2015 ATS optics: Consequences for cleaning and machine protection

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Acknowledgement:
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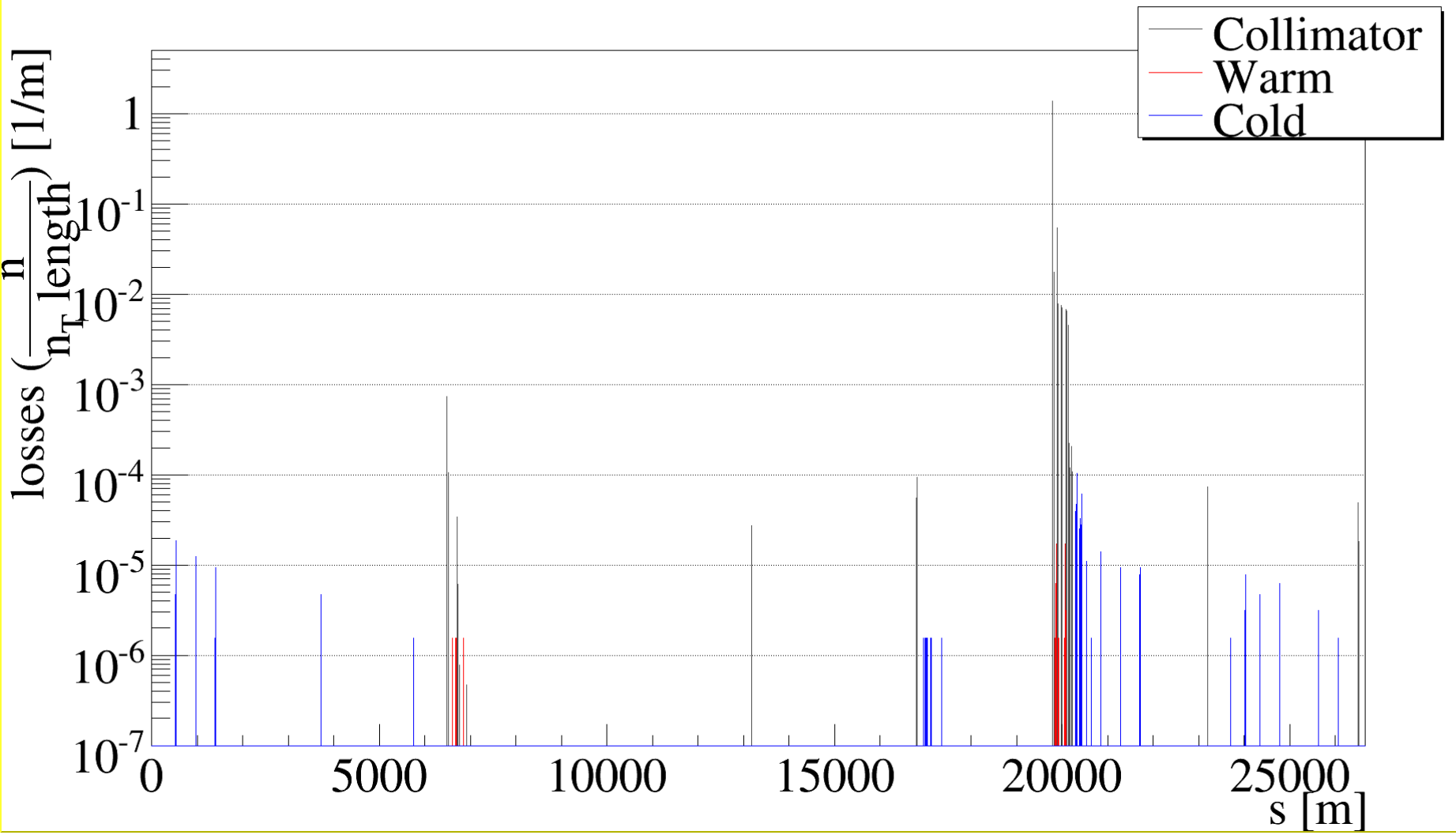
Introduction

- S. Fartoukh in LMC 2014.04.30: ATS optics under study for possible use in 2015
- From collimation side, need to quantify influence on
  - Cleaning
  - Machine protection (TCT impacts during dump failures)
- Detailed talks on the topic in Collimation working group 2014.06.13
- Today: summary of the CWG meeting with some news since then

