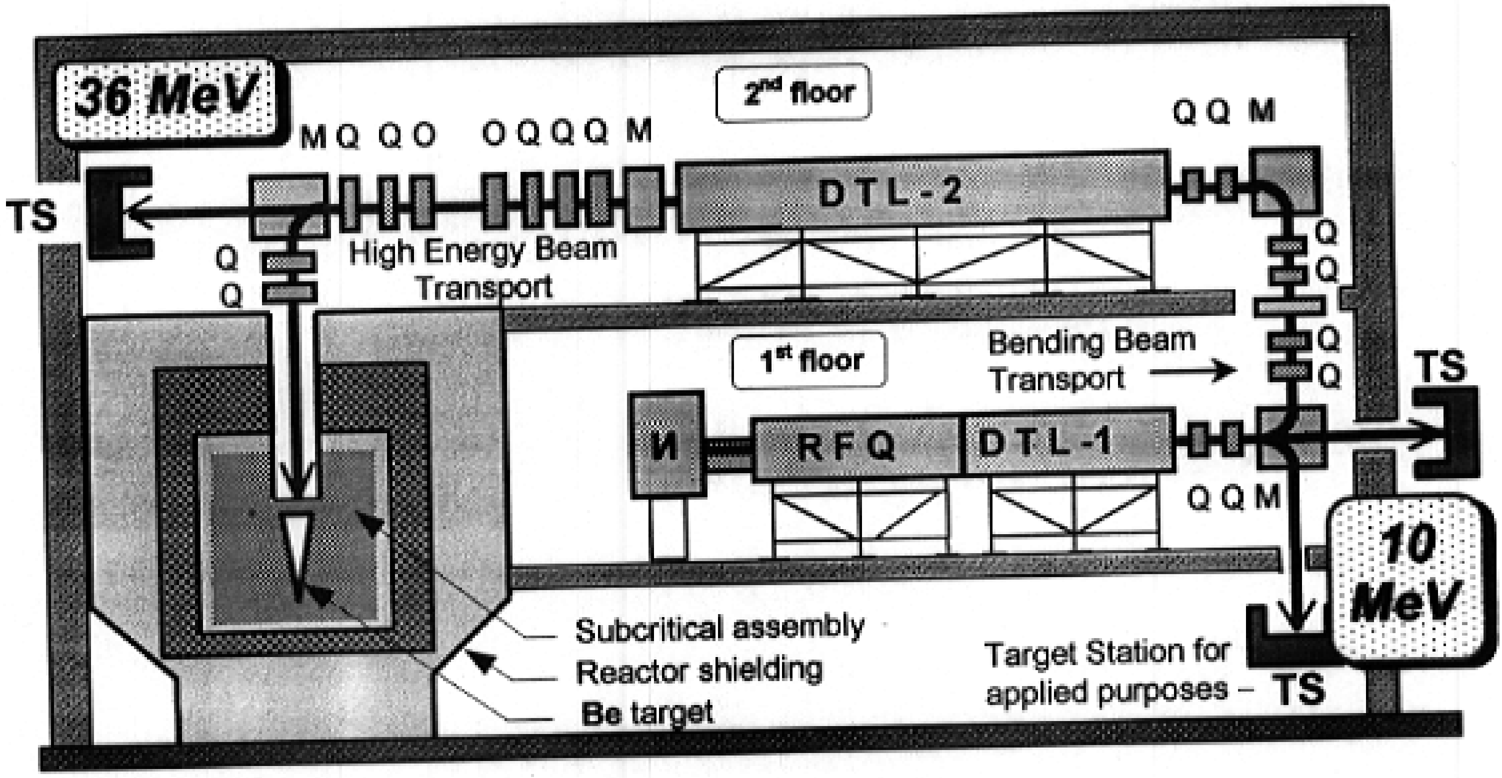


Characteristic properties:

1. **Radiation cleanness:**
   - reduction of particle losses
   - utilize of low-activated materials (graphite, Al and others)
2. **Single-gap or few-gaps cavities in Medium part:**
   - optimal focusing
   - additional decrease of total linac length on 30-40 %
   - simplification of cavities manufacture and tuning
   - non-stop of acceleration process at failure of one or even a few cavities or RF channels

   (Alternative – cylindrical resonators with drift tubes)
3. **Increased reliability of operation:**
   - PMQ's – permanent magnet quadrupoles
   - low voltage injector (≤100 kV instead of former 700-750 kV)
   - non-stop acceleration process in Medium part at failure of one or a few RF channels
   - hot (or stand-by) reserve front-end channel with Injector and Initial part
4. **Ion source** – duoplasmatron type with unheating hollow cathode
   - almost unlimited life time
5. **Economic efficiency**
   - SC (absence of RF loss), diminution of total length linac
   - overall efficiency ~ 50%, full cost of linac is 150-170 M$

Some of physical and engineering solutions will be checked on Linac ISTRA-36 in real condition of experimental ADS facility – ITEP neutron generator



Main facility parameters:

- Proton beam energy	W = 36 MeV
- Average beam current	$I_{avg.}$ = 0,5 мA (may be upgradad up to 5 мA)
- Average beam power	$P_{avg.}$ = 18 кW
- Yield of fast n from target	$3{\cdot}10^{14}$ n/s
- Main multiplyer	^{235}U
- Fuel enrichment of ^{235}U	90 %
- Loading ^{235}U	1,3 кГ
- Moderator and coolant	D_20
- Reflector	D_20; graphite
- k_{eff}	0,95 - 0,97
- Thermal neutrons flux n in experimental channels	$2{\cdot}10^{12}$ n/cm$^2{\cdot}$s
- Thermal power (k_{eff}=0,95)	~ 100 кW

Neutron generator will allow:

- ✓ To develop conceptions of subcritical assembly safe control
- ✓ To study some question of subcritical assembly construction
- ✓ To check validity of blanket calculation codes
- ✓ To produce of cold and ultra-cold (10^{-7}–10^{-8} eV) neutron source for fundamental researches

Structure of Linac:

RFQ (3 MeV; 150 MHz) – DTL1 (10 MeV; 300 MHz) – DTL2 (36 MeV; 300 MHz)

Operation mod – pulse: I_{pulse} = 100 mA

P_{pulse} = 3.6 MW

t_{pulse} = 220 μs

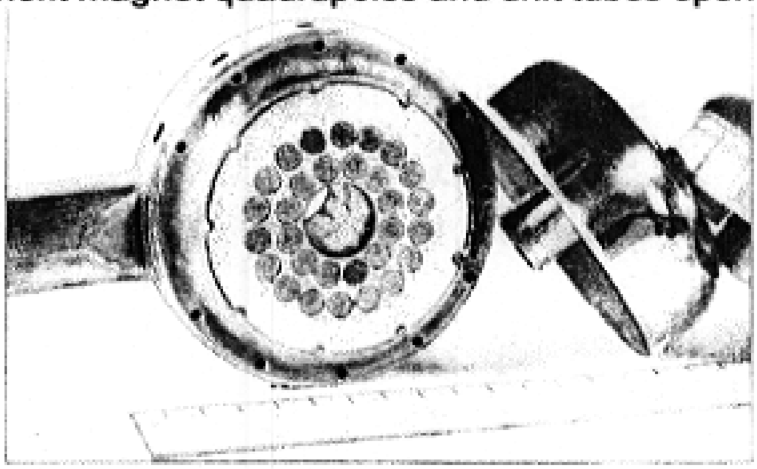
$F_{rep.}$ = 25 Hz

Linac – Driver of ITEP's neutron generator will be allowed:

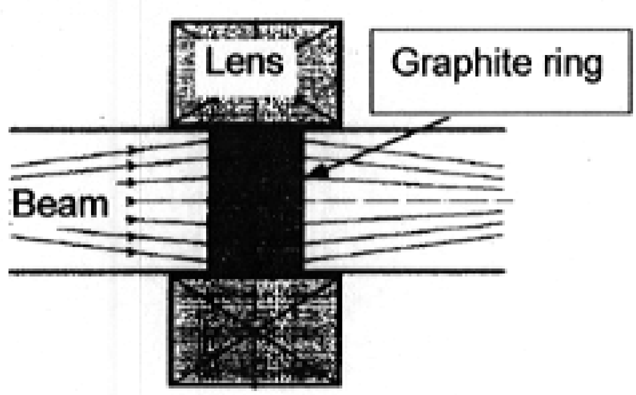
- ✓ To carry out experimental study of characteristic property of Linac operation as facility driver (including off-normal condition)
- ✓ To find and to develop physical and engineering solutions for full-scale ADS Linac-Driver
- ✓ To produce medical, biological and industrial radio-nuclides
- ✓ To carry out radiation tests of materials and things

