TURKISH ACCELERATOR CENTER (TAC) PROJECT

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- Introduction
- Turkish Accelerator Center (TAC) Project
- First Facility (IR FEL & Brems.)
- Technical Design Studies of TAC
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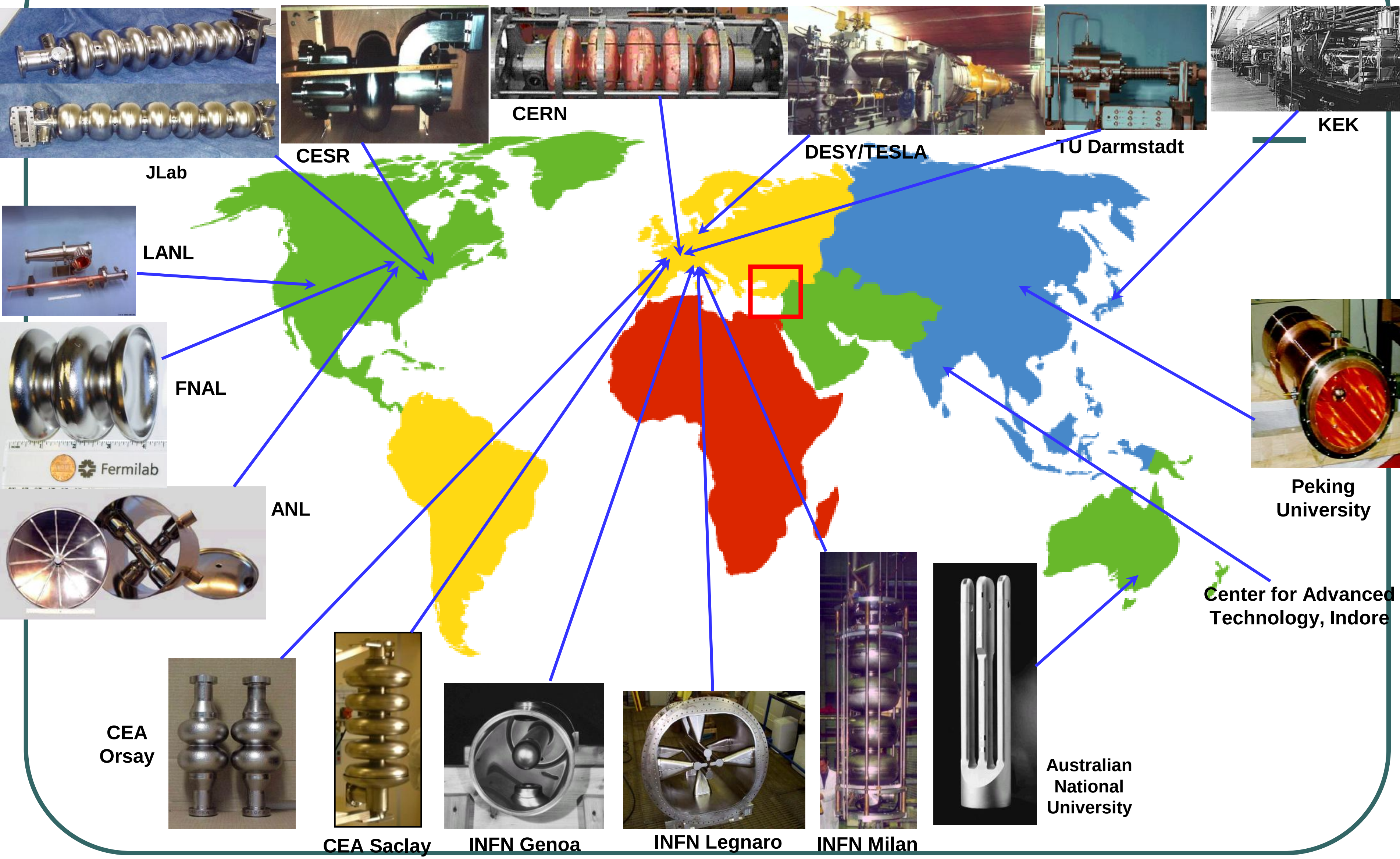
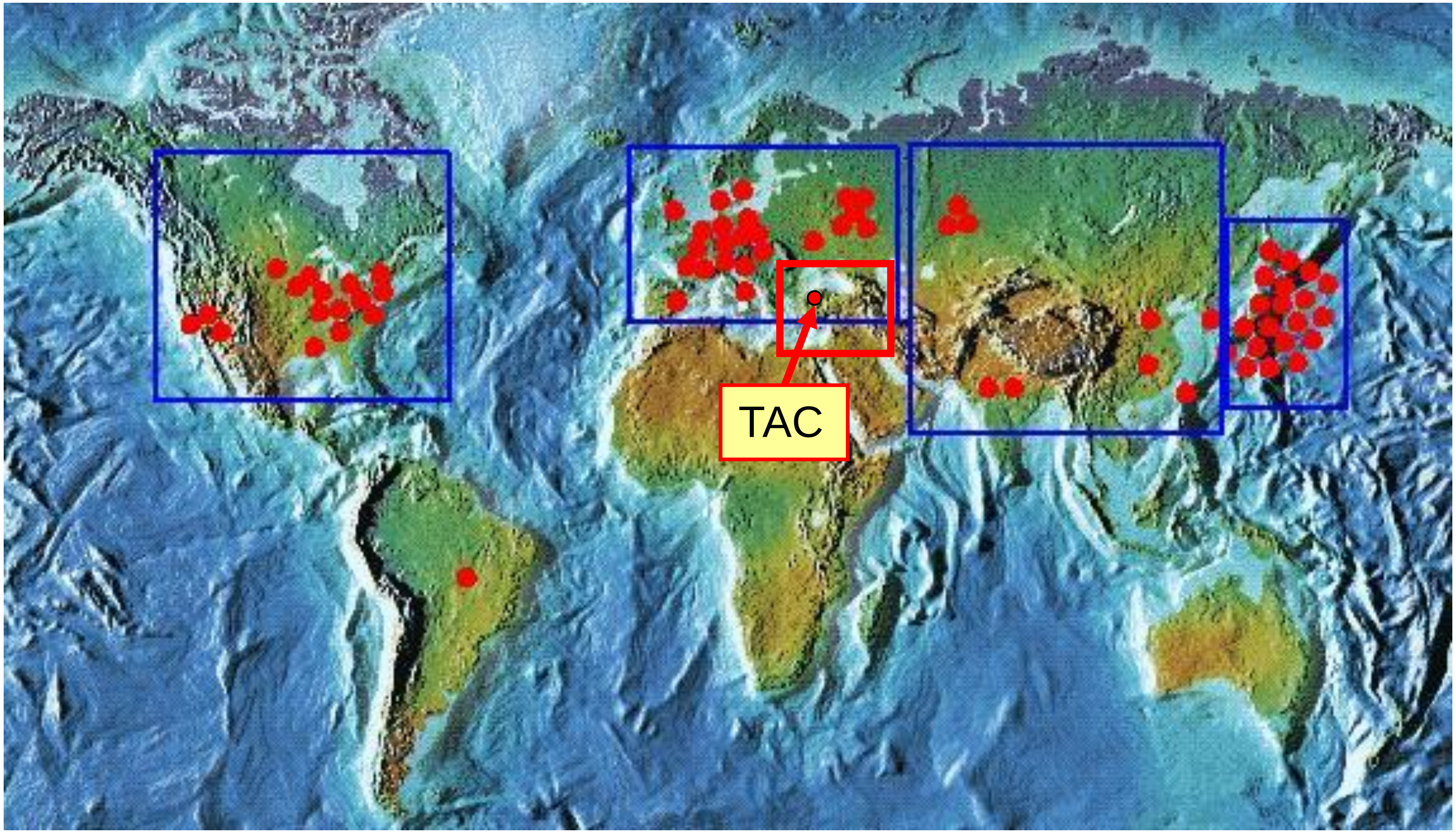
Introduction

- Accelerator technology ➲ a generic technology ➲ locomotive of the development in almost all fields of science and technology.
- Accelerator technology should become widespread all over the world.
- Existing situation: a large portion of the world (the South and Mid-East) is poor on the accelerator technology.

Global View of Accelerator Technology



Distribution of big scale accelerator facilities (SR Facilities) around the world



Projects in Middle East

- SESAME in Jordan (by UNESCO) } SR
- CANDLE in Armenia

- Turkish Accelerator Center (TAC)
  - Light sources (IR FEL, Brems., SR and SASE FEL)
  - Particle physics experiments (Particle Factory)
  - Proton and secondary beam applications

Road map of TAC Project

I. Step: **Feasibility Report for TAC**
(1997-2000)

II. Step: **Conceptual Design Report (CDR) of TAC**
(2002-2005)

III. Step: **- Technical Design Report (TDR) of TAC**
- First Facility (IR FEL & Brems.)
- Institute of Accelerator Technologies
(2006 - 2009 - 2012)

IV. Step: **Construction of TAC (2013-2023)**

TAC: An Inter University Collaboration

10 Turkish Universities

93 members: 41 staff with PhD, 52 graduate students

- Ankara University (Coordinator)
- Gazi University
- İstanbul University
- Uludağ University
- Dumlupınar University
- Boğaziçi University
- Doğuş University
- Erciyes University
- Süleyman Demirel University
- Niğde University

First Facility of TAC

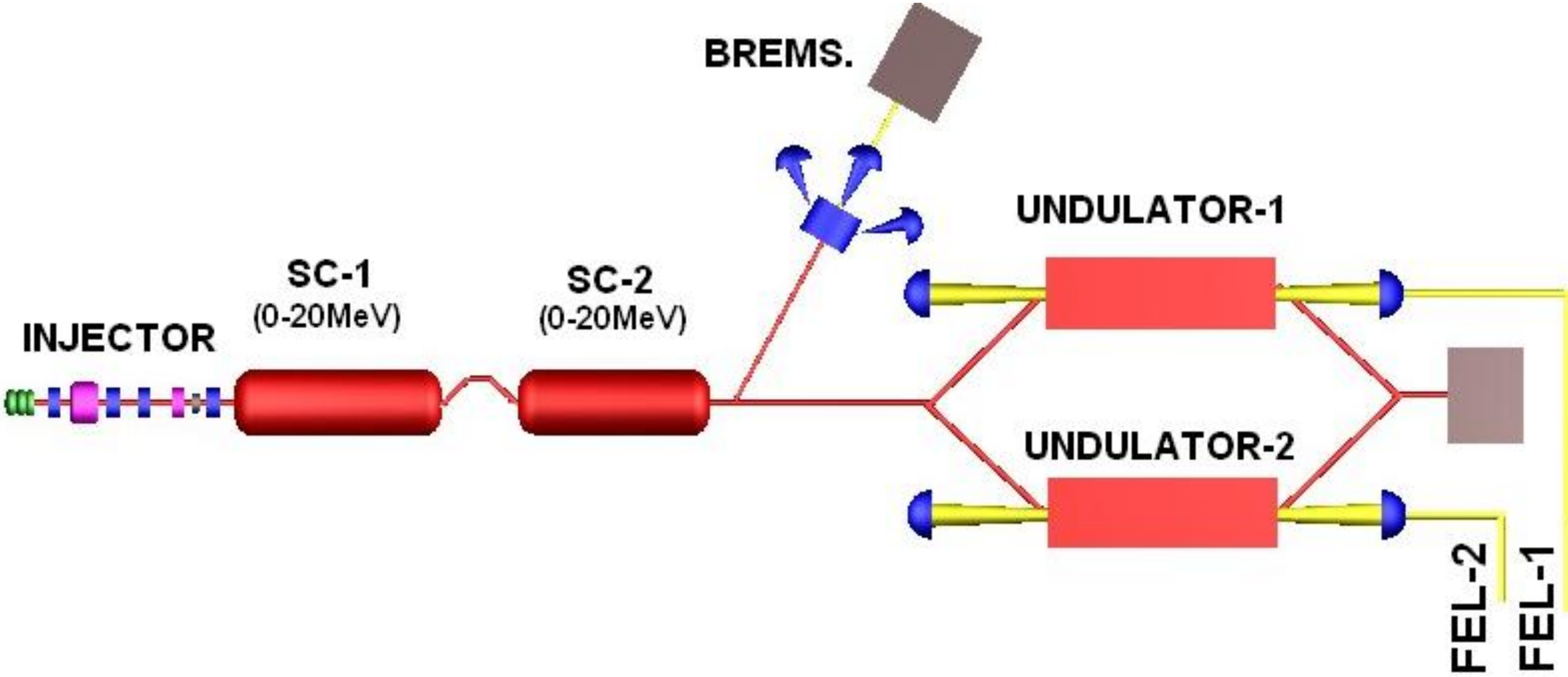
- Turkish Accelerator and Radiation Laboratory at Ankara (TARLA)

