Midas at Mu3e:
Pixel QC test

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Midas Workshop

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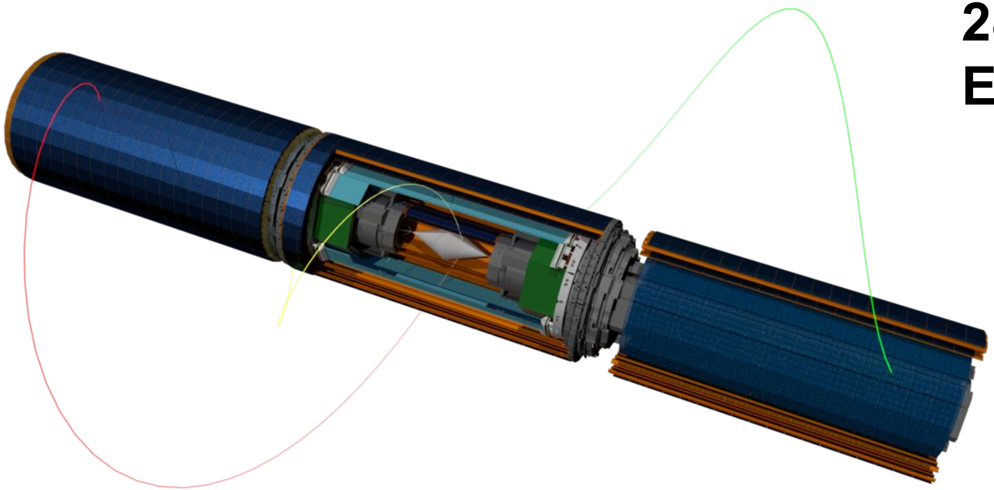
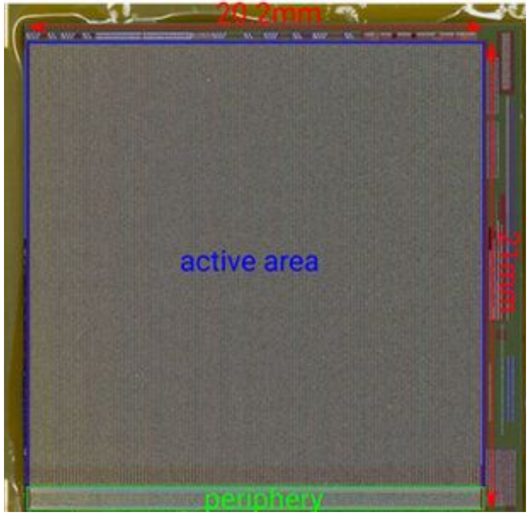
Mu3e at PSI

Mu3e aims to observe/exclude the μ→eee decay with 10^{16} single event sensitivity

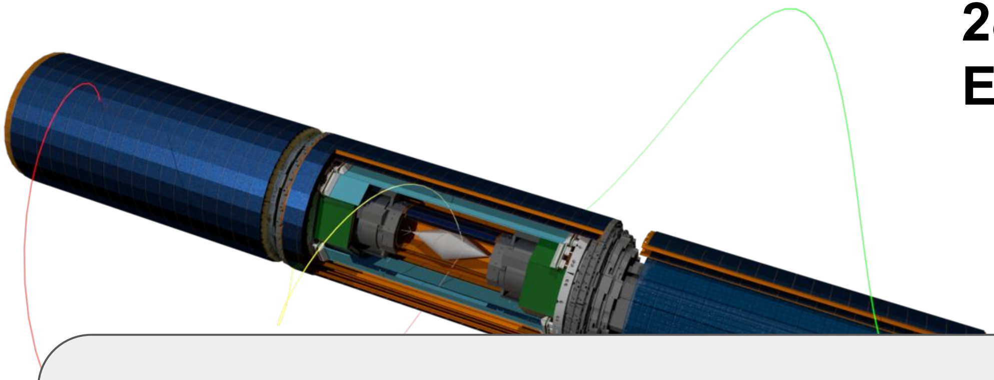


Tracking system needed!
2844 HV-MAPS: Mupix11
Each 20x21x0.05 mm^3



Mu3e at PSI

Mu3e aims to observe/exclude the μ→eee decay with 10^{16} single event sensitivity



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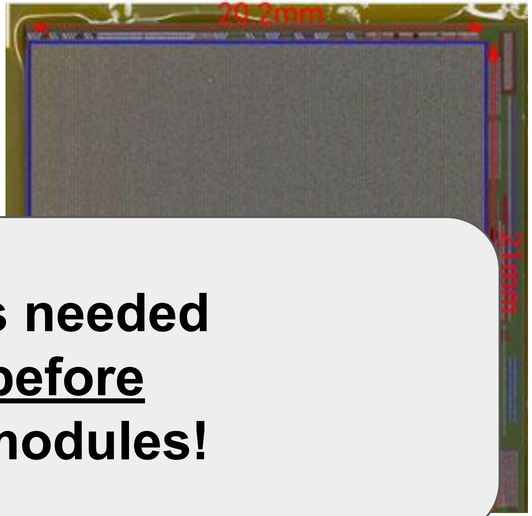
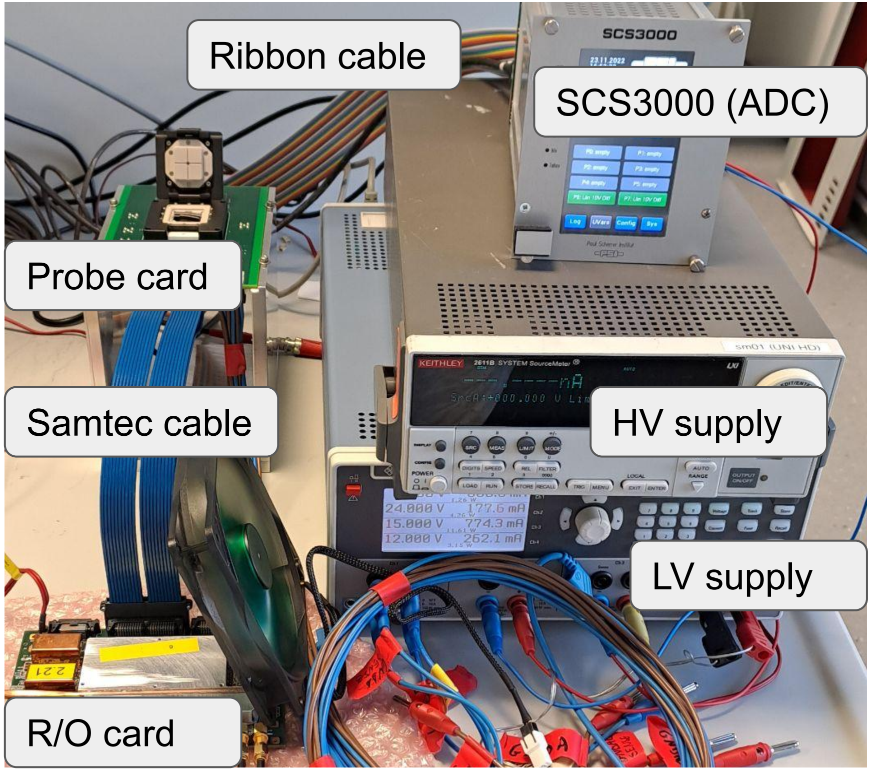


A solid QC testing campaign is needed
All chips must be qualified <u>before</u>
mounting inside the detector modules!

