Expression of Interest (EOI)

This document is a collective expression of interest from the various Indian institutions to participate in the Electron Ion Collider (EIC) experiment at BNL, USA.
There are three primary goals of the scientists from India related to the participation in the EIC program.

(i) To participate and contribute to the physics program of EIC.
(ii) To participate and contribute in two areas of detector research and development in EIC, namely (a) Tracker and Vertex systems and (b) Particle identification systems.
(iii) To participate and contribute to EIC software developments: (a) ESCalate, (b) Fun4All, (c) EIC-Smear and (d) MC-data validation.

These expressions of interests of the group are primarily driven based on

(i) experience and expertise developed by participating in international collaborations like ALICE, STAR, and CMS and Belle II (Also see annexure - III),
(ii) collaboration with non-Indian institutes on detector R&D, and
(iii) current contributions to EIC software efforts (see annexure – II).

Please indicate the name of the contact person for this submission:

(A) Prof. Bedangadas Mohanty, NISER, Bhubaneshwar, India
(B) Primary detector subsystem contacts:
(i) Vertex and Tracking System: Prof. Anju Bhasin, University of Jammu, Jammu Tawi, India
(ii) Particle Identification System: Prof. Bhartendu K. Singh, Banaras Hindu University, Varanasi, India

Please indicate all institutions collectively involved in this submission of interest:

The table below indicates the Indian institutions and names of current faculty/scientific staff who have collectively proposed this EOI.

Sl. No.	Institution	Faculty/Staff	Experiment /Theory	Past experimental participation
1	Akal University	Ramandeep Kumar	Experiment	CMS
2	Aligarh Muslim University	Raktim Abir	Theory	
3	Banaras Hindu University	Bhartendu Singh	Experiment	PHENIX, CBM
4	Central University of Karnataka	Deepak Samuel	Experiment	INO
5	Central University of Tamil Nadu	Nirbhay Kumar Behera	Experiment	STAR, ALICE & CMS
6	DAV College, Chandigrah	Monika Bansal	Experiment	CMS
7	Goa University	Prabhakar Pani	Experiment	miniCLEAN, CDF, SEP, ALICE, ATLAS
8	Indian Institute of Science Research and Education, Berhampur	Md. Nasim	Experiment	STAR
9	Indian Institute of Science Research and Education, Tirupati	Chitrasen Jena	Experiment	STAR & ALICE

10	Indian Institute of Technology Bombay	Asmita Mukherjee Basanta Kumar Nandi Sadhana Dash	Theory Experiment Experiment	WA98, STAR, ALICE, CBM
11	Indian Institute of Technology Delhi	Tobias Toll	Theory	
12	Indian Institute of Technology Indore	Ankhi Roy Raghunath Sahoo	Experiment	CB-ELSA /TAPS,COSY, STAR, ALICE, CBM
13	Indian Institute of Technology Patna	Neha Shah	Experiment	WASA-at-COSY, STAR
14	Indian Institute of Technology Madras	Prabhat Ranjan Pujahari	Experiment	STAR, ALICE, CMS
15	Institute of Physics	Pradip Kumar Sahu S. K. Sahu B. Mallick	Experiment	WA98, STAR, ALICE & CBM
16	Malaviya National Institute of Technology Jaipur	Kavita Lalwani	Experiment	Belle II at SuperKEKB, CMS at LHC, WASA at COSY, IKP, Germany
17	National Institute of Science Education and Research	Bedangadas Mohanty Ranbir Singh Varchaswi KS Kashyap	Experiment	WA98, STAR, ALICE, CBM
18	Panjab University	Lokesh Kumar Natasha Sharma	Experiment	STAR, ALICE, CBM
19	Ramakrishna Mission Residential College, Kolkata	Amal Sarkar	Experiment	STAR, ALICE, CMS
20	Tata Institute of Fundamental Research	Nilmani Mathur	Theory	
21	University of Jammu	Anju Bhasin, Anik Gupta	Experiment	WA98, STAR, ALICE, CBM

Please indicate the items of interest for potential equipment cooperation:

There are two major areas of detector sub-systems to which we would like to contribute. The details of which are listed below.

