Transition form Commissioning to Operation in J-PARC Linac

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Outline

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- Short-term beam stability
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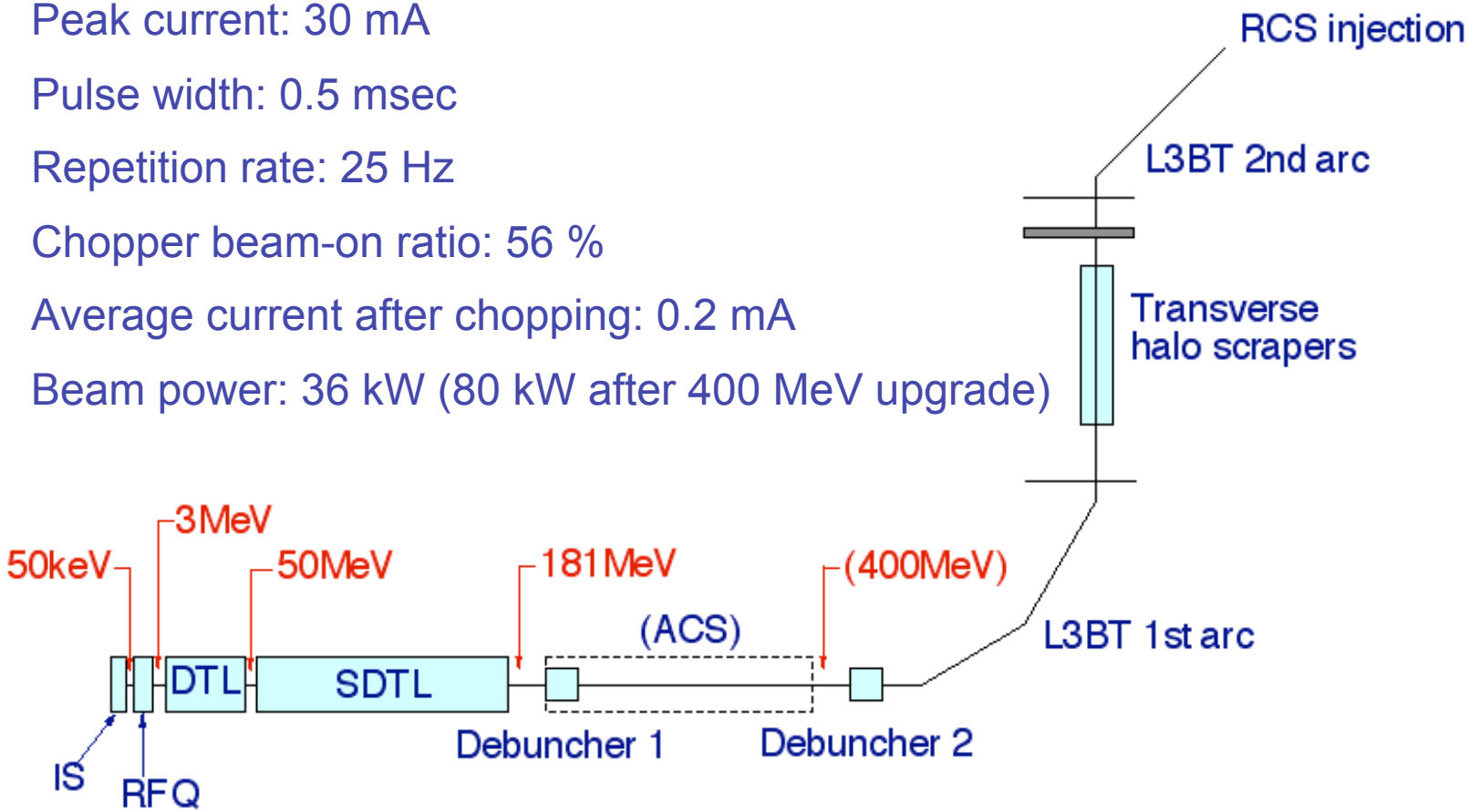
- Summary

Overview of commissioning history and current status

Main parameters for J-PARC linac

- Ion species: Negative hydrogen ion
- RF frequency: 324 MHz (972 MHz for ACS section)
- Output energy: 181 MeV (to be increased to 400 MeV by adding ACS section)
- Peak current: 30 mA
- Pulse width: 0.5 msec
- Repetition rate: 25 Hz
- Chopper beam-on ratio: 56 %
- Average current after chopping: 0.2 mA
- Beam power: 36 kW (80 kW after 400 MeV upgrade)



Commissioning history

- Nov. 2006: Beam commissioning of J-PARC linac started at Tokai site.
- Jan. 2007: 181-MeV acceleration achieved (5 mA).
  Design output energy: 181 MeV
- May 2007: High peak current operation demonstrated (26 mA).
  Design peak current: 30 mA
- Jun. 2007: High duty factor operation demonstrated (0.125 % / 1.1 kW)
  Design duty factor / Power: 1.25 % / 36 kW
- Sep. 2007: First beam delivery to RCS injection
  Completion of initial commissioning of J-PARC linac

Current status

- The beam commissioning of RCS and MR is still continuing, and the priority is given to the associated beam studies.
- In linac, the emphasis has been put on providing a stable beam to RCS and MR with the minimum beam time for the linac tuning.
- Because single-shot and low-duty-factor operations are totally employed in the RCS and MR commissioning, we have accumulated little experience on the machine activation since Oct. 2007. Namely, it is difficult to predict the machine activation level with continuous beam operation, while the beam loss level is suppressed to be barely seen with BLM's.

Current status (cont.)

- Beam conditions, especially the chopper parameters, are frequently changed during a run cycle. This situation makes it difficult for us to monitor the long-term beam stability .

- We plan to start stable beam operation of RCS for neutron production in Sep. 2008. In the same run, 24-hour beam operation will be partially introduced. After this run, we can gain more experience on the long-term beam stability and machine acticavation.

Beam parameters achieved to date

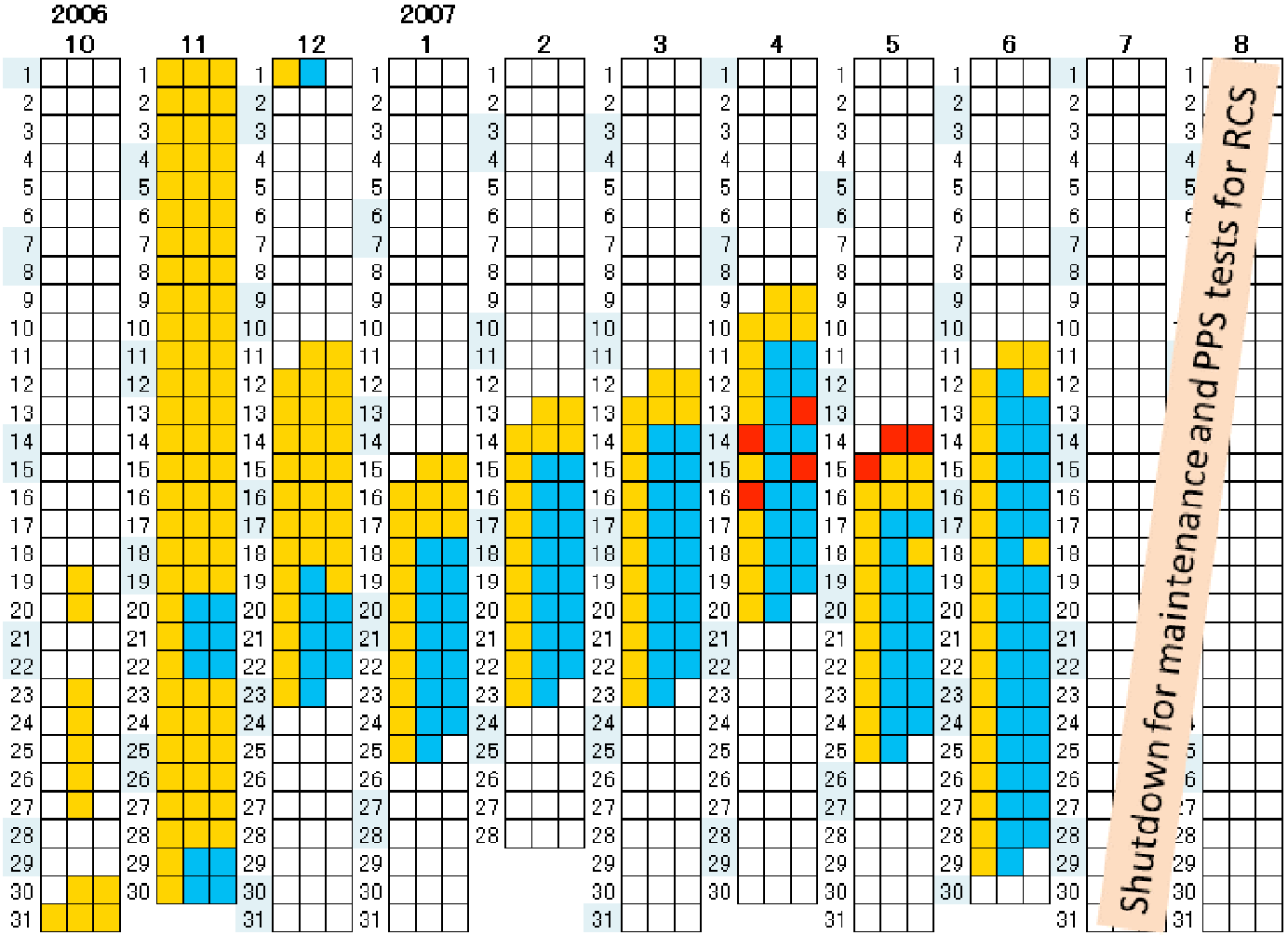
Parameter	Unit	Design	Commissioning goal*	Achieved to date
Output energy	MeV	181	181	181
Peak current	mA	30	25	27 30 (RFQ exit)
Average current after chopping	μA	200	6.6	6.6 (w/o chop) 19.5 (w/ chop)**
Linac beam power	kW	36 (600@3GeV)	1.2 (20@3GeV)	1.2 (w/o chop) 3.5 (w/ chop)**
Pulse length/ Repetition/ Chopper beam-on duty	ms/Hz/%	0.5/25/53	5mA: 0.18/25/30 25mA: 0.035/25/30	5mA: 0.5/5/100 0.05/25/60 25mA: 0.05/2.5/100 0.12/25/26**
RF flat-top width/ Repetition	ms/Hz	0.5/25	0.5/25	>0.5/25

• Corresponding to 20 kW from RCS (to be achieved in 2008 at the latest).
** Sustained only for four minutes due to dump capacity limit.

