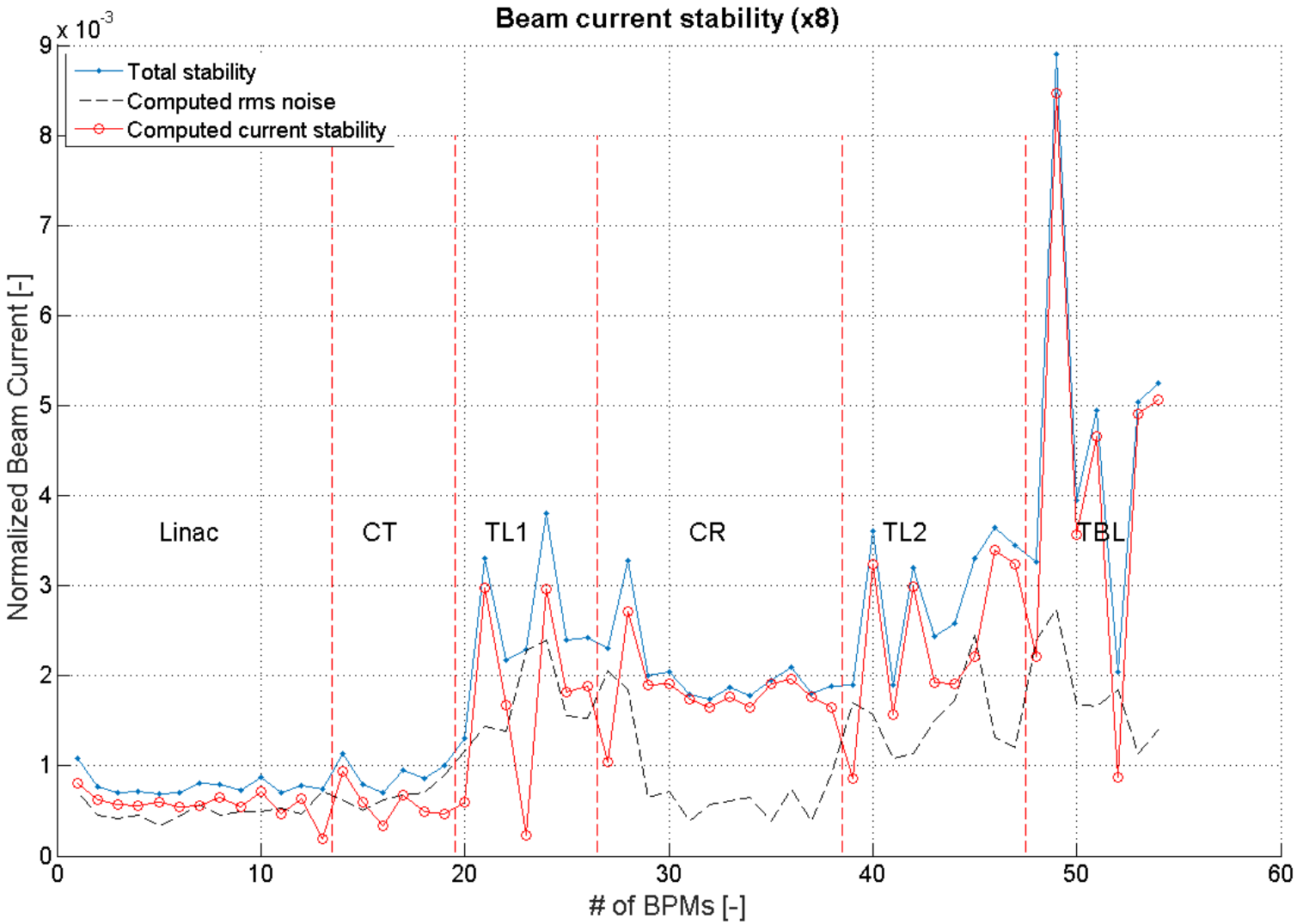
Stability and Feedbacks in CTF3

Presenter: Lukáš Malina

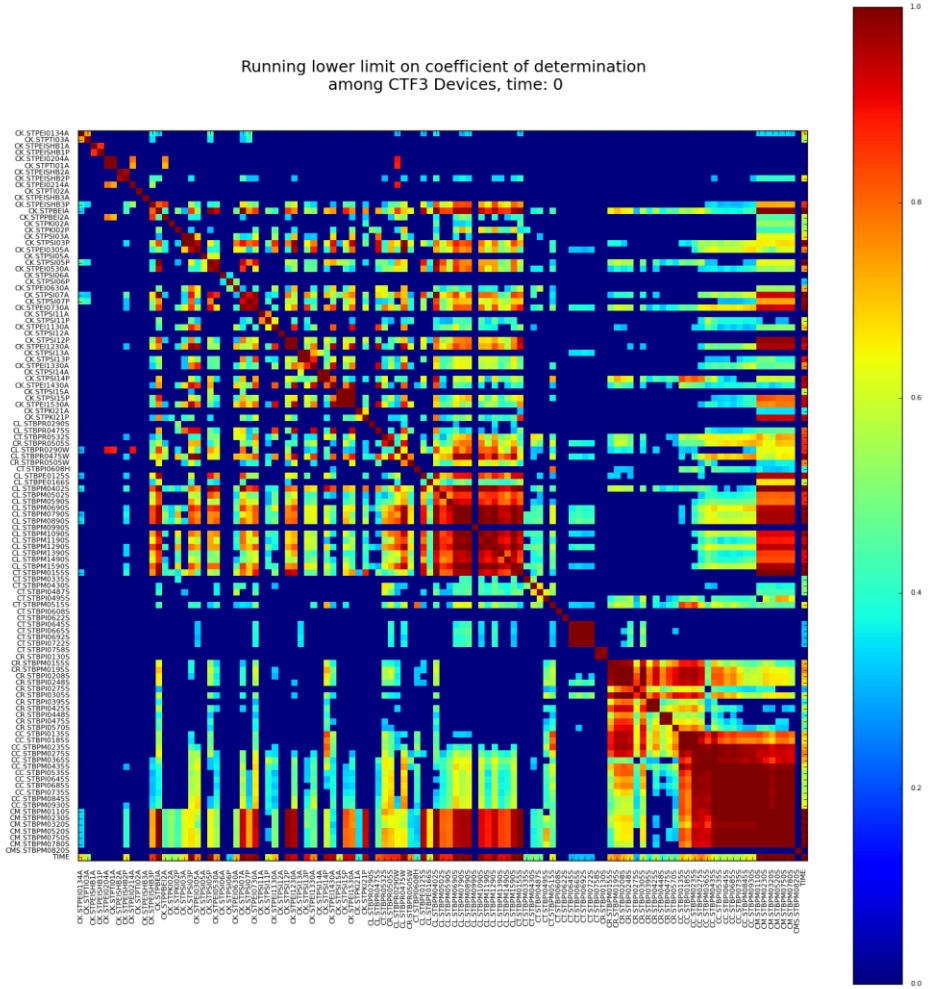
2015 factor 8 stability



- The best achieved
- Period of ~ 2-3 minutes
- In 2016 we focused on longer timescales

Drift and correlation searching tool

- Looks how much is the correlation coefficient of two signals inconsistent with zero (no correlation) in sliding time window
  - Given the requested confidence level and the timescale



Feedbacks

RF feedbacks

- Pulse compressor temperature feedbacks
- Klystron power flattening feedbacks
- RF Phase-loops
- Phase-loops for TWTs NEW

Beam-based feedbacks

- Gun Current feedback*
  - improved hardware
- TWTPhase feedback
- Injector feedback*
  - improved hardware and operational behaviour
- Loading feedbacks*
  - improved penalty function, speed and hardware
- Energy flattening feedback
- BPR0475W flattening NEW

* - Became operational for dogleg beam with quite different parameters (beam current and pulse length)

