Measurements' analysis

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- Introduction
- Techniques, tools
- Results (selected)
- Outlook

Acknowledgements: G. Arduini, H. Damerau, E. Métral, and

OP-PS crew!!!

Introduction - I

- **Aim of these studies:**
  - **Optimisation of various parameters**
  - **Identification of sources (beam dynamics) of trapping fluctuations**
- **Instruments used:**
  - **Mainly transformers in TT2 to evaluate extraction and trapping efficiency**
    - **BCTFI212: spill shape and total intensity**
    - **BCT372: total intensity**
  - **Wire scanner to evaluate islands' parameters and trapping efficiency**
  - **Screens in TT2 to evaluate position fluctuations and emittance/sigma variation**

CERN PS MULTI TURN EXTRACTION

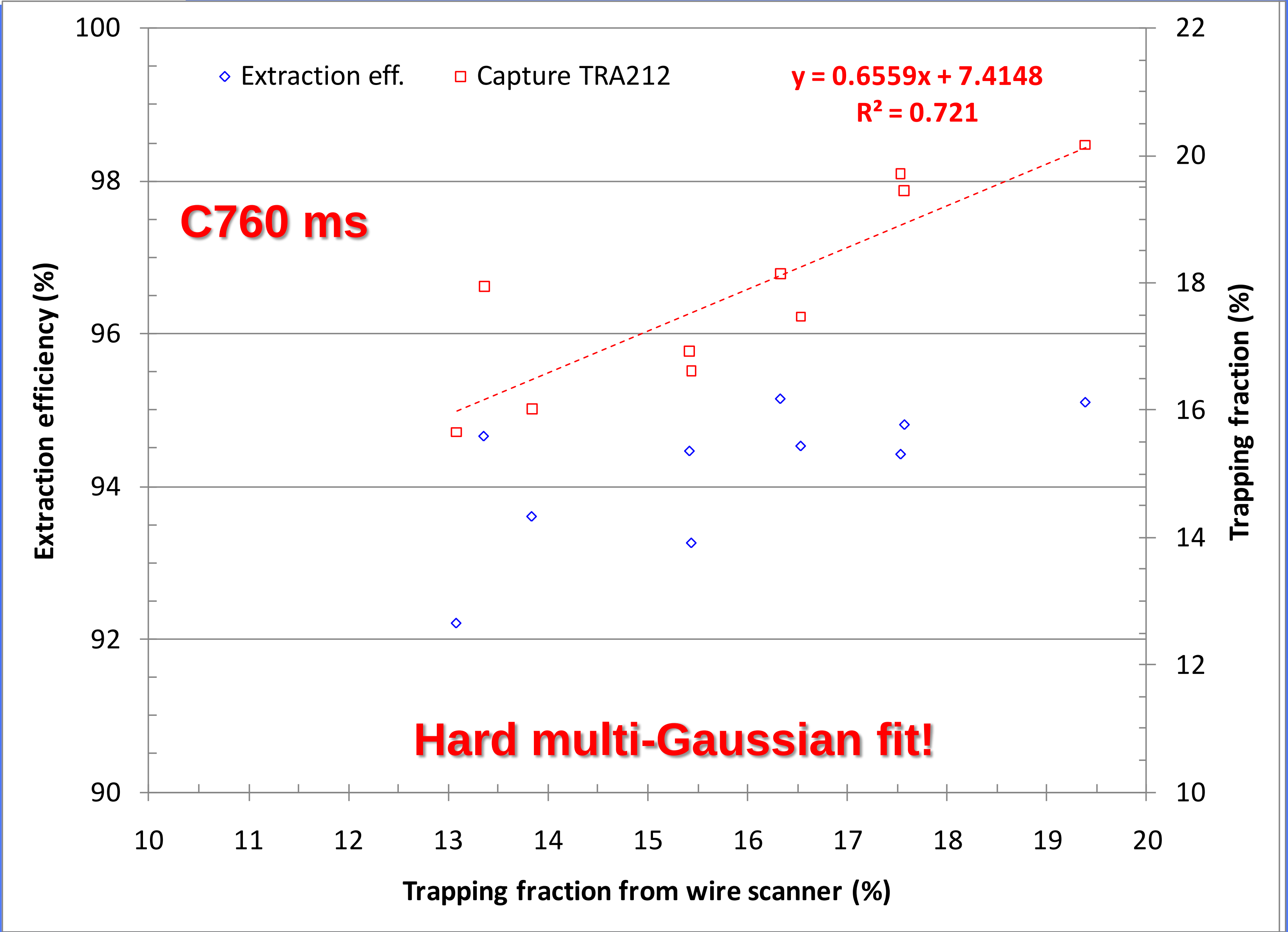
Introduction - II

- General approach
  - Perform scans over selected parameters
  - Estimate trapping/extraction efficiency
  - Compute average/standard deviation of trapping/extraction vs. parameter tested
  - Evaluate correlation between trapping/extraction efficiencies
  - Evaluate frequencies in time-evolution of trapping/extraction efficiency
    - Plain FFT not always applicable (not evenly-spaced data)
    - Lomb periodogramme used
      - Equivalent to fitting sine/cosine functions to measured data
      - Figure-of-merit function suitable for statistical interpretation: significance level of fit frequencies.

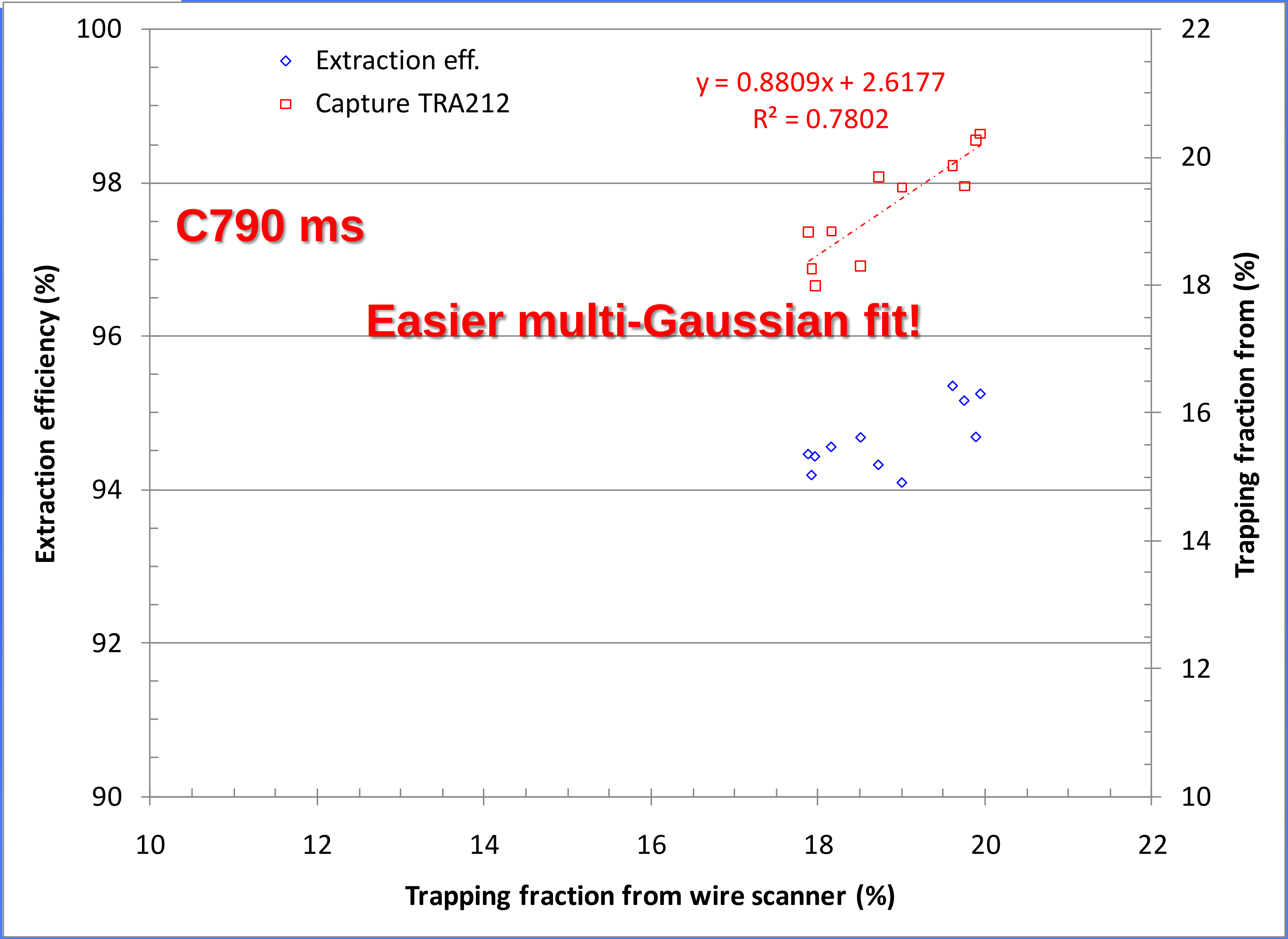
Introduction - III

- Key beam/machine parameters
  - Tune:
    - Resonance crossing
    - Control of adiabaticity of whole process
  - Sextupoles/octupoles
    - Islands' generation
    - Separation
    - Adiabaticity
  - Damper:
    - Used to increase trapping (by increasing horizontal particles' amplitude).

When are the fluctuations generated? – results - I



When are the fluctuations generated? – results - I



When are the fluctuations generated? - conclusions

- **Taking into account that**
  - **It is not possible to collect too much statistics with wire scanners**
  - **The five-Gaussian fit might be hard to perform when the islands are not well separated**
- **Then, the fluctuations seem to be generated right at the beginning of the splitting.**

Damper effect

- **Principle:**
  - It excites the beam at an harmonic (h) of the betatron frequency
  - It excites the beam at a given tune value
  - In summary:
    - $f_{damper}=f_{rev}\ (h+q_x)$
  - Other parameters
    - Kick amplitude
    - Start and end times of excitation
    - Other excitation forms

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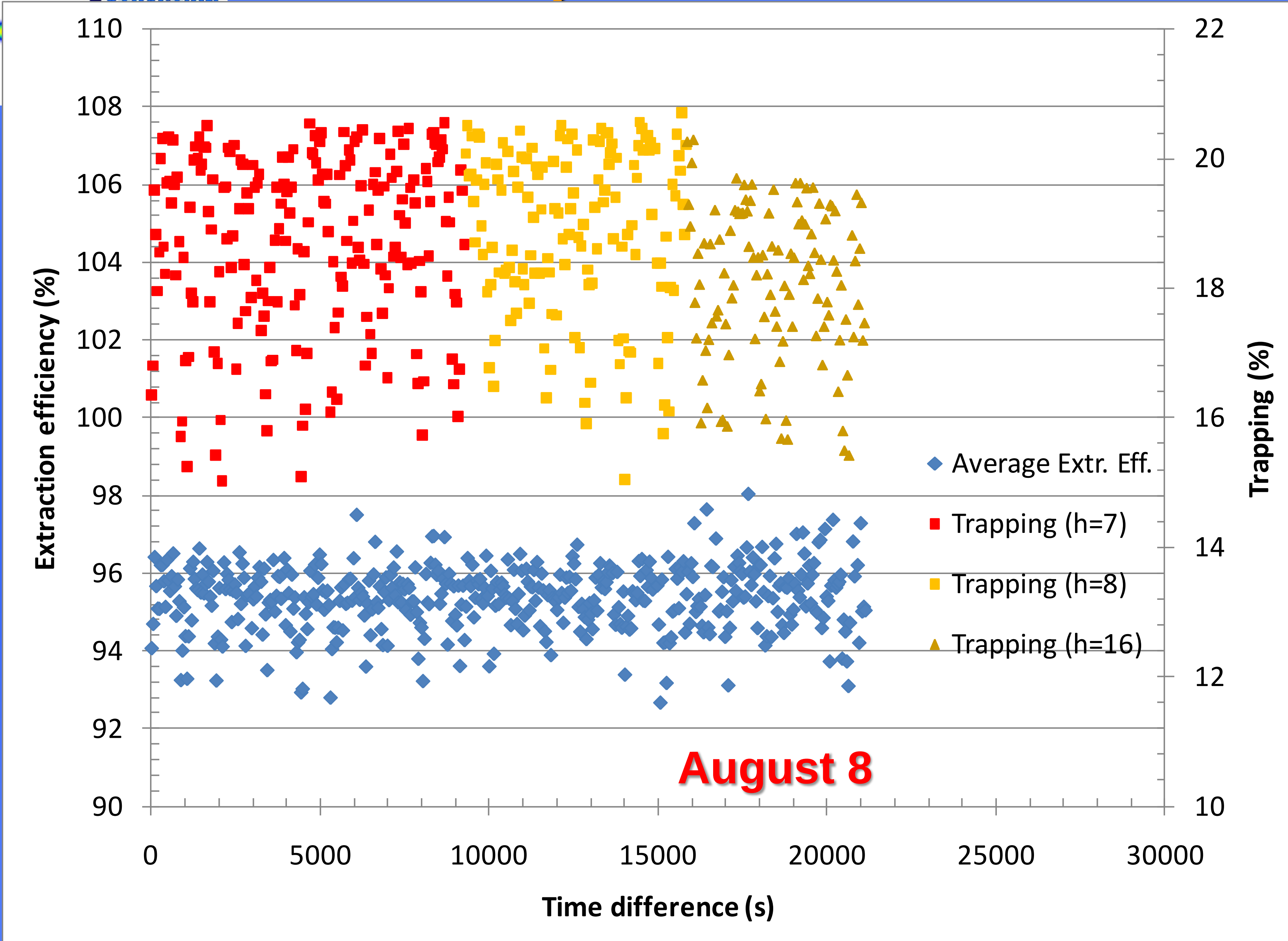
Damper effect – results - I



