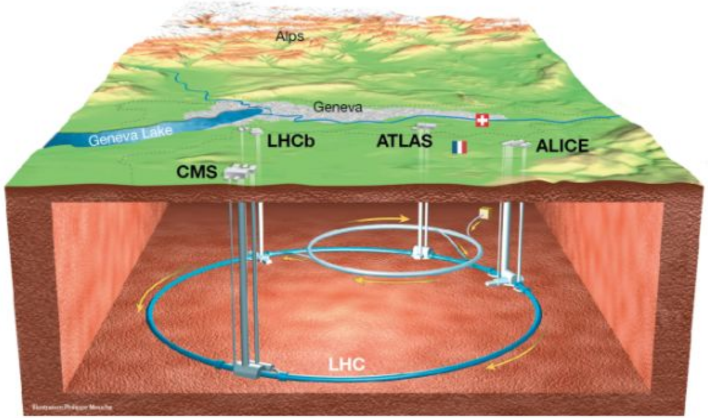
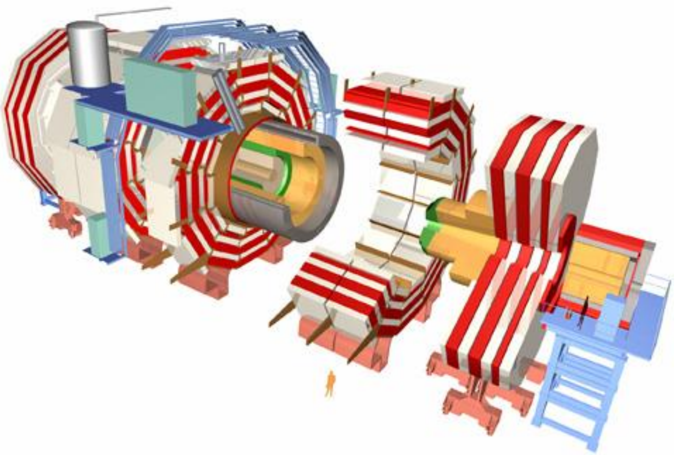
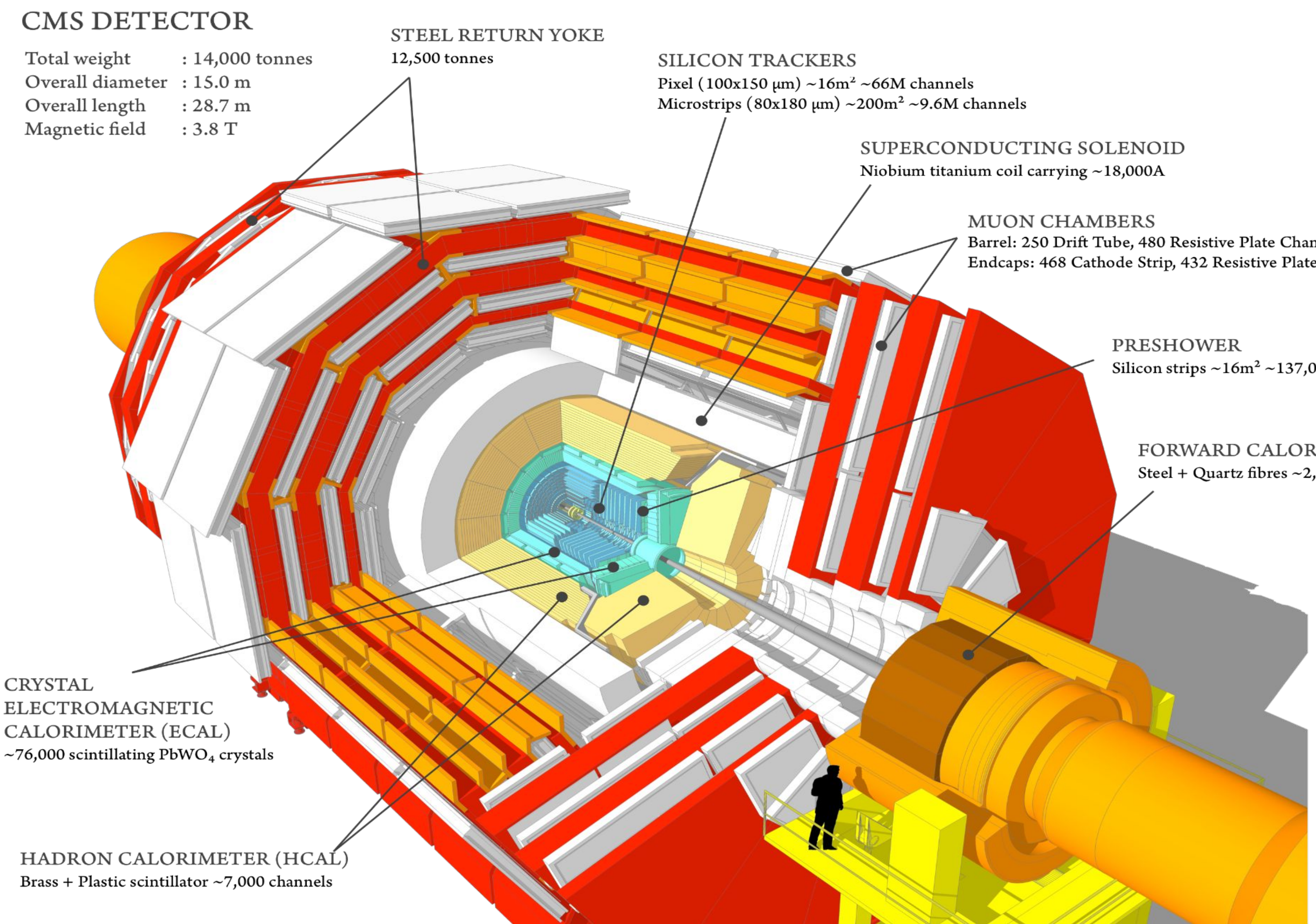
IUT Contribution to the CMS Luminosity Measurement and Higgs Properties Studies

