Preliminary analysis
Hybrid+ measurements in B1H2 and B1V2
(2 May 2024)

LHC Beam Wire Scanner CONS team meeting #15

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13.05.2024

2 May 2024 Hybrid+ measurements on Beam 1

- **Beam 1 tests while Beam 2 was used for a MD**
  “MD#10303 - Characterization of the BSRH (Coronagraph)”

- **From the PSB Abdel created a new beam called LHCINDIV_BWS_2024 with 3 bunches:**
  ~1.2um, ~2um, and ~4um beam emittances

- **Hybrid+: B1H2 (208 scans), B1V2 (241 scans)**
  Legacy: B1H1 (74 scans), B1V1 (72 scans)

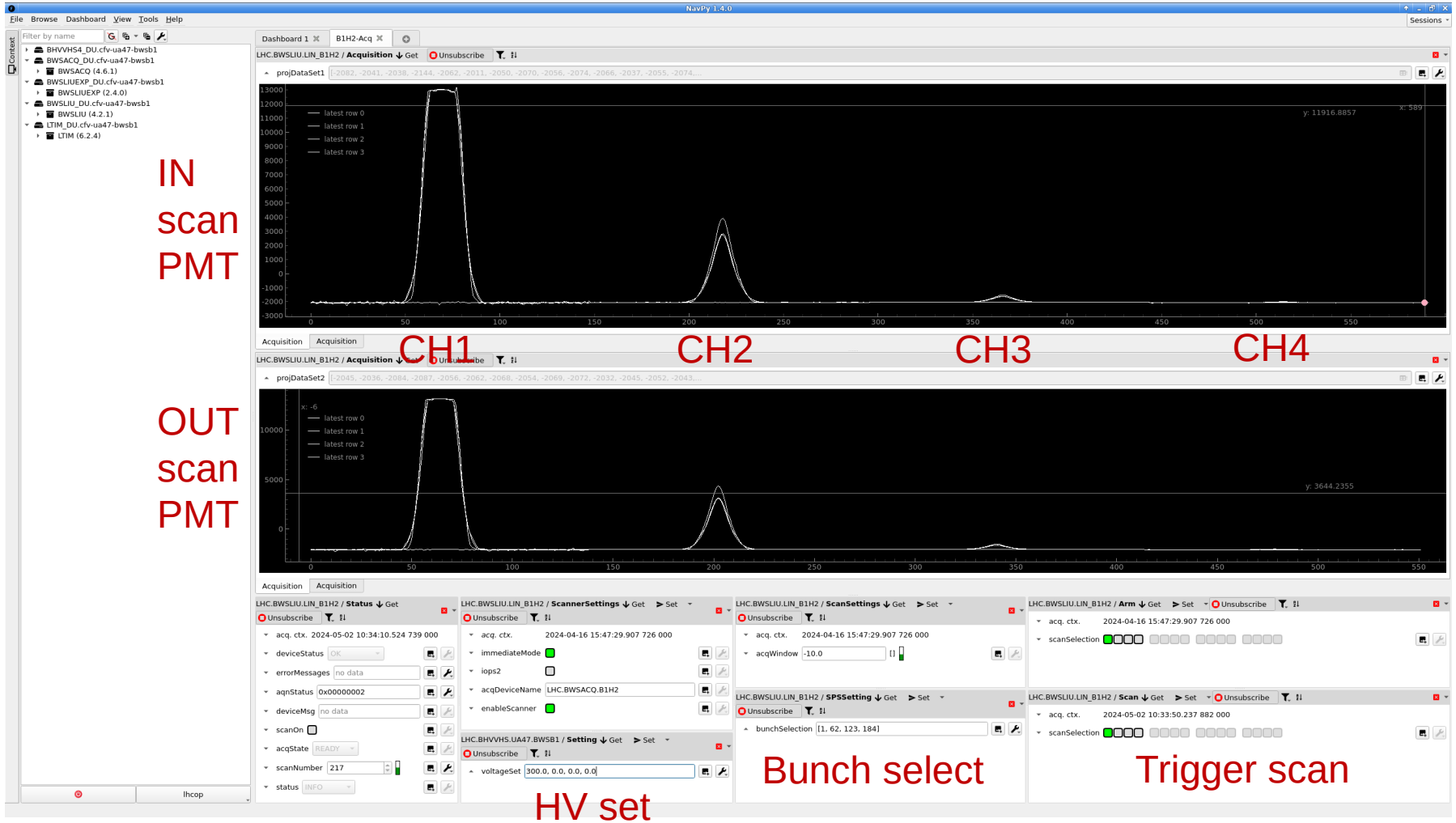
- **Limitations of this session:**

  1) B1H2 stay from time to time to ‘ready position’ (few mm from the home position)
  => require to manually run an expert procedure
  => will be integrated into next SW revision