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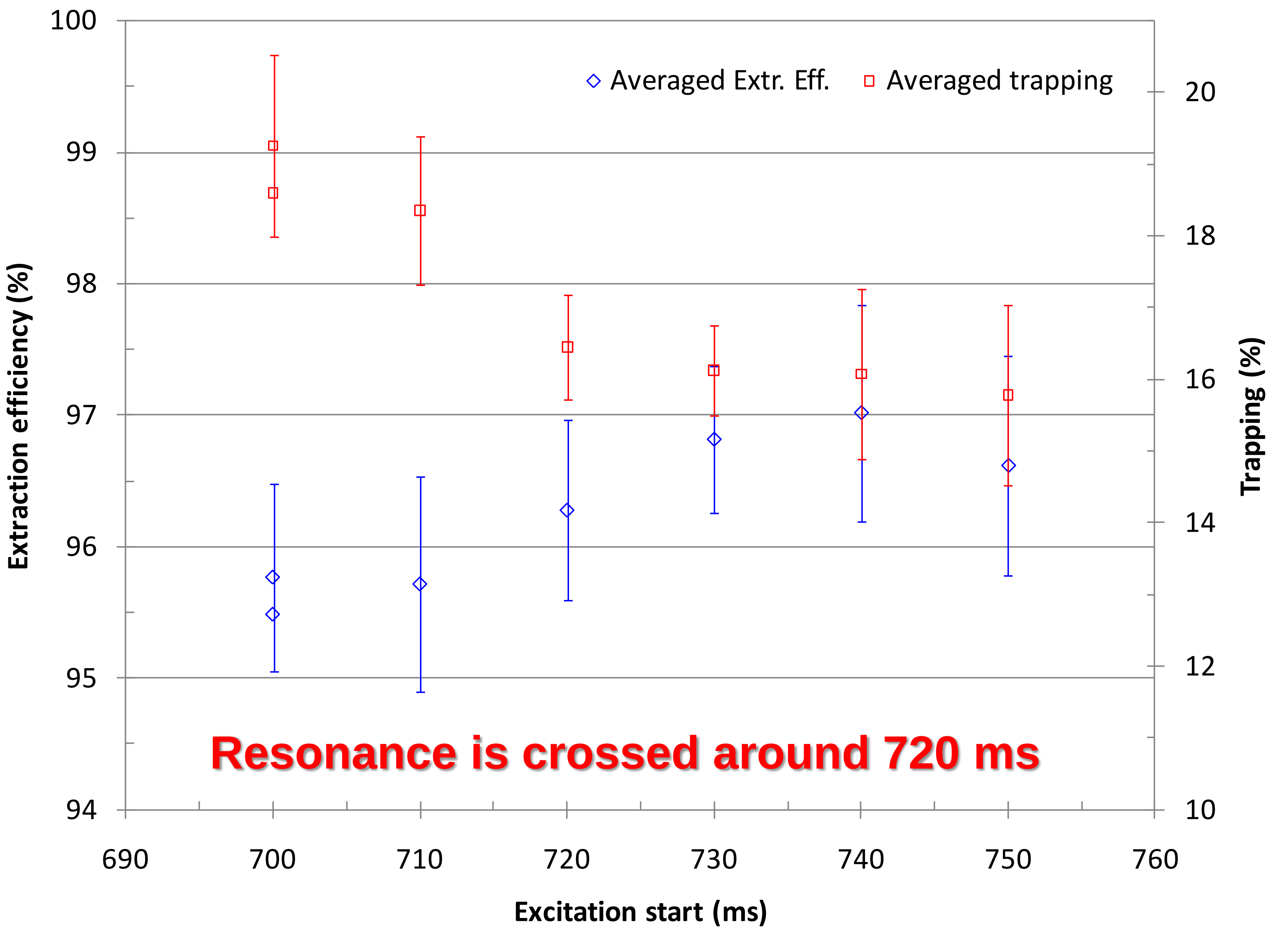
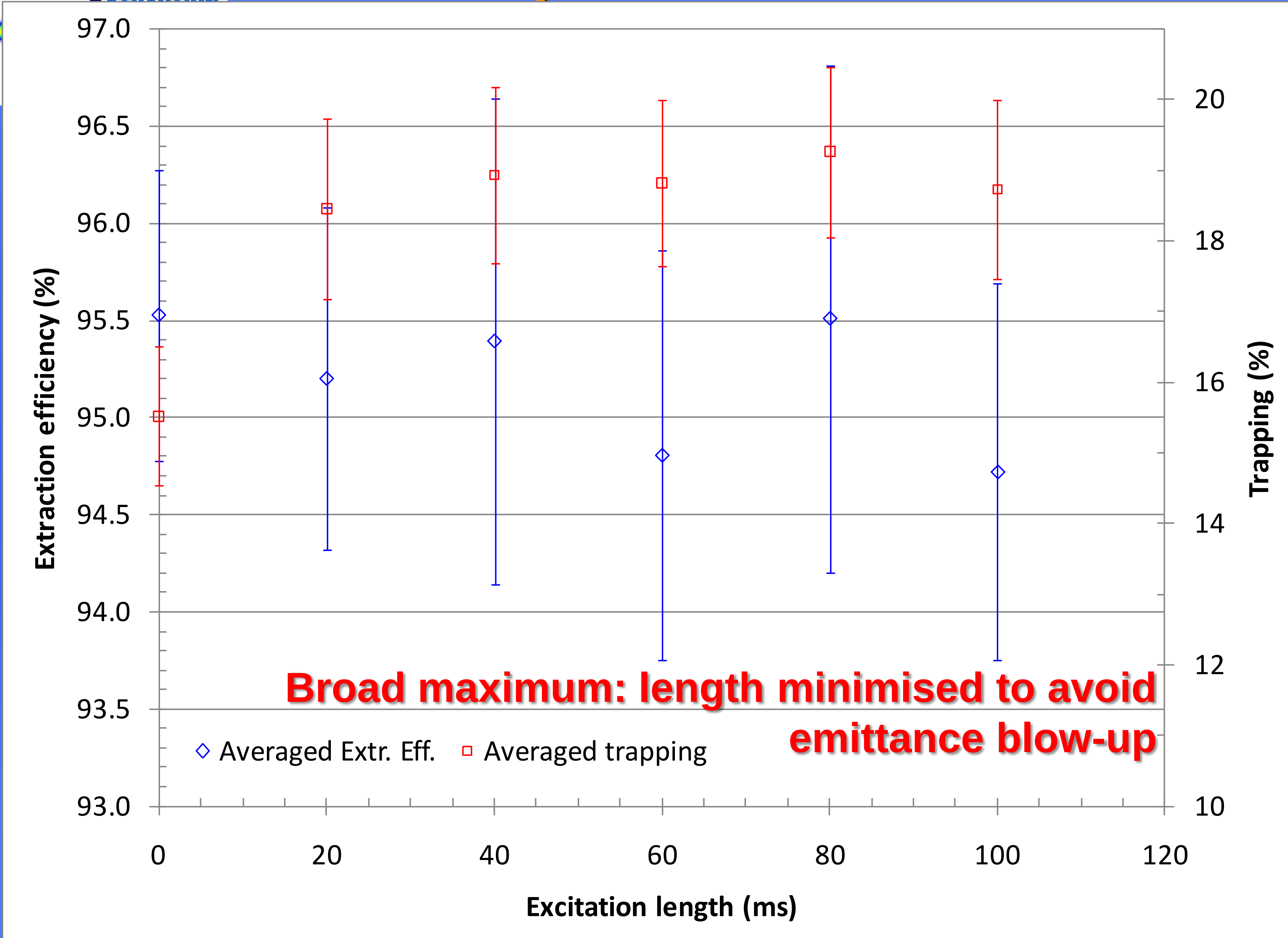
Damper effect – results - II