V. Sedighzadeh
On behalf of IUT CMS Group

INTRODUCTION

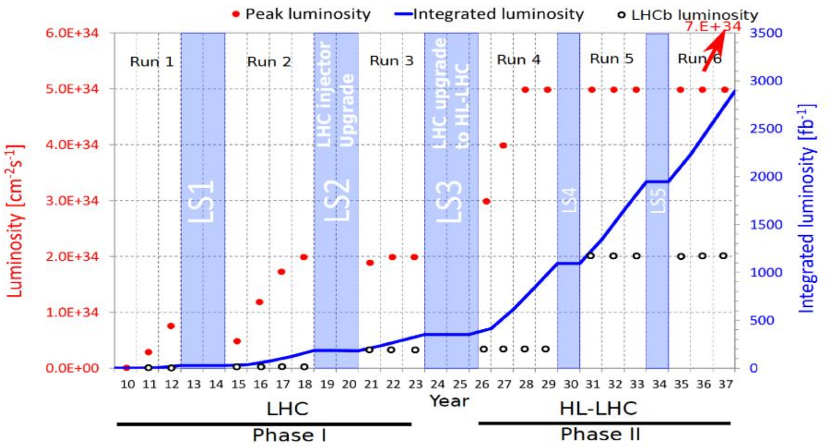


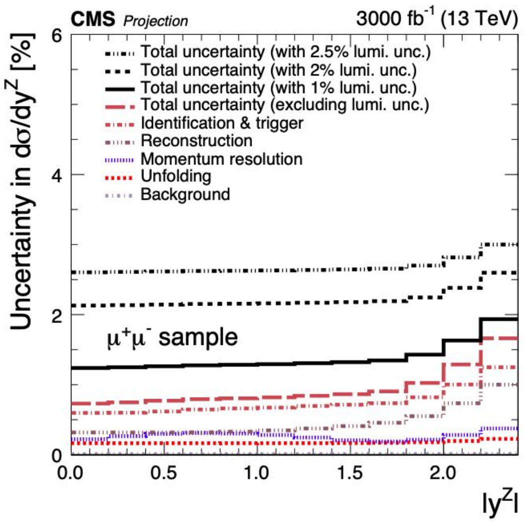



CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16m² ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating PbWO4 crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

Luminosity in Particle detectors

- HL-LHC
  - high number of pp collisions in BX
  - Intense radiation
- CMS detector needs a full upgrade

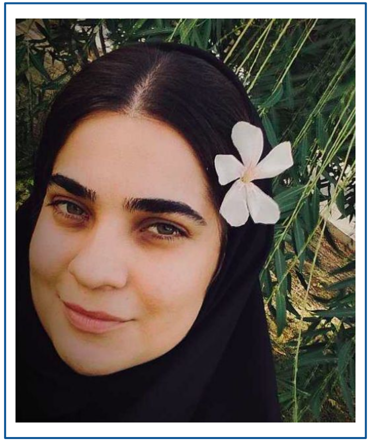




- Precise luminosity calibration → crucial for most of the CMS measurements
- Target of LHC experiments in HL-LHC:
  <1% luminosity uncertainty

- **Luminosity (L)** is one of the **most important** parameters of an accelerator -> Cross section measurement

$$\mathcal{L}(t) = \frac{1}{\sigma}\frac{dN}{dt}$$

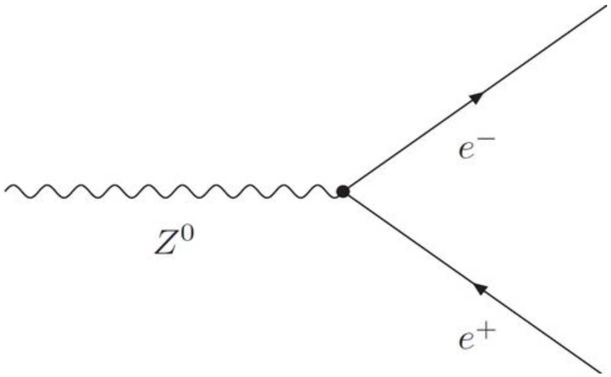


Luminosity measurement using Z boson decays to electrons

ways to luminosity measurement:

- Using luminometer
- **Using Z boson**

Z bosons have large cross section and decay into two muons and two electrons has a **clean signature:**

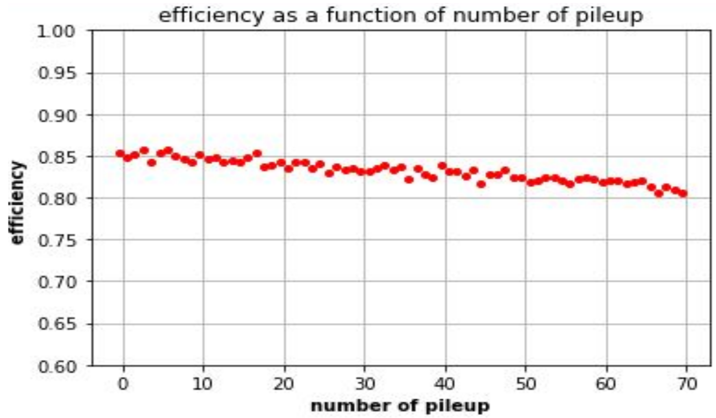


The luminosity measurement was investigated by the Z boson decaying into a muon.

