CMS Outer Tracker Phase -II Upgrade, Dark Matter search using CMS Data, ALICE Data for Quarkonium production

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Quantum Universe Attract Workshop
DESY, Hamburg, November 2025

Scientific Motivation and Content Overview

Aim of the projects:

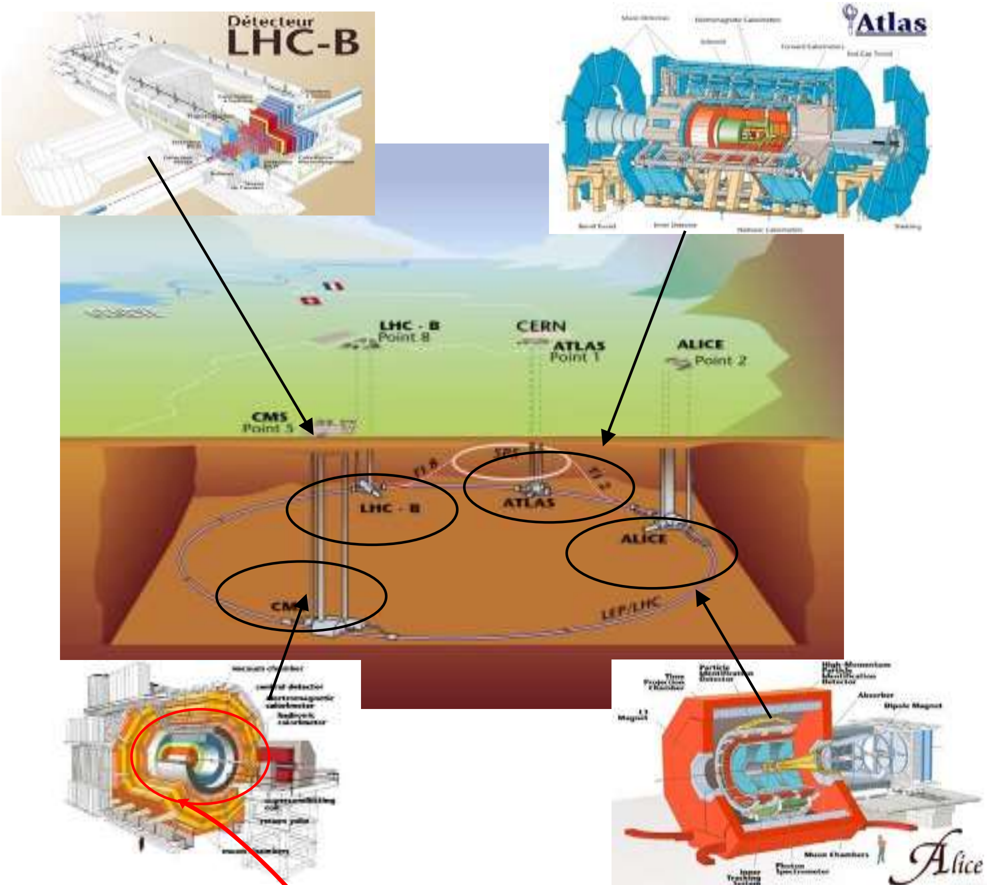
The HL-LHC will cause a significant increase in the number of pile-up interactions, may create difficulties for the current detectors like CMS and ATLAS...

Dark-matter searches with CMS aim to identify signatures of invisible particles predicted by theories beyond the Standard Model.

Content Overview

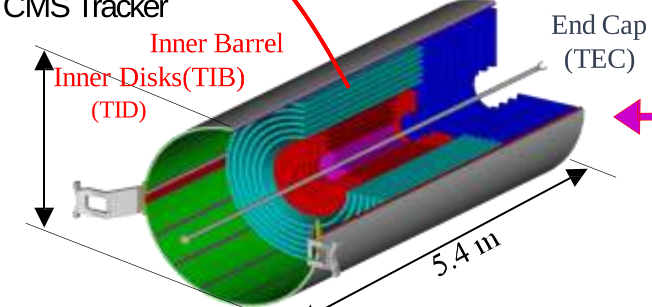
- **CMS Phase-II Upgrade**
- **Assembly steps for Modules**
- **Characterization of the Modules**
- **Dark matter search using CMS data**
- **Quarkonium production using ALICE data**
- **Conclusions and Future Goals**

The Large Hadron Collider (LHC)



- Accelerate protons up to an energy of 7 TeV / beam .
- 27 km in circumference , 3.8 m wide tunnel in the form of a circular ring stationed 100 m under the ground.

