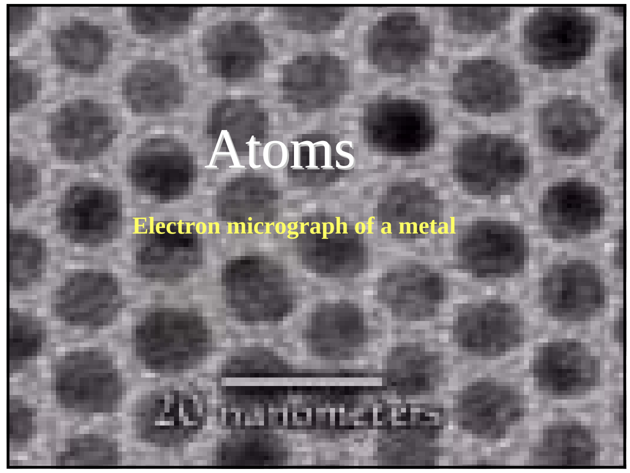
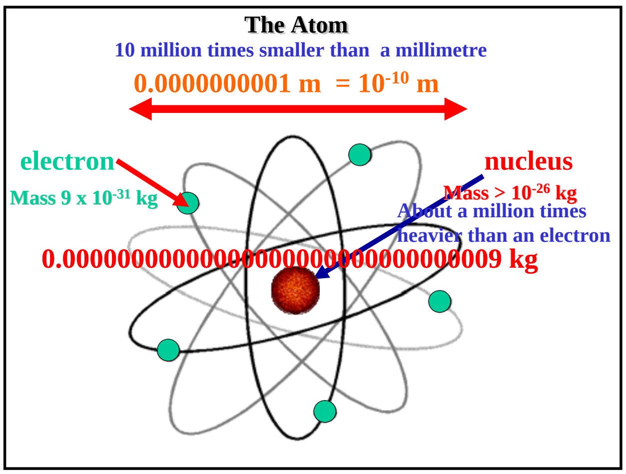
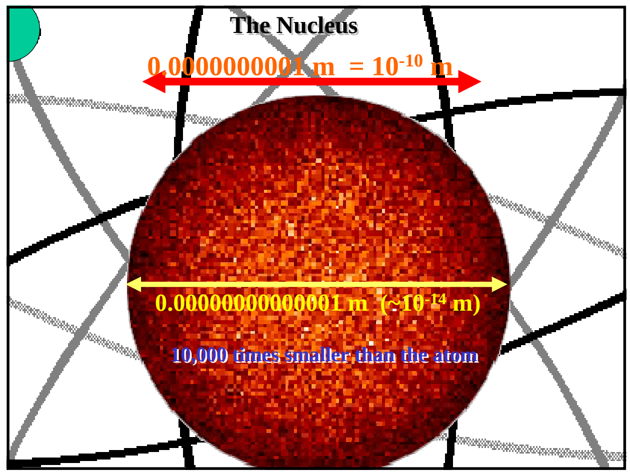
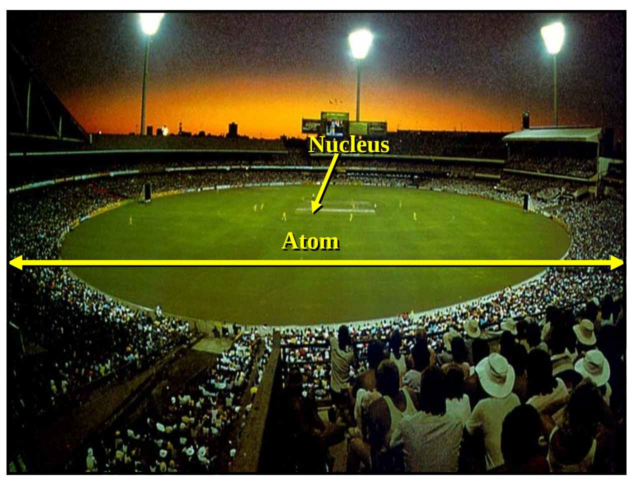

