Ricerca Scientifica e Tecnologica
Ministero dell'Istruzione dell'Università e della Ricerca

REGIONE LAZIO

The SPARX project

C. Vaccarezza

on behalf of the SPARX team

ENEA C.R. Frascati

Consiglio Nazionale delle Ricerche

UNIVERSITA' degli STUDI di ROMA TOR VERGATA

INFN Istituto Nazionale di Fisica Nucleare

Outline:

- Introduction
- The project goal
- The 1-2 GeV Linac options for 13.5-1.5nm source
- First s2e simulation results
- Project schedule & cost estimation

The SPARX Project

- ✓ 2001 proposal submitted to MIUR
- ✓ 2003 approved from MIUR
- ✓ 2005 partial funding of the project :
- ✓ 10+10 M€ (R&D activity⟹Sparxino proposal)

- ✓ 2006 decision from Regional Government of Lazio to support the construction of the
- ✓ SPARX-FEL in two phases.

The project goal is a X-ray FEL facility for:

- Genoma functional and structural characterization studies by molecular crystallography with atomic length resolution.
- Time resolved X-ray diffraction spectroscopy
- Time resolved chemical reaction studies (pump & probe technique)
- Phase transition studies outside the thermodynamic equilibrium condition
- more and more..

Scientific case

- "*Time resolved X-ray microscopy*", D. Pelliccia, CNR-INFN
- *"Image reconstruction of non periodic nanostructured objects using coherent X-ray diffraction (CXD)"* , G. Campi, CNR-IC
- "*Proprietà ottiche del "mezzo vuoto" a corte lunghezze d'onda*" G.Cantatore Uni-TS
- *"Low energy X-rays QED tests"*, M. Milotti Uni-UD
- *and more on* **Radiation Transport, Diagnostics, Beam Handling, Detectors and Ultrashort Radiation Pulses**

FOR MORE INFO...

http://www.lnf.infn.it/conference/sparx05/

..objectives:

- Input from the workshop:

  Wavelength range as close as possible to the water window (~ 2.5 – 4.5 nm)

  ... and to the carbon window

..objective

- Input from the worksh

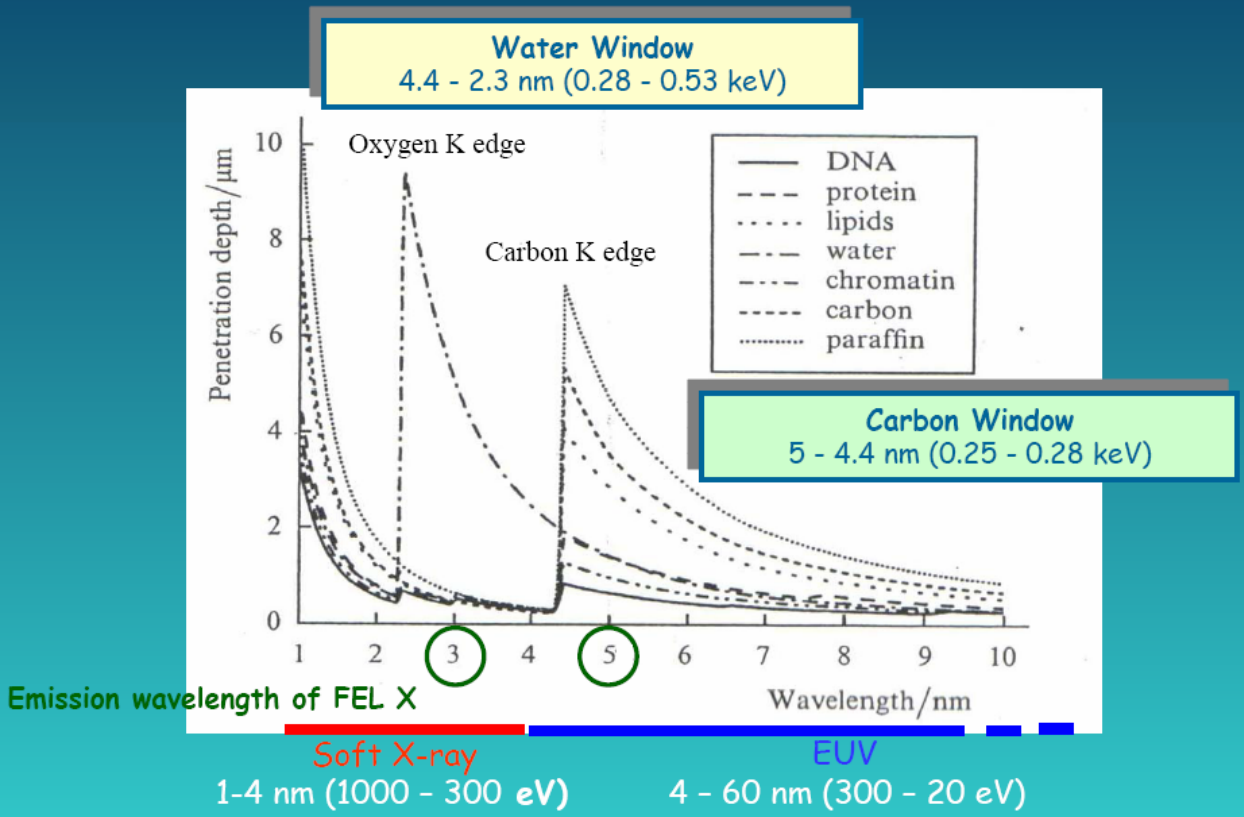
  Wavelength range as possible to the water w (~ 2.5 – 4.5 nm)

  ... and to the carbo

- Flexible design:

  SASE & Seeded configurations

Penetration depth in water and in biological material



F. Bonfigli *et al, SPARX workshop, LNF 9-10 May 2005*

SPARX Project phases:

- 1 GeV Linac to drive SASE and seeded FEL experiment in the wavelenght range:

$$6nm < \lambda < 13.5nm$$

- 2 GeV Linac to reach:

$$1.5nm < \lambda < 6nm$$

Electron Beam parameters

Beam Energy	1-2	GeV
Peak current	1-2.5	kA
Emittance (average)	2	mm-mrad
Emittance (slice)	1	mm-mrad
Energy spread (correlated)	0.1	%

