80 years of neutron choppers

A brief personal history of a need for speed….

(and phase control)

Plan

- Origins
- First steps
- Exploration
- Evolution
- Maturity
- New horizons
- New challenges

Rome

Chicago

ORIGINS
1934 - 1942

1934 University of Rome

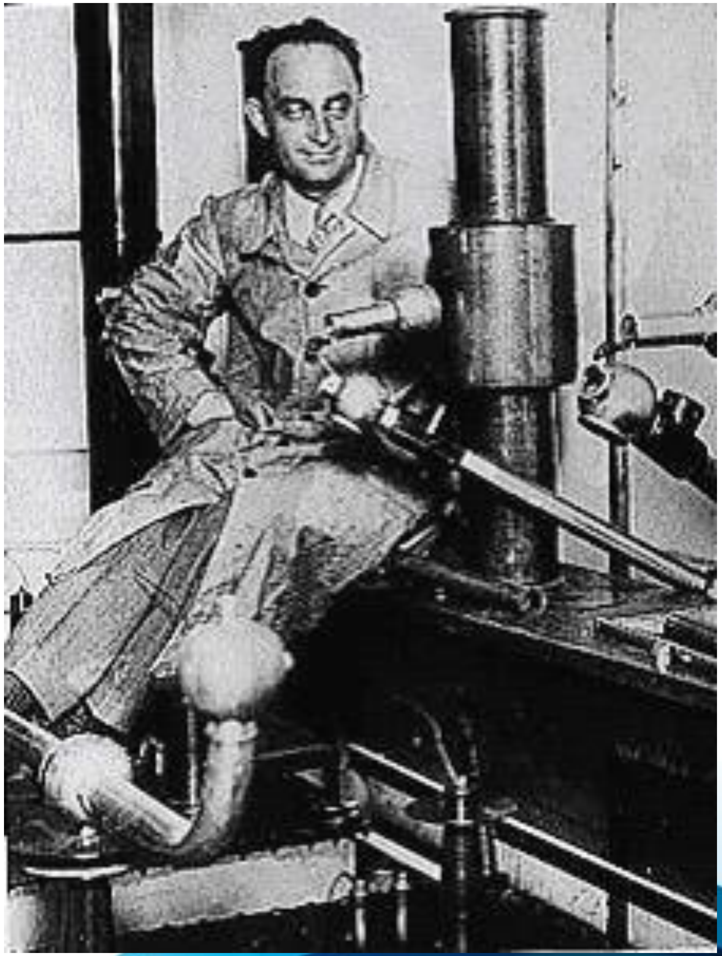
Enrico & Co

Study neutron induced radioactivity to production of artificial radioisotopes.

It is noticed that activation increases on samples in a water bath.

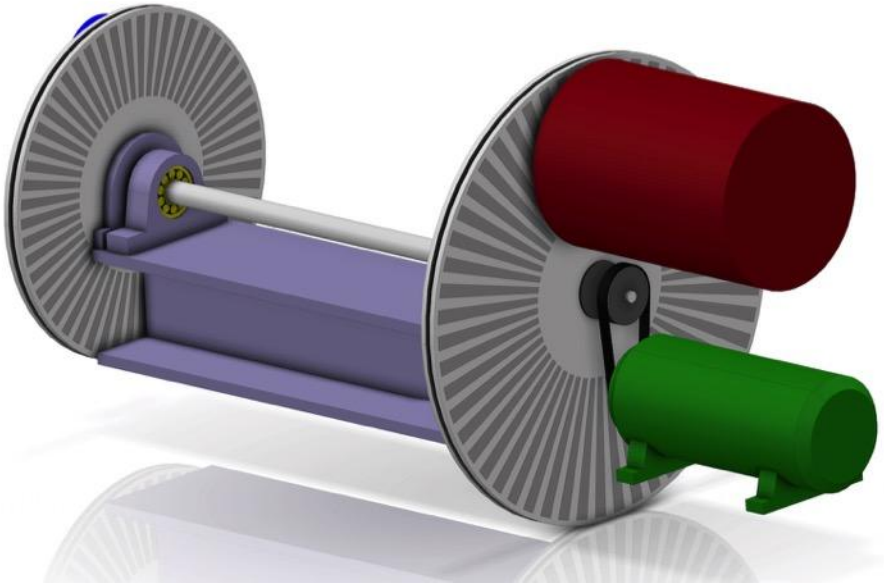
They ‘accidentally’ discover the moderating effect water of on Fast (Re-Be) neutrons.

Fermi theorises that ‘neutrons were loosing energy in collision with protons in the water’….



Historic neutron chopper # 1
The ‘original’ disc chopper

1935 Columbia university

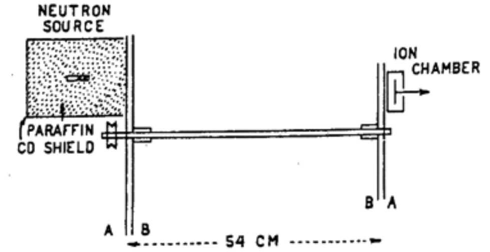


Key features

- (Double) Disc chopper
- Absorber cadmium
- Operating speed 30-60Hz

Function

- Velocity selection



Schematic drawing of mechanical velocity selector for slow neutrons. *A*, rotating disk with Cd sectors; *B*, fixed disk with Cd sectors.

J.R. Dunning, G.B. Pegram, G.A. Fink
D.P. Mitchell and E. Segre
Phys. Rev. 48, 704 (1935)

1942 Chicago University

CP-1

- 2 December 1942
- Worlds first self sustained nuclear reaction

49 present including …

Enrico Fermi, Eugene Wigner, Leo Szilard, Walter Zinn, Herbert Anderson, Leona Marshall, Harold Agnew, Arthur Compton, Norman Hilberry, Frank Spedding

