AREAL

Test Facility for Advanced Accelerator and Radiation Sources Concepts

Part.1 Introduction

V. Tsakanov
CANDLE SRI

01 October 2015

2nd European Advanced Accelerator Concepts

13-19 Sep 2015, Isola d'Elba

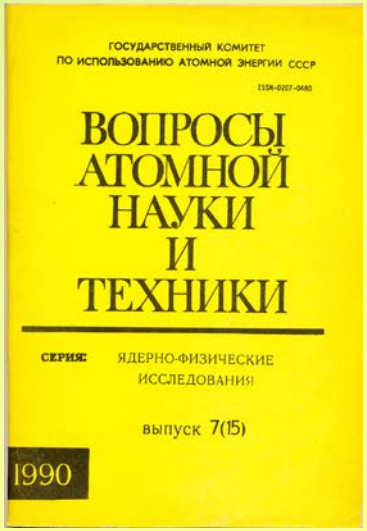
- High Frequency (THz) acceleration in metallic structures
- Plasma accelerators driven by modern lasers
- Plasma accelerators driven by electron beams
- Plasma accelerators driven by proton beams
- Dielectric structures and other novel technologies
- New schemes using advanced technologies (Table-Top FEL)
- Computations, Advanced beam diagnostics
- Laser technology for advanced accelerators

Introduction

2nd All-Union Workshop on New Methods of Particle Acceleration

**A.Amatuni, B. Palmer,
T. Weiland, T. Katsouleas,
J. Simpson, A. Sarantsev,
H. Henke, E. Laziev,
S. Novokhatski,
C. Pellegrini, R. Jameson …**

- **Wake Field Accel.**
- **Plasma WFA**
- **Laser-Plasma Accel**
- **Two Beam Accel.**
- **High Freq. Accel.**
- **Inverse FEL**

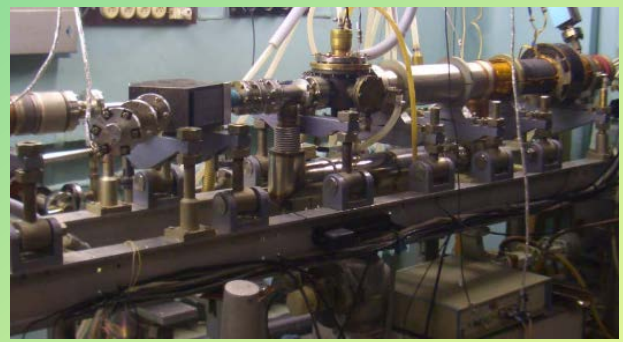


1986-1990 - LUE- 20 MeV Test Facility

Not completed

Prof. Eduard Laziev - Yerevan Physics Institute

Energy –20 MeV
Pulse lenght – 5 psec
Bunch charge – 300 pC
RF frequency- 3 GHz
Emittance – 20 mm-mrad



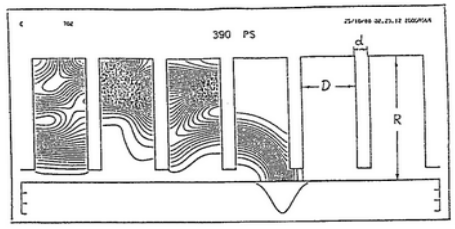


Fig.5 Geometry of the disk–loaded wavequide used in the TBCI calculations (R=5cm, D=2cm, d=0.5cm).

Experimental program

- **Wake Field Accel**
- **Plasma WF Accel.**
- **Two-beam Accel.**
- **THz radiation sources**

High Transf. Ratio
Multi-bunch WFA

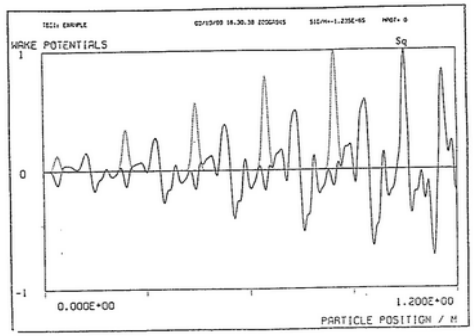


Fig.6 Longitudinal wake potential produced by a train of 5 driving bunches with charge increasing from bunch to bunch. Bunch r.m.s. length σ=8 mm, single bunch transformation ratio k_t = 1.7 and total transformation ratio 7.4

E. Laziev et al, EPI-1040(3) , 1988
T. Weiland et al , DESY M-88-13 , 1988
V. Tsakanov, NIM-A 432, 202, 1999.

2011–2013 - First phase- AREAL

Exit Scenario

- Small facility + Limited investment
- State-of-the art facility –
- Scientific &Technology asset
- Multiple applications
- Training and Educ. Center
- International cooperation