Site map


Map
Satellite
Hybrid
SPARX
UNIVERSITA' degli STUDI di ROMA
TOR VERGATA
Via Angelo Bianchi
Viale della Sorbona
Via del Politecnico
Via Cambridge
Viale Heidelberg
Via di Tor Vergata
Via Salamanca
Via Cracovia
Via Columbia
Via Berkeley
Via di Passolombardo
Via Antonio Carpenè
Via Gioacchino Loreti
Via Pietro Pacchiotti
Viale dell'Archiginnasio
Via Erchie
Via Bovino
Via del Torraccio
Via Stanford
Via Rodolfo Crespi
Via Bernardino Alimena
Via Sante Vandi
Viale Luigi Schiavonetti
Via Sandro Penna
Diramazione Roma Sud
A1dir
Roma Sud
Consiglio Nazionale delle Ricerche
A24
Ciampino
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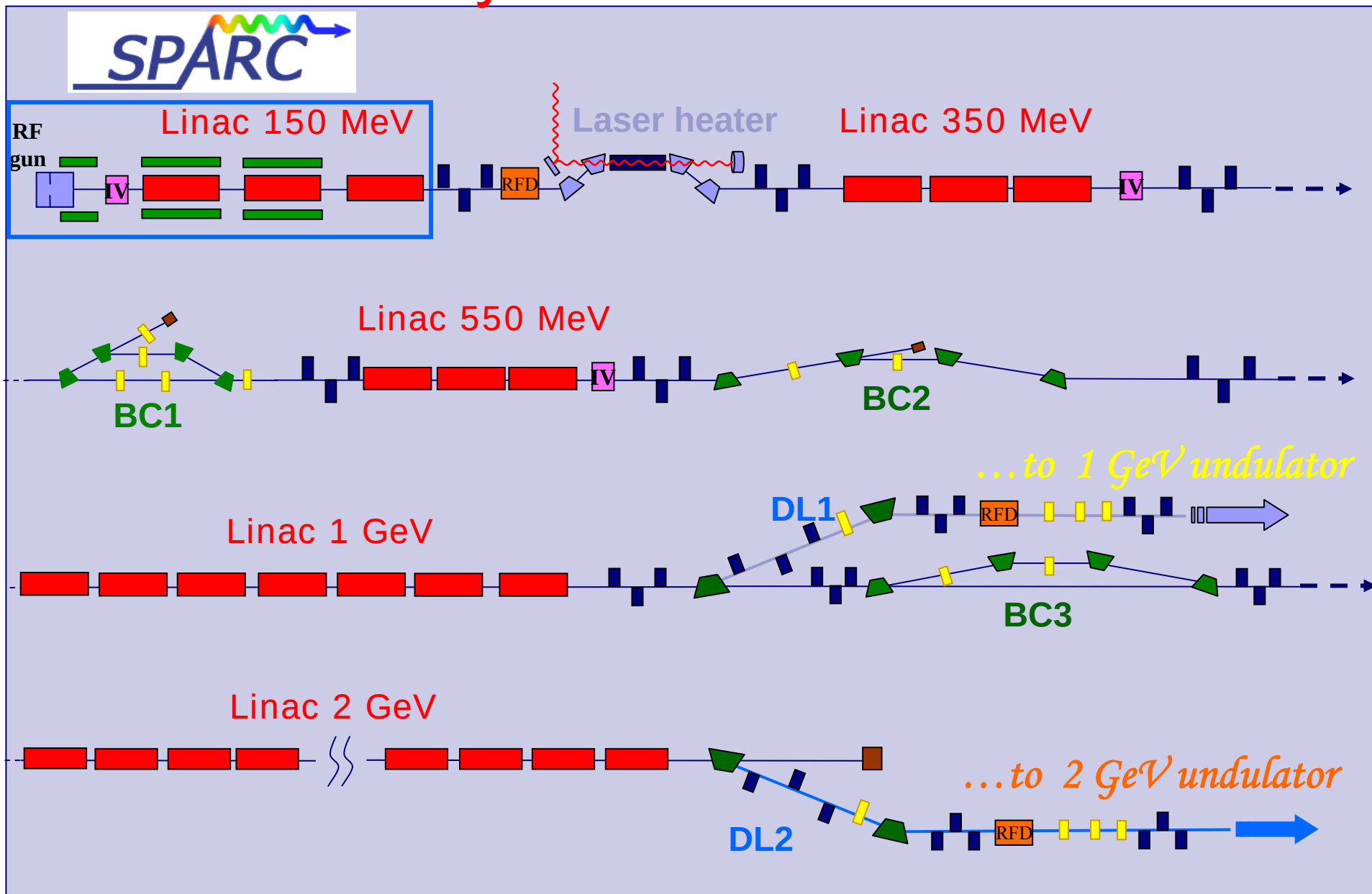
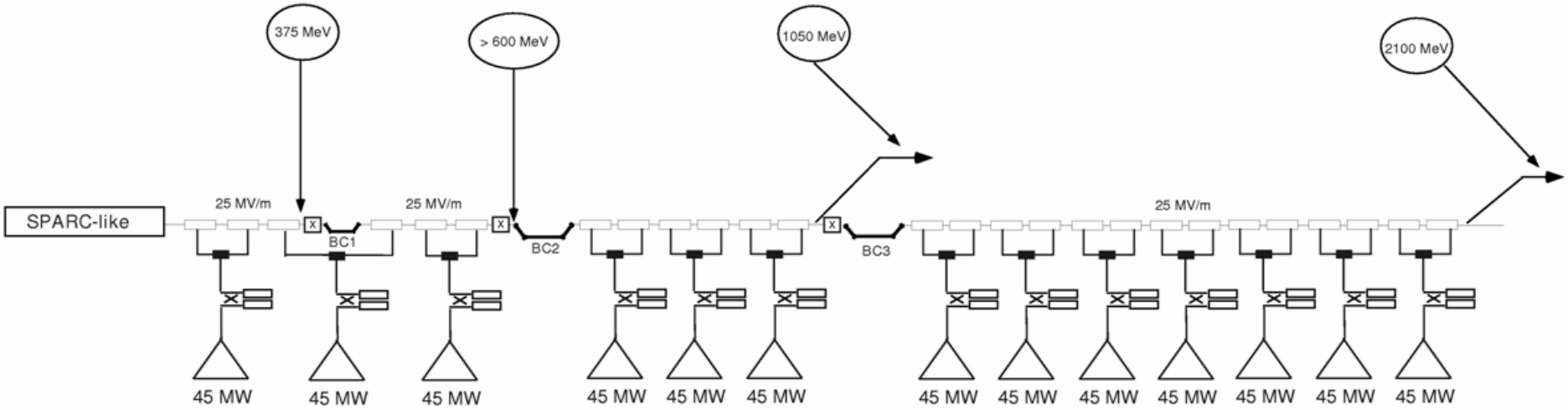
Schematic layout 1-2 GeV

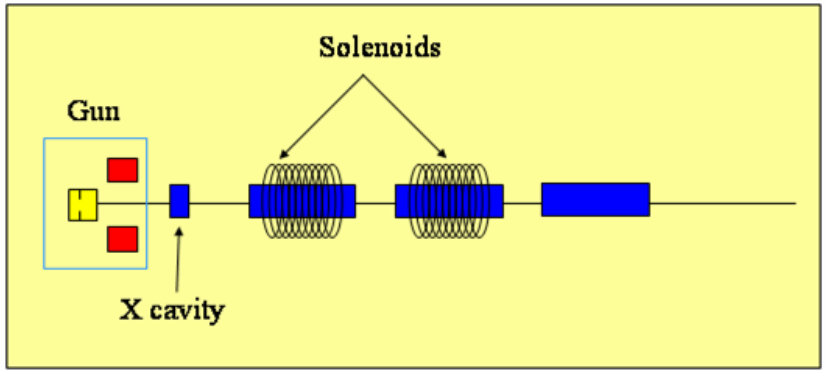


RF schematic layout

SPARX-TV 2GeV



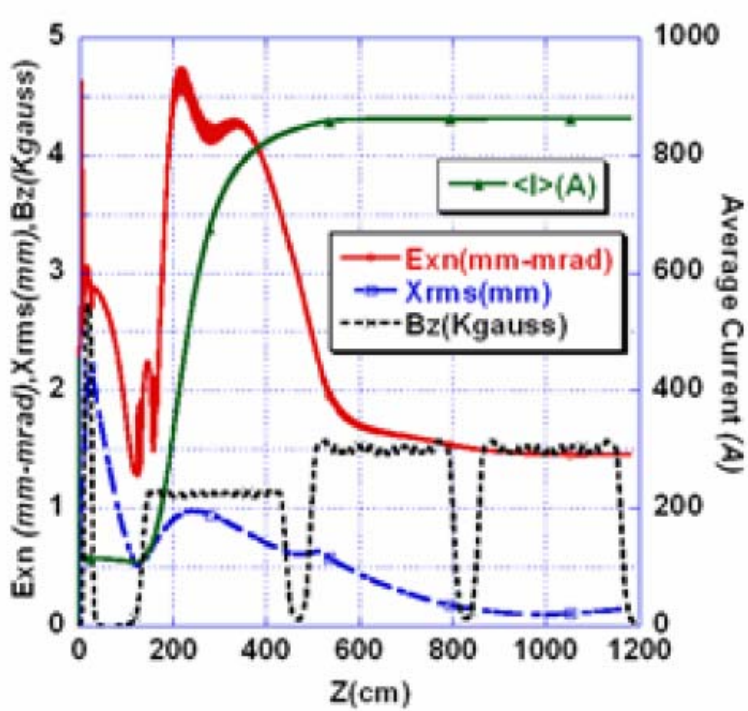
From the SPARC photoinjector:



Schematic layout of the SPARX photoinjector

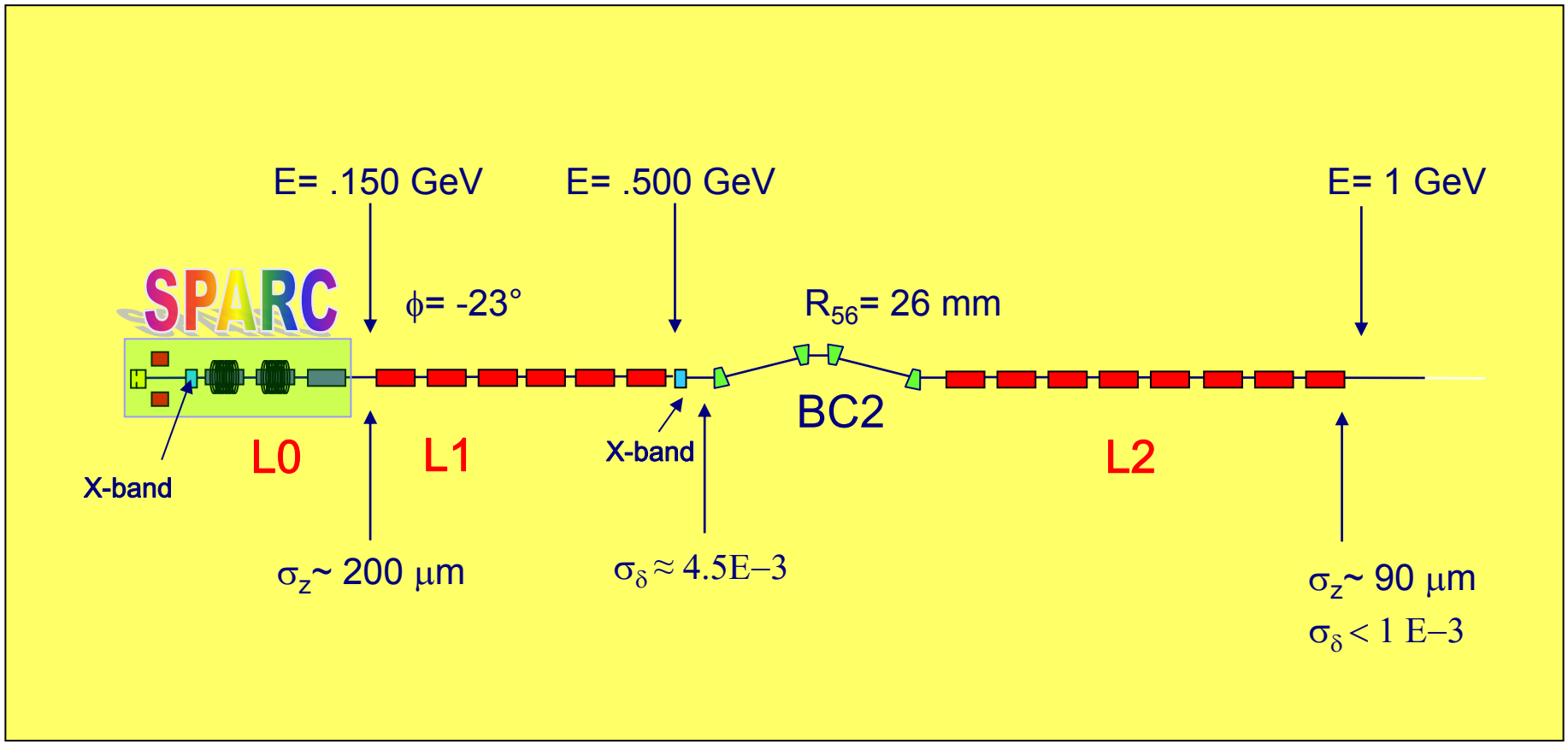
RF compressor Phase range	B1,B2,B3 (gauss)	Current (A)	Max. Emittance (mm)
-60°/-75°	1200,0,0	117-151	0.7
-75°/-83°	1200,1400,0	151-249	0.8
-83°/-87°	1200,1400,0	249-458	1.3
-87°/-91°	from 1200 to 1800	458-1180	2.8

(C. Ronsivalle *et al*, PAC05, Knoxville TN)

