Short overview of previous WP5 failure studies

R. Bruce on behalf of WP5

Annual HL-LHC collaboration meeting, Fermilab, 2019.10.15

Studies of TCT damage limit for asynch. dump

- 3-step simulation of asynch dump in HL-LHC v 1.0: tracking + energy depostion + thermo-mechanical simulation

PHYSICAL REVIEW ACCELERATORS AND BEAMS **20,** 091002 (2017)

Modeling of beam-induced damage of the LHC tertiary collimators

E. Quaranta,* A. Bertarelli, R. Bruce, F. Carra,† F. Cerutti, A. Lechner, S. Redaelli, and E. Skordis
CERN, CH-1211 Geneva 23, Switzerland

P. Gradassi
A.D.A.M. Applications of Detectors and Accelerators to Medicine, CH-1211 Geneva 23, Switzerland
(Received 14 June 2017; published 13 September 2017)

Studies of TCT damage limit for asynch. dump

- Found potentially very high losses on TCTs – still old optics with “bad” phase advance
- Calculated limits used as input to all following studies on asynch dump

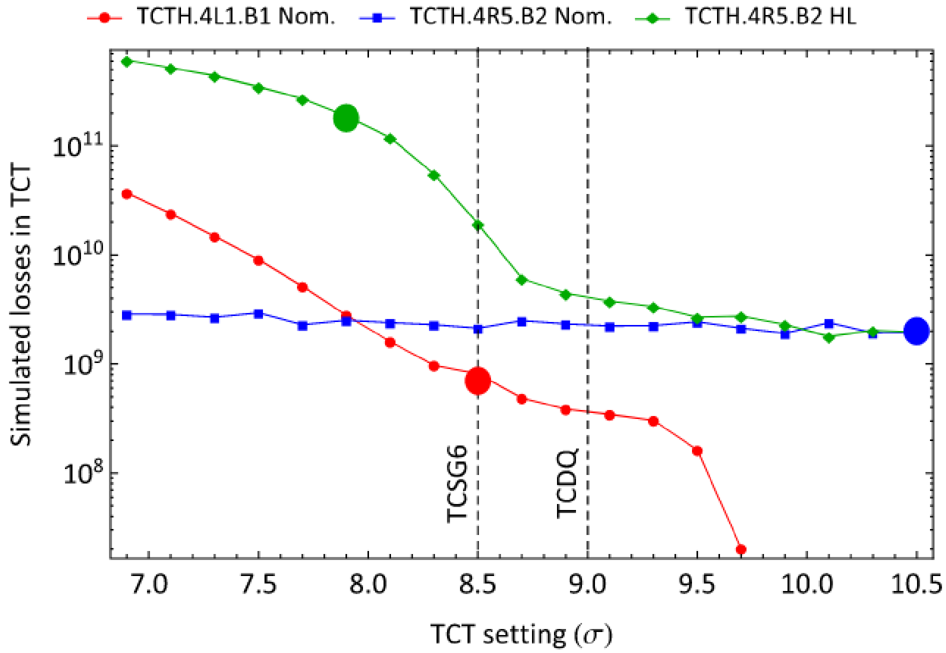


TABLE IV. Damage limits calculated for the tungsten collimator jaw for the three cases discussed in the paper.

	Thresholds (number of protons)		
Material damage	Case 1	Case 2	Case 3
Plastic deformation	1.2×10^{11}	4.6×10^{9}	6.9×10^{9}
Fragment ejection	7×10^{11}	1.8×10^{10}	2.6×10^{10}
Catastrophic damage	1.1×10^{12}	1.4×10^{11}	1.7×10^{11}

Studies on MKD-TCT phase advance

- Studies for the 2016 LHC run: elimination of primary TCT impacts during asynch dump by use of MKD-TCT phase advance

