India in ALICE at CERN

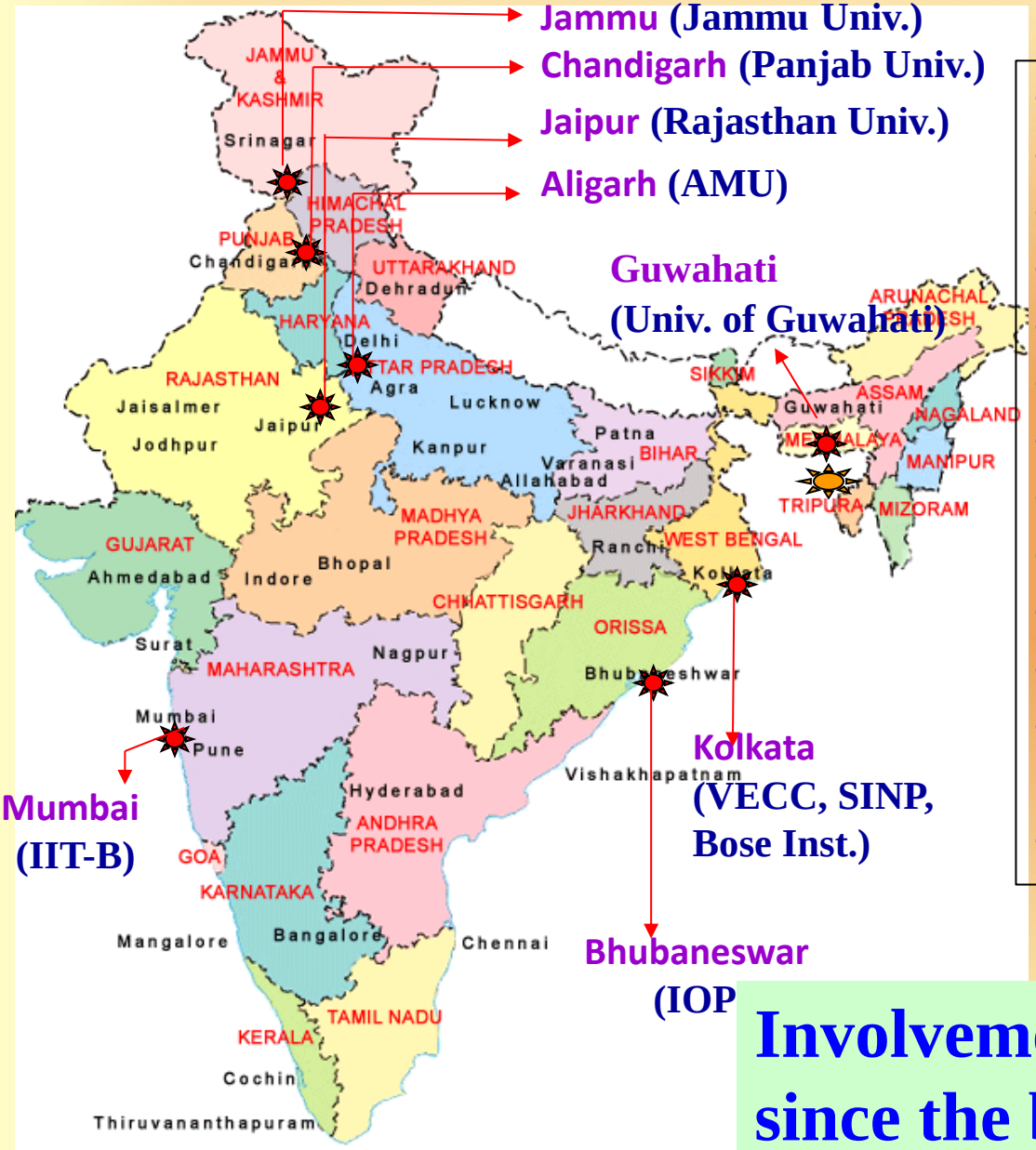
Study of Quark Gluon Plasma

- A journey to the beginning of Universe

IIT - Bombay

April 27, 2013

Indian members in ALICE



85 Members

- Kolkata: VECC
- Kolkata: SINP
- Kolkata: Bose Institute
- Aligarh: Aligarh Muslim University
- Bhubaneswar: Institute of Physics
- Bhubaneswar: NISER
- Chandigarh: Panjab University
- Guwahati: University of Guwahati
- Indore: IIT
- Jaipur: Rajasthan University
- Jammu: University of Jammu
- Mumbai: Indian Institute of Technology, Bombay
- Mumbai: BARC

Involvement of Indian Scientists since the beginning of ALICE

A brief history of the Experimental Program

Funded by DAE & DST

Growing Indian team

SPS	**WA93 and WA98**	1988 – 1996	Completed
	(VECC, IOP, Chandigarh, Jaipur, Jammu)		
RHIC	**STAR**	2000 onwards	Data Taking
	(VECC, IOP, Chandigarh, Jaipur, Jammu, IIT-B)		
	PHENIX	1995 onwards	Data Taking
	(BARC and BHU)		
LHC	**ALICE**	1995 onwards	Data Taking
	(VECC, SINP, IOP, AMU, Chandigarh, Jaipur, Jammu, IIT-B, Bose Inst., Guwahati Univ., IIT-Indore, NISER)		
	CMS		Data Taking
	(BARC)		

Contributions: Detector design and fabrication, electronics, ASIC development, mechanics, control, online/offline software, physics

Photon Multiplicity Detector (PMD)

An example of large-scale instrumentation

Goal: **Measurement of photon multiplicity and its spatial distribution in the forward region on an event-by-event basis**

PMD in WA93, WA98, STAR and ALICE: Indigenous - from conception to commissionin

PMD Probes:

- Rapidity & Multiplicity distributions of photons
- Determination of reaction plane and probes of thermalization via study of azimuthal anisotropy
- Phase Transition: Multiplicity Fluctuations
- Signal of chiral symmetry restoration (DCC) through the measurement of charged particle and photon multiplicities in a common phase space

