WP3 – Gun and Injector

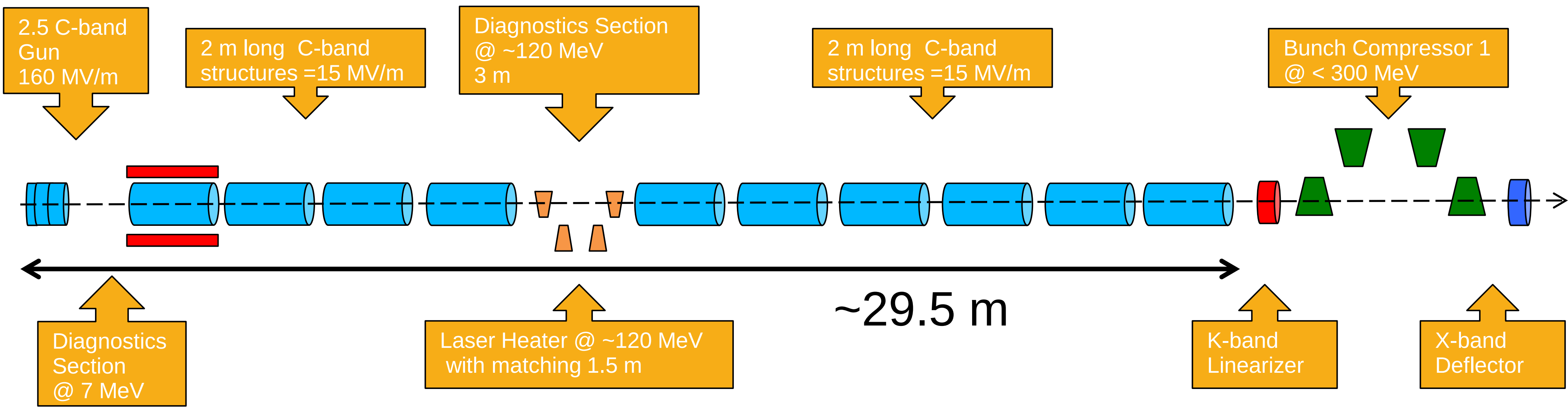
Main goal: define baseline injector layout

Funded by the European Union

Full C—band XLS Injector

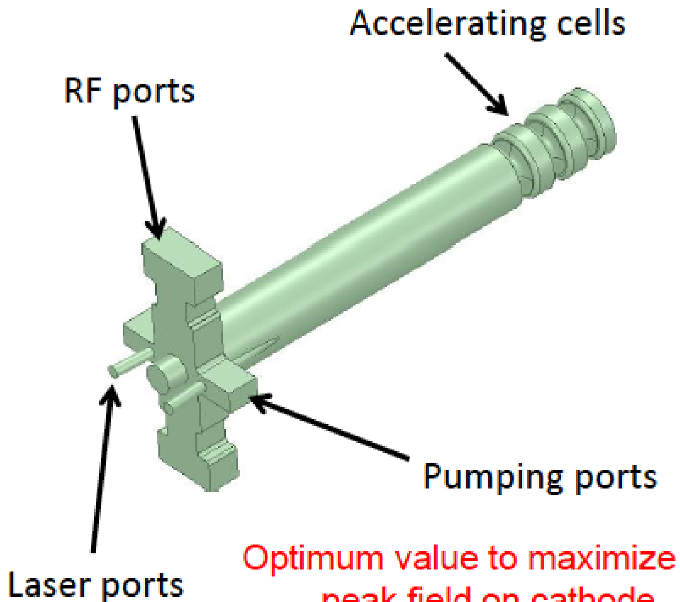
Compact

- One injector for all the operational modes (HRR and LRR)
  - 2.5 C-band gun with 160 MV/m cathode peak field => longer drift for diagnostics
  - Copper cathode and TiSa Laser
  - Same gradients 15 MV/m in the 2 m long C-band structures, 0.4 m spacing, max gain 30 MeV/structure
  - Same diagnostics positions (@ gun exit 7 MeV and in the drift parallel to the LH @ 120 MeV)
  - Same beam parameters at the linac exit
  - Solenoid around first C-band accelerating structure, allows also possible VB operation



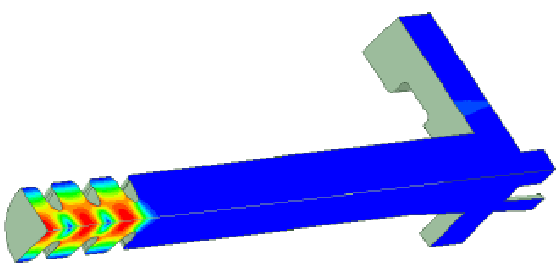
- Optimal BC1 input energy (=> and position)
  - Without Velocity Bunching
  - With Laser Heater
  - K-band Linearizer just before the BC1, X-band RFD downstream BC1