Typical run cycle

- In the beginning (from Nov. 2006 to Feb. 2008),a typical run cycle consisted of two-week beam time with one- to two-week interval.
- Recently (since May 2008), a typical run cycle consists of three-week beam time with one-week interval, which is the originally planned run cycle to realize yearly operational hour of 5500.
- Typically, we need one day for the conditioning of RF cavities, and one day for linac tuning and linac studies.
- The beam commissioning of RCS and MR is still continuing. The rest of the beam time is mostly dedicated for the beam commissioning of RCS and MR.
- The RF sources, magnet power supplies, and ion source are running 24 hours a day, but the beam operation is basically 12 hours a day to realize efficient beam commissioning with limited manpower.

Operation history



Blank: Scheduled down time

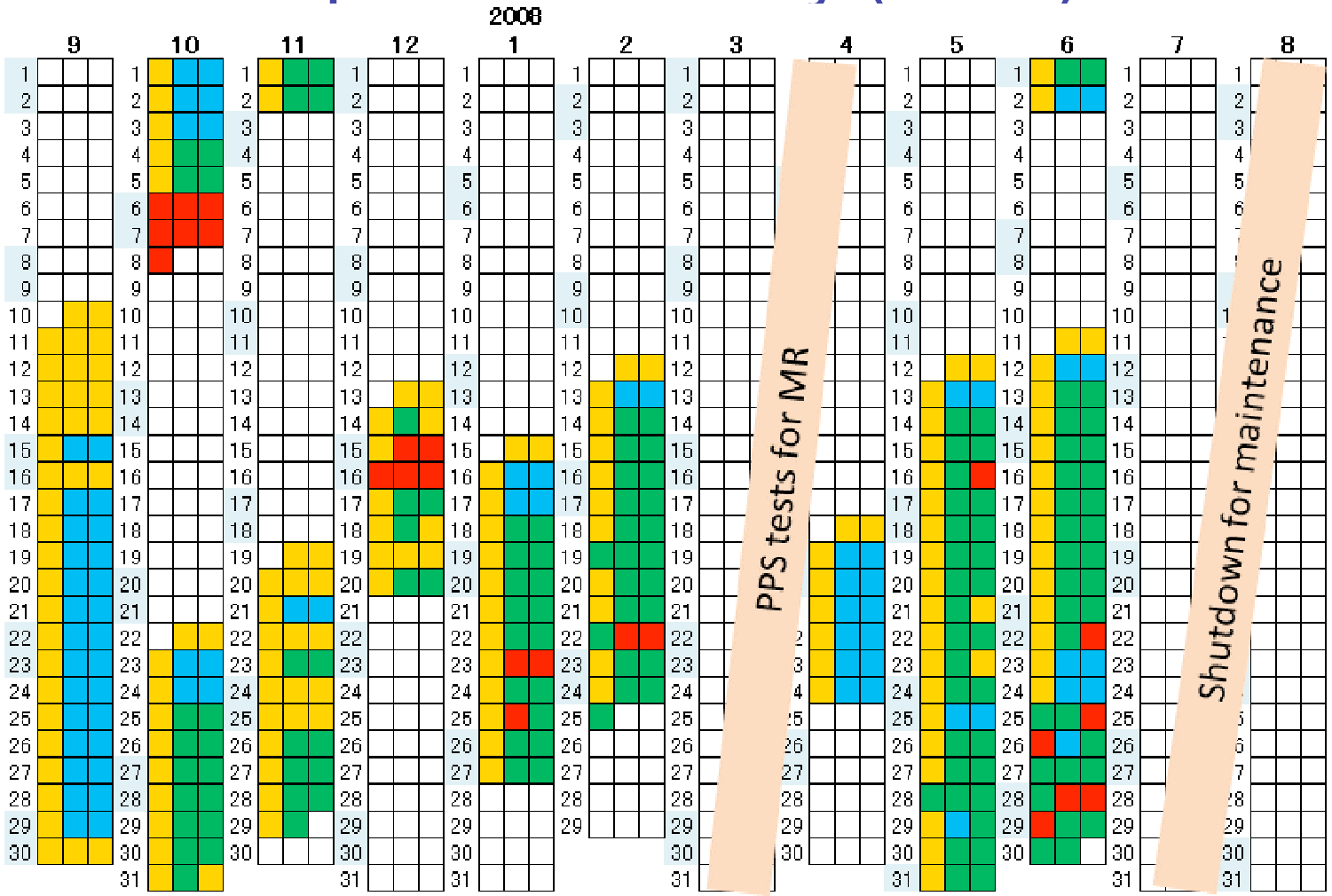
Blue: Beam-on time (linac study)

Red: Unscheduled down time

Yellow: RF Conditioning

Green: Beam-on time (RCS or MR study)

Operation history (cont.)

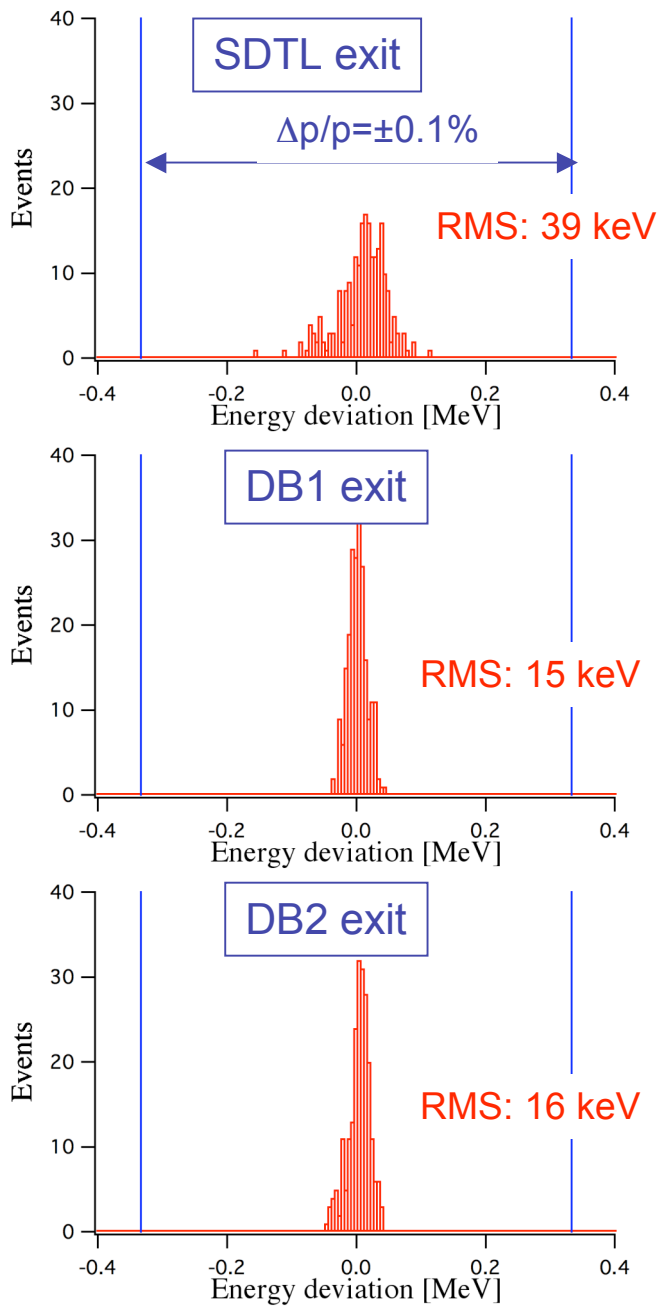


Blank: Scheduled down time
Blue: Beam-on time (linac study)
Red: Unscheduled down time
Yellow: RF Conditioning
Green: Beam-on time (RCS or MR study)

Short-term beam stability

Energy jitter

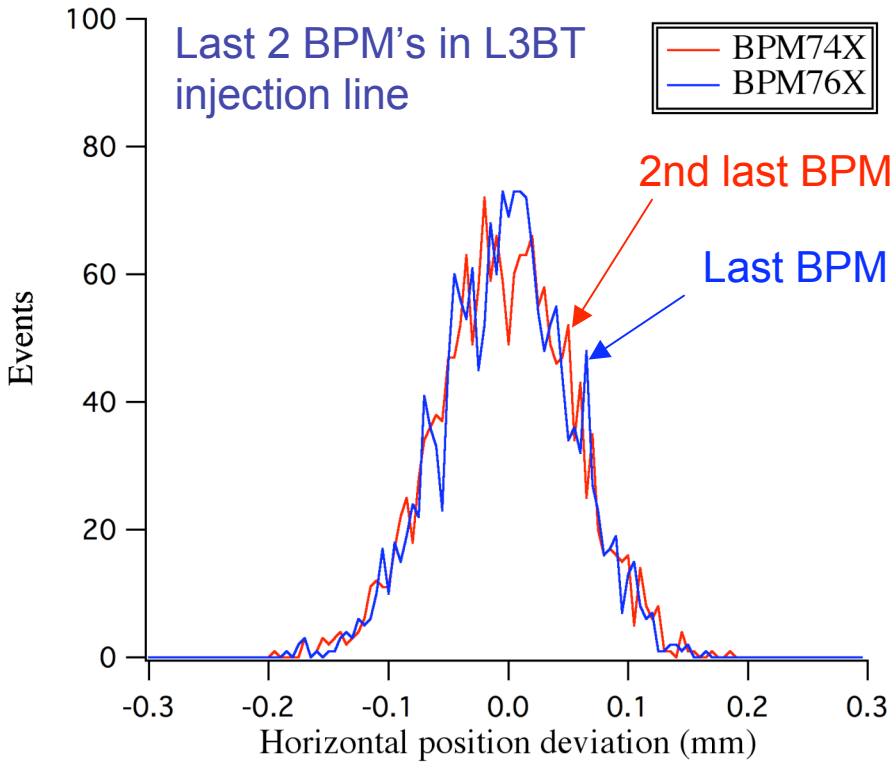
- The energy jitter during 9 hours of single shot operation is monitored with FCT's (Fast Current Transfortmers).
- The jitter correction effect of debunchers has been confirmed.
- The jitter at the RCS injection is less than 20 keV in RMS including the intrinsic jitter (or noise) of the monitor system.



