Analysis and Grading of the Test Performance of PS Modules for the CMS Phase-II Outer Tracker Upgrade

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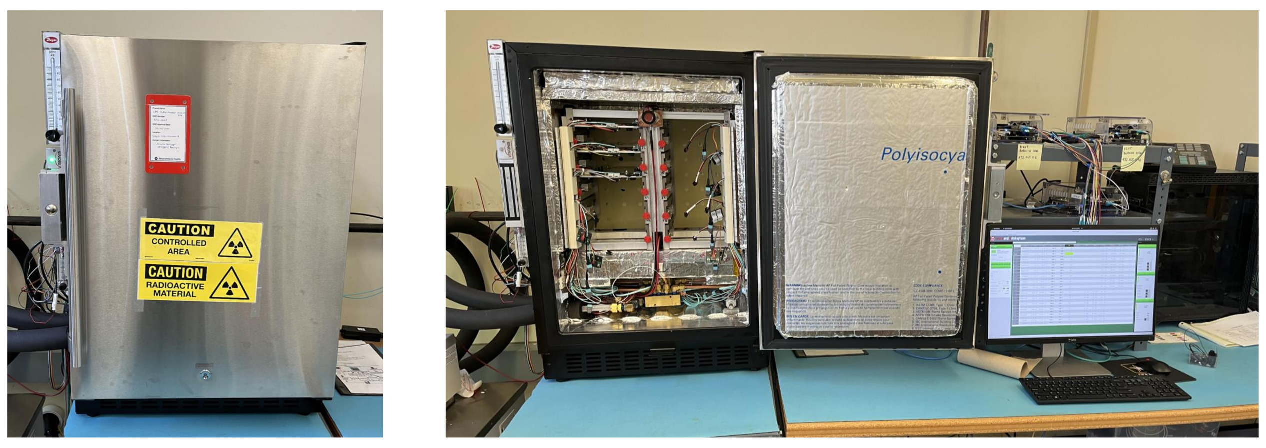
Abstract

The Outer Tracker of the CMS experiment provides information about the trajectory of charged particles produced in proton-proton collisions at the LHC. During the High Luminosity LHC upgrade, scheduled for the late 2020s, the Outer Tracker will be replaced with new modules capable of transmitting data to the L1 Trigger. These modules are being assembled at several facilities around the world, including Fermilab, necessitating coordinated standards of module quality. Here I discuss the development of POTATO (Phase-II Outer Tracker Analyzer of Test Outputs), a C++ software which provides a standardized procedure for analyzing and grading test results of the Outer Tracker modules. The particular focus of this poster is on the analysis and grading of the PS (pixel-strip) modules in POTATO.

Testing

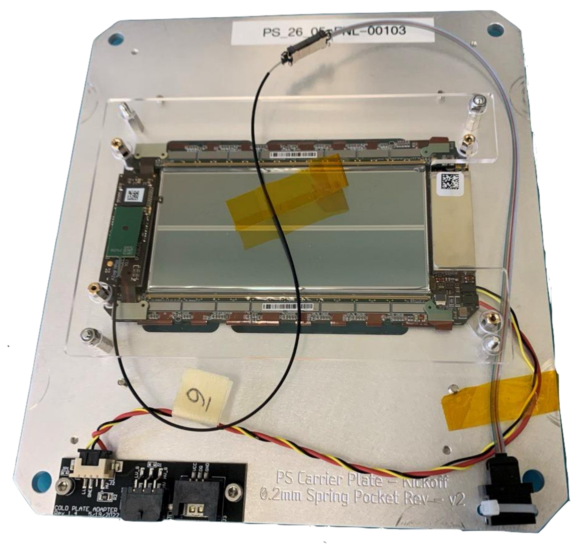
To ensure each assembled module is functional, a series of tests are carried out to evaluate its performance. Noise, pedestal, and other parameters are measured to ensure effective data communication. The test output is summarized in several ROOT histograms for analysis.



Burnin box for testing modules at Fermilab

Analysis

The histograms output by burnin box testing are processed by POTATO to extract relevant quantities. For each variable (e.g., noise), the mean and RMS are computed, and channels with outlying values are identified. The results of this analysis are summarized in an XML file, which is uploaded to a centralized database to be shared with the collaboration.