On Linac ISTRA-36 as on High Power Prototype will be checked (and partly checked now yet):

1. PMQ's - permanent magnet quadrupoles and drift tubes open to high vacuum



2. Graphite absorbers of lost particles



Joint experiments with ITEP participation

CERN	L3
	CHORUS
	OPERA
	ATLAS
	CMS
	ALICE
	LHCb
DESY	H1
	HERA-B
GSI	4π
	HADES
COSY	ANKE
FREJUS	NEMO
ILL	PAVIF
INFN, DAFNE	KLOE
GRAN SASSO	DBA
CELSIUS	WASA
CANFRANC	IGEX
FNAL	SELEX
	CDF
	D0
	MINOS
TJNAF	CLAS

Date: Thu, 23 Sep 1999 23:25:14 +0400
From: Leonid Bezrukov <bezrukov@ms2.inr.ac.ru>
To: "A.N.Skrinsky" <skrinsky@npd.msk.su>
Subject: NICFA meeting
Aleksandr Nikolaevich, below there is the text for publication in NICFA proceedings. Is it O'K?

Status of the non accelerated high energy physics in Institute for Nuclear Research of Russian Academy of Sciences

The Russian American Gallium Experiment (SAGE) observes the reaction 71Ga(neutrino,e)71Ge produced by solar neutrinos. 71Ge atoms are chemically extracted and observed by the subsequent decay. The threshold for this reaction is 233 keV, so that the gallium experiment is sensitive to all of the neutrino-producing reactions in the Sun. The prospect exists that the gallium experiment may be manly sensitive to particle physics effects, as the flux of p-p neutrinos is essentially independent of solar modeling.

SAGE uses the Gallium-Germanium Neutrino Telescope situated in an underground laboratory specially built at the Baksan Neutrino Observatory of the Institute for Nuclear Research of Russian Academy of Sciences in Northern Caucasus Mountains. Los Alamos National Laboratory is the main among US participants.

SAGE initially used 30 tons and at present employs about 50 tons of gallium in the form of the liquid metal.

To check the overall experimental efficiency the calibration experiment was made by using a reactor produced 517-kCi source of 51Cr.

SAGE has measured a 71Ge production rate twice below of a value predicted by solar model.

Another Ga experiment, GALLEX Collaboration, also observes the same low rate. Other solar neutrino experiments observe significant deficits below solar model prediction. This result of SAGE can be considered as the evidence of existence of neutrino oscillations.

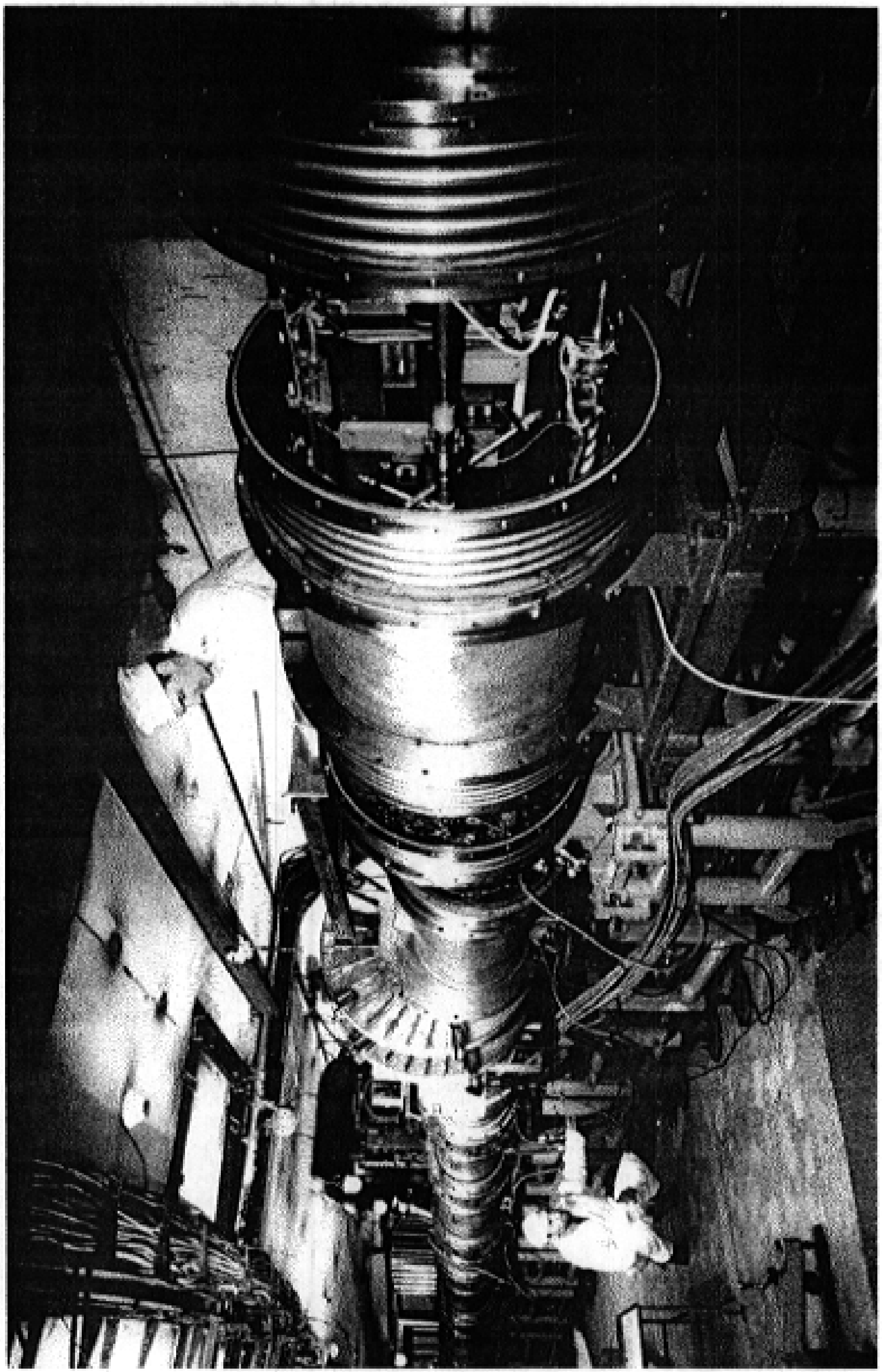
At present SAGE continues the observations.

The deep underwater Neutrino Telescope (NT-200) is deployed in Lake Baikal, Siberia, 3,6 km from the shore at a depth 1,1km. Russian and German physicists take part in this experiment.
Institute for Nuclear Research of Russian Academy of Sciences is the main among Russian participants; DEZY-IfH represents the Germany side.

NT-200 was put into operation in 1998 and consists of 192 optical modules recorded the Cherenkov light. Trajectory of muons can be reconstructed by using the time information. The energy threshold for muon events is 10 GeV. The signature of neutrino induced events is a muon crossing the detector from below to up.

The first atmospheric neutrinos have been identified; limits on the fluxes of magnetic monopoles as well as of neutrinos from WIMP annihilation in the center of the Earth have been derived.

In the following years NT-200 will be operated as a neutrino telescope with the effective area between 1000 and 5000 sq. m. depending on the energy. It will also be a unique environmental laboratory to study water processes in Lake Baikal by using of luminescence of Baikal waters. Apart from these goals NT-200 is regarded to be a prototype for the development a telescope of next generation with lager effective area.



Joint Institute for Nuclear Research

Of course, you know, that the high energy physics programme is developed at the Joint Institute for Nuclear Research in a very wide scale. It is actually impossible to tell about all investigations in this field at JINR during several minutes. So, I would like to emphasize the most significant internal and external current activities being realized in this Institute in the framework of HEP Programme.