Argonne

Clinton

Chalk river

FIRST STEPS 1940 - 1950

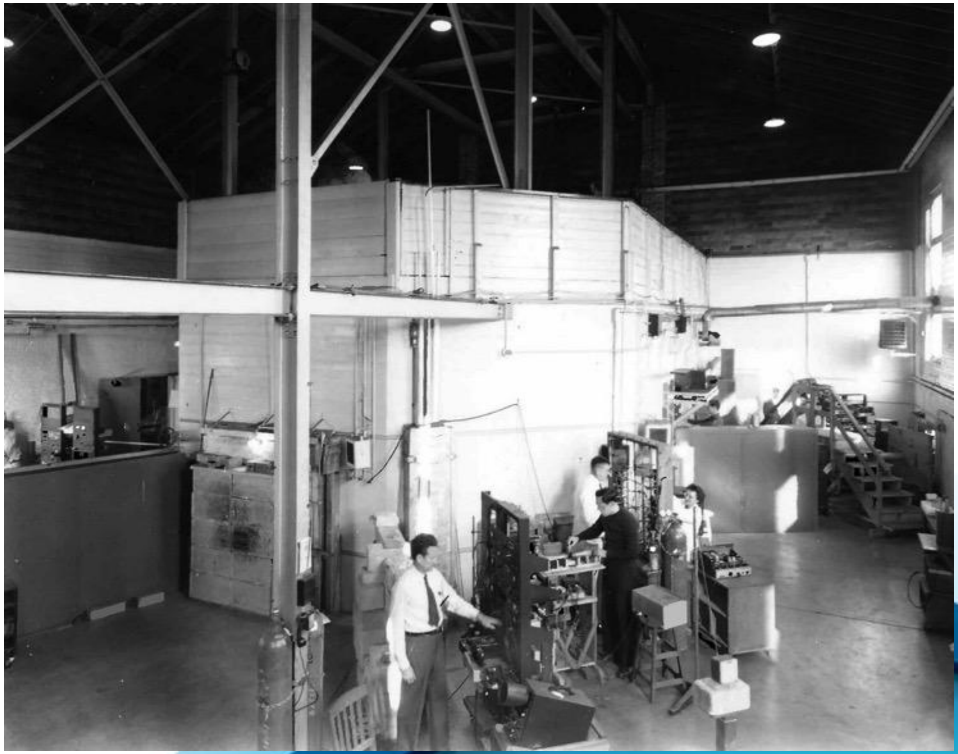
1947 - USA, Oakridge Argonne lab

Sources

CP-1 (rebuilt)

CP-2

CP-3!

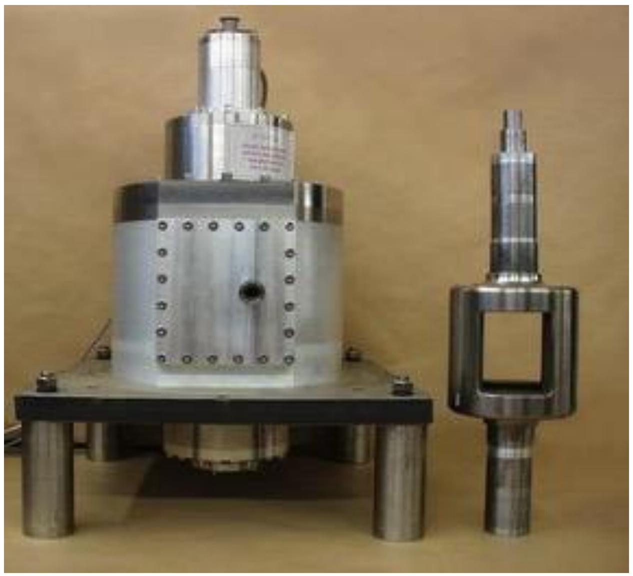


Early instrumentation on CP-3

Walter Zinn at the neutron diffractometer on the CP-3 reactor

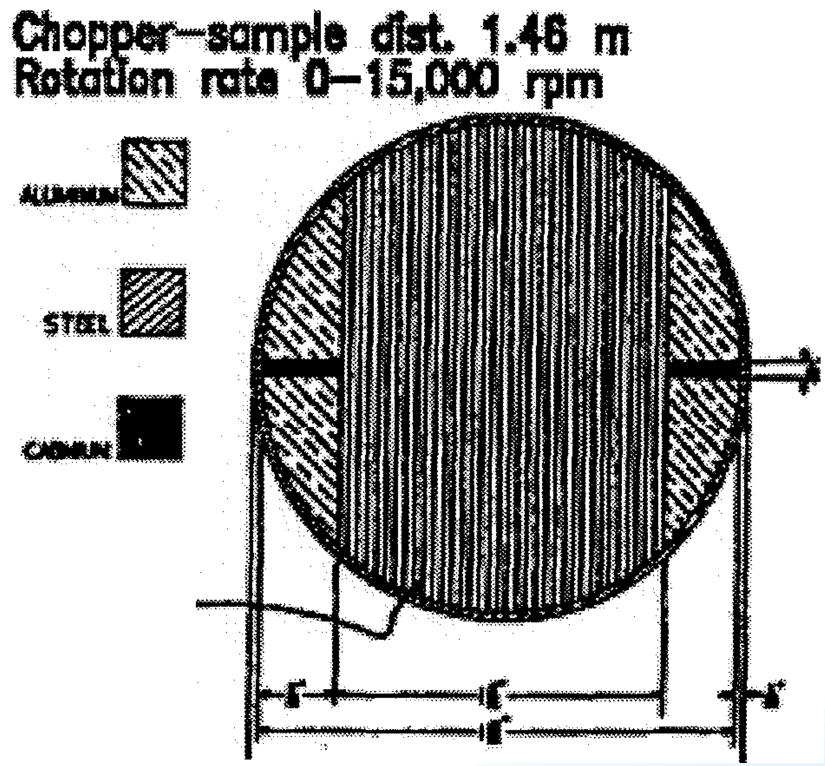
- E. Fermi, J. Marshall and L. Marshall, “A thermal neutron velocity selector and its application to the measurement of the cross section of boron”, *Phys. Rev*. **72,** 193 (1947).

Historic neutron chopper # 2
Fermi chopper



A much more modern fermi chopper
FZ Julich / ISIS

A Slits package



Cross section of the shutter of the velocity selector.
E. Fermi, J. Marshall and L. Marshall
Phys. Rev. 72, 193 (1947)

Chopper Family tree

Neutron Choppers

Orientation of rotation axis wrt neutron beam

- Parallel
  - Disc Chopper — 1935
  - Velocity Selector — ?
- Perpendicular
  - Fermi chopper — 1947

