THE FIRST BEAM:
TEN YEARS IN THE MAKING

M.K. Craddock
(University of British Columbia and TRIUMF)

TRIUMF, Vancouver, BC, 12 December 2014

TIMELINE

1964 Fall: Senior UBC nuclear physicists agree to plan for new accelerator

1965 Mar: Warren memo
May: BC nuclear physicists agree on meson factory

1966 Jan: TRIUMF Project Report
Apr: $100k from AECB
Nov: TRIUMF Proposal

1967 Apr: $100k from AECB

1968 Apr: Federal approval – $19M over 5 years

1969 May: Tree-planting Ceremony
Oct: Office and lab building ready

1970 Jun: Excavation complete

1971 Jun: Main building complete

1972 Apr: Magnet & vacuum tank complete
May: 3-month strike!
Dec: Magnet coils completed – field surveys begin

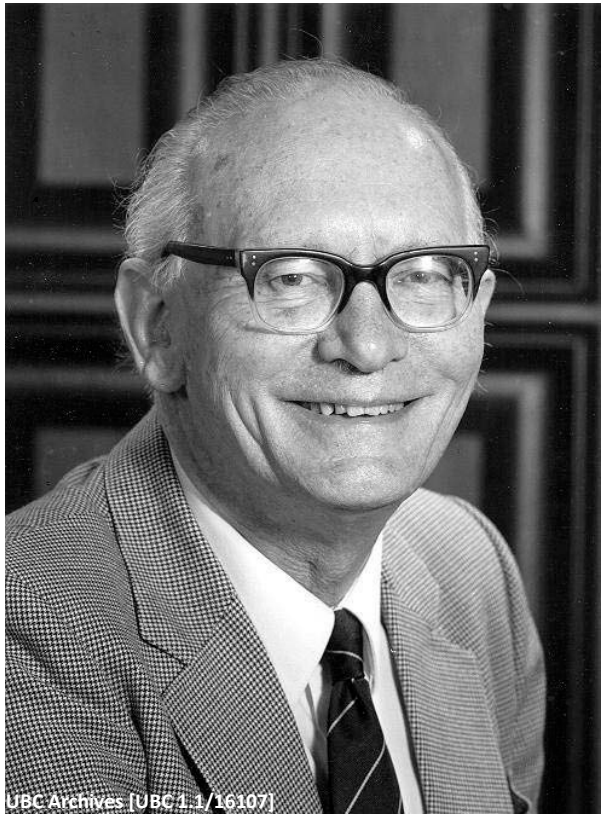
1973 Jun: Central Region Cyclotron gives 100 μA beam at 2.5 MeV
Aug: Magnet yoke remodelling completed

1974 Apr: Magnet pole shimming completed
Nov 15: ISIS, RF, cryopumping, probes, controls, BL1,4,... - installed & commissioned
Dec 15: Beam accelerated to 500 MeV and extracted

THE TRINITY

Three people were crucial to the creation of TRIUMF:

- John Warren, who created the UBC Nuclear Physics Group
- Reg Richardson, who allowed his UCLA cyclotron design to be used
- Erich Vogt, who championed the cause with government



John Warren

Reg Richardson

Erich Vogt

UBC BEFORE TRIUMF I

John Warren arrived at the UBC Physics Department in 1948 with a mandate from the Head, Gordon Shrum, to build a **3-MeV Van de Graaff** accelerator, and create a Nuclear Physics Group.

Home-designed and built, the Van de Graaff came into operation in 1951, hot on the heels of the first accelerators in Canada at McGill (1949) and Queen's (1950).

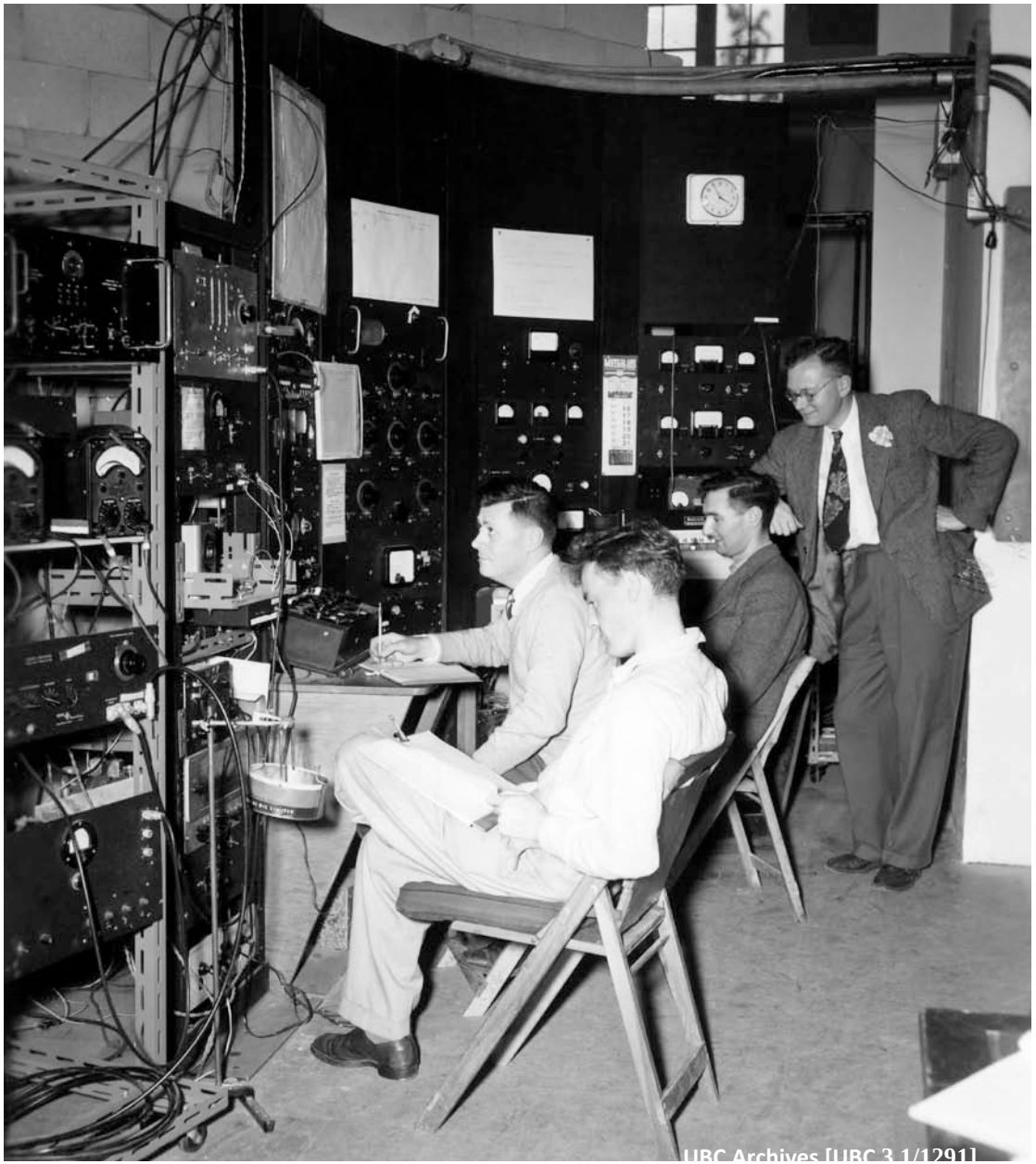
Under John's inspirational leadership the lab prospered, and.....

UBC BEFORE TRIUMF II

.. and by the early 1960s a major fraction (>50%?) of Canada's nuclear physicists were graduates of UBC.

But by then UBC had been left behind by higher energy machines built or under way at other Canadian facilities (McGill, Queen's, Chalk River, Saskatchewan, Laval, Toronto, Manitoba, McMaster).

From 1955, John's ambition was to move into particle physics, but a 1958 proposal for a 7-GeV proton synchro-tron at UBC was rejected.



TRIUMF IS CONCEIVED

By 1964 the NP Group had grown to 10 faculty and rather more graduate students, with some people favouring a **particle-physics** project, and others one for **nuclear physics**.

That Fall the senior faculty agreed to study the alternatives for a joint BC university project in more detail - and **in March 1965 John Warren wrote a memo** comparing their pros and cons and concluding:

> with long drawn out pulses when required. I am also of the opinion that one can do better in intensity of secondary beams by raising the energy, rather than the beam current. The problems of background, sheilding, servicing a radioactively hot accelerator brought on by designing a meson factory are better left to Chalk River.
>
> One would like variable energy, possibility of injecting polarised particles, and a clean 90% extracted primary beam. As an ultimate energy aim I would not settle for less than 3 GeV, preferably with an average current of 0.5 microamperes.

But when I reviewed various recent accelerator proposals it became clear that any machine over 1 GeV would be outside our most optimistic funding expectations – but that a meson factory might be affordable.

In May the NP group met and unanimously decided to go for a **meson factory** – offering interesting physics to both factions – and to chemists and medics:

- Proton and neutron scattering
- Proton- and neutron-induced nuclear reactions
- Pion-nuclear scattering and reactions
- Pion and muon rare decay modes
- Studies of novel radioisotopes
- Nuclear and muonium chemistry
- Biological and medical irradiation by protons, neutrons and pions.

Nuclear physicists and chemists at **UVic** and **Simon Fraser** agreed to take part and the acronym **TRIUMF** was adopted:

TRI-University Meson Facility

A further meeting at the CAP Congress (held at UBC that year), with the UVic & SFU reps and Erich Vogt present, set out an agenda for the next steps (see memo on the right).

June 12 1965

THE UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER 8, CANADA

DEPARTMENT OF PHYSICS — INTERDEPARTMENTAL MEMORANDUM

To: D. Axen, G.M. Bailey, K.L. Erdman, G.M. Griffiths, R.R. Haering, G. Jones, D.L. Livesey, M. McMillan, B. Pate, M. Pearce, E. Vogt, G.M. Volkoff, J.B. Warren, B.L. White

From: M.K. Craddock.

This memorandum is intended as a brief summary of the agreements reached on the TRIUMF(Three UniversitiesMeson Facility) proposal at a lunch meeting on Saturday June 12th. Present: all the above, except for Dr. Livesey.

(1) It was agreed that we should aim to produce a preliminary proposal by March 31st, 1966 with the object of obtaining a grant for a detailed design study. The director and coordinator of this preliminary study will be Dr. E.W. Vogt. The following special responsibilities were allocated:-

Building Layout and Site	Volkoff and Erdman
Experimental Nuclear Physics	McMillan
Experimental Chemistry	Pate
Accelerator	Craddock
Beam Engineering	Pearce
Liaison with Faculty of Applied Science	Griffiths.

Dr. Griffiths will explore the possibility of obtaining assistance from the engineering faculty both with the detailed design and in recommending suitable Canadian engineering firms.

(2) Dr. Warren will contact Dr. J.R. Richardson and Dr. K.R. MacKenzie in California and ask them to visit U.B.C. for discussions towards the end of July or beginning of August. He will also look out for accelerator physicists interested in working for a year or longer in Vancouver, when he is in Europe.

Dr. Jones mentioned that Dr. J.J. Burgerjon, cyclotron engineer at Winnipeg, would be interested in working on the design of the TRIUMF accelerator when work on the University of Manitoba cyclotron was complete, and that the University would not object to his leaving Winnipeg then.

