Department of High Energy Physics

Sudeshna Banerjee

Annual Meeting

May 8, 2018

DHEP Strength

- Academic – 11 Scientific Officers – 45
- Students – 20 Total strength > 100

- Field stations – Hanle, Gauribidanur, Madurai, Ooty
- Foreign Collaborations – CERN (CMS), Fermilab (D0), KEK (BELLE)
- Collaborations with many neighboring engineering colleges (Skill Development)

Physics with High Energy Particles

Particles need to be accelerated

Man made accelerators

Synchrotrons

Several on earth

Natural Accelerators

Cosmic rays

Several in the sky

Cutting Edge Technology

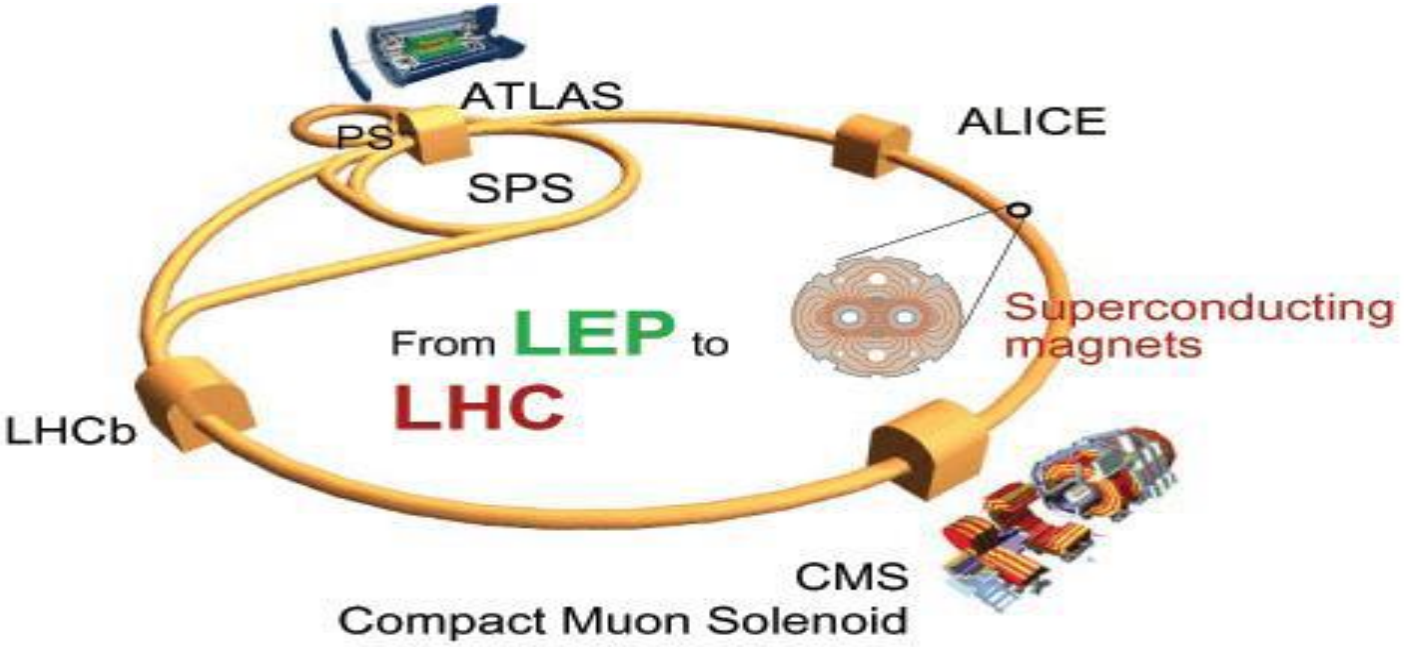
- Analog Electronics
- Digital Electronics
- Embedded Systems
- Firmware Development
- Parallel Computing
- Machine Learning
- Computing Grids

Mechanical Skills – DHEP workshop

The Large Hadron Collider (LHC, CERN)

(Geneva, Switzerland)

T. Aziz, S. Banerjee, S.R. Dugad, M. Guchait, G. Majumder, K. Mazumdar, G.B. Mohanty etal.

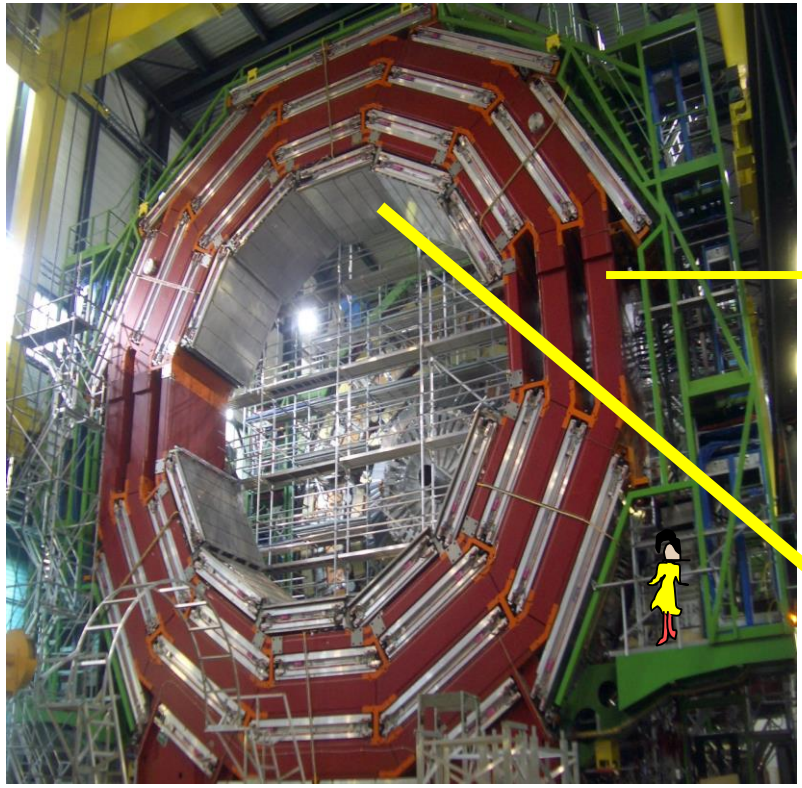


LHC project: model for large scale international scientific collaboration.
Conceived in late 80's, data since 2009, will continue till 2030's (many upgrades planned)
→ **TIFR is participating in full force**

