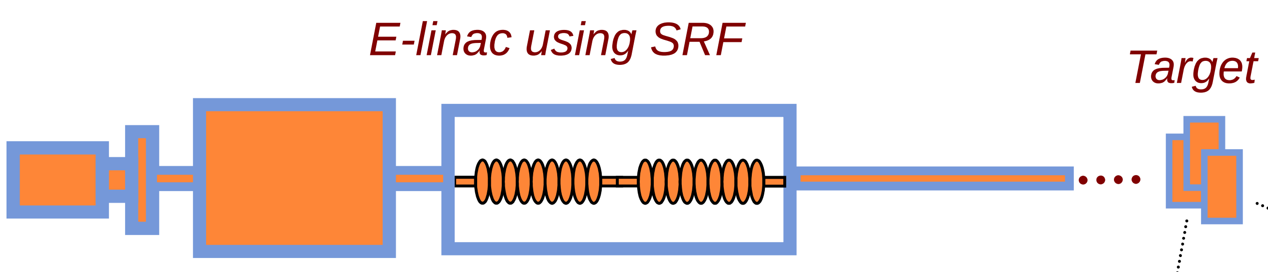
Megawatt-class beams for science, health, and industry

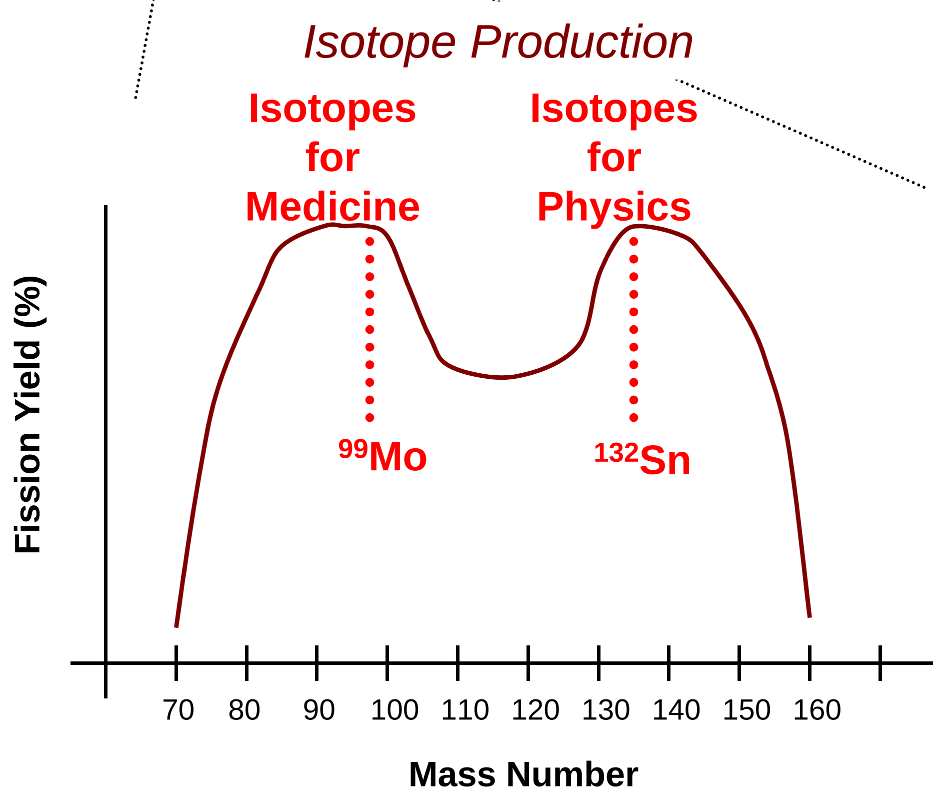
Superconducting electron accelerator for Canada: E-linac

D. Karlen / University of Victoria and TRIUMF

Megawatt-class beams for science, health, industry



- Develop, deploy, & transfer SRF technology to Canadian industry
- Produce novel isotope beams for nuclear physics and materials science
- Demonstrate a transformative approach for producing medical isotopes



Innovative Technology: Keeping Canada competitive

- Superconducting Radio Frequency (SRF) acceleration
  - Pathway to high-power beams for next-generation accelerators
  - Breadth of applications: includes 4G light sources, production of isotopes, neutron sources, and frontier science (CERN SPL, ILC)
  - At its heart are superconducting cavities
    - Made from pure niobium and operated at 2 K

