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EuPRAXIA
Preparatory Phase

RF Components – WP9

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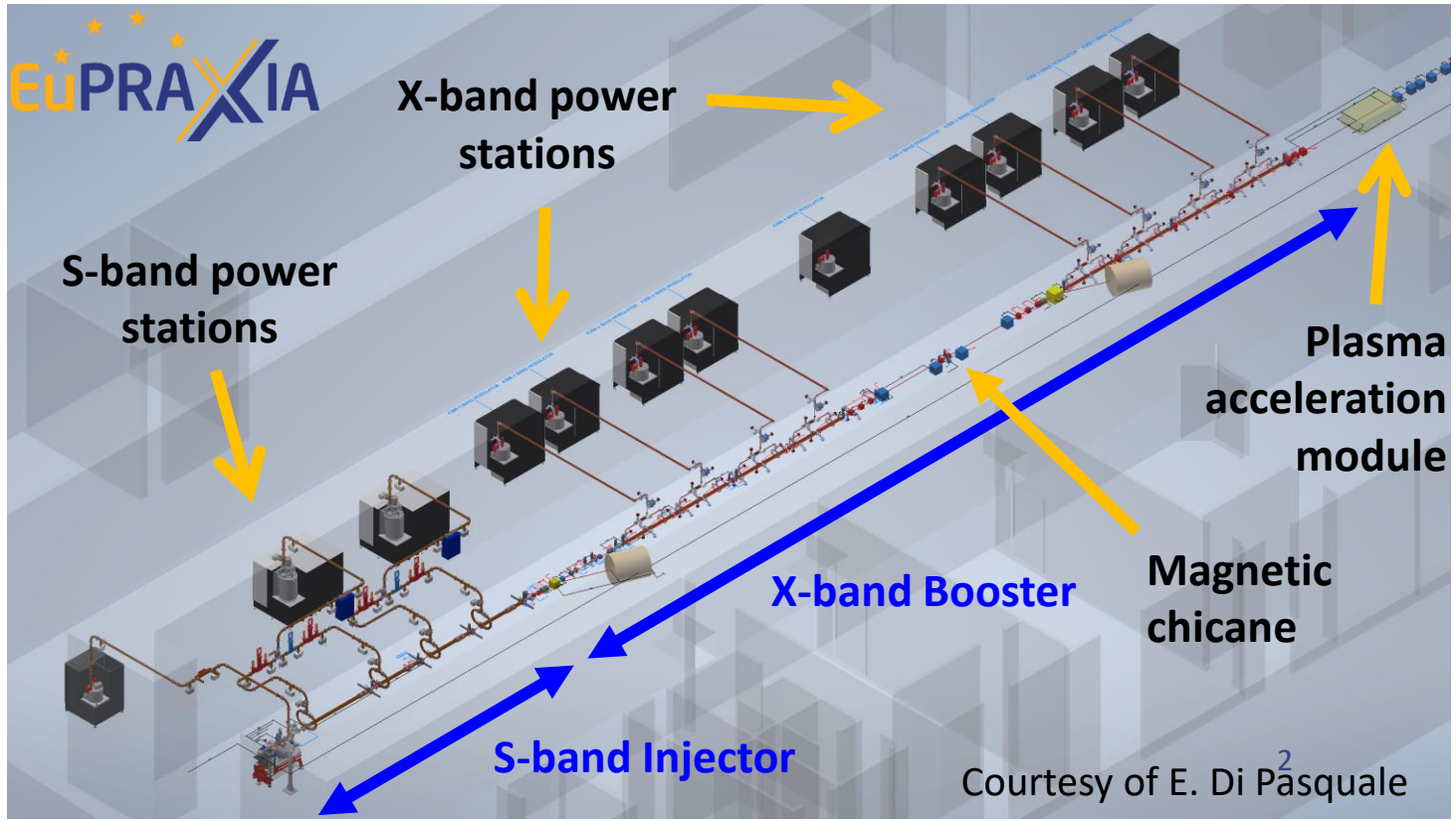
EuPRAXIA@SPARC_LAB project