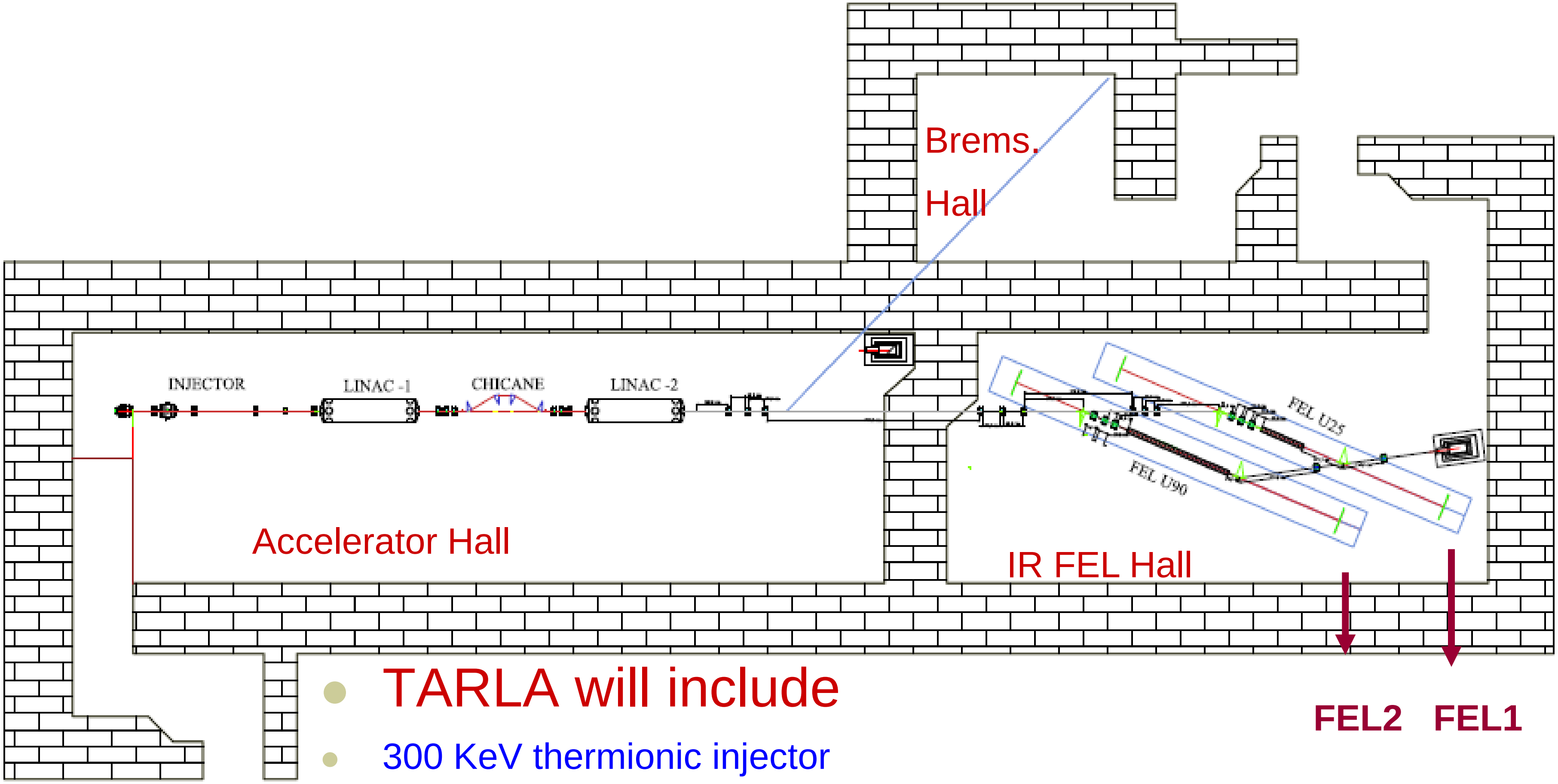
- This facility is planned as a Free Electron Laser & Bremstrahlung Facility

TARLA Facility

- TARLA project aims to produce FEL in oscillator mode between 2-250 micron range using 15-40 MeV electron beam.
- In order to have wide research area we request to have CW electron beam with high averege current as well as pulsed beam with low current.
- Therefore we plan to use high avereage current thermionic DC gun and Superconducting RF cavities with IOT power sources.
- To obtain FEL 2-250 micron range we plan to use 2.5 and 9 cm period length undulators located in different optical resonators..

Schematic view of TARLA Facility





- TARLA will include
- 300 KeV thermionic injector
- 2 Sc RF accelerator module
- 2 FEL line with 25 mm and 90 mm period undulators
- 8 IR FEL experiment stations
- 1 Bremsstrahlung station


ANKARA (15km)
O-20
Ankara Çevreyolu
GÖLBAŞI
Town Gölbaşı
Yaylabağ
A. Ü. Virancık (50. Yıl) Kampüsü
HTE ve THM IR-SEL Laboratuvarı İnşaat Alanı
D-260
Örencik
Gölbasi Campus of
Ankara University
Lake
Mogan
Haymana Yolu
Ankara-Konya Otoyolu
Yurtbeyi
Image © 2008 DigitalGlobe
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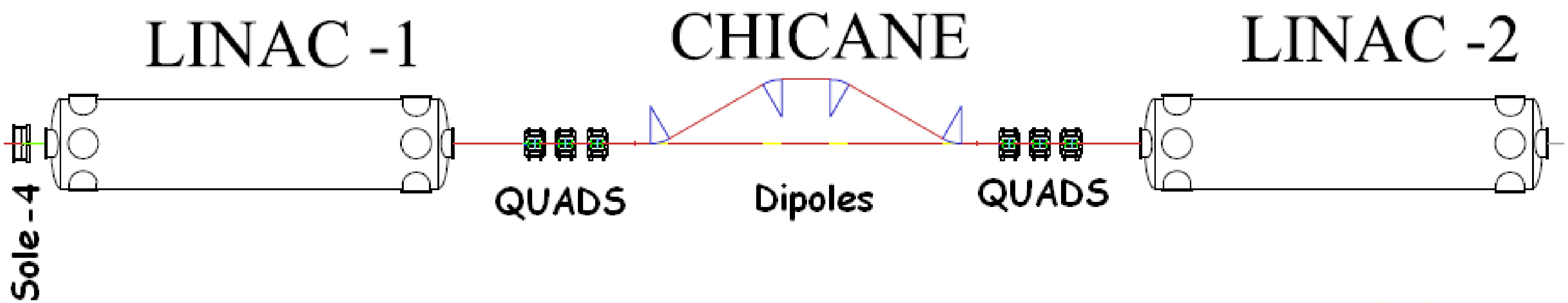
© 2008 Basarsoft
Google
Pointer 39°46'36.37" N 32°49'45.96" E Streaming 100% Eye alt 11.05 km

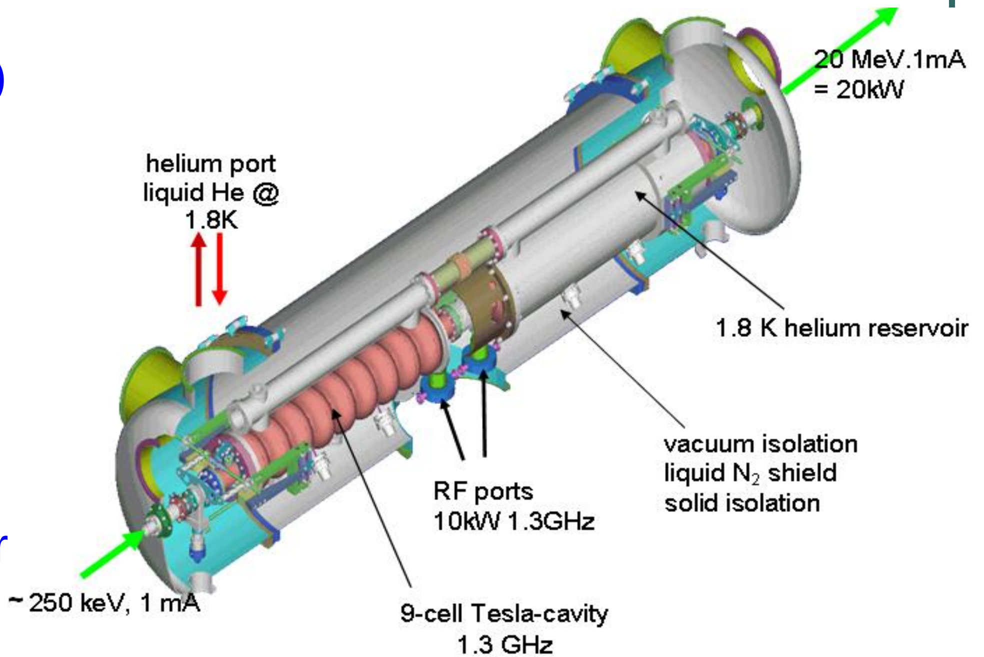
- TARLA will be located at Gölbasi campus area of Ankara University, Ankara



- For Cw operation two Sc RF (ELBE) modules is planed to use in order to reach beam energy up to 40 MeV

- A chicane will be located between two modules

- 16 kW IOTs was proposed as power source



Electron Beam Parameters

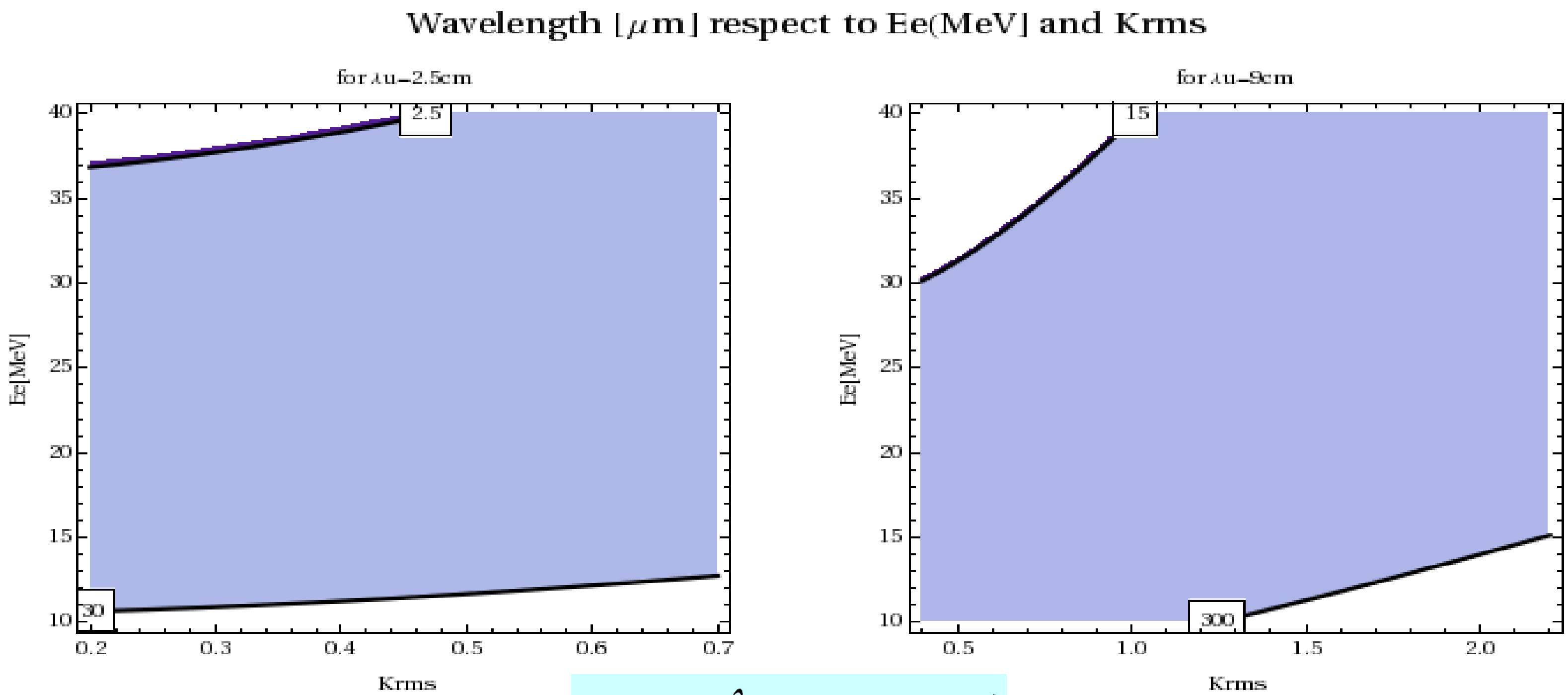
Beam Energy [MeV]	15-40
Max. Average Beam current [mA]	1.6
Bunch Repettion Rate [Mhz]	260*-26-13
Bunch Length [ps]	1-10
Norm. RMS Trans. emit. [mm mrad]	<15
Norm. RMS Long emit. [keV.ps]	<100
Macropulse Length and repetition	CW/tunable

