Updates on β* for 2011

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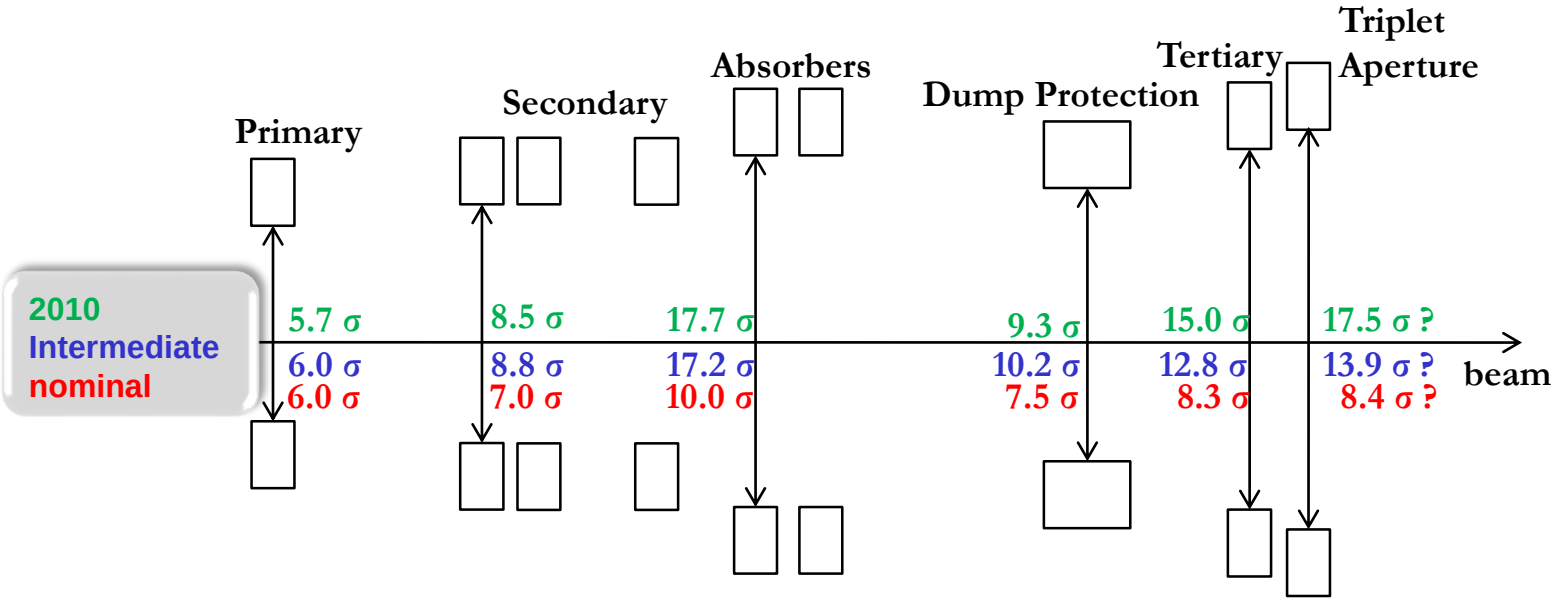
Introduction

- Only limits from aperture considered



- Hierarchy between cleaning stages must be preserved to guarantee protection (should account for β-beat and orbit variation)
- To optimize β*, we have to review
  - Triplet aperture
  - Margins in cleaning hierarchy

