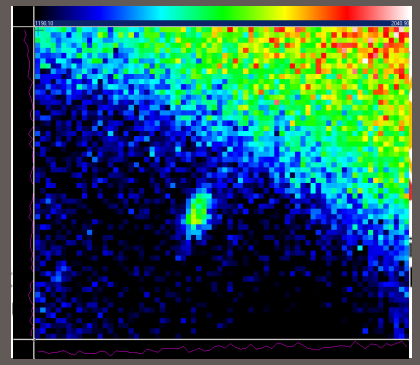
TRIUMF

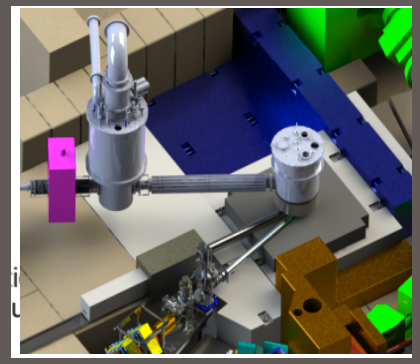
Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

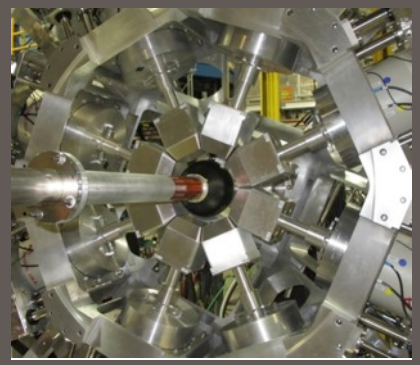
Advanced Instrumentation at TRIUMF

June 16, 2015

Reiner Kruecken | Science Division Head | TRIUMF
Professor | University of British Columbia







United Nations Educational, Scientific and Cultural Organization

International Year of Light 2015

Accelerating Science for Canada
Un accélérateur de la démarche scientifique canadienne

Owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council Canada
Propriété d'un consortium d'universités canadiennes, géré en co-entreprise à partir d'une contribution administrée par le Conseil national de recherches Canada

Outline

- Introduction to TRIUMF
- Accelerator and Experimental Facilities
- Isotopes for Science and Medicine
  - Example Instrumentation (w/ focus on light)
- Particle Physics Facilities
- Conclusions

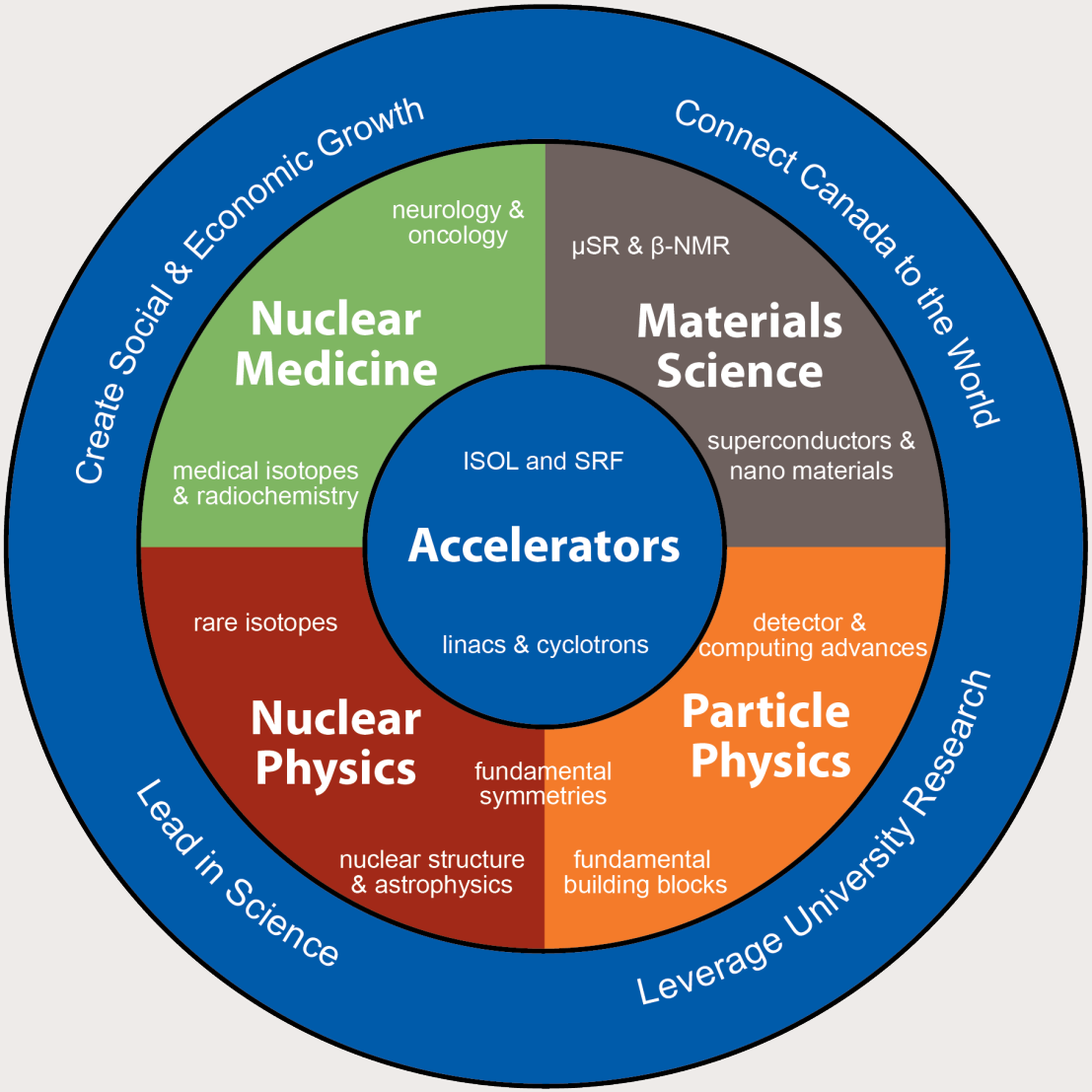
United Nations Educational, Scientific and Cultural Organization

International Year of Light 2015

A National Laboratory

TRIUMF is owned & operated by a consortium of 19 universities
Founded 47 years ago in Vancouver

