Collimation aspects of the PSI beams in the LHC

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LHC Collimation Project CERN

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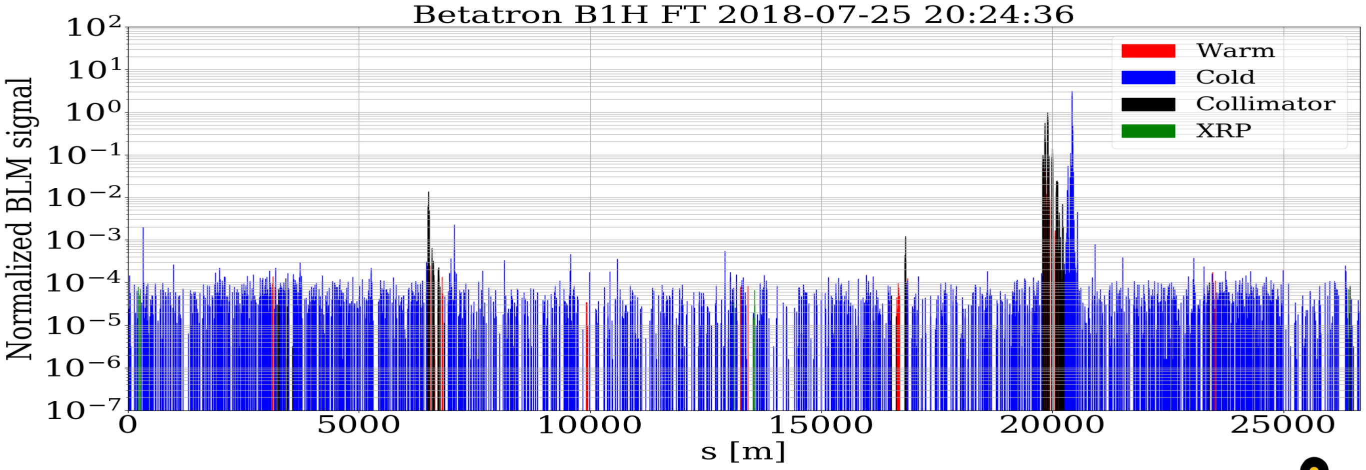
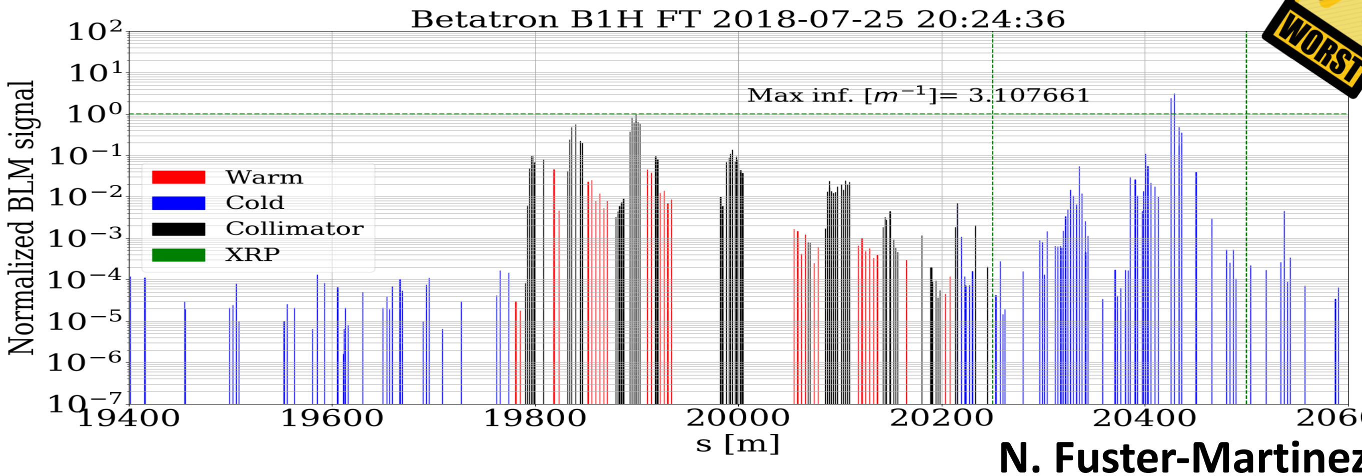
Collimation performance with PSI beams in the LHC