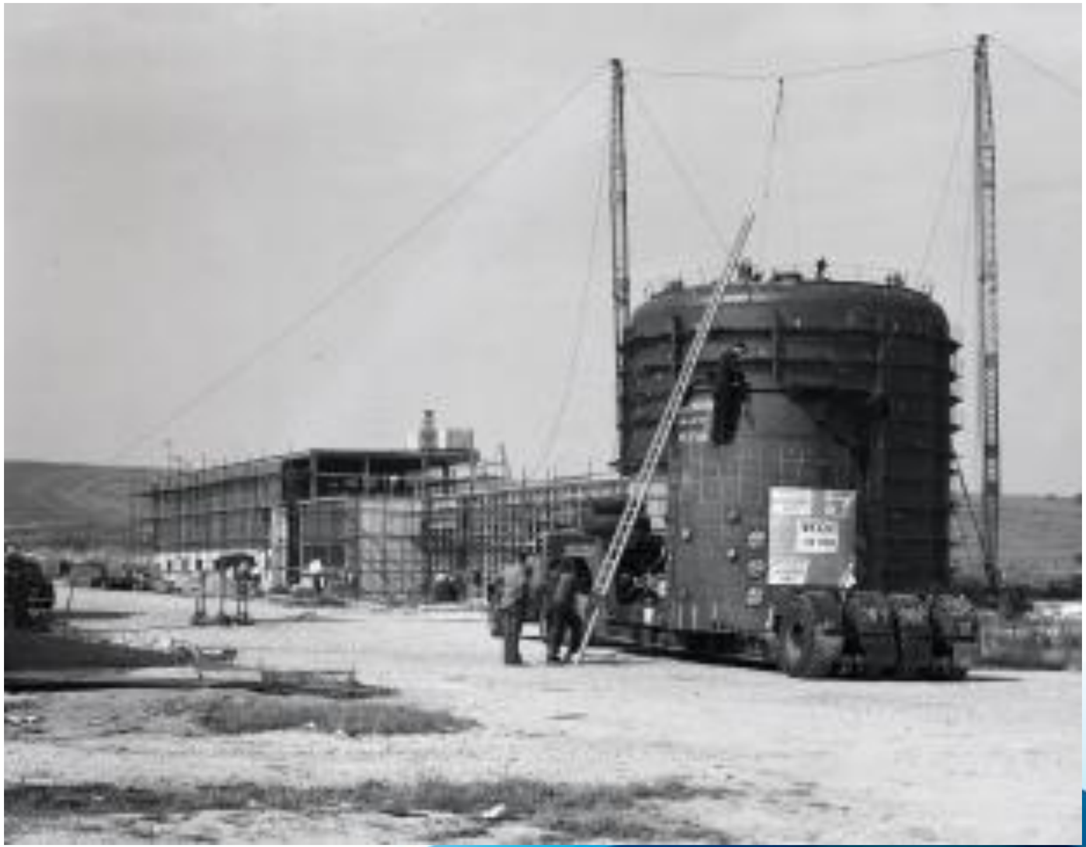
EXPLORATION
1950 – 1960

1956 - UK, Harwell

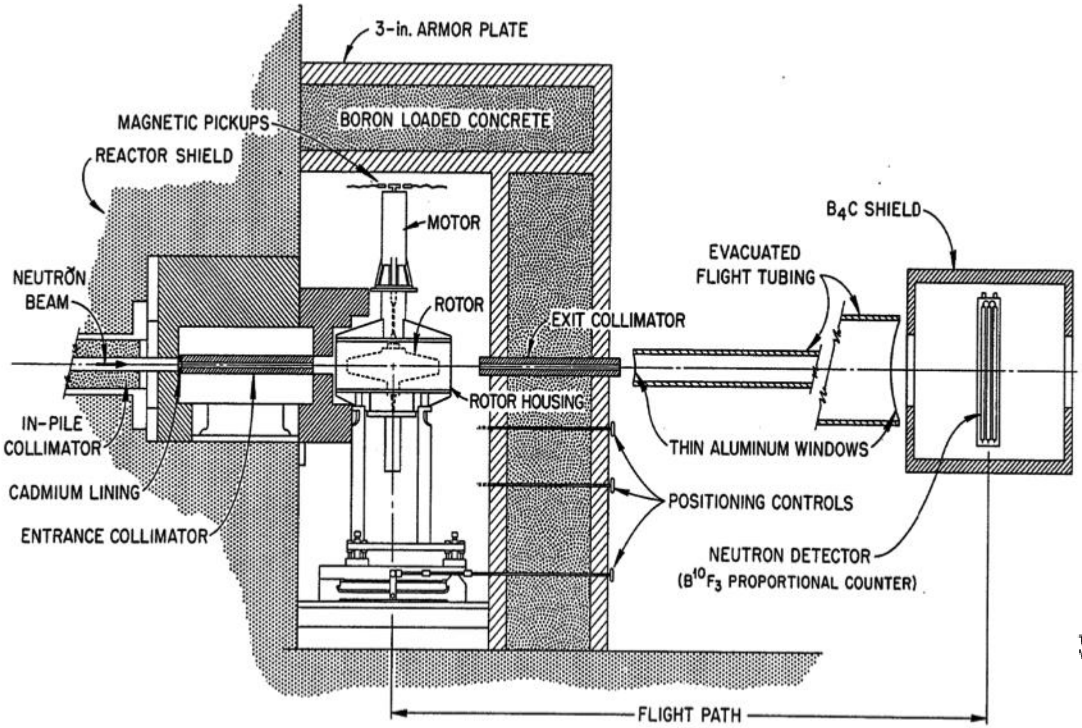
Sources

Pluto
Dido

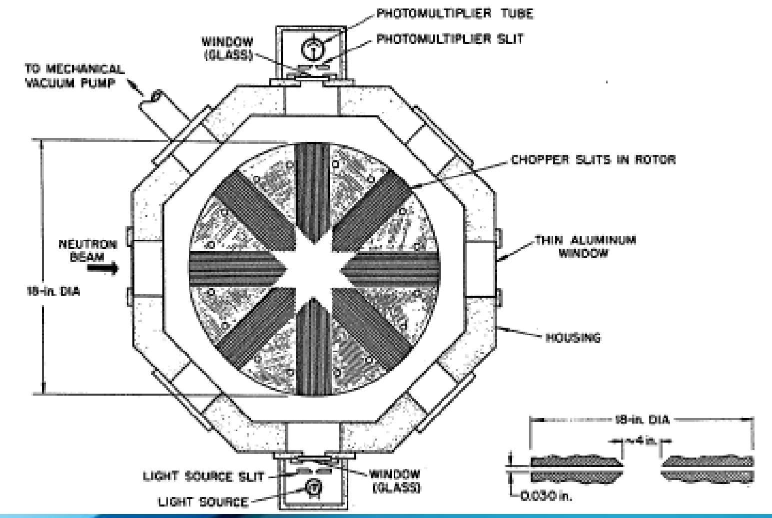
Type : Reactor



The problem with thermal neutrons …



ORNL Fast Chopper Time-of-Flight Neutron Spectrometer



Historic Neutron Chopper # 3 Harwell spinning head mk VII

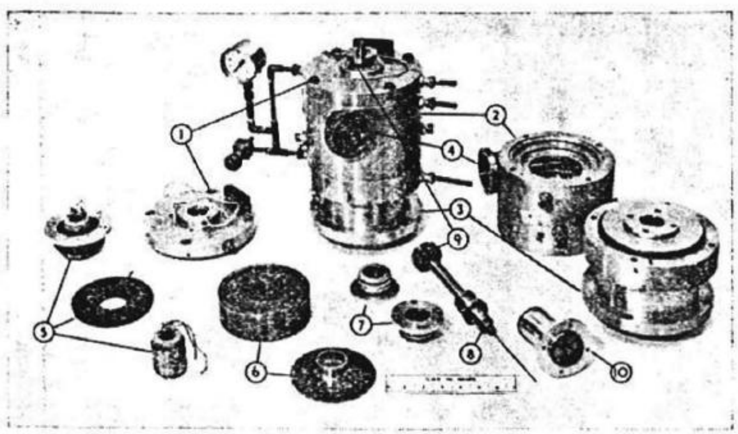
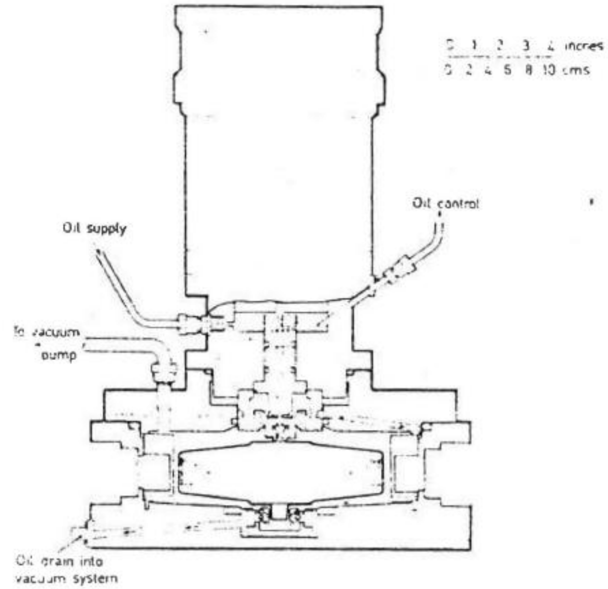
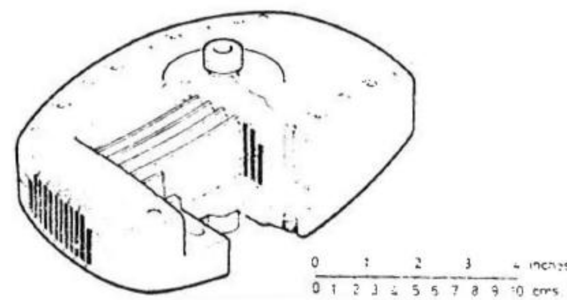


Fig. 3.—An assembled spinning head and its components.

1. Top plate with air bearing.
2. Housing for hysteresis motor and lifting magnet.
3. Housing for lower air bearing, oil seal, and damper.
4. Motor mounting for turning the stator coil.
5. Rotatable stator.
6. Lifting magnet.
7. Air bearings.
8. Shaft assembly, consisting of magnetic drum, upper air bearing surface, hysteresis rotor, lifting-magnet plunger, lower air bearing surface and flexible steel wire.
9. Magnetic drum.
10. Oil seal and damper assembly.





