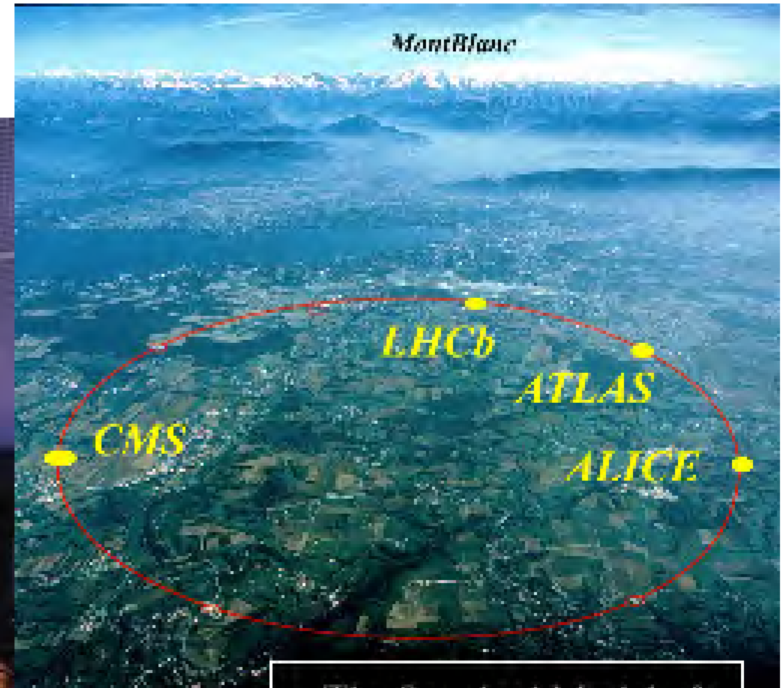
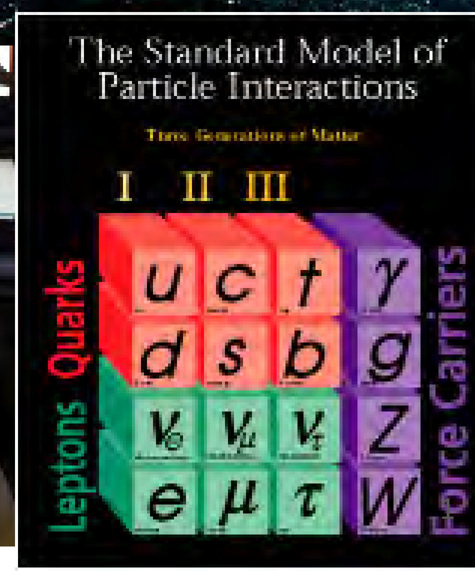
Subatomic Physics Research at UBC





Why Study Particle / Subatomic Physics?

- We address the most fundamental questions in science

- What is matter made of? (and dark matter, and dark energy....)
  - What gives particles mass?
  - Why is universe made of matter? Where is the antimatter?
  - How many dimensions do we live in?

- What are the forces of nature and rules of transformation?
  - Are there new forces waiting to be discovered?

- We use sophisticated tools
  - Particle detectors, with scales from micron resolutions up to the size of office buildings
  - Particle accelerators up to 27 km around and 8 trillion volts
  - Laboratories deep underground for ultrasensitive detectors
  - Computer resources in a "grid" around the world

Why Study Particle / Subatomic Physics?

"Play" with really neat toys

- Giant particle accelerators
- Complex & precise detectors – hardware/software, detector R&D
- Large-scale computer facilities
- Accelerator technology and R&D
- Students typically spend ~>1 yr at host laboratory
- work in small group within large international team, or smaller expts

Spinoff applications

- Large-scale superconducting magnet technology
- Medical imaging (X-ray, MRI, PET)
- Medical treatment (isotopes, particle beams)
- Research (synchrotron radiation, neutrons, muons)
- The WWW was invented at CERN

ATLAS @ LHC

Science at the extremes

LHC

- 27km long accelerator
- 7(14 TeV) collisions recorded(~2015)

ATLAS

- 25m high x46m long, 7000 tons
- Smallest detector element (pixel): 50x400µm, 80.8M of them

Truly global scientific effort

- 3000 scientists
    - ~1000 graduate students
- 174 institutions
- 38 countries

Did we find the Standard Model Higgs?

A. Canepa
TRIUMF / lecturer

ATLAS @ UBC

O. Stelzer-Chilton
TRIUMF /
Adjunct Prof

Diversity

- Close collaboration between UBC faculty & TRIUMF scientists
- Group: 4 faculty, 6 postdocs, 7 students
- Multiple areas of data analysis involvement
  - Searching for
    - SUSY
    - New forces (Z')
    - Using top quarks (Z', Little Higgs,...)
    - Long-lived particles
  - Precision measurements
    - Top quark
    - Higgs boson
- Multiple areas of hardware involvement
  - New Muon Small Wheel (for 2018)
  - Transition Radiation Tracker readout electronics
  - Inner Detector Alignment
  - Monitoring
- Many responsibilities within the collaboration
  - Leading physics groups (Top, SUSY, Exotics)
  - Hardware components (TRT, L1 Calorimeter)

C. Gay
Full Prof
(absent today)

A. Lister
Assistant Prof
(absent today)

Belle II — a next-generation flavor factory

Christopher Hearty hearty@physics.ubc.ca Hennings 268 Friday 1:30 – 4:30 pm
Janis McKenna janis@physics.ubc.ca
Tom Mattison mattison@physics.ubc.ca

- Belle II: e^+e^- collider experiment operating at the same energy as BaBar and Belle, but with 50$\times$ the luminosity.
- Data taking starts 2016, at the KEK laboratory in Japan.