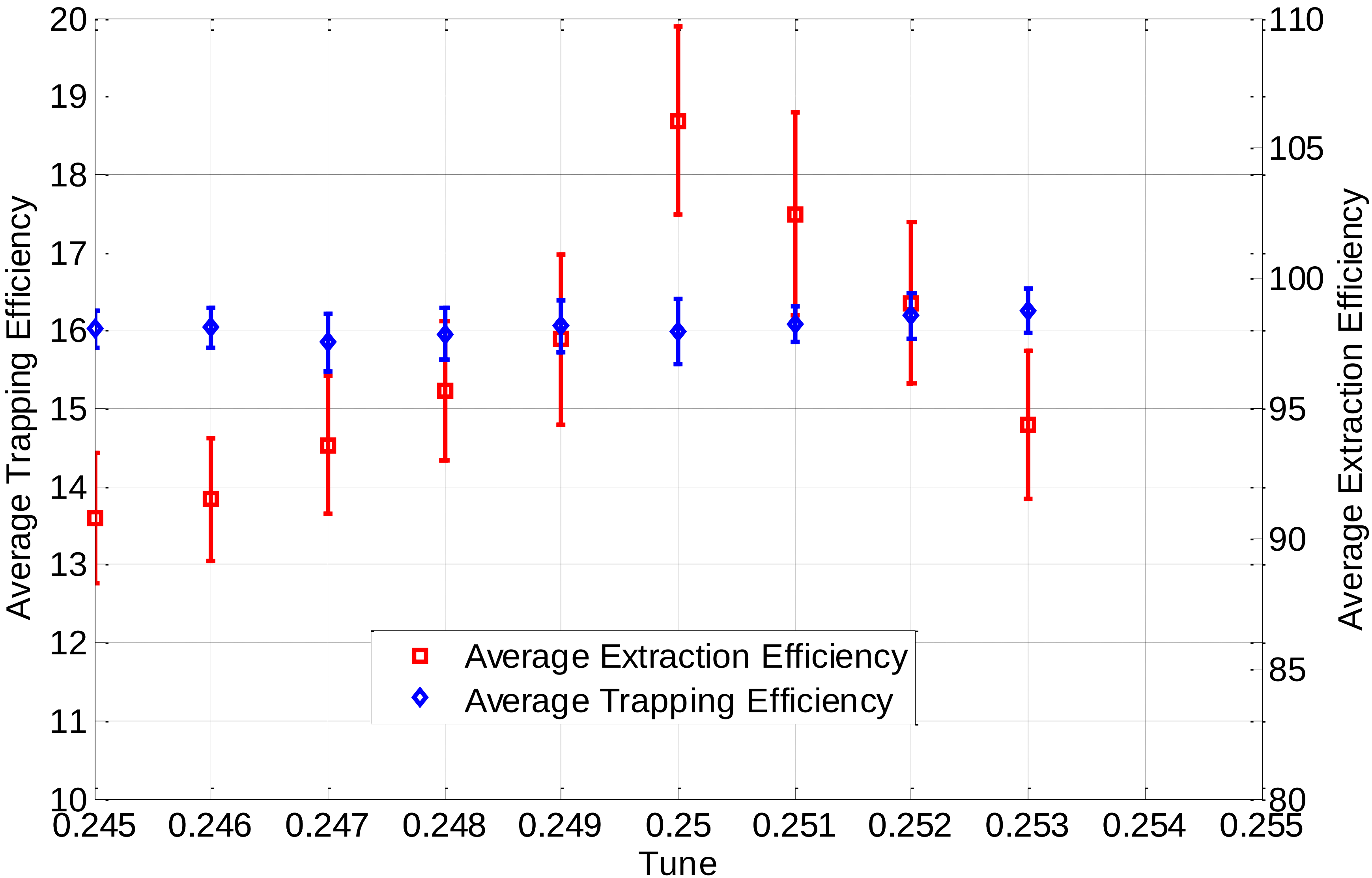


Damper effect – results - III



Broad maximum: length minimised to avoid emittance blow-up

Damper effect – results - IV



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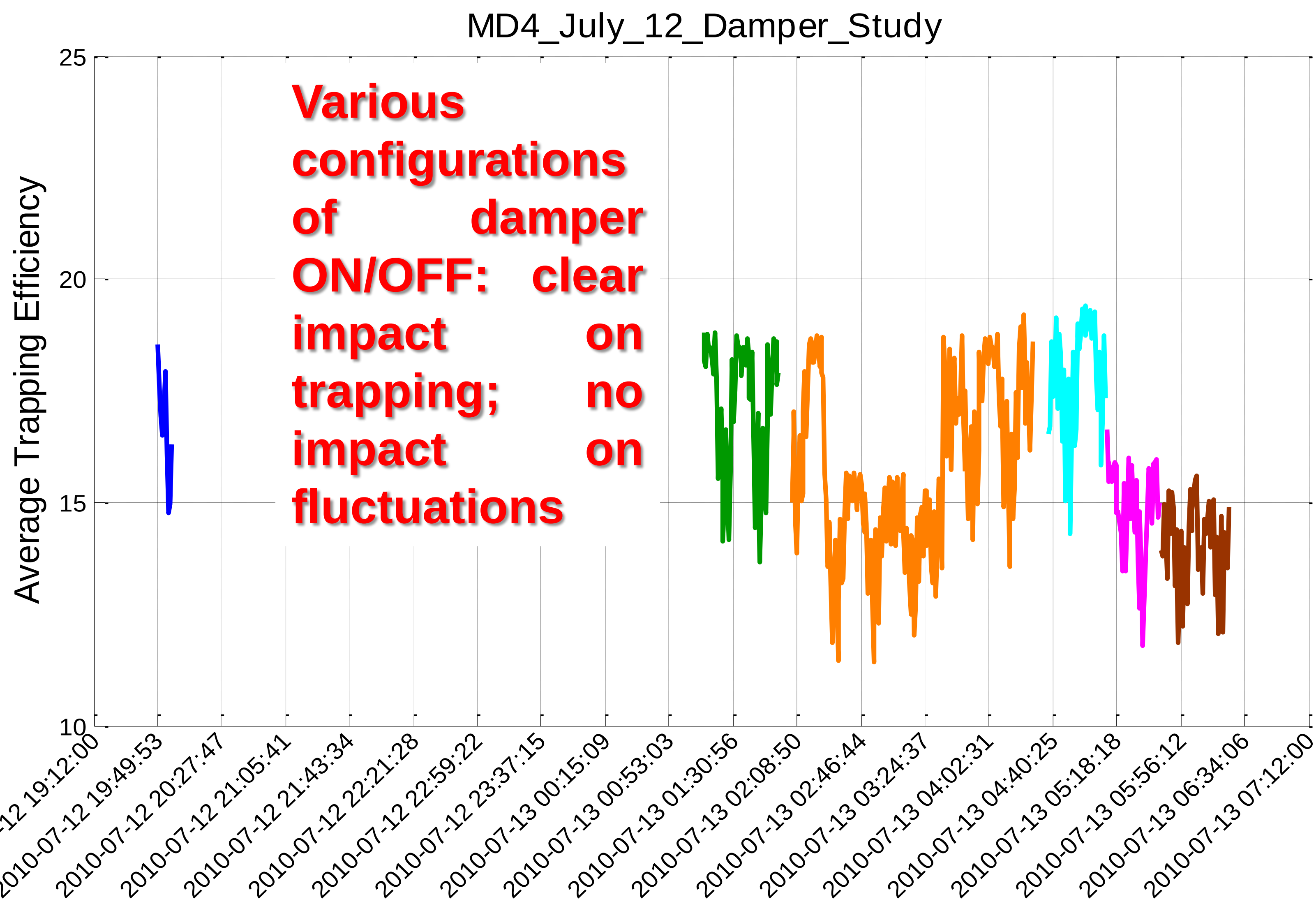
Damper effect – results - V

Various configurations of damper ON/OFF: clear impact on trapping; no impact on fluctuations



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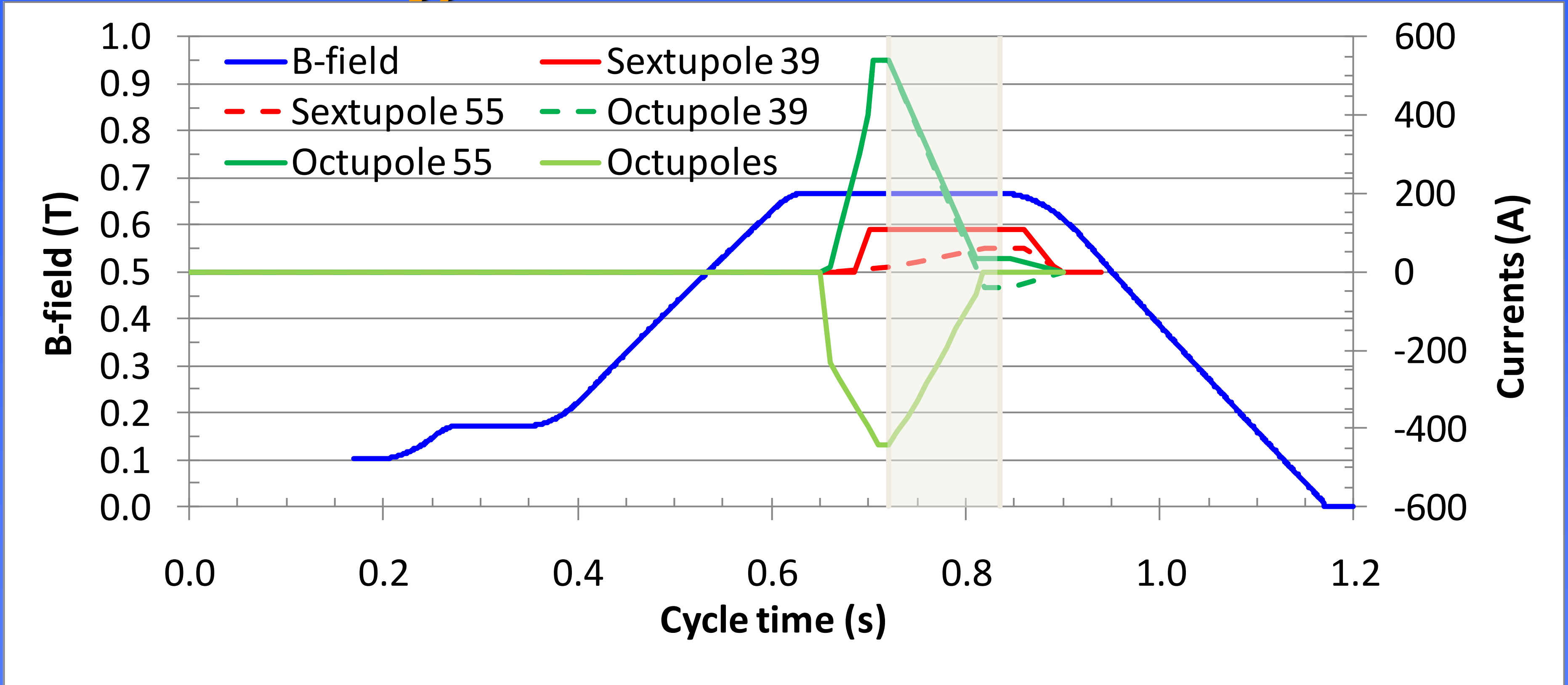
Damper effect - summary

- Mild dependence of trapping on h -> selected h=8
- Strong dependence of trapping on qx -> selected qx=0.25
- Threshold effects on start excitation -> selected 700 ms
- Broad optimum for excitation length -> selected 40 ms
- Essentially no impact of other options (type of modulation, slope in qx vs. time)

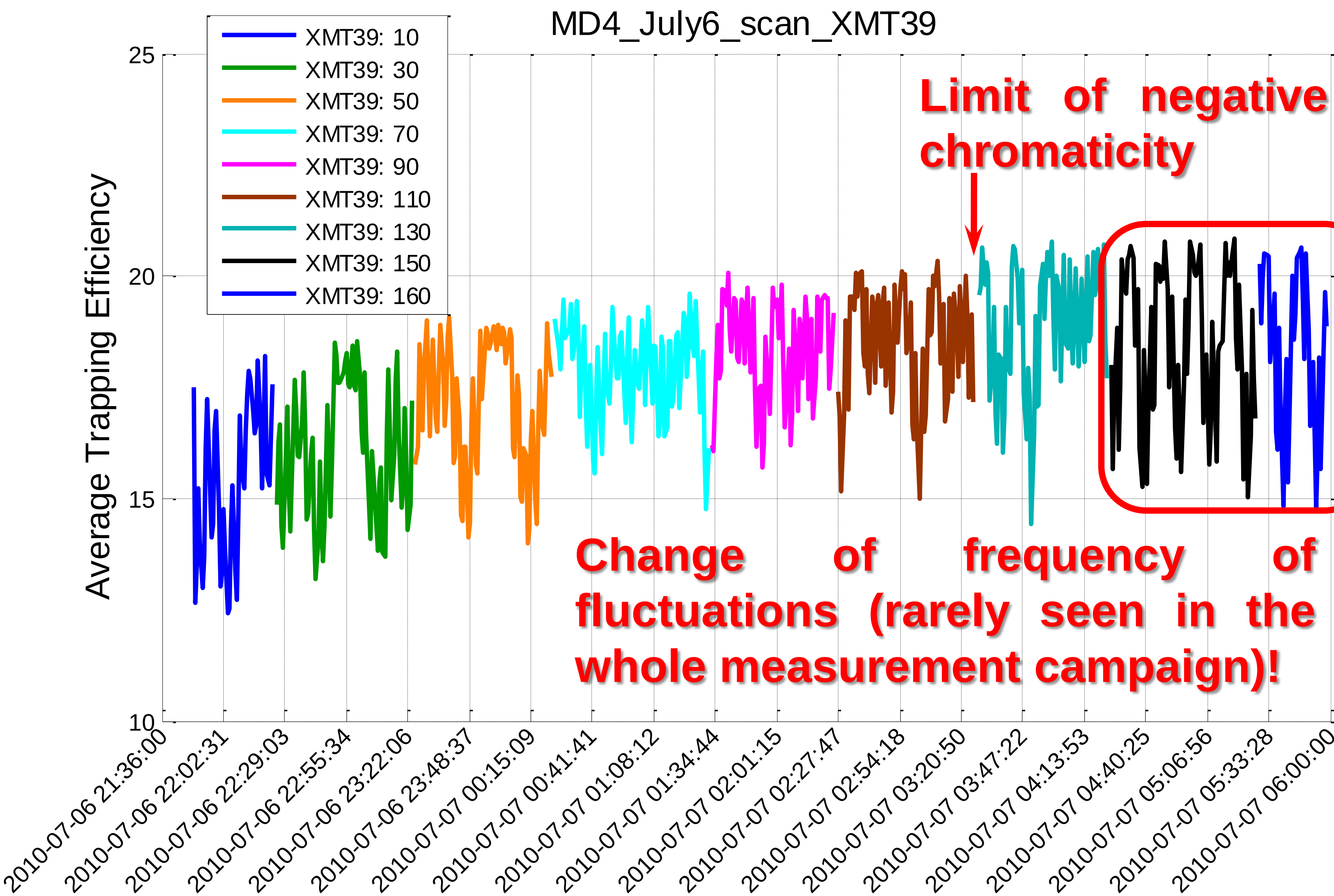
Strong impact on trapping efficiency of damper, but no impact on fluctuations.

Sextupoles/octupoles effect

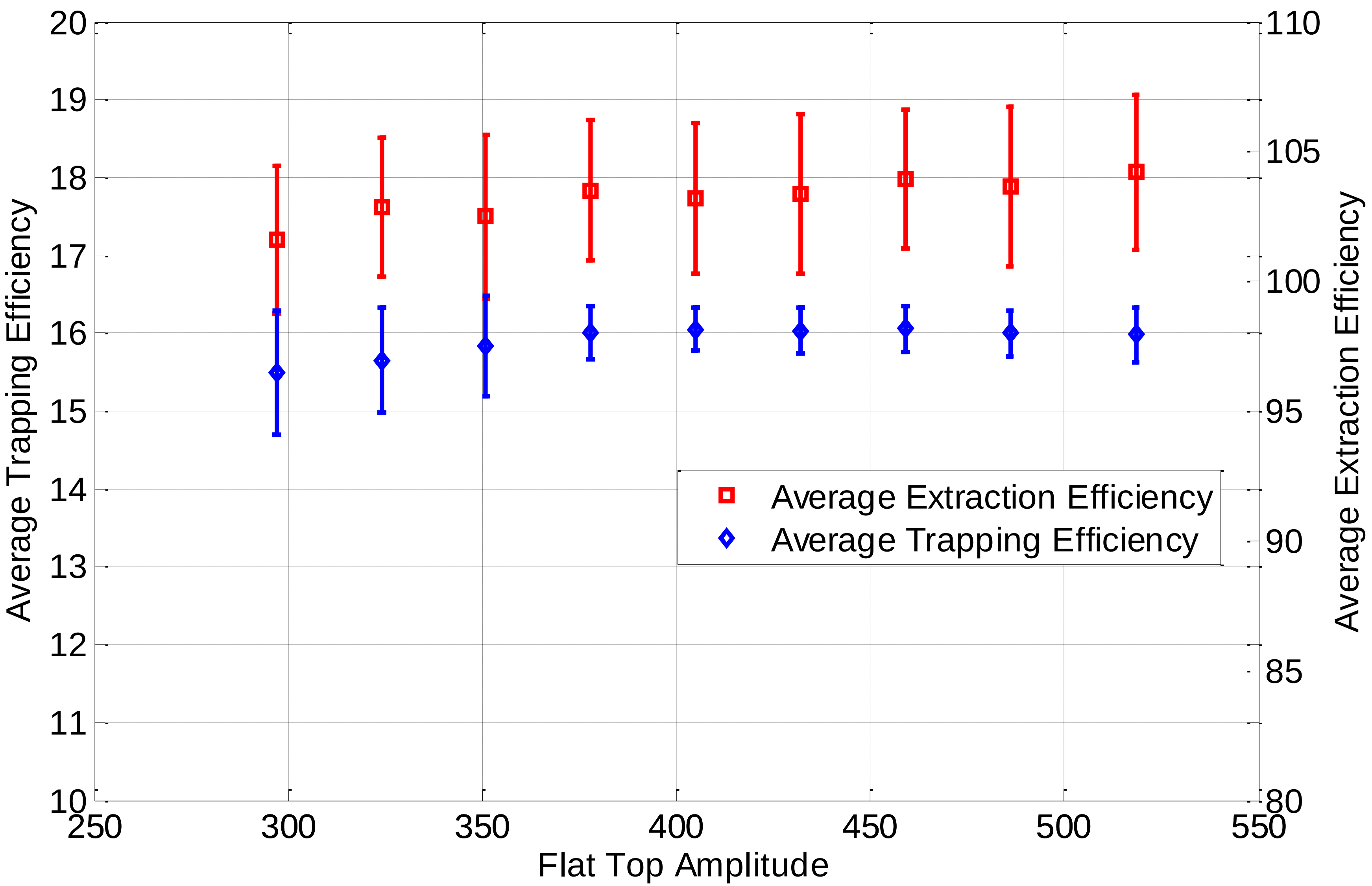
- ODEs are used to compensate the non-linear coupling between H/V plane.
- Sextupoles should not generate negative chromaticity (increasing their strengths reduces chromaticity)!



