CMMS Overview, Sept. 2016

Syd Kreitzman/
Gerald Morris

- The People
- Beam-line operations summary
- M9-T2 update
- Expanding Muon Beamlines at TRIUMF, a CFI proposal
- Liquid Helium Story
- Spectrometer, R&D Update
- 5 Yr. Funding, Operations, Manpower
- Summary

Bottom Line

The unique position of TRIUMF in North America to provide facilities and support for μSR & βNMR research promises a continuing long-term pillar for TRIUMF's mission.

The People:

Facility Scientists:

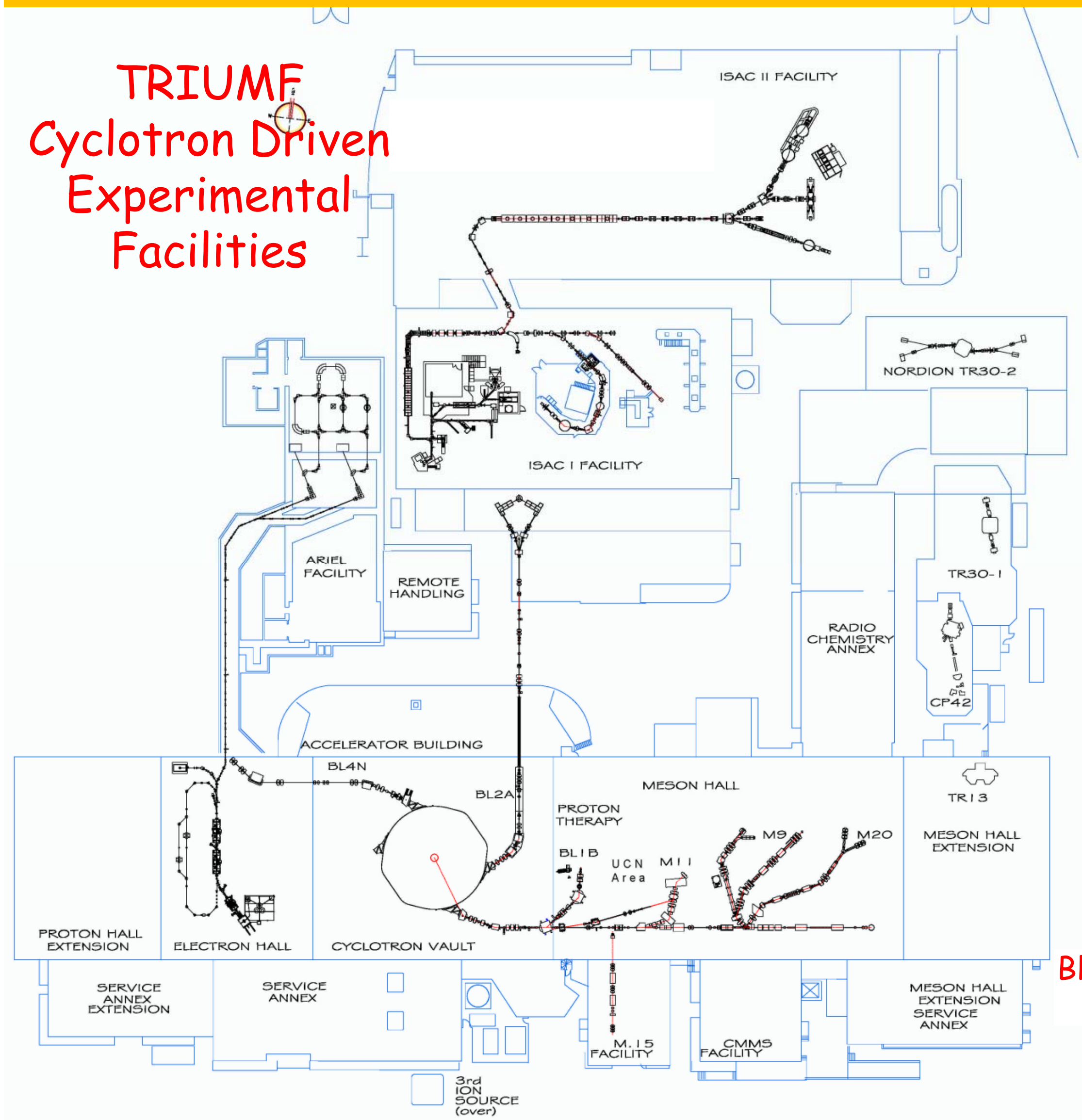
1. Bassam Hitti: Operations Manager
   i. Experimental Setup, Operations and User support
   ii. L-He Coordination
   iii. MRO Coordination
   iv. Scheduling and User Coordination
   v. Device electromagnetic simulation (i.e. Opera)
   vi. Semiconductor Solid State Physics
2. Gerald Morris: Deputy Manager
   i. M20 project management
   ii. βNMR Management & beam line coordinator
   iii. Experimental Setup and User support
   iv. CMMS Experimental Safety reviews
   v. Subsurface layer CM Physics
3. Donald Arseneau: IT /DAQ & Programming Management
   i. Experimental Setup and User Support
   ii. Facility IT, DAQ and programming
   iii. Spectrometer design
   iv. Common Account Assessment Management
   v. Physical Chemistry and Fundamental Kinetics
4. Monika Stachura: βNMR Mg Beam R&D
   i. βNMR experimental engagement
5. Iain McKenzie: Outreach & User Support
   i. Outreach Planning and Implementation
   ii. Liaison with User Community
   iii. EEC Secretary
   iv. Experimental Setup and User Support
   v. Physical Chemistry of Soft Materials Structure and Dynamics of Free Radicals
6. Syd Kreitzman: Manager
   i. Liaison with TRIUMF Management
   ii. M9A beamline project management
   iii. Spectrometer design coordinator
   iv. Experimental Setup and User Support
   v. MuSR Techniques ,Tools & Toys with some Spin Relaxation Theory

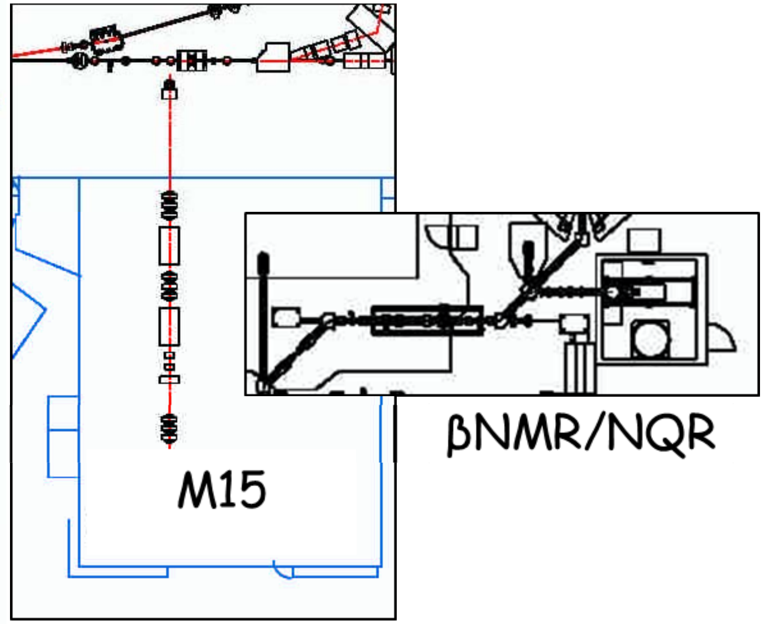
Facility Technicians:

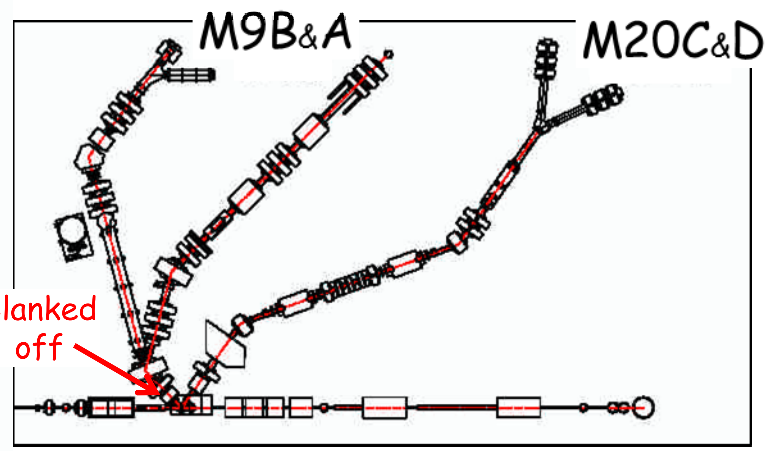
1. Rahim Abasalti: High Vacuum Specialist
2. Mike McLay: Design Technologist
3. Deepak Vyas: Millwright & Work Area Safety Coordination
4. Collin Dick: Liquefier Technician (cryogenics group)

All staff formally TRIUMF employees.
1,3,5 & Technician 5 yr term. 2,6 Permanent
4 Science Div (or Grant) supported