BaBar and Belle were cited in the announcement of the 2008 Nobel Prize

- Broad set of measurements sensitive to physics beyond the Standard Model. Sensitivity can exceed direct search capabilities of the LHC.
- Detector development, plus analysis of first data.
  - advanced photosensors; electronics; analysis; FPGA programming…

THE YEAR IN SCIENCE
Discover
100 top stories of 2013

Le Prix La Recherche 2012

physicsworld
TOP 10 BREAKTHROUGH 2011

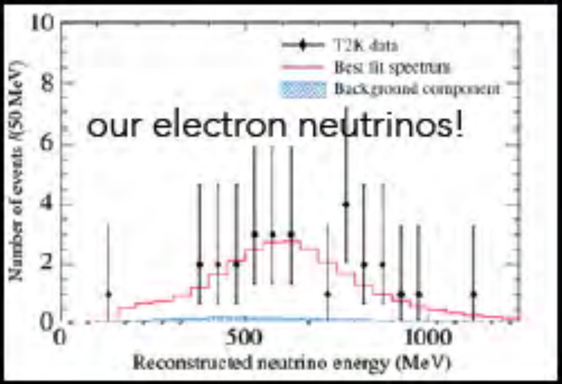
T2K

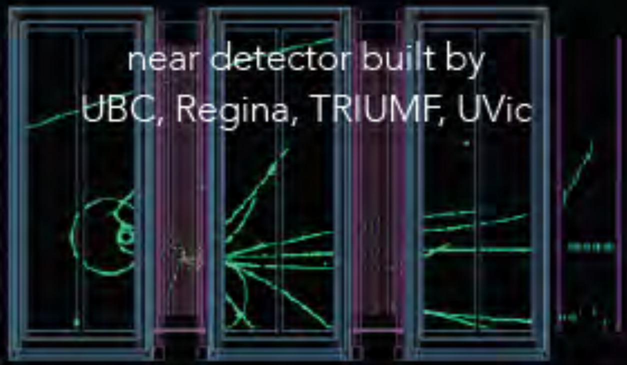
Faculty: S. Oser, H. A. Tanaka

- Study the transmutation of neutrinos as they traverse 295 km across Japan to the Super-Kamiokande detector
  - probe fundamental properties of neutrinos with unprecedented precision and sensitivity
- 2013: discovery of muon neutrinos converting to electron neutrinos!
  - Next step: Search for CP violation in neutrinos to find clues to why the Universe is matter-dominated

this could be you!

Looking for a student to join our effort!



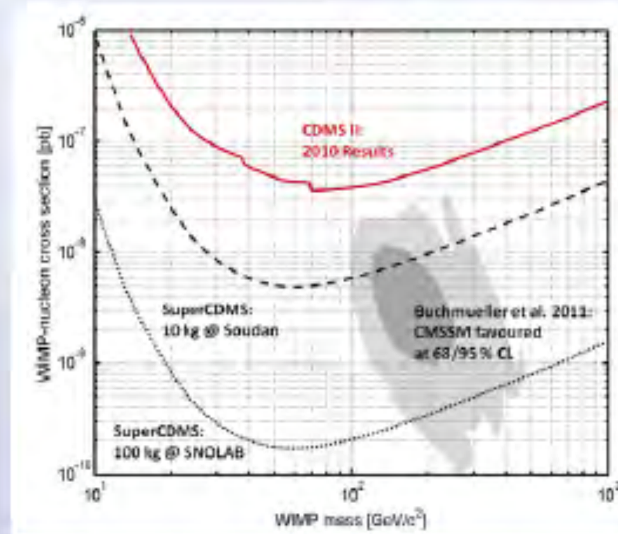


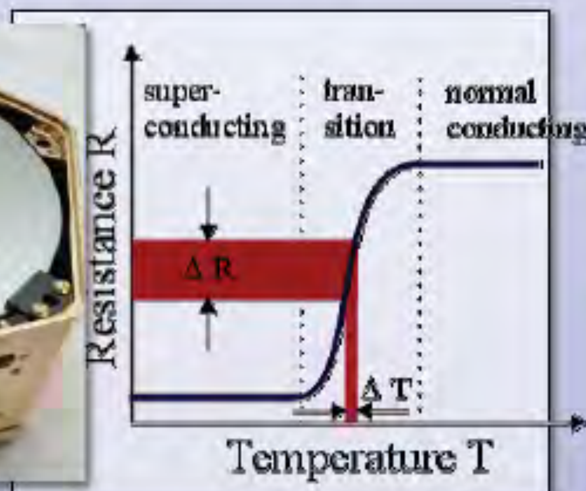
SuperCDMS Dark Matter Experiment

Direct search for dark matter candidates using cryogenic germanium detectors deep underground.

