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WP6 Activity Report

WP6 Team

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WP6: start to end modelling

integrated performance studies of the facility

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- Performing start to end simulations, which cover the beam transport from the cathode to the FEL exit for Soft X-Ray & Hard X-Ray including mechanical tolerance studies
- Providing key parameters and performance estimates of the overall facility.
- Definition the basis for technology choices for critical components and for developing detailed designs of subsystems and components
- Development of tools for modeling the machine, as the basis for the final integrated performance studies.

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Facility Options considered by WP 6

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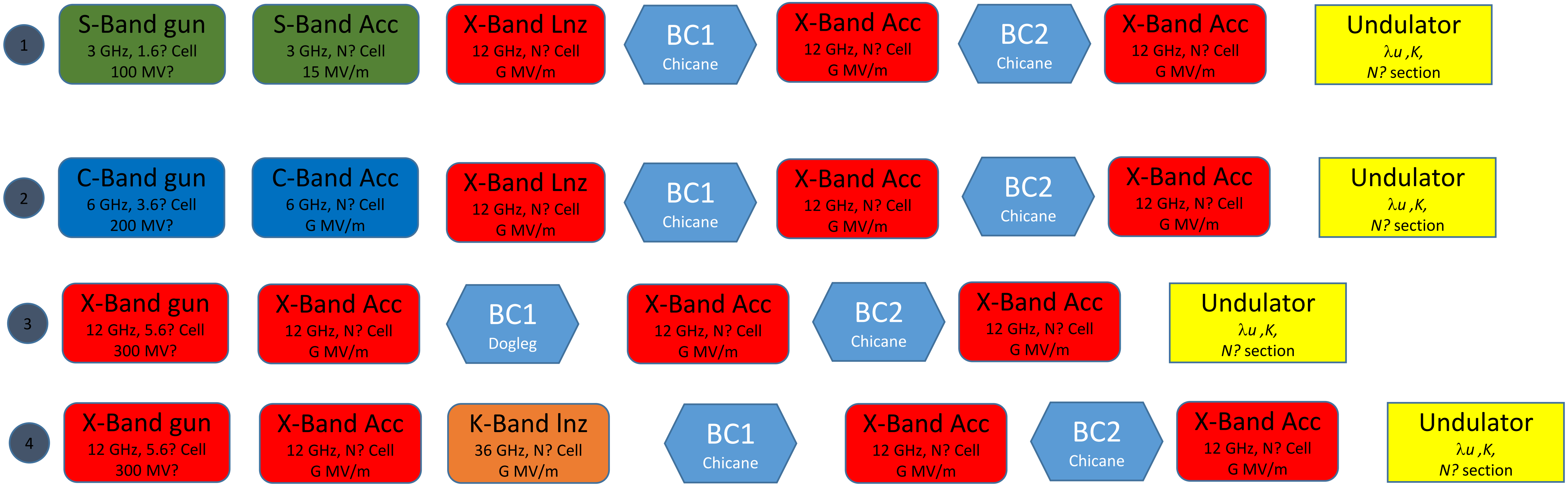

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Tasks and Task members

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	Task 6.1 - Injector				Task 6.2 - Linac				Task 6.3 - FEL		Task 6.4 S2E
	6.1A	6.1B	6.1C	6.1D	6.2A	6.2B	6.2C	6.2D	6.3A	6.3B	6.4A
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				E. Trachanas					F. Nguyen federico.nguyen@enea.it		
Layout	SBand Gun + SBand Acc	CBand Gun + C(S)band Acc	SBand Gun + CBand RF vel. comp + CBand Acc	Xband gun + Xband Acc	SBand Acc + XBand lnrz + BC1 + Xband Acc + BC2 + XBand Acc + BD	XBand Acc + Optic Lnrz XBand Acc + BC2 XBand Acc + BD	XBand Acc + KBand lnrz + BC1 + XBand BC2 + XBand Acc +BD	Beam based alignment for the final layout	Soft X-Ray	Hard X-Ray	Start to End modeling
Codes	GPT ASTRA RF-TRACK T-STEP				ELEGANT PLACET GPT				GENESIS PROMETEO PARSIFEL PERSEO		

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Compact Light FEL Specification

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	Soft x-ray	Hard x-ray
Photon energy [keV] (min-max)	0.25-2	2-25
Wavelength [nm] (max-min)	5-0.6	0.6-0.05
Repetition rate [Hz]	1000	100
Maximum pulse energy [mJ]	Not specified yet (will be < 1mJ)	1 (at 25 keV only, can be less at other energies) – this is 2.5E11 photons/pulse
Pulse duration [fs]	0.1 – 50	
Polarisation	Variable, selectable	Not specified yet
Two-colour pulses: time separation [fs]	-20 -> +40	
Two-colour pulses: photon energy variation (max. of E2/E1)	2 (270-530eV), 1.2 for the rest of the range	1.1

J. Clarke Trieste mid term review, June 2018

Compact Light FEL Specification

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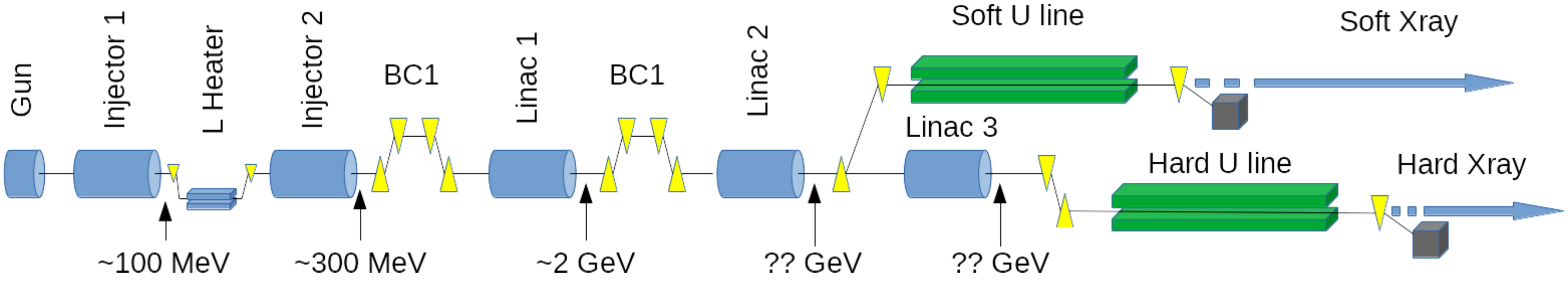

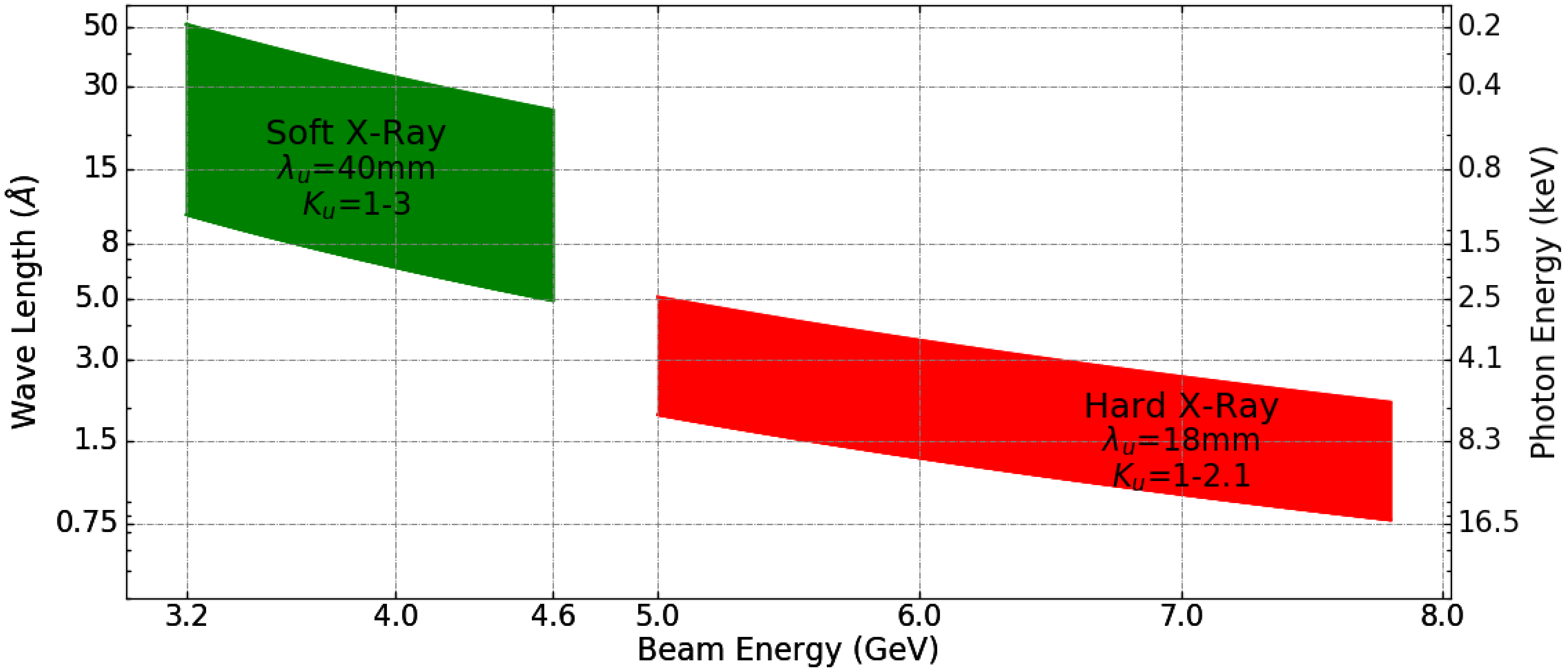

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Current Studies

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- Various injector options with different bunch charge, bunch length are in the optimization process.
- The benchmarking of different codes are ongoing..
  - Some of the code already has chosen..
- Lattice type and module integration studies are on going..
  - Due to strong wake one structure between two quads are foreseen for low energy part of the injector..
  - Determination of diagnostic scheme for module is also taken into account based on alignment method..
- 1D and 3D tracking for various layout have also been preliminarily studied..
- Most of the actions are waiting for the specifying the parameters
- …

