New Proposal

to Search for Neutron → Antineutron Transitions at HFIR/ORNL Reactor

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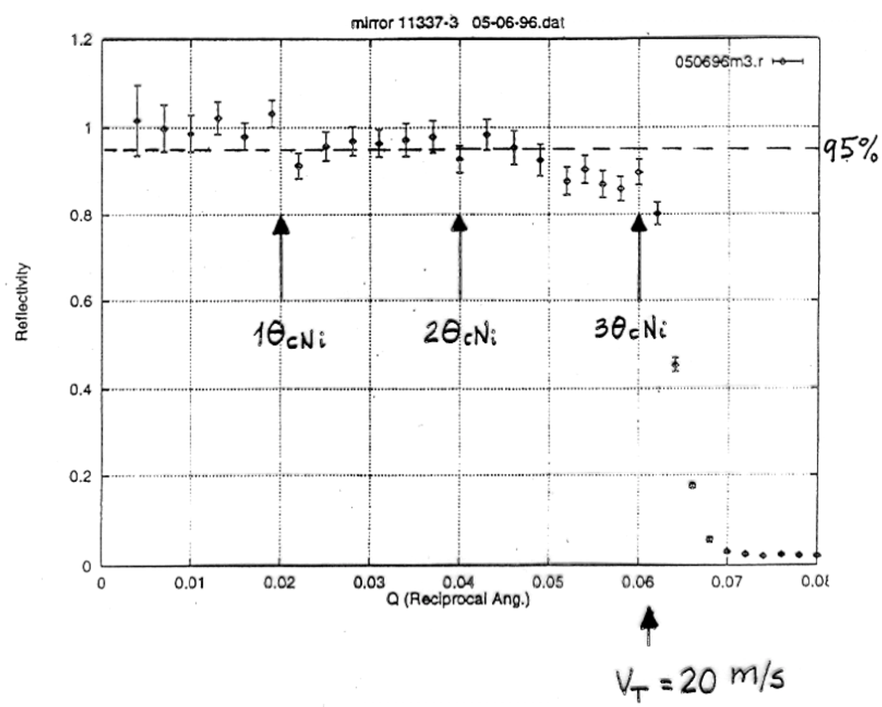
An Advanced Materials and Technology Company

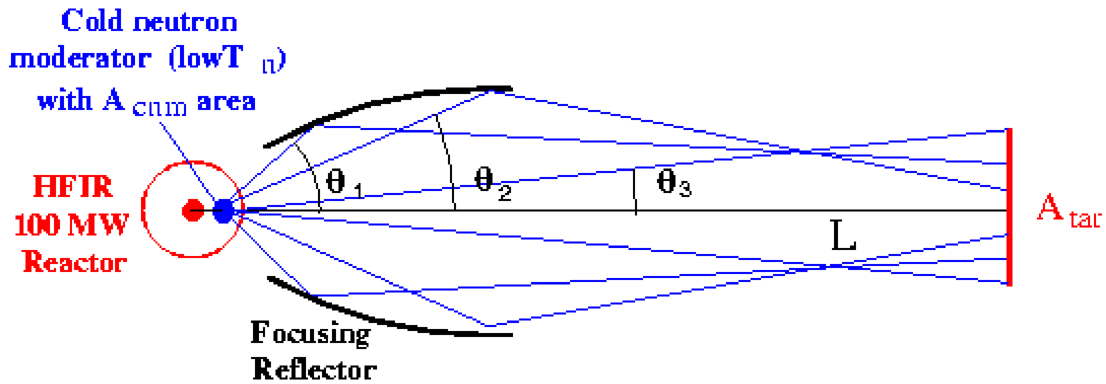
Neutron Optics



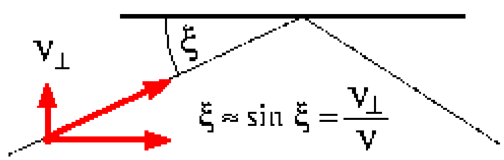
Super-mirror neutron reflector material

Schematic layout of a new experiment with focusing reflector

(not to scale)



Reflection :



