

Summary Talk

DHEP Annual Meet 2016

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Disclaimers

- 📖 Not exactly a summary of all talks
 - 📖 My own (theorist's) view of DHEP
 - 📖 Limited by my understanding
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- 📖 A perspective on what science we do
 - 📖 What issues we want to understand
 - 📖 What physics questions we try to solve
 - 📖 What our tools and approaches are

A unified aim

- 📦 Understanding elementary particles and fundamental interactions
- 📦 Trying to test, confirm and concretize our current knowledge of particle physics
- 📦 Looking for physics beyond our current understanding (Standard Model)
- 📦 Devising methods for probing the unknown
- 📦 Envisioning and executing experiments to test theories

Probing Fundamental interactions

 Strong interactions: CMS

 Electromagnetic interactions: CMS, GRAPES, HAGAR

 (All experiments use electromagnetic interactions as tools)

 Weak interactions: CMS, BELLE, INO

 Gravity: Gravitational waves, equivalence principle

Three approaches: 1/3

| Collider physics:

- ❏ Produce heavy unstable particles by producing and concentrating energy through collisions
- ❏ Study their properties, how fast they decay, how they decay, what they decay to.

- ❏ Energy frontier: p-p collisions at extremely high energies (~ 10 TeV) to directly produce heavy particles (CMS)
- ❏ Intensity frontier: e^+e^- collisions at relatively lower energies (~ 10 GeV), where indirect effects of heavy unknown particles may be observed (BELLE)

Three approaches: 2/3

Astroparticle Physics:

-  Gamma rays from astrophysical objects to learn astrophysical phenomena (HAGAR)
-  Muons produced from cosmic rays in Earth's atmosphere (GRAPES)
-  Neutrinos produced from cosmic rays in Earth's atmosphere (INO)
-  Try to detect gravitational waves from violent phenomena in the universe (LIGO)

Three approaches: 3/3

Precision experiments:

-  Cool atoms and use them for interferometry
-  Test equivalence principle by checking if gravity acts similarly on different objects (Gauribidanur)