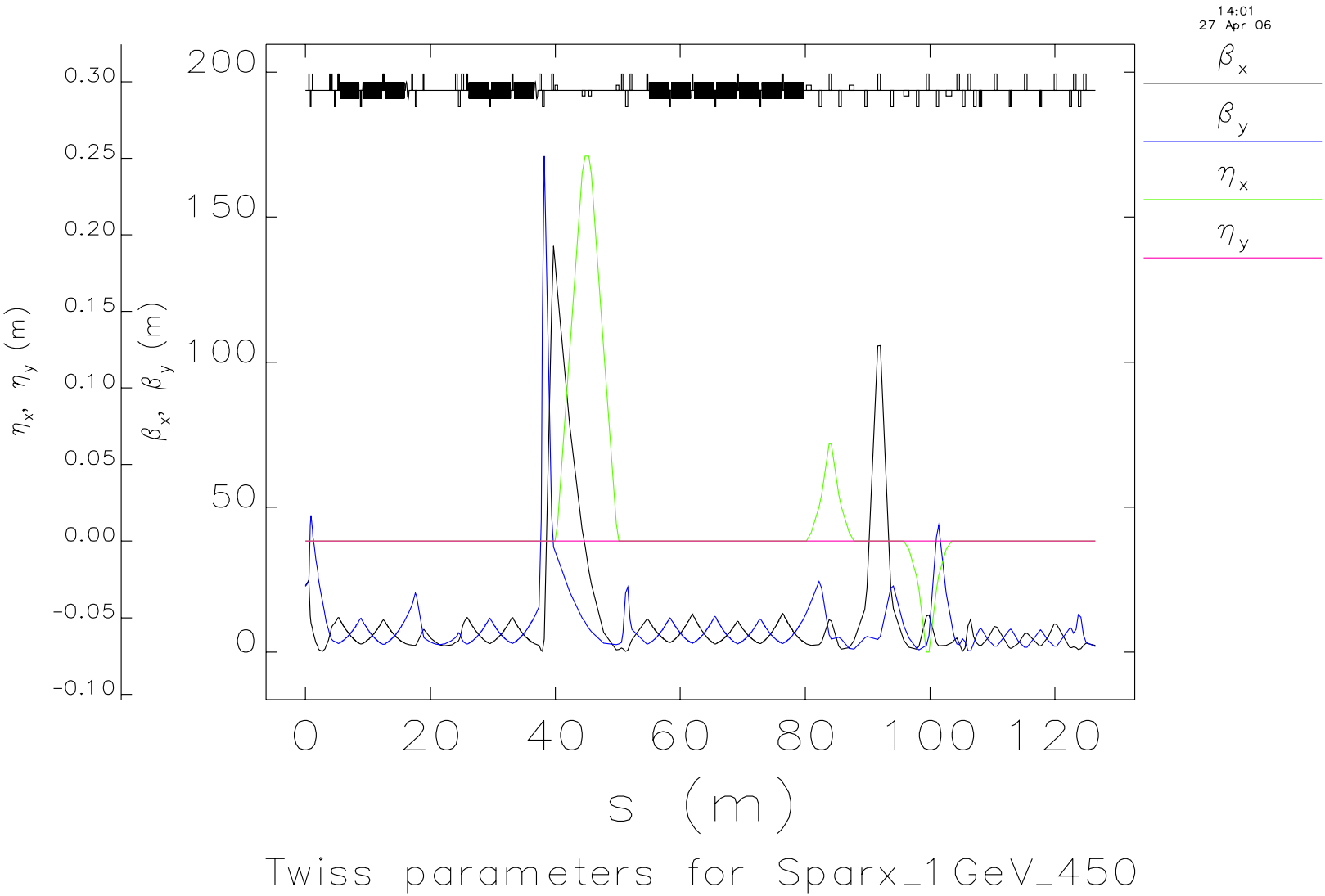


Peak current, normalized projected emittance, beam envelope and solenoid field map for the example compressor working points . (Parmela code , Np=200k)

Schematic layout for the 1 GeV phase:



Twiss parameters for the 1 GeV channel



The BC2 compressor:

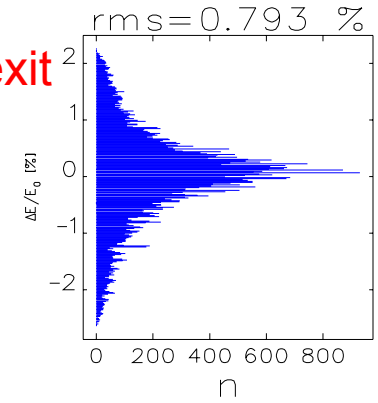
Parameter	Symbol	Unit	Value
Beam Energy	E	GeV	0.5
Initial rms bunch length	σ_{zi}	mm	210
Finale rms bunch length	σ_{zf}	mm	87
Rms total incoming energy spread	σ_{δ}	%	.45
RMS uncorrelated relative energy spread	$\sigma_{\delta u}$	10^{-5}	0.6
Momentum compaction	R_{56}	mm	26
Total chicane length	L_{total}	m	7.4
Length of each dipole magnet	L_B	m	0.25
Length of drift between 1st and last two dipoles	ΔL	m	3.0
Length of drift between center two dipoles	ΔL_c	m	0.40
Bend angle of each dipole	$\lvert\theta_B\rvert$	deg	3.66
Maximum dispersion	$\lvert\eta_{max}\rvert$	m	.25

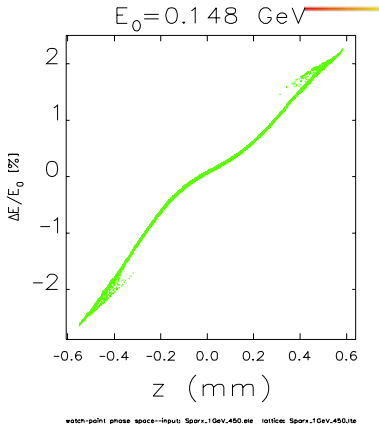
The DL1 dogleg:

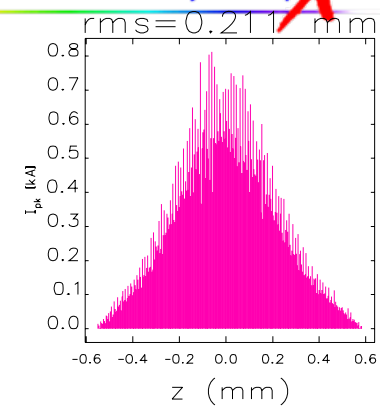
Parameter	Symbol	Unit	Value
Beam Energy	E	GeV	1.
Total horizontal beamline deflection	Δx	M	.46
Nominal rms bunch length	σ_z	μm	90
Rms core relative energy spread	σ_δ	%	<.1
Net momentum compaction	R_{56}	mm	0
Length of each dipole magnet	L_B	m	.80
Bend angle of each dipole magnet	$\lvert\theta_H\rvert$	deg	.80
Length of drift between center two dipoles	ΔL_c	m	0.40
Maximum dispersion	$\lvert\eta_{max}\rvert$	m	.25

