Overview of DS quench margin tests 2011 and goals for 2012

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Collimator losses in the DS of IR7 and quench test at 3.5 TeV

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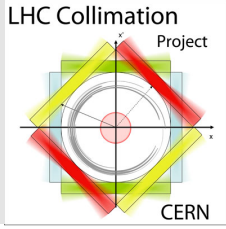
Summary

Beam studies to address the limitations of the Phase I collimation system were performed. The primary goal was to achieve the design loss rates of the collimation system of 500 kW, and to study the behaviour of the system and of the machine in these conditions. The beam-based determination of the quench limits of the cold magnets with highest losses, can also be addresses in this study. Beam tests consisted in increasing the loss rates at 3.5 TeV with nominal machine configuration and collimator settings in order maximise the losses in the dispersion suppressors of IR7, notably in the Q8 quadrupoles that represent the limiting location with highest leakage from IR7. The cleaning performance of IR7 is very good, with a leakage of a few 10^{-4} in the Q8. Therefore, the test had to be performed with stored energies well above the safe limit.

Outline

- **DS quench margin with Protons (08.05.2011)**
  - Results of experiment.
  - Assumptions for intensity limit due to collimation.
- **DS quench margin with IONs (06.12.2011)**
  - Results of experiment
  - Performance reach estimations for 3.5 TeV and 7 TeV
  - Assumptions used for estimate
- **Goals for 2012 DS quench tests**