Run1: 2009-2013 → Highlight: Higgs discovery in 2012, Physics Nobel prize in 2013 to theory, BreakThrough prize in 2013 to CMS, ATLAS experimentalists.
Run2: 2015-2018: TIFR participating in physics, hardware, computing
Successful data collection in 2016, 2017. 2018 just starting → Interesting physics results coming…

CMS Detector – Hadron Outer Calorimeter

Built in TIFR ~2000



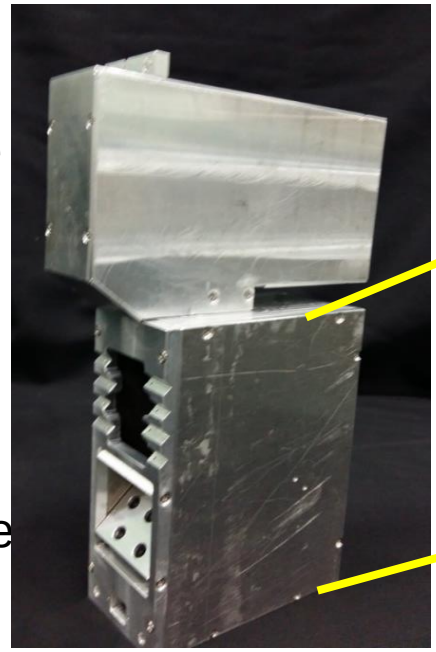
Iron Return Yoke

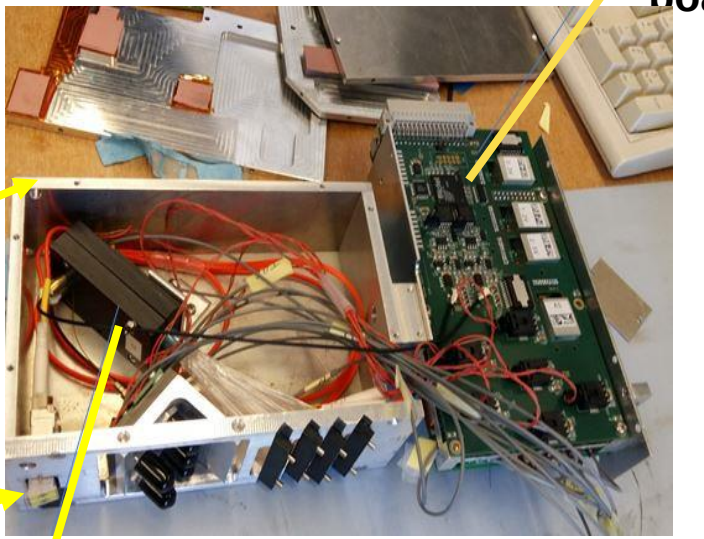
Scintillator counte
built by India

Calibration Unit for Hadron Calorimeter ~2016

Monitor radiation damage

Mechanics of the Al CU Box
TIFR workshop





Pulser board

Light Mixer optics

Involving Indian industry

- **Participation in all aspects of physics.**
- **Data analyses towards: Standard model and beyond, QCD, underlying events, Higgs boson, Supersymmetry ….**

Observation of ttH by CMS

Physicists Find Elusive Particle Seen as Key to the Universe

By DENNIS OVERBYE 8:18 PM ET

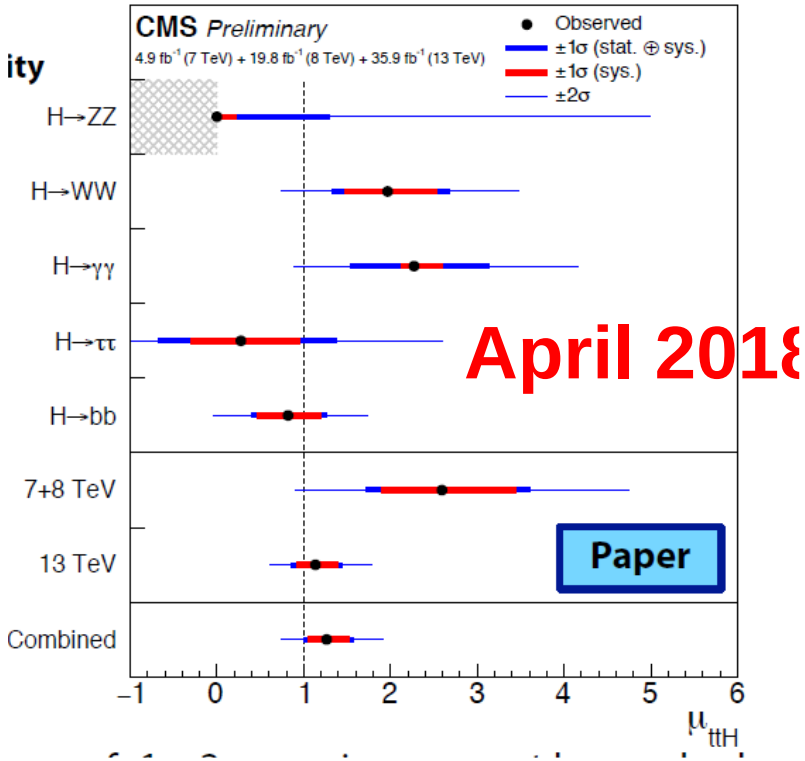
Researchers said they had discovered what looked for all the world like the Higgs boson, a long-sought particle that

