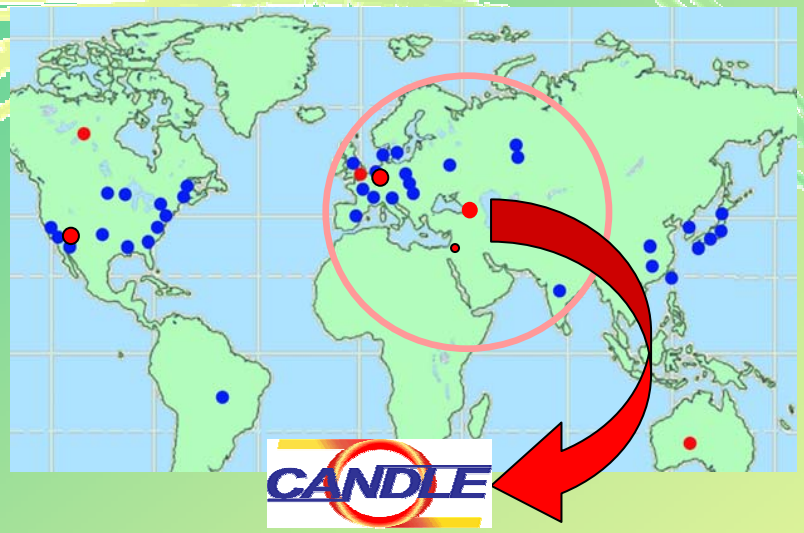
Center for the Advancement of Natural Discoveries using Light Emission



CANDLE- A New Synchrotron Light Source Project in Armenia

Vasili Tsakanov

DESY, 7 Dec 2004

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- ***Introduction***
- ***The Project Overview***
- ***Scientific Program***
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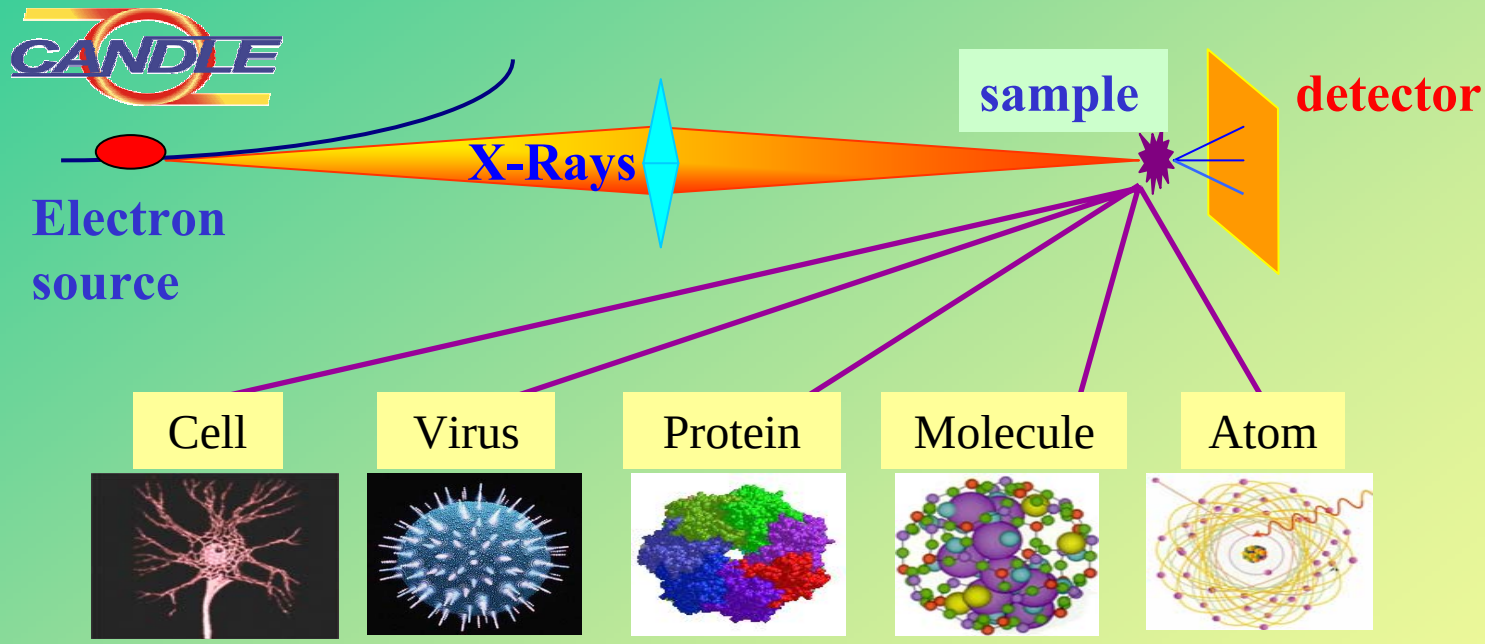
Why Synchrotron Light Source?



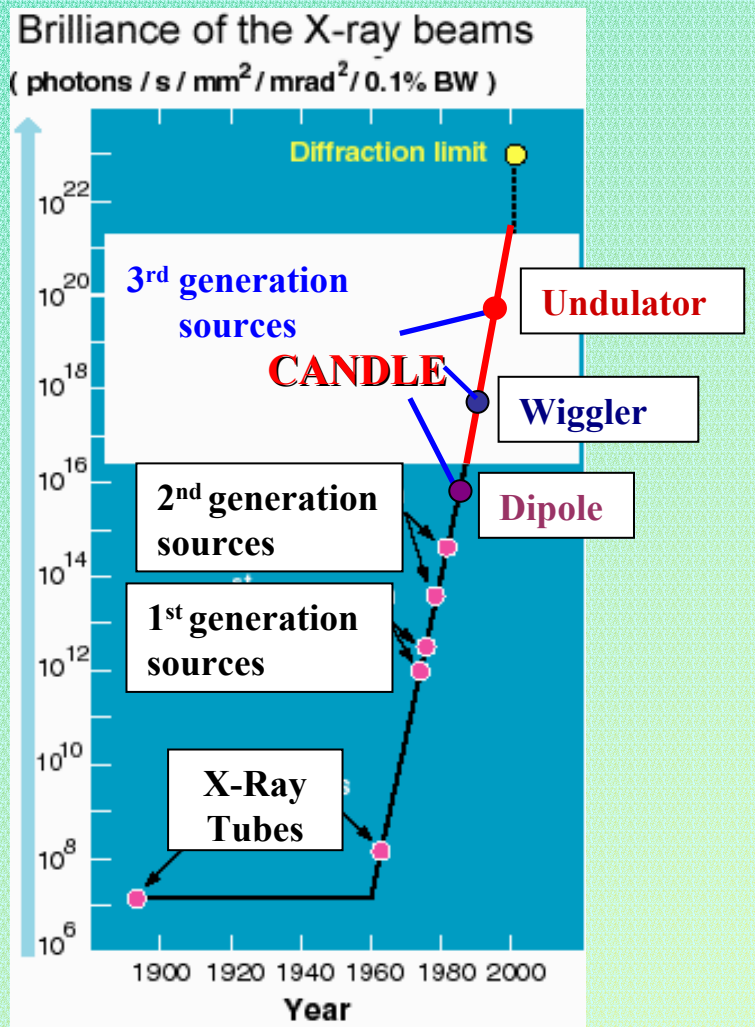
Science

- Biology
- Physics
- Material Science
- Medicine
- Chemistry
- Environments

Industry

- Biotechnology
- Electronics
- New material
- Pharmacy
- Nanotechnology
- Microfabrication

Why Synchrotron Light Source?



- **High Brightness**
- **Continues Spectrum**
- **Tunability**
- **Coherency**

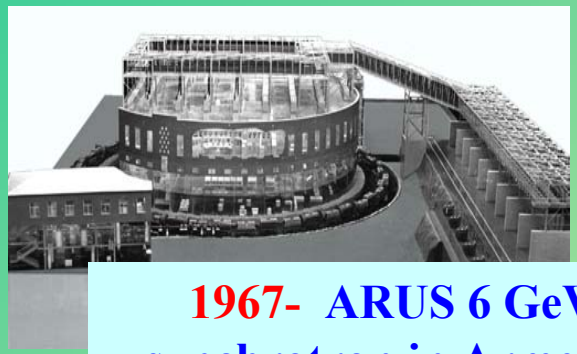
User Demands

3-10 times exceeds

Projects	*Country*	*E* GeV	*L* m	ε Nm
SPEAR3	USA	3.0	240	18
CANDLE	Armenia	3.0	216	8.4
DIAMOND	England	3.0	560	2.0
SOLEIL	France	2.5	354	3.1
Boomerang	Australia	3.0	184	11.5
CLS	Canada	2.9	170	18

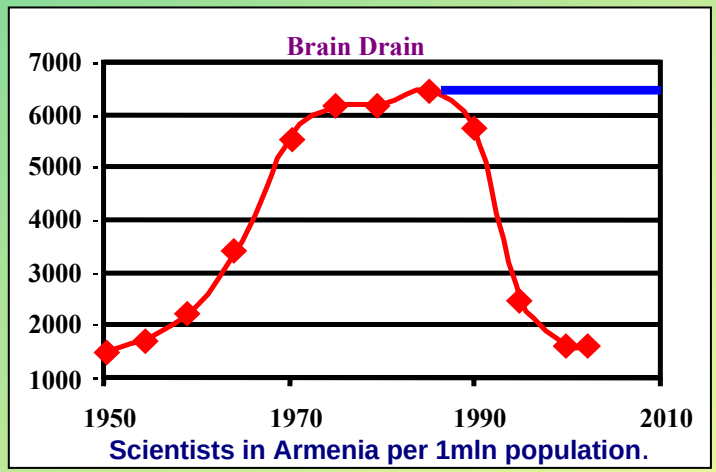
Why in Armenia ?