Ultrafast Science and Technology

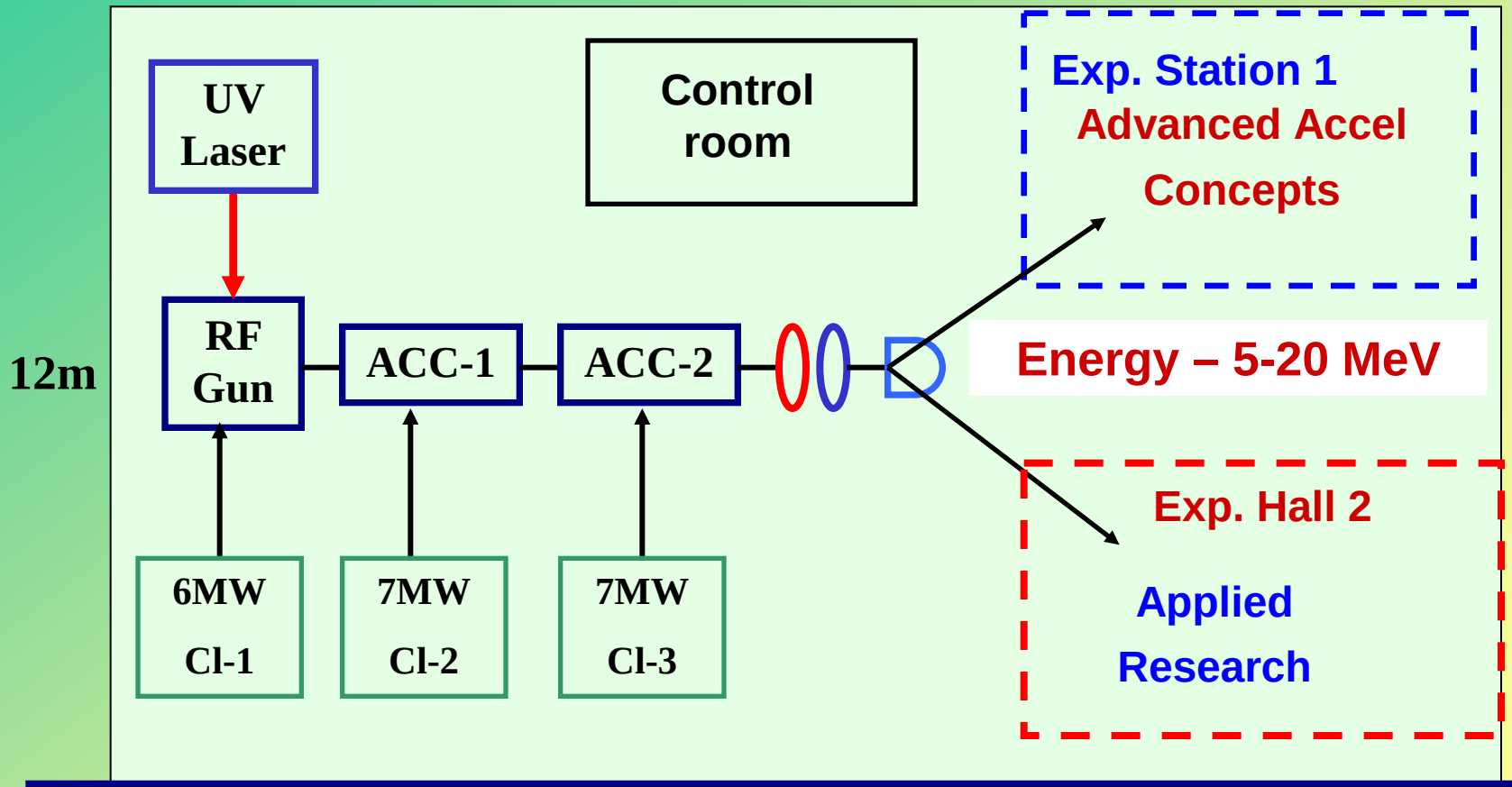
Ultrashort bunches – sub ps

Small emittance < 0.5 μm

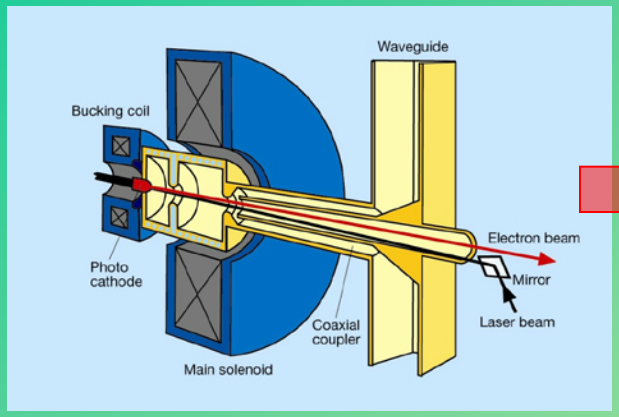
Start –July 2011

Project Development : Exit Scenario

Laboratory for Ultrafast Science and Technology



AREAL – Advanced Research Electron Accelerator Lab



Beam Design Parameters

Energy – 5-20 MeV
Bunch length – 0.3-2 ps
Emittance – 0.3 μm

Bunch charge – 10-100 pC
Frequency – 1-50Hz
Single and multibunch (16) operation

Figure of Merits

Photocathode

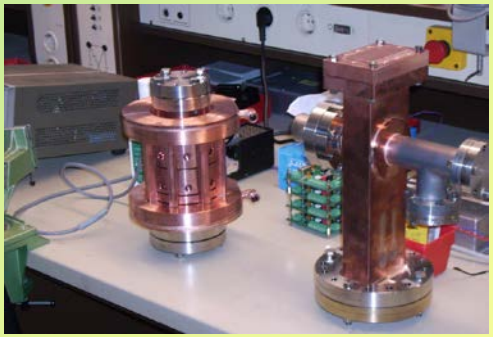
Quantum Effic.
Work function
Damage thresh.
Lifetime
Cost Maintan,

RF Gun

Frequency
Accel. grad
Cost&Mainten

Laser

Wavelength
Power
Pulse length
Time-structure
Cost & Mainten



Photocathode

Parameters	Metals (Cu)	Coated Met. (CuBa)	Semiconduct. (Cs_2Te)
QE (%)	0.001-0.01	0.01-0.1	0.1-10
Work funct W (eV)	3.5- 4.5	2-3	1 -2.5
Damage Thr (mJ/cm^2)	**100**	40	1-2
Lifetime	**>Year**	Months	Weeks
Response Time (ps)	**<0.02**	~ 0.5	>1
Vacuum (nTorr)	**1.0**	0.1	0.01
Cost	**+**	-	-

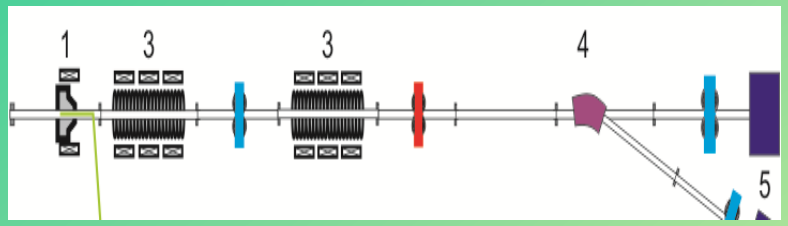
$$P_L(W) = 1240 \frac{I(amp)}{QE \times \lambda(nm)}$$

Cu

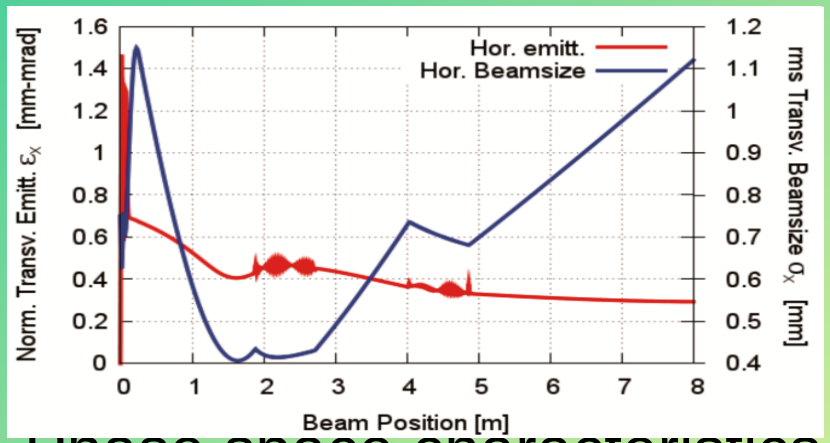
QE=0.01%

W= 4.5 eV

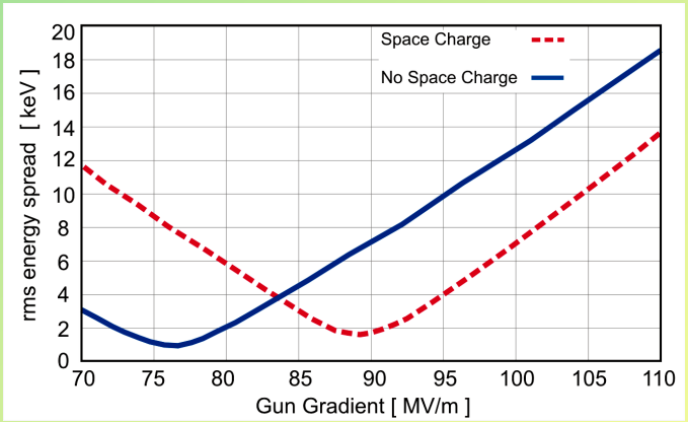
Beam Dynamics



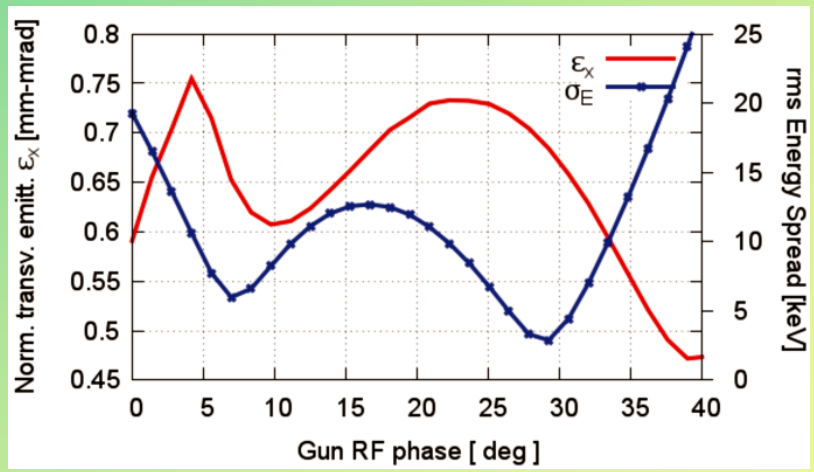
Energy – 5-20 MeV
Emittance < 0.3 um
Energy spread -0.1%
Bunch length – 0.1-1ps
Bunch charge- 10-200pC

