CLS new e-linac and magnet lab

Mark Boland

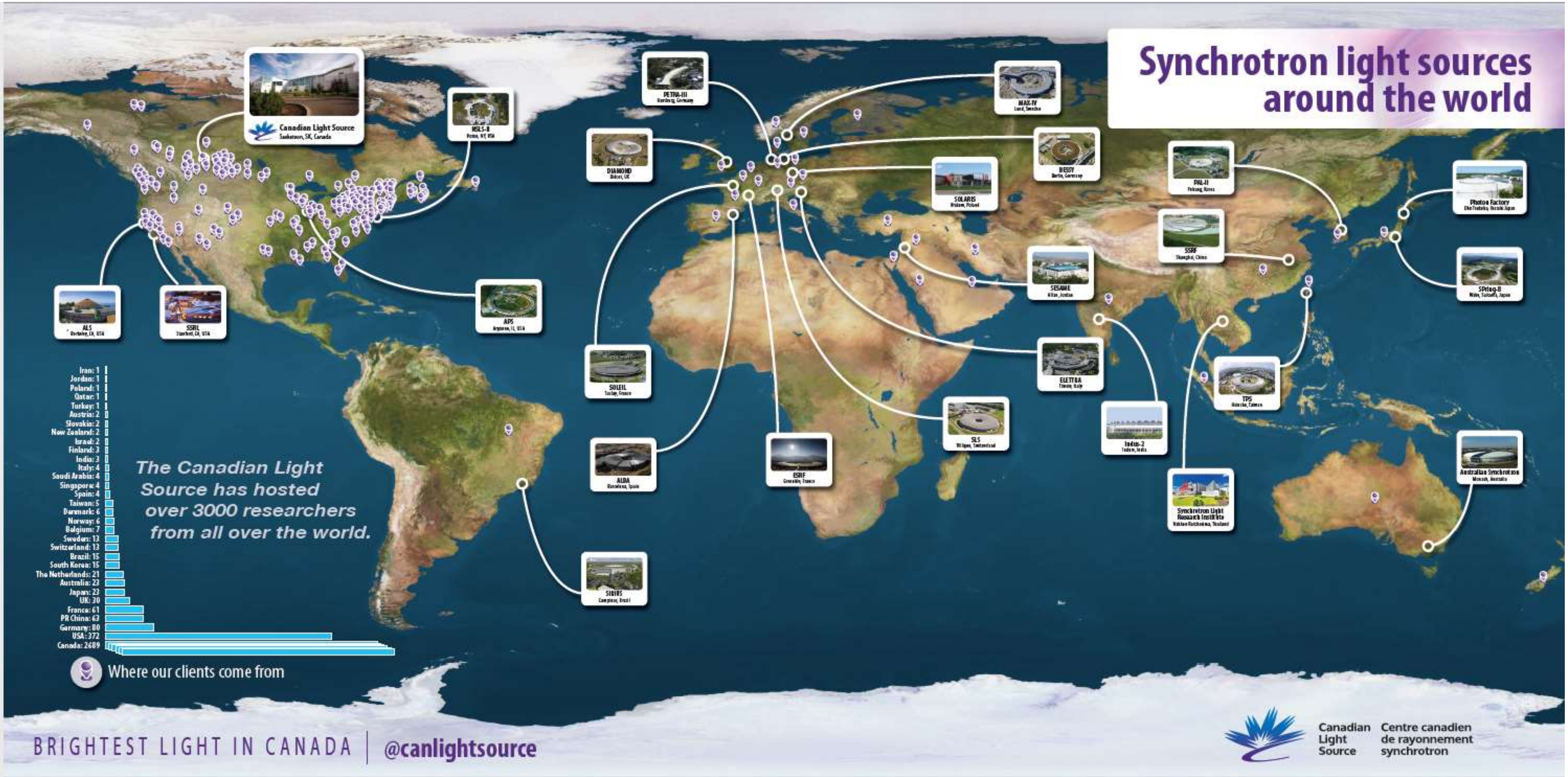
TRIUMF FEL Workshop

19 March 2024

National research facility for synchrotron light

- Canada's only synchrotron light source.
- Owned by the UofS and funded primarily through federal funding.
- Operating since 2005 for open user access.
- One of 20 of its type in the world.
- Used by thousands of researchers from Canada and around the world.

View over CLS beamline experimental floor.


Synchrotron light sources around the world
Canadian Light Source
Saskatoon, SK, Canada
NSLS-II
PETRA-III
MAX-IV
DIAMOND
BESSY
SOLARIS
PAL-II
Photon Factory
SSRF
SPring-8
SESAME
ALS
SSRL
APS
SOLEIL
ELETTRA
TPS
SLS
Indus-2
ALBA
ESRF
Australian Synchrotron
Synchrotron Light Research Institute
SIRIUS
Iran: 1
Jordan: 1
Poland: 1
Qatar: 1
Turkey: 1
Austria: 2
Slovakia: 2
New Zealand: 2
Israel: 2
Finland: 3
India: 3
Italy: 4
Saudi Arabia: 4
Singapore: 4
Spain: 4
Taiwan: 5
Denmark: 6
Norway: 6
Belgium: 7
Sweden: 13
Switzerland: 13
Brazil: 15
South Korea: 15
The Netherlands: 21
Australia: 23
Japan: 23
UK: 30
France: 61
PR China: 63
Germany: 80
USA: 372
Canada: 2689
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https://www.lightsource.ca/public/tours.php#VirtualTour

