Review of Proposed LHC Collimation Work
in Dispersion Suppressor for 2012
Geneva, 8th July 2009

Expected gains from 2012 works

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E. Métral, N. Mounet, A. Rossi, T. Weiler, D. Wollmann

Outline

- **Introduction**
- **Feedback from 2009-2010 OP**
  - *Cleaning performance*
  - *Comparison with simulations*
- **Phase II cleaning**
  - *Layout of new IR3 cleaning*
  - *Simulated performance*
- **Phase II impedance**
- **Conclusions**

Phase I collimation system

Two warm cleaning insertions

- **IR3: Momentum cleaning**
  - **1 primary (H)**
  - **4 secondary (H,S)**
  - **4 shower abs. (H,V)**
- **IR7: Betatron cleaning**
  - **3 primary (H,V,S)**
  - **11 secondary (H,V,S)**
  - **5 shower abs. (H,V)**

Local cleaning at triplets

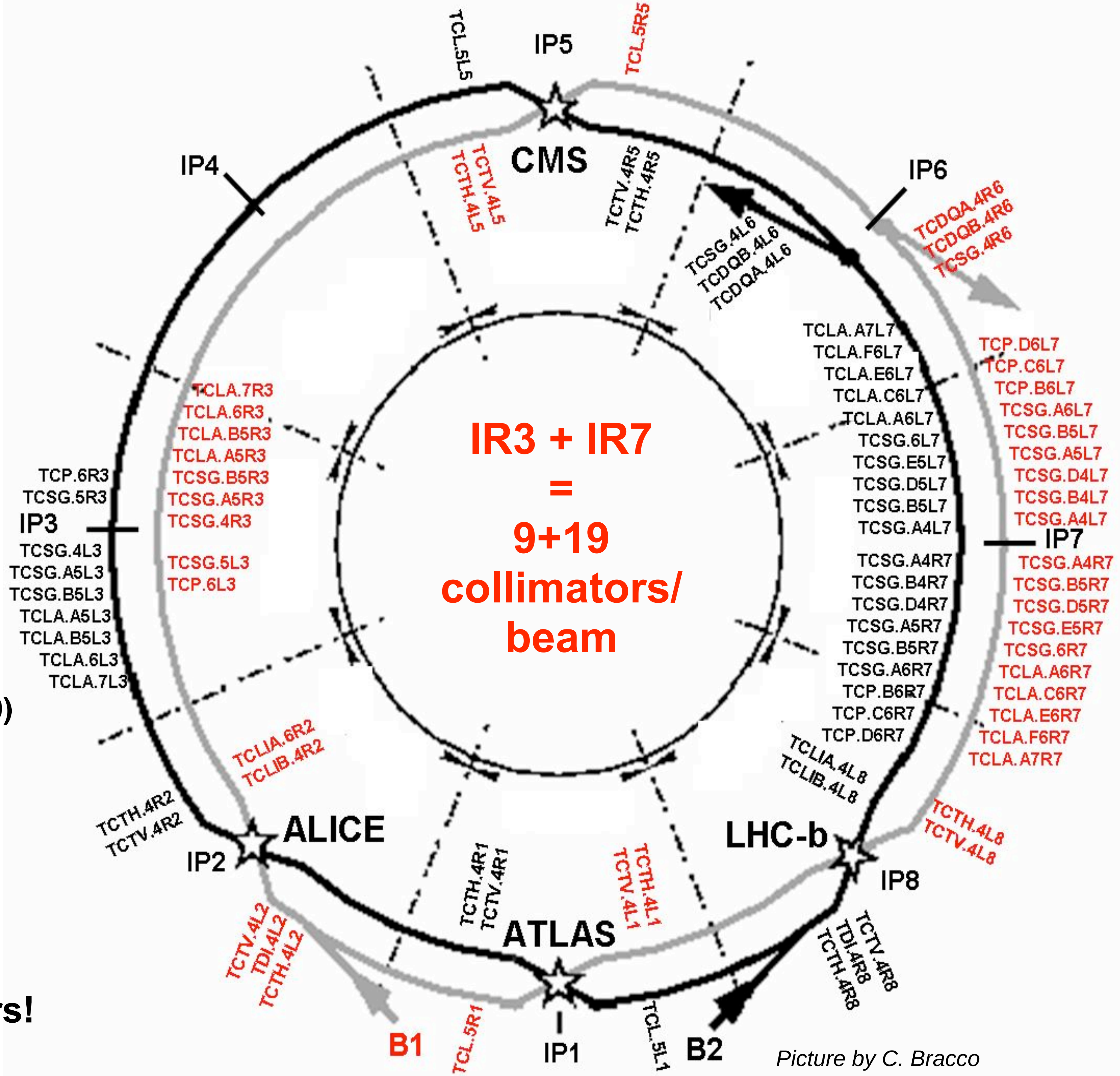
- **8 tertiary (2 per IP)**

Passive absorbers for warm magnets

Physics debris absorbers

Transfer lines (13 collimators)
Injection and dump protection (10)

108 collimators and absorbers!
About 500 degrees of freedom. Most advanced system built for accelerators!



Picture by C. Bracco

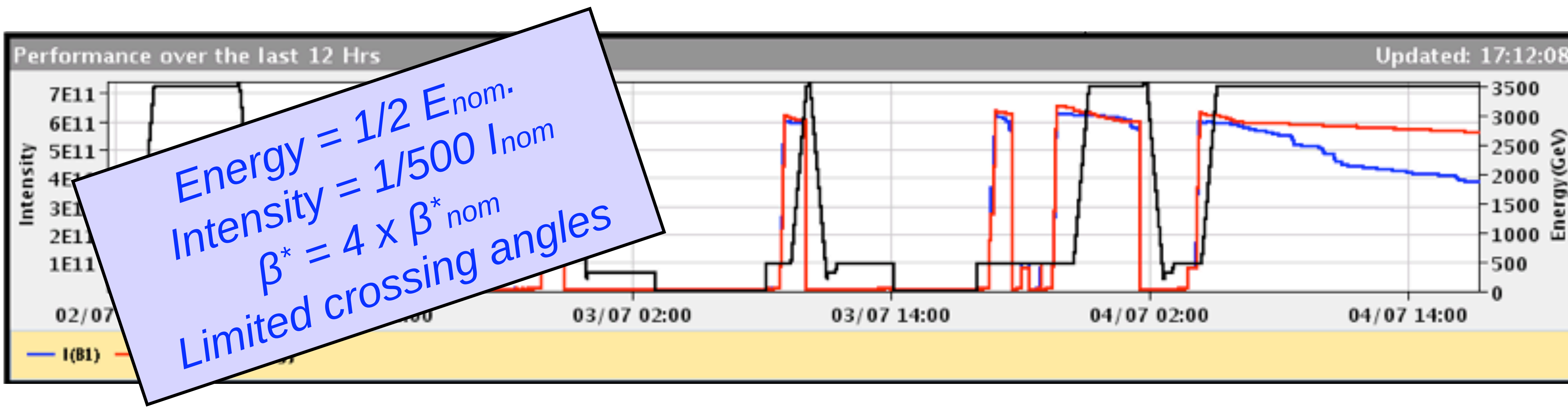
Present beam conditions

Energy: 450 GeV to 3.5 TeV.
Stored energies ~factor 2700 larger than quench limit!

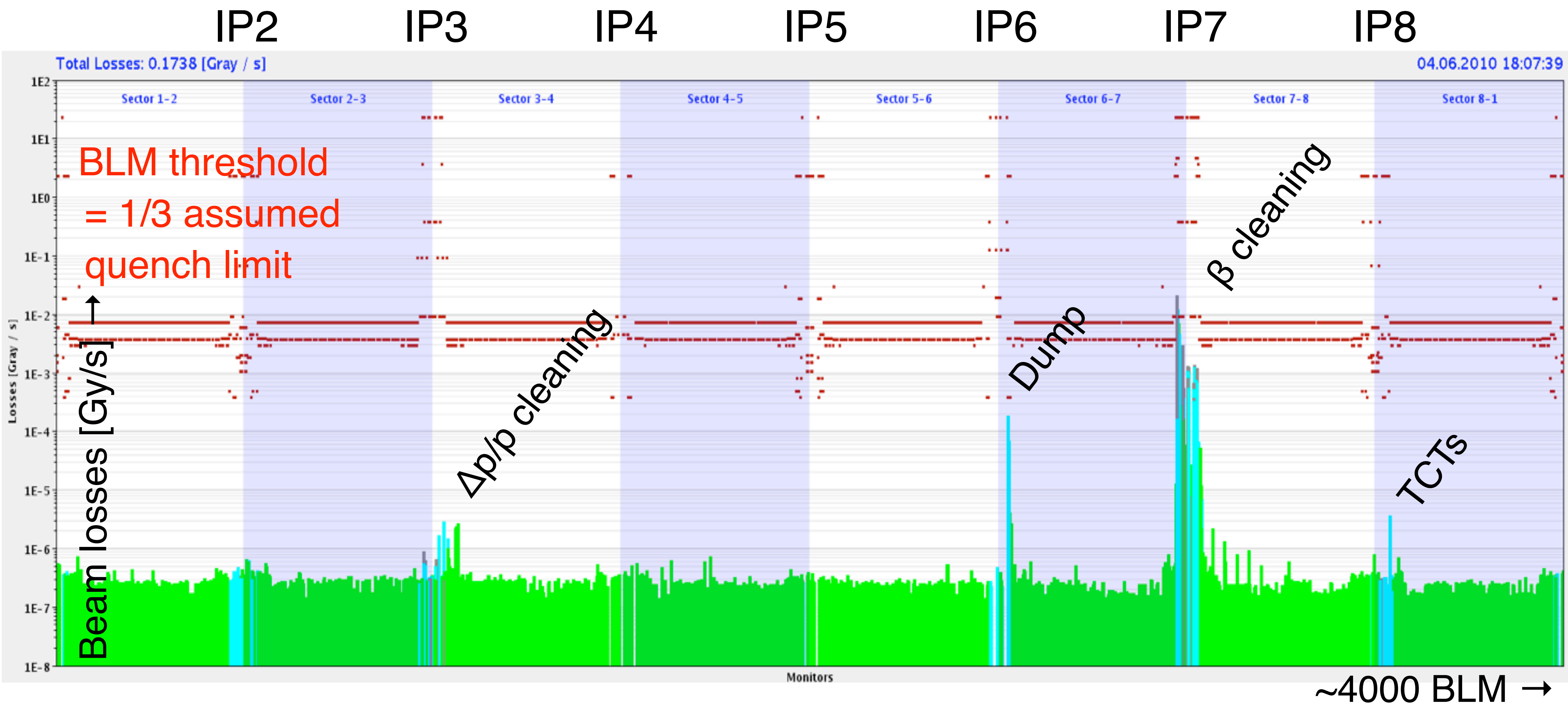
Intensity: Pilots of few 10^9 p to nominal bunches of **> 1.1 10^{11} p**.
Total intensity per beam = **7 x 10^{11} p** (for stable beam).

Optics: Injection and squeezed optics down to 2 m in all IPs.
Present running configuration: **β* = 3.5 m** in all IPs.
Moderate crossing of **100 μrad** in IP1 and IP5 only.
Separation ON and OFF (**± 2 mm**).

Performance: Peak luminosity **~ 10^{30} cm^{-2}s^{-1}** (July 2nd).



Collimator in operation



No indications of primary restrictions outside collimator regions.

No quenches with stored energies up to 2700 x quench limit!

In operation we now **rely much** on the collimation cleaning!

Good cleaning performance has ensured smooth commissioning and operation!
(Price: alignment campaigns to set ~ 80 collimators!)