Compact Muon Solenoid (CMS) experiment

ECAL 76k scintillating PbWO_4 crystals

HCAL scintillator & brass Interleaved

MUON ENDCAPS

473 Cathode Strip Chambers
432 Resistive Plate Chambers

3.8T Solenoid

IRON YOKE

Preshower
Si Strips $\sim 16 \text{ m}^2$

Forward Cal
Steel + quartz
Fibers

YB0

YB1-2

YE1-3

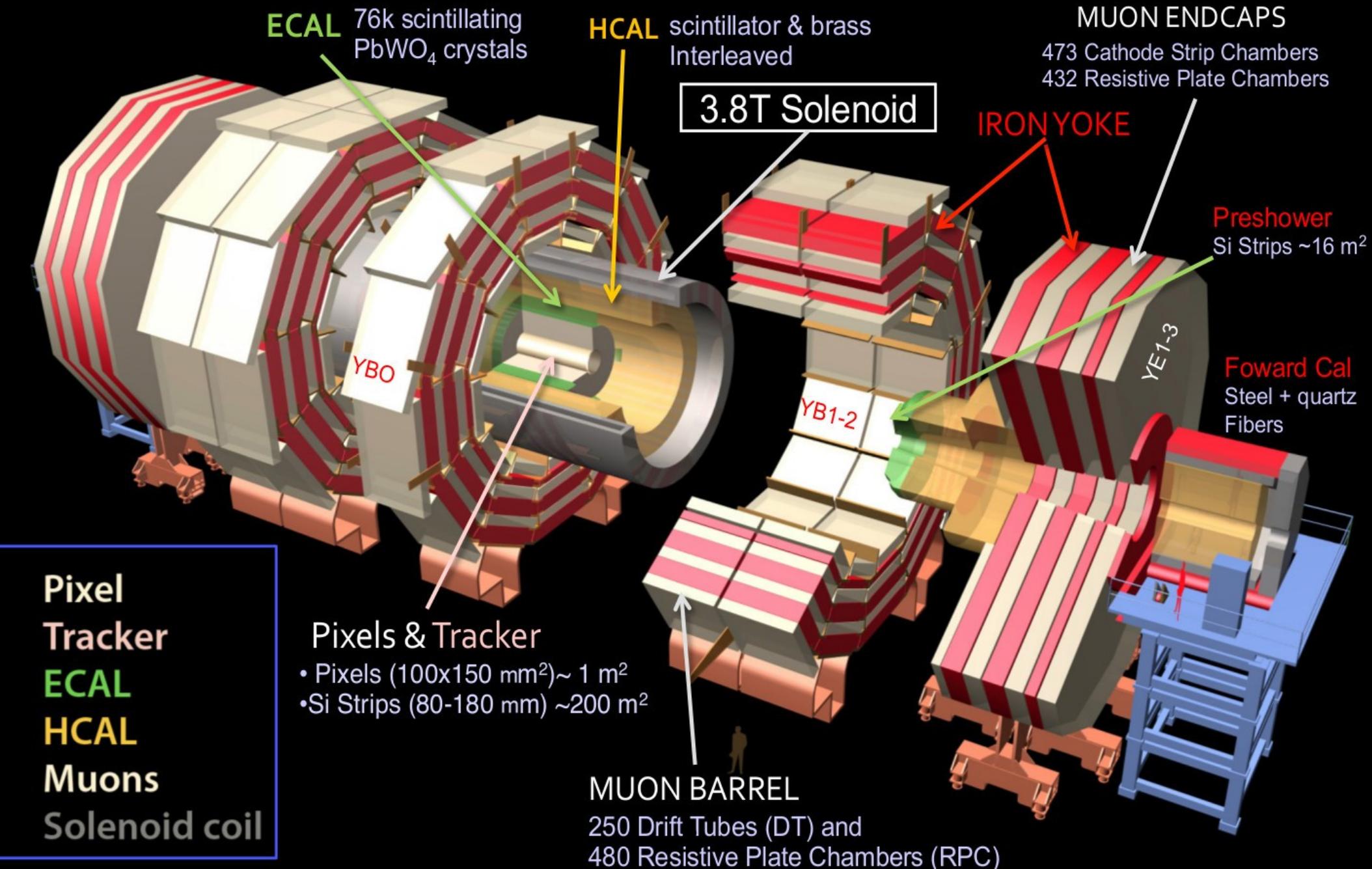
Pixel
Tracker
ECAL
HCAL
Muons
Solenoid coil

Pixels & Tracker

- Pixels ($100 \times 150 \text{ mm}^2$) $\sim 1 \text{ m}^2$
- Si Strips (80-180 mm) $\sim 200 \text{ m}^2$

MUON BARREL

250 Drift Tubes (DT) and
480 Resistive Plate Chambers (RPC)



CMS: physics objectives

- 📦 8 TeV -> 13 TeV proton-proton collisions: the largest energy accelerator so far
- 📦 Expected to produce new heavy particles
- 📦 Higgs: already found !
- 📦 Looking for exotic particles that are predicted under many scenarios: supersymmetry, extra dimensions, multiple Higgs, leptoquarks, ...
- 📦 A discovery machine.

CMS: physics analyses (SM)

- 📦 Drell-Yan mass spectra, inclusive events
- 📦 Inclusive W and Z production, Inclusive jets
- 📦 Constraining total width of Higgs
- 📦 Measurement of t-channel single top quark inclusive cross section
- 📦 $[W^+ + \text{jets} / W^- + \text{jets}]$ ratio as a function of p_T
- 📦 Search for charmonium-like Z states
- 📦 Measurements of p_T distribution of Z for parton distribution functions

CMS: physics analyses (BSM)

- 📦 Search for charged Higgs / heavy neutral Higgs
- 📦 Searches for SUSY / leptoquarks
- 📦 VBF production of charginos / neutralinos
- 📦 MSSM [higgs to $\tau\tau$] search
- 📦 Light Higgs boson in NMSSM
- 📦 Invisible Higgs, top squarks
- 📦 Supersymmetry searches with shape variables

