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Brief History of Particle Accelerators and Colliders

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Accelerator is a machine in which particles are accelerated according to the desire of the Scientists. A Collider is taken to mean a Particle accelerator in which two beams are travelling in opposite directions and collide with each other. Many and most important discoveries in the last 50 years are due to Collider Physics. A Collider has a lot of advantages over the fixed target accelerator.

Sl.No.	Fixed Target	Collider
1	S1/2 α E1/2 lab.	S1/2 α Ecm
2	Energy available for Physics is restricted, as most of it is wasted in balancing the momentum.	All energy is used for Physics purposes.
3	Many kinds of beam possible i.e. P,K+-, π+-,KL0, µ,nu etc.	Only stable and charged particles beam is possible i.e. PP, PP-, e+e-, e-P etc.
4	Different types of target possible.	Only colliding beam particles i.e. PP, PP-, e+e-, e-P etc.
5	High luminosity possible	Limited luminosity

For collider where two beams collide against each other, the luminosity is given by
l=N1 N2/A.f.nb
N1, N2 = No. of particles in each bunch
nb= No. of bunches
f= revolution frequency (sec-1)
A= effective cross-sectional area of the beams
Typical values of luminosity are around: 10 31 – 10 32 cm -2 .sec-1.
Integrated luminosity is defined as: L = l dt on integrating (in cm-2).
For example- If a detector has collected integrated luminosity of 100pb-1, means a process with a cross section of 1pb will produce 100 events.

First came the Stanford e+e- collider (SPEAR) which discovered charm quark in 1974 with the centre of mass energy similar to that of the fixed target Proton Synchrotron at Brookhaven National Laboratory (BNL). The charm quark was simultaneously discovered at both BNL/SPEAR machines in 1974, for which Prof. Burton Richter and Prof.Samuel C.C.Ting got the 1976 half of the Nobel prize. The tau lepton was also discovered at SPEAR in the following year, for which Prof.Martin L.Perl got half of the Nobel prize in 1976.

The bottom quark was discovered in the fixed target Proton Synchrotron at Fermilab. In 1977 and its detail properties were studied at the e+e- collider at Hamburg (DORIS) and Cornel (CESR). Then the e+e- collider (PETRA) at Hamburg resulted the discovery of gluon in 1979.

The CERN P+P- collider with centre of mass energy 100GeV resulted in the discovery of W+- and Z0 bosons in 1983, for which Prof.Simon Van der Meer and Prof. Carlo Rubbia got the Nobel prize in the year 1984. Then the Fermilab.P+P- collider (TEVATRON) with the centre of mass energy around 300 GeV resulted in the discovery of the top quark in 1995.

During 1990 the last batch of machines were the Stanford Linear Collider (SLC) and the Large Electron Positron (LEP). They had helped us to bridge the energy gap between the e+e- and P+P- colliders and made a detailed study of W+- and Z0 bosons. The e-P+ collider (HERA) at Hamburg was probing deeper into the structure of the Proton by extending the deep inelastic e-P+ scattering at SLAC. A Large Hadron Collider (LHC) , being built in the LEP tunnel at a cost of 4-5 billionn dollars has a centre of mass energy of S ½=14 TeV and effective energy of 2 TeV (2000GeV).

Past, Present and Proposed Colliders

Machine	Location	Beam	Energy GeV	Radius	Highlight	Nobel prize
SPEAR	Standford	e+e-	3+3		C, t	1976
DORIS	Hamburg	e+e-	5+5		b	1977
CESR	Cornel	e+e-	8+8	125m	B	
PEP	Standford	e+e-	18+18			
PETRA	Hamburg	e+e-	22+22	300m	g	1979
TRISTAN	Japan	e+e-	30+30			
SPPS	CERN	P+P-	300+300	1Km	W,Z	1984
TEVATRON	Fermilab.	P+P-	1000+1000		t	1995
SLC	Standford	e+e-	50+50		Z	
LEP-1	CERN	e+e-	50+50	5Km	Z	
LEP-2	CERN	e+e-	100+100	5Km	W	
HERA	Hamburg	e-P+	30+800	1Km		
LHC	CERN	P+P+	7000+7000	5Km	Higgs	2012

The CERN-LHC has four colliding junctions known as (i)-ALICE (ii) LHC-ATLAS (iii) LHC-b and LHC-CMS. The Large Hadron Collider-Compact Muon Solenoid (LHC-CMS) is a proton-proton collider with a nominal centre of mass energy of 14 TeV. The CMS experiment was designed for the LHC to study the Standard model. Identification of muons, photons and electrons, and precise measurements of these particles, with an energy resolution of 1% over a large momentum range, are emphasized in design considerations. The CMS hadron collider has a good resolution for measuring missing energy and hadron jet energy, permitting an extensive search for signature of super symmetry and quark structure. In pre shower Si-strip detector as this provides the most effective methodology to identify the Higg's boson decaying into 2 gammas.

The detector development is carried out by SIMULATION & the major activities involved are (i) Process Simulations and (ii) Device Simulations.

In Process simulations we obtain the doping profile& the junction depth of the Si micro strip detector. The doping profile obtained after process simulations is used in device simulation and we get device parameter such as breakdown voltage, leakage current etc.

(i) Simulation of the device using a commercial process simulation such as TMA SUPREME & MEDICI considering the actual geometry.
(ii) Simulation of the detector with guard ring incorporated to understand the improvement of the device performance due to guard ring.
(iii) Simulation of the device with defects such as interface states, oxide charge,bulktraps etc. incorporated to predict the device performance in case of process in induced defect generation.
(iv) Simulation of the device considering radiation induced degradation due to defect generation because of radiation.

Si detector have become indispensable in the recent High Energy Physics (HEP) Experiments because of their excellent position and energy resolution, fast response, compactness etc. For example , various configurations of Si detectors are being used in the inner vertex and pre shower detector of the CMS experiments at the Large Hadron Colliders (LUC0 experiments at CERN, Switzerland.

Si detectors face extremely harsh radiation environment in the present and future HEP Experiments and their continuous operation for the entire life time of these experiments. In fact it is expected that for the luminosity upgrades of the LHC experiments to IE 35/cm2/s (Super LHC), the present available Si detector technology may not be able to match the extreme requirements with respect to necessary radiation tolerance. Si detector placed in the inner most track will face particle fluencies above IE16/cm2/s which is 10 times higher radiation level expected for the tracker detector of the LHC. Radiation hardness study requires detail work on the radiation induced defects in the Si material- both in terms of bulk damage and surface damage. These changes brings deterioration in the performance of the sensors. Choice of even the starting material, Czochraski vs. float zone, is important. Of course , experiments will be very important but ,still, because of of the involvement of the various parameters, simulation of these effects can prove to very effective in analyzing these problems without spending too much money and time.

The International Linear Collider, ILC will be a necessary tool to unlock some of the deepest mysteries about the Universe. The ILC will allow us to precisely explore extremely high energy regions. The ILC experiments may help us to know the most fundamental questions such as (i) What is Dark Matter and Dark Energy (ii) Does supersymmetry exist?

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