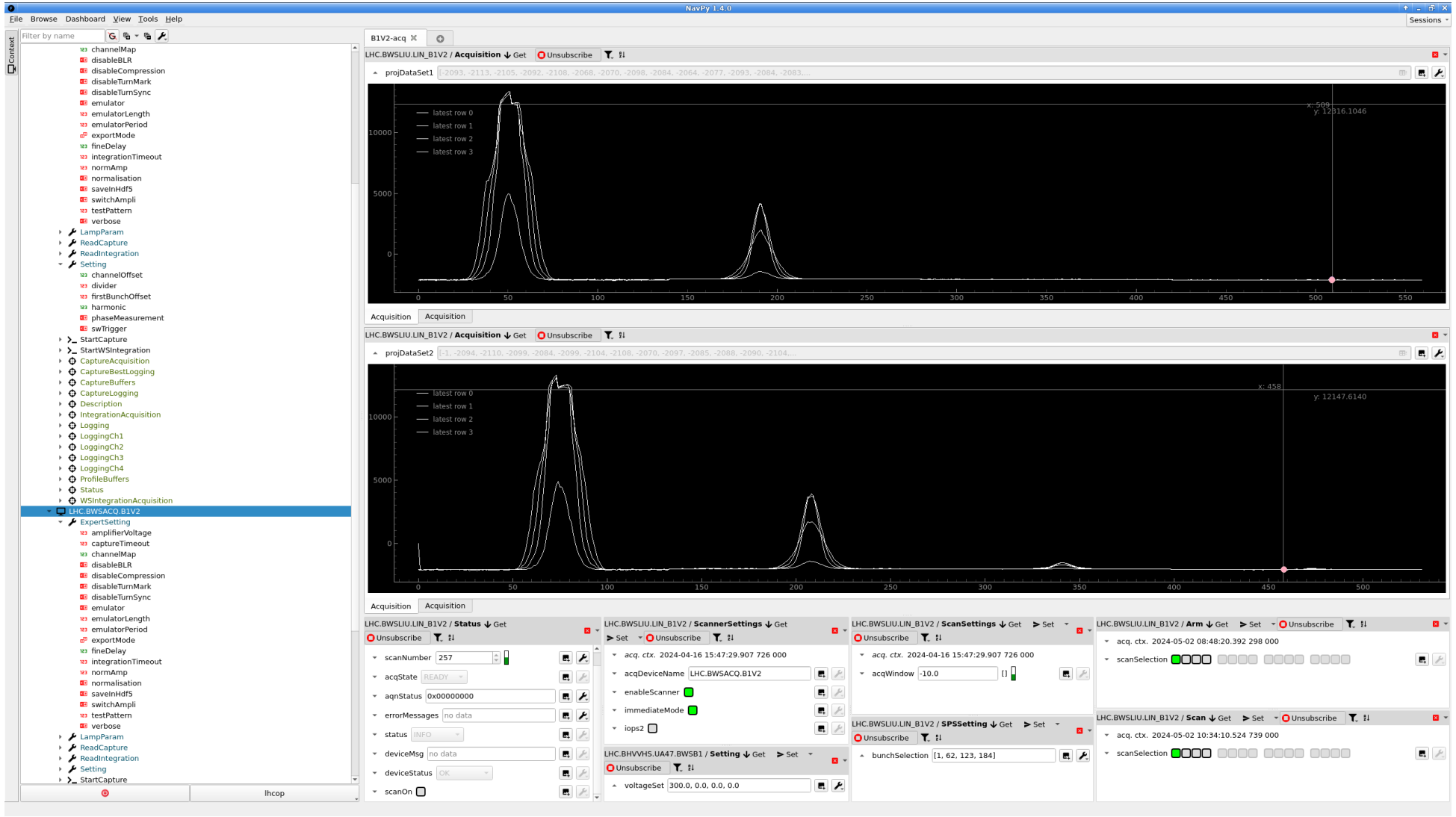
  2) Sometimes out data not up to date
  => SW bug already fixed, but not deployed for this MD

- **Setup:**
  Manual scan triggering and settings changes with:
  - OP application for the Legacy
  - Py FESA Navigator for the Hybrid+ (Georges’ Layout)

FESA py navigator - layout of B1H2 control (thanks to Georges)



FESA py navigator - layout of B1V2 control



Preliminary analysis

- IN and OUT scans processed for the Hybrid+ data
- Reconstruction of the positions using cst speed
- Plot scans over time for all PMT channels excluding scans with R^2<0.95 (Coeff of determination)
- Beam Energy and PMT voltage
- Plots are showing interesting data
- Detailed analysis to quantify the performance w.r.t. the legacy systems will follow next meeting.

Definitions [edit]

A data set has n values marked $y_1, \ldots, y_n$ (collectively known as y_i or as a vector $\boldsymbol{y} = [y_1, \ldots, y_n]^T$), each associated with a fitted (or modeled, or predicted) value $f_1, \ldots, f_n$ (known as f_i, or sometimes $\hat{y}_i$, as a vector $\boldsymbol{f}$).

Define the residuals as $e_i = y_i - f_i$ (forming a vector $\boldsymbol{e}$).

If $\bar{y}$ is the mean of the observed data:

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

then the variability of the data set can be measured with two sums of squares formulas:

- The sum of squares of residuals, also called the residual sum of squares:

$$SS_{\text{res}} = \sum_i (y_i - f_i)^2 = \sum_i e_i^2$$

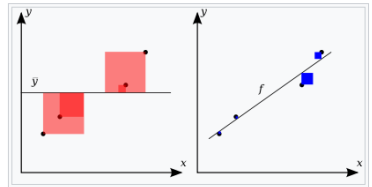
- The total sum of squares (proportional to the variance of the data):

$$SS_{\text{tot}} = \sum_i (y_i - \bar{y})^2$$

The most general definition of the coefficient of determination is

$$R^2 = 1 - \frac{SS_{\text{res}}}{SS_{\text{tot}}}$$

In the best case, the modeled values exactly match the observed values, which results in $SS_{\text{res}} = 0$ and $R^2 = 1$. A baseline model, which always predicts $\bar{y}$, will have $R^2 = 0$. Models that have worse predictions than this baseline will have a negative R^2.

