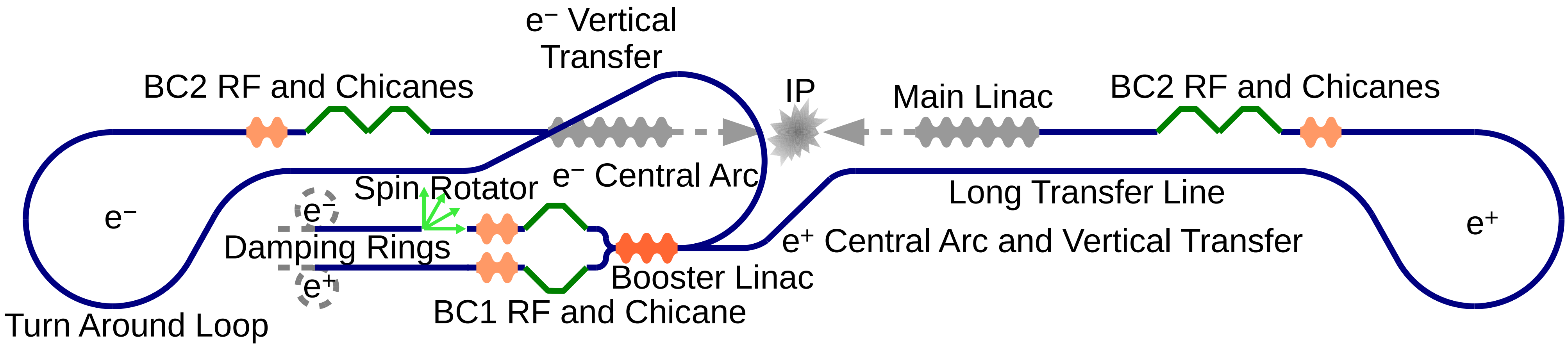
RTML Update

- Status
- Recent Changes
- Outlook

Old Status @ IWLC2010

- Complete set of lattices,
  all sub-systems connected and tracking can be done from
  the exit of the damping rings to the entrance of the main linac,
  though it excludes the delay loop behind the damping rings
- ISR, CSR and (partially) short range wakes studied
- Good static performance, i.e. within specs
- Rough idea of misalignment tolerances,
  micron range, tightest in turn around loops,
  DFS works if lattices pre-alignment to ~100µm (sextupoles ~50µm)
- Considered sufficient for CLIC CDR
- All we had to do was to write the RTML section for the CDR...(and we did ;-))



Evolution

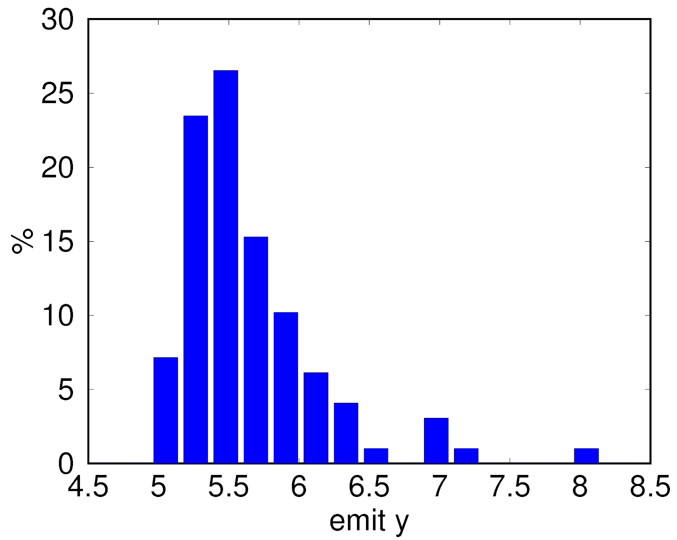
Since the CDR has been delayed, there was time to perform more studies:

- ➔ Misalignment has been studied in more detail, but not in every detail.
- ➔ Long range wakes in the booster linac have been simulated.
- ➔ Short range wakes in the BC2 RF have been studied better.
- ➔ Impact of incoming beam jitter has been evaluated.