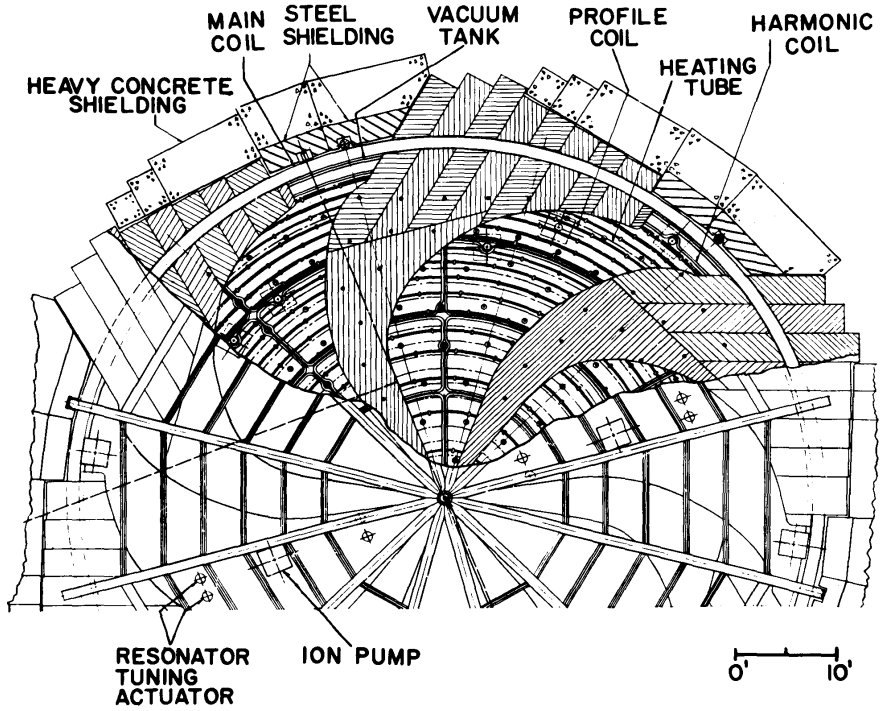
continued---

RICHARDSON CO-OPTED

Several 500-800 MeV meson factory designs were extant (2 linacs, 1 FFAG, 1 H^- and 2 p cyclotrons).

We favoured the 6-sector H^- cyclotron designed by Reg Richardson for UCLA for its versatility and flexibility:

- 100% duty factor
- variable beam energy
- multiple extracted beams.



Reg was the foremost authority on cyclotrons, and had been responsible for breaking Bethe's supposed 8-MeV limit for cyclotrons by building:

- the first synchrocyclotron (1946) and
- the first sector-focused cyclotron (1950).

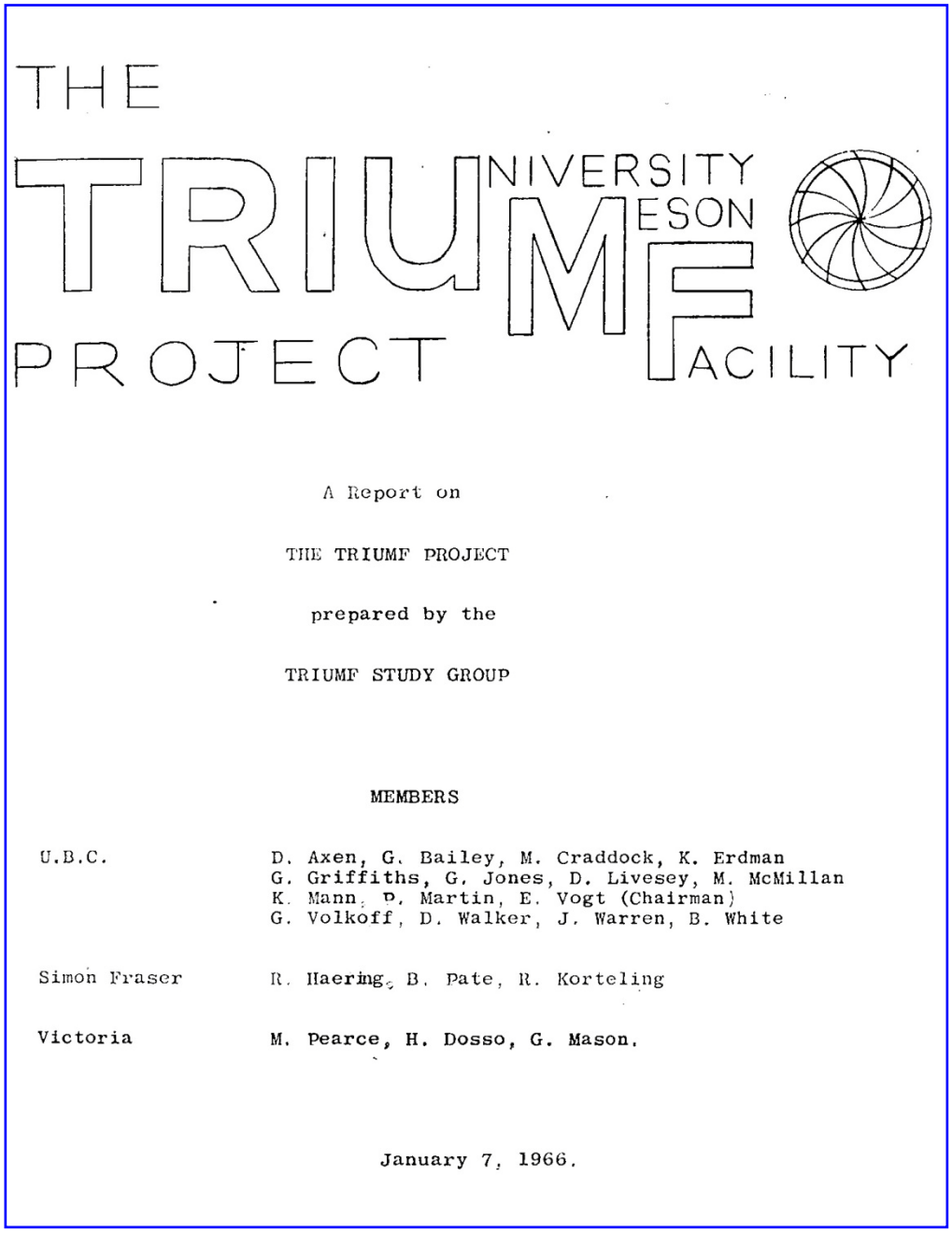
Also he was originally Canadian with a summer home on Galiano Island nearby, where the UCLA design was conceived. But the US had decided to fund a linac at Los Alamos instead - so he was not unwilling to have his baby built at UBC!

ERICH LEADS THE CAMPAIGN

In August 1965 **Erich Vogt** joined UBC after 9 years at Chalk River, and, standing in for John Warren (absent on a year's sabbatical in Europe), chaired the TRIUMF Study Group in preparing an application for a year's funding to produce a design proposal and cost estimate.

There were 20 contributors besides himself, so Erich was kept pretty busy chasing us to meet an end-of-year deadline.

The application was successful and in April 1966, we received a grant of $100,000.



THE

TRIUMF

UNIVERSITY MESON FACILITY

PROJECT

A Report on

THE TRIUMF PROJECT

prepared by the

TRIUMF STUDY GROUP

MEMBERS

U.B.C.	D. Axen, G. Bailey, M. Craddock, K. Erdman G. Griffiths, G. Jones, D. Livesey, M. McMillan K. Mann, D. Martin, E. Vogt (Chairman) G. Volkoff, D. Walker, J. Warren, B. White
Simon Fraser	R. Haering, B. Pate, R. Korteling
Victoria	M. Pearce, H. Dosso, G. Mason.

January 7, 1966.

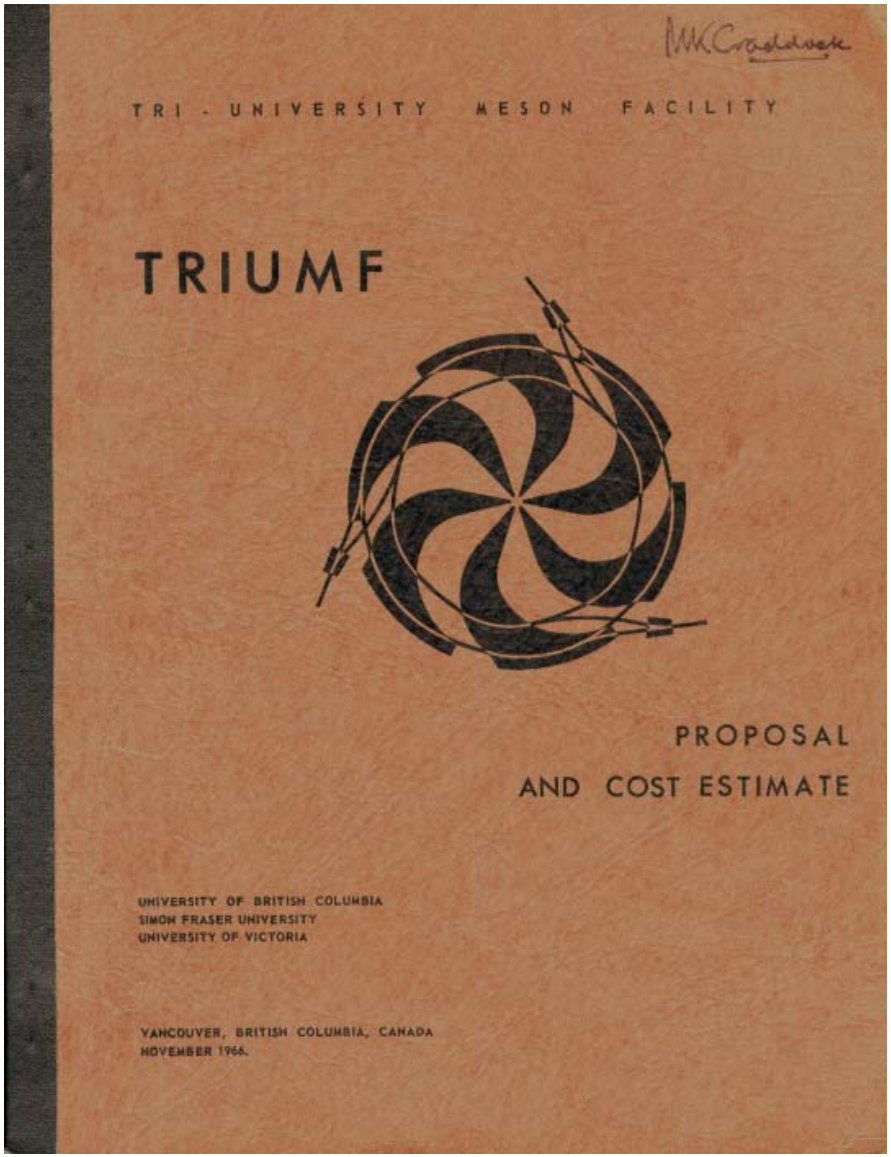
ERICH'S KEY CONTRIBUTIONS - I

The first of these was **experience in writing a major technical proposal** – in his case that for AECL's 1-GeV 65-mA Intense Neutron Generator (ING).