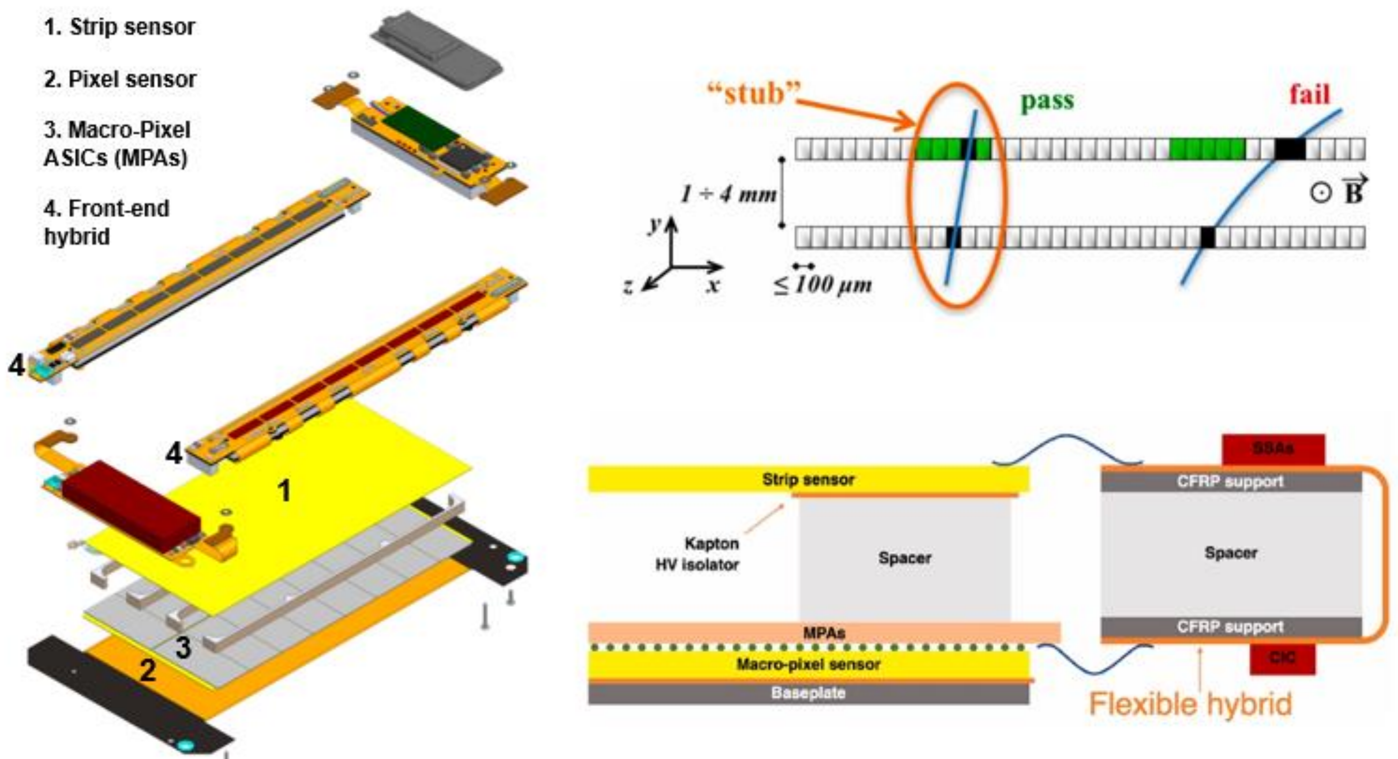


PS module at Fermilab

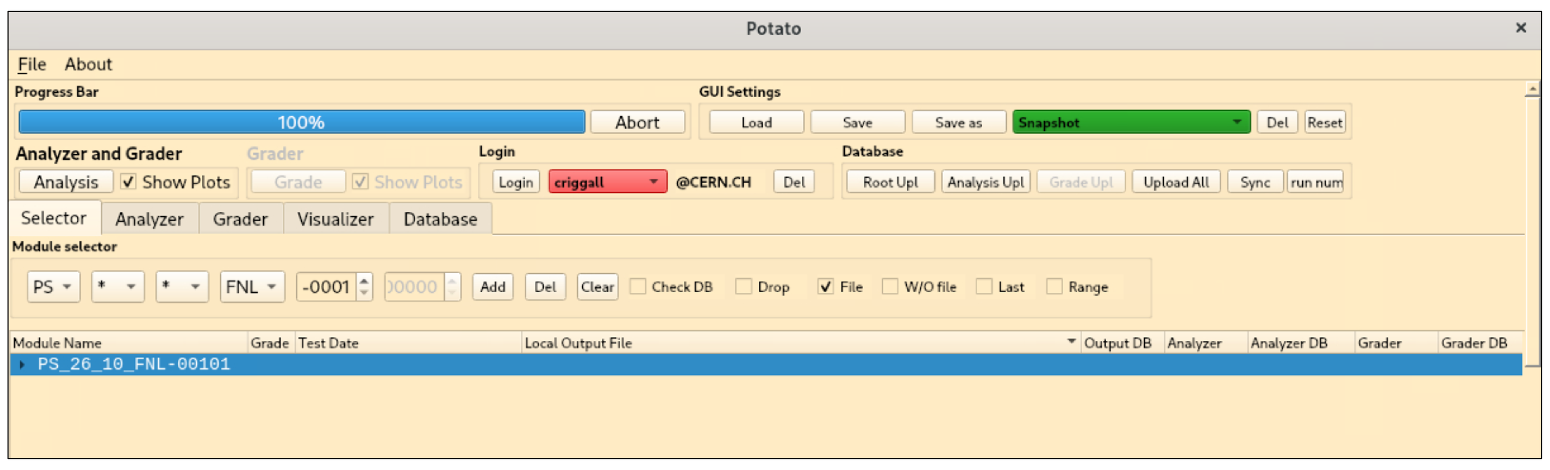
Module Assembly → Module Testing → Test Output (ROOT) → POTATO! → Analysis (XML) / Grading (XML) / Upload to Database

PS Modules

The PS (pixel-strip) are one of two module types in the Outer Tracker. They consist of one silicon strip sensor and one pixel sensor layered on top of each other, allowing for the detection of coordinated particles hits called stubs. Each module also contains two front-end hybrids, composed of 8 SSA (strip) and 8 MPA (pixel) chips each, for a total