

EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS



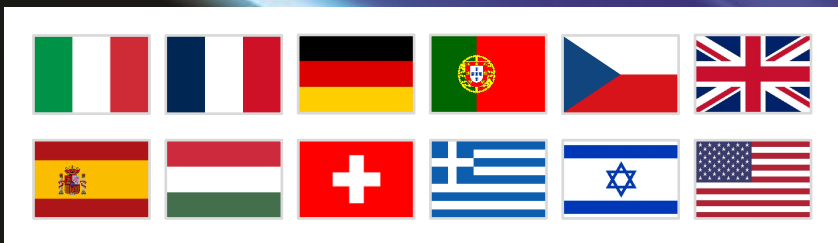
WA2 - Injector

Enrica Chiadroni, Sapienza University and INFN – LNF

On behalf of the WA2 contributors

EuPRAXIA@SPARC_LAB Review Committee

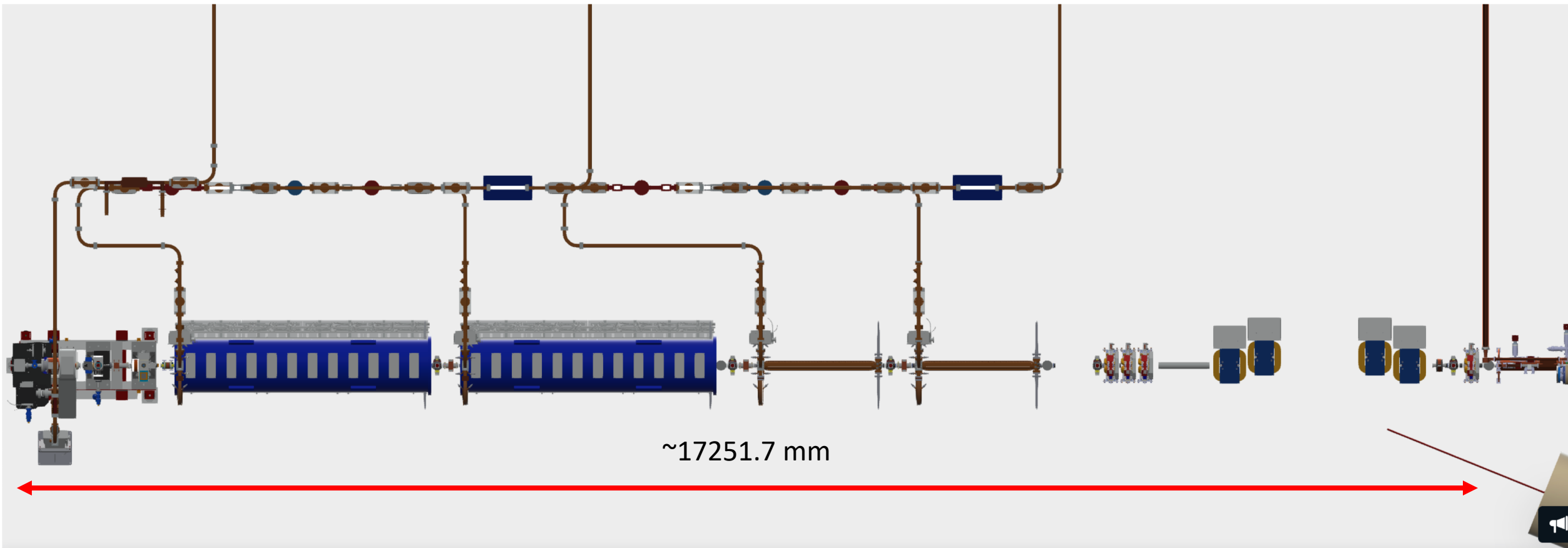
Nov. 25th, 2024



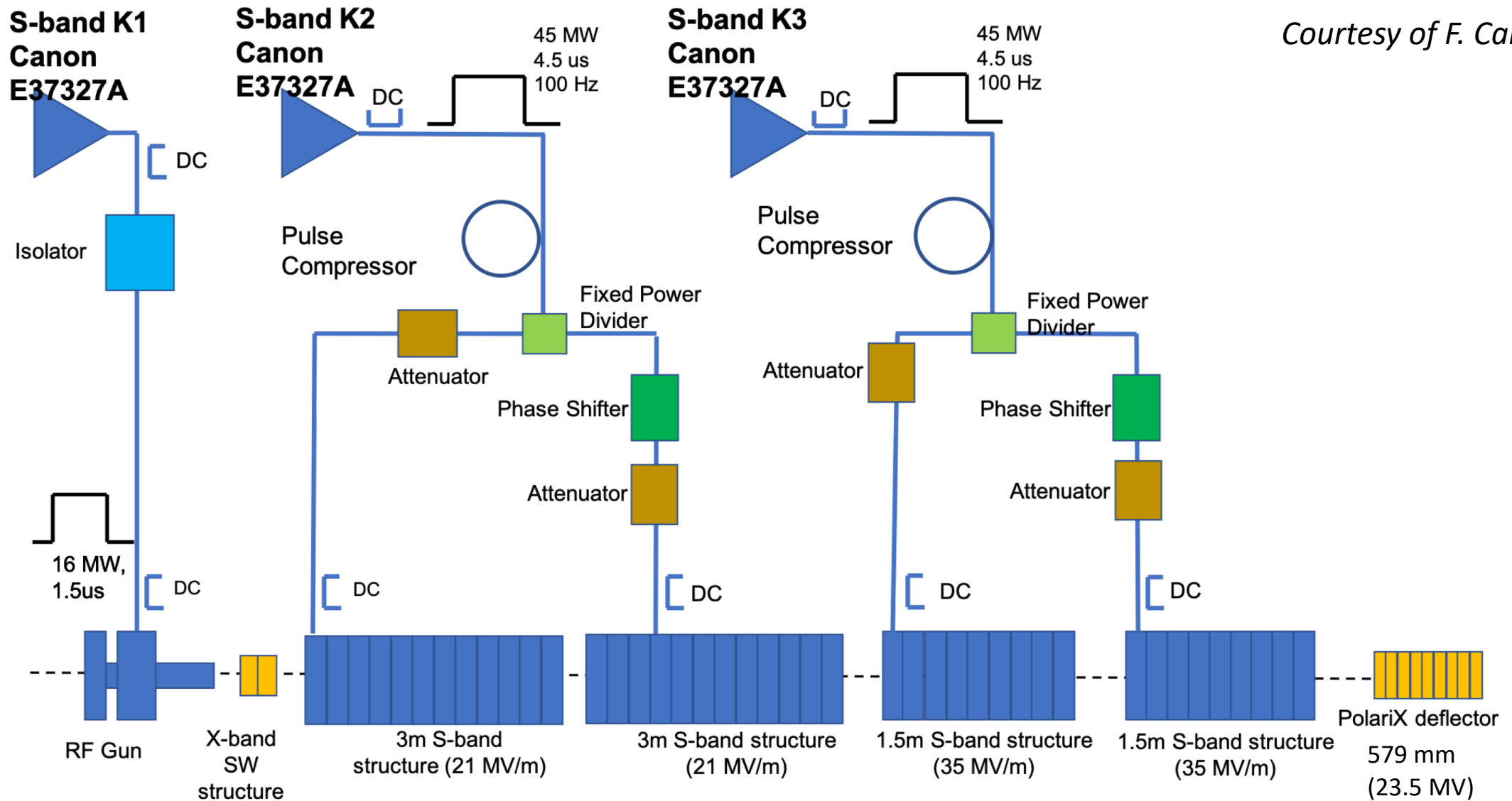
This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101079773

- Frozen points
- Injector Layout and RF Power Distribution
- Baseline working point
- Laser Infrastructure
- RF power distribution
- Stability
- Diagnostics
- Ongoing activity

- **European S-band** => 2.998 GHz
 - Klystron in use at Swiss FEL
- Four S-band structures, Constant Gradient:
 - S1 and S2 => 3 m long
 - S3 and S4 => 1.5 m long
- Vacuum pipe diameter => 30 mm
- Repetition rate => 100 Hz
- Copper cathode



