

*In Memory of Vasili Tsakanov*



# Ongoing Activities at CANDLE, projects, plans

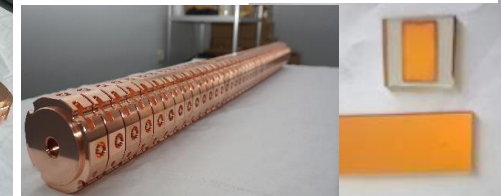
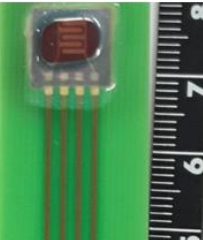
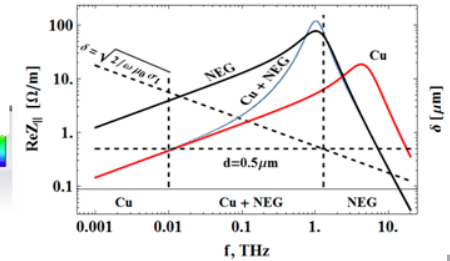
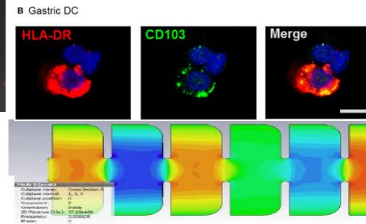
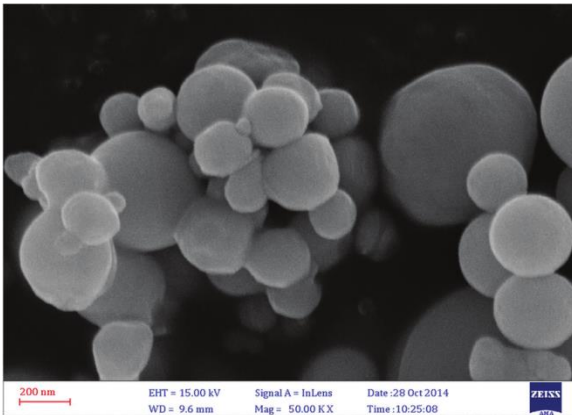
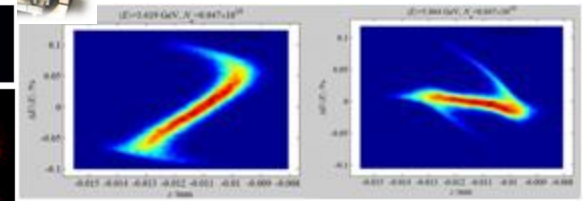
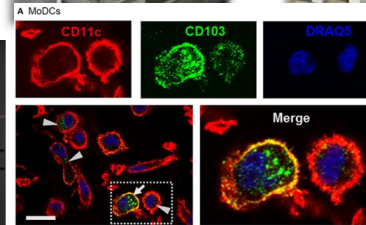
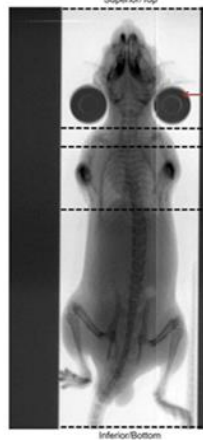
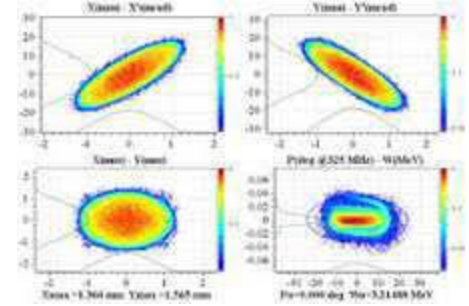
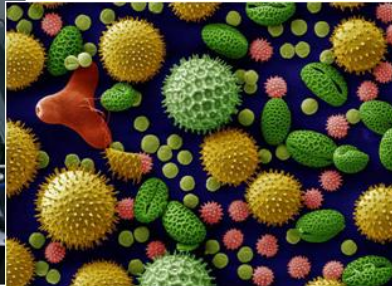
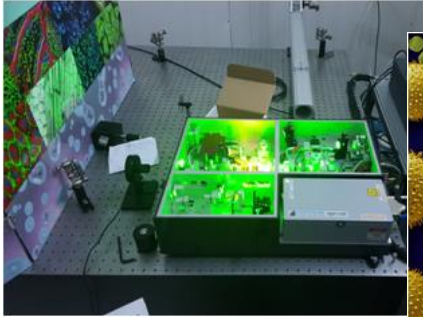
*B. Grigoryan for UBA-22*

# Welcome to CANDLE





# Welcome to CANDLE



# CANDLE Activity

CANDLE Light Source  
3 GeV Synchrotron Project

## Design & Performance

- Overall performance design upgrade
- Beam dynamics – linear, non-linear
- Impedance and Wakes
- Magnets, PS, Control System, etc.
- Other components
- Establishment of User Community

AREAL Accelerator

## Upgrade Program

### Upgrade Program

- **AREAL 50** layout design and beam dynamics
- ALPHA – (FEL radiation) properties, beamline design, use, performance
- BETA – accelerator concepts experiments, beamline design
- Various accelerator components design, prototyping and fabrication
- Development of control and diagnostic equipments
- RF components, development, measurements

### Experimental Programs

- Single mode resonator
- Radiation sources
- New materials for photoemission, radiation (THz) sources, etc.
- Oncology, genetics
- Radiation resistance of viruses and microorganisms
- Ischemic diseases
- Radiation biology – blood protection methods
- Space test stand – experiments on silicon chips in space conditions

# CANDLE Activity

Other  
Experiments,  
Activity ....

Research &  
Training, etc.