Funded by the European Union

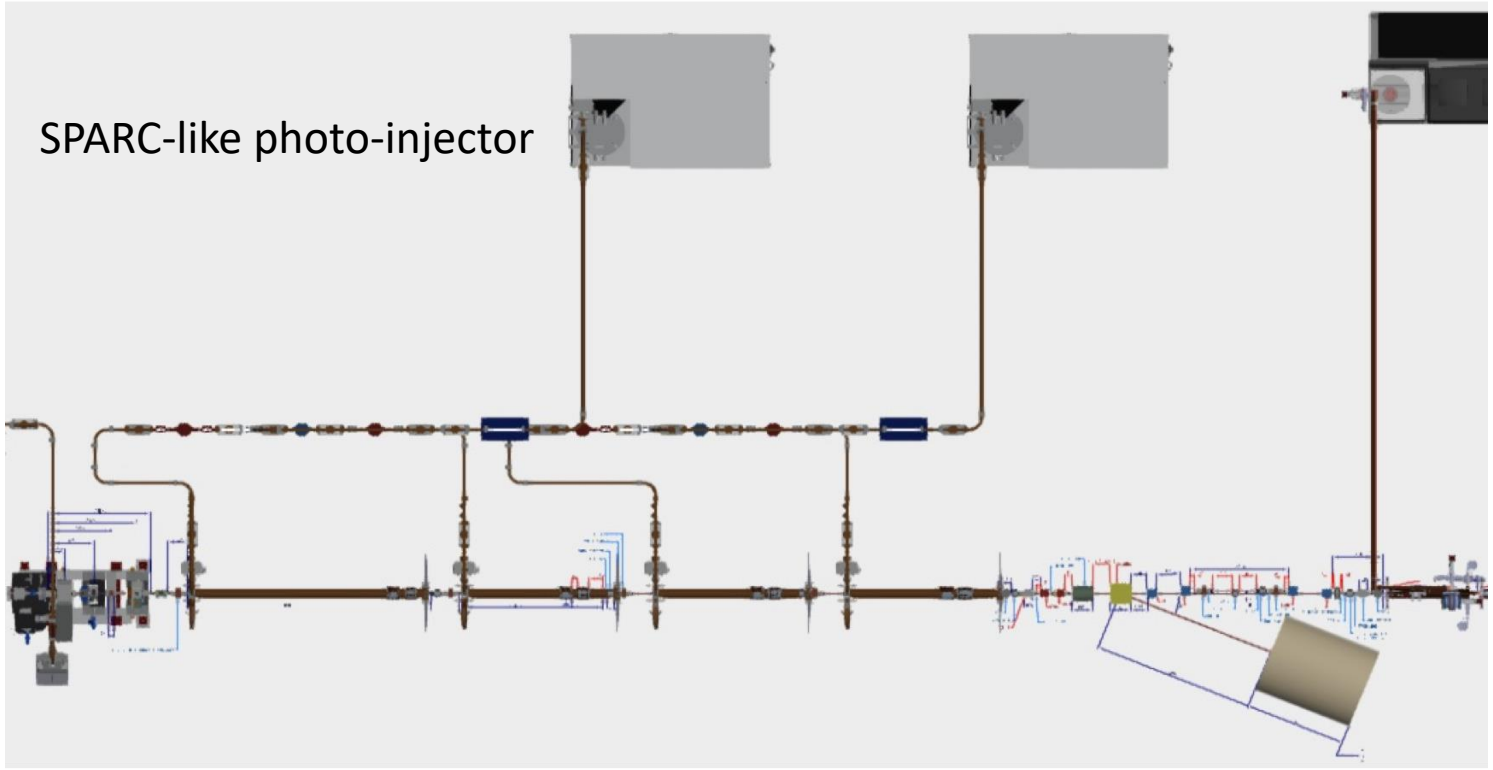
- High brightness 2-bunches electron beam at **500 MeV**, at **100 Hz** repetition rate to drive a PWFA, accelerating the witness up to **1 GeV**
  - The **1 GeV witness** beam will be extracted and injected in **undulator modules** to produce **FEL radiation** in the **VUV – X ray** range
- **S-band (2.856 GHz) injector** composed by a photocathode 1.6 cells SW RF Gun and 1x 3m TW S-band structure and 3x 2m TW S-band structures
- **X-band (11.994 GHz) booster** composed by **16x TW, 0.9 m accelerating structures** with a nominal gradient of **60MV/m**



