OKA:
The experimental program with RF-separated $K^{\pm}$ beam @ U-70 Protvino,Russia.

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representing the OKA collaboration

(IHEP-INR-JINR-...)

Current Kaon experiments in Russia.

- ISTRA+ U-70 IHEP,Protvino

  Unseparated 17-37 GeV; 70 GeV U-70 2(3)/9 sec. cycle.

  $3\% K^-$; $5 \cdot 10^6 (-)$/cycle $\rightarrow$ $1.5 * 10^5 K^-$/cycle; $\sim$ 10m decay volume.

  Tests of SM and χPT in K_{l3}(1M K_{e3}; .5M $K_{\mu 3}$); $K_{l3\gamma}$; $K^- \rightarrow \pi^- \pi^0 \pi^0$ (250 K) ;

  search for sgoldstino in $K^- \rightarrow \pi^- \pi^0 P$;...

- TNF U-70 IHEP,Protvino

  Unseparated ~ 35 GeV; 70 GeV U-70 2(3)/9 sec. cycle.

  $2.5\% K^\pm$; $4 \cdot 10^6 + (-)$/cycle $\rightarrow$ $10^5 K^\pm$/cycle; $\sim$ 60m decay volume.

  Search for CP violation in $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0 (\tau')$ (.5 M) events.

OKA: The experiment with RF- separated high energy $K^{\pm}$ beam

At present there is no RF-separated high energy beams in operation !

In past, ”warm” cavities were used to provide beams for the bubble chambers

- AGS (1965) 12.8 GeV $\rightarrow$ 80” b.c.
- CERN PS (1968) 20 GeV $\rightarrow$ 2m b.c.
- IHEP U-70 ($\sim$ 1973) 30 GeV for ”Mirabelle”; 30 GeV for ”Ludmila”

In 1998 IHEP, Protvino decided to start new project:

- RF Separated beam at IHEP U-70, based on CERN-Karlsruhe Superconducting deflectors: the ”OKA” project

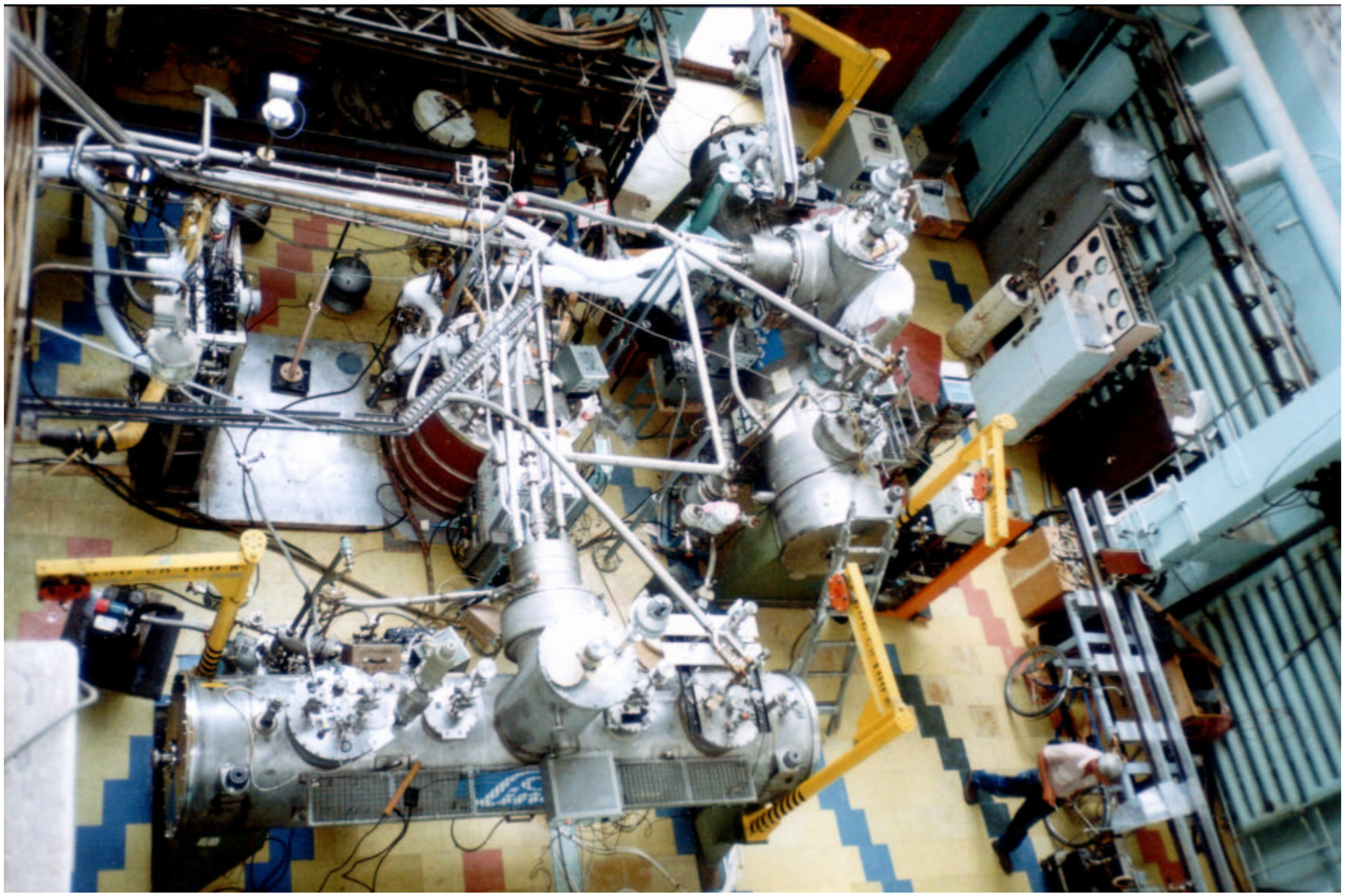
Karlsruhe-CERN superconducting RF separator

The only existing superconductive RF separator was built in Karlsruhe(Germany) and used at CERN SPS in 1978-1981. The main parameters of the deflectors:

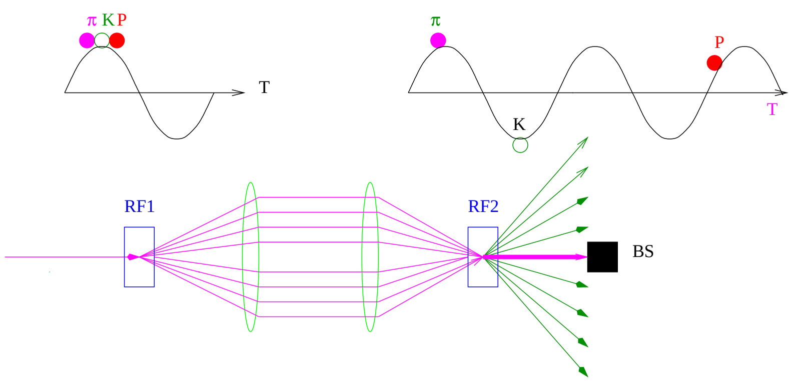
Operating frequency, (S-band)	2865 MHz
Wavelength, λ	$\sim$ 10.5 cm
Iris opening, 2a	40 mm
Effective deflector length	2.74 m
Number of cells/deflector	104
Mean deflecting field	1.2 MV/m
Working temperature	1.8 K