- The first experience of PSI beam collimation was acquired during MD3284 [1].
- Loss map measurements were performed for injection and flat top.
- The highest losses in both cases were recorded in cell 11.
- Severe losses were observed in the cold magnets of the dispersion suppressor of IR7 for flat top.
- With 24 low-intensity bunches a dump was triggered after only 2 minutes at flat top.
- Loss map was taken with only 6 low-intensity bunches.





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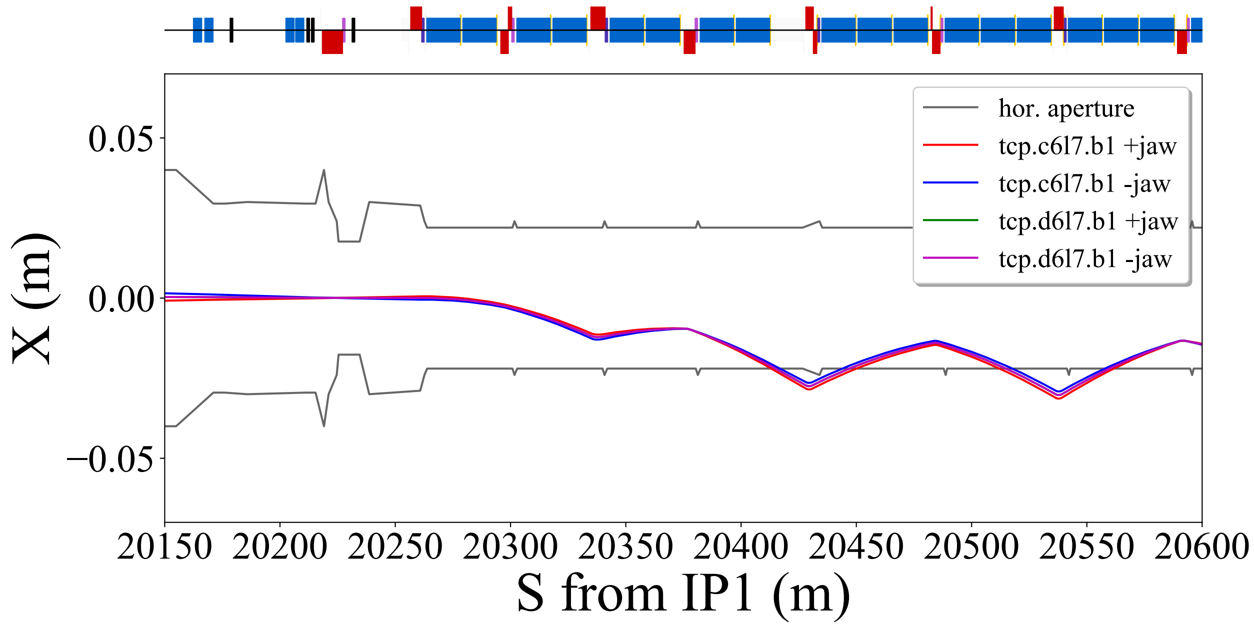
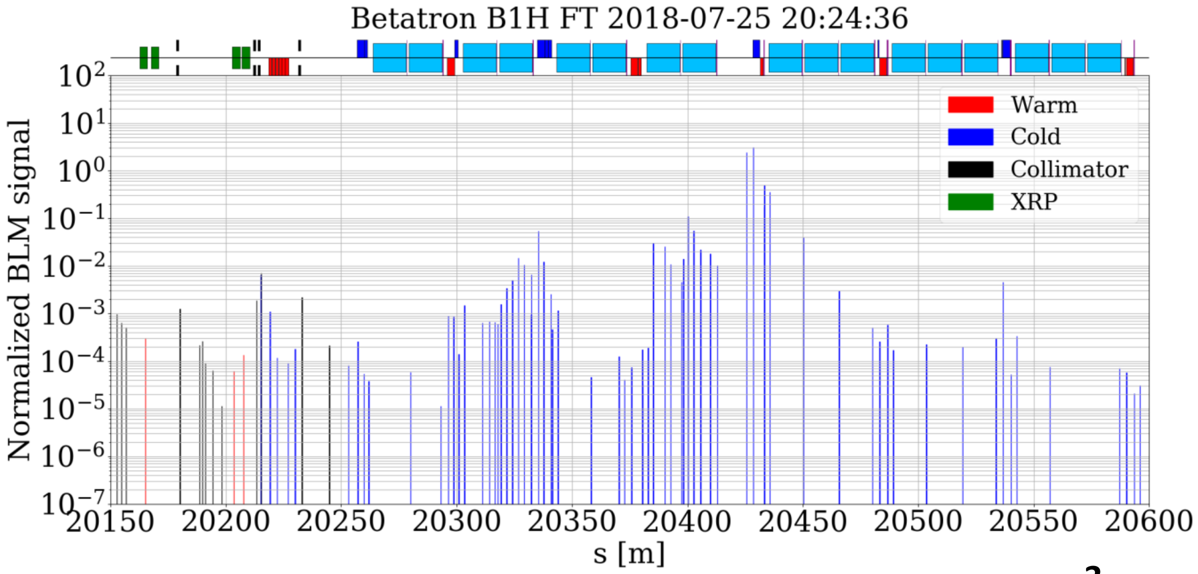
[1] **M. Schaumann**, https://indico.cern.ch/event/781222/