Loss assumptions

Performance reach depends on:

- Collimation cleaning inefficiency;
- Total beam intensity;
- Peak minimum lifetime;
- Quench limit of magnets;
- Loss dilution length.

$$N_p^{\lim} = \tau_{\min} \cdot \frac{R_q}{\eta_{ineff}} \cdot \frac{F_{BLM} \cdot F_{dilution}}{F_{imperfect}}$$

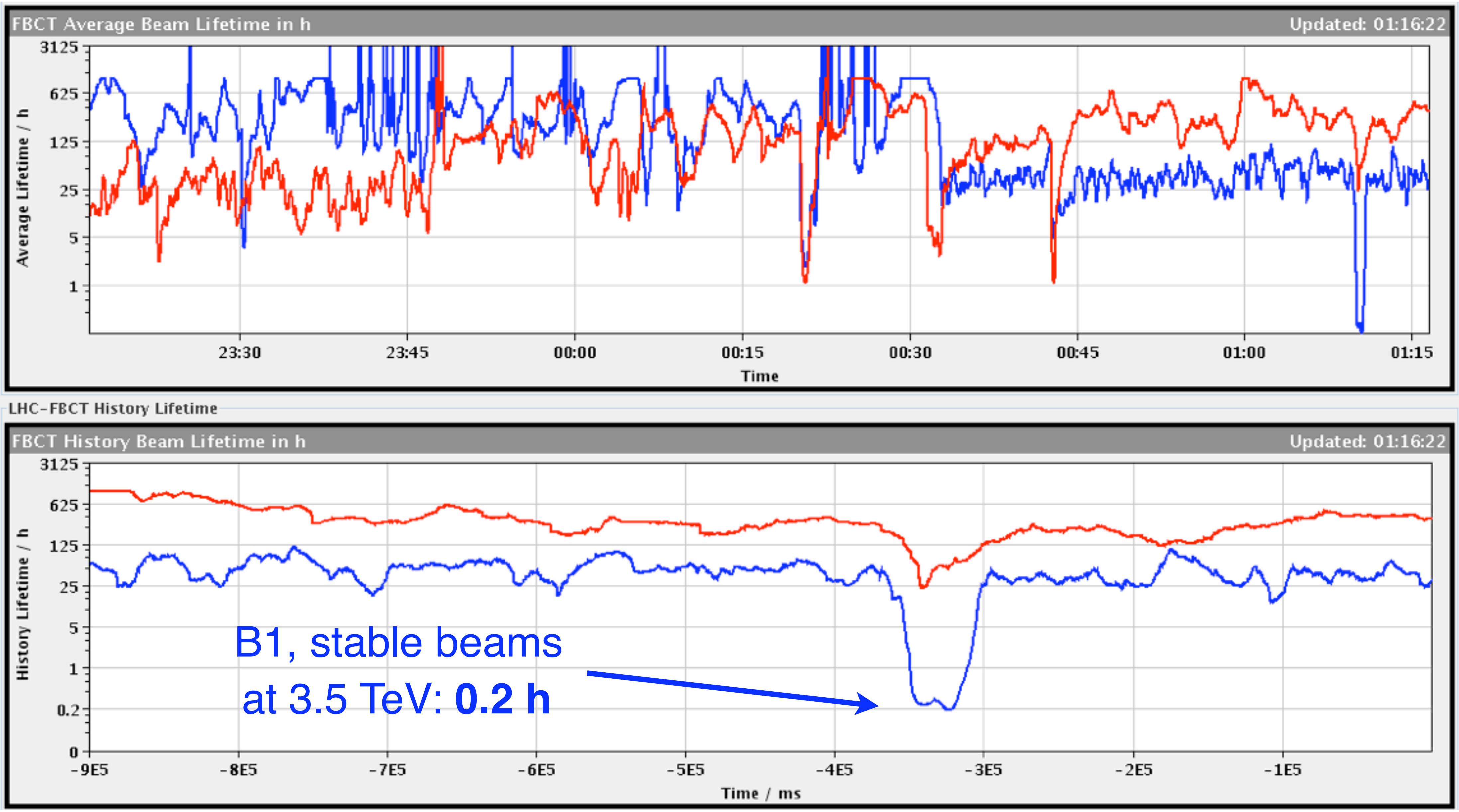
- Intensity Limit
- Quench limit, e.g. 8e6 p/m/s
- Factor for BLM margin, e.g. 0.33
- Factor for shower dilution from FLUKA, e.g. 3.5
- Minimum beam lifetime (peak loss): Assumed input
- Cleaning inefficiency
- Factor for imperfections, e.g. 6

R. Assmann

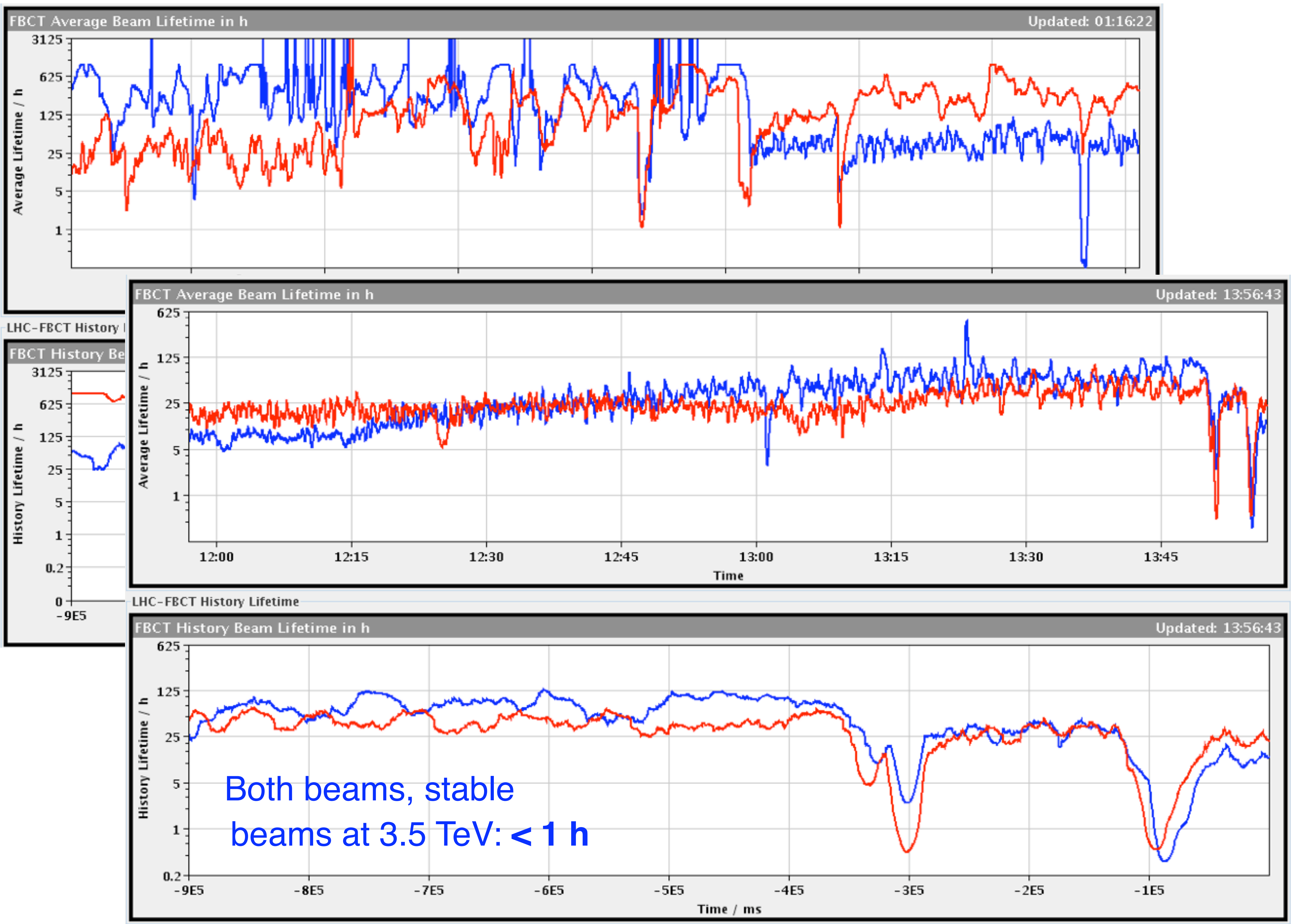
Our design specification:

Mode	T [s]	τ [h]	R_{loss} [p/s]	P_{loss} [kW]
Injection	cont.	1.0	0.8×10^{11}	6
	10	0.1	8.6×10^{11}	63
Ramp	≈ 1	0.006	1.5×10^{13}	1200
Collision	cont.	1.0	0.8×10^{11}	97
	10	0.2	4.3×10^{11}	487