(a) Silicon vertex and tracking detector in Central Tracking

Primary institute from India: University of Jammu
Collaborating Institutes from within India:

(i) National Institute of Science Education and Research, Bhubaneswar
(ii) Institute of Physics, Bhubaneswar
(iii) Indian Institute of Technology Indore
(iv) Central University of Tamil Nadu, Thiruvarur

(v) Goa University

Collaborating institutes from outside India and in EIC:

(i) University of Birmingham, UK
(ii) Lawrence Berkeley National Laboratory, USA

Brief description of the R&D interest: The Indian group led by University of Jammu would like to contribute towards: Quality assurance studies of the sensors for EIC Vertexer and Tracker both in design and final production phase. Test beams programs for characterization of the silicon system.

(b) Particle Identification Detector

(i) RICH and High momentum PID
(ii) Hadron Blind Detector
(iii) Large Area Picoseconds Photo Detector (LAPPD)

Primary institute: Banaras Hindu University
Collaborating institutes from within India:
(i) National Institute of Science Education and Research, Bhubaneswar
(ii) Institute of Physics, Bhubaneswar
(iii) Ramakrishna Mission Residential College, Kolkata
Collaborating institutes from outside India and in EIC:
(i) Stony Brook University, New York, USA
(ii) INFN, Trieste, Italy

Brief description of the R&D interest: The Indian group led by Banaras Hindu University would like to contribute towards the development of a new Particle Identification Detector (PID) for EIC. As an example, we would like to contribute towards development related to photodetectors schemes, cascaded GEM/THGEM with reflective layers of photocathode.

Please indicate what the level of potential contributions are for each item of interest:

(a) Silicon Tracking and Vertex System - Contribute towards the following aspects:
(i) In kind labour contributions for detector R&D, testing, quality assurance, commissioning and operations.
(ii) Detector slow control system related developments
(iii) Provide access to other EIC groups to existing facilities in our laboratory (see Annexure-I) for detector related work.

(b) Particle Identification Detector - Contribute towards the following aspects:
(i) In kind labour contributions for detector R&D, detector simulations, testing, quality assurance, commissioning and operations.
(ii) Provide access to other EIC groups to existing facilities in our laboratory (see Annexure-I) for detector related work.

(c) *EIC Software development:*

i. Collaboration with SBU: Few EIC-India institutes such as Indian Institute of Technology Indore, Indian Institute of Technology Patna, Malaviya National Institute of Technology, Jaipur and Ramakrishna Mission Residential College, Kolkata are working with Stony Brook University, New York, USA on software development for the charged particle tracking in the Time Projection Chamber. The space charge plays an important role in the determination of the track resolution in high multiplicity and high luminosity environment. Currently we are involved in the development of the space charge distortion model and its effect on track resolution.

ii. Validation and benchmarking of EIC-software: There are four areas of the EIC software working group (SWG), viz., Fun4All, Escalate, EIC-smear, and MC-Data Validation, where the validation and benchmarking of the EIC-software is ongoing. Many institutes from EIC-India are participating in these

ongoing efforts in collaboration with the SWG. Please refer to the annexure - II for a brief summary of the current activities.

iii. In addition, the groups will be also involved in the software development of PID and Silicon Vertex detectors, the detector sub-systems to which EIC-India would like to contribute.

Potential contributions: In-kind contribution in terms of manpower and computing resources will be possible by applying for funding to Indian funding agencies.

Please indicate what, if any, assumptions you made as coming from the EIC Project or the labs for your items of interest:

(a) ***Detector development related:*** We assume design and engineering support from the EIC project. Some material and supply costs to be provided by the EIC project. There exists a possibility for partial funding of some of the material and supplies costs if the proposals to Indian funding agencies are successful in near future.

(b) ***Software development related:*** We assume technical support and coordination from the EIC software working group and for heavy computing related work, we need access to computing resources for EIC. In future there exists a possibility of local Indian groups developing computing resources for EIC, subject to proposals of funding to Indian funding agencies are successful.

