Electron Beam Transport

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(on behalf of the NLS Design Team)

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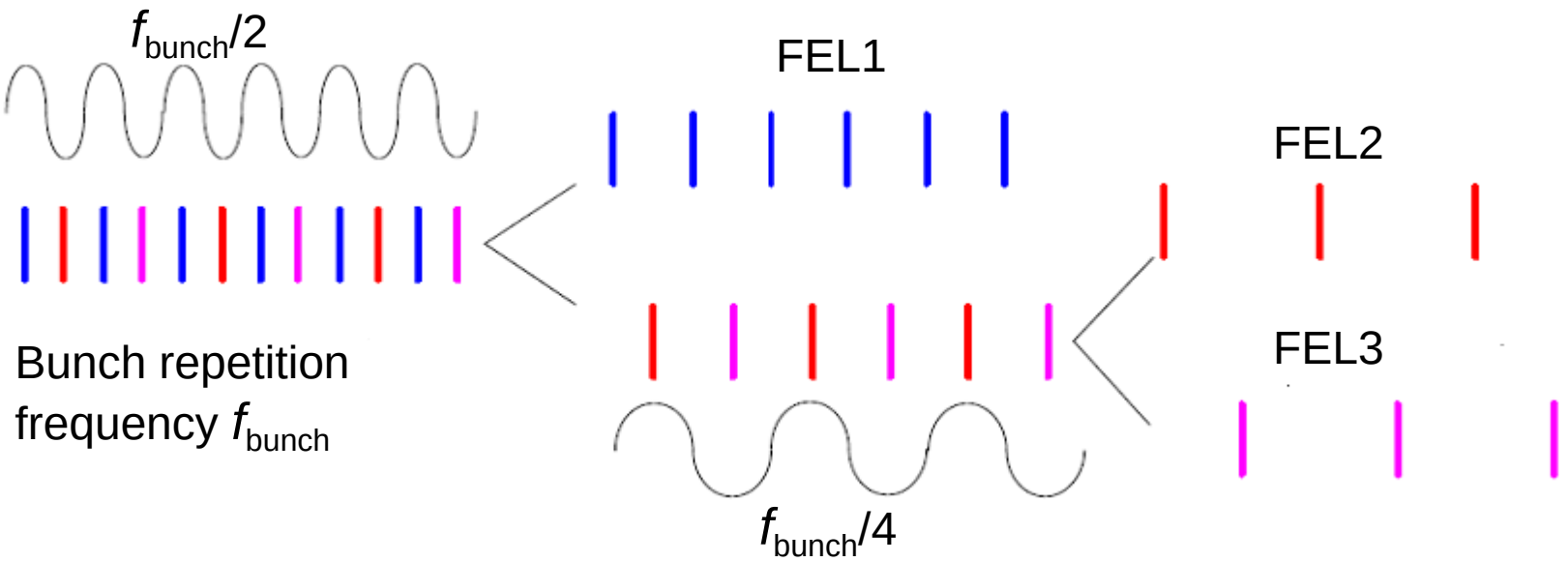
Contents

Beam Switchyard

- Beam switchyard separates and transports the electron beam to different FELs. The design of switchyard should :
  - preserve the beam qualities of compressed bunches
  - consider future upgrades without major construction changes
- The design philosophy remains the same independent of the straight-through or re-circulation option
  - but needs to keep the possibility to extract and transport low energy beam (1.2 GeV)
- NLS requirements :
  - initial 1 KHz repetition rate with even pulse spacing
  - upgrade to 100 KHz each FEL, higher 1 MHz for any FEL operating on its own
  - 3 FELs initially switching at 1 kHz/3
  - up to 5 FELs in a later stage with 1 MHz/5 switching, with an additional requirement to be able to extend the linac energy.

Beam separation possibilities

- Separation using either High-Q resonant kicker or RF deflector.



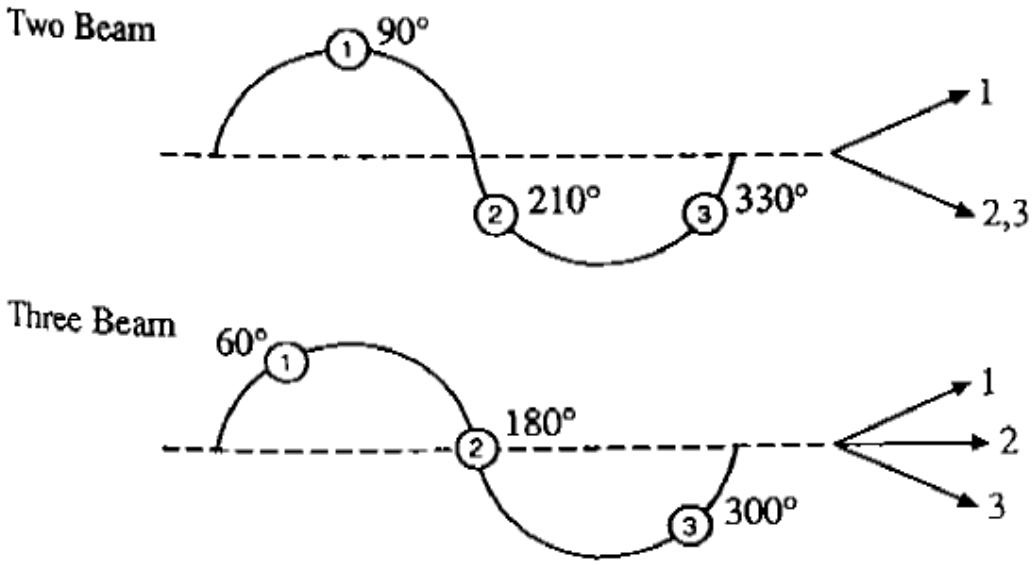
- Fast kickers to switch the beam to different FELs.