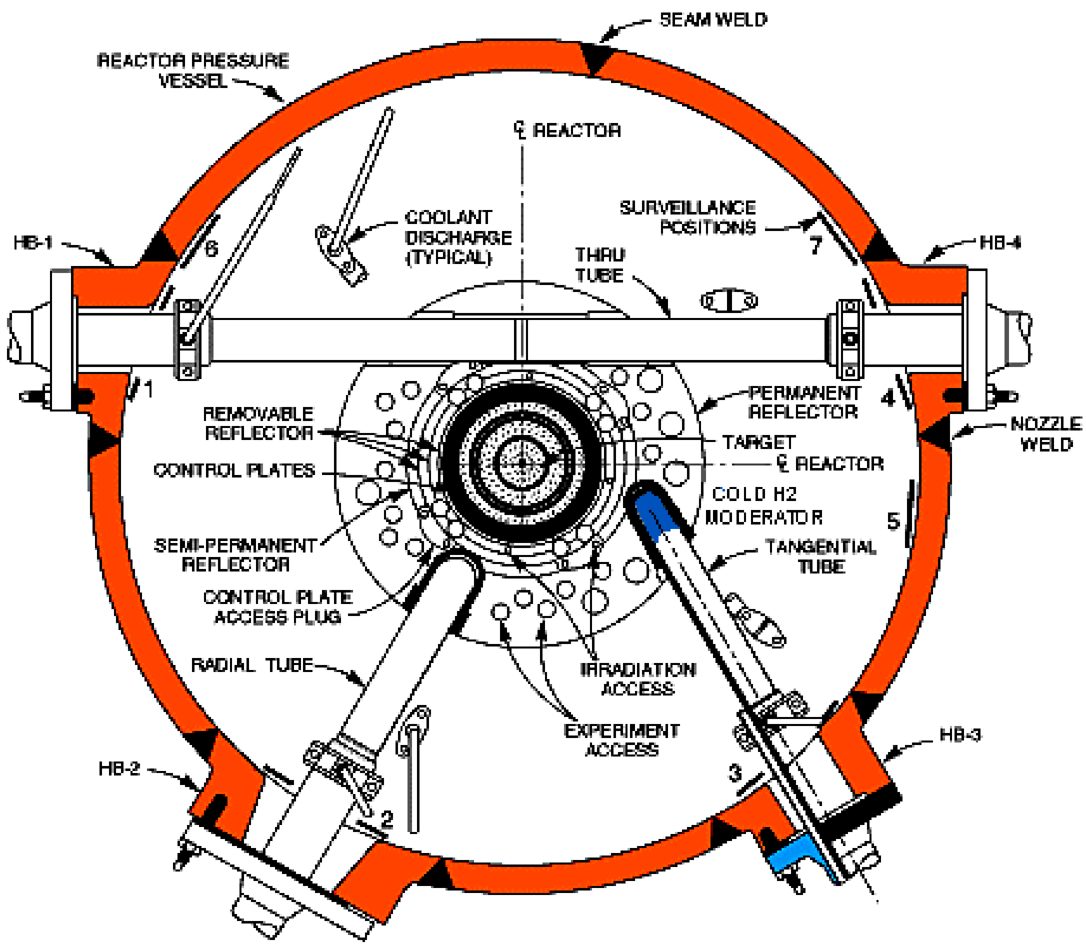
$$\Delta\Omega \sim \xi^2 \sim \frac{1}{v^2} \sim \frac{1}{T^{o}K}$$

$$\theta_1 < \theta < \theta_2 \rightarrow \Delta\Omega; \quad \Delta\Omega \sim \left(\frac{1}{T_n}\right)$$

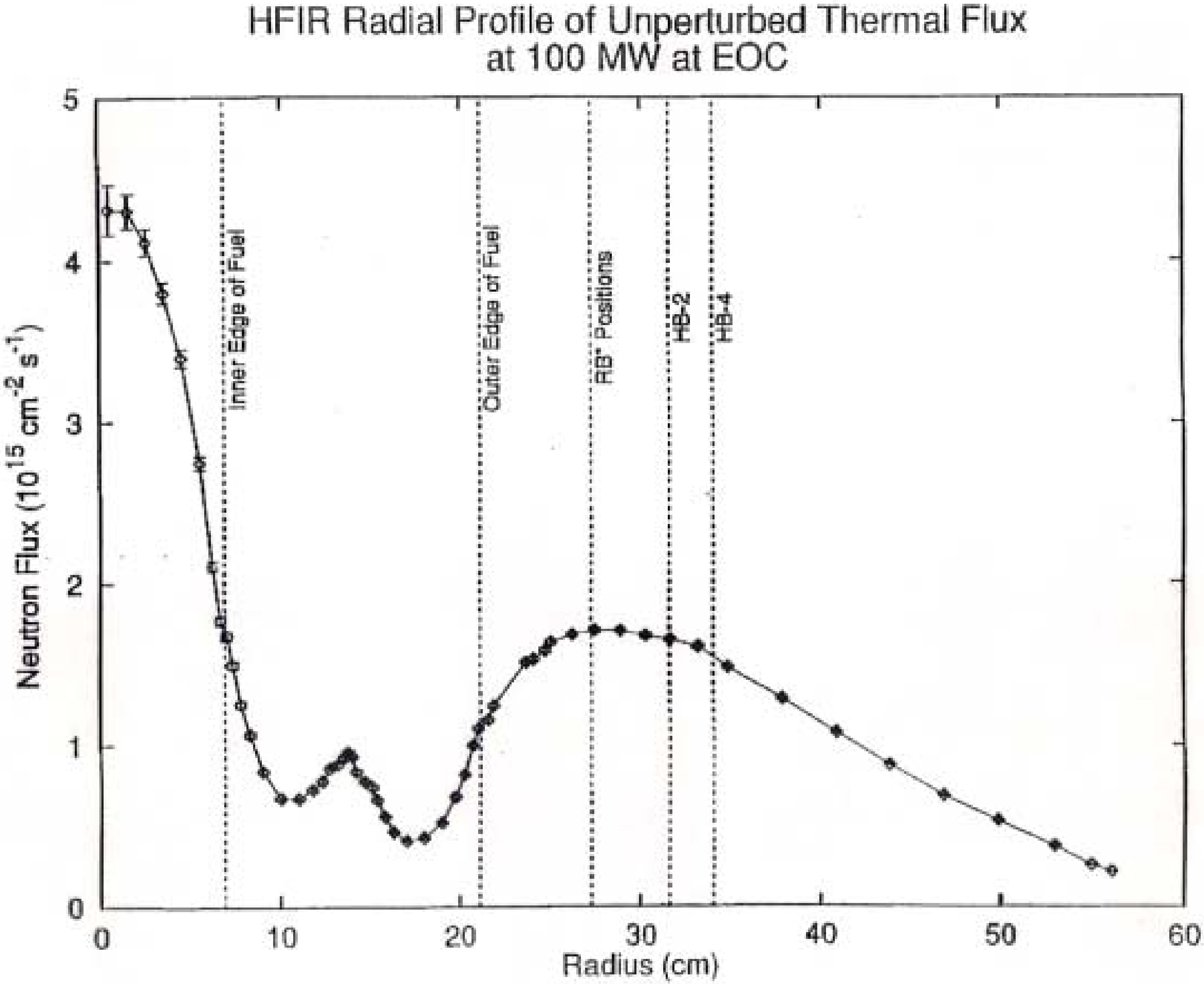
$$D.P. \sim N_{\bar{n}} \sim \Phi_n \cdot A_{cnm} \cdot \frac{\Delta\Omega}{4\pi} \cdot \left(\frac{L}{V_n}\right)^2; \quad \Phi_n \sim V_n$$