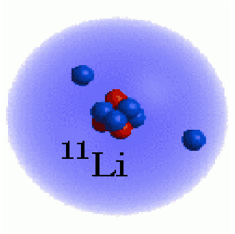
- The high-power e-linac beam will be directed onto targets to produce isotopes through photo-fission

World-class research with high impact

- Nuclear physics
  - Actinide targets produce heavy isotopes rich in neutrons
  - Fundamental nuclear physics and nuclear astrophysics
    - Determine structure of extreme nuclei far from stability
    - Gain understanding in the astrophysical synthesis of the elements
- Materials science
  - Beryllium targets produce ^{8}Li for beta-NMR studies
    - Canadian leadership – quadruple beam time
  - Depth-resolved electronic and magnetic measurements at nanometer scale
    - Critical tool for study of single-molecule magnets
    - Novel storage media technologies, quantum computing

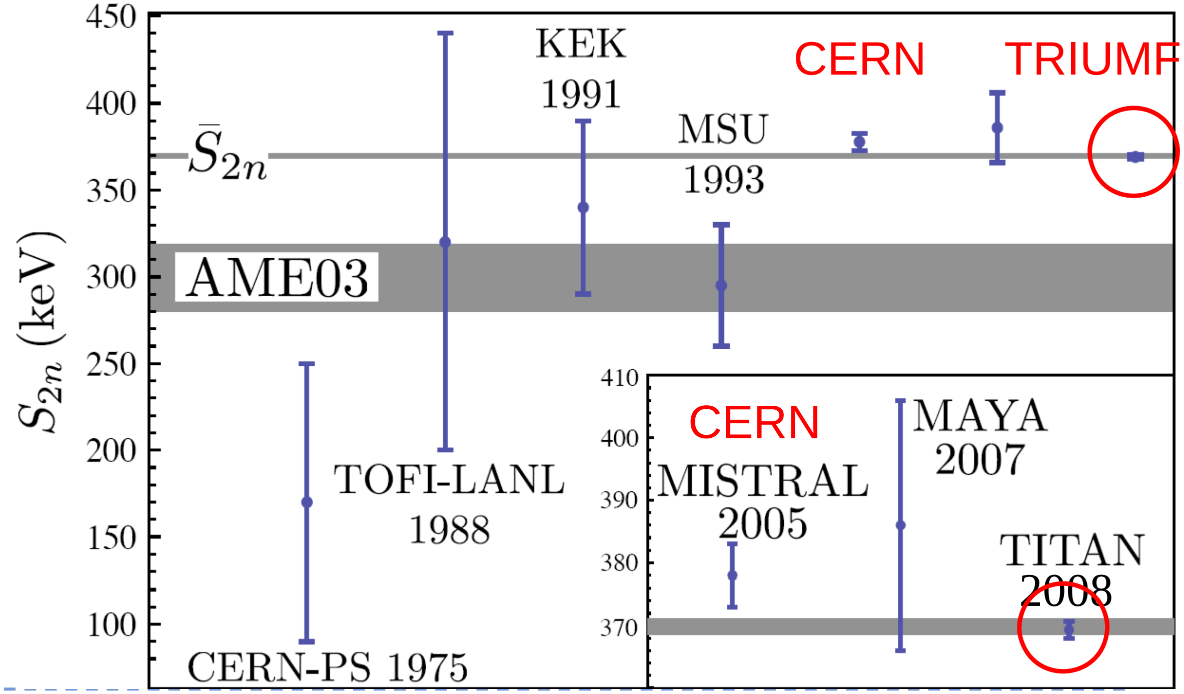
Highly leveraged, ready to use

- Canada has a global advantage in nuclear-isotope physics
  - More than a dozen world-class facilities, supported through national scientific peer-review, already on the floor
  - As a second driver for beams to ISAC-I & ISAC-II, the e-linac would double scientific productivity



new era of world-leading measurements awaits

ISAC-II SRF isotope accelerator



Breakthrough: Alternative for making medical isotopes

- Canada is a world-leader in production of medical isotopes
  - NRU reactor at Chalk River provides high flux of neutrons for irradiation of highly-enriched uranium-235 targets
  - 20 Million patient-treatments/year
    - 1.5 M Canadian-treatments/year
  - Growing safety & reliability concerns

- SRF technology using photo-fission offers an alternative
  - Photons (MW) to fission U-238
  - Avoids weapons-grade U-235
  - E-linac: a demonstration machine

Chalk River reactors a nuclear nightmare

Designed solely to produce medical isotopes

IAN MACLEOD, CanWest News Service
Published: Monday, August 13 2007

A key safety feature in two nuclear reactors northwest of Ottawa won't work despite years of attempted fixes, according to a new Canadian Nuclear Safety Commission report.

