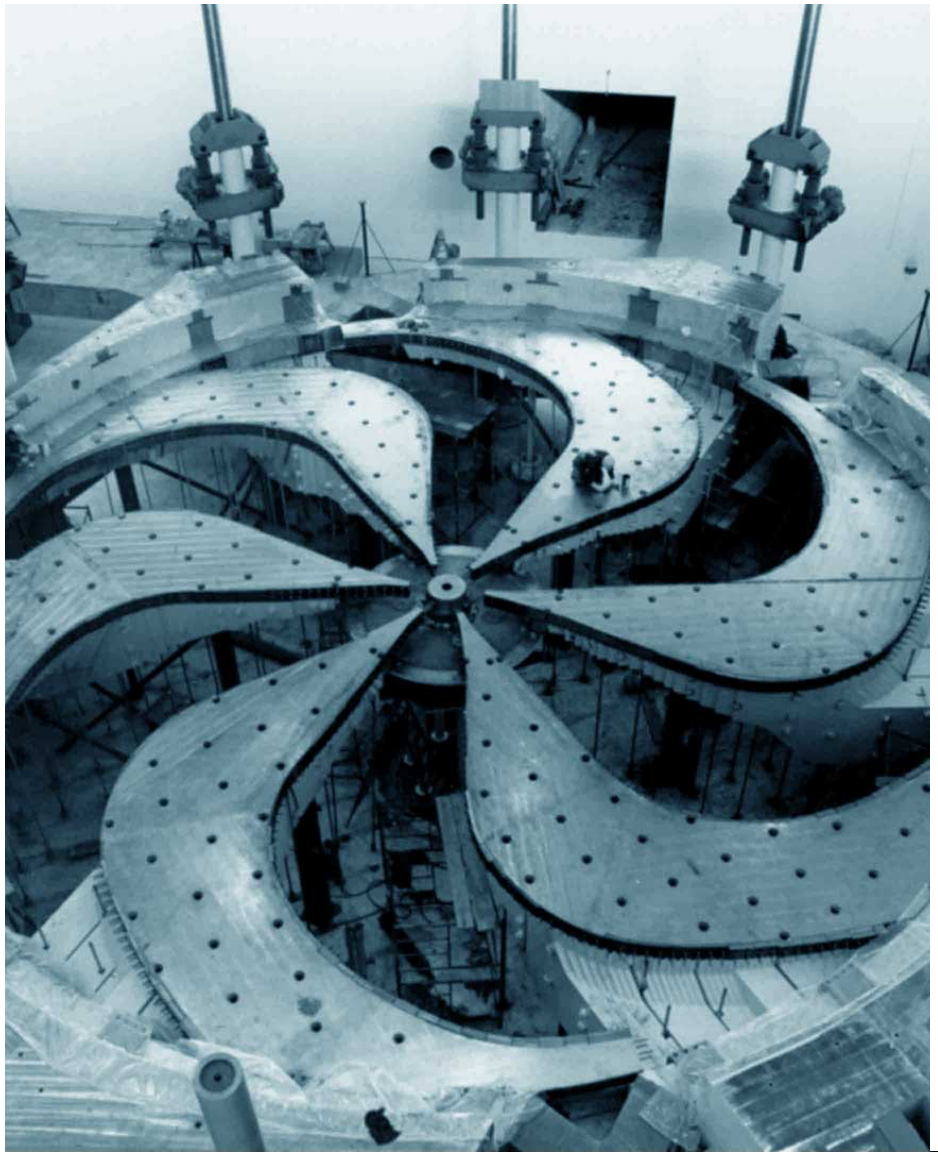
TRIUMF

Status and Plans of Materials Science at TRIUMF



Kenji M. Kojima

Research Scientist, CMMS, TRIUMF

Science Week, August 17-21, 2020

2020-08-16

TRIUMF

Materials Science

- TRIUMF hosts the world's only radioactive nuclear beam resonance facility for thin-film and interface research.

β-NMR

- TRIUMF is the sole facility in the Americas that provides muon spin relaxation spectroscopy for quantum and chemical systems.

μSR

- TRIUMF materials science program is well established and provides critical complementary research probes to Canadian and International experimenters.

Users

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Centre for Molecular and Materials Science (CMMS)

Seven Faculty and Scientists,
Three Technicians, collaborate to

- perform individual research,
- contribute to training and teaching,
- support user experiments and technical projects,
- operate and advance the research infrastructure.

Students join the CMMS for work experiences and training.

