AANL participation in HEP projects

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AANL-JINR workshop

A.I. Alikhanyan National Science Laboratory, Yerevan, Armenia

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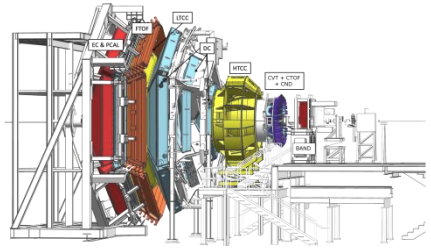
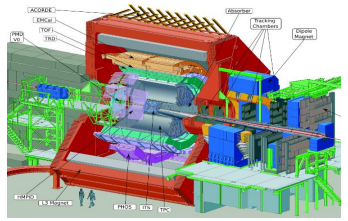
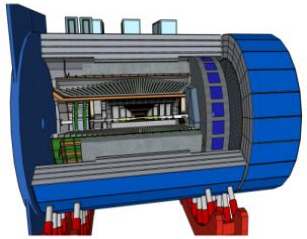
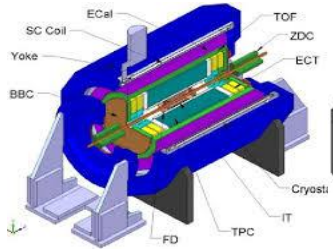
OVERVIEW

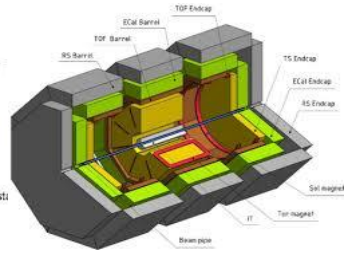
- CERN (Alice, ATLAS, CMS, Compass)
- JLab (Hall A, B, C, D)
- JINR (MPD, SPD)
- BNL (EIC)
- DESY (HERMES)
- KEK (Belle2)
- FermiLab (SpinQuest)

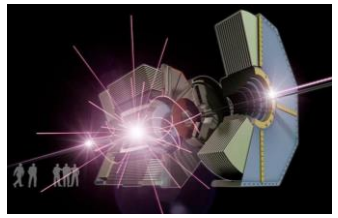


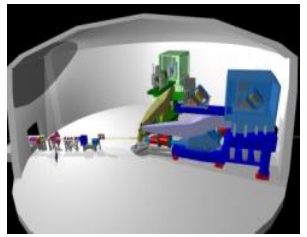


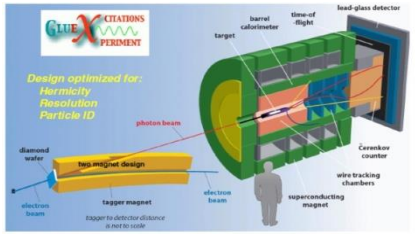


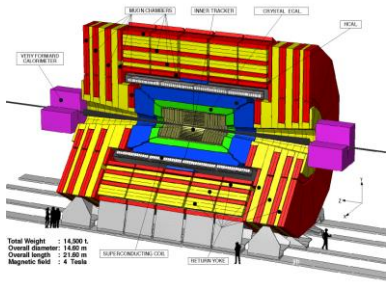


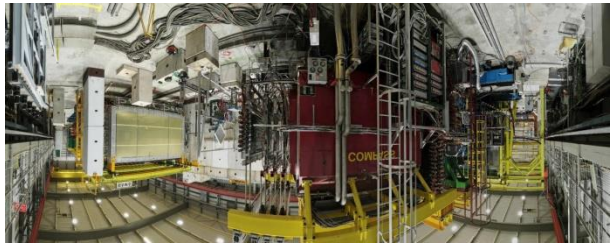


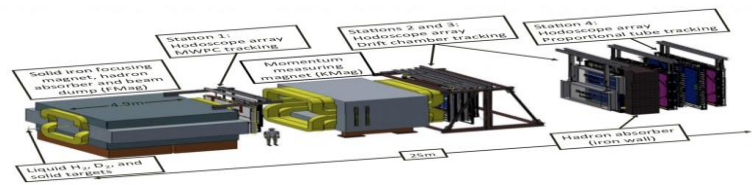


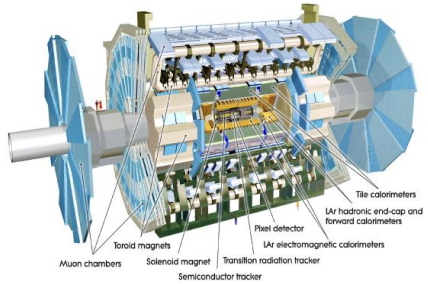












Belle2

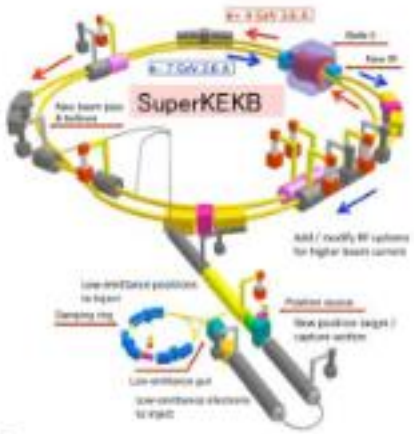
Main activities:

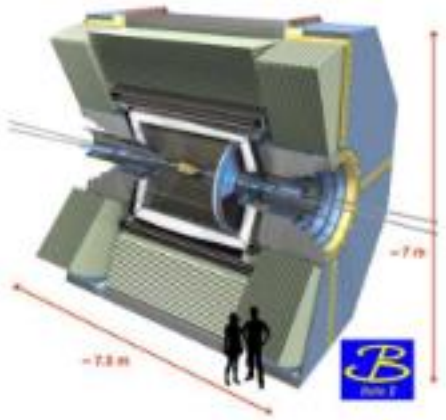
- ❑ Service tasks
- ❑ ARICH detector group activities
- ❑ MC generator group activities
- ❑ Data analysis

in total: 424 fb^{-1} aimed to reach 30-50 ab^{-1} in 10-15 years

SuperKEKB:

- e^+e^- collider with energies 4 GeV and 7 GeV operating around *Y(4S)* resonance.
- Achieved world-record peak luminosity of **4.7×10^{34} cm^{-2} s^{-1}**