The resulting eight-year delay in putting the reactors into commercial production for life-saving medical isotopes could threaten Canada's world dominance of that $3.7-billion global market.

New solution for medical isotope woes
'Uniquely Canadian'; Need for weapons-grade uranium reduced

Margaret Munro
Canwest News Service

Monday, November 17, 2008

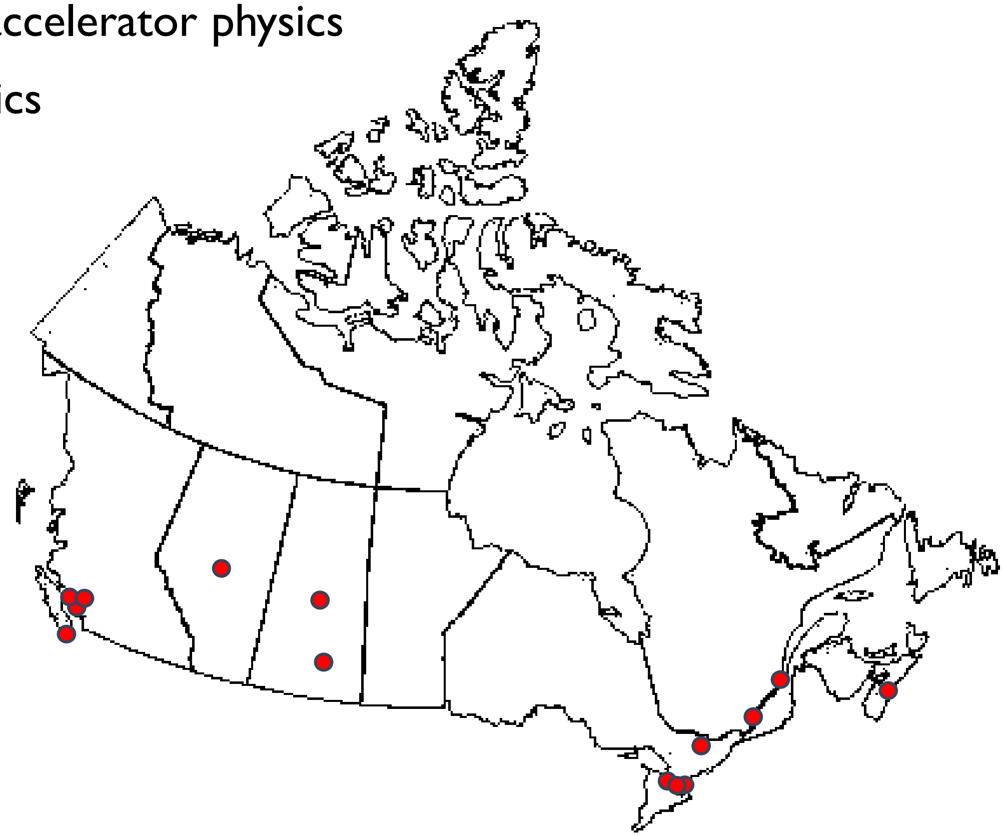
VANCOUVER - Scientists believe they have hit on "a uniquely Canadian solution" to the world's medical isotopes woes.

They say intense beams of light should be able to generate isotopes for nuclear medicine, and eliminate the security risks associated with making the medicines with weapons-grade uranium at the ageing nuclear reactor in Chalk River.