Seven Canadian university faculty affiliated with TRIUMF.

Three TRIUMF faculty affiliated with Canadian universities.

CMMS facility and location in TRIUMF

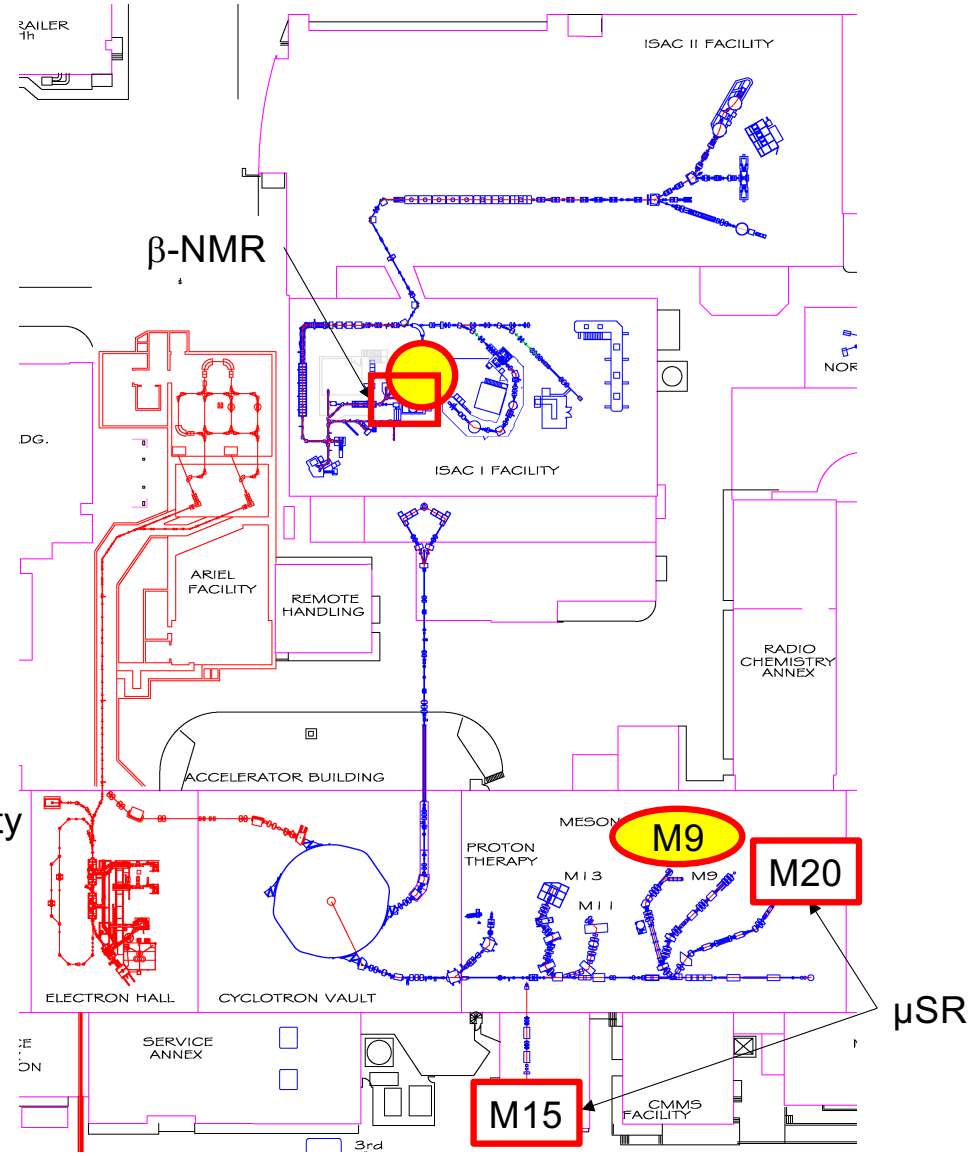
μSR: available at M15 and M20 in Meson Hall, 150 days / year simultaneously

- FUTURE: M9H and M9A will be completed for measurement in extreme conditions and user community expansion.
  M9H is CFI approved: (Kreitzman, Thursday).

β-NMR stations in ISAC-I building, 35 days / year

- FUTURE: ARIEL will expand the beam availability of β-NMR by 3~5 times (5 => 15~25weeks).

- POLARIS (Dunsiger, Wednesday) aims to maximize utility of beams made available by the ARIEL sources.