Please indicate the labor contribution for the EIC experimental equipment activities:

Institution Name	Professor	Staff Scientist	Post doc	Grad. Student	UG student	Engineer	Technician	Total sum
Akal University	0.25				0.2			0.45
Banaras Hindu University	0.2		0.5	0.5	0.2		1.0	
	0.2			0.5	0.2			
				0.5	0.2			
					0.2			4.2
Central University of Karnataka	0.15			0.5	0.2			0.85
Central University of Tamil Nadu	0.2			0.25	0.1			0.55
DAV College, Chandigarh	0.2				0.1			0.3
Goa University	0.25							0.25
Indian Institute of Science Research and Education, Berhampur	0.2		1.0	0.5	0.2			1.9
Indian Institute of Science Research and Education, Tirupati	0.2		1.0	0.5	0.2			
				0.5	0.2			
								2.6

Indian Institute of Technology Bombay	0.1		0.8	0.8	0.6			
	0.2		0.5	0.8	0.4			
	0.2			0.8				
								5.2
Indian Institute of Technology Indore	0.2		1.0	0.5	0.2			
	0.2			0.5	0.2			
				0.25	0.2			
				0.25	0.2			
					0.2			
					0.2			
					0.2			
								4.3
Indian Institute of Technology Patna	0.2		1.0	0.5	0.2			
				0.5	0.2			
					0.2			
					0.2			
								3.0
Indian Institute of Technology Madras	0.2		1.0	0.5	0.2			
					0.2			
					0.2			
					0.2			
								2.5
Institute of Physics, Bhubaneswar	0.2	0.3	0.5	0.25	0.2	0.3	0.3	2.05
Malaviya National Institute of Technology, Jaipur	0.2		1.0	0.5	0.2			
				0.5	0.2			
					0.2			
					0.2			
								3.0
National Institute of Science Education and research	0.2	0.2	1.0	0.3	0.2			
		0.2			0.2			
								2.3
Panjab University	0.2		0.5	0.2	0.2			
					0.2			
								1.3
Ramakrishna Mission Residential College, Kolkata	0.2			0.2	0.2			
					0.2			
					0.2			
								1.0
University of Jammu	0.1		0.5	0.4		0.5	1.0	
	0.1		0.5	0.4		0.5	1.0	
	0.2						1.0	
								6.2
Total	4.55	0.7	10.8	11.9	8.4	1.3	4.3	**41.95**

Please indicate if there are timing constraints to your submission:

(a) As of now, none of the major detector R&D groups proposed here in the EOI are having commitments on detector R&D at other experiments.

(b) Several of the faculty are involved in other experiments such at RHIC and LHC. The RHIC based involvement is expected to end with the STAR experiment running (2024-25). A fraction of their efforts will continue to be there at LHC experiments. LHC participations we anticipate may get further reduced by 2035 when the EIC plans to become operational. The FTE proposed keeps these aspects in mind.

(c) The part of the funding for the supplies and materials and equipment will be possible once the EIC-India project gets approved by the funding agency. This process will start once our EOI is accepted by EIC. There is partial support for personnel requirements in some of the institutes, for the remaining it will be through the EIC-India project funded by Indian funding agency once approved. As an example, in past the Indian funding agency has supported funding for Photon Multiplicity Detector in ALICE@LHC to the tune of 1000K-CHF and is currently supporting 5.5M Euro for the Muon detector system in CBM@FAIR. They have also generously supported the travel to the experimental sites and salaries of Postdoctoral/technical staff for the project period. The PDF hired in EIC will fully focus on this project. The Masters student projects EIC will also have their 100% commitments.

Please indicate any other information you feel will be helpful:

(A) Annexure - I : *Facilities currently available for detector R&D in various groups*

University of Jammu

List of equipment available at University of Jammu are given in the table below. Further equipment as needed will be obtained once the EIC project gets its funding from Indian funding agency.

