Alta Cyclotron Services

A University of Birmingham business

Cyclotron Isotope Production

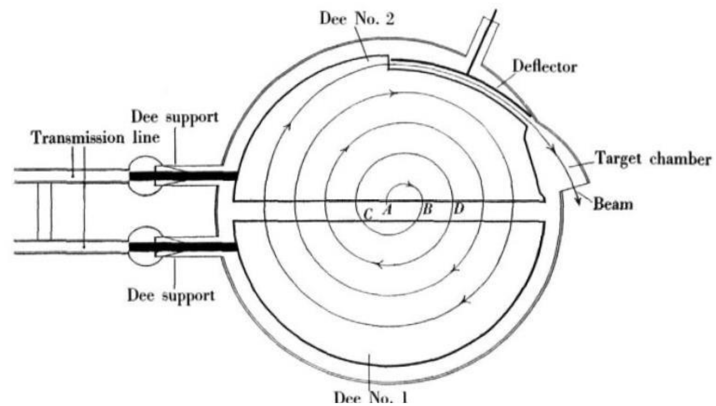
(some history, with particular reference to Birmingham)

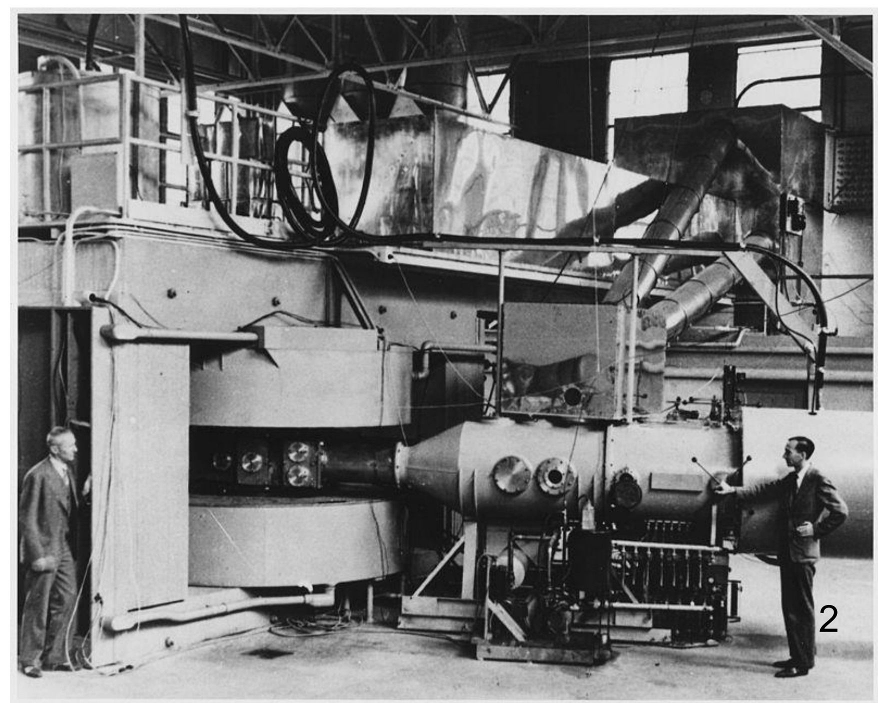
David Parker

University of Birmingham

Cyclotron invented by Ernest Lawrence at University of Berkeley

- 1931 4.5” 80 keV p
- 1932 11” 1.2 MeV p
- 1932 27” 4.8 MeV p
- 1937 37” 8 MeV d
- 1939 60” 16 MeV p





UK cyclotrons

Lawrence's 37" design was copied at Cambridge and Liverpool

Cambridge: Cockroft wanted a cyclotron but Rutherford initially opposed it on the grounds of cost. Cyclotron eventually funded by Lord Austin and became operational in 1939

Liverpool: Chadwick moved from Cambridge to Liverpool in 1935 and promptly organised construction of a cyclotron, which also became operational in 1939

