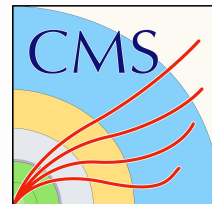




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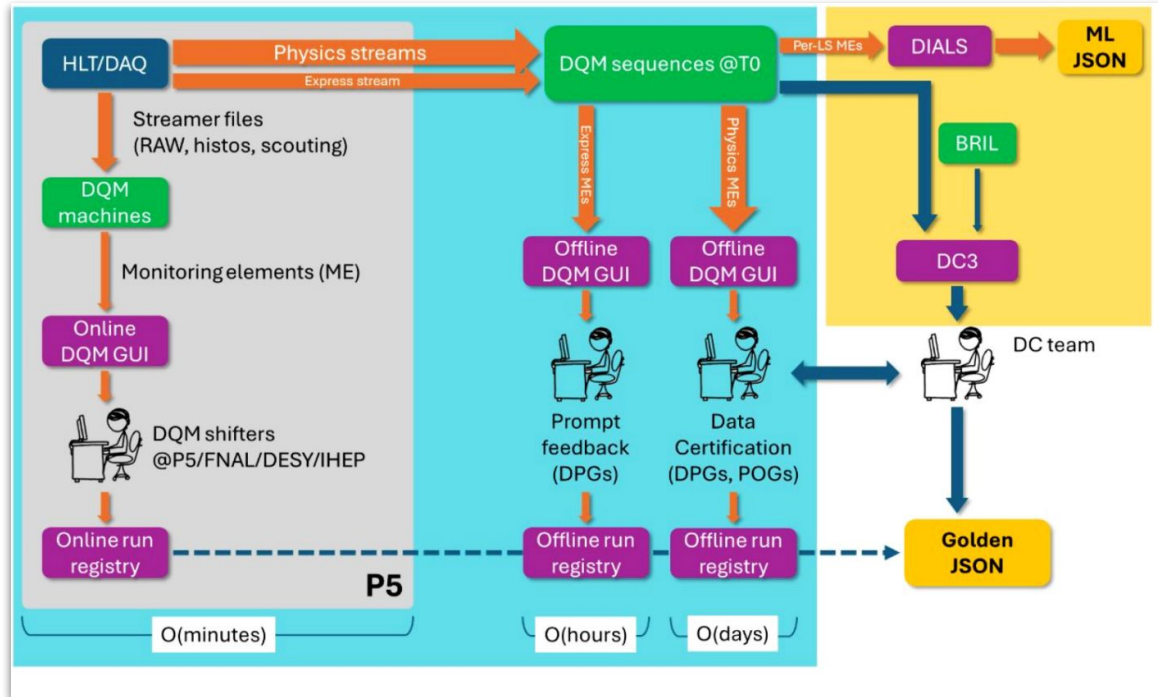


Machine Learning Tools for JetMET Data Certification in CMS

Jawaher Altork
on behalf of the CMS JetMET Group

ML4JETS 2026
Vienna, Austria
14 September 2026

The Run 3 CMS Data Quality Monitoring Workflow



Mostly inherited from Run2 with tweaks and additions over time

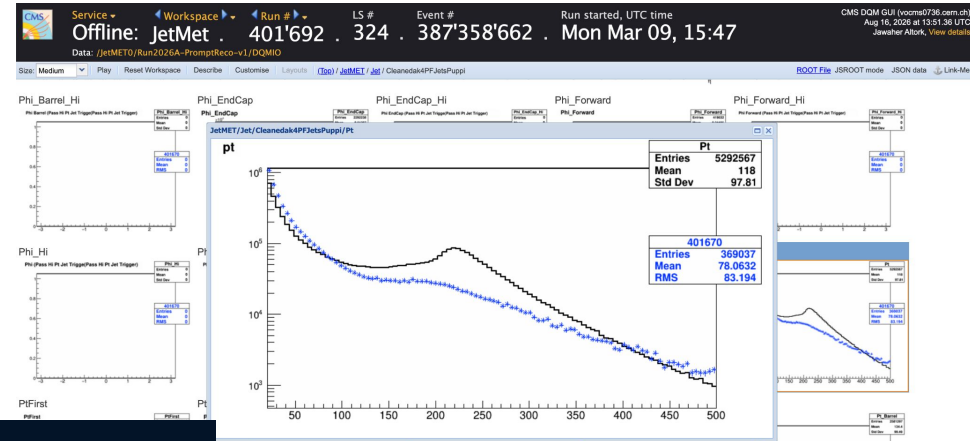
Introduced in Run3

© Roberto Seidita

JME offline Data Certification

Traditional certification workflow:

- Use the [DQM GUI](#) to inspect JME monitoring histograms for each run.
- Compare the distributions with a **good reference run**.
- Identify anomalous or problematic behaviour.
- Assign a **GOOD / BAD** certification.
- Record the certification in the [Run Registry](#).