Measured loss rates

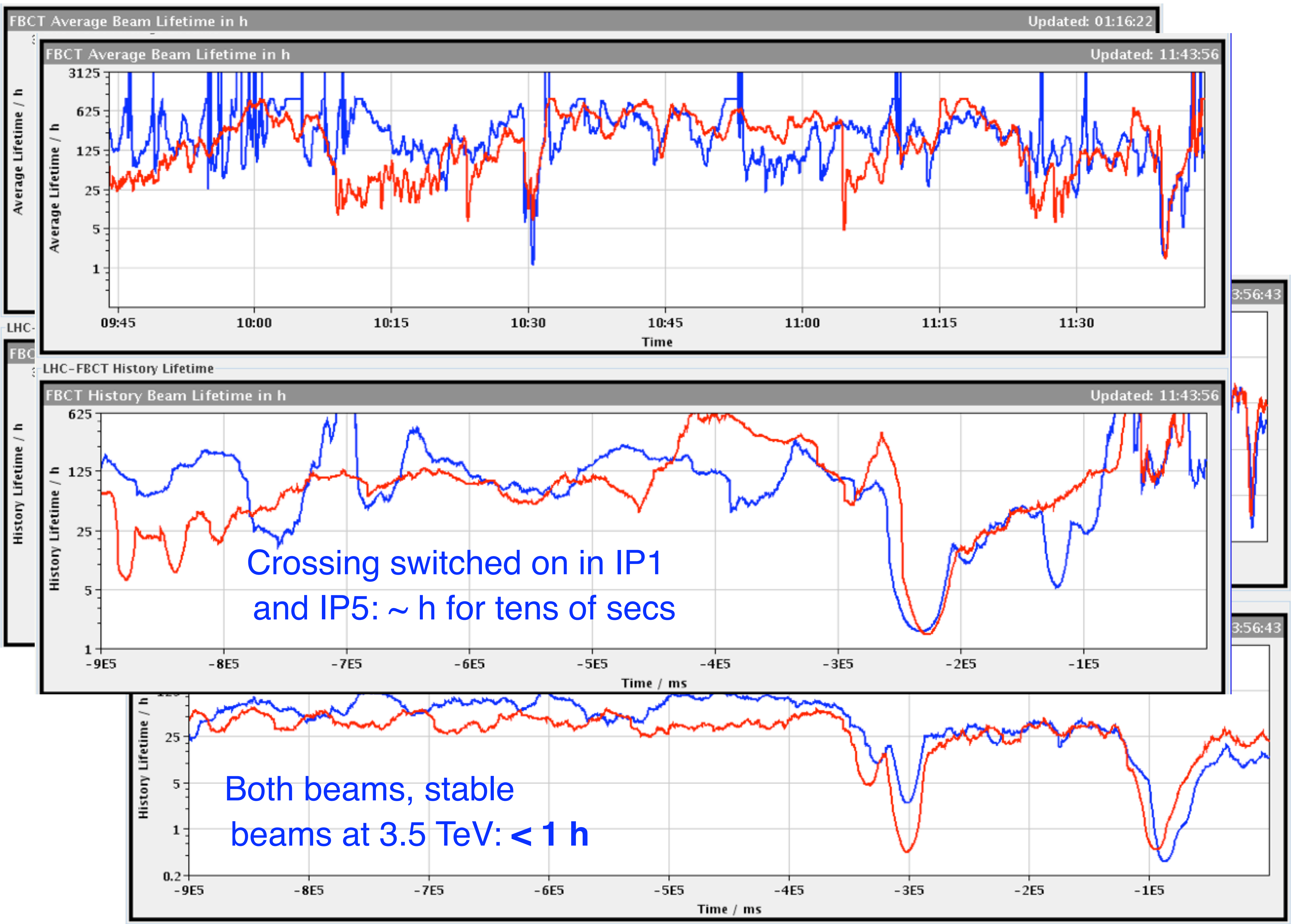


Measured loss rates

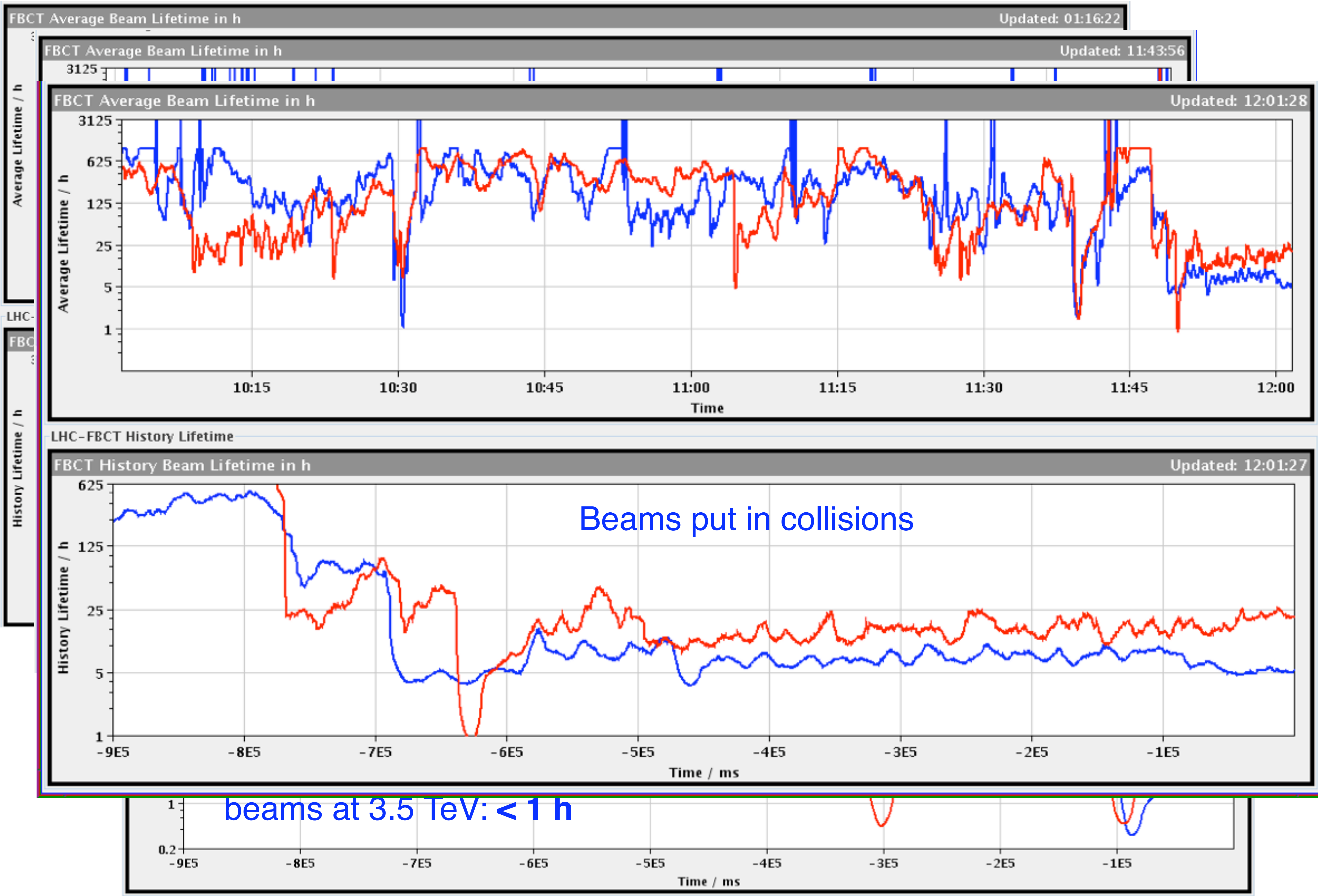


Both beams, stable beams at 3.5 TeV: **< 1 h**

Measured loss rates



Measured loss rates

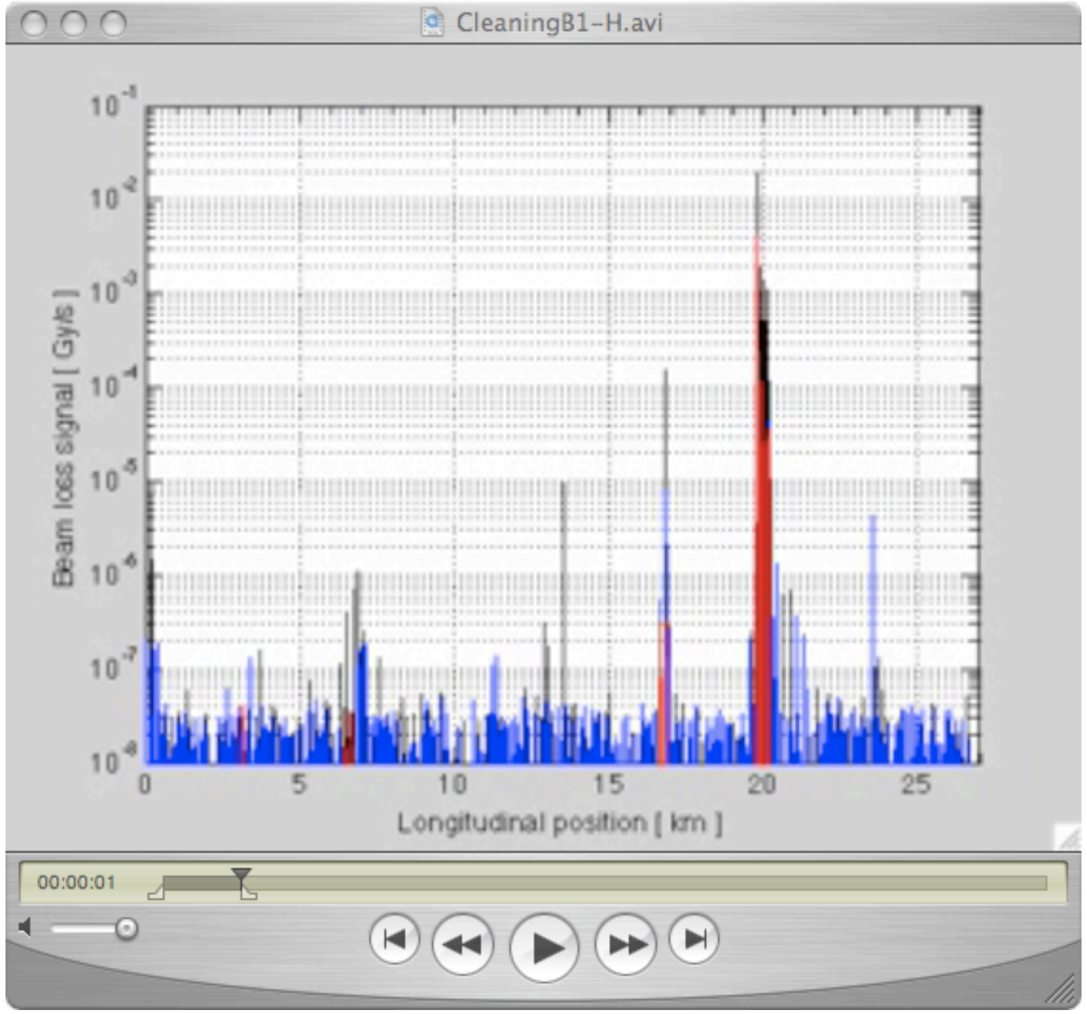


Measured cleaning at 3.5 TeV, β^*=3.5m

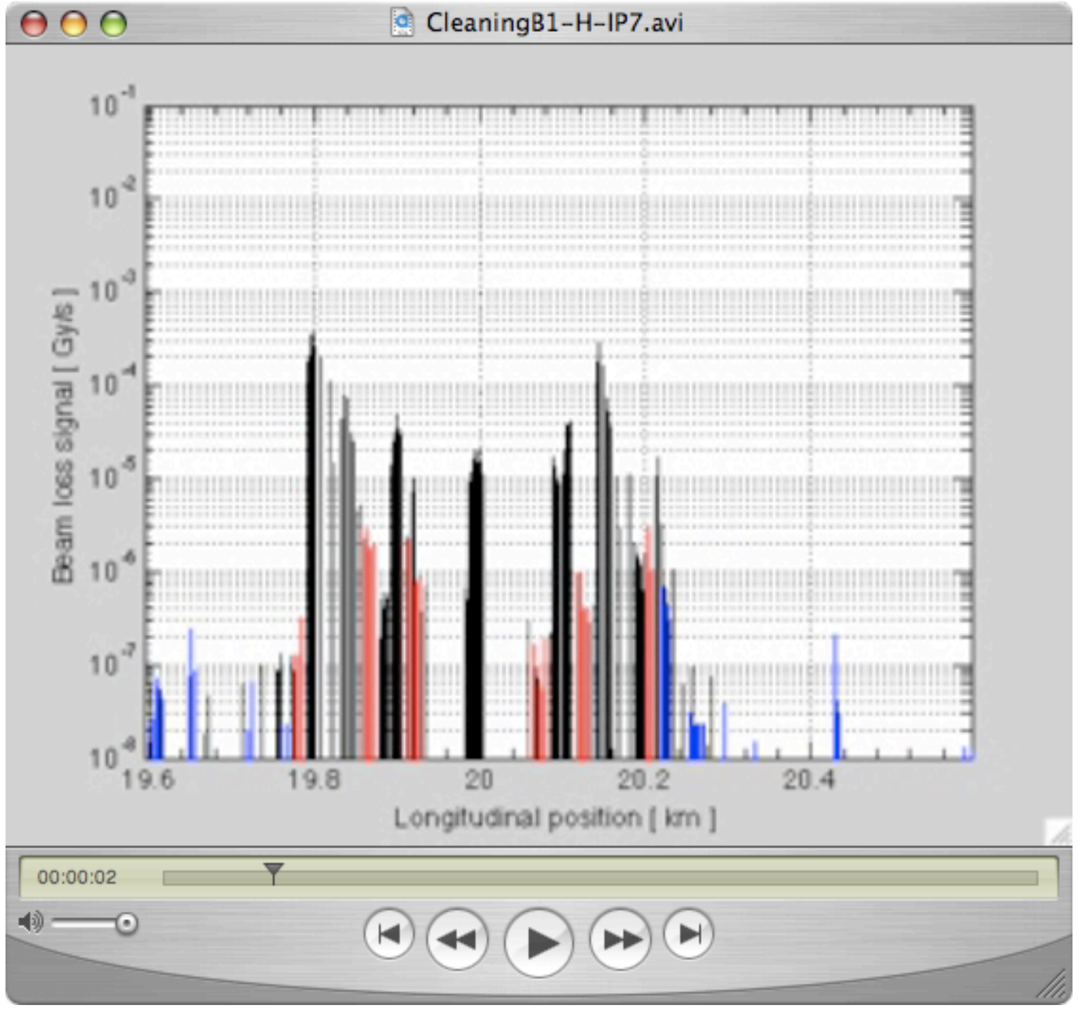
("relaxed" collimator settings)

Excite large beam losses (tune resonance, RF trims) to increase loss rate and compute cleaning efficiency.