1. Internal HEP Programme

Nuclotron

The Nuclotron is a new superconducting (SC) synchrotron with a ring of 251 m in perimeter and based on a miniature iron-shaped field SC-magnets. It will provide a wide programme of research in relativistic nuclear physics. This complex will allow to accelerate nuclei from hydrogen to uranium with the intensity from 10^3 to 10^8 particles per pulse and the energy of 6-7 GeV per nucleon.

A significant progress was achieved in the construction of the Nuclotron beam slow extraction system. In the beginning of the September 1999 a part of the Nuclotron ring with the elements of the slow beam extracted system was fully assembled (see transparency). The run whose main task is to obtain the beam extracted from the Nuclotron will be carried out in the end of September according to the schedule.

2. External HEP Programme. Participation in LHC

ATLAS

One of the major JINR activities in ATLAS is focused on the Hadron Barrel Tile-Calorimeter. During last years the mass production of modules for this calorimeter was organized at JINR. The transparency shows the ZERO MODULE for the Hadron Barrel Tile-Calorimeter at the JINR Workshop on 6 meters in diameter rotating table of milling-boring shop-machine. Two modules were manufactured in this year. Recently the second module has been delivered to CERN.

CMS

JINR is participating in the CMS project in the framework of the Russia and Dubna Member States Collaboration. The involvement of the Member States in this activity through RDMS has given them an opportunity to play leading roles and to contribute significantly to the preparation of the hadron calorimeter, electromagnetic calorimeter and the muon detector.

Following the JINR order, in Belarus a full-scale prototype of the Endcap hadron calorimeter adsorber was developed. A special production line was organized at one of the Minsk plants, equipped with highly accurate machines to produce the adsorber and the support system of the Endcap hadron calorimeters.

LHC Damper

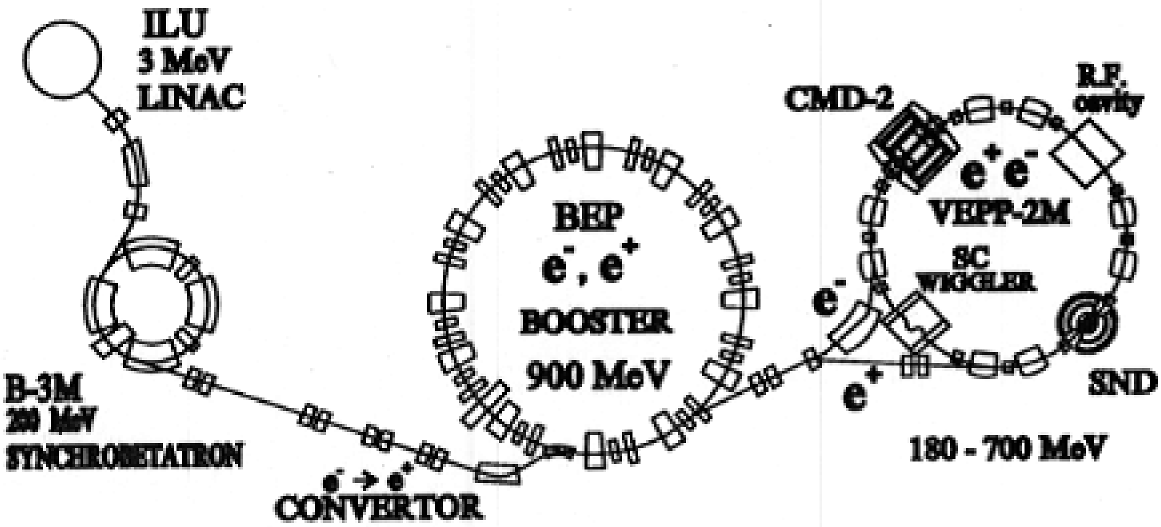
One of the main goals of the JINR participation in LHC Project is to manufacture a wideband amplifier and an electrostatic kicker for the Transverse Feedback System for LHC.

The experts of CERN approve a course of works and achieved results. The plan of the nearest activity on production of the prototype of system was co-ordinated.

At the present time the box of the amplifier is made; one channel of amplification in classical variant is assembled and tested. The manufacturing of a kicker's model is near to finish at JINR workshops. Simultaneously there is a search of materials for the prototype under the standards of CERN.

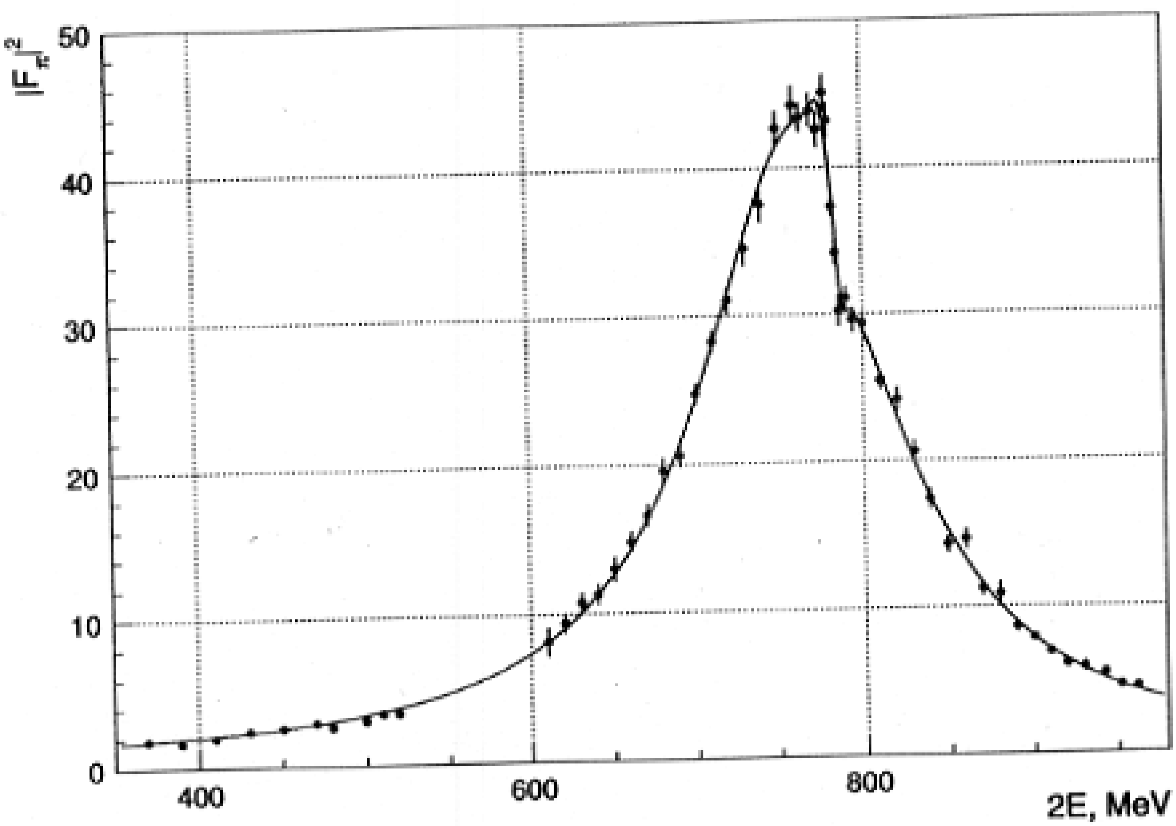
I'd like to point out that in general JINR fulfils its obligations totally.

VEPP-2M Collider Complex



- VEPP-2 - world first e^+e^- machine, operated from 1965 to 1970,
- VEPP-2M - operates since 1974,
- $2E = 0.4 \div 1.4$ GeV,
- $L_{max} = 4 \cdot 10^{30} cm^{-2} sec^{-1}$ at $E_0 = 510 MeV$,
- Total integrated luminosity $\simeq 80 pb^{-1}$.