Courtesy of M. Del Franco

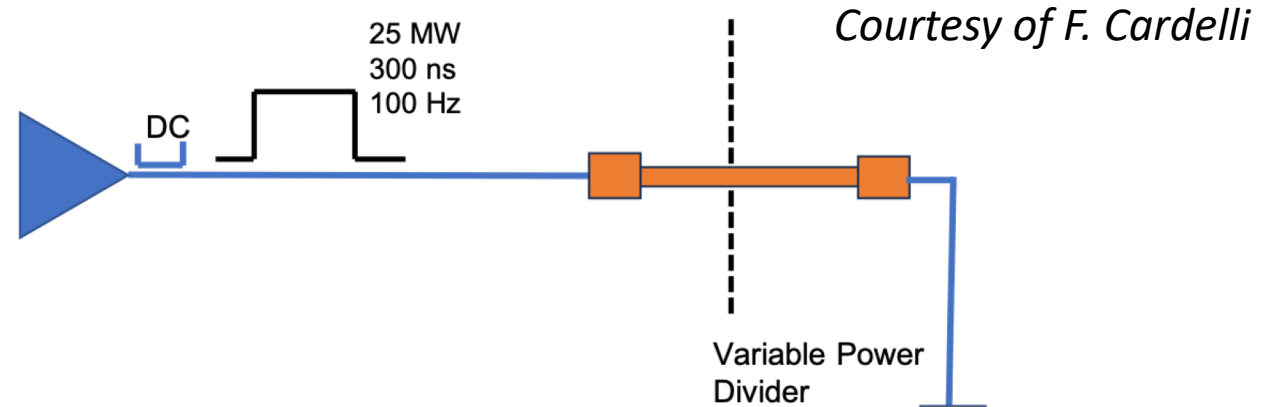


Courtesy of F. Cardelli

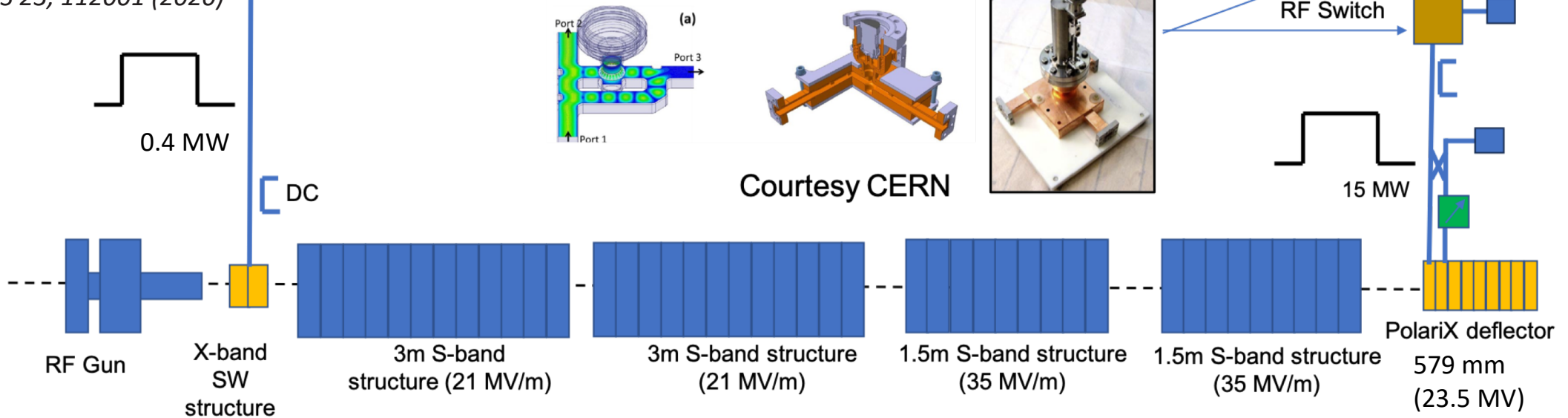
TABLE V. rf parameters for short and long X-band TDS. For operation of the TDS with BOC the following parameters are assumed: $Q_0 = 150000$, $Q_e = 19800$, $t_k = 1500$ ns.

TDS parameter	Short	Long	Unit
Number of cells	96	120	