Full ring (27 km)



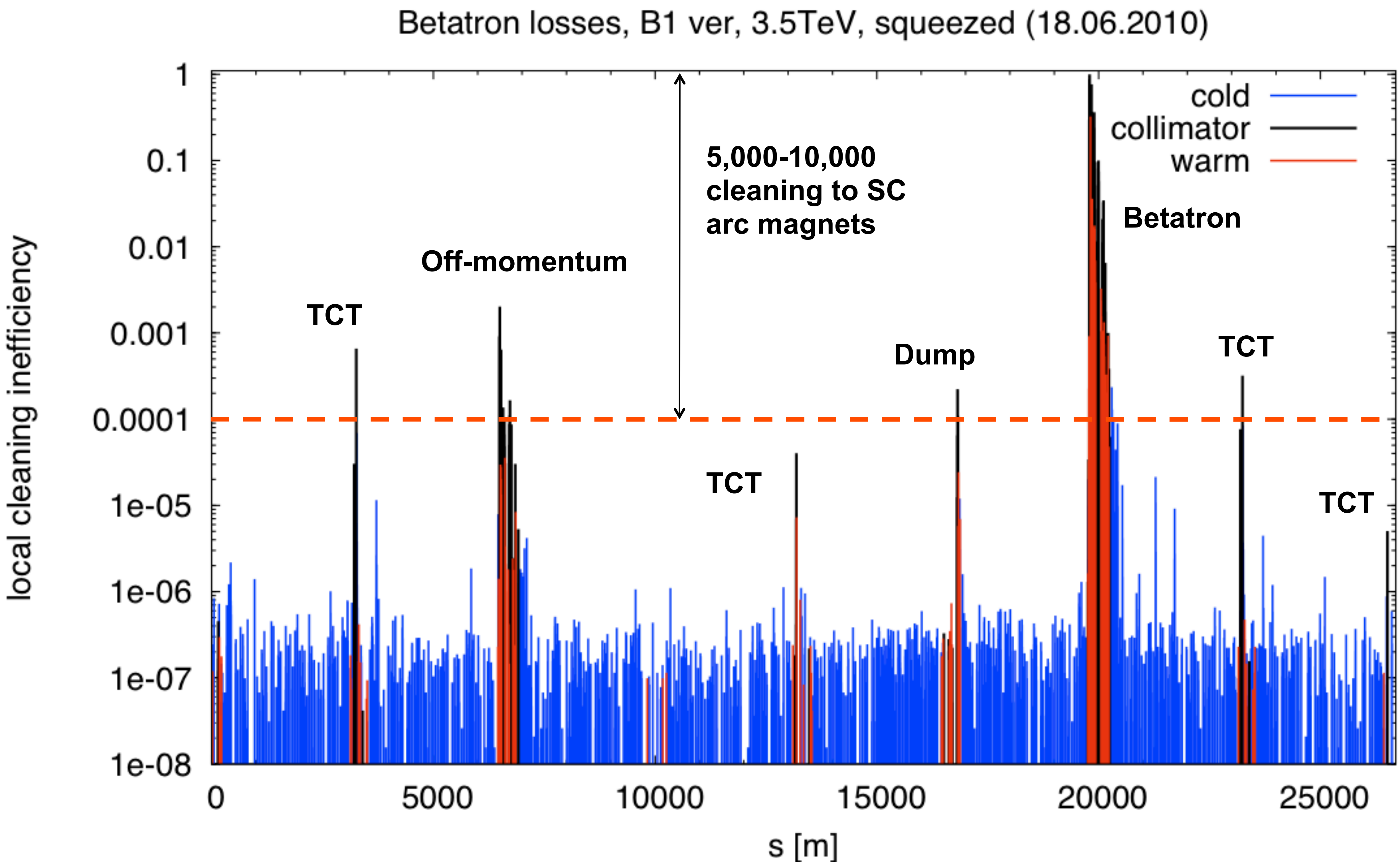
Around IP7 (1 km)



Cleaning efficiency η = 99.98% - 99.99% : Performance close to nominal!

Measured cleaning at 3.5 TeV, β^*=3.5m

("relaxed" collimator settings)



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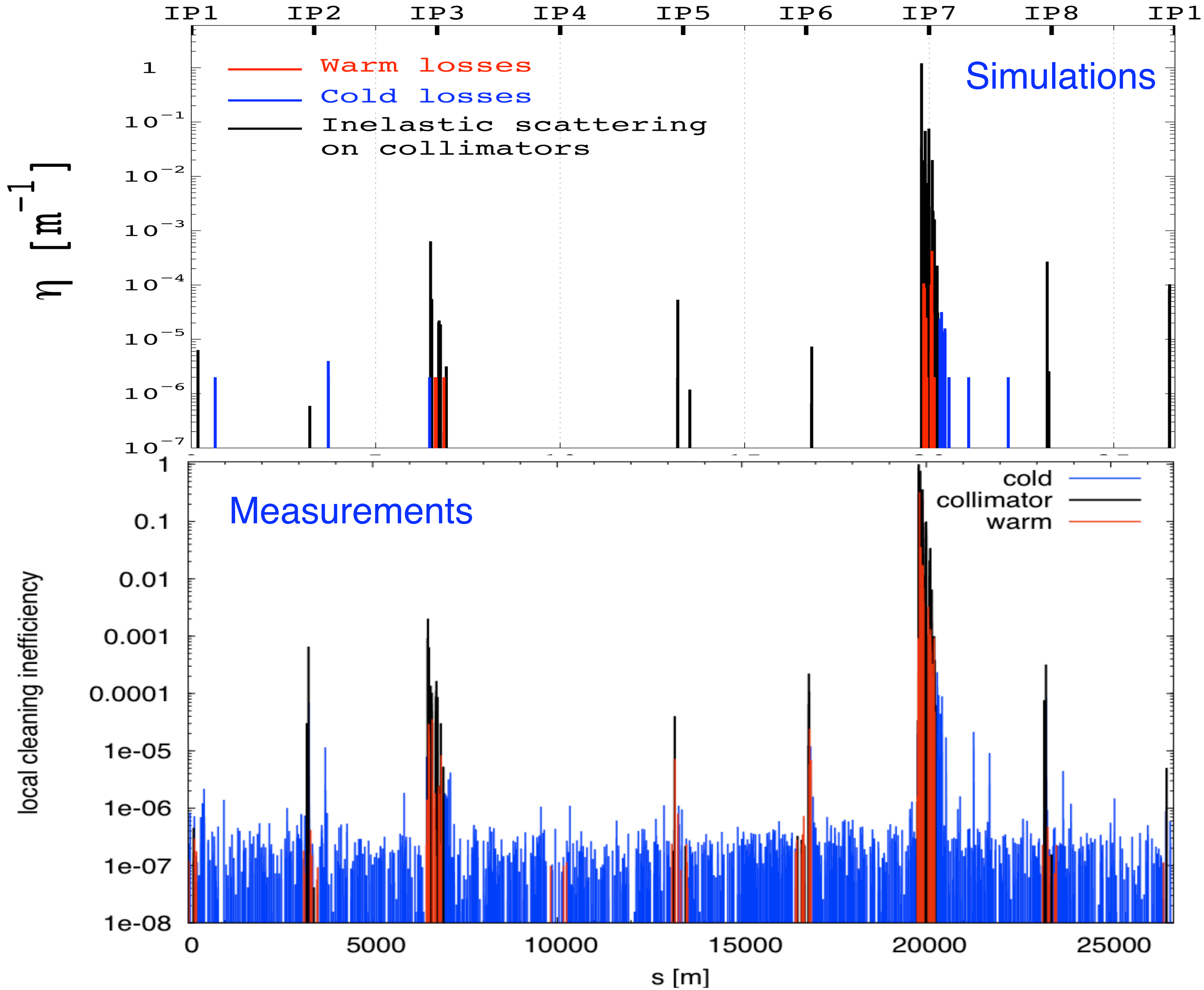
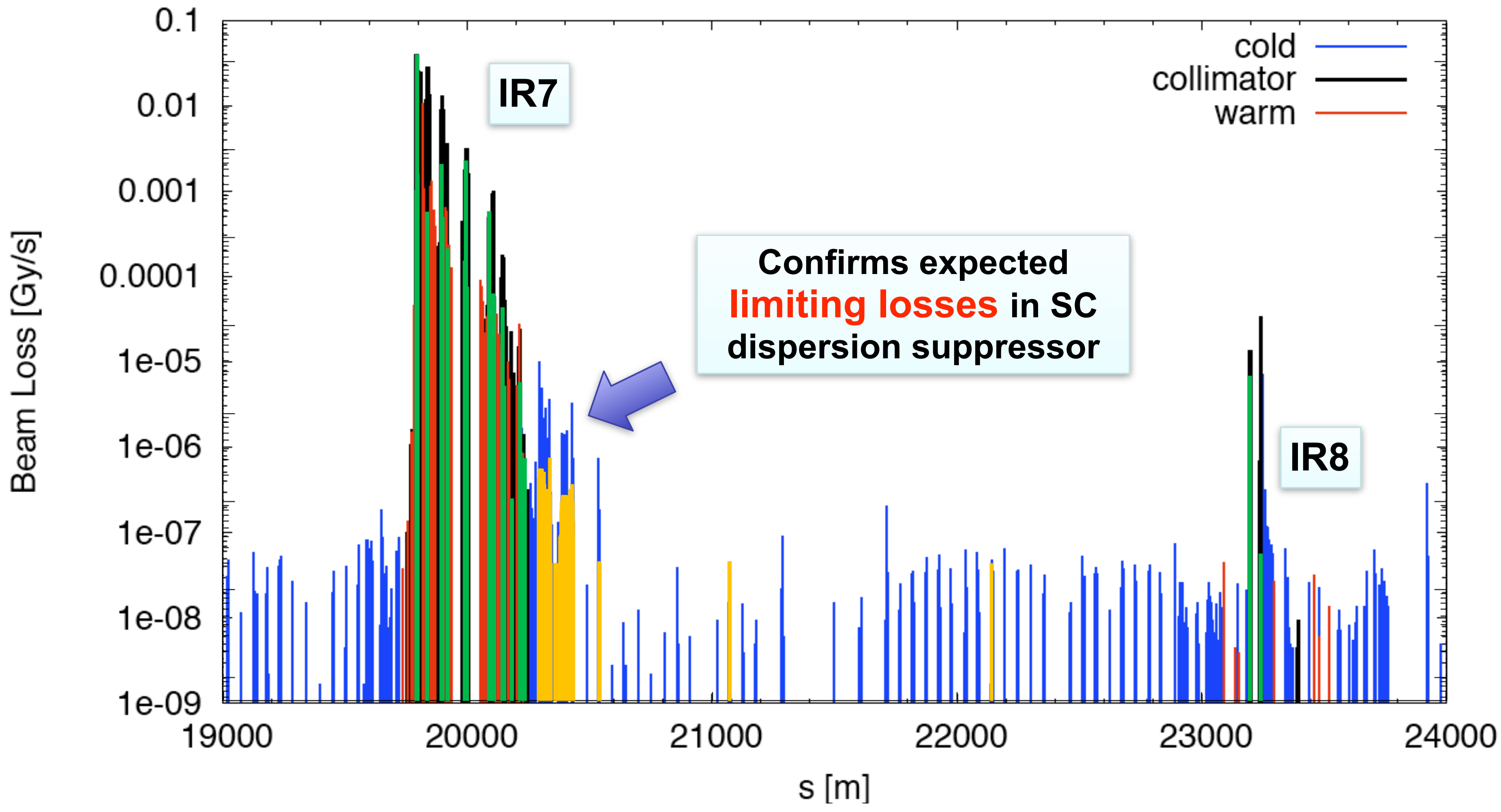
Simulated performance at 3.5 TeV



Simulated performance at 3.5 TeV



Preliminary comparison: **Very good agreement!**

Measurements **confirm** the expected limitation in the **dispersion suppressor**.

We measure a factor < 10 more than simulated (explained by model imperfections)

