The CompactLight Project (XLS) WP3: e-Gun & Injector

3D design efforts of the e-gun

Eugene Tanke

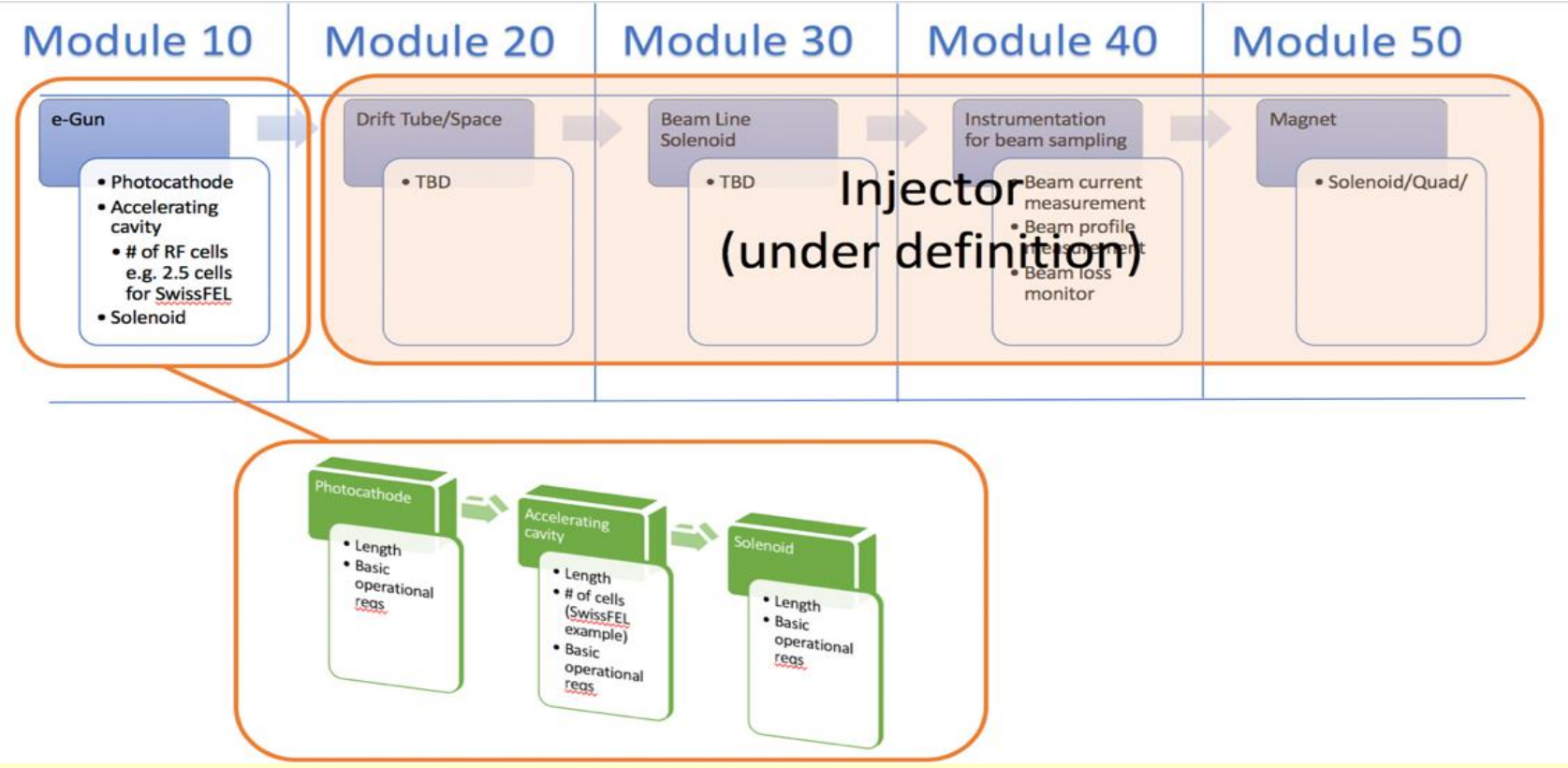
on behalf of the IASA-ESS team

Evangelos Gazis[a,b], Nikolaos Gazis[c], Emmanuel Trachanas[c], Irini Telali[b], Katerina Tzanetou[b]

a) Institute of Accelerating Systems & Applications
b) National Technical University of Athens
c) European Spallation Source

