Iranian Light Source Facility

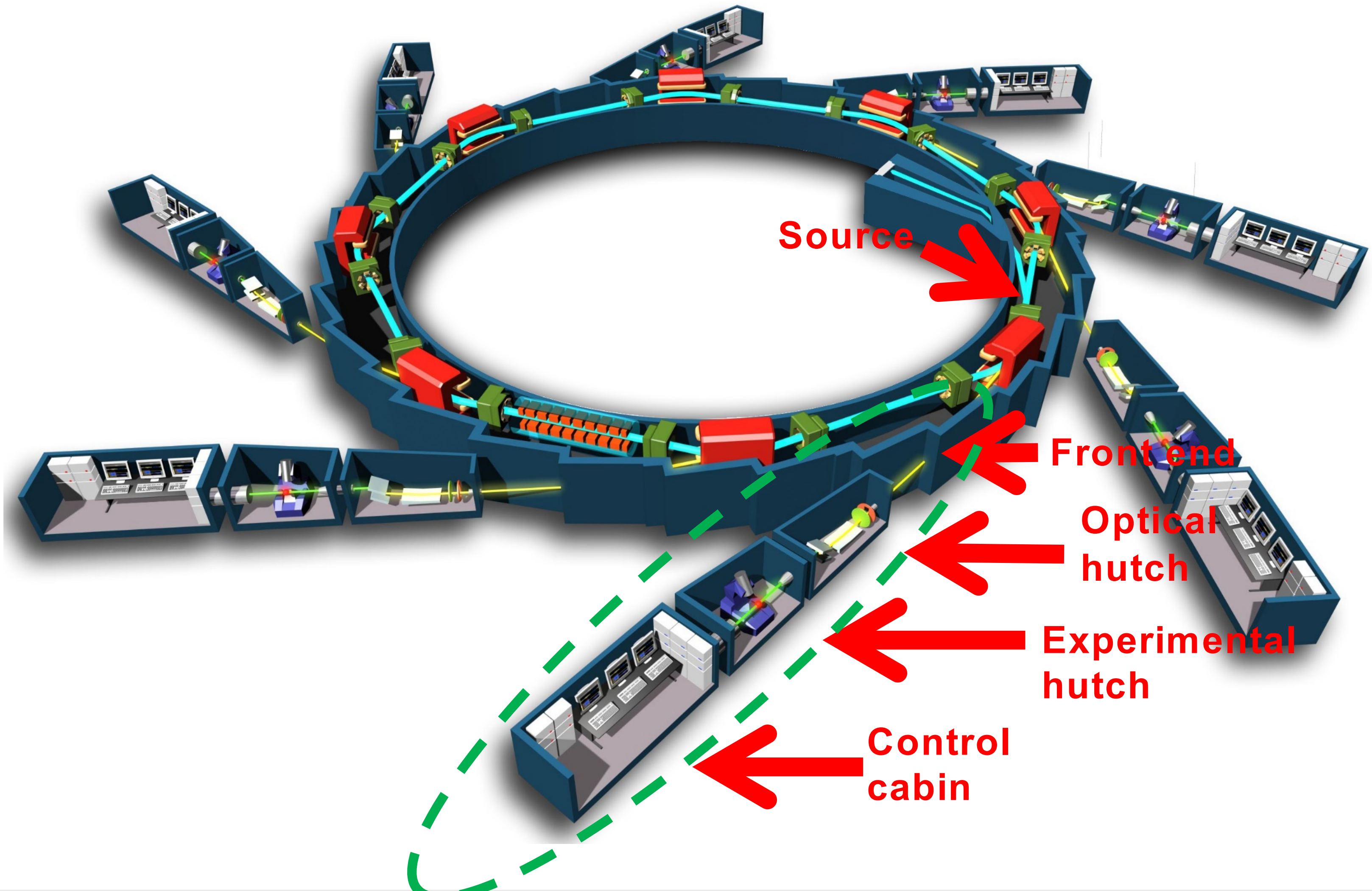
Sara Dastan
ILSF Project & Gilan University

Accelerator Seminar

Contents

- ILSF project
  - IPM and ILSF location
  - Beam properties in ILSF
  - Magnet in ILSF
  - RF in ILSF
  - Beam Diagnostics
  - Vacuum Systems
  - Power Supply
  - People and Collaboration
- Lattice nonlinear optimization in ILSF
- Beam-Optics simulation in ESR

Synchrotron Light Source



IPM Institute

What is IPM?

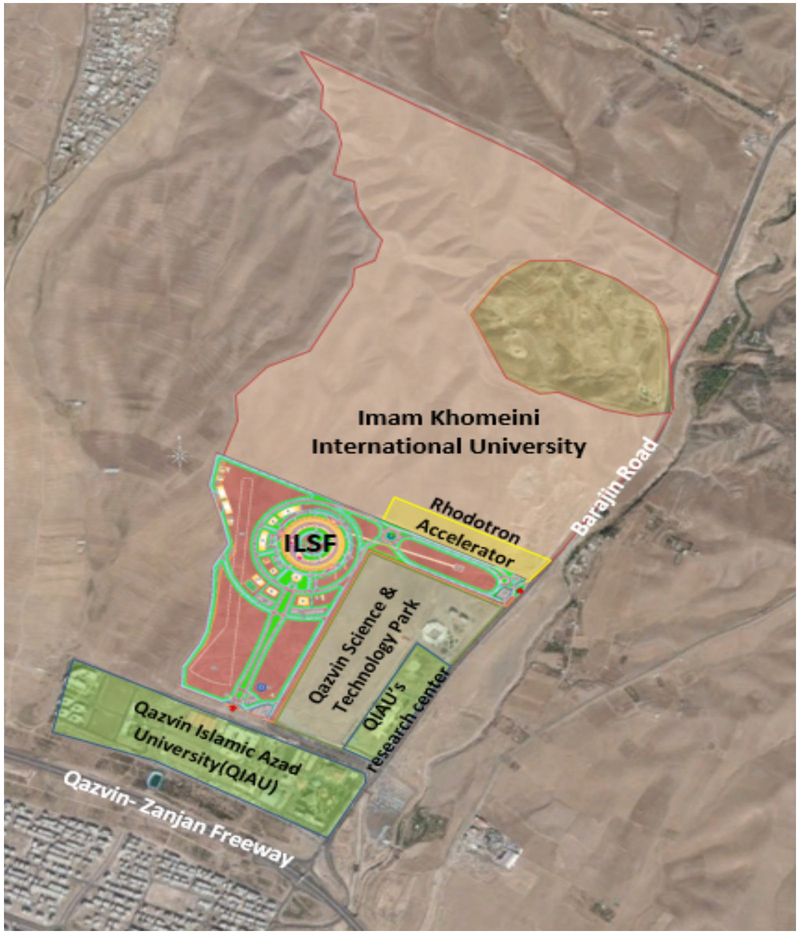
Actually I found 71 meanings of IPM on the net

- Interaction Point Monitor
- International Personal Management
- Institute for Public Management
- Interior Permanent Magnet and ...

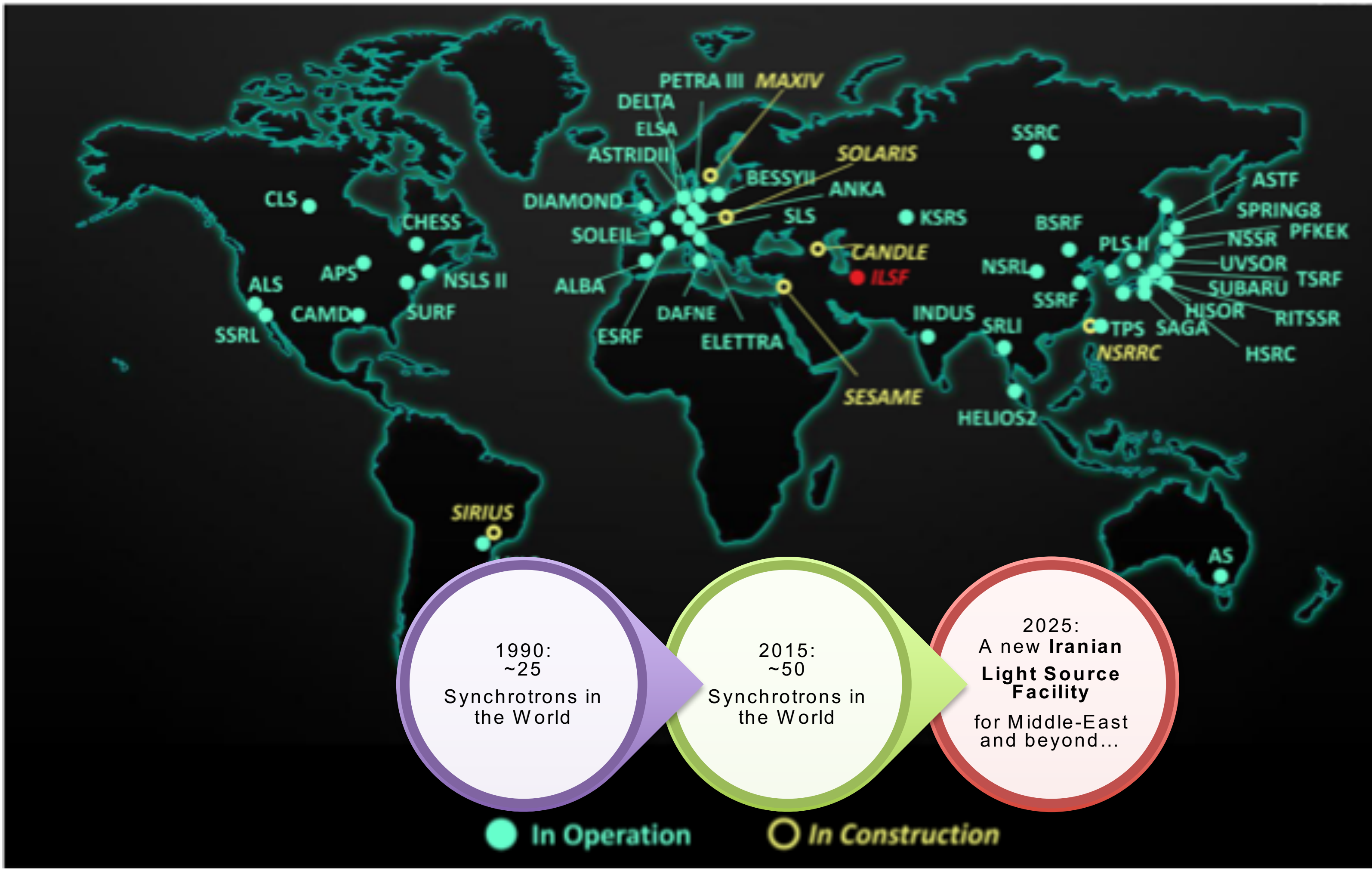
But it does mean during this presentation

Institute for Studies in Theoretical Physics and Mathematics (founded 1989)

