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August 16, 1994

JINR Studies for a Tau-Charm Factory

Workshop on the Tau-Charm Factory in the Era of B-Factories and CESR

August 15 and 16, 1994

SLAC

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THE LEP DATA CONCLUSION:

"There are only three families of fundamental fermions !"

I	II	III
$\begin{pmatrix} \nu_e \\ e \end{pmatrix}_L$	$\begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}_L$	$\begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}_L$
$\begin{pmatrix} u \\ d \end{pmatrix}_L$	$\begin{pmatrix} c \\ s \end{pmatrix}_L$	$\begin{pmatrix} t \\ b \end{pmatrix}_L$

The results of experiments at LEP have shown that there are no new neutrinos, charged leptons, or quarks with masses below 45 GeV/c^2.

It therefore appears that the present three families of fundamental fermions will be the only ones that are experimentally accessible in the immediate - and perhaps far future.

LEPTONS

	e^-	μ^-	τ^-
m (MeV)	0.51099906 ±0.00000015	105.658387 ±0.000034	1784 +2.7; -3.6
$\frac{\sigma m}{m}$%	$\pm 2.9 \cdot 10^{-5}$	$\pm 3.2 \cdot 10^{-5}$	±0.18
MEAN LIFE TIME t	$>2 \cdot 10^{22}$years	$(2.19703 \pm 0.00004) \cdot 10^{-6}$ s	$(0.303 \pm 0.008) \cdot 10^{-12}$ s
$\frac{\sigma t}{t}$%		$\pm 1.82 \cdot 10^{-3}$	2.6
DECAY MODES		$e^- \overline{\nu}_e \nu_\mu \approx 100\%$ $e^- \overline{\nu}_e \nu_\mu \gamma \approx 1.4\%$ $e^- \overline{\nu}_e \nu_\mu e^+ e^- \approx 3.4 \cdot 10^{-5}$	"1 - prong" - 86% $\mu^- \overline{\nu}_\mu \nu_\tau \approx 17.8\%$ $e^- \overline{\nu}_e \nu_\tau \approx 17.7\%$ $\pi^- \nu_\tau \approx 11\%$ $K^- \nu_\tau \approx 0.7\%$ $\rho^- \nu_\tau \approx 23\%$ $\pi^- 2\pi^o \nu_\tau \approx 7.5\%$ $\pi^- 3\pi^o \nu_\tau \approx 3.0\%$ "3-prong" ≈ 14% $\pi^- \pi^- \pi^+ \nu_\tau \approx 7.1\%$ $\pi^- \rho_0 \nu_\tau \approx 5.4\%$ "5-prong" ≈ 0.1% $2\pi^+ 3\pi^- \nu_\tau \approx 6 \cdot 10^{-4}$ $2\pi^+ 3\pi^- \pi^o \nu_\tau \approx 5 \cdot 10^{-4}$ "7-prong" $< 1.9 \cdot 10^{-4}$
	ν_e	ν_μ	ν_τ
	m_ν <17eV	m_ν <0.27MeV	m_ν <35MeV

What we want to learn about the τ and ν_τ

Subject	Search for New Physics	Test Standard Model	Tau-charm Factory
Understand 1-charged particle modes puzzle ?	√ ?	√ ?	√ ?
Untangle multiple π^0 and η in 1-charged particle modes		√	√
Precise measurement of $B(e\nu\nu)$, $B(\mu\nu\nu)$, $B(\pi\nu)$, $B(k\nu)$, $B(\rho\nu)$, and their ratio to 0.5%	√	√	√
Precise measurement of Cabibbo-suppressed modes	√	√	√
Full study of dynamics of $\tau \longrightarrow e\nu\nu$, $\tau \longrightarrow \mu\nu\nu$ analogous to $\mu \longrightarrow e\nu\nu$ in detail	√	√	√
Detailed study of 3-, 5-, 7-charged particle modes		√	√
Find and study rare allowed modes such as radiative decays and second-class currents	√	√	√
Explore forbidden decay modes	√	√	√
Precise measurement of τ lifetime	√	√	
Explore ν_τ mass to a few MeV/c²	√	√	√
Detect ν_τ	√	√	
Study interactions of ν_τ	√	√	
Precise low energy study of $e^+e^- \longrightarrow \tau^+\tau^-, \tau^+\tau^-\gamma$	√	√	√
Precise high energy study of $e^+e^- \longrightarrow \tau^+\tau^-, \tau^+\tau^-\gamma$	√	√	
Study of $Z^0 \longrightarrow \tau^+\tau^-$	√	√	
Study of $W^- \longrightarrow \tau^-\overline{\nu_\tau}$	√	√	
Measure $B(D^- \longrightarrow \tau^-\overline{\nu_\tau})$	?	√	√
Measure $B(D_s^- \longrightarrow \tau^-\overline{\nu_\tau})$	?	√	√
Measure $B(B^- \longrightarrow \tau^-\overline{\nu_\tau})$	?	√	
Make and study $\tau^+\tau^-$ atom	√	√	?

