Calculations of margins in collimation hierarchy

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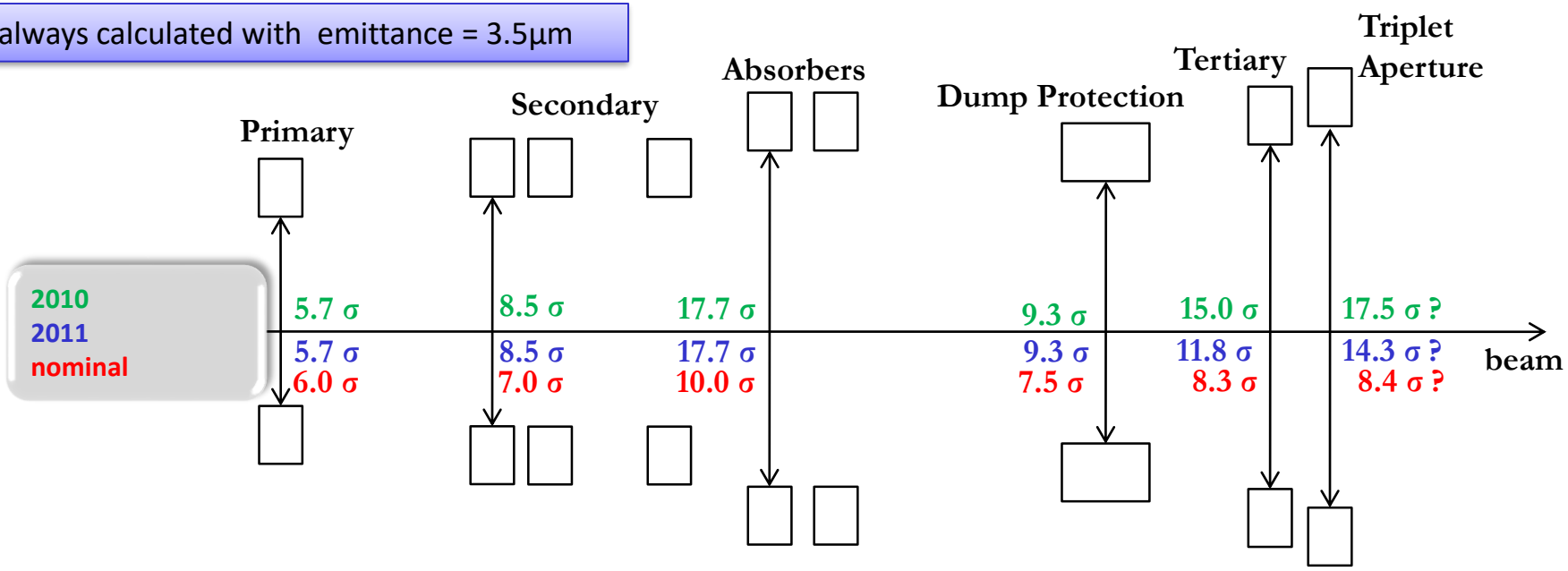
Collimator margins

σ always calculated with emittance = 3.5µm



- Collimation hierarchy has to be respected in order to achieve satisfactory protection and cleaning
- Some margins are more critical for machine protection (IR6-TCTs-aperture), others matter mainly for cleaning (IR7, IR7-IR6, IR3)

Calculation of margins

- In IR7, margins are not critical for machine protection
  - In worst case, if margins are violated, and efficiency and lifetime drops, spurious dumps can occur
- In 2010 and 2011, margins in IR7 calculated by keeping the same retraction as at injection (intermediate collimation scheme) in order to provide room for machine imperfections
- In 2012, we propose to reduce margins in IR7 based on empirical studies (previous MDs on tight settings)
  - Smaller margins were found that provide excellent long-term stability of hierarchy
- Critical margins: If margins IR6-TCTs-aperture are violated, sensitive equipment (TCTs or aperture) might be exposed during the unlikely case of an accident
- Critical margins calculated based on in-depth analysis of previous runs

Components of critical margins (IR6-TCTs-aperture)

- Orbit:
  - margin calculated based on measured orbits in previous run.
  - Reduction in margin calculated based measured orbit at both locations for all fills
  - Taking a 99% confidence interval on the reduction in margin
  - Result from 2011 run: 1.1 σ needed both between IR6-TCT and TCT-aperture
- β -beat:
  - not measured continuously during the year.
  - Assuming 10% larger β at TCT, 10% smaller β in IR6
  - Between TCT and triplet, only counting once due to phase advance and that β-beat is often included in aperture calculation. Also, cannot have both + and -10% at same place!
- Positioning (reproducibility of collimator setting between fills. Affected by e.g. power cuts). Assuming 40 µm
- Setup errors (precision of collimation setup): 10 µm steps used in setup
- Lumi scans: Assuming pessimistically 0.2 σ

Method for adding errors for critical margins

- So far: assuming that all errors could add up simultaneously in bad direction:

$$\Delta_{total} = \sum_i |\Delta_i|$$

- New 2012 proposal: consider the errors as statistically independent random variables => adding errors in squares instead of linearly (except van der Meer scans!)

$$\Delta_{total} = |\Delta_{vdM}| + \sqrt{\sum_i \Delta_i^2}$$

- In the unlikely case that errors would add linearly, count on detection of abnormal behaviour in loss maps and asynchronous dump tests
  - We have to carefully monitor the losses from beam in the abort gap during regular dumps! If problems are detected, try to correct, and in worst case step back and increase margins

Proposed settings

- Proposed settings of collimators at 4 TeV, using square sum

	σ
TCP 7	4.3
TCSG 7	6.3
TCLA 7	8.3
TCSG 6	7.1
TCDQ 6	7.6
TCT	9.0
aperture	10.5

- Note that an additional 0.4σ has been added ad-hoc to the margin between IR6 and TCTs to get margin to the orbit interlock in IR6. This adds extra safety!
- Margin TCSG IR6-TCT is goes from 2.5 σ in 2011 to 1.9 σ in 2012
- Tolerated margin TCT-aperture goes from 2.5 σ in 2011 to 1.5 σ in 2012
  - However, note that predicted aperture is 10.8 σ, using pessimistic scaling (1.8 σ margin)
  - Real aperture is likely to be larger, thus providing even more margin!

What Can Happen?

Error case:

1. We need an asynchronous dump ore one module pre-trigger while we are at low beta* (probability 10^{-7} per second).
2. We need to be out of orbit tolerance from IR6 to a TCT in one IR (probability 10^{-2}).
3. We need to be at maximum beta beat error from IR6 to a TCT in one IR (probability 10^{-2}).
4. Both errors must point in the same bad direction (probability 0.25).

   ➔ Then one TCT is at risk for damage from single bunch (benign damage). Still very unlikely, due to phase advance conditions that must be met.

5. The TCT is out of tolerance with respect to triplet aperture (probability 10^{-2}).
6. We are fully squeezed, still separated (aperture assumption).
7. Beams have additional beam-beam offset reserved for van-der Meer scan (possible?).

   ➔ Then the triplet aperture can be hit by fraction of a bunch, if conditions for TCT hit (see above) are met.

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   ➔ Then the triplet aperture can be hit by fraction of a bunch, if conditions for TCT hit (see above) are met.

Extremely unlikely that anything happens!

Still very conservative (e.g. here we ignored all the smaller errors that anyway add up).

Probably something else (unexpected) will hit us well before we drill a hole into the triplet).

Anything overlooked here?