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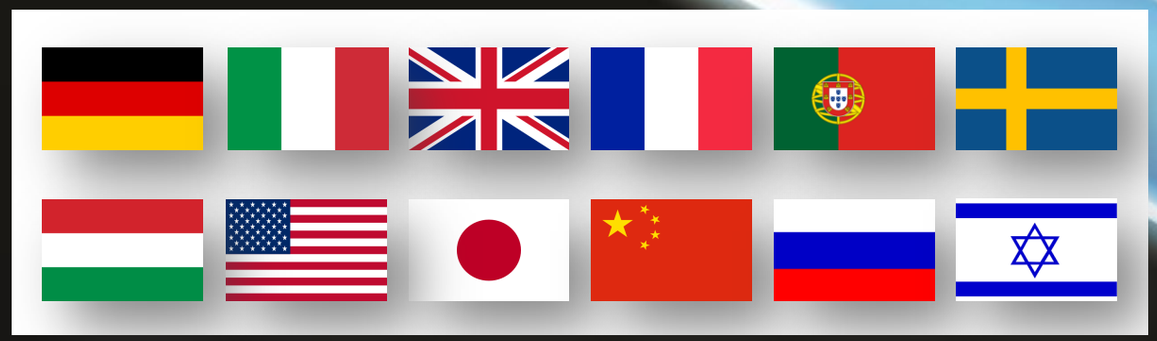
EXCELLENCE IN
APPLICATIONS

EuPRAXIA

WP5 Status and Plans for collaboration week

E. Chiadroni / INFN-LNF - 1st Collaboration Week, 19-23 June, 2017



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WP5 Contributors and Docs

Horizon 2020

- All **WP5 documents** are **on** the **DESYcloud**
  - https://desycloud.desy.de/index.php/apps/files/?dir=/EuPRAXIA_WP5&fileid=79832851
- The contributors list has been updated

email address	WP coordination Task 5.1	Electron Beam for external injection (RF injector) Task 5.2	Electron Beam Manipulation (from plasma to applications) Task 5.3	Electron Beam Diagnostics Practical Issues Task 5.4	Description of work	In-kind resources	Paid Eupraxia
Enrica.Chiadroni@lnf.infn.it	**x**	**x**	**o**	**o**	**WP leader WP5.2 task leader RF injector for ext. Inj.**	**o**	**o**
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david.garzella@cea.fr	o	x	o	o		x	o
barbara.marchetti@desy.de	o	x	o	x	Compression schemes Matching to the plasma Timing	x	o

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john.dale@desy.de	o	x	o	o		o	o
andreas.walker@desy.de	o	o	o	o	Coordination with other WPs In charge of the parameter list	o	x
lucas.schaper@desy.de	o	o	x	o	Plasma target Works jointly with WP9	x	o
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xander.molodozhentsev@eli-beams	o	o	x	o	Beam lines to FEL	o	o
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z.sheng@strath.ac.uk							
federico.nguyen@enea.it	o	o	x	o	Beam line to FEL Works jointly with WP6	x	o

Photo-Injector Highlights

- **Working point for both witness and driver beams at the plasma entrance** (A. Giribono, C. Vaccarezza, INFN-Rm1/LNF)
  - RF photo-injector optimized for witness beam in PWFA
    - **Stability studies on the compression phase** have been done at the photo-injector exit for a witness-like beam
      - An internal note is almost ready
    - PWFA: Preliminary start-to-end simulation for witness interaction in the plasma, assuming an ideal driver (A. Marocchino, INFN-LNF)
    - LWFA: injection of the witness beam into the plasma at higher energy, same as for PWFA
      - Preliminary start-to-end simulations (A. R. Rossi, INFN-Mi)
- **Working point for a comb-like beam (1 driver and witness) at the plasma entrance** (A. Giribono, INFN-Rm1)
  - RF photo-injector optimized for the comb-like beam as requested by PWFA
    - An internal note is in preparation
    - Start-to-end simulation for driver and witness interaction in the plasma on-going (A. Marocchino, INFN-LNF)
- **Exotic photo-injectors studies**
  - the high gradient RF gun (M. Croia, INFN-LNF)
  - the Laminar Velocity Bunching working point (A. Bacci, INFN-Mi)