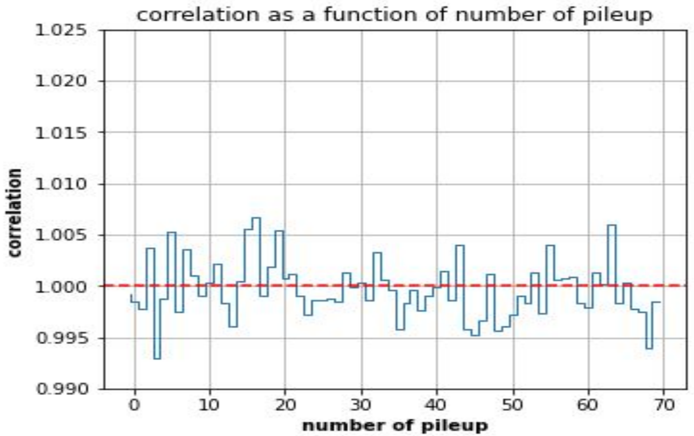
- **Our goal is to investigate this measurement in the electron channel.**

Efficiency measurement in two parts identification (ID) and trigger (HLT) according to the important parameters of the event is one of the important goals to achieve the Z boson number, to calculate the luminosity with high accuracy.

Eff = 2 * N2 / (2 * N2 + N1)



The following plots are efficiency and correlation HLT in terms of the number of pileup.

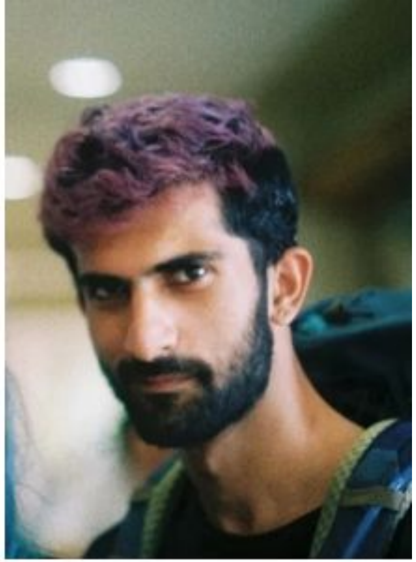


C = N/N2 * (2 * N2 / (2 * N2 + N1))^2


S. Zorrieh


M. khalifeh

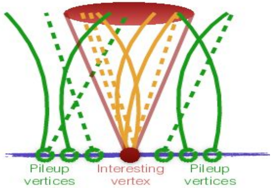

M. Jalalvandi


N. Hamed

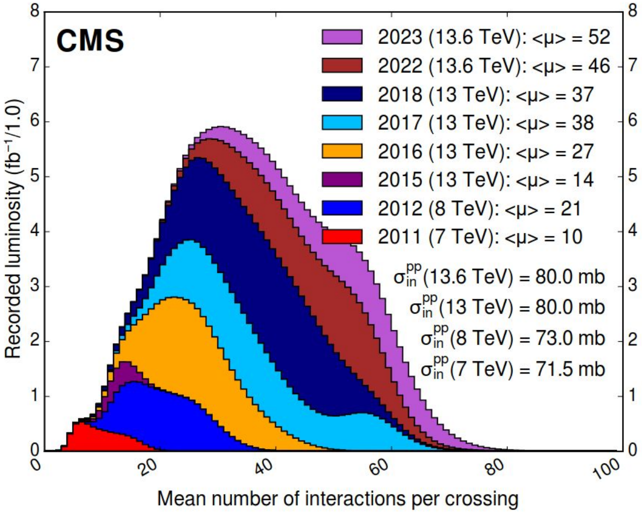
Pile up

Estimate number of pileups using Graph Neural Network (GNN).