Key features

Rotor: Magnesium-Zirconium-Cadmium alloy

Operating speed: 500Hz

Bearings : Air

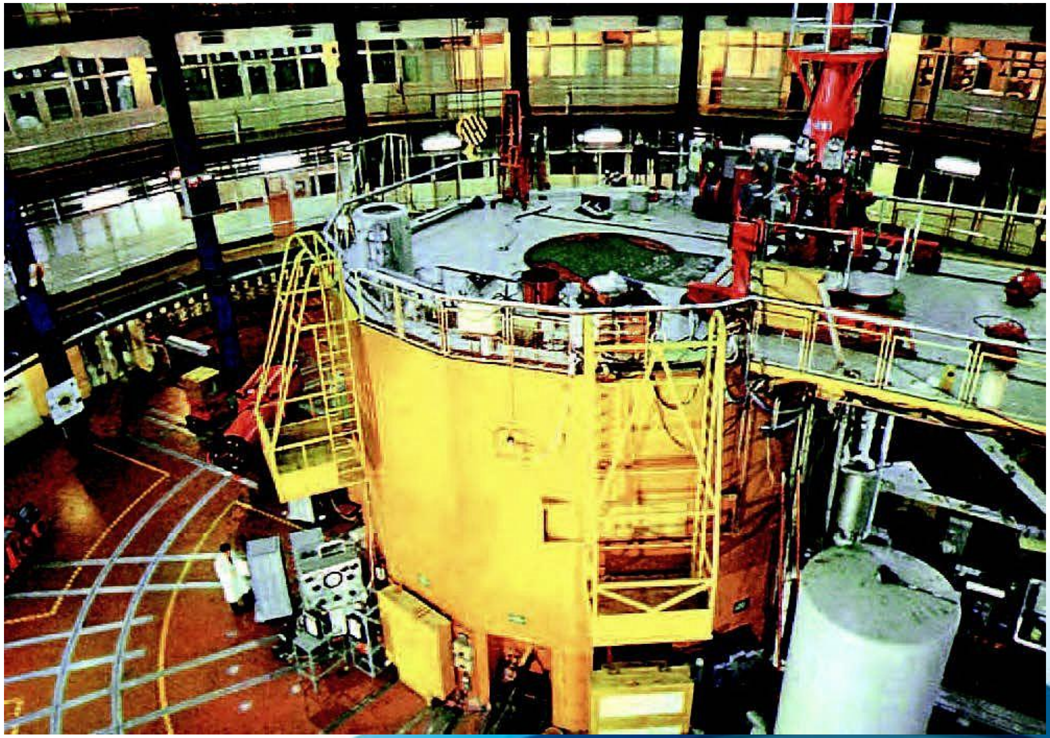
Control : Analogue electronic

1958 - France, Saclay, LLB

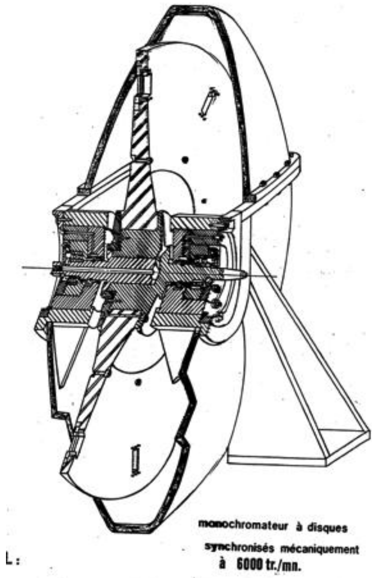
Sources

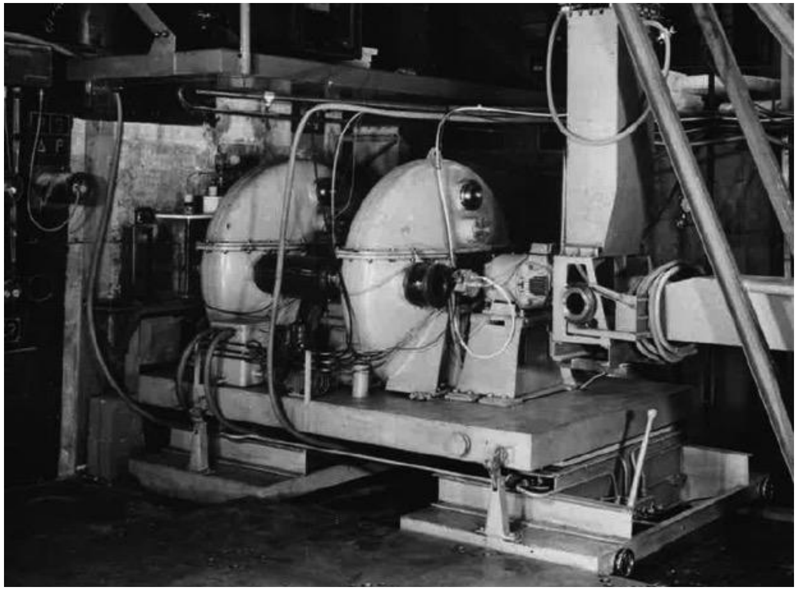
EL2
EL3
Orphee

Type : Reactor



Historic Neutron Chopper # 4 Mechanical syncronisation





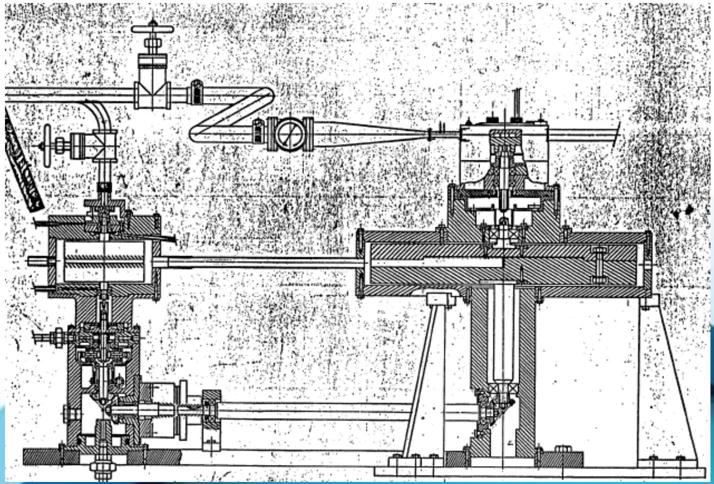
Key features

Rotor: Aluminum / Cadmium absorber

Operating speed: 100Hz

Bearings : Contact

Control : mechanical shaft & gearbox



1959 - Hungary, Budapest
Budapest Neutron Center

Source

BRR

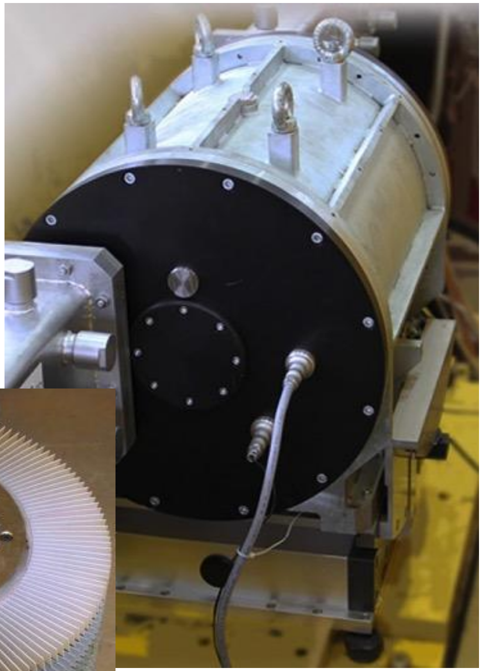
Type
water cooled, water moderated reactor

Commissioned

March 25, 1959

Panorama view of the Reactor Hall

Historic Neutron Chopper # 5 MBR / MRR type 'velocity selector'



Or 'the selection of neutron energies by spiral grooves'
Theorised by J.G Dash & Sommers in 1955

Key features

- 'Like' a series of phased choppers on a common axis
- Rotors with opening or blades monochromatic beam
- Rotation speed