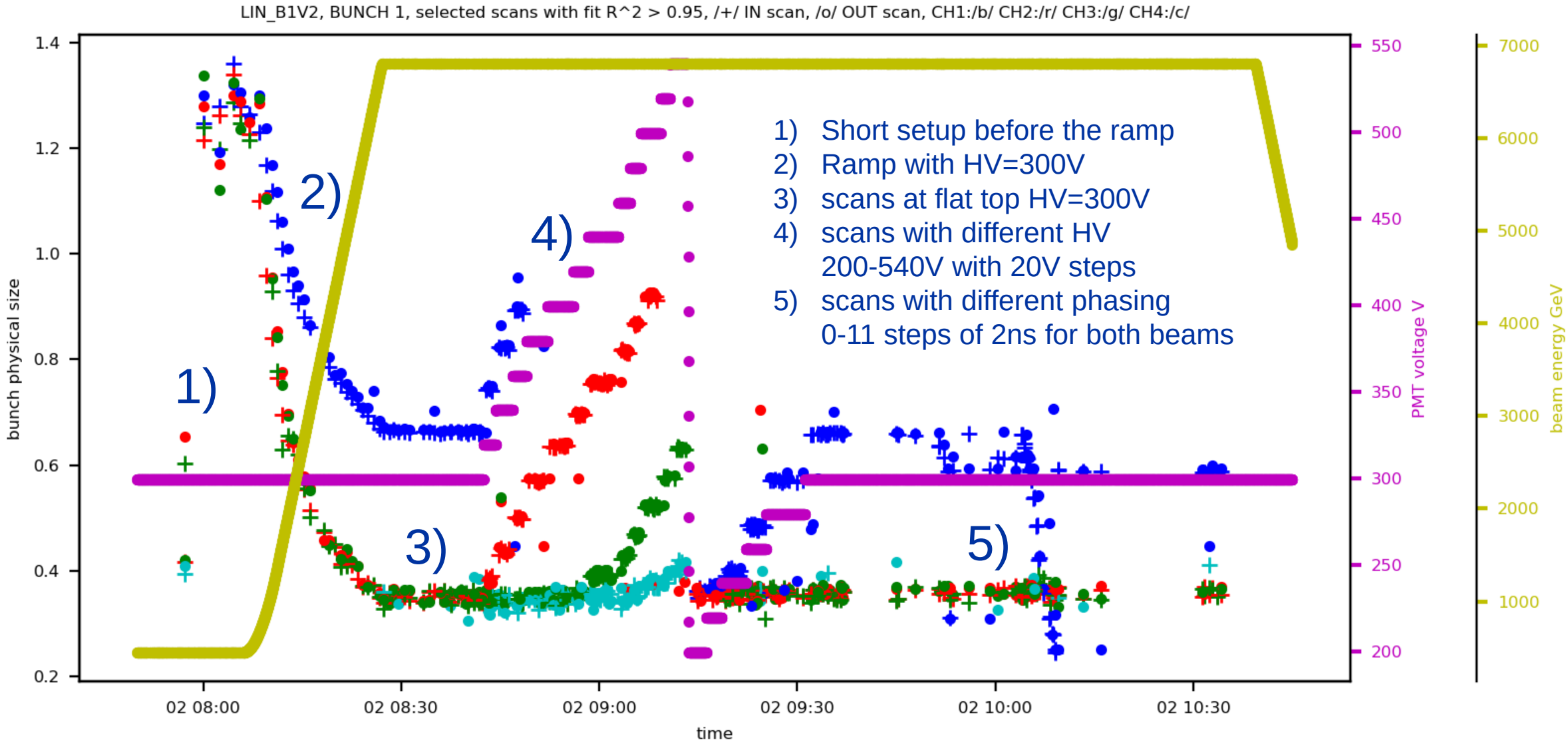


$R^2 = 1 - \frac{SS_{\text{res}}}{SS_{\text{tot}}}$

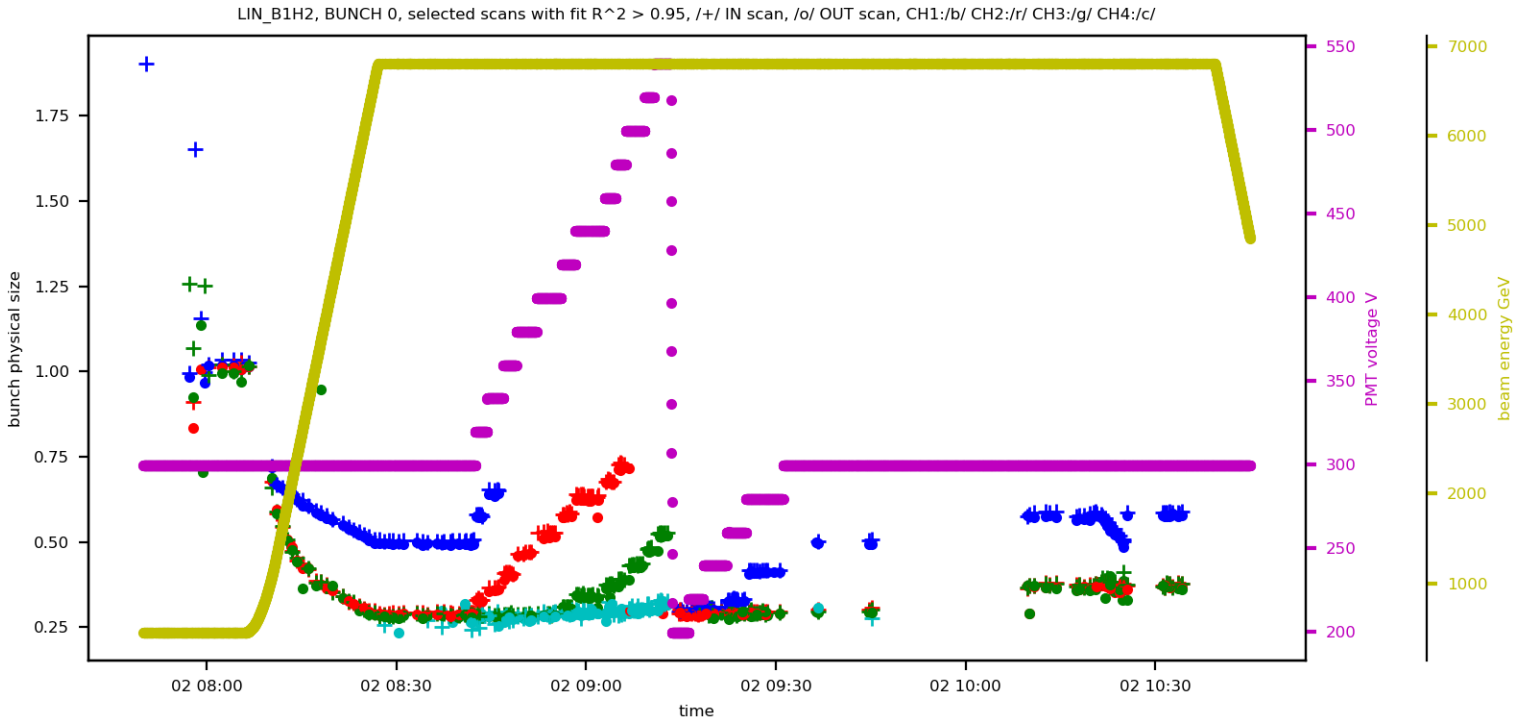
The better the linear regression (on the right) fits the data in comparison to the simple average (on the left graph), the closer the value of R^2 is to 1. The areas of the blue squares represent the squared residuals with respect to the linear regression. The areas of the red squares represent the squared residuals with respect to the average value.