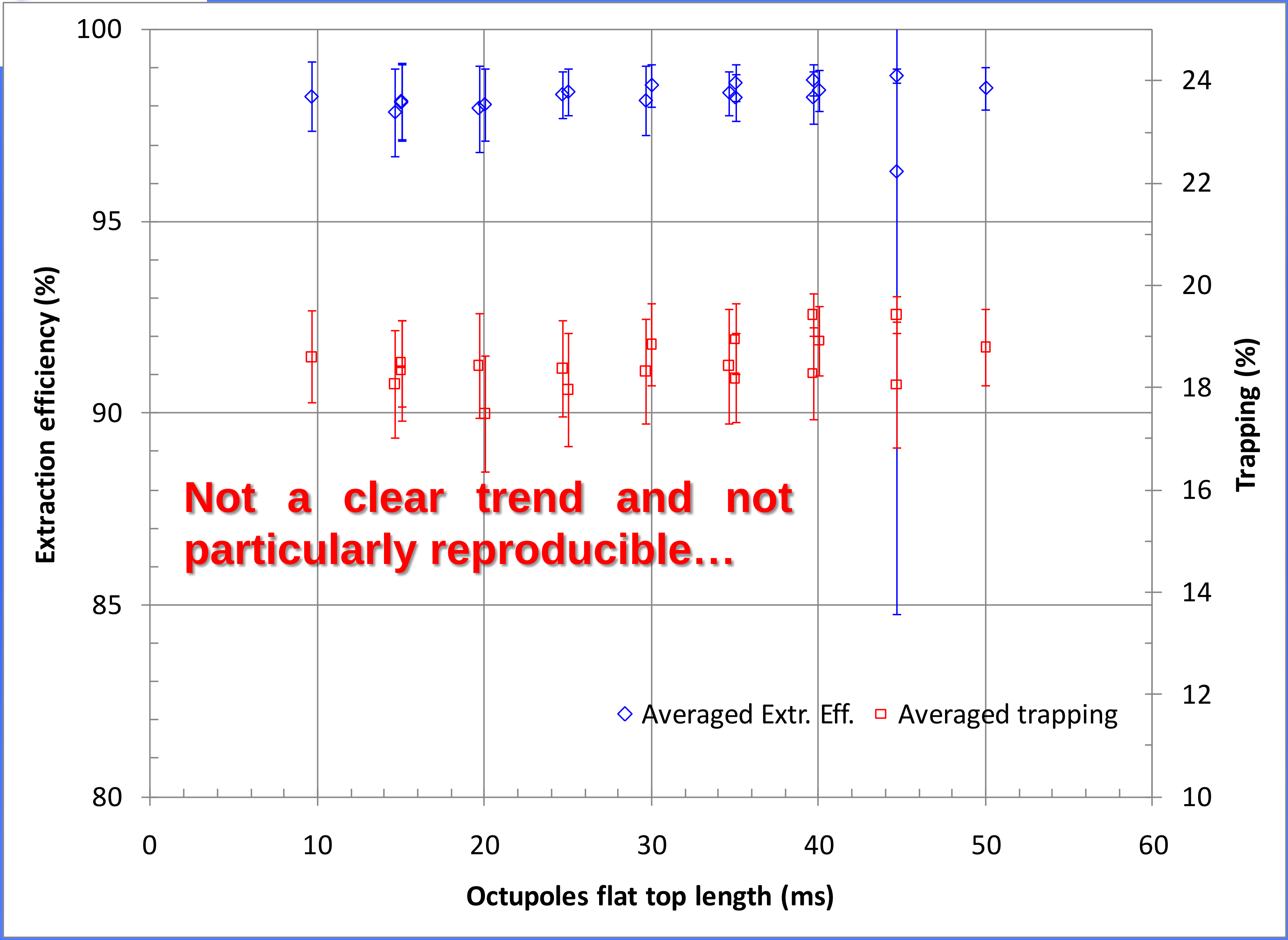
Sextupoles/octupoles – results - I



Sextupoles/octupoles – results - II



Sextupoles/octupoles – results - III



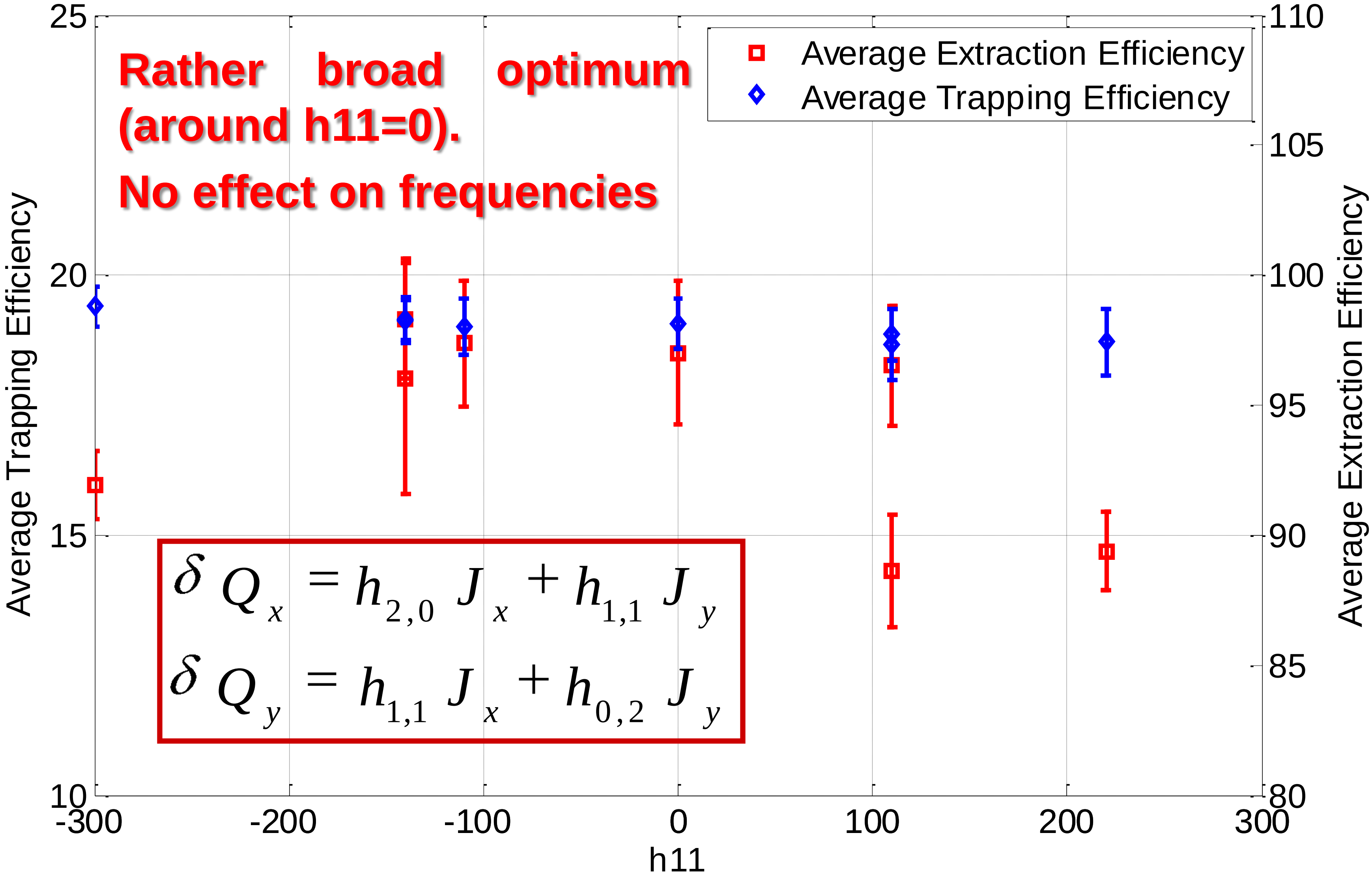
Sextupoles/octupoles – results - IV

Rather broad optimum (around h11=0).

No effect on frequencies

$$\delta Q_x = h_{2,0} J_x + h_{1,1} J_y$$

$$\delta Q_y = h_{1,1} J_x + h_{0,2} J_y$$



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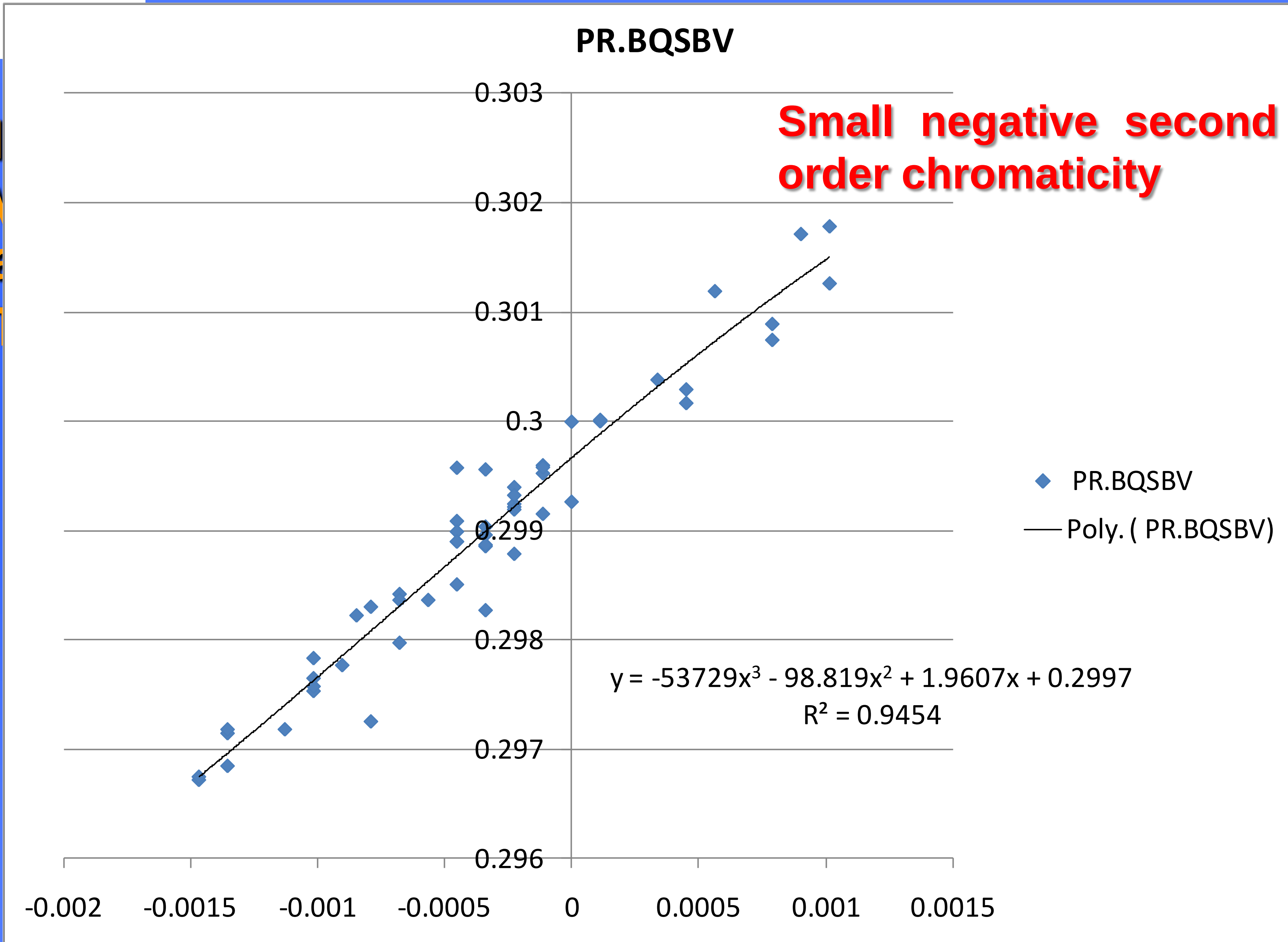
Sextupoles/octupoles effect - summary