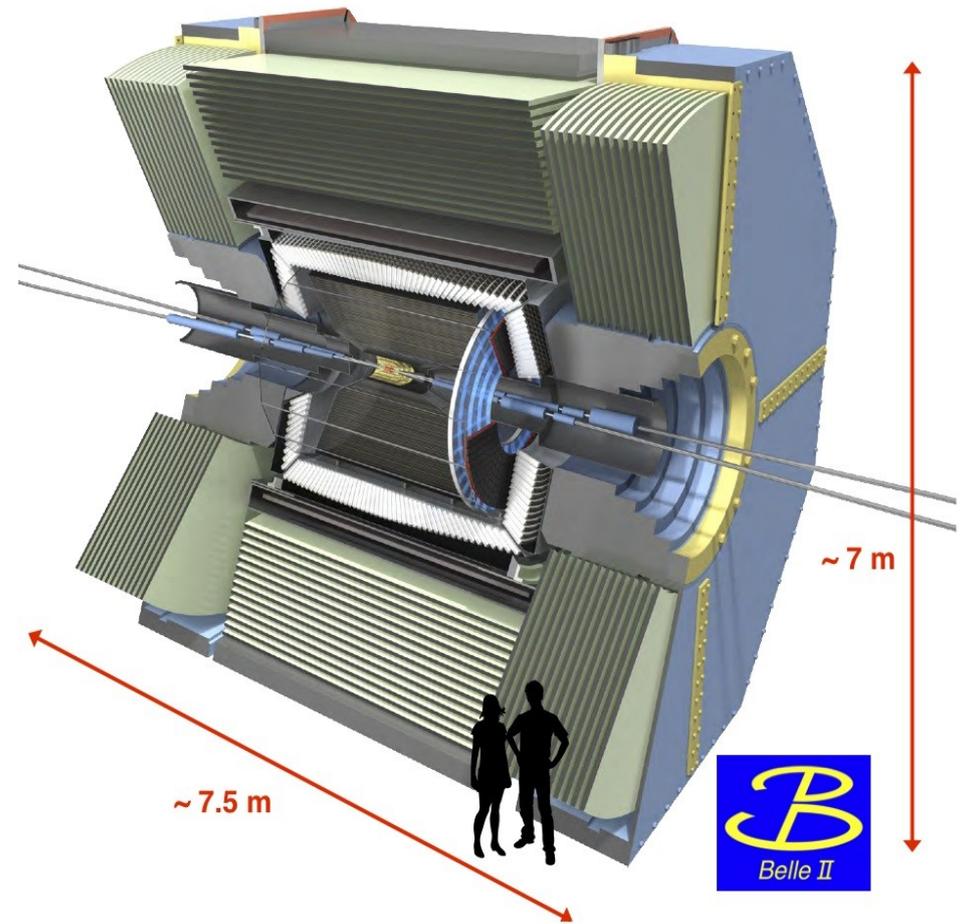
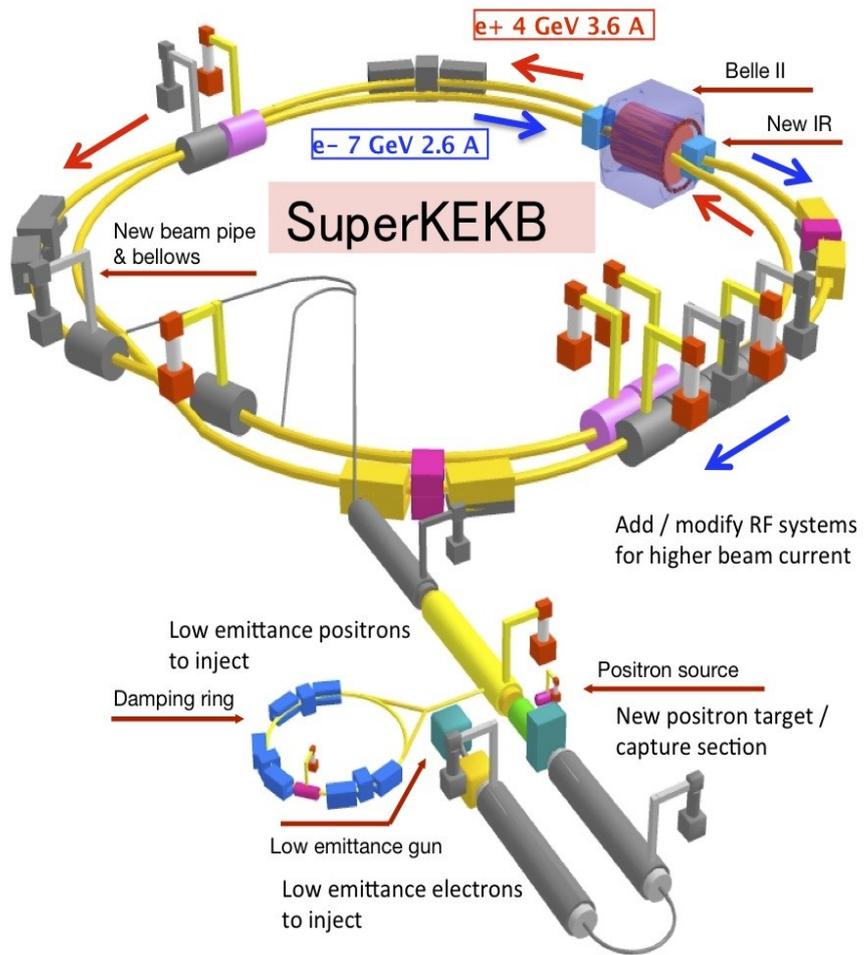
CMS: developing analysis tools