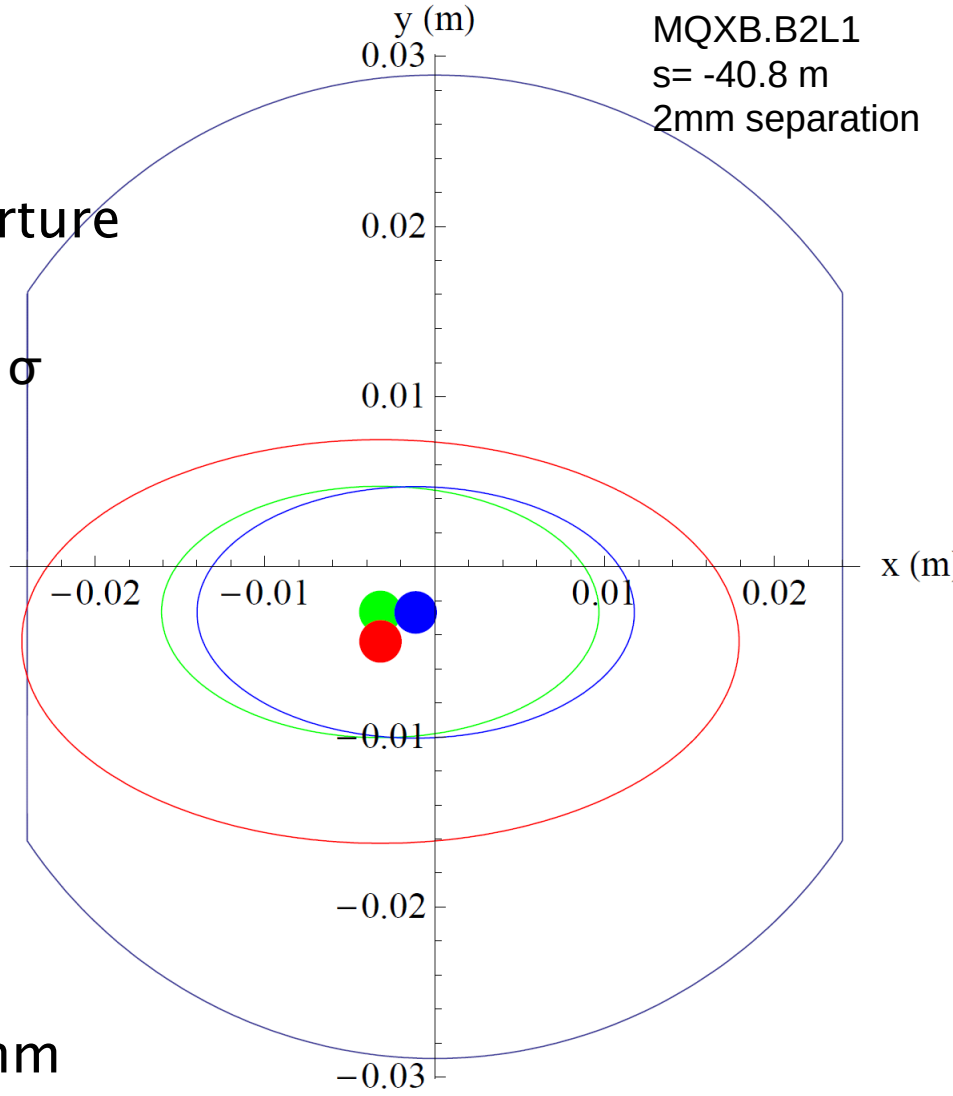
Aperture calculations (review)

Using 2 methods:

- n1
- scaling of measured injection aperture
  - Assume *pessimistically* injection aperture=global limit+2 σ
  - Only one plane matters with good approximation – reduce to 1D
  - Scale beam size to pre-collision