Witness Working Point

Stability studies by Anna Giribono (INFN-RM1)

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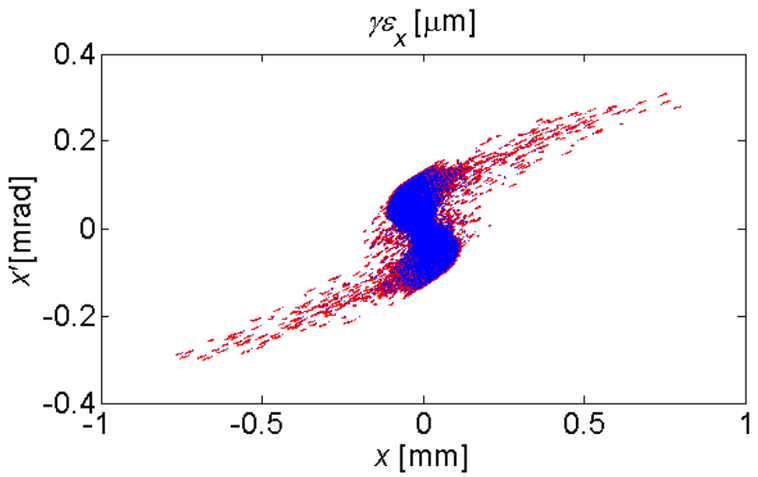
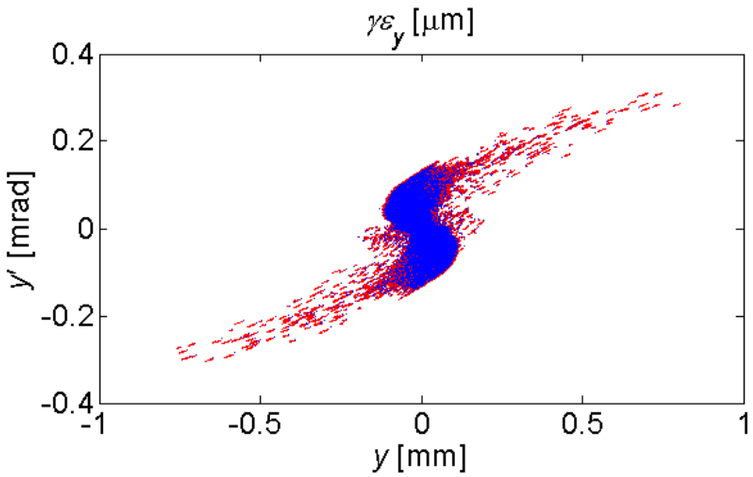
THE MODEL

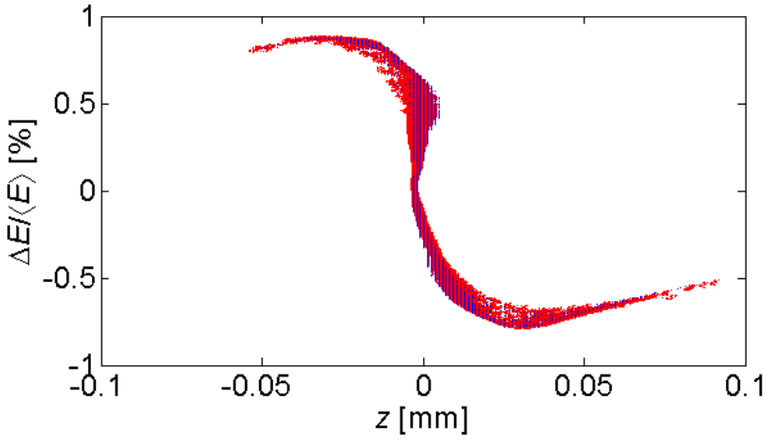
The machine run samples have been obtained generating for each machine a tracking code (Tstep) input, whose element errors are provided, in the chosen range, by means of the Matlab Latin Hypercube.

The effects on the beam quality, in terms of emittance and peak current, have been studied at the end of the injector.