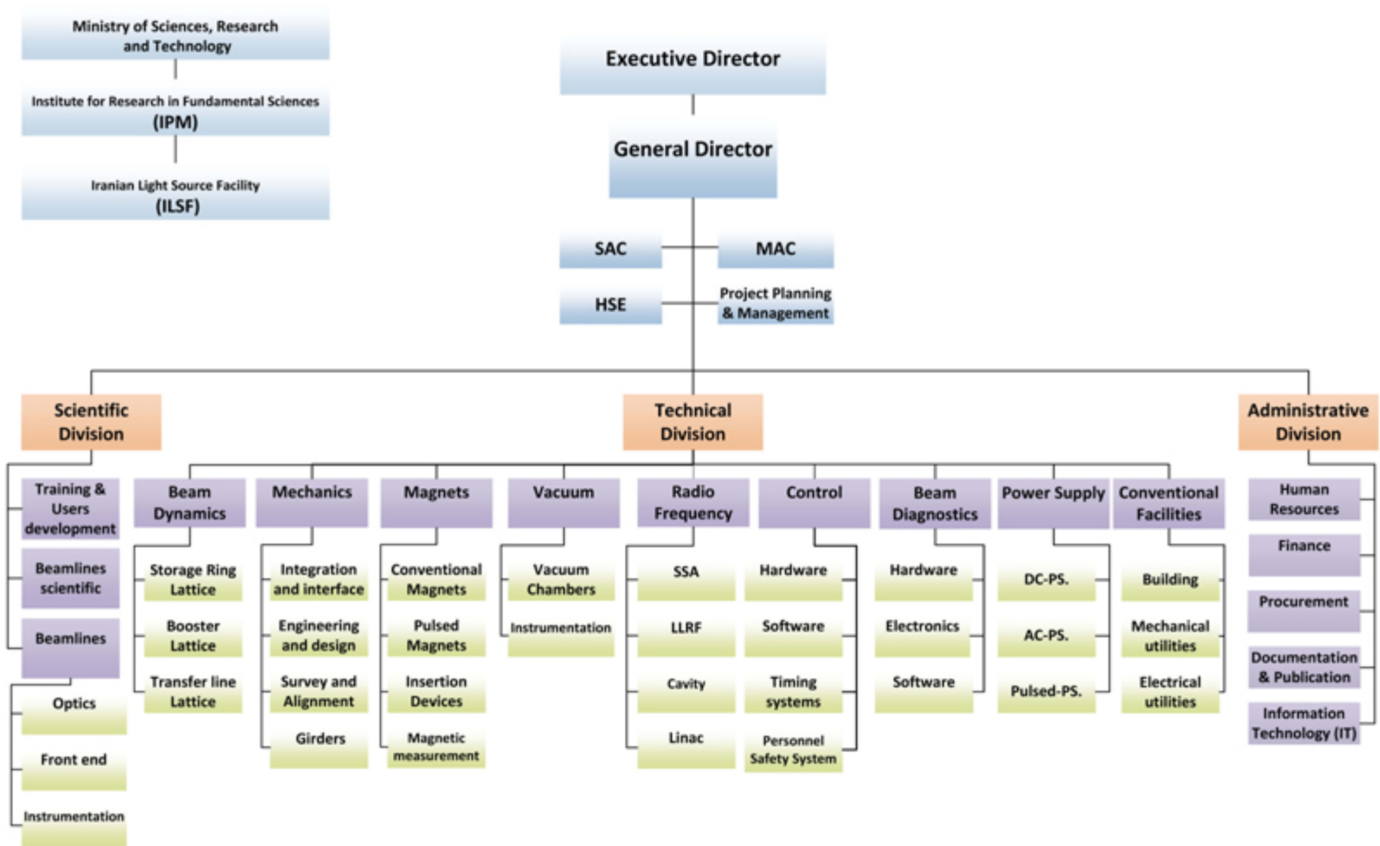
- ILSF, One of the biggest Projects in IPM
- The project is approved and will be funded by the Iranian's government
- First light Source in Iran, and new area of science
- Low emittance (0.28 nm-rad) storage ring
- Circumference of the storage ring is 528 m
- ~ 80 staff working for this project
- The place of this synchrotron ring is in historical city Qazvin, in 2 hours driving (150 km) distance from Tahran



Light Source Around The World



ILSF Organization

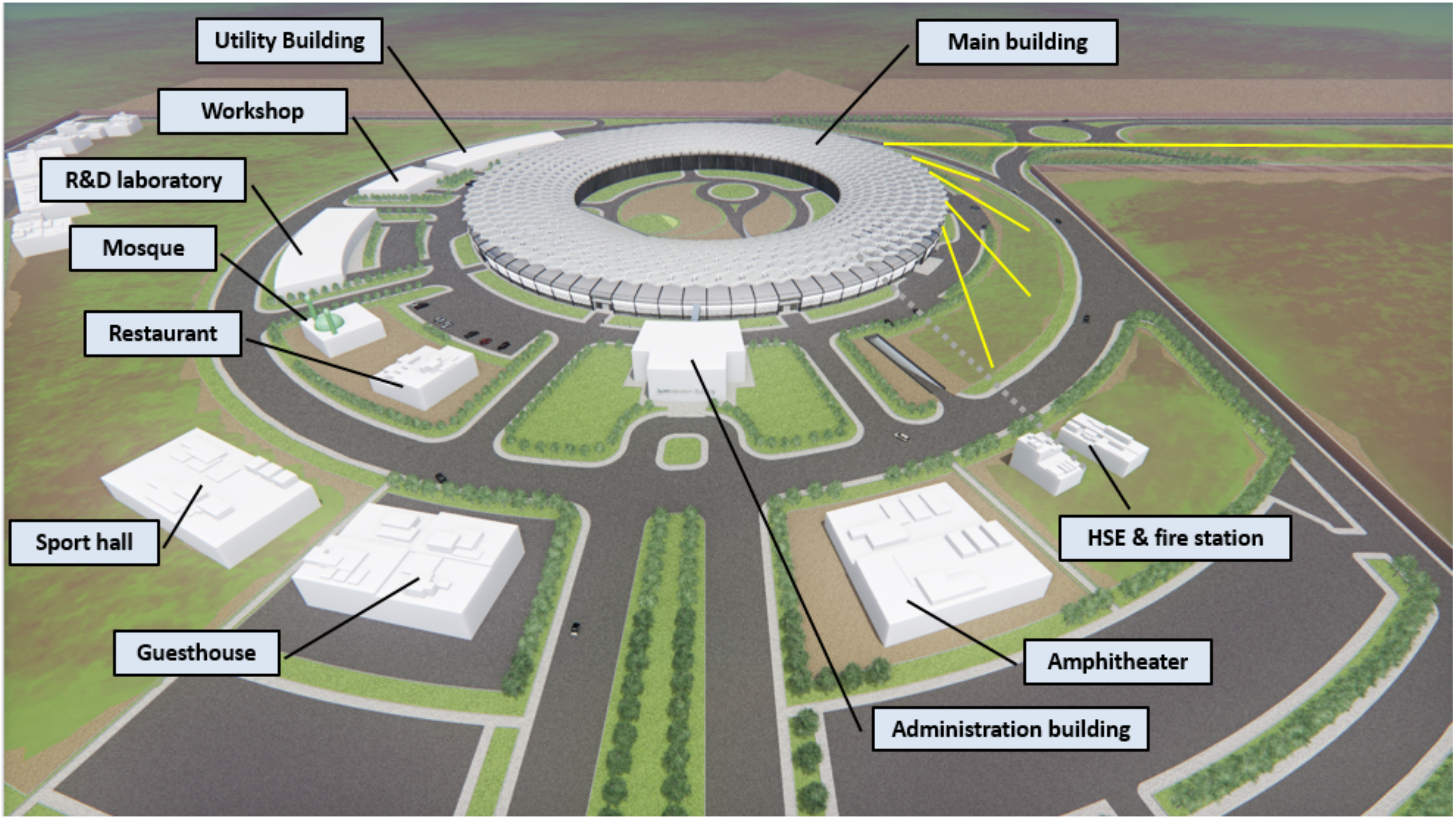


MAC : Machine Advisory Committee
SAC: Scientific Advisory Committee
HSE: Health, Safety & Environment
SSA: Solid State Amplifier
LLRF: Low Level Radio Frequency

R & D in ILSF

- Properties of the Beam for storage ring, Booster and transfer line
- Manufacturing diff. types of magnets and measurement laboratory for magnet tests
- Radio Frequency Systems
- Control system
- Beam diagnostic equipment
- Power supplies
- Ultra-High vacuum technology

3D View of ILSF

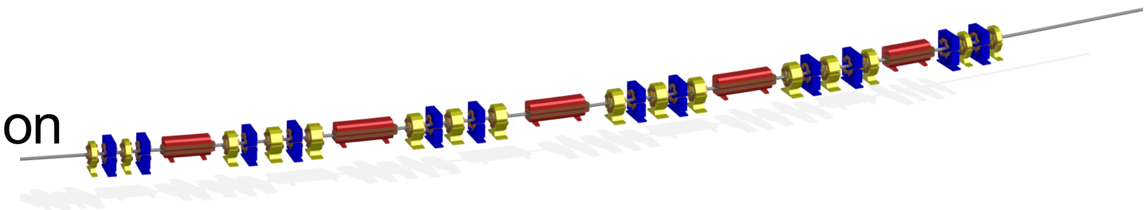


Properties of ILSF Beam in Storage Ring

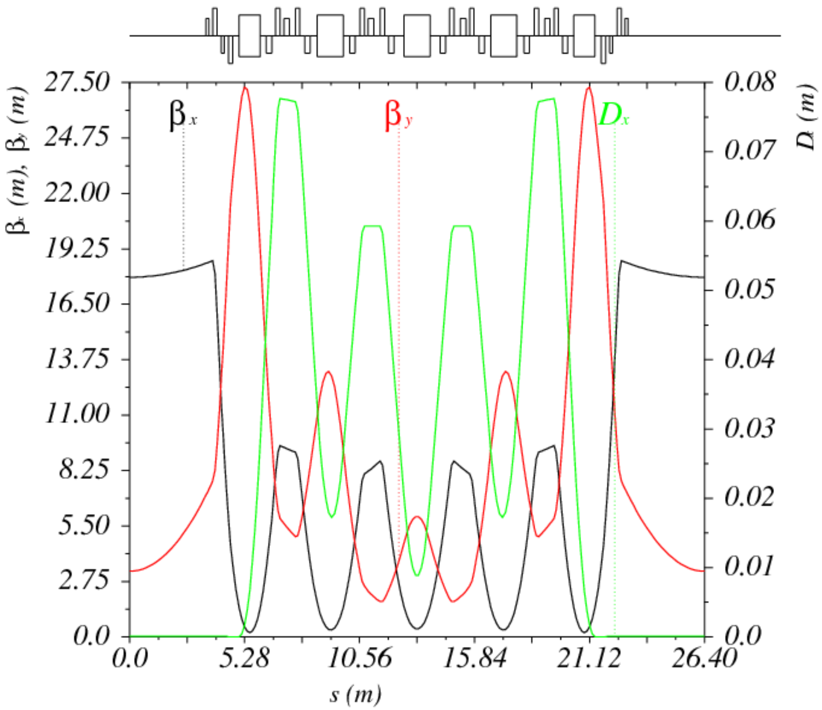
(5 BA) magnetic structure

20 super periods

20 × 7.0 (m) straight section



Parameter	Unit	Value
Energy	GeV	3
Maximum beam current	mA	400
Circumference	m	528
Length of straight section	m	7.0
Natural emittance	pm rad	275
Betatron tune (Q_x/Q_y)	-/-	44.20/16.23
Natural chromaticity (ξ_x/ξ_y)	-/-	-108.30/-61.54
Natural energy loss/turn	keV	406
RF frequency	MHz	100