$$|u_i| + n_i\sigma_i = |u_p| + n_p\sigma_p$$

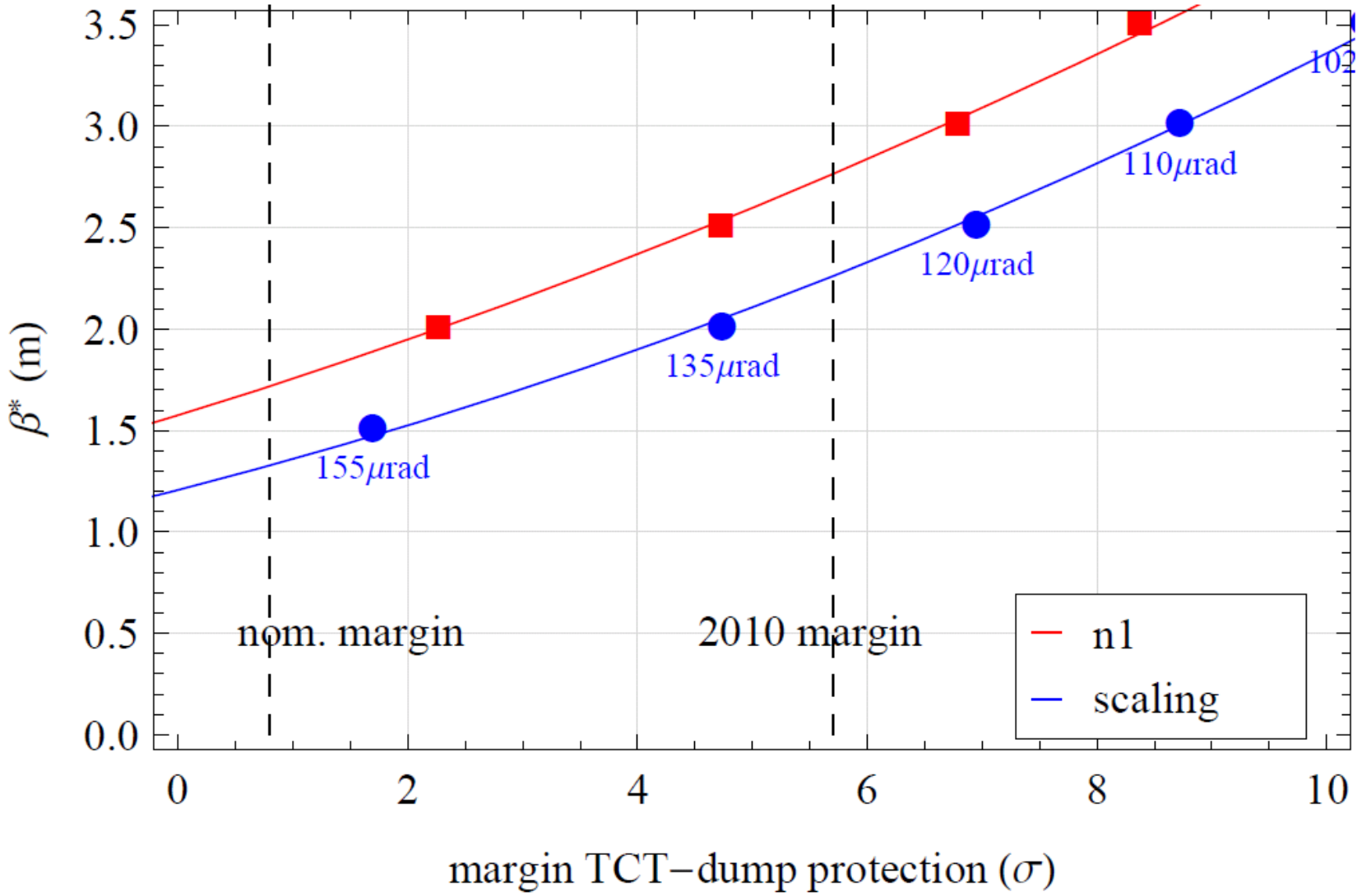
  - Solve for top energy aperture
- Additional assumption: reduce separation to nominal value 0.7 mm



Parameters in aperture calculation

- Scaling
  - All mechanical and alignment errors already included in measurement – nothing changes between injection and top energy
  - 2mm orbit uncertainty (difference between orbit during measurement and top energy)
    - More detailed analysis done, all runs from sept 18 to nov 30, data sampled every 2 minutes in stable beams, excluding points from van der Meer scan
  - β-beat must be accounted for
    - Assuming 5% reproducibility and measured β-beat
- n1
  - 2.3 mm orbit variation (BPMs in triplets, difference to ideal MAD-X orbit)
  - 10% β-beat