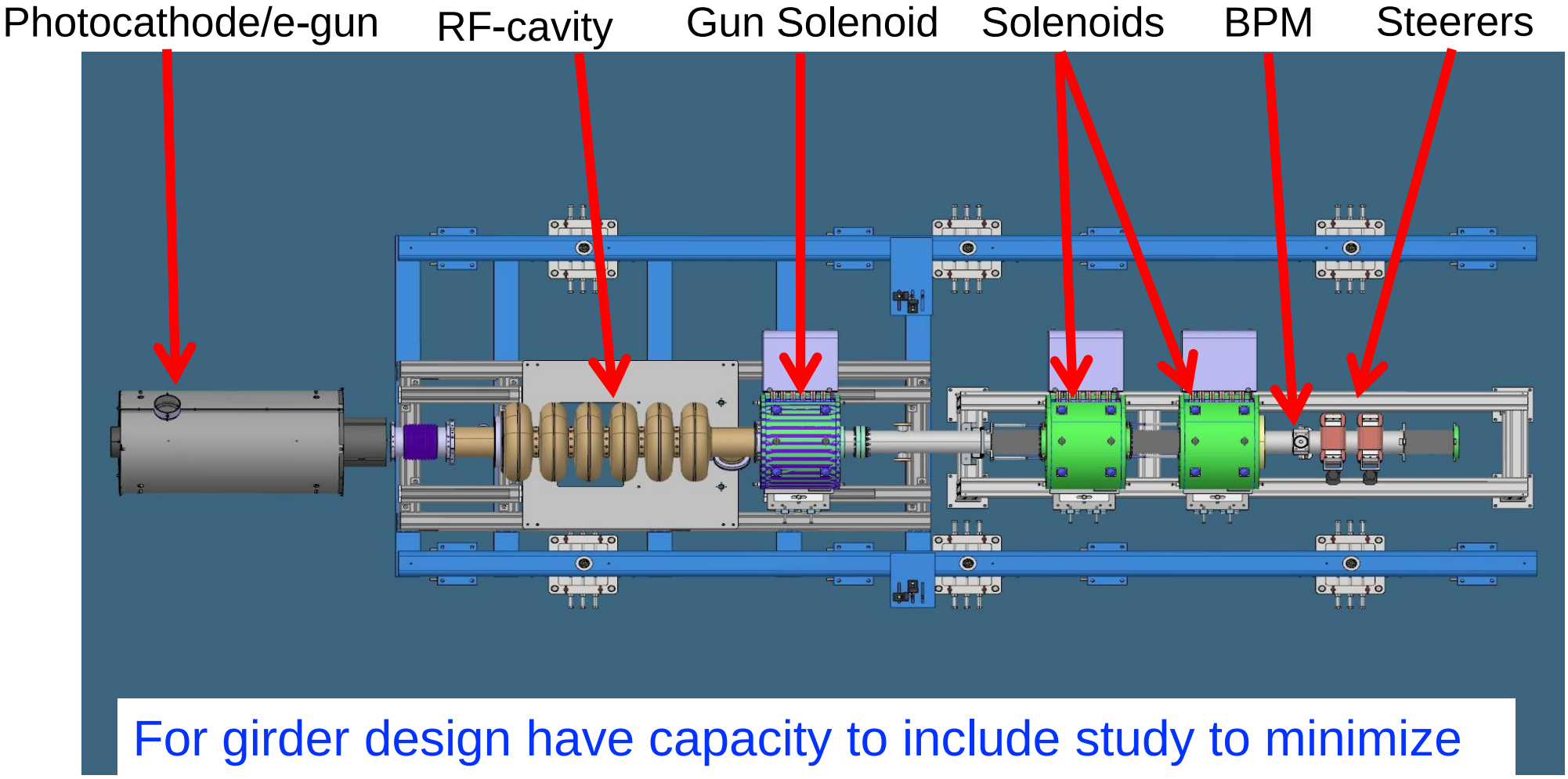
Helsinki Meeting 1-4 July 2019

- **Requirements are under development**
- **Initial simulations and preliminary parameters partially based on SwissFEL and European XFEL**
  - ➢ **Further CompactLight configuration studies ongoing**
- **Propose mechanical layout to be based on sub-assemblies**



Tools for injector 3D conceptual layout in place

- **Example layout with gun and transport line**



For girder design have capacity to include study to minimize vibrations due to mechanical and other noise sources

Tentative injector parameter list established

- **After the Barcelona CompactLight meeting (Dec-2018) tentative C-band injector parameters have been established**

XLS Hard X rays case	Units	After VB and/or Bunch Compressor 1
Charge Uniform Distribution	pC	75
Beam Energy	MeV	300
RMS Bunch Length	fs	350
FWHM Peak Current	A	60
RMS Energy Spread	%	0.5
Projected RMS Norm. emittance	μm	0.2
Repetition rate	Hz	100-1000

- **A preliminary proposal for the XLS photocathode and laser system options has been documented***
  - **a Cs2Te cathode for smaller gradients, with QE ~0.1-0.2 %, Nd: YLF laser with high repetition rate**
  - **a Cu cathode for larger gradients, exploiting the long lifetime of the metal cathode compared to semiconductors**

*** The CompactLight Project (XLS) WP3 Gun & Injector Engineering proposal, E.Gazis et al, May 2019**

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Preliminary parameters of C-band RF Gun and Injector used for simulations*