Belle II:

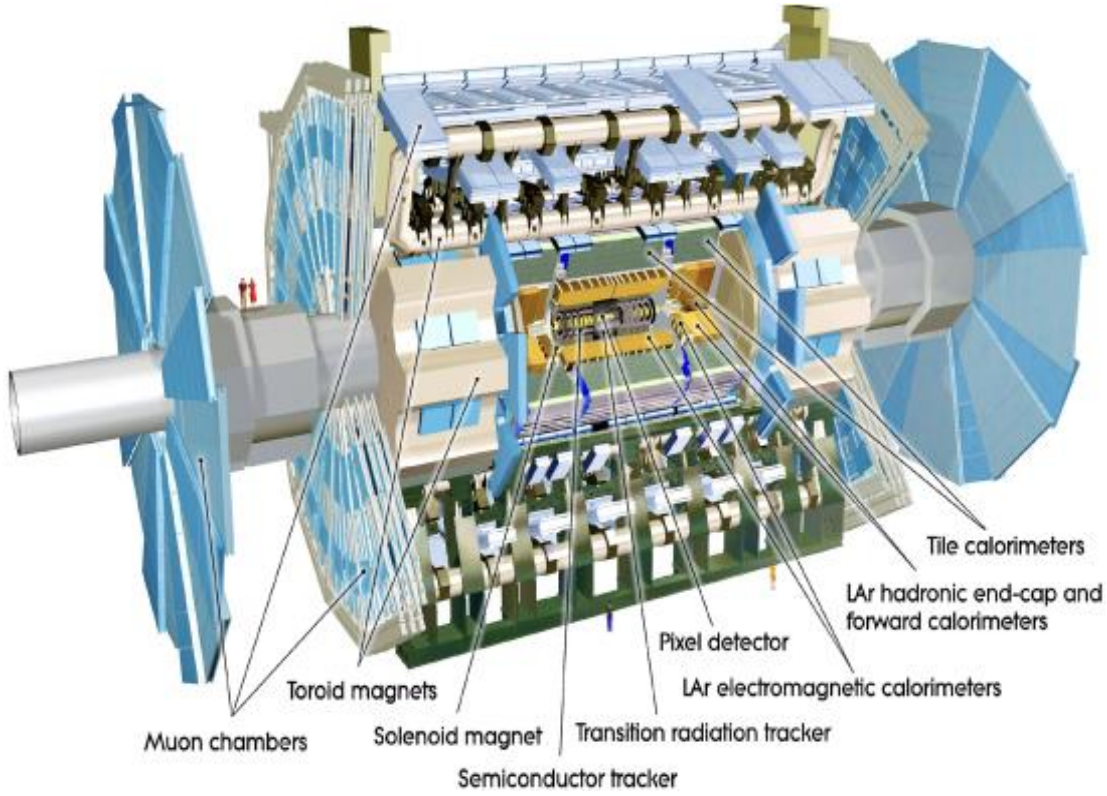
- Nearly 4π detector
- Tracking, PID, and photon reconstruction capabilities
- Similar performance for electrons and muons

Belle II started to collect data in 2019, published already more than 45 papers in leading world journals devoted to searches of CP violation in B-mesons, tau-mesons physics, search of dark sector particles etc.

ATLAS

Expertise:

- Physics analysis;
- Computing, Software development;
- Detector Control System (DCS);
- Computing Infrastructure Support;
- Design, Construction and Installation;
- Electronics design, assembly, installation, maintenance.

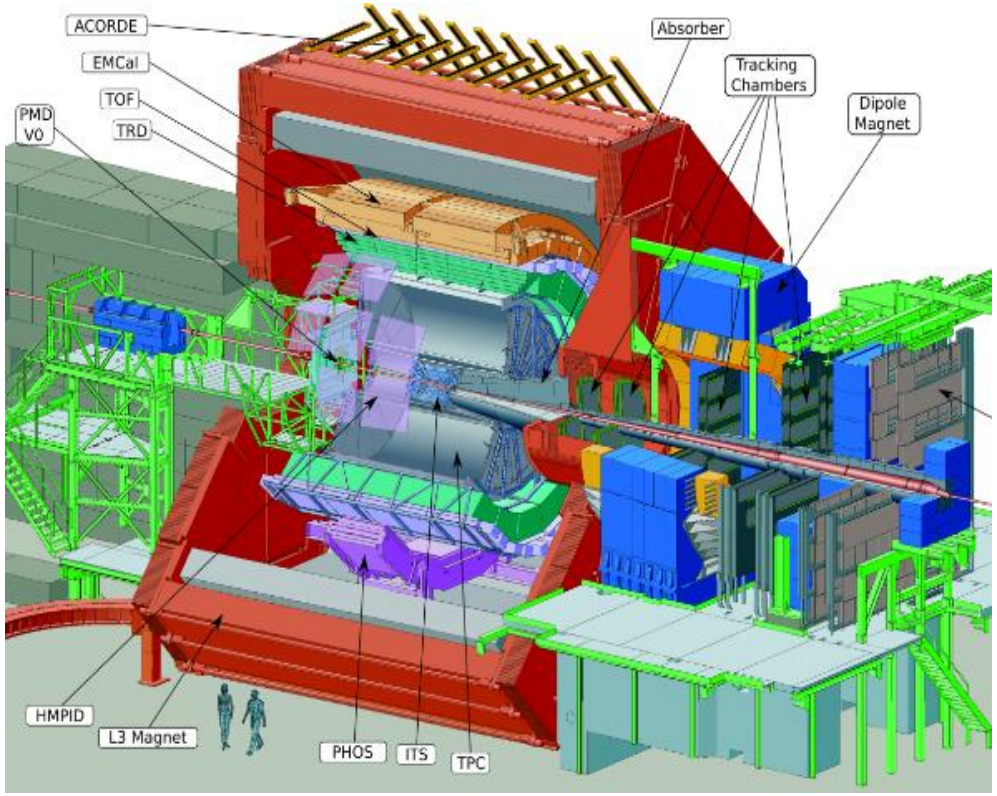


Main activities:

- Development of Tile Calorimeter (TileCal) Data Preparation, Data Quality (DQ) and Performance Tools;
- Simulation and analysis of physics data for validation of the TileCal for Phase-II upgrade;
- Calibration of TileCal modules using particle beams at the CERN SPS accelerator;
- Maintenance, development and testing of the TileCal front-end electronics;
- Controls (WinCC OA) Applications and Frameworks; Automation of software build; quality assurance automatic tests; WinCC OA CERN release generation;
- Trigger Data Acquisition System - Detector Operations, Computing infrastructure support at Point 1;
- Participation to all mechanical consolidation works during maintenance periods and detector shutdown periods in the workshop and assembly areas.