QC test setup: hardware



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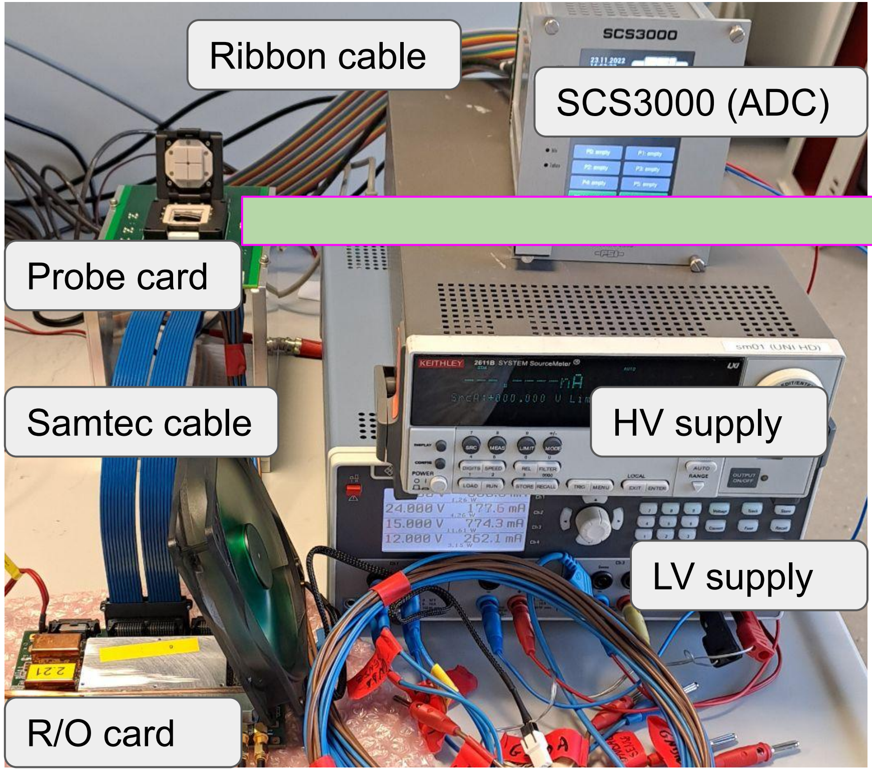

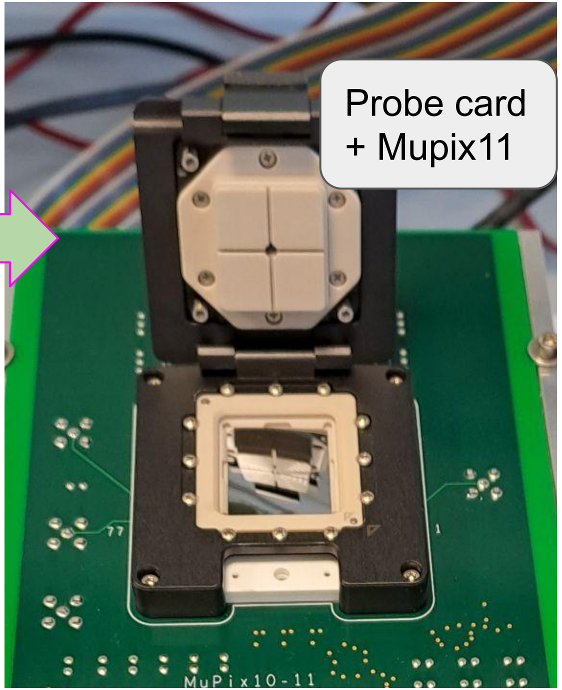

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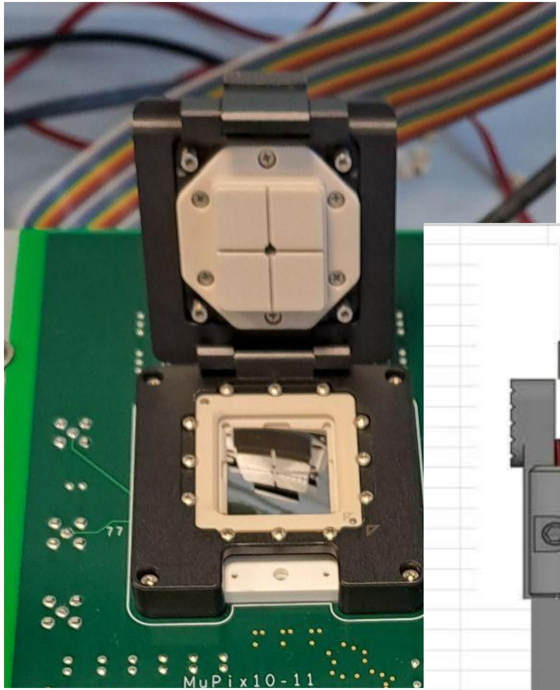
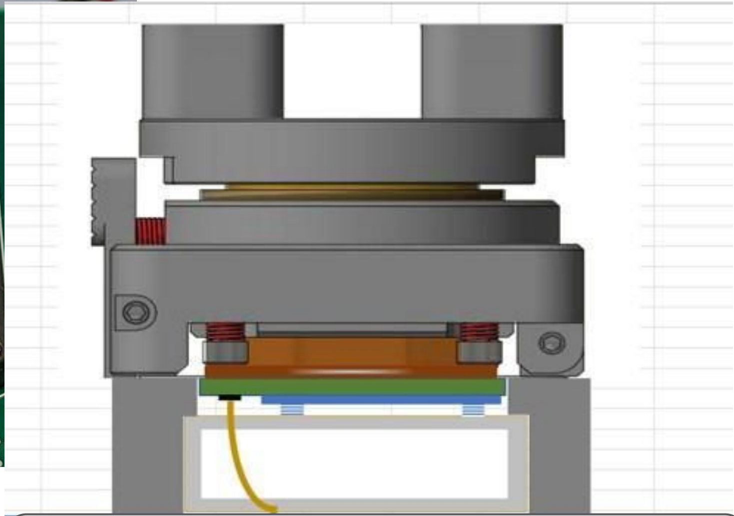