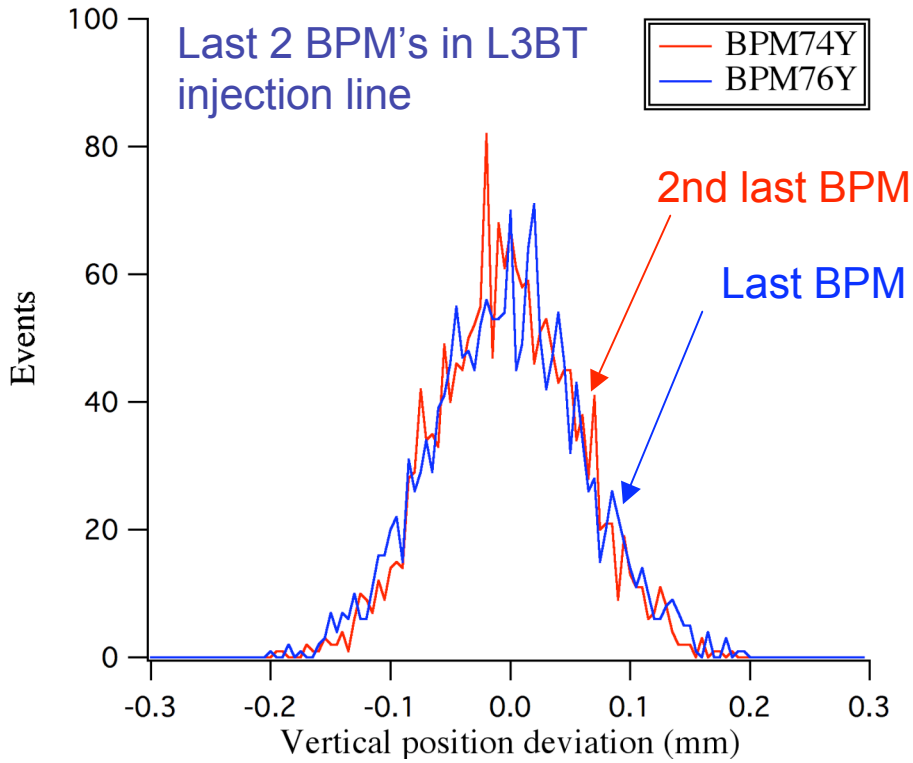
Beam position jitter

RUN12

Horizontal



Vertical



These 2 BPM's are 4.1 m apart.

The position jitter at the RCS injection is around ±0.2 mm (60 μm in RMS) including the intrinsic jitter (or noise) of the monitor system.

Summary for short-term beam stability

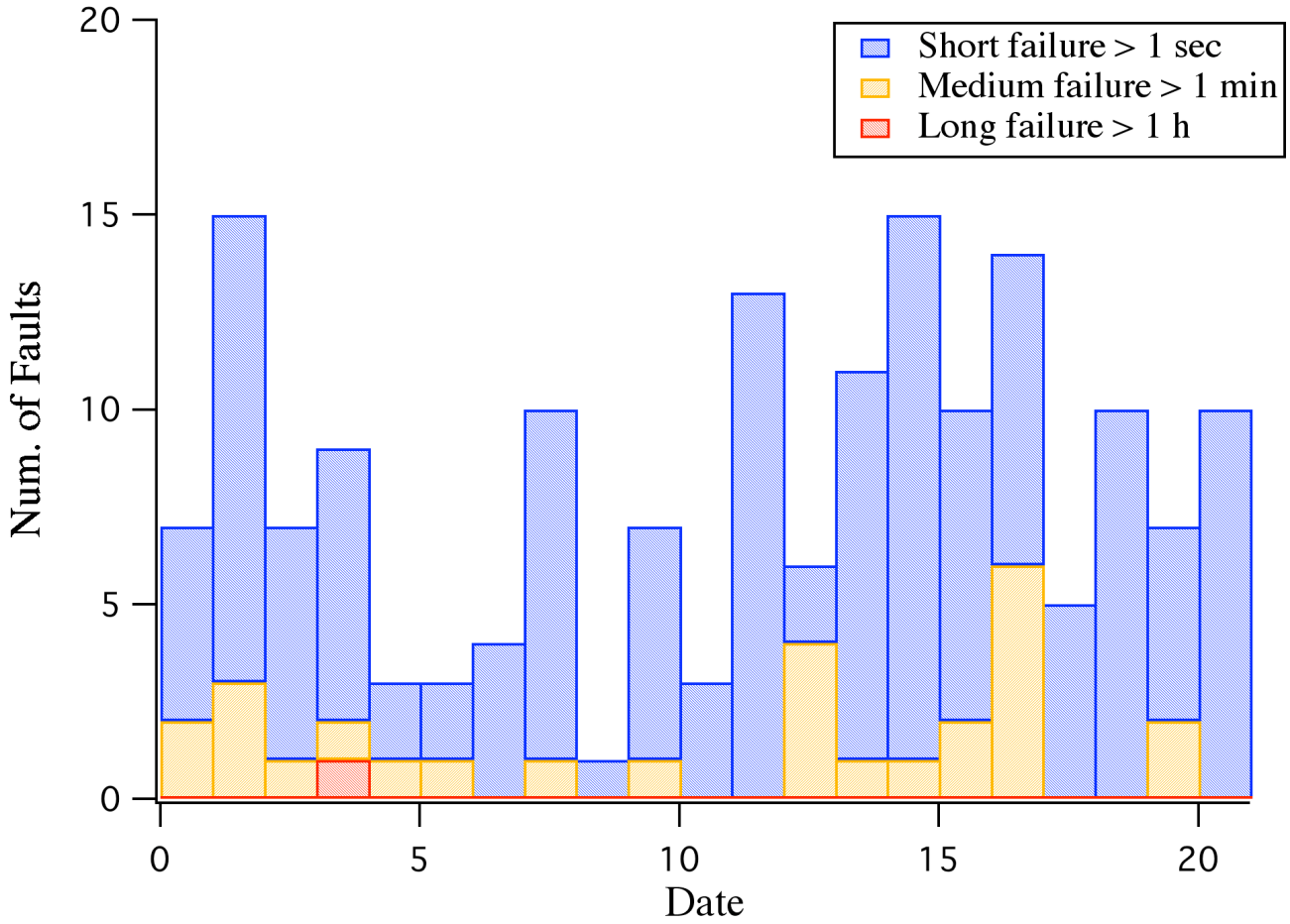
- Short-term beam monitoring over several hours shows sufficiently good stability.
- As we are still in the commissioning of downstream facilities, the beam parameters (especially chopper parameters) are frequently changed. It prevents us from conducting a systematic study of long-term beam stability.
- In this September, we are to start the 24 hour stable beam supply to the neutron source. It provides us with a good opportunity to conduct a systematic survey of the long-term beam stability. The monitoring of the long-term stability will be one of key study items for the coming a few run cycles.

Beam fault statistics

Definitions

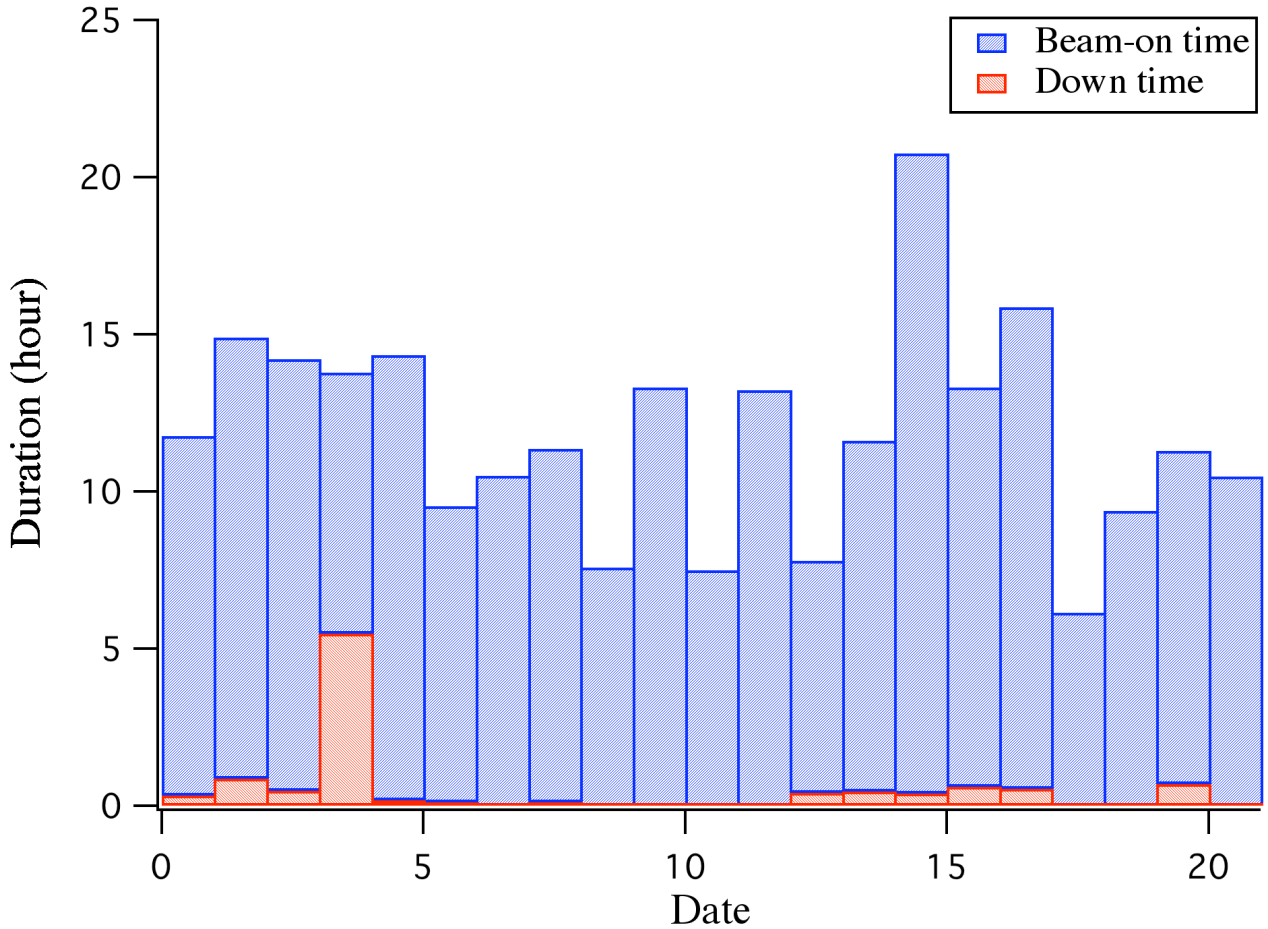
- As we are still in the transitional stage from commissioning to operation, the definition of the “scheduled beam time” is not so clear.
- We here define the “scheduled beam time” to start with extracting the Farady cup in the morning and end with inserting it after the end of the beam study.
- We take only the events related to the linac operation. Then, the obtained fault rate and availability are concerned only with linac, not with the entire J-PARC accelerator.

Number of faults in RUN16 (May 2008)



Total number of faults was 170 for 21 days.
Among them, 26 faults were longer than 1 min,
and one fault was longer than 1 hour.