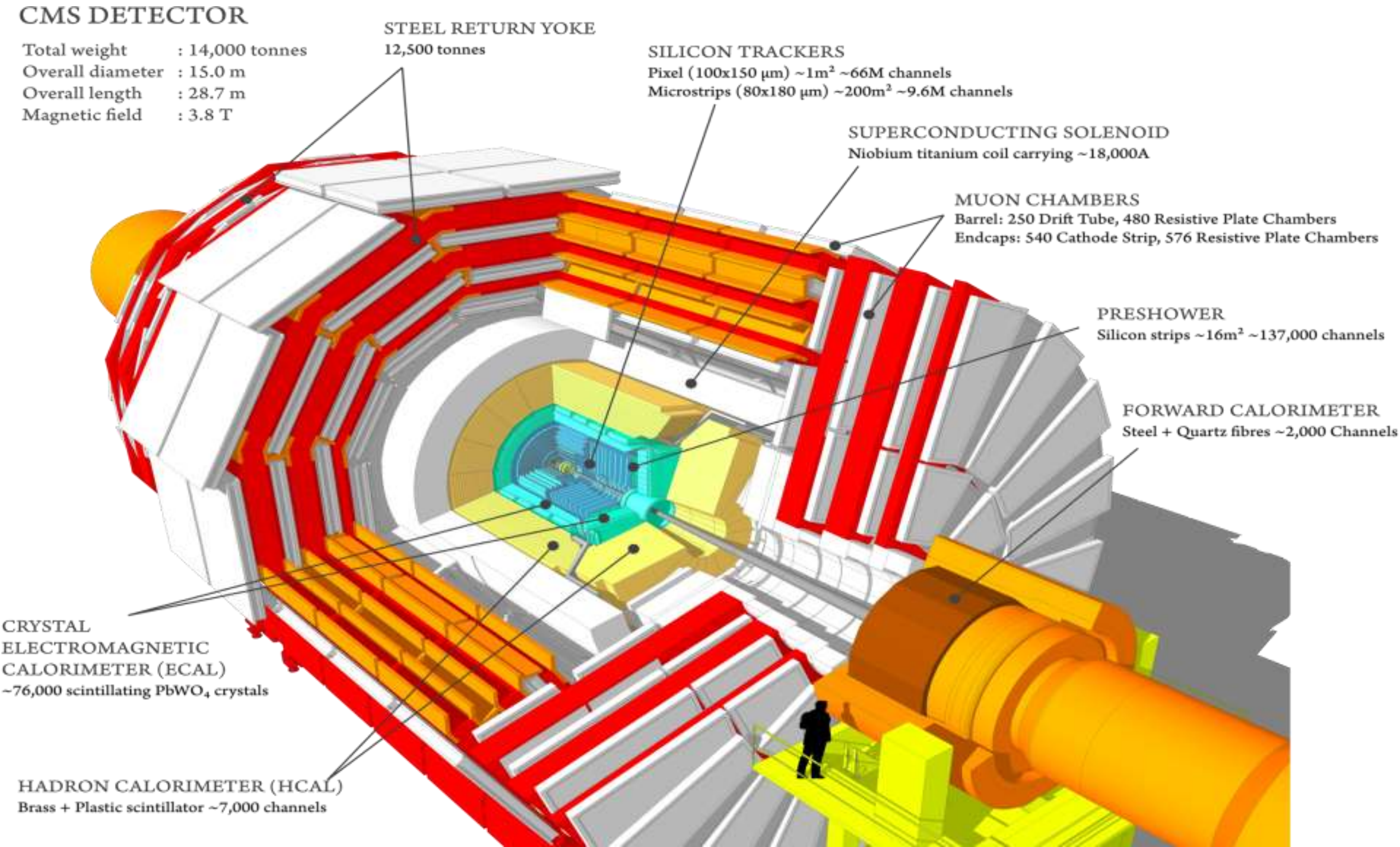
- CMS Tracker



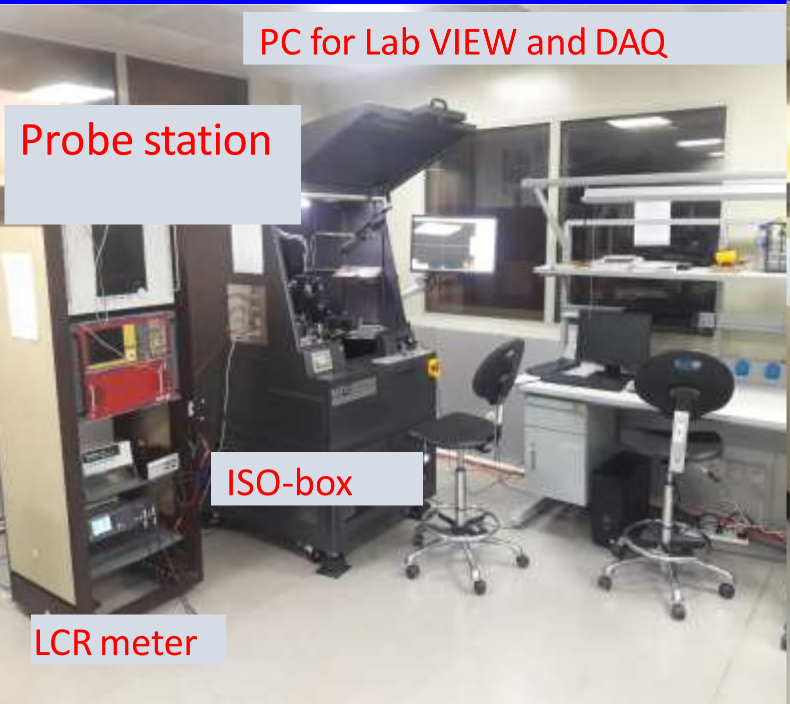
CMS – " Silicon Sensors"

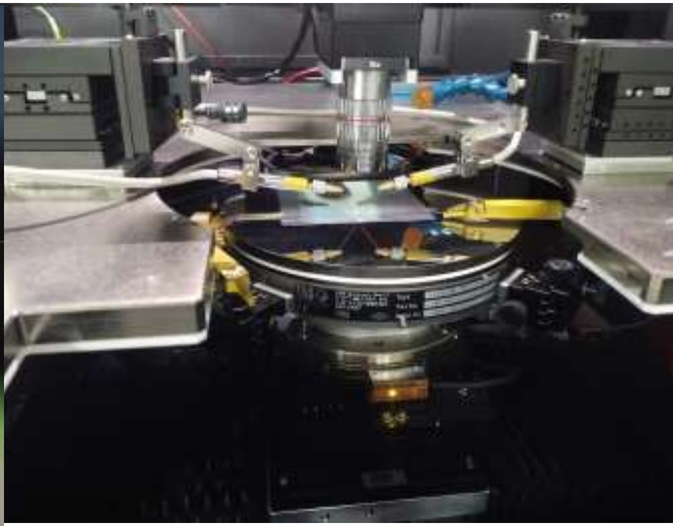
- Micro Strip:
- ~ 214 m^2 of silicon strip sensors, 11.4 million strips
- Pixel:
- 66 million pixels
- Most challenging operating environments (LHC)

CMS Experiment at (LHC)