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Next

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- Defining the excahge format
  - For particle distribution (x [m], Px [eV/c], y [m], Py [eV/c], z [t,m], Pz [eV/c])
  - For accelerating structure field map (axis field normalized ??)
  - For field maps of other elements (solenoids… field map on axis?)
  - For lattice text file?
- To many codes are available
  - We will not give up using any of them but we need to define an Exchange format for results
    - Emittance rms mm.mrad?
    - Bunch length fwhm/rms?
    - Twiss functions ?
    - …
- We need to use GitLab for exhange of results/input files..
- We dont need to wait for polarization, as compression (my idea)

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Agenda

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- 12:00 → 12:10 WP6 Introduction, Avni Aksoy
- 12:10 → 12:25 WP6 Beam dynamics studies for the XLS S-band photoinjector with and without velocity bunching, Anna Giribono
- 12:25 → 12:40 WP6 S-band based linac option status and linac modelling for FELs, Simone Di Mitri
- 12:40 → 12:50 WP6 X-band based linac option and 1 D optimization tool, Xingguang Liu
- 12:50 → 13:05 WP6 3-D simulation for the S-band + X-band option of CompactLight, Eduardo Marin

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Injector Studies
S-Band Injector (Q=75pC)

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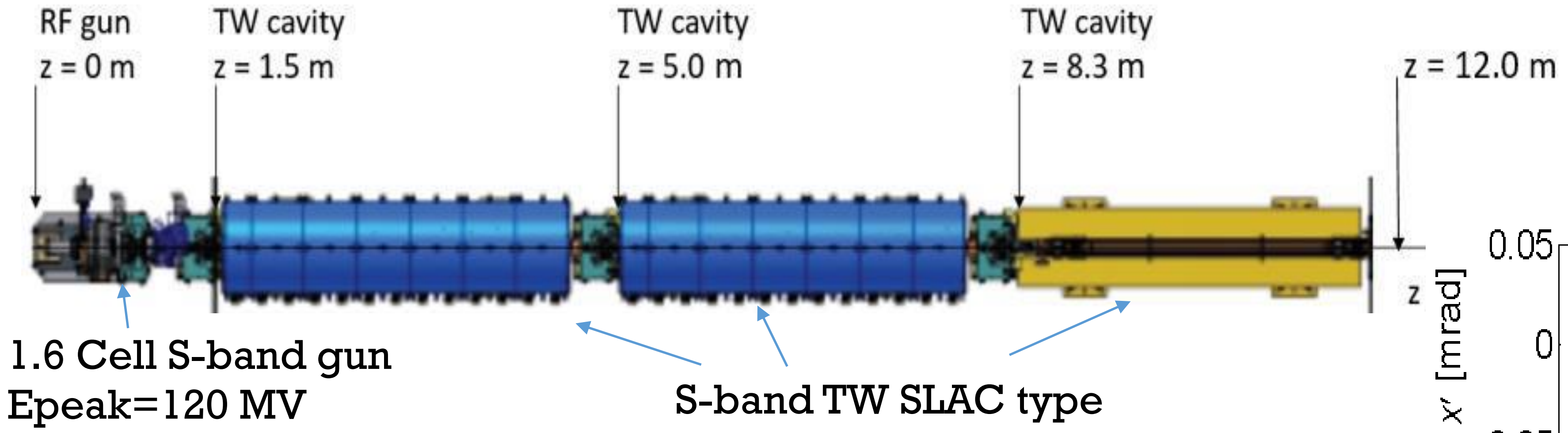
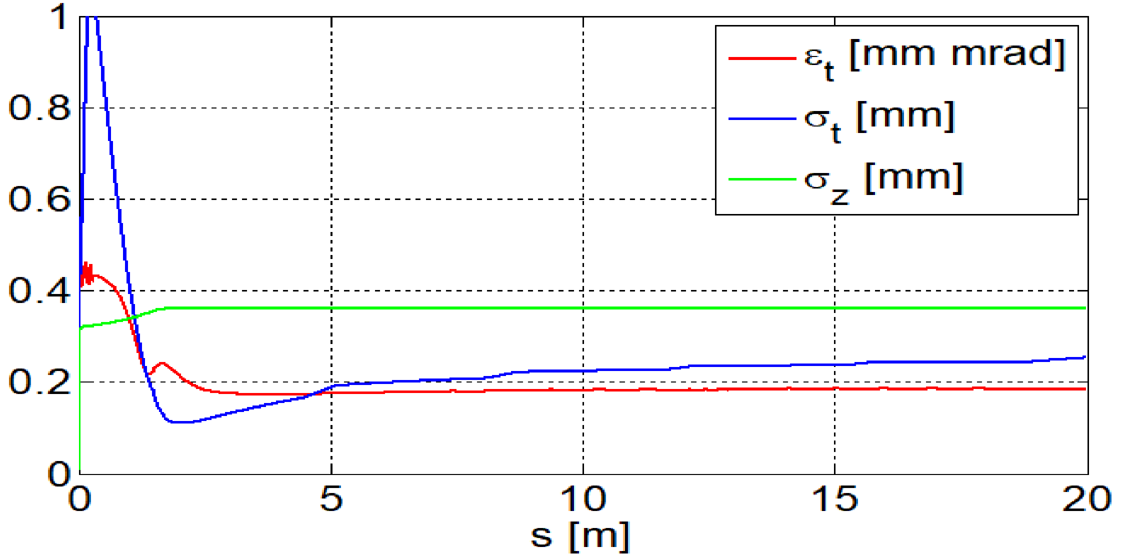
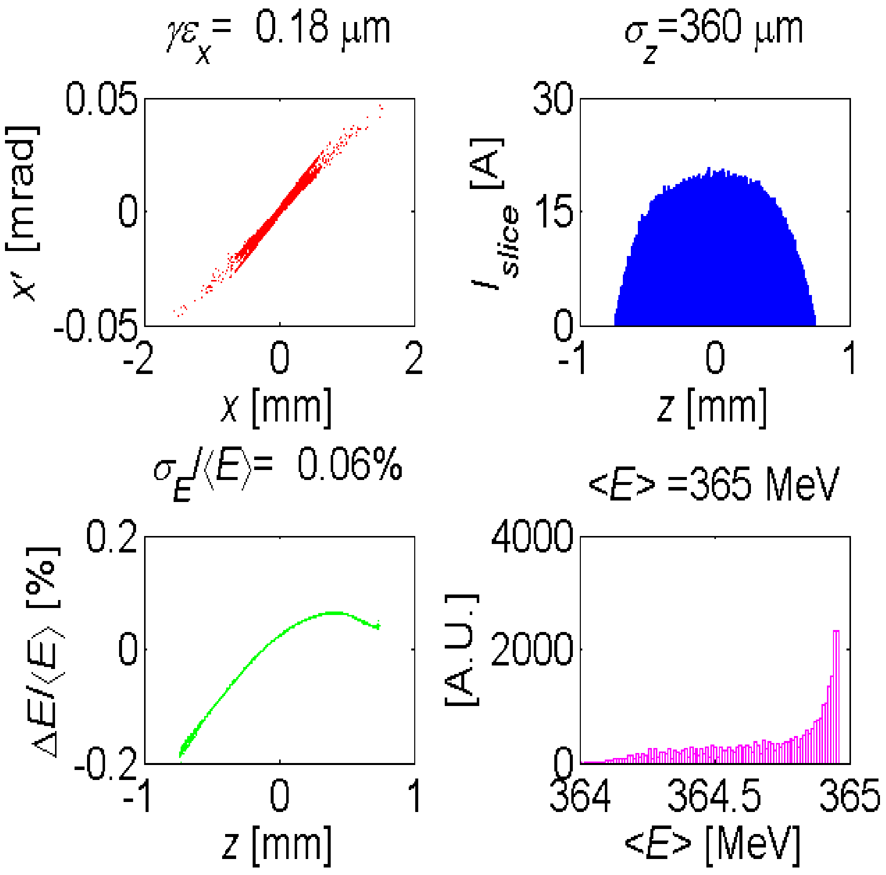
A.Giribono







Injector Studies
C-Band Injector (Q=100pC)

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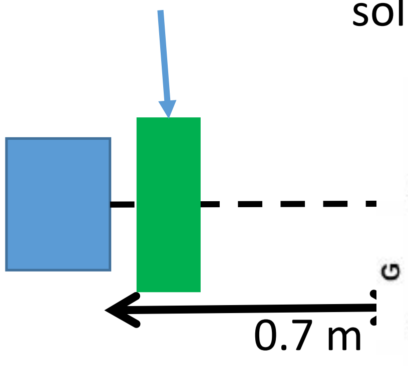
M. Croia