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CMMS history at large

+ my own history

1983: First demonstration (M20) of a dedicated facility based surface muon beam line. (Ken Kendall, Jess Brewer, Jaap Doornbos, Jack Beveridge)

1985: Building of M15, with its dual achromatic spin rotators This became the de-facto model for all the worlds subsequent bulk material muon channels (excepting decay muons).

1988: Building of M9B by the Tokyo group (Nagamine and Co.) with Kakenhi

1998: Introduction of the βNMR facility in ISAC

1999: Invention/introduction of the High Transverse Field (7T) / High-timing resolution MuSR spectrometer

2003: Invention/introduction of a spin-rotated high energy decay μ+ beam (M9B).

2005: CFI Funds rebuilding of M20 into a modern MuSR beam line

2009: TRIUMF Funds the building of M9A

2012: First experiments on the rebuilt M20 C/D surface muon beamline.

2013: TRIUMF saves the CMMS & UCN programs by funding a M-Hall He liquefier

2016: CFI Funds the rebuilding of M9B/H into a versatile decay MuSR beam line

2020: current 5-year plan (high-*P* μ^+ or negative μ^-)

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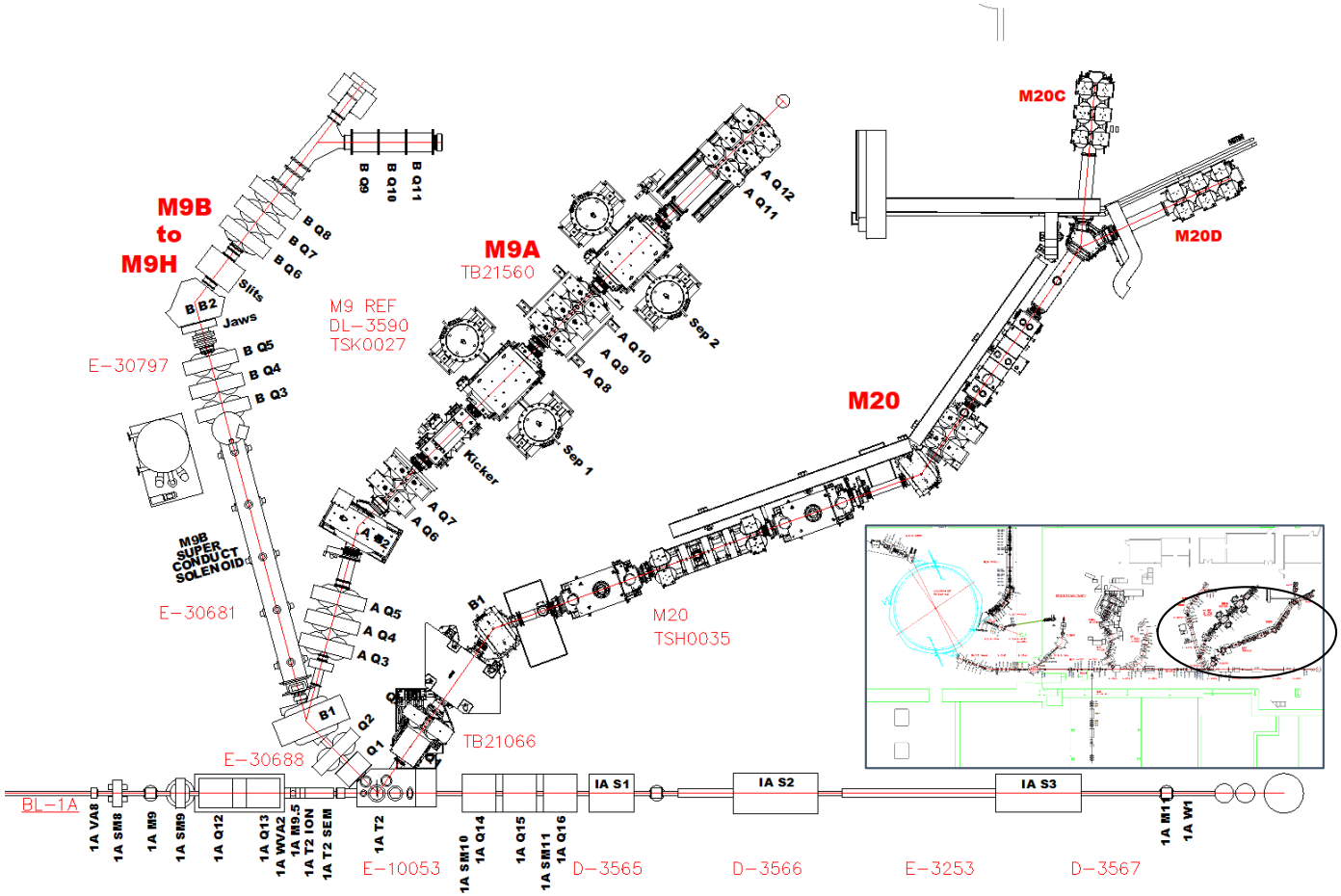
Muons from T2 target: M9 and M20

Expansion to new M9A/H



2020.08: new M9Q1&2 installed and Vacuum being checked !