Elegant code results for the example beam and 1 GeV Linac

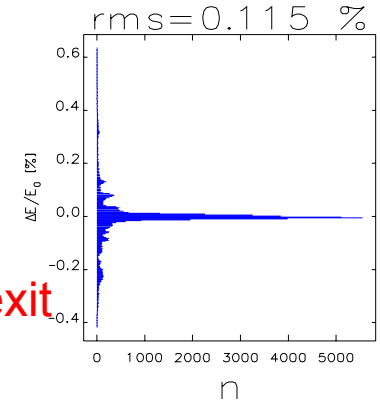
Photoinjector exit

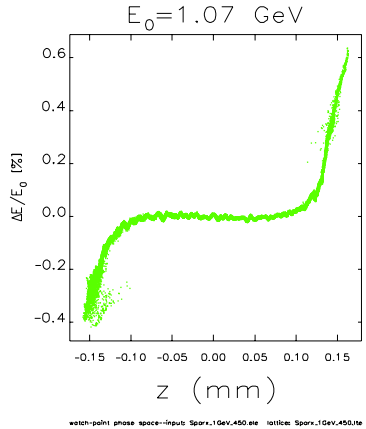


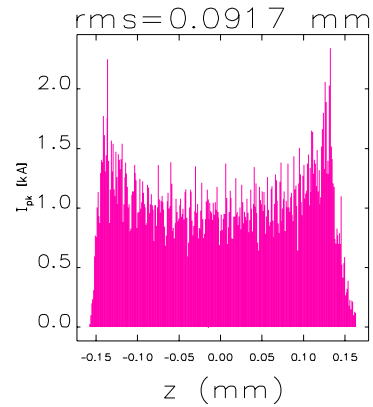




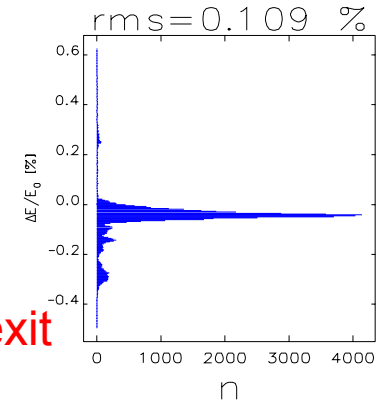
Linac exit

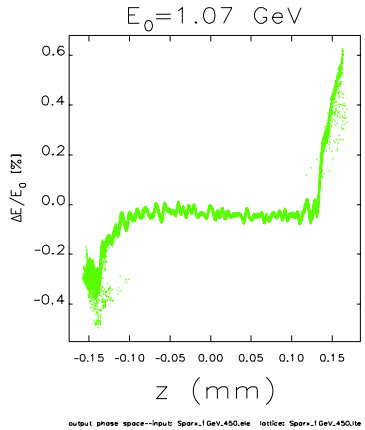


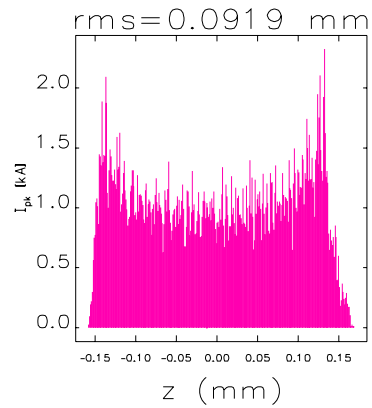




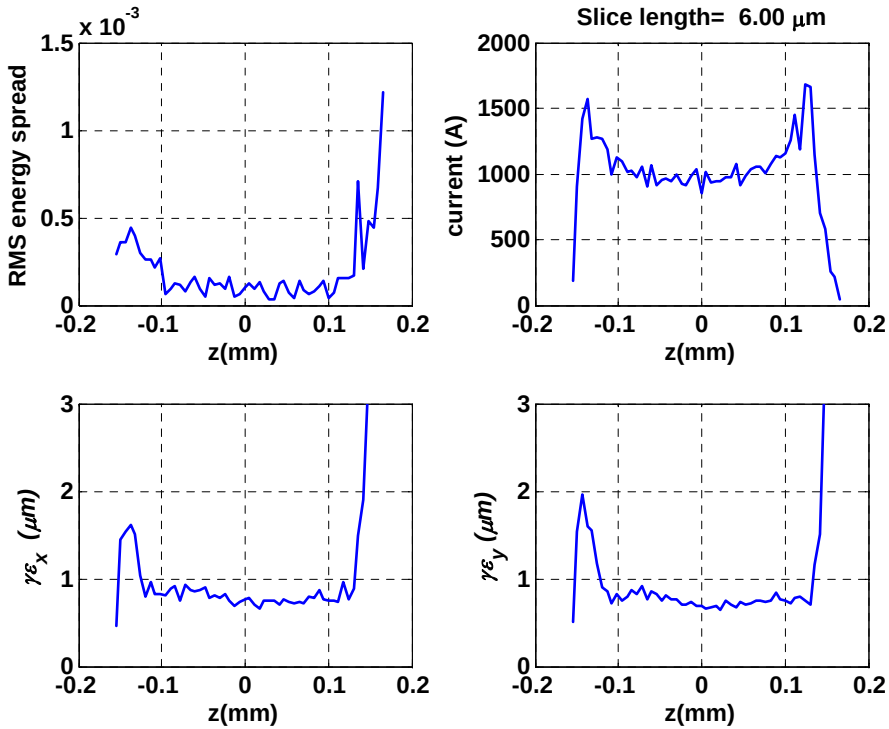
Dogleg exit

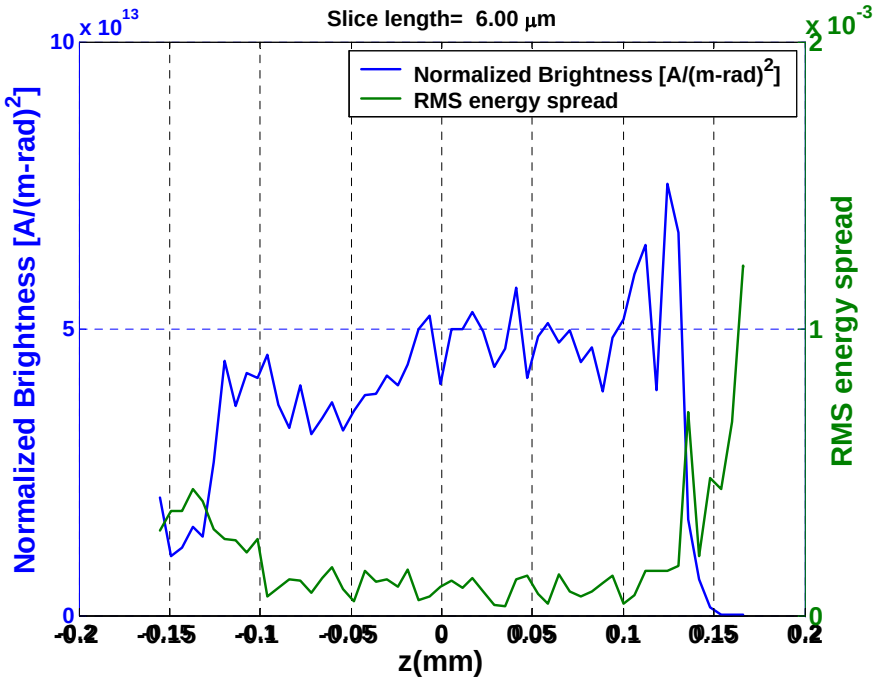




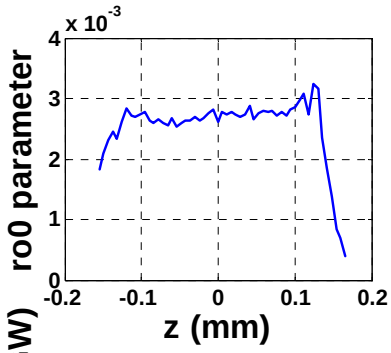


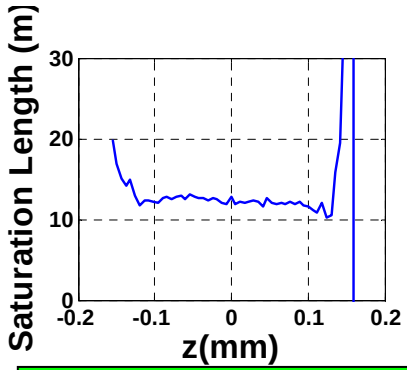
Slice analysis:

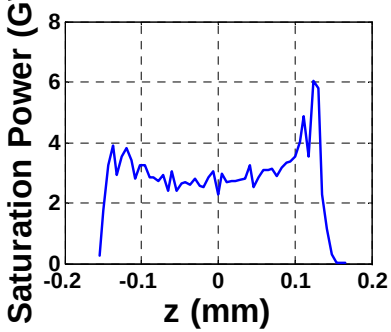




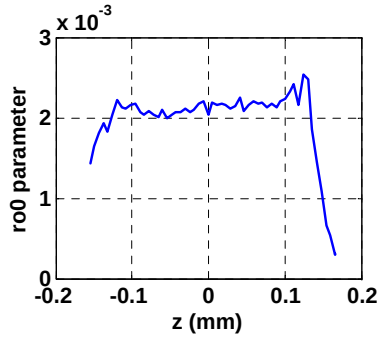
SASE performance E=1 GeV

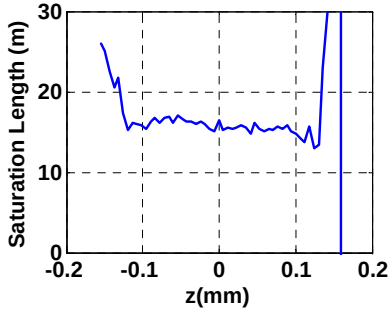


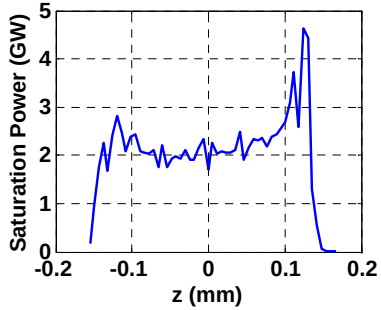




Wavelength= 10.0 nm
Undulator K= 2.055
Undulator period= 2.800 cm
Pmax= 6.022 GW
rms pulse length= 89.292 um
rms pulse length=297.847 fsec
saturation length= 24.000 m
e-beam efficiency= 96.825%
e-beam peak current= 1.681kA

