Collimation cleaning with ATS optics for HL-LHC

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Introduction

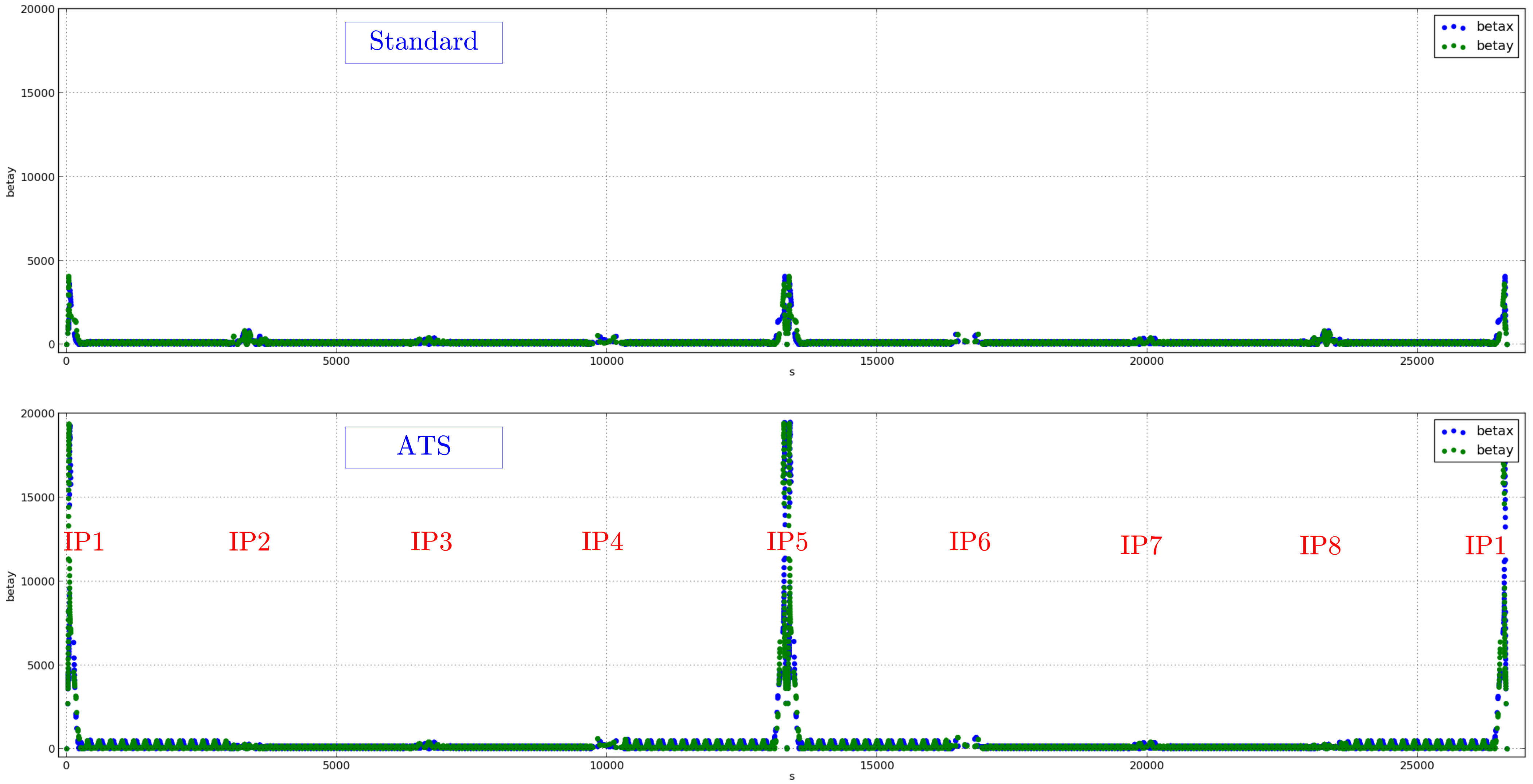
- In the framework of the HiLumi studies for HL-LHC, the first cleaning simulations were set up for the "Achromatic Telescopic Squeeze" optics, including a first baseline for collimation settings
- Compare with standard optics: possible new limitations
- Address these new limitations
- Is there a solution that would solve both cases: standard optics + ATS new limitations
  - Make sure that only one intervention is needed (during LS2) avoiding another one in LS3
- Physics debris: preliminary results

Outline

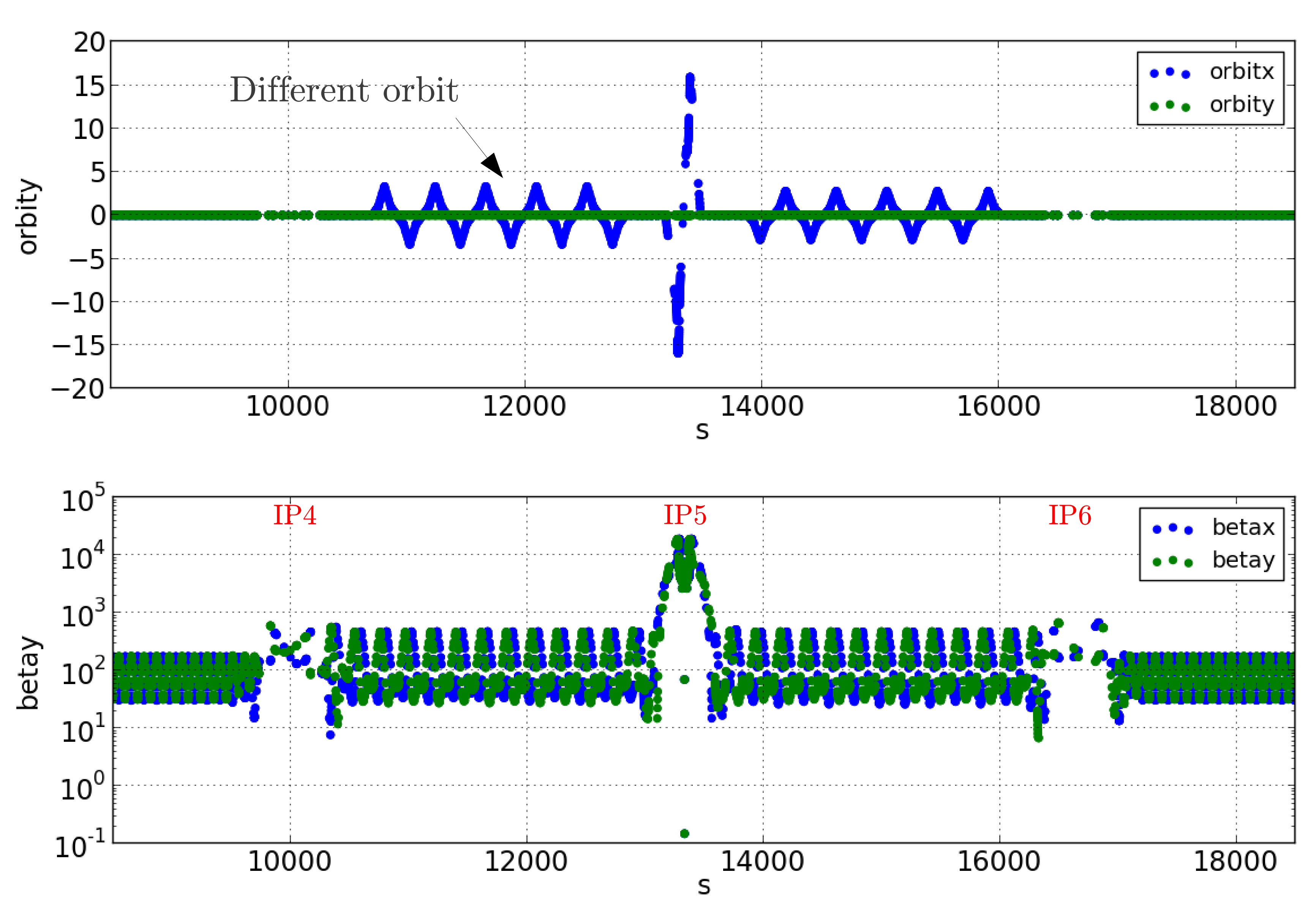
- Introduction
- Presentation of ATS optics for HL–LHC
- Setup of collimation cleaning simulations
- Betatron losses without DS collimation
- Betatron losses with DS collimation
- Comparison with standard optics
- Preliminary thoughts about physics debris cleaning
- Ongoing HiLumi-related activities
- Conclusions

