

APEX: recombination studies

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Radiative recombination of ions was extensively studied experimentally. Perfect agreement between measurements and theoretical prediction for the recombination coefficient was found in a wide range of relative energies between the electrons and ions ($>10\text{meV}$).

However, in the region of extremely small relative energies (which is the region typically used for electron cooling), the measured recombination coefficient for experiments with bare ion was found significantly higher than predicted by standard theory of radiative recombination.

At RHIC during LEReC setup in 2019 the recombination enhancement **was observed first time without continuous** solenoidal field. The goal of this experiment is the systematic study beam losses due to recombination for different energy offsets and energy spread.

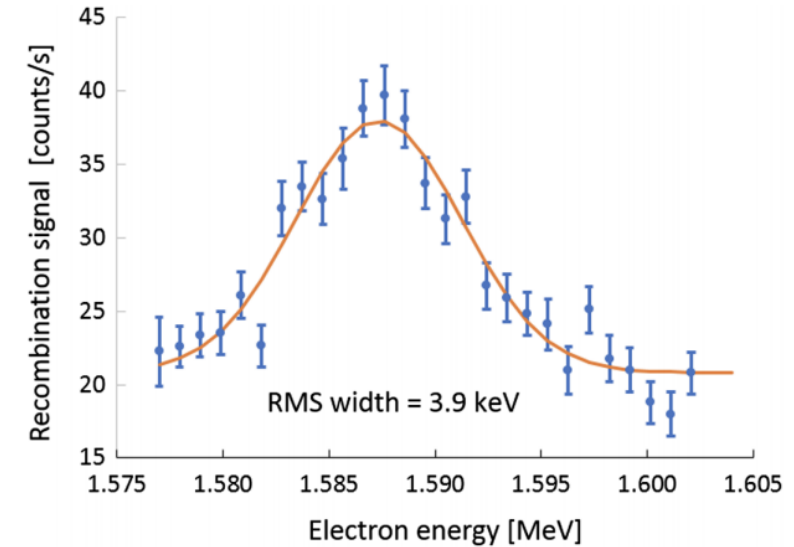
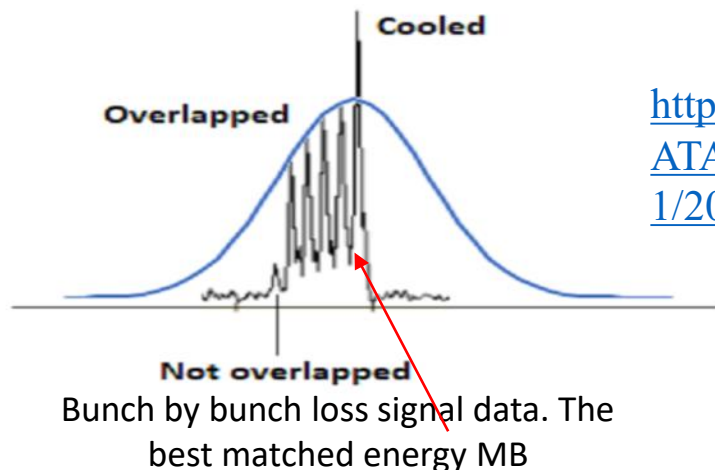


FIG. 7. The recombination signal (blue dots) dependence on beam energy (as measured by spectrometer) during the scan. The error bars for each point represent the rms of the recombination signal at each energy setting averaged over two scans. RMS width of the measured trend is calculated from Gaussian fit of the data (orange solid line).