TRIUMF & CMMS Beamlines

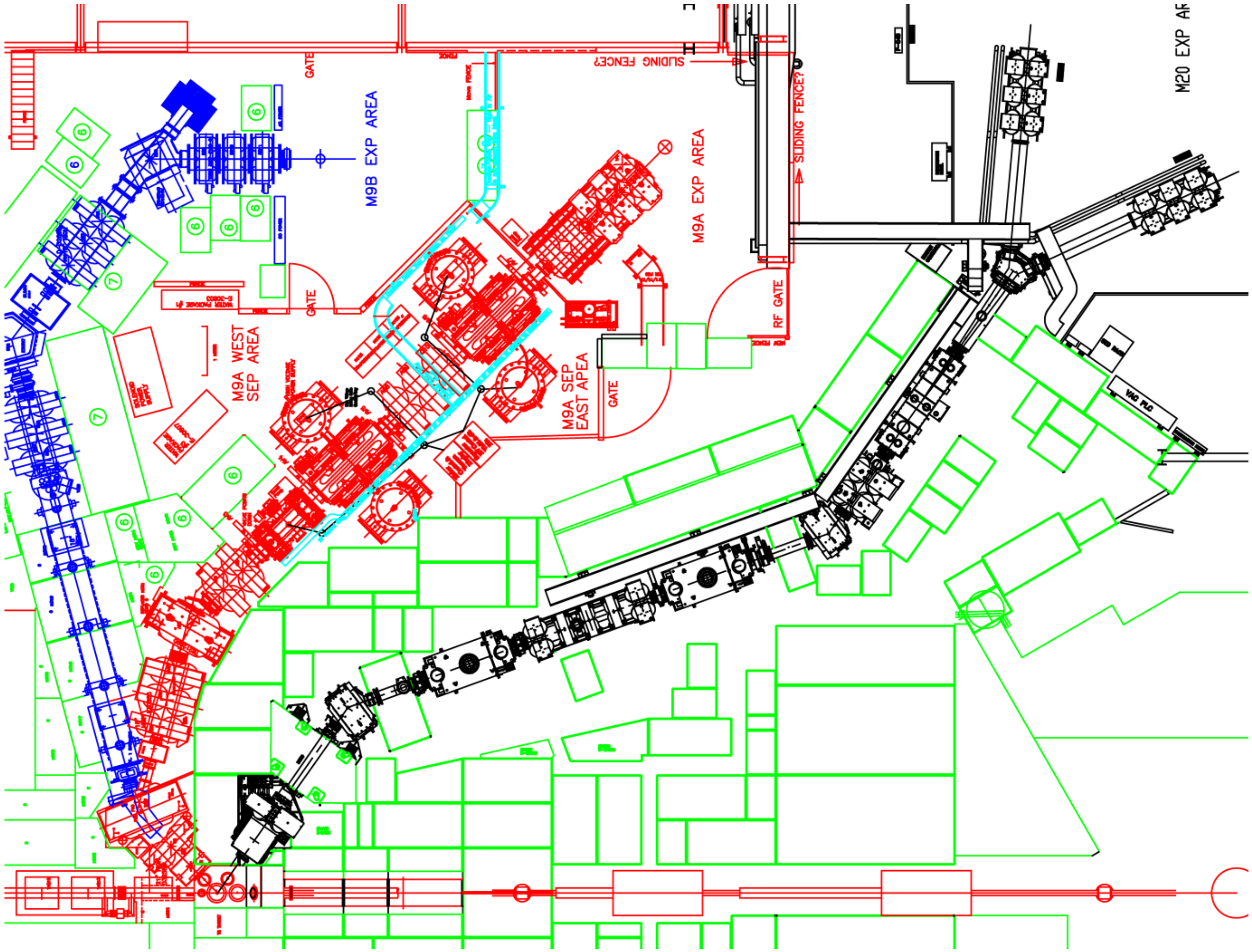






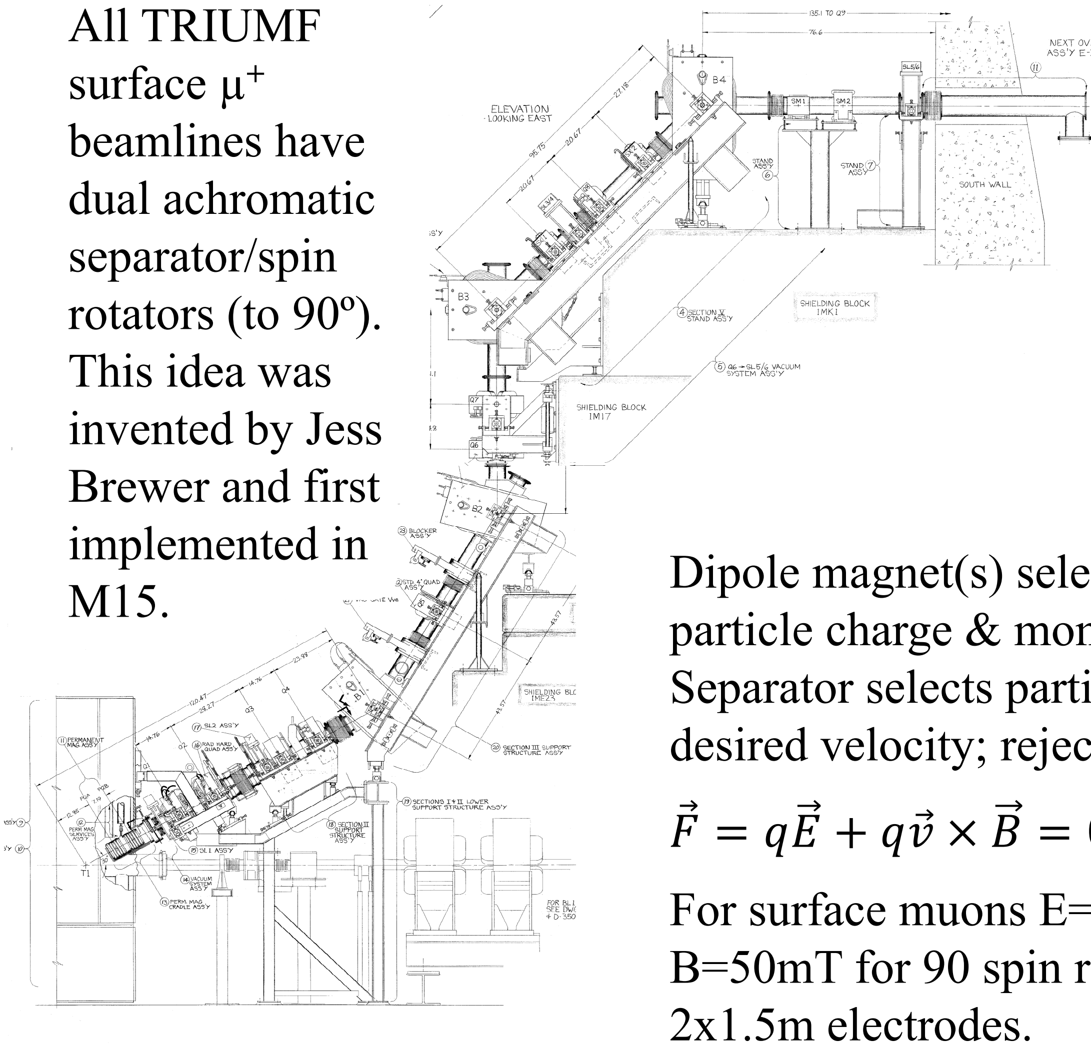
TRIUMF Centre for Molecular and Materials Science

Muon Beam Lines – M9A/B & M20 C/D … From 1A:T2



Muon Beam Lines – M15… From 1A:T2

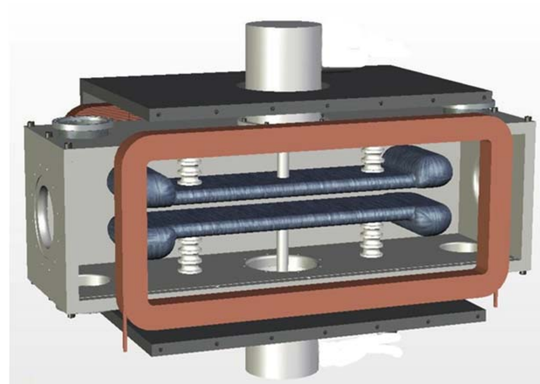
All TRIUMF surface μ^+ beamlines have dual achromatic separator/spin rotators (to 90º). This idea was invented by Jess Brewer and first implemented in M15.



Dipole magnet(s) select particle charge & momentum. Separator selects particles of desired velocity; rejects everything else.

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B} = 0 \;\rightarrow v = \frac{E}{B}$$

For surface muons E=45kV/cm and B=50mT for 90 spin rotation over 2x1.5m electrodes.



Cartoon of a Wien filter / separator / spin rotator.

Beam Line Operations

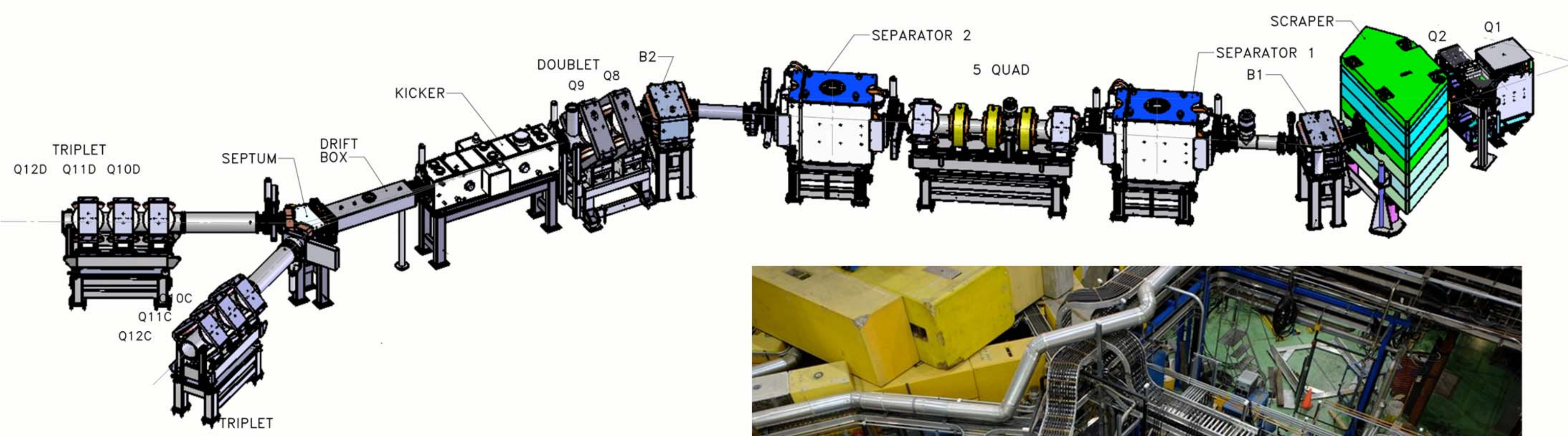
- M15: Nominal operations subject to age-related problems.
  - Ageing electronics (oxidizing connections) … will go away with new DAQ infra
  - Reduced rate … expected from degradation of FE permanent quads …but an initial simulation indicates that this may not be the cause of the losses.
  - Recent replacement of all quad power supplies & dipole water cooled heat sinks
- M20s: (less than More, i.e. no Kicker yet) Normal high productivity operations
  - TD-muSR spectra have no distortions… due to the small uncorrelated background.
  - I-MuSR users would like higher rates (an expansion of the Q3-Q6 beam pipe?)
  - M20 C and D can be effectively run simultaneously in non-MORE mode.
  - Kicker subcontractor bought out by its largest customer … Silicon Power Co. SP has decided that the Kicker must meet its QC standards and as such is revamping the kicker configuration -> installation not until 2017 winter shutdown.
- M9/T2: Down for at least another $1\frac{3}{4}$ years. TRIUMF has committed itself to a repair within the current 5-yr plan. ~<$600K to fix.
  … details to follow
- M9B->H: TRIUMF/SFU/UBC/McMaster/Montreal/Mt. Allison are supporting a $10M CFI application led by Jeff Sonier @ SFU.
  … dtf
- bNMR/NQR: Normal operations @ 1.5 x 5 beam weeks/yr. AREIL commissioning in 2020 -> allocation of 15 beam weeks/yr.

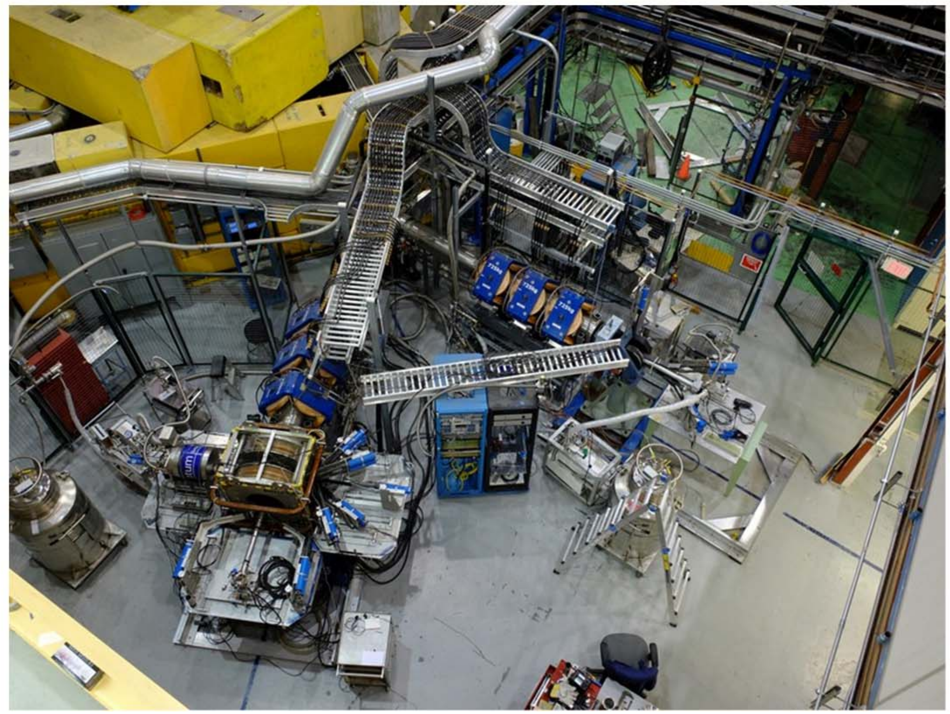
CMMS Beamlines : M15

- muons from BL1A:T1.
- permanent magnet quadrupole doublet is located inside the target monument.
- achromatic dual spin rotators (Wien filter particle separators) operable from ~18 – 90° spin rotation.
- first science runs in 1984.

M15: surface μ^+ beam, p_μ=29 MeV/c +/-5%

CMMS Beamlines : M20 C & D

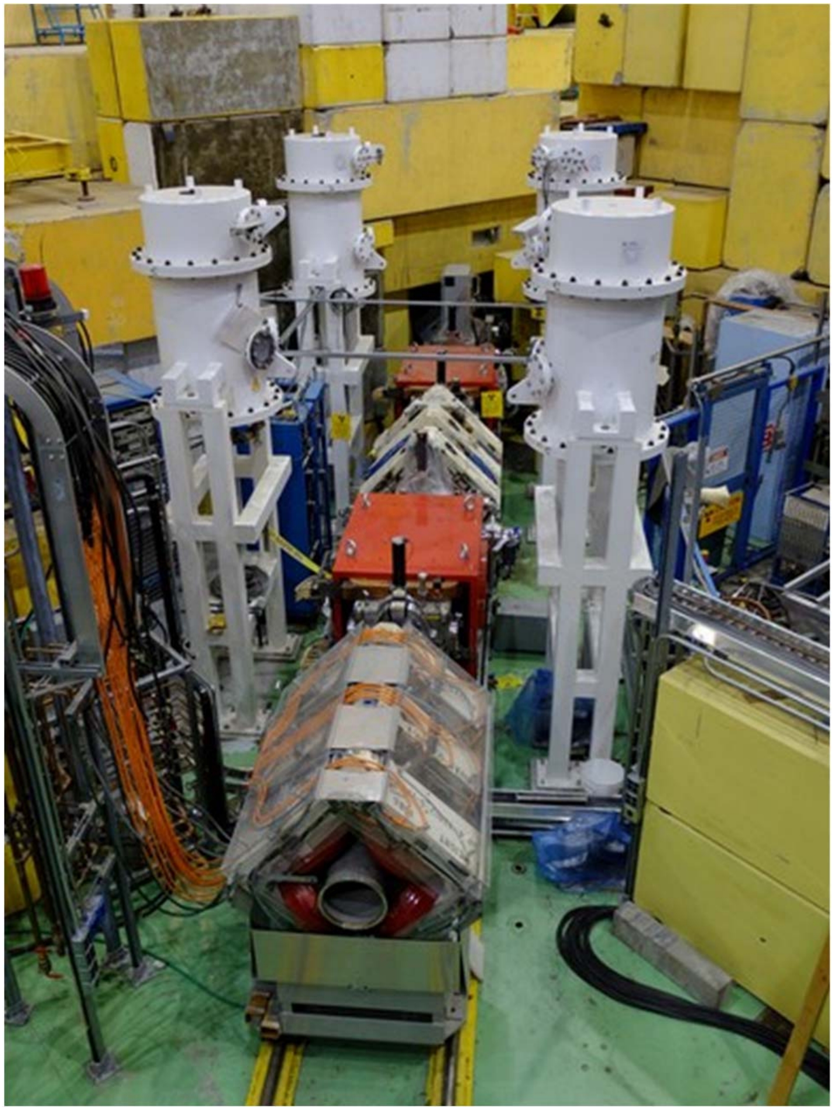




- -Operational since Oct 2012.
- -Surface μ^+ beamline; p_μ= 29 MeV/c. (Lower p is possible at reduced rate.)
- -Achromatic spin rotators: 10-90°
- -Two final legs /w simultaneous operation
- -Fast electrostatic kicker to implement MORE is being fabricated.
- -Small, high luminosity beam spot : 5 x 11 mm FWHM, 550k m^+/s maximum flux.