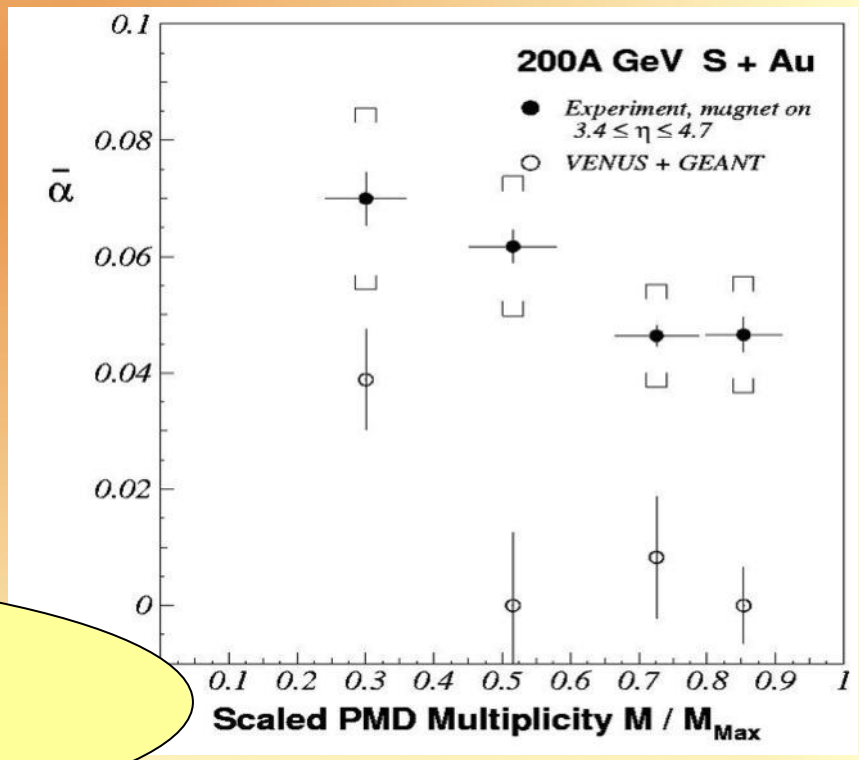
PMD in WA93 Experiment (1990-92)

Preshower detector:

Scintillator pads with wavelength shifting fibres using image intensifier + CCD camera systems readout

8000 pads covering an area of $3m^2$

Building blocks of PMD



First observation of Collective Flow at CERN SPS
Phys. Lett. B403 (1997) 390

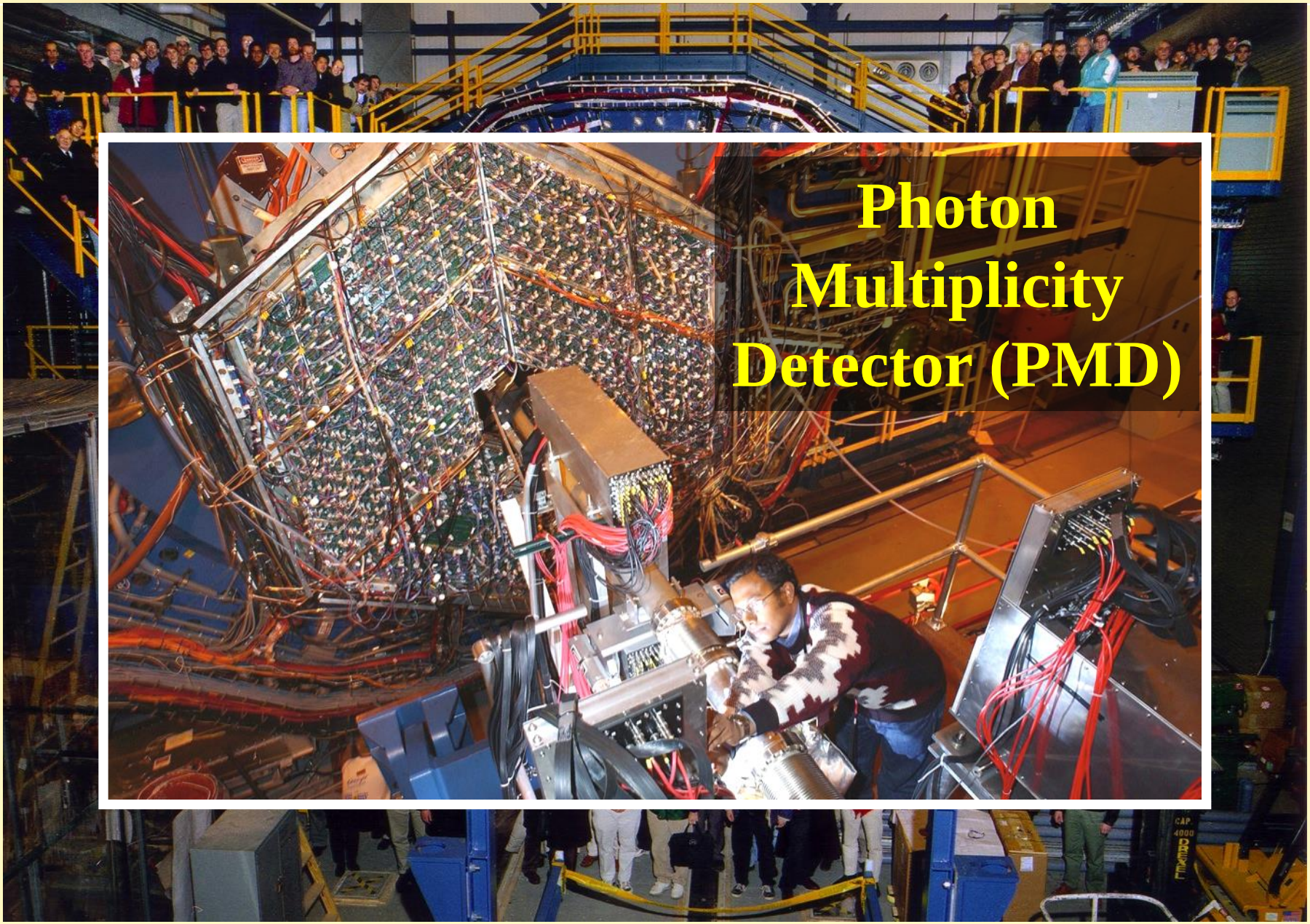
PMD in WA98 Experiment at CERN
(data taking: 1993 – 1996)

Rich harvest of physics

- Observation of collective flow
  Phys. Lett. B403 (1997) 390.
  Eur. Phys.J C41 (2005) 287
- Scaling of particle production:
  Phys. Lett. B458 (1999) 422.
- DCC Search:
  Phys. Lett. B420 (1998) 169
  Phys.Rev.C64 (2001) 011901
  Phys. Lett. B701 (2011) 300
- Fluctuations:
  Phys. Rev. C, May 2002