https://en.wikipedia.org/wiki/Coefficient_of_determination

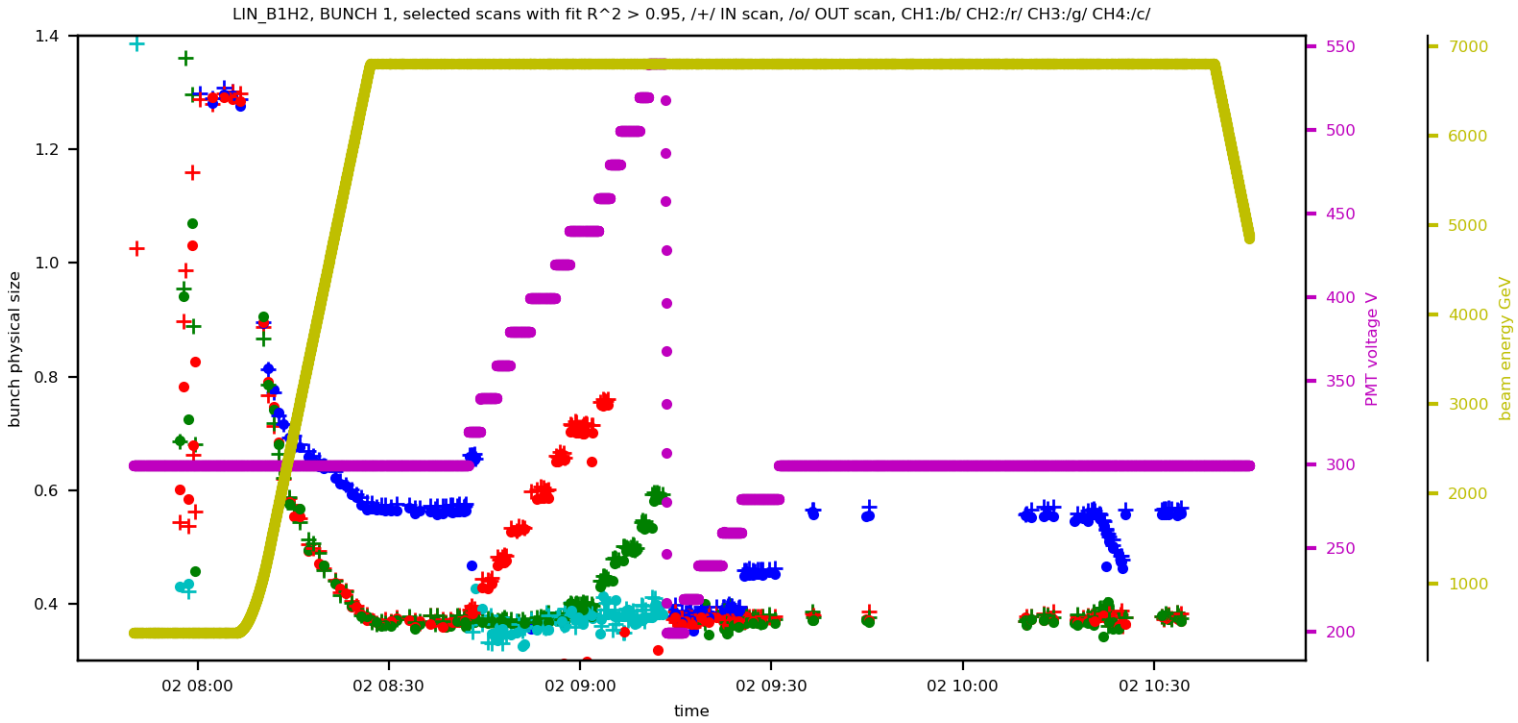
MD phases (UTC time)



B1H2 Bunch 0


LIN_B1H2, BUNCH 0, selected scans with fit R^2 > 0.95, /+/ IN scan, /o/ OUT scan, CH1:/b/ CH2:/r/ CH3:/g/ CH4:/c/
bunch physical size
1.75
1.50
1.25
1.00
0.75
0.50
0.25
PMT voltage V
550
500
450
400
350
300
250
200
beam energy GeV
7000
6000
5000
4000
3000
2000
1000
02 08:00
02 08:30
02 09:00
02 09:30
02 10:00
02 10:30
time

B1H2 Bunch 1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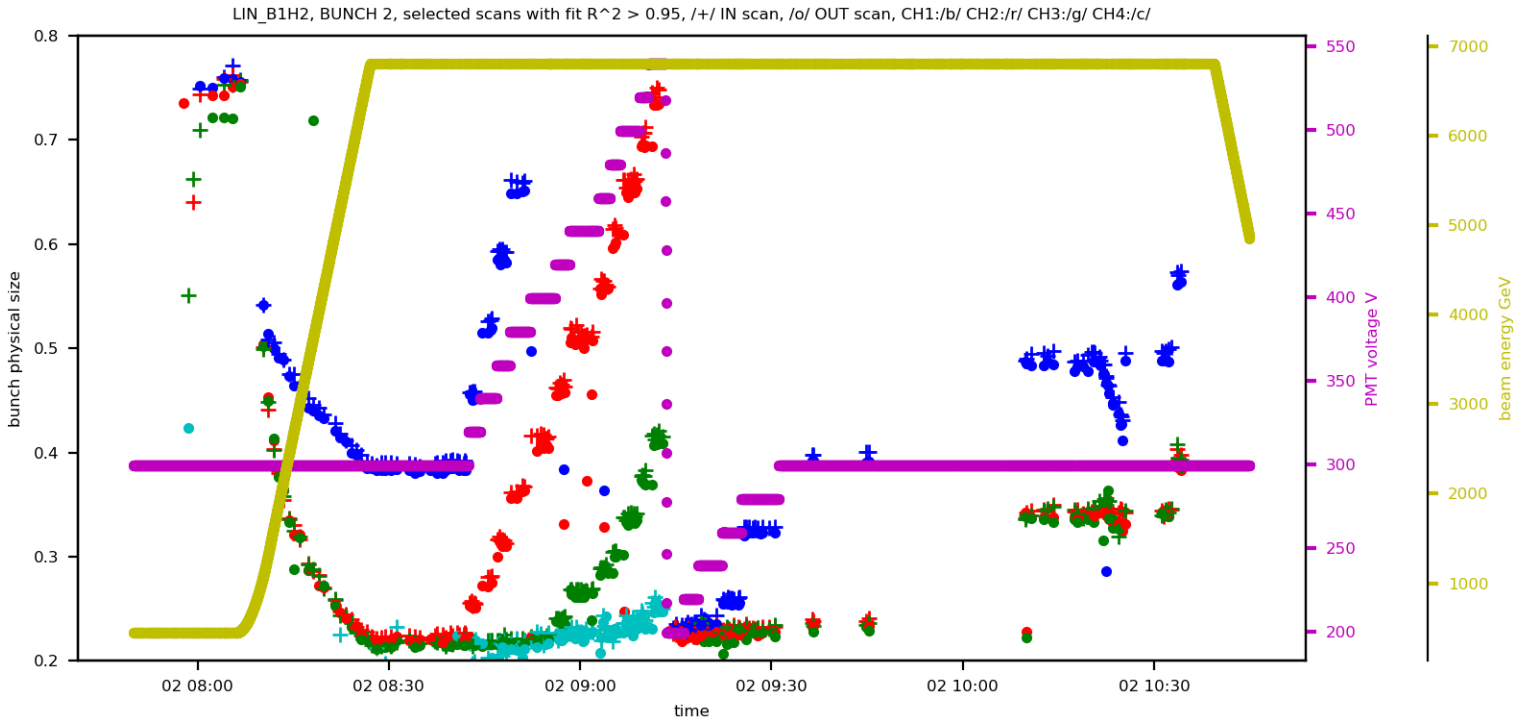
bunch physical size
PMT voltage V
beam energy GeV
time
1.4
1.2
1.0
0.8
0.6
0.4
550
500
450
400
350
300
250
200
7000
6000
5000
4000
3000
2000
1000
02 08:00
02 08:30
02 09:00
02 09:30
02 10:00
02 10:30

