

Preliminary integration studies for 3rd TCDS block

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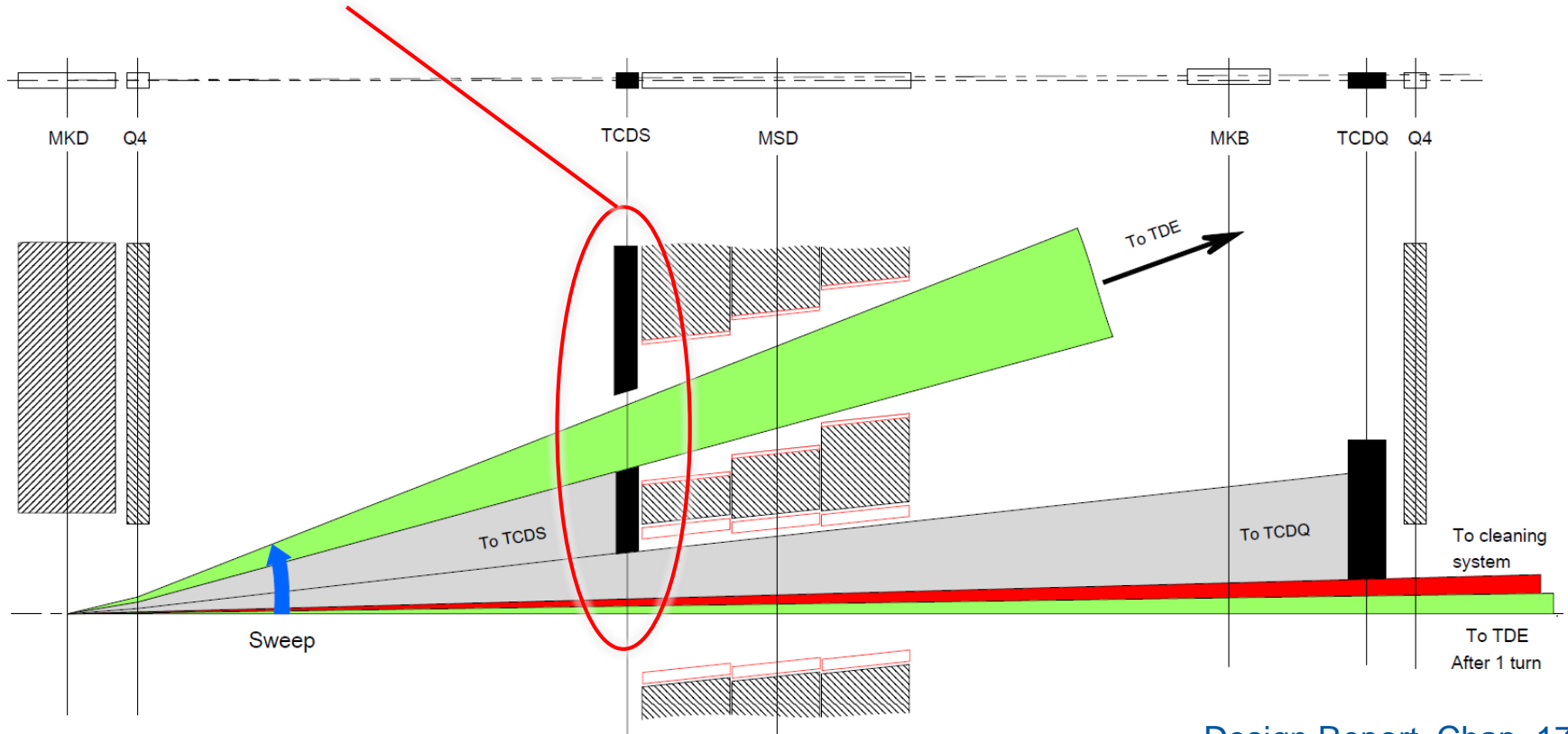
WP14 Meeting
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Outline

- Introduction: TCDS
- Aperture for circulating beam
- Shielding for MSD
- Aperture for extracted beam – nominal case
- Aperture for extracted beam – failure cases
- Summary

Introduction: TCDS

Protection element for Extraction Septum (MSD).