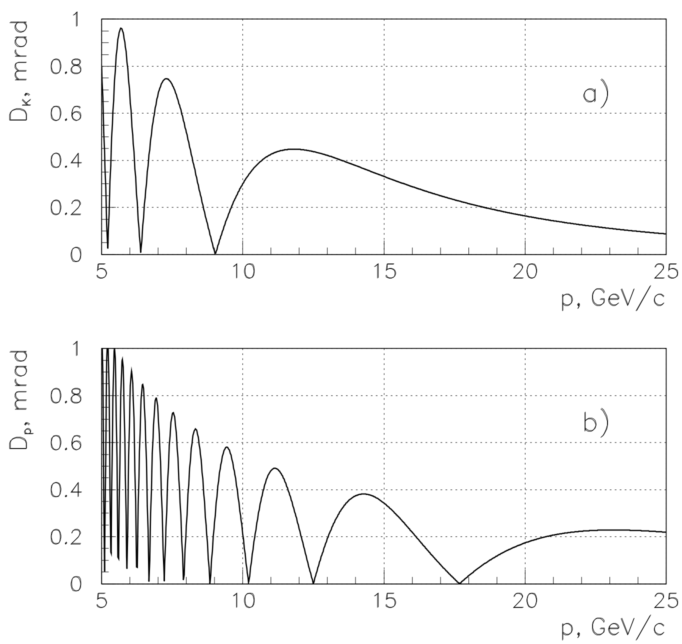
The separators were used to provide $K^{\pm}$ and $\bar{p}$ 3-37 GeV beams for the Ω spectrometer.

In 1996 the negotiations IHEP-CERN started and in 1998 the separators were transported from CERN to IHEP.

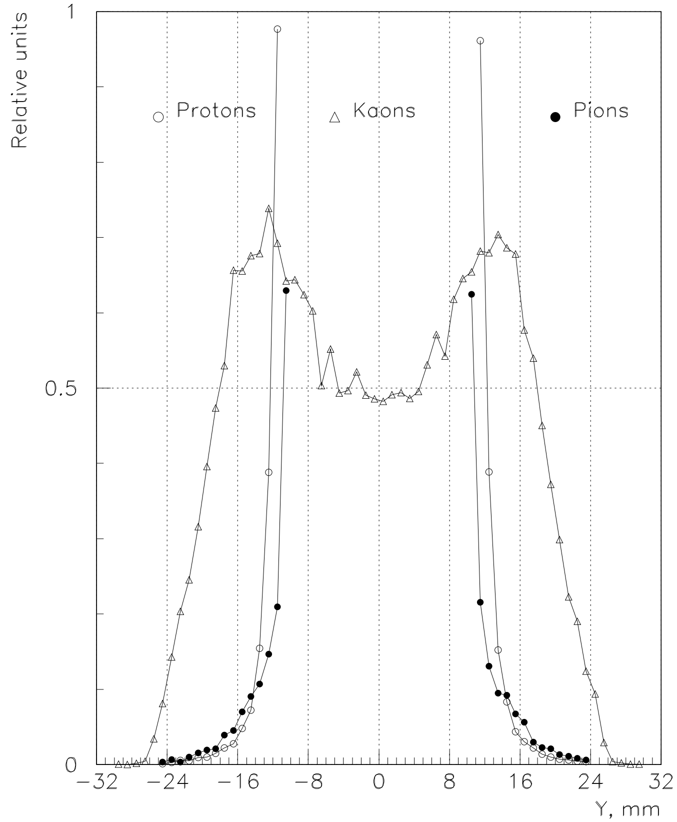


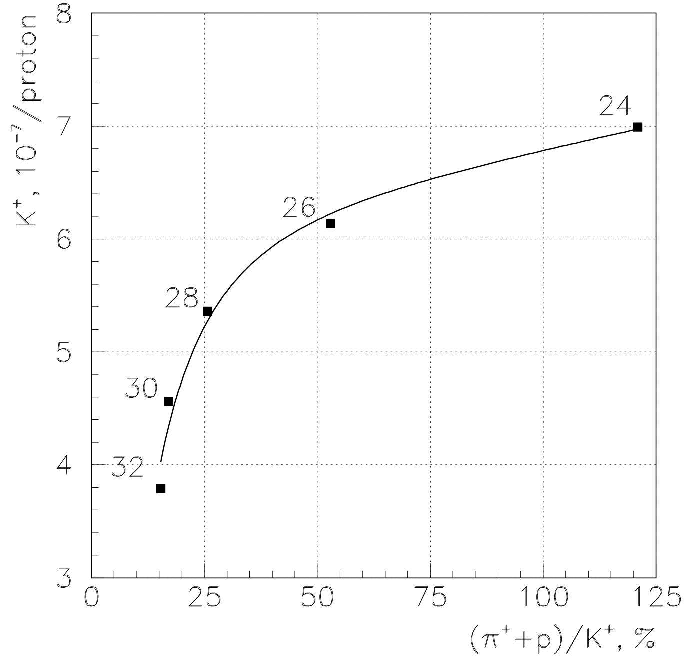
Principle scheme of RF-separation (Panofsky).