Based on R. Brinkmann's presentation "Some considerations on XFEL beam distribution", Oct. 2003

CEBAF RF Separators

CEBAF uses warm sub-harmonic RF separator cavities to extract the beam at different energies.

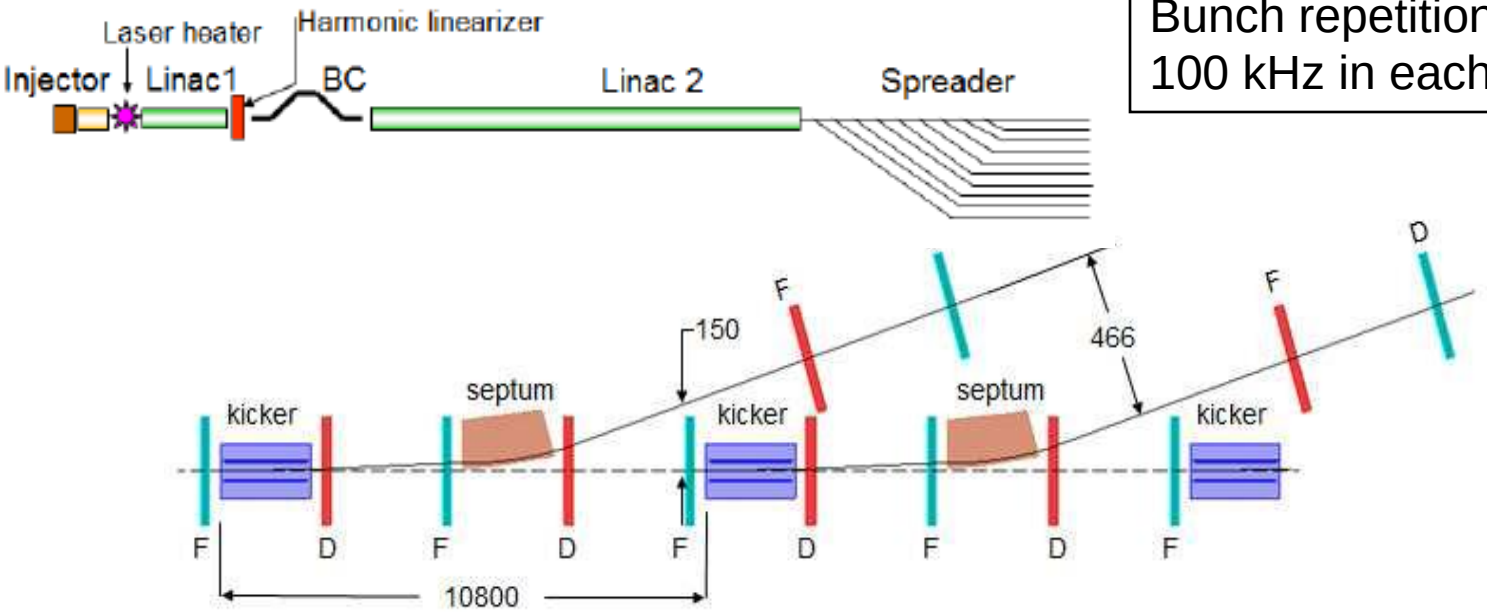
The phasing of the RF in these cavities provides the required separation.



A. Krycuk et al, "Construction of the CEBAF RF Separator", 1993 PAC Proceedings
C. Hovater et al,"The CEBAF RF Separator System", Linac 96 Proceedings

LBNL

Bunch repetition rate 1 MHz
100 kHz in each of ten FEL lines.



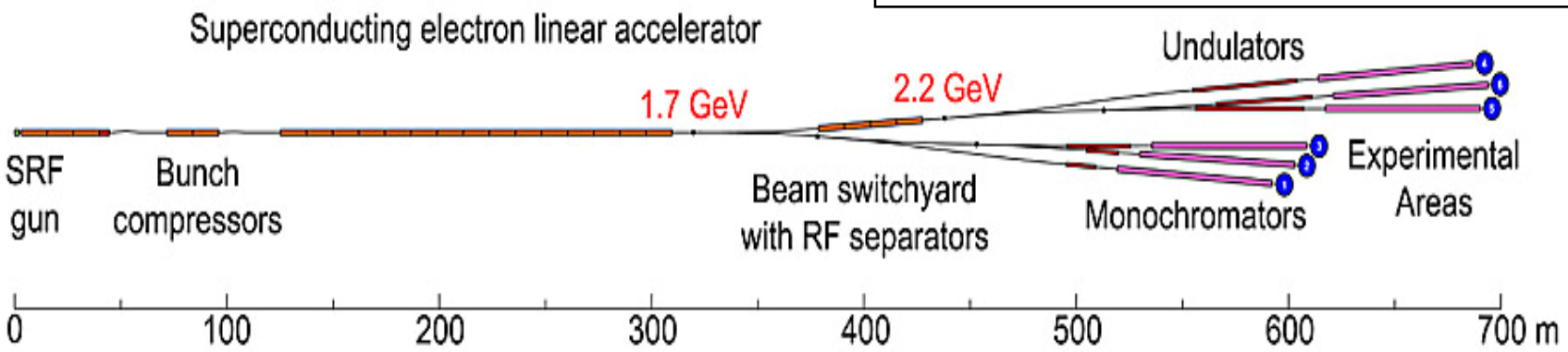
- 2m long stripline kicker with 5 mm gap providing 3mrad kick at 100 kHz rep rate.
- 2m long septum provides 27 mrad turn to the beam.
- Followed by combination of quads and dipoles to make a triple bend achromatic and isochronous beam line.