TRIUMF Research Program & Vision



TRIUMF Laboratory

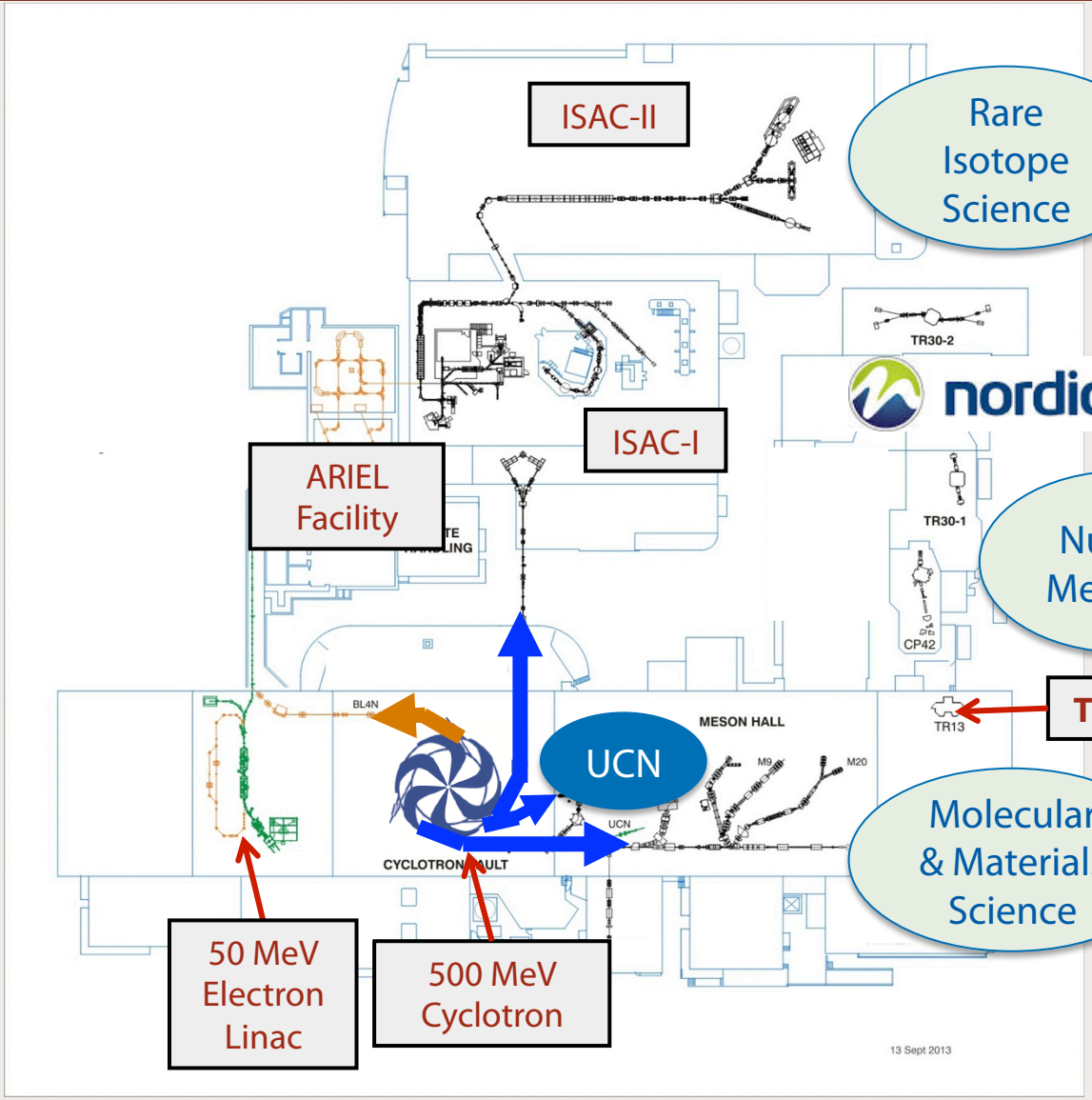
TRIUMF
Accelerator
Complex

Original 520 MeV,
350μA, H^- cyclotron

4 medical isotope
cyclotrons

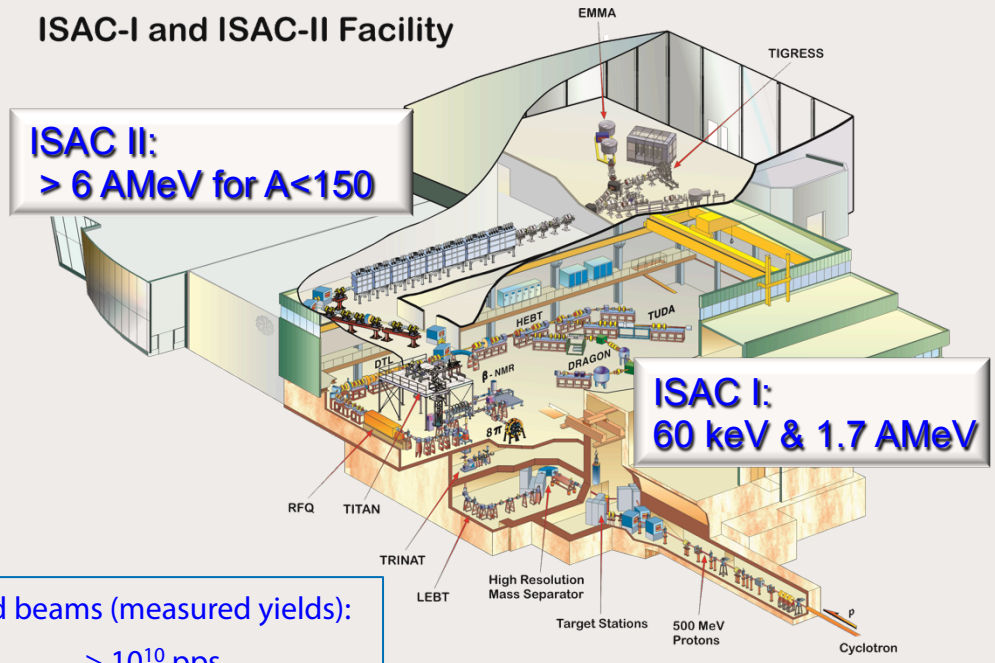
ISAC 50kW ISOL
facility

New ARIEL e-linac
(10mA, 50 MeV)



Isotope Separator and Accelerator (ISAC)

ISOL facility with highest primary beam intensity (100 μA, 480 MeV protons)



Selected beams (measured yields):

^{26}Al	> 10^{10} pps
^{37,38m}K	> 10^{9} pps
$^{211\text{-}213}$Fr	**> 10^{9} pps**
^{225}Ra	> 10^{8} pps
^{103}Rb	3 pps

Select accelerated RIBs:

$^{95}Sr^{15+}$	**10^{7} pps**
$^{11}Li^{+}$	3x10^{3} pps
$^{11}Be^{+}$	10^{5} pps

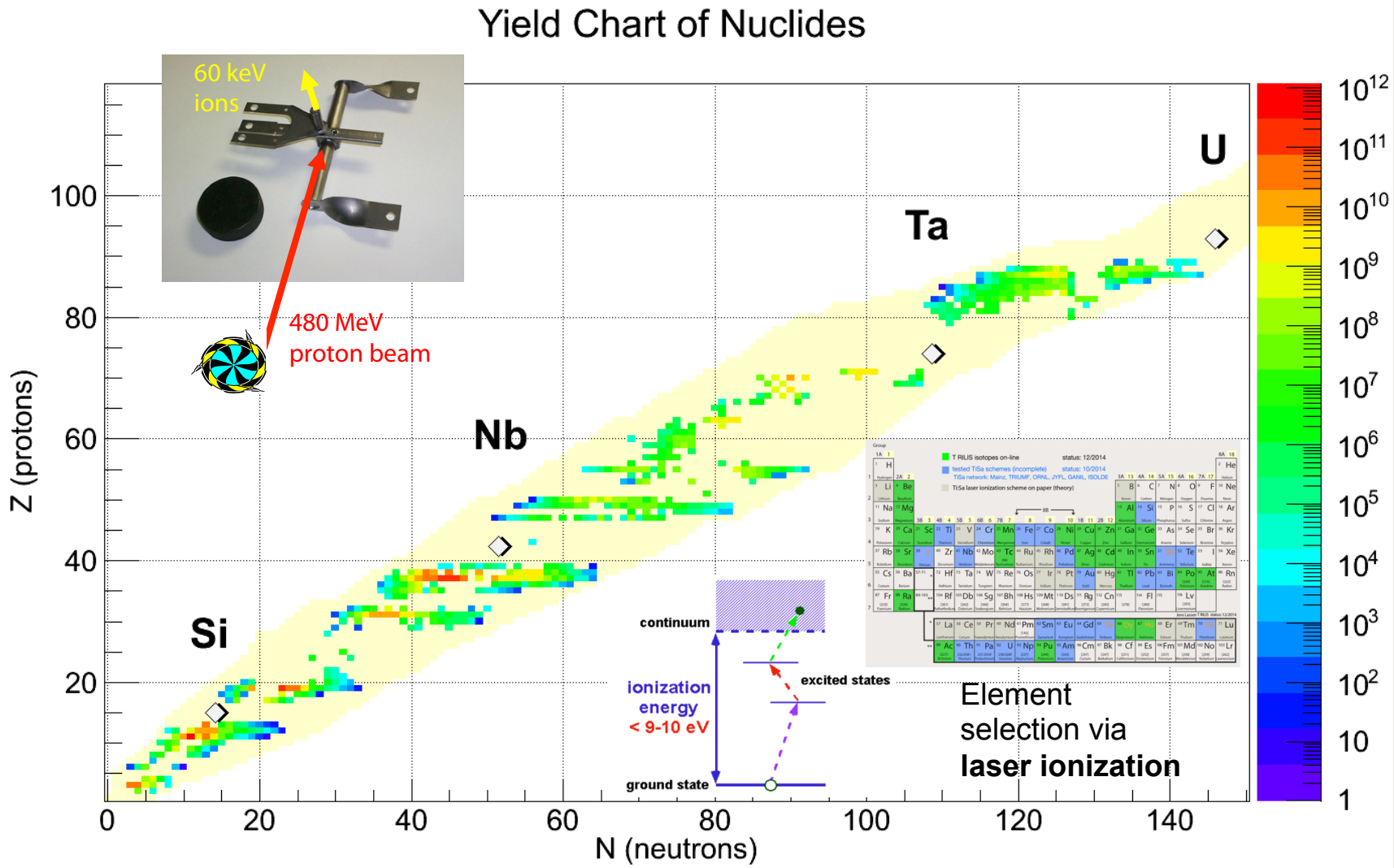
TRIUMF

Programs in

- **Nuclear Structure & Reactions**
- **Nuclear Astrophysics**
- **Fundamental Symmetries**
- **Material Science**
- **Nuclear Medicine**

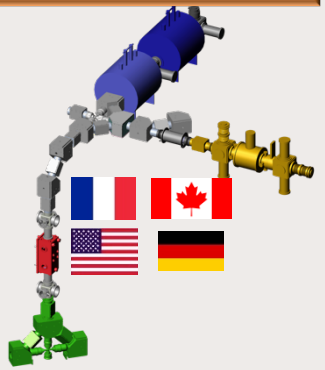
- ~3500 RIB hours / yr
- 600 user community, 2/3 international (~ 120 U.S. users)
- Factor 2-2.5 oversubscribed
- ~ 2 year backlog
- Complementary capabilities to in-flight facilities like FRIB

Measured ISAC RIB Intensities



ISAC Experimental Facilities

TITAN Penning Trap facility



Nuclear Structure

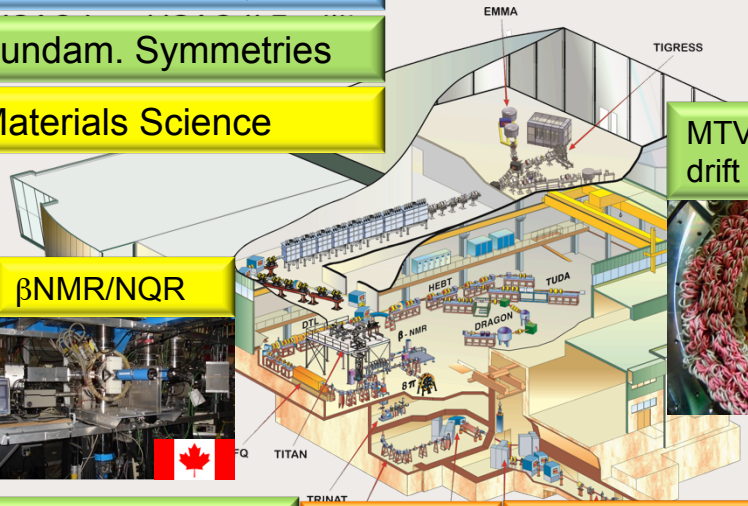
Nuclear Astrophysics

Fundam. Symmetries

Materials Science

EMMA recoil mass analyzer

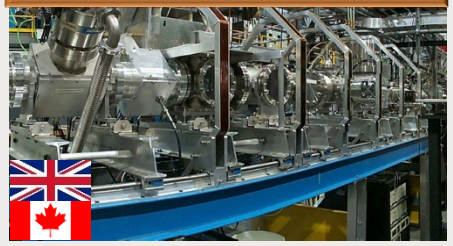
TIGRESS in-beam gamma-ray spectrometer



MTV Mott scatt. drift chamber

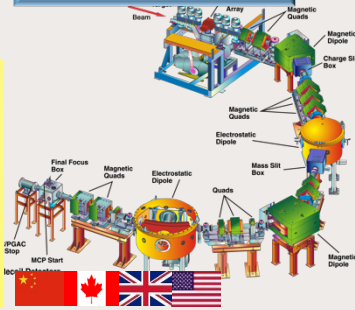
IRIS solid hydrogen reaction set-up

Laser polarizer line

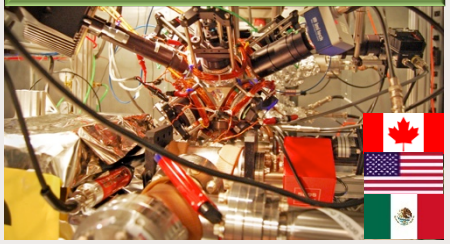


βNMR/NQR

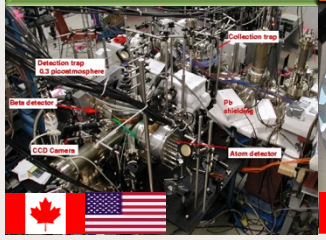
DRAGON recoil separator



Francium trapping facility

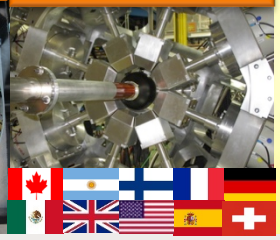


TRINAT magneto optical trap

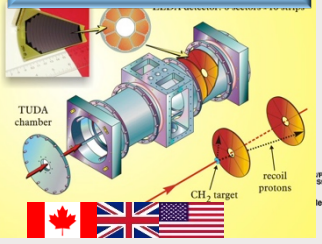


DESCANT neutr. det.