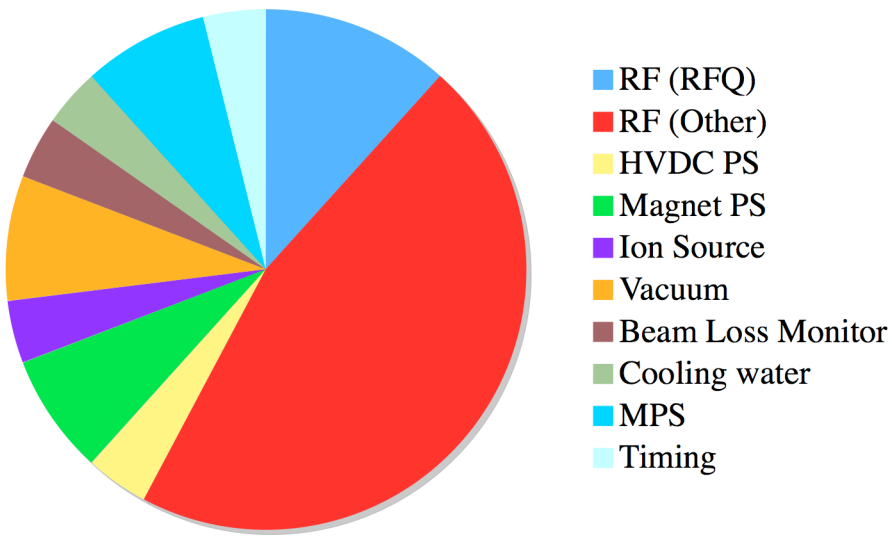
Downtime in RUN16 (May 2008)



Total beam time was 249 hours for 21 days.
Downtime was 10.7 hours (4.3%) in total.
*Only faults longer than 1 min are analyzed.

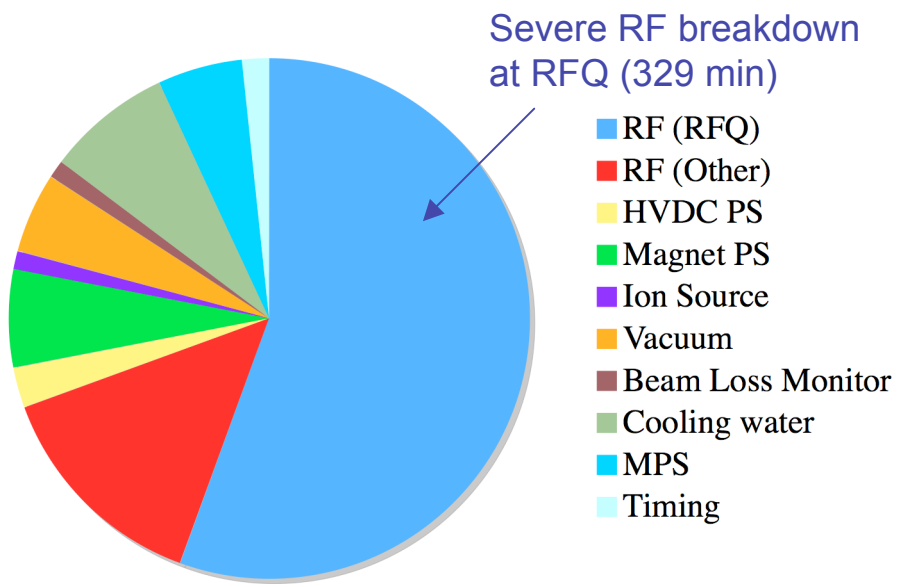
Fault statistics for RUN16 (May 2008)

Number of faults



26 faults in total

Downtime

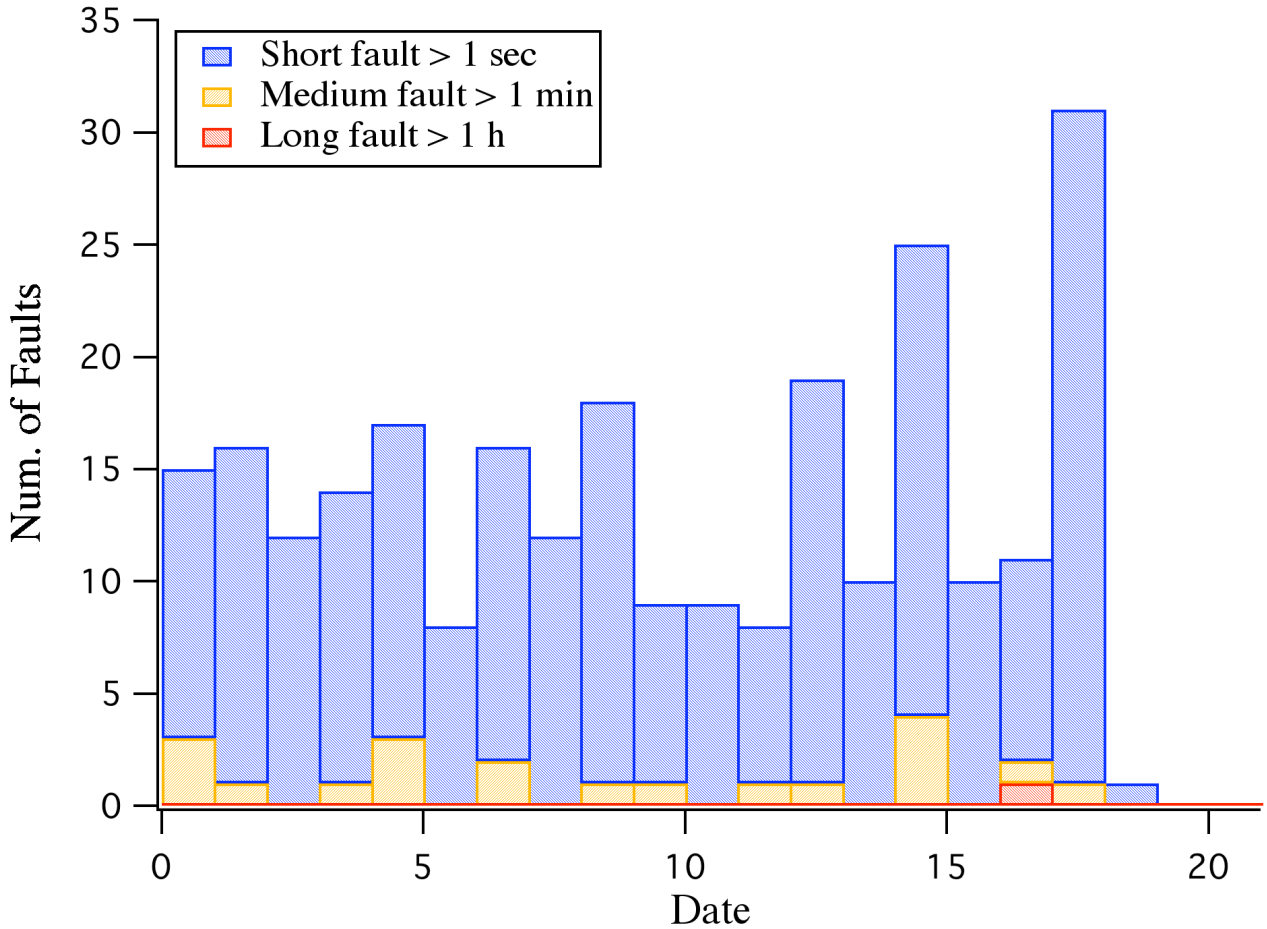


10.7 hour in total

Total beam time: 249 hour / Unscheduled downtime: 4.3 %

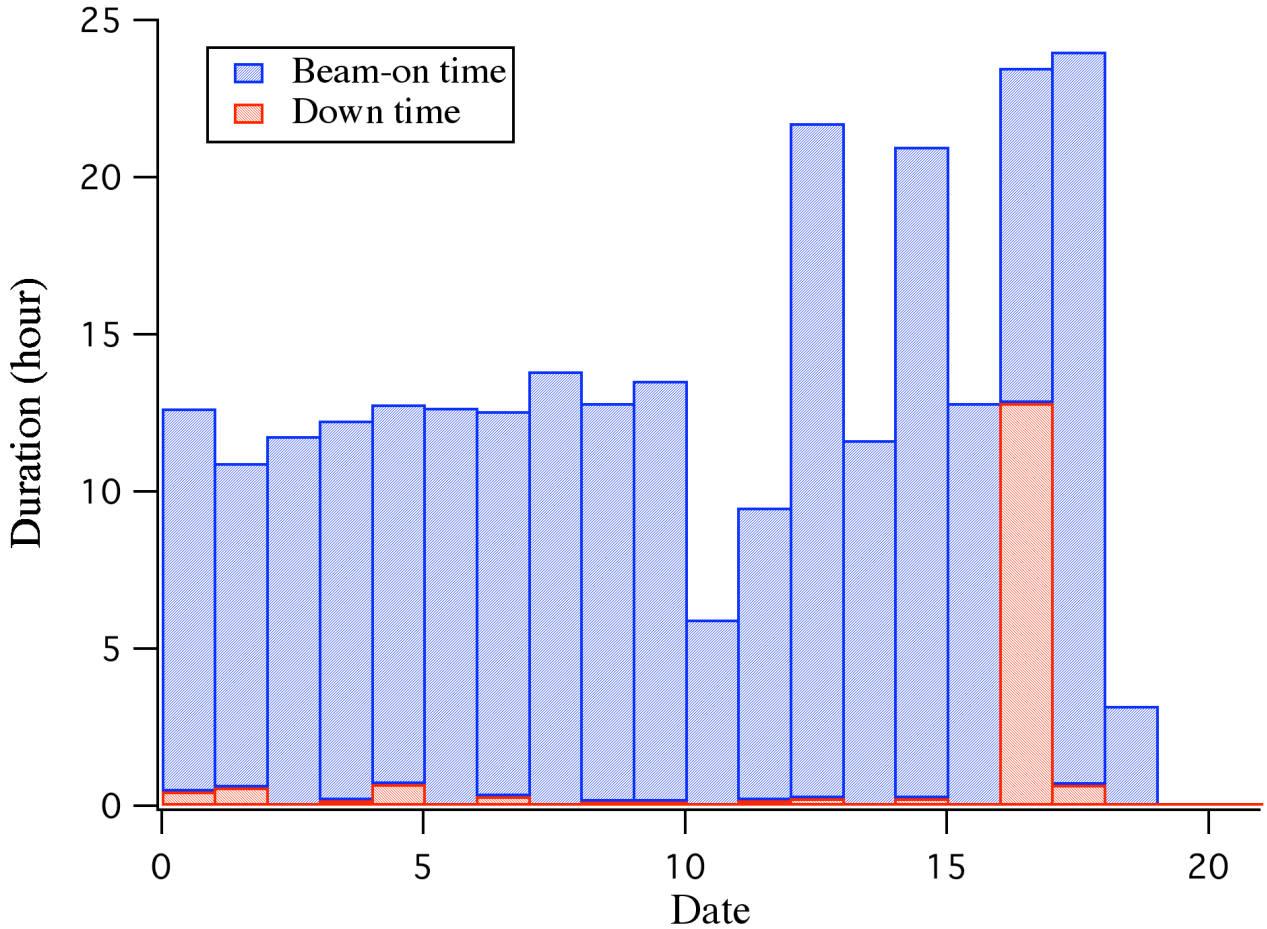
*Only faults longer than 1 min are analyzed.

