# β*-reach and required collimation efficiency

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on behalf of the collimation team

- On behalf of the collimation team: R. Assmann, R. Bruce, F. Burkart, M. Cauchi, D. Deboy, L. Lari, S. Redaelli, A. Rossi, G. Valentino, D. Wollmann


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  - Beta-beat team (R. Tomas, G. Vanbavinckhove)
  - Beam dump team (B. Goddard et al.)

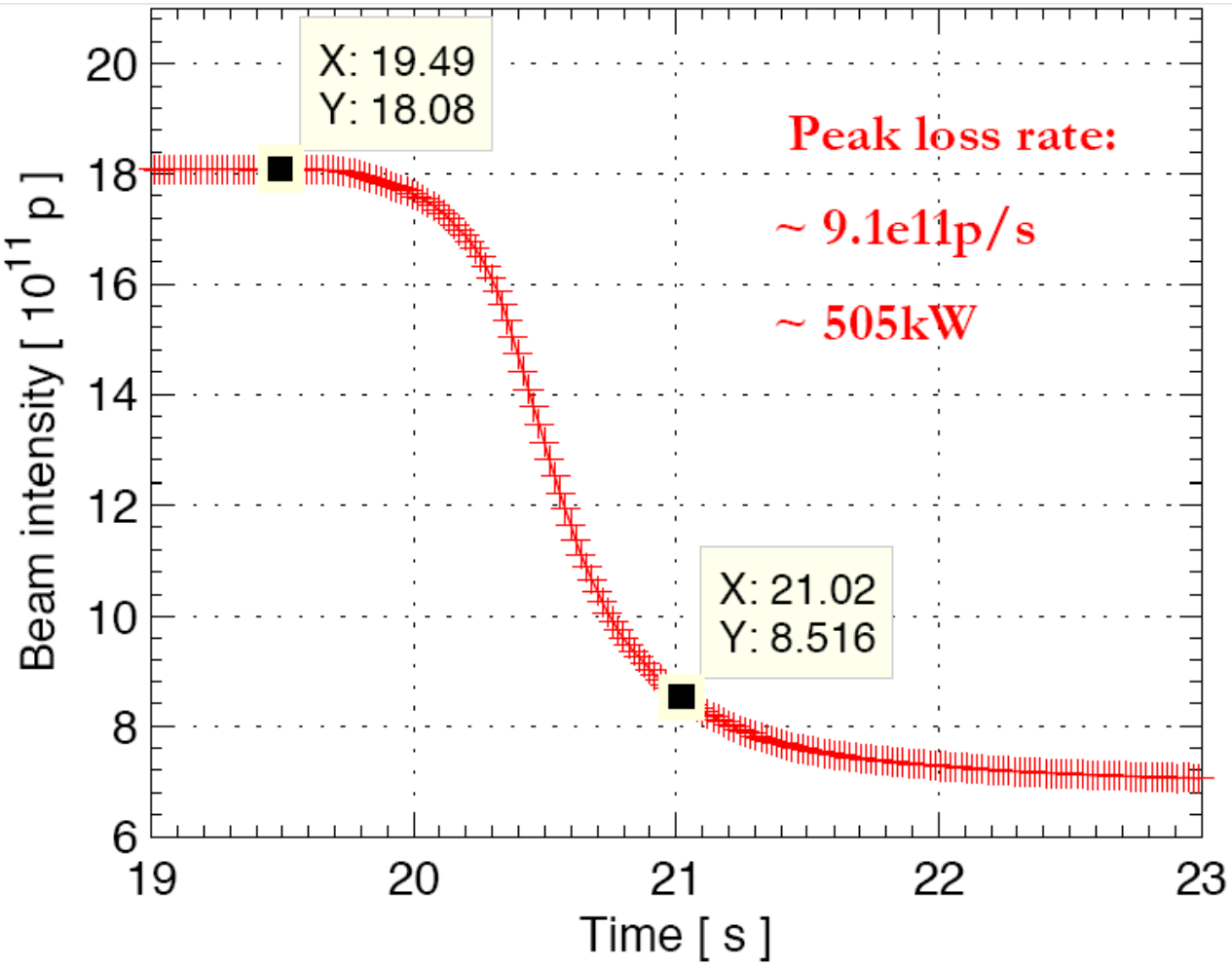
# Outline

- Collimation MD results
  - Quench test (gives intensity reach for observed efficiency)
  - Tight collimator settings
- How can we use the MD results to decrease β*?
- Options for operation
- Conclusions

# Quench test MD

- Beams at 3.5 TeV flat top, several ramps
- 16 bunches used in ramp with highest loss rate
- Crossing 3rd order resonance to induce losses
- Loss map recorded