DS quench margin with Protons (08.05.2011): MD Steps

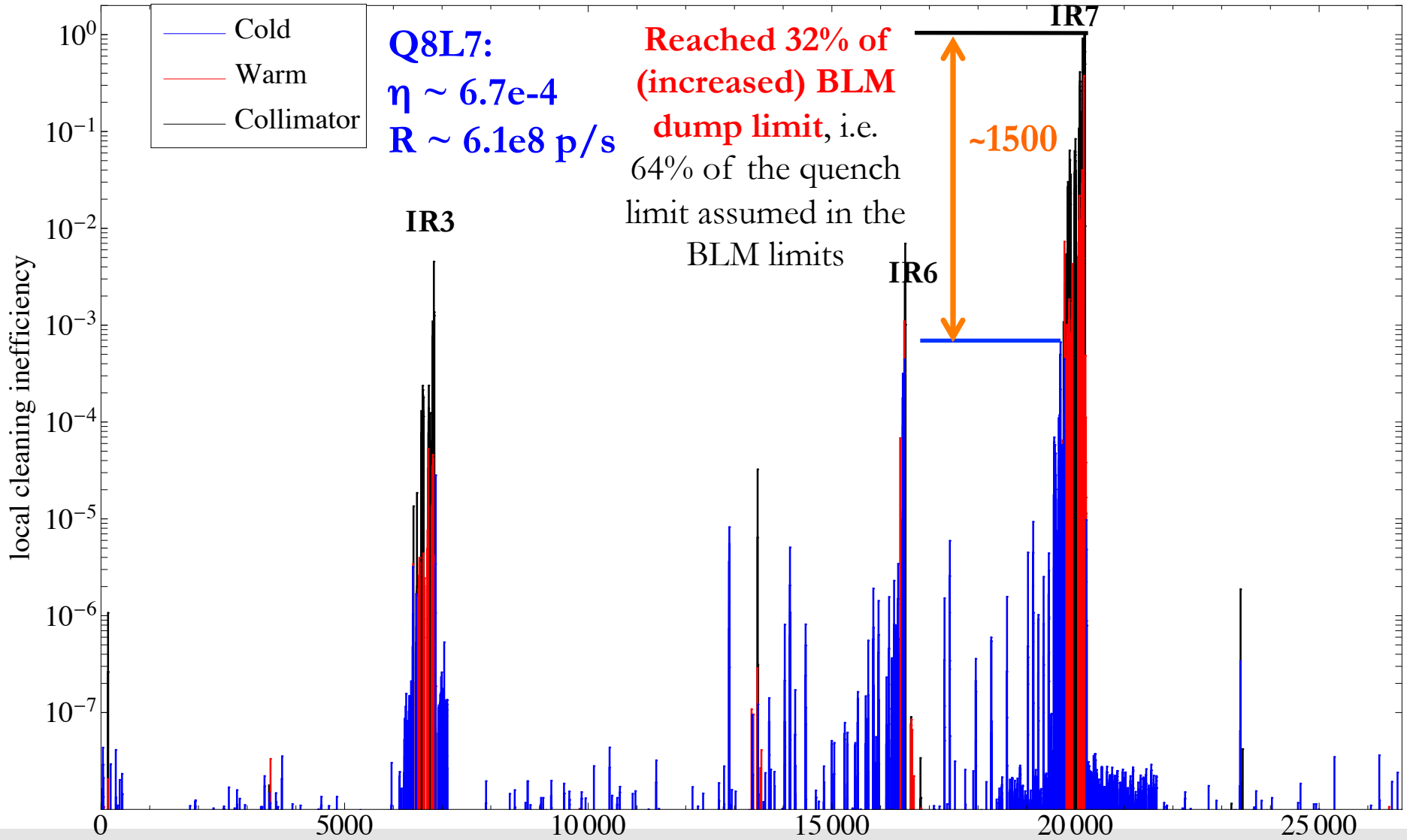


- **Increase thresholds** for ~100 monitors in limiting locations (Collimators, warm magnets, Q6 in IR7, Q4 and Q5 in IR6, Q8 in IR7) for RS09 and higher
- 1st (test) ramp with **3 bunches** per beam and scale intensity linearly up to achieve a loss of 500kW
- 2nd ramp with **16 bunches**, achieved loss rate **of 9.1e11 p/s** in B2 hor (both beams dumped shortly after the loss, due to turning on ADT)
- 3rd ramp with **16/24 bunches** (B1/B2), achieved loss rate 4.2e11 p/s in B1 hor (both beams dumped a few seconds after the loss due to software interlock on BLM voltage supply).
- Put thresholds during TS back to previous settings