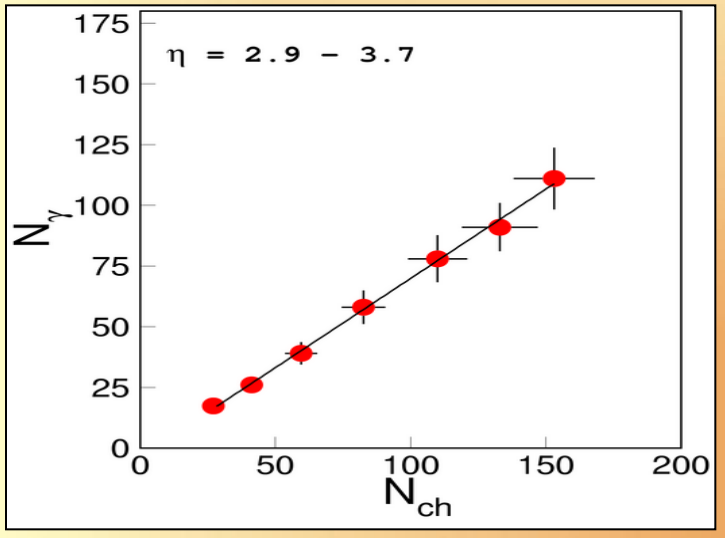
WA98 is the first Heavy-ion experiment to study signals of Disoriented Chiral Condensate (DCC)

STAR experiment at RHIC, BNL

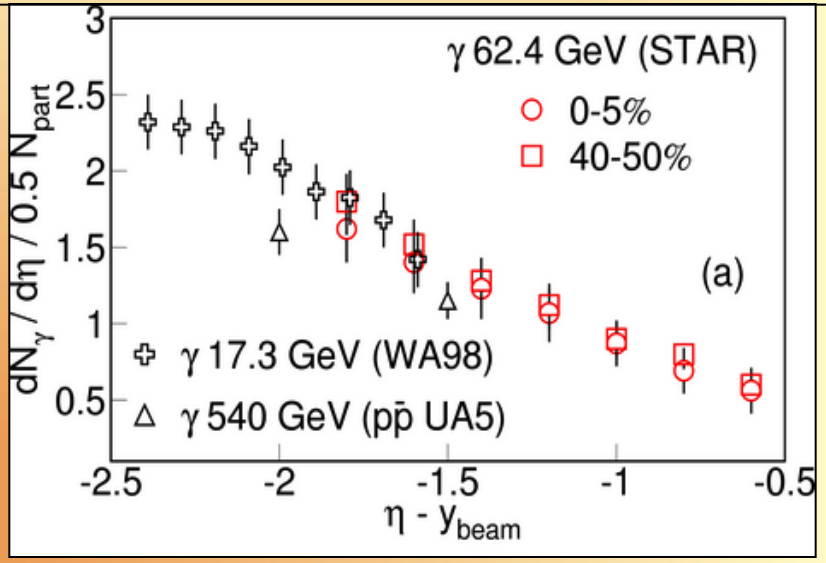


Results from STAR-PMD

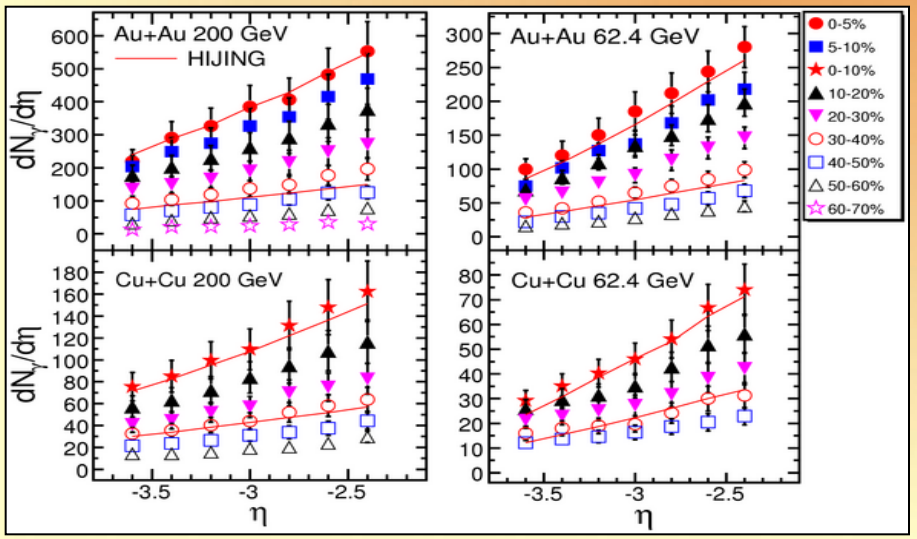
N_γ-N_{ch} correlation (PRC73 (2006))



Limiting Fragmentation behavior (Physical Review Letters 95 (2005))



$dN_\gamma/d\eta$ (NuclPhys A832 (2010))