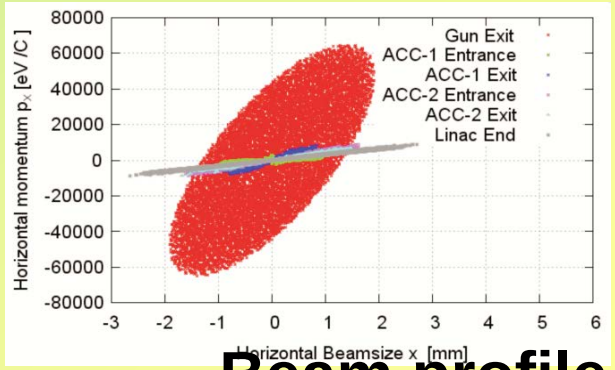


Phase space characteristics



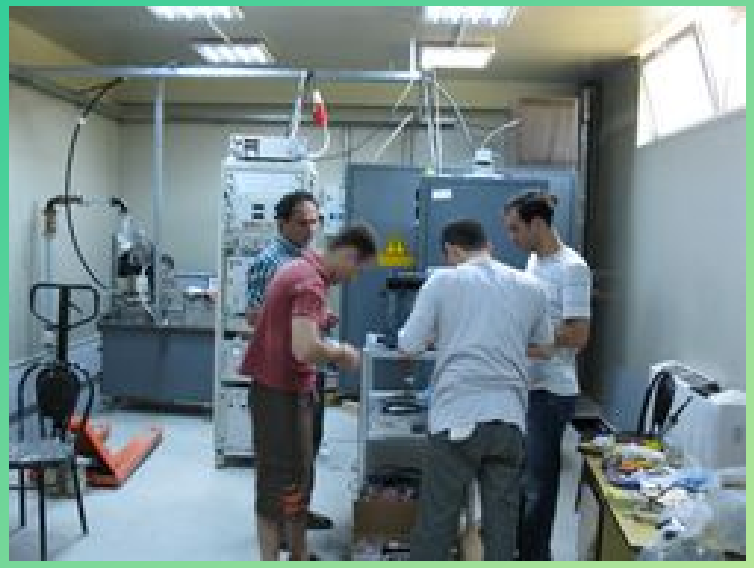
Energy Spread at Gun exit



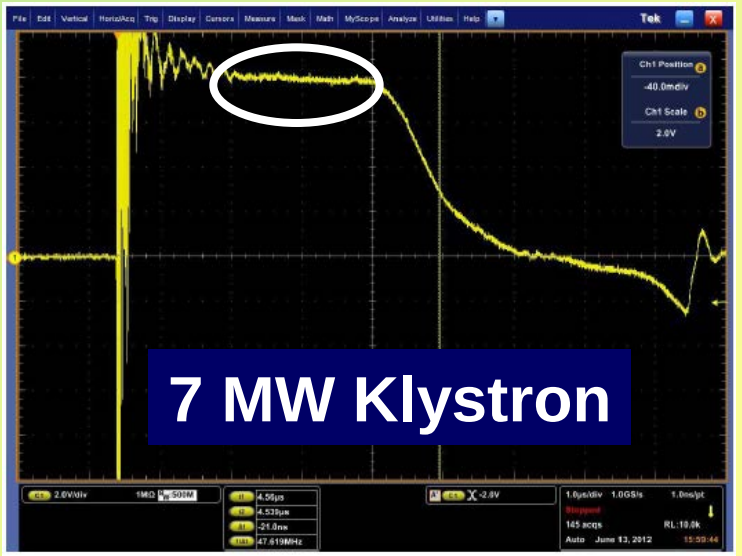


Beam profile

RF System



Main RF Frequency	(GHz)	2.997925
RF pulse Duration	(μs)	4
Operating Repetition Rate	(Hz)	1-50
HV Pulse Duration	(μs)	4
RF Peak power	(MW)	7
Amplitude Stability	(%)	<1.2
Amplitude pulse-to-pulse stability	(%)	<0.5
Phase Stabilization	(° @ 3GHz)	0.1



Amplitude Flatness <1 %

Laser System

t-Pulse Oscillator

Average power	1 W
Pulse duration	200 fs
Pulse energy	20 nJ
Central wavelength	1030 nm
Spectral bandwidth	5 nm
Beam quality	TEM_{00}
Repetition rate	49.9654 MHz
tuning range	10 kHz
tuning accuracy	100 Hz
Gain material	Yb doped
Dimensions	60 x 20 cm

s-Pulse Amplifier

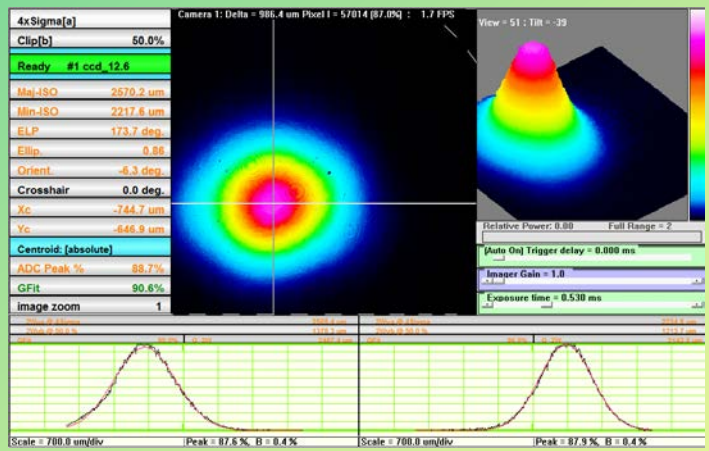
Average power	8 W
Pulse duration	0.5 – 4 ps
Pulse Energy	2 mJ
Central Wavelength	1030 nm
Spectral bandwidth	5 nm
Beam quality	TEM_{00}
	<1kHz
Repetition Rate	1 – 100 Hz
Gain material	Yb:KGW
Dimensions	75 x 50 cm

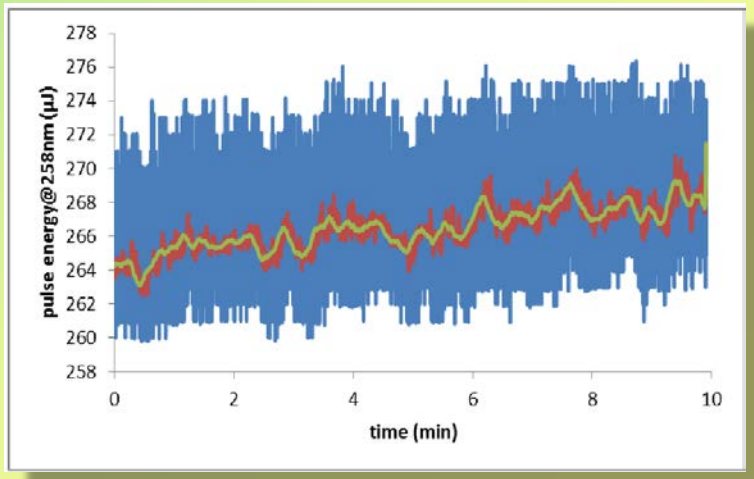
Yb:KGW -Ytterbium-doped Potassium-Gadolinium Tungstate crystals

Output parameters	Single bunch	Multibunch
Central wavelength	258nm ± 1nm	
Pulse width (FWHM)	0.5 – 4ps (motorized tuning)	0.5ps
Pulse to pulse jitter @49.9654MHz	< 0.5ps rms	
Output pulse repetition rate	<1kHz	49.9654MHz
Pulse energy @258nm	> 200µJ	> 10µJ
Number of pulses within 1µs train	1	16
Beam mode	Gaussian, TEM_{00} M^2 < 1.3	
Beam divergence (FWHM)	< 300µrad	< 1200µrad
Beam diameter	4mm	1mm

Laser Performance

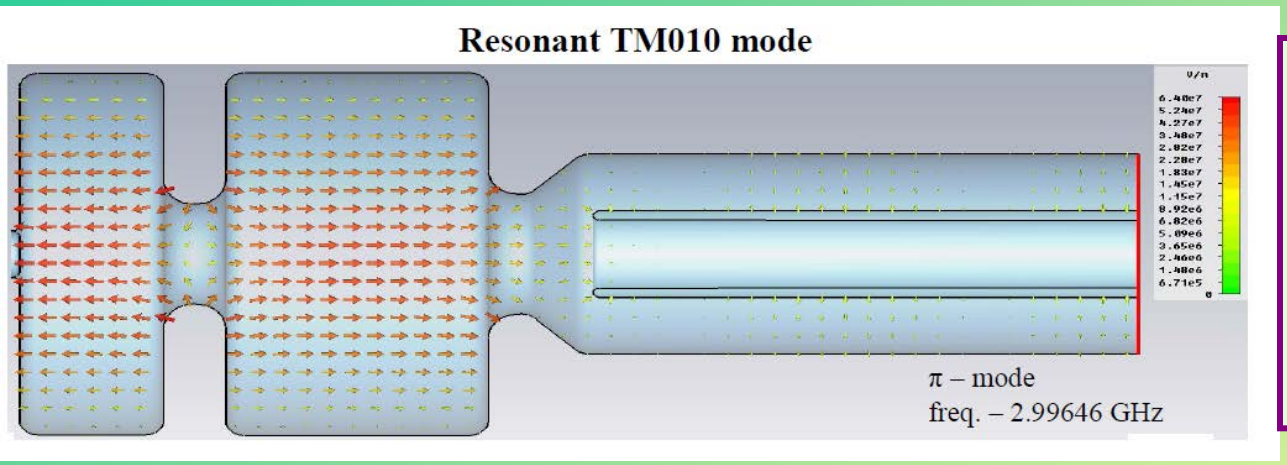
UV – 258 nm
Energy – 300 µJ
Pulse Length – 0.4 ps
Diameter – 4mm
Shape – gaussian





