
CERN

MD4830: Assessing Collimator Coating Robustness with Beam Scraping

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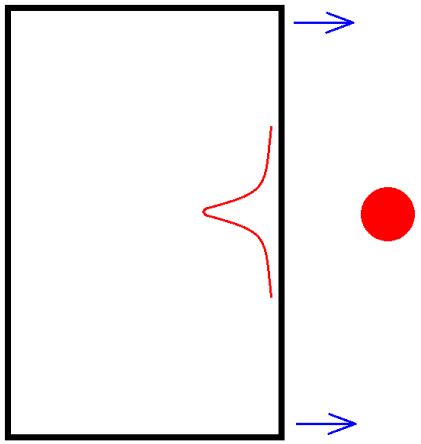
MD Merit

- In HiRadMat tests, Mo-coated MoGr jaw samples showed a resistance to beam impact better than that of Cu-coated samples:
  - Tests not aimed at assessing the on-set of damage but checking survival to failure scenarios (single-pass approach);
- Aim: to test endurance of the coating layers of the TCSPM.D4R7.B2 in a configuration closer to the operational one (multi-turn environment) than that of HiRadMad:
  - ~~Induce damage on coating layer;~~
  - Assess with measurements a safe value of energy/power deposition in Mo layer;
- Direct consequences of measurements on:
  - Alignment procedures of Mo-coated TCSPM collimators, in case BLM-based procedure is followed (e.g. because BPMs are not temporarily usable)
  - Compare to loads on the Mo-layer in case of beam losses with minimum life times;



- Measurements performed scraping the ion beam (~~trains~~ few bunches) at ~~flat top~~ injection with one jaw of the prototype TCSPM.D4R7.B2
  - Power deposition concentrate into the Mo-layer, thanks to scraping movement and use of ions (energy loss dominated by ionisation);
  - ~~Scraping only a fraction of the beam allows to repeat the scraping action more than once with the same beam;~~ Scraping the whole beam at injection allows to:
    - Have a good control on total amount of scraped beam;
    - Not depend on orbit jitters and/or variations of beam transverse distribution;
    - Inject quickly and re-test the jaw at another position of the 5th axis;
  - Configuration similar to alignment situation (apart from beam intensity!);

Setting the Target (more in F.Carra's slides)

- Heating tests (lab) on Mo-coated MoGr samples (M. Taborelli et al.) showed no signs of coating peeling:
  - Jaw block with some thermal cycles:
    - Heated for 6h @400C;
    - UHV test, including bake-out of 48h@250C;
    - heated for 48h @400C: no signs of coating peeling;
    - UHV test, including bake-out of 48h@250C;
  - Small sample (10x10 mm^2) @950C;

- Number of ions necessary to induce a given ΔT (@constant power!):

Endep map (Fluka) by A.Lechner&A.Waets with input (SixTrack) by A.Mereghetti, simulating full beam scraping @ 6.37 Z TeV

Full Beam scraping @ Inj

Number of impacting ions in 1 s			
Temperature	C=500W/m2/K	C=5000W/m2/K	C=infinite
500 C	3E8 ions	1.7E9 ions	4.5E9 ions
1000 C	6E8 ions	3.55E9 ions	1.15E10 ions

Target

Very bad contact (e.g. clamped contact with weak springs)

Small scraping step @ FT

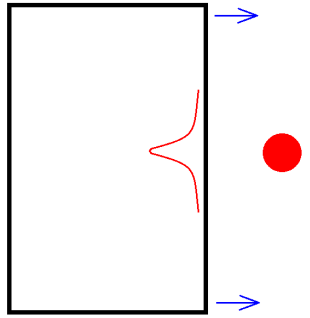
Number of impacting ions in 20 ms			
Temperature	C=500W/m2/K	C=5000W/m2/K	C=infinite
500 C	2.2E7 ions	7E7 ions	1.1E9 ions
1000 C	4E7ions	1.3E8 ions	1.9E9 ions

Courtesy of F.Carra

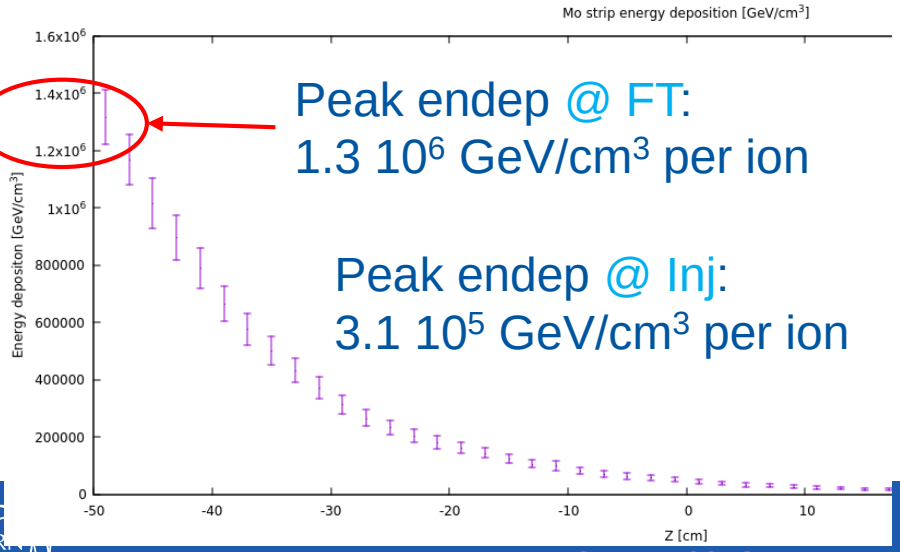
Average contact (e.g. clamped contact with screws or mediocre brazing)