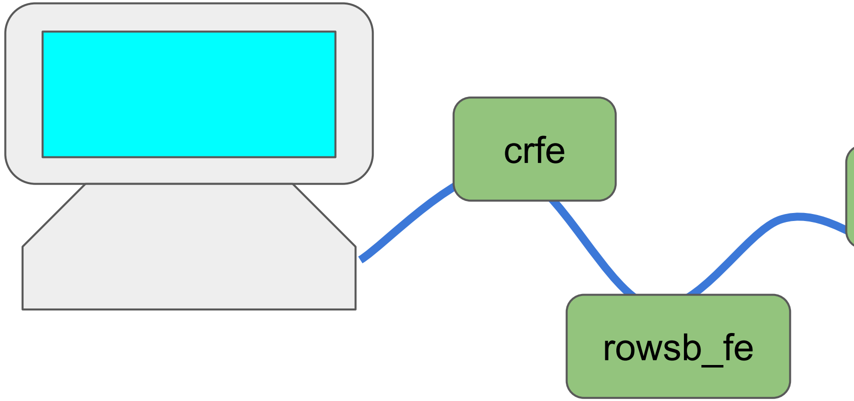
Probe card + Mupix11
Section view

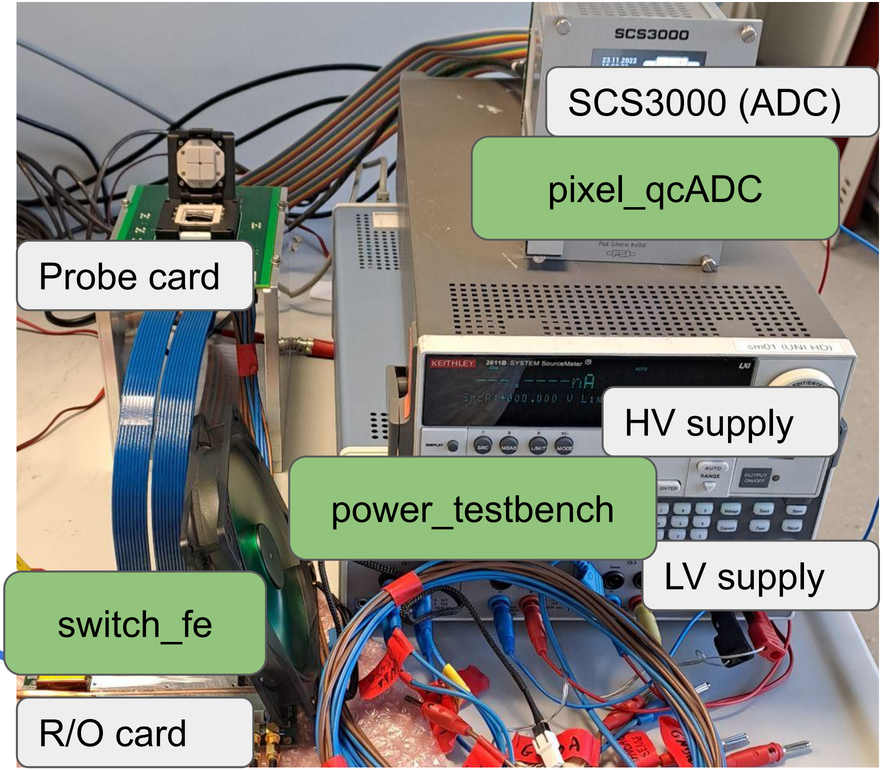
- Chip inserted in guides
- Needles sticking out of PCB against the chip
- Manual actuator presses chip onto needles
- Electrical contact in place
- Tests can be carried out
- Mu3e miniDAQ used: compact version of the DAQ shown in the previous presentation

