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Thermal Neutron Accelerator©

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Abstract

The main aim of this proposal it to reveal the secrets of the universe by accelerating neutrons. The proposal idea in its abridged version speaks about the possibility of making neutrons accelerate with help of thermal energy and magnetic energy under controlled conditions. Which is helpful in revealing the hidden secrets of the universe like dark energy and in finding Higgs Boson.

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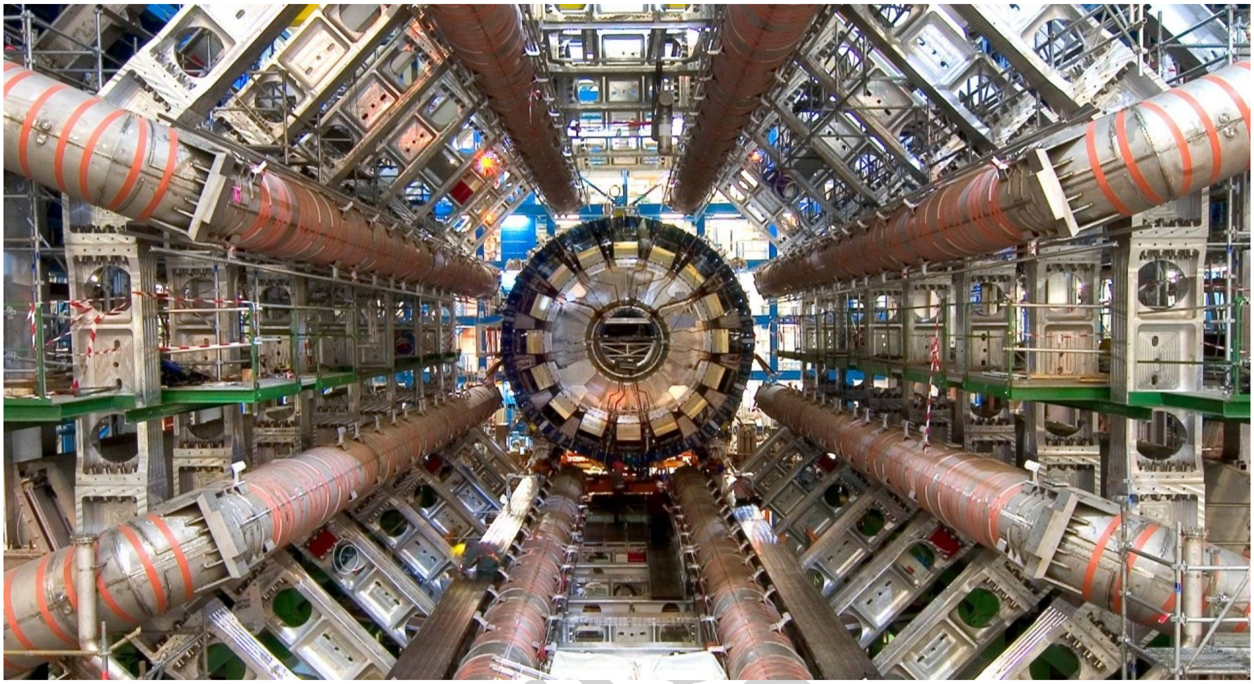
Thermal Neutron Accelerator©®



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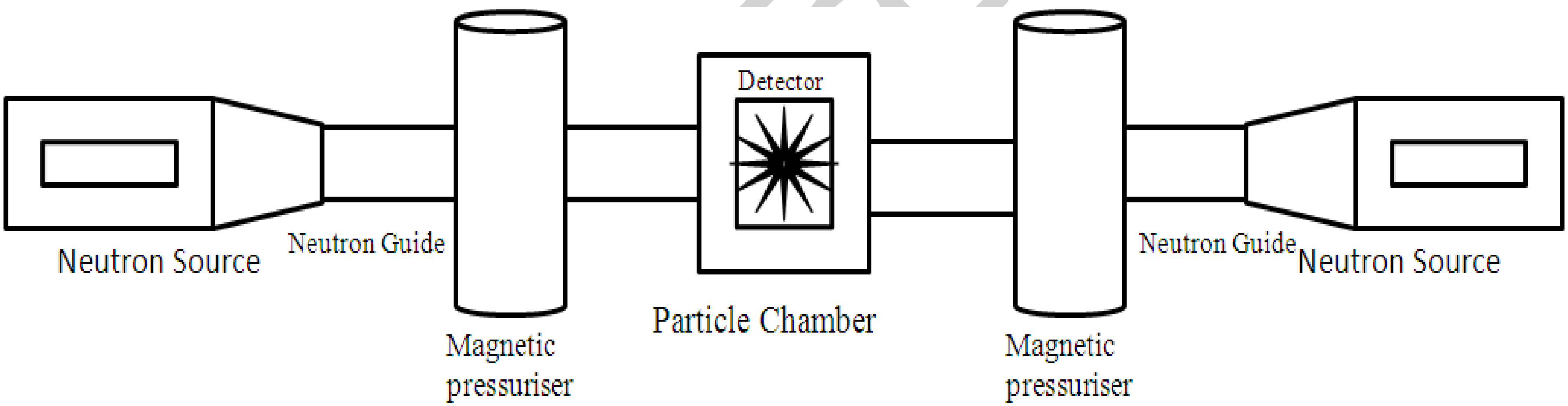
Introduction : There are many hidden secrets in the universe which are yet to be revealed as we see many neutron explosions in space between neutron stars but to have those type of interactions under controlled conditions this type of accelerators are very useful.