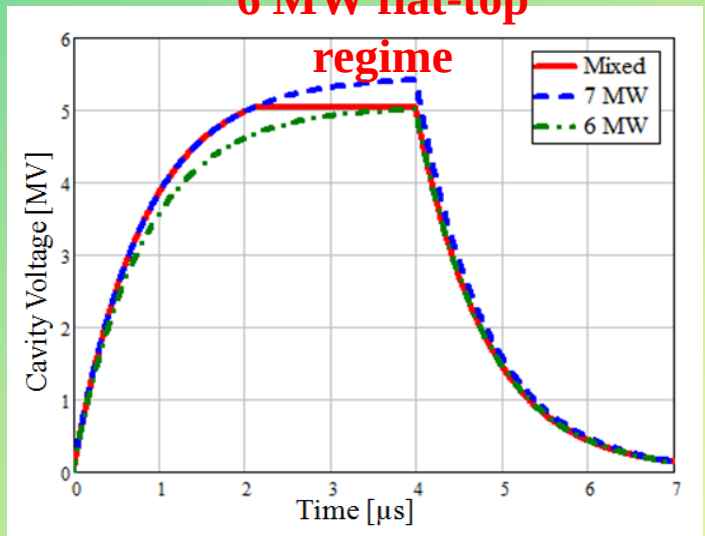
Pulse Energy stability – 0.3%

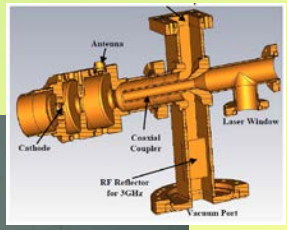
RF Gun



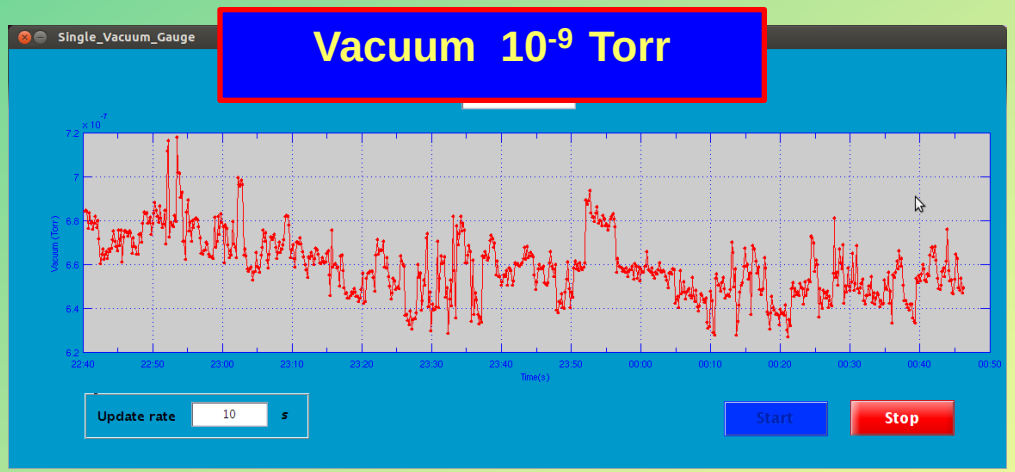
DESY type S-Band gun
1.6 cell RF gun
Freq - 3 GHz
Qual Fact – 15000
Shunt Imp 4.2 MΩ
Peak V– 100 MV/m

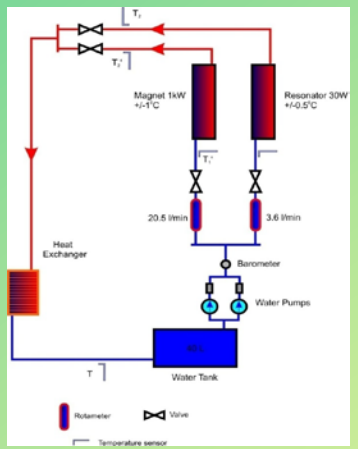
6 MW flat-top regime



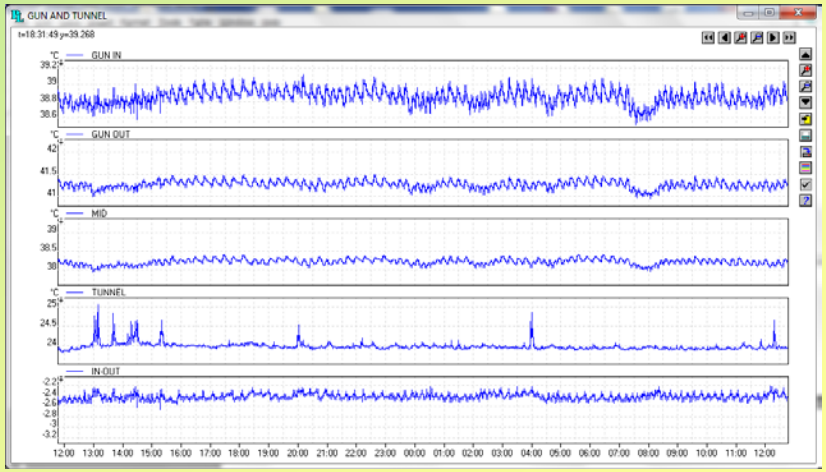


Vacuum & Cooling





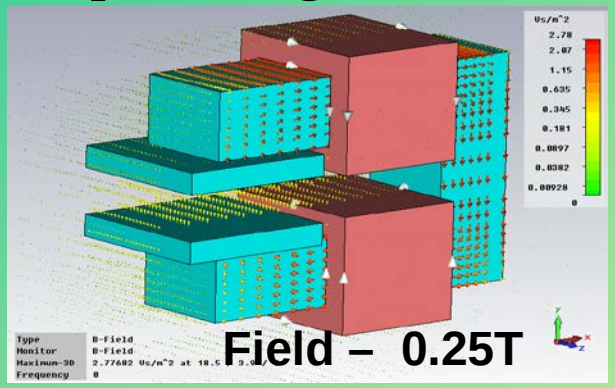
Gun Temp. stabilization- 0.1 degree



Magnets

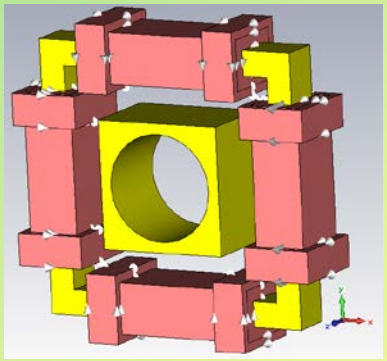
Design-Simulations- Fabrication -Measurements

