

Challenges in Building TRIUMF

(1968-1975)

Ewart Blackmore



1970



2014



Ewart Blackmore

- 1963-1967 Graduate Student, UBC Supervisor – John Warren
“Low energy reactions 3He (3He , $2p$) 4He and $T(3\text{He}, pn)4\text{He}$ ”
using the 3 MeV UBC Van der Graaff and Chalk River Tandem
Coffee table discussions on next accelerator for UBC
- 1967-1969 Post doc at Rutherford Lab, UK
Particle physics – Kaon leptonic decays
Measurement of H^- EM dissociation for the TRIUMF cyclotron design
- 1969-1972 TRIUMF Centre Region Cyclotron
1973-1975 Cyclotron inflector and probes/diagnostics
1975-1980 Assistant Director for Initial Operations
1981 Sabbatical at LAMPF in pion physics
1981-2008 Division Head – Experimental Facilities / Accelerator
Technology /Engineering
1995-2006 Coordinated Canada’s contribution to the LHC at CERN

ELECTRIC DISSOCIATION OF H^- IONS BY MAGNETIC FIELDS

G. M. STINSON, W. C. OLSEN, W. J. McDONALD and P. FORD

Department of Physics, The University of Alberta, Edmonton, Canada

D. AXEN

Department of Physics, The University of British Columbia, Vancouver, Canada

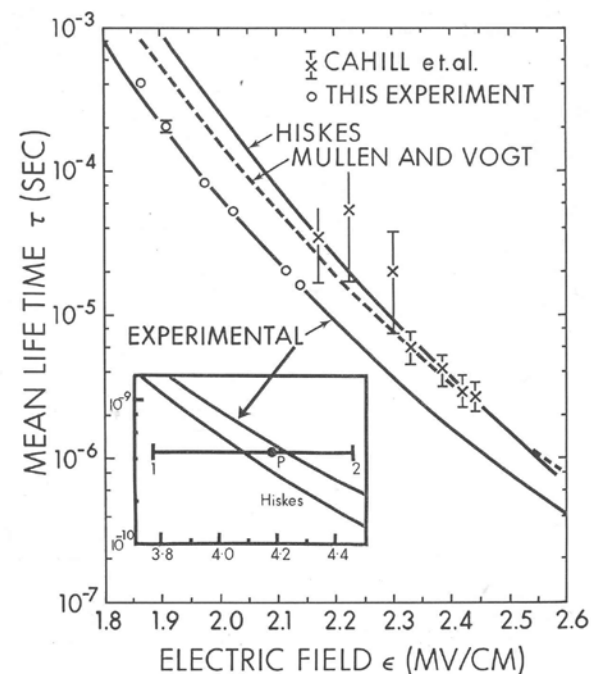
E. W. BLACKMORE

Rutherford High Energy Laboratory, Chilton, Didcot, Berkshire, England

Received 21 May 1969

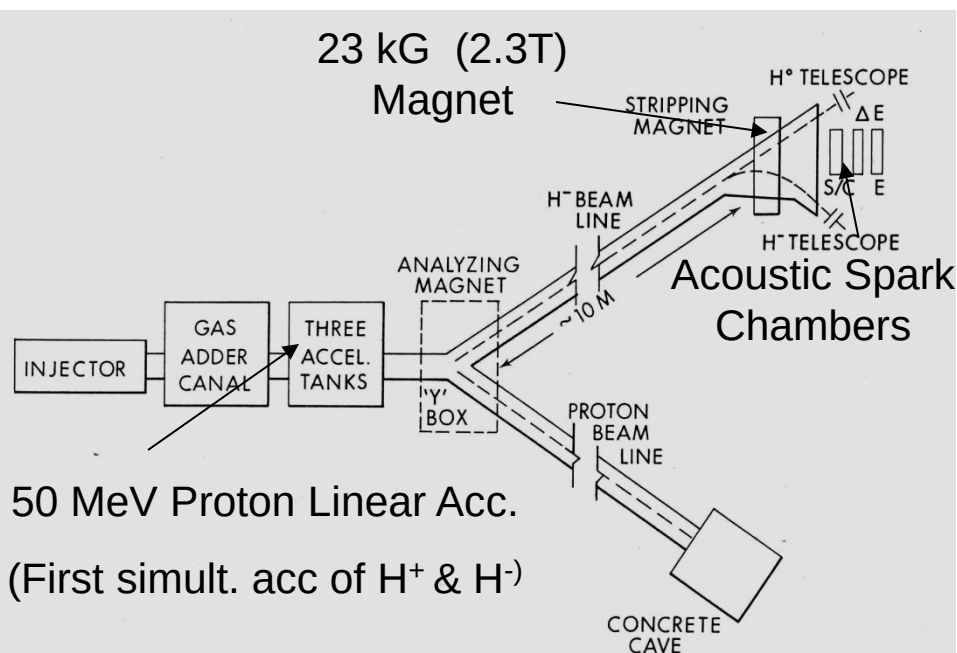
$$E = 0.3\beta\gamma B \text{ MV/cm}$$

$$H^- \text{ ion bound } 0.755 \text{ eV}$$



Consequences

- increase in cyclotron by 4%
- 20 scale model → 20.8 model
- peak field 5.76 kG
- confirmed in 1976 with TRIUMF beam



50 MeV Proton Linear Acc.
(First simult. acc of H^+ & H^-)

TRIUMF Cyclotron

- 500 MeV, 100 μ A, H^- ions
- simultaneous extraction 2 beams
- cost \$8.4M in 1968