Assumption: According to De-Broglie’s dual nature of particles a particle can travel in the form of particles as well as in the form of a wave.

For our convenience in this topic we take the particle nature of neutrons.

Key Words: Neutrons, Thermal energy, Neutron Shield, Magnetic pressure force.

Thermal Neutron Accelerator



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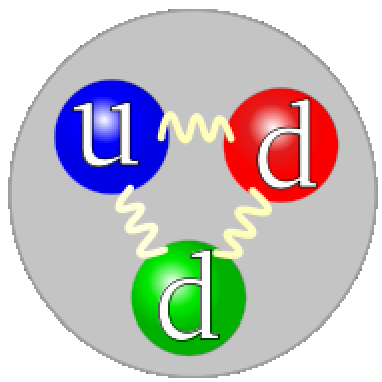
Neutron:

The **neutron** is a subatomic hadron particle which has the symbol n or n^0, no net electric charge.



Properties of neutron:

Classification: Baryon

Composition: 1Up quark, 2 down quarks

Interactions: Gravity Weak, Strong, Electromagnetic

Theorized: Ernest Rutherford (1920)

Mass: $1.674927351(74) \times 10^{-27}$ kg

Mean lifetime: 881.5(15) s

Spin: ½,

Present ways in accelerating a neutron:

One way to accelerate a neutron is to package it with a proton, in a deuterium atom; accelerate that as you would any other charged particle; and then strip off the proton by bashing the deuterium atom into a target. Another way is to accelerate protons to very high energy and bash them into a target, causing atoms in the target to emit neutrons.

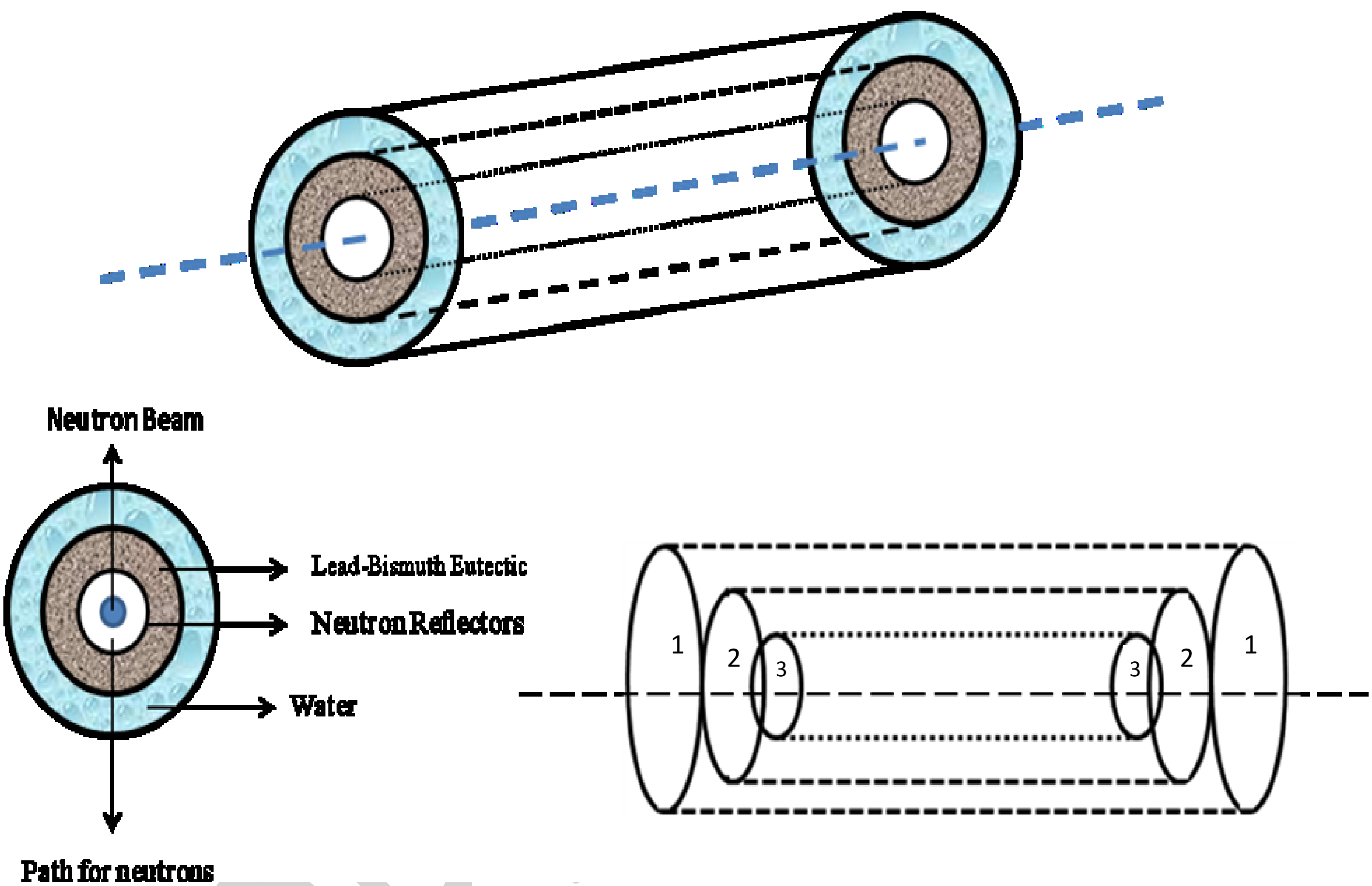
Neutron Source: These are the substances which release neutrons due to radioactive changes occurring in them.