A team of researchers from across Canada

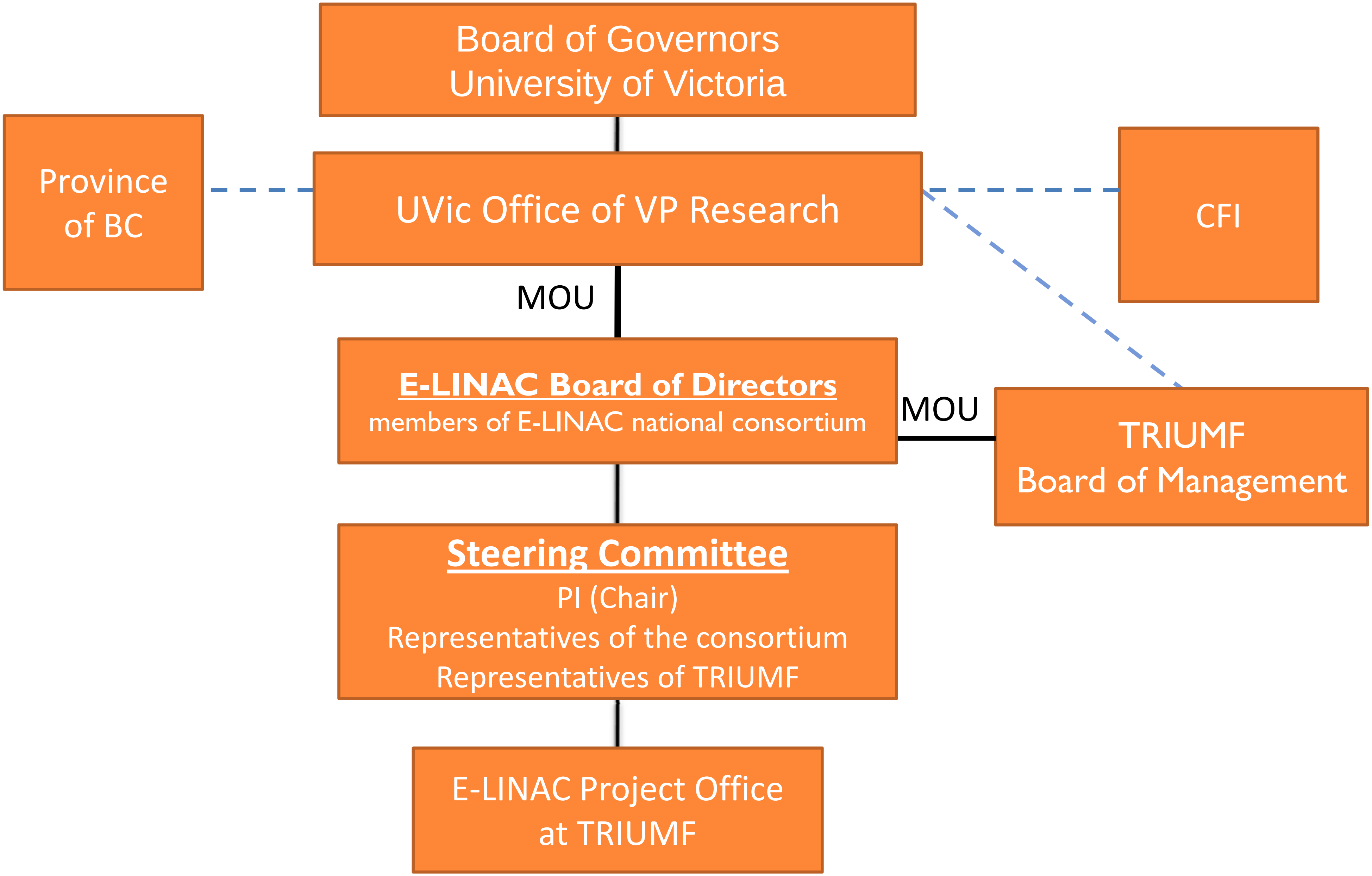
- Each institution brings specialized expertise

UVic	PI, particle and accelerator physics
UBC	materials science, particle and accelerator physics
SFU	nuclear chemistry, nuclear physics
U Alberta	materials science
U Sask / CLS	accelerator physics
U Regina	particle physics
U Guelph	nuclear physics
McMaster U	materials science
U Toronto	superconducting RF
Carleton U	particle physics
U Montreal	nuclear and particle physics
Laval U	nuclear physics
St. Mary's U	nuclear physics



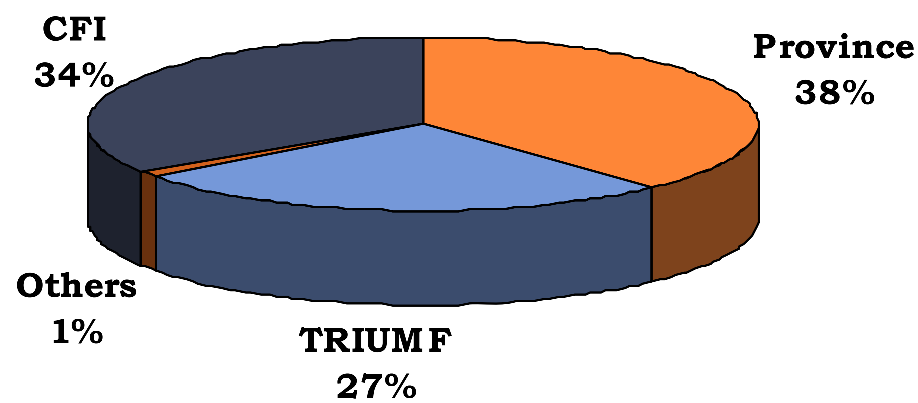
TRIUMF – national laboratory created by Canadian universities to build & operate accelerators for research