The ATS optics: Presentation

- Main characteristics: beta beating in the arcs adjacent to the low β^* IPs



The ATS optics: Presentation



The ATS optics: halo cleaning simulations

- Layout and optics version SLHCV3.1b (R. de Maria)
- IP1 & 5: $\beta^* = 0.15$ m; IP2 & 8: $\beta^* = 10$ m
- Crossing angles:
  - IP1 and 5: 295 μrad; IP2: 240 μrad; IP8: 305 μrad
- No separation (collision)
- New baseline recently defined for 10 cm with partial squeeze in IP8. Not yet taken into account: similar feature expected (triplet aperture follows optics)
- Perfect machine

The ATS optics: halo cleaning simulations

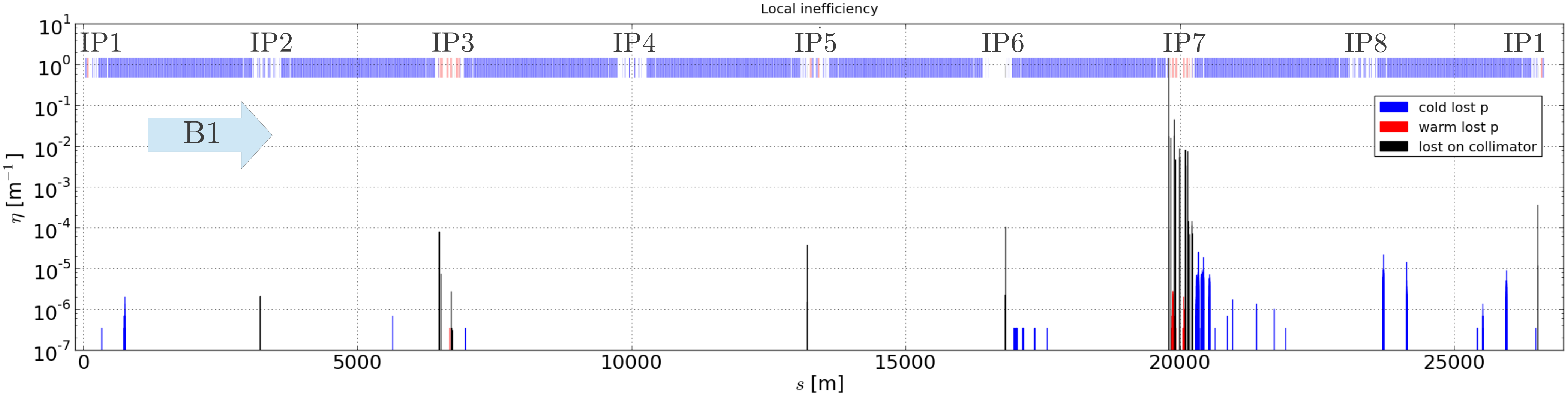
- Tracking 6.4 million particles around the ring for 200 turns with SixTrack; no initial dp/p
- Halo at 6 σ (setting of the primary collimator) in the considered plan (H or V)
- Setting of the collimators:

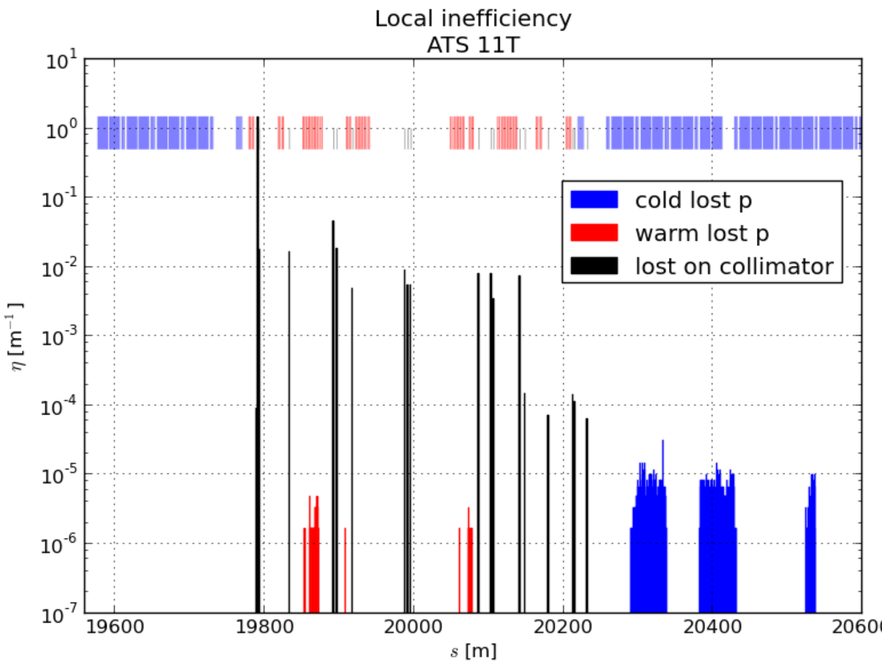
Coll. setting	σ
TCP IR7	6.
TCSG IR7	7.
TCLA IR7	10.
TCP IR3	12.
TCSG IR3	15.6
TCLA IR3	17.6

Coll. setting	σ
TCLP	open
TCLI	open
TCSTCDQ IR6	7.5
TCDQ IR6	8.
TDI	open
TCT IR1/5	8.3
TCT IR2/8	30.