of 32 read-out chips per module. The stub information is sent to the L1 trigger to aid in the selection of events with high momentum tracks.



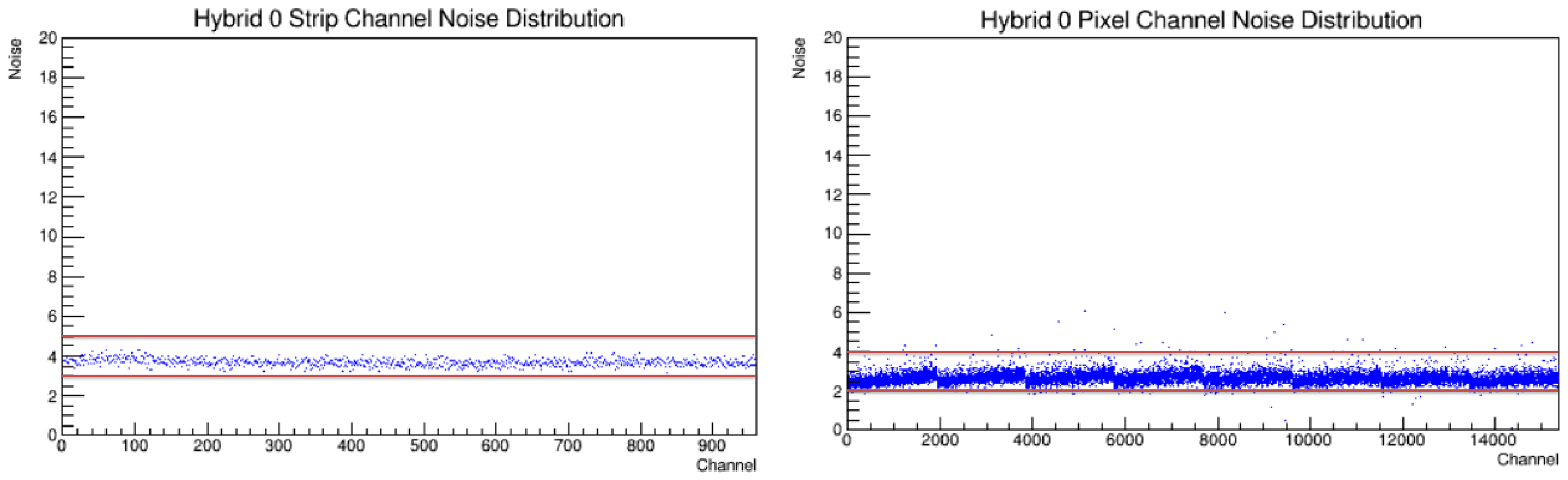
Diagrams of PS module and stub formation



POTATO GUI

Grading

Once analysis is complete, POTATO assigns a grade to the module based on the analysis results. Grades A, B, C, etc. are given for individual parameters (for example, average noise) as well as an overall module evaluation. This grading will ultimately assist in deciding which modules meet the criteria to be used in the experiment.