CMMS

CMMS Beamlines : M9A

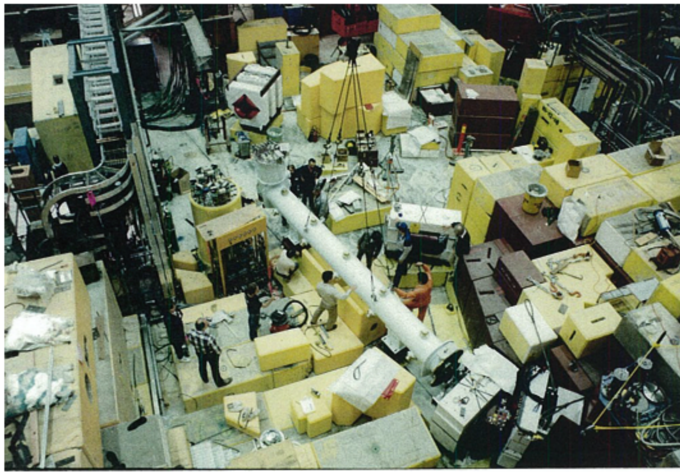


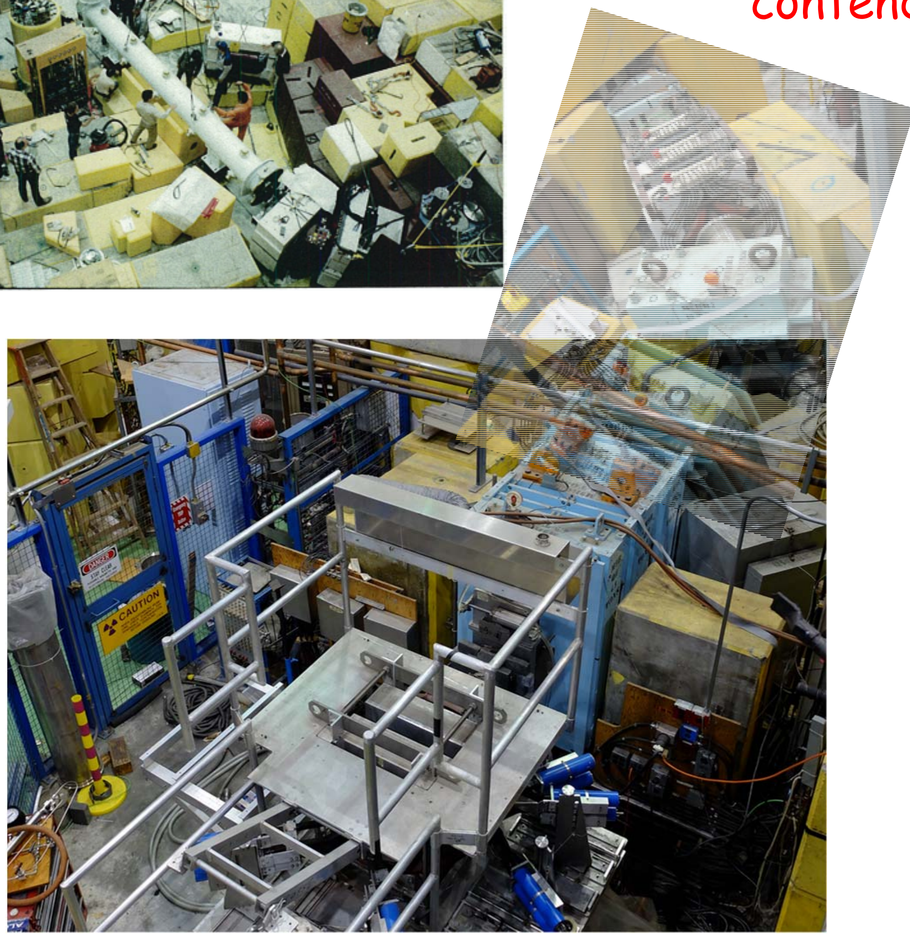
Beam line not in commission due to: M9-T2

- surface μ^+ from BL1A:T2.
- Fast kicker for Muons on Request
- achromatic dual separator / spin rotators.
- optimized for small spot size & high luminosity
- to be fitted with versatile 3T spectrometer
- operational in 2017 .. if M9-T2 fix is on time ?

"Non-cartoon" M9A
Wien Filter S/SR
as built by Bruker

CMMS Beamlines : M9B decay channel





Beam line not in commission due to:
- M9-T2 and;
- insufficient cryogenic manpower to contend with it's unreliable operation

-Incorporates a 6m superconducting solenoid pion decay channel to produce either $\mu^{+/-}$

-p_μ 40 – 105 MeV/c.

-Uniquely produces transverse spin polarization in the higher p_μ regime.

-high p muons are used to penetrate thick-walled pressure vessels.

-muonium (Mu) chemistry in supercritical fluids.

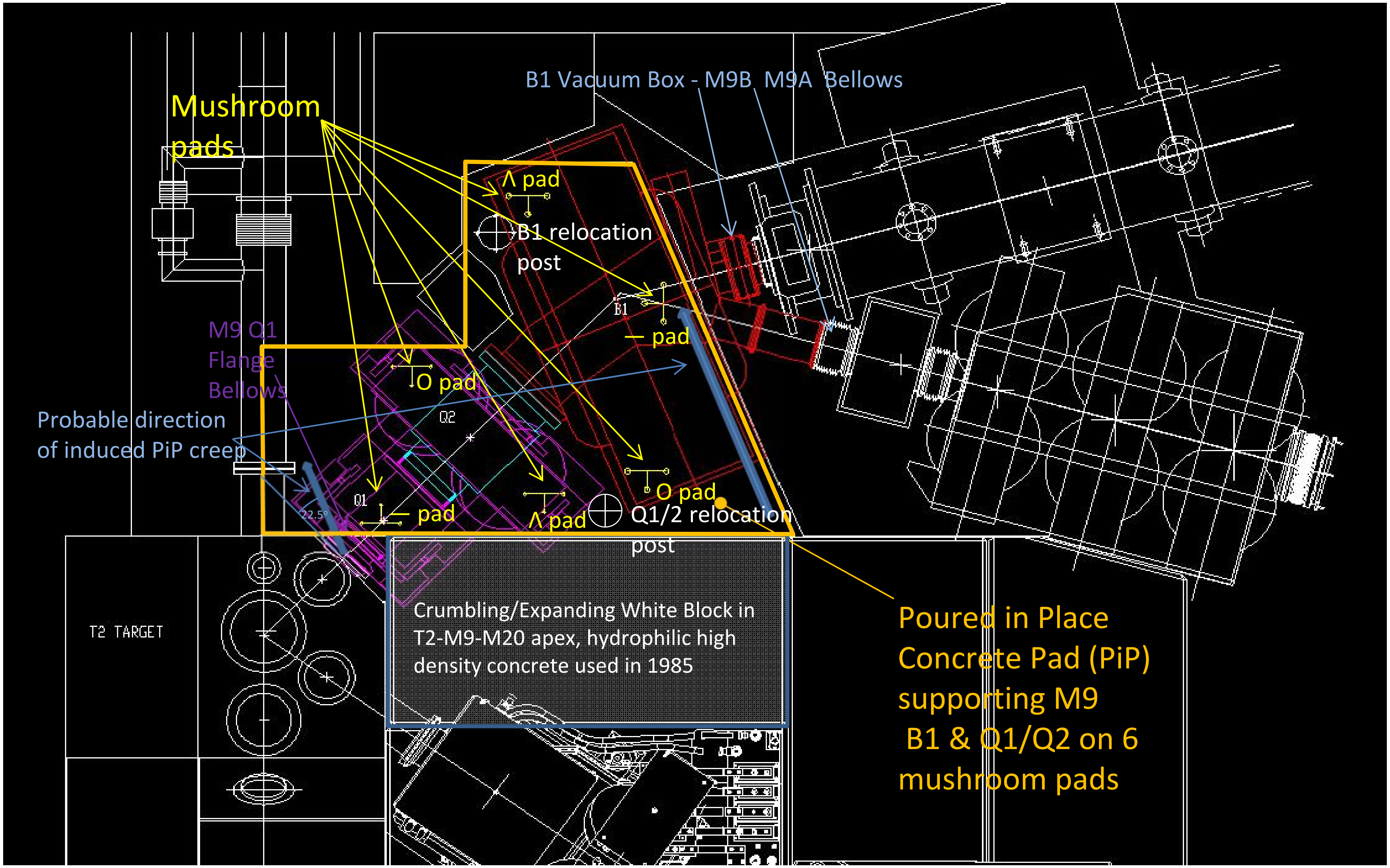
-studies of modified ground state electronic configurations of solids induced by application of pressure, up to ~2GPa.

-Phase transitions at quantum critical points.

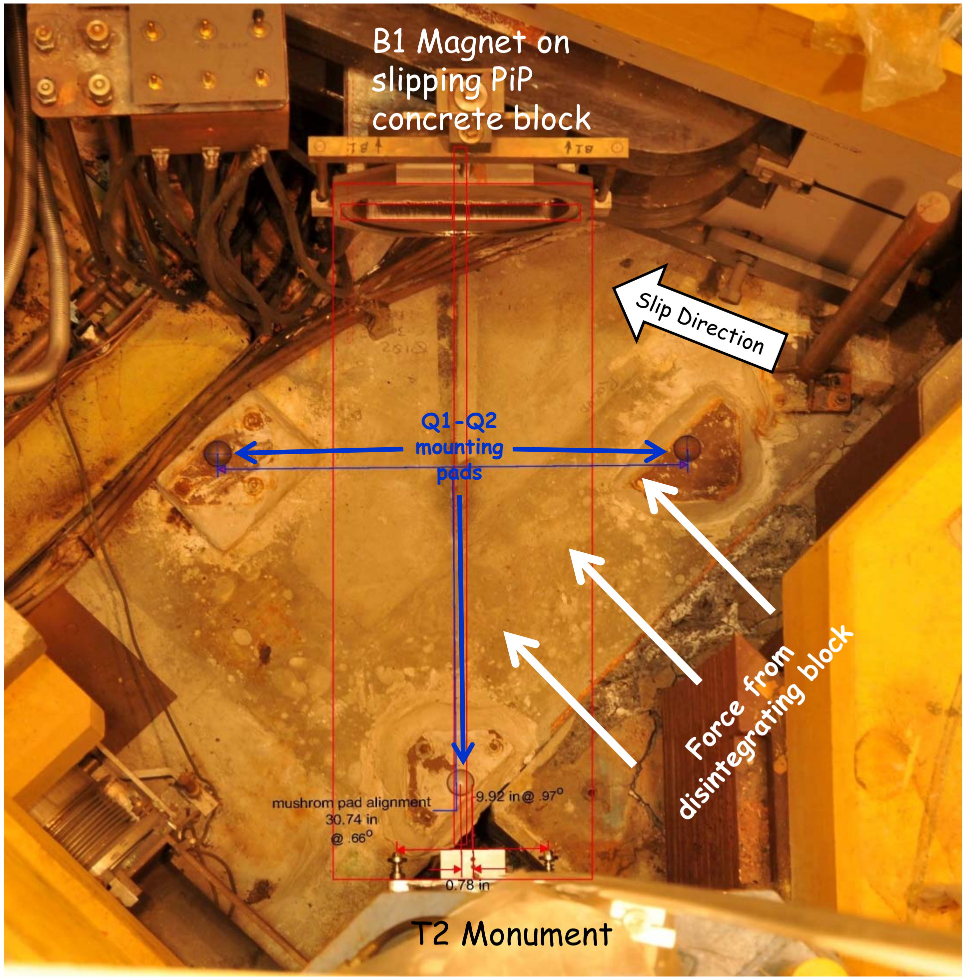
-μ^- beam for muonic atoms, including chemistry :

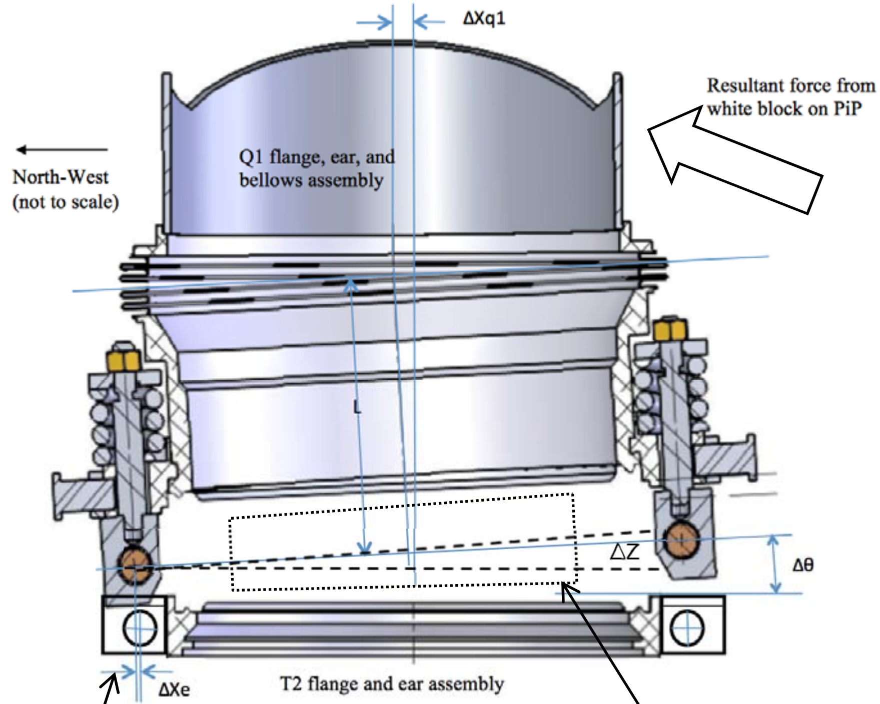
-$^{4.1}$H = μ^-He = massive hydrogen atom for studies of reaction kinetics.

