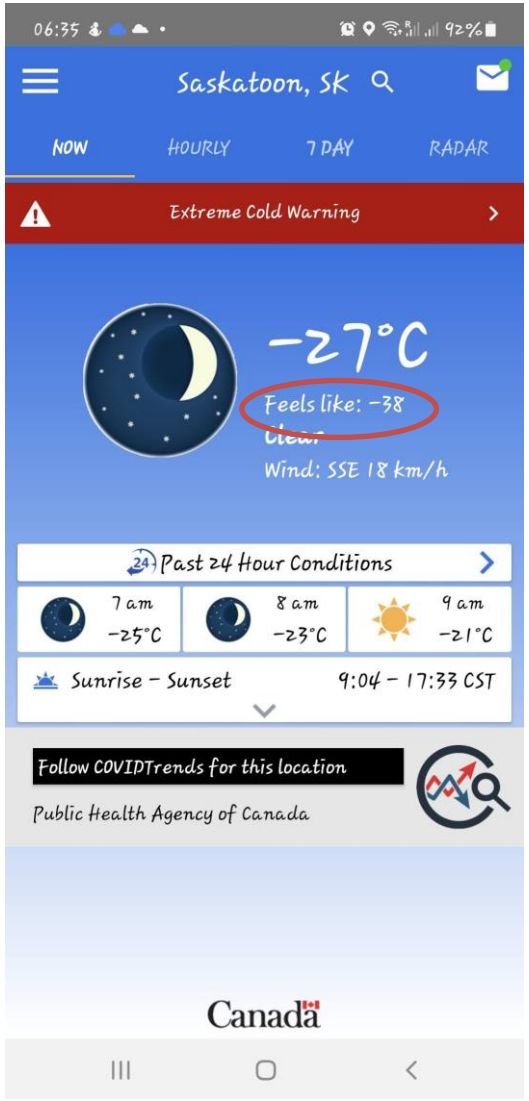
The Brightest Light In Canada

Mark Boland

11 July 2023

IAS 2023

Weather Report – Bring you into my world

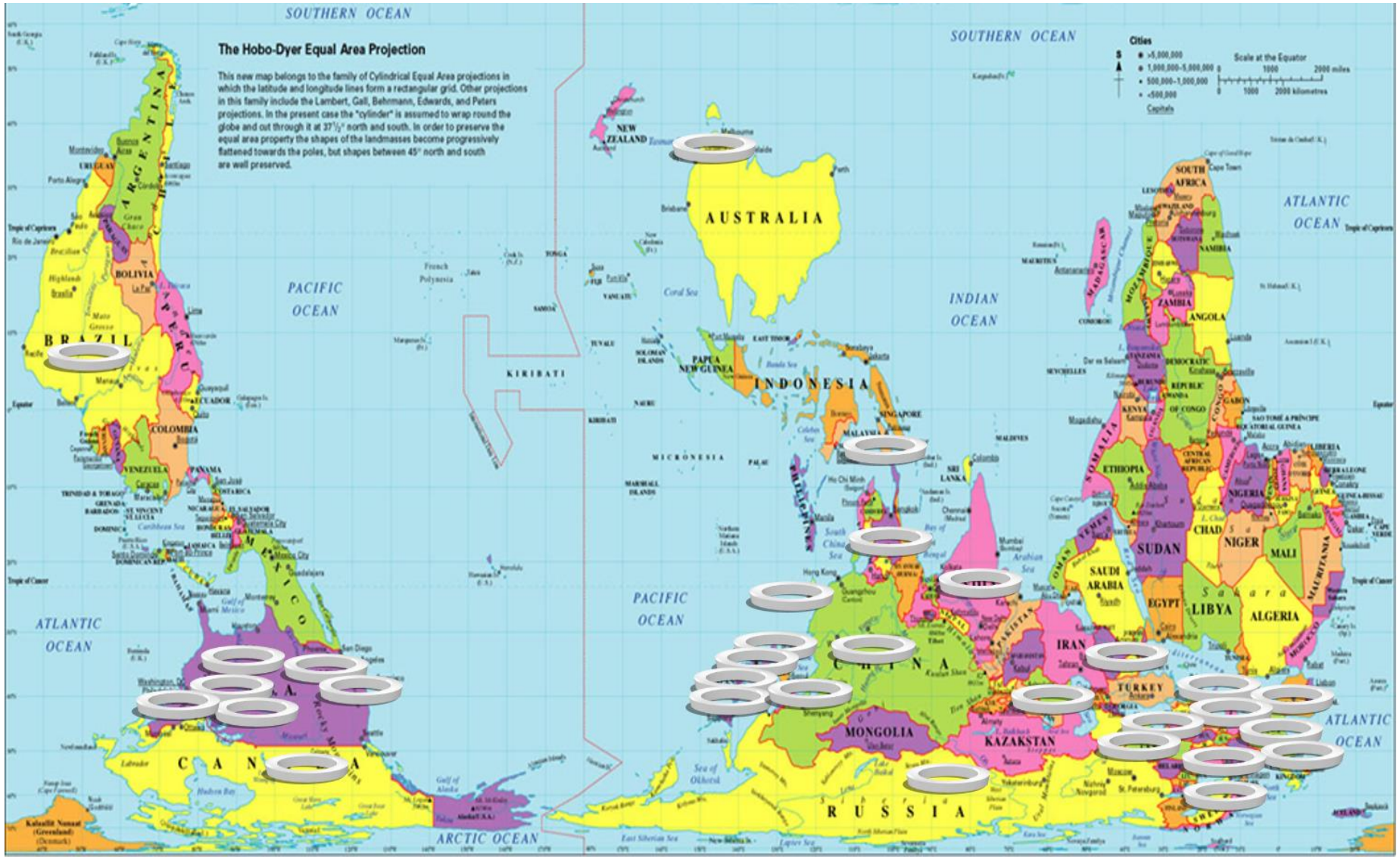


Feels like -38 C

14 Years at the Australian Synchrotron

From down under to the brightest light in Canada

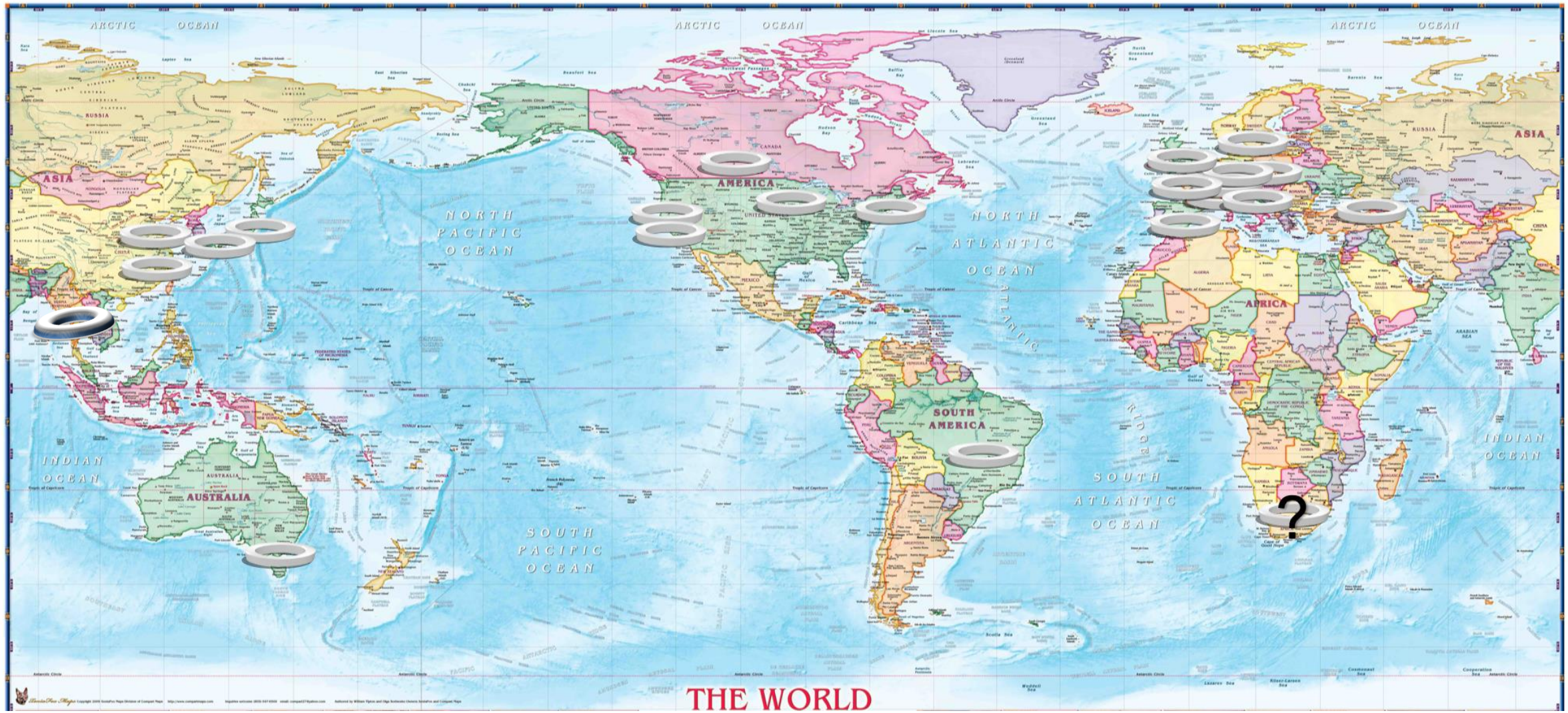
The Synchrotron Light Source World Map



Canadian Light Source | Centre canadien de rayonnement synchrotron

www.lightsources.org

The Synchrotron Light Source World Map



Canadian Light Source | Centre canadien de rayonnement synchrotron

www.lightsources.org

On Campus News UofS, 1 October 1999

Synchrotron project officially launched

At the Sept. 27 official launch of the Canadian Light Source, U of S physics Prof. Emeritus Dr. Leon Katz, left, and Saskatchewan Lt-Gov. Jack Wiebe unveil the sign that will be placed on the campus site of the synchrotron construction project.