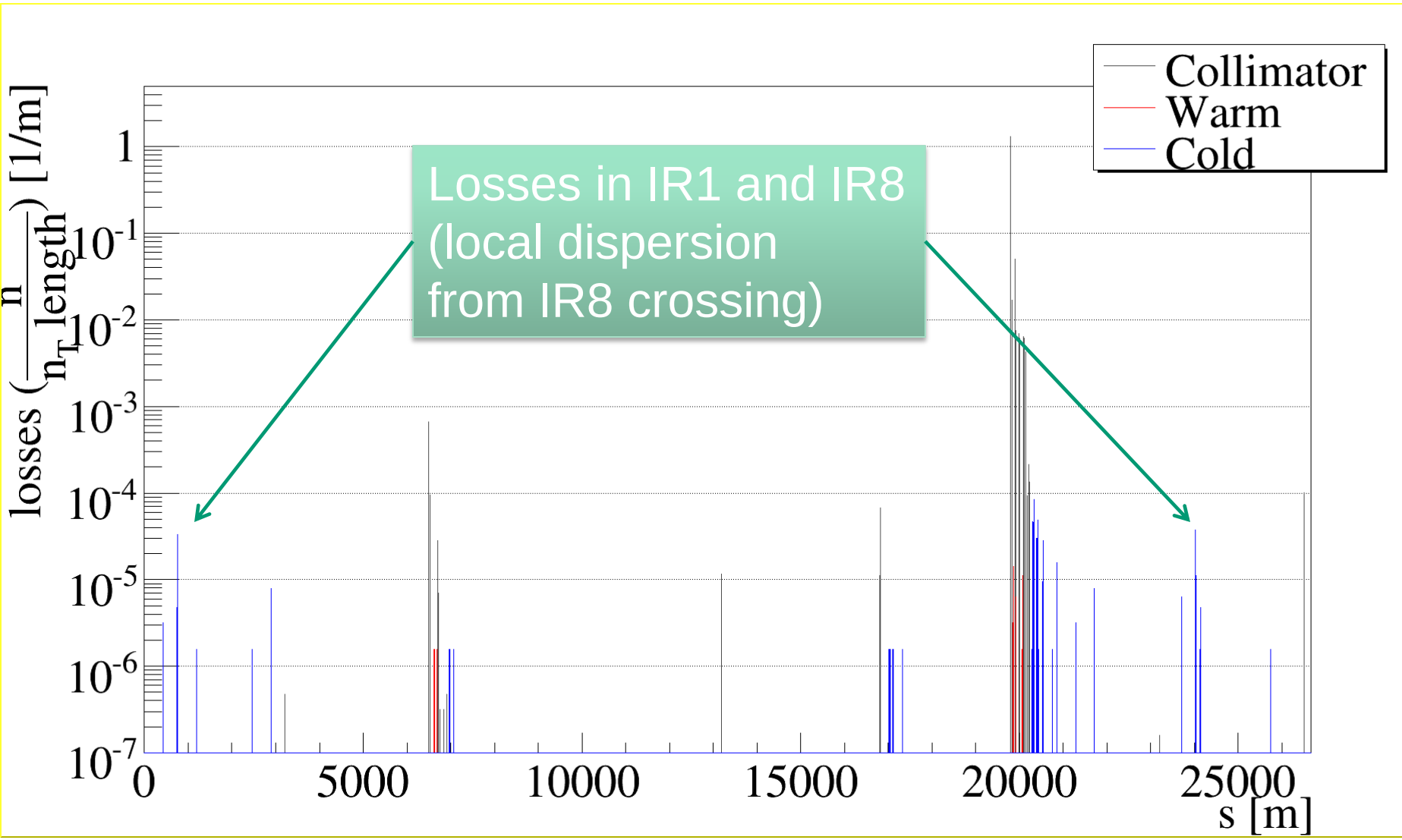
Cleaning

- Simulations performed by D. Mirarchi
- Using SixTrack with collimation to simulate the leakage out of the collimation system.
- Simulation setup:
  - pencil beam on primary collimator,
  - 6.5 TeV,
  - mm kept collimator settings
  - 2015 ATS optics or nominal optics, β*=55cm in IR1/5, 3m in IR8, 10m in IR2
- Results: loss distributions around the ring

