Collimator layout and performance

B. Lindström

Thanks to A. Abramov, R. Bruce, R. De Maria, J. Molson, P. Hermes , S. Redaelli, F. Van der Veken

20th September 2022 – 12th HL-LHC Collaboration Meeting

Introduction

- Continuous review of the collimation system performance is necessary to take ongoing changes to baseline and optics into account
- Main recent changes affecting collimation performance:
  - No TCLD in the IR7 dispersion suppressor
  - Impedance concerns driving a relaxation of collimator settings in RunIV
  - Lack of HEL might also necessitate relaxation of collimator settings to limit loss spikes
  - Inermet (W) decided to be used for new TCTs
- Scope of this talk:
  - IR7 proton cleaning performance, without TCLD, comparing relaxed and tight settings throughout the beta* levelling
  - Optics v1.5 have been used throughout

Run IV collimator layout

- IR3 (momentum cleaning) unchanged
- IR6 (dump protection) unchanged
- IR7 (betatron cleaning):
  - TCP – H/V in MoGr, skew will remain C
  - TCS – 9 will be inMoGr, 2 will remain C per beam
  - TCLA – kept as is
  - TCLD – planned for DS but seems unlikely to arrive
  - Crystal – 1 per beam per plane for heavy ion runs
- TCTs:
  - Set of H/V TCTs to be added in cell 6 around IR1/IR5
  - TCTs in cell 4 IR1/IR5 to be replaced with new 2-in-1 design

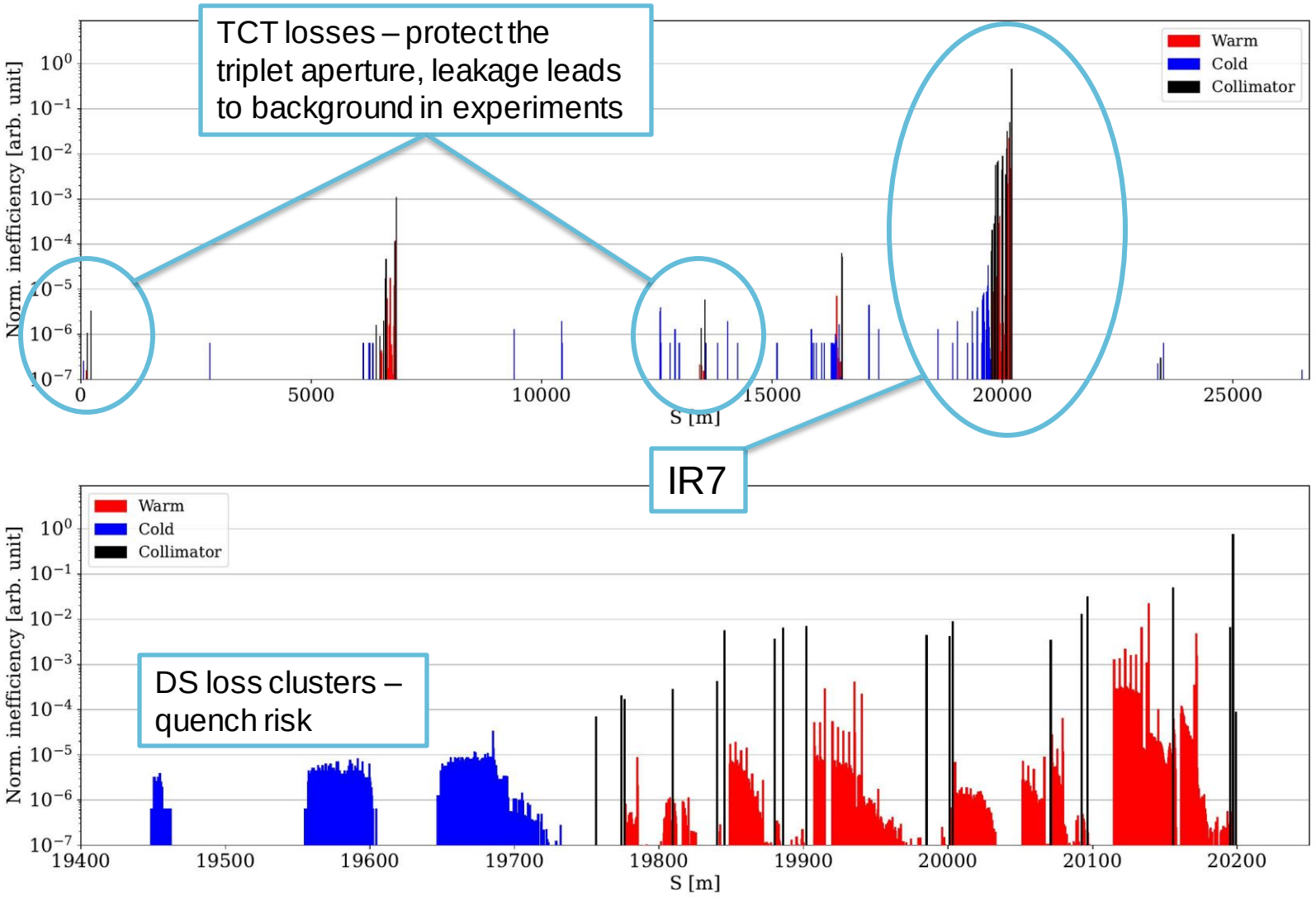
Collimator Settings ($\epsilon_n = 2.5\mu m \cdot rad$)

	Run V		Run IV	
	TDR Baseline (tight settings)	Relaxed Settings		
	15 cm β*	15 cm β*	20 cm β*	100 cm β*
TCP IR7	**6.7**	**8.5**	8.5	8.5
TCS IR7	**9.1**	**10.1**	10.1	10.1
TCLA IR7	**12.7**	**14.0**	**13.7**	**13.7**
TCLD IR7	**16.6**	**n/a****	n/a**	n/a**
TCP IR3	17.7	17.7	17.7	17.7
TCS IR3	21.3	21.3	21.3	21.3
TCLA IR3	23.7	23.7	23.7	23.7
TCS IR6	**10.1**	**11.1**	11.1	11.1
TCDQ IR6	**10.1**	**11.1**	11.1	11.1
TCL IR1/5	14.2	14.2*	**16.4***	**38 – 44***
TCT IR1/5	**10.4**	**11.4***	**13.2***	**23 – 35***
Prot. Aperture IR1/5	**11.8**	**12.8**	**14.6**	**>24.4**
TCT IR2	43.8	43.8	43.8	43.8
TCT IR8	17.7	17.7	17.7	17.7
TDIS	park	park	park	park
TCLD IR2	park	park	park	park

* gap in mm is set to final (15 cm) value and kept constant throughout squeeze
** likely n/a for runIV, status for runV to be confirmed

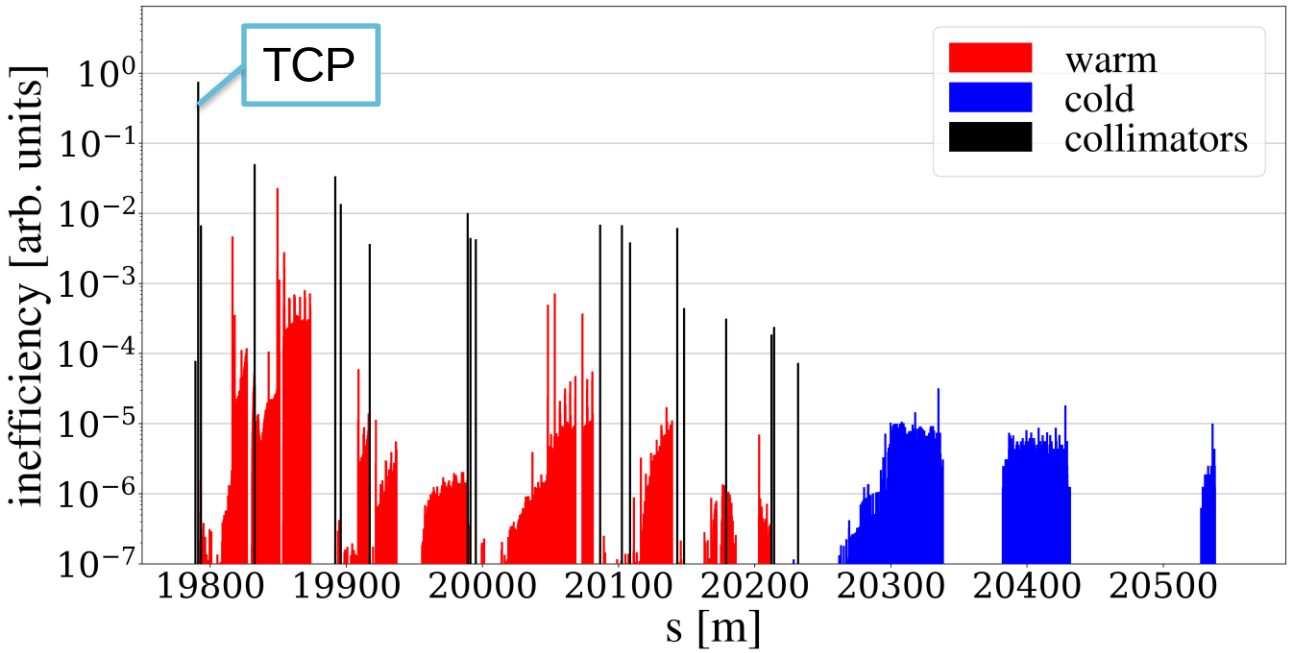
Loss map example

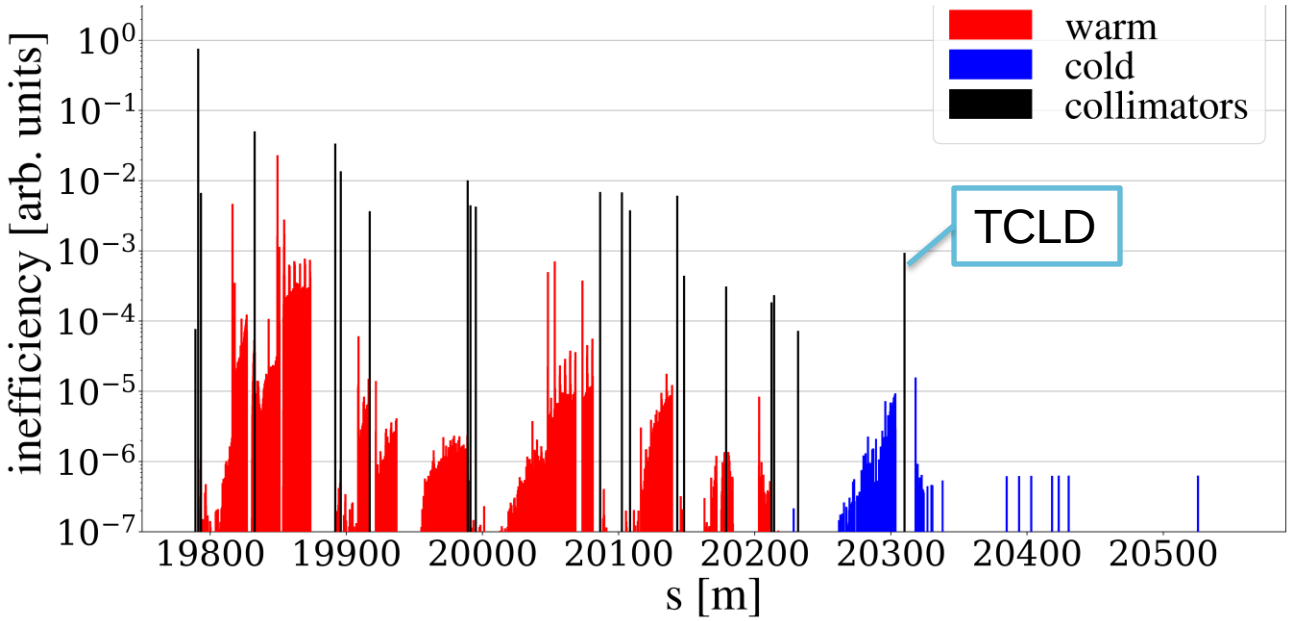
- B2H, 20cm, relaxed settings



TCLD in IR7 dispersion suppressor

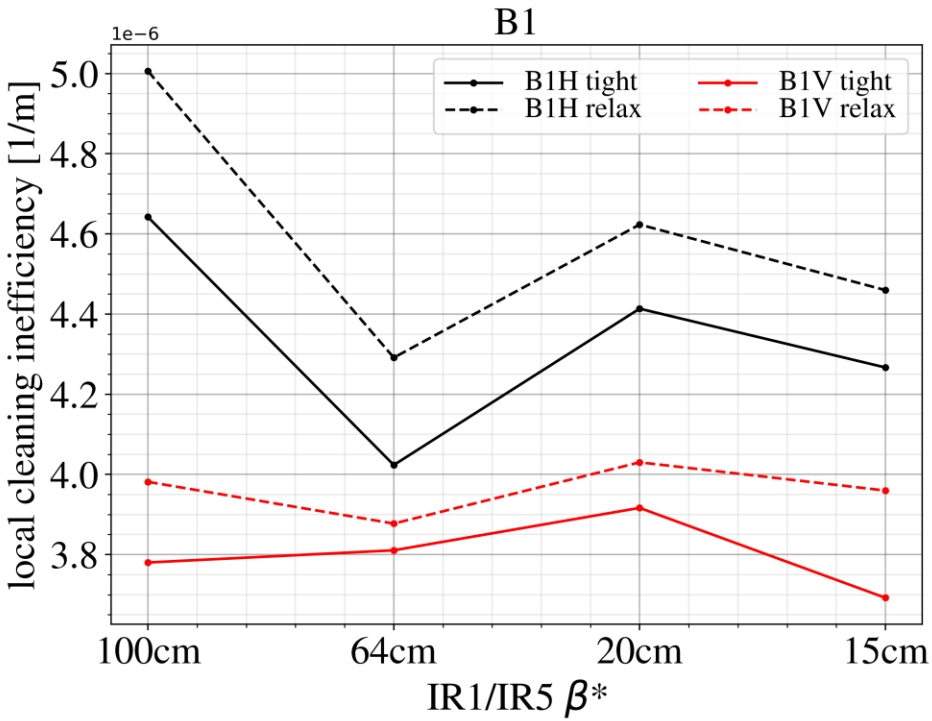
- Planned for RunIII to mitigate quench risk in DS
- Replace one main dipole with two short 11T dipoles
- Production of 11T dipoles delayed – availability for HL-LHC is uncertain
- For ions, DS losses will be mitigated using crystal collimators
- Quench tests needed to conclusively determine necessity of TCLD or other mitigations, for proton operation
- TCLD assumed unavailable in the following results

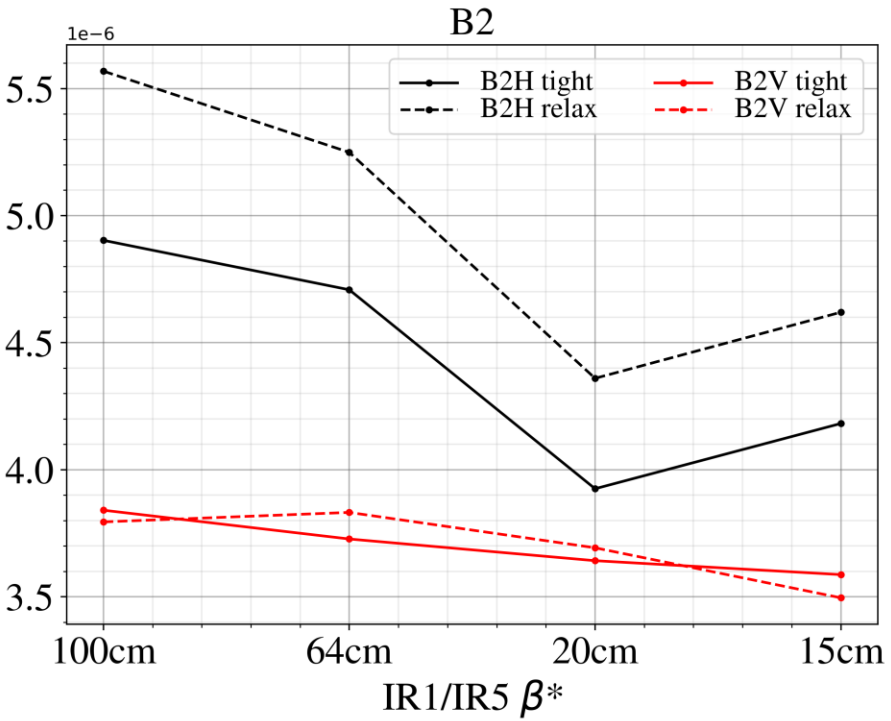




Average inefficiency first DS cluster during levelling

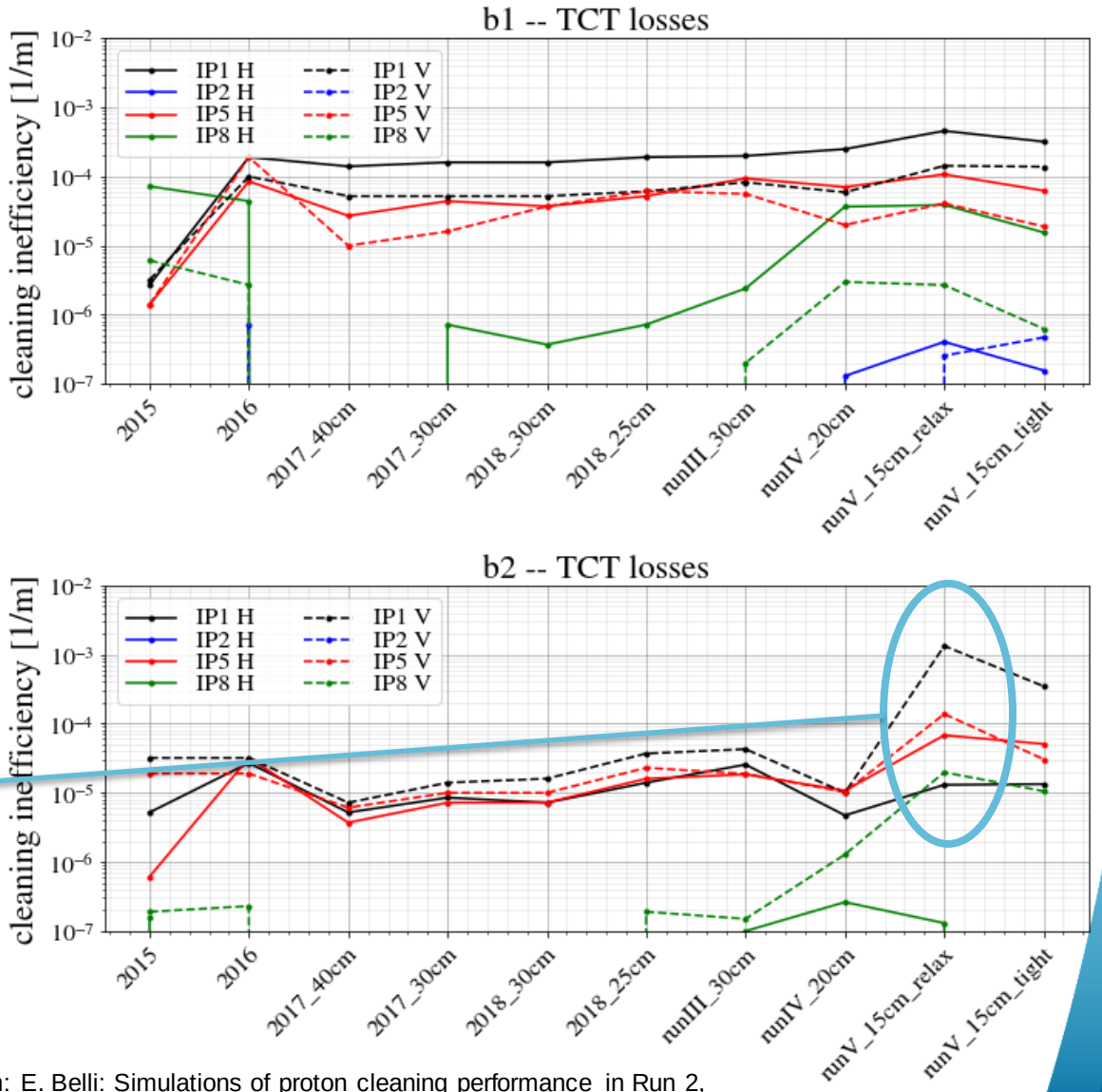
- ~10 % worse at 100 cm than 15 cm for horizontal lossmaps
- Relaxed settings lead to consistently worse performance, although difference is small
- Loss spikes throughout the ring are affected by collimator settings
  - smaller than the DS but need to be studied if they can add further limitations
- Simulations done with perfect machine – error models to be studied





Sum of TCT losses per IP – H/V loss maps

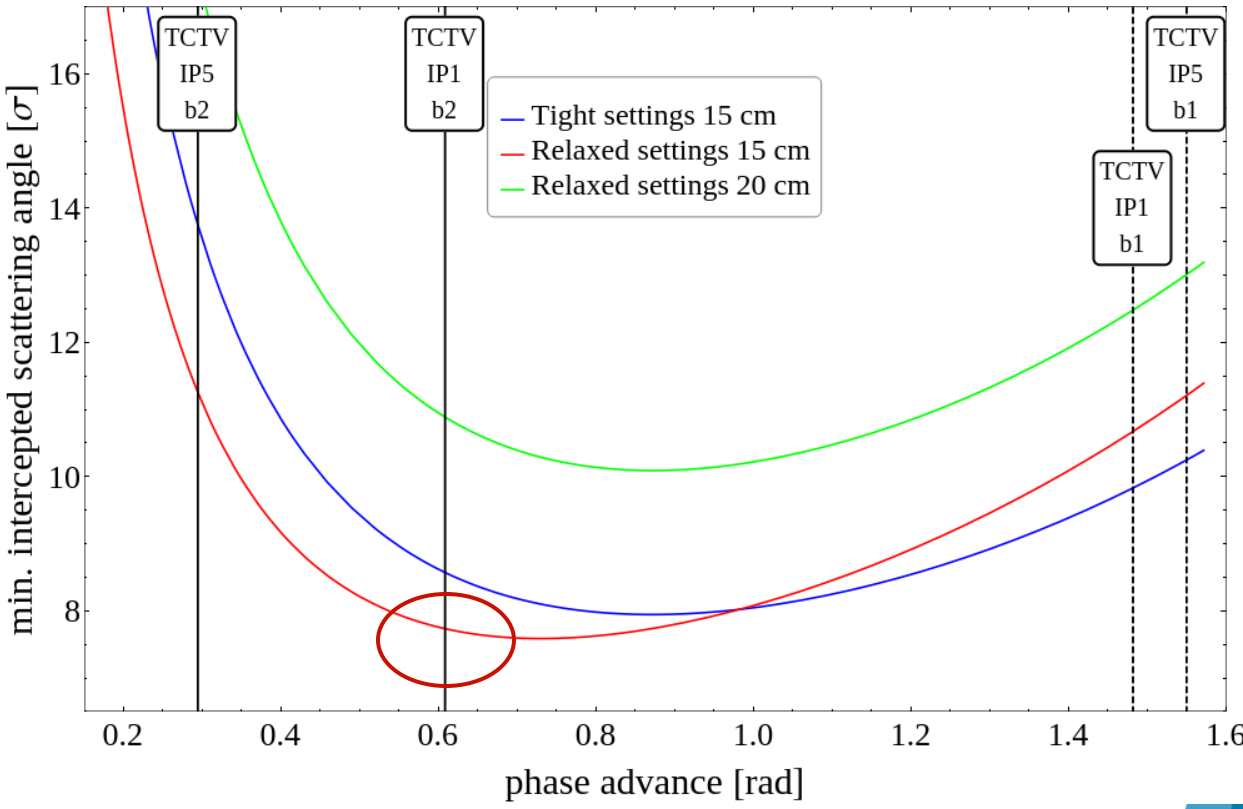
- Normalized cleaning inefficiency in the different TCTs
- Sum of all TCTs per IP
- 2015 low losses due to 80 cm beta* -> large TCT settings
- IR1/IR5 losses relatively stable during runII
- Worsening in runV, 15cm, caused by relaxed settings – in particular b2 IP1 must be mitigated



* 2015-2018 data from: E. Belli: Simulations of proton cleaning performance in Run 2, https://indico.cern.ch/event/828666/#17-simulations-of-cleaning-per

RunV – large losses in IP1

- TCP to IR1 TCT phase advance almost optimal with relaxed collimator settings
- Not a concern at 20 cm (run IV)



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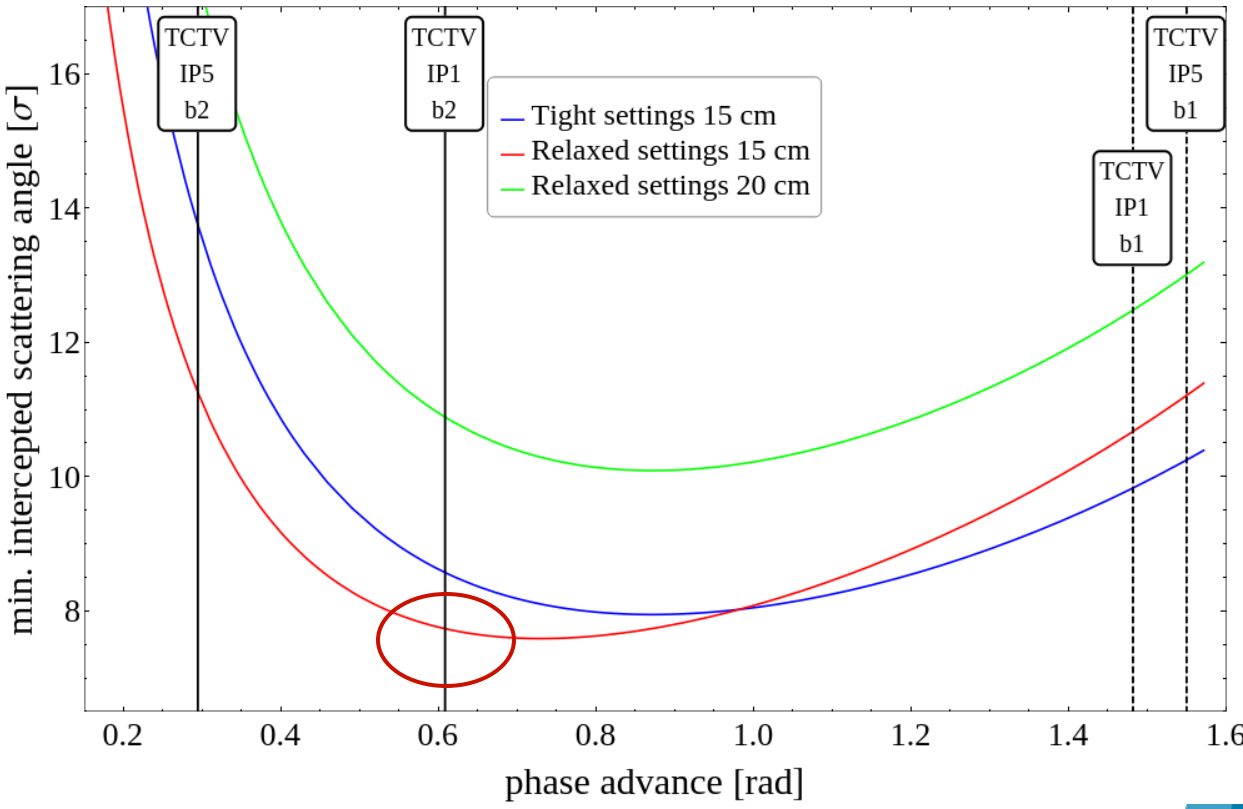
Solutions if relaxed settings to be used at 15 cm?