Management and governance model

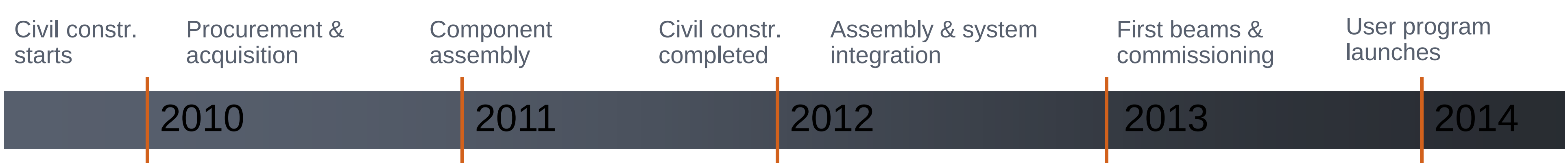


Capital budget and schedule

- Budget - $52M
  - Equipment - $19.5M
    - Cryo-plant: $4.9M; Cryovessels $1.9M
    - Klystrons & RF $2.1M
    - Cavities & Fabrication $1.6M
  - Labour - $12.7M
    - 115 FTE-years
  - Civil infrastructure - $19.8M
    - Beam tunnel & target hall ~20k sq ft
    - Structures & shells $8.4M
    - Interiors $1.3M
    - Services $3.5M
    - Site prep $1.4M
    - Fees, licenses, management, allowances $5.2M



- Provincial match is part of a larger TRIUMF infrastructure upgrade



Operations & Maintenance

- Annual operation/maintenance cost ~ $3M
  - Dominated by electrical power and technical staff for operations and cryo-plant maintenance
- TRIUMF is the ideal vehicle for carrying e-linac operations beyond the CFI project horizon
  - Annual operating budget awarded by Government of Canada in five-year cycles (presently $45 million/year)
  - E-linac is highest priority for the University consortium that owns & operates TRIUMF
- E-linac power upgrade to be undertaken in the future

Highly Qualified Personnel

- World-class project attracts world-class talent
  - Large instruments and facilities built and operated at TRIUMF directly couple to the training of students and postdocs
  - E-linac expected to involve 30 undergrad + 30 grad students per year using the electron accelerator
  - SRF R&D has already attracted a $2.25 million partnership with VECC laboratory in India
- E-linac is establishing a critical mass of talent
  - First-ever UVic/UBC graduate course in accelerator physics is now underway – a course specifically on electron accelerators
    - 20 graduate students from UVic, UBC, SFU, TRIUMF, and Cornell connect by videoconference

Commercialization

- A growing global market for SRF applications
- Only two industrial teams in North America have commercial capability
- E-linac project will develop the third: in British Columbia
  - BC-local company already developing expertise
- Canada will compete globally

ELECTRON BEAM TREATMENT OF FLUE GASES TO REDUCE SULFUR AND NITROGEN OXIDE EMISSIONS: SECOND GENERATION ACCELERATORS AND CHEMICAL REACTORS

Ralf Edinger
PAVAC Industries Inc.
Richmond, British Columbia, Canada

Building on & Expanding Canada's Advantage

- Canada will be the first in the world to use SRF electron linac technology for high-intensity isotope production

