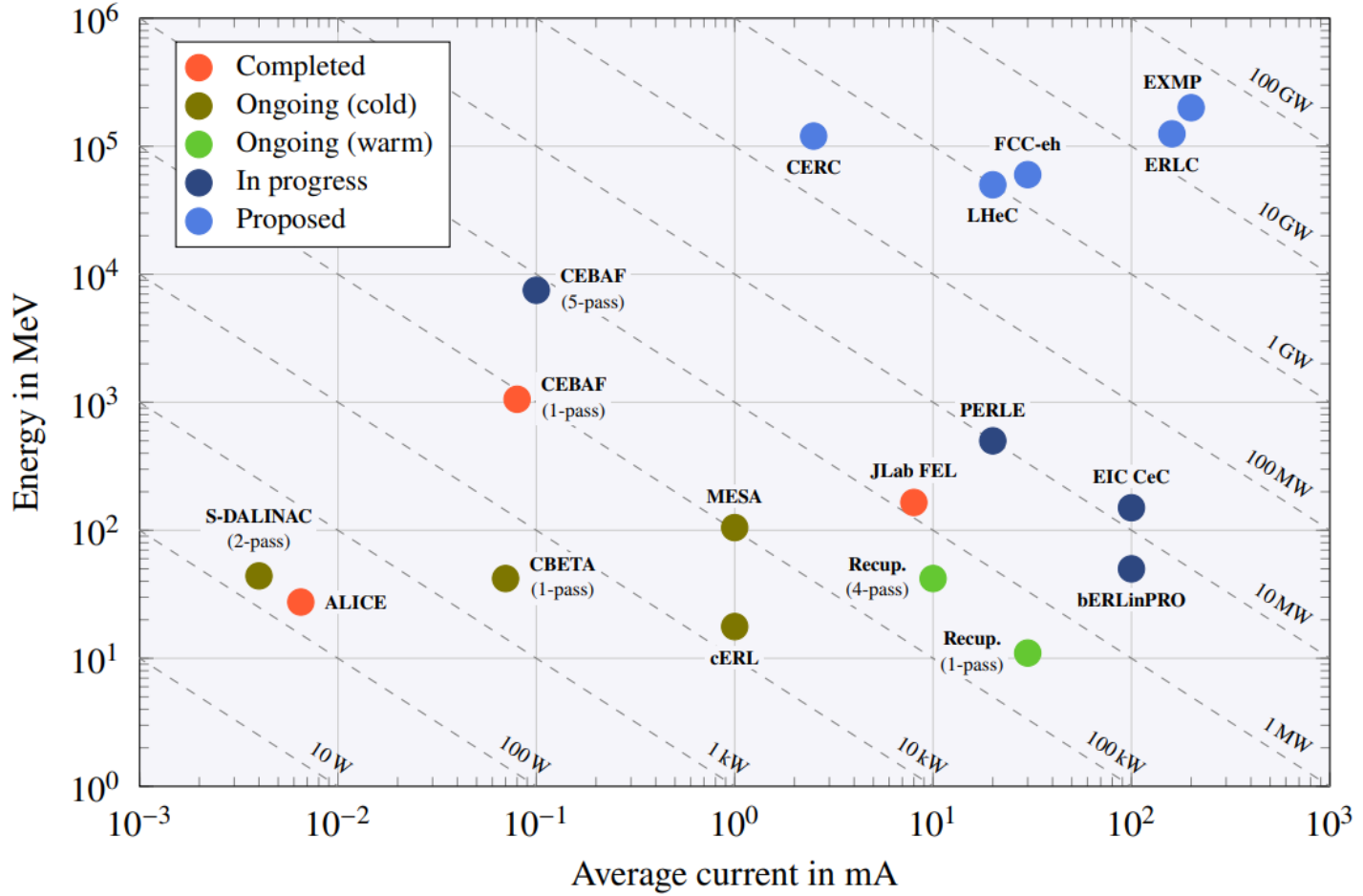
Report WG 1: Facilities

Members of WG 1:

- Michaela Arnold (TU Darmstadt) – Co-Convener
- Tsukasa Miyajima (KEK) – Co-Convener
- Axel Neumann (HZB)
- Achille Stocchi (IJCLab)

ERL Roadmap



Prepared for submission to JINST

The Development of Energy-Recovery Linacs

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[p] *INFN, Milano, Italy, and LASA*
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arXiv:2207.02095 [physics.acc-ph]

See also talk by Andrew Hutton (Mon, 9:50)

Facility Poster and Facility List

- Updates all made? Please check in poster room / contact SPC
- Version of ERL 22 will be made available on indico page

ERL-Facility-Summary-October 2022

Datei Bearbeiten Ansicht Einfügen Format Daten Tools Erweiterungen Hilfe Letzte Änderung vor 2 Stunden von Stephen Benson

Freigeben

A1 Name

Name	JLabFEL	CEBAF-ER	ERL DEMO	ERL Upgr	UV FEL	ER@CEBAF	eIC cooler	cERL	EUV Source	ALICE	bERLinPro	CBETA	nell Light Sou	S-DALINAC	MES.
Institute	JLab	JLab	JLab	JLab	JLab	JLab	JLab	KEK	KEK	STFC	HZB	Cornell	Cornell	U Darmstadt	U Main
Main application: Test Facility [TF], Light Source [LS], User Facility [UF], Physics Application [PA]	LS	TF	TF	LS	LS	TF		TF	LS	TF, UF	TF	TF	LS	TF	PA
Commissioning Start		2003	1997	2001		2018		2013	In planning 2017	2005	2019	2017	Study	2017 (ERL mode)	2
Operation End		2003	2001			2018		2016		2016	tbd	tbd	tbd	tbd	
# Re-Circulations	1	1	1	1	1	5		1	1	1	1	4	1	2	
RF type	SC	SC	SC	SC	SC	SC		SC	SC	SC	SC	SC	SC	SC	
RF Frequency [GHz]	1.5	1.5	1.5	1.5	1.5	1.5		1.3	1.3	1.3	1.3	1.3	1.3	3	
Bunch Frequency [MHz]										81.25		325		3000	
Accelerating Voltage ML [MeV / m]		5, 12				5, 12, 20		8.2	12.5 to 15	10 (14)	19	7	16	5	
Accelerating structure ML		2 linacs in racetrack, 20 CM / linac, 5-cell cavities				2 linacs, racetrack, 25 CM per linac, 5-cell and 7-cell cavities		one cryomodule with 2 9-cell cavities	one cryomodule with 4 9-cell cavities	1 cryomodule with 2 cavities 2	one cryomodule with 3 7-cell cavites	1 cryomodule with 6 7-cell cavities	64 CM with 6 7-cell cavities	4 CM with 2 20-cell cavities each	
Energy gain / linac [MeV]		500	48			700		17	50	24	44	36	5000	30.4	
Accelerating Voltage Injector [MeV / m]														5	
Accelerating structure Injector														CM1: 1 2-cell plus 1 5-cell cavity; CM	
Bunch charge @ inj [pC]	135	0.07	60	135	60	0.2		0.77 to 40	60	80	77	123	77	0.007	
Bunch length [ps]		0.7		0.15		0.7		0.2 to 3	0.05 to 2	1	2	3	2	5	
Energy spread (extraction)		0.0001 (%)		0.5	0.5	0.0001 (2-3%)		1.2 x 10-4	1 x 10-3	5 keV	0.005	4.00E-04	2.00E-04	no data	
Transverse emittance [gamma mm mrad]		0.5		15	10	0.5		1-1.6 (7.7pC/bun	0.8 (60pC/bunch	5 to 10	0.4 - 0.6	0.5	0.3	no data	
Av. Current @ inj [mA]	10	0.035	5	9	5	0.1		1	10	0.013	100	40	100	0.02	
Av. Current @ inj [mA] macro pulse										6.5					
Injector Energy [MeV]		56		9	9	79		2.9	10.5	8.35	6	6	5	7.6	
Max beam energy @ end of accel [MeV]	160	1050	48	170	210	7079		20	800	35	50	150	5	68.4	
Max beam power @ end of accel [MW]	1.6	0.03675	0.24	1.53	1.05	0.7079	0	0.02	8	0.000455	5	6	0.5	0.001368	1
Max total current in cavity [mA]	20	0.07	10	18	10	1	0	2	20	0.026	200	320	200	0.08	