(1972) TRIUMF(110) UBC

Chief Eng'r Joop Burgerjon

Magnet: Al Otter Ed Auld

Beam George Mackenzie Mike Craddock

Dynamics: Gerardo Dutto

Corrie Kost

RF: Roger Poirier Karl Erdman

Milos Zach

Vacuum: Dennis Healey Dave Axen

ISIS: Peter Bosman Bruce White

Probes: Bruno Duelli (EWB)

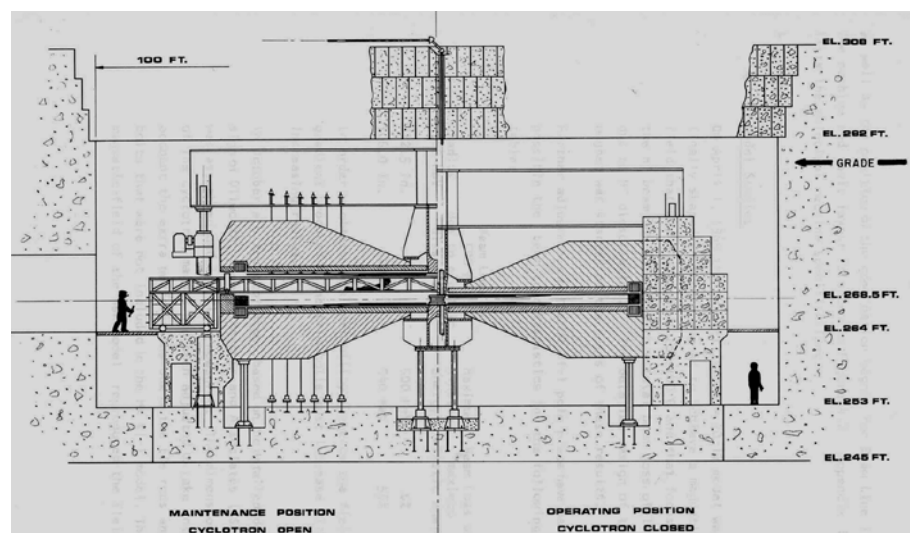
Controls: Don Heywood Dick Johnson

Dave Gurd Ken Dawson (UofA)

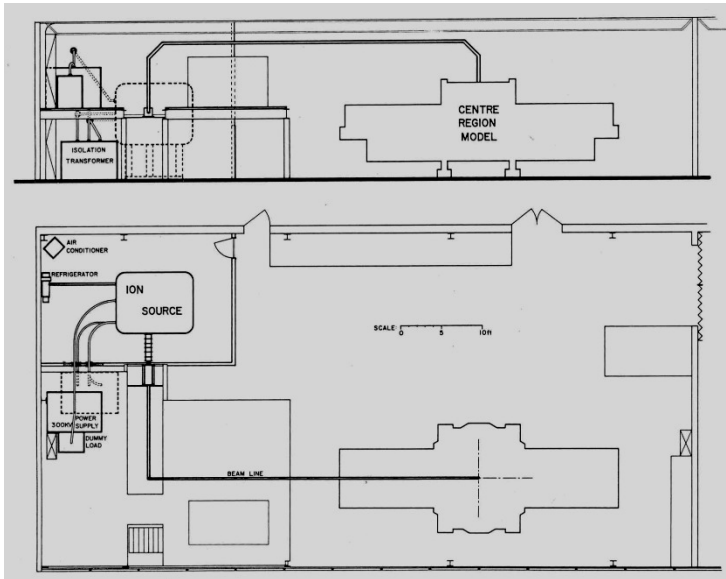
Safety: Ian Thorson Brian Pate (SFU)