GRIFFIN decay spectrometer



TUDA reaction setup



Major thrust: Isotopes for Science and Medicine

- Isotopes for developing a standard model for nuclear physics;
- Isotopes to determine how and where the heavy elements were produced in the universe;
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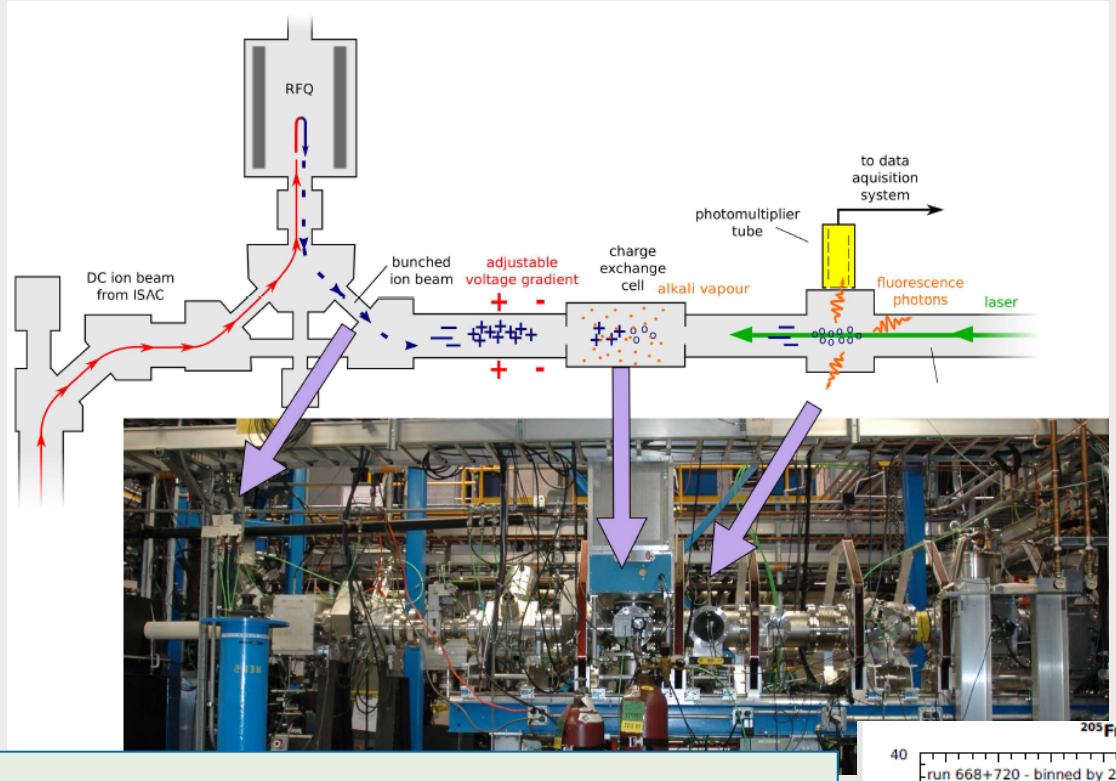
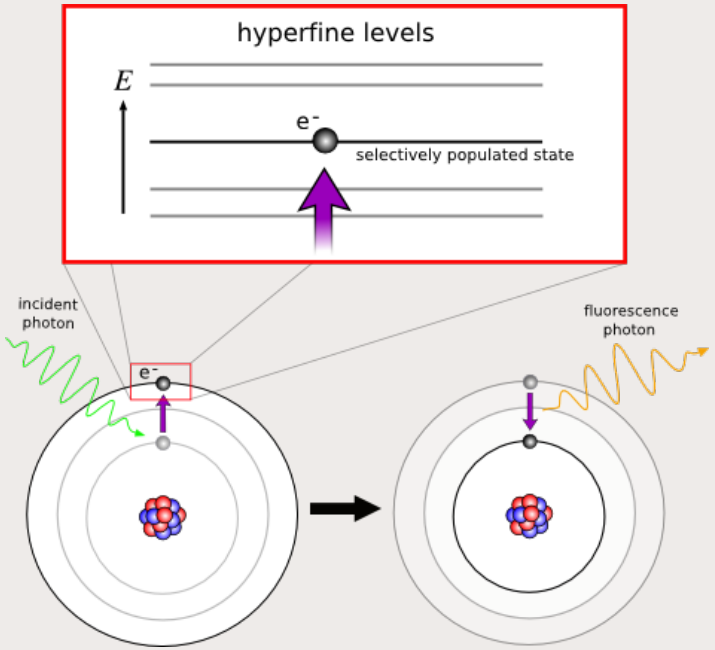
- Isotopes for molecular imaging of diseases and treatment of cancer.

Collinear Laser Spectroscopy

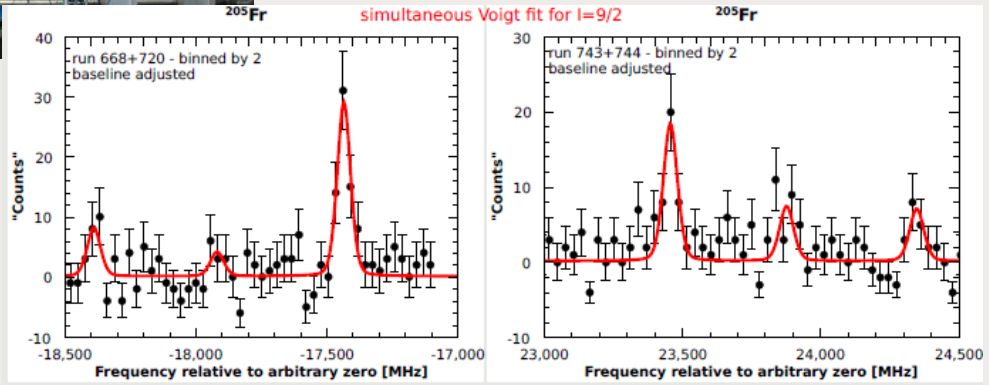




First ever laser spectroscopy of ^{205}Fr

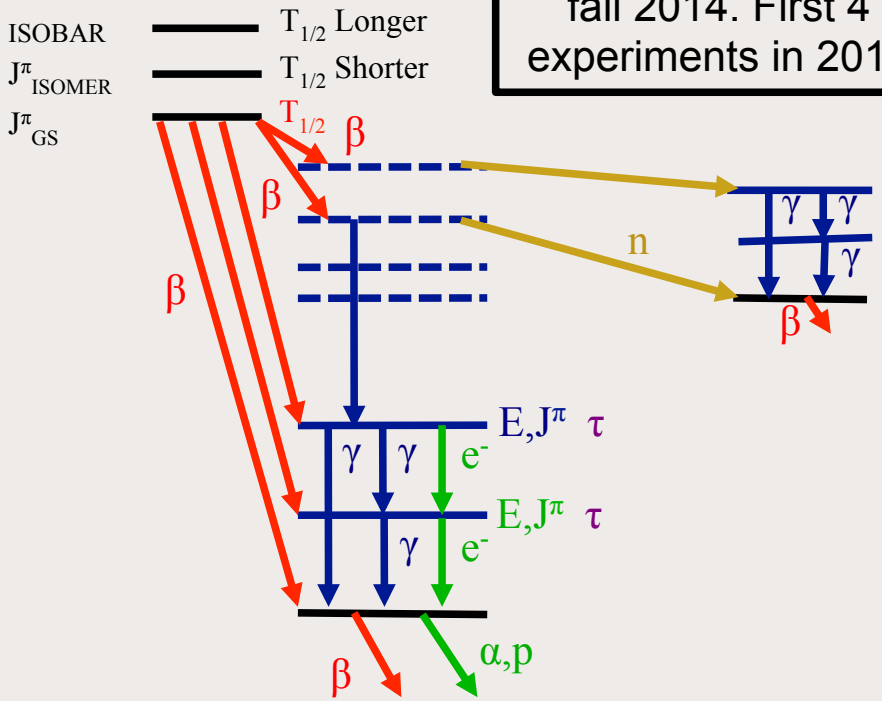
A. Voss et al., PRL 111, 122501 (2013)

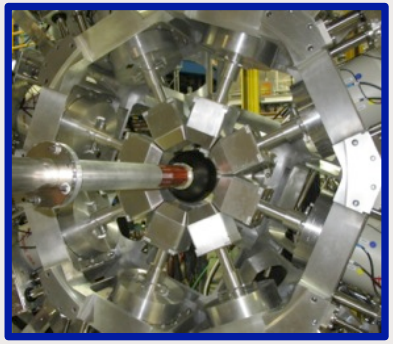
Informs about ground state spin & nuclear size



