THE STATUS OF TURKISH ACCELERATOR COMPLEX PROJECT

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Abstract

The Turkish Accelerator Complex (TAC) is proposed as a regional facility for accelerator based fundamental and applied research in 1997 with support of Turkish State Planning Organization (DPT). The feasibility and conceptual design phases of TAC proposal were completed in 2001 and 2005, respectively. Again with support of DPT, the technical design phase of TAC was started at the beginning of 2006. The complex will include 1 GeV electron linac and 3.56 GeV positron ring for linac on ring type electron-positron collider as a charm factory and a few GeV proton linac. Besides the particle factory, it is also planned to produce SASE FEL from electron linac and synchrotron radiation from positron ring. It is planned that the TDR of TAC Project will be completed in 2011 and the construction will be performed during following ten years.

INTRODUCTION

Fifteen years ago, a linac-ring type c-τ-factory including synchrotron light source was proposed as a regional project for elementary particle physics [1]. Since 1997 the Turkish Accelerator Complex (TAC) project [2] has been developed as a regional facility for accelerator based fundamental and applied research with support of Turkish State Planning Organization (DPT). The Project has four main goals:

- Linac-ring type electron-positron collider as a “Charm” factory with a center of mass energy $\sqrt{s}$ = 3.77 GeV (See Fig. 1).
- A SASE FEL facility based on a 1 GeV electron linac with a wavelength of few nanometers.
- Third generation light source “Synchrotron Radiation” based on 3.56 GeV positron ring.
- GeV scale proton accelerator which consists of 100 MeV linear pre-accelerator and 1 GeV main ring.

As first step of TAC, an oscillator infrared free electron laser (IR-FEL) covering 2-185 μm wavelength range based on an 15-40 MeV electron linac and a Bremsstrahlung facility is planned for accelerator based training and research which will be completed in 2011. For Details see [16].

Today, 70 scientists from 10 different Turkish universities are working for TAC collaboration under coordination of Ankara University. The IR-FEL facility is planned to be constructed in Virancik campus of Ankara University.

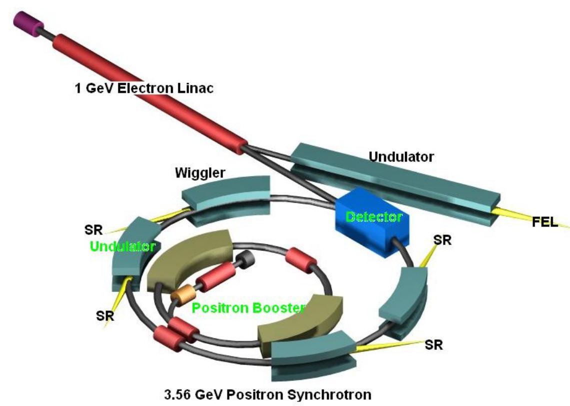

Figure 1: Schematic view of TAC complex.

TAC CHARM FACTORY

It is planned to collide the electrons coming through the linac with an energy of 1 GeV with the positrons coming from the synchrotron with an energy of 3.56 GeV (See Fig. 1). It is aimed to produce Charm particle with a center of mass energy $\sqrt{s}$ = 3.77 GeV. Up to now; φ-, τ-, and c- factory options were analyzed. In principle, $L = 10^{34}$ cm^{-2}s^{-1} can be achieved for all three options. Concerning φ factory option, existing DAΦNE φ factory has nominal $L = 5 \cdot 10^{32}$ cm^{-2}s^{-1} and possible upgrades to higher luminosities are under consideration [3]. Therefore, physics search potential for the φ factory will be essentially exhausted before TAC commissioning. Concerning τ factory option, whereas $e^+e^- \rightarrow \tau^+\tau^-$ cross-section achieves a maximum value at $\sqrt{s}$ = 4.2 GeV, this advantage is dissipated with success of B-factories which has luminosity of 10^{34} cm^{-2}s^{-1} already. Moreover super B-factories with $L = 10^{36}$ cm^{-2}s^{-1} are intensively discussed [4].