A.A. Zholents et al, "LINAC design for an array of soft x-ray FELs", LBNL-1091E

Wi-FEL

Extraction at two energies : 1.7 and 2.2 GeV

Bunch repetition rate Hz-several MHz
Mode : CW



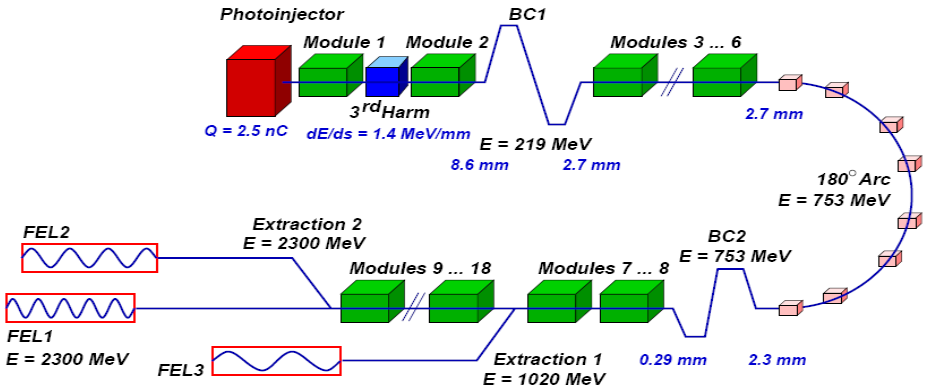
- Beam distribution system based on RF separation.
- Four beam ports possible at each energy, will require additional separators for more ports.
- Separation increased by amplifying the RF kick by downstream defocusing quadrupole.
- Control of photocathode drive laser in the electron gun to select repetition rate of one particular beam line.

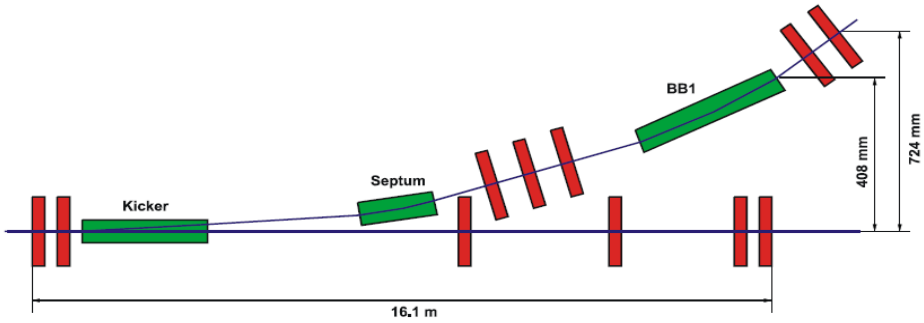
http://www.wifel.wisc.edu/WiFEL_R&D_Proposal.pdf