Betatron losses simulations without DS collimation

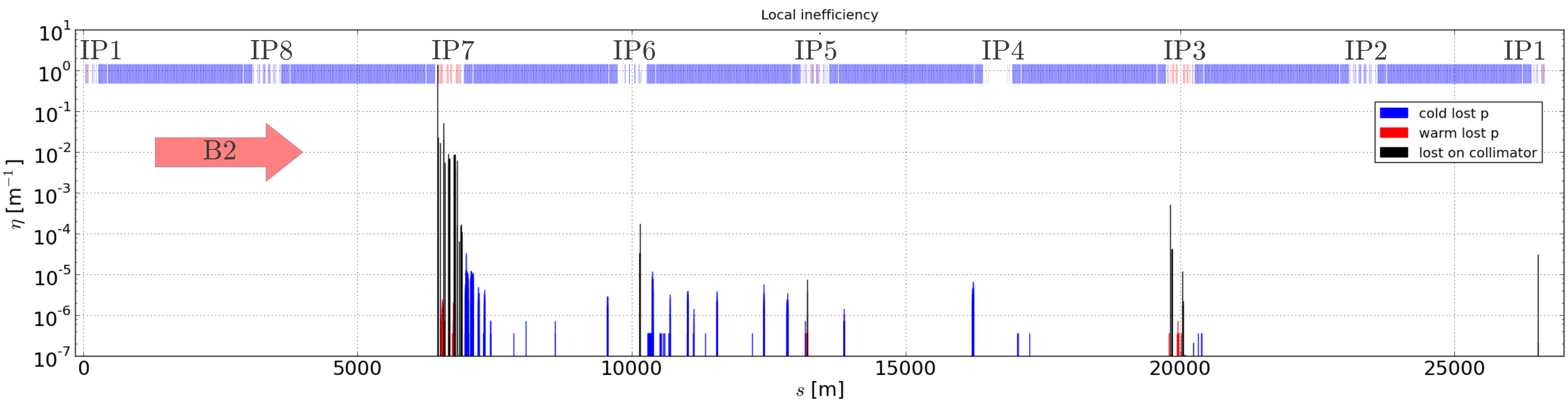
Preliminary simulation results: Betatron losses with current coll.





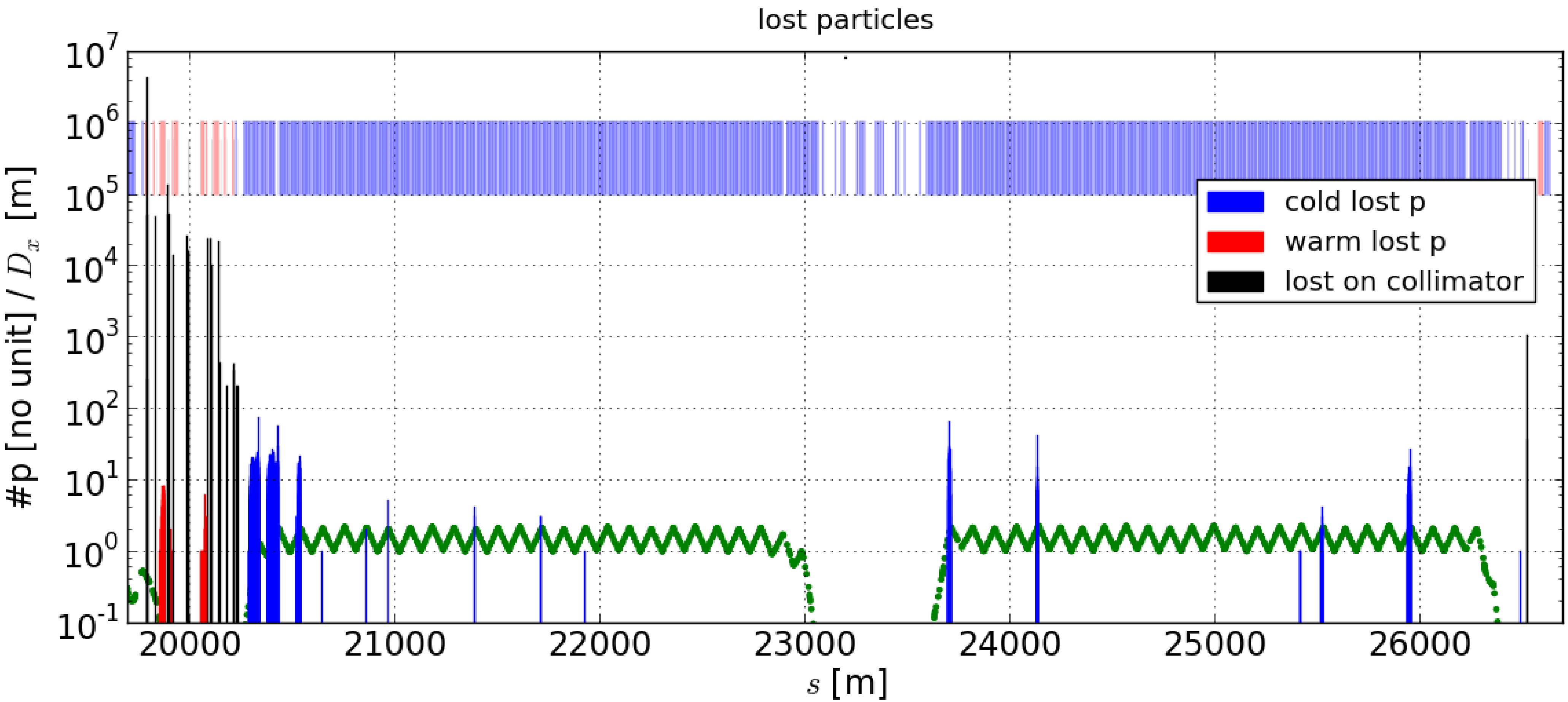
- Horizontal halo, 6 σ, 3e7 protons, perfect machine
- Same limiting losses as standard: leakage downstream of IR7
- Additional limiting locations in arc 8–1
- Potentially serious issue as they have the same level as DS losses!
- Depends on the quench limit