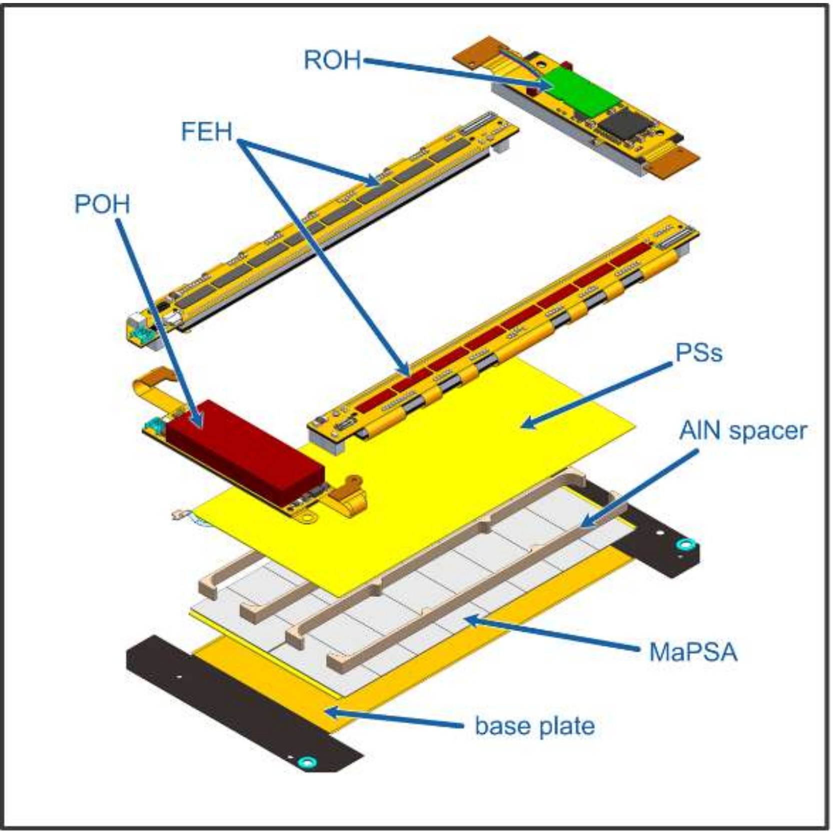


SQC Setup at EHEP Lab Clean room at NCP

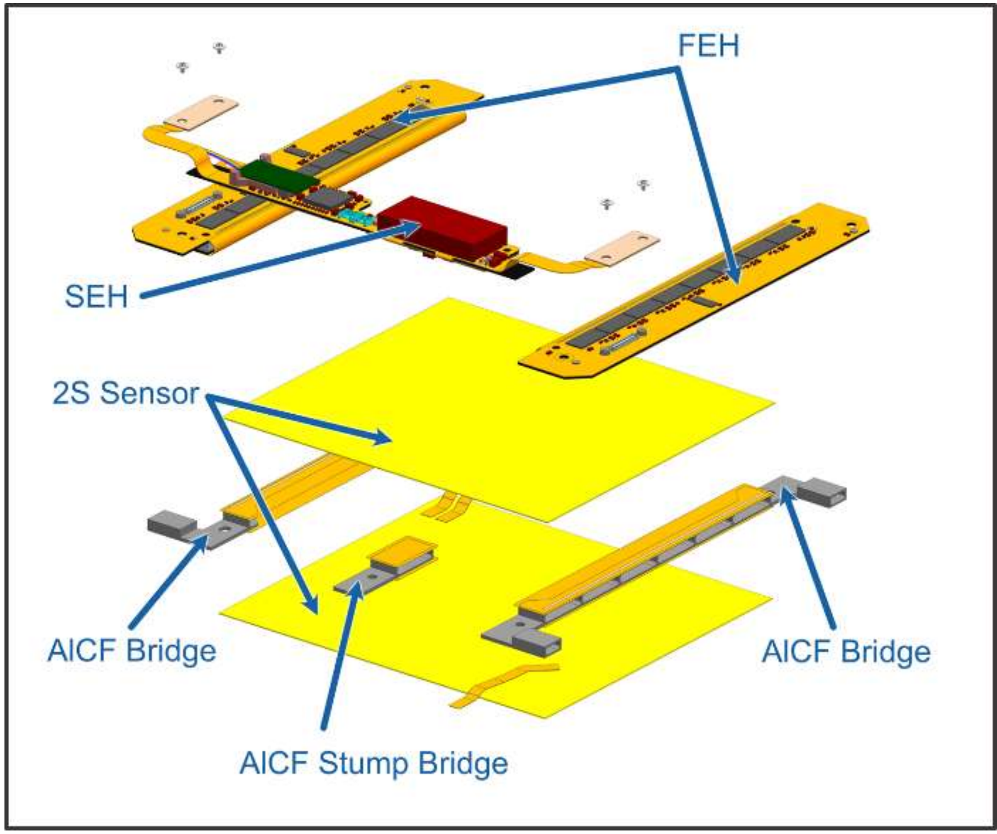




2S(Silicon sensor) Module Assembly steps

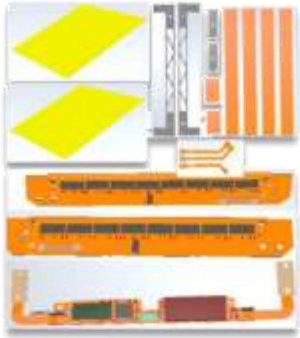


(a)

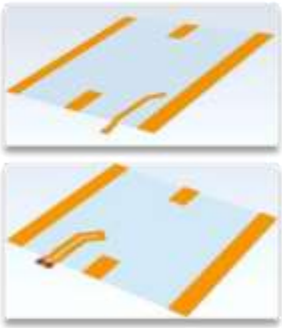


(b)

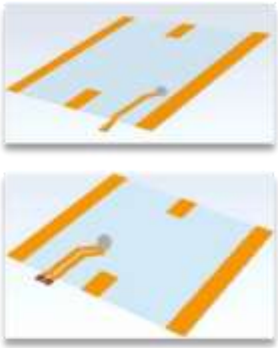
Module Assembly steps



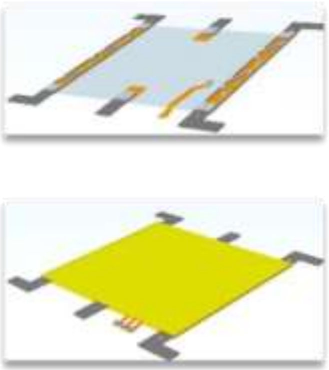
STEP 1: Optical Inspection



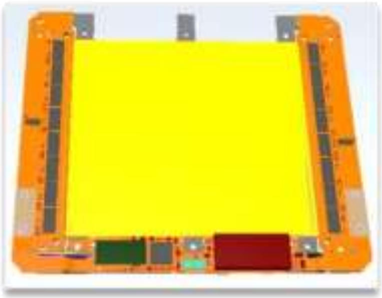
STEP 2: PI-Strips & HV-tail Gluing



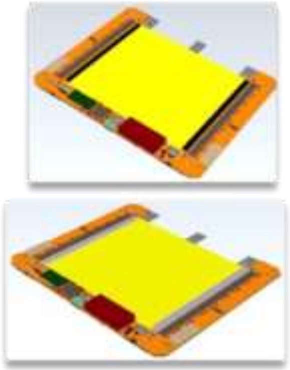
STEP 3: HV-tail Wire-bonding & Encapsulation



STEP 4: Bare-Module Assembly

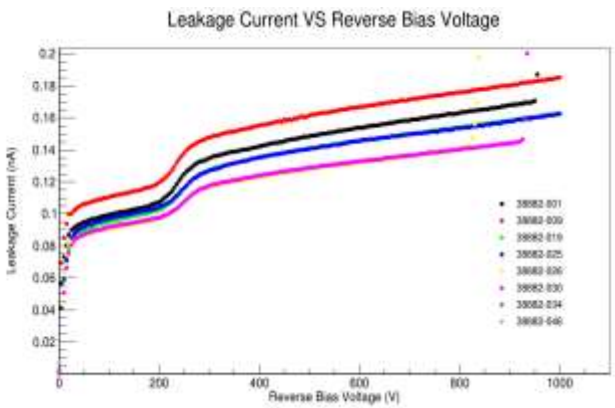


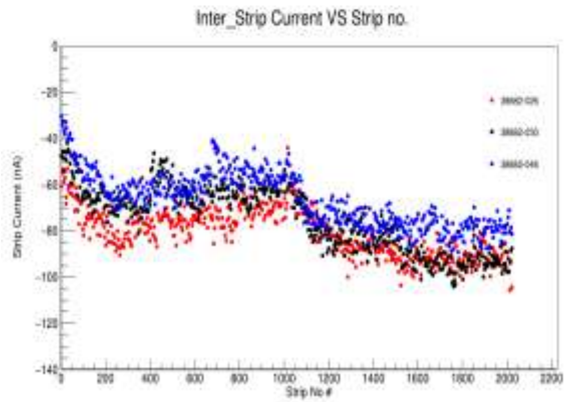
STEP 5: Hybrid Gluing

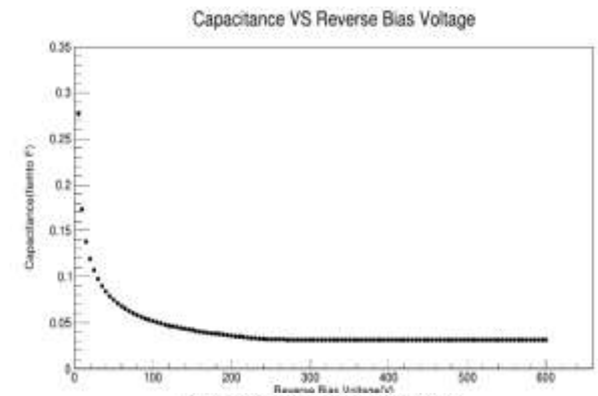


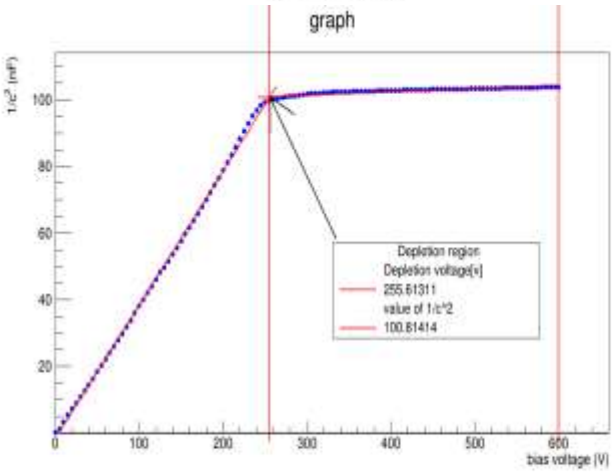
STEP 6: Sensor-to-FEH Wire-bonding & Encapsulation