Emittance Of ILSF

- One way to improve the emittance is by changing the structure of the lattice

Different generation of lattice

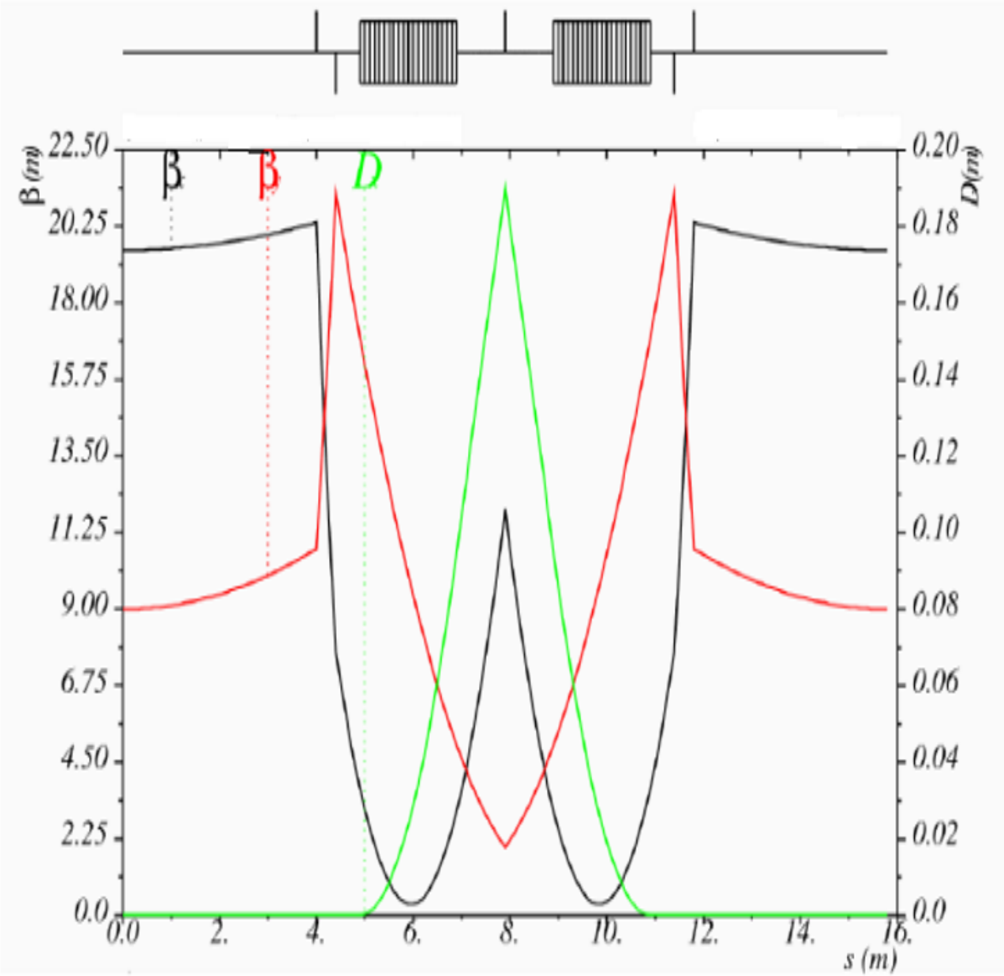
- FODO
- Double-Bend Achromat (DBA)
- Theoretical Minimum Emittance (TME)
- Multi-Bend Achromat, including the Triple-Bend Achromat (TBA)

AND, The ILSF lattice is a 5BA.

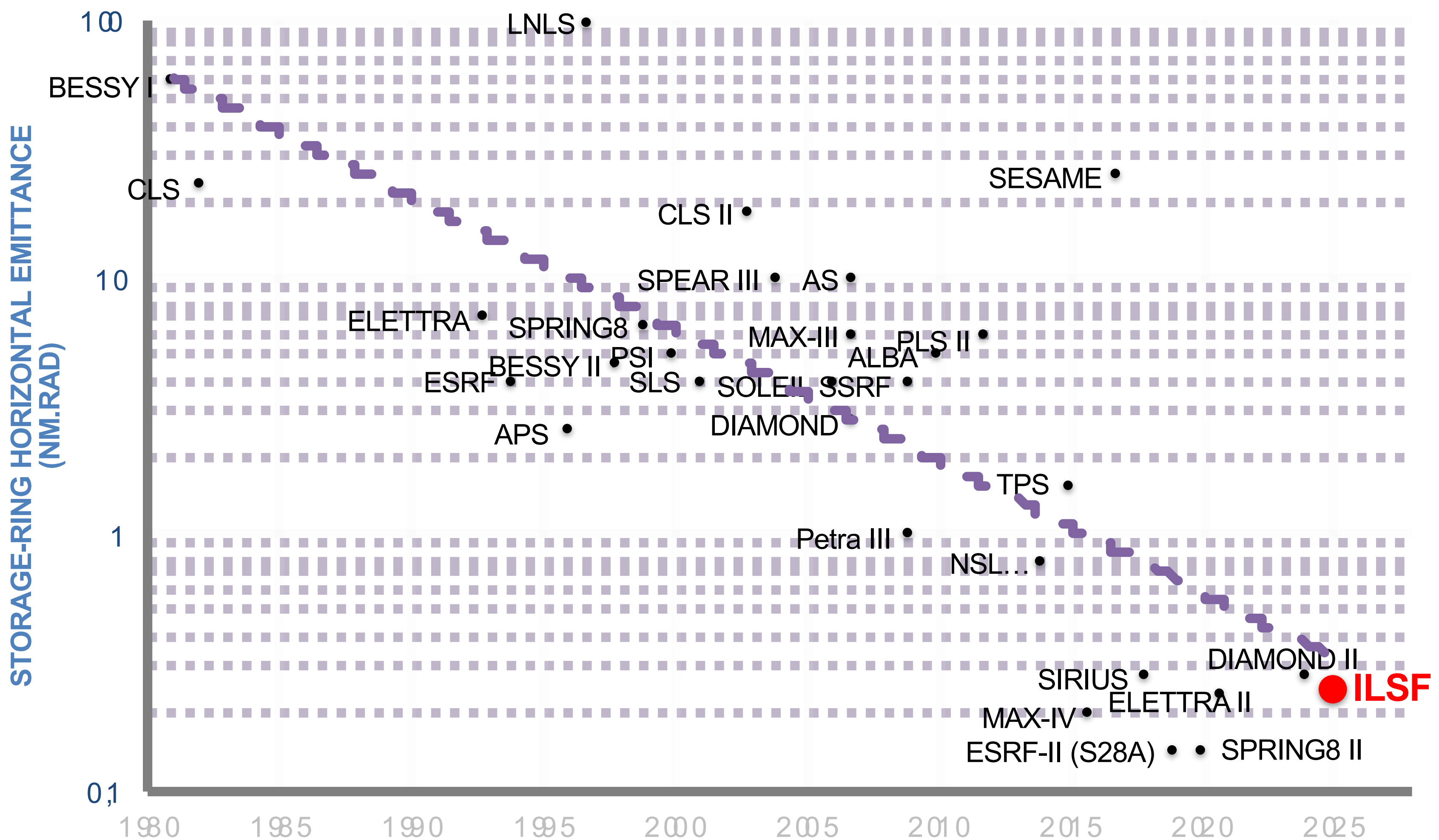
Why Achromat is used in ILSF

Achromats have been popular choices for storage ring lattices in third- generation synchrotron light sources for two reasons:

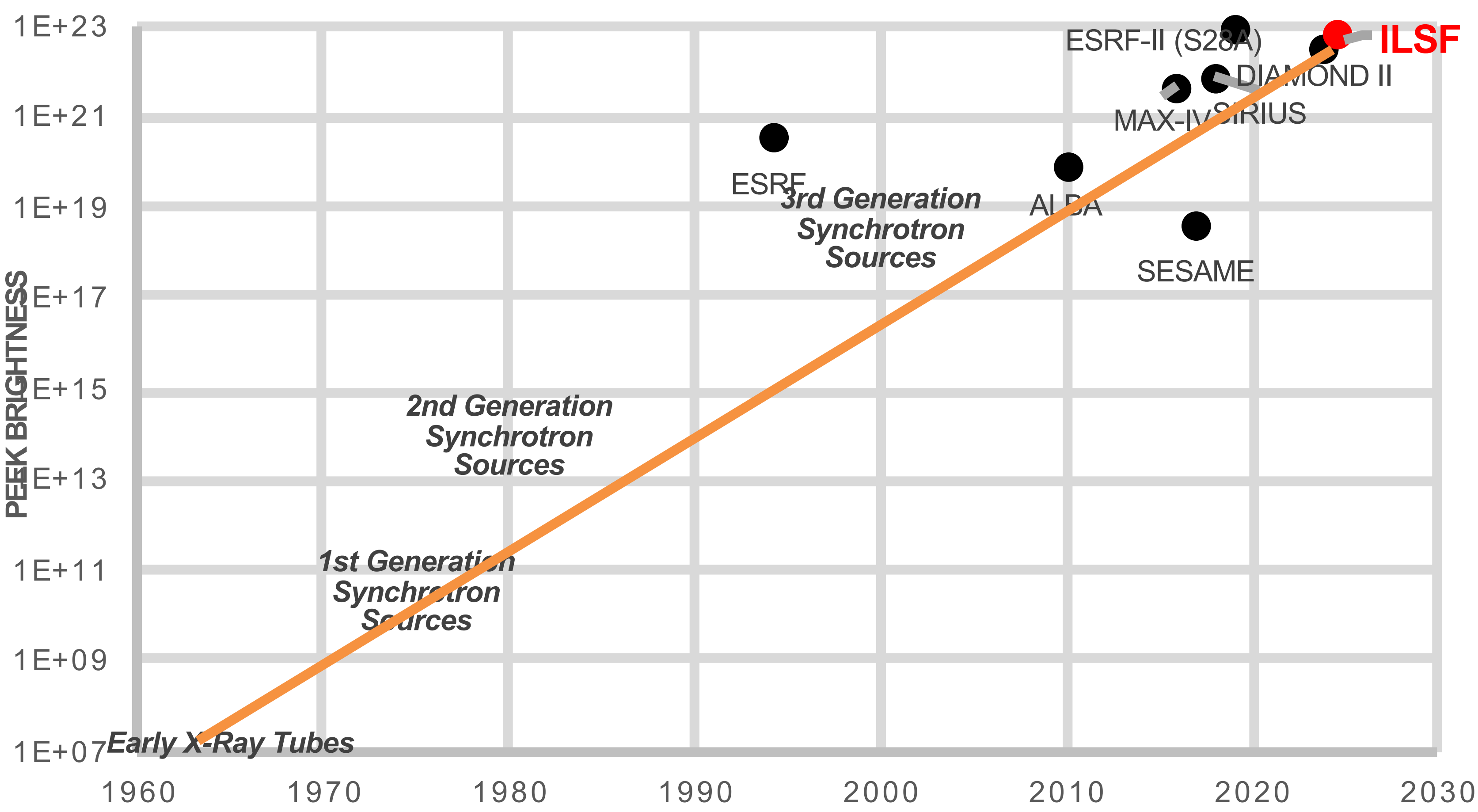
- They provide lower natural emittance than FODO lattices
- They provide zero-dispersion locations which is appropriate for insertion devices (wigglers and undulators)



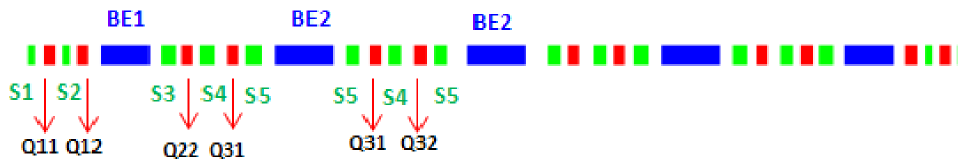
Comparison of Light Source Emittance in the World



