ESLS -2021

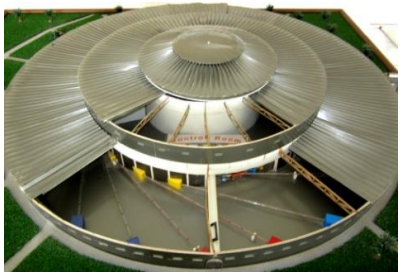
CANDLE Project Status

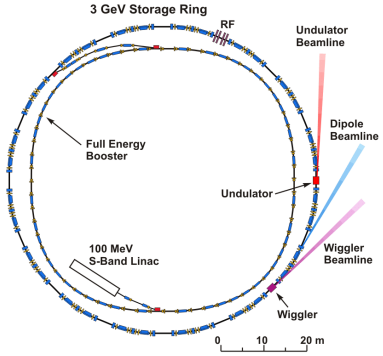
In Memory of Vasili Tsakanov

Presenter - Bagrat Grigoryan

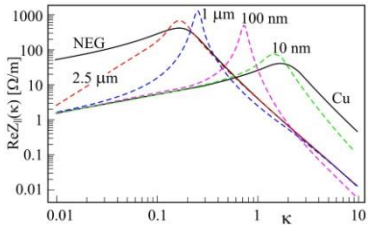
Contents

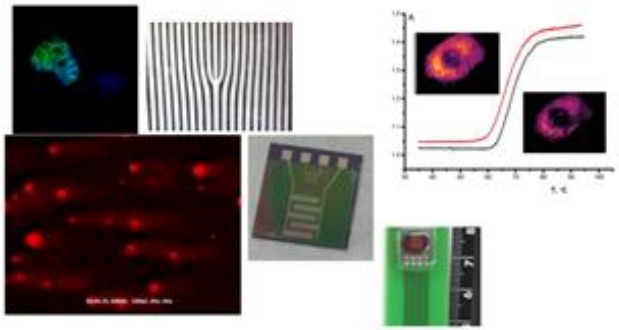
ESLS -2021





- CANDLE Project
- Storage Ring Optimizations
- Impedances
- The link to Users
- Summary





CANDLE Project

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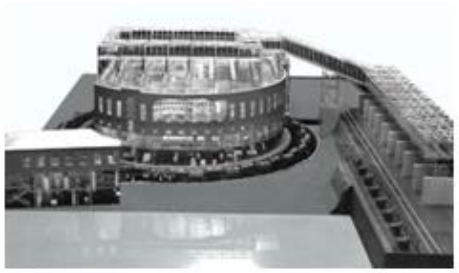
ESRF

6 GeV synchrotron (1967)

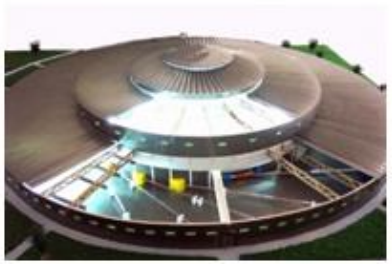


A.I. Alikhanian

3 Synch Rad Beamlines (1973)

3 GeV CANDLE Light Source

V.M. Tsakanov



Energy	3 GeV
Current	350 mA
Circumference	216 m
Emittance	*8.4 nm*

The strong user community will emerge as the facility is readied.

Review Panel

CANDLE Project

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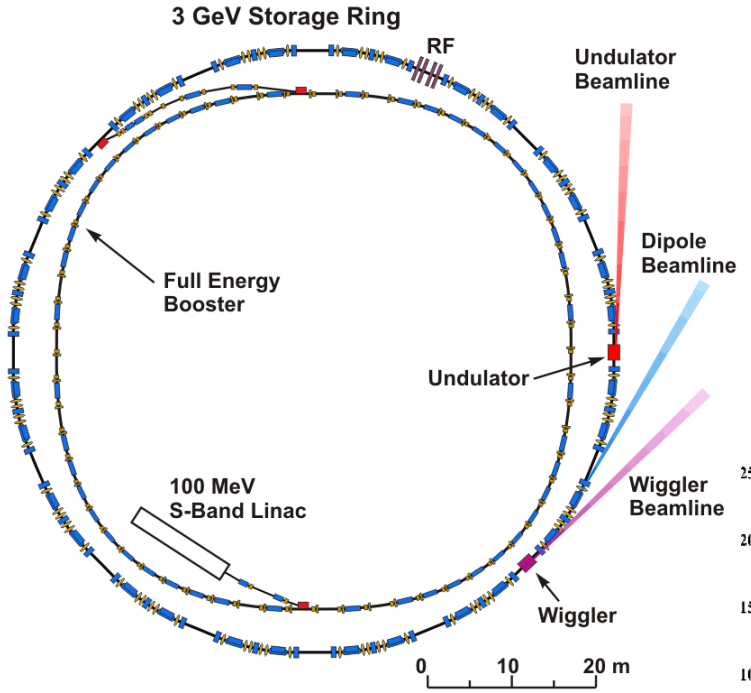