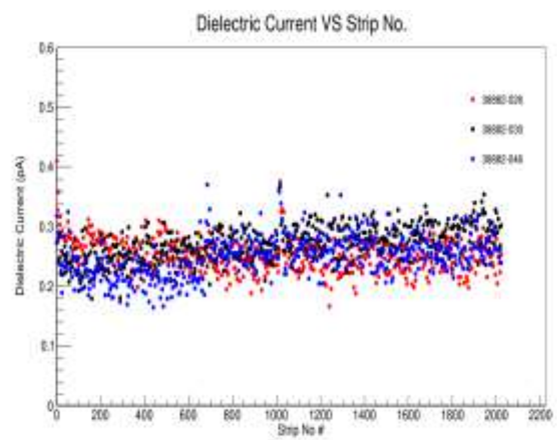
Results of Charaterizations

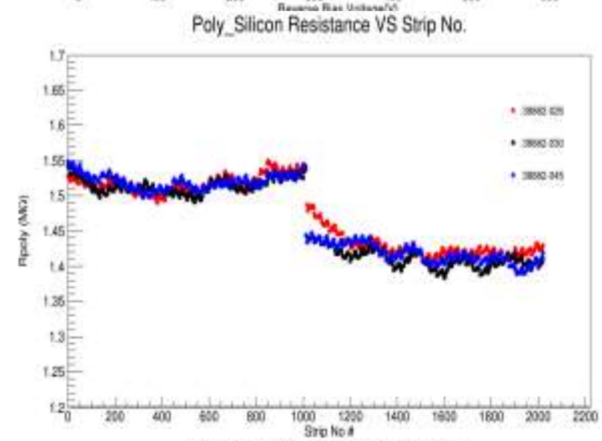


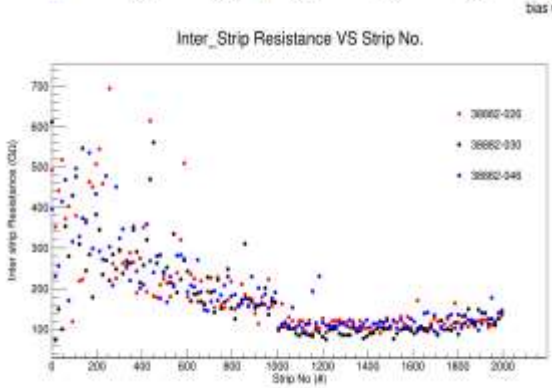


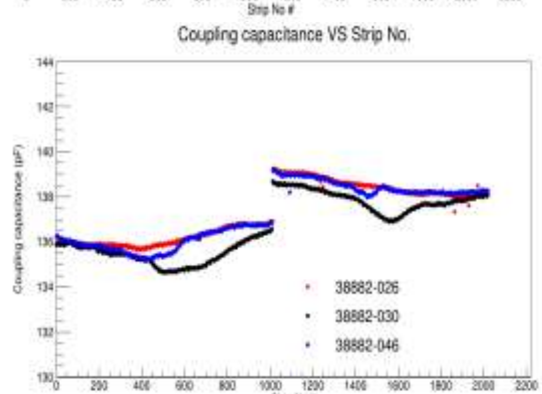


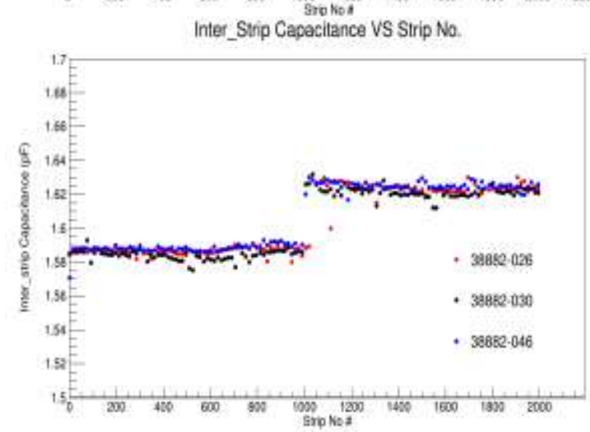












Search for Dark Matter in Missing Transverse Energy at CMS

- ❑ Search for Dark Matter in mono-Z (ℓ+ℓ-) & and mono-Higgs (bb~) channels.

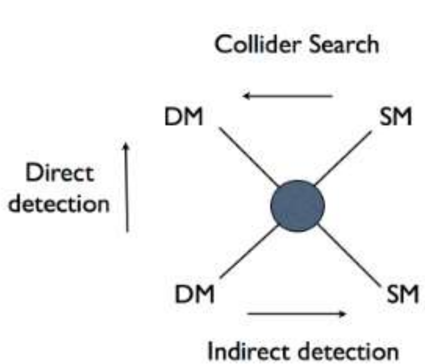
- ❑ **Signal Models**

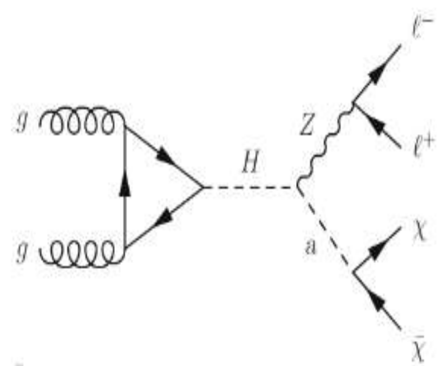
- ❑ **Two Higgs Doublet Model and 2HDM+a**

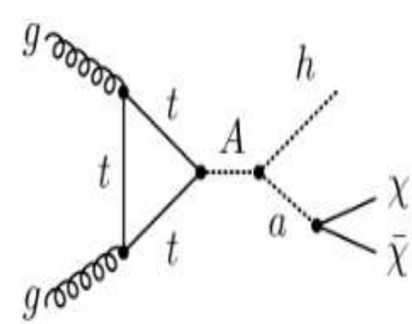
Used a next-generation DM model, called **Pseudoscalar_2HDM+**a for gg > h1 xd xd~[QCD] Identified by LHC Dark Matter Working Group.

- ❑ Why I used **Pseudoscalar_2HDM+**a Model:
  1: Because it allows for new interactions.
  2: Potential dark matter candidates.
  3: Mediators between the dark matter and the Standard Model particles, which can lead to observable effects in experiments searching for DM.

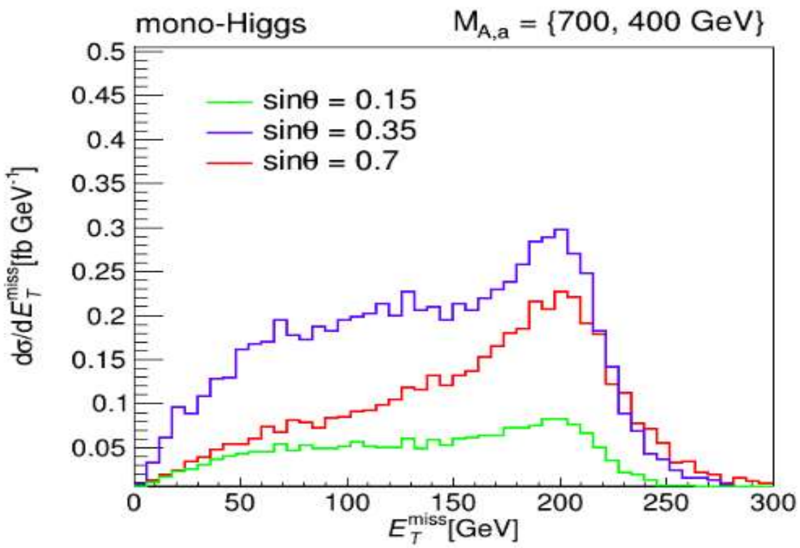
- ❑ I was using MadGraph5_aMC@NLO for Monte Carlo Simulation.
- ❑ **Three methods of DM detection**
- ❑ **Direct search**
- ❑ **Indirect searc**
- ❑ **Collider searc**