Gary Wait

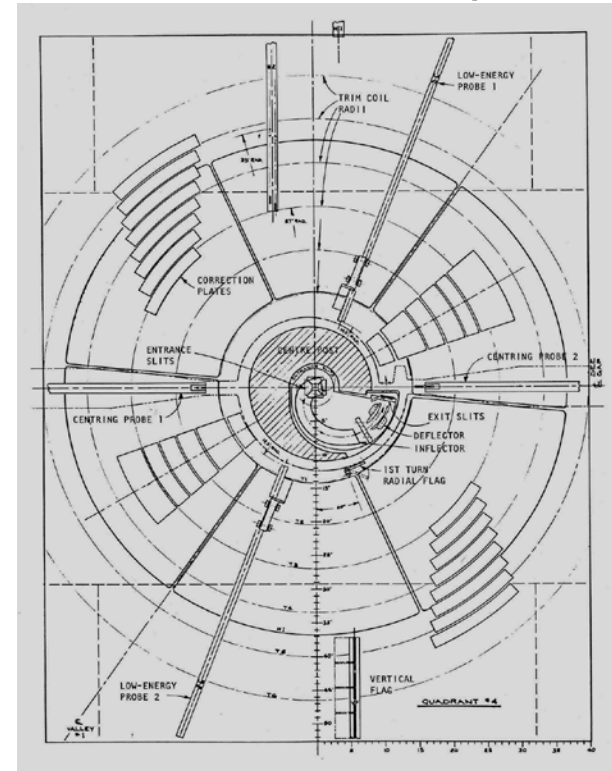
CRC: Ewart Blackmore



Centre Region Cyclotron

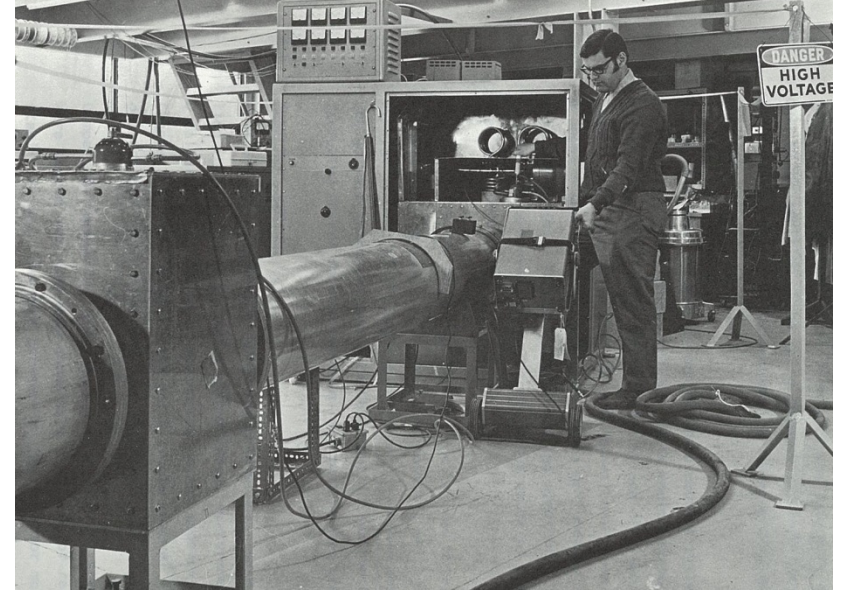
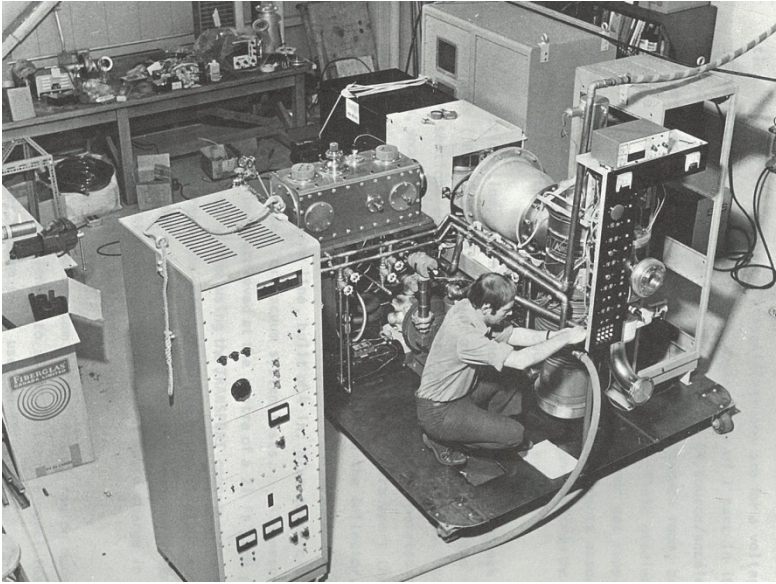


- 80 ton magnet
- 8 resonators with flux guides
- 300 keV ion source 0.5 mA
- 3 MeV in 6.5 turns, 100 μ A



Centre Region Layout

Centre Region Cyclotron



1971

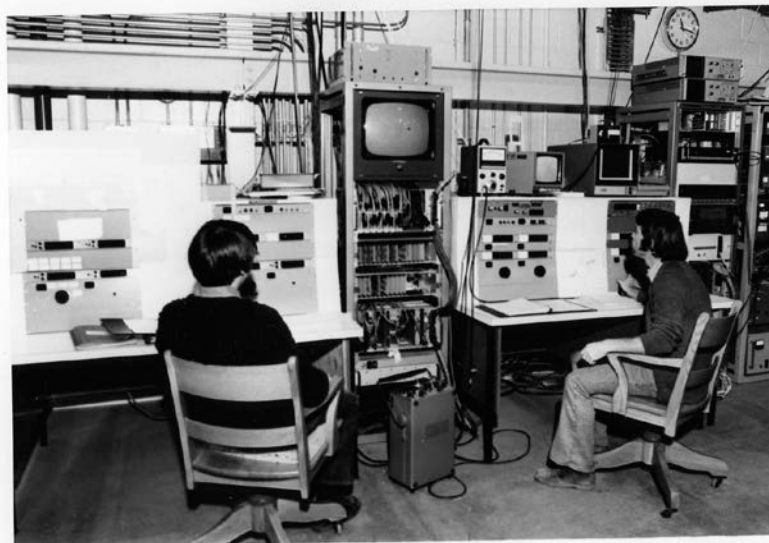
Malcolm Hone – Ion Source

Roger Poirier – RF amplifier

John Yandon – leak checking

Prototype Testing

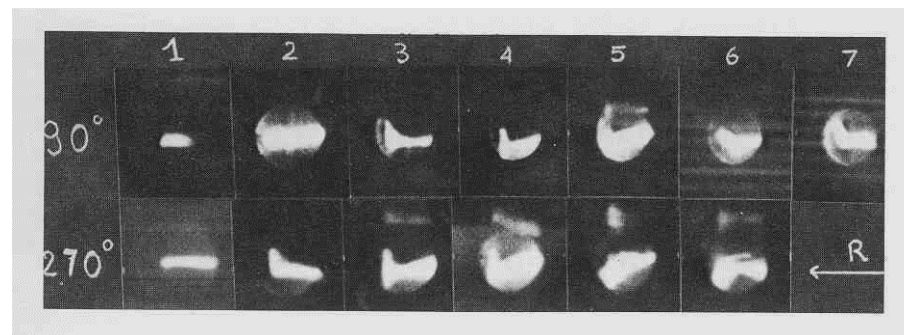
- ion source, injection system
- inflector and centre region
- resonators and rf amplifier
- probes and diagnostics
- magnet & field mapping
- controls