Halo cleaning simulations: B2



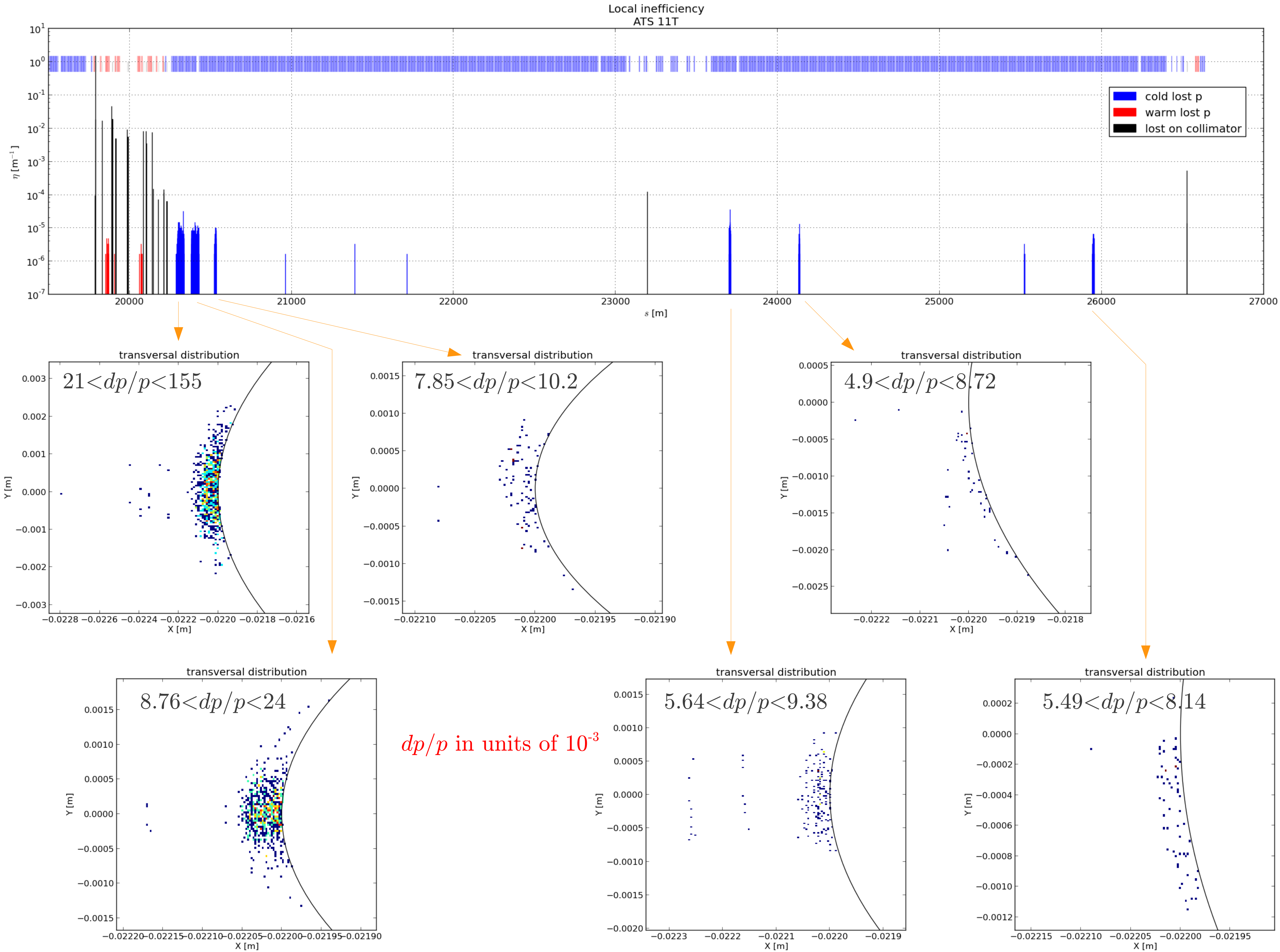
- Reversed longitudinal positions
- Peaks in the arcs at the level of the DS peaks
- Same observations as for B1 (next slides)
- Optics matched less precisely

Loss peaks in arcs 7-8 and 8-1



Peaks appear at maximums of the dispersion and min. $dp/p>0$

$\Rightarrow$ Study the possibility to cure them with the DS collimation in IR7.

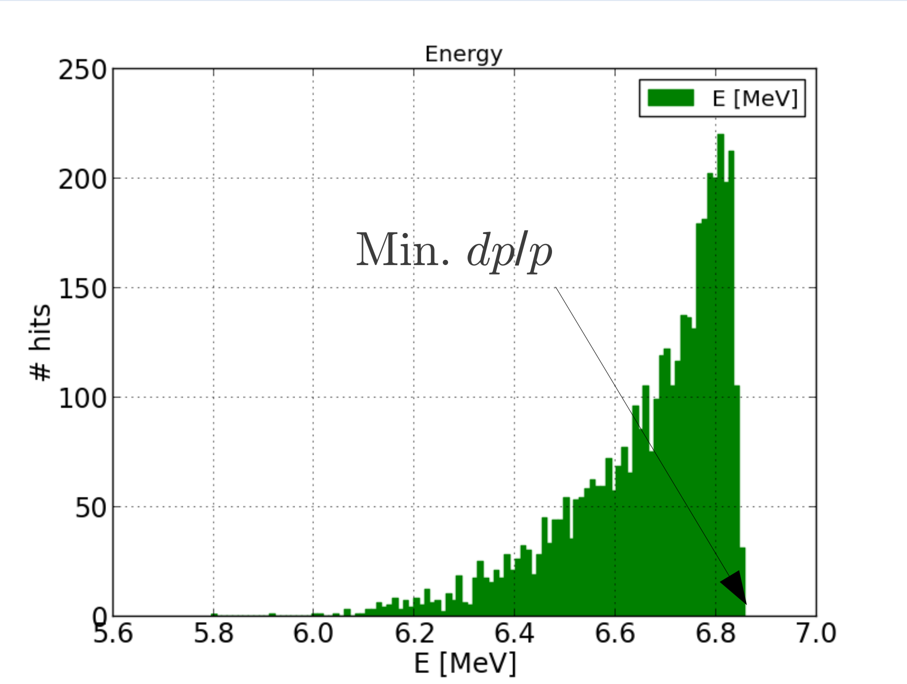


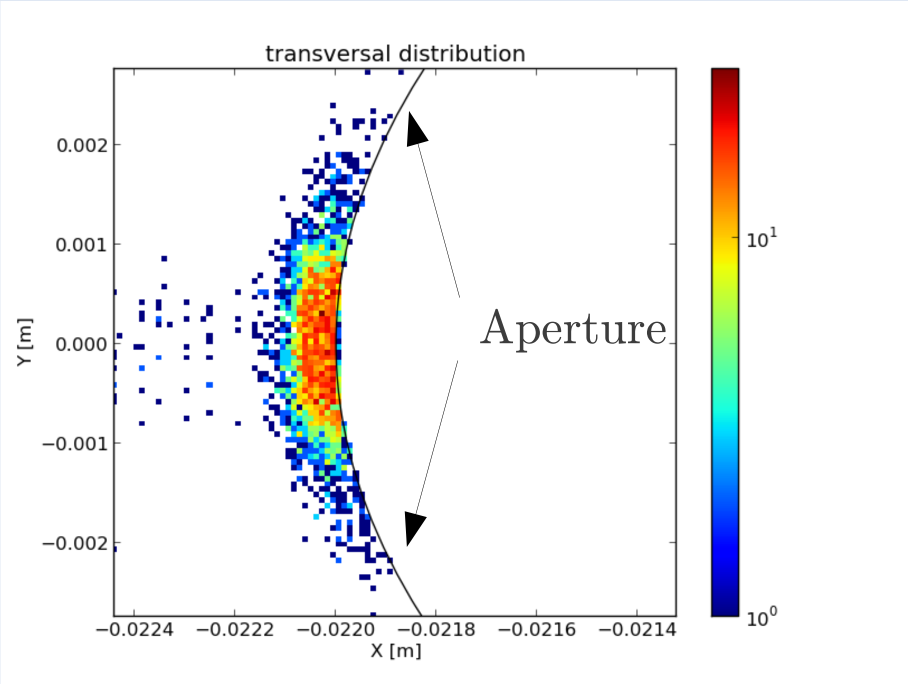
Local inefficiency
ATS 11T
η [m⁻¹]
s [m]
cold lost p
warm lost p
lost on collimator
transversal distribution
21<dp/p<155
7.85<dp/p<10.2
4.9<dp/p<8.72
8.76<dp/p<24
5.64<dp/p<9.38
5.49<dp/p<8.14
dp/p in units of 10⁻³
X [m]
Y [m]

Characterisation of loss peaks

- Considering all particles lost dowsntream IR7
- All lost particles have a dp/p above a given value
- All lost particles are lost at y = 0, x = -0.022 (apert.)