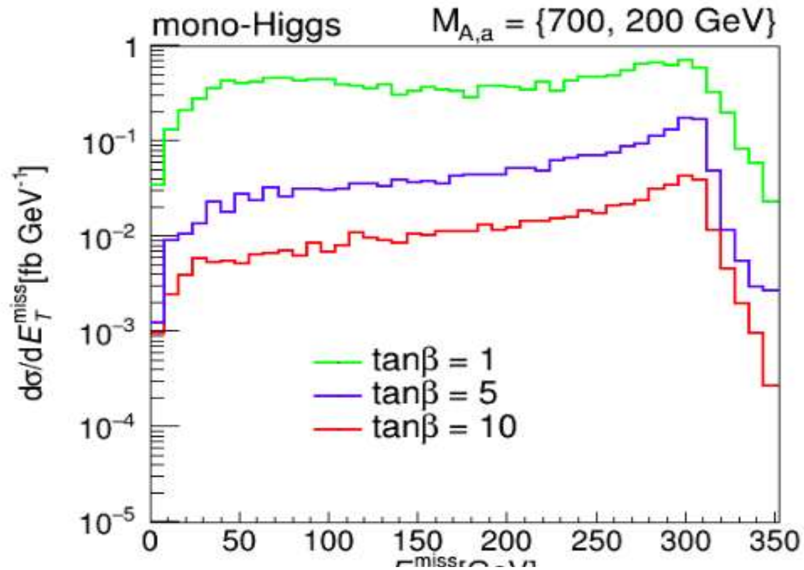


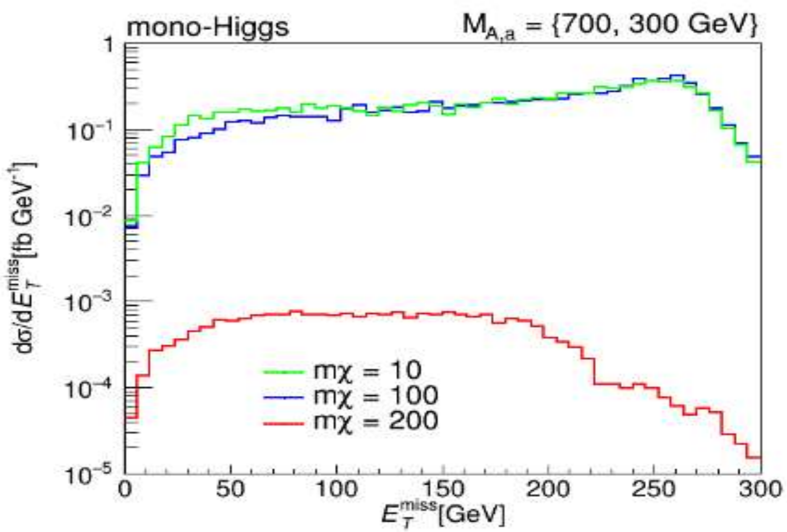


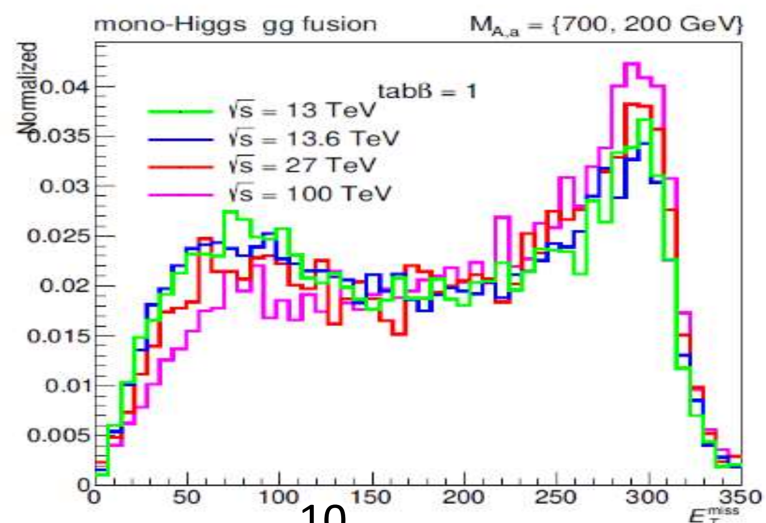


The mono-Higgs(bb~) + E_T^{miss} Analysis

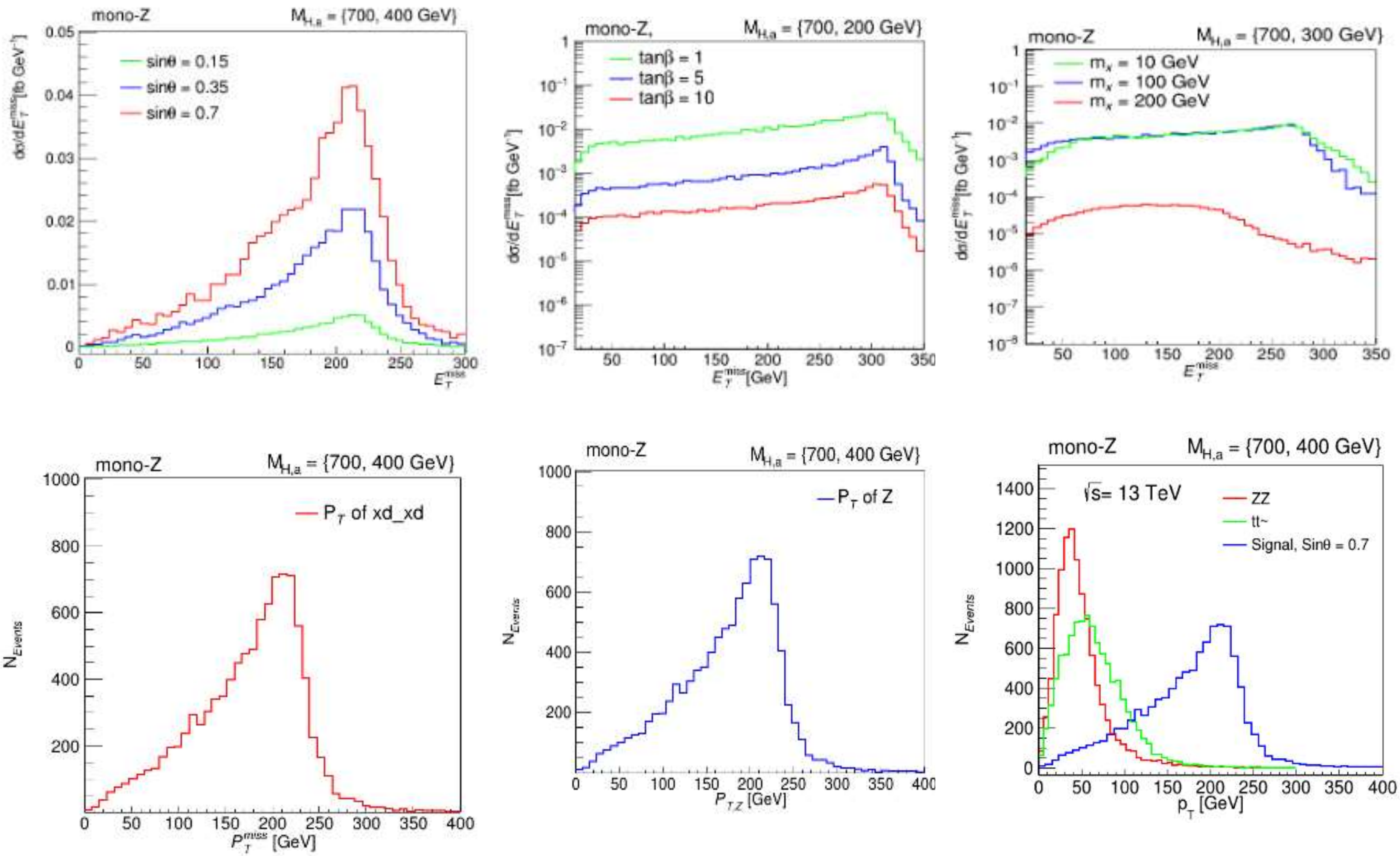








The mono-Z(ℓ+ℓ-) + E_T^{miss} Analysis



To study the thermal freeze out properties of Inclusive quarkonium production in pp collisions at $\sqrt{s}$ = 5.02 TeV

- The inclusive production cross section of charmonium (J/ψ and ψ(2S)) at $\sqrt{s}$ = 5.02 TeV.