HEP Database-2000



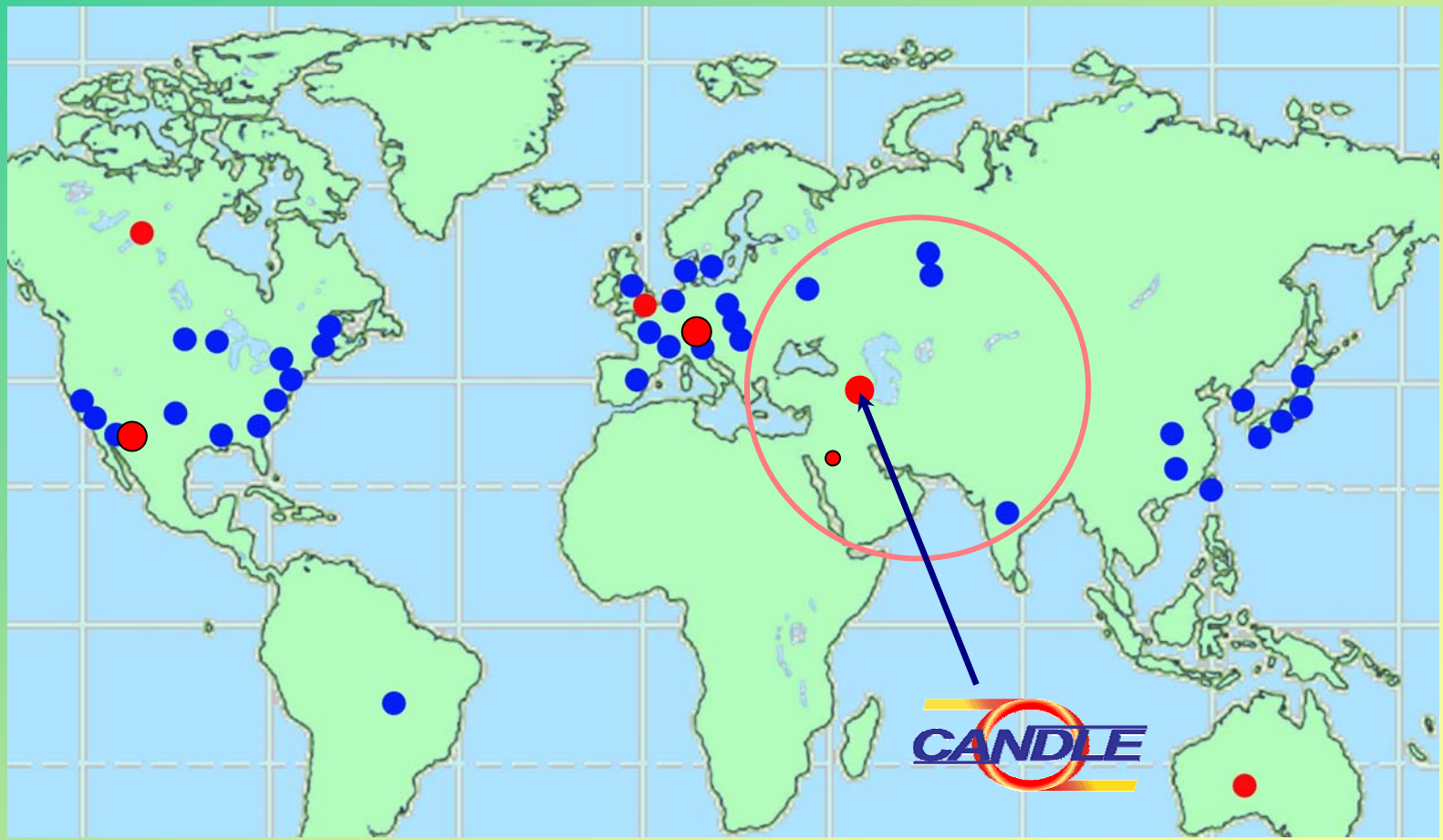
1967- ARUS 6 GeV synchrotron in Armenia

Brain Drain



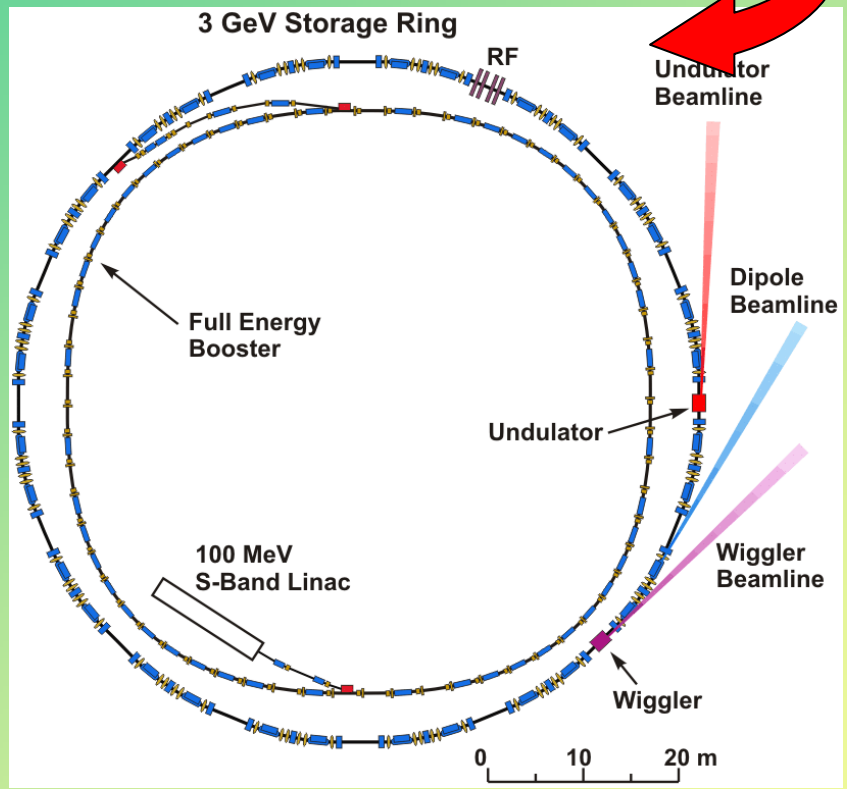
	Total Papers	*Population (mln)*	*Papers/ 1mln*
USA	150 738	270.3	558
Germany	**51 142**	**82.1**	**623**
France	27 937	58.8	475
UK	27 664	59.1	468
Sweden	5 206	8.8	591
Italy	33 307	58	574
Japan	31 390	126	249
Finland	31 18	5.1	611
Switzerland	**33 876**	**7.3**	**4 640**
Israel	**6 236**	**5.4**	**1 154**
Armenia	**2 929**	**3.5**	**813**
Russia	48 577	146.8	331
Georgia	1 626	5.7	285
Estonia	180	1.6	112
Belarus	883	10.4	85
Ukraine	4 241	51.8	82
Kazakhstan	943	17.3	55
Azerbaijan	422	7.8	54
Uzbekistan	887	23	38
Tadzhikstan	99	6.1	16
Turkey	893	63.4	14
Iran	416	64	7

Synchrotron Light Sources

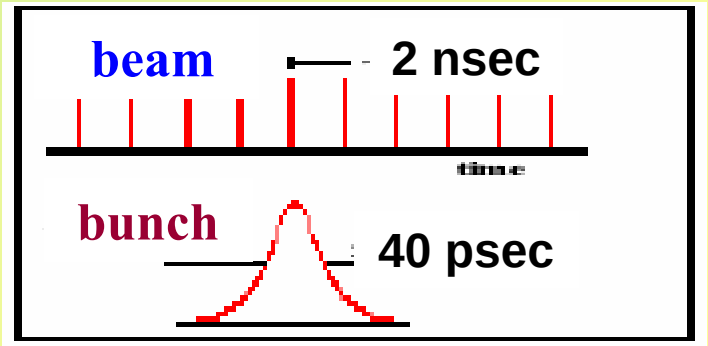


CANDLE will serve scientists of 2000km radius region.

3 GeV CANDLE Light Source

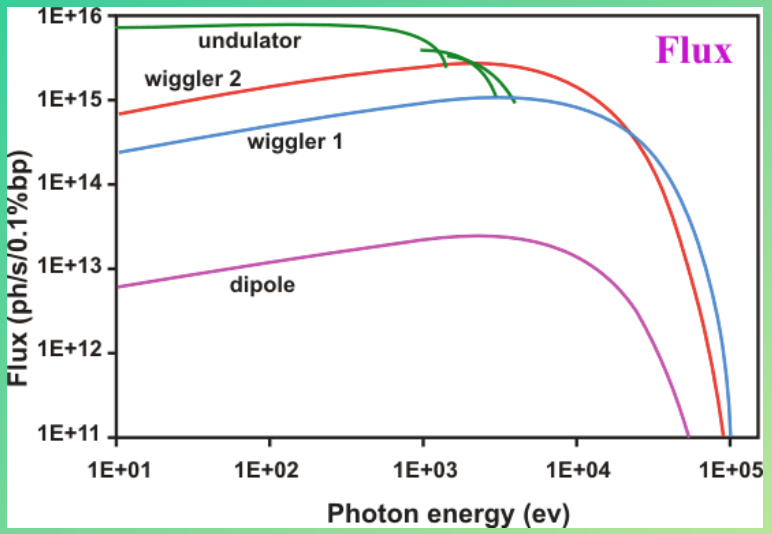


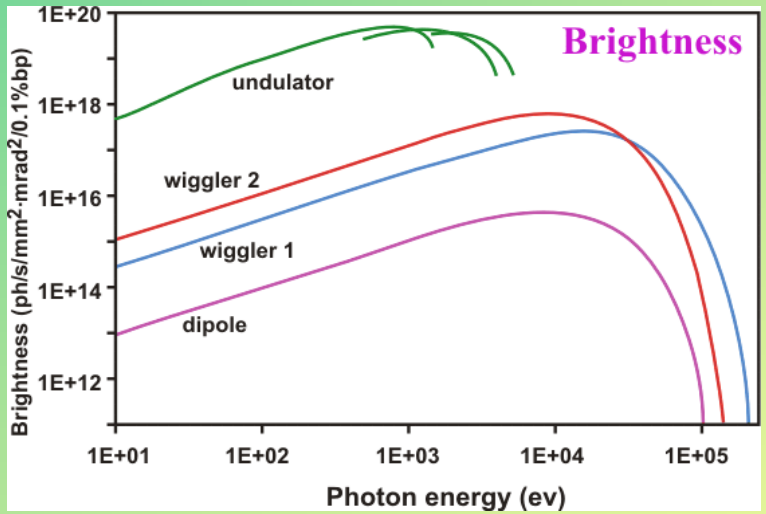
Energy	3 GeV
Current	350 mA
Circumference	216 m
Frequency	499.65 MHz
Harm. Number	360
Periods No	16
Straight section	4.8m
Lattice type	DBA
Emittance	*8.4 nm*
Beam lifetime	*18.4 hours*



Time structure

Radiation Characteristics





Dipole beamline

Dipole field B (T)	1.354
Critical ph. energy (keV)	8.1

Wiggler type I

Magnetic field (T)	1.98
Period length (cm)	17
Critical ph. energy (keV)	11.97

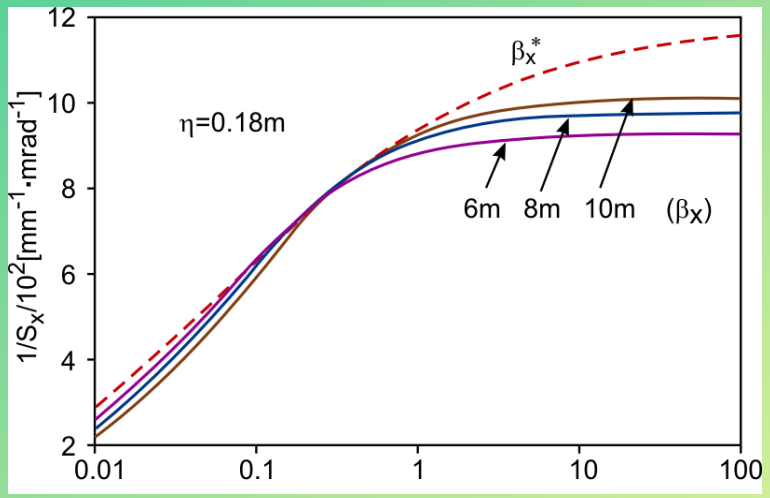
Undulator

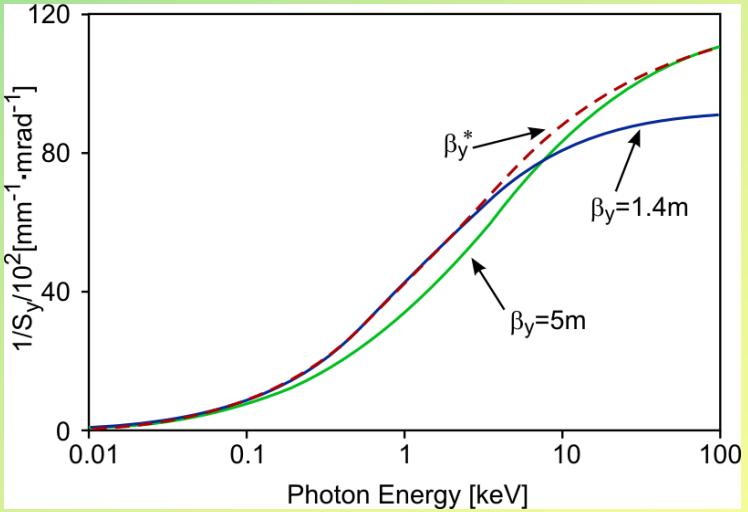
Magnetic field (T)	0.3
Period Length (cm)	5
Photon energy n=1,3,5 (keV)	0.85/ 2.6 /4.3

Storage Ring – Figure of Merit

Brightness

$$B = \frac{N_{ph}}{4\pi^2 S_x S_y}$$





V. Tsakanov et al, Rev. Sci Instr., 2002

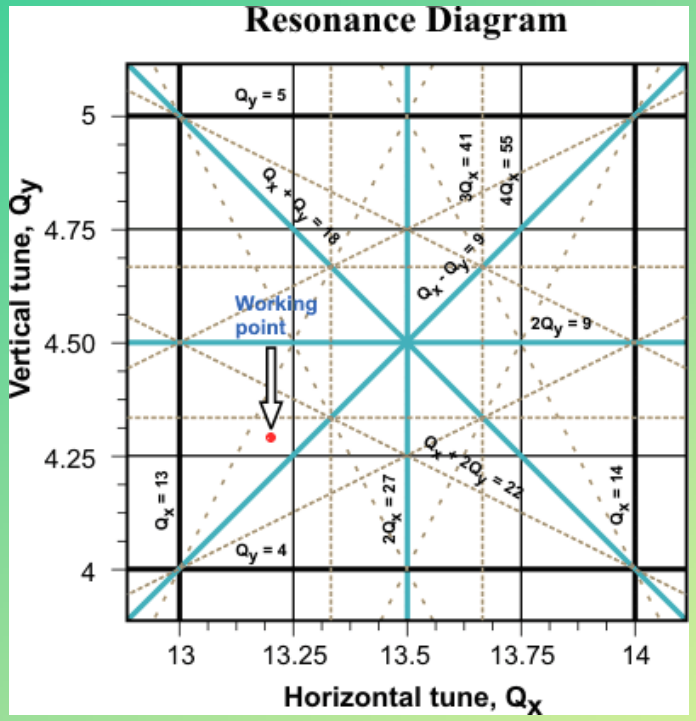
M. Ivanian et al, Nucl. Inst. Meth. (A) 2004