- Adjust phase advance?
- Retract TCTV in IR1 by 0.5 sigma (reduces margin in 15 cm optics)
- Insert TCP.D by 0.5 sigma (increases impedance)
- Insert TCS by 0.4 sigma (increases impedance)



more details: R. Bruce – https://indico.cern.ch/event/828666/#17-simulations-of-cleaning-per

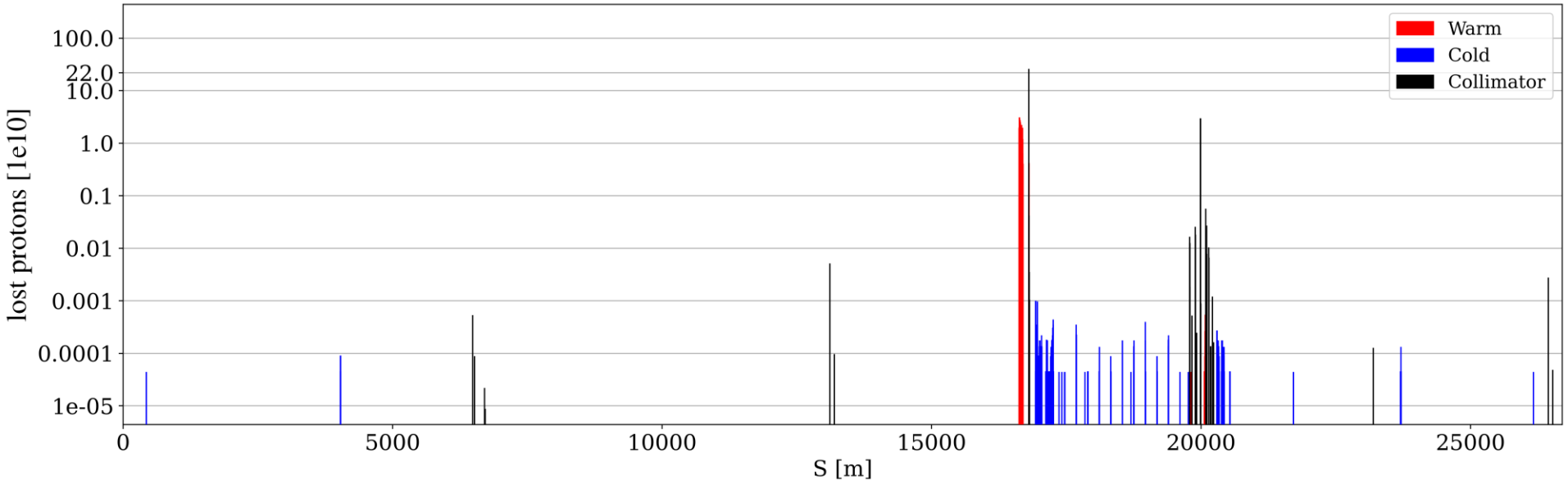
Collimator materials

- New TCSs in IR7:
  - A set of Mo-coated MoGr TCSPMs were installed in LS2
  - More will be installed in LS3, but might have Cu-coating instead
  - This mainly concerns impedance, not the cleaning performance
- New TCTs in IR1/IR5:
  - Will be Inermet (W) in RunIV as decided in last TCC
  - Copper diamond (CuCD) still possible for later?
  - CuCD is more robust, but leads to more leakage to the experiments
  - Motivation for CuCD is to be safe against asynchronous beam dumps

For more details, M. Sabata Gilarte, Review of energy deposition simulations (next talk): https://indico.cern.ch/event/1161569/contributions/4921469/

Asynchronous beam dump (SMPFO)

- Out of asynchronous beam dump-related failures, single module prefire (SMPF) is the most critical
- One MKD fires spuriously – the rest triggers after a delay



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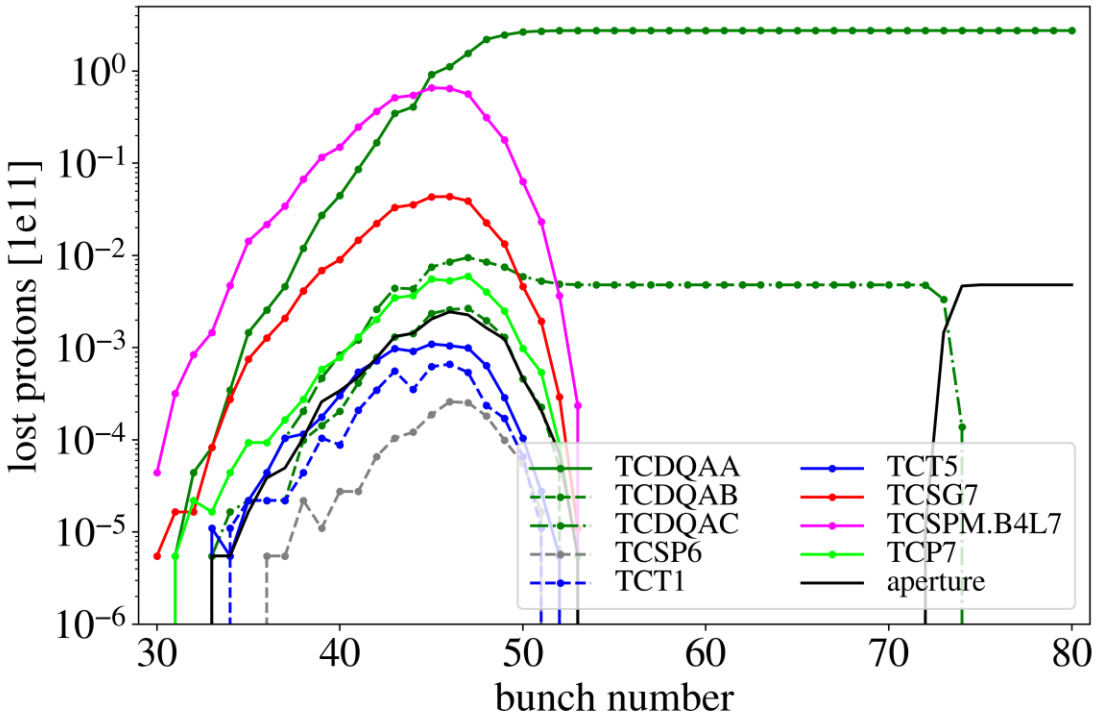
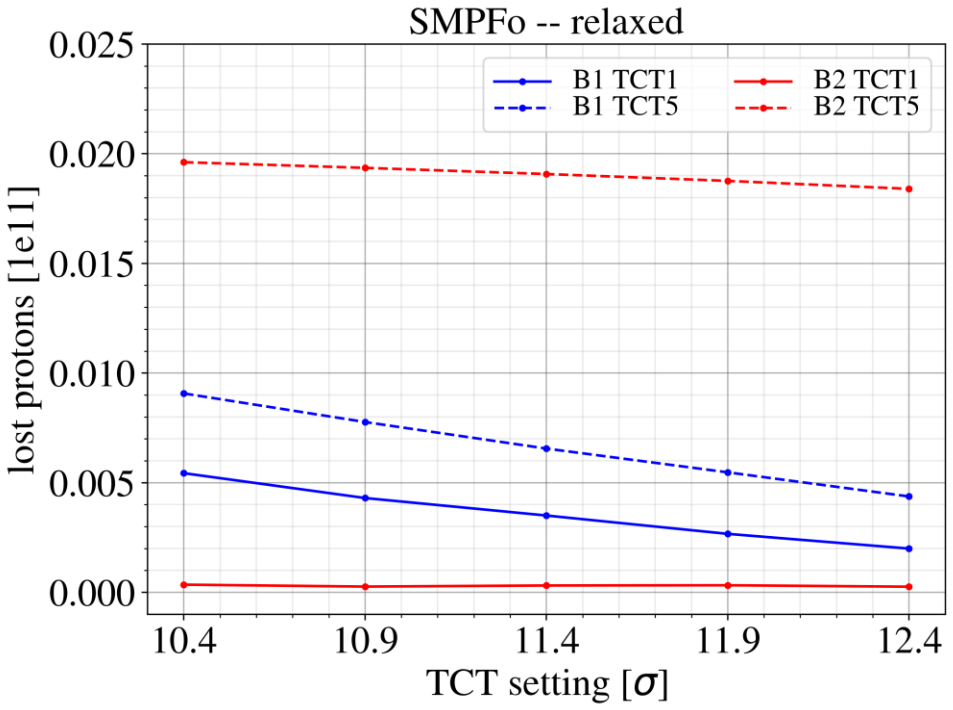
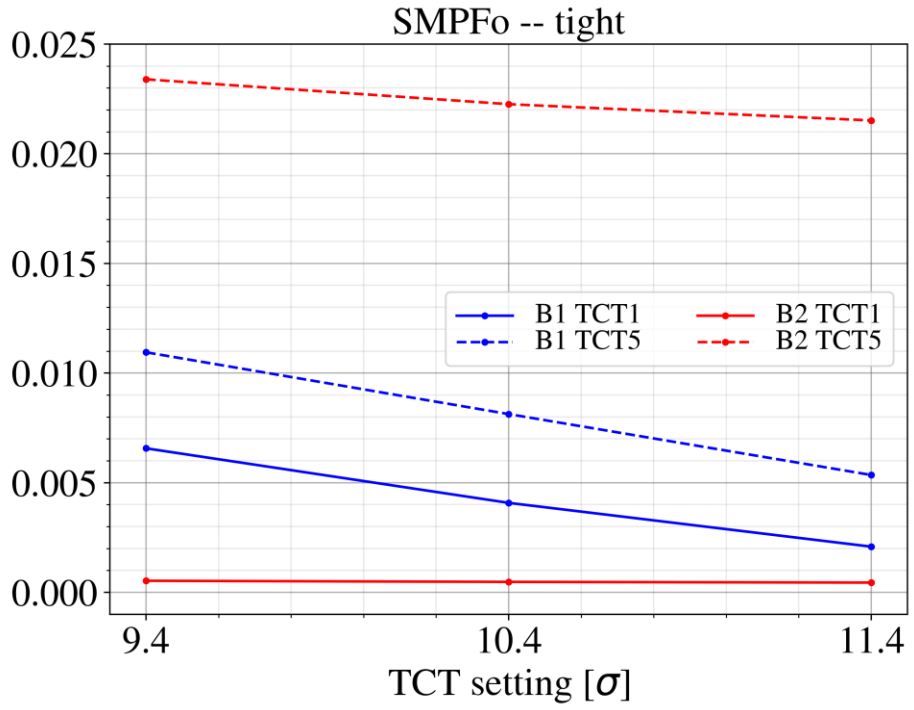
- Loss location depends on bunch number (bunch 0 being the one present at MKD as it fires)



TCT impacts during SMPFO

- Horizontal TCTs are sensitive to this failure type
- TCT6 recieves factor of ~10 more losses than TCT4
- Losses above ~0.05e11 protons can cause plastic deformation
- Impacts dominated by secondary halo, diffusing losses over larger volume
- Should be safe in terms of TCT losses
  – need to be cross-checked with SixTrack-FLUKA





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- Relaxed colimator settings have been requested for RunIV to avoid limitations due to impedance *(2.3e11 ppb, 2.0/1.7 µm rad)*
  - These settings are likely feasible, but reduce cleaning performance
  - Up to 14 % larger DS losses at 100 cm
  - Larger TCT losses, in particular IP1 for B2V at 15 cm
    → potential solutions: retracting TCT by 0.5 sigma, inserting TCP/TCS by 0.5/0.4 sigma
  - TCT losses not expected to be an issue at 20 cm
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  - IR5 is worst for both beams
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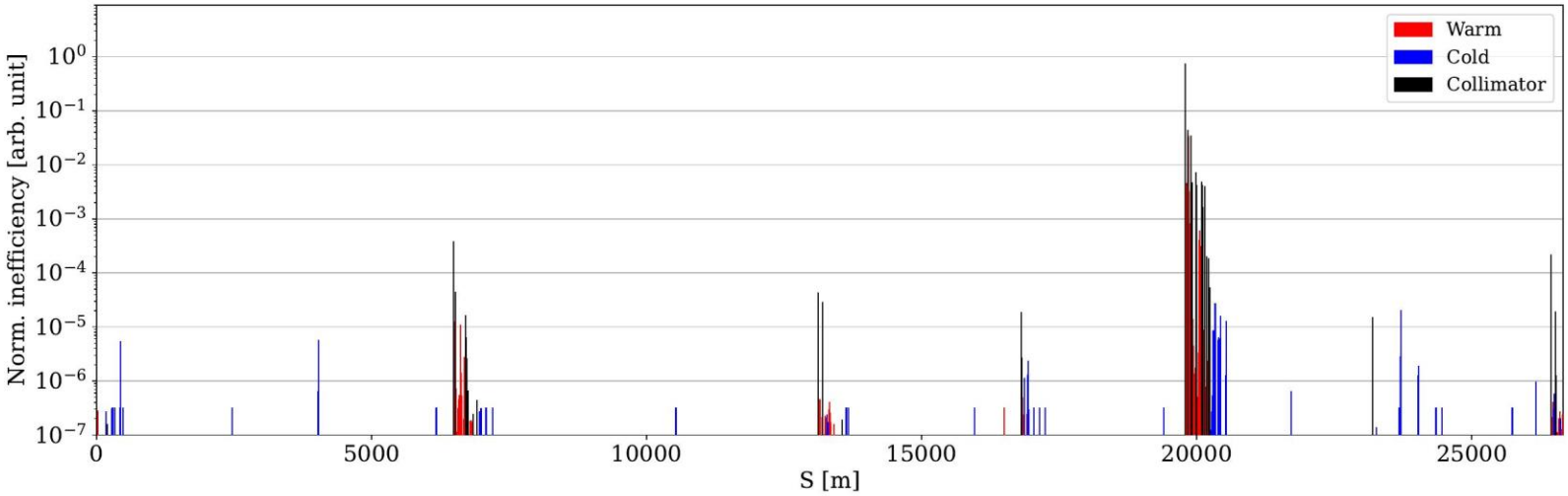
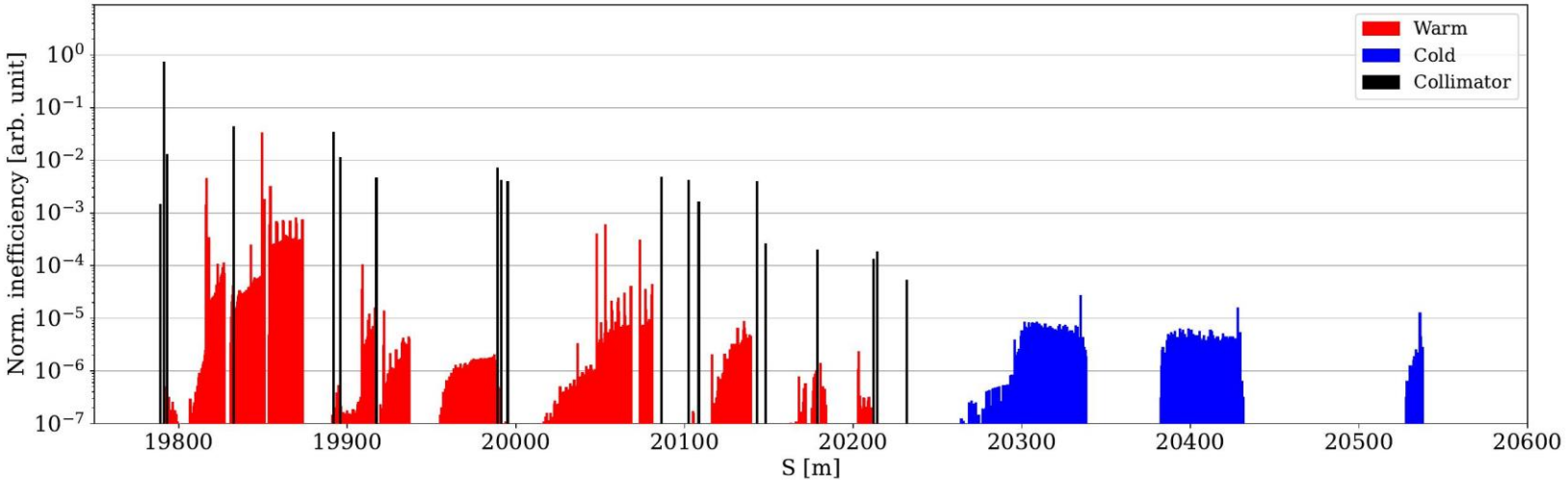
  - Most losses on TCTs in cell 6
  - IR5 is worst for both beams
  - Relaxed settings are ~15 % worse than tight, although there is margin until plastic deformation is expected
- Optics v1.6: no IR7 optics changes, but some changes to phase advances and TCT positions. Impact on collimation performance to be studied

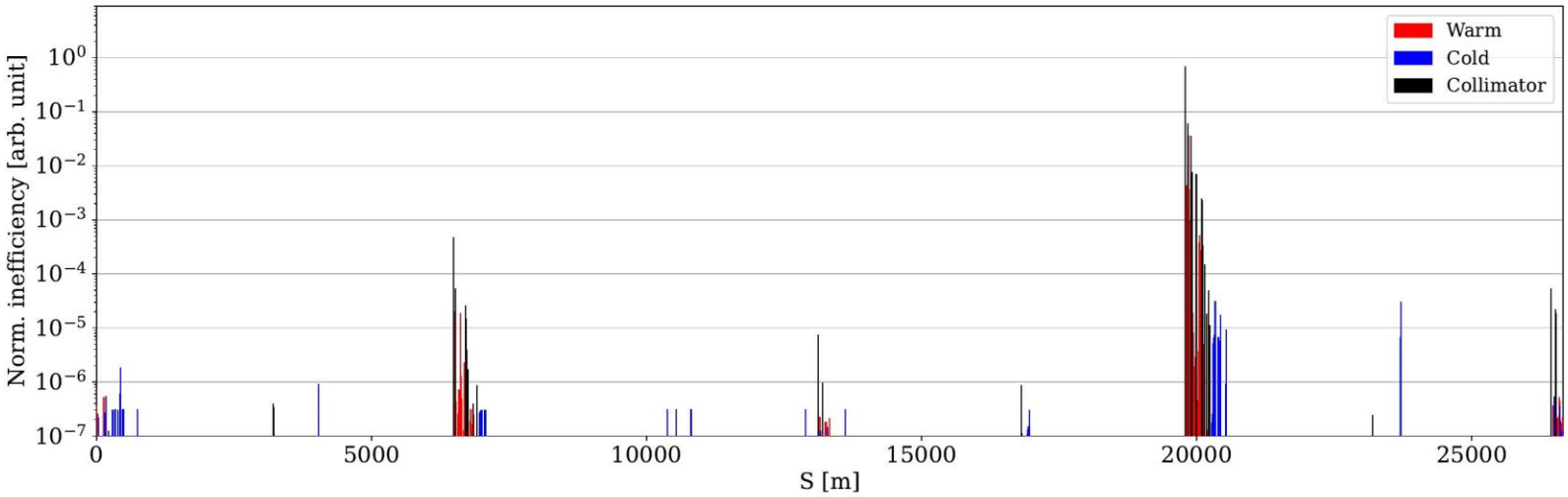
Lossmaps – B1 tight settings

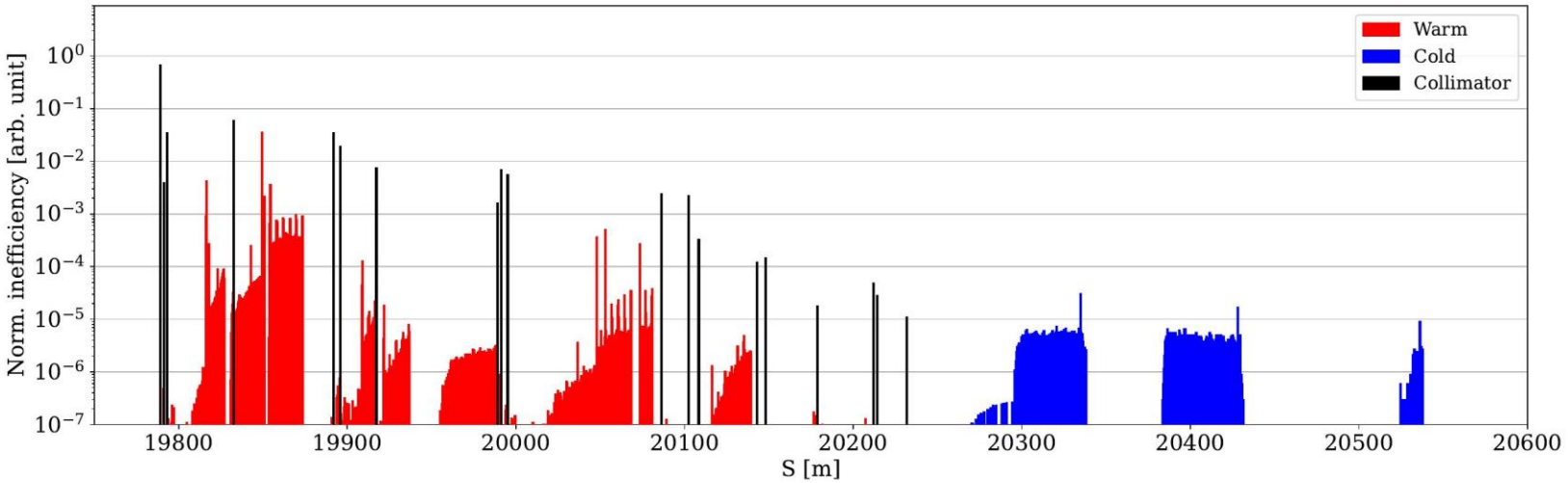
B1H – 15 cm – tight – no TCLD





B1V – 15 cm – tight – no TCLD





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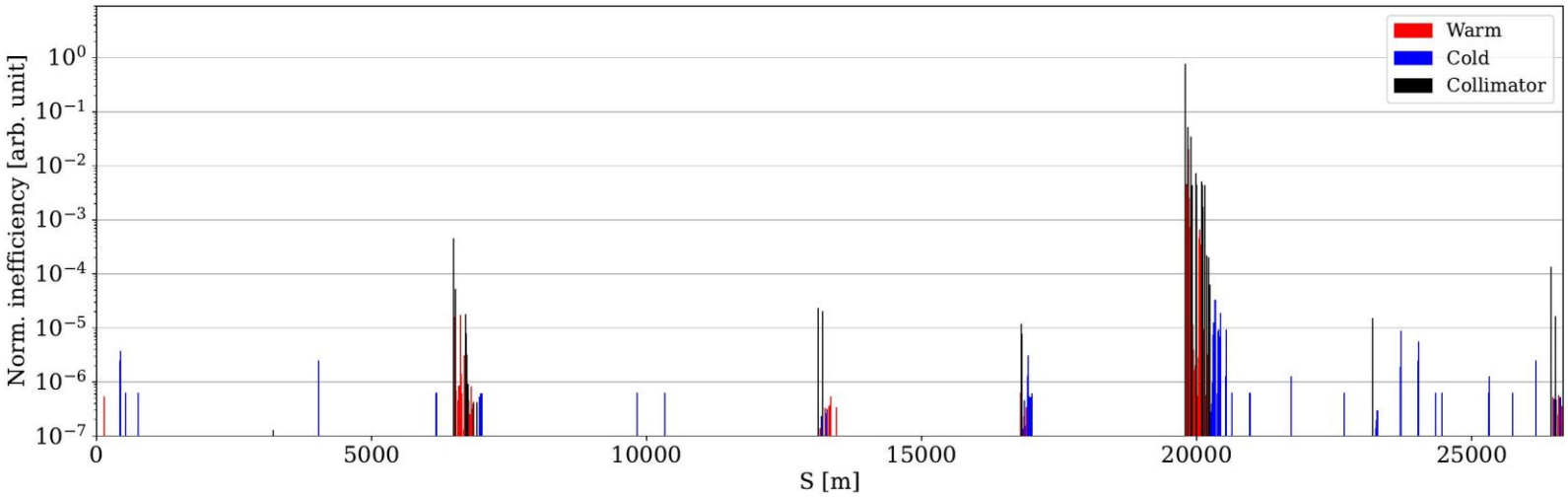