UBC Faculty: Scott Oser and Hirohisa Tanaka

Superconducting sensors operated at transition point used to measure tiny increase in crystal temperature caused by dark matter interactions, along with ionization of crystal.





Currently operating ~10kg experiment in Soudan, Minnesota, and planning for 100kg next-generation experiment in SNOLAB

Particle Physics: Rare Decay Group

Prof. Doug Bryman (Warren Chair)

doug@triumf.ca
At TRIUMF 2-5pm Friday

Seeking new physics at 1000 TeV mass scales by searching for deviations from precise SM predictions.

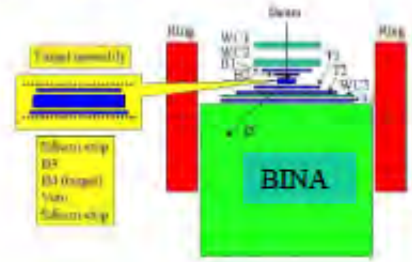
Advanced hardware development; thesis topics with great discovery potential!

PI E NU

Data analysis topics

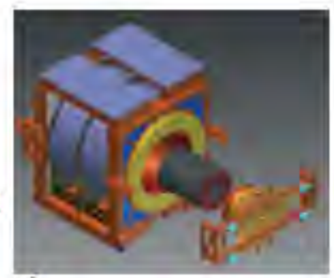
Most precise test of e-μ universality:

$$R_{\pi\to e}=\frac{\Gamma(\pi\to e\nu(\gamma))}{\Gamma(\pi\to \mu\nu(\gamma))}$$



KORKA

Profs. Bryman and Hasinoff



New Experiment at Fermilab to Measure $K^{+}\to\pi^{+}\nu\bar{\nu}$

Highest sensitivity: 1000 events at $B_{SM} = (7.8 \pm 0.8) \times 10^{-11}$

- 5σ reach for discovery of non-SM effects ($B>1.3\ B_{SM}$)
- Many other important rare decay searches and measurements
- Drift chamber R&D, design and construction

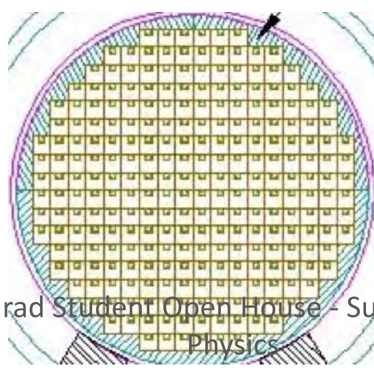
TREK @ J-PARC

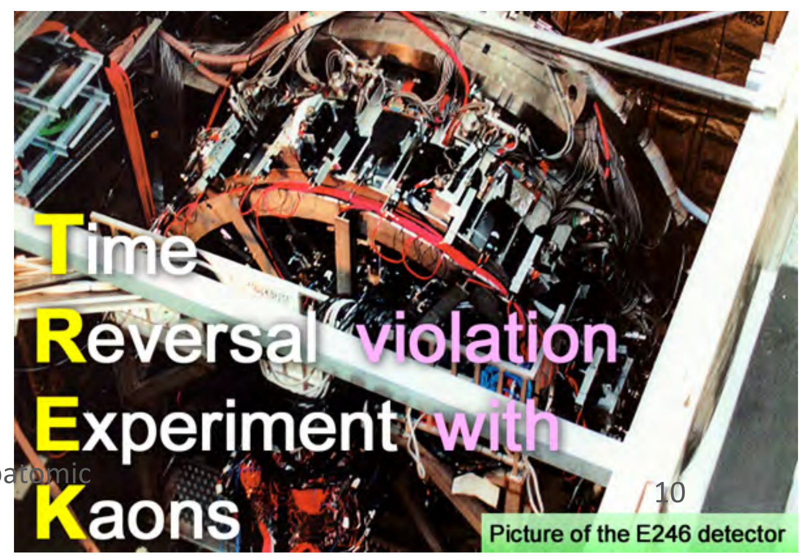
TREK is preparing two experiments at J-PARC

- **$K_{e2}/K_{\mu 2}$ measurement to test lepton universality & a search for heavy sterile neutrinos (2014-15)**
  - **- Use E-246 apparatus with partial upgrades**

Prof Hasinoff

- **Measurement of the T-violating transverse muon polarization in $K_{\mu 3}$ decay (~2016)**
- **"K1.1BR" secondary beamline has been commissioned**
- **Large potential for discovery of New Physics beyond the SM**
- **UBC/TRIUMF is constructing a new 256 element sci-fibre target**