Tasks of the Tau-Charm Factory detector group

- Development (adaptation) of a physics programme for the JINR Tau-Charm Factory.
- Selection of the optimum detector design adequate to the physics programme and real conditions of the JINR.
- Setting up of expert groups that can carry out designing and methodical research and become kernels of future collaboration after the project is approved.
- Establishment of contacts with leading centres with a view to possible wide international collaboration within the framework of the JINR project.

CHARM TU

WORKSHOP
on JINR CTau-FACTORY

(29-31 May 1991, JINR,Dubna)

Tentative topics:

1. Physics investigation program at CTau-factory
   - 1.1 Tau-lepton and tau-neutrino physics
   - 1.2 Charmed meson physics
   - 1.3 J/Psi-particle physics
   - 1.4 Charmed baryon physics
   - 1.5 Other physics problems
2. Accelerator physics
3. Detector
   - 3.1 Small-angle detectors
   - 3.2 Tracking system
   - 3.3 Particle identification system
   - 3.4 Electromagnetic calorimetry
   - 3.5 Superconducting solenoid
   - 3.6 Muon detector
   - 3.7 Triggers
   - 3.8 Monte-Carlo simulation
4. Data acquisition and analysis system

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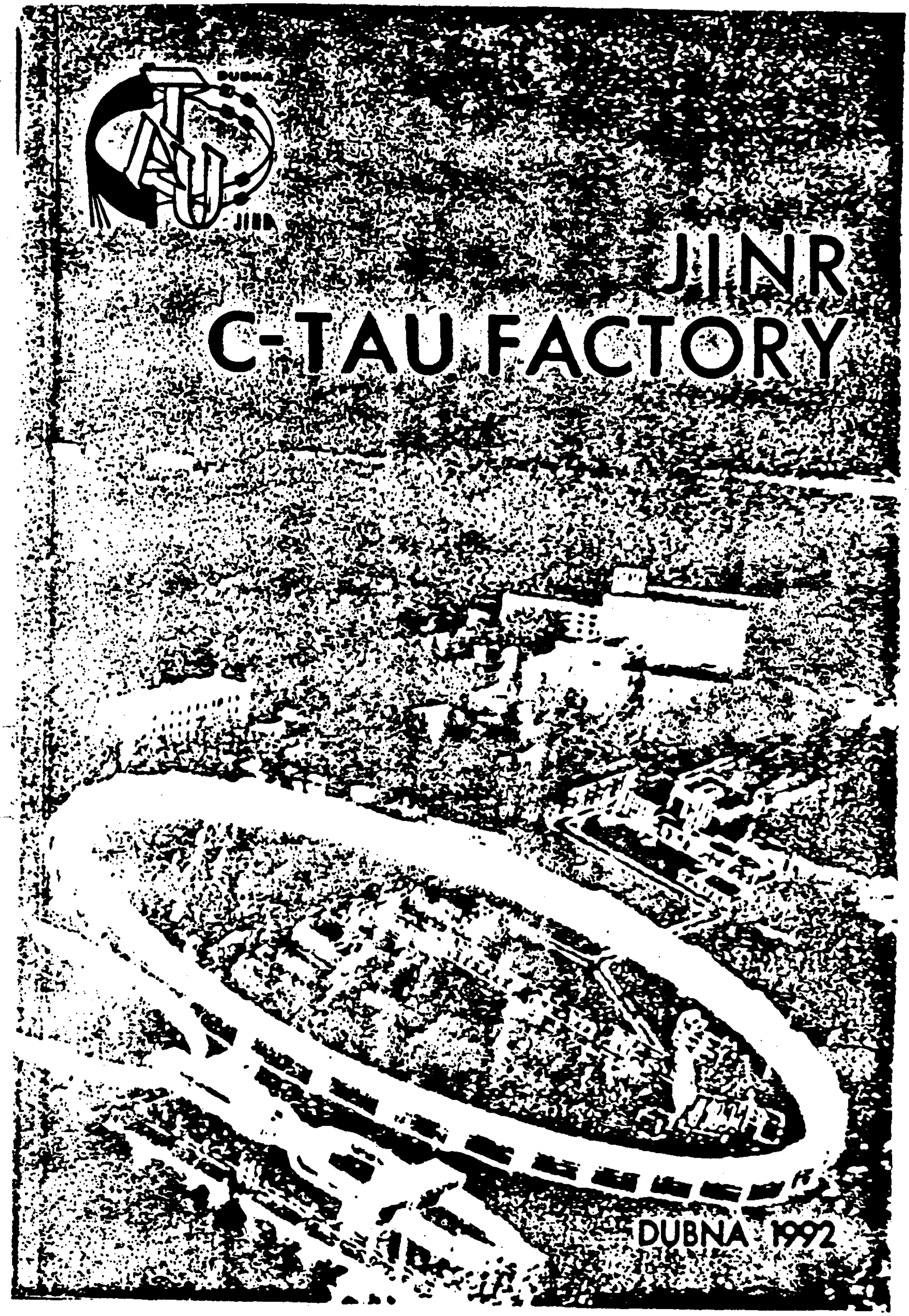
JINR
C-TAU FACTORY
DUBNA 1992