Our proposal benefitted greatly from UCLA's earlier work, but was no trivial reproduction. In particular, Erich led a thorough revamp of the scientific case to match the anticipated interests of Canadian scientists.

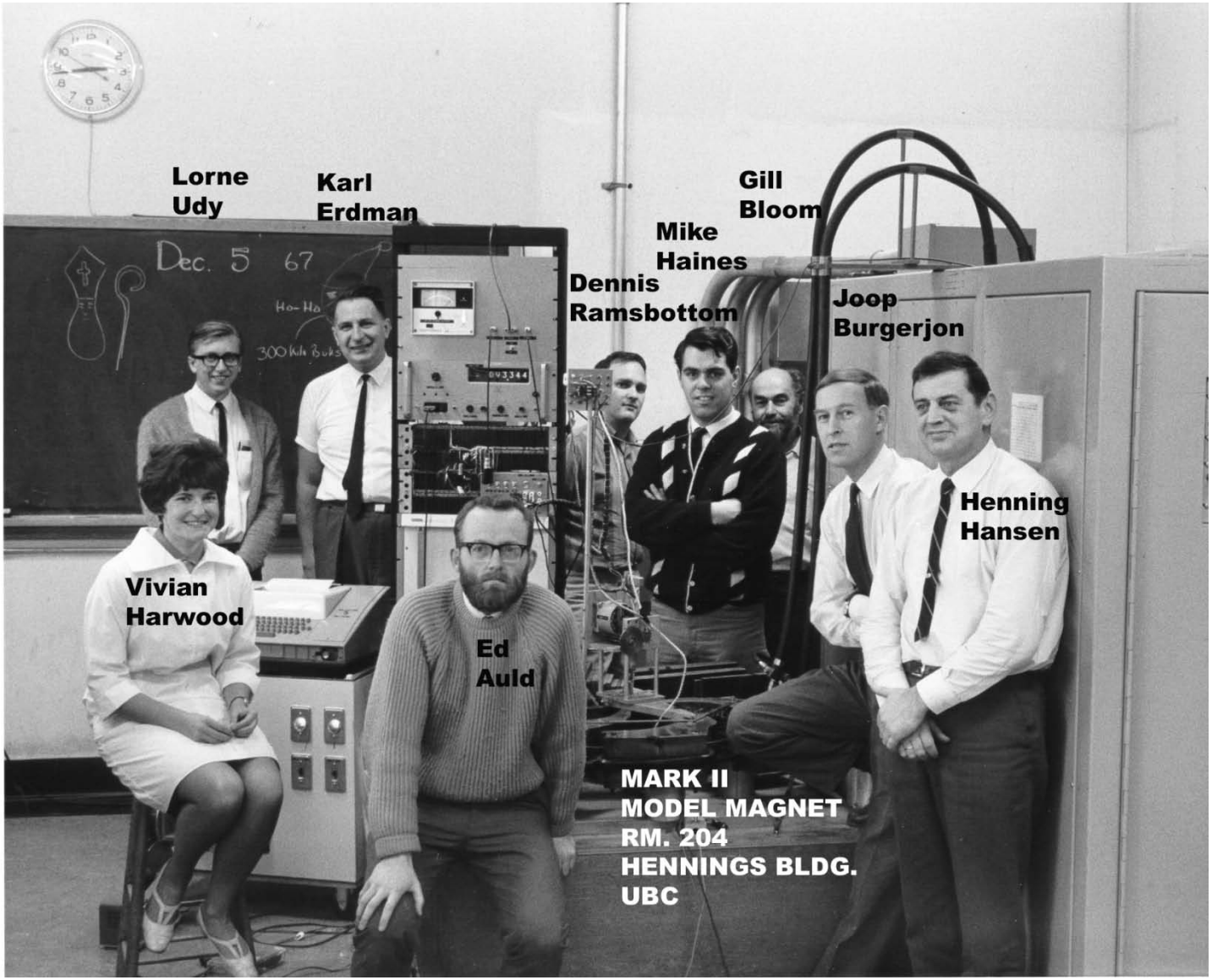
UCLA had already scaled their design, originally 700 MeV, down to 550 MeV - but even 550 MeV was deemed too expensive for Canada, so we settled for 500 MeV. And initially there would only be one experimental area, not two.

The proposal came out November 1966.



TECHNICAL BEGINNINGS

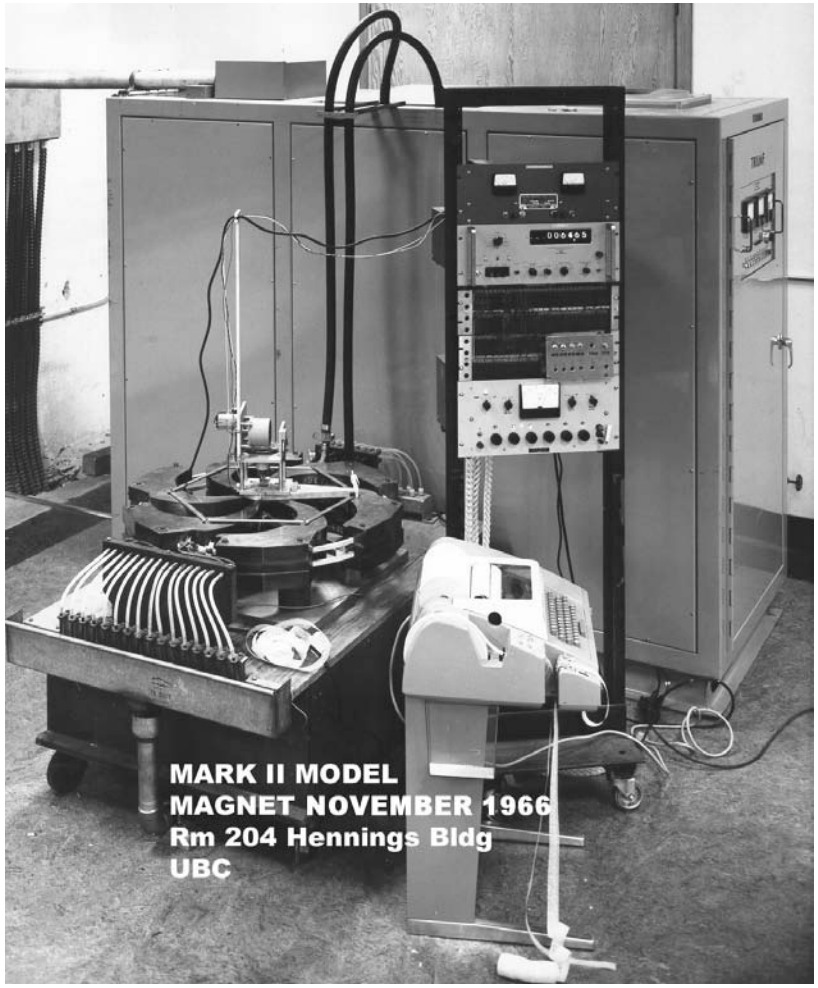
The $100,000 grant, repeated in 1967, also allowed us to hire staff and begin magnet, rf, vacuum and beam dynamics studies.



MODEL STUDIES

UCLA lent us a rudimentary model magnet, a 150-kW 3000-A dc power supply was purchased and a Hall probe installed on a computer-controlled rotating arm (right).

The field-survey measurements were then recorded using the latest technology – paper tape!



Left: A $\frac{1}{4}$-scale model of the rf resonators - the first in a long tradition of plywood and copper-sheet rf cavities at TRIUMF.

ERICH'S KEY CONTRIBUTIONS - II

Erich brought two more important attributes to the campaign:

- **a close knowledge of the eastern establishment**
  - both scientific and governmental
- **his political skill and persuasiveness**, based on diplomacy, an infectious enthusiasm and considerable self-confidence.

These skills were extensively deployed in 1966-7 as negotiations with Ottawa were largely delegated to Erich – and were much needed, because the cost was estimated at $19 million (≈M$130 today), greatly exceeding any previous university research project.

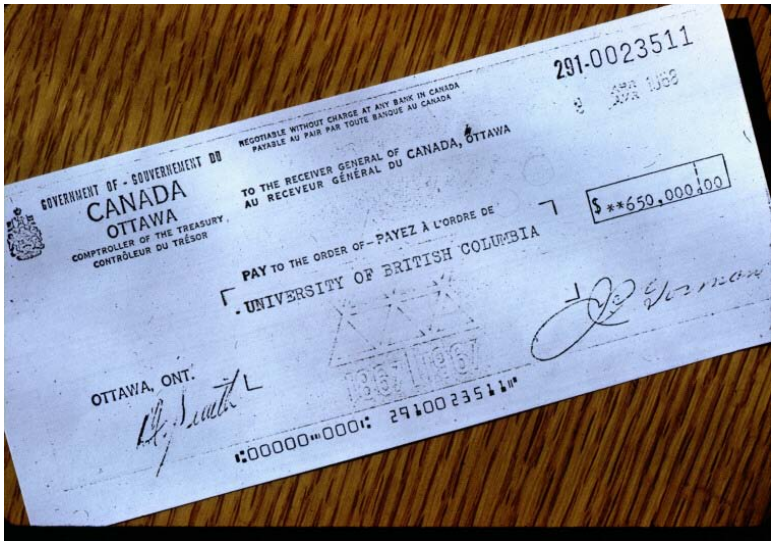
Fortunately two strong supporters were secured:

- George Lawrence, President of the Atomic Energy Control Board
- Jean-Luc Pépin, Minister of Energy, Mines and Resources

Erich explores the newly-cleared site
- leaping tall buildings would come later

APPROVAL!

Federal approval was announced in April 1968 ($17 million over 5 years), with the four universities (Alberta joined in 1967) funding the civil construction portion ($2 million).



The reality was as exciting as the news!

A four-university Board of Management was set up, and appointed:

- John Warren as Director
- Erich Vogt as Associate Director
- Joop Burgerjon as Chief Engineer.

More hiring began.

TREE PLANTING

In May 1969, to mark TRIUMF's birth, a formal ceremony was held at the TRIUMF roundabout, attended by representatives of the four universities – at which **Minister Pépin** and **John Warren** jointly planted a scion of Isaac Newton's apple tree.

CONSTRUCTION BEGINS

By that time the frame for the Office Building was already up

By October it was complete.....

and we were able to move in.....

and even hold TRIUMF's

first Christmas party!