Energy
from
The Nucleus

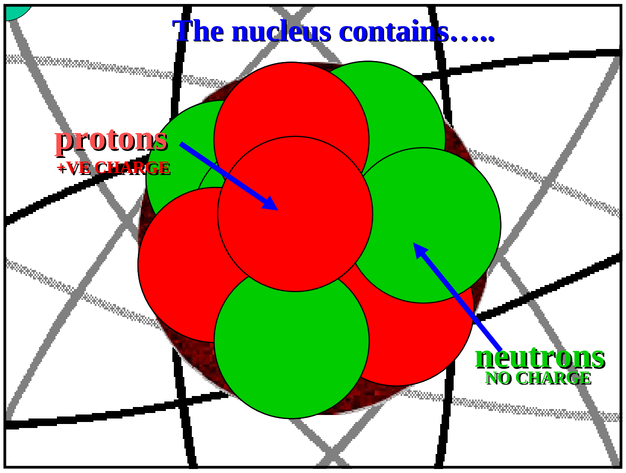

Atoms
Electron micrograph of a metal

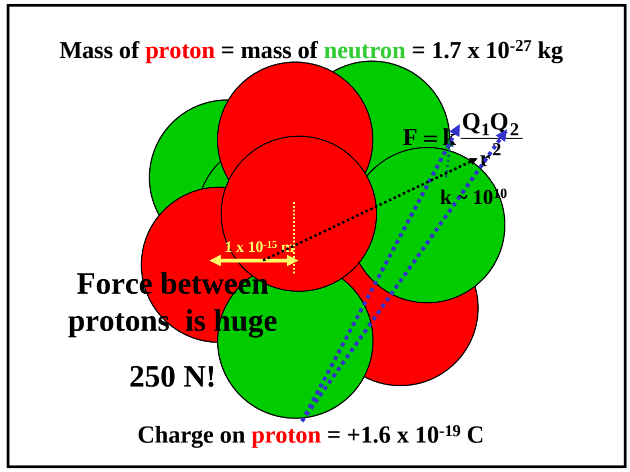

The Atom
10 million times smaller than a millimetre
0.0000000001 m = 10^{-10} m
electron
Mass 9 x 10^{-31} kg
nucleus
Mass > 10^{-26} kg
About a million times heavier than an electron
0.0000000000000000000000000000009 kg

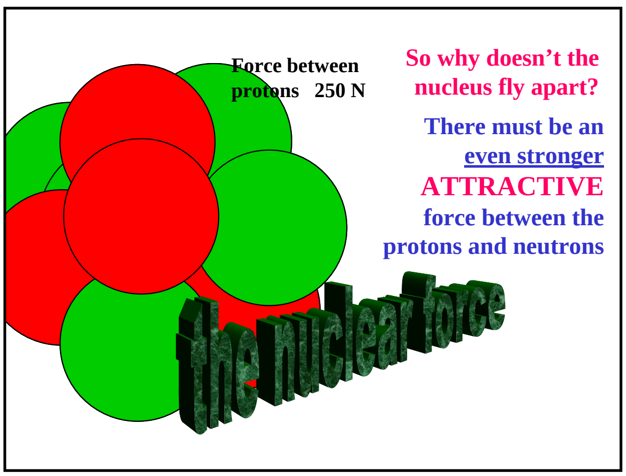

The Nucleus
0.0000000001 m = 10^{-10} m
0.00000000000001 m (~10^{-14} m)
10,000 times smaller than the atom


Take the nucleus to be the size of a golf ball, and throw it to the middle of the MCG