EVOLUTION 1970-1990

1971 - France, Grenoble
Institut Laue-Langevin

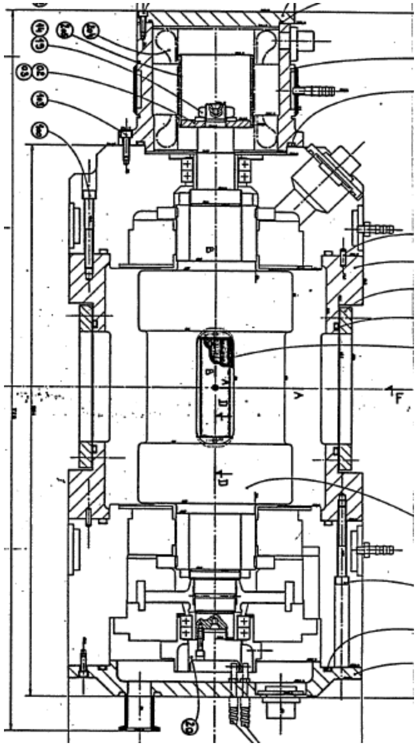
Sources

RHF

Type
Water cooled, heavy water moderated HEU. Reactor

Commisioned
1971

In-house chopper development

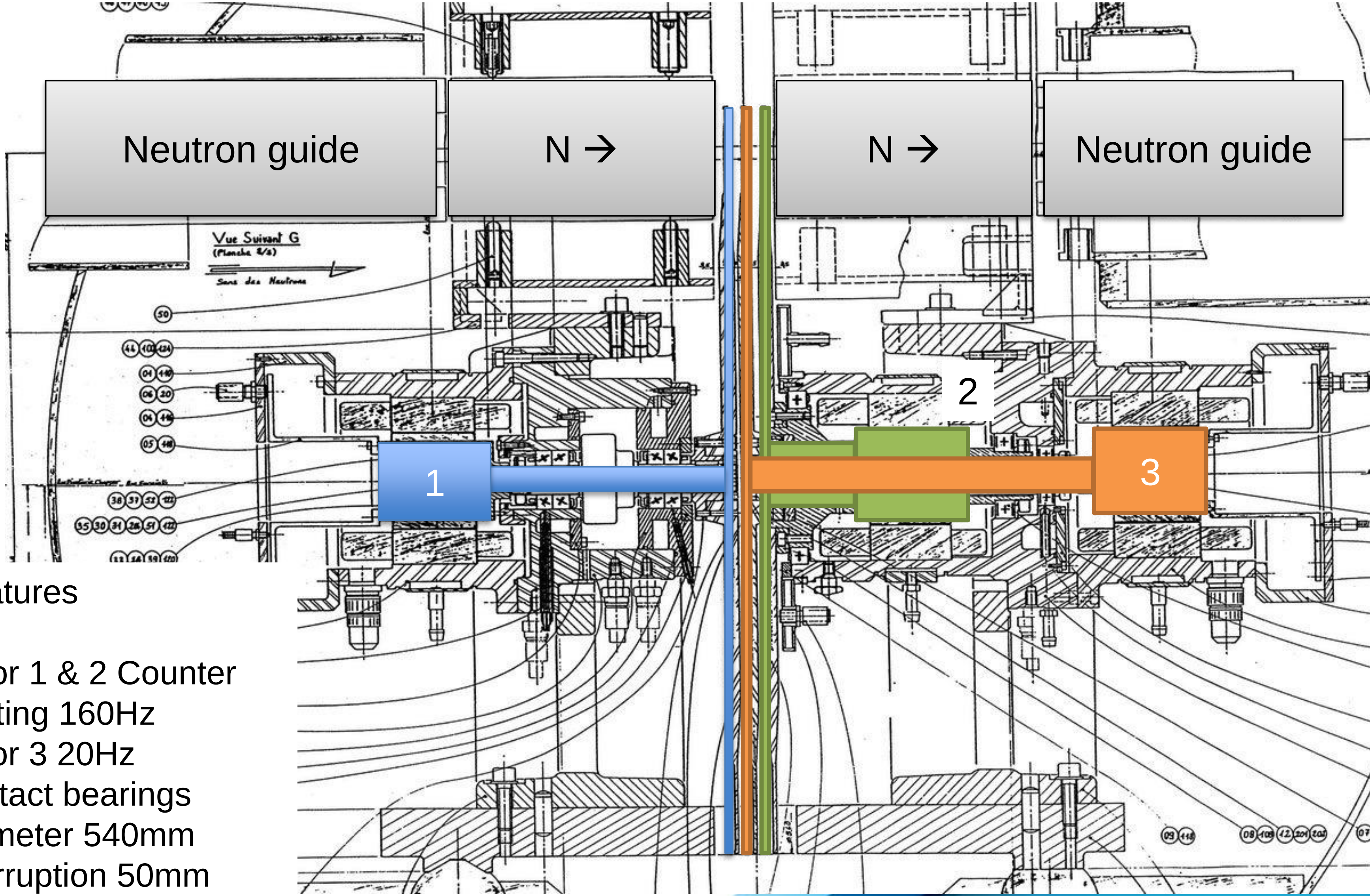


Mag Bearing
Fermi choppers

‘Thermal’ disc chopper

330Hz disc chopper
Contact bearings

Historic neutron chopper # 6
IN15 'triple chopper'



Key features

- Rotor 1 & 2 Counter rotating 160Hz
- Rotor 3 20Hz