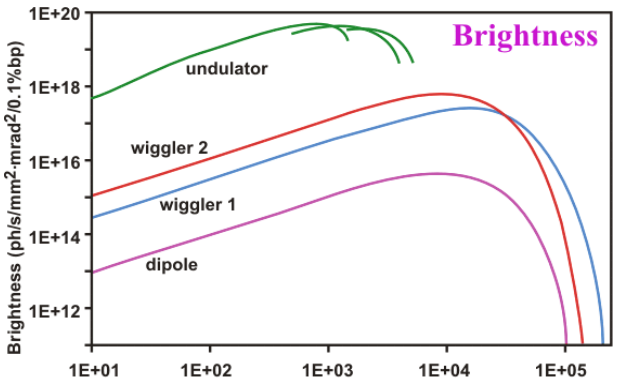

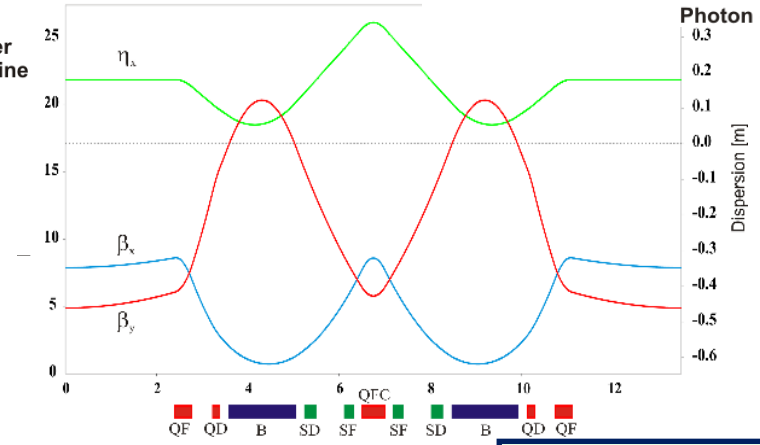

Energy E (GeV)	3
Circumference (m)	216
Current I (mA)	350
RF frequency (MHz)	499.654
Harmonic number	360
Number of lattice periods	16
Straight section length (m)	4.8
Lattice type	DBA
Bending radius ρ (m)	7.385

Energy	3 GeV
Current	350 mA
Circumference	216 m
Emittance	*8.4 nm*

Storage Ring Optimizations

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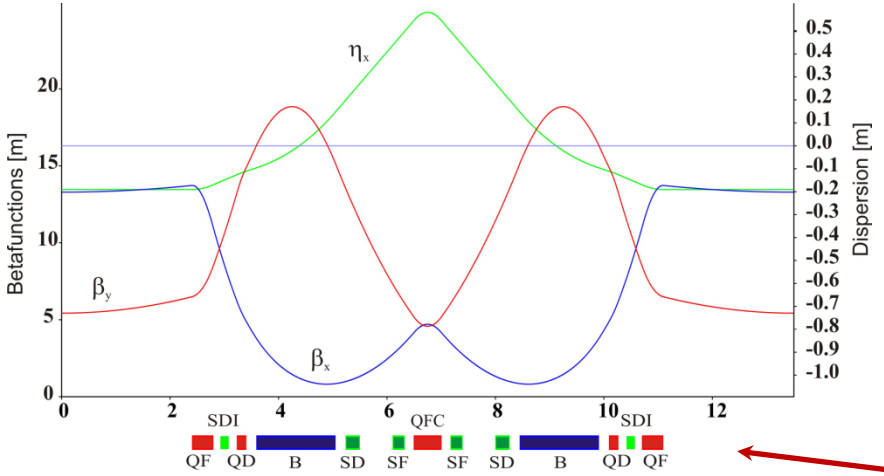
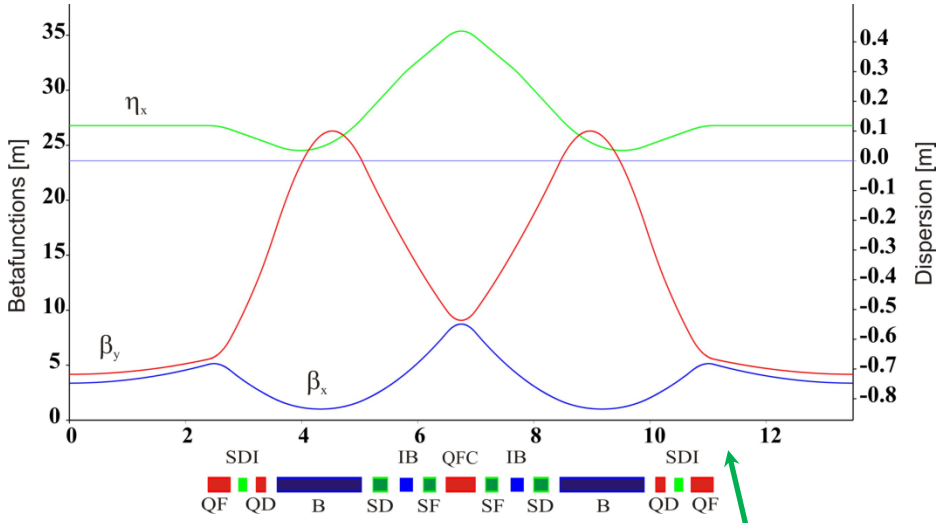
ESRF

Low alpha:
Short pulse SR +
Coh. THz radiation





Parameter	Original lattice	High emittance lattice	Low emittance lattice
α_0	$2*10^{-3}$	$2*10^{-5}$	10^{-4} ($2*10^{-5}$ is infeasible)
α_1 (with/without sext. opt)	$3*10^{-3}$	10^{-4}/$-7.3*10^{-3}$	$4*10^{-3}$/$6.3*10^{-3}$
Emittance (nm rad)	8.4	59	27
rms energy spread (%)	0.104	0.095	0.116
Momentum acceptance (%)	2.4	10	1.25