S.No.	Name of Equipment
1	200 mm Semi automatic Probe Station Model SEMI200MC
2	VME based Data Acquisition System consisting of: (a) VME64 8U Crate Model CAEN V8100 (b) VME- USB 2.0 Bridge Model CAEN VI718 (c) 16 channel Multi-event TDC Model CAEN V775N (d) 16 channel Low Threshold Discriminator Model CAEN V814B (e) 8 channel Dual Range ADC Model CAEN V965A (f) Quad 4-fold AND/OR MAJ, NIM-TTL- NIM Adapter Model CAEN V976B (g) NIM- ECL Translator Model CAEN V538AB (h) 8 channel 12 bit digitizer Model CAEN V1720 (i) 8 MCX To LEMO Adapter Model CAEN A 65 (j) Dual Timer Model CAEN V993C
3	Photodiode Test Solution System having IV and CV measurement capabilities (a) High Voltage Source Meter Keithley 2410 (b) USB to GPIB interface Keithley KUSB-488B (c) Single Slot Semiconductor Switching Mainframe Keithley 708B (d) High Voltage Semiconductor Matrix card Keithley 7072 (e) CV Power Package Keithley 4200-CVU-PWR (f) Software for component test Keithley ACS-BASIC (g) Shielded GPIB cable length 3 meters Keithley 7007-3 (h) Dual banana to BNC Coaxial adapter Keithley BG-18 (i) 3 slot Male TRIAX to BNC adapter Keithley 7078-TRX-BNC (j) 3 Slot TRIAX cable Keithley 7078-TRX-5 (k) 2 slot BNC male to 3 lug female TRIAX Keithley 237-BNC-TRX (l) TRIAX to Banana plug Keithley 237-BAN-3A
4	2.5 GHZ Digital Phosphor Oscilloscope. 4 channel, Color LCD Model DPO 7254, Make Tektronix
5	VME Crate make Wiener
6	VME Bus Processor Board VM316

7	Local Trigger Board
8	TTCex MK ALICE Trigger Board equipped with 3 lasers
9	Multichannel Analyzer ORTEC Make Model ASPEC 927
10	N455 Quad Co-incidence Unit CAEN Make
11	N89 NIM-TTL-NIM Adapter CAEN Make
12	N108A Dual Delay Unit CAEN Make
13	NIM Bin Make Fast ComTec Model DS 7033
14	Main Frame Universal Multichannel Power Supply system Model SY2527 Make CAEN
15	12 channel High Voltage Board A1821N Make CAEN
16	4 channel Programmable Power Supply Make CAEN , Model N 470
17	Dual Timer Make CAEN, Model N 93B
18	Quad Linear Fan In/ Fan Out Make CAEN, Model N 625
19	Quad Scalar and Counter/ Timer Make CAEN, Model N 1145
20	8 channel Leading Edge Discriminator Make CAEN, Model N 840
21	Spectroscopy Amplifier Model ORTEC 572-A
22	Pre amplifier ORTEC Model 142IH
23	Dual output Low Voltage Power Supply 0-32 volt / 0-5 Amp / Aplab Make / Model LD3205.
24	Agilent LCR meter Model E 4980A
25	Keithley Source Meter Unit Model 2410
26	Sepia II Diode Laser System including Laser Head, diode controller, Optical Fibre cable

Banaras Hindu University

S. No	Facility
1	**Photocathode preparation system**: This complex 2-chamber high vacuum thermal evaporation system equipped with Residual Gas Analyzer will permit for: substrate baking and in-situ photocathode deposition on baked substrate. In the longer run, it may be equipped with a VUV monochromator system for photocathode characterization.
2	**Optical properties facilities**: Reflectance, transmittance and absorbance properties of different types of prepared photocathodes can be analyzed by means of Mcpherson-made VUVAS system in the wavelength range of 115-340 nm. This facility basically provides an eye to optimize the thickness of a photocathode for maximum absorbance of UV photons.
3	Absolute **QE measurement** of thin film photocathode: Mcpherson-made set up where we can measure absolute QE measurement for UV photocathode (similar to BNL set up with Craig Woody)
4	**Electron multiplier studies**: In our laboratories exists a fully equipped experimental facility for developing and characterizing electron multipliers such as Gas Electron Multipliers (GEMs) and thick GEMs. Their properties can be studied in combination with thin film layer of photocathodes prepared at our research laboratory.