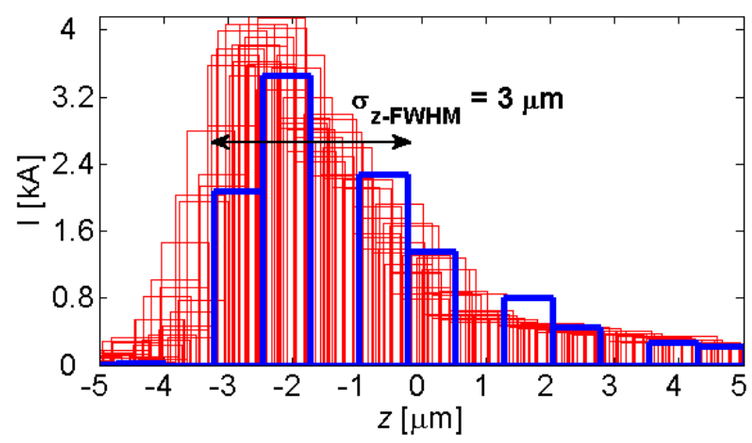




Jitter on Accelerating Sections Δϕ = ± 0.1 deg



Slice Peak Current [kA]



RF Gun		
RF Voltage [ΔV]	0.2	%
RF Phase [Δϕ]	0.05 – 0.1	*deg*
S-band Accelerating Sections		
RF Voltage [ΔV]	0.2	%
RF Phase [Δϕ]	0.05 – 0.1	*deg*
Cathode Laser System		
Charge [ΔQ]	5	%

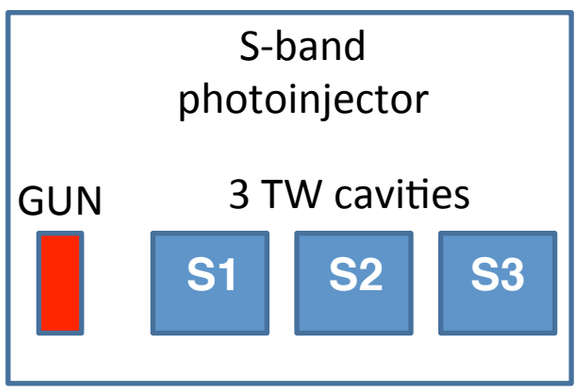
Beam parameters @Inj.Exit	
E [MeV]	98.8 ± 0.5
ΔE/E [%]	0.30 ± 0.01
$\varepsilon_{x,y}$ [mm mrad]	0.58 ± 0.02
$\sigma_{z\text{-rms}}$ [μm]	5.6 ± 0.1
$\sigma_{z\text{-FWHM}}$ [μm]	~ 3.0
$I_{peak\ –\ FWHM}$ [kA]	~ 3.0

Witness Working Point

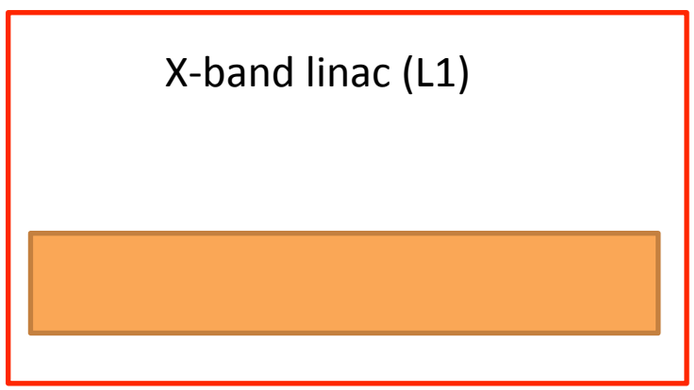
by Anna Giribono (INFN-RM1) and C. Vaccarezza (INFN-LNF)

- Working point for the witness at the plasma entrance for both external injection schemes