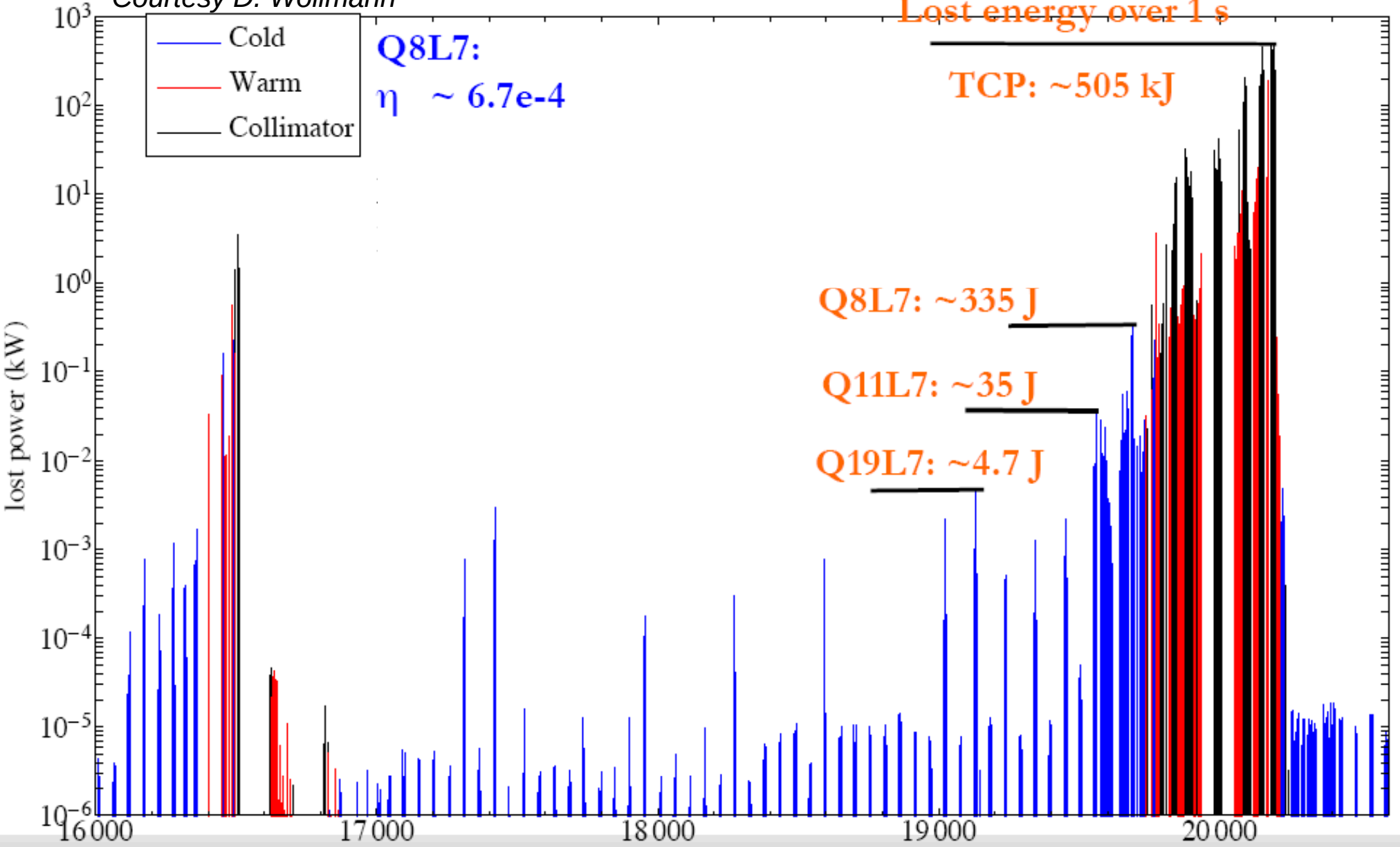
*Courtesy S. Redaelli*




*See MD note for more details*

# Quench test MD

*Courtesy D. Wollmann*




**R. Bruce 2011.07.15**

# Conclusions from MD

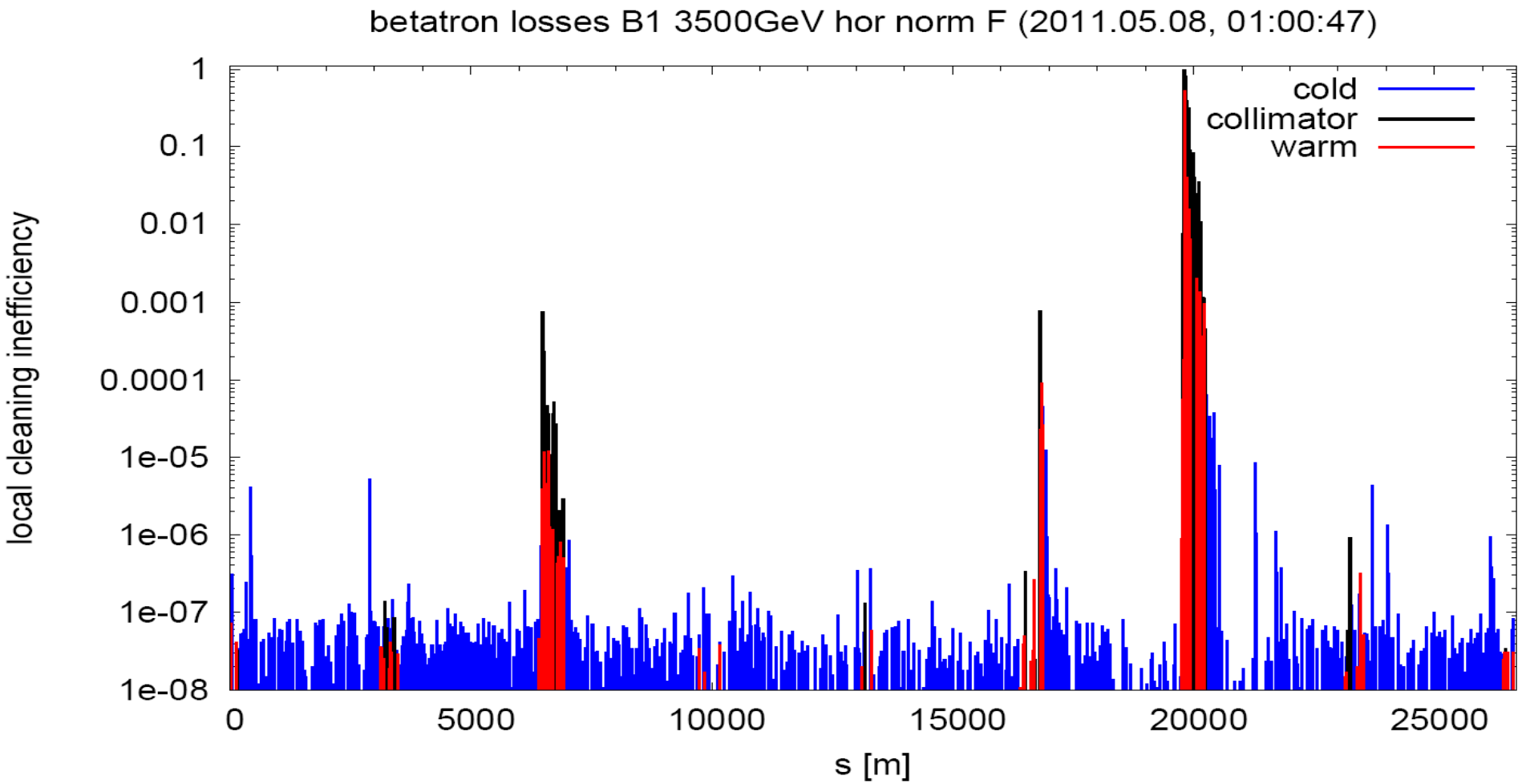
- ~500 kW loss power on TCP, but no quench!

- Extrapolation to higher intensities:
  If we assume that the observed lifetime (1h) does not drop, there is essentially no intensity limit from collimation inefficiency
  - For more info: See presentation R. Assmann in collimation review and LMC, MD note