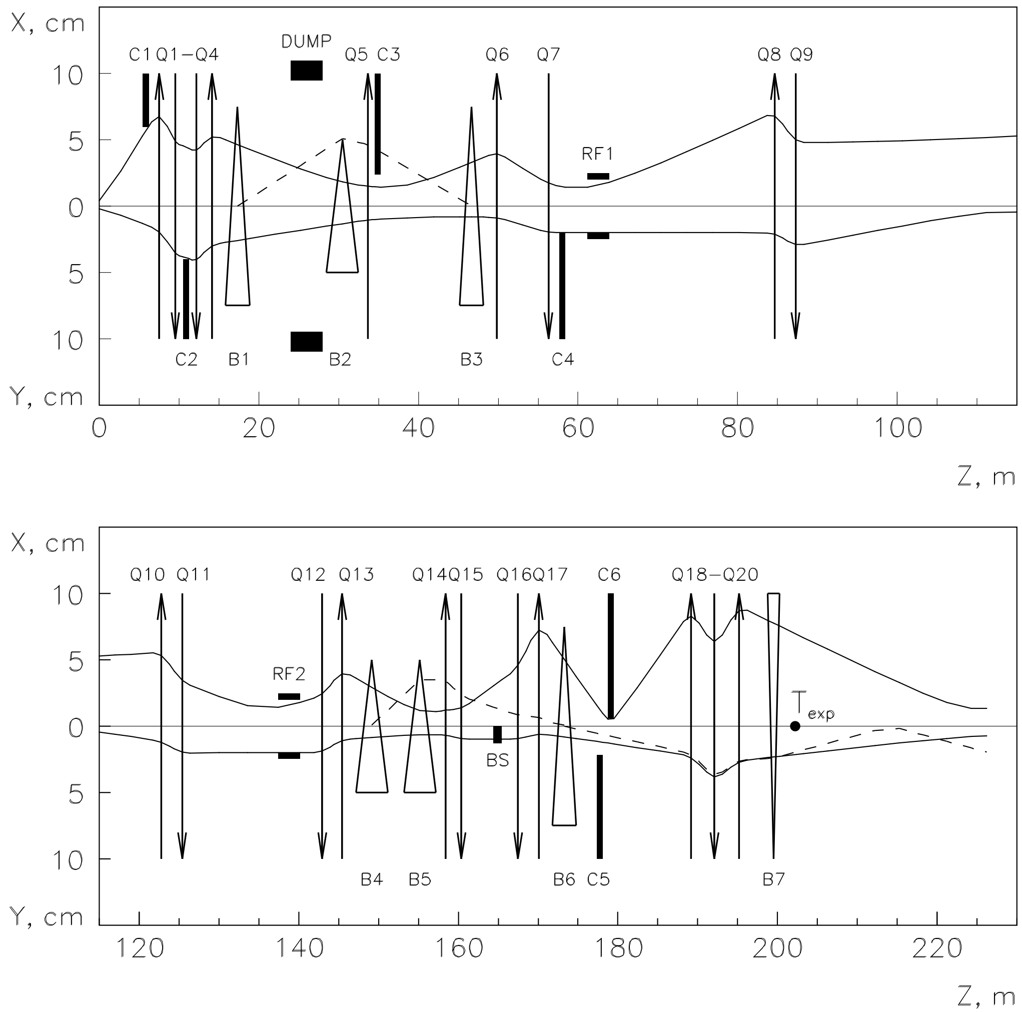


RF separation



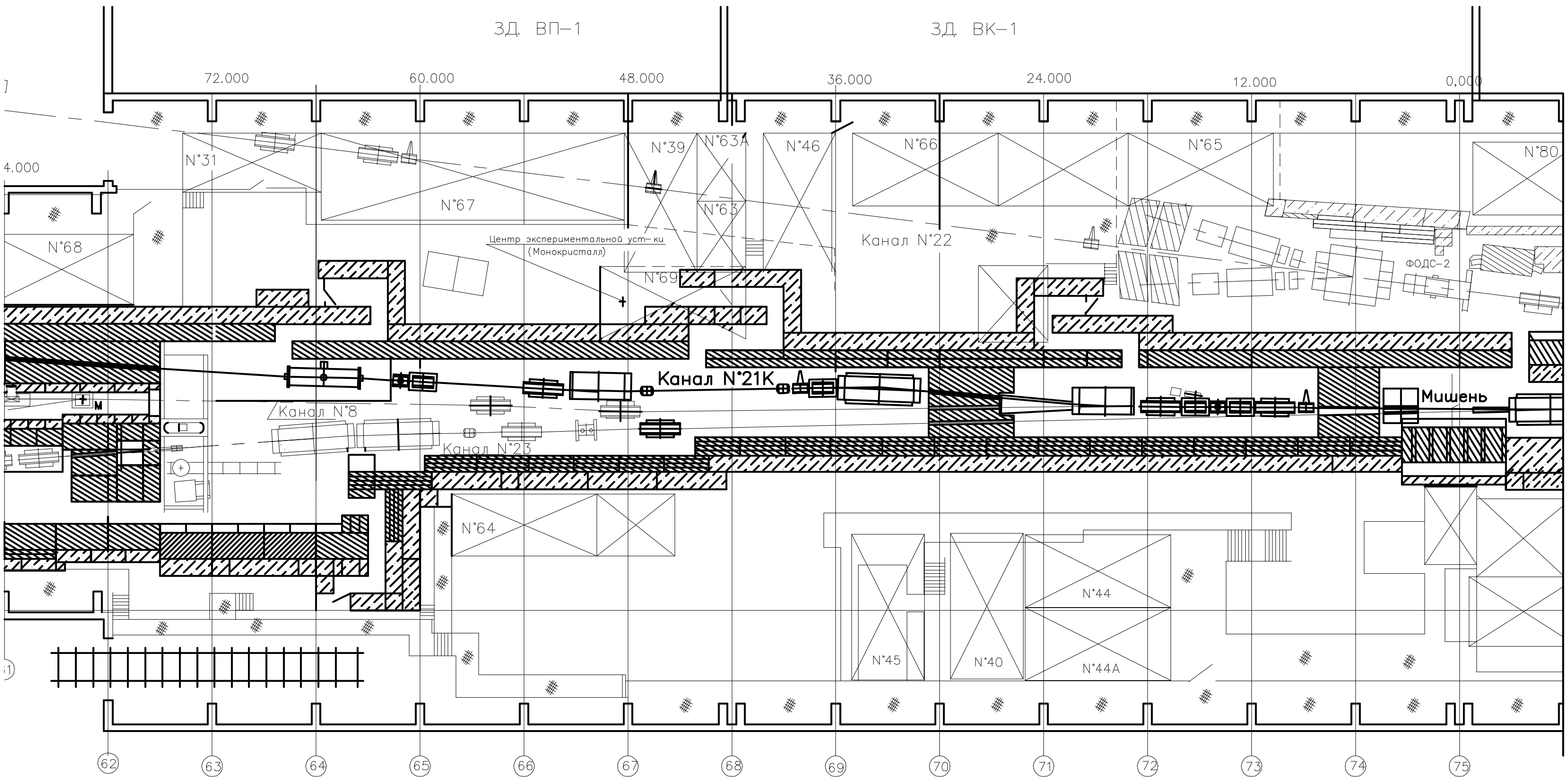


Optical scheme of the ”OKA” RF-separated beam



Beam parameters.