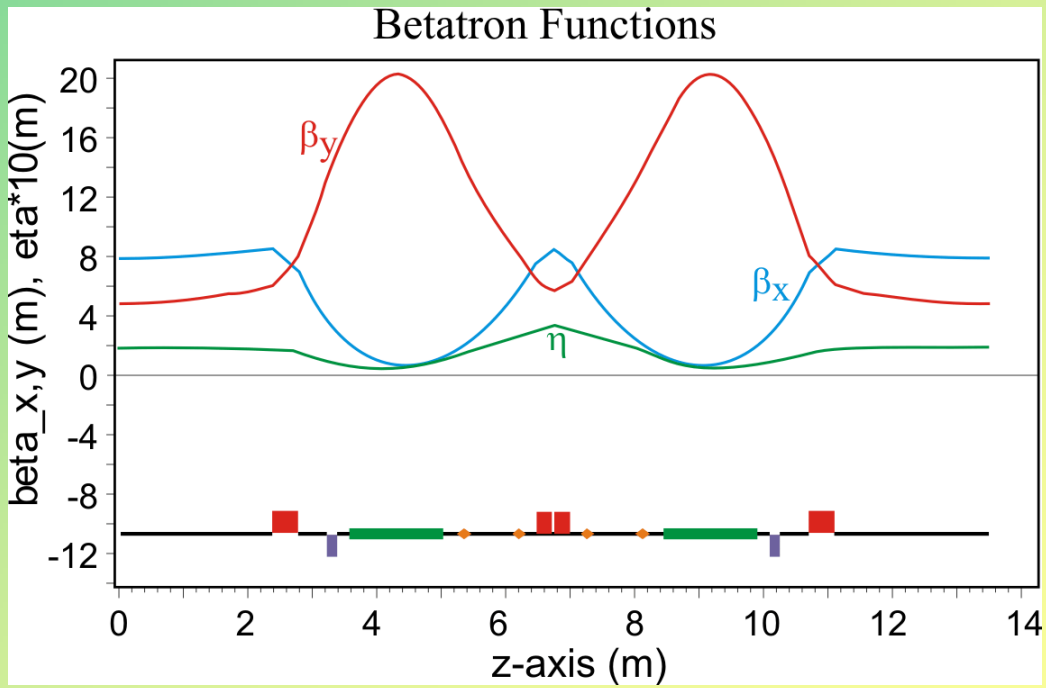
$$\eta = 0.18\ m$$

$$\beta_{x,y} = 7.9m\ /\ 4.8m$$

High Brightness & Stable Beams

Storage Ring- Optics





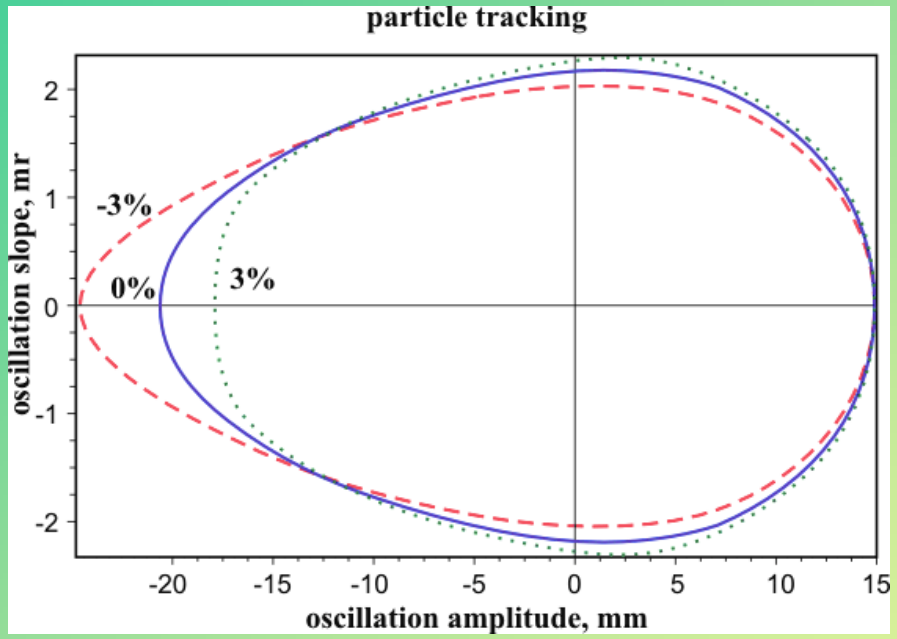
$$Q_x = 13.22 \quad Q_y = 4.26$$

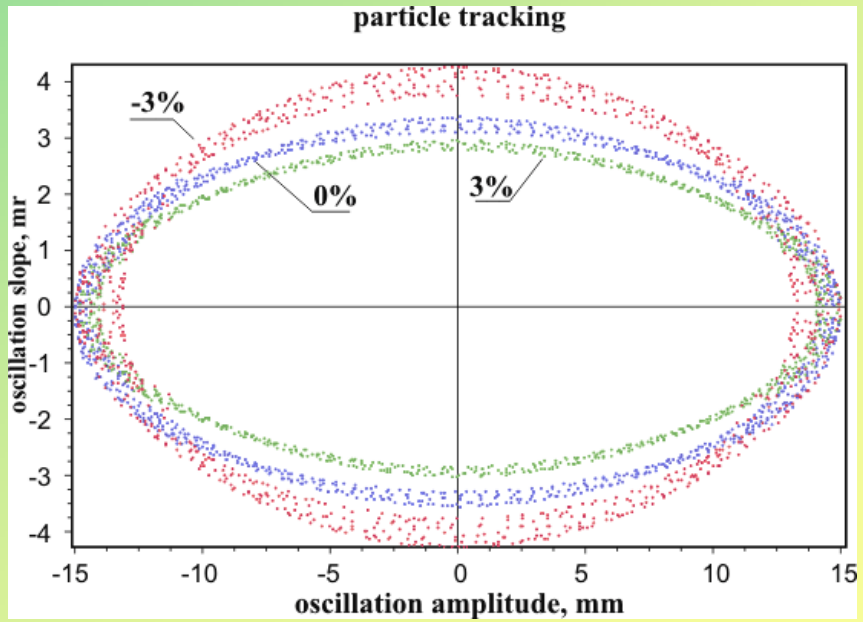
Emittance

$$\varepsilon_x = 8.4\, nm \cdot rad$$

Storage Ring – Dynamics

Dynamical Aperture



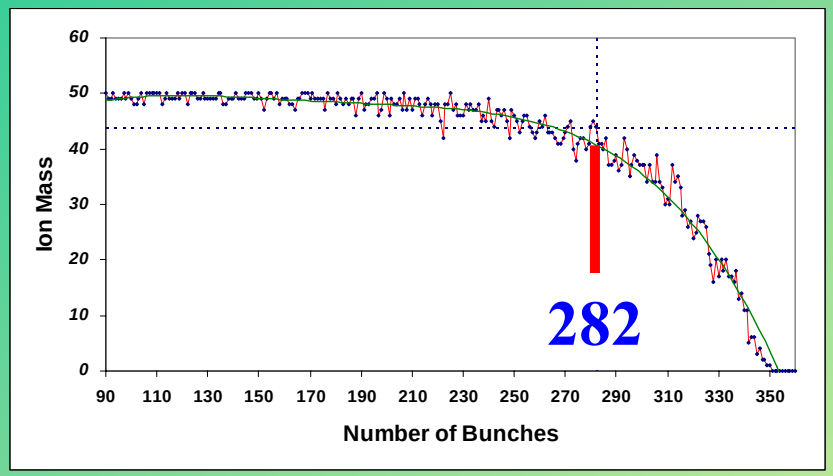


Horizontal

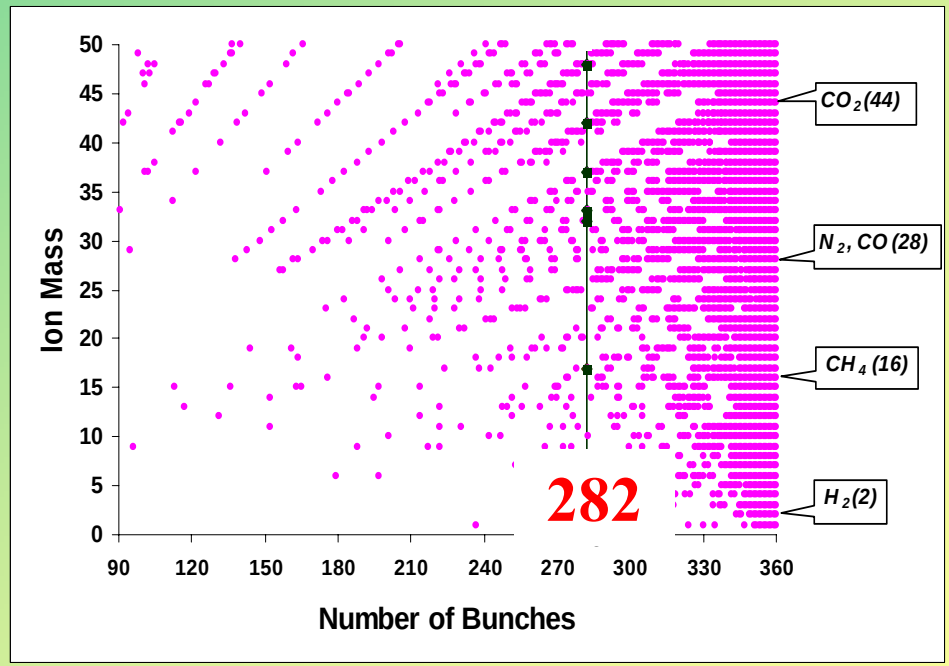
Vertical

Storage Ring – Ion Traping

Non-stable ions

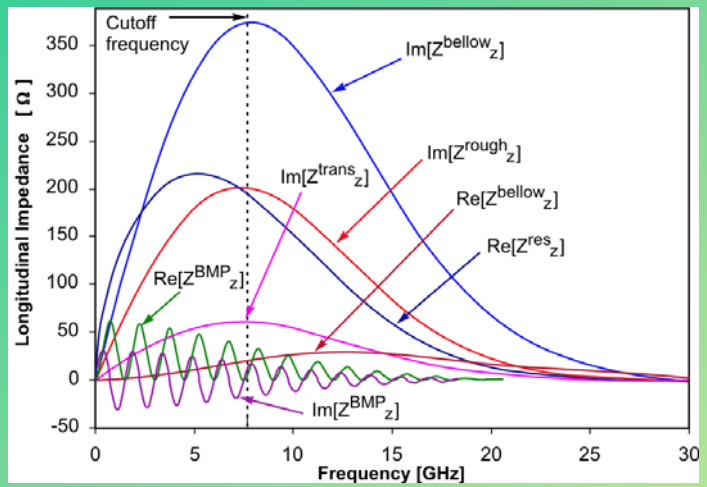


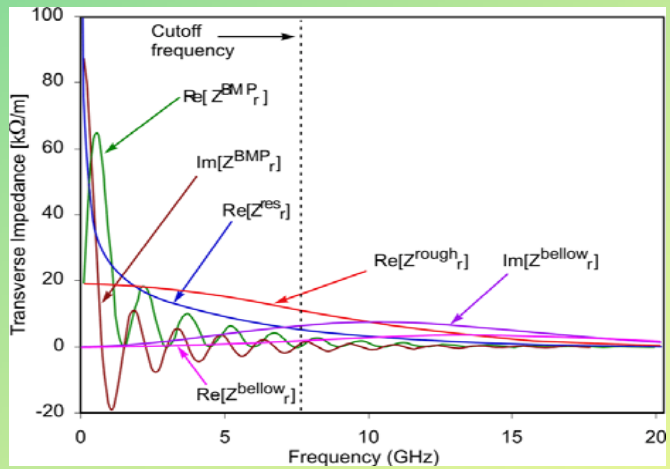
Stable ion mass	Residual gas species
-	2, H_2
-	16, CH_4
17	-
-	28 , N_2 , CO
32	-
33	-
37	-
42	-
-	44, CO_2
48	-