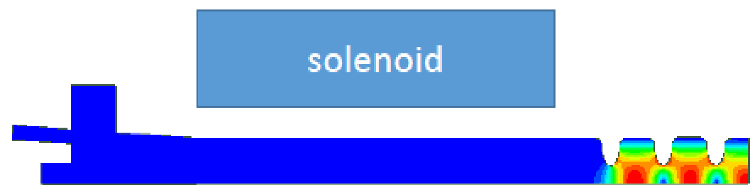
C-band gun design



Optimum value to maximize the peak field on cathode

E_{cath}	160 MV/m
$\Delta f_{\pi/2-\pi}$	≈ 52 MHz
Q_0	11600
β	3
Filling time (τ_F)	160 ns
P_{diss} @160MV/m	9.7 MW
$E_{CAT}/\sqrt{P_{diss}}$	51.4 [MV/m/(MW)$^{0.5}$]
Rep. Rate	1000 Hz
Peak Input power P_{IN}	17.5 MW
Pulsed heating (T_{puls})	<20 °C
RF pulse length (T_{RF})	300 ns
Av diss power (P_{av})	2300 W

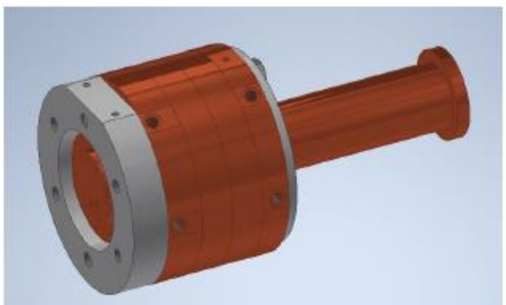


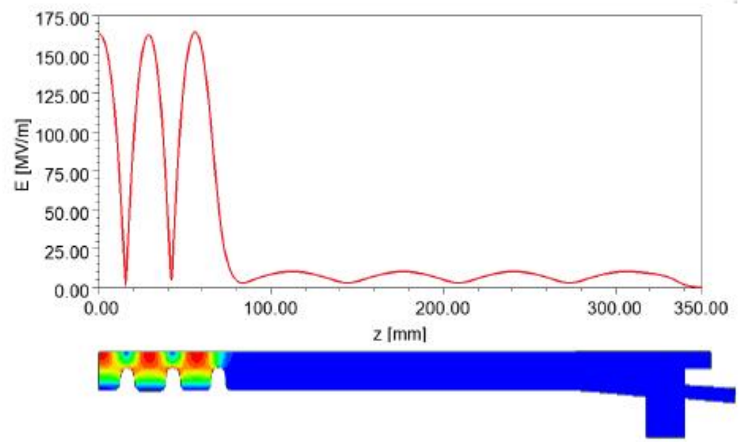


Funded by the
European Union

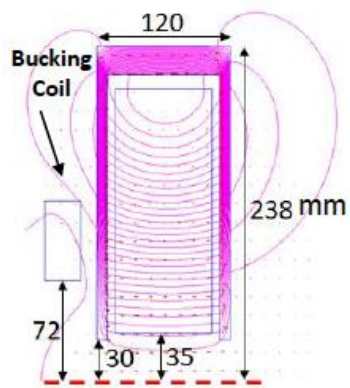
C-band gun design

G. Di Raddo

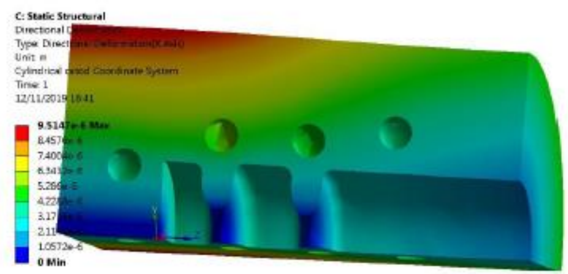




1.5 cells



A. Vannozzi



L. Pellegrino

In progress:
Mechanical drawing of the gun and solenoid and final **termo-mechanical analisis**

Preliminary Design of 15 MW, 5.996 GHz Klystron

Table 2 – Predicted (1-D code) minimum, nominal, and maximum operational parameters for a typical 15 MW, 5.996 GHz pulsed klystron

Parameter	Minimum	Nominal	Maximum	Units
RF Operating Frequency	----	5.996	----	GHz
Peak Power Output	15	15.4	----	MW
Average Power Output	20	20.54	50	kW
DC to RF Efficiency	42	45	----	%
Beam Voltage	----	220	230	kV
Beam Current	----	154.7	165.4	a
Average Beam Power		170	190	kW
Micro-Perveance	1.45	1.5	1.55	$a/V^{3/2}$
RF Power Gain	49	54	----	dB
RF Input Drive Power	----	70	160	w
Pulse Width (video)	5.0	----	----	us
Pulse Width (RF)	2.0	----	3.0	us
Pulse Repetition Frequency	400	----	1000	Hz
Video Duty Factor	----	0.3	----	%
RF Duty Factor	----	0.2	----	%
Instantaneous Saturated Bandwidth < 0.2dB Power Variation	----	>6	----	MHz
VSWR Tolerance	----	----	1.2:1	----