QC test setup: software

Based on MIDAS

Several front-ends for the different components



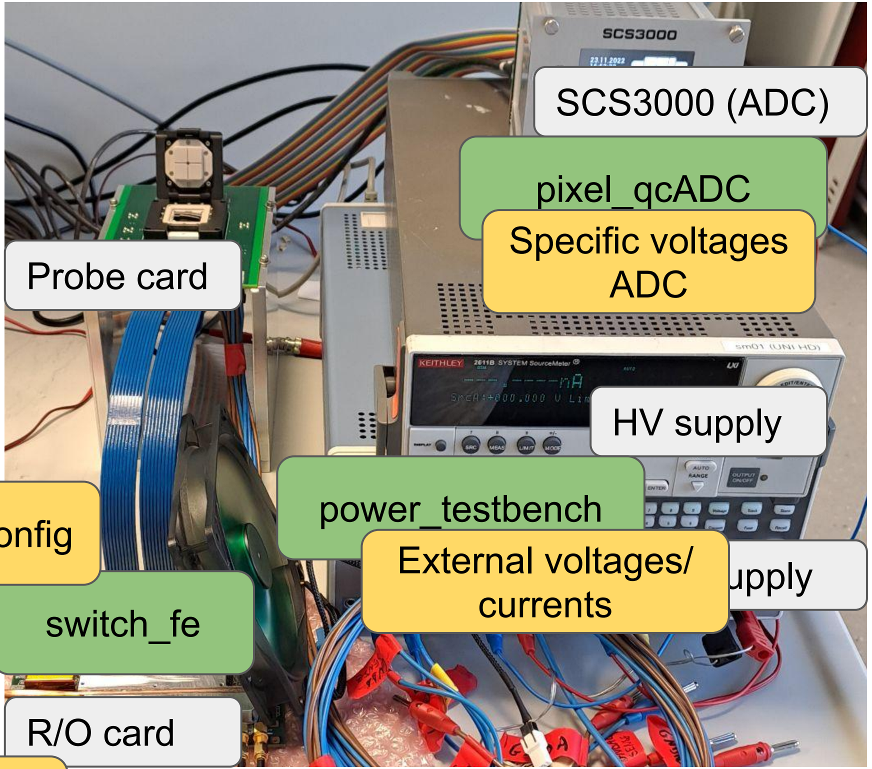


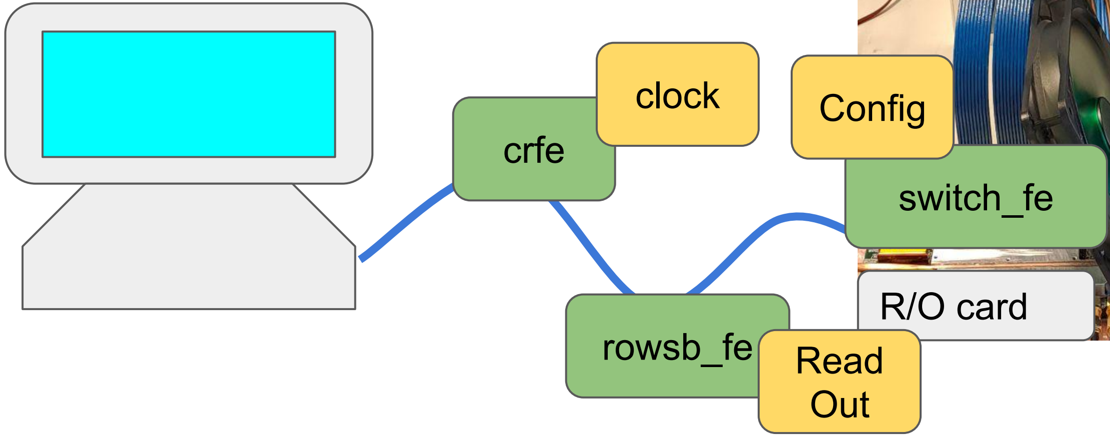
QC test setup: software

Based on MIDAS

Several front-ends for the different components

Each with its functionality

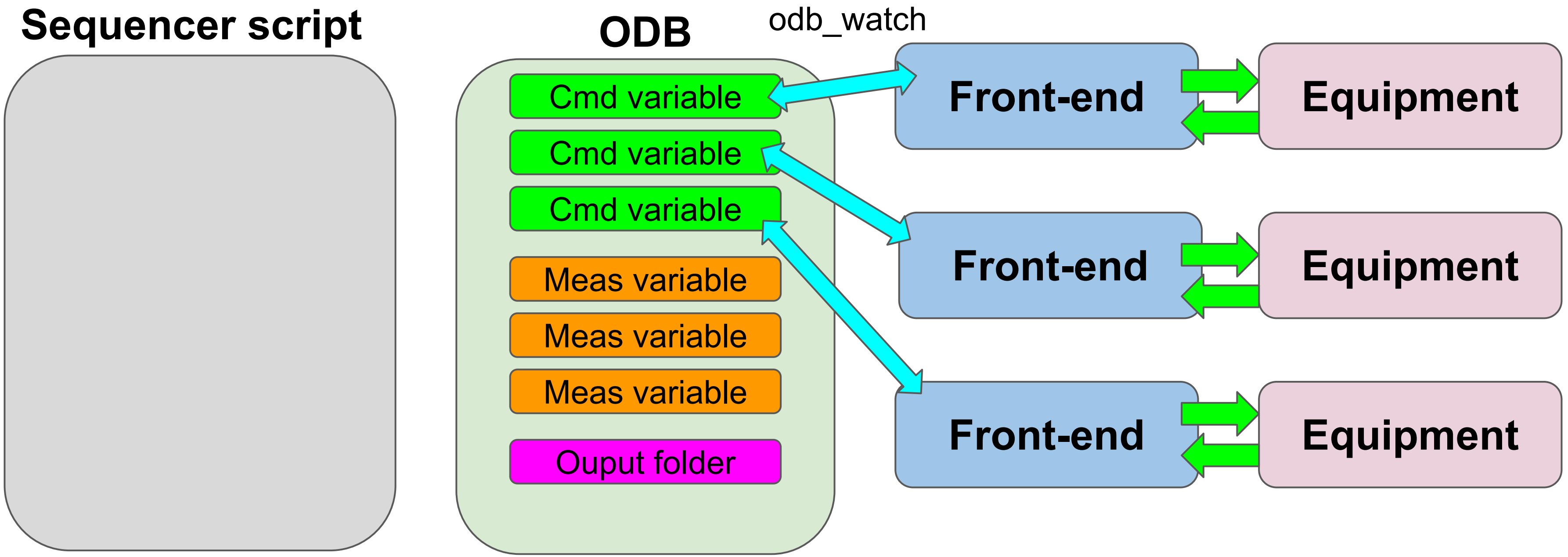




QC test setup: software principle

One full QC test is a sequence of single tests

Each single test is run by a sequencer script



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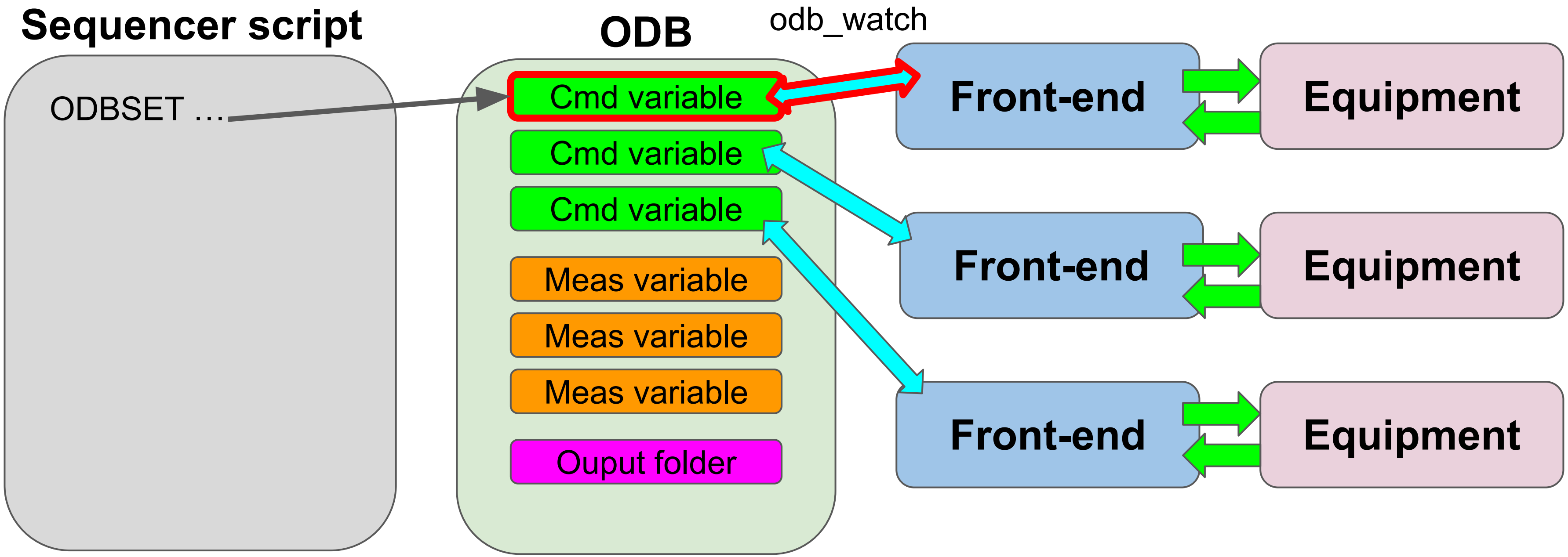

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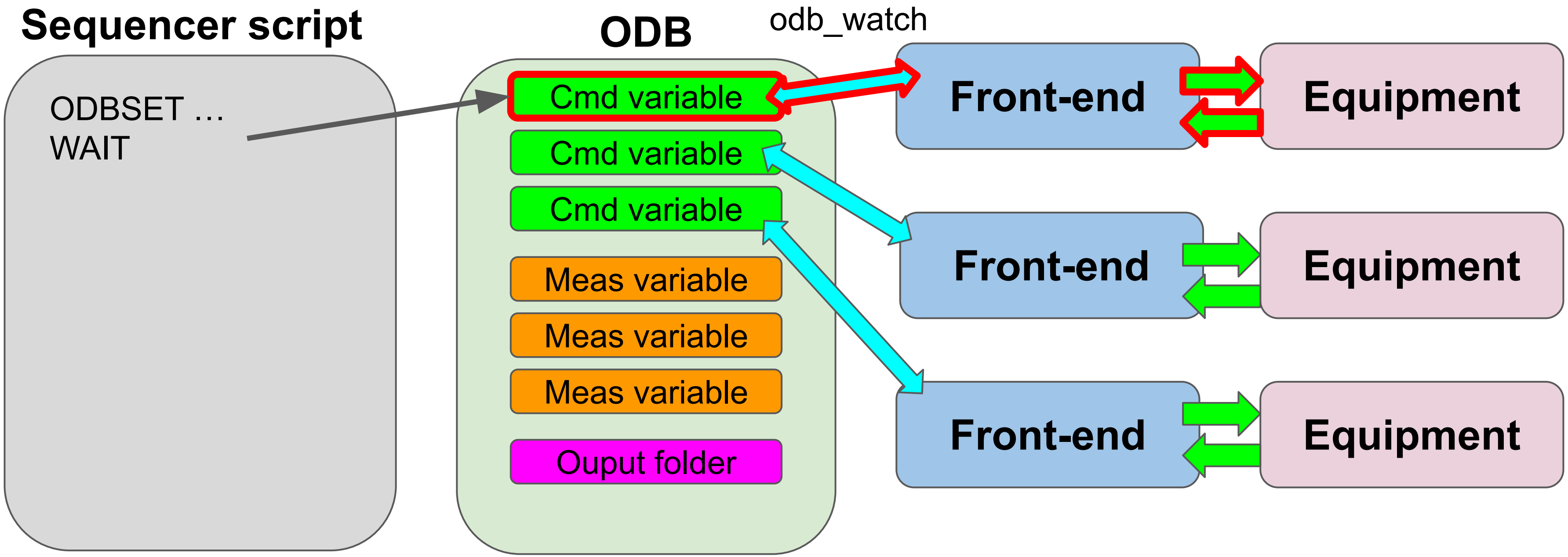