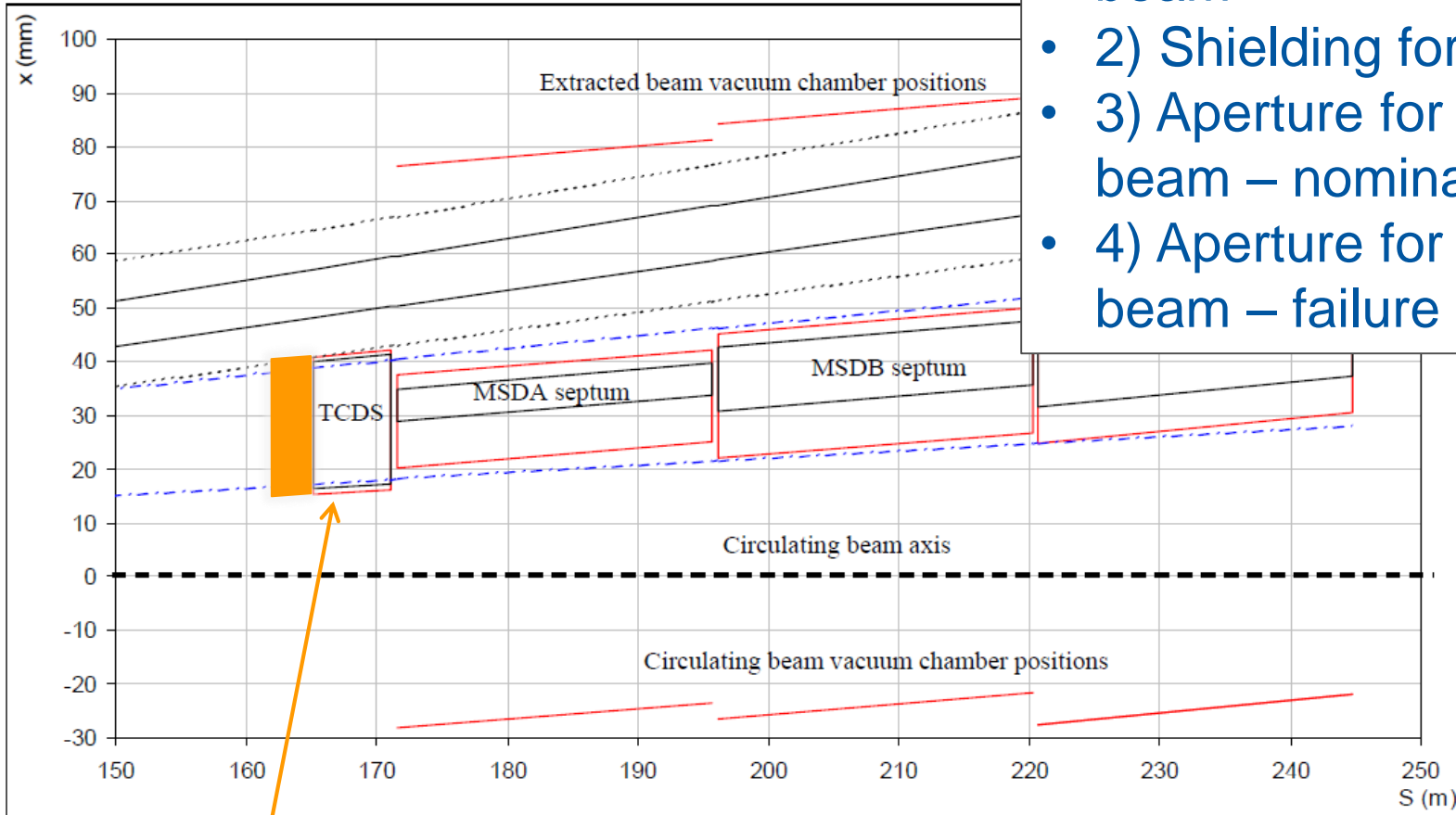


Design Report, Chap. 17

TCDS

To be checked:

- 1) Aperture for circulating beam
- 2) Shielding for MSD
- 3) Aperture for extracted beam – nominal case
- 4) Aperture for extracted beam – failure cases



[B.Goddard, M.Gyr, *LHC Project Note 320*, 2003-08-13]