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European XFEL RF Gun parameters	
Cathode type	Cs_2Te cathode illuminated by a UV laser pulse
Electron Gun	1.3 GHz RF Gun 1.5 cells
Gun Solenoid	0.19 T centered at z=0.4 m
Charge	1 nC
Laser pulse length (total)	20 ps
Laser pulse rise/fall time	2 ps
Laser spot radius	1.1 mm
Peak electric field on the cathode	60 MV/m
Solenoid peak field	0.19 T
Solenoid centre position (with respect to cathode)	0.41 m

SwissFEL RF Gun parameters		
Cathode type	Cu Photocathode driven by a frequency-triplet TiSa laser	
Electron Gun	3 GHz RF Gun 2.5 cells	
Gun Solenoid	0.35 T centered at z = 0.3 m	
Operation Mode	**Long Pulse**	**Short Pulse**
Bunch Charge	200 pC	10 pC
Beam Current	20 A	3 A
Laser spot transverse size (rms)	215 μm	101 μm
Laser pulse length (Full Width)	9.9 ps	3.7 ps
Gun Gradient	100 MV/m	100 MV/m
Intrinsic (Thermal) emittance	0.195 μm	0.092 μm
Laser Rise and Fall time	0.7 ps	0.7 ps
K_{av}	0.4 eV	0.4 eV

XLS C-band RF Gun and Injector parameters	
Laser Wavelength	267 nm
Laser Pulse Length	3.8 ps (Uniform)
Laser Spot size radius	324 μm (Uniform)
Thermal Emittance	0.9 μm/mm
RF gun	1.6 cells
Cathode Peak Field	240 MV/m
Bunch Charge	100 pC
Energy	184 MeV
Beam Current	1 A
Energy Spread	0.4 % rms
Emittance	0.19 μm

* F. Cardelli, M. Diomede, G. Castorina, B. Spataro, M. Croia, M. Ferrario, A. Mostacci

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Gun Solenoid Design Study based on Requirements

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Preliminary Gun Solenoid Requirements