Hardware improvements

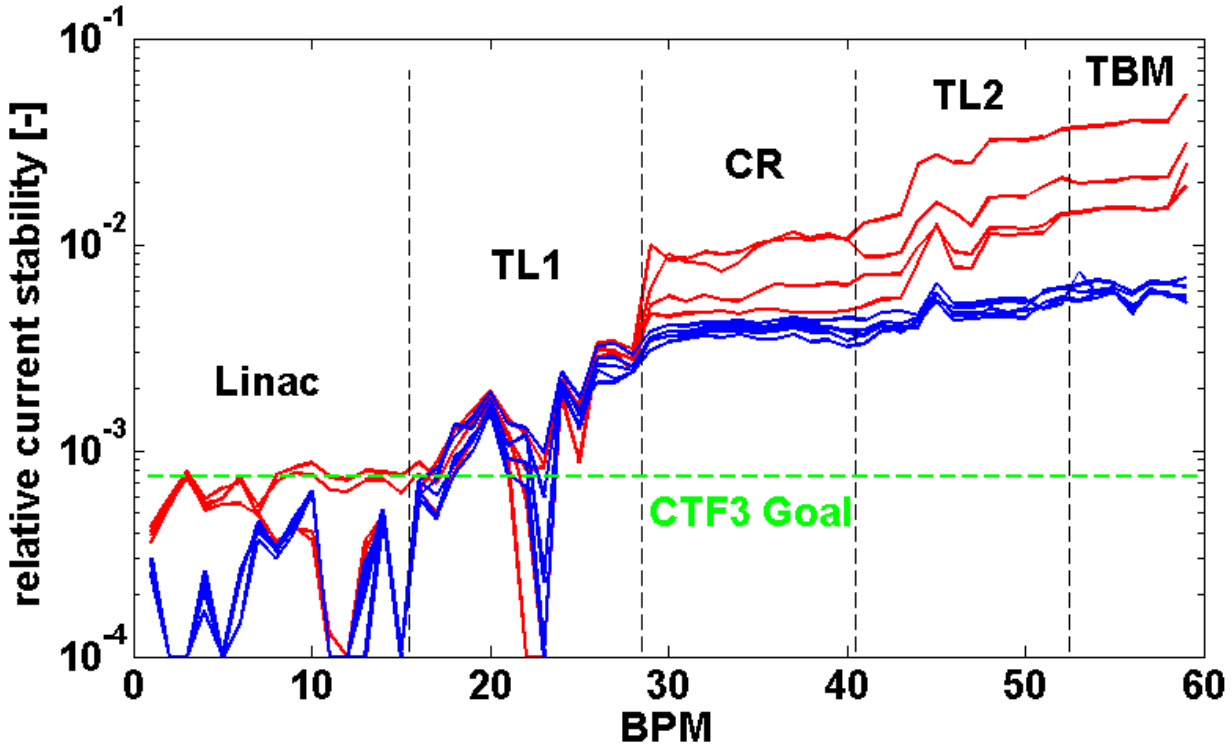
- Minimal phase shifter step in two injector klystrons (2 and 3) has been reduced from 0.36° to 0.01°
- BPR0290S resolution improved by additional amplification to use full dynamic range
- Attenuation from power signals at the exit of structures 6 and 12 has been removed
- Gun pulser has been exchanged
- Unused stepping motors at girder 4 were inducing noise at BPM0402
  - Disconnected – reduced noise by factor 3

Beam phase and energy stability

- **Beam phase 0.15° - 0.3°**
  - In long-term typically limited by the drift of the phase measurement
- **Beam energy ~ $8 \cdot 10^{-4}$**
  - If pulse-to-pulse stability of gun is good the relative energy stability may go down to $5 \cdot 10^{-4}$