New TCDS with 3rd module

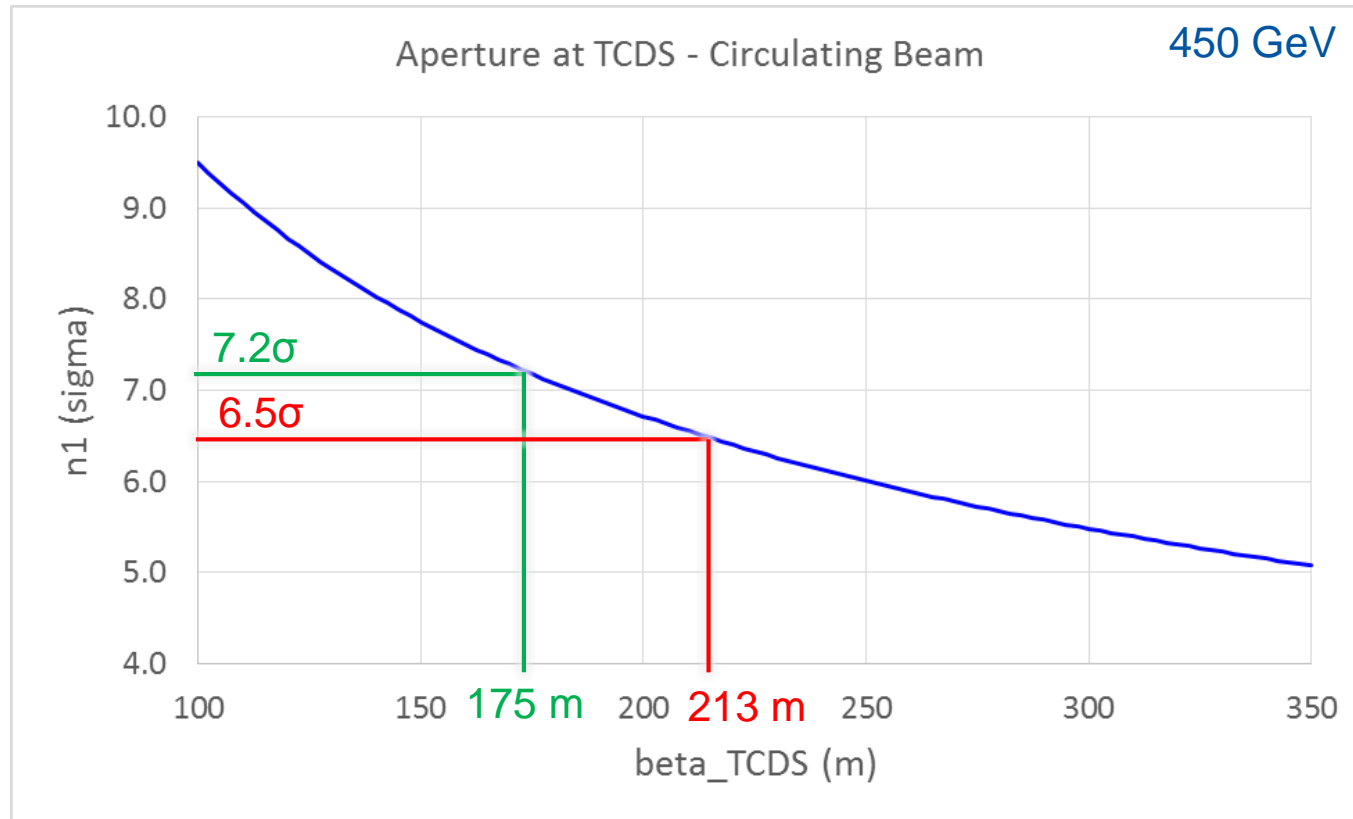
Assumed Parameters

	LHC PN 320 (2003)	HL-LHC	
Beam Energy	450	450	GeV
Emittance ϵ_x	3.5 (?)	3.5	um
Beta function β_x at TCDS	?	175	m
Beta beating factor k_β	$\sqrt{1.42}$	$\sqrt{1.2}$	-
Beta safety factor (in case of optics changes)	1.17	1.0	-
Horizontal beam size σ_x	?	1.1	mm
Maximum horizontal closed orbit excursion co_x	± 4	± 4	mm
Sum of mechanical and alignment tolerances δ_x	± 1	± 1	mm
Dispersion D_x	?	± 2	m
Momentum spread in beam δ_p	1e-3 (?)	2e-4	-
Aperture n_1	6.5	7.2	sigma
Calculated inner position of TCDS x_{TCDS}	16.3	16.3	mm
Inner position of TCDS as build [LHC-MS-EC-0001]	16.28	16.28	mm

$$x_{TCDS} = 1.22k_\beta\sigma_x^{TCDS}n_1 + co_x + \delta_x^{TCDS} + k_\beta\delta_pD_x^{TCDS}$$

[B.Goddard, M.Gyr, LHC Project Note 320, 2003-08-13]

Aperture – Circulating Beam



For present constraint of max. β_x at TCDS = 175 m, the aperture is: $n1 = 7.2\sigma$.
Requirement of $n1 > 6.5\sigma$ is fulfilled for β_x at TCDS < 213 m.

Shielding of MSD

- Outside edge of TCDS is given by :

$$x_{TCDS} = \frac{\left(x_{MSDC} + N \cdot a \cdot \sigma_x^{MSDC} + a \cdot c o_x \sqrt{\beta_x^{MSDC} / \beta_x^{MKD}} \right)}{b \cdot \sqrt{\beta_x^{MSDC} / \beta_x^{TCDS}}} + \delta_x^{TCDS}$$

[B.Goddard, M.Gyr, *LHC Project Note 320*, 2003-08-13]

- Current position is $x = 39.84$ mm [LHC-MS-EC-0001].
- Moving TCDS upstream \rightarrow MSD still protected by the TCDS against primary p+.
- Energy deposition of secondary particles to be checked for HL-LHC parameters.
- Are mitigations for sudden pressure rise and shockwaves in MSD required?