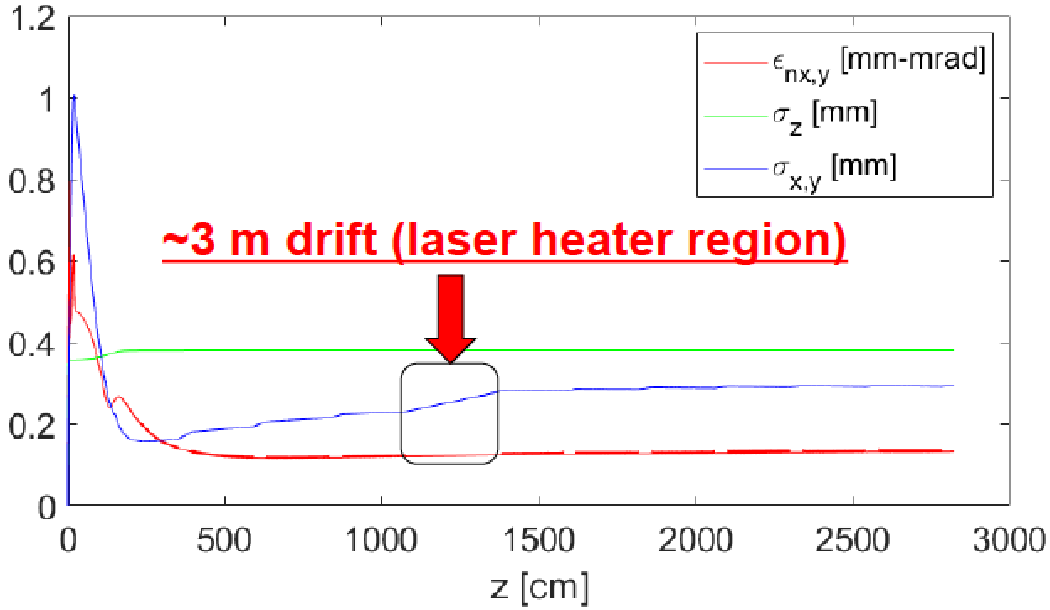
CPI Communications & Power Industries

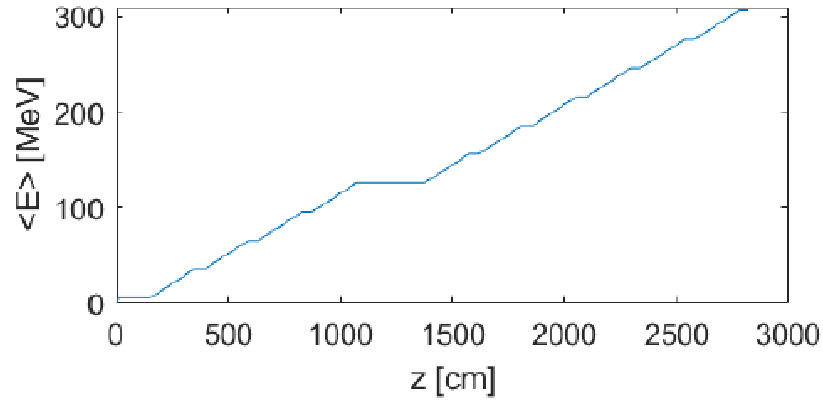
1 Kly for the Gun

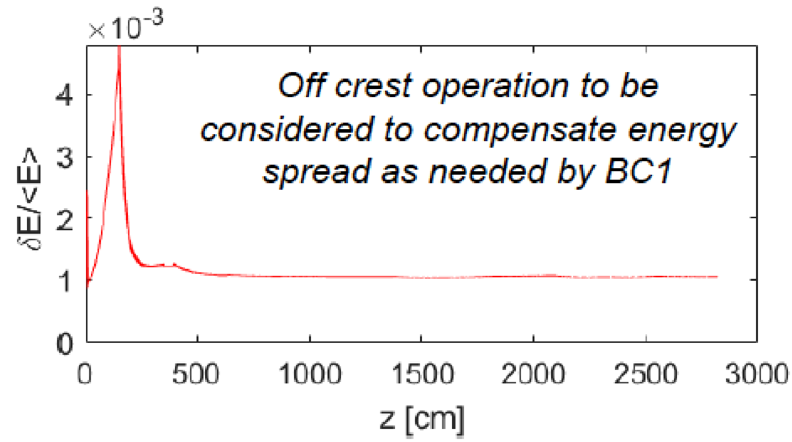
1 Kly for 2 accelerating structures => 5 Kly

Space charge effects up to injector exit

- Space charge effects along the overall C-band linac have been investigated by means of beam dynamics simulations → matching to be addressed (see C. Vaccarezza's talk)