Traped ions

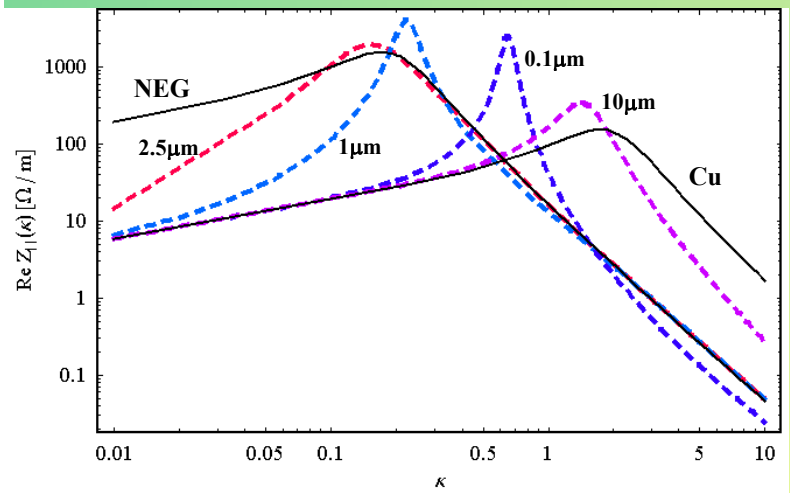
Ring impedance





Longit. Impedance - 0.314 Ω

Trans. Impedance - 12.5 kΩ/m

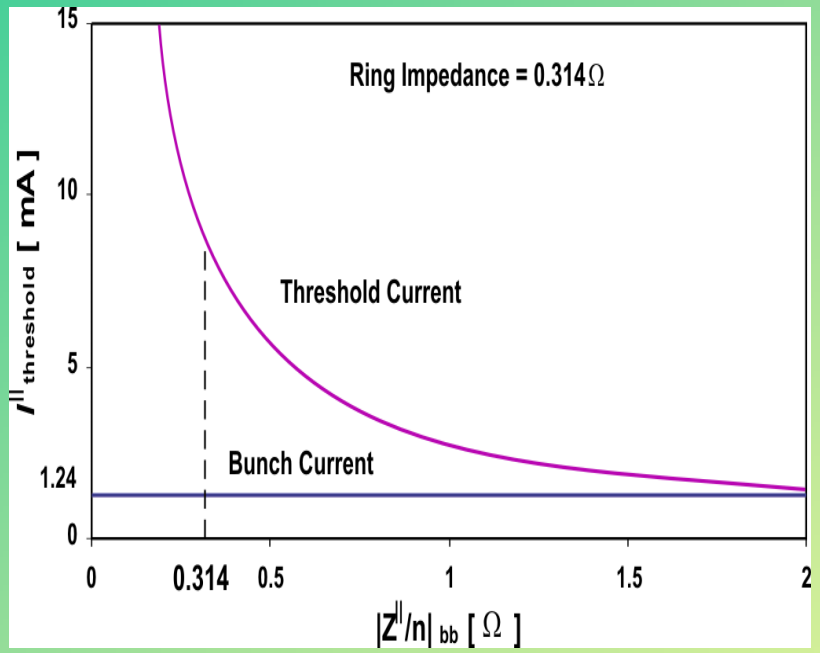


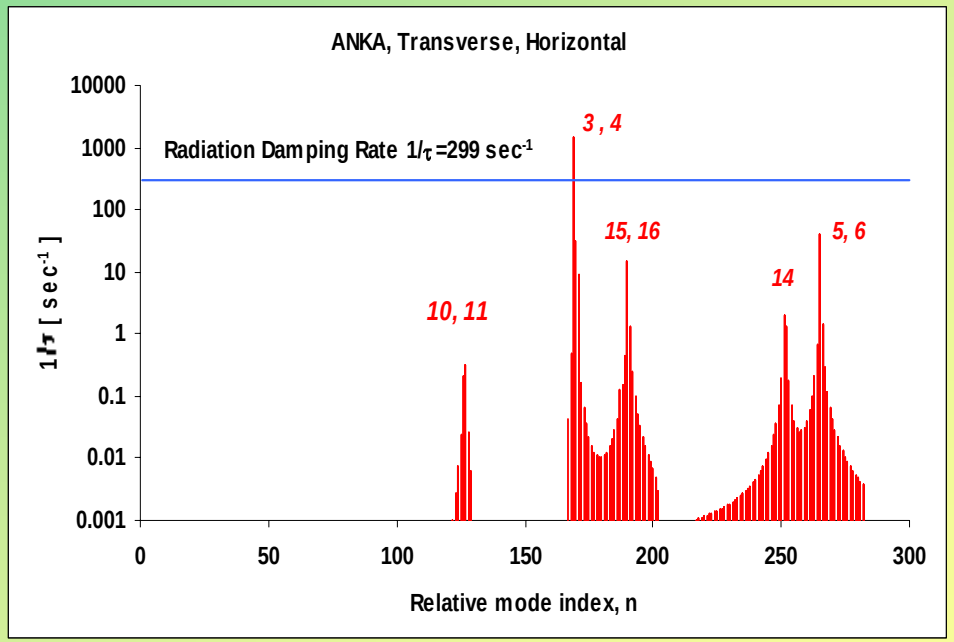
Small Gap undulator Impedance

$$Z(k) = -\frac{jZ_0}{\pi k}\left(a^2 + 2\frac{a\varepsilon_3}{\varepsilon_0\chi_3}\times\frac{1+\alpha th(\chi_3 d_3)th(\chi_4 d_4)}{th(\chi_3 d_3)+\alpha th(\chi_4 d_4)}\right)^{-1}$$

M. Ivanian et al, Phys. Rev STAB-2004

Storage Ring – Instabilities

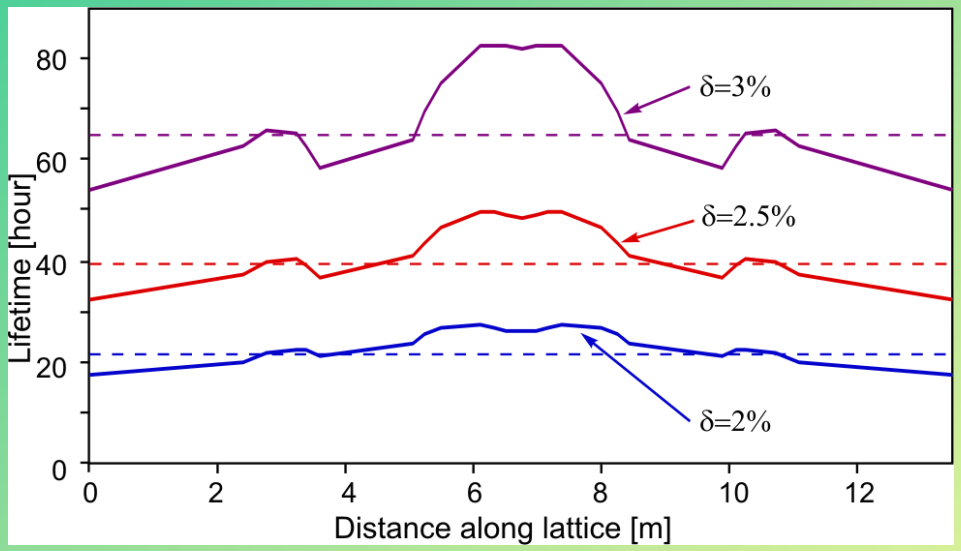




Single bunch Instability

Multi-bunch Instability

Beam Lifetime



Touschek Lifetime

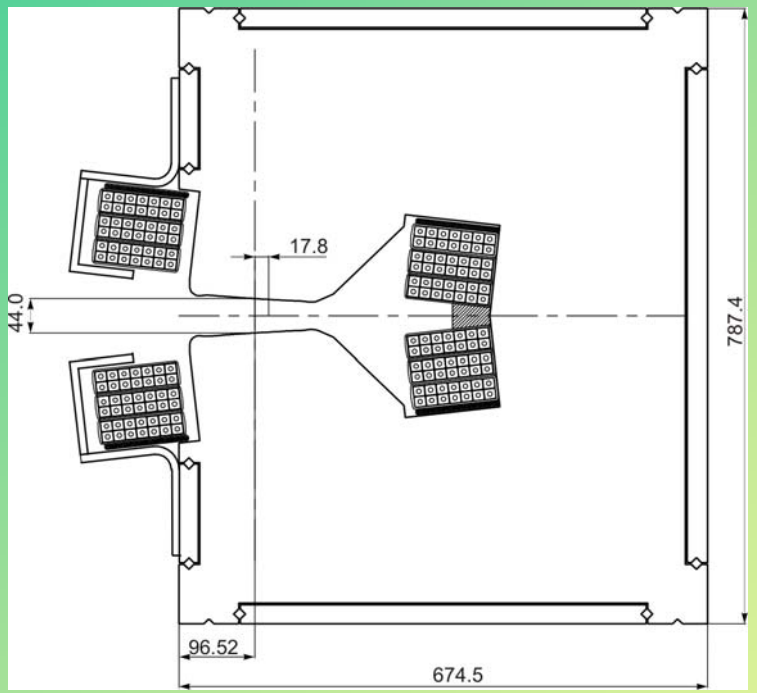
Coupling	1%
Gap Voltage	3.3 MV
Energy Accept.	2.4%
Vacuum	1 nTorr

- Elastic scattering 91.4
- Inelas. Scattering 55.4
- Tousch. Lifetime 39.5
- Quant. Lifetime 10^{38}