$$D.P. \sim N_{\bar{n}} \sim \frac{L^2}{T_n^{3/2}}$$ (if no gravity)

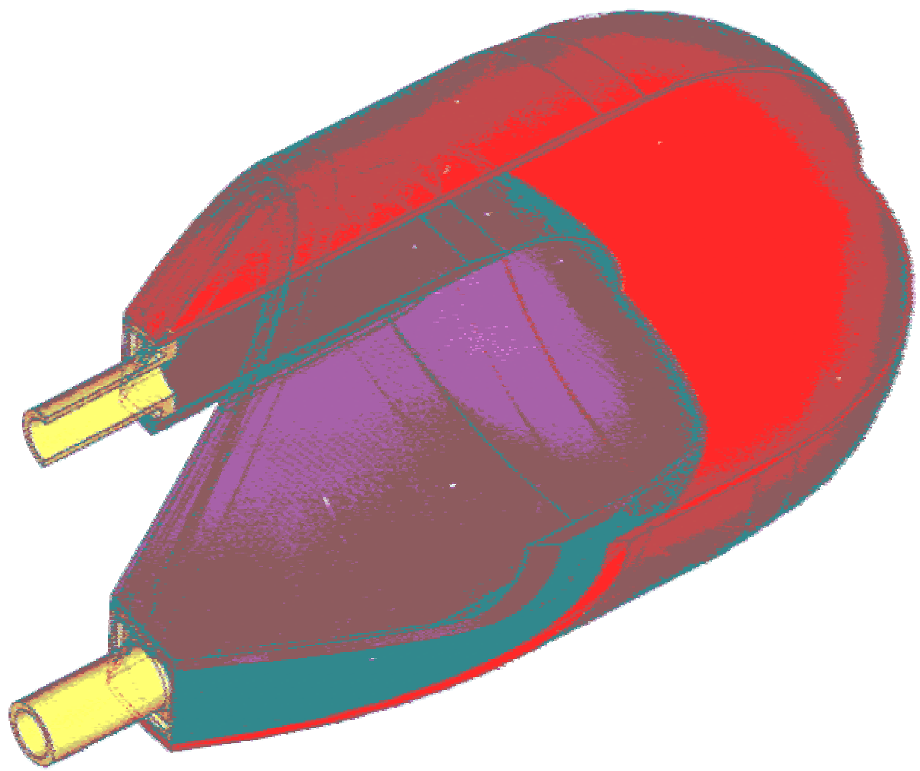
When focusing reflector is used, the large distance L and low neutron temperature T_n are most essential for discovery potential improvement



Section view of ORNL/HFIR reactor core. For the $n \to \overline{n}$ search experiment the cold supercritical hydrogen moderator should be installed in the HB–3 beam tube.