B1H2 Bunch 2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bunch physical size
PMT voltage V
beam energy GeV
time
0.8
0.7
0.6
0.5
0.4
0.3
0.2
550
500
450
400
350
300
250
200
7000
6000
5000
4000
3000
2000
1000
02 08:00
02 08:30
02 09:00
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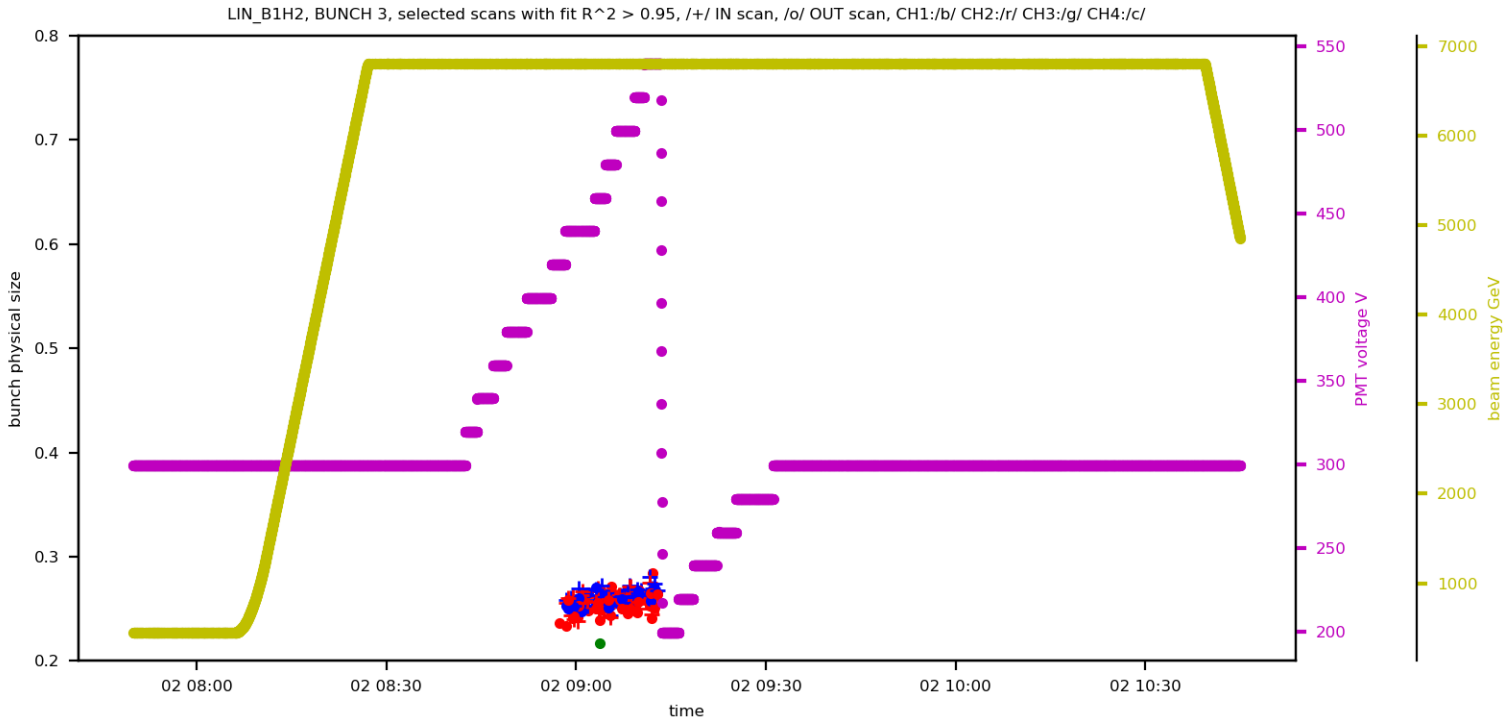
02 10:30