New GRIFFIN Facility at TRIUMF
Sensitive Decay Spectroscopy

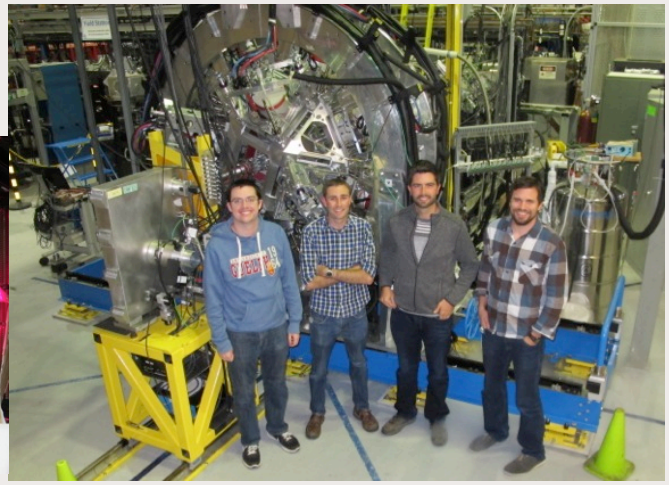
Initial operation since fall 2014. First 4 experiments in 2015





HPGe: 16 Clovers

Detect gamma rays and determines branching ratios, multipolarities and mixing ratios



- Custom designed high-performance digital readout electronics (U. Montreal, TRIUMF)
- Implantation of radioisotope in tape followed by observation of decay radiation
- Specialized detector systems for **gammas**, betas, neutrons, conversion electrons

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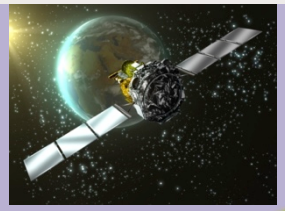
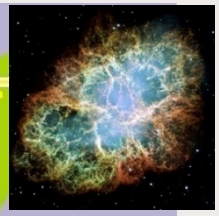
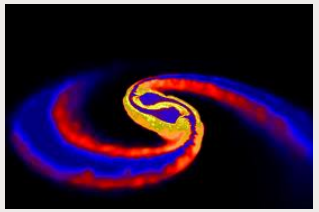
Nuclear Astrophysics at TRIUMF

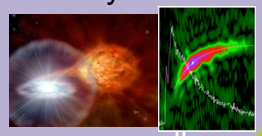
ISAC program has concentrated on directly measuring reactions in proton-rich outflows in novae, x-ray bursters, core collapse supernovae

➔ determine production/destruction of cosmic gamma ray emitters: ^{18}F, ^{22}Na, ^{26}Al, ^{44}Ti




Supernova


Neutron-star merger



Rapid neutron capture process (r-process) remains major mystery in physics:

- **Site of r-process path still unknown, despite producing half the elements above iron**
- **Nuclear Physics data needed, i.e. masses, half-lives, shell structure**
- **Fission of actinides with protons & photons (ARIEL) enable access to r-process path**

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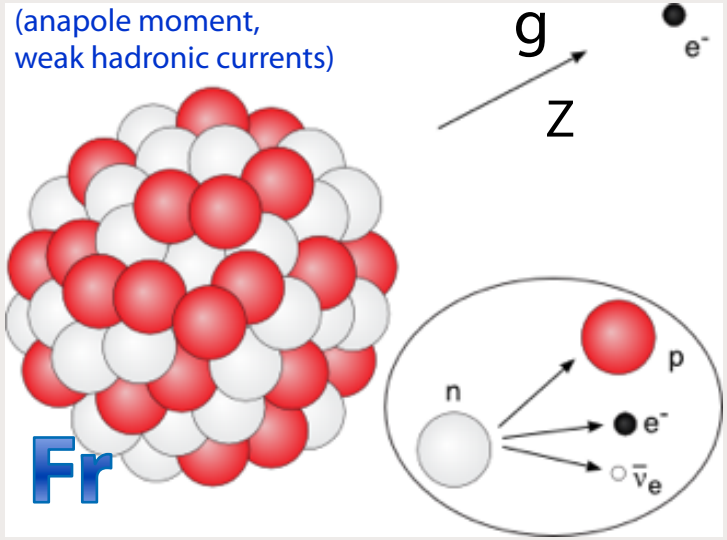
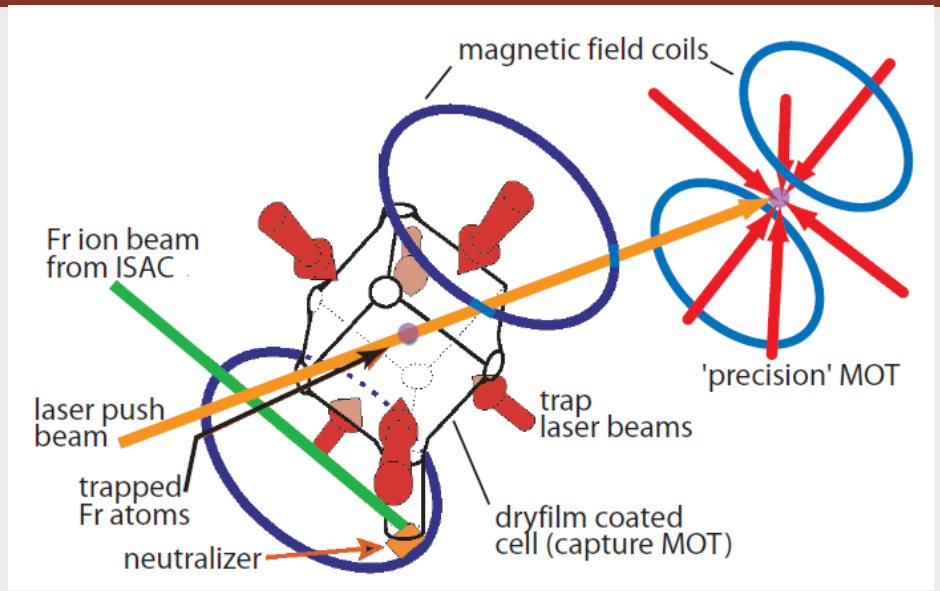
Francium Atomic Parity Violation Program

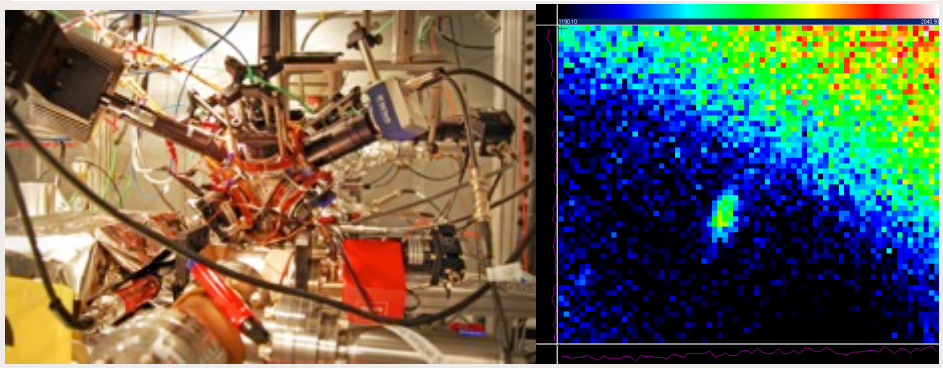
Atomic Parity Violation



Sensitive probe of weak interaction between electron and quarks

Search for Physics Beyond the Standard Model of Particle Physics





Successful Francium trapping of ^{207,209,221}Fr in new Magneto Optical Trap (MOT)

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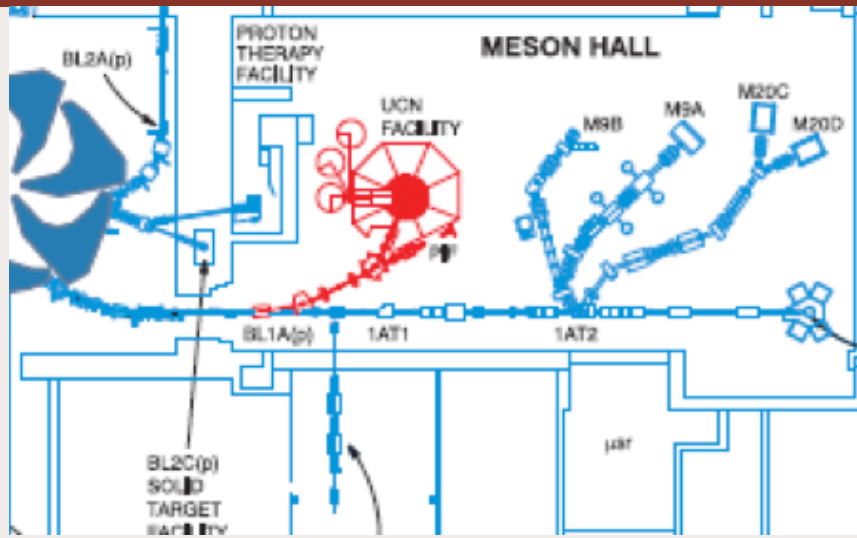
Centre for Molecular and Material Science

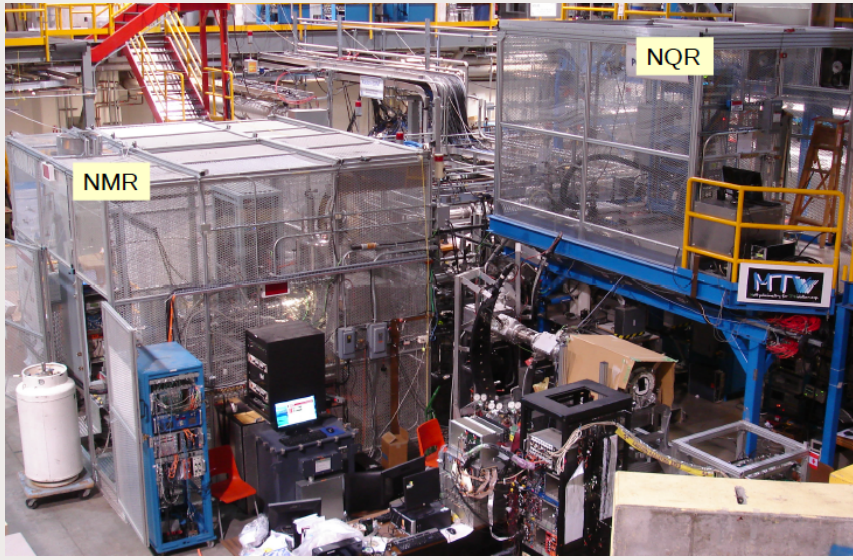
Muon Spin Rotation (MuSR)