Generally certain isotopes undergo spontaneous fission with emission of neutrons. The most commonly used spontaneous fission source is the radioactive isotope californium-252. Cf-252 and all other spontaneous fission neutron sources are produced by irradiating Uranium another transuranic element in a nuclear reactor, where neutrons are absorbed in the starting material and its subsequent reaction products, transmuting the starting material into the SF isotope. Cf-252 neutron sources are typically 1/4" to 1/2" in diameter and 1" to 2" in length. When purchased new a typical Cf-252 neutron sources emit between 1×10^7 to 1×10^9 neutrons per second and with an energy of 8-10 MeV, with a half life of 2.6 years, this neutron output rate drops to half of this original value in 2.6 years. The price of a typical Cf-252 neutron source is from $15,000 to $20,000.

Neutron Guide: This is the main part in transportation of neutrons from one place to other in the accelerator.

This must be perfectly shielded for reduction of neutron leakage.

Design of neutron guide:



“Shields are made of aluminum which acts as neutron shield.”

1st Shield: The outer surface of the shield is build with concrete and the gap between 1st and 2nd is filled with water which also acts as neutron shield.

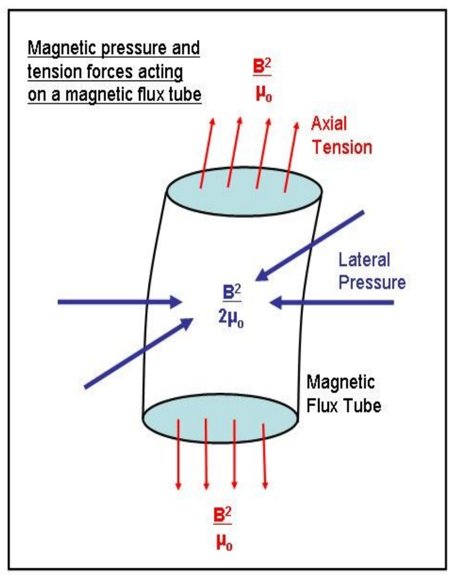
2nd shield: The gap between 2nd and the 3rd shield are coated with Lead-Bismuth e which acts as neutron reflectors.

3^{rd} shield: The third sheet is hollow which acts as a path for neutron beam. This is hollow and is of vacuum.

Magnetic Pressure: Magnetic pressure is an energy density associated with the magnetic field. It is identical to any other physical pressure except that it is carried by the magnetic field. Any magnetic field has an associated pressure that is contained by the boundary conditions on the field, and a gradient in field strength causes a force due to the magnetic pressure gradient this force is called the **magnetic pressure force**.