B1H2 Bunch 3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bunch physical size
PMT voltage V
beam energy GeV
time
0.8
0.7
0.6
0.5
0.4
0.3
0.2
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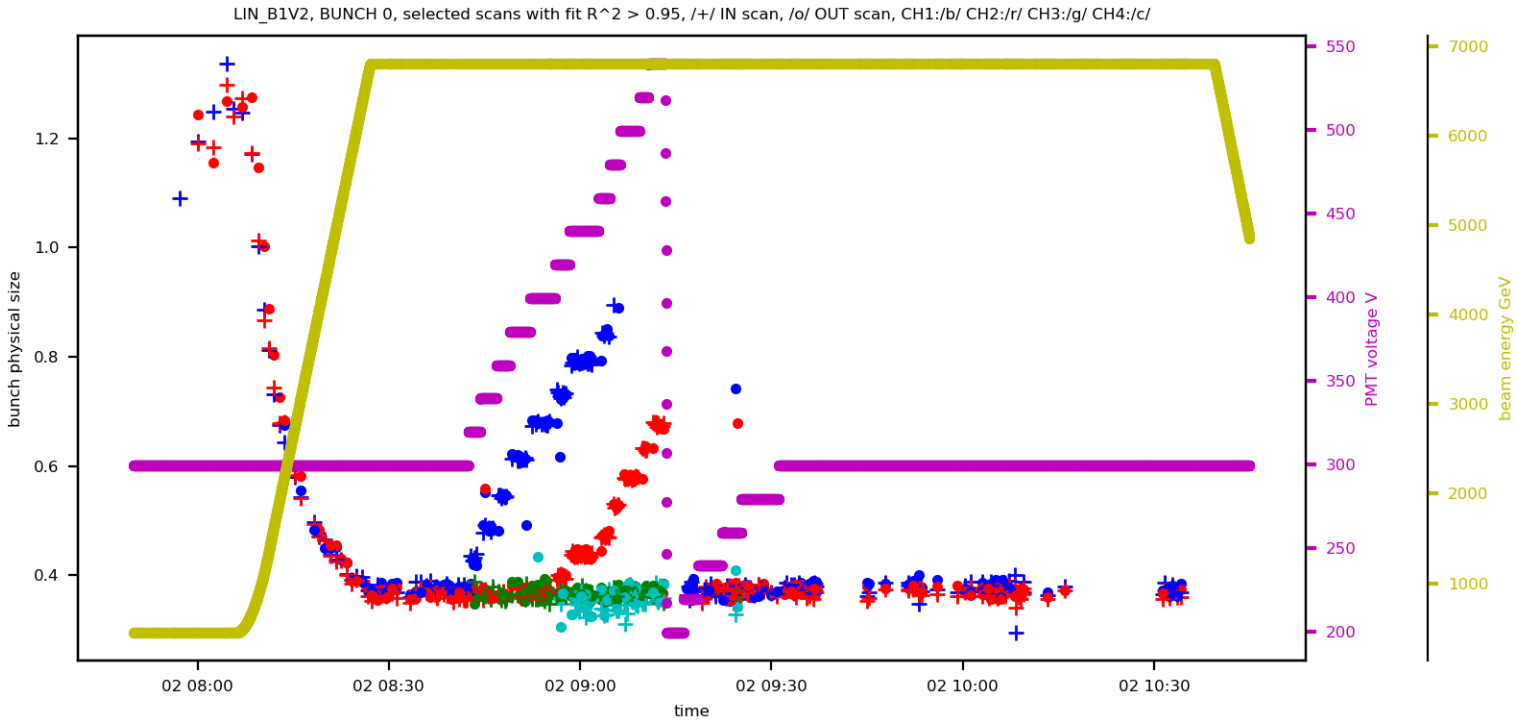
B1V2 Bunch 0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bunch physical size
1.2
1.0
0.8
0.6
0.4
PMT voltage V
550
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beam energy GeV
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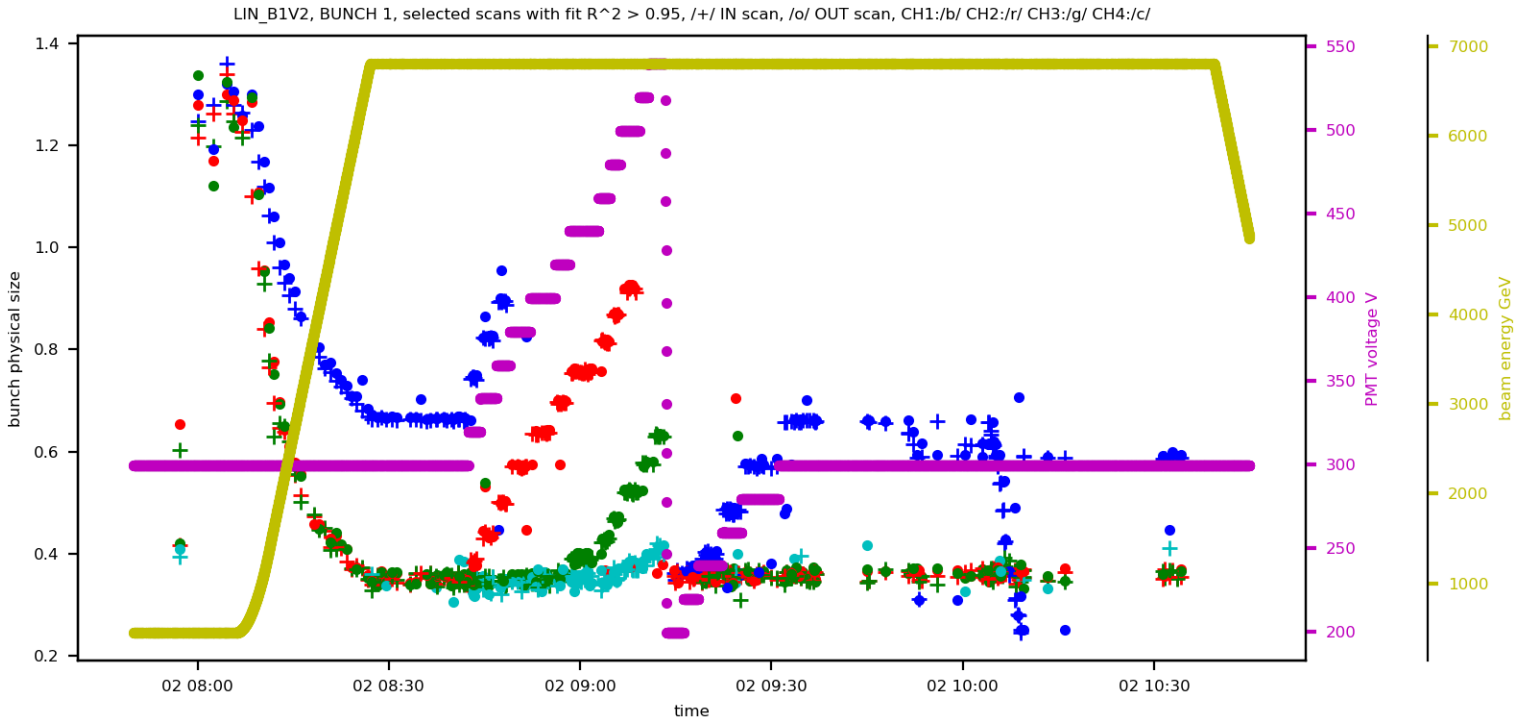
02 10:30
time