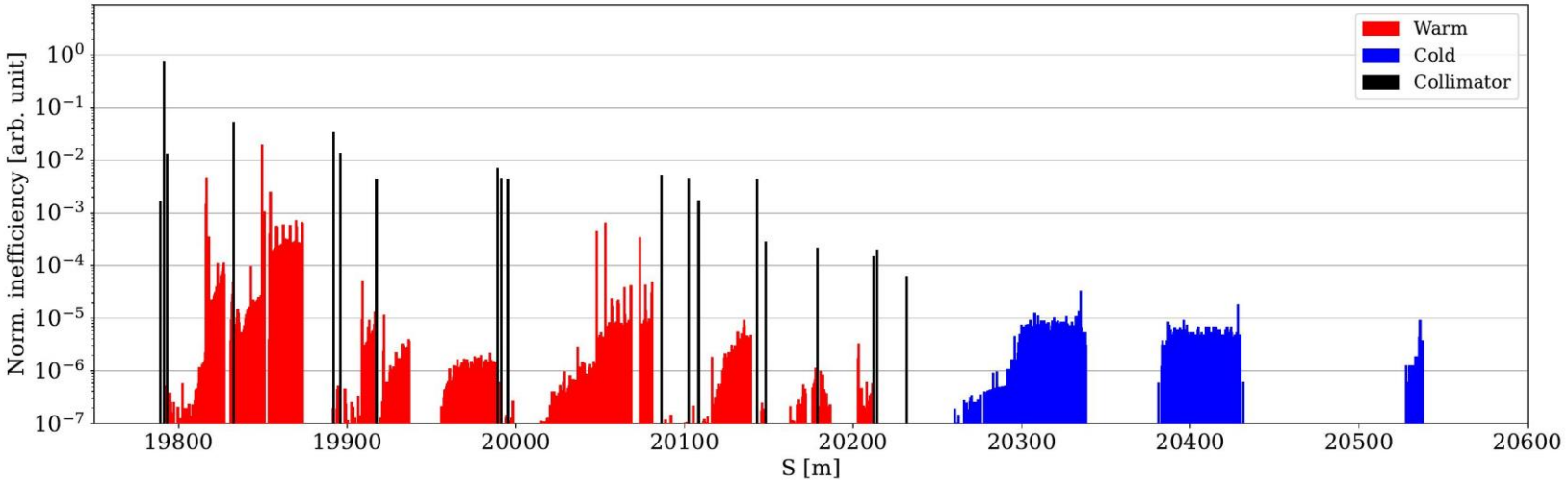

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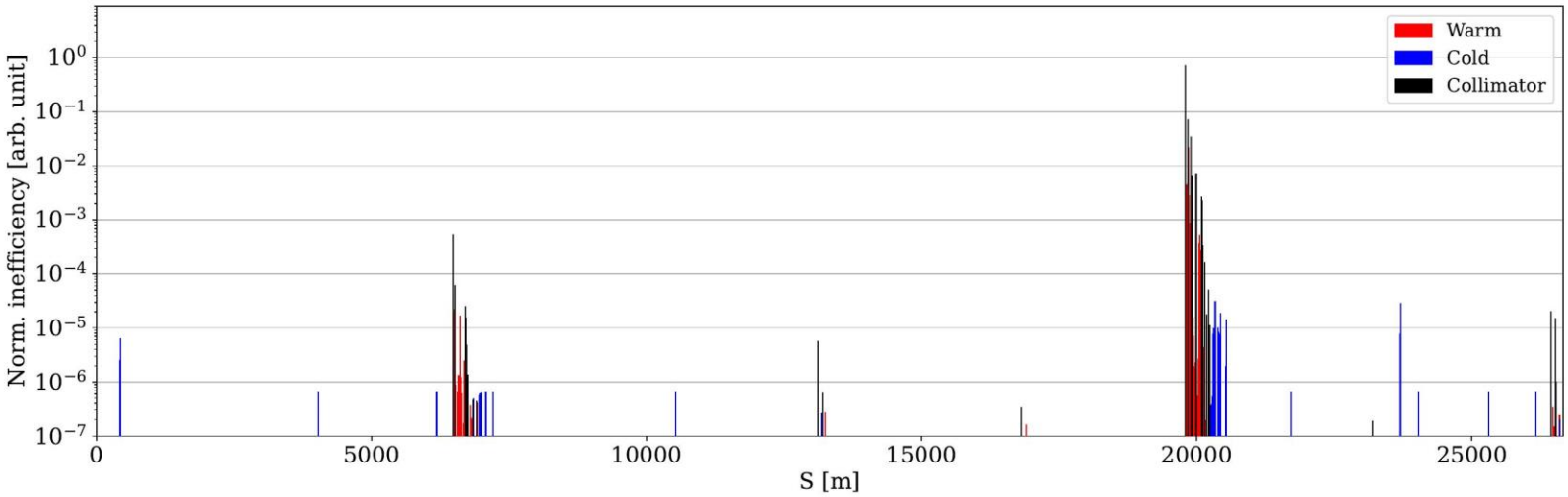
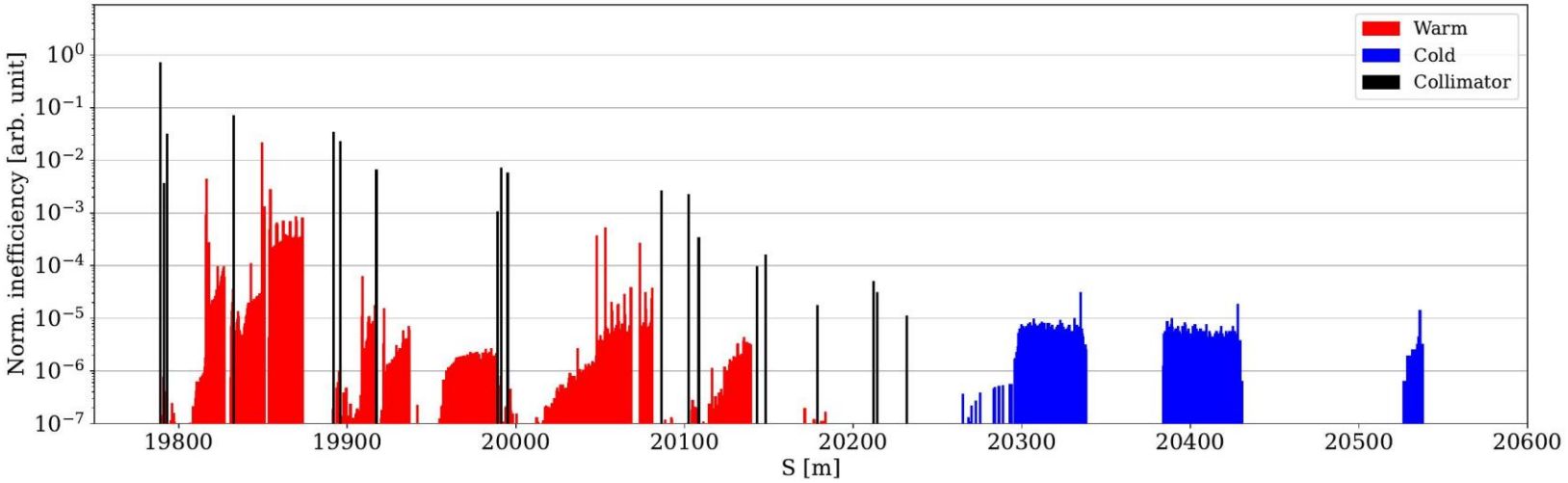
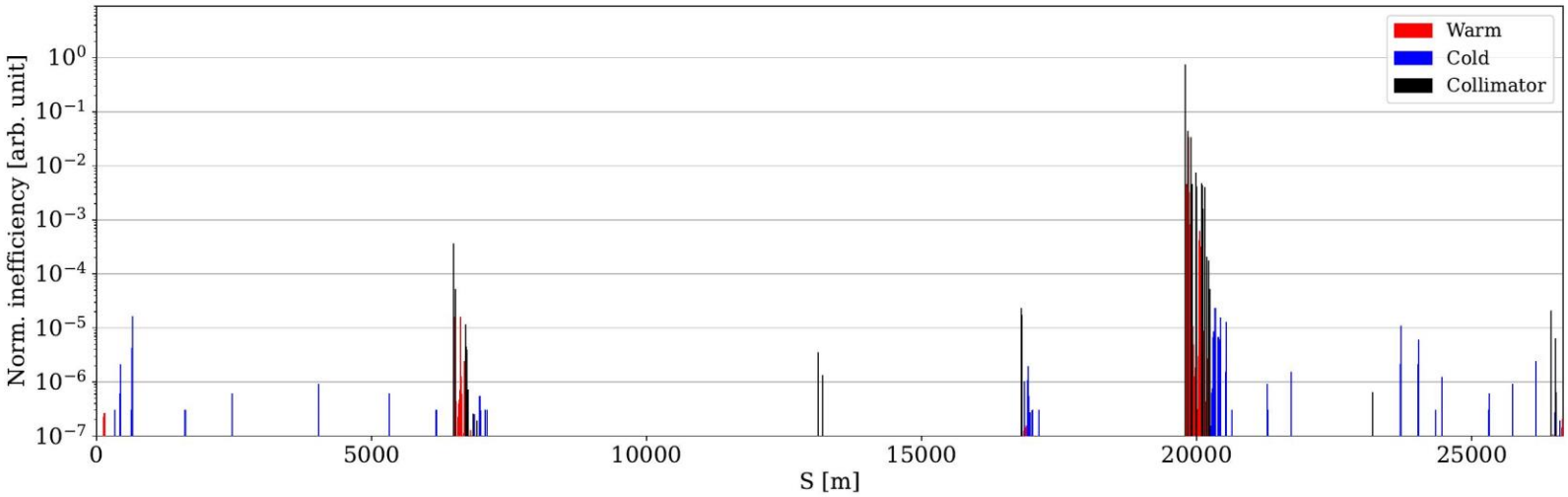
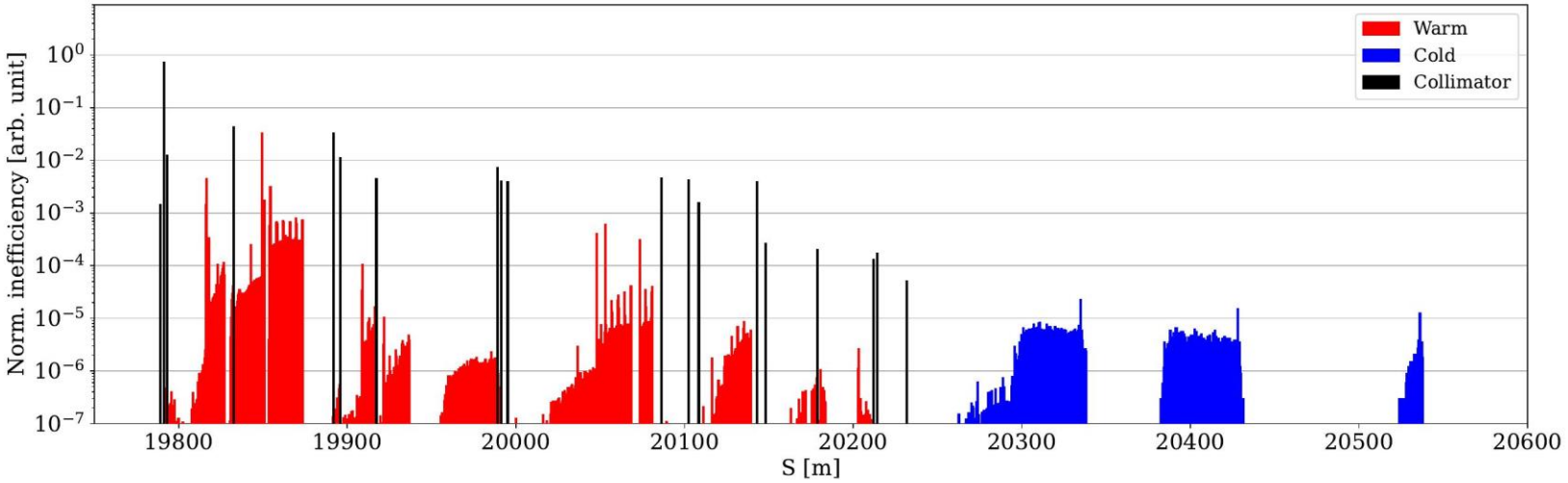




B1H – 64 cm – tight – no TCLD





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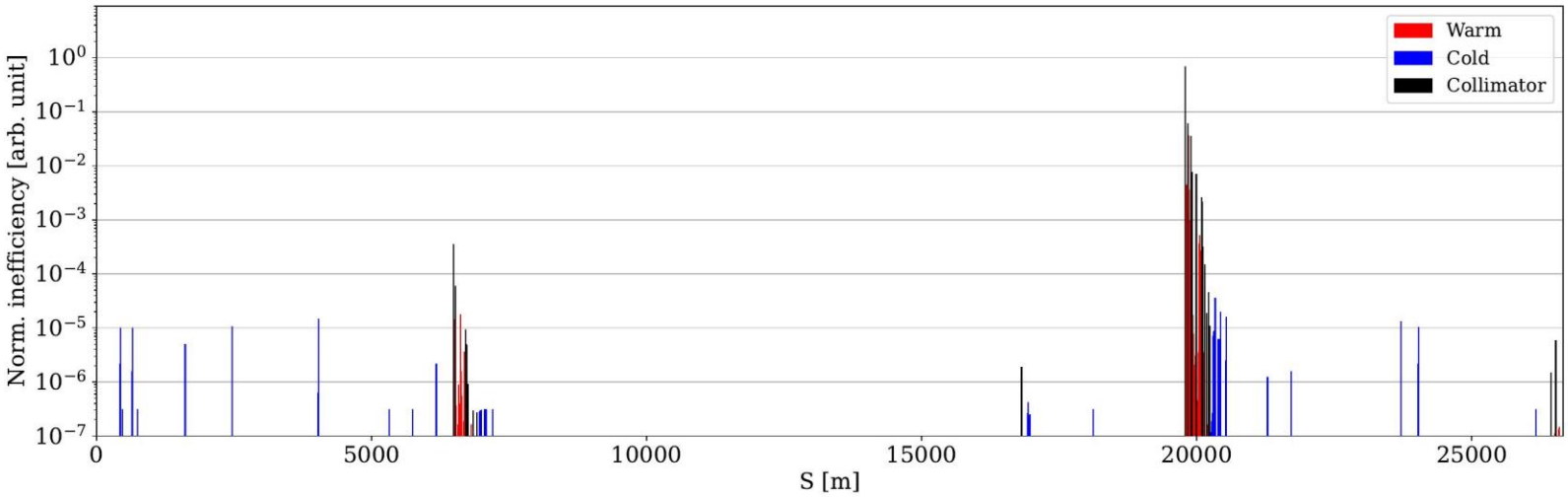
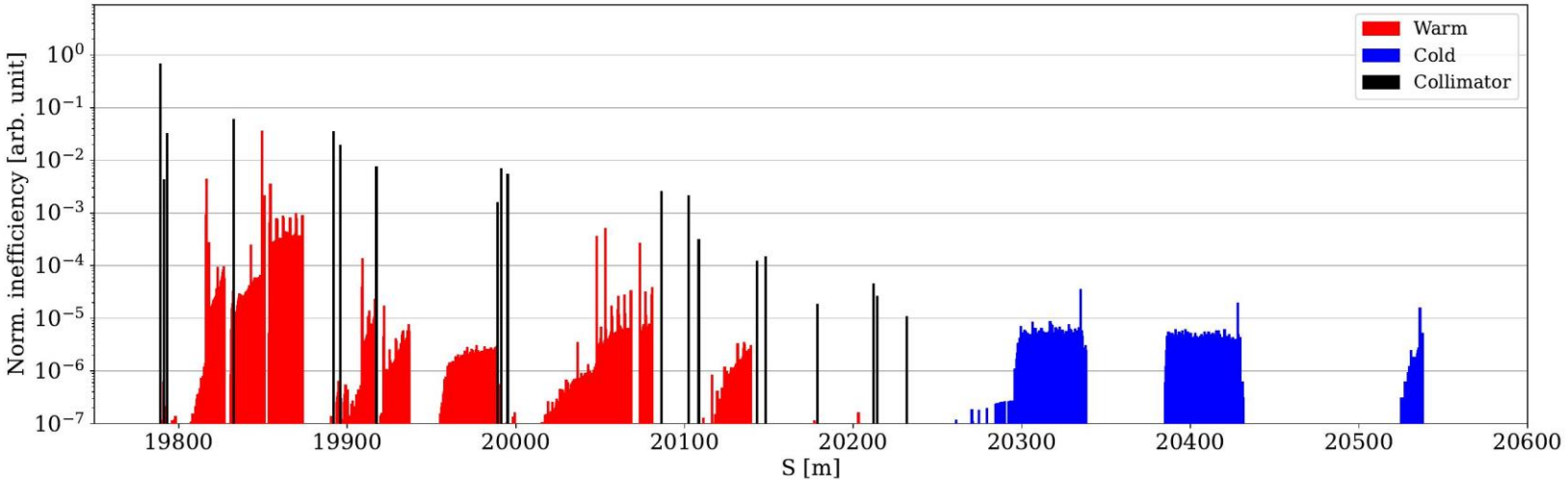
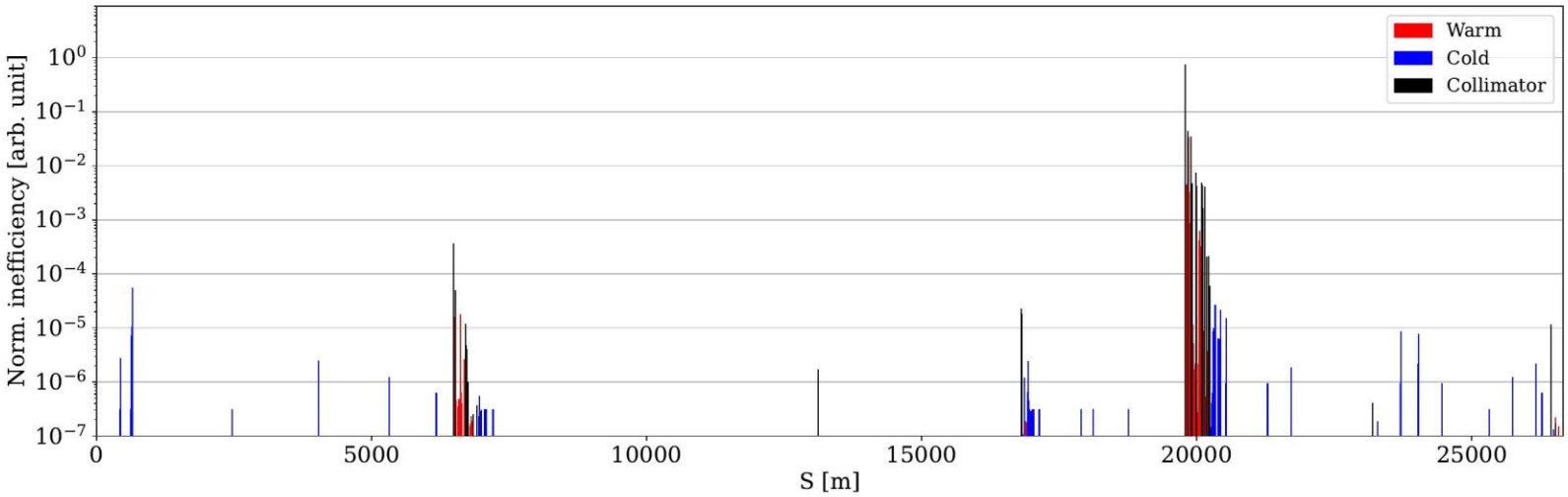
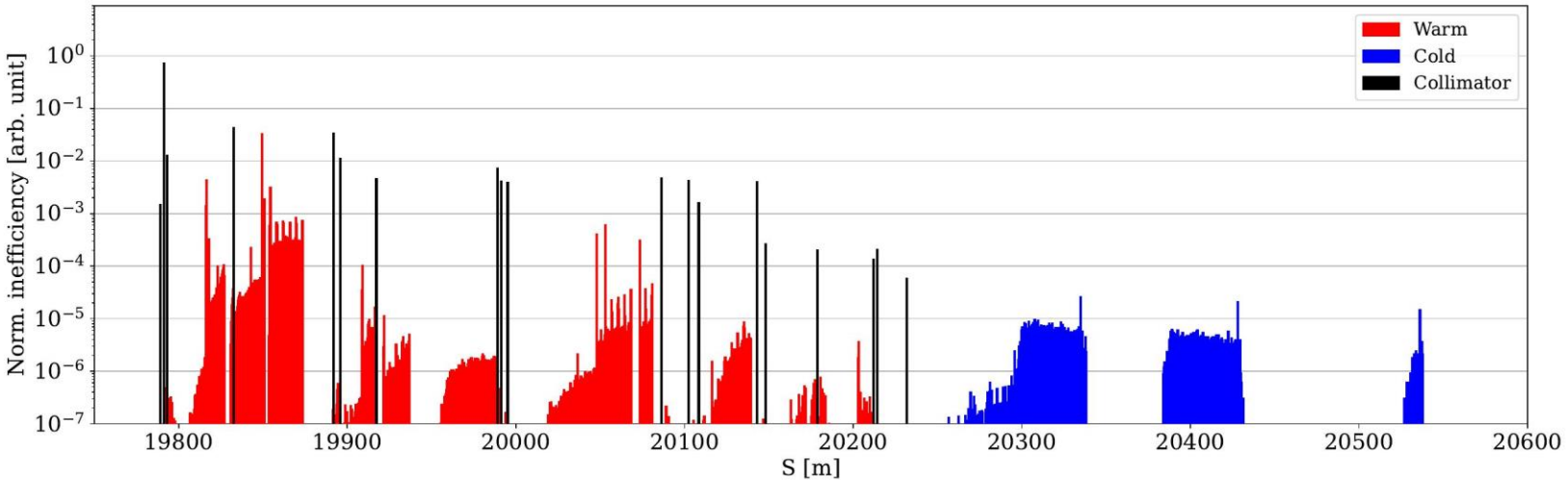