A fit of CMD-2 (94,95,96) data



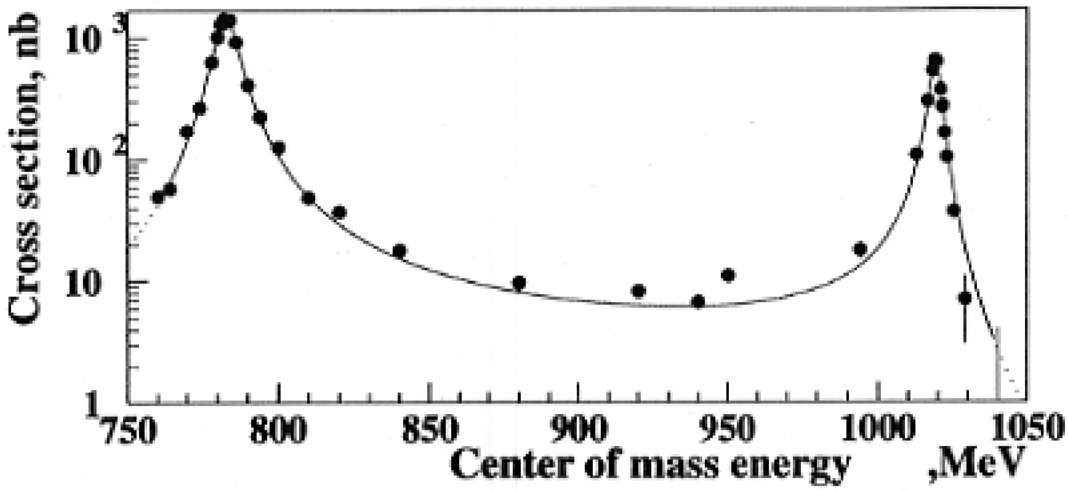
ρ meson parameters

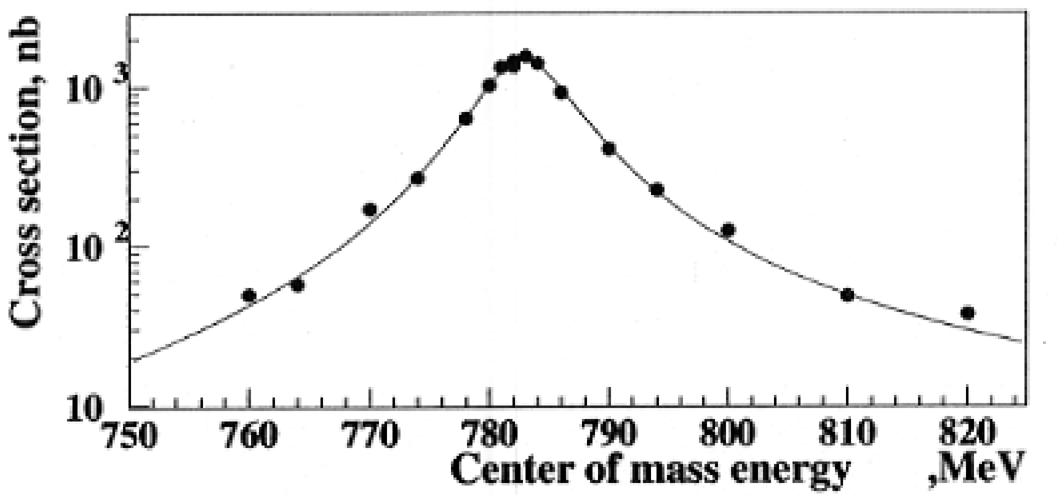
	CMD-2 94-95 data	PDG-98 $e^+e^- + \tau$ data
M_ρ, MeV	$775.3 \pm 0.6 \pm 0.2$	776.0 ± 0.9
Γ_ρ, MeV	$147.7 \pm 1.3 \pm 0.4$	150.5 ± 2.7
$\Gamma(\rho \to e^+e^-)$, keV	$6.93 \pm 0.11 \pm 0.10$	6.77 ± 0.32
$Br(\omega \to \pi^+\pi^-)$, %	1.31 ± 0.23	2.21 ± 0.30 [a]
$< r_\pi^2 >$, fm^2	$0.421 \pm 0.002 \pm 0.003$	

[a] Our fit gives (1.88 ± 0.31)%.

CMD-2 94-96 data : 130000 $e^+e^- \to \pi^+\pi^-$ events total.

$e^+e^- \to \pi^+\pi^-\pi^0$ measurements with CMD-2 detector





- Total integrated luminosity:
  at ϕ-meson — 1425 nb^{-1} (1993)
  at ω-meson — 1546 nb^{-1} (1998)
  between ω and ϕ — 1620 nb^{-1} (1998)
  above ϕ-meson — 5760 nb^{-1} (1997)

	PDG data	CMD2 results (~10% of statistic analysed)
m_ω, MeV	781.94 ± 0.12	$782.71 \pm 0.07 \pm 0.04$
Γ_ω, MeV	8.41 ± 0.09	$8.68 \pm 0.23 \pm 0.10$
Γ_{ee}, keV	0.60 ± 0.02	$0.605 \pm 0.014 \pm 0.010$

- Total number of $e^+e^- \to \pi^+\pi^-\pi^0$ events ~ 50000

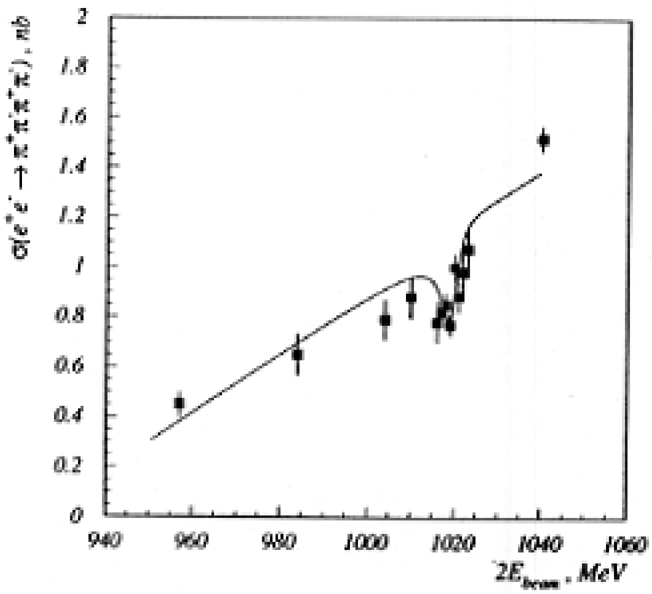
Analysis of the $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$

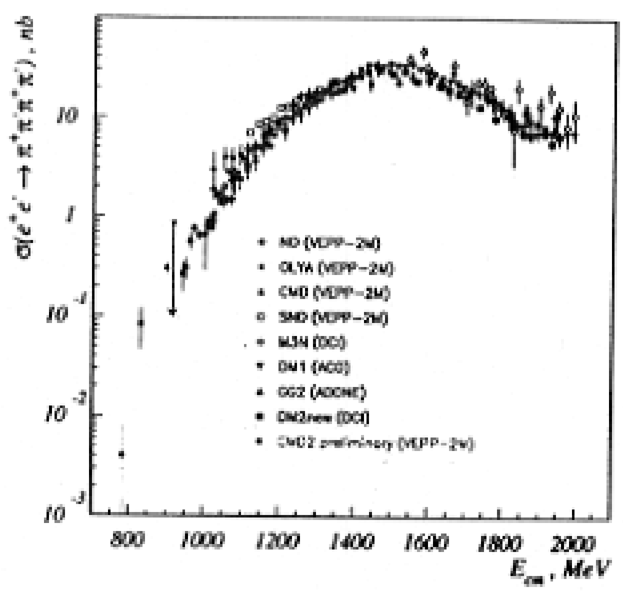
$L = 21\ pb^{-1}$; $0.6 < 2 \cdot E_{beam} < 1.38$

$N_{track} = 4$; $\left|\Sigma_i\ E_i - 2E_{beam}\right| < 0.1 \cdot 2E_{beam}$, $min\ \psi(\pi^+\pi^-) > 0.3$