Number of faults in RUN17 (Jun. 2008)



Total number of faults was 261 for 19 days.
Among them, 21 faults were longer than 1 min,
and one fault was longer than 1 hour.

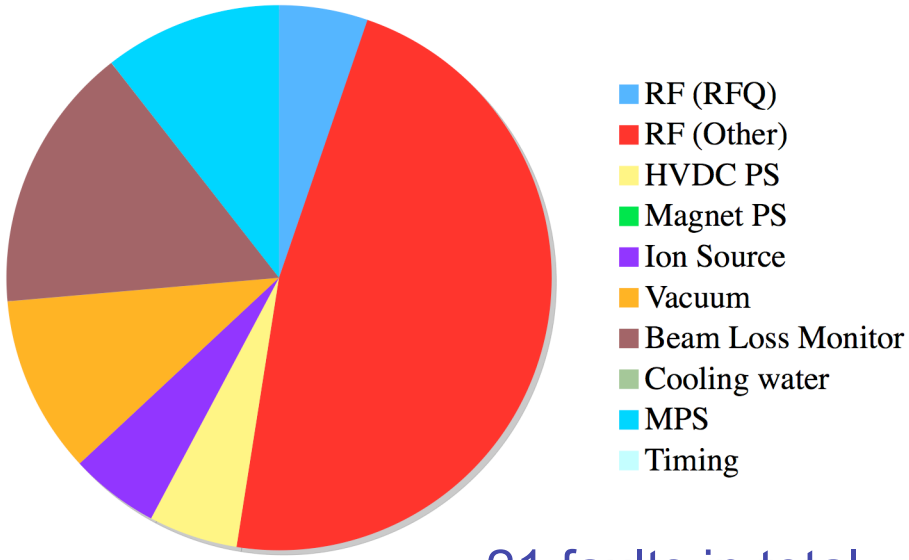
Downtime in RUN17 (Jun. 2008)



Total beam time was 259 hours for 19 days.
Downtime was 16.6 hours (6.4%) in total.
*Only faults longer than 1 min are analyzed.

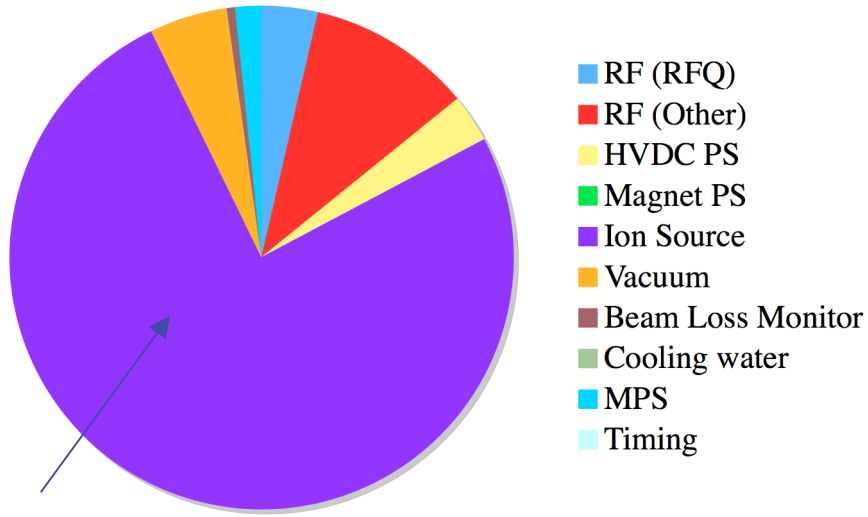
Fault statistics for RUN17 (Jun. 2008)

Number of faults



21 faults in total

Downtime



IS filament breakdown (743 min)

16.6 hour in total

Total beam time: 259 hour / Unscheduled downtime: 6.4 %

*Only faults longer than 1 min are analyzed.

Summary for fault analysis

- Typical fault rate is currently

  ~0.6-0.9/hour for > 1 sec. (~ Once in 1 hour)

  ~0.08-0.1/hour for > 1 min. (~ Once in 10 hour)

  ~0.004/hour for > 1 hour (~ Once in 1 run cycle)

- We don't have sufficient statistics for the klystron lifetime and ion source lifetime yet.

↓

Potential source of a long fault

- In the early stage, cooling-water system caused several long faults, but it has been prevented in recent 6 months.

Residual radiation level

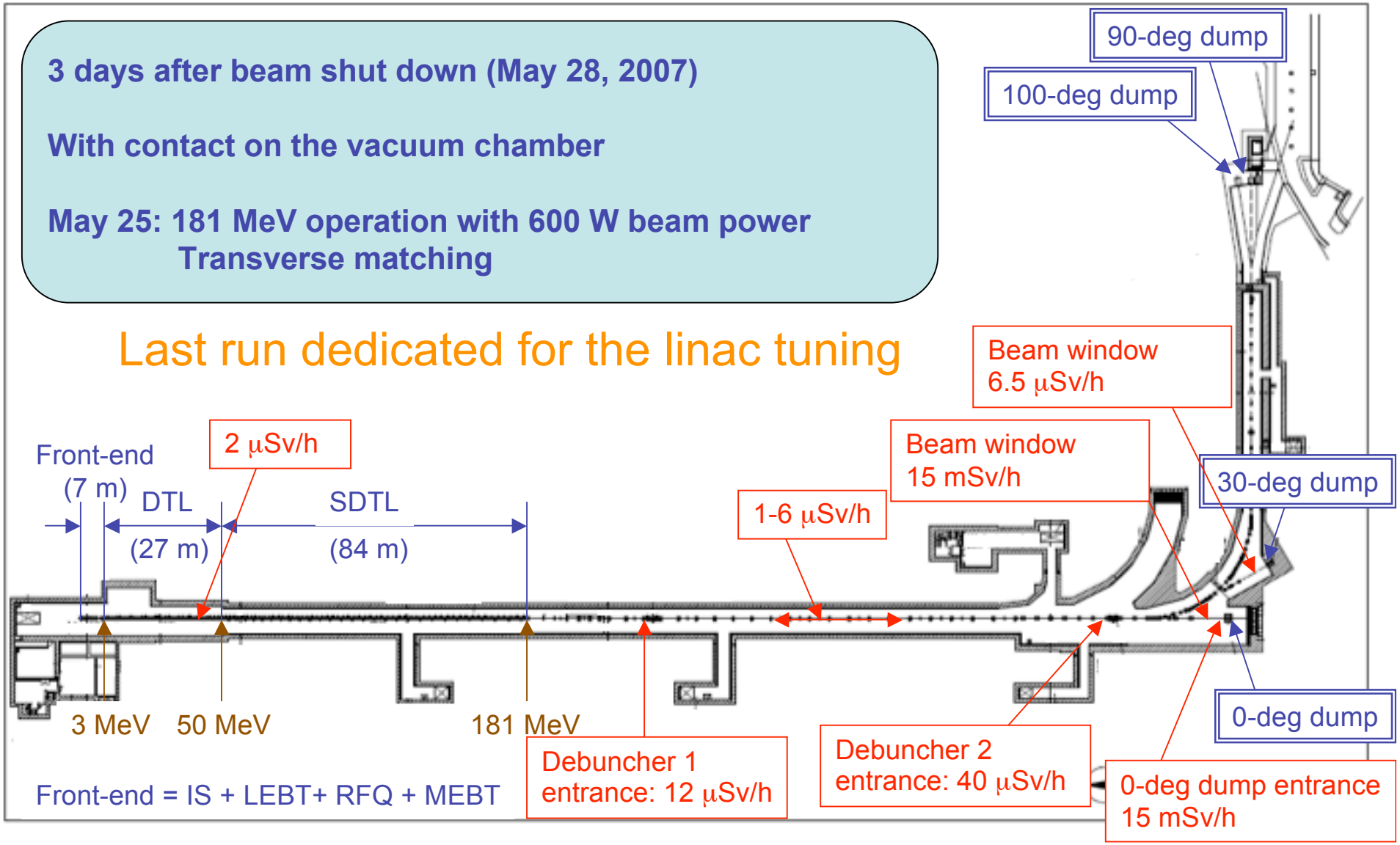
Residual radiation level after RUN7

3 days after beam shut down (May 28, 2007)