Therefore, we inclined towards charm factory option. The center of mass energy is fixed by the mass of Ψ(3770) resonance. Existing CLEO-c [5] works with $L = 10^{32}$ cm^{-2}s^{-1}. The BEPC charm factory proposal [6] has design luminosity of 10^{33} cm^{-2}s^{-1}. Therefore, TAC charm factory with $L = 10^{34}$ cm^{-2}s^{-1}, planned to work in mid 2010’s, will contribute charm physics greatly. Differing from K and B mesons, where possible new physics manifest itself as a deviation from standart model background, D mesons has negligible standart

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model background. The main parameter set of TAC charm factory is presented in Table 1.

Table 1: Tentative parameters of TAC charm factory.

Parameter	**e^{-} linac**	**e^{+}-ring**
Energy, GeV	1.00	3.56
Particles per bunch, 10^{10}	0.55	11.00
B function at IP, cm	0.45	0.45
Norm. emittance, μm.rad	6.17	22.00
Bunch length, cm	0.10	0.45
Transverse size at IP, μm	3.76	3.76
Beam-beam tune shift	-	0.056
Collision frequency, MHz	30	
Luminosity (H_D.L)	1.4 10^{34} $cm^{-2}s^{-1}$	

The restriction on luminosity coming from linac beam power can be relaxed by using of energy recovery linac (ERL). ERL technology will give opportunity to construct super-charm factory with L well exceeding 10^{35} $cm^{-2}s^{-1}$ [7].

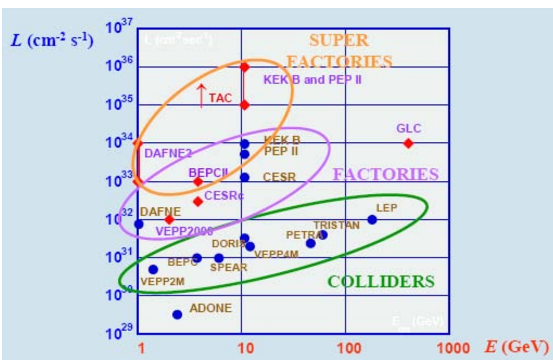

Figure 2: Past, present and future $e^{+}e^{-}$ colliders.

Concerning the charm physics search program [8]:

- Even with L = 10^{34} $cm^{-2}s^{-1}$ there are a number of processes which will be better studied at dedicated charm factory than at the super-B factory with L = 10^{36} $cm^{-2}s^{-1}$
- With L = 10^{35} $cm^{-2}s^{-1}$ dedicated charm factory cover almost all topics which can be investigated at super-B
- With L = 10^{36} $cm^{-2}s^{-1}$ super-charm factory will give opportunity to touch charm physics well further than super-B.

The last option could realized by using cw s.c. energy recovery linac (ERL) [9].

SYNCHROTRON LIGHT SOURCE

It was planned to obtain a third generation light source "Synchrotron Radiation" from the positron ring with energy of 3.56 GeV [1, 2]. Because of beam-beam tune shift restriction, the emittance of colliding beams in standart (ring-ring) type colliders inevitably should be chosen to be relatively large to obtain high luminosity:

$$L = f_c \frac{4\pi\gamma_p\gamma_e\Delta Q_p\Delta Q_e\varepsilon_p}{r_0^2\beta_e^*}$$

where subscript e (p) corresponds to electron (positron). This restricts the performance of synchrotron radiation obtained from insertion devices placed in standard type colliders.

Fortunately, this is not the case for linac-ring type machines. In this case, emittance of the positron beam does not essentially affect luminosity performance of the collider:

$$L = f_c \frac{\gamma_p\Delta Q_p N_p}{r_0\beta_p^*}$$

Therefore, the emittance of the positron beam can be chosen small enough to behave as a third generation light source in principle. Normalized emittance of the positron beam given in Table 1 corresponds to transverse emitance of 3 nm·rad, which is well below 20 nm·rad (upper limit for third generation SR sources).

