

The world of particle physics and TIFR

मूलकणांचे विश्व आणि टी आय एफ आर

मूलकणों का विश्व और टी आइ एफ आर

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Founder's Day, TIFR,

Oct 30, 2012

This talk is for you if ...

- You are curious about what is particle physics, and why scientists in TIFR work on it
- You want to know of some of the achievements of TIFR
- You want to tell your family, friends and relatives exactly what this “Tata Company” does
- You want to relax while watching some nice pictures

This is not a history of particle physics at TIFR. Just some major points

Very small and very large

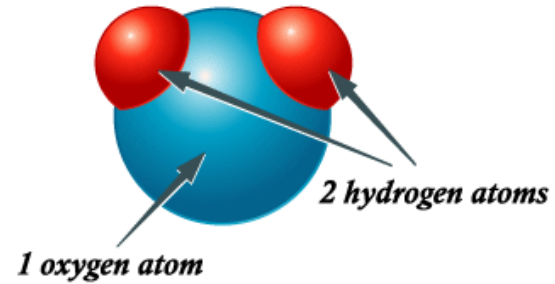
अतिसूक्ष्म आणि अतिभव्य

अतिसूक्ष्म और अतिभव्य

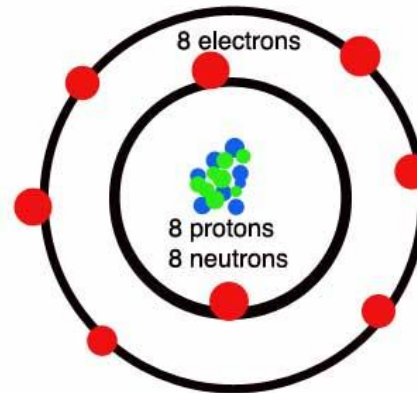
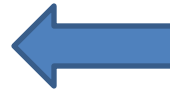
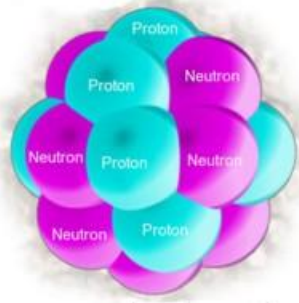
Looking at smaller and smaller objects



Water Molecule

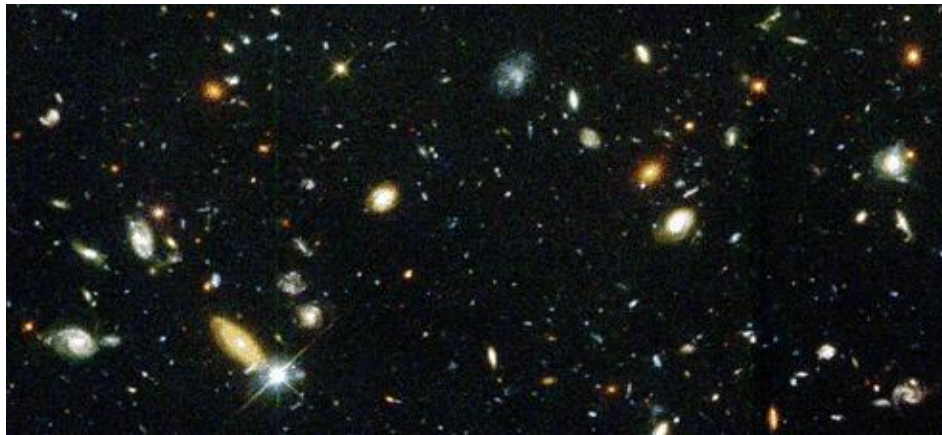
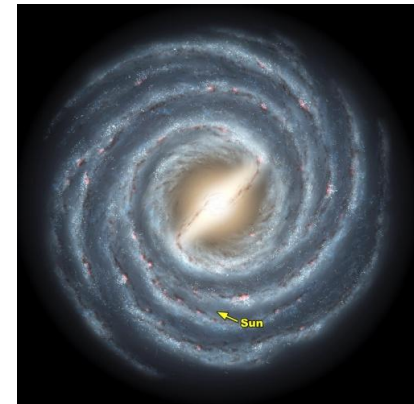
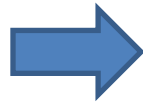