CONCLUSIONS

of The First Workshop on JINR C-TAU Factory

29-31 May 1991, Dubna

1. The $c\tau$ -factory physics programme for the precision study of the properties of the τ-lepton and c-quark-containing particles near their production threshold is of current importance and aimed at studying the fundamental problems of particle physics. It can not be implemented at the existing or planned facilities.

2. In general, the research programmes proposed now for high-intensity $e^+ e^-$ colliders (ϕ-, $c\tau$-, B-, Z-factories) complement one another and are likely to yield the best results if fulfilled together.

3. Implementation of this programme will take at least 10 years after putting into operation the above installations.

4. As the research programme is rather wide, it is reasonable to construct at least two installations of each type, which will also ensure the necessary confidence level of the data obtained.

5. Being a project of a perfect facility for modern particle physics, the $c\tau$-factory and universal detector project is relatively cheap and feasible for the JINR.

6. The significance of the project is far beyond the above-mentioned scientific reasons:

- development and construction of this collider allows a new modern basic facility of world class in the JINR for particle physics research;
- participating in this work based on the advanced technological experience many specialists (accelerator and other physicists, engineers, designers, workers) will improve their professional skills, which will raise the general level of the scientific research in the JINR;
- new competitive basic facility will allow the JINR to remain attractive to the scientists of the member-states for another 10-15 years and to attract scientists of other research centres;
- construction of the $c\tau$-factory in the JINR will allow many young specialists of the member-states to be trained according to the present-day requirements and will be helpful in replenishing the JINR staff with talented youth.

STATUS REPORT ON THE JINR TAU CHARM FACTORY PROJECT.

A. SISSAKIAN, E. PERELSTEIN

1. INTRODUCTION.

The project of an electron- positron storage complex is presently studied at JINR to provide promising investigations in the Institute's traditional fields of elementary particle physics, nuclear physics, condensed matter physics, as well as applied investigations [1]. The project discussed involves: a high resolution neutron source (IREN), a Tau Charm Factory (TCF) and an 8-10 GeV positron (electron) storage ring (NK-10). The construction of the complex is expected to have three stages. At the first stage, the high resolution neutron source is to be built. The IREN construction decision was approved at the 76th session of the JINR Scientific Council in June, 1994. The second stage is the construction of the Tau Charm Factory. A successful discussion of the Tau Charm Factory proposal took place at the past 75th session of the JINR Sientific Council in 1994. For successfull realization of the TCF project it is expected to organize a wide international collaboration to include as many countries from all continents having an interest to Tau Charm Physics as possible.

