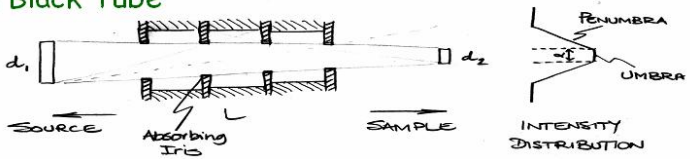
Lecture 3. Instrument Components

1. Neutron Beam Transport
   - a. Black tube
   - b. Soller collimator
   - c. Neutron guide
2. Mechanical velocity selectors
   - a. Helical velocity selector
   - b. Disc chopper
   - c. Fermi chopper
3. Crystal monochromators & analysers
4. Neutron Detectors

1. Neutron Beam Transport

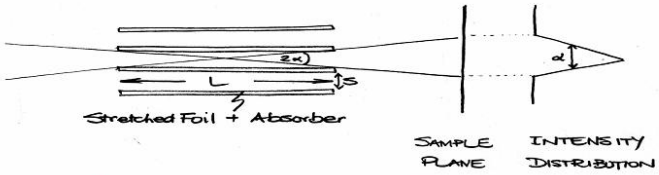
a. Black Tube



Beam divergence $\alpha = (d_1 + d_2)/2L$

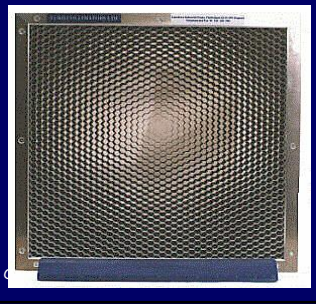
b. Soller Collimator

better angular resolution & large beam area

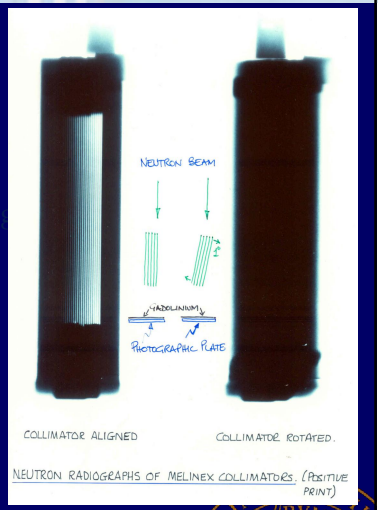


Beam divergence $\alpha = s/L$

Collimators for improved resolution & background suppression



Honeycomb Collimator

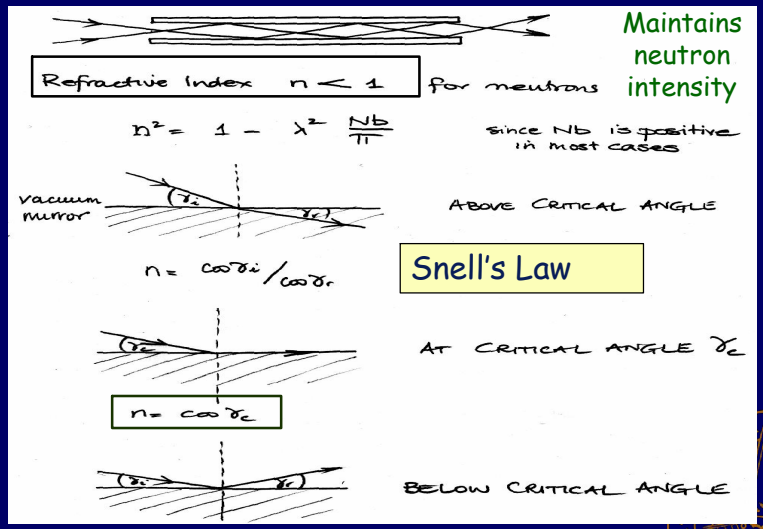


NEUTRON RADIOGRAPHS OF MELINEX COLLIMATORS. (POSITIVE PRINT)