Filling time	104.5	129.5	ns
Attenuation	-5.21	-6.48	dB
Active length	800	1000	mm
Total length	960	1160	mm
TDS alone			
$R_{\perp, TDS}$	27.3	37.5	M Ω
Power-to-voltage	5.2	6.1	MV/MW ^{0.5}
TDS + BOC			
$R_{\perp, TDS}$	142	178	M Ω
Power-to-voltage	11.9	13.3	MV/MW ^{0.5}

X-band Klystron Canon E37119

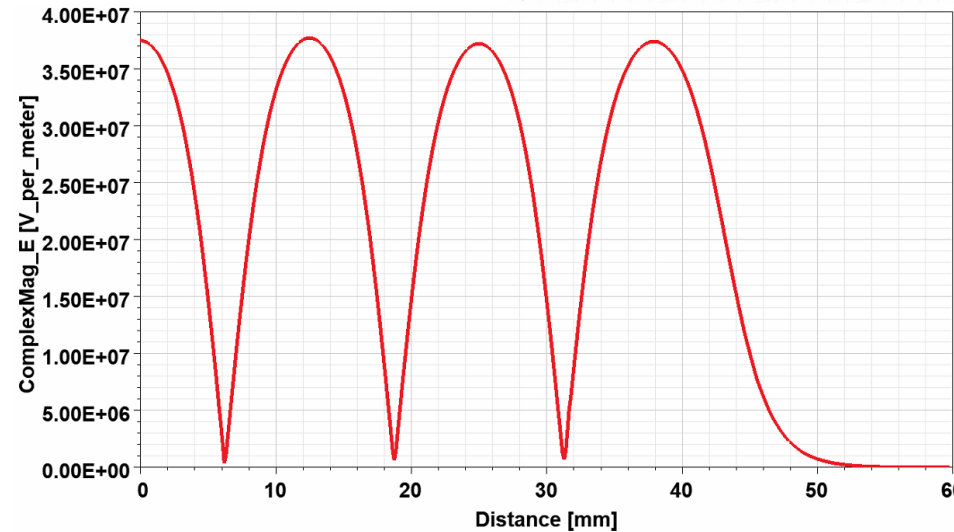
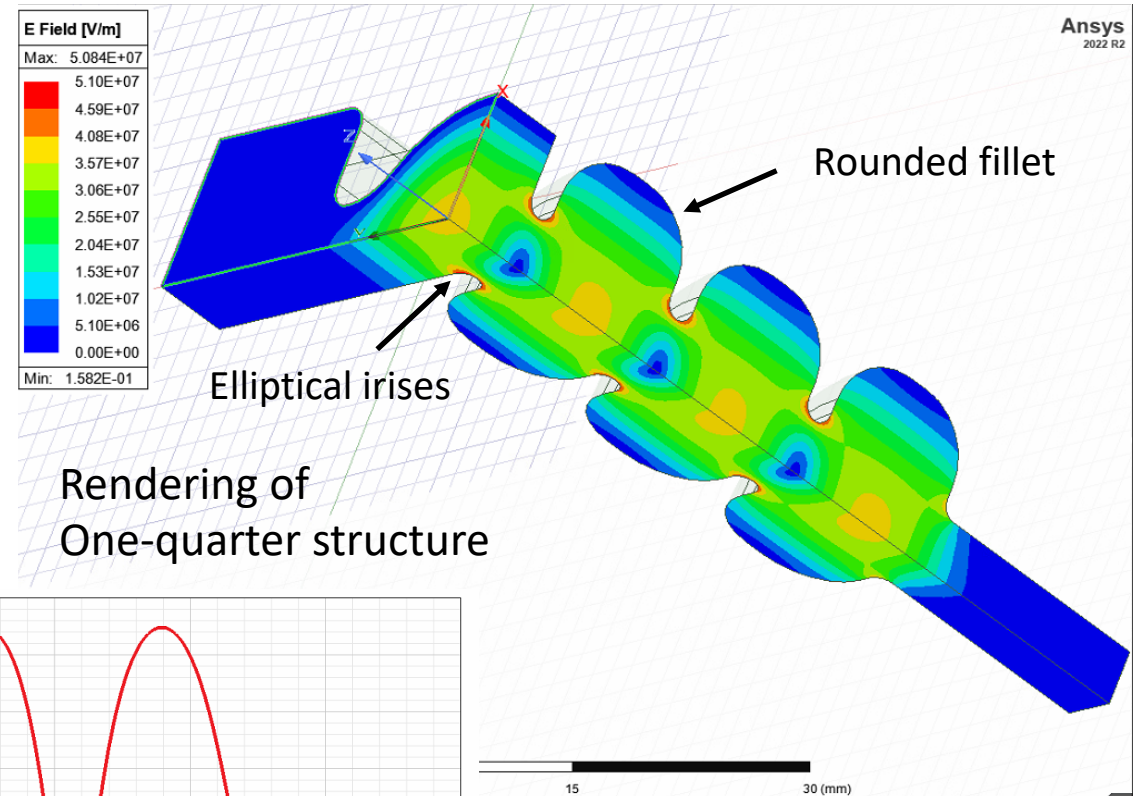


