Magnets in High Energy Physics

David Harding
Fermilab Ask-A-Scientist
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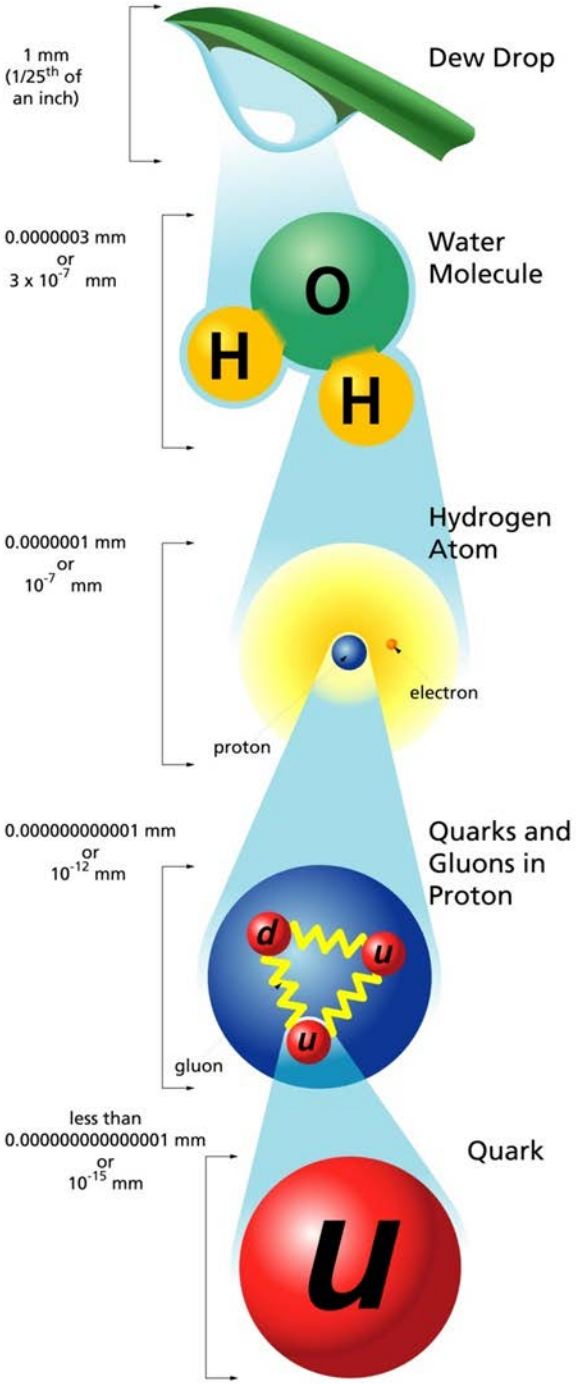
Fermilab: High energy particle physics research

What is the universe made of?
How do the pieces behave?
How do the pieces interact?



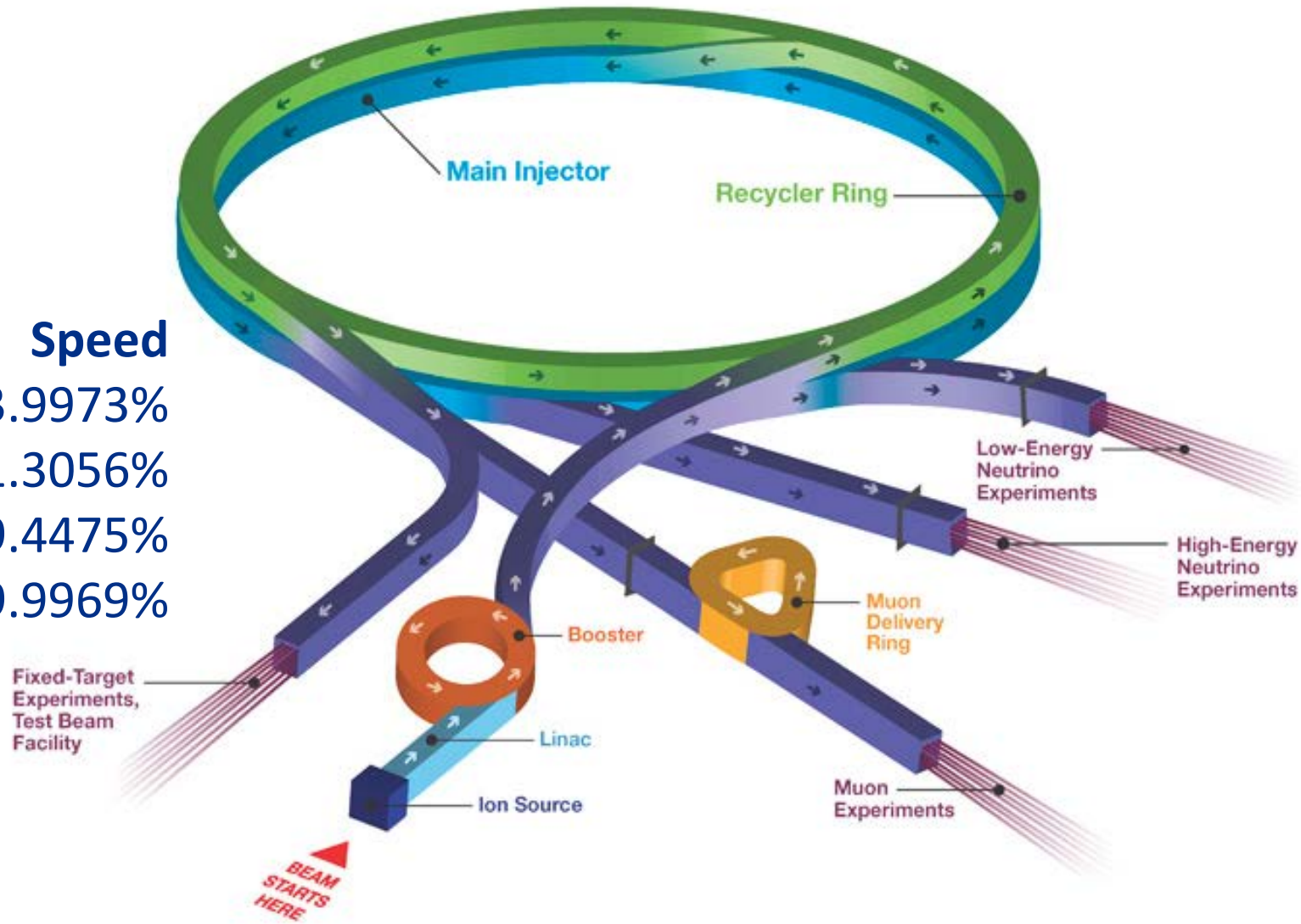
Where do new particles come from?

$$E = mc^2$$

$$m = E/c^2$$

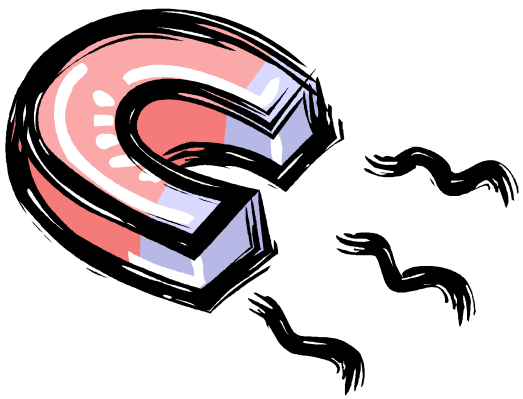
Fermilab Accelerator Complex

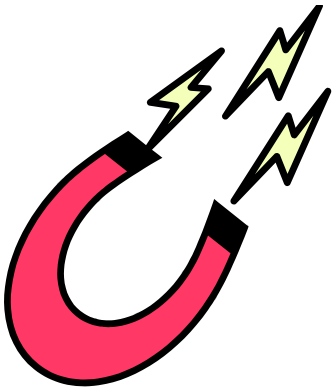
Energy	Speed
750 KeV	3.9973%
400 MeV	71.3056%
8 GeV	99.4475%
120 GeV	99.9969%

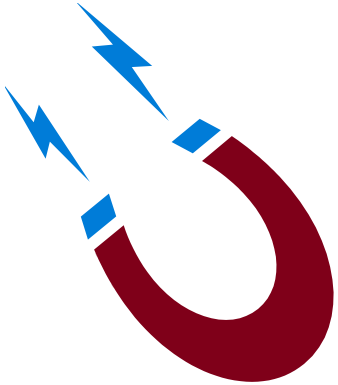


Fermilab Accelerator Complex

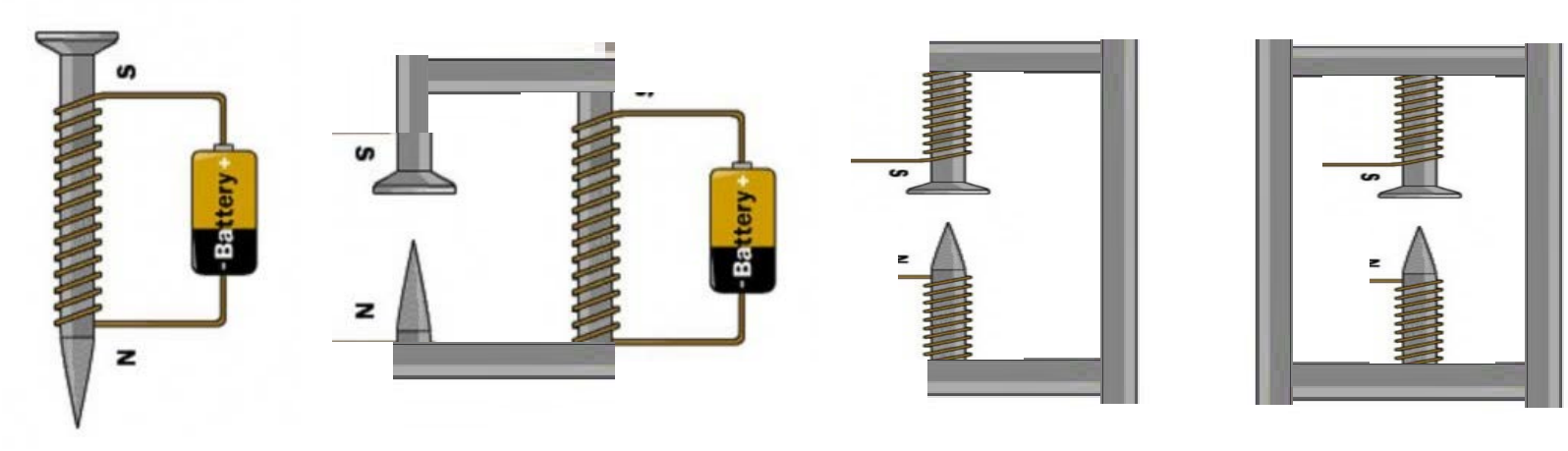
What is a Magnet?

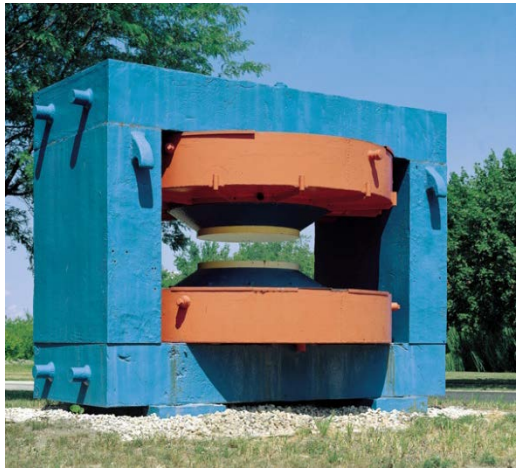






How to make an electromagnet





Basic uses of magnetic fields

- Measure particles

  Experiments use magnets to analyze events

- Control particles

  Accelerators use magnets to steer beams

- Measure muons

  Muon g-2 experiment will use a magnet to measure the magnetic moment of muons by observing the precession of the muon spin

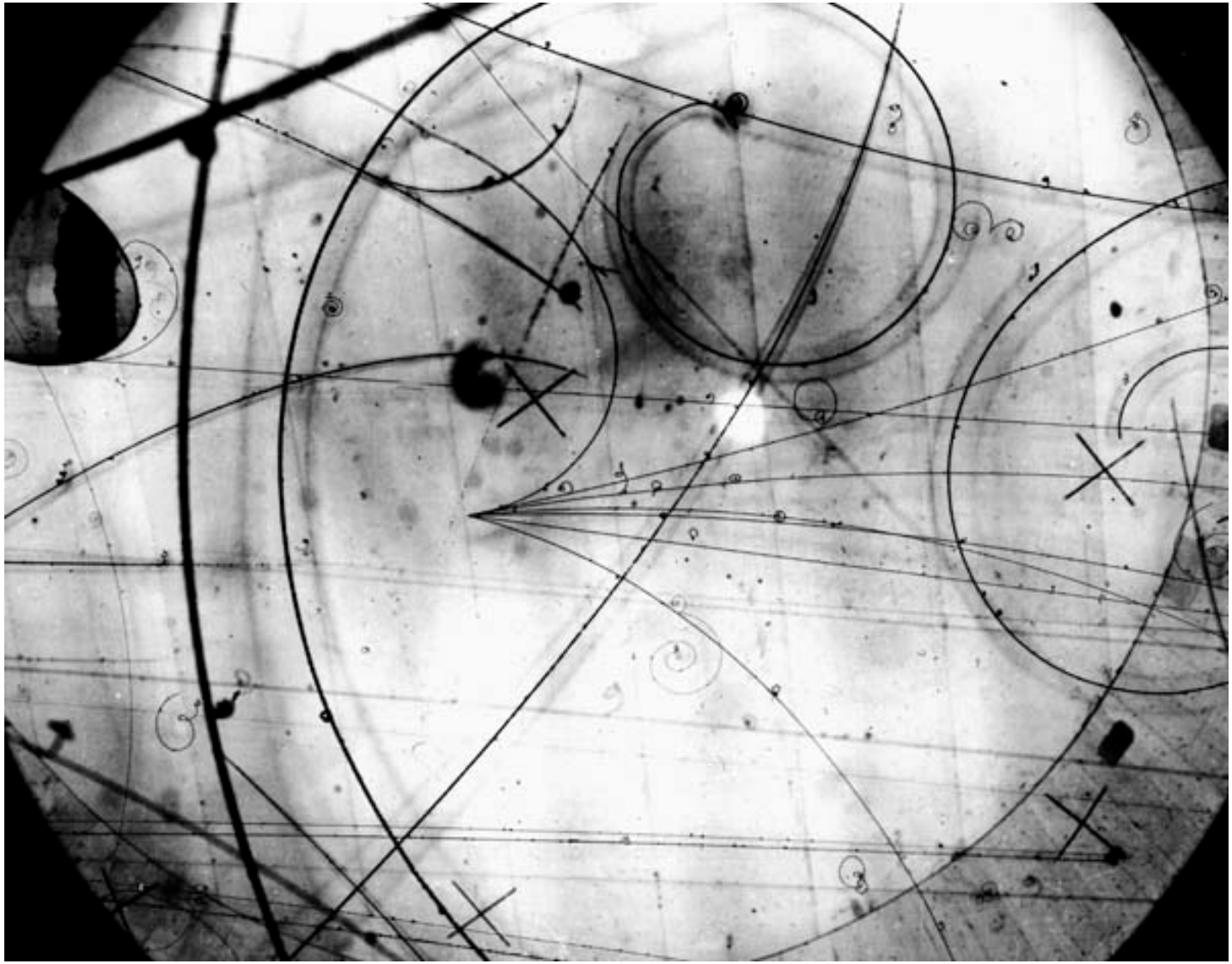
A charged particle moving in a magnetic field feels a force

The force is sideways

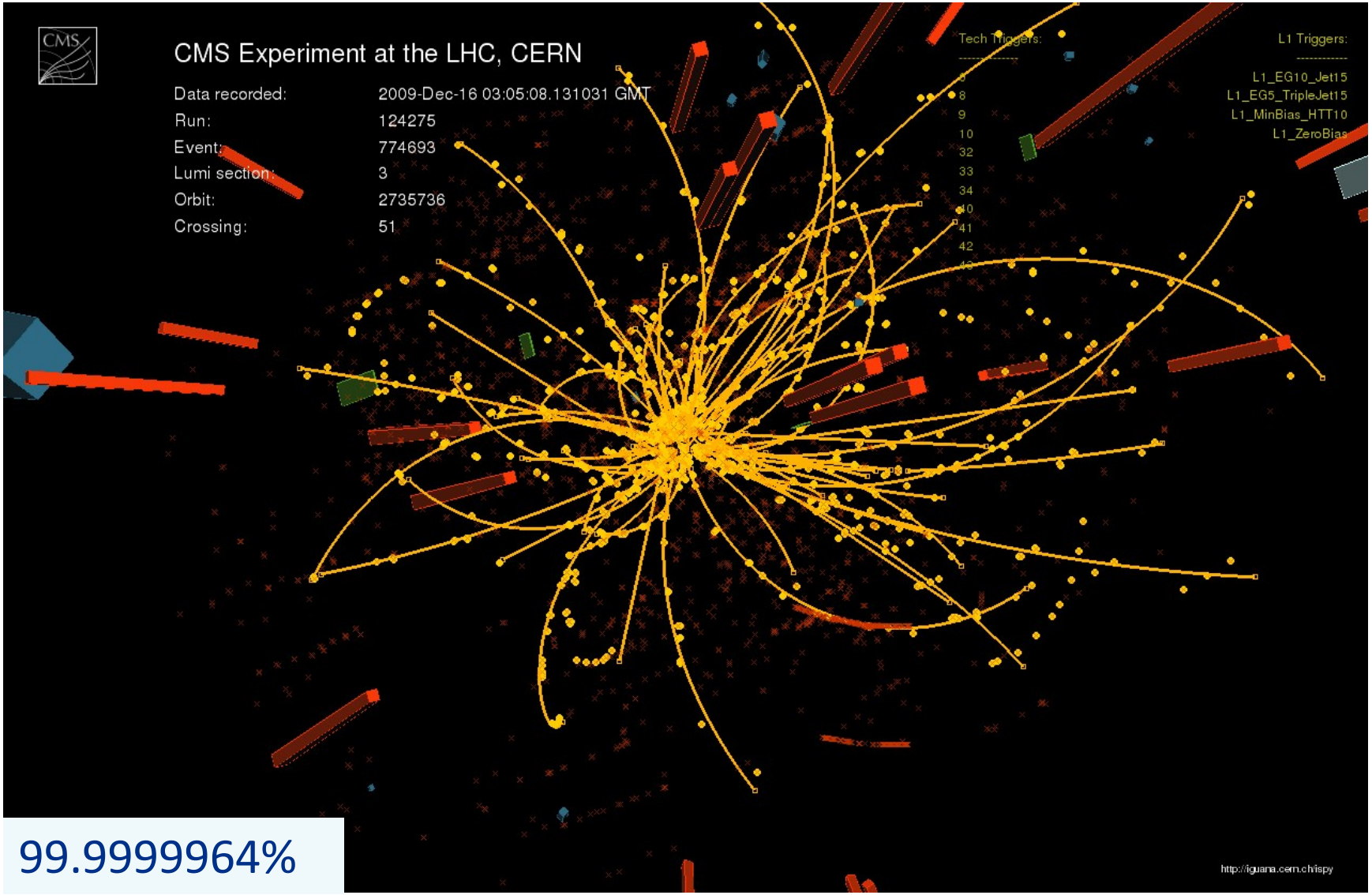
$\Rightarrow$ The particle bends in a circle

- Strong magnetic field, small circle
- High momentum particle, big circle

Bubble chamber tracks

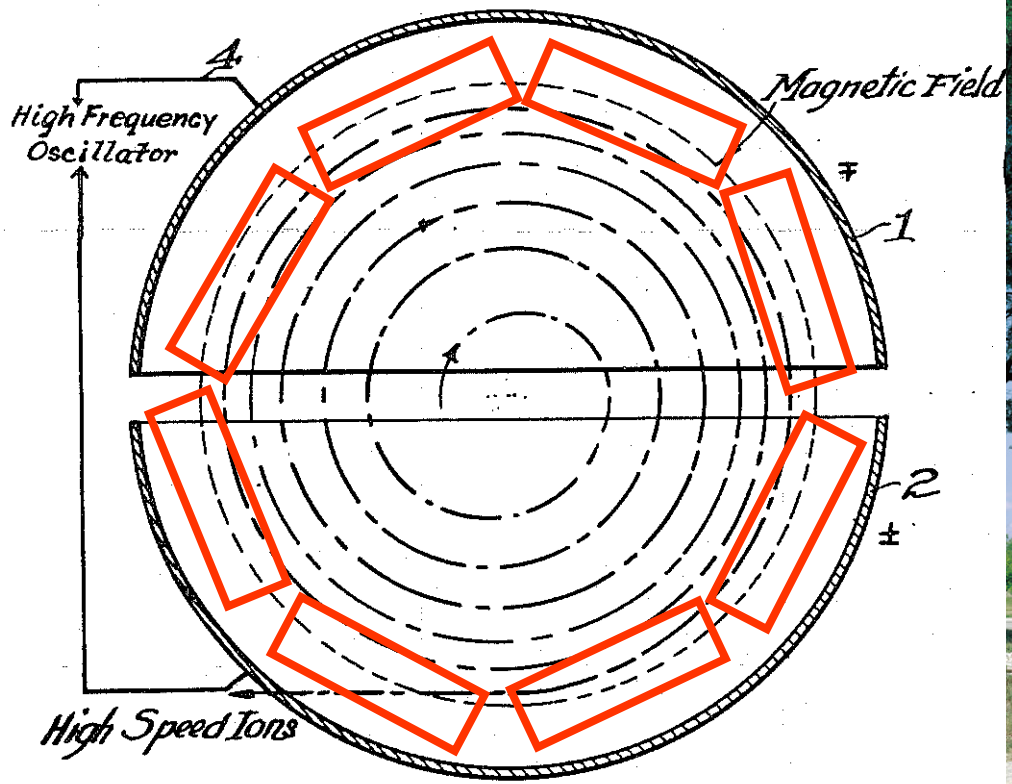


Collider detector tracks (CMS)



99.9999964%

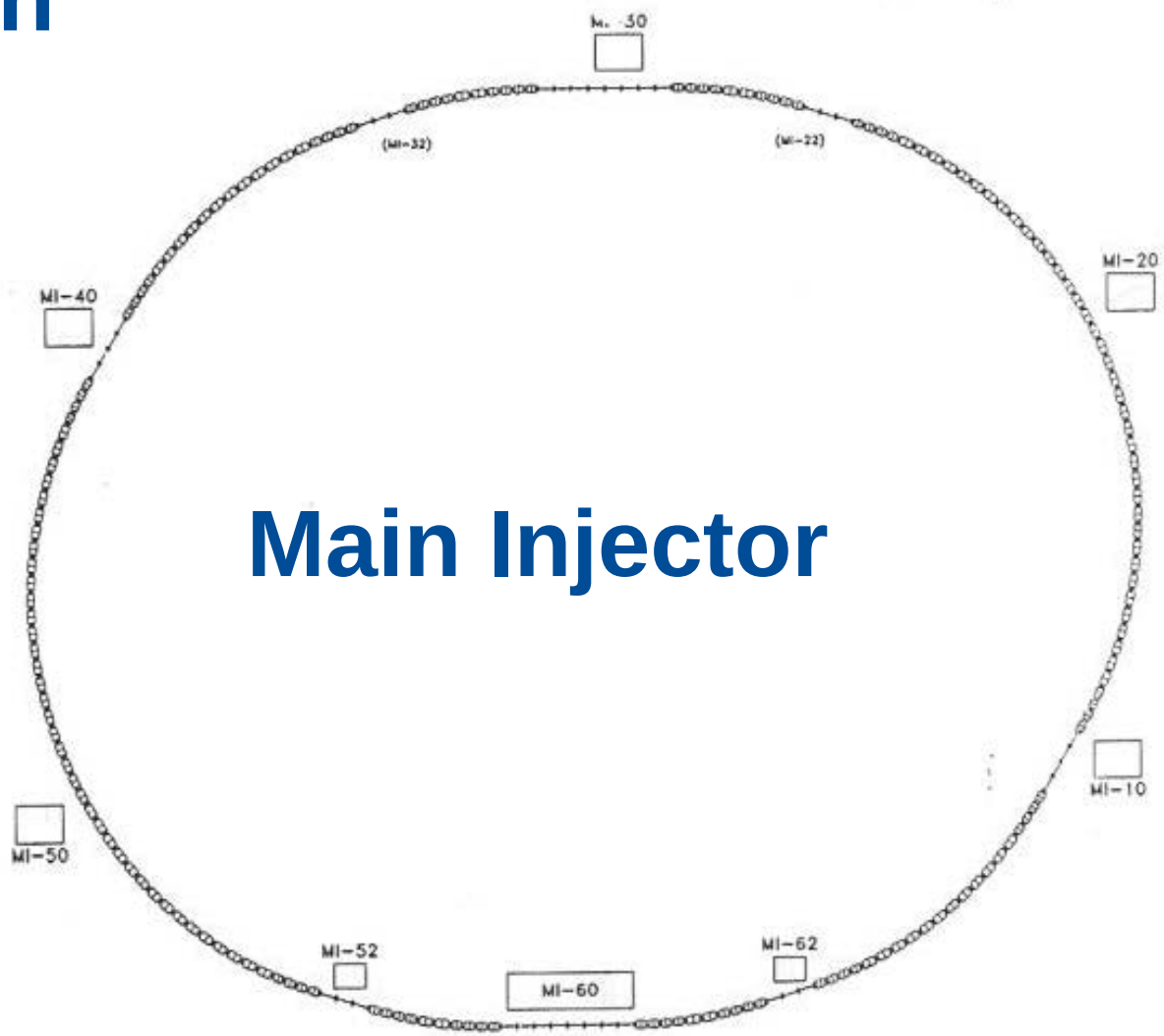
Cyclotron



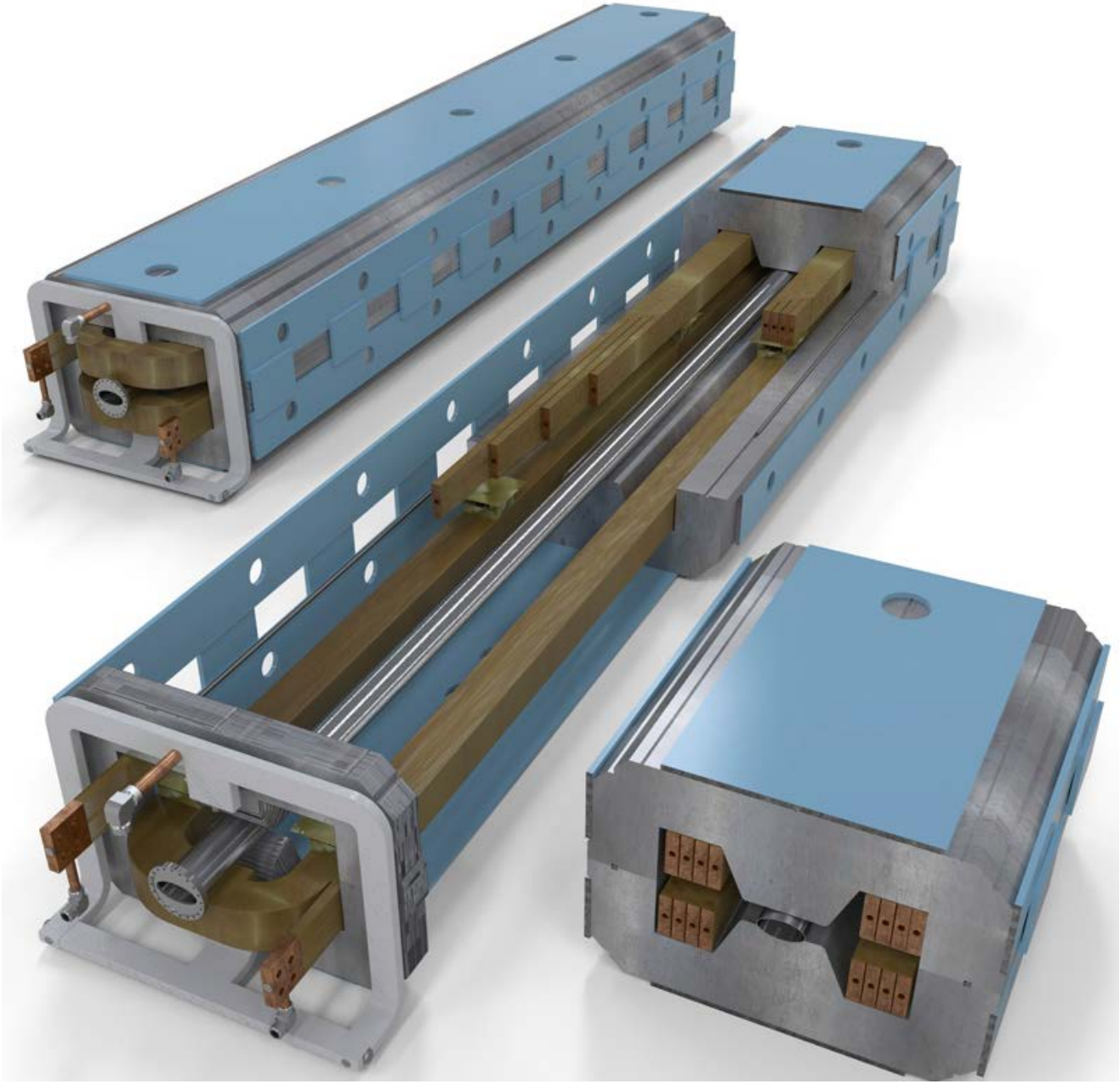
Ernest Lawrence

Synchrotron

String together many long skinny magnets in a big ring.



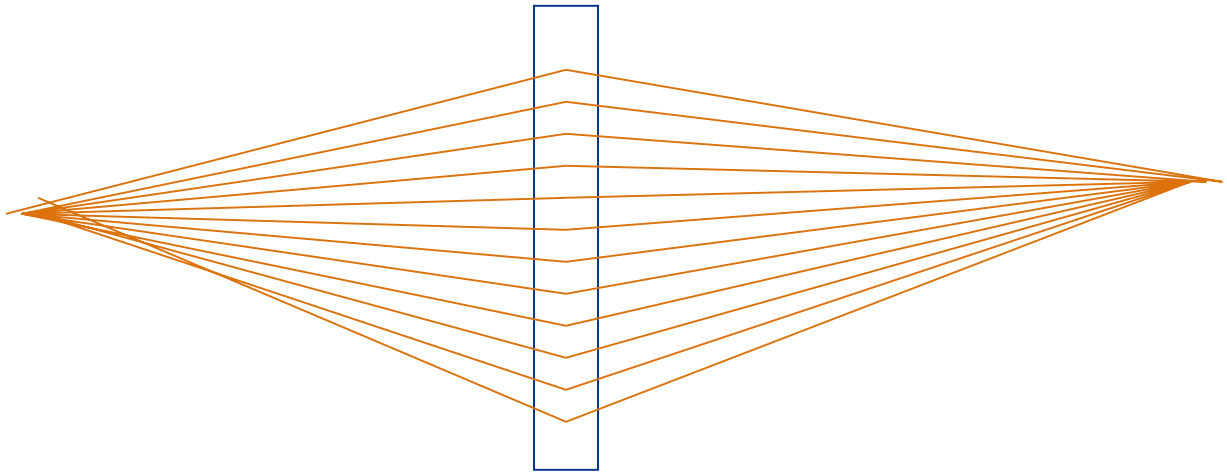
Main Injector dipole magnet



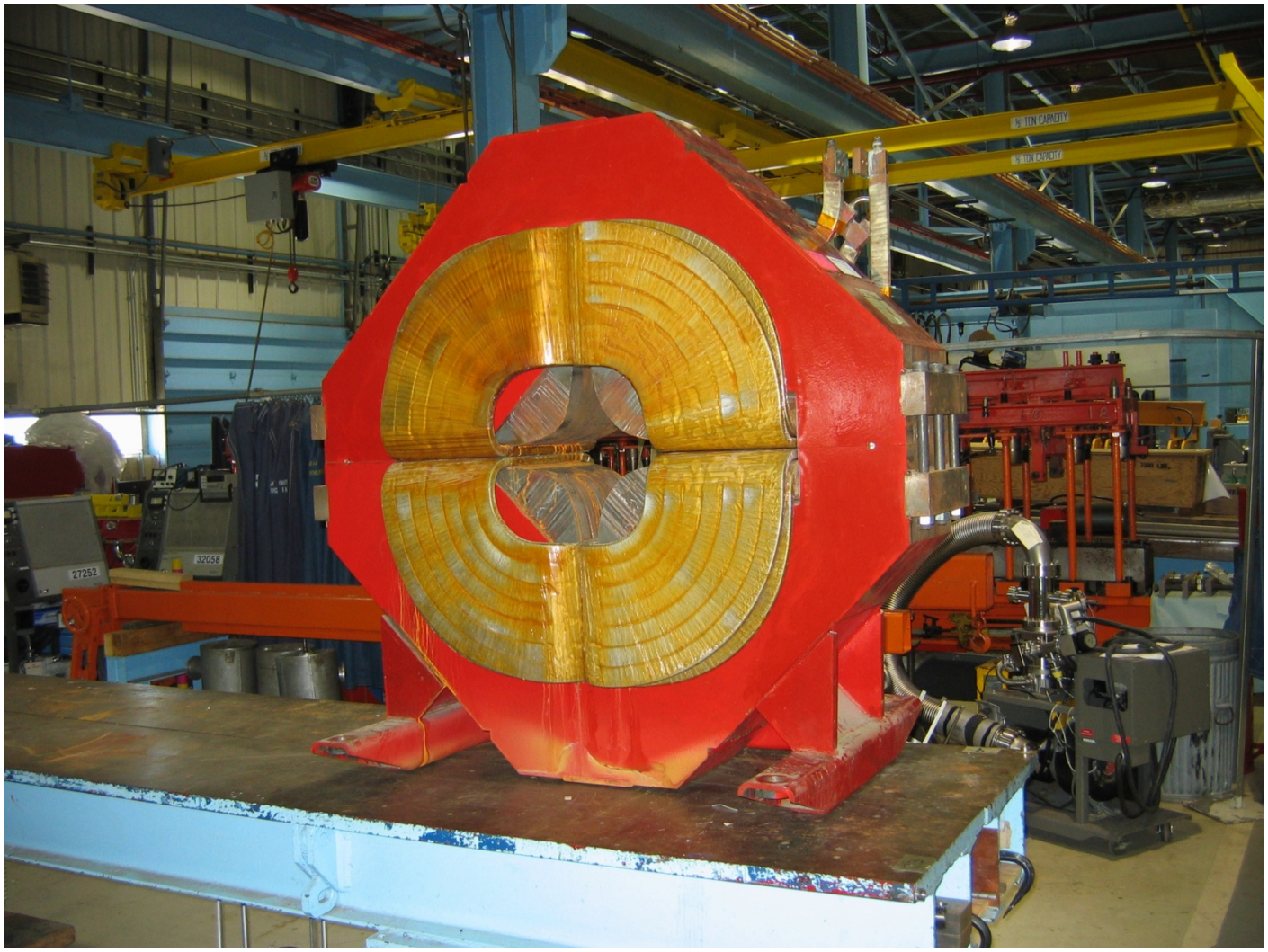
Magnets in Main Injector

Focusing magnets

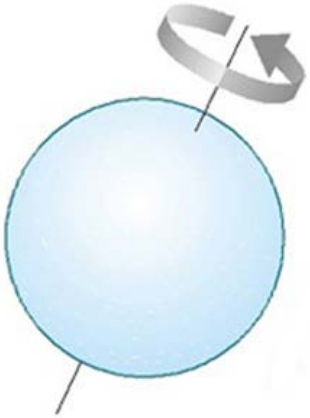
- Beam tends to spread out
- Must constantly focus the beam
- Special magnets do the job



Focusing magnet



Muon g-2 experiment



Magnetic moment of the muon

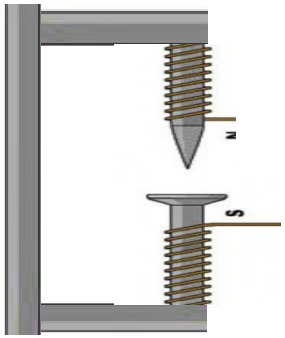
$$\vec{\mu} = -g\frac{e}{2m_\mu}\vec{S}$$

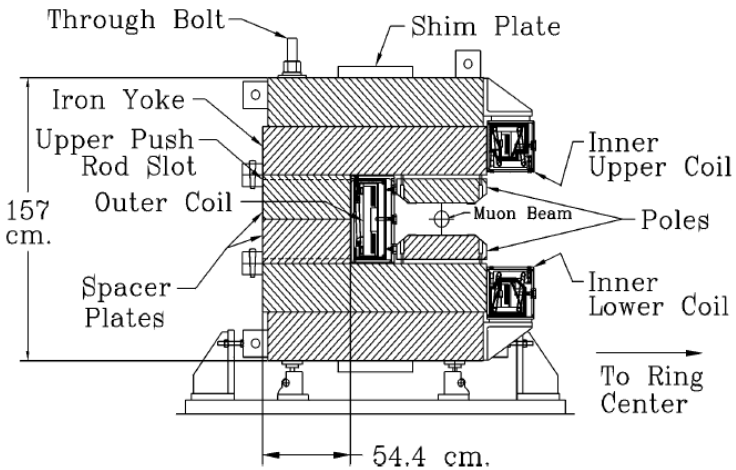
- The simplest quantum mechanical theory calculates the value of g=2
- The first correction is about 0.1%
- So we talk about measuring the difference between g and 2

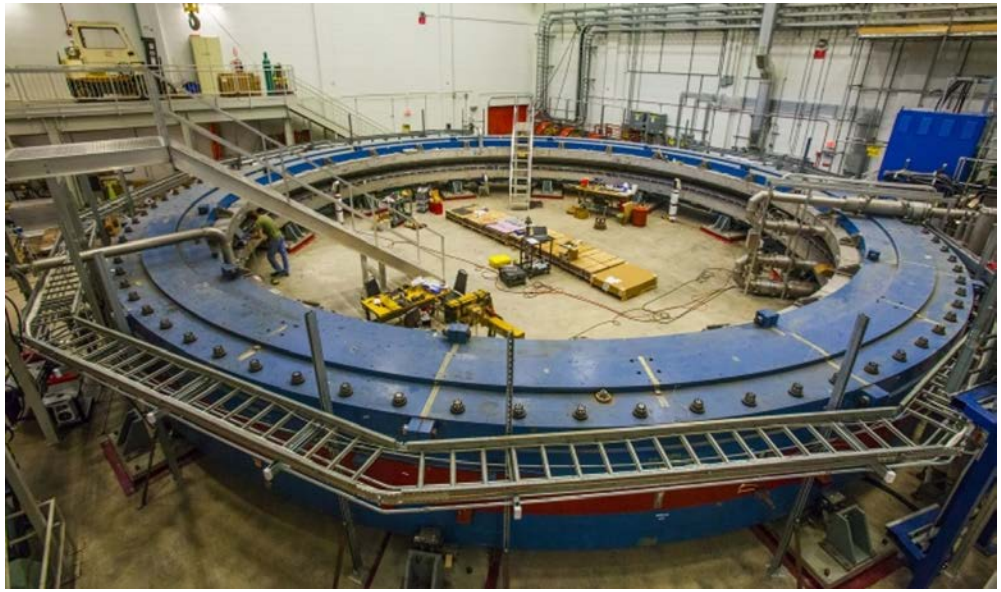
» g-2

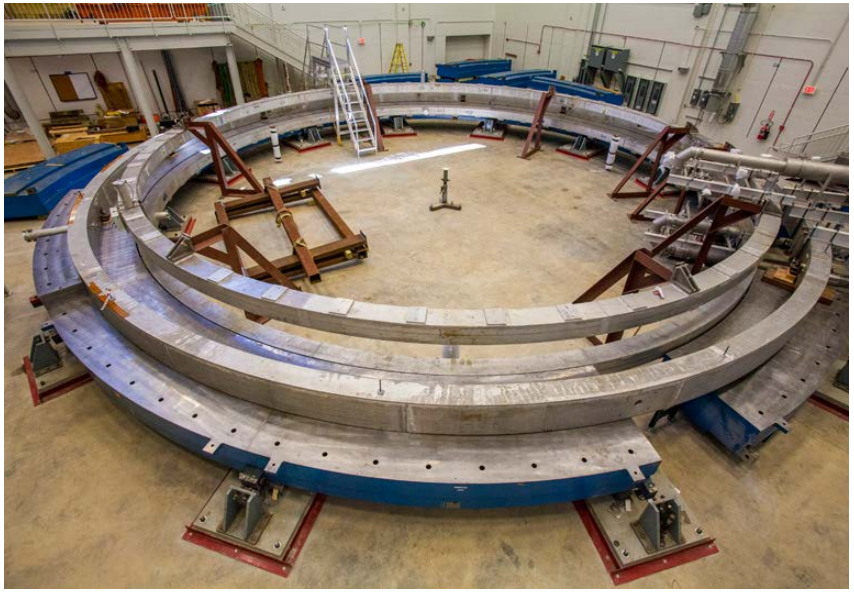
Fermilab

Need a magnet to hold the muons and to cause them to precess

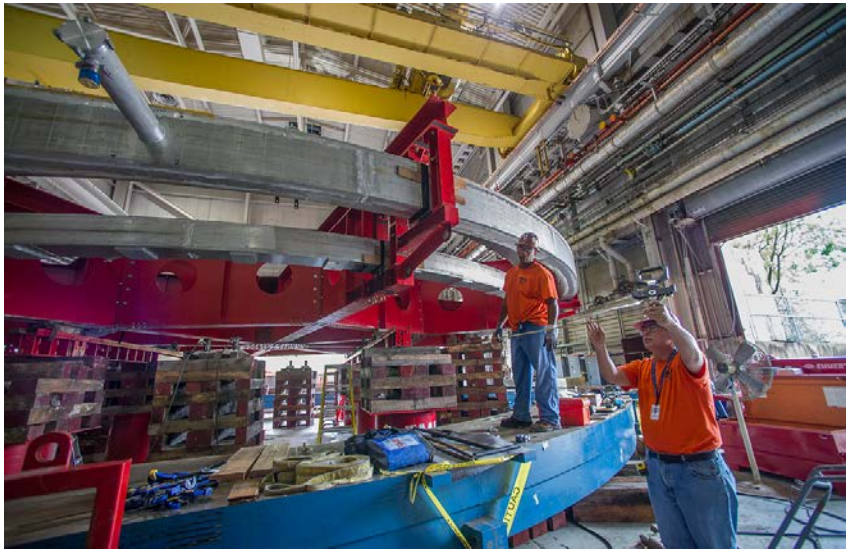








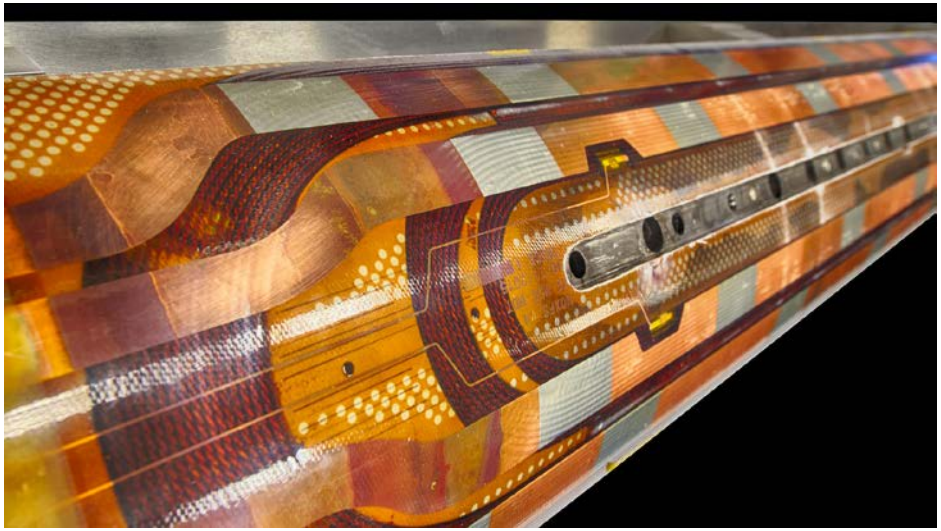
The Big Move



Magnet Research & Development

Figuring out how to build stronger superconducting magnets

- Bend higher energy beams
- Squeeze beams smaller



More to do at Fermilab

- **www.fnal.gov**
- Lederman Science Center
- Buffalo, prairie viewing
- Bicycling, walking
- Concerts, dancing
- Lectures, seminars
- Educational programs

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