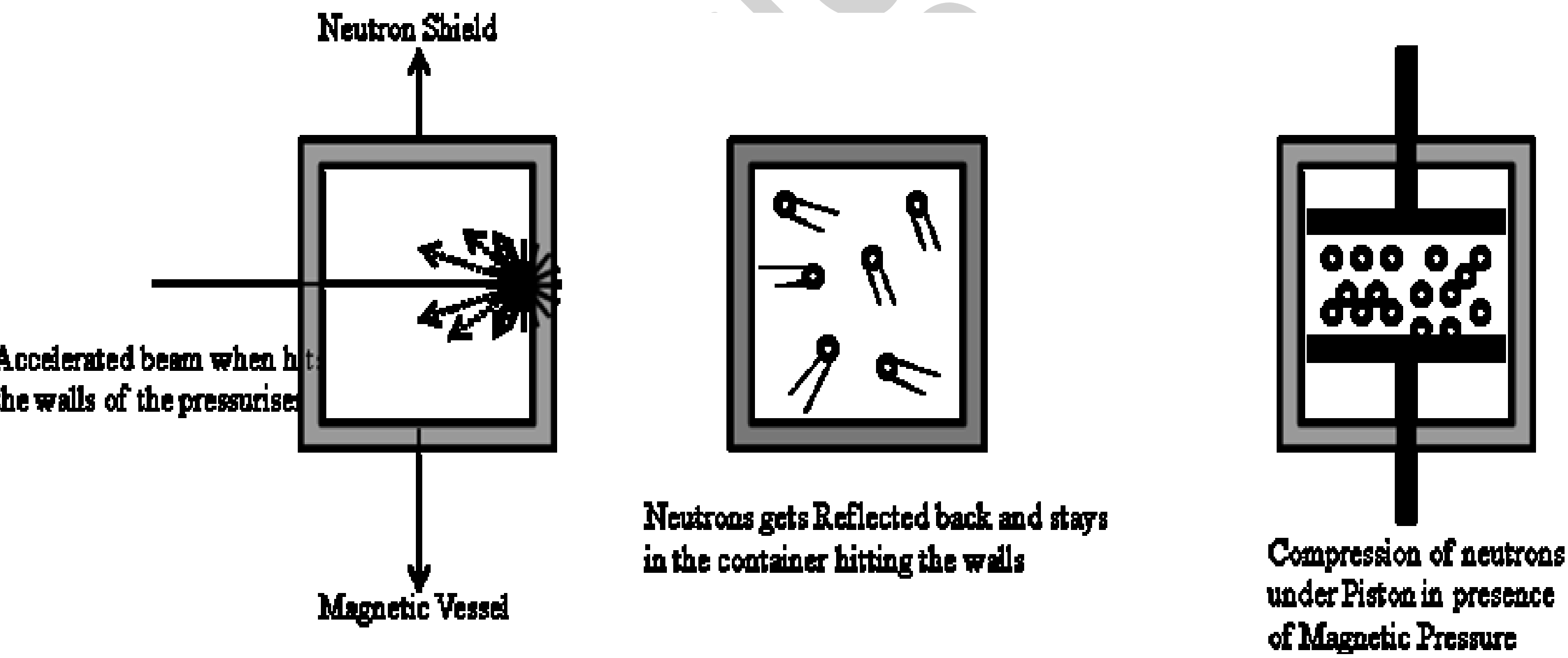
The magnetic pressure P_B is given by:

$$P_B = \frac{B^2}{2\mu_0}$$



Design of Magnetic Pressuriser

When the neutron beam enters into the magnetic pressuriser the beam gets reflected due to lead-bismuth eutectic which acts as neutron reflector. The reflected neutrons stay in the container with continuous striking against walls of the magnetic vessel. Now pressure is applied physically with the aid of two pistons in presence of magnetic field. These compressed neutrons are directed towards neutron guide which ultimately reaches collision chamber. In the same way the other neutron beam also reaches the collision chamber.



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Working of thermal of Thermal Neutron Accelerator:

Origin of neutrons:

Neutron source consists of radioactive isotope californium-252 packed in an aluminum box which is coated with Boron-Silicon mixture from inside they both acts as neutron shield. Boron-Silicon mixture has a neutron resistivity of 5×10^9 neutrons/sec.

Transportation of neutrons:

The neutrons produced in the source initially contain some kinetic energy this energy is utilized by the neutrons to reach the magnetic pressuriser through the neutron guide.

Thermalisation of Neutrons:

The neutrons entered are subjected to undergo magnetic pressure under controlled conditions.

Heating by magnetic compression is identical with the compression of gas by adiabatic method. Where the raise in temperature of plasma is achieved by increasing pressure on the neutrons and if the plasma is surrounded by a magnetic field, it is subjected to a pressure of μH2/8π per unit volume.

Magnetic Pressure $P_m = B^2/8\pi$.

Thermodynamic pressure $P_t = 2nkT$.