Inflector/Deflector

Achieved/Learned

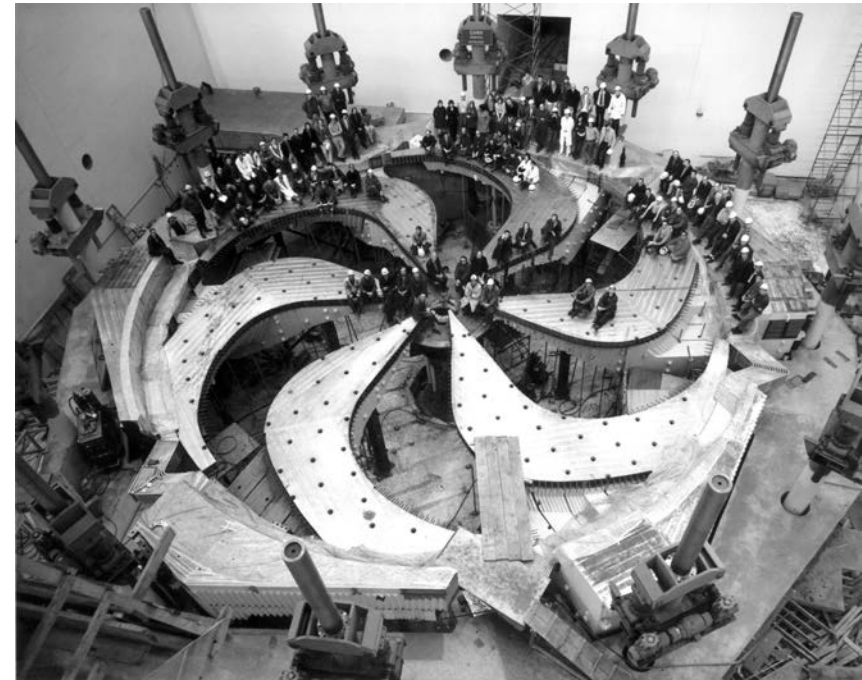
- first beam to full energy October 1972
- intensity to 100 μA June 1973
- resonators too sensitive to temperature
- correction plates required (G. Dutto)
- beam dynamics understood
- ISIS, inflector and probes design
- fabricator identified (EBCO Industries)



First six turns of beam

Magnet

- fabrication and assembly went well (1972)
- 4000 tons of steel in 50 ton shipments
- first field maps-centre field too high by 100 g
- difference in steel permeability 0.5" vs 5"
- required gouging out 16 tons of steel
- field tolerance of 1 g required (1 in 4000)
- took ~ 9 months of shimming/measurements
- delays gave other groups time to be ready



Field mapping
using flip coils

Radiofrequency System

- 80 resonators, 1.8 MW 23 MHz
- installation and alignment
- water connections, rf contacts

August 1974 RF early operations

- outgassing and hydrogen pumping
- water leaks and vibrations
- rf contact damage, strongback temp.

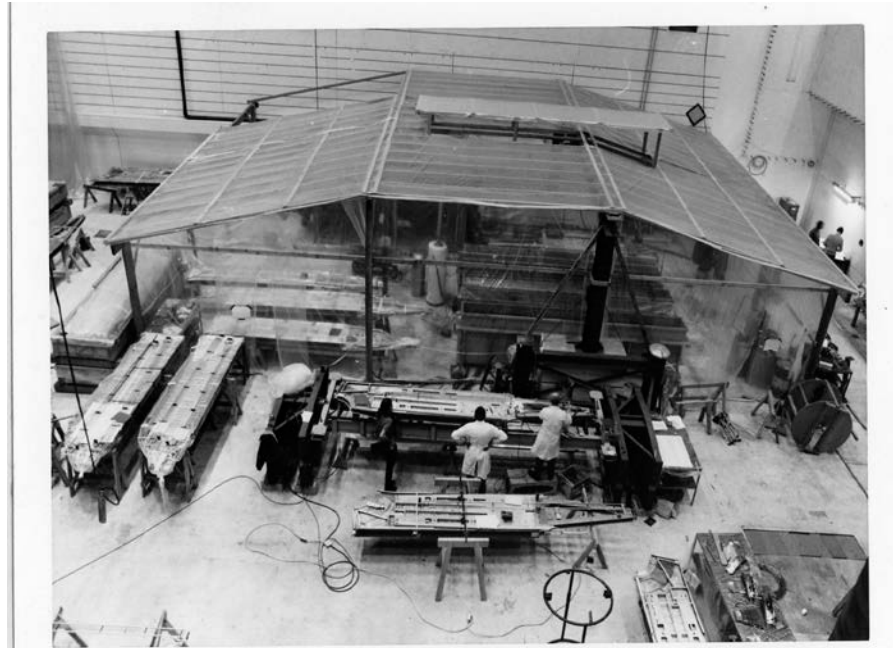
Later 1975-80

- centre region electrodes melting
- damage to diagnostic probes
- resonator strongback sagging