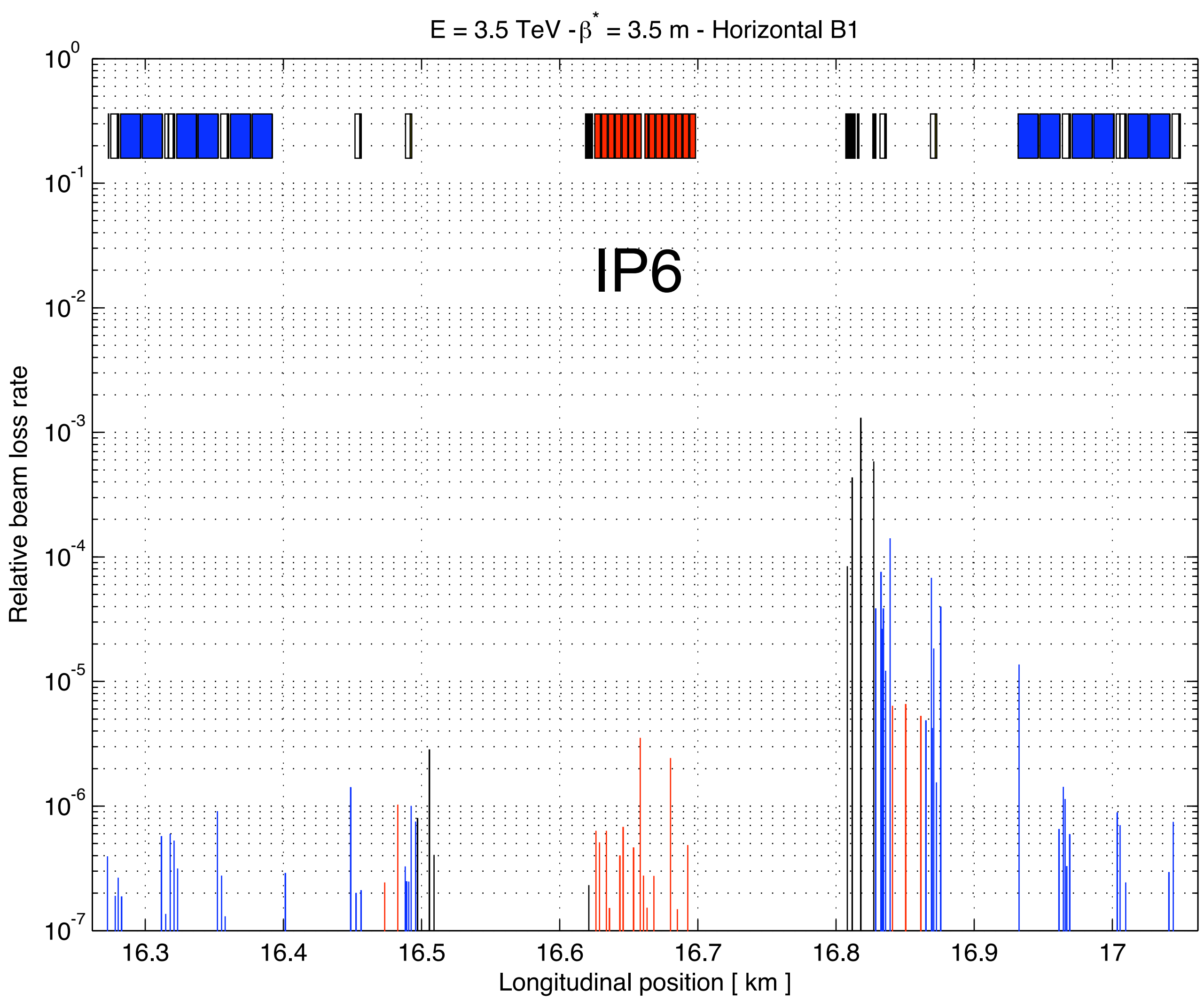
Other observed limitations

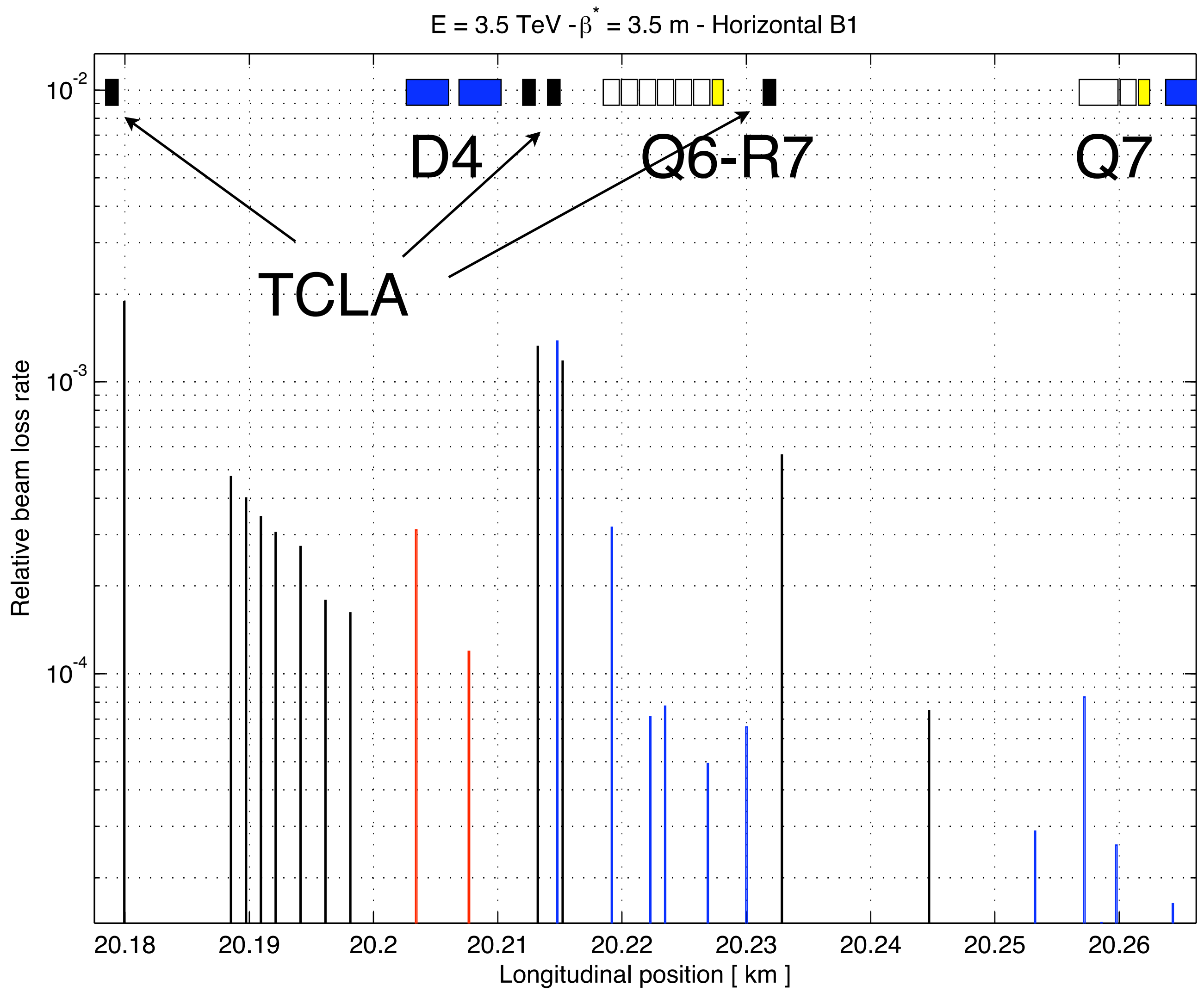
Losses in Q4 in point 6 (will be addressed by the 2015-16 upgrade).

BLM cross talk: Q6 in IP7 close to TCLA collimators.

Showers in the triplet BLM from the tertiary collimators.

DS losses are the only physics limitation found so far (in present beam conditions).





Operational feedback

(with present beam conditions)

- The Phase I collimation system works **very well**!

  Close to nominal cleaning with relaxed settings at 3.5 TeV!

  Certainly adequate for present low intensity operation.

- **High cleaning performance** is important for smooth and safe commissioning + operation.

  No single quench with circulating beam yet!

- Main choices are confirmed and validated by beam experience.

- But:

  - We see already **limitations** of **cleaning**, as expected: this will limit the total intensity. Difficult to extrapolate to nominal case.
  - The system alignment is very **difficult** and **lengthly**!
  - The collimation system **constrains** a lot operation:

    Tight orbit and optics tolerances; limited range for luminosity scans

    Limit values of beta due due to collimation hierarchy,*

Future system upgrades must address these aspects.

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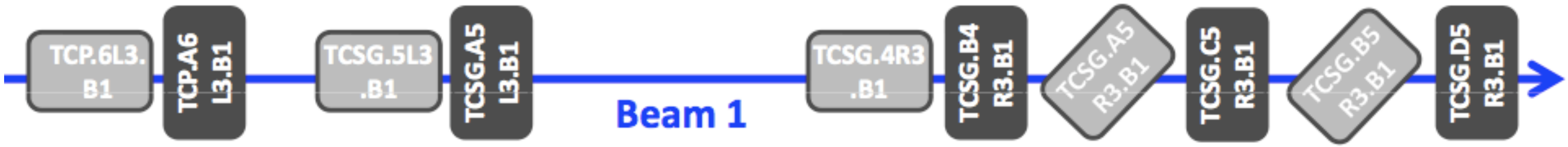
- Conclusions

Layout of IR3 combined cleaning



Beam 1		
Phase I	Phase II	angle, material
	TCP.6L3.B1	Hor
	TCP.A6L3.B1 replacing TCHSH.6L3.B1	Ver
TCSG.5L3.B1	TCSG.5L3.B1	Hor
	TCSG.A5L3.B1 replacing TCSM.5L3.B1	Ver, Carbon Hor, Copper
TCSG.4R3.B1	TCSG.4R3.B1	Hor
	TCSG.B4R3.B1 replacing TCSM.4R3.B1	Ver, Carbon Hor, Copper
TCSG.A5R3.B1	TCSG.A5R3.B1	Skew = 170 deg
	TCSG.C5R3.B1 replacing TCSM.A5R3.B1	Ver, Carbon Skew, Copper
TCSG.B5R3.B1	TCSG.B5R3.B1	Skew = 113 deg
	TCSG.D5R3.B1 replacing TCSM.B5R3.B1	Ver, Carbon Skew, (

Phase I layout (9 +19 coll in IR3/7):

1 primary (H) + 4 secondary (H)

+ 4 absorbers (H+V)

Phase II layout (28 coll in IR3):

- Add 1 primary and 4 secondary vertical collimators (in existing slots)
- Combine momentum and betatron cl.
- Still can decouple functionalities by using different settings for left/right jaws

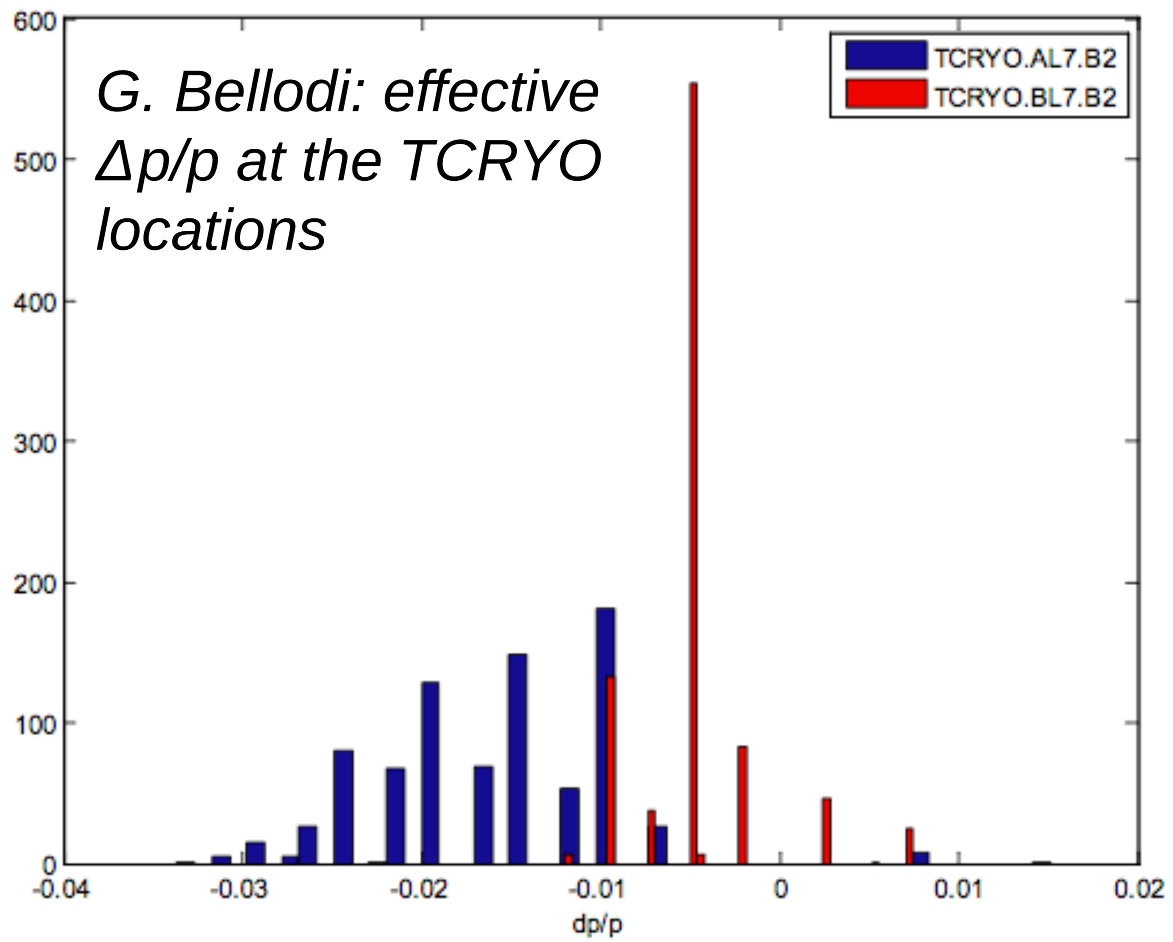
Gain factor 80-100 on radiation to electronics

STUDIES ON COMBINED MOMENTUM AND BETATRON CLEANING IN THE LHC

R. Assmann, G. Bellodi, C. Bracco, V. Previtali, S. Redaelli, CERN, Geneva, Switzerland
T. Weiler, CERN and University Karlsruhe, Germany

