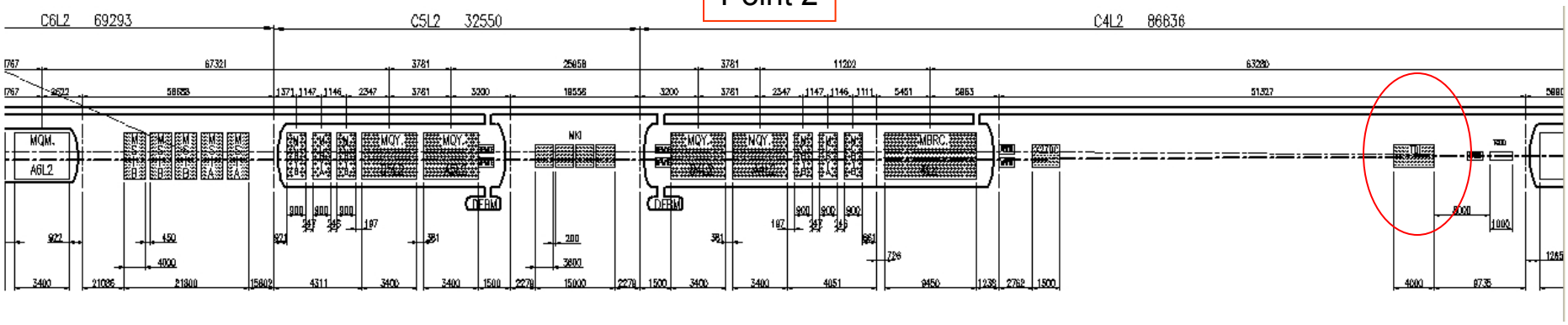
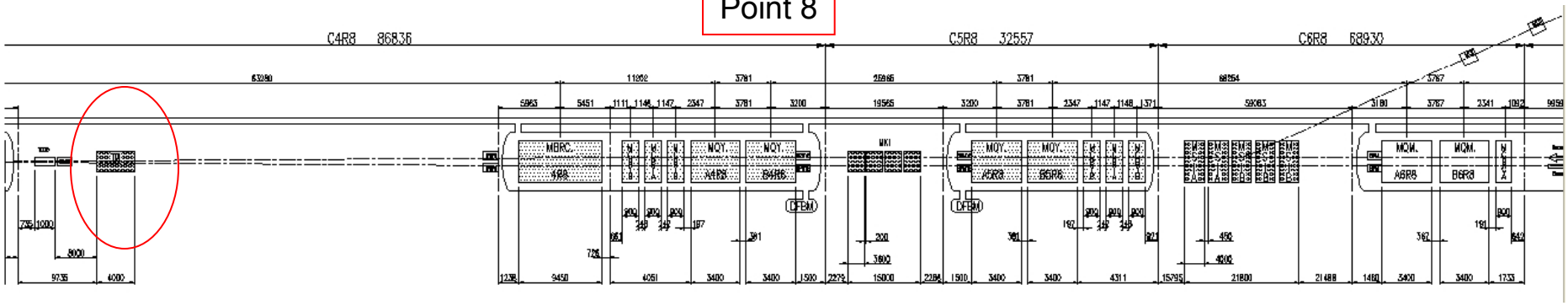
TDI settings and protection

TDI : protects LHC from miskicked injected beam (setting up, timing errors, kick setting errors, MKI failure). In position during injection process only.

