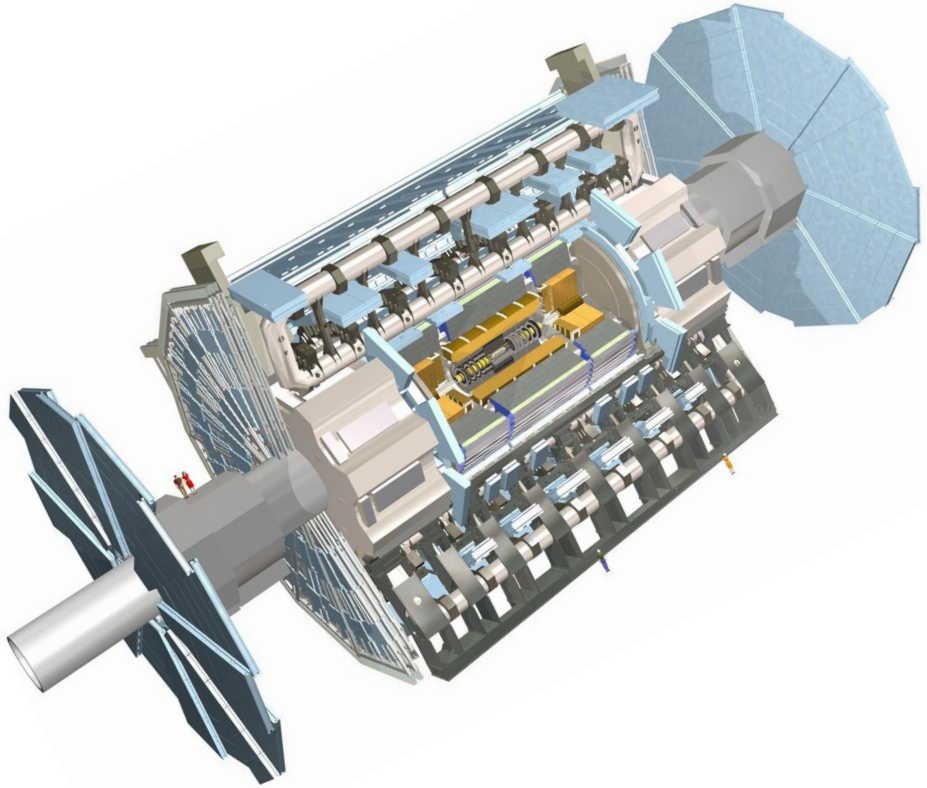
Production Phase GUI Tool for Type-1 Data Services for ITK

Quratulain Zahoor

Supervised by: Stephan Eisenhardt, Liza Mijovic

School of Physics and Astronomy

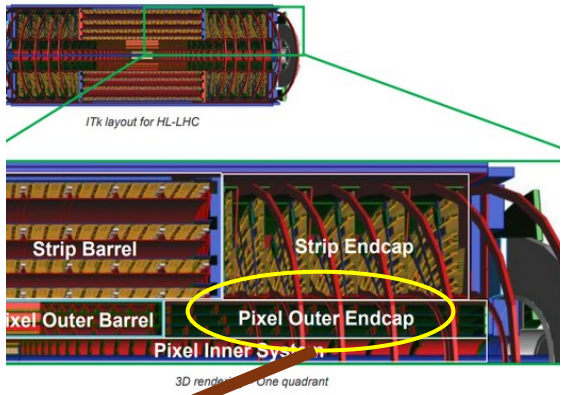
University of Edinburgh



Project Background

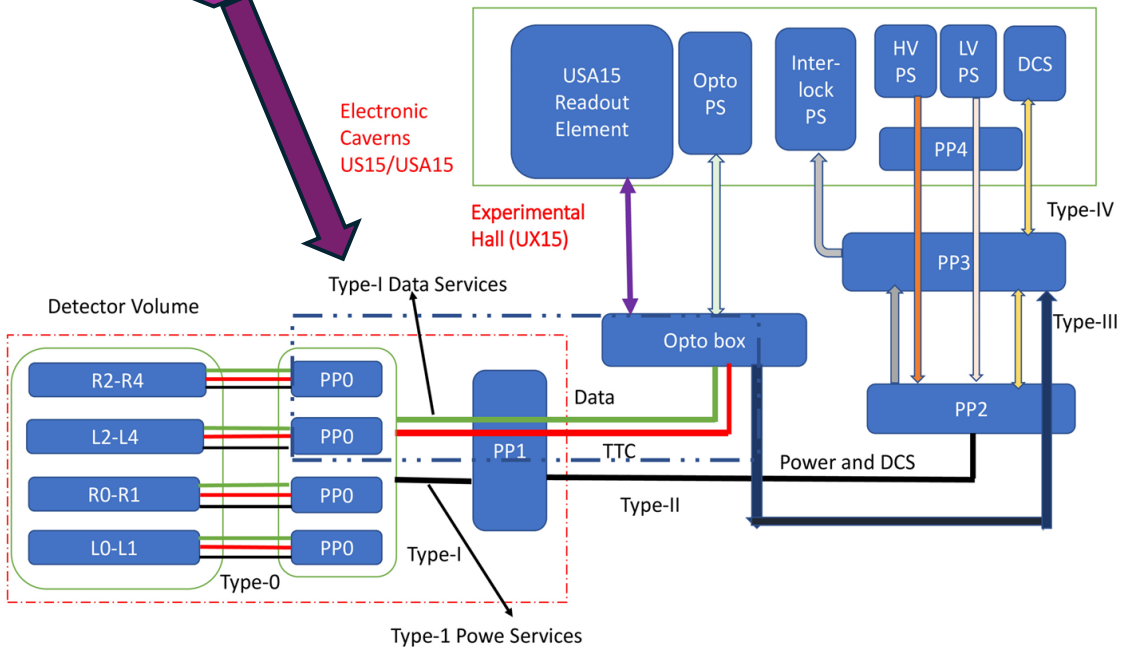
- To meet the HL-LHC experimental conditions, ATLAS has developed a new all-silicon Inner Tracker (ITk) with
  - enhanced granularity
  - radiation hardness, readout speed
  - low material budget

to ensure improved performance in the harsh HL-LHC environment and provide better tracking efficiency.



Edinburgh ITk team is working with Pixel Outer Endcap

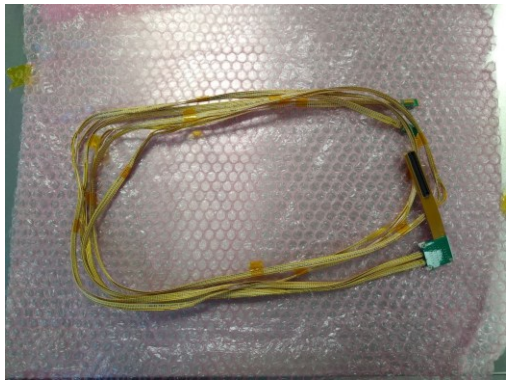
The ATLAS ITk upgrade for 2028 requires ~26,000 high-speed (1.28 Gbps) CMD and data links to read out its three subsystems



The services of the ITk pixel detector connect the detector modules and auxiliary components to the necessary equipment for operating the detector and collecting its data.

The QC/QA Testing Procedure

- ✓ Type-1 Data Services undergoes a set of QC/QA tests that confirm the quality of the cables.
  - ✓ Electrical tests help us to identify the quality of signal transmission via the Eye Diagram.
  - ✓ Time Domain Reflectometry is a QA test that helps to detect faults and discontinuities in the signal transmission. This test is applied only when the Electrical QC fails



1- Visual Inspection

2- Geometrical Test

-Connectivity Test

4- Electrical Quality Control Testing

5- Time Domain Reflectometry

Type-1 Data links Quality Control Testing setup

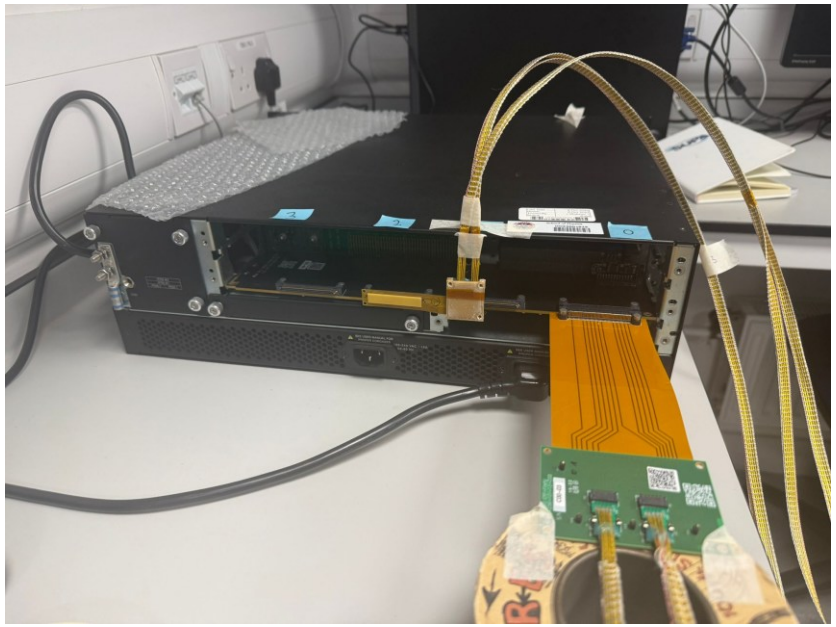


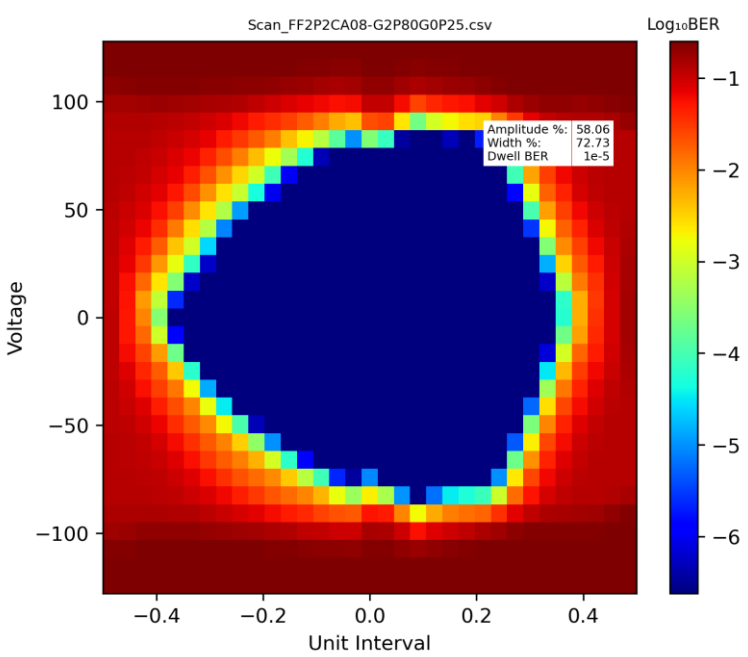
Fig: The quality Control testing setup shown with Type-1 Data bundle Flavor B attached.