- Muon as Probe of Bulk Magnetism
  - New superconductors
  - New semiconductors
  - Lithium diffusion in battery materials
- Muonium Chemistry
  - Hydrogen atom kinetics
- Muoniated Free Radicals
  - Gen IV reactor chemistry

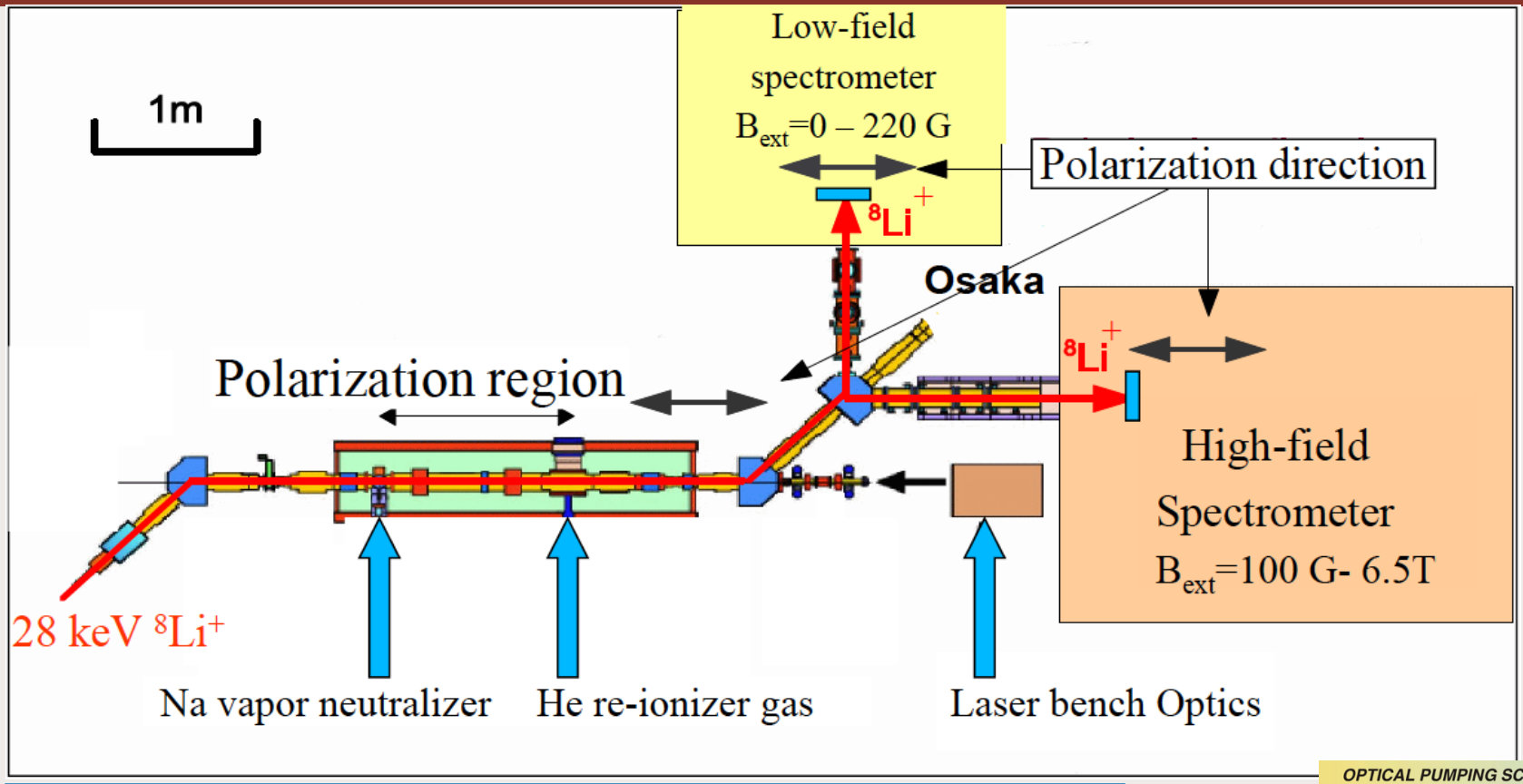
betaNMR

- Magnetic Properties of
  - at interfaces
  - on surfaces
  - in thin films
- Nanometer Depth Resolution

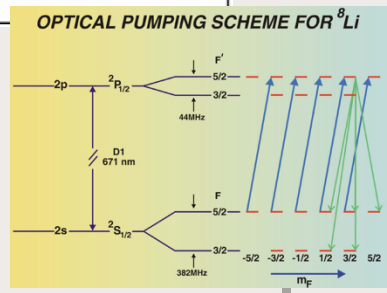




Depth Controlled BetaNMR with spin-polarized ^{8}Li



- Optical pumping with a tuned laser is used to achieve ~70% of spin polarization.
- Electrostatic deceleration is used to control the depth of the implanted ions (2-500nm)



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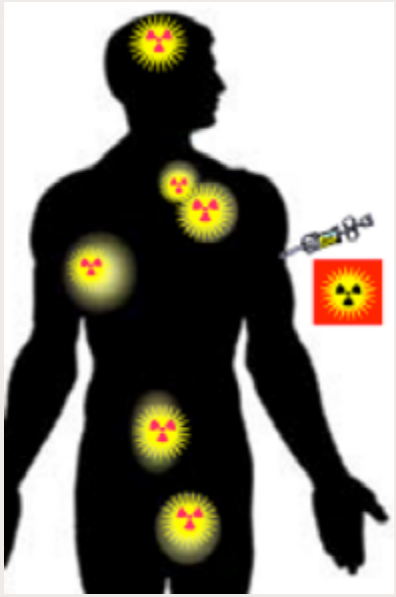
Isotopes for Medical Application: Tumor Treatment and Imaging



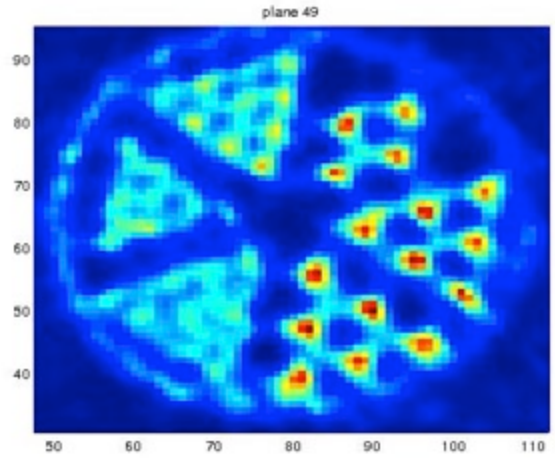
Alpha emitting isotopes:
powerful way for direct tumor treatment

Clustered DNA damage due to
'heavy particle' stopping power, short range.

^{211}At particularly well suited

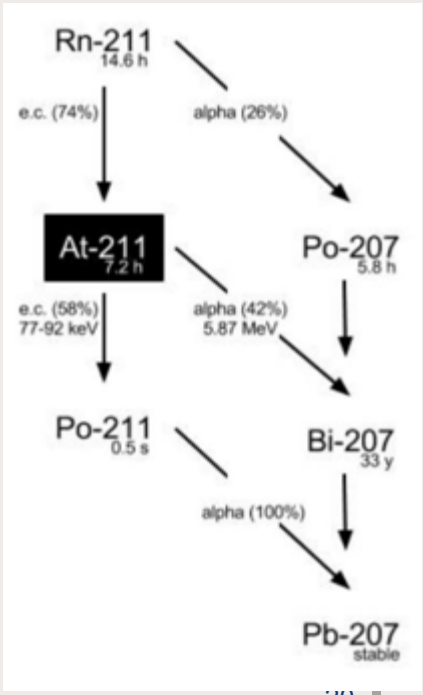
Gamma-emitting ^{209}At can be used to test functionality via imaging