M9-T2 Problems, poor choices in 1980s



Detailed Illustration of the Problem





$\Delta Xq1 \sim= \Delta Xe + L*\Delta\theta$

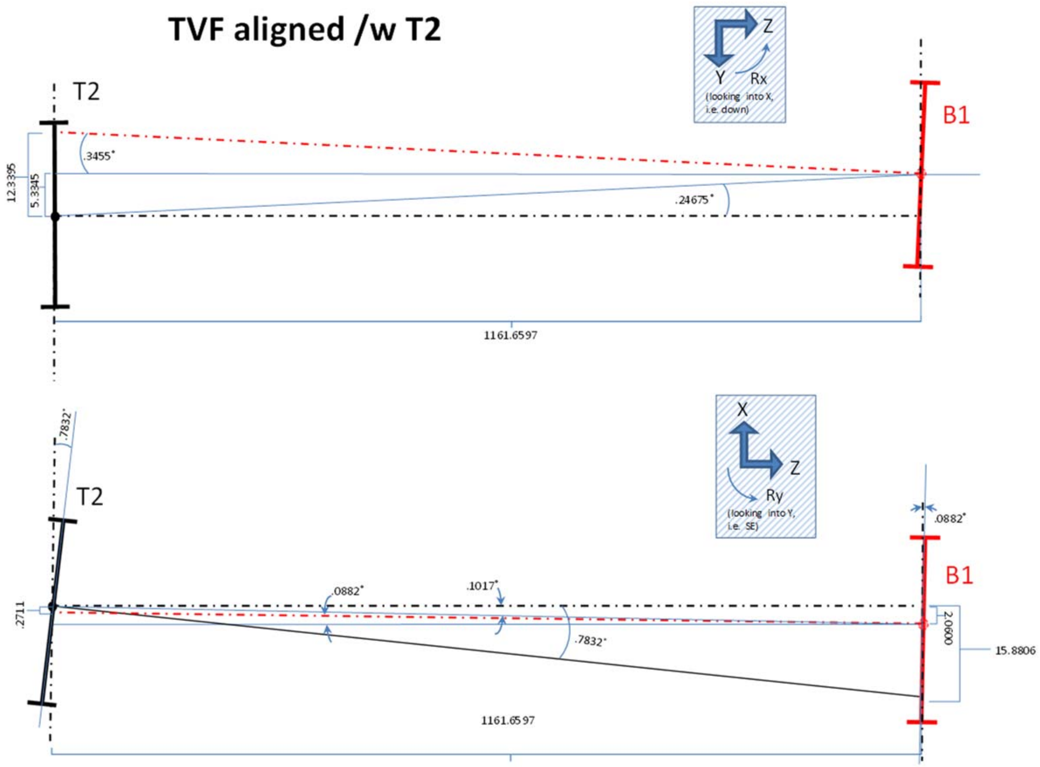
T2-M9 flange West alignment eye-bolt. Undersized eyebolt pins required with misalignment present

L~75mm
ΔXq1~5mm
Δθ~4°
ΔZ~12mm

Volume for a customized double indium ring seal transition piece

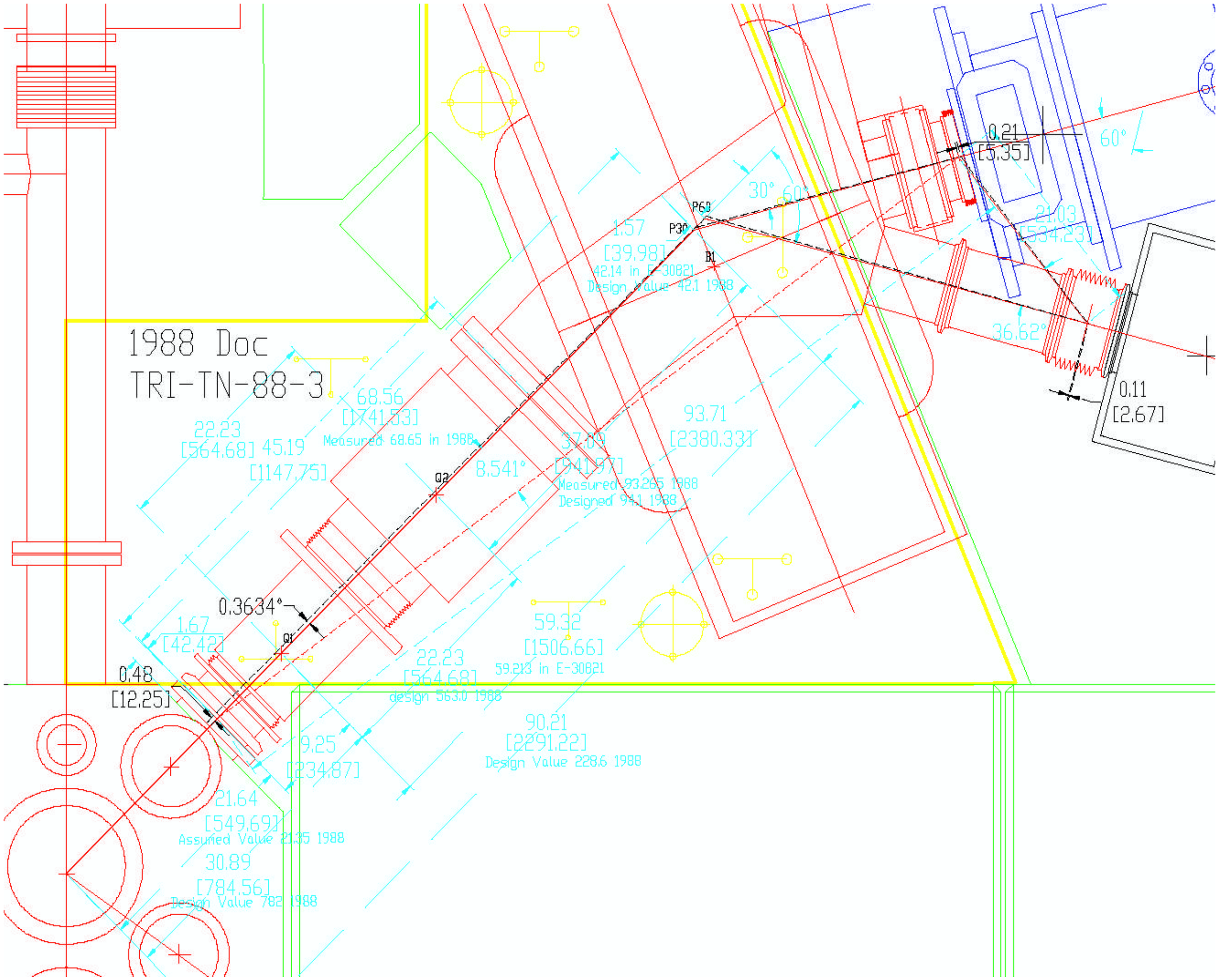
When ΔZ is too large for East eye-bolts to sufficiently overlap, bellows must give in the "hard" X direction to reduce Δθ. After the available give is exhausted, seal cannot be made even with a customized transition piece.

March 2015: Measurements of the Misalignment



Pos or Rotation	B1 Center	B1 Normal	B1 Normal Rot Angles	T2 Center	T2 Center Rot Angles	T2 Normal Rot Angles	T2 Normal B1 Intersect
X / Ry	0	-.001540	-.0882°	2.0600	-.09864°	-.7832°	-13.8208
Y / Rx	0	0	0°	12.3393	.60858°	.3455°	5.3347
Z	0	.999981		-1161.6599			-0.0213

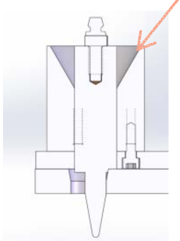
The Abracadabra Solution: R(0.363°)+T_{M9B}(5.35mm)

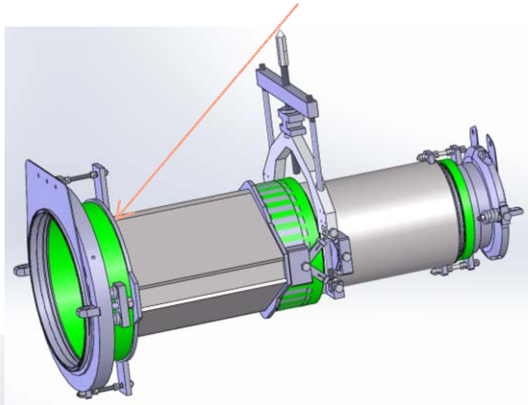


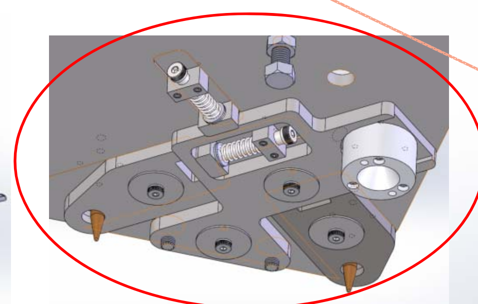
Progress toward a M9-T2 Fix: Conceptual Design

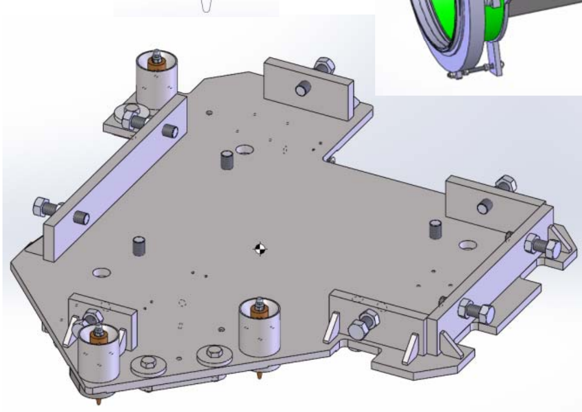
Design Concept: **Free beam pipe /w redundant back-up system of shifting Q1Q2 stand**

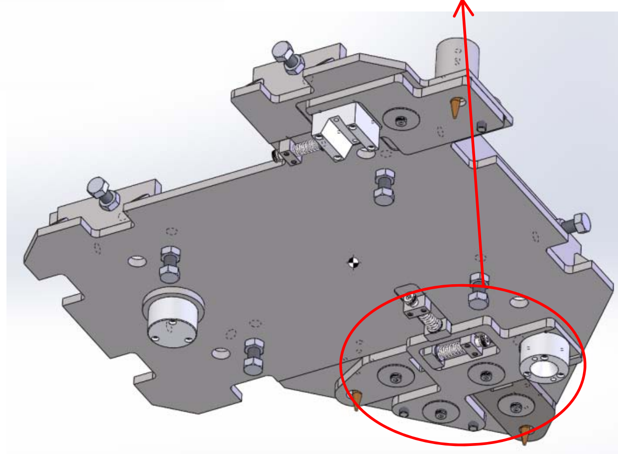
1) More space in a new rad-resistant Q1 -> the beam tube is not constrained by the magnets
2) Remotely installable pins can shift the dynamical mounts under the Q1Q2 stand
3) No adjustment to B1 is required since its vertical field is uncorrelated with horizontal BL alignment … but a new Q2-bellows-B1 section in the beam pipe allows for a dynamic connection

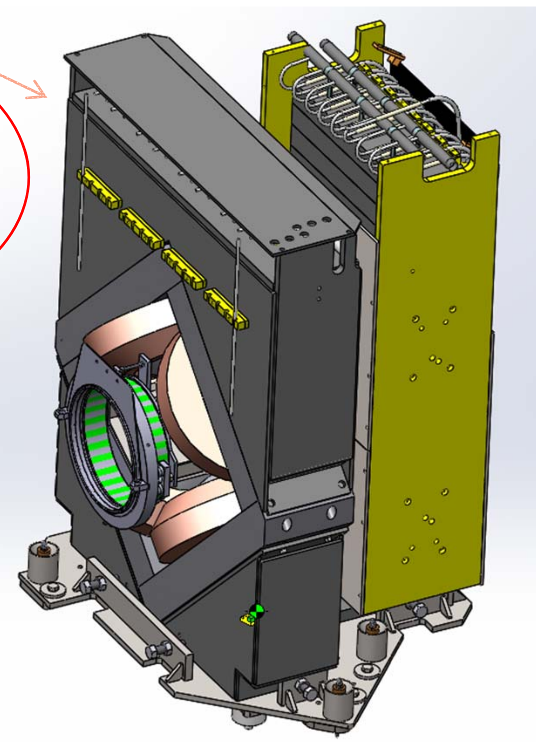




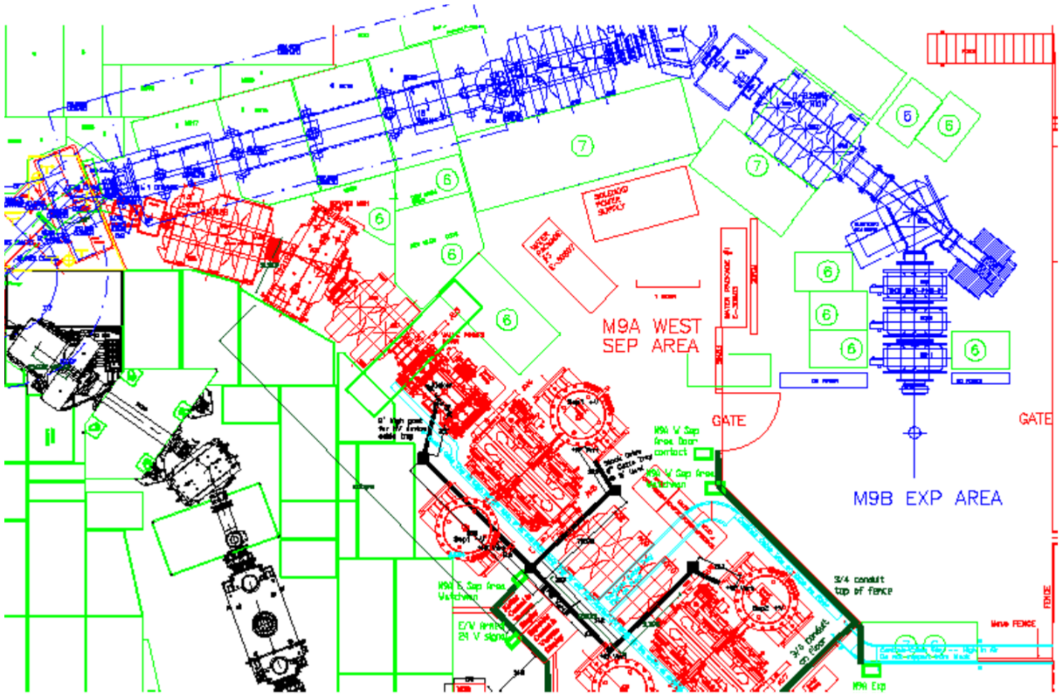








Plans for M9~~B~~H

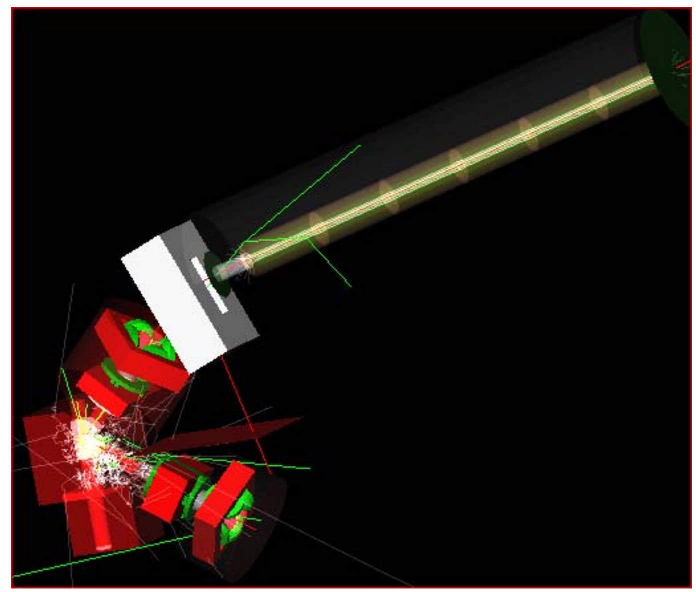


Aspects of current Solenoid infrastructure obsolete & unmanageable (i.e. the controls), however … the only muon decay channel at TRIUMF, the only one in the **world** that has Spin Rotation (i.e. HTF) capabilities.