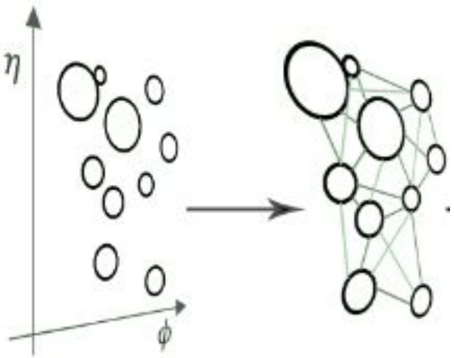
- **Pile up**

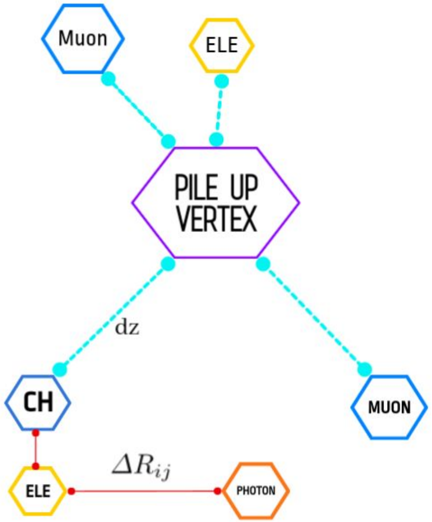


- **Interactions per crossing (pileup) in a fixed interval of time.**

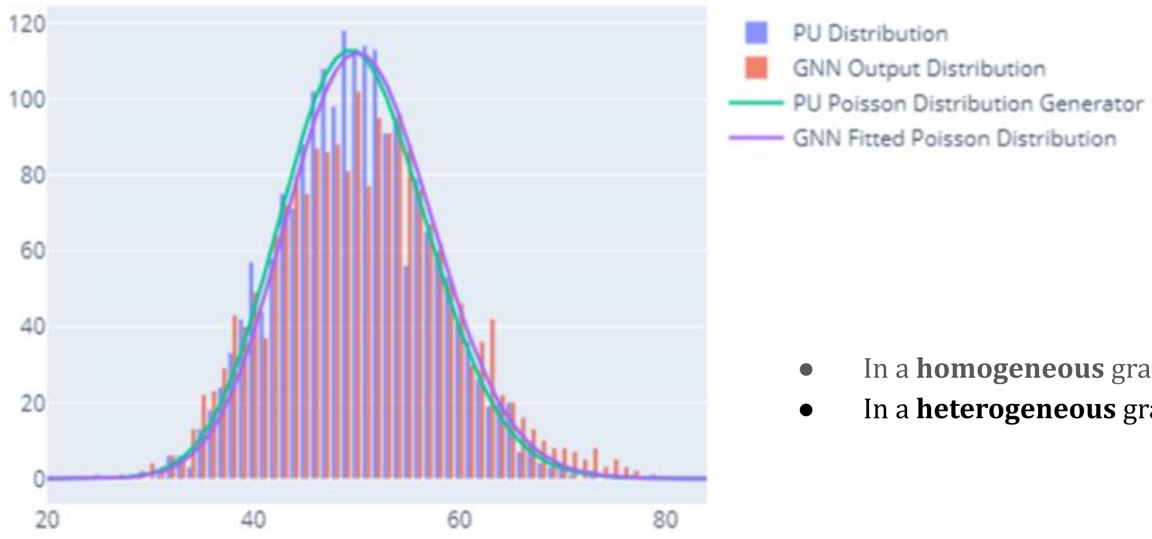


- **Construct Graph Representation from Data**
  - Edges (connection between nodes):
    - $$\Delta R_{ij} = \sqrt{\Delta\phi^2 + \Delta\eta^2}$$
    - Distance of particles from pile up vertices. [dz]
  - Nodes:
    - **Particle Candidates**
    - **Pile up vertices**





Train GNN model for Pileup Distribution Estimation



- In a **homogeneous** graph, all nodes and edges belong to the same type.
- In a **heterogeneous** graph, nodes and edges can belong to different types.

The output of a GNN model with **Homogeneous** Graph

Implementation needed for GNN model on a Heterogeneous Graph

Optimizing PU simulation: How to extract PU distribution in data

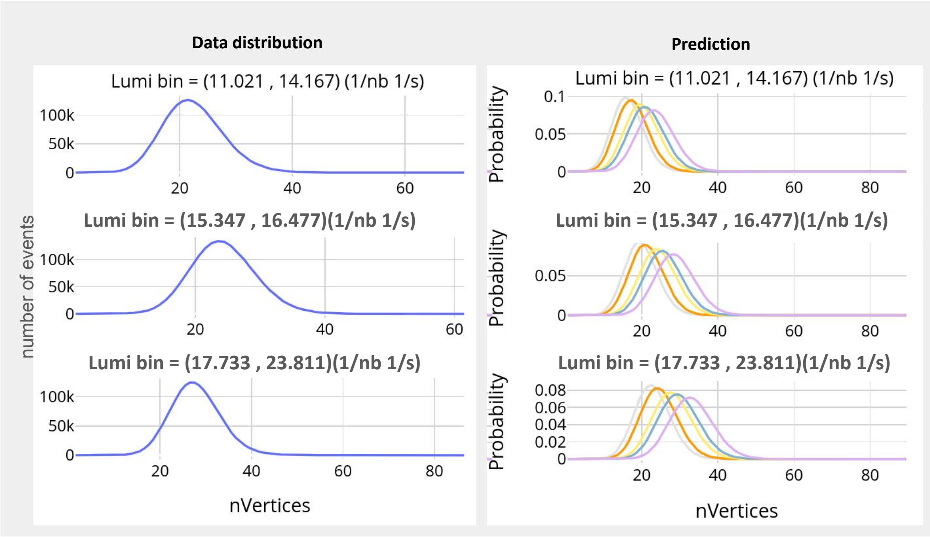
1. Compare predicted and data distribution for each variable

   a. Pu distribution:

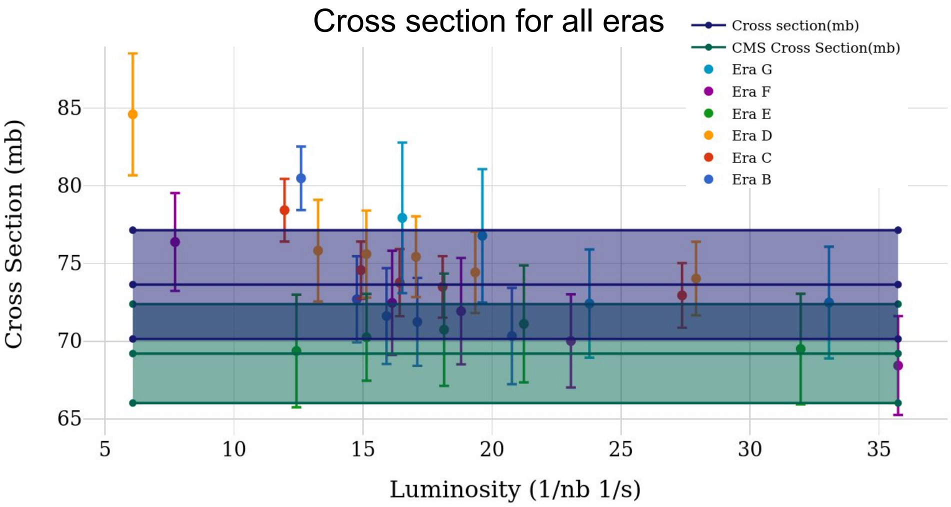
$$f(pu|\sigma) = \int poisson(pu; \lambda = \sigma \times l) g(l) dl$$

   b. Variable distribution:

$$f_{exp}(v|\sigma) = \sum_{pu} f_{sim}(v|pu) \times f(pu|\sigma)$$



2. Calculate fit qualities and select some variables with best fits for each era



Proposed cross section:
73.64 ± 3.5 (mb)

Next step:
extract cross section from **2023** CMS data

Fast Beam Condition Monitor (FBCM)