Understanding the losses

- The most likely explanation of the extreme losses in the DS is that the primary collimators can strip the electron from PSI in the halo without fragmenting them.
- The resulting off-rigidity fully-stripped ions are lost on the cold aperture in the DS where the dispersion ramps up.
- Simulations of equivalent off-momentum trajectories in MADX backs this theory and predicts the loss location with good accuracy.





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Mitigation strategies

- With the current collimation configuration the losses greatly limit the possible intensity reach. Mitigation strategies considered include:

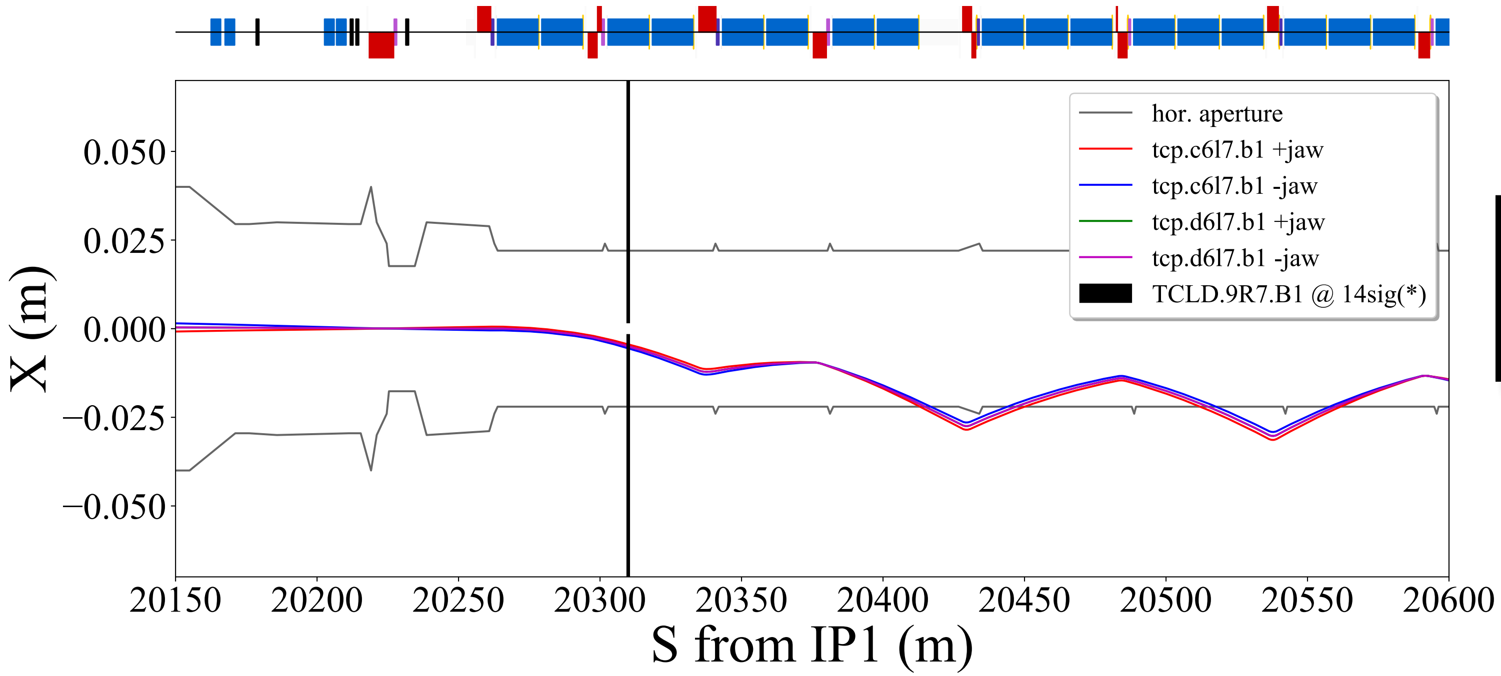
Dispersion suppressor collimator (TCLD)