A. Sargsyan *et al* 2015 *JINST* 10 T10002

DOI: 10.1088/1748-0221/10/10/t10002

Storage Ring Optimizations

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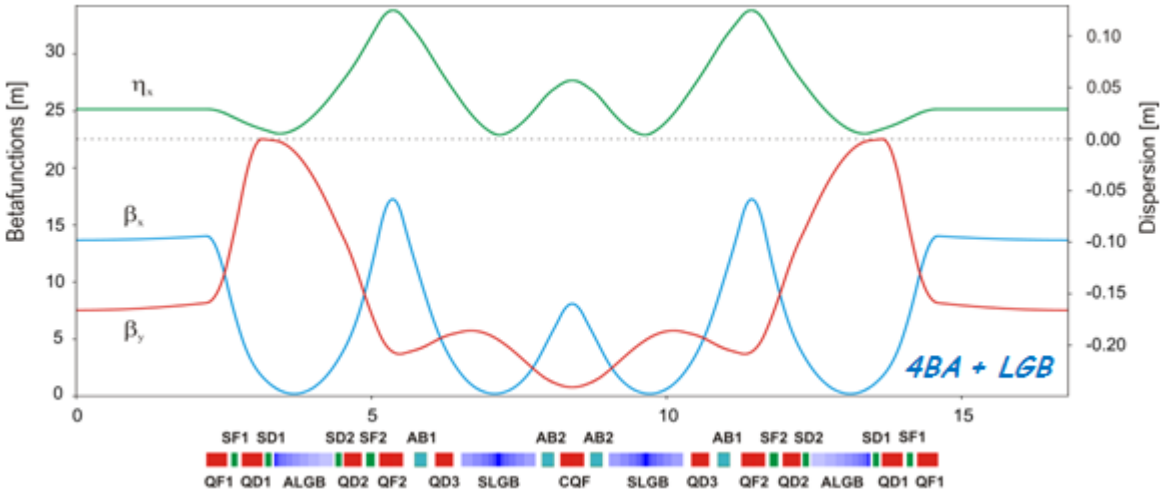
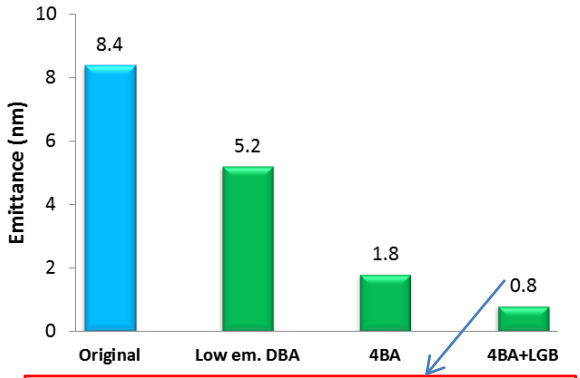


A. Sargsyan et.al. ***NIM A***, 2016.
https://doi.org/10.1016/j.nima.2016.06.129

Optimizations for low emittance



0.435 for 268.8m circumf.

Parameter	Original	Low emit. DBA	4BA	4BA+LGB
Circumference (m)	216	216	258	268.8
Number of periods	16	24	16	16
Straight section length (m)	4.8	4.4	4.2	4.4
Energy (GeV)	3	3	3	3
Emittance (nm rad)	**8.4**	**5.2**	**1.1**	**0.435**
Energy spread (%)	0.1	0.15	0.1	0.11
Overall mom. acc. (%)	2.4	2.1	3.9	2.6
Natural chrom. (hor./vert.)	-18.91/ -14.86	-13.64/ -24.27	-38.27/ -26.04	-95.16/ -33.92
Betatron tunes (hor./vert.)	13.2/ 4.26	14.17/3.19	24.61/14.37	29.2/8.36

Storage Ring Optimizations

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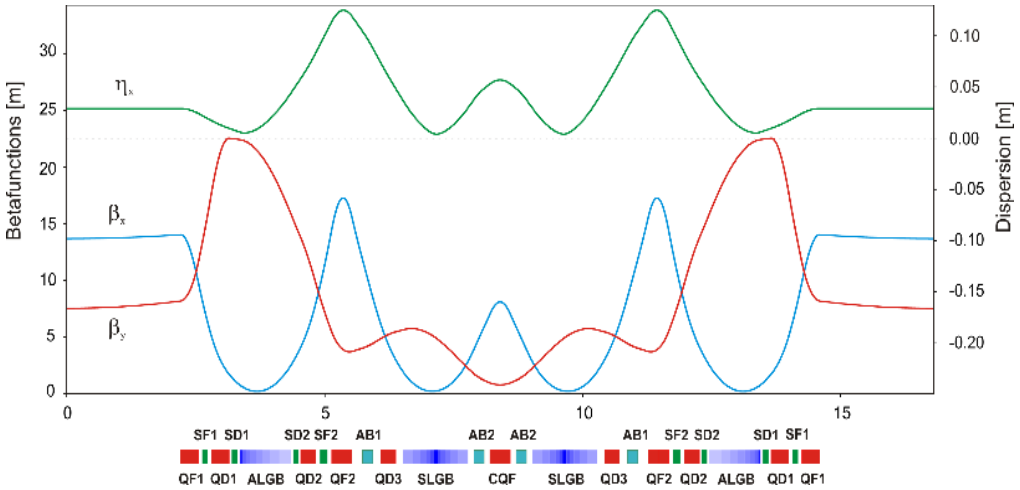
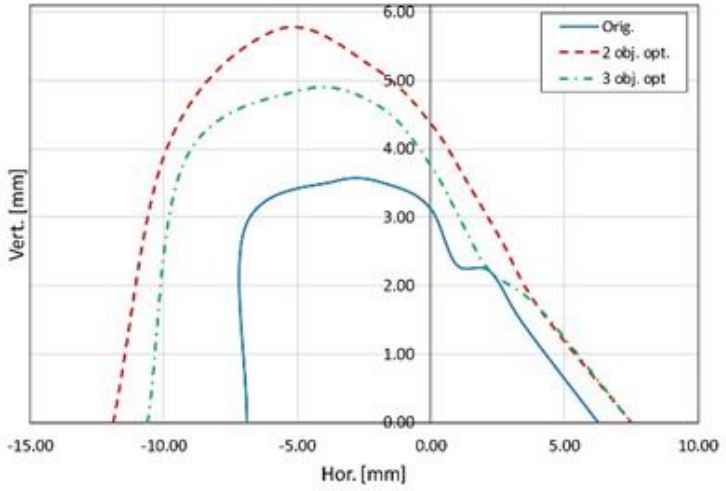