Nuclear Instruments and Methods in Physics Research A 848 (2017) 19–30

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

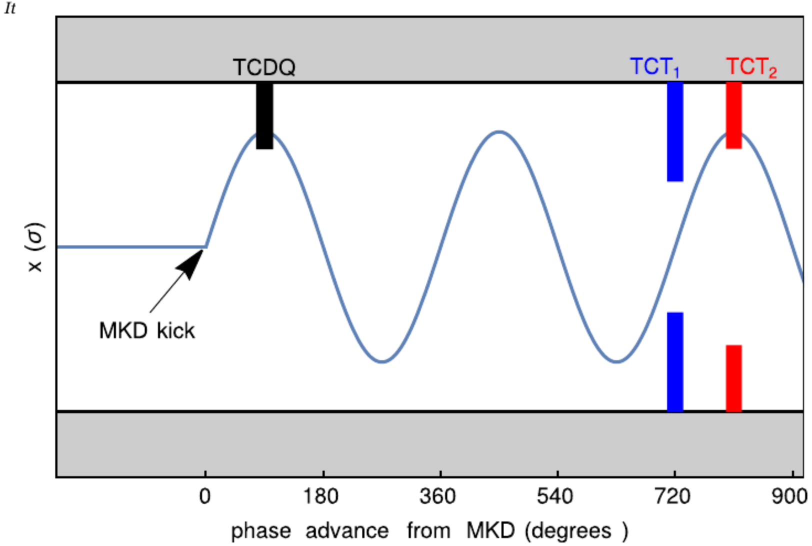
journal homepage: www.elsevier.com/locate/nima

Reaching record-low β^* at the CERN Large Hadron Collider using a novel scheme of collimator settings and optics

CrossMark

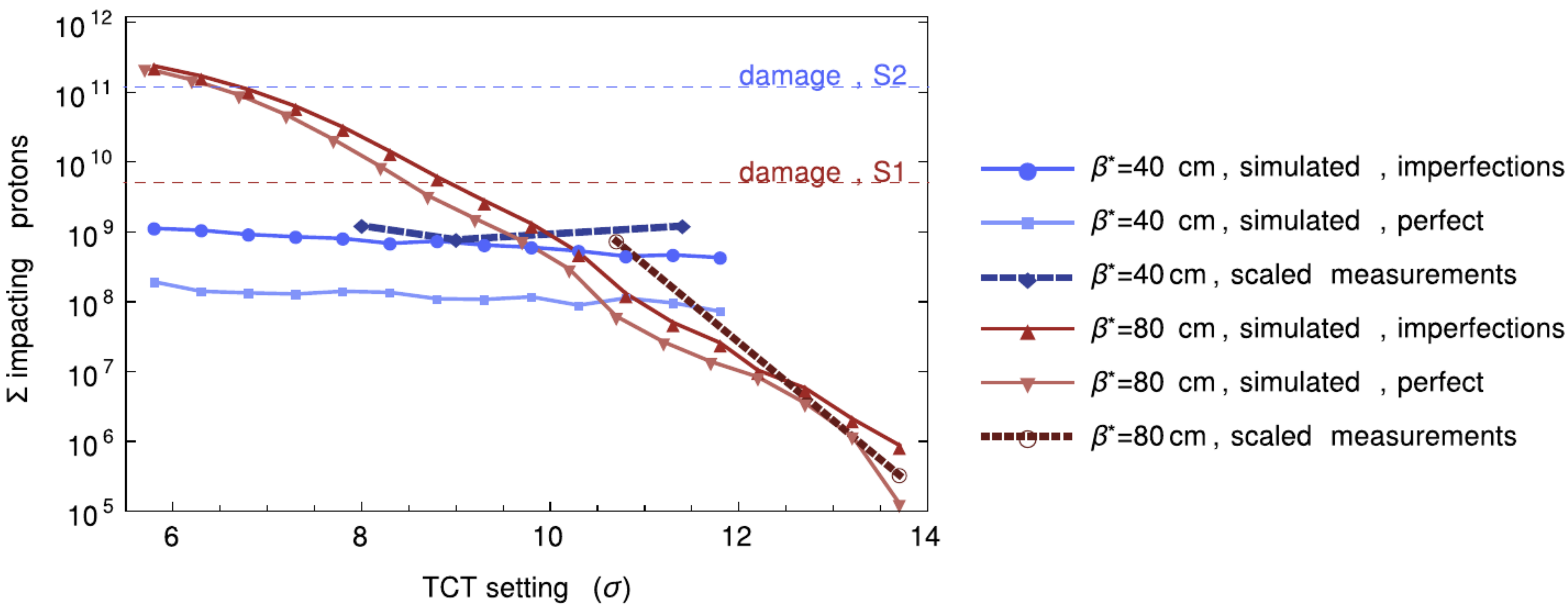
R. Bruce[a,*], C. Bracco[a], R. De Maria[a], M. Giovannozzi[a], A. Mereghetti[a], D. Mirarchi[a], S. Redaelli[a], E. Quaranta[a,b], B. Salvachua[a]