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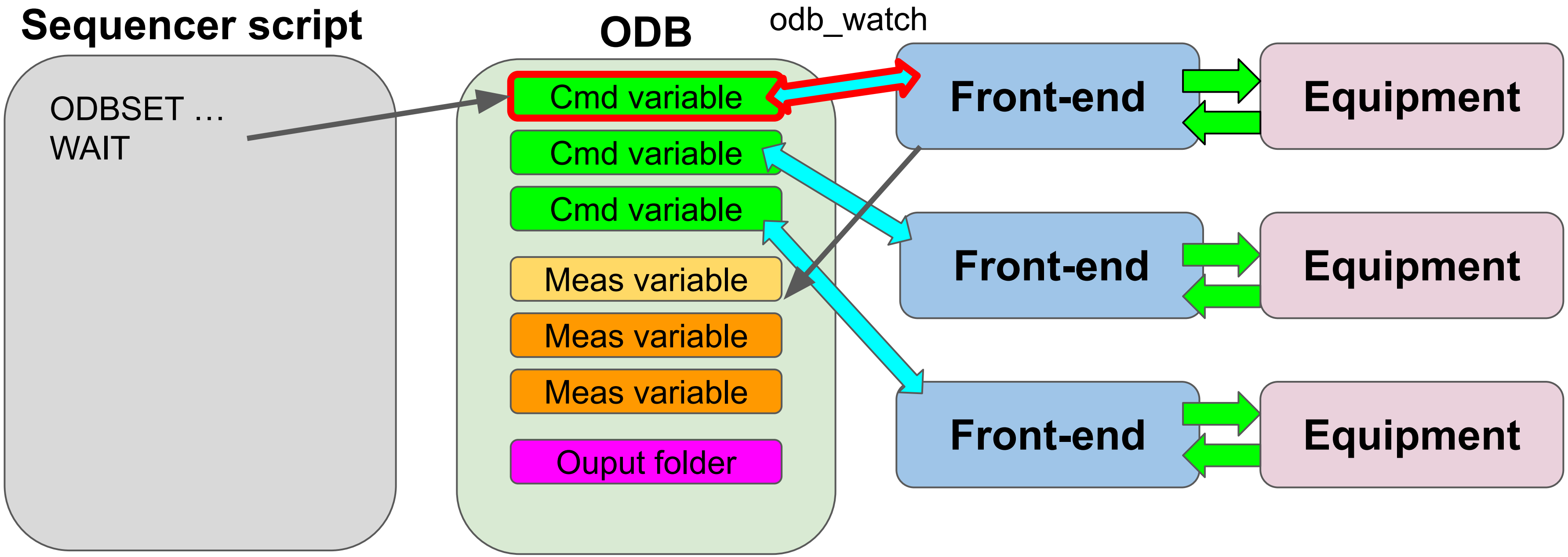

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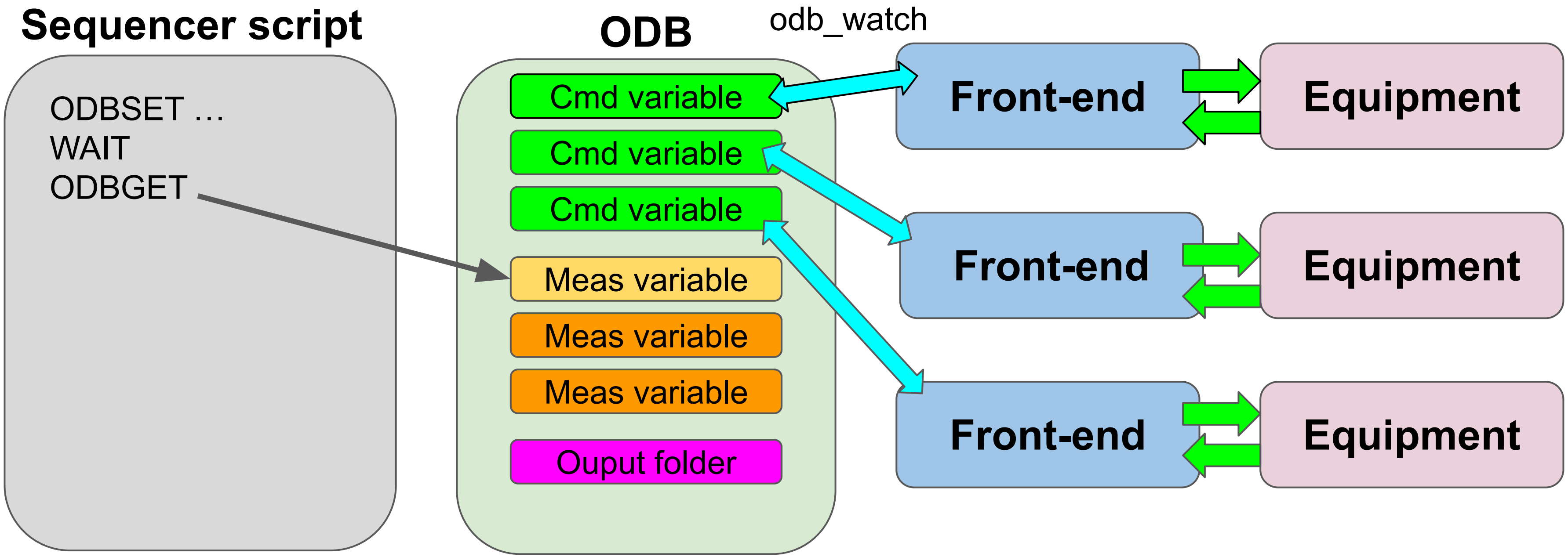