Target	50 cm Be
Primary proton beam energy	65-70 GeV
Primary proton beam intensity	10^{13} ppp
Secondary beam momentum	12.5 or 18 GeV
Δp/p $\%$	± 4
Horizontal acceptance	± 10 mrad
Vertical acceptance	± 1.9 mrad
Length of the beam line	$\sim$ 200 m
Distance between separators	76.3 m
Intensity of K^+ at the end	5×10^6
π^+, p contamination	$< 25\%$
Muon halo	$< 100\%$



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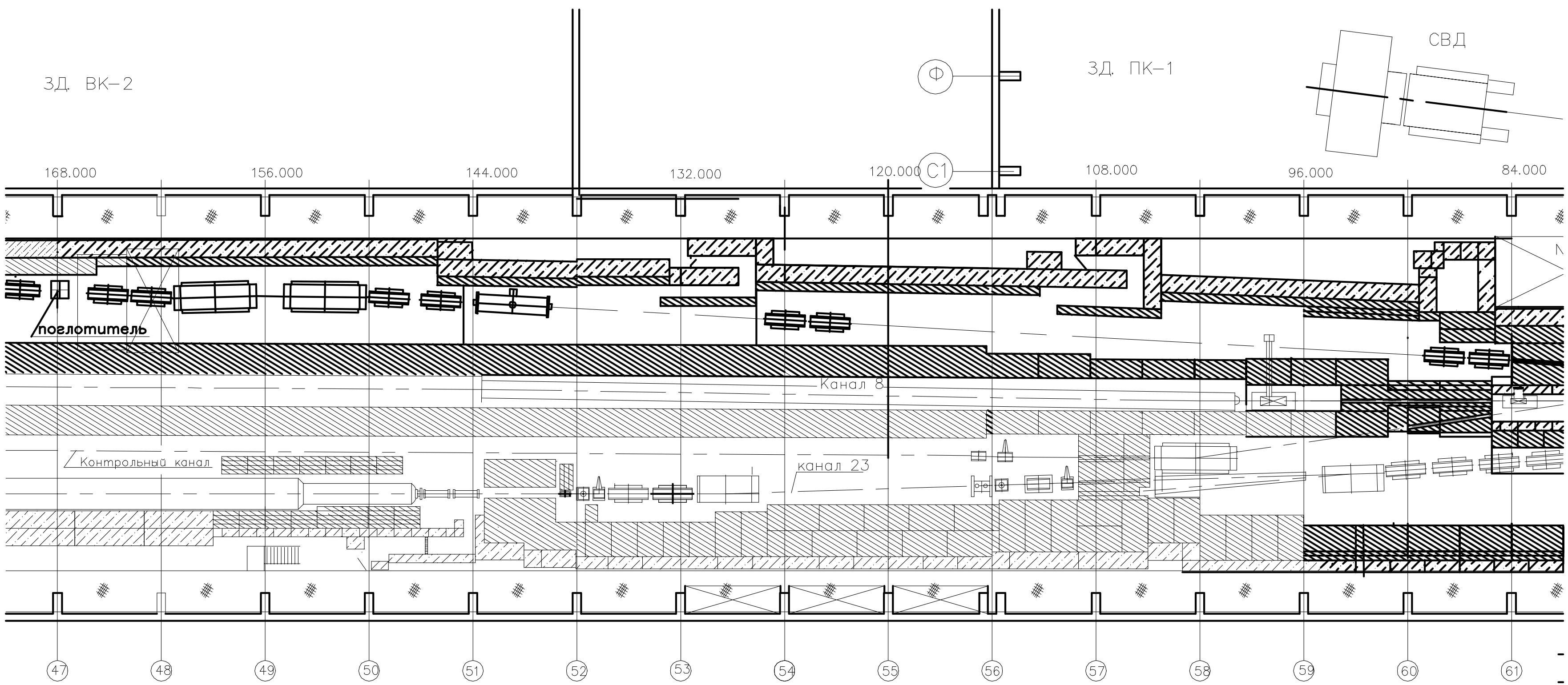
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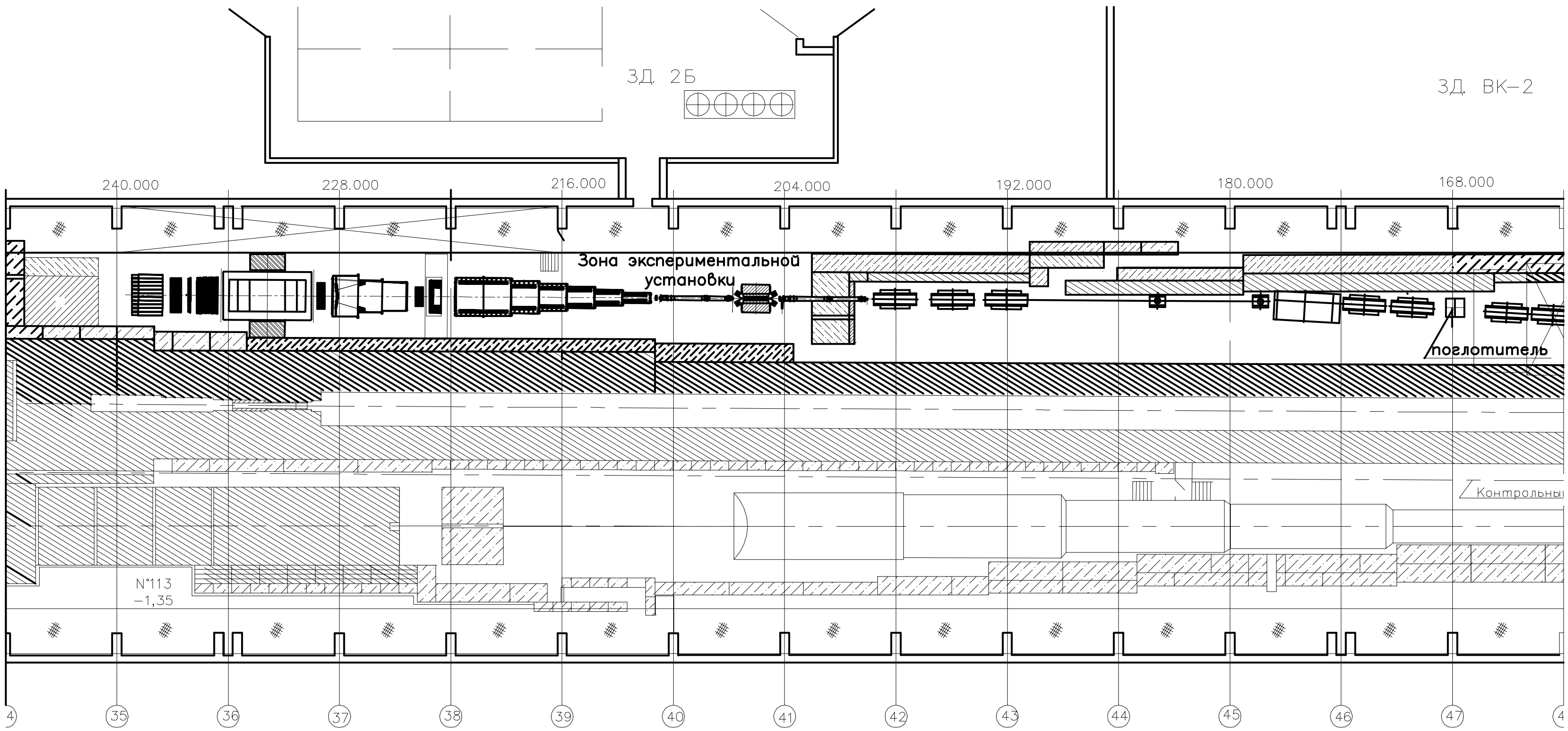
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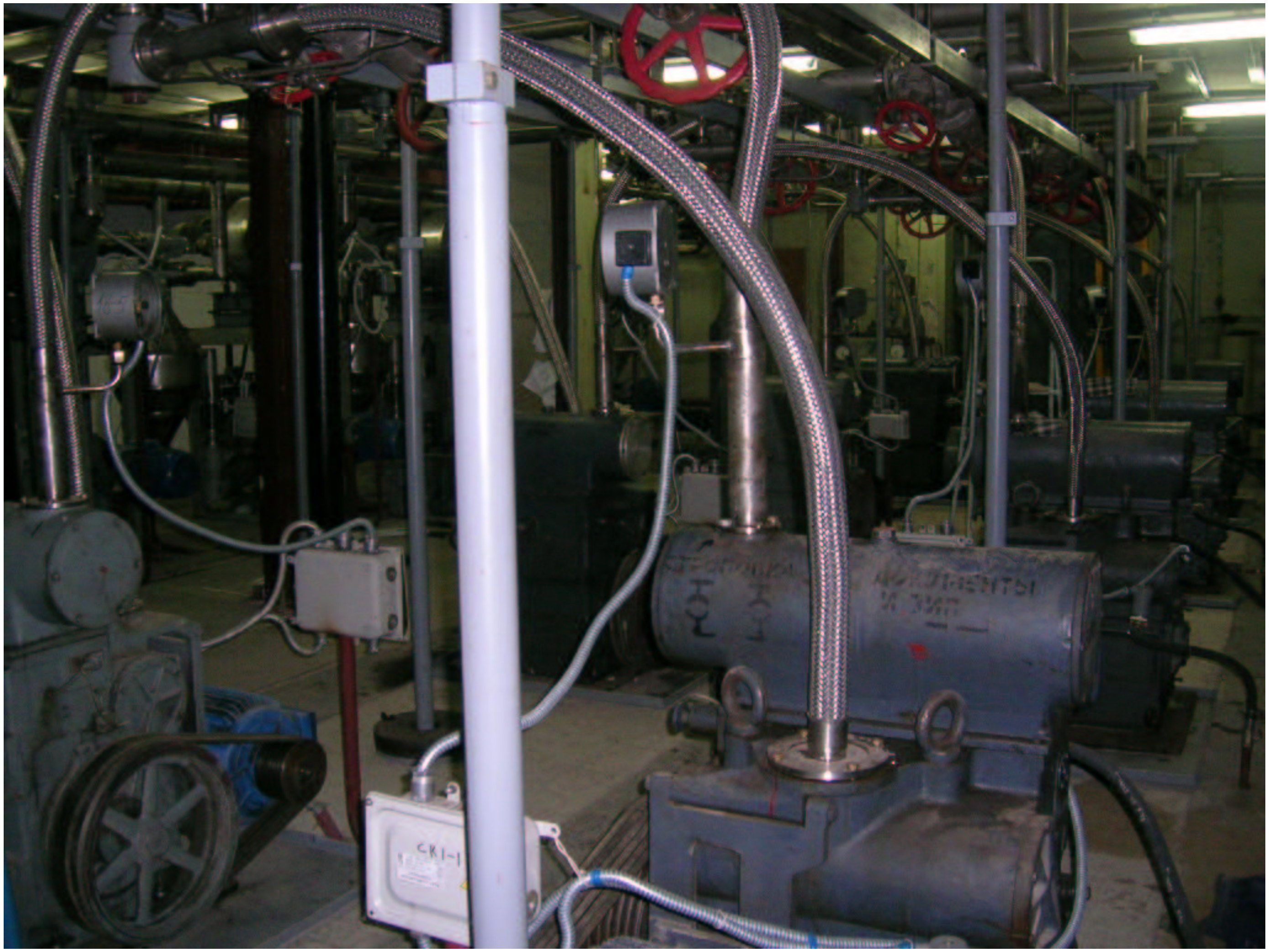
Time schedule for the design and construction of the RF-separated beam