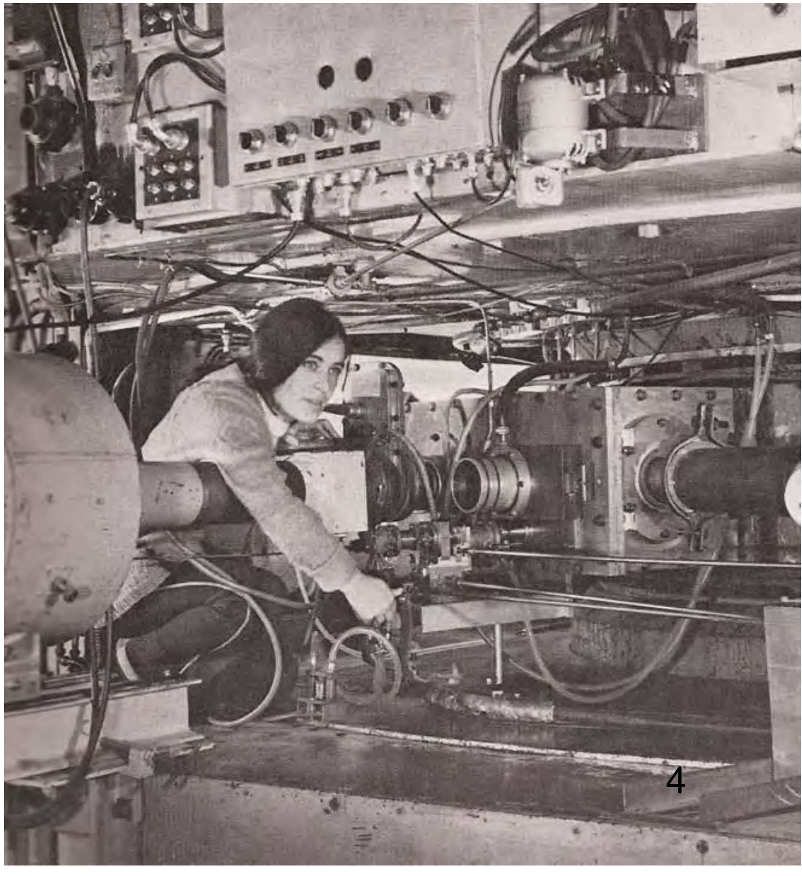
After an interruption due to WW2, both cyclotrons operated until early 60s (when the Cambridge cyclotron moved to Birmingham and was completely rebuilt as the Radial Ridge Cyclotron)

Birmingham – The Nuffield Cyclotron

At Birmingham, Marcus Oliphant wanted to build a copy of Lawrence's 60" cyclotron. Lord Austin refused funding, but Oliphant eventually got funds from Lord Nuffield (Wm Morris). Construction started in 1939 but was interrupted by WW2.
The Nuffield Cyclotron finally began operating in 1948.

50th birthday party 1998
(oldest working cyclotron)

Closed 1999 (upgrading shielding too expensive)



Nuffield Cyclotron

Initially used for nuclear physics research
(extracted beams of 10 MeV p, 20 MeV d, 30 MeV He-3 and 40 MeV α)
research subsequently transferred to Radial Ridge Cyclotron from early 60s.

Then devoted to isotope production, mainly using internal beams
(up to 1mA of 10 MeV p):

- ^{22}Na (2.6 y) produced using protons on Mg: $^{25}Mg(p,\alpha)^{22}Na$
- ^{109}Cd (1.3 y) produced using protons on Ag: $^{109}Ag(p,n)^{109}Cd$
- ^{81}Rb (4.6 h) produced using 40 MeV alphas on NaBr: $^{79}Br(\alpha,2n)^{81}Rb$

^{81m}Kr generators

^{81}Rb → ^{81m}Kr → ^{81}Kr

4.6 h — 13 s: 190 keV γ

"A new generator for krypton-81m",
JH Fremlin, K Stammers, FR Stewart, NIM156(1978)369-373

Parent ^{81}Rb is trapped on a filter.
Blowing air through the filter entrains ^{81m}Kr gas.
Gas is used for lung ventilation imaging (planar/SPECT) diagnosing pulmonary embolism via comparison with perfusion images.