## **! Experimental Researches**

- Advanced Materials (Scanning Electron Microscopy, spectrometry)
- Micro-fabrication – development of optics and optical devices
- Vacuum oven – film coating, brazing, welding, technology development

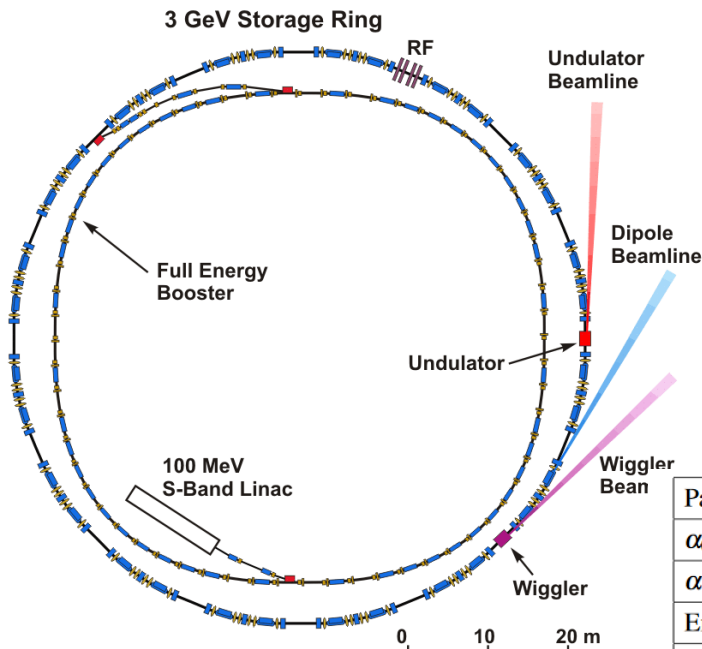
## **! Educational and Research Activity**

- Practical courses YSU
- Practical courses NPUA
- German – Armenian Practical course on accelerator physics
- Internship programs
- Grant projects – researches, infrastructure, etc.
- Collaboration tasks – DESY, PSI, JINR, etc.

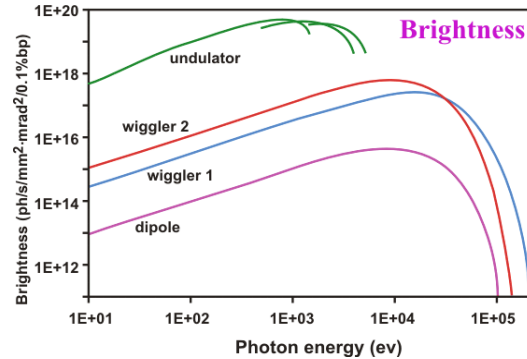
## **! Others**

- Accelerator based machine learning systems (**Artificial Intelligence**)
- **AI** for Biological researches
- Miniature accelerators

# CANDLE Synchrotron



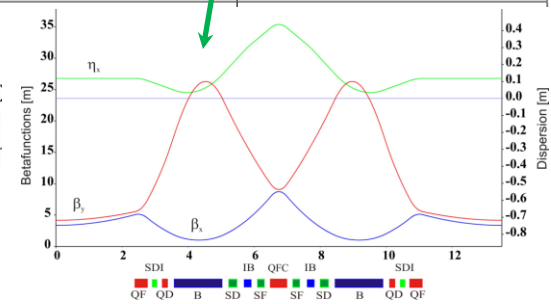
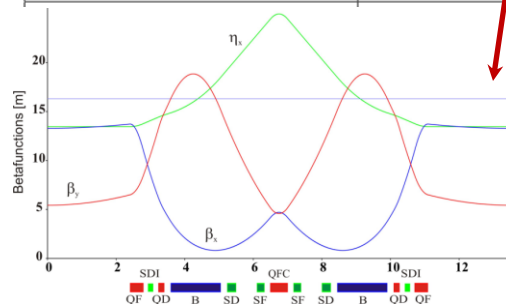
Energy E (GeV)	3
Circumference (m)	216
Current I (mA)	350
RF frequency (MHz)	499.654
Harmonic number	360
Number of lattice periods	16
Straight section length (m)	4.8
Lattice type	DBA
Bending radius $\rho$ (m)	7.385



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

**Low alpha:  
Short pulse SR +  
Coh. THz radiation**

Parameter	Original lattice	High emittance lattice	Low emittance lattice
$\alpha_0$	$2 \cdot 10^{-3}$	$2 \cdot 10^{-5}$	$10^{-4}$ ( $2 \cdot 10^{-5}$ is infeasible)
$\alpha_1$ (with/without sext. opt)	$3 \cdot 10^{-3}$	$10^{-4}/7.3 \cdot 10^{-3}$	$4 \cdot 10^{-3}/6.3 \cdot 10^{-3}$
Emittance (nm rad)	8.4	59	27
rms energy spread (%)	0.104	0.095	0.116
Momentum acceptance (%)	2.4	10	1.25



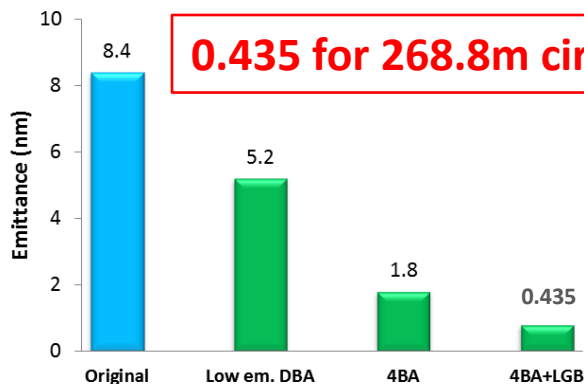
Reported at ESLS -2021, ESRF Grenoble, France