-Bore diameter of the solenoid > 40 mm
-Solenoid coils polarity configurations (++, +-)
-Bmax in ++ configuration ~0.75 T
-Bmax in +- configuration ~0.5 T
-Integrated field in ++ configuration ~0.06 Tm
-Good field region radius 15 mm
-Cathode position from the center of the solenoid ~100 mm
-Solenoid length ~ 90-100 mm

Bucking Coil Requirements

-Ensure <10G (Gauss) at cathode plane

- **Different topologies based on the design by A.Vannozzi have been simulated with Poisson/Superfish:**
  - Single Coil- Attached Bucking Coil
  - Double Coil- Attached Bucking Coil
  - Double Coil- Separate Bucking Coil

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Example for the Double Coil-Attached Bucking Coil case (- ++ polarity)

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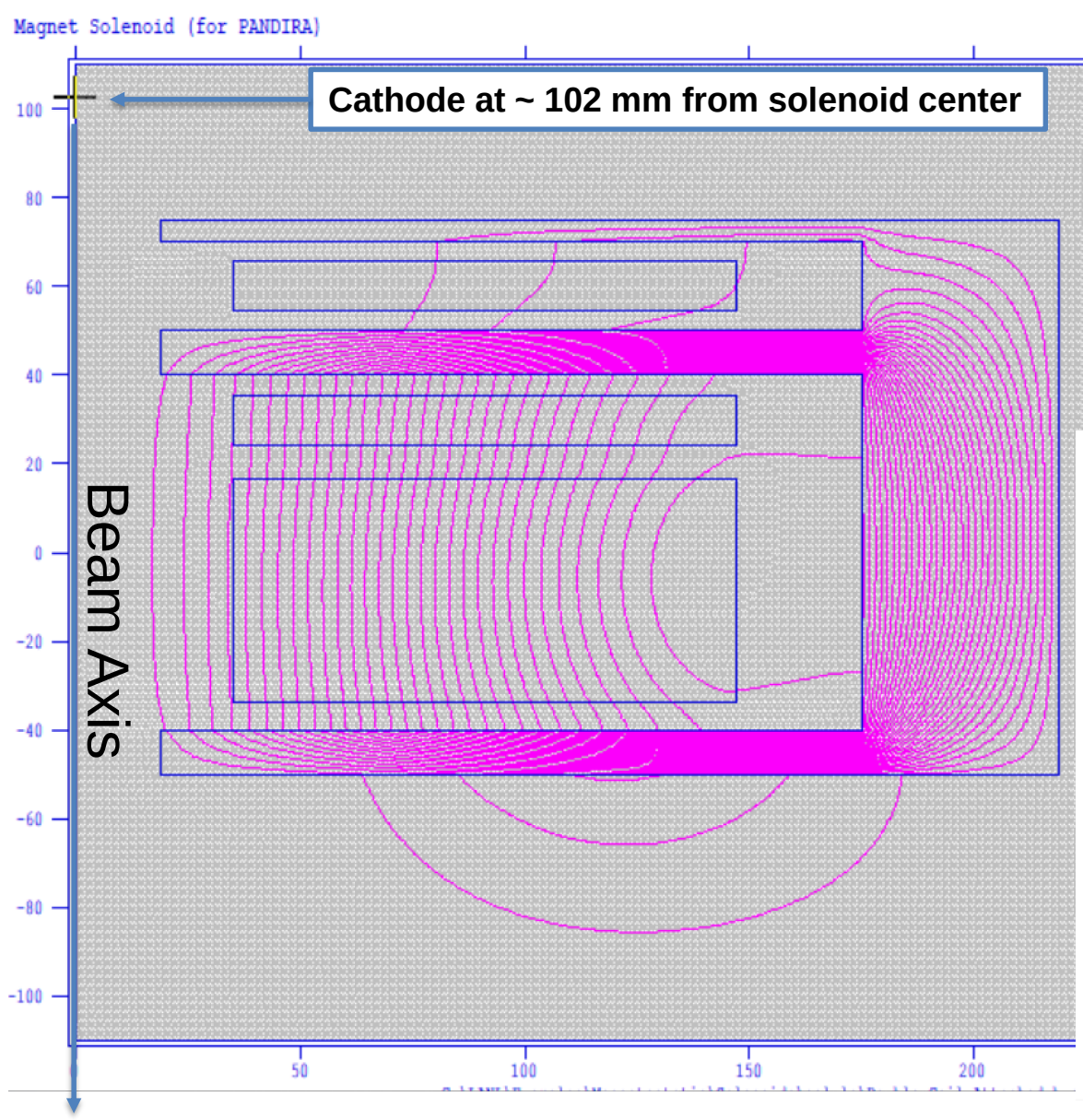
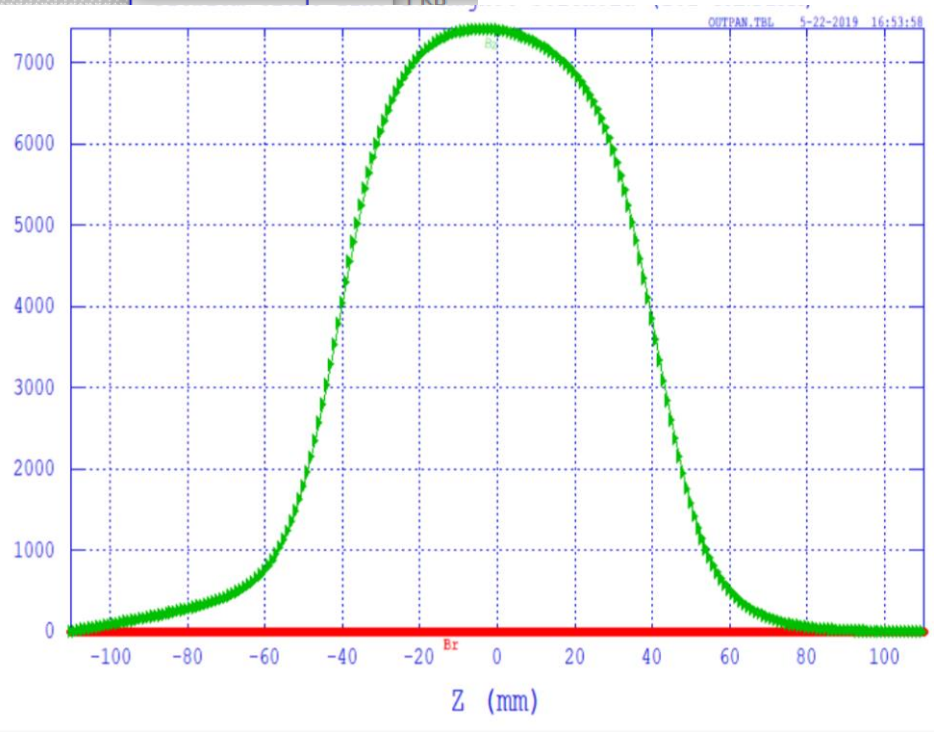


Cursor location and fields

M= 1 K= 1 L= 214 Fn37
R = 2.78089E-02 mm
Z = 102.59 mm
Br = 8.4630E-03 G
Bz = 3.821 G
B = 3.821 G
A = 5.3132E-03 G-cm
rA = 1.4776E-05 G-cm^2

Field on cathode plane



Example for the Double Coil-Separated Bucking Coil case (- ++ polarity)