1.6 cell RF gun operating at 240 MV/m cathode peak field

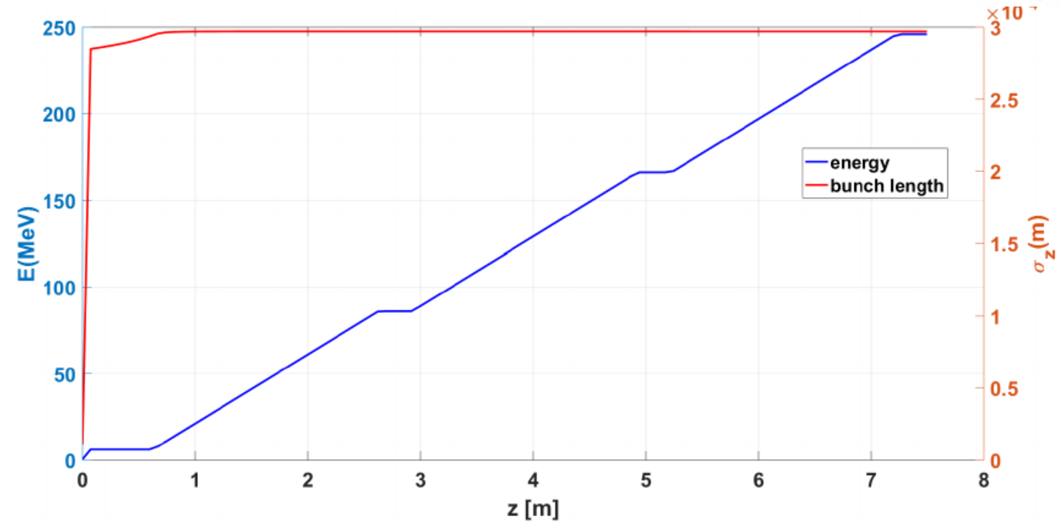
Gun solenoid

TW structures solenoids

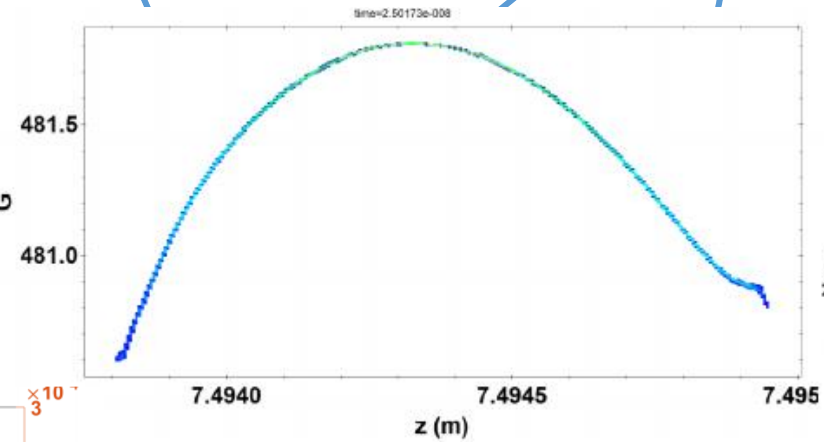
2 C-band TW structures, with solenoid around, operating at 40 MV/m average accelerating gradient (as example, PSI-like structures with 1 klystron every 2 sections)

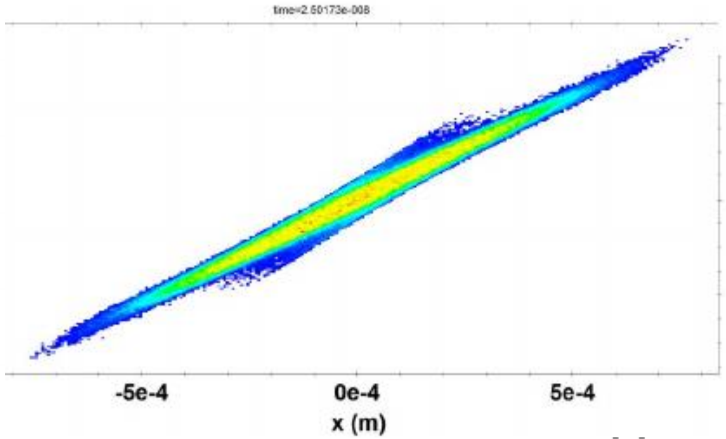


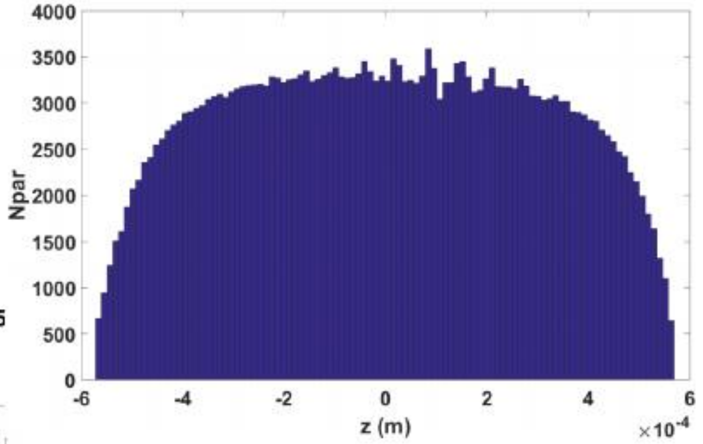
Laser/cathode parameters	
Pulse length	3.8 ps (Uni)
Spot size radius	324 µm (Uni)
Thermal emit	0.9 µm/mm



$\sigma_{z,final} \approx 300\ \mu m$







$\sigma_{z,fwhm} \approx 1mm$

$\epsilon_{n,rms,final} \approx 174\ nm$

Injector Studies
X-Band Injector (Q=250 pC)

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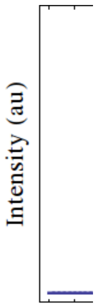
c

c



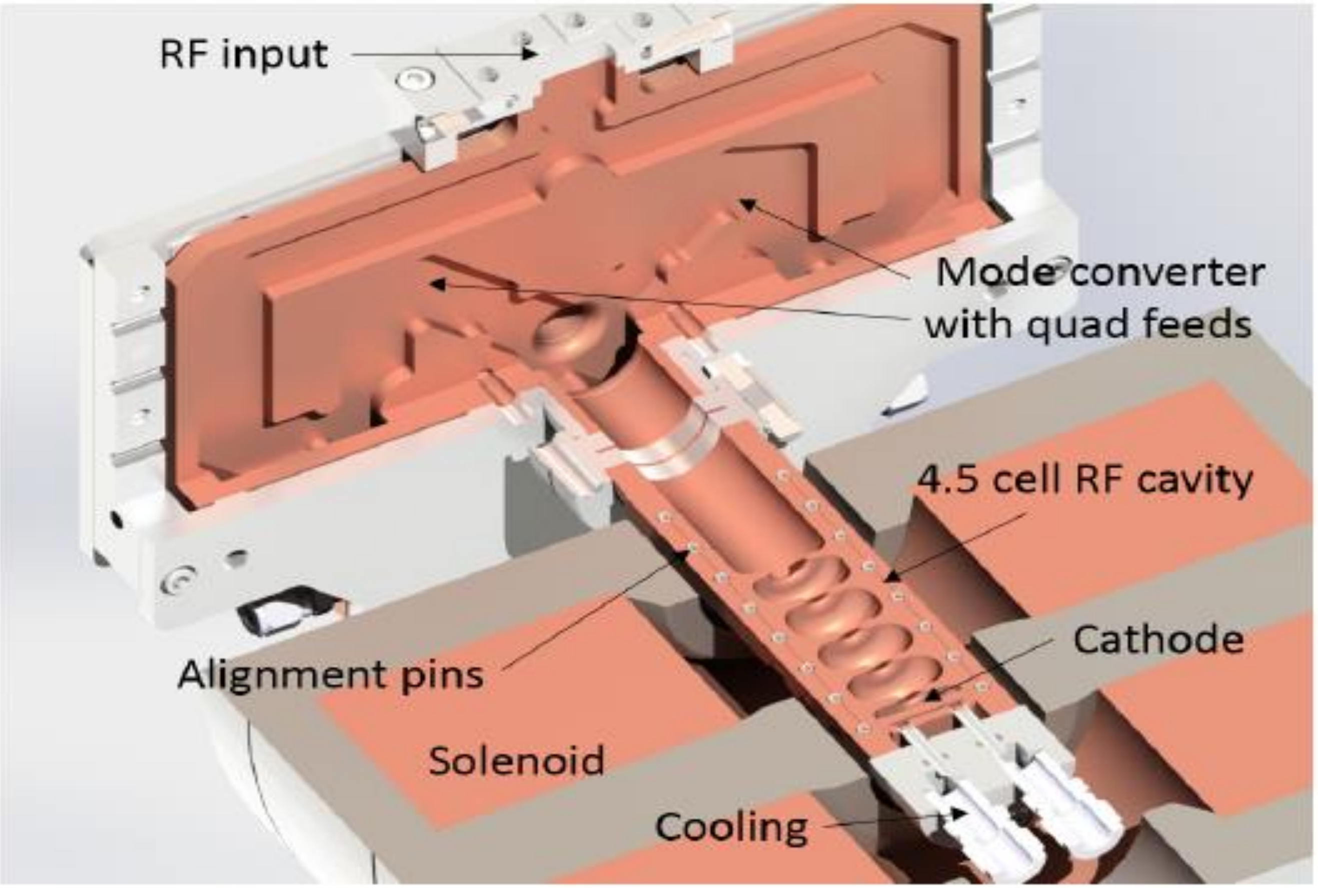
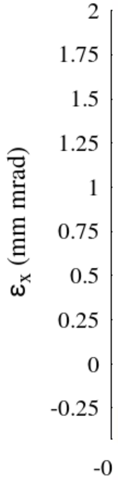
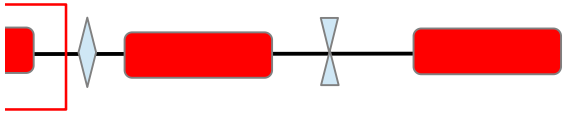