# CANDLE Synchrotron

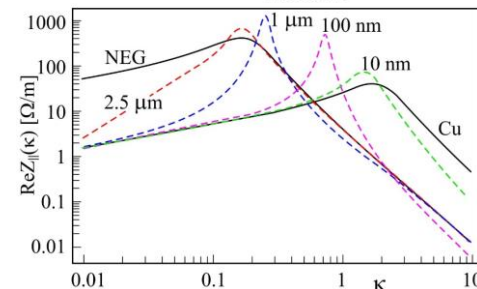
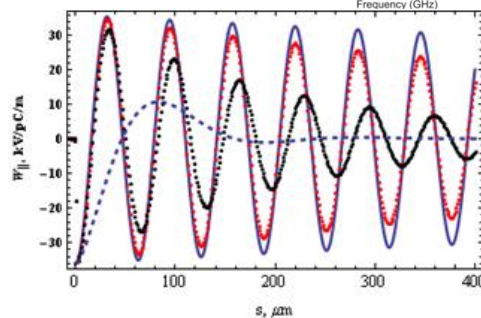
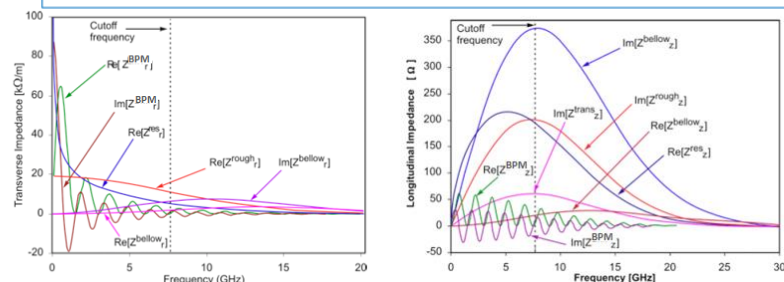
## Optimizations for low emittance

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
<b>Emittance (nm rad)</b>	<b>8.4</b>	<b>5.2</b>	<b>1.1</b>	<b>0.435</b>
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



## Impedances and Wakes

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



**Cu - NEG**

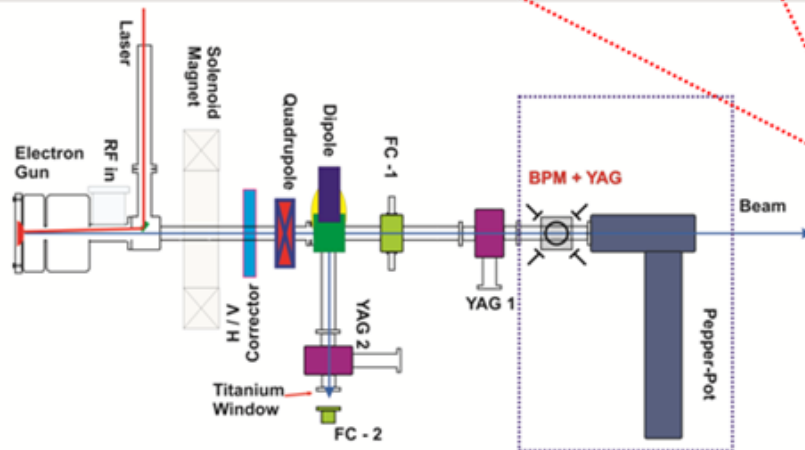
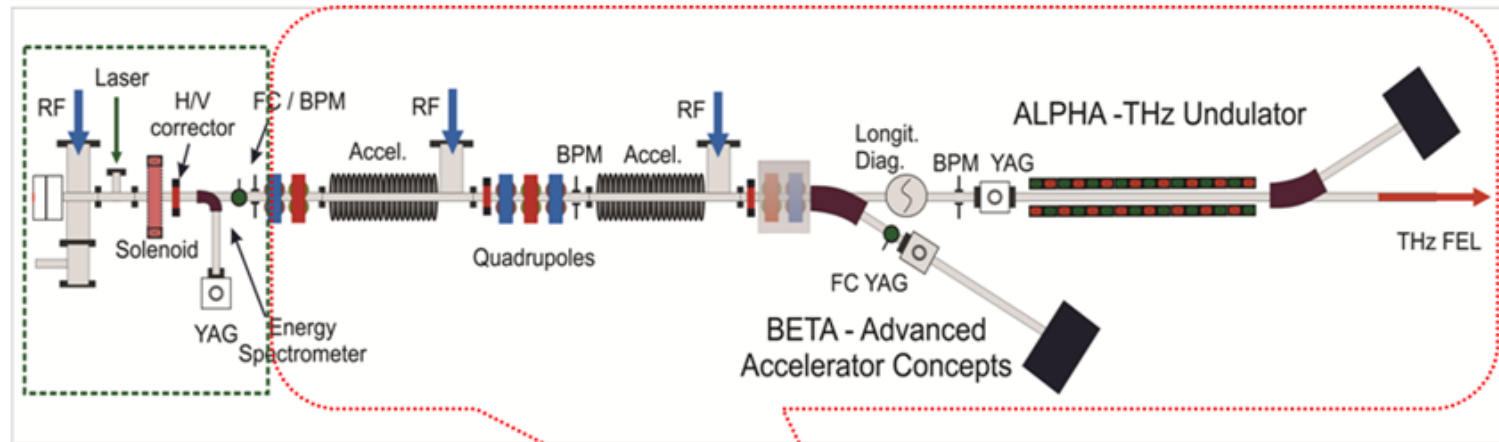
Long. resistive wakes for different copper pipe radii.

Longitudinal Impedances for several NEG thicknesses.