Dr. Sedghi

Dr. Gholami

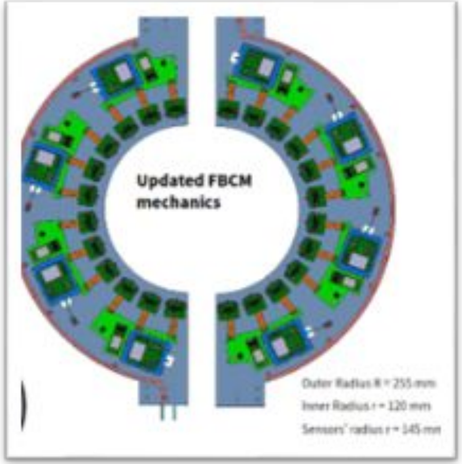
V. Sedighzadeh

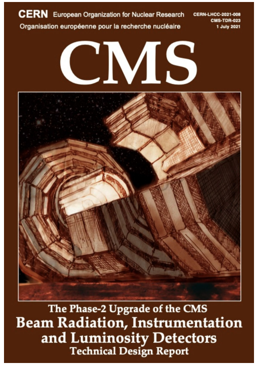
F. Gagonani

M. Ebrahimi

FBCM: The Independent Luminometer for CMS in HL-LHC

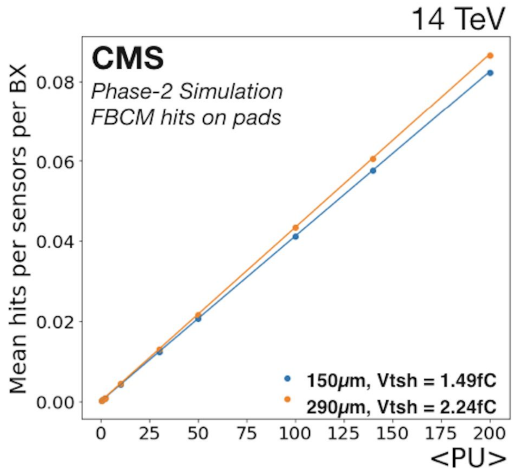
- A silicon base detector to measure **luminosity** and other beam conditions
- Should be **fast** (~ns response) and **independent** from CSM detector
- Proposed by IUT team to the CMS group
- Optimized using detailed simulation based studies
  - 336 si-pad sensors ~3mm^2
  - Located in R~15cm and Z~2.8m
- Proposal approved by CERN
  - documented in the official Technical Design Report (TDR) of the CMS upgrade (2021)
  - Costs: ~1MCHF

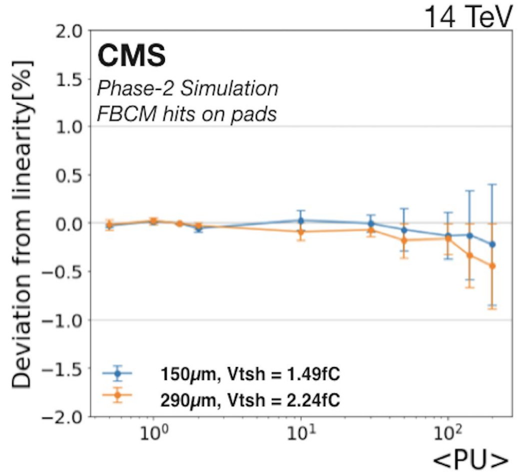




FBCM: Status

- Sensors: 2 options under investigation
  - 150 µm / 290 µm
  - Simulation to make sure **both are linear**
  - Should investigate the effect of radiation
- Electronics
  - ASIC is designed
  - Will be tested in Q2 2024
- Mechanics
  - For cooling and cabling
- Simulation
  - IUT plans to merge the FBCM simulation package in the CMS Software





IUT Responsibility

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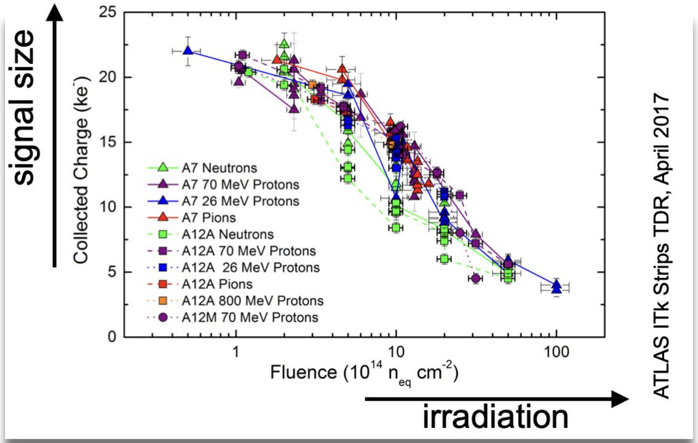