- Mild dependence of trapping on OMTs strength at top energy
- Mild dependence of trapping on OMTs flat top length
- Broad optimum of h11 around 0.
- Clear impact of XMT39 strength on trapping and frequencies

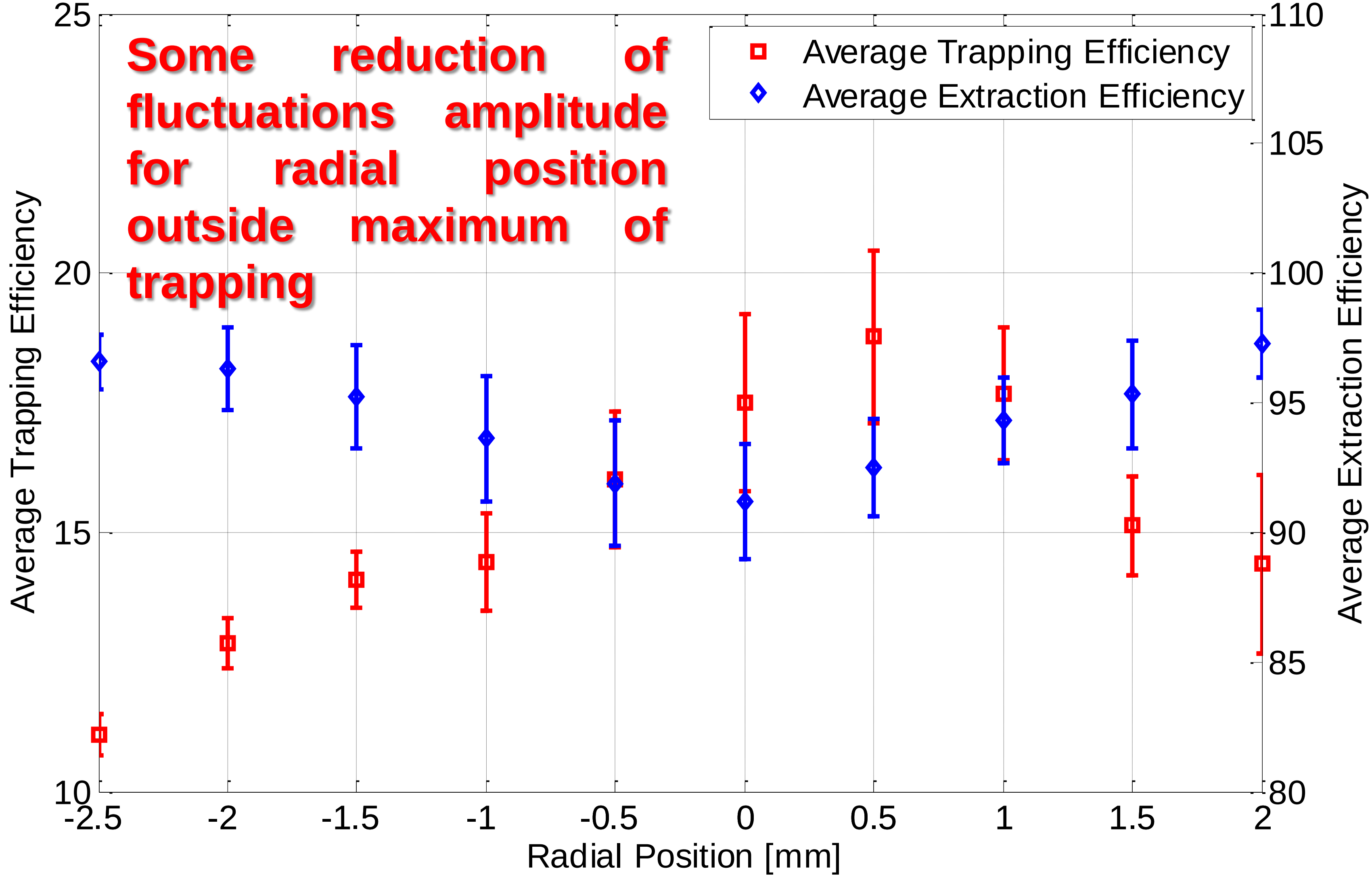
No strong impact of sectupoles/octupoles on amplitude of fluctuations.

CERN PS Multi Turn Extraction

Radial position effect



Radial position effect - results



CERN PS Multi Turn Extraction

Some figures

- **Amplitude of fluctuations is about 3-4%.**
- **From the results of the measurements this could be generated by:**
  - Fluctuation in the start timing of t[illegible]per -> 20 ms
  - Fluctuation in the quadrupole[illegible]ings to generate a jitter of 20 ms in the reso[illegible]crossing timing
  - Fluctuation in the q_x va[illegible]he damper -> ~2×10^{-3}
  - Fluctuation in the q[illegible]poles' settings to generate a tune fluctuatio[illegible]
  - Fluctuation i[illegible]eference of f_{rev} for the damper -> ~2×10^{-4} (as[illegible]g h=8)
  - Fluctu[illegible]r the radial position -> ~1 mm
  - Flu[illegible]n in beam energy/B_{field} -> 0.6×10^{-3}

These effects have not been found (yet)

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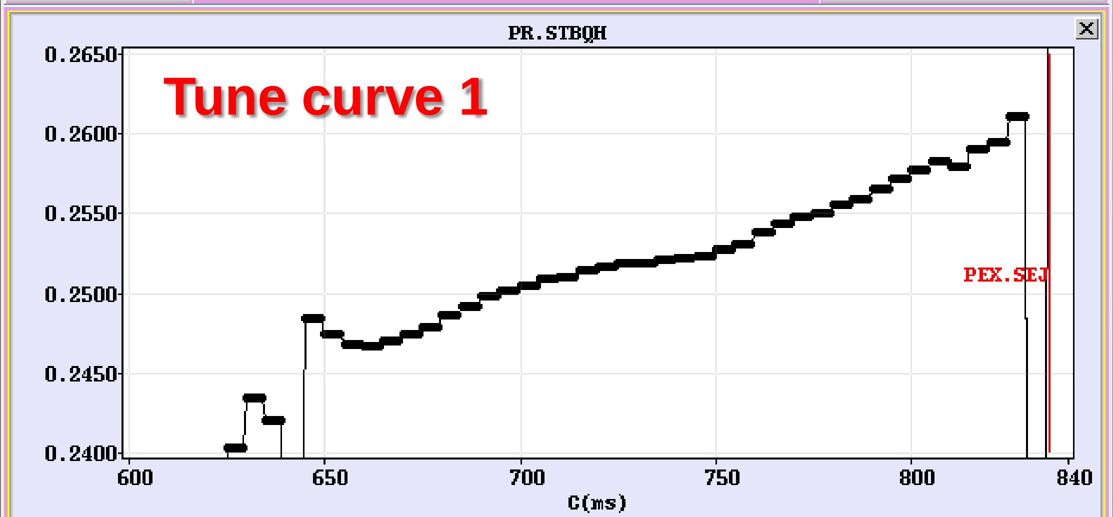
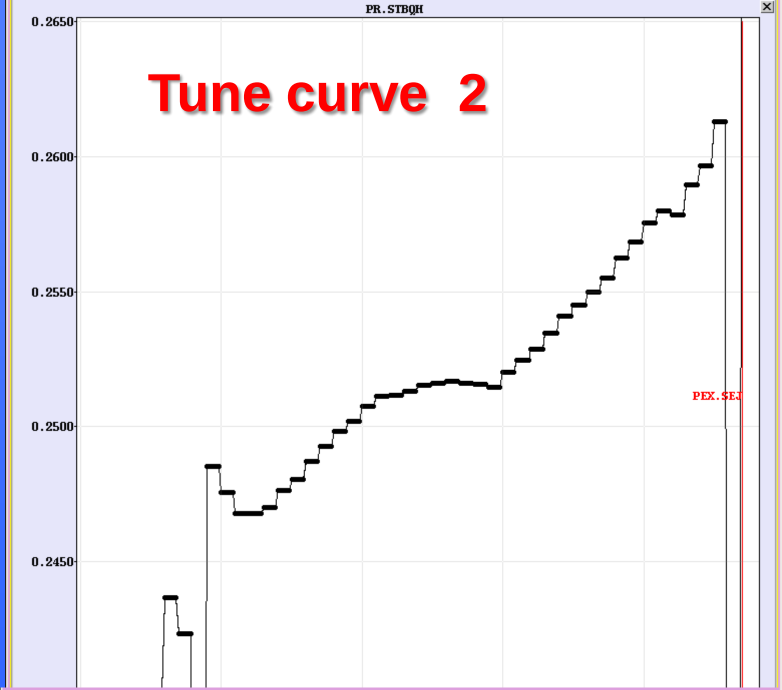
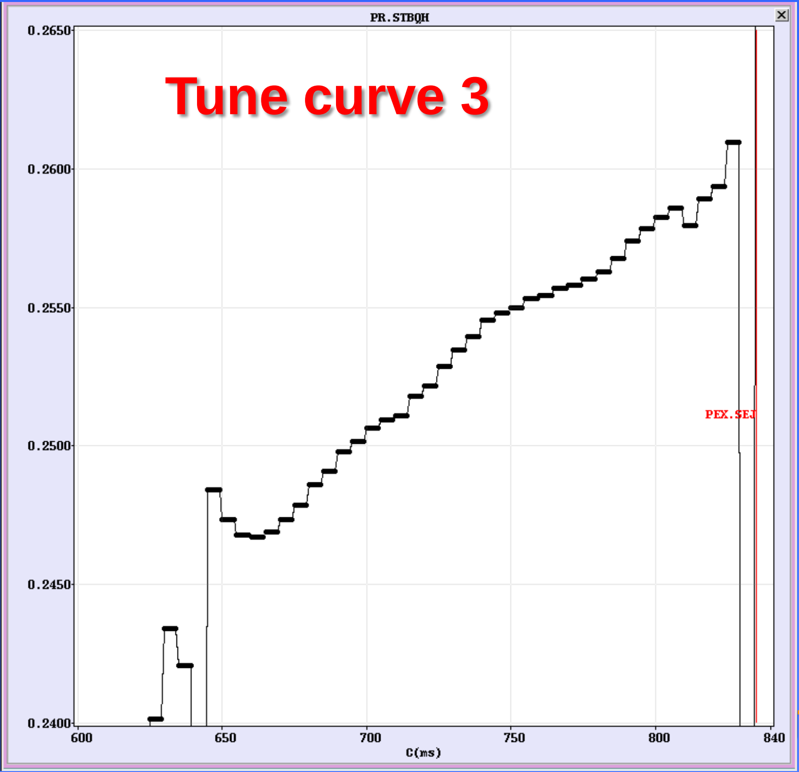
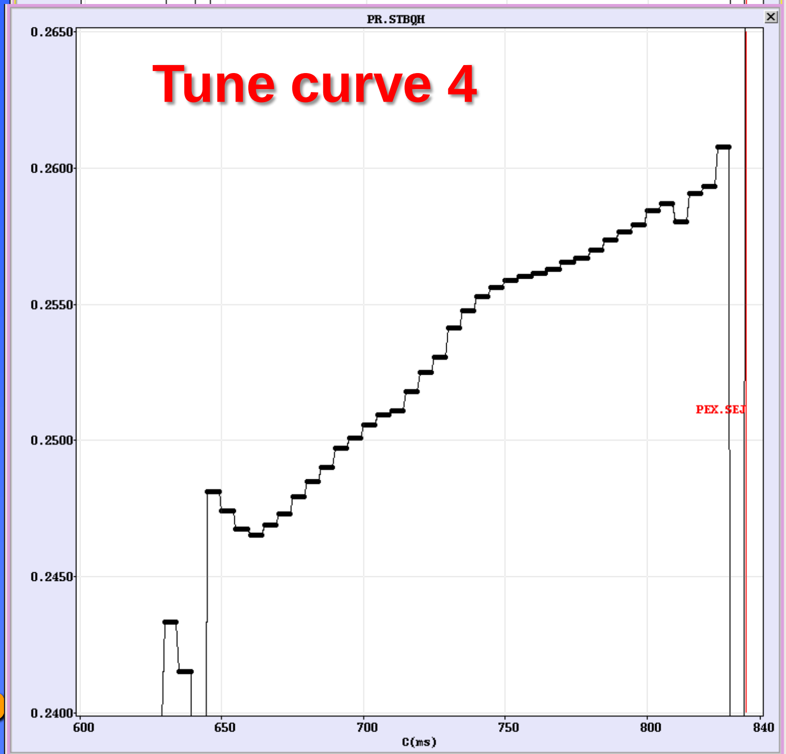
Impact of tune