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

Reported at ESLS -2021, ESRF Grenoble, France

# AREAL



## AREAL-50 Upgrade Program

- 20,50 MeV electrons
- FEL Radiation
  - Wavelength 2- 6.7  $\mu\text{m}$
  - Frequency 45 -125 THz
  - Pulse energy 60-100  $\mu\text{J}$

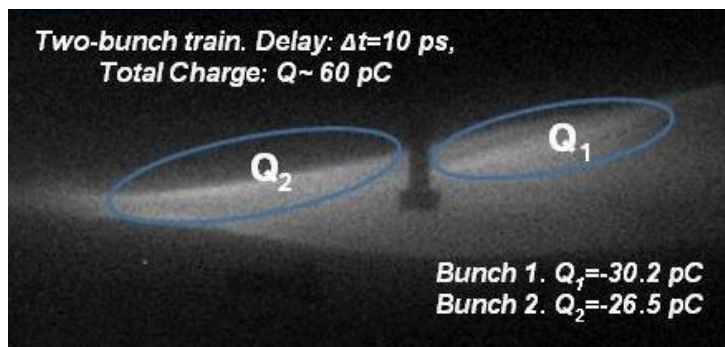
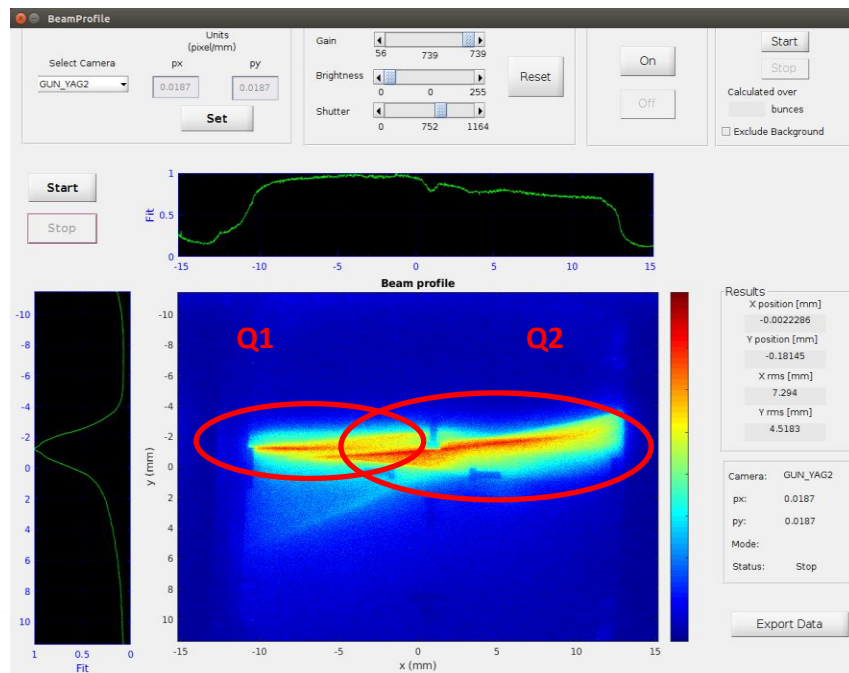
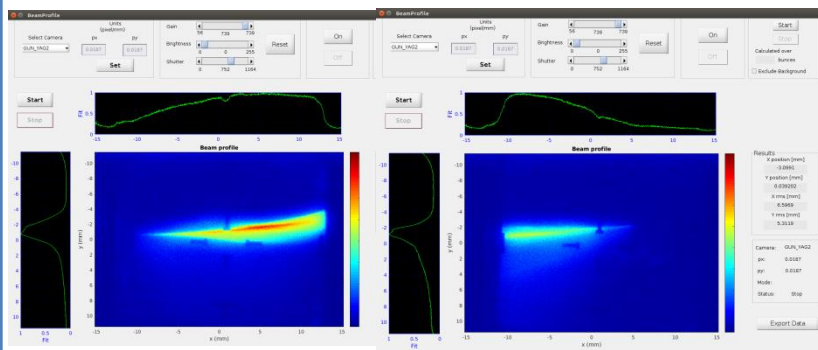
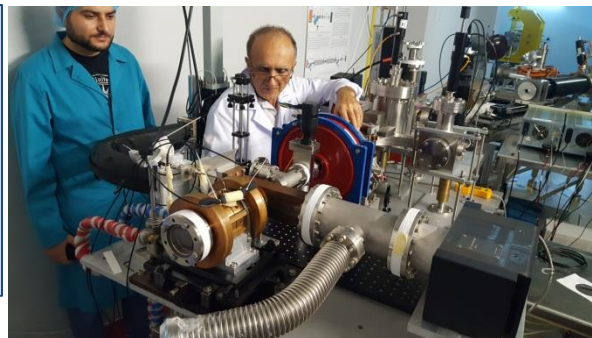


# AREAL Upgrade 2021-22

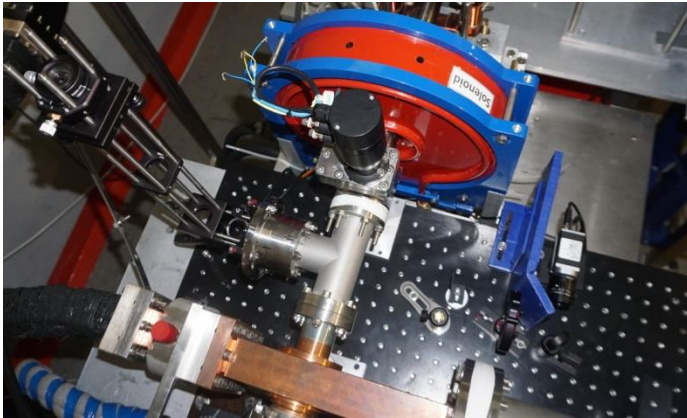


## Laser Pulse Splitting

- Several experiments for reproducibility
- Adjustable delay up to 30 ps
- Split pulses identification (1, 2 and 1+2)