- Contact bearings
- Diameter 540mm
- Interruption 50mm
- In air

1962 – Germany Kernforschungsanlage Jülich, KFA

Source

FRJ-2 (DIDO)

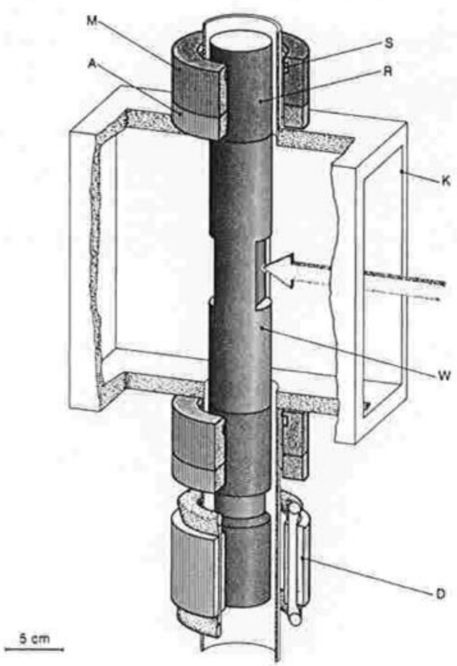
Type
Reactor

Criticality
14 november 1962

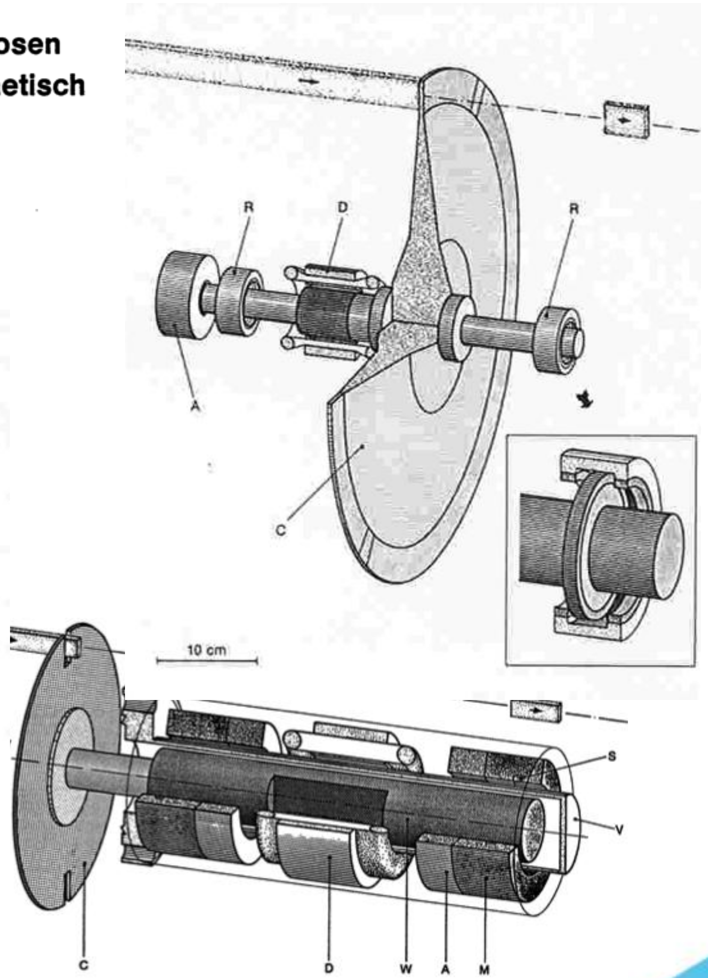
In-house development

Magnetlager zur berührungslosen Führung von Rotoren in hermetisch abgeschlossenen Systemen

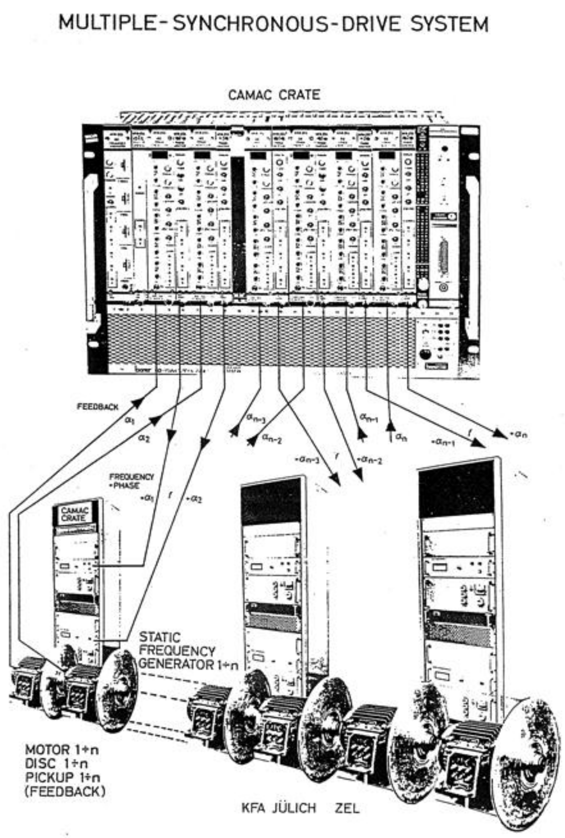
Johan K. Fremerey und Karl Boden



PE configuration
(Fermi chopper)