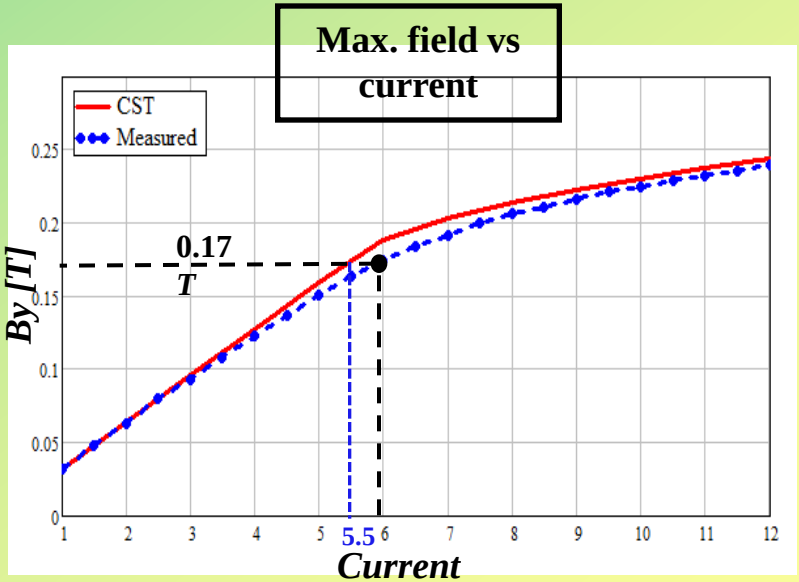
Dipole magnet



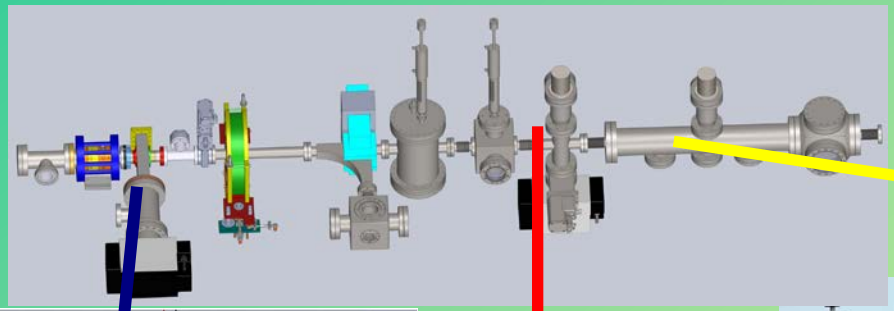
Solenoid

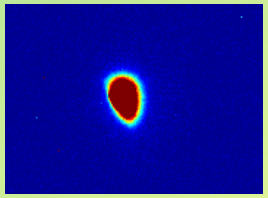
Corrector



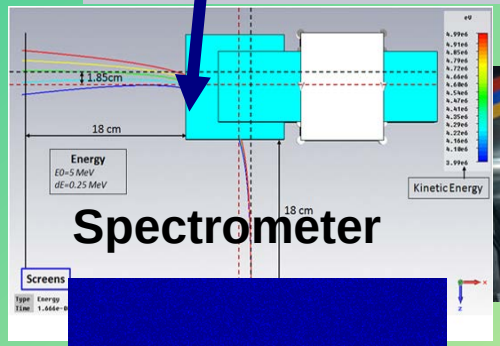


Beam Diagnostics & Control

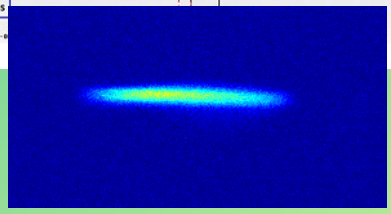


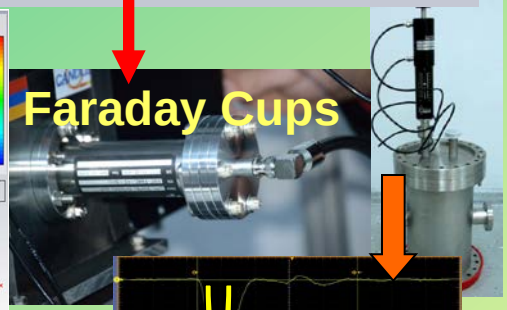


Beam Profile

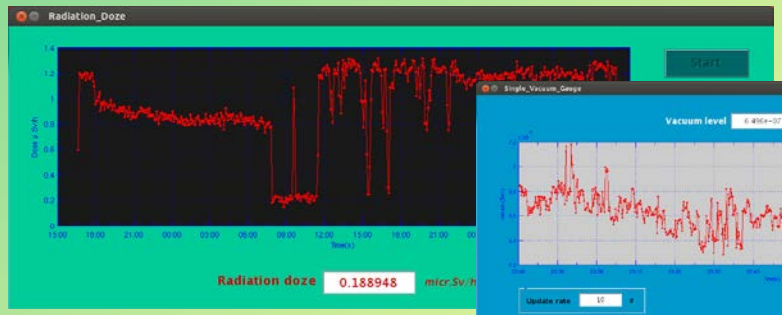


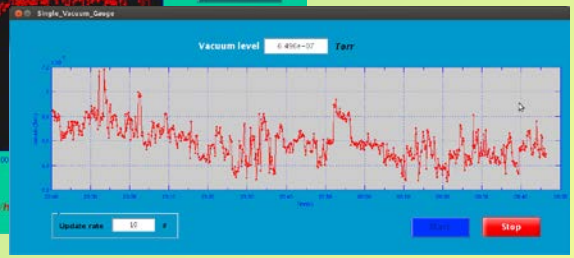
Spectrometer





Faraday Cups

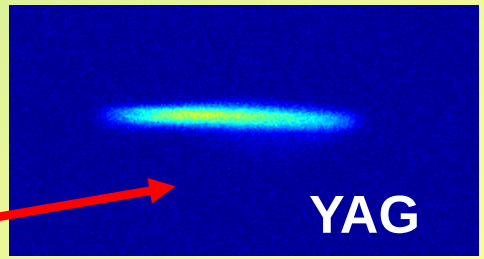


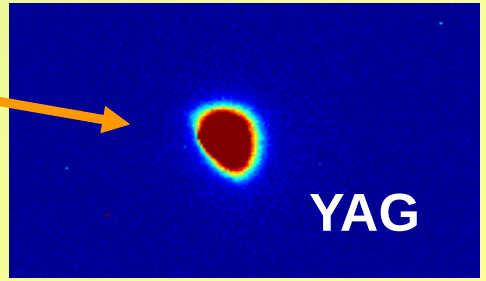


2013-2014- First Beam and Commissioning

17:32 - 20 Dec 2013 - First Beam – 36 pC charge

- Charge 20 - to 236 pC
- Energy 2.5- 4.5 MeV
- Time structure 0.3 – 8 ps
- Energy spread < 1.7%
- Beam profile (rms) 0.62 mm
- Emittance ~ 0.5 um
- Repetition rate 1-20 Hz





Sept-2015- High Charge Operation Mode (WFA)

Maintenance and Perfor. upgrade

Cathode

- Position Alignment
- Laser Spot Alignment
- Working surface cleaning

Electron Gun

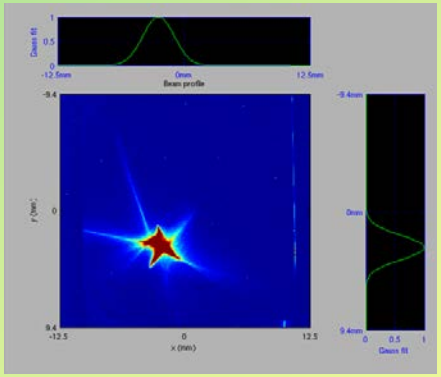
- Resonance tune by cathode position
- Conditioning for High Power RF
- Gun Temper. Stabilization upgrade

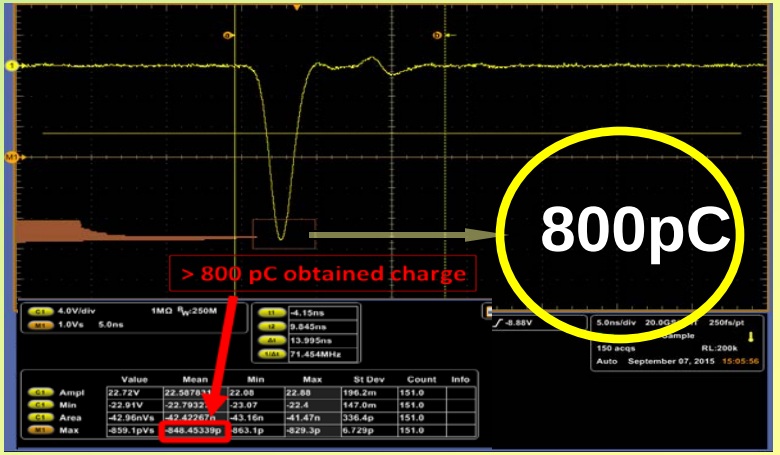
RF System

- Fine Tune of Power Components
- Timing Adjust. for better performance

HC Operation Mode

Max Energy – 4.8 MeV
Bunch charge – 800 pC
Energy Spread < 1%
Norm emittance ~0.5um





Exper. Program -Multiple applications

Advanced Concepts

- New High Freq. Structures
- Plasma based concepts
- New accel. methods
- New Radiation Sources

Accel. Technology

- New diagnostic tools
- Novel accel technology
- Ultrafast timing& Control
- New electron sources

AREAL

Applied Research

- Material Science
- Life Sciences
- Environmental Science

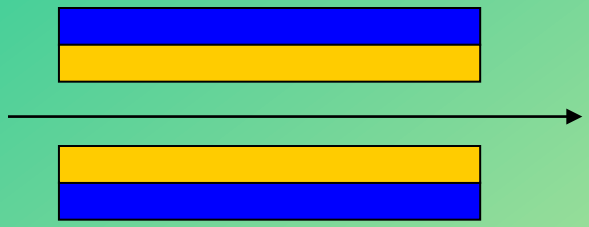
Advanced technique

- Electron Diffraction
- Pulse radiolysis
- Time-resolved exper.
- Pump-probe exper.

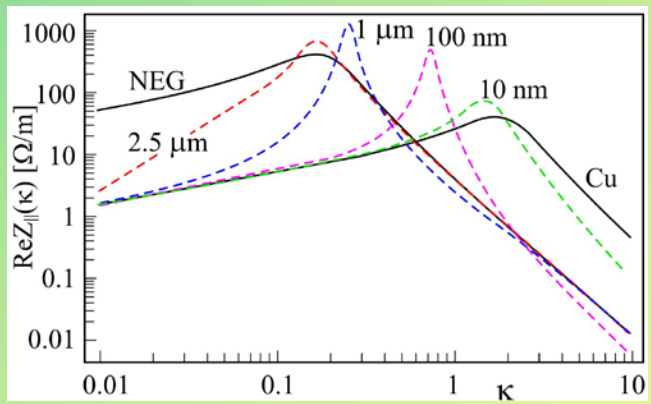
New Structures

THz Single Mode Accelerating Structure (ICTP)