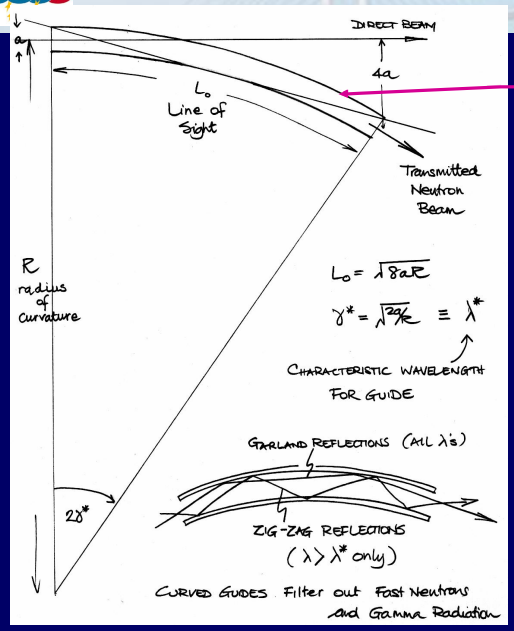
Radial Collimators

c. Neutron Guide Tubes

Totally reflecting tube



Curved Guides



Nickel plated
1 m long sections

$n = \cos\gamma_c$

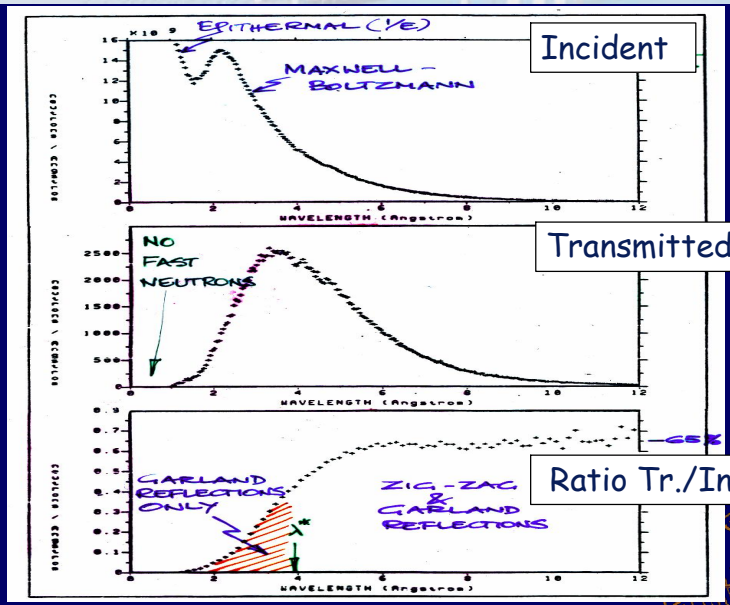
for small γ_c $n^2 = 1 - \gamma_c^2$

so $\gamma_c = \lambda \{Nb/\pi\}^{1/2}$

$\gamma_c = 0.0017\ \lambda$ (Å) radians for nickel

~ 0.2° to 1.0°

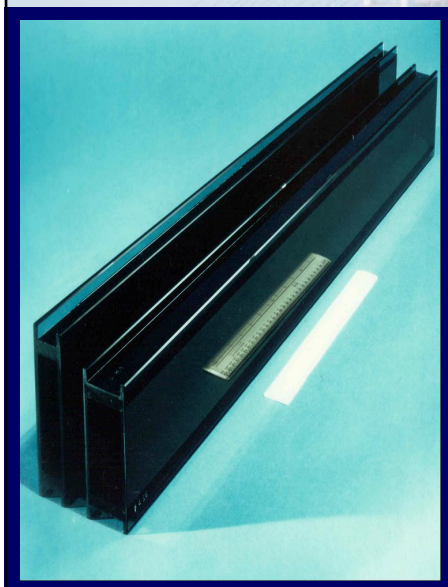
Transmission of a Line of Sight Guide



Incident

Transmitted

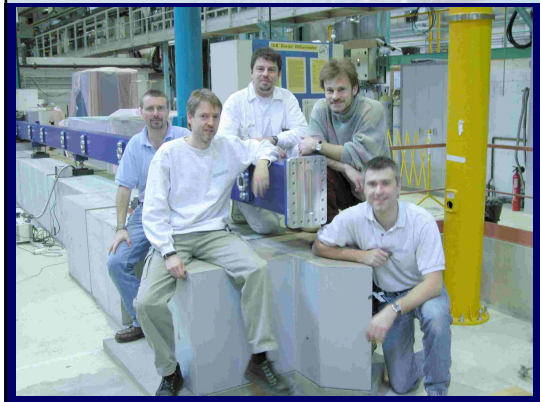
Ratio Tr./Inc.