PA configuration
(disc chopper)



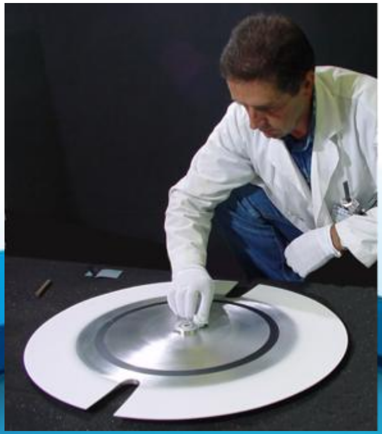
Control systems

Historic Neutron Chopper # 7 Julich/ILL ‘IN5 CRD’

Key features

- Julich magnetic spindle & control
- ILL high speed aluminum
- Diameter 700mm
- Rotational speed 278Hz

Partnership continued for NIST



A new paradigm

mature technology

‘more’ sources

commercial integrators

MATURITY
1990 - 2000

EUROPEAN SPALLATION SOURCE

1985 – UK, Harwell RAL ,ISIS

Source

Target station 1

Target station 2

Type
Short pulse spallation

Science & Technology Facilities Council ISIS

Historic neutron chopper # 7 ISIS ‘T’zero

Key features

- Blocks ‘prompt pulse’
- Inconel hammer (300mm)
- Rotation speed 100Hz
- Operation in air

USA	SNS	2006
JAPAN	MLF (J-PARC)	20
UK	TS2	20

NEW HORIZONS 2000 - 2010

2006 – USA, Oakridge lab SNS

Source

Target station 1

Target station 2

Type
Short pulse
Spallation

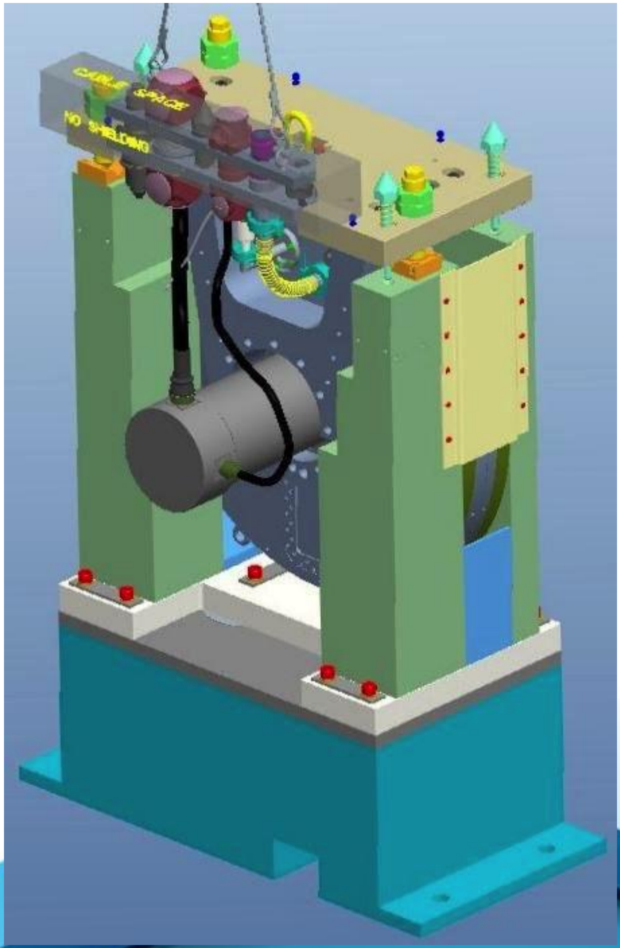
Commissioned 2006

Historic Neutron Chopper #8
SNS ‘standard chopper system’

Key features

- A ‘universal’ support
- Pre-alignment ready
- Standardised connections
- Remote handling capable

Built in serviceability

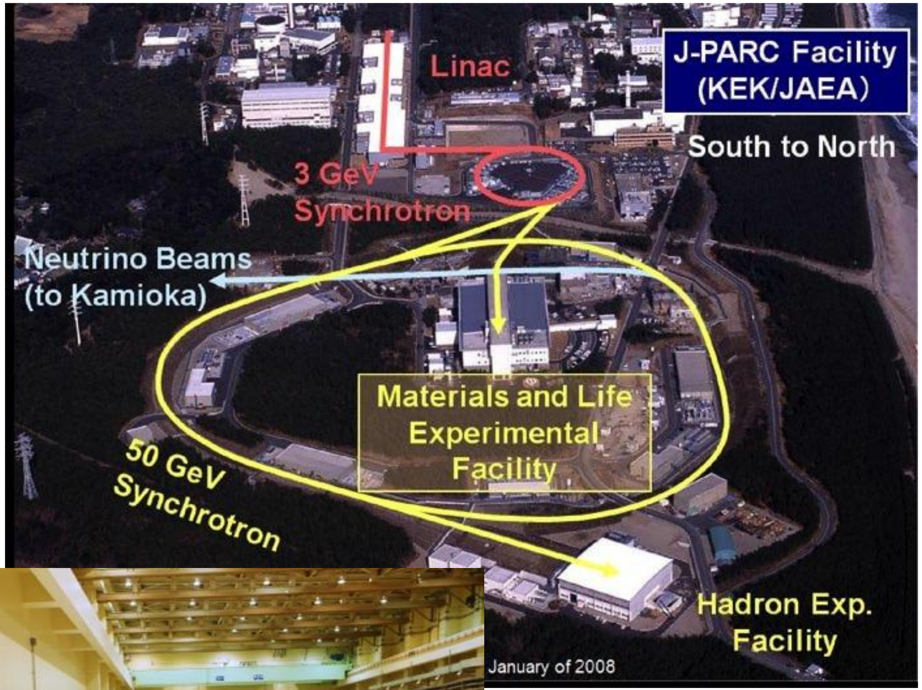


2008 – Japan, Tokai
J-Parc, MLF

Source
Target station

Type
Short pulse spallation

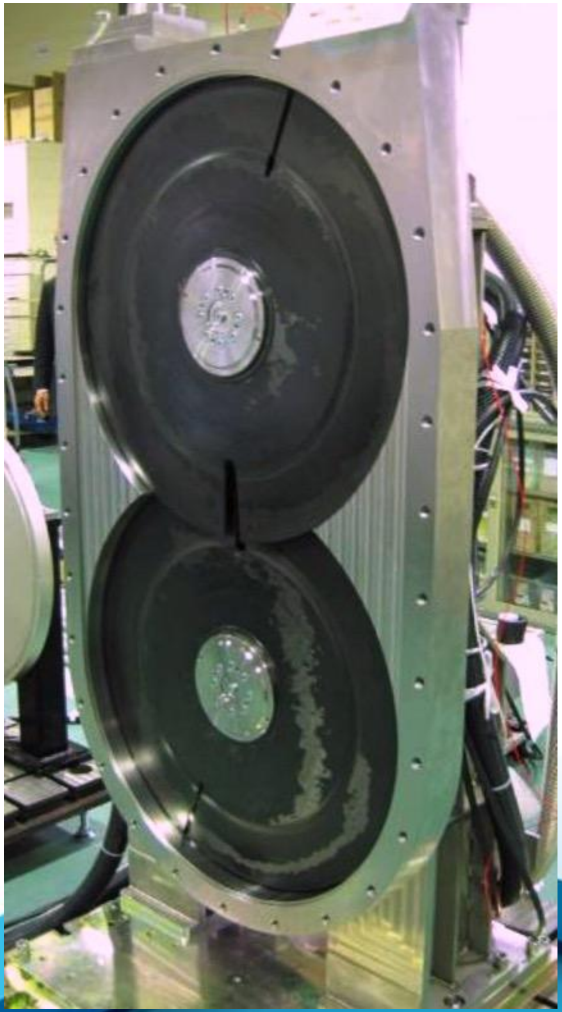
Commissioned 2008



Historic Neutron Chopper #9 Amataras ‘CRD’