Overview Energy-Power Sheet3 Erkunden

Programme WG Facilities

Facility Report MESA — *Florian Hug*
Cornell University 10:50 - 11:10

Facility report of Compact ERL (cERL) at KEK — *Hiroshi Sakai*
Cornell University 11:10 - 11:30

Status and Perspective of the Energy Recovery Linac at HZB — *Axel Neumann*
Cornell University 11:30 - 11:50

Facility Report PERLE — *Walid Kaabi*
Cornell University 11:50 - 12:10

Facility Report CBETA — *Georg Hoffstaetter*
Cornell University 13:10 - 13:30

ERL Operation of the Superconducting Darmstadt Electron Linear Accelerator S-DALINAC – a Facility Report*
Dr Michaela Arnold

CEBAF 5-pass — *Gustavo Pérez Segurana*
Cornell University 13:50 - 14:10

TRIUMF e-Linac facility and ERL upgrade — *Ms Aveen Mahon*
Cornell University 14:10 - 14:25

BriXSinO high-flux dual X-ray and THz radiation source based on Energy Recovery Linacs — *Dr Dario Giove*
Cornell University 14:25 - 14:40

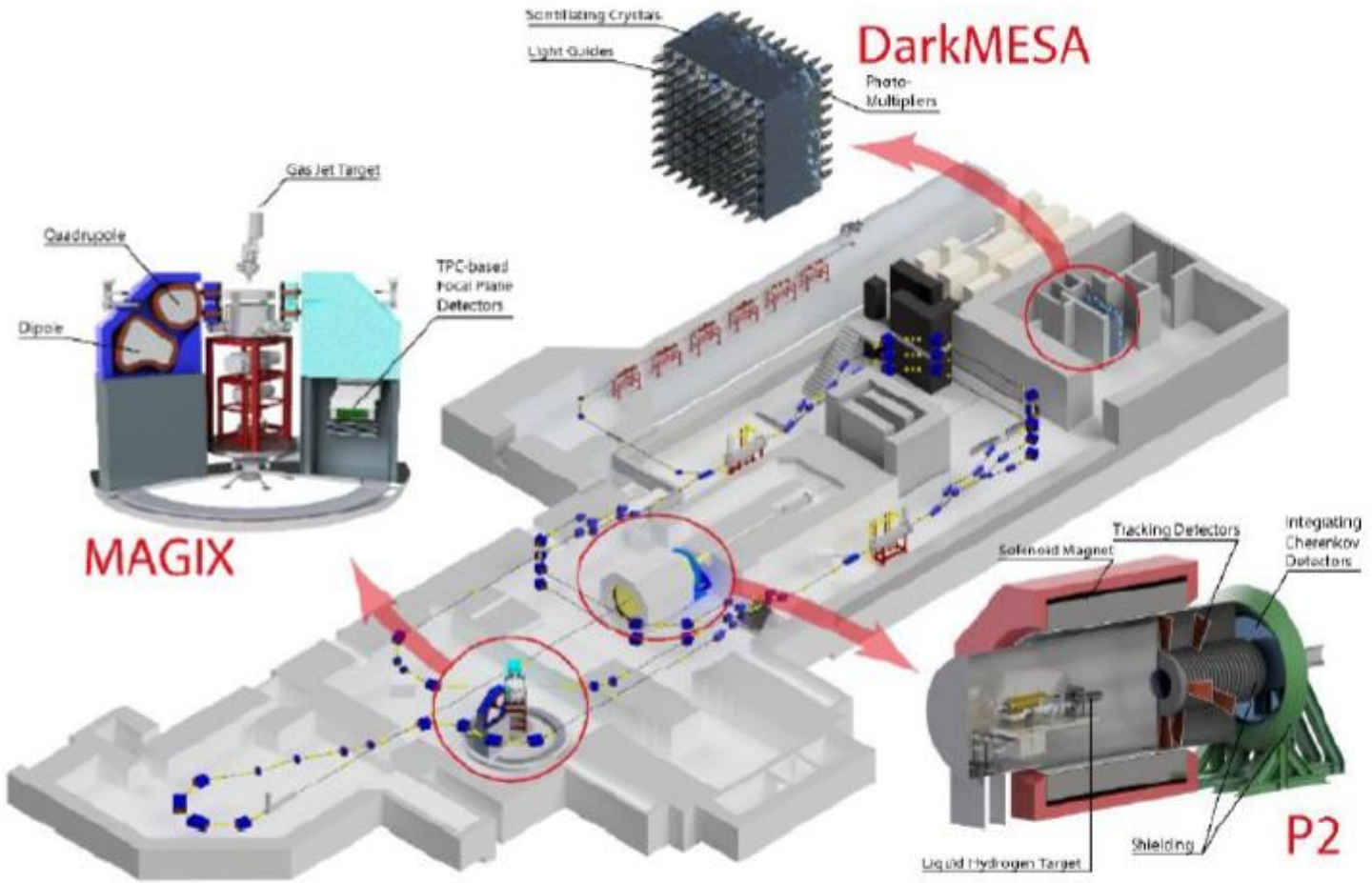
MESA Status Summary

- MESA is a fully instrumented ERL facility for nuclear and particle physics experiments