First image ^{209}At with ISAC isotopes

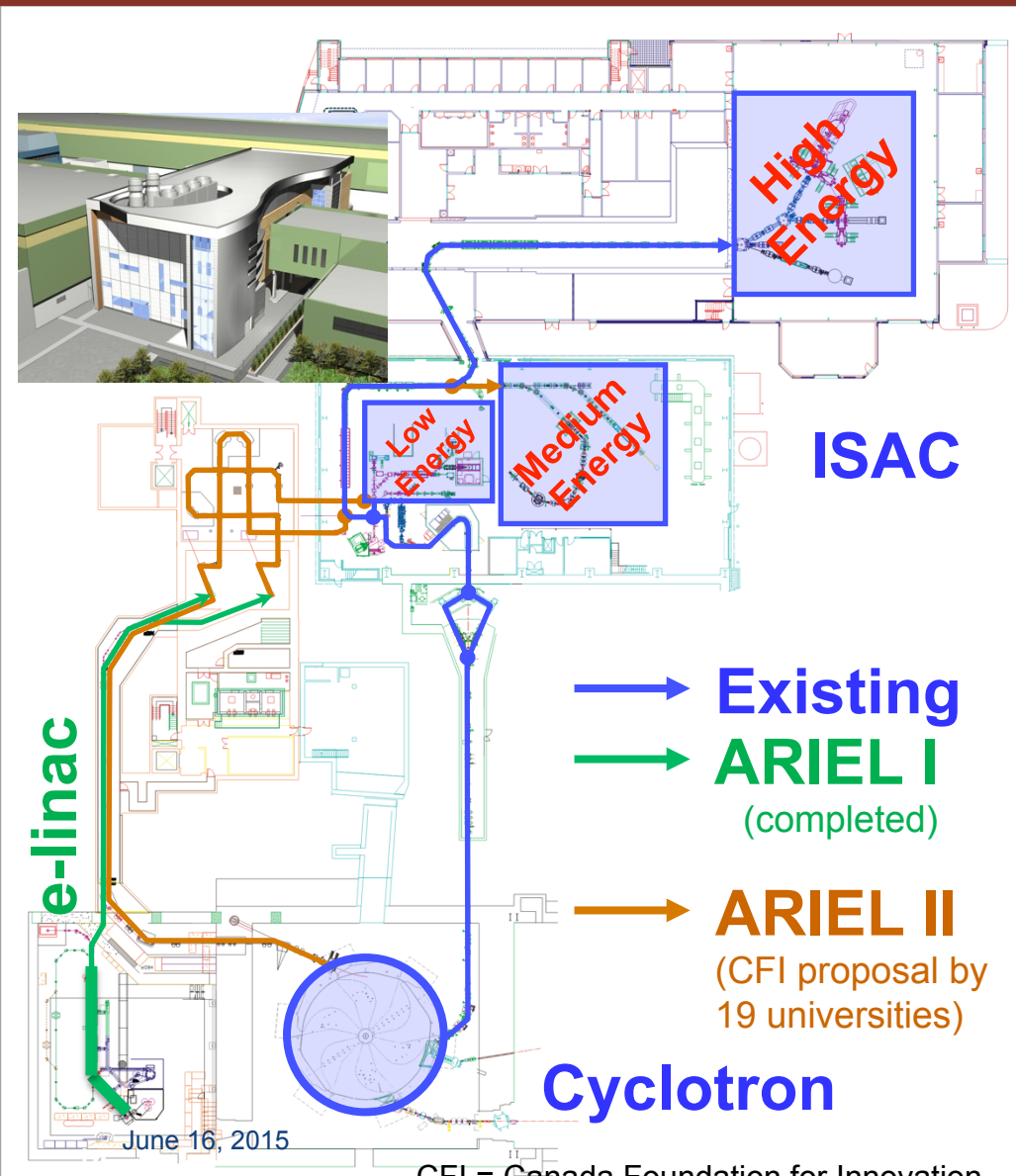


^{211}At is generated via ^{211}Rn at ISAC & ARIEL via proton induced spallation

Another isotope of interest for target alpha therapy is **^{225}Ac** also produced at ISAC & ARIEL



The Advanced Rare Isotope Laboratory (ARIEL)



TRIUMF's flagship project:
➔ Isotopes for Science & Medicine

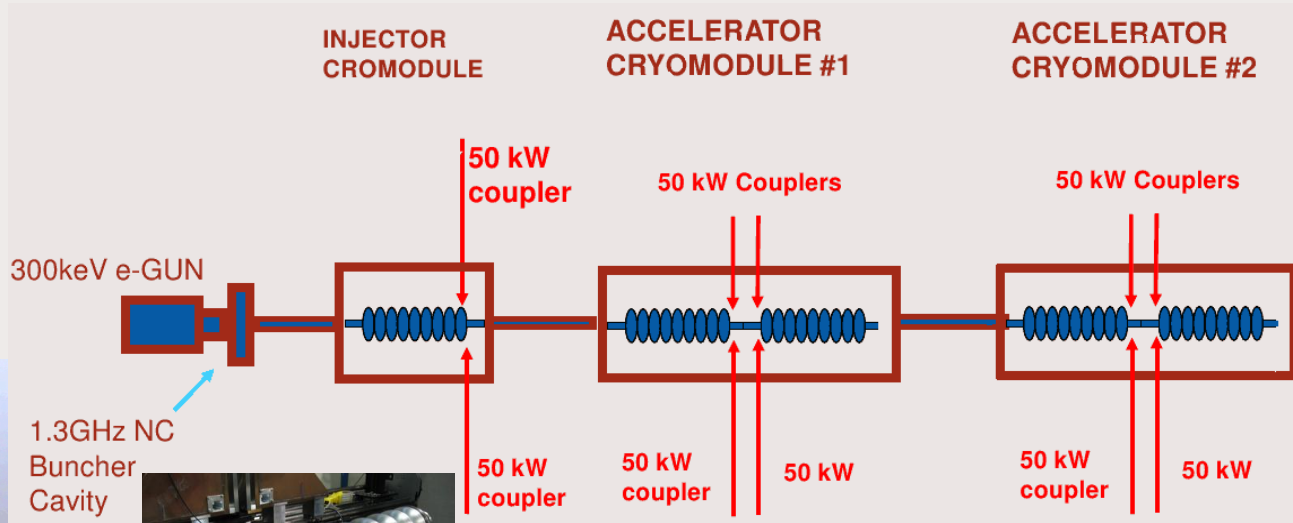
Expanding Canadian capabilities

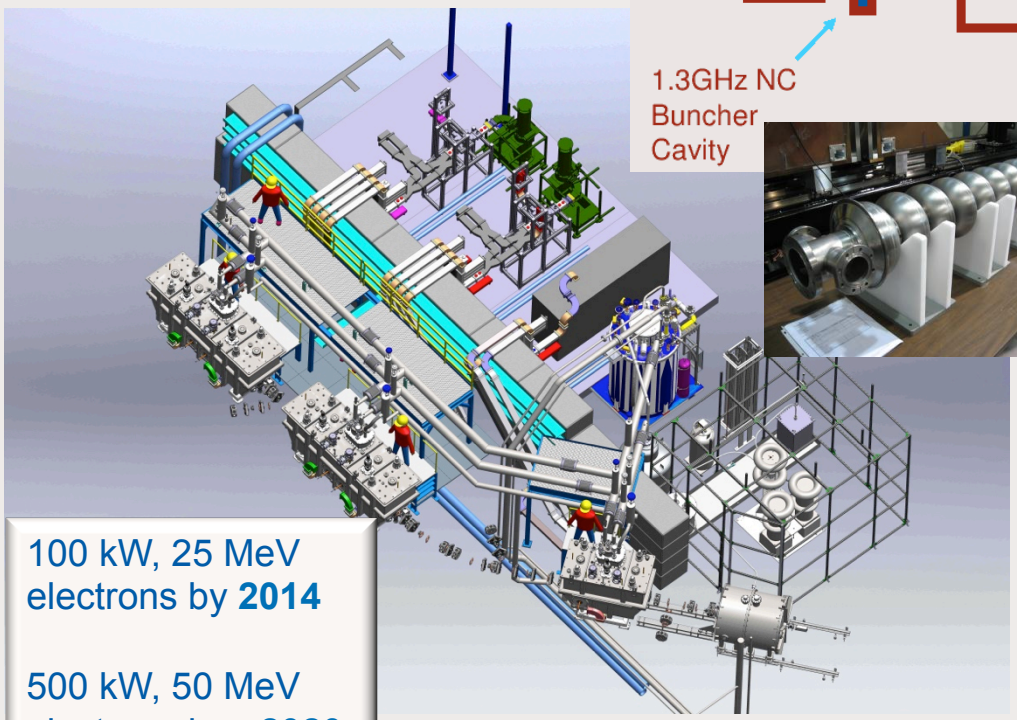
- three simultaneous beams
- more "time" for science
- more and new isotopes
- more national & international users
- phased implementation
- interleave science with construction
- compete with the best in the world

CFI = Canada Foundation for Innovation

e-linac: MW-class Superconducting Electron Accelerator

Kinetic energy (MeV)	50
Average current (mA)	10
Duty Factor	100%
Beam Power (MW)	0.5





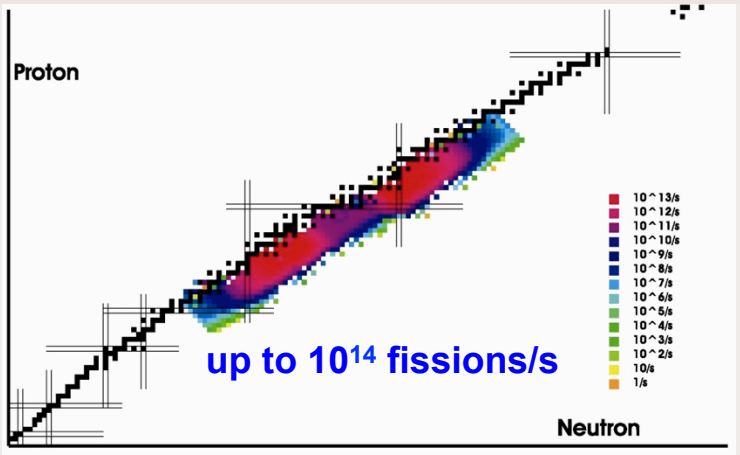
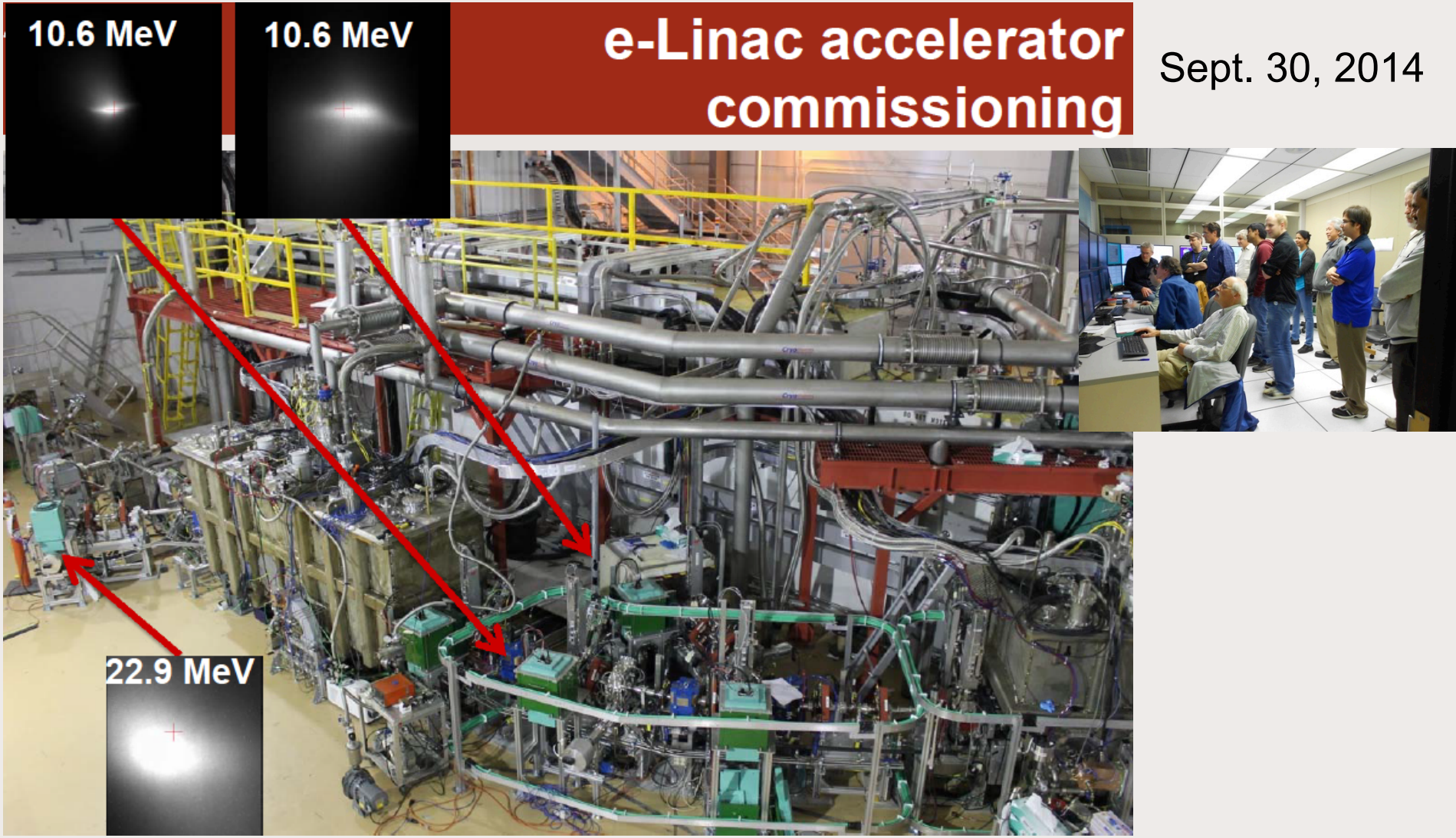