***** For Bremsstrahlung applications

Resonator & Undulator Parameters for IR FEL

Parameter	Resonator/Und-1	Resonator/Und-2
Magnet Material	SmCo	SmCo
Period Length (mm)	25	90
Number of periods	60	40
Magnet block dimensions (mm)	74*26*10.5	90*90*35
Steel pole dimensions (mm)	74*18*2	70*20*10
Magnetic gap (mm)	15	40
Effective field (T)	0.3591	0.4205
Krms	0.71	2.5
Optic cavity length, L_c [m]	11.53	11.53
Resonator Type	Symmetric, concentric	Symmetric, concentric
1th Mirror, radius of curvature, R_1 [m]	5.86	6.32
2nd Mirror, radius of curvature, R_2 [m]	5.86	6.32
Rayleigh length, Z_R [m]	0.75	1.8
Mirror Material	Au / Cu	Au / Cu
Radius of out coupling hole [mm]	01/02/09	2/3/4
Waveguide	Not determined	Not determined

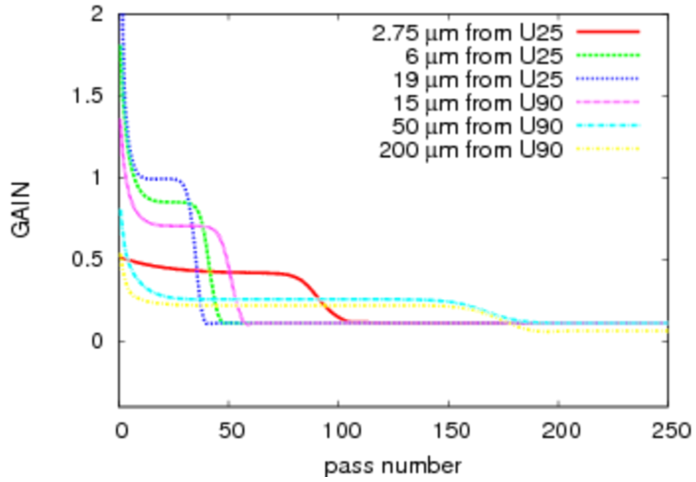
FEL Wavelength ranges for U25 and U90

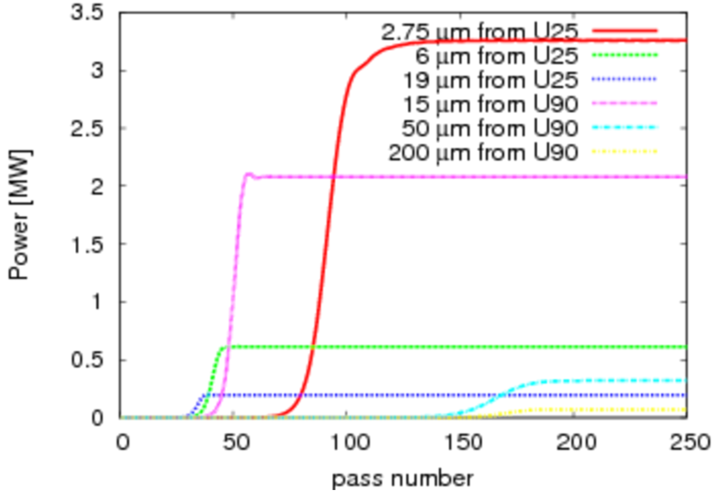


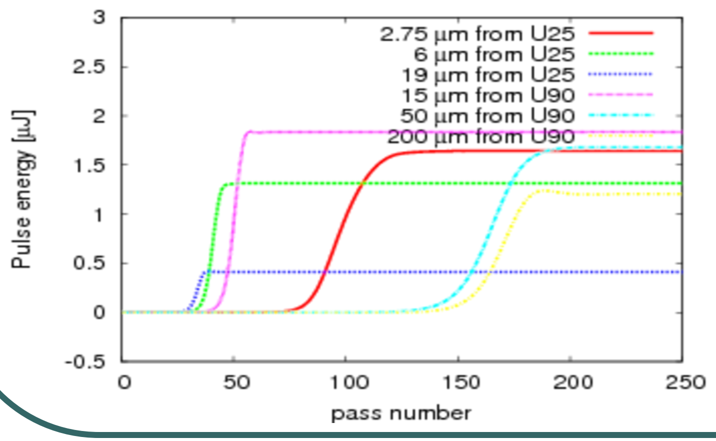
$$\lambda_{FEL} = \frac{\lambda_U}{2\gamma^2}\left(1 + K_{rms}^{2}\right)$$

- Without taking into account the nonlinear effects inside the optical resonators it is possible to obtain FEL between 2.5 μm and 250 μm range

FEL Saturation Process







- Saturation Process for some wavelength, obviously the saturation takes long time for longer wavelengths
- Power for shorter wavelenths reaches up to 4 MW (it can be higher for shorter bunch lengths)
- Pulse energy as well

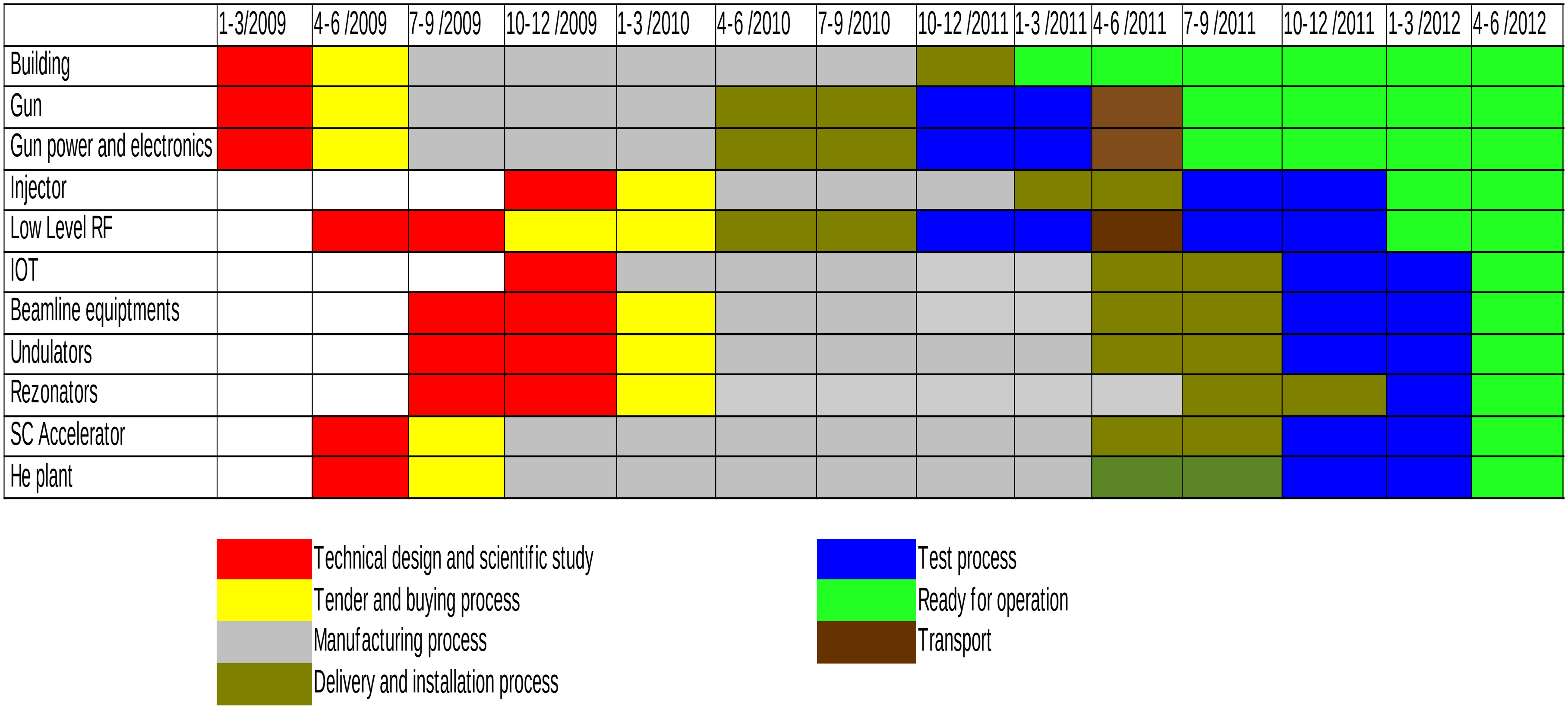
Expected IR FEL Parameters

	U25	U90
Wavelength [μm]	2-30	15-250
Micropulse repetition [Mhz] **	13-26	13-26
Max. Peak Power [MW] *	0.1 – 6	0.01-2
Average Power [W] *	1-100	1-100
Max. Pulse energy [μJ] *	0.1-3	0.1-3
Peak Brightness		
[ph/(s mm^2 $mrad^2$ 0.1% bw)]*	~10^30	~10^29
Pulse length [ps] *	1-10	1-10

** We still study on 26 MHz opsion

* Depending on wavelengths

TIME SCHEDULE OF TAC IR-FEL PROJECT



Plan for experimental stations of TARLA

- **Exp. Station No 1:**
  Research on Photon (FEL) Science

- **Exp. Station No 2:**
  General IR FEL Spectroscopy (vibrational and rotational IR spectroscopy for solid, gases and liquid materials)
  FTIR spectroscopy, Raman spectroscopy

- **Exp. Station No 3:**
  IR FEL Spectroscopy and microscopy for material science and semiconductors
  SFG & Pump probe techniques

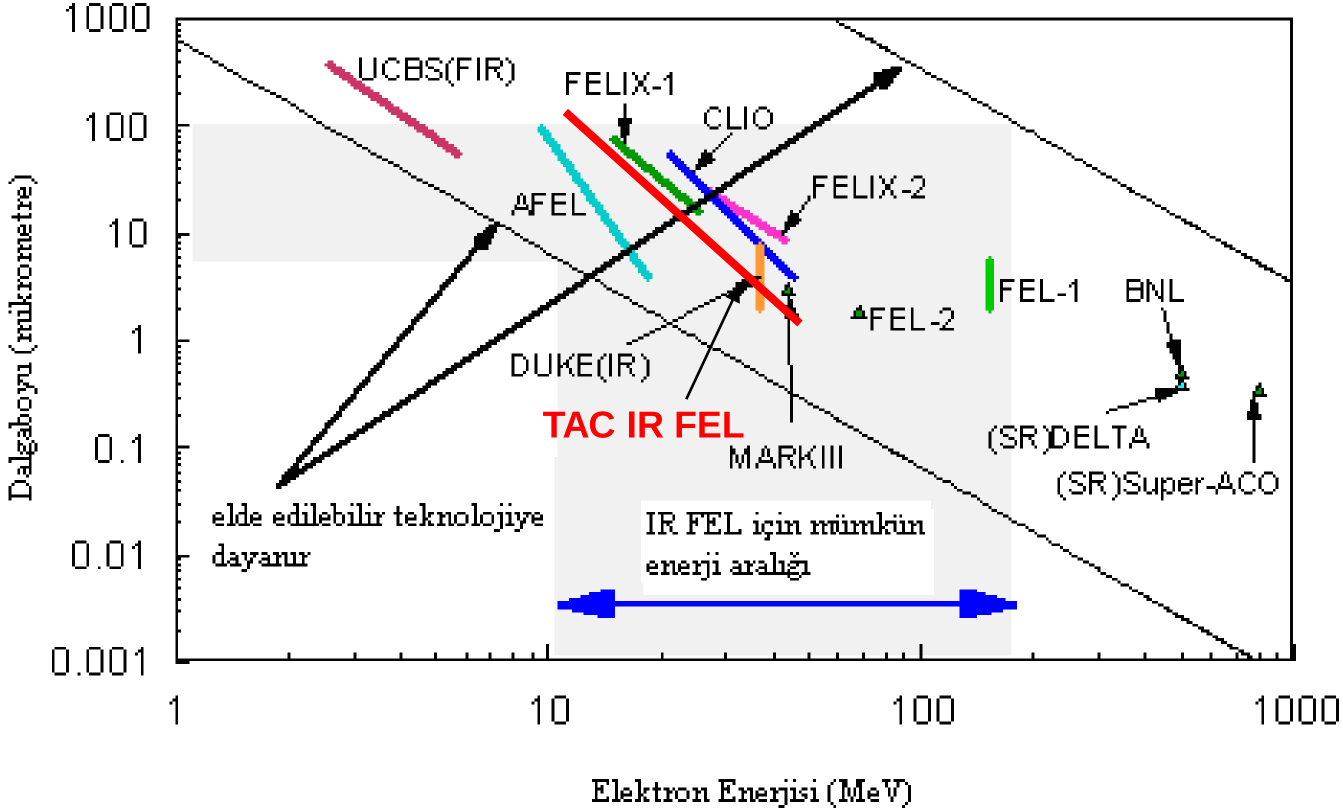
- **Other 5 Stations:** These stations will be planned to use in non-linear optics, nanotechnology, photochemistry, medicine and biotechnology based on user projects