Courtesy of F. Cardelli

Injector Design - Layout

At the EuPRAXIA@SPARC_LAB facility, the main challenge for the RF photo-injector comes from the request of producing ultra-short (witness beam ~ 7 fs rms), high brightness electron beams



- 1.6 cell UCLA/BNL type SW RF gun, equipped with a copper photo cathode and an emittance compensation solenoid
- ~11 cm X-band linearizing cavity for jitter optimization in the two-bunch (*comb-like*) configuration
- four TW SLAC-type sections: 1x 3m and 3x 2m TW S-band structures
- two compensation solenoids surround the first two S-band cavities for the operation in the velocity bunching scheme (RF compression)

Courtesy of E. Chiadroni

Injector Design - Choice

- The choice of different length structures is based on the fact that the first S-band cavity is operated at 90 deg off crest for RF bunch over-compression; eventually the final driver and witness durations, and their temporal separation, are completed in the second S-band structure
  - A dedicated, optimized design of the RF structure is mandatory to take into account for the different filling times in the 3 m and 2 m long structures, in order to optimize the RF power distribution

Layout S band Structures (m)	WoP 1 (pC)	S1 accel grad (MV/m)	S2 accel grad (MV/m)	S3 accel grad (MV/m)	S4 accel grad (MV/m)	X band accel grad (MV/m)
3+2+2+2	30 – 200	21	21	30	35	----------
3+2+2+2	50 – 250	21	21	30	35	----------