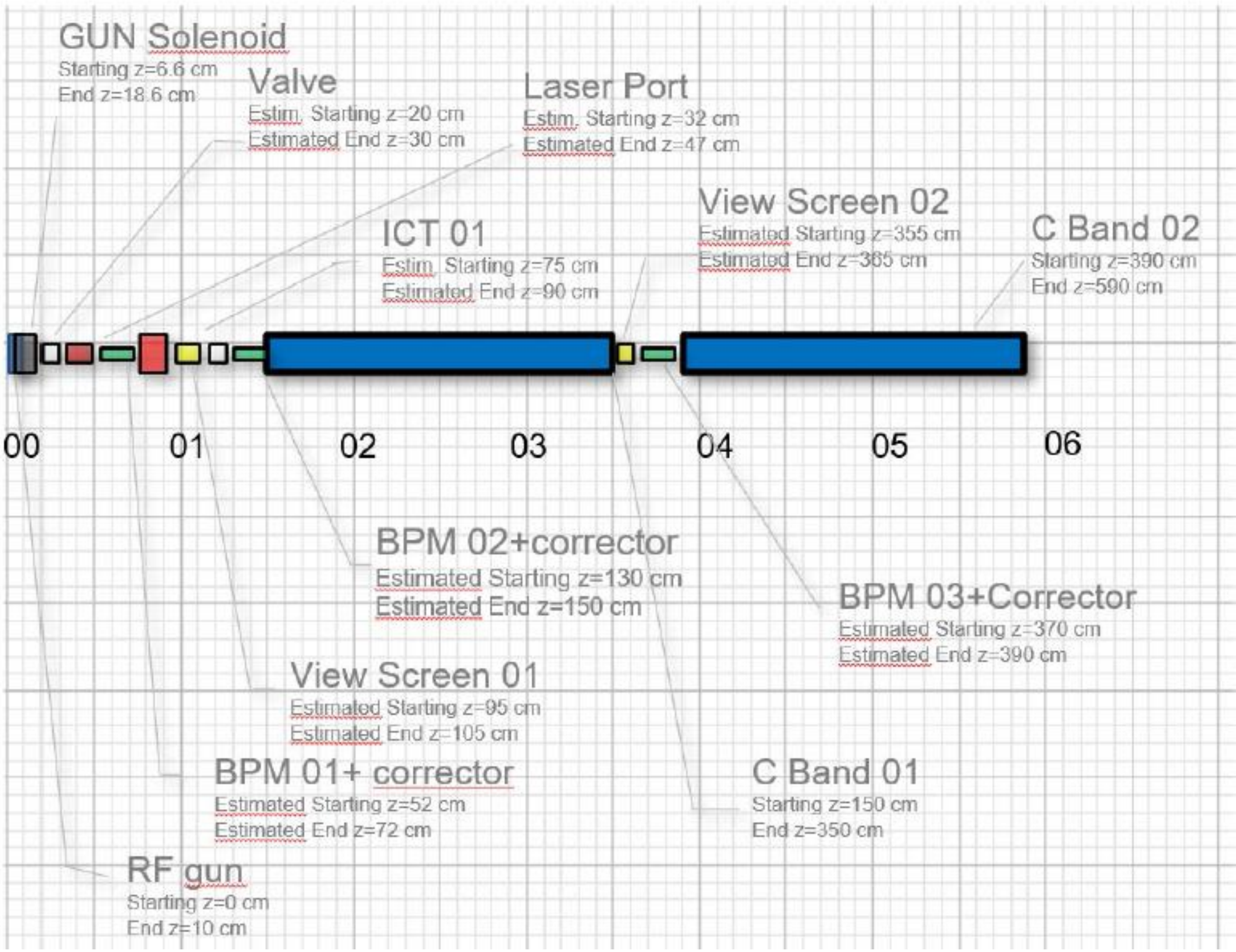




Funded by the European Union

Injector Diagnostics

Compact



Funded by the European Union

Charge Scaling Procedure

If the charge density remains constant => the beam line does not change

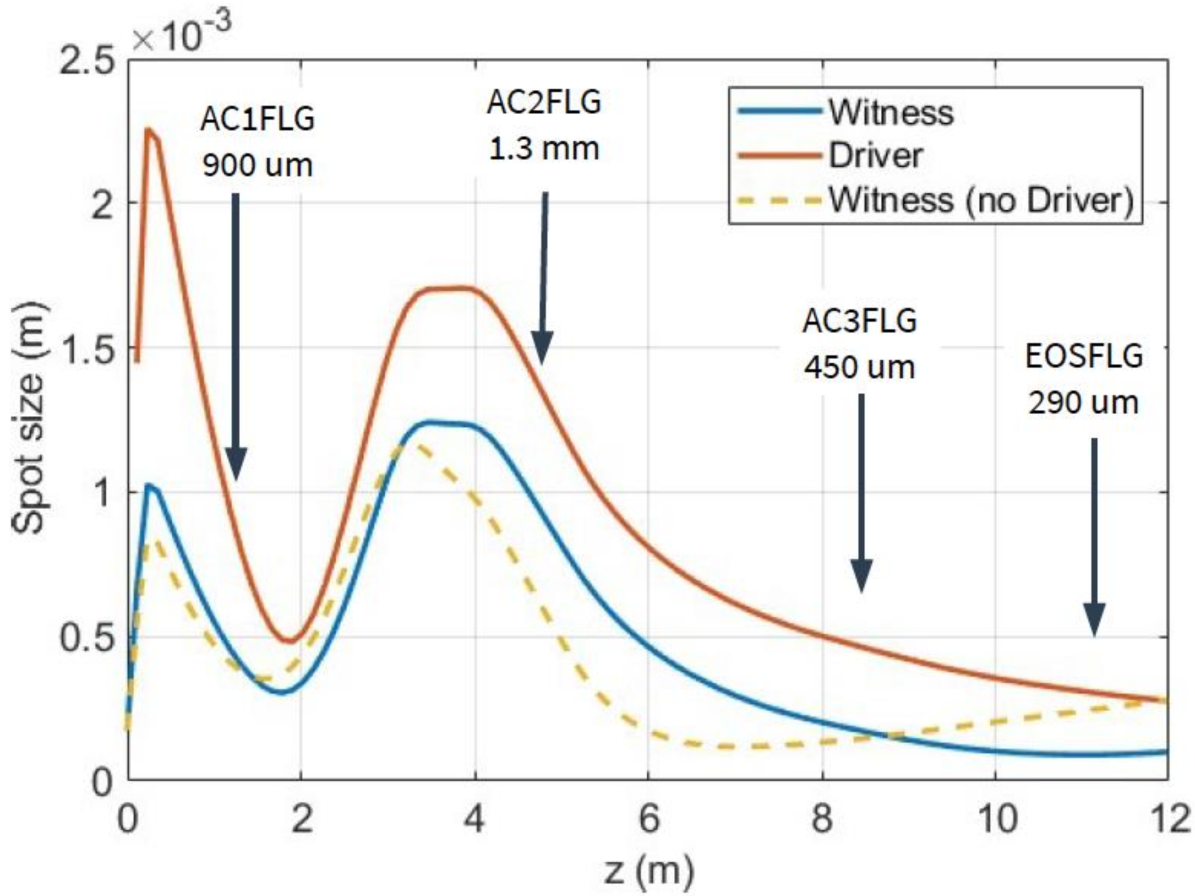
Parameter	Charge	Ex: 2xQ
s_x, s_y, s_z	$\mu\ Q^{1/3}$	1.26
e_{sc}	$\mu\ Q^{2/3}$	1.59
e_{th}	$\mu\ Q^{1/3}$	1.26
e_{rf}	$\mu\ Q^{4/3}$	2.52
I	$\mu\ Q^{2/3}$	1.59