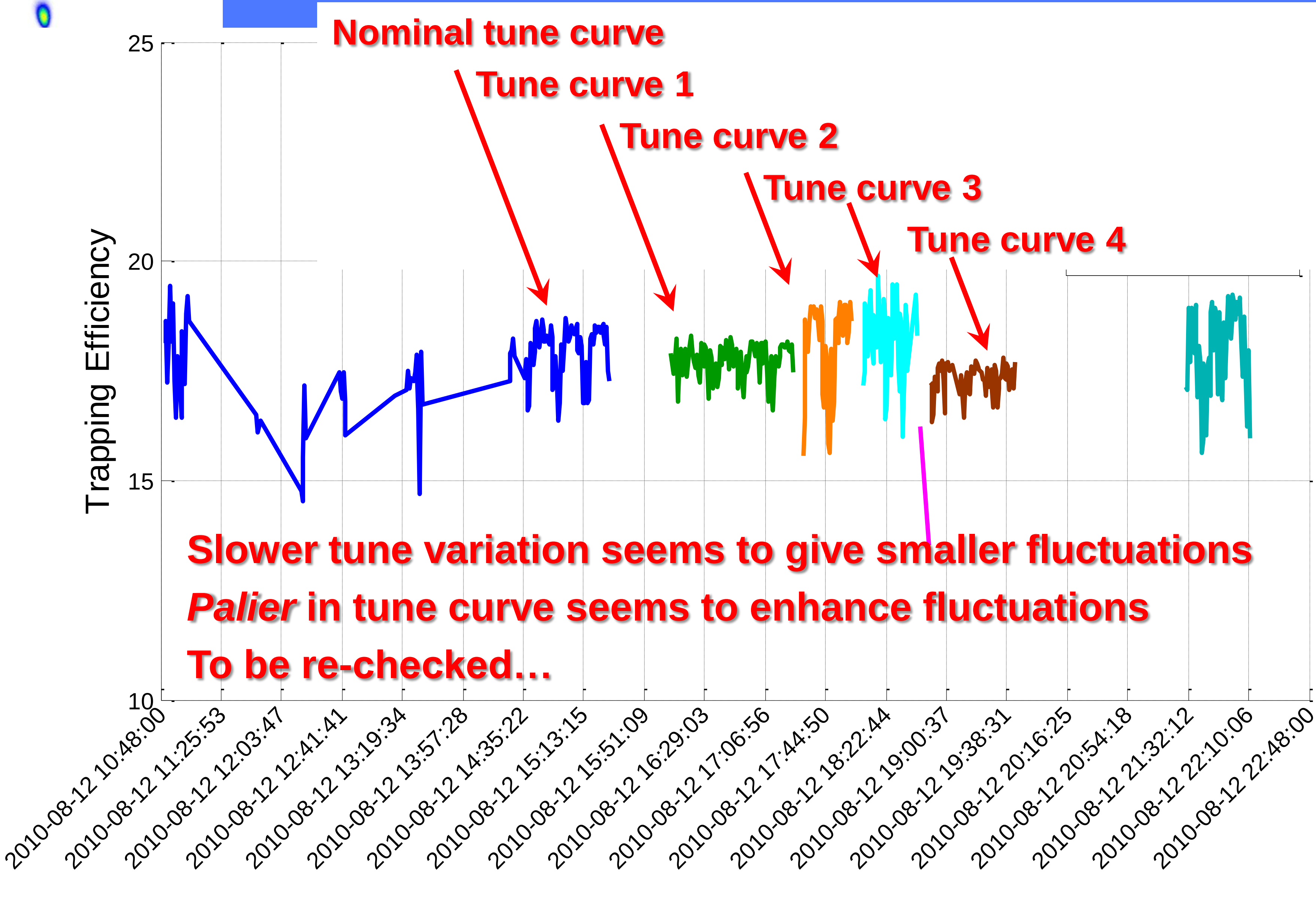








Impact of tune variation – results - I



Slower tune variation seems to give smaller fluctuations

Palier **in tune curve seems to enhance fluctuations**

To be re-checked…

Impact of intensity

- To assess the impact of intensity on splitting behaviour:
  - MD1: initial beam used for SPS setting up. Total intensity of about 3-4×10^{12} ppp.
  - MD4: intermediate intensity about 1.7-1.8×10^{13} ppp.
  - MD4: high intensity about 2.1×10^{13} ppp.

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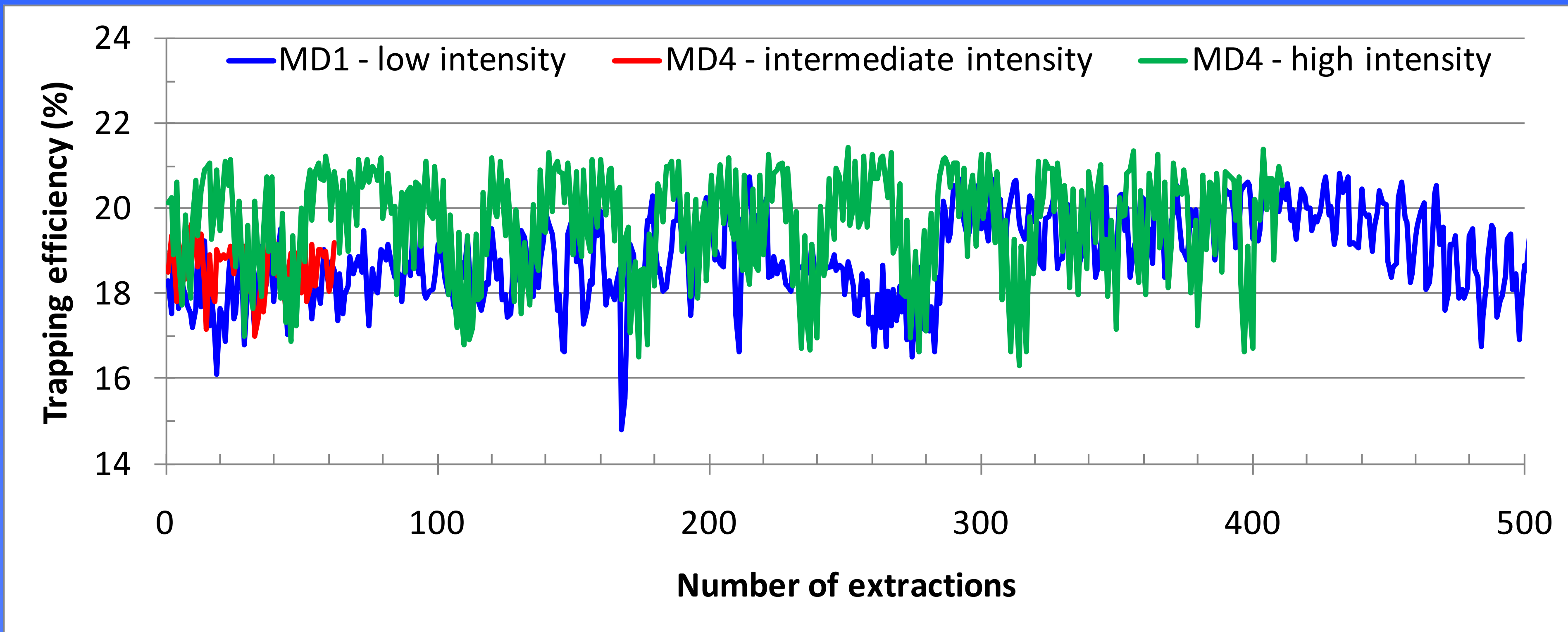
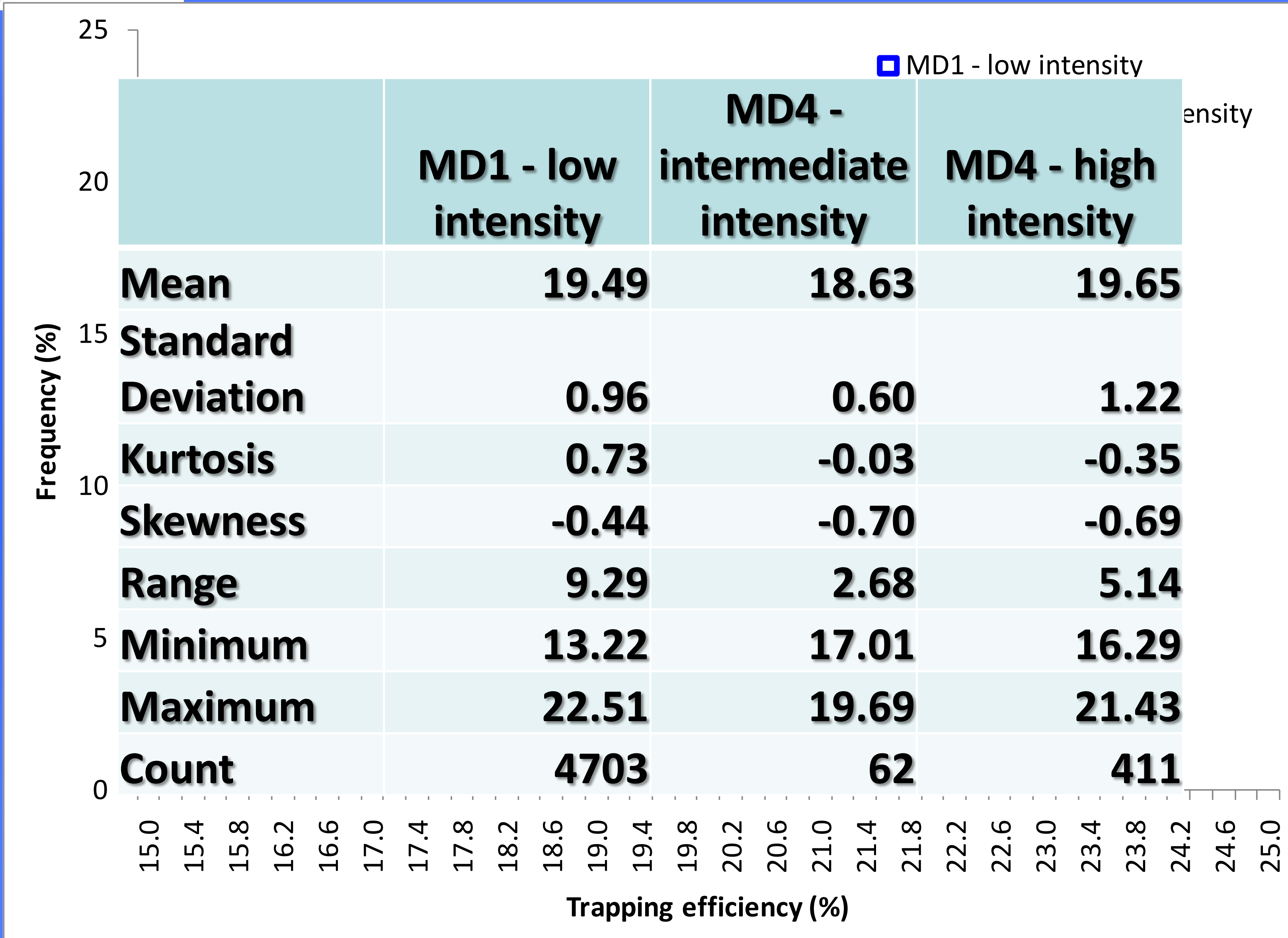
  - MD4: high intensity about 2.1×10^{13} ppp.