- 📦 Hadronic event shape variables to tune QCD MC event generators
- 📦 W+X charge asymmetry to improve parton distribution function of proton
- 📦 Tools for monitoring HCAL gain
- 📦 Problem in muon charge misID identified and corrected
- 📦 Pileup mitigation

CMS: hardware/computation

- 📦 Outer hadron calorimeter + upgrade
- 📦 Embedded DAQ system for radiation monitoring in HF region
- 📦 HGCAL and tracker upgrade
- 📦 HGCAL test beam activities
- 📦 Upgrade of HCAL front-end electronics
- 📦 SiPM development with DCMPMS colleagues
- 📦 India-CMS T-2 Grid computing at TIFR

Belle and Belle -II



B factories: physics objectives

- ❏ Electron-positron collider with 10-GeV centre-of-mass energy
- ❏ Produces bottom (B) and charmed (D) mesons whose properties can be studied
- ❏ High-luminosity precision machine, looking for indirect signals of physics beyond the Standard Model

Belle: physics analyses

- 📦 CP asymmetries in decays to KK , $K\pi$ and $\pi\pi$
- 📦 CP violation in $[D^0 \text{ to } \pi\pi]$ and search for $[D^0 \text{ to } \gamma\gamma]$
- 📦 Search for bottomonium states in $Y(2S)$ decays

Belle II: hardware/computation

- 📦 Silicon vertex detector (SVD) ladder assembly
- 📦 Belle-II Physics Analysis Centre

GRAPES-3



Grapes 3: objectives

- 📦 Looking at universe in high energies, Signals from large distances:
- 📦 Acceleration in atmospheric electric field:
Energy ~ 100 MeV, distance $\sim 10^5 - 10^6$ cm
- 📦 Solar flares, Coronal Mass Ejections
Energy $\sim 10^{10}$ eV, distance $\sim 10^{11} - 10^{13}$ cm
- 📦 Galactic Cosmic Rays at “ Knee ”
Energy $\sim 10^{15}$ eV, distance $\sim 10^{21} - 10^{23}$ cm
- 📦 Diffuse multi-TeV γ -rays
Energy $\sim 10^{20}$ eV, distance $\sim 10^{24} - 10^{26}$ cm

GRAPES-3: physics analyses

- 📦 Solar diurnal anisotropy
- 📦 Cosmic rays-solar wind correlation
- 📦 Pressure and temperature variation of muon flux
- 📦 Moon shadow
- 📦 Large scale dipole asymmetry in muon flux

GRAPES 3: hardware

- 📦 Development of plastic scintillator detectors
- 📦 Proportional counter fabrication
- 📦 FPGA (field programmable gate array)-based building blocks for new applications



HAGAR

(Atmospheric Cherenkov)



HAGAR: objectives

- 7 atmospheric Cherenkov telescopes at Hanle
- Indirect detection of VHE γ rays (10 GeV -- 100 TeV) from astrophysical sources
- High altitude => low energy threshold