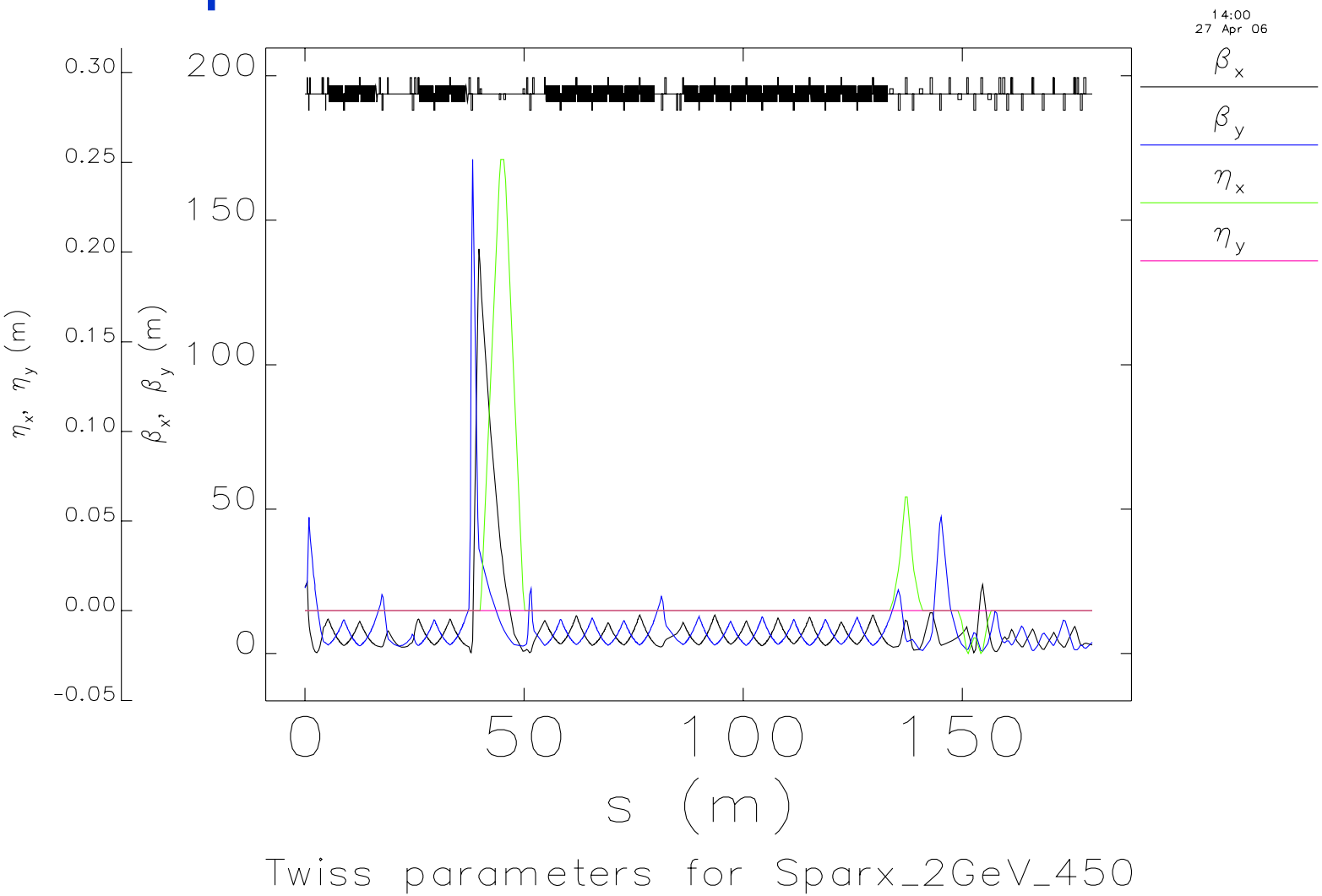




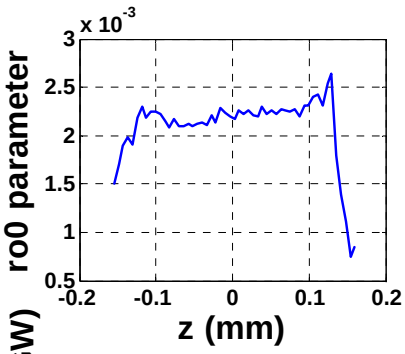


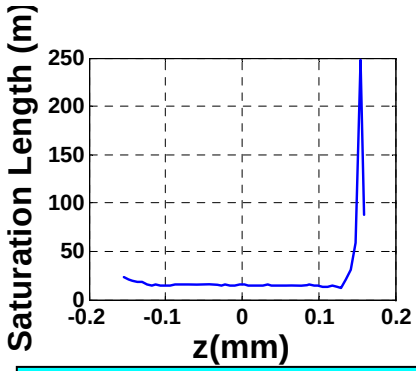
Wavelength= 6.0 nm
Undulator K= 1.317
Undulator period= 2.800 cm
Pmax= 4.637 GW
rms pulse length= 86.232 um
rms pulse length=287.638 fsec
saturation length= 24.000 m
e-beam efficiency= 92.812%
e-beam peak current= 1.681kA

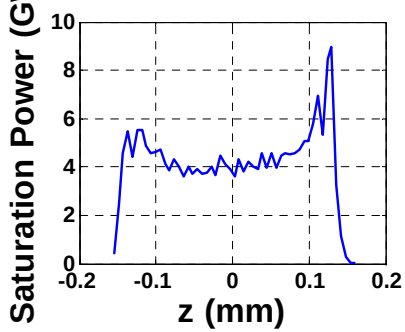
Twiss parameters for the 2 GeV channel



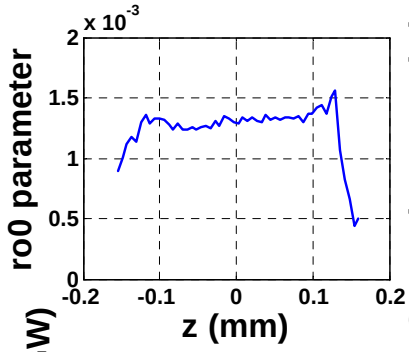
SASE performance E=2 GeV

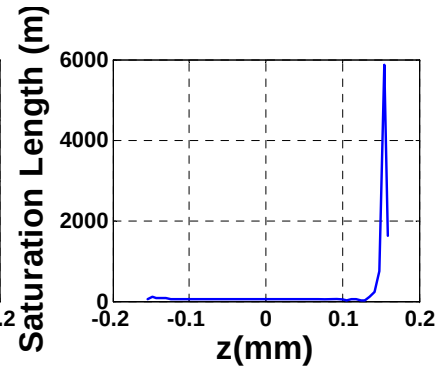


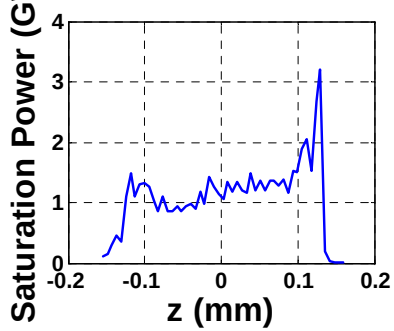




Wavelength= 5.0 nm
Undulator K= 3.063
Undulator period= 2.800 cm
Pmax= 8.975 GW
rms pulse length= 89.027 um
rms pulse length=296.962 fsec
saturation length= 44.000 m
e-beam efficiency= 96.761%
e-beam peak current= 1.692kA