Discove
acceler

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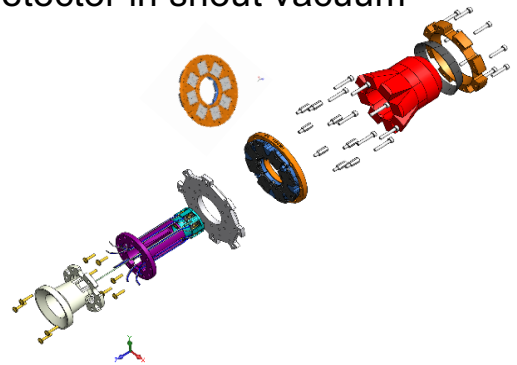
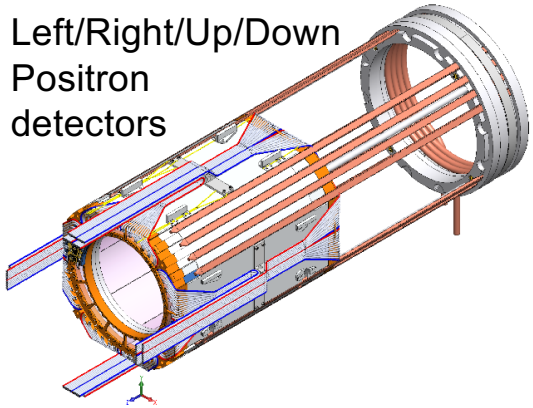
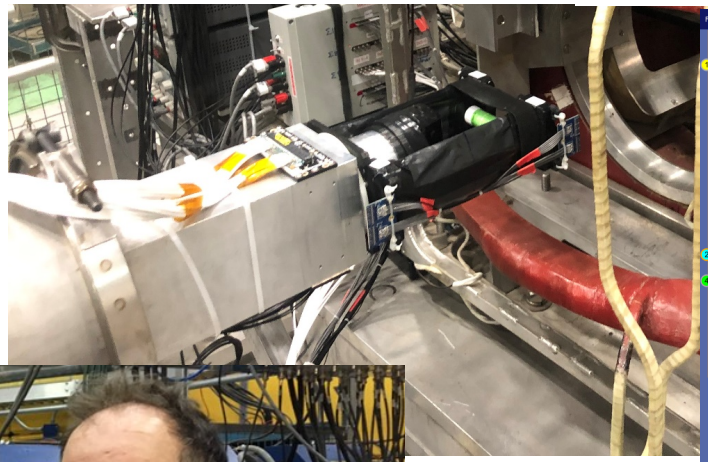
Muon detector in snout vacuum