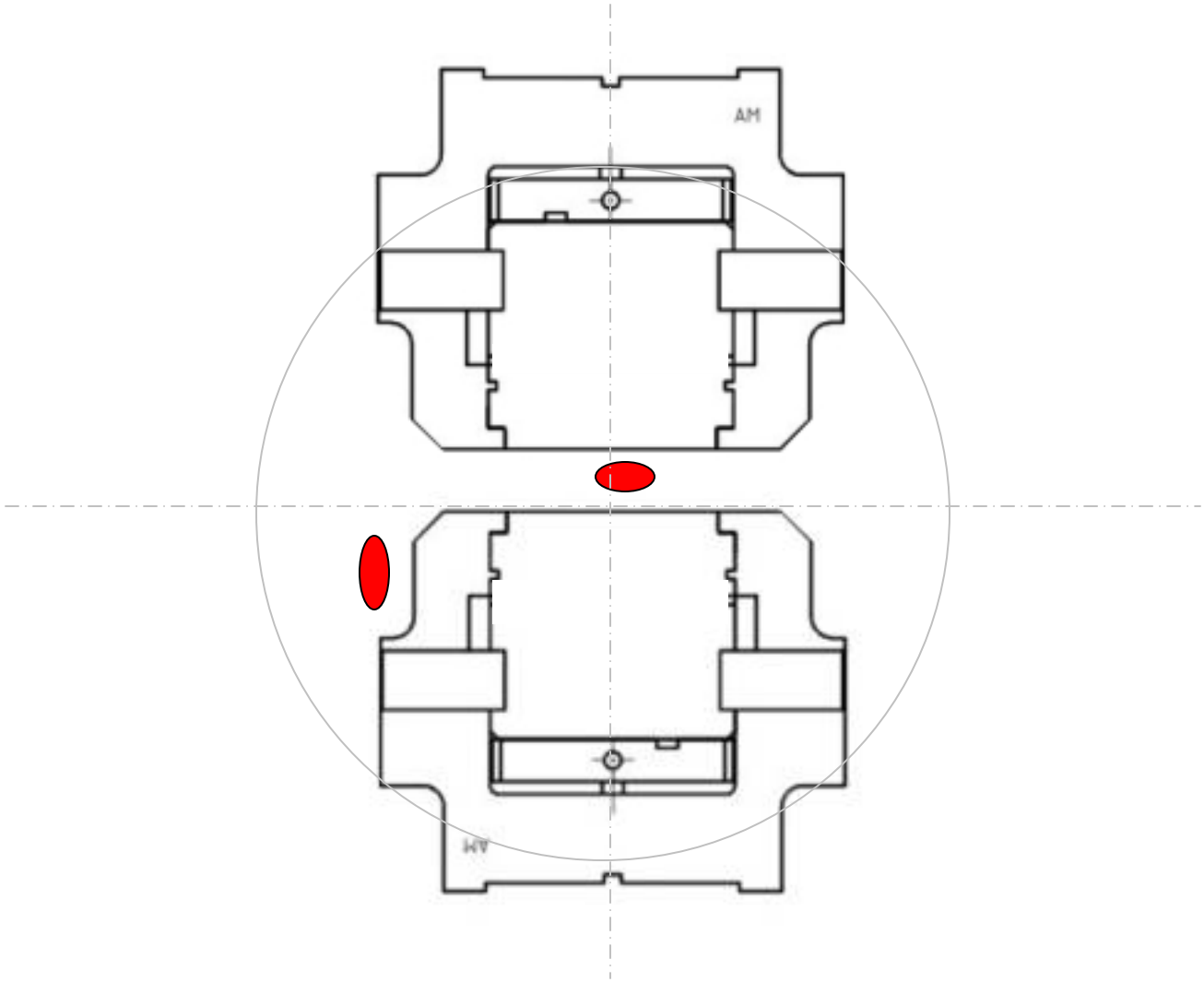
Point 2



Point 8



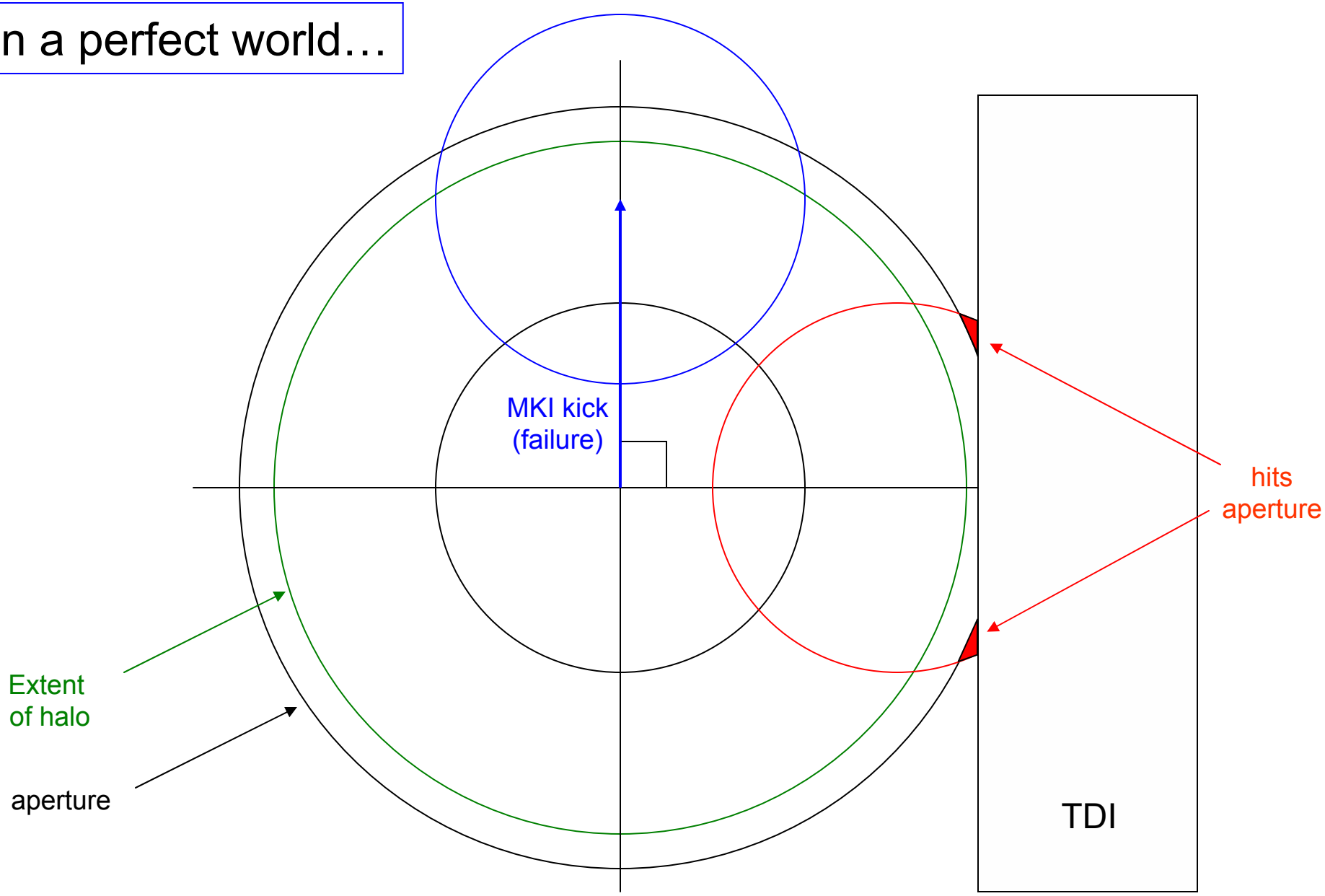
TDI jaws set around injected beam



Setting the TDI

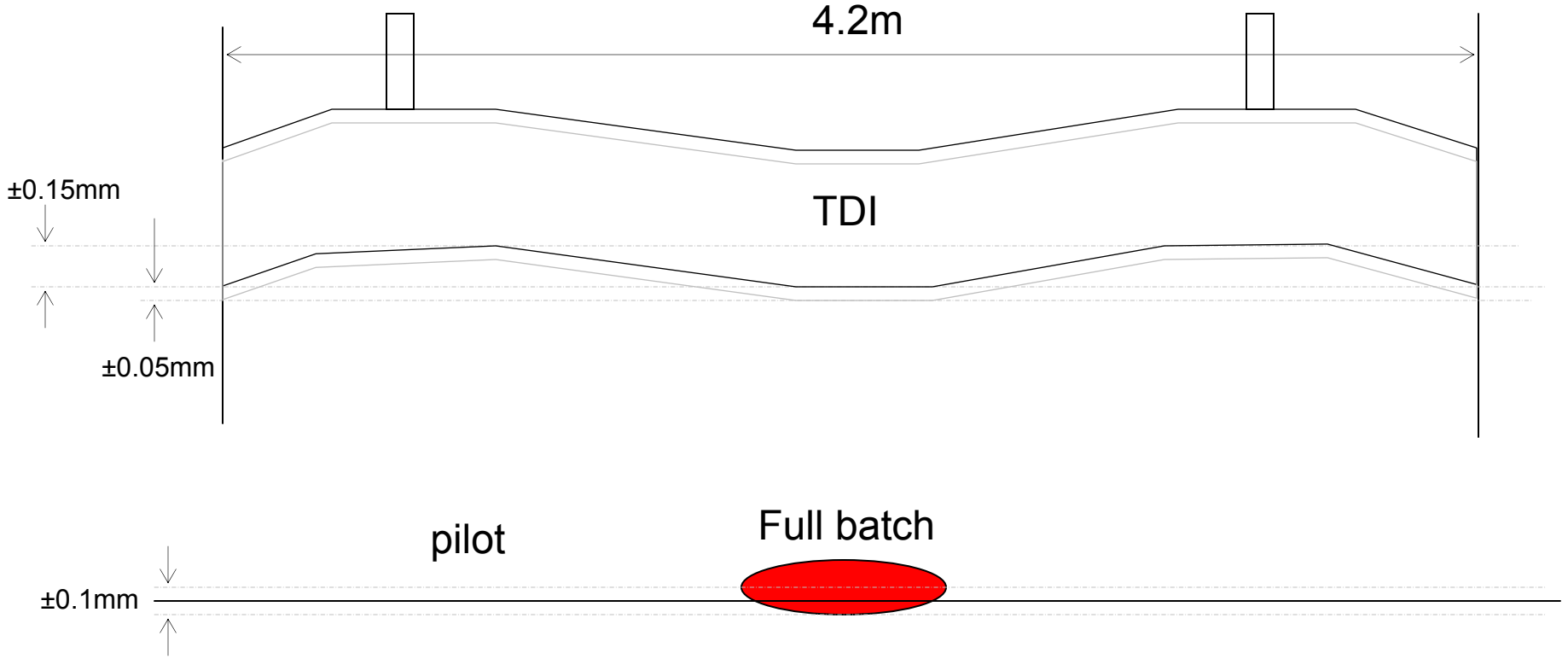