TX	RX	Configuration	Type-1 Data links(B)
0	2	02	20
0	3	03	20
1	2	12	20
1	2	13	20

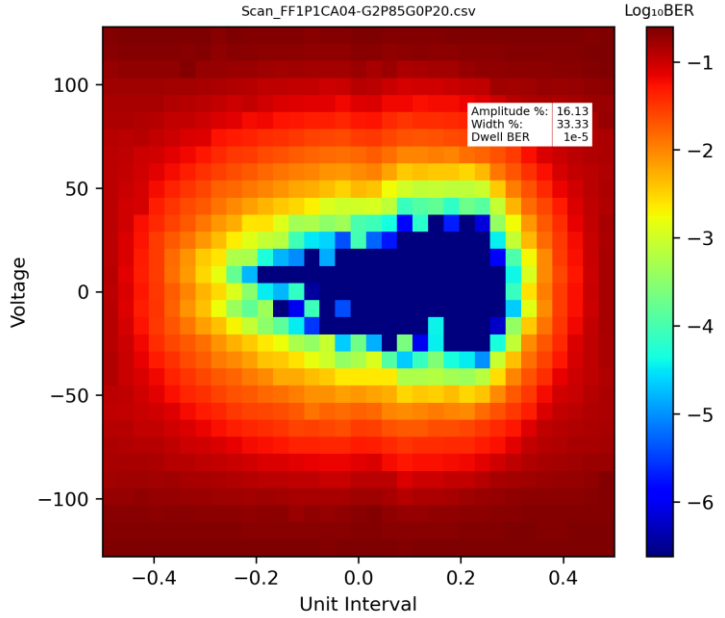
Problem: 01

For the Production Phase, we would have multiple bundles, so it not ideal to test all configuration , we need to select the one that perform best and we can rely on.

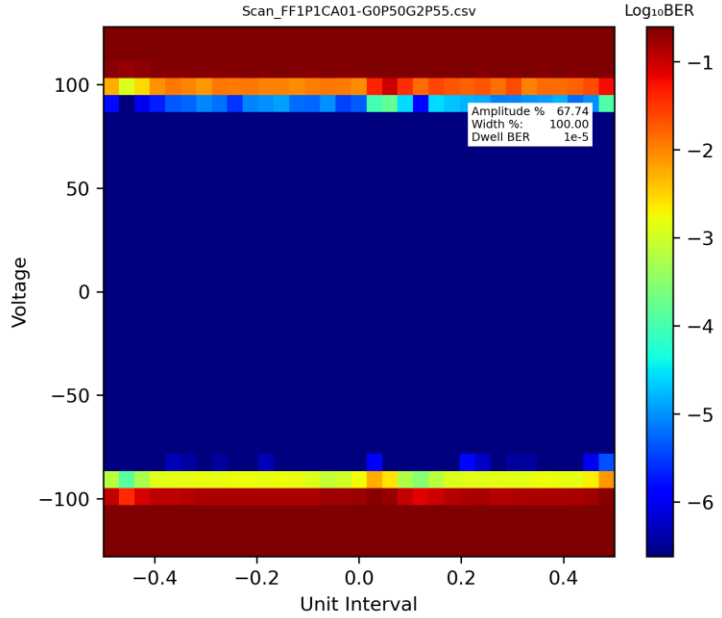
Classification of Eye Diagram



(a): Wide eye opening, excellent transmission(Green Category)



(b):Marginal eye opening, poor transmission (Yellow Category)



(c): Faulty link, no transmission (Red Category)

Problem 02

Examining each eye diagram by manually classifying them, and then comparing good and bad links without any predetermined threshold criteria, is a time-consuming process that increases the risk of human error. The Production Phase will become considerably more challenging.

Solution: A Production Phase GUI

- I developed a Production Phase GUI Tool that solved both problems.
  - ❖ I implemented a set of thresholds for the Type-1 Data link after performing detailed studies.
    - ✓ Set of universal set thresholds (Global Threshold), applicable to all DAQ channels. (default mode)
    - ✓ DAQ-channel-dependent sets where data transmission is reported to be weak (Individual Threshold) (Solution for problem 1, find the best possible configuration 13)
  - ❖This GUI Tool can do all the processing automatically, with all defined criteria.
    - ✓ Process and plot the data from multiple runs in minutes
    - ✓ Apply automated categorisation
    - ✓ Display to the user for cross-checking and decision-making on edge cases
    - ✓ Create test reports
    - ✓ This is a fully functional production-phase QC tool with a GUI, easy to use for non-experts.

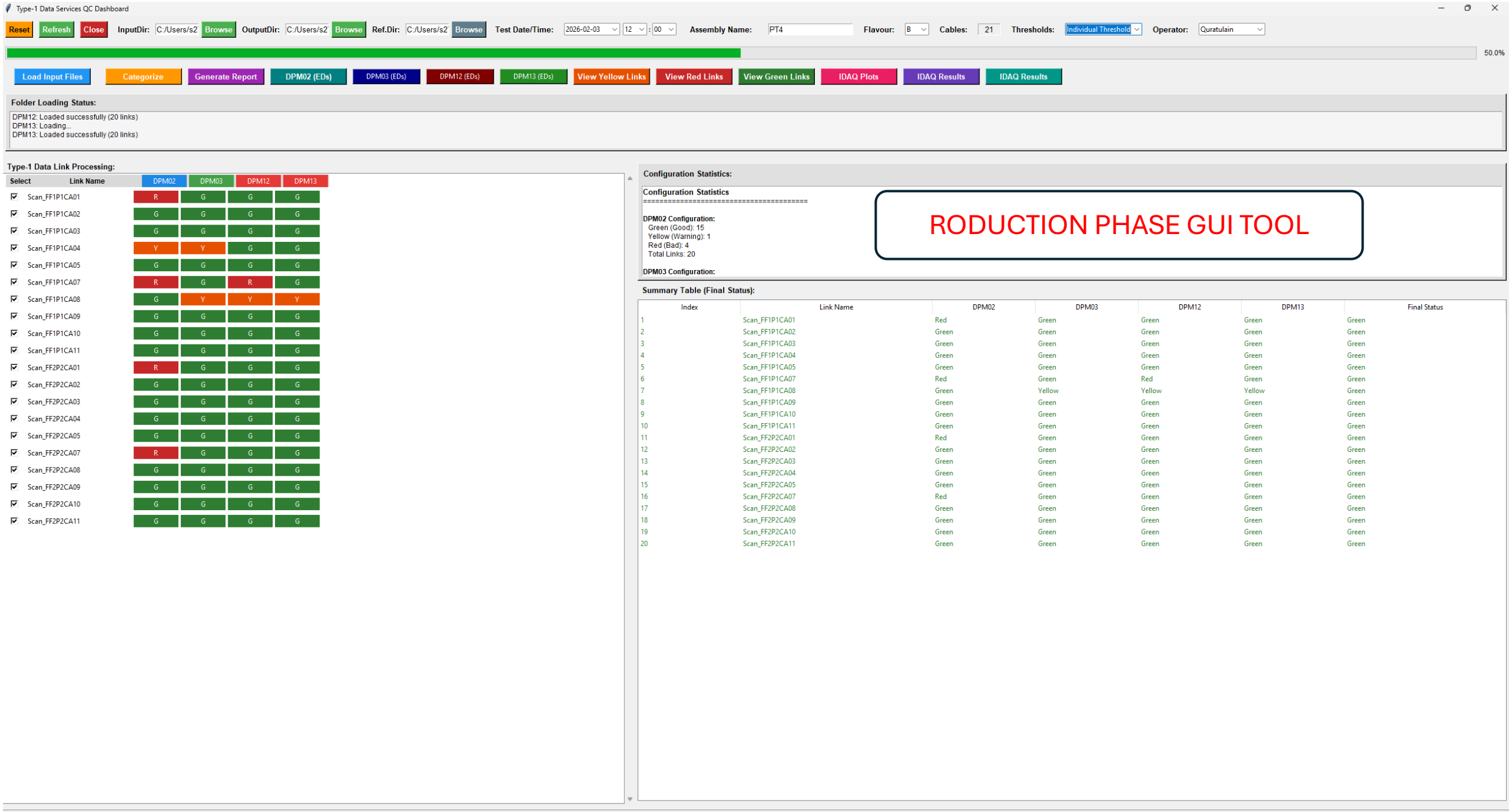
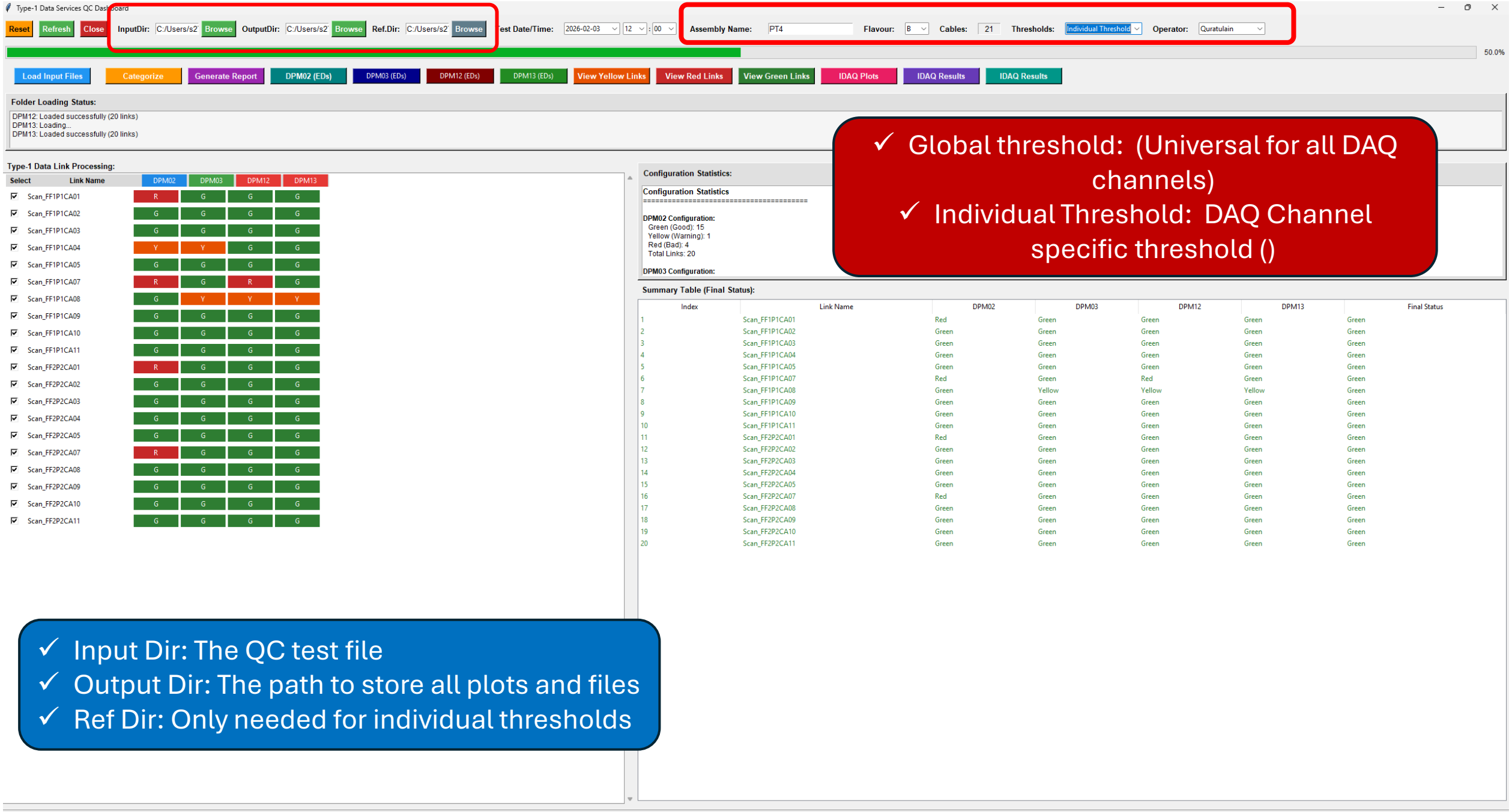