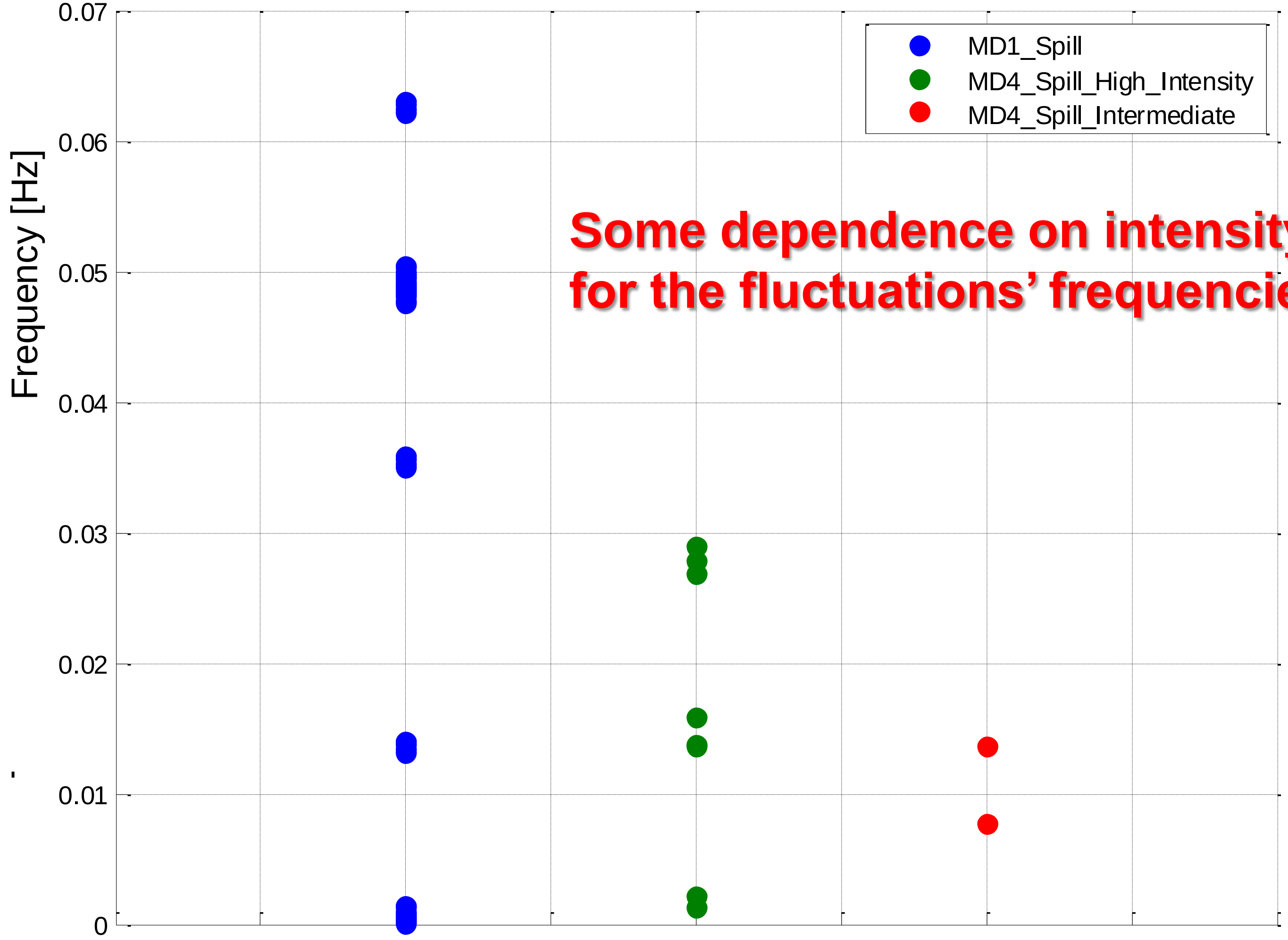


Impact of intensity – results - I

	MD1 - low intensity	MD4 - intermediate intensity	MD4 - high intensity
Mean	19.49	18.63	19.65
Standard Deviation	0.96	0.60	1.22
Kurtosis	0.73	-0.03	-0.35
Skewness	-0.44	-0.70	-0.69
Range	9.29	2.68	5.14
Minimum	13.22	17.01	16.29
Maximum	22.51	19.69	21.43
Count	4703	62	411



Impact of intensity – results - II



Some dependence on intensity for the fluctuations' frequencies

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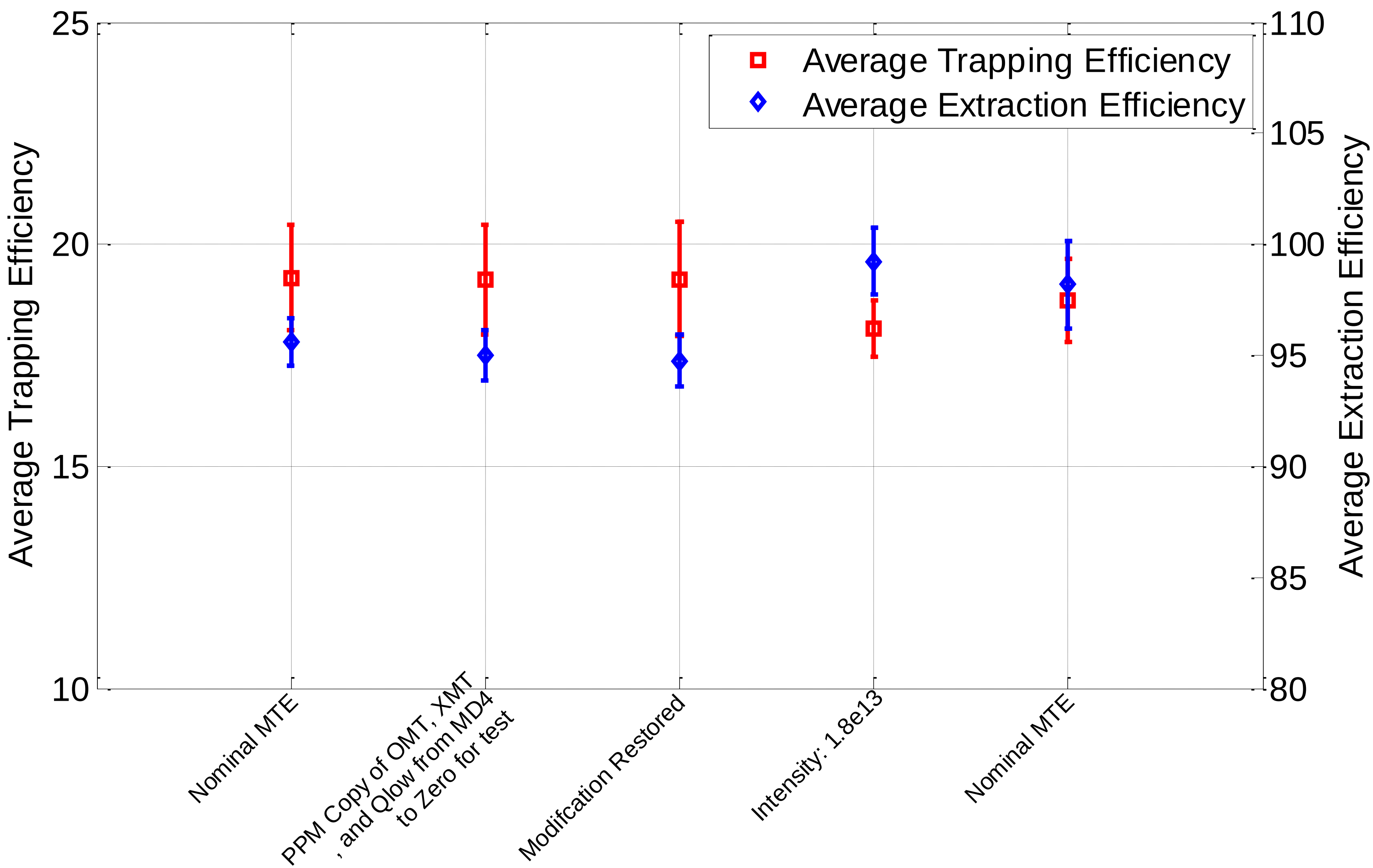
Other checks: magnets pulsing on zero cycle

- Test to assess impact of MTE elements pulsing on other users.
- Selected ZERO cycle.
- Copied:
  - XMTs
  - OMTs
  - Low energy quadrupoles