Photo-fission products using 50 MeV 10 mA electrons onto Hg convertor & UC_x target.

100 kW, 25 MeV electrons by **2014**

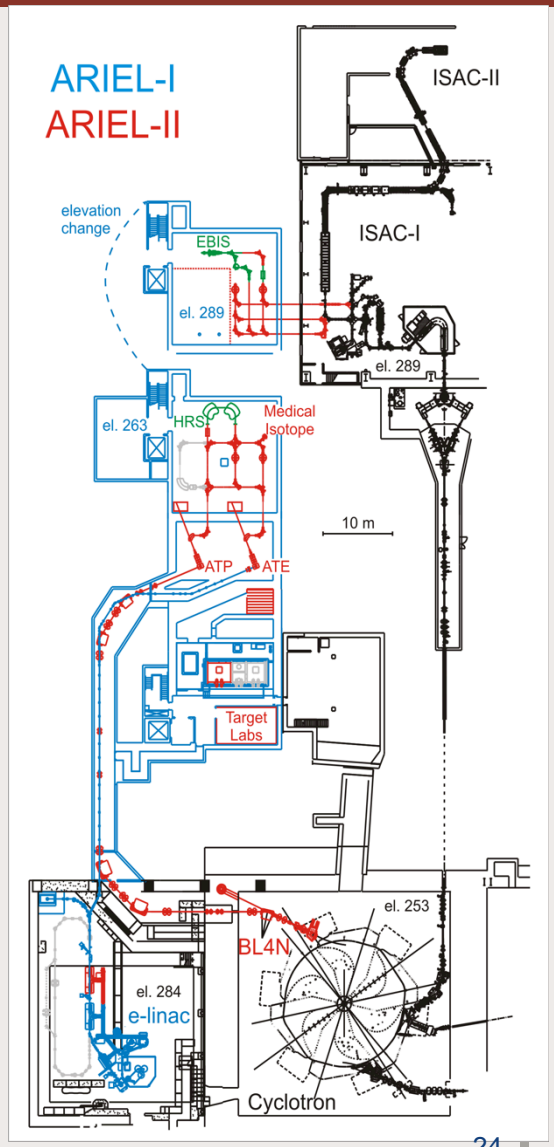
500 kW, 50 MeV electrons by **~2020**

ARIEL e-Linac: on-time, on budget

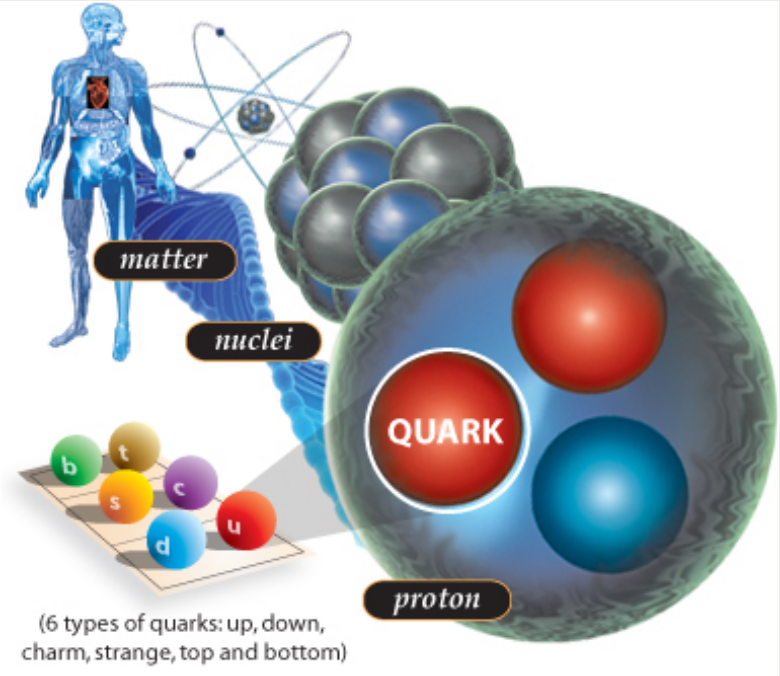


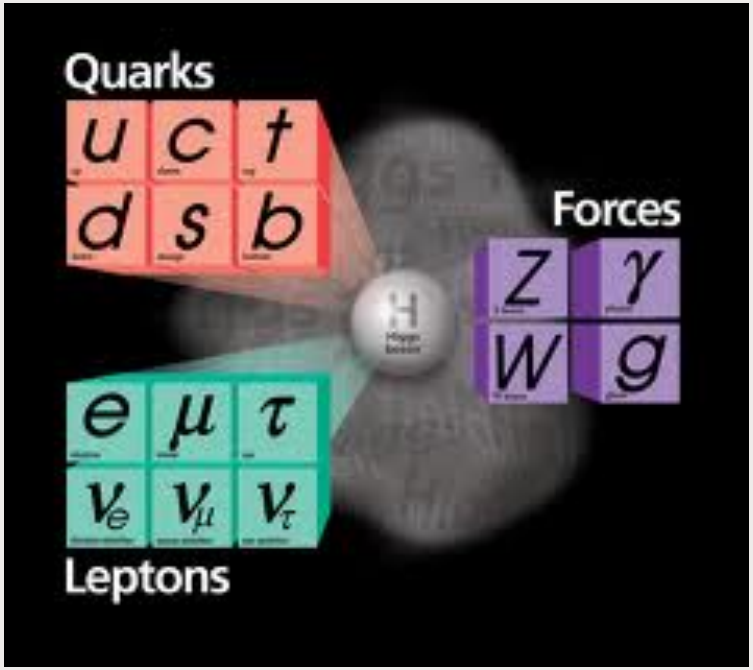
ARIEL: A staged Project

- **ARIEL-I** (2010-2014): (CFI, UVic et al.)
  - Civil construction for full ARIEL scope
  - Electron linac up to 25 MeV, 100 kW
- **CANREB** (2014-2019): (CFI, SMU, UoM)
  - High Resolution Mass Separator
  - EBIS Charge breeder
- **ARIEL-II** (2016-2021): (CFI, UVic et al.)
  - Completion and scientific utilization of ARIEL facility
    - RIB targets & delivery infrastructure
    - New proton beamline
    - Full power electron linac (500kW)
  - Phased approach to bring science online
  - CFI approved project (C$34M)