Fig: The Production Phase Tool GUI Interface

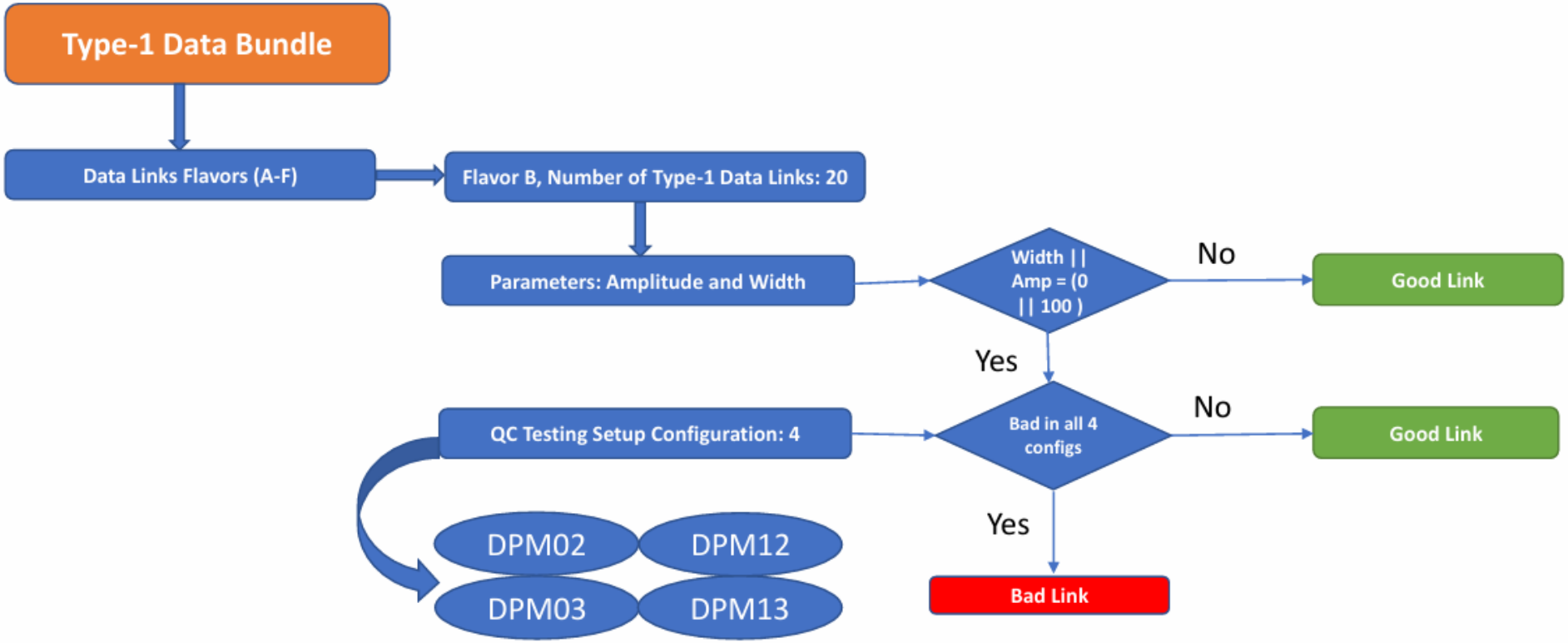


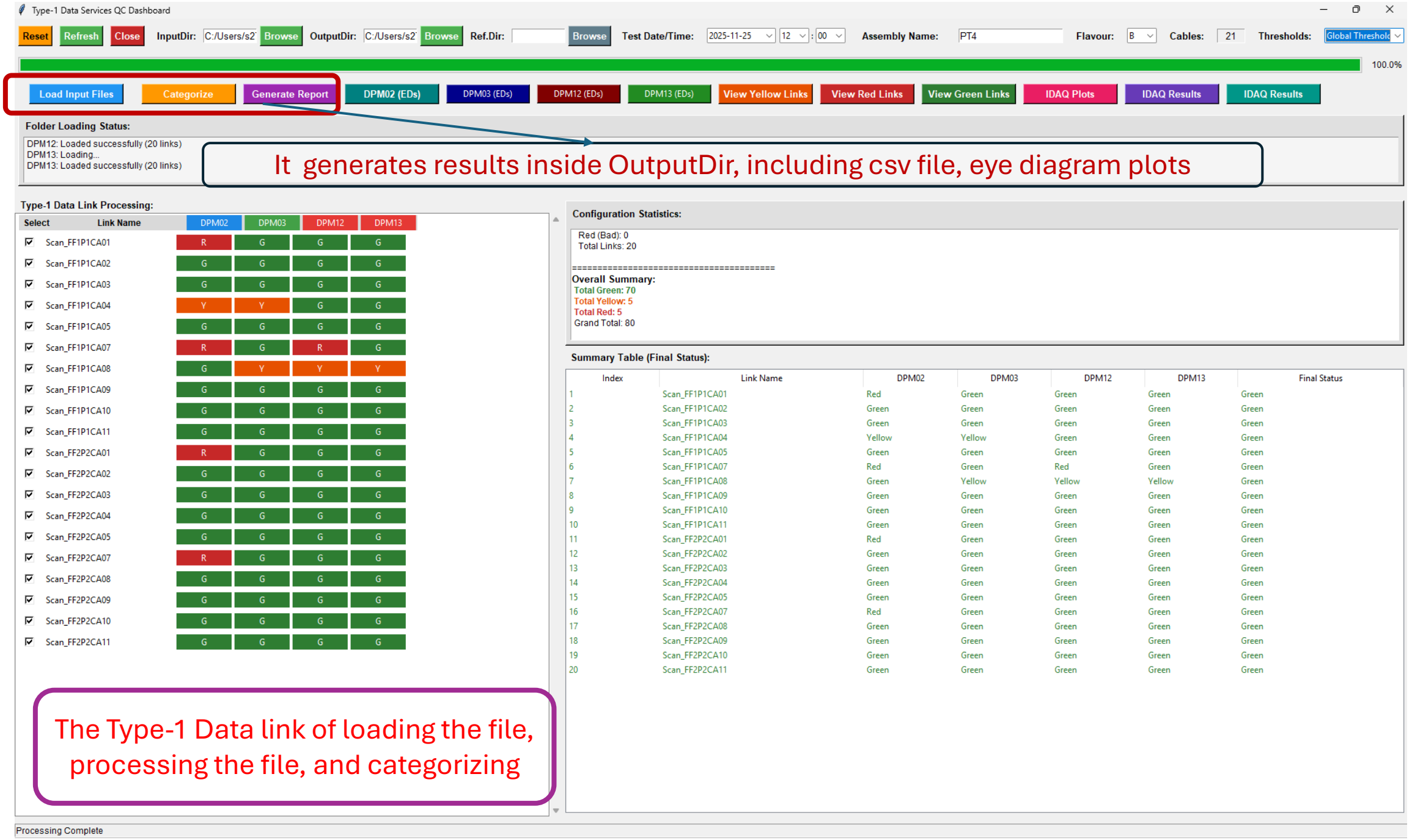
✓ Global threshold: (Universal for all DAQ channels)
✓ Individual Threshold: DAQ Channel specific threshold ()

