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

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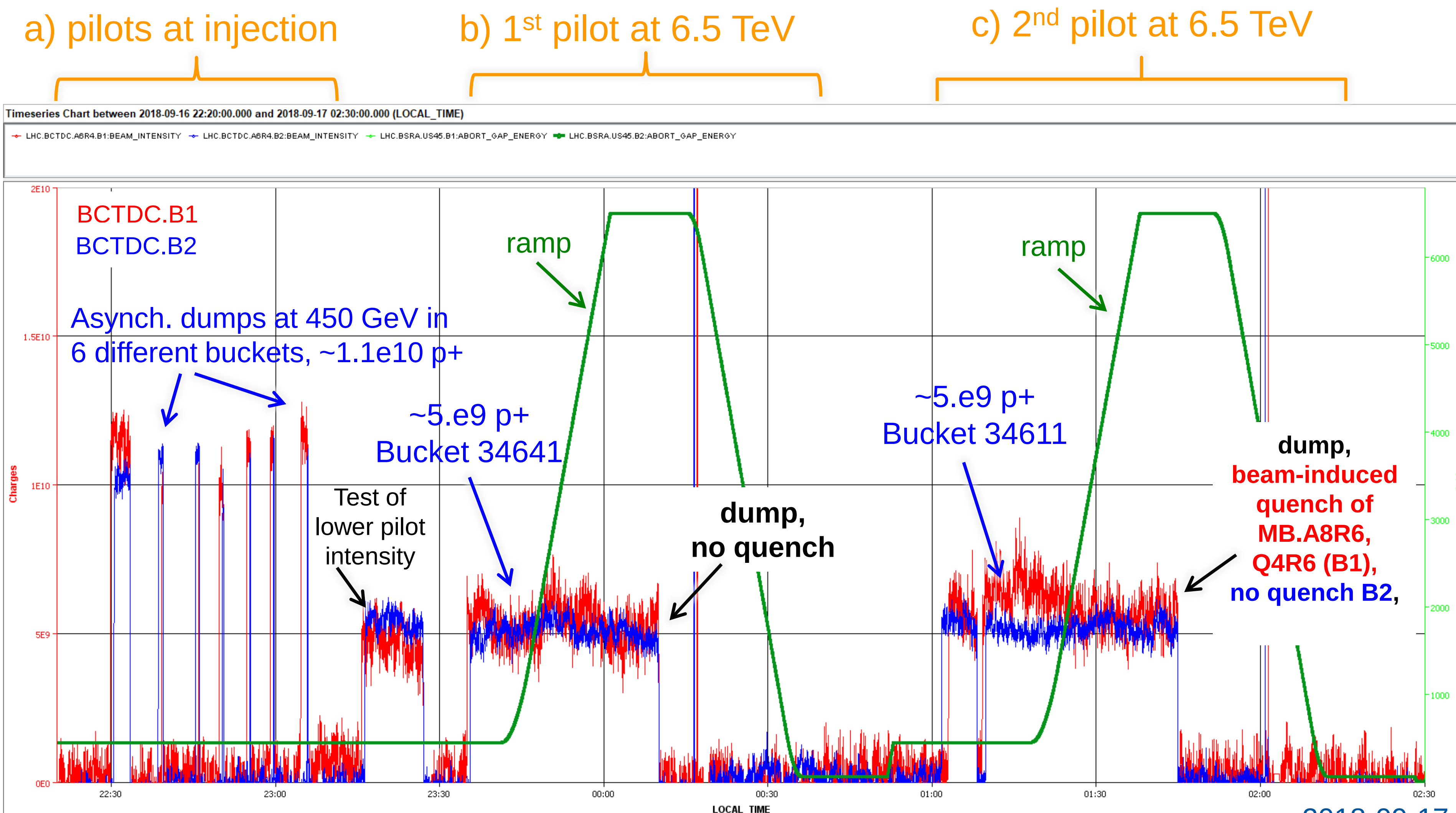
# MD Procedure

1) Preparation of the MD
    - Modify MKI settings and mask AG-relevant interlocks to allow injection into the AG
2) Single pilots in AG at **450 GeV**, ~1e10 p+
    - Check reproducibility of the results of MD2930 using 6 different buckets.
3) Single pilots in AG at **6.5 TeV**, ~5e9 p+
    - Inject single pilot for both beams simultaneously and dump
    - 1) Bucket **34641**, 5e9 p+, **no quench**
    - 2) Bucket **34611**, 5e9 p+, **quench**
    - No bump at TCDQ
3) Recovery
    - Reverted MKI settings in SIS directly after MD
    - Reverted MKI settings in LBDS expert application and revalidated with beam at restart after TS2