- Vacuum tests of RF cavities December, 1998 $\rightarrow$ Helium tests Summer, 1999 $\rightarrow$ Complex RF-tests at 4.2 K Summer 1999
- Construction of cryogenics for 1.8 K tests 1999-2000
- Complex RF-tests at 1.8 K , cleaning of the RF2 Nov. 2000- Dec. 2004
- Beam-line design 1998$\longrightarrow$ technical project 1999$\longrightarrow$ construction 2002-2004
- Cryogenic system design 2000-2001$\longrightarrow$ construction and assembly 2001-2005
- RF-system construction and assembly 2004-2005
- Modernization of the U-70 slow extraction 2000-2002 $2.5 \times 10^{13} ppp$ achieved.
- New setup on the basis of SPHINX, ISTRA+, GAMS 2003- 2005
- ”Warm” beam commissioning December, 2004
- ”Cold” beam commissioning December, 2005

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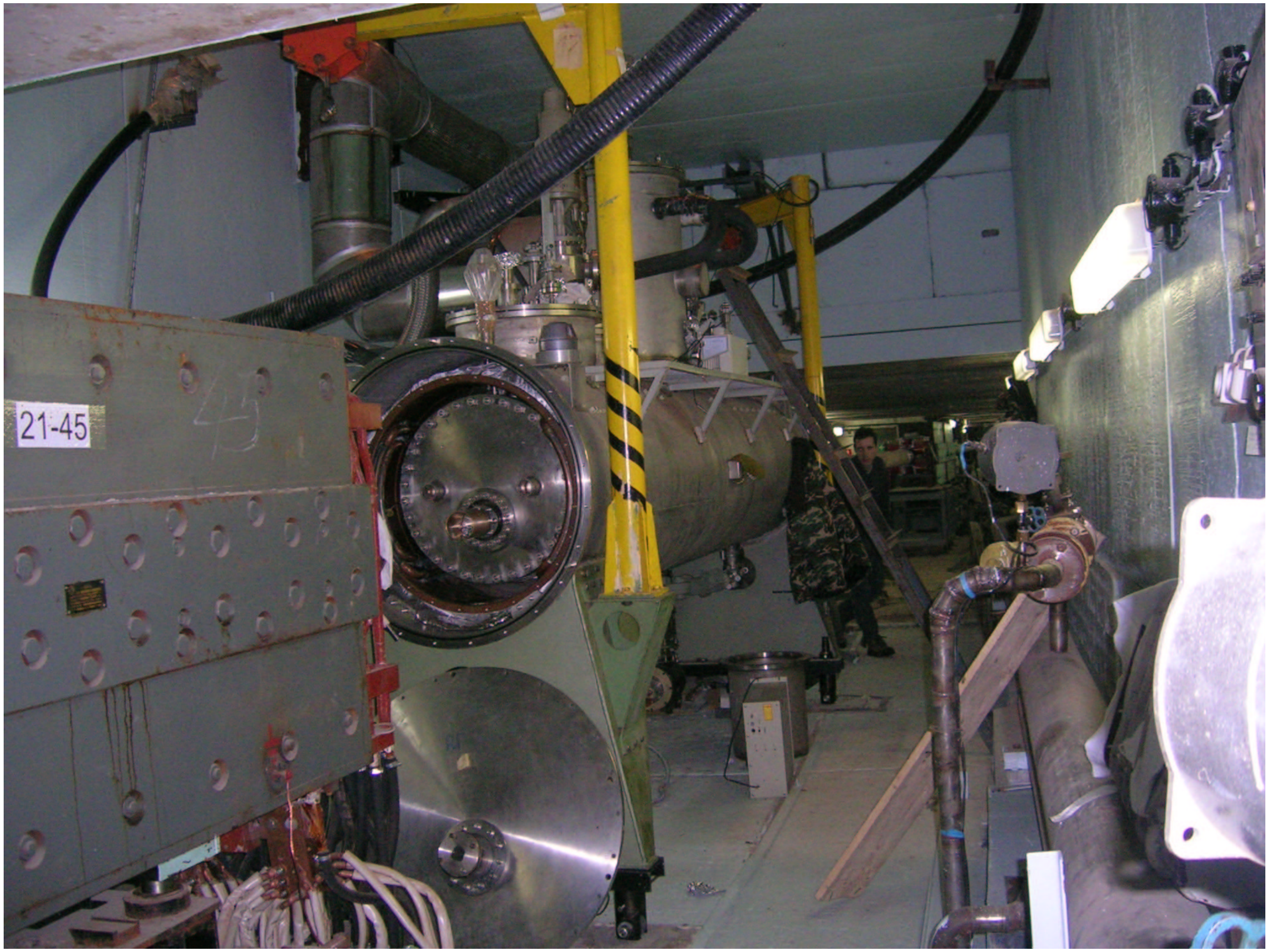
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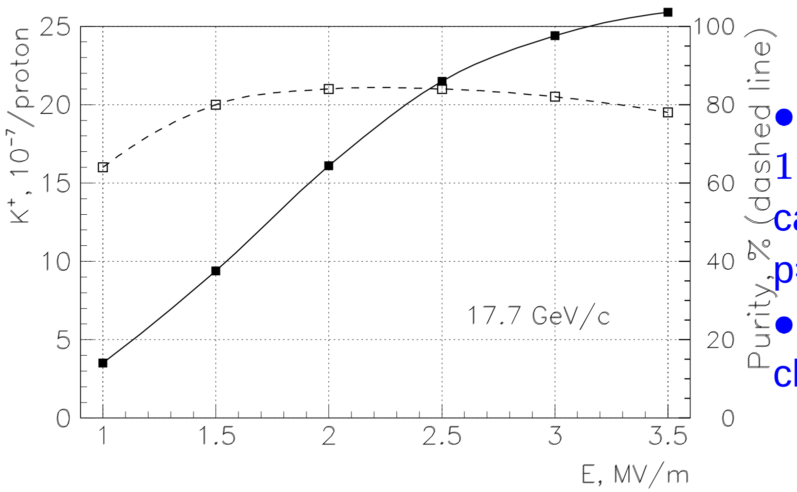
Long-term plans for the intensity increase

•Present Design goal- $5. \times 10^6 K^+$ per 3 sec. flat-top; 9 sec spill.

Slow extraction intensity 10^{13} ppp is assumed. As $2. \times 10^{13}$ppp is reached $\rightarrow$ $10^7/$spill is in hand.

Possible restrictions from radiation safety in the target region



• Beam intensity is limited by the RF-cavities field of $1.MV/$m. Simulation of the beam line with $3MV/$m cavities gives the intensity of $2.5 \times 10^7/10^{13}$ppp for p=17.7 GeV

• A possibility of construction of μ-bunched beam synchronized with cavities RF is under study.

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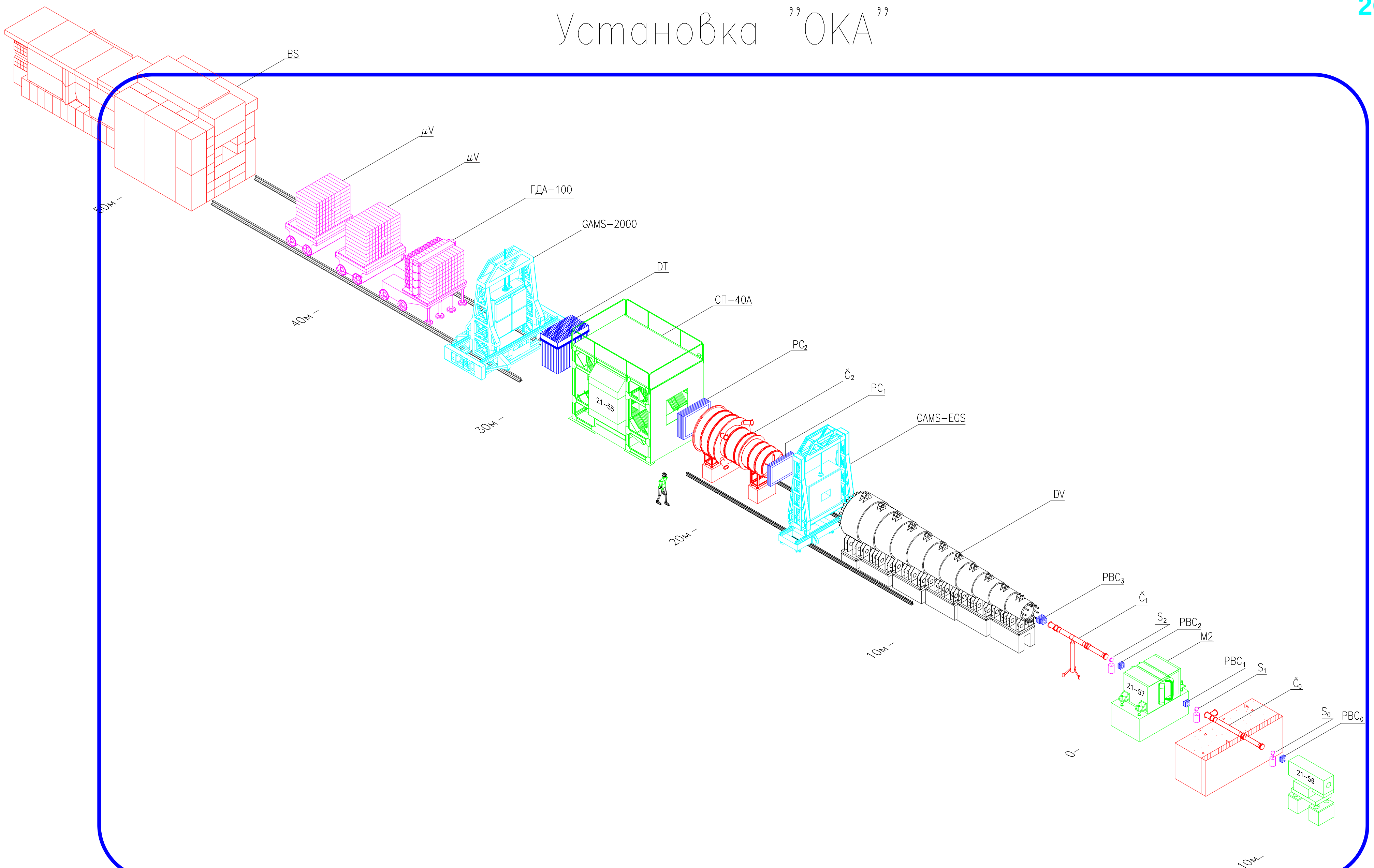
Given this estimates we put forward a long-term goal to reach intensity of 10^8/spill$\Longleftrightarrow$ 10^7/sec