- **CLIC Stability Goals**
- **Beam phase ~ 0.2 °**
- **Beam energy ~ 10^{-3}**

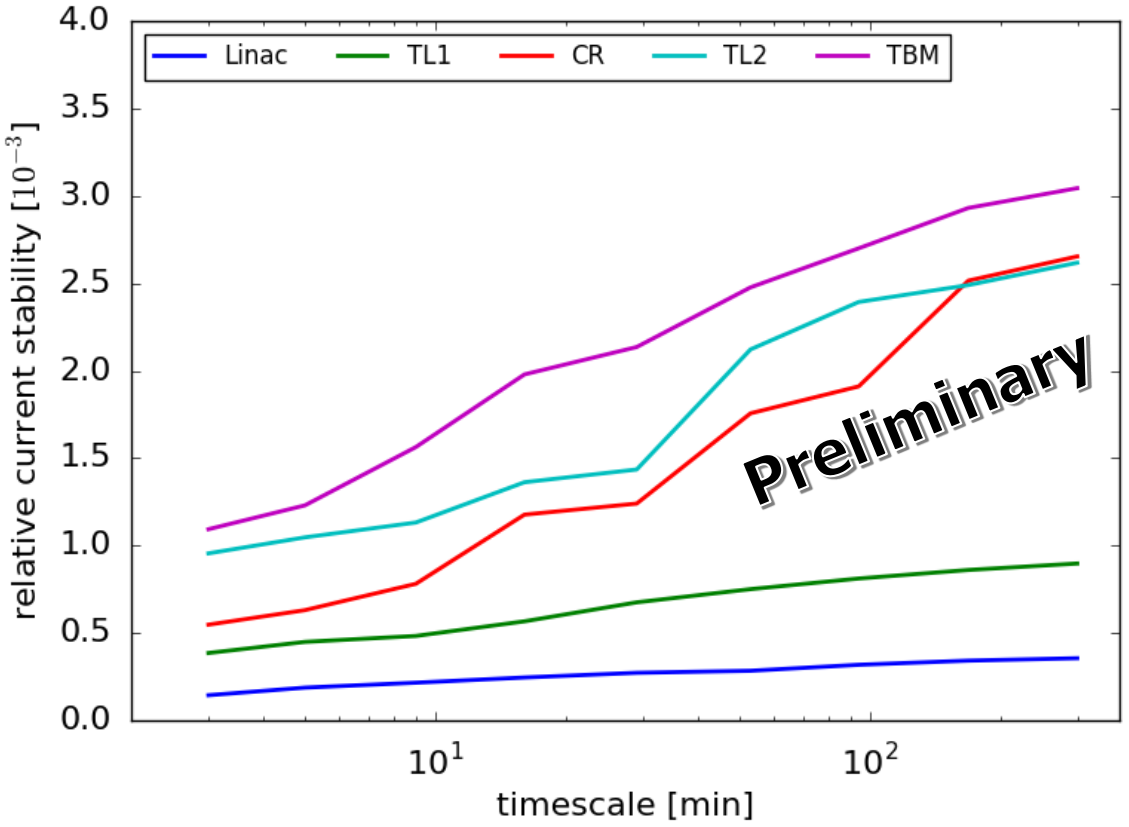
Effect of beam-based feedbacks



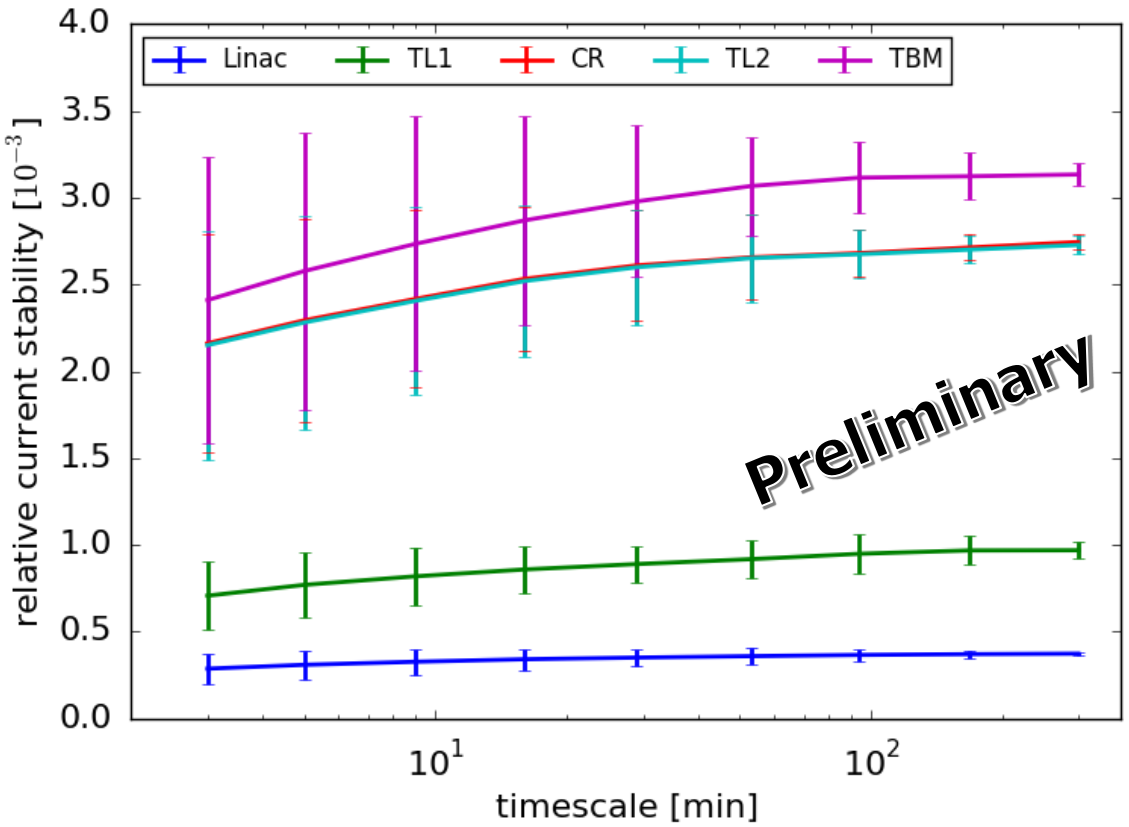
- 3 GHz factor 4 beam
- Each line refers to stability over an hour
- Beam-based feedbacks
  - off in red
  - and on in blue