DS quench margin with Protons

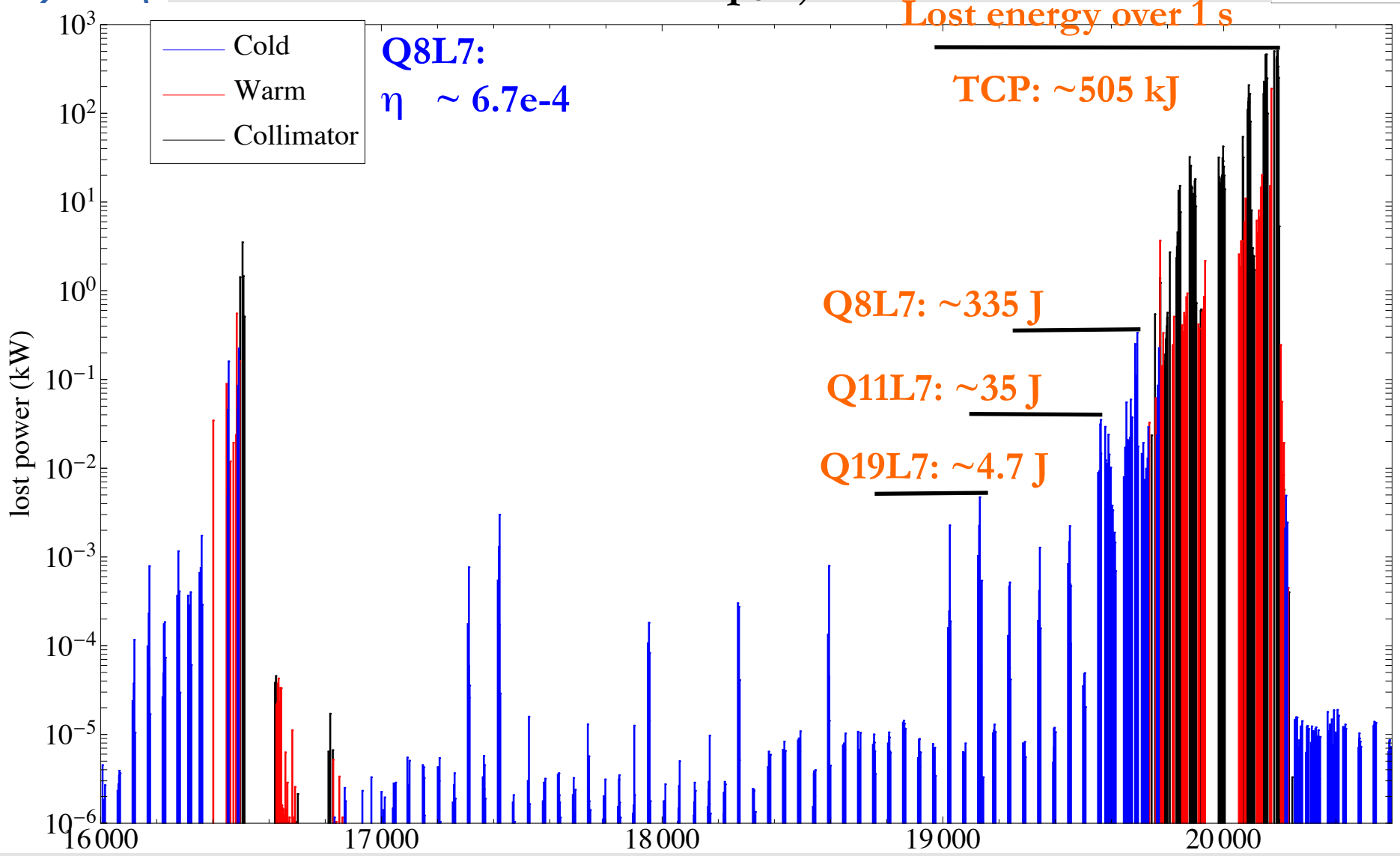
Losses B2 hor, 2nd ramp

peak loss rate ~ **9.1e11 p/s**



DS quench margin with Protons

Measurement: **500kJ losses** at primary collimators (loss rate: **9.1e11 p/s**) – IR7



Proton Performance Reach
Measured Collimation Dependent Intensity Limit

Collimation dependent **beam lifetime: ~1h**

Ratio of **cleaning inefficiency** between intermediate and tight collimator settings: **~3.3**

Maximum **loss rate** at primary collimators before causing a quench: **9.1×10^{11} p/s**