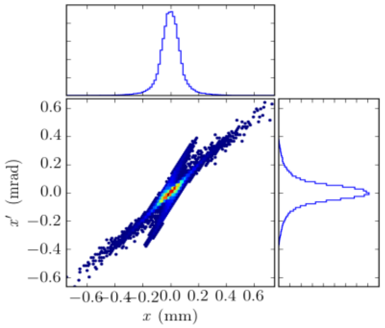
Figure 1: Cutaway view of photoinjector assembly including mode launcher with quadrupole symmetry, 4.5 cell RF gun, and solenoid magnet.





ave structures

lV/m, 150 degree



Parameter	Unit	Value
E	MeV	59.746
$\varepsilon_{n,x}$	mm.mrad	0.445
$\varepsilon_{n,y}$	mm.mrad	0.447
ε_z	MeV.μm	16.196
σ_x	mm	0.084
σ_y	mm	0.084
σ_z	μm	206.018
σ_E	MeV	0.455
$\Delta E/E$	%	0.762

DESIGN OF AN X-BAND PHOTOINJECTOR OPERATING AT 1 kHz, IPAC2017, TUPAB139

1D Run for S-Band based injector and X-Band main linacs

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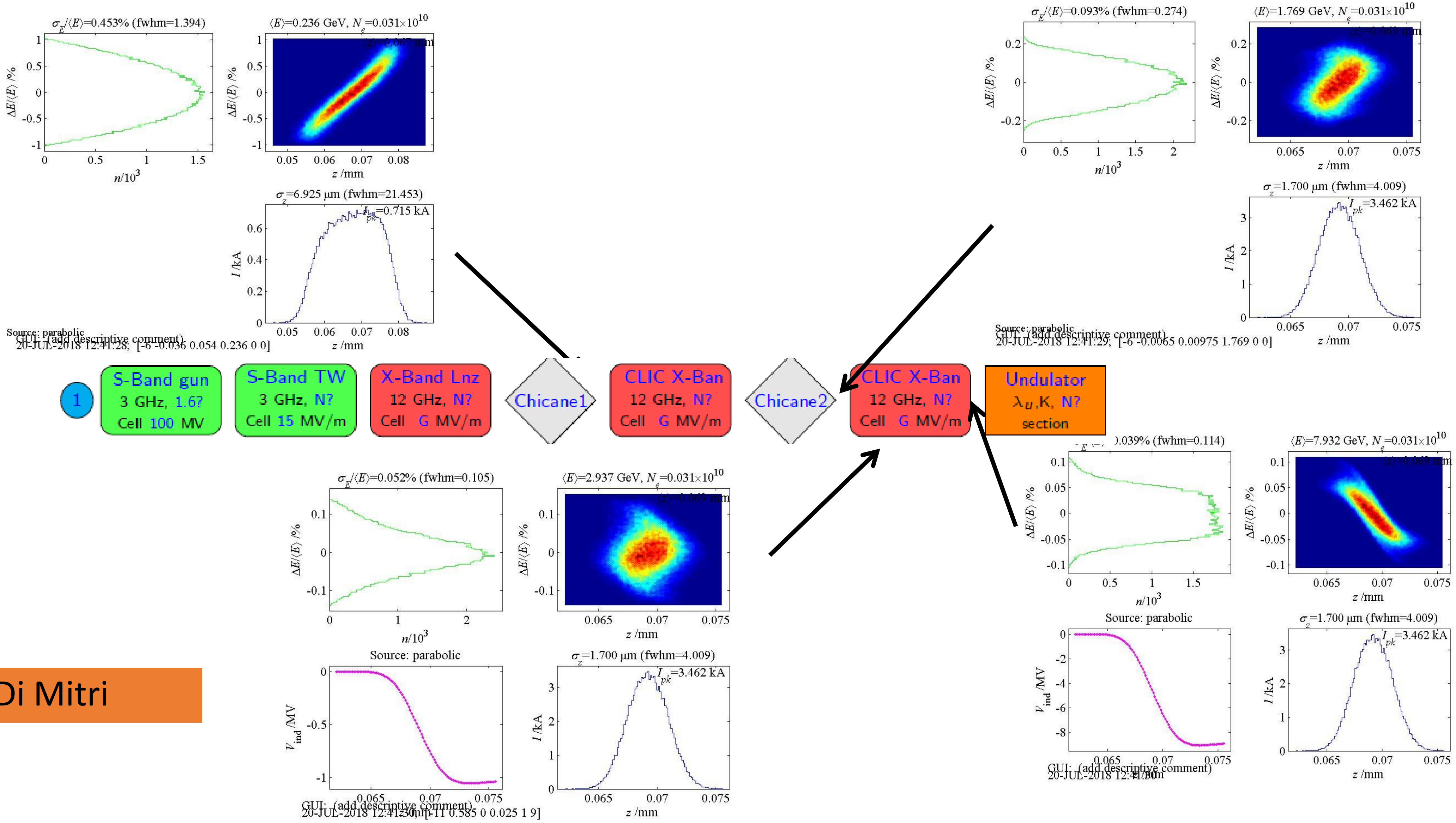

S. Di Mitri

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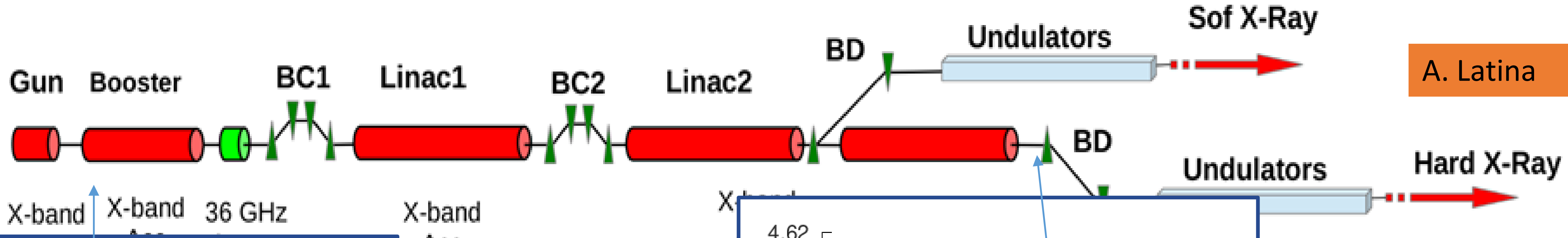
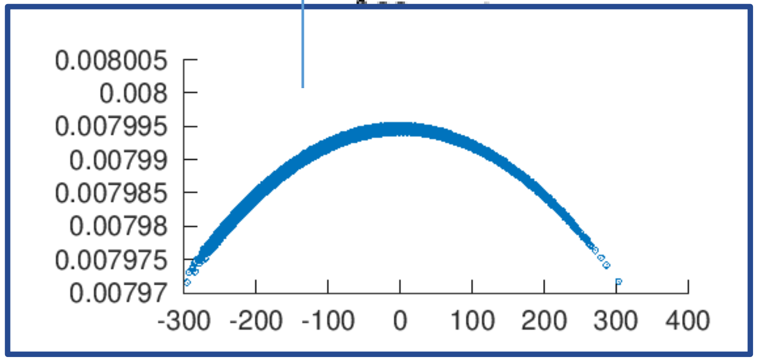
Linac Studies

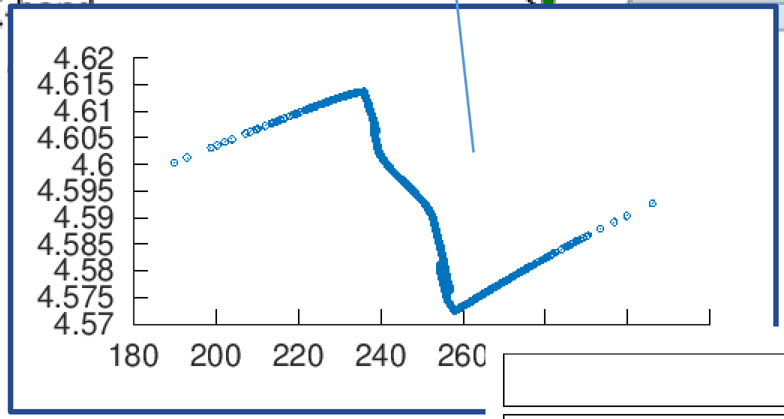
K-Band linearizer for all X-Band Option

Compact

A. Latina







	σ_z μm	$\langle P \rangle$ GeV/c
After Gun	131.3	8
After K-band	-	**0.160**
After BC1	**64**	-
After Linac1	-	**1.6**
After BC2	**8**	-
After Linac2	-	**4.6**

- We started to optimize the 5th layout option

$$\text{Gun} \Rightarrow \underbrace{\text{X0}}_{\text{X band}} \Rightarrow \underbrace{\text{K}}_{\text{K band}} \Rightarrow \text{BC1} \Rightarrow \underbrace{\text{X1}}_{\text{X band}} \Rightarrow \text{BC2} \Rightarrow \underbrace{\text{X2}}_{\text{X band}}$$