We believe that the location of TCF or a similar installation at Dubna has many advantages. It would open new possibilities to advance high energy physics in East European Countries where JINR is a well-known scientific centre, to develop new high technologies and to raise the education level of young people in this region, as well as to create an international collaboration in this field of physics. JINR has a Training Centre, and on this basis it is possible to establish an International University at Dubna where the particle physics students could have their using practice at the modern facility such as TCF. Presently there are about 500 high energy physicists in the JINR staff. The development of the international collaboration around the JINR TCF will be based on a wide access to TCF for a large number of visiting scientists and students, the progress with JINR's computer net communications, the geographical location of Dubna (near Moscow, near the international airport Sheremetyevo), the available infrastructure of JINR as an international scientific centre.

2. TAU CHARM FACTORY PHYSICS PROGRAMME.

The requirements for TCF physics, machine and detector have been discussed at many workshops [2],[3], [4],[5],[6]. The scientific research programme for the Tau Charm Factory includes tau-lepton and tau-neutrino physics, charmonium spectroscopy, CP violation experiments, charmed baryon physics and meson spectroscopy.

The core of the experimental programme for Tau Charm Factories must be: the study of properties of the second-generation quarks and the third-generation leptons through investigations in tau-lepton physics, charmed meson physics, charmonium physics, charmed

Experiment	Collider	E_{cm}(Gev)	Number of $\tau^+\tau^-$
BES	BEPS	4	10^4
ARGUS	DORIS	10	$3.75 \cdot 10^5$
CLEO	CESR	10	$2 \cdot 10^6$
ALEPH	LEP	91	$5 \cdot 10^4$
DELPHI	LEP	91	$5 \cdot 10^4$
OPAL	LEP	91	$5 \cdot 10^4$
L3	LEP	91	$5 \cdot 10^4$
	TCF	3.57	$4 \cdot 10^6$
JINR	TCF	3.67	$2 \cdot 10^7$
	TCF	4.25	$4 \cdot 10^7$

Table 1: $\tau^+\tau^-$ production at e^+e^- colliders (presented by Prof. Alan Weinstein). CESR: $L > 2 \cdot 10^{32} cm^{-2} s^{-1} = 10 pb^{-1}/day = 1.5 fb^{-1}/year$. CESR - upgrade: N_{bunch} : 7 x 1$\rightarrow$ 9 x 5$\rightarrow$ $L = 10^{33}$(1996). B - factories: SLAC ($3 \cdot 10^{33} cm^{-2} s^{-1}$), KEK ($10^{34} cm^{-2} s^{-1}$).

baryon physics. This is the energy region where the BEPC facility recently built in Beijing (China) operates. Nevertheless, the experimental statistics for this energy region is far from being rich. So, one of the reasons for building Tau Charm Factories is to get higher luminosity.

In Table 1 there are the tau- lepton pair production rates for different centres [7] and for the JINR TCF.

Besides, TCF allows one to study properties of tau-leptons and charmed baryons near their production threshold and thus to obtain high-quality information at a uniquely low background.

So TCF is an ideal instrument to investigate most interesting features of the Standard Model and the hadrons as a composite system [8]. It plays a role of source of τ and D-mesons with $\sim 10^7$ events per year which provide rather good statistical accuracy ($\leq 1\%$).

3. THE PRESENT STATUS OF THE ACCELERATOR PART OF THE JINR TCF PROJECT.

Presently two TCF projects with a centre-of-mass energy range 3-5.7 GeV are being studied. The first one aims at CERN-ISR site, so taking advantage of the existing powerful injector, and the second one is directed towards construction at Dubna. These projects have many common features, apart from the site, because of well identified constraints and a strong collaboration between designers. We have three possible phases for the TCF project [9].

The first phase of JINR TCF operation is planned to be conventional scheme. The next one may be monochromatization [10] or crossing angle scheme [12],which provides a luminosity of 3÷5$\cdot 10^{33}$ cm^{-2} s^{-1}.