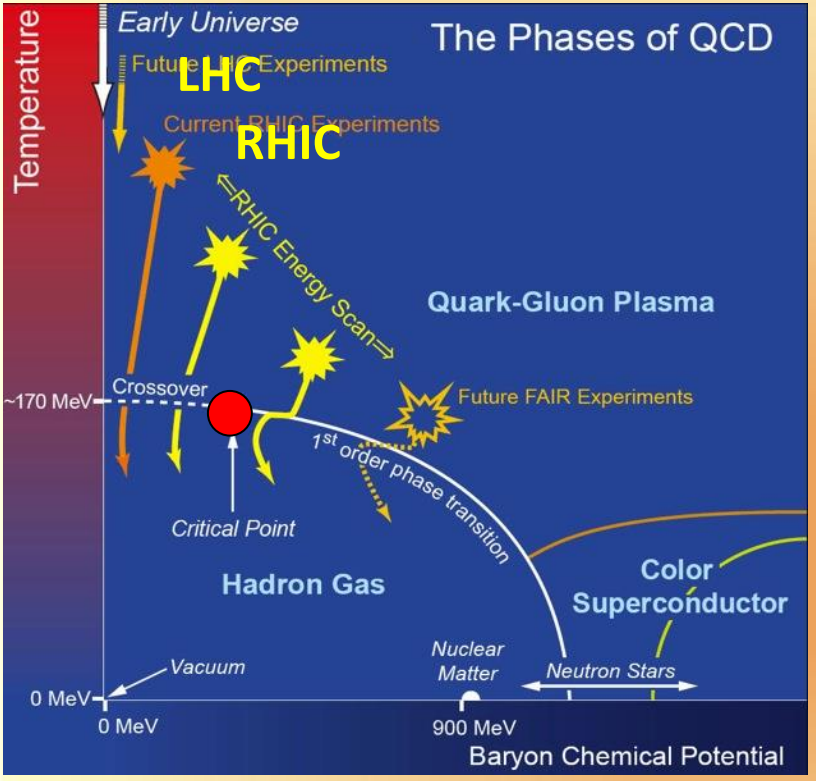


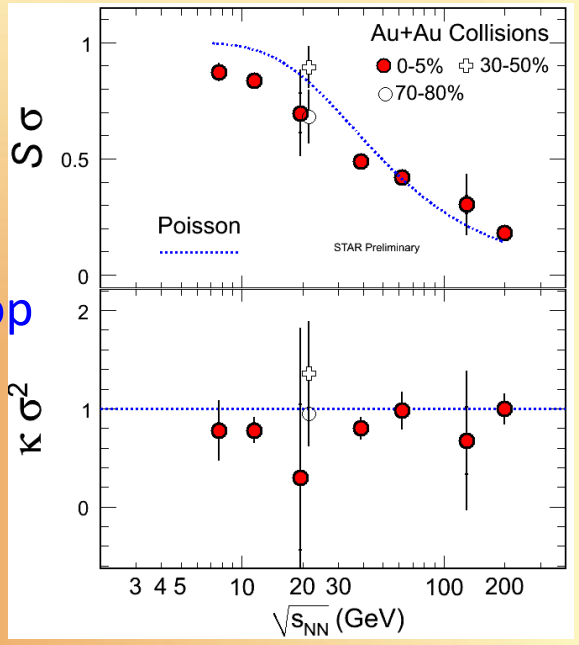
- Photon multiplicity and rapidity distributions
- Correlation of photons with charged particles
- Limiting fragmentation behaviour

Analysis in progress: Flow, DCC and QCD Critical Point

Search for QCD Critical Point

RHIC Beam Energy Scan Program

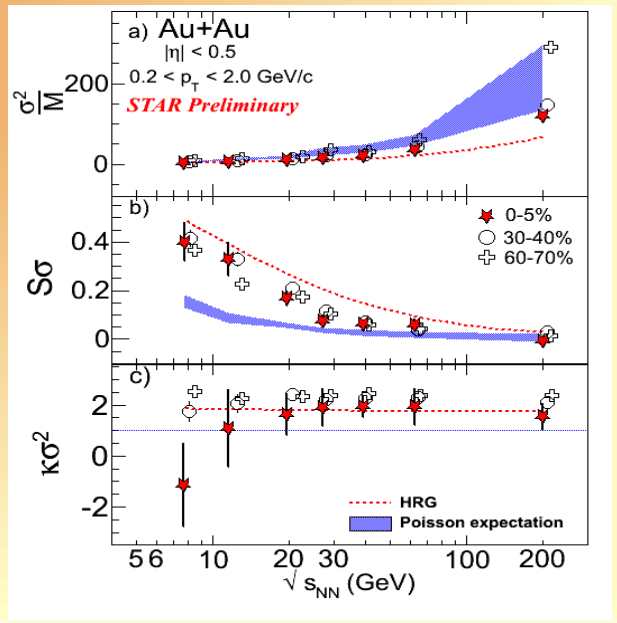




Two STAR PRLs at top RHIC energies:

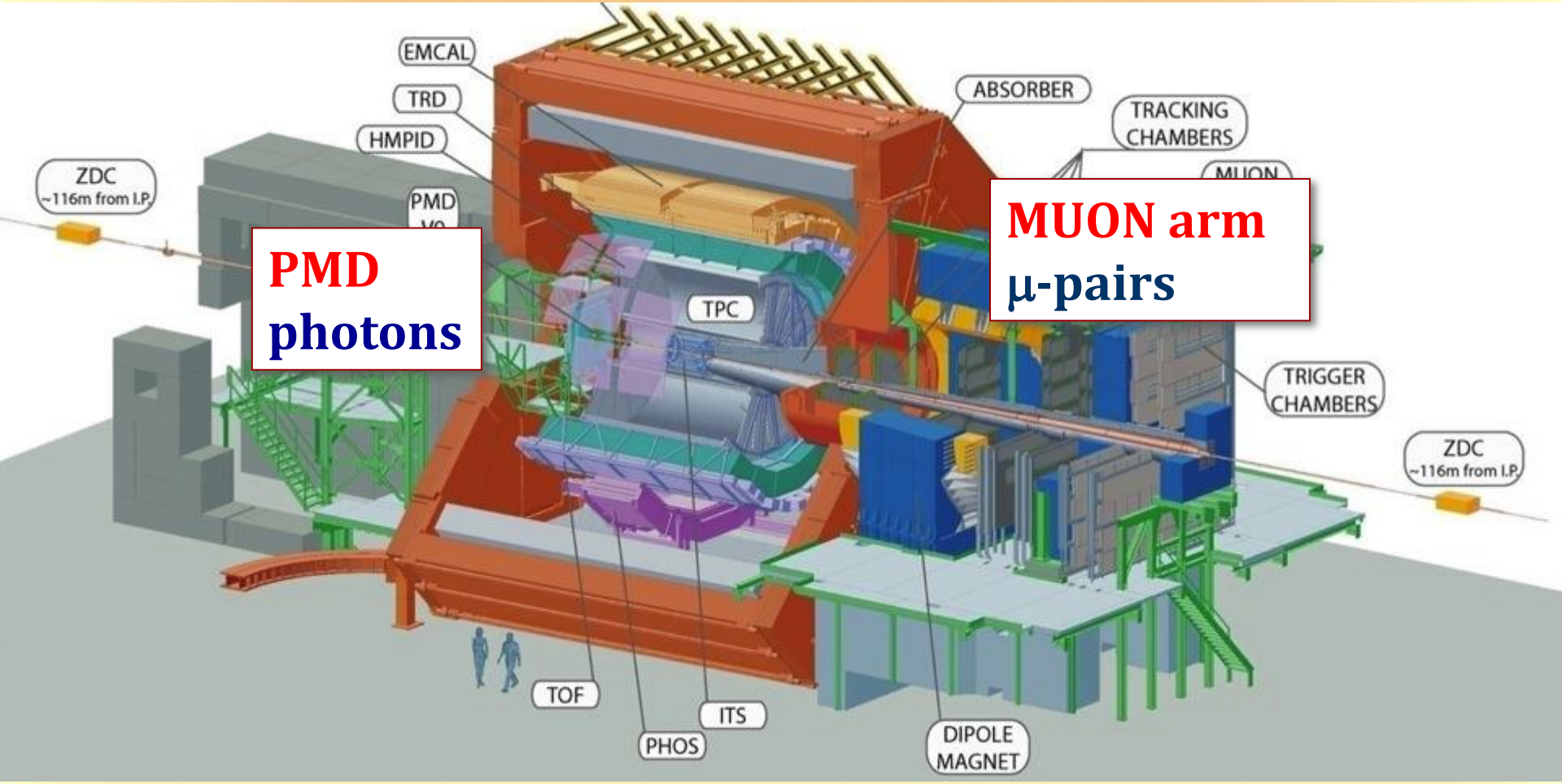
- **PRL 105 (2010) 022302**
- **PRL 103 (2009) 092301**

New analysis in progress



Higher Moments of Conserved Quantities (in Collaboration with Lattice Theory Group, TIFR)