Total - 18.4 hours

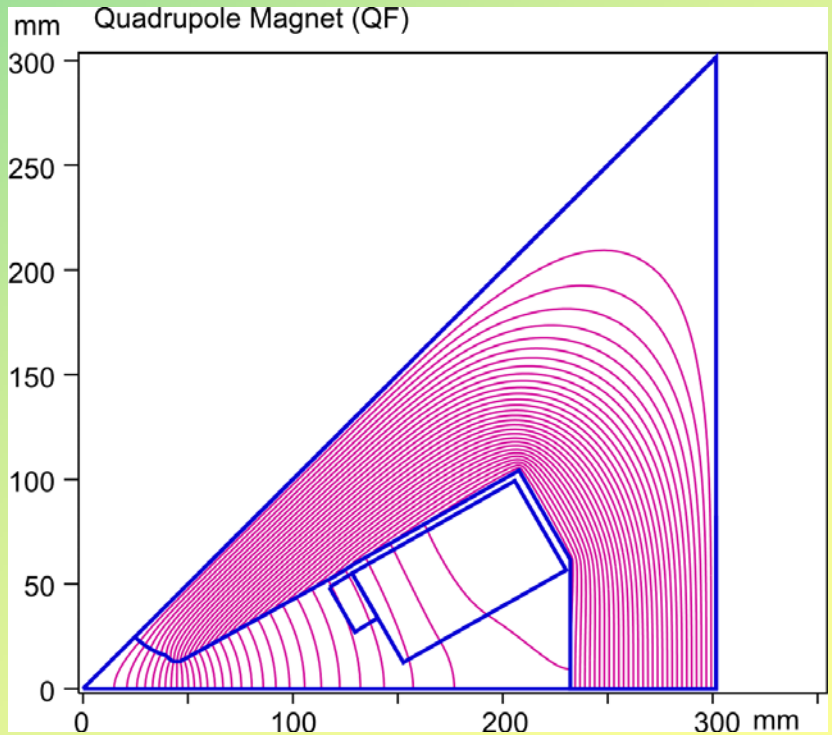
Storage Ring – Magnets

Dipole



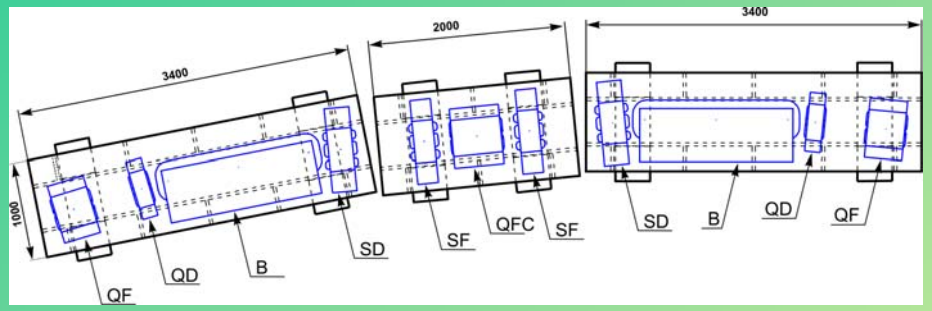
B=1.354 T, G=3.3T/m
aperture=44mm

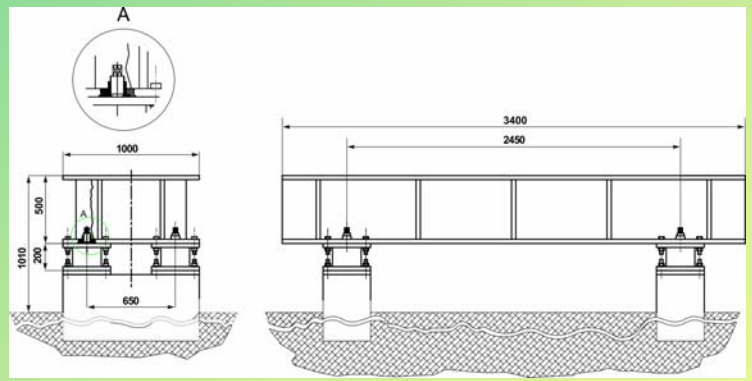
Quadrupole

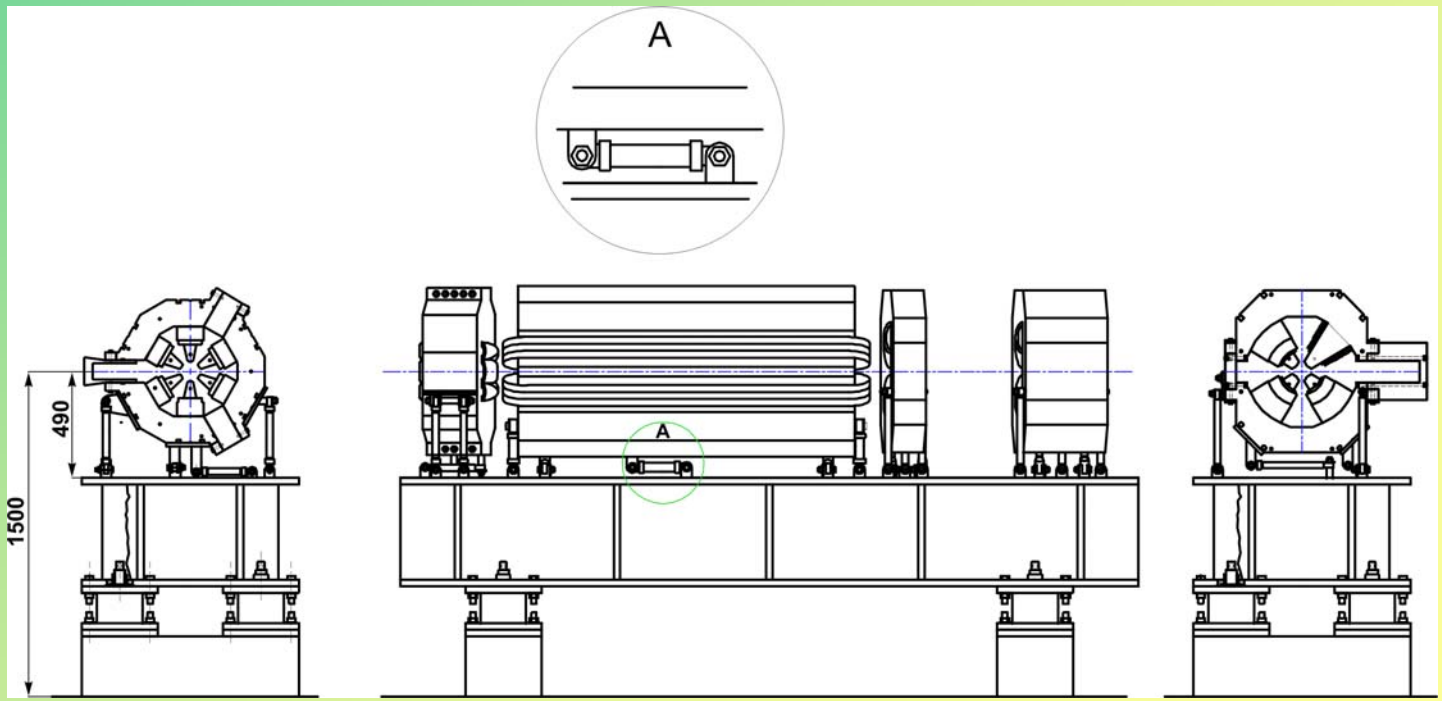


G=20 T/m
aperture=50mm

Magnet supports







Storage ring – Vacuum system

Material – Stainless Steel

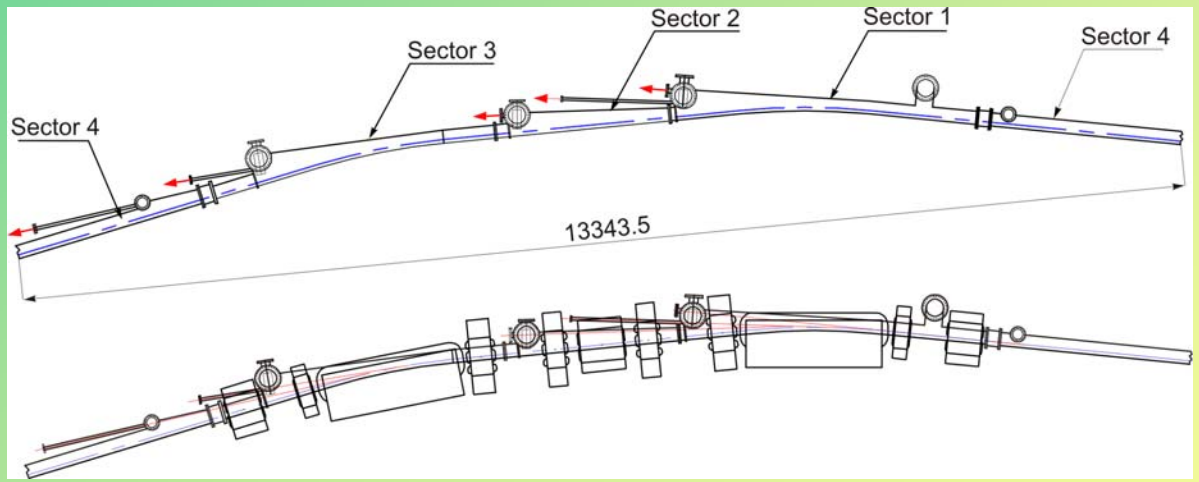
Vacuum – 1 nTorr

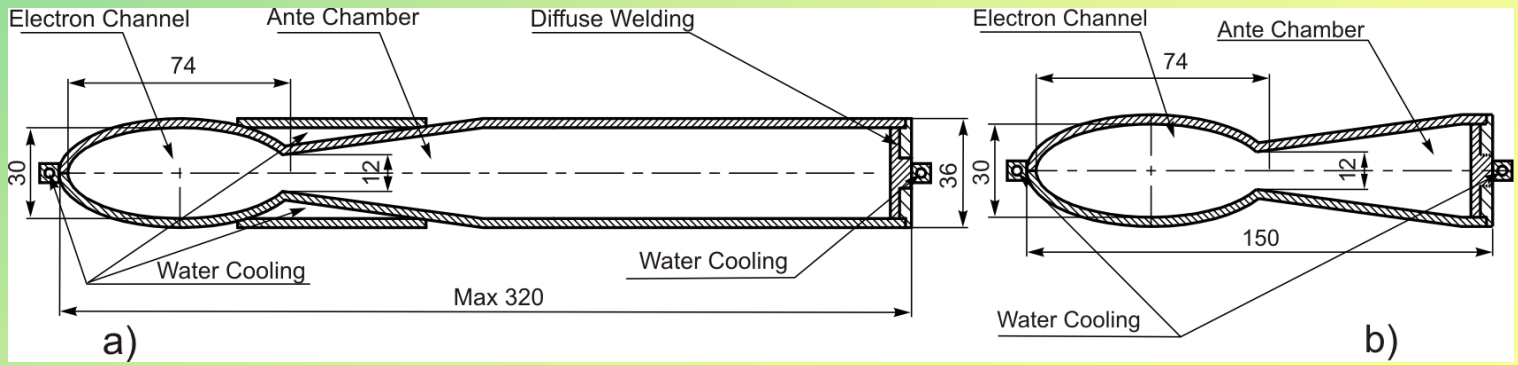
Fore-vacuum - 2

Turbo-molecular – 16

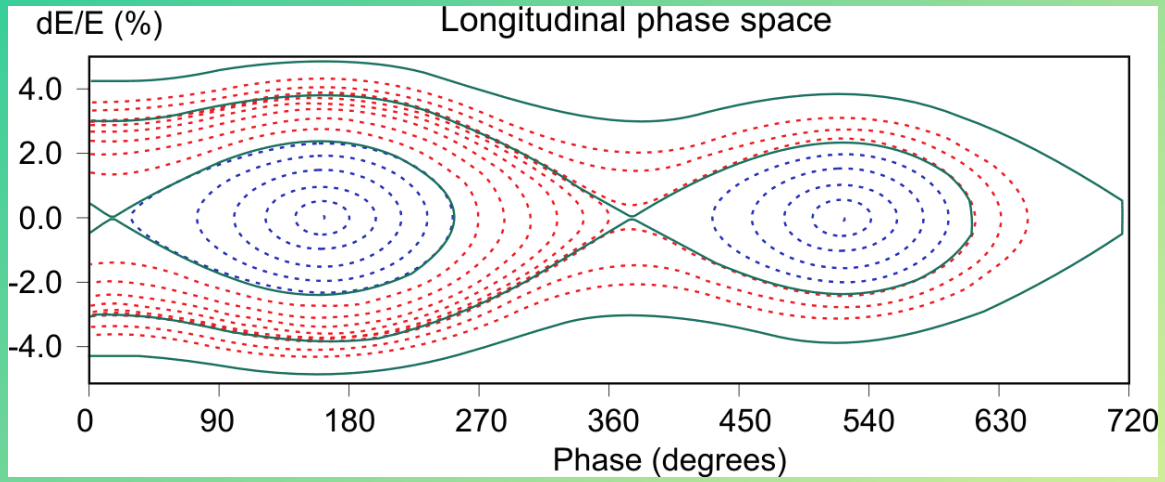
Titan-sublimation – 80

Ion pumps - 64

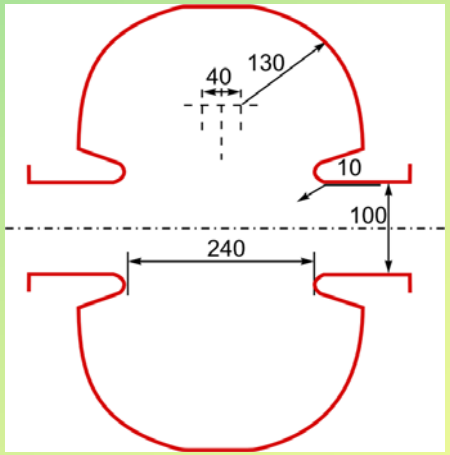




Storage Ring – RF

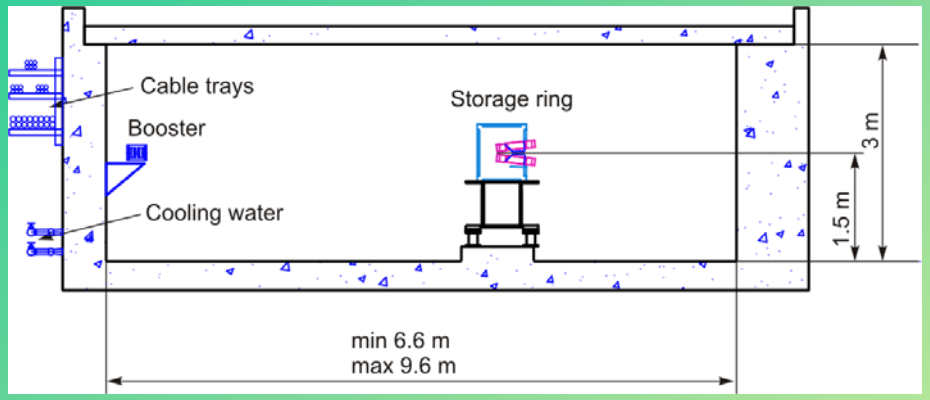


ELETTRA cavity

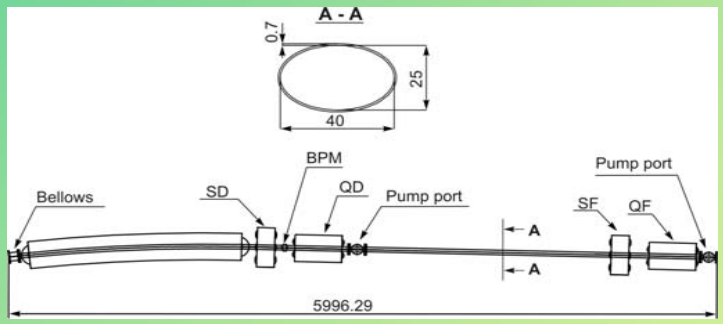


Energy loss/turn	**0.97 MeV**	**1.39 MeV**
Shunt Impedance	**6x3.4 MΩ**	
Total RF power	**660 kW**	**830 kW**
Gap Voltage	**3.3 MV**	**3.3 MV**
Energy acceptance	**2.4%**	**2%**
Energy Spread	**0.1%**	**0.1%**

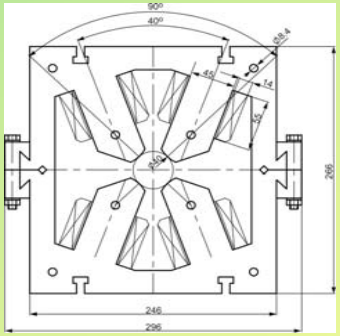
Booster synchrotron



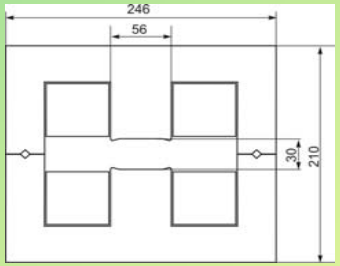
Energy	3 GeV
Pulse current	10 mA
Repetition	2Hz
Circumference	192 m
Emittance	75 nm-rad