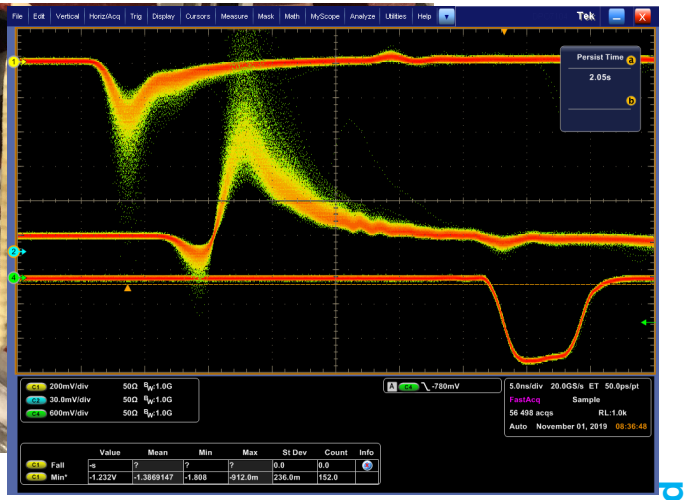


Left/Right/Up/Down Positron detectors



M9A: 3Tesla-spectrometer and SiPM detectors





High timing resolution of ~200 ps has been achieved

Discovery, accelerated

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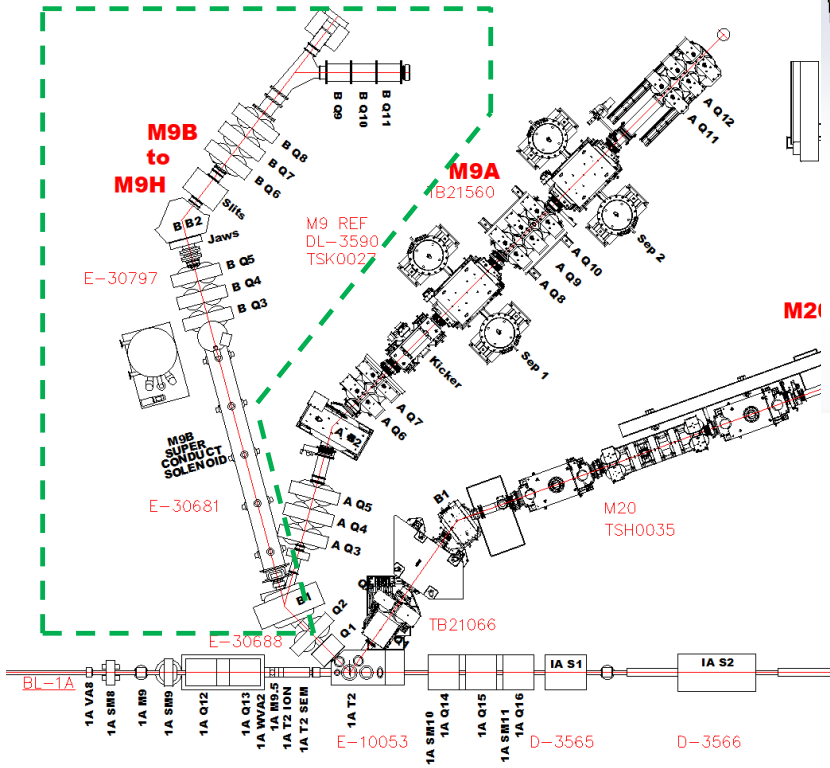
Syd Kreitzman

Proj. Eng. Mahdiar Khosravi

M9H solenoid



High momentum μ^+: GPa high pressures at mK or 1000 K

Negative muons μ^- : muonic X-ray element analysis

Gate-2 Review passed: 2020.07.

Solenoid fabricators are being invited to bid.

Discovery, accelerated

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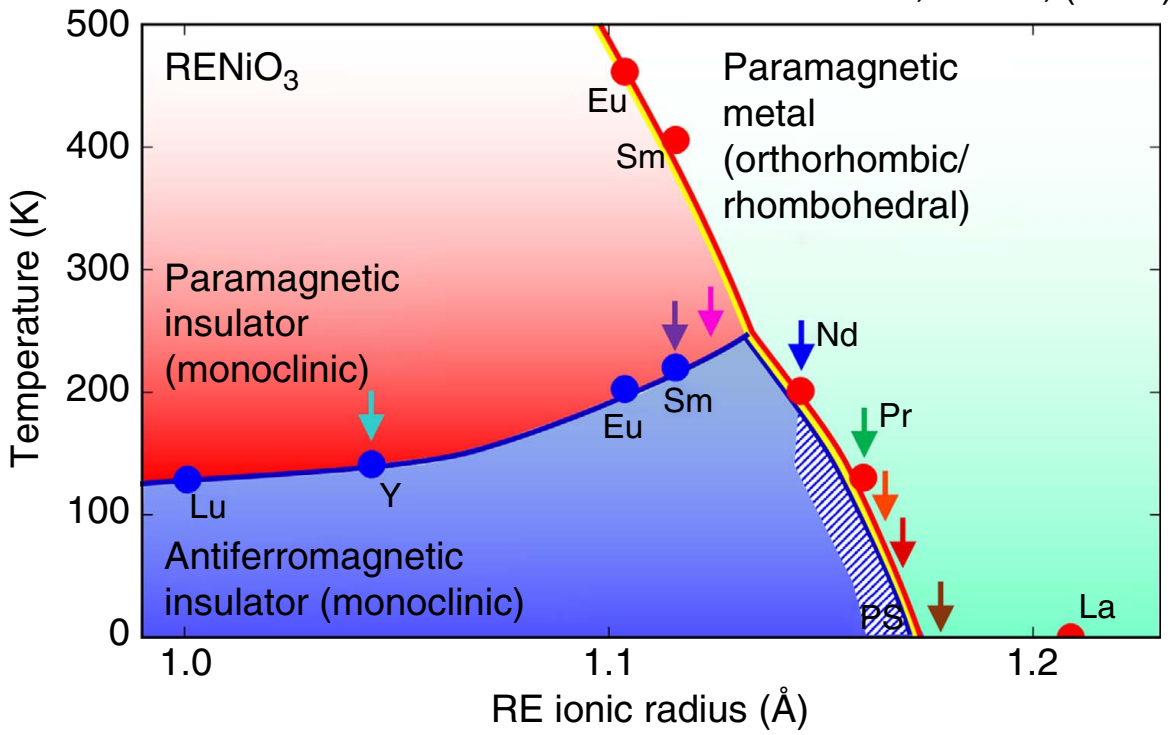
Alannah Hallas's talk on Wednesday on other Quamtum Materials