Higgs boson * bosons, fermions

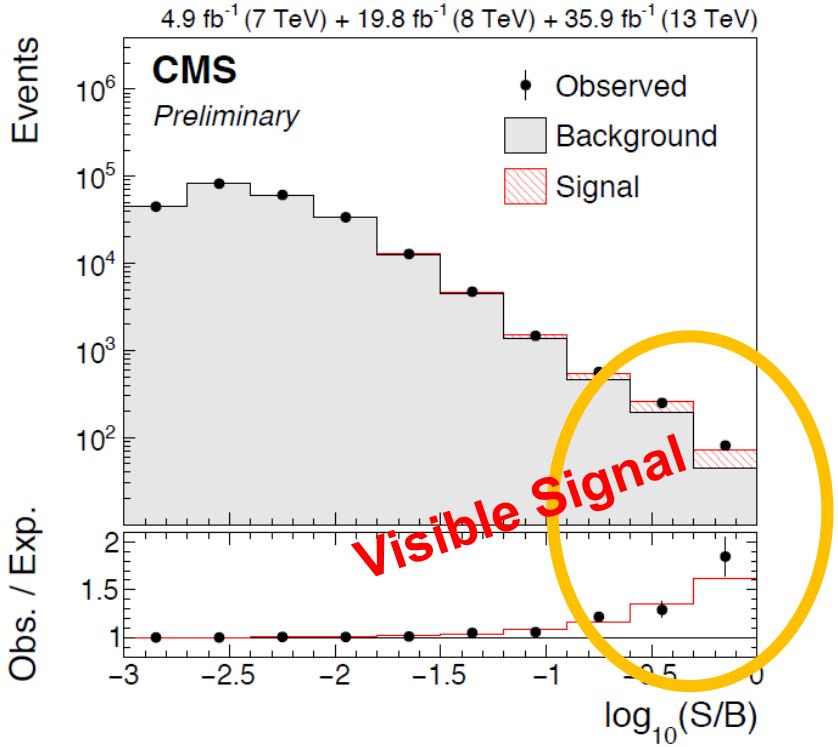
Higgs boson * W, Z, τ, b, μ, t ??

here: $\kappa_{F,i} = v\frac{m^{\epsilon}_{F,i}}{M^{1+\epsilon}}$ $\kappa_{V,i} = v\frac{m^{2\epsilon}_{V,i}}{M^{1+2\epsilon}}$

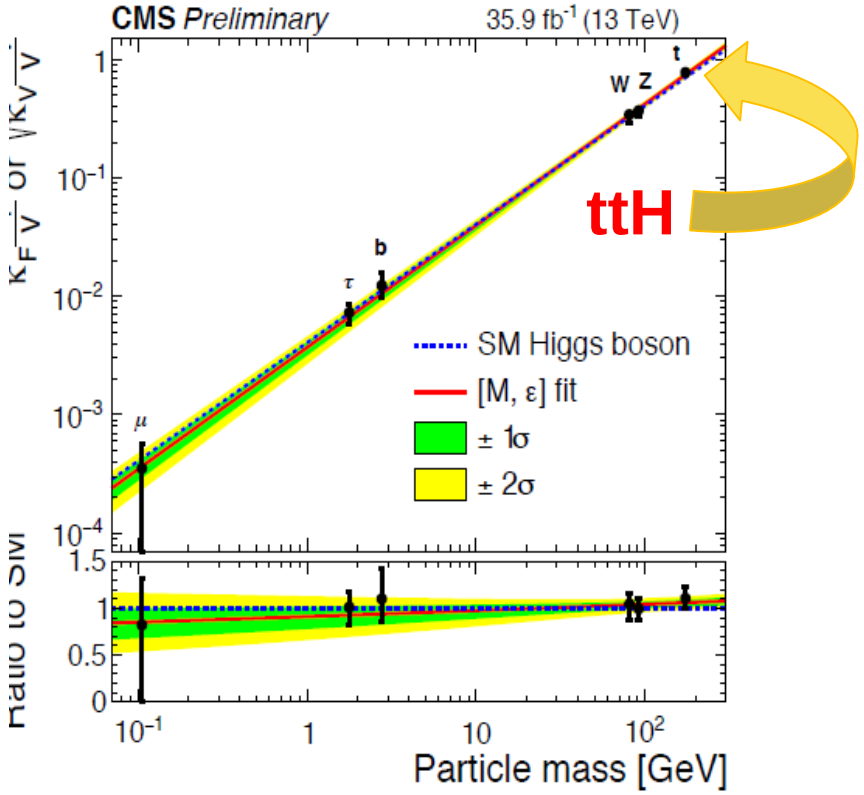
$$\mu_{t\bar{t}H} = 1.26^{+0.31}_{-0.26} = 1.26^{+0.16}_{-0.16}(\text{stat})^{+0.17}_{-0.15}(\text{expt})^{+0.14}_{-0.13}(\text{bkg th})^{+0.15}_{-0.07}(\text{sig th})$$



April 201



Visible Signal



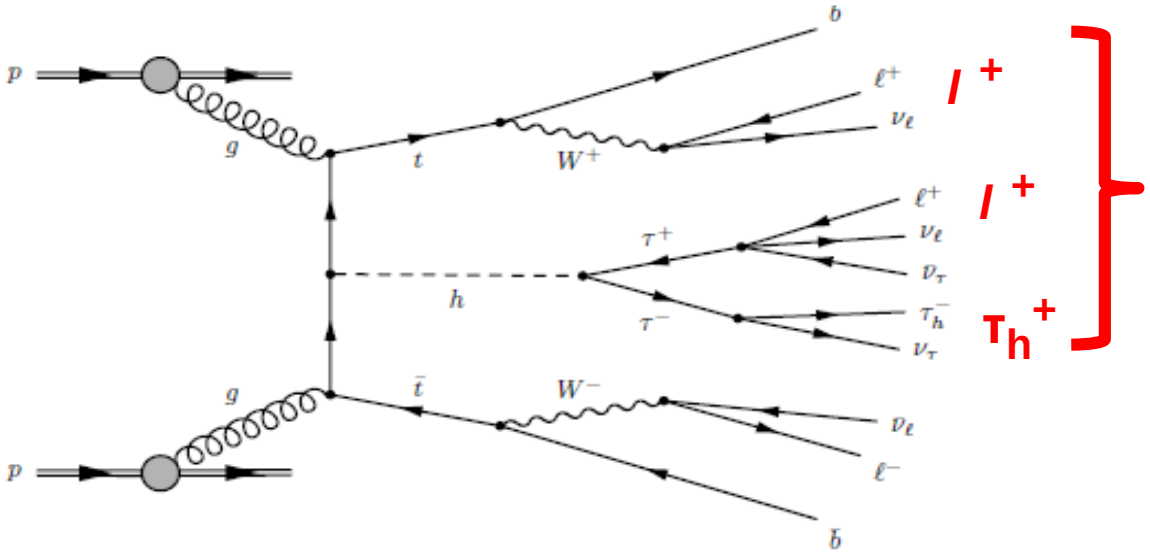
ttH

ttH production with 5.2σ significance -> combination of Run-1 (7, 8 TeV) and Run-2 (13 TeV) analyses