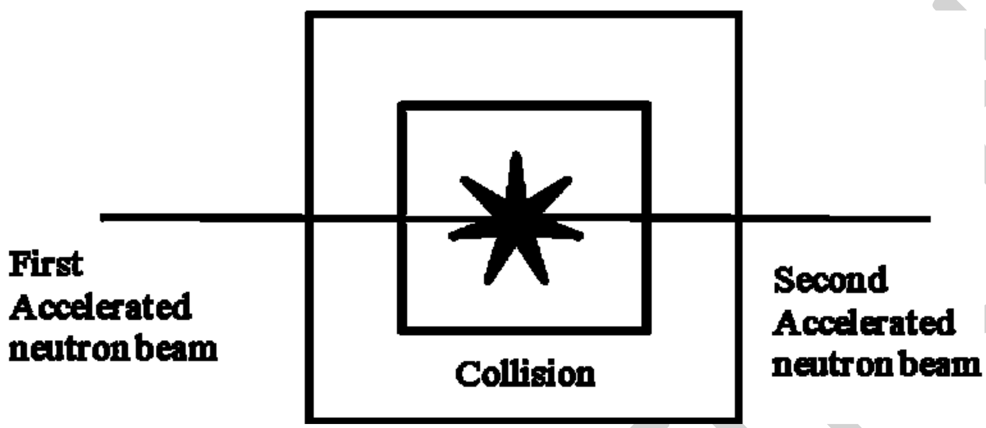
Comparing the magnetic and thermodynamic pressures, we can write

$$B^2/8\pi = 2nkT.$$

B = Gauss, T = Kelvin , n = density of neutrons.

Collision and Detection:

When the required temperature is acquired the accelerated neutron beam comes into the collision chamber in the same way another accelerated neutron beam also enters and collide each other.



For understanding let us take an example:

To make a collision with two beams of velocity $0.5C_o$ (Speed of Light) at a neutron density of 10^{15} with pressuriser of thickness 100mm.

<u>Calculating required temperature:</u>

Most probable velocity of neutron is $V_{n} =$ Sqrt($\mathbf{2kT/m_n}$).

Required Velocity = $0.5\ C_o = 150 \times 10^6$ mts/sec = $V_{n.}$

Squaring on both sides we get;

$$(150 \times 10^6)^2 = \frac{2 \times 1.38 \times 10^{-16} \times T}{1.67 \times 10^{-27}}.$$

➔ $T = 136 \times 10^3$ K.

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Calculating required Magnetic Field:

B=2x 10 ^{20}x1.38x10 $^{-23}$x136x10 ^{3}x8xπ

=97 Tesla.

Therefore, required magnetic field is 97 Tesla.

Calculating collision frequency with the container:

$$\text{No. of moles} = \frac{\text{No. of particles}}{\text{Avagadro number}}$$

No. of moles = 1.66x10^{-9} moles.

Collision frequency with respect to wall = Z_{wall} = P/sqrt(2xπxmxk_BxT)

= 2.64x10^{18} neutrons /sec.

Finding the Lorentz factor (β,γ):

These are dimensionless quantities.

Lorentz factor = β = (v/c)

Required velocity = 0.5 C

β = 0.5

Lorentz factor = $\gamma = \left(\sqrt{1-\beta^2}\right)^{-1}$

γ = 1.1547

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Calculating initial velocity of neutron:

Cf-252 emits neutrons with an energy of 8 – 10 MeV.

10 MeV = 1.602 x 10^{-18} Joules

From Einstein's Energy – Mass relevance;

$$E = mc^2$$

$$C = \sqrt{\frac{E}{m}}$$

$$C = \frac{1.602 \ x\ 10^{-18}}{1.674\ x\ 10^{-27}}$$

C = 30,919.2 mts/sec

C = 31 km/sec

Calculating total energy of beam at 0.5C_0 :

Firstly calculating the **Kinetic Energy (K.E)** of an individual neutron:

Velocity v = 0.5C

Kinetic Energy = **K.E** = 0.5 x 1.67492716x10^{-27} x 2.246887947x10^{16}

= 1.881 x 10^{-11} Joules. (For a single neutron in a beam)

Now Calculating the **Wavelength** of the neutron:

$$\lambda = h/ (sqrt (2 \text{ x K.E. x } M_n)$$

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Where h = planck's Constant and M_n = Mass of the neutron

$$\lambda = (6.62 \times 10^{-34})/(2.51 \times 10^{-19})$$

$$\lambda = 2.64 \times 10^{-15} \text{ mts.}$$

Now calculating the **Energy of the beam**:

$$\mathbf{E = hc / \lambda}$$

$$\mathbf{E} = (6.62 \times 10^{-34} \times 3 \times 10^{6}) / 2.64 \times 10^{-15}$$

$$\mathbf{E} = 7.57 \times 10^{-11} \text{ Joules}$$

We know that 1 Joule = 6.2415×10^{18} eV.

Therefore the energy of the beam is **47 GeV**.