By June 1970 a large hole had been excavated

TRIUMF SITE

1970 Rev. 1 May 6/04

1. BRUCE WHITE?
2. HAROLD BATHO
3. GEORGE GOODMAN
4. PHIL BENNETT?
5. JOHN CRESSWELL
6. ? SLOAN?
6a. DON HEYWOOD
7. KEN EDWARDS
8. LORNE UDY
9. TERRY BOWYER
10. UNKNOWN
11. TERRY HODGES?
12. NICK REHLINGER
13. ED AULD
14. TOM MITCHELL
15. REG RICHARDSON
16. DON MARQUART?
17. AL ?
18. SONJA ?
19. DON CALDER
20. BILL RAWCHUCK
21. MALCOLM HONE
22. BRUNO DUELLI
23. OLAF FREDRIKSSON
24. WALTER FREY
25. ROGER POIRIER
26. SHERMAN ORAAS
27. UNKNOWN
28. ADA SRATHDEE
29. NEIL BREARLY?
30. DICK JOHNSON
31. KURT ?
32. LYNN BASS
33. NANCY PALMER
34. MARGE WILLIAMS
35. COLLEEN MEADE
35. UNKNOWN
36. JEAN BOLDUC
37. ROBIN LOUIS
38. JACK CAREY
39. JOHN TANTON?
40. UNKNOWN
41. UNKNOWN
42. UNKNOWN
43. HENNING HANSEN
44. PAUL VAN ROOK
45. JOHN WARREN
46. ERICH VOGT
47. HAROLD JOHNS?
48. JOOP BURGERJON
49. JOE KILPATRICK
50. MILOS ZACH
51. IAN THORSON
52. A. PROCHAZKA
53. TERRY CREANY
54. ROBIN GUMMER
55. JIM FOWLEY
56. STAN OLSEN
57. BILL BRYSON
58. DAVE SMITH

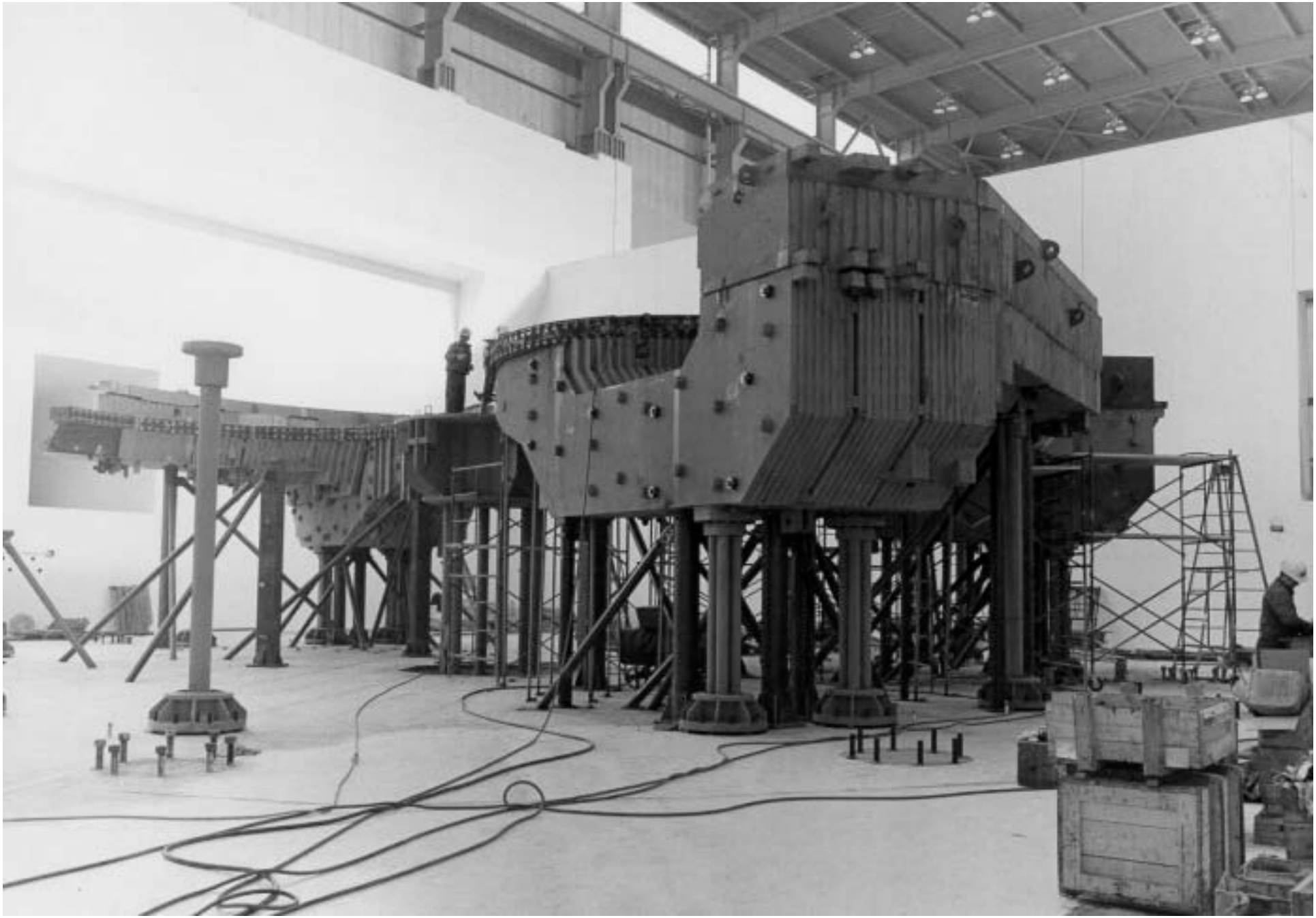
Including staff on contract from Crippen Assocs., Montreal Eng. & Shawinigan Eng.