New dispersion suppressor layout

Beam 1		
Phase I	Phase II	angle
	TCRYO.AR3.B1	Hor, Tungsten
	TCRYO.BR3.B1	Hor, Tungsten

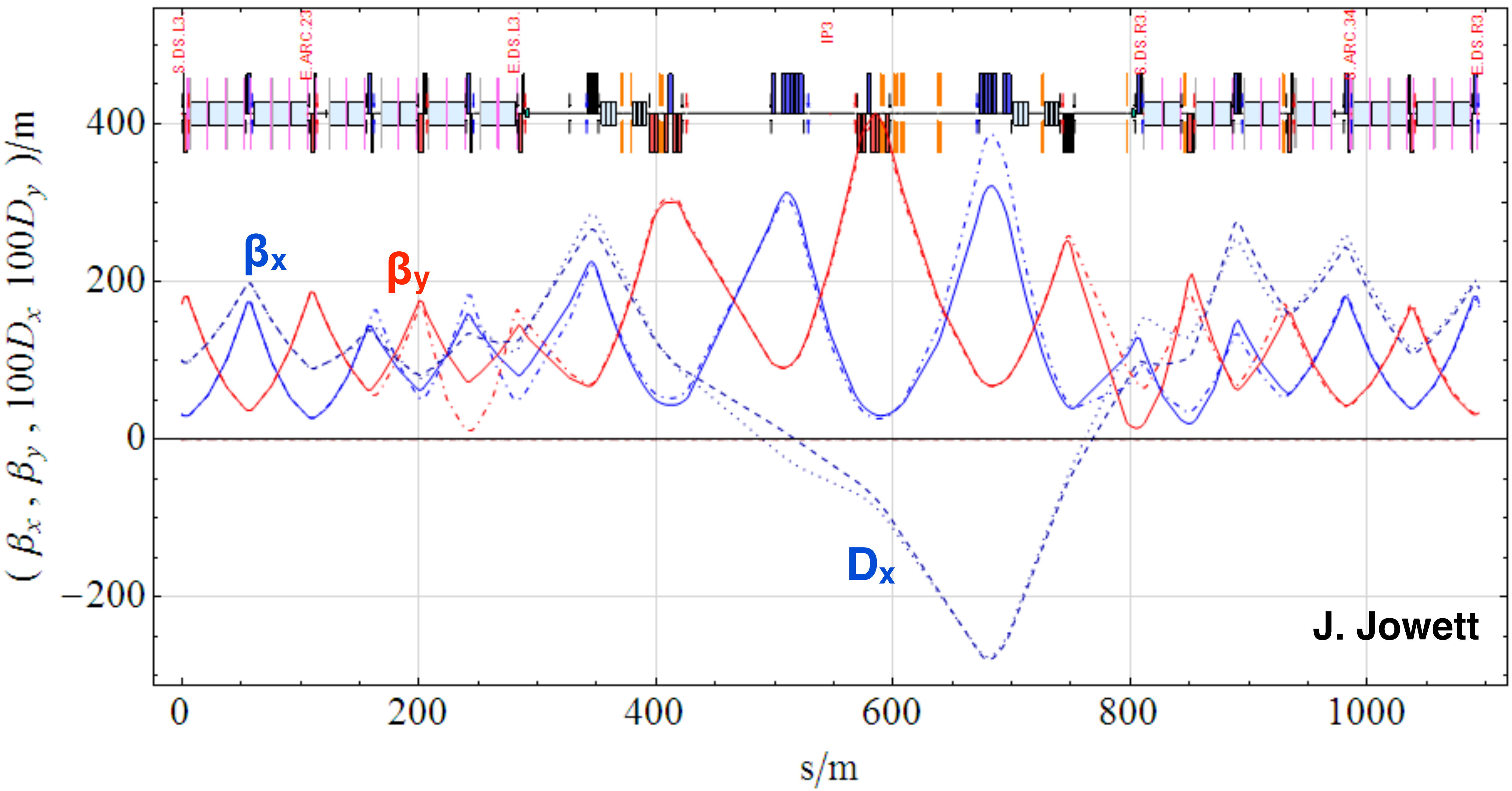


Specifications from accelerator physics requirements:

- Only horizontal plane
- Must be movable to avoid injection bottlenecks
- Must be 2 sided (ions)

*This requires to **displace** the DS magnets!*
Details of design and integration issues in the next talks.

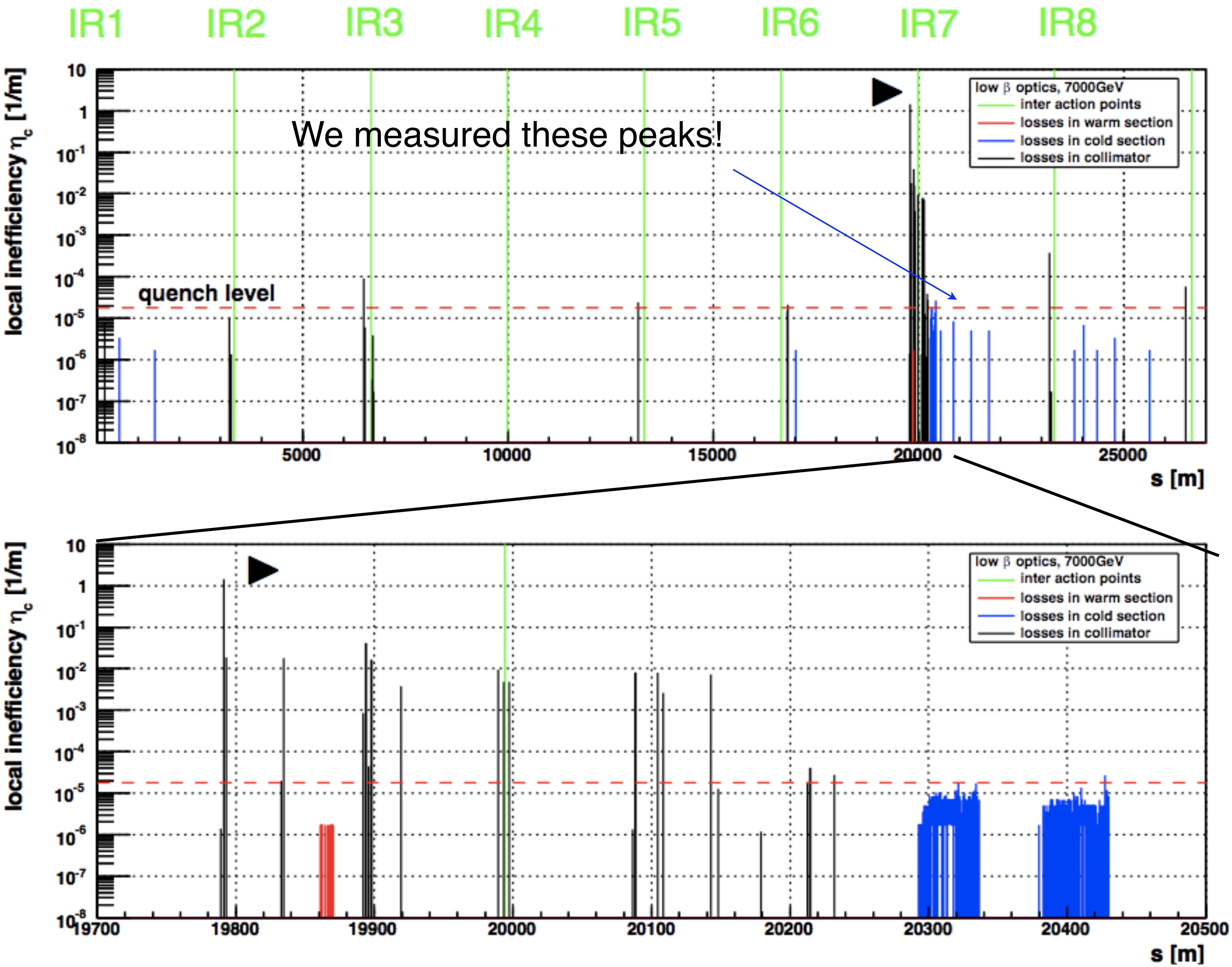
IR3 optics with displace magnets



Perfect match – same transfer matrix over IR3 - (also for Ring 2) so can be used in modular way with all existing LHC optics configurations.

Adjusted β-function peaks so available **aperture** is not changed significantly.