<u>Center of mass of energy of colliding beams:</u>

Center of mass of energy of two colliding beams is $\mathbf{E_{CM} = 2\,E}$

$$\mathbf{E_{CM} = 94 \text{ GeV}}$$

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Beam Characteristics:

Charge of Neutron: 1.1×10^{-21} e

Bending radius of motion of particle in dipole field:

Bending Radius = $1/\rho = eB/pc$

e = Charge of neutron, B = Magnetic field, p = momentum,

C = Velocity of light

$$1/\rho = \frac{1.1 \times 10^{-21} \times 24.25}{7.5266 \times 10^{-21}}$$

$1/\rho = 3.54$ mts

Luminosity of the collider at 0.5 C :

Measures interaction rate per unit cross section -an important concept for colliders.

$$L = \frac{N^2}{t \times S_{eff}}$$

$N = 10^{15}$ neutrons/bunch $t = 1.3 \times 10^{-6}$ sec

S_{eff} = Surface effective = $4\pi r^2$ (r = 11 microns)

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Large Hadron Collider (L.H.C.) has a beam radius of 16 microns.

Radius of Proton = 0.87 fermi

Radius of Neutron = 0.3 fermi

From this we can expect that the radius of a beam of neutrons will be less than the beam of neutrons.

Let us consider the radius of the neutron beam be: 11 microns.

Effective Surface Area of the beam = 1.52×10^{-5} mts^2

$L = 5.06 \times 10^{40}\ cm^{-2}\ s^{-1}$

Producing required magnetic field and calculating required current:

Producing 97 Tesla magnetic field is a difficult job.

So four 24.25 Tesla (~25 T) magnets are placed at every 20mts.

According to the formula:

$$\mathbf{B = \frac{\mu_0 I}{2\pi d}} \quad \textbf{(For free space: } \mu_0 = 4\pi \times 10^{-7}\textbf{)}$$

→ So to get more magnetic field (B) distance (d) should be less as they are inversely proportional to each other.

B = 24.25T, d = 20mts, $\mu_0 = 4\pi \times 10^{-7}$

On calculating we get $I = 2.425 \times 10^{9}$ Amps.

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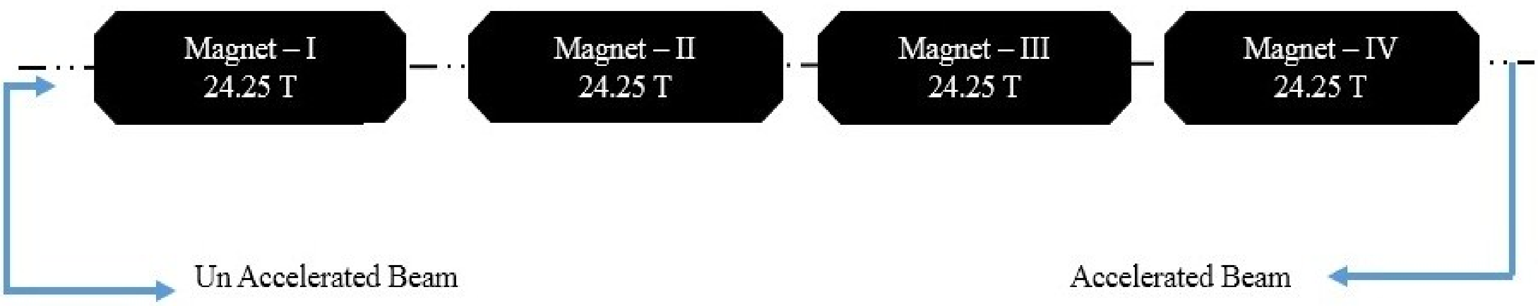
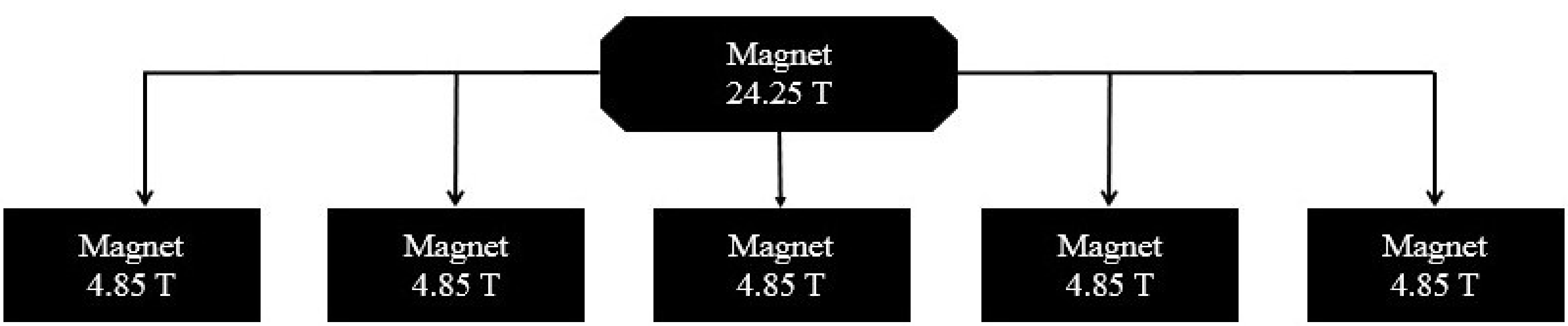
The four Magnetic Pressurisers are arranged in a straight line so that beam can pass on its own to Magnet – I to Magnet – IV.