Phase diagram of Quantum Materials

B.A. Frandsen *et al.*, Nature Comm. 7, 12519, (2016).



Pressure capability:

TRIUMF has mapped out phase diagram of quantum materials with μSR as a magnetic probe.

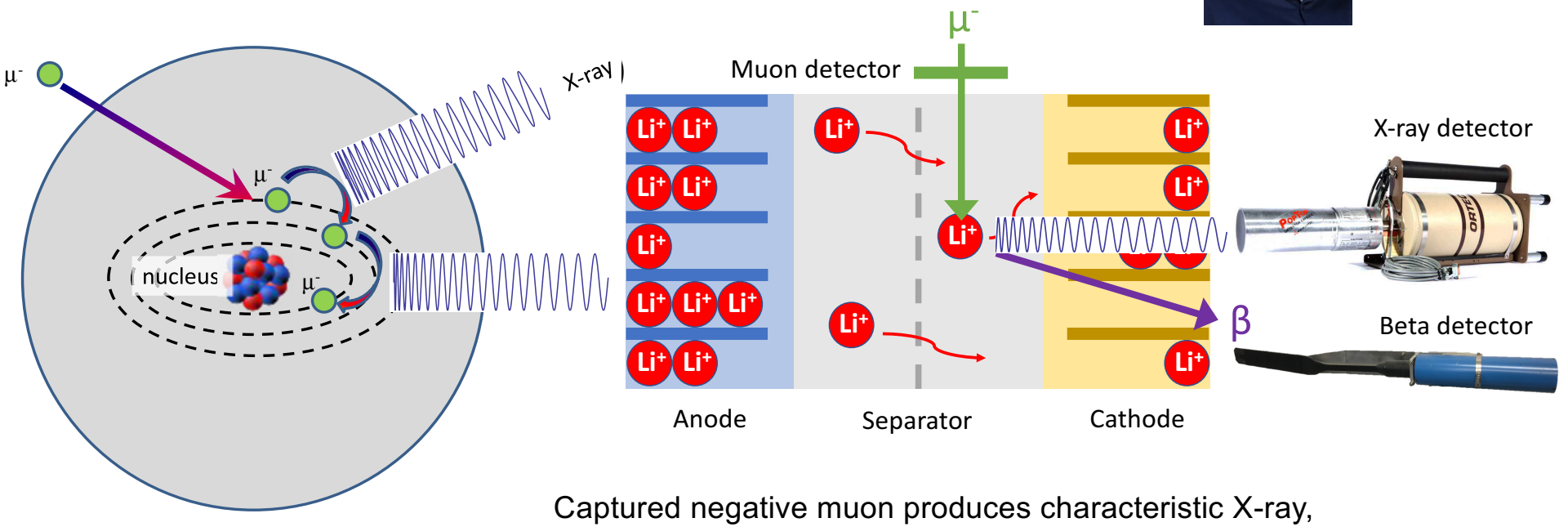
Instead of Chemical pressure by element substitutions, real pressure may be used as the controlling parameter.

Discovery, accelerated

TRIUMF

Materials Science with negative Muon (μ^-)

Iain McKenzie



Captured negative muon produces characteristic X-ray, which enables non-destructive element analysis.
Diffusion of Li-ion may be investigated in the working battery.

J-PARC pulsed μ^- facility is limited to 25Hz. TRIUMF will be able to measure in kHz.