Nucleus
Atom

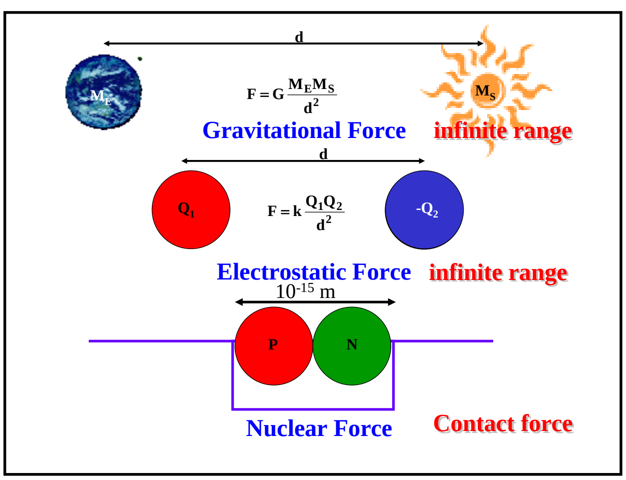


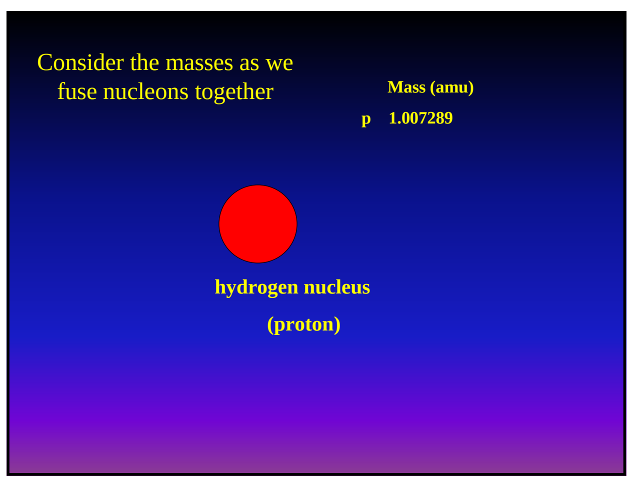




The Nuclear Force

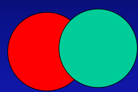
- The strongest force in nature
- Only exists between protons and neutrons
- Only operates when nucleons are 10^{-15} m apart





Consider the masses as we fuse nucleons together

	Mass (amu)	Components
p	1.007289	1.007289
n	1.008071	1.008071
d	2.013135	2.015360

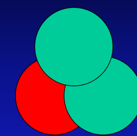


deuterium nucleus

(heavy hydrogen)

Consider the masses as we fuse nucleons together

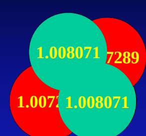
	Mass (amu)	Components
p	1.007289	1.007289
n	1.008071	1.008071
d	2.013135	2.015360
t	3.014950	3.023431



tritium nucleus

Look at the masses!

	Mass (amu)	Components
p	1.007289	1.007289
n	1.008071	1.008071
d	2.013135	2.015360
t	3.014950	3.023431
α	4.002424	4.030720



helium nucleus (α)

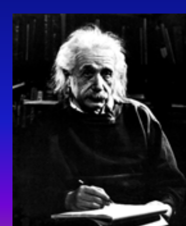
4.030720 − 4.002424 = 0.038296 amu

By combining 2 protons and 2 neutrons to form an α, we have eliminated about 1% of the mass!!

By combining 2 protons and 2 neutrons to form an α, we have eliminated about 1% of the mass!!

nuclear fusion!!

Albert had something to say about this:



a tiny bit of mass

$$E = mc^2$$

gives a HUGE amount of energy

Many Physics Research Labs. are trying to produce energy by nuclear fusion

In practice they are trying to fuse a deuteron and a triton to form an α particle plus a neutron that carry the energy as Kinetic (motion) energy

component mass

t (^{3}H)	3.014950 amu
d (^{2}H)	2.013135 amu

minus

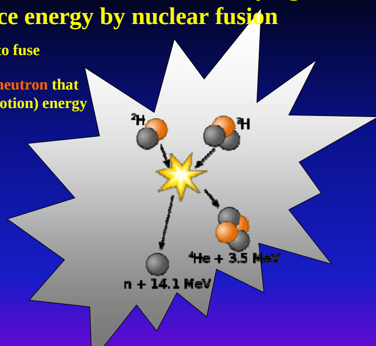
product mass

α (^{4}He)	4.002424 amu
n	1.008071 amu

missing mass

Δm 0.023846 amu

(about ½% of mass)



E = mc^2 ➡ ~17 MeV per reaction

~0.000000000003 J per reaction (Tiny)

How much energy?