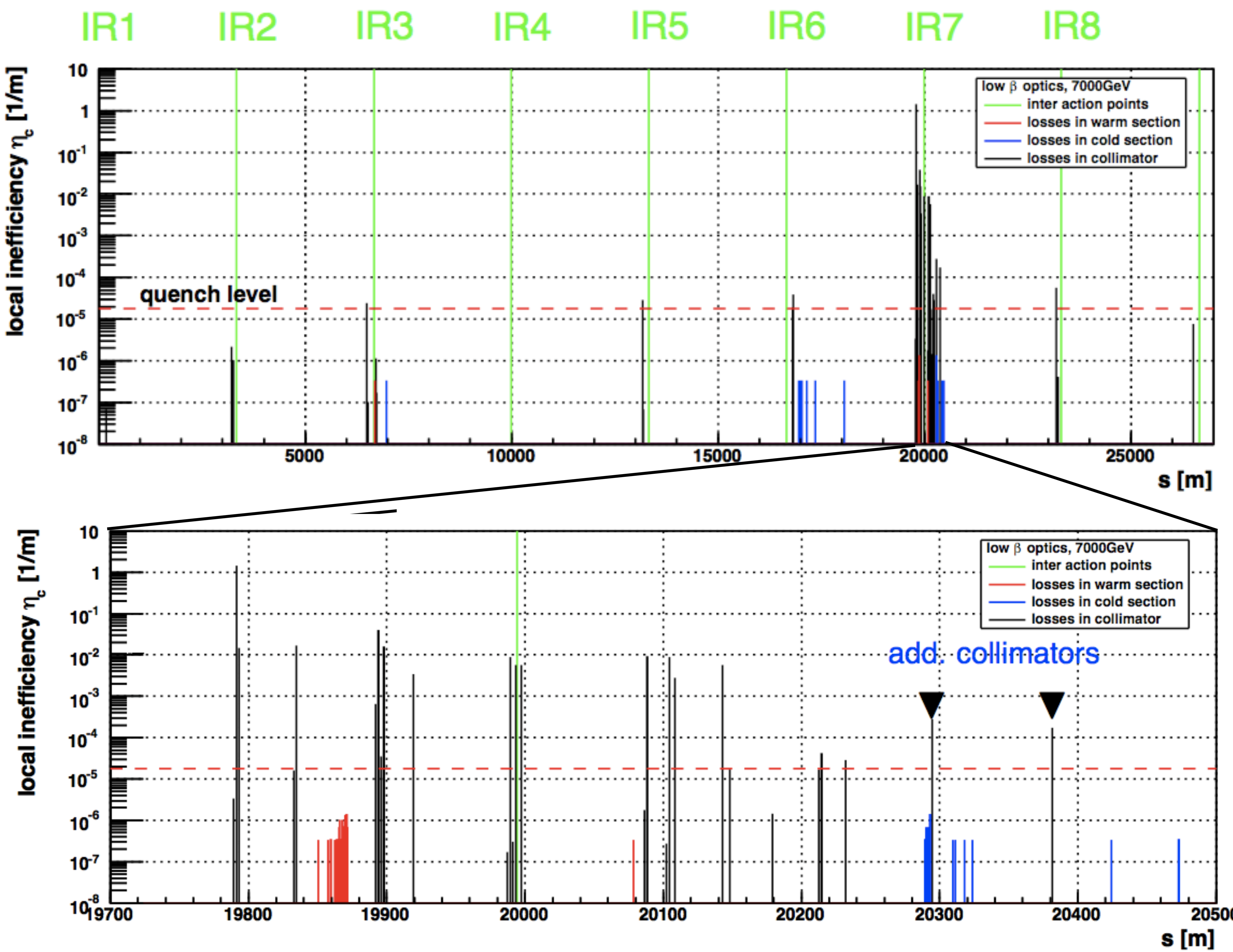
Predicted performance



7 TeV
Hor. halo
Perfect
machine

T. Weiler

Predicted performance



7 TeV
Hor. halo
Perfect
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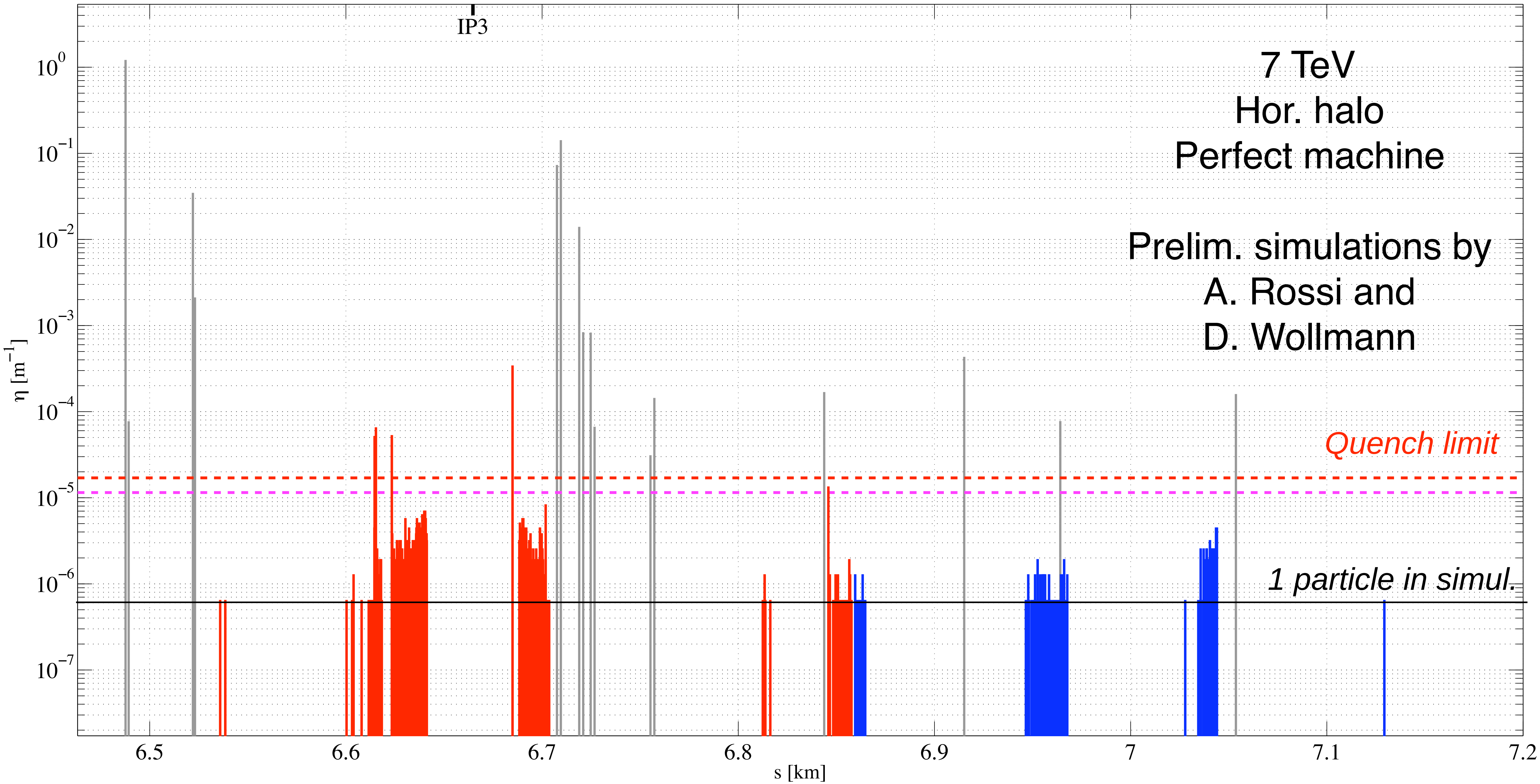
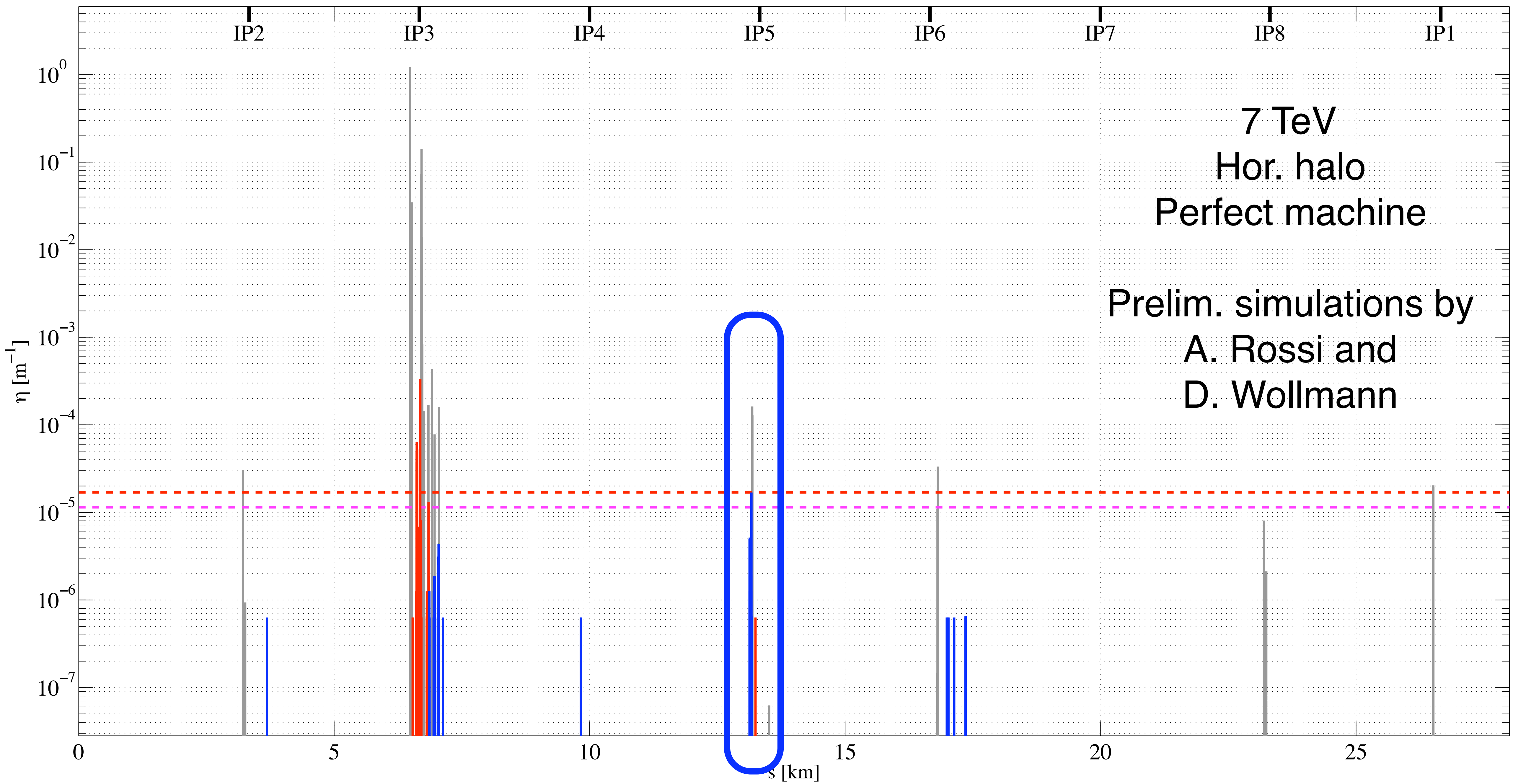
Cleaning performance (I)



Losses in the DS are caught by the local collimators: losses in magnet below quench limit!

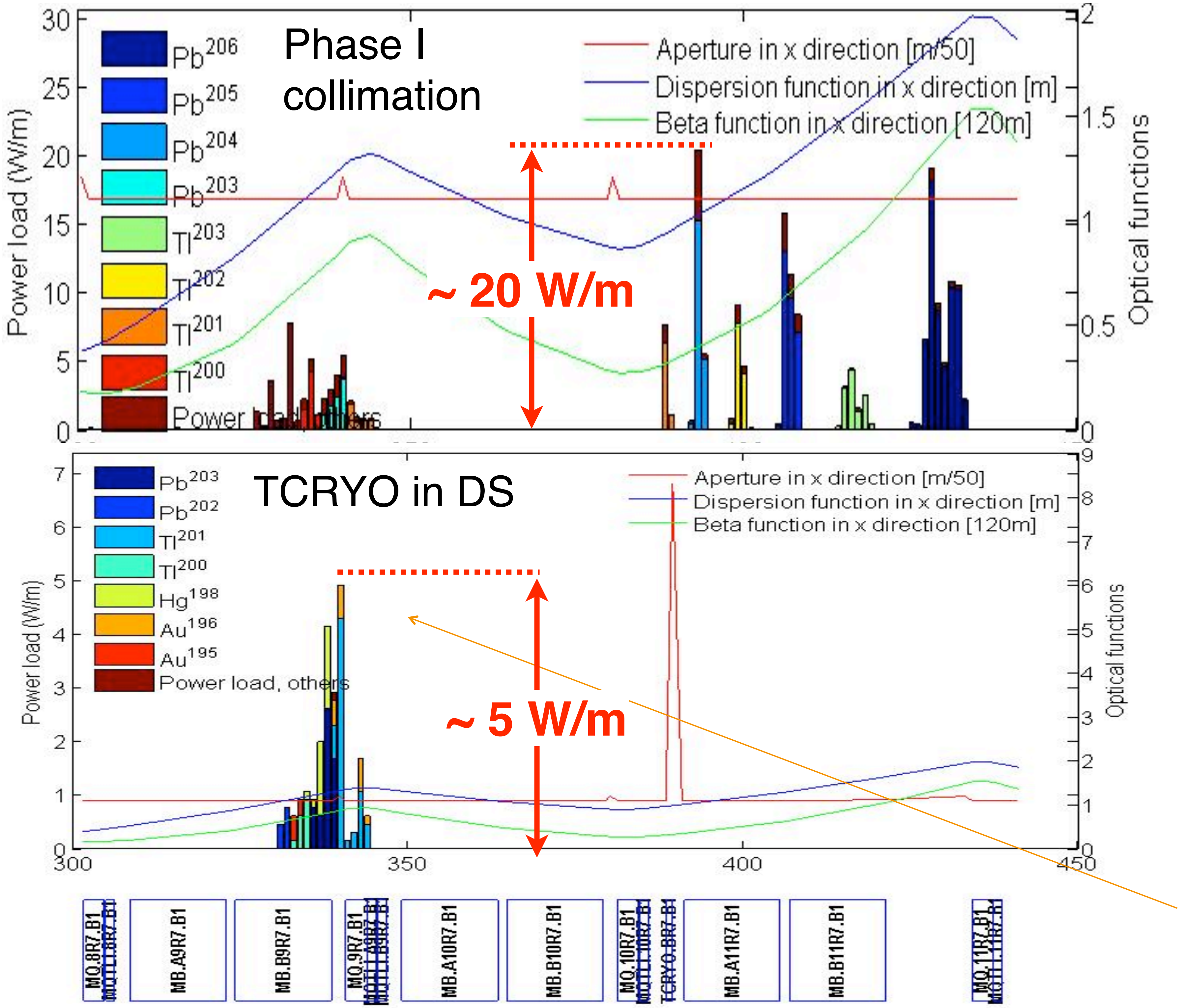
Cleaning performance (II)



Losses below quench limit in all the ring.

Increased losses in IP5: close to quench limit for perfect machine.
Worst for vertical halo.
This needs to be addressed.

Ion cleaning performance



Simulations by G. Bellodi:
- Ongoing for new IP3 optics
- Proof-of-principle by **IP7 simulations** (shown here)

Collimator in DS reduces loss peaks below quench limit in all the machine and as well as loads on TCTs.

Works well also for light ions.

This was identified as the only feasible solution that can solve the ion cleaning issue!

Below quench limit if TCRYO at 40 sigma!