Shutter guide for FRM-II Munich

Guides for HRPD & IRIS at ISIS

Super-mirror guides



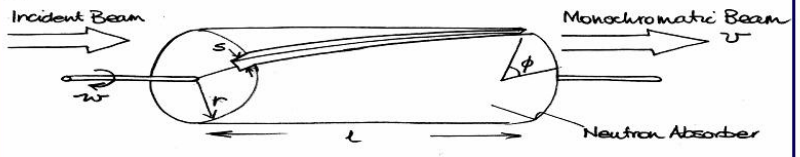
Guide has been installed by Swiss-Neutronics (SN) end of February within 3 days.

tolerance : ±0.003 mm
reflectivity at m=2 : 92%
flux - 3-5 times present
in vacuum tube

Institut Laue Langevin

2. Mechanical Velocity Selectors

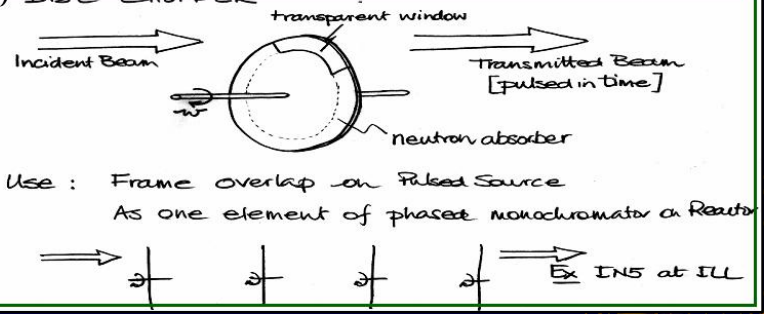
(i) HELICAL VELOCITY SELECTOR



Neutron velocity $v = \frac{\omega l}{\phi}$ Resolution $\frac{\Delta v}{v} = \frac{2s}{r} \cdot \frac{1}{\phi}$

Best for Slow Neutrons Ex. Small Angle Scattering Spectrometer

(ii) DISC CHOPPER



Use : Frame overlap on Pulsed Source

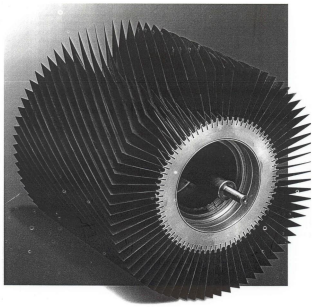
As one element of phased monochromator on Reactor