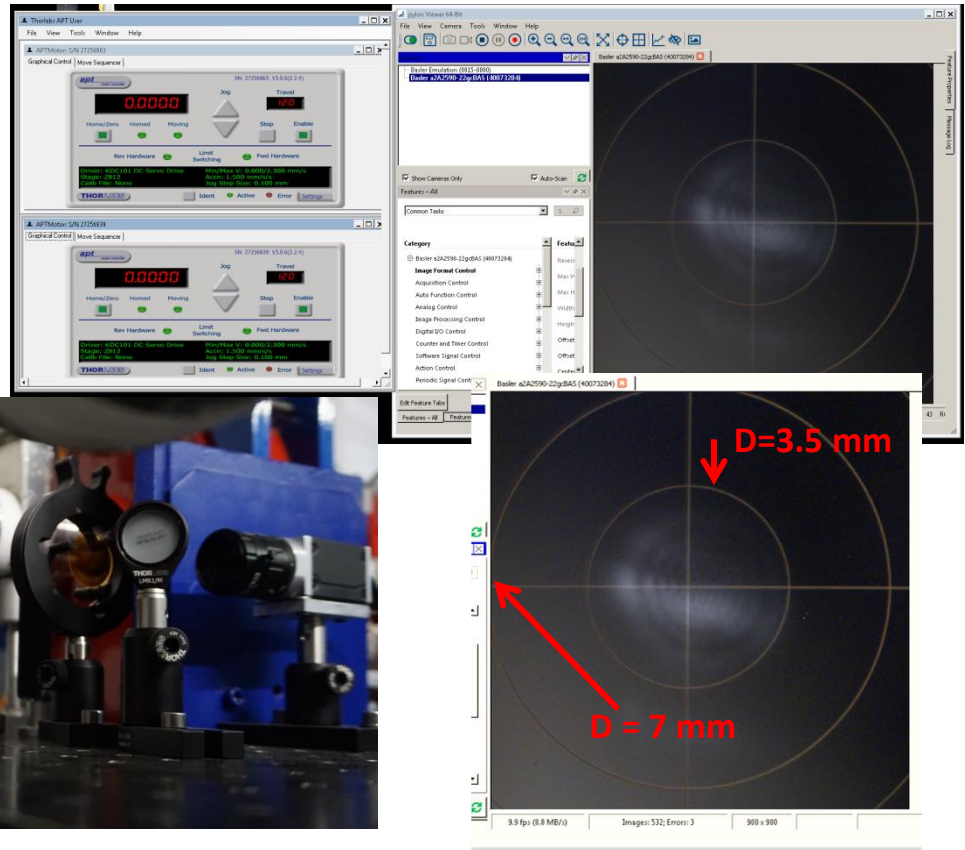


# AREAL Upgrade 2021-22



## Laser Spot Replica System

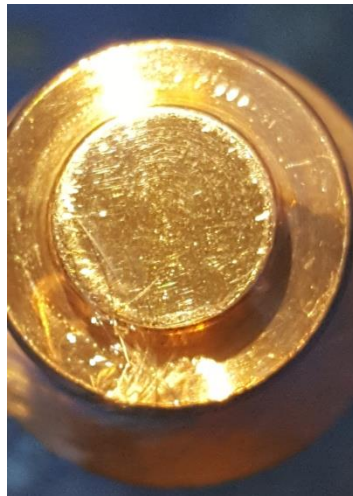
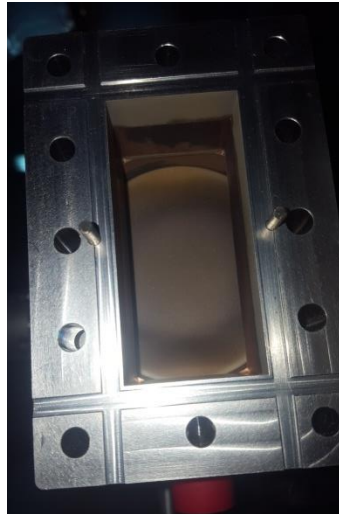
- Motorized movers
- Extra Range (more than on cathode)





# AREAL Upgrade 2021-22

Cathode,  
Spring,  
RF Waveguides

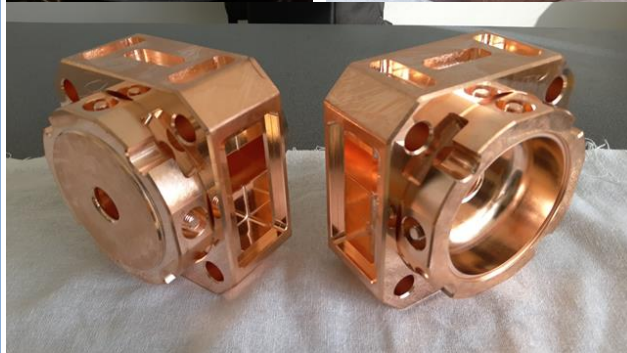
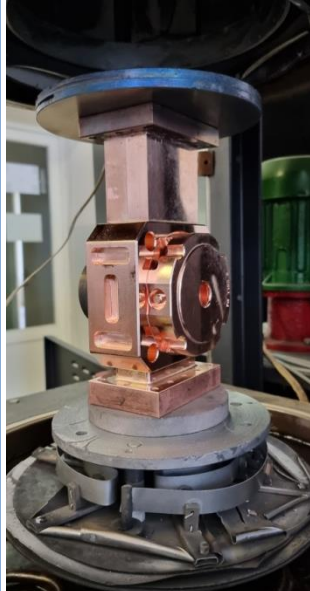