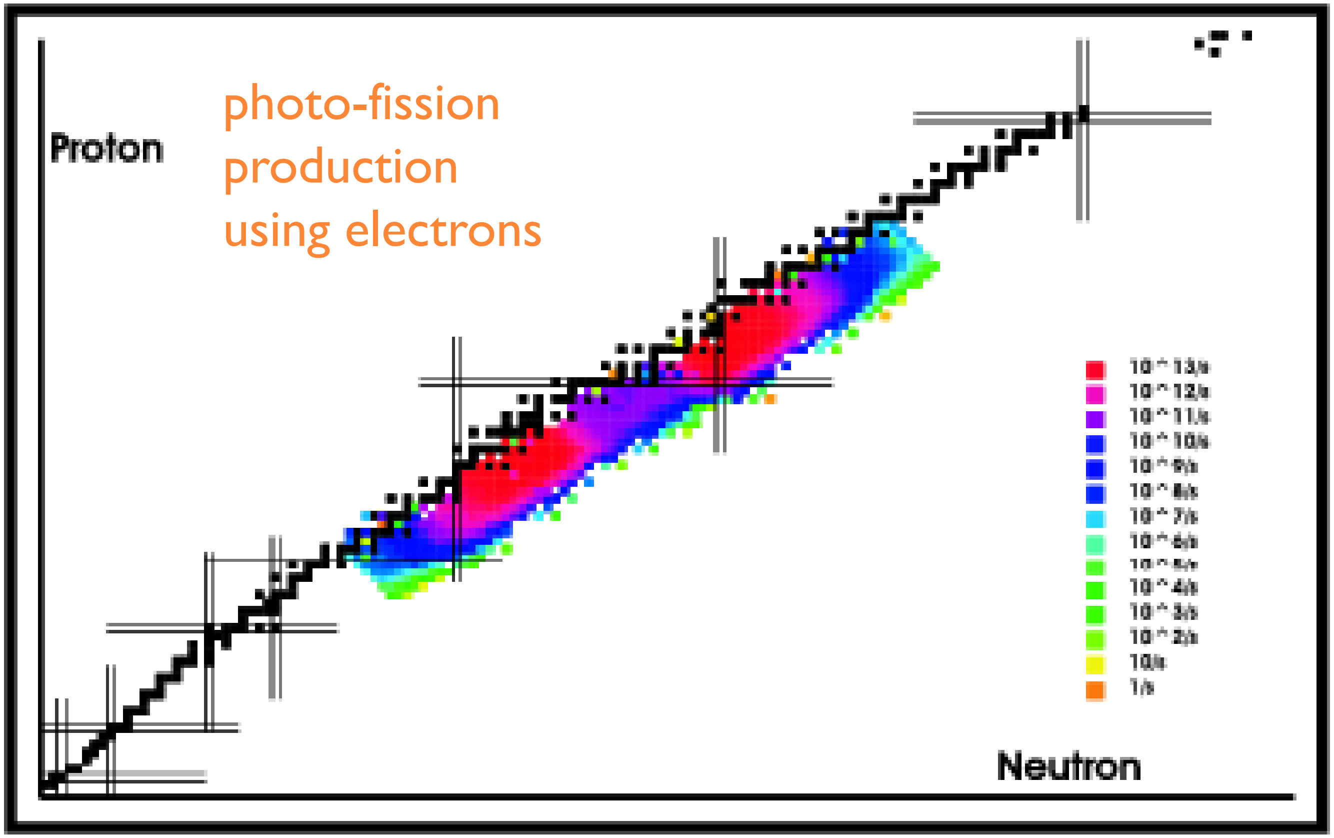
- The e-linac will have a transformative impact on Canada in:
  - Technology
  - Science (Rare isotope beams & materials science)
  - Health
  - Environment