Funded by the
European Union

SPARC_LAB example

Compact

Using scaling laws we can accelerate two beams 1 ps apart with 200 pC (Driver) and 20 pC (Witness) running together in the same SPARC_LAB beam line

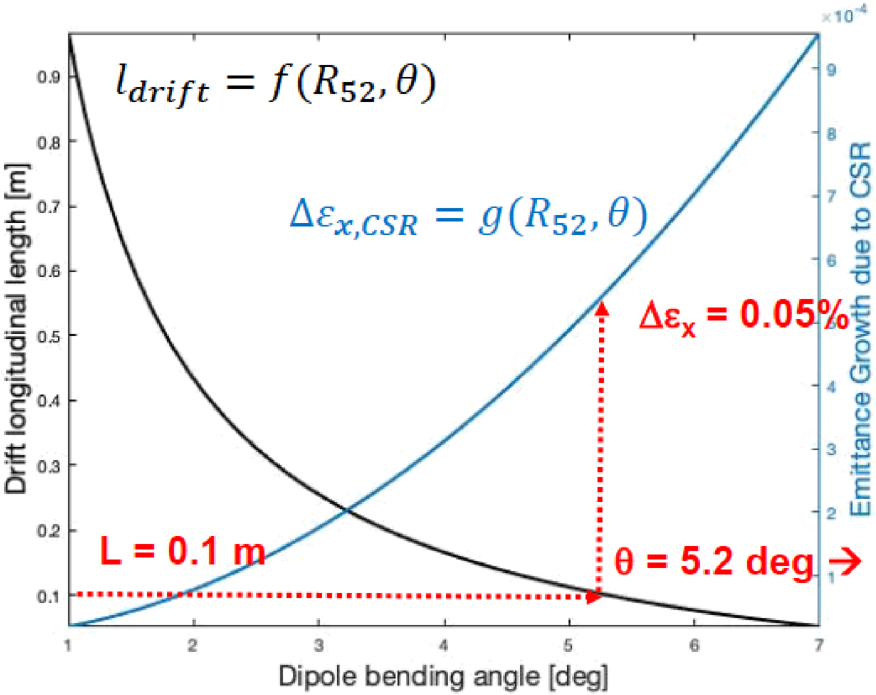


Courtesy R. Pompili

Laser Heater

For large smearing of the laser modulation, we impose: $R_{52} \approx 3 \times \frac{\lambda_{laser}}{2\pi\sigma'_x} \approx 18$ mm.