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7-cell SW RF Cavity
12 cm long
pi-mode

Iris aperture radius, a	4 mm
Resonant frequency, f	11.9942 GHz
Quality factor, Q	9,900
Eff. Shunt Impedance, r	83.5 M Ω /m
Accelerating field	20 MV/m
Peak field	38 MV/m
Number of cells	7
Coupling coefficient, β	1.23
Field build-up, τ	117 ns
Input power	400 kW



Courtesy of L. Faillace

- Laser Comb Technique
 - Driver and witness bunches generated directly at the cathode
 - Velocity bunching to compress the two bunches and set the proper distance for PWFA

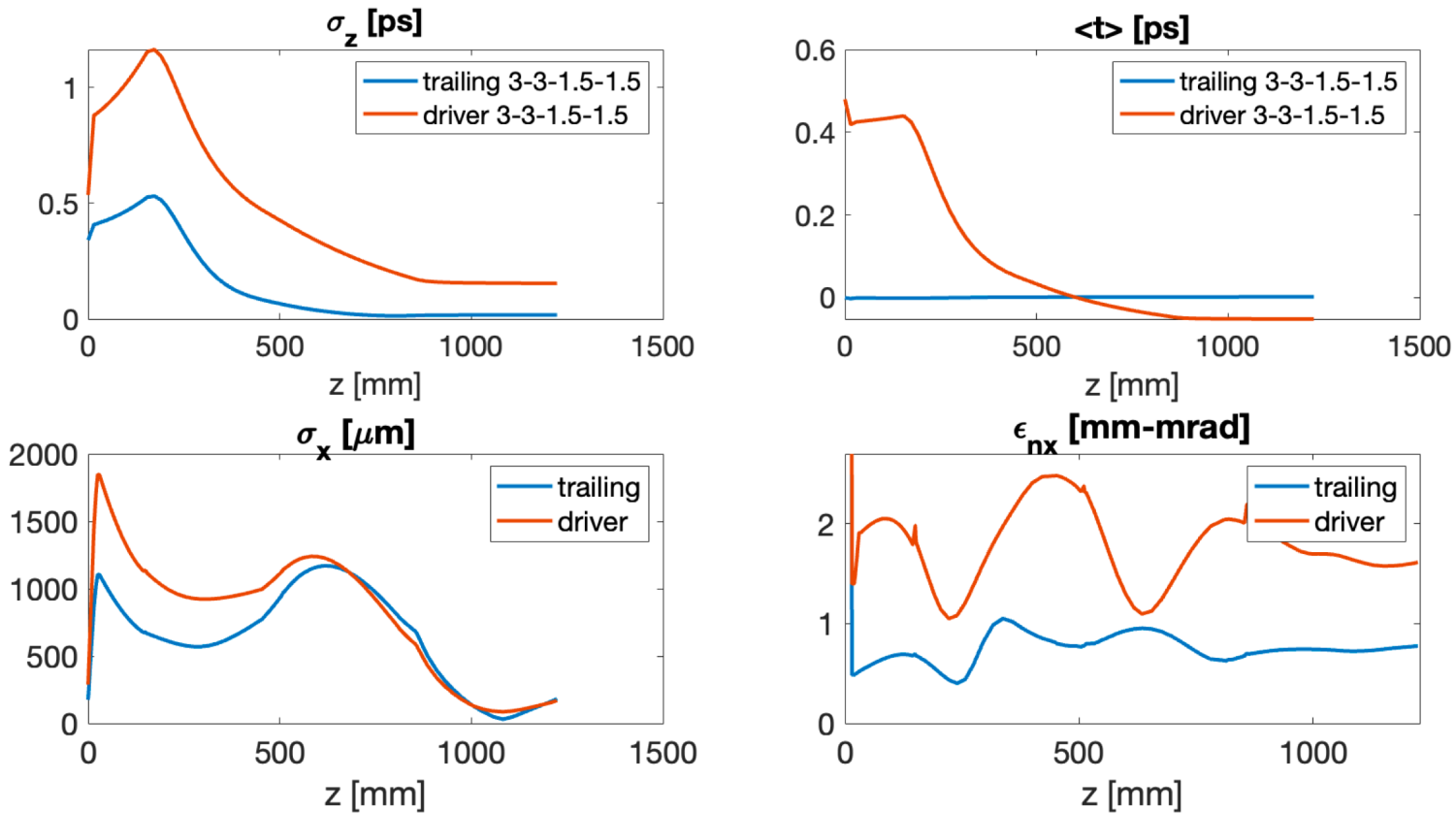
Cathode Laser System			
	Witness	Driver	
Charge [Q]	30	200	pC
Time delay [Δt]	- 4.8	0	ps
Laser Spot size [σ_r]	175	300	μm
Laser Pulse length [σ_t]	0.30	0.40	ps