New β* without changing margins

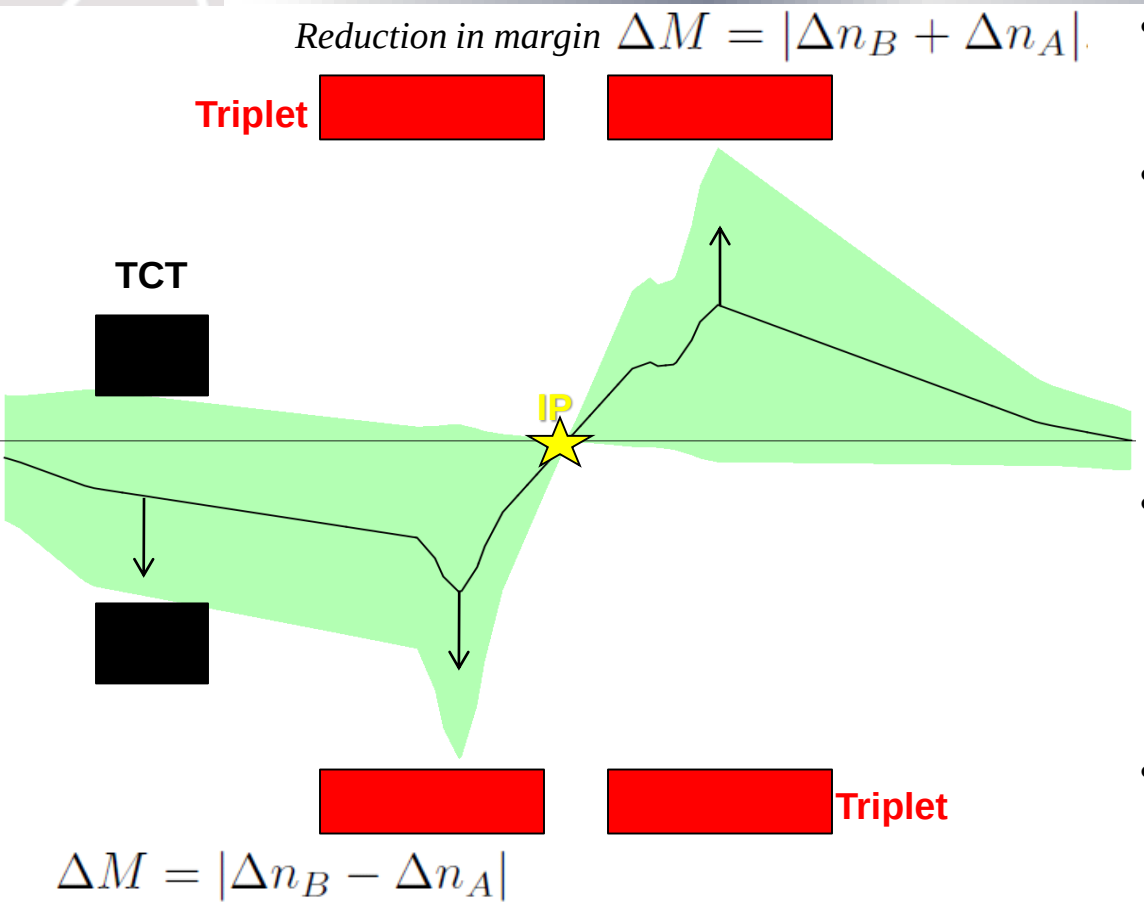


Margins in cleaning hierarchy

- Orbit: separate analysis on following slides
- 10% β-beating. Bias in correction at TCT-triplet wanted
- 40 μm positioning error
- 10 μm setup error
- Small lumi scans can be included in the margin

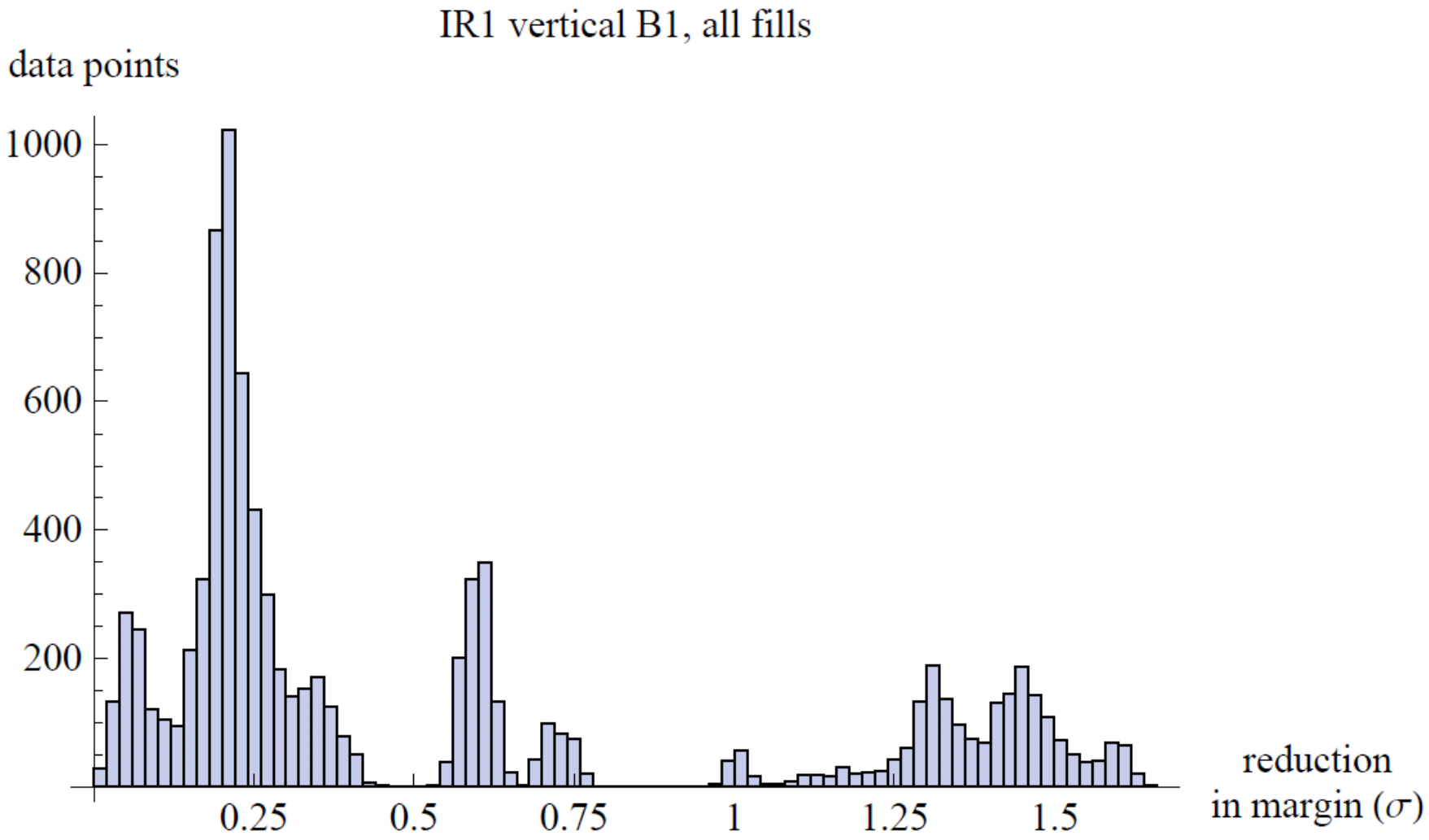
Element	β-beat	position	setup	scans	sum
TCT	0.73	0.1	0.025	0.2	1.06
TCSG6	0.45	0.06	0.015		0.53
TCSG7	0.41	0.2	0.05		0.66
TCP7	0.28	0.14	0.035		0.46