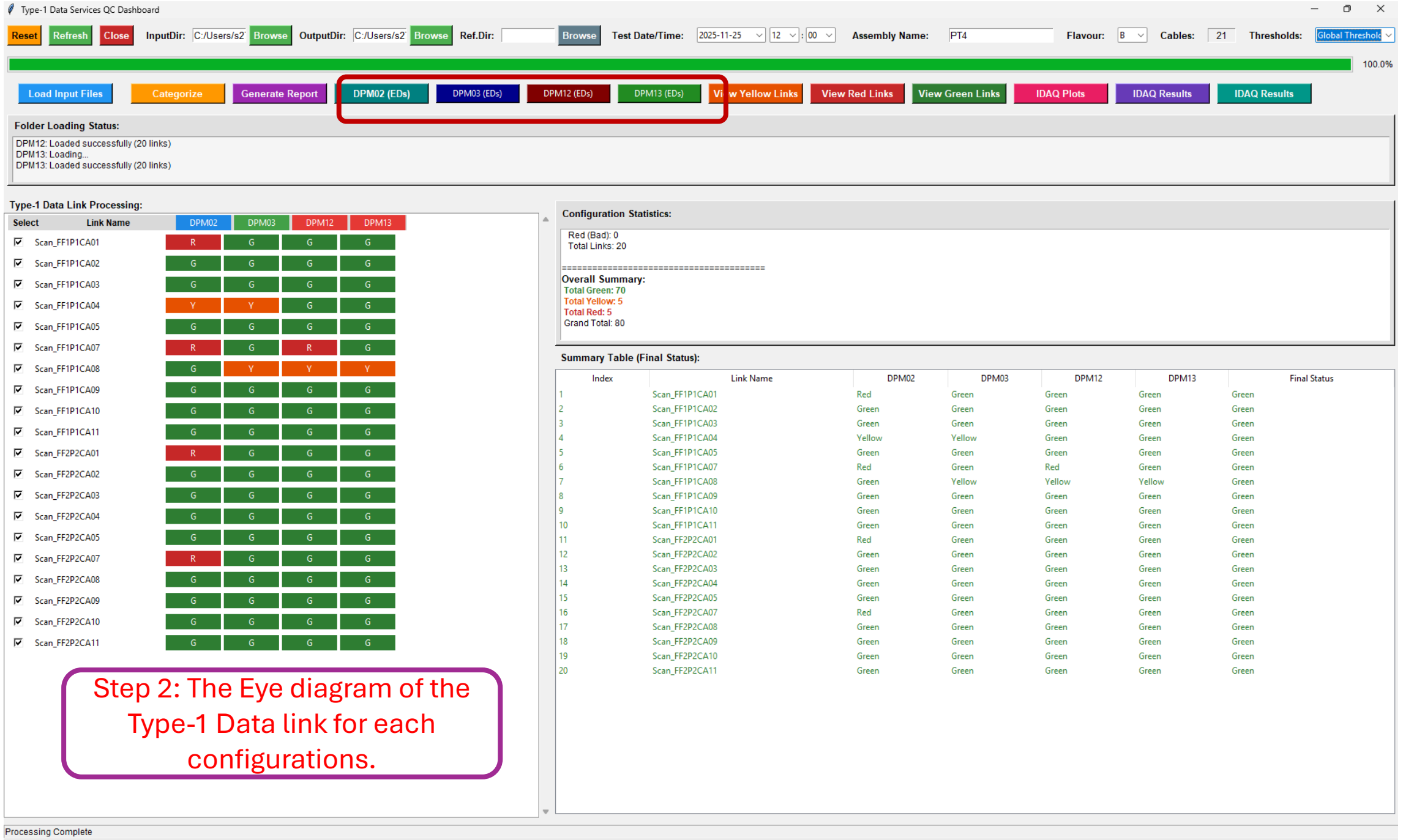
✓ Input Dir: The QC test file
✓ Output Dir: The path to store all plots and files
✓ Ref Dir: Only needed for individual thresholds