National Institute of Science Education and Research

S.No.	**Name of Equipment**
1	ISO-5 (Class 100) cleanroom of ~200 sq.ft for assembling advanced gaseous detectors such as MPGDs.
2	5 channel gas mixing system. This system can mix 5 gases in arbitrary concentrations with a maximum flow rate of 400 sccm.
3	X-ray irradiation enclosure made of copper with A Mini-X2 X—ray source for characterizing MPGD. The gun can be manually moved in X, Y and Z directions
4	VME and NIM based Data Acquisition System consisting of: (k) VME64 8U Crate Model CAEN V8100 (l) VME Optical link controller CAEN V2718

	(m) 128 channels Multihit TDC Model CAEN V1190A (n) 32 channels Individual gate QDC CAEN V862 (o) CAEN Programmable logic unit V2495 with accessories > 128 channels (p) CAEN NIM logic units (Model: N405, N455), (q) CAEN dual delay unit (Model: N108A) (r) CAEN discriminators (8 channel, 16 channel LED (Model: N840, N841)), (s) CAEN Quad-scaler and preset counter/timer (N1145) (t) CAEN dual timer (Model: N938) (u) CAEN NIM to TTL converter (Model: N89) (v) 16 channels, 14-bit digitizer Model CAEN V1730 with 500 MS/s with DPP-PSD and DPP-PHA firmwares (w) N1470 NIM HV power supplies (x) CAEN N968 and Ortec 572A spectroscopy amplifiers (y) CAEN Model 1068S, 16 channel spectroscopy amplifier (z) Ortec Model 142IH charge sensitive preamplifiers (aa) CAEN Model N638 NIM-ECL/ECL/NIM translators (bb) Ortec Model 550A SCA (cc) Ortec 935 Quad CFD (dd) Ortec 566 TAC (ee) CAEN N979 16 channel Fast Amplifiers
5	Keithley Model 6485 Picoammeter
6	Agilent 81110A 165/330 MHz, Pulse/Pattern generator
7	Megger High voltage Insulation tester model MIT 485/2
8	0-250 mbar ESI-TEC pressure transducer for measurement of leak in gas detectors
9	CAEN power supply Main Frame: Universal Multichannel Power Supply System Model SY5527 (a) A1536N 6 channel negative HV module (Voltage range: 0 to 15 kV: 1 mA) (b) A7236DN 12 channel negative HV module (Voltage range: 0 to 3.5 kV: 1.5 mA)
10	Teledyne Lecroy Wavesurfer 510, 1 GHz, 10 GS/s, 4 channel Digital Storage Oscilloscope.
11	Dehumidifiers

Institute of Physics

Sl.No.	Name of Equipment
1	NIM BIN,CAEN HV Mode, Discriminator Quad Coincidence, TTL Counter, Signal Splitter, Dual Timer, VME Crate with controller, Spectroscopic Ampelifier (CAEN)
2	Scintillator paddle, Single GEM Detector, Quad GEM Detector, Ampetek Mini-X (X-Ray tube source, Gold)
3	Electronics Lab, 10G/s four channel oscilloscope,Temperature controlled soldering station Precession Power supply (0-48V), Precession function generator and noise generator
4	Dual channel MCA
5	Clean Room (class100) with all accessories

*(B): **Annexure - II** : Our current contribution to software developments in EIC*

The Indian groups are participating in the benchmarking and validation of EIC software. There are four subgroups of the EIC software group in which the benchmarking and validation is going on. These are: Fun4All, Escalate, EIC-

smear, and MC- Data Validation. A brief summary of current activities and long-term goals within each subgroup is given below. **Escalate: (i)** Participate in Escalate framework development: improvement of reliability, performance, user experience, implementation of new features within the framework. (ii) Create a common software environment for cross checking and analyzing results from various simulation and reconstruction tools for EIC. **Fun4All :** (i) Perform quality assurance of calorimeters (forward and barrel) and trackers. (ii) Characterization of calorimeters and QA of tracking geometry. (iii) Test different input generators for actual physics signals with full detector simulations. **EIC-Smear :** (i) Participate in the development of unit tests using catch2. (ii) Development of QA suites based on the requirements of various Physics working groups. (iii) Improvement of existing and future detector concepts (e.g., BeAST, ePHENIX, JLEIC) and their GEANT counterparts. (iv) Developing the PID suite for the EIC. **MC-Data Validation : (i)** Test and validate different Monte Carlo simulation (MCS) tools for investigation and evaluation of multiple types of phenomena or processes expected to influence the final observables at EIC. (ii) Use Rivet framework for validating various physics analysis at EIC energies. (iii) Improvise the existing MC models to include effects of inclusive and semi-inclusive DIS processes.