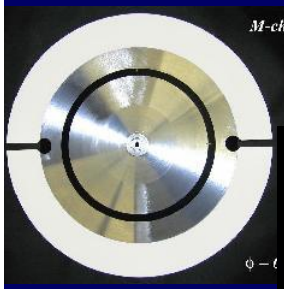
Ex IN5 at ILL

b. Disc Choppers for IRIS & IN5

Daimler-Benz Aerospace
Dornier
Dornier Satellitensysteme GmbH

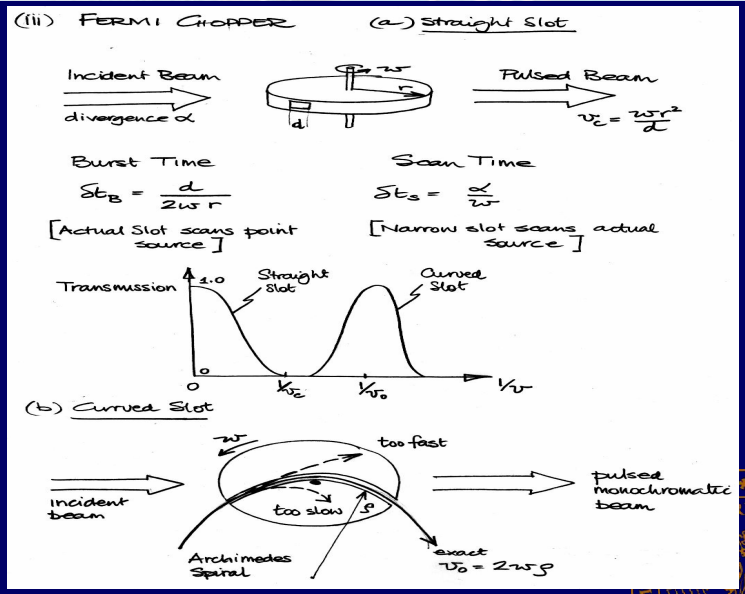
Neutron
Velocity Selector



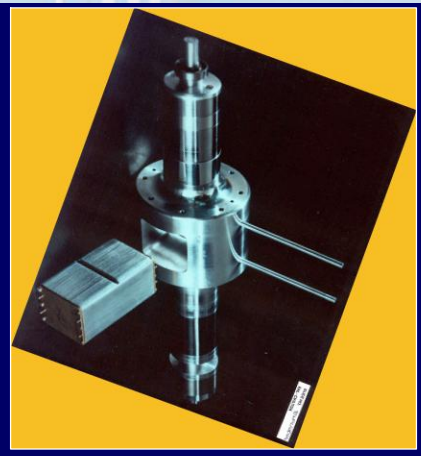


Velocity Selector

c. Fermi Choppers

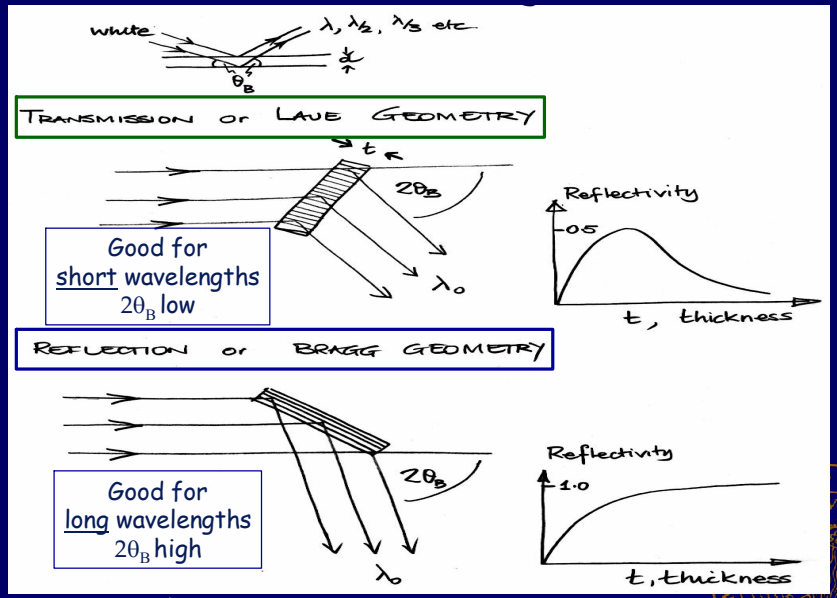


Fermi Chopper with Magnetic Bearings



HET, MARI, MAPS

3. Crystal Monochromators & Analysers

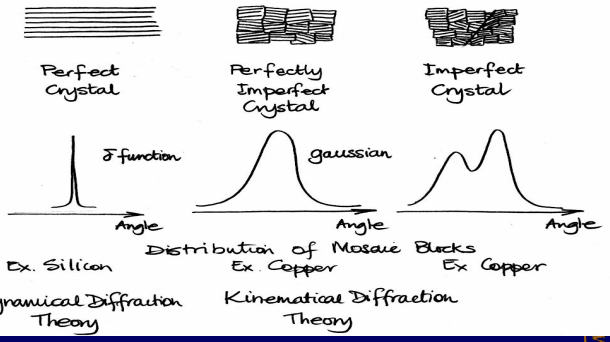


Pre-ILL Days in Grenoble - 1963

Properties of an Ideal Monochromator

1. High coherent scattering length density
2. Low absorption
3. Low thermal diffuse scattering
4. Appropriate lattice spacing
5. Ideal mosaic spread
6. Ease of growth

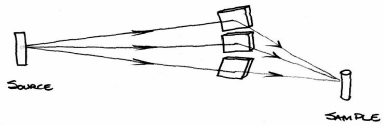
What is Mosaic Spread?