Установка "ОКА"



OKA setup at U-70 IHEP

- SPHINKS,ISTRA,GAMS $\rightarrow$ OKA

1. Beam spectrometer
   1mm pitch PC's ($\sigma_p/p \sim 1\%$); threshold Č + Kaon RICH; 6 trigger Sc Fi Hod.
2. Decay volume with veto system:
   12m; Veto: ~ 670 Lead-Scintillator sandwiches 20 $\times$ (5mm Sc + 1.5 mm Pb), WLS readout
3. PC's and DT's for the magnetic spectrometer:
   $\sim$ 5000 ch. PC (2 mm pitch)+ 1000 DT (6 cm ϕ)
4. Magnet:
   $\int B \cdot ds \sim$ 1 Tm. ; aperture 200$\times$ 100 cm^2
5. Gamma detectors:
   GAMS2000, EHS-backward EM cal. $\sim$ 4000 LG + 256 PWO crystals.
6. Muon Identification
   4 sections of Sc-Iron HCal+ μ range stack (30 planes of former D0 forward μ DT)

OKA setup at U-70 IHEP

1. Trigger
   - Beam K (Sc + Č counters) $\rightarrow 5 \cdot 10^6$/spill
   - K decay (ScFi Hodoscope logic) $\rightarrow 5 \cdot 10^5$/spill
   - $K \rightarrow \mu\nu$-suppression (> 1 MIP threshold in EM calorimeters) $\rightarrow 2 \cdot 10^5$/spill
   - PC farm to suppress $K \rightarrow \pi\pi^0 \rightarrow 10^5$/spill
2. DAQ
   - $2 \cdot 10^5$/spill= 25 Mb/sec;
   - 5000 ADC (10 μsec conversion time);
   - 1000 TDC (.8 nsec, CERN HPTDC);
   - 10000 PC (10 nsec shift registers).

Main directions of the experimental program

- Search for deviations from the SM

  search for T,S,P in $K^+ \to e^+\nu$; $e^+\nu\gamma$; $\mu^+\nu\gamma$; $e^+\nu\pi^0$;$\mu^+\nu\pi^0$

- Search for pseudoscalar sgoldstino(P) in $K^+ \to \pi^+\pi^0 P$ decay

- Search for T-odd effects

  Measurement of the $\frac{\vec{p}_\gamma \cdot (\vec{p}_\pi \times \vec{p}_\mu)}{|\vec{p}_\gamma| \cdot |\vec{p}_\pi \times \vec{p}_\mu|}$-correlation in the decay $K^+ \to e^+(\mu^+)\nu\pi^0\gamma$

- Search for direct CP violation

  Measurement of the $\frac{\delta g_\pm}{2g}$ in the decays $K^\pm \to \pi^\pm\pi^\pm\pi^\mp$; $K^\pm \to \pi^\pm\pi^0\pi^0$

The program is being tuned depending on the results of the current experiments:

ISTRA+, KLOE, E949, NA48/2

"OKA" fix-target program

SLAC LASS experiment (K^-p @ 11 GeV) reached 4.1 ev/nb; OKA(2 month) $\sim$ 300 ev/nb.

- Search for exotic states with hidden strangeness
  F.Close and P.Page predict $s\bar{s}g$ $J^{PC} = 2^{-+}$ Γ=120 MeV $\rightarrow K_2^*(1430)K$; $K_1(1270)K$.
  OKA can look for this state in $K^- p \rightarrow K^+ K^- \pi^0 \Lambda$
- Search for pentoquark states $uuss\bar{s}$:
  CERN(2m) and Argone(15 ft) bubble chambers saw narrow ($\Gamma < 20$MeV) state in the reaction $K^- p \rightarrow Y^{*+} + \pi^-$; with $Y^{*+} \rightarrow \Sigma K \bar{K} + 2\pi$
- Spectroscopy and Decays of light mesons
  $K^- p \rightarrow f_2(1515) + \Lambda$; $f_2(1515) \rightarrow \phi\gamma$ ($f_1(1285) \rightarrow \phi\gamma$)
  $K^- p \rightarrow f_0(400 - 1200) + \Lambda$; $f_0 \rightarrow \pi\pi$; $K\bar{K}$
- Primakoff physics
  R.Rogaliov Phys.Atom. Nucl. **64**(2001) compared $\sigma(K^+ Z \rightarrow K^+ \pi^0 Z)$ and $\sigma(K^+ Z \rightarrow K^0 \pi^+ Z)$. In the 1$^{\underline{st}}$ process Wess-Zumino-Witten(WZW) anomaly contributes $\rightarrow \sigma_1/\sigma_2 \sim$ 80 nb/ 15 nb near threshold. Nobody tested WZW with s-quark !
  "Polarizability" of K in $K^+ Z \rightarrow K^+ \gamma Z$.