# MD on tight collimator settings

- Collimators in IR7 and IR6 driven to tighter settings (TCP at 4 nominal σ), keeping the old centers from previous setup
- Qualified with loss maps

*See MD note for more details!*



# Conclusions from MD

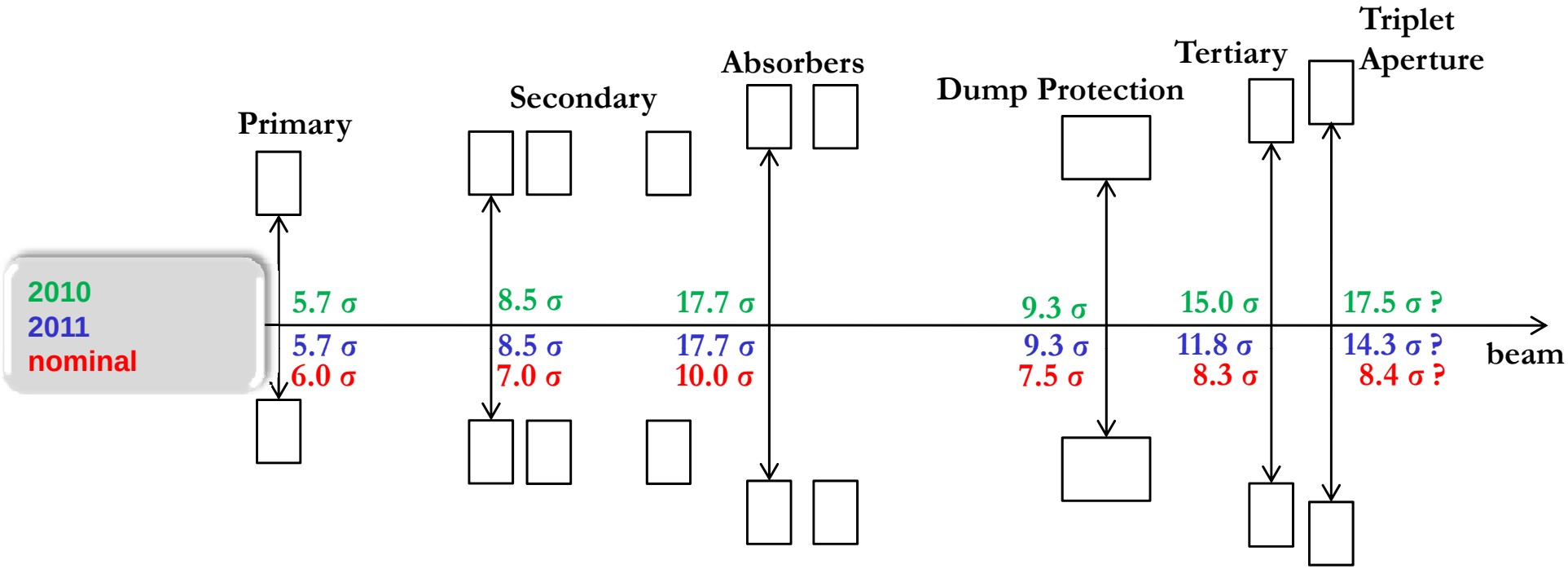
- Loss map with 4-6-8 σ (nominal) OK ⇒
  - Can be used in operation without additional setup. Only qualification of cleaning and protection needed.
  - Drive in to tight settings at flat top or during ramp?