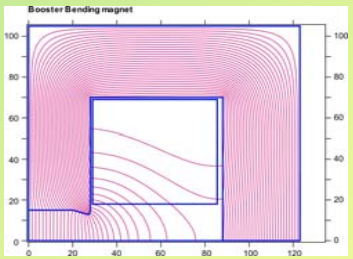


Lattice with missing dipole

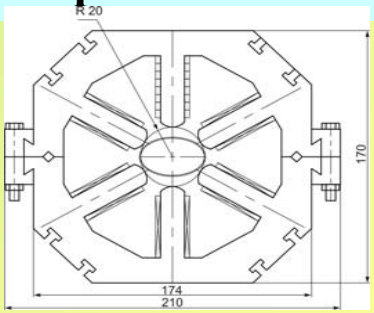


Quadrupole G=10-13 T/m



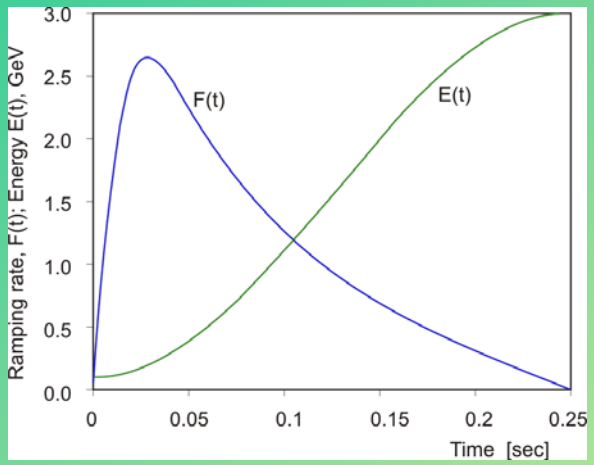


Dipole B=0.024 - 0.72T

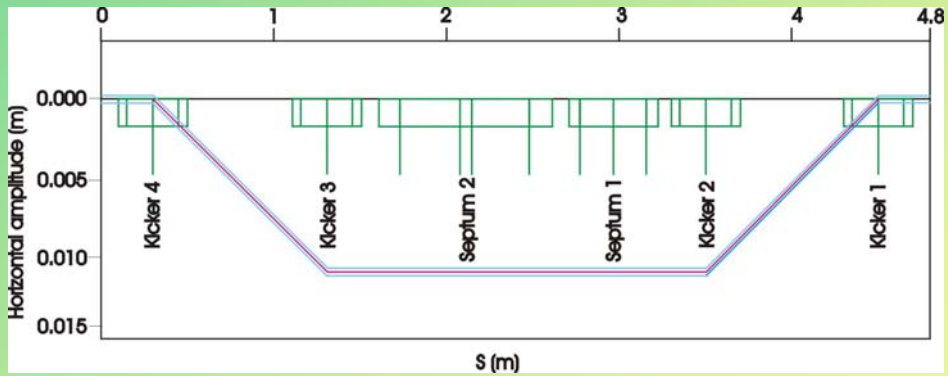


Sextupole S=90/110 T/m2

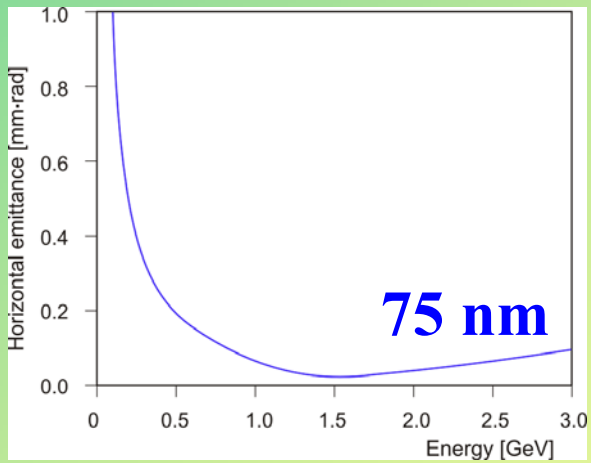
Energy ramp and Injection



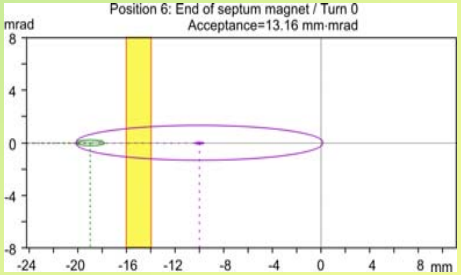
Dipole ramping rate and energy gain

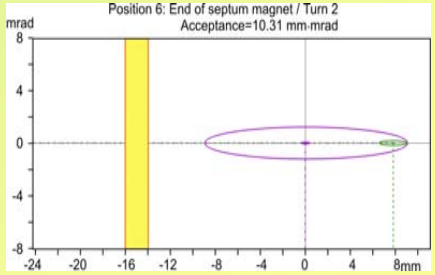


Injection bump



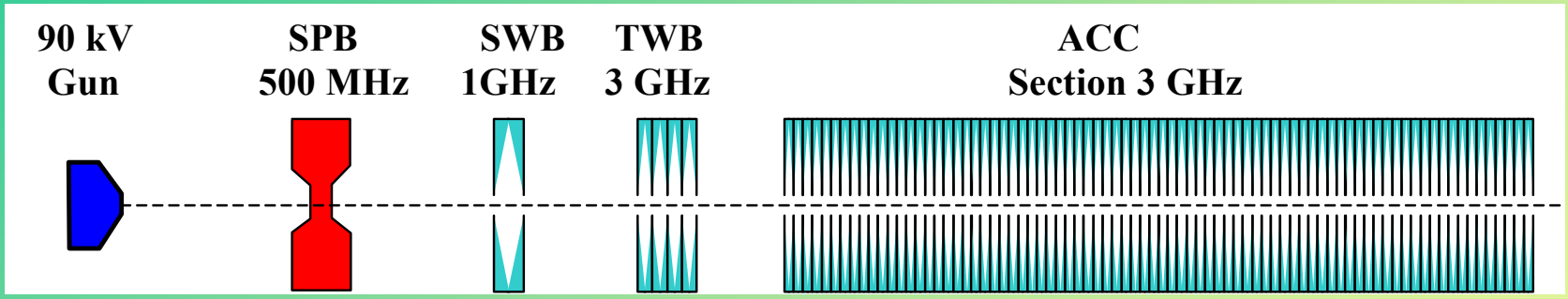
Emittance vs energy

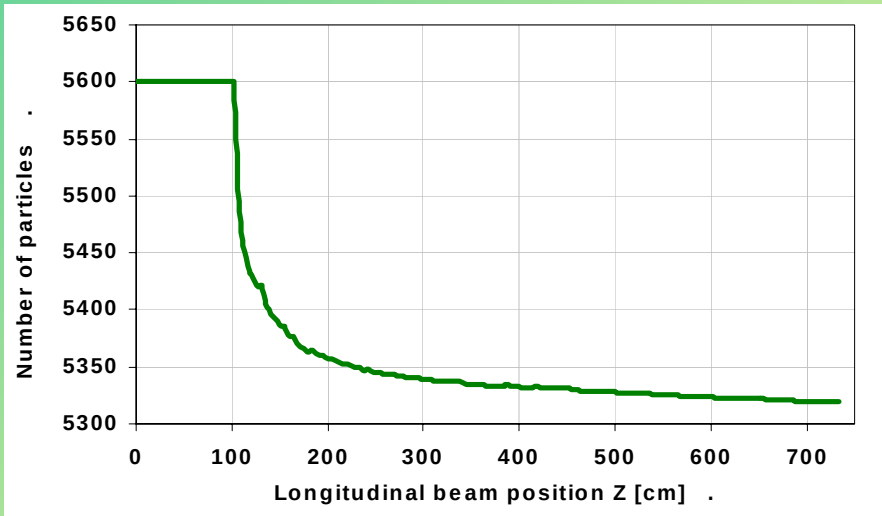


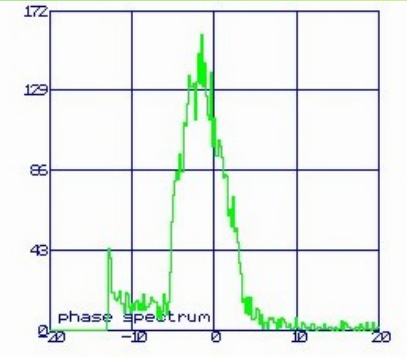


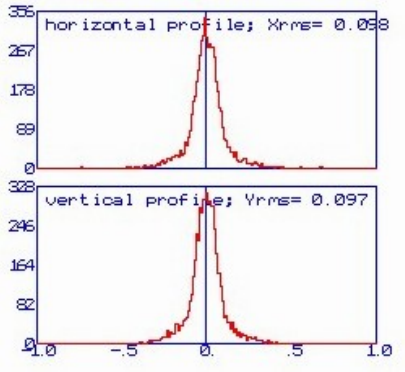
Injected beam: 1 and 3 turns

Linac









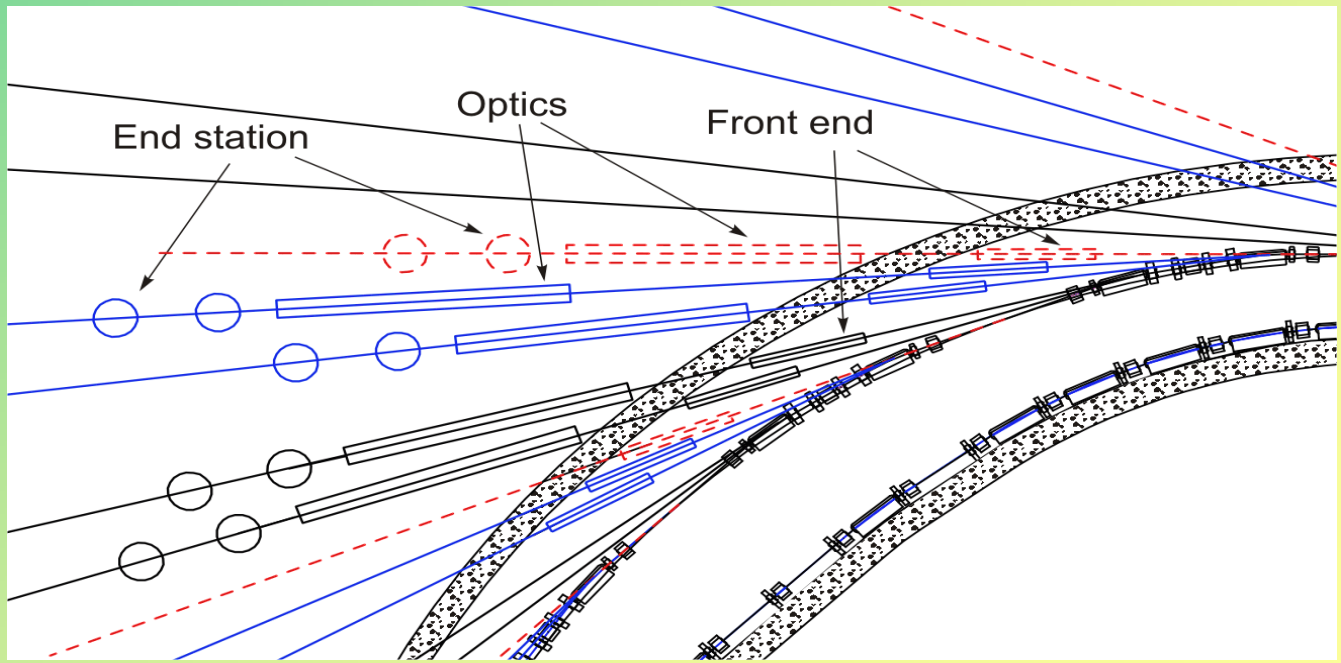
Energy	100 MeV
Current	1- 20 mA
Pulse length	2-600 nsec
Frequency	3 GHz
Energy Spread	< 1%
Emittance	< 1 mm-mrad

Beamlines

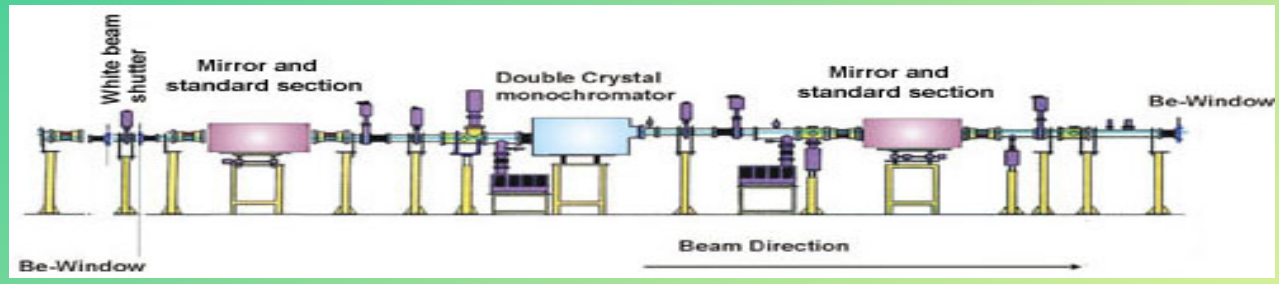
Dipoles – 32
Wigglers – 8
Undulators-4
Exp. Stations ~40

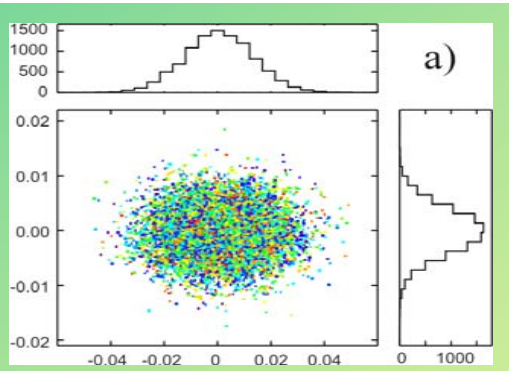
1st Stage

1. Diffraction&scattering (dipole)
2. Protein crystallography (dipole)
3. LIGA (dipole)
4. Medical applications (wiggler)
5. Soft X-ray microscopy and spectroscopy (undulator)

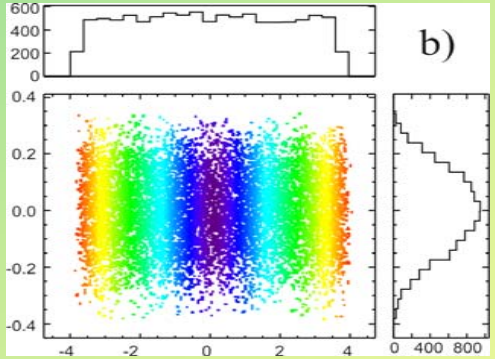


Diffraction & Scattering Beamline

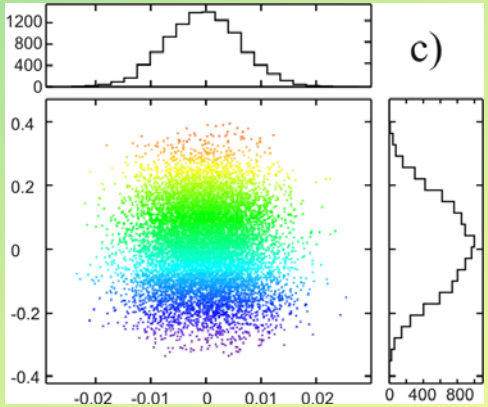




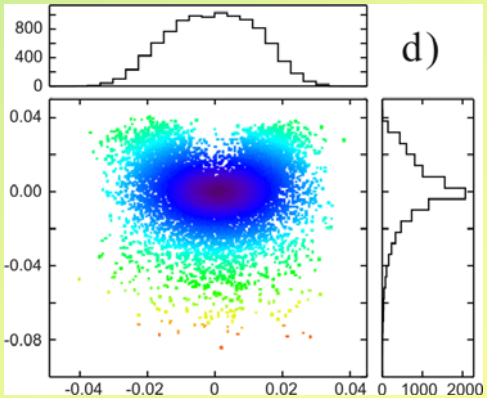
Initial beam



After mirror M1



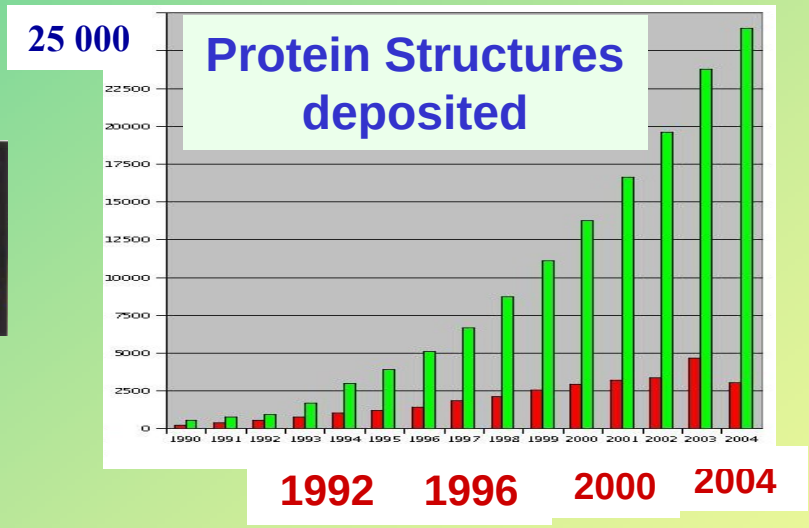
After DCM



Focused Beam

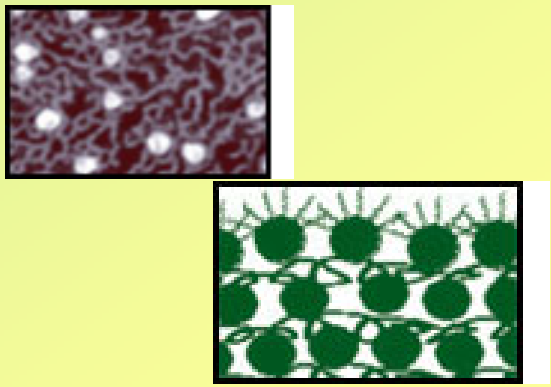
Structural Biology

- *Structural Genomic*
- *Genes and Drugs*
- *DNA complexes*
- *Protein Structure*
- *Drug design*
- *High Capacity Crystallogr.*