Sudeshna Banerjee,
Saikat Karmakar,
Siddhesh Sawant

Search for ttH production in CMS by TIFR

- Plan: Working on 2017 data, continue with 2018 data
- Complete legacy analysis 2016 + 2017 + 2018 data



l^+
l^+
τ_h^+

l^+
τ_h^-
τ_h^+
l^-

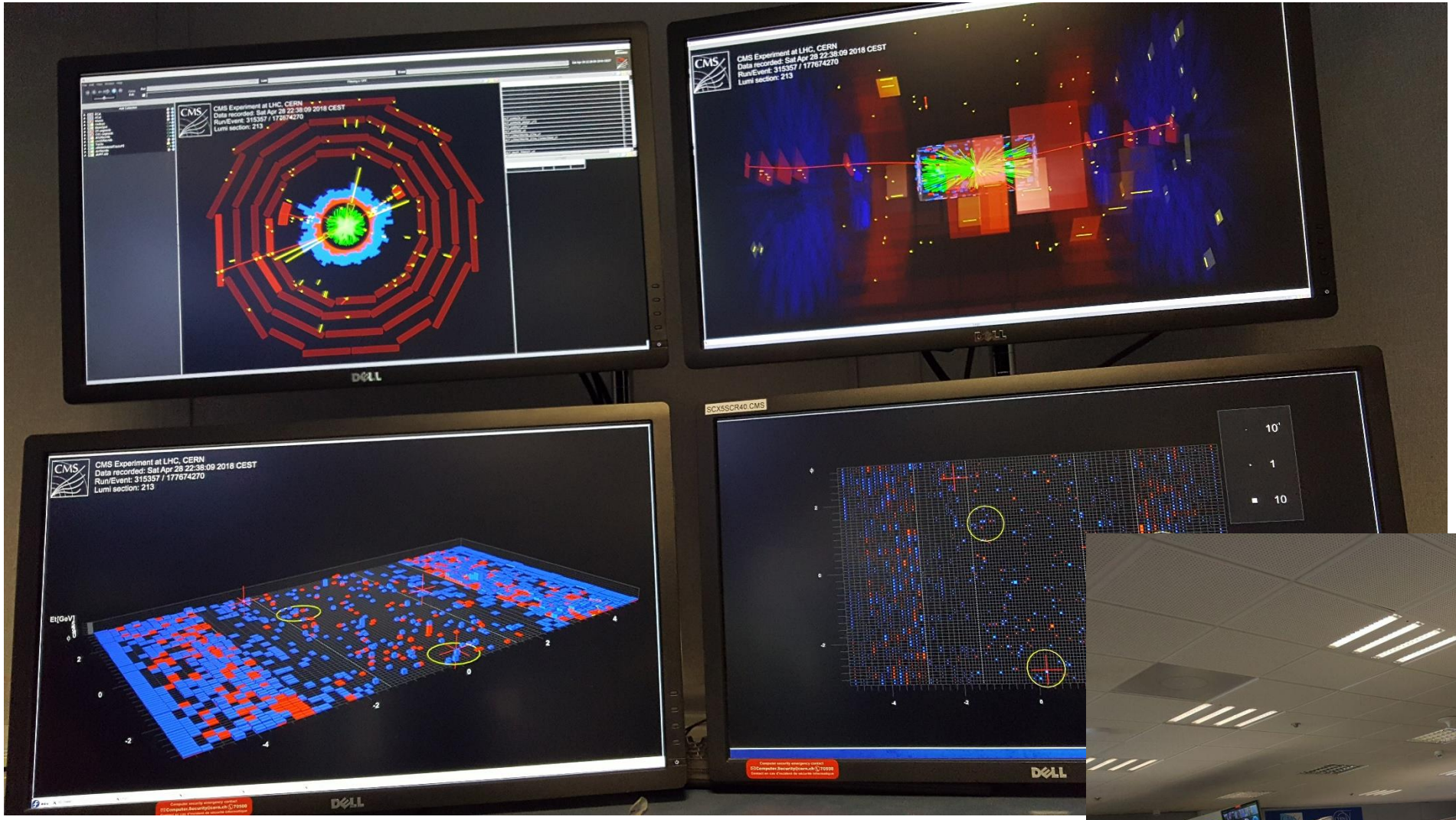
2 same sign leptons (electron or muon) + 1 τ_h

2 leptons (electron or muon) + 2 τ_h

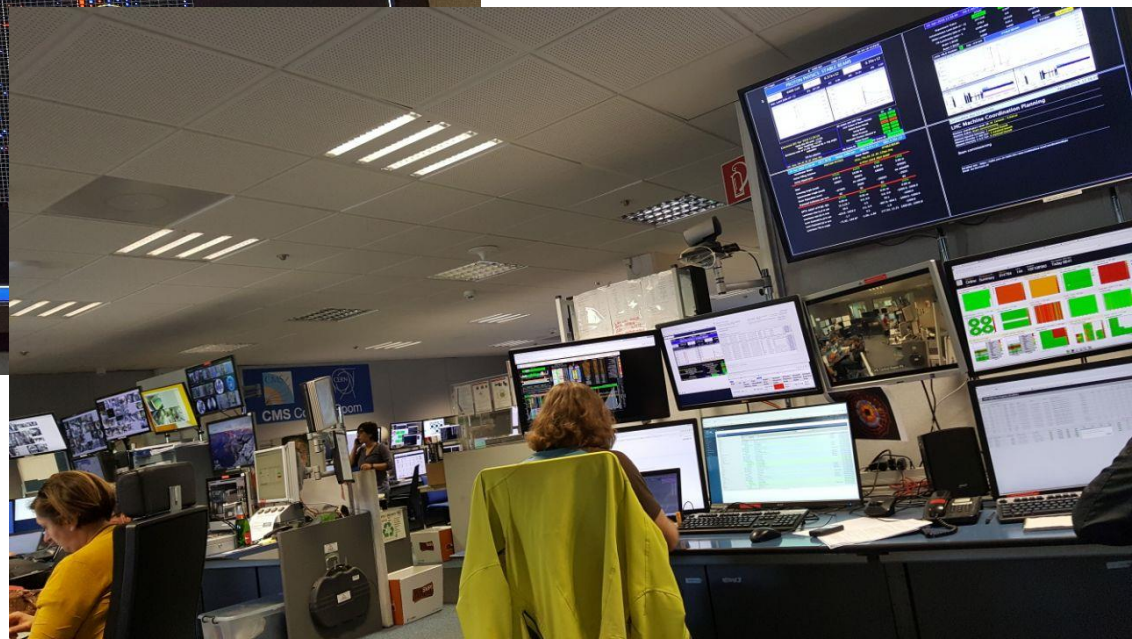
Particle identification is important in general: electrons, muons, jets, missing energy
Specifically: bottom quark tagging – Methods are well established, ~70% efficiency
More recently: top quark tagging - Developing