- Gain factor 3.3 in efficiency compared to 2010 average ⇒
  Even higher intensity reach

- Using these settings gives more room to squeeze β*

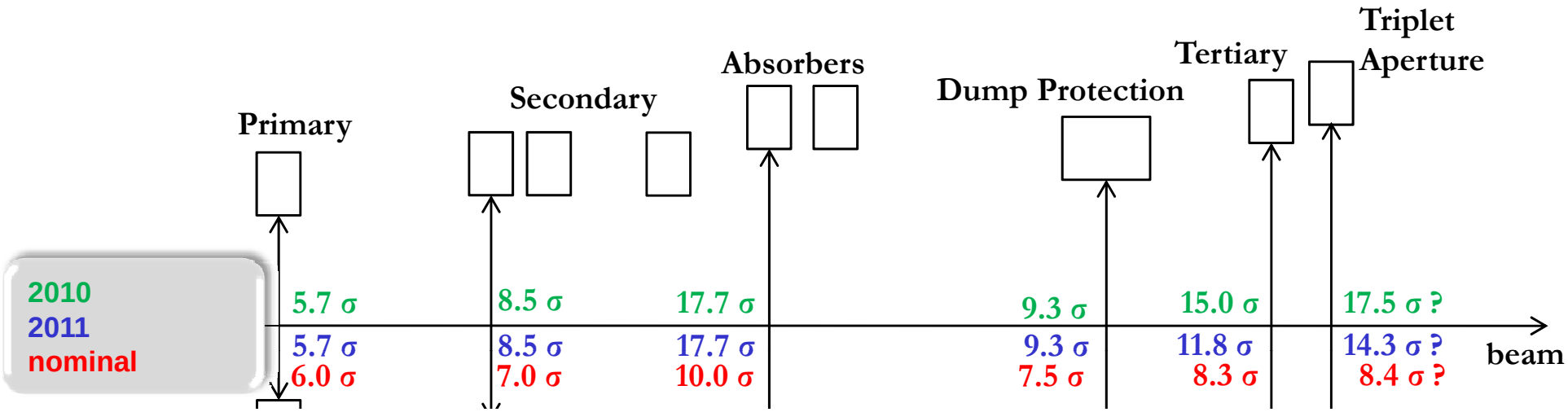
- Impedance will be higher but no limit predicted so far (studies ongoing). It would be interesting to see a limit!
  *(reference: presentation N. Mounet in collimation review).*

# Importance of collimation for β*




- Triplet aperture must be protected by tertiary collimators (TCTs)
- TCTs must be shadowed by dump protection
- Dump protection must be outside primary and secondary collimators
- Hierarchy must be satisfied even if orbit and optics drift after setup » margins needed between collimators