With contact on the vacuum chamber

May 25: 181 MeV operation with 600 W beam power
Transverse matching

Last run dedicated for the linac tuning

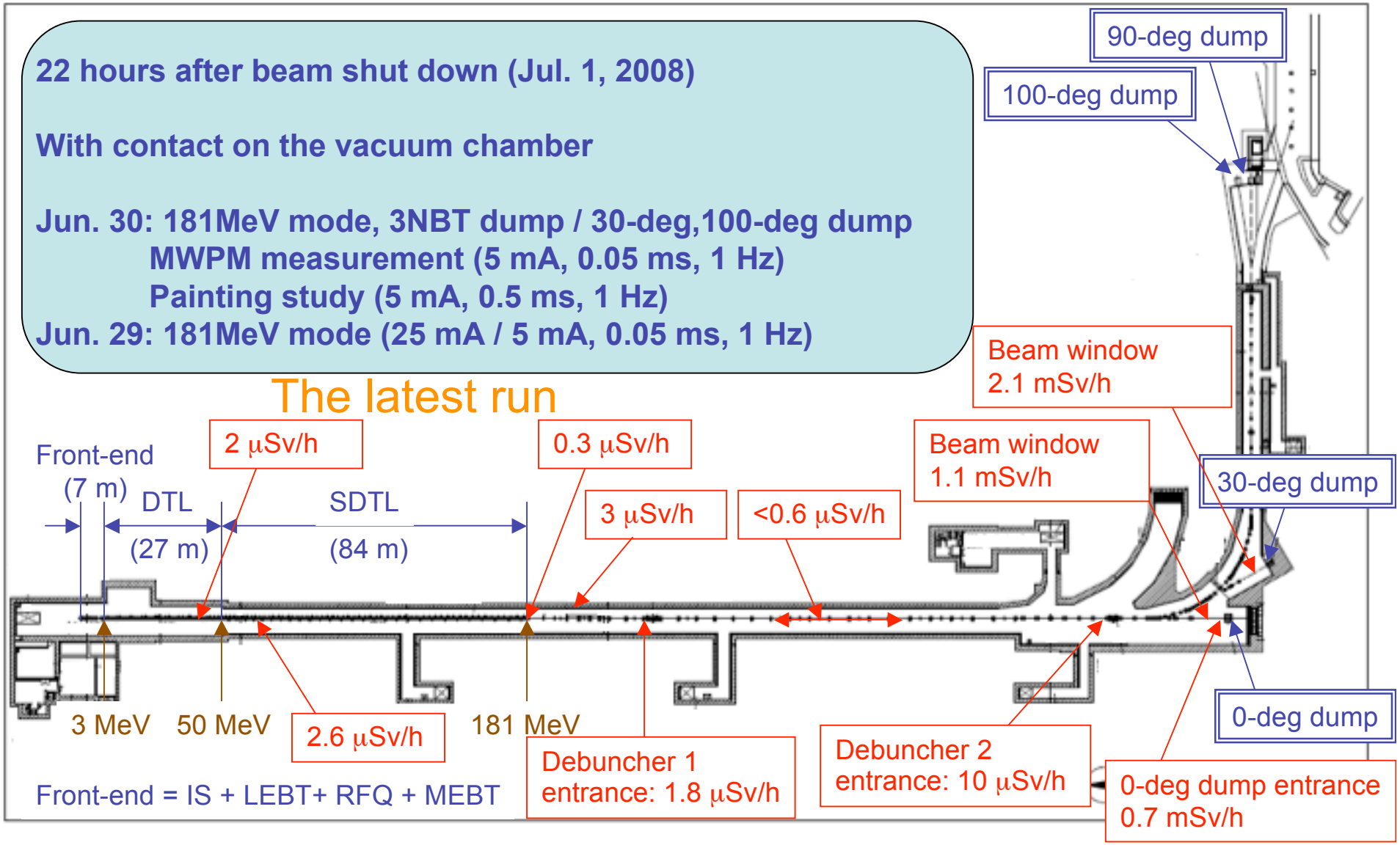


Residual radiation level after RUN17

22 hours after beam shut down (Jul. 1, 2008)

With contact on the vacuum chamber

Jun. 30: 181MeV mode, 3NBT dump / 30-deg,100-deg dump
MWPM measurement (5 mA, 0.05 ms, 1 Hz)
Painting study (5 mA, 0.5 ms, 1 Hz)
Jun. 29: 181MeV mode (25 mA / 5 mA, 0.05 ms, 1 Hz)



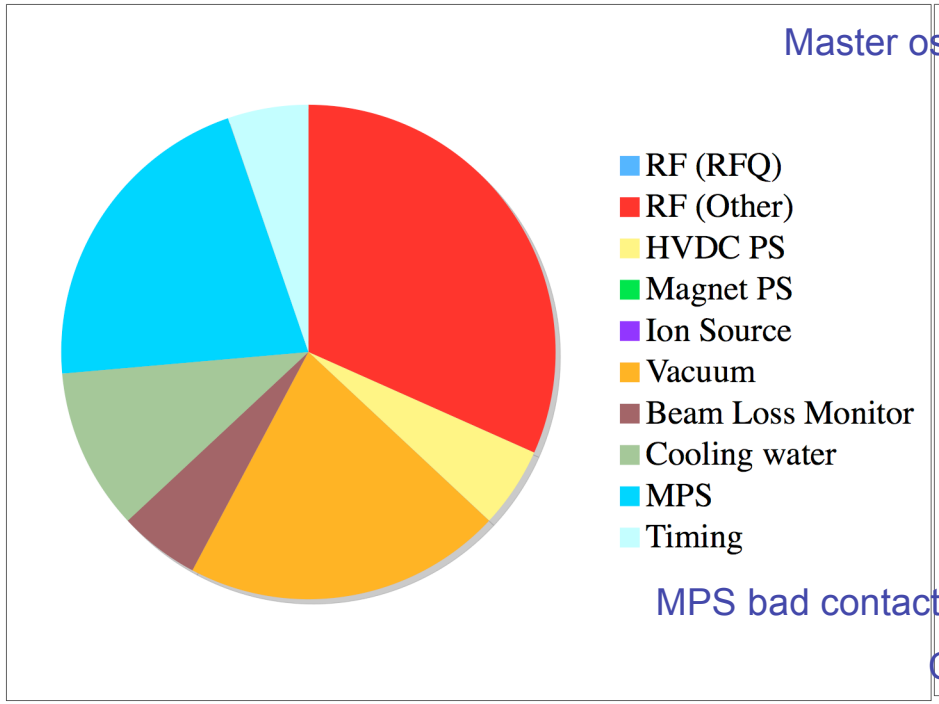
Summary

- While the linac has been operated to provided a stable beam for the downstream facilities for nearly one year, the commissioning of the downstream facility is still continuing.
- This peculiar situation has prevented us from accumulating the experience on the long-term beam stability and machine activation.
- The short-term beam stability and the beam availability are sufficiently good for the present stage.
- The stable beam supply to the neutron source will be started in the next month, and it will provide us with an opportunity to gain those experiences.
- The short-term beam stability and the fault rate have already been in the sufficient level.

Reserve

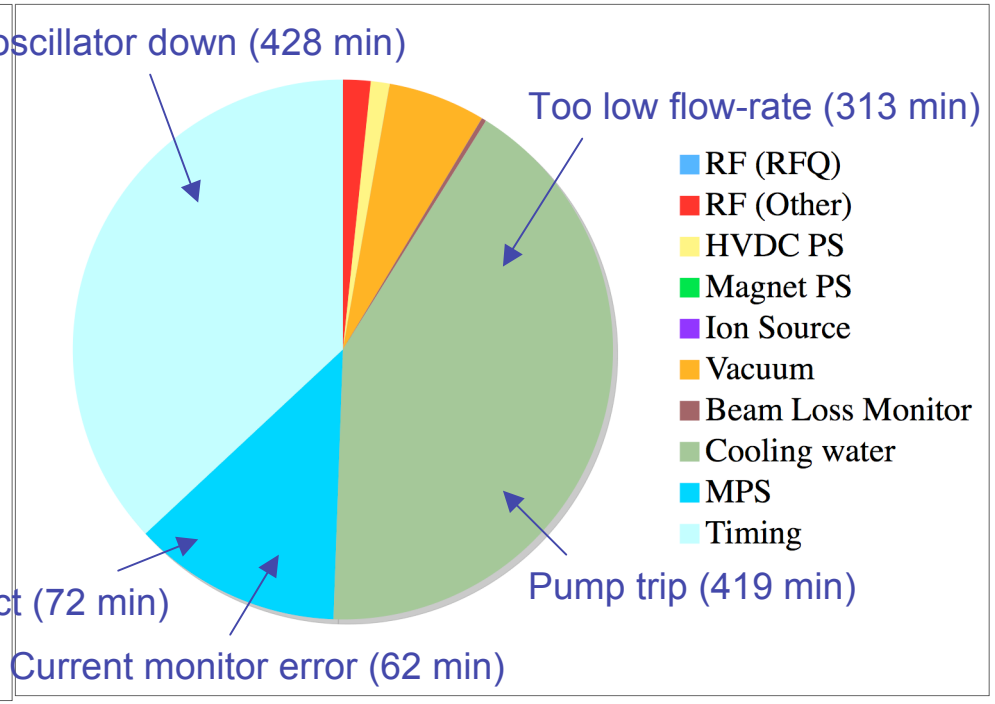
Fault statistics for RUN10-12

Number of faults



19 faults in total

Downtime



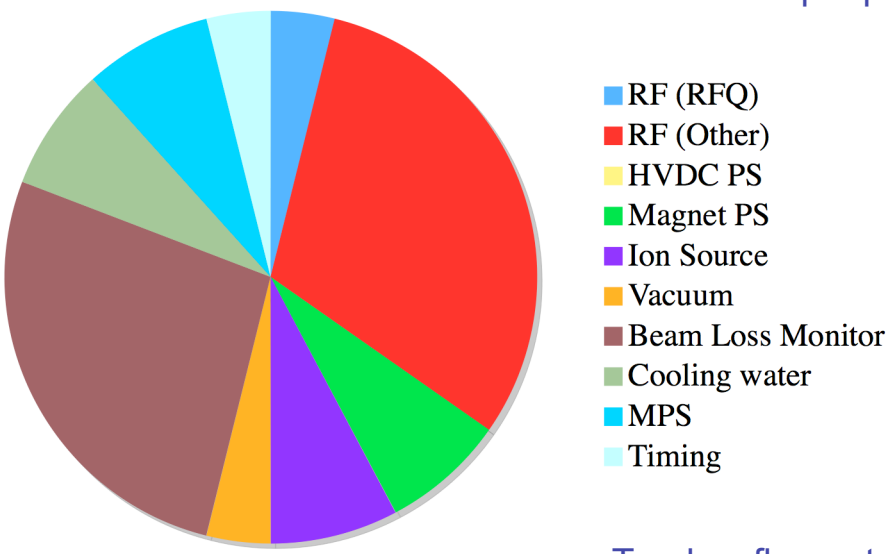
19.3 hour in total

Total beam time: 176 hour / Unscheduled downtime: 10.1 %

*Only faults longer than 1 min are analyzed.