[a] *CERN, Geneva, Switzerland*
[b] *Politecnico di Milano, Milan, It*



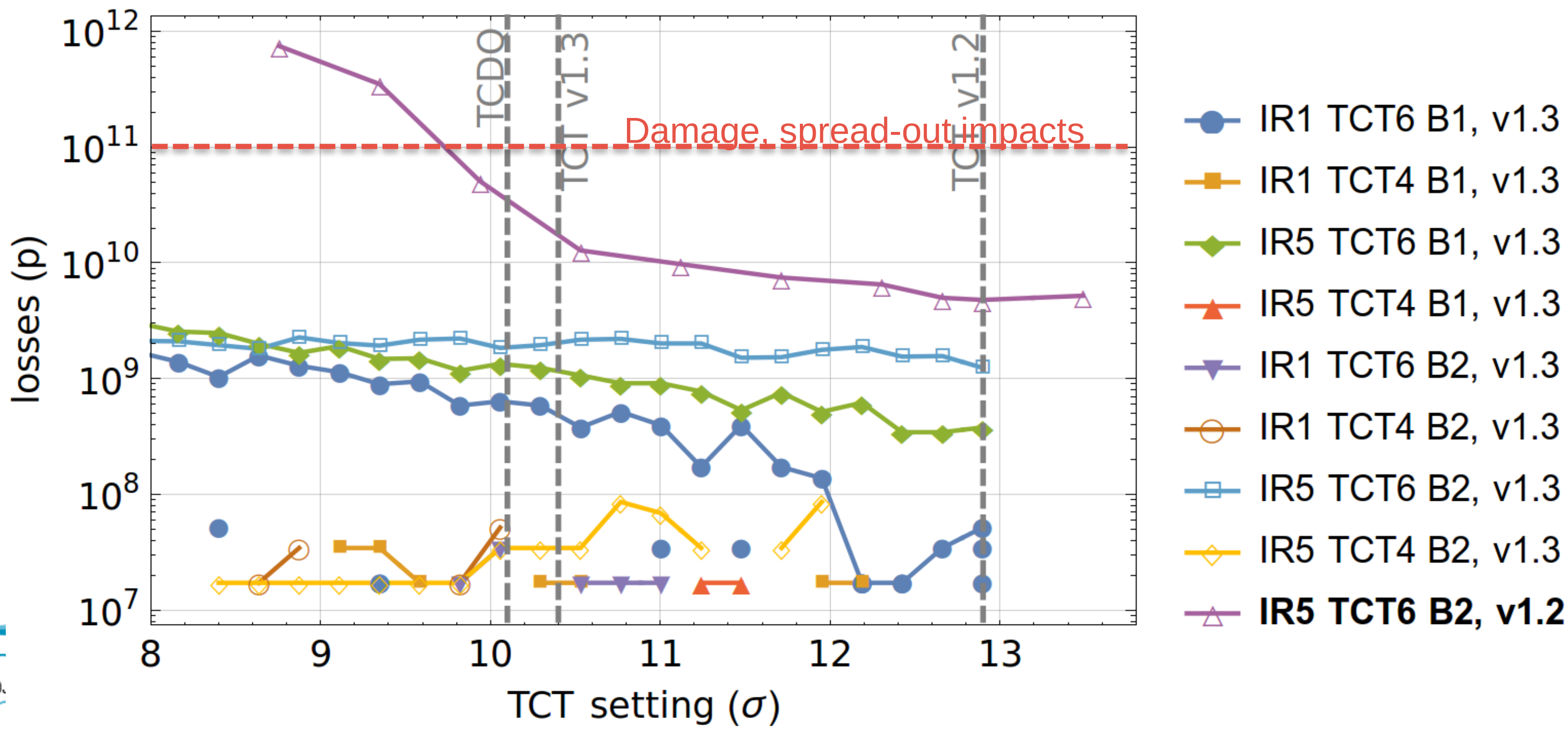
Studies on MKD-TCT phase advance

- "safe" situation, not limited by asynch. Dump, for MKD-TCT phase < 30 deg
- Successfully implemented strategy in 2016 and **allowed to reach β*=40 cm**
- Successfully benchmarked simulation with measurements