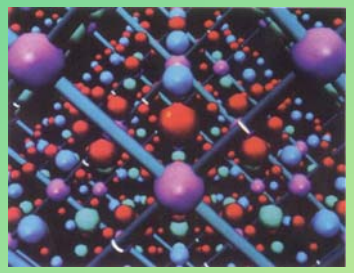
Physics

- *Macro-molecular physics*
- *High-Temp superconductivity*
- *Physics of nano-particles*
- *Surface physics*
- *Heavy fermions*



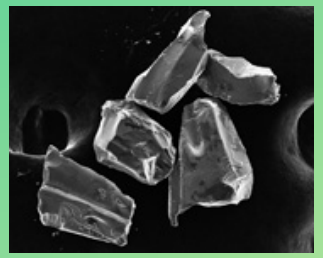
Material Science

3D structure of new material

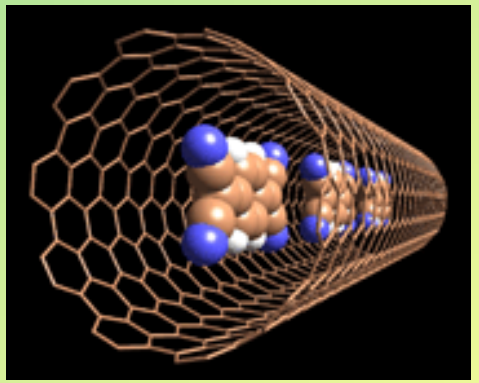


Crystal growth

New Crystals



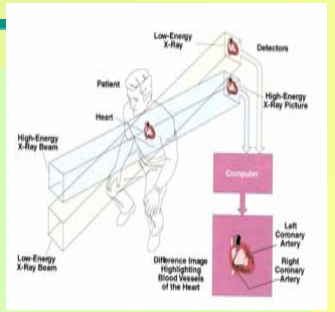
- *Nano-structures*
- *Nano-tubes*



Chemistry

- *Chemical Dynamics*
- *Polymers*
- *Nanoscale chemistry*
- *Biochemistry*
- *Catalytic Interfaces*

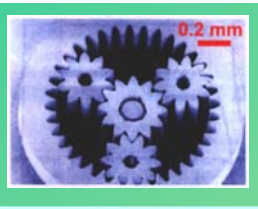
Medicine

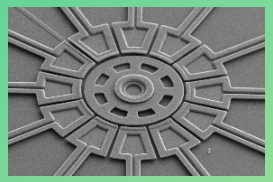


- *Angiography*
- *Bronchography*
- *Mammography*
- *Computed Tomography*
- *Photon Activation Therapy*
- *Microbeam Radiation Therapy*

Micro-fabrication

X-Ray Lithography - LIGA



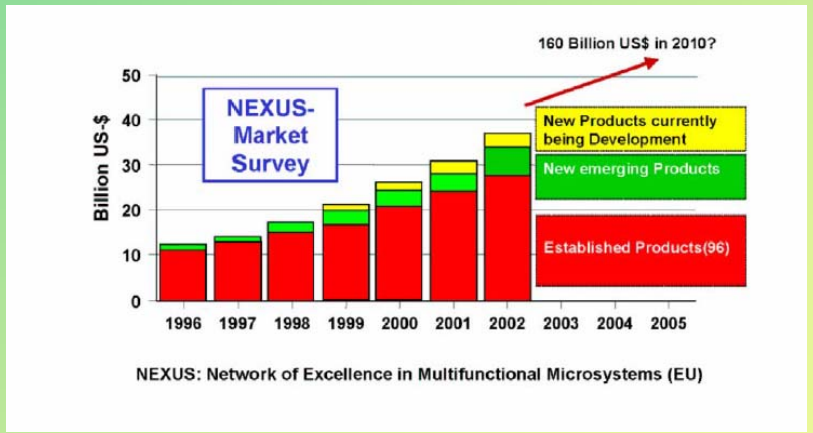


Annual Microfabrication Market

–

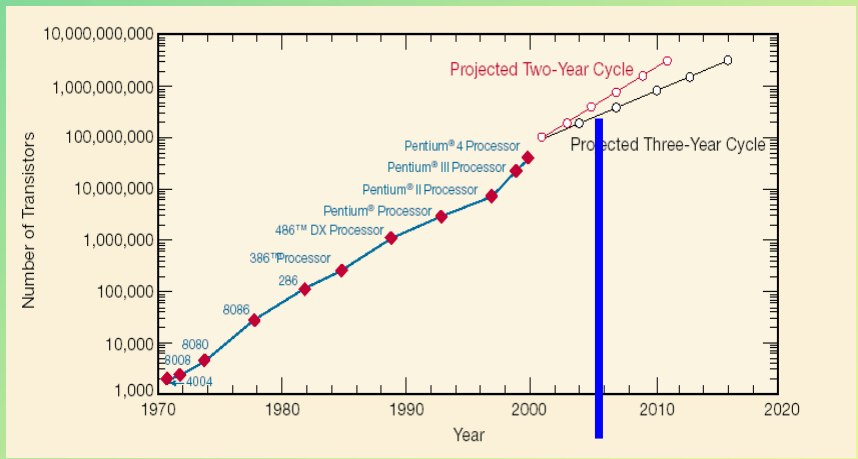
25 *billions doll. in* 2002

160 *billions doll. in* 2010



NEXUS: Network of Excellence in Multifunctional Microsystems (EU)

Electronics



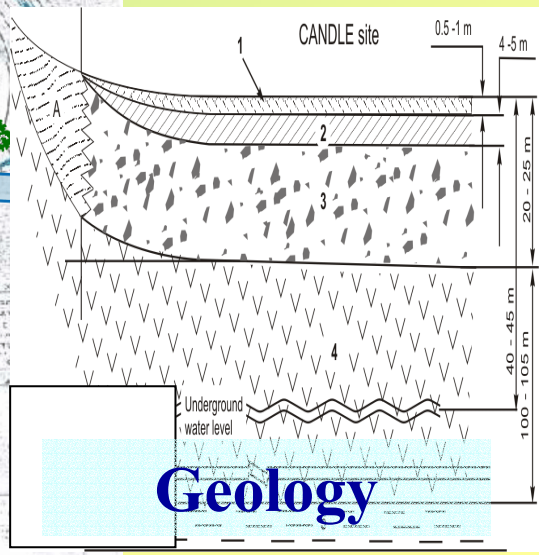
2007

λ=308 nm, refraction, lense, scale- 130nm

EUV, λ =13 nm, reflection, mirrors, scale-13nm

Site

- Easy Access
- Flatness
- Geology
- Office Building



CANDLE Activity

08 December 2001

01 February 2002

01 July 2002

08 July 2002

ASLS-CANDLE R-001-02

July 2002

CANDLE

Design Study of 3 GeV Synchrotron Light Source

A. Abashian[7], M. Aghasyan[6], G. Amatuni[1], V. Arakelyan[3], V.Avagyan[1],R. Avakian[3],V. Ayvazyan[4],H. Gagiyan[1], A.Grigoryan[2],B.Grigoryan[1],M. Ivanian[1], V.Jalalyan[1], S. Harutiunyan[2], V. Harutunyan[3], A. Kirakosyan[2], V.Khachatryan[1],E.Laziev[1],Y.Martirosyan[1], A. Melkonyan[1], R. Mikaelyan[1],S. Minasyan[1], S. Nagdalyan[1], A. Petrosyan[1], K. Rehlich[4], K. Sanosyan[1], S.N. Simrock[4], S. Tatikian[1],V. Tsakanov[1], A.Vardanyan[1],V. Vartanian[5], A. Yayloyan[1],H. Yeritsyan[3]

[1] CANDLE, Yerevan, Armenia

[2] Yerevan State University YSU, Yerevan, Armenia

[3] Yerevan Physics Institute YerPhI, Yerevan Armenia

[4]Deutches Electronen Synchr. DESY, Hamburg, Germany

[5]Stanford University, Stanford, USA

[6] CAMD, Baton Rouge,USA

[7]Virginia Tech., Balcksburg, USA

Review Panel, 14-15 Aug 2002

State Dept.

E. Smith, M. Longi, T. Adams

World Bank

P. Nicholas

L. Freinkman

Panel

G. Shenoy, ANL

B. Batterman, Cornell

T. Narain, Serv. Assoc.

M. Duffey, G. Wash.Univ.

H. Winick, Stanf. Univ.

E. Gluskin, ANL

J. Galayda, Stanf. Univ.

D. Moncton, ANL,

M. Tigner, Cornell Univ (Chair)

"CANDLE is a world-class project enabling frontier research in a whole spectrum of basic and applied sciences.

an excellent investment from scientific-technical point of view."

From Panel Report

Offices & Laboratories

08 Dec 2001

18 Feb 2002

Offices

Workshop

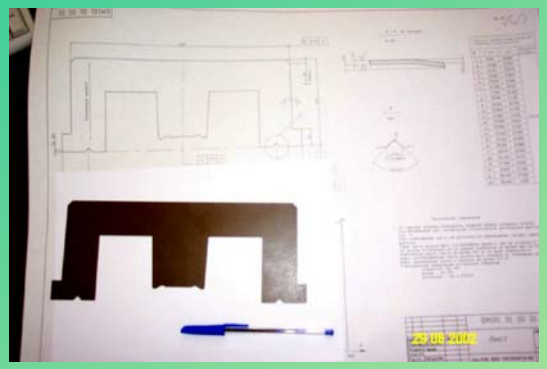
Beamline Lab

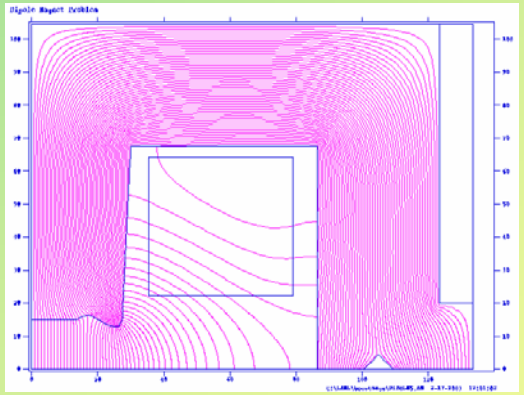
Vacuum Laboratory

First Magnet

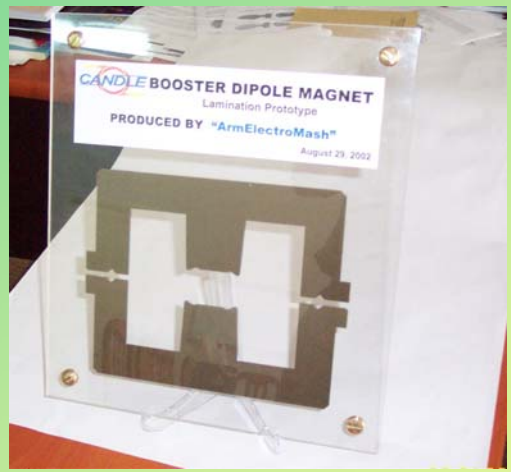
From Design

Simulation





To Fabrication



MADE IN ARMENIA

Proposals

- Total number of proposals – 82
- Number of Scientists - 284
- Number of Institutes - 41
- Countries - 7

  Armenia, England, Germany, Georgia, France, Russia, USA

Fields :

Physics, Biology, Medicine, Chemistry, Environment, Material science,

Vision by 2010

Scientists	~ 2000/ year
Institutions	>200
Industrial Comp.	>30
Countries	~20

ALS, SPEAR3, SLS, BESSY, ELETTRA

Armenia

1. Yerevan State University
2. Yerevan Phyisics Institute
3. Yerevan Engineering University
4. Institute of Applied Researchl
5. Inst. Of Radiophysics and Electronics
6. Institute of Physical Research
7. Yerevan Medical University
8. Orbeli Inst. Of Physiology
9. Inst. Of Common and Nonorganic Chemistry
10. Inst. Of Botany
11. Yerevan Architectural University
12. Center of Molecular Study

"From a review of the 69 experimental proposals , it is clear that strong Armenian user community will emerge as the facility is readied"

From Panel review

Armenia

We believe the project is worthy of support by the private sector, the international community, the US and Armenian governments.