To resurrect this (blue) beamline … a CFI proposal is being assembled given the recent positive responses to the Gate 0 & 1 Reviews.

Major Components of Proposed CFI application

- Persistent Coil Solenoid /w Enhanced Polarization Selection
- Dilution Fridge for high pressure experiments
- 4.5T Generalized magnet for high transverse field (HTF)
- Funding for M9-T2 fix, M9A completion, 3T Spectrometer



Radiation heating studies indicate a persistent solenoid is feasible, avoiding power bump issues.

Expanding Muon Beam Facilities at TRIUMF: Status

- Multi-Institutional CFI Proposal:
  - Rebuild M9B with new/upgraded solenoid and a spectrometer for high pressure, high field studies in a Dilution Fridge
  - M9-T2 repair + 3T spectrometer + M9A completion included in the proposal budget
  - Full blown proposal … with new persistent field solenoid ~$10M
- TRIUMF Gate 0 & 1 Reviews positive … with a very significant caveat:
  - total cost to TRIUMF should not exceed that associated with fixing M9-T2!
- Response of University Partners Extremely supportive:

CFI Multi-Institutional Lineup	Principals	CFI Caps Allocated $C	Institutional Cap Required based on Current Budget
SFU	Sonier (PI), Percival	2,000,000	1,999,715
UBC	McFarlane,Kiefl,Brewer	1,000,000	999,857
McMaster	Luke	790,944	790,831
U. Montreal	Bianchi	300,000	299,957
Mt. Allison	Ghandi	200,000	199,971
Sherbrooke	Quilliam	0	0
Total University CFI Cap		**4,290,944**	**4,290,332**
Total Budget Based on CFI Cap		**10,727,360**	10,725,829

- TRIUMF expands its in-kind contribution to include M9A3T Spectrometer -> total cost of project (if successfully funded) is ~ $100K, i.e. < 1% of total

Scientific Impetus of the M9H proposal:

- Quantum systems under normal and extreme conditions of very low or very high temperature and/or very high pressure.

  In particular, it will enable muon studies of emergent quantum phases in condensed matter, which are anticipated to fuel future materials-based technologies.

- Chemistry under extreme conditions.

  Dynamics and kinetics studies in systems relevant to green chemistry and energy production, i.e. the reaction kinetics of hydrogen atoms and other short-lived species created by the radiolysis of water under conditions which mimic those of a pressured-water nuclear reactor.

- Extending the hydrogen isotope mass scale:

  The beam line will also re-establish a source of polarized negative muons at TRIUMF, which will be used to extend the hydrogen isotopic mass scale. The importance of a change in isotopic mass, and in particular of hydrogen, in studies of reaction rates and equilibrium in the chemical and biological systems is well established. i.e.

- Other potential research activities:

  - Studies of electrode materials for solid-state fuel cells;
  - Muonic X-rays for non-destructive elemental analysis;
  - Subatomic physics R&D for rare μ-decay experiments at future high-intensity muon sources

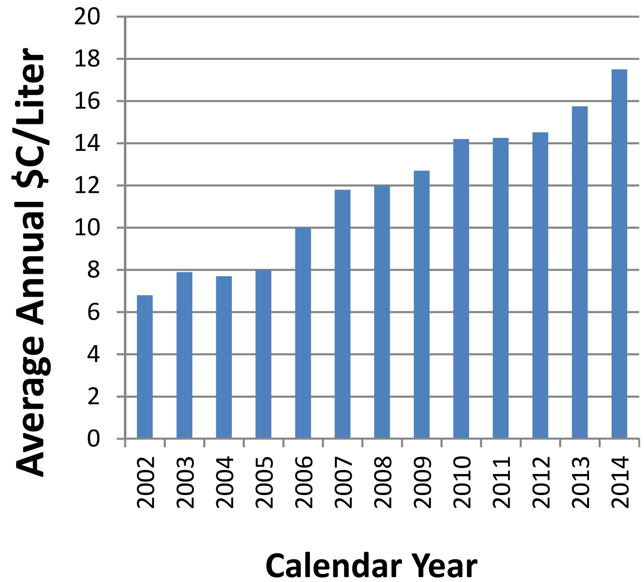
Cost of the M9H proposal:

Item number	Expenditure Type (#)	Item description	No. of items	Cash	In-kind	Total
1	13	M9 Front End	1	0	387,908	387,908
2	13	5T 6M Transport Solenoid	1	3,565,737	556,500	4,122,237
3	13	Blocks / Walls	1	71,546	0	71,546
4	13	Standard Beamline Devices	1	286,792	0	286,792
5	13	M9H Experimental Target Station	1	2,417,514	352,800	2,770,314
6	13	3T Spec+M9A Completion	1	0	141,565	141,565
7	13	Magnet Power Supplies	1	376,111	43,659	419,770
8	13	Vacuum System Elements	1	372,063	0	372,063
9	16	Ancillary B-L Components	1	23,400	0	23,400
10	13	PLC/EPICS Control Systems	1	208,464	0	208,464
11	20	Decommissioning	1	38,462	0	38,462
12	20	Electrical Services	1	144,231	0	144,231
13	20	Water & Air Services	1	29,015	0	29,015
14	15	Personnel Costs	1	1,009,729	662,734	1,672,463
15	17	Travel Costs	1	37,600	0	37,600
		TOTAL		**8,580,663**	**2,145,166**	**10,725,829**

Items 1-13 & 15 are all "capital" costs. Item 14 encompasses all the project manpower not associated with TRIUMF cost centers

L-Helium – The Lifeblood of CMMS

- As of the fall of 2013 TRIUMF bought/imported from Texas all of its L-He for the CMMS program.
- Costs >$14 per liter (¼ paid by users) ➜ $400K/yr and became prohibitive.
- Poor quality helium caused blockages in cryostats.
- Uncertain availability led to cancellation of experiments.
- Reductions of costs & securing supply essential to preserve programs and not to scare away new users.



The Solution: A CMMS/UCN Liquefier

CMMS Operations

- 10<->18 L/hr without LN2
- 1000 L/wk requirement 4<->3 days on, 3<->4 days off
- High Pressure Storage capacity = 3500 Liquid He Litres
- Recovery Capacity 60sfcm ~ 150L/hr
- ~ ½ inventory deployed in experiments at any given time

Planned LN2 Upgrade (2016)

- 60<->70 L/hr

For future UCN operations at close to full power:

- Second Compressor boosts liquefier to 90L/hr, or
- Second stand alone closed cydle liquefier with its own compressor

CMMS/UCN Helium Recycling/Liquefier Installation

The new TRIUMF open system Helium recovery & liquefaction system was installed in late 2013. It secures a high quality supply of this vital commodity for the Molecular & Materials Science and the future Ultra Cold Neutron experimental facilities.