RF Gun		
RF Peak Voltage [V]	120	MV
RF Phase [ϕ]	-30	Deg
S-band Accelerating Sections		
RF Voltage (on average) [V]	21,21,35,35	MV
RF Phase [ϕ]	-92,-84,-10,-10	deg

Magnets		
Type	B_{max} (T)	Length (m)
Gun Solenoid	0.3	2 coils (SABINA like)
Acc. Structures solenoids	0.035, 0.075	4 triplets, 3 triplets (SABINA like), 0, 0

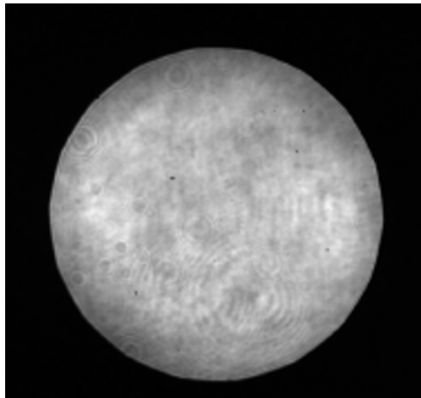
Courtesy of A. Giribono

- Laser Comb Technique
 - Driver and witness bunches generated directly at the cathode
 - 200 pC (D) + 30 pC (W)
 - Velocity bunching to compress the two bunches and set the proper distance for PWFA at $n \sim 10^{16} \text{ cm}^{-3}$
 - 118 MeV, 154 fs (D) and 17.6 fs (W), time distance: 530 fs