Kinematic fit

- Energy-momentum conservation





OZI and G suppresed decay of ϕ-meson

$$Br(\phi \to \pi^+\pi^-\pi^+\pi^-) = (0.77 \pm 0.21 \pm 0.20) \cdot 10^{-5}$$

$730 < 2E_{beam} < 810$ MeV ; $N_{event} = 3$; $N_{bckgr} = 1$

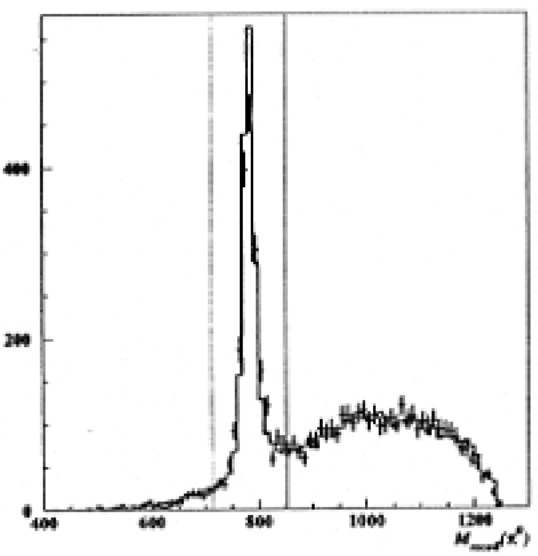
$$\Gamma(\rho \to \pi^+\pi^-\pi^+\pi^-) < 3\ keV\ at\ 90\%\ CL$$

Analysis of the $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$

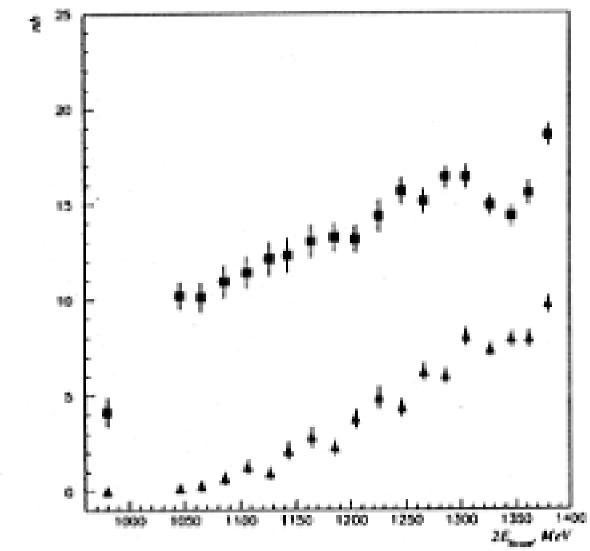
$L = 5.8\ pb^{-1}$; $1.05 < 2 \cdot E_{beam} < 1.38$
$N_{track} = 2$; $N_\gamma (E_\gamma > 20\ MeV) > 3$

Kinematic fit

- Energy-momentum conservation
- $M_{inv}(\gamma_1\gamma_2) = m_{\pi^0}$, $M_{inv}(\gamma_3\gamma_4) = m_{\pi^0}$
- $min(|M_{recoil}(\pi^0) - m_\omega|) < 70\ MeV$ ($\omega\pi^0$ mainly)
- $min(|M_{recoil}(\pi^0) - m_\omega|) > 70\ MeV$ ($\pi^+\pi^-\pi^0\pi^0$ mainly)



π^0 recoil mass
for $\pi^+\pi^-\pi^0\pi^0$



upper points - $\sigma(e^+e^- \to \omega\pi^0)$
lower - $\sigma(e^+e^- \to \pi^-\pi^+\pi^0\pi^0)$

Study of dynamics shows the dominance of $a_1(1260)\pi$ channel in the $e^+e^- \to \pi^-\pi^+\pi^0\pi^0$ reaction

Hadronic Contributions to $a_\mu = (g-2)_\mu$

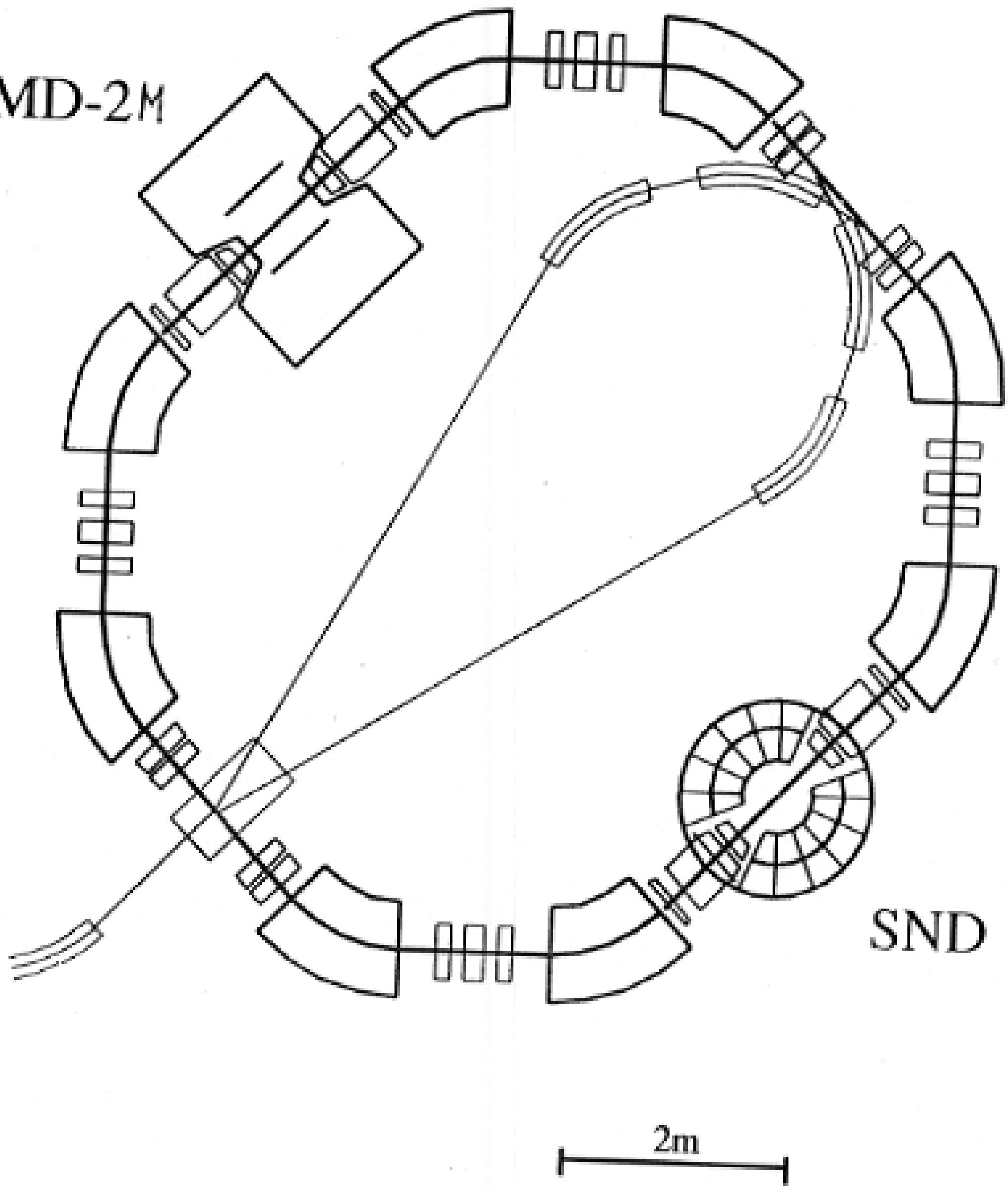
The experimental uncertainty (in 10^{-10})
$\Delta a_\mu^{had} = 73$
should be improved at E821 (BNL) to ~ 4