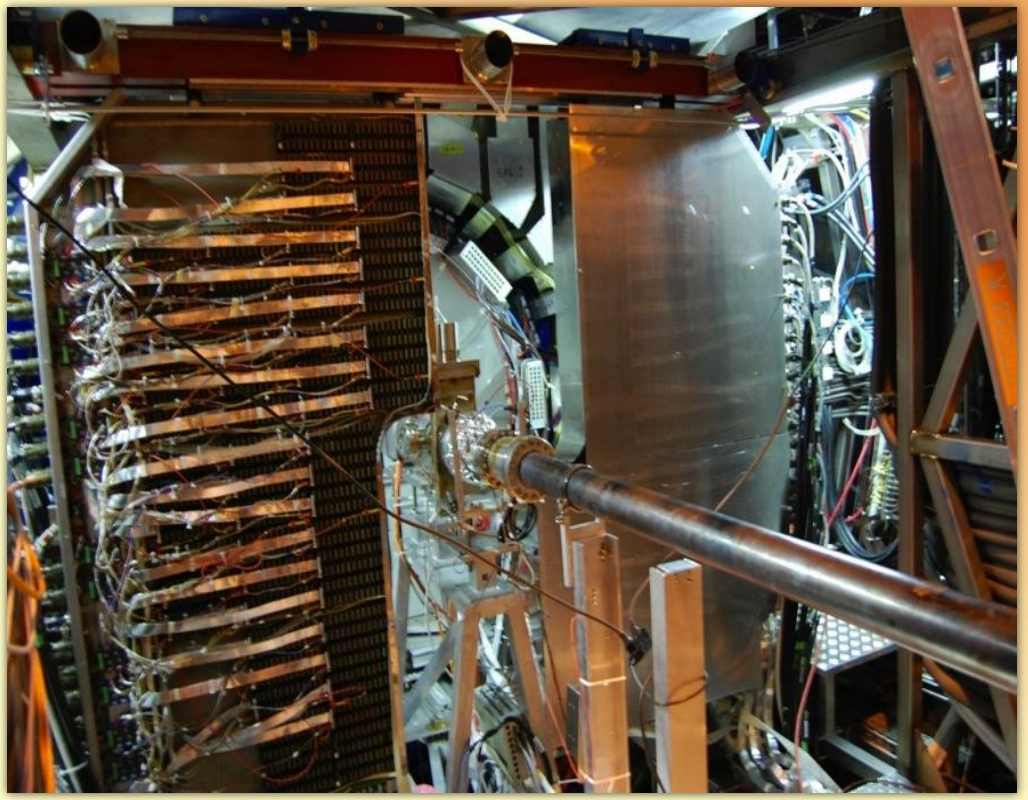
India in ALICE



PMD: Photon Multiplicity Detector

Fully Indian effort: from conception to commissioning (Design, Fabrication, Installation, Detector Control and Data Acquisition)

Measurement of photon multiplicity and spatial distribution of photons in the forward region on an event-by-event basis

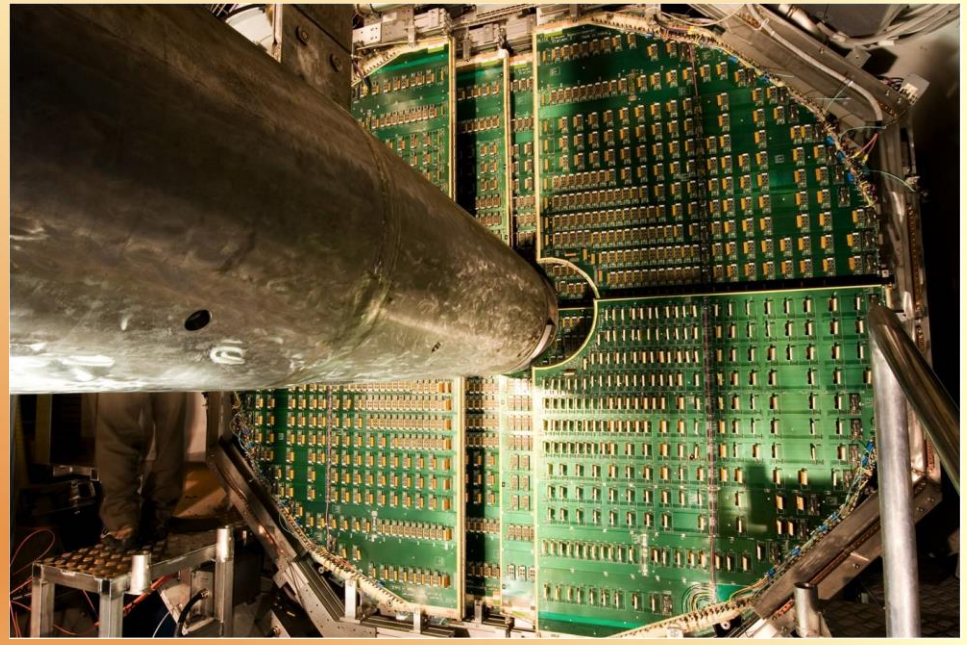


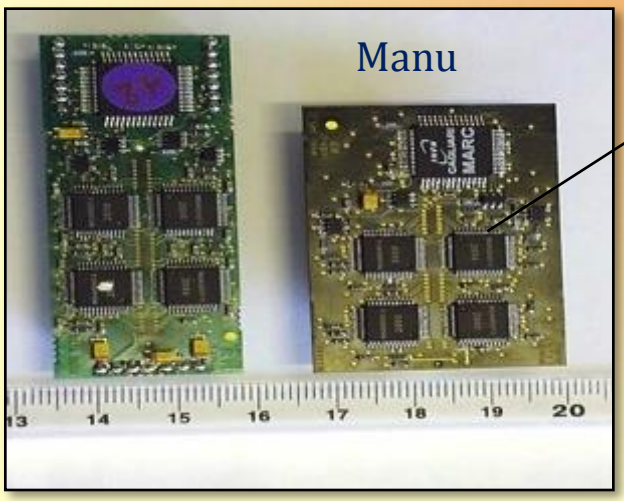
- Total no of honeycomb cells = 221184
- Cell depth = 0.5 cm
- Cell Cross section = 0.23 cm^2
- 1 module = 4608 cells read
- 1 module read by 72 FEE boards
- 1 FEE board = 64 cells (4 MANAS Chips).
- Each MANAS reads 16 channels
- Sensitive medium : Gas (Ar+CO_2 in the ratio 70:30)
- Total no of Modules = 48

Muon Tracking Chambers

Collaboration France, India, Italy, Russia:

- **5 stations of two Cathode Pad Chambers ~ 100 m^2**
- **1.1×10^6 channels, occupancy < 5% (in Pb+Pb) → Read out at 1 kHz**
- **Chamber thickness ~ 3% X0**
- **Beam test results for the spatial resolution : 50 μm for a required resolution < 100 μm**