HFIR Radial Profile of Unperturbed Thermal Flux
at 100 MW at EOC
Neutron Flux (10^{15} cm^{-2} s^{-1})
Radius (cm)
Inner Edge of Fuel
Outer Edge of Fuel
RB* Positions
HB-2
HB-4
0
1
2
3
4
5
0
10
20
30
40
50
60

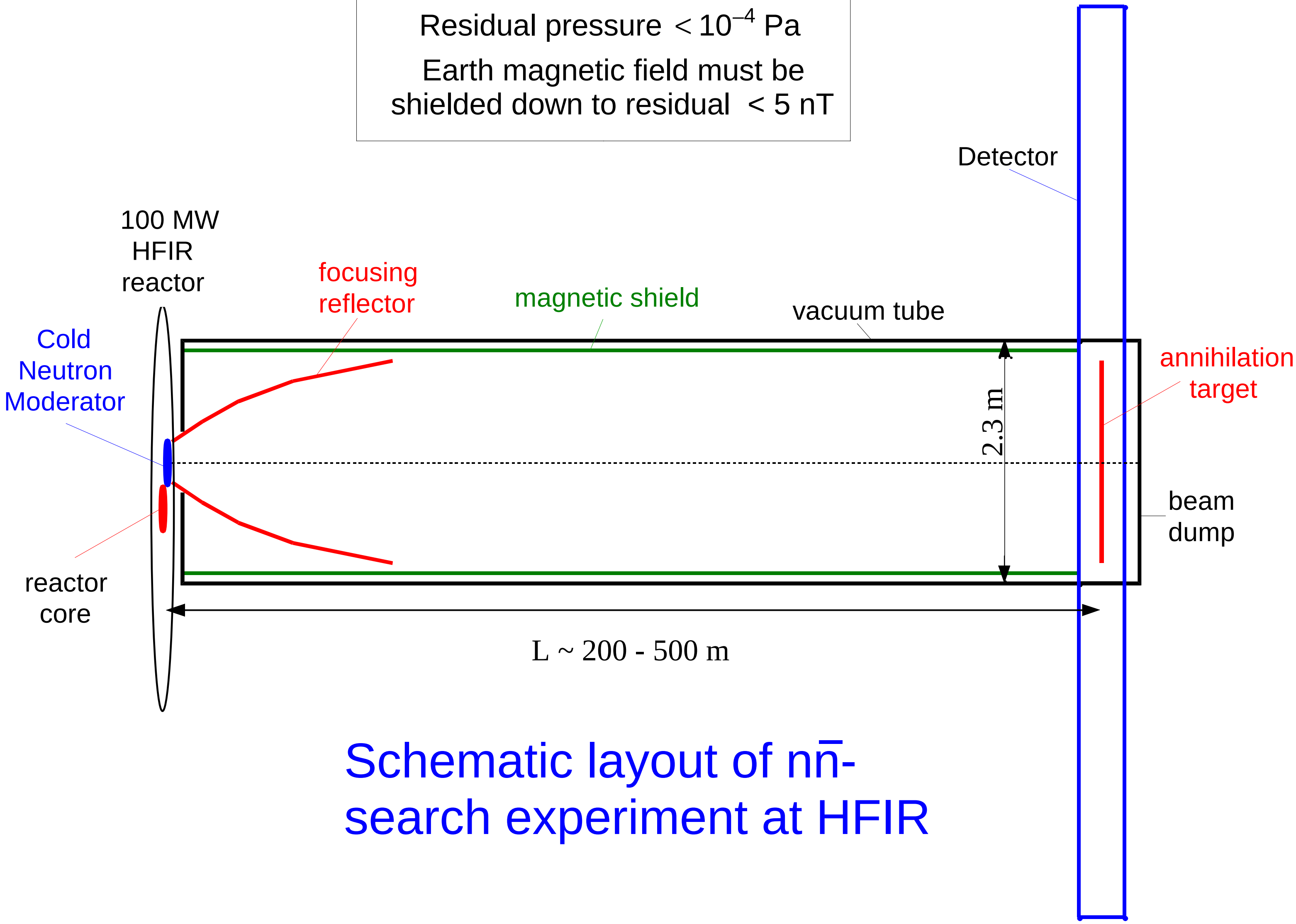


Super-critical hydrogen cold neutron moderator