$$\frac{\Delta\epsilon_x}{\epsilon_x} \simeq \frac{1}{2}\left(\frac{R_{52}\sigma_E}{\sigma_x E}\right)^2 < 0.3\%$$ emittance growth from laser interaction in a dispersive region



emittance growth CSR in a chicane

- ***Total LH length including diagnostics is ≤ 1.5 m***
- ***Does not need dedicated matching quads***
- ***At least 30 keV added***

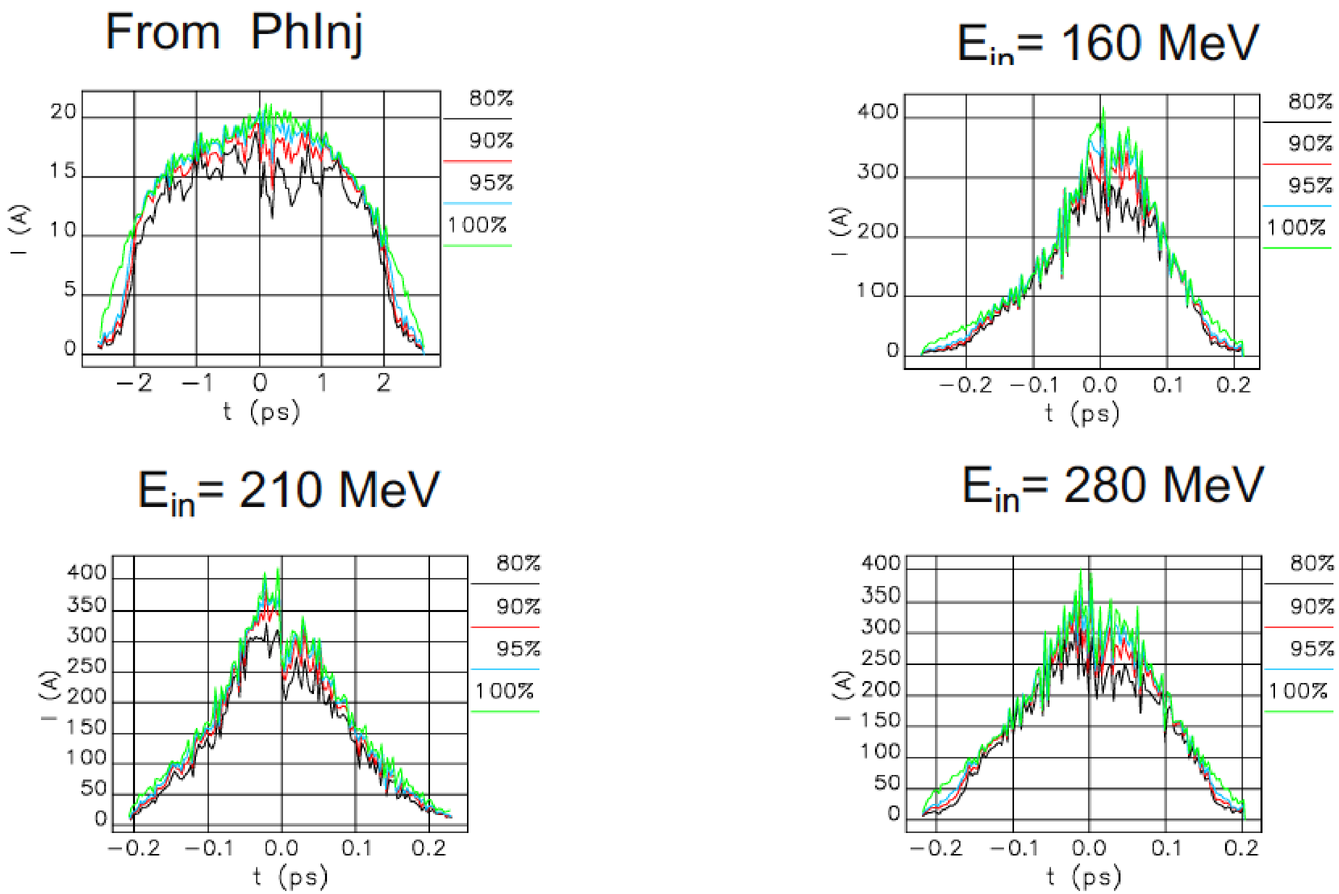
Ka Linearizer

Structure Options

- Ka-band SW solution.
  - Considers 12MW matched input power (w/SLED).
  - Integrated voltage of 11MV/section (10cm), see: link.
  - If higher voltage is needed, then multiple sections are needed (i.e. for 20MV, 2 sections suffice).
  - 2 structures + hybrid needed to avoid reflections to the source.
- SW in a cryo-structure (T=77K).
  - Considers 12MW matched input power (w/SLED).
  - Integrated voltage of 16MV/section (10cm).
  - Heat load and cryogenic capacity to be checked.