Courtesy of E. Chiadroni and A. Giribono

X-band Linearizing Cavity

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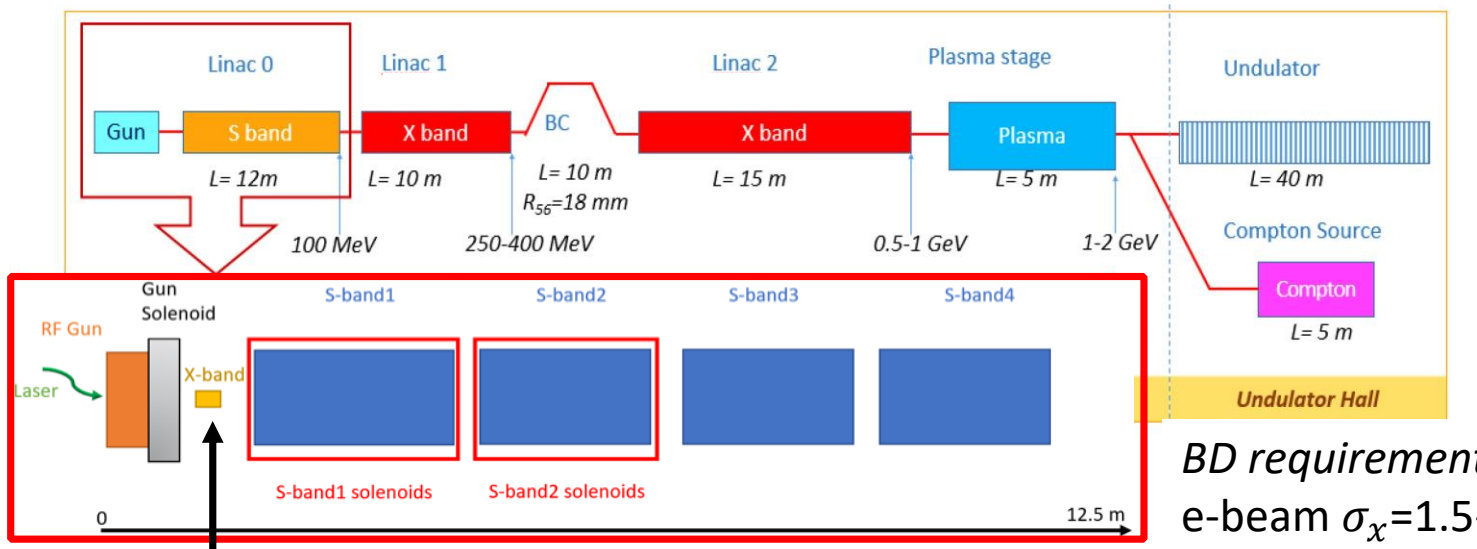
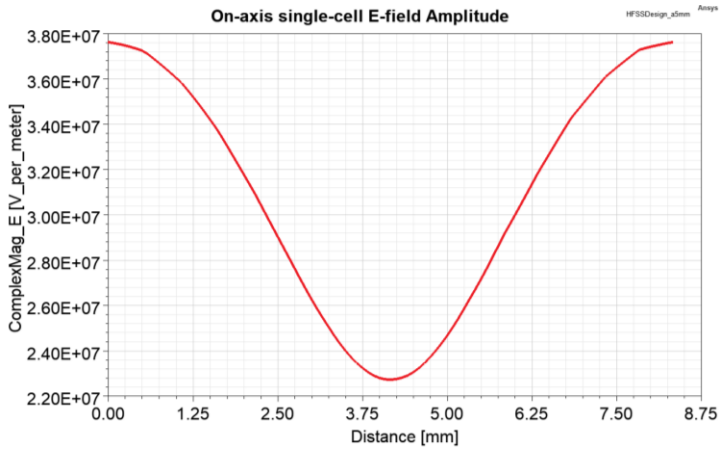


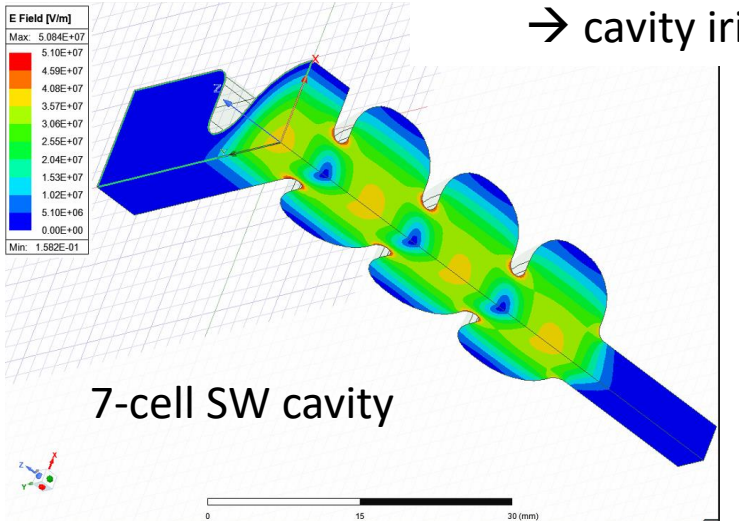


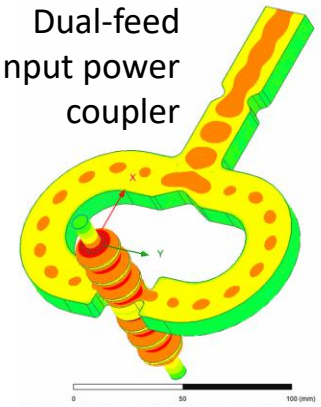
X-band	
Resonant frequency	11.9942 GHz
E acc	20 MV/m
E peak	38 MV/m
Number of cells	7
Length	11 cm