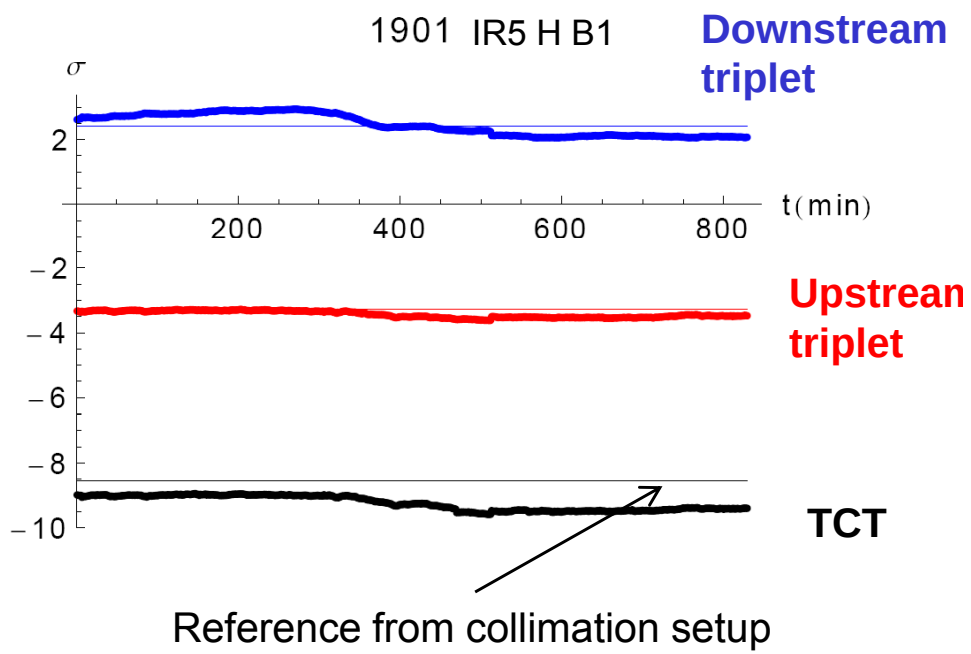
# Importance of collimation for β*

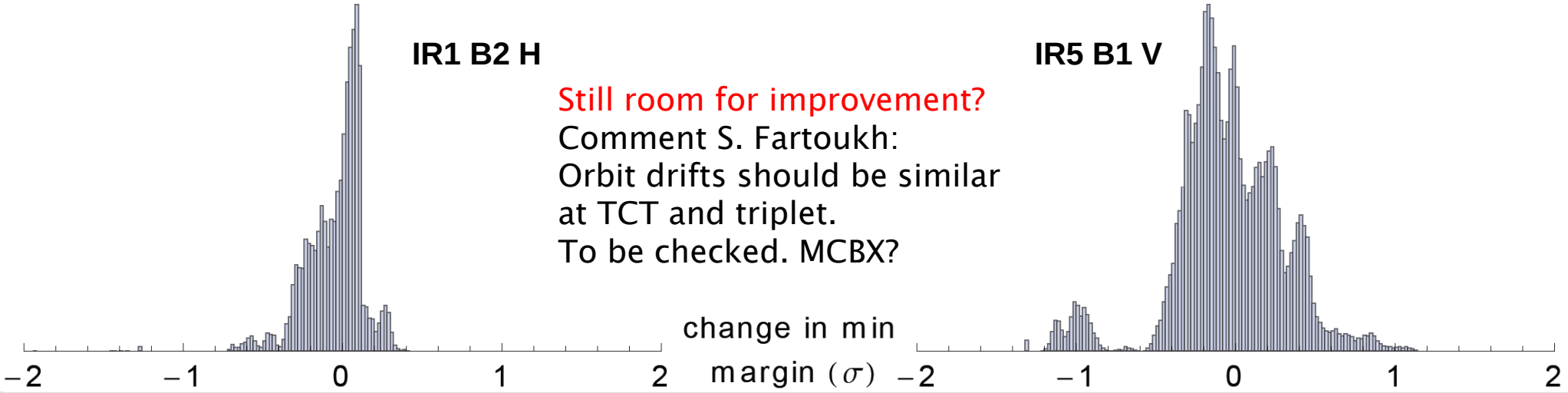



- Collimation system defines minimum aperture that can be protected
- Possible values of β* depend on the settings of all collimators and therefore on machine stability and frequency of collimation setups!
- To optimize β*, we have to review
  - Machine stability and necessary margins in collimation hierarchy (gives minimum value of triplet aperture that can be protected)
  - Triplet aperture

# 2011 orbit stability triplets/TCTs

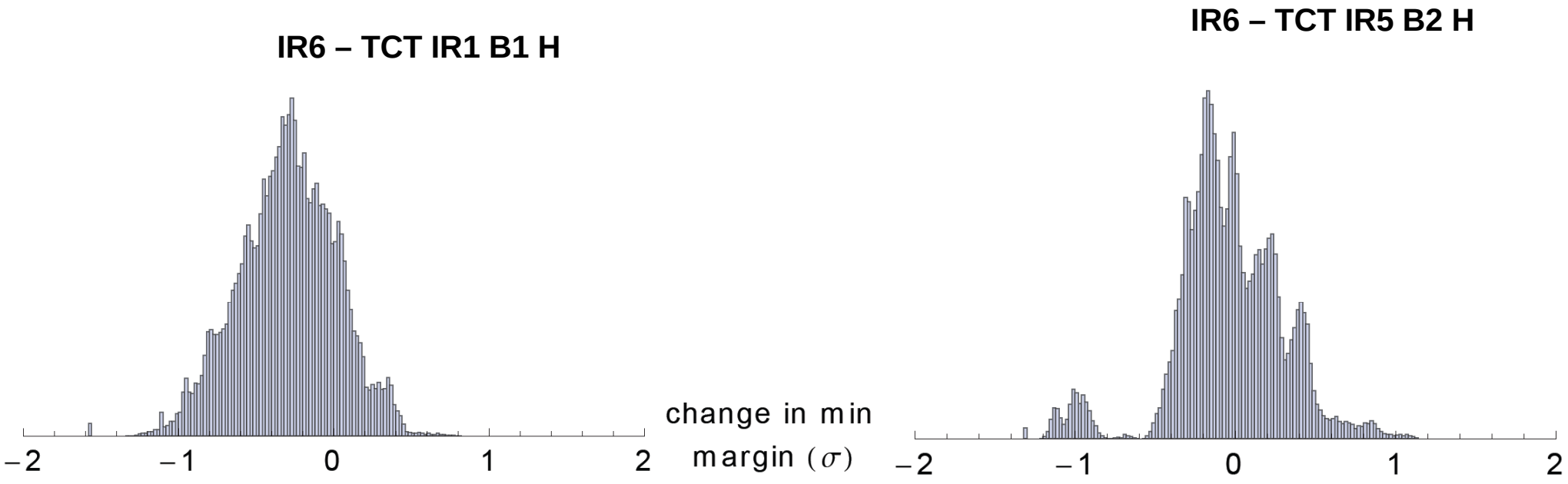
- In many cases better than 2010
- Example: recent fill 1901. Very good stability within fills
- change in minimum margin TCT-triplets during all 2011 stable beams
- 1.1 σ margin needed for 99% coverage (gain 0.5 σ). Consistent with J. Wenninger analysis
- Note: 1.5σ drifts in positive direction!