(1990-1992) Resonator replacement

- 24 new resonators installed -stiffer

(2000-present) RF Amplifier refurbish

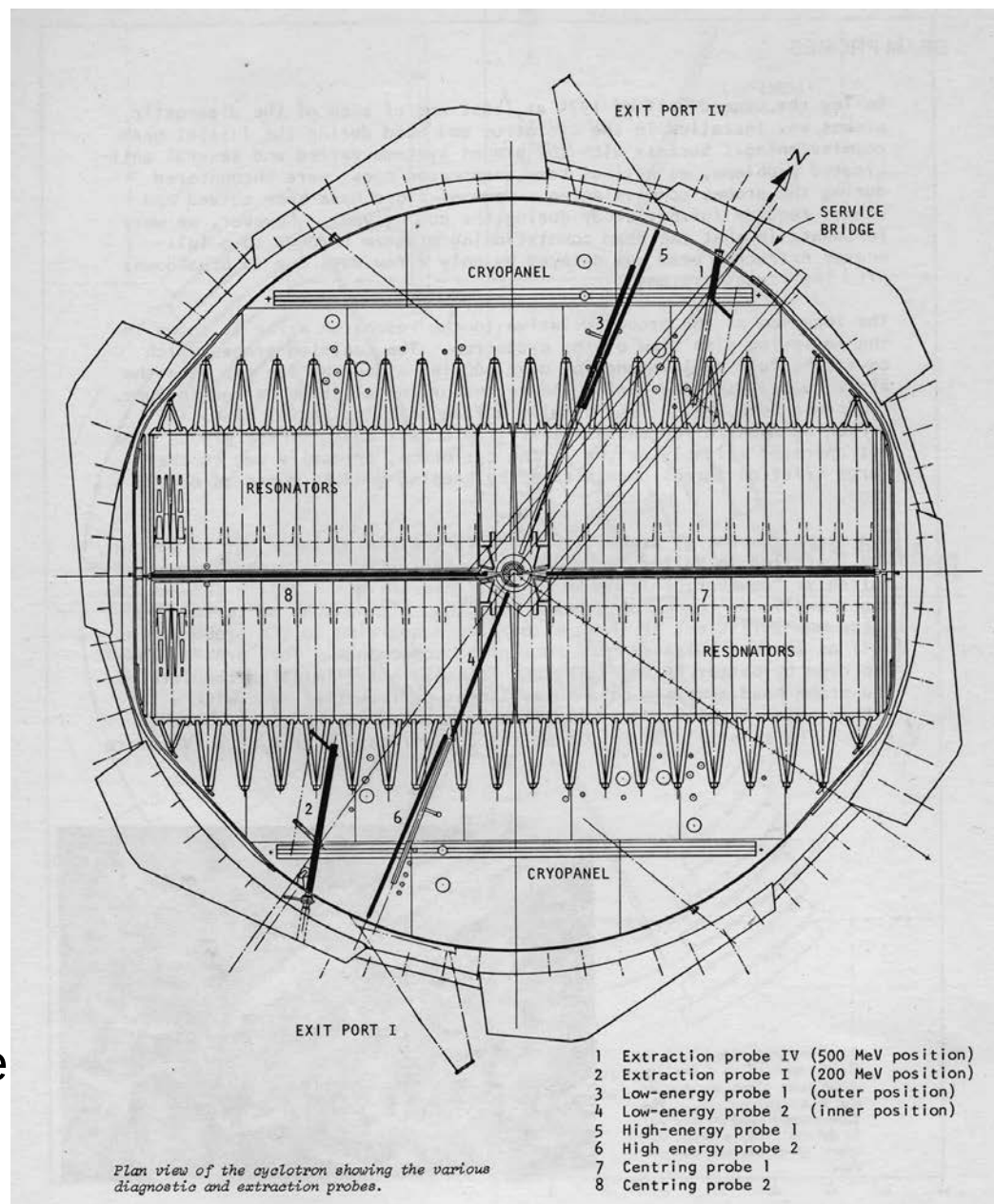


Probes & Beam Diagnostics

- Some probe concepts did not work eg RF gap probe
- LE probes very sensitive to RF fields in gap
- HE probes pretty reliable
- Temporary extraction foil installed for 500 MeV

Later 1975

- Extraction probes 1 and 4 installed and proved reliable.
- Installed water-cooled probe and PIPs for quicker tuning.
- Found TOF method for tuning isochronism

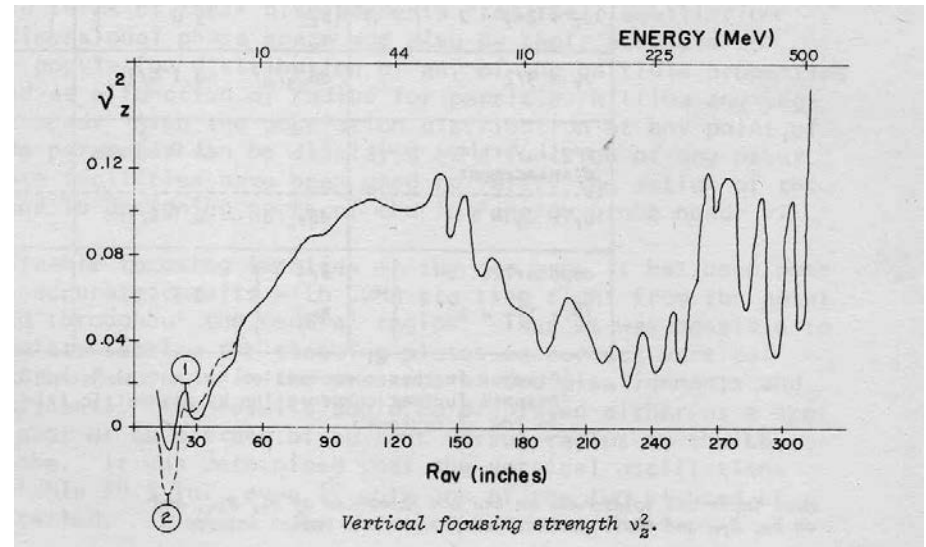


Beam Dynamics

- large magnet, low field, large gap
→ weak focusing
- low $\Delta E/\text{turn}$ → many turns, tight tolerance on mag field, isochronism and vertical centring
- high intensity → space charge, large phase acceptance