BESSY

Extraction at two energies : 1.02 and 2.3 GeV

Bunch repetition rate 1-25 kHz
Mode : CW

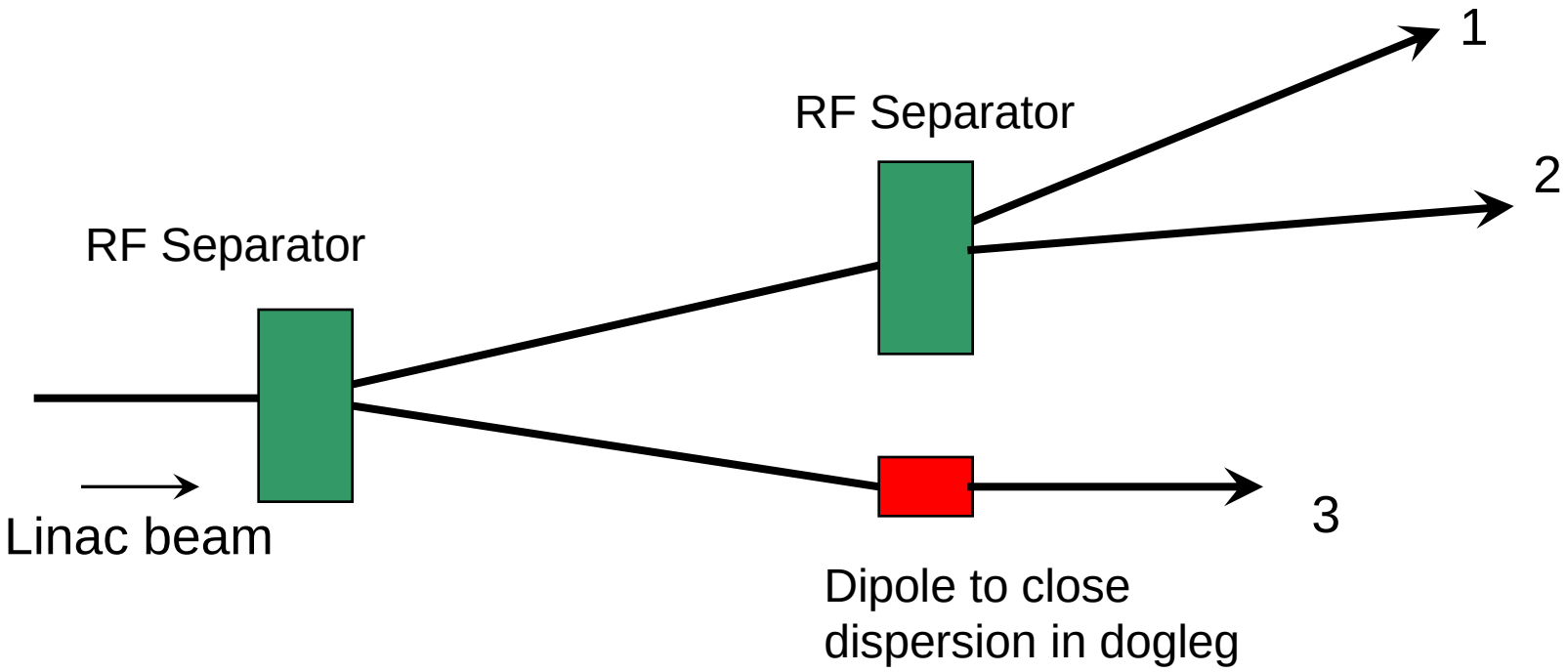




- Design constraints due to physical space, geometry considerations to the optics and the linac timing structure.
- Fast magnetic kicker with time constants in μsec range give 5 mrad kick.
- Long drift to allow clearance to non deflected bunches, septum gives second kick.
- Quadrupole triplet and dipole BB1 makes the system achromatic (but not isochronous, R_{56}=0.3cm)