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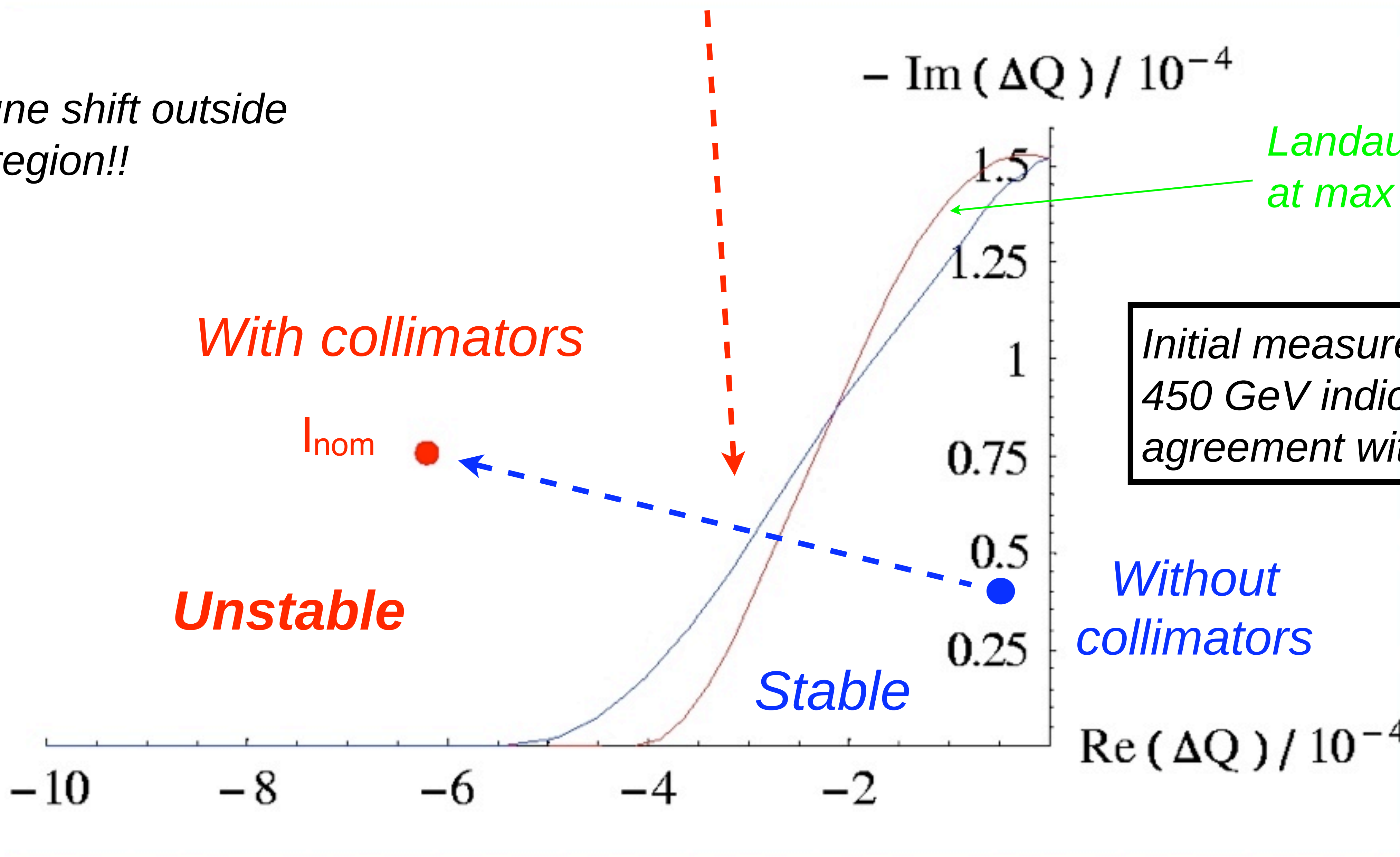
Impedance limitation of Phase I

$I_{max} \approx 40\% \; I_{nom}$

I_{nom} → tune shift outside stability region!!



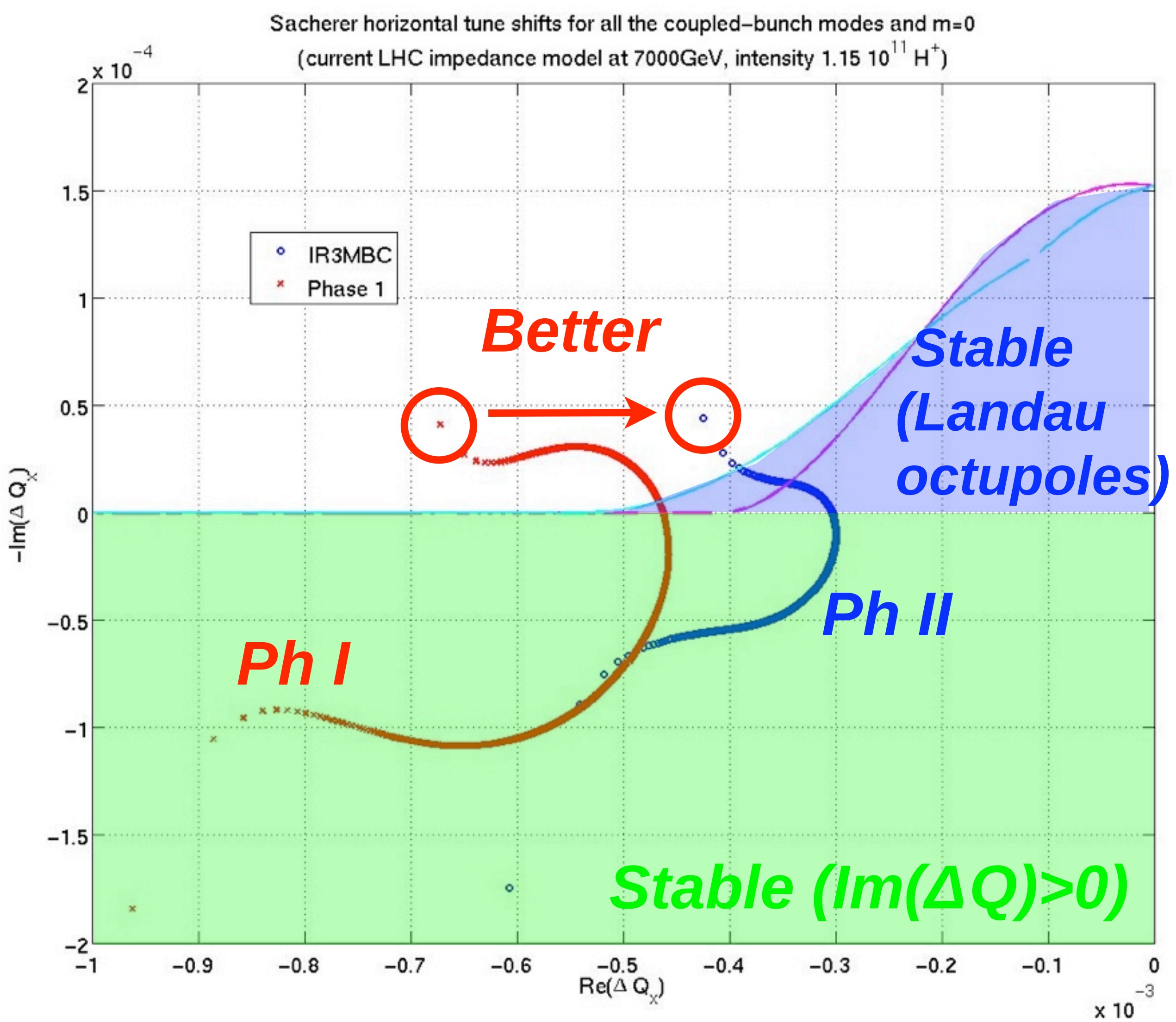
Landau octupoles at max strength

Initial measurements at 450 GeV indicate a good agreement with theory!

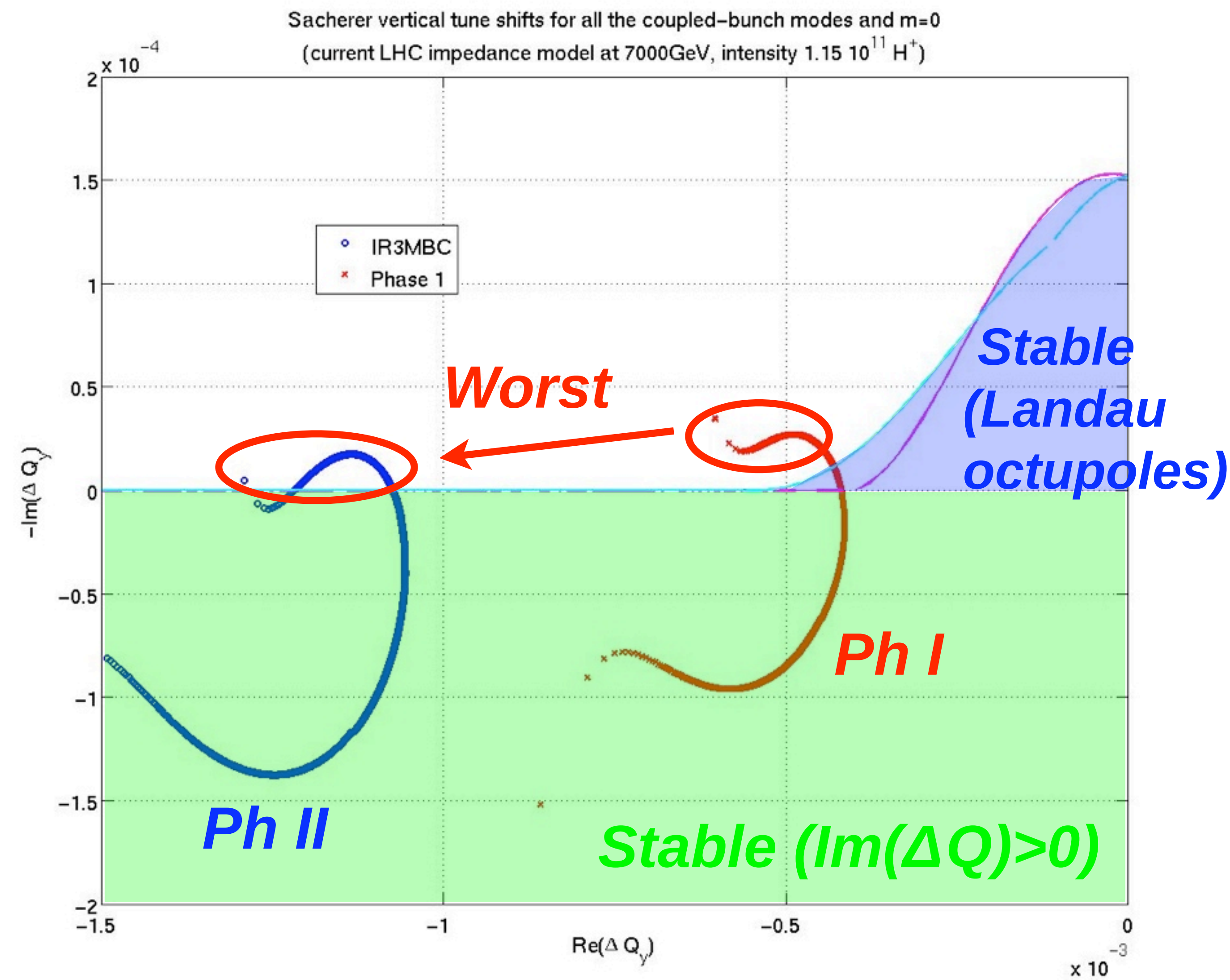
Courtesy of E. Métral, BE-ABP

Impedance for combined IR3 system

Horizontal stability diagram



Vertical stability diagram



*Preliminary results by **E. Métral** and **N. Mounet**, BE-ABP, indicate that*

- *The horizontal impedance improves with respect to Phase I!*
- *The imaginary part of the vertical impedance is worse by a factor 1.5 to 3*
  - *⇒ outside stability diagram + larger tune shift*
- *Head-tail simulations will address the single-bunch instabilities.*

Conclusions

- **Operation profits a lot from a good halo cleaning!**
  No quenches yet, but each fill would have with nominal intensity
- **First period of operation confirm our design assumptions**
  Cannot rely on too optimistic assumptions on lifetime.
  Cleaning limitation in dispersion suppressor are confirmed.
- **Reviewed various aspect of the proposed works in DS of IR3**
  More favorable for R2E aspects, according to simulations.
  Faster set-up with less collimators.
- **Performance of the Phase II combined system in IR3**
  Losses in DS are improved. Very promising for ion collimation.
  Additional losses in IP5 close to quench.
  Impedance improved in horizontal but is worst in vertical.
- **Other aspects not addressed by this review**
  Other limitations that require local cleaning -> Q4 in IP6
  BPM integrated design will speed-up setup procedure.