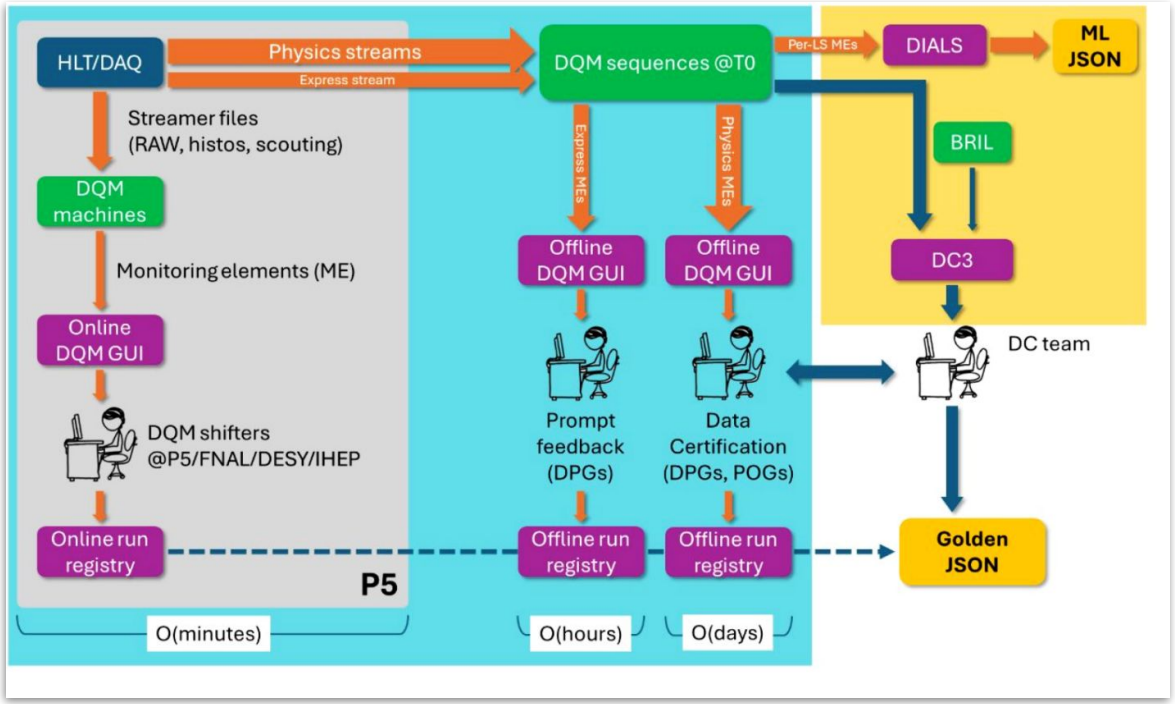
Machine Learning Tools for JetMET Data Certification in CMS

Jawaher Altork
on behalf of the CMS JetMET Group

ML4JETS 2026
Vienna, Austria
14 September 2026

The Run 3 CMS Data Quality Monitoring Workflow



© Roberto Seidita

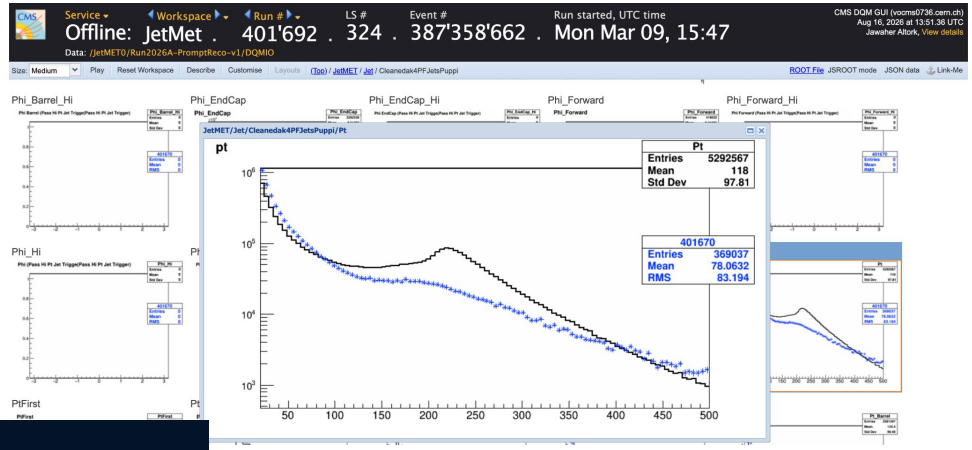
Mostly inherited from Run2 with tweaks and additions over time

Introduced in Run3

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**.