Orbit movements TCT-triplet



- Correlated orbit movement at TCT and triplet considered
- Because of phase advance, orbit movements in the same direction will cancel at the first triplet and add up at the second
- Reduction in margin calculated in both planes for each triplet separately over full data set
- 1.6 σ covers all triplets 99% of the time in stable beams for IR1, IR5, IR8
- 2.4 σ needed in IR2 (large static orbit offsets)

Example: IR1 B1 V



Margins between collimators

- A similar analysis (but more pessimistic, without phase considerations) shows
  - 99% of the time in stable beams, all horizontal TCTs are shadowed by the dump protection with a 1.1σ margin (presently 5.7σ total margin)
  - We should not reduce the margin between IR7 and dump protection
  - We should not reduce the margin between primary and secondary collimators in IR7 (possible loss in cleaning efficiency)

Damage risks

- What does a 99% coverage mean in terms of damage risks?
  - Assume 1 asynchronous dump per year
  - Assume 1% of the time the margin dump-TCT is violated (uncorrelated to async. dump)
  - Assume 1/3 of the time spent in stable beams
    => 1 event in 300 years could be dangerous for the TCTs
  - Assume 1% of the time the margin TCT-triplet is violated
    => 1 event in 30000 years could be dangerous for the triplets
  - This considers only orbit. Simultaneously all other errors have to add up pessimistically at both locations.
    => **The real risk is much lower!**
  - In case of the TCT being hit by a bunch there is no catastrophic damage, most likely it will be scratched and we can use a spare surface (see talk A. Bertarelli in Chamonix)
- To further reduce the risk we propose interlocks or warnings before the orbit runs out of limit

Proposed margins and settings

Summing *linearly* we get the margins

	2010		2011	
	(σ)	(mm)	(σ)	(mm)
triplet–TCT	2.5	0.9–2.1	2.3	1.1–2.7
TCT–TCSG IR6	5.7	3.5–4.4	2.5	1.3–1.8
TCSG IR7–TCP	2.8	0.6–1.6	2.8	0.5–1.5

and the settings

TCP IR7	TCS IR7	TCS IR6	TCT	aperture
5.70	8.50	9.30	11.80	14.10

Assuming IP2 remains at larger margins. Proposed settings very similar to what was used in 2010 run with $\beta^*=2.0$m