- Find the axis of the circulating beam with pilot bunches
  - Measure the beam position with BPMs?
  - Measure the losses with the TDI jaws and BLMs??
- Set the jaws symmetrically about this position
- Inject the full batch…
- Consider MKI flashover failure (worst case)

In a perfect world…



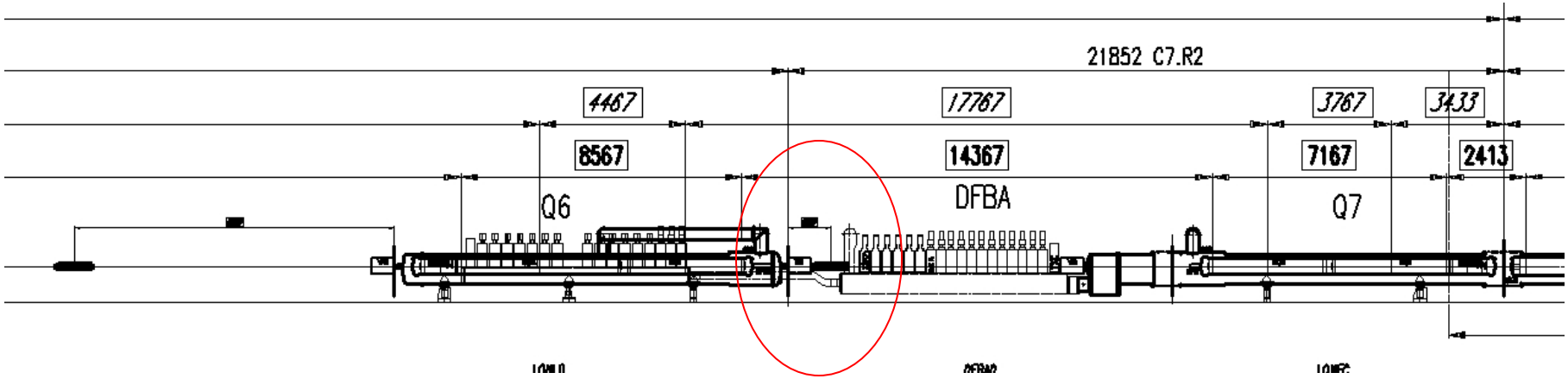
…the TDI can be positioned nicely between the edge of the halo and the aperture