Linde L1610 Liquefier

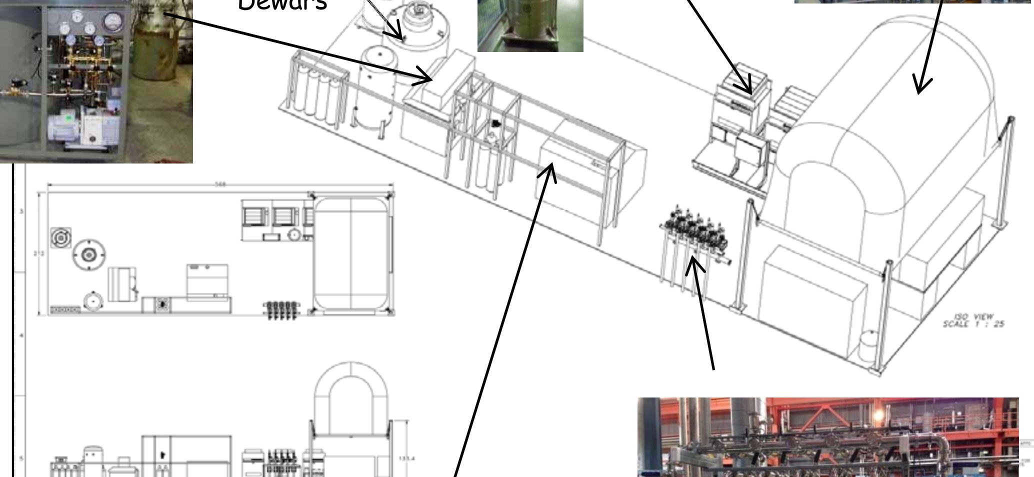
Recovery Compressor

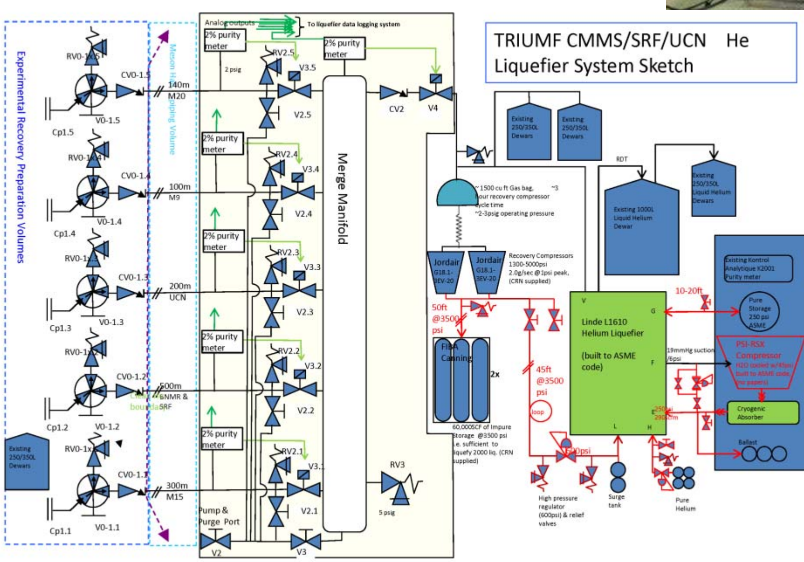
External 3600psi impure storage

1500Cuft Gas bag

1000L 350L

Dewars





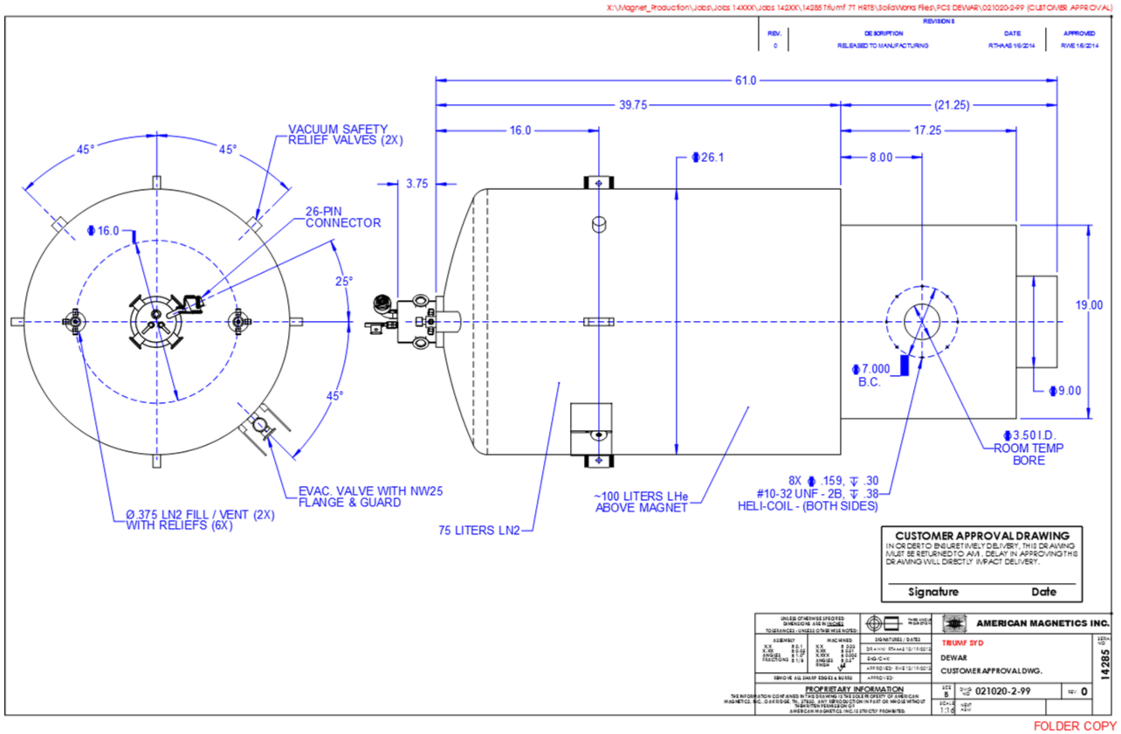
RSX liquefier Compressor

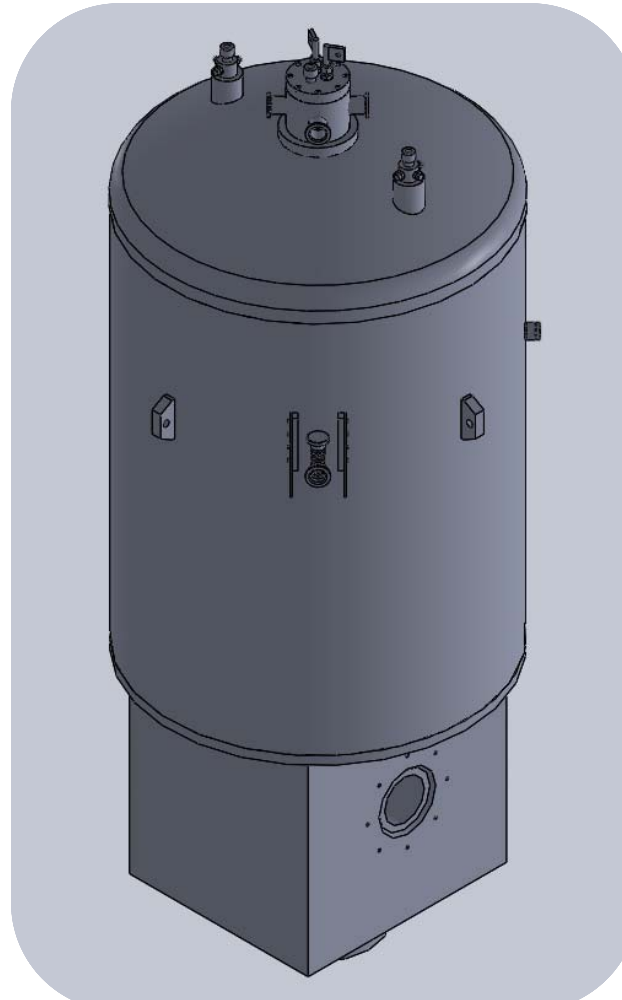
Recovery merge manifold

Spectrometer Resources

- NuTime: 7T transverse field (tf) – 1.5 ppm homogeneity
- Helios: 6T large bore general purpose, (3T tf)
- DR: 6T dilution refrigerator 15mK-20K, (5T tf)
- LAMPF: 0.4T general purpose, with low & ultra low background inserts
- βNMR/NQR: 9T (RF<40MHz) .1-30KeV / 24mT .5-30KeV
- OMNI': 0.3T general purpose
- SFUMU: 0.45T general purpose suitable for high momentum
- Hodgepodge: 0.3T tf in "X" direction; for tf μSR with spin || face of sample

NuTime Spectrometer : High Homogeneity 7T Magnet





American Magnetics built

- 1.5 ppm homogeneity
- ZF X,Y,Z coils
- dBz/dz gradient coils
- <.5ppm/hr decay rate
- >4 day LHe hold time

but

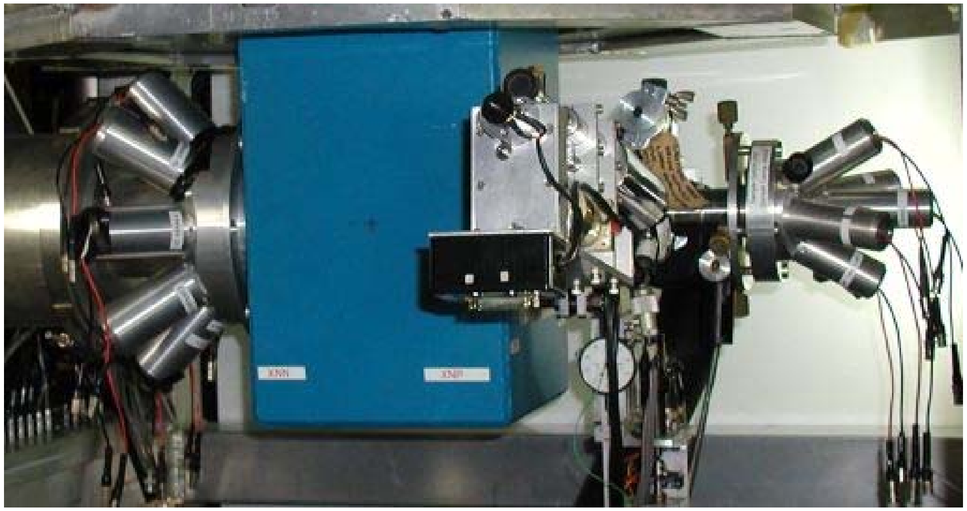
Sweet spot was not centered in the bore

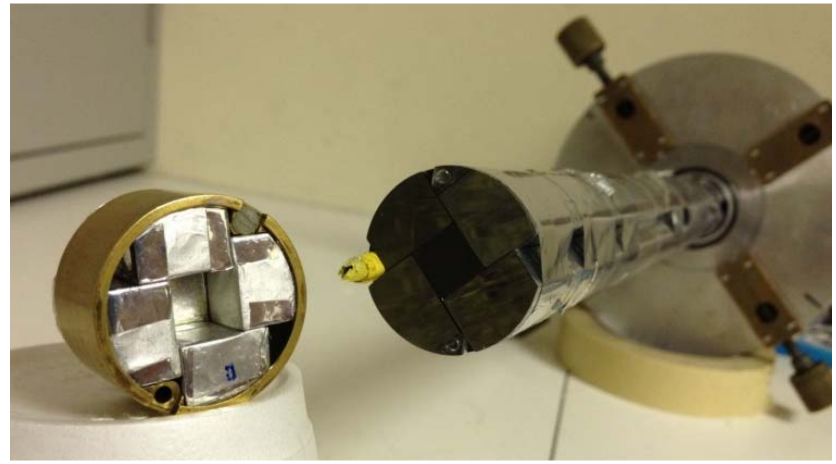
so

We designed a Terbium room temp shim to align field with bore exactly

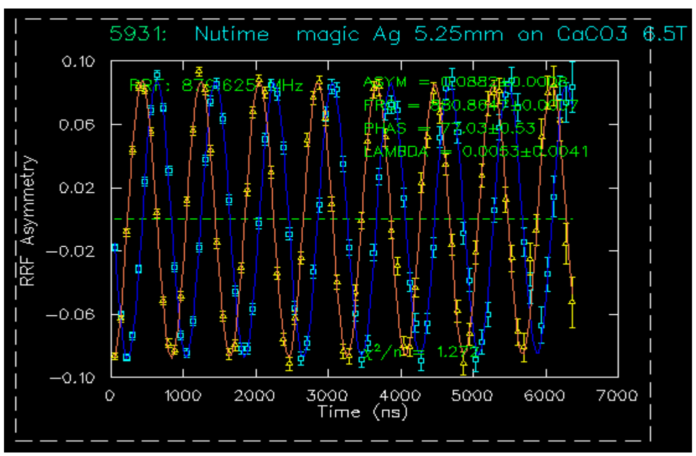
7T NuTime Performance

NuTime Spectrometer = NuTime Magnet +"Streched" HiTime Detectors





Windmill Positron & Muon Veto Detectors ….
with mating light guides



6.5T 880MHz 5K A=.088 λ= .0053μs^{-1}

- NuTime is now "in production".
  - Larger/longer bore -> degraded timing with same detectors as HiTime … as expected
- Intrinsic relaxation rate is "undetectable"
  - An order of magnitude better than HiTime
- When fitted with new "fat" cryostat &SiPMs we expect timing resolution to be restored and indeed significantly improved wrt HiTime, see slides wrt detector R&D

Helios … the 6T (3T TF) Workhorse

Stable standard facilities. Optimized for large form factor experiments (Chemistry / harsh environments) as well as the standard condensed matter flow cryostats / ovens.

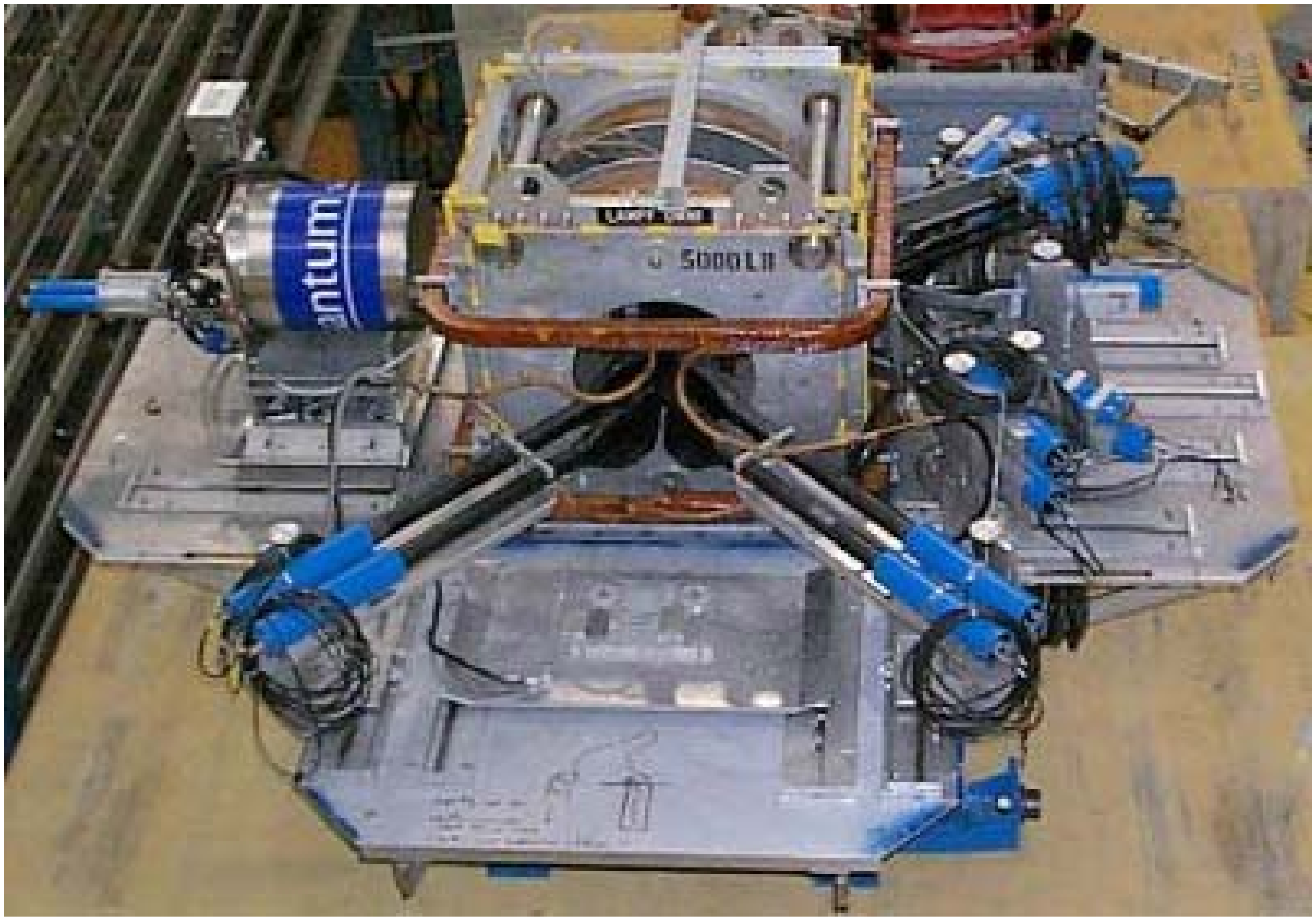
DR … MuSR from 12mK @ 5T

The dilution refrigerator (DR) spectrometer provides a low temperature high field environmental parameter space.

- 12mK-20K
- top loading with 4 hr sample change turn around time back to 50mk
- separated forward and muon veto counters

TF detectors (light guides and PMTs) are to be replaced by closely fitting MPPC arrays.

LAMPF, a "traditional" semi-dinosaurian General Purpose MuSR rig



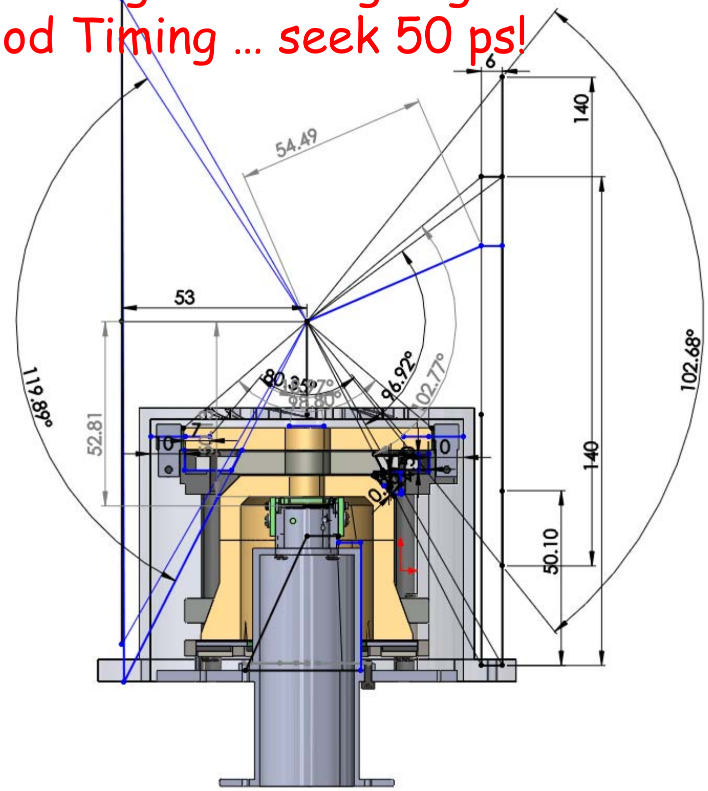
A general purpose uSR rig built around a .4T magnet originally used in the (now lost) Los Alamos Muon Facility.

An ultra low background (ulb) capability is available on this instrument allowing measurements for samples as small as $3mm^2$.