The Indian groups are also getting involved in the hardware development of the PID and Silicon Vertex detectors. The Indian software groups which are involved in the above-mentioned benchmarking and validation work, will also be involved in the software development of PID and Silicon Vertex detectors.

(C) ***Annexure - III:*** *Past experience of various groups*

Akal University**:** Study of hadron collisions at the LHC: Study of multiple parton interactions in proton-proton collisions using CMS data and phenomenological studies on the same subject; Fabrication and characterization of Resistive Plate Chambers assembled in the Muon System of the CMS detector.

Aligarh Muslim University: Experience in working in the area of heavy quarks, jets, small-x, BK-JIMWLK equations, TMD PDFs, etc. - in the interface of HIC and EIC theory/phenomenology.

Banaras Hindu University*:* Metamaterial studies: We will also try to search for a material with negative refractive index for its use in particle identification techniques. Already we have submitted a joint scientific proposal of BHU and Stony Brook University based on Metamaterials under the SPARC scheme, Govt. of India which encourages Indian Institutions for research collaboration with the top research group in the leading universities of the world in various areas.

Central University Karnataka*:* Part of the INO-ICAL collaboration for about 12 years in which we contributed to the development of the data acquisition system, analysis of cosmic-muon data and to the development of simulation tools. Also have contributed partly to the development of resistive plate chambers and to the trigger system. Recently, we have been focussing on developing machine learning based tools for event classification and momentum reconstruction.

Central University of Tamil Nadu*:* Experience in the simulation study of Time of Flight detector of the STAR experiment at RHIC, Testing & characterization of MAPS technology-based prototype ALPIDE chips. Mass chip testing, and modules assembly of silicon chips for ALICE Inner Tracking System Upgrade and experience in experimental data analysis: Correlation-fluctuations study, light flavor and heavy-flavor measurement.

DAV College, Chandigrah: Measurements of Drell-Yan and multiple parton interactions in pp collisions with CMS experimen. L1 Muon trigger calibration with cosmic data. Phenomenological work on the subject of double parton scattering.

Goa University: Experience in devising a method for real-time monitoring of charged particle beam profile and fluence. This technique was used to irradiate and test silicon tracking detectors for the LHC upgrades using our custom diode array system which was placed in the path of the 800 MeV proton beam at the LANSCE facility of Los Alamos National Lab (LANL). Experience in working on miniCLEAN dark matter experiment, which utilizes 500 kg of liquid Argon detector to identify dark matter and neutrinos. Contributed on calibration of photomultiplier tubes, implementation of the acrylic wavelength shifter, and the ultraviolet LED set up that was used in the optical cassette system. Experience in working on SPiRIT project with a Symmetry Energy Project (SEP) collaboration at NSCL. Led the development of SPiRITROOT software framework for simulation, digitization and reconstruction of tracks inside Time Projection Chamber (TPC) as well as data analysis software framework based on ROOT. Contributed to build TPC geometry and integrate it with SPiRITROOT to transport events using GEANT3/GEANT4 model. Worked on digitization framework in tasks like cluster formation, drifting of electrons,

and avalanche process, which contributed towards the successful working of digitization. contributed physics analysis - bottom baryon resonance state Λ_b^{*0}; Underlaying Event activity in small systems; cross-section of top-quark pairs (tt-bar) in l+jets and dilepton channels and measurements of photon-induced processes (Light-by-Light Scattering and search for Axion Like Particles) in Ultra-Peripheral Collisions of heavy ions.