The electroweak contribution is 15 ± 1
The hadronic contribution is 696 ± 15

Improvements from e^+e^-

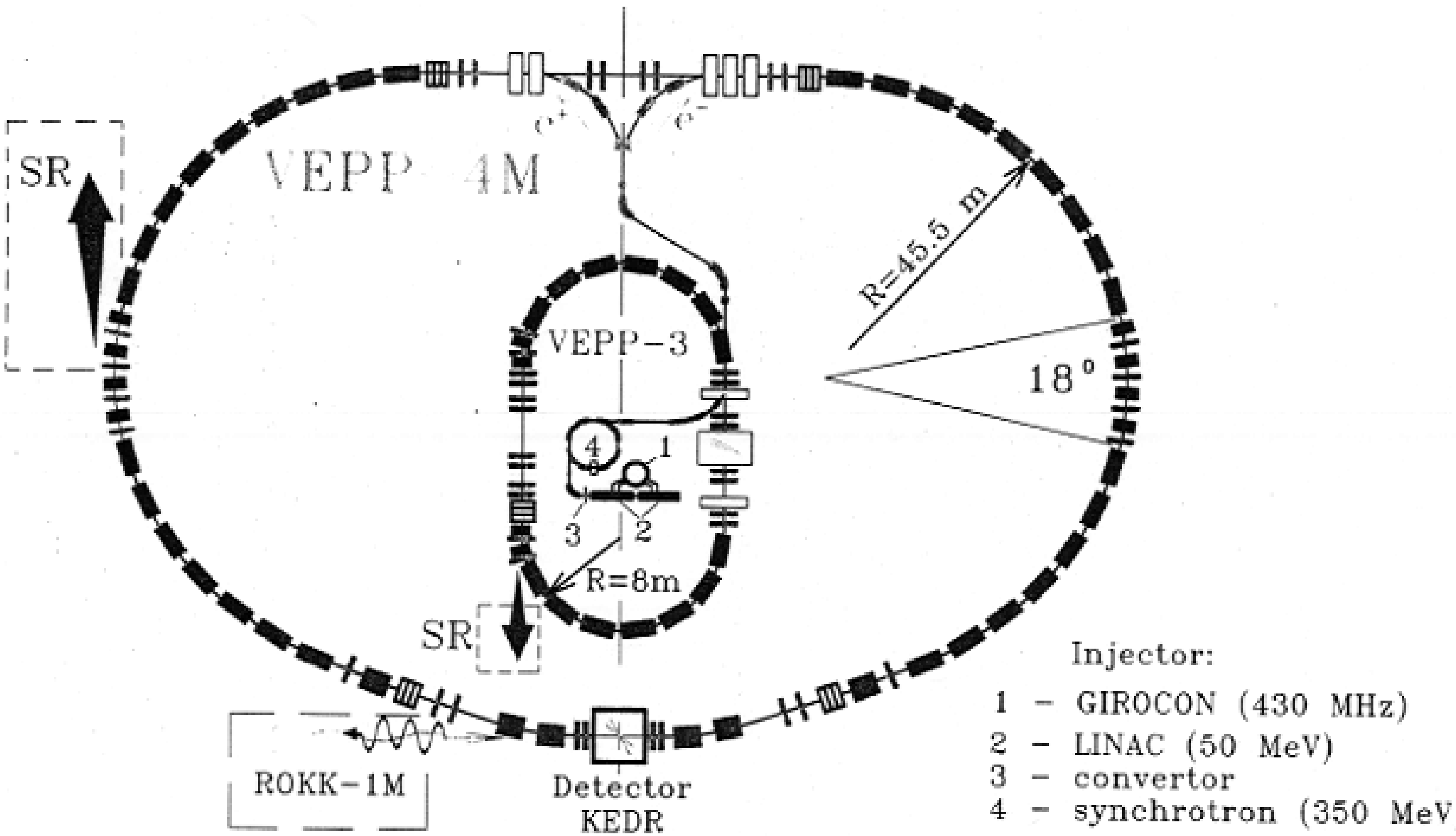
Date	Experiment	$\sqrt{s}$, GeV	Δa_μ^{had}
1995	World data	0.3 – 40	15
1999	CMD-2 + SND	0.3 – 1.4	10
2001	CMD-2 + SND	0.3 – 1.4	8
2003	CMD-2M	0.3 – 2.0	3 – 4
	BES	2 – 5	
	KEDR	2 – 10	