Non linear dynamics optimizations for low emittance

Sext	Original [m^{-3}]	Optimized [m^{-3}]
SF1	110.1	113.7
SD1	-425.4	-406.3
SD2	-516.4	-544.4
SF2	313.2	347.8
AB1	-59.9	-75.5
AB2	211.6	166.9

Circumference [m]	268.8
Lattice Type	4BA
Number of Periods	16
Straight length [m]	4.4
Beam Energy [GeV]	3
Horiz. Emittance [nm-rad]	0.435



V.V. Sahakyan and A.A. Sargsyan 2019 *JINST* **14** T04002.
https://iopscience.iop.org/article/10.1088/1748-0221/14/04/T04002

Impedances

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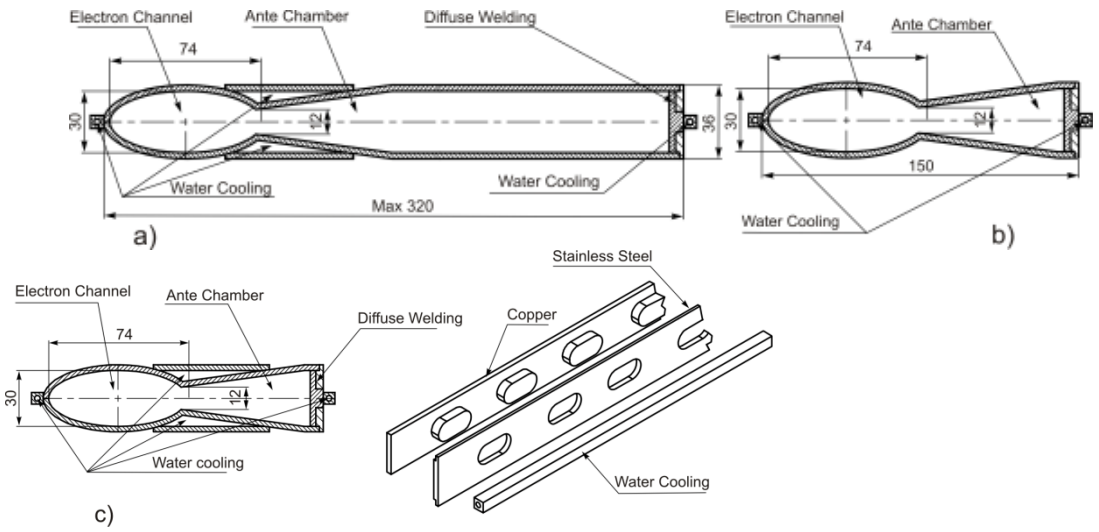

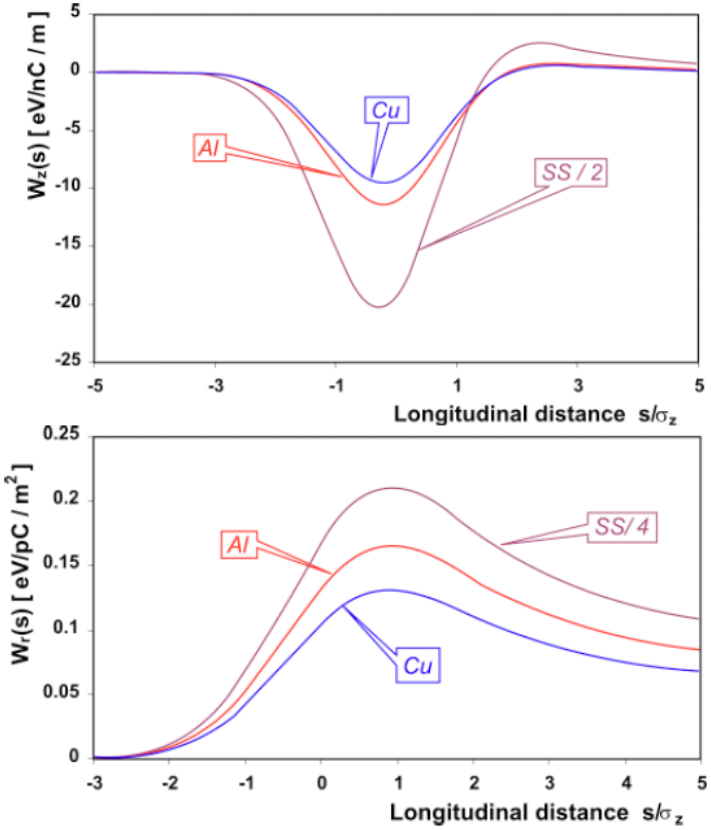

Material	Conductivity σ ($10^7 \Omega^{-1} m^{-1}$)	Characteristic distance s_0 (mm)	Short-range wake correction
Stainless Steel	0.14	0.12	$2 \cdot 10^{-3}$
Aluminum	3.65	0.041	$4 \cdot 10^{-4}$
Copper	5.93	0.035	$3.2 \cdot 10^{-4}$