We are studying the matching of reconstructed jets of radius 0.4 to 1.5 to simulated top quarks to develop the best matching conditions

CMS Event Display



April 29, 2018



CMS Control Room

India-CMS Tier 2 LHC grid computing center at TIFR

Location → **CG-17**

- National contribution to CMS international collaboration at LHC
- Average availability and reliability: ~ 97%
- One of the largest T2 centres (out of 50 world -wide) for the CMS experiment
- One of the earliest T2 centres in Asian region , active since 2008
- Crucial contribution for Higgs discovery in 2012.

- Two commissioned sites for CMS central computing
  - **T2_IN_TIFR**
  - Dynamic resources site – **T3_IN_TIFRCloud,** Public Cloud ISPs since 2017
- Tier3 site for analysis **~ 100 active users from collaborating Indian Institutes connected via NKN-TIFR-LHCONE Peering**

T2 Resources:	CPU (cores)	Storage (PB)
2017-2018:	2.5k → 3k	3.2 → 5.2
T3:	100	250 TB

Dedicated link to CERN: 10 Gbps
+ shared connectivity via NKN

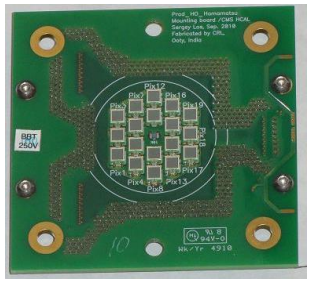
Silicon Photomultiplier Activities

Upgrade of HO Detector with SiPM

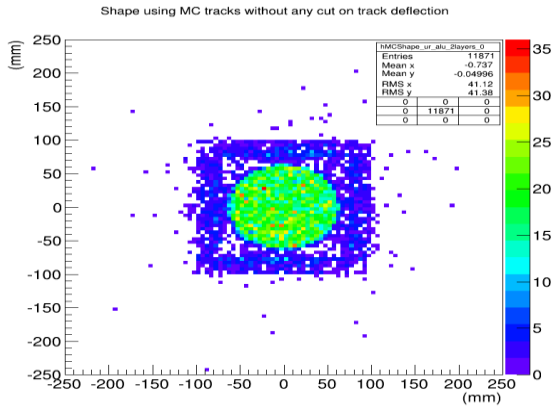
- **Validation of SiPM for CMS environment**
  - Testbeam studies, stability, radiation hardness, magnetic field immunity, and saturation effects
- **Fabrication of 160 SiPM Control Boards at CRL, Ooty, India**
  - Each board has 18 Channels
  - Control boards provides generates bias voltage for each channel, monitors current, temperature etc.
  - Entire production and quality control of 160 boards to be carried by Indian group in India
- **Quality Control of Control Boards and SiPM Boards (160+160) at India:**
  - Setting up stand-alone DAQ system for Control and SiPM boards
  - Development of software for QC Data Analysis
  - Generating QC report for each board
- **Installation and Commissioning:**
  - Removal of 132 Readout Modules, Assembly of Readout Modules, QC and burn-in test at CERN, Installation of 132 Readout Modules
- **Project Leaders for Fabrication:**
  - ***Funded by TIFR, FNAL, DESY***

HO Readout Module Assembly

SiPM Control Board



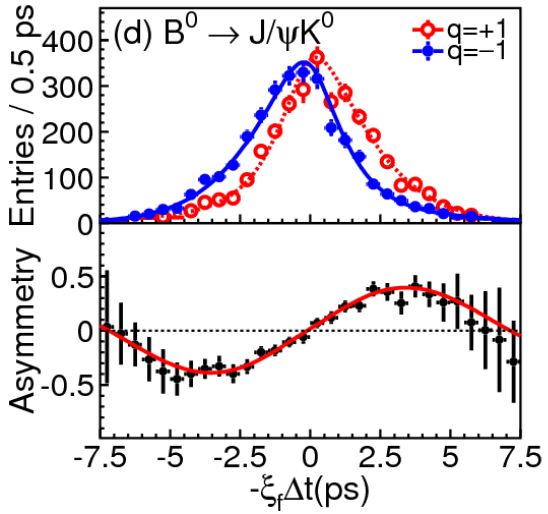
SiPM Mounting Board

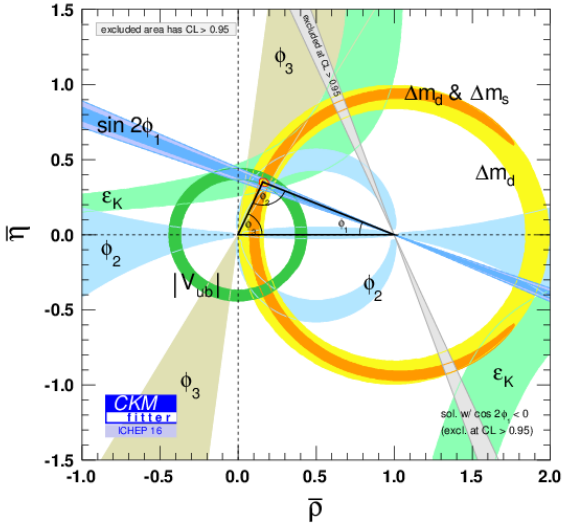


Belle and Belle II at KEK, Japan

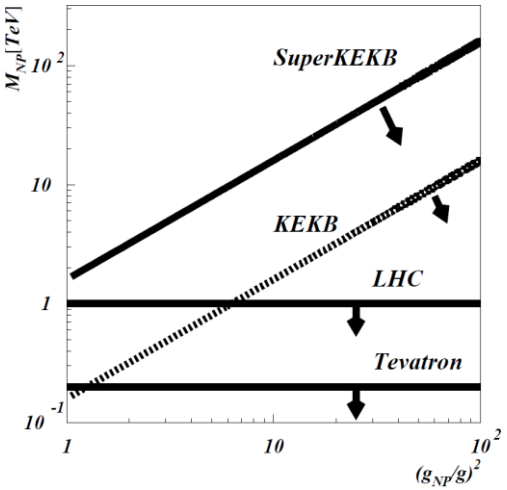
T. Aziz, G.B. Mohanty et al.