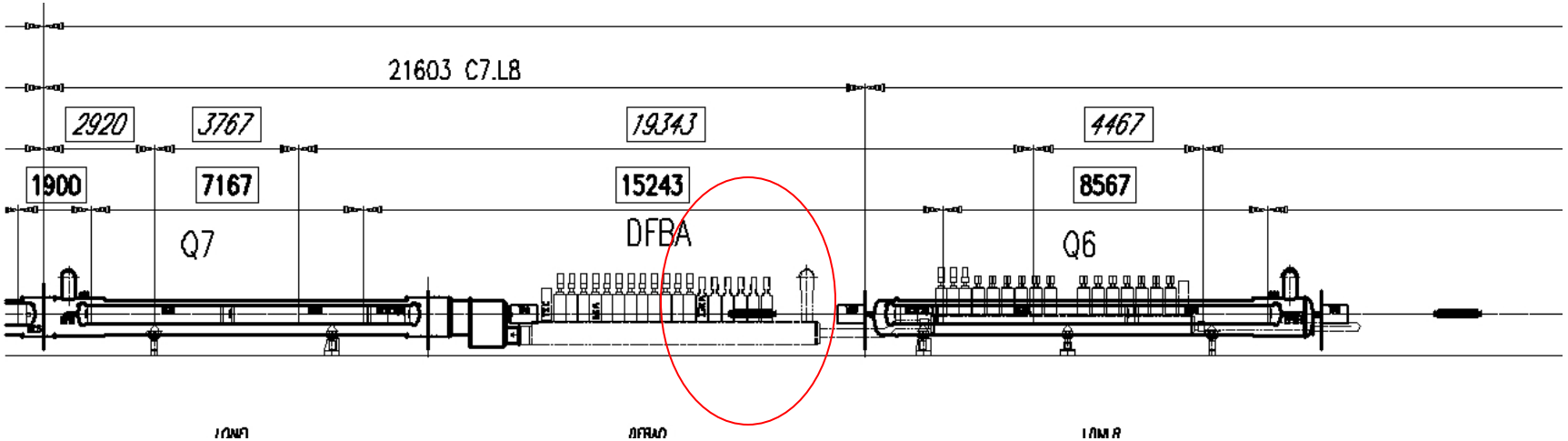
Unfortunately, (as we all know) the world is not perfect….



- plus random errors on the injected beam position / angle (0.2 σ_y)
- plus optics errors changing the phase advance from MKI to TDI (≤20˚)

2 TCLIs per IP at 360±20˚ from TDI foreseen to protect against MKI-TDI phase errors – but now location at +20˚ next to Q7 is impossible…





So… do we need 2, or 1, or even 0 TCLIs?

- Checked protection afforded by TDI ONLY with the ‘realistic’ errors
- Also checked protection afforded by TDI plus ONE TCLI at 360˚ from TDI
  - Some hope since TCLI 1m Cu with better precision
- Also checked protection afforded by TDI plus TWO TCLIs at 360±20˚ from TDI