MANAS electronic chip: 16-channel Amplifier, shaper, track-and-hold

-

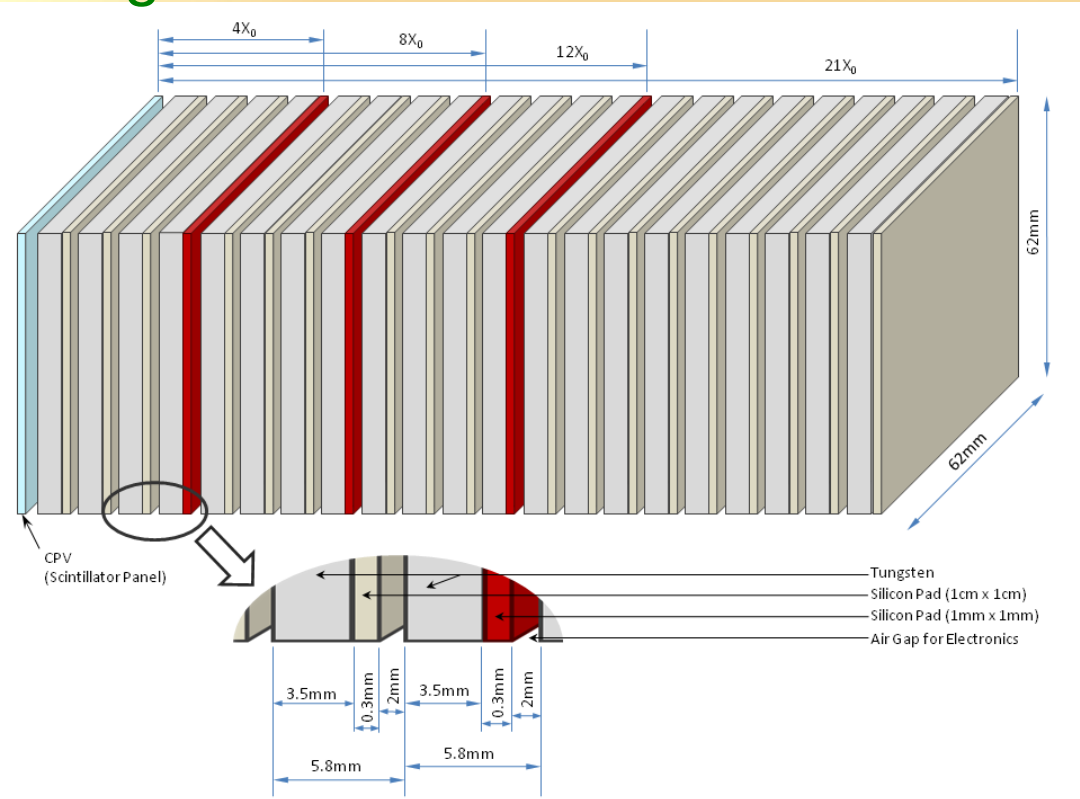
Reads 1.1 million pads of tracking chambers of ALICE

ALICE Future Upgrade: Forward Calorimeter in ALICE

Tungsten – Silicon Calorimeter

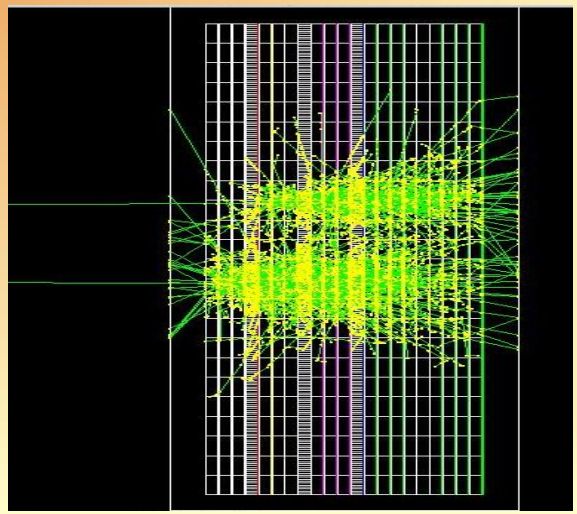
Collaboration with BEL and BARC

Needs High Resolution Silicon Sensors



25 Layers Silicon layers

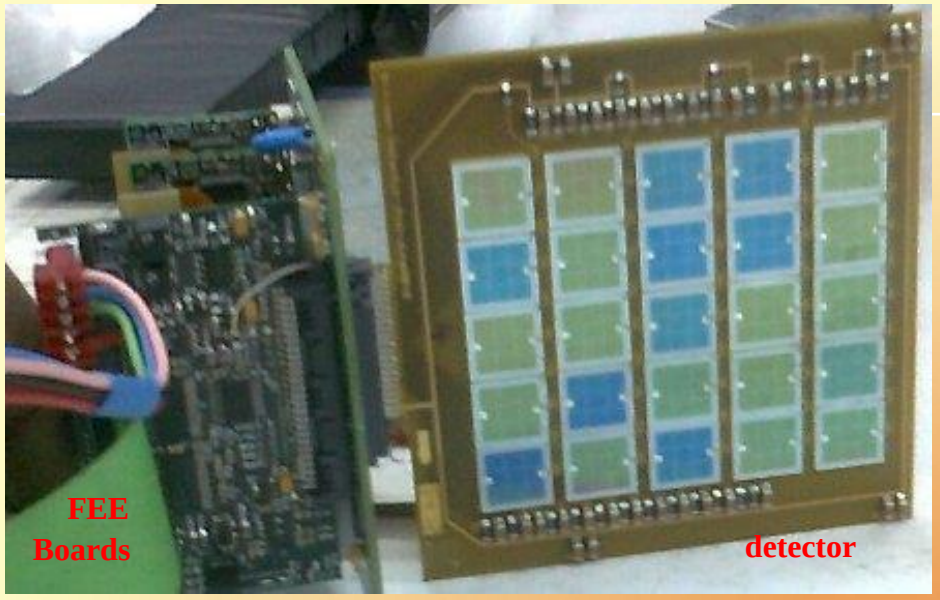
- **22 layers of 1cm x 1cm silicon pads (500 K channels)**
- **3 layers of 1mmx1mm silicon pads (3 Million channels)**



