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Compact

WP8 Diagnostics

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First iteration

- This is the summary of the diagnostics meeting + several iterations with some people in order to meet the diagnostic requests with the machine layout
- It is an ongoing process and every time we learn something.
- We are not yet addressed special diagnostics as BAM (Beam Arrival Monitors) and BLM (Beam Loss monitor) for their limited impact in the layout
- We are open not only to the already developed diagnostics but also to R&D and ongoing processes (wakefield monitor for instance)
- The polar star is the wise use of the space, however pushing the requests for resolutions to high level impacts to the space occupancy.

Working point

Table 3: Injector beam parameters.

Parameter	At gun exit	At L0 exit	Units
Repetition rate	0.1, 0.25, 1		kHz
Charge	75		pC
Proj. norm. emittance (RMS)	0.15 (x), 0.15 (y)		μm rad
Energy	6	280	MeV
Rel. energy spread (RMS)	0.7	0.5	%
Bunch duration (RMS)	1.2	0.4 (w/ VB)	ps
Peak current (core)	20	60 (w/ VB)	A

Table 5: Electron beam parameters at undulator entrance.

Parameter	Value
Max. Energy	5.5 GeV @ 100 Hz
Max. Peak Current	5 kA
Norm. Slice Emittance	0.15 μm rad
Bunch charge	< 100 pC
Bunch duration (RMS)	< 50 fs
Slice Rel. Energy Spread	0.01%
Max. repetition rate	1 kHz

However a flexibility to measure bunch with charge down to few pC has an impact in

- Trajectory (5 μm is the requested resolution) ->> requires cavity BPM
- Bunch length down to fs level ->> requires high resolution measurement
- Beam size can be very small at very low charge. It is important to set some thresholds.

Charge

Integrated current monitors:

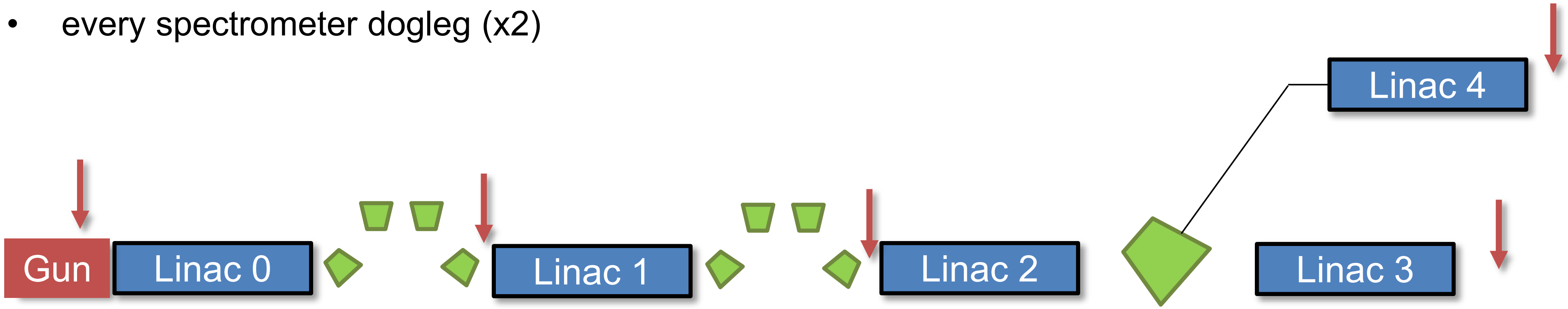
They can measure down to fC (in the Turbo-ICT variation).

Very compact, 10 cm length.

Widely used

We plan to use at least 7,

- the gun area,
- after each bunch compressor,
- before the undulator (x2)
- every spectrometer dogleg (x2)



Trajectory

We set 5 μm as desired resolution, not only at 75 pC but also with few pC charge.

The only device that can achieve such resolution even with small charge is the cavity BPM.

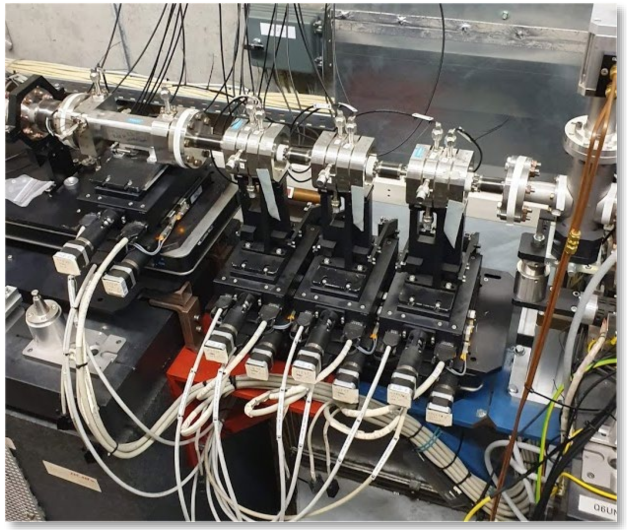
In the PSI design CBPM is only 10 cm long, 16 mm diameter (10 for E-XFEL).