Failure studies including MKD-TCT phase for HL-LHC v1.3

- Included LHC experience in HL-LHC design, with requirements on MKD-TCT phase advance
- Presented at the 2017 annual HL-LHC meeting (indico links: 1,2)
- Conclusion: tungsten TCTs well below damage limit for *secondary impacts*
- Allowed tighter TCT setting at 10.4 σ → pre-requisite to reach 15 cm after rebaselining



Calculation of allowed settings vs phase

- Achieved phase advance in HL v1.3 and later allows tighter TCTs and aperture
- Calculation of protected aperture for different MKD-TCT phase advance

CERN-ACC-2017-0051

$\Delta\mu$ MKD-TCT	Protected aperture (σ)	
	LHC, ϵ_n =3.5 μm	**HL-LHC, ϵ_n =2.5 μm**
0°	9.5	**11.2**
10°	9.5	**11.2**
20°	9.5	**11.2**
30°	10.0	**11.9**
40°	10.9	**12.9**
50°	11.7	**13.8**
60°	12.3	**14.5**
70°	12.3	**14.6**
80°	12.3	**14.6**
90°	12.3	**14.6**

CERN-ACC-2017-0051

FLUKA studies of TCT shower during failure

- Studies of energy deposition on downstream elements for asynch dump: input from previous tracking studies
- Simulated cases with both “bad” and “good” MKD-TCT phase advance
- See A. Tsinganis et al. at HL-LHC meeting 2017 and at IPAC

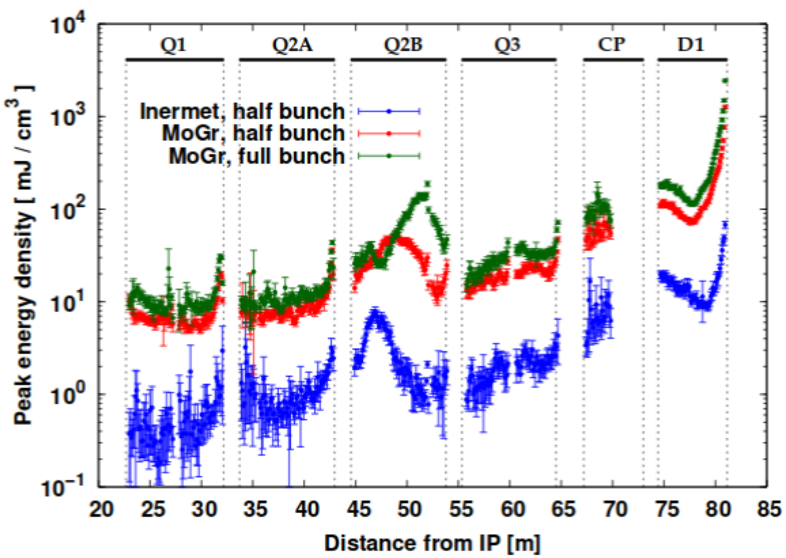
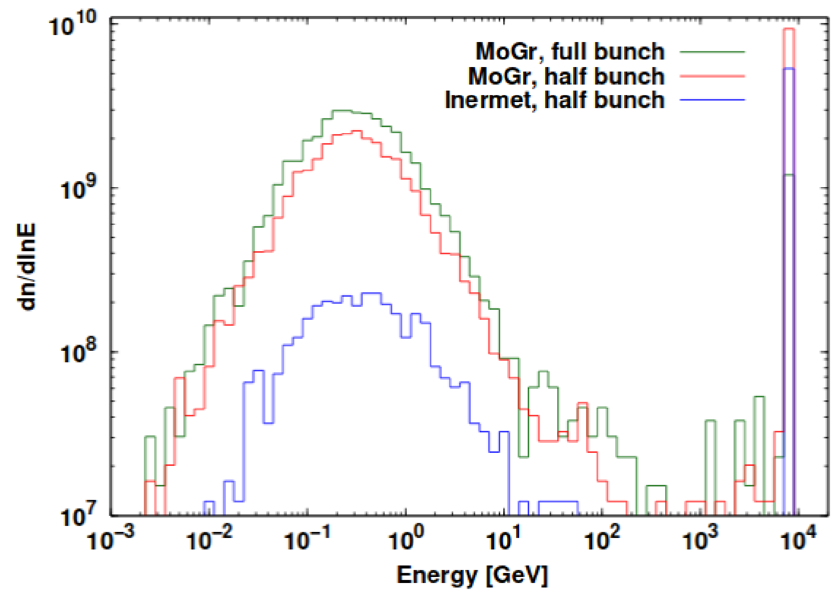