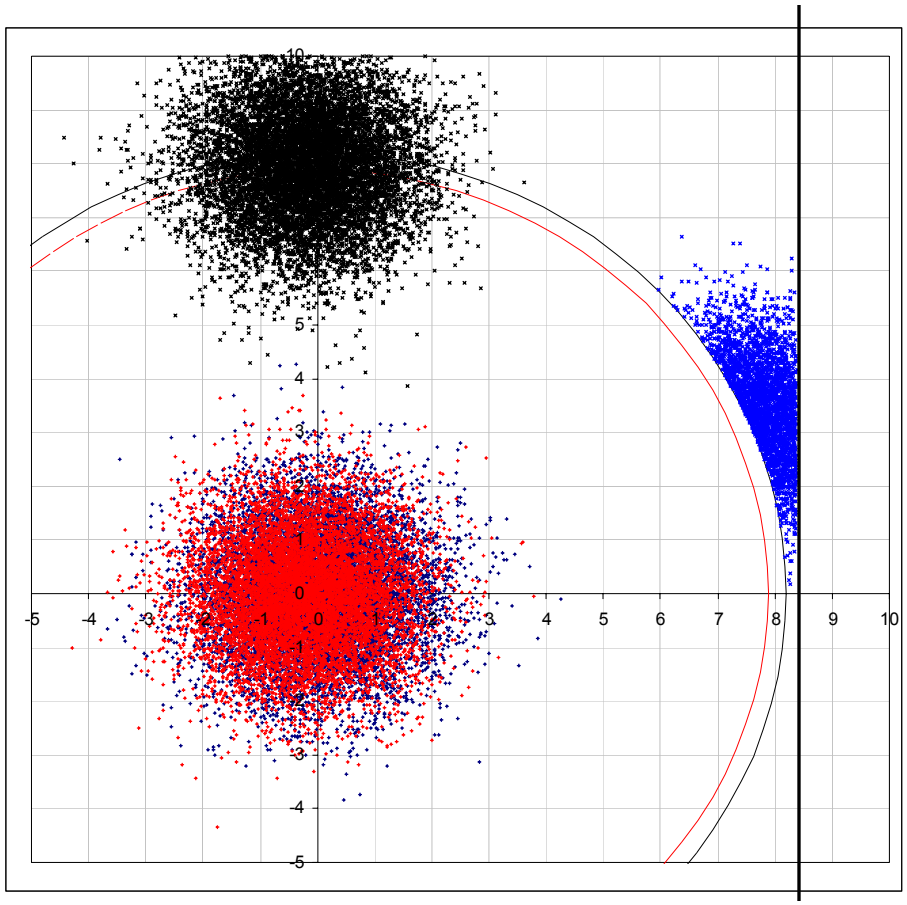
Checked particles outside aperture for these errors, by scanning MKI kick to obtain highest transmission…

<u>Assumed errors:</u>

Injection error ±0.2 σ
MKI-TDI phase error ±0-20˚
Orbit – TDI/TCLI precision ±0.1mm (±0.17 σ)
TDI mechanical error ±0.2mm (±0.33 σ)
TCLI mechanical error ±0.075mm (±0.13 σ)

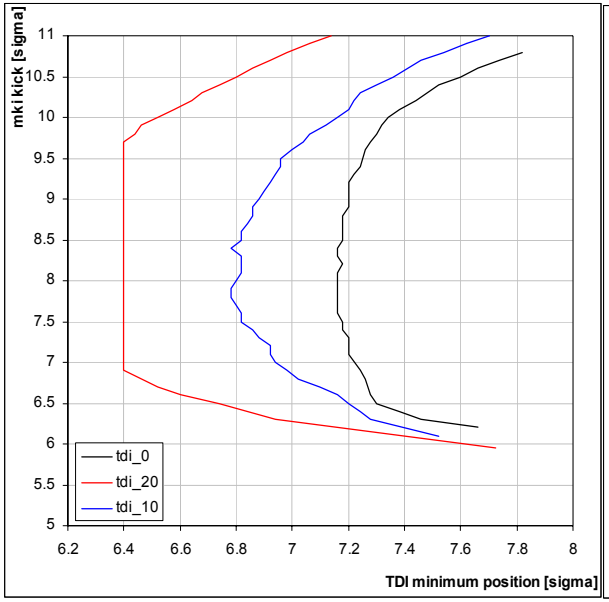
<u>Other assumptions</u>

288 x 1.15 x 10^{11} p+
Gaussian beam in Y, Y'
Extent of secondary halo: 7.88 σ
Vertical aperture limit: 8.2 σ
Damage limit 2% of full batch

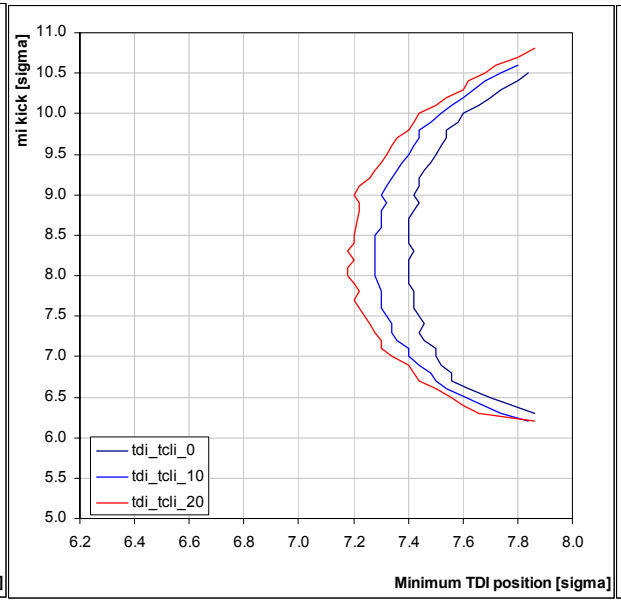


Regions where beam outside 8.2 σ exceeds damage limit (2% of total) as a function of MKI kick and TDI advance, for 0, 10 & 20 degree MKI-TDI phase errors