Main parameters of TAC SR Facility were reported at EPAC 2000 [10]. Since then, construction of SESAME [11, 12] has begun in Jordan and CANDLE [13] project has been developed in Armenia, in design studies of TAC SR facility we are considering some design and construction experiences of these regional SR facilities. TAC SR facility will give typical third generation light source and will give a chance to users from our region to make SR based research in basic and applied sciences. Several samples of optical beam line design and related studies on TAC SR facility can be found in [14].

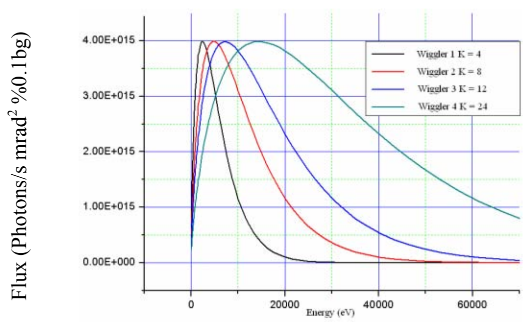

Figure 3: Flux vs photon energy.

SASE MODE FREE ELECTRON LASER FACILITY

A SASE FEL facility is also planned as 4th generation ligth source in the frame of TAC (See Fig. 1). Such a facility may be based on 1 GeV electron linac of the collider or a special independent linac. As an alternative, electron accelerator which will drive SASE FEL, energy recovery linac (ERL) can be proposed. For SASE FEL production, to achieve the peak power about ~GW, the required peak current must be about ~kA. To raise the peak current, modifications for bunch sizes and emittance manifest that the linac design which will be done for SASE FEL must be performed completely different from the collider's [15]. Some parameters of 1 GeV electron beam, undulator and SASE FEL are given in Table 2.

Table 2: 1 GeV electron beam, undulator and SASE FEL parameters.

Beam energy (GeV)	1
Number of electrons per bunch (10^9)	5.5
Peak current (A)	2106
Energy spread (%)	0.1
Normalized emittance (μm.rad)	3.1
Period length, λ_u (cm)	3.0
Gap, g (cm)	1.2
Peak magnetic field, B_u (T)	0.498
K parameter	1.395
Undulator saturation length (m)	36
Number of periods, N	1200
SASE FEL wavelength, λ_{FEL} (nm)	7.7
SASE FEL energy, E_{FEL} (eV)	160.5
P parameter	0.0018
Peak power, (GW)	1.4
Peak flux, (photons/s)	1.5×10^{26}
Peak brightness (photons/s/mrad^2/0.1%bg)	1.7×10^{29}

Further steps in technical design of SASE FEL facility, mentioned linac structures will be analyzed in detail by concerning developing accelerator technologies. TAC SASE FEL facility will play a role to complete the spectrum in addition to IR-FEL, Bremsstrahlung and synchrotron radiation sources.

PROTON ACCELERATOR

TAC proton accelerator proposal consists of 100÷300 MeV energy linear pre-accelerator and 1÷5 GeV main ring or linac. The average beam current values for these machines would be ~30 mA and ~0.3 mA, respectively. Proton beams from two different points of the synchrotron will be forwarded to neutron and muon regions, where a wide spectrum of applied research is planned. In muon region, together with fundamental investigations such as test of QED and muonium-antimuonium oscillations, a lot of applied investigations such as High-T_c superconductivity, phase transitions, impurities in semiconductors *et cetera* will be performed using the powerful Muon Spin Resonance (μSR) method. In neutron region investigations in different fields of applied physics, engineering, molecular biology and fundamental physics are planned.

CONCLUSION

Realization of the TAC project will accelerate the development in almost all fields of science and technology in Turkey and around. At the same time, TAC will be a major regional international research center in the field of particle physics, accelerator technology and applications.

ACKNOWLEDGEMENTS

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