BD requirement

e-beam σ_x=1.5-2 mm

→ cavity iris radius a=4mm



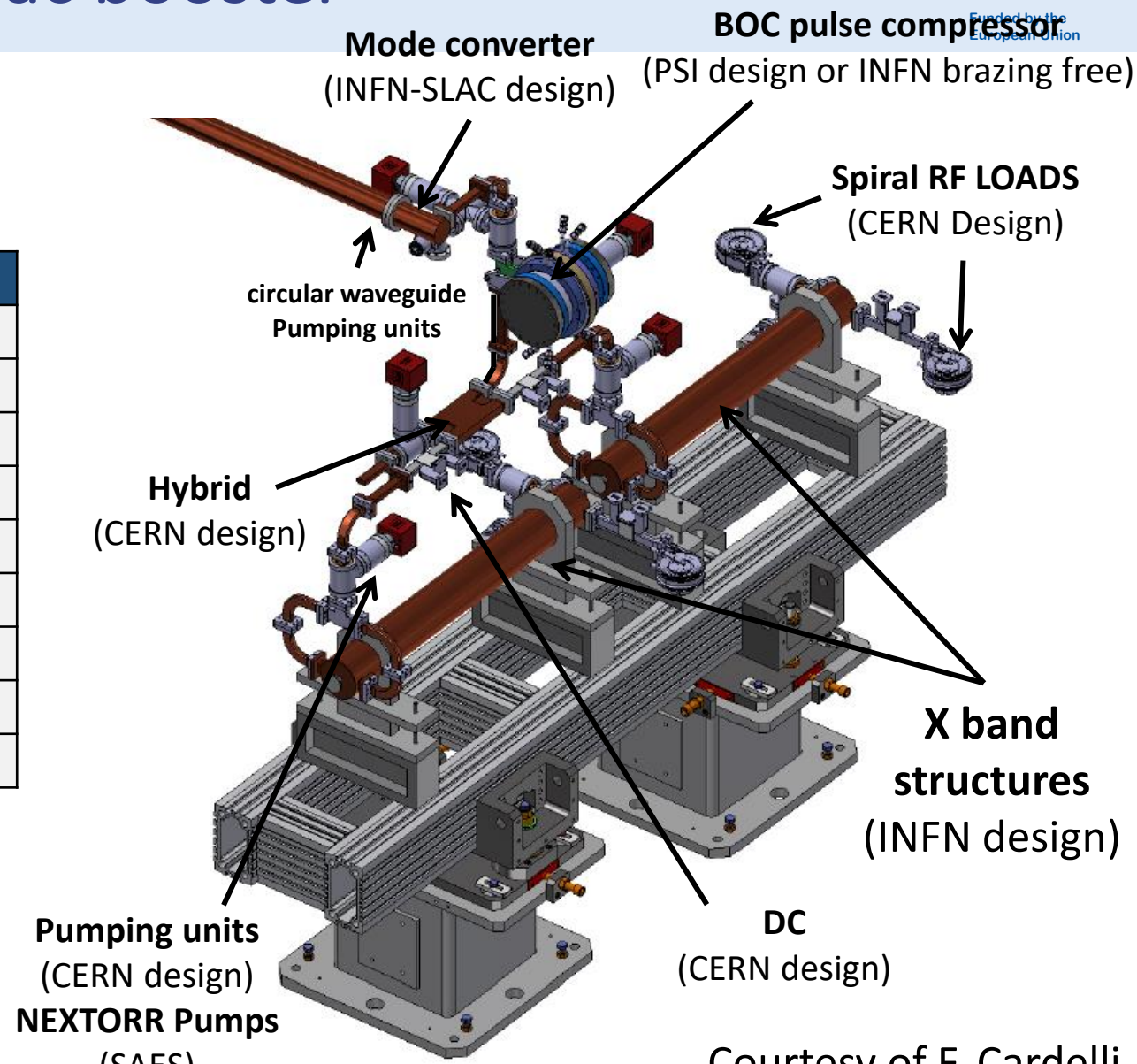


a = 4 mm	TW	SW
f	11.9942 GHz	11.9942 GHz
Q	6600	8,600
Vg	3.6 %	-
r	85.3 MΩ/m	80 MΩ/m
Eacc	16.5 MV/m	16.3 MV/m
alpha	0.63 1/m	-
Lt	10 cm	10 cm
Coupling β	-	2
Fill time Tf	9.3 ns	-
Build up τ	-	76 ns*
Pin	3.2 MW	0.37 MW

X-band linac booster

PARAMETER	Value
Frequency [GHz]	11.9942
Average acc. gradient [MV/m]	**60**
Structures per module	2
Peak input power per structure [MW]	70
Input power averaged over the pulse [MW]	51
Filling time [ns]	130
Required Kly power per module [MW]	**22.5**
Kly RF pulse length [μs]	**1.5**
Repetition Rate [Hz]	**100 (400)**

- The RF Power Source: 25 MW Solid State Pulsed Modulator + Klystron



Courtesy of F. Cardelli

X-band structure activity and Future Plan