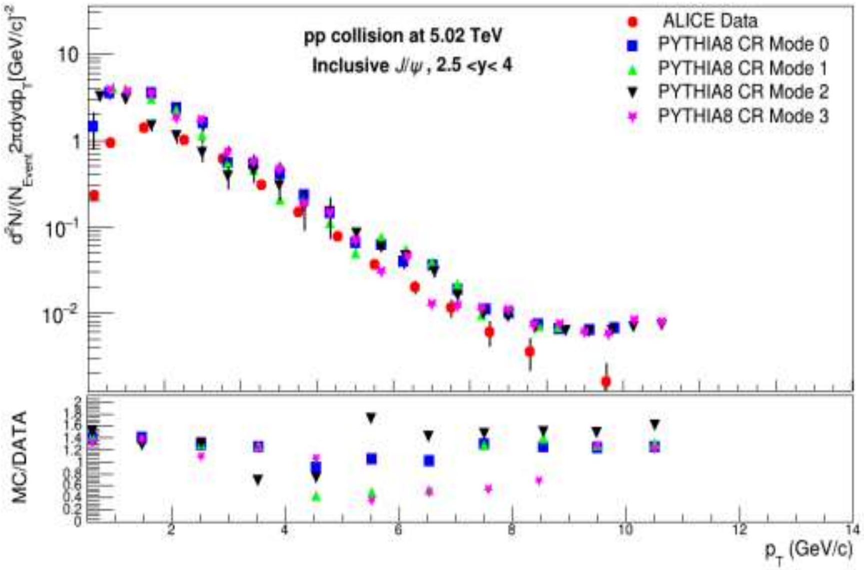
- I have worked on the measurements of pp collisions at $\sqrt{s}$ = 5.02 TeV integrated over 2.5 < y < 4
and pT < 20 GeV/c.

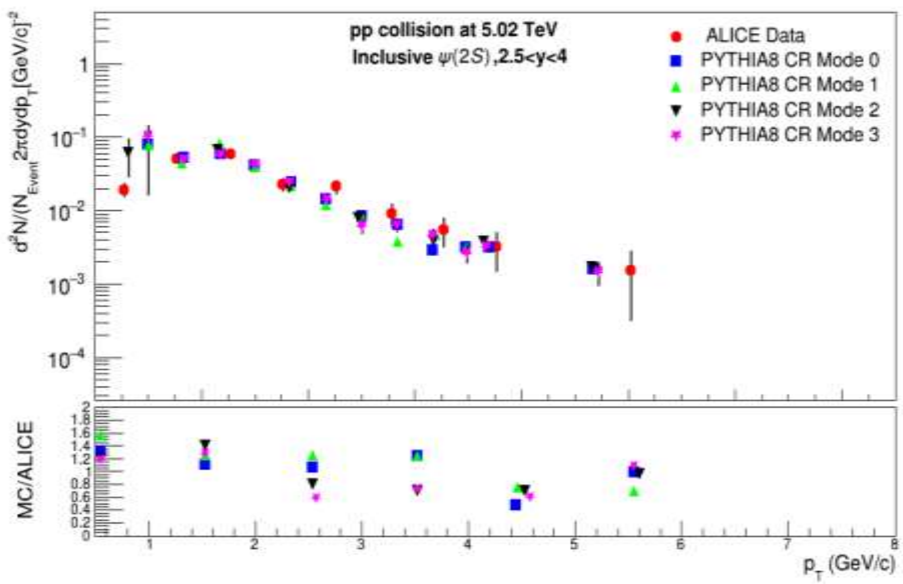
- The inclusive ψ(2S) production cross section integrated over pT < 12 GeV/c and for 2.5 < y < 4.

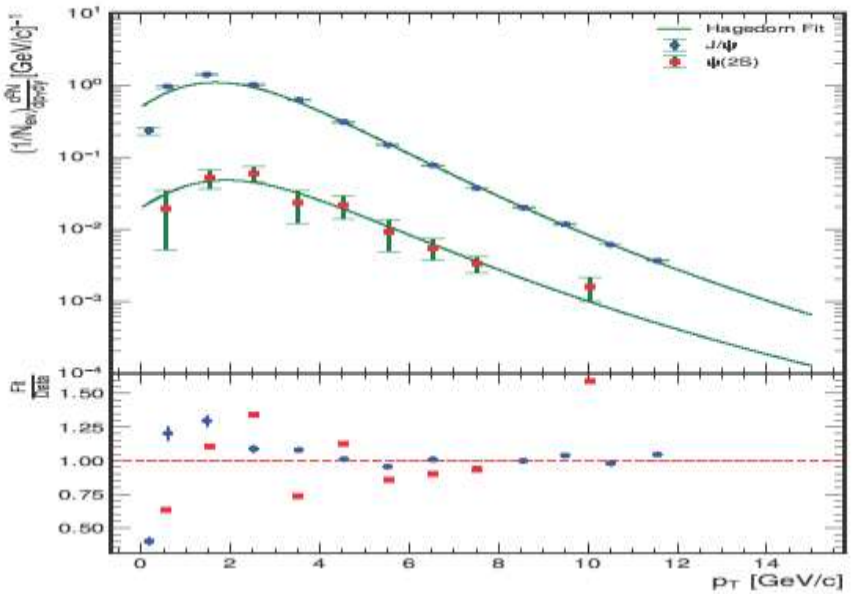
- The ALICE data and the simulations of the MC event generator PYTHIA8 with various CR Modes are comparable.

- I have also used the non-extensive Tsallis distribution function and the modified Hagedorn function to fit the doubly differential transverse momentum distributions of the ALICE data with Python and Root.

Results for (J/ψ and ψ(2S))