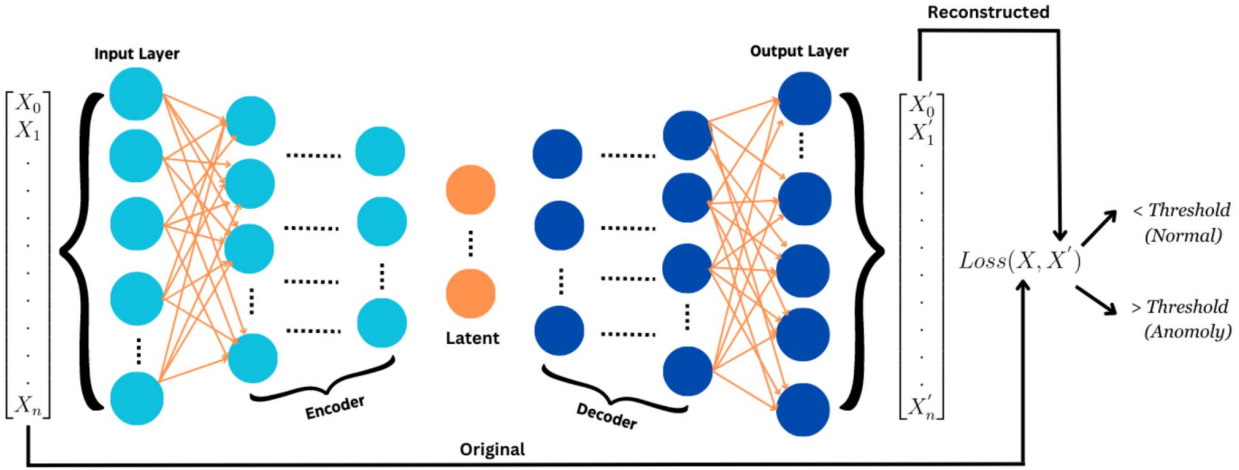
Run Number	Dataset Name	Class	Manage / LS	GUI Link	OMS	jetmet State	LS Duration	jetmet
368453	/PromptReco/C...	Collisions23	Manage / LS	GUI Link	OMS	COMPLETED / move	11	GOOD
368452	/PromptReco/C...	Collisions23	Manage / LS	GUI Link	OMS	COMPLETED / move	12	GOOD
368451	/PromptReco/C...	Collisions23	Manage / LS	GUI Link	OMS	COMPLETED / move	154	GOOD
368437	/PromptReco/C...	Collisions23	Manage / LS	GUI Link	OMS	COMPLETED / move	37	BAD
368423	/PromptReco/C...	Collisions23	Manage / LS	GUI Link	OMS	COMPLETED / move	538	GOOD

- **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.