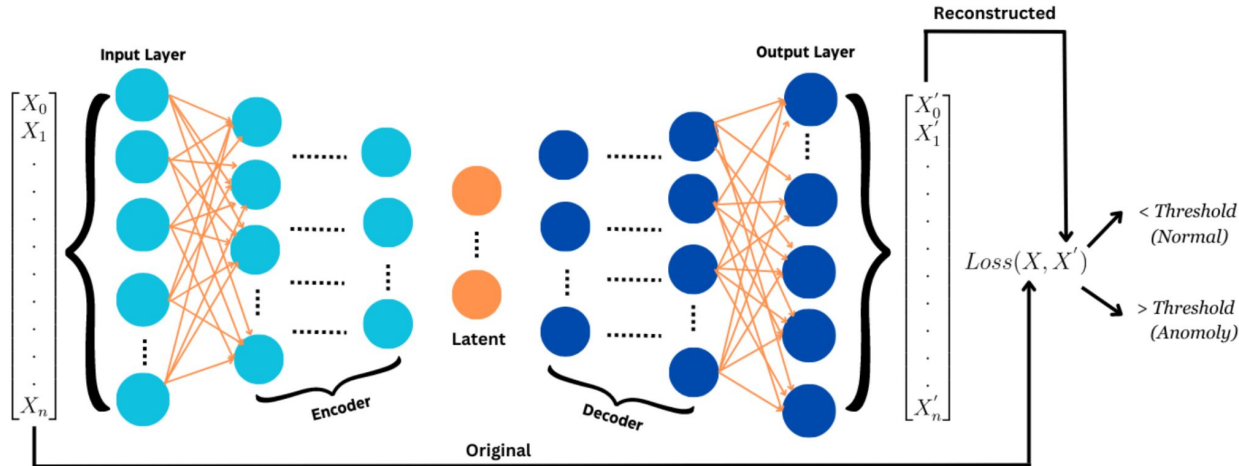
 Run Registry ONLINE OFFLINE JSON PORTAL LOG								
Run Number	Dataset Name	Class	Manage / LS	GUI Link	OMS	jetmet State	LS Duration	jetmet
368453	/PromptReco/C...	Collisions23	Manage / LS	GUI Link ▼	OMS	COMPLETED / move	11	
368452	/PromptReco/C...	Collisions23	Manage / LS	GUI Link ▼	OMS	COMPLETED / move	12	
368451	/PromptReco/C...	Collisions23	Manage / LS	GUI Link ▼	OMS	COMPLETED / move	154	
368437	/PromptReco/C...	Collisions23	Manage / LS	GUI Link ▼	OMS	COMPLETED / move	37	
368423	/PromptReco/C...	Collisions23	Manage / LS	GUI Link ▼	OMS	COMPLETED / move	538	

- **Lumisection (LS):** ~23 seconds of data taking.
- **Run:** a period of continuous data taking made up of many lumisections.

ML-based anomaly detection

- A large number of monitor elements distributions need to be inspected for each run.
- Manual inspection is time-consuming and subtle deviations can be difficult to identify.

Machine Learning is the ideal solution to help reduce the manual workload and human error.