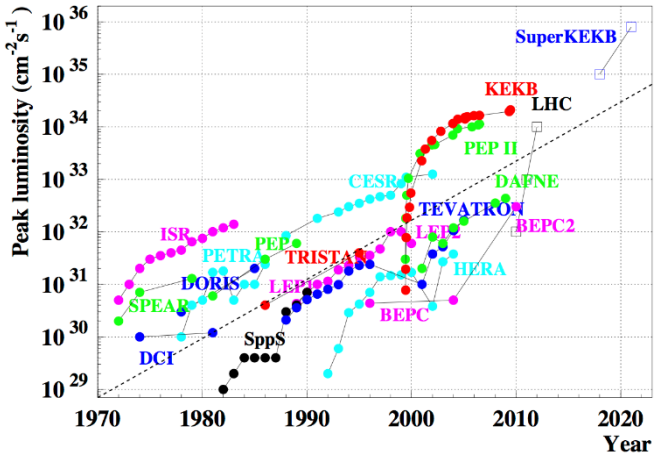
- Experimental verification of the mechanism for CP violation in the Standard Model
  - Led to the 2008 Physics Nobel Prize awarded to Kobayashi and Maskawa

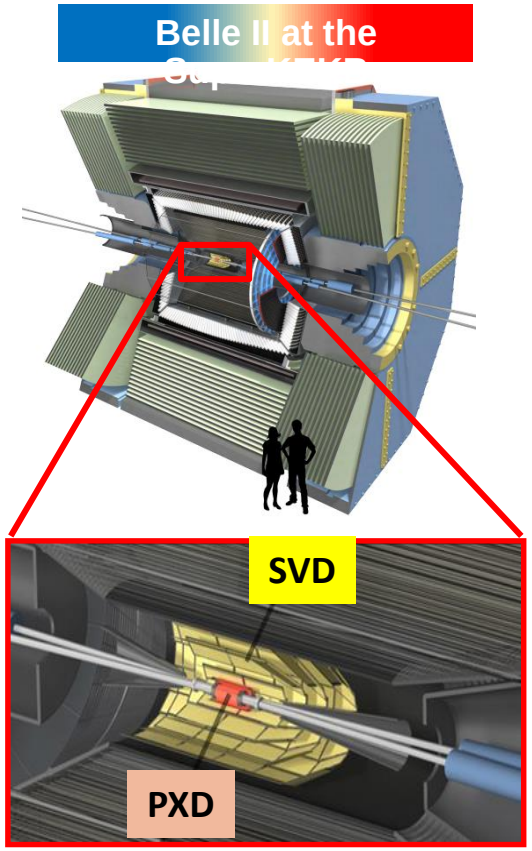




- Search for new physics using rare decays of beauty, charm mesons and tau leptons as an indirect probe complimentary to LHC







- Design, prototype and building one layer of the Silicon Vertex Detector (SVD)
  - Such sophisticated detectors are built for the first time in India

The GRAPES-3 Experiment at Ooty

S.K. Gupta, S.R. Dugad, P.K. Mohanty

Contents:

1) 400 plastic scintillator detectors

2) 560 m^2 muon detector (world's most sensitive)

Each detector component including high quality plastic scintillators and associated electronics developed in-house

Expansion of the muon detector

Challenging task of fabricating 3800 proportional counters for the muon detector has been achieved

and 90% of the counters have been installed in the field

Discovery of Transient weakening of Earth's magnetic shield

P.K. Mohanty et al., PRL, 117, 171101 (2016)

P.K. Mohanty et al., PRD, 97, 082001 (2018)

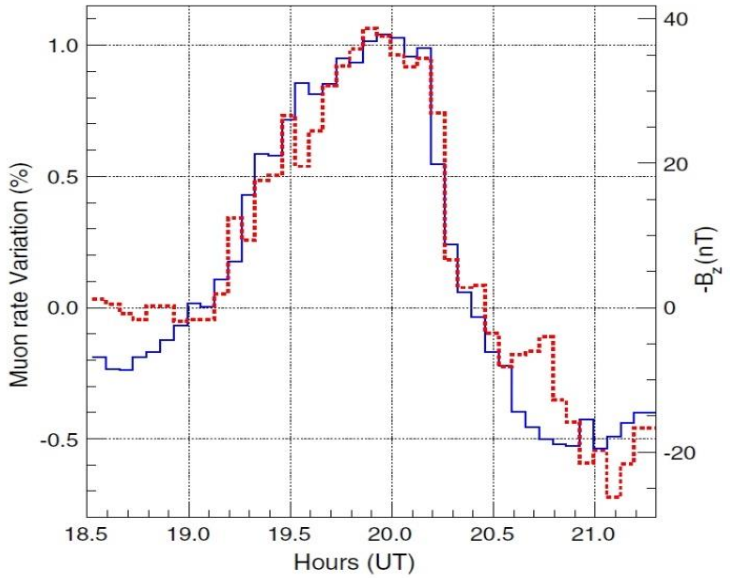


FIG. 2. Muon-rate (solid line) and $-B_z$ (broken line) on 22 June 2015, correlation coefficient $R = -0.94$.