https://ocnarchives.usask.ca/Oct1-99/news1b.html

1999

2000

2000

2000

2000

2001

2001

2001

2001

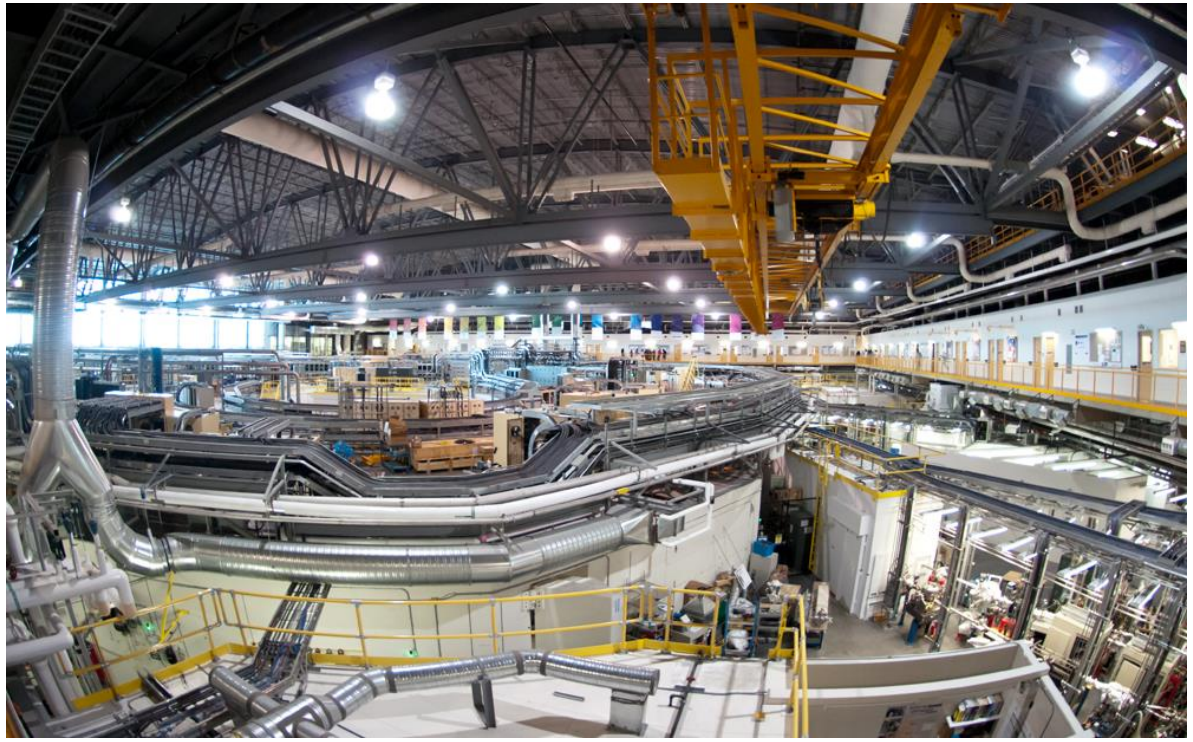
2004

2014

Canadian Light Source on the UofS campus

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.