Figure 2: Peak energy density profile in the triplet-D1 inner coils (CP stands for ‘Corrector Package’) for the three investigated scenarios. Values are normalised to the HL-LHC bunch population of 2.3×10^{11} protons.



(c)

Figure 3: Energy spectra of (a) photons, (b) neutrons and (c) protons crossing the scoring plane at 22.6 m from the IP, i.e. moving towards the CMS experimental cavern. Values are normalised to the HL-LHC bunch population of 2.3×10^{11} protons.

HiLumi HL-LHC PROJECT

CERN

Input to energy deposition

- Particles entering the detector used as input to FLUKA study of ATLAS detector by A. Sbrizzi et al.
- Even with MoGr TCTs (unrealistically light) we are at least a factor 300 below ATLAS damage limit

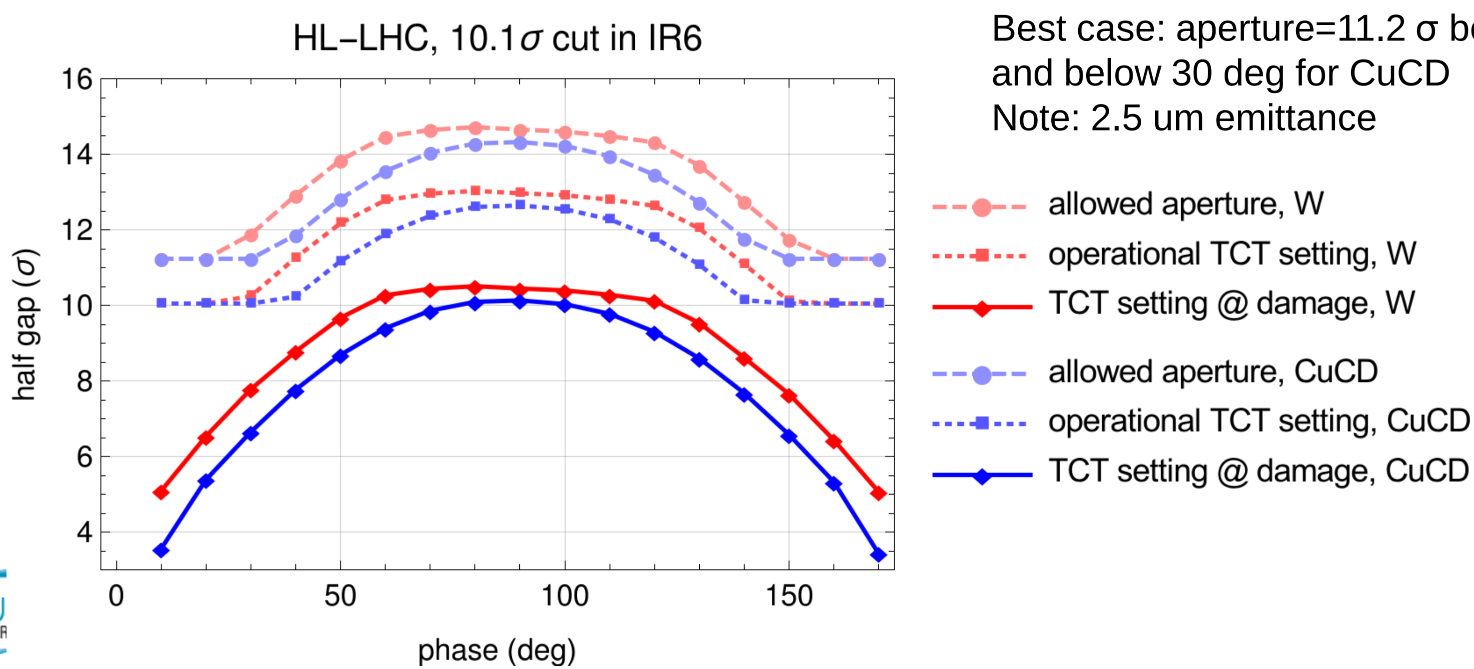
A. Sbrizzi, ATLAS non-collisional background meeting 9/4/2018