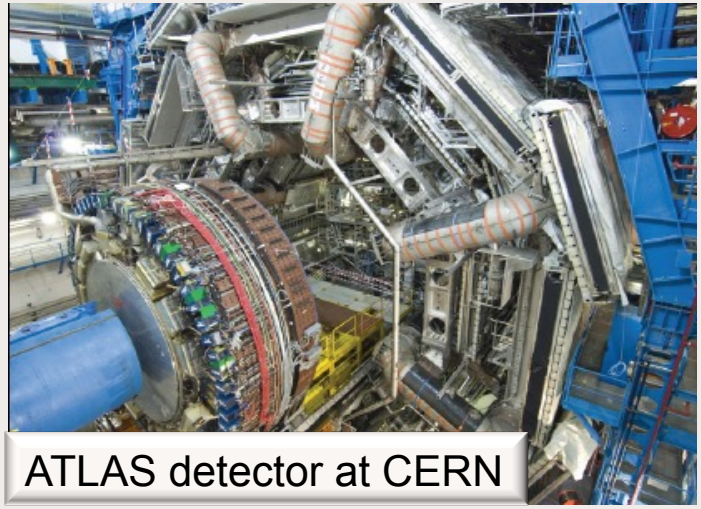


Particle Physics Facilities





ATLAS Tier – 1 Centre



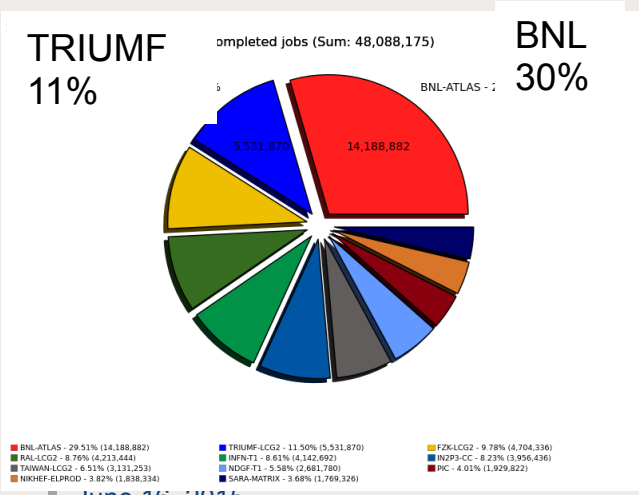
ATLAS detector at CERN

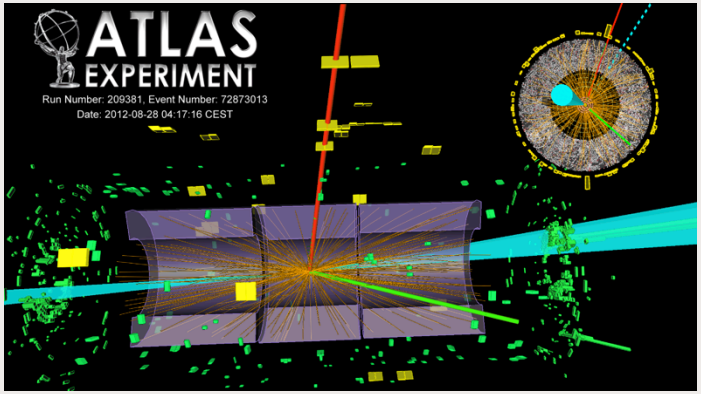
7.8 PB disk
8.8 PB tape
4830 cores
90 servers

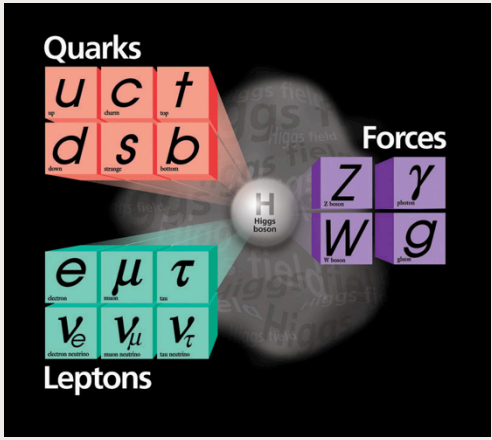
ATLAS Tier 1 at TRIUMF

Urgent, large simulations for Higgs analysis in summer 2012 were done at TRIUMF

Highest availability of 10 Tier-1 centers worldwide

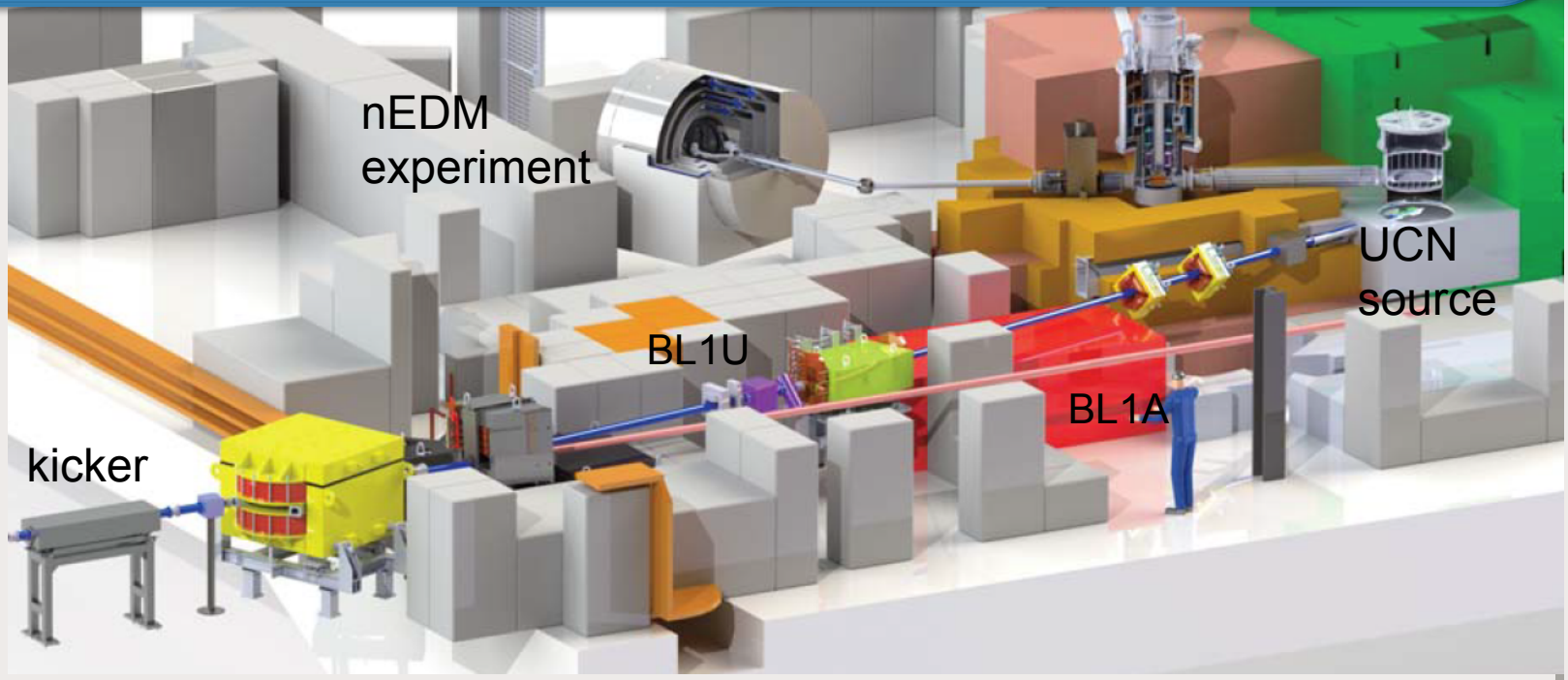






Future Ultra Cold Neutron Facility

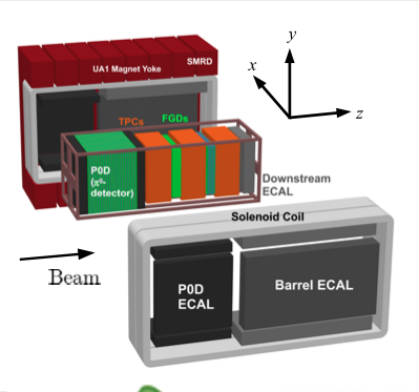
- Japan-Canada collaboration (KEK, RCNP, Winnipeg, Manitoba, UBC, SFU, TRIUMF)
- 40 μA protons on spallation neutron target
- He-II source concept developed and being tested at RCNP
- Small room temperature EDM apparatus with dual co-magnetometer
- Installation of new beam line and source at TRIUMF 2014-16
- **Goal: 3000 UCN/cm^3 in EDM cell, 10^{-28} e•cm sensitivity by ~2020**



TRIUMF's role in the Canadian and international community

TRIUMF & international projects:

- Scientific Leadership
- Unique capabilities and infrastructures
- Detector design and construction
  - T2K near detector TPC, FGD
  - Qweak
  - ALPHA2 cryostat
- Electronics & DAQ development
  - T2K, DEAP, GRIFFIN, MIDAS DAQ



T2K T2K

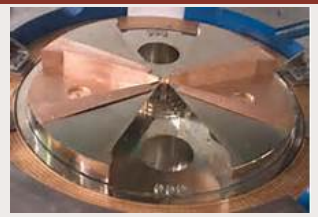
Detector facilities

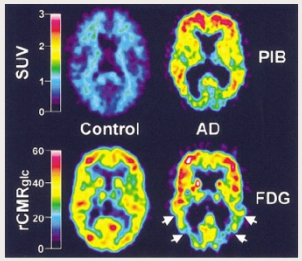
Detector integration

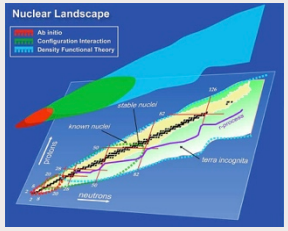
Electronics Development

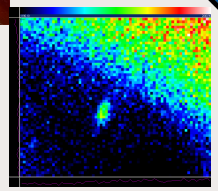
DEAP readout

TRIUMF Research Program & Vision









Create Social & Economic Growth

Connect Canada to the World

Lead in Science

Leverage University Research

neurology & oncology

μSR & β-NMR

Nuclear Medicine

Materials Science

medical isotopes & radiochemistry

superconductors & nano materials

ISOL and SRF

Accelerators

linacs & cyclotrons

rare isotopes

detector & computing advances

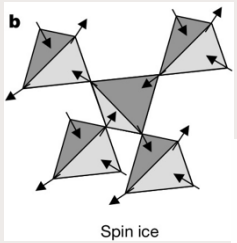
Nuclear Physics

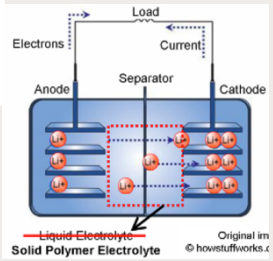
Particle Physics

fundamental symmetries

nuclear structure & astrophysics

fundamental building blocks





ATLAS EXPERIMENT

T2K

Enriched Xenon Observatory EXO for double beta decay

ALPHA

SNO+

DEAP 3600

TRIUMF

Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

Thank you!
Merci

TRIUMF: Alberta | British Columbia | Calgary | Carleton | Guelph | Manitoba | McGill | McMaster | Montréal | Northern British Columbia | Queen's | Regina | Saint Mary's | Simon Fraser | Toronto | Victoria | Western | Winnipeg | York

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