Located in the UofS ecosystem

CLS Accelerator Complex

2 T Superconducting Wiggler magnets

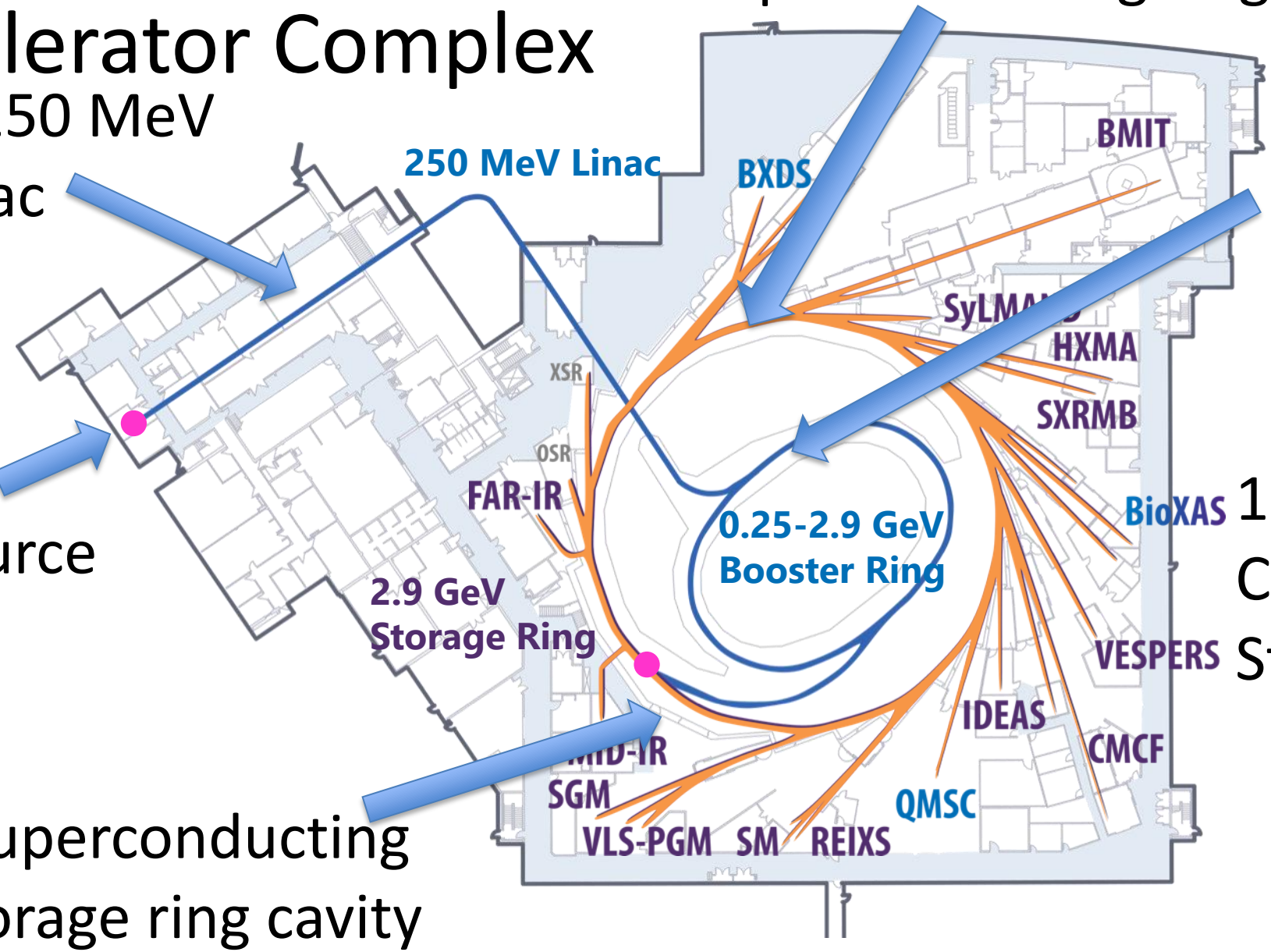
2856 MHz 250 MeV electron linac

500 MHz 0.25-2.9 GeV booster cavity

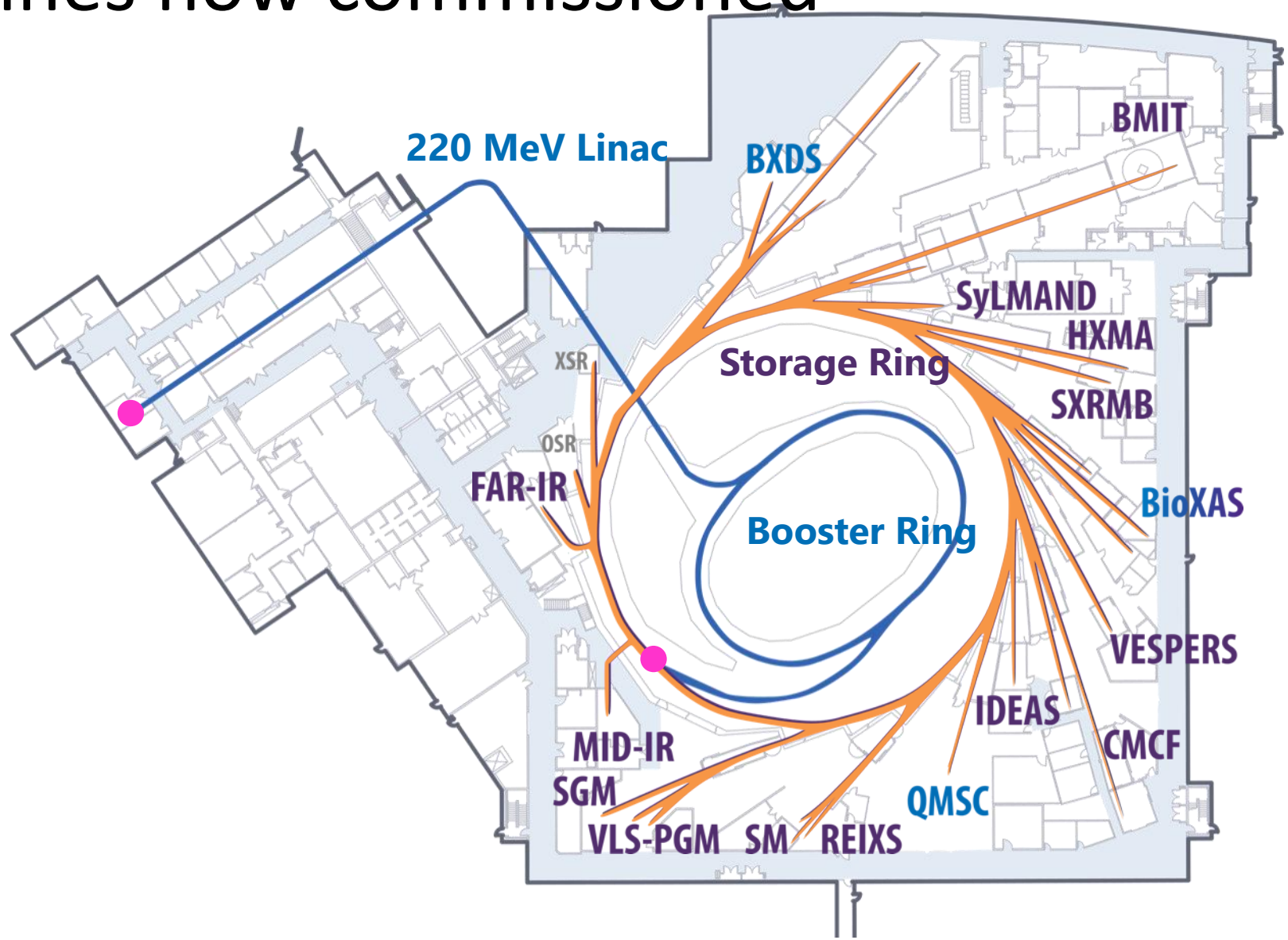
250 kV DC electron source

171 m Circumference Storage Ring

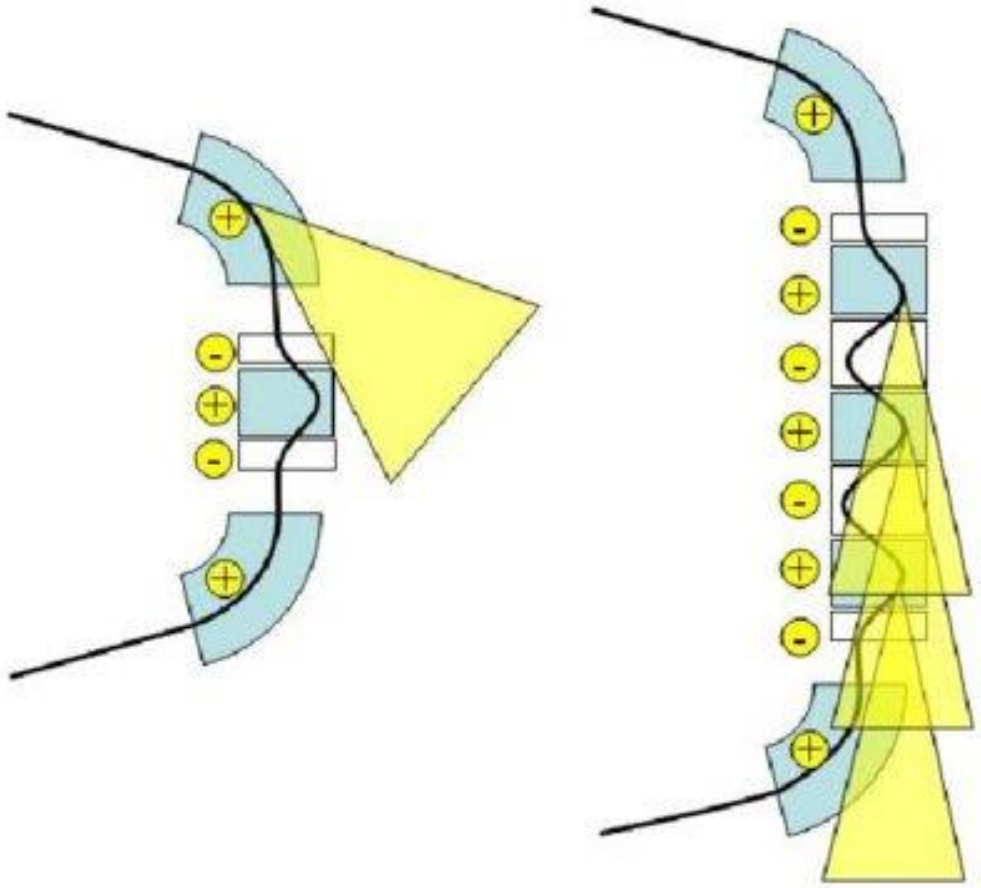
500 MHz Superconducting 2.9 GeV Storage ring cavity



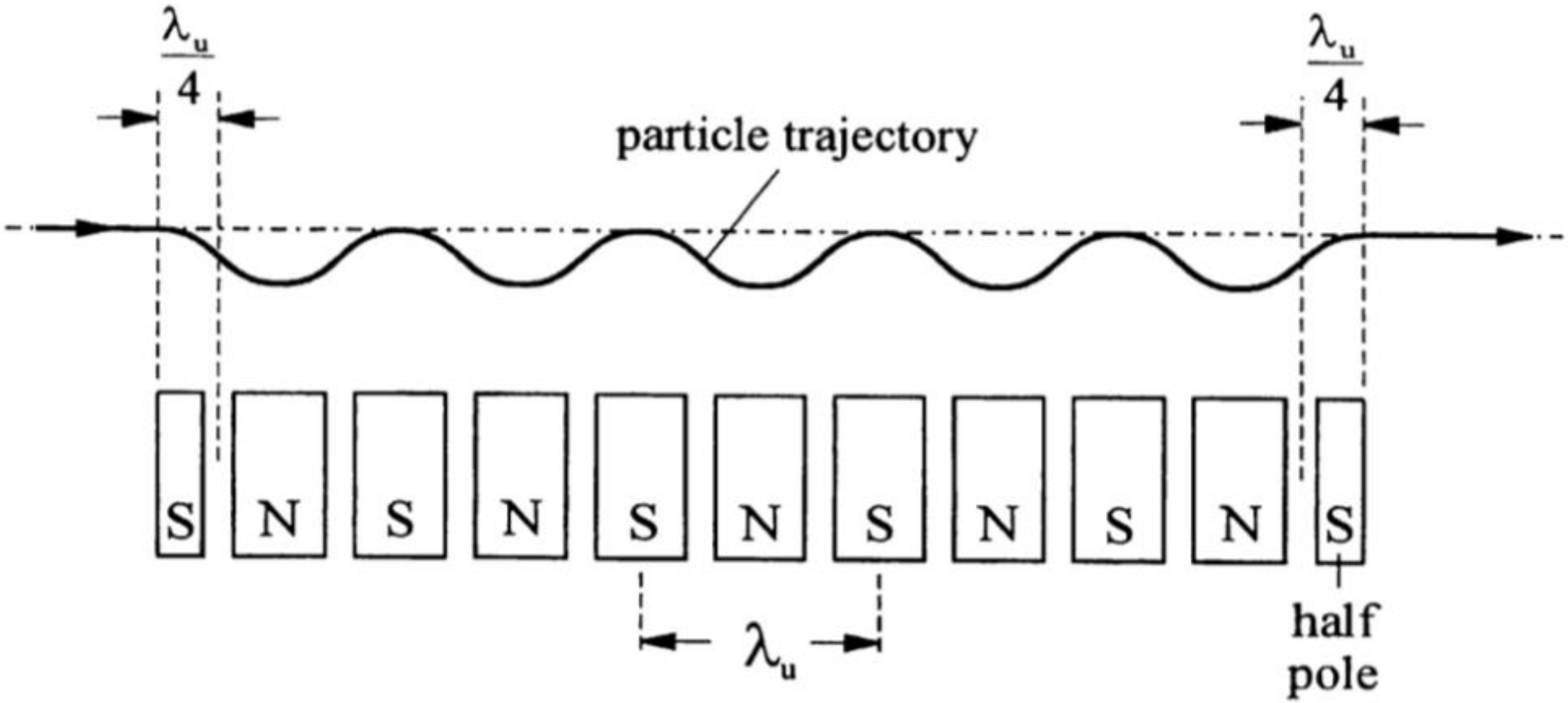
22 beamlines now commissioned



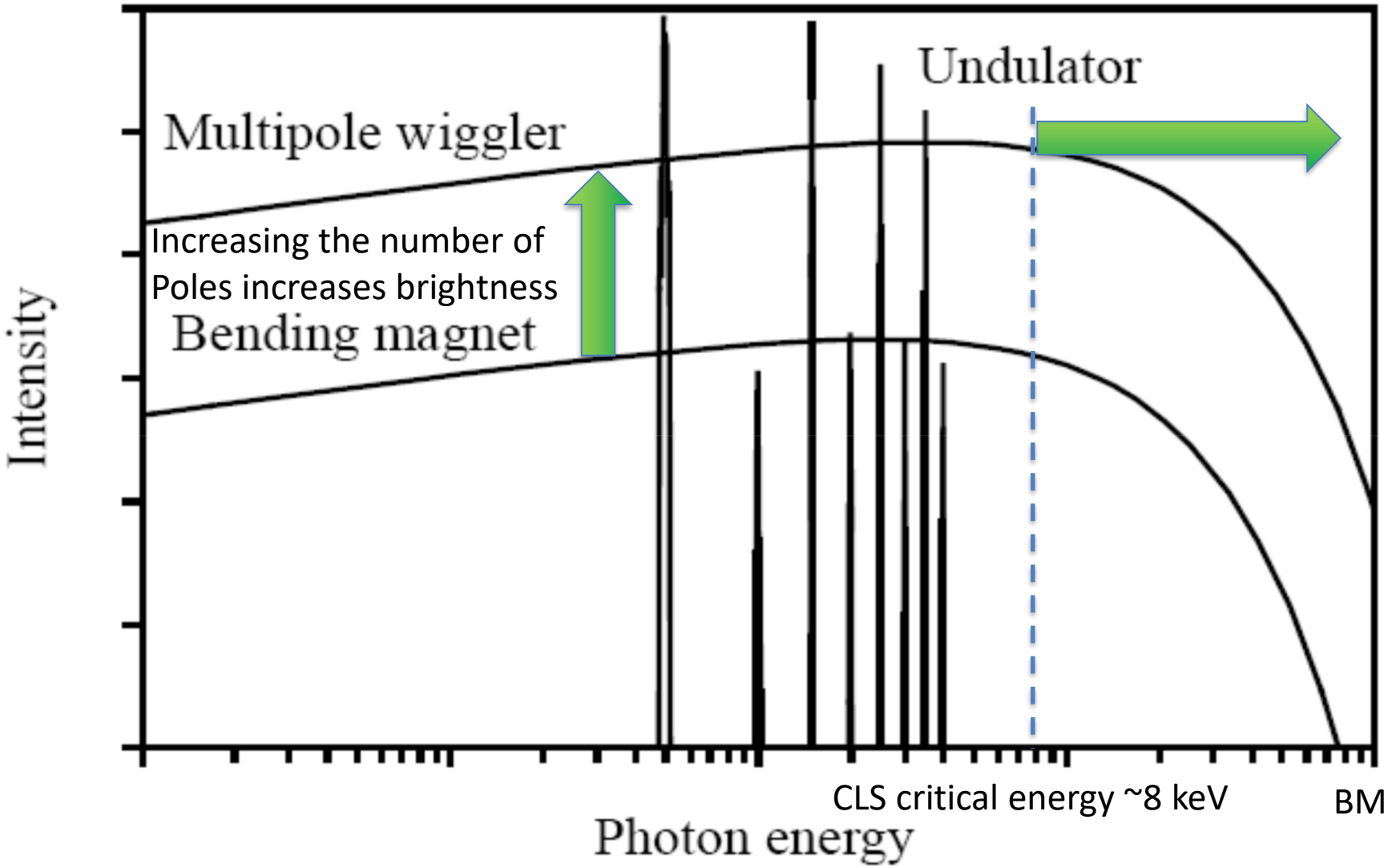
Radiation fan from a dipole magnet



Multipole wiggler concepts



Advantages for SC magnets for producing light



Increasing B-field
Increases x-ray energy

CLS critical energy ~8 keV

BMIT SC Wiggle -> 150 keV

Power of synchrotron radiation

$$P_\gamma[\mathrm{MW}] = 0.0885 \frac{E^4\ [\mathrm{GeV}]^4}{r\ [\mathrm{m}]} I\ [\mathrm{A}]$$

P – Power radiated by electron,
Needs to be replenished to keep constant energy to store the beam