- **Main magnet parameters**

XLS Gun Solenoid		
Parameters	**Units**	
Position (from photocathode)	m	0.1
Aperture	mm	38
Outer Diameter	mm	219
Magnetic strength	T	**0.74 on ++ 0.59 on +-**
Mechanical Length	m	0.1
Yoke Material	-	Low Carbon Steel
Integrated Field in $\int Bdz(0)$ on ++	Tmm	64..4
$\Delta \int Bdz(r)$ / $\int Bdz(0)$ on ++	-	20X 10^{-5}
B at Cathode : 102.55 mm from center	T	7.1 X 10^{-4}
Good field region	mm	10mm
Coil Specification		
Number of Turns	-	COIL 1:40 COIL 2:180
Conductor Dimension	mm	5.6x5.6 /bore 3.6
Coils Placement	-	2x20 9X20
Current	A	260
Inductance	mH	5.9
Resistance 25	Ohm	0.125
Voltage	V	32.5
Heat	W	8457.28
Cooling Interface		
DT Water	^{O}C	30
Cooling Water flow	l/m	4
Pressure drop	bar	7.25

Smaller Aperture

~0.75 T expected — Dual Polarity

Compact design

~60 Tmm expected

Better Field quality than other 2 cases

Small field at cathode

Good field region radius 15 mm

Common Power Supply

SwissFEL Gun Solenoid		
Parameters	**Units**	
Position (from photocathiode)	m	0.3
Aperture	mm	80
Outer Diameter	mm	385
Magnetic strength	T	0.35
Mechanical Length	m	0.26
$\int \frac{\Delta B}{B} . ds$		10^{-4}
Magnetic axis measured accuracy	mm	0.1
Maximum Current	A	220A
Resistance (50 °C)		110 mOhms
Conductors		Geometry 2coils-161 turns/coil-Each coil consists of 14 layers glued with glass-epoxy

Example for the Double Coil-Separated Bucking Coil case (- ++ polarity)

- **Bucking coil parameters**

XLS bucking coil		
Parameter	**Units**	
Bucking Coil (Centered at 2.55mm from cathode)		
Turns	-	8
Conductor (mm):	mm	5.6 x 5.6 mm /bore 3.6
Current (A)	A	35 ++ 4.5 +-
Coils placement	-	1x8
Aperture	mm	19
Outer Diameter	mm	81
Length	mm	20mm
Electrical Interface		
Inductunce	mH.	0.0069
Resistance 20°C	Ohm	0.003
Water Cooling Interface		
ΔT	°C	0.41
Water flow	l/m	0.1
Pressure Drop	bar	0.94

SwissFEL bucking coil		
Parameter	**Units**	
Location	mm	z = –60
Aperture	mm	220
Strength at Cathode	mT	4.3
Cooling		Air
Maximum Current	A	10

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Proposed Next Steps for Injector Design Study

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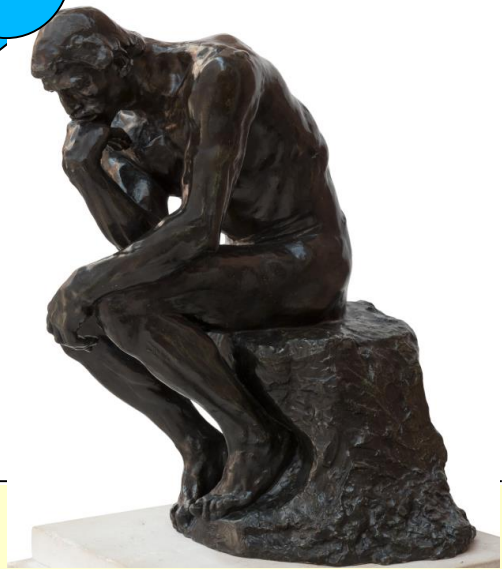
1. Reiterate on requirements
2. Choice of gun cathode and solenoid topology - update field maps based on updated requirements, as needed
3. ASTRA simulations with the extracted fieldmap for gun solenoid
4. Simulation and Design of the gun solenoid (CST Microwave Studio)
5. Simulations with ASTRA based on CST fieldmap for the gun solenoid
6. Draft Design of TWS and TWS solenoids
7. Astra and DYNAC simulations of entire injector