B1V2 Bunch 1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bunch physical size
PMT voltage V
beam energy GeV
time
1.4
1.2
1.0
0.8
0.6
0.4
0.2
550
500
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350
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250
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7000
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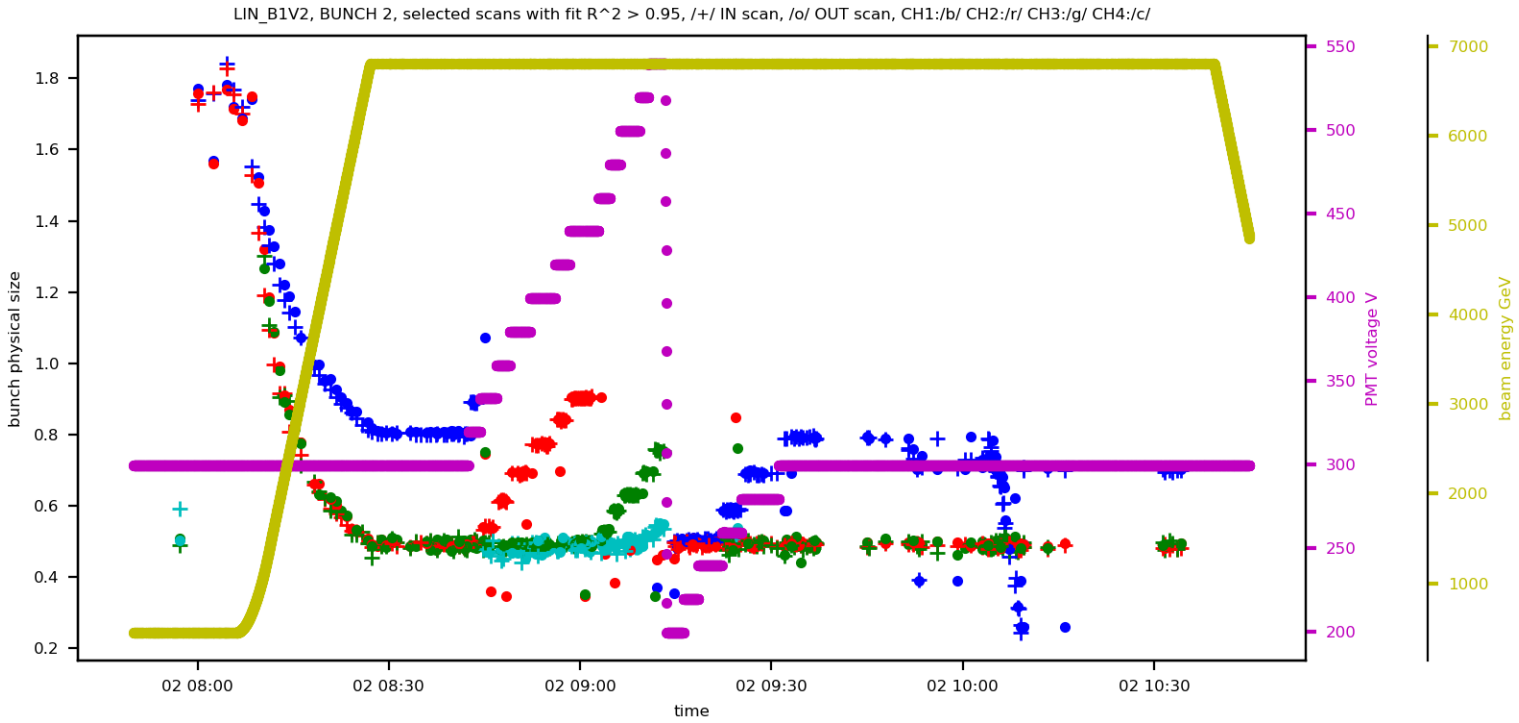
02 10:30

B1V2 Bunch 2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bunch physical size
PMT voltage V
beam energy GeV
time
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02 09:00
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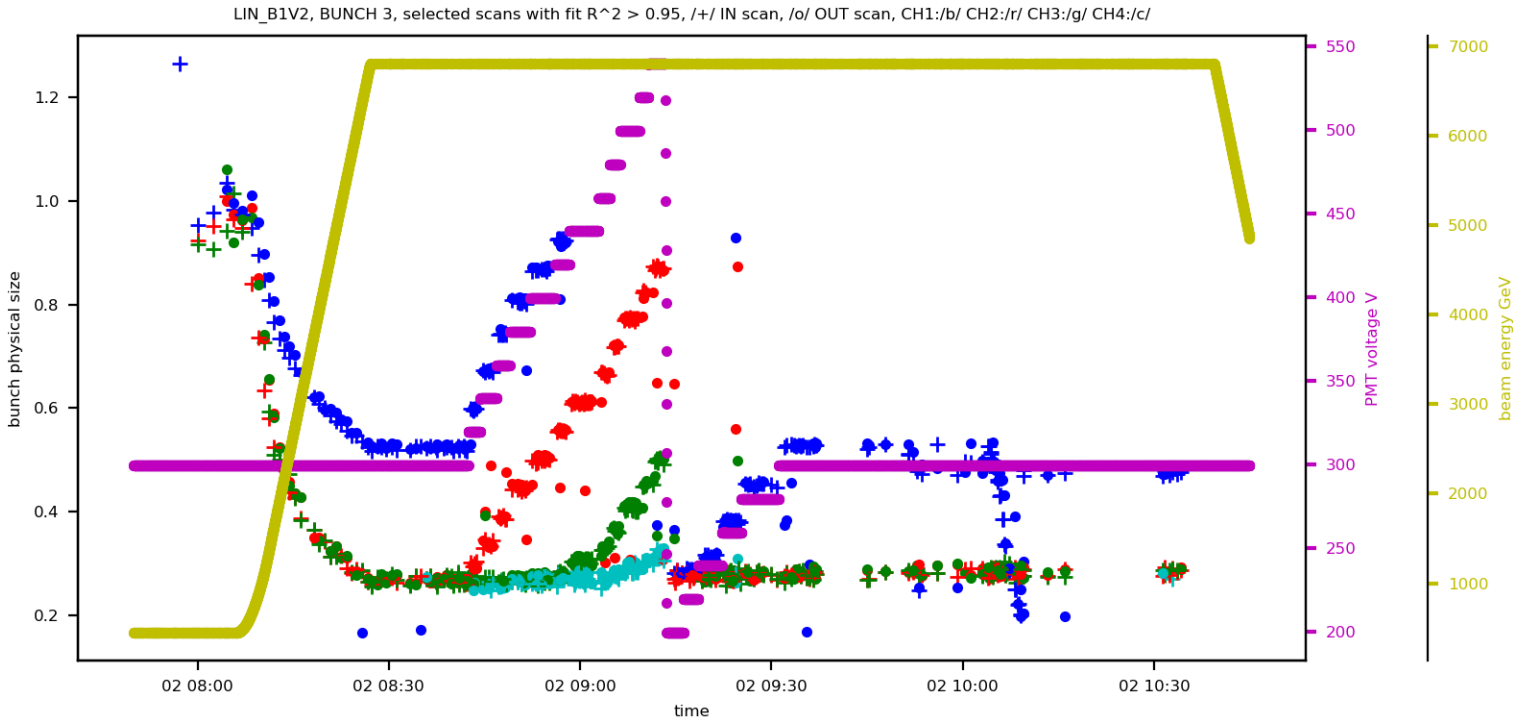
02 10:00
02 10:30