Aperture – Extracted Beam (Nominal Case)

Assuming that all bunches are on the nominal trajectory that is defined by the nominal kicks of the MKD (15×19.0553 urad) and the Q4 (to be discussed).

Using HL-LHC parameters (450 GeV):

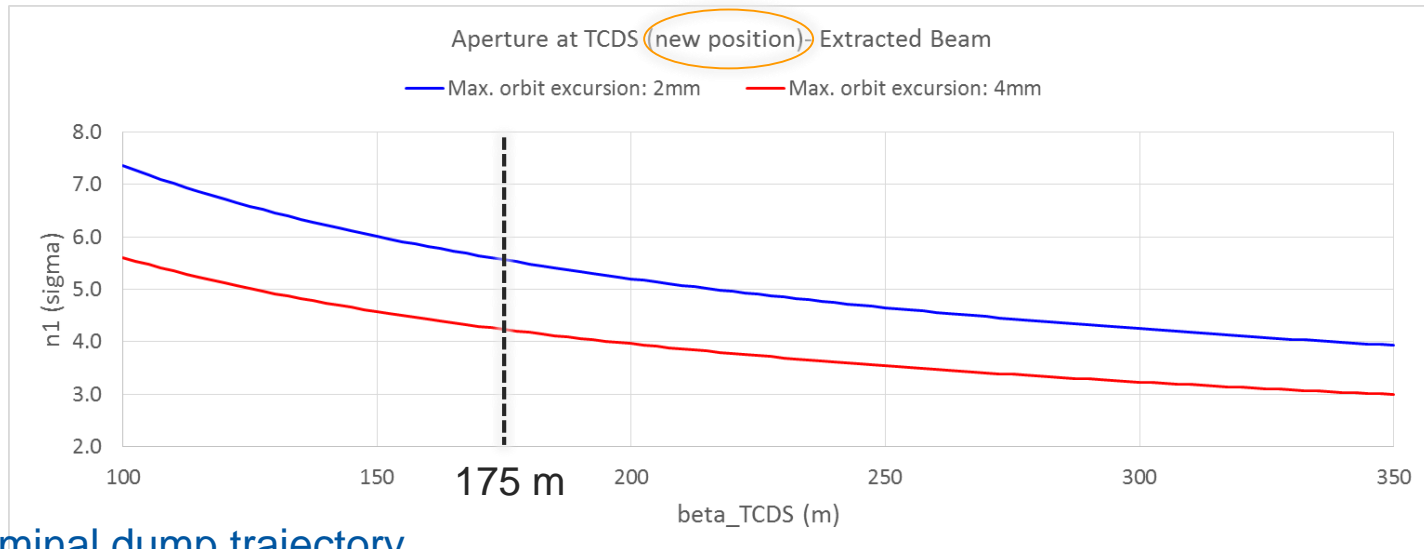
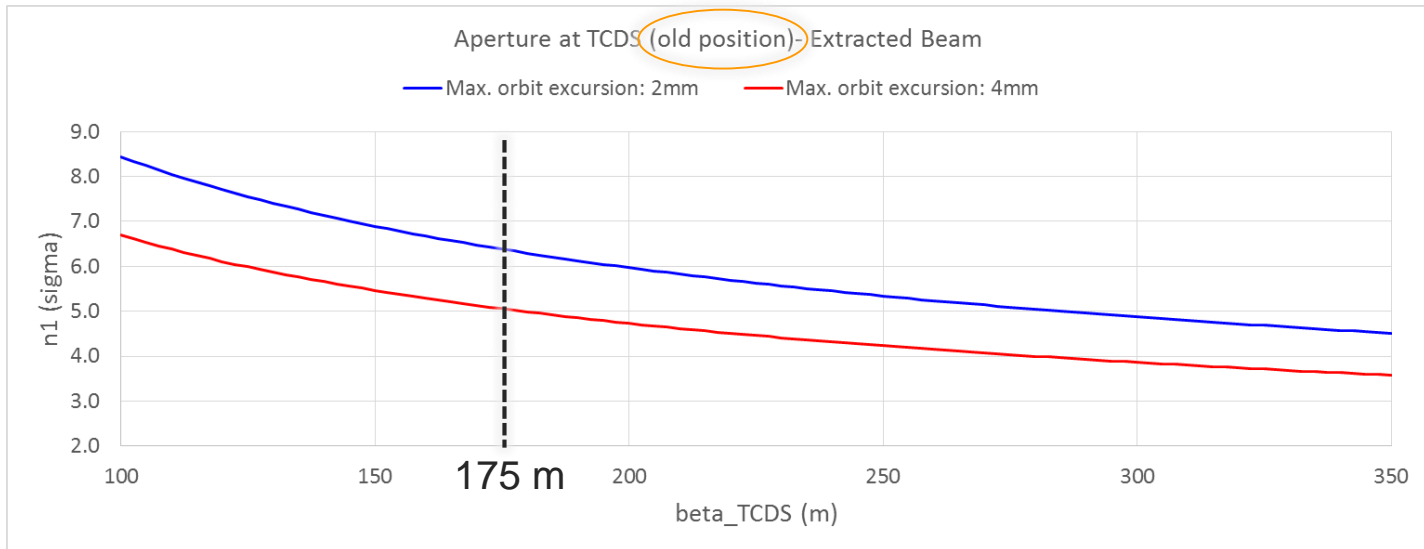
- Free aperture for extracted beam with $\beta_x=175$ m:
 $n1 = 5.04\sigma$ (old TCDS position)