All X-Band Layout -2
phase space along beam line

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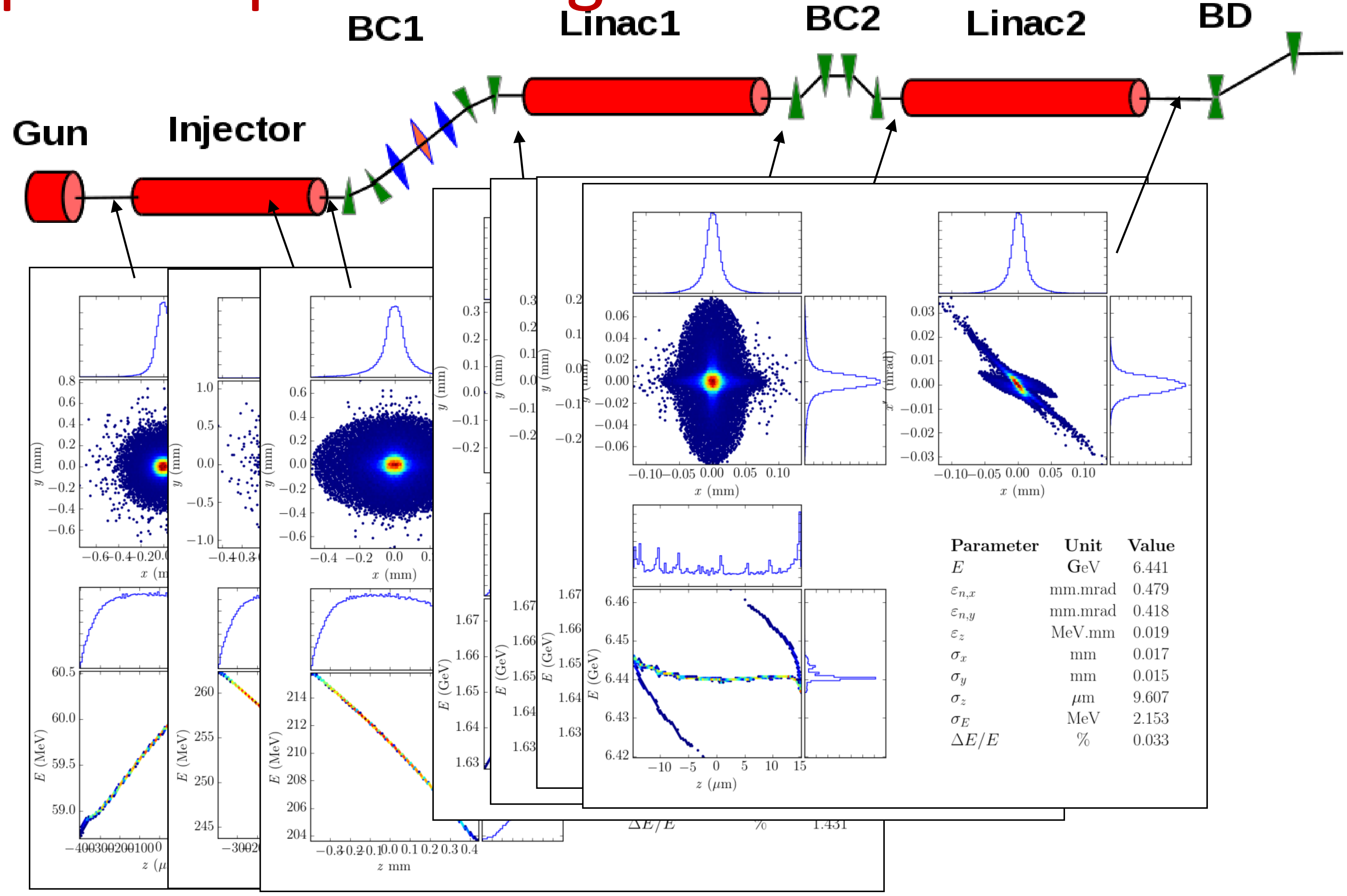

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Lattice Optimization

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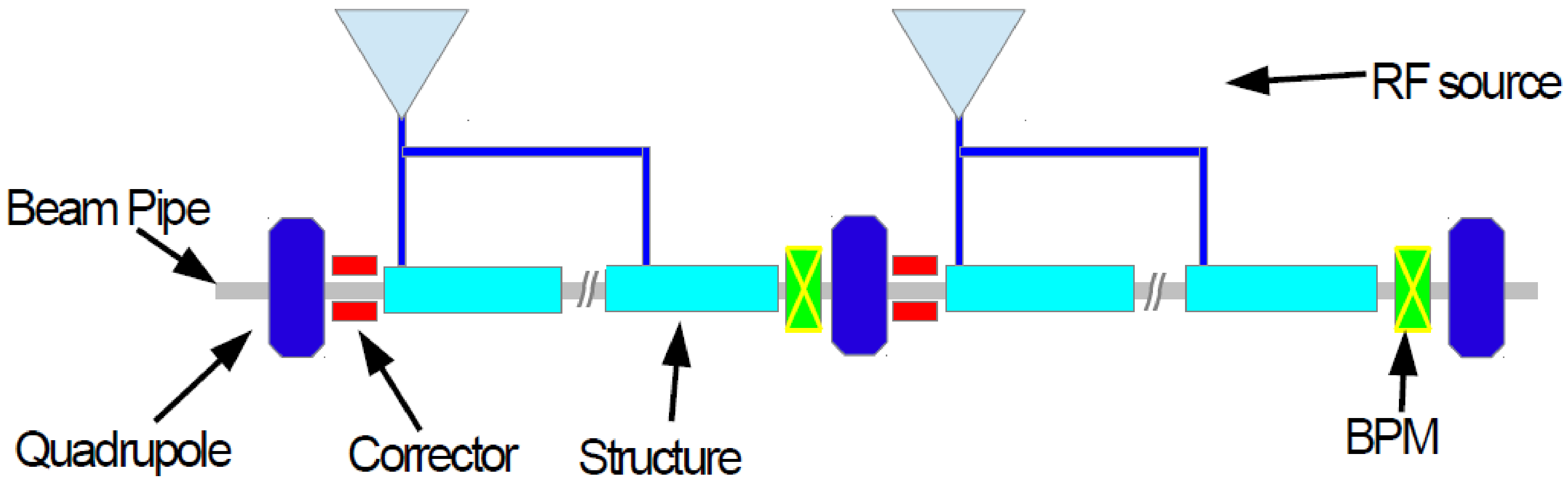
- The transverse deflection of beam is proportional $\Delta x, \Delta x' \propto \int_0^L \frac{\beta(s)}{E(s)} ds$
- The most critical section is the injector and linac 1 since the energy is low and bunch length is long



$N_{struc}/FODO/2$=1-3
Total number of structures=46
Initial energy = 250 MeV
Final energy =~5 GeV
Structure parameters from A. Gallo WP4 meeting, 20.09.2018

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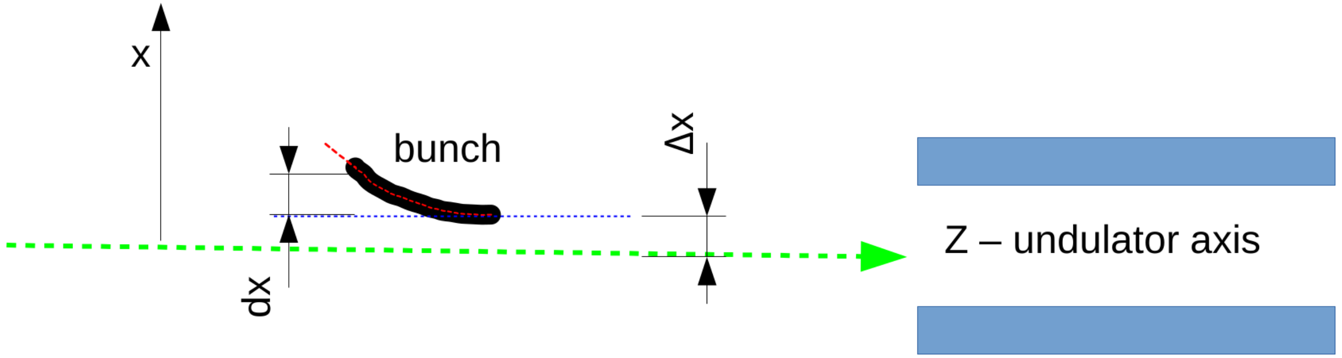
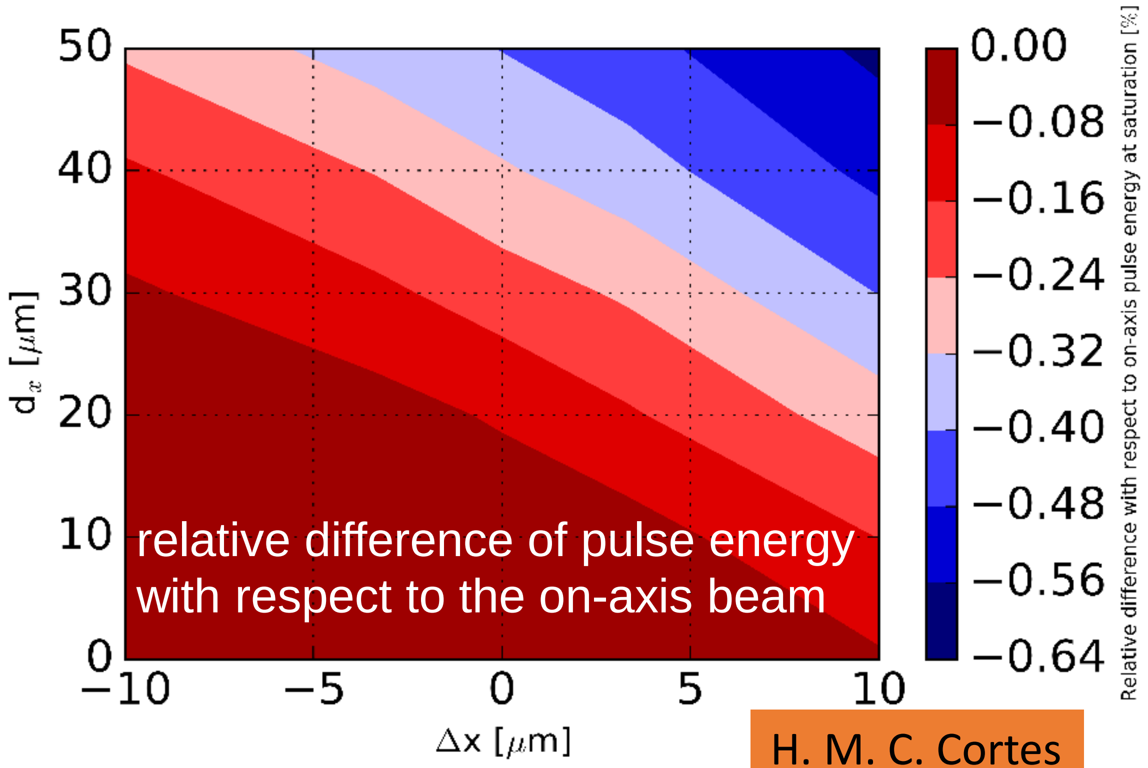
BD in Undulators