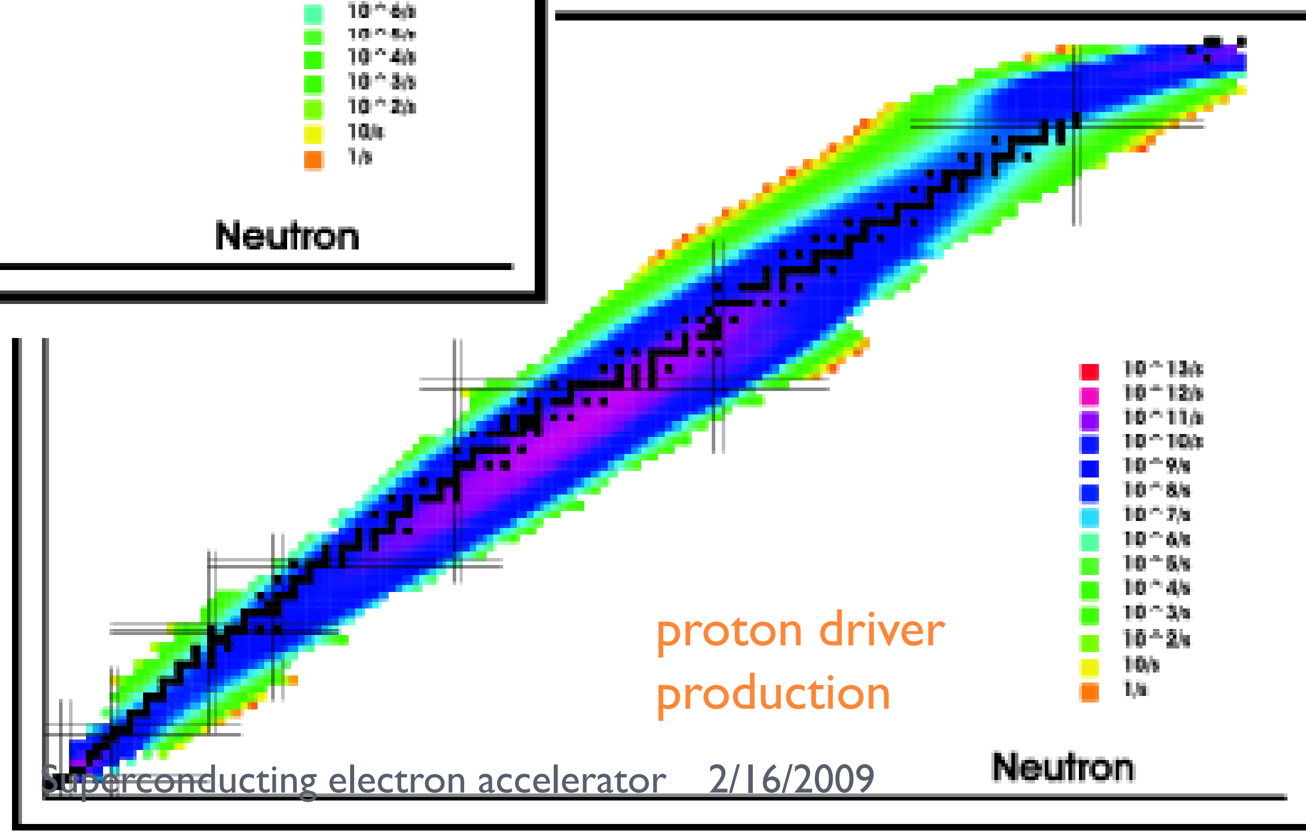
- Build upon and leverage existing expertise and investments in equipment, knowledge transfer, and international partnerships

- The investment in e-linac will propel Canada to the forefront of science and technology