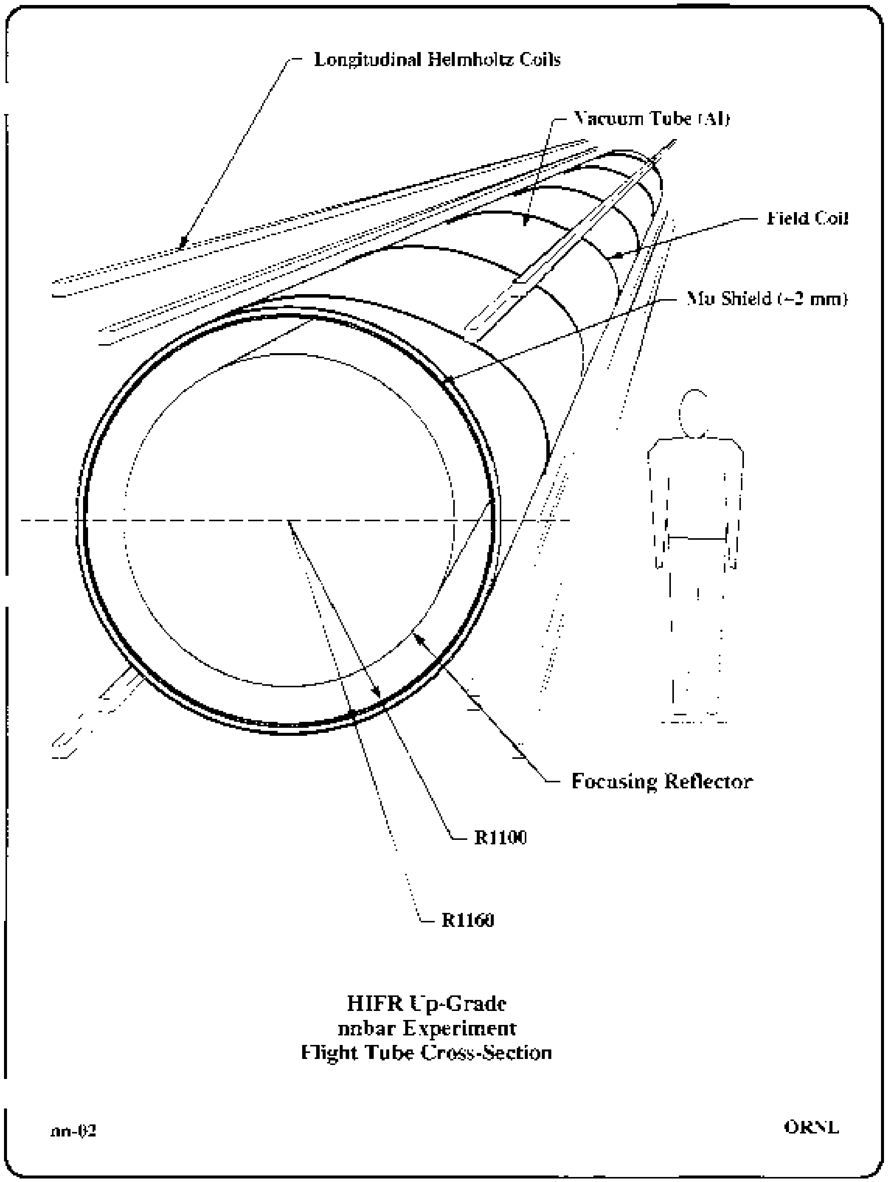
Technical issues

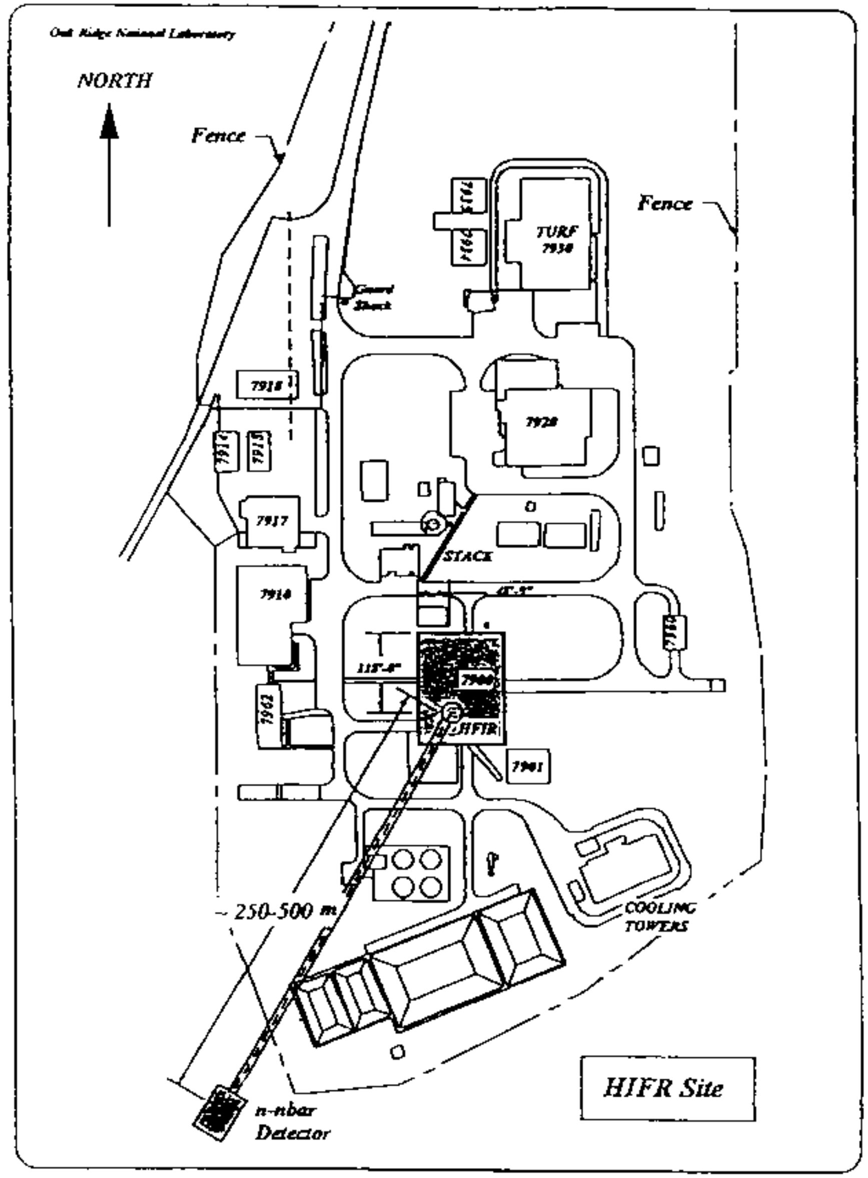
Residual pressure $< 10^{-4}$ Pa

Earth magnetic field must be shielded down to residual < 5 nT



Schematic layout of $n\bar{n}$-search experiment at HFIR

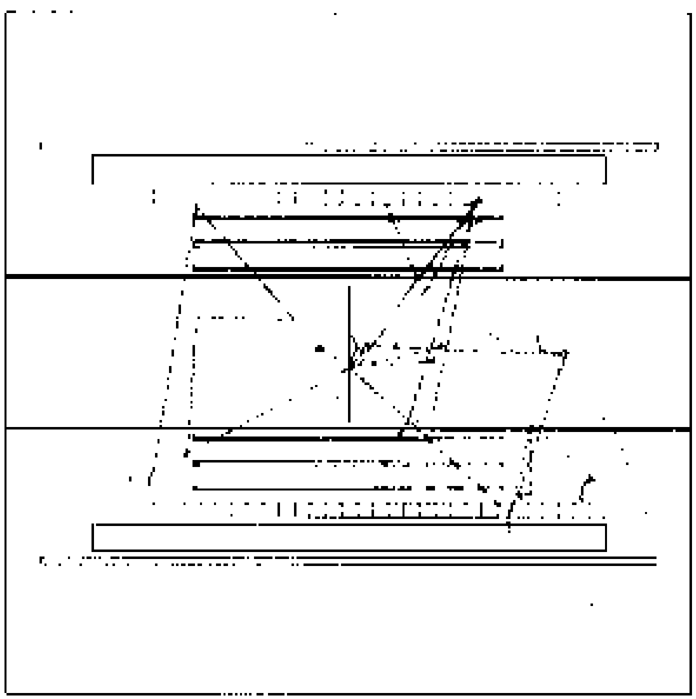