Impact of Beam off-set due to wake field to FEL performance

- The beam can be injected to with an ofset to the undulator section
- The tail of beam can be kicked due to wakefield in accelerator section
- The impact of such problem to the FEL performance has been checked with following inputs





In or to have «acceptable» pulse energy degration, saturation legnth increase etc.. (i.e. <10%) maximum injection errors must be

- Injection offset $\Delta x <$ 20% of $\sigma_{transverse}$
- Tail kick dx < 40% of $\sigma_{transverse}$

H. M. C. Cortes

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Impact of transverse wakefield along linac

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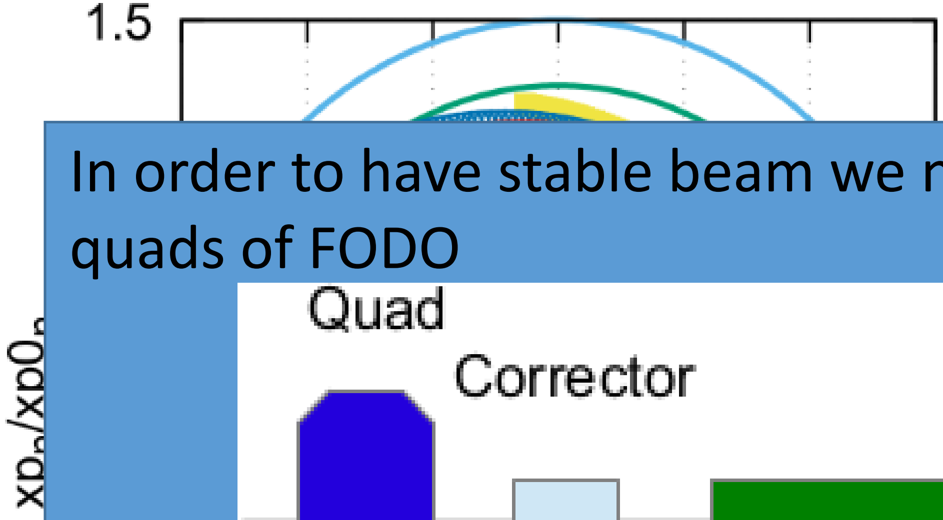
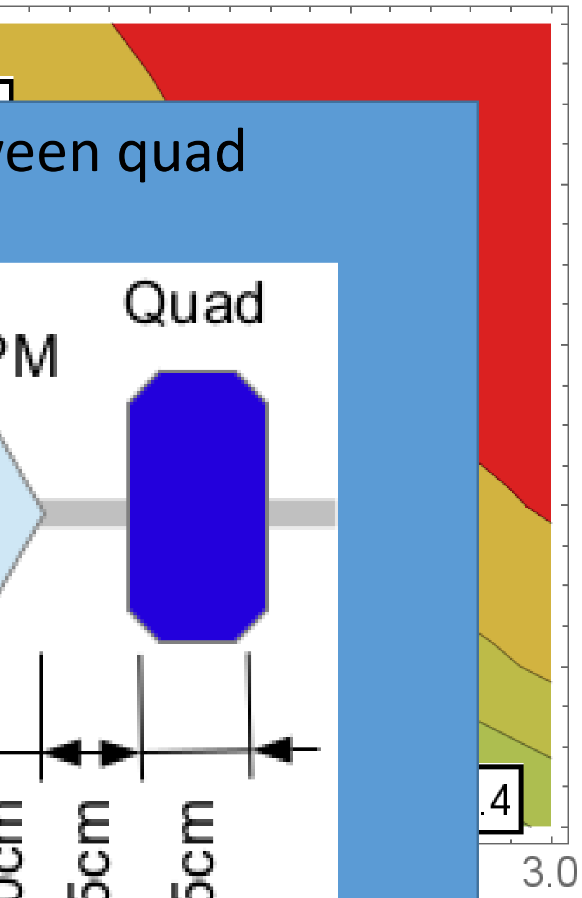
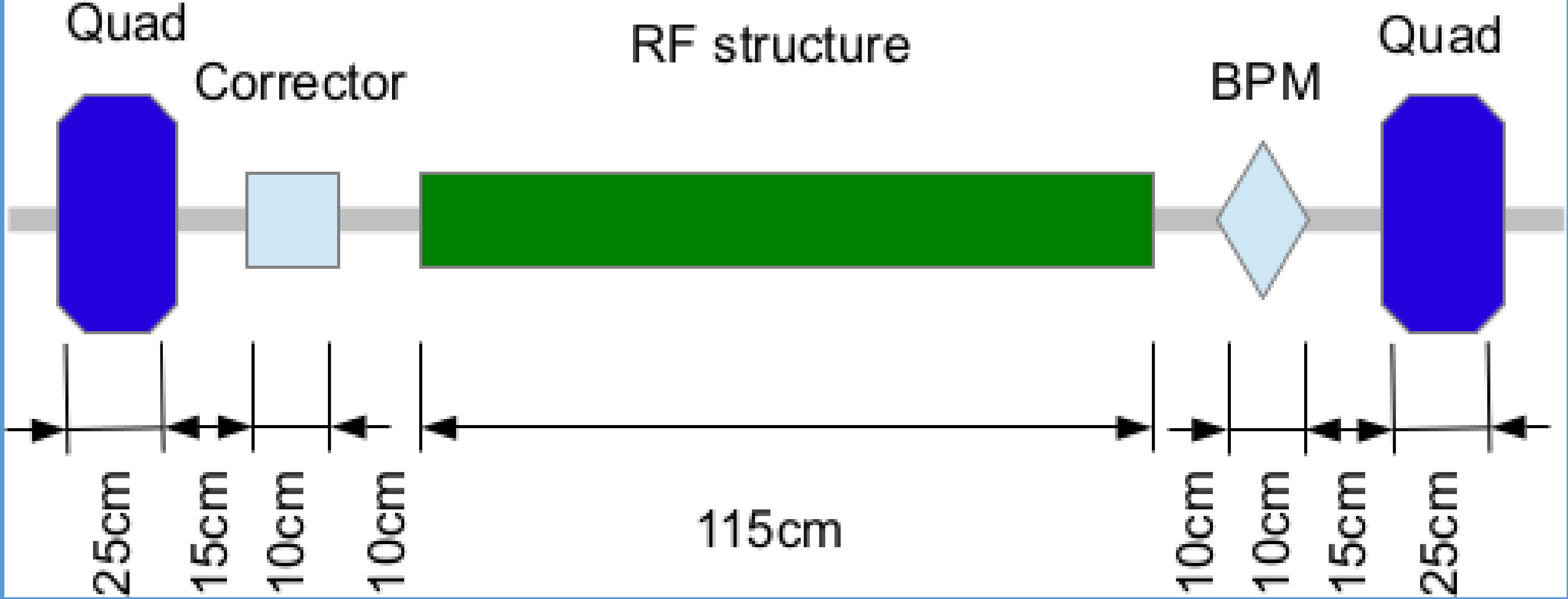
Normalized phase space of center of slicec along bunch at the end of linac 1

$$Ax = \frac{1}{X_n(0)}\sqrt{X_n(L)^2 + Xp_n(L)^2}$$





In order to have stable beam we need to loace 1 strcutre between quad quads of FODO