Moving 1st TCDS module 3.3 m upstream leads to...

- geometric aperture reduction for the extracted beam by $3.3 \text{ m} \times 373 \text{ urad} = 1.24 \text{ mm}$
- i.e. geometric aperture at TCDS.START is reduced:
 - from 13.05 mm to 11.8 mm.
 - Free aperture reduced to $n1 = 4.2\sigma$ (new TCDS position)
- Requirements for clean extraction: 4σ at 450 GeV?
- Is assumption of 4 mm orbit excursion too pessimistic?

Aperture – Extracted Beam (Nominal Case)

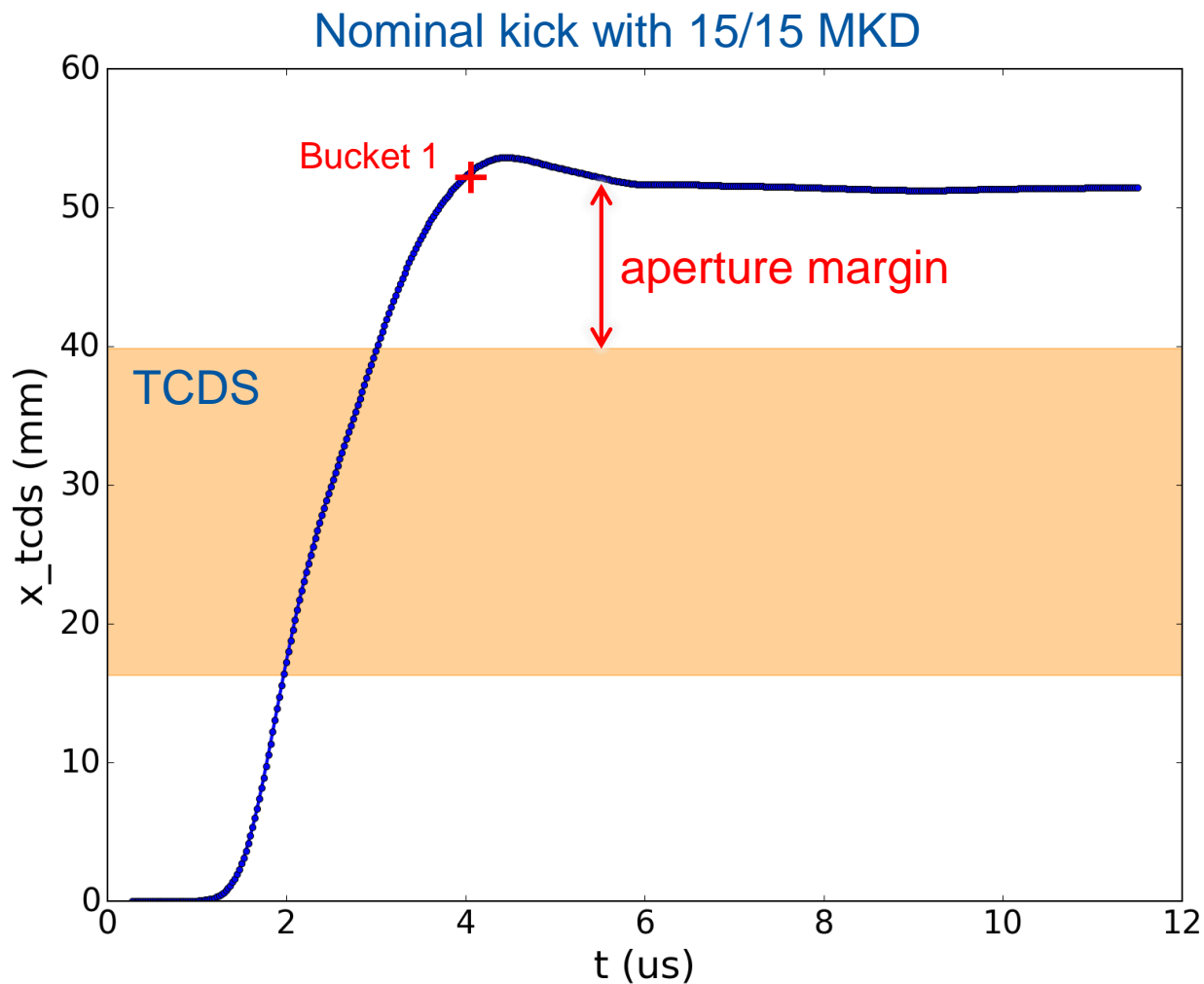
450 GeV



Assuming nominal dump trajectory

Kick at TCDS

Simulated using nominal, measured waveform from 2016-07-22, 17h01 dump event