2016 factor 4 x 3 GHz stability

Best

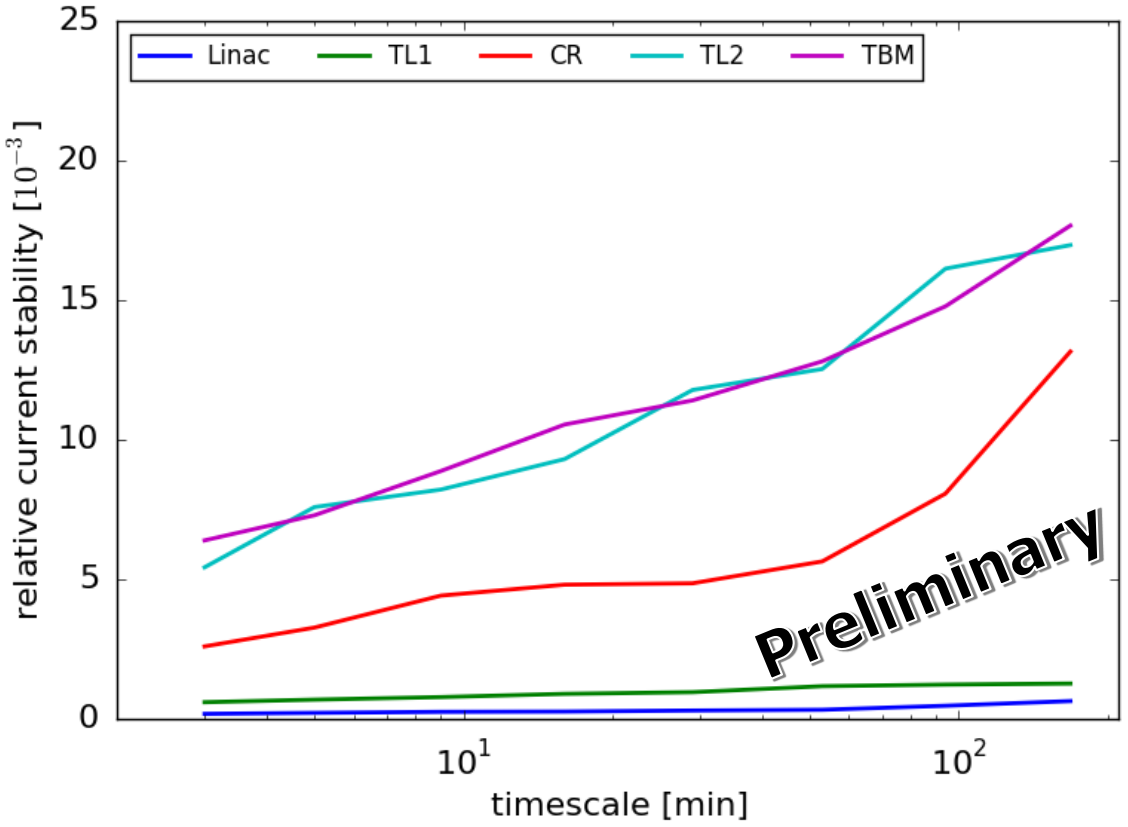


Average

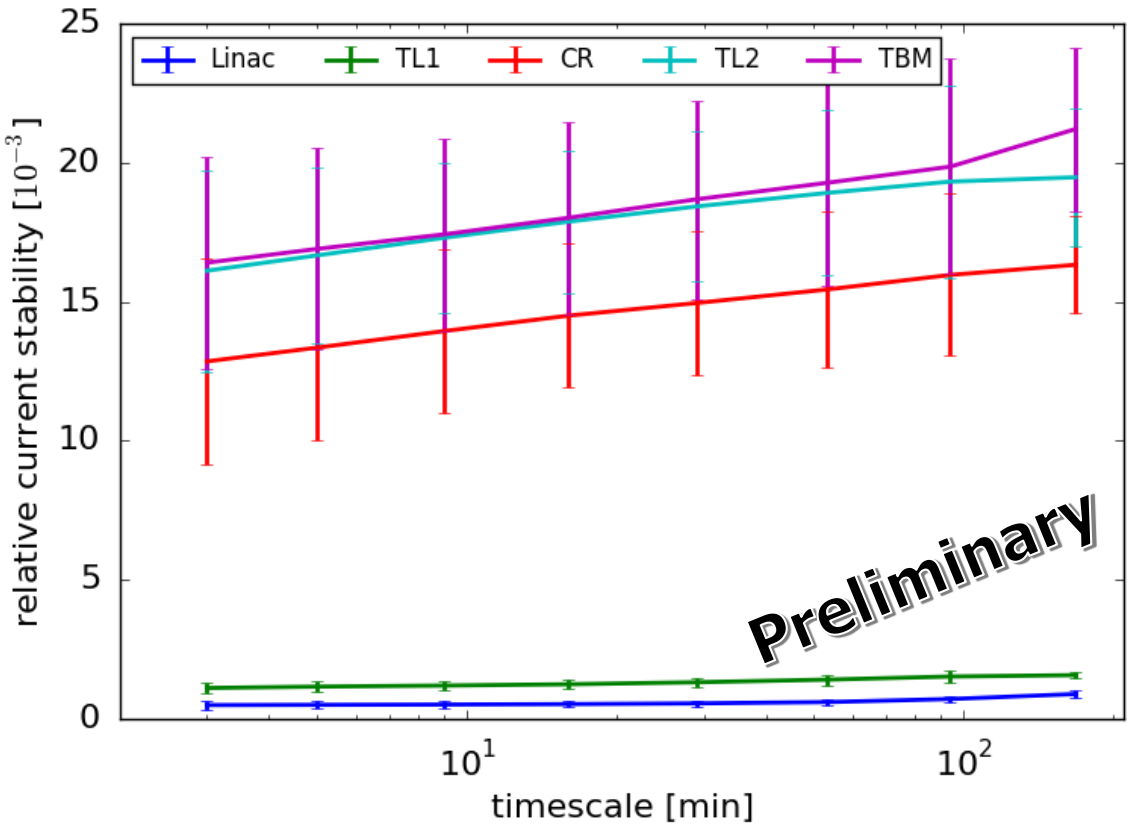


2016 factor 8 stability

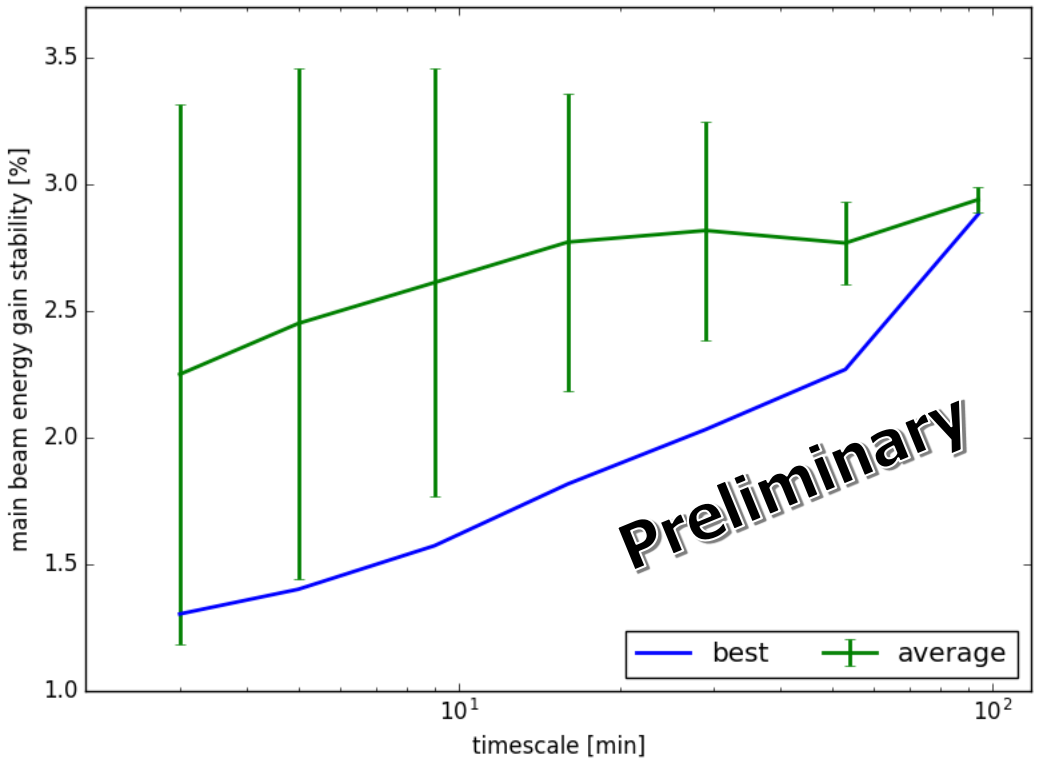
Best



Average



MB acceleration by factor 8 DB



- Same setup as in Wilfrid's presentation
- Only full acceleration, no phase scan
- Energy gain ~ 43 MeV
- Energy spread - σ ~ 1 MeV

Problems of stabilisation

In general

- Drifts of the measurements itself
  - Machine cannot be more stable than the measurements used for stabilisation
  - For example the reference RF for phase measurements
- Low resolution of measurement
  - Beam phase measurements
  - Power measurements at the exit of accelerating structure (for Beam loading feedback)