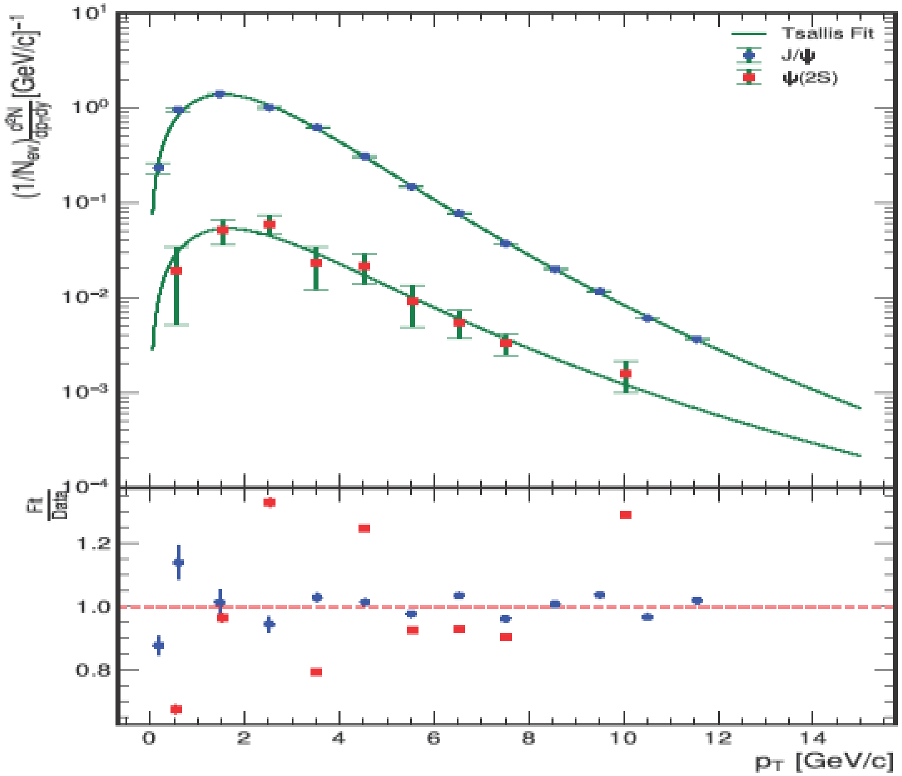




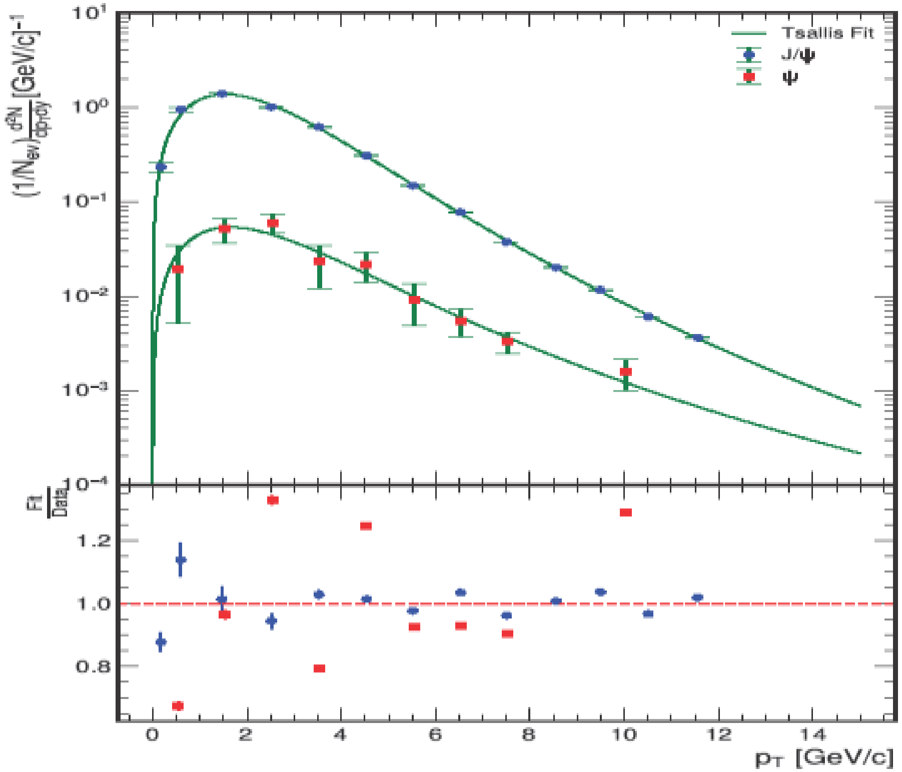


Results for Tsallis Fit

Tsallis distribution function with chemical potential μ



Tsallis distribution function without chemical potential μ




5th International Workshop on Tracking Detectors
In High Energy Physics
24 - 28 October, 2022
ICTP


Conclusions and Future goals

- The CMS Phase-II upgrade is designed to deliver enhanced radiation tolerance and high-granularity tracking performance required to sustain efficient operation under the extreme particle pileup of the HL-LHC.

- An efficient and reliable assembly and testing facility for CMS Phase-II 2S modules has been successfully developed, with all produced modules meeting the required mechanical and electrical tolerances.

- Both mono-H(bb) and mono-Z($\ell\ell$) channels show clear sensitivity to dark-matter signals.

- High missing-energy regions and multivariate techniques significantly improve background rejection, and strengthen the potential to probe 2HDM+a dark-matter scenarios at the LHC.

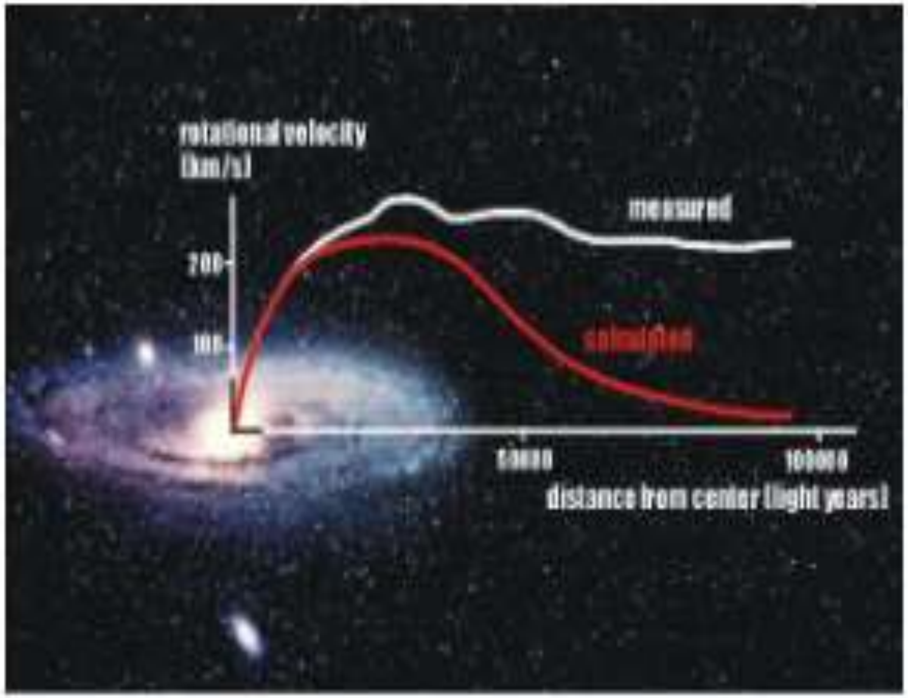
- The transverse momentum spectra of J/ψ and ψ(2S) in pp collisions at $\sqrt{s}$ = 5.02 TeV are well described by Tsallis and modified Hagedorn functions.

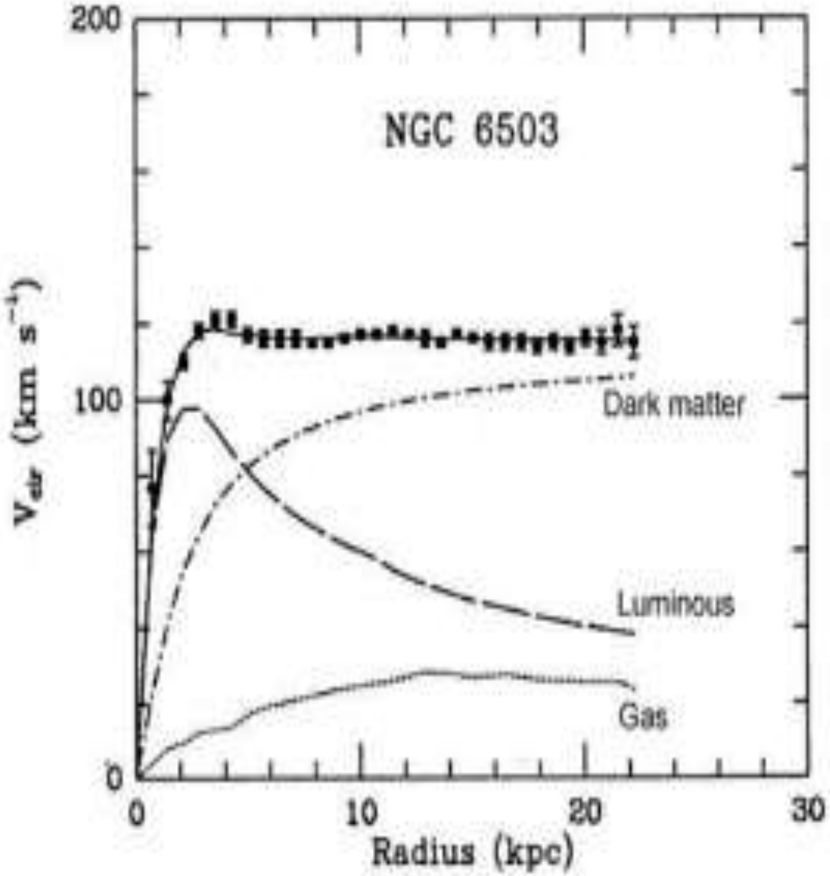
- The analysis indicates distinct freeze-out characteristics for J/ψ and ψ(2S) mesons.