Application fields of Infrared FEL (IR FEL)

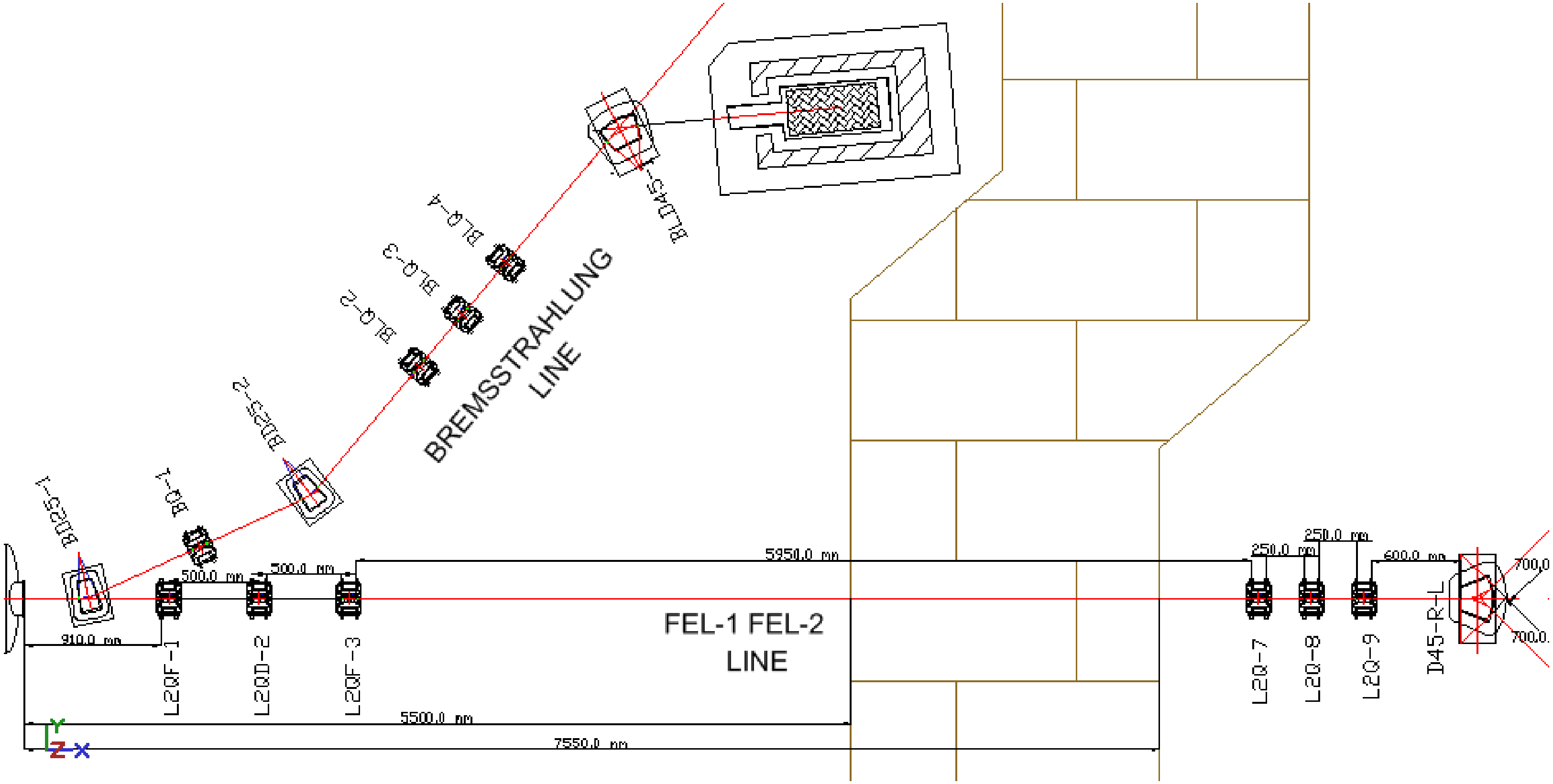
- Infrared spectroscopy
- Infrared microscopy
- Infrared imaging
- Material science
- Semiconductors
- Photochemistry
- Impurities
- Elipsometry
- THz spectroscopy
- Photo-thermal spectroscopy
- Photo-acustic spectroscopy
- Sum frequency spectroscopy
- Near field optical microscopy
- Pumb-prob measurements
- Vibrational and rotational spectroscopy
- Characterization of molecular structures

- Structural changes in DNA
- Protein dynamics
- Nonlinear optics
- Quantum dots
- Super lattices
- Photo-chemistry
- Radio-chemistry
- Photon science
- Photoconductivity
- Electron spin resonance
- Magnetic properties of matter
- Multi photon ionization
- Biotechnological research
- Medical applications
- Human neurosurgery and ophtalmic surgery

The Place of TAC IR-FEL



Bremsstrahlung Station

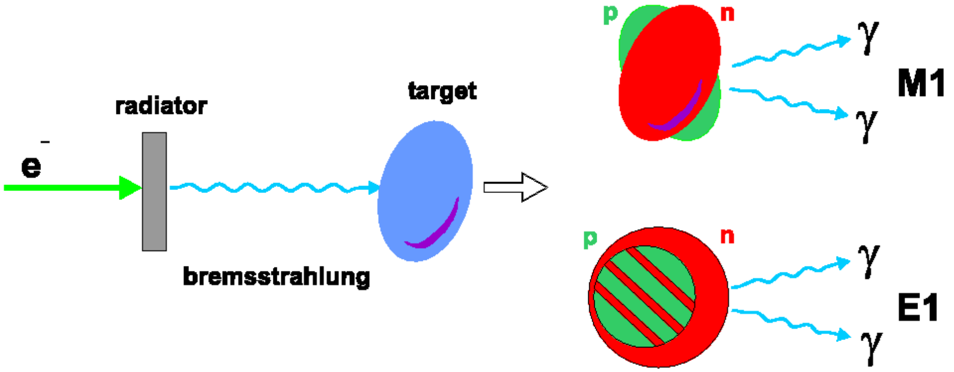


Bremsstrahlung Station

A Bremsstrahlung beam line and experimental stations for nuclear physics studies are planned in TARLA Facility .

It is planned that, electron beam of 20 MeV energy from LINAC will be sent to Bremsstrahlung experimental hall.

Main aim of Bremsstrahlung station is to study nuclear spectroscopy.



Committees for TARLA

- Local Committees

  - Machine Committee (Head: Dr. S. Ozkorucuklu)
  - IR FEL Exp. Stations Committee (Head: Dr. P. Arikan)
  - Bremstrahlung Committe (Head: Dr. I. Akkurt)

- Int. Machine Advisory Comittee

  Peter MICHEL (FZD, Germany)
  Hideaki OHGAKI (Kyoto University, Japan)
  Dieter TRINES (DESY, Germany)
  Ernst WEIHRETER (BESSY, Germany)

TAC Proposal

Technical Design Studies of TAC

We have four main working groups (WGs),
International scientific collaboration agreements, and
International **S**cientific **A**dvisory **C**ommittee **(ISAC)**
for TDR of TAC studies.

Technical Design Report (TDR) Studies of TAC

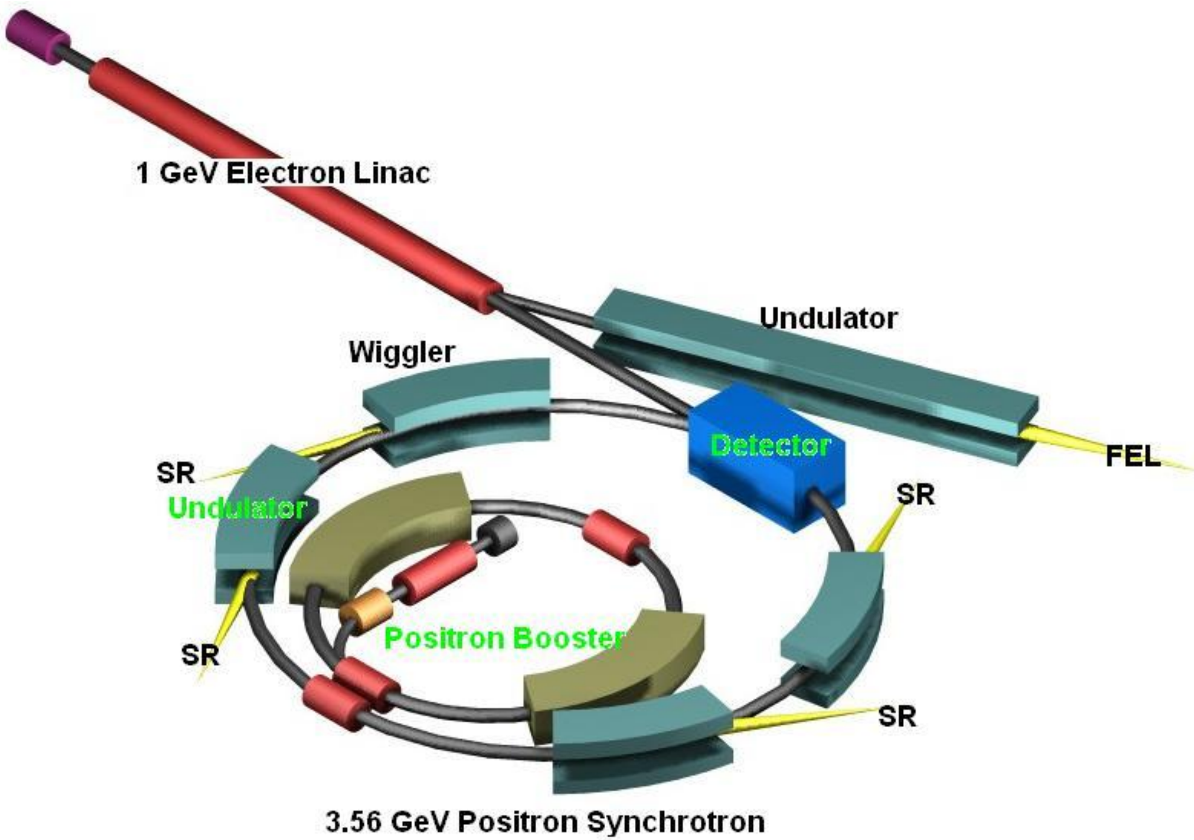
It is proposed that TAC will include;

1. Linac on ring type electron-positron collider as particle (charm) factory
2. Synchrotron light source facility based on positron ring (SR)
3. SASE FEL facility based on electron linac
4. GeV scale proton accelerator facility

1. TAC Particle Factory

- Considered:
  - linac-ring type ϕ factory (feasibility report, 2000)
  - linac-ring type τ factory
  - **linac-ring type charm factory**,
- $L = 10^{34} cm^{-2} s^{-1}$ can be achieved for all three options.