ALICE

- Design, R&D study, construction and installation of the elements for ALICE setup;
- Developments and upgrades for the computing environment of ALICE;
- Design, simulation studies, R&D, construction and installation of Geometry Monitoring System;
- (GMS) for ALICE Dimuon Forward Spectrometer;
- MC simulations and data analysis;
- Development of the software and generators for simulation of different quarkonium states production in dimuon decay mode in pp, p-A and A-A collisions;
- Investigation of hadrons momentum distributions in pp, p-A and A-A collisions.

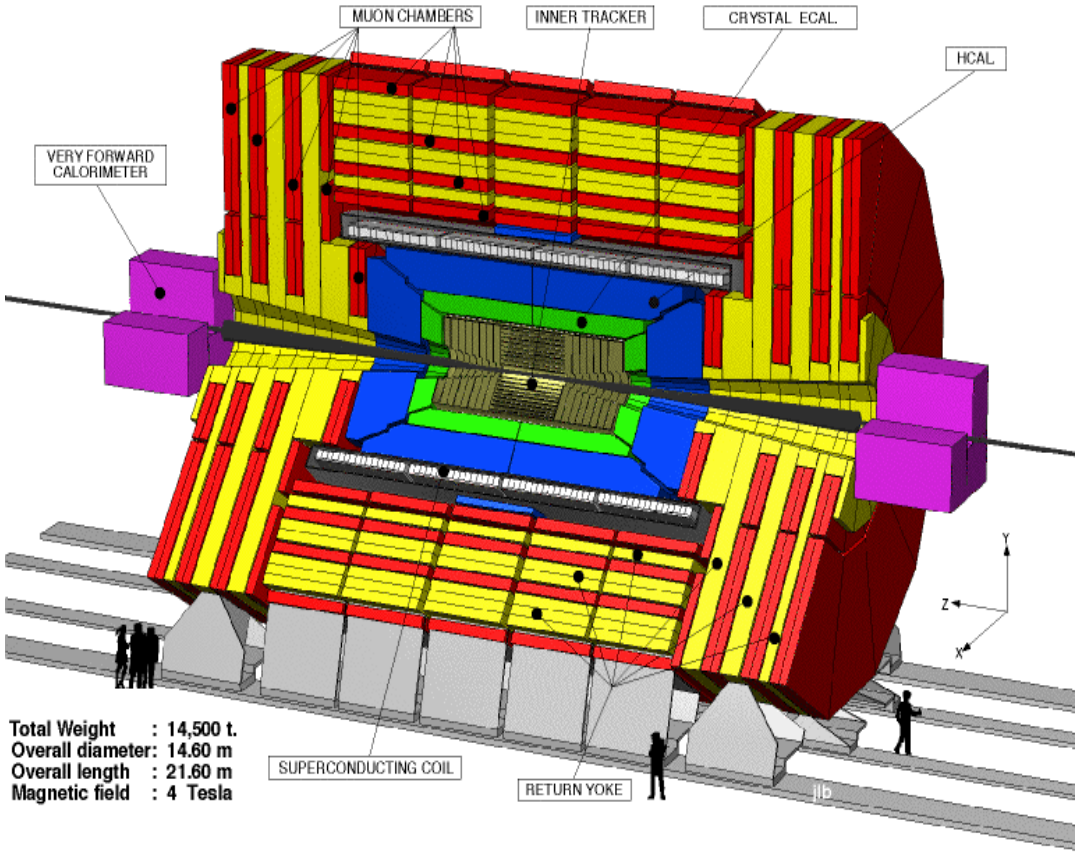


CMS

- MC simulations / Data analysis,
- CMS Database upgrade
- Detector performance / control system / calibration
- Data quality / Certification
- Phase 2 upgrade (HGCal prototype tests, EndCup timing detector)
- Reconstruction algorithms
- Triggers (L1-HLT)

Physics analysis

- Search for Higgs boson in VBF process
- Search for Di-Higgs production
- Search for Dark Matter
- SUSY: search for long lived charged and neutral leptons
- Di-Muon analysis / Multijet analysis,