Impedances

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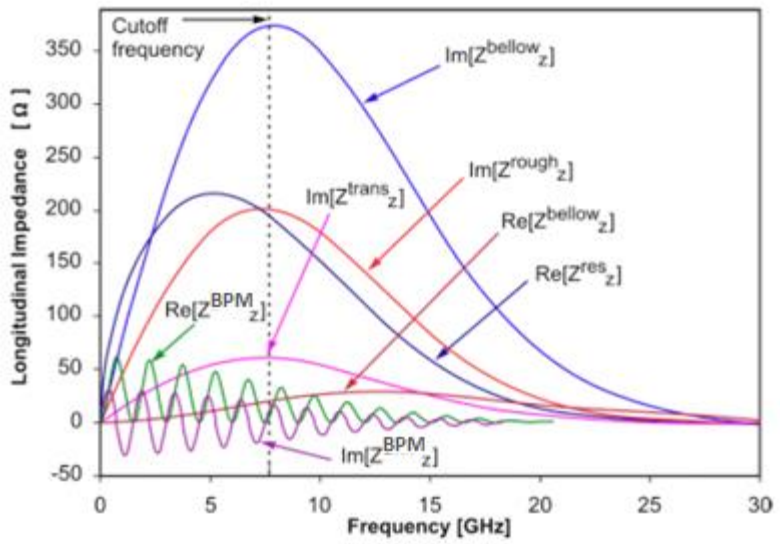
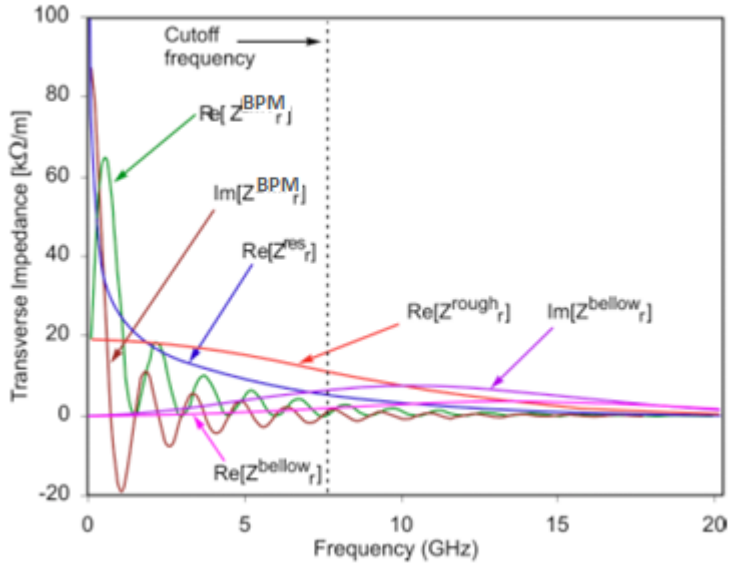
Parameters of Impedance sources

Source of wake	Quantity	Parameters
Resistive walls	-	Stainless Steel, Conductivity: 1.4 10^6 $\Omega^{-1}m^{-1}$
Roughness	-	RMS Height: 5 μ m
Transitions	6	Length: 7cm, 5:1 taper
Bellows	100	Length; 5mm; Height: 2mm
BPM	100	Length:10cm; End Impedance-5 Ω, angle π /2





Impedances

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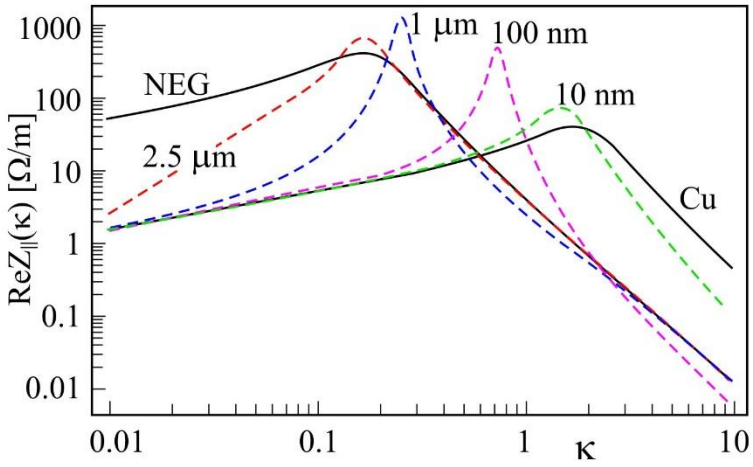
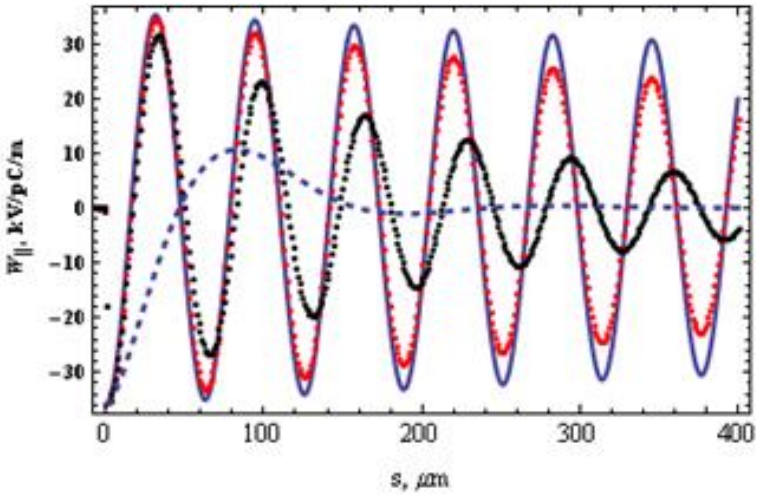
For chamber design optimizations laminated structure considerations SS-NEG **Cu-NEG** were considered

Cu - NEG

M. Ivanyan, et al, PRSTAB, 2014
M. Ivanyan, et al, NIM (A), 2016



Longitudinal Impedances for several NEG thicknesses.



Long. resistive wakes for different copper pipe radiuses.