August 1970

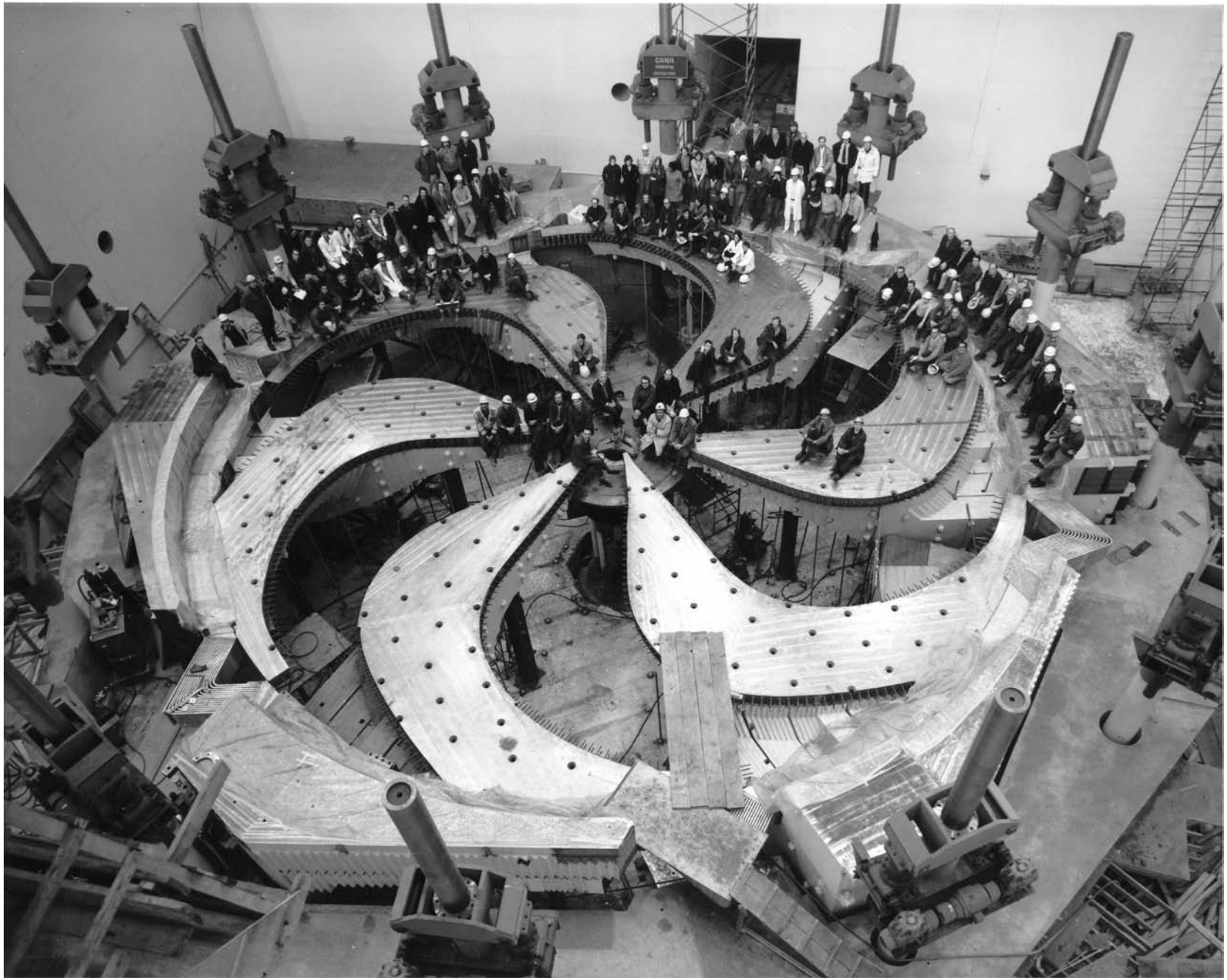
February 1971

April 1971

August 1971

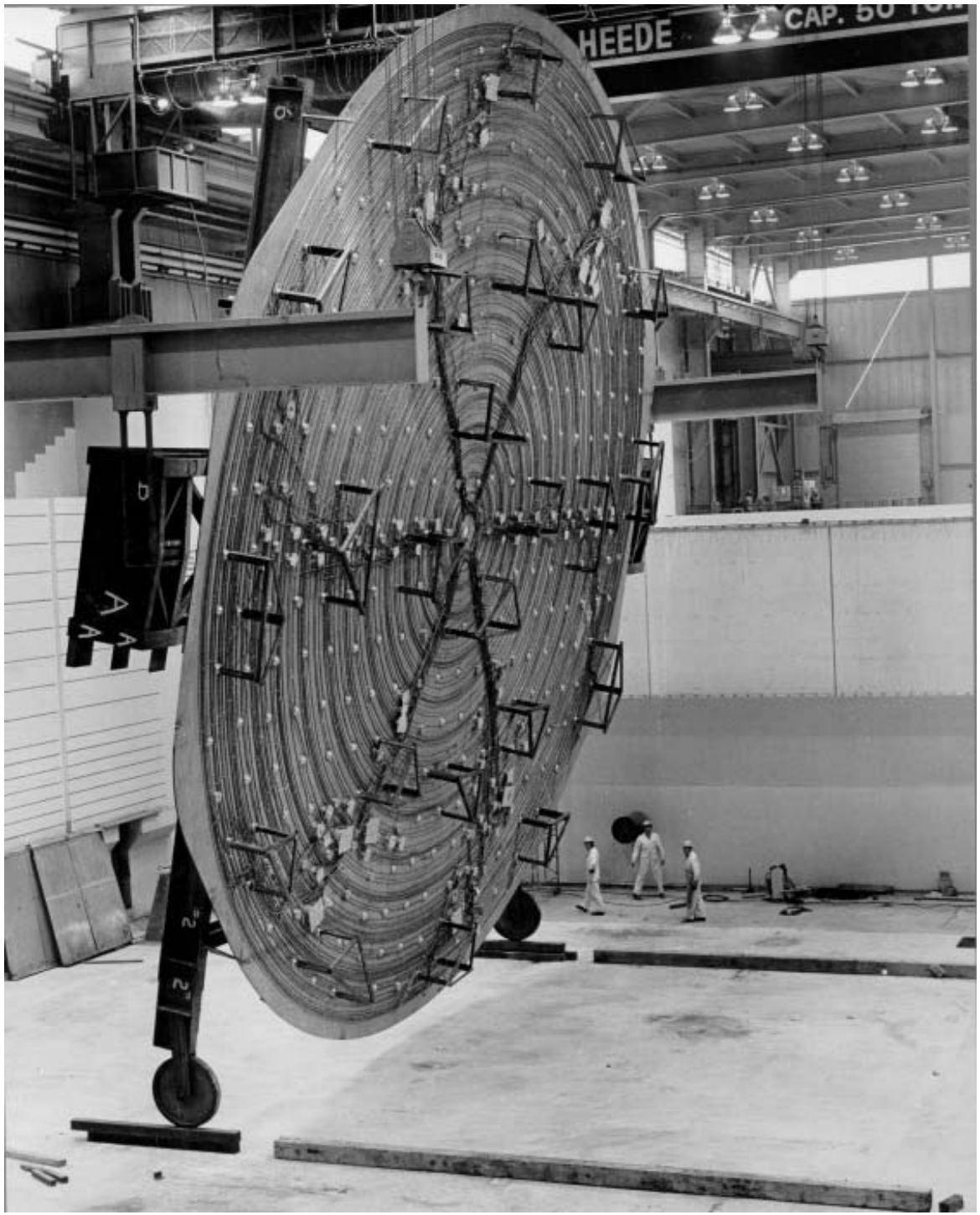


The magnet sectors began arriving in July 1971

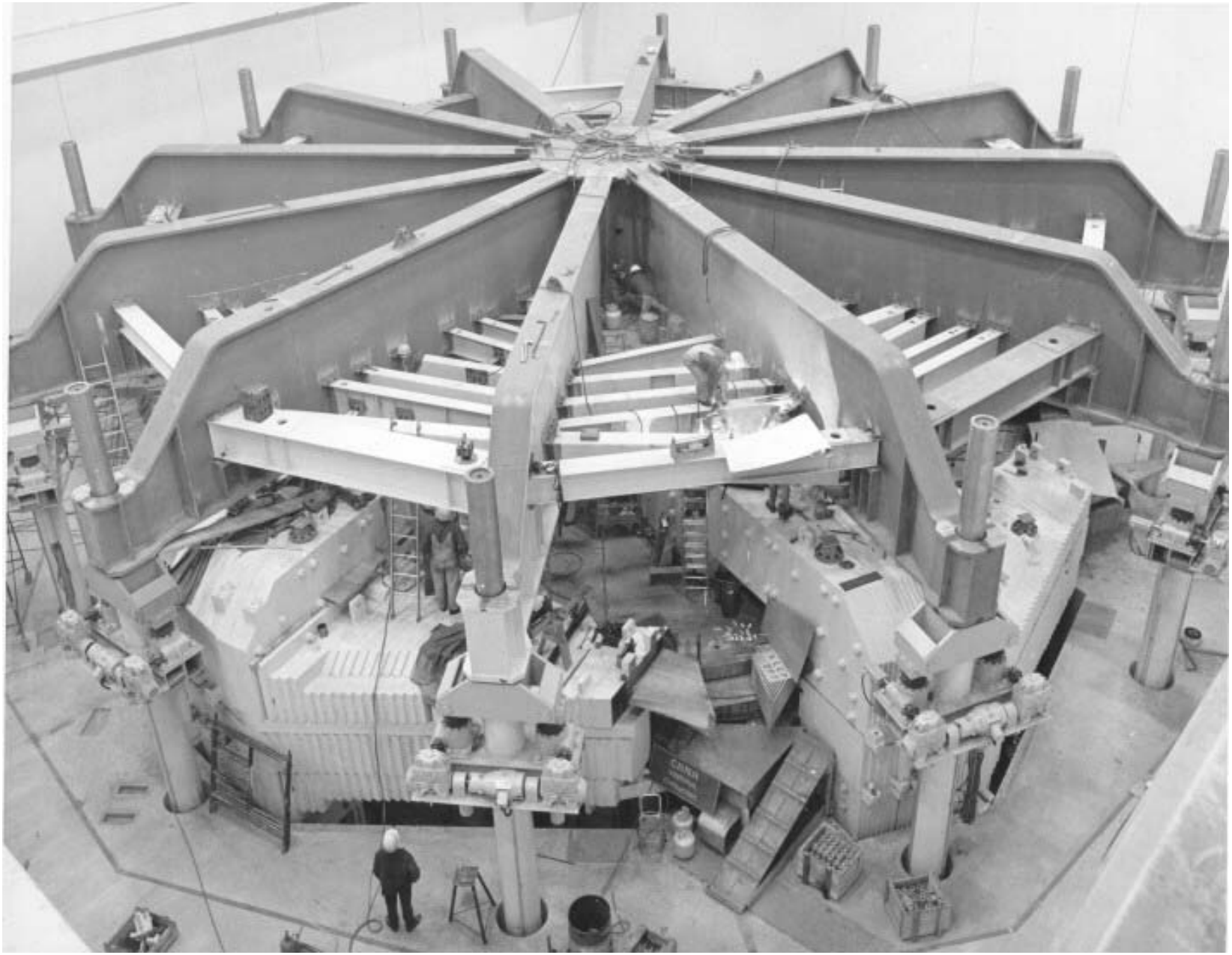


..... and by January 1972 the lower half was complete.

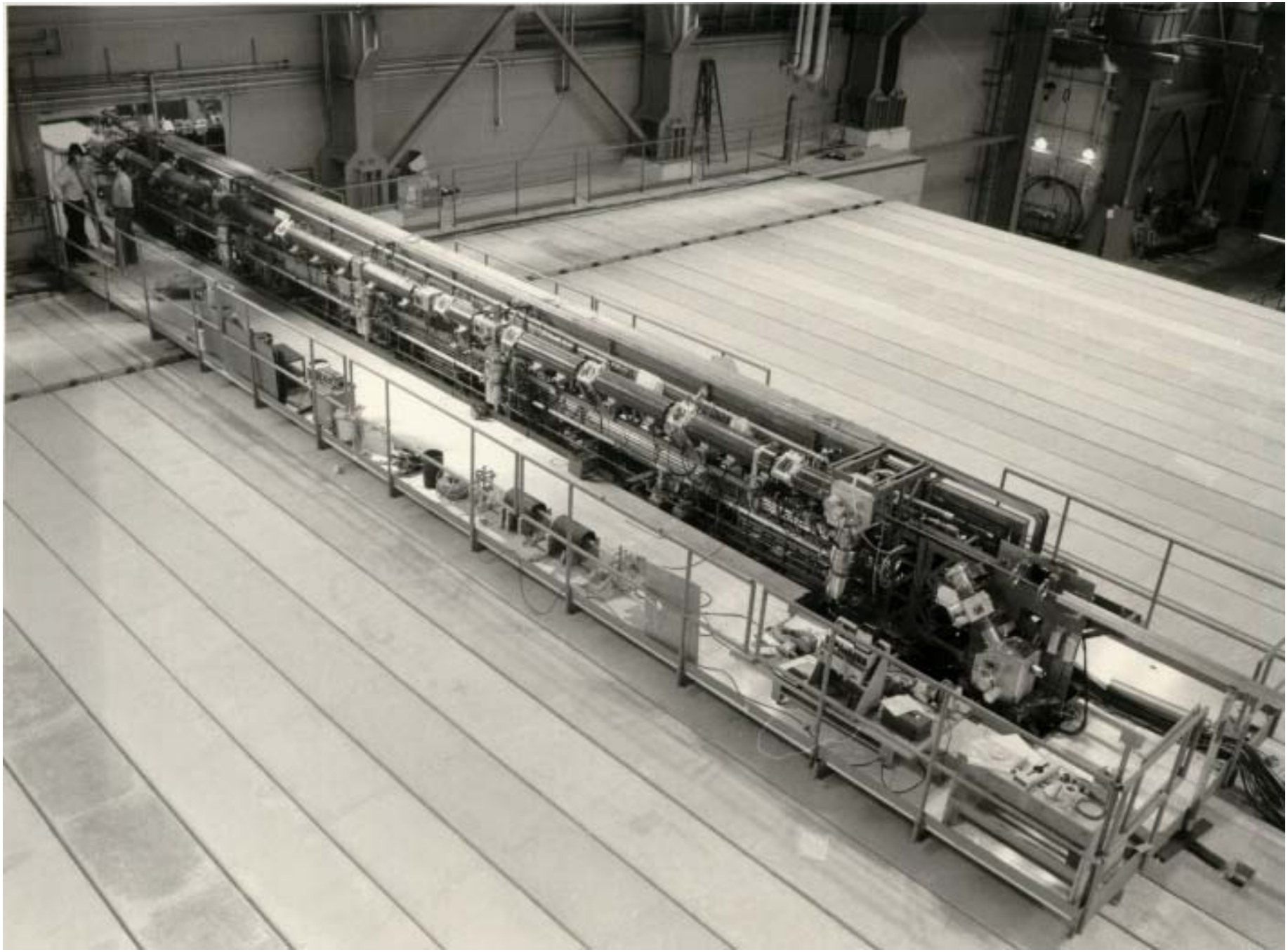
Meanwhile the vacuum tank and lid were being assembled in the Meson Hall.....



...and in February 1972 were lowered into place.



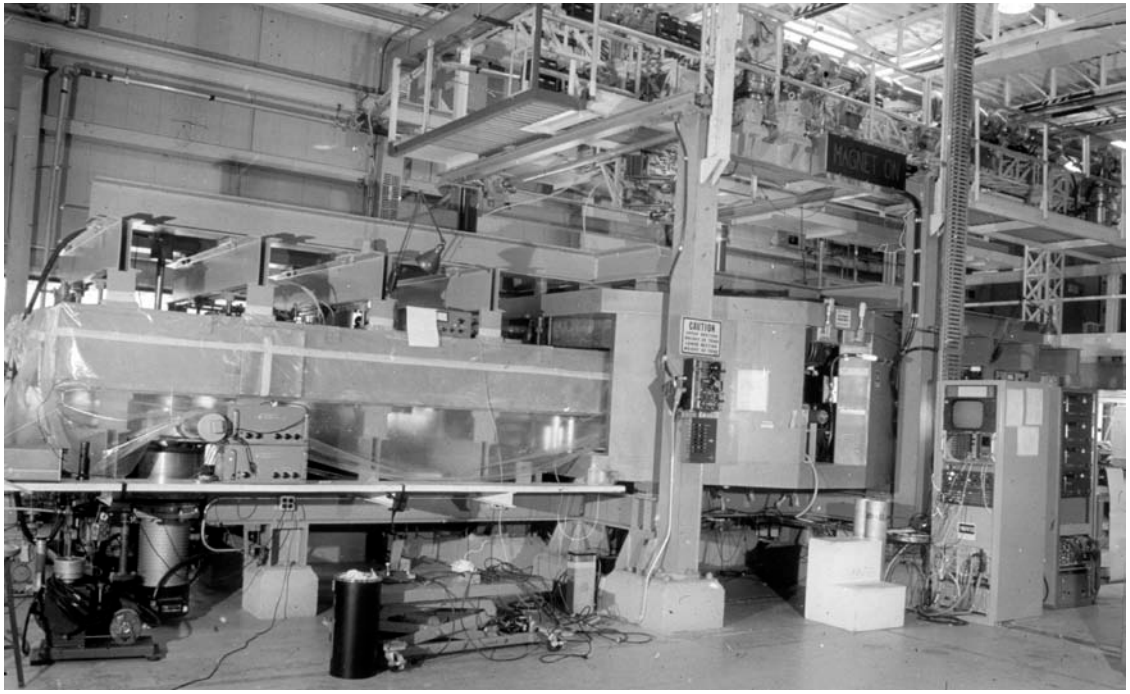
In spite of a 3-month strike that summer, the magnet, support structure and elevating jacks were complete by September.