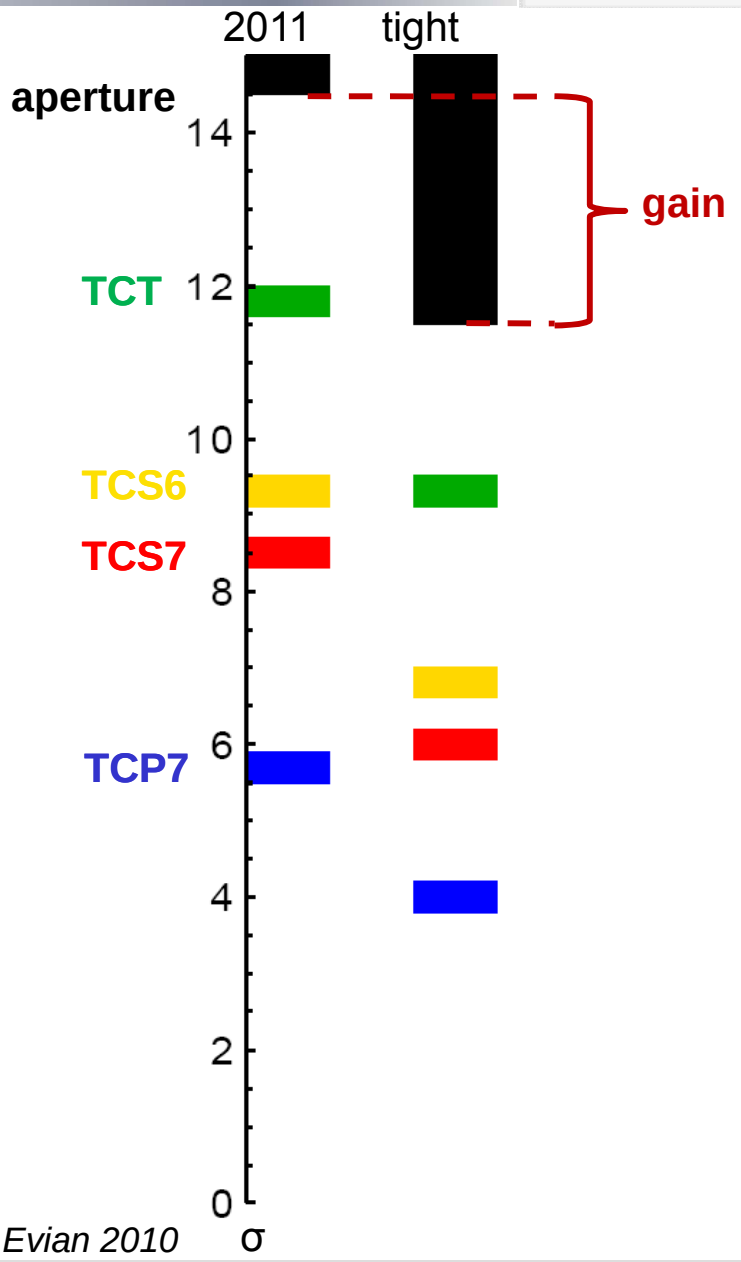
# 2011 orbit stability TCTs/IR6

- For orbit margin between TCTs and IR6, 1.1 σ needed and allocated (no reduction possible) for 99% coverage
- Reminder: 99% coverage ⇒
  - expected impact during async. dump on TCT once in 300 years
  - expected impact during async. dump on triplet once in 30 000 years



# Minimum aperture we can protect

- Combine
  - MD result: move in TCP, decrease margins between TCP and TCS in IR7
  - Orbit analysis (small reduction in margin)
- Keep the other allocated margins
- ⇒ we can protect ≈ 11.3 σ aperture.
  Gain ≈3σ