Indian Institute of Science Education and Research Berhampur*: M*ain expertise is physics data analysis. We are actively involved in the STAR experiment at RHIC. We study the production and azimuthal correlation of the produced particles in heavy-ion collisions (HIC). Our main focus is the strange and heavy quarks carrying hadrons. By measuring yield and azimuthal correlation, we study the initial condition of HIC and properties (partonic vs hadronic degrees of freedom, transport properties, etc) of the produced medium in HIC.

Indian Institute of Science Research and Education Tirupati**:** Group has the experiences of working in large-scale experiments such as the STAR experiment at RHIC and ALICE at LHC. The group has the expertise on the measurements of the transverse momentum spectra and azimuthal anisotropies of light- and heavy-flavor hadrons, resonances, and light (anti-)nuclei. The group members were also involved in the fabrication, testing, and installation of the Photon Multiplicity Detector (PMD) in ALICE at the LHC.

Indian Institute of Technology Bombay*:* Group has been involved in WA98 (at CERN SPS) and STAR experiment (at RHIC) in the past. Currently an active member of ALICE collaboration and associate member of CBM (at FAIR) collaboration. Involved in the PMD software development, PMD detector and associated electronics development and data analyses in the past and are currently actively contributing to the ALICE data analyses.

Indian Institute of Technology Indore: Raghunath Sahoo has worked for the STAR and ALICE PMD unit module fabrication, supemodule testing, commissioning and data taking at BNL and CERN, respectively. In addition, he has contributed to the ALICE pre-production prototype testing, data analysis. From the physics analysis, he has contributed to transverse energy measurement, e-D0 correlations in STAR and then heavy-flavor quarkonia and resonance production in ALICE.

Ankhi Roy has investigated the rare decay channels of pseudoscalar mesons in the intermediate energy range with CB-ELSA/TAPS experiment, Germany during her PhD . In her postdoctoral research, she has studied the transition form factor of light mesons with WASA-at-COSY experiment. Presently ,she is working in Heavy Flavour Physics with the ALICE experiment.

Indian Institute of Technology Patna: **C**urrently our group is working with the STAR experiment at RHIC. Primary focus is on physics analysis in three main areas: (a) Search for exotic hadrons (pentaquark and dibaryons) in heavy-ion collisions, (b) understanding baryon-baryon interactions using two-particle correlation functions and (c) strangeness production in beam energy scan to identify the phase boundary and onset of deconfinement in the QCD phase diagram. In addition, the group has experience of working on eta-meson production at intermediate energy, understanding meson-nucleus interactions using Dalitz plot.

Indian Institute of Technology Madras: Prabhat Pujahari has worked in STAR and ALICE experiments in past and currently working in CMS experiment. The group is expertised in various physics measurements which include particle production, transverse momentum spectra, correlations and fluctuations, heavy-flavor, ultra-peripheral collisions. In addition, Prabhat Pujahari has worked in ALICE PMD detector and took part in data taking, calibration and software development during the initial phase of the detector. Currently, we are working on CMS pixel moodle mechanics for the upgradation.

Institute of Physics: The Institute of Physics had past experience in the following activities, WA98 detector fabrication, STAR FEE board testing and fixing, ALICE - PMD detector module assembling and testing of FEE boards. The detector module mounting on superstructure and installation of electronics at CERN. CBM, Ethernet based HV control unit and part of DCS work is assigned and work is still going on.

Malaviya National Institute of Technology Jaipur (MNIT Jaipur):

MNIT Jaipur has been working in the software and hardware activities for following three High Energy Experiments: *Belle II at SuperKEKEB:* Software development: Involved in the preparation of the Module on Track related clusters, their intercept and dE/dx information for Data/MC comparison in SVD (Silicon Vertex Detector) framework of Belle II. Hardware Detector R&D: Our group has been working in the development of Silicon Strip Detectors and its testing in collaboration with TIFR for the Belle II experiment. Physics Analyses: D0-D0 bar mixing and CP asymmetry in D0 meson decays. *CMS at LHC:* Worked for the Design, fabrication and characterization of Silicon Strip Sensors, Participated in the Design, Fabrication and Characterization of Optical

Splitters for CMS HCAL electronics upgrade at Delhi University. *WASA-at-COSY:* Involved in the Physics Analysis of rare decay of eta meson.