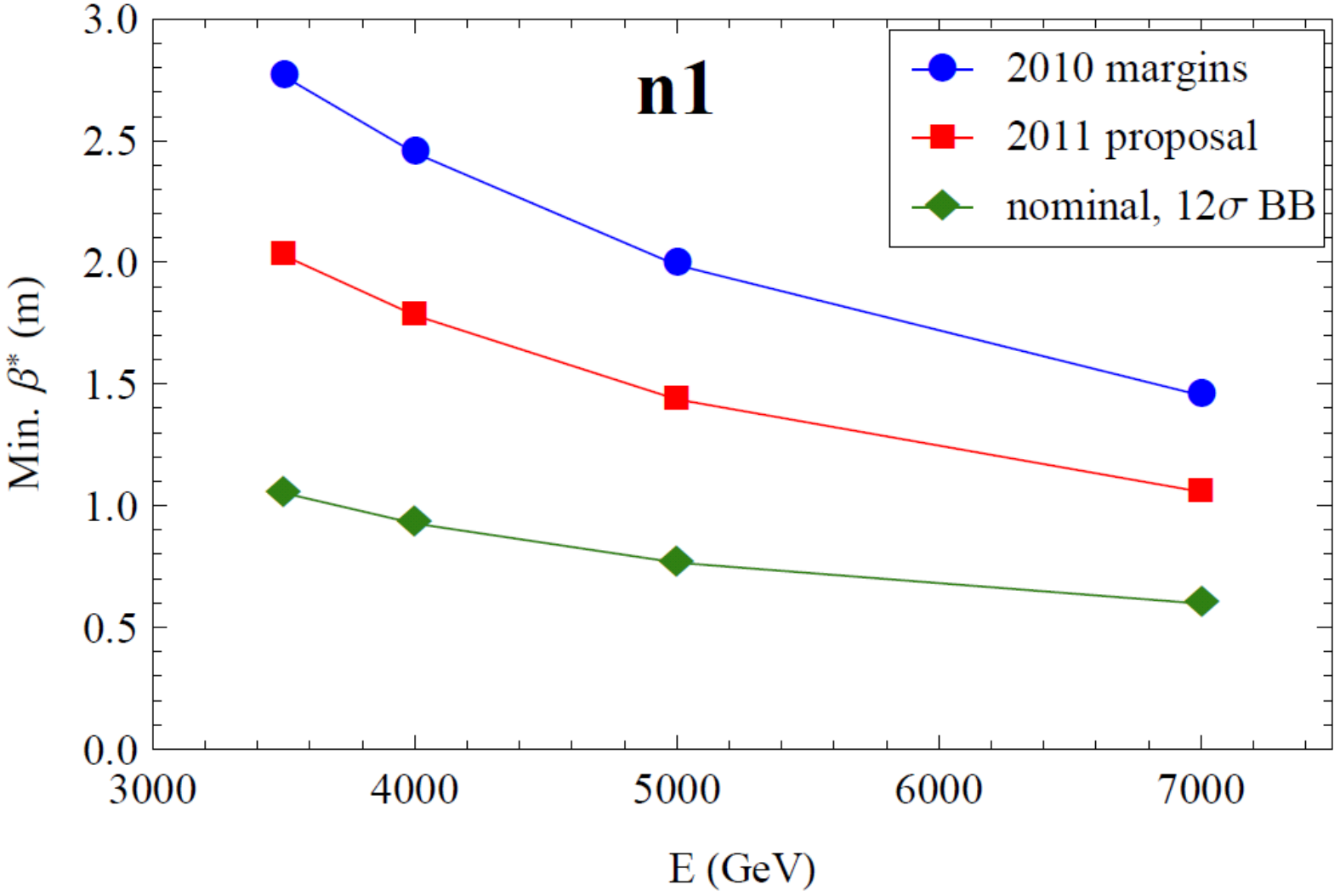
Operational proposals

- Reduce the separation at the IPs to its nominal value of 0.7 mm
- Measure the triplet aperture locally
- β-beating below 10%, reproducibility 5%, bias at TCTs/triplets
- Interlocks or warnings to reduce damage risk further
- New settings to be qualified with loss maps and async. dump tests. Problems => margins and β^* to be increased
- cleaning hierarchy to be verified on a regular basis
- Detailed study to correlate n1 calculation and measurements