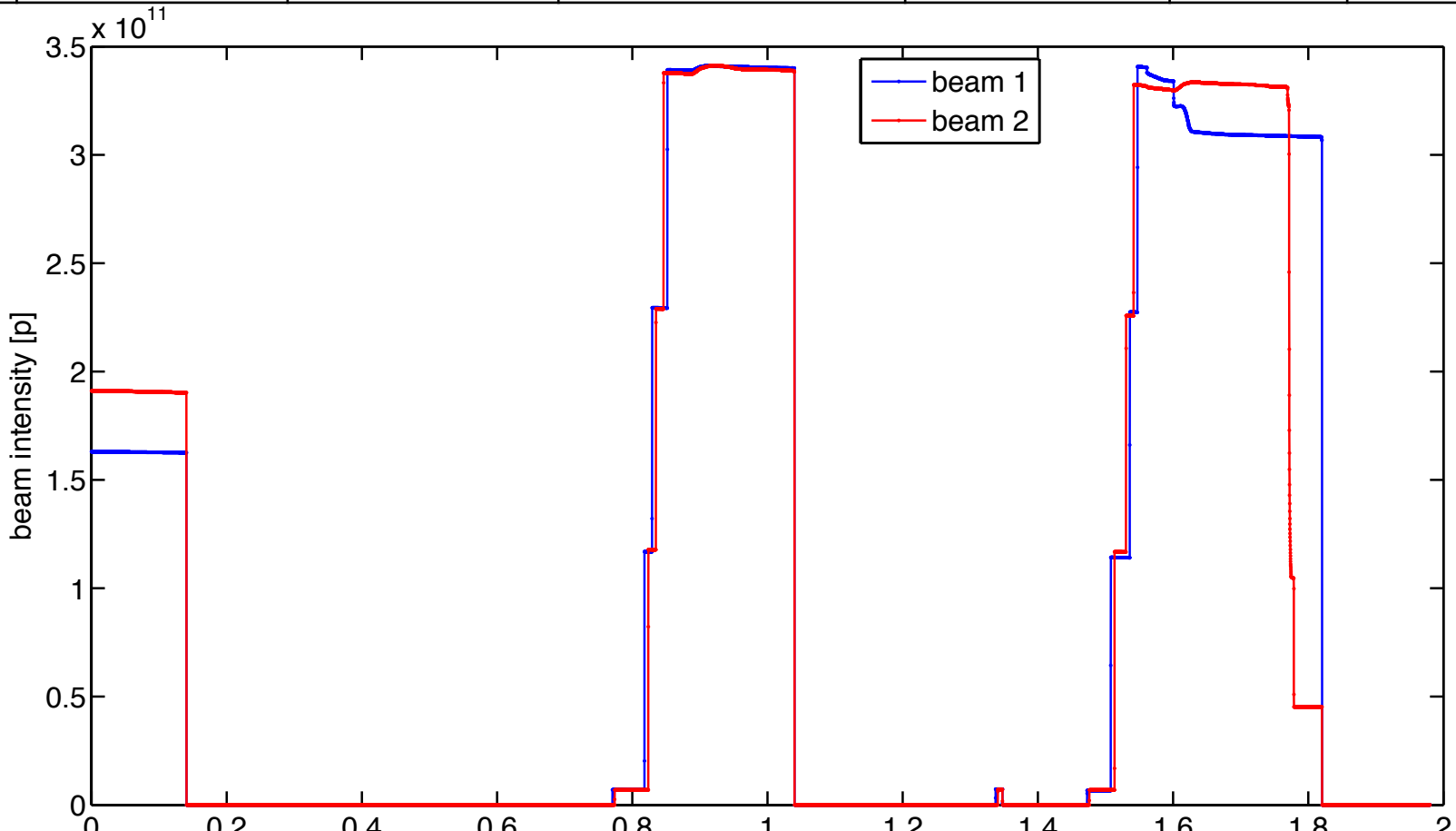
$$N_p^{\max} \geq c_{clean} \cdot \tau \cdot R_{loss}^{prim} = 1.1 \times 10^{16}\, p$$

- 30 times nominal intensity (~3×10^{14} p) at 3.5 TeV.
- Scaling to 7 TeV: sufficient for nominal and ultimate intensity.

➔ **Upgrade** of DS in IR3 with collimators **postponed to after LS1**.

DS quench margin with Ions (06.12.2011):
3 Ramps, 3 experiments with B2, 1 with B1

Ramp	I (B1) [charges]	I (B2) [charges]	$(dI/dt)_{max}$ [charges/s]	$\mathbf{(dI/dt)_{time}}$ **[ms]**	Dump	Magnet
1	1.64e11 (20b)	1.9e11 (24b)	**B2:** 2.7e11	**75**	RS06	Q9.L7
2	3.4e11	3.4e11	**B2:** 2.5e11	**100**	RS07	Q19.L7
3	3.4e11	3.4e11	**B2:** 4.9e10	**1000**	-	-
3	3.4e11	3.4e11	**B1:** 1.1e11	**200**	RS07	Q11.R7