21 publications from GRAPES-3 in international referred journals

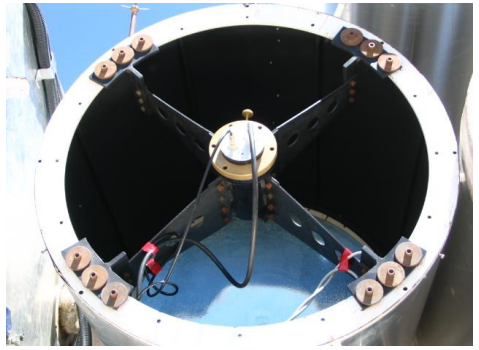
Future plans

1. Expansion of the scintillator array

2. Extraction of results on space weather, cosmic ray composition, cosmic ray anisotropy, diffuse gamma rays by exploiting the unique instrumental capability of the GRAPES-3

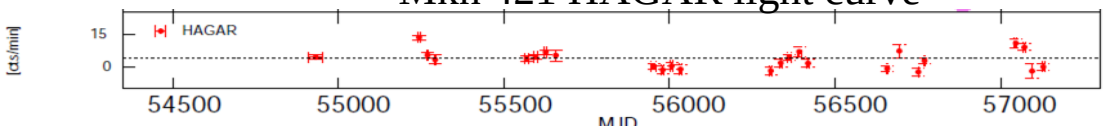
Ground-based Gamma-ray Astronomy at Hanle

V. Chitnis etal.

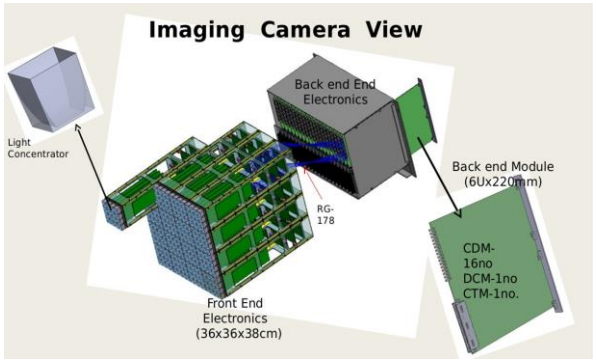


Installation during 2005-2008
Energy threshold ~ 210 GeV
Total observation duration
(Sept, 2008 – March, 2018) :
6000 Hours

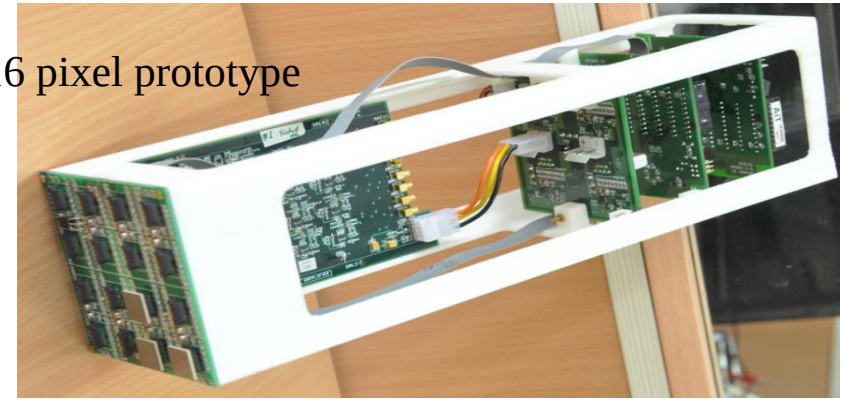
Mkn 421 HAGAR light curve



G-APD (SiPM) based imaging camera



16 pixel prototype



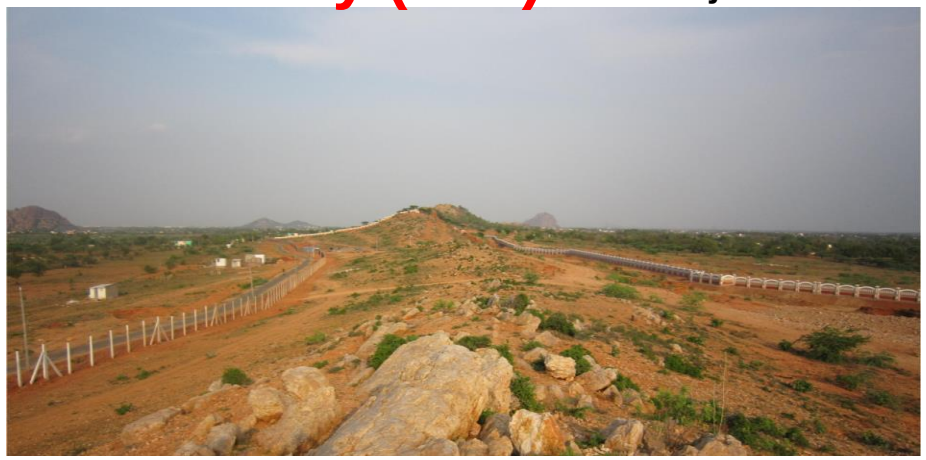
256 pixel imaging camera for 4m class telescope for monitoring bright blazars

India Based Neutrino Observatory (INO)

G. Majumder, S. Banerjee etal.

INO Sites

THE SITE: Bodi West hills at Pattipuram near Devaram in Theni district,



Inter-Institutional Centre for High Energy Physics (IICHEP), Madurai

The primary goal of INO is neutrino physics.

A national collaboration of scientists from about 25 groups belonging to DAE institutions, IITs and Universities.

The project includes:

- construction of an underground laboratory and associated surface facilities,
- construction of a Iron Calorimeter (ICAL) detector for neutrinos,
- setting up of Inter-Institutional Centre for High energy Physics (IICHEP).

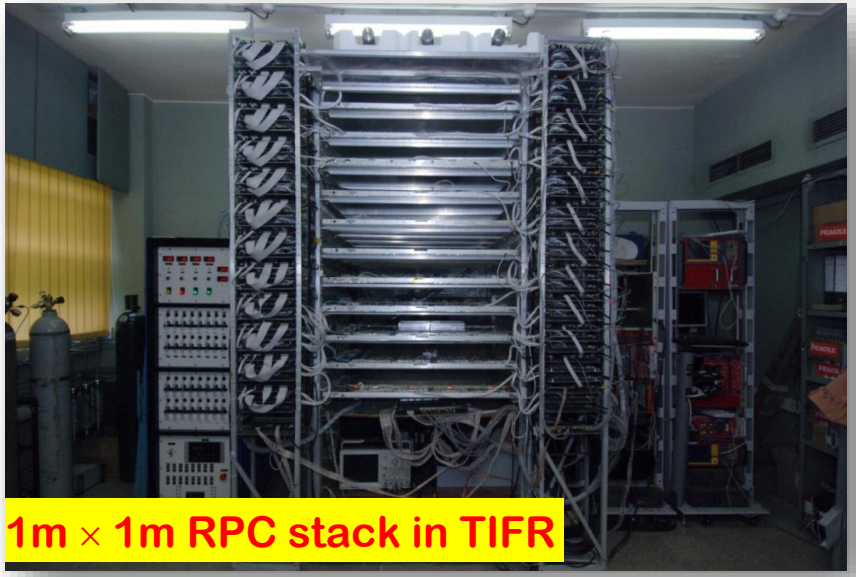
A successful INO-Industry interface developed because of the large scale of experimental science activity involved.