- IBL damage threshold: $dN_{MIPs}/dS = 10^{13}/cm^2$ (measured @ HiRadMat)
  - $dE_{thr}/dV = (dN_{MIPs}/dS)\,(dE_{MIP}/dx) = 3.87*10^{13}$ MeV/cm^3
  - $dE_{dep}/dV = (dE_{dep}/dVdN_p)\,N_p$

TCT4 material	Impact scenario	$N_p/10^{11}$	dE_{dep}/dE_{thr} [%]	
			TAS ∅ 60 mm	TAS ∅ 34 mm
W alloy	Half-bunch	1.167	0.0048	0.0016
Mo graphite	Half-bunch	1.167	0.17	0.038
Mo graphite	Full-bunch	2.184	0.30	0.078

TCT impacts with new material: CuCD

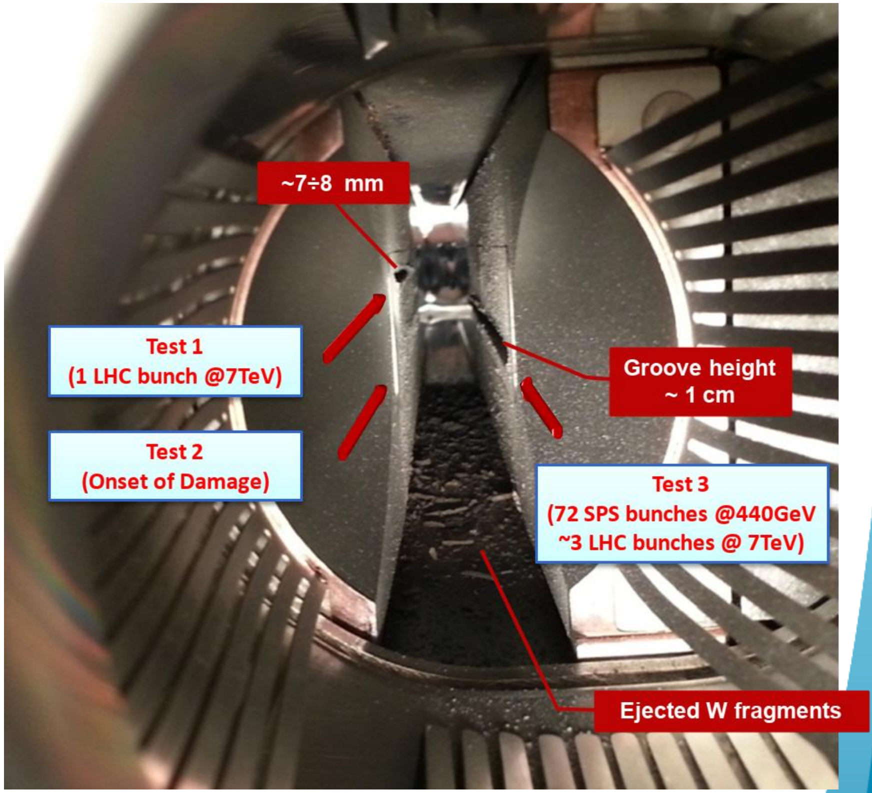
- With CuCD, improvement in robustness. TCT can take more protons before being damaged
  - Possibility for tighter TCTs and tighter protected aperture
- See ColUSM [115]



Best case: aperture=11.2 σ below 20 deg for W and below 30 deg for CuCD
Note: 2.5 um emittance

HiRadMat tests

- Experimental validation of robustness of material samples as well as full collimator jaws
- Assessing impacts of async. dump and injection failure
- Some references:
  - Overview of Multimat (HRMT 36)
  - Paper on HRMT 23, comparison of W and CuCD
  - Overview of earlier HiRadMAt studies



A. Bertarelli, F. Carra et al.