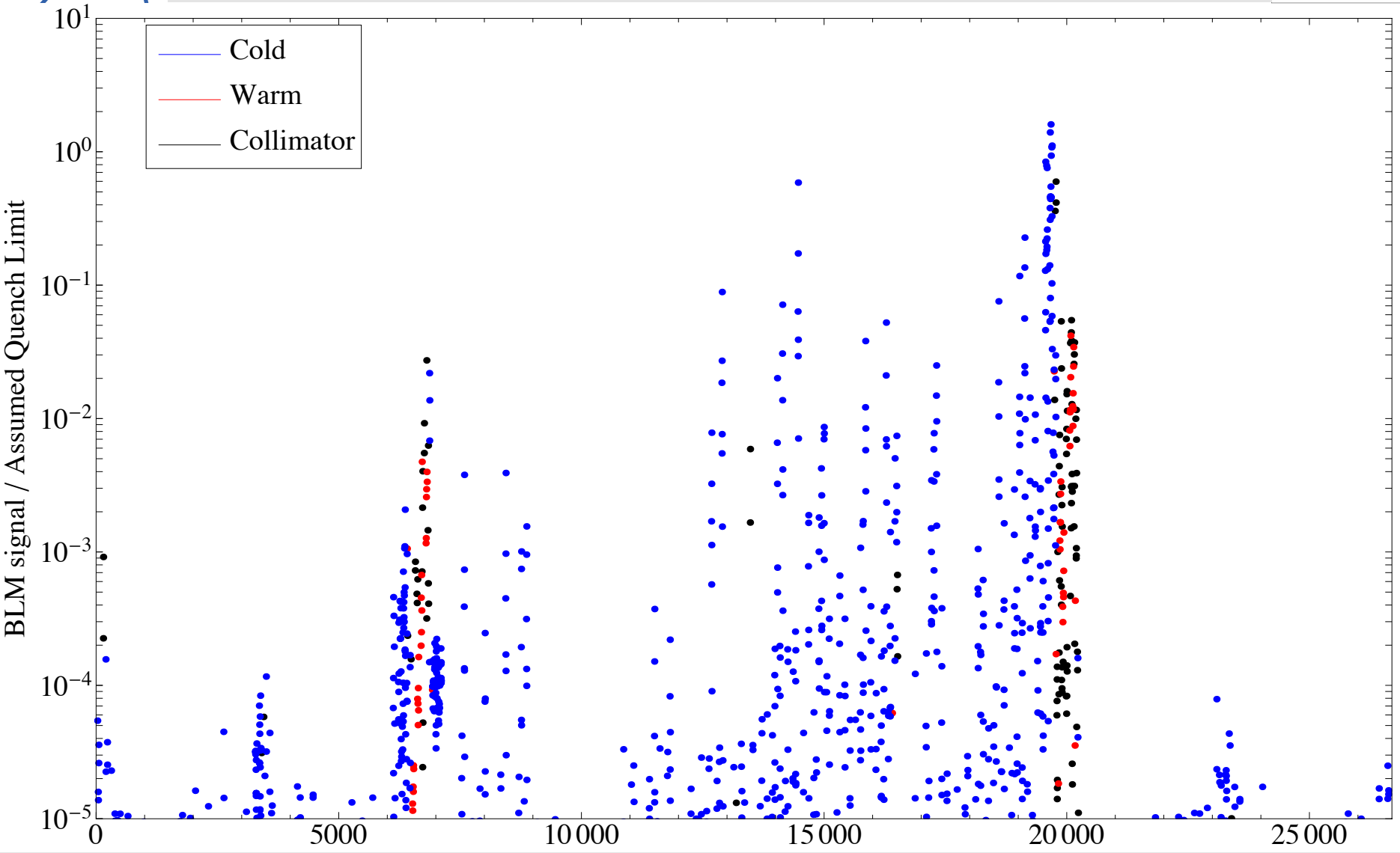
DS quench margin with Ions: Results of experiment

Ratio of BLM-Signal to assumed quench limit (i.e. 3x operational BLM dump thresholds)