Discovery, accelerated

TRIUMF

β-NMR vs. μSR

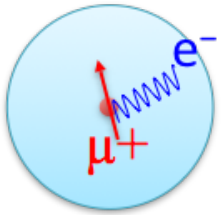
Nuclear Magnetic Resonance of implanted probes

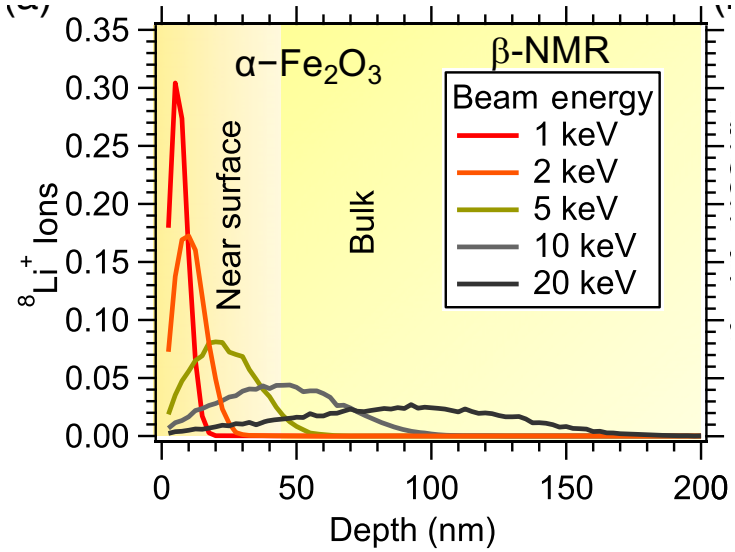
Muon (~10μsec) and ^{8}Li (~10 sec) maximum time scales

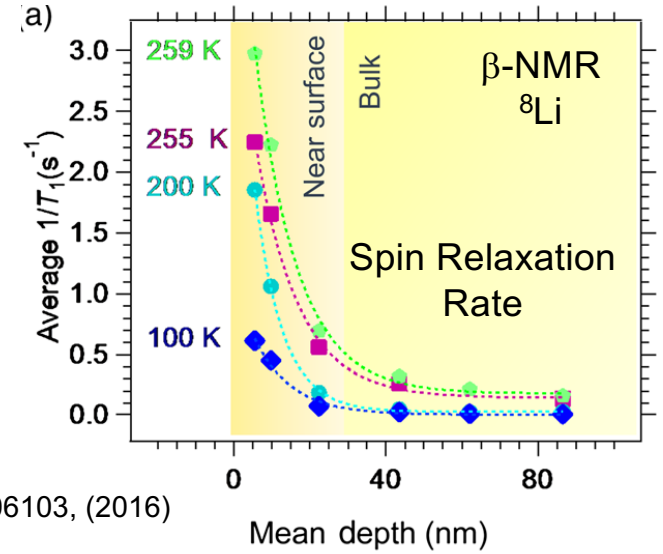
β-NMR stops probe particles in nano-meters with controlled depth

$^{8}Li^{+}$ +e charge, S=2 polarized

Muon +e charge, S=1/2 polarized, 1/9 Hydrogen mass
= spin polarized proton isotope, simulates Hydrogen







D.L Cortie *et al.*
Phys. Rev. Lett. **116**, 106103, (2016)

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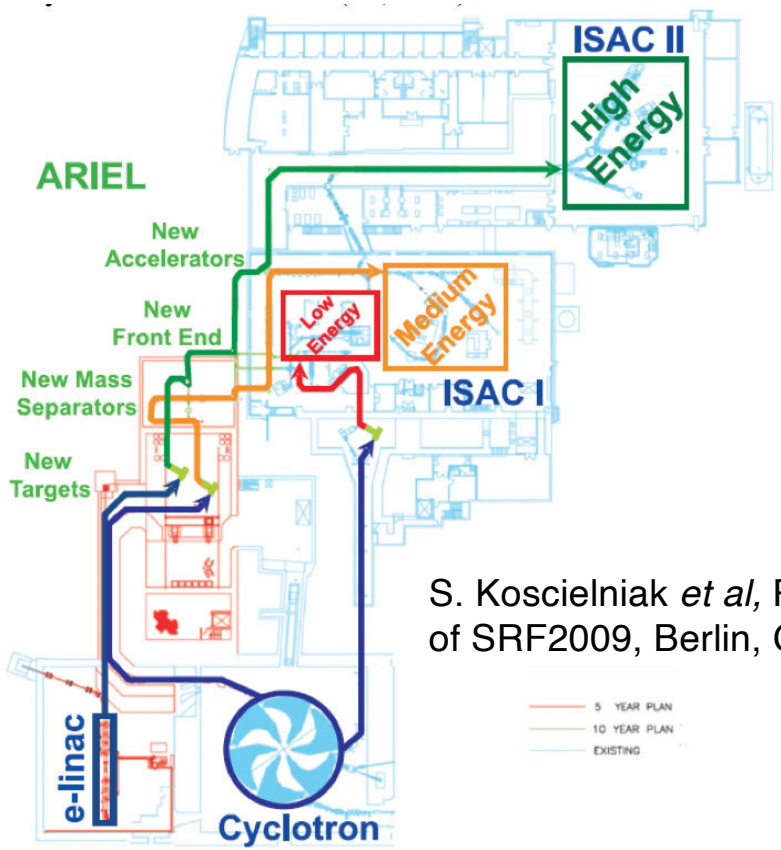
More β-NMR beamtime with ARIEL in operation