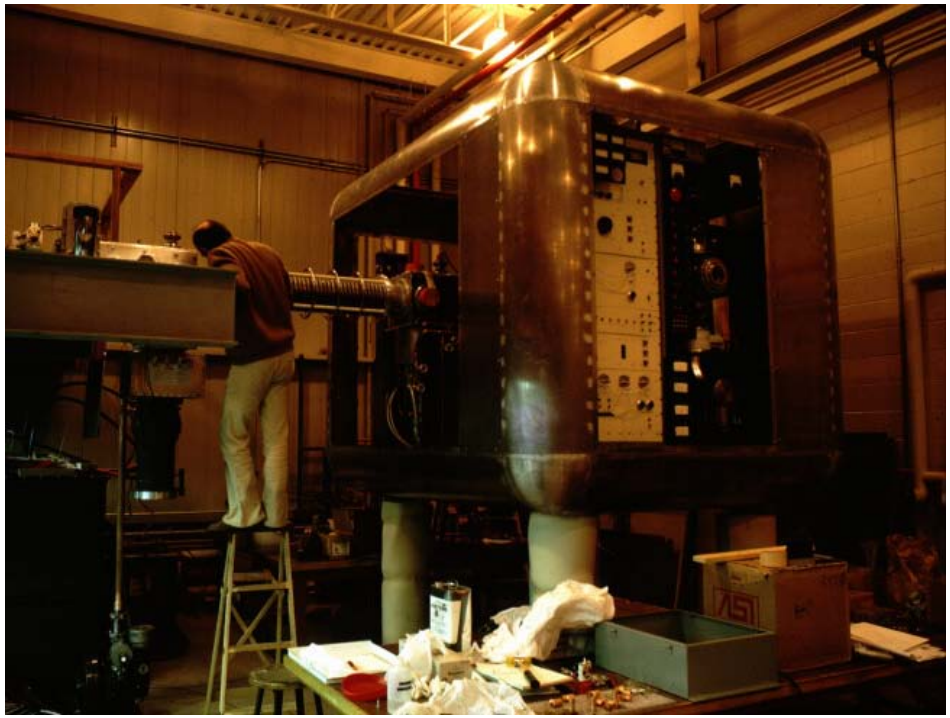


The vault roof beams were then installed, followed by the 300-keV injection line.

CRM CYCLOTRON

Meanwhile, the **Central Region Model Cyclotron** was being assembled in the Office-Lab Building – a full-scale device to test the novel axial injection scheme and rf resonator design. 3-MeV beams were achieved in 1972 and the full 100 μA in 1973.





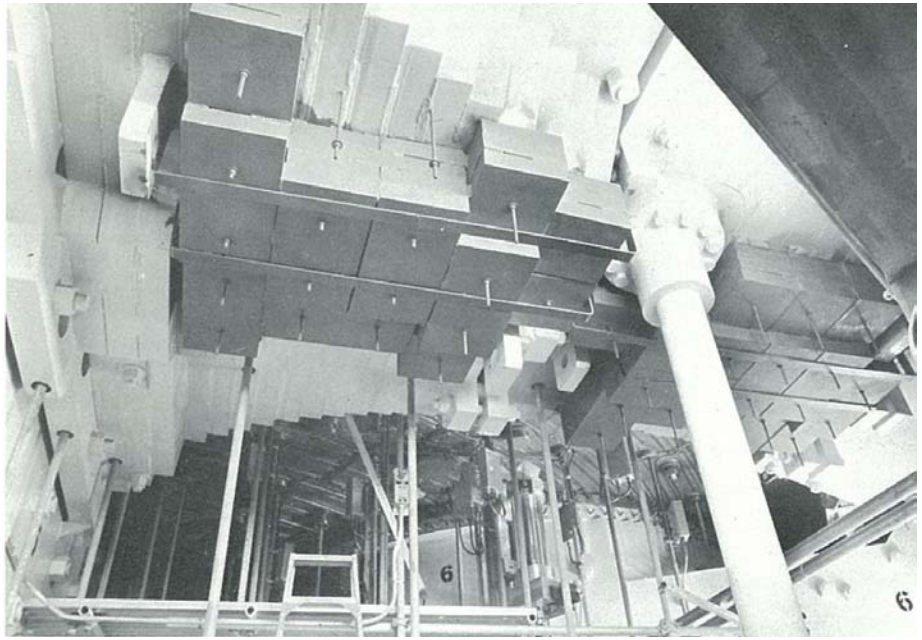
Back at the big cyclotron the **magnetic survey arm** had been installed and field measurements were begun on a grid of 105 radii and 360 angles.

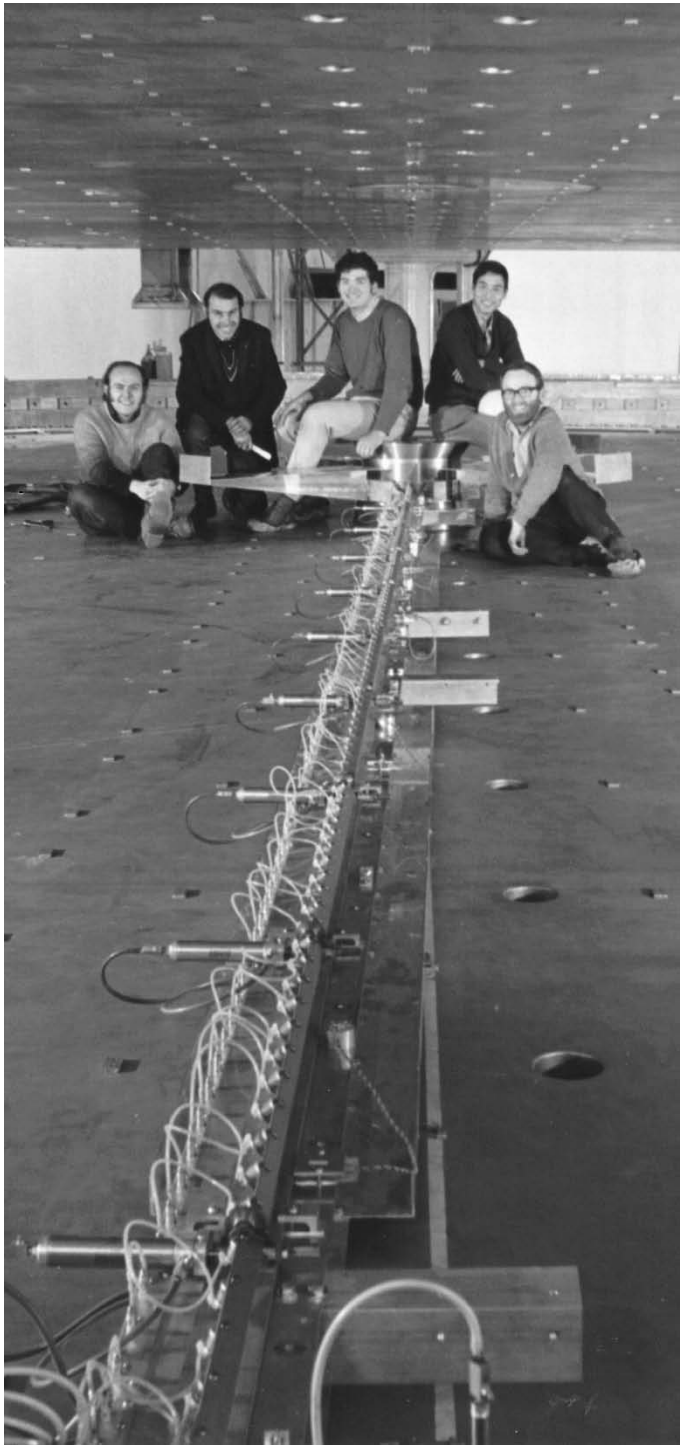
First results in December 1972 were alarming:

- the mean field strength was 3% too high over the inner region and 3% too low at the outside – rather than the ± 0.01% required.

Massive surgery was needed:

- 100 tons of steel were added to the outer yokes and 16 tons cut away from the inner.



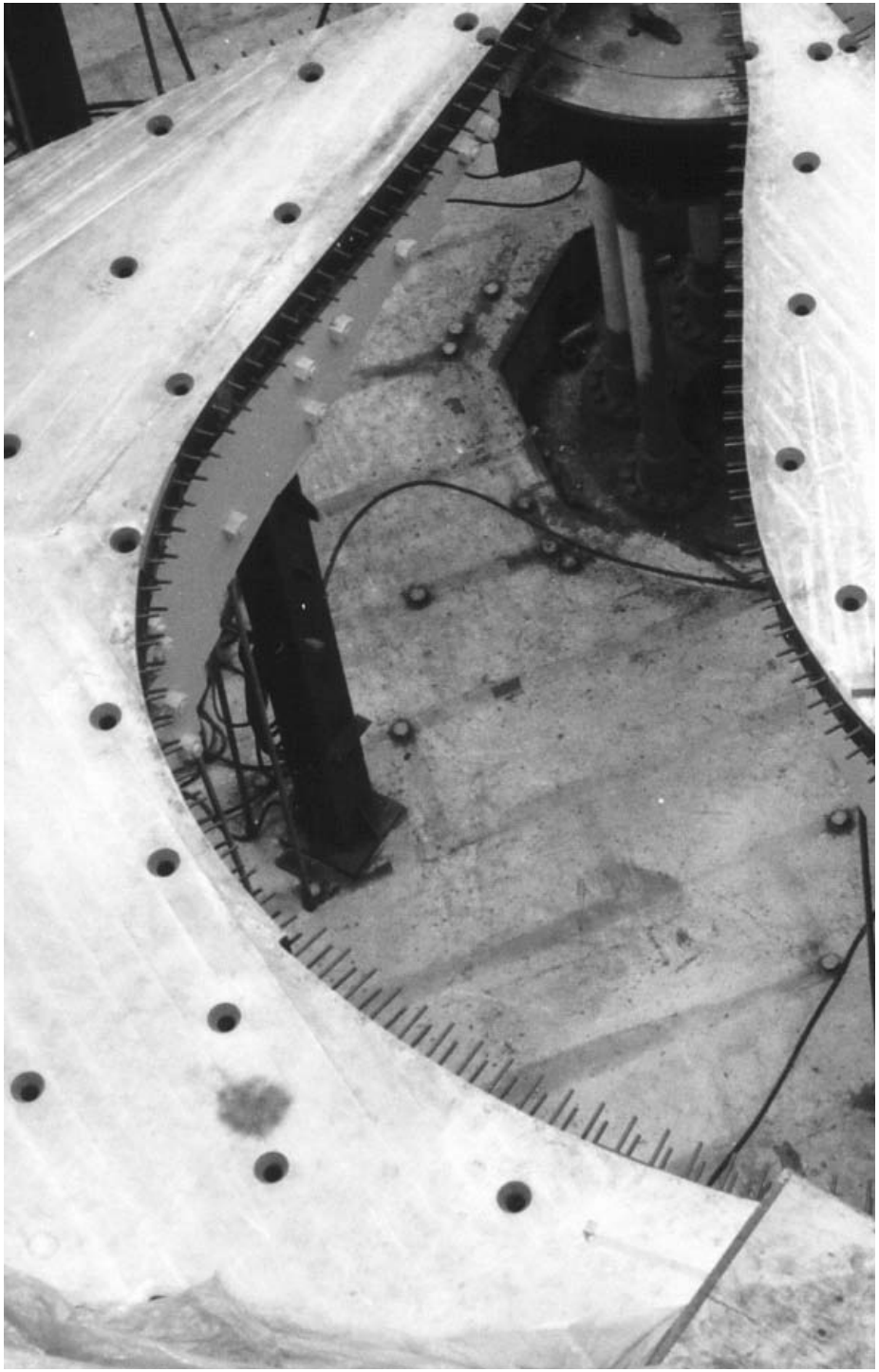


By September 1973 the field errors had been reduced enough to be corrected by the **pole shims** – thin steel plates mountable at 666 pairs of studs around the 24 pole edges.