3T Spectrometer: "M9" General Purpose

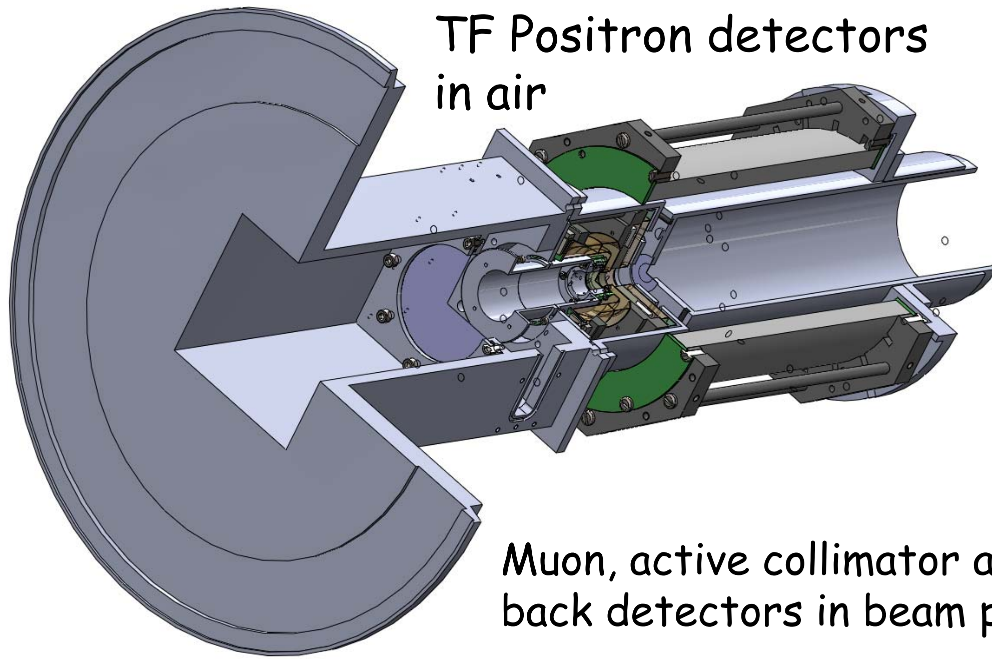
Initial concept Kyle Boone, A. Kahn /w CMMS and finalized by Detector Group (R. Henderson)

Spectrometer using SiPMs located in the bore of the high field magnet: No light guides -> Good Timing … seek 50 ps!

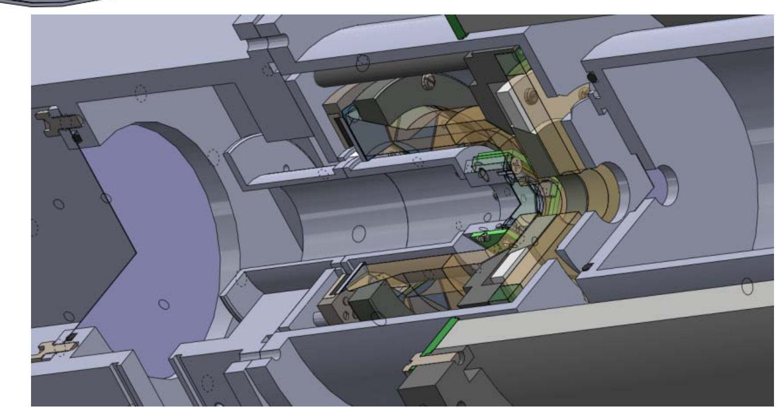


Muon, active collimator and back detectors for M9A spectrometer

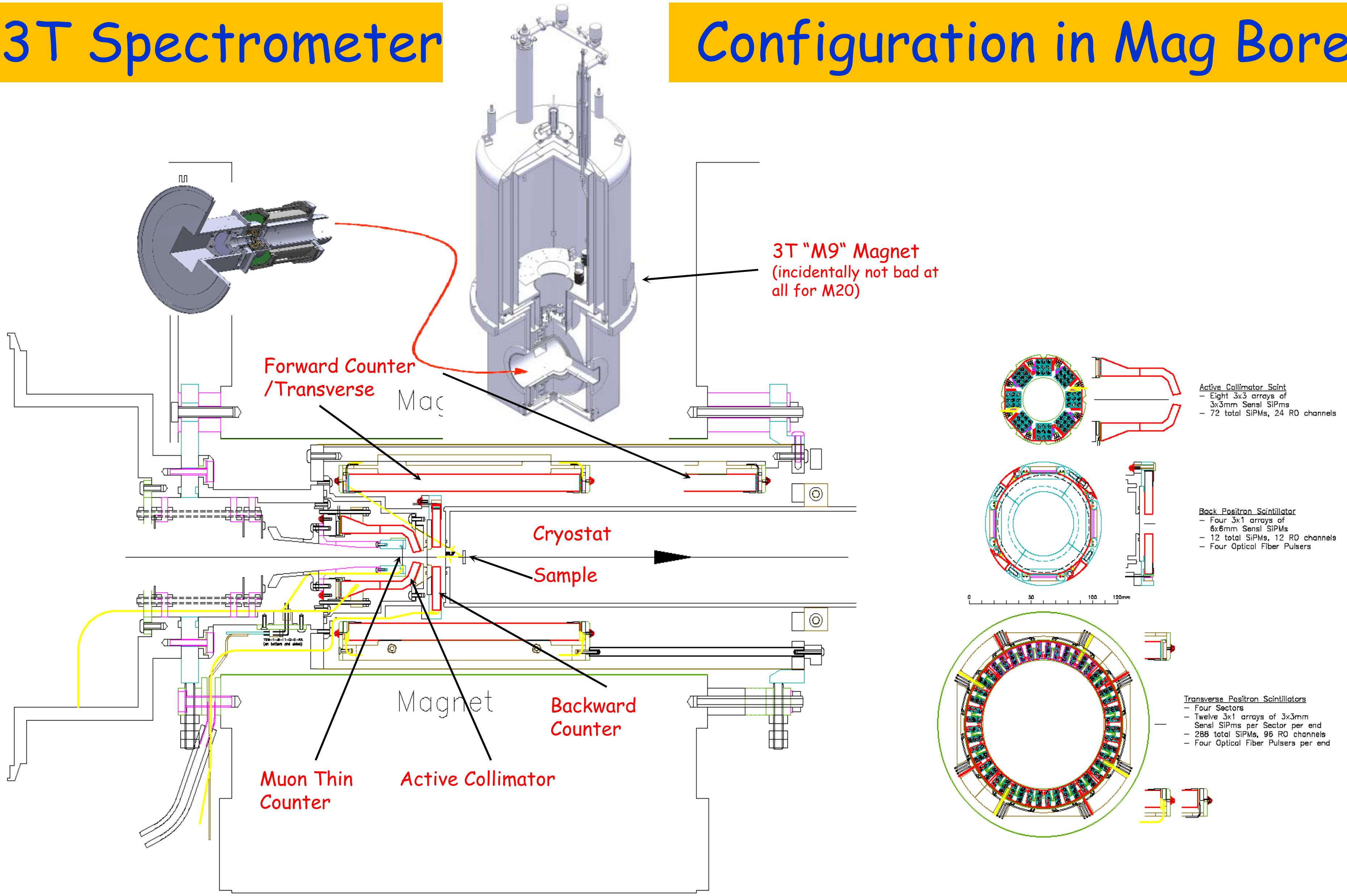
TF Positron detectors in air



Muon, active collimator and back detectors in beam pipe



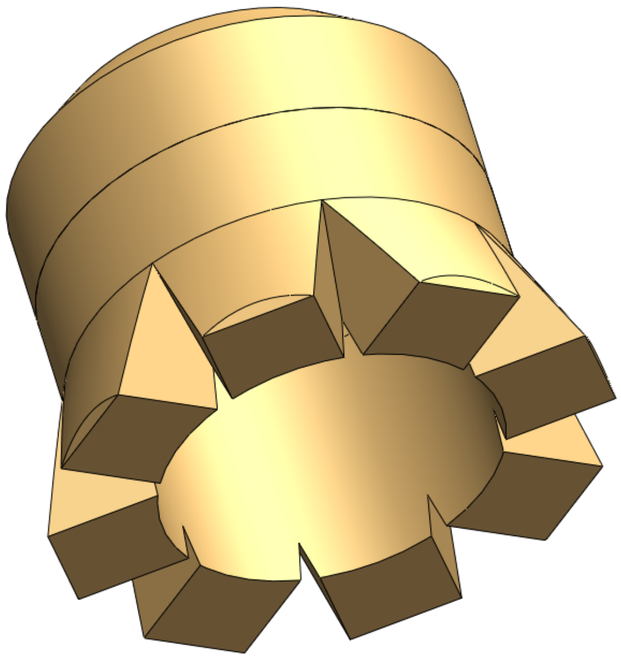
3T Spectrometer Configuration in Mag Bore



M9 General purpose 3T MuSR spectrometer as refined by R. Henderson

Detector Philosophy: SiPMs on the Scintilators

Next Generation Detector Design with APD based detectors
"in the magnet"



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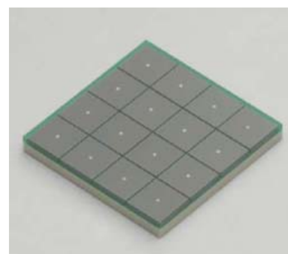

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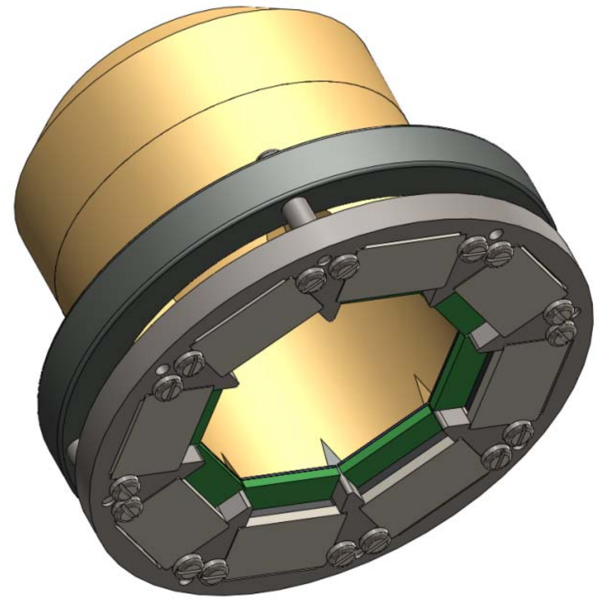


SiPMT array detectors (APD PMT substitute) on active collimator is illustrated. Highly efficient coverage of scintillator edges /w coincidence to control dark noise.

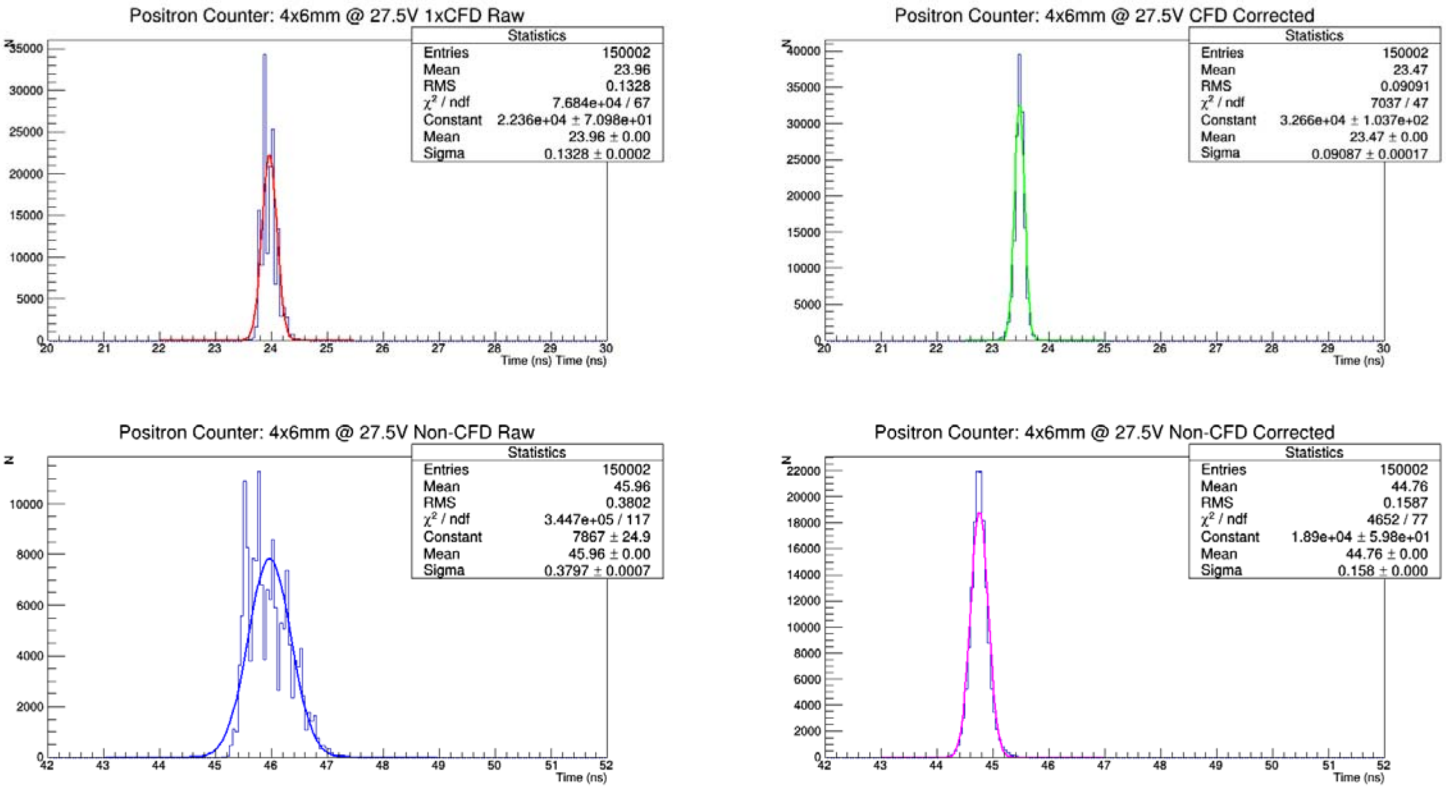
SiPM electronics design by Detector Group (L. Kuchaninov, Miles Constable, F. Retiere) and testing by Jerin Roberts.