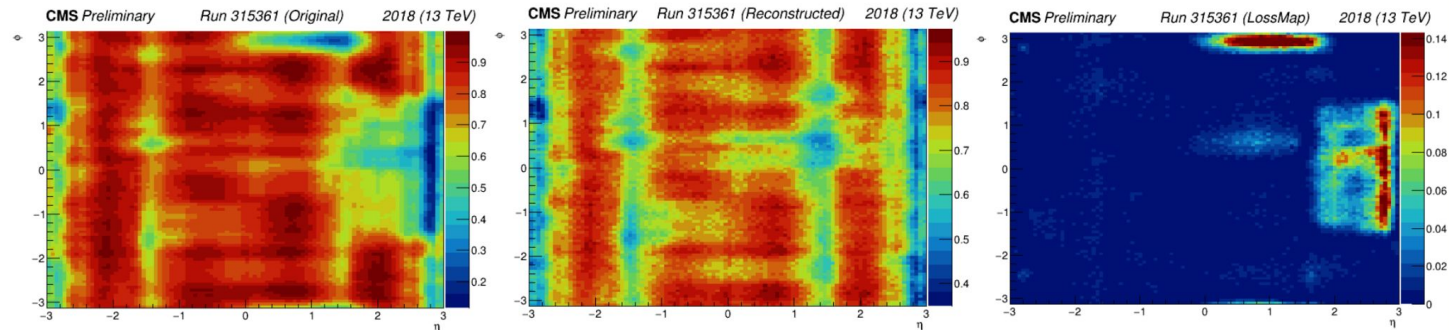
ML-based anomaly detection: Per-Run

➤ First approach: per-run anomaly detection ([DP-note](#)):

- A feed-forward autoencoder with 5 encoder/decoder layers was trained on good runs.
- The network compresses the input into a 2D latent space and reconstructs the input.
- The MSE reconstruction error is used as the per-run anomaly score.
- High reconstruction error → anomalous data.

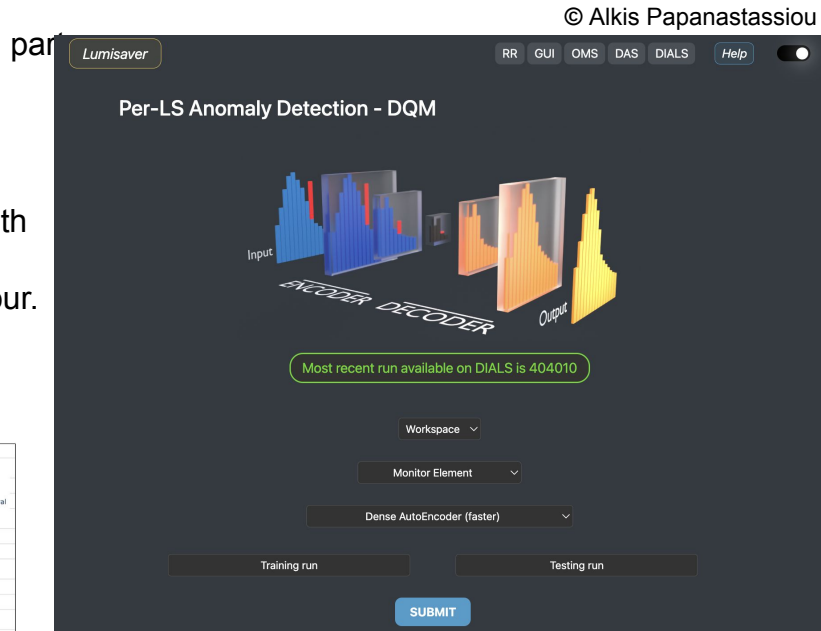
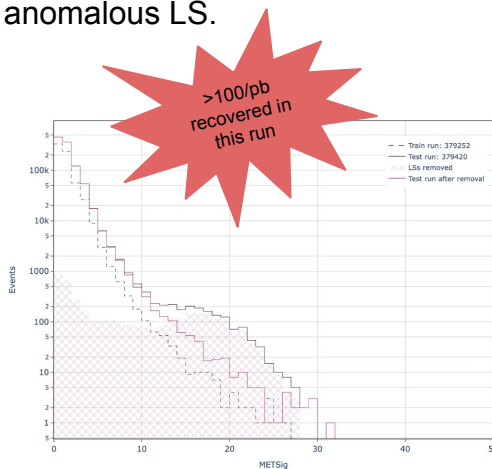
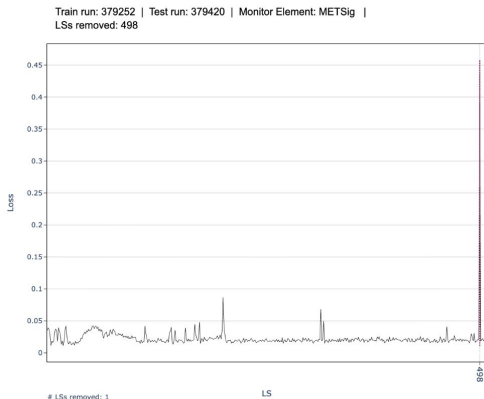
$$MSE = \frac{1}{n} \sum_{i=1}^n (y_i - \tilde{y}_i)^2$$