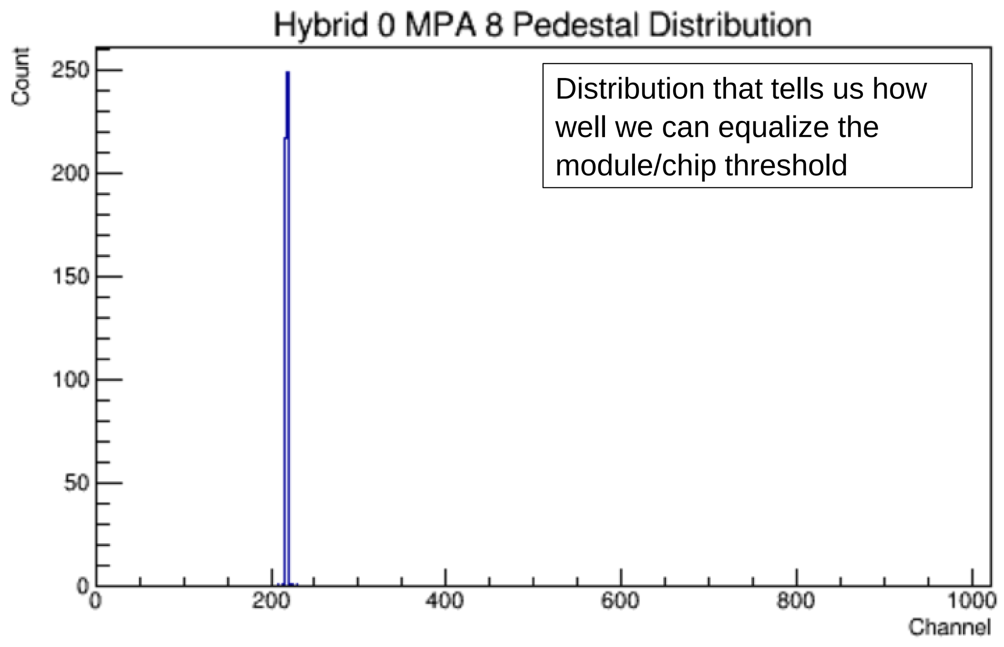
Noise distribution histograms for SSA (left) and MPA (right) chips with example grading cuts

CMS_TRK_TRKER_COND.MOD_PS_ANL_SMMRY			
P	*	RECORD_ID	NUMBER (38)
F	*	CONDITION_DATA_SET_ID	NUMBER (38)
F	*	ROOT_FILE	NUMBER (38)
	*	ANL_VER	VARCHAR2 (40 BYTE)
	*	ANL_CUTS_VER	VARCHAR2 (40 BYTE)
		LV_CURR_AMP	FLOAT (126)
		IV_CURR_MAMP	FLOAT (126)
		IV_RATIO	FLOAT (126)
		IV_BREAKDOWN_V	FLOAT (126)
		READ_ERR	FLOAT (126)
		NOISE_AVG_MPA	FLOAT (126)
		NOISE_AVG_SSA	FLOAT (126)
		NOISE_RMS_MPA	FLOAT (126)
		NOISE_RMS_SSA	FLOAT (126)
		NOISE_NOUTL_LOW_MPA	NUMBER (38)
		NOISE_NOUTL_LOW_SSA	NUMBER (38)
		NOISE_OUTL_LOW_MPA	VARCHAR2 (2000 BYTE)
		NOISE_OUTL_LOW_SSA	VARCHAR2 (2000 BYTE)
		NOISE_NOUTL_HIGH_MPA	NUMBER (38)
		NOISE_NOUTL_HIGH_SSA	NUMBER (38)
		NOISE_OUTL_HIGH_MPA	VARCHAR2 (2000 BYTE)
		NOISE_OUTL_HIGH_SSA	VARCHAR2 (2000 BYTE)