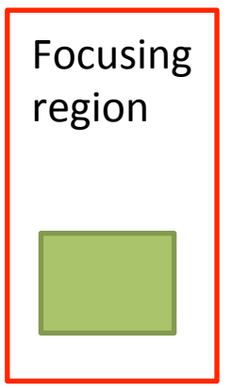
TSTEP



Elegant

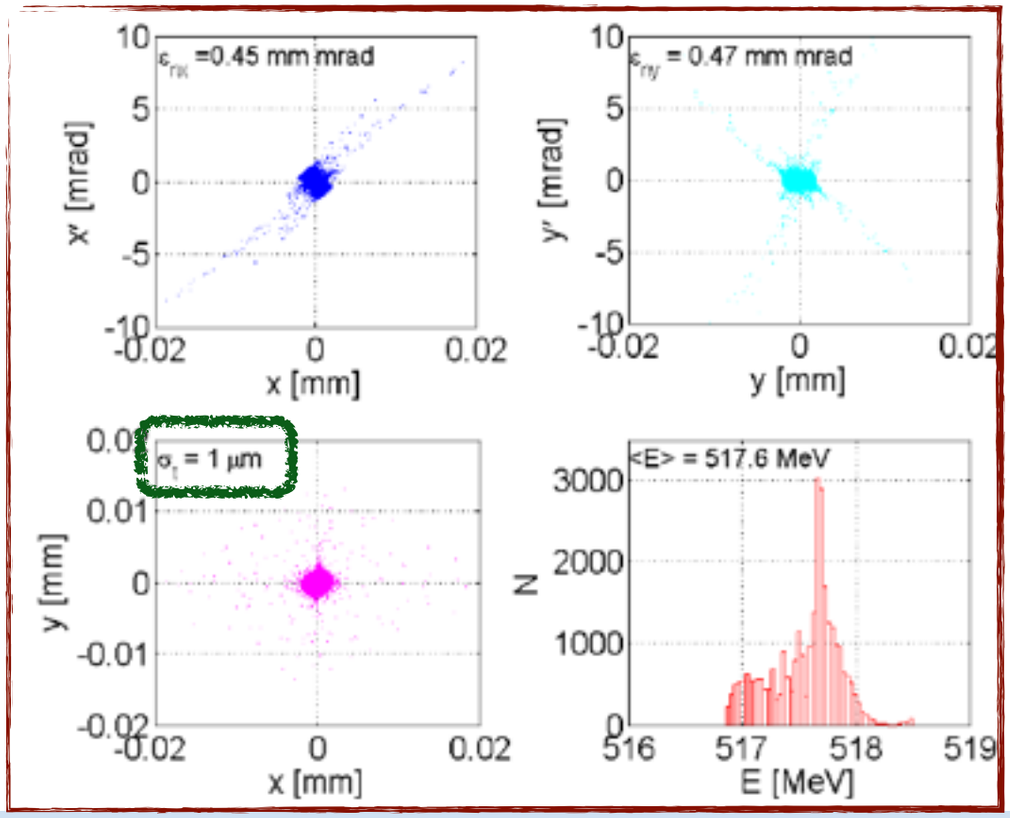


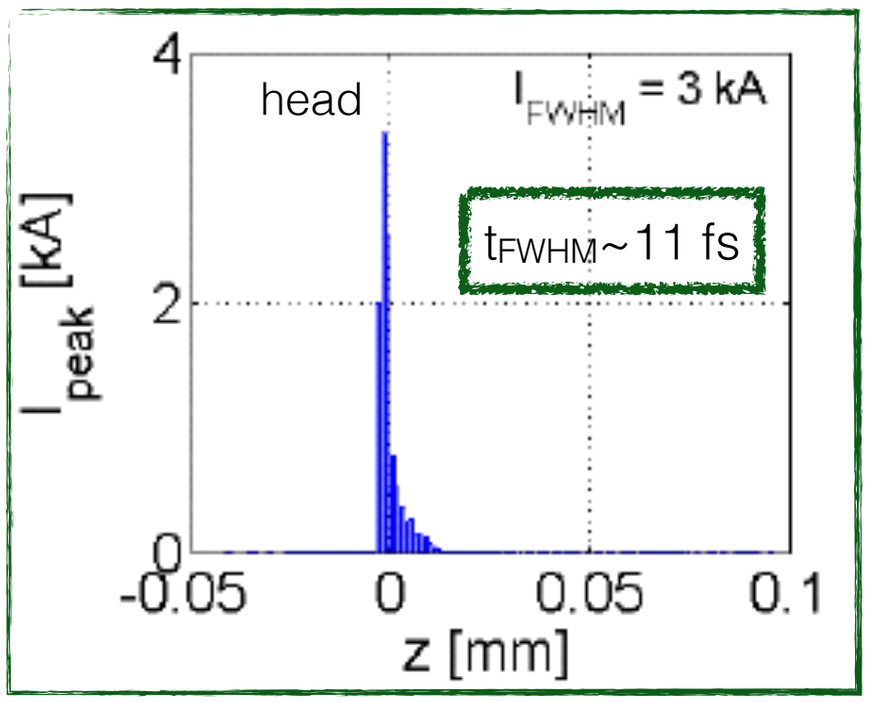
Elegant and TSTEP

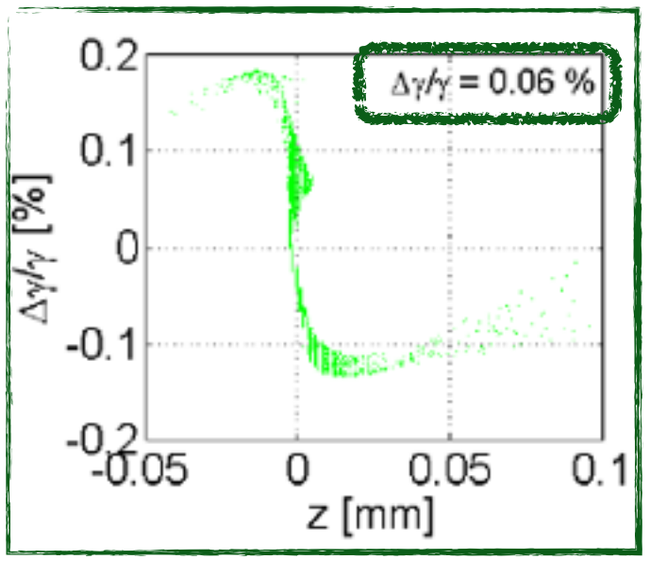


E [MeV]	**518**
ΔE/E [%]	**0.06**
$I_{peak - FWHM}$ [kA]	**3**
Q [pC]	30
$\sigma_{z\text{-}rms}$ [μm]	**6**
$\sigma_{z\text{-}FWHM}$ [μm]	**3**
$\varepsilon_{x,y}$ [mm mrad]	**0.46**
$I_{peak - Slice}$ [kA]	3.5

Velocity bunching in S1 and S2







Achieved beam parameters

	Units	EuPRAXIA FEL-CDR 1 GeV Witness bunch	
No.bunches		1	
Bunch separation	ps		
Rep. rate	Hz	10	
Injector energy	GeV	0.15	
Xband Acc. Gradient	MV/m	> 70	
Exit linac energy	GeV	0.5	
Rms Energy Spread	%	<1	<1
FWHM Peak current	kA	3	1.5
Bunch charge	pC	30	10
Bunch length ~~rms~~ FWHM	μm (fs)	3 (10)	2 (7)
Rms norm. emittance	μm	<1.5	<1
Slice Length	μm	0.75	0.75
Slice Charge	pC	7.5	3.7
Slice Energy Spread	%	0.1	0.1
Slice norm. emittance	μm	1	0.5
Undulator period	cm	1.5	1.5
K		1	1
ρ	x 10^{-3}	1.1	1.1
Radiation wavelength	nm (KeV)	3. (0.4)	3. (0.4)
Saturation length	m	26	27
Saturation power	MW	1210	492
Energy	μJ	12	3.3
Photons/pulse	x 10^{10}	17.	4.8

Full VB and X-band linac

~0.1
~60
0.518
0.06
~3 at the final focus
30
~3 (10)
~0.46

PWFA 2 FEL-SASE 1 GeV 1 Drive bunch
1
1.
10
0.15
> 70
0.5
< 1
1.8
200
34 (112)
< 2