CLS Accelerator Complex

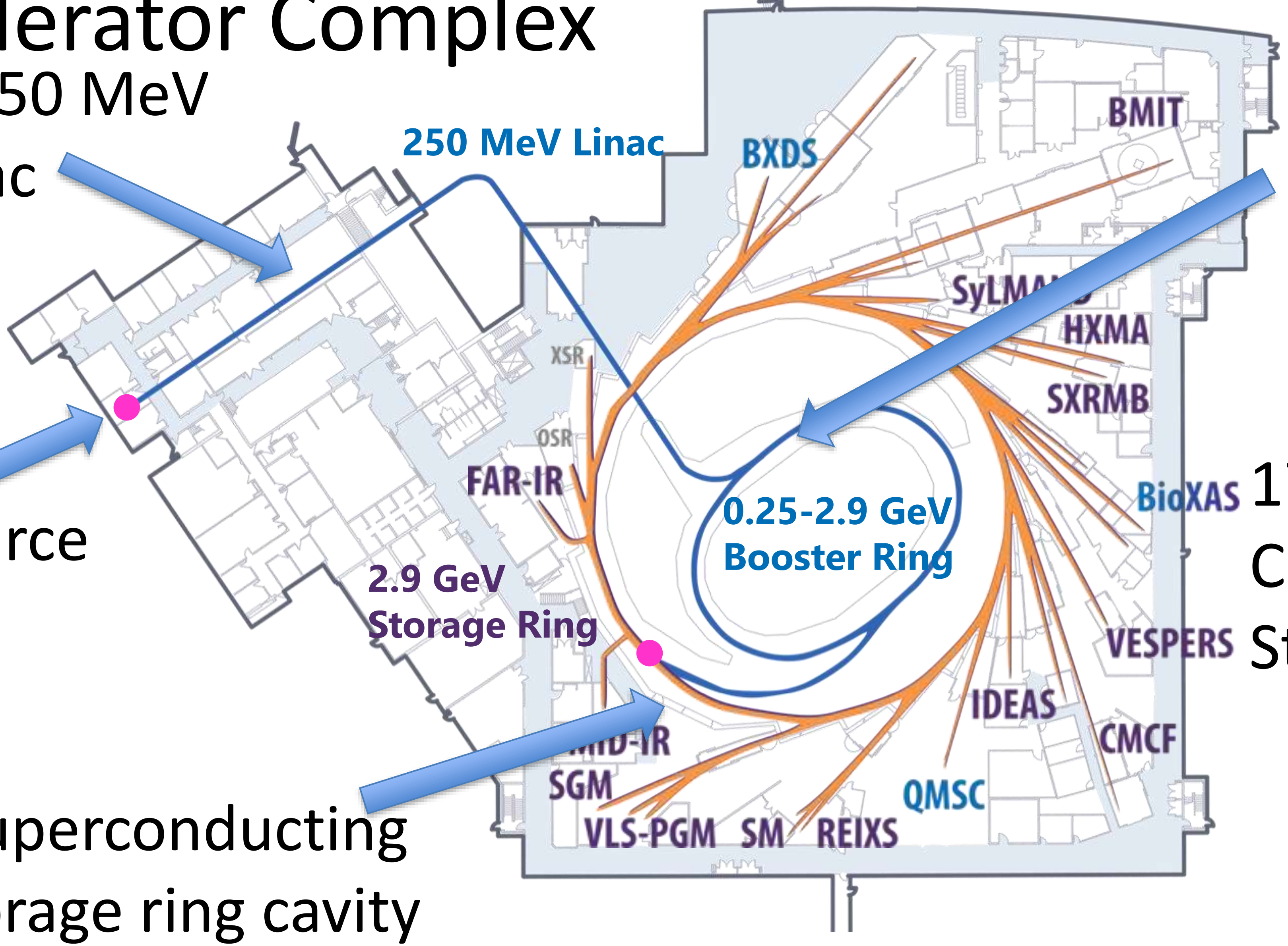
2856 MHz 250 MeV electron linac

250 kV DC electron source

500 MHz 0.25-2.9 GeV booster cavity

171 m Circumference Storage Ring

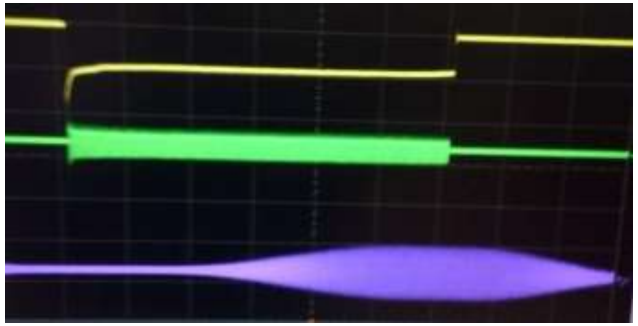
500 MHz Superconducting 2.9 GeV Storage ring cavity



CLS Electron Injection Scheme

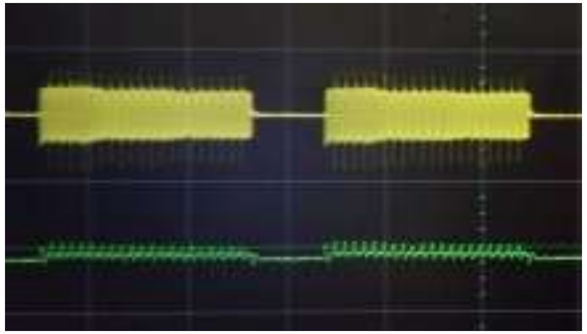
- Linac: 250 MeV, 1-140 ns, 3 nC, 1 Hz rep. rate. (booster limit)
- Booster Synchrotron: 0.25 – 2.9 GeV, 1 Hz ramp, 65% eff. to SR
- Storage Ring: 0.5 nC every 3-4 minutes across 500 ns train

Booster Ramp



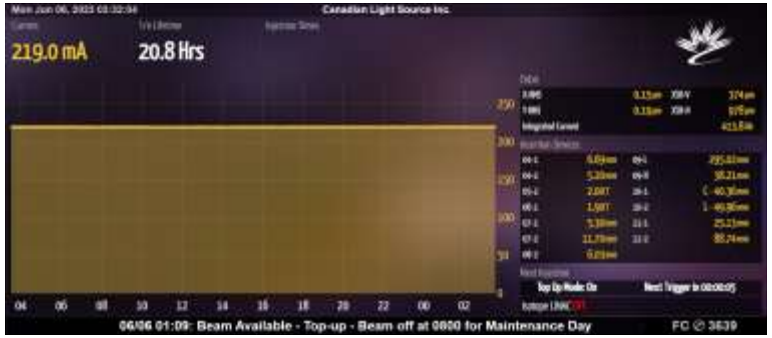
1 second

Stored Bunches



500 ns

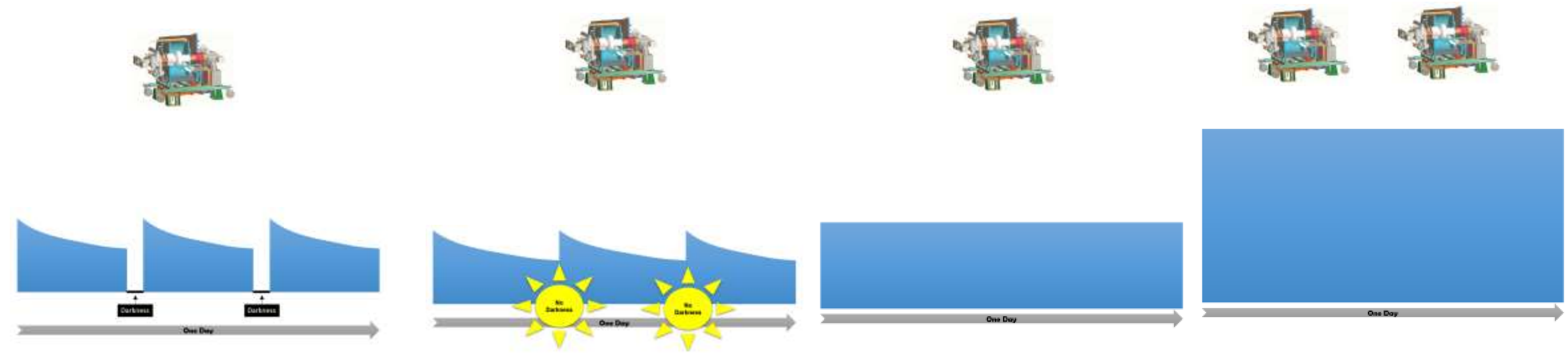
Top-Up User Beam



1 day

CLS Operations Evolution

- Decay mode: linac used every 8 hours to fill storage ring
- Top-Up: mode every 2-3 minutes require 0.5 nC from linac
- Currently limited by RF power