Misalignment in the Turn Around Loops

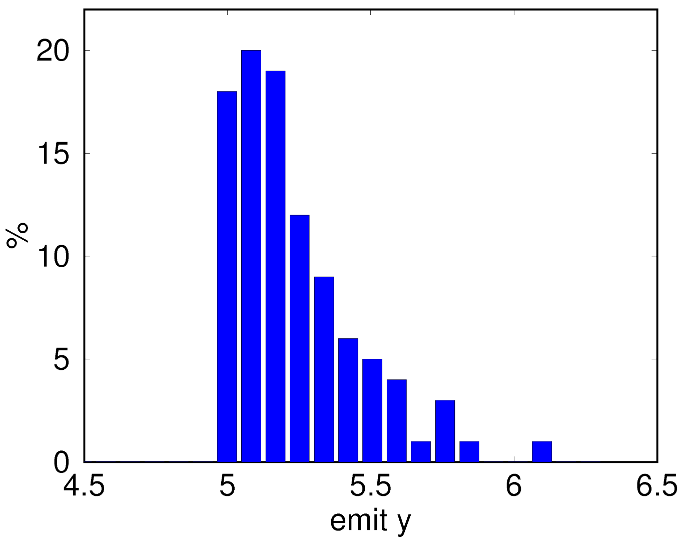
- TAL lattice should have small ISR emittance dilution and should be isochronous, i.e. strong quads are required (the strongest ones are at maximum dispersion...) => many strong sextupoles needed to correct chromaticity.
- Each turn around loop consists of 822 magnets and is ~2 km long.
- A trivial but important remark: Outgoing beam position jitter depends only on our knowledge of BPM position and BPM resolution at the end of the loop! Outgoing beam position has to stay within 10% of beam size, in vertical plane ~1 µm beam size => 100 nm tolerance => 100 nm BPM resolution.

Misalignment in the Turn Around Loops



100 µm rms quads and bends,
50 µm rms sextupoles,
1 µm rms BPMs, 100 nm BPM resolution
=> p90 = 6.2 nm rad after DFS

This is what we can expect as static performance



1 µm rms all magnets,
1 µm rms BPMs, 100 nm BPM resolution
=> p90 = 5.6 nm rad after SVD

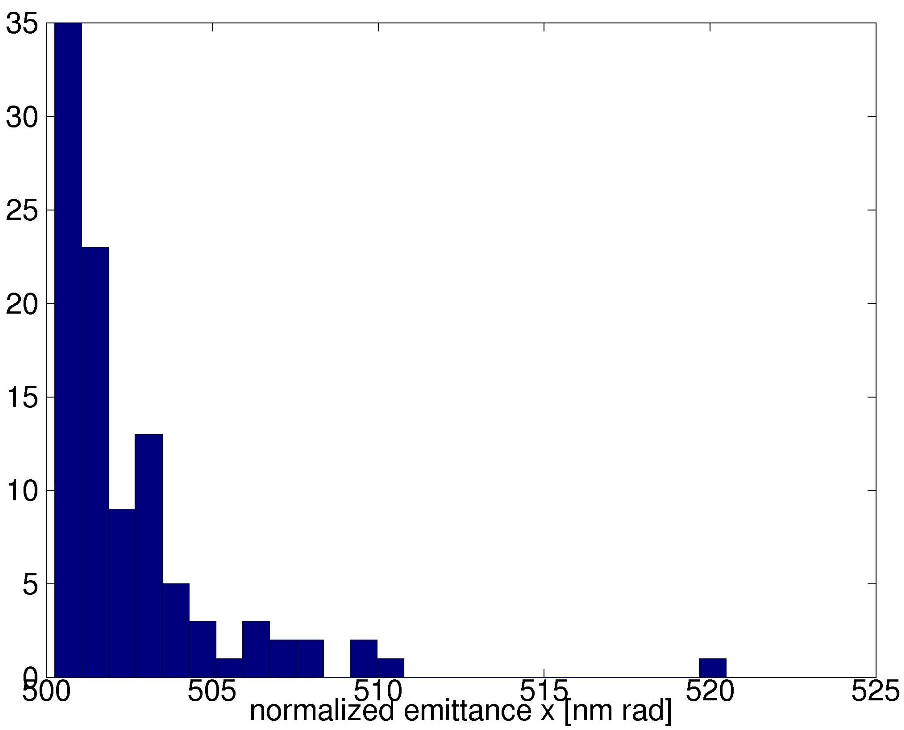
This is something like a worst case for the dynamic performance and set an upper limit when DFS has to be used again.