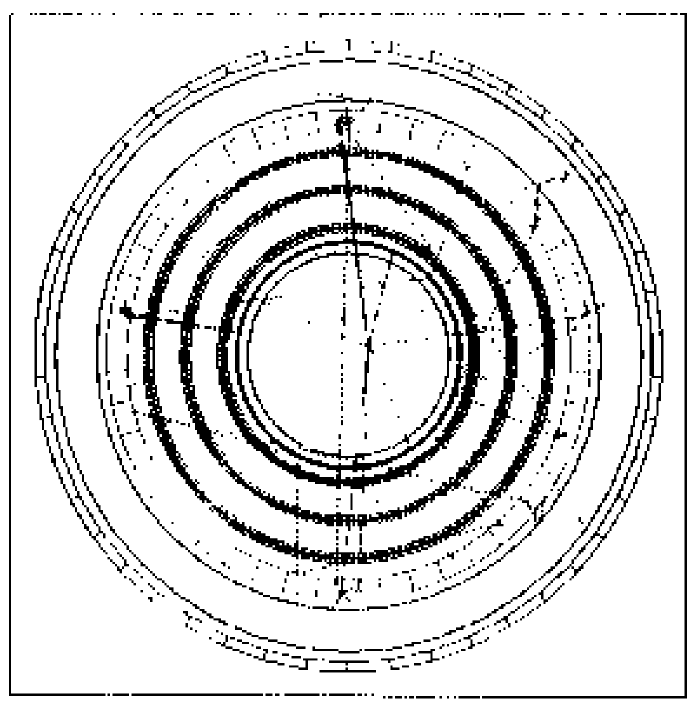


Possible layout of the proposed experiment at the HFIR site.

Monte-Carlo simulated anti-neutron annihilation event in proposed N-Nbar Detector

Intranuclear anti-neutron-carbon annihilation model-generator
(1996, E. Golubeva, A. Iljinov et al.)