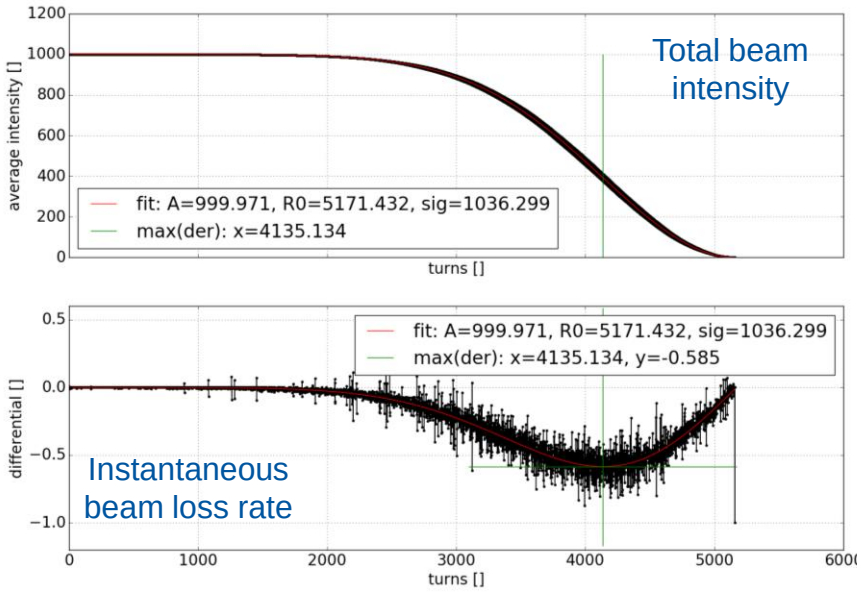
Simulations (tracking + Endep)

- Fluka-SixTrack coupling used to evaluate impact distribution at TCSPM.D4R7.B2:
  - Full beam scraping with upper jaw of TCSPM.D4R7.B2;
  - Gaussian beam (both x and y), ε_N=1.39 μm, 6.37 Z TeV (monochromatic);
  - Due to jaw movement, all ions impact on the Mo coating layer (front face):
    - 5 μm max impact parameter;
    - Regular beam s visible in impact distribution on the other transverse plane;



- Impacts loaded in Fluka for full shower cascade simuation;





Energy/Power Deposition Overview

Item	Beam Type and Energy	Time domain	Beam Intensity	Energy/Power density
HiRadMat-35/-36	p@440GeV	Shot of 7.2 μs	288 bunches, ~1.2 10^{11} p/bunch	(est) ~14 kJ/cm^3
Simulations	p@7TeV	12min BLT for 1-10s	HL-LHC beam parameters	300 W/cm^3 (most loaded TCSG)
	Pb@6.37Z TeV	20ms scraping step	2.2 10^7 ions	(tot) 4.6 kJ/cm^3 (avg) 230 kW/cm^3
	Pb@450Z GeV	1s full beam scraping	3 10^8 ions	(tot) 15 kJ/cm^3 (avg) 15 kW/cm^3