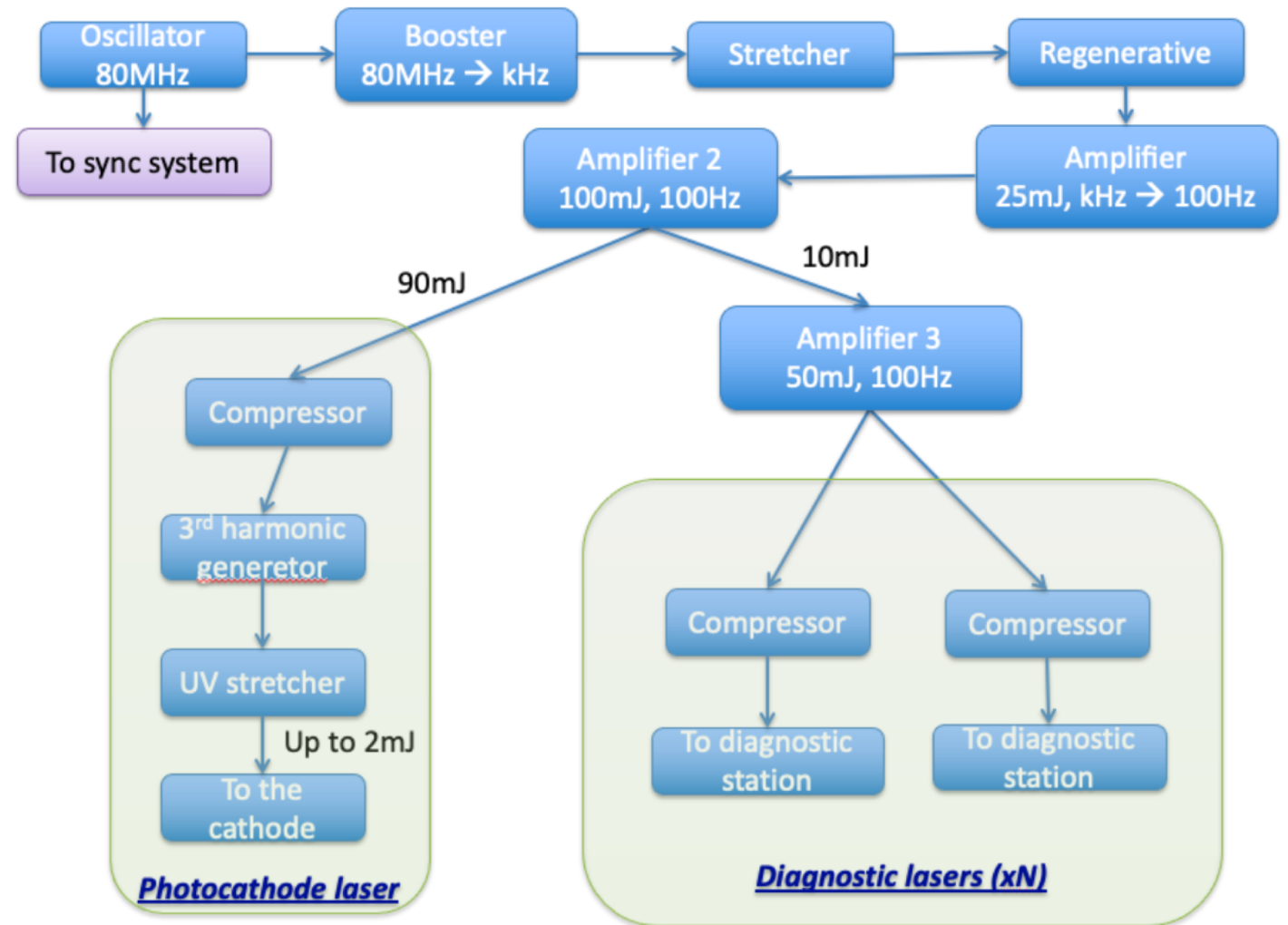


Courtesy of A. Giribono

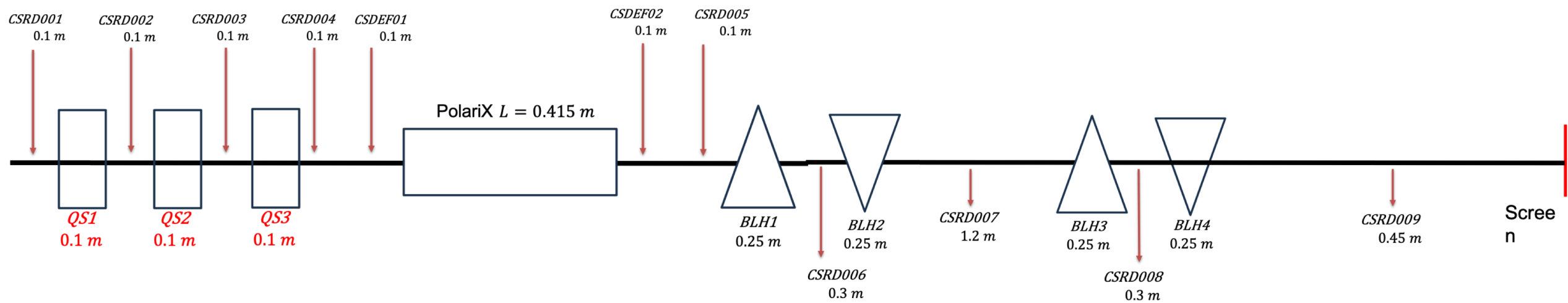
- **Transverse uniformity**
 - < 10% (peak-to-peak difference)



- **IR rms energy shot-to-shot jitter**
 - 0.7%
- **Pulse FWHM minimum duration**
 - 30 fs