BD in Undulators

Impact of Resistive Wakefield in undulator

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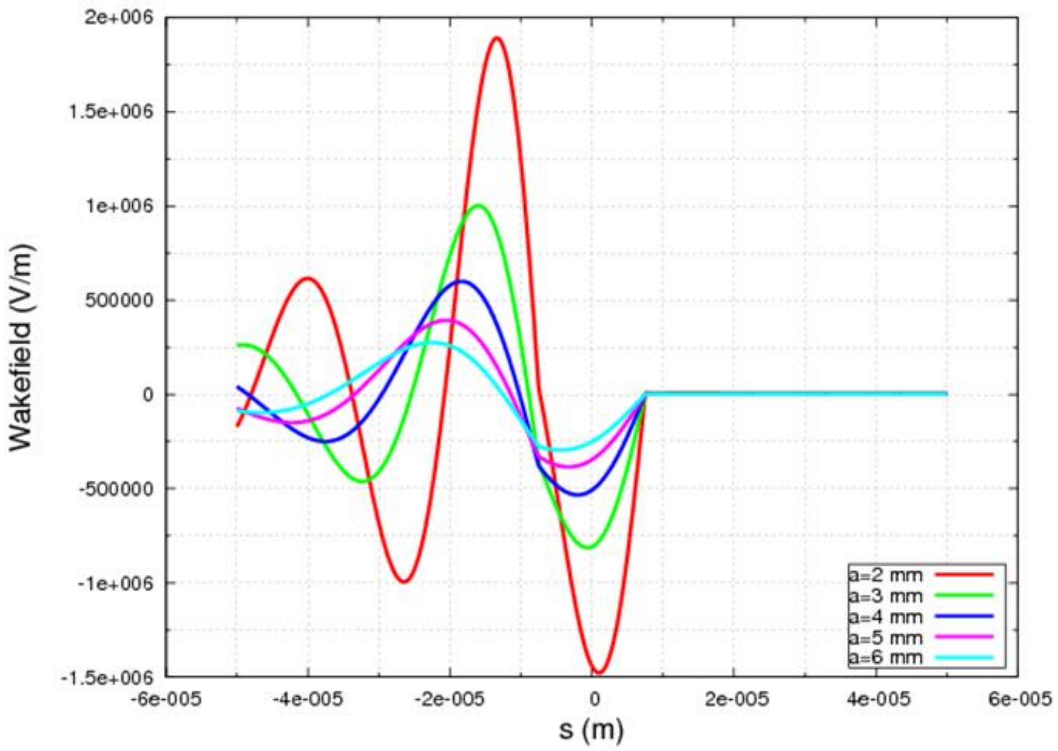

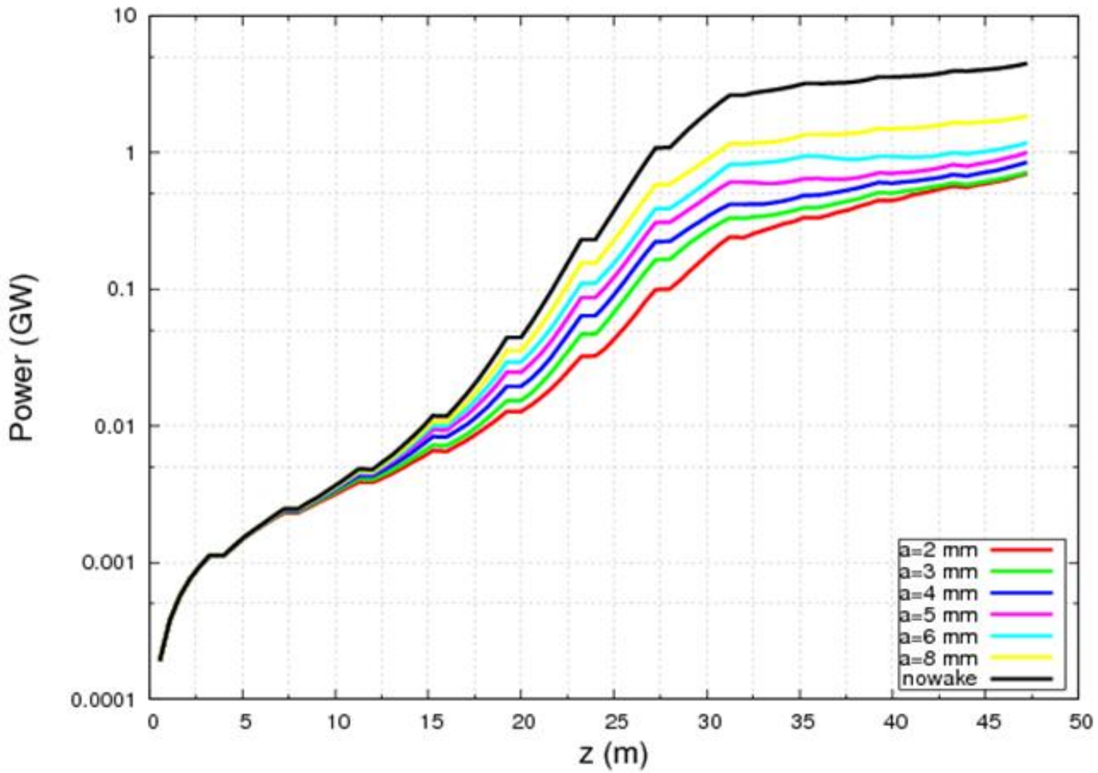

Z. Nergiz

- Saturation power decreases with gap of the undulator (beam pipe inside undulator) due to strong wakefiled
- The gap of the undulator must be larger than 3 mm for CompactLight parameters

Soft X-Ray Design

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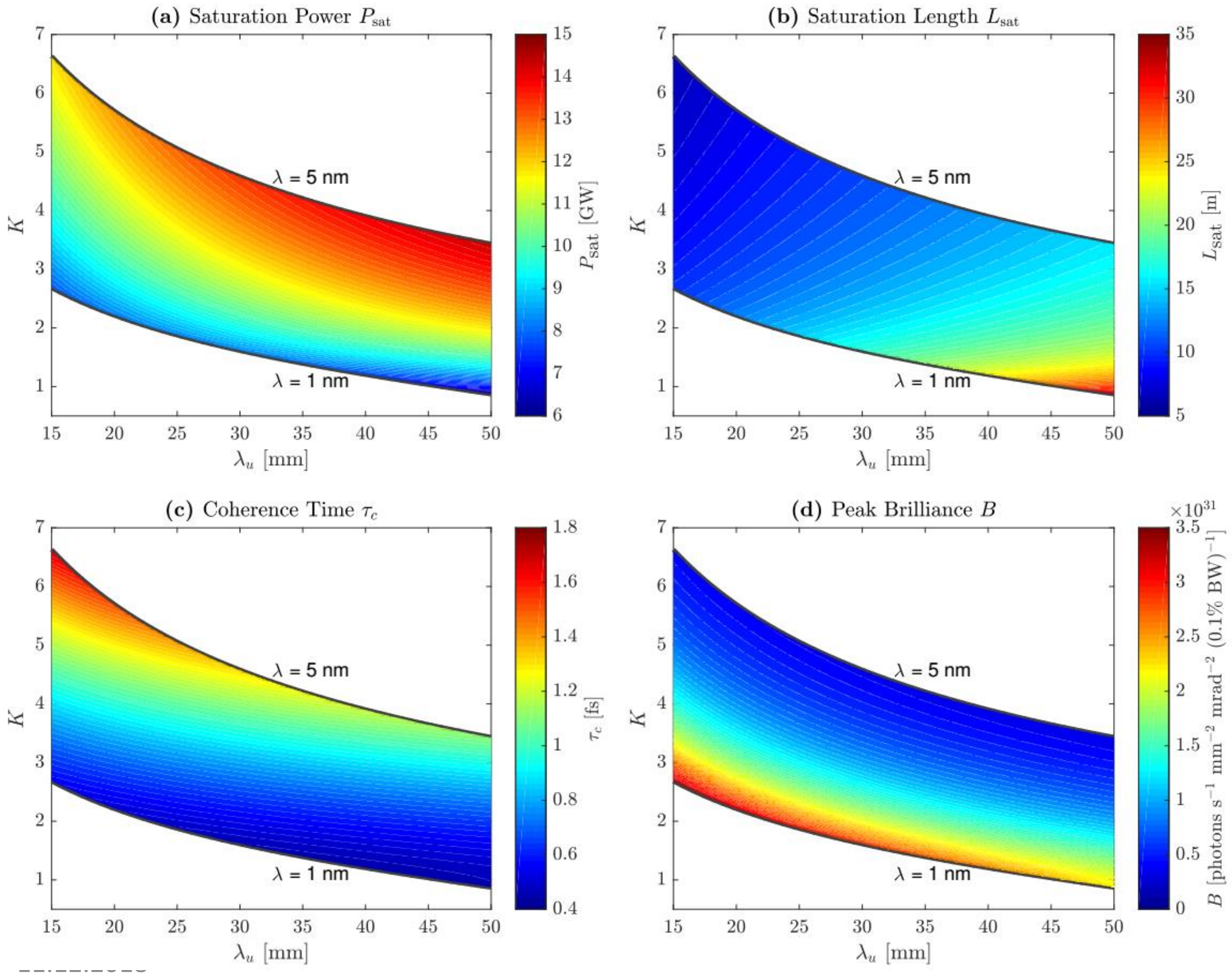
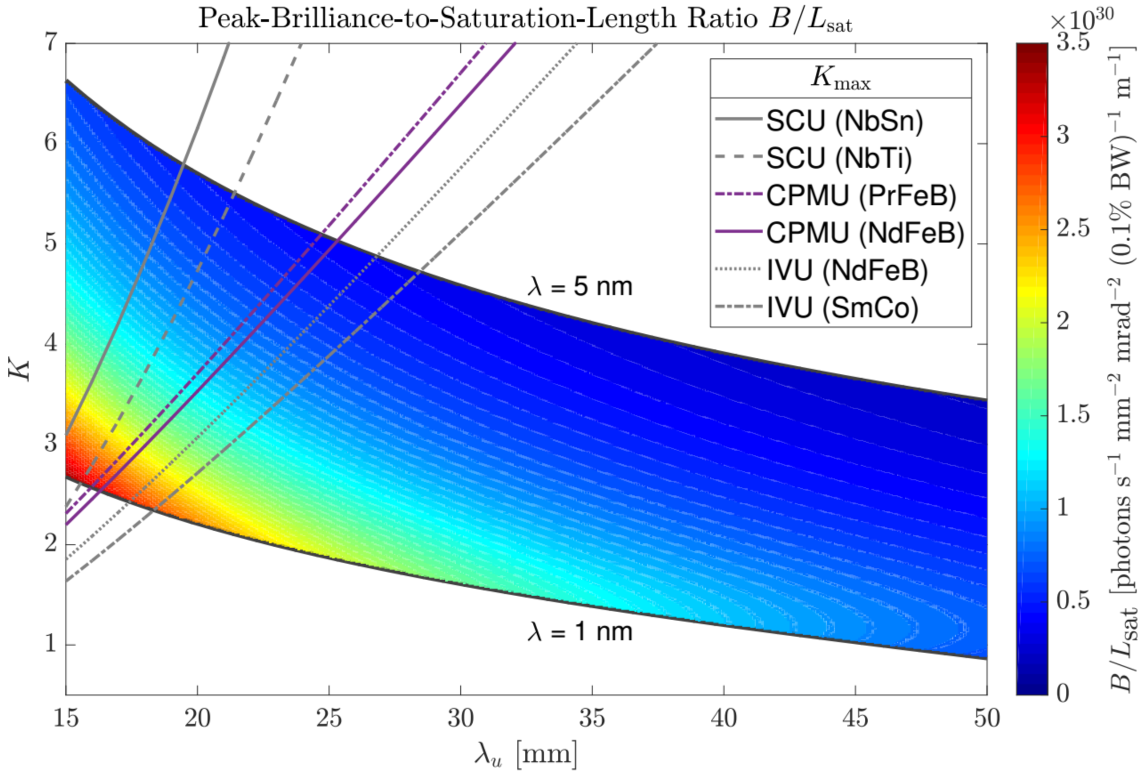