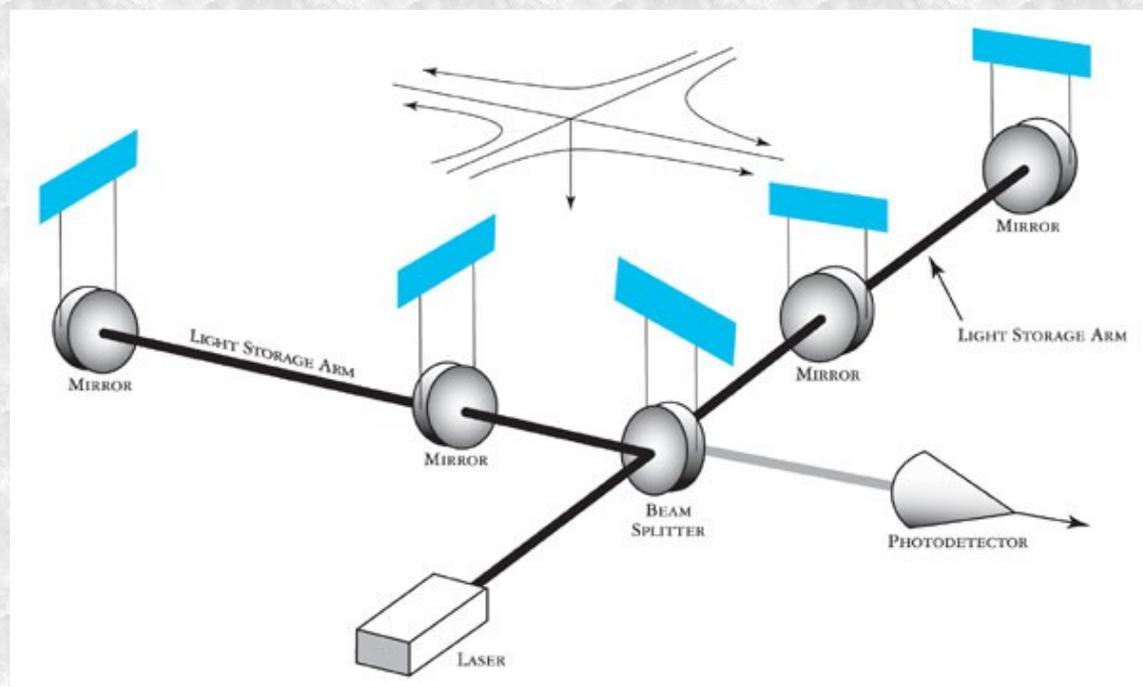
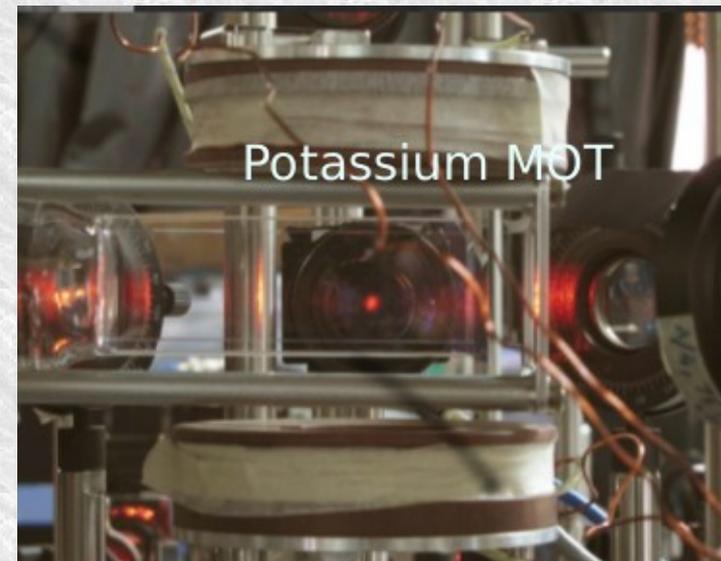
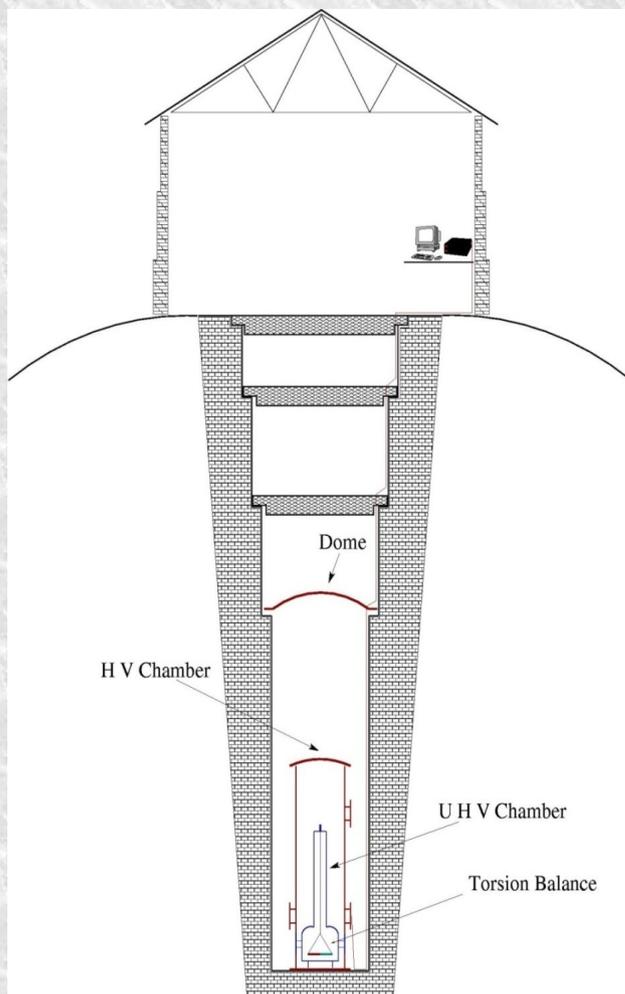
HAGAR: physics results