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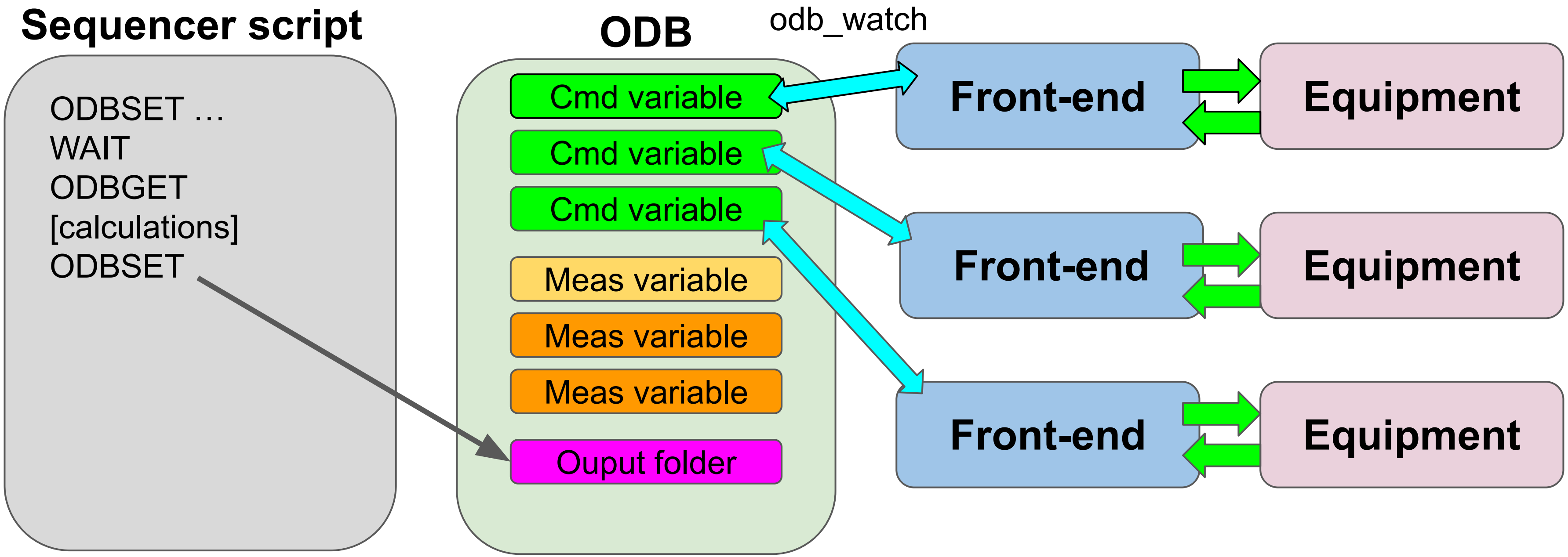

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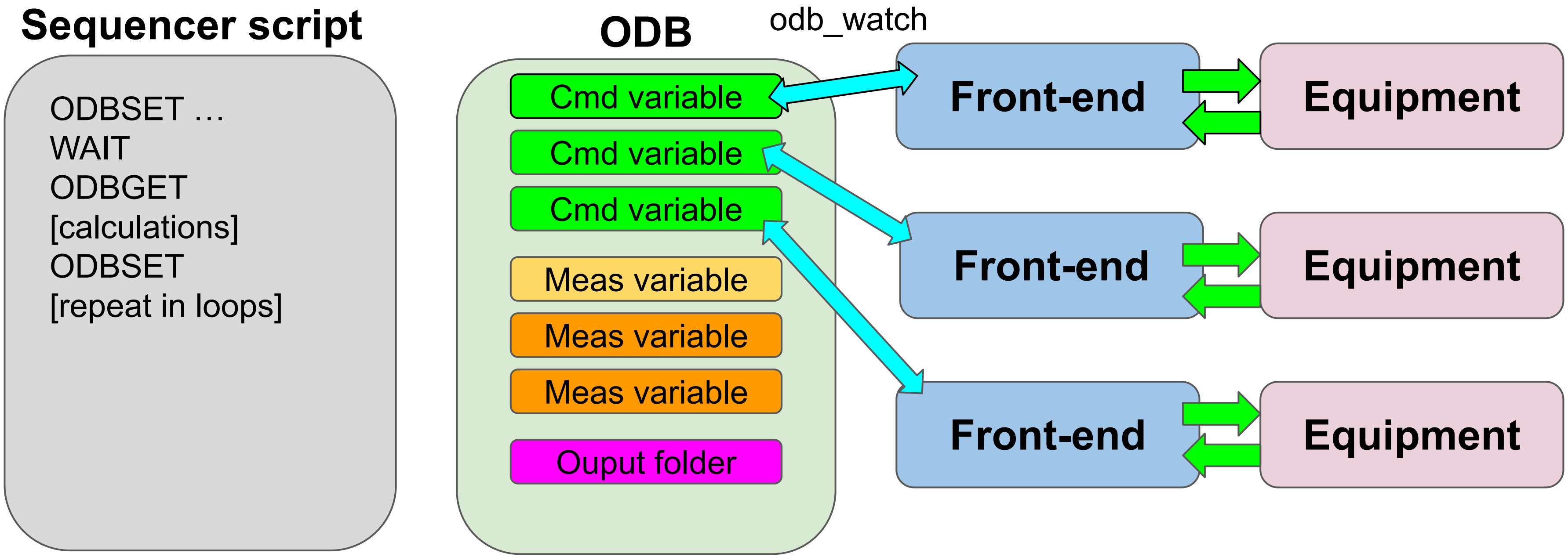

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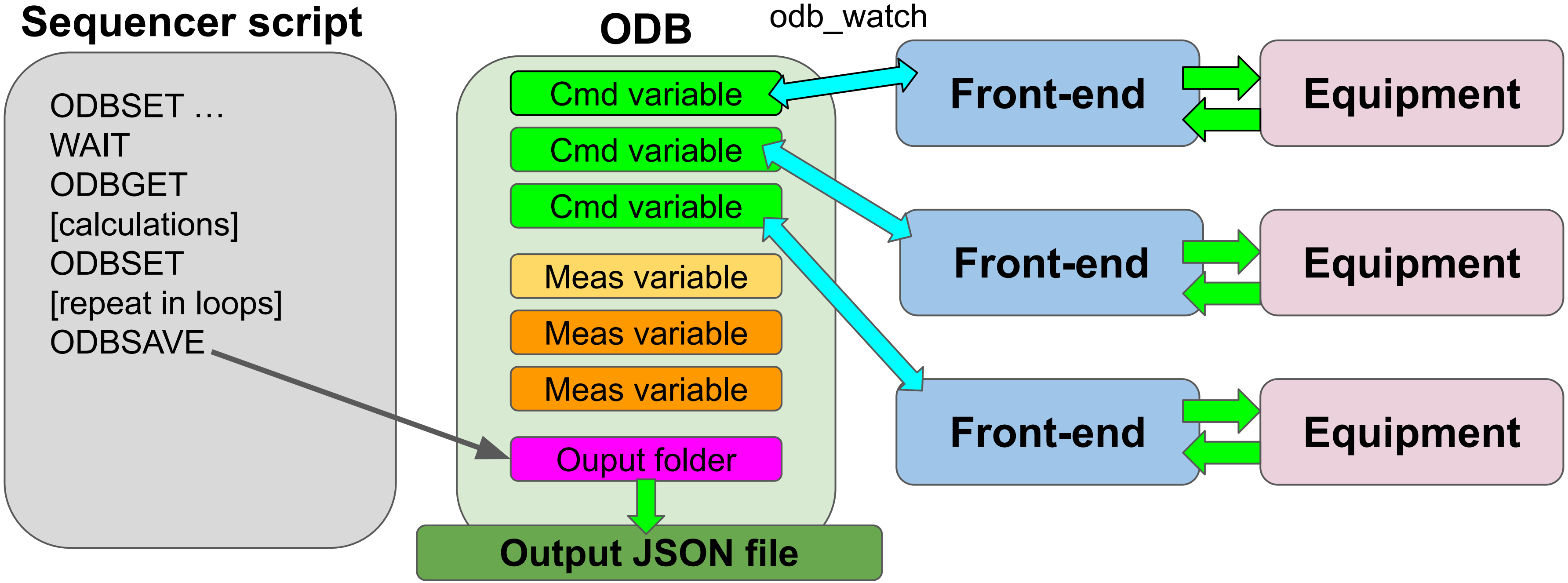