Isochronous cyclotrons are very demanding: tight tolerances are needed on the magnetic field at each radius:

- mean value
- flutter (mean square variation)
- 1^{st}, 2^{nd} and 3^{rd} harmonics
- top-bottom asymmetry.

Altogether, 15 parameters had to be corrected at each of 103 radii.



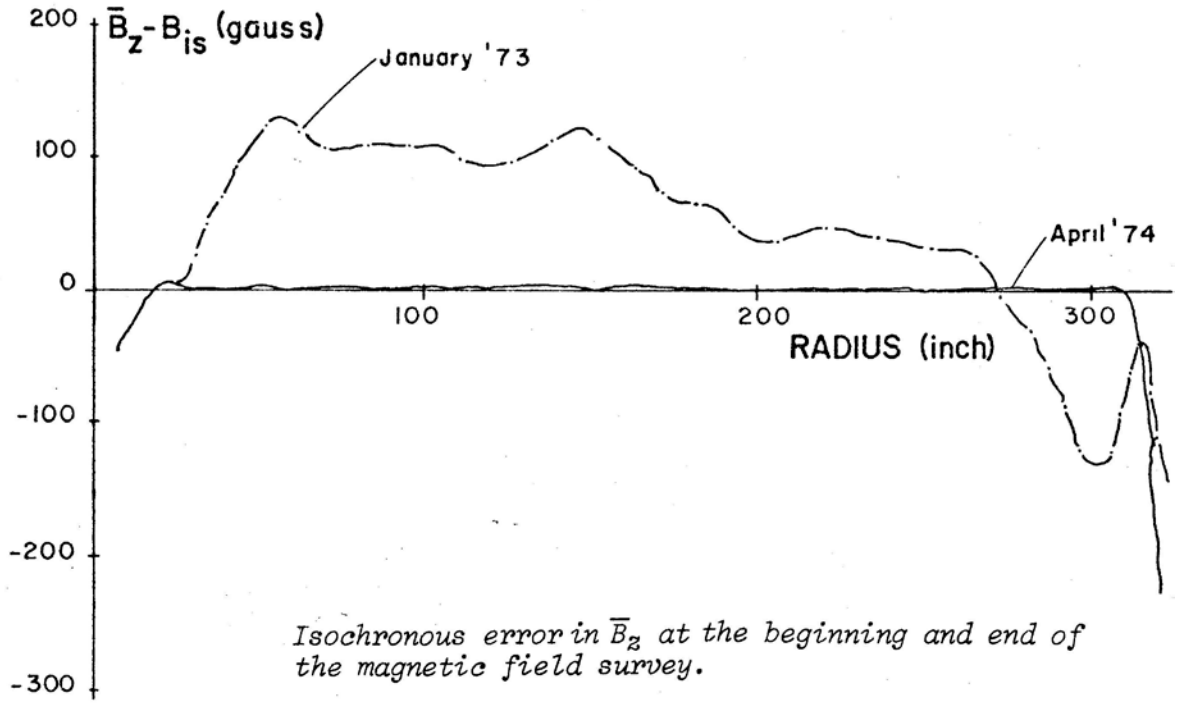
A **near-daily routine** began:

- change shims
- survey magnetic field
- compute orbit properties
- compute next shim changes (tying up UBC's IBM 360/67 overnight)

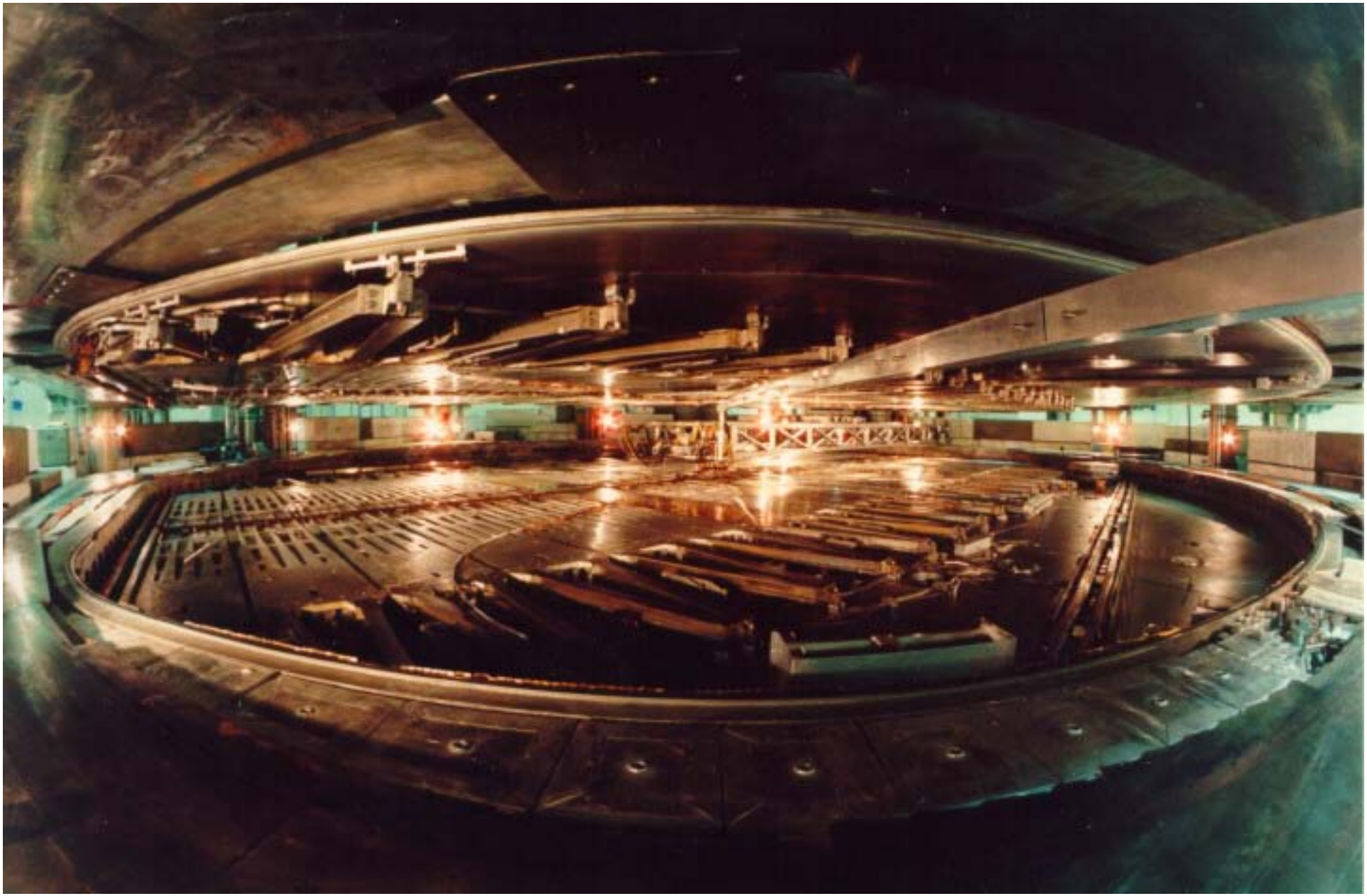
- and continued for seven months!

The three shimming teams had professional cores - but consisted mainly of volunteers - involving nearly everyone on site.

Progress was frustratingly slow – but by April 1974 the desired accuracy had been achieved.



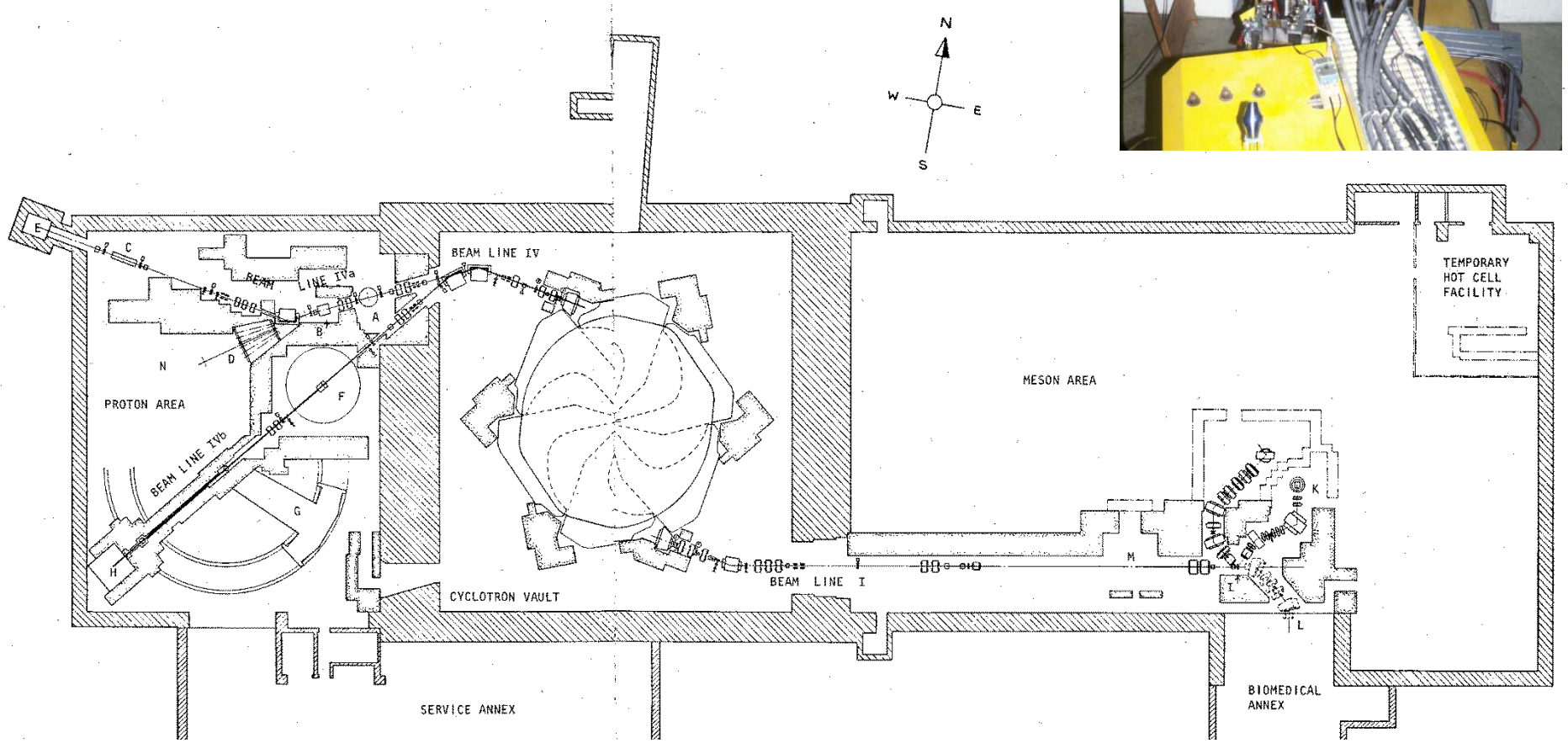
Isochronous error in $\bar{B}_z$ at the beginning and end of the magnetic field survey.