INO Graduate Training Programme under the umbrella of Homi Bhabha National Institute (HBNI) - is in its eighth year (30 Ph.D. students in Physics, detectors and electronics).

Mini ICAL (prototype) is currently being commissioned in Madurai

Study of Atmospheric Neutrinos

Prototyping of ICAL detector



1m × 1m RPC stack in TIFR

2m × 2m RPC test stand in TIFR

1m × 1m RPC stack in Madurai

1m × 1m RPC stack in VECC

Gravity and Fundamental Interactions

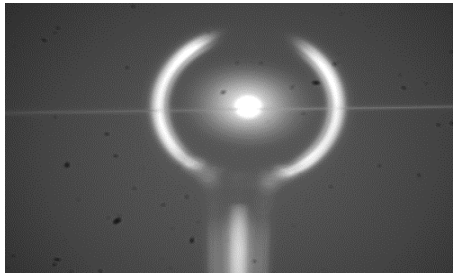
C.S. Unnikrishnan etal.

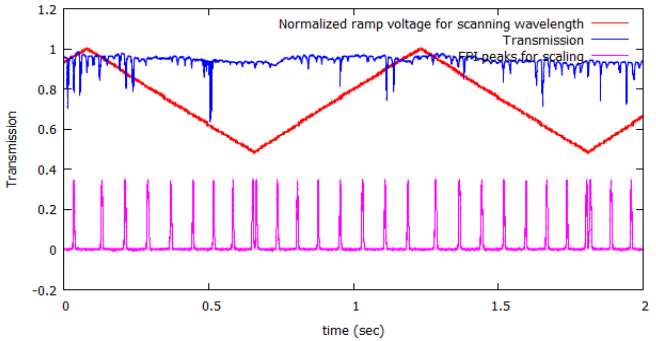
Recent Activities:

1. The exploration of Time Dependent Optical Cavities with very high finesse – (Thesis: Meenakshi Gaira)
2. A novel homodyne measurement of quantum optical noise WITHOUT a beam splitter to show that the "vacuum mode" is NOT essential for explaining results of such experiments - (Thesis: Ninad Jetty)
3. An Atom-Interferometer designed to measure rotation , gravity and acceleration (S. Sankaranarayanan – PDF)
4. Several results related to Cosmic Relativity – a theory of relativity and dynamics based on the gravity of the observed universe: (examples)
   a) The propagation of sound and light are IDENTICAL in nature -- Galilean.
   b) The derivation of COMPLETE motional relativistic effects in GPS clocks.
6. LSC: Several gravitational wave detections and discussions around papers (Shapiro delay, gravitational bending, LIGO-India science case)

Future (next 5 years):

1) LIGO-India instrumentation and Commissioning preparation support.
2) Atom Interferometers for gravity studies and Navigation applications (with RCI/DRDO)
3) Substantial progress in the problem of conflict between QED vacuum and Cosmology
4) Definite completion of Cosmic Relativity as an essential paradigm for relativity and dynamics (agrees with ALL known empirical results.)





Light from a 1 micron tapered fibre coupled to a silica microsphere. Resonances are seen (blue) as the wavelength is scanned.

Gravitation Experiments Group

N. Krishnan et al

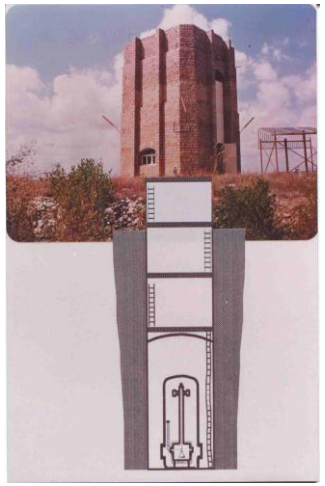
Experimental Study of Gravity as a Fundamental Interaction (Torsion Balance Experiments)

Questions that interest us:

Limits to validity of the Principle of Equivalence

Possible Violation of the Inverse Square law of Gravity at short length-scales

Existence of Fundamental Forces other than the 4 known ones



The unique **Gauribidanur Underground Laboratory**, schematically with a Torsion Balance in Ultra-high-vacuum chamber at base, 80 ft underground.

Our proven torque sensitivity < 10^{-17} Nm

Torsional Suspension for Eq. Pple Expt.
-- composite mass-bob (Lead-Copper) and mirror for angle-tracking.

"Mass Monopole / Compositional Dipole"

Examples of Technology Development in various areas:

Large Volume Active Temperature Control (sub-Millidegree C over days in 30 m^3 volume);
Autocollimating Optical Lever (sub-Nanoradian sensitivity);
UHV Wire-gasket Seals (good for 10^{-9} mbar) – cold welding process honed in-house

Future

Every group in DHEP is gearing up towards the future with more sophisticated hardware, software and analysis:

1. CMS experiment is about to undergo a major upgrade. TIFR is planning to participate in the new Hadron Calorimeter and the Trigger system. This participation includes hardware, firmware and software.
2. The HAGAR group are working hard towards the construction of a G-APD camera. They will soon have a prototype.
3. The Belle experiment is almost done with their tracker upgrade. They are currently waiting for beam (early 2019), so that they can commission the detector and collect physics data.
4. INO has started installation and commissioning of the miniICAL detector.
5. The gravitation group will participate in LIGO-India as soon as the activity starts.

DHEP is a department with great capabilities to build sophisticated hardware systems. Members are currently involved in several projects which require the construction of big and complicated detectors. This is leading to successful representation of TIFR and India in the world, as well as training young manpower in the country.
This is in parallel to the physics analyses with the current data which has already yielded many new results.