Fig: The Production Phase Tool GUI Interface

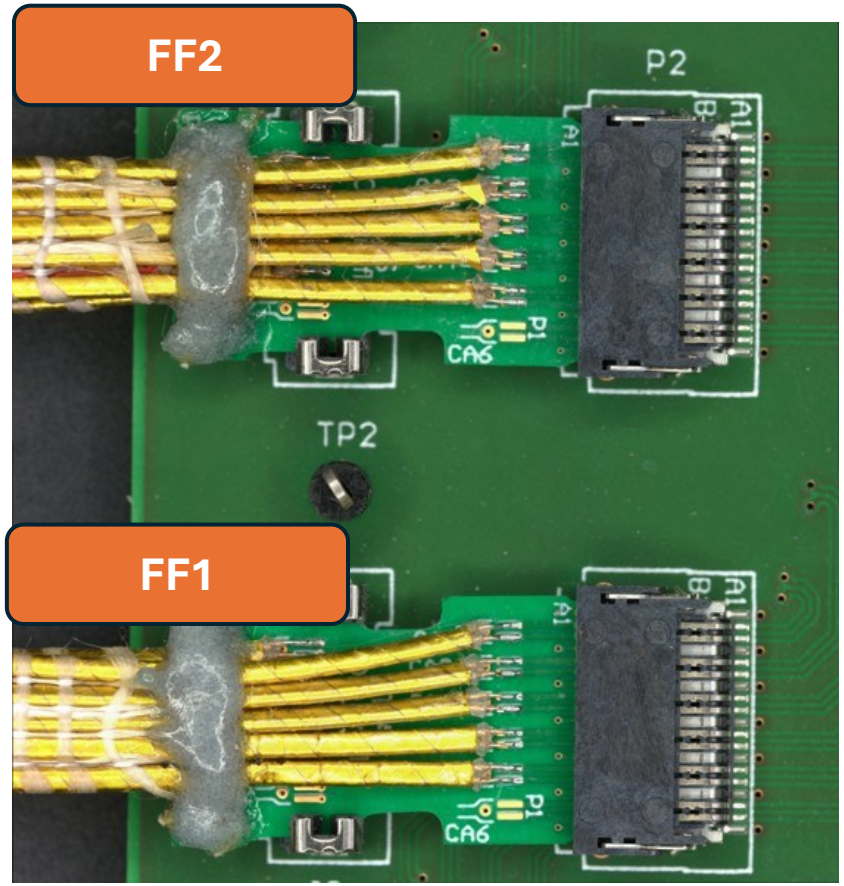
Global Threshold criteria

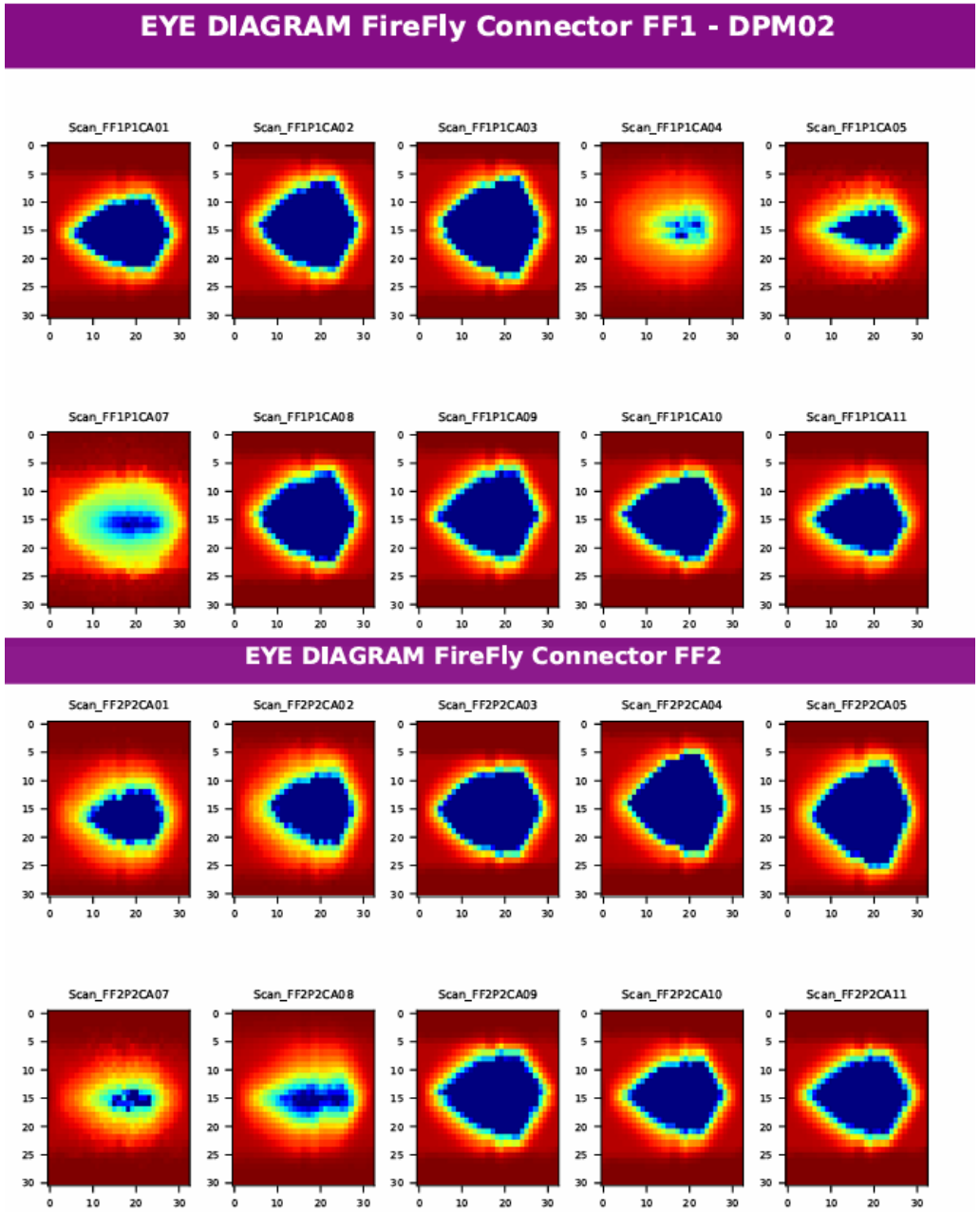



Type-1 Data Services QC Dashboard
Reset
Refresh
Close
InputDir:
C:/Users/s2
Browse
OutputDir:
C:/Users/s2
Browse
Ref.Dir:
Browse
Test Date/Time:
2025-11-25
12
00
Assembly Name:
PT4
Flavour:
B
Cables:
21
Thresholds:
Global Threshold
100.0%
Load Input Files
Categorize
Generate Report
DPM02 (EDs)
DPM03 (EDs)
DPM12 (EDs)
DPM13 (EDs)
View Yellow Links
View Red Links
View Green Links
IDAQ Plots
IDAQ Results
IDAQ Results
Folder Loading Status:
DPM12: Loaded successfully (20 links)
DPM13: Loading...
DPM13: Loaded successfully (20 links)
It generates results inside OutputDir, including csv file, eye diagram plots
Type-1 Data Link Processing:
Select
Link Name
DPM02
DPM03
DPM12
DPM13
Scan_FF1P1CA01 R G G G
Scan_FF1P1CA02 G G G G
Scan_FF1P1CA03 G G G G
Scan_FF1P1CA04 Y Y G G
Scan_FF1P1CA05 G G G G
Scan_FF1P1CA07 R G R G
Scan_FF1P1CA08 G Y Y Y
Scan_FF1P1CA09 G G G G
Scan_FF1P1CA10 G G G G
Scan_FF1P1CA11 G G G G
Scan_FF2P2CA01 R G G G
Scan_FF2P2CA02 G G G G
Scan_FF2P2CA03 G G G G
Scan_FF2P2CA04 G G G G
Scan_FF2P2CA05 G G G G
Scan_FF2P2CA07 R G G G
Scan_FF2P2CA08 G G G G
Scan_FF2P2CA09 G G G G
Scan_FF2P2CA10 G G G G
Scan_FF2P2CA11 G G G G
The Type-1 Data link of loading the file, processing the file, and categorizing
Configuration Statistics:
Red (Bad): 0
Total Links: 20
==========
Overall Summary:
Total Green: 70
Total Yellow: 5
Total Red: 5
Grand Total: 80
Summary Table (Final Status):
Index
Link Name
DPM02
DPM03
DPM12
DPM13
Final Status
1 Scan_FF1P1CA01 Red Green Green Green Green
2 Scan_FF1P1CA02 Green Green Green Green Green
3 Scan_FF1P1CA03 Green Green Green Green Green
4 Scan_FF1P1CA04 Yellow Yellow Green Green Green
5 Scan_FF1P1CA05 Green Green Green Green Green
6 Scan_FF1P1CA07 Red Green Red Green Green
7 Scan_FF1P1CA08 Green Yellow Yellow Yellow Green
8 Scan_FF1P1CA09 Green Green Green Green Green
9 Scan_FF1P1CA10 Green Green Green Green Green
10 Scan_FF1P1CA11 Green Green Green Green Green
11 Scan_FF2P2CA01 Red Green Green Green Green
12 Scan_FF2P2CA02 Green Green Green Green Green
13 Scan_FF2P2CA03 Green Green Green Green Green
14 Scan_FF2P2CA04 Green Green Green Green Green
15 Scan_FF2P2CA05 Green Green Green Green Green
16 Scan_FF2P2CA07 Red Green Green Green Green
17 Scan_FF2P2CA08 Green Green Green Green Green
18 Scan_FF2P2CA09 Green Green Green Green Green
19 Scan_FF2P2CA10 Green Green Green Green Green
20 Scan_FF2P2CA11 Green Green Green Green Green
Processing Complete

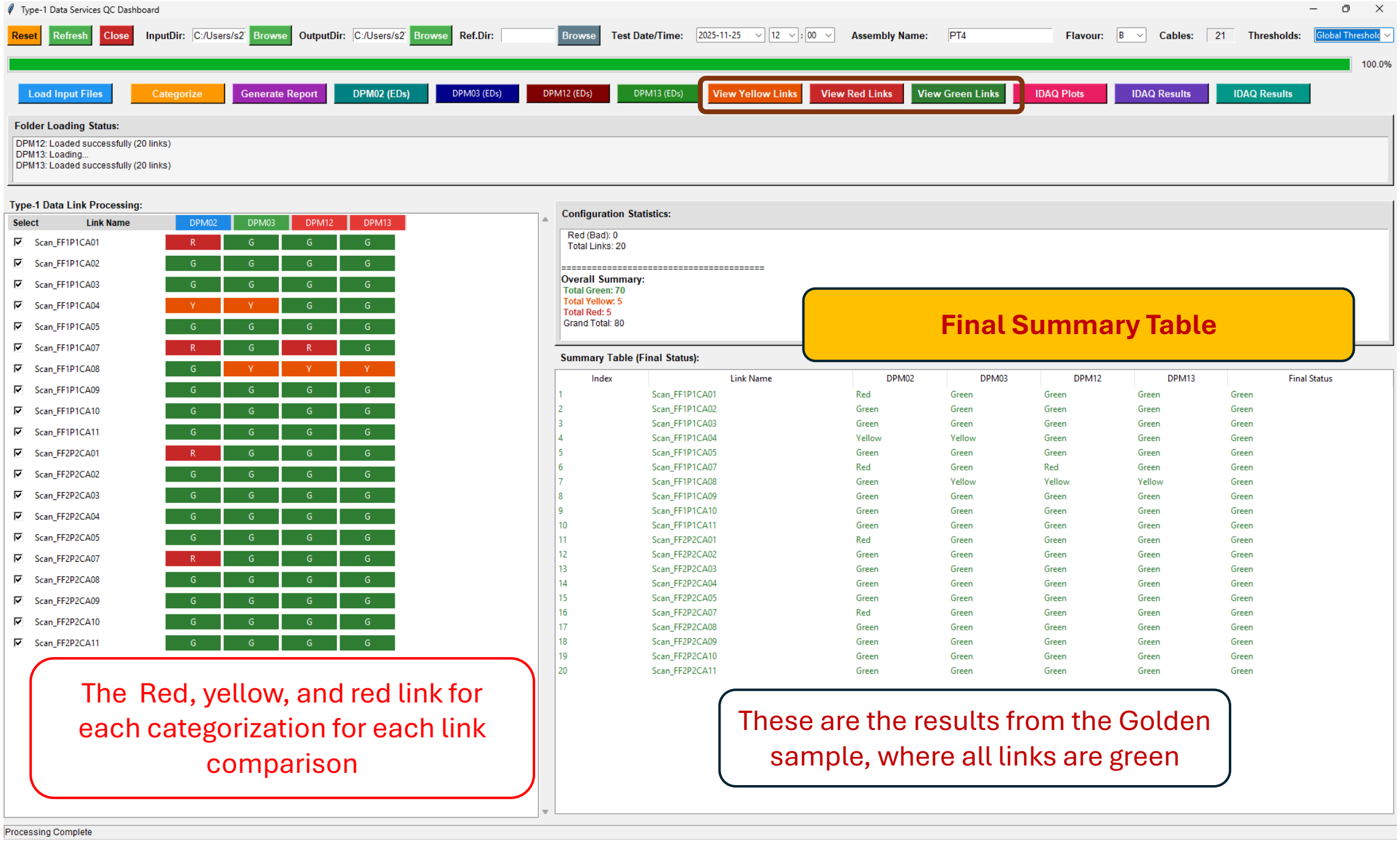

Type-1 Data Services QC Dashboard
Reset
Refresh
Close
InputDir:
C:/Users/s2
Browse
OutputDir:
C:/Users/s2
Browse
Ref.Dir:
Browse
Test Date/Time:
2025-11-25
12
00
Assembly Name:
PT4
Flavour:
B
Cables:
21
Thresholds:
Global Threshold
100.0%
Load Input Files
Categorize
Generate Report
DPM02 (EDs)
DPM03 (EDs)
DPM12 (EDs)
DPM13 (EDs)
View Yellow Links
View Red Links
View Green Links
IDAQ Plots
IDAQ Results
IDAQ Results
Folder Loading Status:
DPM12: Loaded successfully (20 links)
DPM13: Loading...
DPM13: Loaded successfully (20 links)
Type-1 Data Link Processing:
Select
Link Name
DPM02
DPM03
DPM12
DPM13
Scan_FF1P1CA01 R G G G
Scan_FF1P1CA02 G G G G
Scan_FF1P1CA03 G G G G
Scan_FF1P1CA04 Y Y G G
Scan_FF1P1CA05 G G G G
Scan_FF1P1CA07 R G R G
Scan_FF1P1CA08 G Y Y Y
Scan_FF1P1CA09 G G G G
Scan_FF1P1CA10 G G G G
Scan_FF1P1CA11 G G G G
Scan_FF2P2CA01 R G G G
Scan_FF2P2CA02 G G G G
Scan_FF2P2CA03 G G G G
Scan_FF2P2CA04 G G G G
Scan_FF2P2CA05 G G G G
Scan_FF2P2CA07 R G G G
Scan_FF2P2CA08 G G G G
Scan_FF2P2CA09 G G G G
Scan_FF2P2CA10 G G G G
Scan_FF2P2CA11 G G G G
Step 2: The Eye diagram of the Type-1 Data link for each configurations.
Configuration Statistics:
Red (Bad): 0
Total Links: 20
==========
Overall Summary:
Total Green: 70
Total Yellow: 5
Total Red: 5
Grand Total: 80
Summary Table (Final Status):
Index
Link Name
DPM02
DPM03
DPM12
DPM13
Final Status
1 Scan_FF1P1CA01 Red Green Green Green Green
2 Scan_FF1P1CA02 Green Green Green Green Green
3 Scan_FF1P1CA03 Green Green Green Green Green
4 Scan_FF1P1CA04 Yellow Yellow Green Green Green
5 Scan_FF1P1CA05 Green Green Green Green Green
6 Scan_FF1P1CA07 Red Green Red Green Green
7 Scan_FF1P1CA08 Green Yellow Yellow Yellow Green
8 Scan_FF1P1CA09 Green Green Green Green Green
9 Scan_FF1P1CA10 Green Green Green Green Green
10 Scan_FF1P1CA11 Green Green Green Green Green
11 Scan_FF2P2CA01 Red Green Green Green Green
12 Scan_FF2P2CA02 Green Green Green Green Green
13 Scan_FF2P2CA03 Green Green Green Green Green
14 Scan_FF2P2CA04 Green Green Green Green Green
15 Scan_FF2P2CA05 Green Green Green Green Green
16 Scan_FF2P2CA07 Red Green Green Green Green
17 Scan_FF2P2CA08 Green Green Green Green Green
18 Scan_FF2P2CA09 Green Green Green Green Green
19 Scan_FF2P2CA10 Green Green Green Green Green
20 Scan_FF2P2CA11 Green Green Green Green Green
Processing Complete