In close collaboration with JINR within RDMS

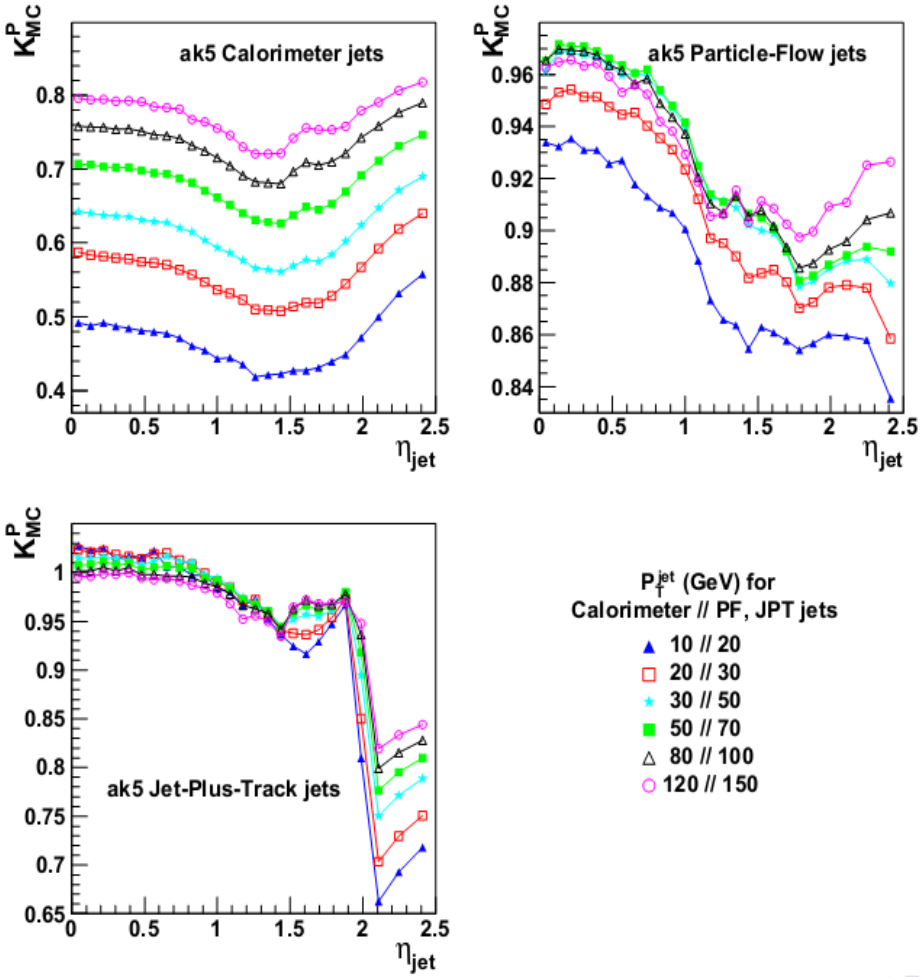
CMS HCal and related topics

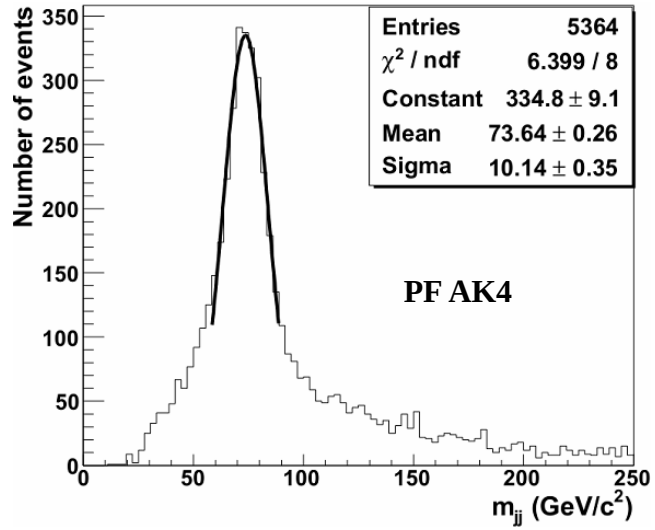
HCal

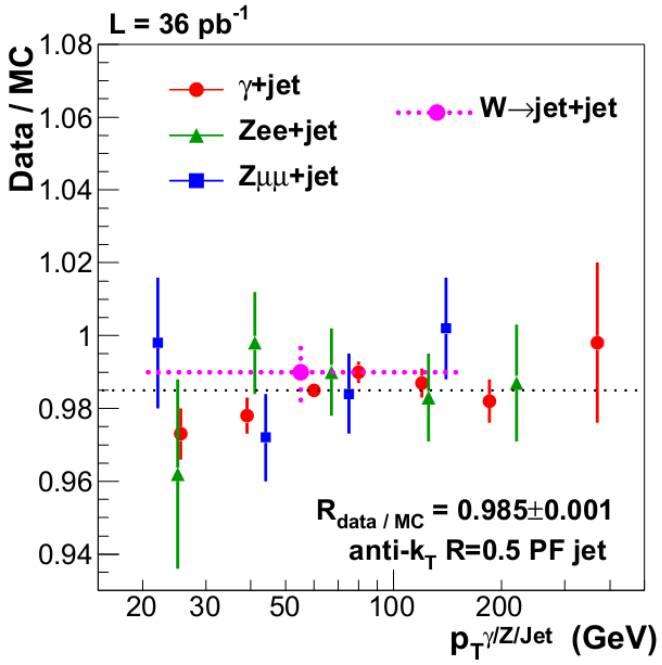
- Online control
- Online /offline DQM and certification
- Conditions loading and calibration
- DQM system update

Jet energy scale calibration

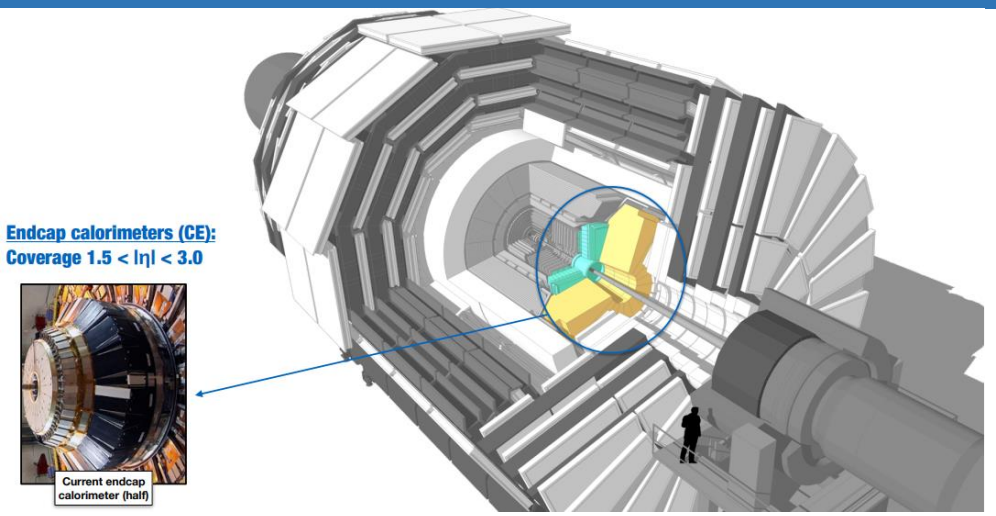
- Novel approach with resonant decay process (W→$q\bar{q}$ decay in $t\bar{t}$ process)
- Jet reconstruction algorithms test
- Implementation of ML methods for jet pairing (W-reconstruction)
- Different types of calibration (p/E)