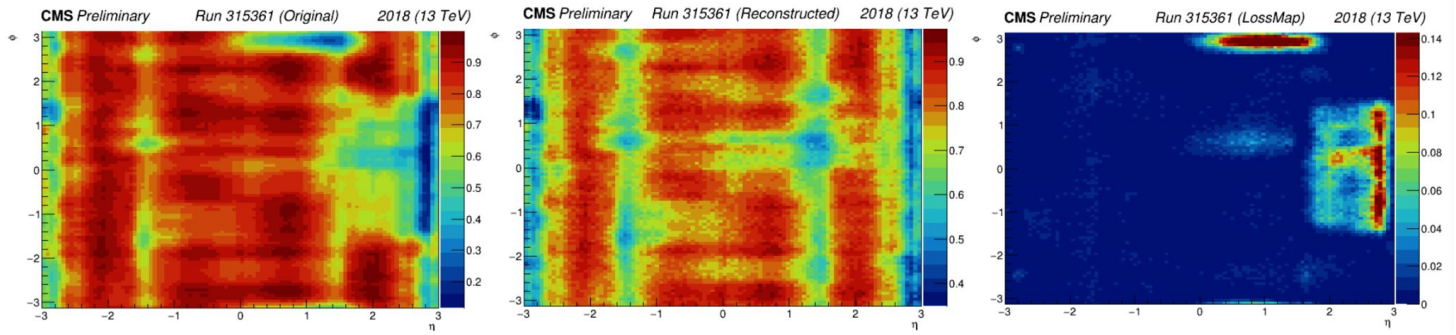


ML-based anomaly detection: Per-Run

- 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

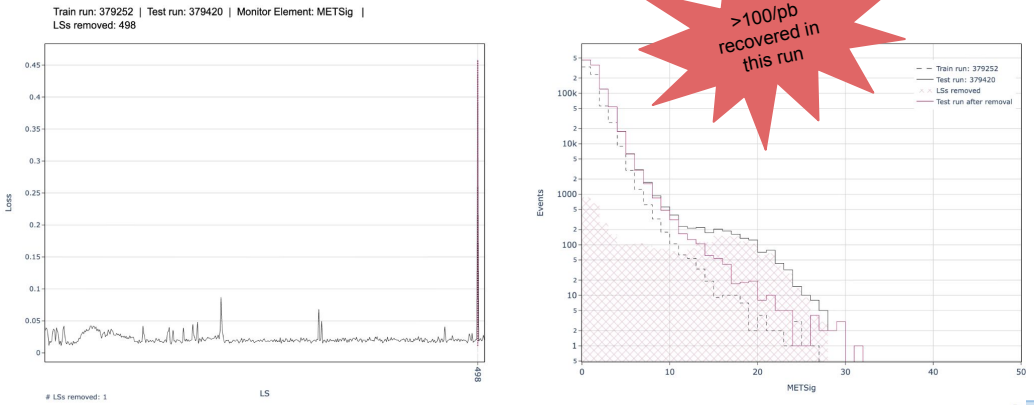


ML-based anomaly detection: Per-Lumi section

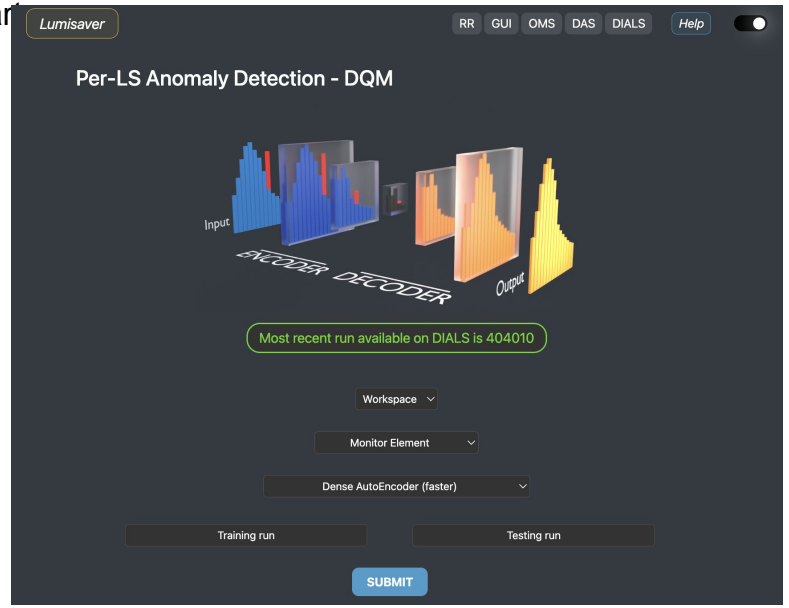
- Per-run certification is too coarse when an anomaly affects only par
  of a run.
- A finer time granularity allows good lumi sections to be retained.