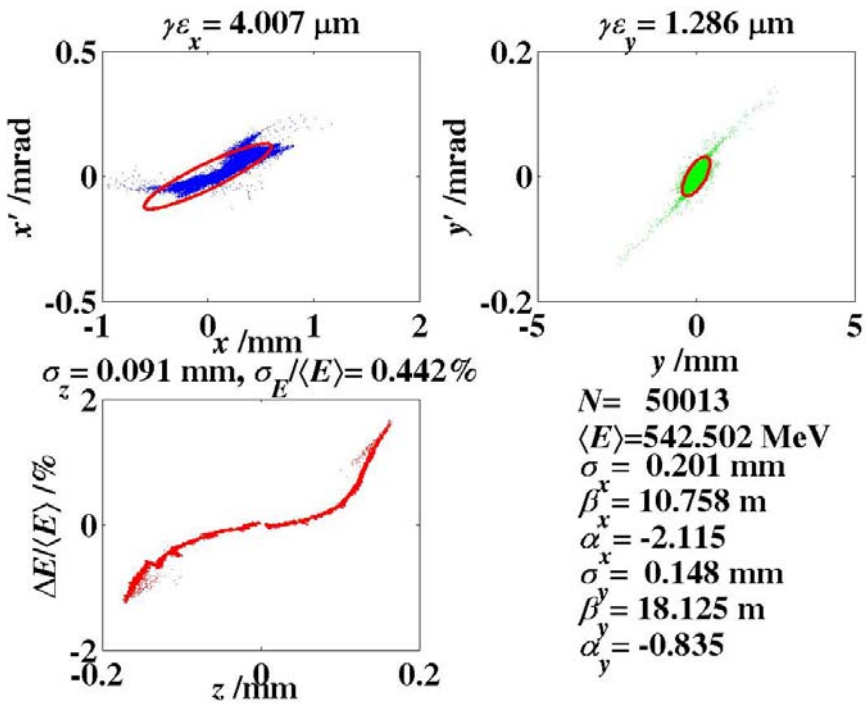


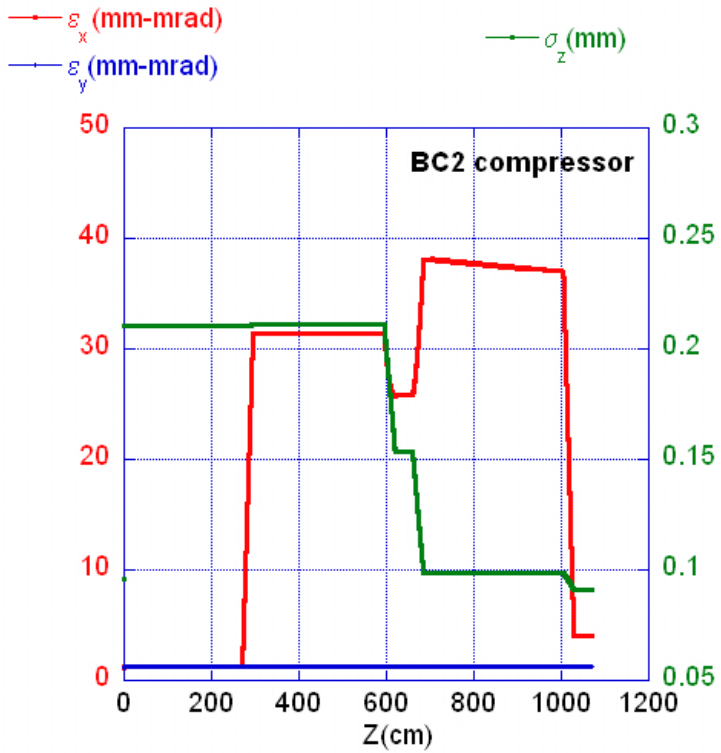




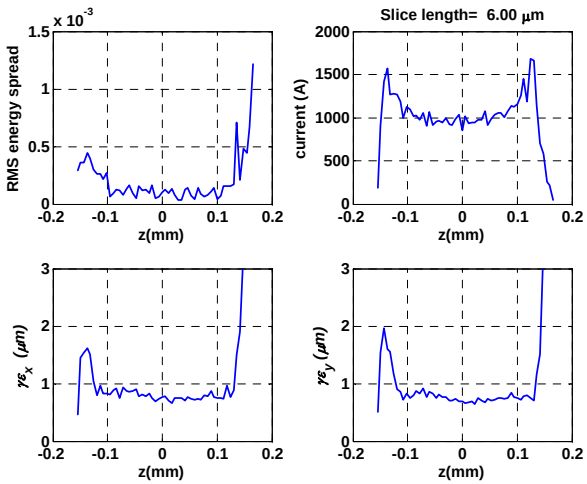
Wavelength= 1.5 nm
Undulator K= 1.190
Undulator period= 2.800 cm
Pmax= 3.207 GW
rms pulse length= 77.033 um
rms pulse length=256.956 fsec
saturation length= 44.000 m
e-beam efficiency= 81.620%
e-beam peak current= 1.692kA

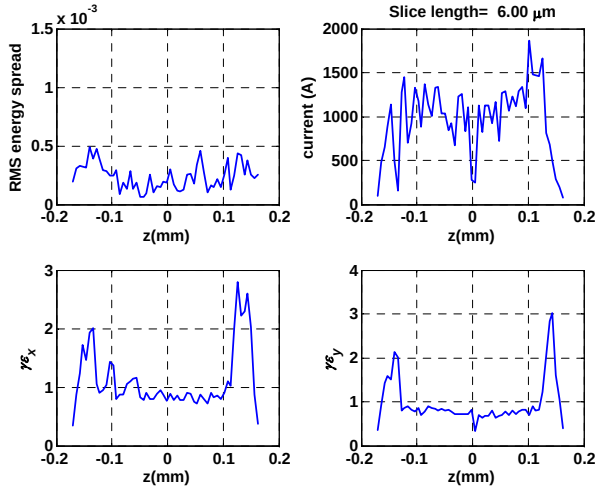
First results with space charge & CSR from Parmela





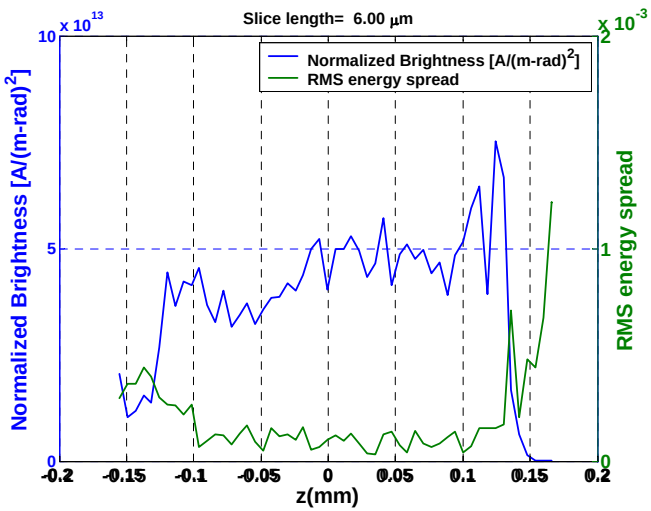
..tracking the beam up to 1 GeV:

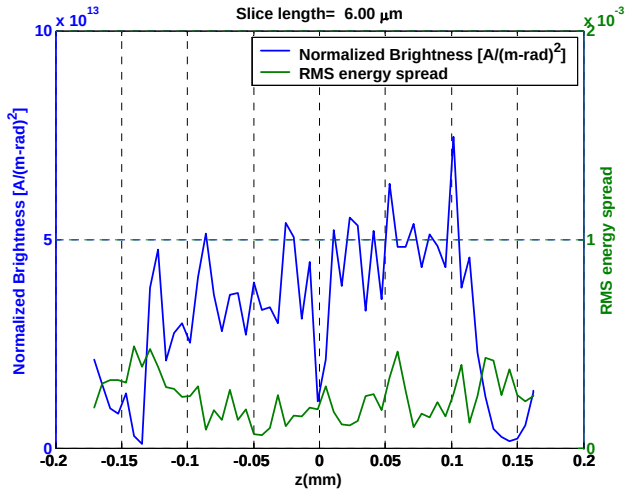




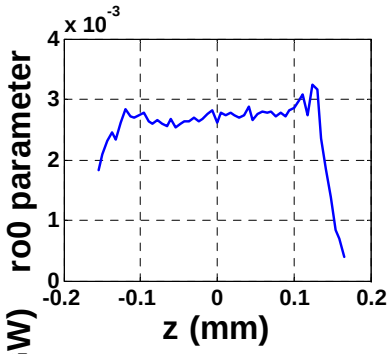
CSR only in BC2

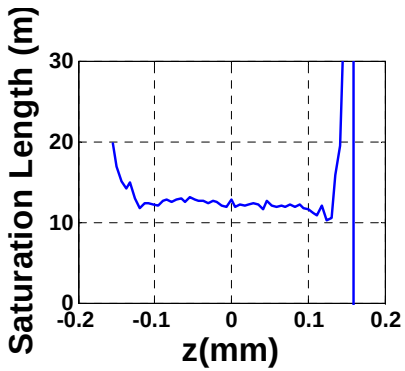
CSR +SC in BC2

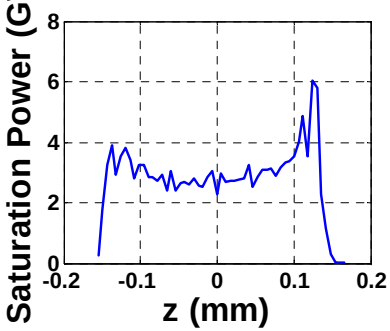




CSR only in BC2

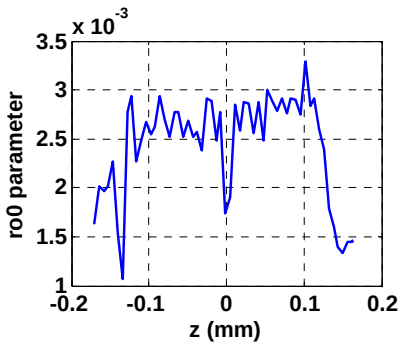


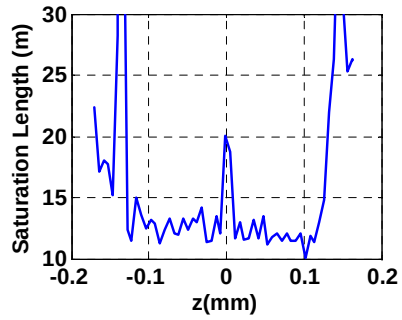


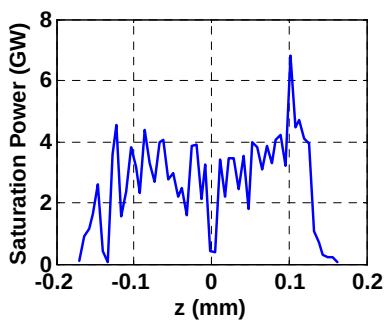


Wavelength= 10.0 nm
Undulator K= 2.055
Undulator period= 2.800 cm
Pmax= 6.022 GW
rms pulse length= 89.292 um
rms pulse length=297.847 fsec
saturation length= 24.000 m
e-beam efficiency= 96.825%
e-beam peak current= 1.681kA

CSR +SC in BC2



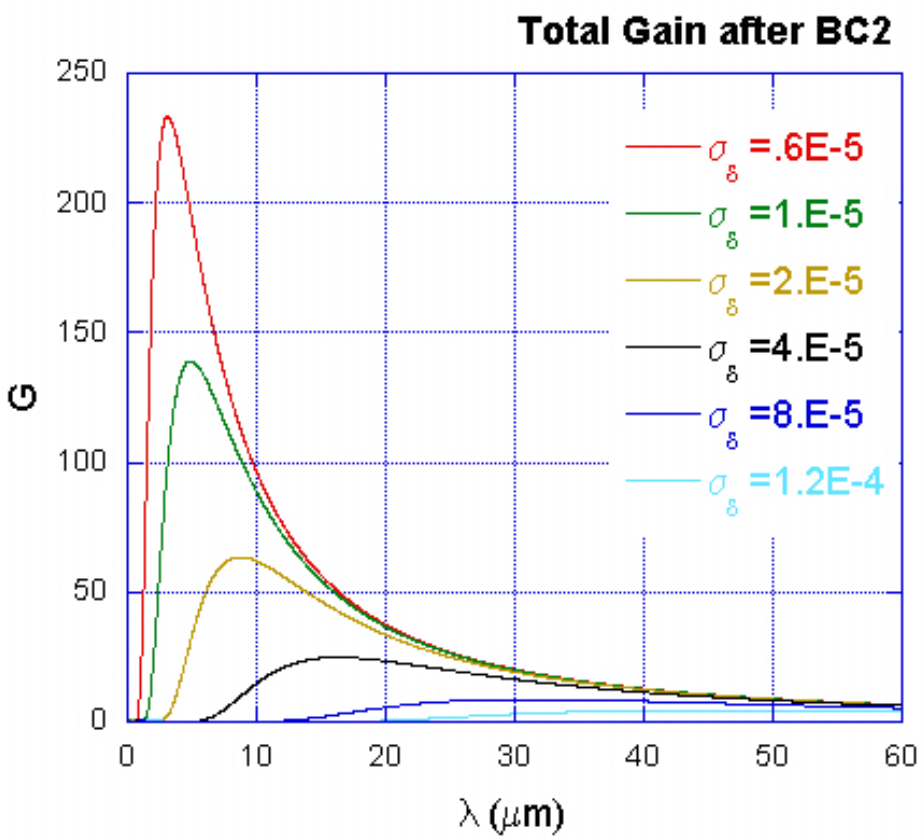




Wavelength= 10.0 nm
Undulator K= 2.055
Undulator period= 2.800 cm
Pmax= 6.815 GW
rms pulse length= 84.583 um
rms pulse length=282.139 fsec
saturation length= 24.000 m
e-beam efficiency= 92.000%
e-beam peak current= 1.863kA

Microbunching gain up BC2

$$G = \left|\frac{b_f}{b_0}\right| \approx \frac{I_0}{\gamma I_A}\left| k_f R_{56} \int ds \frac{4\pi Z(k_0;s)}{Z_0}\right| \exp\left(-\frac{1}{2}k_f^2 R_{56}^2 \sigma_\delta^2\right)$$



where:

$$Z_{LSC}(k) = \frac{iZ_0}{\pi k r_b^2}\left[1 - \frac{kr_b}{\gamma} K_1\left(\frac{kr_b}{\gamma}\right)\right]$$

(Z. Huang *et al*, PRSTAB 7,074401)

Project schedule & cost estimation

Schedule:

- 2006-07: 1 year for Technical Design Report.
- 2006-09: Civil construction & site arrangement
- 2007-09: Device construction & procurement
- 2010-11: Installation & Commissioning

Cost :

- 50 M€ for the 1 GeV first phase,
- 50 M€ for the 2 GeV phase.