- 📦 ~5 major galactic, ~10 extragalactic sources, observations for ~4000 hours
- 📦 Pulsation of crab nebula
- 📦 Observations of X-ray flares
- 📦 Multiband observations of TeV binary
- 📦 TeV observations of blazars

Beyond HAGAR: Hardware/computation

- ❏ G-APD (Geiger Avalanche Photo-diode) – based imaging camera for TACTIC
- ❏ MACE telescope installed at HANLE
- ❏ Calibration box (nanosecond light flasher) for LST (Large Size Telescope) of CTA (Cherencov Telescope Array)
- ❏ All-sky camera at CTA
- ❏ OPC-UA platform implementation for CTA

Tests of fundamental interactions



Testing fundamental theories

Physics objectives:

- ❑ Testing predictions of gravity, relativity, QFT
- ❑ Repulsive Casimir effect in spherical cavities
- ❑ Gravitational wave detection

Strategy:

- ❑ Laser trapping and cooling of atoms to sub-mK
- ❑ Beam splitters and mirrors for atoms using laser pulses => atom interferometry
- ❑ High sensitivity to gravitational effects
- ❑ Constructing sensitive laser interferometer for GW

Test of Equivalence principle

Physics objective:

- 📦 Test of General Theory of Relativity:
inertial mass = gravitational mass ?