ऑक्सिजन केंद्रक :
प्रोटॉन, न्यूट्रॉन



ऑक्सिजन
अणू

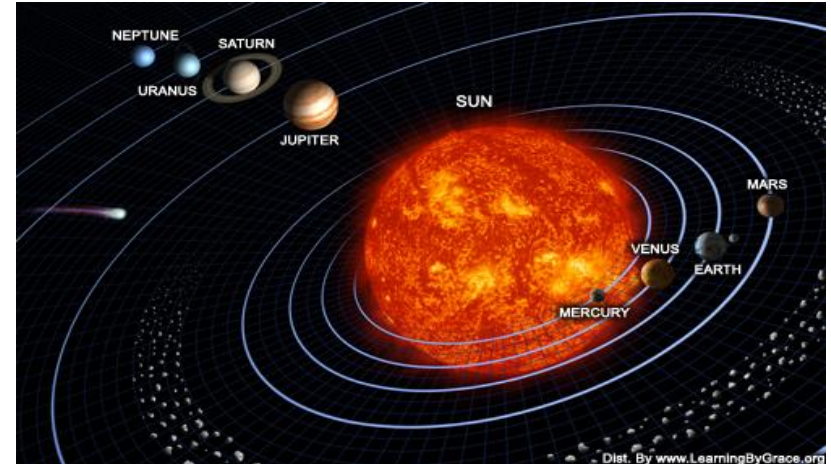
Looking at larger and larger objects



Galaxy clusters

**Our galaxy:
Milky way**

Everyone obeys the same rules



Fundamental forces of nature:

- Gravity (गुरुत्वाकर्षण बल)
- Electricity and magnetism (विद्युत् चुंबकीय बल)
- Strong nuclear force (तीव्र केंद्रकीय बल)
- Weak nuclear force (क्षीण केंद्रकीय बल)

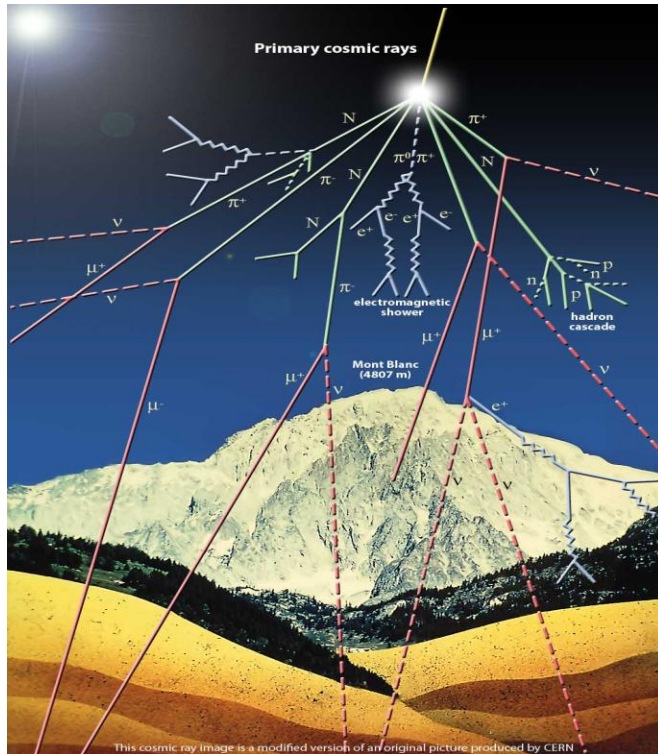
मूलकण तथा उनके बलों की जानकारी याने Particle Physics.

Cosmic rays: particles from the sky

विश्वकिरण – कणांची वृष्टी आकाशातून

विश्वकिरण – कणाँ की वृष्टी आसमान से

100 years of cosmic rays

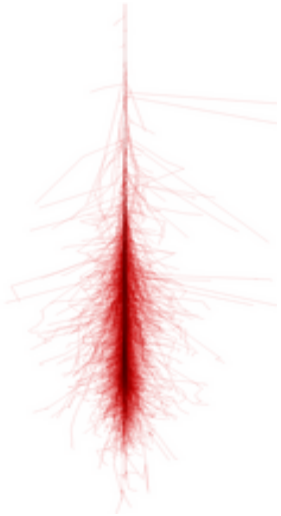


विश्वकिरण-वृष्टि
Particle showers in the
atmosphere: some reach
the earth, some die out



व्हिक्टर हेस: १९१२
Balloon ride to detect
cosmic rays high up

Shower shapes for different particles



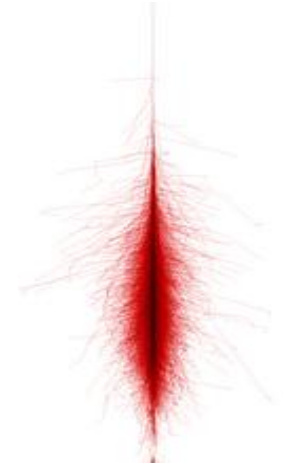
Photon / electron



Proton



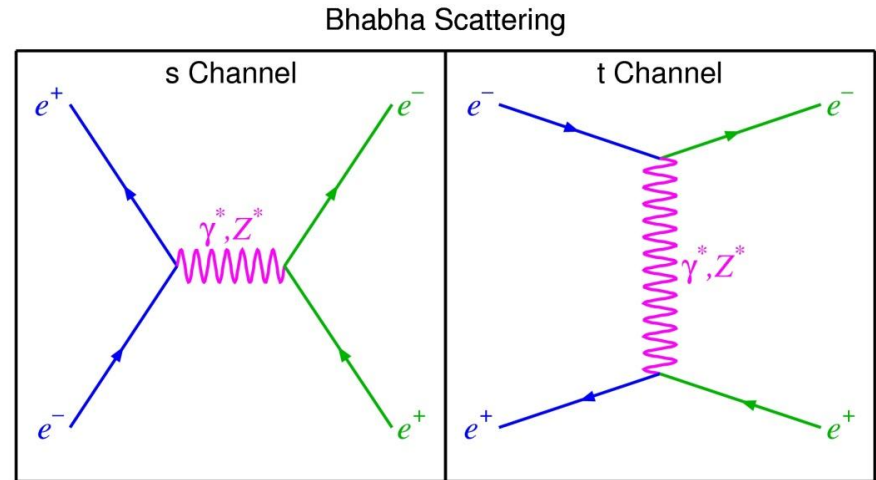
Iron nucleus



Muon

- Many new particles were discovered in cosmic rays:
Pions, Kaons, Muons, ... (ये बस नाम हैं |)
- Many of them are short-lived: they are produced when cosmic rays hit air molecules, and die out in a short time.

Bhabha and cosmic rays



- Bhabha was the first to calculate theoretically **how electrons and positrons (anti-electrons) react with one another.**
- He studied the development of cosmic ray showers theoretically and experimentally.

Bhabha and the muon (μ)

- There were particles that looked like electrons, but their behaviour was confusing.

In 1937, Bhabha showed that these must be some new particles, about 100 times heavier than the electron.

- These particles were short-lived.
- In 1938, Bhabha proposed a method for showing that when these particles move fast, they live longer (relativity).
- 1939: Named these particles as “mu-mesons” (Now they are called “muons”).

Early cosmic ray research in TIFR



- Bhabha started cosmic ray research in TIFR from its inception
- Experiments at **Hyderabad, Ooty, Kolar** gold mines
- Important results on new particles like “**K-mesons**” and “**Hyperons**”.

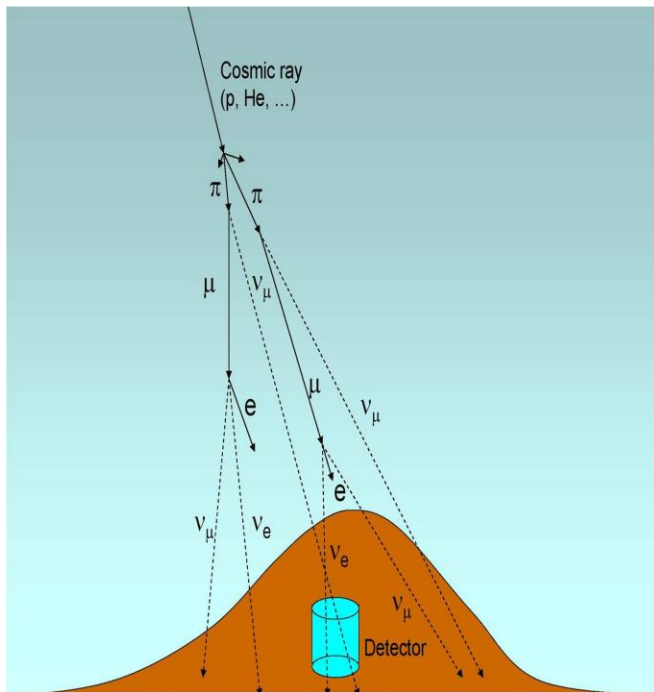
Hiding from the cosmic rays

विश्वकिरणांपासून लपण्यासाठी

विश्वकिरणां से छिपने के लिए

Why hide from the cosmic rays ?

To look at neutrinos (न्यूट्रीनो) !



- Neutrinos : important for shining of the sun, nuclear reactions, and radioactive decay.
- Very difficult to detect. For every neutrino detected, more than a billion other cosmic rays.
- Solution: go where other cosmic rays cannot reach, but neutrinos can (inside mountains / mines).

Kolar Gold Fields (KGF) experiment

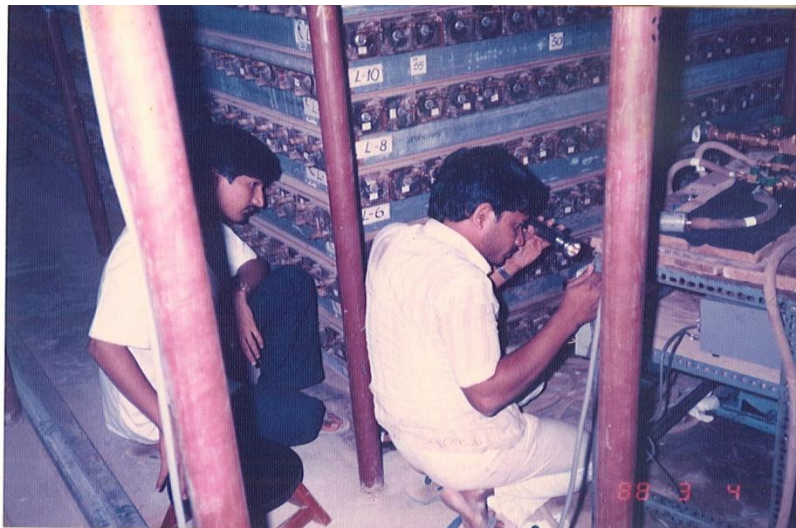


- Kolar Gold mines: almost 3 km deep
- Experiments on proton decay and high energy muons



- In 1965: the first observation in the world of neutrinos from cosmic rays; the so-called “atmospheric neutrinos”

Some familiar faces from KGF

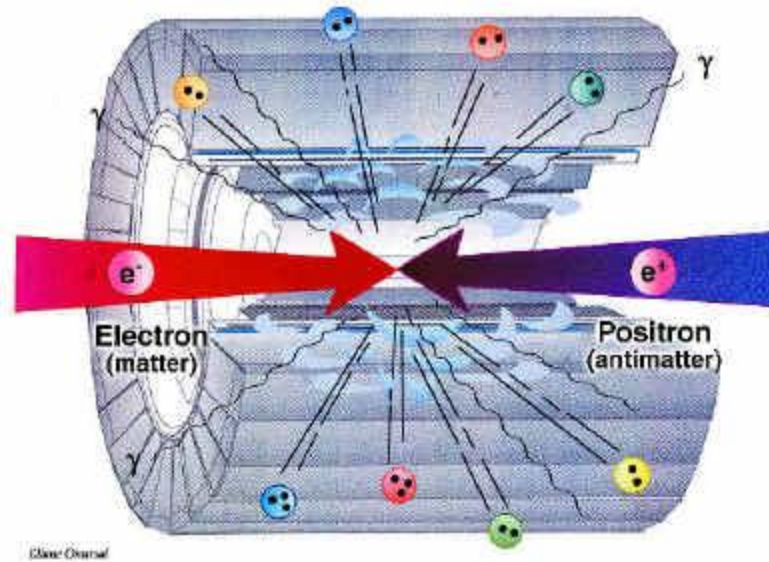


Bringing cosmic rays to laboratory

विश्वकिरण प्रयोगशाळात

प्रयोगशाळा में विश्वकिरण

Collide fast-moving particles

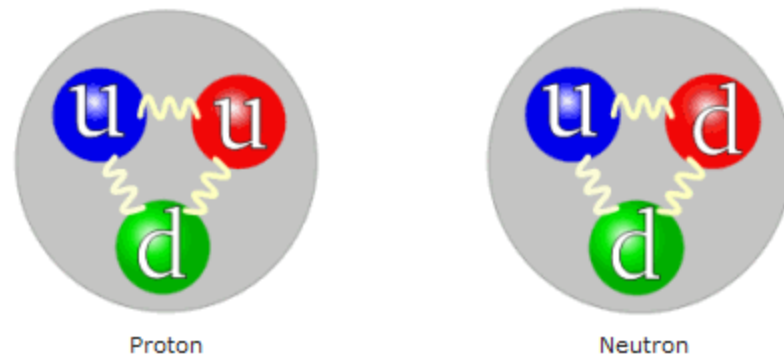


$E = m c^2$: ऊर्जा से नए कणों की निर्मिती

- Recreate cosmic ray collisions in the laboratory
- Collision with larger energy → produce particles with larger masses

Protons and neutrons are **NOT** elementary particles! (They are made of quarks)

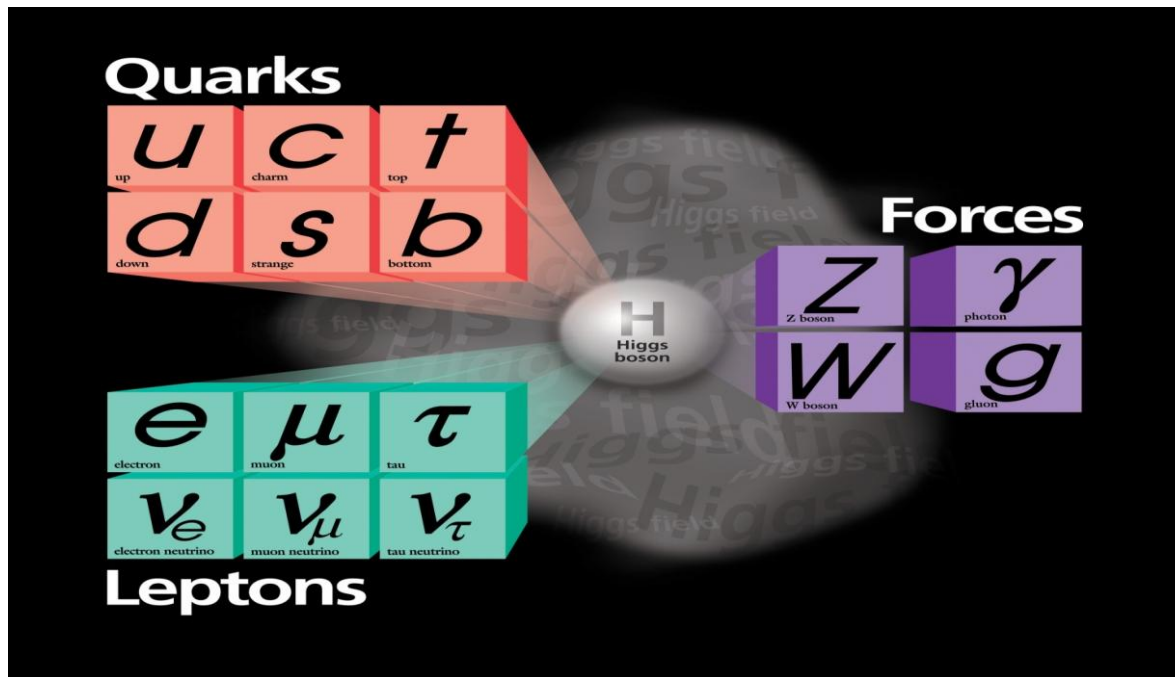
प्रोटॉन और न्यूट्रॉन मूलकण नहीं हैं, वे “quark” कणों से बने हैं ।



Quark composition of a proton and a neutron (diagrams from *Wikipedia*)

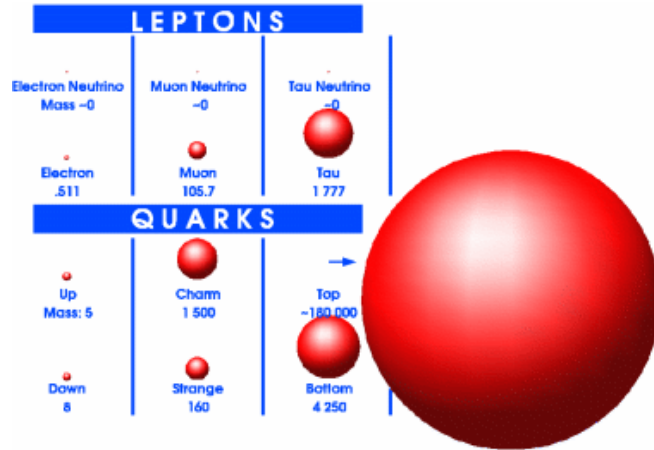
- Made of **up-quark** (charge $+2/3$) and **down-quark** (charge $-1/3$)
- **Proton**: Two up-quarks and one down-quark, **total charge +1**
- **Neutron**: One up-quark and two down-quarks, **total charge 0**.

Standard model of particle physics



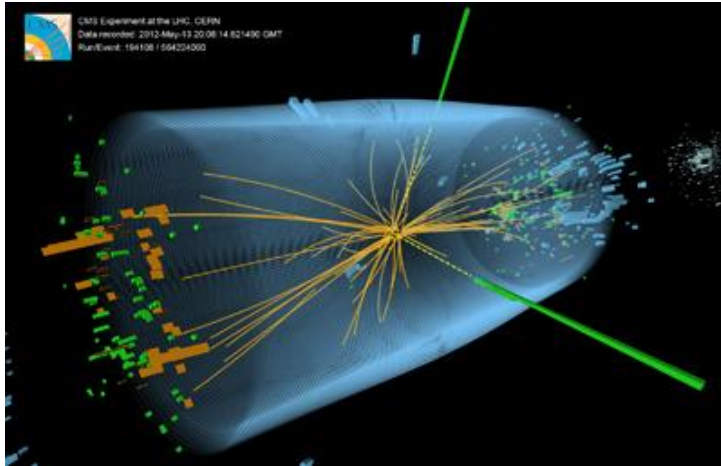
Discoveries of many of these particles have got Nobel prizes !

Discovery of the heaviest quark (TOP)



- Top quark: the last quark to be discovered
- Discovered at Fermilab (1995) in D0 experiment that TIFR was a part of.

Discovery of the Higgs particle



- Higgs was needed to give masses to electron, muon, quarks, ...
- TIFR was part of the CMS experiment at CERN that discovered Higgs !

What is this about the “God Particle”?

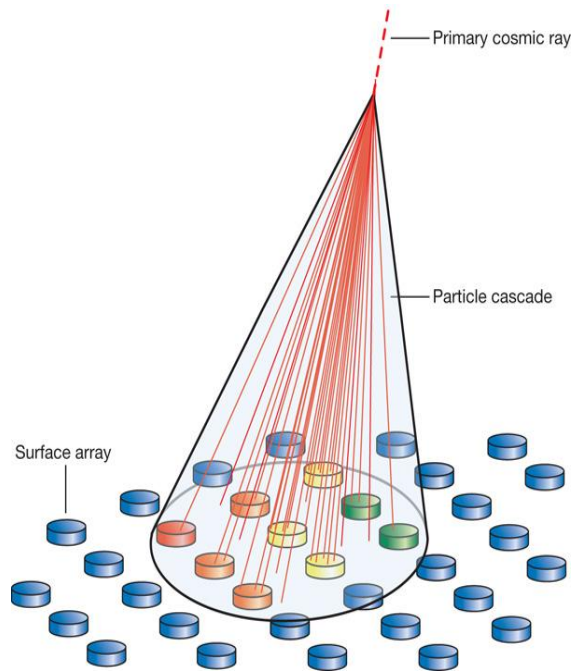
- When Higgs was not found for 30 years, experimentalists were getting frustrated, and Leon Lederman wrote a book about it, which he wanted to name “The Goddamn particle”
- The later story in Lederman’s own words:
“.. the publisher wouldn’t let us call it The Goddamn Particle, though that might be a more appropriate title, given its villainous nature and the expense it is causing.”
- The publisher changed the title to “The God particle”
- The book sold a lot of copies

Current particle physics activities in TIFR

TIFR मधील मूलकणांवरील चालू संशोधन

TIFR में चल रहा मूलकणों का अन्वेषण

Cosmic Rays



How cosmic ray showers are detected on earth

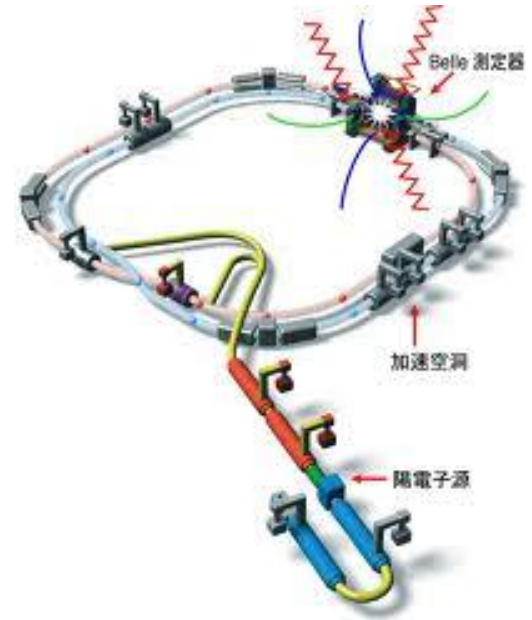
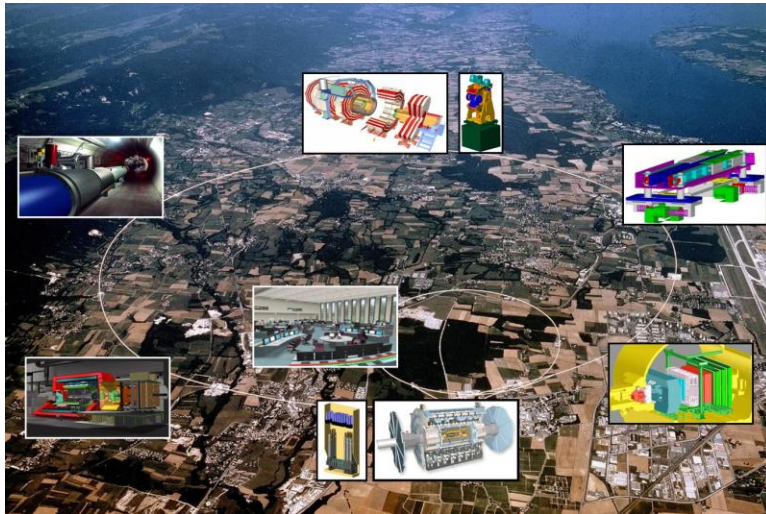


Hanle, Ladakh



GRAPES-3, Ooty

Particle colliders and accelerators



CERN, Geneva and various particle physics experiments

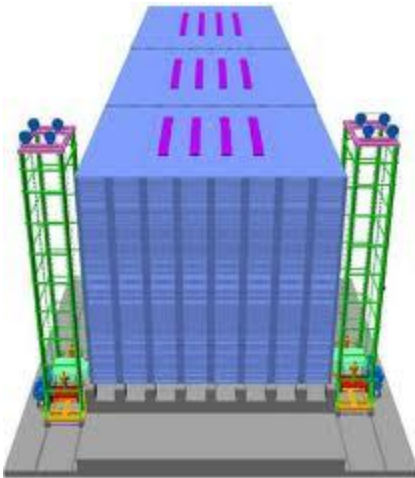
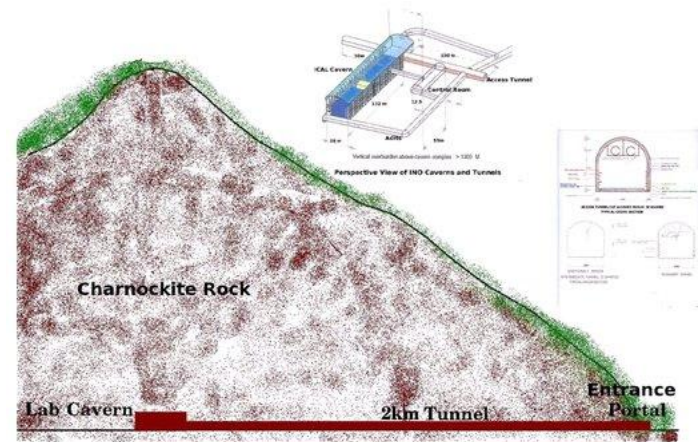
プロトン → ← プロトン

Belle experiment in Japan

इलेक्ट्रॉन → ← पॉज़िट्रॉन

Neutrinos

India-based Neutrino Observatory (INO)



- Inside a mountain near Madurai
- The largest detector of its kind in the world

Contribution of all of us...

आपला सर्वांचा सहभाग

हम सब का योगदान ...

ज्ञानदेवे रचिला पाया, उभारिले देवालया
नामा तयाचा किंकर, तेणें केला विस्तार
जनार्दन एकनाथ, खांब दिला भागवत
भजन करा सावकाश, तुका झालासे कळस
- बहिणाबाई (वारकरी चळवळीबद्दल)

Gyandev laid the foundation
Namdev expanded its scope
Ekanath provided the pillars
Tukaram became the pinnacle

- Bahinabai (about the Vaarkari movement)

Though the names of ज्ञानबा-तुकाराम , the founder and the
pinnacle, get chanted, the contribution of those providing
the supporting role is equally crucial.

Final remarks

- The success and achievements of TIFR so far have been due to the contribution of all of us, whether academics, scientists, administration, support staff, students, ...
- The success of TIFR is the success of all of us.
- All of us therefore should be proud of the achievements of TIFR, and help each other to raise it to greater heights.
- That is what the Founder would have expected from us !