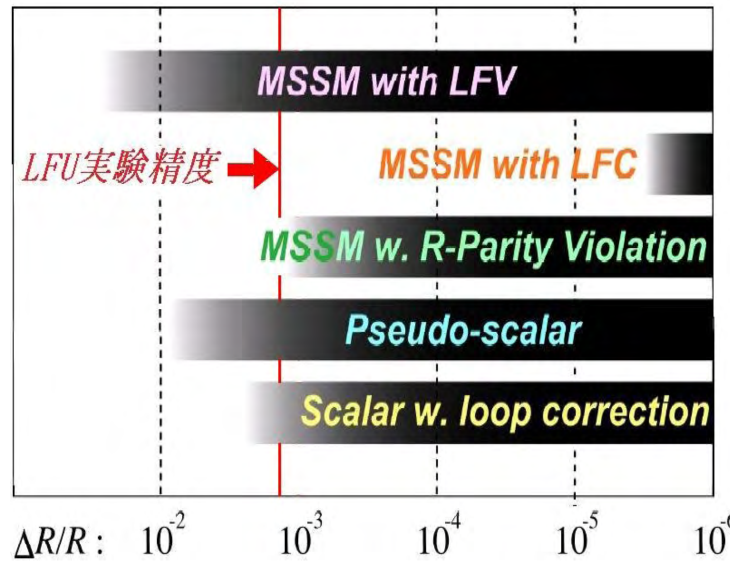
Picture of the E246 detector

Stopped K^+ Experiments @ J-PARC (Japan)

Measurement of R_K = G(K^+ → e^+n) / G(K^+ → m^+n)

and a search for heavy sterile neutrinos

Prof Hasinoff



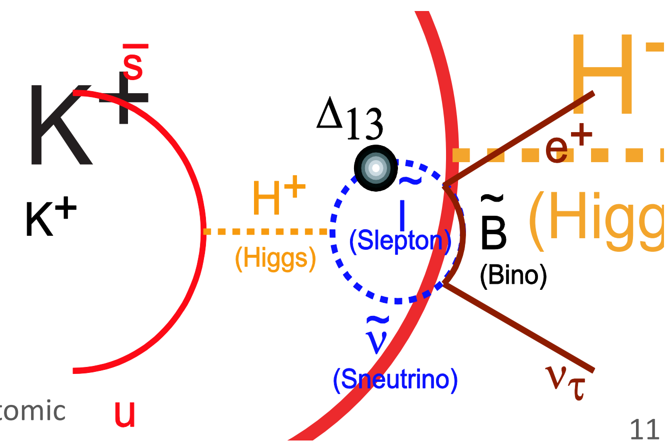
- Possible New Physics
  - MSSM with LFV
  - MSSM with R-parity violation
  - Pseudoscalar interaction
  - Scalar with loop correction

- SUSY with LFV for K_{e2}

$$R_K^{LFV} = R_K^{SM}\left(1 + \frac{m_K^4}{M_{H^+}^4}\cdot\frac{m_\tau^2}{m_e^2}\Delta_{13}^2\tan^6\beta\right)$$

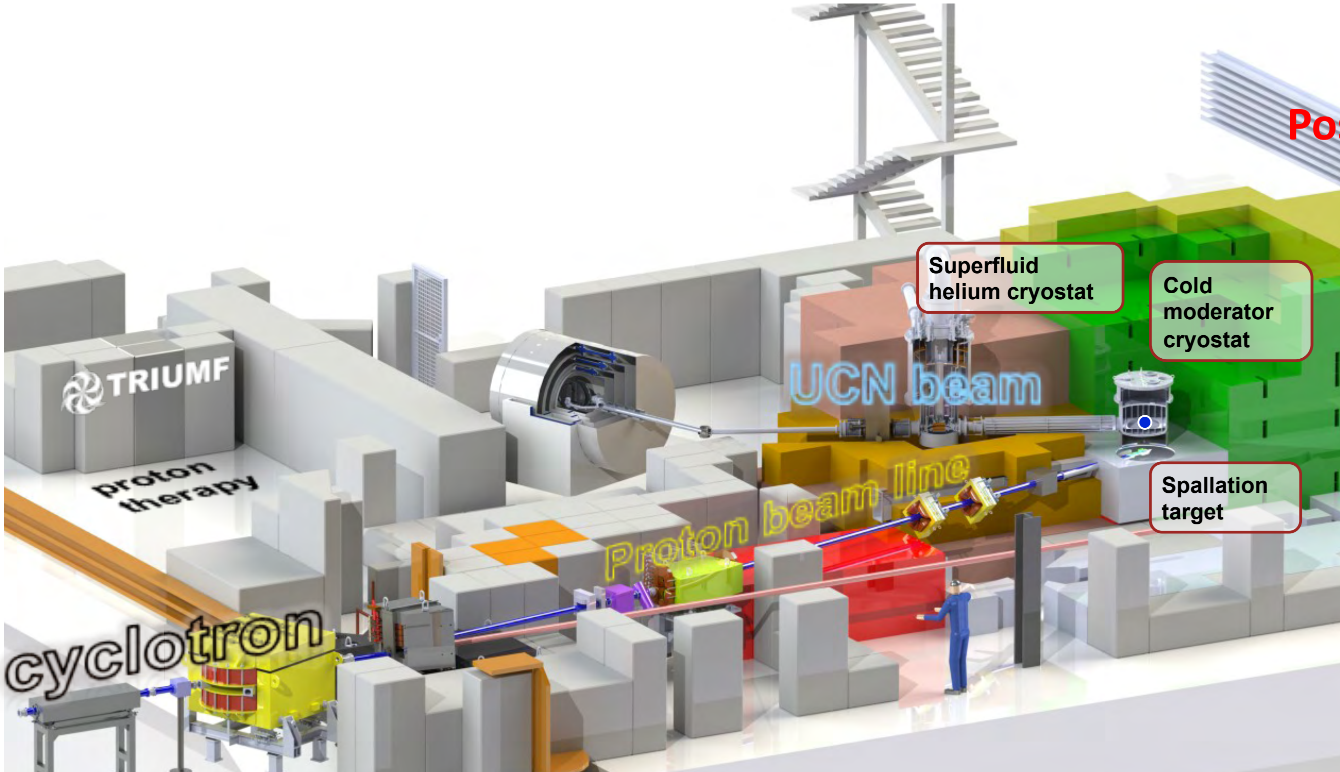
- Charged Higgs H^+ mediated LFV SUSY
- Large enhancement from m_t^2/m_e^2
- A sizable effect -- D$R_K/R_K \leq 1.3\%$ is possible