I - Current in the storage ring

r – bending radius of a dipole magnet

$$B = \left(\frac{1}{re}\right) p$$

Limit of power

Power Loads of CLS Devices			*Insertion device*					***Loss Per Turn A***		***Loss Per Turn B***		***Loss Per Turn C***		***Loss Per Turn D***	
			Sinusoidal	Peak Field	Period	Poles	Length	**Presently Running IDs†**		**Presently Installed IDs**		**All Planned IDs**		***All Planned; QMSCH Only†***	
Device	*Notes*	*Location*	Approx.	*B, T*	*λ, mm*		*m*	*keV*	*Power, kW*	*keV*	*Power, kW*	*keV*	*Power, kW*	*keV*	*Power, kW*
SGM	PPM	11-1	Y	0.843	45	53	1.189	4.50	1.16	4.50	1.09				
PGM	PPM	11-2	N	0.751	185	17	1.635	5.19	1.33	5.19	1.26				
SM	EPU	10-1	Y	0.742	75	41	1.591	4.66	1.20	4.66	1.13	4.66	1.01	4.66	1.02
HXMA	SC wiggler	6-2	Y	2.2	33	62	1.056	27.20	6.99	27.20	6.61	27.20	5.91	27.20	5.96
CMCF	IVU	8-1	Y	1.066	20	157	1.583	9.57	2.46	9.57	2.33				
Phase I sub total:								***51.1***	***13.1***	***51.1***	***12.4***	***31.9***	***6.9***	***31.9***	***7.0***
BMIT	SC wiggler	5-1	Y	4.3	48	25	0.624	61.40	15.77	61.40	14.91	61.40	13.34	61.40	13.44
REIXS	EPU	10-2	Y	0.742	75	41	1.591	4.66	1.20	4.66	1.13	4.66	1.01	4.66	1.02
Phase II sub total:								***66.1***	***17.0***	***66.1***	***16.0***	***66.1***	***14.4***	***66.1***	***14.5***
Brockhouse	IVU	4-1	Y	1.049	20	156	1.5826			9.27	2.25	9.27	2.01	9.27	2.03
	IVW	4-2	N*	2.51	80	32	1.56			52.30	12.70	52.30	11.37	52.30	11.45
BioXAS	Hybrid Wiggler	7-1	N	2.103	150	20	1.6385	52.44	13.47	52.44	12.74	52.44	11.40	52.44	11.48
	Hybird IVU	7-2	Y	1.016	18.6	168	1.582	8.69	2.23	8.69	2.11	8.69	1.89	8.69	1.90
QMSC	EPU	9-all	N	0.697	180	41	3.834					9.58	2.08		0.00
	EPU	9-all	Y	0.877	55	141	3.924	16.06	4.13	16.06	3.90	16.06	3.49	16.06	3.52
Phase III sub total:								***77.2***	***19.8***	***138.8***	***33.7***	***148.3***	***32.2***	***138.8***	***30.4***
Section 3	Worst case ID's	3-1	N	2.103	150	20	1.6385					52.44	11.40	52.44	11.48
	(i.e. 2 more wigglers)	3-2	Y	2.103	150	20	1.6385					52.44	11.40	52.44	11.48
CMCF-2	IVU (see CMCF)	8-2	Y	1.066	20	~300	3.82					23.10	5.02	23.10	5.06
SGM-2	EPU	11-1	Y	0.8284	54.2	60	1.640					5.99	1.30	5.99	1.31
PGM-2	EPU	11-2	N	1.037	142	22	1.630					9.33	2.03	9.33	2.04
Phase IV sub total:								***0.0***	***0.0***	***0.0***	***0.0***	***143.3***	***31.1***	***143.3***	***31.4***
IDs total:								***194.4***	***49.94***	***256.0***	***62.17***	***389.6***	***84.65***	***380.0***	***83.20***
SR Dipoles			N/A	1.354	N/A	N/A	1.87	876	225.04	876	212.78	876	190.35	876	191.80
Total:								**1070.4**	**275.0**	**1132.0**	**275.0**	**1265.6**	**275.0**	**1256.0**	**275.0**
Max Allowed Current (A)									**0.2569**		**0.2429**		**0.2173**		**0.21895**
Max Allowed Current (mA)									**257**		**243**		**217**		**219**

* Lacking a RADIA model of the BXDS IVW to generate B fields, we're using sin. approx

† Brockhouse IDs kept open for now (commissioning)

† The QMSC beamline can only use one ID at a time

Beam Energy (GeV)	2.9
Stored Current (A)	0.25
SR-RF Trip point (kW) (from JS)	275

Text Colour Legend

#'s are Verified in a Design Report / CAD drawing / FAT document / etc.

#'s are Obtained from Radia Model

#'s are "Made up" / Predicted

219 mA limit

SC cavity to replace energy lost to light production

Energy loss in the CLS storage ring on one orbit around the ring

$$\Delta E\ [\mathrm{keV}] \ = 88.5 \frac{E^4\ [\mathrm{GeV}]^4}{R\ [\mathrm{m}]}$$

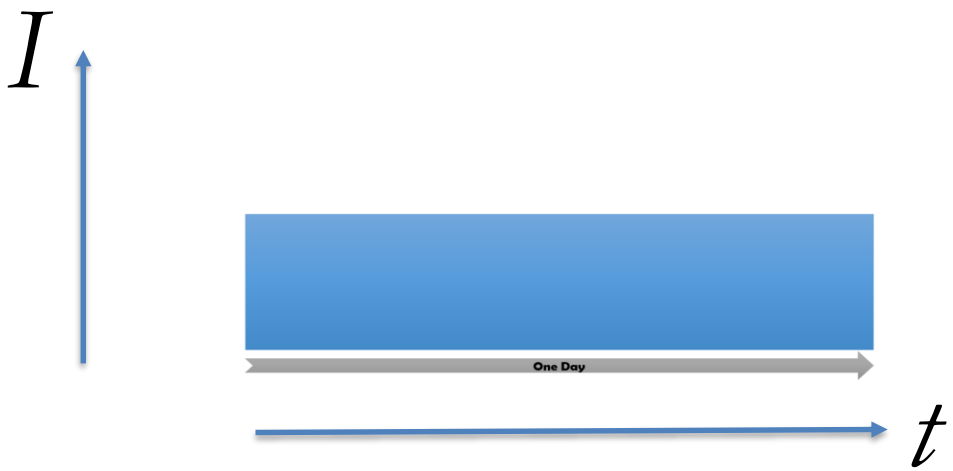
- For the CLS the energy is 2.9 GeV, the circumference is 171 m and the dipole bend radius is approx. 7 m, so we get

$$R \sim 7\ \mathrm{m}, E \sim 2.9\ \mathrm{GeV}$$

$$\Delta E = 894\ \mathrm{keV}\ \text{or}\ \frac{\Delta E}{E} \sim 3 \times 10^{-4}$$

Need around 1 MV field, too high for most normal conducting cavity. Superconducting cavity can produce over 2 MV.

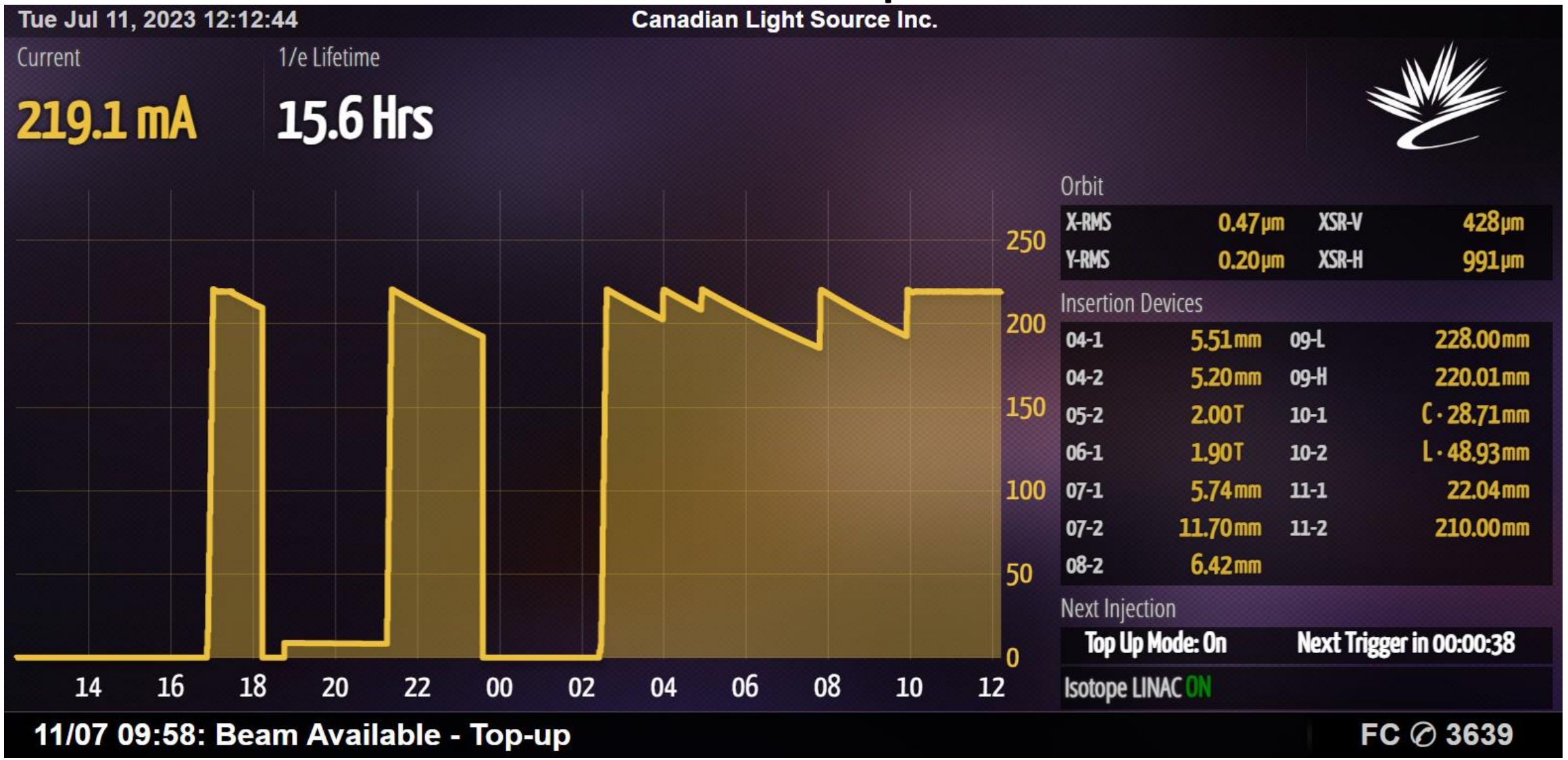
CLS Plans for second SC cavity for high current