RF Cooling Upgrade

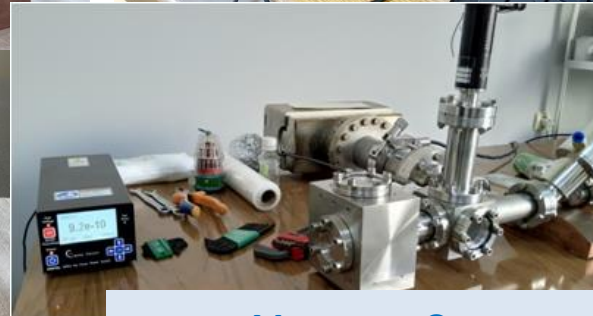
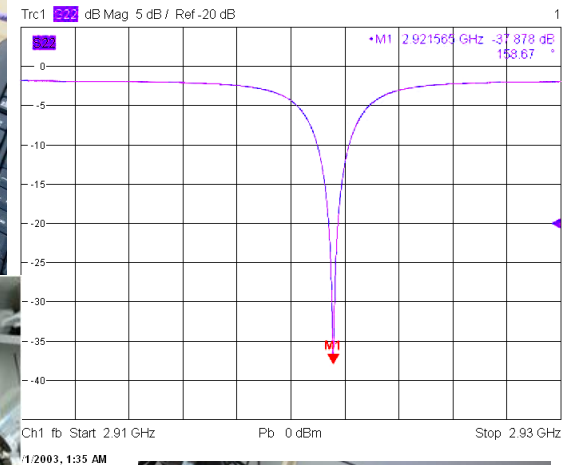
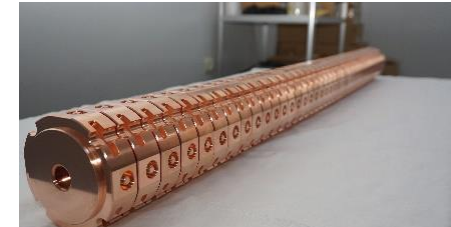
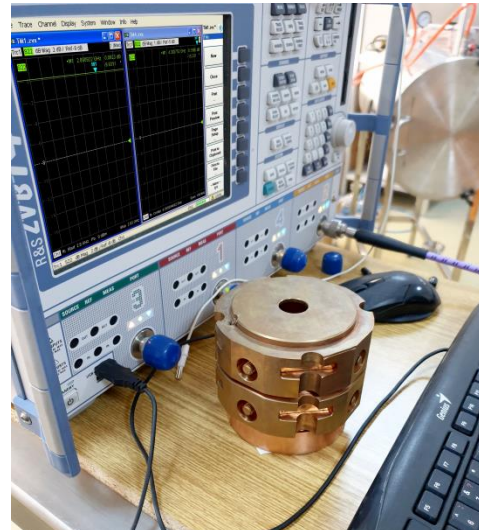


# AREAL Upgrade 2021-22

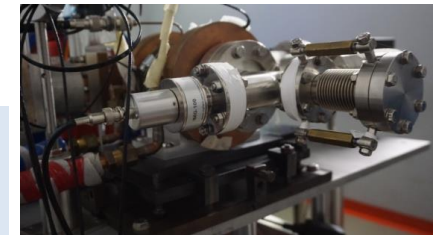
## ACC Couplers Vacuum Welding



## ACC Cells one-by-one geometry Measurements



## Vacuum System maintenance/replacements

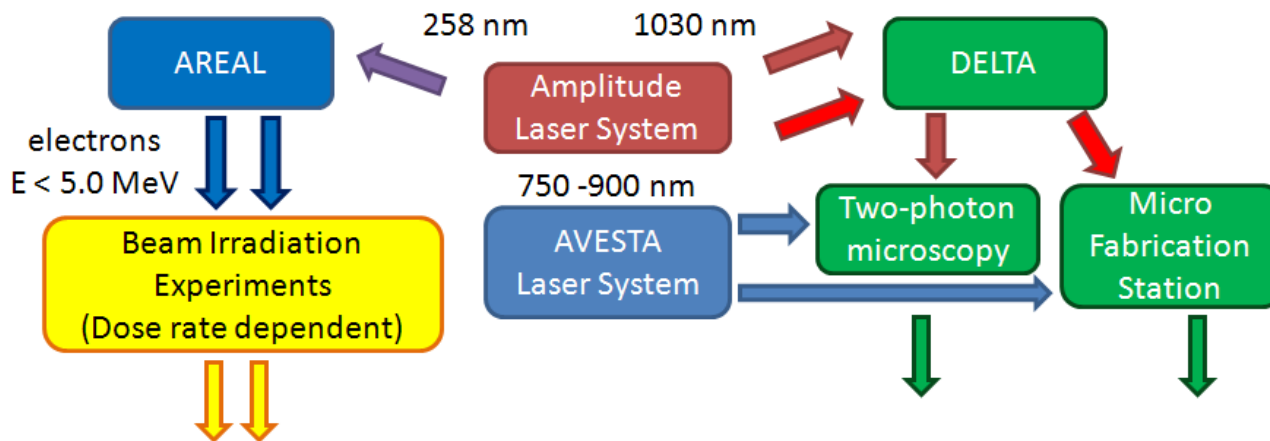




# Experimental Capacity: Labs & Facilities



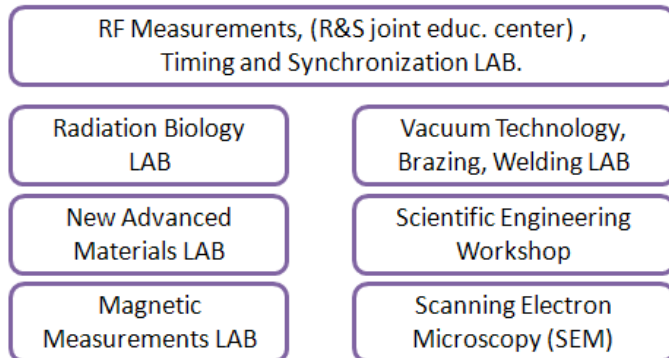
## *The link to Users*



Expected end of the year



X-Ray Cabinet



### Laser based THz Spectrometry (will complete soon)

Electron Beam  
 $E = 20, 50$  MeV

FEL  $\lambda = 2.5 - 30$   $\mu\text{m}$   
pulse energy 60-100 mJ

0.35 THz Radiation &  
accelerator technology (BETA)



Online electron beam dosimeter

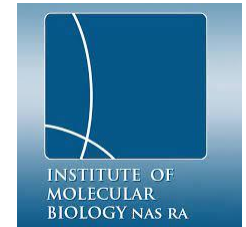
# Collaborations



PAUL SCHERRER INSTITUT



Istituto Nazionale di Fisica Nucleare



**HZB** Helmholtz Zentrum Berlin



Istituto Nazionale di Fisica Nucleare



TECHNISCHE  
UNIVERSITÄT  
WIEN  
Vienna | Austria



UNIVERSITÀ  
DEGLI STUDI  
DI BRESCIA



POLITECNICO  
MILANO 1863  
DIPARTIMENTO DI FISICA



**Grant Programs 2021 and 2022**



Universität Hamburg  
DER FORSCHUNG | DER LEHRE | DER BILDUNG



**Armenian German Student Course**



ИХФ им. Семёнова, РАН

**Radiation Biophysics. Experimental Program**

# International Collaborations

**Armenia**  
CANDLE

**China**

Beijing National Laboratory KOF CAS  
IOF, Chinese Academy of Science  
Shanghai Jiao Tong University  
Tsinghua University