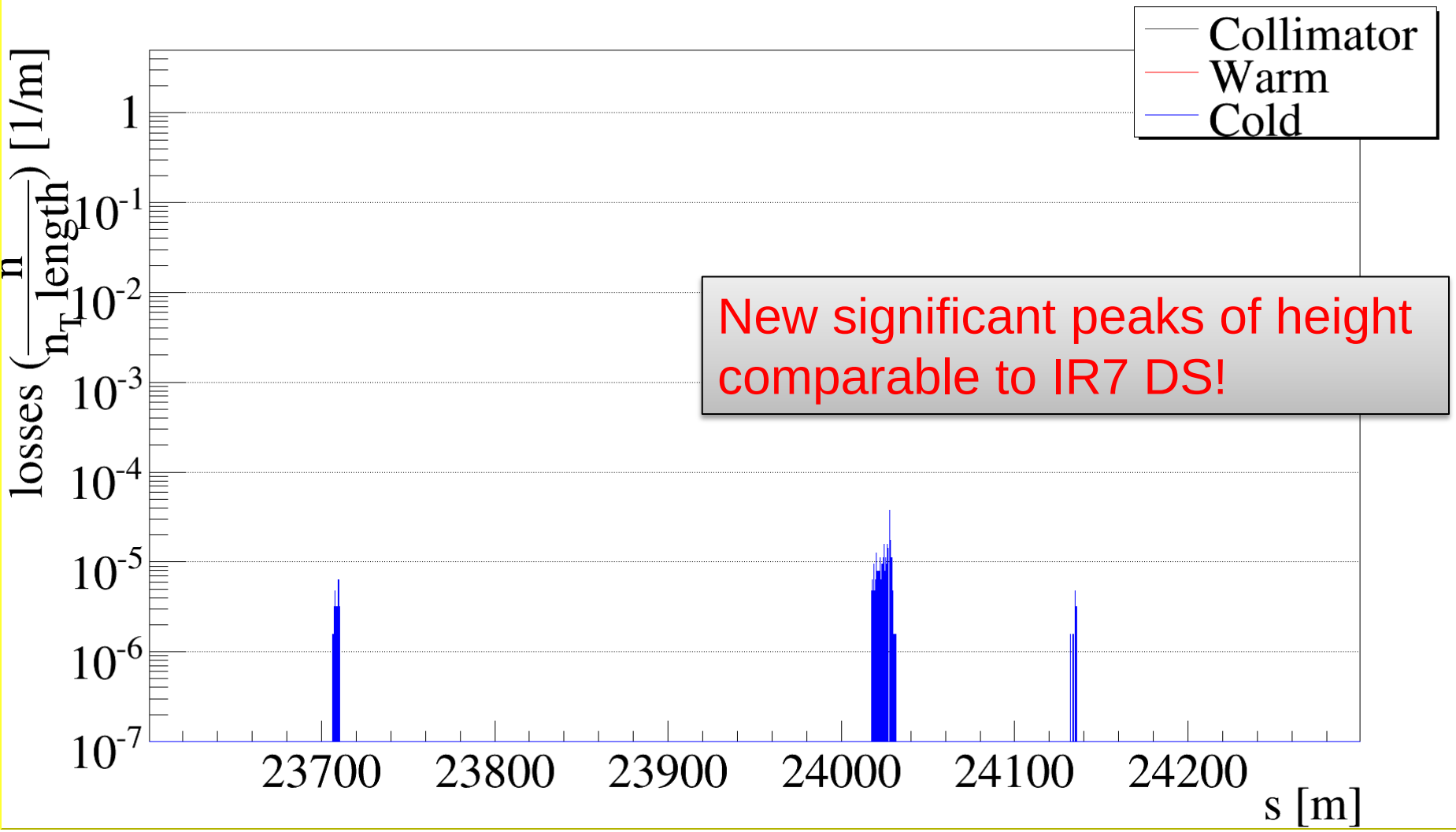
Loss map nominal optics, B1H



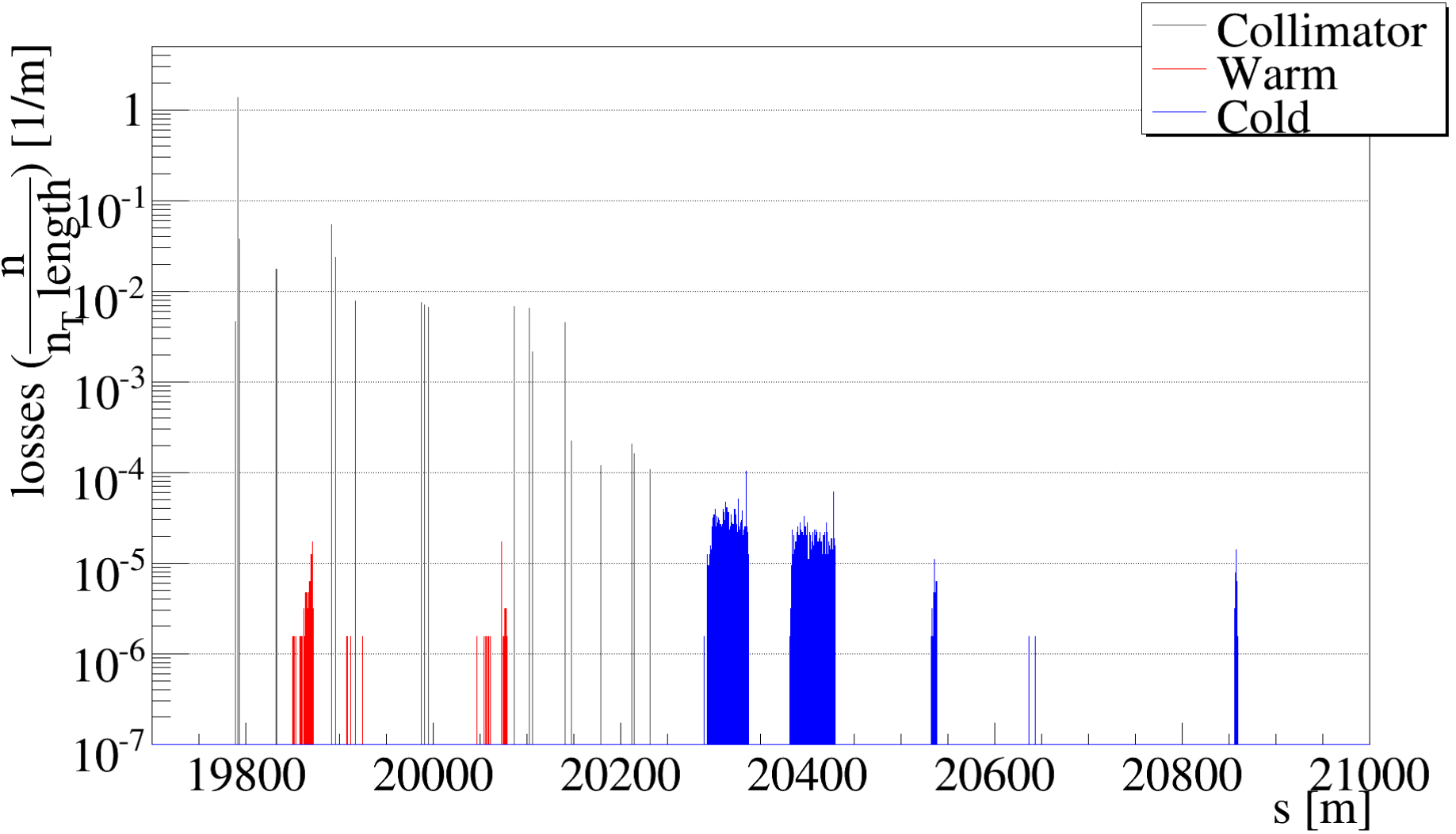
Loss map ATS optics, B1H



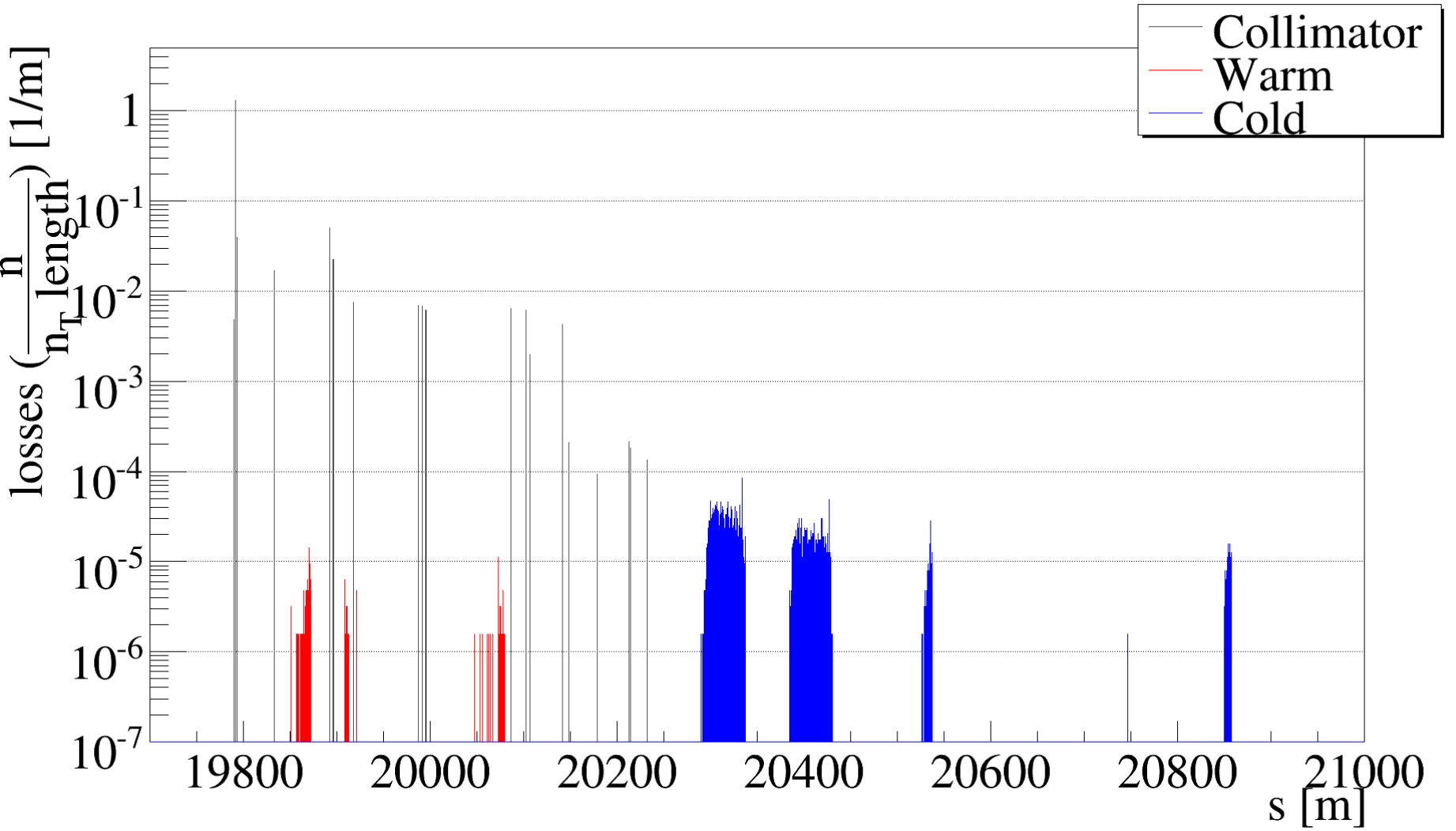
Zoom IR8, ATS optics



Zoom in IR7, nominal



Zoom in IR7, ATS



Conclusions on cleaning with ATS optics

- With ATS optics:
  - **10% higher integrated losses** in the first **IR7 DS cluster**: not worrisome
  - New loss spike in **IR8,** comparable height to IR7 DS: possibly worrisome. We don't want new losses in addition to other doubts for the 2015 config
  - Higher losses in **IR1**: possibly worrisome
- Vertical plane shows similar features in B1
- B2 loss maps similar with ATS and nominal
- New losses in IR1/8 could possibly be mitigated by re-matching the optics (S. Fartoukh). Preferred solution
- No immediate showstopper, but if new loss spikes persist: Need FLUKA study of energy deposition in superconducting magnets before final conclusions can be drawn and giving green light