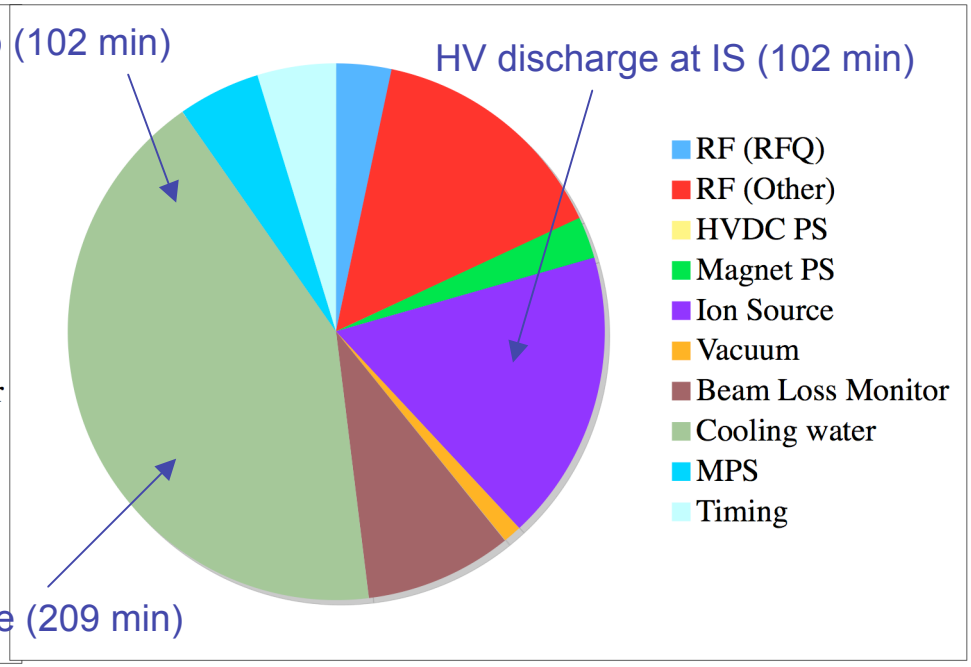
Fault statistics for RUN13,14

Number of faults



26 faults in total

Downtime



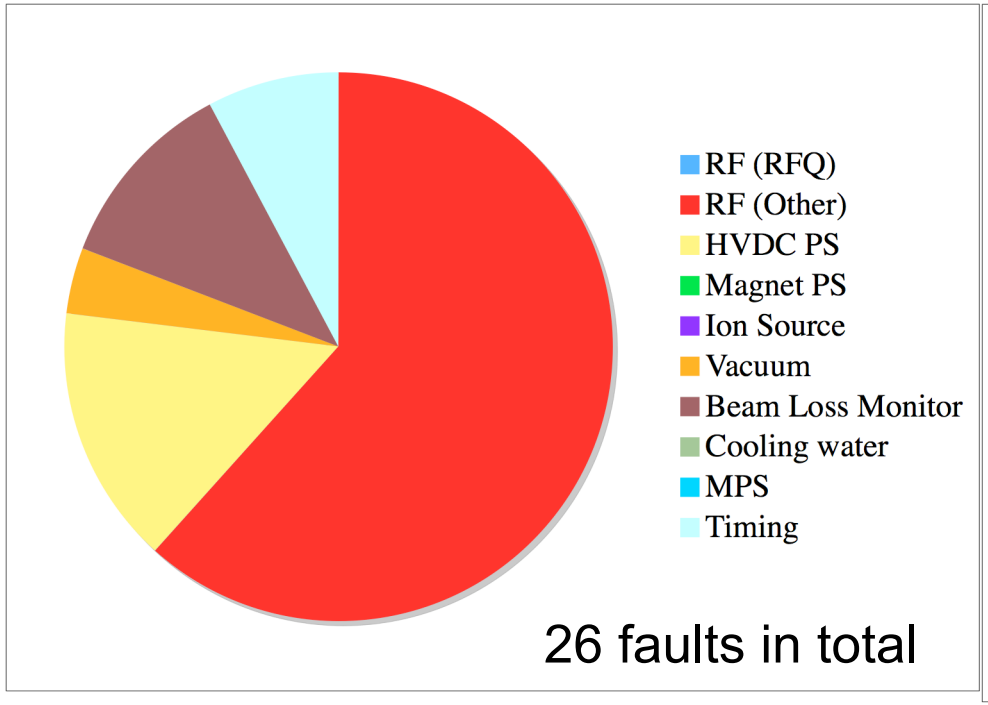
12.2 hour in total

Total beam time: 278 hour / Unscheduled downtime: 4.4 %

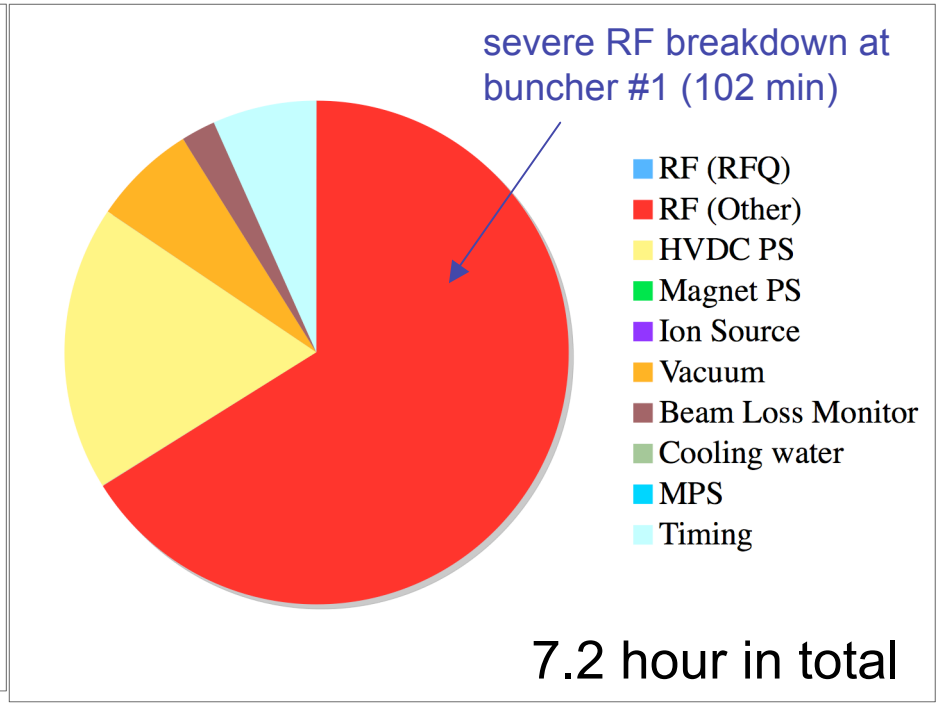
*Only faults longer than 1 min are analyzed.

Fault statistics for RUN15

Number of faults



Downtime

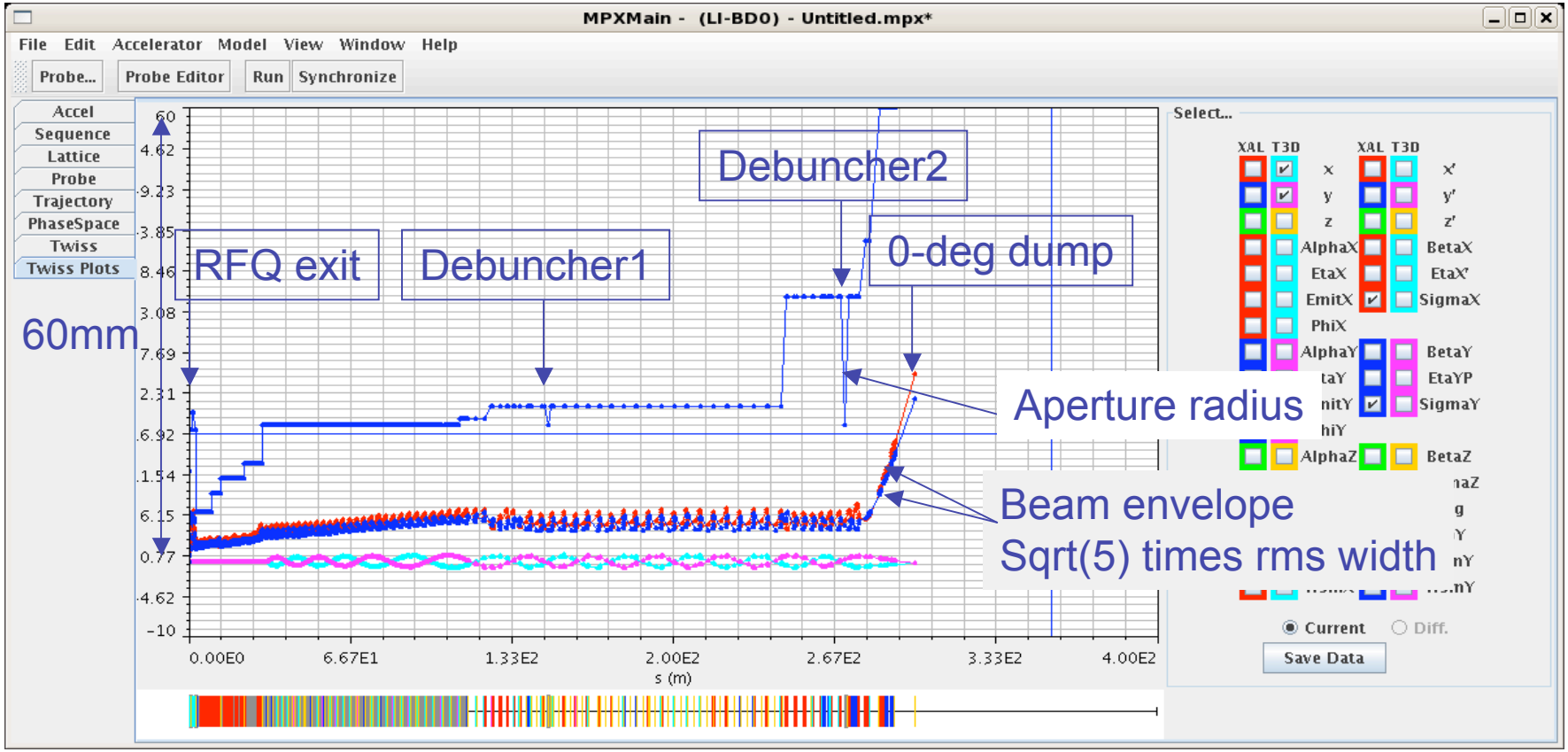


Total beam time: 73 hour / Unscheduled downtime: 9.9 %

Dedicated run for linac tuning, and after a two-month shutdown.

*Only faults longer than 1 min are analyzed.

Aperture along the linac



In 181 MeV operation, the last two SDTL tanks are utilized as debunchers, which makes narrow sections in the beam transport.
Excess beam losses have been anticipated in these sections.