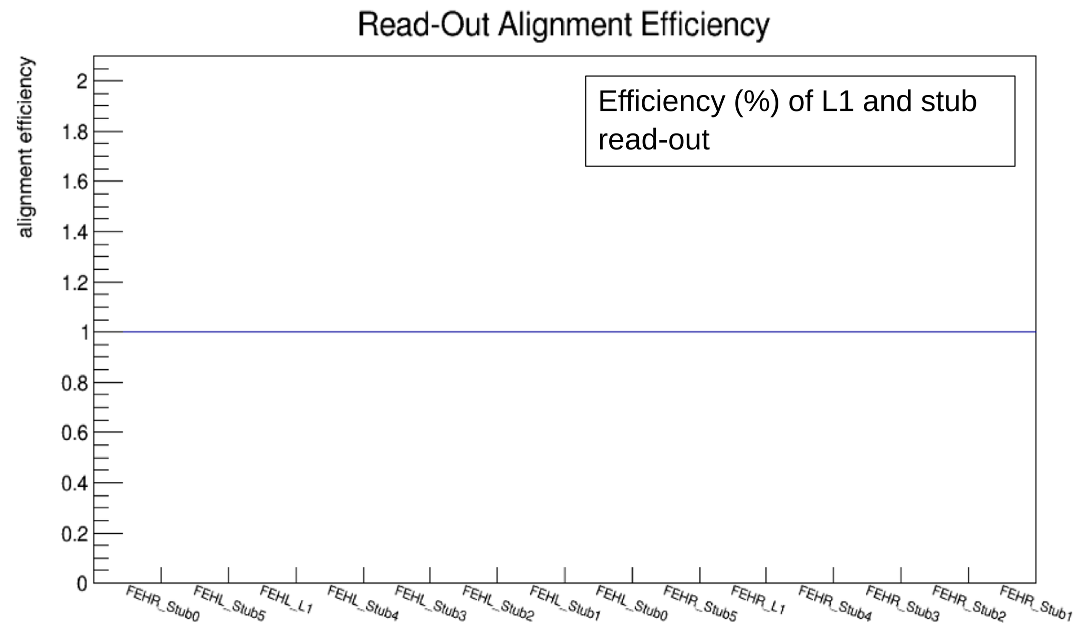
Example table of analysis variables

CMS_TRK_TRKER_COND.MOD_GRADING			
P	*	RECORD_ID	NUMBER (38)
F	*	CONDITION_DATA_SET_ID	NUMBER (38)
		OVERALL	VARCHAR2 (6 BYTE)
		LV_CURR_AMP	VARCHAR2 (6 BYTE)
		IV_CURR_MAMP	VARCHAR2 (6 BYTE)
		IV_RATIO	VARCHAR2 (6 BYTE)
		IV_BREAKDOWN	VARCHAR2 (6 BYTE)
		NOISE_AVG	VARCHAR2 (6 BYTE)
		NOISE_RMS	VARCHAR2 (6 BYTE)
		NOISE_NOUTL_LOW	VARCHAR2 (6 BYTE)
		NOISE_NOUTL_HIGH	VARCHAR2 (6 BYTE)
		SCURVE	VARCHAR2 (6 BYTE)
		FEHL_OVERALL	VARCHAR2 (6 BYTE)
		FEHL_NOISE_AVG	VARCHAR2 (6 BYTE)
		FEHL_NOISE_RMS	VARCHAR2 (6 BYTE)
		FEHL_NOISE_NOUTL_LOW	VARCHAR2 (6 BYTE)
		FEHL_NOISE_NOUTL_HIGH	VARCHAR2 (6 BYTE)
		FEHR_OVERALL	VARCHAR2 (6 BYTE)
		FEHR_NOISE_AVG	VARCHAR2 (6 BYTE)
		FEHR_NOISE_RMS	VARCHAR2 (6 BYTE)
		FEHR_NOISE_NOUTL_LOW	VARCHAR2 (6 BYTE)
		FEHR_NOISE_NOUTL_HIGH	VARCHAR2 (6 BYTE)

Example table of grading variables



Pedestal distribution histogram for an MPA chip



Alignment efficiency histogram for a PS module

Progress and Future Work

During this internship, I have contributed to the completion of the first version of POTATO, which includes procedures for evaluating module performance based on noise, pedestal, and alignment efficiency. I am currently working on adding scripts to the POTATO user interface which will allow for downloading and plotting data from the centralized database of module test results. This update, and others later, will be included in future versions of POTATO. Future work will also focus on the inclusion of additional histograms output by the testing process.

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