[Masiero, Paradisi and Petronzio, Phys. Rev. D74 (2006) 011701]



Ultra-Cold Neutrons at TRIUMF

- Ultra-cold neutrons (<300 neV) are **ideal for studying fundamental properties** of the neutron
- A facility with **unprecedented UCN densities** is built at TRIUMF (first UCN 2016)
- First experiment: search for the **E**lectric **D**ipole **M**oment of the neutron
  - Rules out many theories over the last decades
  - Can contribute to solving the **matter-antimatter asymmetry** puzzle



planned UCN facility in the Meson hall at TRIUMF

Possible grad student projects:

Development
- neutron storage/HV cell
- UCN beam line
- UCN detector
- magnetic shields
- optical comagnetometer

Analysis/Simulation
- systematic effects
- field simulation

Measurements
- UCN beam characterisation
- Cold neutron flux

etc.....

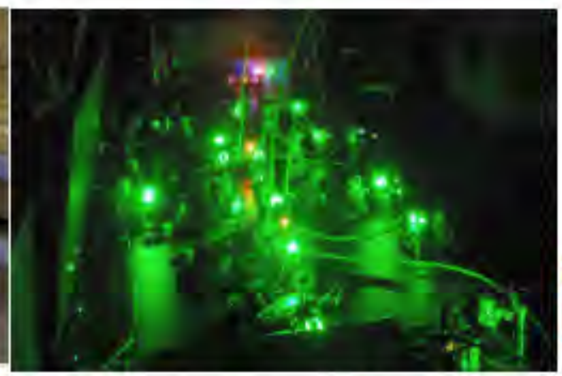
CONTACT: David Jones, Kirk Madison, and Taka Momose (momose@chem.ubc.ca)

ALPHA Antihydrogen Project at CERN

http://cern.ch/alpha; http://triumf.ca/alpha

- Trapping and spectroscopy of antimatter atoms (antihydrogen)
- Precision test of the Standard Model
- Antimatter gravity measurement

Antihydrogen Detector



Lyman-alpha laser @ Momose lab

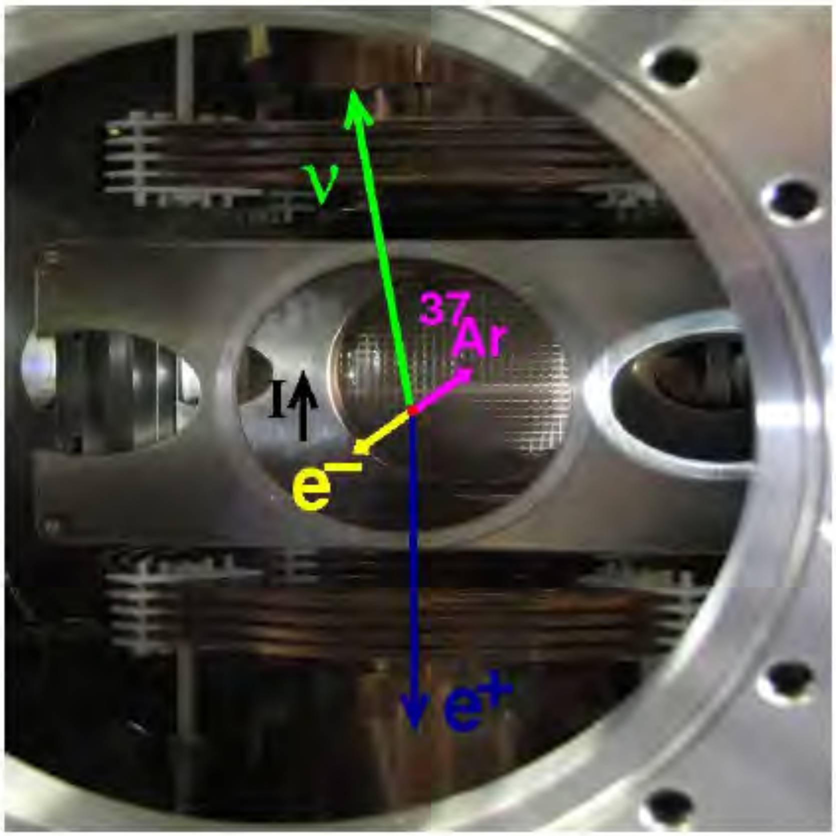
- **Student opportunities**
  - International and interdisciplinary project
    - Particle, Atomic Plasma Physics; laser, microwaves, cryogenic, ion/atom traps
  - Strong UBC/TRIUMF activities
    - Momose: laser spectroscopy and cooling
    - Hardy: microwaves
    - Fujiwara: particle detector, gravity measurement