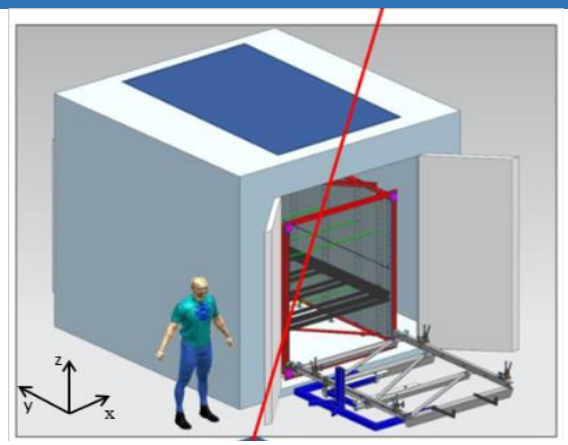


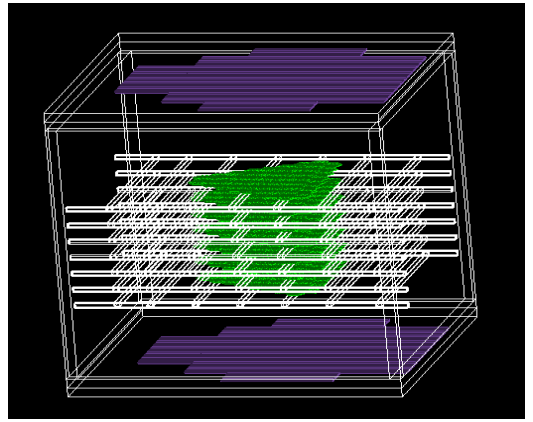


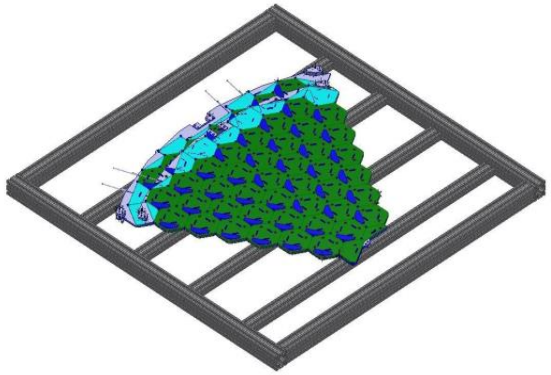


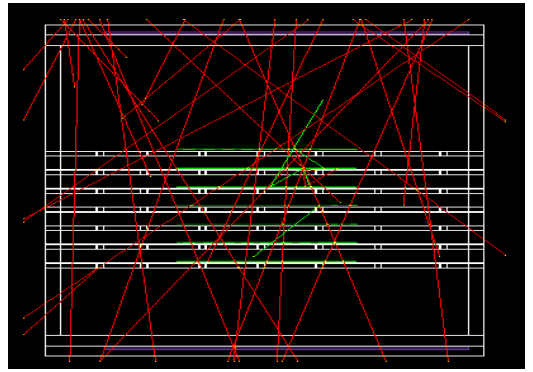
CMS Phase2 Upgrade: HGCal





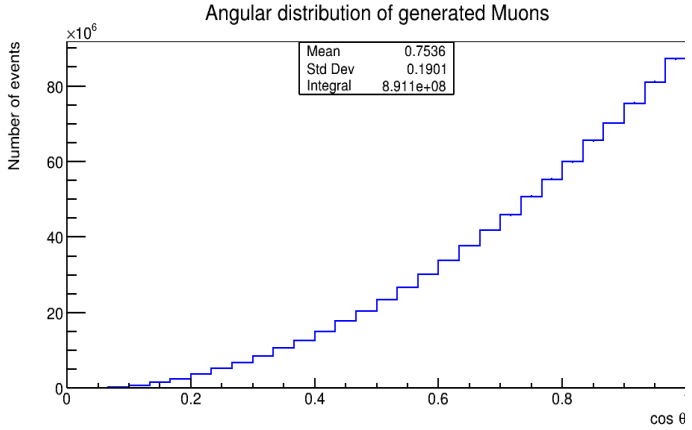


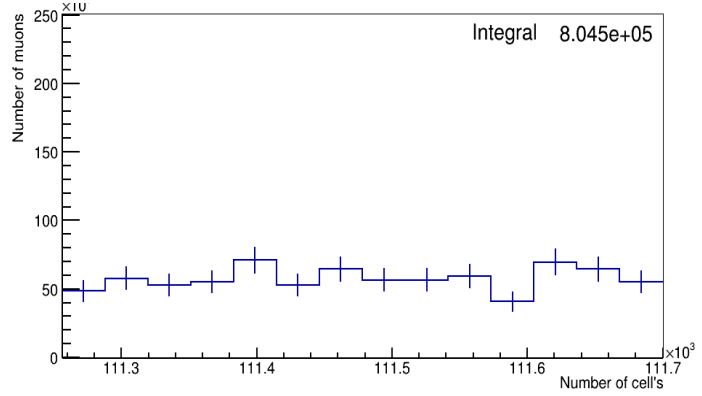




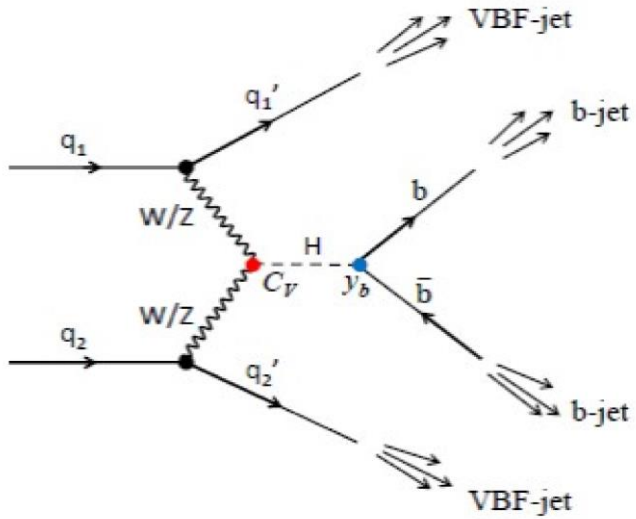
Steps and current status

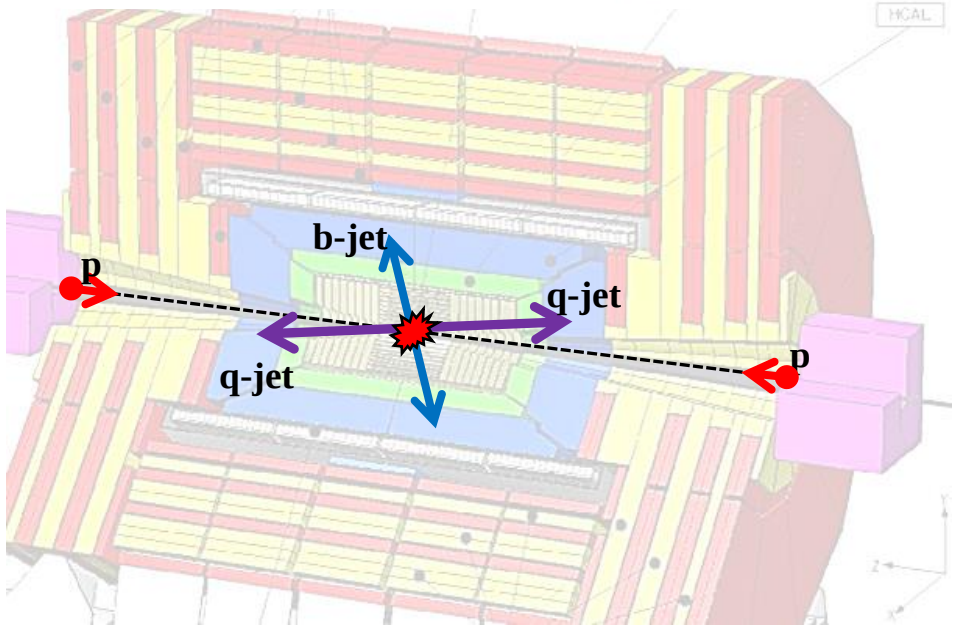
- ❑ Geant4 Simulation of facility and HGCal cassettes
- ❑ Cosmic muons simulation with Reyna function
- ❑ Trigger geometry optimization
- ❑ Estimation of intensity in each cell
- ❑ Integration to CMSSW: simulation (done)
- ❑ Integration to CMSSW: reconstruction
- ❑ Data analysis





VBF Hbb, Hcc





CMS 2016 and 2018 data of pp-collisions at 13 TeV corresponding to ~91 fb^{-1}

Two main analysis classes based on two main features of VBF_Hbb process:

- **SingleB** relies on **tight** VBF topology and **loose** b-tagging (≥1 b-tagged jets)
- **DoubleB** relies on **loose** VBF topology and **tight** b-tagging (≥2 b-tagged jets)

Dominant QCD background

ML signal-background discrimination

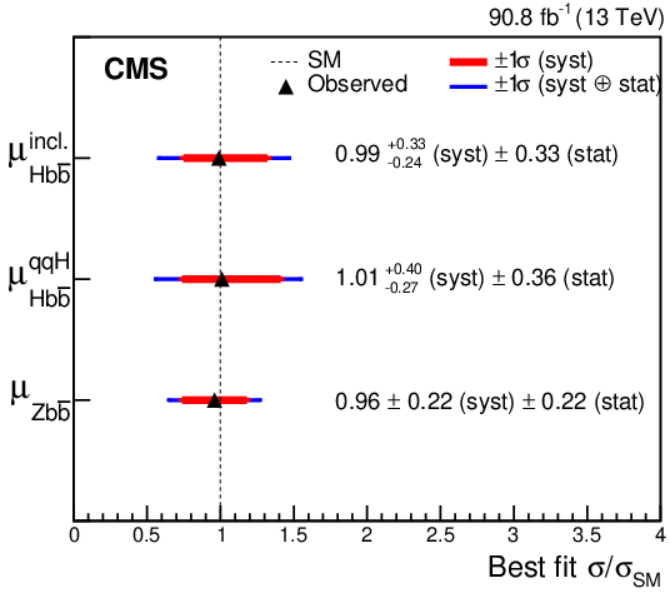
Results CMS **JHEP 01 (2024) 173**

- **Inclusive $H \to b\bar{b}$ (VBF+ggF):**

  Significance (obs./exp.) = 2.6 / 2.9

- **Pure VBF**

  Significance (obs./exp.) = 2.4 / 2.7



Ongoing

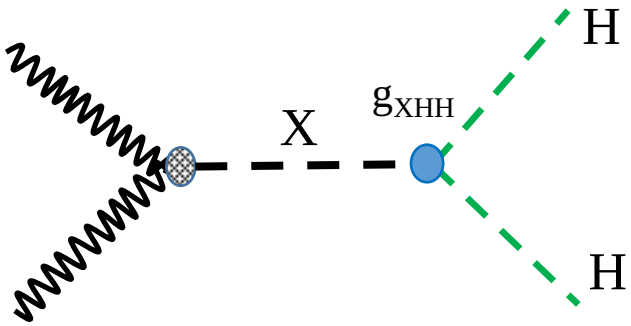
- **VBF Hbb with Run3**
- **VBF Hcc with Run2**
- **VBF Hcc with Run3**

Di-Higgs production

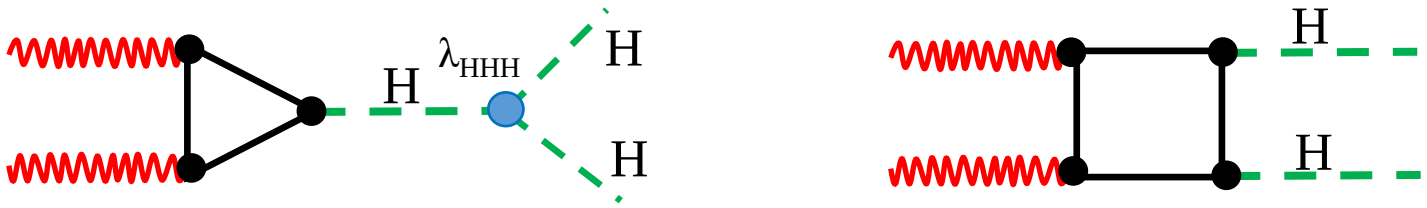
- One of the important tasks of LHC physics for coming years (especially at HL)
- Allows to probe the BSM hypothesis and SM trilinear coupling