Crystal collimation

Orbit bump

Mitigation strategies - TCLD

- The plan is to install a dispersion suppressor collimator (TCLD)during LS2.
- The location of the TCLD was changed from cell 8 to cell 9 in December 2018.
- In cell 8 the collimator wasn't expected to intercept the losses, but in cell 9 it there is a good outlook that it will.
- At present, without energy deposition studies, it is not possible to quantify the intensity limit with the TCLD in as the load on the collimator will likely be very high.



Preliminary plot with the TCLD at the nominal opening of 14 sigma

Mitigation strategies - other

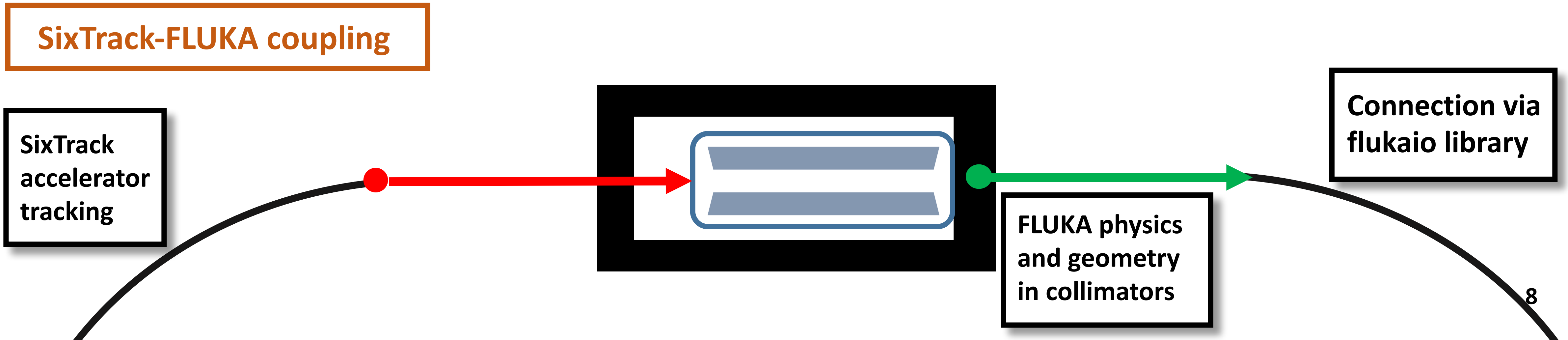
- **Crystal collimation**
  - Another potential strategy is to use crystal collimators.
  - It is theorised that both partially stripped and fully stripped ions can be channeled onto an absorber before they leave the warm collimation insertion.
  - In addition to this, the channeling is expected to suppress the interaction cross-sections.
  - MD4166 was approved to test this concept, but never took place due to technical problems.
- **Orbit bump**
  - Orbit bumps are used to move cold losses from BFPP in the DS of experimental insertions to a more favorable location like the connection cryostat.
  - Such a bump can be considered for the DS of IR7.
  - May not be needed if the TCLD is found to be effective.