Antineutron detection is well understood

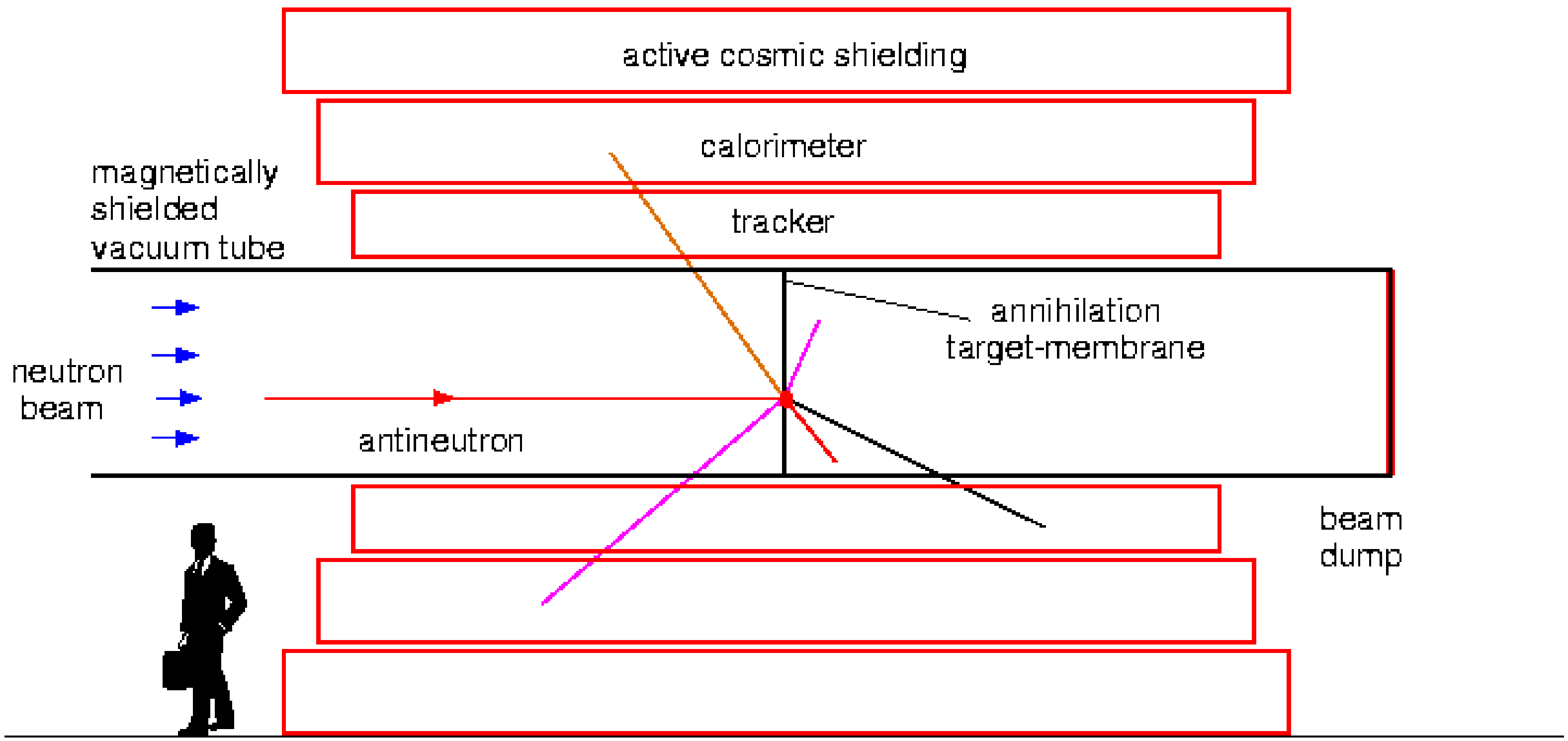
(thanks to LEAR physics)

$$\bar{n} + A \rightarrow \langle 5 \rangle \; pions \quad (1.8\ \text{GeV})$$

Target: 100μ thick Carbon film

$\sigma_{\text{annihilation}} \sim 40$ Kb $\quad \sigma_{\text{nC capture}} \sim 4$ mb

(Typical cold neutron: E ≈ 6 meV; $v \approx 1000$ m/s; λ ≈ 4 Å)