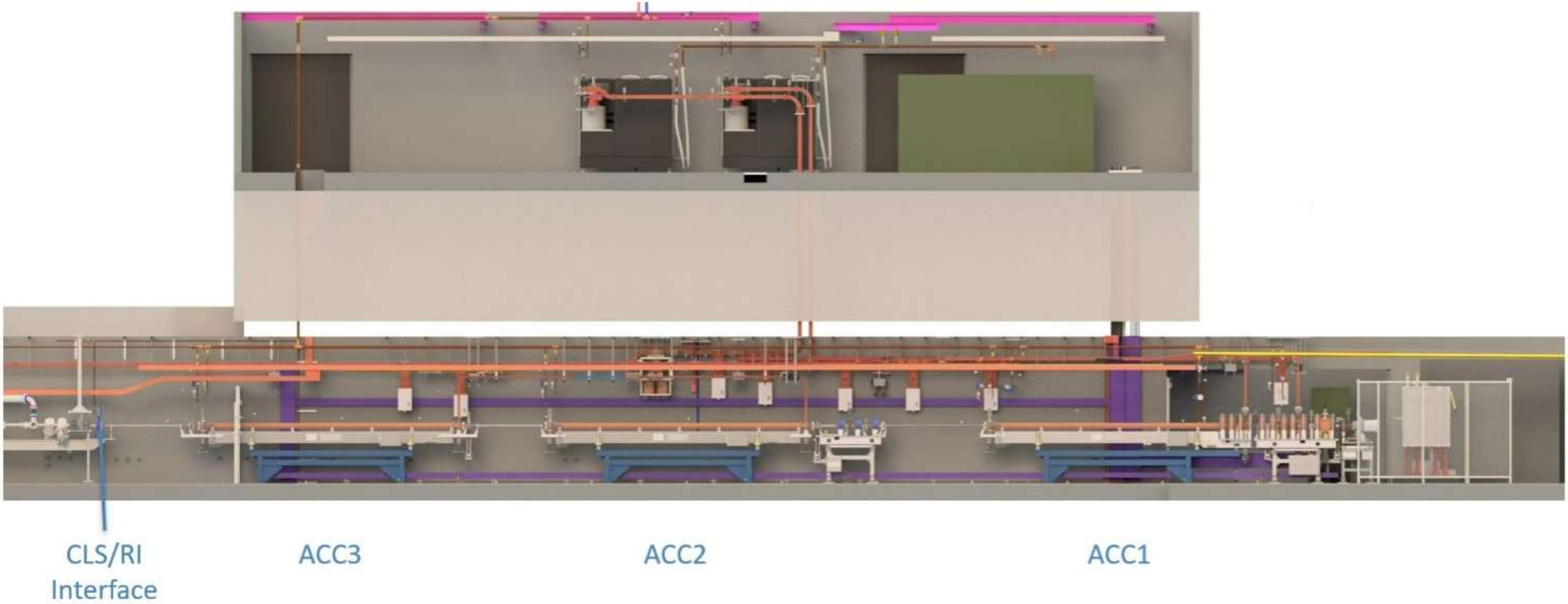
2005-2017 2018-2020 2021-2025 2026-2029

New Linac

- Funded project 2022-2025
- Negotiating contract with industry
- Dark period ~4-5 months in

- Old SAL linac 2856 MHz
- New linac 3000 MHz synchronized with 500 MHz ring frequencies
- Design with SLED RF pulse compression and half length

RI Linac CAD Design



Canadian Light Source Centre canadien de rayonnement synchrotron

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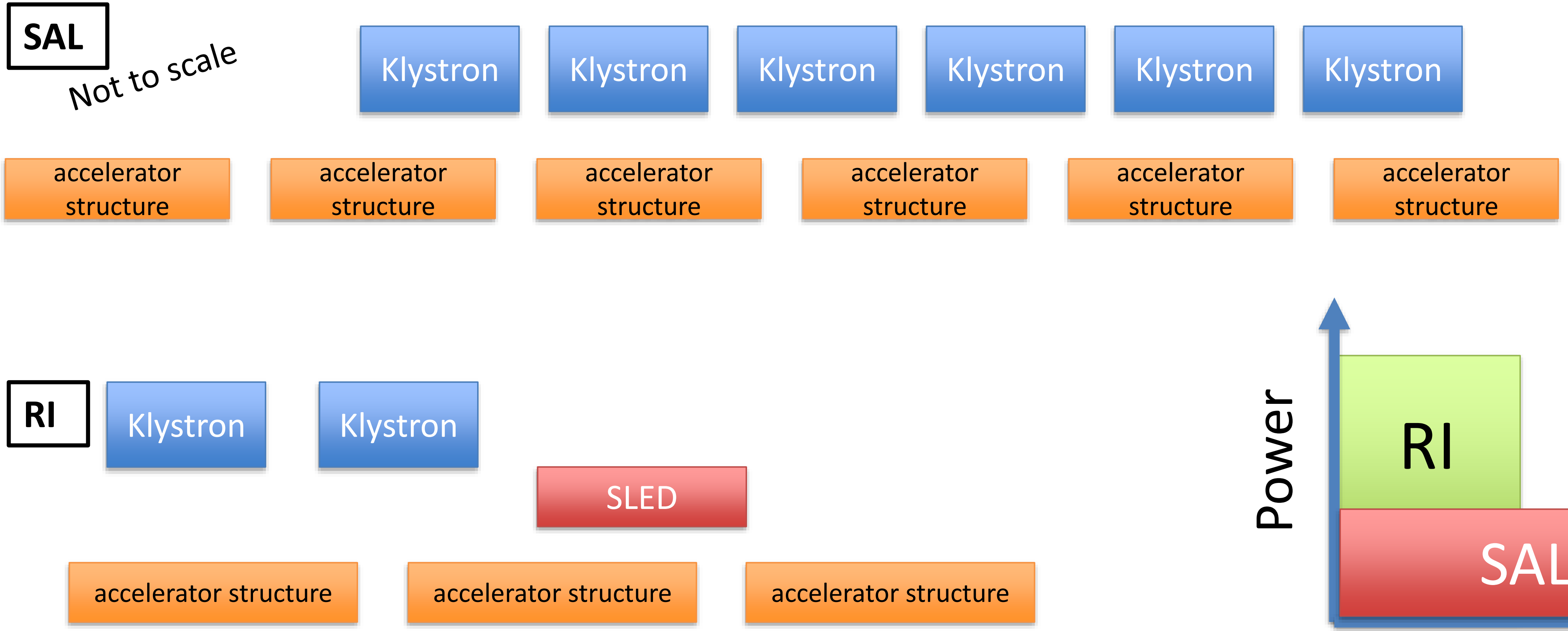
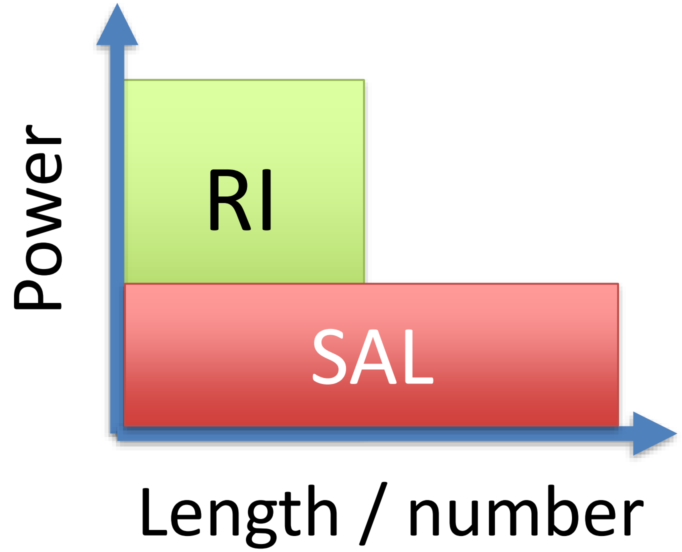
Linac Technical Requirements

Parameters	Values	Units
Nominal Beam Energy	250	MeV
Minimum Beam Energy in any RF failure mode	180	MeV
Beam charge	3	nC
Bunch Train Length, 1 to 70 bunches at 500 MHz (2 ns RF buckets)	1 to 140	ns
Center energy stability (pulse to pulse)	≤0.1	%
Energy Spread	≤0.5	%
Normalized Emittance (1σ) (X or Y)	≤50	π mm·mrad
Injector Frequency	3000.24	MHz
Booster Synchrotron RF Frequency	500.04	MHz
Injector Nominal Repetition rate	1	Hz
Modulators and Klystrons Repetition Rate	1 to 60	Hz

Layout Comparison

SAL	RI
Source 250 kV in oil	90 kV in air
250 MeV	250 MeV

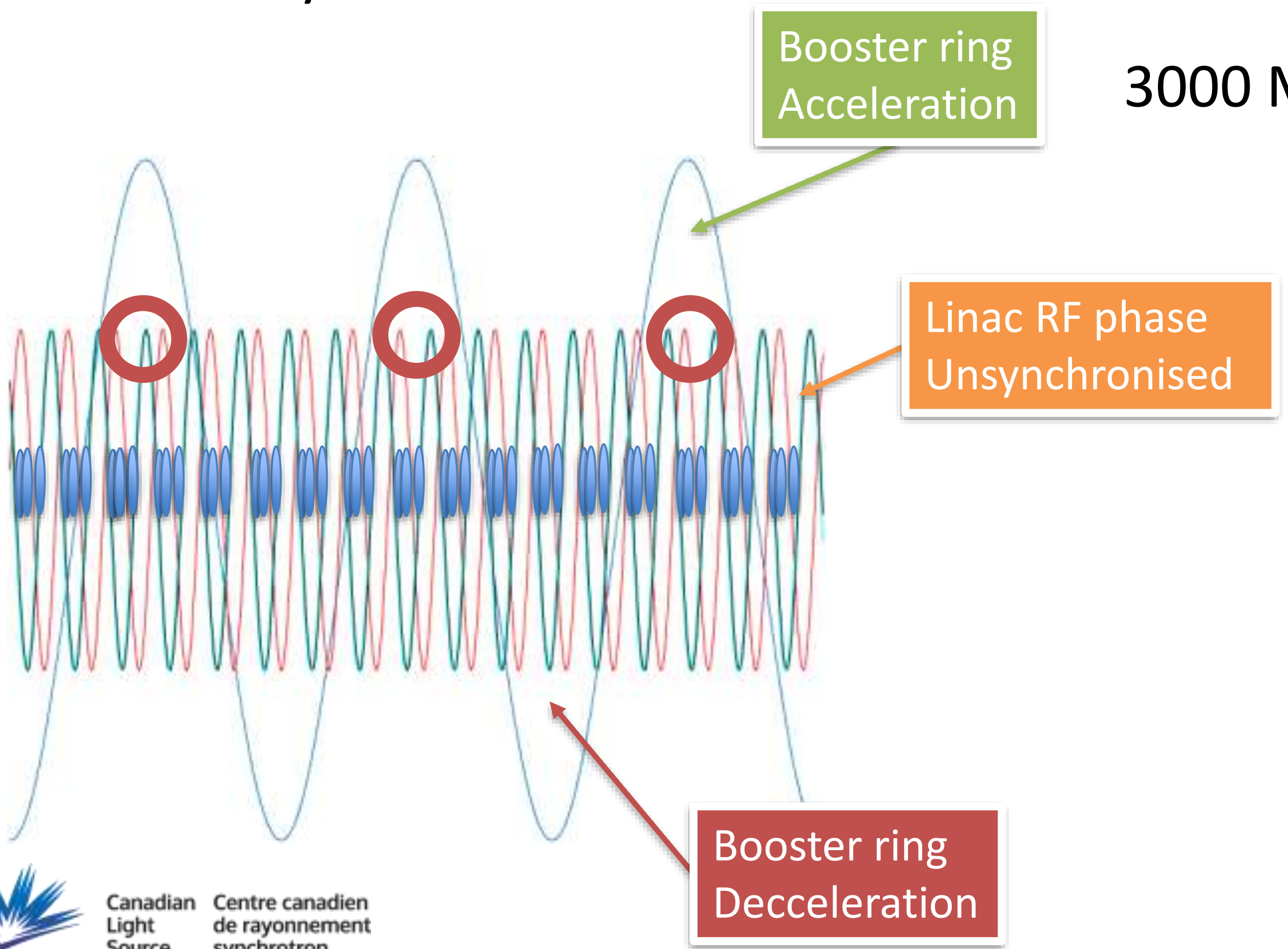