Special case: analyzer

- What reported so far works nicely for “slow control”
  - With pixel data (64,000 pixels per chip) not possible to work with ODB calls
- The Mu3e DAQ takes data from the chip and dump them to Midas events
- An analyzer based on manalyzer runs in parallel with the QC
  - The analyzer can interact with the ODB via odbxx
- The procedure is then
  - Sequencer script starts run and wait the necessary time
  - Analyzer collects and analyze data (AnalyzeFlowEvent)
  - Sequencer script stops run
  - Analyzer extracts the relevant measurements from the data (end of run function)
  - Analyzer writes the relevant measurements in the ODB
  - Sequencer scripts gets those measurements for its algorithm
- **Analyzer acts like a front-end**

QC test: file structure

global_basic_functions

- Functions and variables used in any test
- Parameters and Variables:
  - Global: common to all test stands
  - Local: specific of a test stand

iv_scan

lv_power_on

…

Full QC script to run all in sequence

Html custom page to select tests, load scripts, run, control,...

QC test: custom page

Control parameters

Sequencer status	
Name	Value
Sequencer running	
Sequencer file	configure_chip.msl

ADC Readings	
Name	Value
BL	0.0012689328
BLPix	0.001308514
TemperatureDiode	2.7086816
TestOut	0.0013162207
ThPix	-0.00017555431
ThHigh	-0.000084959902
ThLow	-0.000060803723

Monitoring	
LV current	On
HV current	On
Heat dissipation:	400 / 0 / 0.00 mW/cm²

General Chip Configuration	
Name	Value
Is Mupix11	☑
Use Serial Input	☑
Chip Type	0x017e

Links				
Link	Locked	Ready	Disperr	Num Hits
A			125473379	0
B			125473377	0
C			125473381	0
D			125473378	0

Power Setup | **Manual Chip Control** | **QC tests**

HV SUPPLY (192.168.0.068)						
Channel	State	Demand Voltage	Voltage	Current Limit	Current (uA)	Description
0	☑	-5	5.000e+0	2.000e-5	1.694e-5	HV SUPPLY

LV SUPPLY						
Channel	State	Demand Voltage	Voltage	Current Limit	Current	Description
0	☑	2.07	2.07	1.000	0.000	Chip Power
1	☑	24.00	24.00	1.000	0.180	SCS/3000
2	☑	17.00	17.00	1.000	0.674	FEB
3	☐	2.00	0.00	1.000	0.000	Fan

QC test: custom page

Power Setup | Manual Chip Control | **QC tests**

Object ID		
Part No.	Lot No.	Item No.
382	3	31

Choose a QC test: Full

Start Chip QC

Parameters

Name	Value
Low voltage (V)	$global_lv_voltage
HV voltage (V)	$global_hv_voltage
HV current limit (uA)	$global_hv_current_limit
IV scan LV off (boolean)	1
IV scan LV on (boolean)	0
IV scan chip configured (boolean)	1
IV scan: HV start voltage (V)	0
IV scan: HV stop voltage (V)	27
IV scan: HV step size (V)	2
IV scan: HV fine step size (V)	0.5
IV scan: Current fraction (fine steps)	0.5
Power on: HV on (boolean)	1
on-chip Volt: Adjust voltage (boolean)	1
on-chip Volt: Number of iterations	2
on-chip Volt: VDD(A) target voltage	$global_vdd_target_voltage
on-chip Volt: VSSA target voltage	$global_vss_target_voltage
VDAC scan: ThHigh start	90
VDAC scan: ThHigh stop	120
VDAC scan: ThHigh steps	5
VDAC scan: ThLow start	90
VDAC scan: ThLow stop	120
VDAC scan: ThLow steps	5
VDAC scan: Baseline start	85
VDAC scan: Baseline stop	115
VDAC scan: Baseline steps	5
VDAC scan: BLPix start	60
VDAC scan: BLPix stop	160
VDAC scan: BLPix steps	10
VDAC scan: ref_Vss start	140
VDAC scan: ref_Vss stop	210
VDAC scan: ref_Vss steps	10
VDAC scan: Sequential scan (boolean)	0
LVDS links: VPVCO start	12
LVDS links: VPVCO stop	37
LVDS links: VNVCO start	$VPVCO_start+1
LVDS links: VNVCO stop	$VPVCO_stop+1
LVDS links: VCO step size	5

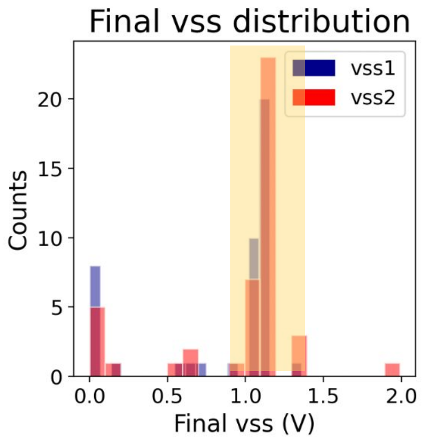
QC grading parameters:

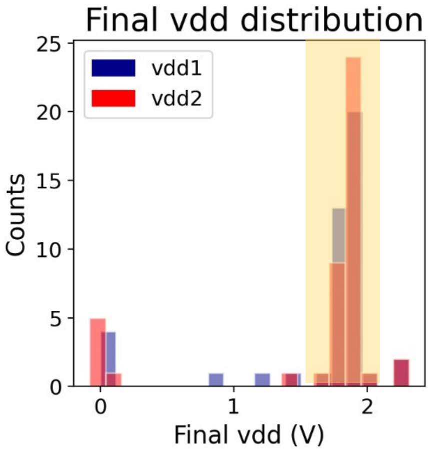
	Name	Value
	Max. allowed QC score	10
	no FullQC canceling (boolean)	1
FAIL	Minimum HV	10
GRADE	Operational HV	25
FAIL	Min. LV current (mA) Bias Off	20.0
FAIL	Min. LV current (mA) Bias On	300.0
FAIL	Max. LV current (mA) Bias Off	200.0
FAIL	Max. LV current (mA) Bias On	600.0
GRADE	Min. LV current (mA) Bias Off	30.0
GRADE	Min. LV current (mA) Bias On	400.0
GRADE	Max. LV current (mA) Bias Off	100.0
GRADE	Max. LV current (mA) Bias On	500.0
FAIL	Min. TempDiode Voltage	0.5
FAIL	Max. TempDiode Voltage	1.1
FAIL	Max. ΔVDD to target voltage	0.1
FAIL	Max. ΔVSSA to target voltage	0.1
GRADE	Max. ΔVDD to target voltage	0.025
GRADE	Max. ΔVSSA to target voltage	0.025
GRADE	Max. AVG VDD(A) deviations	0.05
GRADE	Max. AVG VSSA deviations	0.05
TARGET	ThHigh Slope (V/DAC)	0.0065
FAIL	ThHigh slope difference (rel.)	0.2
GRADE	ThHigh slope difference (rel.)	0.1
FAIL	ThHigh AVG rel. slope deviations	0.001
GRADE	ThHigh AVG rel. slope deviations	0.005
TARGET	ThLow Slope (V/DAC)	0.0
FAIL	ThLow slope difference (rel.)	0.2
GRADE	ThLow slope difference (rel.)	0.1
FAIL	ThLow AVG rel. slope deviations	0.001
GRADE	ThLow AVG rel. slope deviations	0.0005
TARGET	Baseline Slope (V/DAC)	0.0065
FAIL	Baseline slope difference (rel.)	0.2
GRADE	Baseline slope difference (rel.)	0.1
FAIL	Baseline AVG rel. slope deviations	0.001
GRADE	Baseline AVG rel. slope deviations	0.0005
TARGET	BLPix Slope (V/DAC)	0.0065
FAIL	BLPix slope difference (rel.)	0.2
GRADE	BLPix slope difference (rel.)	0.1
FAIL	BLPix AVG rel. slope deviations	0.001
GRADE	BLPix AVG rel. slope deviations	0.0005
TARGET	ref_Vss Slope (V/DAC)	0.006
FAIL	ref_Vss slope difference (rel.)	0.5
GRADE	ref_Vss slope difference (rel.)	0.1
FAIL	ref_Vss AVG rel. slope deviations	0.002
GRADE	ref_Vss AVG rel. slope deviations	0.0005