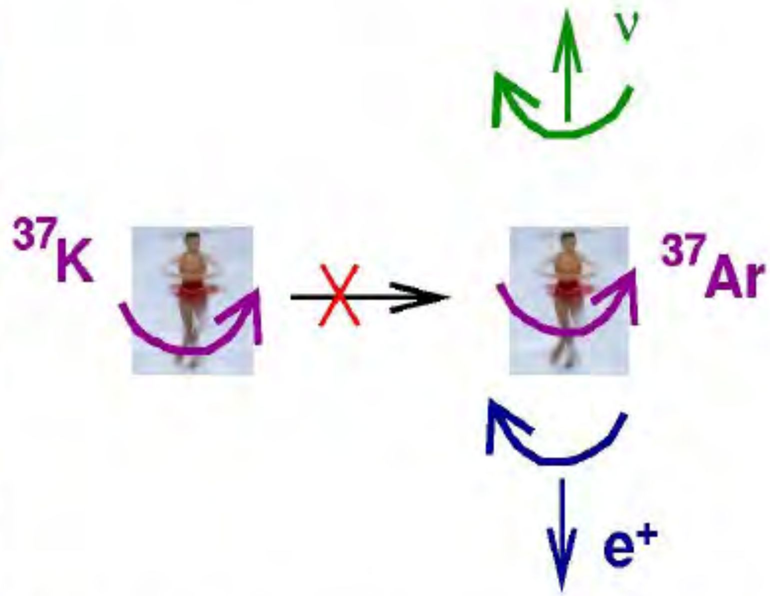
Our graduate students play leading roles in the project!

CONTACT: Walter Hardy (hardy@phas.ubc.ca), Taka Momose (momose@chem.ubc.ca)

TRIUMF's Neutral Atom Trap for Beta Decay
Are neutrinos always left-handed?

Neutrino asymmetry w.r.t. nuclear spin will tell us





This decay pattern is forbidden unless Right-handed neutrinos exist

Contact: John Behr, TRIUMF for atomic, nuclear experiment
See also Saturday tour

TITAN

ISAC-TRIUMF

TRIUMF's Ion Trap for Atomic and Nuclear Science

Ion-trap for precision mass measurements, fed by TRIUMF's ISAC accelerator to produce rare short-lived isotopes

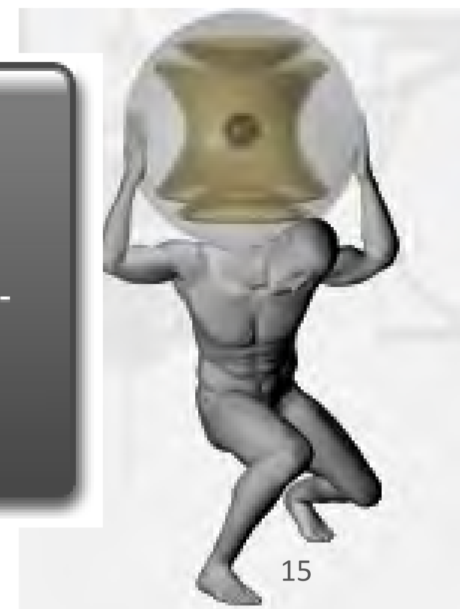
Dr. Jens Dilling (TRIUMF, UBC adjunct)

See TITAN and Jens on TRIUMF tour Saturday.