Vardan Oskanian (Minister Of FA)

National Academy of Sciences expresses the lasting support for the CANDLE creation and usage.

Resolution of NAS RA

CANDLE will drive the country development as a high technology and excellence island in this part of the word.

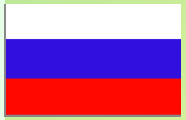
L. Mkrtchian (Minister of Science and Educat.)

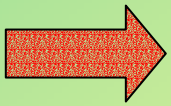
International Collaboration





- Armenia - NAS, YSU, YerPhI
- Bulgaria - Inst. Nucl. Research
- Germany - DESY, ANKA, BESSY, TUD, RU
- Greece - Inst. Accel. Syst., Athens Univ.
- France - Provence Univ, ESRF
- Italy - ELETTRA
- USA - DOE, Virginia Tech, SLAC
- Russia - JINR, IMT, FIAN
- Georgia - Tbilisi Univ, NAS
- Tailand - SIAM



- *Letter of Supports*
- *Memorandums of Understanding*
- *Collaboration Agreements*

International Collaboration

Armenia, Germany, France, Italy, USA, Russia, Bulgaria, Greece, Georgia

European Laboratories

European Round Table for SR and FEL

International Atomic Energy Agency

- ***Letter of Supports***
- ***Memor. of Understanding***
- ***Collaboration Agreements***

DESY contribution

3 GHz RF components

Control Systems

150 MW S-Band Klystron

Deutsches Elektronen-Synchrotron DESY
in der Helmholtz-Gemeinschaft

Chairman of the Board of Directors

DESY

e of Armenia
e

creation of the new synchrotron
ring a long term experience
vare on the favorable recommend
upports the creation of the new

e last decade of research in li
velop new technologies for the a
ontinuously increasing worldwi
reason for DESY to consider a
ity in 2007 in addition to the TES

There is no doubt that a scientifically sound project as CANDLE will be an asset for Armenia with its long tradition in basic and applied science. DESY and CANDLE already established a cooperation agreement on accelerator physics and synchrotron radiation usage. Within the framework of this cooperation, DESY expressed its willingness to make in kind contribution to the new project by means of the components of the S-Band linear accelerator for the injector system of CANDLE.

I am confident that CANDLE upon its completion will enable the Armenian scientists and their foreign colleagues to perform frontier research in a wide spectrum of basic and applied sciences. Please accept my lasting support for this project .

Sincerely Yours

Prof. Dr. Albrecht Wagner

Notkestraße 85, D-22607 Hamburg, Germany
phone: + 49 40 8998-3000/ -2405
fax: +49 40 8998-4304
Email: albrecht.wagner@desy.de

9 Sept 2003 – Permission by State dept. for technology transfer

University of Region de Provence

UNIVERSITE DE PROVENCE
(AIX-MARSEILLE I)
SECRETARIAT GENERAL - DIVISION DE LA RECHERCHE
CONSEIL SCIENTIFIQUE
Séance du 13 décembre 2002

T DU REGISTRE DES DELIBERATIONS

(Centre pour l'Avancement des Découvertes Naturelles en
LE) » en ARMENIE

e le projet : il rappelle que la lumière synchrotron permet de
ntifiques, médicaux et technologiques. Le projet est porté par
atenu par l'UNESCO, et consiste à construire à EREVAN, une
Etats unis soutiennent financièrement le projet. M. LE LAY,
allation d'un synchrotron sur le plateau de l'Arbois, à pro
tivités territoriales et de la forte communauté arménienne de la
re. Une aide sera également demandée à la Communauté
ersités est un soutien scientifique. Les liens entre l'Université
tive du Président de l'Université, M. KAFTANDJIAN se sont
ion avec l'université d'EREVAN en 1994.

nité son intérêt pour le projet CANDLE et lui apporte son

Pour extrait certifié conforme,
Marseille, le 23 MAI 2003
r le Président et par délégation
crétaire Général de l'Université
Gérard BARBERAN

Téléx AMUP 402014 Télécopie 04 91 10 60 06

MEMORANDUM OF UNDERSTANDING

on the establishment of the international collaboration between the
Universities of Region Provence (France)
and the
Center for the Advancement of Natural Discoveries using Light Emission
(Armenia).

On the occasion of the visit of Prof. Jean Marc Layet, Prof. Guy le Lay, Dr. Georges Terzian (Université de Provence in Marseille) and Prof. Patrick Soukiassian (Université de Paris-Sud/Orsay) to CANDLE laboratory in Armenia, 3-11 April 2003, discussions taken place during the meetings, the following memorandum of understanding is considered to be an important stage for the establishment of international cooperation on the creation and usage of the CANDLE facility.

CANDLE is a world-class 3 GeV intermediate energy 3rd generation synchrotron radiation facility that will provide high brightness photon beams ranging from the UV to hard X-Rays. The facility will be capable of providing the frontier research in such diverse fields of science and technology as structural biology, bio-informatics, physics, medicine, chemistry, material and environmental sciences, microfabrication and nanotechnology. The facility is considered to serve an international center with the large involvement of scientific groups from all over the world.

The creation of such facility in the region opens an excellent opportunity for the cooperative research programs between scientific institutions and high-technology related organizations of both parties to perform frontier researches leading to advance scientific and technological achievements. The collaboration will include:

- An establishment of joint research groups on Laboratories and Universities level;
- Organization of joint seminars and workshops on synchrotron radiation usage;
- Development of the beamline instrumentation and end stations for CANDLE;
- Development of the research programs to be conducted on CANDLE.
- Exchange of specialists and training of young scientists.

The success of the collaboration, especially at the initial stage of the project, needs a wide promotion among the scientific community with the aim to establish a corresponding infrastructure of the CANDLE oriented user community according to world-class standards developed in other similar laboratories in Europe and the USA.

We are excited with the outlooks that CANDLE opens for the broadband scientific research and are confident that a strong user community will be developed for this new state-of-the-art synchrotron radiation facility.

Professor Jean-Marc Layet
Dean of the Department "Sciences de la Matière"
Université de Provence in Marseille,
France

Professeur Vasili Tsakanov
Technical director
CANDLE
Armenia

Support to the CANDLE project and express of interest in

- *Structural biology*
- *Nanostructures*

European Union

European Parliament Resolution
26 February 2004

"An Involvement of the Union in the Armenian CANDLE synchrotron project would be a sign of encouragement to this project which concerned chiefly the European scientific teams "

Amendment 102

Armenia

04 June 2004

Meeting of President RA with CANDLE Board

Cost & Schedule

2002 –2003 - Design

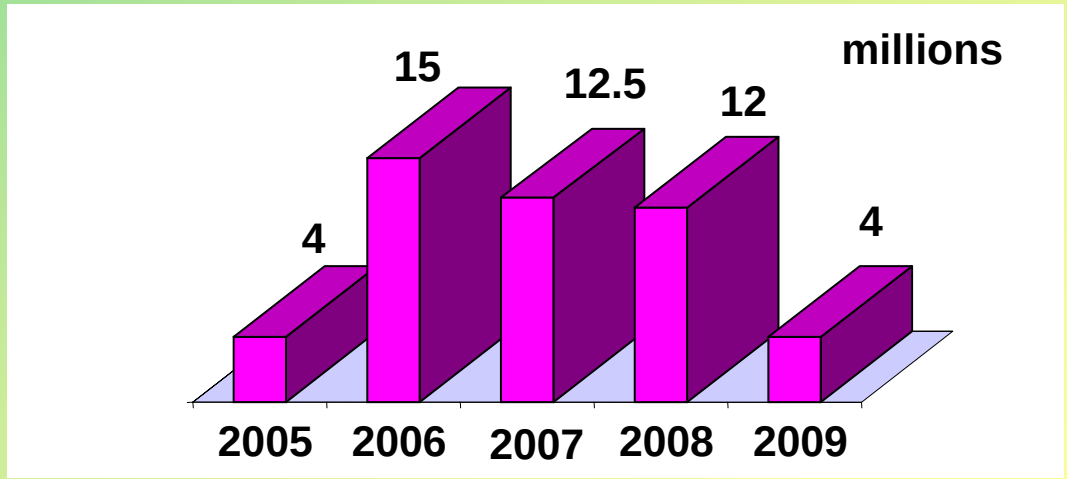
2003-2005 – Prototyping

2005-2008- Construction

2009 - Operation

Cost - *$48 mln*

with 5 exper. stations



Stage 2 (2005) – 4 mln doll.

Prototypes,
Test stands,
Infrastructue

→ ***Armenia and CANDLE is ready for construction***

Organizational issue

→ ***Consul, Board, Advisory committees***

Development of User Case !

↓

Funding Sources

2006–2009

Construction

→ ***Arm. Government, State Dept. , European Union, Diaspora, Direct Collab, Companies, Internat. Org.***

Committee on Science and Technology in Armenia

February- October 2004

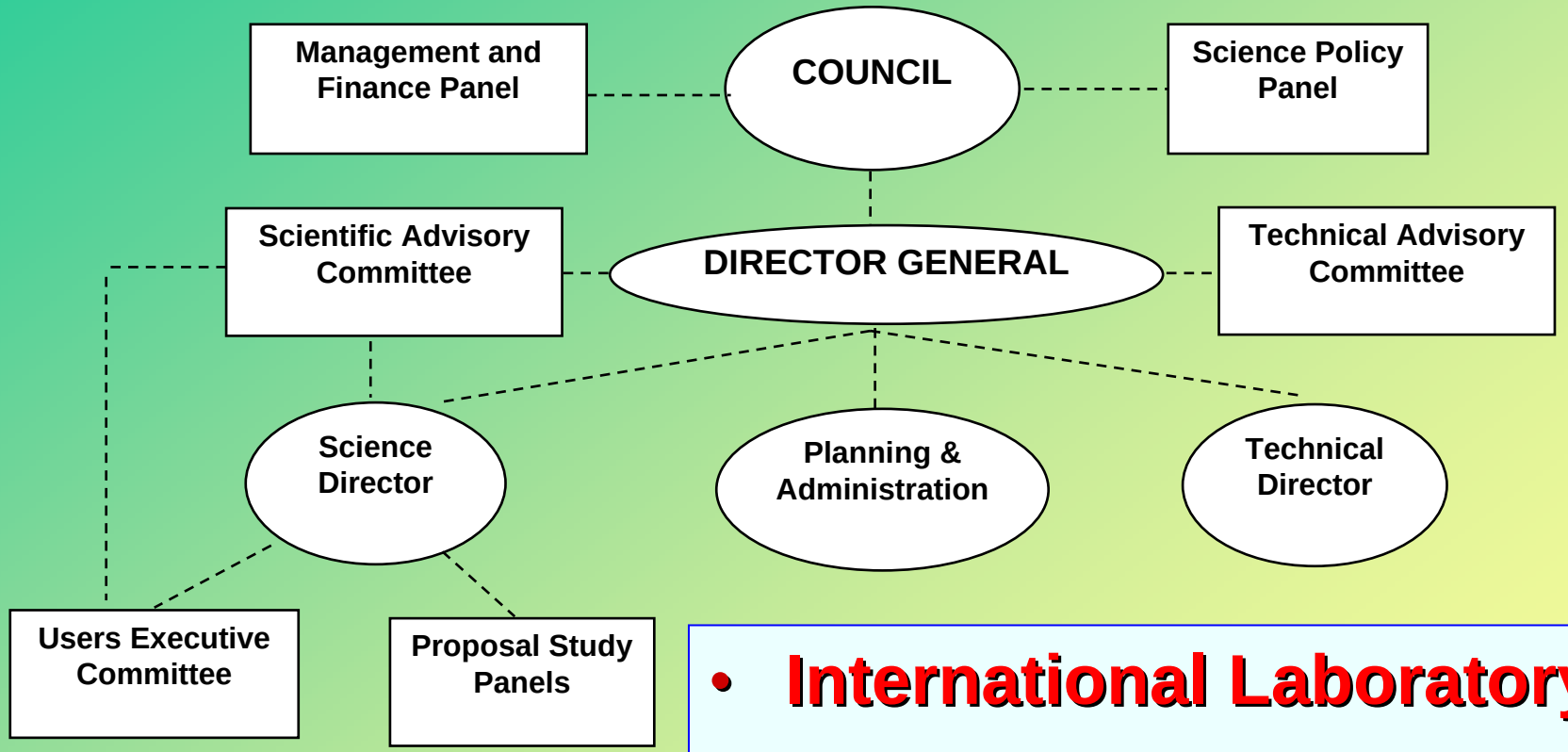
J. Baldeschwieler (Nat. Acad)

Barry Barish (CalTech)

N. Neureiter (Nat. Acad.)

- CANDLE is a place where investment to enable the next step might lead to a major improvement in S&T infrastr. in Armenia
- Recommendation for allocation of 4 mln $US for 2005

CANDLE Organization (vision)



- International Laboratory
- User Friendly Environment
- World Class Research

Welcome to CANDLE