Machine protection – dump failures

- **Dump failures** (single module pre-fire, asynchronous dump) imposes limit on retraction TCDQ – TCT, as TCTs are not robust
- TCTs must also protect triplet at all times and cannot be too open
- Major difference ATS/nominal optics: changing B2 phase advance from MKDs to IR5 TCT
  - Nominal optics: ~180 deg. => TCT5 out of phase, impossible to hit with primary beam during dump failures
  - ATS: ~80 deg at β*=55cm, closer to 90 deg at smaller β* => TCT5 in phase with dump kick. Possible risk of being hit during dump failures
- **Need to quantify the influence of this change** on machine protection
  - In addition: 25 ns => potentially double the TCT impacts. 6.5 TeV => lower damage limit in number of protons

Calculation of collimation margins

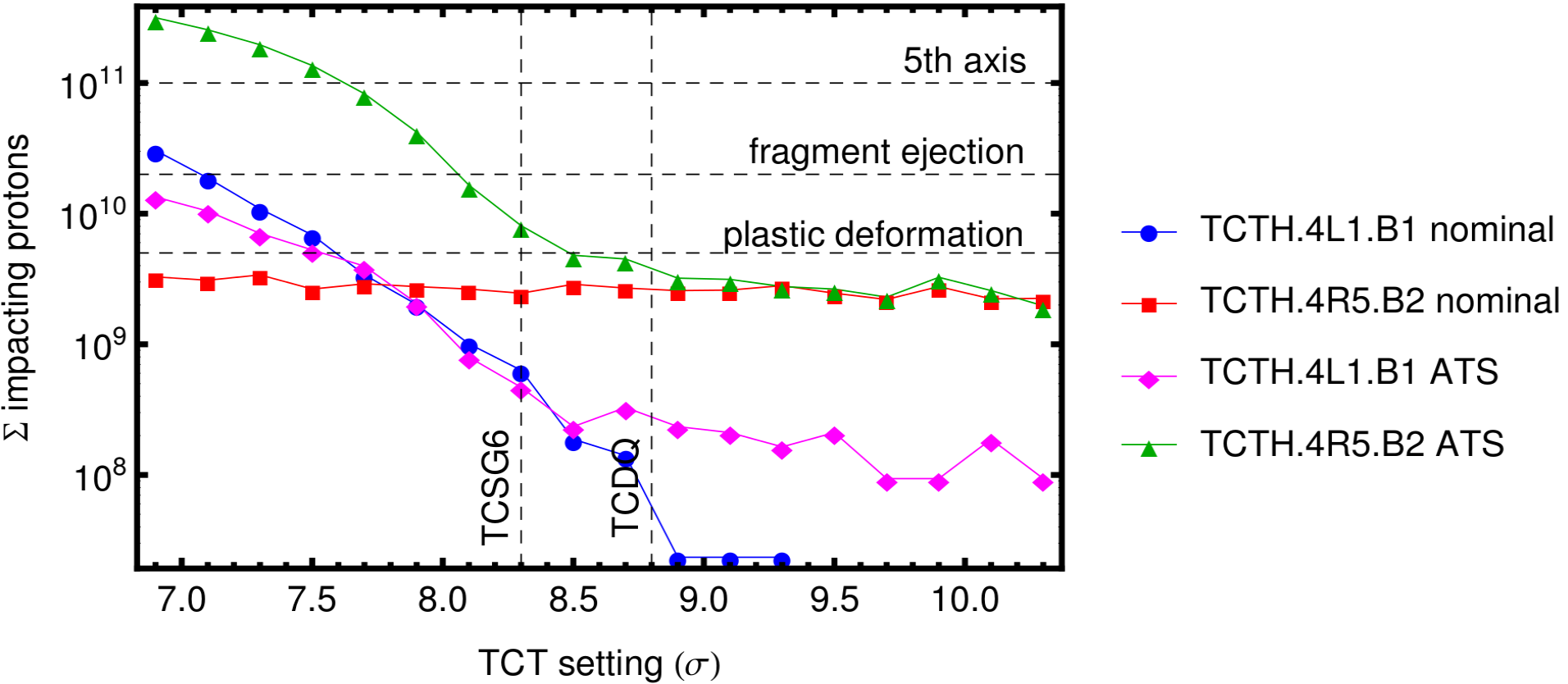
- In Run 1, used **simplified model** for calculating margins and resulting β*.
- Using "**direct shadowing**" to quantify protection, i.e. if a TCT is outside the cut of the TCDQ, it is considered protected. Underlying simplifying assumptions:
    1. Implies 90 deg phase advance – in Run 1, we knew that real phase advance was better (hidden margin). Pessimistic!
    2. Most exposed TCT in Run 1 was in IR1 B1, after passing IR7. But protection of these collimators not included (hidden margin). Pessimistic!
    3. No out-scattering included. Optimistic!
- We used a simplified model, but knew that it rested mainly on pessimistic assumptions
- With ATS: assumptions 1-2 no longer pessimistic but reflects reality - we now have this case! 3 remains optimistic. => Need **better quantitative assessment** if margins are sufficient