Key features

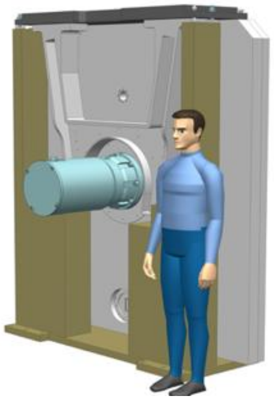
- Magnetic bearings
- Rotor diameter 700mm
- Rotation speed 350Hz
- CFRP rotor
- Stainless steel containment housing



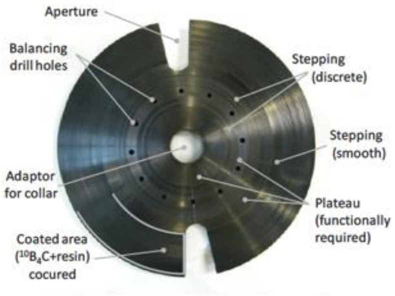
Europe	ESS	2019
China	CSNS	2017
USA	SNS TS2	202?

NEW FRONTEIRS 2015 >

New challenges

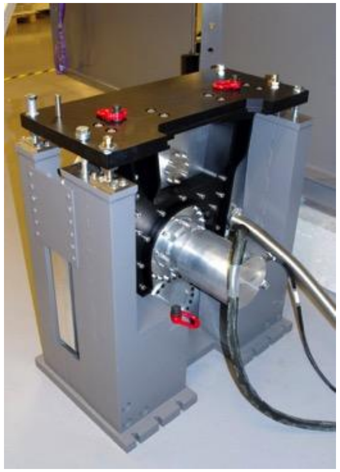


Higher !



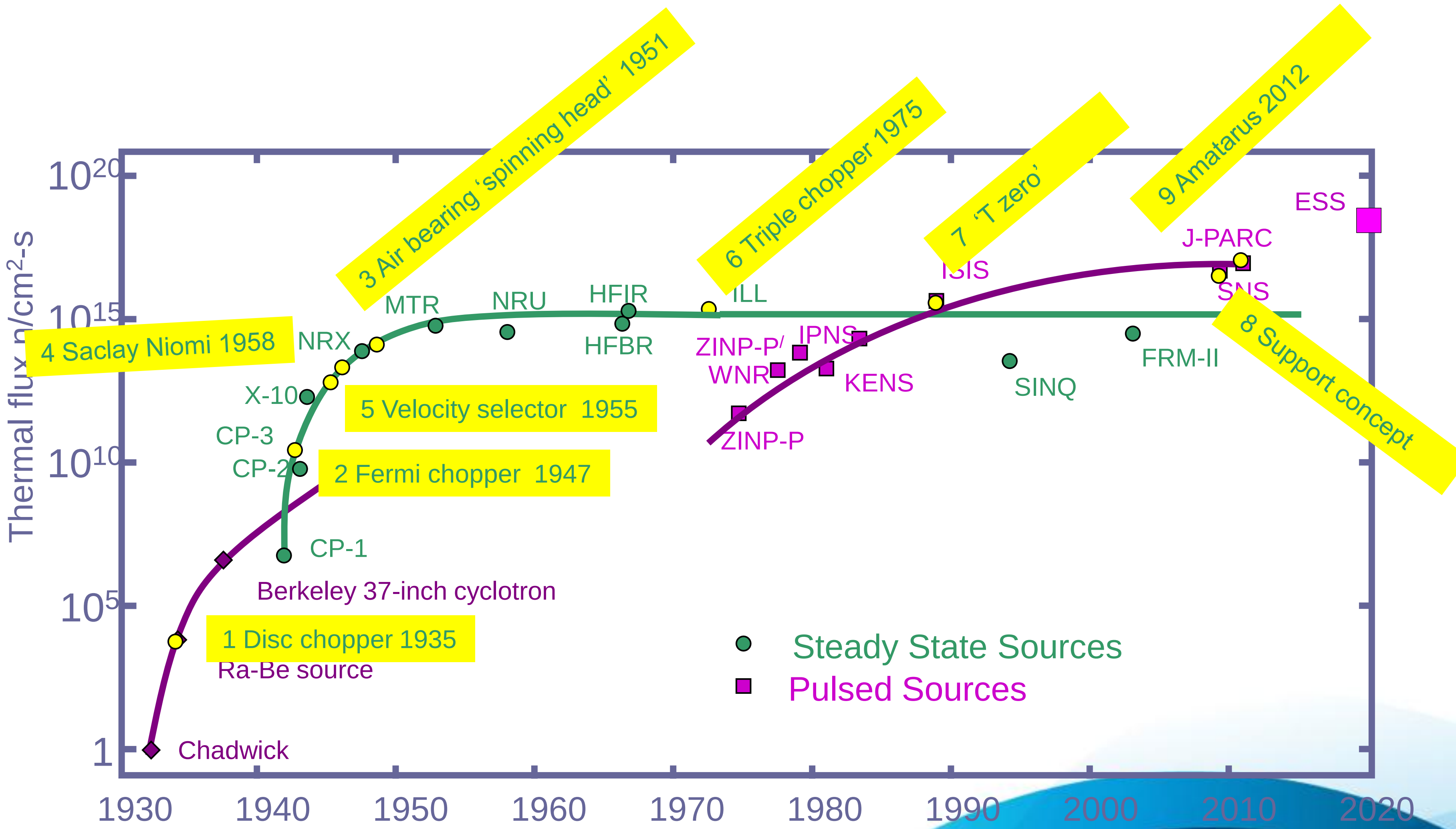
Faster !!!

Stranger !!



Cheaper !!!!

Summing up



(Updated from *Neutron Scattering*, K. Sköld and D. L. Price, eds., Academic Press, 1986)

The End

I thank you for your attention

a very big thank you to all of you who contributed to this talk

- My colleges ESS chopper group
- Chopper technical advisory panel
- The chopper manufacturers
- The Neutron Facilities

A very special thanks to Dr Roup Lechner