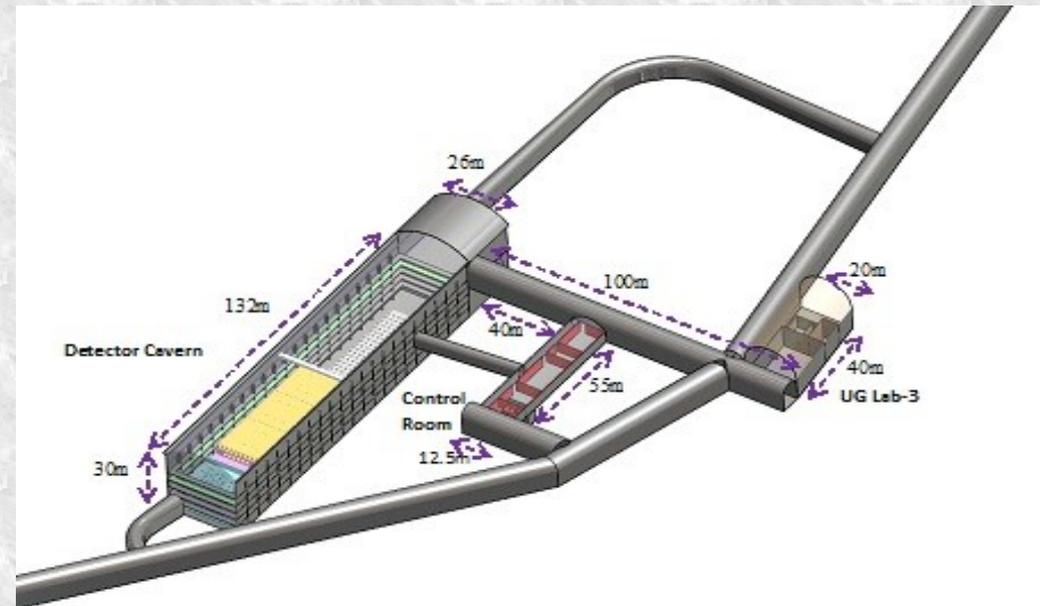
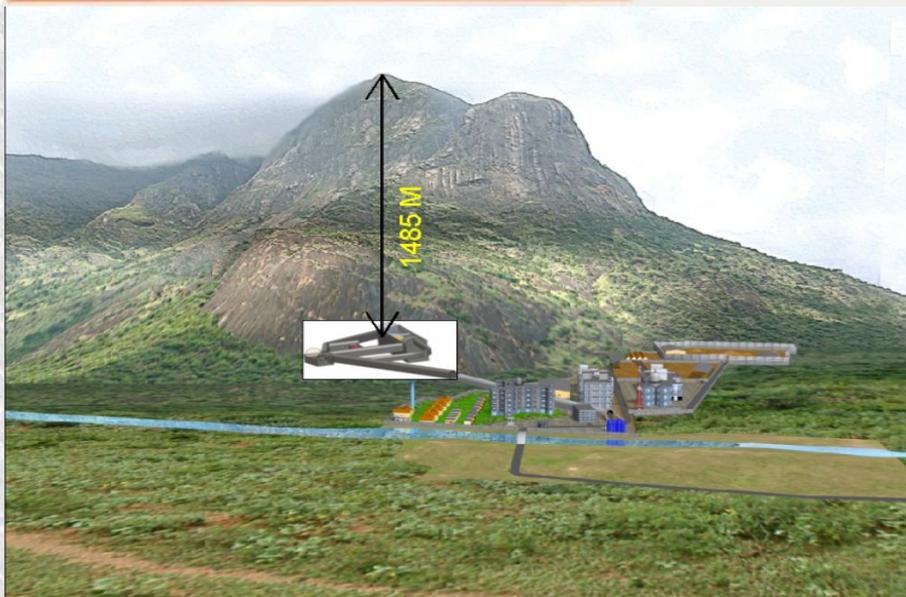
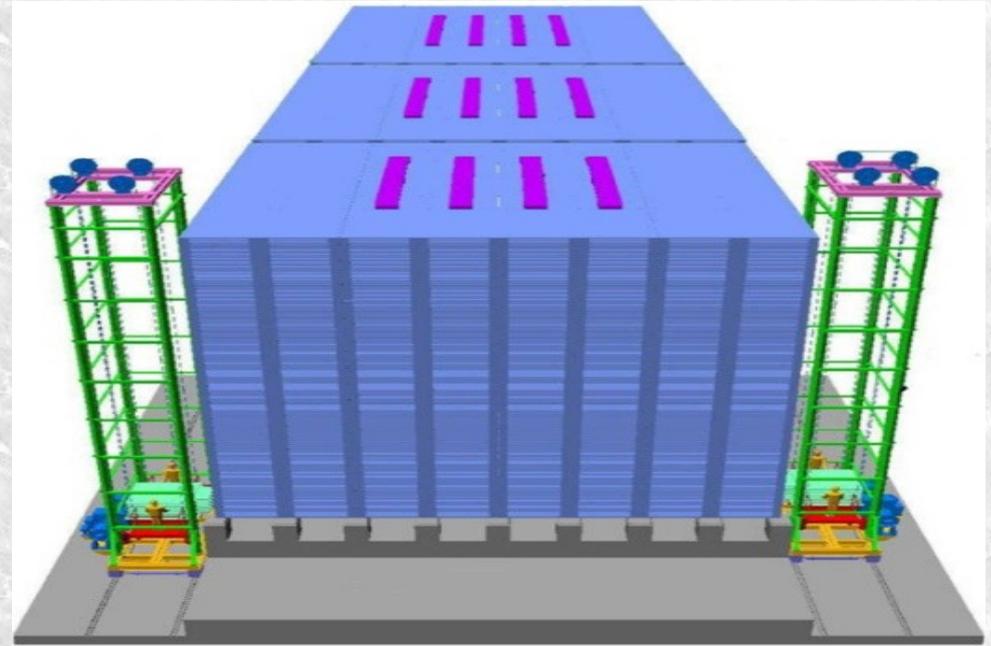
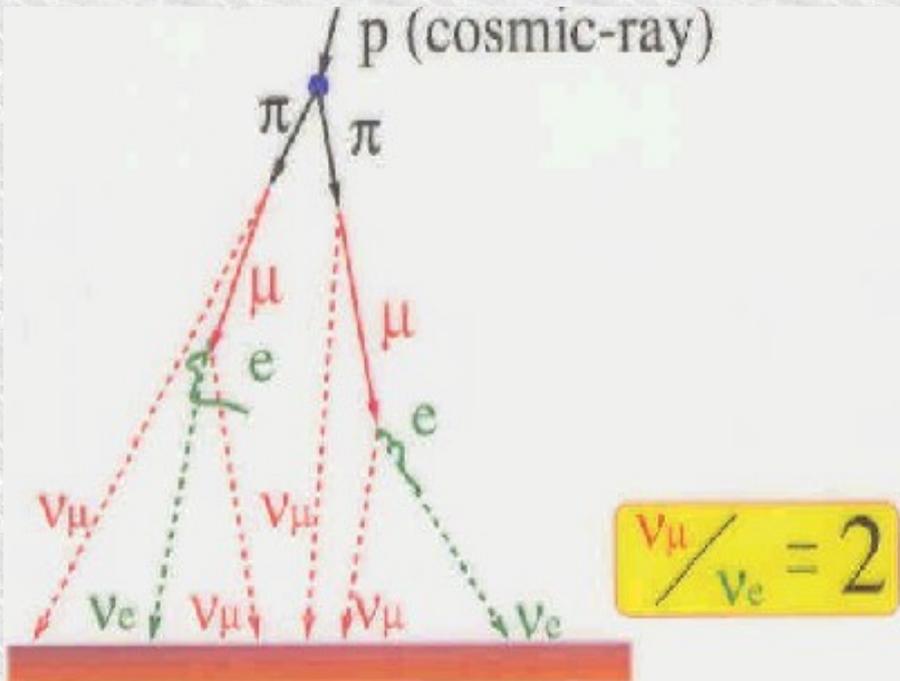
Strategy:

- 📦 Compare effect of Sun's gravity on two masses
- 📦 Measure sun-synchronized oscillations of the torsion balance

Recent improvements:

- 📦 Thermal control system
- 📦 Automated calibration system for autocollimator

ICAL@INO



INO: objectives

- 📦 Observations of neutrinos produced in Earth's atmosphere from cosmic rays
- 📦 Precision measurements of atmospheric neutrino oscillations
- 📦 Identification of neutrino mass ordering
- 📦 Addressing new physics questions like sterile neutrinos, non-standard interactions, dark matter, magnetic monopoles, etc.

ICAL@INO: hardware

- 📦 Development of RPCs (resistive plate chambers) of 2m x 2m size
- 📦 R&D for multigap RPCs
- 📦 Closed-loop gas recirculation system, leak tests

ICAL@INO: simulations

- 📦 GEANT-4 based simulation framework set up

Near future...

- 📦 CMS -> CMS upgrade
- 📦 Belle -> Belle II construction
- 📦 GRAPES 3 -> completion of the array
- 📦 HAGAR -> MACE, CTA
- 📦 IndIGO -> LIGO India
- 📦 INO -> tunnel digging ?? ICHEP ??

Here is wishing

Happy New Year (guDhi padwa)

and

an “event”ful future

to DHEP.....