Systematic view of 4 magnetic pressurisers



Producing 25 Tesla at a time is difficult job so every magnet is divided into 5 sub - categorized into five magnets producing 4.85 T each together produces 24.25 Tesla per set.



Therefore 4 sets of magnets produce 97 Tesla totally …..

*Specification of **Magnet**:*

Type : Quadrapole.

Pole type : Dipole

Magnetic Field : 24.25 (~25) Tesla

Current Requirement : 2.425 X 10^9 Amps

Distance between two magnets : 20mts

Bending Radius : 3.54mts

Temperature produced : 34000 Kelvin

Type of cooling : Cryogenic

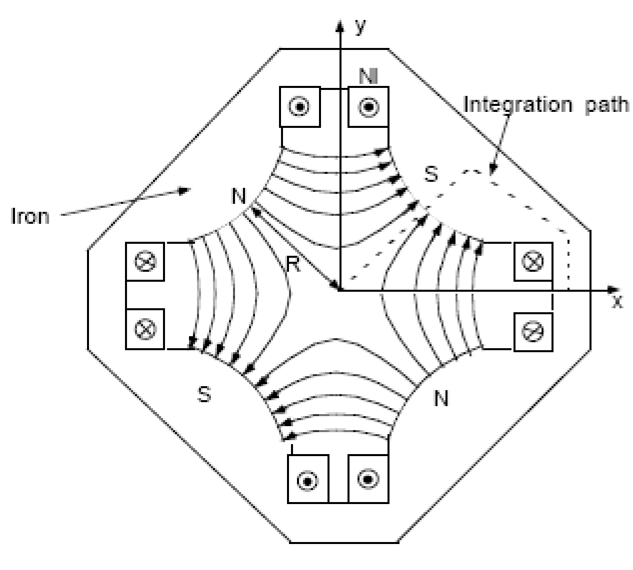
Type of Coolant : Liquid Helium

Why to use Quadrapole Magnet??

A quadrupole magnet imparts a force proportional to distance from the center.

This magnet has 4 poles:

Consider a positive particle traveling into the page (into the magnet field).



Pure quadrupole, NI turns/pole

According to the right hand rule, the force on a particle on the right side of the magnet is to the right, and the force on a similar particle on left side is to the left.

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The field lines are denser near the edges of the magnet, meaning the field is stronger there.

The Magnetic Field at a quadrapole magnet is **ZERO** !!!

So the beam moves unaffected by the magnetic field. If there is any deflection it is suppressed by the magnetic fields

<u>Heat produced in magnets due to joule effect:</u>

The magnets gets heated due to the resistance of the copper wire surrounded around the solenoid.

By Joule Effect:

$$\mathbf{P = i^2R}$$

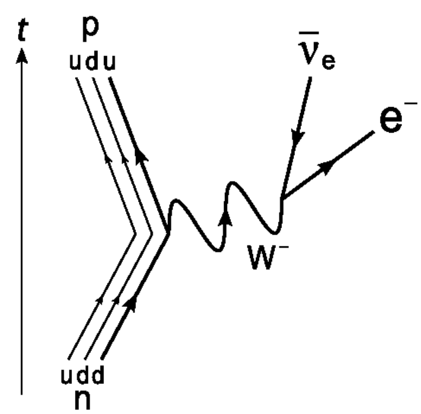
I = 2.425 X 10^9 Amps, R (copper) = $1.68\times10^{-8}\ \Omega$

Therefore heat produced is = P = 4 x 10^{11} Joules

<u>The precious 15 minutes !!!</u>

Neutron Decay:

Free neutrons are unstable and have a mean lifetime of 881.5±1.5 s (about 14 minutes, 42 seconds)



Therefore the half-life for this process (which differs from the mean lifetime by a factor of

ln(2) = 0.693) is 611.0±1.0 s (about 10 minutes, 11 seconds).

Free neutrons decay by emission of an electron and an electron antineutrino to become a proton, a process known as beta decay:

$$n^0 \rightarrow p^+ + e^- + \nu_e$$

The decay energy for this process (based on the masses of neutrino, proton, and electron) is 0.782343 MeV.