OKA: search for deviations from SM in the decay $K^+ \to e^+\nu$

- Theoretical predictions:

$$R(K^+ \to l^+\nu_l)_{SM} = \frac{Br(K^+ \to e^+\nu_e)}{Br(K^+ \to \mu^+\nu_\mu)} = \frac{m_e^2}{m_\mu^2} \cdot \frac{(m_K^2 - m_e^2)^2}{(m_K^2 - m_\mu^2)^2}(1+\delta_r) =$$
$$2.569 \cdot 10^{-5}(1 - 0.0378 \pm 0.0004) = (2.472 \pm 0.001) \cdot 10^{-5}$$
$$R(K^+ \to l^+\nu_l) = R(K^+ \to l^+\nu_l)_{SM}[1 \pm \frac{|G|_{PS}}{G_F \cdot V_{us}} \cdot \frac{m_K^2}{m_s m_e}]$$

- Experiment: Two measurements (1975,1976) CERN PS, 938 events:

$$R(K^+ \to l^+\nu_l)_{exp} = (2.44 \pm 0.11) \cdot 10^{-5} = R(K^+ \to l^+\nu_l)_{SM} \cdot (0.987 \pm 0.045)$$

$|G|_{PS} < 3.5 \cdot 10^{-11}$ GeV^{-2} ; $\Lambda_{LQ} > 85$ TeV

- Prospects for OKA: Expected statistics - 10^5 events $\to$ stat. accuracy $3 \cdot 10^{-3}$.

MC study of the main background processes $K^+ \to e^+\nu\pi^0$ and $K^+ \to e^+\nu\gamma$, have shown, that it is possible to suppress background to $< 3 \cdot 10^{-7}$

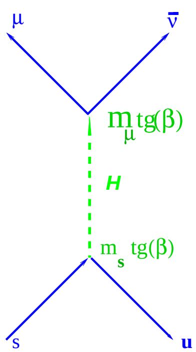
$|G|_{PS} < 10^{-12}$ GeV^{-2} ; $\Lambda_{LQ} > 500$ TeV

Search for SM-violation in $K_{e3} - K_{\mu 3}$ decays

ISTRA+ has established best limits on f_T and f_S formfactors:

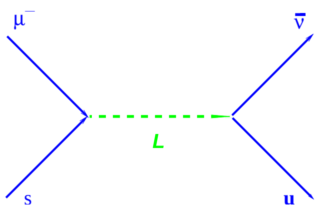
$$f_T/f_+(0) = (0.1 \pm 0.65(stat) \pm 0.2(syst))\%$$
$$f_S/f_+(0) = (0.07 \pm 0.15(stat) \pm 0.09(syst) \pm 0.53(theory))\%$$

the last result assumes $\lambda_0 = 0.017 \pm 0.004$ J.Gasser and H.Leutwyler, Nucl.Phys B250(1985)



$$f_S^{2hdm} = \frac{m_\mu (m_K^2 - m_\pi^2) tg^2\beta}{2m_H^2 m_K} f_0(t) \rightarrow$$
$$\frac{tg(\beta)}{m_H} = 0.17 \pm 0.1(stat) \pm 0.26(th) GeV^{-1};$$

Recent Lattice calculations have improved accuracy: $\lambda_0 = 0.012 \pm 0.002$
D.Becirevic et al., hep-lat/0411016



Fiertz transformation : $(\bar{s}\mu)(\bar{\nu}u) = -\frac{1}{2}(\bar{s}u)(\bar{\nu}\mu) - \frac{1}{8}(\bar{s}\sigma_{\alpha\beta}u)(\bar{\nu}\sigma^{\alpha\beta}\mu)$

The second term- effective T V.V.Kiselev et al., hep-ph/0204066 $\rightarrow$

$$\frac{f_T^{LQ}}{f_+(0)} = \frac{\sqrt{2}}{32 G_F |V_{us}|} \frac{m_K}{m_{K^*}} \frac{1}{\Lambda_{LQ}^2} \quad \Lambda_{LQ} > 3TeV (90\% \text{ CL})$$

OKA will allow to increase statistics of K_{l3} decays by factor of 100

OKA: search for CP-violation in τ , τ' decays.

10^{13} 70 GeV ppp; 2s/9s cycle. $\rightarrow$ $5(2) \cdot 10^6 K^+(K^-)$/cycle. ;

12m decay volume; 120 days 50% eff.

optimal strategy: $I^- = \sqrt{3} \cdot I^+ \rightarrow 10(6) \cdot 10^{10} K^+(K^-)$ decays

$\rightarrow (3.8 + 2.1) \cdot 10^9 \tau$; $(3.3 + 1.9) \cdot 10^8 \tau' \rightarrow \frac{\delta g_\pm}{2g} \sim 1.(1.3) \times 10^{-4} \tau(\tau')$

Should be compared with NA48/2:

$\frac{\delta g_\pm}{2g} = (0.5 \pm \frac{3.2}{\sqrt{2}}) \times 10^{-4} (\tau)$; $\frac{\delta g_\pm}{2g} = (? \pm \frac{2.2}{\sqrt{2}}) \times 10^{-4} (\tau')$

OKA: search for T- violation in $K^{\pm}$ decays

- T-odd correlation in $K \to e\nu\pi^0\gamma$ ($\mu\nu\pi^0\gamma$)

$\xi = \frac{\vec{p}_\gamma \cdot (\vec{p}_\pi \times \vec{p}_\mu)}{|\vec{p}_\gamma| \cdot |\vec{p}_\pi \times \vec{p}_\mu|}$; $A_\xi = \frac{N_{\xi>0} - N_{\xi<0}}{N_{\xi>0} + N_{\xi<0}}$ (J.Gevais, J.Iliopoulous, J.Kaplan 1966)

SM FSI: V.Braguta et al., Phys.Rev.D65,2002:

$K \to e\nu\pi^0\gamma \;\; A_\xi \sim 0.5 \times 10^{-4}$; $K \to \mu\nu\pi^0\gamma \; \sim 10^{-4}$

In extensions of SM (V.Braguta et al., Phys.Rev.D68,2003) larger effects are predicted:

$A_\xi \sim 3 \times 10^{-4}$

The only exp. results are from ISTRA ($K \to e\nu\pi^0\gamma$, 1986): $A_\xi = 0.03 \pm 0.08$; 192 ev;

and ISTRA+ ($K \to e\nu\pi^0\gamma$, 2005): $A_\xi = -0.015 \pm 0.021$; 1382 ev;

In OKA $\sim 2 \times 10^5$ events $\to$ $A_\xi < 2 \cdot 10^{-3}$

Conclusions

- The construction of the RF separated high energy kaon beam at IHEP, Protvino is close to completion: The ”worm” beam was commissioned in December 2004, the commissioning of the cryogenics is in progress, the complex startup of the separated beam is scheduled for December, 2005.
- The experimental setup is under construction
- New collaborators are welcomed !