Ion Source & Injection

- high intensity → reliability and filament lifetime
- polarized source polarization and intensity
- 40 m long injection line, cyclotron fringe field, reproducibility
- inflector HV reliability at high current



Cyclotron Commissioning



Reg at the controls

Milestones

Injected beam	November 17, 1974
500 MeV	December 15, 1974
100 μ A	July 1977 (beam dump)



The "Commissioning Team"

Don Heywood	Reg Richardson
Dave Gurd	George Mackenzie
Corrie Kost	Ewart Blackmore
Gerardo Dutto	Milos Zach
missing Mike Craddock	

First Beam December 15, 1974

	Maximum Radius of Beam	Energy (if centred)
Nov. 17	42 in.	6 MeV
Nov. 18	55 in.	10 MeV
	(Radiation in vault!)	
	85 in.	24 MeV
	Replaced low-energy probe	
Nov. 22	150 in.	71 MeV
Nov. 23	183 in.	113 MeV
	Replaced B-20 cryogenerator	
Nov. 25	179 in.	109 MeV
	Vacuum problems	
Nov. 26	195 in.	135 MeV
	Deflector sparking	
Nov. 27	223 in.	195 MeV
Nov. 28	231 in.	210 MeV
	Check $v_z^2 = 0.02$ at R=223in.	
Dec. 1	259 in.	295 MeV
Dec. 3	265 in.	315 MeV
	Beam appears to be centred 300 kV supply in ISIS kaput	
Dec. 11	Trying to re-establish beam RF problems	
Dec. 12	273 in.	345 MeV
	Sparking in ISIS	
Dec. 14	278 in.	363 MeV
Dec. 15 12:10	278 in.	363 MeV
	13:07	309 in.
		500 MeV



PROGRESS ACHIEVED
for 15th DEC. 74

15 nA @ 500 MeV
RF @ ~ 92 kV

AT EXTERNAL DUMP IN VAULT
10 nA

CONGRATULATIONS TO
YOU ALL.



First Extracted Beam Dec 15th 14:00

Beam spot distribution as measured with a multi-wire chamber immediately after the beam had been extracted. The horizontal scan is on the right and the vertical on the left.

**Used a thin
aluminum foil
positioned at about
507 MeV**



**Horizontal
Beam right**

**Vertical
Beam low**

**32x32 Profile Monitor
located after combination
magnet and focusing
quadrupoles**

Cyclotron Operations and Beam Delivery

IEEE Transactions on Nuclear Science, Vol.NS-22, No.3, June 1975

PRODUCTION OF SIMULTANEOUS, VARIABLE ENERGY BEAMS FROM THE TRIUMF CYCLOTRON

J. Reginald Richardson*, E.W. Blackmore, G. Dutto,
C.J. Kost, G.H. Mackenzie, TRIUMF and M.K. Craddock
Physics Department, University of British Columbia,
Vancouver, B.C.

Specification (1972)

2 beams – 100, 10 μA

180-520 MeV

Achieved (today)