**Czech Republic**  
ELI Beams

**France**

CEA/CNRS  
Ecole Polytechnique  
EBSA Paris tech  
IN2P3  
LAL  
LPGP  
LUL  
PHLAM Université de Lille  
Soleil

**Germany**

Deutsches Elektronen-Synchrotron (DESY)  
Ferdinand Braun Institut  
Forschungszentrum Jülich  
Fraunhofer ILT  
Gesellschaft für Schwerionenforschung (GSI)  
Helmholtz Institutes Jena  
Helmholtz-Zentrum Dresden-Rossendorf  
Karlsruhe Institute of Technology  
LMU University Munich  
Max-Planck-Institute for Quantum Optics  
Max-Planck-Institute for Physics  
TU Darmstadt  
University Düsseldorf  
University Erlangen  
University Hamburg  
University Jena



**Hungary**

Wigner Research Center

**Italy**

CNR, Istituto Nazionale di Ottica – Pisa  
INFN Frascati  
INFN Milano  
INFN Roma1  
University of Rome Tor Vergata  
University of Rome La Sapienza  
University of Pisa

**Japan**

Kansai Photon Science Institute  
KEK  
Osaka University  
RIKEN Spring-8

**Netherlands**

Eindhoven University of Technology

**Norway**

University of Oslo

**Portugal**

Instituto Superior Tecnico de Lisboa

**Russia**

JINT of Russian Academy of Sciences  
Budker Institute of Nuclear Physics  
Institute of Applied Physics RAS

**Sweden**

Lund University

**Switzerland**

University of Bern  
Paul Scherrer Institut

**UK**

ASTeC  
Cockcroft Institute  
JAL – Imperial College  
Lancaster University  
Manchester University  
Oxford University  
Queen's University of Belfast  
STFC Rutherford Appleton Laboratory  
STFC Daresbury Laboratory  
University College London  
University of Liverpool  
University of Strathclyde

EUROPEAN NETWORK FOR NOVEL ACCELERATORS

**EuroNNAc<sub>3</sub>**

supported by EU via ARIES



**USA**

Brookhaven National Laboratory  
Fermi National Accelerator Laboratory  
Lawrence Berkeley National Laboratory  
Lawrence Livermore National Laboratory  
SLAC National Accelerator Laboratory  
University of California Los Angeles

**International**

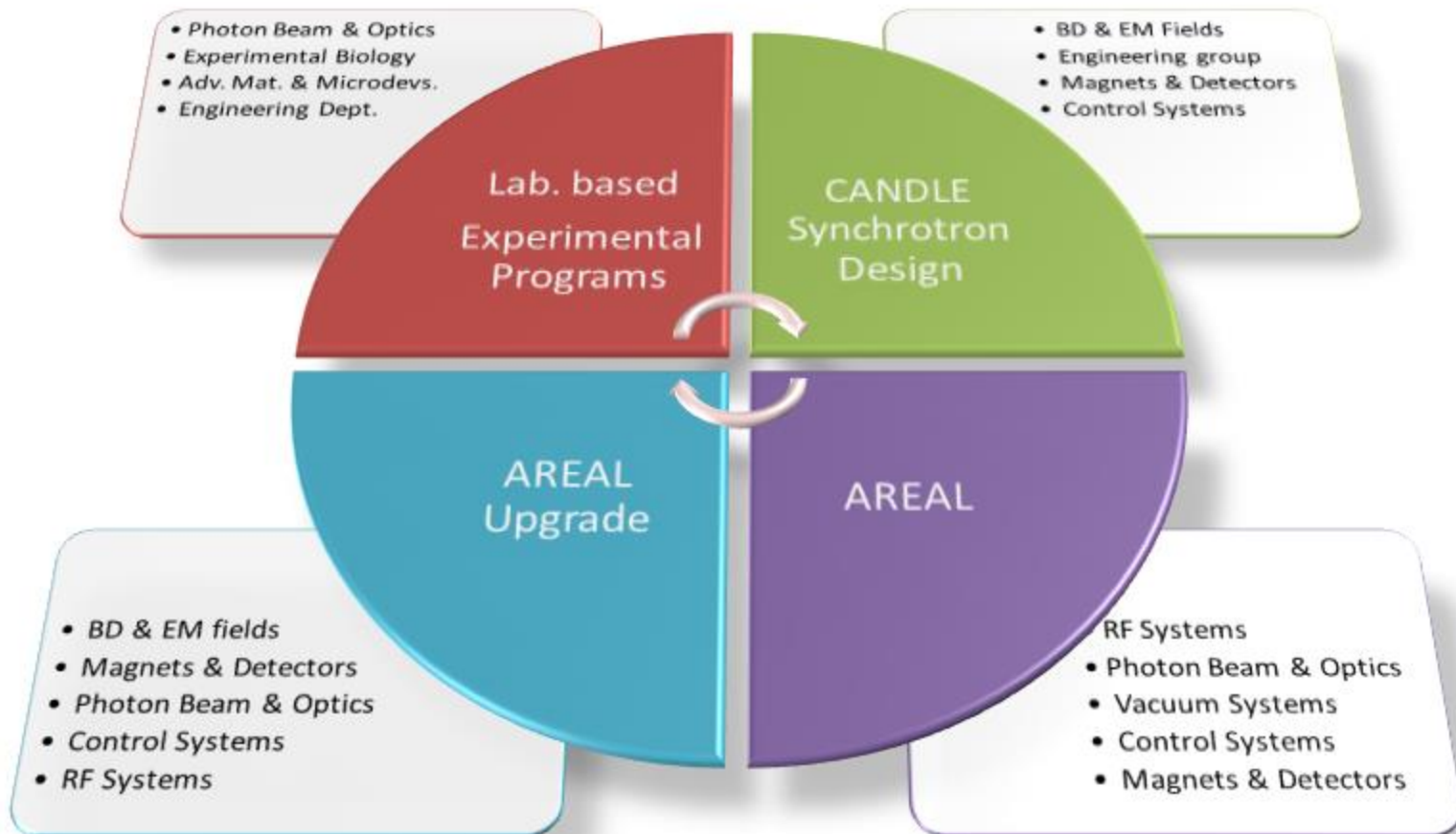
European Organization for Nuclear Research (CERN)  
ELI Beamlines