Eye Diagram/ QC test setup configuration (DPM02)

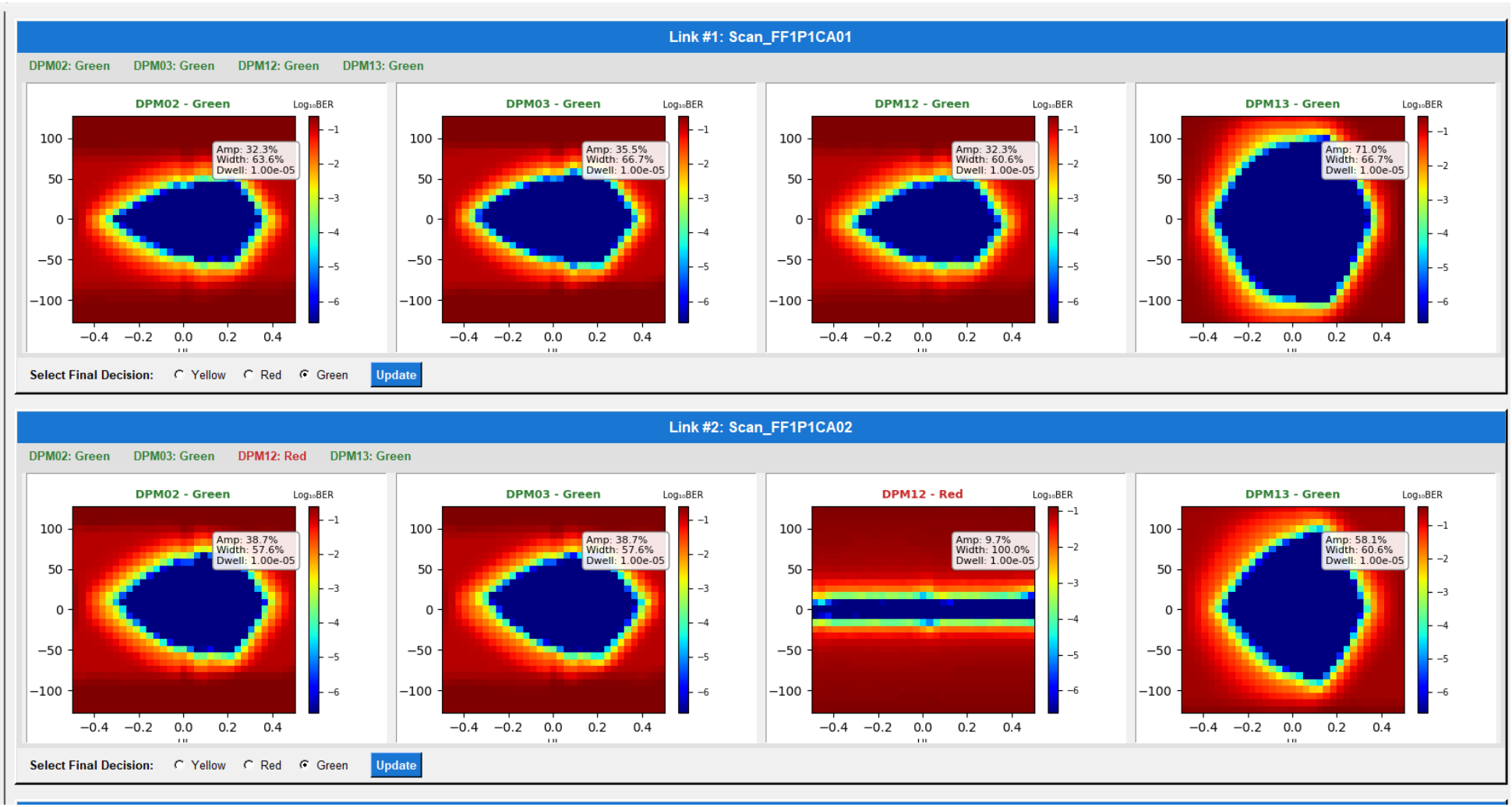




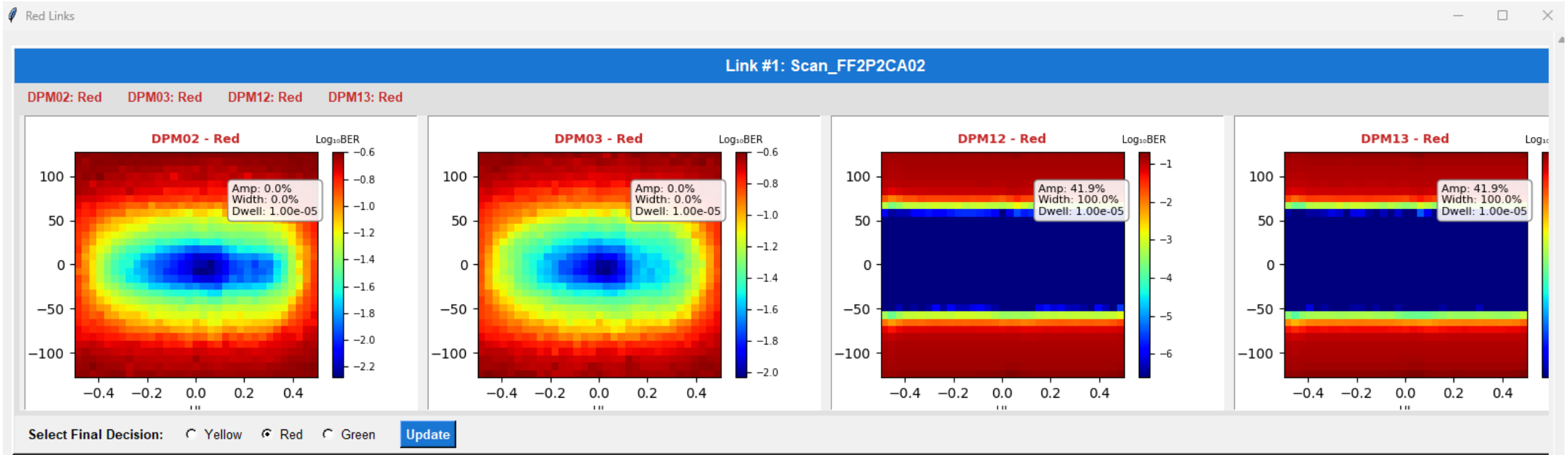
Note: The same pattern applies to the rest of the three configurations


Type-1 Data Services QC Dashboard
Reset
Refresh
Close
InputDir:
C:/Users/s2
Browse
OutputDir:
C:/Users/s2
Browse
Ref.Dir:
Browse
Test Date/Time:
2025-11-25
12
00
Assembly Name:
PT4
Flavour:
B
Cables:
21
Thresholds:
Global Threshold
100.0%
Load Input Files
Categorize
Generate Report
DPM02 (EDs)
DPM03 (EDs)
DPM12 (EDs)
DPM13 (EDs)
View Yellow Links
View Red Links
View Green Links
IDAQ Plots
IDAQ Results
IDAQ Results
Folder Loading Status:
DPM12: Loaded successfully (20 links)
DPM13: Loading...
DPM13: Loaded successfully (20 links)
Type-1 Data Link Processing:
Select
Link Name
DPM02
DPM03
DPM12
DPM13
Scan_FF1P1CA01 R G G G
Scan_FF1P1CA02 G G G G
Scan_FF1P1CA03 G G G G
Scan_FF1P1CA04 Y Y G G
Scan_FF1P1CA05 G G G G
Scan_FF1P1CA07 R G R G
Scan_FF1P1CA08 G Y Y Y
Scan_FF1P1CA09 G G G G
Scan_FF1P1CA10 G G G G
Scan_FF1P1CA11 G G G G
Scan_FF2P2CA01 R G G G
Scan_FF2P2CA02 G G G G
Scan_FF2P2CA03 G G G G
Scan_FF2P2CA04 G G G G
Scan_FF2P2CA05 G G G G
Scan_FF2P2CA07 R G G G
Scan_FF2P2CA08 G G G G
Scan_FF2P2CA09 G G G G
Scan_FF2P2CA10 G G G G
Scan_FF2P2CA11 G G G G
The Red, yellow, and red link for each categorization for each link comparison
Configuration Statistics:
Red (Bad): 0
Total Links: 20
==========
Overall Summary:
Total Green: 70
Total Yellow: 5
Total Red: 5
Grand Total: 80
Final Summary Table
Summary Table (Final Status):
Index
Link Name
DPM02
DPM03
DPM12
DPM13
Final Status
1 Scan_FF1P1CA01 Red Green Green Green Green
2 Scan_FF1P1CA02 Green Green Green Green Green
3 Scan_FF1P1CA03 Green Green Green Green Green
4 Scan_FF1P1CA04 Yellow Yellow Green Green Green
5 Scan_FF1P1CA05 Green Green Green Green Green
6 Scan_FF1P1CA07 Red Green Red Green Green
7 Scan_FF1P1CA08 Green Yellow Yellow Yellow Green
8 Scan_FF1P1CA09 Green Green Green Green Green
9 Scan_FF1P1CA10 Green Green Green Green Green
10 Scan_FF1P1CA11 Green Green Green Green Green
11 Scan_FF2P2CA01 Red Green Green Green Green
12 Scan_FF2P2CA02 Green Green Green Green Green
13 Scan_FF2P2CA03 Green Green Green Green Green
14 Scan_FF2P2CA04 Green Green Green Green Green
15 Scan_FF2P2CA05 Green Green Green Green Green
16 Scan_FF2P2CA07 Red Green Green Green Green
17 Scan_FF2P2CA08 Green Green Green Green Green
18 Scan_FF2P2CA09 Green Green Green Green Green
19 Scan_FF2P2CA10 Green Green Green Green Green
20 Scan_FF2P2CA11 Green Green Green Green Green
These are the results from the Golden sample, where all links are green
Processing Complete