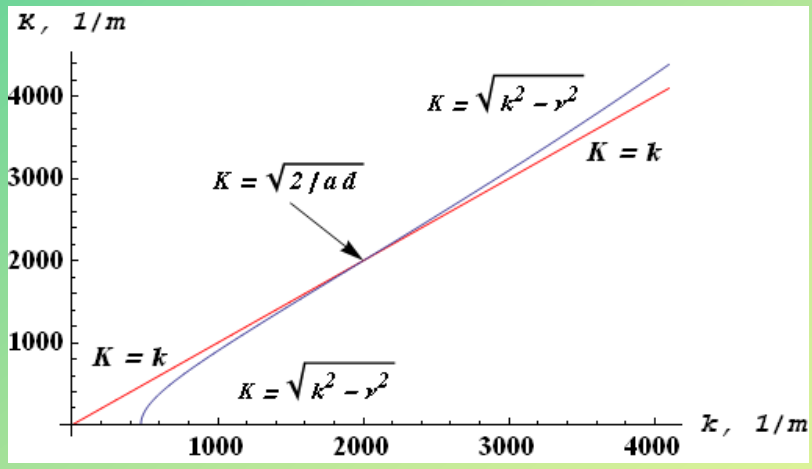
Principle proof experiment



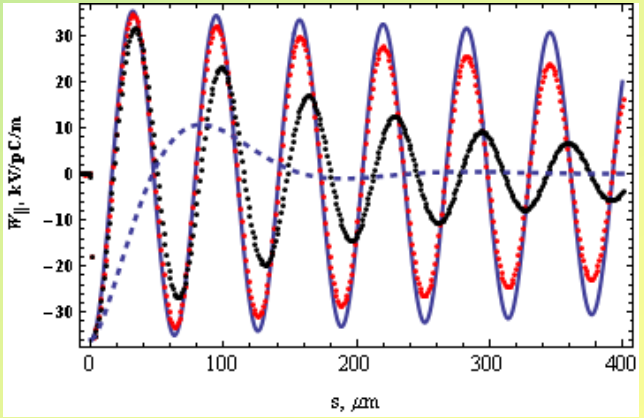
$$\omega = c / \sqrt{2ad}$$



Impedance



Dispersion Curve

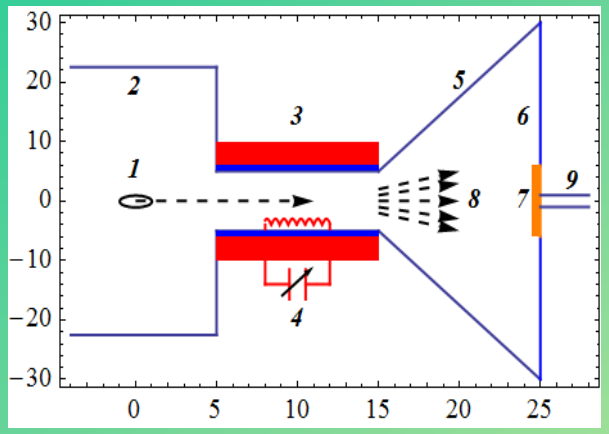


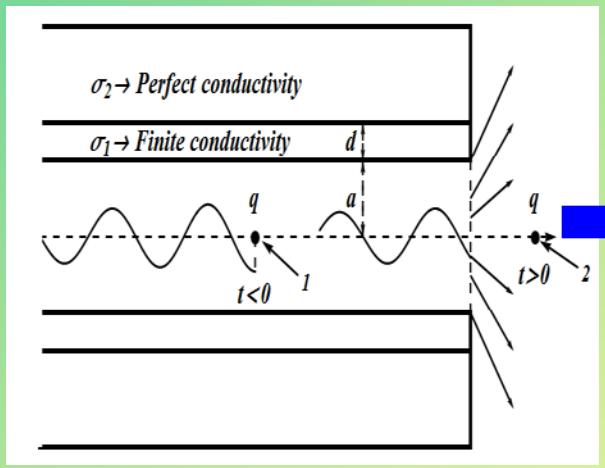
Wake potentials

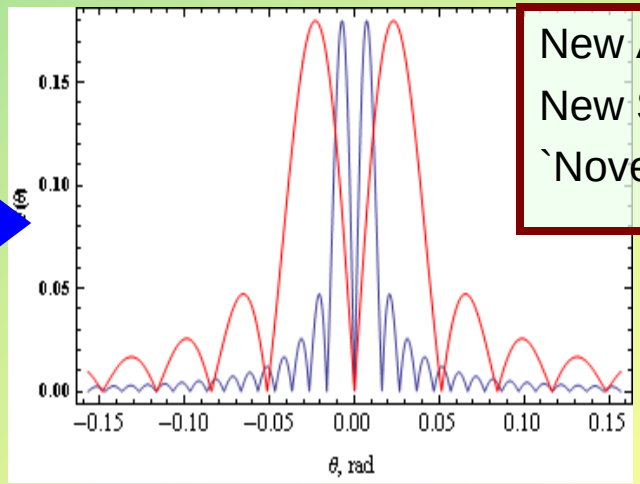
M. Ivanyan, Phys. Rev STAB 7, 114402 (2004)
M. Ivanyan et al, Phys. Rev STAB 17, 021302 (2014)
M. Ivanyan et al, Phys. Rev ST - AB 17, 074701 (2014)

Poster-170

2015-2016- Experimental Schedule







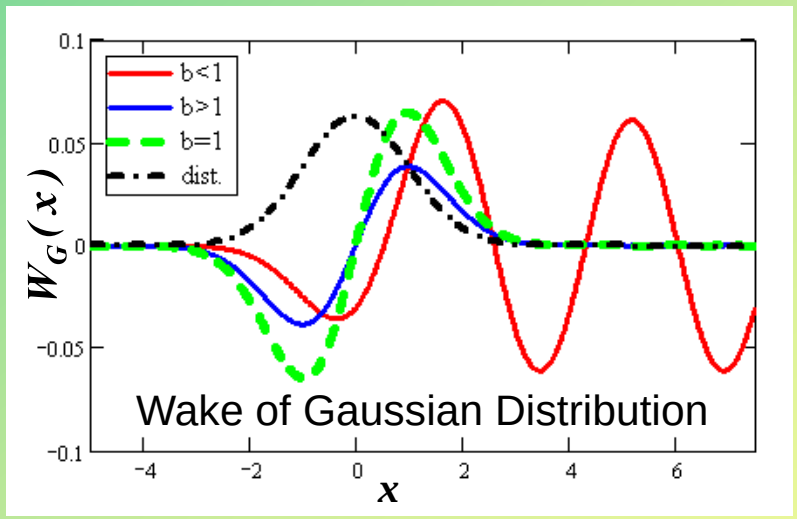
New Acceleraing Structure
New Source of THz radiation
`Novel Beam Diagnostics

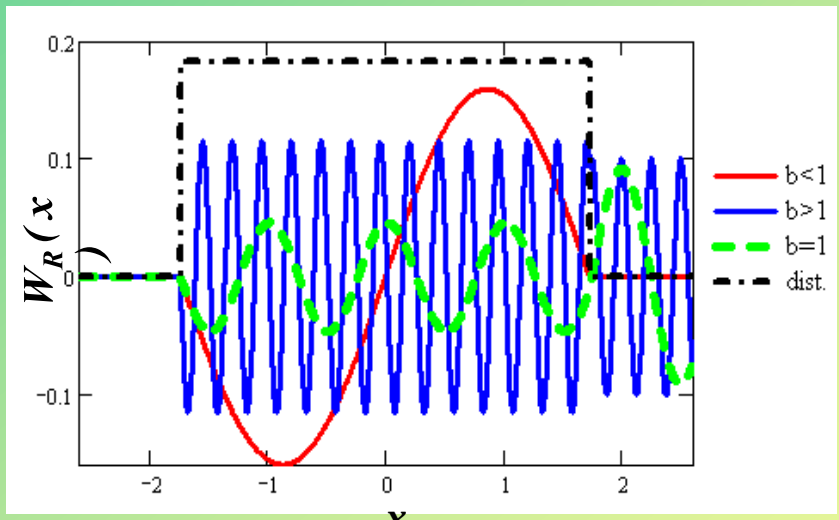
a=0.1-1cm, Frequency range – 1-5 THz

Microbunching in Single mode structure (Plasma, ICTP)

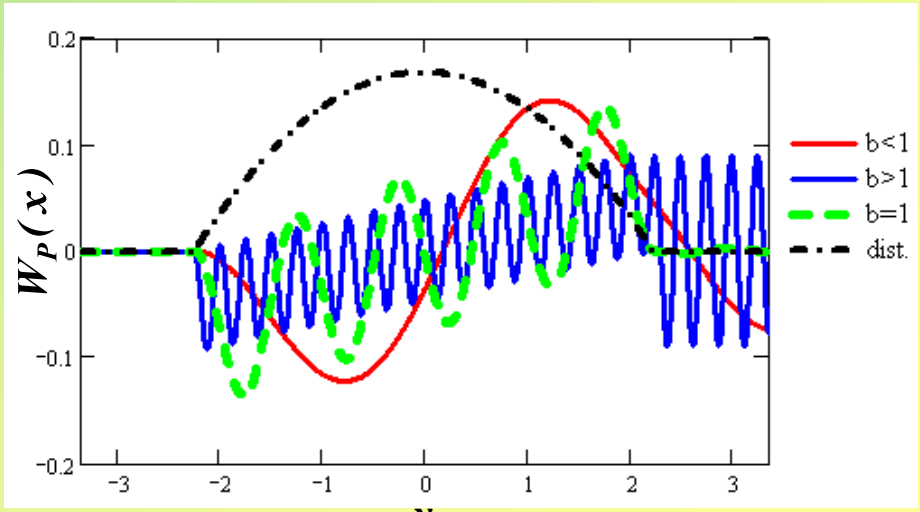
Low energy
- Energy Modulation
- Ballistic Microbunching