Full VB and X-band linac

0.1
~60
0.518
0.25
~3 at the final focus
200
~20 (67)
~4

The slice length is 0.75 um

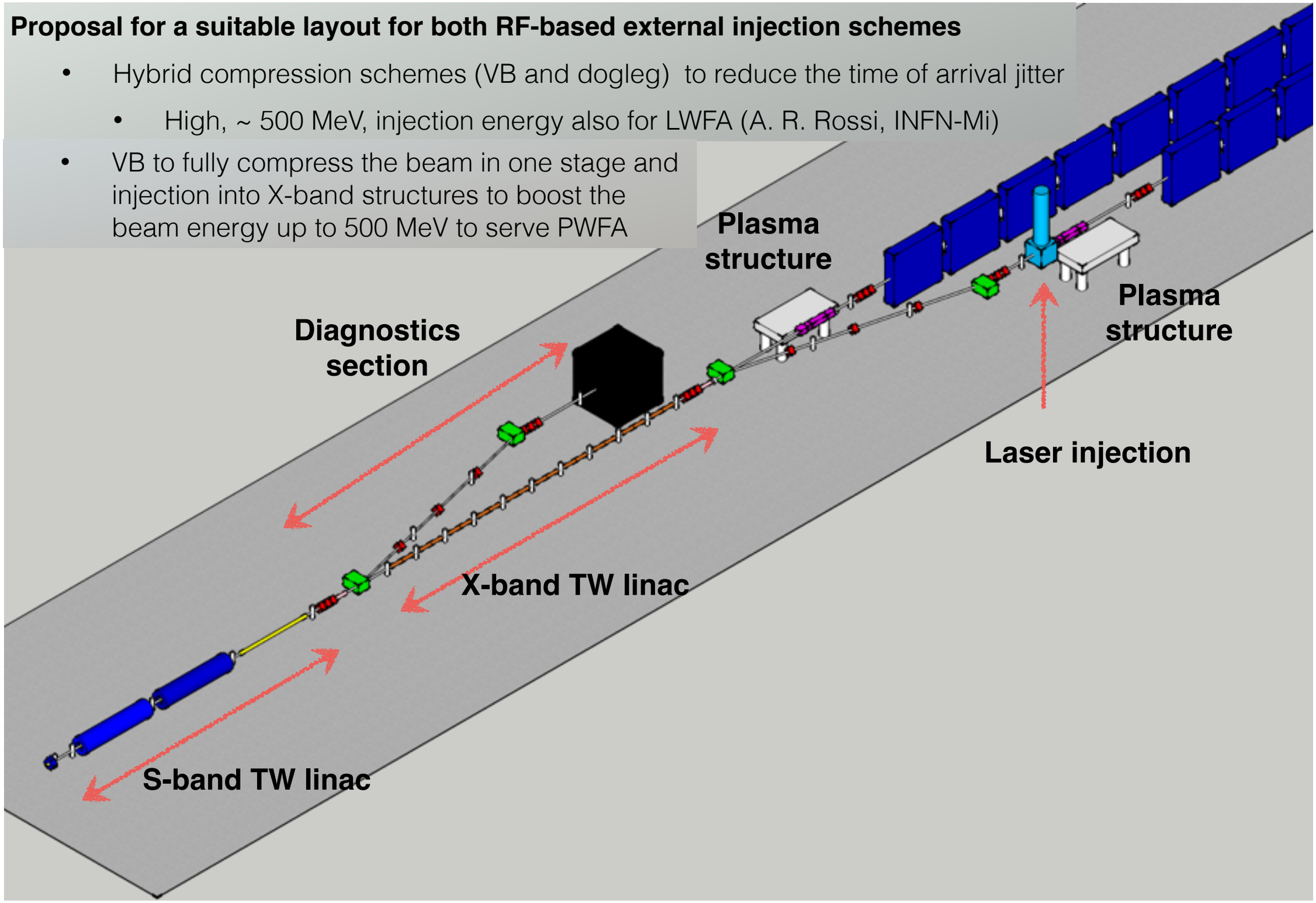
~4 slices with ~3 kA => more than half of the charge contributes to lasing

These parameters have been obtained as there were two injectors!!