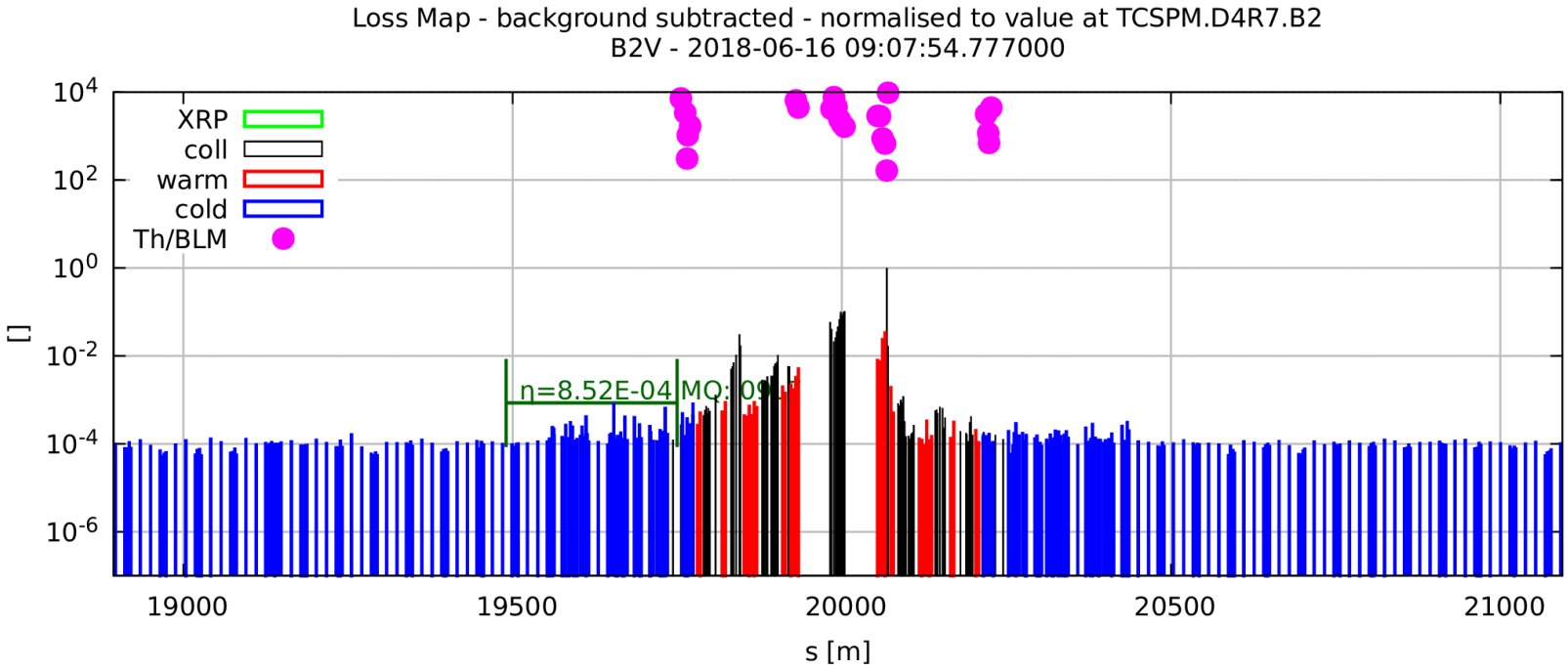
- Load on Mo coating during present test would sit in-between HiRadMat high-energy, fast event and expected regime of power deposition in case of drops of beam lifetime:
  - Good occasion to verify with beam that expected operational loads are within limits;
  - Test could reduce the range where onset of damage is found – the range can be further reduced in future HiRadMat tests, if deemed necessary;
- To be noted that typical collimator manipulations during commissioning take place with a total beam intensity >3 10^8 ions (or equivalent number of charges – e.g. IR7 alignment on the night between 6th and 7th Nov 2018) → what if collimator expert accidentally scrapes full beam during setting up?
- LMs are obtained losing typically few/some 10^9 charges;

Rationale Behind Choices

- Why full-beam scraping:
  - Good control on total beam intensity scraped – it coincides with the stored one;
  - Test cannot be jeopardized by orbit jitters or local changes in transverse beam distribution;
- Why injection energy?
  - Possibility to quickly re-inject and be back in business rapidly;
  - Much lower probability to get prematurely dumped by IR7 BLMs;
- How confident are we that coating will not suffer?
  - Endep map obtained with Mo density of ~10 g/cm^3, instead of ~7.5 g/cm^3 (C.Accettura);
  - With ε_N=1.7μm, full beam scraping (covering 3.5σ) takes 1.4s vs 1s;
  - Worst value of conductance of Mo-MoGr interface – should be closer to 5000 W m^{-2} K^{-1} rather than to 500 W m^{-2} K^{-1};

Losses during test

- During MD1653 (BLM response in IR7 and at TCLs), a LM was taken with TCSPM.D4R7.B2 as primary collimator – p@450GeV!
- No BLM found close to the threshold within a factor 100;



Procedure

Main activities:

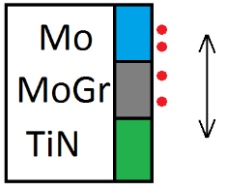
1. Inject a 4-bunch train of ions;
   - get normaised emittance with wire scan and BSRT;
   - Get rid of 2 bunches, to attain 3 10^8 ions;
   - If remaining intensity is still too high, gently blow up remaining bunches and induce tiny little losses to attain 3 10^8 ions;
2. Centre collimator with BPMs;
3. Align TCPSM 5th axis to Mo layer and scrape the whole beam with upper jaw:
   1. 1st spot: aim at 400C – 5th axis position: 9.87 mm;
4. Repeat previous steps with different 5th axis position:
   1. 2nd spot on Mo: 5th axis position: 7.87 mm;
   2. 1st spot on MoGr: 5th axis position: 3 mm;
   3. 2nd spot on MoGr: 5th axis position: -3 mm;

Still to finalise:

1. Actual procedure inspection to be finalized with EN/STI;

Requests:

- 6h MD time – should be enough for 4 scrapings;
- Measurements at injection energy;
- Tests only B2 (TCSPM available only there);



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