2021-2025

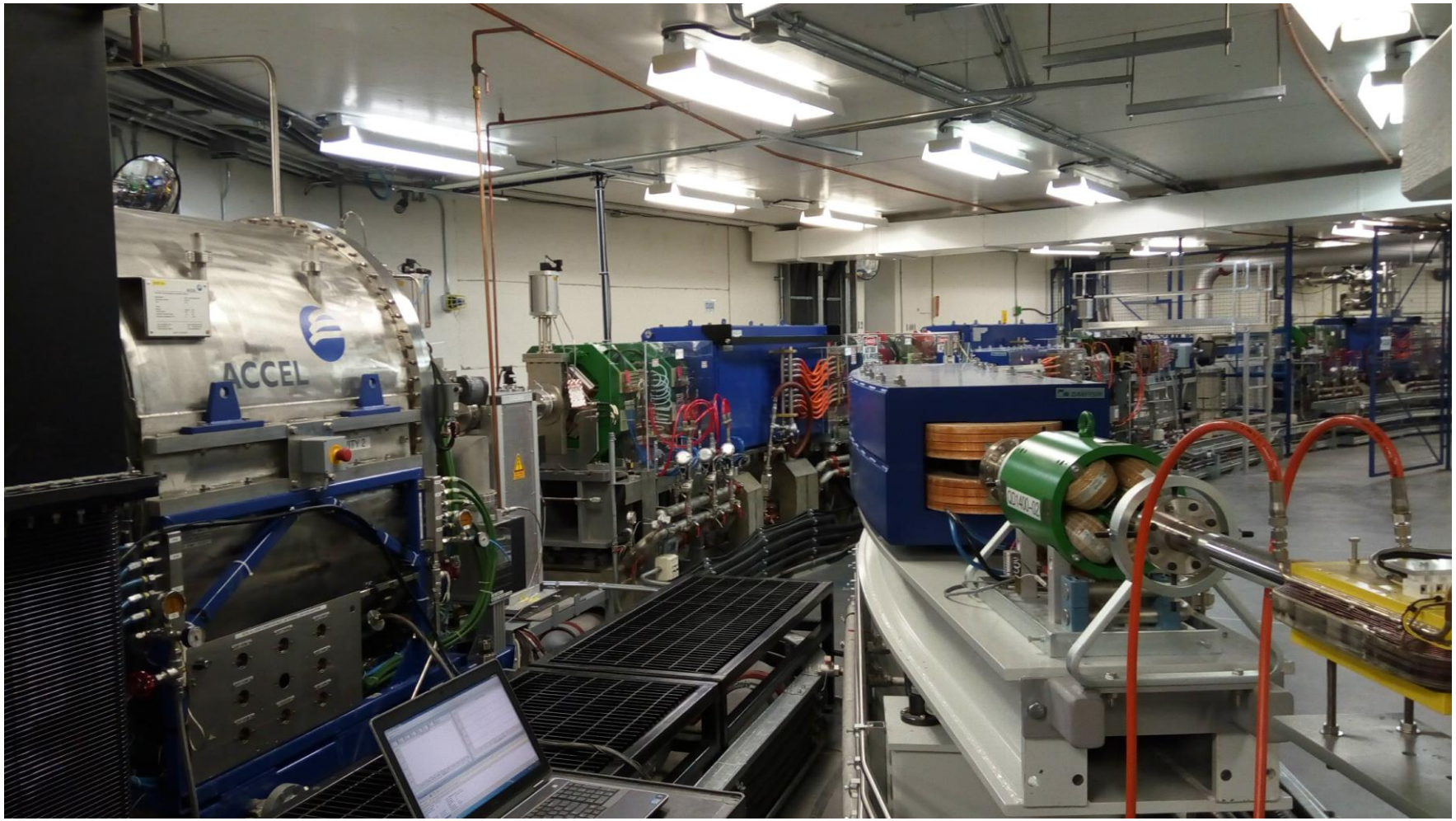
2026-2029

CLS 24 hours of operation



Second Cavity in the Storage Ring

- Motivation
- Status
- Plans

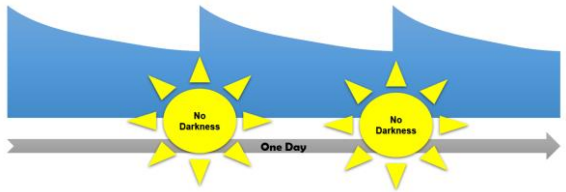


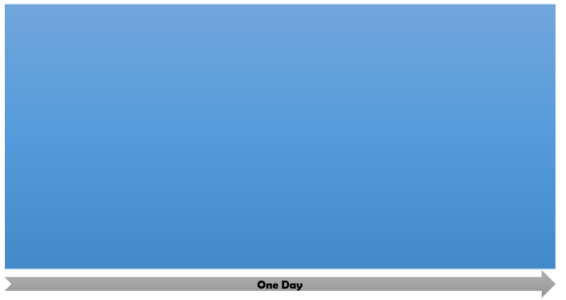
Big Picture Vision

- Let us dare imagine…if you can't imagine it will be hard to achieve
- Picture of facility with new linac and new cavity
- 5,000 hrs per year high current top-up image









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

Where have we come from?

BUILDING THE LIGHT

A HISTORY OF CANADIAN SCIENTIFIC LEADERSHIP AND INNOVATION

SASKATCHEWAN SCIENCE

1948 The University of Saskatchewan becomes home to Canada's only betatron, giving the department of physics a first-class facility for radiation treatment research and nuclear research.

1951 The world's first non-commercial cobalt-60 therapy unit for cancer treatment opens at the U of S.

1962 Sod turning for the Saskatchewan Linear Accelerator, an 80-foot electron accelerator tube that created energy six times that of the betatron.

Sir John Cockcroft, Nobel Laureate, turns the first sod for SAL, May 10th 1962. University of Saskatchewan President J.W.T. Spinks watches.

1964 Saskatchewan Linear Accelerator opens.

THE EARLY DAYS

UNIVERSITY OF WISCONSIN-MADISON

1975 1st Canadian experiment conducted at Tantalus, Madison, WI.

Mike Bancroft giving a talk on his first results from Tantalus

1977 1st paper on work done at Tantalus published.

1978 After a successful submission to the National Research Council (NRC), a Canadian beamline is built at the Canadian Synchrotron Radiation Facility (CSRF) at the Synchrotron Radiation Center at the University of Wisconsin-Madison.

1983 Grasshopper at Tantalus, CSRF is born.

1990 DCM beamline completed on time and on budget.

1998 SGM beamline operational and exceeding specification.

1999 CLS CONSTRUCTION BEGINS

September 27, 1999 Official sod-turning event and the start of construction of the main experimental hall.

September 1999 | January 2000 | June 2000 | January 2001 | March 2001 | June 2001 | July 2001

1994 The Natural Sciences and Engineering Research Council of Canada recommends that a full service national facility be developed. This led to an open competition in which groups from Eastern Canada and Western Canada competed.

1990 The Canadian Institute for Synchrotron Radiation is created, composed of synchrotron scientists from across the country. The goal: to build a synchrotron for Canada.

CISR Canadian Institute for Synchrotron Radiation / Institut Canadien du Rayonnement Synchrotron

1996 In 1996 a peer review committee, administered by NSERC and chaired by Alex McAuley (University of Victoria) re-affirmed the need for a light source and recommended that Saskatoon be the site. NSERC council accepted the recommendations of the McAuley committee in November 1996.

1999 Formal announcement by the Canada Foundation for Innovation that Canadian Light Source Project funding was approved. The formal start of the CLS Project, March 31 1999.

The Star Field of beams

2001 The completion of the experimental hall is celebrated with a building dedication ceremony, February 26.

2002 Start of commissioning the synchrotron booster, the main component of the CLS injector. The 2.9 GeV electrons produced are the highest energy achieved by any Canadian particle accelerator.

2004 October 22, 2004 Official grand opening

2005 May 27, 2005 First CLS user Allen Pratt of Natural Resources Canada CANMET Labs using the VLS-PGM beamline.

BRIGHTEST LIGHT IN CANADA | @canlightsource

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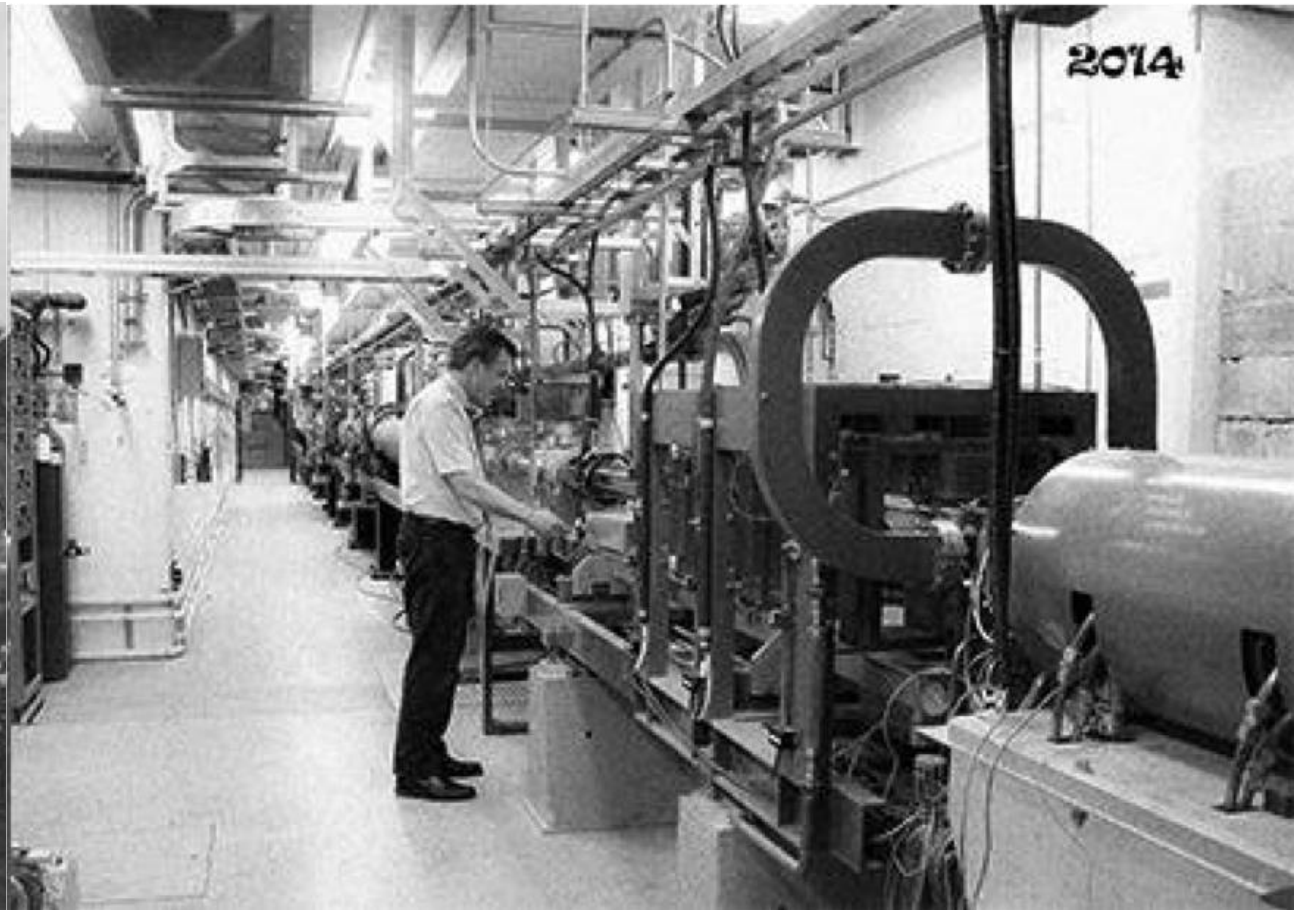
CLS Emerged from SAL