Long Bar 3T TF SiPM Detector Performance

2x2 SiPM Array covering ½ Positron Counter End

- MIDAS based Timing Performance test /w TDC and QCD

Tests by Jerin Roberts. R&D support by Detector Group



The level of timing for performance indicated in the top right histogram for the "long" positron counters found in the 3T spectrometer is fully adequate for it to operate at its maximum diamagnetic frequency without compromise.

For the much shorter counters like those that will be in NuTime, we can expect significantly better performance.

We have discovered that the best timing scheme is based on amplitude corrected CFD discrimination, as opposed to ac "early" photon detection.

This is the "pay dirt" of our R&D effort … ½ the photons give ~91ps

Future of βNMR -> User Facility

Evolving the βNMR beamlines toward a user facility.

The key issues here are:

a) Technically the βNMR experiment is much more complicated than its MuSR cousin; Currently it requires the 24/7 attention of an expert.

b) A priori knowledgeable users will not exist i.e. from similar facilities, since there are none.

So the choices of supporting βNMR in the face of greatly expanded beam-time and users in 2019 are:

i) Have sufficient trained facility staff always on hand, and/or

ii) Train a group of potential users beforehand so that they can manage better alone

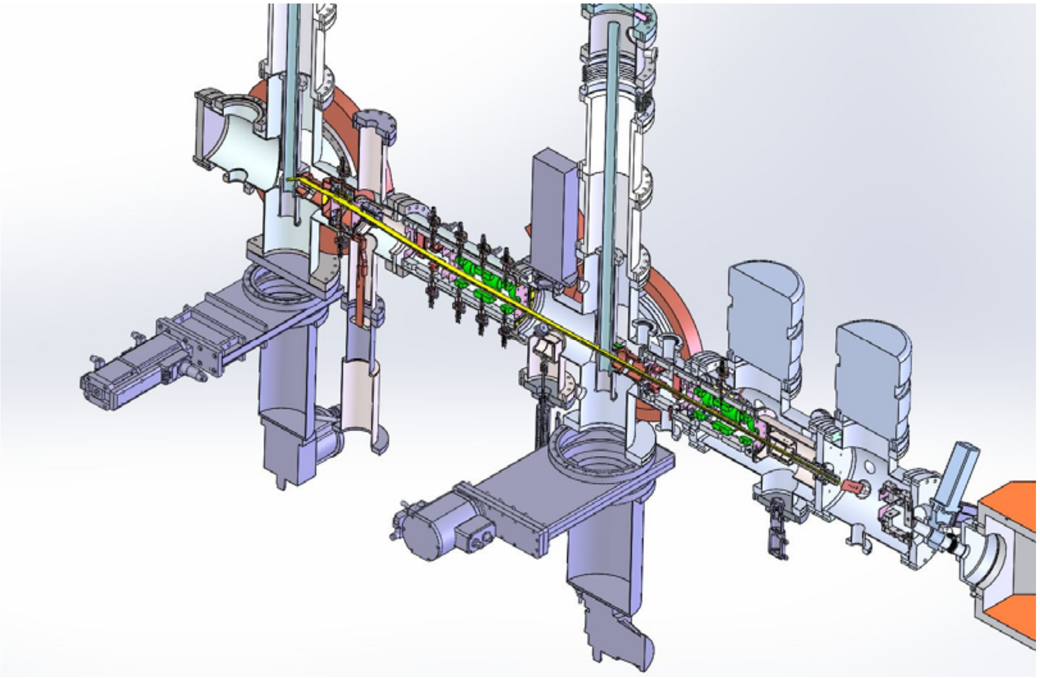
iii) Improve the operations so they are simplified and less technique specific.

A plan to help accomplish the task might look like:

- Active encouragement of new βNMR users should wait until closer to expected delivery of beam from Ariel, which is currently 2019. At present there is not enough beam for all of the users. We currently have two external groups running; Jun Sugiyama, Louis Bouchard (UCLA), Zaher Salmon, Sarah Dunsiger
- Early in 2018 the addition of βNMR specialized facility scientist.
- Iain engages in a tour/outreach campaign, also early in 2018.
- The transition from the 5 weeks a year that we currently have to the 15 weeks or more promised with Ariel might resemble a step function and it will be impossible to accommodate new users if they have not been trained. Thus the hosting of a summer school in 2018 (and insisting new users attend) expressly for this purpose will be required.
- Systematically examine the experiment to identify aspects which can be made more user friendly.
- Utilize the existing groups as a nucleus to expand/partner them with new users … as a means of incorporating a core of knowledgeable users. Without such a core, supporting even 15 weeks of βNMR time would take 3 dedicated experts during the beam time, i.e. ½ the current facility scientific staff.

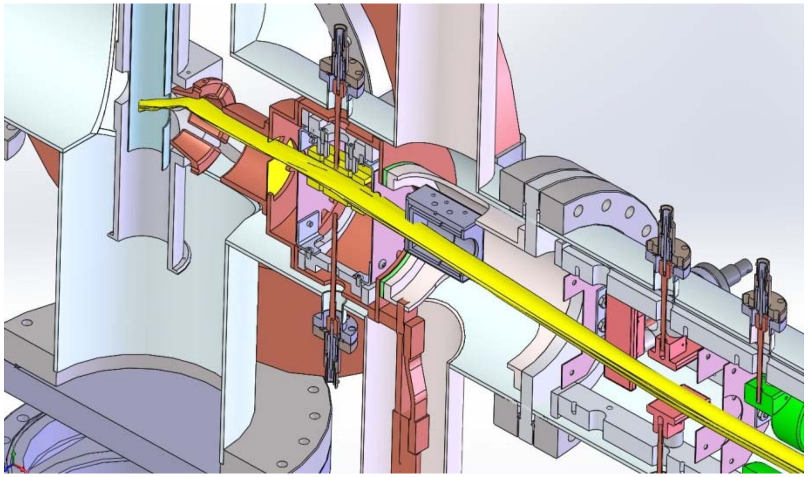
Planning for a || Geometry βNMR Station

Higher-Field and Low Temp || G βNMR station (is funded)



Meissner State Geometry
i.e. Field || Nb Sample Γ P

Field penetration profile in Nb Cavity Materials relevant to advanced SRF research …
Can we figure out why different surface prep treatments have superior flux pinning & higher Q ?

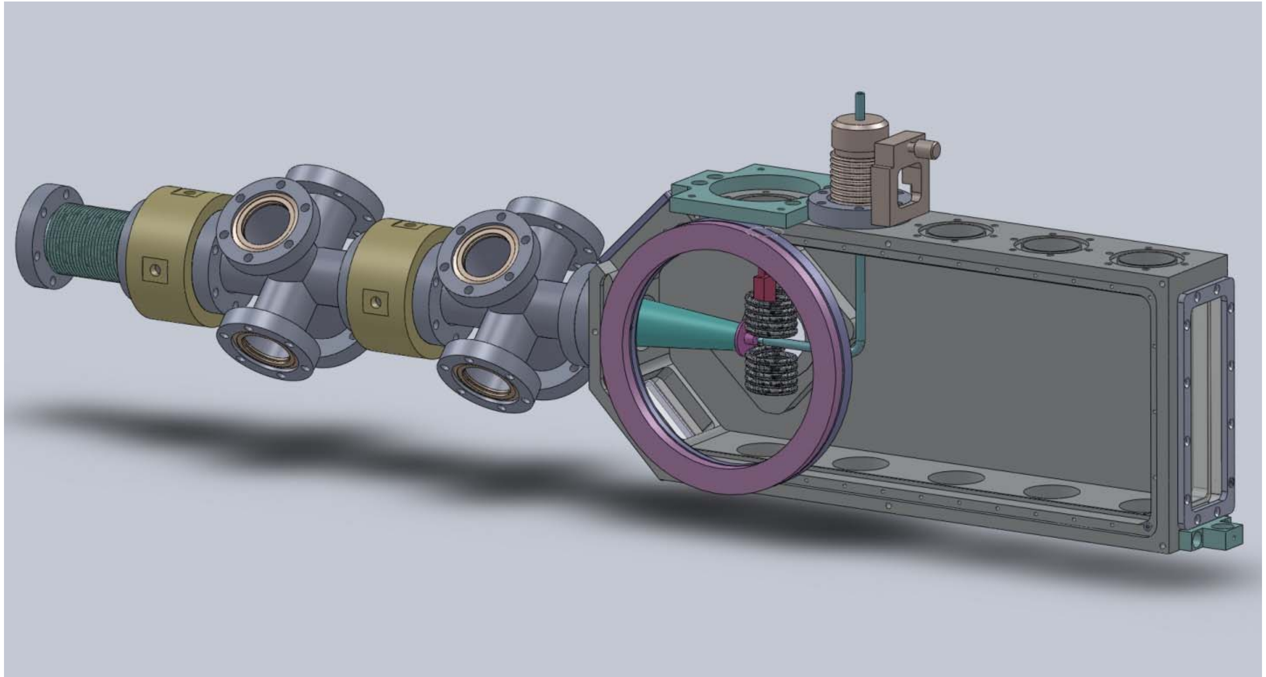


Extremely flexible new βNMR rig
- 0 -> 2.2 KG
- 300 mK -> 300K
- 2mm diameter beam spot
- .1 – 30Kev

Potential Liquid βNMR Mg beam to study biological systems

Quoting from the Gate 0 Review Submission: (M. Stachura) …

"To set up a compact β-NMR apparatus for studying biological systems, specifically metalloproteins, peptides, DNA and small biologically relevant compounds, in their natural aqueous environment. The system will allow for both, connecting high-vacuum and liquid environments as well as manipulating the liquid sample in the restricted environment of the spectrometer and of the ISAC-I experimental hall."



A test of the production of a polarized ^{31}Mg beam has been carried out on the βNMR beamline during Dec 16 -19, 2015.

70% Polarization achieved -> viable experiment.

Funding & Manpower Status

- Current (see below) Status Quo to be Maintained "until further notice"
- Current manager's perspective is that when M9 becomes operational (as predominantly a non-expert facility) and before βNMR undergoes utilization expansion in 2019 at least 1-2 scientists + one technician will be required for the facility to function smoothly
- Current manager >65 yrs old -> room for new blood in the foreseeable future

CMMS Funding Source	$	Status @ 2015
NSERC->NRC (~2.7 scientists + 3 technician salary component only)	442,800	Contingent on Renewal Report due 2017
- TRIUMF will top up this base salary	~200,000	Stable for 5 yr plan
Common Account User Fees (MRO funds)	0	**User Fees Eliminated**
TRIUMF assumes Operating and R&D budget	~130,000	**Stable for 5 yr plan**
Commercial Beam Time Fees (based on 2015)	~30,000	Variable availability
User Le Helium Fees ($1.75/L, MRO + ½ tech)	42,000	Remain in effect
TRIUMF project capital	250,000	new M9 FE
TRIUMF project in-kind	~.5 FTE	3T / M9-T2 support
TRIUMF CMMS Staff	2 FT + 6 term	Stable for 5 yr plan

MuSR Current and Future Milestones

i. Implications of the "User Fee" removal

a) Significantly less burden on individual (often modest) research grants.
b) Removal of access barrier from those institutions are not allowed to pay user fees
c) Solidifies long term financial operating and R&D budget for the 5 yr period:
Specifically a detailed 5 Yr budget totalling ~140K/yr has been submitted. It is inclusive of; Facility MRO, Detector R&D, Spectrometer SiPM rebuilds and beamline DAQ upgrades.

ii. Major infrastructure initiatives for the 5-Yr period

a) fix M9-T2, put M9A into operation,
b) Proposal for new or upgraded decay M9B->M9H channel
c) ISAC-II Expansion of MMS βNMR facilities in 2019-20
d) A potential Liquid βNMR Mg beam for biological research

iii. Outreach Program focused toward US institutions

a) Plan for presentations at the North American neutron scattering facilities;
i.e. SNS (Oak Ridge, done yesterday) and NIST (Maryland).
b) Arrange out-reach visits to leading universities on the west coast, specifically to those in which some exposure to μSR currently exists. i.e. UCLA (Louis Bouchard; M1399 /1351 & Mike Bridges; M1411), Berkeley (Joel Moore; MMS-EEC panel), UC Davis (Nick Curro; M1132), UCSD (DN Basov; M1529).

Summary

TRIUMF Perspective

- TRIUMF has now integrated its MuSR program into its mission
- With the pending repair of M9-T2 (as required by it's current NRC agreement) TRIUMF will enable its maximal μSR capability
- The initiation of the Ariel project in 2019-20 will dramatically boost the beamtime available for the βNMR program

Specific Projects to Advance MuSR/βNMR

- Commission M9A: The "turnkey" non-expert user beamline
  Reinvigorate M9H (if funded): Providing high pressure μSR capability
- Fully incorporate SiPM technology into spectrometers
- Advance βNMR science capability (i.e. with the new spectrometers & modern NMR techniques) and evolve infrastructure into a user facility

Future User Directions

- Outreach to broader Science community to expand User Base

What Will Put SNS on a Pinnacle of the MuSR World ?

- Emulate RF pulse techniques (similar to ISIS) for Muon Magnetic Resonance … but at much higher RF pulse power.

What is needed:

- The time structure that you naturally have
- Superconducting RF technology that can develop a phase coherent (with pulse envelope) H_1 magnetic field at the sample:
  - ~150G @ 20-1000 MHz for diamagnetic studies
  - ~10-20G @ 1000-3000 MHz for Muonium studies
- Superconducting coils/cavities required to prevent RF heating and enable experiments < 4K.

The unique μSR Technical Capabilities that are Provided:

- Very high resolution final state or slowly relaxing MuSR capabilities
- Muon spin echo, double resonance and spin decoupling capabilities

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

Thank you!

Merci!