Simulation methods

- Due to the bound electrons and additional physics interactions involved, it is not currently possible to perform direct collimation cleaning efficiency studies for PSI beams.
- As a start, attempt to recreate the measured loss maps as accurately as possible using available tools and some assumptions, e.g. all beams ions stripped at the collimator.
- In addition, work towards integrating support for PSI tracking and physics interactions to existing radiation transport frameworks.

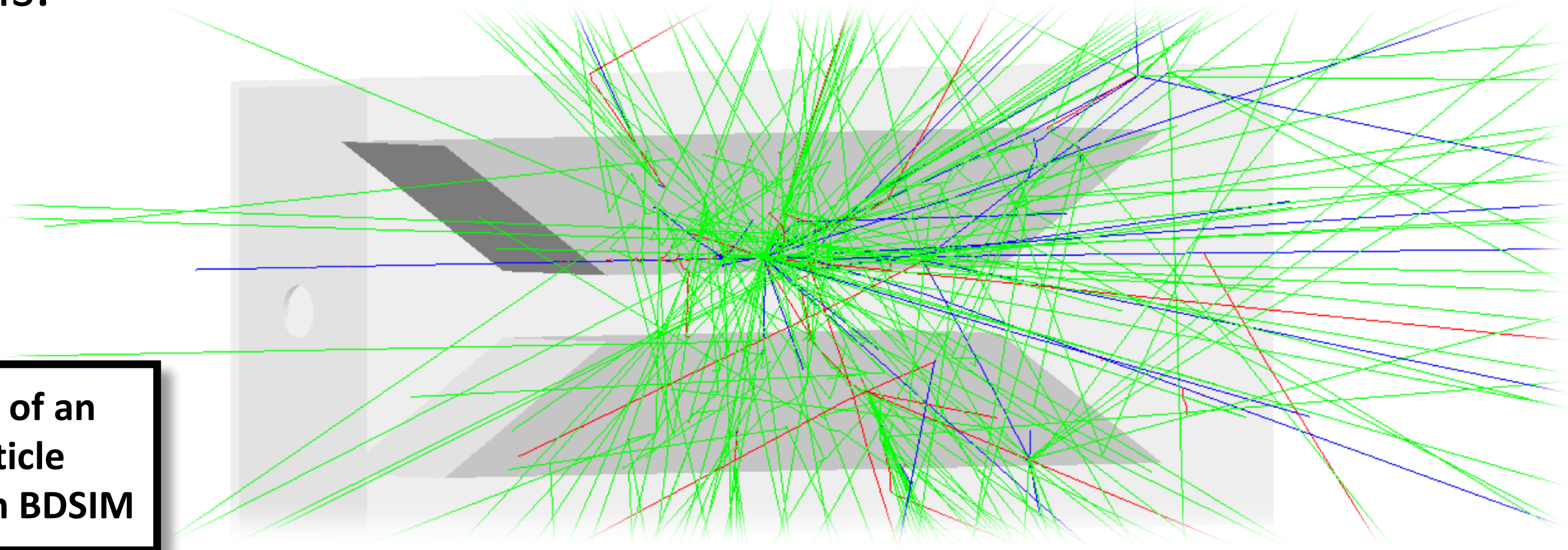
SixTrack – FLUKA active coupling

- The SixTrack-FLUKA coupling combines tracking in SixTrack and Monte Carlo simulation of physics interaction inside the collimators in FLUKA.
- One of the trusted standard frameworks for collimation studies.
- Supports arbitrary ions species.
- Available immediately.
- Does not currently support partially stripped ions, but there are some ideas of extending it.
- The plan is to perform studies using off-rigidity fully-stripped ions starting at the primary collimator, similar to the MADX studies.