➢ 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 → anomalous LS.



© Alkis Papanastassiou

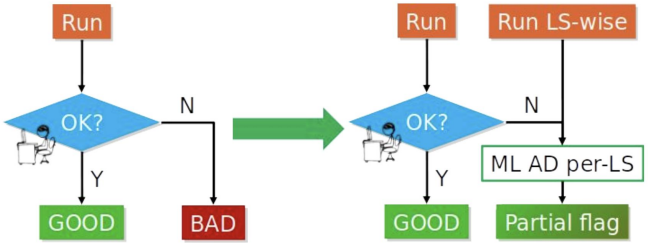


Web application developed to train, test and visualize the ML anomaly detection at LS level.

From Per-Run to Per-LS Certification

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

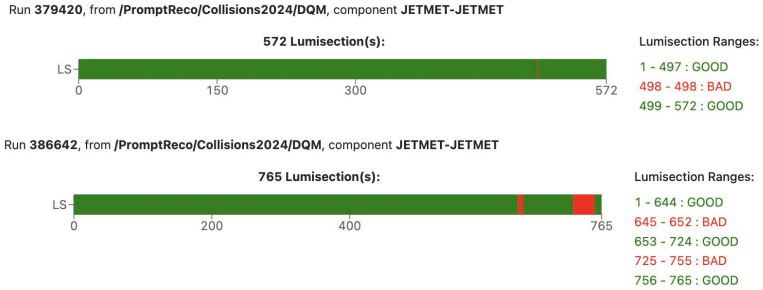
- Standard offline certification was performed per-run until the beginning of Run 3.
- If only part of a run had issues, good data could be lost.
- Detailed inspection of long runs could recover some good data, but shorter runs could still be flagged as fully BAD.



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

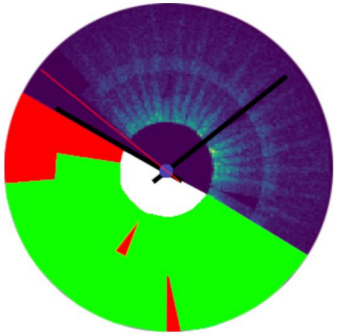
Examples of long runs partially bad

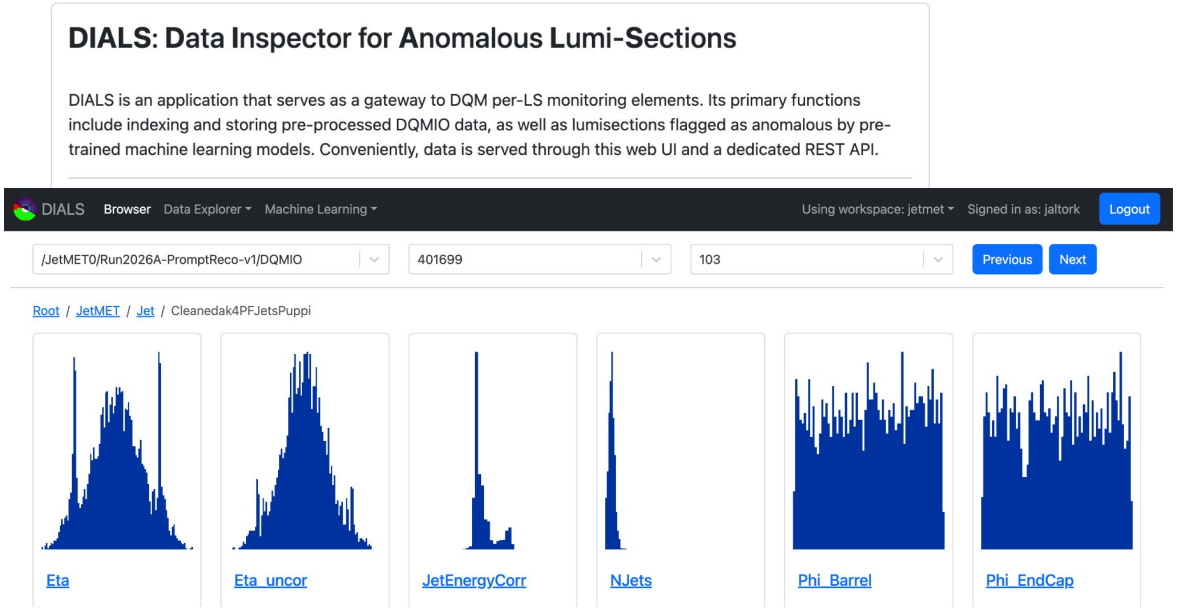
with a good fraction certified as good:



Tool for per-LS certification: DIALS

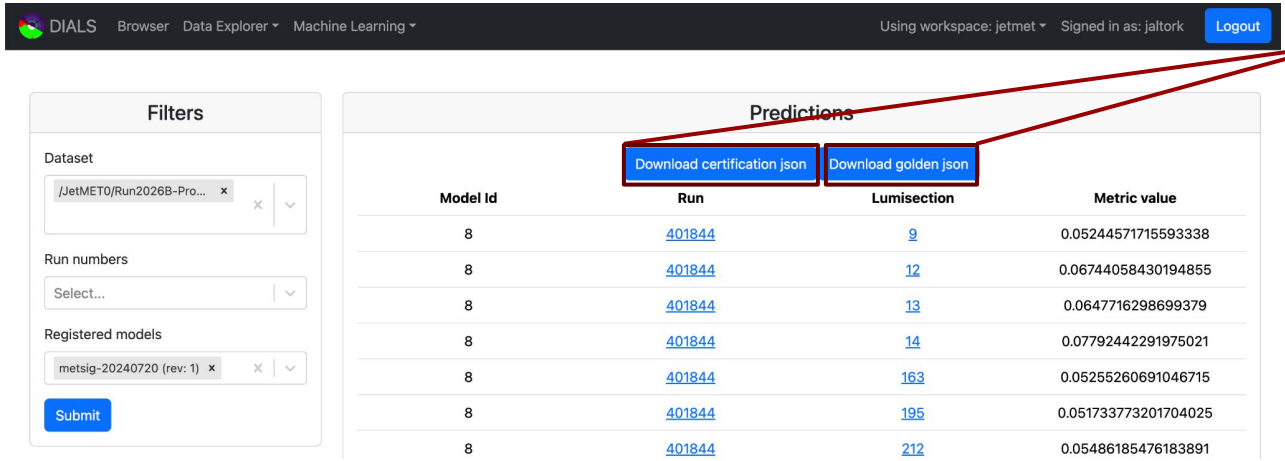
DIALS Interface





- 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



GOOD LSs → Golden JSON
BAD LSs → Certification JSON

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**

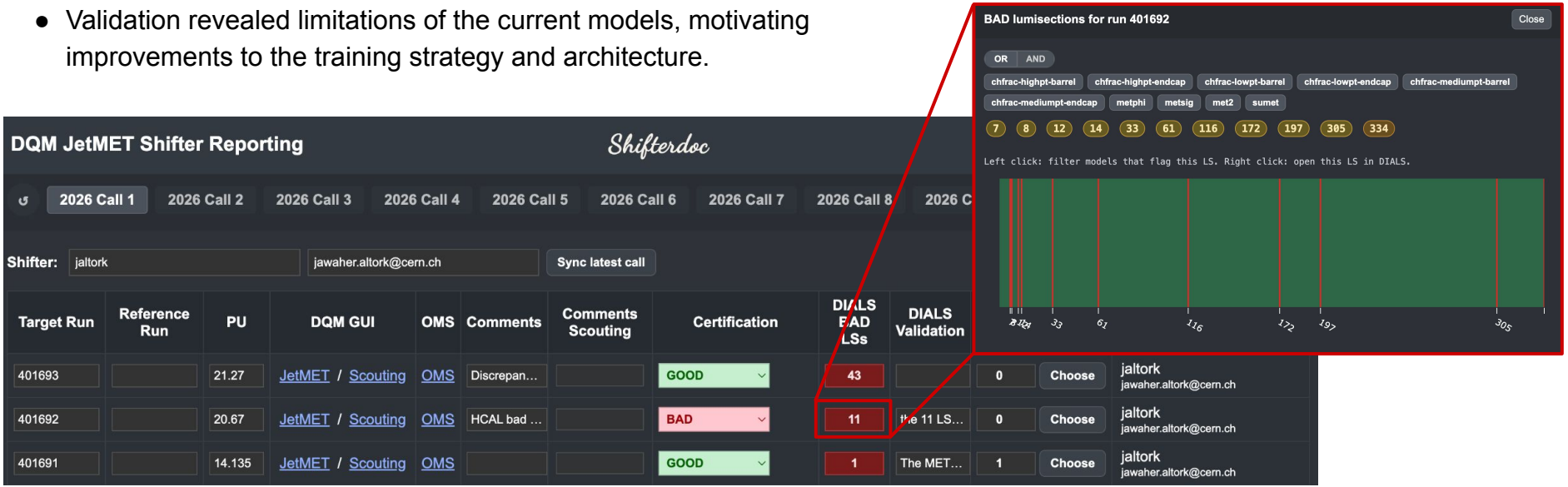
Selected JME MEs:

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

Threshold = μ +3 σ

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.



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

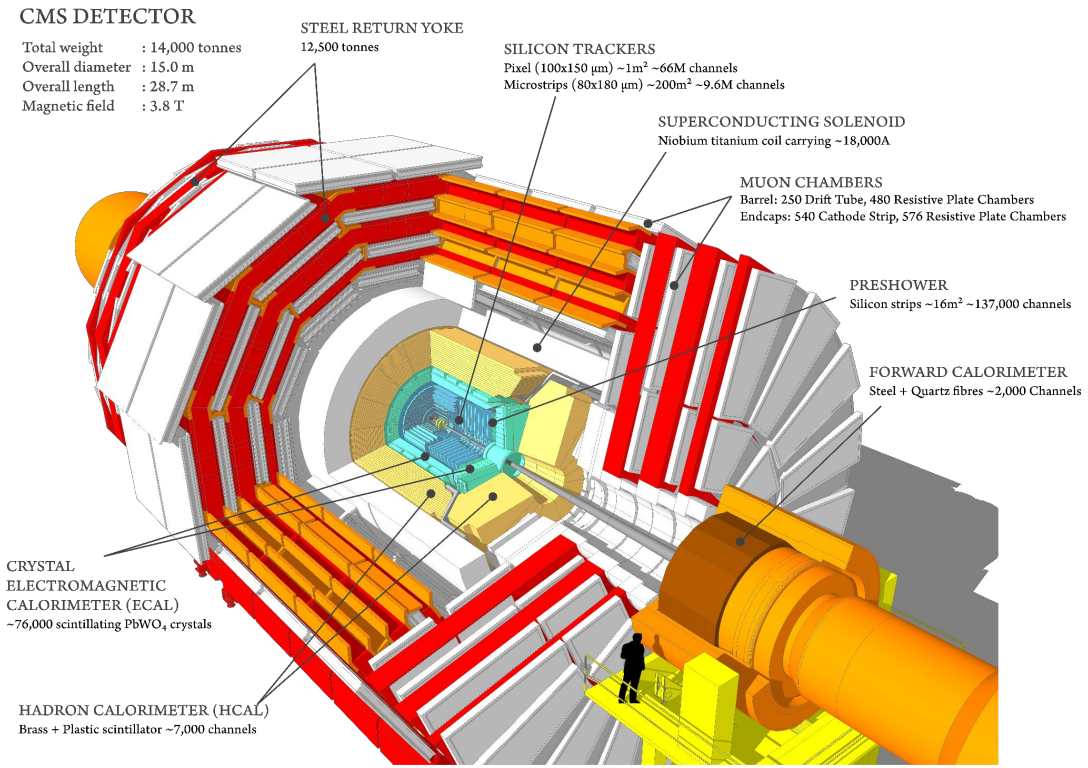
Summary and Conclusion

- 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



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.