The MC40 cyclotron

is the third cyclotron to be operated at the University of Birmingham

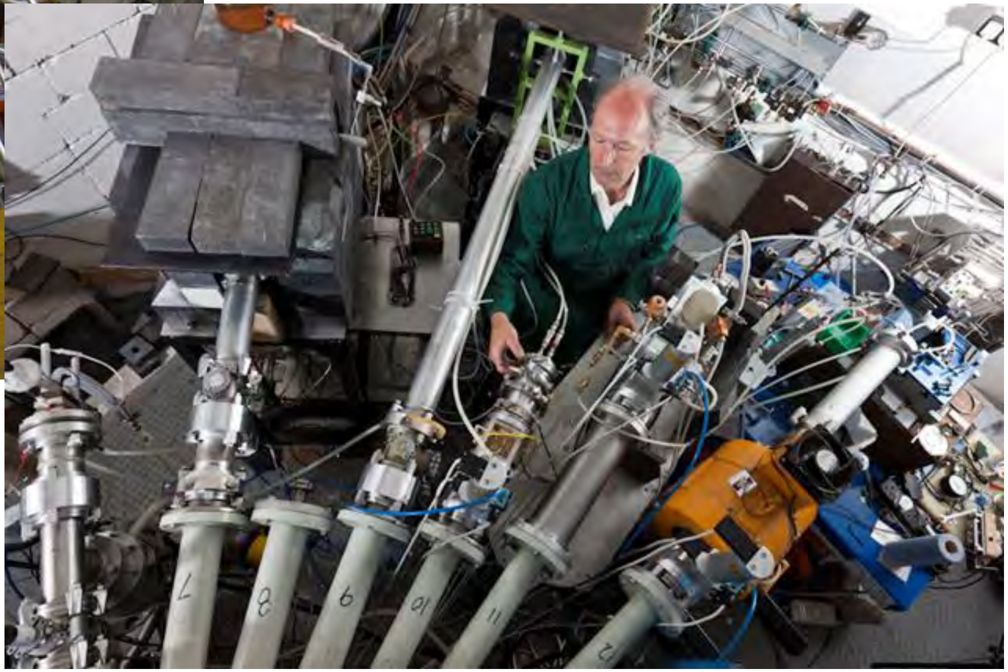
In 2002-2004 transferred from Minneapolis

p 11-39 MeV and 3-9 MeV
d 5.5-19.5 MeV
α 11-39 MeV
^{3}He 33-54 MeV and 8-27 MeV

(Same as old Hammersmith cyclotron)