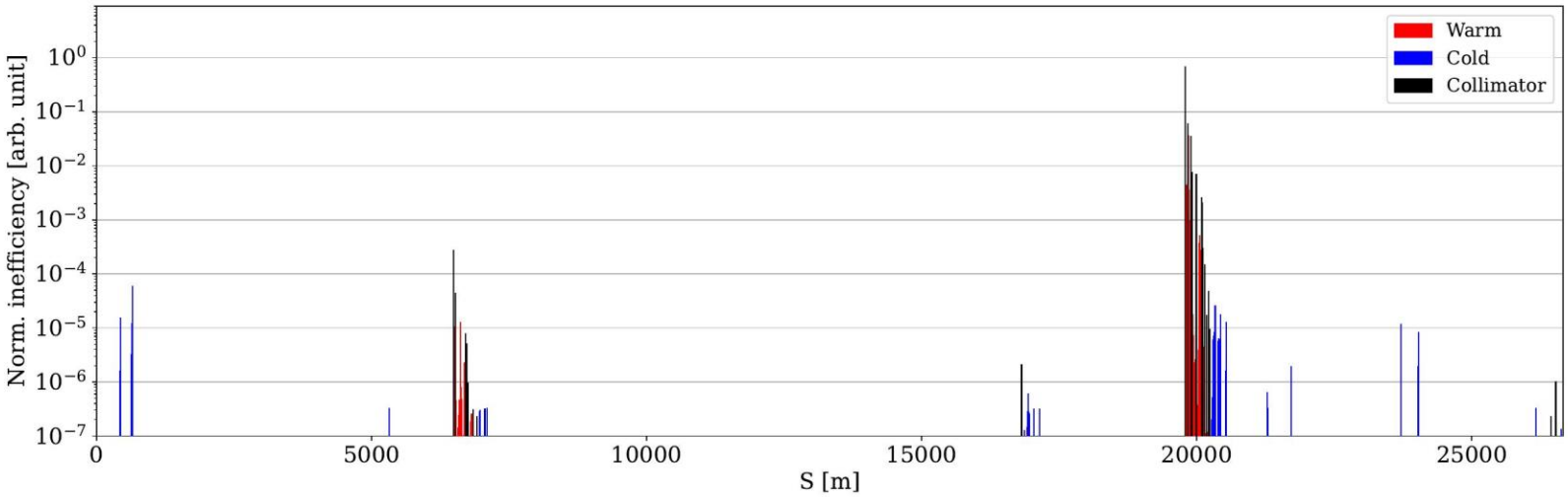


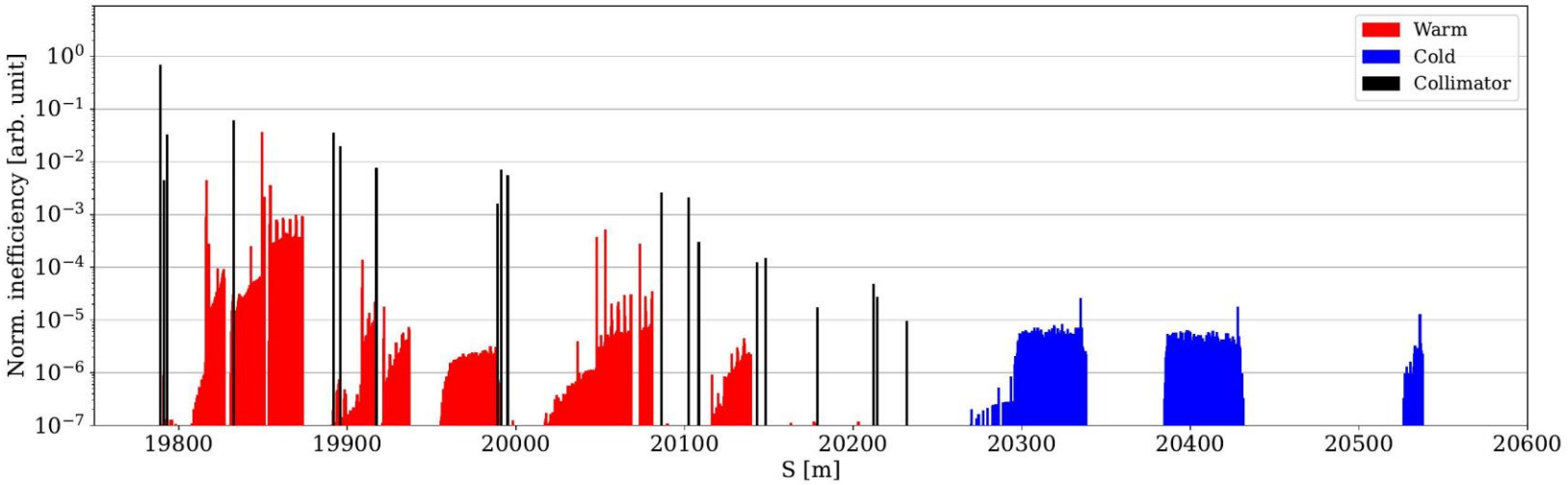
B1H – 100 cm – tight – no TCLD





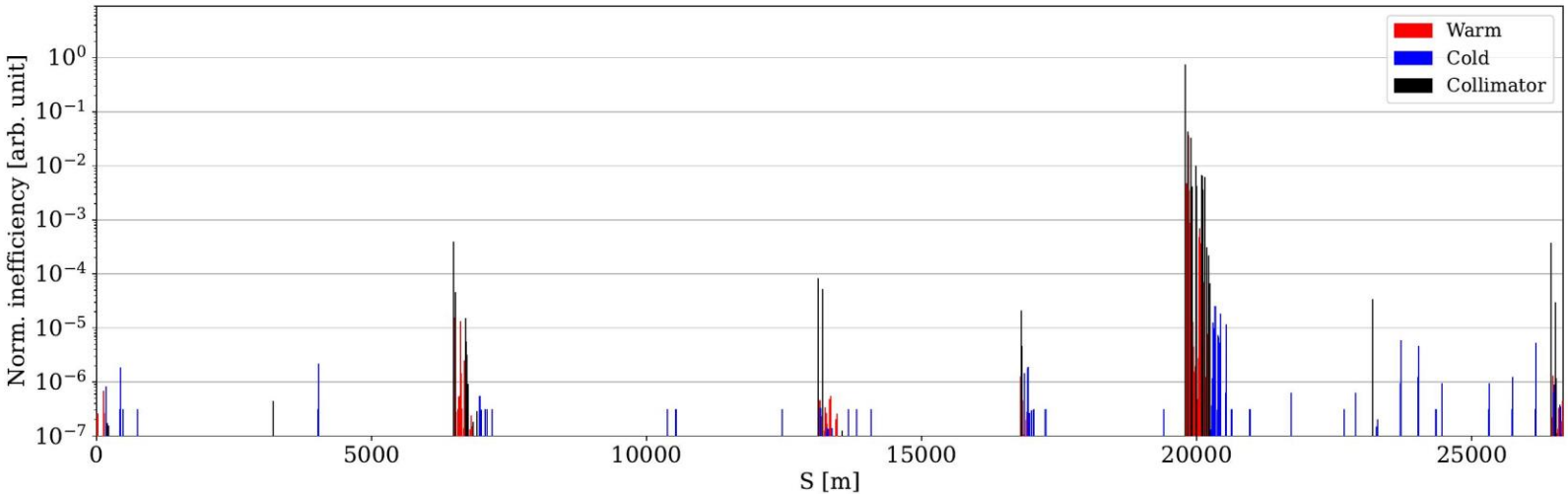
B1V – 100 cm – tight – no TCLD

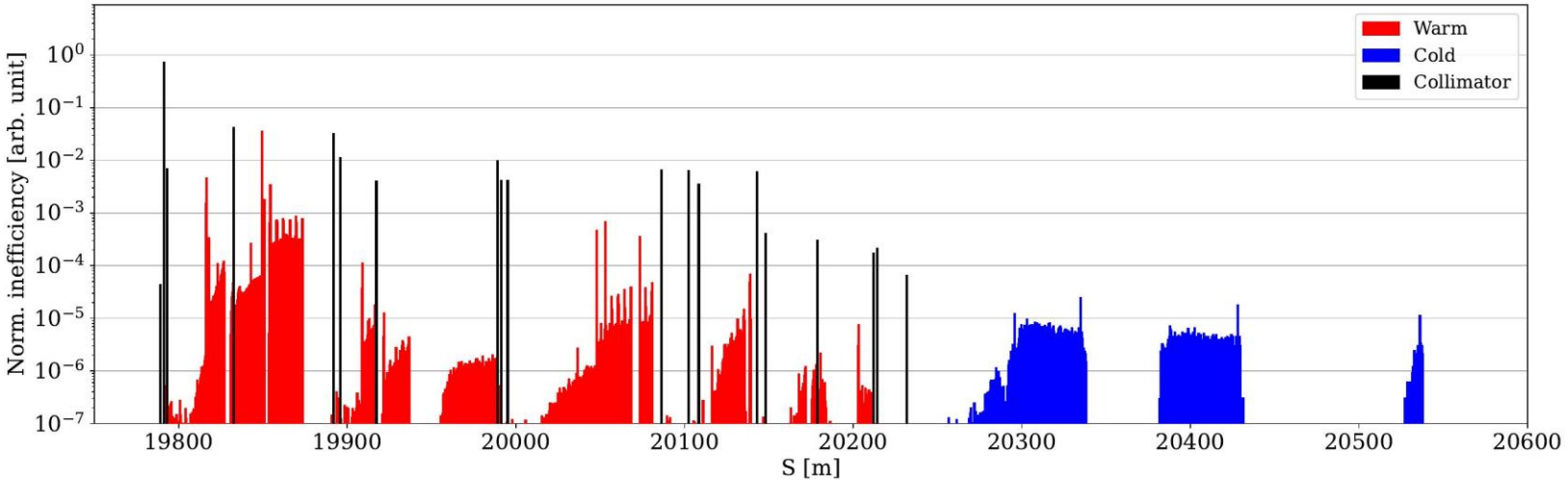




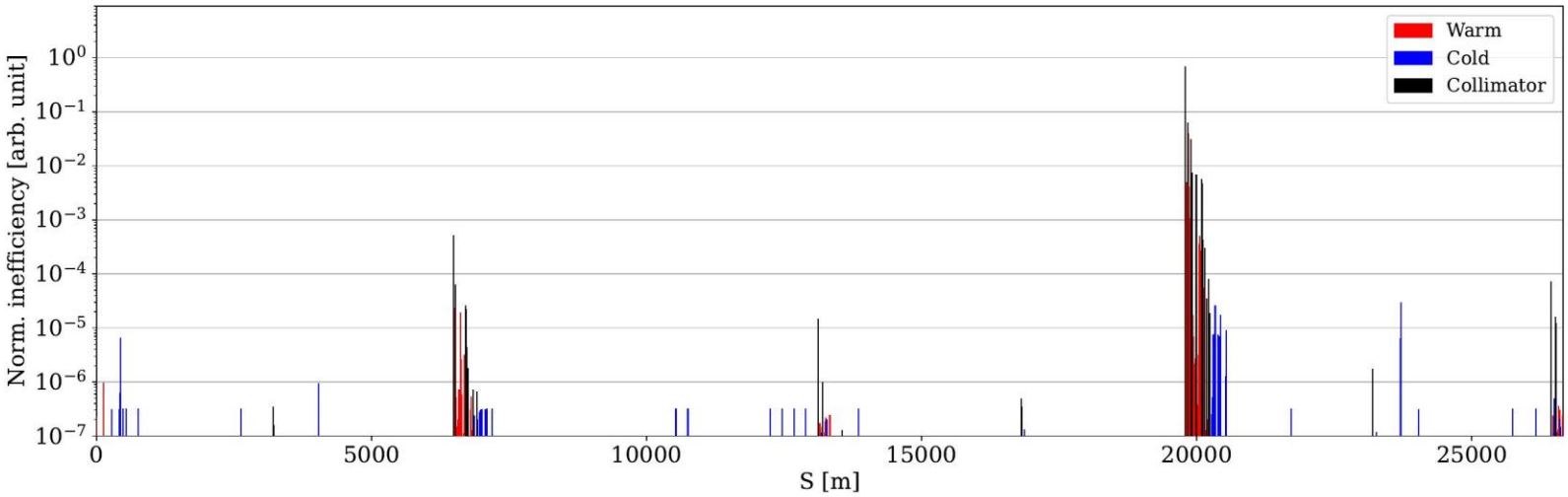
Lossmaps – B1 relaxed settings

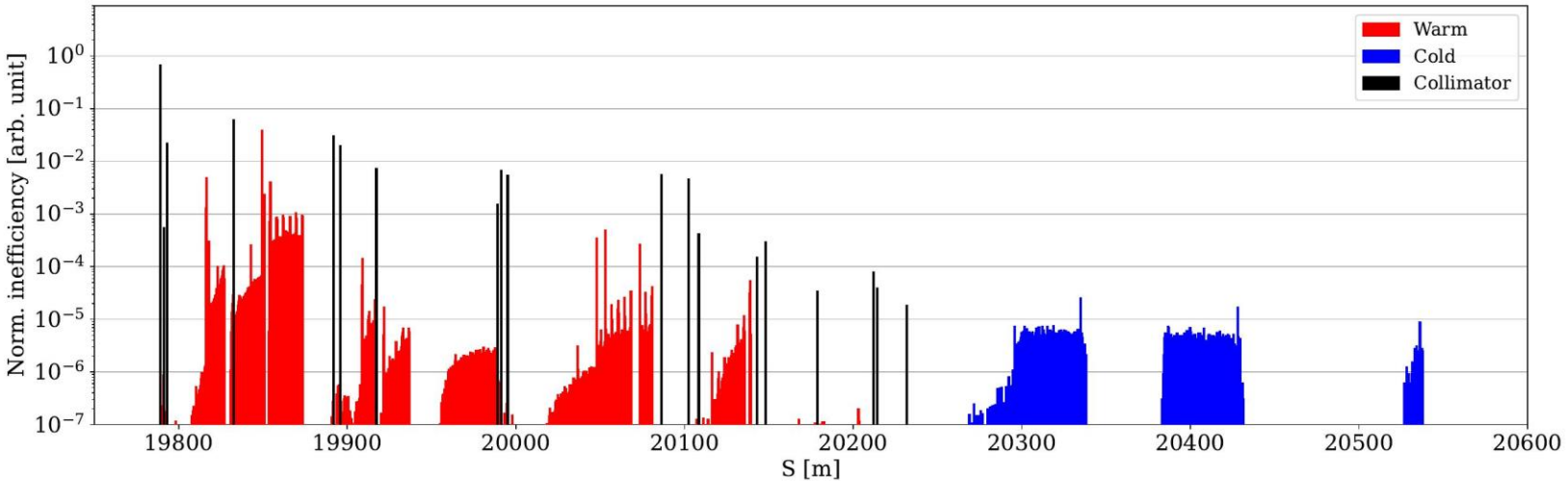
B1H – 15 cm – relaxed – no TCLD



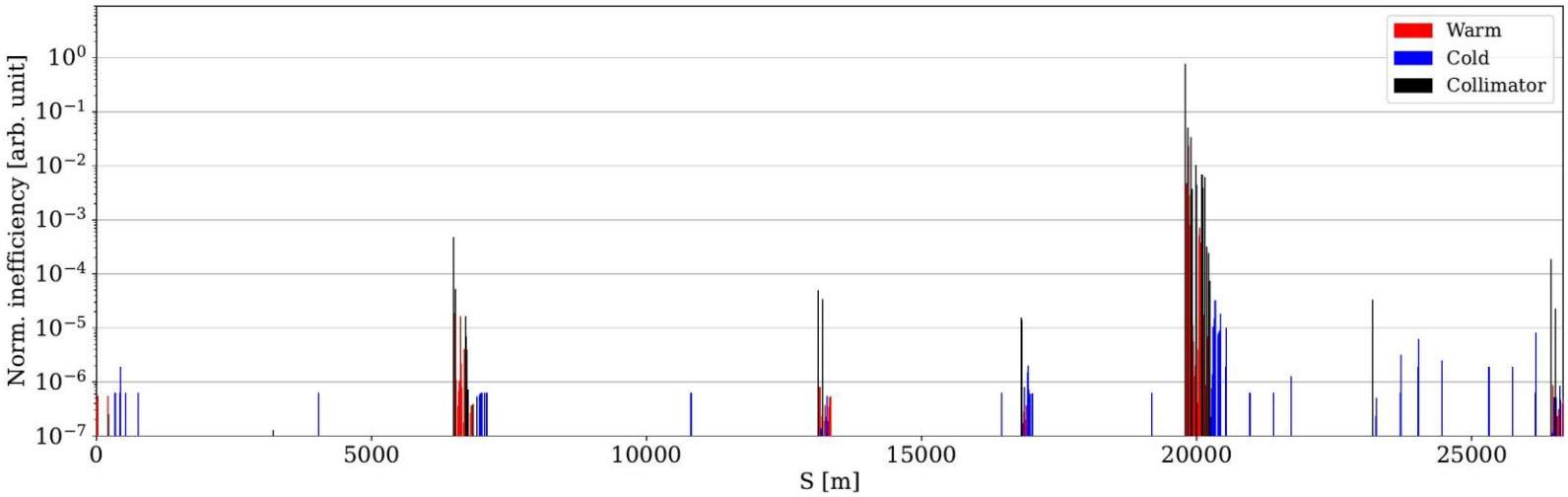


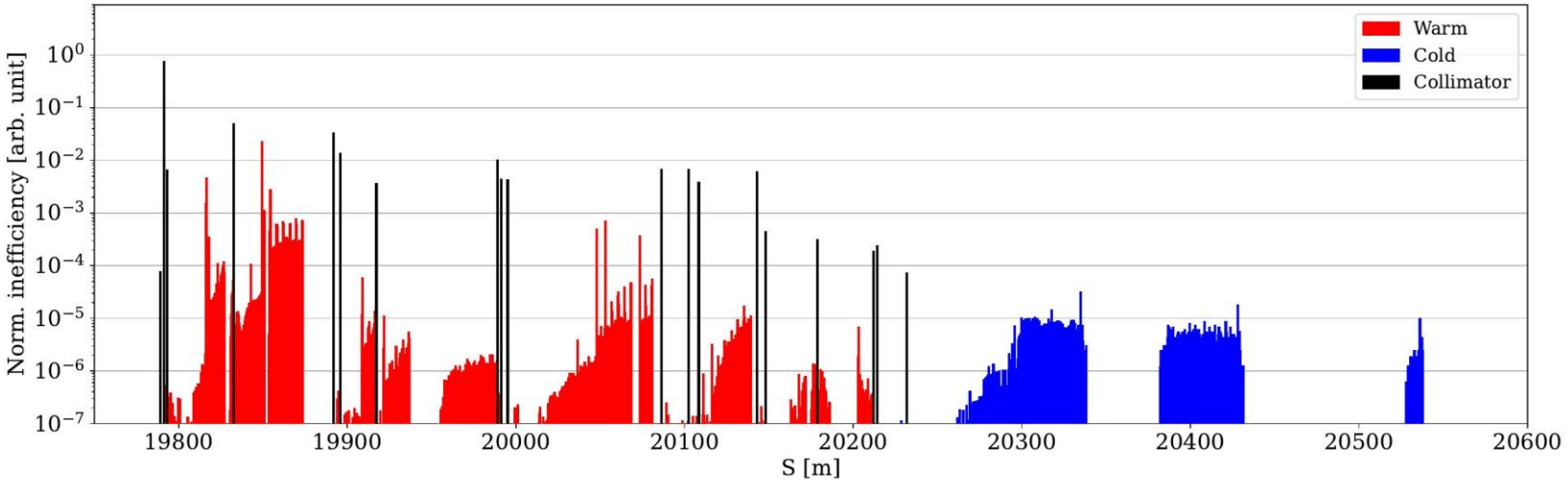
B1V – 15 cm – relaxed – no TCLD



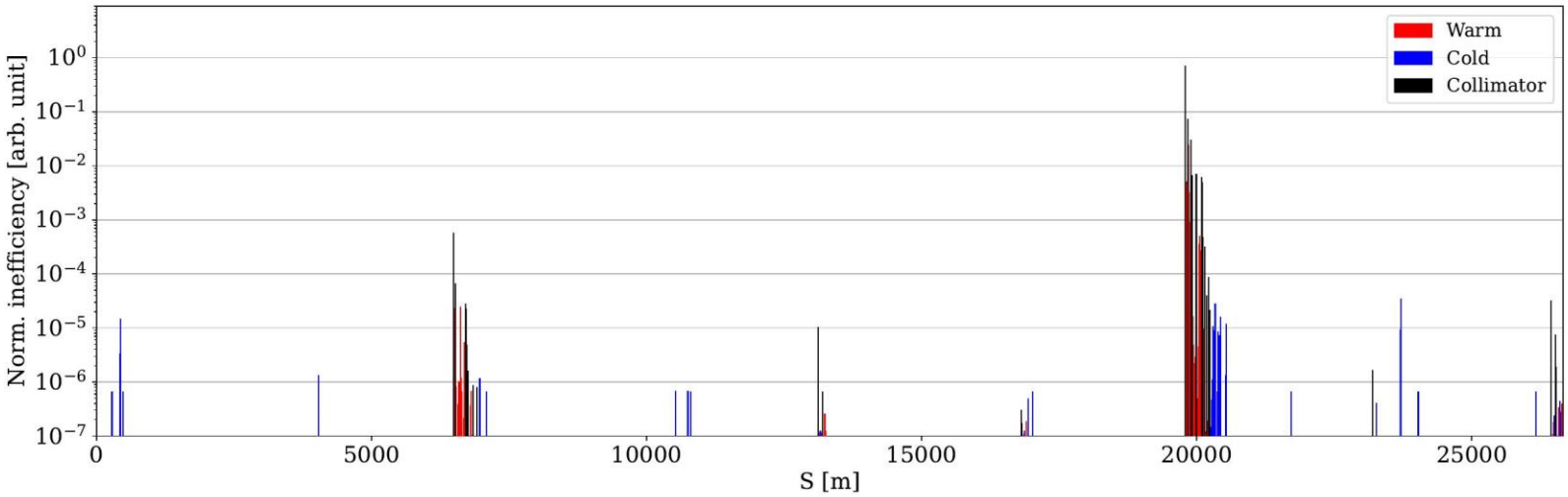


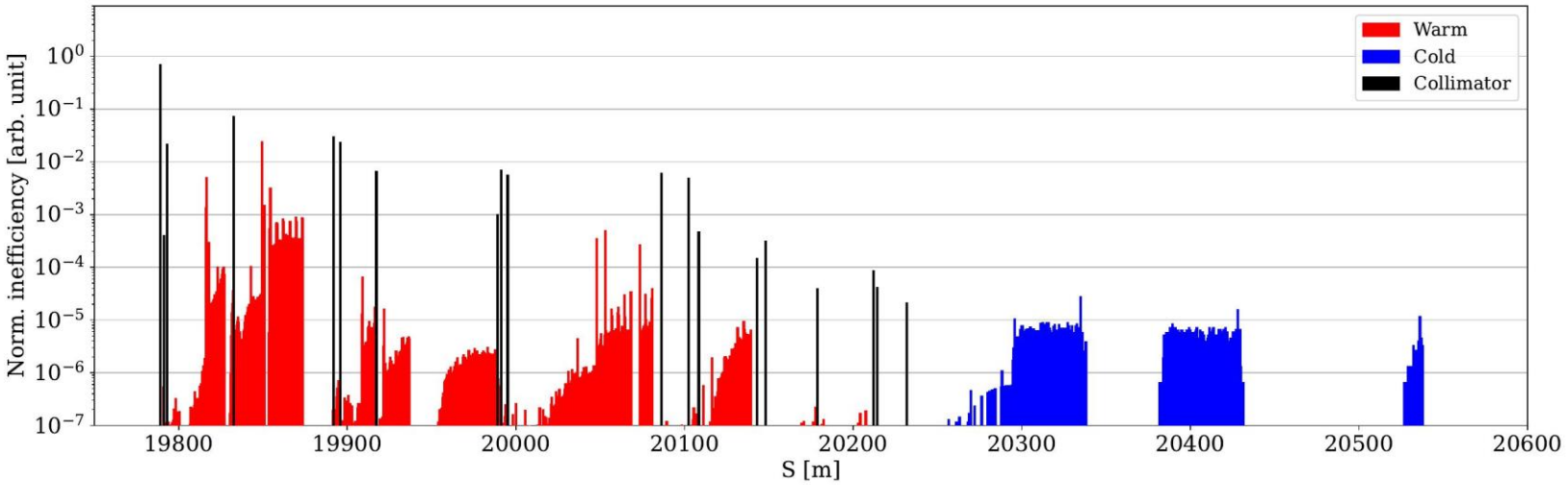
B1H – 20 cm – relaxed – no TCLD



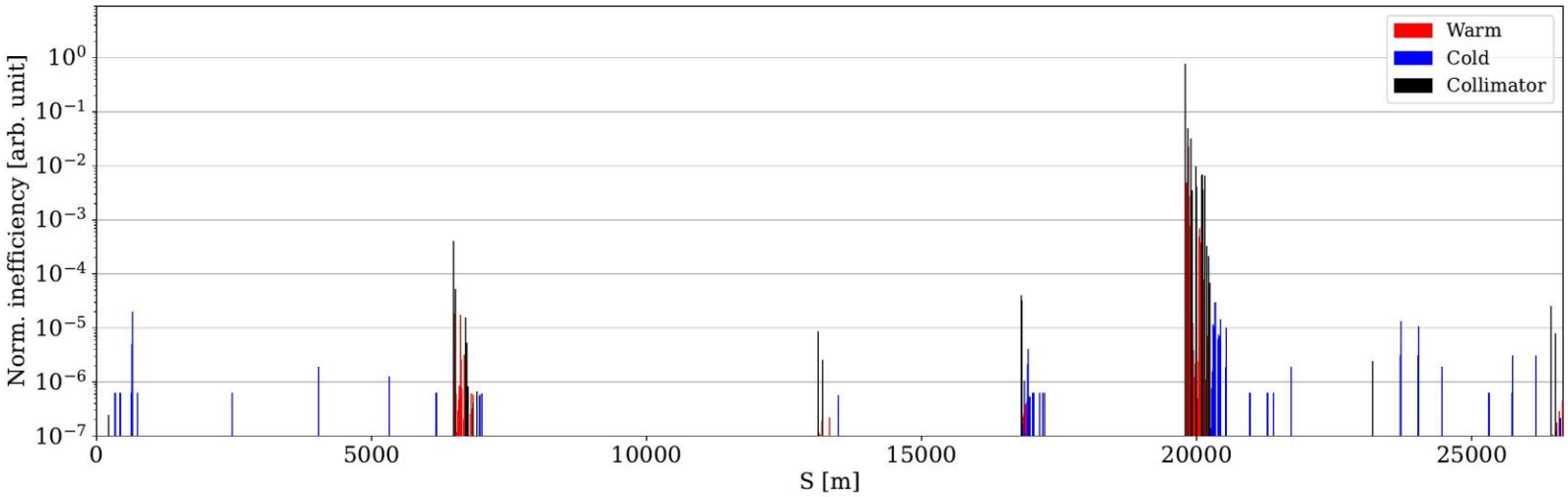


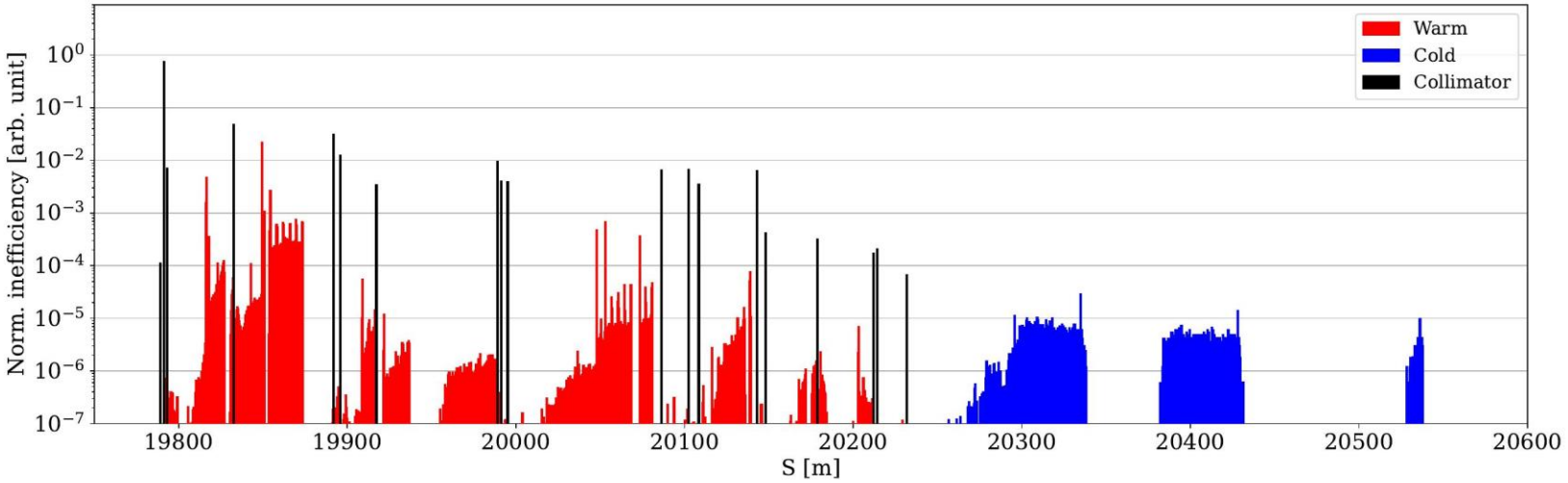