Green Link View

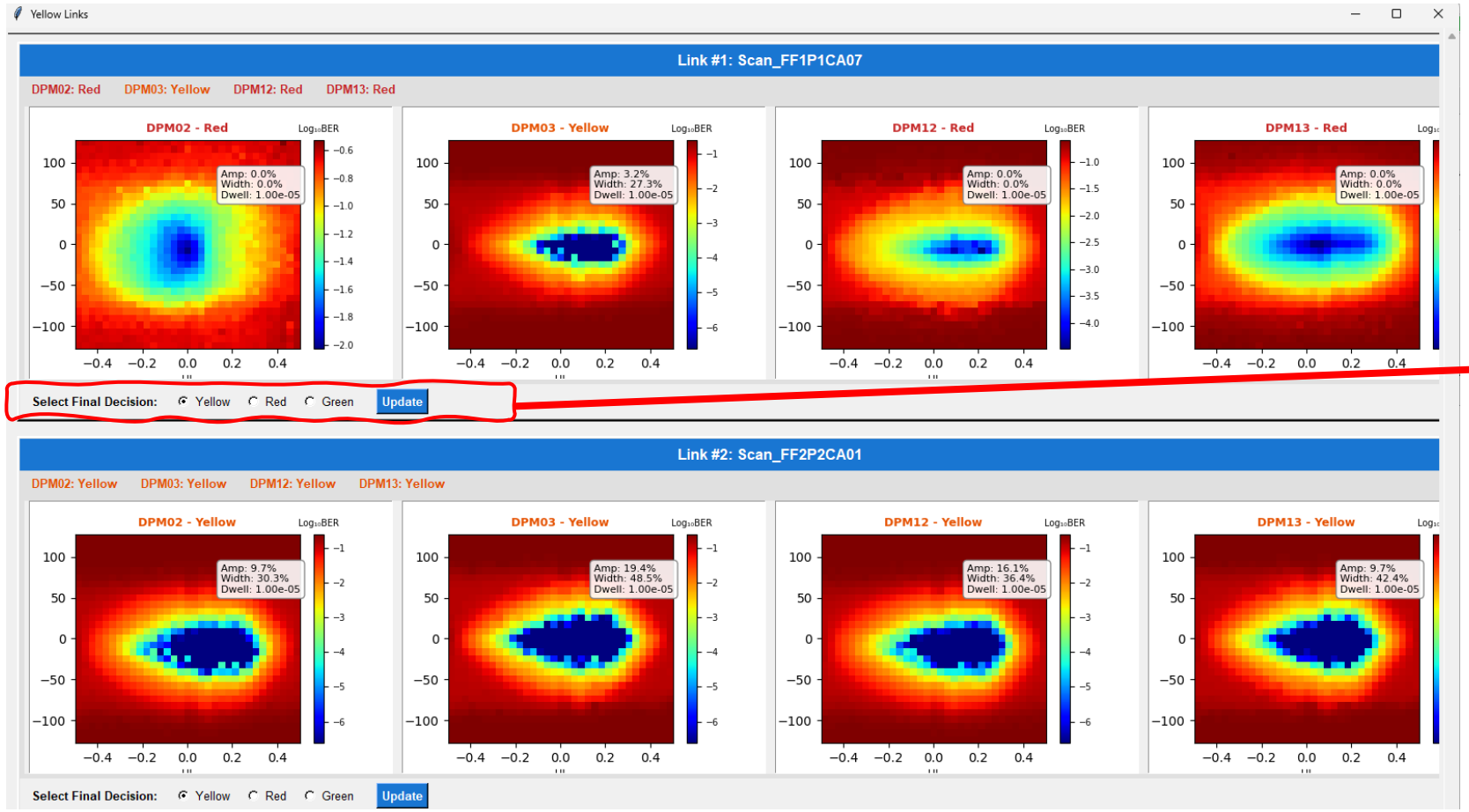


View Red Links



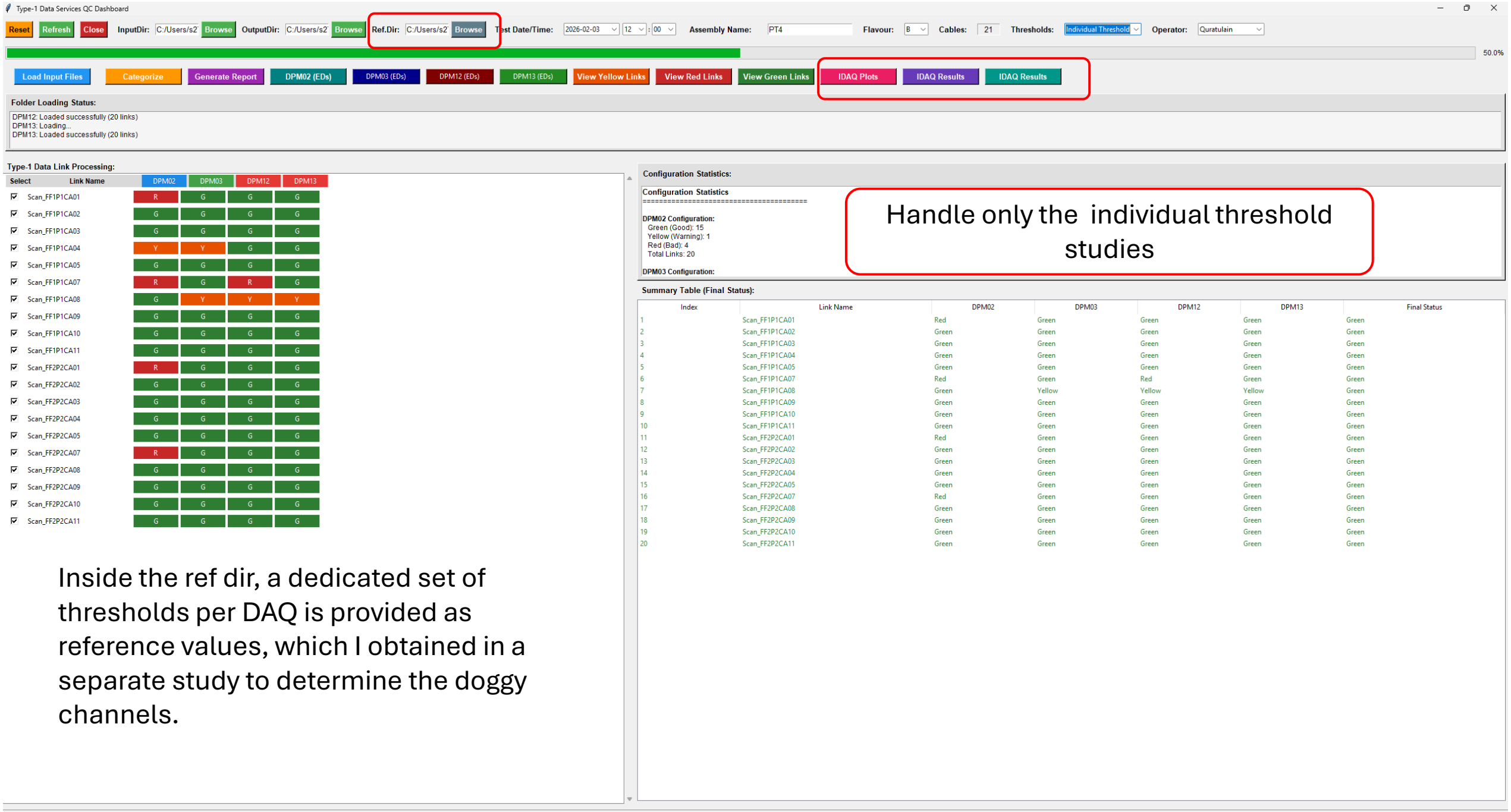
Note: I have just shown a red link view as an example