Comparison of Synchrotron Brightness in the World



Properties of Magnets in ILSF



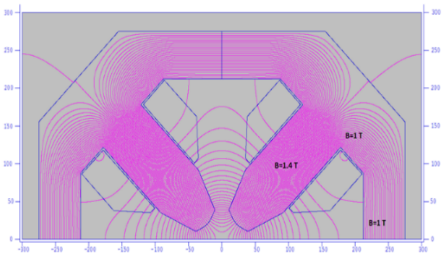
Dipole	Quantity	Length (m)	Magnetic field (T)	Deflecting angle (Deg.)	Bending radius (m)
BE1	40	0.9692	0.56	3.15	17.629
BE2	60	1.2	0.56	3.9	17.629

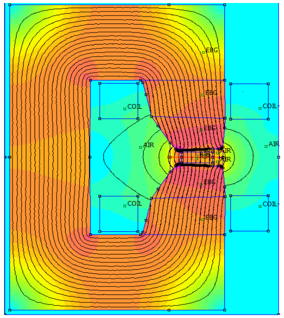
Quadrupole	Num.	Length(m)	Gradient B' (T/m)
Q11	40	0.2	36.33
Q12	40	0.2	12.74
Q22	40	0.2	39.67
Q31	80	0.2	35.05
Q32	40	0.2	30.62

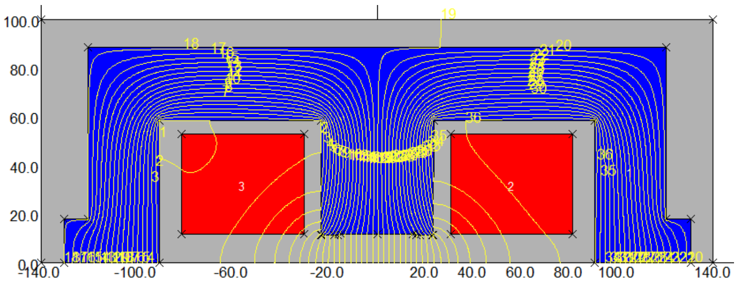
Sextupole	Num.	Length (m)	Strength B'' (T/m^2)
S1	40	0.13	1132.4
S2	40	0.13	1243.58
S3	40	0.2	1438.75
S4	80	0.25	2140.00
S5	120	0.25	1396.45

Magnet Design

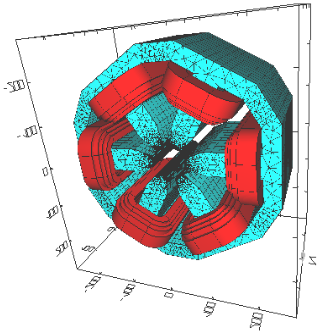
2D design: (Poisson ,FEMM, Opera2D)

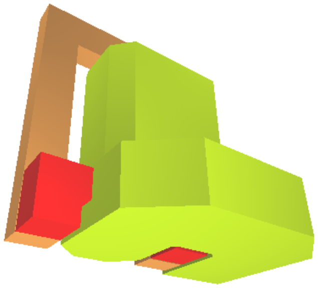


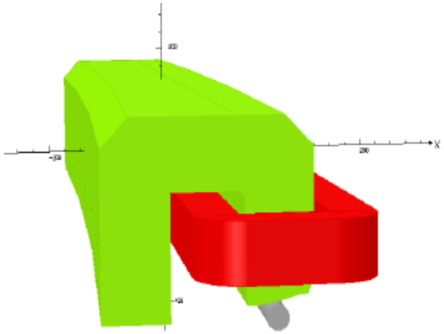




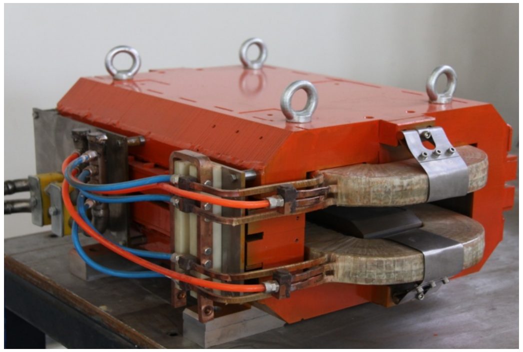
3D design:(Radia, Mermaid, Opera3D)

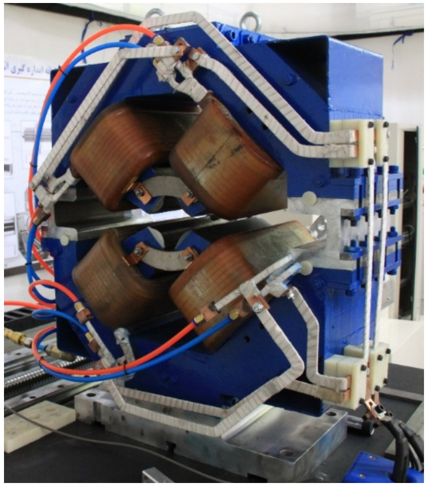






Prototype Magnets for ILSF





Dipole-H

Parameter	Value
Field	0.5 T
Iron Length	50 cm
Gap height	34 mm
Good Field Region	±20mm

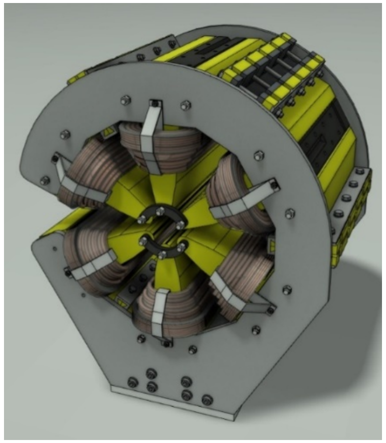
Quadrupole

Parameter	Value
Field Gradient	18 T/m
Iron Length	233 mm
Aperture radius	30 mm
Good Field Region	±18mm

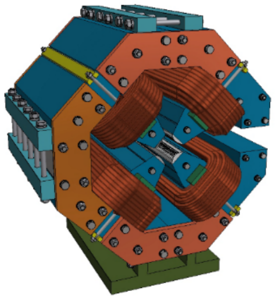
Alpha magnet

Parameter	Value
Field Gradient	4.5 T/m
Iron width	400 mm
Effective depth	250 mm

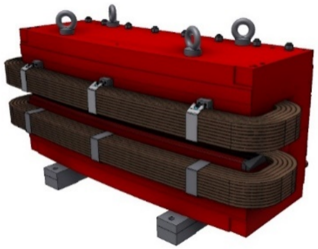
Magnet in construction phase



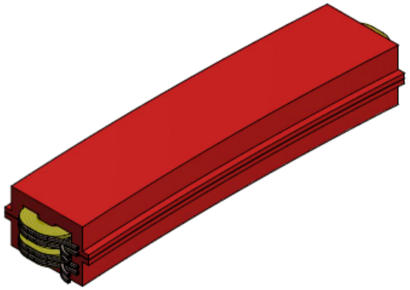
Sextupole(SR)



Quadrupole(SR)



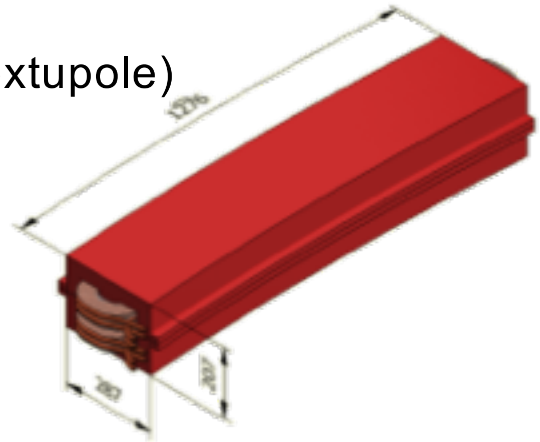
C-type Dipole(SR)

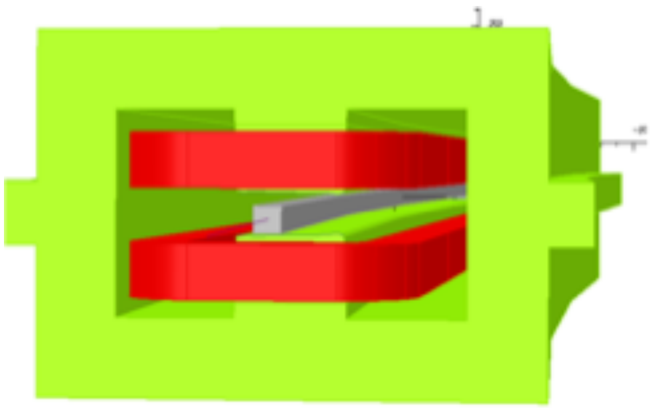


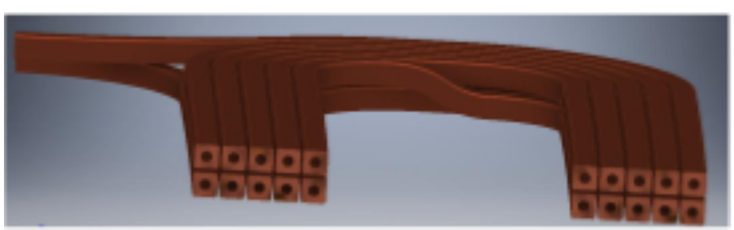
H-type Dipole(BR)

Other Magnet Project

- H-type combined Dipole Magnet(Dipole + Quadrupole+ Sextupole)
  - Design completed
  - material procurement for manufacturing
  - Collaboration with local companies in IRAN



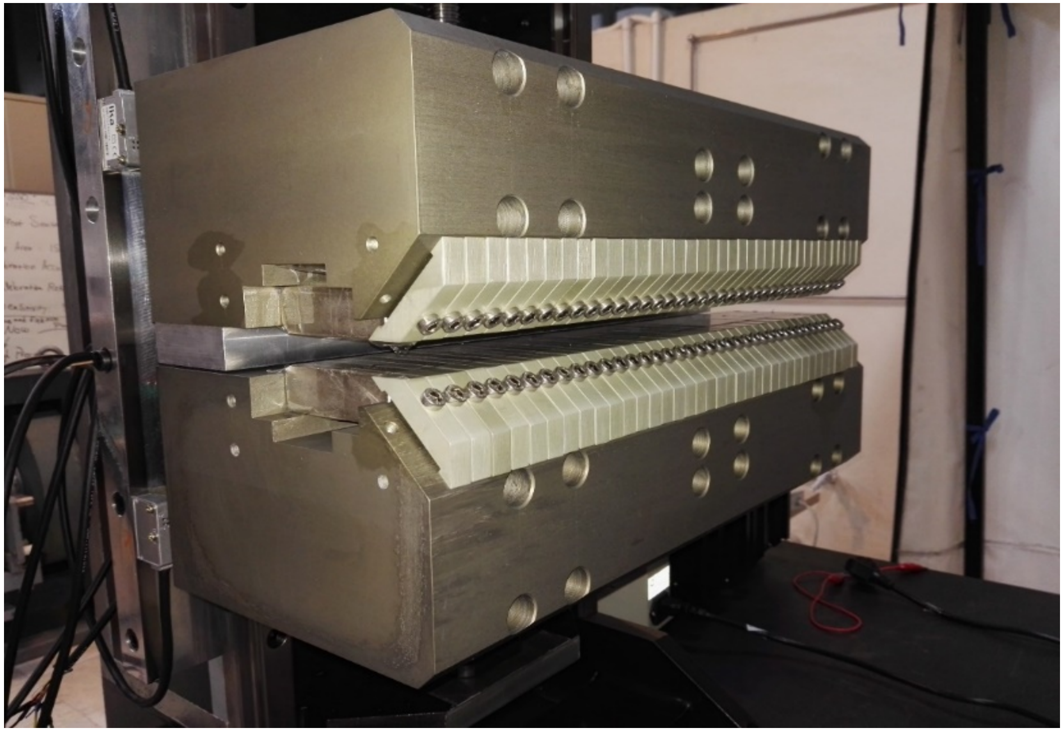




Parameter	Unit	“H-type”-BE
QTY	-	50
Bending radius	m	10.345
Field @ extraction (B_0)	Tesla	0.9667
Extraction Field gradient (B')	Tesla/m	1.791
Extraction Sextupole component (B'')	Tesla/m^2	43.8
Gap	mm	24
Horizontal good-field region	mm	±6
Magnetic length	m	1.300
Field quality	-	1×10^{-4}

Undulator Prototype

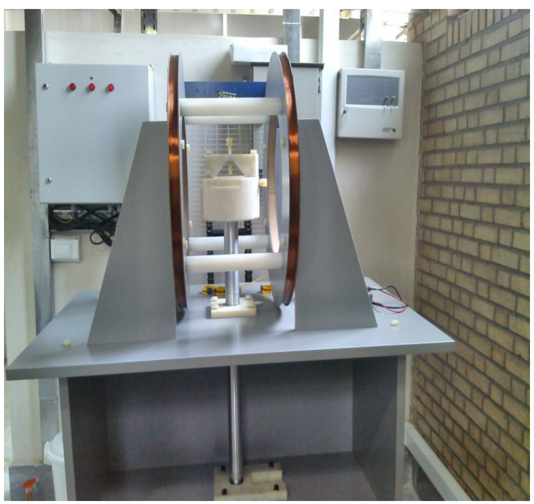
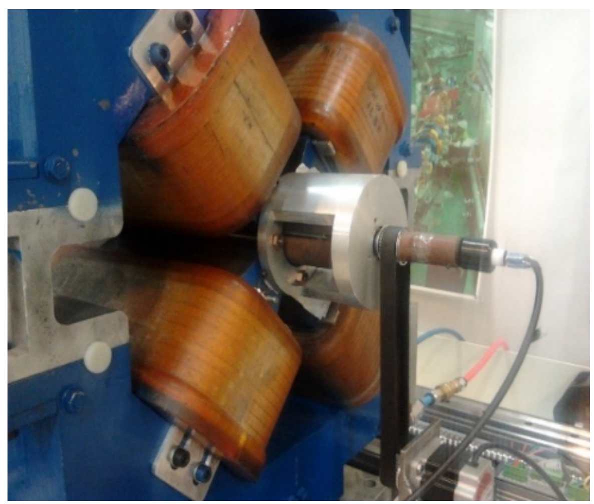
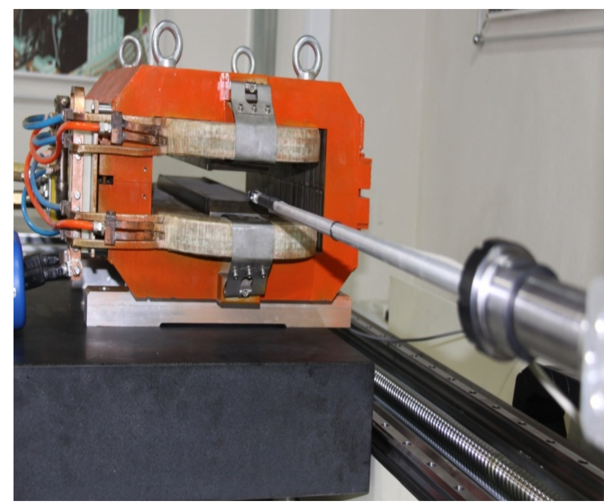
- ILSF First Undulator Prototype (Permanent Magnets)
- Probe Measurement System: @gap=15mm, $B_{y,max}$= 0.75 T



Magnet Group

Many sub-projects carried by the Magnet group, including:

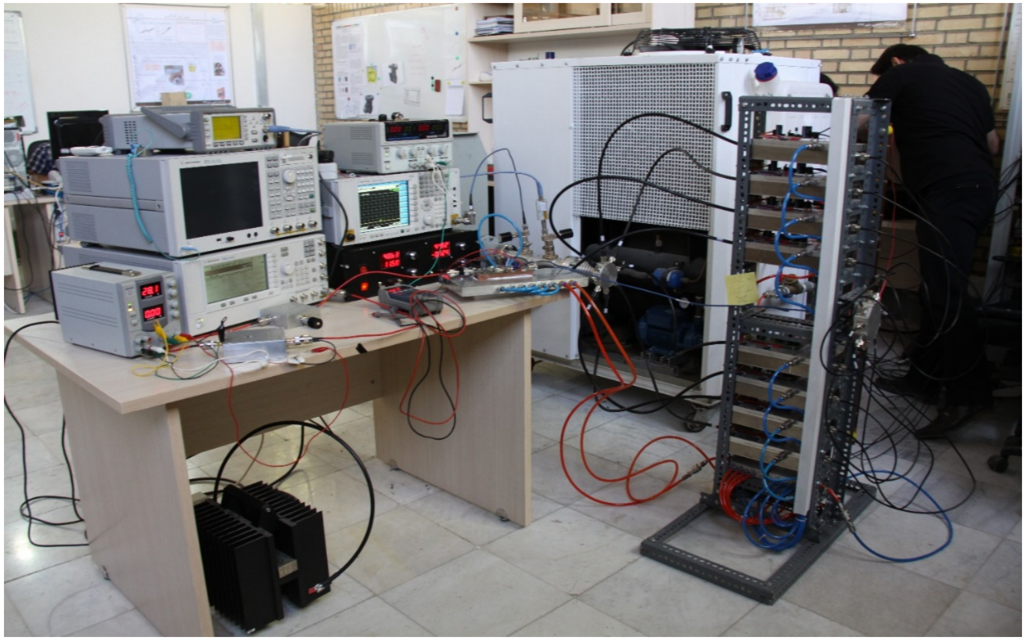
- Helmholtz Coils
- Un-compensated Coils for Prototype Quadrupoles
- Hall Probe measurement

High Power RF Amplifier

- 4kW 500MHz SSA prototype

(developed successfully, 59% efficiency)

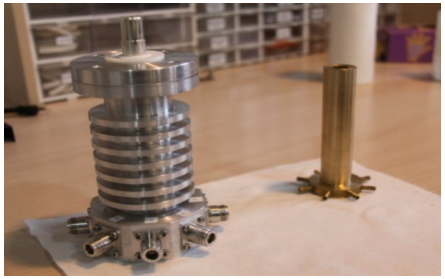


- 30kW 100MHz SSA prototype

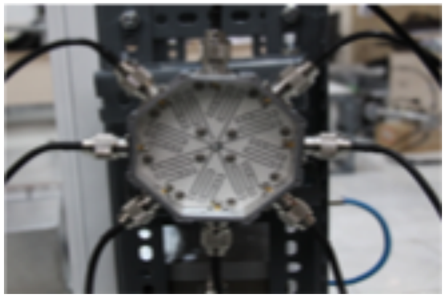
as one forth of 120kW (under investigation)

Amplifier Module (Based on BLF578 Transistor)

8:1 Combiner



1:8 Divider



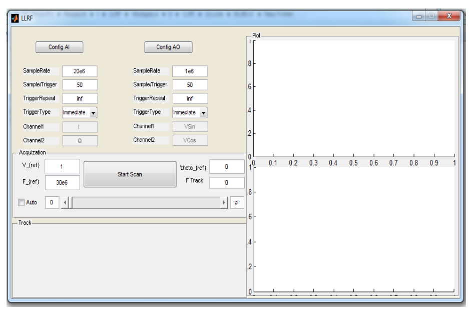
Low Level RF control system

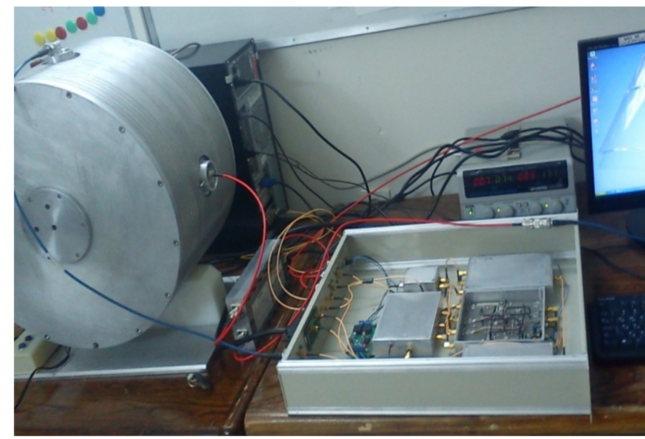
- Semi-digital prototype (developed successfully)

Analog Sections

Digital Sections

Software

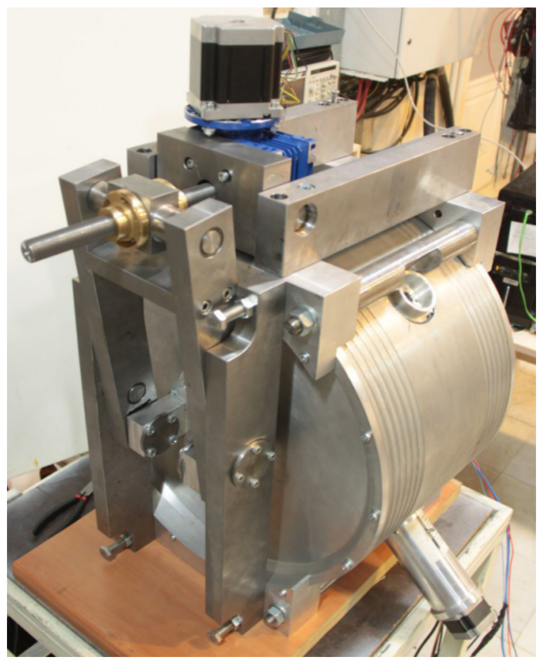


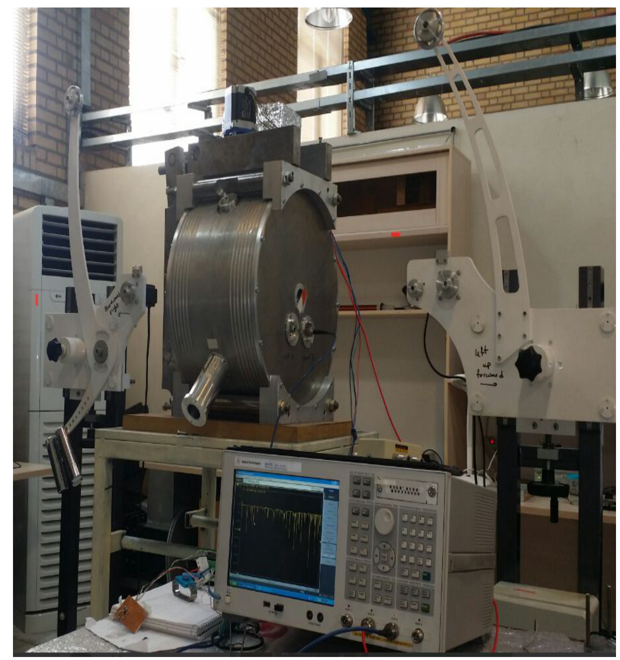


- **Fully-digital LLRF system (Designed, under fabrication)**

Design and Construction of 125 MHz Cavity

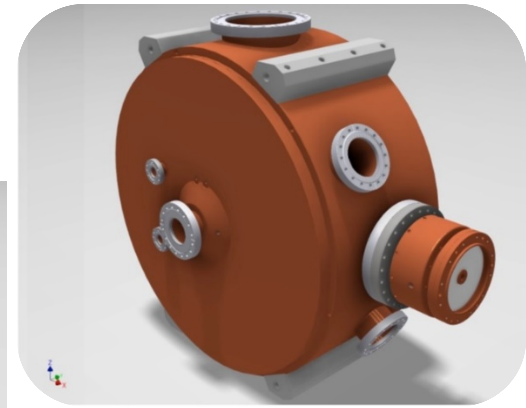
- 500MHz pillbox is modified to 125MHz capacity loaded
  - Comparison of simulation & measurement results (1st mode & HOMs)
  - Comparison of 2 tuning methods & effects on HOMs
  - Comparison of wire impedance method & beadpull measurement
  - Adding HOM dampers (in future)

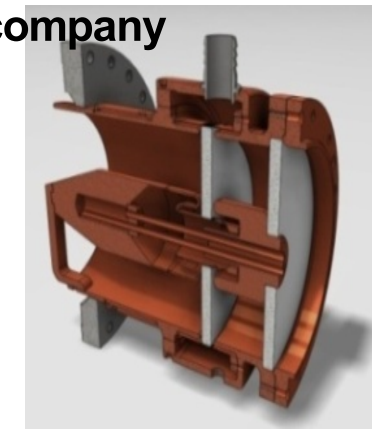


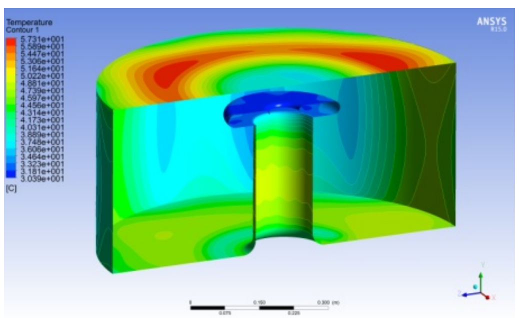


100 MHz Cavity under construction

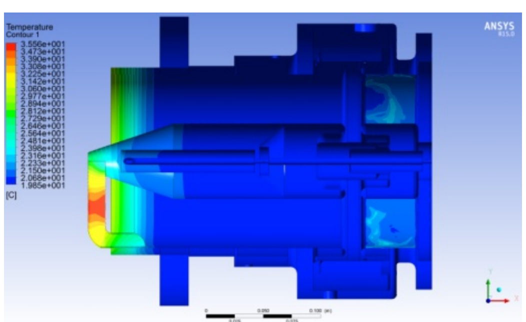
- 100 MHz Cavity
  - Electromagnetic & mechanical design
  - Feasibility study & RF preparation
  - **Fabrication is initiated by local company**

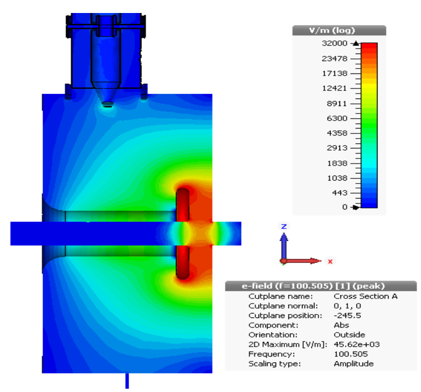






Cavity body thermal analysis





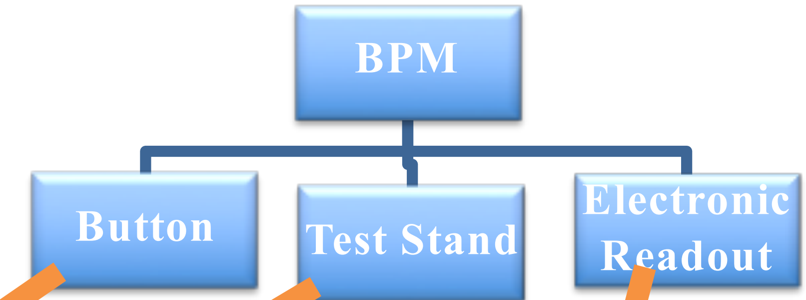
Cavity coupler thermal analysis

Beam Diagnostics

Instrument Name	Detecting Parameters	Required Number	Estimated Cost $
Beam Position Monitor	Position	400	3,800,000
Stripline BPM		7	126,000
Faraday Cup	Current-Charge	1	10,000
Fast Current Transformer		12	180,000
Wall Current Monitor		8	8,000
Beam Charge Monitor		5	75,000
DC Current Transformer		2	100,000
Annular Electrode		2	20,000
Fluorescent Screen/OTR	Profile-Size	13	50,000
Visible Synch.Rad.Monitor		3	250,000
X-Ray Synch.Rad.Monitor		1	10,000
Beam Loss monitors	Beam loss	129	129,000
Scrapers	Beam halo-others	4	20,000

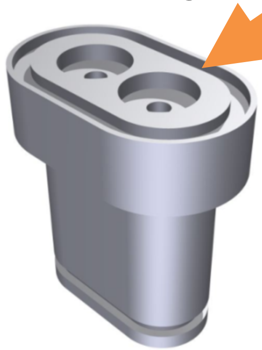
Beam position Monitor of ILSF

- Beam size is 60×6 μm^2
- Beam displacement is less than 20 μm
- BPM resolution should be at least 1 μm

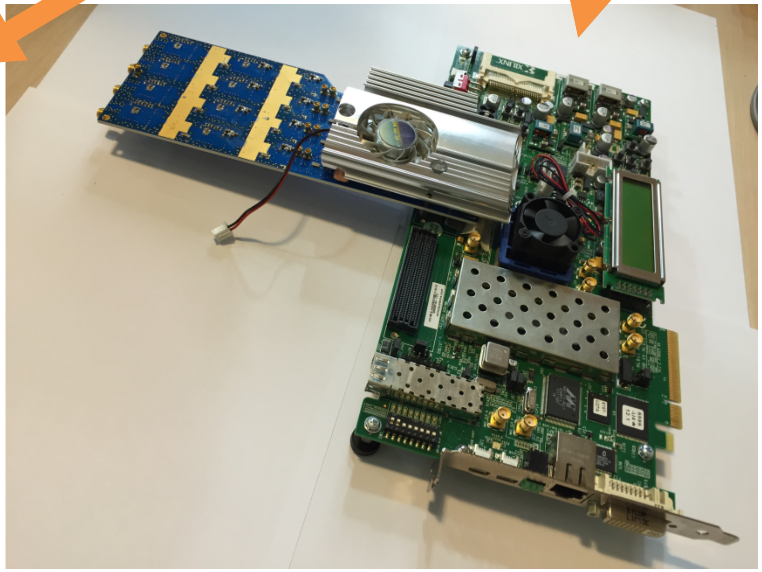


Design is done successfully

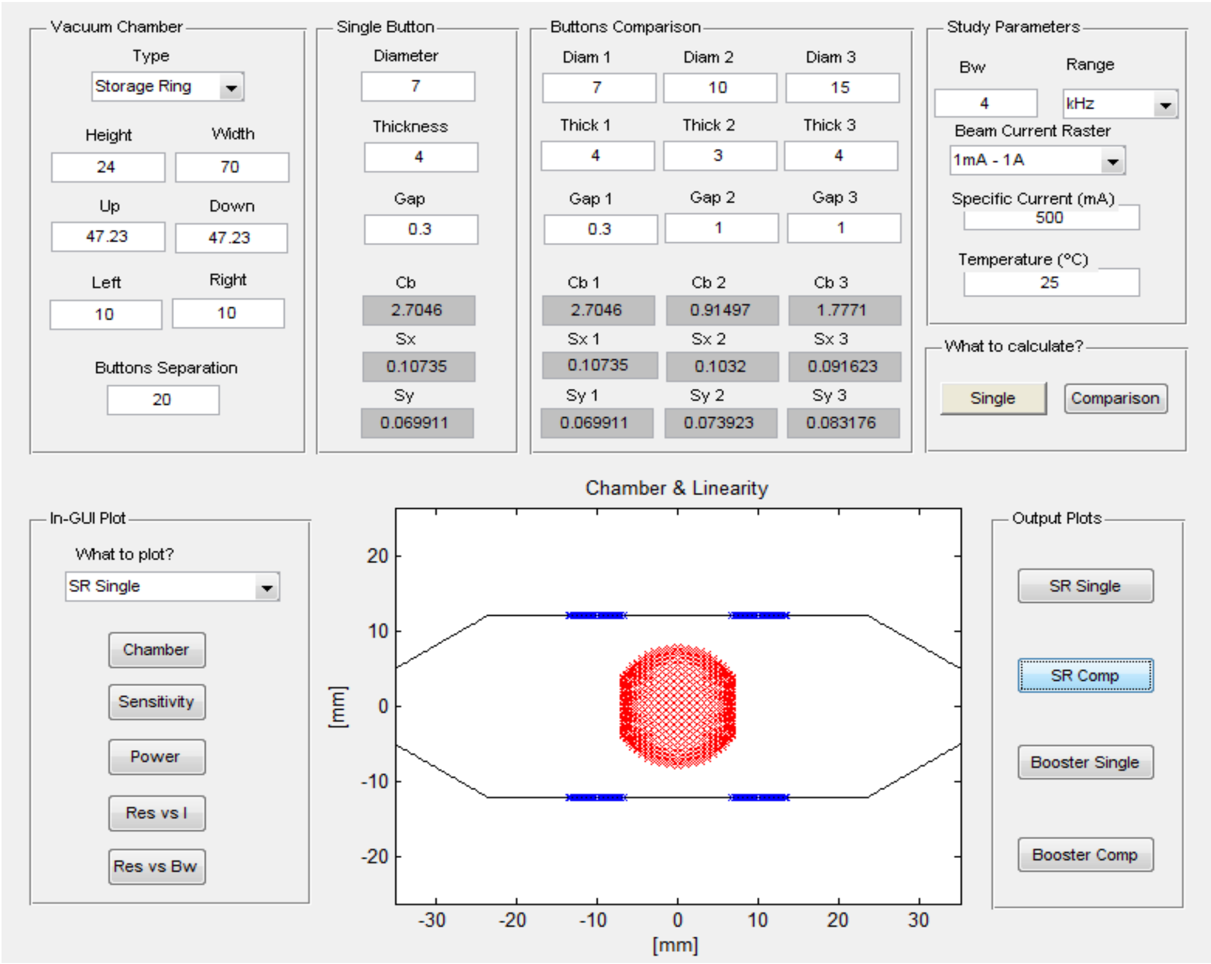
Final design of Button BPM with 7mm diameter, 4mm thickness and 0.3mm annular gap



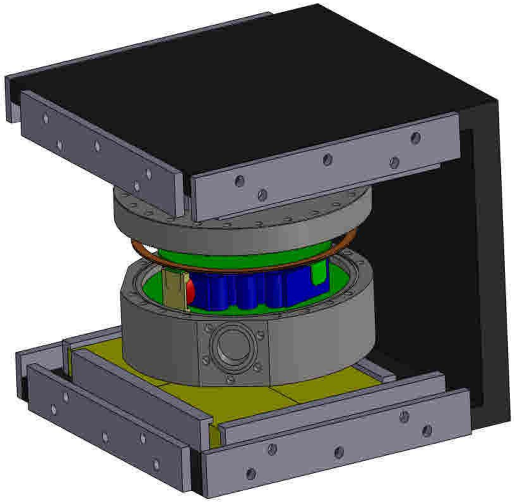
Design & Fabrication done successfully

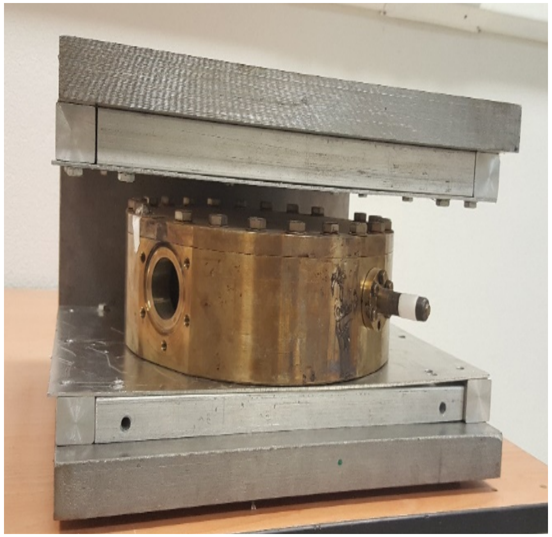


Developed code in C#

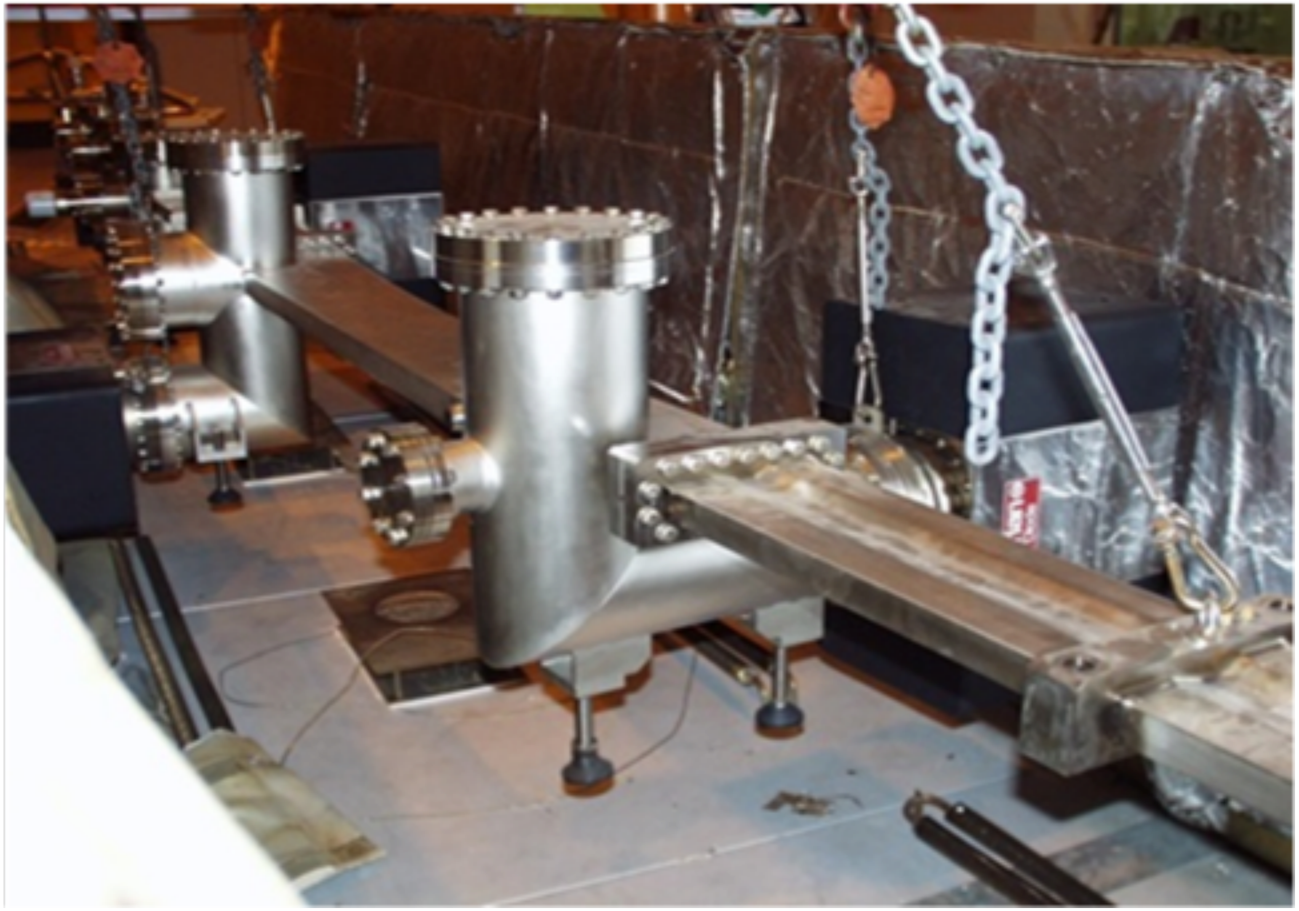


- Design and construction of an Ion pump prototype for Iranian light source facility with a final pressure of 10^{-11} *mbar*



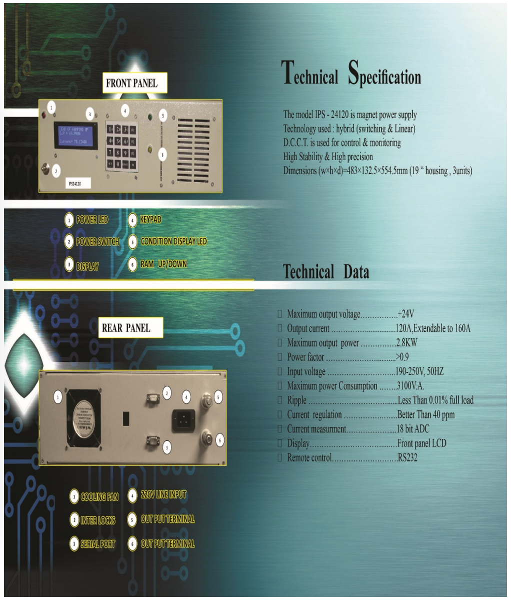


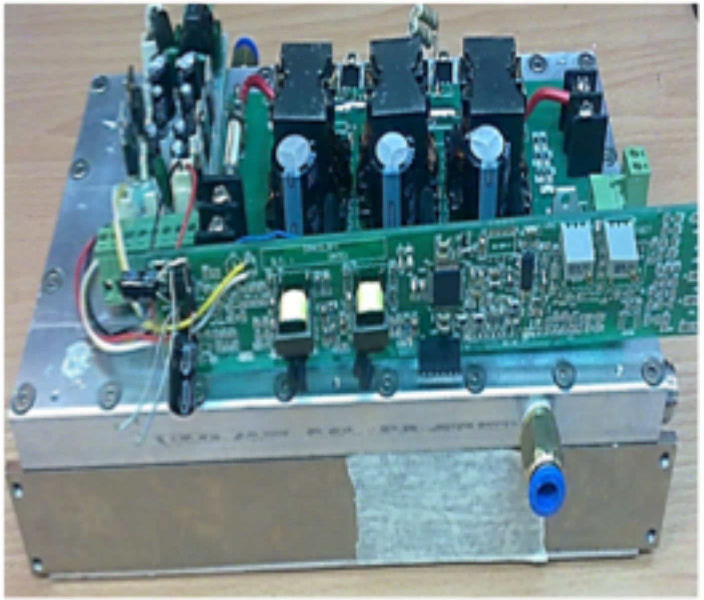
Prototype of Vacuum Chambers



Power Supply

- Prototype of AC Power Supply for Booster
- Prototype of DC Magnet Power Supply
- Power Supply for Solid State RF Amplifier



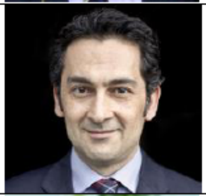


People

IPM
INSTITUTE FOR RESEARCH IN FUNDAMENTAL SCIENCES
Atomic Energy Organization of Iran
Iranian Light Source Facility
9th ILSF Users' Meeting
go.ilsf.ir/ilsfum2017
9th ILSF Users' Meeting
3rd & 4th May 2017
Qazvin, IRAN

International Advisory Committee

1	Riccardo Bartolini	Professor of Accelerator Physics Group at Diamond, England	
2	Dieter Einfeld	Former Technical director of ALBA , Presently technical director of ESRF	
3	Helmut Wiedemann	Stanford University Applied Physics Department	
4	Yannis Papaphilippou	Senior Accelerator Physicist at the European Organization for Nuclear Research, Switzerland	
5	Gwo Huei Luo	Deputy Director, NSRRC, Taiwan	
6	Liu Lin	Physicist Group leader, Brazilian Synchrotron Light Laboratory	

1	David Attwood	Professor in Residence Emeritus of Berkeley California	
2	Maya Kiskinova	Coordinator of Research Projects, Elettra-Sincrotrone Trieste, Italy	
3	Miguel A. G. Aranda	Scientific Director, ALBA Synchrotron Light Source, Spain	
4	Sam Bayat	Professor of Physiology, Grenoble University Hospital, France	
5	Majid Kazemian Abyaneh	Senior Support Scientist for Beamline I08, Diamond Light Source, UK	

Lattice nonlinear optimization in ILSF

- I joined the beam-dynamic group of ILSF and I'm currently working on my PhD thesis
  - What is my task?
  - The natural chromaticity of a storage ring is large that the tunes of particles with even modest energy deviation can hit integer or half-integer resonances.

→ **This can lead to rapid loss of particles from the beam.**

Fortunately, there is a (relatively) easy way to control the chromaticity in a storage ring using sextupoles

But every solution like medicine has side effects, what is the side effect of sextupoles

- Dynamic Aperture (DA)(the stability region of phase space) **decreased**
- Momentum Acceptance (MA) (the maximum energy excursion) **decreased**
- Injection efficiency (the Efficiency of the transfer of electron bunches), **decreased**
- Touschek lifetime (the scattering and loss of charged particles), **decreased**

MY purpose: optimization of DA and MA

The optimization procedure

Optimization is done with 2 codes

ELEGANT and MOGA

In non-linear case:

- optimization variables are the strengths of sextupoles

Goals:

- Chromaticity correction
- DA and MA improvement

In Linear case:

- optimization variables are Strengths of Quadrupoles

Goals:

- tune and twiss parameters in the defined values

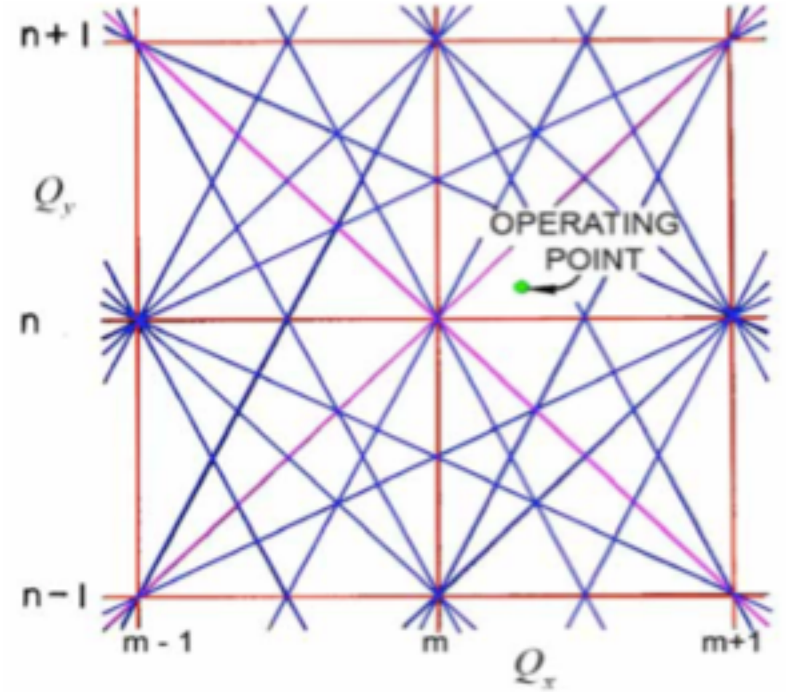
ELEGANT

- In the tune diagram, we defined dangerous resonances.