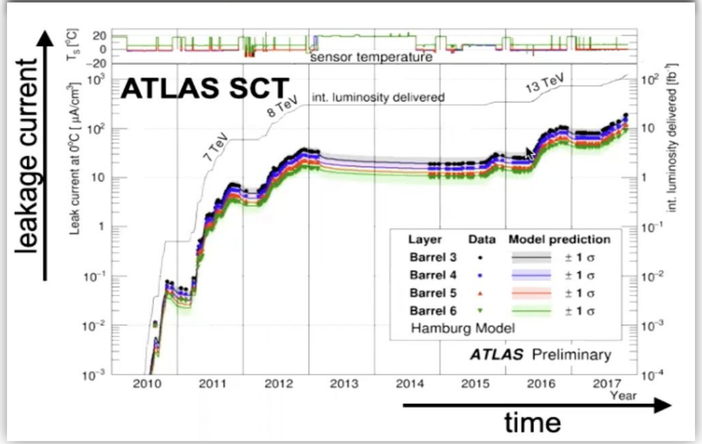

Currently based on test beam
IUT PLAN: employ simulation

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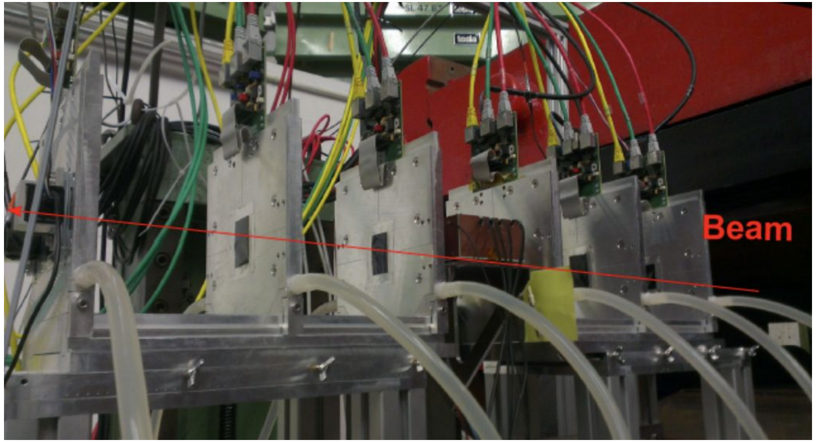
Test Room:



We plan to actively participate in the test beam

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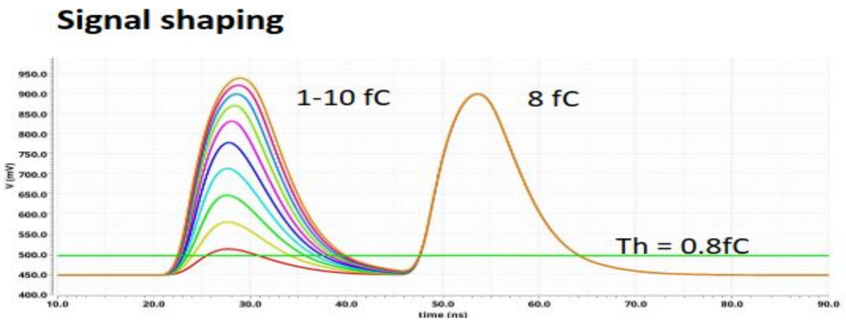

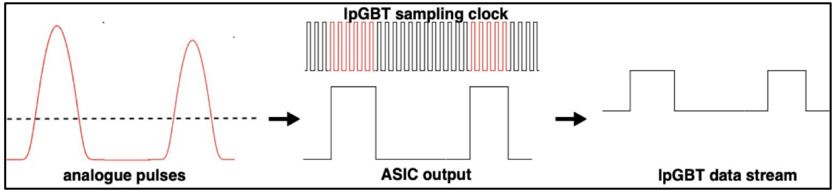

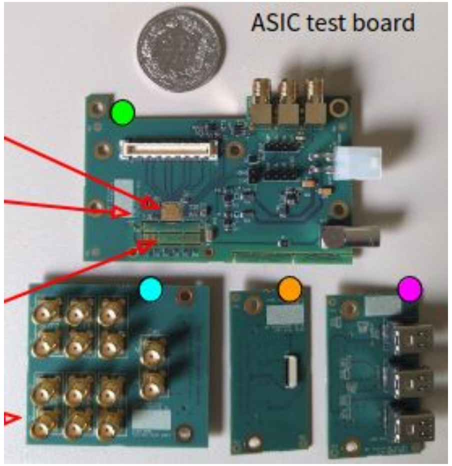

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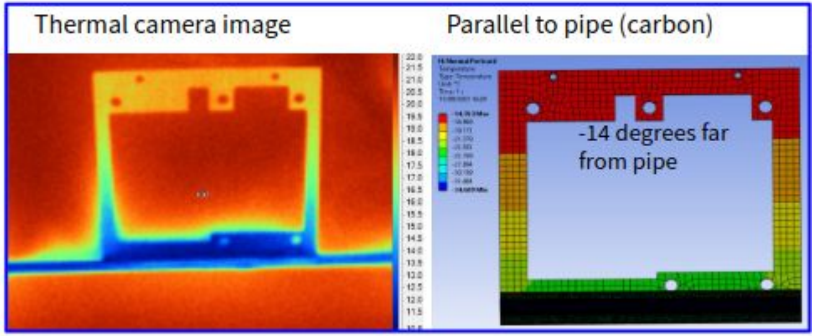

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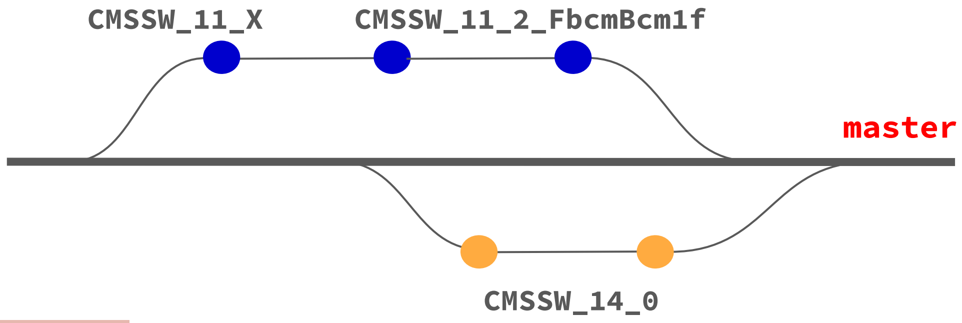