A possible layout

Proposal for a suitable layout for both RF-based external injection schemes

- Hybrid compression schemes (VB and dogleg) to reduce the time of arrival jitter
  - High, ~ 500 MeV, injection energy also for LWFA (A. R. Rossi, INFN-Mi)
- VB to fully compress the beam in one stage and injection into X-band structures to boost the beam energy up to 500 MeV to serve PWFA



Status of the transfer line

- A **meeting with WP6 occurred on 23/03/2017**:
  - At high energy (more than 1 GeV), the **advantage of a demixing chicane** like in COXINEL is **not so obvious** (the optimum value of R_{56} is very near 0)
  - **A dogleg is an option** to separate laser and radiation coming from plasma from the e- beam going through the undulators. The other interest is to enable chromatic correction with sextupoles and to have some dispersion for the alternative with transverse gradient undulators
  - Matching conditions to the undulators
    - periodic conditions are needed because of the value of the amplification channel. One issue is the **phase advance between the undulators**. Currently, that is 90°, which means that we cannot keep astigmatism conditions for all undulators

Open Issues

- Investigation of the effect of a higher harmonic cavity to linearize the longitudinal phase space
  - interaction with WP6 is needed in order to understand if the longitudinal triangular shape (with most of the charge on the head of the bunch) is suitable for FEL
- Plasma source
  - interaction with WP3
- Beam parameters at proper positions to start definition of transfer lines and diagnostics
- Diagnostics for femto-second bunches
  - Driver and laser beams removal (WP4,WP9)
- Laser and electron beam synchronization
  - Photo-cathode laser parameters (WP4)
- Transport and matching from plasma to the pilot application
  - Contacting WP3 and WP2 to validate the input at the exit of the plasma chamber (realistic betatron functions, minimum spacing)
  - Optimizing the capture doublet (or triplet)
  - Defining the matching conditions to the undulators: which periodic channel? (WP6)

Agenda for WP5 meetings

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Wednesday, 21st of June 2017

- **14:00 -15:30 => <u>RF injector working points</u>**
  - Layout introduction and Parameters table (including Twiss functions at peculiar positions) (E. Chiadroni, INFN)
  - RF compression for driver and witness up to the plasma (A. Giribono, INFN)
  - RF and magnetic compression (J. Zhu, DESY)
  - **Discussion**
    - **Bunch shapes, synchronization, …**
- **16:00 -18:00 => <u>Diagnostics</u>: Joint meeting WP3-WP5**
  - Electron diagnostics
    - Diagnostics conceptual design of EuPRAXIA-like machine (A. Cianchi, Roma2)
    - 6D characterization of witness beam before injection (B. Marchetti, DESY)
    - Beam Diagnostics for Plasma Accelerators (J. Wolfenden , CI)
    - Discussion on plasma-based devices for e-beam diagnostics
    - WP14: Challenges in diagnostics of ultrahigh 6d-brightness and laser insertion/ removal (B. Hidding, U. Strathclyde)
  - Compatibility with plasma implementation
  - Plasma sources (for both LWFA and PWFA)
    - Plasma diagnostics
  - Radiation diagnostics

Agenda for WP5 meetings

Thursday, 22nd of June 2017

- **09:00 -10:30 => <u>Transfer lines</u>**
  - Optimization of the capture section (K. Wang, CNRS/LAL)
  - Matching and transfer lines in plasma injector (WP3)
  - Plasma lenses as novel transfer line devices (A. Marocchino, INFN)
  - Matching conditions to the undulator (WP6)
    - Discussion on witness beam longitudinal distribution
  - Matching conditions to HEP experiments (WP7)
  - **Discussion**
    - **Driver and laser beams after the plasma: how to remove them?**

- **11:00 -12:30 => <u>Joint meeting WP2-WP5-WP9</u>**
  - Code benchmarking discussion
  - Optimization of a comb-like beam down to the plasma for PWFA experiments
  - Discussion on driver and witness separation
  - Plasma source