No impact at all on trapping and fluctuations

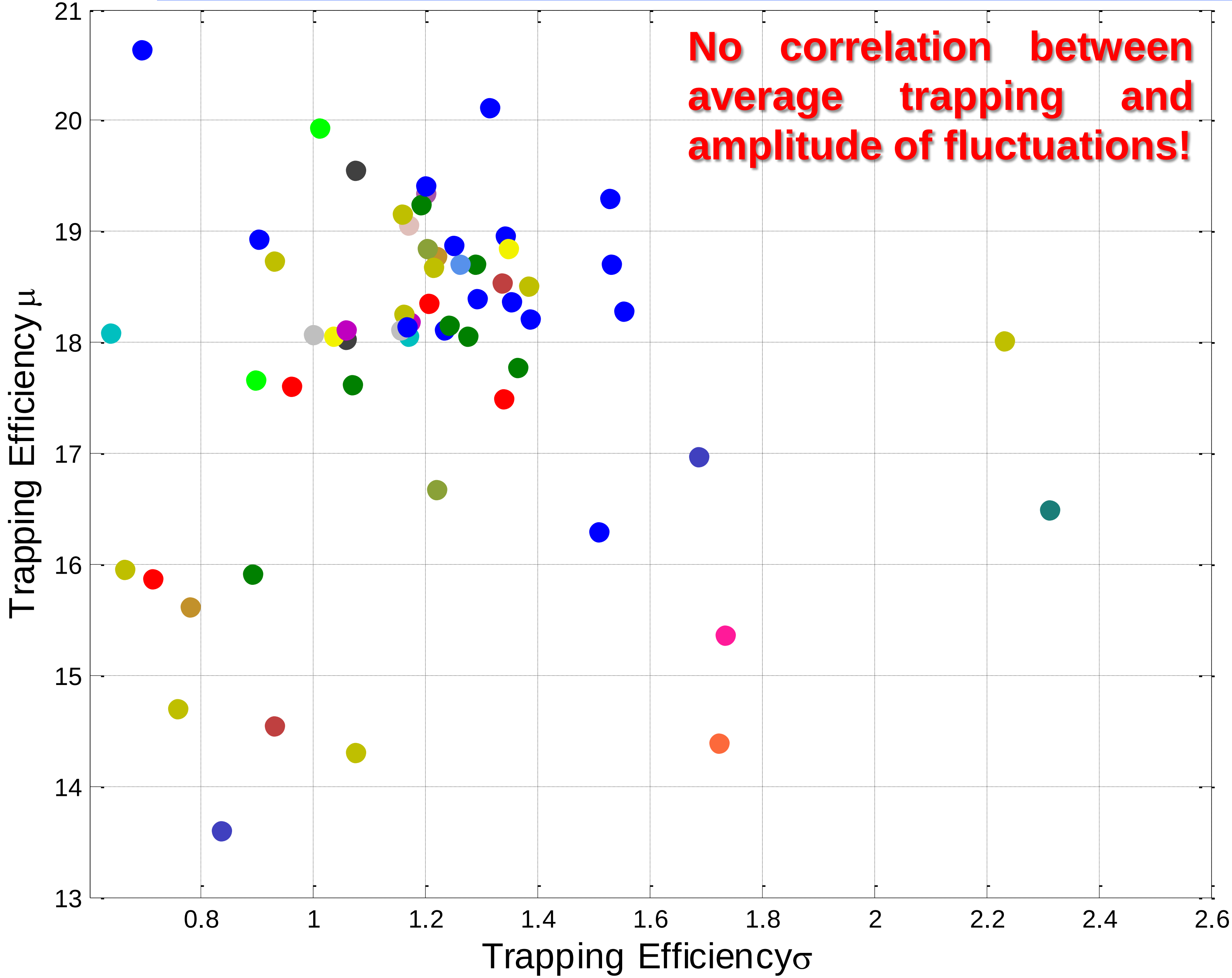
Other checks: magnets pulsing – results



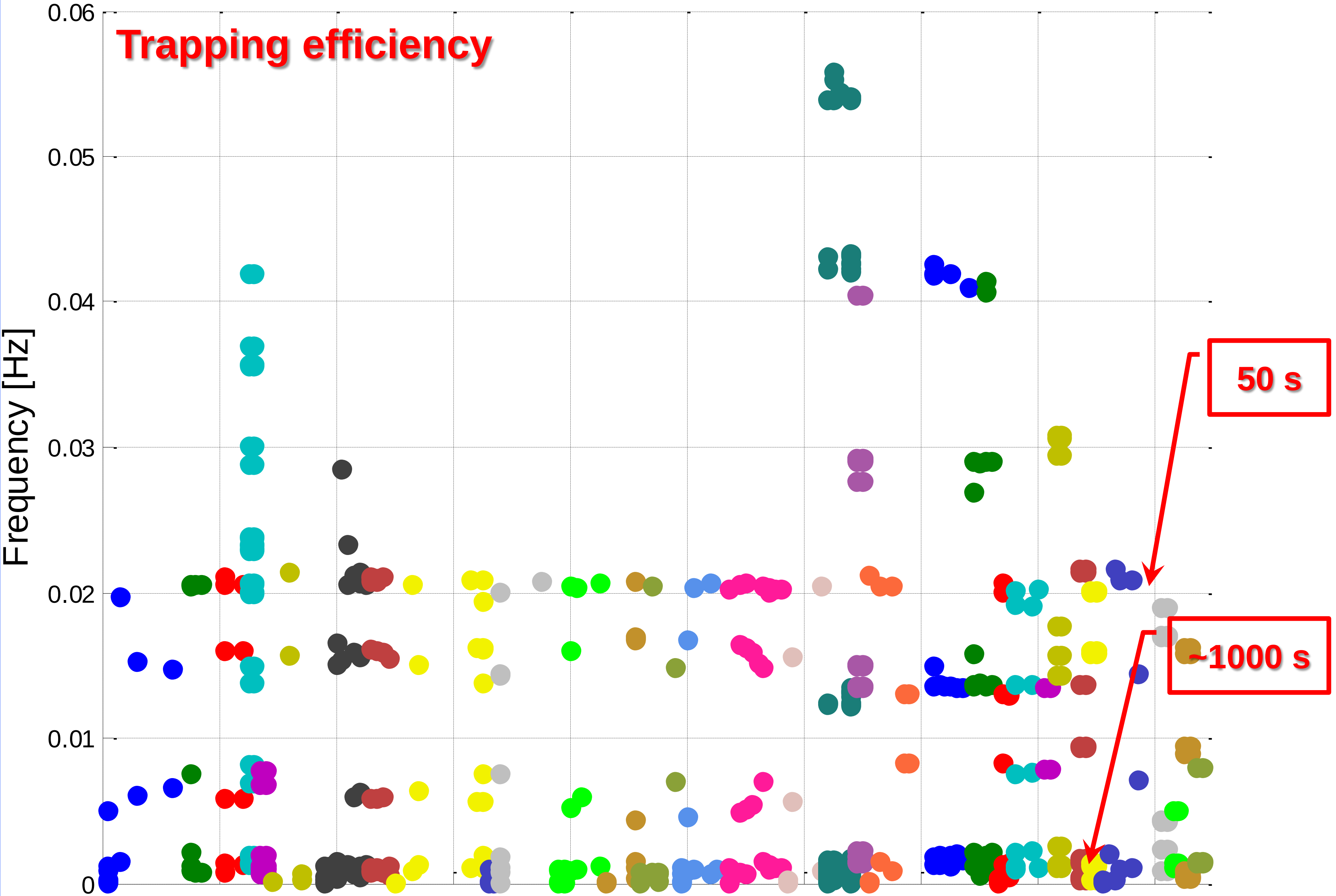
Global overview of studies - I

CERN PS MULTI TURN EXTRACTION

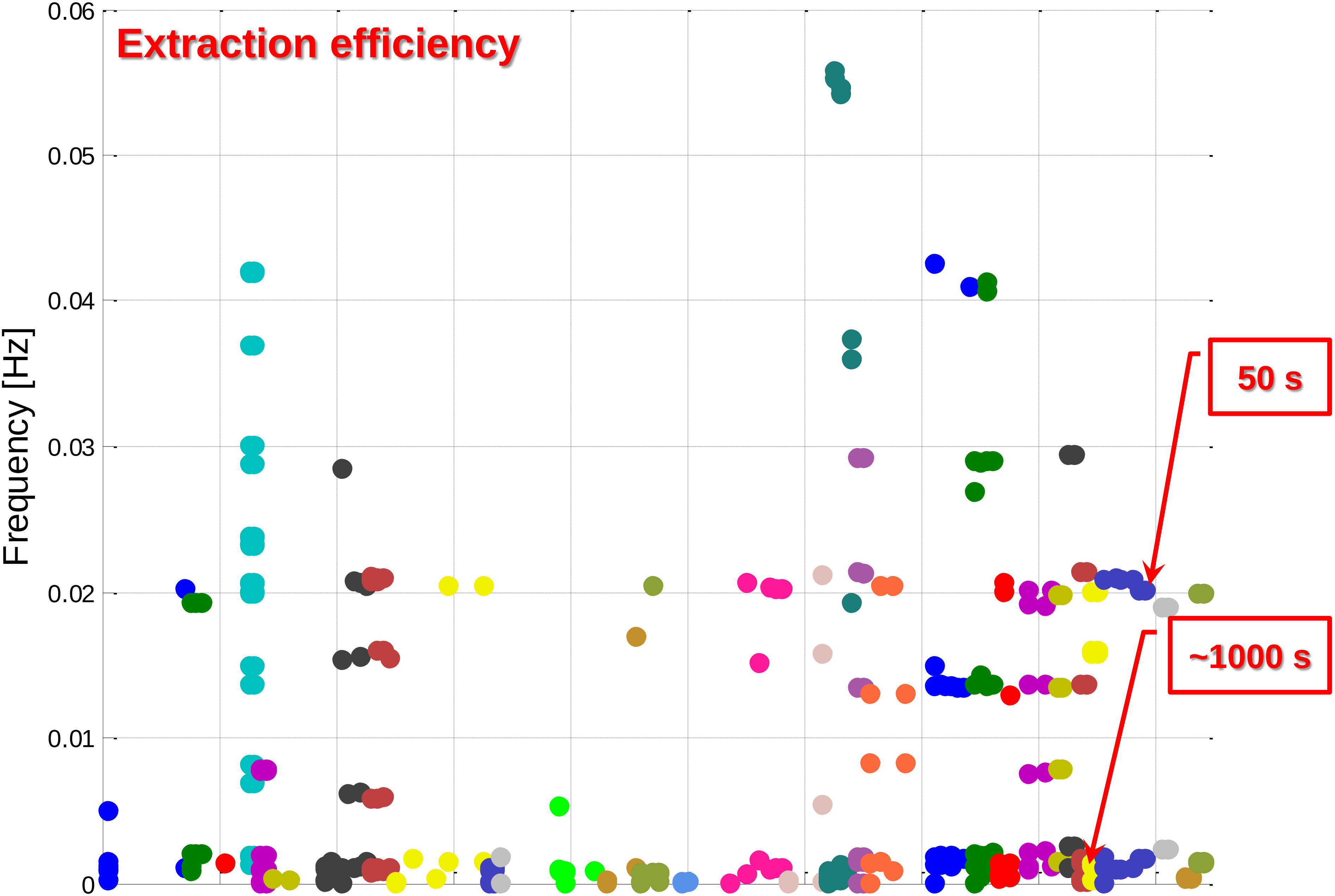
Global overview of studies - II



Global overview of studies - III

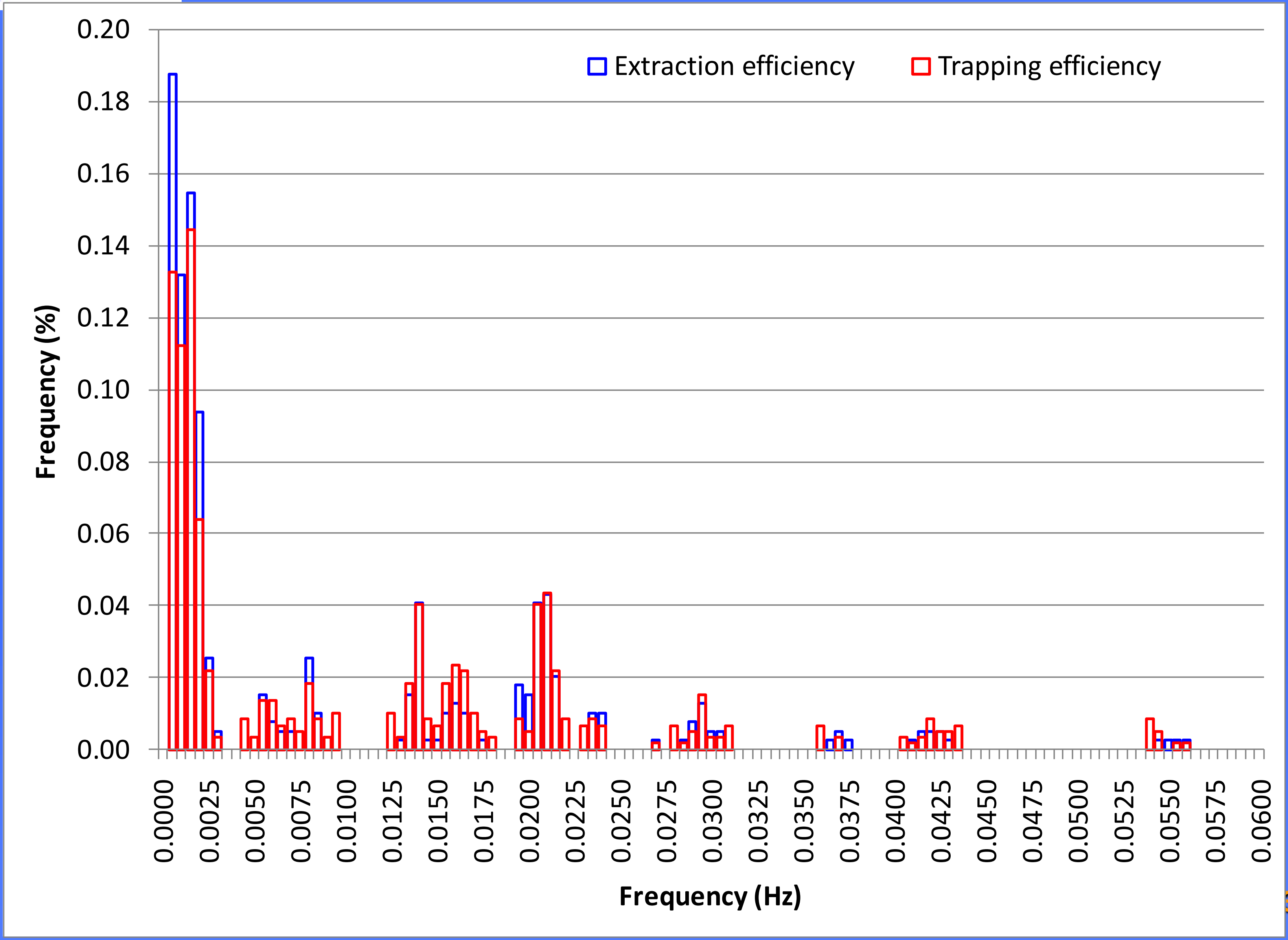


Global overview of studies - III

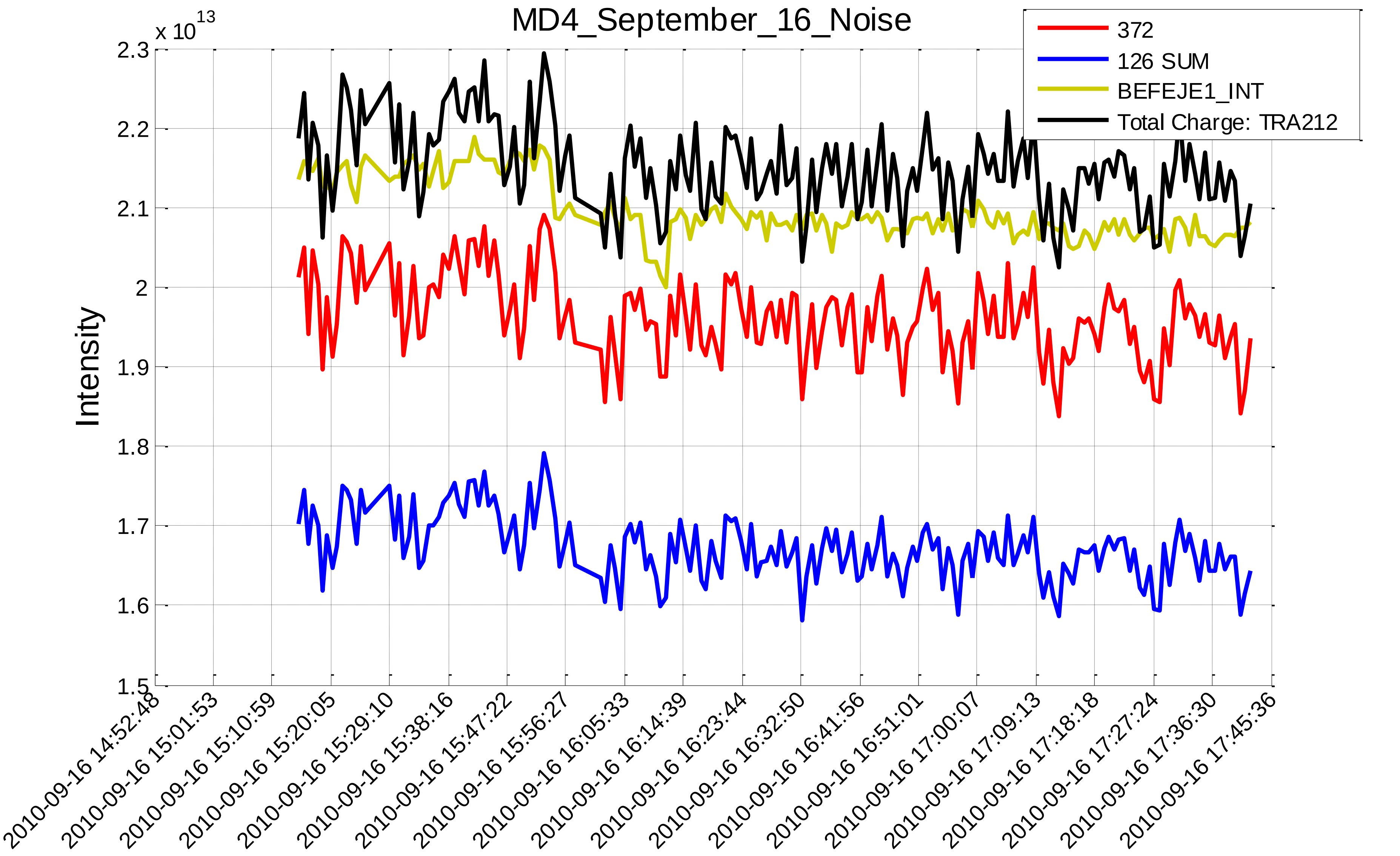


CERN PS MULTI TURN EXTRACTION

Global overview of studies - IV



Comments on BCTs in TT2



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Outlook

- Detailed studies of the dependence of the trapping on many parameters done.
- Optimisation done for:
  - damper settings
  - sextupoles
  - octupoles
  - radial position
- Still some studies to be performed with the variation of the tune with time.
- Fluctuations are still there:
  - They seem intrinsic to the splitting process
  - They are not affected by the damper
  - They are generated during the splitting proper
  - Fluctuations amplitude: not particularly affected by the parameters analysed so far
  - Fluctuations frequency: seems to be affected by chromaticity and intensity