Aperture – Extracted Beam (Failure Cases)

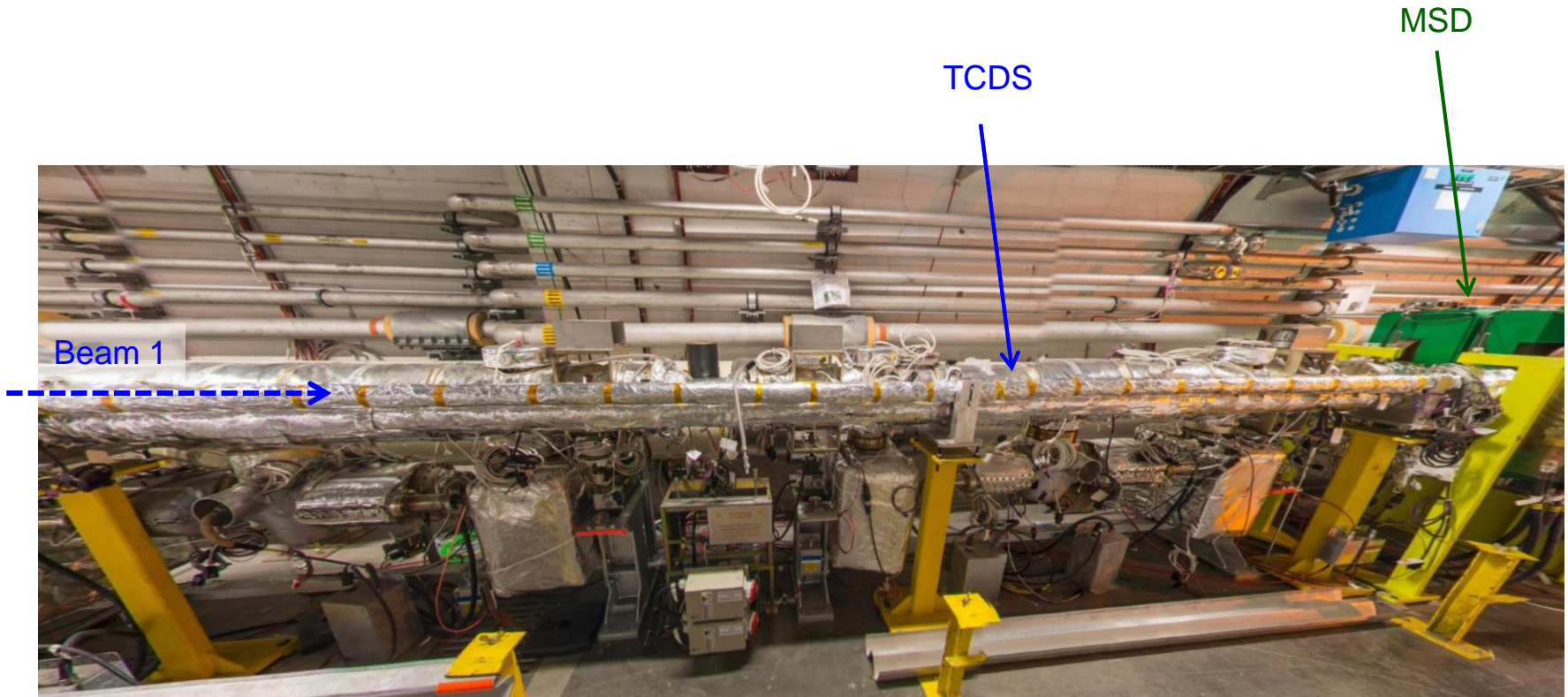
- Accepted failure case is 14/15 MKD firing.
- For worst case of missing MKD.O: deflection of extracted beam is reduced to $\approx 92\%$.
- Free aperture (incl. 4mm orbit excursion) reduced to
 - 2.2σ (old TCDS position) and 1.4σ (new TCDS position)
- Conclusion 2003: *“it is clear that, for even moderate orbit excursions, the TCDS will receive some beam in the event of an MKD missing, with the attendant risk of quenches in downstream superconducting magnets or of damage to the TCDS”* [LHC Project Note 320]
- → To be checked with energy-deposition studies for HL-LHC parameters.