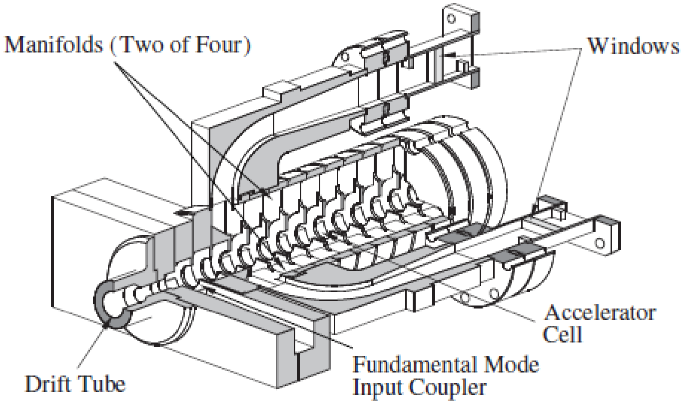
We agreed to have the correctors together within the quads, so we need about 7 more meters in the whole machine to allocate the CBPM.

This is not bad because the smallest aperture for a stripline is 30 mm, while the quad bore now is 15.5 mm, so it is impossible in the actual configuration to put the striplines inside the quads

It is important to know the transverse dimensions in the bunch compressor to understand if we need a different type of cavity.

The option with the wakefield monitor is still open.





C. Adolphsen et al., Wakefield and Beam Centering Measurements of a Damped and Detuned X-Band Accelerator Structure, SLAC–PUB–8174

Envelope beam size

Beam envelope measurement is fundamental to measure the beam size in different positions and to compare with simulations.

Very compact design, 10 cm length in longitudinal dimension, but it could even more compact.

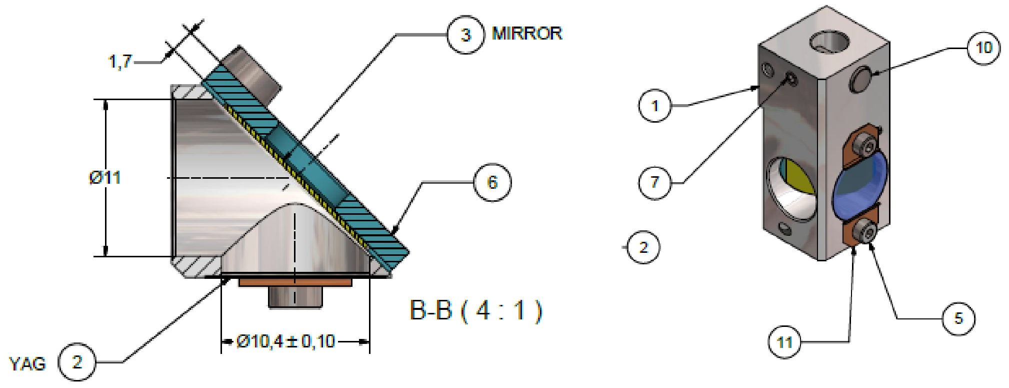
YAG:CE 100 μm thick normal to the beam to eliminate the blurring and the deep of focus or directly OTR

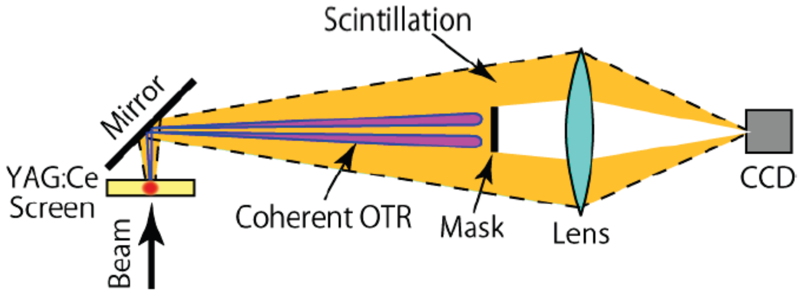
Mirror on the back at 45 degrees quite thin (300 μm) to reduce the multiple scattering in case of YAG:Ce

Possible risks: COTR

Mitigation: SACLA approach is the most compact

Problem: resolution limited even with OTR to few μm, keep β under control to avoid problems at 5 GeV