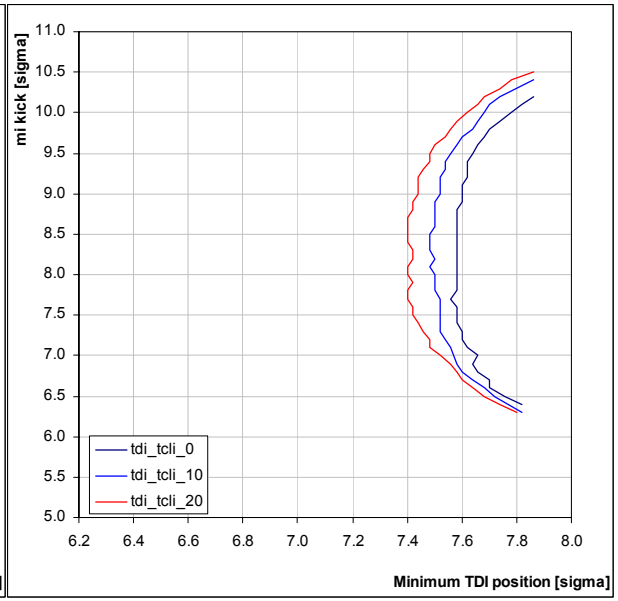
TDI only



TDI with TCLI at 360˚



TDI with 2xTCLI at 360±20˚



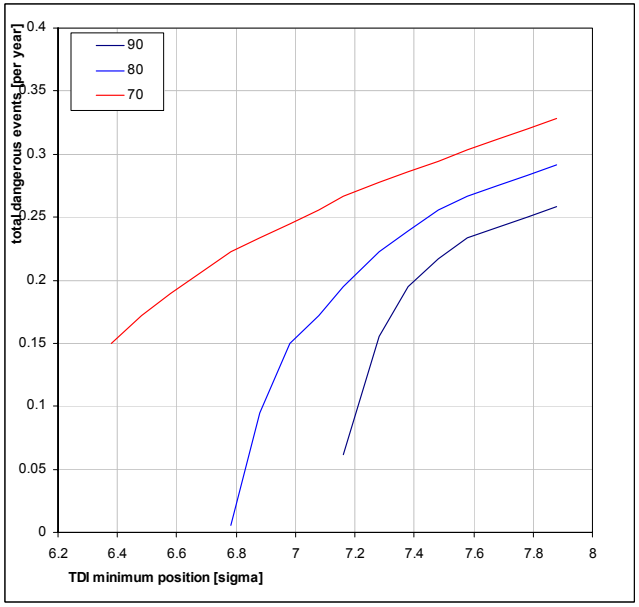
Note: the TDI NOMINAL position (i.e. the ‘setting’) is 0.5 σ larger.

What does this mean in terms of likelihood for damage?

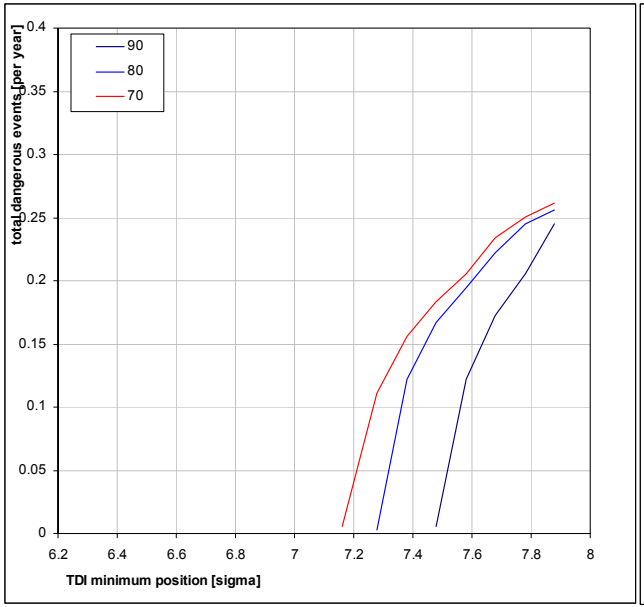
- Assume 1 MKI flashover per 8 magnets per year (expected rate extrapolated from measurement on 1 prototype magnet)
- 1.09 σ deflection per MKI cell (2 x I_{nom})
- 33 cells per MKI magnet
- 2 dangerous kick regions (grazing upper or lower TDI jaw)