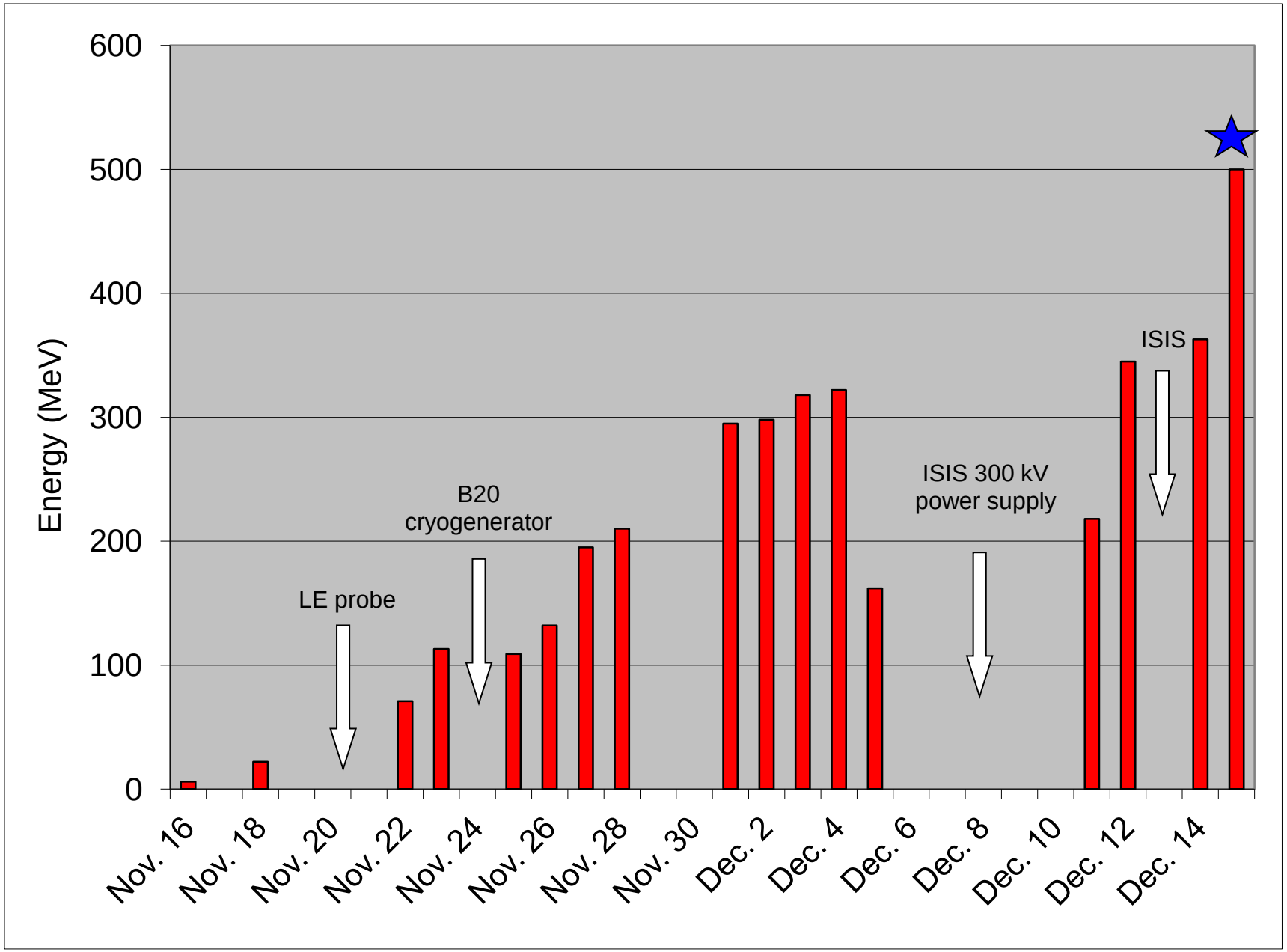
The rf resonators, cryopanels, and diagnostic and extraction probes had all been installed by November 1974 – the cyclotron was ready for beam!

Beyond the cyclotron just a few beam lines had been installed:

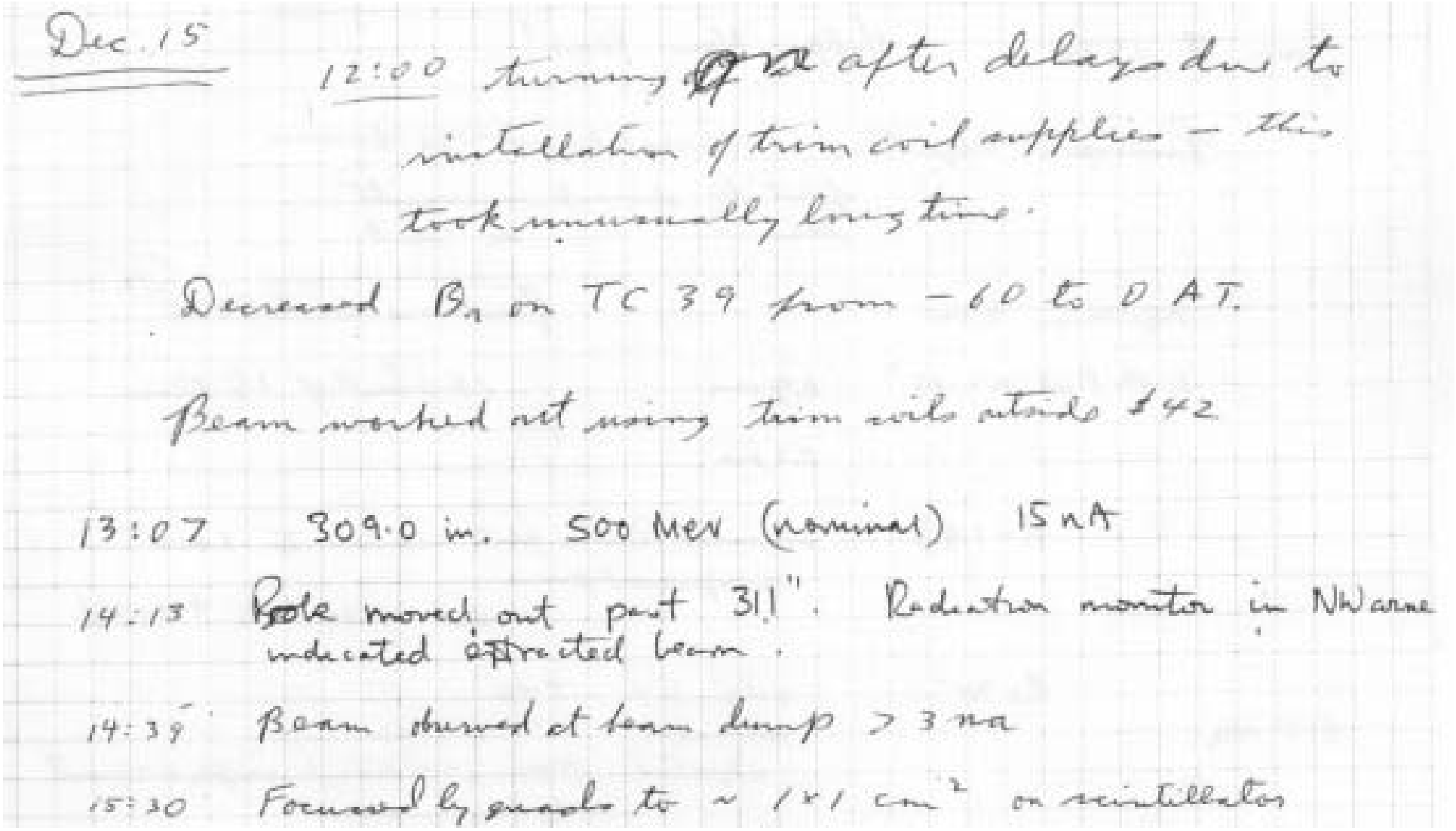
- BL4A and BL4B for proton experiments
- BL1A for π and μ production
  - but only the T2 target.



So the Director's chair was moved to the Control room
- and Reg "Two Hands" Richardson began the final magnet tune-up
using the 54 circular trim coils,
with the H^- ion beam itself as the probe.



Occasional equipment breakdowns apart, progress was at first steady - but became very difficult above 300 MeV as the orbits get closer together.


Dec. 15

12:00 turning on after delays due to installation of trim coil supplies – this took unusually long time.

Decreased B_n on TC 39 from −60 to 0 A.T.

Beam worked out using trim coils at/or 942

13:07 309.0 in. 500 MeV (nominal) 15 nA

14:13 Probe moved out past 31.1". Radiation monitor in NW area indicated extracted beam.

14:39 Beam observed at beam dump > 3 na

15:30 Focused by quads to ~ 1x1 cm² on scintillator

But on December 15th, the log jam seemed to have magically disappeared:

- Reg was able to take the beam from 360 to 500 MeV in just one hour
- and extract it into beam line 4V one hour later.

An afternoon of great relief and exhilaration after so many years!

The screen shows the 500-MeV beam spot on an internal target
-just a few nanoamps
- and 19 minutes old.

Visitors poured in from around the lab and beyond.....

.....and celebrations ensued!

FORTY YEARS ON!

For **Reg**, this was the crowning achievement of a notable career;
For **everyone else involved** – an exciting and rewarding adventure;
For **the users** – just a beginning....

But much remained to be done:

- **Beam current** to be raised to the 100 μA target (1977) - and later 300 μA
- **Reliability** improved to acceptable levels
- **Beam lines and experimental facilities** completed – a decade-long task.

Happily **the users** have been able to put this powerful tool to effective use – **delivering 40 years of highly productive research in a variety of fields**.

Indeed, without the **users' efforts** demonstrating the cyclotron's usefulness
- as much as those of **devoted cyclotron staff** improving its performance
- **we'd have no anniversary to celebrate today!**

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Indeed, without the **users' efforts** demonstrating the cyclotron's usefulness - as much as those of **devoted cyclotron staff** improving its performance - **we'd have no anniversary to celebrate today!**

So let's hope good science continues to emerge - and plan for

ANOTHER 40 YEARS!

Thank you! **Merci!**