Misalignment in the Turn Around Loops

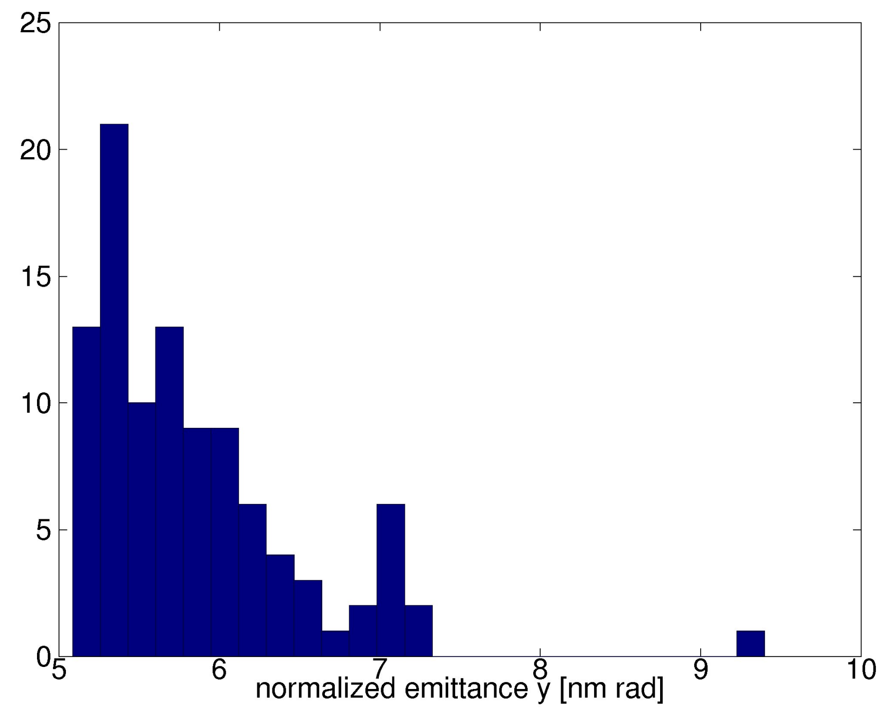
- The limit are the sextupoles.
- If performance of the TAL should get better, the sextupoles must get weaker.
- That means also the quadrupoles must get weaker.
- But beam sizes in the dipoles must remain small to limit emittance dilution due to ISR, i.e. focusing must stay strong.
- And the loop should remain isochronous... or may be not...
  Do we REALLY need this?

Long Range Wakes in the Booster Linac

100 µm / 100 µrad RMS cavity and quadrupole misalignment,
10 µm BPM misalignment with respect to quadrupole axis, 1 µm BPM resolution,
no incoming beam jitter, after applying dispersion free steering,
with single and multi bunch wakes, no HOM damping



RMS = 502.6 nm rad
90th percentile = 506.1 nm rad



RMS = 5.9 nm rad
90th percentile = 6.9 nm rad

Long Range Wakes in the Booster Linac

Amplification factors for beam jitter entering the booster linac according to Daniel's PAC09 paper "Multi-bunch calculations in the CLIC main linac"

no HOM damping:

$F_c = 3.8$

$F_{rms} = 1.7$

$F_{worst} = 62$

=> too strong jitter amplification, even worse than main linac

with HOM damping (Q=30):

$F_c = 1.0$

$F_{rms} = 1.1$

$F_{worst} = 5.0$

=> within specs:

$F_c < 1.5$

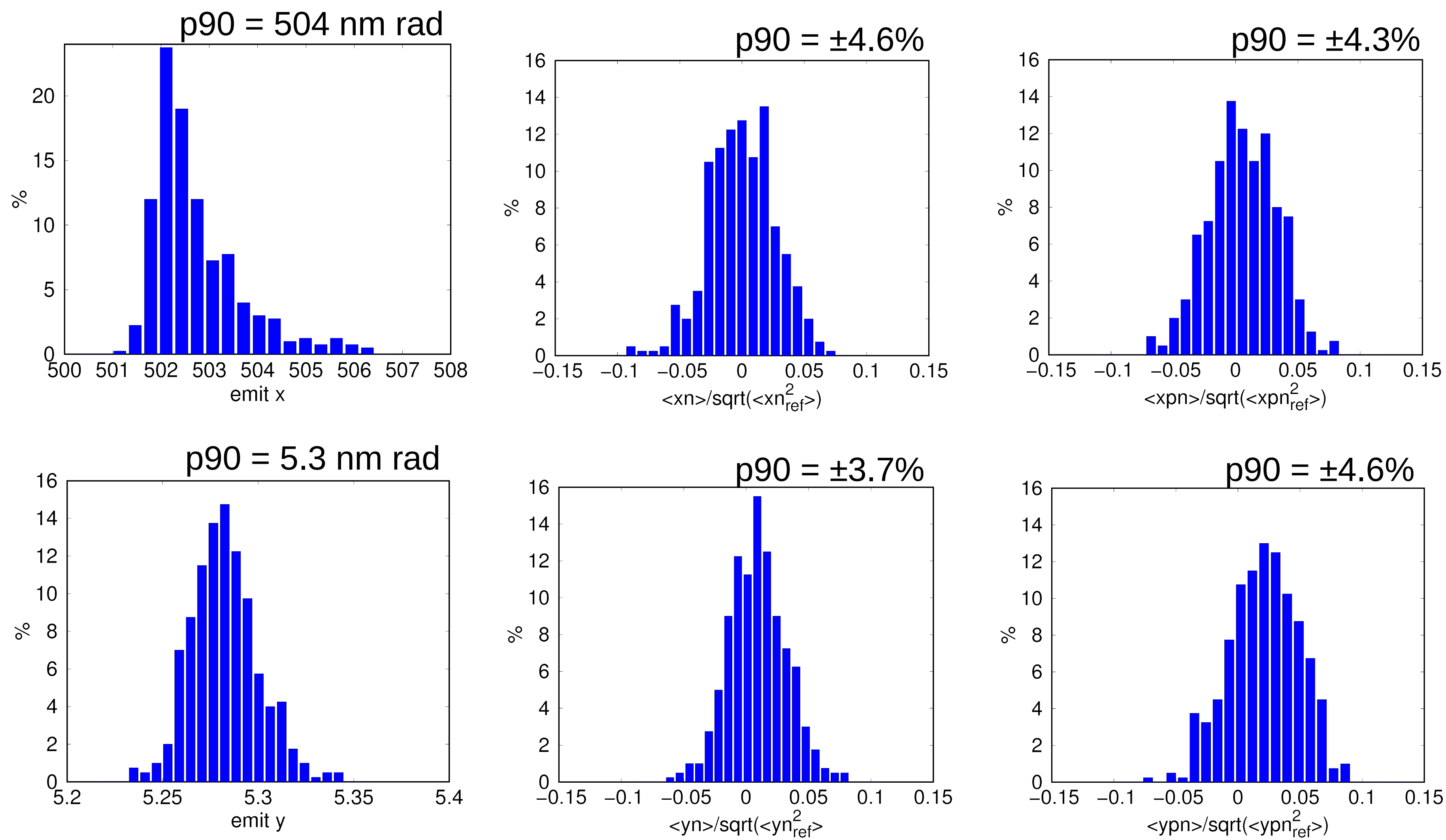
$F_{rms} < 1.5$

$F_{worst} < 5$

- During these studies optimized slightly the lattice, i.e. slightly stronger focusing, 72deg phase advance
- The same lattice is now used for BC1 RF
- HOM damping will be mandatory. And it will be even more important for CLIC500 due to double charge