Δm = 0.023846 amu

E = mc^2 ➡ 17 MeV per reaction

~0.000000000003 J per reaction

(as kinetic energy of n and α)

2 gram of deuterium (1 mole)

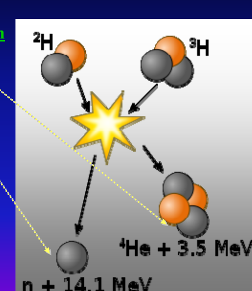
3 gram of tritium (1 mole)

each contains 6 x 10^{23} atoms

(600000000000000000000000 atoms)

~2 x 10^{12} J

➡ ~2 TJ !!!!!!!! (HUGE)



Requirements for practical fusion energy

1 Large-scale system

We know we can produce energetic neutrons and α particles in the nuclear laboratory

We need $10^{a\ lot}$ reactions per second.

many gram of deuterons

interacting with many gram of tritons

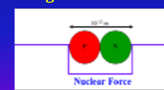
Requirements for practical fusion energy

2 Nuclei not Atoms

Remember Atoms are huge:

100,000 times larger than a nucleus

To interact the nuclei must get within the range of the nuclear force: 10^{-15} m.



Separate electrons from nuclei ➔ PLASMA

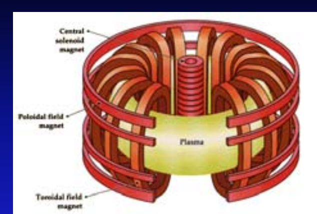
Requirements for practical fusion energy

3 Get the nuclei close together

Give nuclei sufficient energy to overcome coulomb repulsion, and get close together

Heat the plasma to a very high temperature, so that the kinetic energy of the nuclei is high.

An "in principle" tokomak reactor



Need to

- heat the plasma of deuterons and tritons
- Confine the plasma long enough for lots of fusion to occur.

Energy from the nucleus:- Fission

Fusion

For light nuclei, we saw that the mass of the resulting nucleus was less than that of the two components

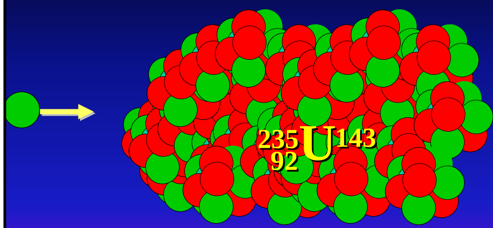
The missing mass was available as Energy

Fission

For really heavy nuclei, the mass of the fission components is less than that of the initial nucleus

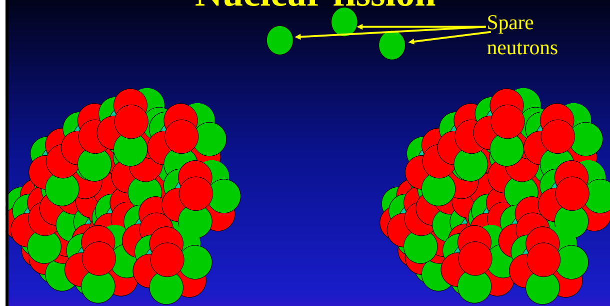
The missing mass is available as Energy

Nuclear fission



A really, really heavy nucleus

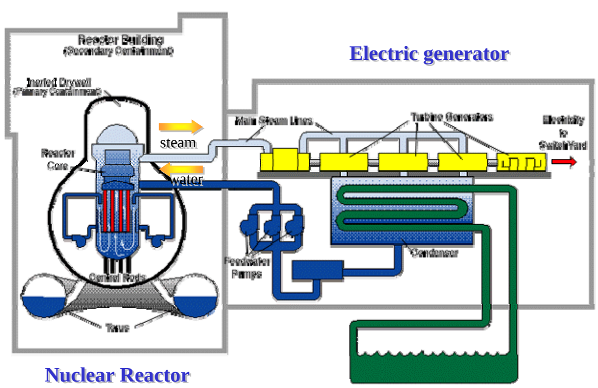
Nuclear fission



Total energy released due to mass decrease is ~200 MeV

0.00000000004 J per fission

Energy is in the form of KE which must be converted to heat



Some people worry about nuclear reactors

What are the valid dangers of Nuclear Power?

Worry	Solution
Major catastrophe	Modern designs (Cando)
Waste disposal	Synrock (HLW) Burial
Reprocessing to weapons-grade material	A political problem

Energy from the nucleus

Dr. Max. Thompson