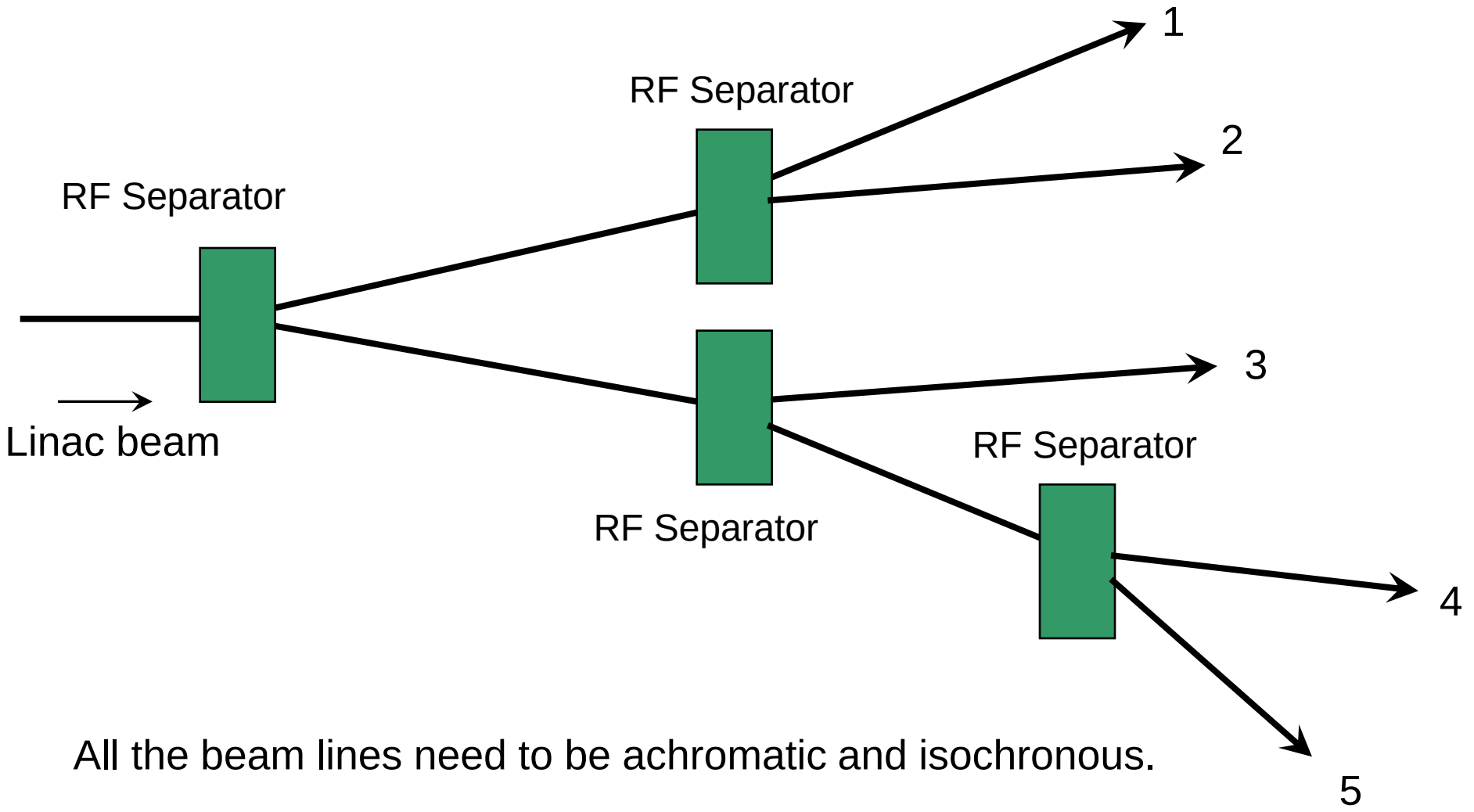
BESSY FEL TDR

NLS Baseline : 3 FELs using RF separators



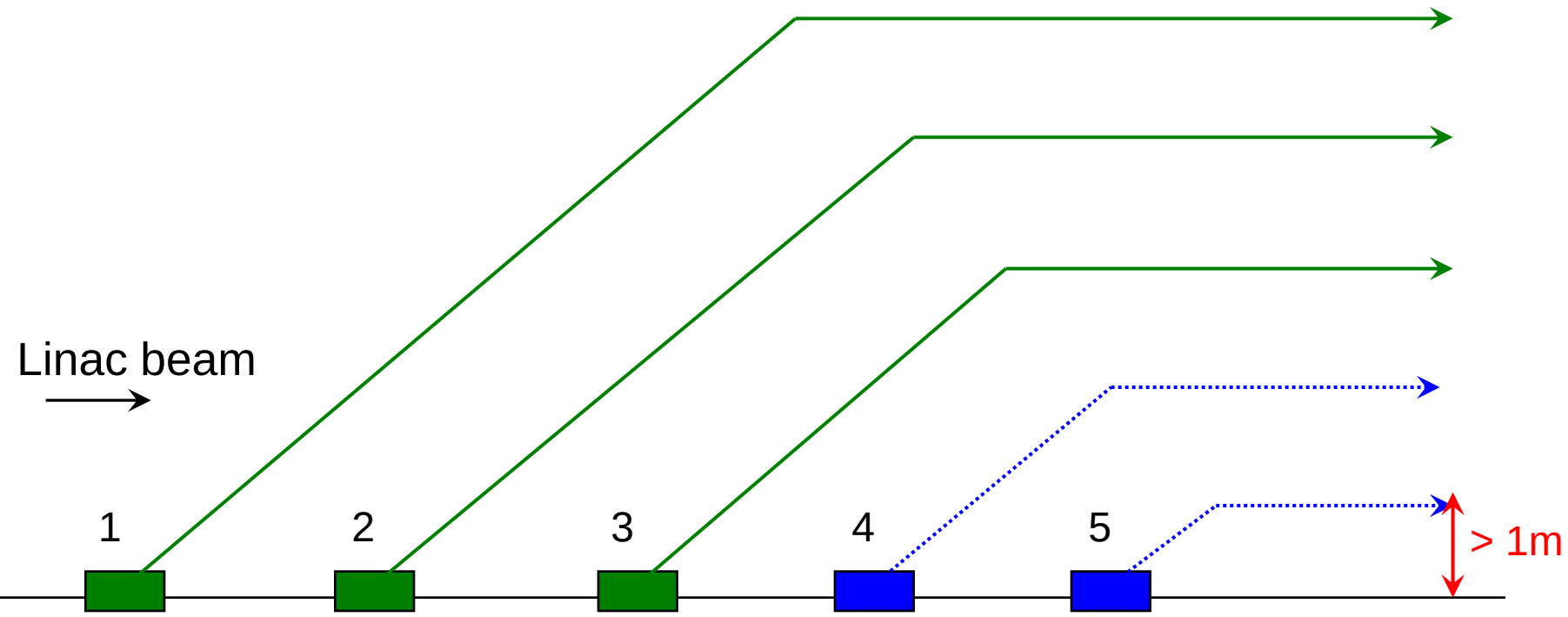
All the beam lines need to be achromatic and isochronous.

NLS Upgrade : 5 FELs using RF separators



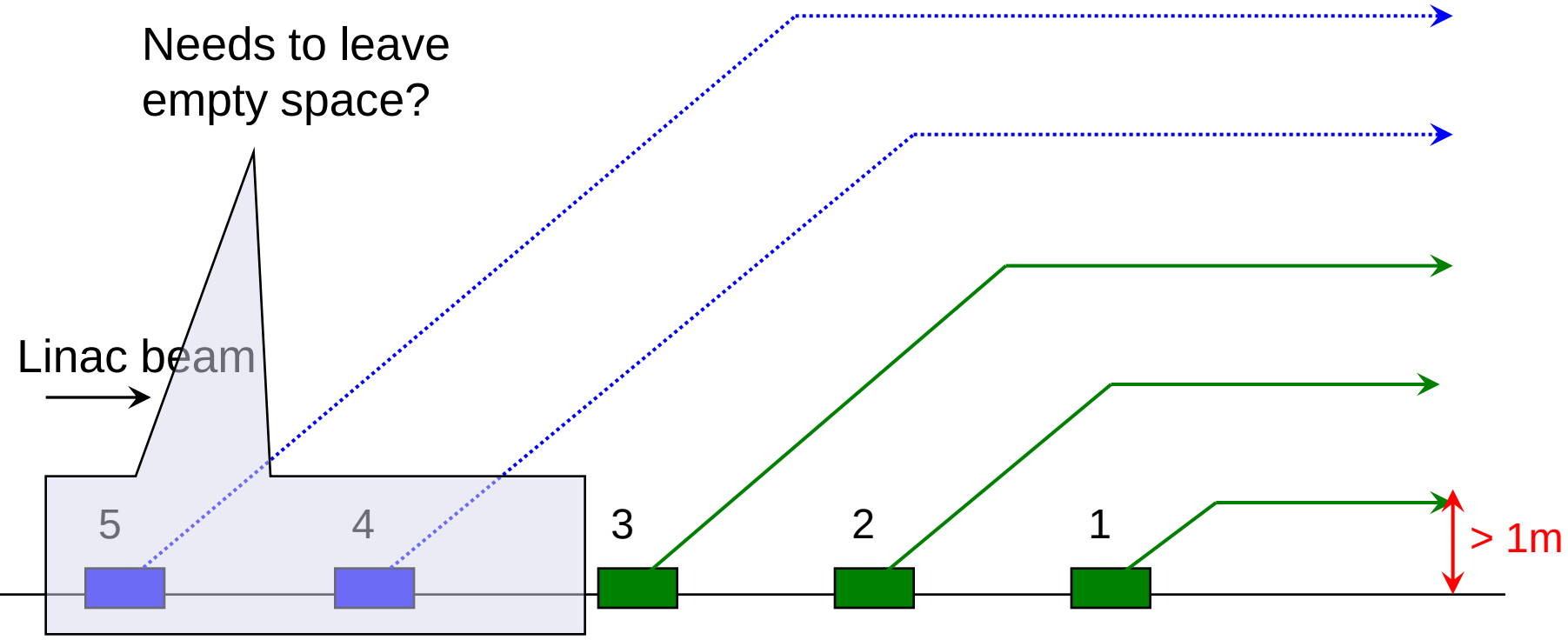
All the beam lines need to be achromatic and isochronous.