Geant4 / BDSIM

- Geant4 natively supports the definition of ions with non-zero electron occupancy, but no relevant charge-changing physics processes are currently available.
- A stripping physics process and the other necessary physics configurations are being implemented in BDSIM and can later be integrated into a new Geant4 release.
- Can tie in with other processes like crystal channeling for ions and PSI laser excitation and de-excitation being developed for BDISM/Geant4.
- It is possible to couple Geant4/BDSIM to SixTrack and utilise those processes on a per-element basis.



Visualisation of an example particle interaction in BDSIM

Summary

- In the first test with PSI in the LHC the collimation cleaning performance was observed to be prohibitively low for operation with high-intensity beams.
- Analysis of the measured loss maps and initial simulations have helped identify the reason for the inadequate cleaning – the stripping action of the primary collimators.
- Several mitigation strategies are being investigated – TCLD collimator, crystal collimation and an orbit bump.
- The first comprehensive collimation studies are ongoing and new simulation methods are actively being developed.

Appendix - Injection B1H

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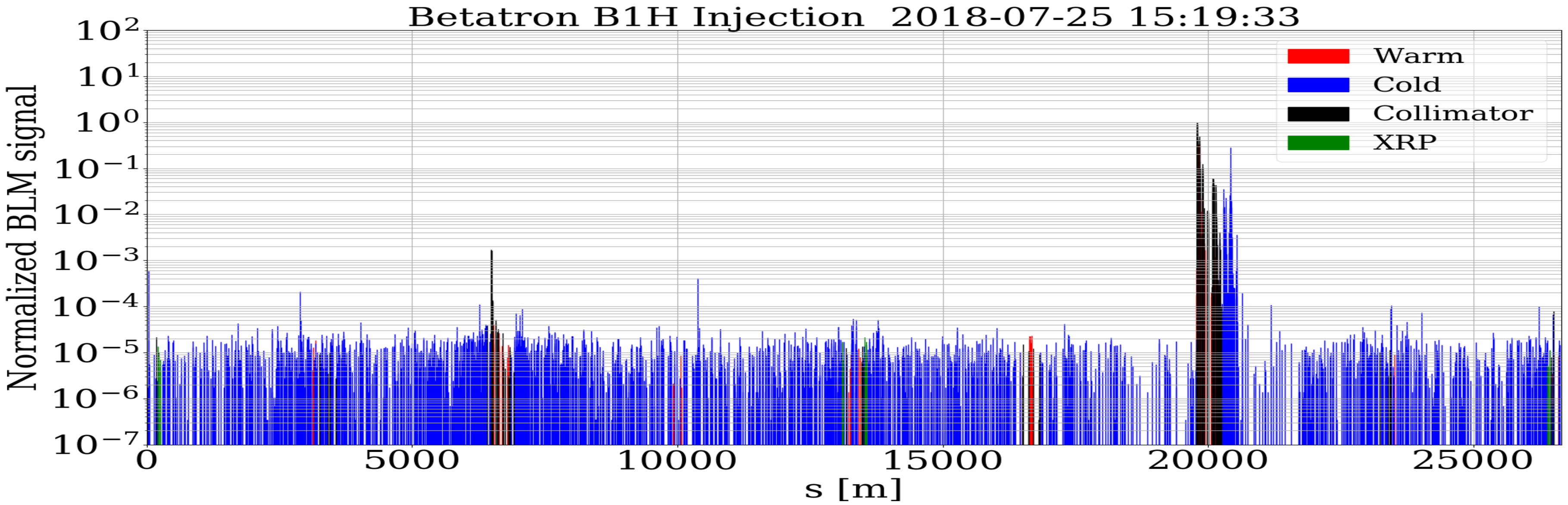