ARIEL will enhance the β-NMR beamtime by 3-5 times (35 days / year to 100-150 days /year), because it feeds the competing Medium and High Energy part of ISAC-I & II.

More β-NMR user programs will be accommodated.

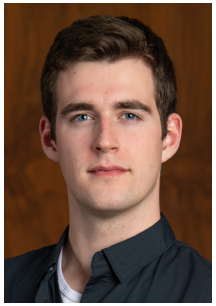
Variety of probe nucleus is explored: ^{8}Li, ^{31}Mg, Cu, …

S. Koscielniak *et al,* Proceedings of SRF2009, Berlin, Germany

TRIUMF

β-NMR:
Detector system upgrade for **high-rate competency**
SiPM + hardware (developed at KEK)

Kenji Kojima



Jack deGooyer (Dalhousie)

Hardware

Hans-Ulrich Berendes (Friedrich-Alexander University, Germany)

DAQ Software (with Ben Smith)

Expansion of Polarized unstable nuclei facility: POLARIS

+ new unique sample environments
with more efficient use of the beam through multiplexing

Sarah Dunsiger
(Talk on Wednesday)

TRIUMF

2020~: User facility in COVID era

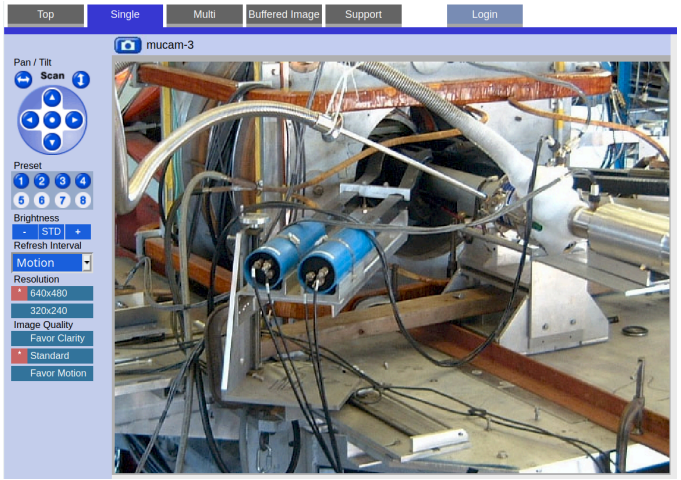
We are trying a new model of collaboration this Summer-Autumn beamtime: Experiments without having external scientists visiting on site.

(1) Samples mailed in and internal scientists sets up the measurements in person

(2) Online communications during the measurements with external scientists.

(3) Remote access to the experiment and Autorun have been running.

An extreme example of remote access



Web cams to monitor the apparatus

Summary

- ARIEL will expand β-NMR beam availability.
- Our initiatives in 5YP 2020- and future (CMMS):
  - Expanding Muon Beam Facilities at TRIUMF: M9A & M9H (CFI grant: J. Sonier (SFU))
    - Muonic X-ray spectrometer for elemental analysis ... (I. McKenzie)
  - M15 Revitalization and Upgrades in Meson Hall (S. Kreitzman)
  - Expansion of the β-NMR and other unstable nuclear beam usage, POLARIS (S. Dunsiger + life science + nuclear science + accelerator)
  - CMMS user programs will be COVID resilient
- Proton Beamline 1A Modernization is necessary for sustainable operation.

With the CMMS infrastructures, various materials and molecular systems will be investigated, including Quantum Matters, Soft Matters and Radicals, etc