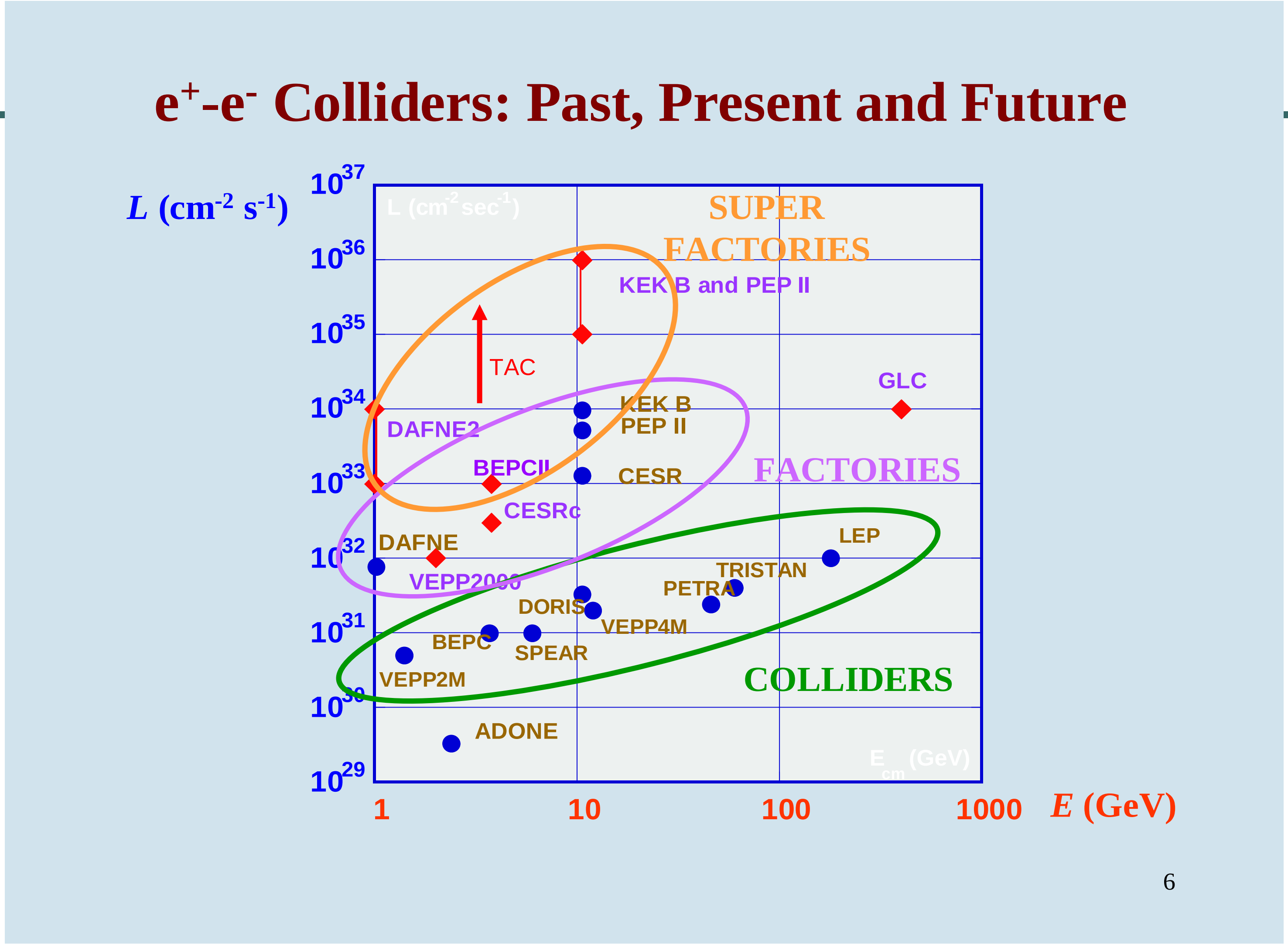
Linac on ring collider



Tentative parameters of TAC charm factory (Ec.m.=3.77 GeV)

Parameter	e^--linac	e^+-ring
Energy, GeV	1.00	3.56
Particles per bunch, 10^{10}	0.55	11.00
β function at IP, cm	0.45	0.45
Normalized 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} $cm^{-2}s^{-1}$	

Place of TAC particle factory



2. TAC Synchrotron Light Source

- Is additional positron storage ring dedicated for production of synchrotron radiation necessary?

- Ring-ring collider: beam-beam tune shift restriction ➲large emittance ➲ high luminosity:

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

SR in linac-ring type machines

- Luminosity independent of emittance➡

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

- Chosen emittance (8.8 nm·rad) of the positron small enough ➡ a third generation light source (< 20 nm·rad)

TAC Synchrotron Radiation

Storage Ring

TAC Main Ring Lattice

Insertion Devices

185 mm-U

75 mm-U

22 mm-U

45 mm-U

33 mm-W_{sc}

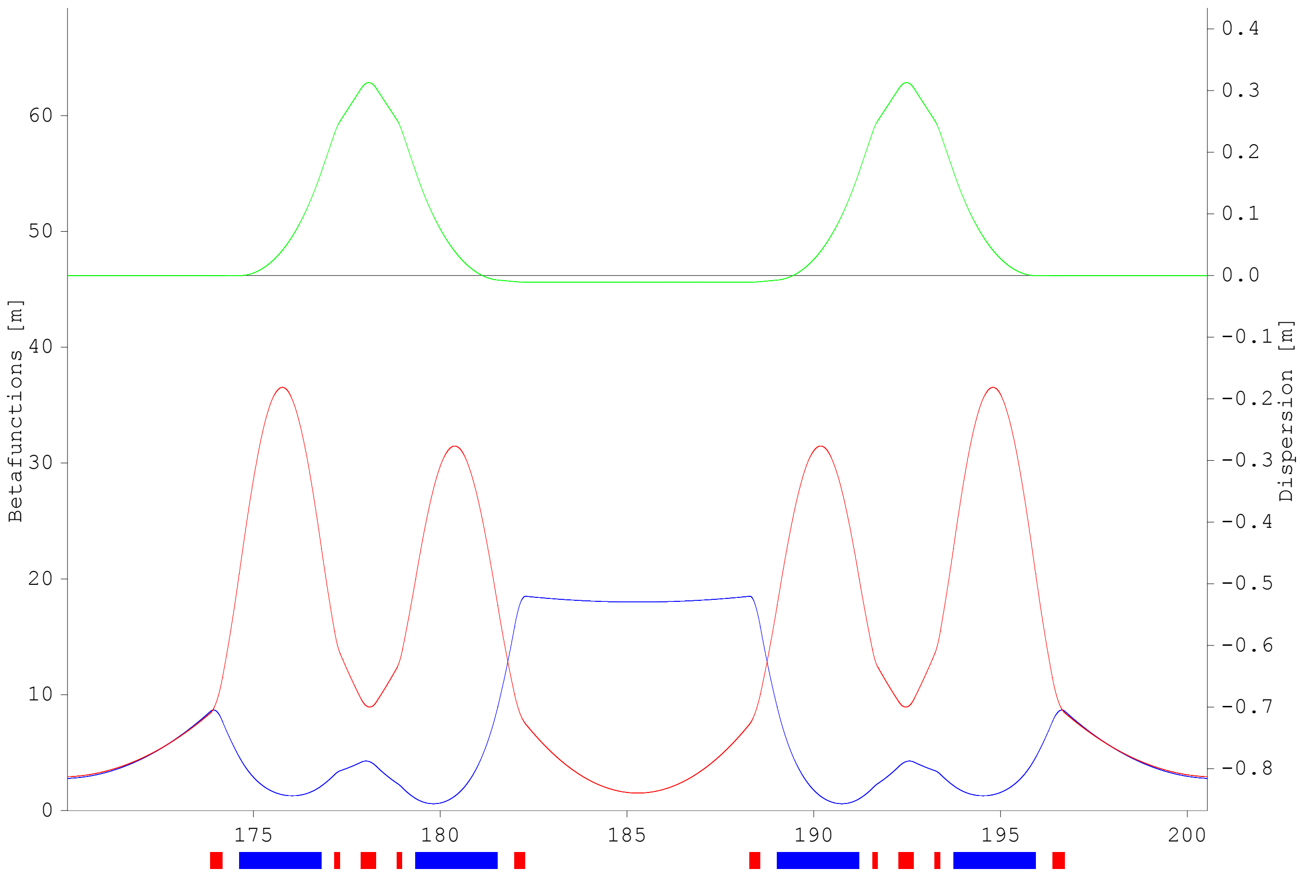
User Potential

TAC Storage Ring & Lattice

For the TAC at 3.56 GeV, the double-double bend achromat (DDBA) lattice has been studied with a type of lattice composed of combined function bending magnets and quadrupole doublet.*

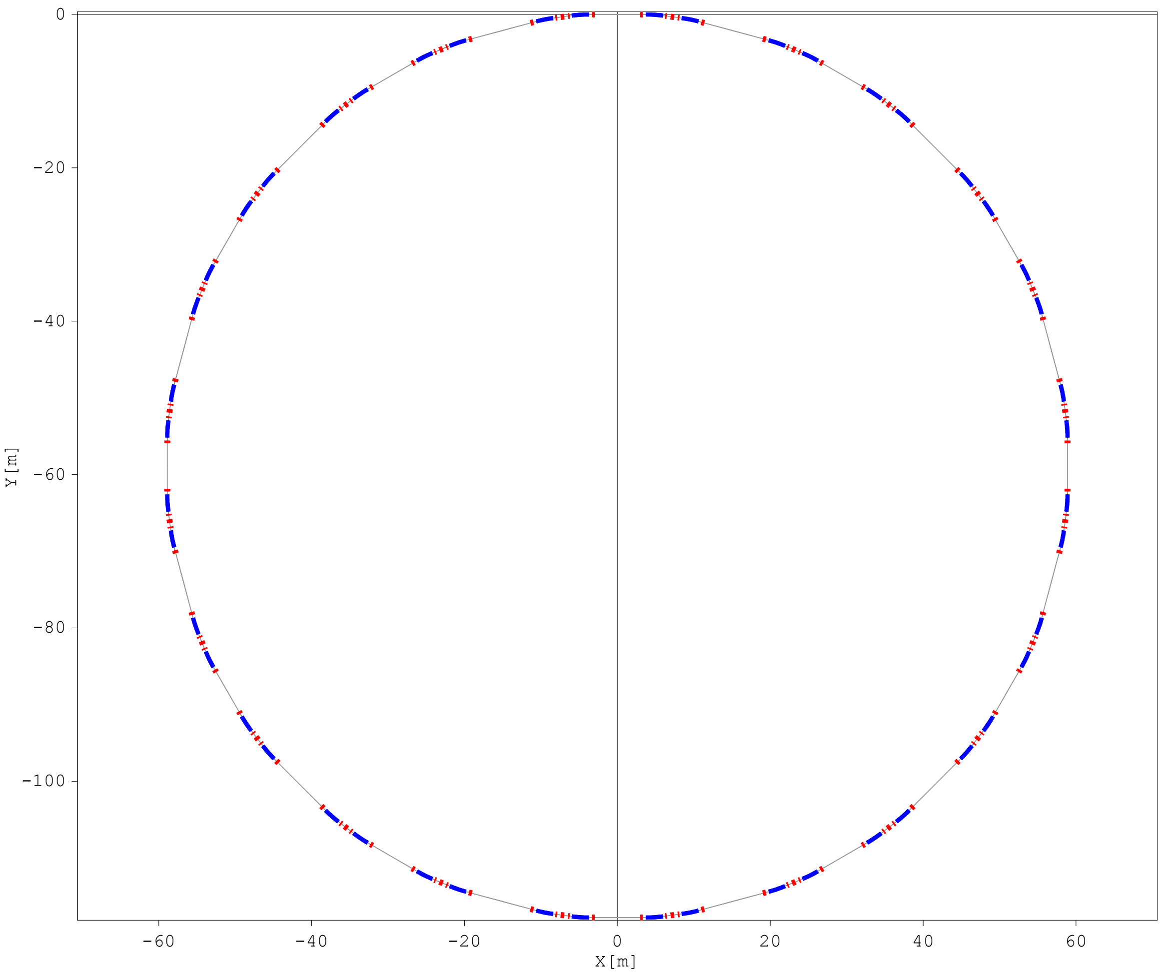
$$\varepsilon_{DDBA} = C_q \frac{\gamma^2}{4\sqrt{15}} \frac{\theta_p^3}{J_x} \frac{1}{96}$$

Where θ_p is the deflection angle per period, γ is the Lorentz factor of the beam, J_x is the horizontal partition factor and $C_q = 3.84 \times 10^{-13}$m.



