Review Sheet for Group 6: Particle detectors and accelerators

- Accelerators and Detectors allow scientists to observe the production of subatomic particles, and their reactions with each other
  - gives further understanding of basic matter of universe, and how the universe began
- The technology gives particles energies in the range of MeV to TeV
  - the smaller the particle, the higher the energy required to produce/observe
- The major centers of experimentation today are:
  - Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, Large Hadron Collider (LHC) at CERN, Tevatron at Fermi, Stanford Linear Accelerator (SLAC)
- Linear particle accelerators-Particles accelerated in a straight line
  - Longer the path, faster it will go
  - Are used to start the particles in other larger accelerators
- Cyclotrons - particles are accelerated, spiraling out
  - Traditionally uses a pair of large hollow D shaped alternating electrodes sitting between two large opposite poles
- Synchrotrons – can apply more energy to particles than cyclotrons
  - Particles will move in a large ring of a constant radius, or a rounded polygon shape with straight segments
  - Varying magnetic fields along the path curve the particle around
  - Energy is limited by size and strength of the electromagnets
- Storage rings : basically a simple and constant energy synchrotron
- Synchrocyclotron: variation of a cyclotron with only one D electrode and a varying frequency to make up for the mass gain of particles
- Isochronous cyclotrons: another variation in which the magnetic field radius is changed to make up for the mass gain of particles
- Betatron: specifically accelerates electrons in a torus shaped vacuum using an alternating current in a large coil, like a giant transformer.
- Particle source
  - Electrons source can come from heating up or applying a large voltage to a cathode
  - Positron source come from an electron beam on a target
  - Proton source can come from ionizing hydrogen gas
  - Heavier ions can be produced by heating or a large magnetic bottle, then separated using a magnetic field
- Particle Detectors
  - Scintillators: record when particles hit them. Atoms in scintillator release photons, which is converted into an electronic signal. Study cosmic rays, other radiation
  - Bubble chambers: Mostly obsolete. Particles travel through liquid, make the liquid boil, leaving a trail of bubbles in its path
  - Gas filled radiation detectors: Works by ionizing gas in a region of small potential, allowing the particles to be counted. Example: Geiger counters (if high voltage applied)
  - Silicon Strip & Wire chambers: Like bubble chambers in showing particle's path, but much more exact and easy to measure. Create electrical signals to show path.
  - Calorimeter: Measure energy and momentum of incident particles by looking at the results of collisions of the particles with lead. Good for detecting neutrons
  - Cherenkov Detectors: Light is slowed down in certain mediums so that particles can travel through that medium faster than the light. Particle creates a shockwave of light. Gives you the particle's velocity, other detectors can tell you momentum, so you can identify the particle

    - Neutrino Detectors: Neutrinos have no charge so hard to detect. Don't interact much. Can be detected by filling an underground chamber with water, so that when the neutrino strikes a water molecule, the interaction can be detected.
- Uses of Particle Detectors
    - Positron Emission Tomography (PET), Carbon Dating, Inspection, X-ray Spectroscopy, Research in Muon Detection, Ionizing Smoke Detectors
- Uses of Particle Accelerators
    - Cathode Ray Tube (CRT) monitors, Creating Short Lived Isotopes for PET scanner use, Electron Gun for cancer treatment
- Historical Overview: new types of accelerators through time
    - Cathode ray tubes (late 1800s)→Cockcroft Walton→Cyclotrons→Linear Accelerator→synchrocyclotrons→synchrotron→colliders→combinations (today)
- Significant discoveries (general):
    - X-rays, electrons, splitting nucleus, radioactive elements (artificially create), cancer treatment, many other elementary particles and their interactions, advances in the Standard Model of particle physics
- Hopes for the future
    - Create Quark Gluon Plasma? (state of matter at beginning of universe)
    - Higgs Boson: theoretical force-carrier of mass. Does it exist?
    - Solidifying or modifying the Standard Model
    - Do the theoretical supersymmetric partners of the known particles exist?
    - Potentially create and "observe" dark matter
    - Do the known forces unite at high energies/temperatures?
    - Why is gravity so much weaker than the other known forces?
- Making a black hole:
    - In order to make a black hole, we simply can accelerate two beams inside LHC and make the collision happens between them .Then a very high density thing is made and that becomes a very ting black hole.
- Why people fear black holes at the LHC?
    - We still don't know how to control the size of a black hole, since black holes can attract anything nearby and absorb them; Without control, it may becomes larger and larger and the earth would be destroyed.
- Really a risk? No, the black holes created at CERN will be so small that they will decay almost instantaneously, before they would do any harm. But it would give us insight into particle creation!