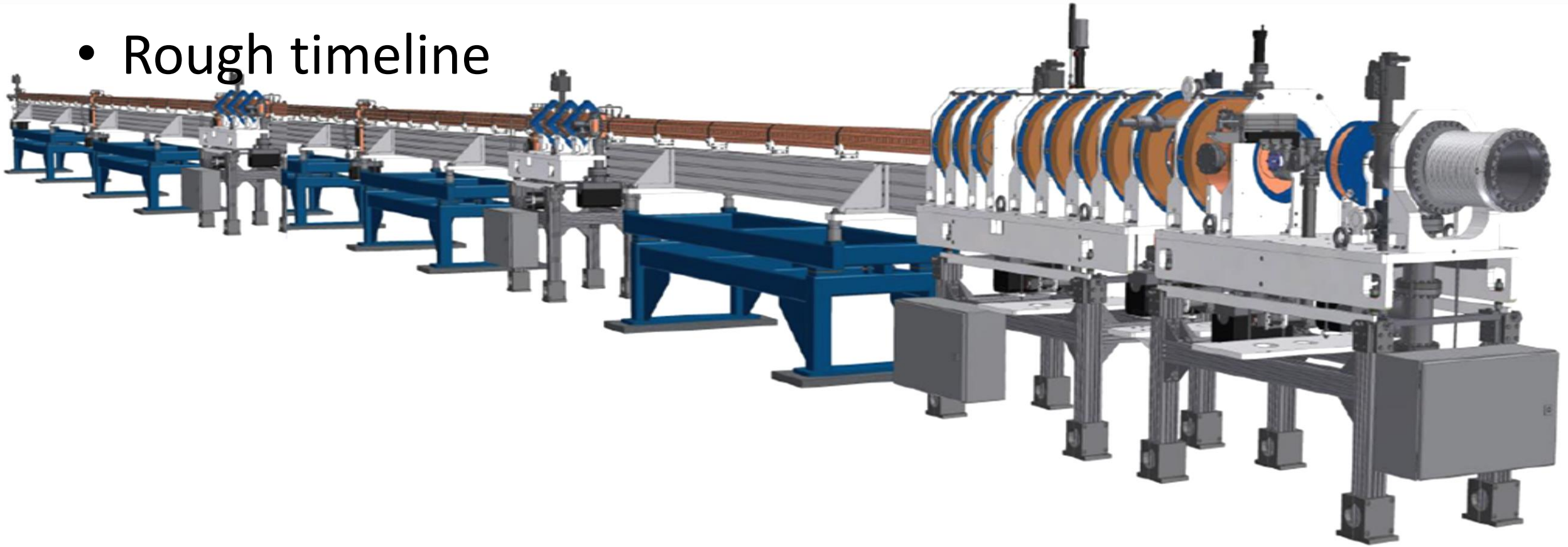
Sir John Cockcroft, Nobel laureate, turns the first sod for the Saskatchean Accelerator Laboratory. May 10th 1962. University of Saskatchewan President J.W.T. Spinks watches.

CLS built on historical SAL established in 1962

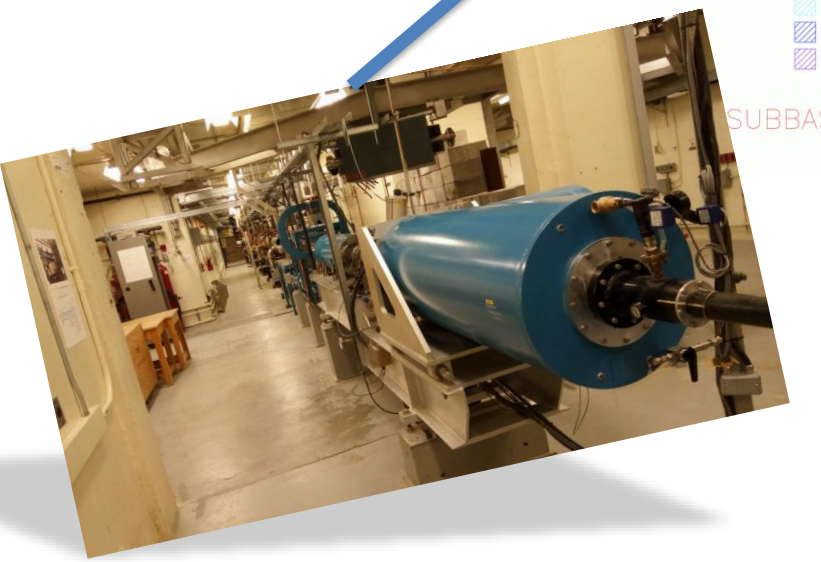


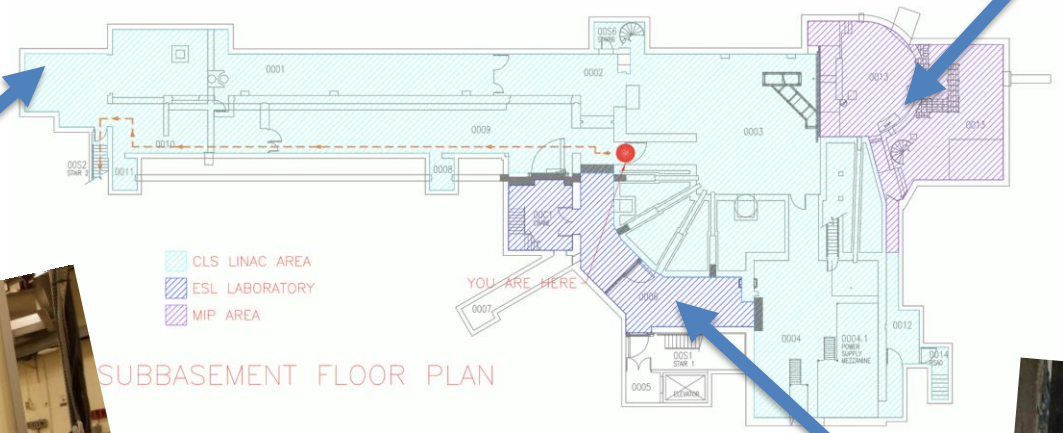
New Linac

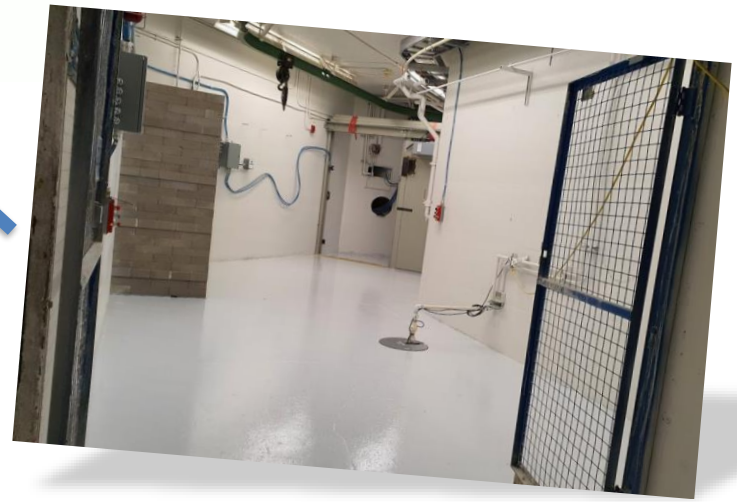
- Background
- Status
- Rough timeline



CLS Accelerator Tunnels







Available e- guns:

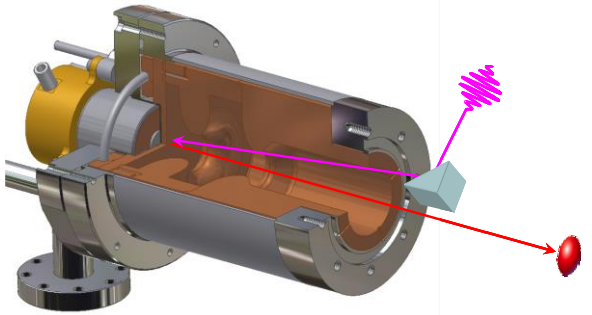
MAX IV

- 500 keV, DC thermionic gun

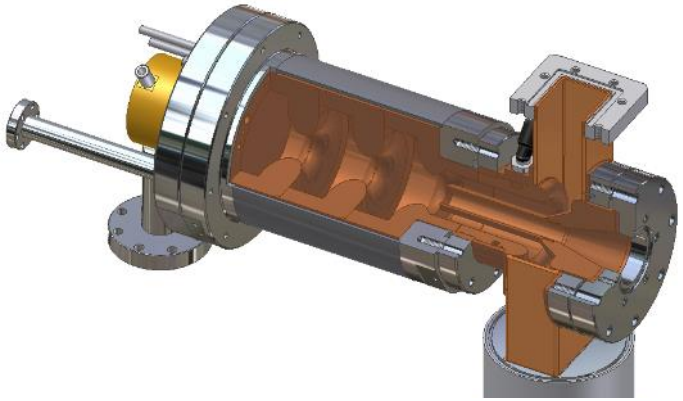
- 2.3 MeV, thermionic RF-gun

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

- 4.4 MeV, 1.5 Cell RF photogun

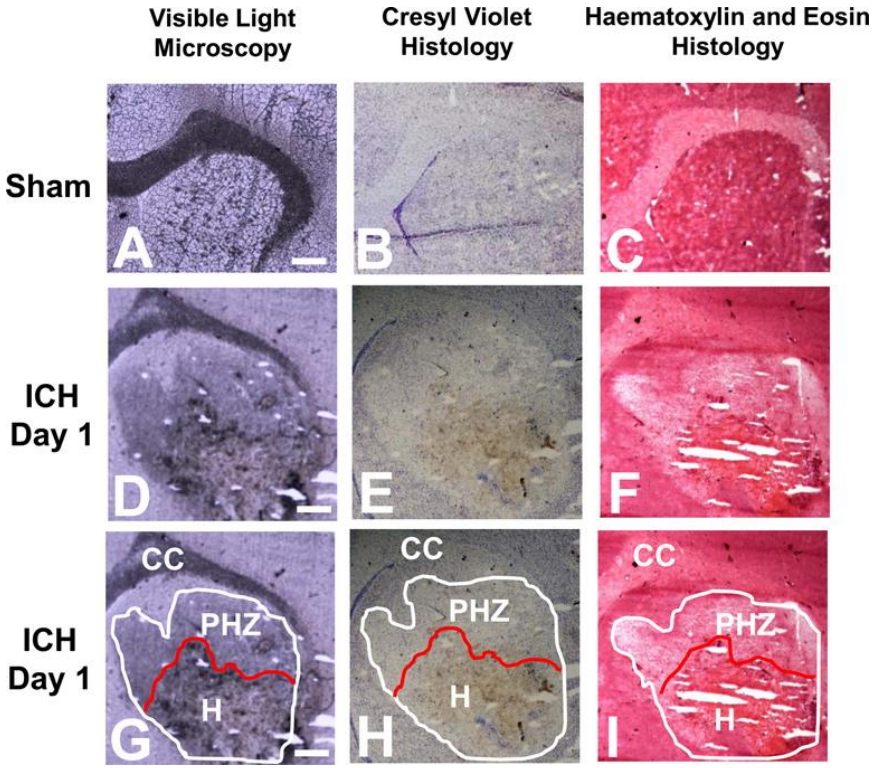


- 7.4 MeV, 2.6 Cell RF photogun



A brighter future after stroke

Visualizations of brain tissues help indicate the toxic iron pathways following haemorrhagic stroke. This data is vital to developing effective treatments for this severe type of stroke.



Temperature increases affecting crop yields

Scientists discover the ‘why’ of heat tolerance in peas

Cause of wheat resistance to scab discovered

Images of diseased and healthy florets in the spikelets of wheat cultivars using phase contrast X-ray imaging at 4 days after inoculation with FHB.

Light saving lives - isotopes

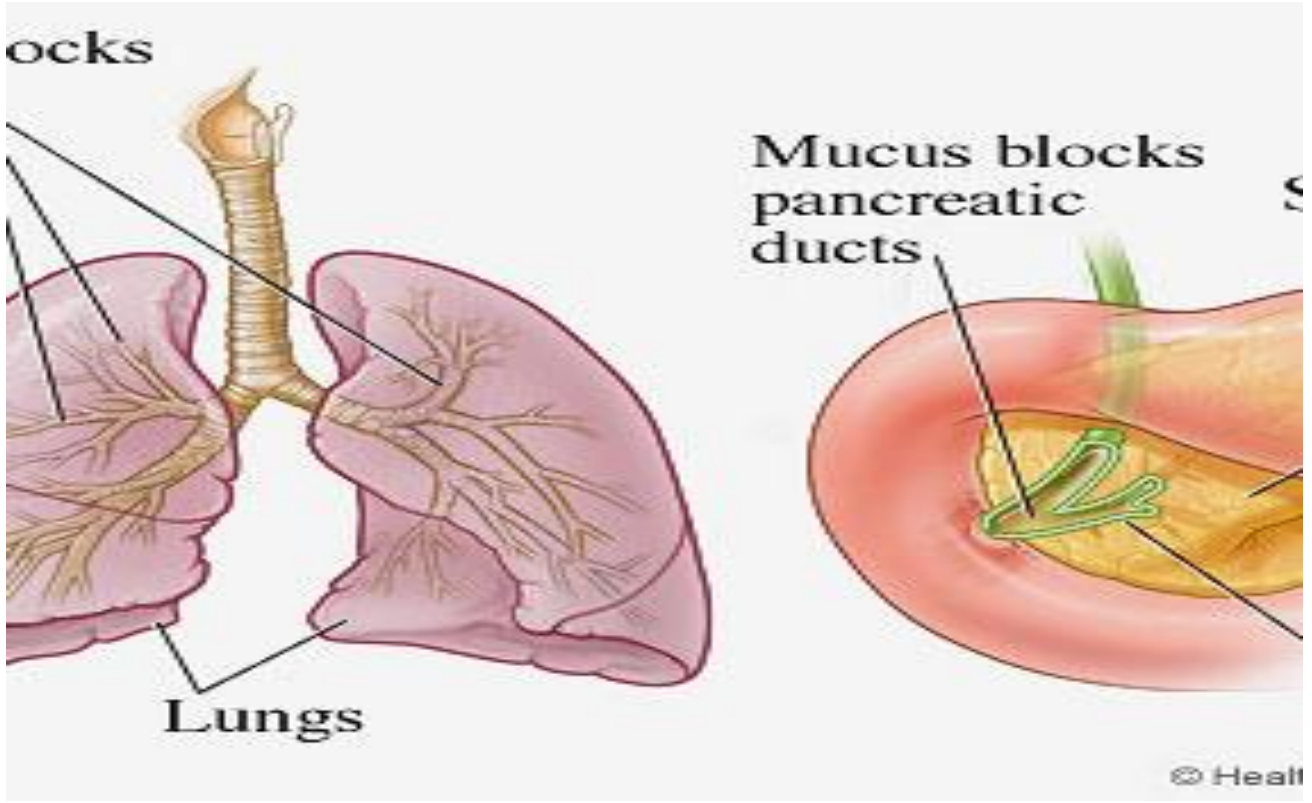
These disks alone will be used for 1000 medical scans.

Researchers find novel approach for controlling deadly C. difficile hospital infections

Llama-derived antibodies open door to development of new treatment

New synchrotron imaging technique reveals how cystic fibrosis makes lungs vulnerable to infection

The discovery suggests that by helping this component function better – for example, through early and sustained use of antibiotics – it may be possible to improve lung function in cystic fibrosis patients.



Energy and Mining: Reducing Pollution

Uranium producer AREVA maintains ISO 14001 Environmental Accreditation using synchrotron data.

Seeing a solution to cleaner oil

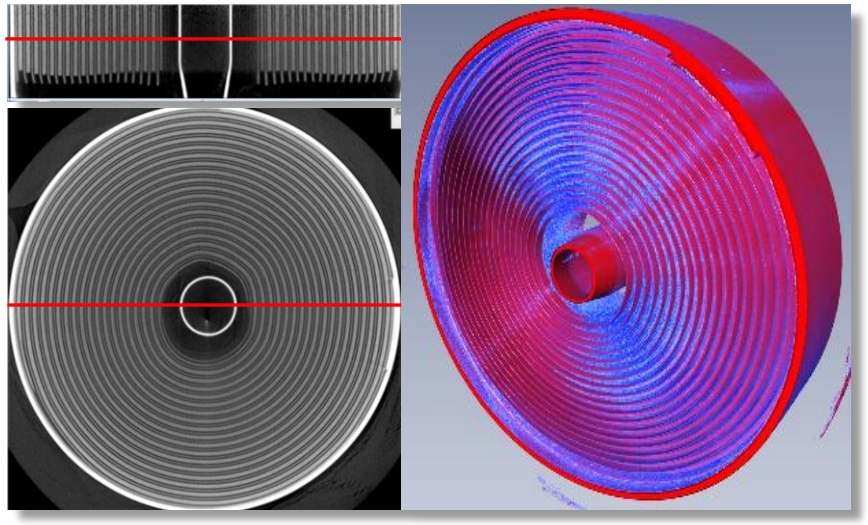
New research will reduce environmental impact of recovery

Protecting Canada's Mineral Sector

Working with Vale to characterize nickel species present in inhalable aerosols in processing plants to assess risk and set policy.

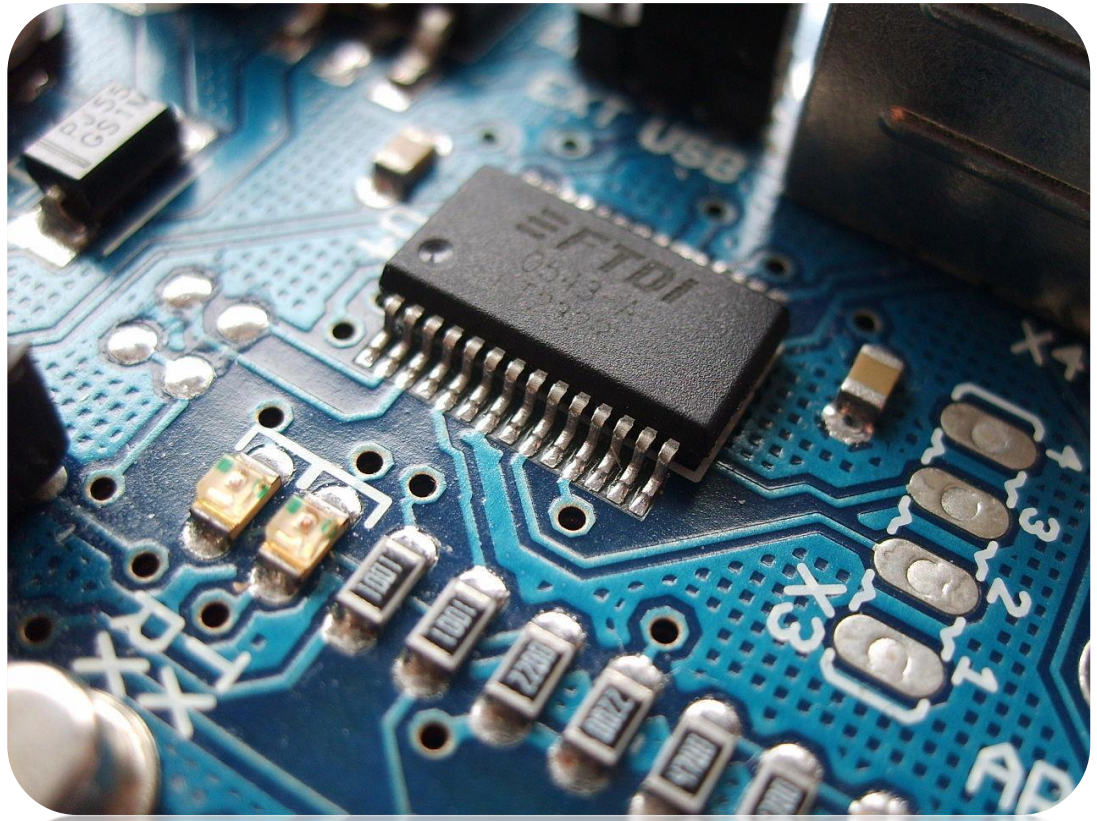
Developing the battery of the future

New methods and materials could lead to the development of safer, cheaper, more powerful, and longer-lasting power source



An interesting glimpse into how future state-of-the-art electronics might work

Smart, innovative and highly sensitive technology could become a reality thanks to this innovative research.