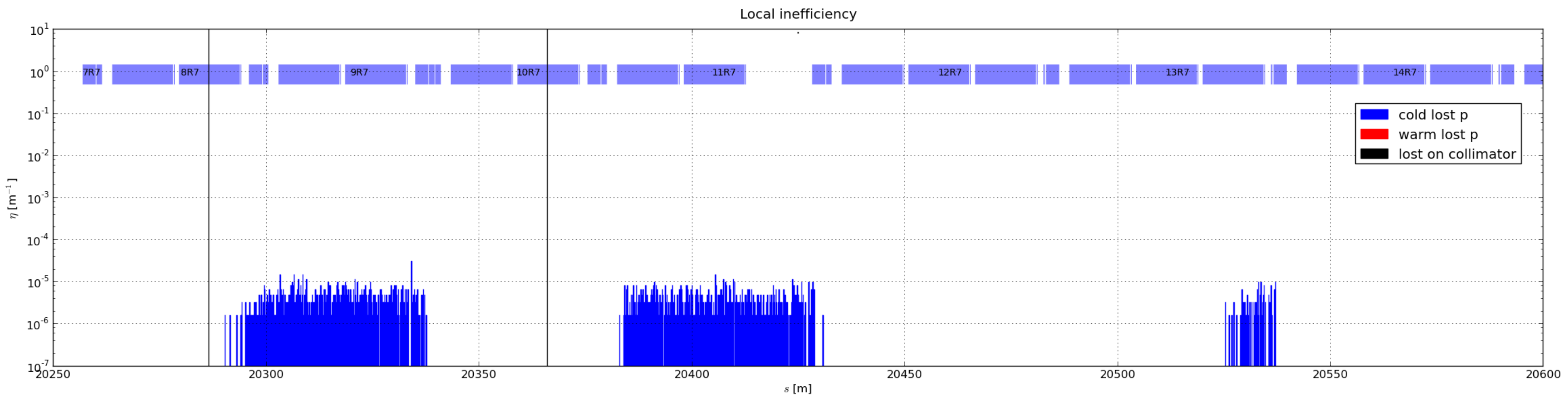
  $\Rightarrow$ dispersive losses
- Can DS collimators protect from them?



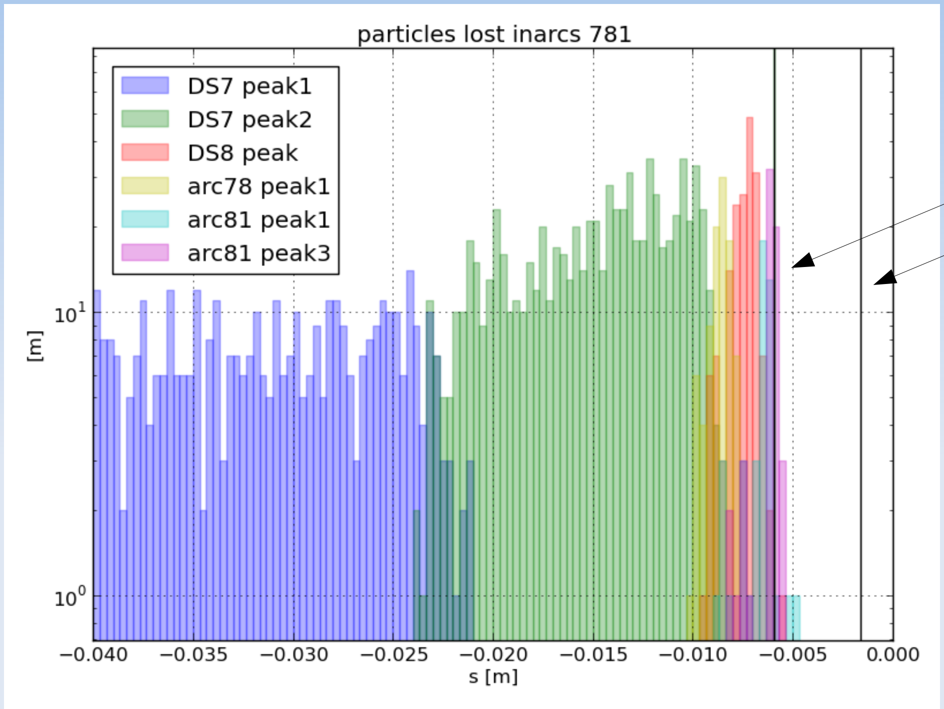


Collimators in the Dispersion Suppressors

- Longitudinal space created by the 11T dipoles
- Would protect locally from the loss peaks in the DS
- Importance of location (value of dispersion function):
- Could protect the arcs if their dp/p cut is sufficient