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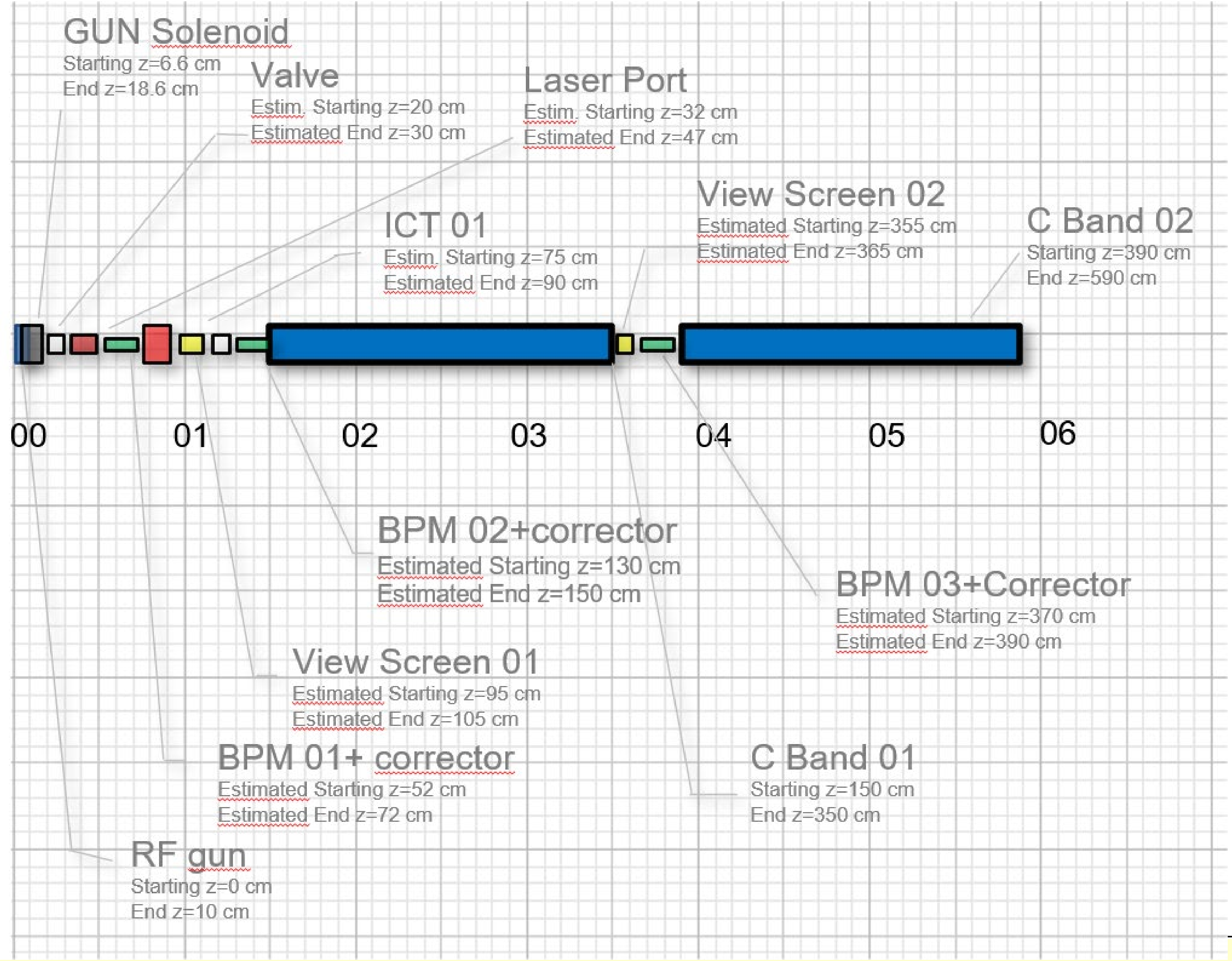
Injector diagnostics