Foldable tablets, wrap-around TVs, and the next generation of electronics

Research gives further insight into graphene-based devices

Shutout Solutions Inc.

SK SME/ Start-up used CLS for product proof of concept

Wrong Place at the right time

Siberian Bronze Age skull reveals secrets of ancient society

Revealing the mechanisms of malaria & toxoplasmosis

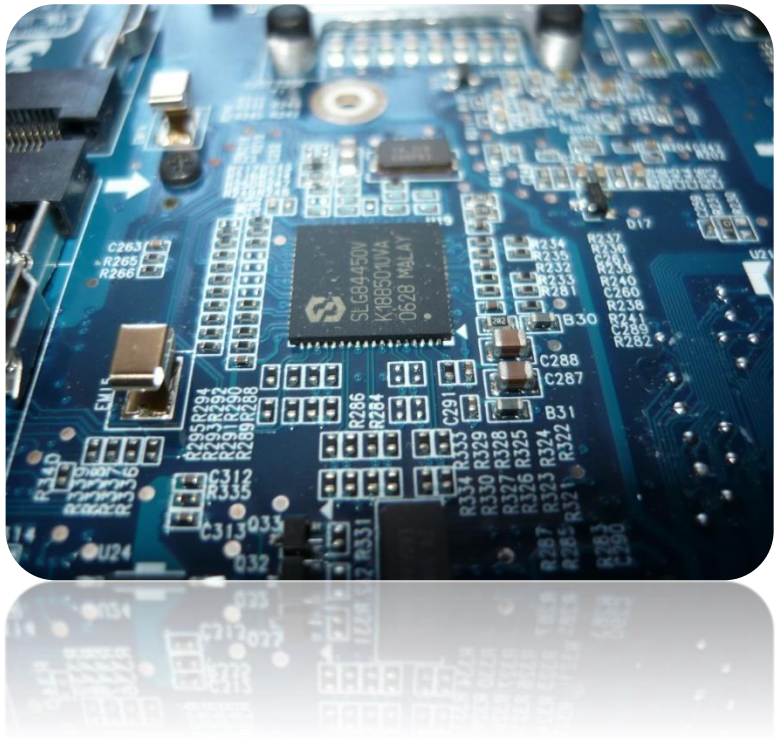
- University of Victoria researchers used the CLS to reveal the complex cell injection mechanism of Apicomplexa parasites, which cause malaria and toxoplasmosis
- To develop treatments and, potentially, a malarial vaccine
- Malaria infects over 200 million people around the world, and is the leading cause of death in many developing countries, affecting mostly children and pregnant women

New way to produce live-saving Medical Isotopes

- The Medical Isotope Project (MIP) facility at the CLS is the first of its kind in the world, relying on powerful X-rays to produce Molybdenum-99 isotopes, unlike traditional nuclear reactor-based methods.
- The isotopes are used in about 5,000 medical scans in Canada every day, and the MIP is projected to become a major supplier by 2016

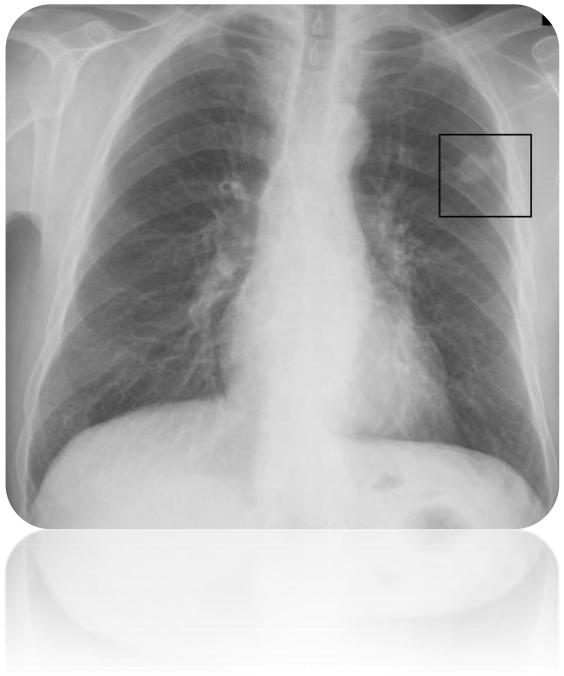
Graphene: the material of the future

- Graphene, a one-atom thick graphite crystal (the same stuff in pencil mines), intrigues scientists with its excellent conductivity and thermal conductivity.
- The first STXM scans of the material, which is already being used in “smart” electronics’ windows that harvest light, revealed electronic and physical structures which are invaluable to developments of new applications.
- Graphene is the most likely replacement for silicon within the next few years, and holds enormous potential impact for the $2 trillion global electronics industry sector



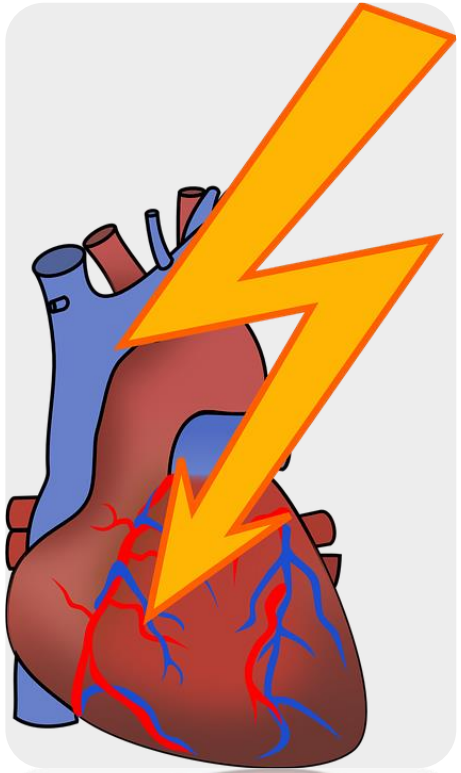
Cancer drug resistance

- Finding the molecular mechanism of resistance is critical to the rapid development of more durable treatments for patients who develop resistance to cancer drug treatments.
- Researchers from the Massachusetts Cancer Centre identified the mutation responsible for resistance to Crizotinib, an anti-lung-cancer drug.
- Lung cancer is the leading cause of cancer deaths in Canada



Heart modelling for better screening

- A 3D model was created using imaging results from the CLS that reveals for the first time how gene mutations affect the pathway in heart muscle cells that control its rhythm.
- Cardiologists at Vancouver general hospital are using this data to develop better genetic screening for life-threatening arrhythmia risk.
- This is critical research for the over 1 million Canadians who live with heart disease



Mine waste cleanup

- Working with universities and industrial partners, CLS scientists have applied advanced scanning techniques to improve mining discovery and reclamation.
- Synchrotron mapping has helped better predict gold and uranium deposit locations, and afforded new insight into the aging mechanisms of mine waste.
- The mining sector is estimated as contributing $57 billion to Canada's GDP in 2014 alone

Long term nuclear cleanup

- As governments move towards cleaner nuclear energy sources as a replacement for fossil fuels, understanding the best way to deal with their waste products is a high priority.
- Using CLS data, researchers have identified long-term, sustainable solutions to nuclear waste, helping work towards a cleaner future.
- Global nuclear power generating capability is estimated to increase by as much as 68% by 2030, making waste cleanup an important priority.

Maximizing crop growth

- Researchers used the CLS to better understand how phosphorus behaves in prairie soil and which type should be used in fertilizers for optimum growth.
- The study showed that retention of phosphorus in soil varied depending on the landscape conditions and fertilizer type, making it possible to hone phosphorous for better crop growth in Canada.
- Phosphate fertilizers represent nearly 20% of total Canadian agriculture fertilizer use

Keeping wheat from going bad

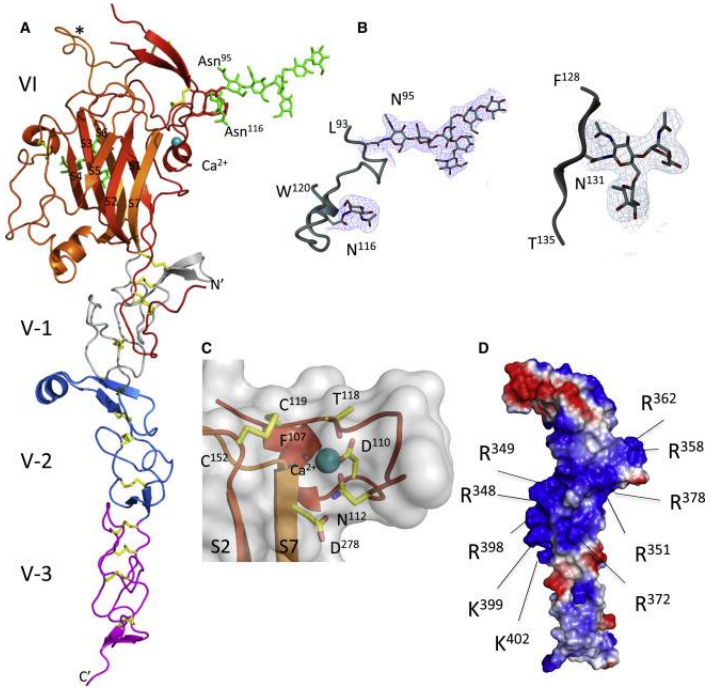
- Researchers from Manitoba teamed up with Agriculture and Agri-Food Canada and the CLS to investigate how fungi degrade the quality of wheat -impacting how long grain can be stored and decreasing the crop's value.
- The CLS enabled the analysis of single kernels to determine the significance of changes in fat and protein content, as well as where damage has occurred in the seed.
- Wheat harvests add $11 billion yearly to the Canadian economy

Tackling transfusion with a universal blood type

- Researchers have developed a technique to turn nearly any blood into a universal type resembling O-type blood, a development which could transform blood transfusion and human health.
- Based on CLS imaging of the structures active in removing A- and B- blood type antigens, University of British Columbia were able to develop an enzyme that was 170 times more effective at removing antigens than any previous tool.
- Half of all Canadians will need a blood transfusion at some point in their lives

Killing Cancer Cells

- Cancer accounts for around 30% of *all* mortality, a percentage that has been stable since at least the turn of the last century.
- Netrin-1 is a protein found in a large fraction of human cancers, and known to inhibit cancer cell death.
- Using the high-resolution capabilities of the CMCF beamlines at the CLS, a Canadian-European collaboration was able to identify the part of Netrin-1`s structure that actually performs this function.
- Using this information they designed an antibody to target that area of Netrin-1, and showed it triggers death of cancer cells under laboratory conditions.
- The antibody, now named NP137, is licensed to a start-up company and is **now in clinical trials.**

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