Resonant

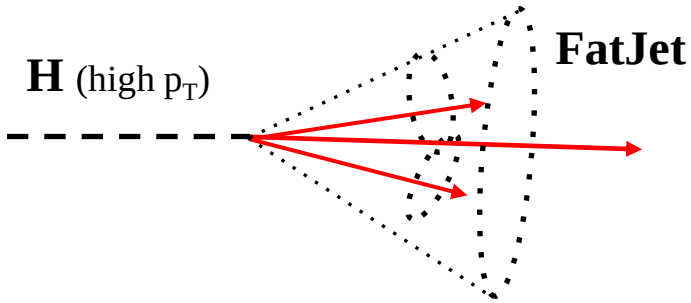
- Two-Higgs-doublet model (2HDM) with heavy scalar resonant
- Randall-Sundrum Graviton



Non-Resonant (main production mode is ggF: ~ 90%)



Golden channel for di-Higgs search considered to be $HH \to b\bar{b}\,\gamma\gamma$
$HH \to b\bar{b}\,\tau^{-}\tau^{+}$ is also attractive for this search
Perspectives of $HH \to b\bar{b}\,b\bar{b}$ channel, despite the highest BR (58% × 58% = 33.6%), seemed to be not very good, because of large background and reconstruction difficulties, but special event topology, where one of the H-bosons is highly boosted, is very promising providing almost the same sensitivity as golden channel.



- QCD and TTbar dominated backgrounds
- Boosted, Resolved, Semi-Boosted analysis categories
- Dedicated triggers
- Novel ParticleNET algorithm for **b** and **bb** tagging
- Novel ParticleNET algorithm for **FatJet** mass regression
- ML Signal-background discrimination

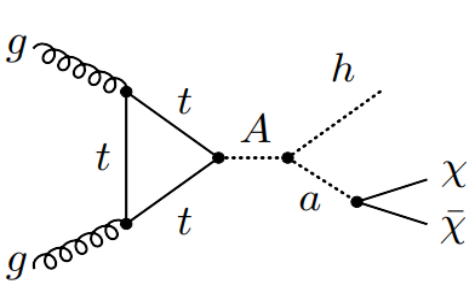
CMS AN-2023/96

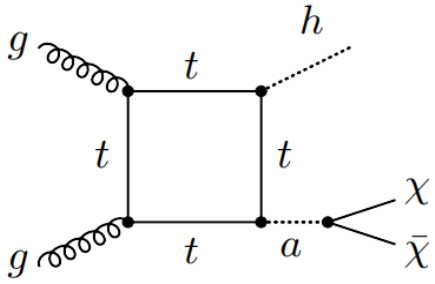
CMS AN-2023/151

BSM analysis: Dark Matter search

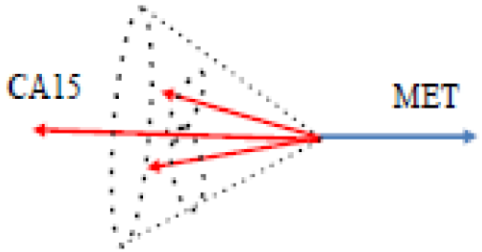
Search for Dark Matter produced in association with the SM Higgs boson predicted by the "2HDM+a" model

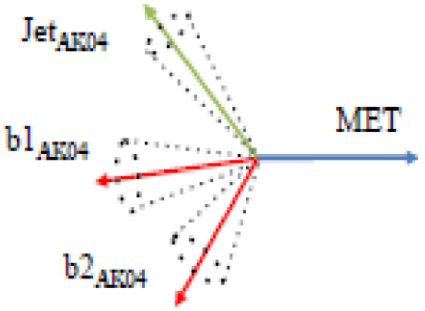
Main contribution comes from



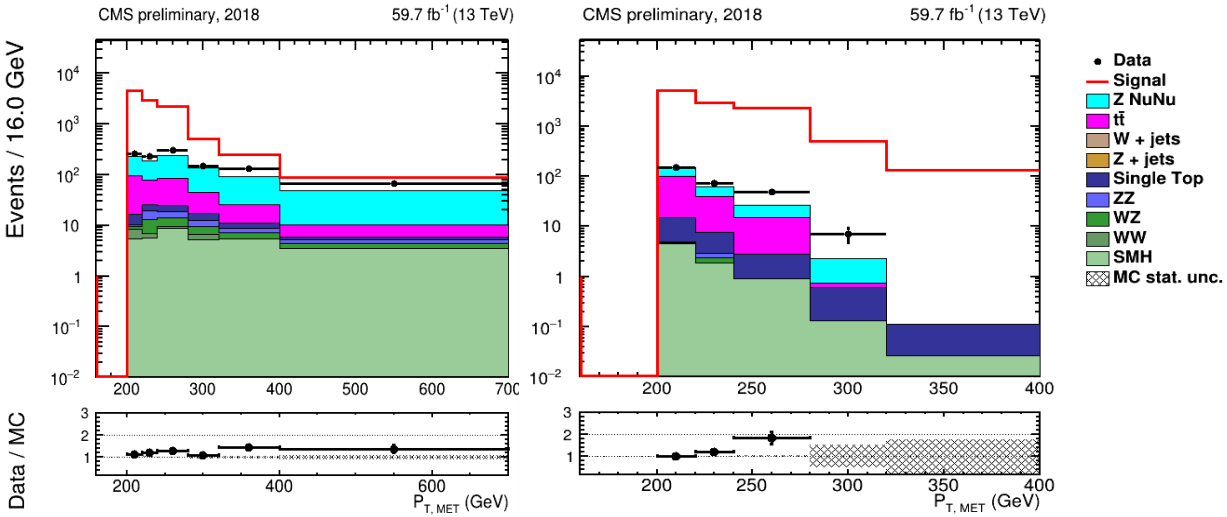


Two analysis categories: boosted and resolved





Selection	Boosted	Resolved
HLT	HLT_PFMETNoMu120_PFMHTNoMu120_IDTight_PFHT60	
Lepton veto	Yes	Yes
Photon veto	Yes	Yes
MET > 200 GeV	Yes	Yes
Additional jets veto	Yes	Yes
Δφ (MET, any jet) > 0.4	Yes	Yes
CA15-jet with p_T > 200 GeV, $\|\eta\| < 2.4$	Yes	No
CA15-jet with Double-DeepCSV > 0.9	Yes	No
100 GeV < M_{CA15} < 150 GeV	Yes	No
Two AK04-jets with p_T > 30 GeV, $\|\eta\| < 2.4$	No	Yes
AK04-jets (b1, b2) with DeepCSV > 0.75	No	Yes
100 GeV < $M_{b1,b2}$ < 150 GeV	No	Yes
Signal selection efficiency	1.36 %	1.44 %