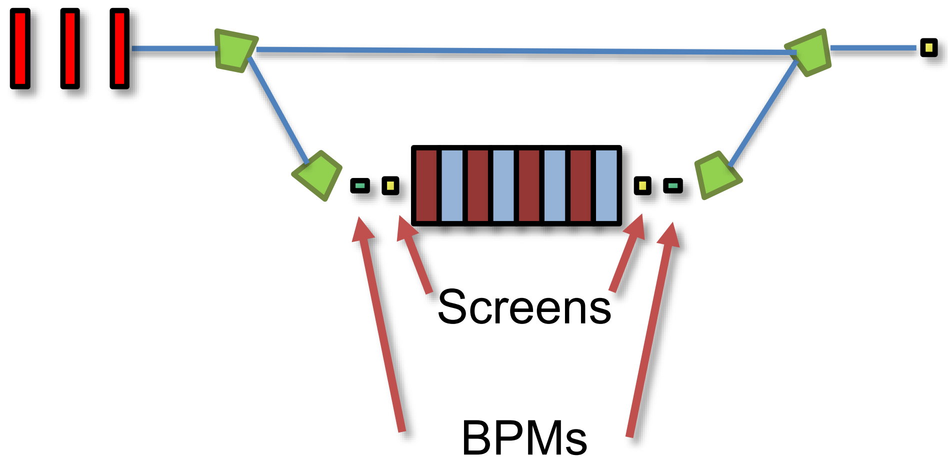


Laser heater

Matching section at 120 MeV

Nice place to have emittance measurements

At least 1.5 m long, as PSI case, maybe longer to have emittance measurement



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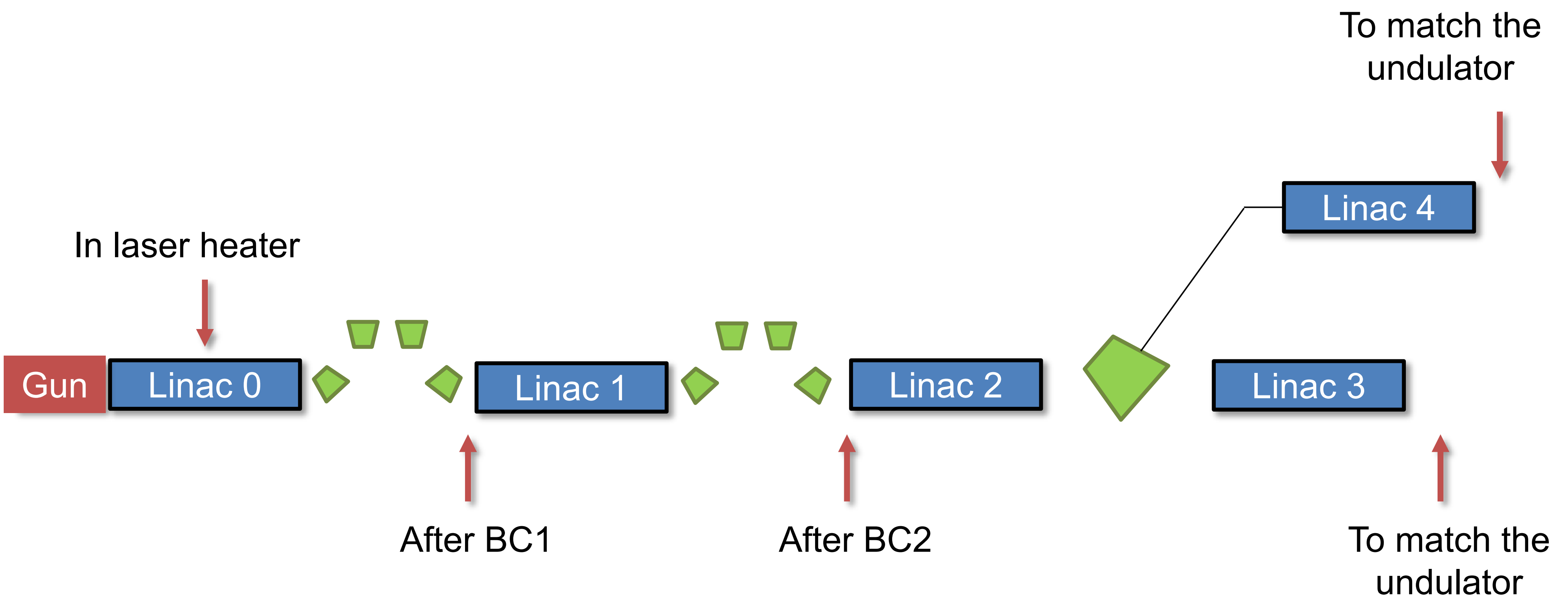
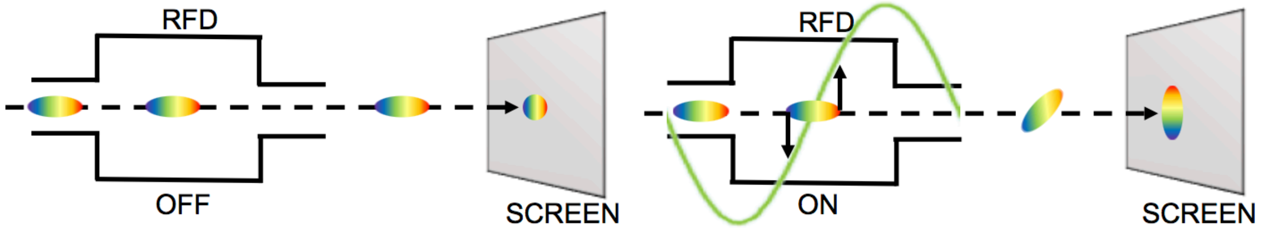
Transverse emittance and Twiss parameters