Aperture Measurements

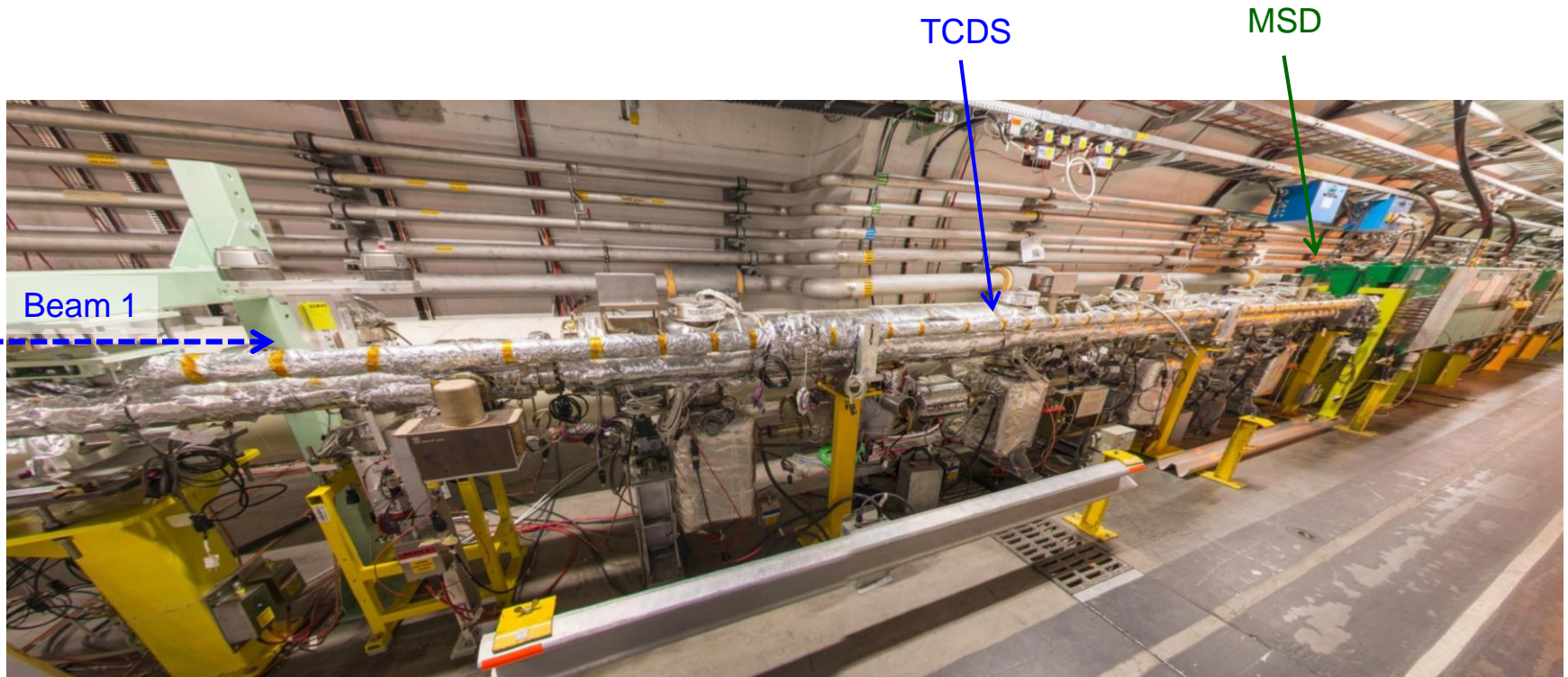
- Aperture measurement for extracted beam were performed in May 2017 during LHC recommissioning at 450 GeV.
- Aperture margin of more than ± 1 MKD confirmed for nominal beam parameters.