Backup Slides

Evidence of Dark Matter
Galaxy Rotation Curve

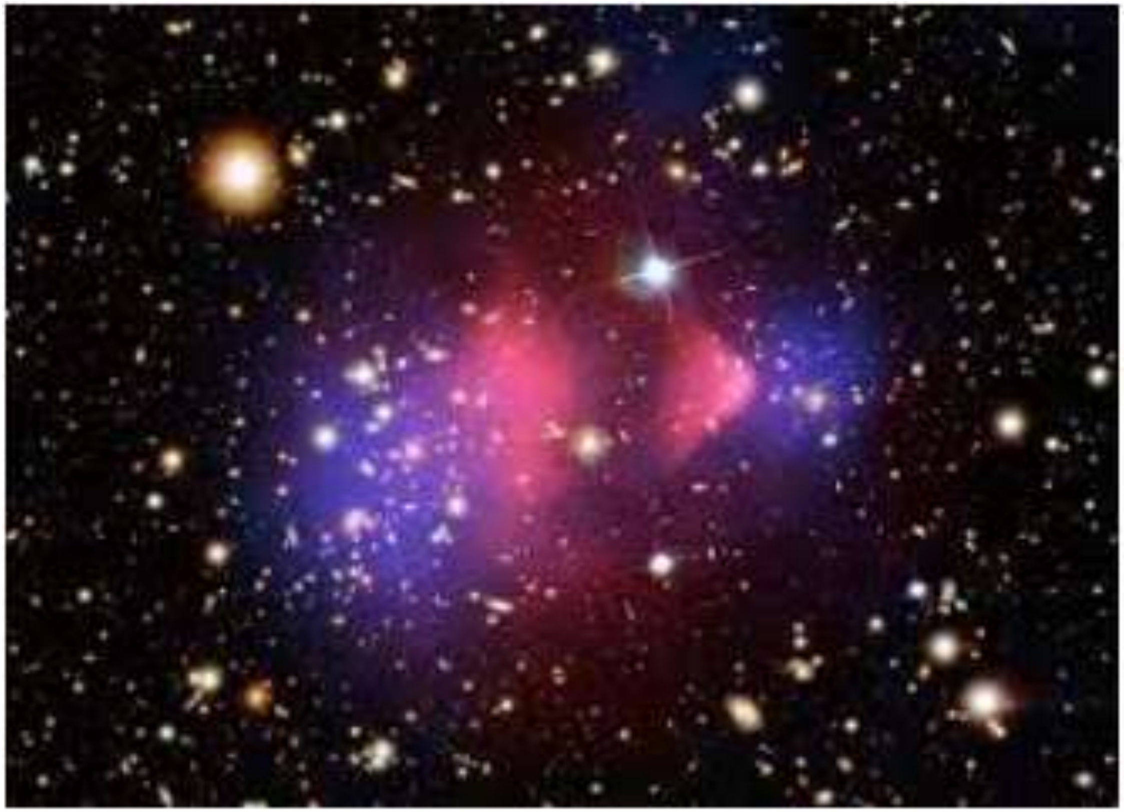
$$v(r) = \sqrt{\frac{GM(r)}{r}}$$





Gravitational lensing

- The pink region in the image shows X-ray emitting gas.
- While the blue region shows dark matter located indirectly through gravitational lensing within the cluster.



Particle	Description
χ	Fermionic DM particle
ϕ_u, ϕ_u h, H	Two Higgs doublets Light and heavy neutral CP-even scalars
$H^{\pm}$	Charged heavy Higgs
a, A^0	Light and heavy neutral CP-odd pseudoscalar
Parameter	**Description**
m_x	DM mass = 10 GeV
m_H	Mass of the heavy neutral CP-even scalar
m_h	Mass of the light neutral CP-even scalar, m_h = 125 GeV
$m_{H^{\pm}}$	mass of the heavy charged CP-even scalar
tanβ	the ratio of the VEVs of the two CP even Higgs bosons
α	the mixing angle between the CP even scalar Higgs bosons
θ	the mixing angle between the two neutral CP-odd Higgs bosons

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

- **Aims and objectives:**
- The aim of the research is efficiently processing and analyzing large astrophysical datasets.

- The cosmological simulations and Astrophysics generates massive datasets from
- simulations like the DEMNUni suite, which model the universe's evolution.

- A single-threaded process struggles with massive datasets due to speed and memory limitations.

- Parallel computing using MPI, OpenMP and OpenACC overcomes this with dividing the task into multi processing and multi threading and taking data in chunks Efficiently.

Here is the link to my GitHub repository which contains code parallelized with MPI and OpenMP.

https://github.com/itxsaimali/VisIVOServer-PointDistribute-miniapp/tree/Parallel-code

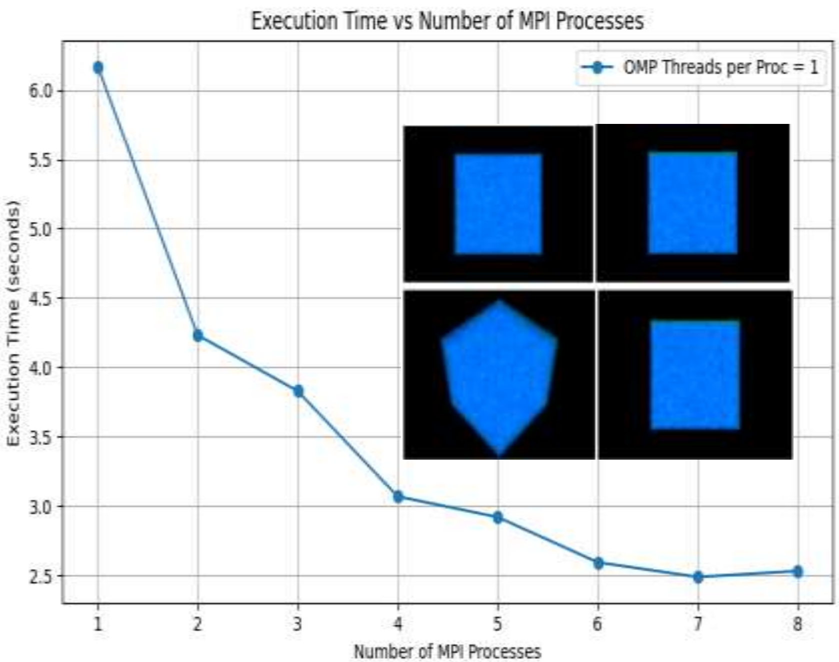
Benchmarking:

- I have tested code with binary data file of 50 as well as 100 million records data points with the parallel version of the code with different number of processes and multi threading.

# of MPI Processes: 1

# of OMP Threads per Proc: 1

Execution time: 6.1681 seconds



Output tables

1	Constant	1	Constant
2	10545583	2	6203770.5
3	23943208	3	12441248
4	24228336	4	11560599
5	25557256	5	12217056
6	26100540	6	12521256
7	26244184	7	11490184
8	24662636	8	12265409
9	26491526	9	11456545
10	26797914	10	12636130

Compare the performance of ML models trained for a binary of the Higgs search with the CMS detector.

- Description: In these dataset there are signal and background events for the research of the Higgs boson in its decay to two charm quarks using the CMS detector at the LHC.

- These dataset are full simulations. In class we tried to discriminate signal and background using a few variables, including the mass and the type of the decay.

- A proposed work is to see what happens when we try to create a discriminator (classification task) using more variables without using the most discriminating one (the dijet mass mjj).

- Decision trees, boosted or not, random forest, CNN, KNN or other architecture compare in this task. Considering this can produce the ROC curve for the different ML architectures and optimise the threashold of the discriminator.