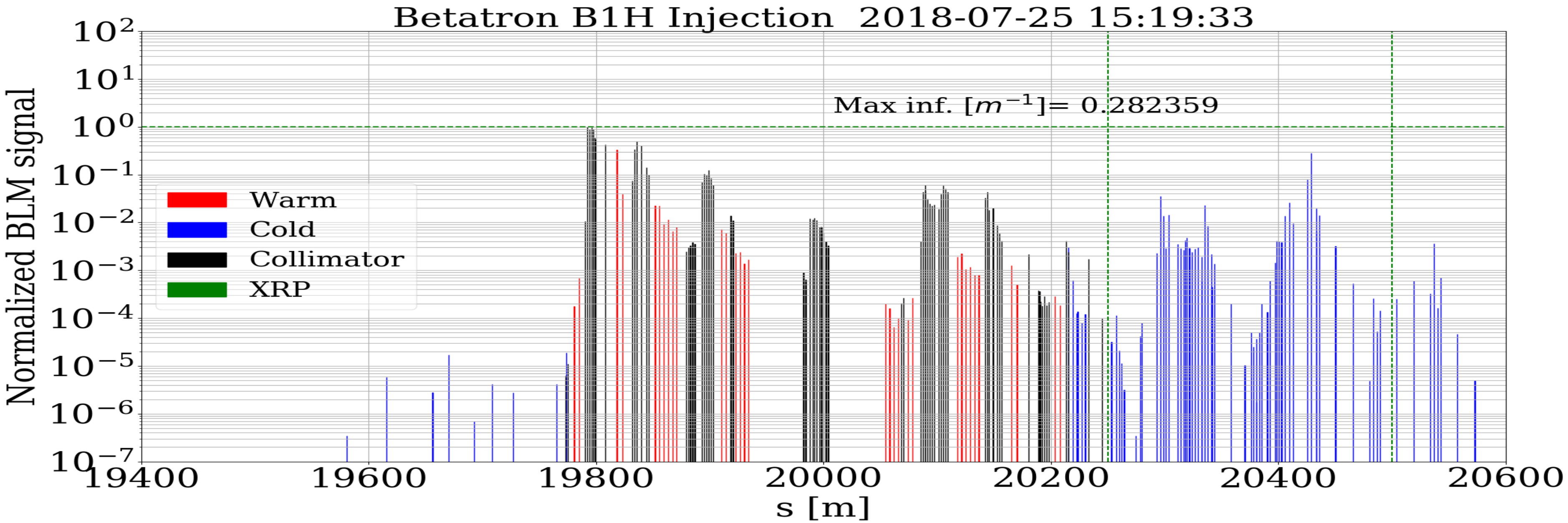

Appendix - Injection B1V

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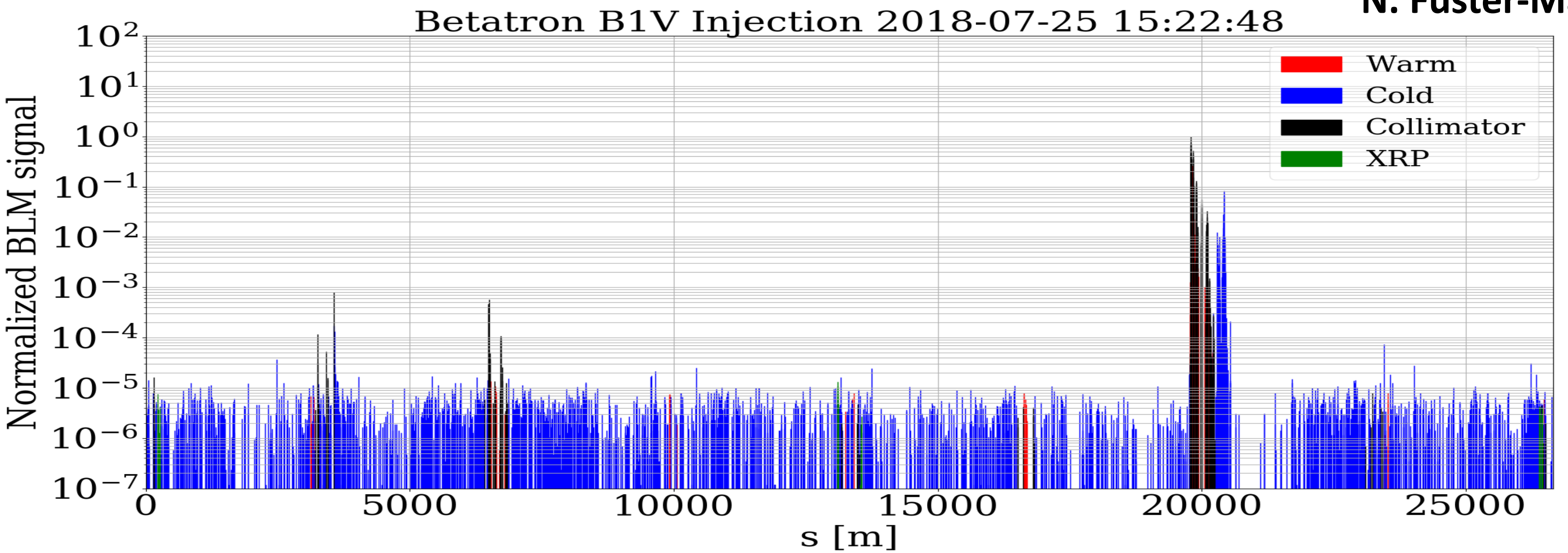