Focussing Geometries

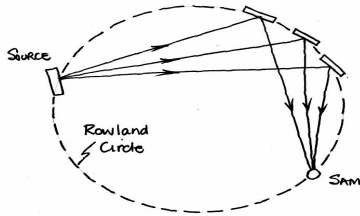
To increase Intensity of Monochromatic Beam

(i) Vertical Focussing



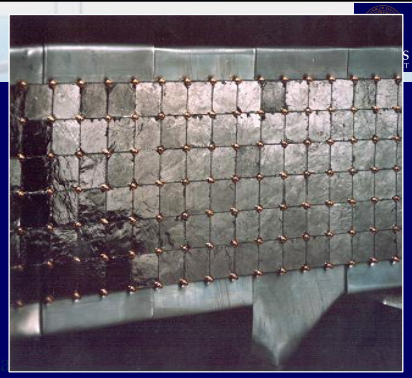
No λ spread
No L spread
∴ No t spread
} Ideal for Continuous and Pulsed Sources

(ii) Horizontal Focussing



No λ spread
L spread
} o.k for continuous not for pulsed source

Focussing Geometry can gain ~ x10 Ex: IN6 ILL



New horizontally
& vertically focussing
germanium monochromator
for D20

Silicon, Graphite & Copper on the IN8 Triple Axis Spectrometer

Gain > 5

4. Neutron Detectors

Weak Interaction → useful for solid state investigation

but → difficult to detect

direct ionization at thermal energy [negligible]

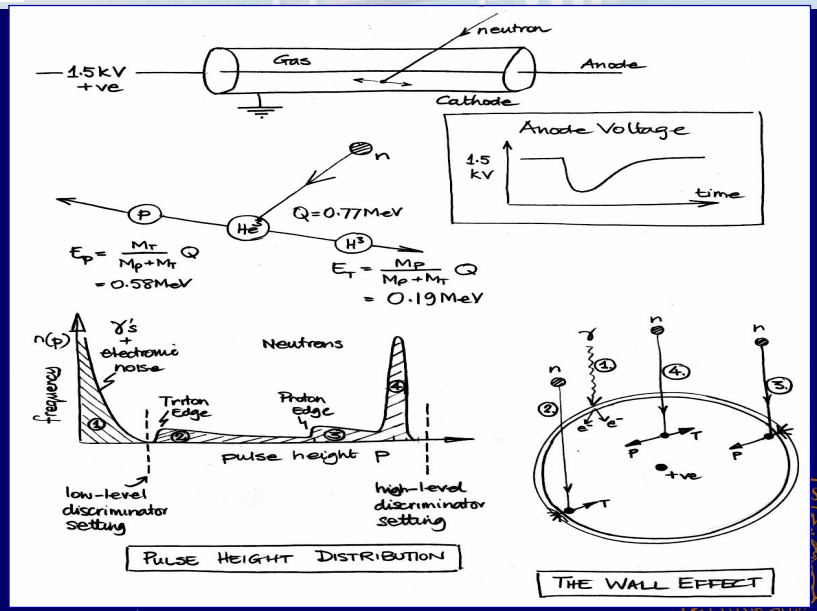
must be detected by [secondary ionization]

neutron → nuclei = either γ decay [scintillation detector] or [gas proportional counter]

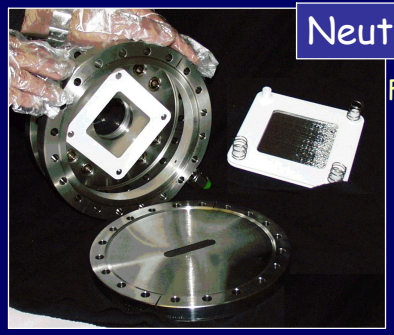
Examples

$n + He^3 \rightarrow H^3 + p + 770\ keV$		He^3 gas detector
$n + B^{10} \rightarrow Li^{7*} + \alpha + 2.3\ MeV$ (93%)	$Li^{7*} \rightarrow Li^7 + \gamma + 0.5\ MeV$	BF^3 gas detector
$n + B^{10} \rightarrow Li^7 + \alpha + 2.8\ MeV$ (7%)		
$n + Li^6 \rightarrow H^3 + \alpha + 4.79\ MeV$		Scintillation detector
$n + U^{235} \rightarrow$ fission $+ 195\ MeV$		fission chamber