example: Hadron occupancy in the η - ϕ plane



ML-based anomaly detection: Per-Lumi section

- Per-run certification is too coarse when an anomaly affects only part of a run.
- A finer time granularity allows good lumi sections to be retained.
- Second approach: per-LS anomaly detection ([DP-note](#)):
 - Feed-forward autoencoder: 2 layers of encoder and decoder with MSE as the loss.
 - Trained on one selected GOOD run to learn normal LS behaviour.
 - Anomaly score: high MSE $\rightarrow$ anomalous LS.

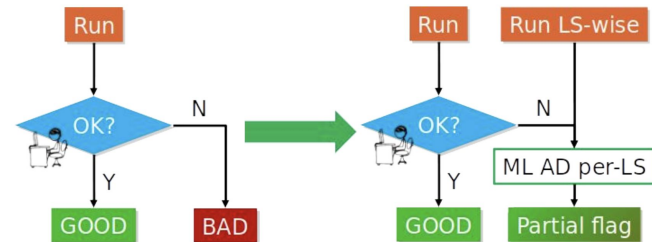


[Web application](#) developed to train, test and visualize the ML anomaly detection at LS level.

From Per-Run to Per-LS Certification

Why move from per-run to per-LS certification?

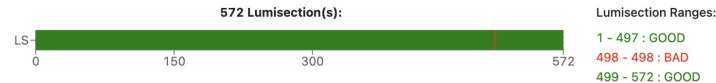
- Standard offline certification was performed per-run until the beginning of Run 3.
- If only part of a run had issues, good data could be lost.
- Detailed inspection of long runs could recover some good data, but shorter runs could still be flagged as fully BAD.



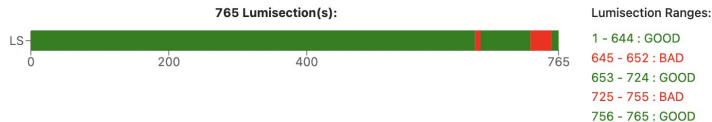
Run 3 introduced the change of paradigm: per-run → per-LS certification

Examples of long runs partially bad
with a good fraction certified as good:

Run 379420, from /PromptReco/Collisions2024/DQM, component JETMET-JETMET

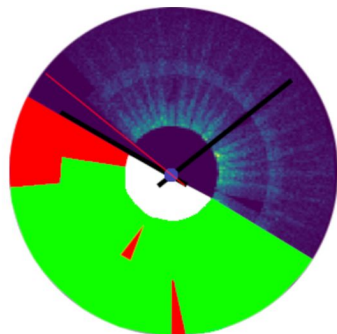


Run 386642, from /PromptReco/Collisions2024/DQM, component JETMET-JETMET



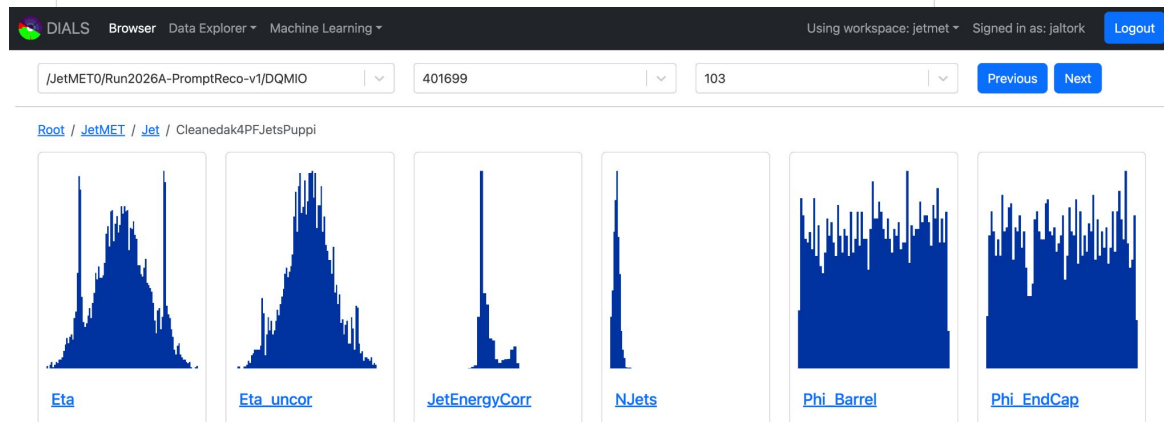
Tool for per-LS certification: DIALS

DIALS Interface



DIALS: Data Inspector for Anomalous Lumi-Sections

DIALS is an application that serves as a gateway to DQM per-LS monitoring elements. Its primary functions include indexing and storing pre-processed DQMIO data, as well as lumisections flagged as anomalous by pre-trained machine learning models. Conveniently, data is served through this web UI and a dedicated REST API.