# MD Overview

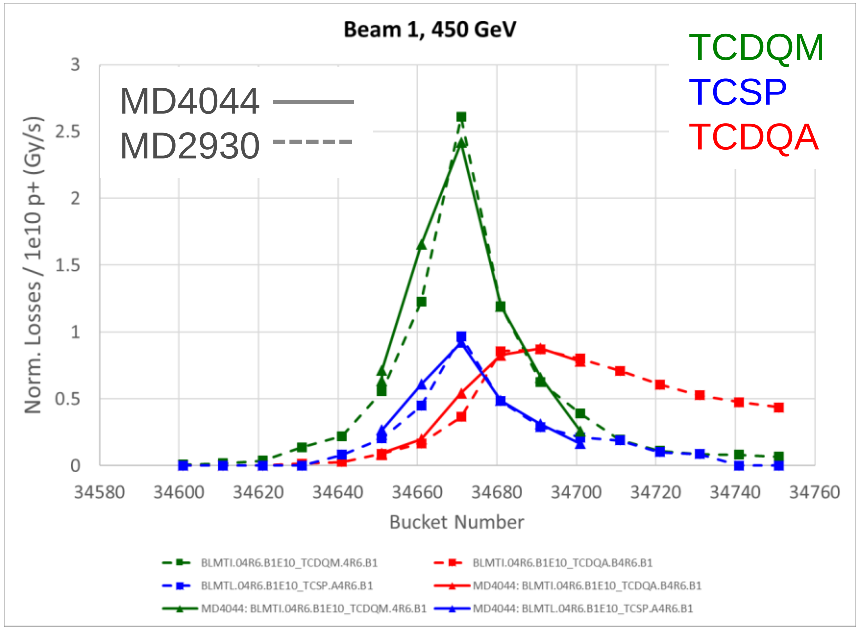



2018-09-17

# Reproducibility at 450 GeV

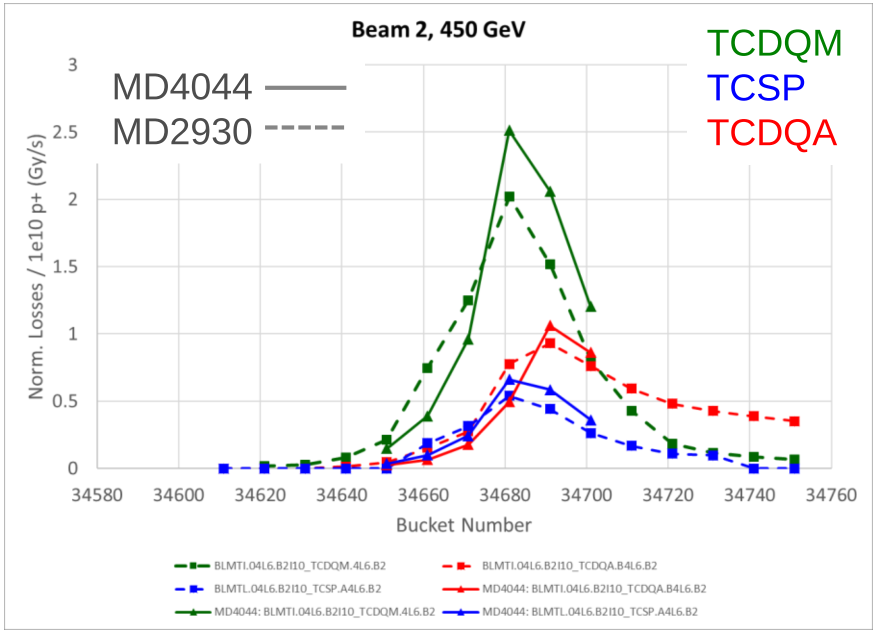
Comparison with MD2930 (3.12.2017):

- Good reproducibility of the loss distribution as a function of the bucket number, i.e. of the TCDQ impact parameter
- Good reproducibility of the absolute loss levels for Beam 1




← smaller MKD kick | larger MKD kick →

← lower impact parameter | higher impact parameter →




← smaller MKD kick | larger MKD kick →

← lower impact parameter | higher impact parameter →

# Quench behaviour B1, 6.5 TeV

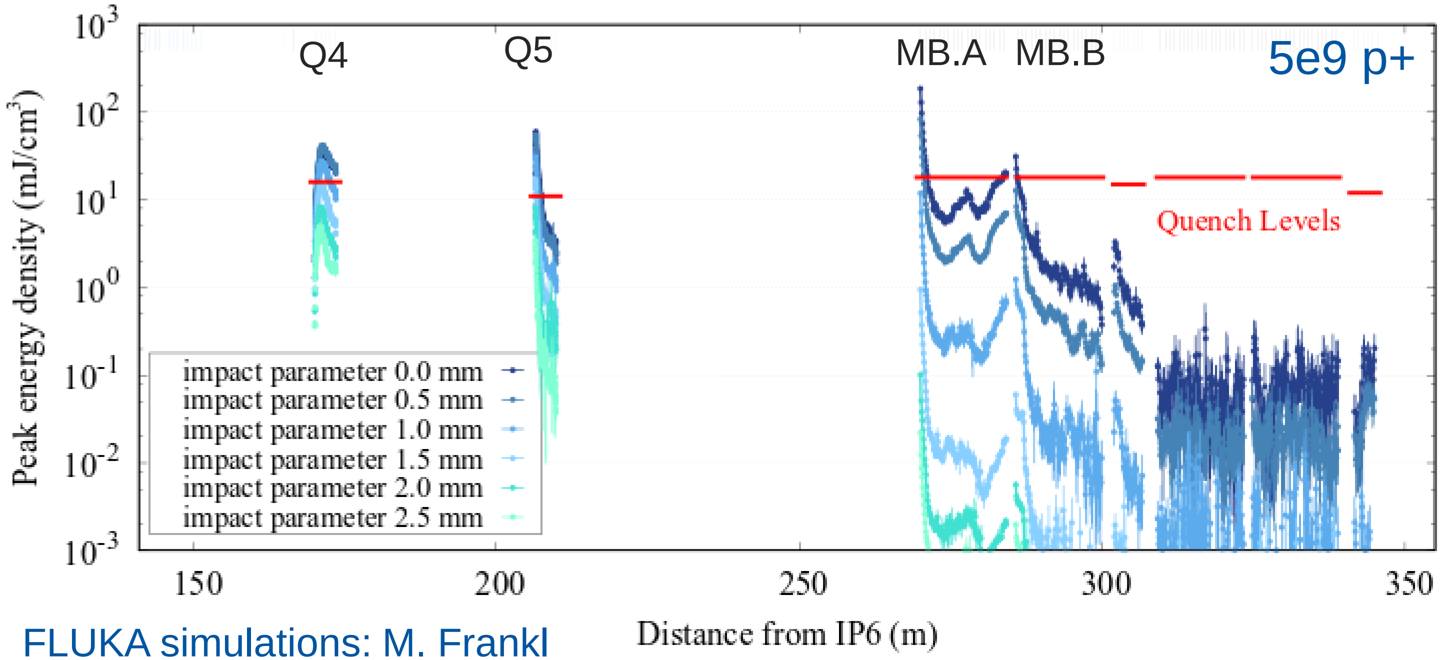
| | | ASD test, 2016-05-15 | MD4044 | MD2930 | MD2930 | MD4044 |
|---|---|---|---|---|---|---|
| Intensity | | ~3e10 on TCDQ (based on BSRA) | 5e9 p+ | 1.8e10 p+ | 1.0e10 p+ | 5e9 p+ |
| Bucket | | Debunched beam | 34611 | 34621 | 34631 | 34641 |
| Estimated TCDQ impact parameter | | Debunched beam | ~0 mm (?) | ~0.8 mm (?) | ~1.6 mm (?) | ~2.6 mm (?) |
| Magnet | T (K) | Quench? | Quench? | Quench? | Quench? | Quench? |
| MQY.4R6 | 4.5 | No | Yes | Yes | No | No |
| MQY.5R6 | 4.5 | No | No | No | No | No |
| MB.A8R6 | 1.9 | Yes | Yes | Yes | No | No |
| MB.B8R6 | 1.9 | (Yes)* | (Yes)* | (Yes)* | No | No |
| MQML.8R6 | 1.9 | (Yes)** | (Yes)** | (Yes)** | No | No |
| MB.A9R6 | 1.9 | No | No | No | No | No |
| MB.B9R6 | 1.9 | No | No | No | No | No |
| MQM.9R6 | 1.9 | (Yes)** | (Yes)** | (Yes)** | No | No |

$\sigma_x$ at TCDQ ≈ 0.4 mm

*quenched due to heat propagation
**quenched due to electro-magnetic coupling

# Results I

- **Q8/Q9** behavior now understood: Quench of MB.A8 leads to secondary quenches of Q8 and Q9 due to electro-magnetic coupling. The MB.B8 is then quenched due to heat propagation.
- **MB.A/Q4***:* First analysis indicates that quench behavior for Beam 1 is consistent with quench limits and simulated beam impact parameter. To be checked in detail. Beam 2 behavior to be further analysed.

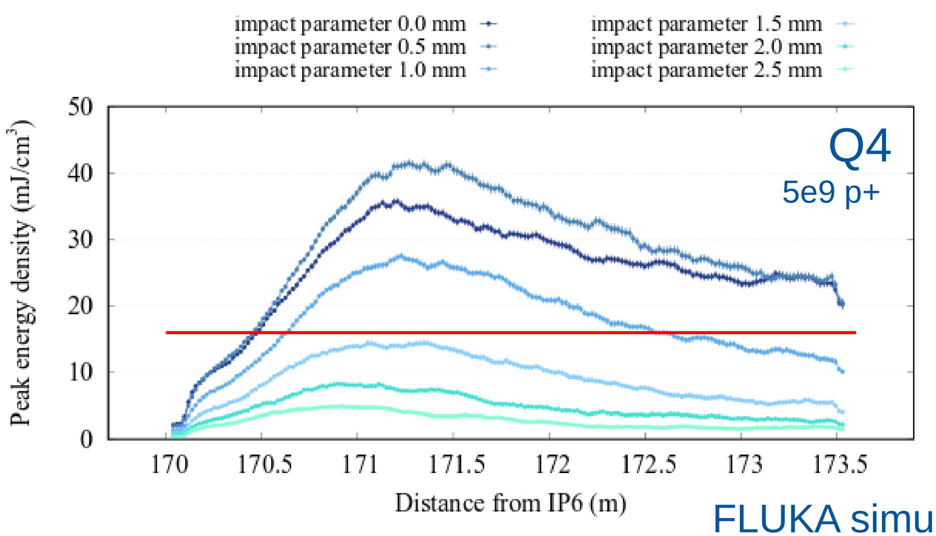


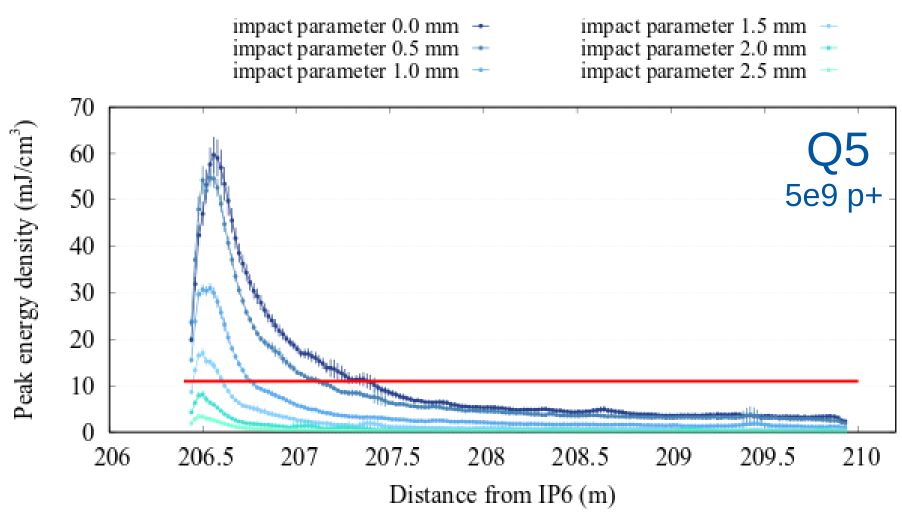

FLUKA simulations: M. Frankl

# Results II

**Q4/Q5**:

- FLUKA results show lower peak energy deposition in the Q4 (which quenched) than in the Q5 (which didn't quench)
- Quench behavior might be explained by different longitudinal loss pattern:
  - Q4: broad loss maximum in magnet center (where quench limit is lower)
  - Q5: loss peak at the beginning of magnet/coil (where quench limit is higher)
  - Detailed analysis of longitudinally changing quench limits will be performed by MPE-PE




FLUKA simulations: M. Frankl

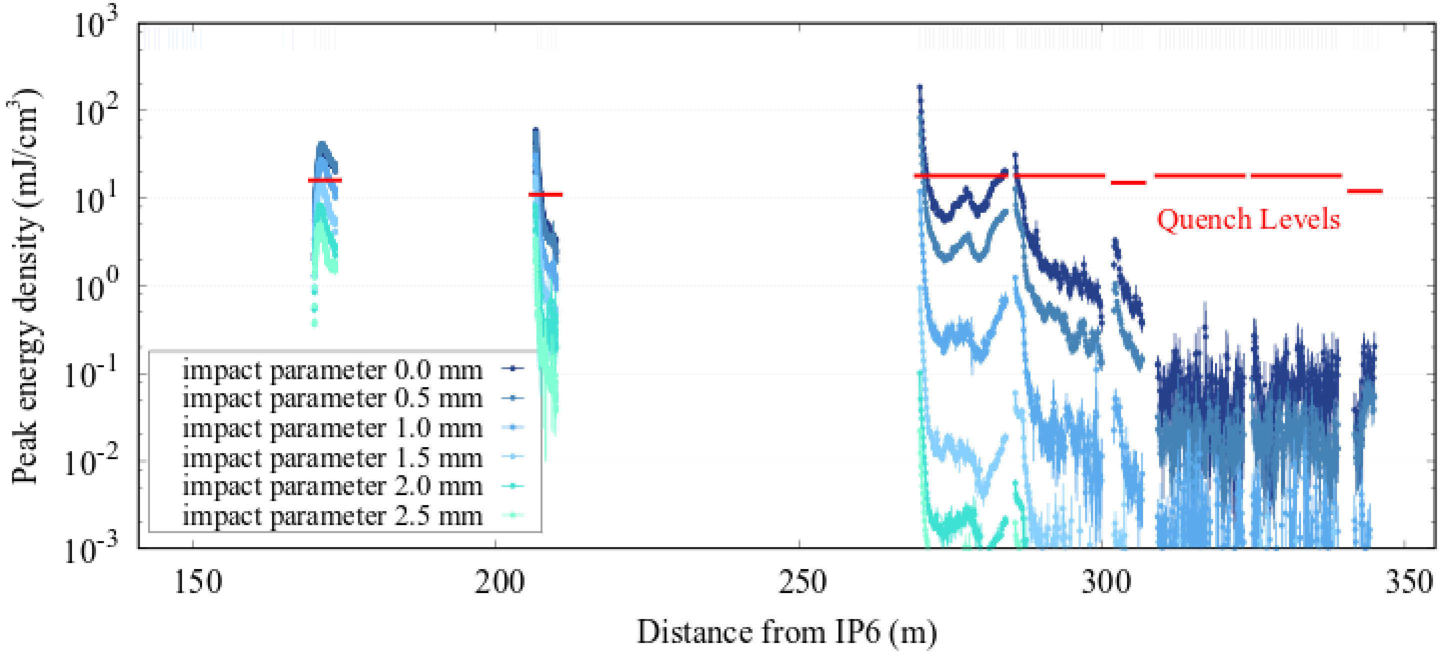
Thank you for your attention!

# Quench behaviour B2, 6.5 TeV

| | | | MD2930 | | MD4044 | |
|---|---|---|---|---|---|---|
| | | **2016-05-15 – Beam 2** | **2017-12-04 – Beam 2** | | **2018-09-17 – Beam 2** | |
| Intensity | | ~2.5e10 on TCDQ (based on BSRA) | 1.0e10 p+ | 1.8e10 p+ | 5e9 p+ | 5e9 p+ |
| Bucket | | Debunched beam | 34631 | 34621 | 34641 | 34611 |
| Magnet | T (K) | Quench? | Quench? | Quench? | Quench? | Quench? |
| MQY.4L6 | 4.5 | No | No | Yes | No | No |
| MQY.5L6 | 4.5 | No | No | No | No | No |
| MB.A8L6 | 1.9 | No | No | No | No | No |
| MB.B8L6 | 1.9 | No | No | No | No | No |
| MQML.8L6 | 1.9 | No | No | No | No | No |
| MB.A9L6 | 1.9 | No | No | No | No | No |
| MB.B9L6 | 1.9 | No | No | No | No | No |
| MQM.9L6 | 1.9 | No | No | No | No | No |

# Energy Deposition

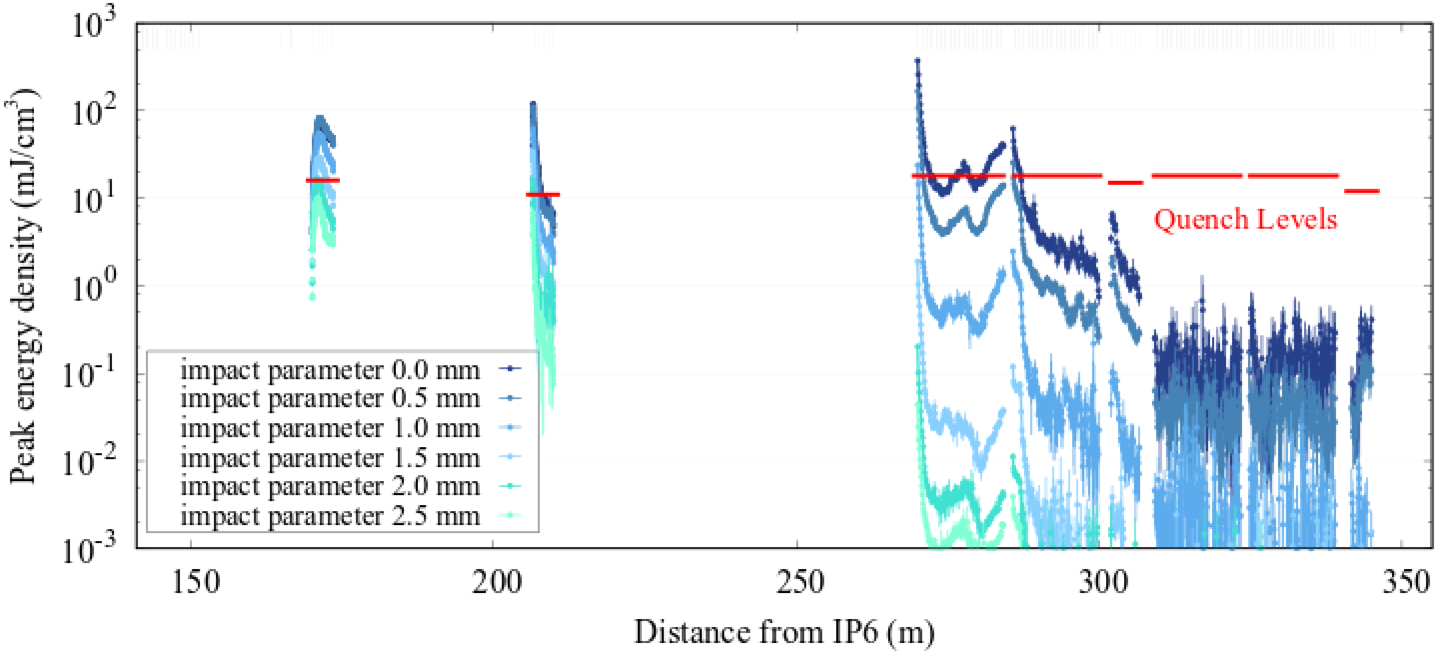
5e9 p+




FLUKA simulations: M. Frankl

# Energy Deposition

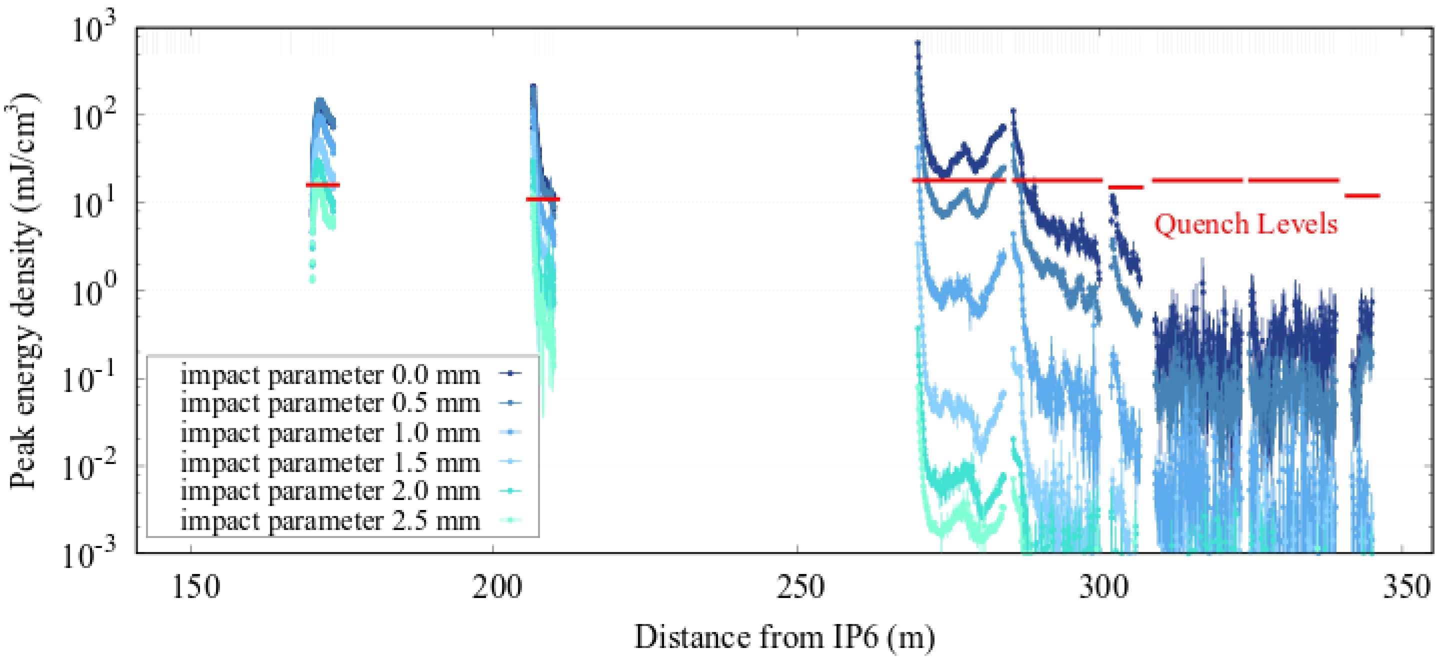
1e10 p+




FLUKA simulations: M. Frankl

# Energy Deposition

1.8e10 p+

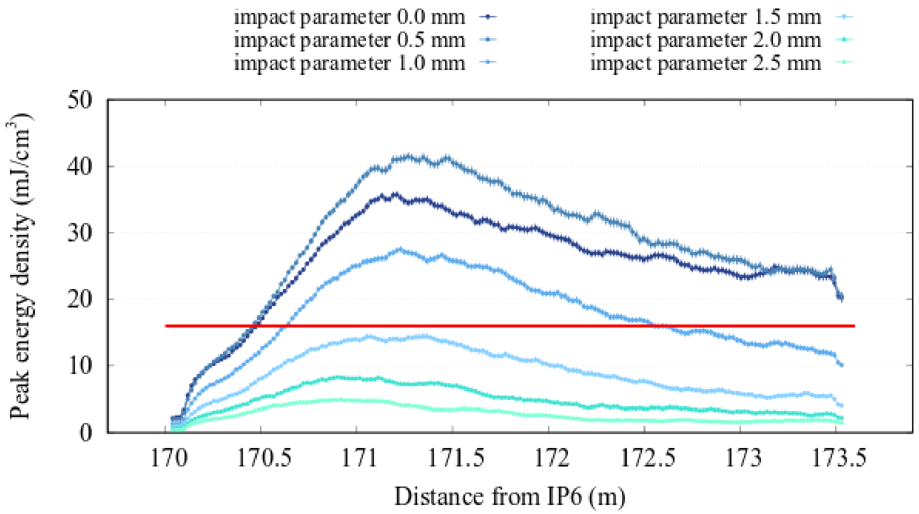



FLUKA simulations: M. Frankl

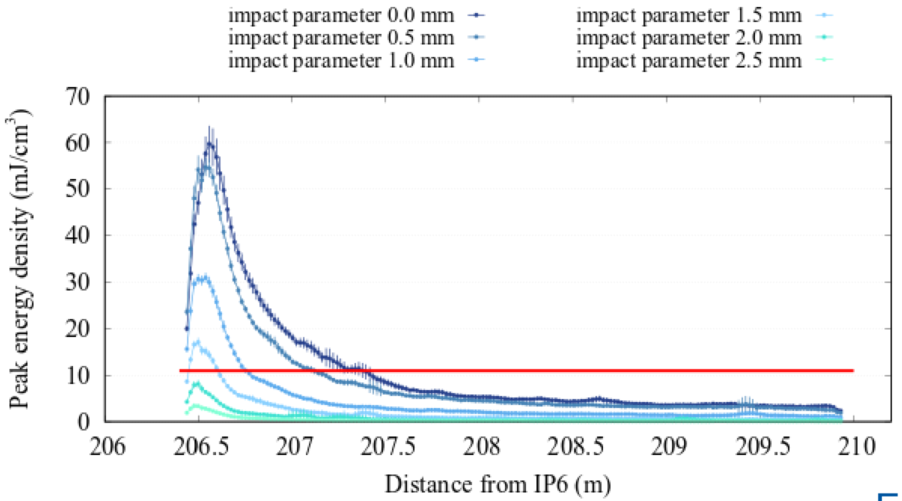
# Energy Deposition

Q4

5e9 p+




Q5

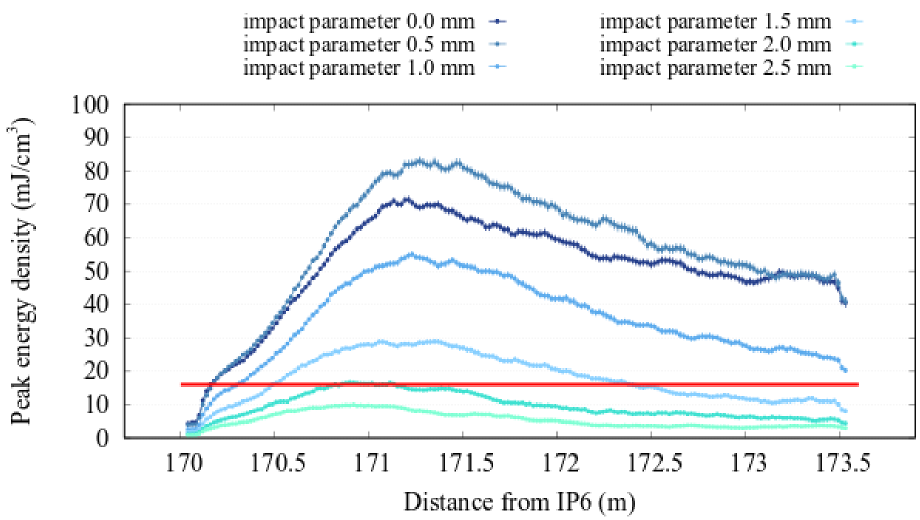



FLUKA simulations: M. Frankl

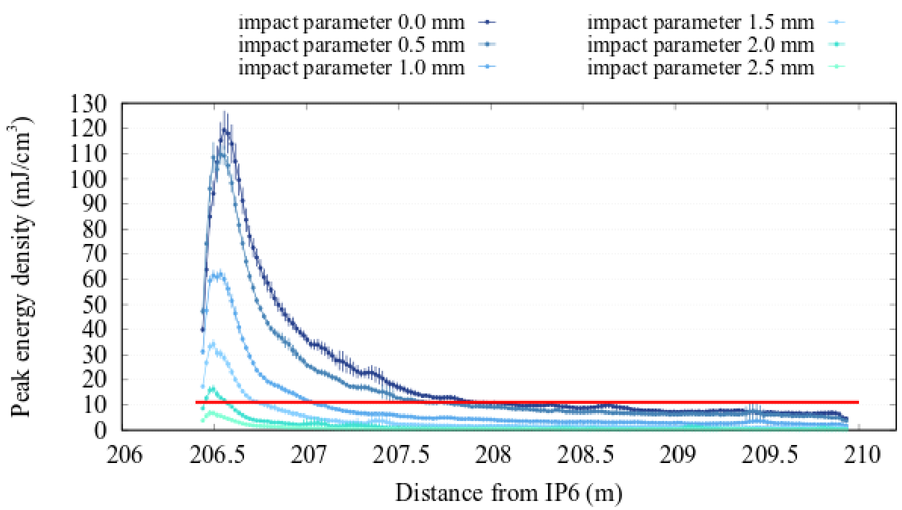
# Energy Deposition

Q4

1e10 p+




Q5

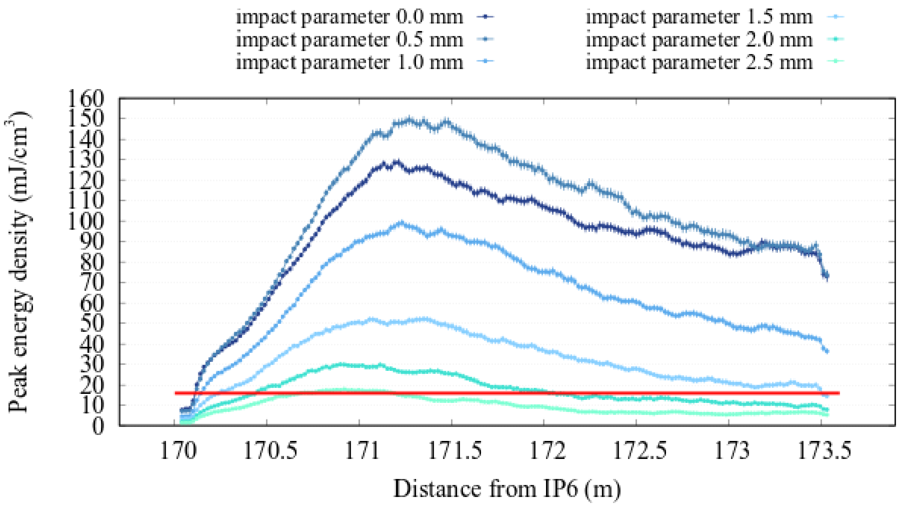



FLUKA simulations: M. Frankl

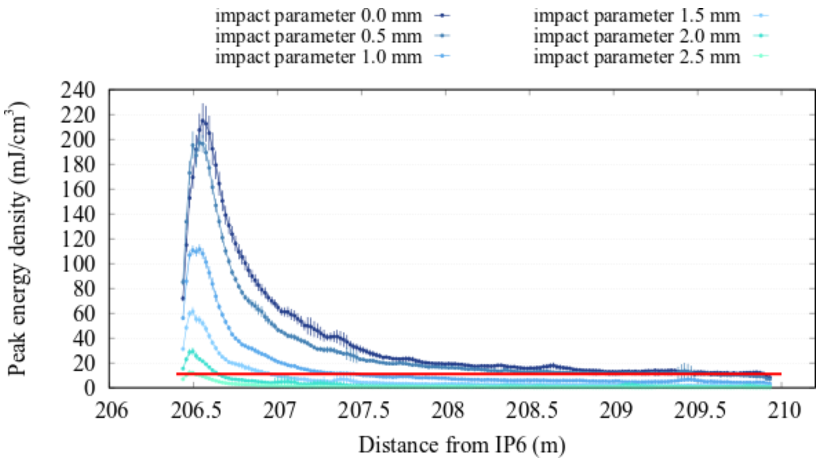
# Energy Deposition

Q4

1.8e10 p+

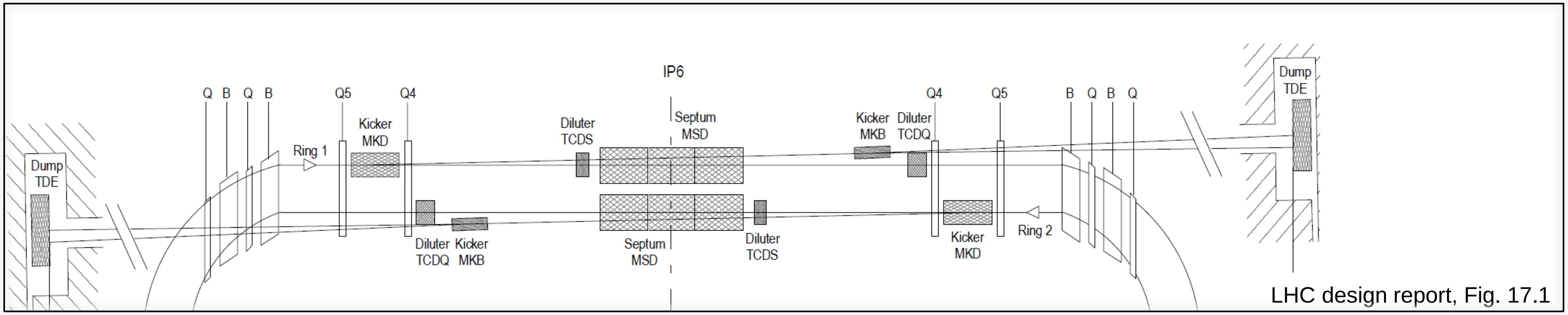



Q5



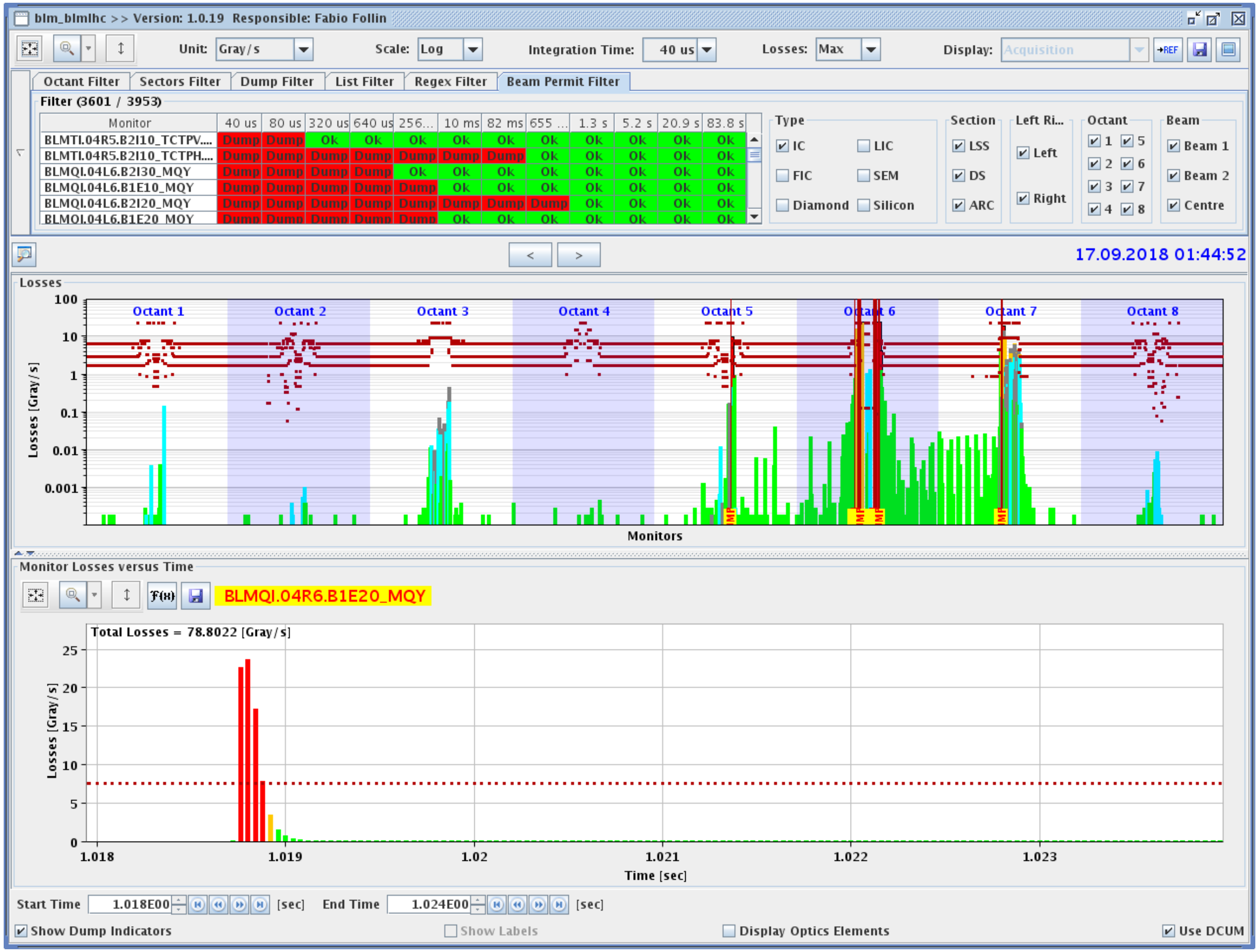

FLUKA simulations: M. Frankl

# IR6 Overview



LHC design report, Fig. 17.1

# Beam Losses: Bucket 34611




5e9 p+
→ Quench MBA/Q4 (B1)

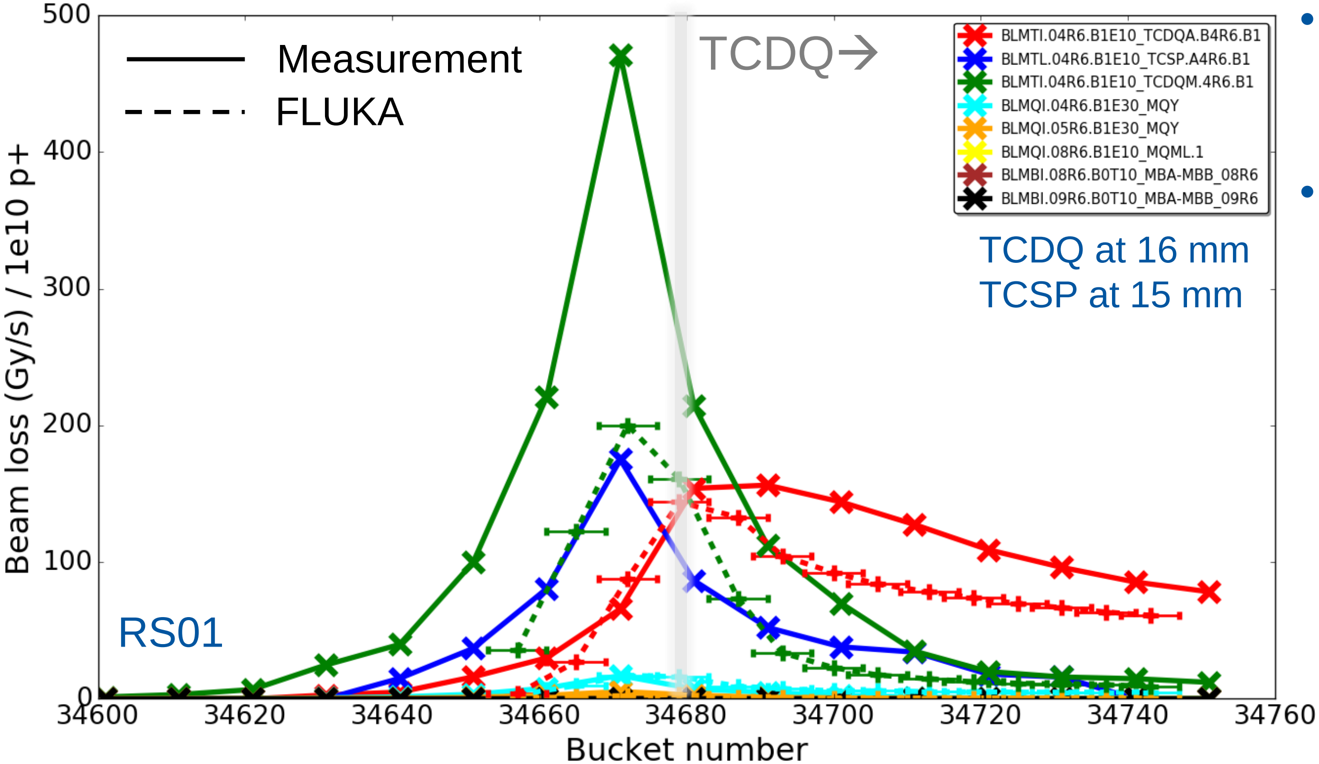
More leakage for B2 visible (IP5, IP3, IP1, IP8)

# 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.
- Ignore 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)

# Beam-loss behaviour at 450 GeV

## Beam 1




← less MKD kick　　　　more MKD kick →

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

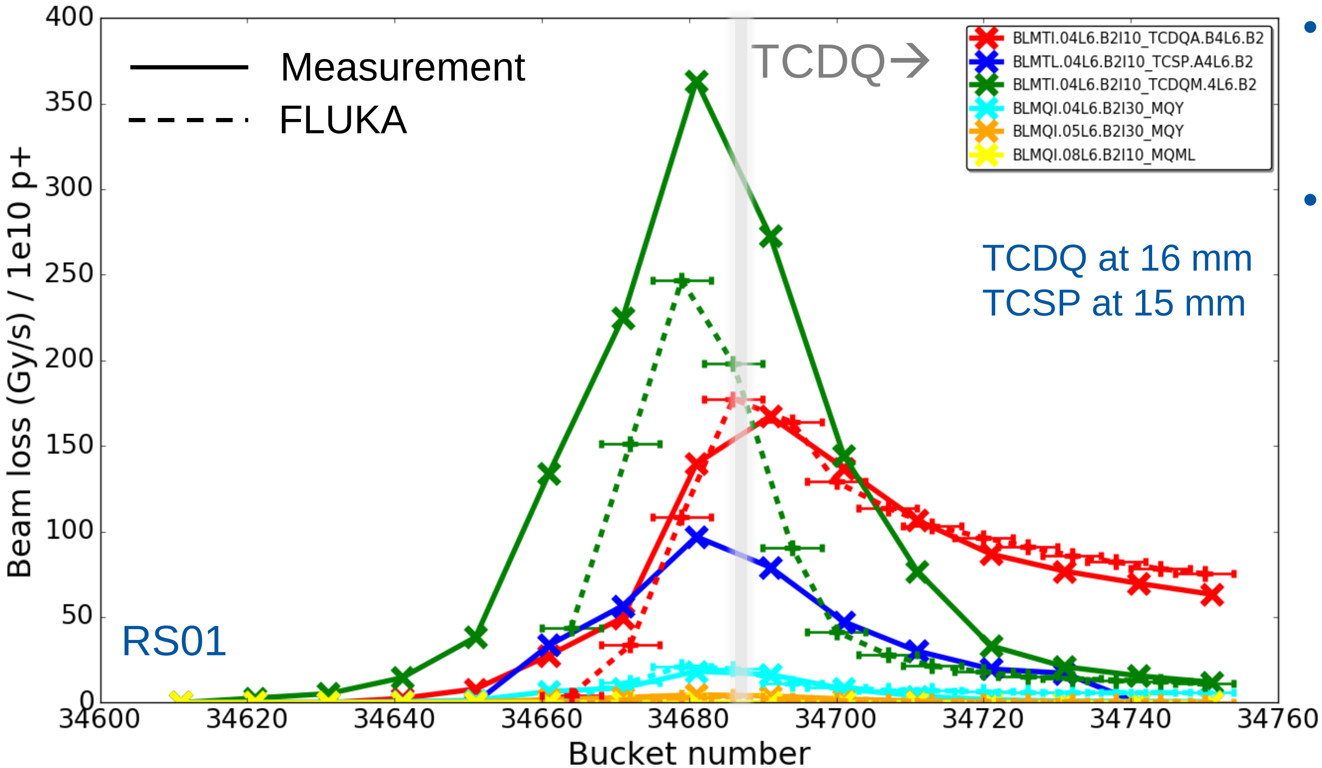
FLUKA simulations by M. Frankl

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




← 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 0.36/40us

- 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, ...)