Compact

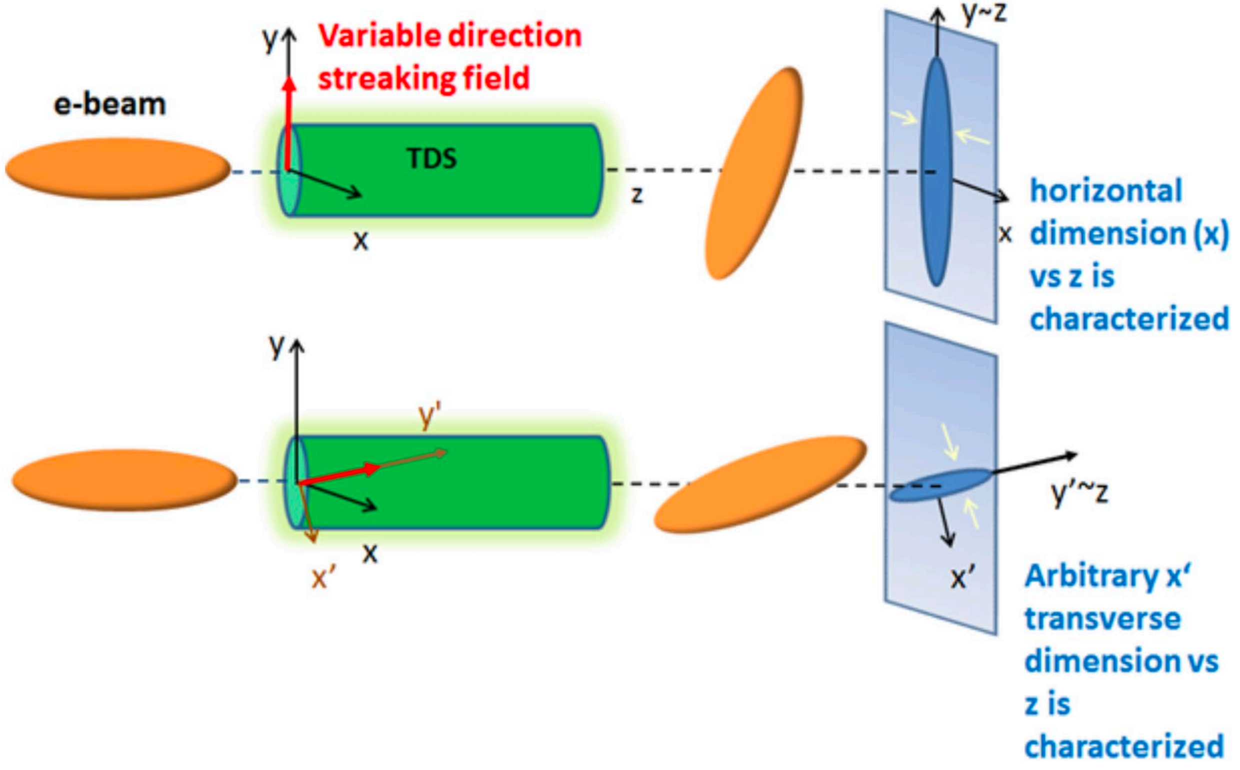


RF deflectors

Standard Design

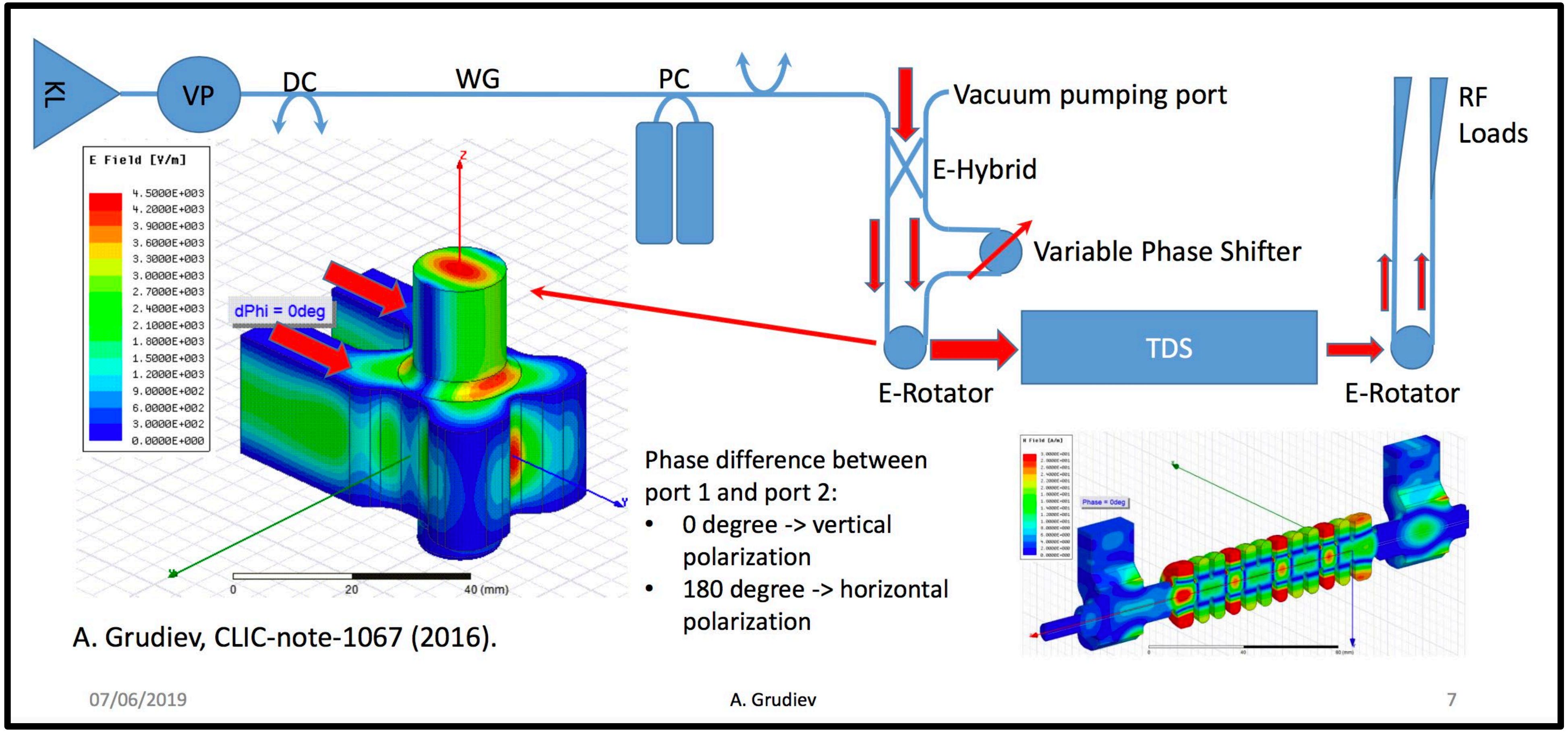


Advanced Design



PolariX TDS

PolariX TDS is a variable **Polari**zation **X**-band **T**ransverse **D**eflecting **S**tructure



A. Grudiev, CLIC project meeting, 7/05/2019, CERN

Machines with PolariX

Parameters	SINBAD ARES	FLASH II	FLASHForward	ATHOS SwissFEL	Unit
Charge	0.5-30	20-1000	20-500 (driver) 10-250 (witness)	10-200	pC
Norm. emit. (rms)	0.1-1	0.4-3	2.0-5.0 (driver) 0.1-1.0 (witness)	0.3	mm
Bunch length (rms)	0.2-10	<3-200	50-500 (driver) 1-10 (witness	2-30	fs
β function @TDS	10-50	7-20	50-200	50	m
Beam energy	80-200	400-1400	500-2500	3400	MeV
Rep. rate	10-50	10	10	100	Hz
TDS voltage	25-40	30-45	25-30	30-60	MV
# TDS	2	2	1	2	
Max. length (flange to flange)	3	<1.91(8)	<2	4	m
TDS iris	4	4	4	4	mm
TDS frequency	11991.6	11988.8	11988.8	11995.2	MHz
Temperature range	48	62	62	25-35	°C

DESY.