➔**Beam Decay:** This shows that the neutron beam gets decayed within 881 seconds (~ 15 minutes) .

Initial velocity of neutron : 30 km/sec

Velocity at every 4.85 T magnet : 7.49 x 10^6 meters/sec.

As assumed above that length of the accelerator be 1000 mts.

By the fundamental formula

$$\text{Speed} = \frac{Distance}{Time}$$

Time taken by the beam to approach collider is :

Time (t) = 1 x 10^3 / 30 x 10^6 (Average Velocity)

Therefore time taken (t) = **33 micro second**.

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Summary:

In the scenario where the:

Neutrons/bunch = 10^{15}, required velocity = 0.5 C

Thermal Neutron Accelerator	**Value (all in M.K.S Units)**
Temperature required	136×10^3Kelvin
Magnetic Field	97 Tesla
Lorentz factor β	0.5
Lorentz factor γ	1.1547
Initial Velocity of neutron when ejected from spallation source	31 kms/sec
Beam energy at 0.5 C	47 GeV
Center of mass of energy	94 GeV
• Luminosity	5×10^{40}
Bending Radius for 25 T Magnet	3.54 mts
Time taken by beam to reach collider is	33 µsecond
Cross section area of beam	1.52×10^{-5} mts^2
Coolant Type	Liquid Helium

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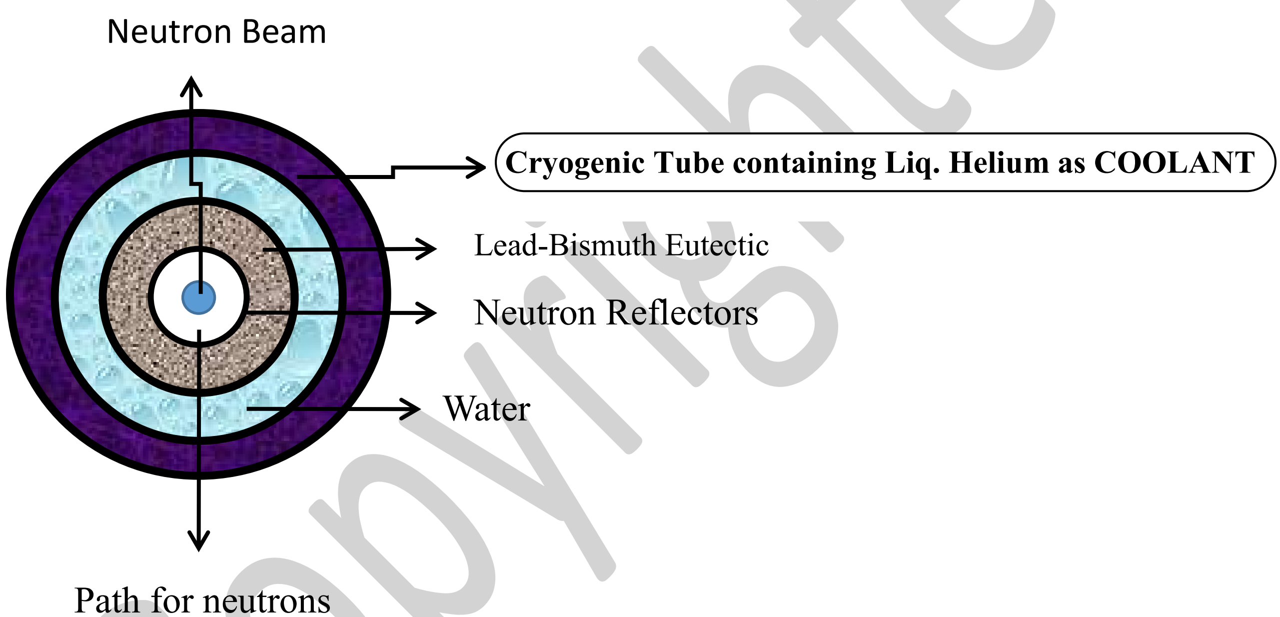
Usage of cryogenics in accelerator :

Liquid Helium under very low temperature, about 2 K (-271°C), a temperature colder than outer space.

When helium is cooled further it undergoes a second phase change at about 2.17 K (–271.0 °C) to its "superfluid" state.



The accelerator contains an additional tube called "Cryogenic Tube".

The first consisting of the magnets and neutron accelerating cavities and the second so-called "cryogenic tube".

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Wave nature of the beam when accelerated with a velocity $0.5C_o$

Now, when we come back to the wave nature of the neutrons initially when they come out of Cf-252 isotope the neutron guide is directly guided towards the magnetic pressuriser and gets accelerated and is directed towards the collision chamber at this stage the beam will be in the state of "terahertz radiation" in the same way the other beam also will be in the state of terahertz radiation they both collide releasing lot of energy.

Author's Credentials: