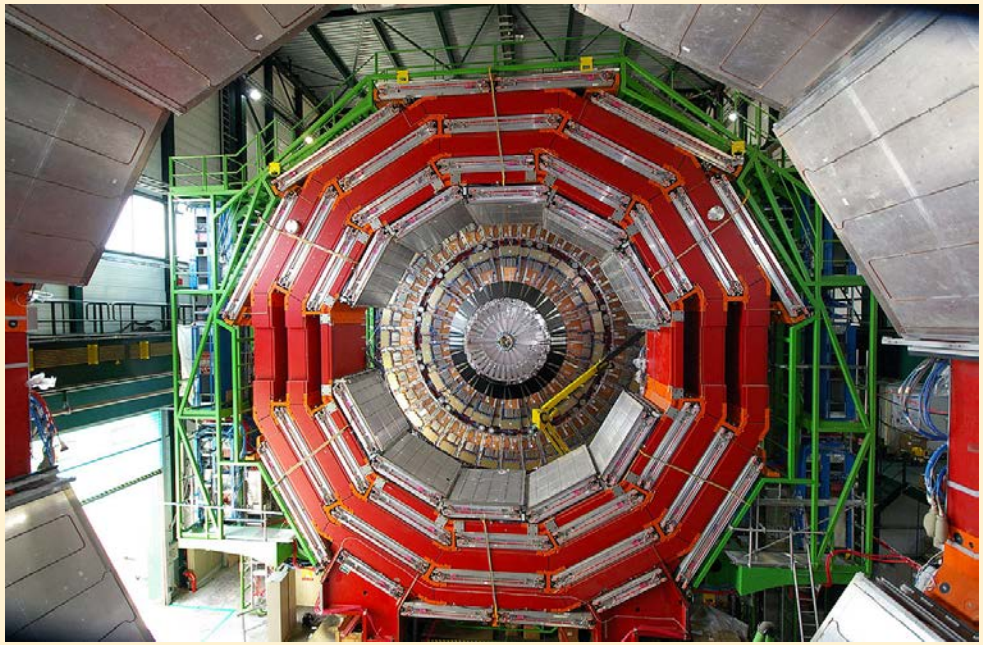
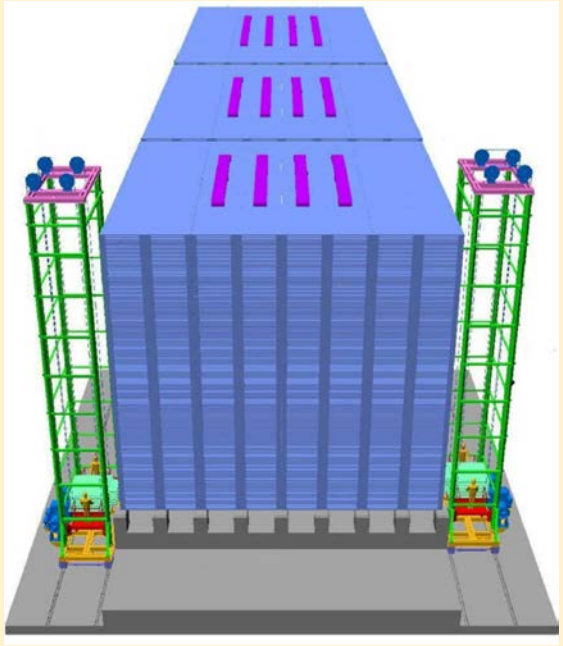
Science in India in the era of mega-projects:

Large projects in High-Energy Physics





Sunil Mukhi
IISER Pune

INSA Anniversary Meeting
IISER Pune, 28 December 2017

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1. High-energy physics: goals

- HEP: Study of fundamental and composite particles (CMS, Atlas, LHCb at LHC, Neutrino Expts).
- Also hot, dense matter like quark-gluon plasma (RHIC, Alice at LHC).
- Goals: to discover and study the ultimate constituents of matter and their bound states.
- Also to study “laboratory big-bangs”.

1. High-energy physics: goals

- Relativity equation $E=mc^2$ means that producing heavy particles requires very high energy (rare, light particles also).
- Accelerators therefore tend to be big (27 km!) and expensive. Thus, require multi-country financing and scientist/staff support.

1. High-energy physics: goals

- One exception: neutrinos. They are light and abundant in cosmic rays and reactors.
- We want to detect them and study their properties. Since they interact weakly, this requires large detectors (50-100 kilotons).

1000-2000 ×

1. High-energy physics: goals

The key pure science goals:

- Dark matter
- Matter-antimatter asymmetry
- Neutrino masses and mixing
- The hierarchy problem and its resolution (supersymmetry, extra dimensions?)
- Higgs sector
- Anything we didn't think of so far.

1. High-energy physics: goals

4-fold collateral benefit of HEP experiments:

- Theory: Stimulate us to develop theoretical tools.
- Detector development: deploy and create new expertise in advanced materials and electronics.
- Accelerator science: stimulates precision engineering.
- Big data, machine learning: bring about development of new tools and techniques.

2. India's history with HEP experiments

- Though he was a theorist, Homi Bhabha led India into experimental HEP research.
- Kolar Gold Fields: First detection of cosmic-ray neutrinos.

DETECTION OF MUONS PRODUCED BY COSMIC RAY NEUTRINOS DEEP UNDERGROUND

C. V. ACHAR, M. G. K. MENON, V. S. NARASIMHAM, P. V. RAMANA MURTHY and B. V. SREEKANTAN,
Tata Institute of Fundamental Research, Colaba, Bombay

K. HINOTANI and S. MIYAKE,
Osaka City University, Osaka, Japan

D. R. CREED, J. L. OSBORNE, J. B. M. PATTISON and A. W. WOLFENDALE
University of Durham, Durham, U.K.

Received 12 July 1965

2. India's history with HEP experiments

In the past:

- Proton decay experiment at KGF (1984-86).
- L3 experiment at LEP, CERN (1989-2000).
- D0 experiment at Fermilab, USA.
- Belle, KEK, Japan (ongoing).

3. Current HEP projects involving India

CMS at the Large Hadron Collider, CERN (16 institutes = 5 “old” members + 11 joined more recently)

Alice at the Large Hadron Collider, CERN

RHIC at Brookhaven National Lab, USA

Belle II, KEK, Japan

INO: India-based Neutrino Observatory (unique project of domestic origin and location).

3. Current HEP projects involving India

Governmental support for some HEP mega-projects:

- CMS Collaboration, CERN: Rs 80 cr for five years (13 institutions).
- Associate membership of CERN (from January 2017): Rs. 40 crore per year.

"Indian industry will be entitled to bid for CERN contracts, which will allow it to work in areas of advanced technology. So the "Make in India" will get a boost due to CERN"

-- Dr Shekhar Basu, Chairman DAE

- INO: Rs 1500 crore (based on 2015 completion).

3. Current HEP projects involving India

INO timeline:

1989: INO conceived in informal discussions.

2000-2001: Discussed in meetings and conferences.

2002: Formal proposal to DAE, MOU signed among participating institutes.

2009: Ministry denies permission for site on environmental grounds. Suggests new site.

2010: Environmental clearance for new site obtained from Ministry of Environment and Forests.

2012: Land allocated, project due to start and be completed by 2015.

3. Current HEP projects involving India

2012-2017: Stalled due to environmental challenges (including allegedly dangerous radiation due to neutrinos!).

2015-2017: Clearance from Tamil Nadu Pollution Control Board is pending.

November 29 2017: PM Modi assigns cabinet secretary P.K. Sinha to monitor INO. Also suggests its name be changed.

Contrasting picture: Daya Bay, International project based in China (250 scientists from 39 institutes).

2004: Ideas

2006: Proposal.

2007: Construction started.

2012: Key result published (measurement of the neutrino mixing parameter θ_{13}).

2016: Among the winners of Breakthrough Prize in physics.

Observation of electron-antineutrino disappearance at Daya Bay
Daya Bay Collaboration (F.P. An (Beijing, Inst. High Energy Phys.) *et al.*). Mar 2012.
Published in **Phys.Rev.Lett. 108 (2012) 171803**
DOI: 10.1103/PhysRevLett.108.171803
e-Print: **arXiv:1203.1669 [hep-ex]** | PDF

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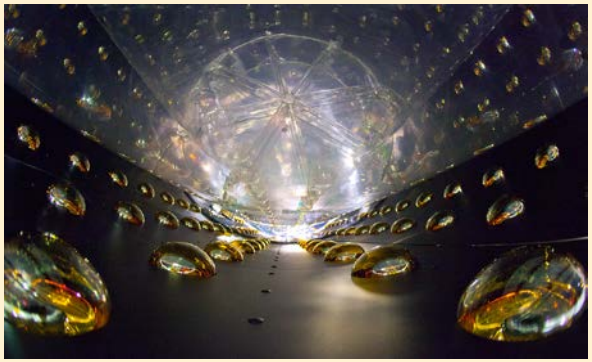
ADS Abstract Service; OSTI Information Bridge Server; Interactions.org article; I

Detailed record - Cited by 1856 records 1000+



4. Looking forward

Number of institutes in India involved in HEP experiments has grown rapidly in the last decade.

NISER, IISER Pune, IIT Chennai, IISc, IOPB, IIT Bhubaneswar, Khalsa College Punjab… Interest from University of Hyderabad, some IIT's …

High schools can now get talks by faculty from their neighbouring institutes – plays an important role in attracting students to science!

4. Looking forward

- With a larger national involvement, we would be able to effectively support multiple themes within HEP.
- Enormous enthusiasm from young students to be involved in HEP mega-projects. On the other side, enormous need for human resource. A perfect match?
- But today, the enthusiasm is nowhere near being harnessed! Most IISER's, IIT's, Universities have no presence in HEP. Very unfortunate, why?

4. Looking forward

Perhaps there are some misconceptions among our science leaders:

- Questions regarding science goals of HEP.
- Skepticism regarding social benefit of HEP.
- Concern about special culture of HEP (mega-papers, travel needs).
- But we are scientists: all these questions have answers.

Y.P. Viyogi, "Sociology of large scientific collaborations", Current Science, Vol.99, No.7, 890, 2010.

Sunil Mukhi, "Diversity of the science ecosystem", Current Science, Vol.105, No.7, 2013.

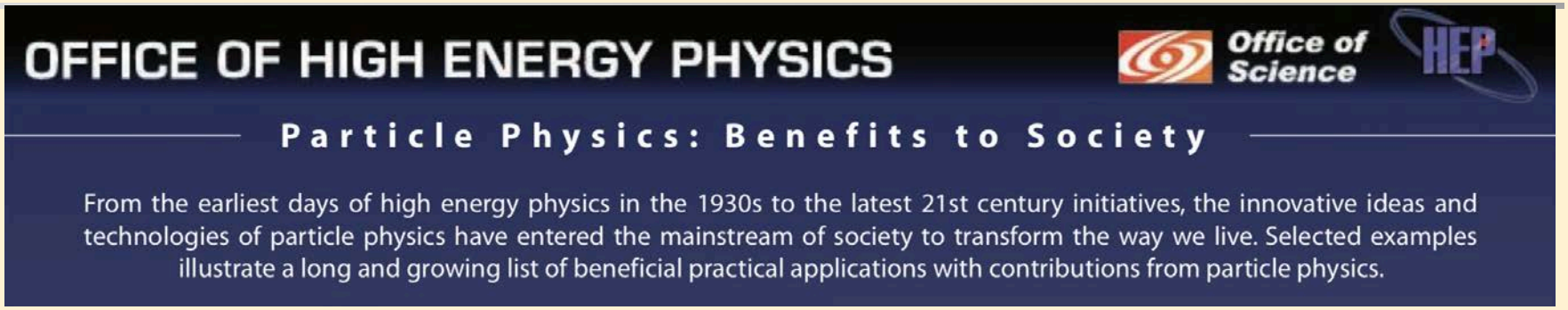
5. Concluding remarks

- HEP mega-projects have led to dramatic understanding of the fundamental constituents of matter: neutrinos, heavy leptons, quarks, W and Z bosons, Higgs.
- They have led to life-changing improvements to society: World-Wide Web!

Even CERN did not appreciate its importance! In 1992 the Computing and Networking Dept decided that creating a "facility to exchange information within the scientific community" was "not the core activity of CERN and was a misallocation of CERN's IT resources".

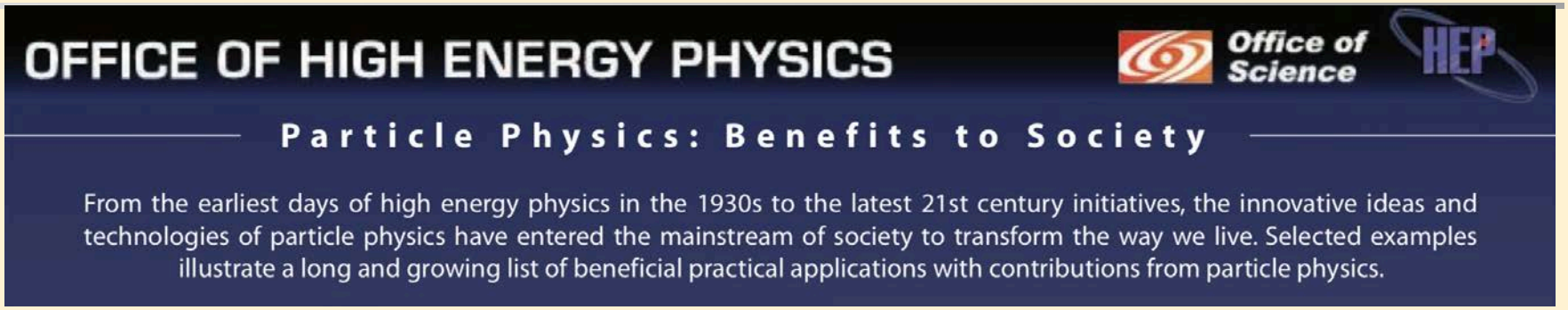
Following this decision, Tim Berners-Lee left CERN for MIT.

5. Concluding remarks



- Medicine: cancer therapy, diagnostic instrumentation.
- Security: nuclear waste monitoring.
- Industry: power transmission.
- Industry: biomedicine and drug development.
- Industry: understanding turbulence.
- Computing: World Wide Web
- Computing: the Grid
- Science: Synchrotron light sources

5. Concluding remarks



"Medicine: diagnostic instrumentation

Particle detectors first developed for particle physics are now ubiquitous in medical imaging. Positron emission tomography, the technology of PET scans, came directly from detectors initially designed for particle physics experiments sensing individual photons of light."

5. Concluding remarks

India is well-placed to make key contributions to the great discoveries that will certainly happen in the next few decades.

These contributions will go into journals and then into history books. Via industry, they will change the lives of ordinary Indians.

The activities are ongoing and supported, but greater institutional involvement (=hiring faculty) is crucial at this stage.

Thank you