- *Collaborations PETRA IV (DESY), SLS 2 (PSI)*
- *Project of impedance measurements test stand for different thickness of NEG*

CANDLE Project. Phase 1

ESLS -2021

ESRF

- *"**CANDLE** is a world-class project enabling frontier research in a whole spectrum of basic and applied sciences".*
- ***Excellent investment*** *from scientific-technical point of view.*
- ***Strong user community*** *will emerge as the facility is readied.*

From Review Panel Report

2002

- **State-of-the-art facility**
- **Multiple applications**
- **Small facility + Lim invest.**
- **Scientific & Tech. asset**
- **Training and Educ. Center**
- **International cooperation**
- **Strategic Highlights**

From meeting of international experts with RA government

2010

The link to Users

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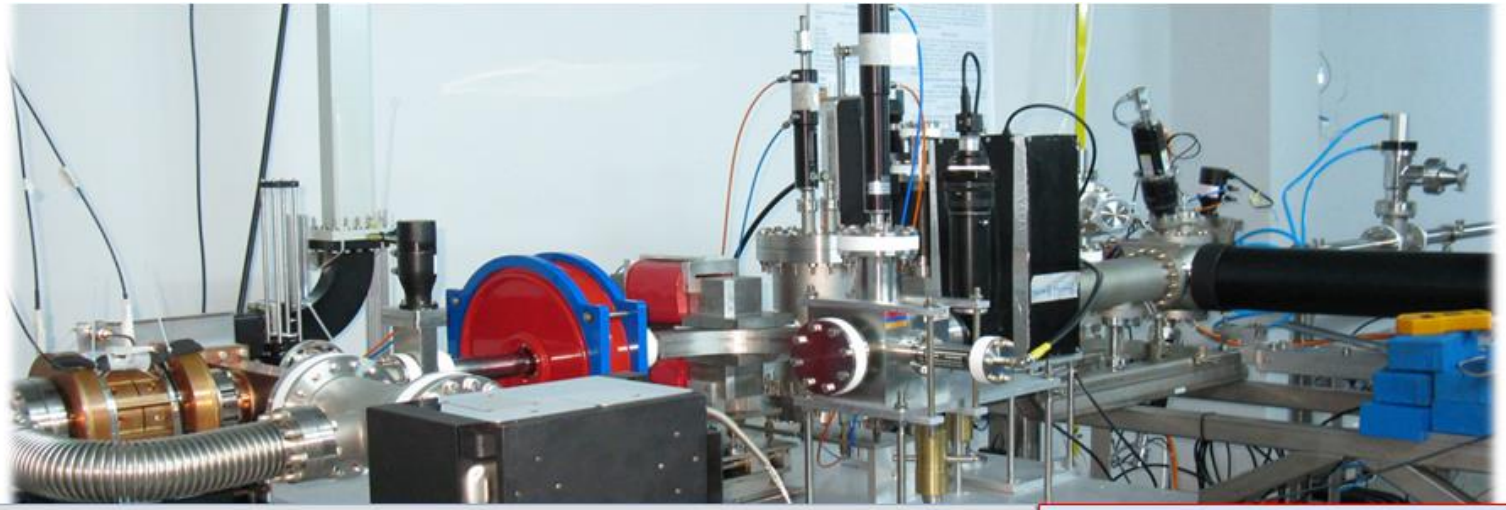

AREAL General Parameters:

Charge	10 - 850* pC (150-250 pC nominal)
Bunch length -FWHM (ps)	0.4 - 10
Repetition rate	1- 50 ** Hz
Transv. beamsize (x/y)	2/3 (@ straight) 20 / 8 mm (@ dipole)
Norm. Transv. emitt. (x/y)	≤ 1 mm-mrad
Energy	≤ 5.0 MeV
Energy spread (at dipole)	< 0.5%
Experiment duration	1 - 744*** hours

* High charge regime for dedicated experiments (achieved November 2015)

** Tests were performed up to 47 Hz with nominal charge of 150 pC. (end 2015)

*** 31 days of uninterrupted operation in May-June 2014, September-October 2018.

Fields of Potential Interest:

Solid State Physics

Biology

Molecular Physics

Optics

Material Science

Food Processing

Chemistry

Oncology

Medical Equipment Sterilization

The link to Users

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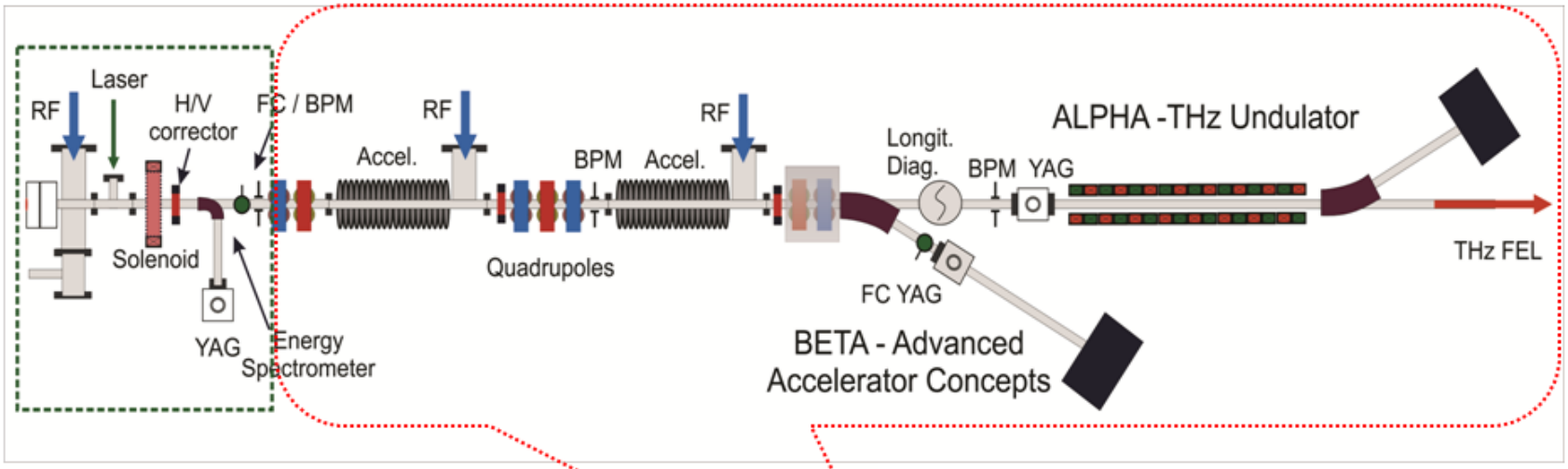

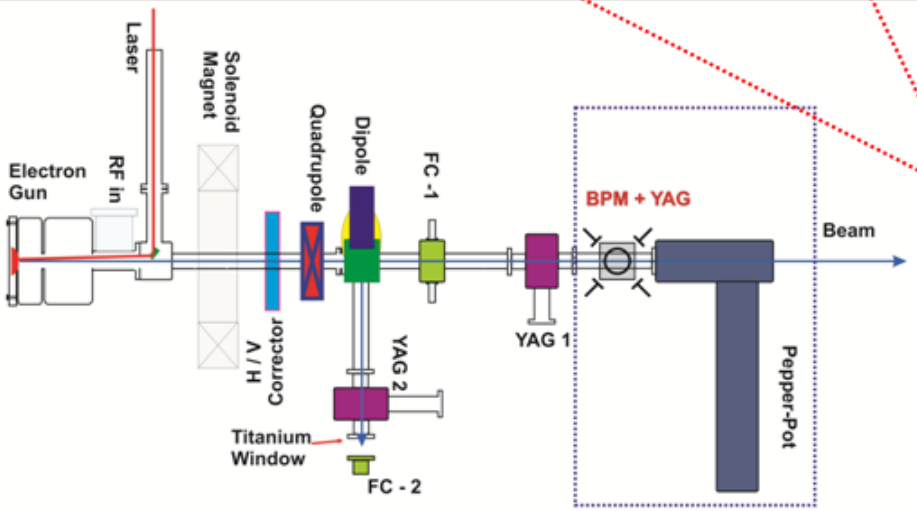

AREAL -50 Upgrade Program

- *20,50 MeV electrons*
- *FEL Radiation*
  - *Wavelength 2- 6.7 um*
  - *Frequency 45 -125 THz*
  - *Pulse energy 60-100 uJ*

The link to Users

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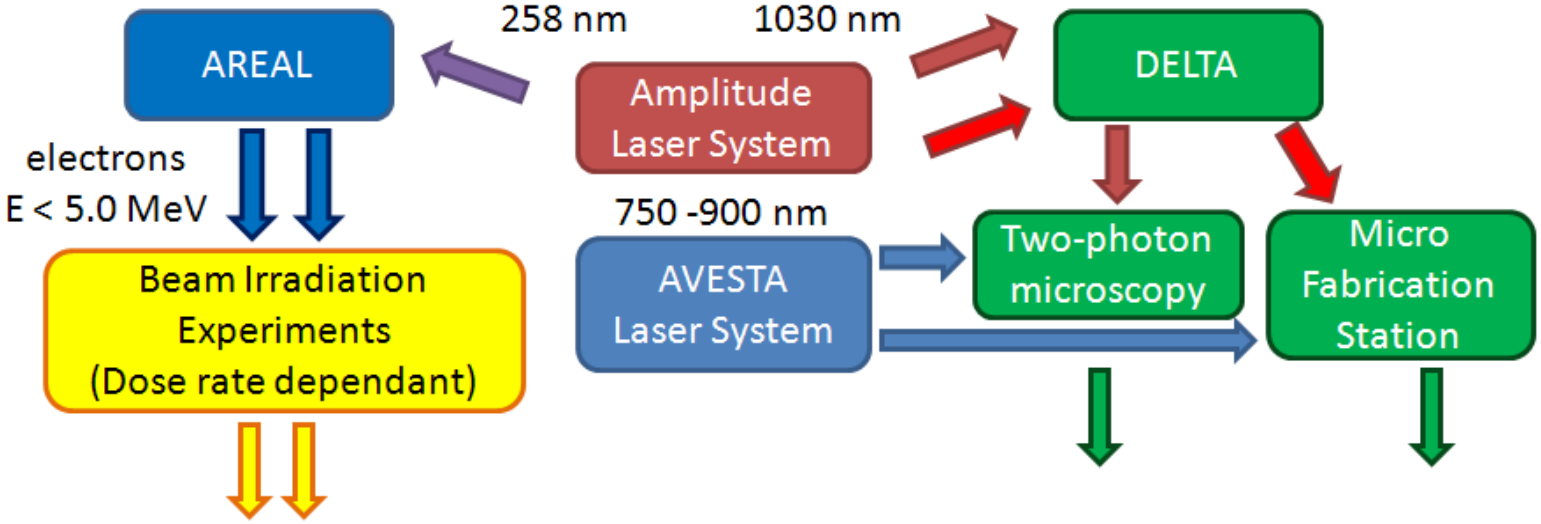

RF Measurements, (R&S joint educ. center) , Timing and Synchronization LAB.

Radiation Biology LAB

Vacuum Technology, Brazing, Welding LAB

New Advanced Materials LAB

Scientific Engineering Workshop

Magnetic Measurements LAB

Scanning Electron Microscope

Electron Beam
E = 20, 50 MeV

FEL λ = 2.5 -30 um
pulse energy 60-100 μJ

0.35 THz Radiation & acceleration (BETA)

The link to Users

ESLS -2021

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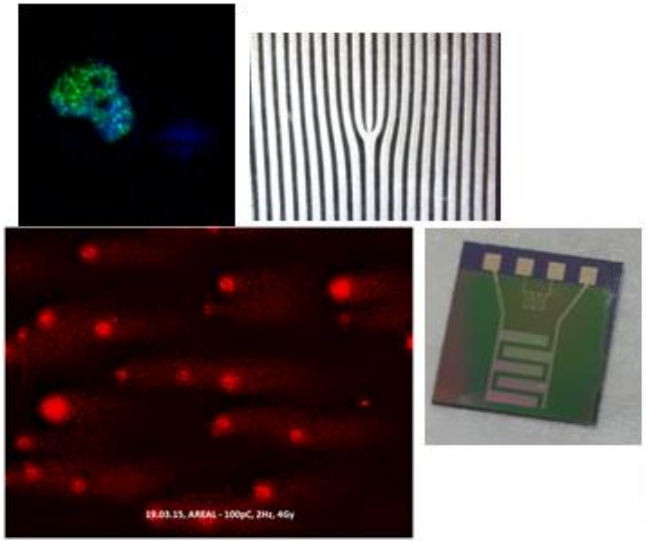
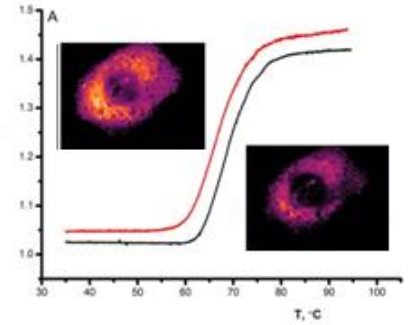
Experiments 2015-2019:

1. YerPhI (Semiconductors)
2. YSU (Genetics)
3. NAS RA (Molecular physics)
4. NPUA (Microelectronics)
5. CANDLE (EM fields)
6. NAS RF (Radiation Biophysics)

Experiments. Starting 2020:

1. YerPhI (Semiconductors)
2. YSU (Genetics)
3. NAS RA (Molecular physics)
4. State Agrarian Univ. (Food Processing)
5. CANDLE (Single Mode Resonator)
6. NAS RF (Radiation Biophysics)





Operating Parameters:

Charge	30 - 50 pC
Repetition rate	2- 25 Hz
Transv. size (x/y)	20 / 8 mm
Energy	2.8 – 4.7 MeV
Av. exper. duration	1 – 8 hours

The link to Users

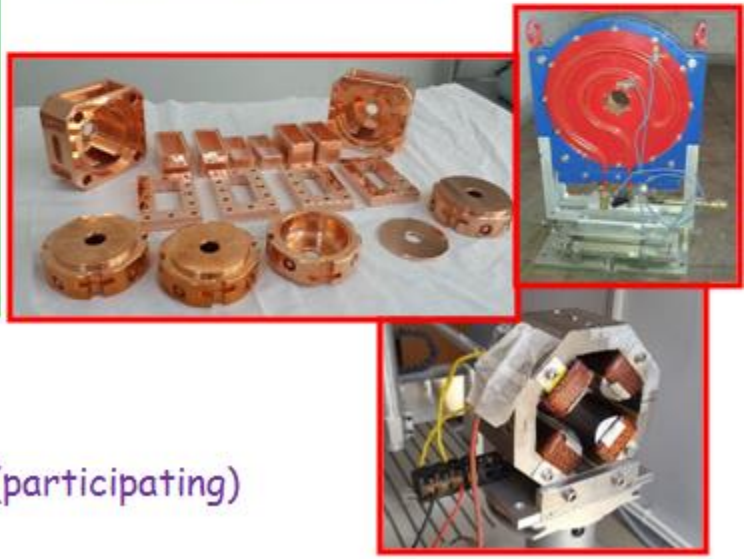
ESLS -2021

ESRF

AREAL – Linear Accelerator (in operation)

Experimental Disciplines and Activity

- Solid State Physics
- Radiation Biology
- Advanced Materials
- Food Processing
- Scanning Electron Microscopy
- Optical (laser-generated) THz sources



- THz radiation sources (linac based)
- Advanced accelerator concepts (on-chip accelerators)
- Reverse Compton Scattering and other radiation sources (participating)
- Design and Fabrication of accelerator equipment

International Collaborations

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CANDLE

DESY

PAUL SCHERRER INSTITUT

PSI

FELIX

Free Electron Lasers for Infrared eXperiments

INFN

Istituto Nazionale di Fisica Nucleare

TU WIEN

TECHNISCHE UNIVERSITÄT WIEN

Vienna | Austria

Université Paris-Saclay

UNIVERSITÀ DEGLI STUDI DI BRESCIA

POLITECNICO MILANO 1863

DIPARTIMENTO DI FISICA

NATO – CALL 2021

(Miniature accelerator Security & Medicine)

UHH Universität Hamburg

DER FORSCHUNG | DER LEHRE | DER BILDUNG

Armenian German Student Course

Inverse Compton Scattering Light Sources

European XFEL

PITZ

ИХФ им. Семенова, РАН

Radiation Biophysics. Experimental Program

Summary

ESLS -2021

CANDLE Synchrotron Light Source

- The design is continuously under development to satisfy to the latest demands and state-of-art technologies available.
  - Low-alpha mode (Short SR pulses, Coherent THz)
  - Low emittance mode (Two options are available, further optimization in progress)
  - Impedances and Wakes are calculated for vacuum chamber.

  Redesign (magnets gap minimization, magnets design change, chamber adv. materials, etc.). A smaller vacuum chamber and NEG coating is under consideration.

First Phase – AREAL linear accelerator

- Low energy, variable length, ultrashort pulses, under operation
- Experiments in several disciplines
- Consideration of User Community Establishment
- International collaborations on CANDLE and AREAL machines + Experiments

Future Accelerators and Light Sources

- Participating in developments and ongoing researches of miniature (on-chip) accelerators and alternative radiation sources

CANDLE

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ESRF

Thank you and Welcome to Armenia