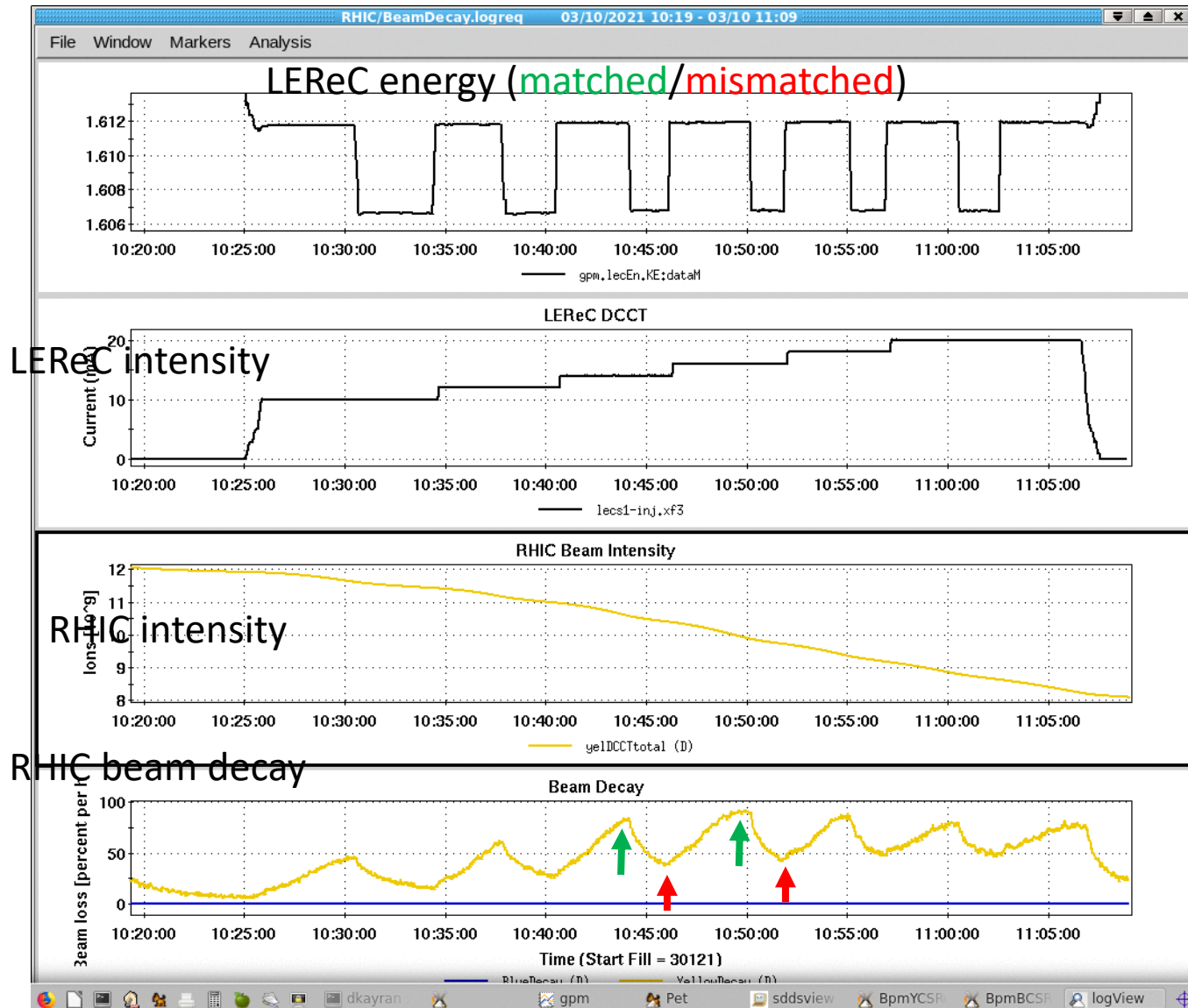
[Phys. Rev. Accel. Beams 22, 111004](#) –
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http://www.cadops2.bnl.gov/elogs/entryList.jsp?DATABY=day&ELOG=LEReC_2019&DATE=04/11/2019&DIR=none#968776

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Observed recombination effects on ion lifetime during APEX March 10



Ions Lifetime degradation is observed as a result of interaction with e-beam for both configurations matched and unmatched energy

The difference between matched and unmatched energy is very well measured $\sim 25\text{-}30\%/h$ for given LEReC and Ion parameter during this APEX

Plans for APEX

- Make sure that recombination monitor system is proper setup to measure losses due to recombination (includes RHIC lattice or local bump setup, and proper data acquisition) ~1 hour
- In order to reduce beam losses background and unnecessary bunch size growth due to other collective effects, we plan to conduct studies at reasonable Low RHIC intensity
- Measure background signal due to other losses without electrons
- Study lifetime/beam losses with different energy offset and energy spread.
- Optional: One of the possible experiment configurations: setup RHIC with 6 bunches and LEReC in 76kHz mode with 5 MBs train then compare bunch by bunch losses (or/and intensity): of well-matched, non-interacted and interacted bunches but with energy offset due to beam loading effect.
 - Update: if possible, use more M-bunches (10) per TRAIN to cover larger energy spectrum in one test