BC1 Simulations

Current Distribution at BC1 exit



Funded by the European Union

Achieved parameters

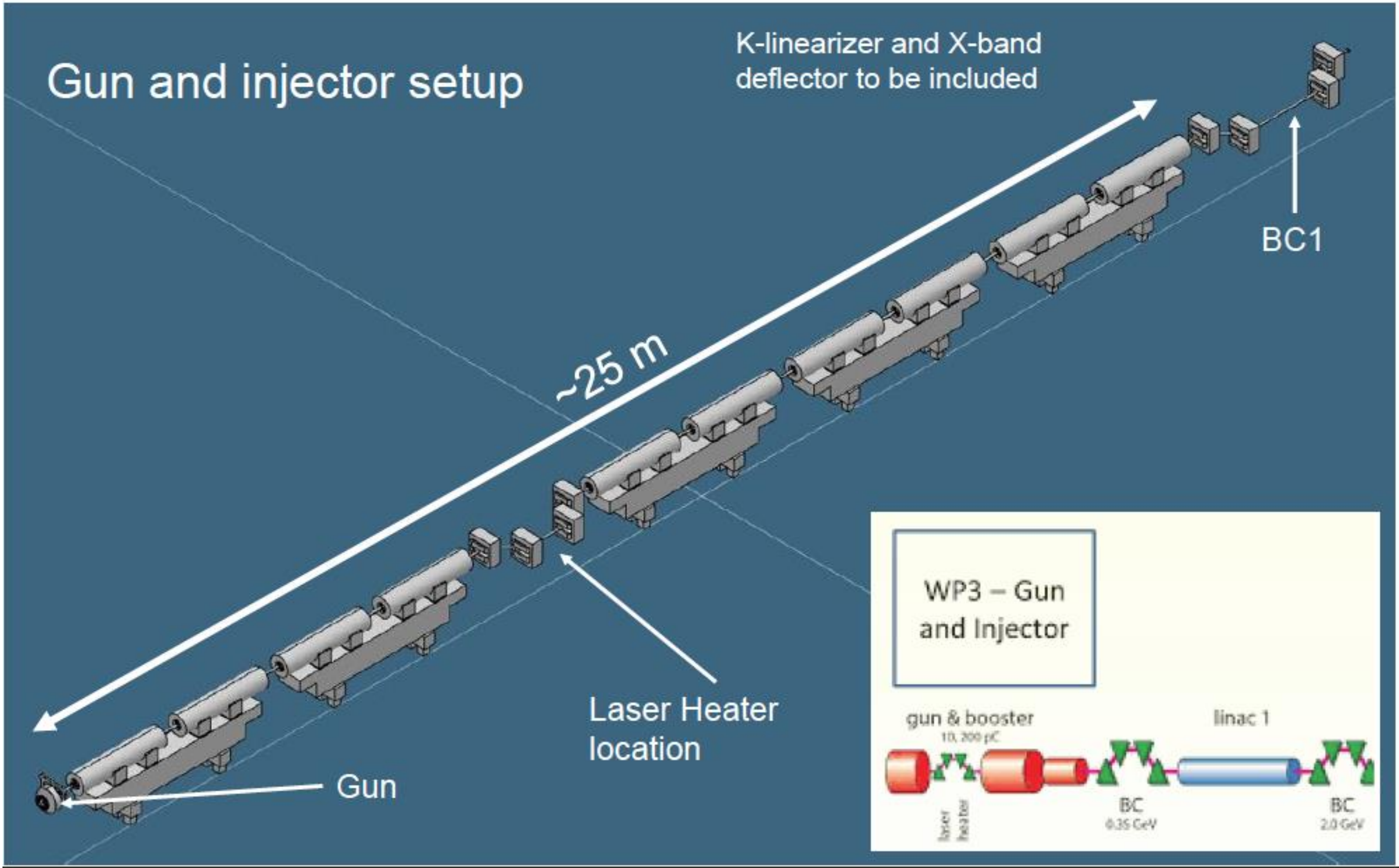
Compact

	@laser heater entrance	@BC1 entrance	@BC1 exit	units
Q	75			pC
Rep. rate	1000			Hz
E	126	275	275	MeV
σ_E/E	0.11	1.9	1.9	%
$\epsilon_{n,rms}$	**0.12**	**0.16**	**0.2 (CSR) 0.5 (SC)to be optimized**	**µm**
σ_z	380	380	26	μm
I_{peak}	20	20	300	A