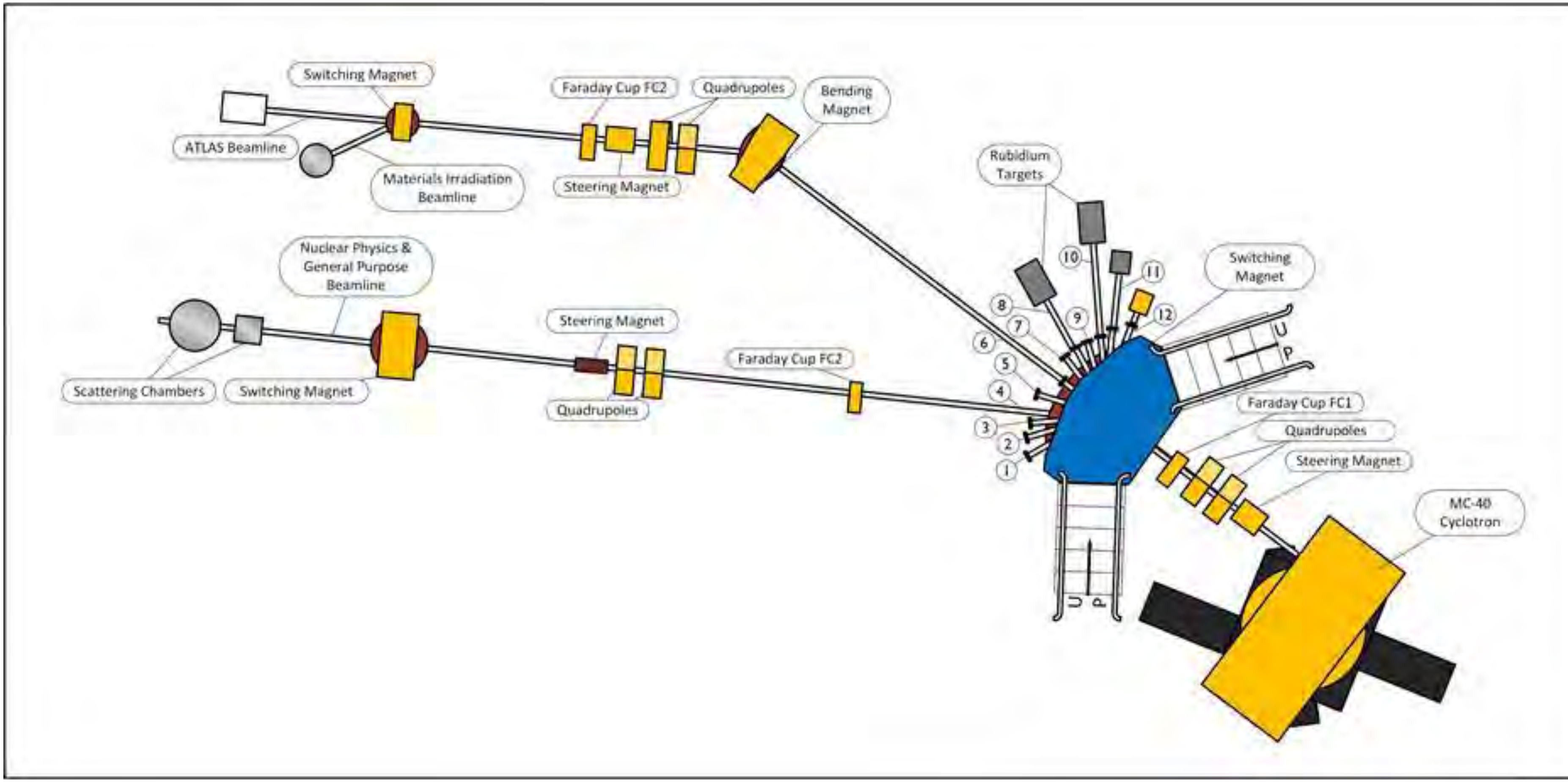
to Birmingham

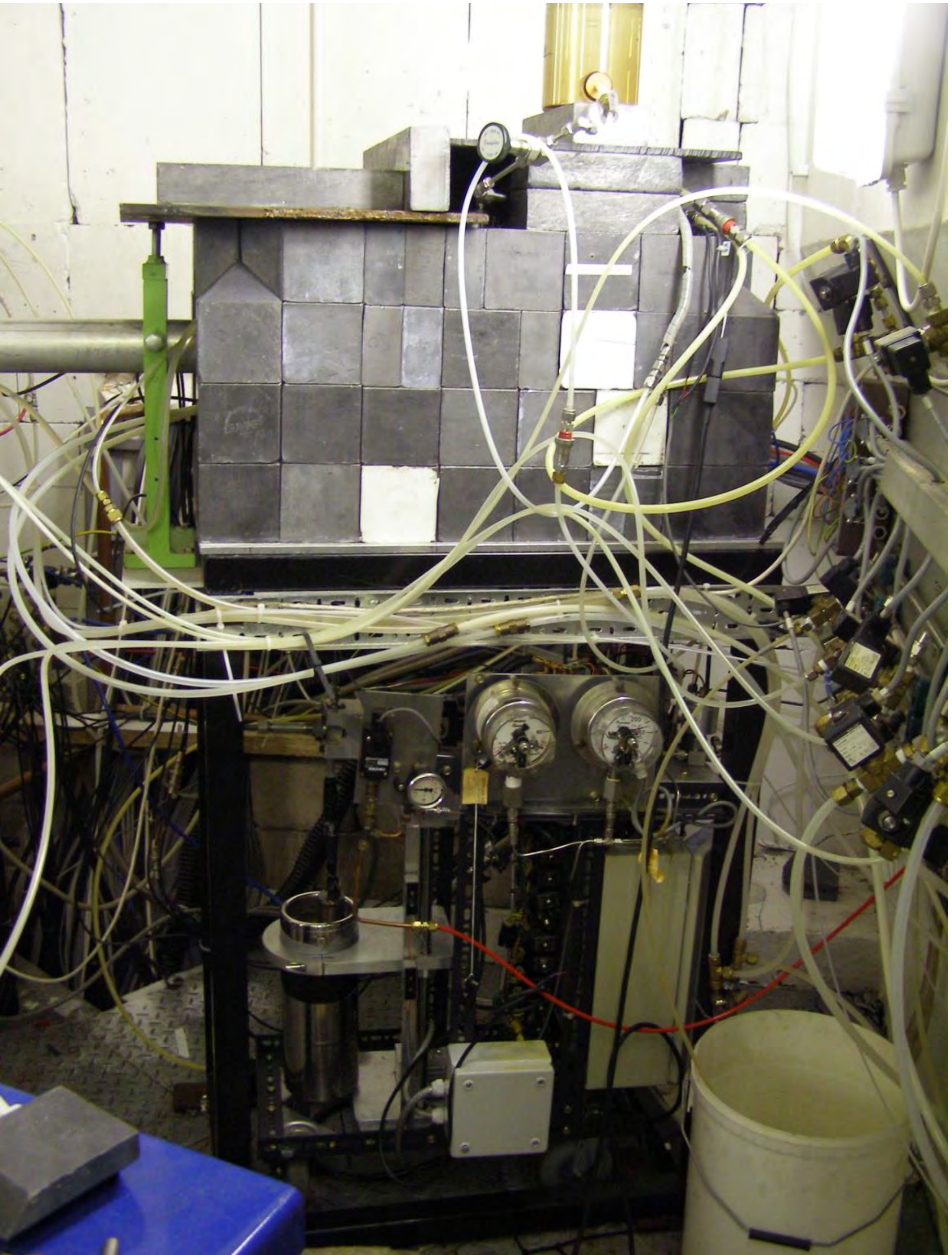
In 2005 we added a 12-way switching magnet (blue) [ex Vivitron]