SixTrack simulations of ATS optics

- Can do improved assessment of TCT damage risk using new simulation tools: New **SixTrack** version available (L. Lari et al, IPAC2013,IPAC2014)
  - SixTrack simulates dump failures with full collimation system in place, including scattering, and realistic bunch distribution
- Could conclude on suitable margins based on damage onset
- Simulation setup:
  - 6.5 TeV, Single module pre-fire, 2 σ retraction settings (more pessimistic than mm kept), Nominal 55cm and ATS 2015 55cm optics, B1 and B2, Gaussian beam with 3.5 um emittance, energy spread 1.1e-4
  - Separate simulation for each bunch with 25 ns spacing, different kicks. Post-processing: sum all bunches, normalize to 1.3e11 p/bunch

Losses at TCTs vs retraction

- Summing all bunches in MKD sweep, TCTs in IR1/5, both beams, ATS + nominal optics, β*=55cm. **Scan over TCT settings**
- Compare with damage limits (A. Bertarelli, MPP workshop 2013)
  - Plastic deformation: 5e9, Fragment ejection 2e10, 5th axis unusable 1e11.



Remarks on results

- With proposed settings and 2012 error probabilities, TCT could be as deep as the TCDQ level.
  - Main contribution: orbit uncertainty, followed by β-beat
- Constant "background" on IR5 TCT also at larger openings – out-scattering
- Significantly higher losses on TCTs with ATS optics than nominal
- Reaching plastic deformation at 7.5σ for worst TCT in nominal optics and at 8.5σ with ATS. Fragment ejection reached at 7.0σ and 8.0 σ respectively

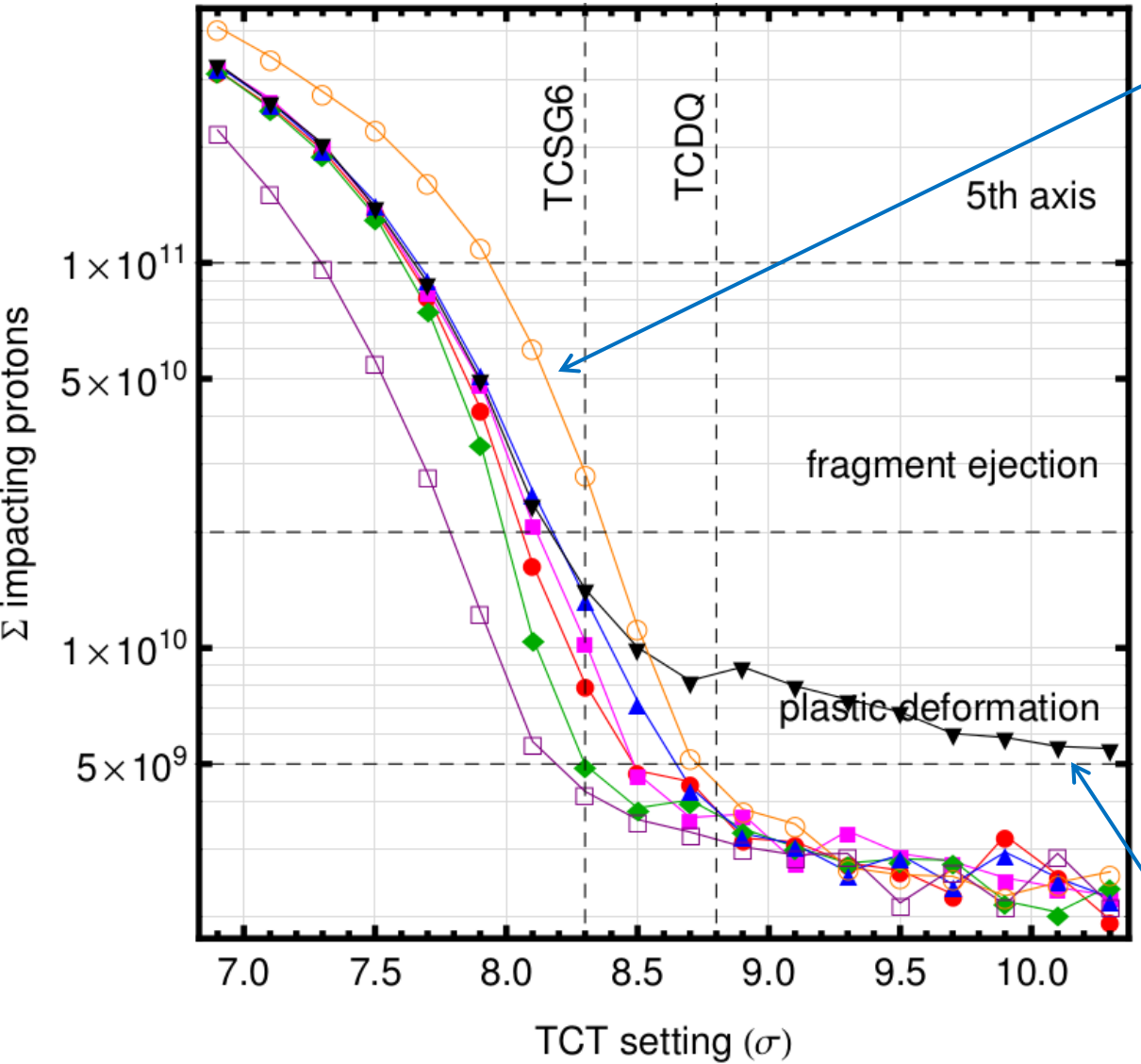
  => Same damage reached with TCTs 1 σ further out in ATS