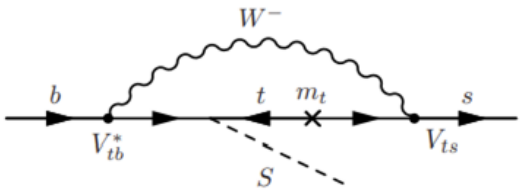
BSM analysis: Search for long lived particles

The search for **long-lived particles (LLPs)** in the muon system.

The **signal model** is based on the "**Higgs portal**".

$$\mathcal{L}_{SH} = \mathcal{L}_{\mathrm{SM}} + \underbrace{\frac{1}{2}\partial_\mu \hat{S}\,\partial^\mu \hat{S} - \frac{\mu_S^2}{2}\hat{S}^2}_{\mathcal{L}_{\mathrm{DS}}} - \underbrace{\left(A_{HS}\,\hat{S} + \lambda_{HS}\,\hat{S}^2\right)\hat{H}^\dagger \hat{H}}_{\text{Higgs portal}}$$

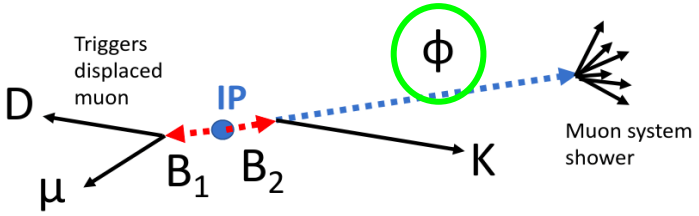
A_{HS}: controls the $\hat{H}-\hat{S}$ mixing; λ_{HS}: controls $Br(H \to SS)$



The LLPs decays into a pair of pions which create electromagnetic showers in the muon system

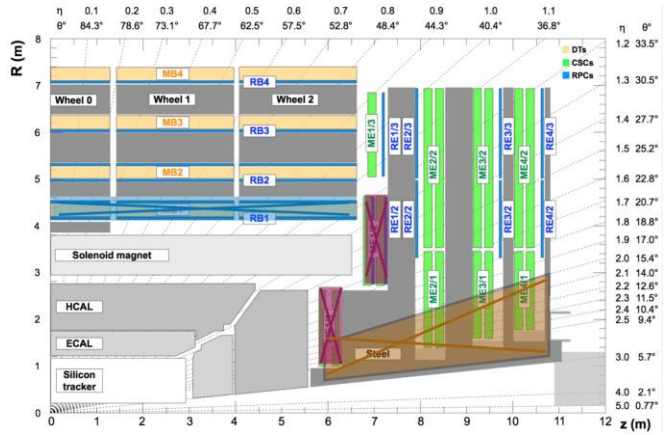
The goal is to enable the searches for LLPs beyond the tracker region.

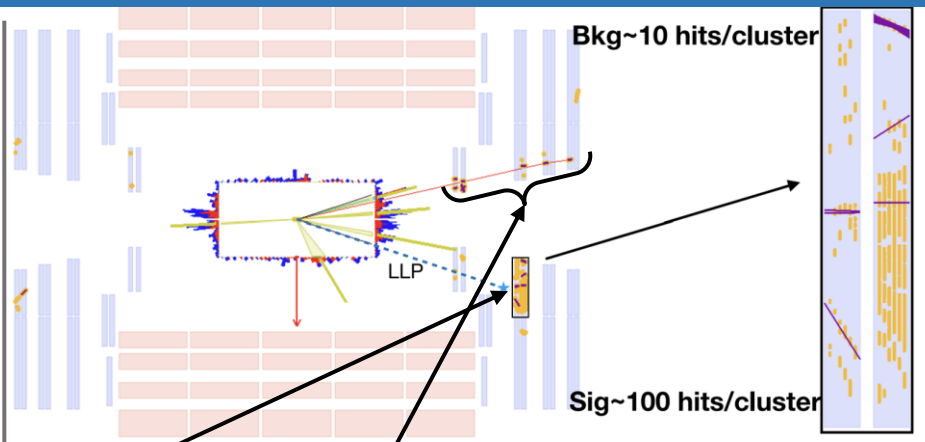
The LLPs are produced from the decays of B mesons.



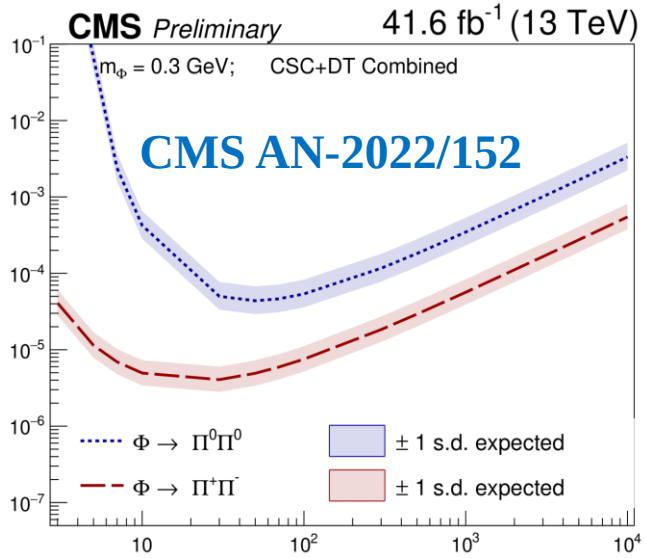
The background data is the **B-Parking** dataset, which contains data with B meson decays and has ~10^9 events.

The data categories: LLPs had decayed in CSC or in DT chambers.





LLP decays produce high hit multiplicity **clusters**, while **muons** only create a few hits.



Estimated limits for the combined category and for two different LLP decay channels.

Thank you