B1V2 Bunch 3


LIN_B1V2, BUNCH 3, selected scans with fit R^2 > 0.95, /+/ IN scan, /o/ OUT scan, CH1:/b/ CH2:/r/ CH3:/g/ CH4:/c/
bunch physical size
PMT voltage V
beam energy GeV
time
02 08:00
02 08:30
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02 09:30
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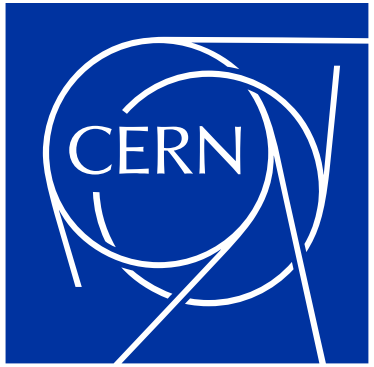
02 10:30

Summary

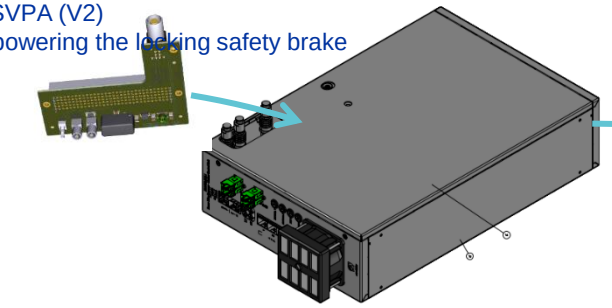
- This session was successful with more than 200 scans per plane done
- PMT HV was scan (200 V to 540 V) – beam size was measured by all 4 PMT channels
- Digital integration fine delay was tested with its complete span (0-11)
- Preliminary analysis shows many usable data to characterise the system
- Next:
  - Verify B1H2 (delay?) since bunch 3 wasn't measured properly
  - generate statistics of the beam size
    to compare: IN – OUT / PMT channel / PMT HV
  - benchmark with Legacy measurements
  - Find best operating point
  - Propose changes to PMT filters to optimize acquisition on multiple channels

  => Build new PMT assemblies with optimized filters



home.cern

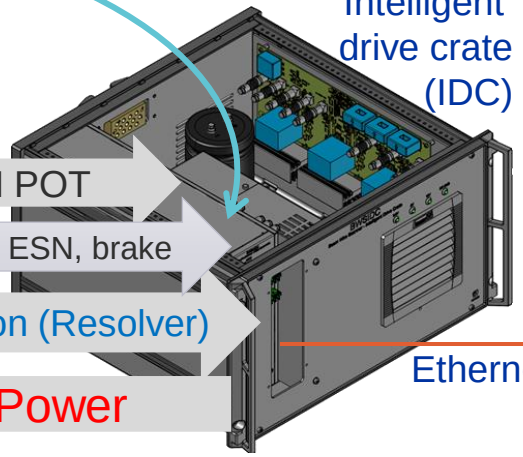
LHC hybrid prototype with LIU electronics



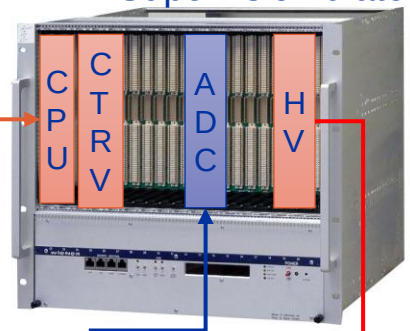
BWSVPA (V2)
For powering the locking safety brake

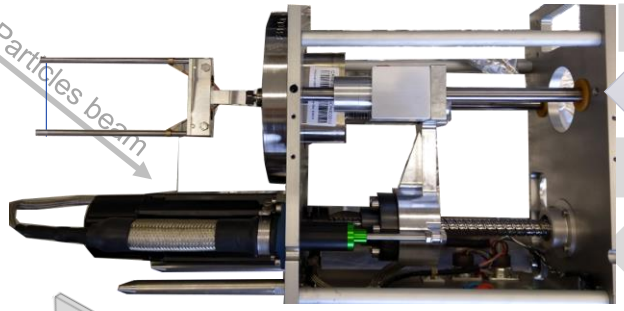
Motion Controller Unit (MCU)

Intelligent drive crate (IDC)



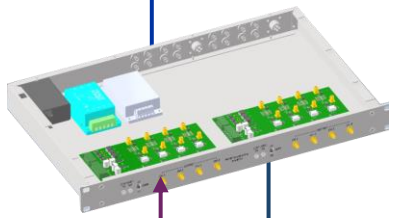
Acquisition & Supervision crate

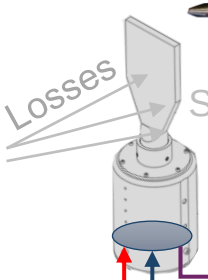




LIN POT
Wire, ESN, brake
Position (Resolver)
Power

Ethernet





4x signal PMTs
Lamp test + supplies
PMT supply

The linear wire-scanner hybrid does not have a linear optical encoder, so the BWSLIUEXP FESA class is now simulating it using the resolver data

TIMBER

SWAN

Storage Database (NXCALS)

BWS - FESA software structure

BWSLIU

BWSLIUEXP

BWSACQ

HD Storage (in HDF5 format)