*Reference: R.Bruce,R.Assmann, Evian 2010*

# Triplet aperture

- Using two methods: scaling of aperture measurements at injection and n1

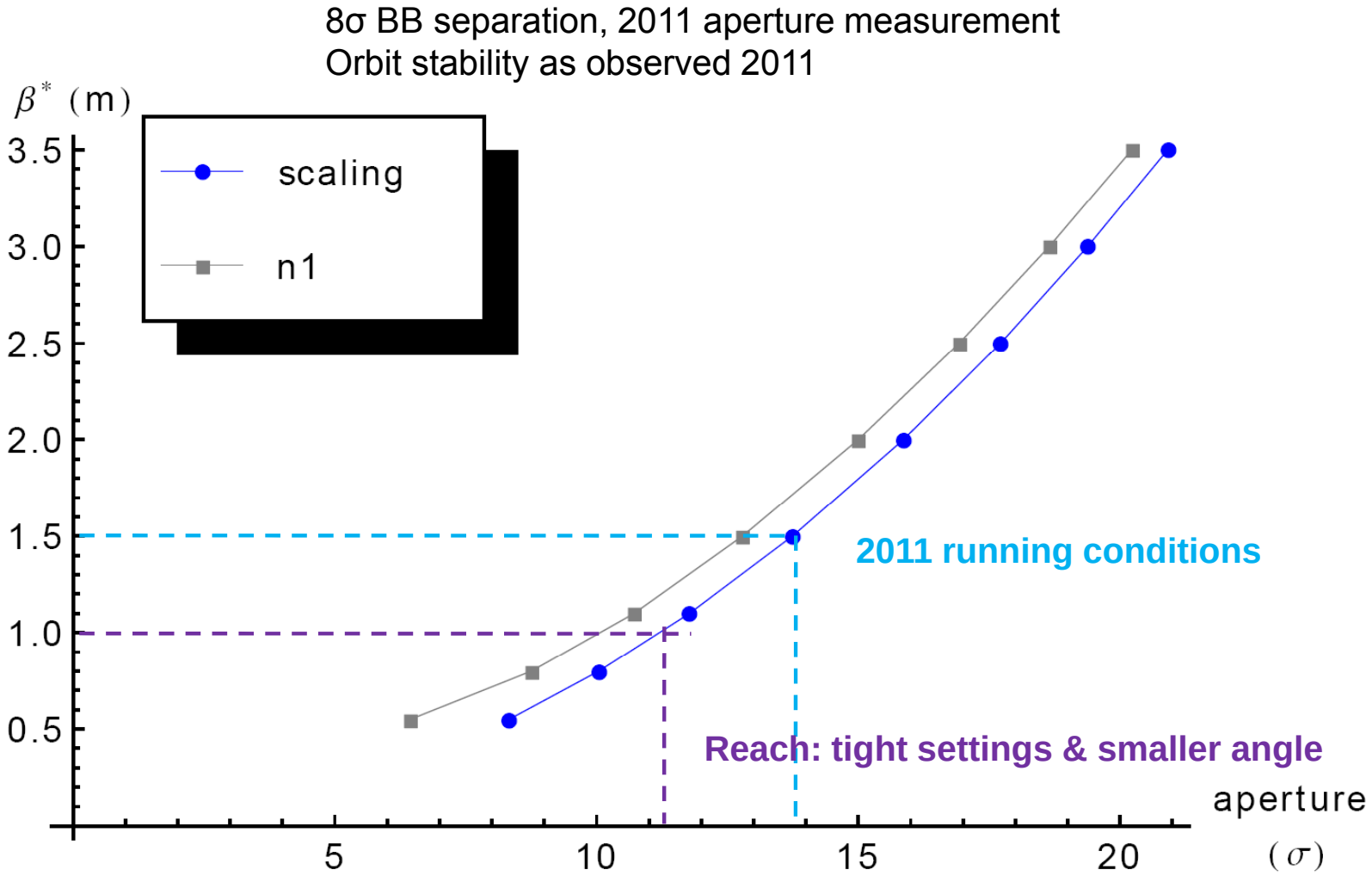
- Triplet aperture measured in crossing plane in 2011 and global aperture re-measured: in some cases slightly more pessimistic aperture than in 2010. Limitation in many cases in separation plane, where no local measurements were done.

- Beam-beam MD: We can go to 8σ BB separation for ε=2.5 μm and 50 ns (see talk W. Herr)
  - Smaller crossing angle allowed. Example half angle: 85 μrad for β*=1.5m. ⇒ Gain in aperture
  - Unfortunately the full gain can not be used, since bottleneck jumps to separation plane with scaling method. Can parallel separation be reduced?