Beam	Losses
Beam 1	Start seeing losses on TCDS at 13 MKD and no losses for 16 MKD
Beam 2	Start seeing losses on TCDS at 12 MKD and 17 MKD

Integration: Tunnel View



Integration: Tunnel View

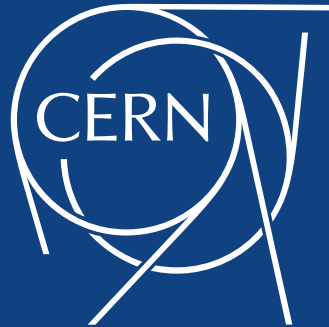


- Upstream elements:
BTVSE.A4L6.B1, BPMSE.4L6.B1, BPMSA.A4L6.B1, BPMSA.B4L6.B1
and vacuum components.
- Distance to MKBH.B2 > 60 m.

(Preliminary) Conclusions

- Aperture for circulating beam: $n1 > 6.5\sigma$ 😊
- Shielding for MSD: OK for primary p+. To be checked for secondaries. 😊
- Aperture for extracted beam – nominal case: $n1 > 4\sigma$ 😊
- Aperture for extracted beam – failure cases: For worst-case assumptions: losses at TCDS expected for 14/15 MKDs 😞
- Energy-deposition studies required for the HL-LHC parameters.
- Physical integration of 3rd module seems possible (to be confirmed).

Thank you for your attention!



Aperture Measurements

- Aperture measurement for circulating beam performed in May 2017 during LHC recommissioning.
- Free aperture confirmed.

Plane	Beam	Aperture
Horizontal	Beam 1	+15 mm (TCDS)/ -20 mm (TCSP)
	Beam 2	+15 mm (TCSP)/ -16 mm (TCDS)
Vertical	Beam 1	+16 mm (TCSP)/ -19 mm (TCSP)
	Beam 2	+17 mm (Q5)/ -18 mm (Q5)

Shielding of MSD

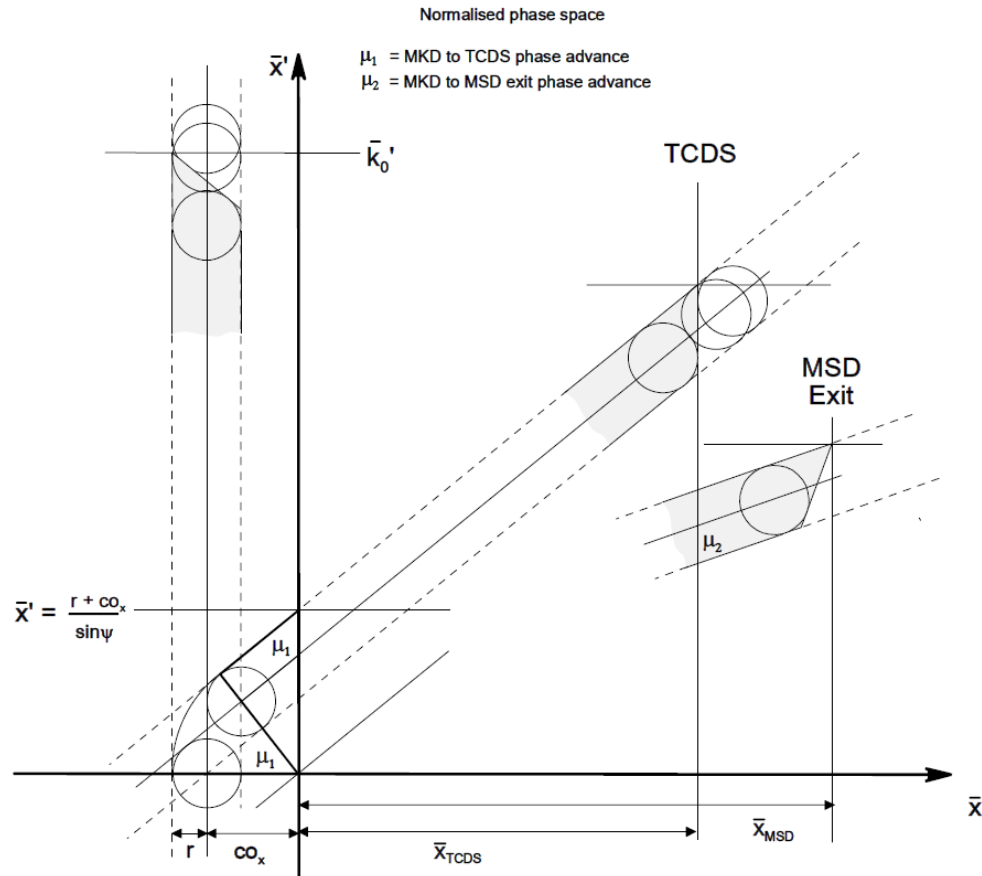


Figure 2. Normalised phase space diagram showing particles grazing TCDS and MSDC vacuum chamber.

[B.Goddard, M.Gyr, LHC Project Note 320, 2003-08-13]