B1V – 20 cm – relaxed – no TCLD



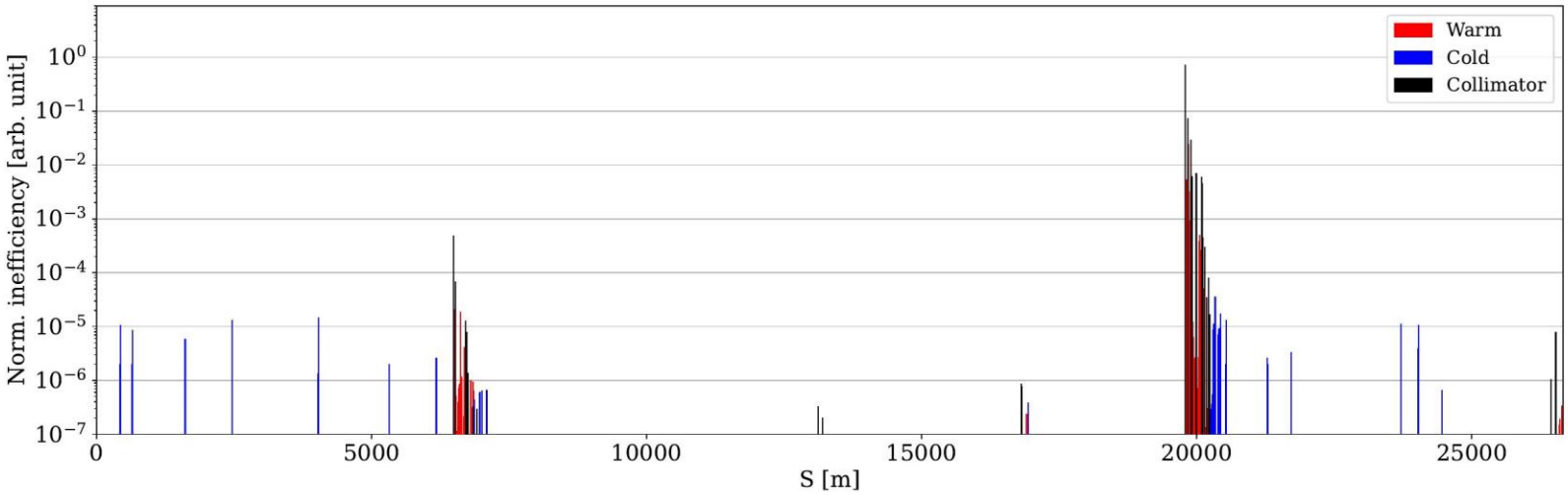


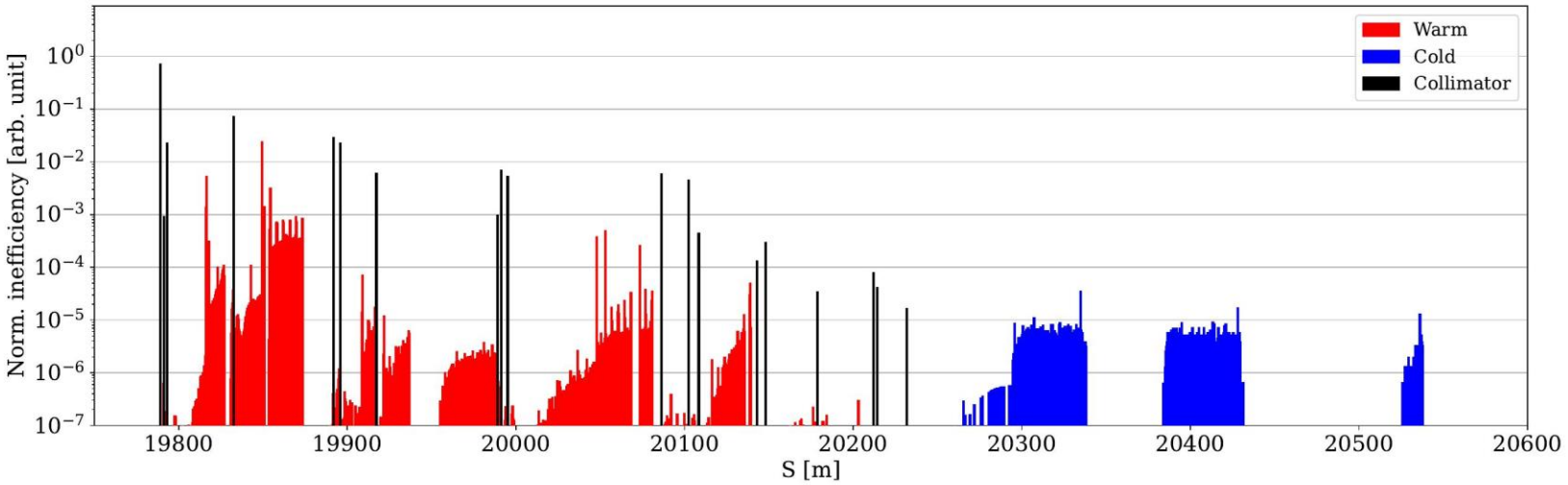
B1H – 64 cm – relaxed – no TCLD



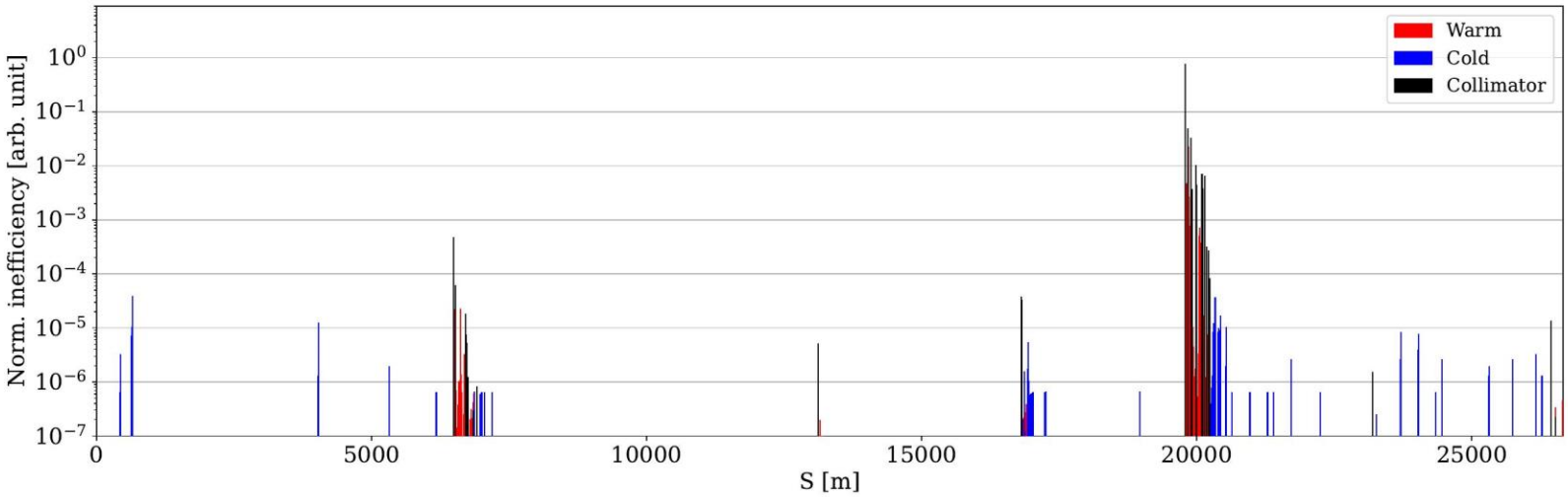


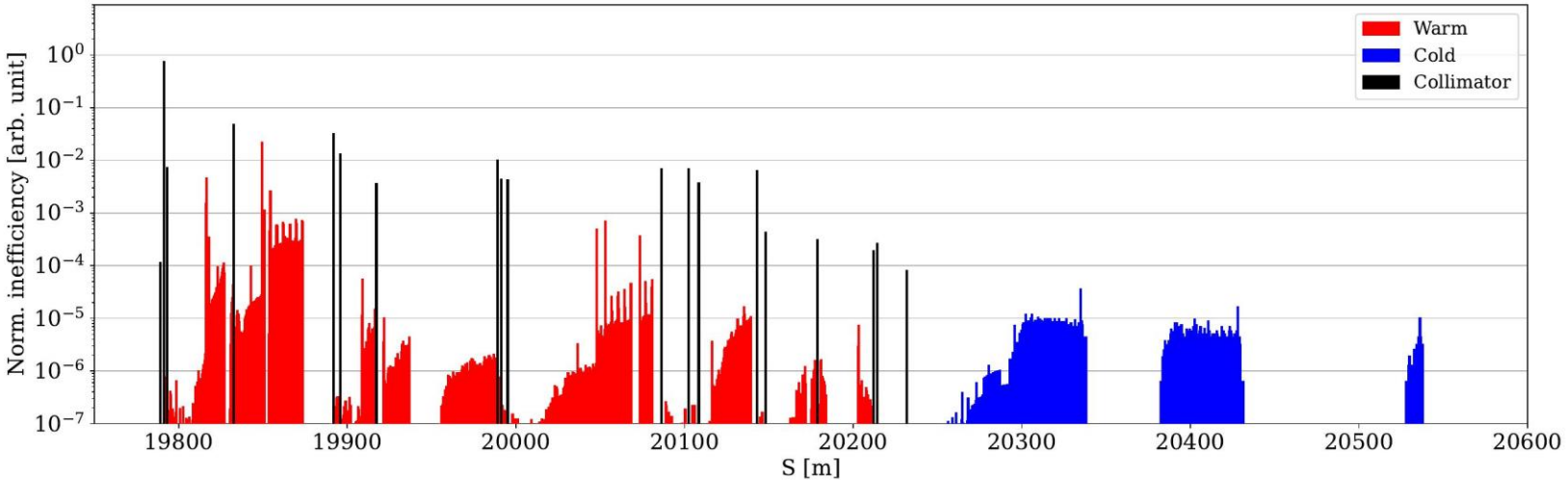
B1V – 64 cm – relaxed – no TCLD



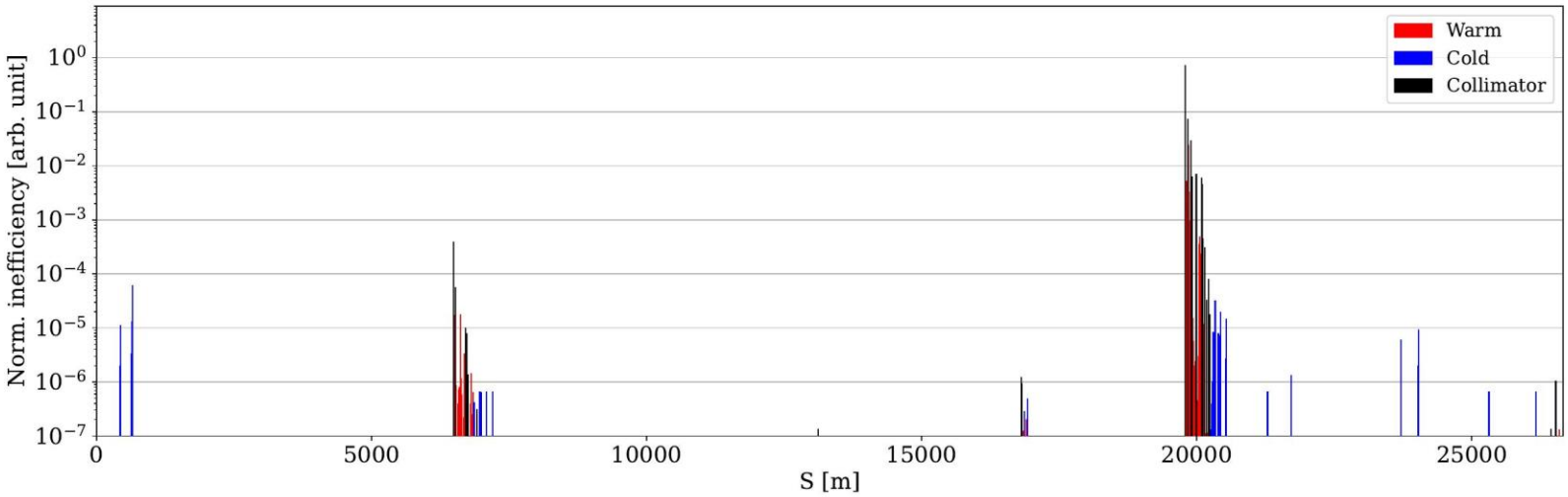


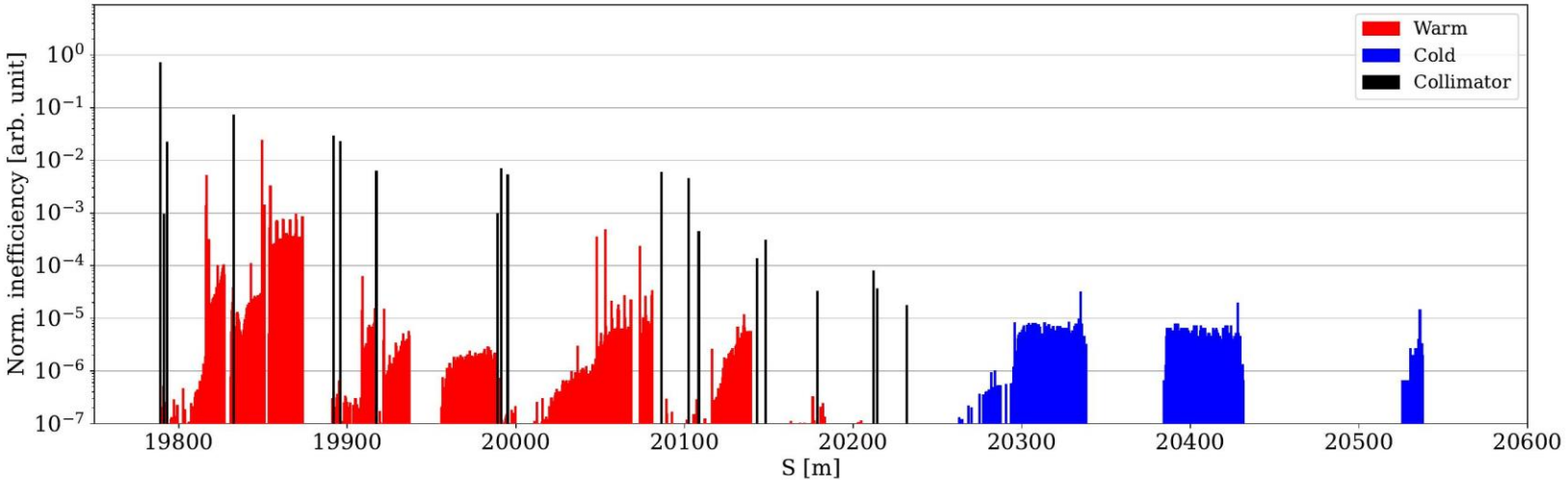
B1H – 100 cm – relaxed – no TCLD





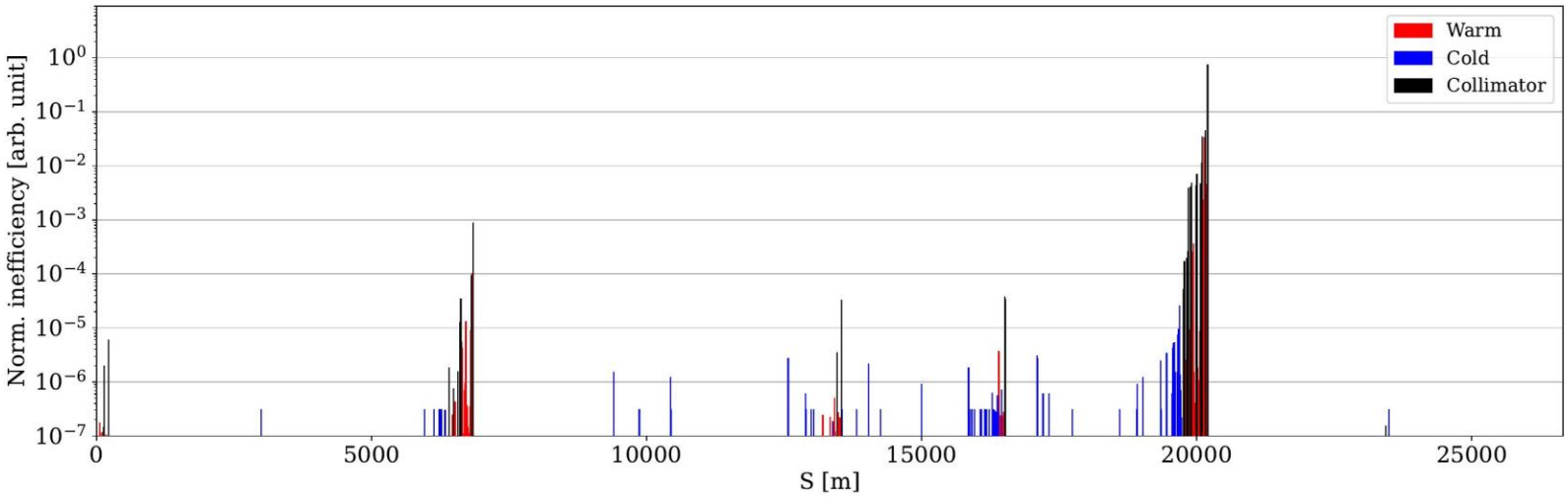
B1V – 100 cm – relaxed – no TCLD

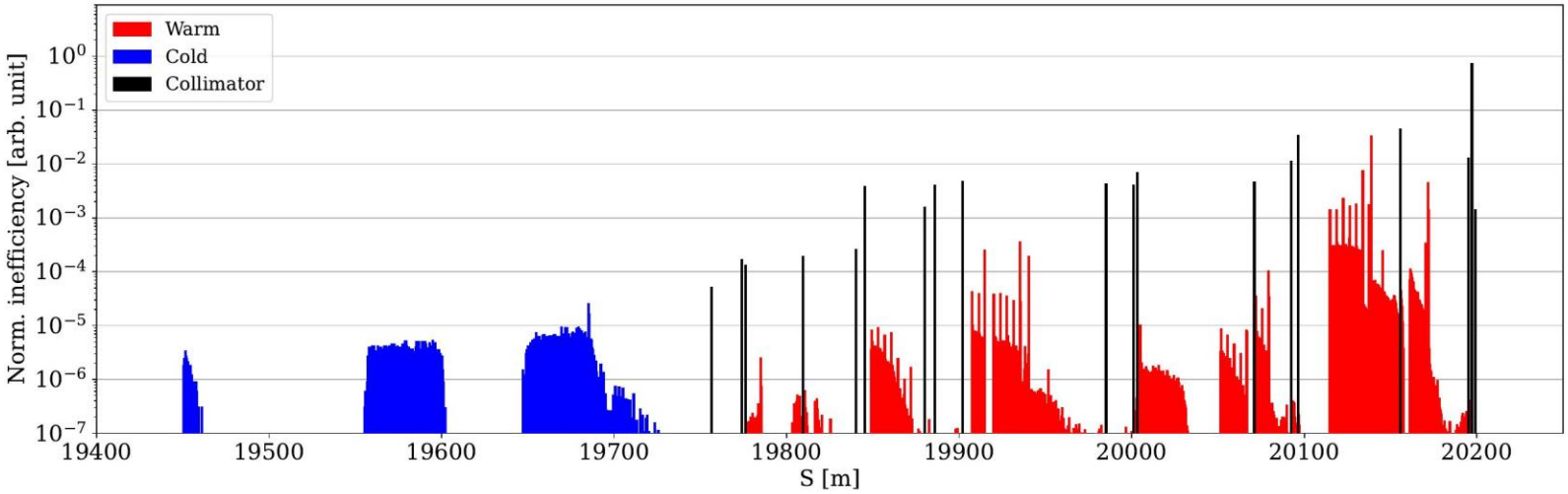




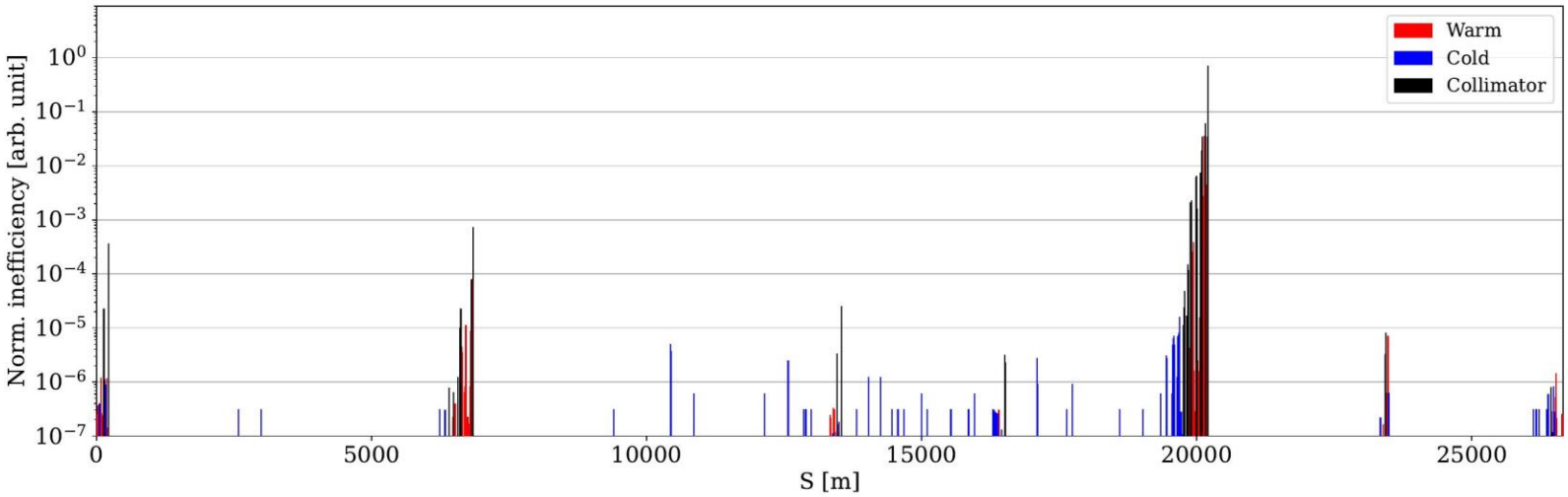
Lossmaps – B2 tight settings

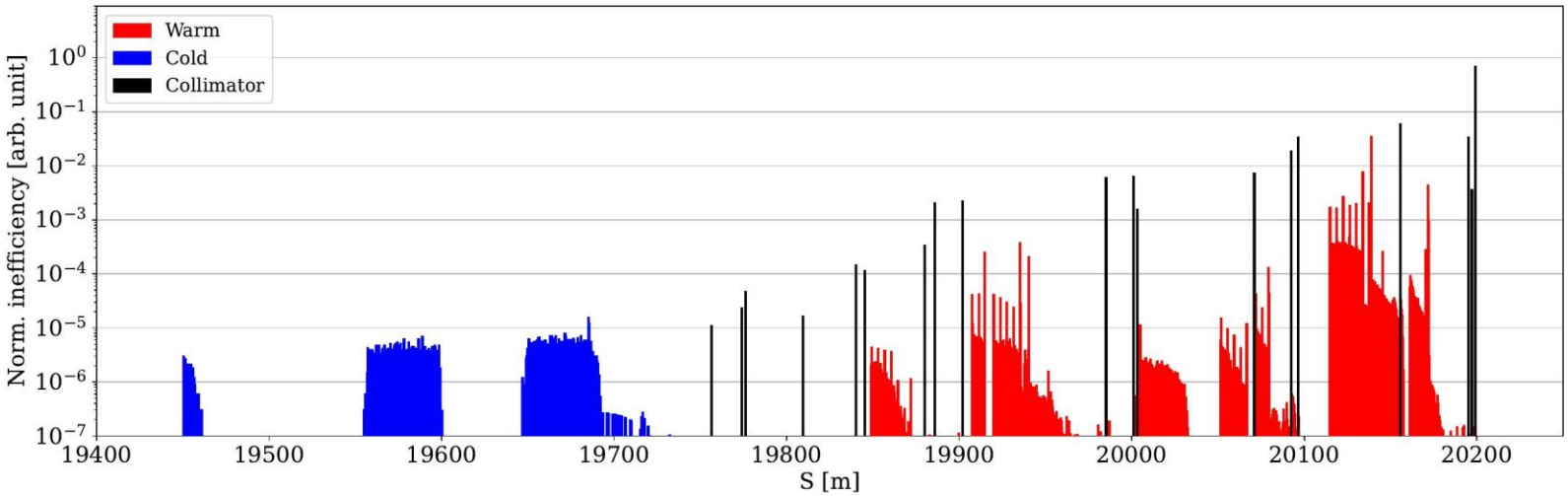
B2H – 15 cm – tight – no TCLD