Courtesy of M. P. Anania



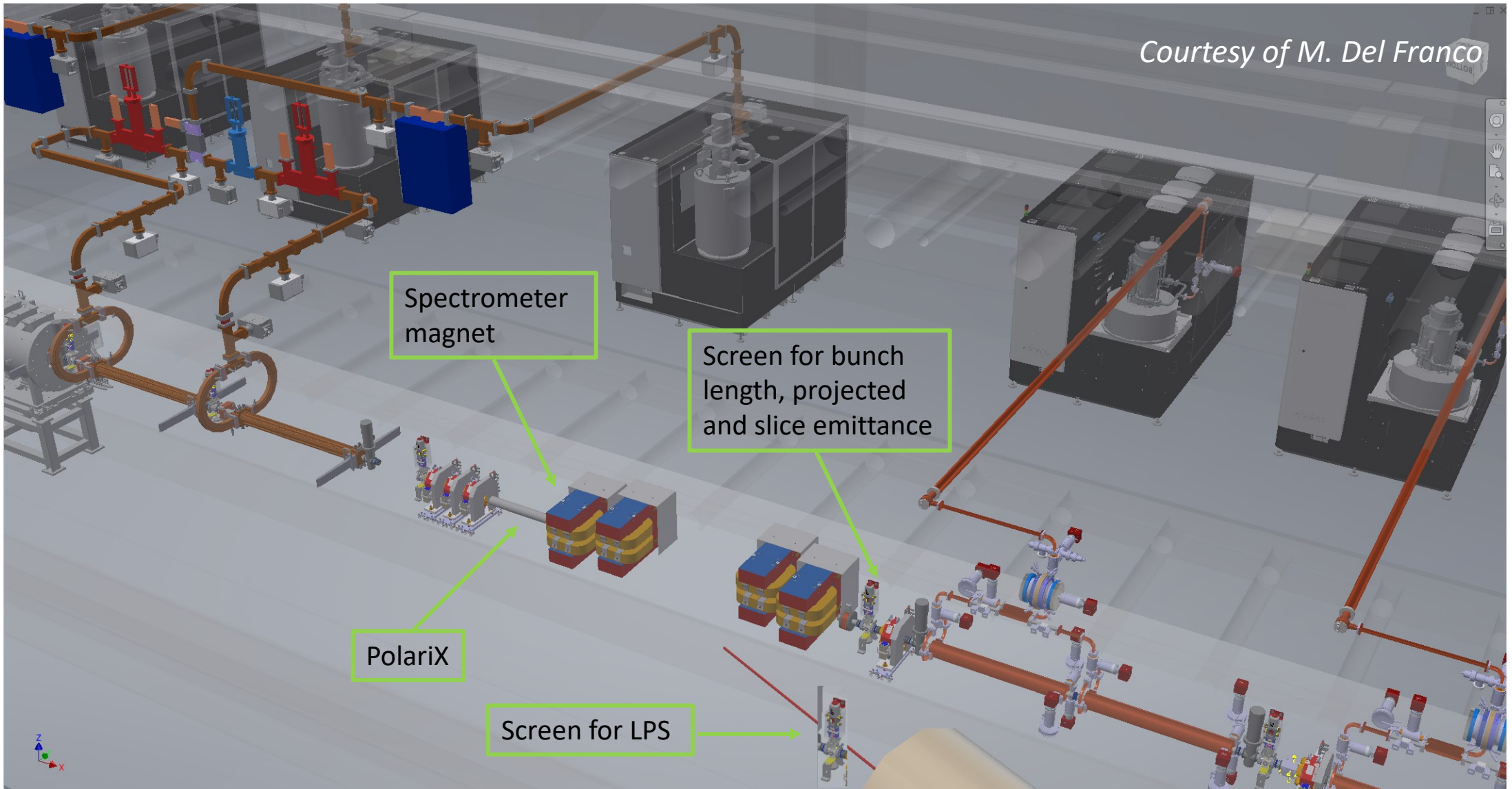
Cell parameter		Unit
Frequency	11995.2	MHz
Phase advance/cell	120	°
Iris radius	4	mm
Iris thickness	2.6	mm
Group velocity	-2.666	c/c
Quality factor	6490	
Shunt impedance	50	MΩ/m