Periodic	ok
Periods	1
Length [m]	370.560
TuneX	20.19718
TuneY	9.71290
ChromX	-29.631
ChromY	-47.009
Alpha [xE-3]	0.871
Jx	1.67959
Energy [GeV]	3.560
EmitXo [nm rd]	8.872
dE/turn [keV]	845.4
Espread [xE-3]	0.916
TauX [ms]	6.198
TauY [ms]	10.411
TauE [ms]	7.884
Location	START
Position m	0.000
BetaX m	18.001
AlphaX	0.0000
BetaY m	1.507
AlphaY	0.0000
Disp. m	-0.0107
dD/ds rad	0.0000
PhiX/2pi	0.0000
PhiY/2pi	0.0000
curly H m	0.000006

Lattice functions for 12 period DDBA lattice



	Units	DDBA
Energy	**GeV**	**3.56**
Superperiod		12
Circumference	m	370.56
Straight Sections		
Long	m	12x8 m
Short	m	12x6 m
Total	%	45.34
Beta functions at long straight		
Horizontal	m	2.76
Vertical	m	2.9
Dispersion	m	0
Beam Size		
Short straight		
Horizontal	μm	156
Vertical	μm	16
Long straight		
Horizontal	μm	405
Vertical	μm	25.7

The Layout of the Main Ring

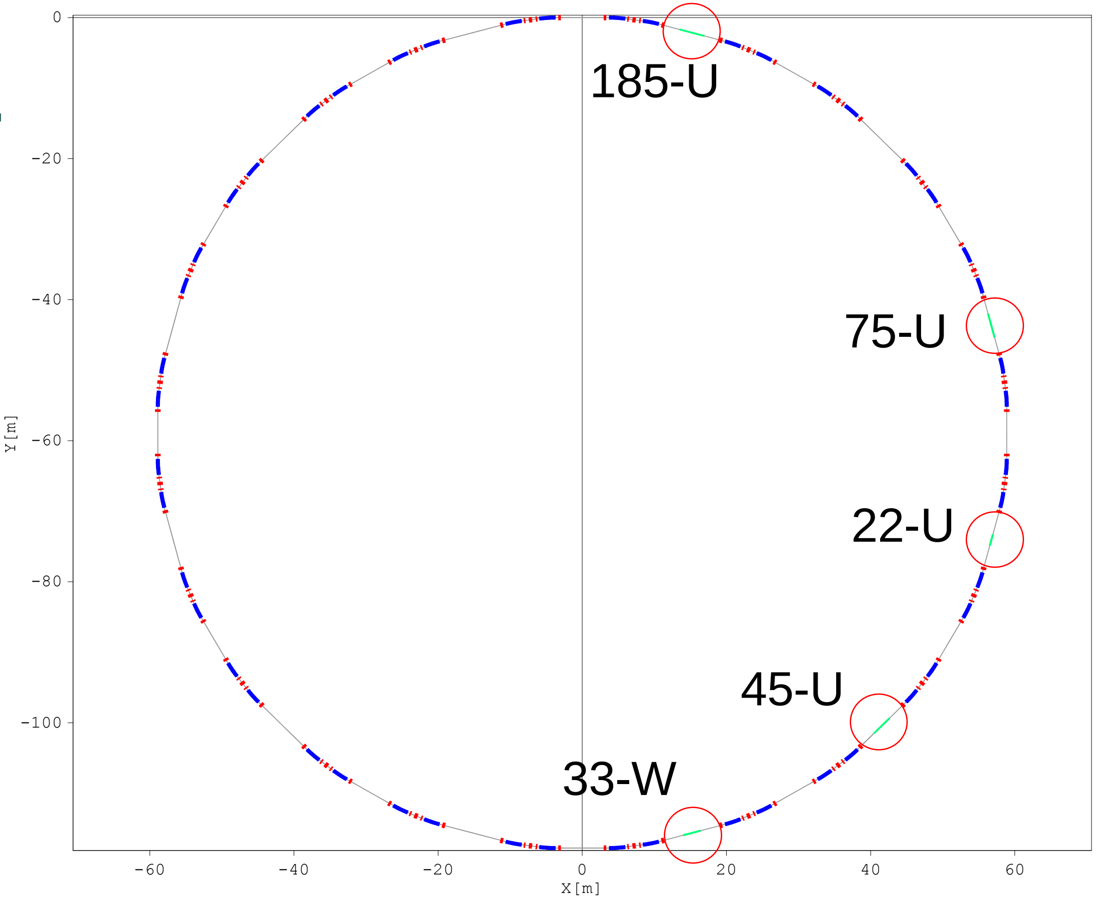
Insertion Devices (IDs) for TAC SR

Parameters of the IDs at the ring*

ID	Length (m)	Period Number	Magnetic field (T)	Max.K
185-U	3.515	19	0.751	12.97
75-U	3.45	46	0.747	5.23
22-U	1.606	73	0.91	1.87
45-U	2.97	66	0.843	3.54
33-W_{sc}	2.442	74	1.917	5.91

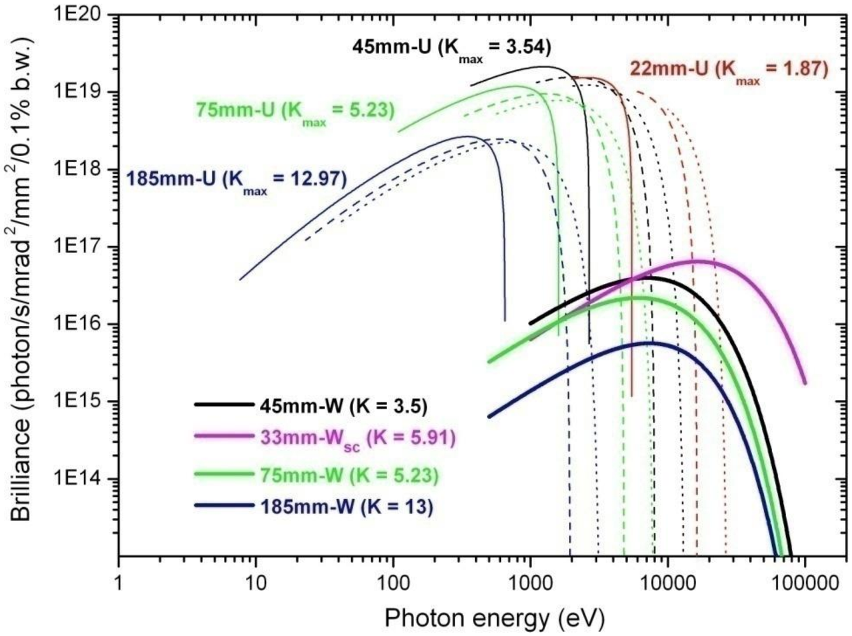
*PAC09, TU5RFP001,Vancouver-CANADA

TAC SR



Schematic Layout of the Main Ring with IDs

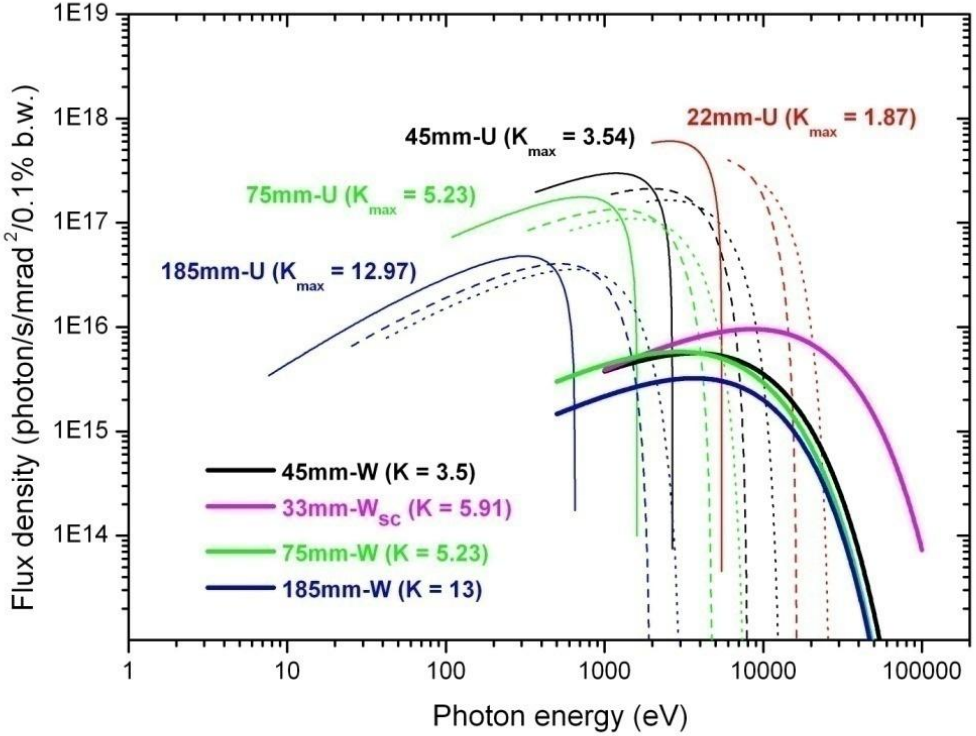
Brilliance of TAC SR



Brilliance of synchrotron radiation emitted from the undulators and wiggler at the TAC positron ring.

The parameters of complementary undulators and wiggler are determined. It is shown that the insertion devices with the proposed parameter sets produce maximal brilliance values to cover 10 eV – 100 keV photon energy range.

Flux densities of TAC SR



Flux density of the synchrotron radiation from IDs

Some selected techniques and energy ranges for usage of SR

EXAFS (Extended X-ray Absorption Fine Structure)

XAFS (X-ray absorption fine structure)

XANES (X-ray absorption near edge structure)

SEXAFS (Surface EXAFS is a surface sensitive version of EXAFS)

XPS (X-ray photoelectron spectroscopy)

ARPES (Angle resolved photoemission spectroscopy)

SAXS (Small Angle X-ray Scattering

Protein Crystallography :
energy range: 5-15 keV
source: in-vacuum undulator

XAFS /XRF
energy range: 3-30 keV
source: wiggler

Powder Diffraction
energy range: 3-25 keV
source: wiggler

SAXS / WAXS
energy range: 10 keV
source: undulator

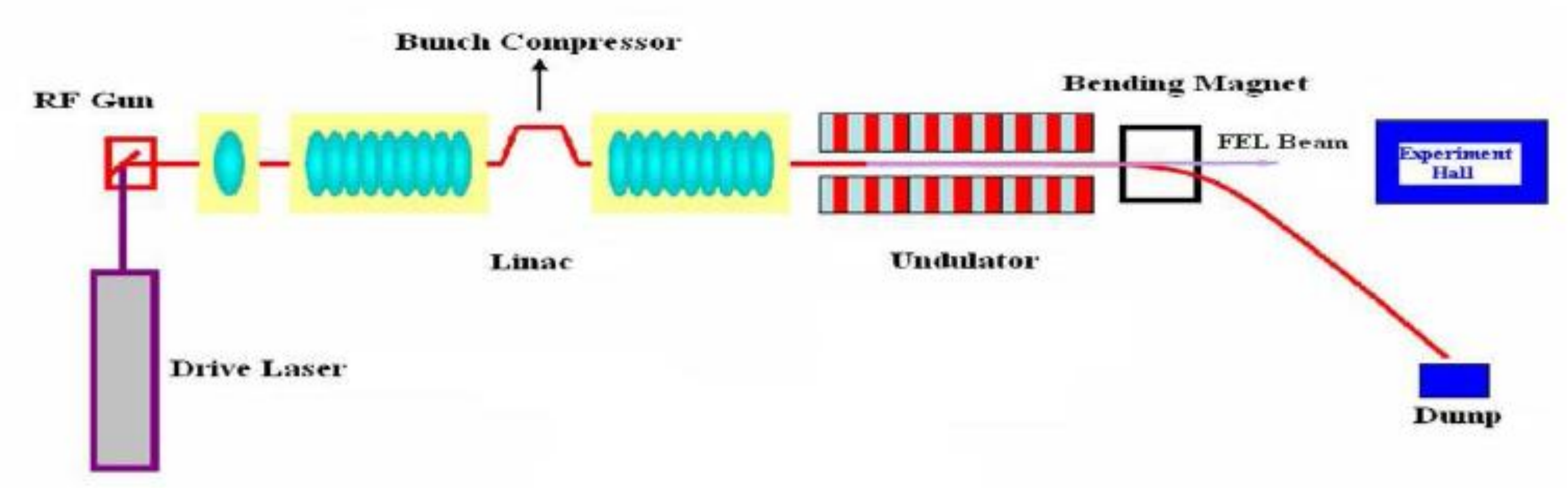
User Potential_of SR in Turkey and Our Region

TURKEY

- 134 Universities in 81 cities
- National Institutes:
  Biotechnology, Nanotechnology, Accelerator, Mine, Medicine, Pharmachology, Metrology, etc.
- National Authorities:
  TUBİTAK (Tech. and Sci. Reserach)
  TAEK (Atomic Energy)
  MAM (National Research Labs.)
- Industry, Technocities, Technoparks
- Army
- **Our Region:** Turkic States,
  West South Asia, East South Europe
  Middle East and North Africa

3. TAC SASE FEL

- With 1 GeV electron beam, wave length range of SASE FEL is planned as 1-100 nm



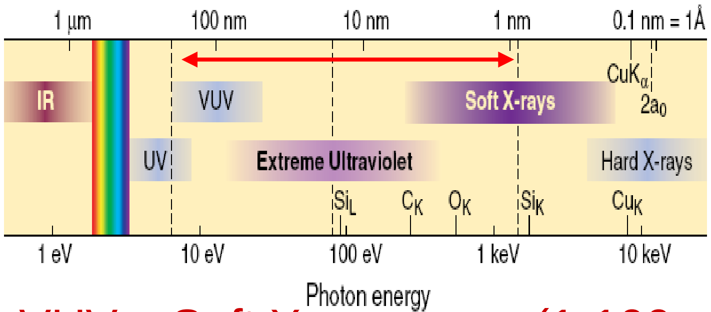
Schematic view of TAC SASE FEL Facility

Proposed 1 GeV electron beam parameters

Beam energy (GeV)	1
Number of electrons per bunch (x 10^9)	5.5
Beam current (mA)	26.4
Peak current (A)	2106
Energy spread (%)	0.1
Normalized emittance (μm.rad)	3.1
Transverse beam sizes (μm)	75.2
Longitudinal bunch length (mm)	0.05

Undulator & wavelength range

Undulator	
Period length, λ_u (cm)	3
Gap, g (cm)	1.2
Peak magnetic field, B_u (T)	0.498
K parameter	1.395
Saturation length (m)	36
Number of periods	1200



VUV – Soft X-ray range (1-100 nm)

Typical parameters of TAC SASE FEL

Wavelength, λ_{SEL} (nm)	7.7
Photon energy (eV)	160.5
ρ parameter	0.0018
Peak power (GW)	1.4
Average power (kW)	21.8
Gain length, L_g (m)	0.75
Gain length, 3D L_g (m)	1.57
Peak flux (photons/s)	1.5×10^{26}
Peak brightness (Photons/s/mrad^2/0.1%bg)	1.7×10^{29}
Peak brilliance (photons/s/mm^2/mrad^2/0.1%bg)	2.9×10^{30}

ERL option as a driver for SASE FEL and Collider

A more promising option, namely ERL, is arising nowadays for both collider and SASE FEL proposals of TAC.