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Courtesy of B. Marchetti, DESY

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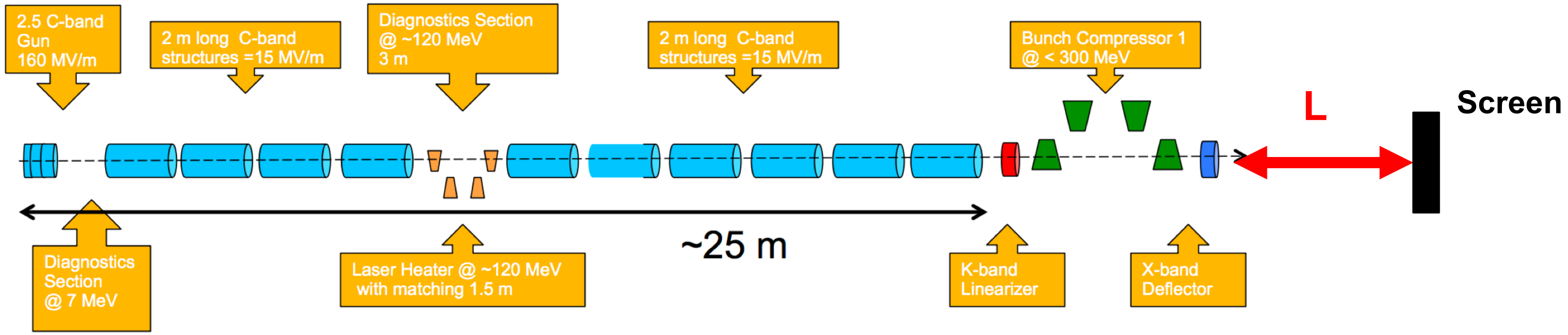
Scaling from FlashForward to XLS



$$\sigma_{screen} = \omega_{RF}\, L\, \frac{V_t}{E_0/e}\, \sigma_t$$

neglecting the RFD-off beam size (to see the scaling law with the main parameters)

FLASHForward installation
(reference case to be scaled to XLS)

TDS-Screen distance	**L = 5m**
Klystron nominal power	**6MW**
TDS length	**<2m**
Deflecting voltage	**V_t = 25MV**
Beam Energy	**500MeV**
Quadrupoles before/after the TDS	

[redacted]

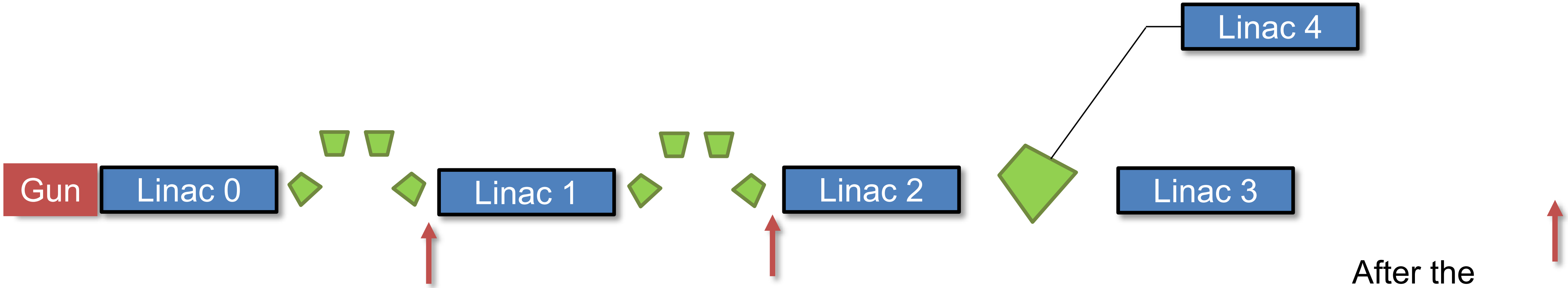
XLS Bunch length (rms) @ 280MeV

1ps (370um)	**with BC off**
90fs (26um)	**with BC on**

C. Vaccarezza, A. Giribono et al. talk

On going work by Sapienza + IASA

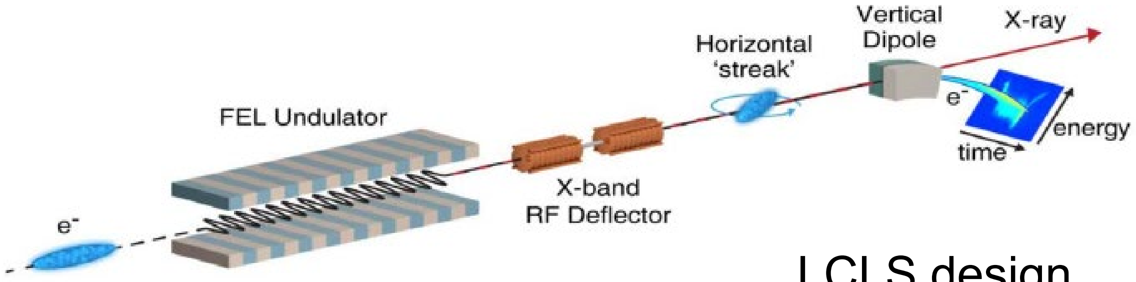
Longitudinal measurements



After BC1 with
BC1 on/off
With TDS
+
Spectrometer

After BC2 with
BC2 on/off
With coherent
radiation

After the
undulators with
TDS
+
Spectrometer



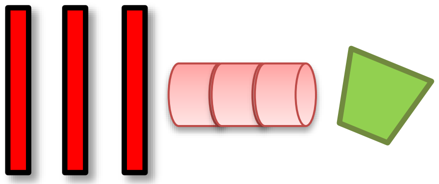
LCLS design

6D phase space

Longitudinal and transverse phase space information

We need:

- 5 Quadrupole scan stations
  - In the laser heater
  - After the BC1
  - After BC2
  - Before undulators (x2)
- 3 Spectrometers
  - after the BC1
  - Before/after the undulators (x2)
- 3 Polarix for longitudinal phase space
  - After BC1
  - Before/after undulators



Additional beam size monitors

The modules are different in Linac 1,2 with respect to Linac 3

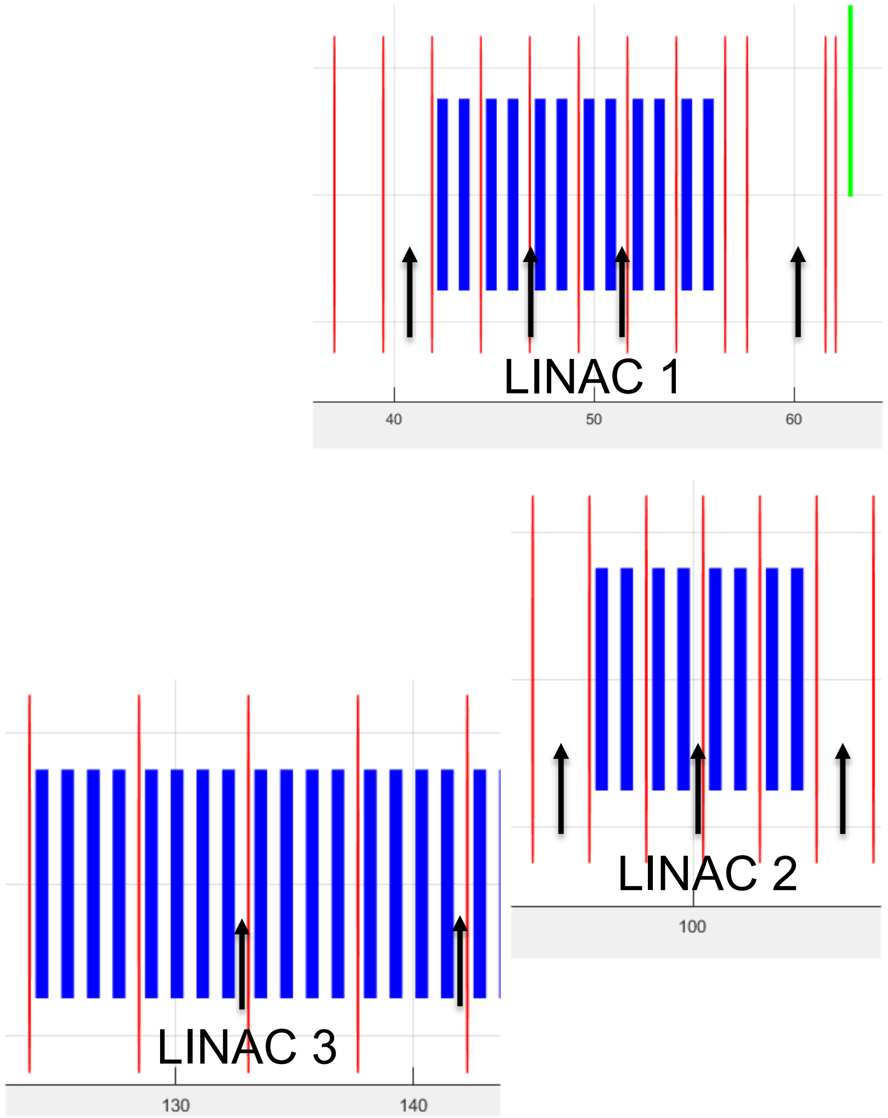
The quadrupoles are every 2 structures in Linac 1-2 and every 4 in Linac 3

We can put 1 view screen every 4 structures in Linac 1

The same for Linac 2

Every 8 structures in Linac 3

The screen is very compact, just 10 cm long



Conclusions

- We continue to update and refine the diagnostics in connection with others WGs.
- The use of TDS requires 90 degrees of phase advance in the plane where we take the measurement. This space can be very large at high energy, and for sure it is not short even at 300 MeV.
- Beam size must be larger than few microns in order to be measured, even at 5 GeV and few pC.

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