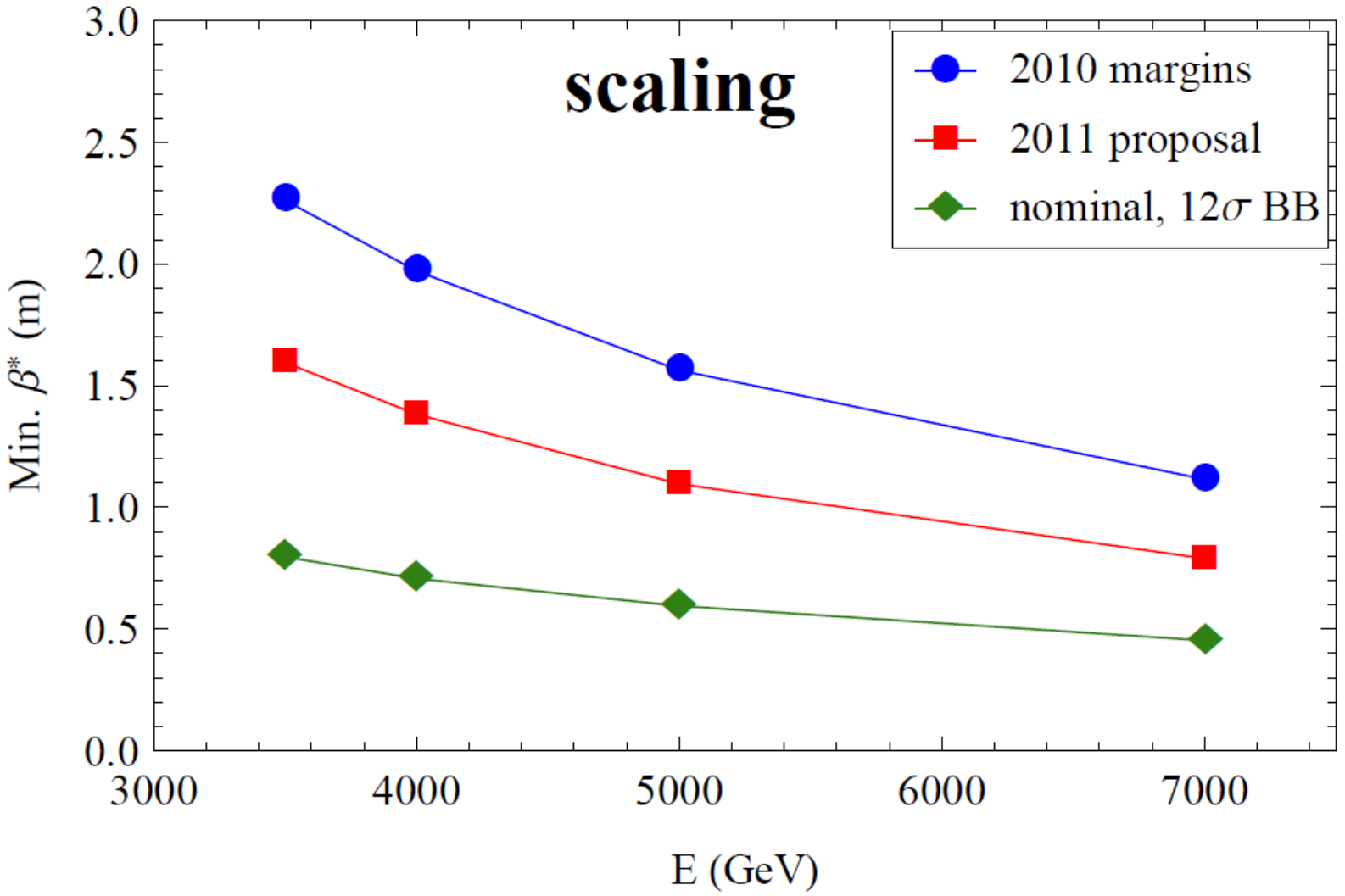
Reach in β*

- Minimum β* calculated for three options, using n1 and scaling method:
  - 2010 margins
  - 2011 margins (as calculated on previous slide)
  - Nominal collimator settings with increased beam-beam separation
- Assumptions in calculations:
  - Always taking min margin over all IPs, planes and beams
  - Minimum β* given by intersection between interpolation and desired margin (see slide 9)
  - Using nominal 0.7 mm separation and nominal emittance
  - Using measured β-beat at injection and top energy with 5% reproducibility, 10% β-beat in n1 calculation
  - Assuming max 2 mm orbit shift in pessimistic direction between measurement at injection and top energy , 2.3 mm orbit in n1
  - Assuming 12 σ beam-beam separation (larger than nominal)
  - Triplet aperture at injection assumed 2 σ larger than global limit