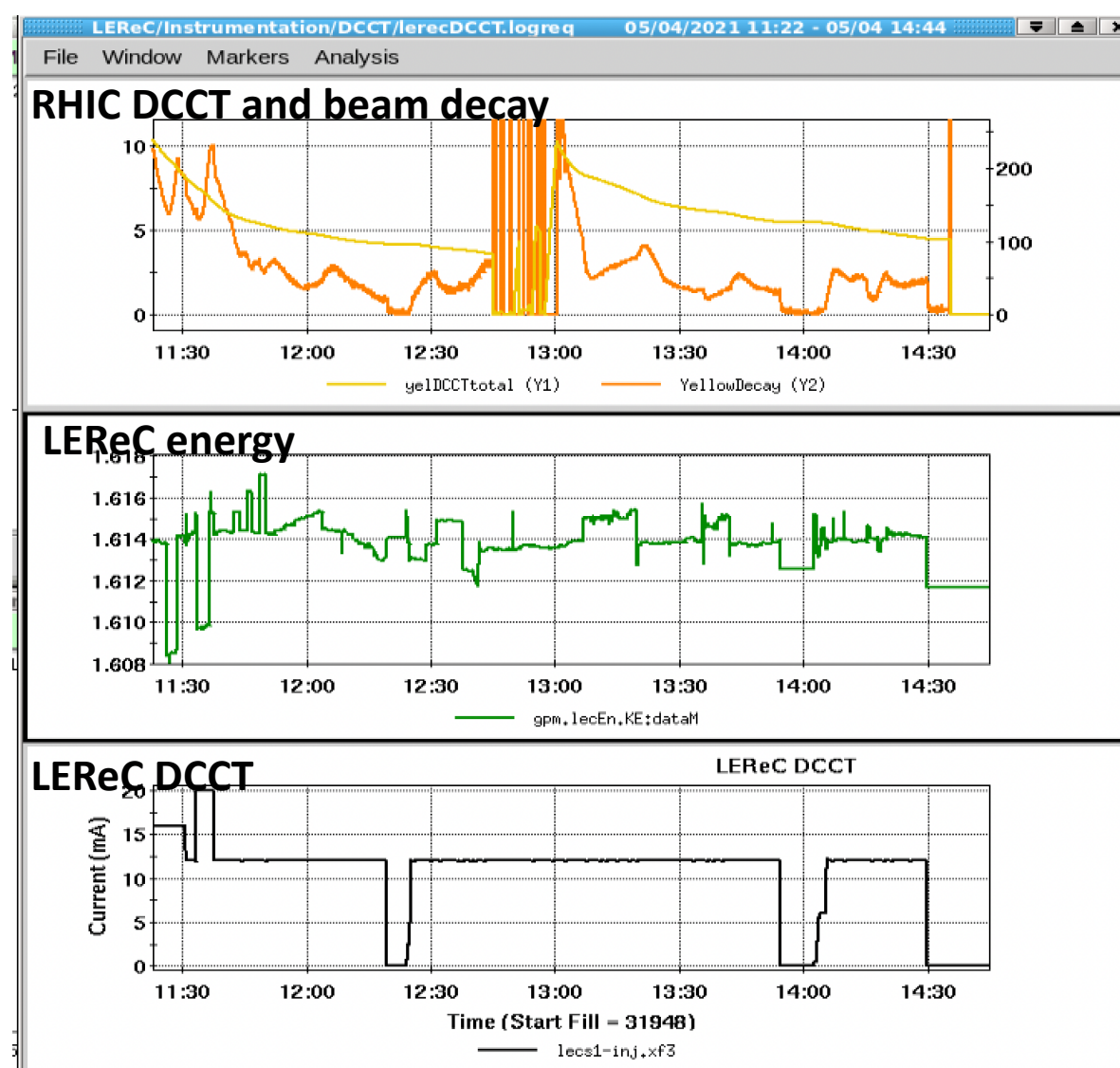
APEX 2021-05-04 report

Setup:

- Collect data in parallel with other APEX
- RHIC: physics lattice (no local bumps or special dispersion excitation), Ion intensity $5-9 \times 10^9$
- LEReC: **short** bunches, CW 9 MHz mode, beam current 12 mA

Test run 2021-05-04:

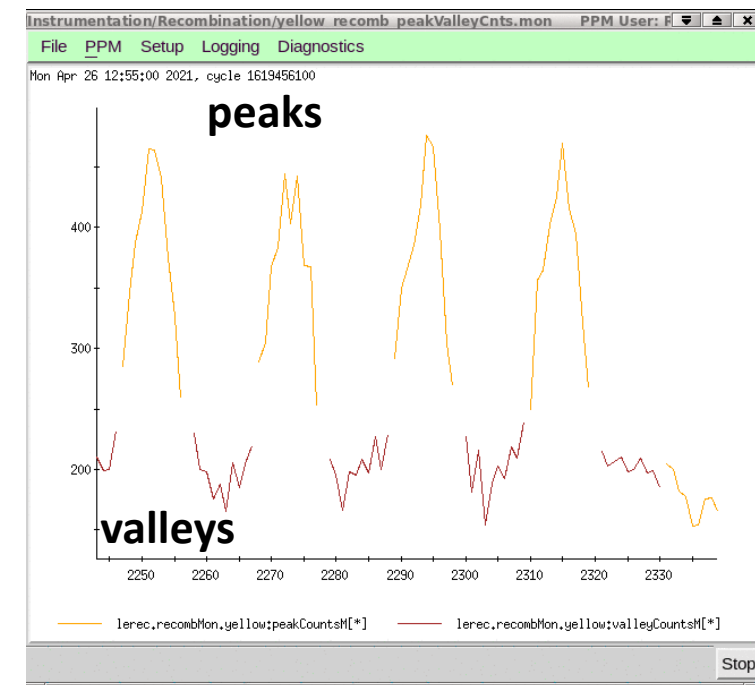
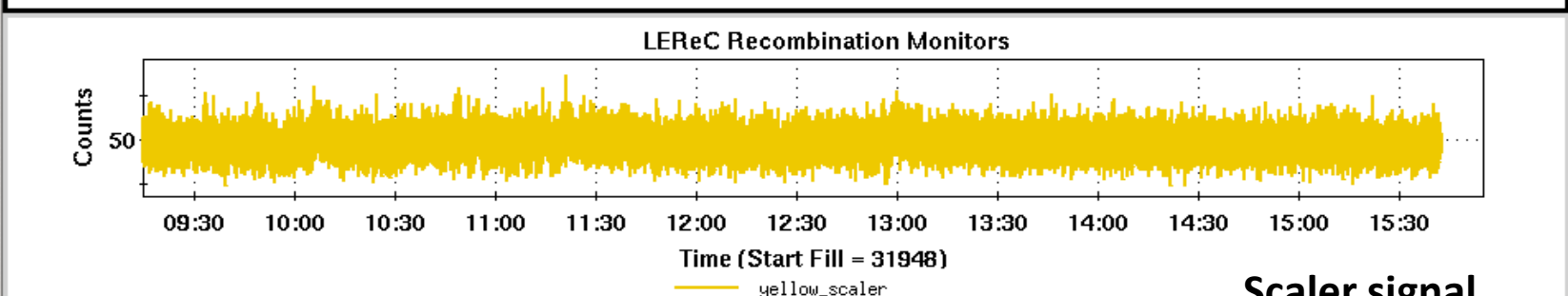
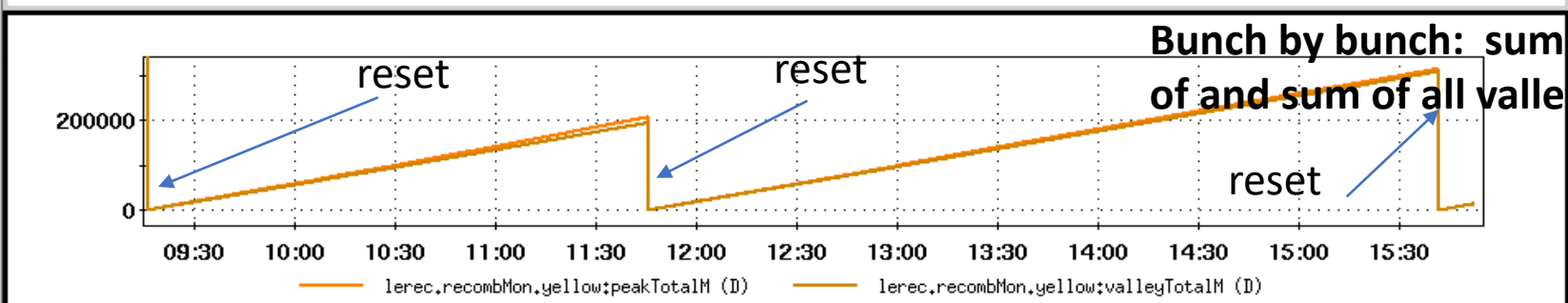
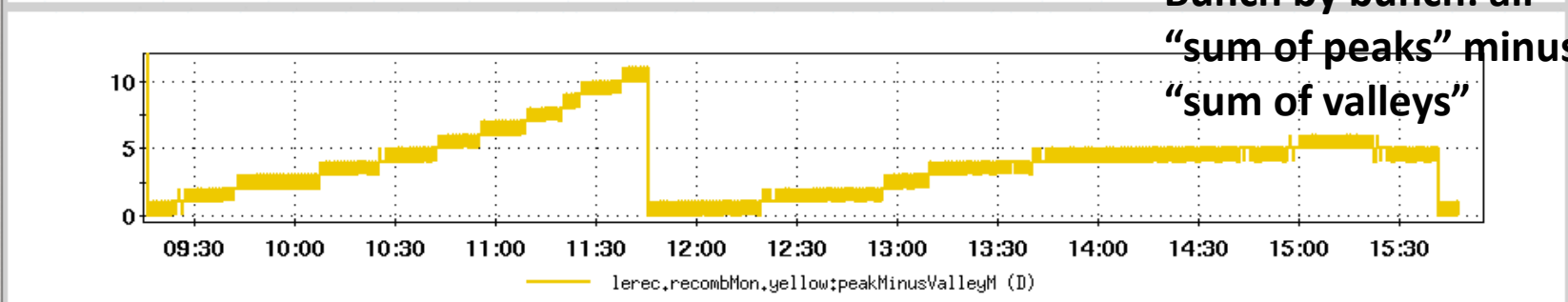
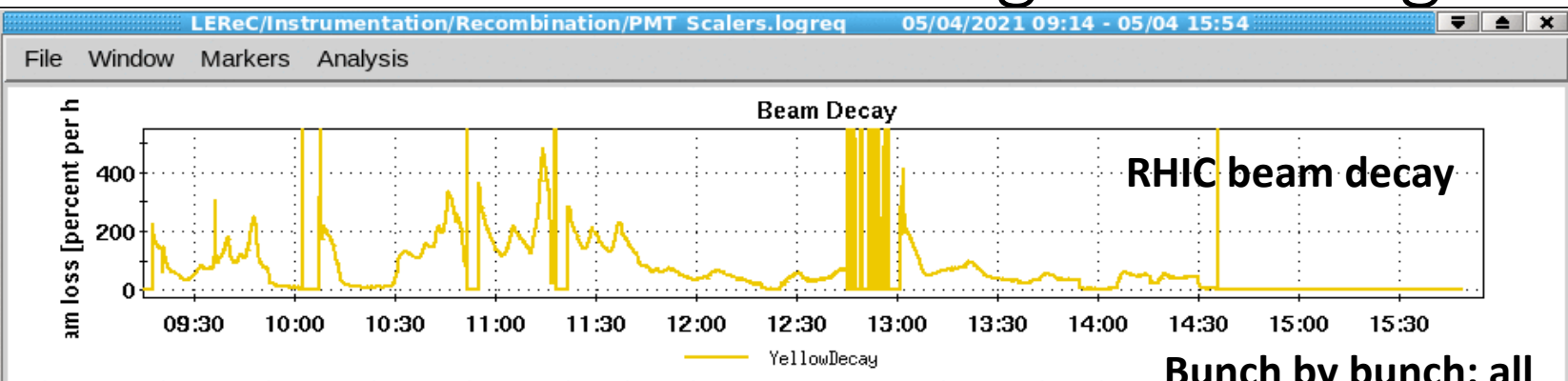
- Recombination monitor signal:
 - Scaler: noisy signal and no any correlation with LEReC energy tuning
 - Bunch by bunch counter using V301: low signal.
- RHIC beam decay time signal is very controversial.
 - In some cases, we observed more losses when energy matched. In other cases, we observed less losses when velocity is matched and LEReC provide good cooling.
 - The changes of loss rate could be result of combination of different effects