Gas Proportional Counters

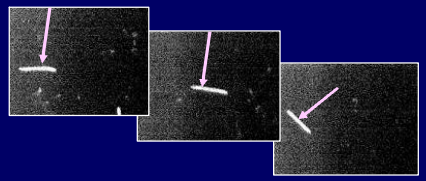


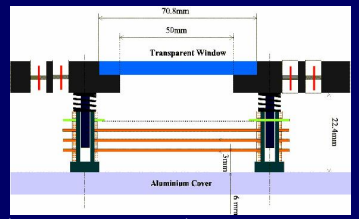
Detecting the neutron's energy

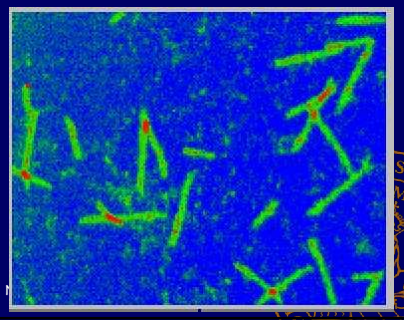


Neutron tracks in a GEM detector

Fraga, Margato, van Vuure & Guerard

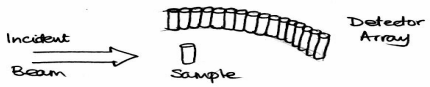




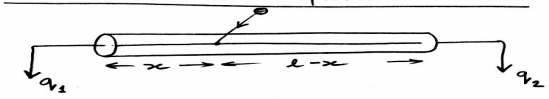


Position Sensitive Detectors

1. Individual Counter Array



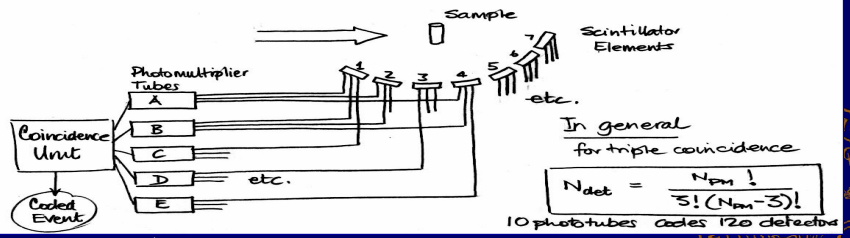
2. Resistive Wire Gas Proportional Counter



$q_2 / x = q_1 / \ell - x$

Measure q_1, q_2 hence x

3. Fibre Optic Coded Discrete Scintillator Detector

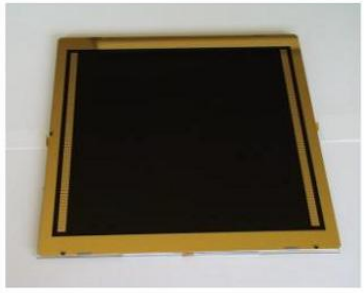


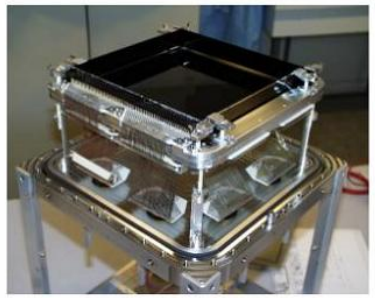
In general

for triple coincidence

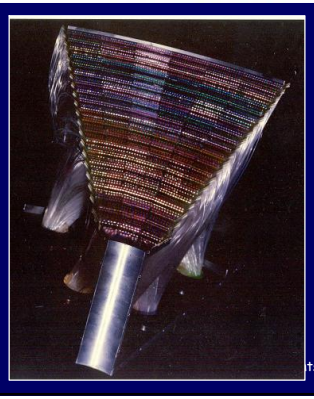
$$N_{det} = \frac{N_{PM}!}{5!(N_{PM}-3)!}$$

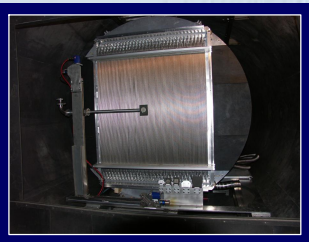
10 phototubes codes 120 detectors





Microstrip detectors
&
Scintillator detectors

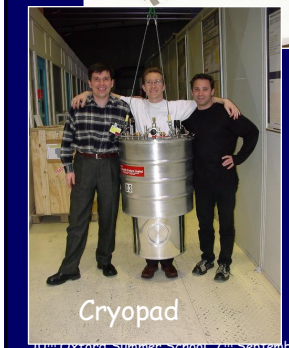




3 metre-long position sensitive multi-tube detector for IN5

Polarisation techniques are important

D7 polarising supermirrors



Cryopad

IN20 Heusler monochromator

Polarising ^{3}He Project

Further Reading

Choppers

S J Cocking in Thermal Neutron Scattering
P A Egelstaff Academic Press

Crystals

A Freund in Hahn Meitner report
and NIM paper

Detectors

Position Sensitive Detectors
by Convert & Forsyth 1984