Variations in simulation

- The simulation result could be sensitive to several parameters – investigating through simulations of worst case (ATS B2)
  - Decreased transverse emittance 3.5 um -> 1.7 um
  - Increased energy spread 1e-4 -> 3e-4
  - Error on TCSG-TCDQ retraction (increasing 0.5 σ -> 1.5 σ)
  - Non-Gaussian tails from measured profile (see S. Redaelli, IPAC 13 or F. Burkart's master thesis)
  - Phase errors – one "good" and one "bad" case from random variations in MADX

Simulated variations

- ATS 2015 optics, B2 with above variations

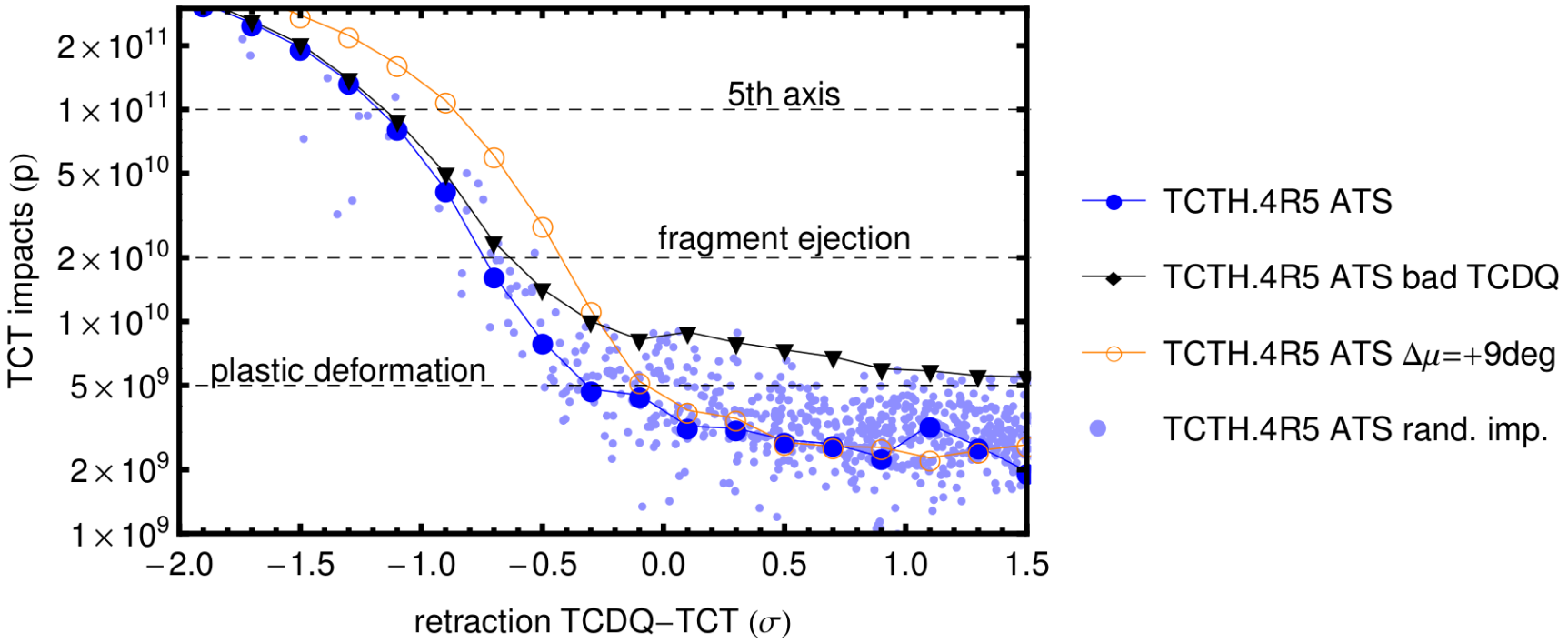


Phase very important! Better phase advance could help mitigating the losses!

Regardless of optics, watch out with TCDQ alignment and tilt!

Additional cross-check: simulating random variations

- Simulating single module pre-fire in **1000 random machine configurations.**
- All collimators kept at ideal settings, but **imperfect orbit offsets, β-beat, collimator tilts**
- Spread introduced around curve for ideal machine
- Imperfection seeds contained below curves on previous slide.



Conclusions on dump failures with ATS optics

- ATS optics more challenging in terms of load on TCTs, due to different phase advance IR6 -> IR5 in B2
  - Run 1 assumptions for margin calculation no longer valid – better assessment needed
- 1 σ difference ATS-nominal in setting where damage limit is crossed
- With 99% confidence on drifts, simulations suggest we are still safe, but on the limit of plastic deformation.
  - However, significant uncertainties on damage limit and simulation
  - Very sensitive to phase advance. **Can we change it?**
- Nominal optics: Run 1 assumptions on margins can safely be used
- **More margin needed for ATS**

Backup

Summary H plane Beam1

Config.	Average losses		Integrated losses	
	Q8-9	Q10-11	Q8-9	Q10-11
mm+ ATS	1.91e-05	1.29e-5	6.05e-4	3.47e-4
mm+ NOM	1.78e-5	1.43e-5	5.51e-4	3.86e-4

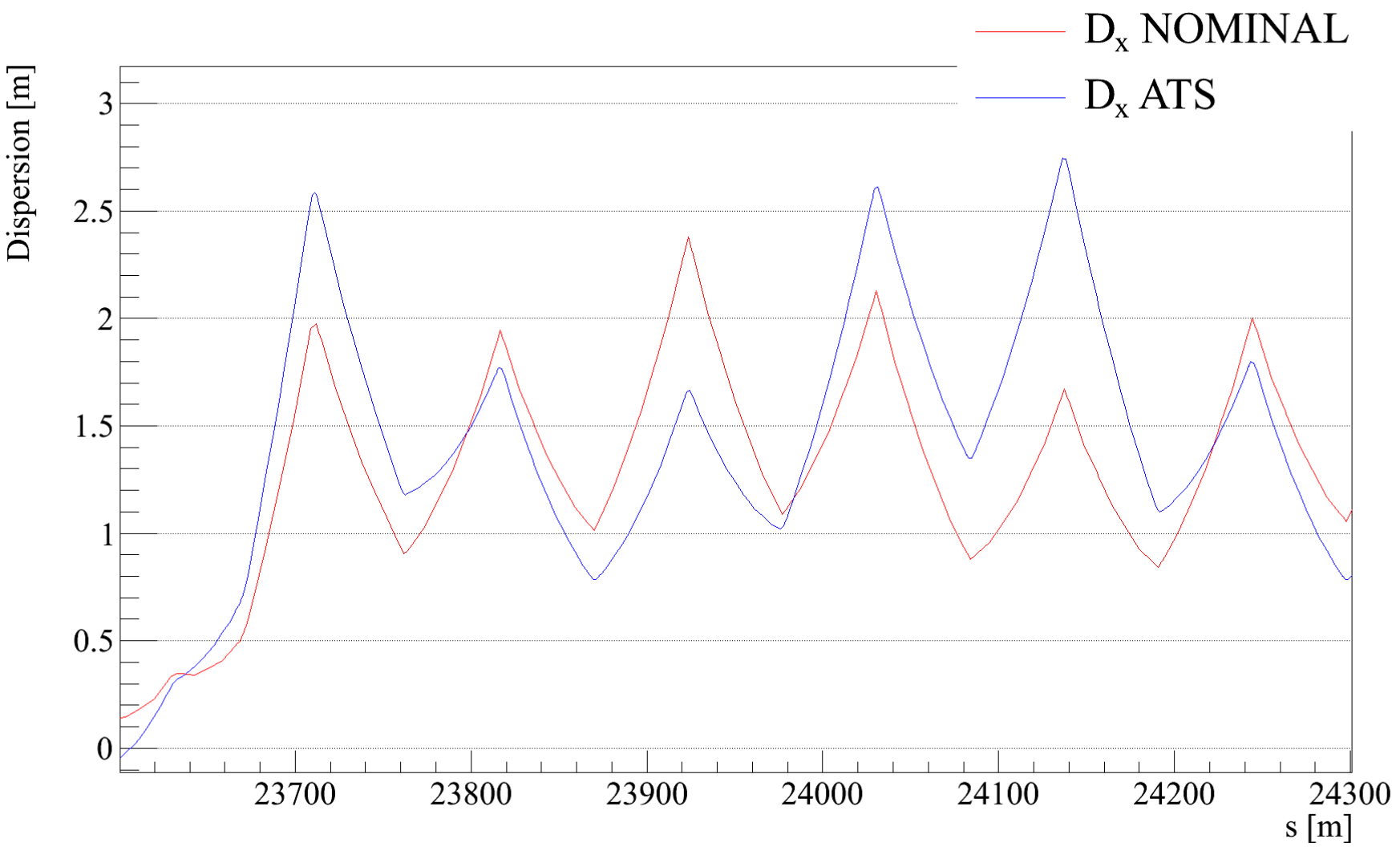
Source of integrated losses in IR7-DS:

MQ	First pass		Multiturn	
	ATS Opt.	Nom Opt.	ATS Opt.	Nom Opt.
8-9	2.64e-4	2.79e-4	3.41e-4	2.72e-4
10-11	1.69e-4	1.84e-4	1.77e-4	2.02e-4

Conclusions:

- with ATS we lose 7% on avr. losses and 10% on int. losses on Q8-9 due to multiturn losses, but we gain ~10% both avr.&int. losses on Q10-11 because now we lose more in the two following clusters of losses (see zoom IR7)
- Peaks at IP1/8 are given by a mismatch in the non-periodic dispersion due to the crossing scheme

Dispersion IP8 peaks



Phase advances

- Fractional phase advances from MKD to TCTs in different optics:

(deg)	7TeV nominal, 55 cm	ATS 2015, 55cm
Beam1		
TCTH.4L1.B1	56	124
TCTH.4L2.B1	257	57
TCTH.4L5.B1	47	40
TCTH.4L8.B1	336	160
Beam2		
TCTH.4R1.B2	198	**106**
TCTH.4R2.B2	170	137
TCTH.4R5.B2	176	**77**
TCTH.4R8.B2	19	170

- Preferable: phase advance is >40 deg away from 90 or 270 deg
- B2 IR5 most critical, since no cleaning insertion in between