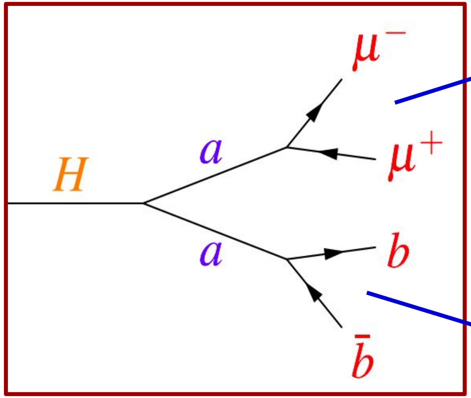
Higgs

Dr. Jafari

Dr. Khazaie

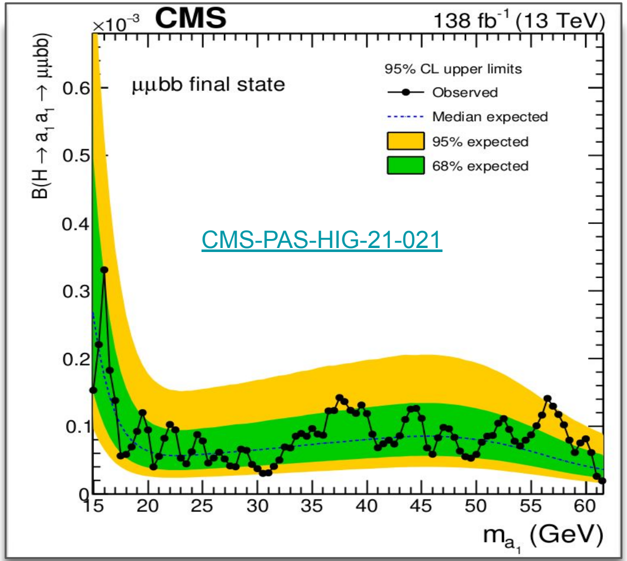
V.sedighzdeh

Exotic decay of the Higgs boson: H→aa→$\mu\mu bb$



having two easily detectable muons with an extremely precise mass resolution

Large BR in many parts of the parameter space



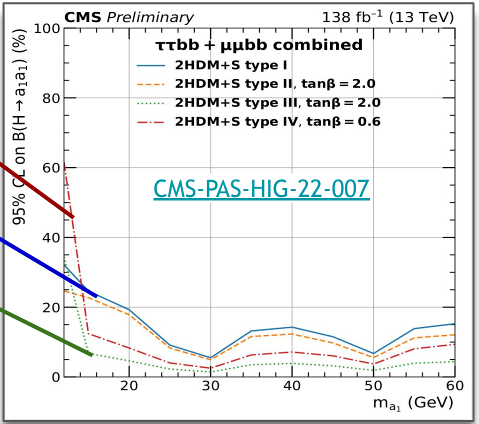
- Large improvement w.r.t to 2016 beyond the increase of luminosity
- A slight improvement in comparison with ATLAS results is observed
- Analysis statistics limited

No excess was observed above SM backgrounds

$\mathcal{B}$ (H→aa→μμbb) < (0.17 – 3.3) × 10^{-4}

Combination of μμbb and ττbb channels

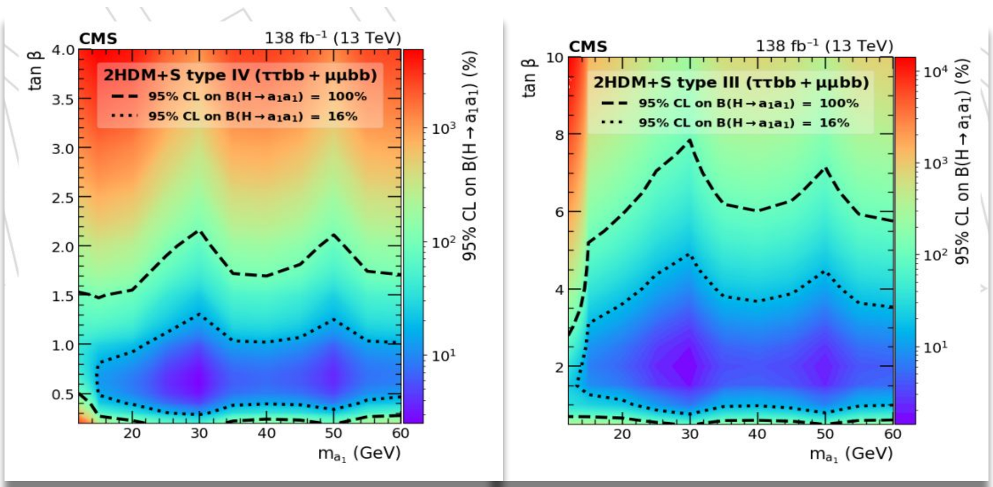
- $\mathcal{B}$(H →aa) is obtained upon a reinterpretation of the μμbb and ττbb results
  - In different types of 2HDM+S and tanβ values for 15 ≤ ma ≤ 60 GeV
- $\mathcal{B}$(H→aa) > 23% are excluded at 95% CL in most Type II scenarios



Type IV

Type I

Type III



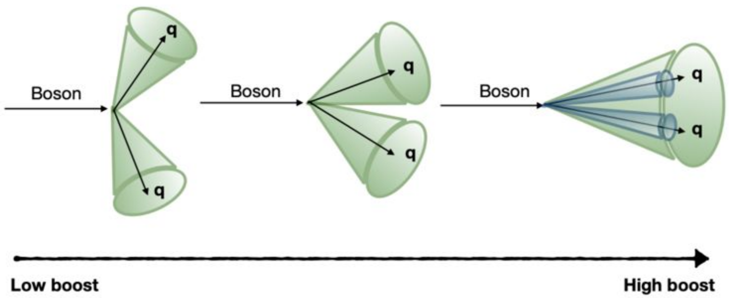
CMS-PAS-HIG-22-007

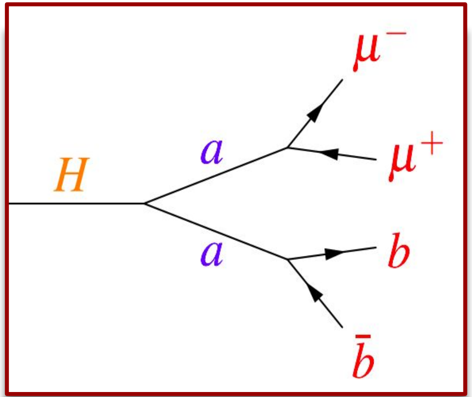
Allowed values of tanβ and ma1 shown in the context of Type III and Type IV 2HDM+S, for the combination of μμbb and bbττ