The TITAN Experimental Program

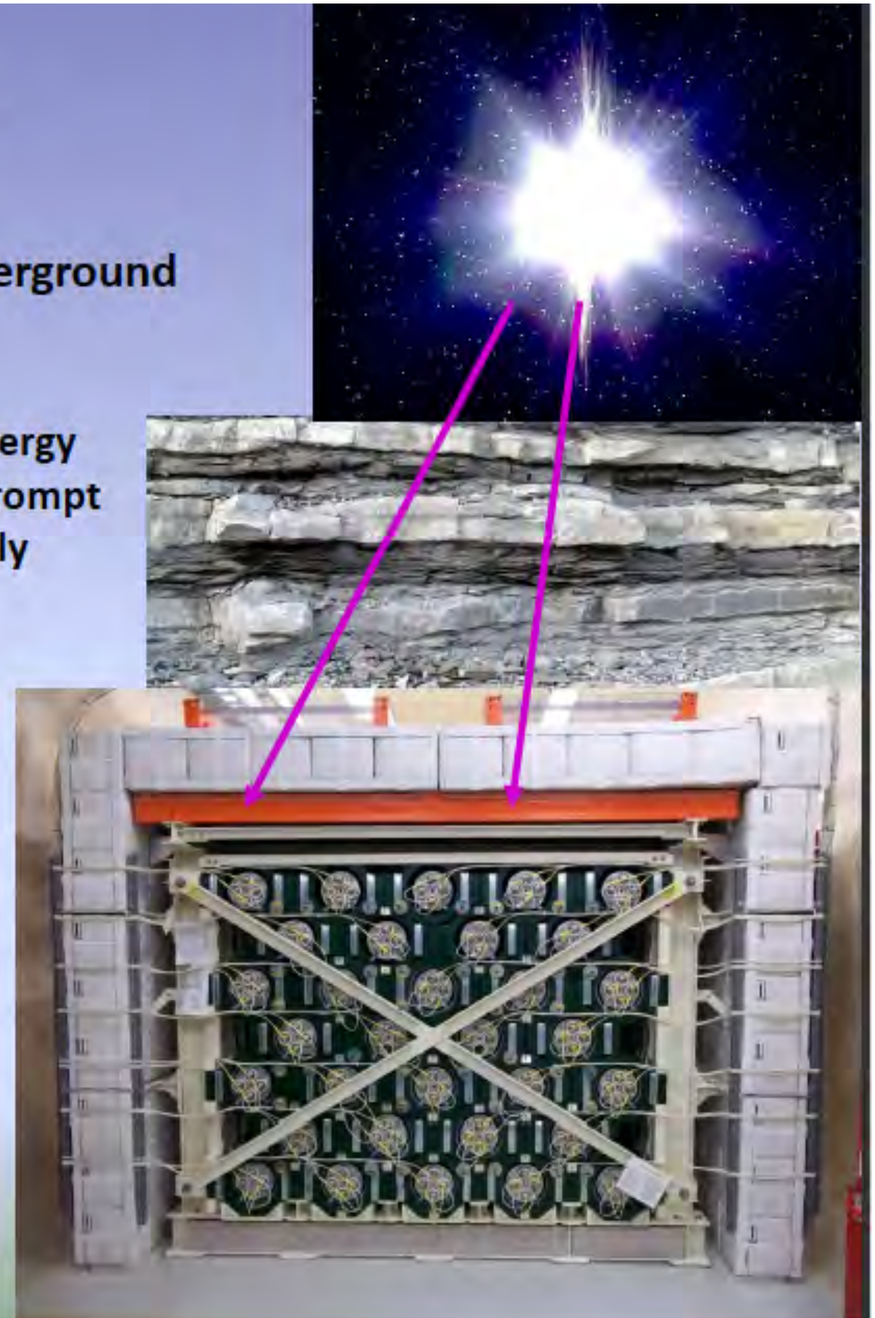
Measuring the mass of short-lived isotopes with high precision

Radioactive isotopes from ISAC are sent to TITAN to undergo cooling, charge-breeding and trapping. The entire process occurs in about 10 milliseconds, allowing radioactive isotopes with short half lives to be studied.



Stanley Yen, TRIUMF stan@triumf.ca

HALO (Helium And Lead Observatory)
A supernova neutrino detector 2 km underground in SNOLAB



A core-collapse supernova emits 99% of its energy in the form of neutrinos. Neutrinos offer a prompt early warning of a supernova, and give the only direct information about the nuclear processes occurring inside.

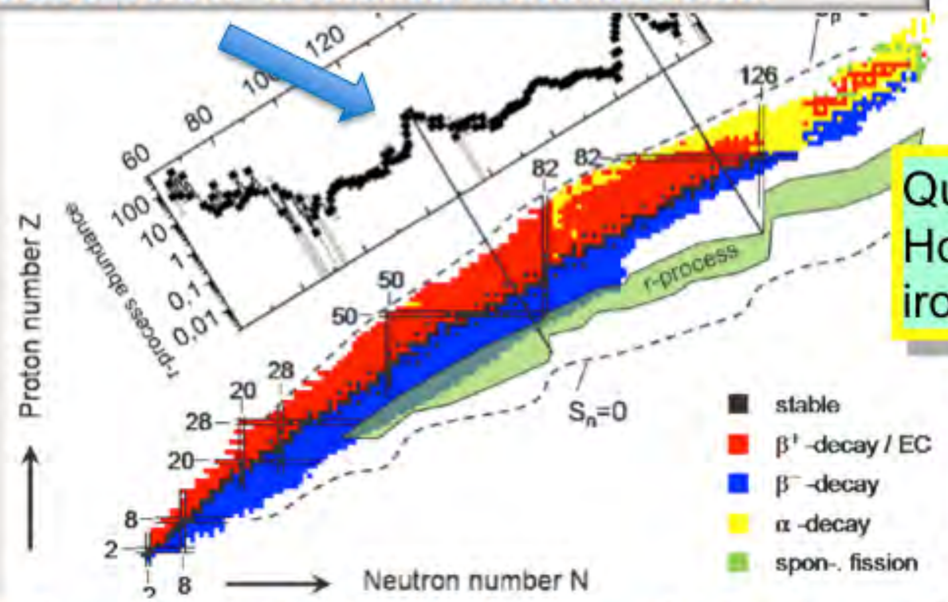
HALO is a dedicated supernova detector with primary sensitivity to ν_e, in contrast to other detectors which are primarily sensitive to anti- ν_e.

Opportunities exist for development of monitoring systems for HALO, and R&D of a 2nd generation supernova detector.