International Committee for Future Accelerators

International Committee on Ultra High Intensity Lasers



# Task Distribution





# Plans - Accelerator Physics

## Accelerator Physics

Advanced  
Concepts

Radiation  
sources

High  
frequency  
structures

Miniature  
accelerators

Single  
mode  
structures

THz  
Sources

Undulator  
Radiation  
(FEL &  
THz)

Single  
mode  
structures

# Plans - Experiments

## Experimental Studies

Radiation  
Biology

Materials  
Science

New device  
developments

Applications  
of ultra short  
electron  
beams

Time resolved  
experiments

Irradiation  
influence on  
properties

Thin films

Diagnostics  
development

Ultrafast  
timing

New electron  
sources

# Plans (Other)

## Collaboration Activity

- Recover participation
- New collaborations

## Educational Activity

- New PhD Programs
- Master Programs
- Joint Schools
- New test - stands

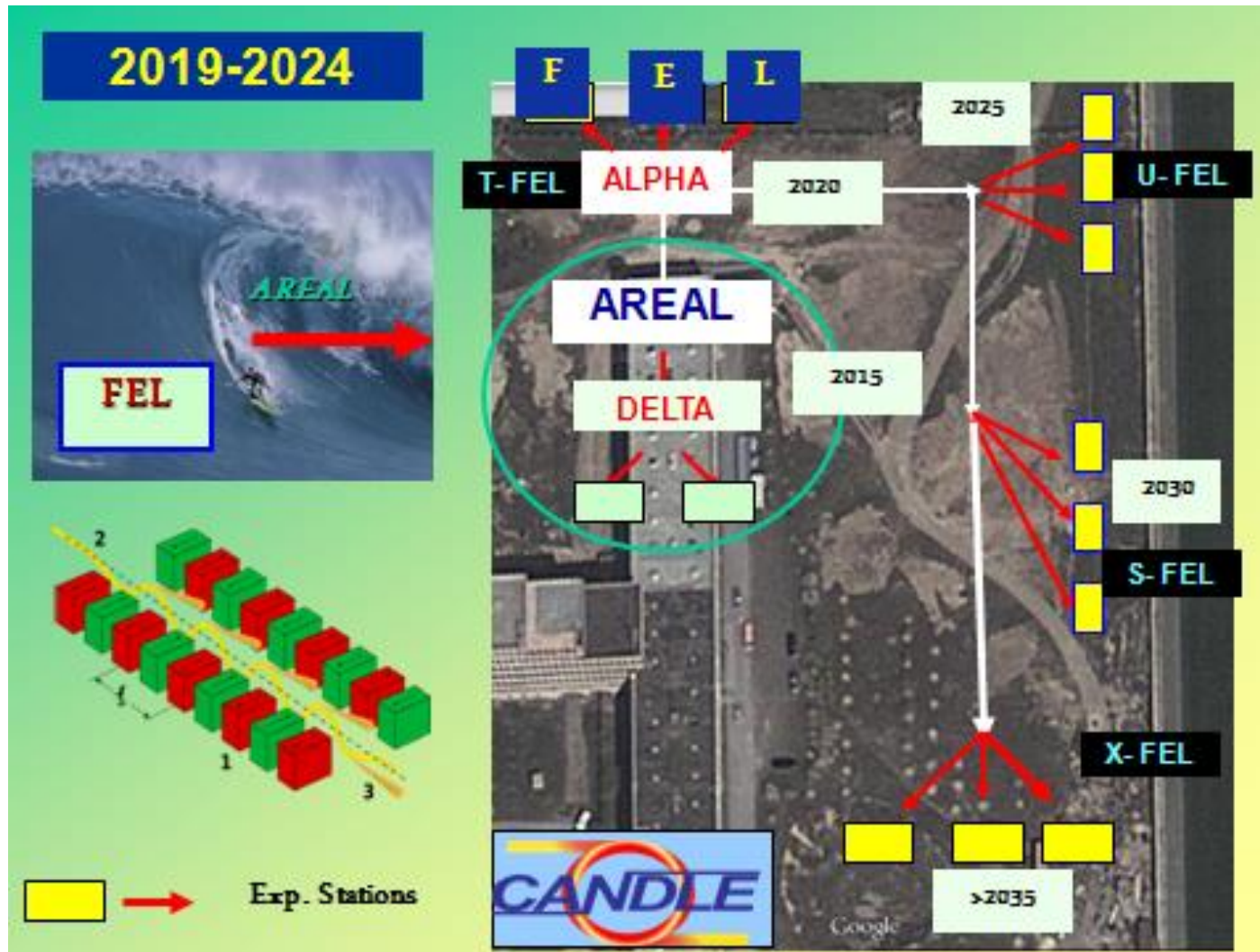
## Research Grant Programs

- Balanced activity
- Joint Grants

## Infrastructure

- Improvement
- New multi-use laboratories

# Plans



Future Plans  
from

V. Tsakanov





**UBA -2022**