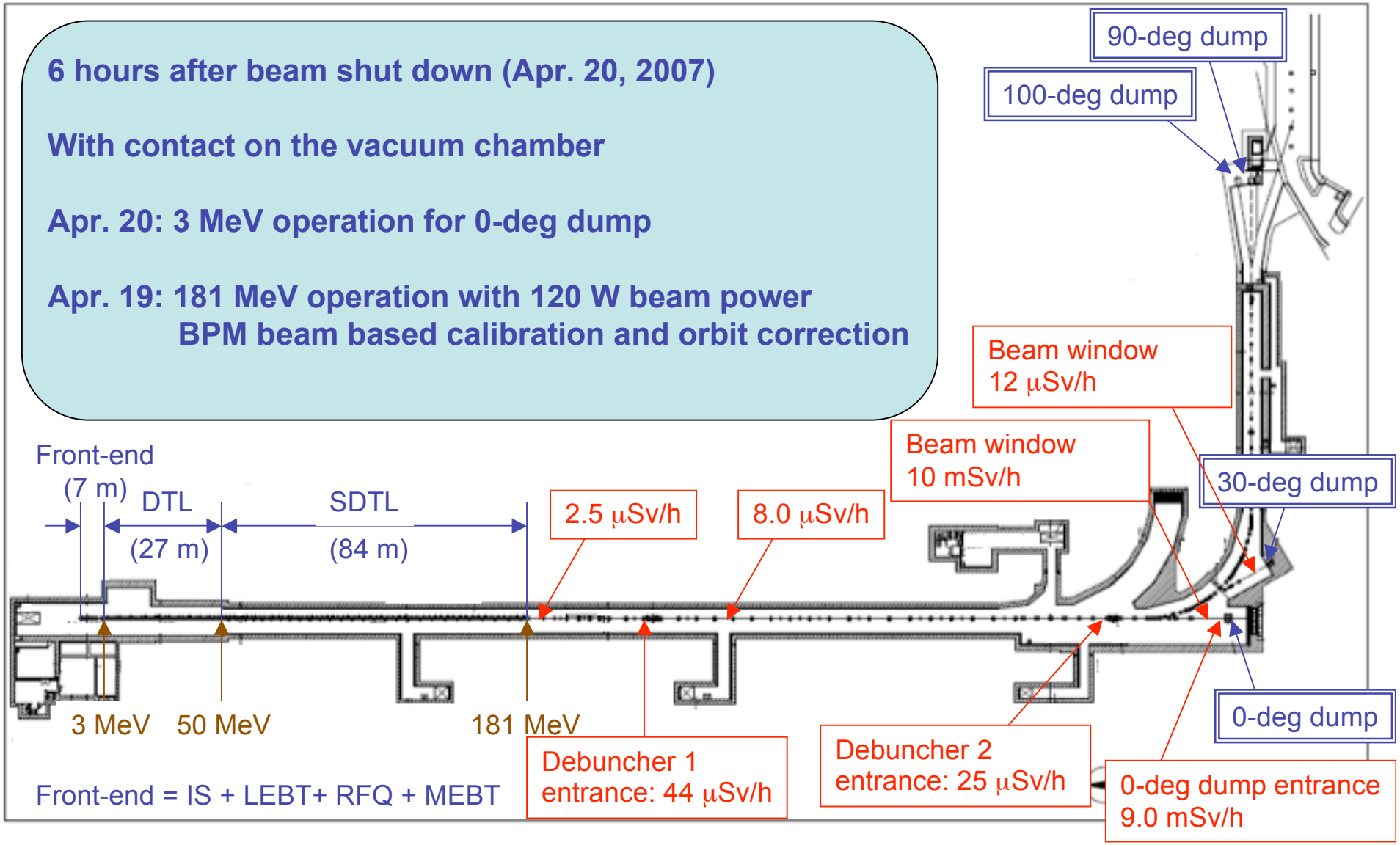
Residual radiation level after RUN6

6 hours after beam shut down (Apr. 20, 2007)

With contact on the vacuum chamber

Apr. 20: 3 MeV operation for 0-deg dump

Apr. 19: 181 MeV operation with 120 W beam power
BPM beam based calibration and orbit correction



History of residual radiation levels

Location	Debuncher 1	Debucher 2	Remark
After RUN2	0.7 μSv/h	65 μSv/h	50 MeV, 12 W operation
After RUN3	15 μSv/h	88 μSv/h	Phase scan with 45 W 181 MeV, 120 W operation
After RUN4	7.8 μSv/h	85 μSv/h	181 MeV, 120 W operation
After RUN5	240 μSv/h	150 μSv/h	Phase scan with 120 W
After RUN6	44 μSv/h	25 μSv/h	181 MeV, 120 W operation

6 hours after beam shut down
With contact on the vacuum chamber.
The radiation level is typically decreased to about one third in a few days.

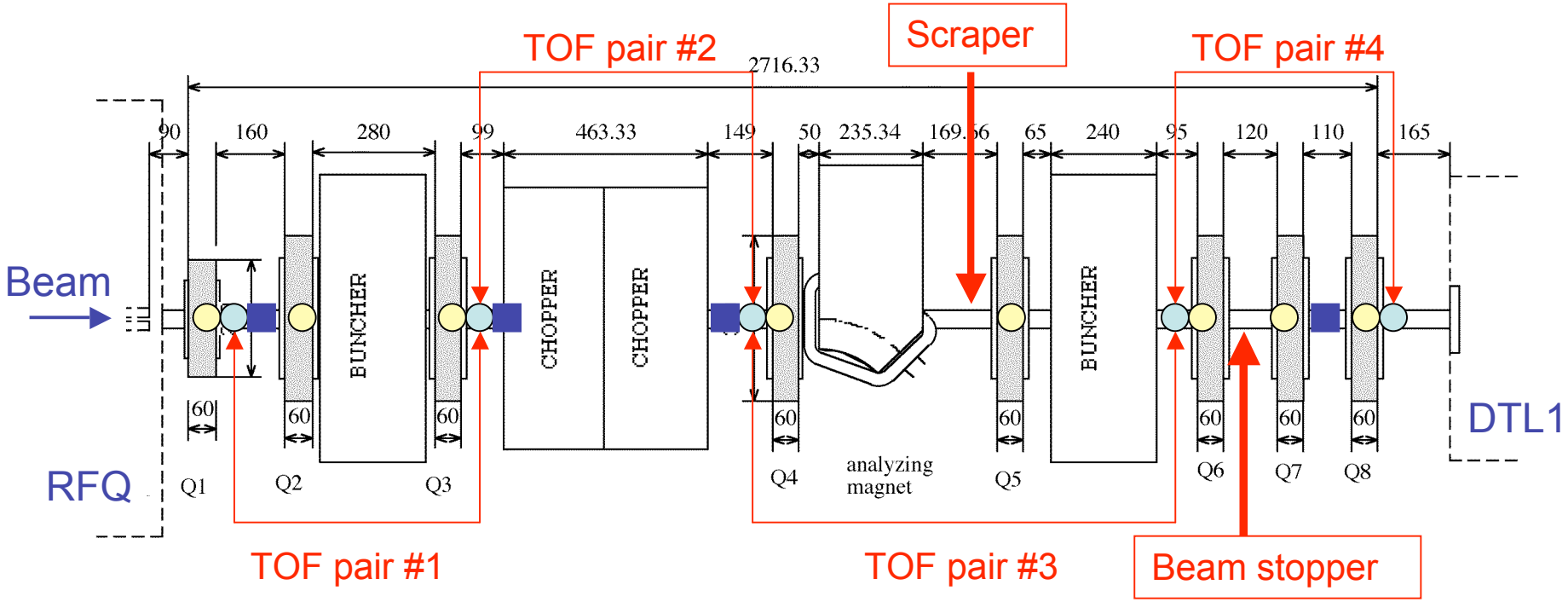
Beam loss: status

- We have experienced the residual radiation level of 150-240 μSv/h at debuncher locations with the beam power of 120 W. This level of beam loss has been clearly detected with the BLM's (Beam Loss Monitors).

- While it has been reduced to 25-44 μSv/h after conducting a fine RF tuning, the present level of fractional losses still exceed the tolerable range considering that the current beam power is only 0.3 % of the design value.

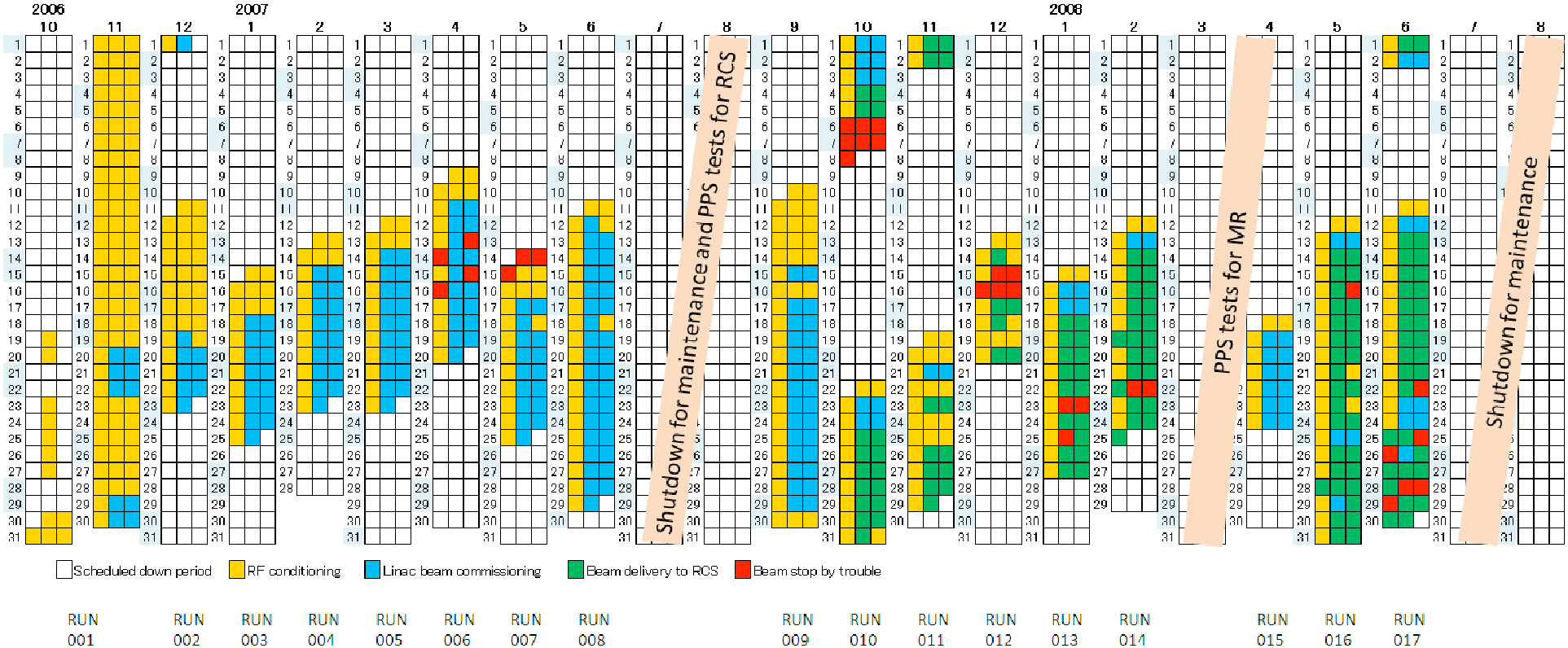
- Finer tuning should be pursued to reduce uncontrolled losses. In parallel, we need to closely watch the trend as we increase the linac beam power. Counter measures, such as adding local shielding, should be made in an appropriate timing if needed.

MEBT monitor layout



- FCT (Fast Current Transformer) and SCT (Slow Current Transformer)
- BPM (Beam Position Monitor)
- WS (Wire Scanner)

Operation history



- Blank: Scheduled down time
- Yellow: RF Conditioning
- Blue: Beam-on time (linac study)
- Green: Beam-on time (RCS or MR study)
- Red: Unscheduled down time

- Klystron operation time: 5900 h
- Ion source operation time: 3360 h
- Beam-on time: