MD 4044: Asynchronous beam dump test with bunched beam at flat top

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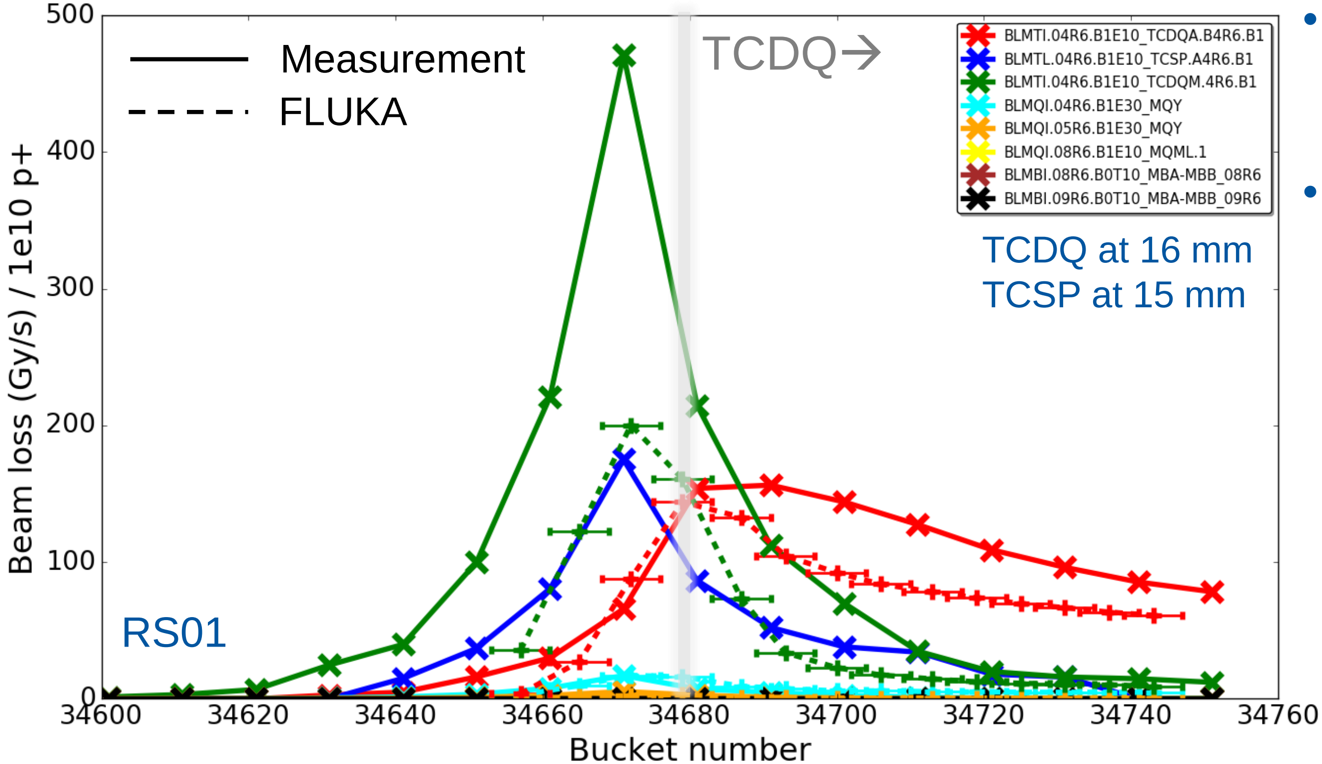
Motivation

- Understanding of asynchronous beam dumps and predictions for HL-LHC rely on
  - Beam-transport model in extraction region
  - Energy-deposition studies (FLUKA)
- FLUKA studies show that energy deposition strongly depends on the TCDQ impact parameter
- Measurements of asynchronous beam losses in controlled conditions for different impact parameters are required to validate models
- Still to be understood:
  - Why is Beam 1 more likely to quench a magnet?
  - Why is Q4 more likely to quench than Q5, even though FLUKA results indicate higher energy deposition in Q5 than in Q4?

Beam-loss behaviour at 450 GeV

Beam 1



← less MKD kick　　　　more MKD kick →

← closer to circulating beam center　　　　higher impact parameter on TCDQ →

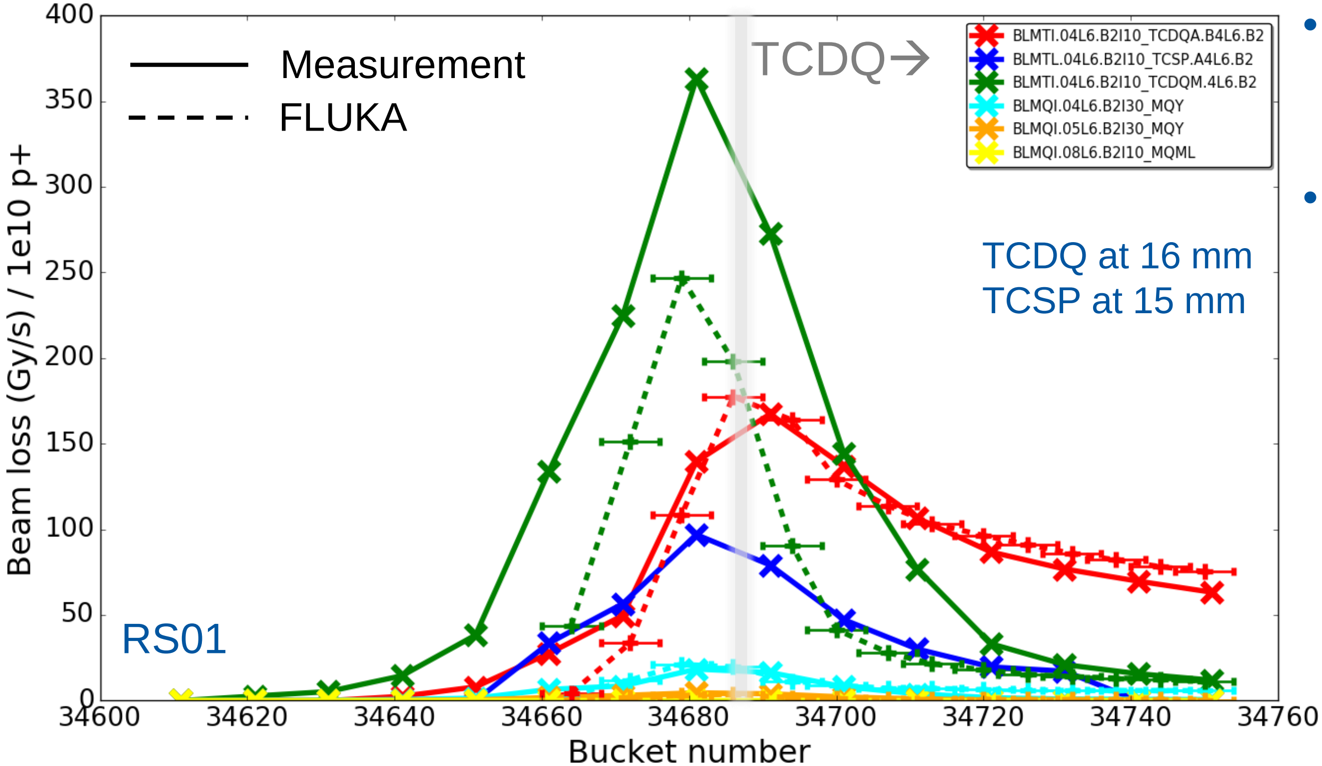
FLUKA simulations by M. Frankl

FLUKA values scaled with factor 0.29/40us

- MD2930, Part 1: Pilots at 450 GeV injected into abort gap and dumped
- FLUKA studies show:
  - Qualitative loss behaviour can be reproduced
  - Absolute level of predicted losses have to be further investigated (effect of BLM saturation, RC filter, ...)

Beam-loss behaviour at 450 GeV

Beam 2



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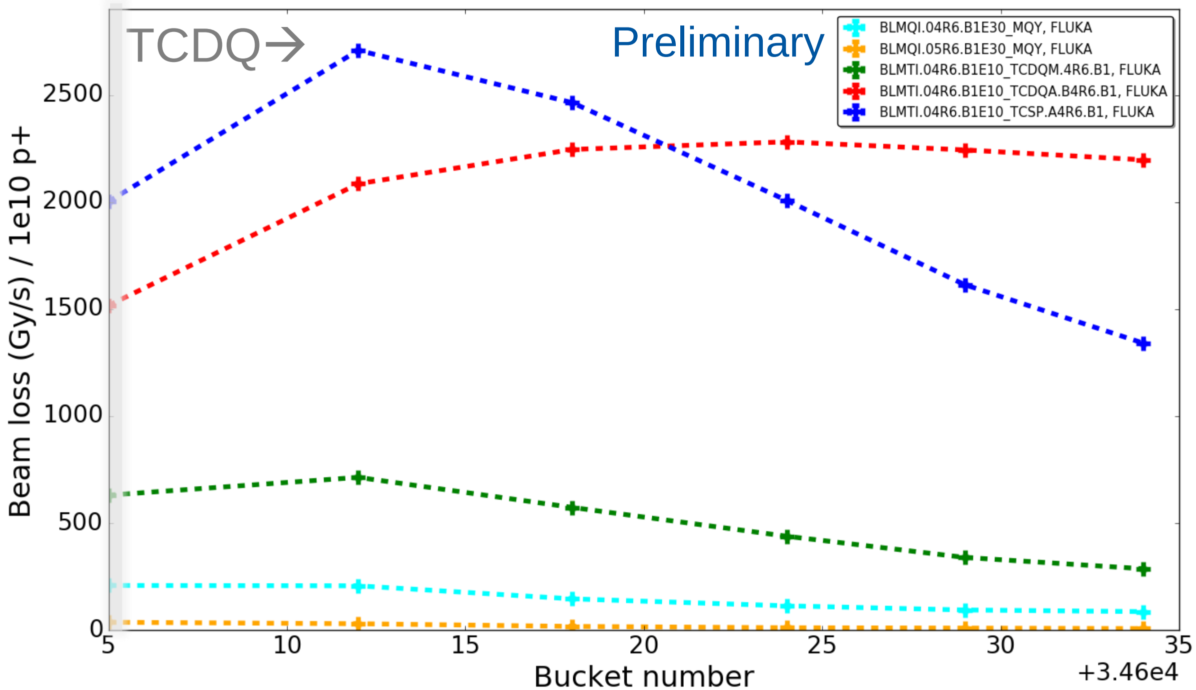
FLUKA simulations by M. Frankl

FLUKA values scaled with factor 0.36/40us

Beam-loss behaviour at 6.5 TeV?

Expected energy deposition at 6.5 TeV (FLUKA)



FLUKA simulations by M. Frankl

MD4044: Measure BLM response at 6.5 TeV as a function of the TCDQ impact parameter

- 2 Buckets measured in MD2930:
  - Bucket 34621: 1e10 p+
  - Bucket 34631: 1.8e10 p+
- Still some uncertainty in the impact parameter
- At least 3 more buckets required: 34641, 34611, *34621*, (34601)?
- Measure buckets for both beams simultaneously
- Use single pilots: ~5e9 p+
  - → Avoid BLM saturation
  - → Reduce risk of magnet quench

Beam-loss behaviour at 6.5 TeV?

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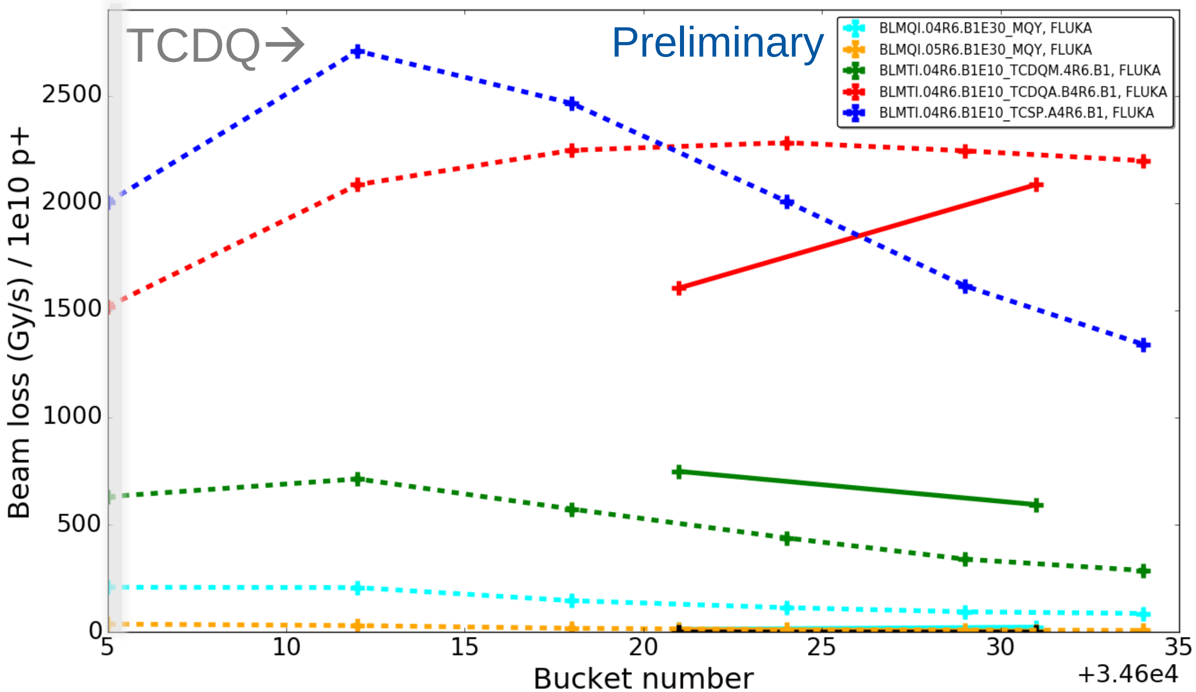

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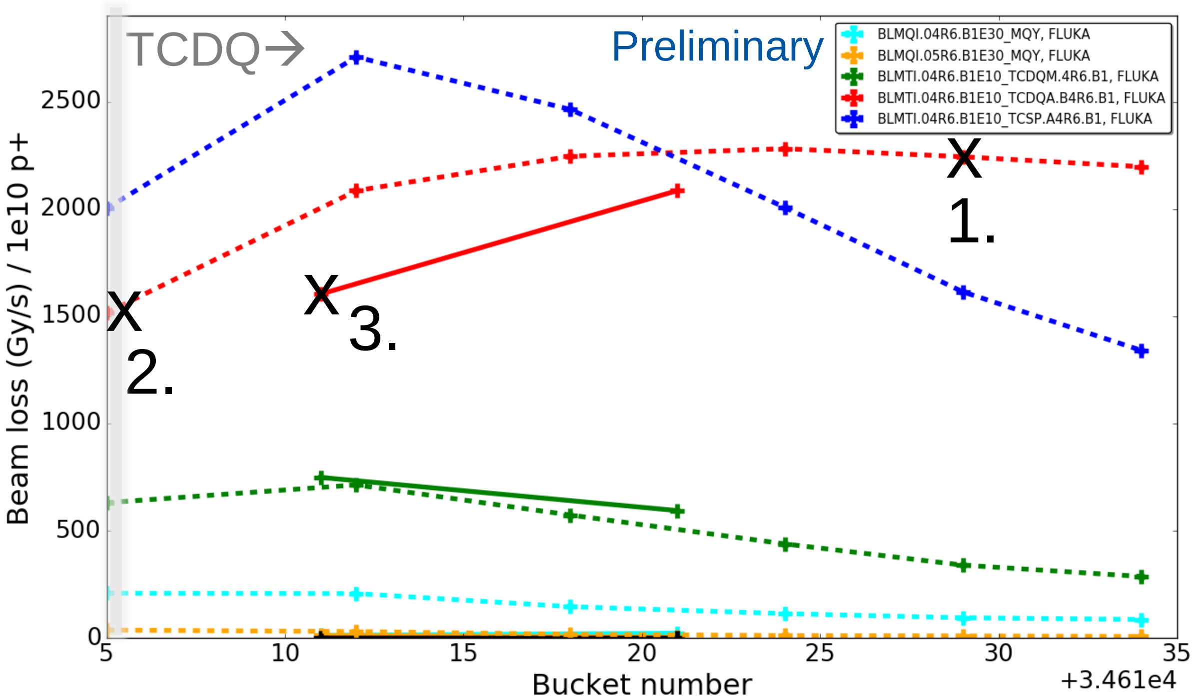

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Procedure

1) Preparation of the MD (1 hour)

- Modify AG settings to allow injection into the AG: procedure as established during MD2930.
  - New: MKI fine delay settings have to be changed also in the SIS (if not maskable?)

2.1) Probe AG with pilots at 450 GeV (0.5 hours)

- Check reproducibility of the results of MD2930 for ~6 characteristic points.

2.2) Probe AG with pilots at 6.5 TeV (6.5 hours)

- Inject single pilot for both beams simultaneously and dump
- Repeat for 3 to 4 pilots
- No bump at TCDQ

3) Recovery (2 hours)

- Roll back AG settings (unmask interlocks, roll back MKI settings)
- Revalidation:
  - if possible (e.g. no quench): revalidate AG-protection functionality with beam at the end of the MD
  - otherwise: revalidate at restart after TS2

Summary of MD Parameters

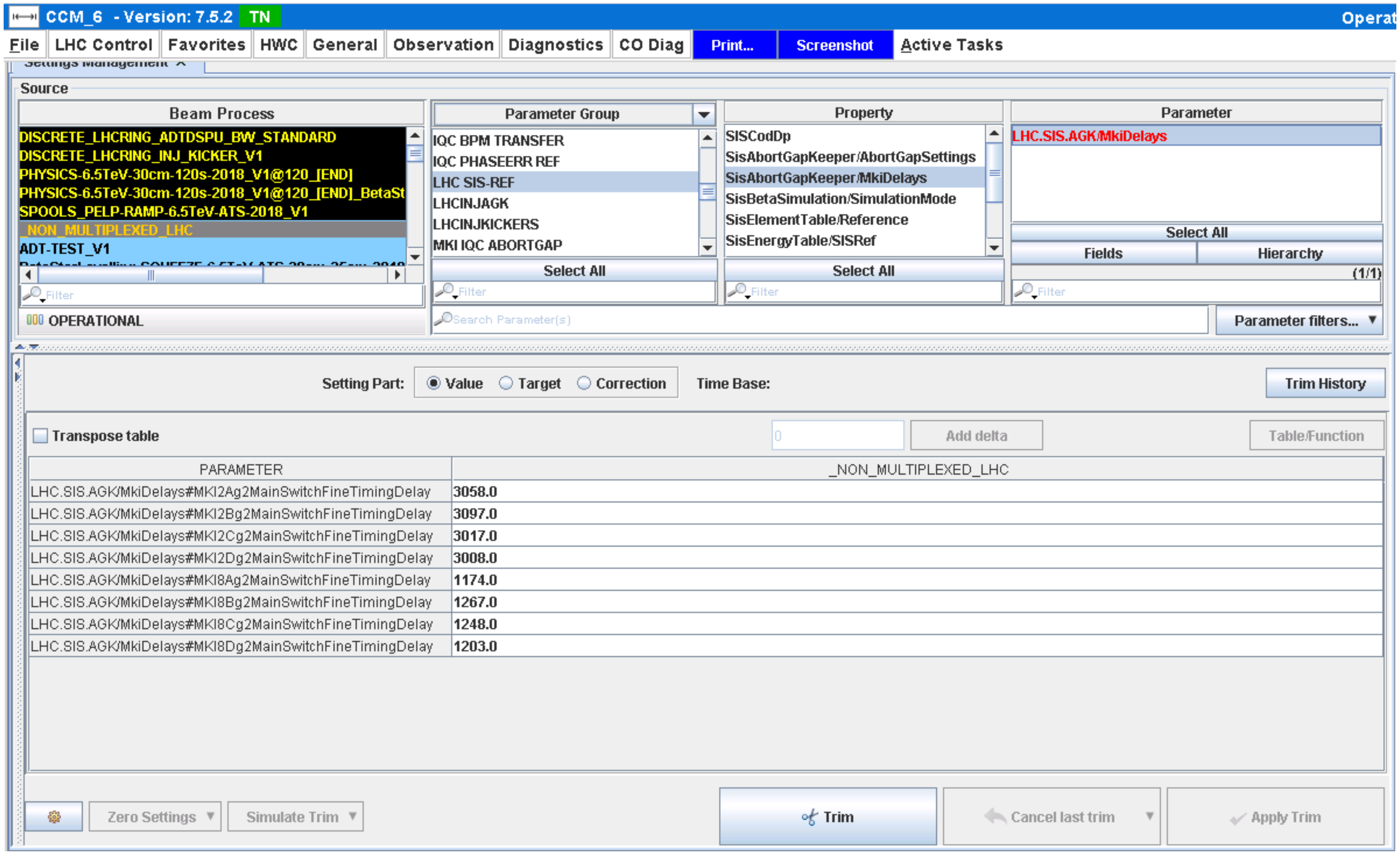
Specie	Protons
Category	Normal MD
Time required [h]	10 hours
Beams required [1, 2, 1&2]	Both
Beam energy [GeV]	450 GeV / 6.5 TeV
Optics (injection, squeezed, special)	Injection / Flat top with 1m beta*
Bunch intensity [#p, #ions] and Number of bunches	Single pilots (~5e9 to 2e10 p+)
Transverse emittance [m rad]	Nominal values (exact value not critical)
Bunch length [ns @ 4s]	Nominal values
Optics change [yes/no]	No
Orbit change [yes/no]	No
Collimation change [yes/no]	No
RF system change [yes/no]	No
Feedback changes [yes/no]	No
What else will be changed?	In order to inject into the Abort Gap (AG), the AG protection settings have to be modified before the measurement and revalidated after the measurement.
Are parallel studies possible?	No
Other info/requests	Risk of magnet quenches in IR6?

Thank you for your attention!

Changes of Abort-Gap Protection

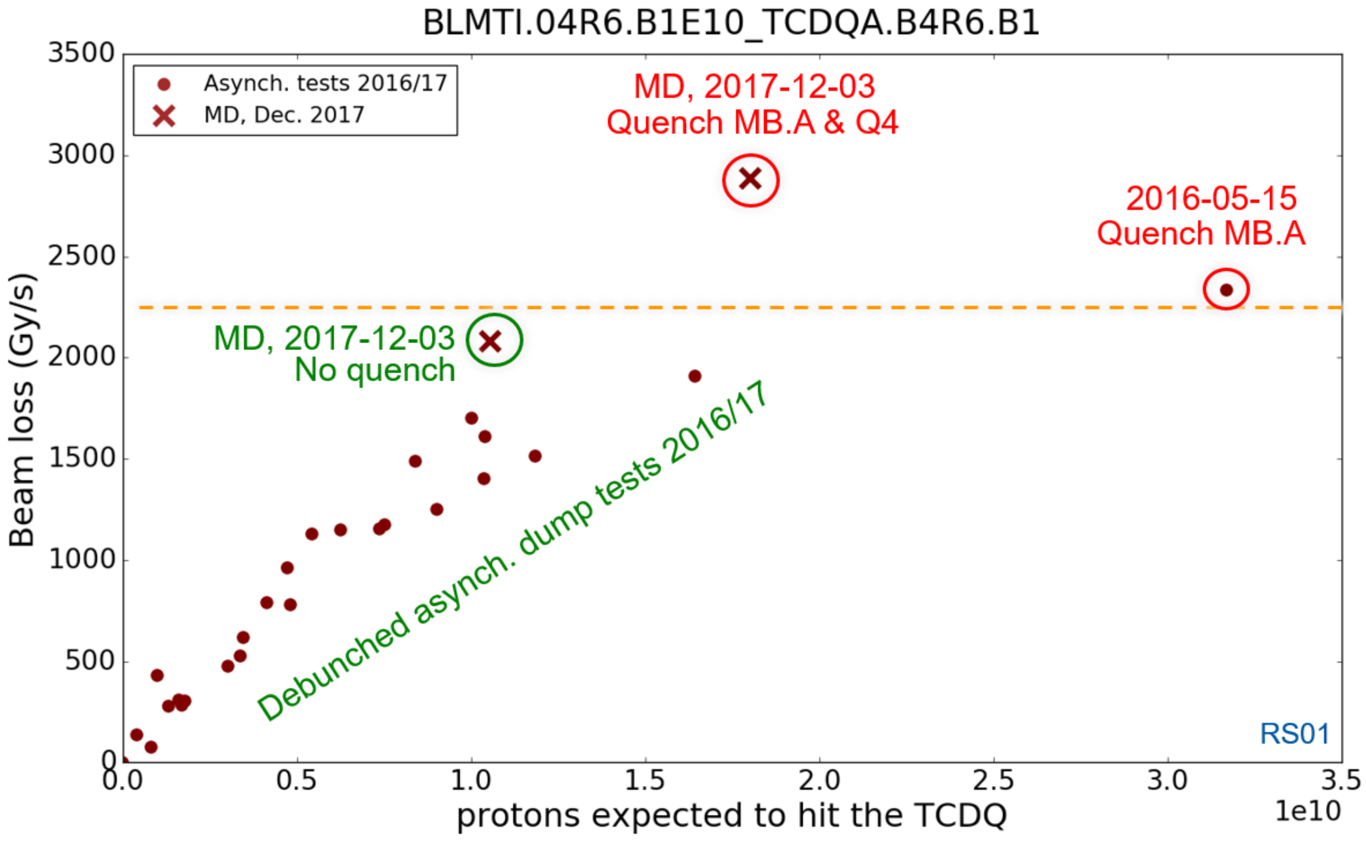
- Change the four MKI fine delay settings each by +20 us for both MKI.2 and MKI.8.
  - Now, injection into the abort gap should be possible, but injection between +12 us to +20 us (buckets ~4800 to ~8000) should be blocked.
- Change MKI settings in the SIS (if not maskable)
- Disable abort-gap cleaning.
- Disable steps in the injection sequencer that check:
  - if first bucket is not after LAST_LEGAL_INJECTION_BUCKET
- Mask abort-gap relevant interlocks in SIS:
  - INJ_PERMIT tree (Acting on both beams):
  - SPS_BQM
  - INJECTION_REQUEST_BUCKET_NO_BUNCHES
  - INJ_B1(2)_PERMIT trees (Acting on a single beam):
  - INJECTION_BUCKETB1(2)

MKI Delays (SIS)



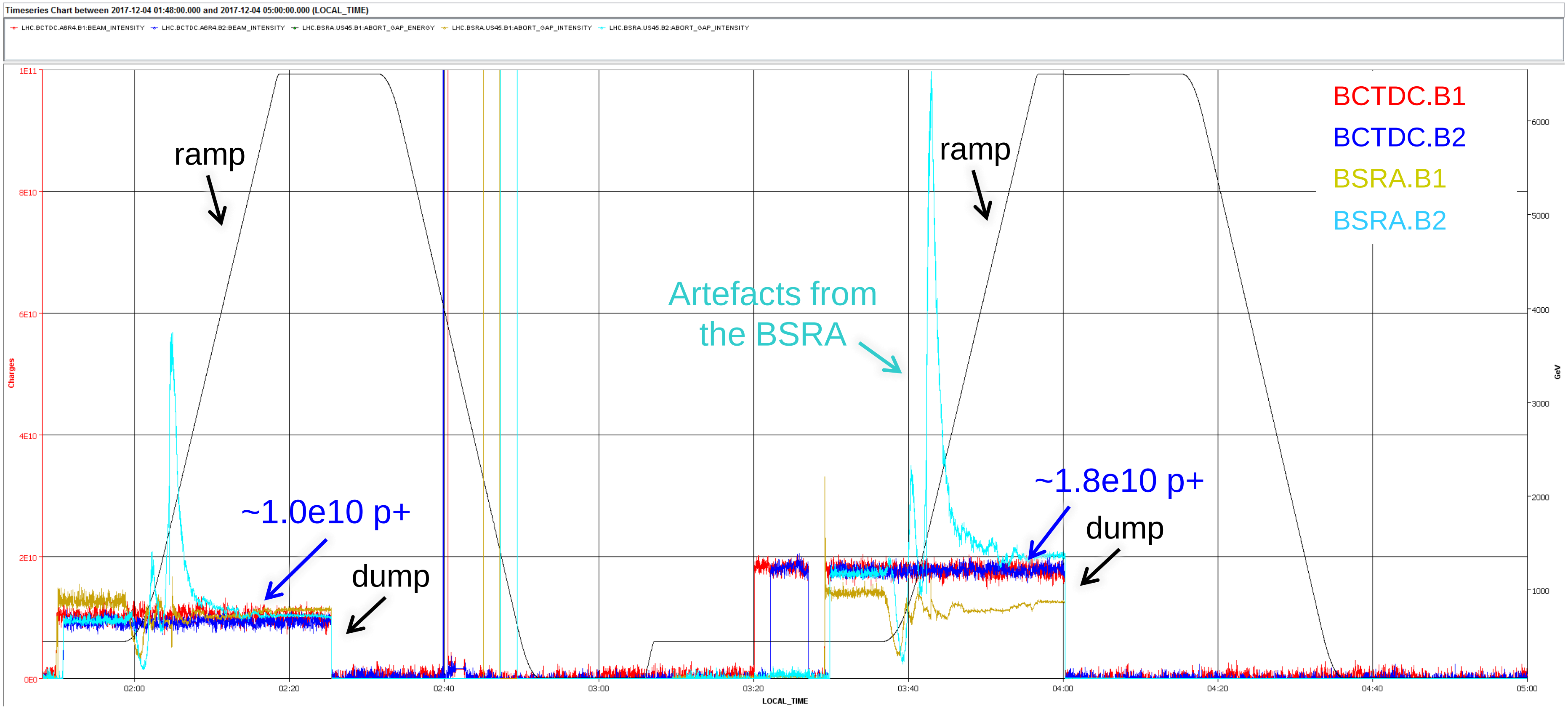
Loss Limits

Beam 1



MD2930: Single Pilots at 6.5 TeV

- One pilot in the abort gap close to the TCDQ edge for both beams
- First time that LHC was ramped with bunched beam in the AG (?)
- Intensity ~1.0e10 p+ in bucket 34631 → **No quench.**
- Intensity ~1.8e10 p+ in bucket 34621 → **Quench.**



MD2930: Single Pilots at 6.5 TeV

Beam 1:

- **Q4 and MB.A8R6 quenched due to beam losses**
- Q5 did not quench even though higher energy deposition than Q4 expected
- **Q8 and Q9 quenched due to electro-magnetic coupling** from the MB

		2016-05-15 – Beam 1			2017-12-04 – Beam 1	
Magnet	T (K)	ρ_{energy} (mJ/cm³)	Quench expected?	Quench observed?	Quench expected?	Quench observed?
MQY.4R6	4.5	30	Yes	No	?	Yes
MQY.5R6	4.5	50	Yes	No	?	No
MB.A8R6	1.9	27	Yes	Yes	?	Yes
MB.B8R6	1.9	5	No	(Yes)*	?	(Yes)*
MQML.8R6	1.9	1.5	No	(Yes)**	?	(Yes)**
MB.A9R6	1.9	< 0.1	No	No	?	No
MB.B9R6	1.9	< 0.1	No	No	?	No
MQM.9R6	1.9	0.25	No	(Yes)**	?	(Yes)**

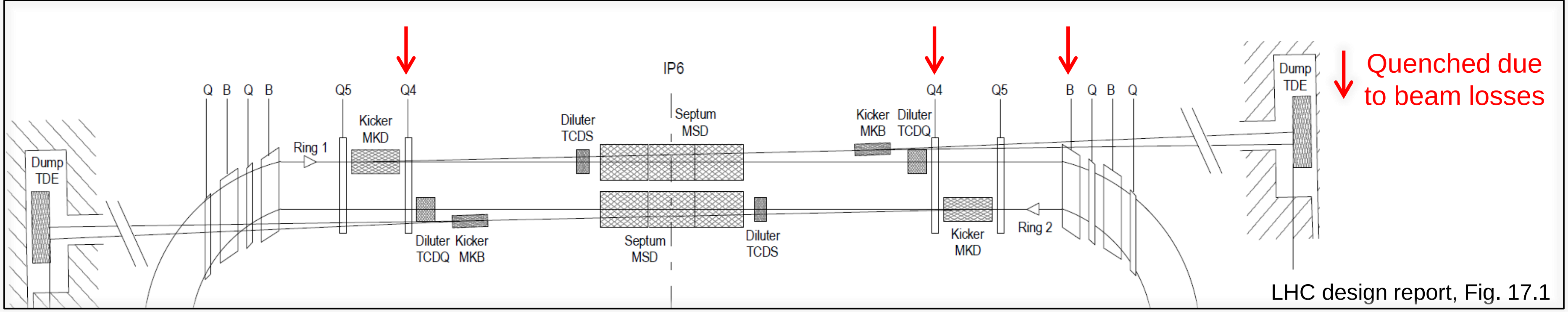
*quenched due to heat propagation
**quenched due to e-m coupling?

MD2930: Single Pilots at 6.5 TeV

Beam 2:
- **Q4 quenched due to beam losses**
- Q5 did not quench even though higher energy deposition than Q4 expected

2017-12-04 – Beam 2

Magnet	T (K)	Quench observed?
MQY.4R6	4.5	Yes
MQY.5R6	4.5	No
MB.A8R6	1.9	No
MB.B8R6	1.9	No
MQML.8R6	1.9	No
MB.A9R6	1.9	No
MB.B9R6	1.9	No
MQM.9R6	1.9	No



LHC design report, Fig. 17.1