Ramp	Ratio RS02	Ratio RS04	Ratio RS06	Ratio RS07	Ratio RS09
1	MB9.L7: 0.26	MB9.L7: 0.07	Q8.L7: 0.57	Q8.L7: 1.14	MB9.L7: 0.29
2	Q8.L7: 0.08	Q8.L7: 0.16	Q8.L7: 1.66	Q8.L7: 2.35	Q9.L7: 0.49
3	MB9.L7: 0.005	MB9.L7: 0.015	Q8.L7: 0.15	Q8.L7: 1.03	MB9.L7: 1.60
3	Q11.R7: 0.01	Q11.R7: 0.03	Q11.R7: 0.46	Q11.R7: 1.16	Q11.R7: 0.55

- **Fast losses, almost in UFO regime.**
- Dumps due to high losses in short running sums (RS06, RS07): Ramp 1, 2 and 3 (B1).
- Ramp 3 (B2): creating high slow losses by carefully approaching the third order integer resonance.
- RS09: MB9.L7 reached 1.6 x assumed quench limit
- Cryo: Significant temperature increase in connection cryostat (ramp 3).

Ration of BLM signal to assumed quench limit (Ramp 3 B2, RS09)



Performance estimate with Ions for 3.5TeV and 7TeV

- Ion design intensity: $N_{tot,des}$= 4.1e11 ions * 82 charg/ion= 3.4e12 charg
- **Measured** loss rate for long slow losses: **4.9e10 charg/s**
- Performance **improvement** compared to design loss rate (τ = 0.22h, $N_{tot,des}$): 4.3e9 charg/s ➔ 4.9e10 / 4.3e9 **= 11.4**
- **Scaling** from 3.5 to 7 TeV: decrease of **quench limit** [mJ/cm^3] : factor ~4.5 (source A. Verweij); **deposited energy** per charge increases ~ 2; I.e. scaling by ~**1/9** ➔ 11.4 / 9 = **1.3**
- **Estimated total intensity** with Ion at 7TeV taking into account that lifetime τ_{meas}**> 1h** (4.5 x 0.22h): $N_{tot,est}$= 1.27 x 4.5 = **5.7 x $N_{tot,des}$**
- **Luminosity limit**: Losses in 8.L7 **~100 x higher** than losses in 10.L2 during Ion luminosity runs (10.L2) ➔ translates into **2 - 5 x design lumi at 7 TeV**
- **Note: Figures are conservative**
  - Used losses in 1s time scale: factor ~5
  - Scaling to 7 TeV: factor ~3