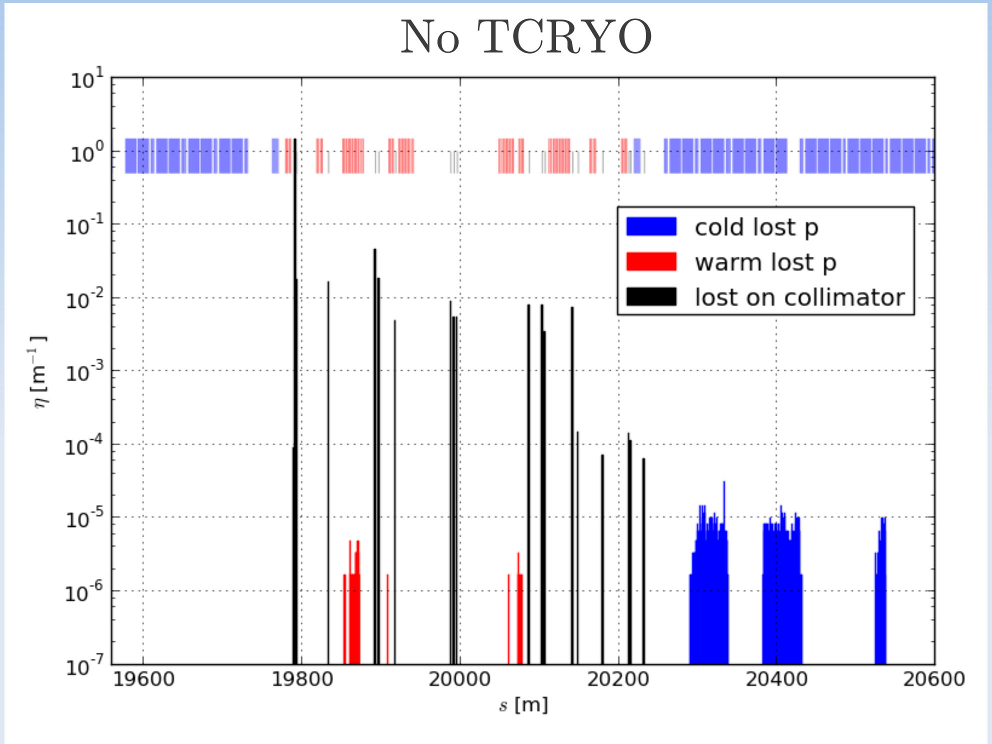
Observations on dp/p cut

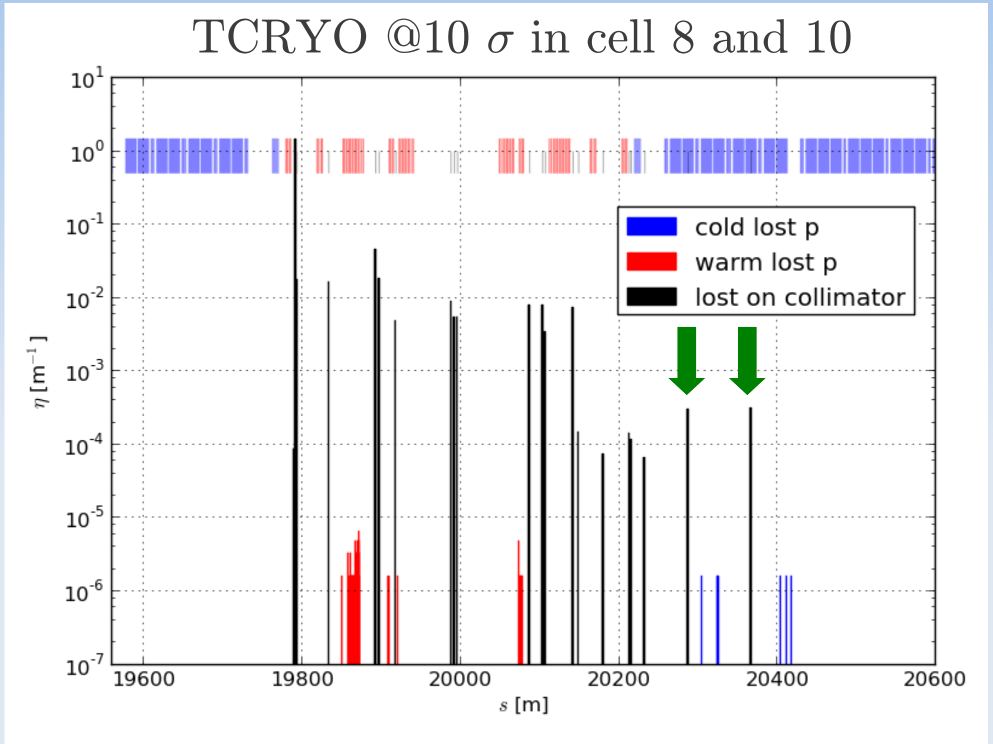


- Majors peaks of arcs 7–8 and 8–1
- Min. dp/p for all lost particles: 4.9e-3
- dp/p cut @10σ for particles at (0, 0, 0, 0) seems enough
- But secondary particles can have big position offsets!
- Only simulations can give full answer

Betatron losses simulations with DS collimation

Betatron losses with two TCRYO collimators

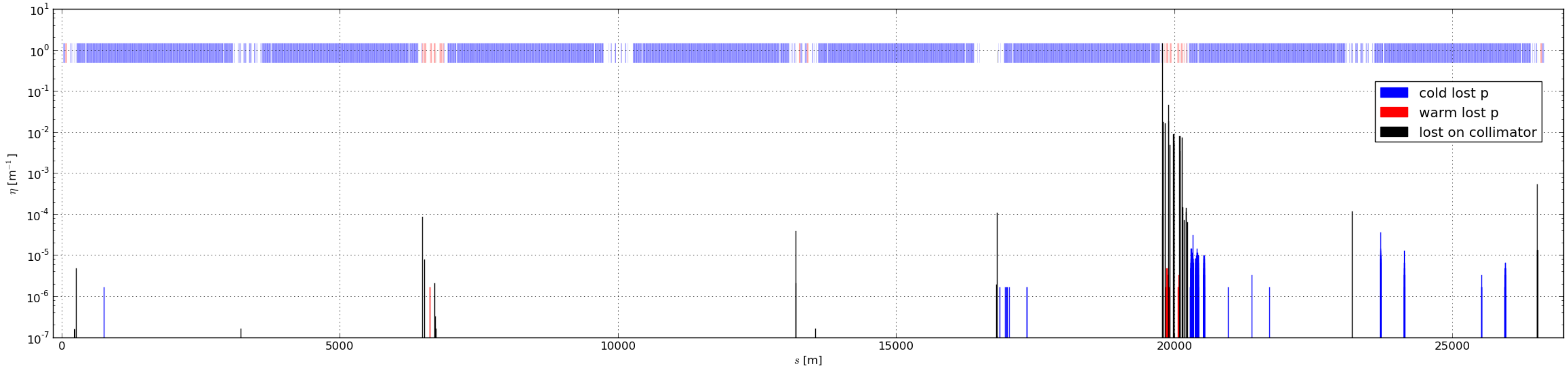




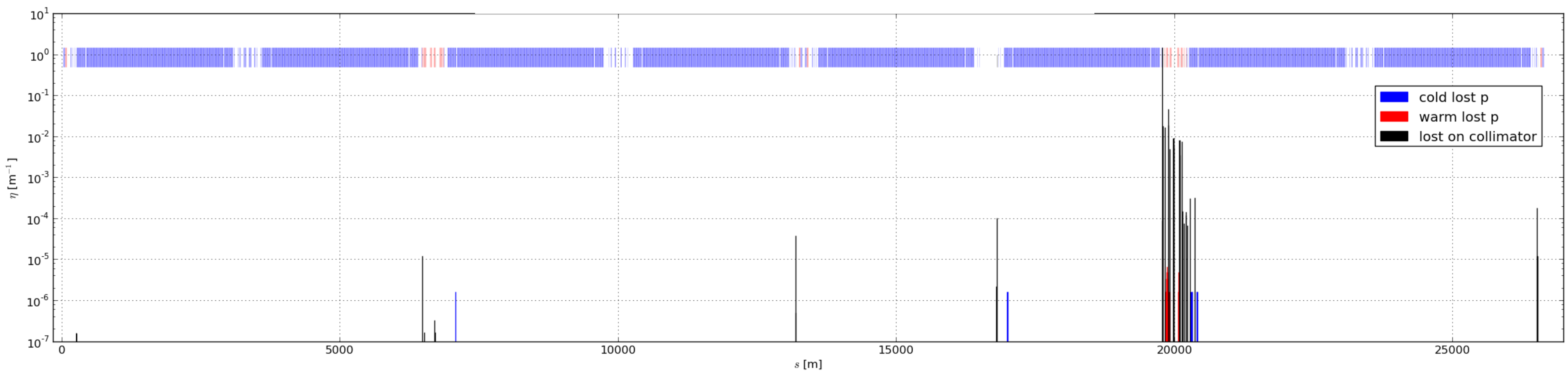
- The TCRYO.10 has a smaller dp/p cut
- All particles are stopped, including further downstream in the arcs
- Also protected for 15 σ