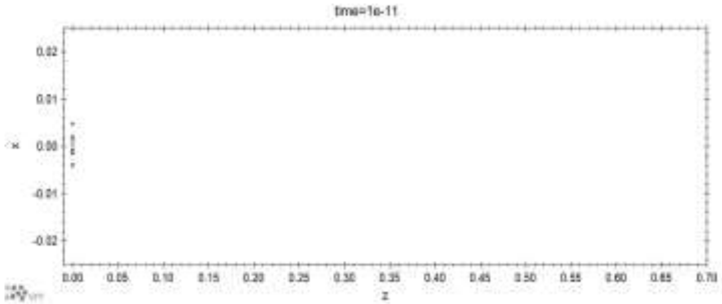
SAL vs RI Linac

SAL Linac

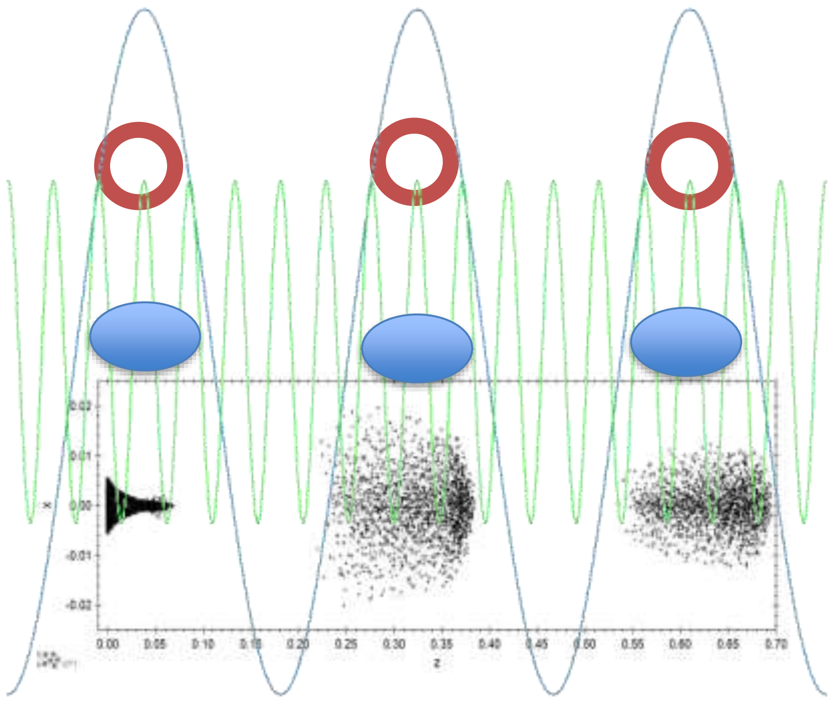
2856 MHz -> unsynchronised



RI Linac



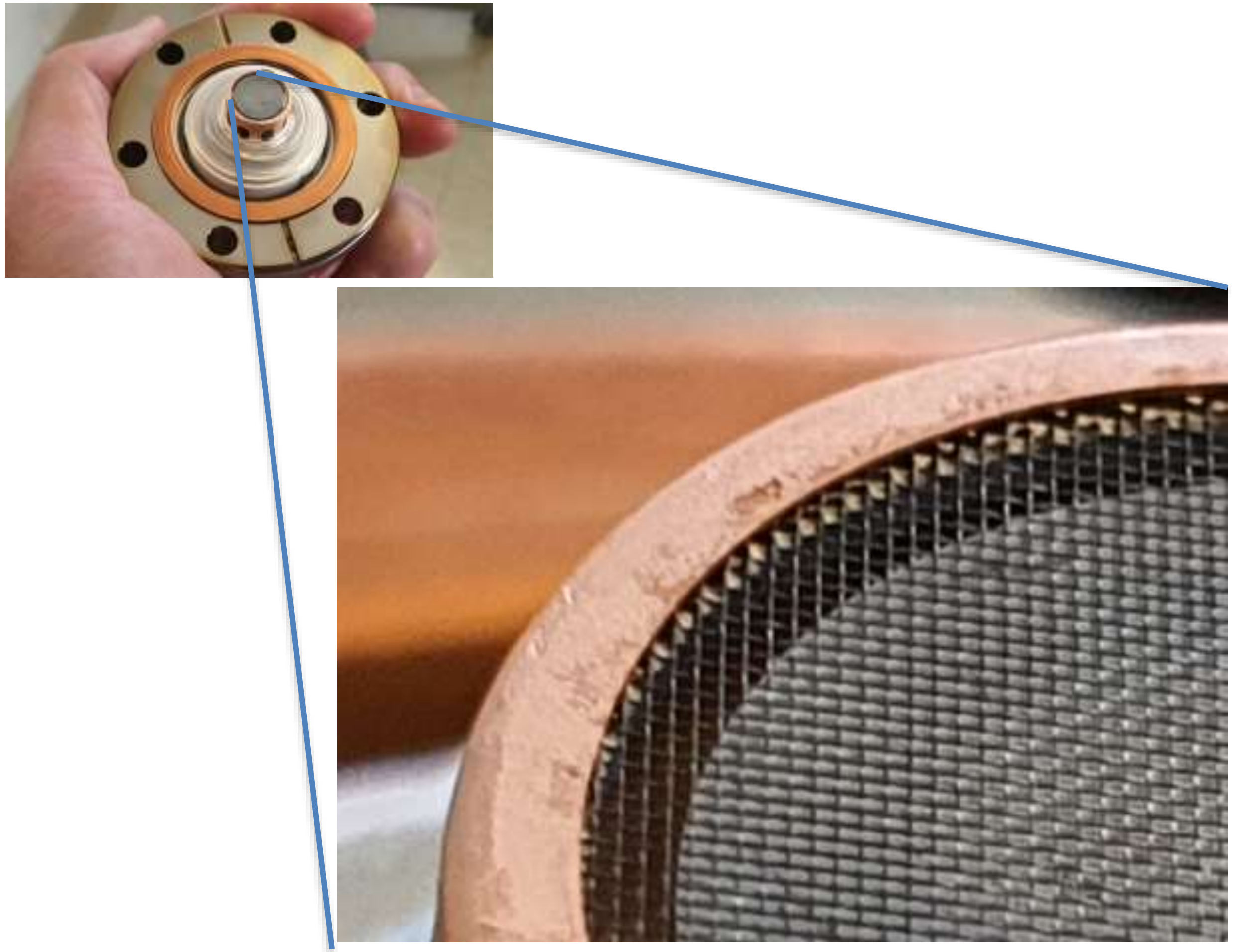
3000 MHz = 6 x 500 MHz matches rings



RI Linac Assembly and Test in Germany

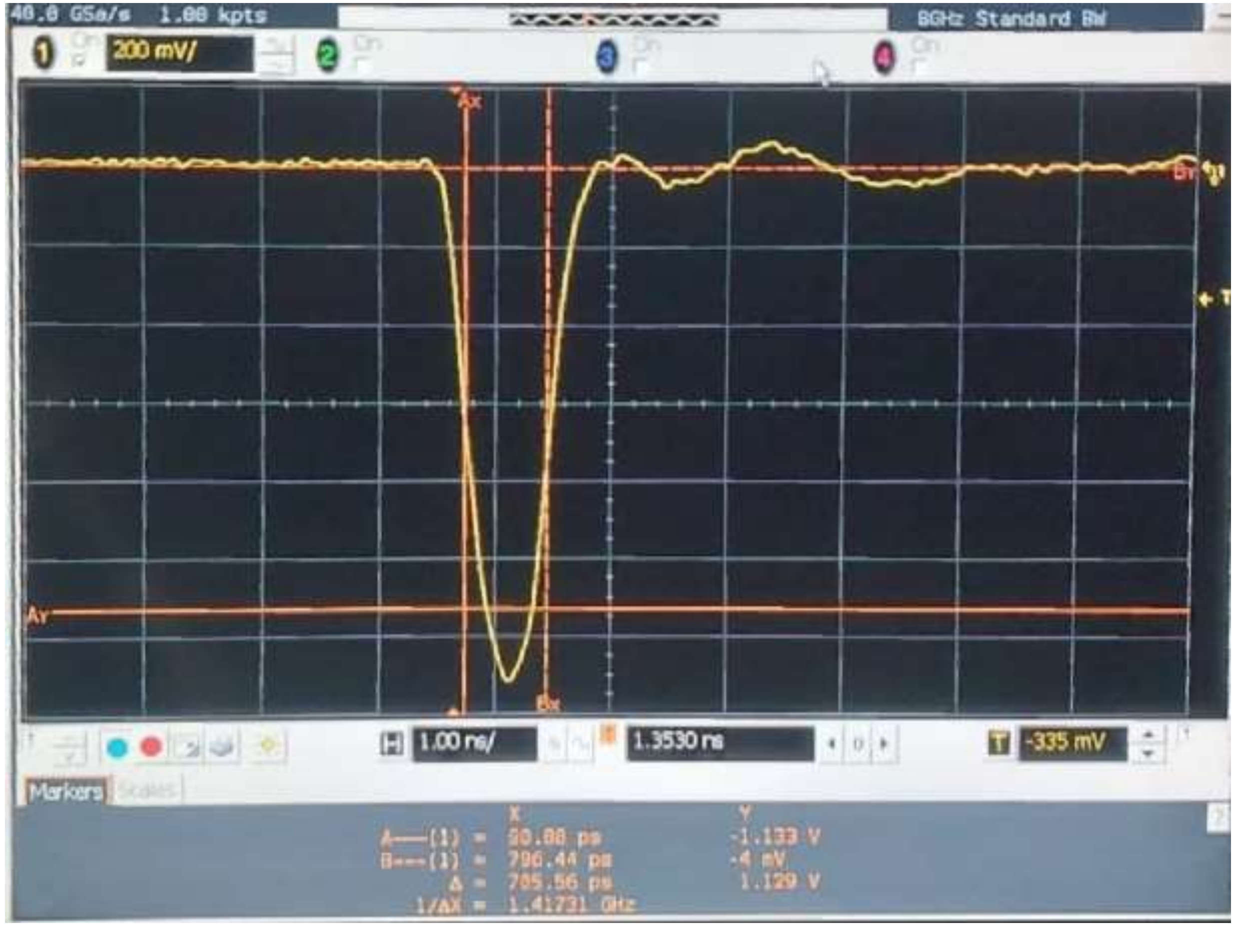
Electron Source test March 2024

Cathode with pulsed grid

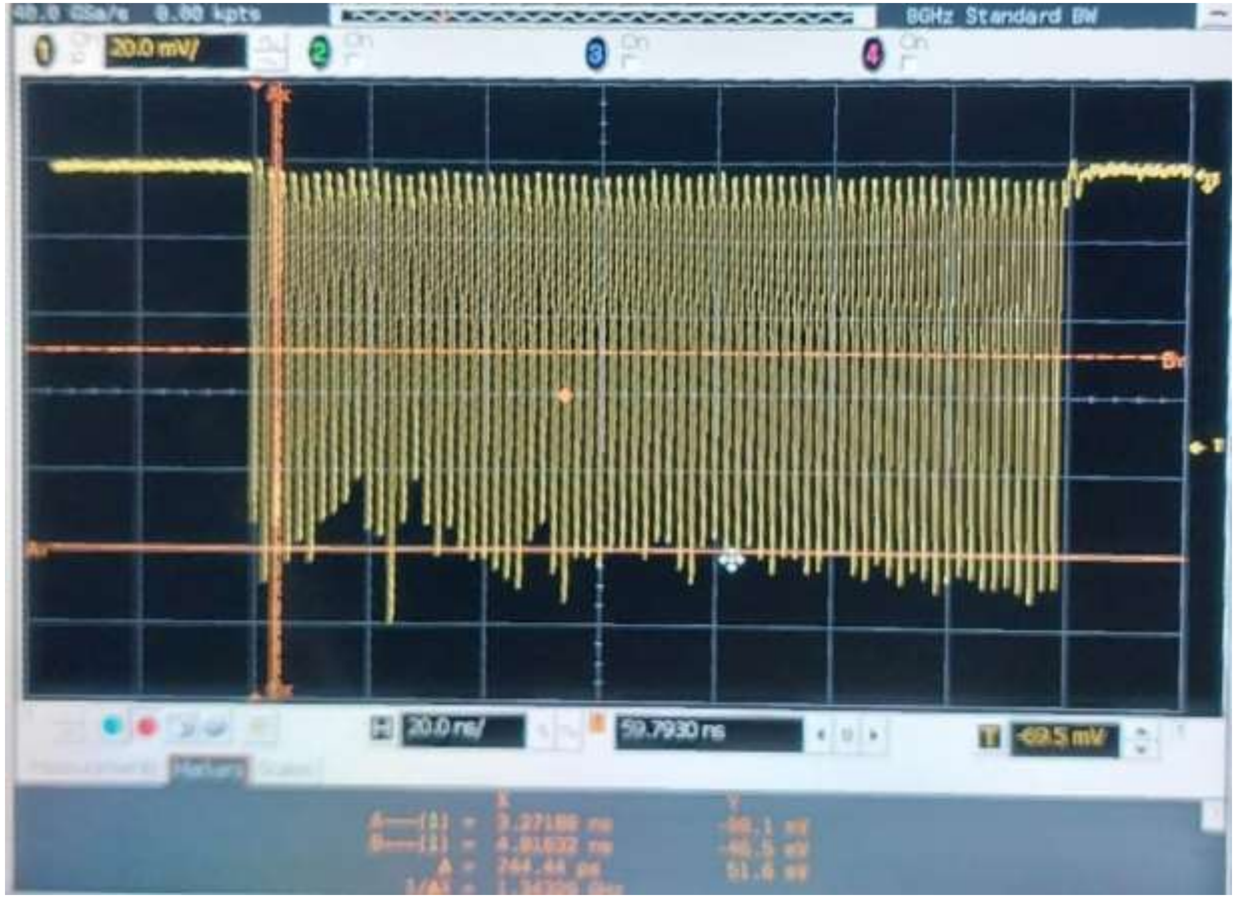


RI Linac Electron Source – First Beam

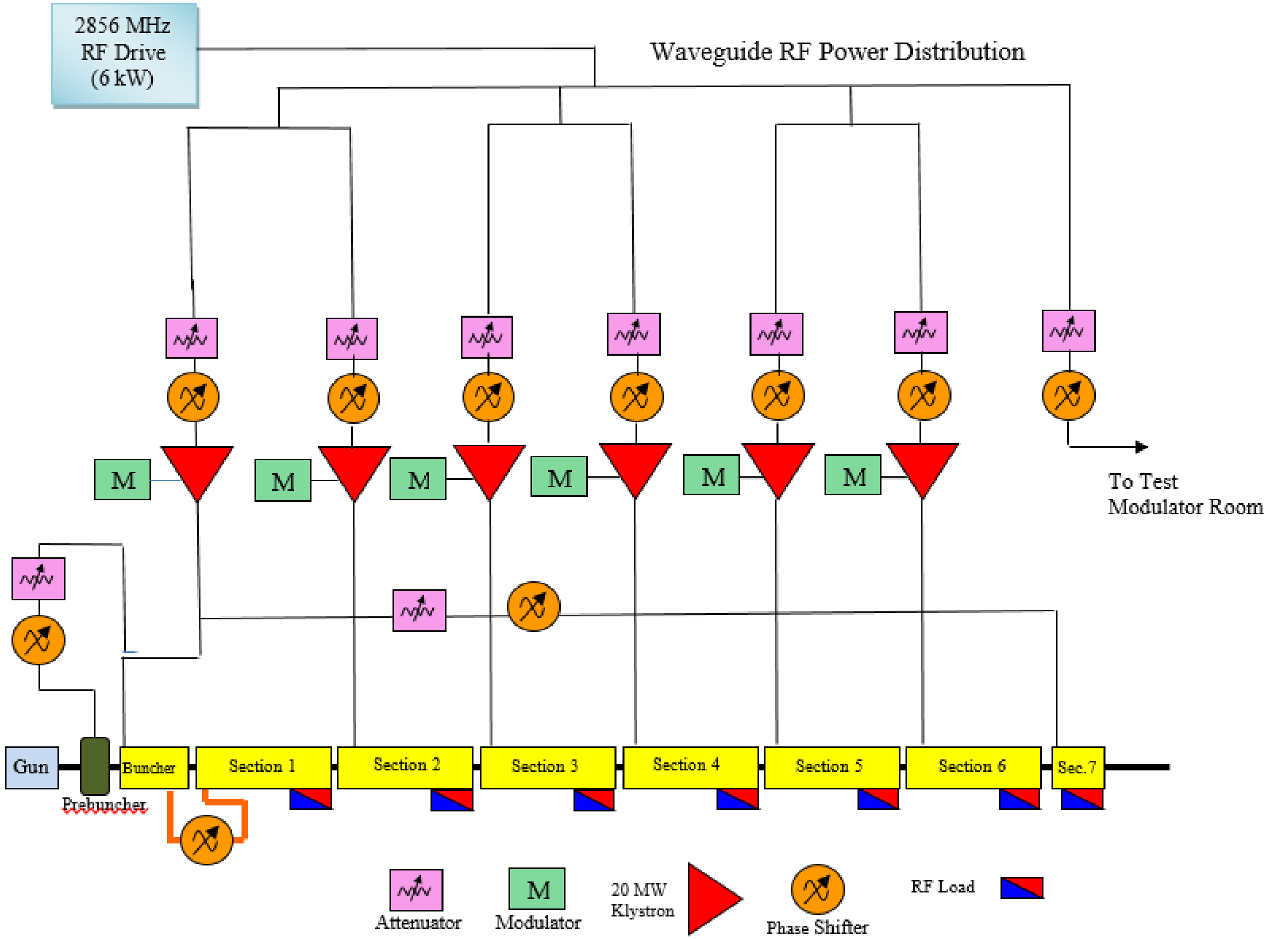
Single bunch sigma = 300 ps



Multi bunch 70 bunches in 140 ns pulse