High energy
- Energy Modulation
- Dispersion section
- Microbunching





Wake of Rectangular Distribution



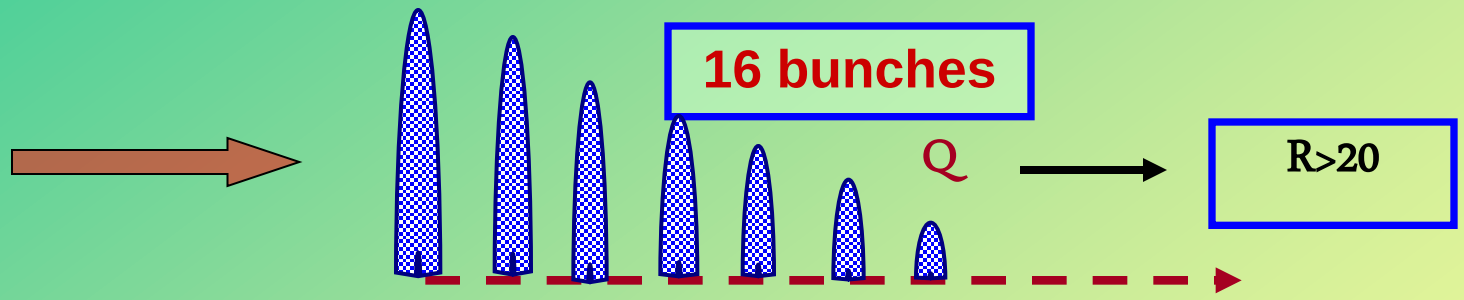
Wake of Parabolic Distribution

Advanced Accelerator Concepts – WFA

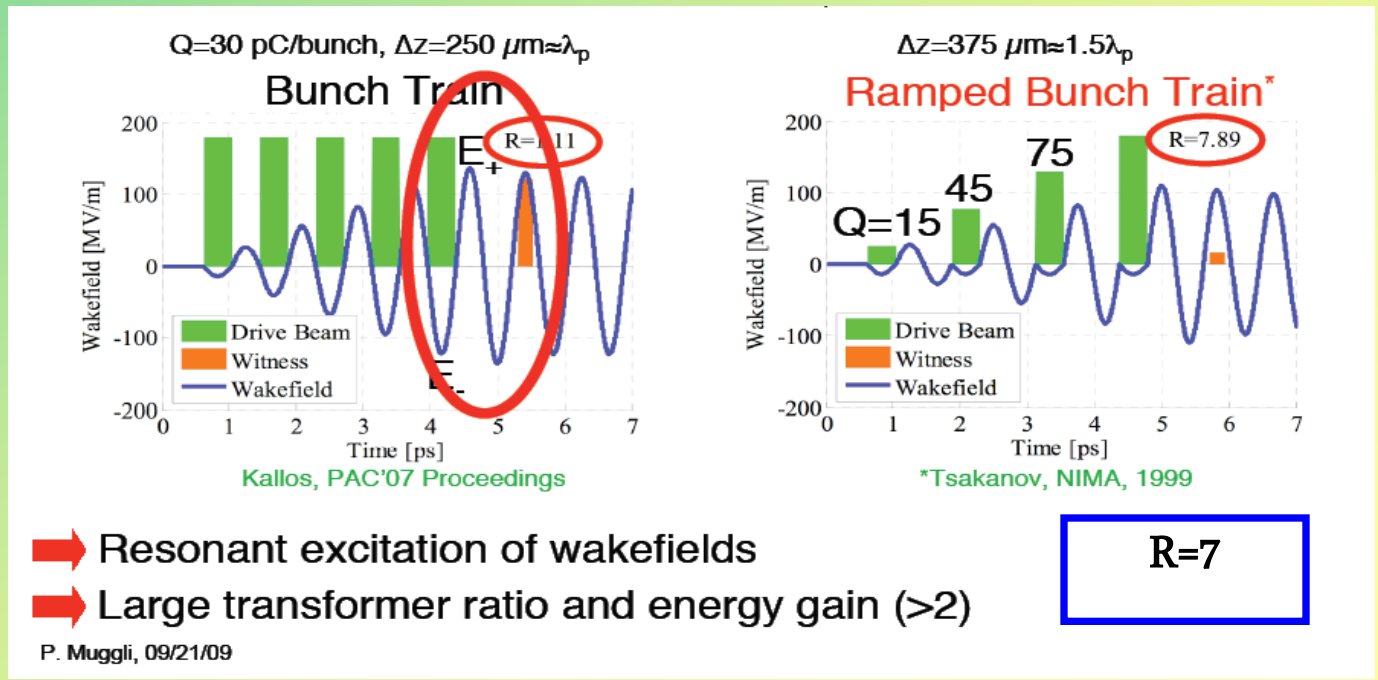
High Transformer Ratio Multi-Bunch WFA

Collinear WFA

AREAL Multi-bunch mode

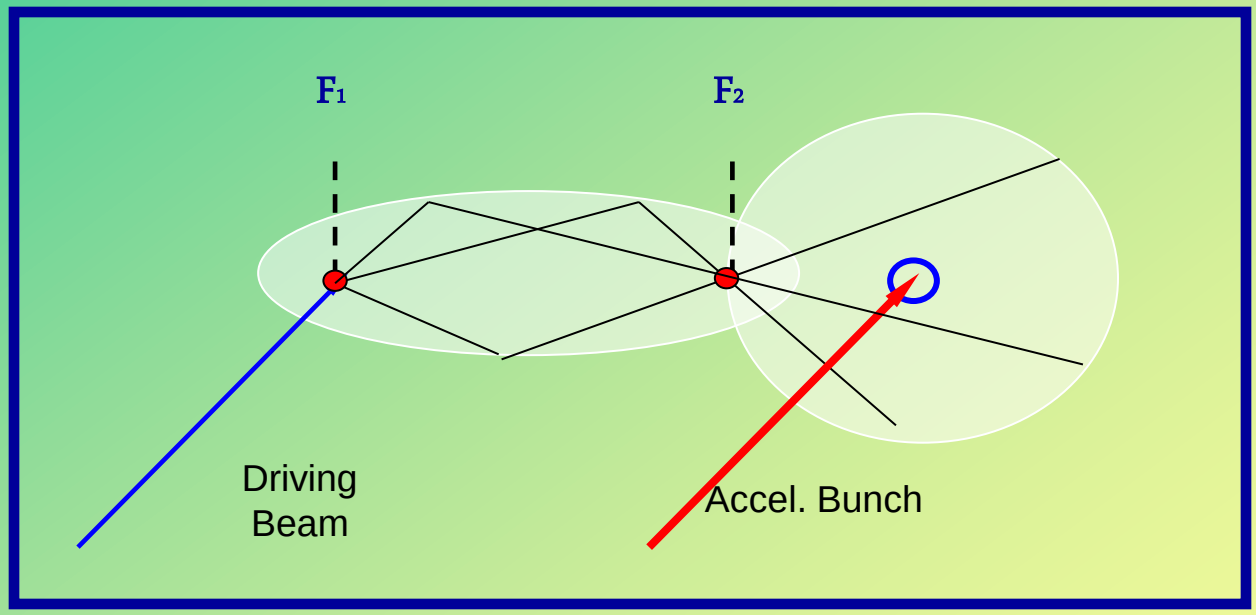


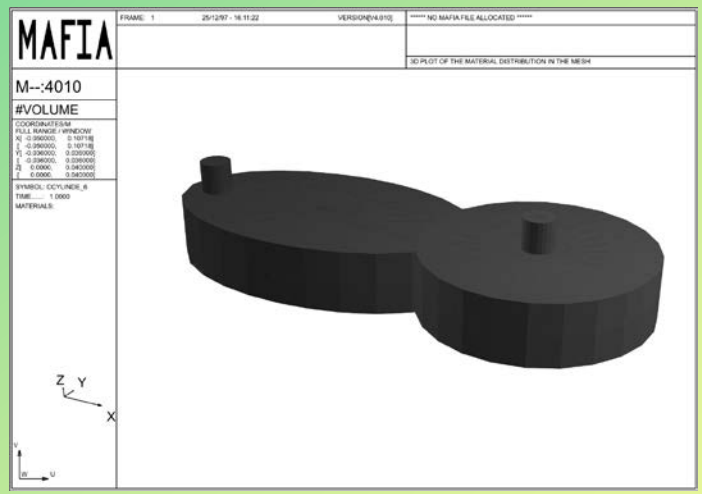
FACET (SLAC)-2012



Two-Beam WFA

Transformer –Storage Acceleration Concept





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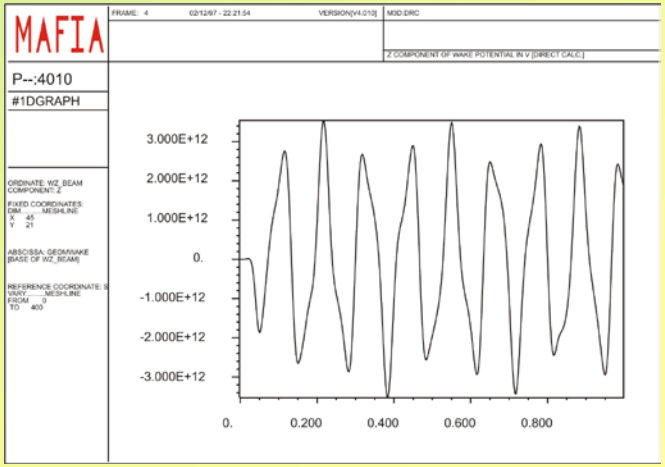
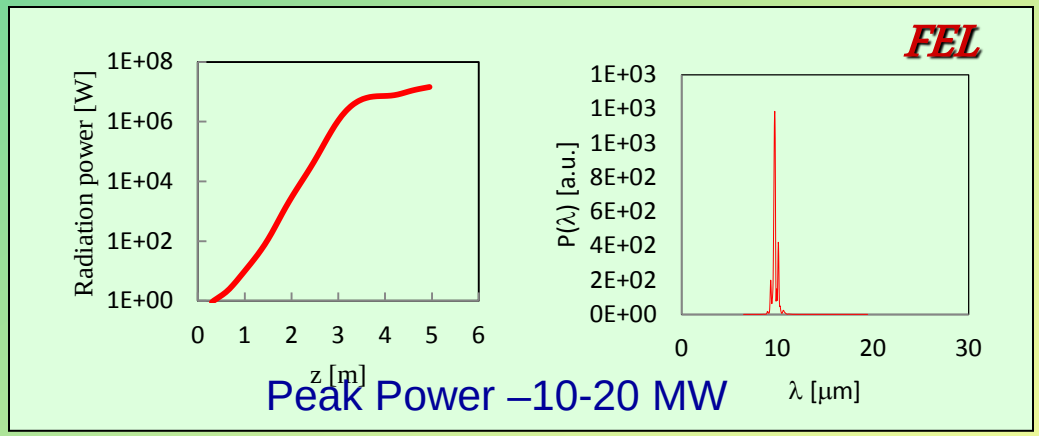


Highlights – 2015-2017

ALPHA Station – THz SASE Free Electron Laser

Wavelength –10 - 100μm



Peak Power –10-20 MW

Study of Waveguide Mode-Enhanced THz SASE FEL

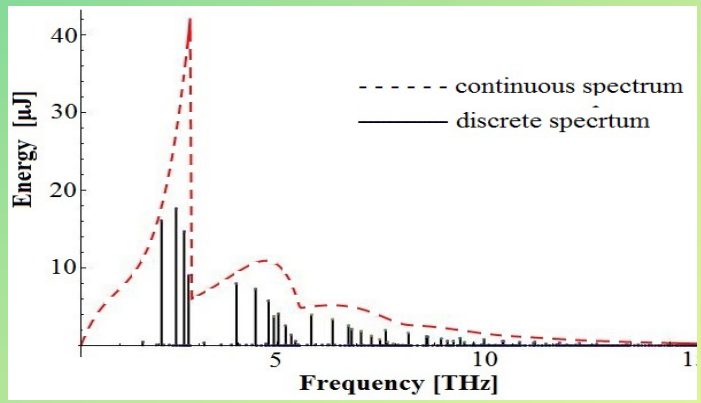


Fig. Comparison of line and discrete spectrums