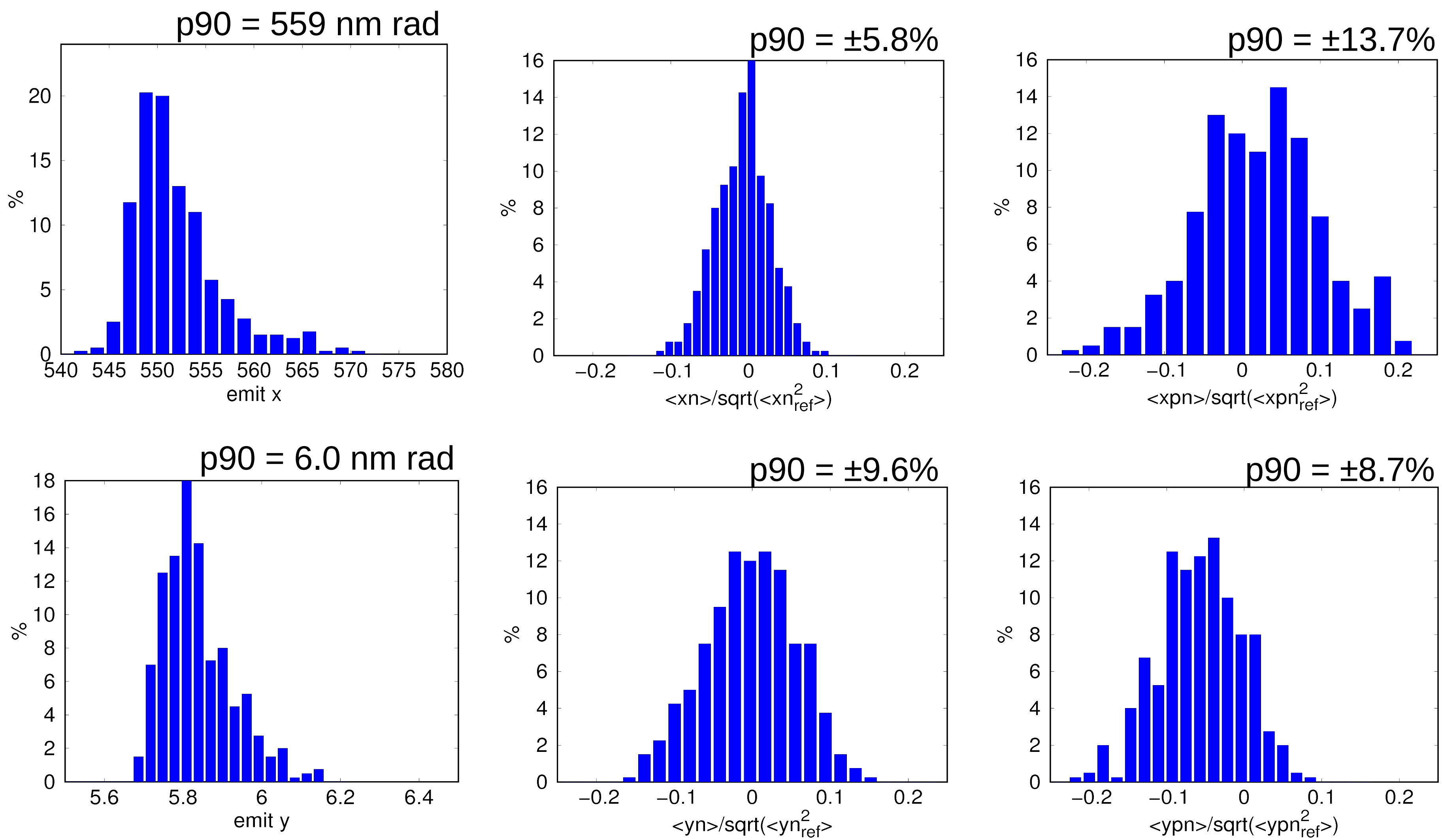
Incoming Beam Jitter

5% rms incoming electron beam jitter (Gaussian) ≈ 90% of cases within ±8% jitter, no correction, no misalignment, plots show distribution at the end of the RTML, normalized values, no ISR, no wakes