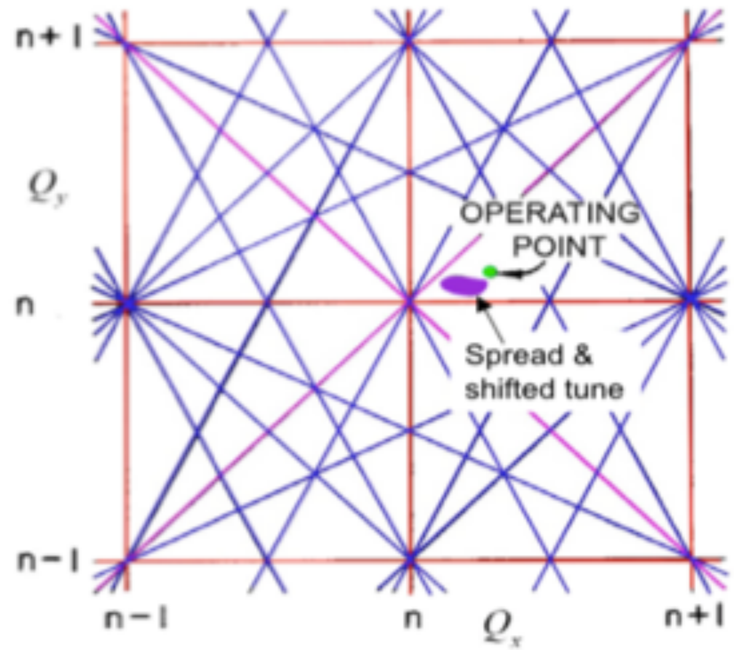
  Dangerous resonance → Instability
- Give higher weight factor to dangerous resonance, so in this situation the particles are more stable.
- Correct the chromaticity in the optimization.
- Optimize and check if the DA is improved or not.
- The Best DA is our goal.
  - Advantage: It can be done with our computers and it takes about 20-24 hours of simulation.
  - Disadvantage: I should change the weight factor of the resonance for every run manually.

Tune diagram

with out sextupoles and field errors



with sextupoles and field errors



MOGA

- In MOGA, linear and non-linear optimizations have been done simultaneously.
- Also, The target tune and the best area of DA calculated simultaneously.

  - Advantage: No values to enter manually.
  - Disadvantage, every run in this algorithm needs much consuming time and it should be done with clusters.

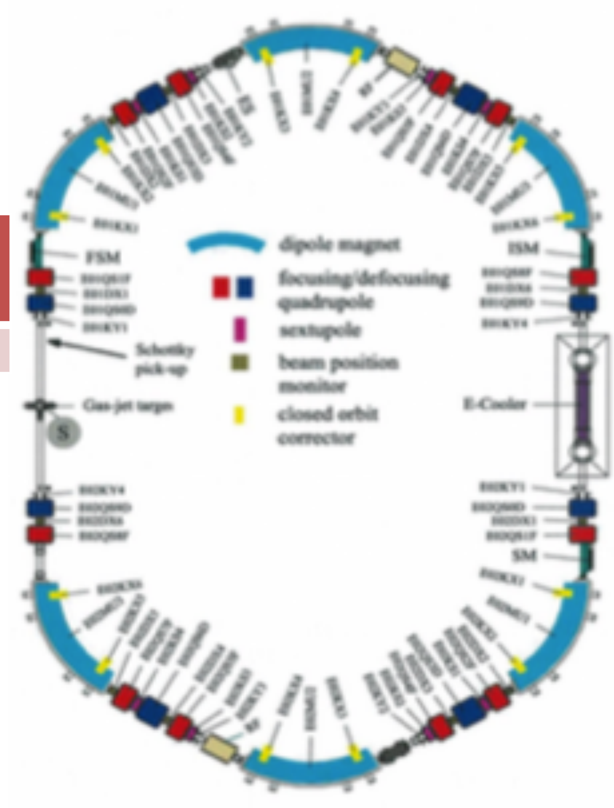
Beam-Optics simulation in ESR

- **Circumference**= 108.3 m
- In ELEGANT and MAD-X, I use these input parameters

Magnet	Quantit y	Length (m)	Magneti c field (T)	Deflecting angle (Deg.)	Bending radius (m)
BE1	6	6.25	0.56??	60	6.009

Quadrupole	Num.	Length(m)	Gradient B' (T/m)
Q1	4	0.821	-0.499866
Q2	4	0.834	0.457584
Q3	4	0.821	0.335650
Q4	4	1.24	-0.445888
Q5	4	0.821	0.422140

Sextupol e	Num.	Lengt h (m)	Strength B'' (T/m^2)
S1	4	0.34	-0.44
S2	4	0.34	0.23

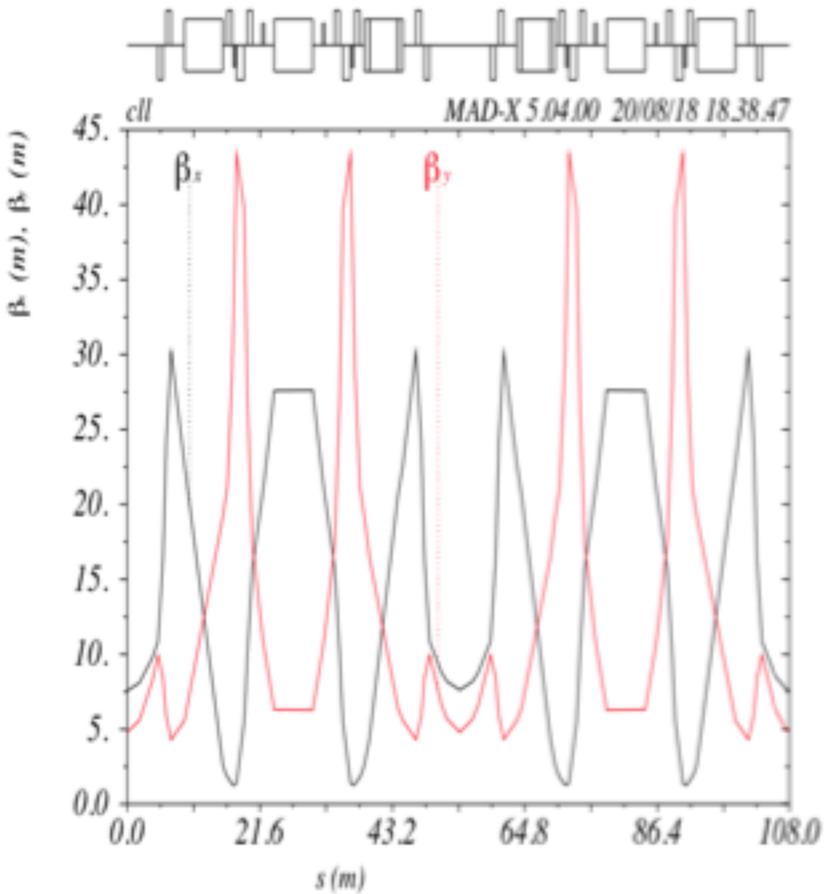


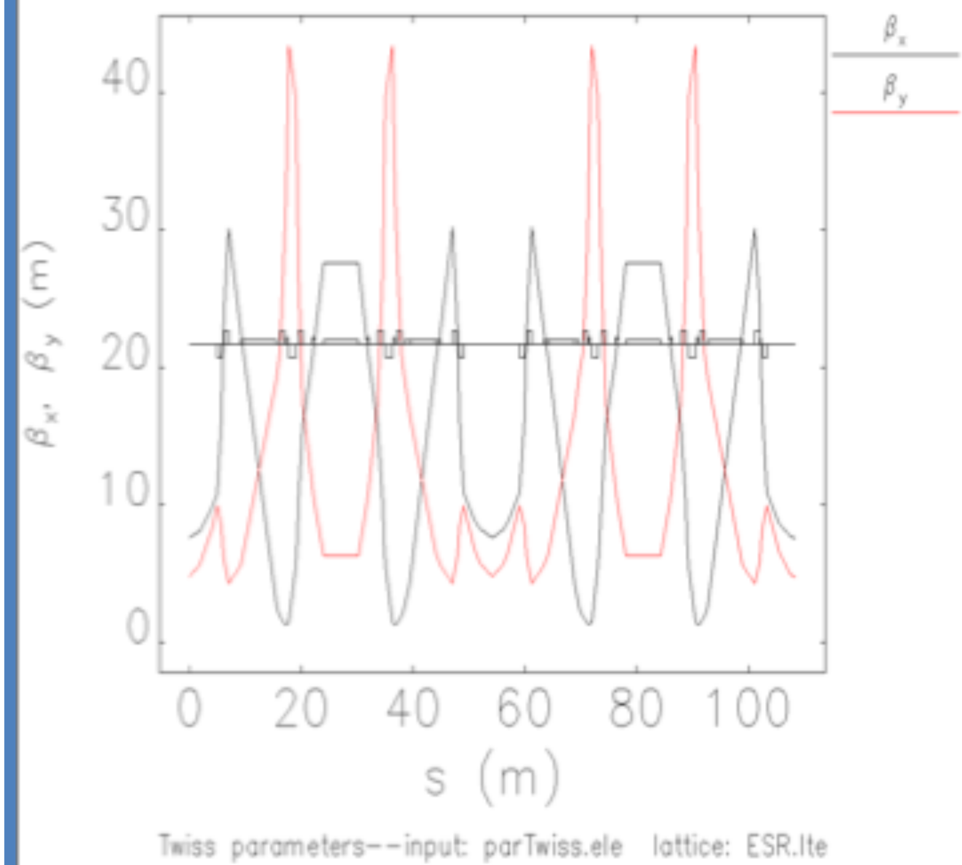
Oleksi Gorda PhD thesis, "**Field Interference of Magnets and its Influence on Beam Dynamics in Storage Rings** "

- Twiss parameter, dispersion and tune using ELEGANT and MAD-X (Bare Lattice)

parameter	ELEGANT Value	MAD-X value	Definition
ν_x	2.441889537	2.441889537	tune
ν_y	2.295835413	2.295835413	tune
ξ_x	-1.7705536	-5.131589949	chromaticity
ξ_y	0.2105368	-1.613414185	chromaticity
η_x	5.078751993	5.078751993	Max-Dispersion
β_x	30.16907073	30.16907073	Max-Beta
β_y	43.3695182	43.3695182	Max-Beta

MAD-X and ELEGANT





And what else…

- Field harmonic magnet errors and analyzing optic changes in ELEGANT and MAD-X
- Electron cooling, injector, orbit correctors, horizontal bumps and analyzing the optics change in ELEGANT and MAD-X.
- Tracking dynamic aperture in ELEGANT and MAD-x.
- Analyzing the isochronous mode optics in MAD-x and ELEGANT.
- Measurements and comparing the result of simulation and measurement will be available…☺

Final Word

- We in ILSF warmly invite you to our project in Iran for just visiting, or join our scientific advisory committee or start a collaboration.

Suggestion for free time during your visit