Courtesy Giribono & Vaccarezza

Funded by the
European Union

CAD Injector Model



Courtesy N. Gazis

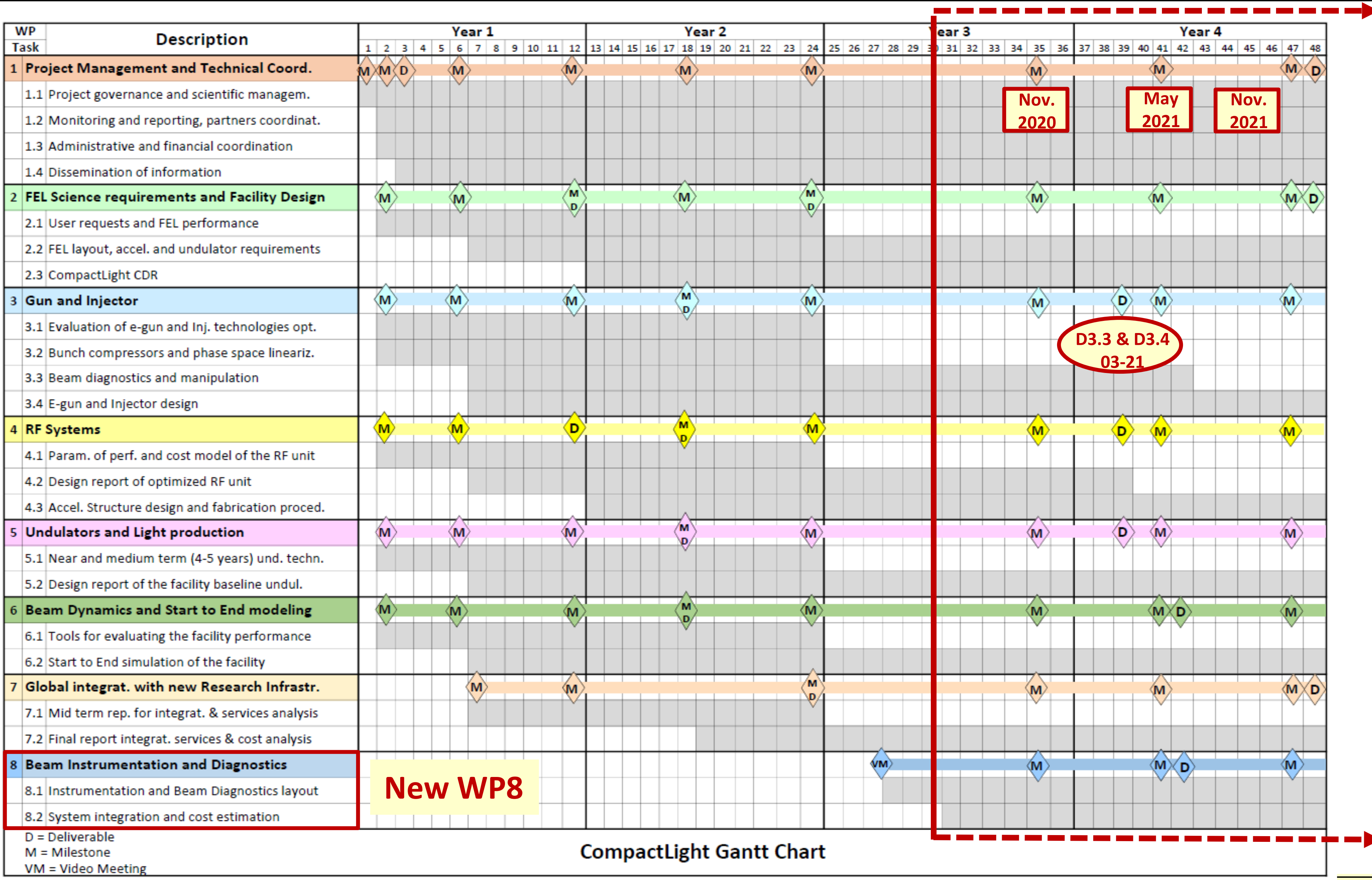
To Do

- Laser/Cathode system survival at 1 kHz
- Include fringing fields in the gun region
- C-band Power source OK?
- Verify LH energy, not excluding possible VB
- X-band module @ 30 MV/m after LH =>7.5 m less?
- Fix the voltage in the k-band linearizer
- Injector CAD model very welcome

Funded by the
European Union

New XLS Gantt Chart

Compact



WP3 Deliverables

- **D3.1** - Preliminary assessments and evaluations of the optimum e-gun and injector solution for the CompactLight design, **(=>M18**).
- **D3.2** – A review report on the bunch compression techniques and phase space linearization, (**=>M18**).
- **D3.3** – Design of the injector diagnostics/beam manipulations based on a X-band cavities, (**=>M39**).
- **D3.4** - Design of the CompactLight e-gun and injector, with phase space linearizer (**=>M39**).
- **WP3 CDR Contribution**

Funded by the European Union

Compact

Thank you!

CompactLight@elettra.eu www.CompactLight.eu

CompactLight is funded by the European Union's Horizon2020 research and innovation programme under Grant Agreement No. 777431.