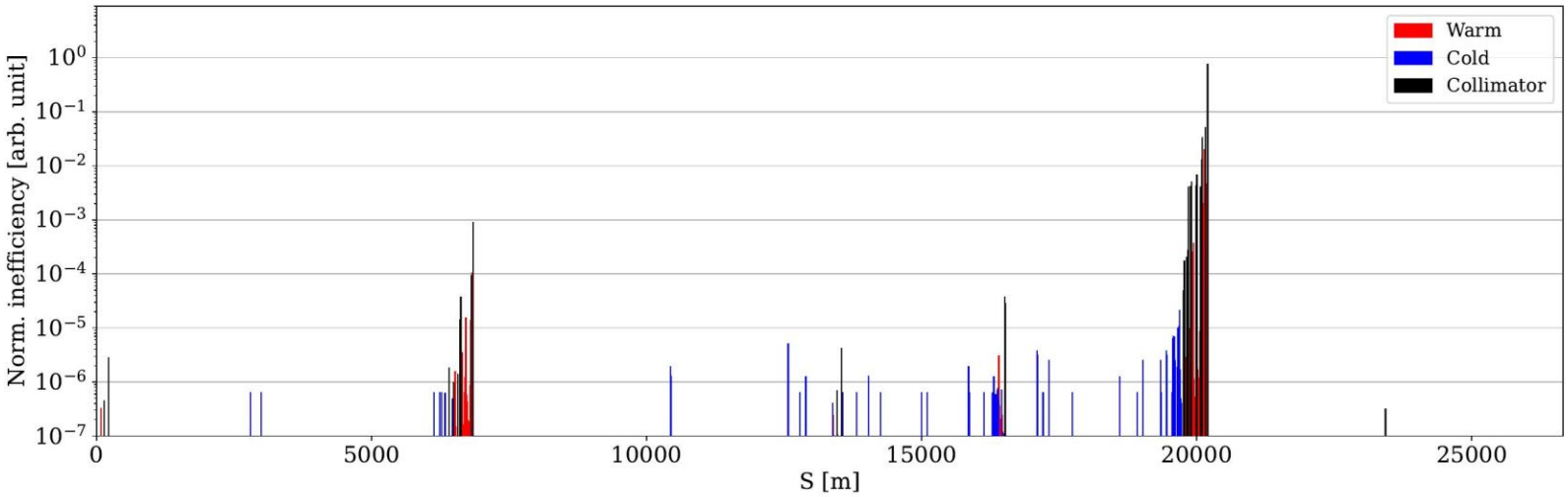


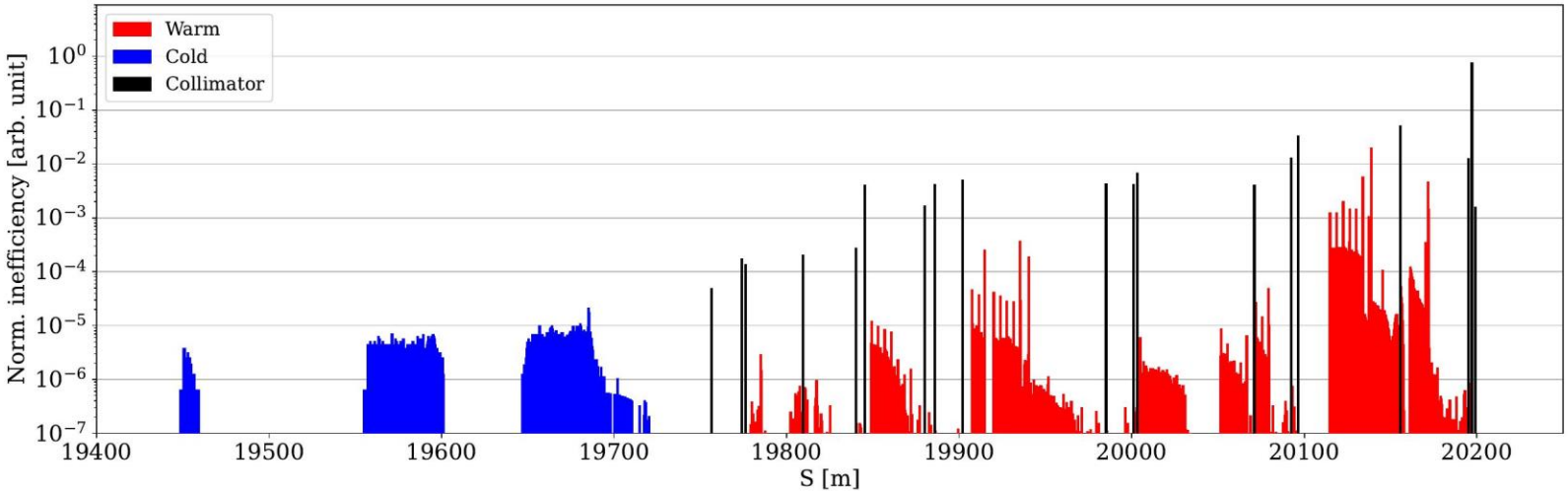
B2V – 15 cm – tight – no TCLD



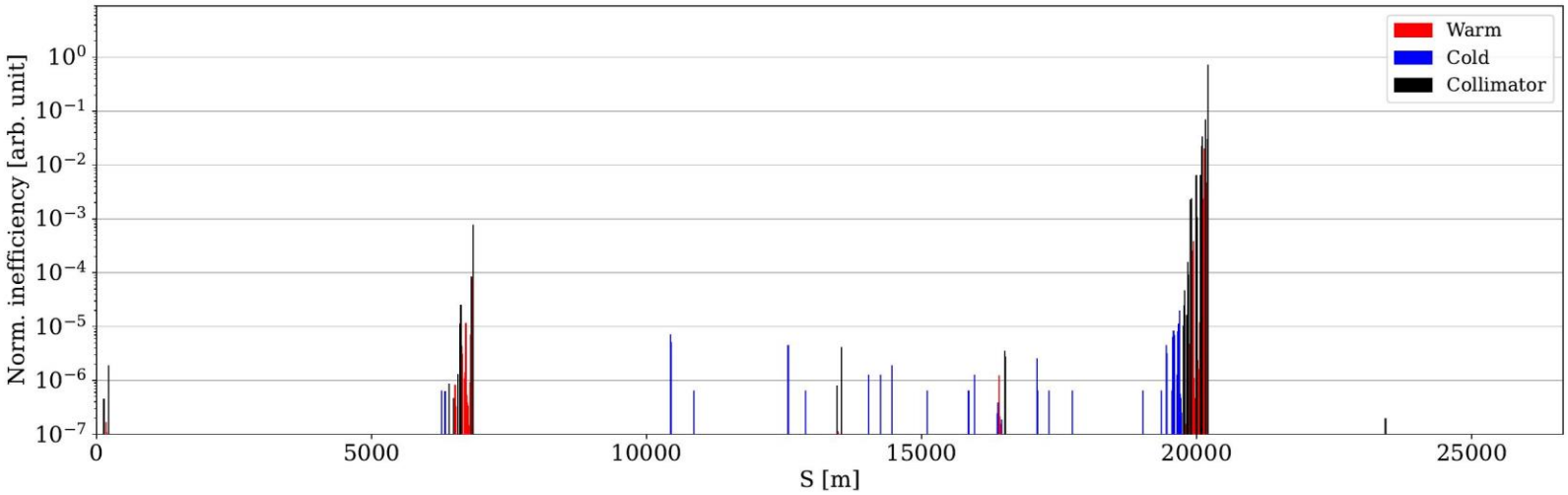


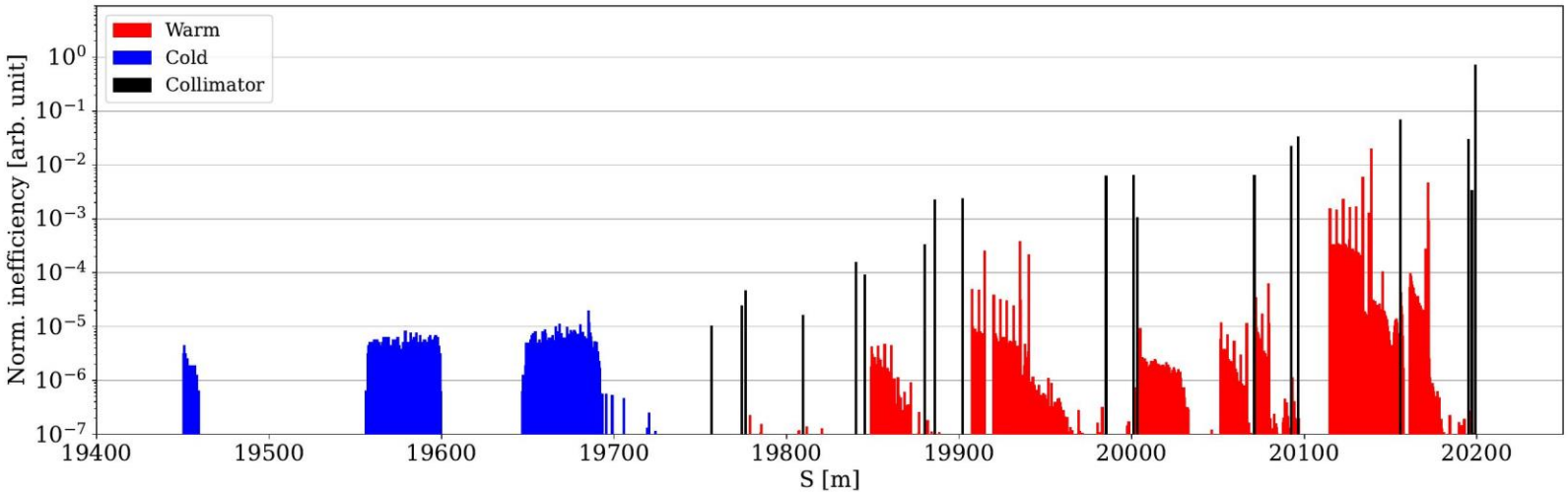
B2H – 20 cm – tight – no TCLD



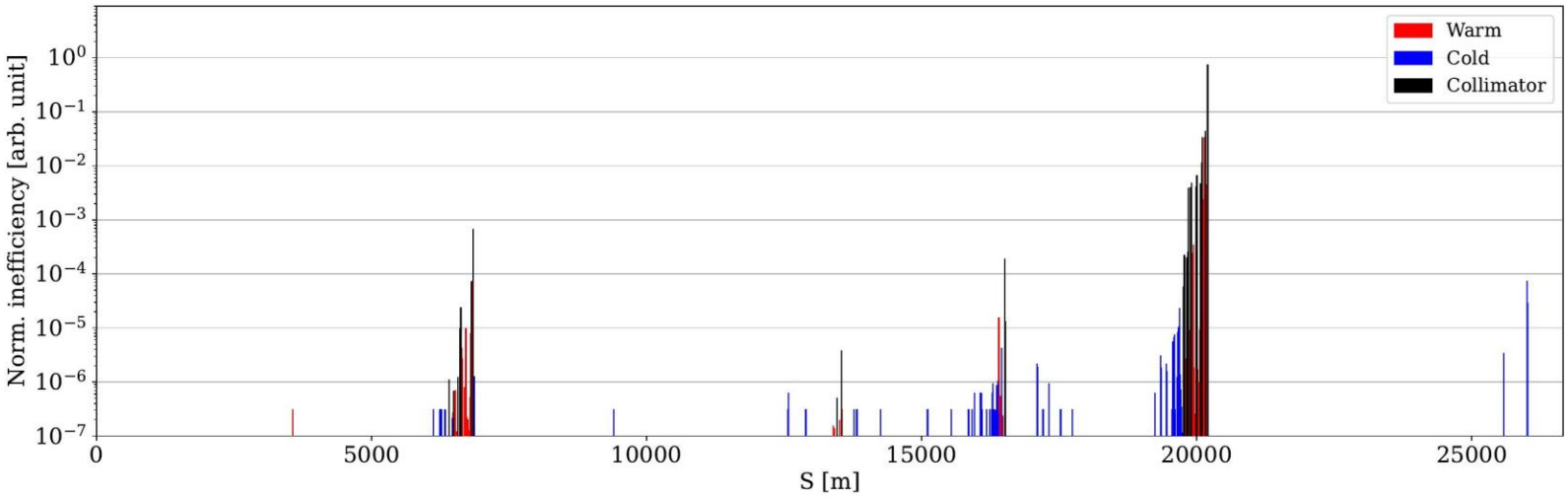


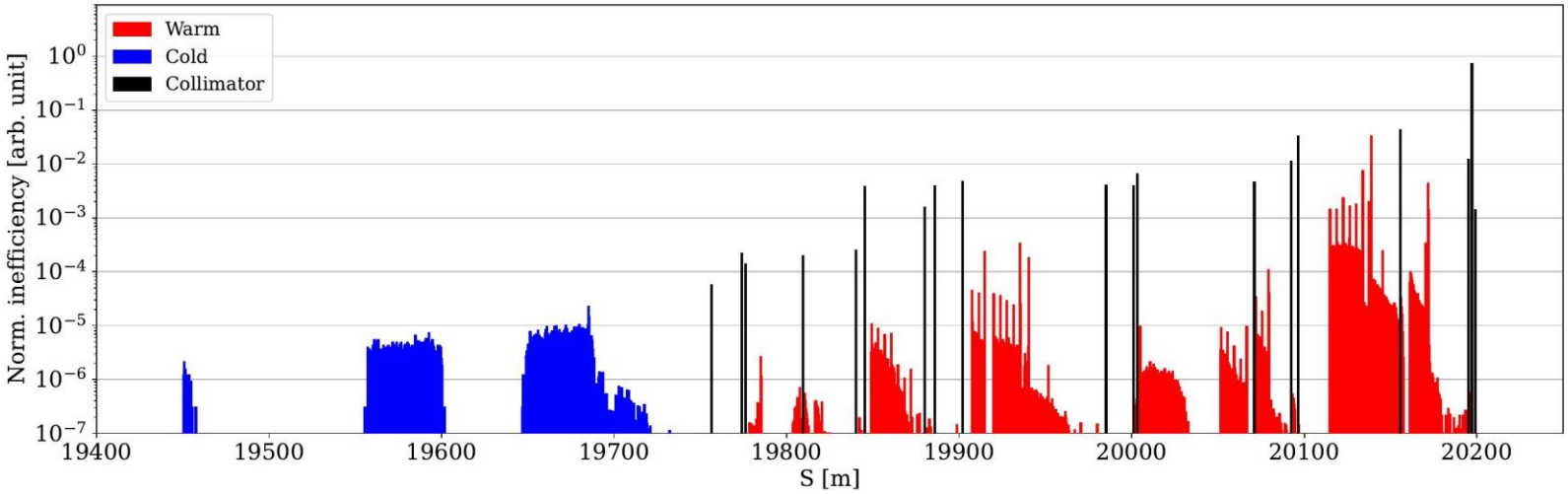
B2V – 20 cm – tight – no TCLD



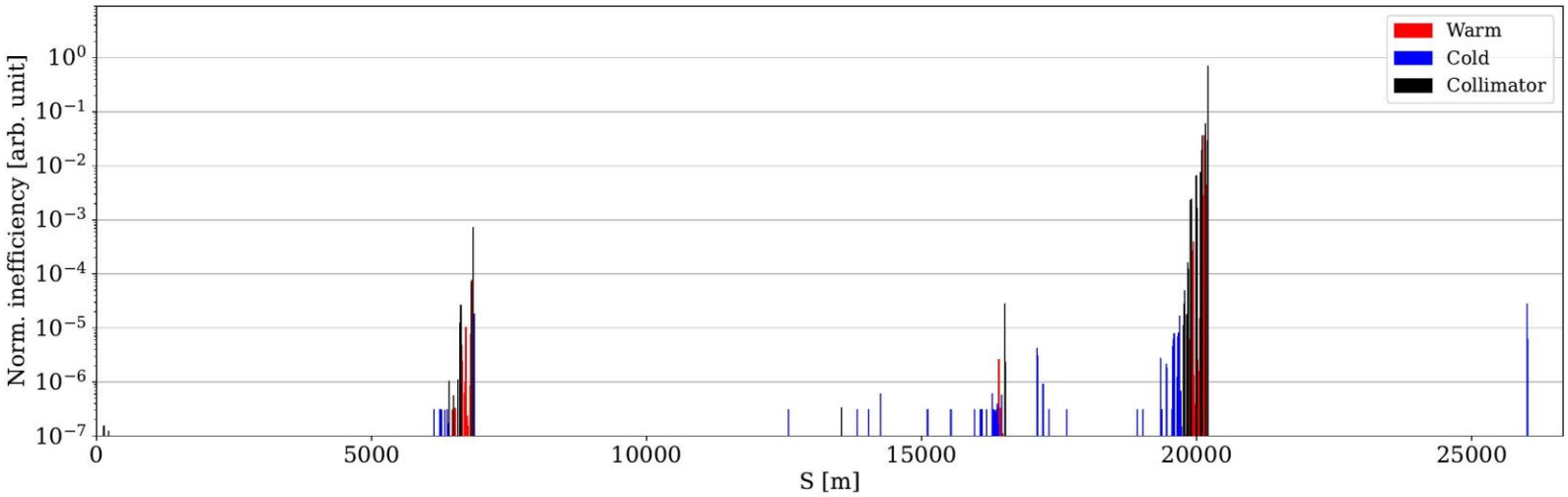


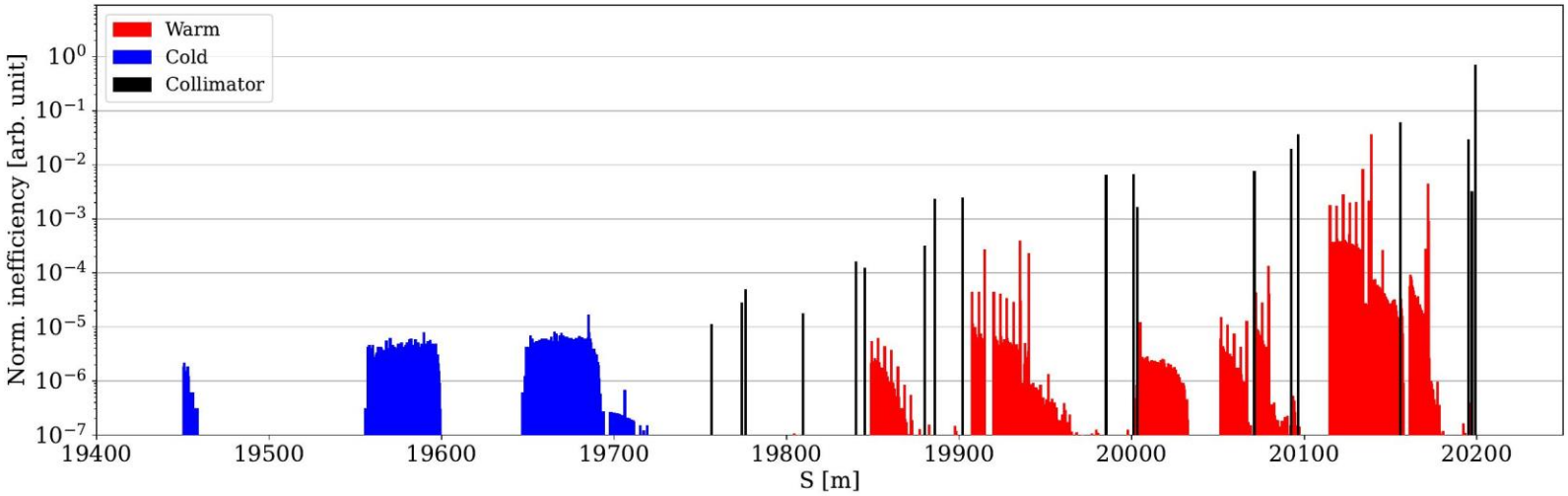
B2H – 64 cm – tight – no TCLD



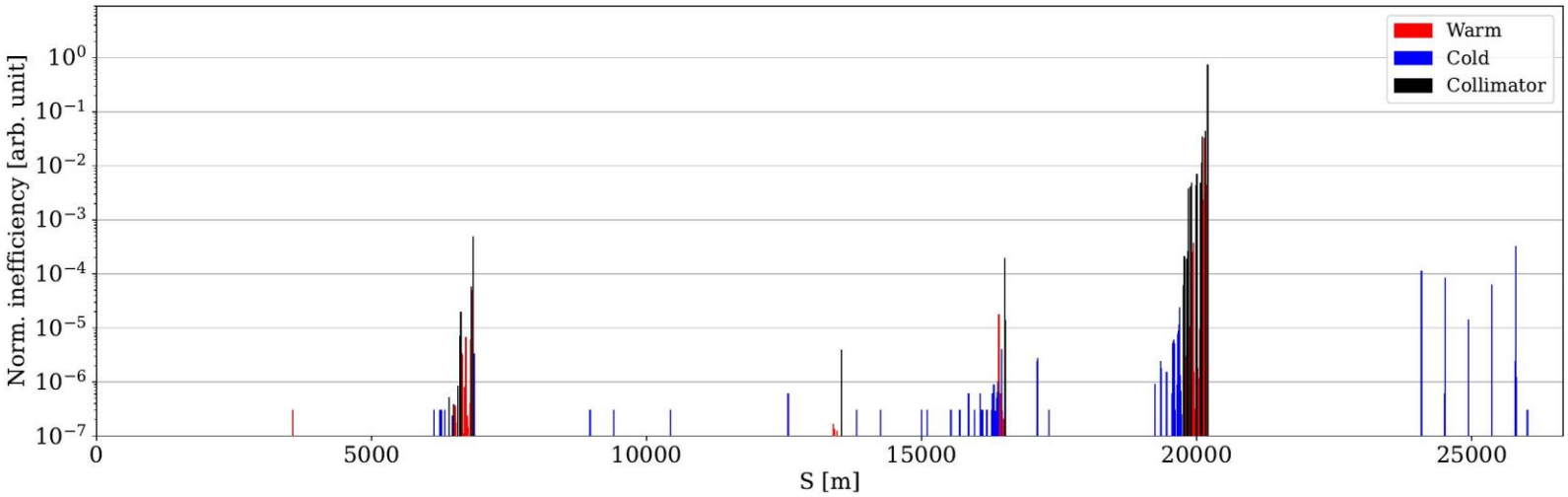


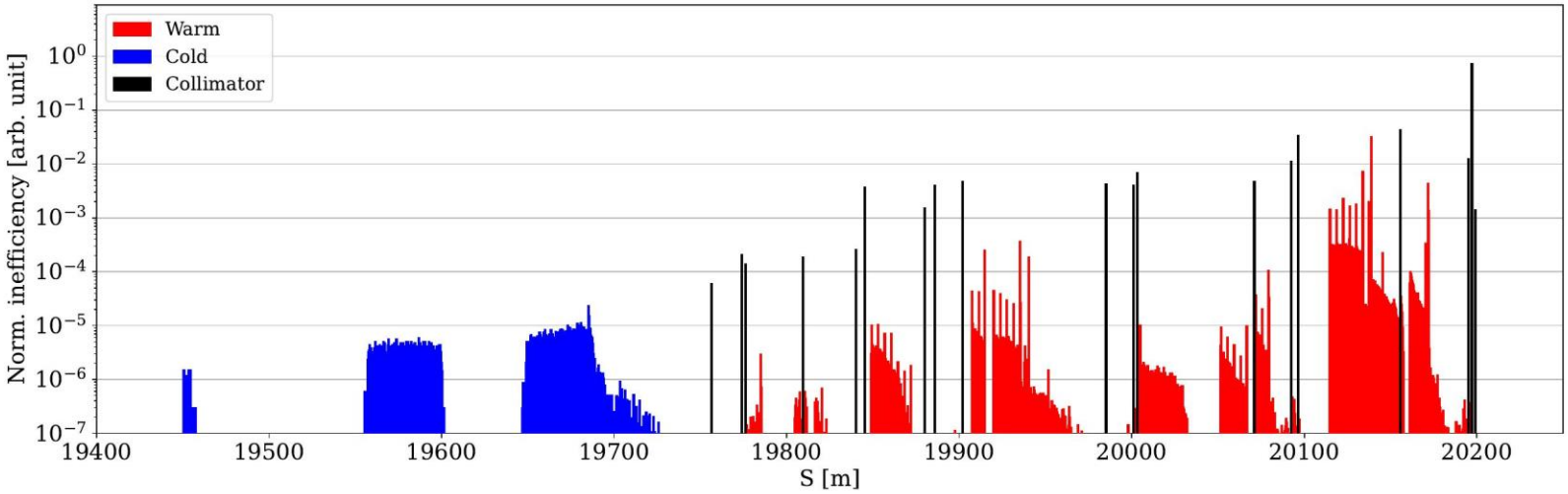
B2V – 64 cm – tight – no TCLD



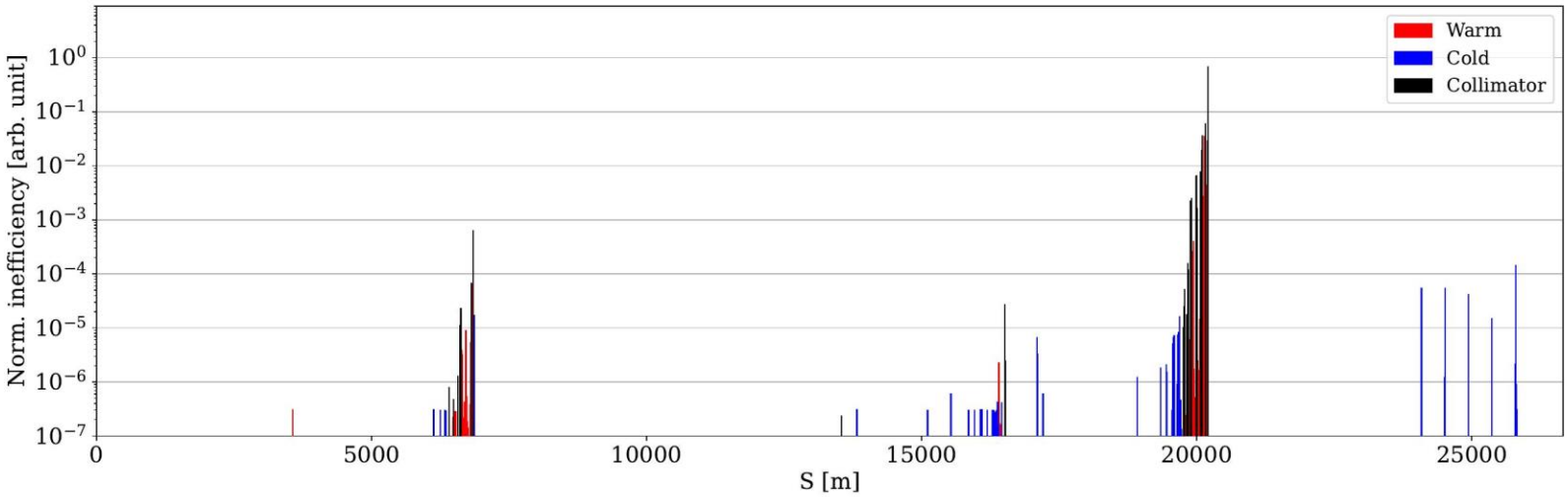


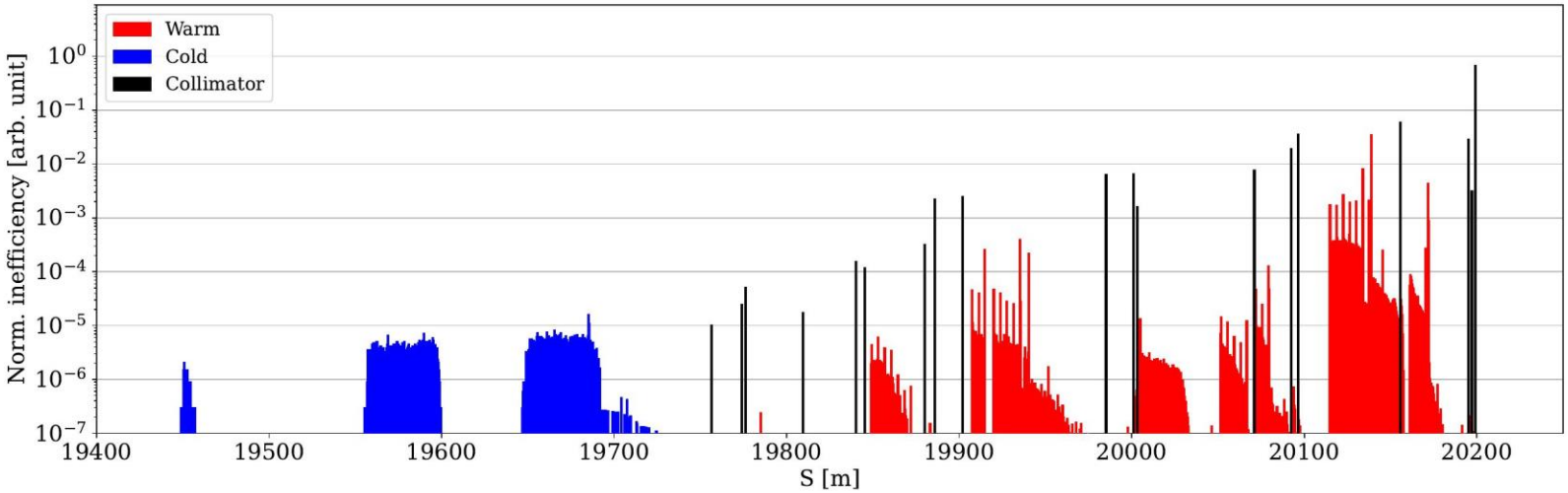
B2H – 100 cm – tight – no TCLD





