# Analysis of astrophysical phenomena using efficient and parallelized models on HPC computing systems.

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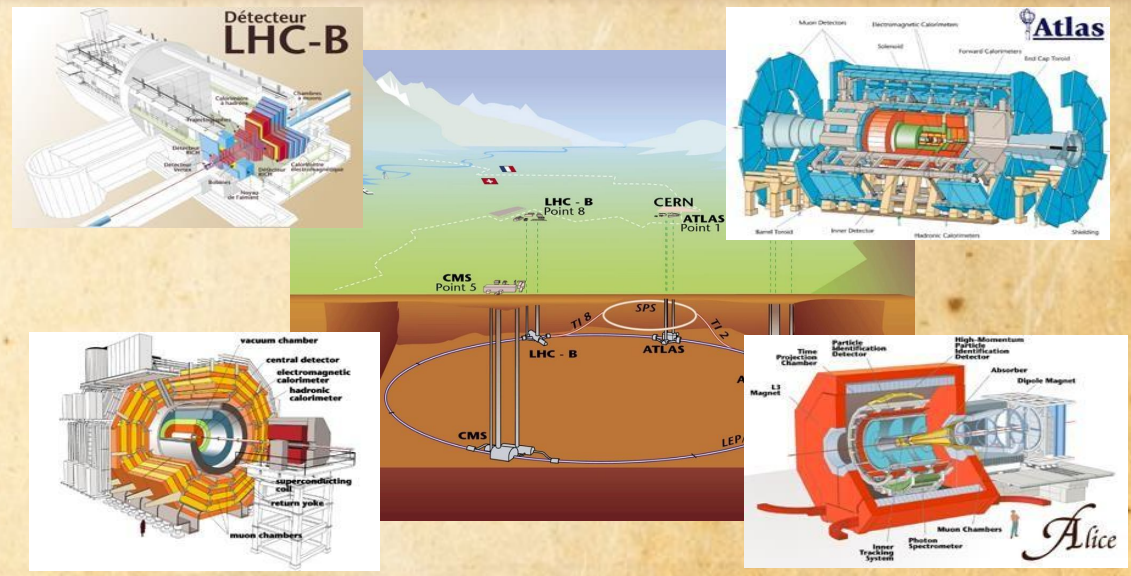
PhD course of National Interest in Technologies for Fundamental Research in Physics and Astrophysics

# Characterization of Silicon Sensors of the CMS Outer Tracker, Dark Matter analysis using CMS Data and ALICE Data for Heavy ion physics analysis

- Bachelor of Studies in **Physics** with Research in Plasma Physics.
- Master of Philosophy in **Experimental High Energy physics** at **National Centre for Physics** Pakistan in Collaboration with **CMS and ALICE experiment at CERN.**
- I have worked on the Characterization and assembly of **silicon sensors** for the phase II upgrade of **CMS outer tracker.**
- **Dark matter analysis** using **CMS data** and **Heavy ion Physics** analysis using **ALICE data**.



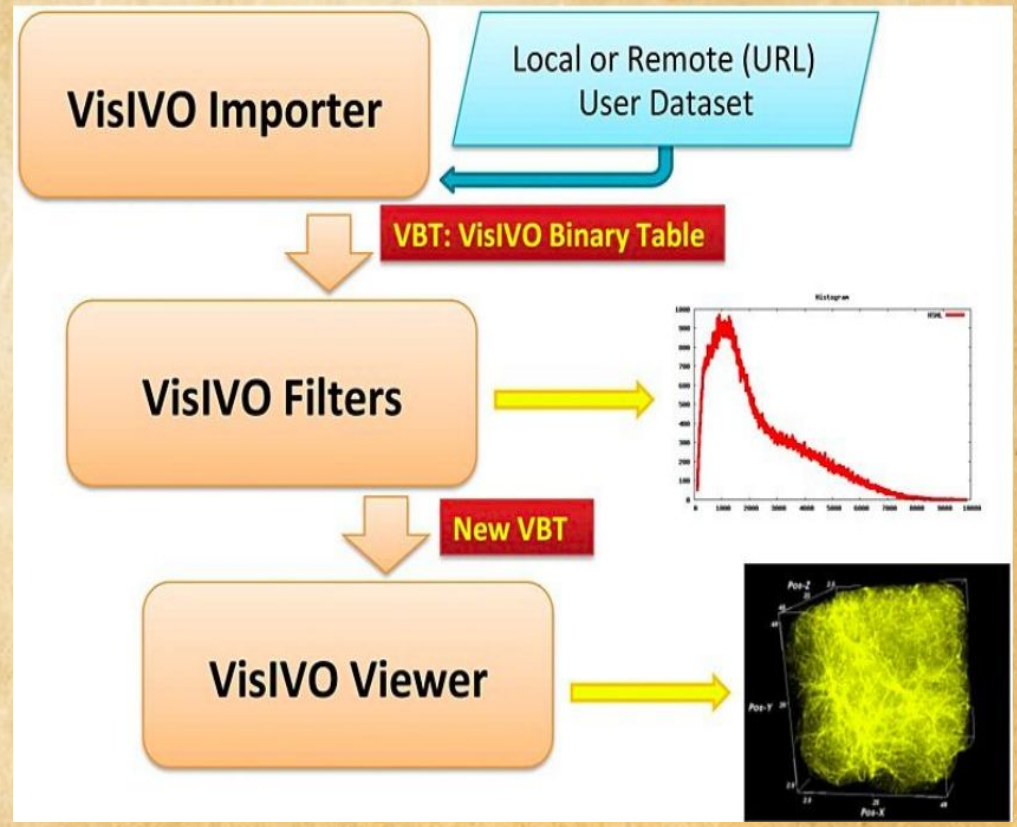
# Analysis of astrophysical phenomena using efficient and parallelized models on HPC computing systems.

- This research aims to efficiently process and analyze large astrophysical datasets using parallel processing, wth **MPI (message passing interface), OpenMP (open Multi processing)** and **OpenACC (Open Accelerator).**

- The cosmological simulations and Astrophysics generates massive datasets from simulations like the **Dark energy and massive Neutrino Universe (DEMNUni)** suite.

- We are using **VisIVO server** for this project, which has three parts:
  **VisIVO Importer, VisIVO Filter, VisIVO Viewer.**

- The VisIVO Server provides a variety of filters, with my research focusing on:
  **Point Distribute Filter,** which employs three interpolation algorithms:
  - **Cloud-In-Cell (CIC)** using in my research,
  - **Triangular Shaped Cloud (TSC)**, and
  - **Nearest Grid Point (NGP).**



# Task Parallelization with timeline

- **1. Data Distribution with MPI_Scatter:  (feb to april 2025)**
- **2. Data Collection and Communication with MPI_Reduce  (may to june 2025)**
- **3. Parallel Processing with OpenMP (july to august 2025)**
- **4. OpenAcc (Open Accelerators)(sep to oct 2025)**

- **Challenges | Solution**
- Unequal load Balancing **(MPI)** | Implement dynamic workload balancing
- Race Conditions **(OpenMP)** | Use atomic operations for shared memory updates
- Communication overhead | Use **non-blocking communication MPI_Isend** and **MPI_Irecv**
- Memory Constraints | Distribute, optimize memory transfers
- **(OpenACC/OpenMP**
- Results do not match so far: **Parallel vs. Serial code** | Need to do an accurate test, verify parallel code.