The conceptual scheme of antineutron detector

Comparison

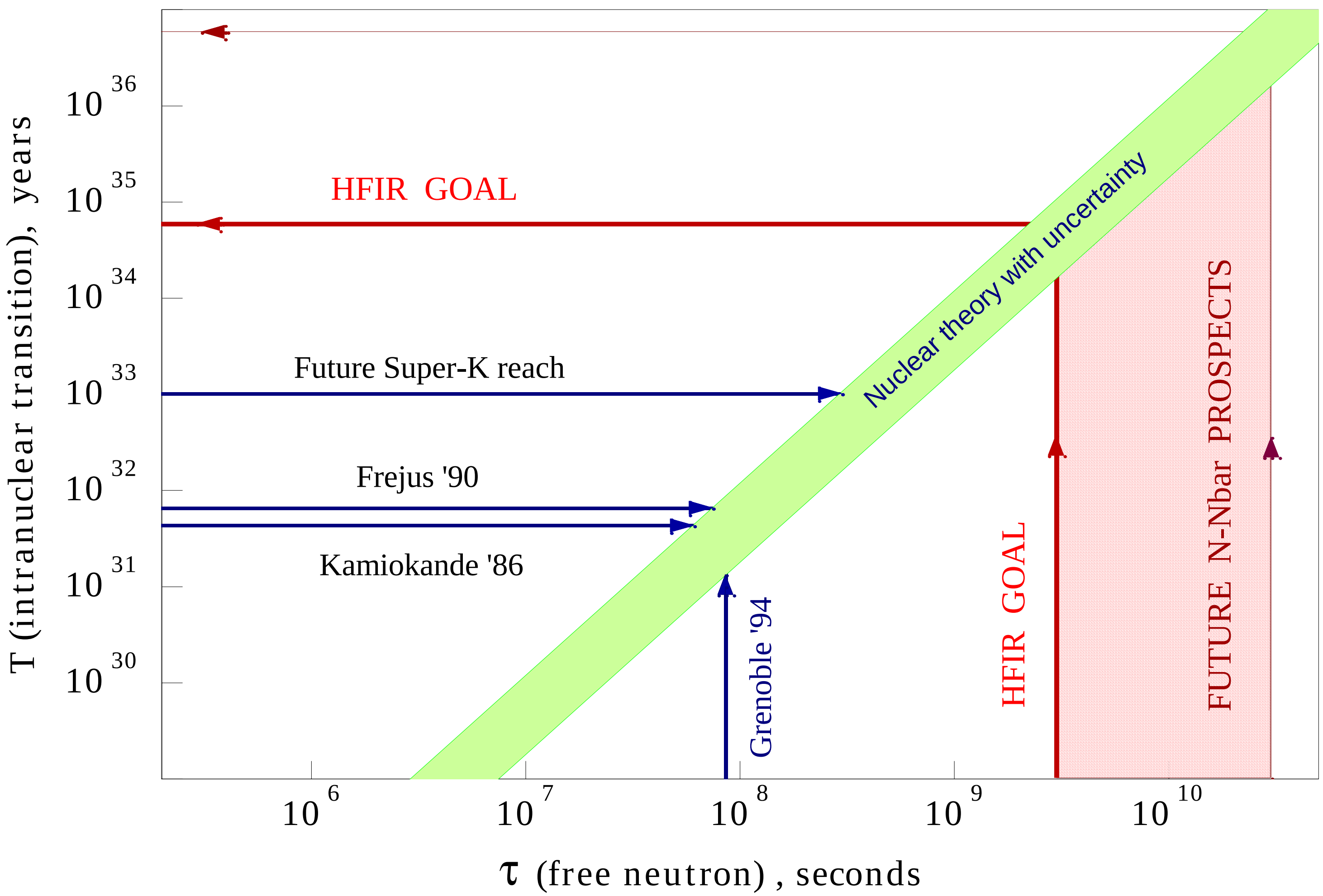
of the major parameters of the new $n \rightarrow \bar{n}$ search experiment proposed for HFIR HB–3 beam at ORNL with another recent reactor-based experiment.

Neutron source	RHF/Grenoble	HFIR/Oak Ridge (HB–3 beam)
Reference	M. Baldo-Ceolin et al., Z. Phys. C63 (1994) 409	W. Bugg et. al, LOI UTK-PHYS-96-L1
Status	Completed experiment	Proposal
Reactor power (MW)	58	(85) 100
Reactor's peak thermal n-flux	$1.4 \cdot 10^{15}$ (n/cm^2/s)	$1.5 \cdot 10^{15}$ (n/cm^2/s)
Moderator	Liquid D_2	Supercritical H_2
Source area	6×12 cm^2	~ 11 cm dia.
Target diameter	1.1 m	2.0 m
Flight path	76 m	300 m
Neutron fluence @ target	$1.25 \cdot 10^{11}$ n/s	~ $8.5 \cdot 10^{12}$ n/s
Average time of flight	0.109 s	0.271 s
Detector efficiency	0.48	~ 0.5
Operation time (s)	$2.4 \cdot 10^7$	$7 \cdot 10^7$ (~3 years)
$\tau_{n\bar{n}}$ limit (90% CL)	$8.6 \cdot 10^7$ s	$3.0 \cdot 10^9$ s
Discovery potential per second	$1.5 \cdot 10^9$ n·s^2	$6.2 \cdot 10^{11}$ n·s^2
Sensitivity	**1**	**~ 400**

For *one day* of operation at HFIR in a new proposed n-nbar search one can obtain the same Discovery Potential as for *one year* of the previous RHF-based experiment in Grenoble.

Stability of matter from Neutron-Antineutron transition search

$$T_{intnuc} = R * (\tau_{free})^2$$, where R is "nuclear suppression factor" in intranuclear transitions



Scientific reach of $n \to \bar{n}$ experiment

If discovered:

$n \to \bar{n}$ will establish a new force of nature and a new phenomenon leading to the physics at the energy scale of $\sim 10^5$ GeV.

New physics emerging from the models with low quantum gravity scale can be revealed.

Will provide an essential contribution to the understanding of baryon asymmetry of the universe.

New symmetry principles determining the history of the universe during the 1st second of creation can be established: $\Delta(B-L) \neq 0$.

Further experiments with free reactor neutrons will allow testing with unprecedented sensitivity:

– whether $m_n = m_{\bar{n}}$ (CPT theorem) with $\Delta m/m \approx 10^{-23}$

– gravitational equivalence of baryonic matter and antimatter

If NOT discovered:

within the reach of 1,000 times improved experimental sensitivity a new limit on the stability of matter at the level of ~ 10^{35} years will be established. Wide class of SUSY-based models will be removed *(K. Babu and R. Mohapatra, 2001).*

Major Physics Motivation

is to increase the discovery potential of $n \rightarrow \bar{n}$ search by big factor 1,000 for three years of operation at the existing reactor HFIR.