$L = 4.665$ m

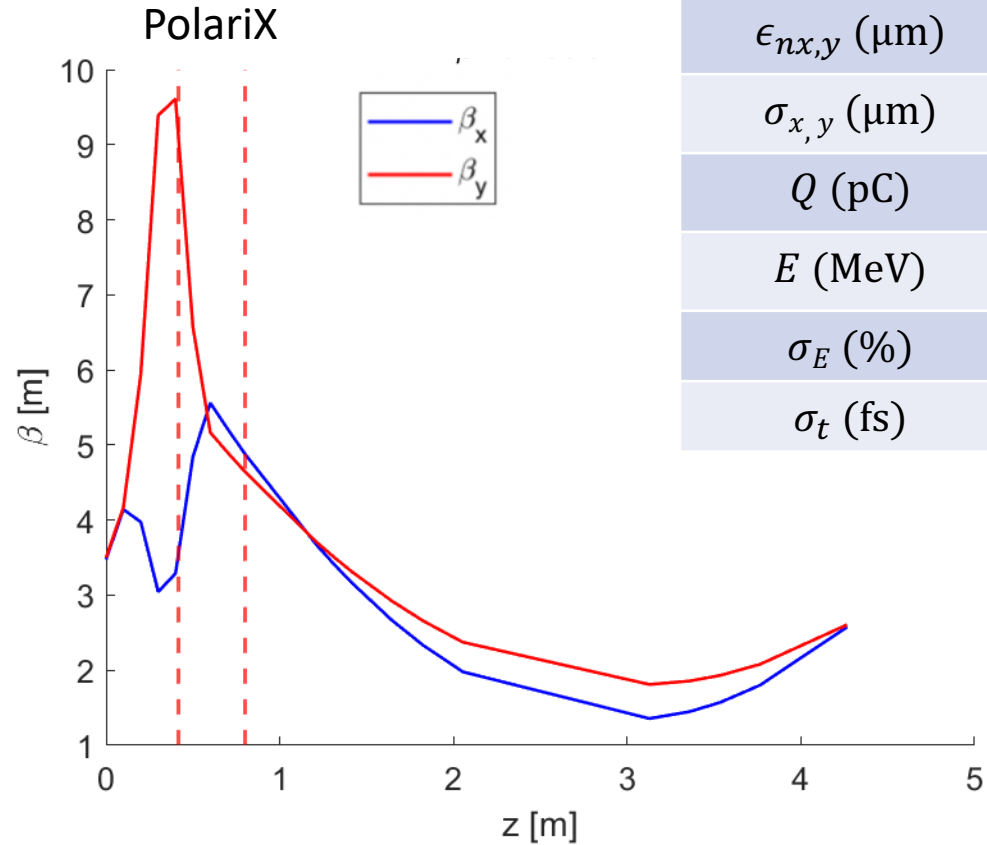
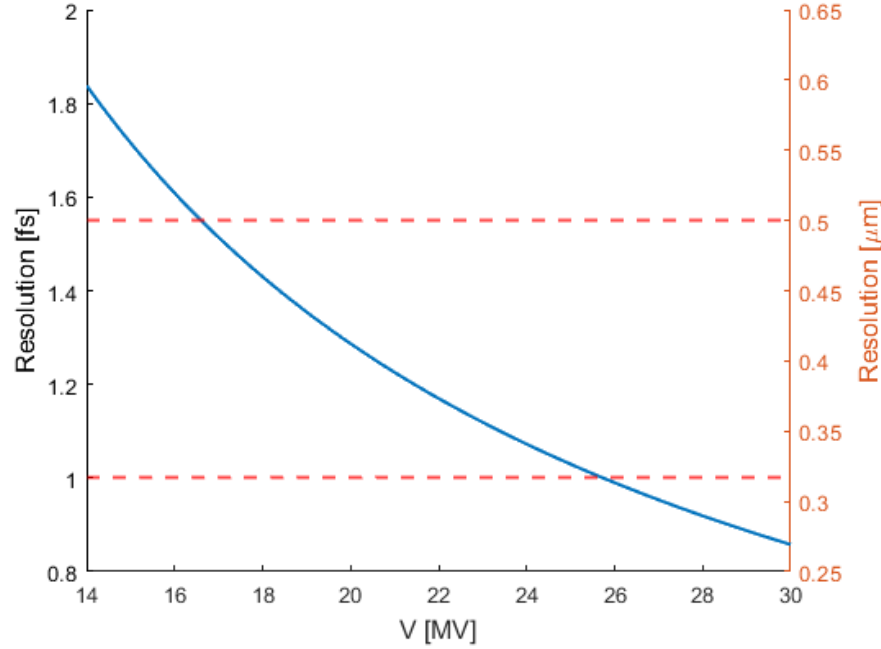
$L = 3.45$ m

PolariX Parameters	
N_{cells}	50
Single Cell Length (mm)	8.3
Total cells length (m)	0.415
Single Coupler Length (cm)	~8
Total Length (m)	0.579
Maximum Voltage (MV)	23.5

Courtesy of F. Demurtas



Courtesy of M. Del Franco



Input at Quads	Witness	Driver
$\beta_{x,y}$ (m)	3.5	7.6
$\alpha_{x,y}$	-3.2	-3.4
$\epsilon_{nx,y}$ (μm)	0.7	1.5
$\sigma_{x,y}$ (μm)	100	221
Q (pC)	30	200
E (MeV)	118	119
σ_E (%)	0.1	0.7
σ_t (fs)	17	193

Measurement Witness Parameters	
Energy (MeV)	118
σ_{off} (μm)	~ 60
Voltage V_0 (MV)	23.5
Drift Length (m)	3.45
Resolution (fs)	1.1

Courtesy of F. Demurtas

- Laser Heater studies and implementation
- Slice emittance and LPS virtual measurement
 - Realistic field maps for the scaled TDS to be used in the simulation
 - Mechanical design to be optimized for the scaled TDS
- RF Power distribution for PolariX to be updated in the CAD
- TDR chapter completion

- Injector Layout Finalized
 - Few refinements must be added (e.g., X-band linearizer mechanical design, ..., laser heater, vacuum chamber in laser heater area, ...)
- RF Power Distribution Finalized
 - Only X-band RF power must be inserted in the CAD
- Beam dynamics studies for baseline working point completed
- Diagnostics layout Finalized
 - Virtual measurement on going
- TDR Injector Chapter
 - Writing Readiness => 70%
 - Technical readiness => 70%

- Link to the Injector Chapter
 - <https://www.overleaf.com/project/65129aaa7bccc6c2f61c58b0>

- Anania, Bellaveglia, Cardelli, Cianchi, Del Franco, Demurtas, Galletti, Ghigo, Giribono, Piersanti, Sabbatini, Stella, Vaccarezza

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- EuPRAXIA Preparatory Phase



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- EuPRAXIA Doctoral Network



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- EuAPS



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