Yellow Link view



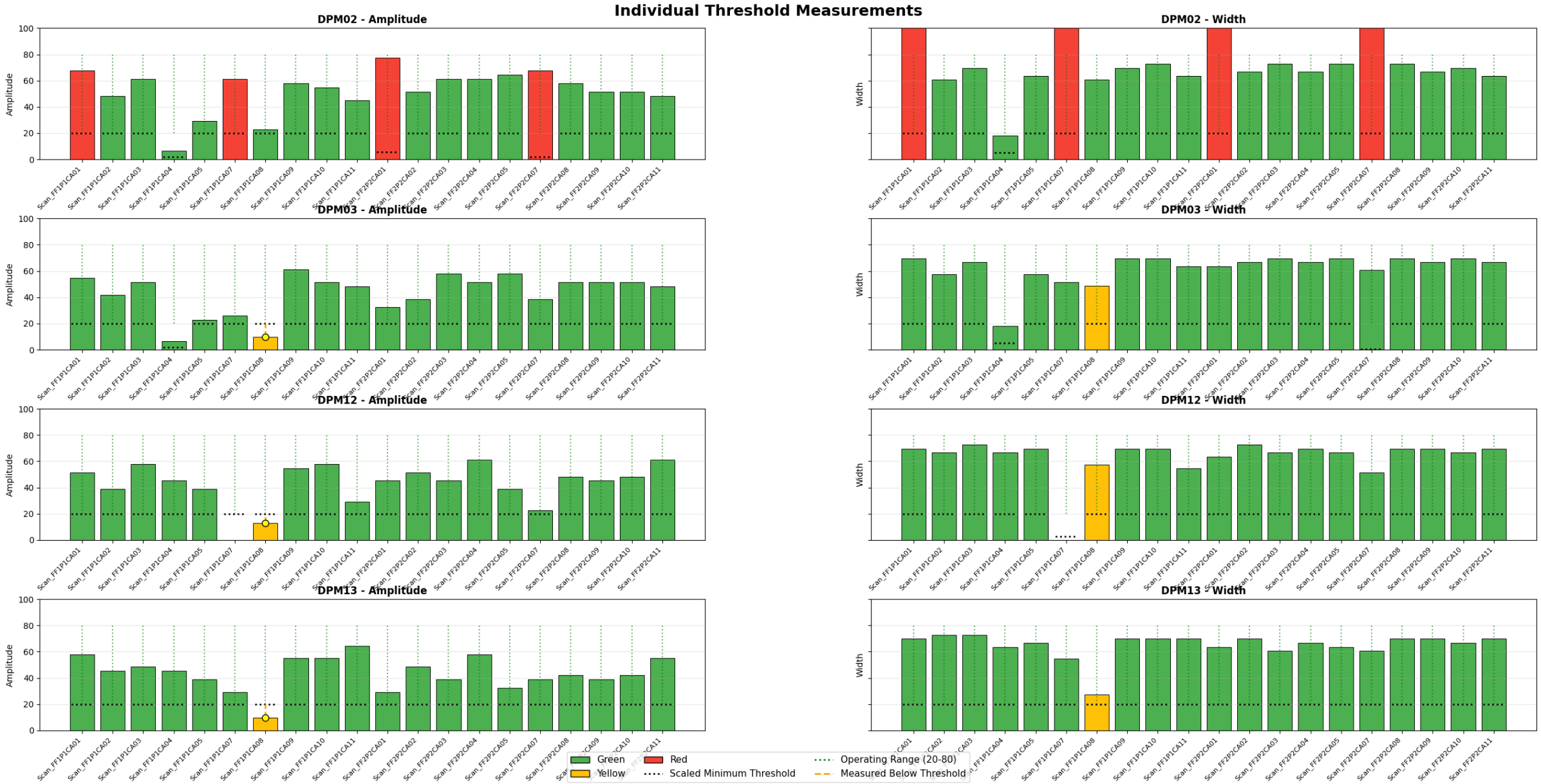
The user can update the final decision in case of any special observation.

Note: This is the special category where the link is not 100% bad, but we still have poor data transmission. Sometimes , we prefer to have an expert view on these link.



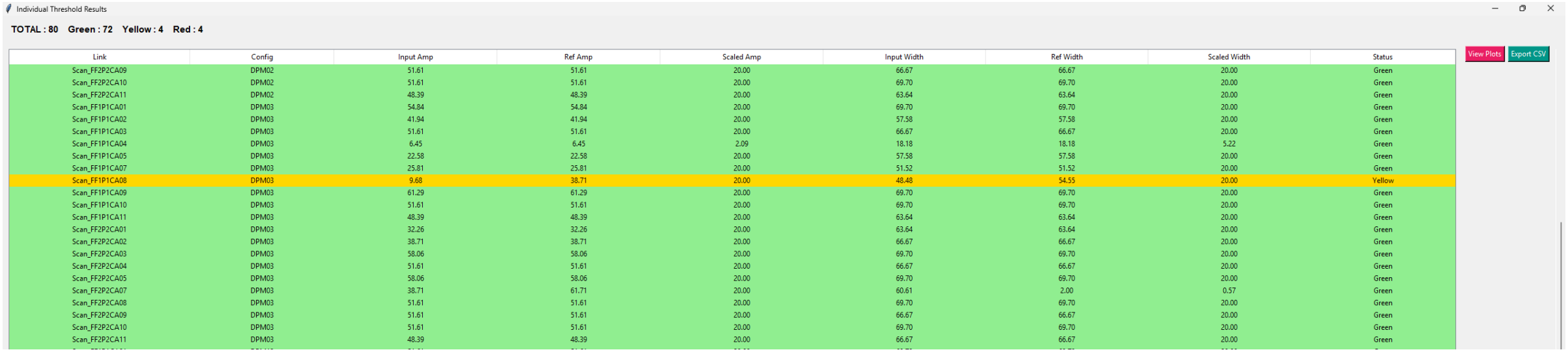
Inside the ref dir, a dedicated set of thresholds per DAQ is provided as reference values, which I obtained in a separate study to determine the doggy channels.

Fig: The Production Phase Tool GUI Interface



Note: This comparison is relative to the reference value per DAQ channel. Where we have the minimum criteria lowered for some channels than the global (20)

Individual Threshold Tabular format



Link	Config	Input Amp	Ref Amp	Scaled Amp	Input Width	Ref Width	Scaled Width	Status
Scan_FF2P2CA09	DPM02	51.61	51.61	20.00	66.67	66.67	20.00	Green
Scan_FF2P2CA10	DPM02	51.61	51.61	20.00	69.70	69.70	20.00	Green
Scan_FF2P2CA11	DPM02	48.39	48.39	20.00	63.64	63.64	20.00	Green
Scan_FF1P1CA01	DPM03	54.84	54.84	20.00	69.70	69.70	20.00	Green
Scan_FF1P1CA02	DPM03	41.94	41.94	20.00	57.58	57.58	20.00	Green
Scan_FF1P1CA03	DPM03	51.61	51.61	20.00	66.67	66.67	20.00	Green
Scan_FF1P1CA04	DPM03	6.45	6.45	2.09	18.18	18.18	5.22	Green
Scan_FF1P1CA05	DPM03	22.58	22.58	20.00	57.58	57.58	20.00	Green
Scan_FF1P1CA07	DPM03	25.81	25.81	20.00	51.52	51.52	20.00	Green
Scan_FF1P1CA08	DPM03	9.68	38.71	20.00	48.48	54.55	20.00	Yellow
Scan_FF1P1CA09	DPM03	61.29	61.29	20.00	69.70	69.70	20.00	Green
Scan_FF1P1CA10	DPM03	51.61	51.61	20.00	69.70	69.70	20.00	Green
Scan_FF1P1CA11	DPM03	48.39	48.39	20.00	63.64	63.64	20.00	Green
Scan_FF2P2CA01	DPM03	32.26	32.26	20.00	63.64	63.64	20.00	Green
Scan_FF2P2CA02	DPM03	38.71	38.71	20.00	66.67	66.67	20.00	Green
Scan_FF2P2CA03	DPM03	58.06	58.06	20.00	69.70	69.70	20.00	Green
Scan_FF2P2CA04	DPM03	51.61	51.61	20.00	66.67	66.67	20.00	Green
Scan_FF2P2CA05	DPM03	58.06	58.06	20.00	69.70	69.70	20.00	Green
Scan_FF2P2CA07	DPM03	38.71	61.71	20.00	60.61	2.00	0.57	Green
Scan_FF2P2CA08	DPM03	51.61	51.61	20.00	69.70	69.70	20.00	Green
Scan_FF2P2CA09	DPM03	51.61	51.61	20.00	66.67	66.67	20.00	Green
Scan_FF2P2CA10	DPM03	51.61	51.61	20.00	69.70	69.70	20.00	Green
Scan_FF2P2CA11	DPM03	48.39	48.39	20.00	66.67	66.67	20.00	Green

Note: The data can also be extracted in table format, where the reference and observed values are compared in more detail for each configuration. Results can be exported and stored for later use.

Type-1 Data Services QC Report

Date and Time: 2026-07-28 13:11:55

General Information

QC Test Perfomed on date: 2026-02-18
QC Test Time (Hour): 12
QC Test TIme (Minute): 00
Operator: Quratulain
Assembly: Pre-Production 4th Bundle
Flavour: B
Cables: 21
Threshold: Global Threshold

Detailed Results:

#	Link Name	DPM02	DPM03	DPM12	DPM13	Final Status
1	Scan_FF1P1CA01	Red	Green	Green	Green	Green
2	Scan_FF1P1CA02	Green	Green	Green	Green	Green
3	Scan_FF1P1CA03	Green	Green	Green	Green	Green
4	Scan_FF1P1CA04	Yellow	Yellow	Green	Green	Green
5	Scan_FF1P1CA05	Green	Green	Green	Green	Green
6	Scan_FF1P1CA07	Red	Green	Red	Green	Green
7	Scan_FF1P1CA08	Green	Yellow	Yellow	Yellow	Green
8	Scan_FF1P1CA09	Green	Green	Green	Green	Green
9	Scan_FF1P1CA10	Green	Green	Green	Green	Green
10	Scan_FF1P1CA11	Green	Green	Green	Green	Green
11	Scan_FF2P2CA01	Red	Green	Green	Green	Green
12	Scan_FF2P2CA02	Green	Green	Green	Green	Green
13	Scan_FF2P2CA03	Green	Green	Green	Green	Green
14	Scan_FF2P2CA04	Green	Green	Green	Green	Green
15	Scan_FF2P2CA05	Green	Green	Green	Green	Green
16	Scan_FF2P2CA07	Red	Green	Green	Green	Green
17	Scan_FF2P2CA08	Green	Green	Green	Green	Green
18	Scan_FF2P2CA09	Green	Green	Green	Green	Green
19	Scan_FF2P2CA10	Green	Green	Green	Green	Green
20	Scan_FF2P2CA11	Green	Green	Green	Green	Green

Summary Statistics:
Total Links Processed: 20
Green (Good): 20
Yellow (Human Help): 0
Red (Bad): 0

Type-1 Data Services QC Test Results summarized in this report

The Final QC report is generated and stored in outputDir

Conclusion

Validated the QC test setup and implemented a threshold definition that will be used for the Production Phase.

Development of the Production Phase GUI Tool, which can address all problems in testing (Processing each stage and plotting automatically)

The fully functional tool for the production phase is ready ☺ after validation and testing with data

Stephan, Thanks for your continuous guidance, and Liza for feedback.

Currently, I am working at CERN on the development of a DCS system for the ITk Pixel System.