- Newly developed tool to handle per-LS DQM.
- Selected DQM histograms are stored for every LS.
- These histograms are used as input to the ML anomaly-detection models.

DIALS: ML JSON


 DIALS
 Browser
Data Explorer
Machine Learning
Using workspace: jetmet
Signed in as: jaltork
Logout

Filters

Dataset

./JetMET0/Run2026B-Pro... x | v

Run numbers

Select... | v

Registered models

metsig-20240720 (rev: 1) x | v

Submit

Predictions

[Download certification json](#)
[Download golden json](#)

Model Id	Run	Lumisection	Metric value
8	401844	9	0.05244571715593338
8	401844	12	0.06744058430194855
8	401844	13	0.0647716298699379
8	401844	14	0.07792442291975021
8	401844	163	0.05255260691046715
8	401844	195	0.051733773201704025
8	401844	212	0.05486185476183891

GOOD LSs → Golden JSON
BAD LSs → Certification JSON

Selected JME MEs:

- CHFrac (high /medium /low pT × Barrel /EndCap)
- MET
- MET Phi
- MET Sig
- SumET

Histogram → Encoder → 8D latent space → Decoder → Reconstructed histogram

- 10 autoencoder models, one for each selected JME monitoring element.
- Trained on GOOD LSs from a GOOD run.
- Applied to new runs LS by LS, using the MSE reconstruction loss to measure deviations from the learned behaviour.
- **MSE > threshold → LS flagged as anomalous**

Threshold = $\mu + 3\sigma$

Shifter-Doc Web App

- Developed to validate the ML JSON produced by DIALS during 2026 data taking, providing a practical interface to inspect and verify ML anomaly flags at the LS level.
- At the same time, supports JME shifters by providing a centralized place to document observations, comments, and certification decisions.
- Validation revealed limitations of the current models, motivating improvements to the training strategy and architecture.

DQM JetMET Shifter Reporting

2026 Call 1 2026 Call 2 2026 Call 3 2026 Call 4 2026 Call 5 2026 Call 6 2026 Call 7 2026 Call 8 2026 Call 9

Shifter: Sync latest call

Target Run	Reference Run	PU	DQM GUI	OMS	Comments	Comments Scouting	Certification	DIALS BAD LSs	DIALS Validation
401693		21.27	JetMET / Scouting	OMS	Discrepan...		GOOD	43	
401692		20.67	JetMET / Scouting	OMS	HCAL bad ...		BAD	11	The 11 LS...
401691		14.135	JetMET / Scouting	OMS			GOOD	1	The MET...

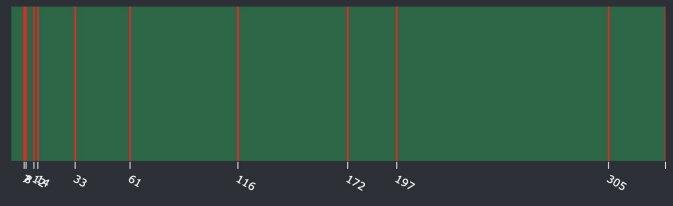
BAD lumisections for run 401692

OR AND

chfrac-highpt-barrel chfrac-highpt-endcap chfrac-lowpt-barrel chfrac-lowpt-endcap chfrac-mediumpt-barrel chfrac-mediumpt-endcap metphi met2 sumet