- Construction of injector is ongoing
  commissioning starts 2022

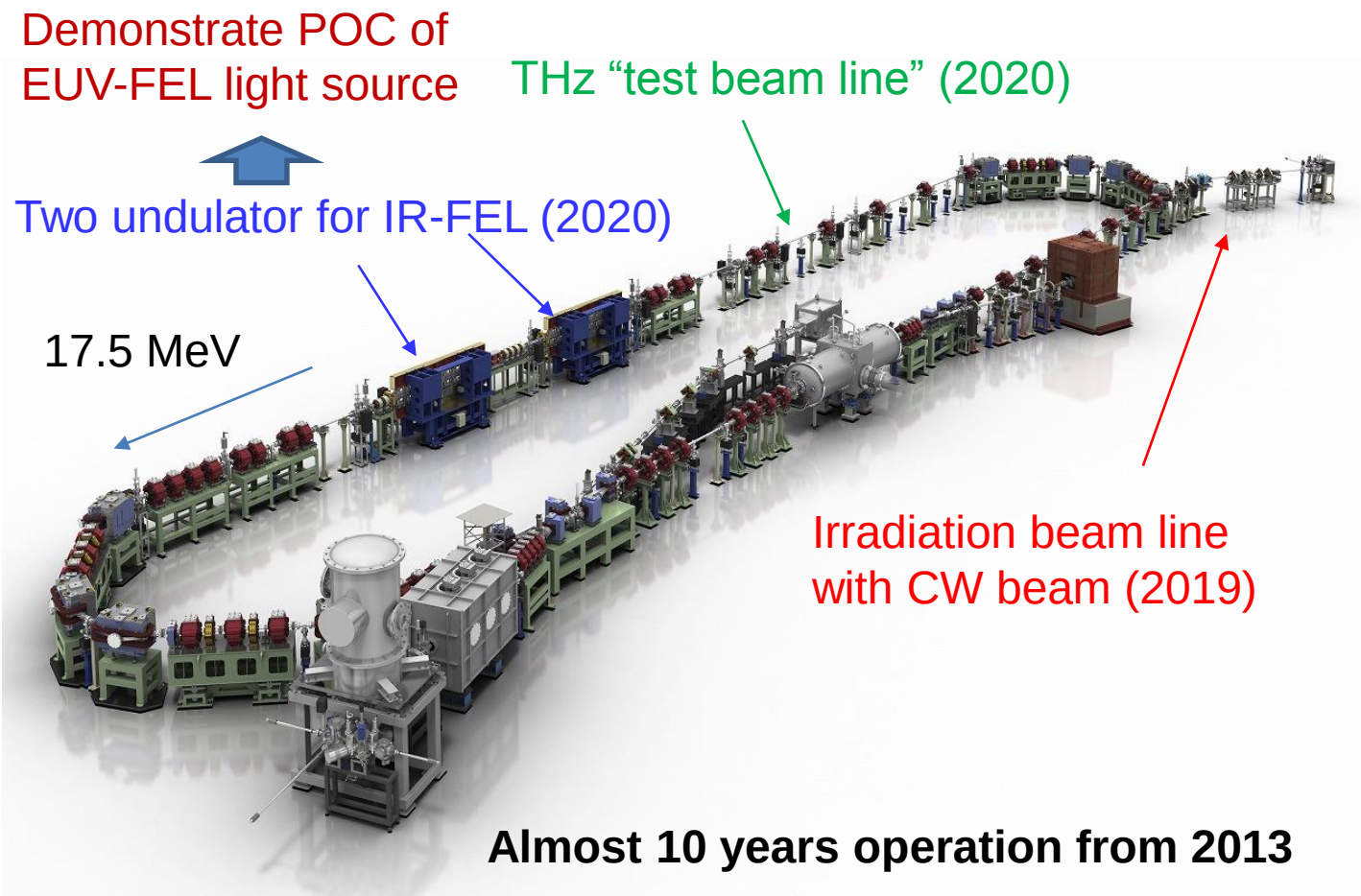
- First beams at low energy (15-55 MeV, 1 Recirculation) to the experiments can be expected 2 years after building occupancy (~2025)

- External Beam operation (P2/BDX experiment):
  polarized beam, up to 150 µA @ 155 MeV
- ERL-operation (MAGIX experiment):
  (un)polarized beam, up to 1 (10) mA @ 105 MeV



Facility report of Compact ERL (cERL) at KEK : H.Sakai (KEK)

The cERL was constructed and beam operation was started in 2013. and 1mA ERL was done in 2016. The unique performance (high current, low emittance, short bunch with ERL) gives us several important industrial applications in cERL until now.



Almost 10 years operation from 2013

cERL beam operation for latest 3 years (2019~2022)

- cERL now move to use for the industrial application by using SCRF technology.
- In order to demonstrate ERL-SASE-FEL scheme, IR-FEL production started in cERL. High power IR-FEL with SASE scheme was produced by constructing 2 x 3 m undulators in cERL beam line based by using AI method.
- THz beam line was constructed and successfully transfer to the experimental room.
- Irradiation beam line was built for RI production and material irradiation with CW beam of 10uA and successfully produce not only 99Mo but also 67Cu.
- We also proceed material irradiation to woods to produce nanocellulose in cERL.
- High current ERL beam operation for EUV-FEL is under testing. 0.3 mA CW ERL was done with undulator . We plan to increase beam current to 10 mA for POC of EUV-FEL by using ERL-SASE-FEL scheme.
- Under CW operation, we broke the screen monitor due to mismatch mode selection of laser system→ ITL system is very important for CW operation.
- 500kV DC Gun meet HV severe spark trouble → 480kV beam can be operated after recovery work.

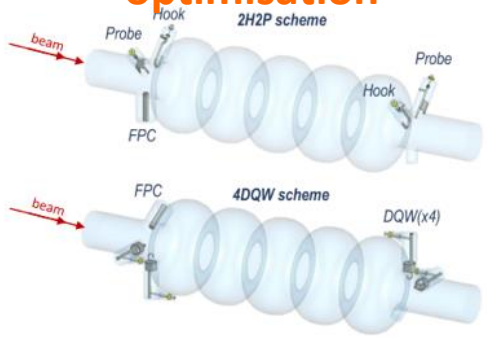
Status of bERLinPro

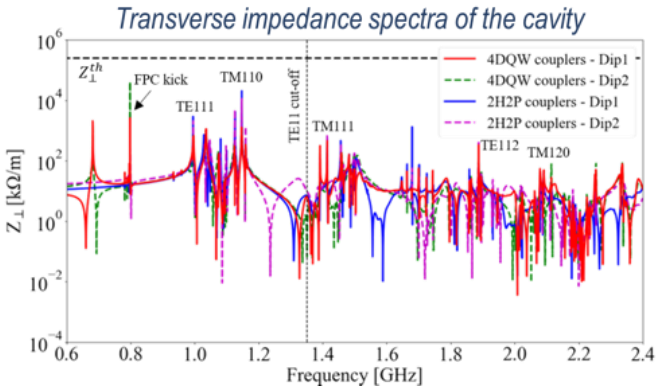
bERLinPro accelerator hall

- Project officially accomplished with building and warm machine ready in 2020
- Commissioning and setup work concentrates on getting the SRF cryo-module for the SRF gun and booster assembled and running
- Main focus will be the injector operation the coming years and to continue ERL studies, plus opening up the machine for additional applications
- The approach will be two-fold:
  - Study the complete parameter space of the injector from shortest bunches low charge up to highest possible currents and high charge regime
  - Resume Linac studies to complete the ERL recirculator
- A first pilot application of the injector is demonstrating short electron beam with low jitter for UED studies
- bERLinPro will contribute together with PERLE strongly to the European ERL roadmap initiative by injector and Linac studies
- For the Linac, an energy efficient approach with FE-FRT tuner systems and potential 4K operation is envisaged
- Currently the SRF gun coldstring is in the cleanroom.
  We expect to have first beam about summer 2023