Results n1


n1
2010 margins
2011 proposal
nominal, 12σ BB
Min. β* (m)
E (GeV)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3000
4000
5000
6000
7000

Results with aperture scaling



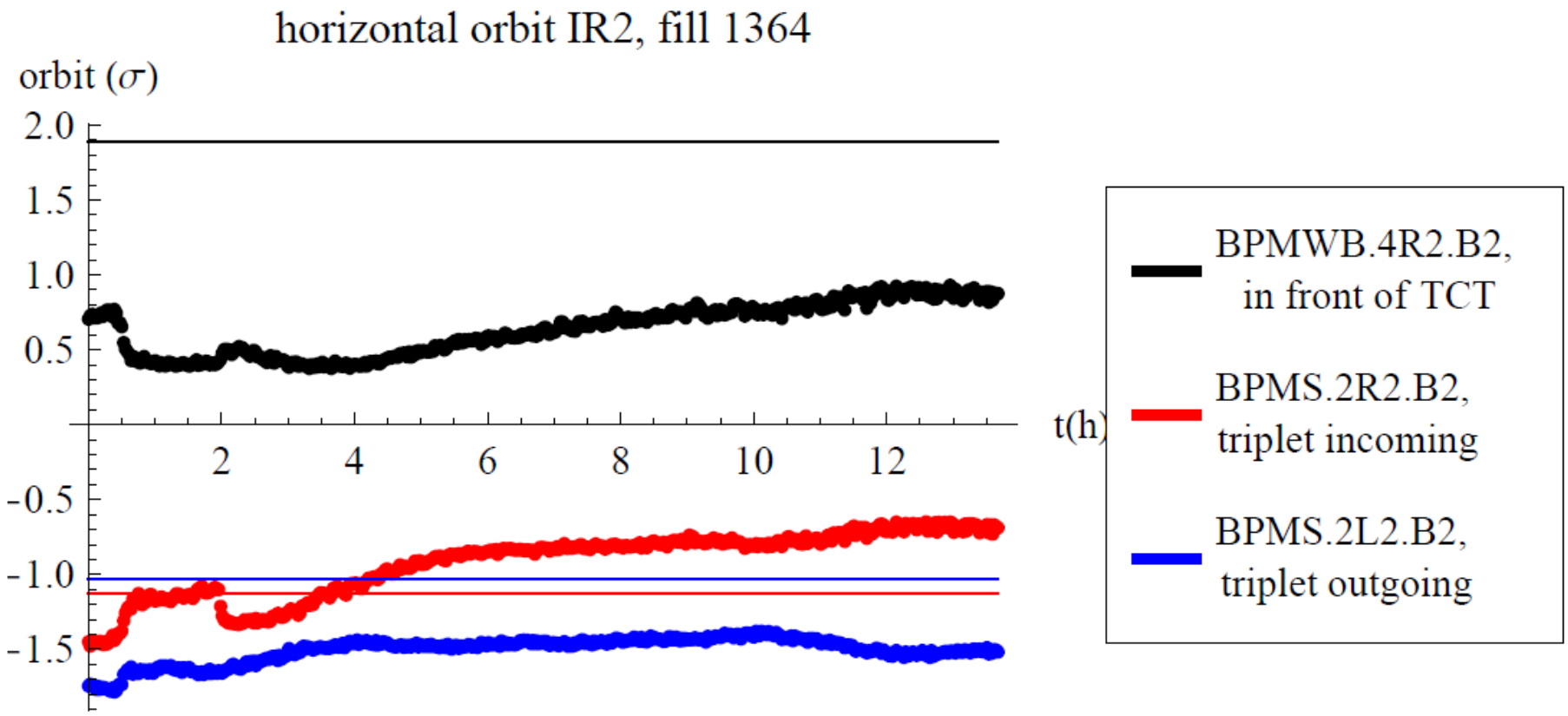
Conclusions

- Reviewed both aperture estimate and margins
  - Measurements show larger aperture, orbit and β-beat better than traditionally used in n1-model
  - TCTs can be moved in closer to dump protection
- Choice of β* should maximize performance without risking safety

	3.5 TeV		4 TeV	
	β^* (m)	α (μrad)	β^* (m)	α (μrad)
2010 margins	2.3	125	2.0	125
2011 proposal	1.6	150	1.4	150

- Proposal: start at **4 TeV, β*=1.5m, 2011 margins**
  - Measure local triplet aperture
  - Collimator settings to be qualified through provoked losses before being used during runs

Backup – orbit during fill IR2



Backup – orbit IR1