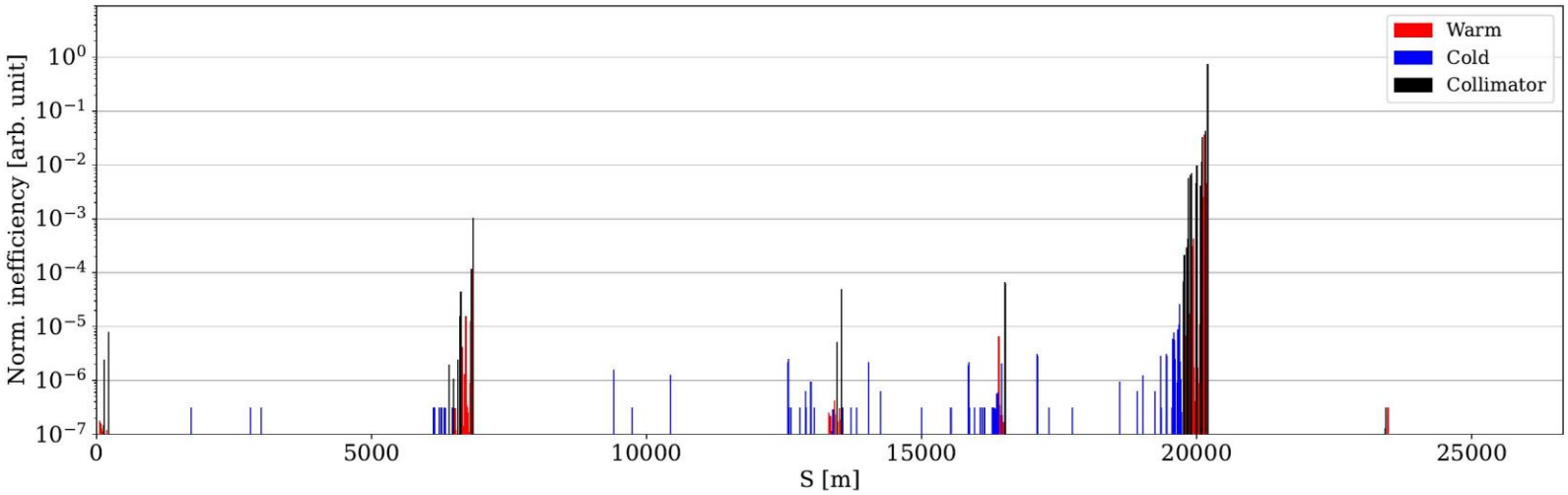
B2V – 100 cm – tight – no TCLD

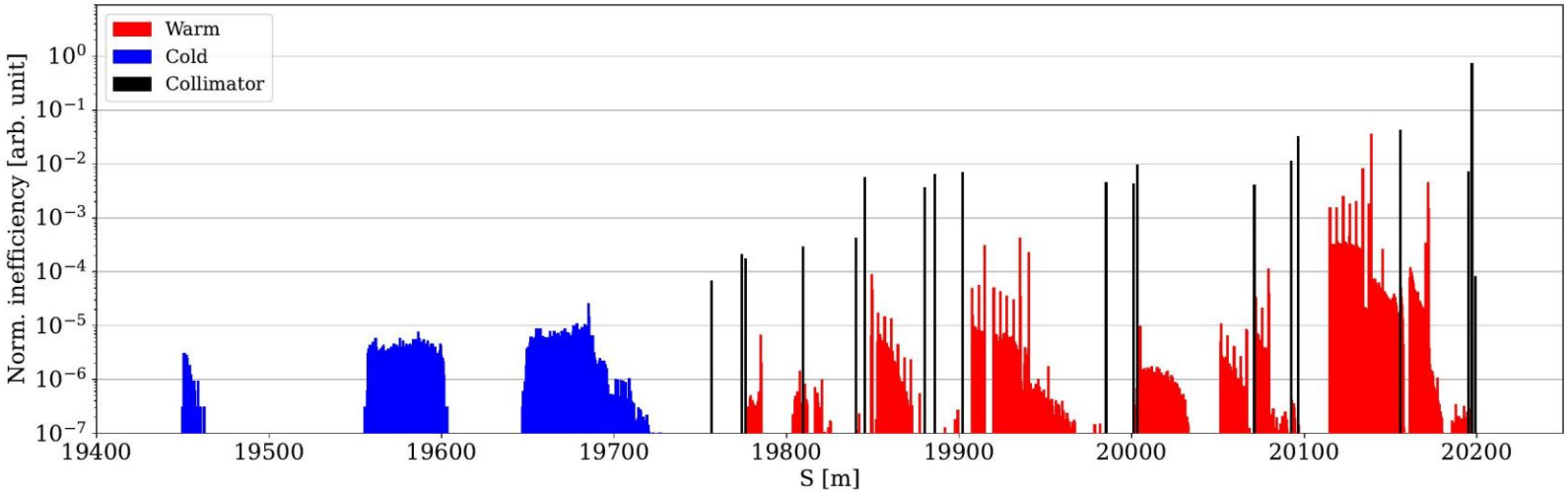




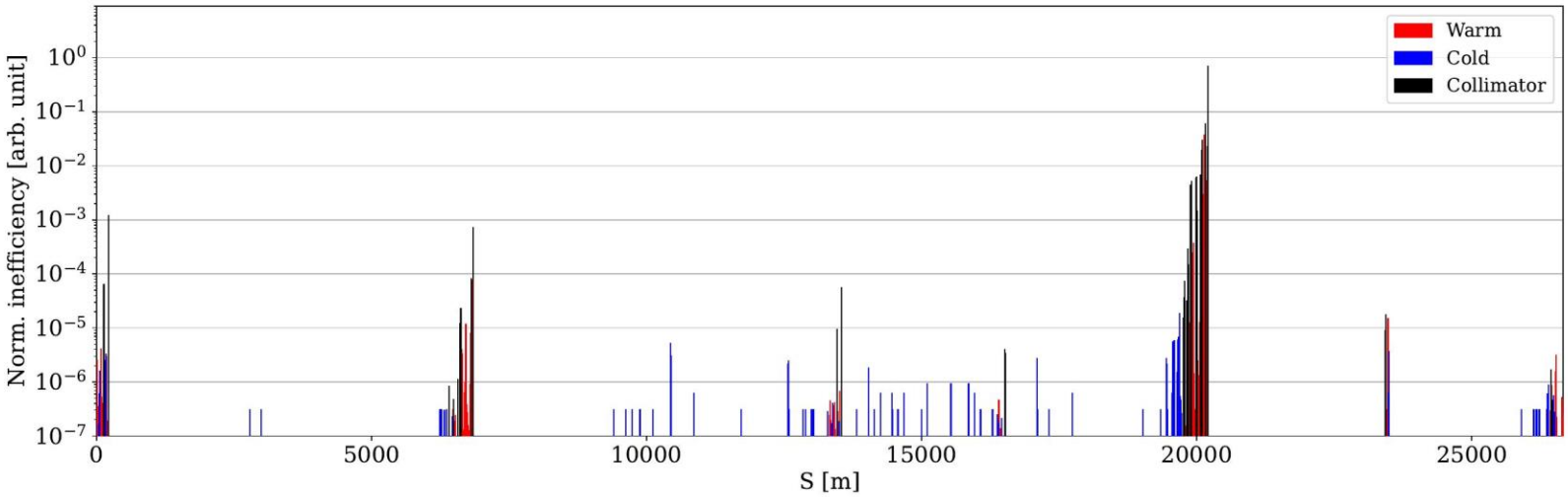
Lossmaps – B2 relaxed settings

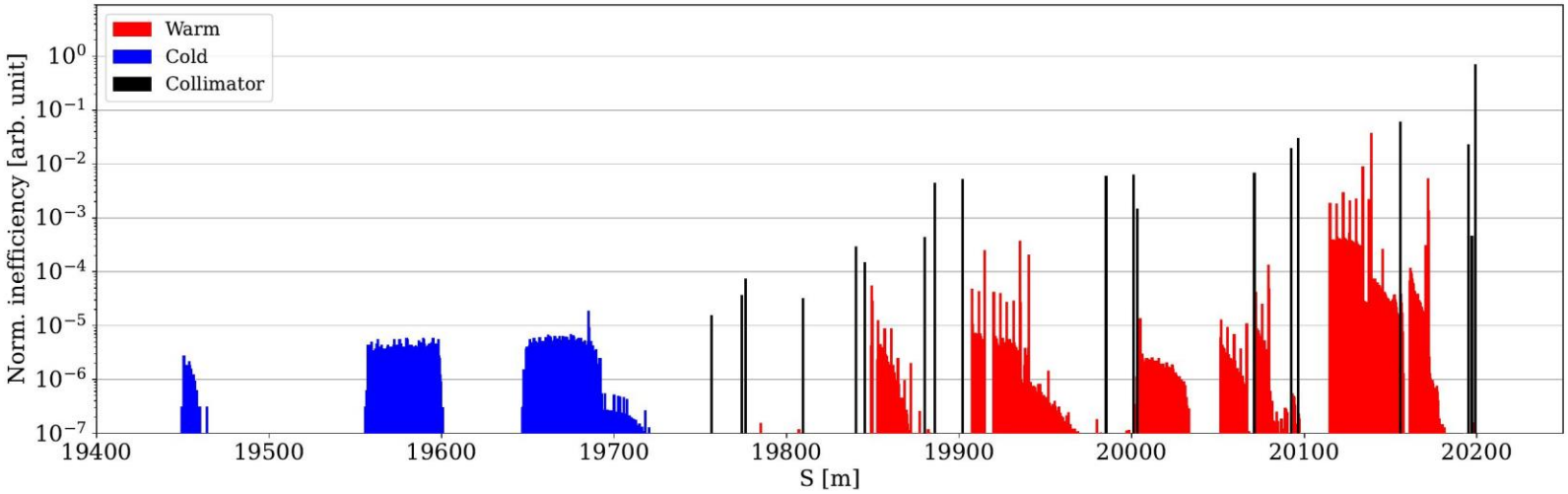
B2H – 15 cm – relaxed – no TCLD



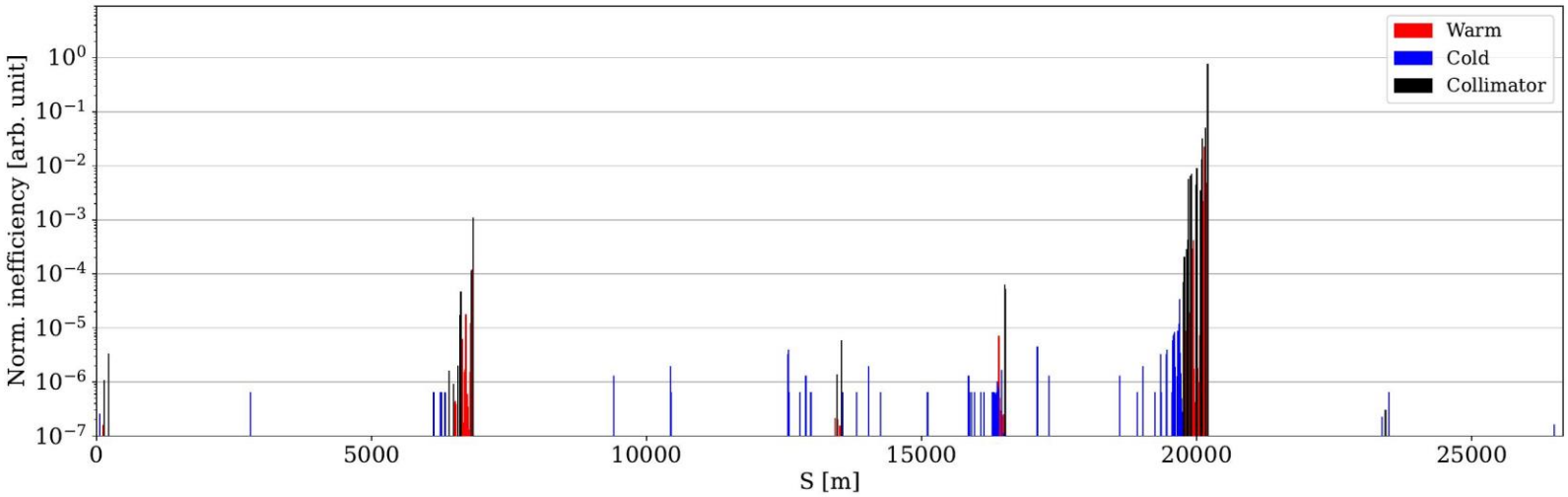


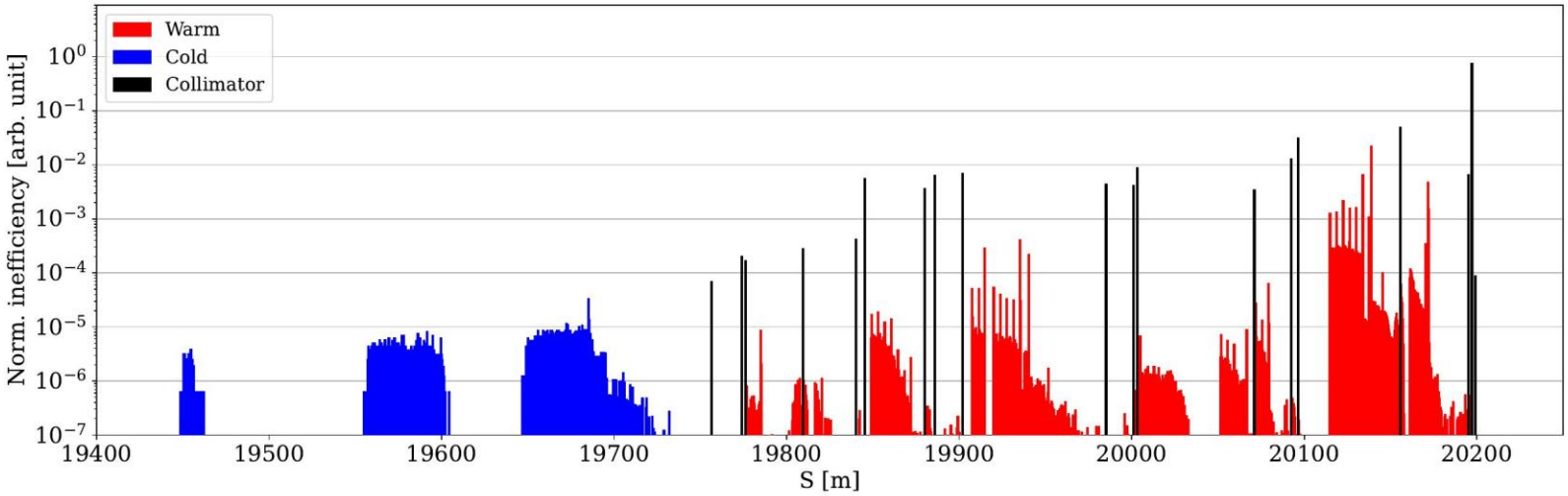
B2V – 15 cm – relaxed – no TCLD



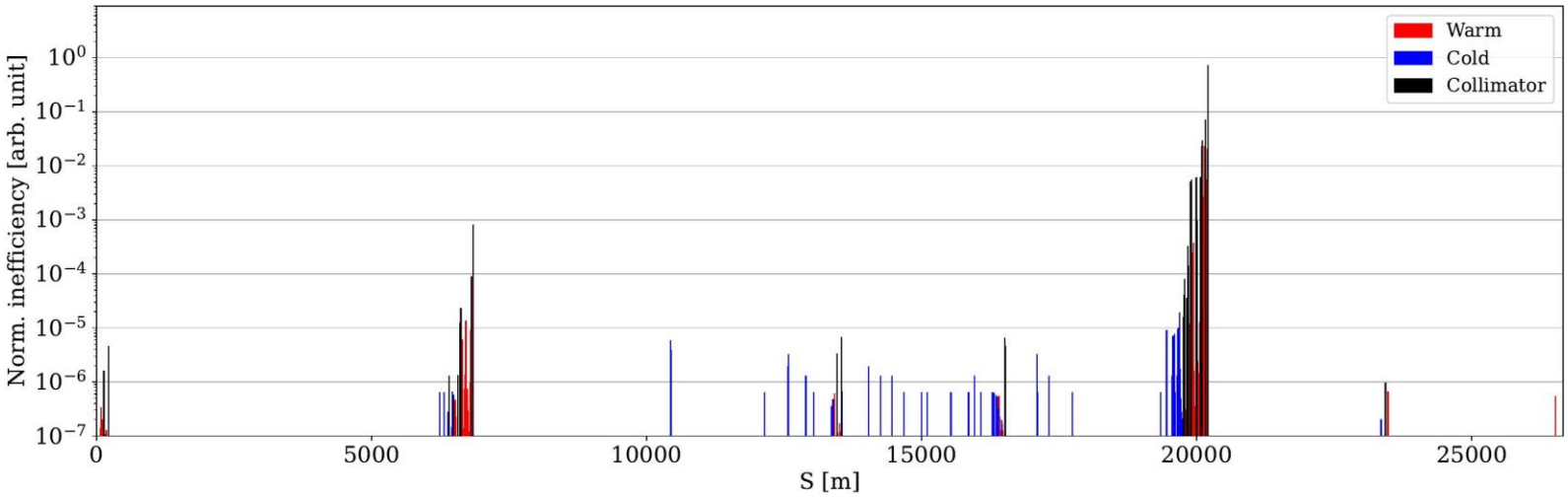


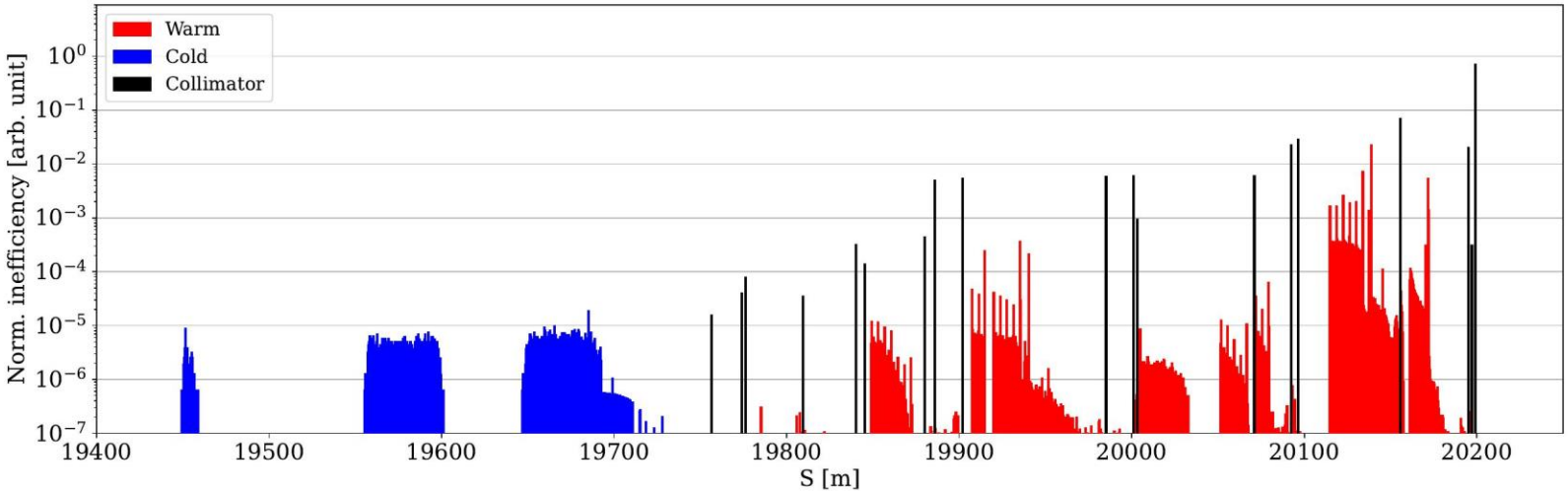
B2H – 20 cm – relaxed – no TCLD



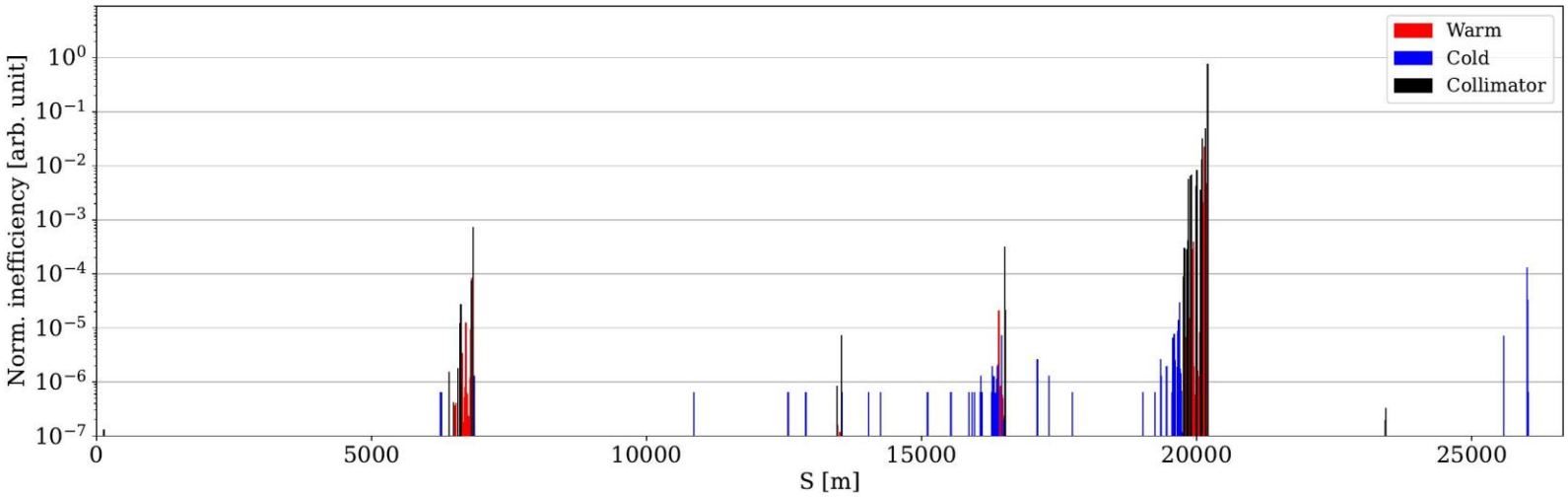


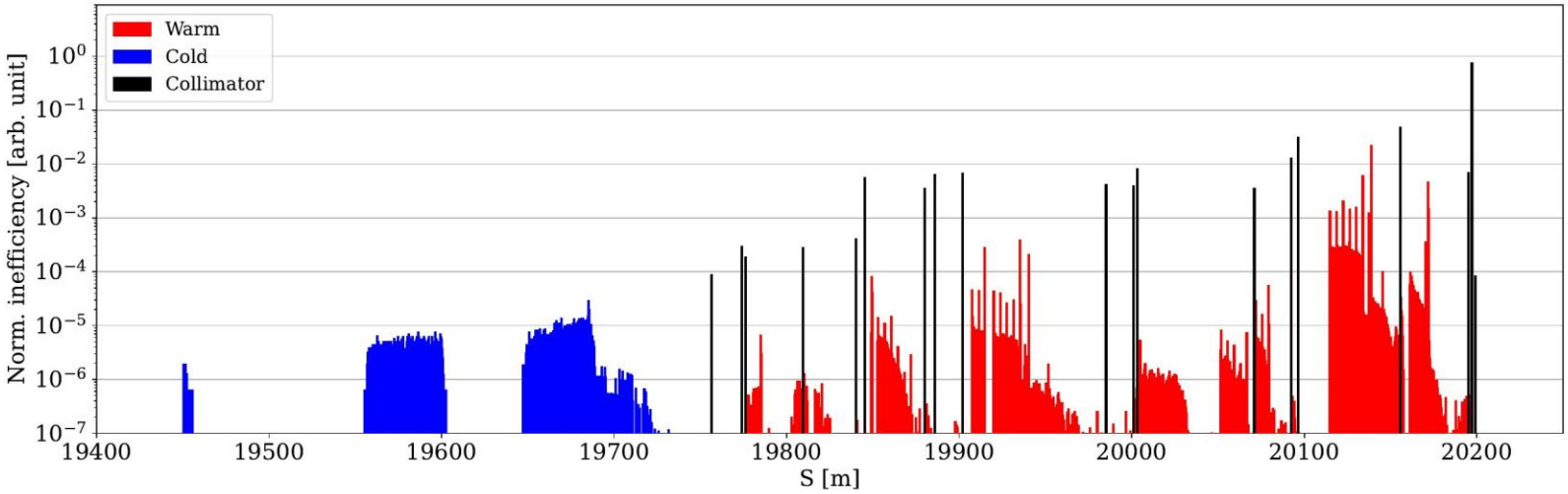
B2V – 20 cm – relaxed – no TCLD



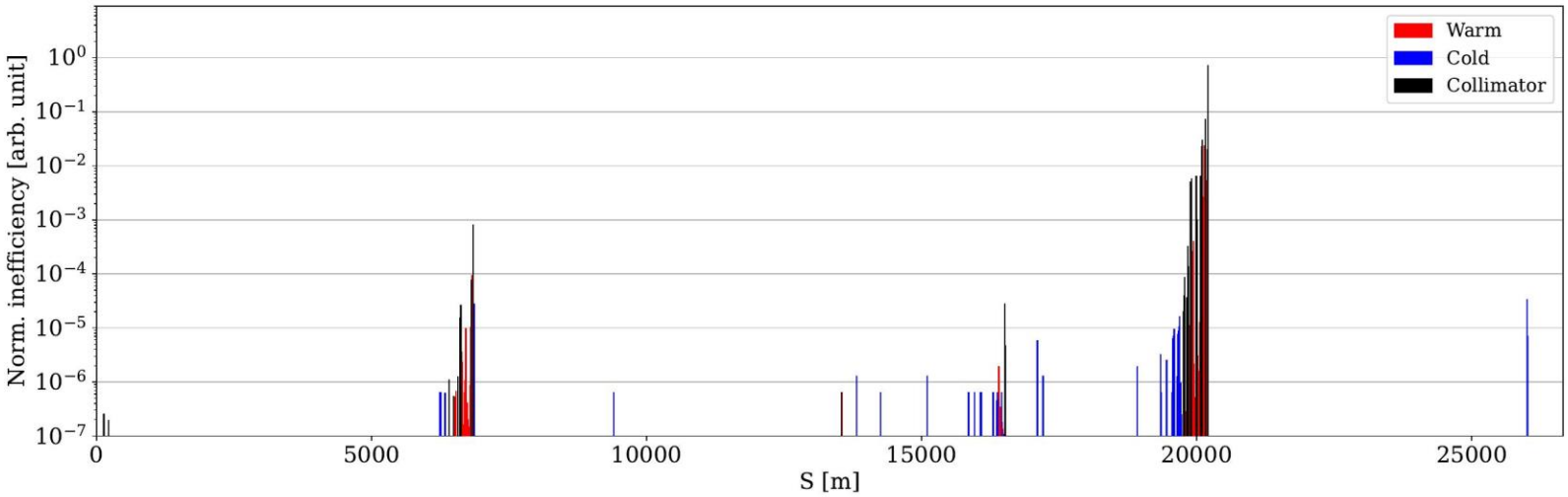


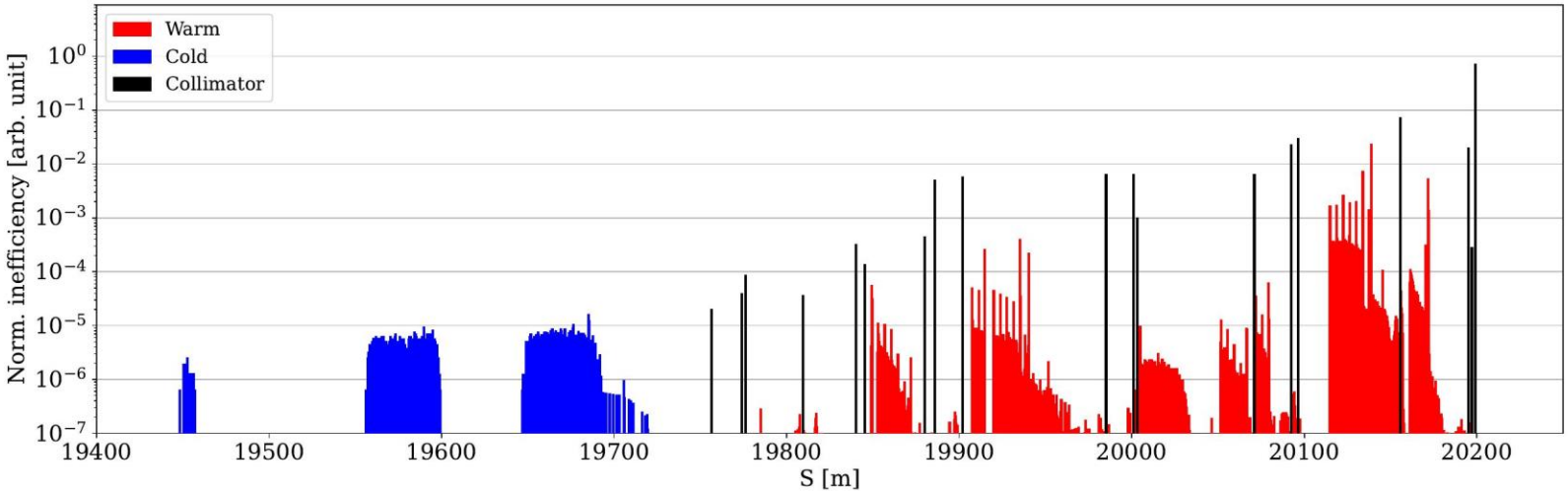