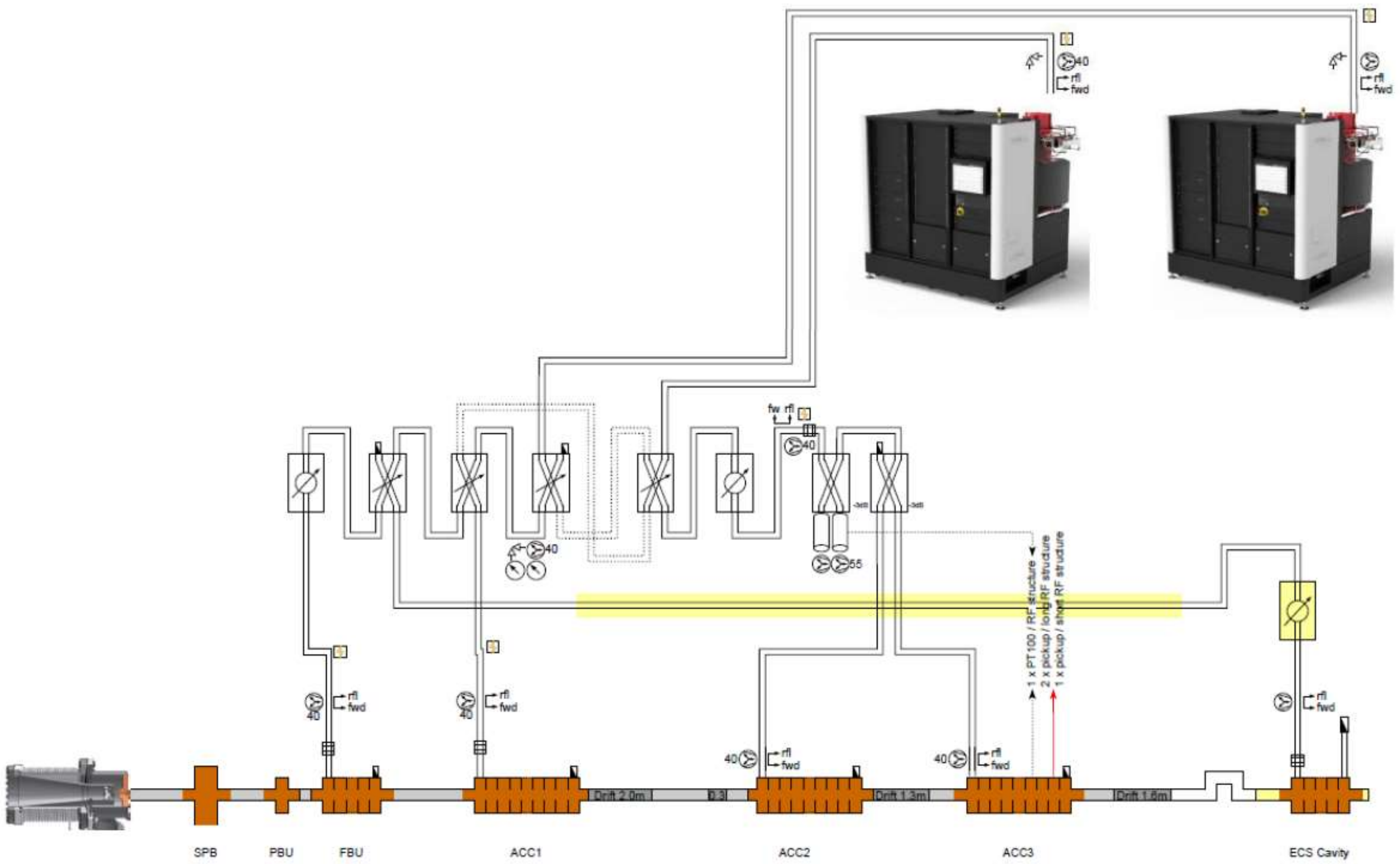


SAL Linac RF Layout



Schematic Drawing of Linac RF system

RI Linac RF Layout



Linac Procurement Roadmap Estimate

Calendar Year Quarters
Based on CLS new linac
Need to scale for smaller linac and FEL Project

01 Tech. Spec. RFP
Modification of FHI
Q2 2024

02 Contract Award
For large components
Q3 2024

03 Final Design
With manufacturers
Q3 2025

04 Manufacture
Managing suppliers
Q2 2026

05 Delivery and Installation
Depends on building availability
Q1 2027

06 Commissioning
Beam performance demo
Q3 2027

Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4

2024 **2025** **2026** **2027**

Magnet Measurement Lab at CLS

Equipment

Hall Probe (HP) bench

Flip Coil (FC) bench

Vibrating wire

Analysis Software

- Numerical optimization codes
- Analysis and characterization of magnetic fields

Capabilities

- Insertion Devices performance characterization
- Assembly and shimming of permanent magnet IDs
- Fiducialisation and alignment measurements of magnet systems
- Magnetic field maps
- Ramping curves for electro magnets
- Magnetic field quality, including multipole components, homogeneity, field roll-off, and fringe fields.