3(4) beams

BL1A -170 μA 500 MeV

BL2A -100 μA 500 MeV

BL2C -100 μA 100 MeV

Total – 300 μA today

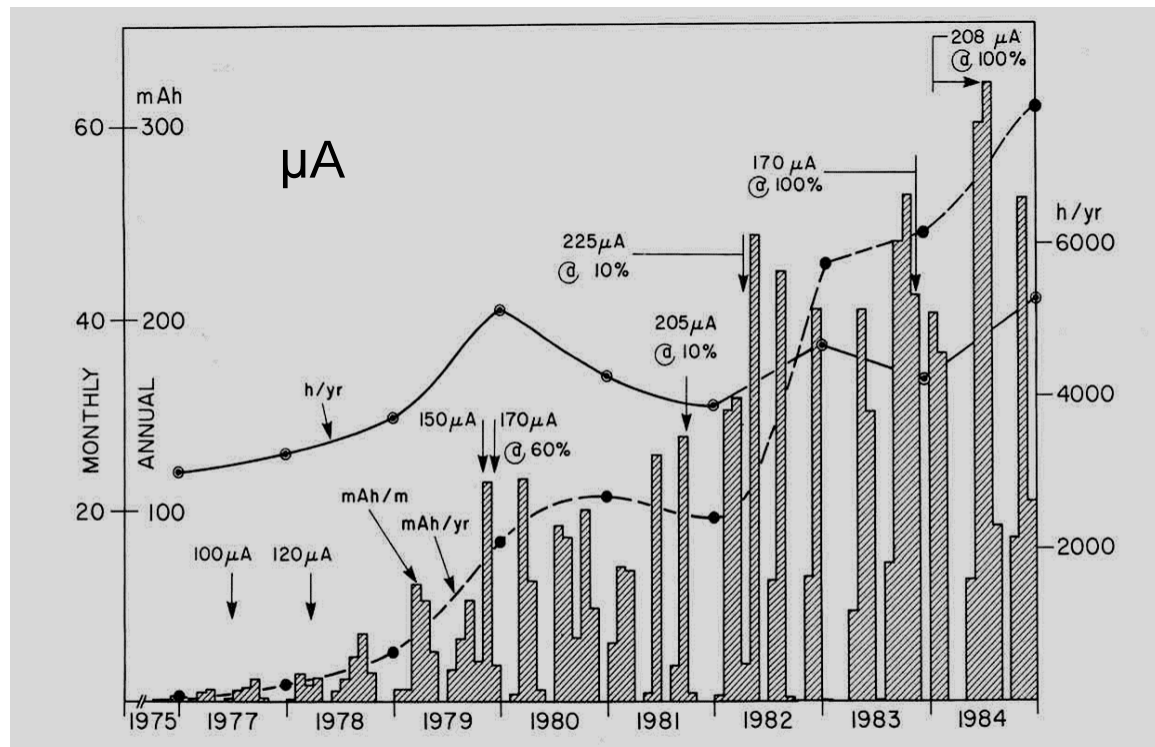


Fig. 71. Beam charge delivered (broken line) and hours of operation (solid line) over the past several years. Milestones in extracted peak current are also indicated. The histogram shows the charge delivered per month.

1974 Personnel in MCR and Vault

Operations Staff Shift Supervisors

John Yandon
Jim McIlroy
Ken Lucas

Operators

Gord Roy	Neil England,
Fred Bach	John Kaminski
Mike McDonald	Geoff Wight
Andy Hurst	Brian Stanton

Controls - Software/Hardware

Dave Gurd	
Don Heywood	
John Cresswell	
Brian Evans	Don Marquardt
Erwin Klassen	Wayne Fung
Naomi Shibaoka	Pam Brown
Roy Moore	
Dave Smith	