The injection complex consists of a preinjector and a fast booster synchrotron, where electrons and positrons are finally accelerated up to the main ring energy [11]. The

		Standard scheme	Monochrom. scheme	Cros. angle scheme
Beam energy, GeV	E	2.0	2.0	2.0
Luminosity, $cm^{-2}s^{-1}$	L	$1.0 \cdot 10^{33}$	$0.9 \cdot 10^{33}$	$3.5 \cdot 10^{33}$
C.M. energy resolution, MeV	σ_w	1.9	0.14	1.7
Circumference, m	C	377.8	377.8	377.8
Natural emittance, nm	ε_0	426	17.0	299
Damping partition numbers	$J_x/J_y/J_s$	0.6/1/2.4	2/1/1	0.6/1/2.4
Bending radius in arc, m	ρ	10.5	10.5	10.5
Damping times, msec	$\tau_x/\tau_y/\tau_s$	37/22/9	18/35/34	41/25/11
Momentum compaction	α	$1.58 \cdot 10^{-2}$	$8.02 \cdot 10^{-3}$	$1.59 \cdot 10^{-2}$
Energy spread	σ_E	$6.66 \cdot 10^{-4}$	$7.32 \cdot 10^{-4}$	$5.89 \cdot 10^{-4}$
Total current, A	I	0.566	0.479	2.0
Number of particles per bunch	N_b	$1.49 \cdot 10^{11}$	$1.26 \cdot 10^{11}$	$1.05 \cdot 10^{11}$
Number of bunches	k_b	30	30	150
RF voltage, MV	V	8	5	7
RF frequency, MHz	f_{RF}	476	476	476
Harmonic number	q	600	600	600
Energy loss per turn, kV	U_0	226	143	199
Bunch length, mm	σ_s	8.15	8.06	7.72
Bunch spacing, m	S_b	12.6	12.6	2.52
Required long. impedance, Ohm	$\|Z_n/n\|$	0.25	0.18	0.27
Beta functions at I.P., m	β_x^*/β_y^*	0.20/0.01	0.01/0.15	0.50/0.01
Vertical dispersion at I.P., m	D_y^*	0.	0.36	0.
Beam-beam parameters	ξ_x/ξ_y	0.04/0.04	0.04/0.03	0.04/0.04

Table 2: List of parameters of tau-charm collider

preinjector energy 500 MeV will be also suitable for initial acceleration of particles for the Synchrotron Radiation (SR)- source NK-10 in future. The average luminosity is ensured at the level of 80 % of peak one.

The conventional scheme is considered as the basic one for the JINR TCF. The versatile design of the collider provides the possibility to work with the monochromatization for the experiments requiring a small energy resolution [10]. The horizontal crossing angle option with minimum modifications in the storage ring is discussed in [12]. Only interaction and separation regions have been replaced, while keeping the arcs and the long straight section opposite to interaction point untouched. The list of TCF parameters for three options is given in Table 2.

The main features of the design prepared by JINR (Dubna), SRIEA (St. Petersburg), RIPR (St. Petersburg) on the base of the versatile lattice were discussed in [10].

The aluminum vacuum chamber of TCF is designed in such a manner that SR goes through next straight section and is absorbed at the bending magnet end. Providing the chemical cleaning and heating of the vacuum chamber the outgassing rate of aluminum much less then stimulated desorbtion. Using the combined pumps one gets the pressure about $2 \cdot 10^{-7}$Pa at the absorber location, which corresponds to the beam lifetime of 30 h. The additional pump is used for the pumping of the remaining part of vacuum volume and provides the pressure at the level $2 \cdot 10^{-8}$Pa.

The 500 MHz superconducting RF cavities is planned to use. The total value of SR and HOM losses at energy $E = 2.0$ GeV is of order 300 kW and the maximum RF voltage is of 8 MV for one ring. The RF power supply scheme for TCF is grounded on the principle of separate supply of each cavity using the 80 kW klystrons developed at "SVETLANA" (St.Petersburg). The RF power supplier consists of 4 independent FR lines with the total output power 320 kW.

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