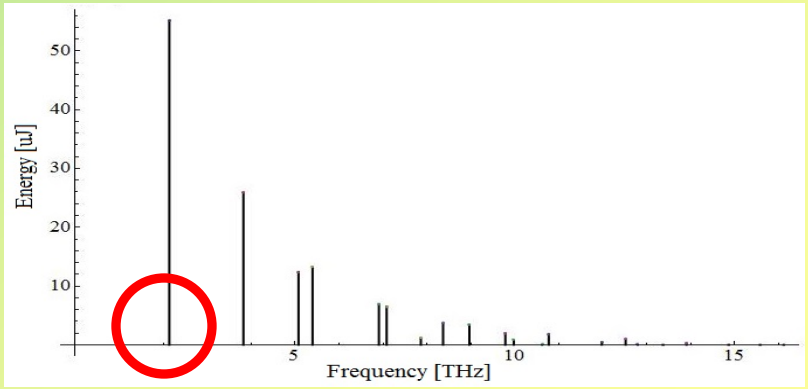
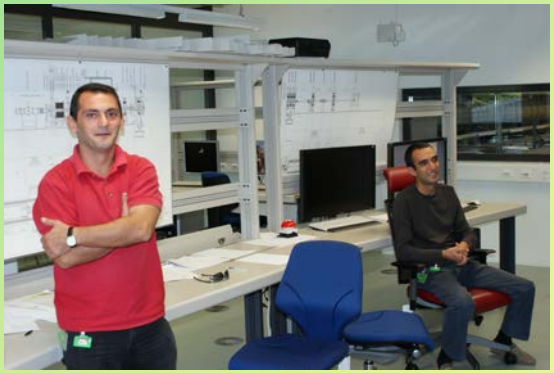


Fig Discrete energy spectrum for guide radius 0.3cm.

International Cooperation

Technical Advisory

Training

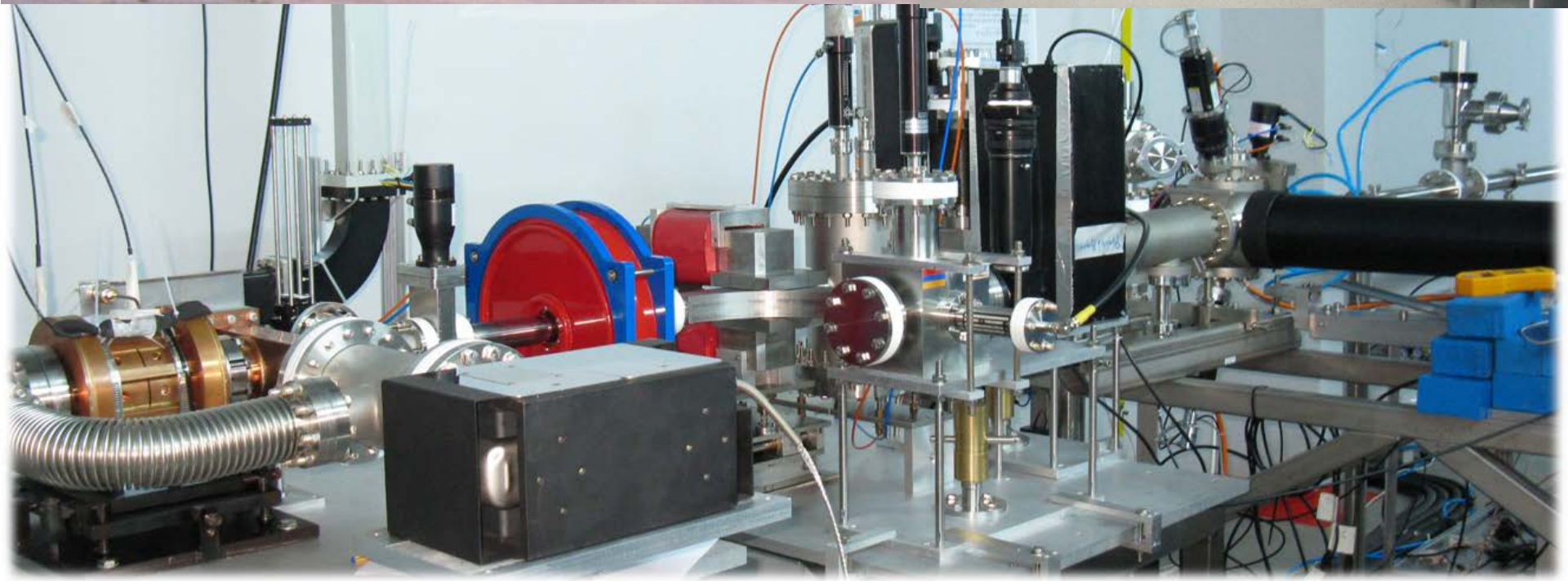


In kind Contributions

DESY – RF comp

PSI-Diagnostics

Welcome to AREAL !



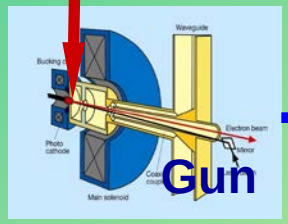
Highlights - 2015-2017

Laser

IR

UV

DELTA

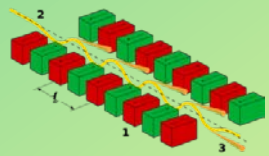


Linac

Acc1

Acc2

AREAL



50 MeV

ALPHA

BETA

Experimental Stations

DELTA – Dedicated Experimental Lines for Time-resolved Applications

Laser driven Microscopy and Microfabrication stations.

ALPHA – Amplified Light Pulse for High-end Application

A project of THZ Free Electron Laser

DESY THz Undulator

BETA – Booster for Emerging Technology Accelerators

A test stand for advanced accelerator concepts

Vacuum Evaporation