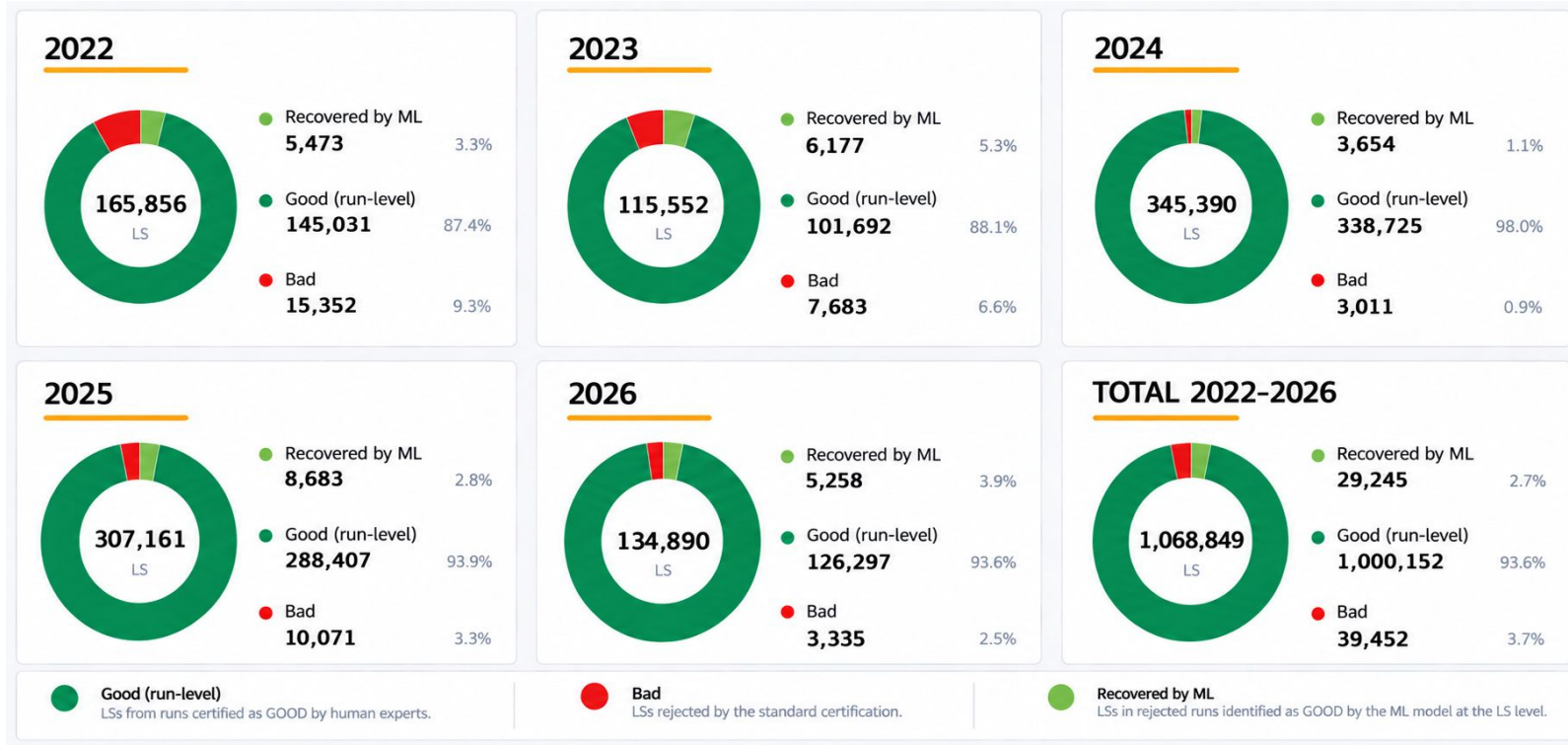
7 8 12 14 33 61 116 172 197 305 334

Left click: filter models that flag this LS. Right click: open this LS in DIALS.



0	Choose	jaltork jawaher.altork@cern.ch
0	Choose	jaltork jawaher.altork@cern.ch
1	Choose	jaltork jawaher.altork@cern.ch

Impact of ML Tools Into the JetMET Certification in Run-3



Summary and Conclusion

- Developed an ML-based anomaly detection workflow for JetMET DQM data at two granularities:
 - Per-run anomaly detection
 - Per-LS anomaly detection
- Developed DIALS to host and visualize per-LS histograms and run the ML models to produce the ML JSON.
- Developed ShifterDoc to validate the ML JSON from DIALS on real data and provide a centralized interface for JME shifters to document observations and certification decisions.
- Validation on 2026 data identified limitations in the initial ML models and motivated further improvements (to be deployed soon):
 - Distinguish EMPTY from BAD histograms.
 - Retrain with Run-3 data and a larger set of good runs.
 - Use PUPPI-based monitoring elements instead of CHS JET collections.