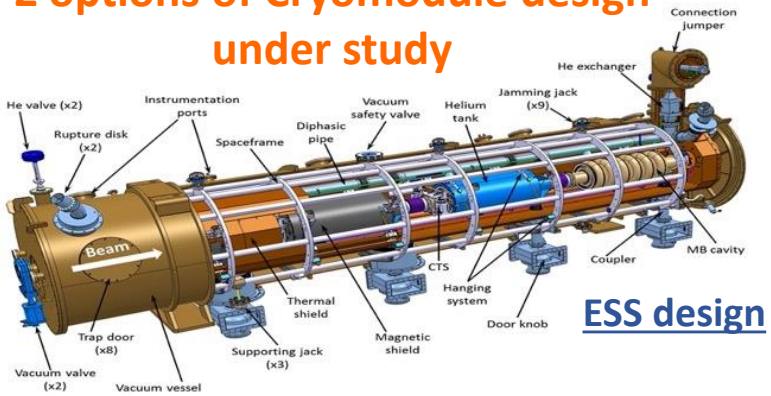
PERLE Status Report

HOMs study & dumping scheme optimisation

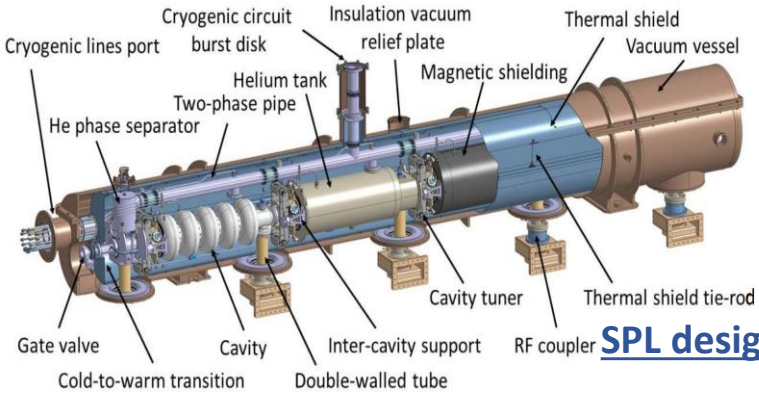




2 options of Cryomodule design under study



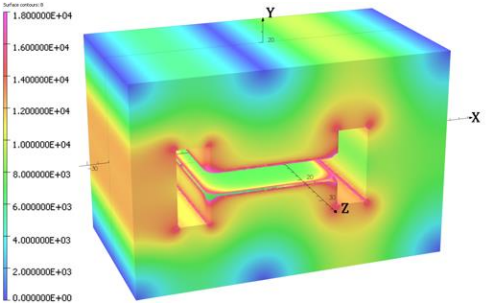
ESS design

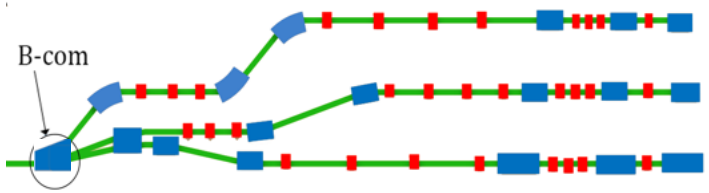


SPL design

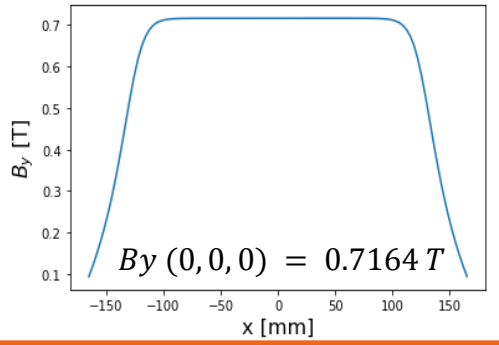
Injection line design optimisation

	Achieved values	Specification
Horiz. emittance	5.23 mm mrad	< 6 mm mrad
Vert. emittance	3.34 mm mrad	< 6 mm mrad
Bunch length	3.22	3 mm
Kinetic energy	86.1 MeV	88.6 MeV
Horiz. beta function	7.89 (mismatch 8.3 %)	8.6
Horiz. alpha function	-0.74 (mismatch 11.6 %)	-0.66
Vert. beta function	8.76 (mismatch 1.8 %)	8.6
Vert. alpha function	-0.67 (mismatch 1.5 %)	-0.66





B-COM magnet design

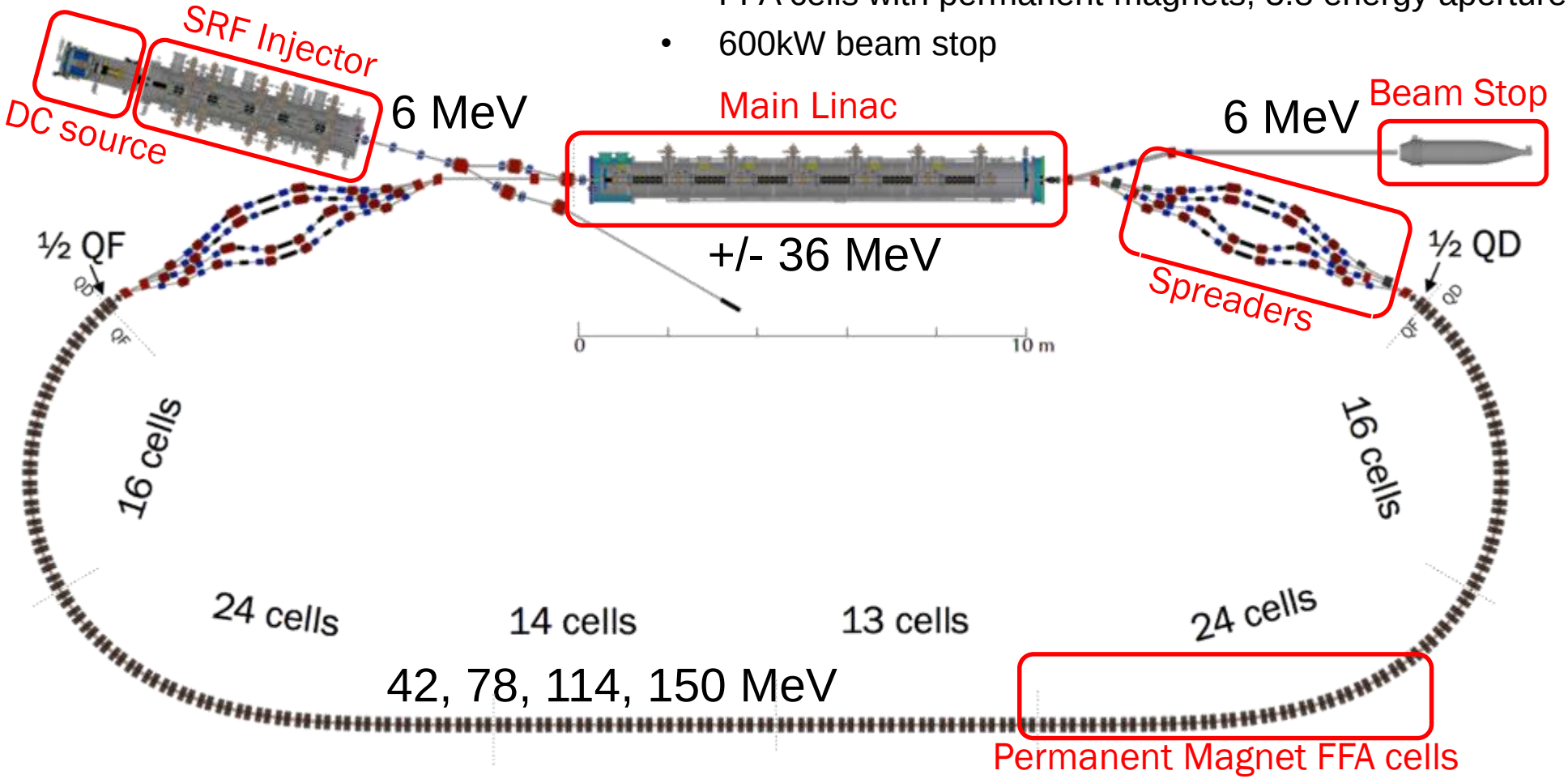


Starting DC gun installation

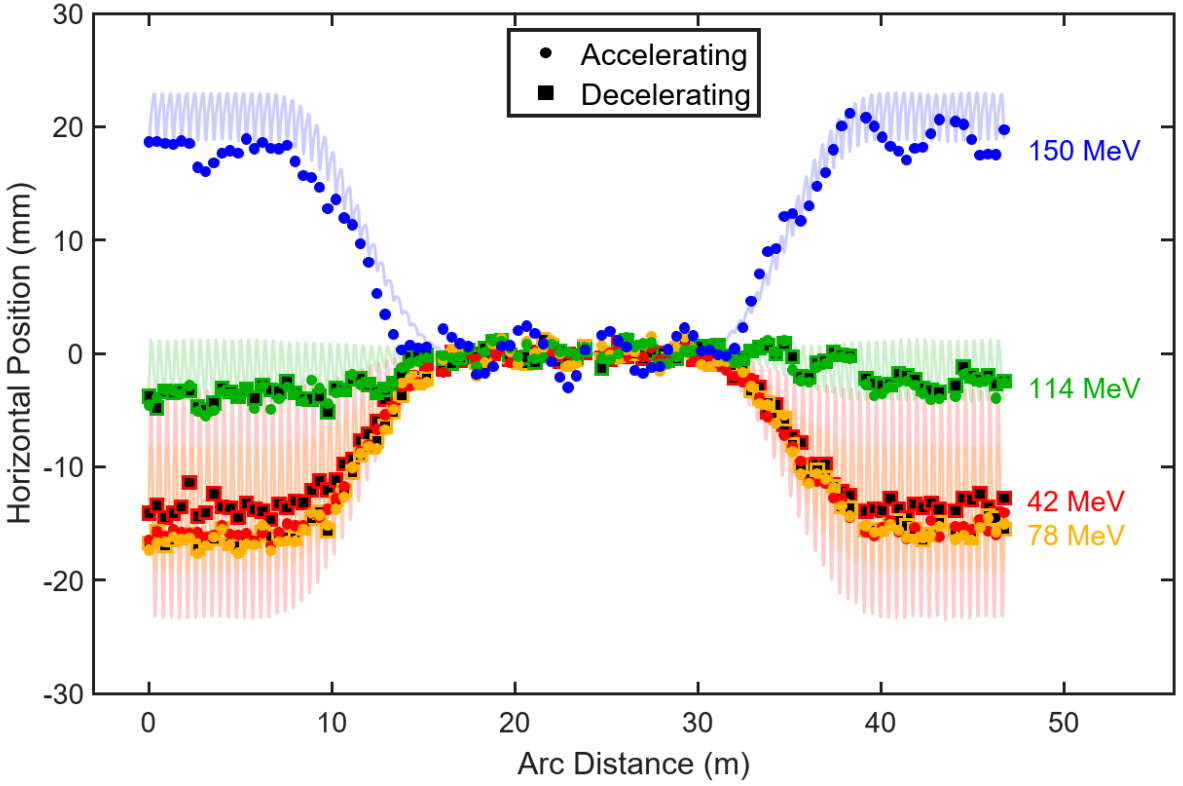
CBETA: The test ERL at CBETA

CBETA

- Cornell DC gun, 2nC peak
- 100mA, 6MeV SRF injector (ICM), 1.3GHz
- 320mA, 6-cavity SRF CW Linac (MLC), 1.3GHz
- 4 Spreaders / Combiners with electro magnets
- FFA cells with permanent magnets, 3.8 energy aperture, 7 beams
- 600kW beam stop



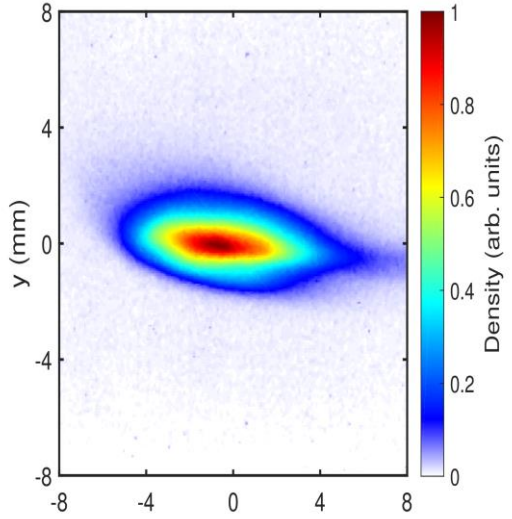
First multi-turn ERL operation

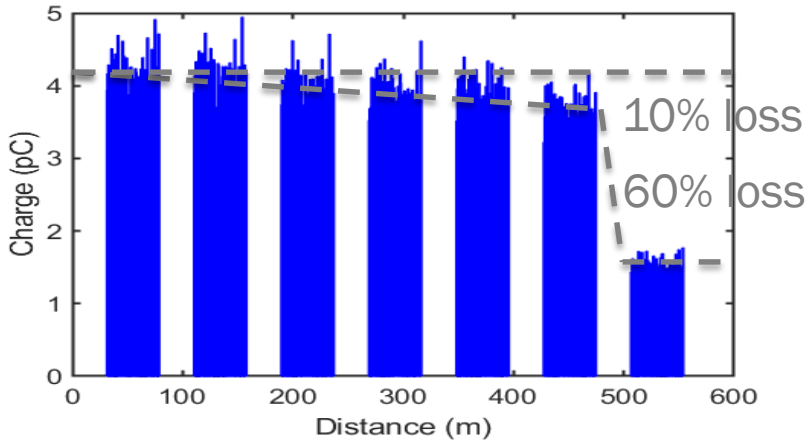


7 beams in the same FFA beamline, accelerated and energy-recovered.

Reports appeared in Nature, Phys. Rev. Letters, Forbes Magazine, EEE Spectrum, reddid.com, and others.

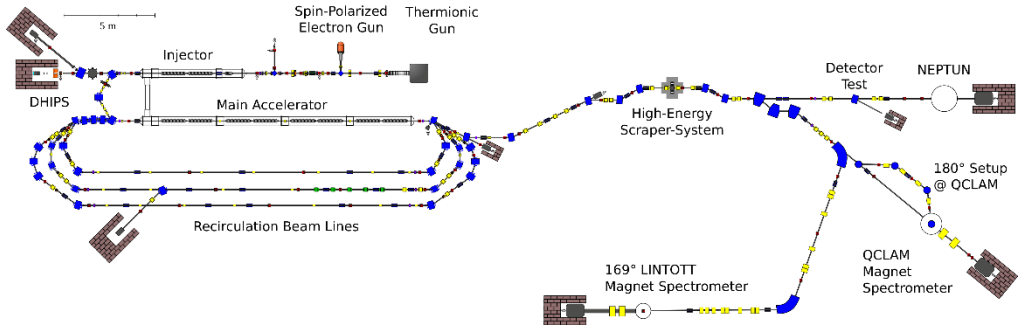
Beam in the beam stop after 8 passes.



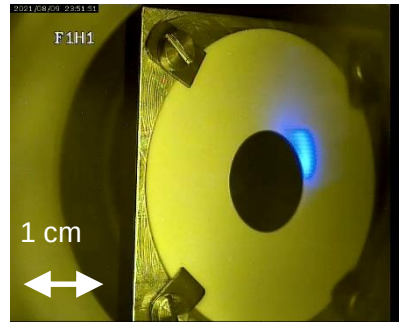


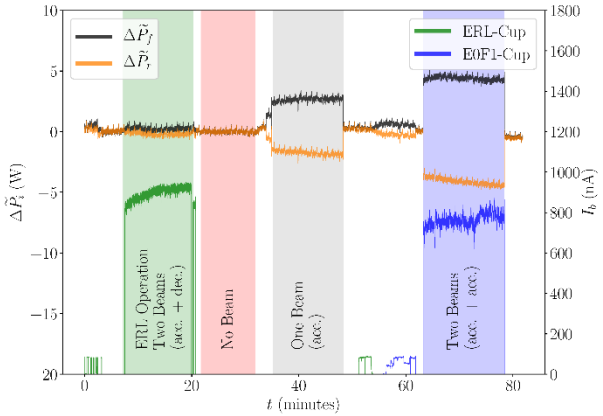
Before the 7th FFA pass, 60% loss

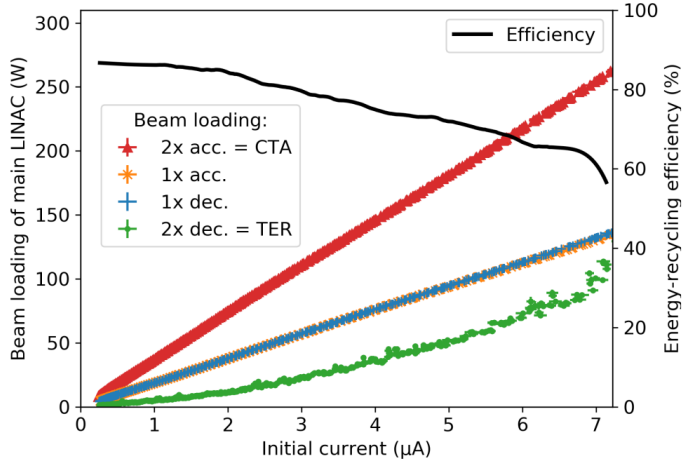
S-DALINAC

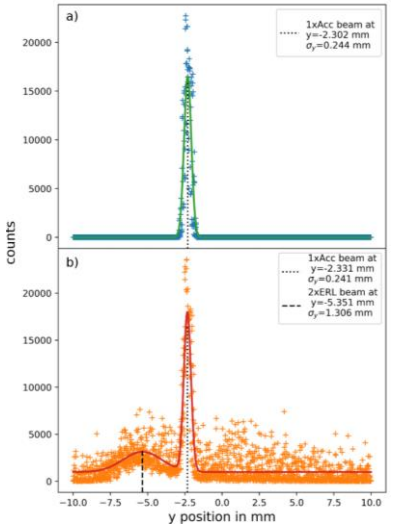


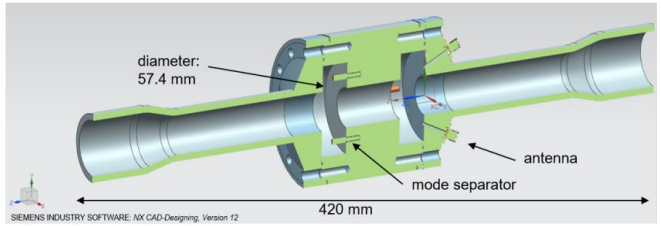
- Installation of new beamline (15/16) + ERL option
- Commissioning of modes
- 1-turn ERL: August 2017
- 2-turn ERL: August 2021
- ERL diagnostics
- Future plans

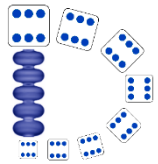








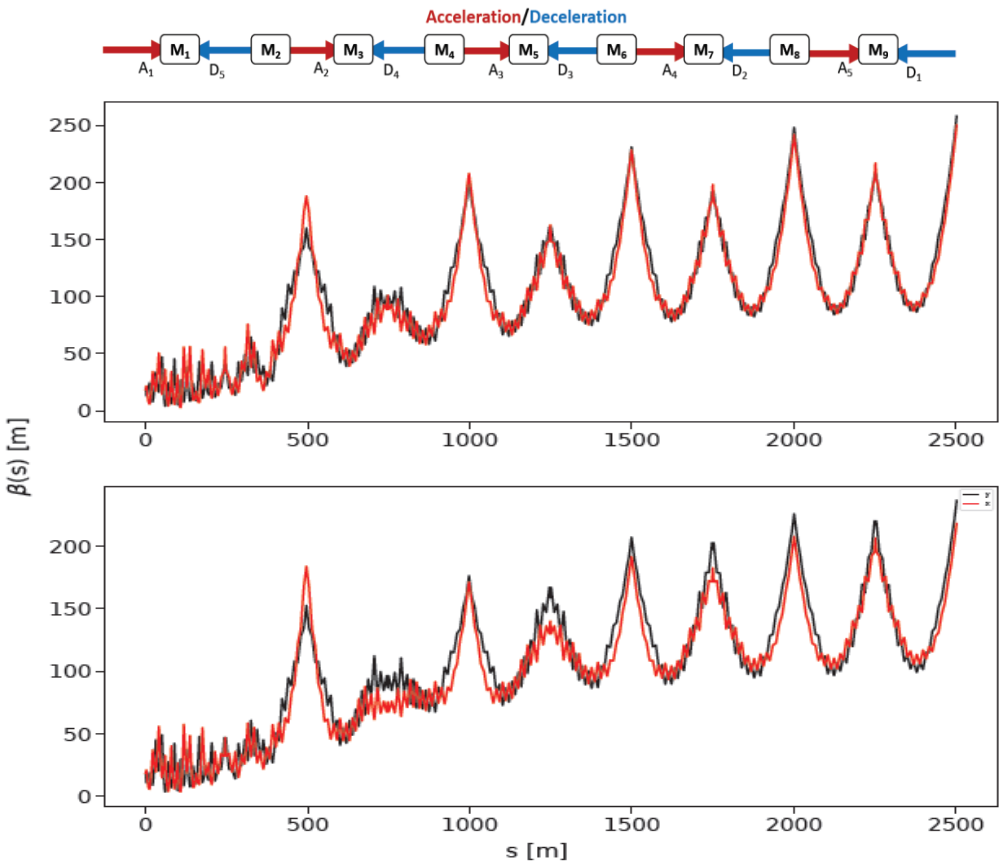




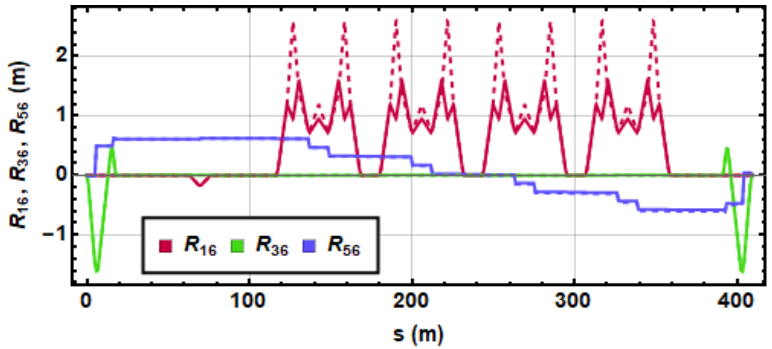
DICE
(**D**armstadt **I**ndividually-recirculating **C**ompact **E**RL)

ER@CEBAF: A 5-PASS ENERGY RECOVERY EXPERIMENT

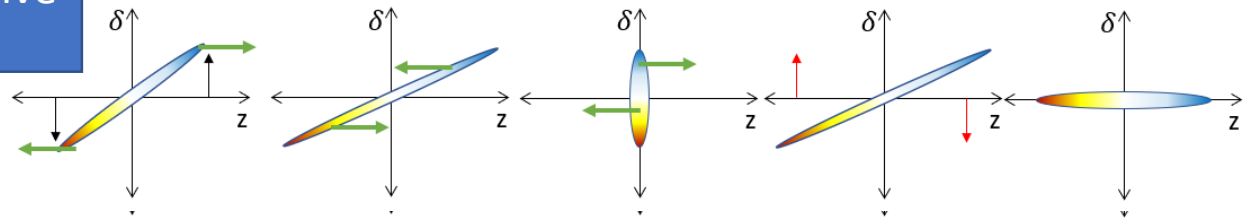
Optimization of transverse multipass RF optics



Arc & Injector tuning

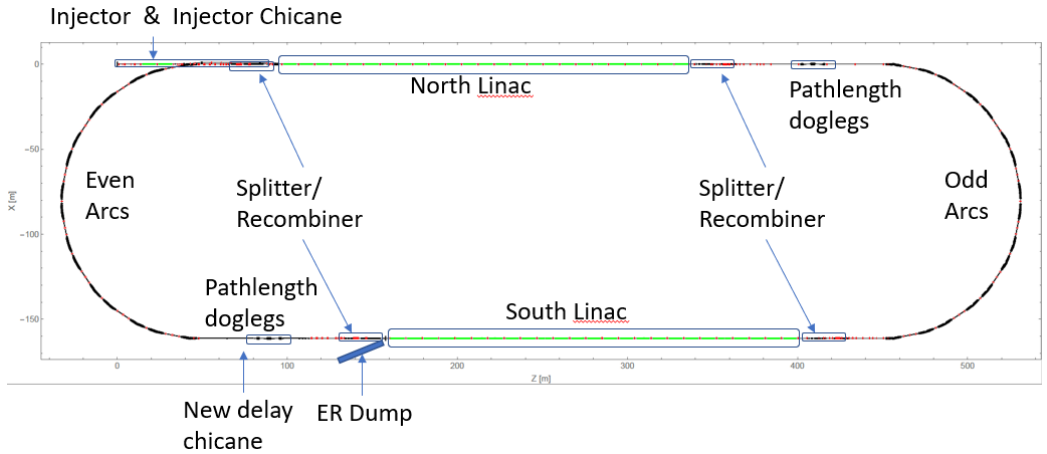


Compressive match



Hardware Update

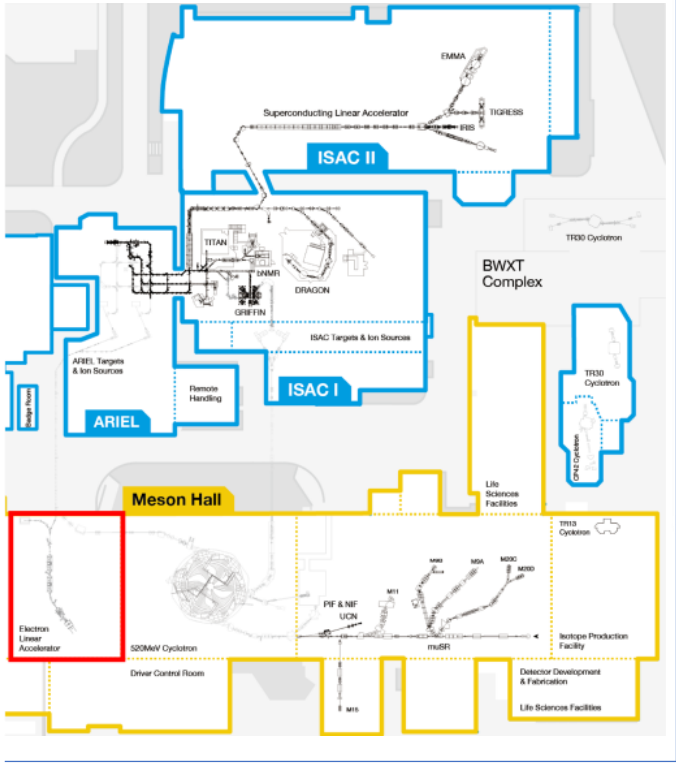
- 4 spare bends for bypass chicane
- Beam dump – relocated from FEL
- Sextupoles for inj. Chicane – from Arc 1 or Arc 2



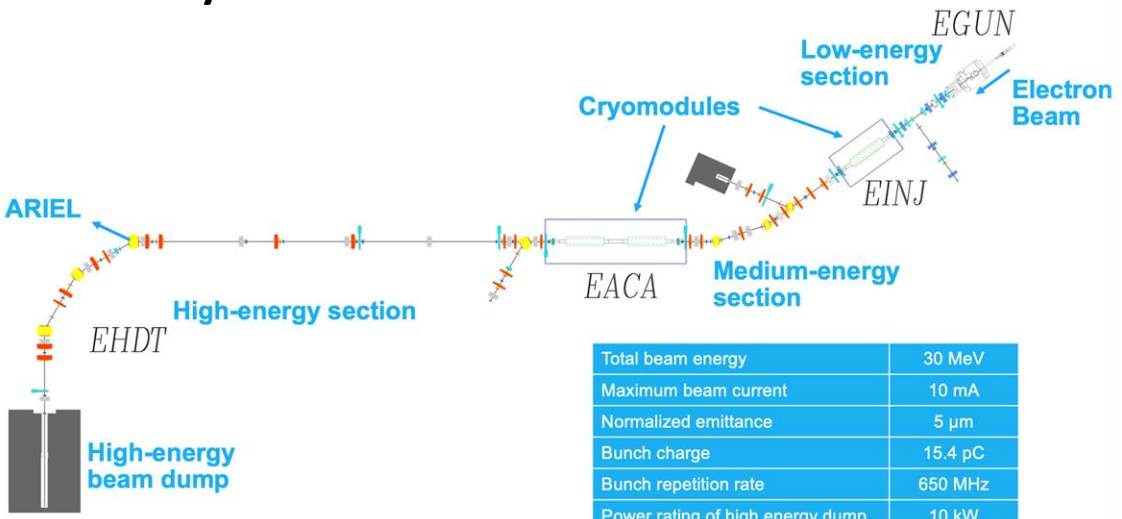
TRIUMF e-Linac and ERL upgrade

Aveen Mahon | TRIUMF | ERL22

Site layout:



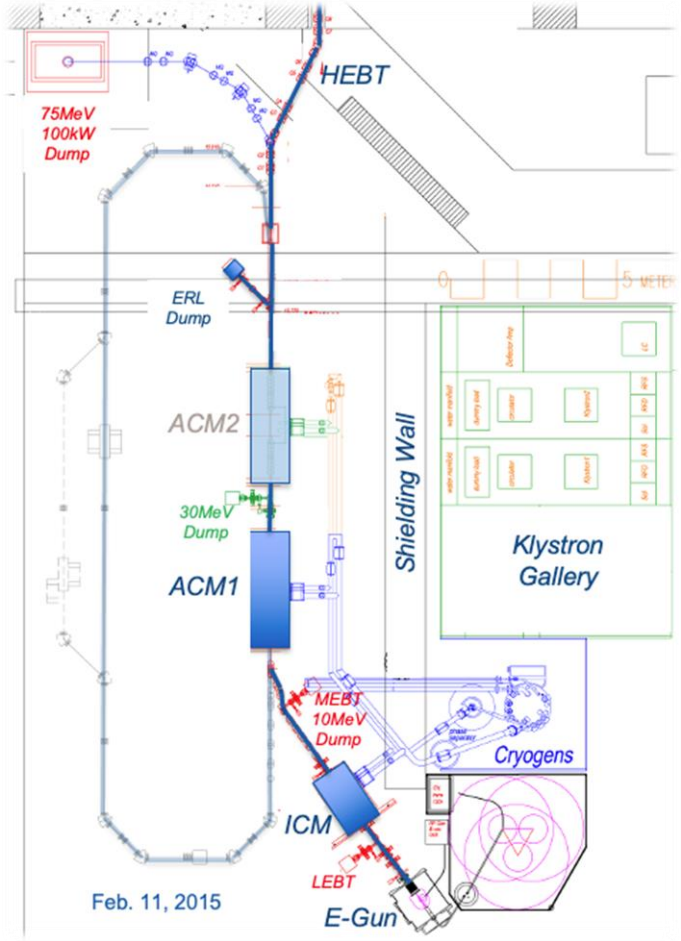
e-Linac layout:



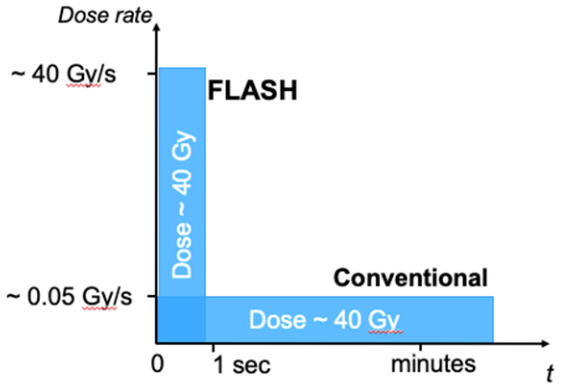
Total beam energy	30 MeV
Maximum beam current	10 mA
Normalized emittance	5 μm
Bunch charge	15.4 pC
Bunch repetition rate	650 MHz
Power rating of high energy dump	10 kW

Commissioned to 30MeV at 10kW

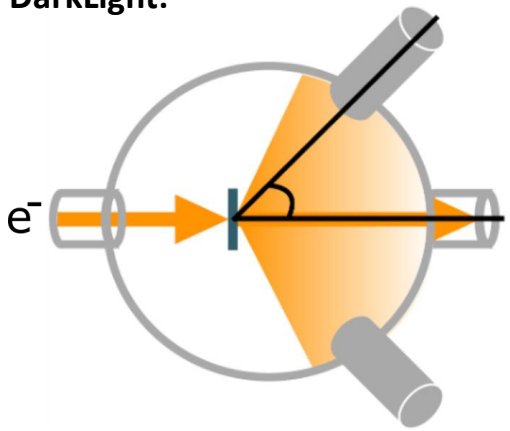
Envisioned ERL Upgrade :



FLASH:



DarkLight:

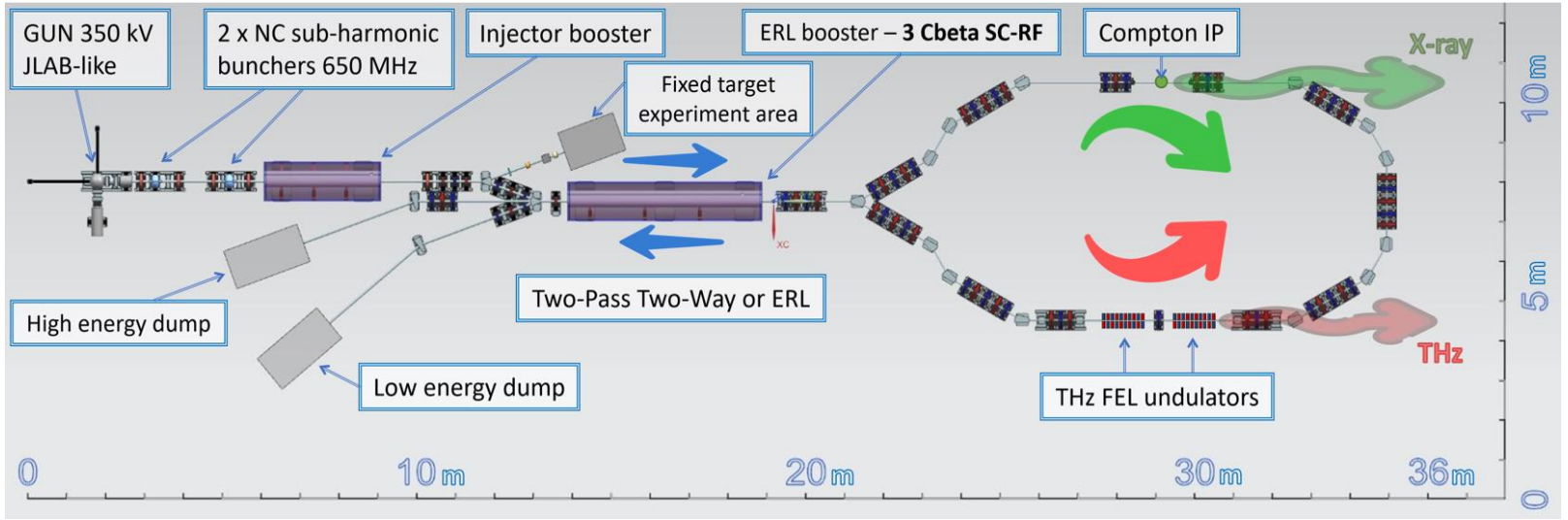


Current Science Users:

- FLASH Radiotherapy Experiment
- DarkLight Scattering Experiment

The BriXSinO Proposal

BriXSinO (the acronym for **Bri**lliant source of **X**-rays based on **S**ustainable and **innO**vative accelerators) is a project for a small research infra-structure based on super-conductive accelerators with very high energy sustainability, oriented towards the frontier of high intensity in electron beams with high average power.



BriXSinO is a demonstrator of a new acceleration mechanism – two way in the same Linac, pursuing at the same time research of beam and machine operation in E.R.L. (Energy Recovery Linac) mode, following the original Maury Tigner's configuration of opposite way, dog-bone recirculation.

BriXSinO's mission is the demonstration of high peak and average brightness beam generation, acceleration and manipulation with large energy sustainability. Besides such a primary mission, that is in the mainstream of future strategies for large scale particle accelerators, **BriXSinO** will offer unique radiation beams to users of X-rays and THz, thanks to the very large expected electron beam power/brightness.

Due to constraints in the footprint available at the foreseen installation laboratory (lab. **LASA** of the Milan INFN unit), and budget/resources limitations typical of a demonstrator, **BriXSinO** will be restricted to modest beam energy, below 50 MeV in ERL mode, and 90 MeV in two-way mode, a minimum requirement in order to conceive a machine set-up composed of multiple accelerating sections, operated with Super-conducting CW RF cavities, within a configuration capable to effectively test two-way and E.R.L. operation modes.

Nevertheless, the beam power achieved is expected to reach up to **250 kW**, carried by **a CW 5 mA - 50 MeV electron beam**, that is **recirculated** by a proper arc-shaped beam transport line, and decelerated through the main SC Linac back down to the injector beam energy, at about 5 MeV. The challenge is to generate, accelerate, manipulate, characterize, deliver to users and recover back such a large beam power, at the same time reaching the high phase space density (*i.e.* peak brightness) requested by the **Compton source** and the **THz FEL operation**.

The document related to the Brixsino proposal has been submitted to INFN to open a discussion about it.
A **first funding** of 1 Meuro has been received by INFN in September 2022 **to start the construction of the DC Gun in 2023**.

Thanks to all contributions and discussions!