NLS Baseline and Upgrade FELs using fast kickers



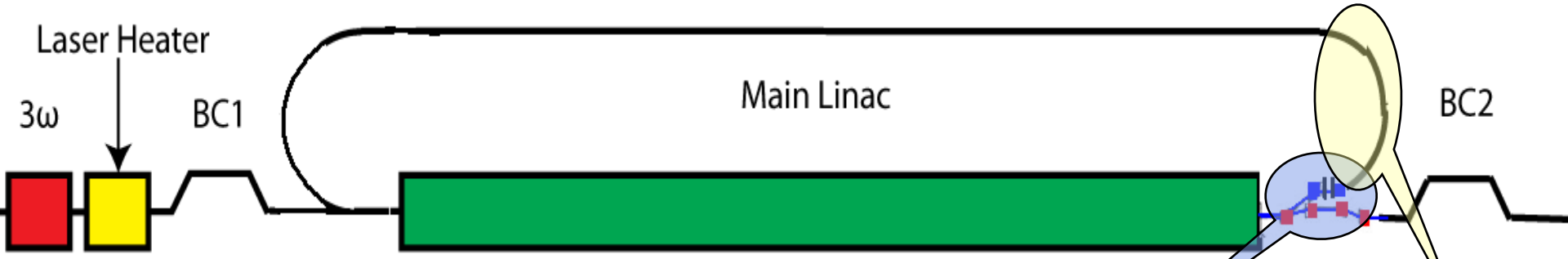
To consider : Maximum separation to accommodate 5 FELs
Kicker/septum designs
Achromatic and isochronous beam transport

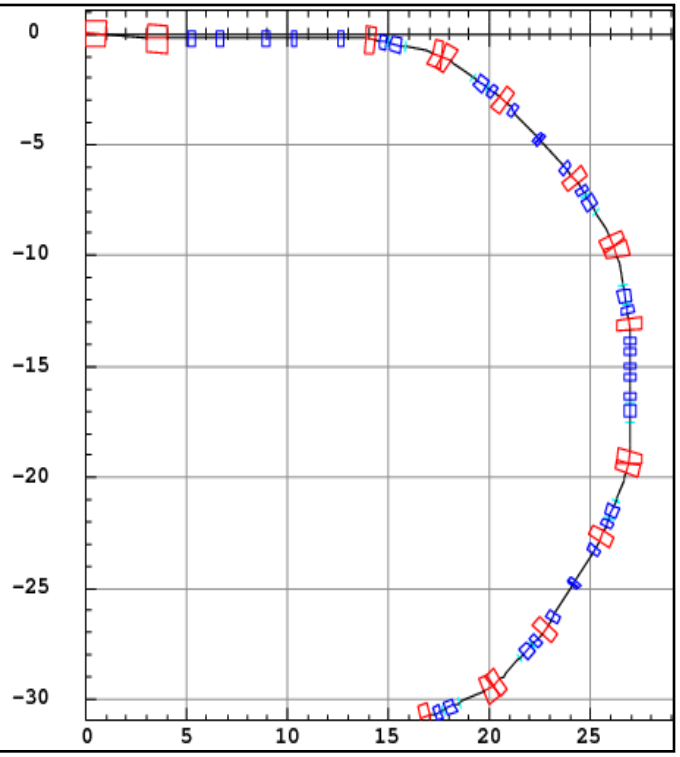
NLS Baseline and Upgrade FELs using fast kickers



To consider : Maximum separation to accommodate 5 FELs
Kicker/septum designs
Achromatic and isochronous beam transport

Beam spreader : Matching into the arc at 1.2 GeV





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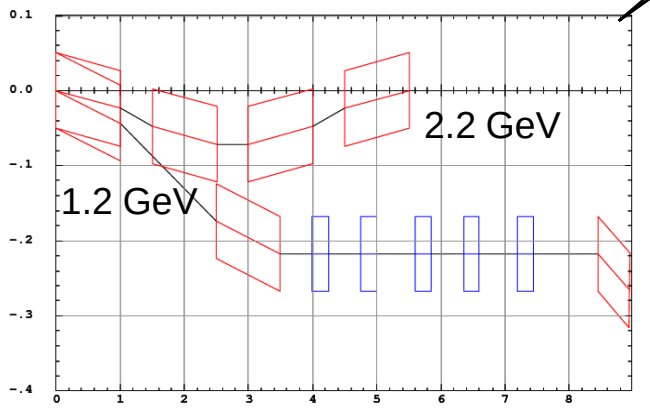