For good data we need to find APEX condition in which recombination losses could be distinguished from other losses.

Recombination monitor signals during APEX

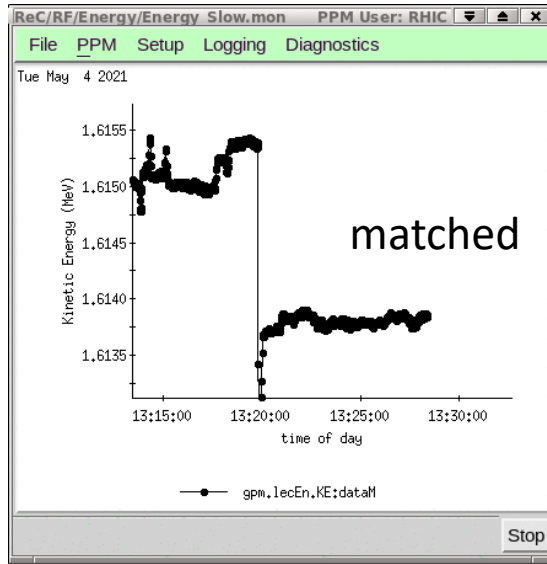
Bunch by bunch recombination monitor signal is taken during regular store at **different time**



Maybe longer acquisition time for each energy step or averaging would help to see the difference

Correlation between energy changes, cooling efficiency and beam losses

Energy change



Bunch length