Expected dangerous events per year (total for the 2 injections) as a function of TDI/TCLI setting, for 0, 10 & 20 degree MKI-TDI phase errors

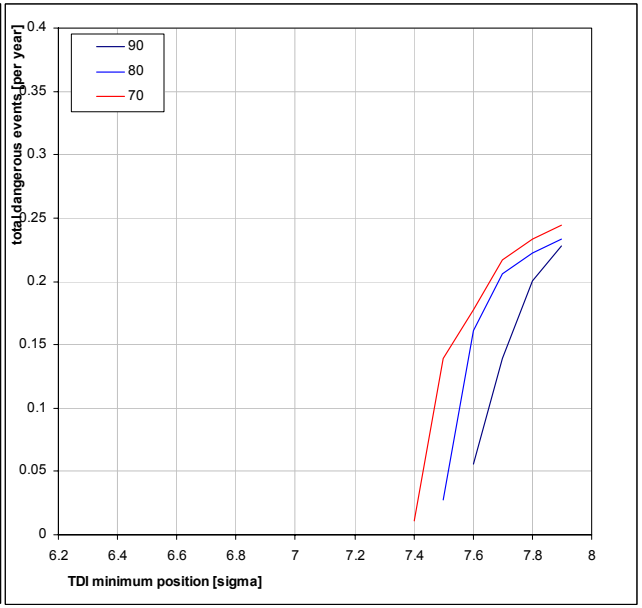
TDI only



TDI with TCLI at 360˚



TDI with 2xTCLI at 360±20˚



Note: the TDI NOMINAL position (i.e. the ‘setting’) is 0.5 σ larger.

Zero TCLIs

If MKI-TDI phase error ≤ 10 degrees,
And TDI can be set at 7.7 σ (i.e minimum position at 7.2 σ)
Then risk of damage due to MKI flashover every 5 years without TCLIs.

One TCLI at 360˚ from TDI

If MKI-TDI phase error ≤ 20 degrees,
And TDI can be set at 7.7 σ (i.e minimum position at 7.2 σ)
Then risk damage due to MKI flashover every 20 years with one TCLI.

Two TCLIs at 360 ±20˚ from TDI

If MKI-TDI phase error ≤ 20 degrees,
And TDI can be set at 7.9 σ (i.e minimum position at 7.4 σ)
Then risk damage due to MKI flashover every 40 years with two TCLIs.

1. Always assume here that MKI-TCLI phase advance is perfect……but should also check for errors in TDI-TCLI phase advance. OB to provide an idea of expected errors.

2. Risk of damage to TCLI itself non-negligible… to be evaluated in similar way.

What about positions for TCLIs?

- Next to Q6 is OK (340 or 360˚)
- Next to Q7 is out… (DFBX interference)
- Next to D1 (180 +20˚)? But 2 beams in same chamber… full analysis needed for TDI / TCLI / TCDD / TCT
- 640 degrees…. into continuous cryostat. Ugly.
- So one TCLI is OK, but 2nd only fits neatly at D1…

So where do we go from here?

- Reserve (again!) space next to Q6 for one TCLI
- Investigate feasibility of having TDI advanced to ~7.2 σ
  - Expected particle load
  - Effect on collimation system
  - Effect on TDI (activation, heating)
  - Effect on insertion (quenches?)
- Investigate feasibility of combined TCLI / TCT at D1 (anyway similar study being done for TCDD / TCT)
- Check damage expectation to Cu TCLI under the same assumptions
- Obtain realistic estimate of expected optics errors (MKI-TDI-TCLI phase advances)
- Suggestions for improving positioning tolerances welcome
  - Any optimists out there?