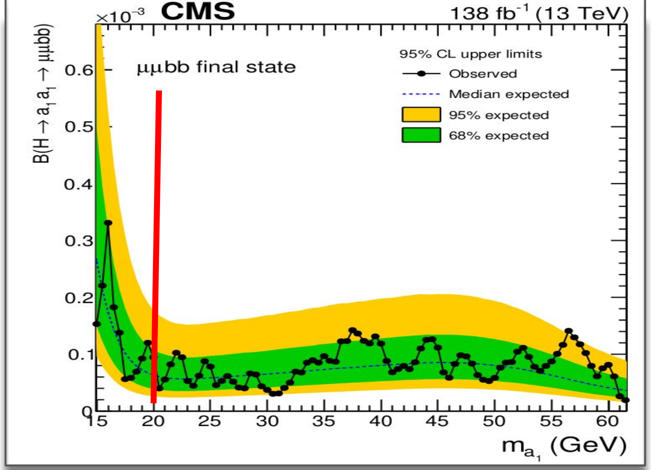
The dashed contours represent the 95% upper limits on $\mathcal{B}$ (H→aa) = 100% or 16%

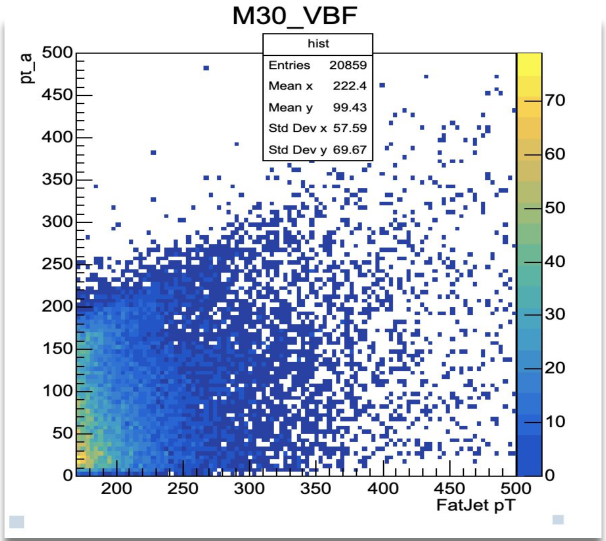
What is next:

- smaller m_a $\rightarrow$ larger momentum
- Larger momentum → boosted Jets
- Boosted Jets → FatJet

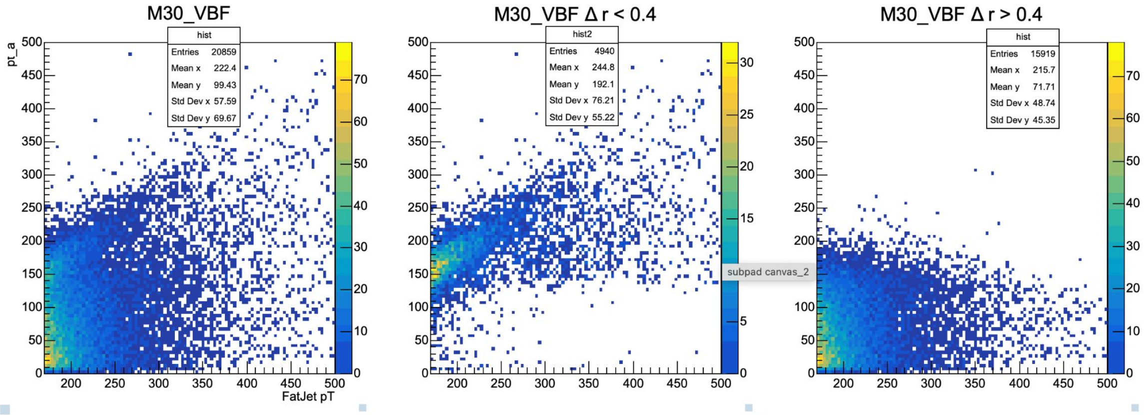


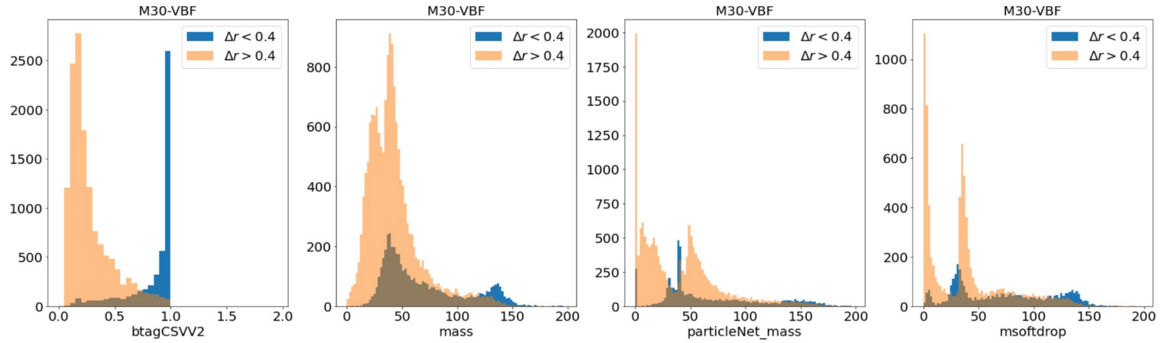






- The BTagger algorithm is performing well
- The ParticleNet, SoftDrop algorithms are not yielding satisfactory results.
- We plan to train a machine to extract the mass of bosons, aiming to enhance the sensitivity of the analysis in the low-mass regime.





Thanks for your attentions!