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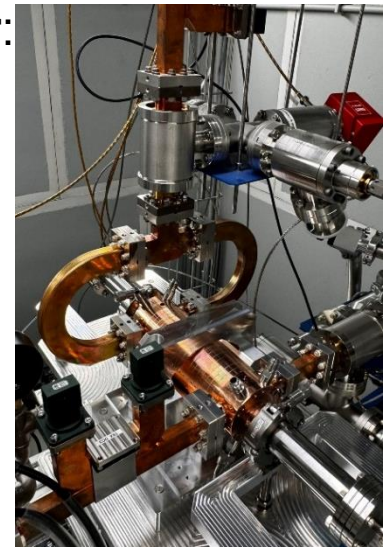
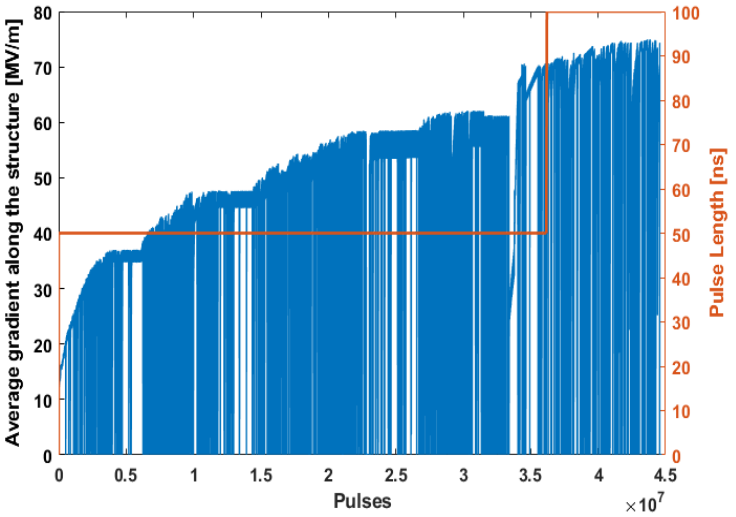
An intensive prototyping activity is ongoing exploiting the new vacuum furnace at LNF.

- The **full-scale mechanical prototype** brazing test gives optimum results in term of straightness and vacuum
- The **20 cells CI RF prototype** has been realized
- Low power RF measurements showed that the cells are all the same but smaller by approx ±2 μm
- The **20 cell-structure was brazed and tested at high power**:

PARAMETER	Value
Frequency [GHz]	11.9942
Average acc. gradient [MV/m]	**74**
Peak input power [MW]	35
Pulse length [ns]	100
Repetition Rate [Hz]	50
Breadown rate probability	1e-5





- A **full-scale 0.9m RF prototype is in production.**

Acknowledgements

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Thanks for your attention!