Assumptions / Uncertainties for the Estimate

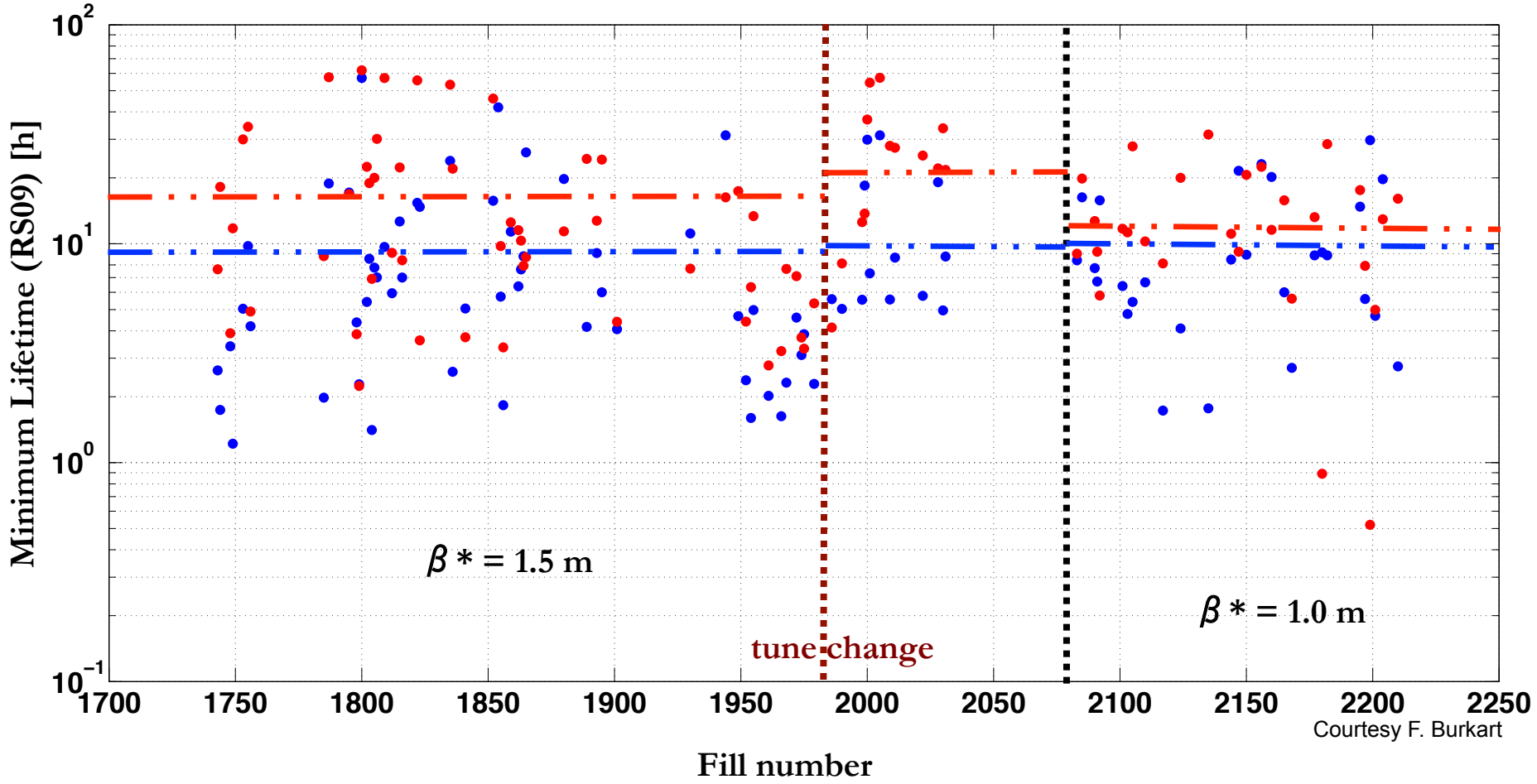
- No quench achieved, i.e. these figures are conservative.
- Used loss rate of Ramp3 (B2) as significant losses above assumed quench limit in RS09 were only achieved.
- Uncertainty in scaling of quench limit from 3.5 TeV to 7TeV (1/9 compared to the 1/3).
- Same cleaning inefficiency at 7TeV as at 3.5TeV. Probably not true: should be worse?
- Same lifetime assumed for 7TeV as measured at 3.5TeV.
- Loss pattern seems to be different in the fast and slow loss cases. Does this have beam dynamics reasons?
- Improvement of cleaning with nominal/tight collimator settings?
- Peak loss rate was not achieved for times > 1s

Goals for DS quench tests 2012 preliminary, tbc

- Commission and use **ADT** to create **losses** in a more **controlled** way.
- Define quench limit by **causing a quench of a DS magnet** (e.g. Q8) with a relevant loss pattern (for Protons & Ions).
  - Increase **peak loss rate** at primary collimators.
  - Increase the **length of losses** at primary collimators. ➔ Peak loss rate at primary collimators for ~ 10s.
- Verify results in the DS left and right of **IR7 and IR3.**
- Verify the Ion luminosity limit assumptions.

Backup Slides

Collimation dependent Beam Lifetime



- Average: B1: 9.9h, B2: 16.8h
- **Minimum:** B1: 1.3h, B2: 0.52h