B2H – 64 cm – relaxed – no TCLD



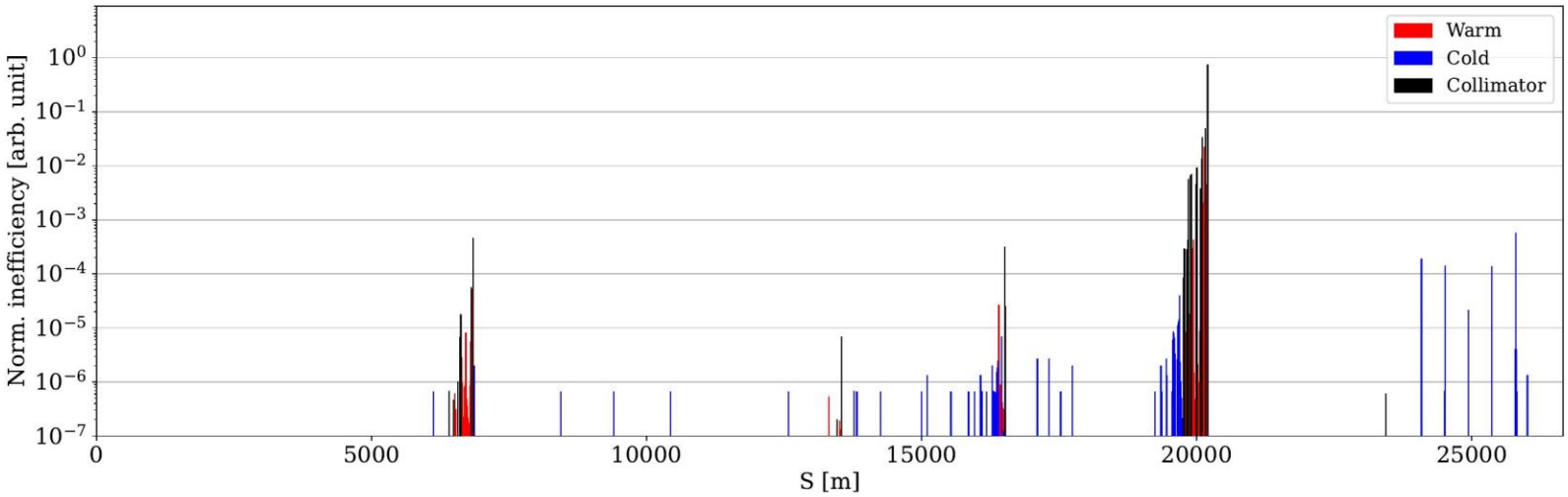


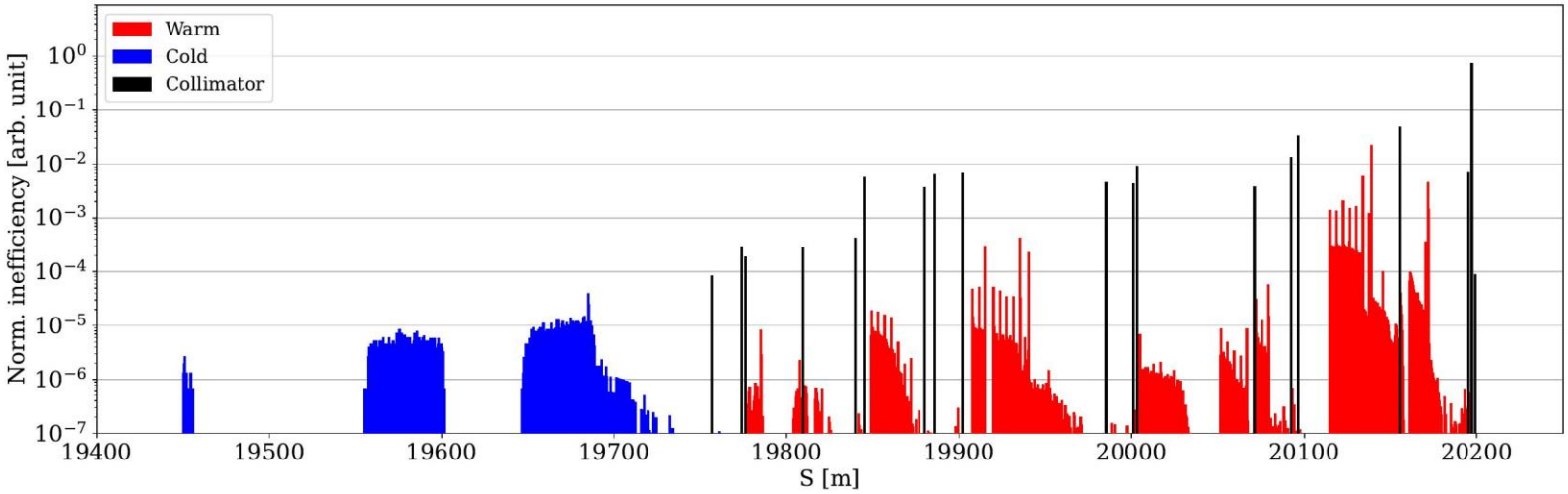
B2V – 64 cm – relaxed – no TCLD



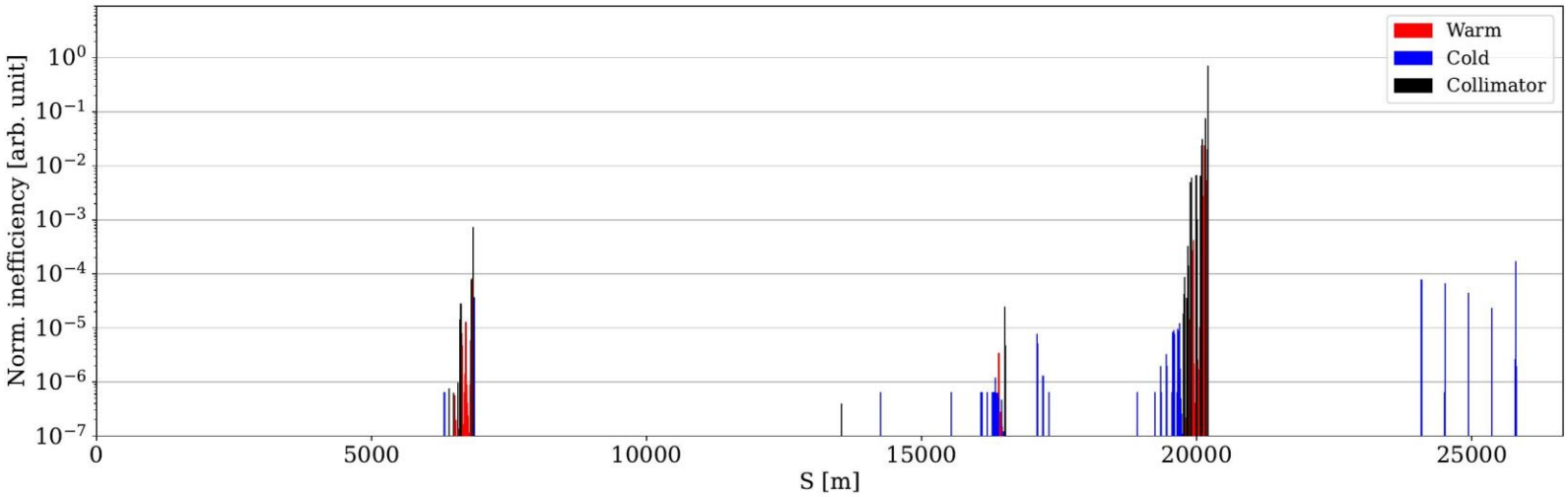


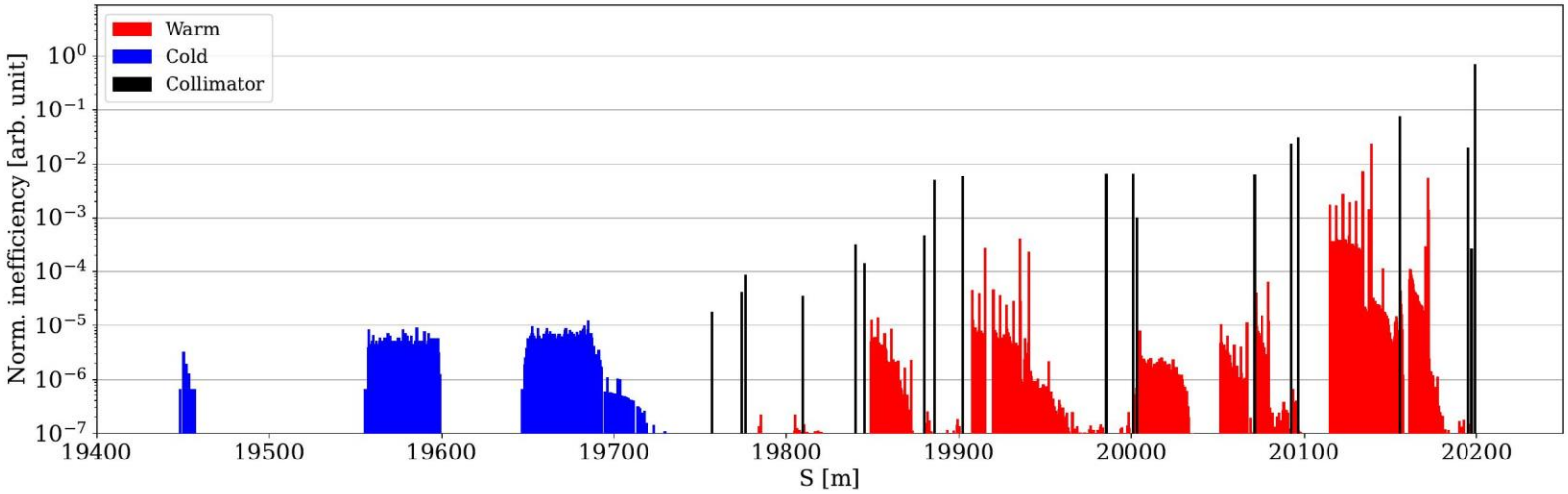
B2H – 100 cm – relaxed – no TCLD





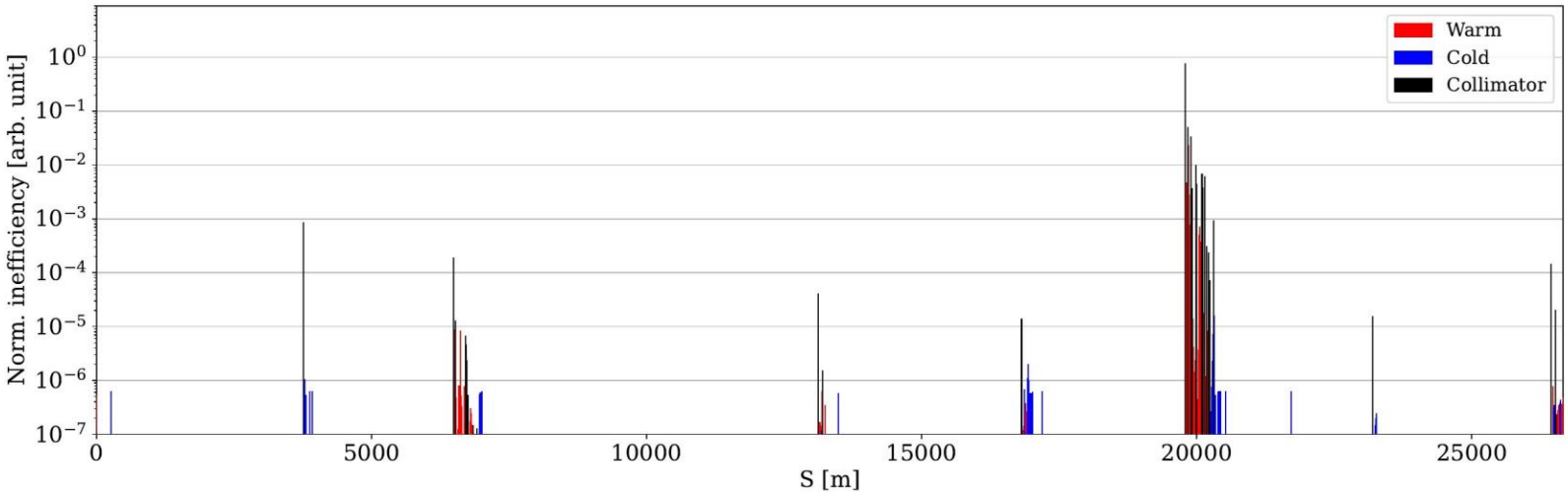
B2V – 100 cm – relaxed – no TCLD

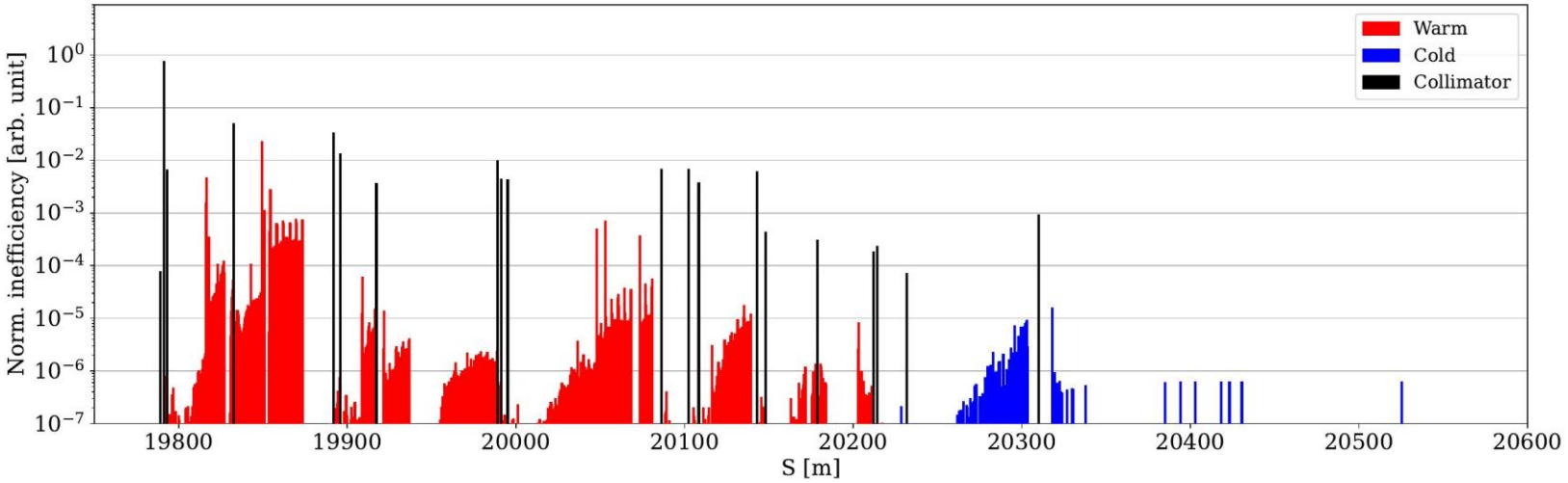




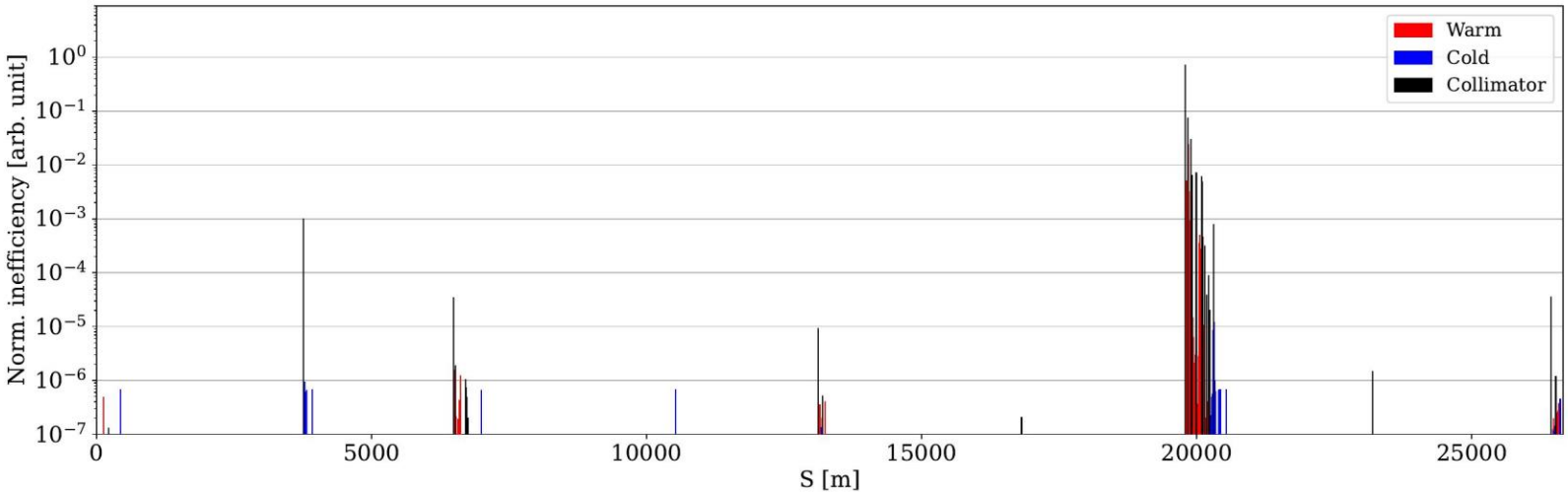
TCLD

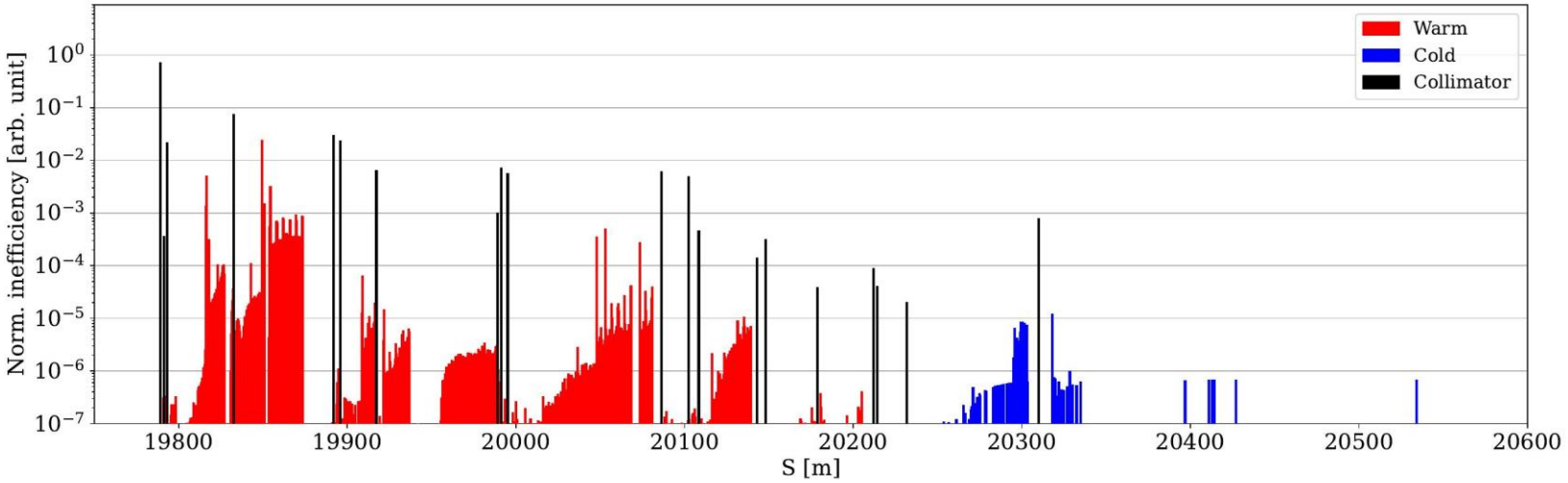
B1H – 20 cm – relaxed –TCLD



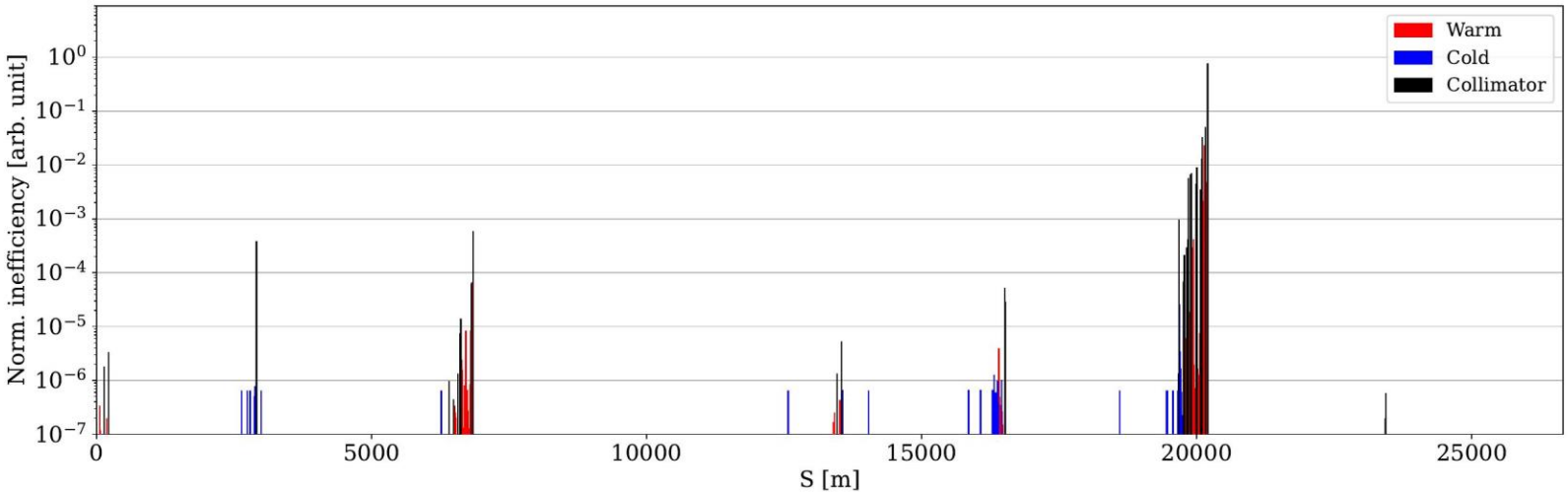


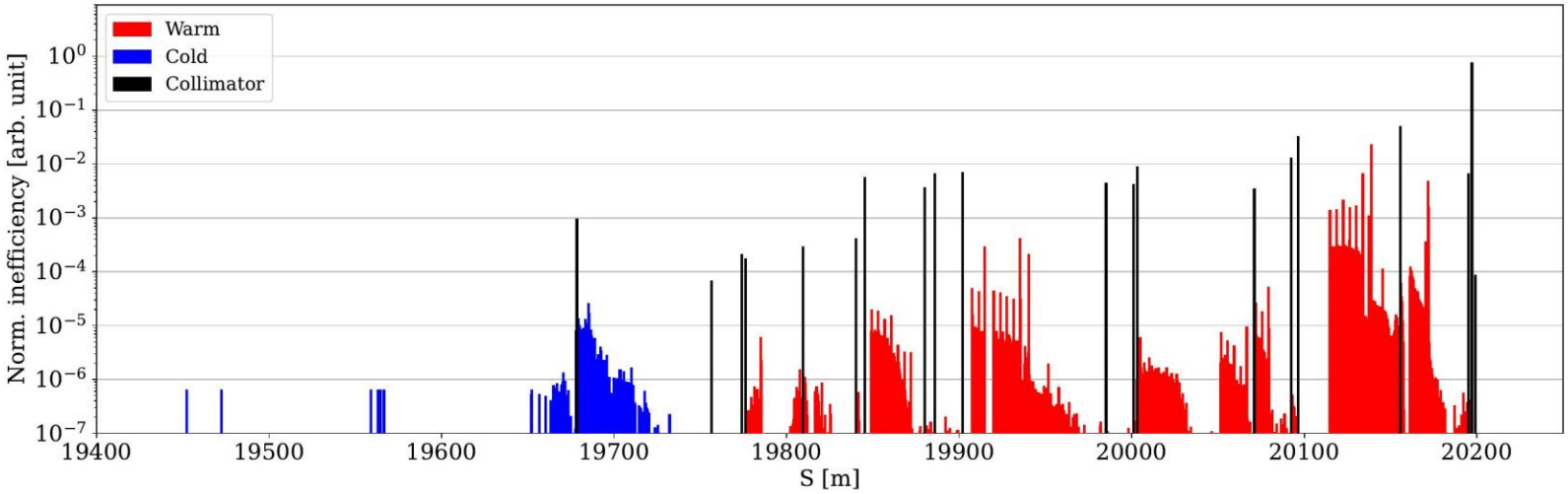
B1V – 20 cm – relaxed –TCLD





B2H – 20 cm – relaxed –TCLD





B2V – 20 cm – relaxed –TCLD