Safety

Gary Wait
Dave Gill
Lutz Moritz
Tom Moskven
Lorne King
Aivor Teteris

Radiofrequency

Roger Poirier	Jim Fawley
Robin Gummer	Howie Simmonds
Milos Zach	

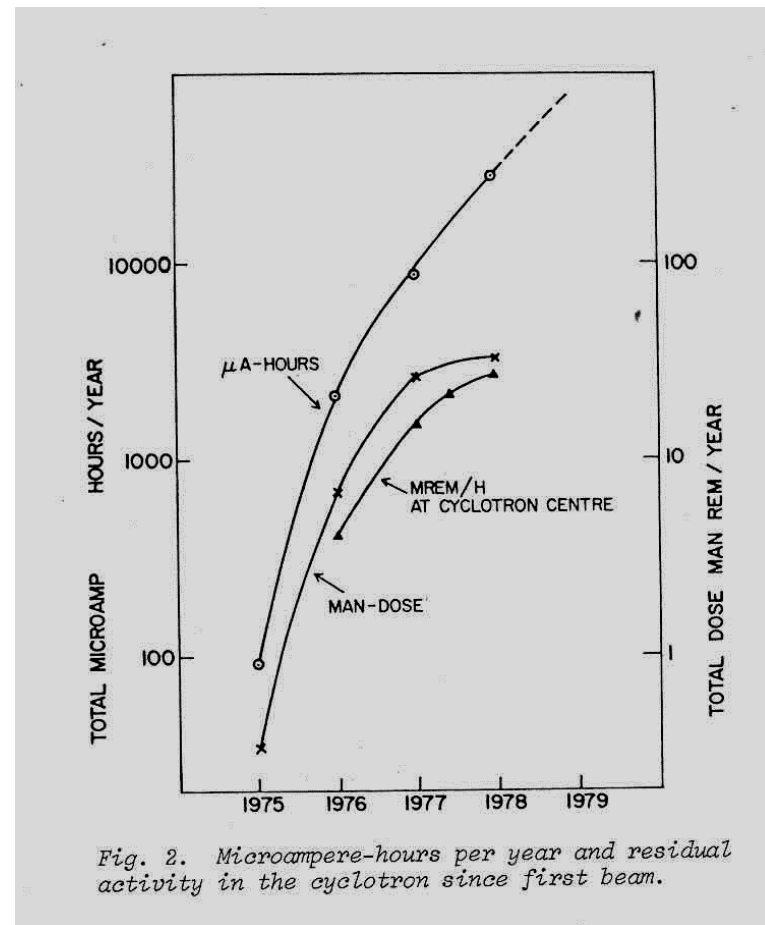
Probes Diagnostics

Ewart Blackmore	Peter Taylor
Bill Cameron	John Stewart

ISIS, Beam Lines, Power Supplies, Vacuum, Plant, DO & MS

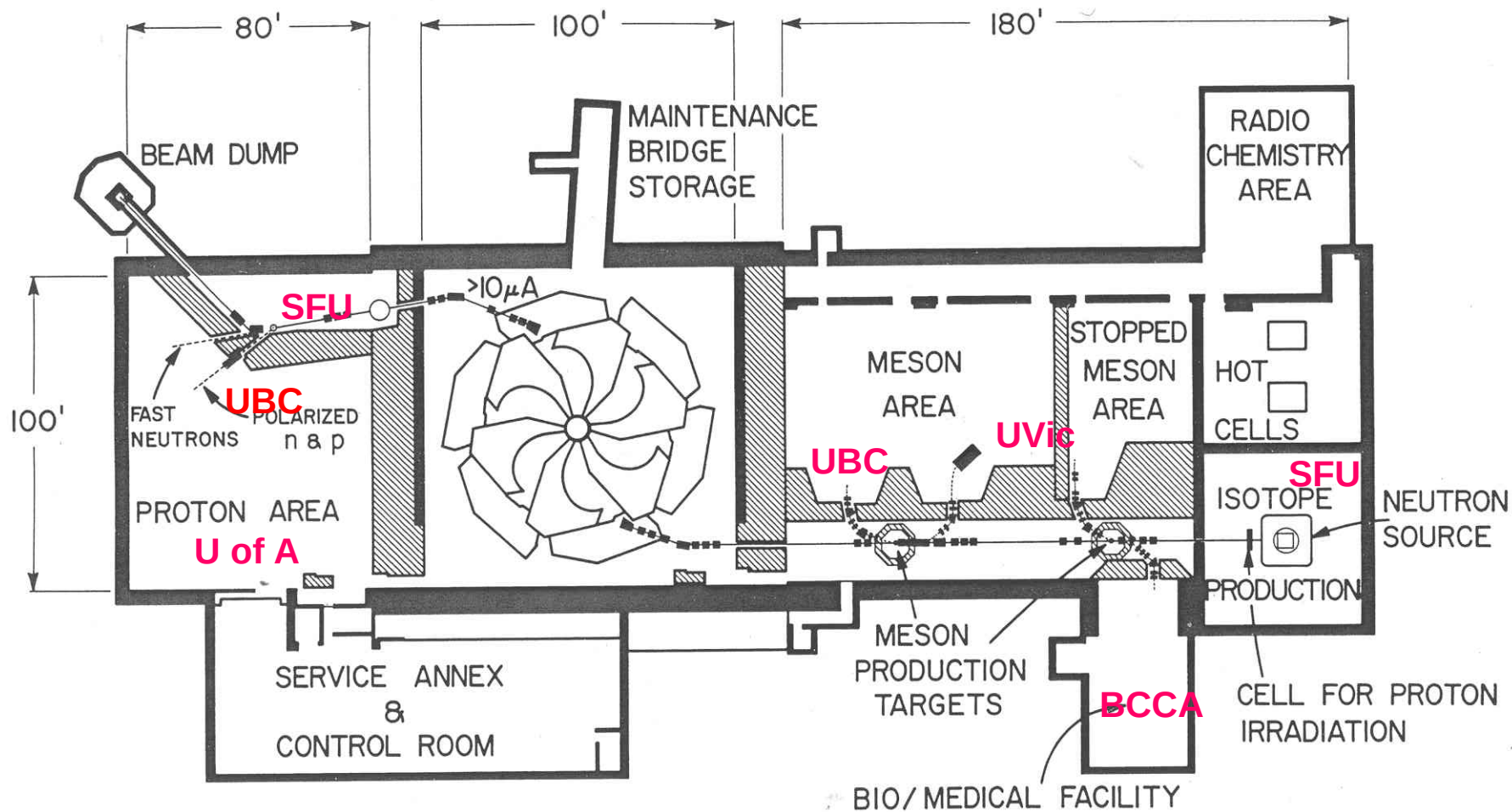
Safety and Remote Handling

- understanding beam losses in cyclotron and minimizing
- system reliability inside cyclotron
- improved remote handling capability for routine and more complicated tasks
- beam lines, target areas, TNF etc



	<u>mA-hrs</u>	<u>Dose mSv</u>
1984	322 (88%)	474
1994	490 (90%)	267
2004	687 (92%)	307 (ISAC)

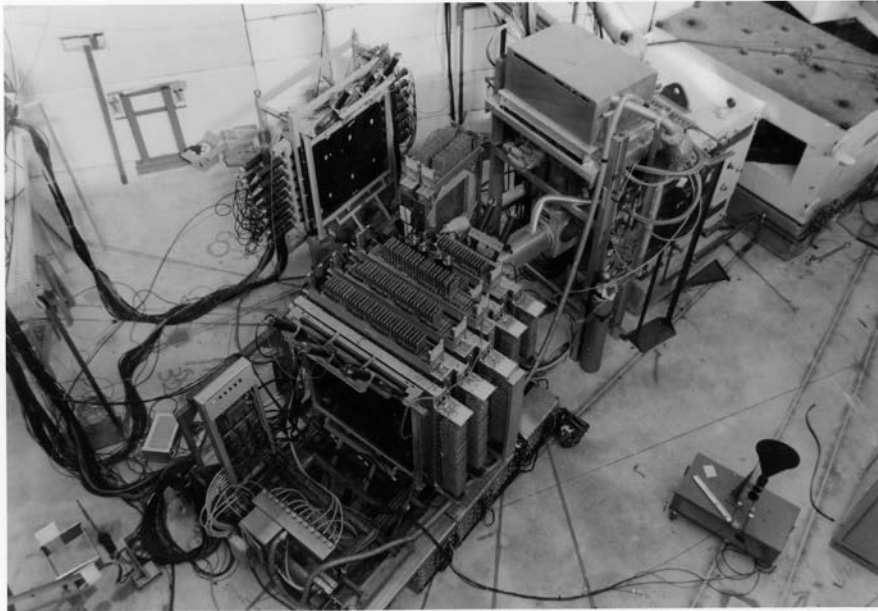
Experimental Areas & Beamlines



Planned layout 1970

Experimental Areas & Beamlines

Proton Hall



Basque Experiment - 1975



**MRS Spectrometer
1976**

Experimental Areas & Beamlines

Meson Hall



**T2 target M9, M20, M8
(1975)**



**TNF Beam Dump
(1977)**

TRIUMF Cyclotron (1974-2014)

“A 40 year Success Story”

Real Advantages

- simultaneous beams, variable energy & intensity
- reliability after initial teething problems
- versatility in meeting science demands

Real Surprises

- delivers 3x more beam than originally specified
- has lasted 40 years and still going strong
- nuclear physics (original motivation and back again)
 - particle physics
 - material sciences
 - isotope production (TR series of cyclotrons)
 - medical and other applications
 - ISAC (nuclear physics)

Thanks to All That Contributed !