Jordi Marcos, PM Undulators

3 GeV beam, I=1.4 kA, 0.4 mm mrad

<βx,y> =5 meters



V. Goryashko

Hard X-Ray Design

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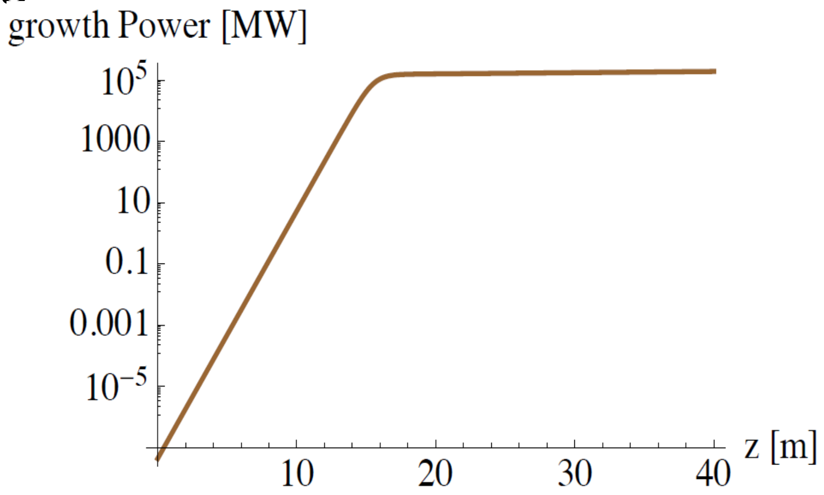
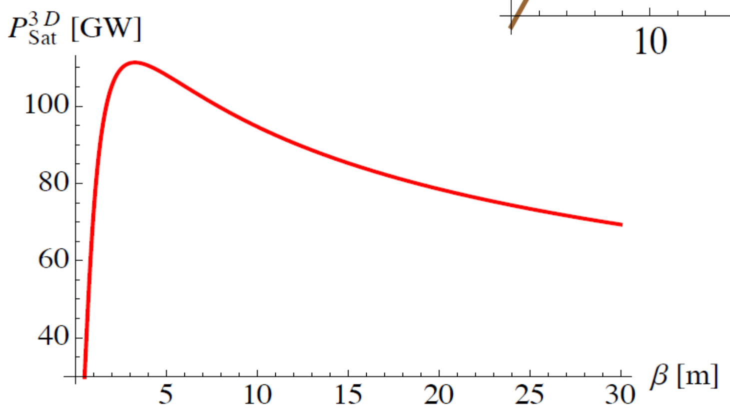
F.Nguyen

Undulator Paramters	
Undulator Period	1.3 cm
Undulator Gap	3 mm
Undulator Strenght (rms)	1.17
Beam Parameters	
Beam Energy	9 GeV
Bunch lenght (FWHM)	7.5
Bunch charge	75 pC
Peak current	9 kA
Norm Emittance	0.12µmrad
Energy Spread	0.01%
FEL parameters	
Wavelength (energy)	0.05nm (25 keV)
Nphoton/pulse	$2{\times}10^{11}$
Efel/pulse	1.06 mJ
Saturation length	25 m

- To reach 1 mJ energy/pulse hig bunch charge or low emittance, Hard to achieve much lower emittance with such a charge





<βx,y> =5 meters

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Shall we work on about them at this stage?

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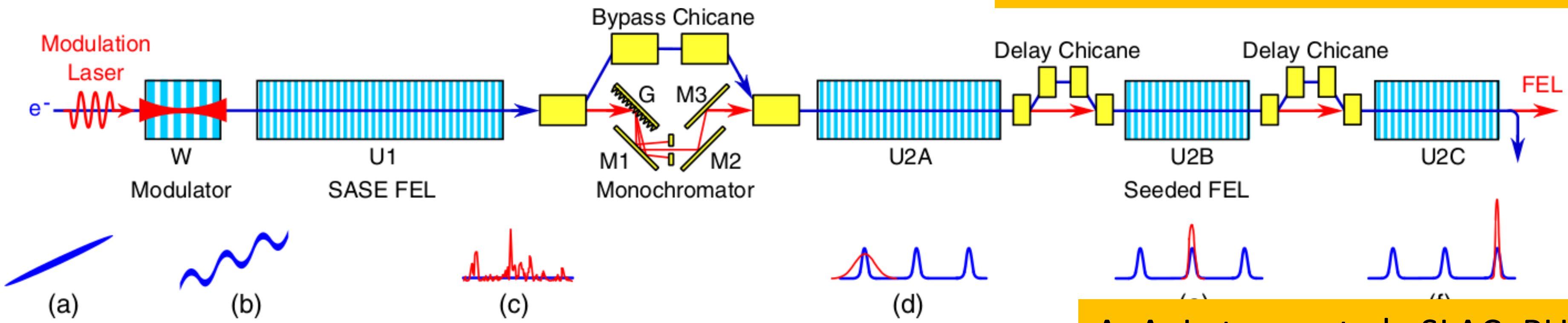
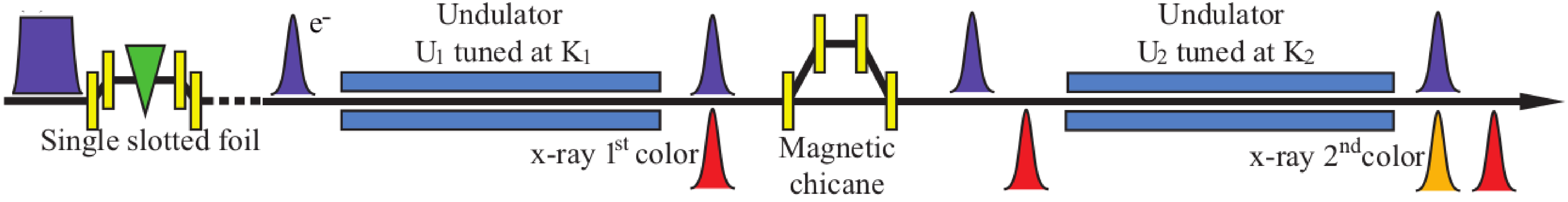
S. Huang et.al. PRST-AB, 19, 080702 (2016)

a.s. FEL pulses



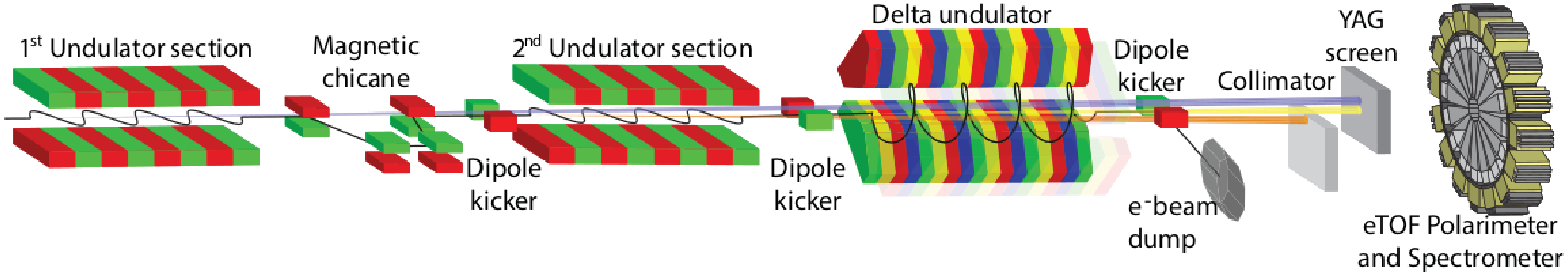
A. A. Lutman et.al, SLAC–PUB–15420

Two Color FEL pulses



A. A. Lutman et.al, SLAC–PUB–16827

Polarized two color FEL



Thank you!

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