Slides by Michael Sigrist for TRIUMF FEL workshop 2024-03-19

* Content contributions from Cameron Baribeau @ CLS

ID design

CLS has built or purchased 16 insertion devices (currently operating 13):

	Insertion Devices															
	Permanent Magnet														SC	
	Pure Permanent Magnet (PPM)								Hybrid (Fe alloy poles)							
	Out of Vacuum									In Vacuum						
	Elliptical polarisation – APPLE-II						Planar									
location	ID11-1	ID9he	ID10-1	ID10-2	ID11-2	ID9le			ID7-2	ID7-1	ID8		ID4-1	ID4-2	ID6	ID5
Period, mm	54.2	55	75	75	142	180	45	185	150	19.1	20	20	20	80	33	48
Length, m	1.6	3.9	1.6	1.6	1.6	3.8	1.2	1.6	1.6	1.6	3.8	1.6	1.6	1.4	1.1	0.6
Min. Gap, mm (magnetic)	14	14.5	18	16	15	15	12.5	25	11.5	5.2	5.45	5.2	5.2	5.2	13.5	14
K	4.2	4.6	5.2	5.2	14	9.7	3.5	13	35	1.8	2.0	1.8	2.0	14	5.9	19
Material	$Nd_2Fe_{14}B$											Sm_2Co_{17}			NbTi	

Insertion Device Procurement

Procurement options:

- CLS provides performance specification, design review and FAT approval
- CLS provides preliminary or detailed magnetic designs, auxiliary systems designed by vendor
- CLS assembles components from multiple vendors (magnets, holders, support structure, control system)
- Design of mechanical, drive systems, motion control, or vacuum systems.
- Build to print of mechanical parts.
- Supervision of FAT and/or confirmation of magnetic measurements with SAT using CLS magnet laboratory
- Previous work with local Canadian manufacturers for mechanical systems and parts

Insertion Device Team at CLS

Slides by Michael Sigrist for TRIUMF FEL workshop
2024-03-19
* Content contributions from Cameron Baribeau @ CLS

Comparison of undulators at CLS and selected IR-FEL facilities

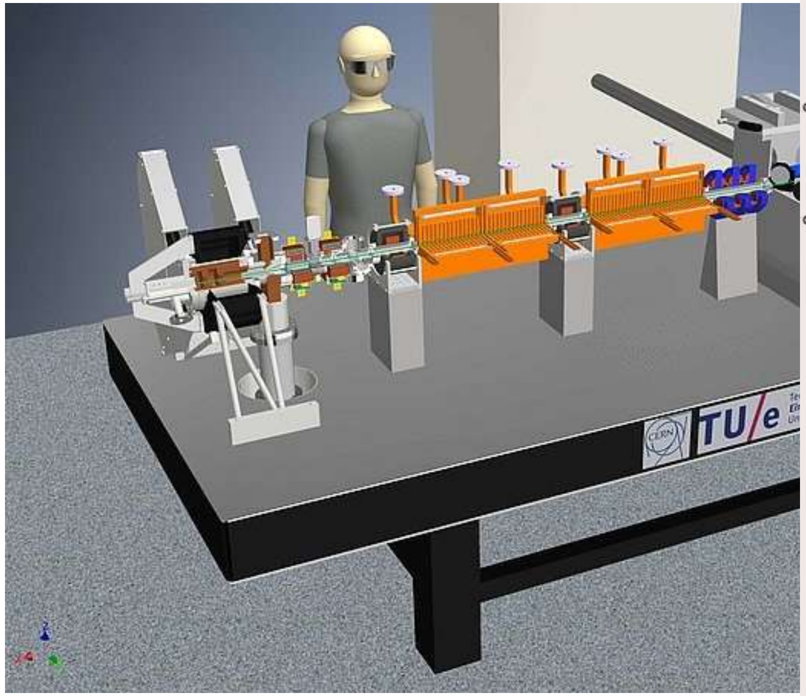
PPM or planar hybrid style out of vacuum devices used at existing IR-FEL facilities have many similar parameters and specifications to IDs designed and built at the CLS.

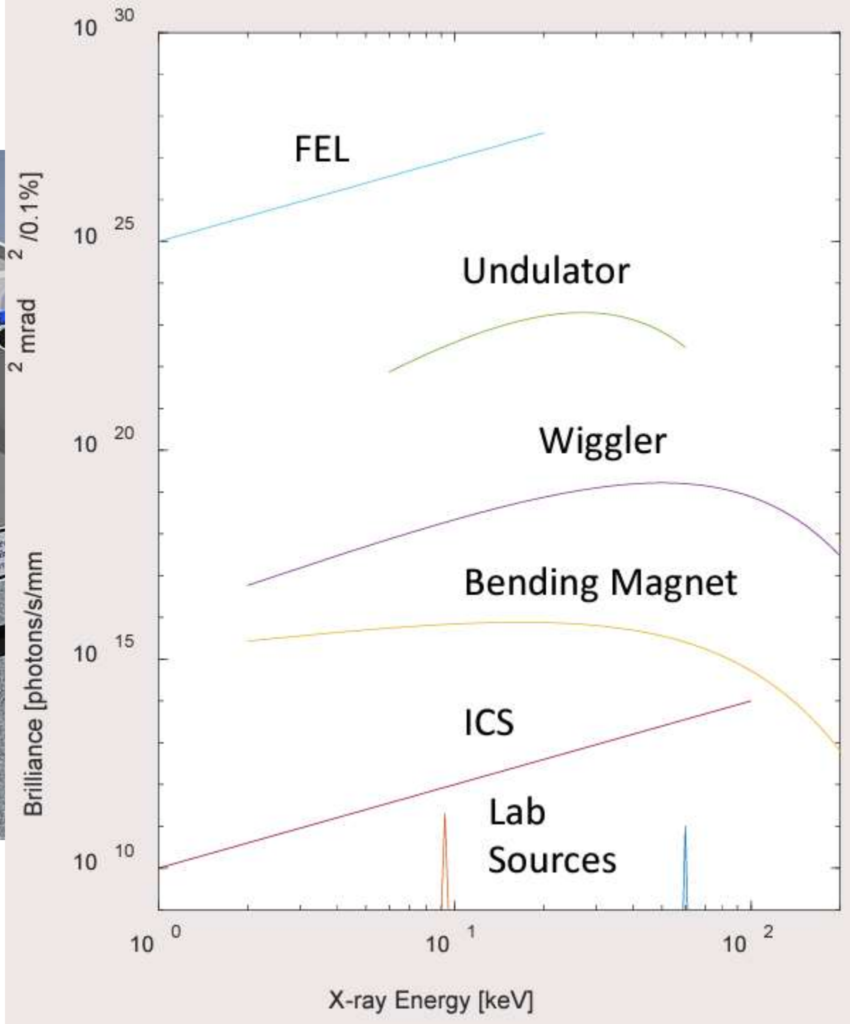
									CLS contribution						
Institute		Magnetic Material	Magnetic period, mm	Minimum gap, mm	Magnetic length, m	Undulator parameter, K	Hybrid design, Y/N	In-vacuum, Y/N	Magnetic Design	Magnetic Spec.	Mechanical Design	Motion Control	Magnetic FAT/SAT	Final Assembly	Installation
CLS	U45	$Nd_2Fe_{14}B$	45	12.5	1.2	3.5	☐	☐	☑	☑	☐	☑	☑	☑	☑
CLS	BXDS	Sm_2Co_{17}	80	5.2	1.4	14	☑	☑	☑	☑	☐	☑	☑	☐	☑
CLS	BioXAS	$Nd_2Fe_{14}B$	150	11.5	1.6	35	☑	☐	☑	☑	☐	☑	☐	☐	☑
FHI[1]	MIR	$Nd_2Fe_{14}B$	40	16.5	2.0	1.6	☑	☐							
FHI[1]	FIR	$Nd_2Fe_{14}B$	110		4.4	3.0	☑	☐							
FELIX[2]		SmCo type	110	24	4.5	3.5	☐	☐							
FLARE[2]		SmCo type	65	22	2.8	2.1	☑	☐							

[1] doi: 10.1117/12.2182284
[2] FEL2013 TUPSO54

Compact Light – Compton Back Scatter X-Ray Source

Concept Drawing





Constructed Machine