*reference R.Bruce,R.Assmann, Evian 2010*

# New reach in β*

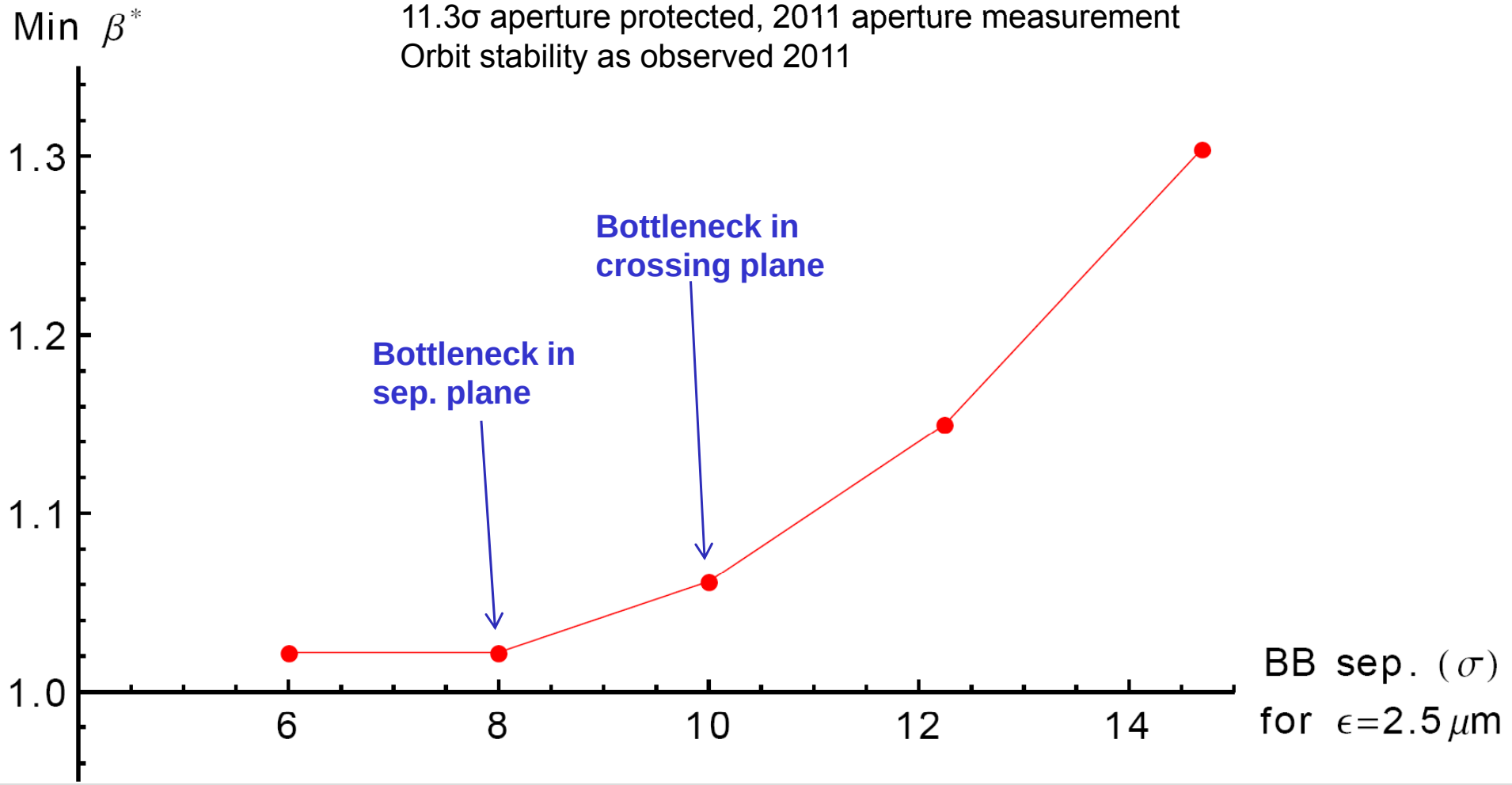
- Evian 2010 analysis ⇒ we are now comfortably running at β*=1.5 m
- With tight settings and smaller crossing angle, we can go to β*≈1 m, half angle ≈100 µrad




- Any new settings must be qualified before operational use

# β* vs beam-beam separation

- For the moment, no gain in reducing to less than 8 σ beam-beam separation, since aperture bottleneck is in the separation plane.



# Can we go lower in β*?

- Ways to reach smaller β* with the present machine
  - Decrease margins in collimation hierarchy (improvements in machine reproducibility required, or taking risks, e.g. scratch TCT)
  - Move in primary collimator closer to beam
  - Decrease beam-beam separation (gains aperture)
  - Decrease parallel separation (gains aperture) → can we collapse separation during or before the squeeze to gain both aperture and operational time?
- Upgraded collimators with built-in BPM buttons allow collimators to be quickly re-centered without touching beam ⇒ decreased margins
  - Prototype installed in the SPS. Promising MD results (D. Wollmann in IPAC11)
- Upgraded magnets and new ATS optics (flat beams?) allow much smaller β* (L. Rossi, S. Fartoukh et al)

# Operational strategy

How can we operationally use the presented results?

- Ramp up intensity until we see limitations
  - Present collimator settings can be used – no loss in time
- Use tight settings: gain efficiency and learn about impedance for the future.
  - Qualify settings for collimation and protection (betatron lossmaps, async dump tests – 2 fills). No new collimation setup required!
  - Probably not needed at 3.5 TeV.
- If margins kept constant, then use room for squeeze to 1m. Requires recommission of squeeze, beta-beat correction, collimator functions, collimation setup at low β*.
- Alternative approach: Stick to present settings this year and focus on luminosity production. Push β* in 2012
  - We could re-setup the system next time with tight settings

# Conclusions

- Based on the quench-test MD, we can continue intensity increase until other limitations occur (no real limit from inefficiency)
- β* is dependent on settings and margins in collimation and protection system. Present limitation on β* in the LHC.
- A careful analysis allowed us to reduce β* from 3.5m to 1.5m in 2011
- Based on the performance in 2011 and the MDs on tight collimator settings and long-range beam-beam, we can now go to β*=1m, but setup time overhead