Origin of the heavy chemical elements

Each heavy atom in our body was built and processed through ~100-1000 star generations since the initial Big Bang event!

characteristic patterns in element abundances are result of properties of atomic nuclei & nuclear reaction rates

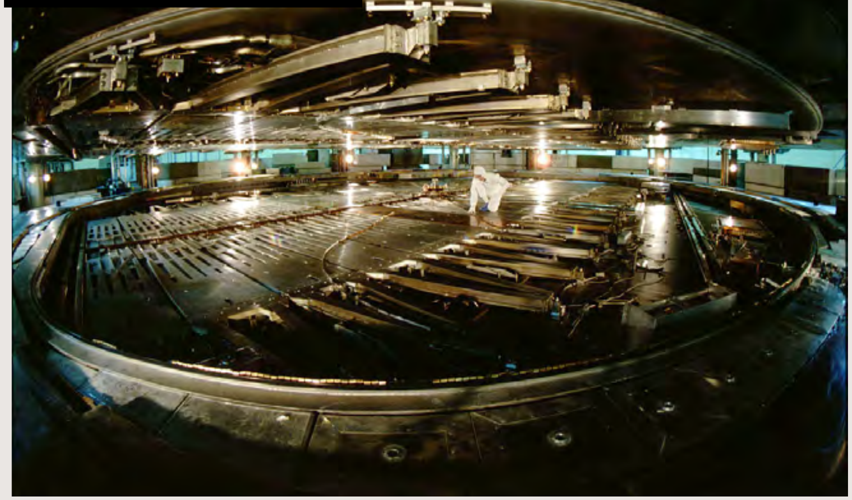


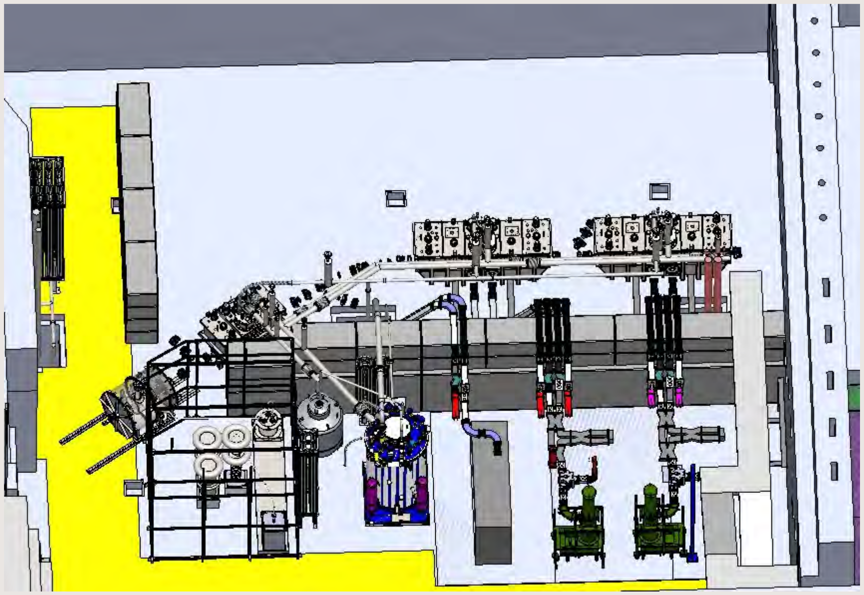
Question 3
How were the elements from iron to uranium made ?

ISAC at TRIUMF allows us to study short lived nuclei that are only produced for brief moments in star explosions or star collisions

➔ **Unraveling the mystery of where the heavy elements are made in the Universe**

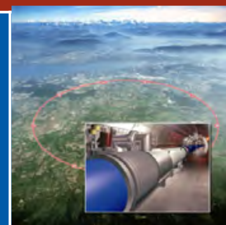
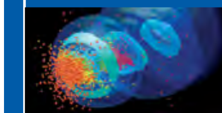
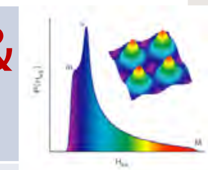
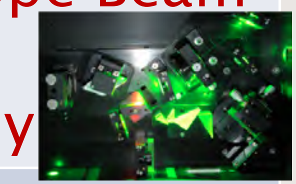
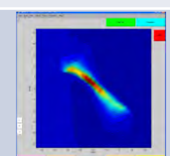
Accelerator Science & Engineering Research at TRIUMF





Lia Merminga, Director Accelerator Operations, TRIUMF

Advanced Accelerator R&D at TRIUMF

R&D areas / Accelerators	ARIEL 	ISAC 	ARIEL ERL/FEL 	LHC/ Isolde 	ILC 	Plasma accelerators 
SRF science & technology 	●	●	●	●	●	
Rare Isotope Beam science & technology 	●	●		●		
Beam Physics 	●	●	●	●	●	●
Advanced concepts			●	●	●	●
Beam Diagnostics 	●	●	●	●	●	●

TRIUMF
Canada's National Lab for Subatomic Physics

500 MeV high-current cyclotron
- Experiments and test beam facility

ISAC-I, ISAC-II radioactive beam facility

ARIEL electron linear accelerator

Infrastructure, engineering and technical center of Canadian particle physics
- Large Hadron Collider kicker magnets, installed at CERN
- ATLAS forawrd calorimeter at LHC
- BaBar drift chamber
- Rare-decay detectors
- Electronics, computing, engineering
- T2K detector
- Belle-II calorimeter upgrade
- Test beams

Isotopes for medicine, research

Tour Saturday