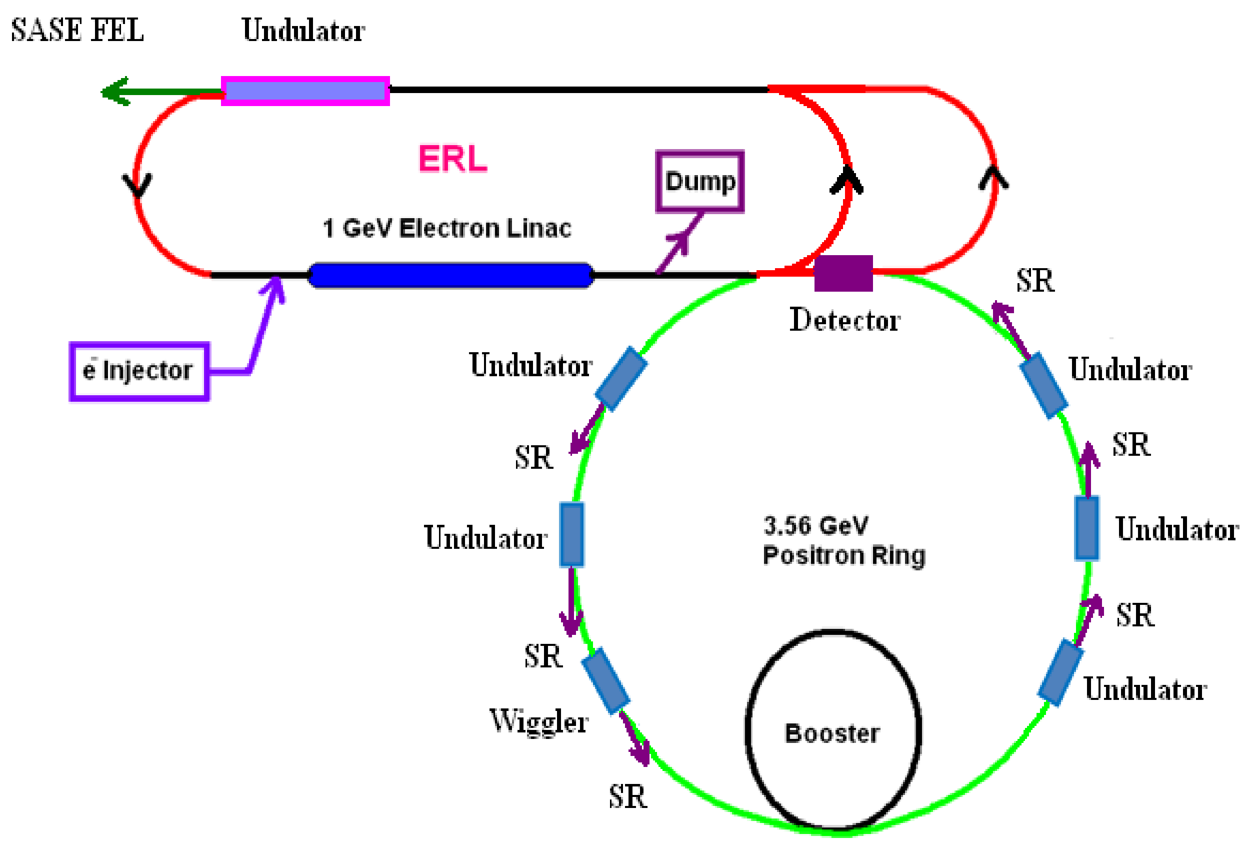
Today, ERLs provide a powerful broad range of applications like: electron cooling devices, high average brightness, high power FELs, short-pulse radiation sources and high luminosity colliders.

Because of the high luminosity (~ 2.3·10^35 cm-2s-1) requirement of the TAC collider and high peak power (~2–3 GW) & high average brightness (10^25–10^30 photons/s/mrad2/mm2/0.1%bw) requirements of TAC SASE FEL, 1 GeV electron accelerator sector of the collider should be based on an Energy Recovery Linac.

Especially, the average brightness value mentioned above, exceeds the rest of the light sources (existing and proposed) by about five orders of magnitude.

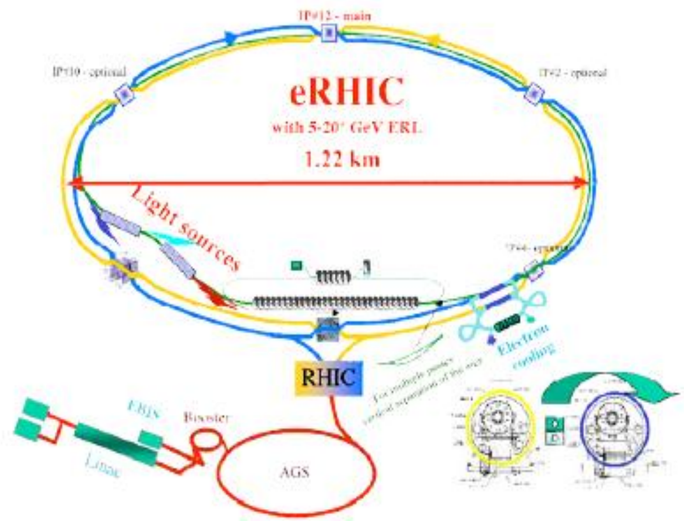
The *asynchronously* ERL operation option for both collider and SASE FEL, is still under discussion and R&D stage.

ERL on Ring Collider & ERL Based SASE FEL



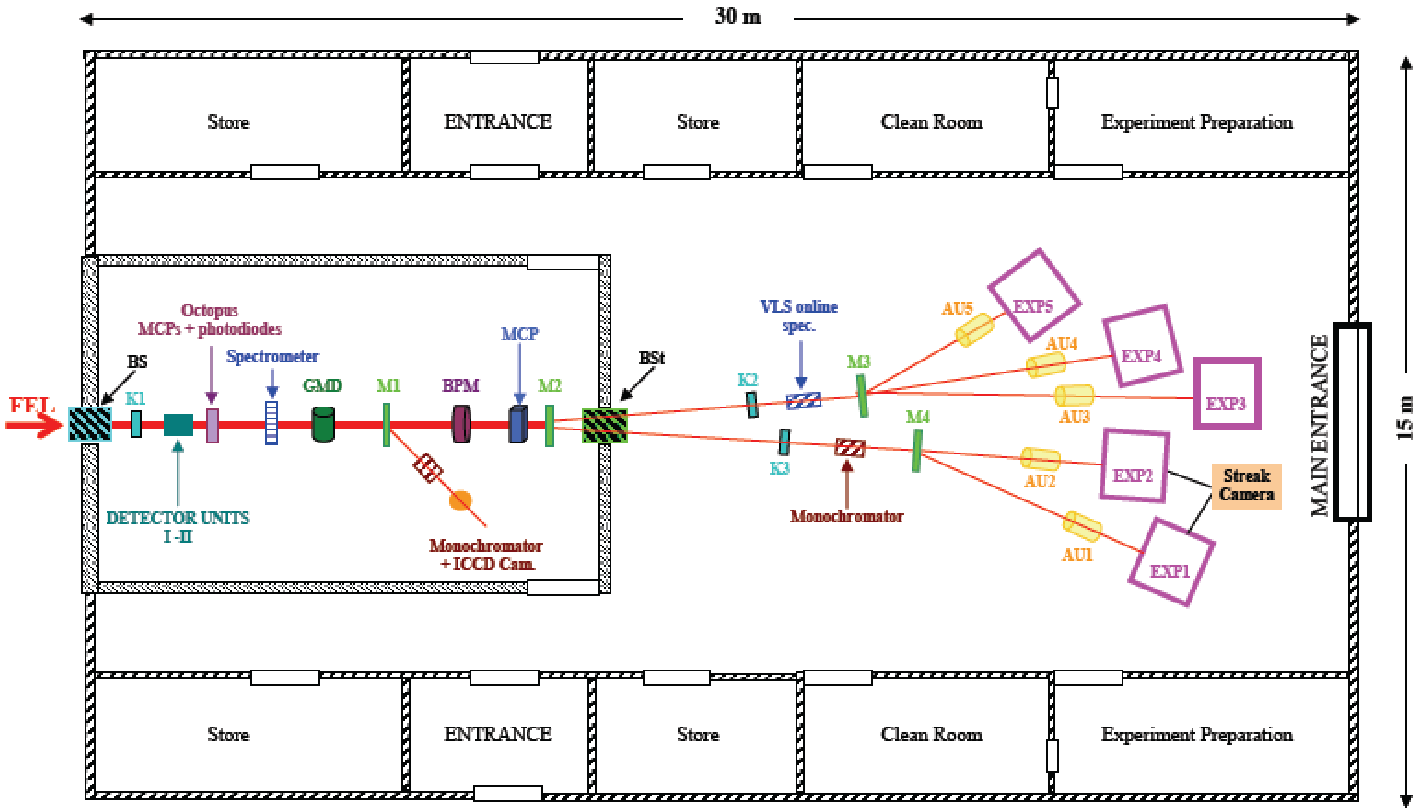
Parameters	cw e^- ERL	e^+ Ring
Beam energy (GeV)	1	3.56
Number of particles per bunch (x 10^{10})	2	6
Bunch charge (nC)	3.2	9.6
Bunch repetition rate (ns)	6.67	6.67
Bunch length (ps)	20	20
Number of bunches	- (cw)	125
RF frequency, f_{RF} (MHz)	$\approx f_{coll} = 150$	$\approx f_{coll} = 150$
Revolution frequency, f_{rev} (MHz)	-	1.2
Collision frequency, f_{coll} (MHz)	150	
β_x (mm)	20 @ IP	20 @ IP
β_y (mm)	0.5 @ IP	0.5 @ IP
Normalized emittance, ε_x (μm)	3.92	14
Normalized emittance, ε_y (μm)	0.06	0.2
Transverse emittance, ε_x (nm)	2	2
Transverse emittance, ε_y (nm)	0.03	0.03
σ_x (μm)	6.32	6.32
σ_y (μm)	0.12	0.12
σ_z (mm)	6	6
cw average current (A)	0.48	1.44
Peak current (kA)	0.16	0.48

Proposed parameters of ERL on ring type collider for TAC Charm factory



Ref: ERL based e-RHIC
+ ERL based X-FEL

Schematic wiev of diagnostics room and experimental stations of TAC SASE FEL



BS	: Beam Shutters	M1-M4	: FEL Mirrors
K1- K3	: Collimators	BPM	: Beam Position Monitor
MCP	: Micro Channel Plate Detector	BSt	: Beam Stop
GMD	: Gas Monitor Detector	AU1-AU5	: Autocorrelotors

Advantages of SASE FEL & Typical Applications

Advantages of SASE FEL:

Tunable wavelength (ranging from UV to soft X-rays)
Ultra-short pulse duration (~ fs)
High peak power (~ GW)
High peak brilliance (~10^30)
Average brightness (~ 10^21)
Coherency