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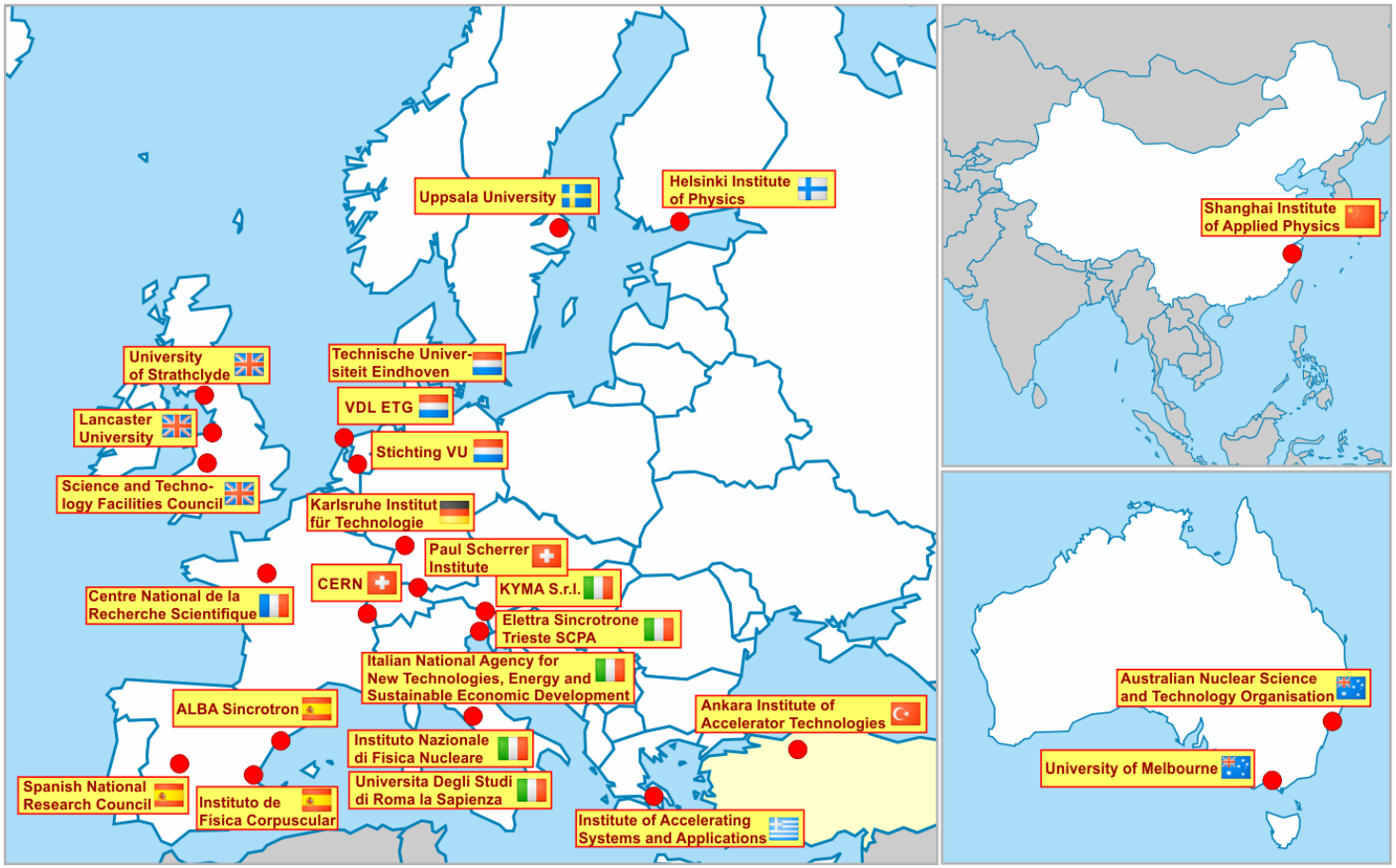
Thank you!

CompactLight@elettra.eu

www.CompactLight.eu



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