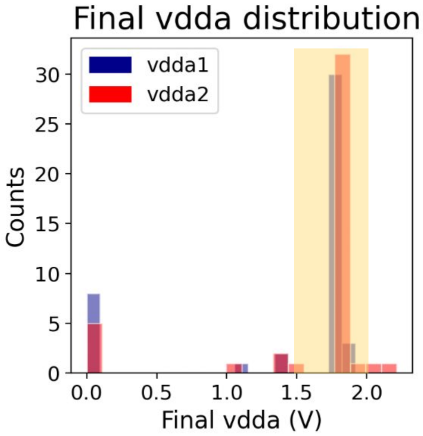
The html page takes care of the interaction with the sequencer (load script, set parameters, start)

Generally the default parameters work, only experts will change them

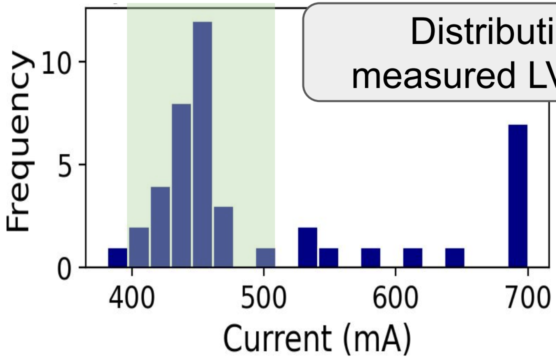
QC test: sparse results



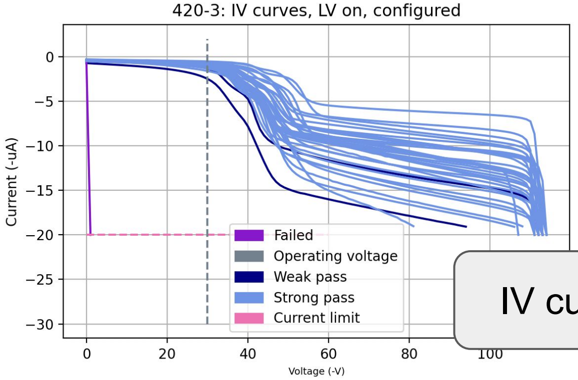




Distributions of measured voltages



Distributions of measured LV currents



IV curves

A.L. Fuchs

QC setup: near future improvements

These scripts will become the basis of all QC tests for Mu3e Pixels

More elaborate components will be tested, with up to 36 chips at the same time

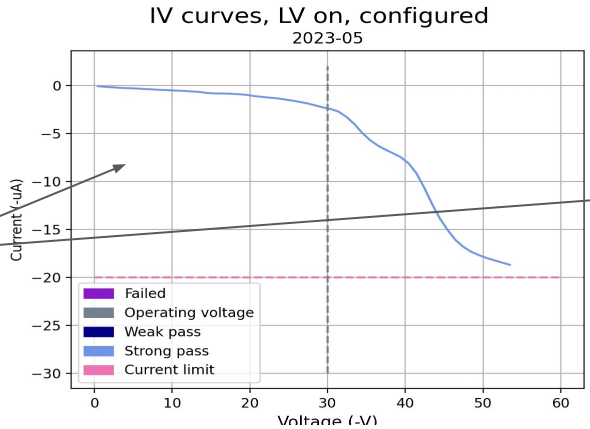
Efforts are being made to have more flexible testing schemes:

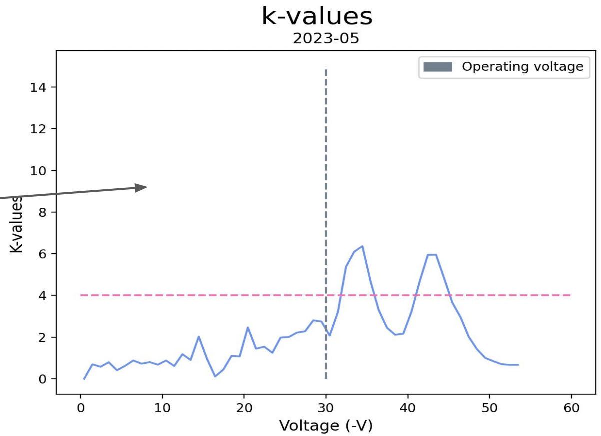
- More elaborate ODB folders for configuration and output
  - to loop over all chips in the system
- More dynamic html custom page

QC setup: further future improvements

Online Plots!

Examples from the analysis code





It would be nice to have them running online

The x and y axes are vectors in the ODB

Javascript library coming…?

Not really necessary in the long run (ideally once the QC works no need to check the page)

QC setup: even further future improvements

Integrate Python API…?

- Analysis code written in Python
  - More elaborate calculations (cross-test correlations, multiple chips,...)
  - It loads the output JSON files
- The analysis could work online alongside the testing procedure
  - It will access directly the values in the ODB
  - Updating results as it goes

Why sequencer?

Possible other candidates would be Javascript pages, Python API, or special frontend,...

- Test routines use sequential commands
  - Javascript async
- Test routines can be executed remotely and possibly by more people
  - Everybody can see if the sequencer is running
  - Less risk of conflict

The QC scripts will be the blueprint for calibration procedures in the experiment!

Backup

QC test setup: relevant details

Some features implemented in Midas to perform Mu3e pixel QC test

- ODBSAVE command to save an ODB folder in JSON format
- TinyExpr library to convert more complicated math expressions

Small gimmicks:

- Generic functions to be used by all scripts are defined in the entry script as SUBROUTINEs
  - They can not have return statements
  - All return variables defined in entry script and changed by the subroutines
- We want to run all tests in sequence or just one at a time
  - For each test 2 scripts:
    - The first contains the routine itself as one subroutine
    - The latter sets the input parameters and run the subroutine from the first
  - The full QC script loads all the scripts containing the routines and sets all parameters