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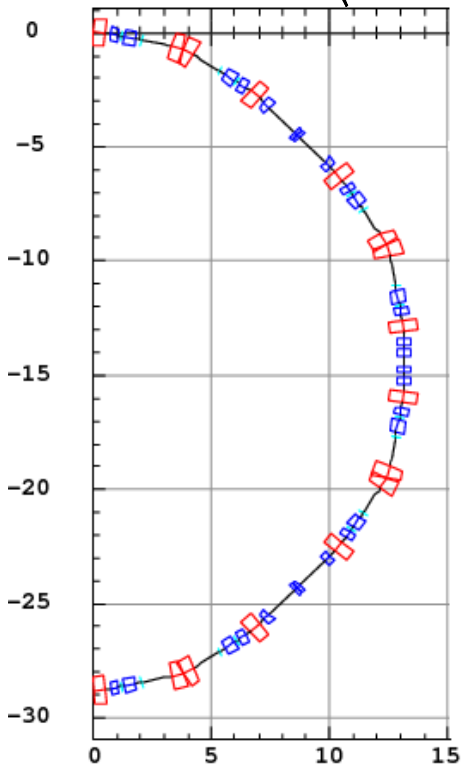
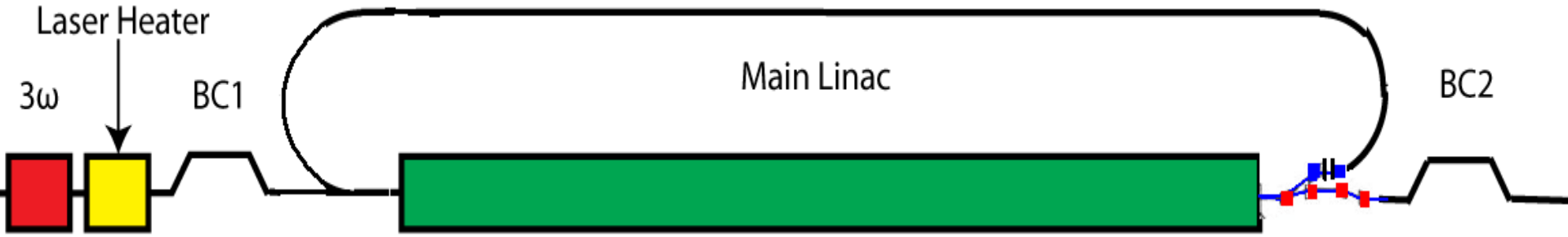
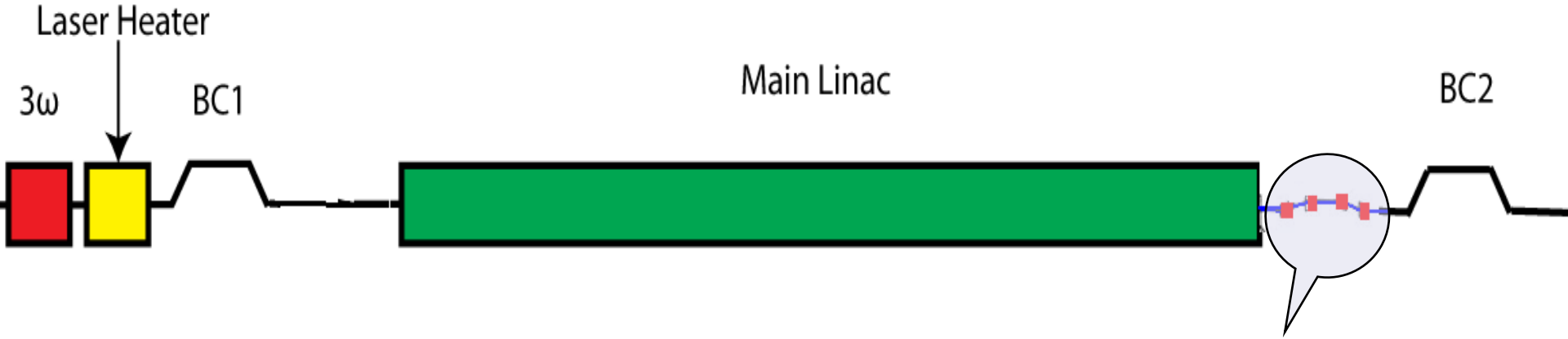


Finite R_{56}?
Design being finalised.

Re-circulation option : Extraction of 1.2 GeV

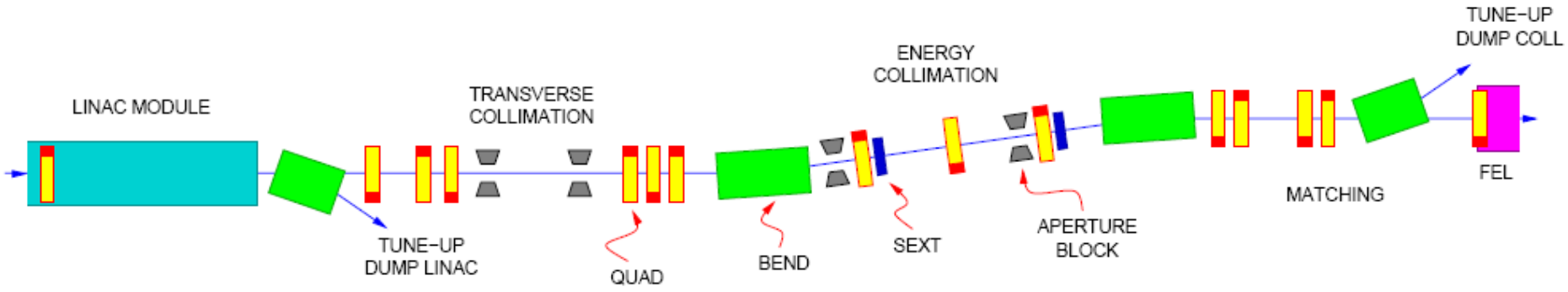




If to extract only at 1.2 GeV - reduce strengths of these dipoles by 2.2/1.2.