National Institute of Science Education and Research: Physics programs of STAR, ALICE and CBM experiments. Detector related R&D for the CBM experiments.

Panjab University, Chandigrah: Members have been involved in the photon multiplicity detector (PMD) installed at both STAR and ALICE. PMD Fabrication, high voltage testing, test beam activities and installation of the detector at the site. PMD Software development such as clustering, calculating efficiency and purity using embedding technique. Monitoring of various detectors of STAR and ALICE during the data taking, online QA shifts. Physics analysis - photon multiplicity measurements using the PMD; pi, K, p spectra analysis using the TPC and TOF detector of STAR; Nuclei and anti-nuclei production using the TPC and TOF detector of ALICE; phi-meson production using the TPC and TOF detector of ALICE and pT fluctuations and correlations.

Ramakrishna Mission Residential College, Kolkata: Hardware experiences are encompassing widely in ALICE, STAR and CMS experiments. Assembling, calibrating and optimizing Resistive Plate Chambers (RPCs) in CMS experiment. Fabrication and testing of Multi-wire Resistive Plate Chamber (MRPC). Calibrating, optimizing, operating ALICE Muon arms (Muon Chamber and Muon Trigger) in the ALICE detector. Work as an on-call expert for ALICE Muon system during the experimental data taking. Study of momentum resolution for the STAR TPC tracks using cosmic ray data from MTD. Studied resolution of the individual TPC sectors and the dependency of TPC anode voltage on the efficiency of track reconstruction. Wide experience in experimental Heavy Ion and Particle Physics analysis. Worked in the ALICE (W and Z boson measurement and D0 measurement) and CMS (Z' measurement) and in the STAR (Higher moments study) experiment at the RHIC.

Tata Institute of Fundamental Research: Lattice QCD calculations are integral parts of theoretical studies related to various proposals of EIC experiments. We have experience in zero as well as finite temperature and finite density lattice QCD calculations. The first lattice QCD calculations on the quark orbital angular momentum contribution to the nucleon spin was performed by us. With modern lattice gauge ensembles, we will be involved in calculating the quark and gluon angular momenta, particularly the orbital components as well as PDFs. We would also like to study the gravitational form factors as well as pressure distribution and shear forces within a hadron using lattice QCD. We are also interested in studying QCD at finite density.

University of Jammu: Detector fabrication, testing, installation and commissioning. WA98 Experiment**:** Contributed to a large and highly granular preshower photon multiplicity detector (PMD) for the WA98 experiment at the CERN SPS proton synchrotron. The photon multiplicity detector consists of a matrix of scintillator pads placed in light-tight boxes and mounted behind the lead converter plates. The light from the scintillator pads is transported to the readout system using wavelength shifting (WLS) fibres. STAR Experiment: The members of the High energy physics group contributed for fabrication, testing, installation and commissioning of the STAR Photon multiplicity detectors (PMD) along with the other collaborating Indian institutes. The PMD for STAR consists of two planes of detectors with a lead converter plate sandwiched in between and having a total of about 82000 tiny hexagonal proportional counters. PMD for ALICE Experiment: For ALICE-PMD, about 30% of the total detector were fabricated in Jammu. The ALICE PMD consists of two planes of detectors with a lead converter plate sandwiched in between and having a total of about 200000 tiny hexagonal proportional counters.

DCS Development for Photon Multiplicity Detector: At ALICE Jammu group was entrusted with the responsibility of the ALICE PMD Detector Control Systems which was designed and developed at Jammu. The DCS for ALICE is based on a SCADA (Supervisory Control and Data Acquisition) system called PVSS (Process Visualization and Supervisory Software) now called WINCC, which is standard across all the four LHC experiments at CERN. The control system met all the parameters specified by Alice Controls Coordination committee and was successfully running the PMD during the LHC runs. *Trigger Developments at NA57/ALICE Experiment*: The Jammu Group has been involved in Trigger software development for the NA57 and ALICE experiment, which is used to emulate the logic LTU and CTP boards and has also been involved in the development of the graphics, controlling and monitoring of trigger electronics for the experiments. At Jammu we have now setup the trigger system for large experiments to do our own trigger tests, trigger simulation software.