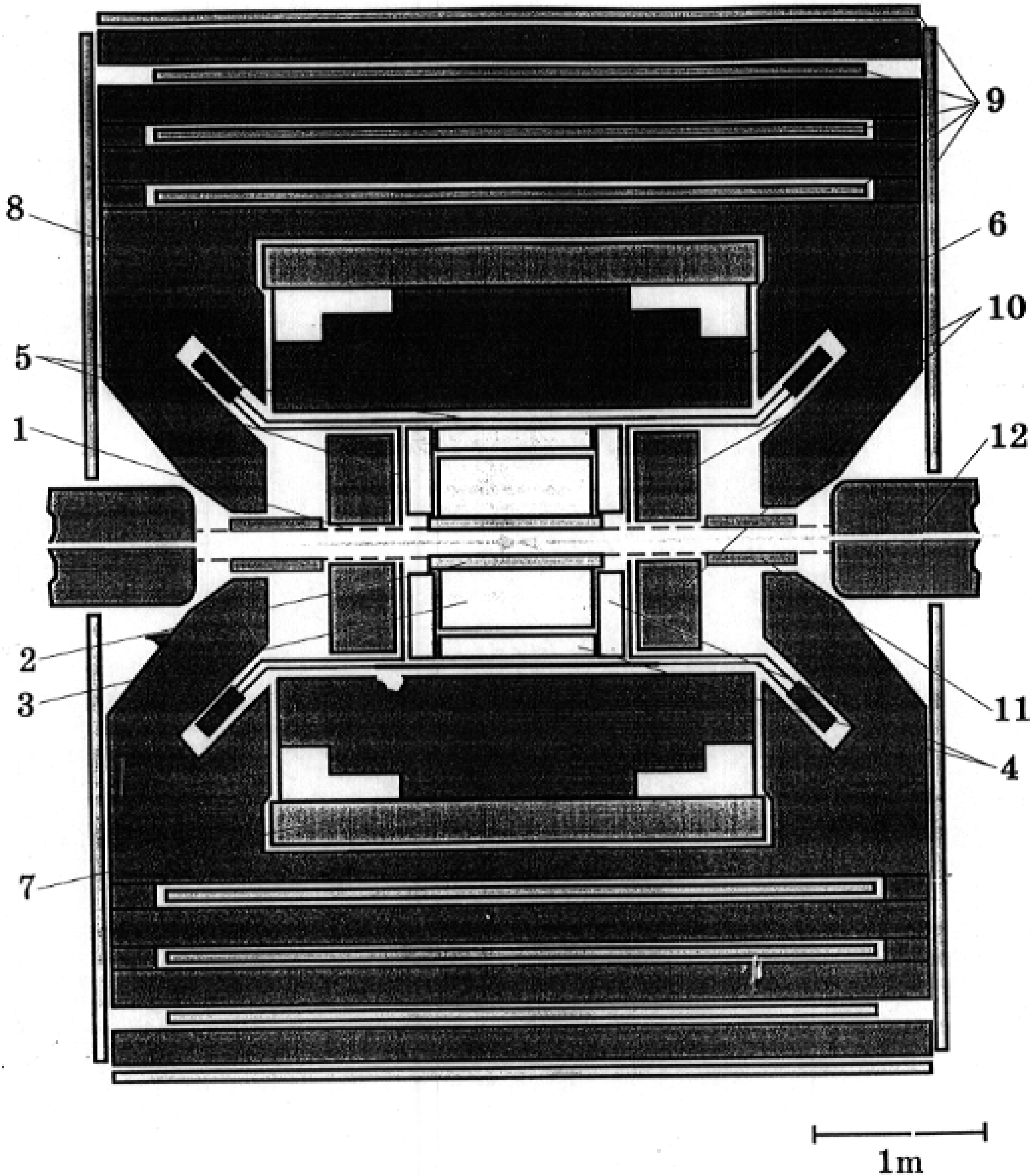
VEPP-2000



VEPP-2M & VEPP-2000 parameters

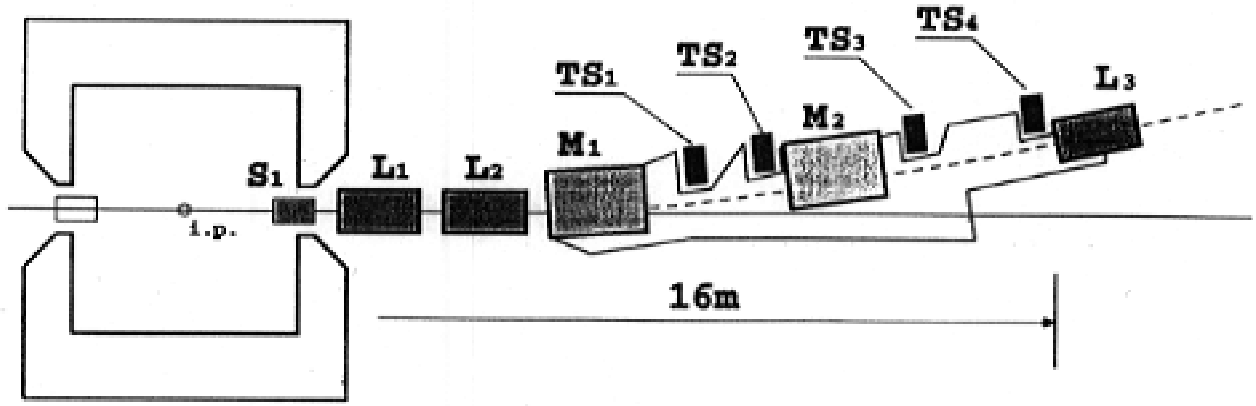
	VEPP-2M $E_m = 700$ MeV	VEPP-2000 $E_m = 1000$ MeV	
E (MeV)	510	510	900
Π (cm)	1788	2438.8	
$\mathcal{I}^+, \mathcal{I}^-$ (mA)	40	34	200
$\varepsilon \cdot 10^5$ (cm · rad)	3	0.5	1.6
β_x (cm) β_z (cm)	40 5	6.3 6.3	
ξ_x ξ_z	0.016 0.050	0.075 0.075	0.075 0.075
$\mathcal{L}$ ($cm^{-2}s^{-1}$)	$3 \cdot 10^{30}$	$1 \cdot 10^{31}$	$1 \cdot 10^{32}$

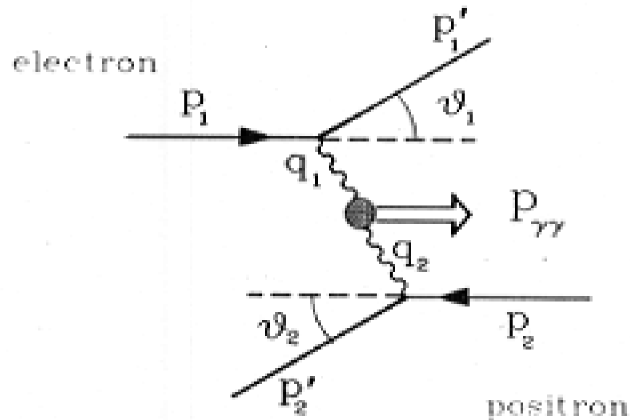

SR
VEPP 4M
R=45.5 m
VEPP-3
18°
R=8m
SR
ROKK-1M
Detector
KEDR
Injector:
1 - GIROCON (430 MHz)
2 - LINAC (50 MeV)
3 - convertor
4 - synchrotron (350 MeV)



1 - Beam pipe
2 - Vertex detector
3 - Drift chamber
4 - Aerogel threshold counters
5 - ToF counters
6 - Lkr calorimeter
7 - Superconducting coil
8 - Yoke
9 - Muon chambers
10 - CsI calorimeter
11 - Compensating solenoid
12 - Quadrupole

Detector KEDR at VEPP-4M
Tagging system





$$M_{\gamma\gamma}^2 \approx 4\omega_1\omega_2; \qquad \omega_i = E_i - E_i'$$

1. VEPP-4M with KEDR detector

Main parameters of VEPP-4M

Energy	$2 \times 1.5 GeV$	$2 \times 5.6 GeV$
Number of bunches	2×2	2×2
Max currents	$5 \times 5\ mA^2$	$50 \times 50\ mA^2$
Beta-functions, B_x, B_y	$2.5 cm, 200 cm$	$2.5 cm, 200 cm$
Bunch crossing	$611\ ns$	$611\ ns$
Max Luminosity	$2 \times 10^{30} cm^{-2} s^{-1}$	$1.5 \times 10^{32} cm^{-2} s^{-1}$

KEDR is general purpose detector for experiments at VEPP-4M e^+e^- collider in energy range $2E = 3(1.5?) \div 5.6\ GeV$

KEDR collaboration:

Novosibirsk, Milano, Bologna, Pavia and Upsala.

- First experience with KEDR

  - *Nov. 97* — main subsystems (except LKr calorimeter and Aerogel counters) where installed at VEPP-4M.

  - *Dec. 97 – Feb. 98* — tuning of the detector, background optimization.

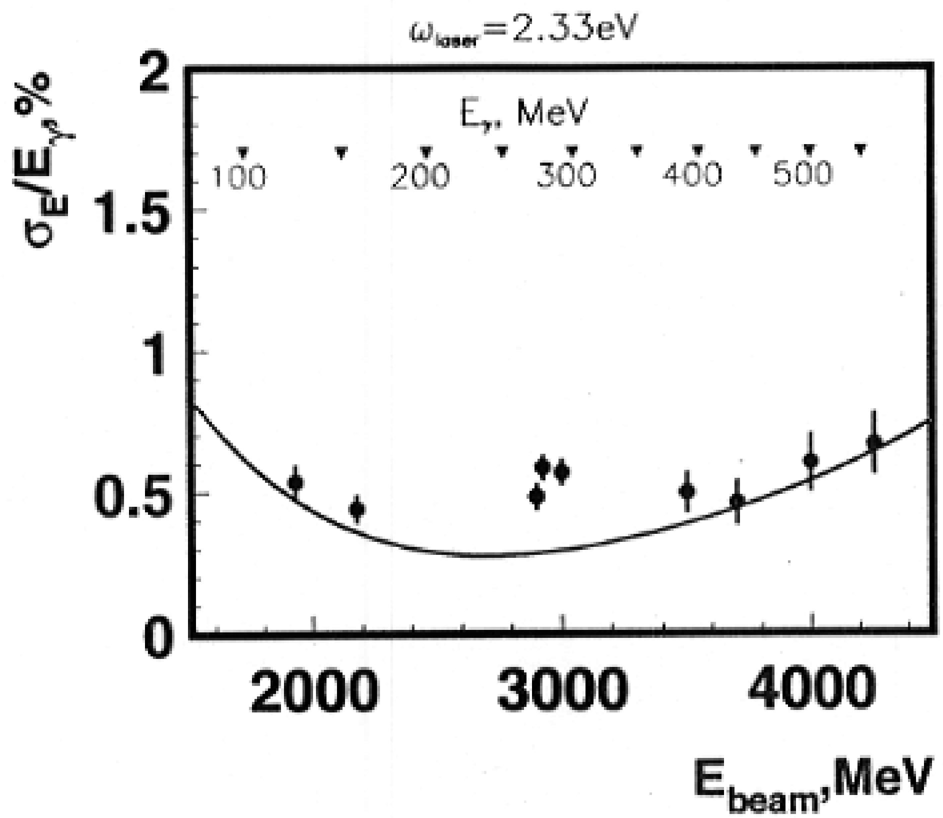
  - *March. 98 – May. 98* — scan of the energy region near J/Ψ.