Effect of the DS collimators

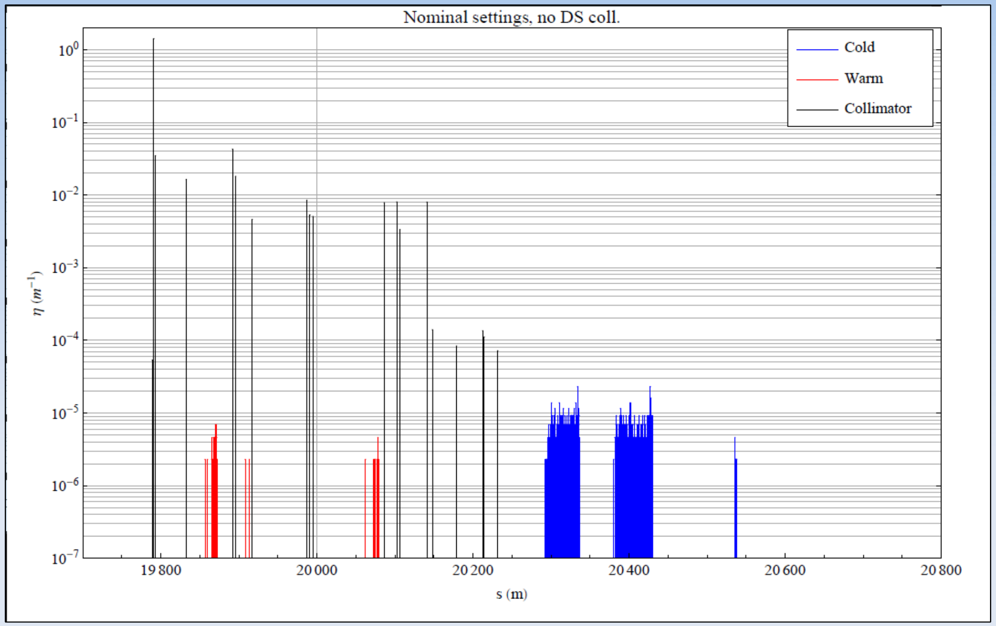
No TCRYO

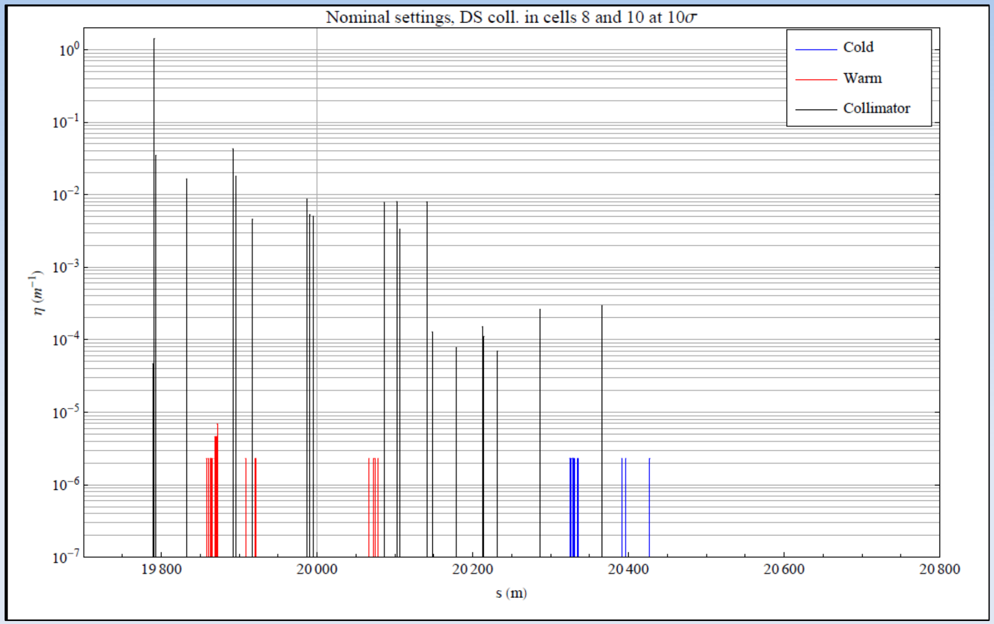


TCRYO @10σ in cells 8 & 10



Standard optics: similar solution R. Bruce





- No peak further than beginning of arc 7–8
- One collimator does not remove all peaks
- Two collimators in cells 8 and 10 provide protection.

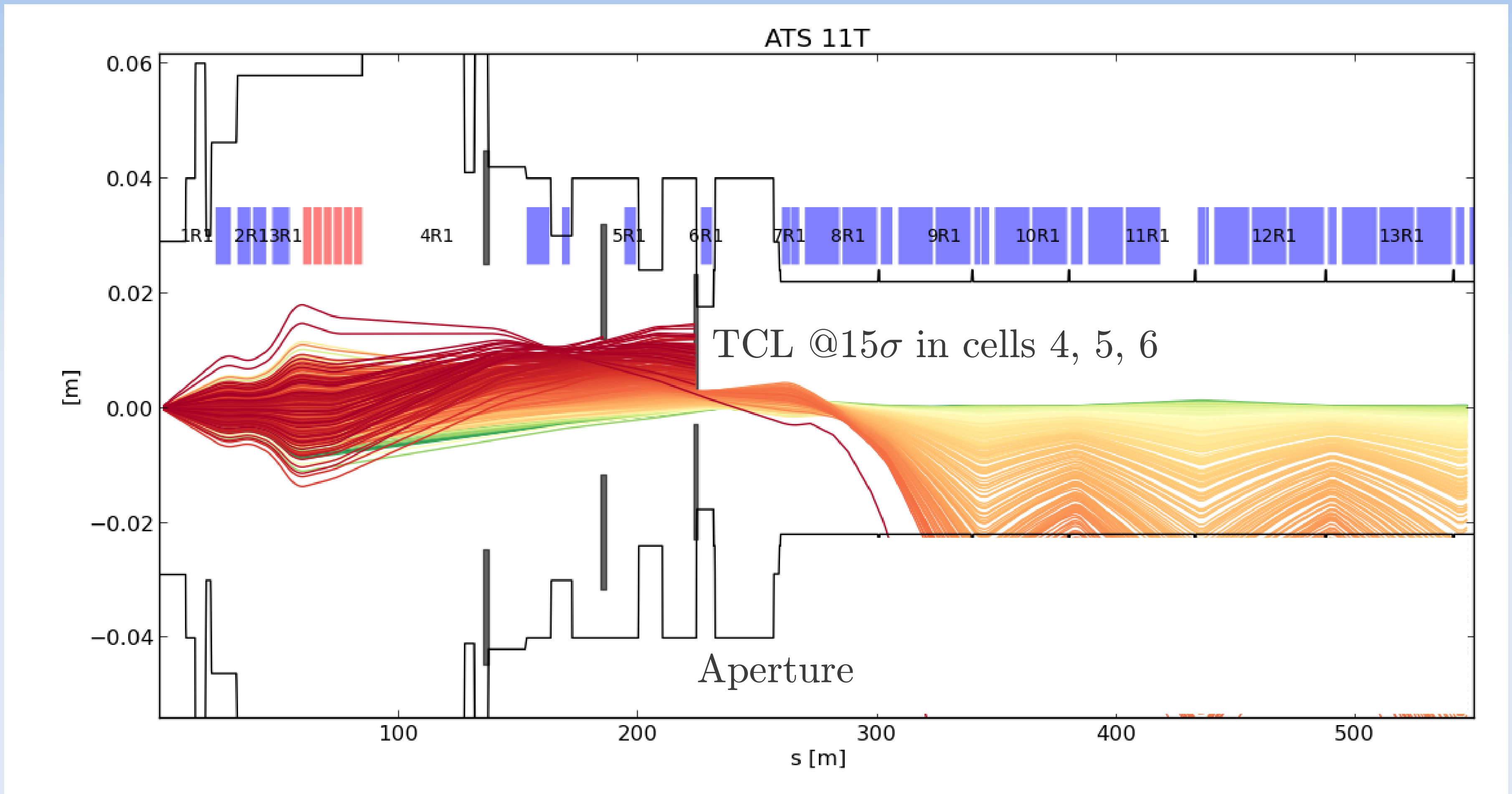
$\Rightarrow$ DS collimators work in two cases