This provides 12 independent target positions

Two beam lines extend into next room for nuclear physics/radiation damage studies





Two of the target stations are dedicated to ^{81}Rb production

Uses protons on enriched ^{82}Kr gas (12% of natural krypton)

$^{82}Kr(p,2n)^{81}Rb$
Threshold 14 MeV
Cross-section peaks above 20 MeV

^{81}Rb production

Using the technique developed at MRC Cyclotron Unit (Hammersmith):

- Irradiate target containing 20cm ^{82}Kr gas (6 bar pressure) with 28 MeV protons (30μA = 840 W). Protons lose ~6 MeV in gas.
- ^{81}Rb is produced and deposits on walls of target
- At end of irradiation, recover ^{82}Kr gas cryostatically
- Then elute ^{81}Rb from target: 3 x 40ml transferred to dispensing room.
- Finally evacuate target ready for reuse.

Entire procedure is controlled by PLC

81Rb Production statistics

Started 81Rb production in March 2006

Production is performed 5 days/week, 50 weeks/year

To end of May 2019, attempted production on 3280 days,
with 96% success rate.

Produced 39.8k generators

Production takes place typically 4pm-8pm
(later production would be more efficient
but would require expensive dedicated transport)

Beam Extraction

Birmingham cyclotrons have all been positive ion cyclotrons
Extraction of final beam is achieved using a Deflector comprising a pair of curved electrodes to pull the beam out of the magnetic field on its final orbit

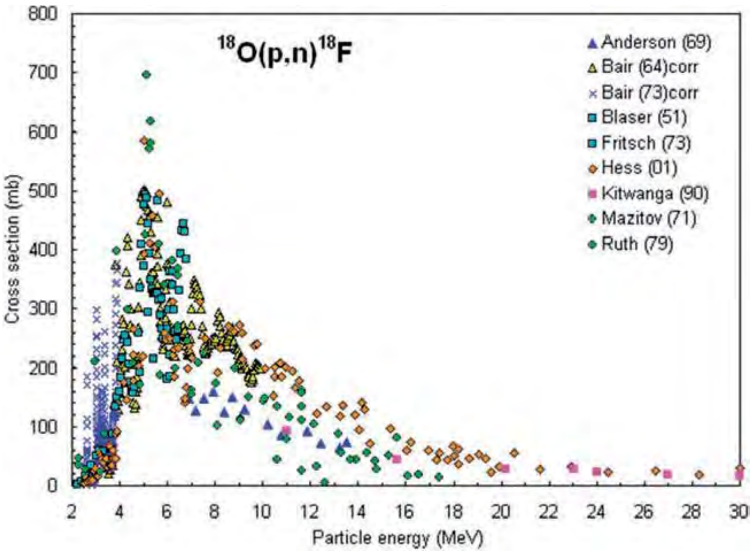
If one accelerates negative ions (e.g. H^-), then the final beam can be cleanly extracted by passing it through a thin foil to strip off the electrons.
Good for hydrogen beams.
Much harder to produce –ve ions of helium,

^{18}F fluorodeoxyglucose for PET imaging

NCRI PET Trials website
http://www.ncri-pet.org.uk/pet_scanning_and_cyclotron_facilities.php
lists 13 "academic" and 9 "commercial" cyclotrons in UK+Ireland.

Of these, all but Birmingham supply ^{18}F-FDG
Produced by $^{18}O(p,n)^{18}F$

110 min half-life imposes tight constraints on scheduling



Biggest challenge is GMP radiopharmaceutical production