THANK YOU

Backup

The CMS Detector

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 ($100 \times 150 \mu\text{m}$) $\sim 1\text{m}^2$ $\sim 66\text{M}$ channels
 Microstrips ($80 \times 180 \mu\text{m}$) $\sim 200\text{m}^2$ $\sim 9.6\text{M}$ channels

SUPERCONDUCTING SOLENOID
 Niobium titanium coil carrying $\sim 18,000\text{A}$

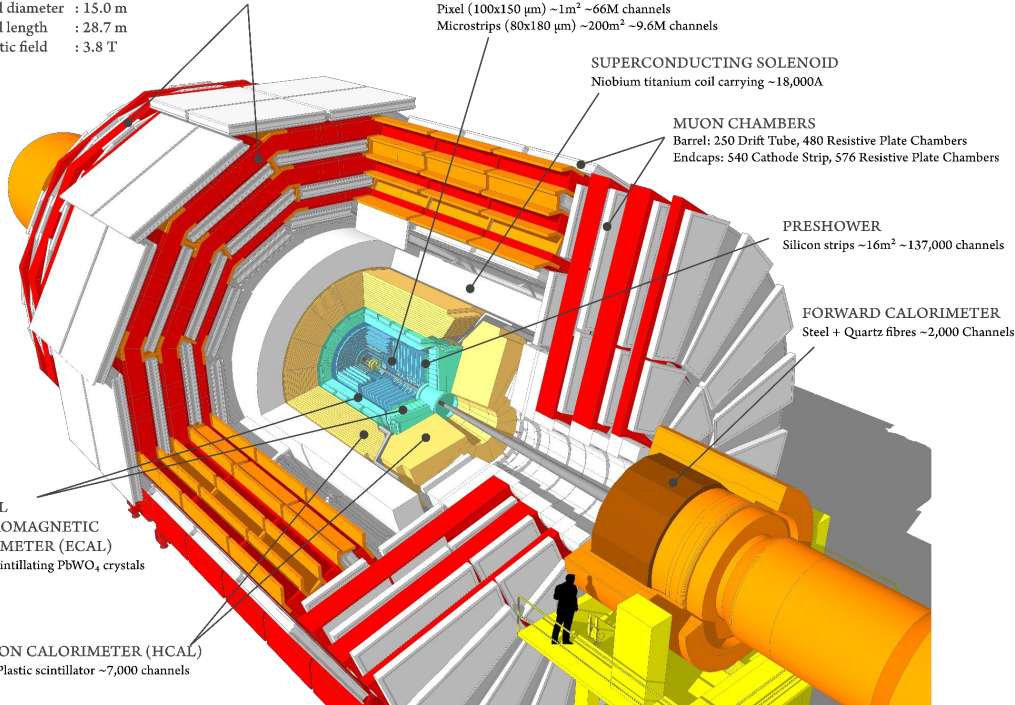
MUON CHAMBERS
 Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
 Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers

PRESHOWER
 Silicon strips $\sim 16\text{m}^2$ $\sim 137,000$ channels

FORWARD CALORIMETER
 Steel + Quartz fibres $\sim 2,000$ Channels

CRYSTAL
 ELECTROMAGNETIC
 CALORIMETER (ECAL)
 $\sim 76,000$ scintillating PbWO_4 crystals

HADRON CALORIMETER (HCAL)
 Brass + Plastic scintillator $\sim 7,000$ channels



JME Monitor Elements

Observable Name	Description
CHFrac highPt, lowPt, mediumPt (Barrel, EndCap)	Charged hadron energy fraction relative to corrected jet energy of high, low, medium Pt for CMS HCAL Barrel and EndCap
Phi	The total measurement of the azimuthal angle for corrected jet.
Pt	Total transverse momentum of corrected jet.
Hadron occupancy	Two-dimension histogram of eta and phi of particle flow hadron candidates.
Eta	Pseudo rapidity (the angle of a particle in relation to the particle beam or z-axis) for each of the sub detector components,
MET	Magnitude of the missing transverse momentum.
MET Significant	how significant the observed MET is relative to detector resolution.
MET Phi	Azimuthal direction of the missing transverse momentum.
SUM ET	Total transverse energy in the event.

Pt ranges → low: 20-50 GeV, medium: 50-140 GeV, and high: >140 GeV.