    - test of the detector

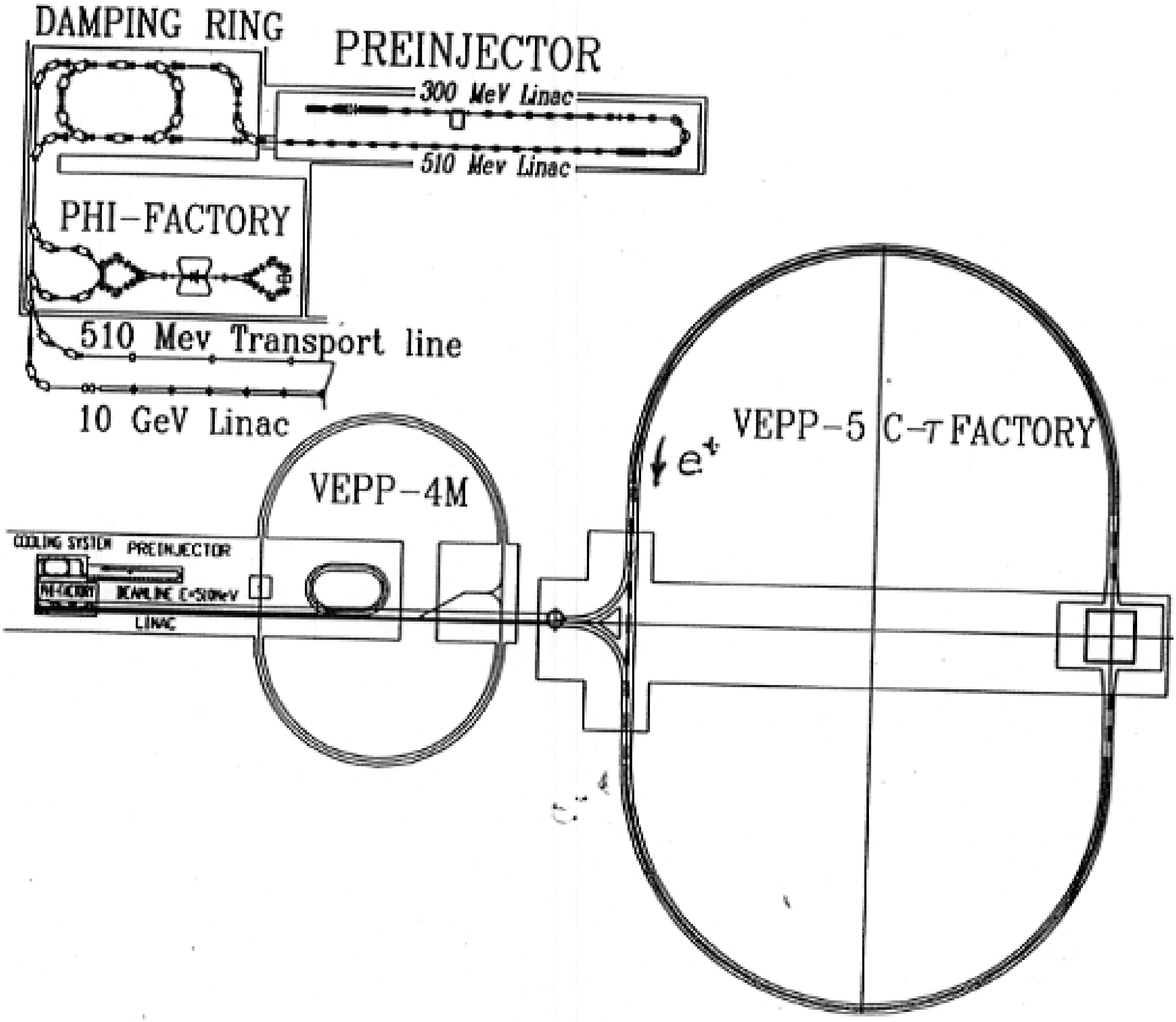
    - determination of the energy and energy spread of VEPP-4M

Detector KEDR at VEPP-4M

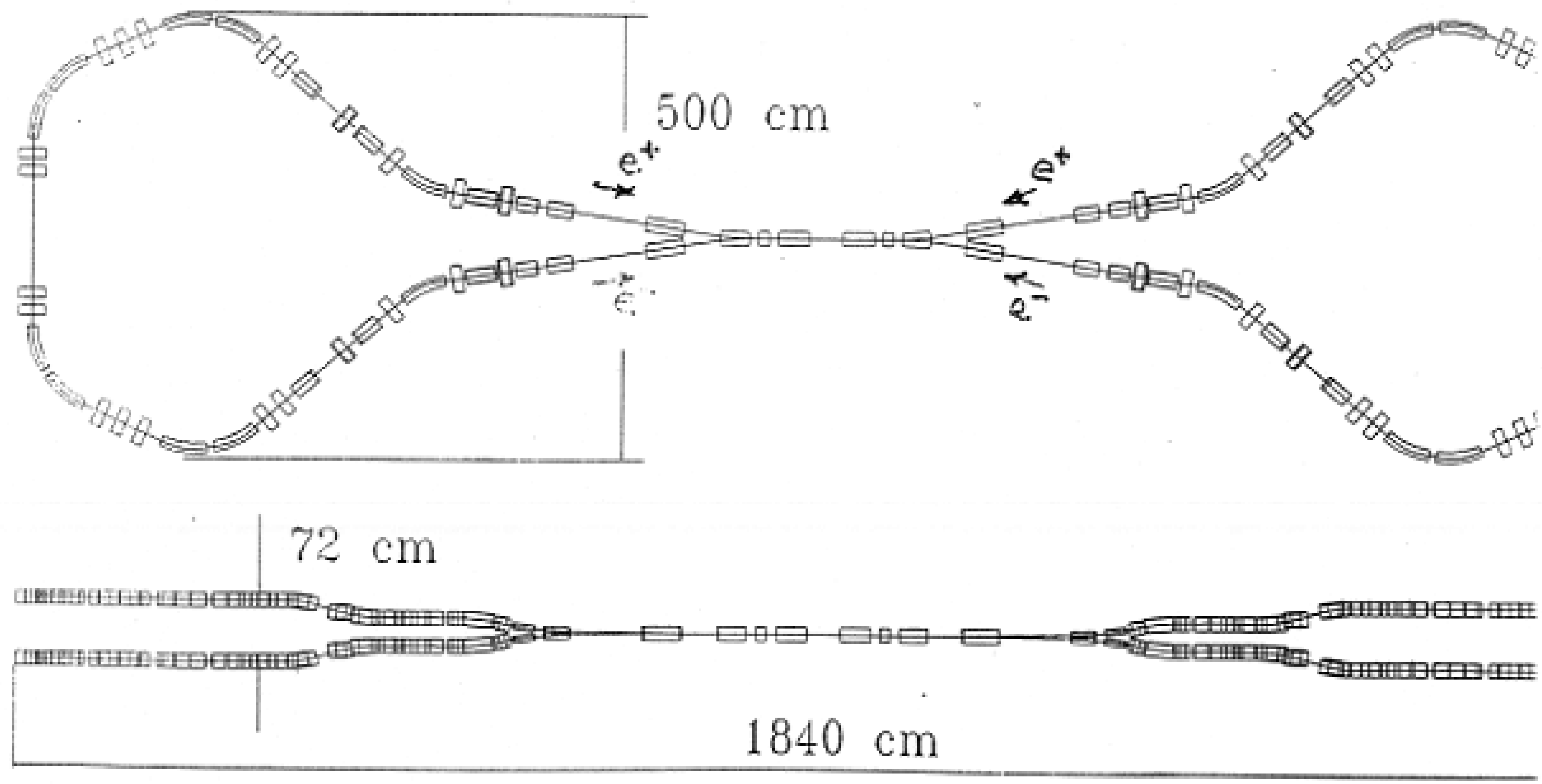
Tagging system energy resolution



- Future experiments with KEDR
  - J/Ψ physics
    - world statistics — 25×10^6 (CRYSTAL BALL, MARK-III, DM-2, BEIJING)
    - We can have $10^8/year$ $(L = 2 \times 10^{30} cm^{-2} s^{-1})$
      KEDR has:
      * High resolution e.m. calorimeter $\sigma_E/E = 2.5\%/\sqrt{E}$
      * High momentum resolution for charged particles
        $\frac{\sigma_p}{p} \approx (0.003)^2 + (0.0033p)^2, \quad p(GeV/c)$
      * Good identification systems
  - $e^+e^- \rightarrow hadrons$ in energy range $2E = 1.4(?) - 5\ GeV$
  - Υ - physics
  - 2γ - processes



DAMPING RING
PREINJECTOR
300 MeV Linac
510 Mev Linac
PHI-FACTORY
510 Mev Transport line
10 GeV Linac
VEPP-4M
VEPP-5 C-τ FACTORY
COOLING SYSTEM
PREINJECTOR
LINAC



Four-wing Fi Factory → $\geq 1 \cdot 10^{34}\ cm^{-2} s^{-1}$?

(compensated scheme!)