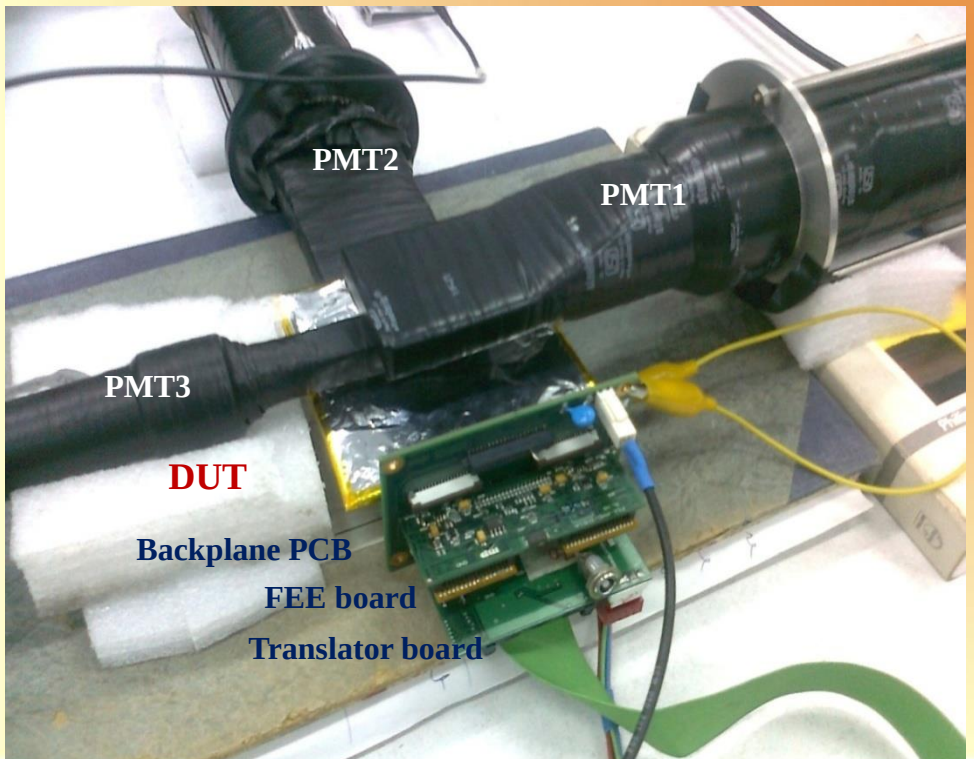
Physics:

- **Initial State: Low-x Gluon Saturation**
- **Initial State: Nuclear PDFs**
- **Probing the strongly interacting matter thru jet quenching, flow and correlations.**

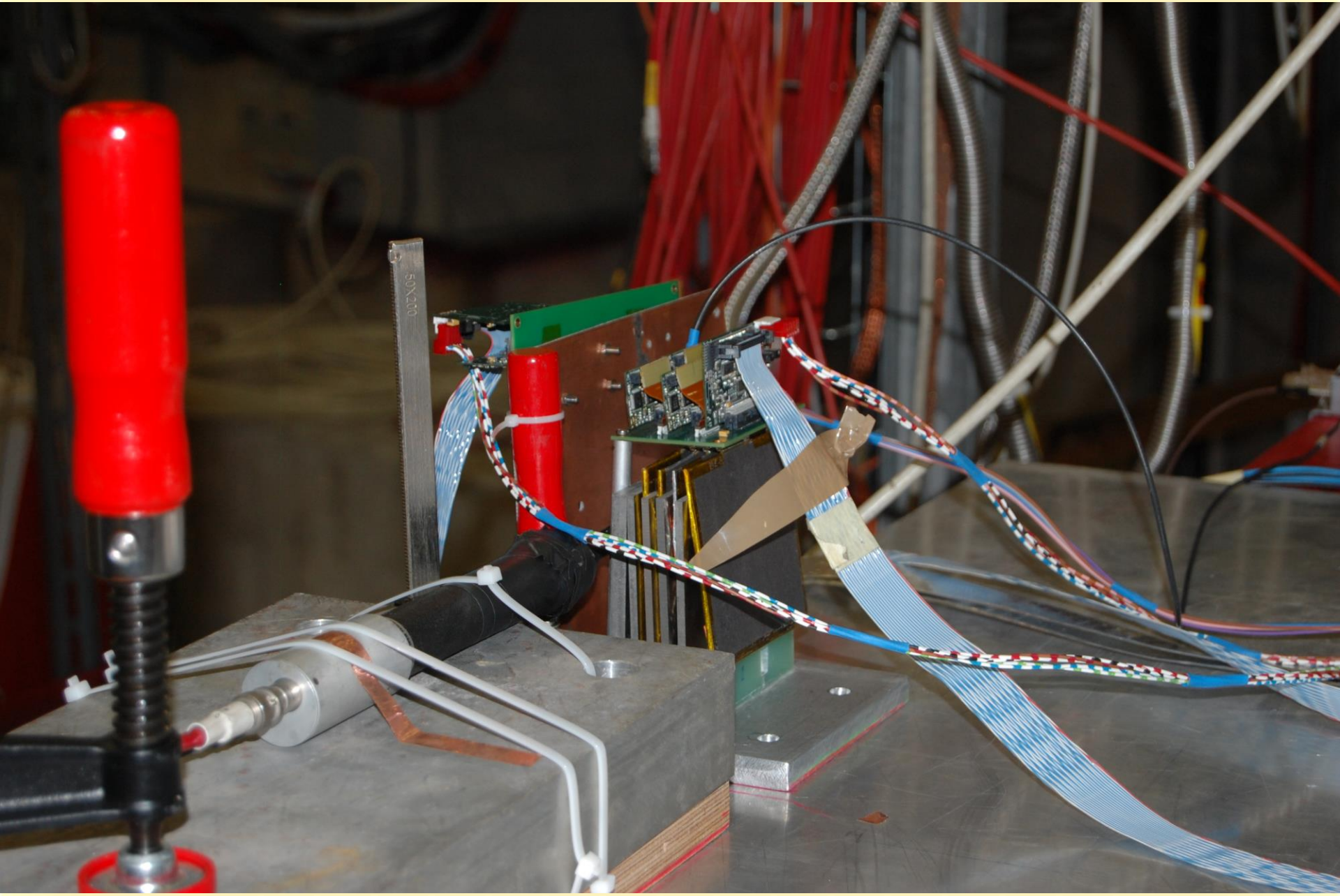
Silicon pad detector array Tests at VECC



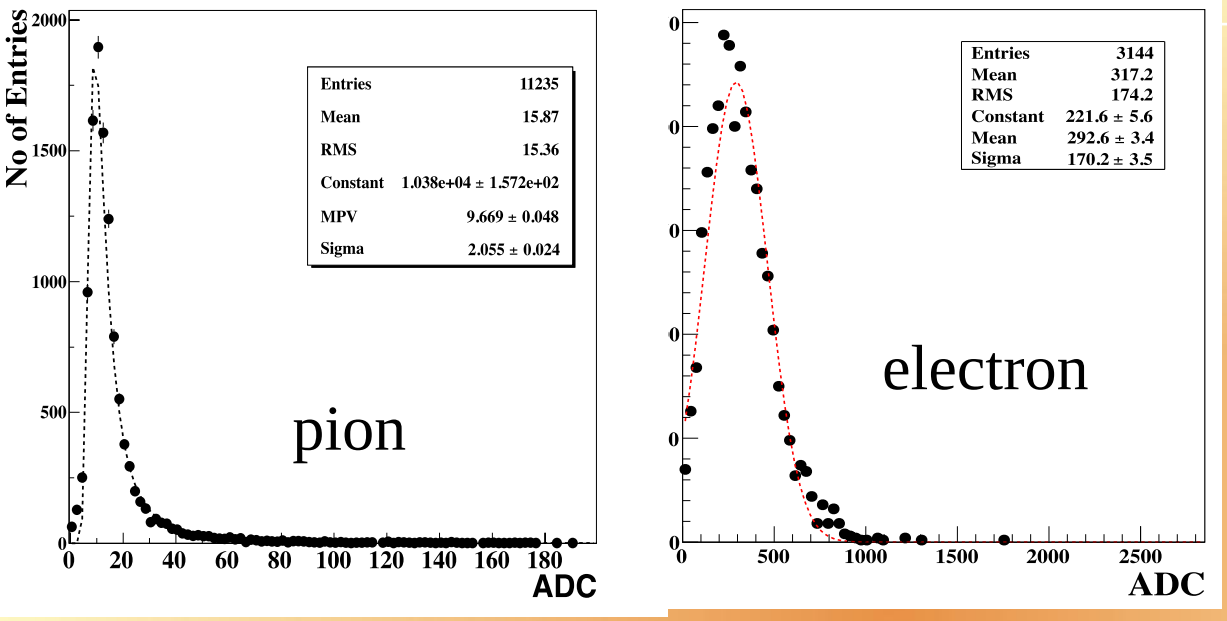
Tests with MANAS FEE

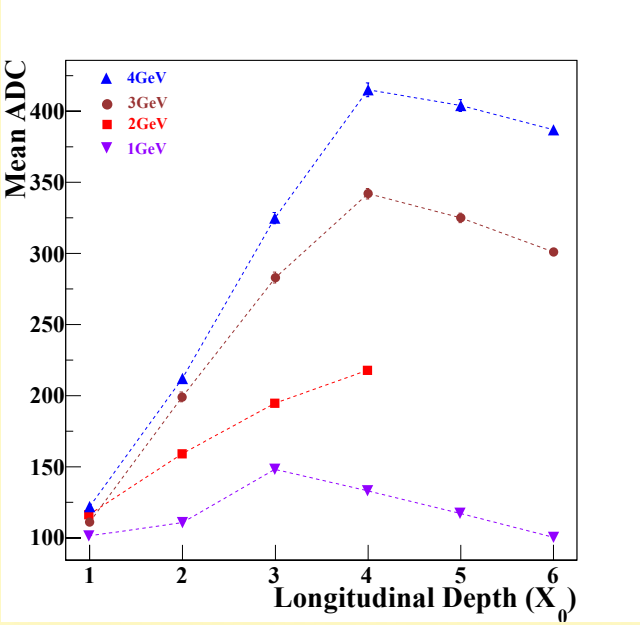


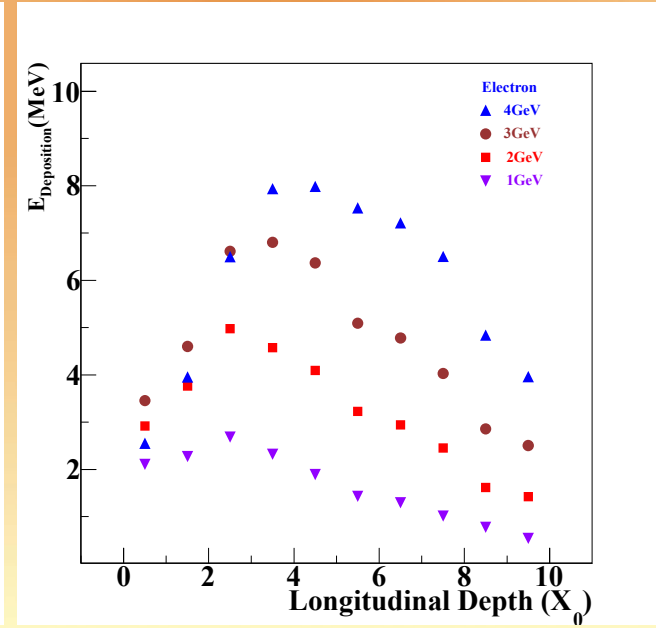
Tests with ANU FEE



Results from the Testbeam







Research Scholars in ALICE Experiment

Sanjib Muhuri	VECC	• Design of Forward EM Calorimeter • Study of gamma-tagged jets
Sudipan De	VECC	• Photon Multiplicity • Long range correlations
Subhash Singha	NISER (VECC)	• K* resonance • Photon Multiplicity
Sumit Basu	VECC	Indentified particle spectra and Temperature fluctuations
Maitreyee Mukherjee	VECC	Multiplicity and charged-neutral fluctuations using FMD and PMD
Subikash Choudhury	VECC	Dihadron correlations
Debojit Sarkar	VECC	Dihadron correlations
Somnath Kar	VECC	D(0)-hadron correlations

Satyajit Jena	IIT-B	• Net-charge fluctuations • Photon Multiplicity
Anitha Nyatha	IIT-B	• Azimuthal Asymmetry of photons, analysis in advanced stage
Greeshma	IIT-B	• Tagged di-hadron correlations
Nirbhay Behera	IIT-B	• Higher moments of conserved quantities such as net-charge and net-proton
Jitendra Kumar	IIT-B	• D+ hadron correlations
Divyash Pant	IIT-B	• Photon Flow
Nileema	IIT-B	

Rama Chandra Baral	IOP	• Lambda resonance spectra and flow
Srikant Tripathy	IOP	
Palas Khan	SINP	Upsilon studies
Biswarup Paul	SINP	J/Y(1S) and J/Y(2S) studies
Aditya Mishra	IIT – Indore	Photon – charge fluctuation
Rakesh Majumdar	IIT – Indore	pT fluctuations for identified particles
Puja Parikh	IIT - Indore	

Deepika Rathee	Panjab U.	• Fluctuation of particle ratios
Ranbir Singh	Jammu U.	• Azimuthal asymmetry of photons and charged particles
Rohni Sharma	Jammu U	• Particle fluctuations
Sonia Rajput	Jammu U.	• D^{*}- hadron correlation
Ankita Sharma	Jammu U.	• D+ - hadron correlation