Beam Collimation and machine protection

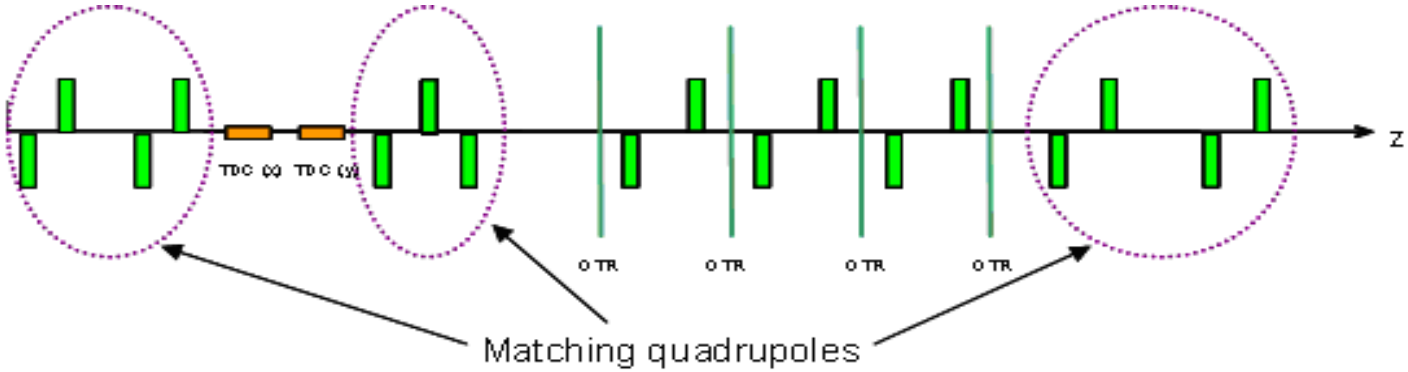
- Beam collimation is essential to provide protection of the undulator modules as well as to remove halo and dark current created and transported through the upstream linac.
- Location and design of collimation section to be worked out for NLS.
- Transverse and longitudinal collimation section proposed for BESSY FEL ~43 m long.



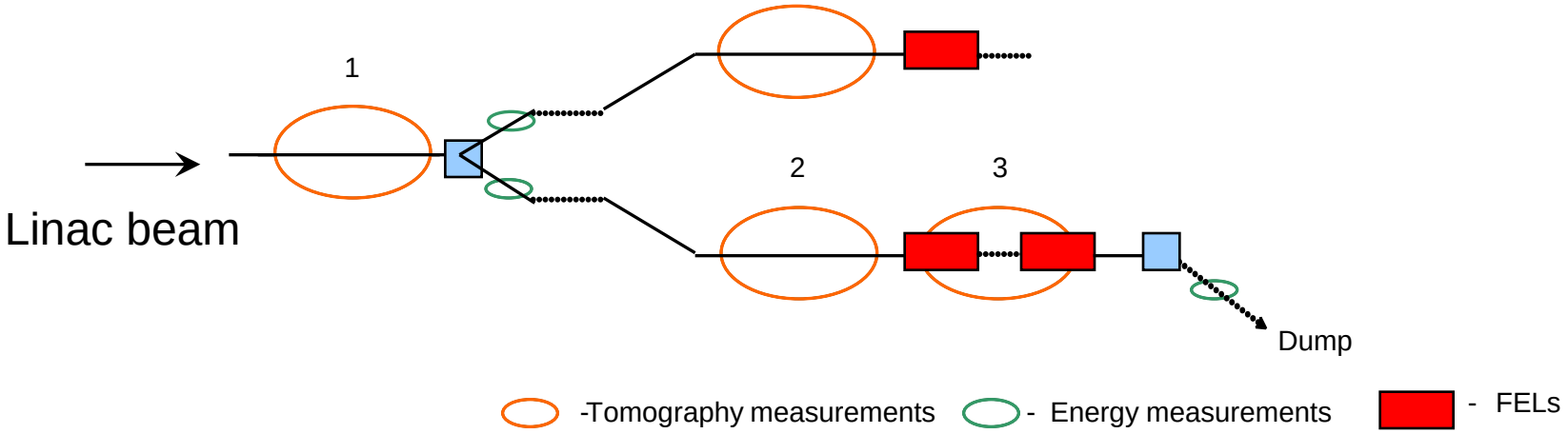
T. Kamps, "Collimation system for the BESSY FEL", Proc. Of 2004 FEL conference

Tomography diagnostics section

- Tomography section provides the complete 6D characterisation of phase space of electron bunches essential for the FEL operation.
- It consists of four screens with 45˚ phase advance between them to reconstruct the transverse phase space and hence the projected emittance in both planes.
- Tomography section is preceded by two transverse deflecting cavities (one/plane), which provide measurements of bunch length and slice emittance.



Tomography diagnostics section



- Possible layout options
  1. Before beam switchyard

     Any disruptive effects due to beam separation optics (and possibly collimation) in the beam entering the FELs will not be detected.
  2. Before FELs

     May not be necessary to repeat full diagnostics in each FEL. Can be done in one branch. Provide a location for beam dump for energy measurements.
  3. Within FELs

     Possible with certain constraints.
- Longitudinal space requirements (~25-30 m)

Summary & Plans

- To meet the NLS baseline and upgrade requirements, beam switchyard design will be based on either fast kicker or RF separator.
- The choice of beam line design (dog-leg or not) will decide the layout of the facility (or the other way round).
- The detailed design will be done after assessing these options.
- Design requirements and locations of the collimation and tomography diagnostics sections to be decided.
- Start-to-end simulations will then be extended through the beam collimation, diagnostics and beam spreader sections to ensure that the beam quality satisfies the requirements for the FELs.

Acknowledgements to:

The NLS Physics and Parameters Working Group

Swapan Chattopadhyay, Hywel Owen