Physics debris simulations

Preliminary thoughts about physics debris cleaning

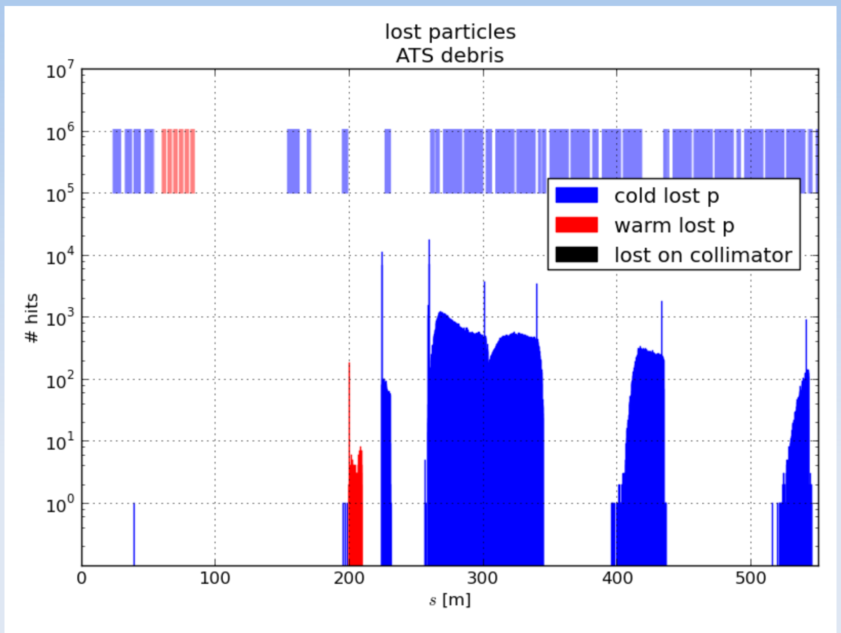
- Debris: products of p-p collisions simulated by FLUKA (F. Cerutti)
- Mainly protons with extra kicks x', y' and momentum offset dp/p
- Lost during the first turn
- Results cross-checked with FLUKA simulations
- Considering TCLs in cells 4, 5 and 6
- Different settings and position can be checked

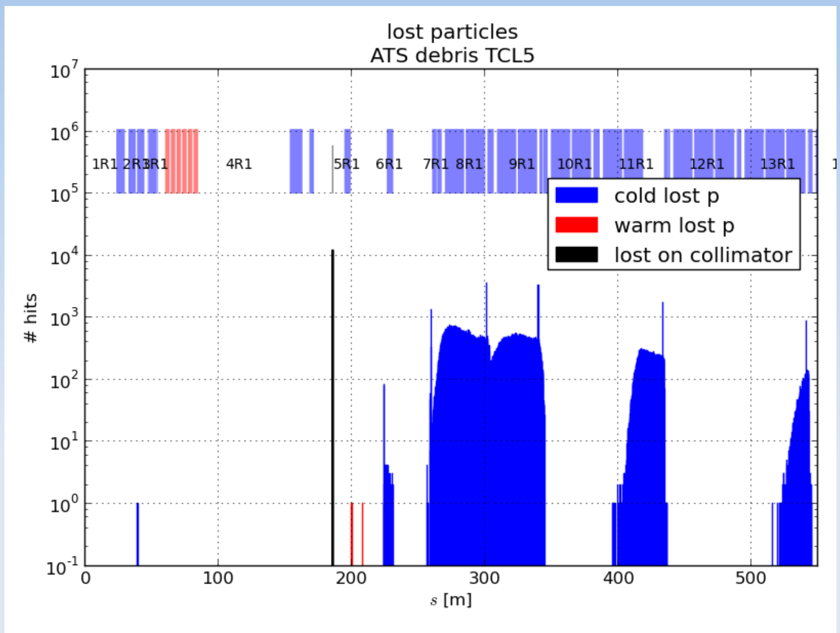
Preliminary thoughts about physics debris cleaning

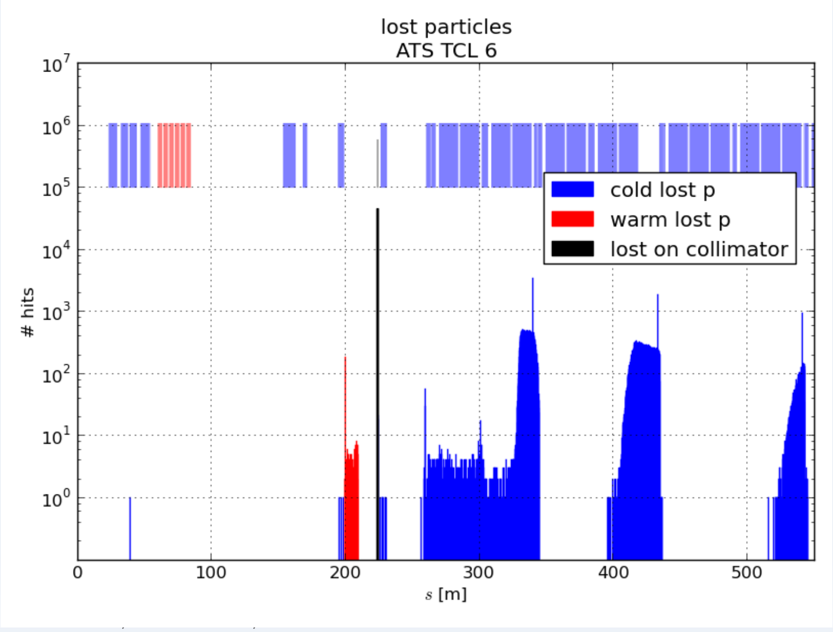


- Particles sorted by dp/p (color scale)
- Dispersion is again the dominating effect

Preliminary simulations with physics debris







- Different positions provide different dp/p cuts
- Has to be expressed in p/m/s for comparison with FLUKA
- Differs from standard optics

Conclusion

- ATS scheme presents the same collimation issues than standard optics + extra limitations
- One extra collimator in DS is not enough
- Two DS collimators would provide a solution in both cases (including the extra loss locations of ATS)

- Debris: first results & comparison with FLUKA are very promising
- Full study with scans ongoing

- Other tasks

Ongoing HiLumi-related activities

- Update simulation models for latest ATS baseline (10cm)
- Add progressively error models (collimation + optics)
- Complete studies in IR1/5 for ATS vs STD layout
- Check the pre-squeeze ATS optics (halo + debris)

- In parallel, other non-DS related studies of HL collimation upgrade are ongoing:
  - background experiments from halo, new layouts in IR1/5, failure scenarios and impact on collimator loads, ...

Thank you.