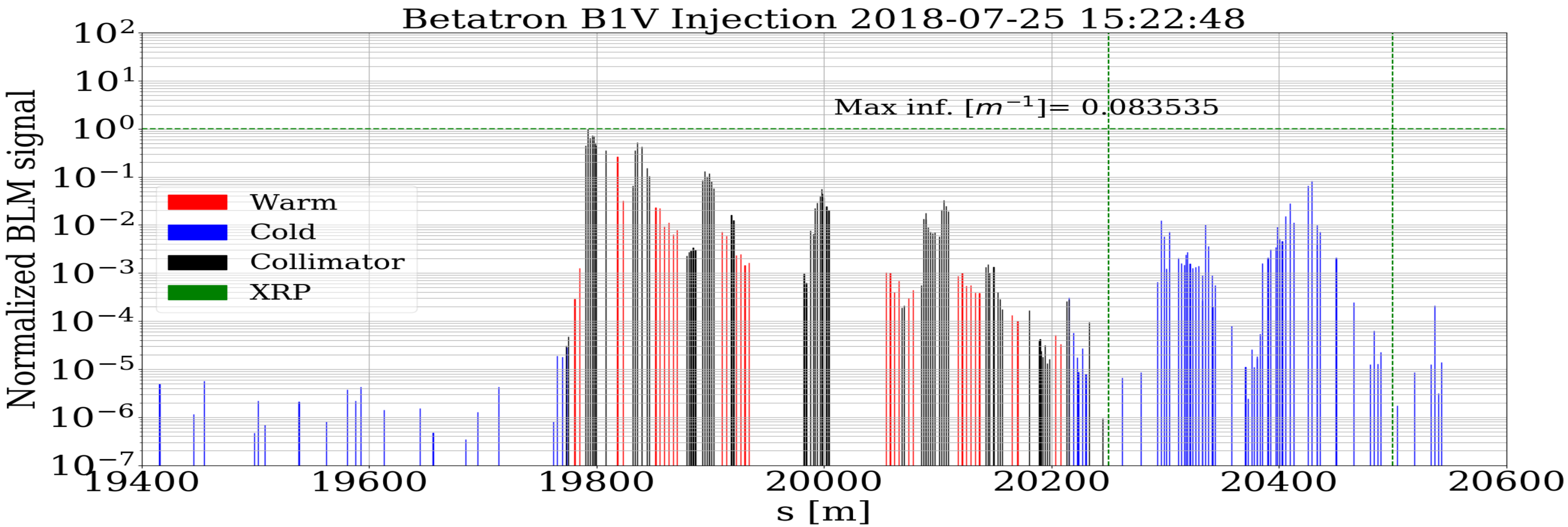

Appendix - Flat top B1V

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