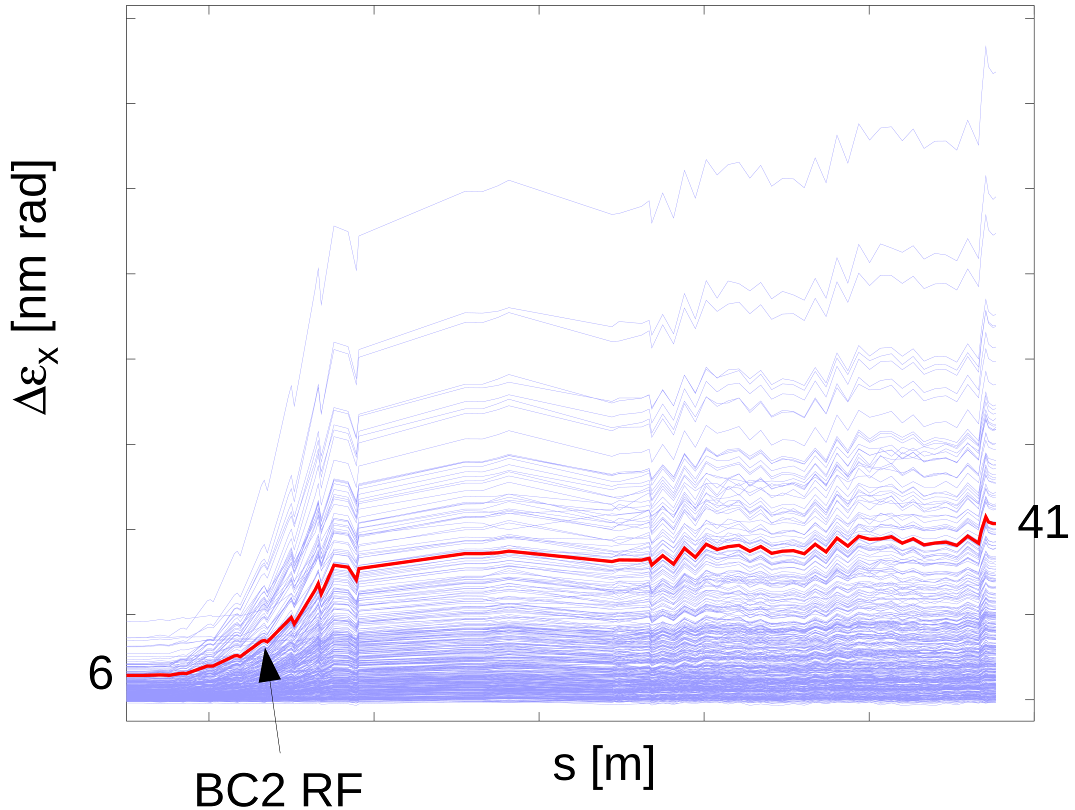
Incoming Beam Jitter

5% rms incoming electron beam jitter (Gaussian) ≈ 90% of cases within ±8% jitter, no correction, no misalignment, plots show distribution at the end of the RTML, normalized values, with ISR, with short range wakes



Incoming Beam Jitter

- These studies revealed that the problem is actually the BC2 RF.
- The beam jitter was well transported through the rest of the RTML.
- The BC2 RF lattice just has never been optimized and utilized pretty weak focusing.



10% rms jitter, no ISR, with single bunch wakes,
red line shows 90th percentile of single bunch emittances

Incoming Beam Jitter

- After adapting BC2 RF lattice to match the start of the main linac performance is o.k. Though it could certainly be better.
- Now the transport lines need some improvements. Especially the one in front of the booster linac seems to induce some emittance growth.
And unfortunately, it seems I made it a little worse.

no wakes, 10% rms jitter:

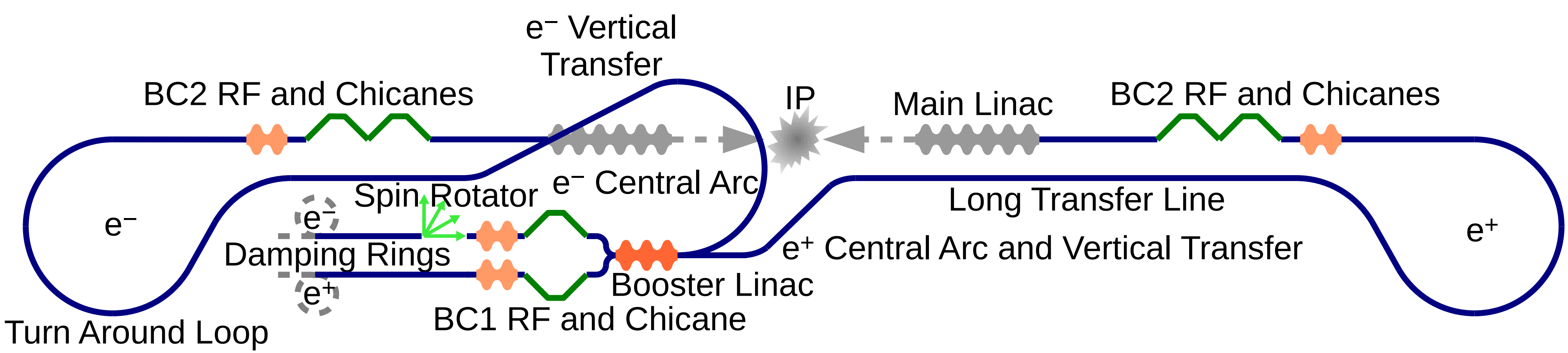
emit x: p90 = 511.6 nm rad, xn: p90 = ±8.5%, xpn: p90 = ±8.3%, growth projected emit x = 3.6 nm rad
old = 1.9 nm rad
emit y: p90 = 5.5 nm rad, yn: p90 = ±7.9%, ypn: p90 = ±6.5%, growth projected emit y = 0.4 nm rad
old = 0.3 nm rad

with single bunch wakes, 10% rms jitter:

emit x: p90 = 511.6 nm rad, xn: p90 = ±8.8%, xpn: p90 = ±9.3%, growth projected emit x = 3.8 nm rad
old = 16.1 nm rad
emit y: p90 = 5.4 nm rad, yn: p90 = ±9.1%, ypn: p90 = ±7.9%, growth projected emit y = 0.3 nm rad
old = 0.3 nm rad

New Status

- The general RTML layout is unchanged.
- But a couple of lattices have been revised:
  - BC1 RF
  - Booster Linac
  - BC2 RF
- BC1 has also been slightly adjusted to fit to the damping ring parameters, 1.8 mm initial bunch length instead of 1.6 mm.
- I tried to improve the turn around loops, but failed...
  though I can tell you that it really looks most promising to allow some R_{56}.
- There is still a lot room for improvements all along the RTML.
- The static performance is a little worse (more CSR in BC1), but the dynamic performance is better (less wakes).



Outlook (post CDR)

- The current RTML lattice is nice for the CDR, but anyone who looks into the details will see that nobody would build the RTML like that.
- But before changing lattices a few basic questions need to be answered:
  - How does the 6D phase space look like at the entrance of the RTML? This is important for the tuning of the bunch compression system.
  - What is worse, static or dynamic bunch quality degradation? There is some trade-off to be done during lattice design.
  - Is it really acceptable to place both spin rotators at the start of the RTML? How much loss of e+ polarization is allowed?
  - Which performance is expected from the feed-forward system and which parameters should it correct?
  - How strong are long range wakes in the 12 GHz cavities of the BC2 RF? In case the BC2 RF needs to be shorted this will impact the whole bunch compression system. And may be the TAL if it has a non-zero R_{56}.
  - ...there might be more...

Outlook (post CDR)

➔ Once it's time for some lattice design:

- Turn around loop lattice (incl. central e- arc) must get another revision to relax alignment tolerances further without increasing ISR.
- Re-optimize the full bunch compression scheme. Could we allow stronger CSR in BC2 to allow some decompression in the TAL? That would make TAL lattice A LOT easier!
- Improve vertical arcs to make quads and sextupoles weaker. There is not much to gain here, but the lattices are crappy ;-)
- All lattices must be checked for their performance and potential for simplifications.

Outlook (post CDR)

- Booster linac currently relies on strong HOM damping (Q<30)
  (for CLIC500 it will be even worse due to doubled charge).
  Someone has to see what can be done by improving the lattice,
  i.e. stronger focusing.
- Booster linac frequency needs to be evaluated, i.e. 2 GHz vs 4 GHz.
- BCs need to be re-optimized (incl. shielding) to reduce CSR.
- Note, that I do not believe that it makes much sense at the moment to study misalignment a lot further (may be in booster linac).
- And don't forget that there are some tight beam phase and energy jitter tolerances to be met at the main linac entrance...

  ...this could have filled a whole talk on its own, but I leave it to you to read my draft paper, which hopefully will become a CLIC note...
  Frank Stulle "Beam phase and energy tolerances in the CLIC RTML"

Whoever continues on the RTML, I wish you success and luck!