Factor 8

- Delay-loop and septa power supply jitter
- less stable when all three sub-harmonic bunchers are powered (compared to two)
- Availability of TWTs

Reproducibility

- Reference watchdog application for quick view of differences to the saved reference values
- Quick switching between 1.5 GHz and 3 GHz
- Same optics for beam to TBL and TBM
- Starting the beam in the morning is easier as the feedbacks are keeping the reference
  - Getting back to the correct working point is matter of less than a minute

Consequences for CLIC

- CLIC main beam acceleration by the drive beam is feasible
- Feed-back systems are inevitable to keep the machine stable
  - RF phase-loops and amplitude
  - Gun current feedback
  - Beam phase in the injector steering the phase-loops
  - Power at the exit of acceleration structure steering the phase-loops
  - Beam energy feedback steering the waveform of klystron(s)
  - Possibly many more
- Need for precise and stable measurements used for feedbacks
  - Drifts or lack of sensitivity degrade the machine stability and reproducibility
  - The more precise the measurement is the faster the feedback can be

Conclusions

- CTF3 machine was well reproducible
- In 2016 beam stability has been greatly improved in terms of
  - Phase – CLIC goal reached
  - Energy – CLIC goal reached
  - Factor 4 beam current
- CLIC main beam acceleration by the drive beam is feasible

Thank you for your attention