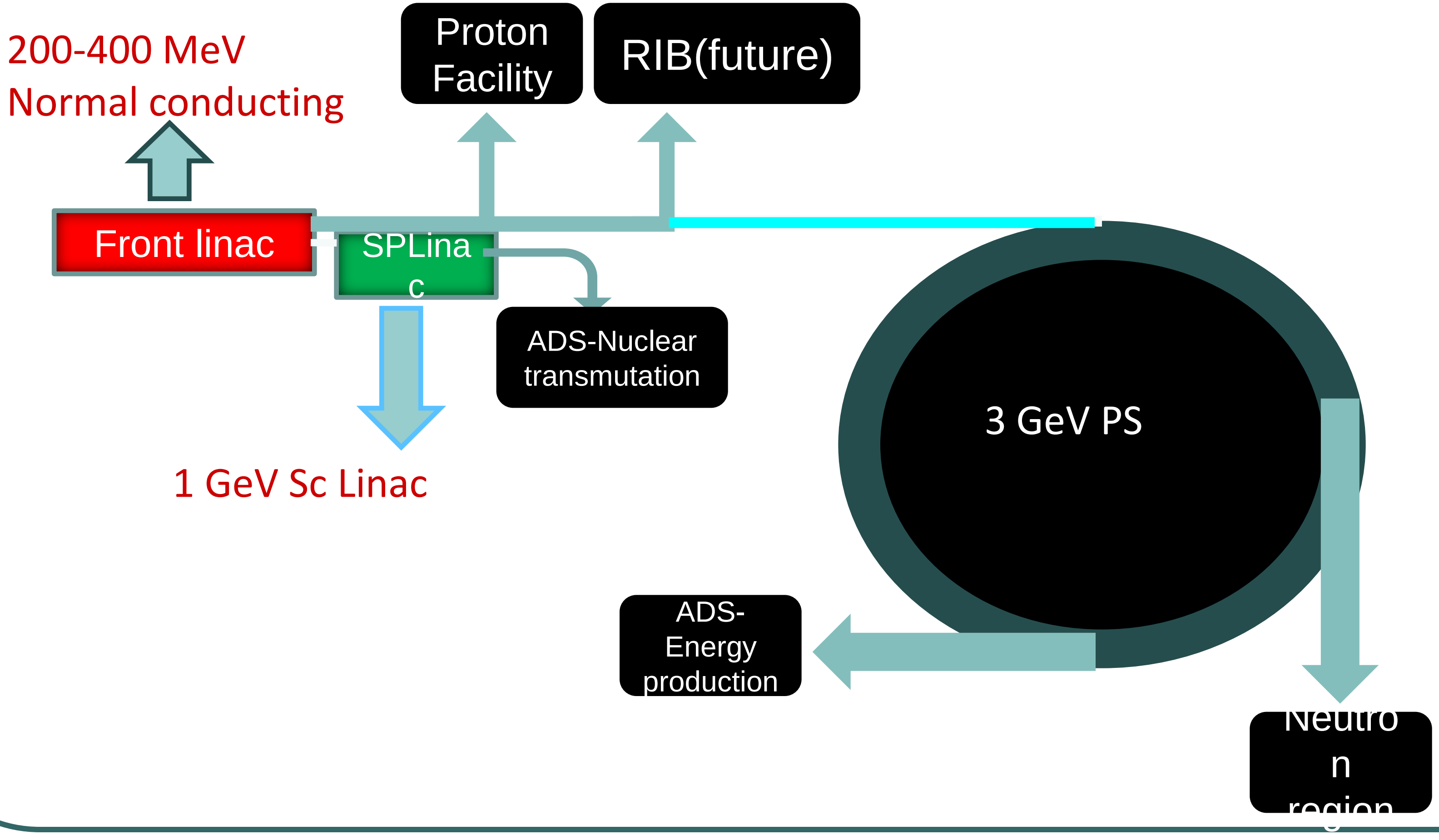
Main apllications of SASE FEL:

Atomic, molecular and cluster phenomena, plasma physics
Non-linear processes
Quantum optics
Condensed matter physics
Materials science
Ultra-fast chemistry
Life sciences

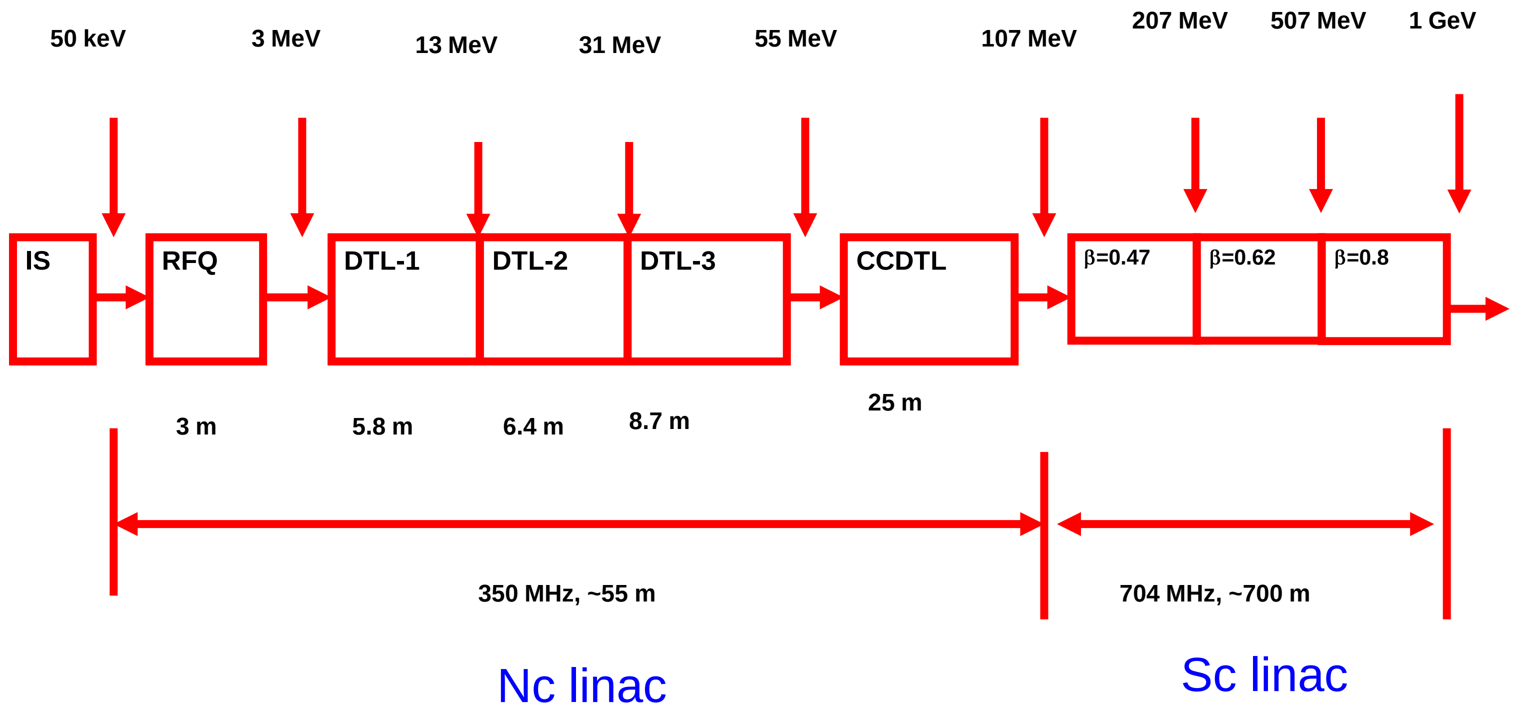
4. Proton Accelerator Facility

- A multipurpose facility
- Beam power 1 MW and 1-3 GeV Energy
- A world class pulsed neutron source for neutron scattering for engineering and industrial applications
- Medical facility for cancer therapy
- Irradiation and isotope production facility
- Radioactive Ion beam facility (in future)
- Nuclear transmutation facility(in future)
- ADS applications (EA etc.)

Proposed proton accelerator chain

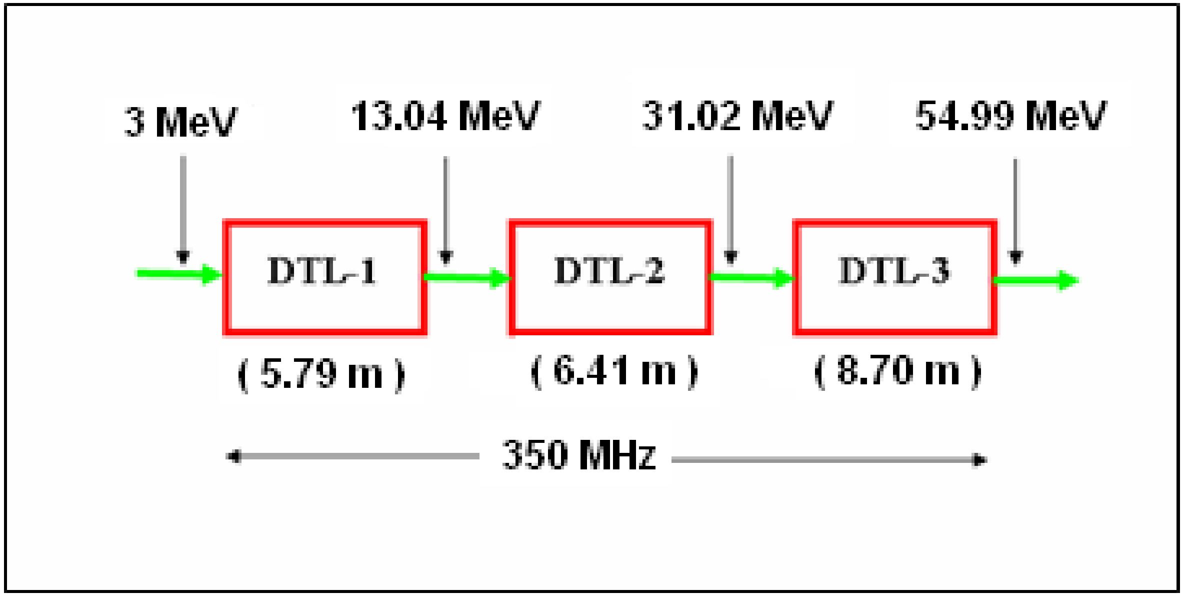


Accelerator Scheme for 1 GeV



DTL Design

- The design of the DTL was started with a 3 MeV input energy and by using three tanks, 55 MeV output energy is planned.



Proposed Research Potential

- Coulomb excitation
- (p,xn) reactions, angular distribution of neutrons
- (p,γ) reactions
- p scattering
- Spallation reactions
- Cross section measurements
- Excitation of high spin isomers
- Radioisotope production above 30 MeV
- Typical ADS applications (EA etc.)
- RIB-Nuclear Astrophysics
- Phase transitions
- Material Science
- Medical applications

Main presentations about TAC Project after 2006 (Third Phase of Project)

- **EPAC06, 2006, ENGLAND**
- **XI. VUV, 2007, GERMANY**
- **WIRMS07, 2007, JAPAN**
- **EPAC08, 2008, ITALY**
- **FEL08, 2008, KOREA**
- **V. Euroasia Conf. on Nuclear Sciences, 2008, TURKEY**
- **PAC09, 2009, CANADA**
- **FEL09, 2009, UK**
- **BPU-7, 2009, GREECE**
- **WIRMS09, 2009, CANADA**

International Collaborations

Scientific Collaboration Agreements:

- **CERN** (Geneva) (2005-2011)
- **DESY** (Hamburg) (1996-2011)
- **BESSY** (Berlin) (1997-2011)
- **FZR** (Drseden) (1997-2011)

Scientific Contacts:

- **4GLS (Daresbury)**
- **iFEL (Osaka Univ.)**
- **John Adams Inst. (Oxford Univ.)**
- **ELETTRA (Trieste)**
- **SESAME (Jordan)**
- **FNAL (USA)**
- **ANL APS (USA)**
- **JLab (USA)**
- **LCLS (USA)**

International Scientific Advisory Committee (ISAC) of TAC

- Ercan ALP (Argonne National Laboratory, USA)
- Behçet ALPAT (INFN Perugia, Italy)
- David M. ASNER (CLEO, Canada)
- Swapan CHATTOPADHYAY (Cockroft Institute, UK)
- Wolfgang EBERHARDT (BESSY, Germany)
- Eisuke J. MINEHARA (JAERI, Japan)
- Luigi PALUMBO (INFN Frascati, Italy)
- Ken PEACH (JAI, Oxford University, England)
- Roland SAUERBREY (FZD, Germany)
- Zehra SAYERS (Sabancı University, Turkey)
- Saleh SULTANSOY (TOBB ETU, Turkey)
- Gökhan UNEL (CERN, Switzerland)
- Helmut WIEDEMANN (Stanford University, USA)
- Frank ZIMMERMANN (CERN, Switzerland)

International Scientific Advisory Committee (ISAC) of TAC

First meeting of ISAC of TAC will be held on

8-9 October, 2009

in

Ankara University, Ankara, TURKEY

Conclusion

Priority of proposed facilities in TAC will be described depend on reports of ISAC and new trends on accelerator science and applications.

It is planned that first facility (TARLA) and Technical Design Report of TAC will be completed in 2012. The completion of construction of TAC is planned as 2023 (100. anniversary of Rep. of Turkey !)

TDR of TAC will be presented as a new project to the Turkish Goverment to get budget.

Realization of the TAC project will accelerate the development in almost all fields of science and technology in our country and region.

It is clear that, we need more close collaboration with international accelerator community to realize TAC

M. Kemal ATATÜRK

Founder of Republic of TURKEY

In most Turkish schools, the following mantra by K. Ataturk is prominently displayed: "Hayatta en hakiki mürşid ilimdir".

It can be loosely translated as "the guiding principle in life is science".

Today's Turkey, at the threshold of the European Union membership, is committed to have world-class research facilities, and TAC is going on to be yet another example of this commitment.

Thank you…