Extra materials

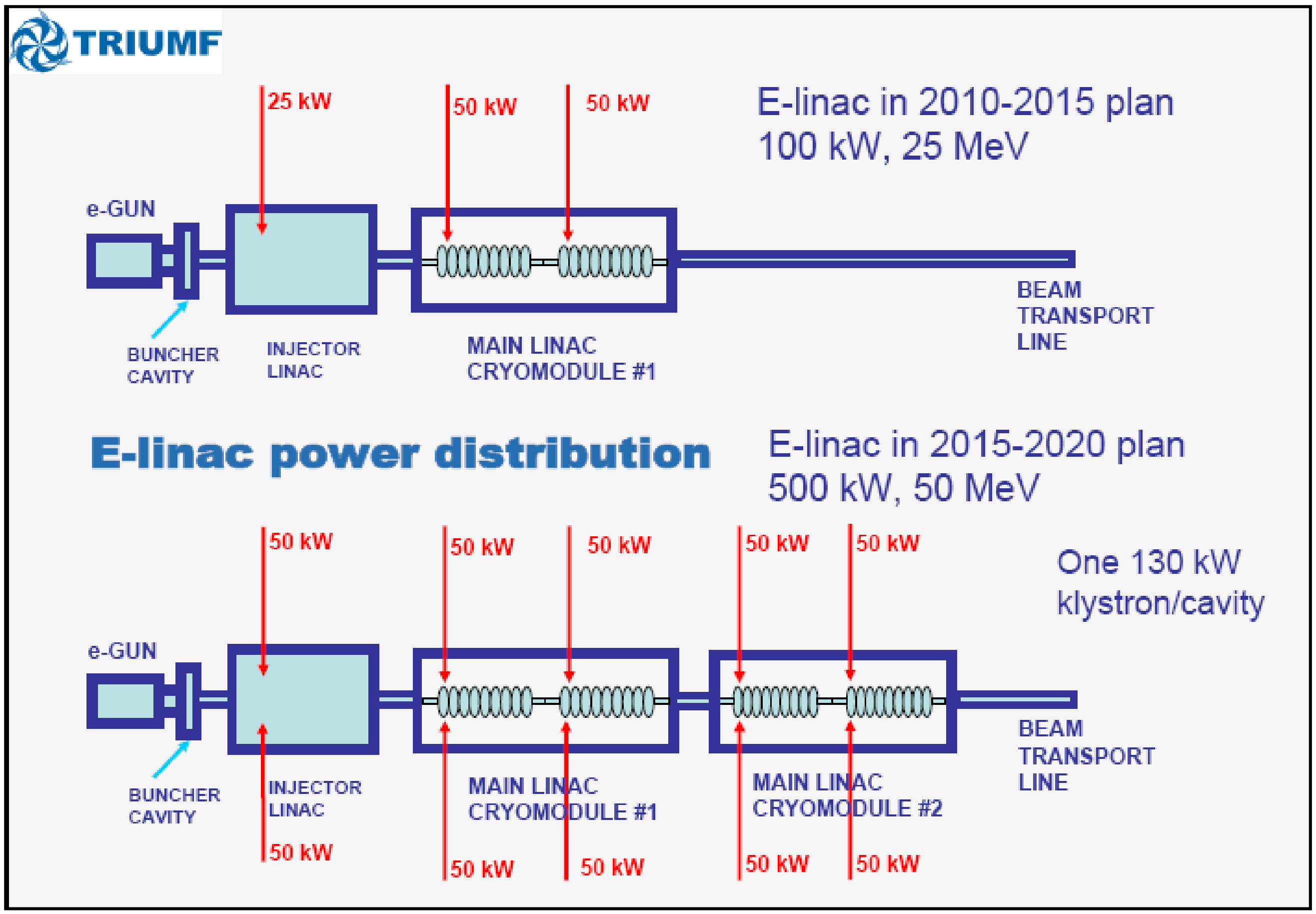
Comparing production rates





Second phase

- The "e-linac" is a high intensity electron accelerator with the ultimate design goal:
  - 50 MeV, 10 mA, continuous wave → 0.5 MW beam power



Leading Rare Isotope Facilities

Industrial accelerators sold world-wide

Robert W. Hamm
Reviews of Accelerator Science and Technology
Vol. 1 (2008) 163–184

Table 1. Total number of industrial accelerators sold world-wide (not including medical accelerators).

Application	Total (2007)
Ion implantation	$\sim$ 9500
Electron cutting and welding	$\sim$ 4500
Electron beam & x-ray irradiators	$\sim$ 2000
Ion beam analysis (including AMS)	$\sim$ 200
Radioisotope production (including PET)	$\sim$ 900
Nondestructive testing (including security)	$\sim$ 650
Neutron generators (including sealed tubes)	$\sim$ 1000
Synchrotron radiation	50
Total	18,700

EBFGT in the world

WEC REGIONAL ENERGY FORUM – FOREN 2008
Neptun, 15-19 June 2008

Table 1: EBFGT- industrial plants – operation data

Parameter		**Industrial plants**			
		Chengdu (1998)	Hangzhou (2002)	Beijing (2005)	Pomorzany (1999)
Boiler power	MW	90	90	150	130
Flue gas flow	Nm^3/h	300000	305400	630000	270000
Inlet SO_2/NOx conc.	Ppm	1800/1400	967/200	1470/583	525/292
Outlet PM conc.	Mg/Nm^3	<200	<200	<190	<50
SO_2/Nox removal efficiency	%	80 / 10	85 / 55	90 / 20	90 / 70
Inlet flue gas temp.	^0C	132	150	146	130-150
Dose	kGy	3	4	4	8-12
Electron accelerator	(kV/mA)*no.	(800/400)*2	(800/400)*2	(1000/500)*2 (1000/300)*1	(800/300)*4
Power consumption (acc.power/total power)	kW	640 / 1900	640 / 1896	1300 / 2850	1000 /…….
Total capital cost	M$	11.4	11.4	11.9	21
Unit capital cost	$/kWe	126.5	126.5	79.5	160
Unit operation cost	$/kW	16.5	16.5	3.8	7.35
	$/ton SO_2	120	120	55.8	1061
By-product (fertilizer)	t / h	2.3	1.7	4.9	0.3